

Fermilab Accelerator Complex Qualitative Beam-On Surveys

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A concern was raised by Fermilab DOE Site Office (FSO) in their conditional approval of the Accelerator Safety Envelope (ASE) Revision 12 (dated August 25, 2020, approved September 29, 2020) pertaining to potential dose to the public due to accelerator operations:

As the Fermilab site is closed to the general public, the otherwise publicly accessible areas of the site that could exceed public dose restrictions (if not for occupancy adjustment) do not represent a public risk. Prior to Fermilab allowing public access to the site, the areas that would then be publicly accessible, that could exceed public dose restrictions (if not for occupancy adjustment), must be posted as restricted to Fermilab workers unless a subsequent DOE external review proposes alternative expectations that are subsequently accepted by the FSO Manager.

This concern was captured in the iTrack review for the “400 MeV Test Area (MTA) Accelerator Readiness Review (ARR)”, item 104538, since the ASE revision was due to changes assessed in the ARR.[1]

In response to this concern, beam-on measurements were performed along the machines making up the main Fermilab accelerator complex as they resumed beam operations following the 2020 Summer Maintenance Shutdown. These surveys were not intended to be quantitative, but rather to identify if there are any areas of concern that warrant further investigation and focus. Approximately ~300 passive area monitor badges are now deployed as part of the routine area monitoring program. Prior to 2021, ~200 passive area monitors were used. Tracking of quarterly area monitor results will take place through the area monitoring program.

These surveys were performed using the following guidelines:

- Beam has been established in each machine and is running stably.
- Survey points should be at a location accessible to the public (i.e., parking lots or roads) nearest to the berm or fencing.
- Survey points should be evenly spaced along the entire length of the beamline.
 - Additional survey locations may be added in points of interest (i.e., MI-30 collimator region)
- Survey should be performed using instrument(s) that measure both gamma and neutron radiation. Background and beam-on surveys should be conducted, using one-minute count times.
 - Bicon analysts were used to survey gamma radiation, with results in counts per minute (cpm), where 10,000 cpm is roughly equivalent to 0.05 mR/hr.
 - Bicon analysts were deemed sufficient for these surveys, over other instruments such as a Log Survey Meter (LSM), because they are more sensitive

and can detect slight increases due to beam or radioactive material stored within buildings. These are not quantitative surveys so a rough equivalency to dose rate is sufficient. The main goal of these surveys is to identify locations with high enough count rate that it could be $\gtrsim 0.05$ mR/hr, in order to ensure those areas are included in the routine area monitoring program.

- In practice, a “rule of thumb” that has been used for estimating dose rates based on counts per minute is 320-400 cpm ≈ 1 μ R/hr. 320 cpm is derived from detector efficiency, and 400 cpm comes from previous field surveys comparing Bicon readings with other dose rate instrument readings. Other previous studies show that 2,000 cpm ≈ 10 μ R/hr. [2] To be conservative, for the purpose of this study, 2,000 cpm ≈ 10 μ R/hr will be used to convert to dose rates.

$$2,000 \text{ cpm} \cong 10 \text{ } \mu\text{R/hr}$$

$$200 \text{ cpm} \cong 1 \text{ } \mu\text{R/hr}$$

$$200,000 \text{ cpm} \cong 1 \text{ mR/hr}$$

$$10,000 \text{ cpm} \cong 0.05 \text{ mR/hr}$$

- REM 500s were used to survey neutron radiation, with results in mrem, equating to mrem/min with the one-minute count time.
- Once background and beam-on surveys were completed, results should be compared to identify locations with net results equivalent to:
 - > 0.025 mR/hr with the Bicon
 - > 0.05 mR/hr with the Bicon
 - > 0.001 mrem/hr with the REM 500
- Based on the results of the survey, additional area monitors will be deployed for additional, ongoing monitoring.

Beam began to turn on following the 2020 Summer Shutdown starting in early October 2020, rolling through various machines until mid-January 2021. (*Note: NM and FAST remained off during this time frame due to continued experiment reconfiguration and equipment issues, respectively.*) Background and beam-on surveys were taken at various times, as described in Table 1, based on machine turn on. Table 2 compares beam intensity at the time of the beam-on survey relative to the nominal and Operating Limit intensities. If intensities at the time of the beam-on survey were much lower than the Operating Limit intensities,[3] either repeat surveys will be conducted when intensities increase or area monitors in place as part of the routine area monitoring program will be used to continue monitoring the area as intensities increase.

Table 1. Survey Dates

Machine	Background Survey Date(s)	Beam-On Survey Date(s)
Linac	10/8/2020	12/22/2020
MeV Test Area (MTA)	2/3/2021	2/5/2021
Booster	10/9/2020	12/22/2020
8 GeV	11/17/2020	12/28/2020
Booster Neutrino Beam (BNB)	Included in the 8 GeV survey	Included in the 8 GeV survey
Main Injector (MI) / Recycler (RR)	11/17/2020	12/18/2020 & 12/28/2020
NuMI	Included in the MI/RR survey	Included in the MI/RR survey
F Sector (shared beamlines for SY and Muon Campus)	12/11/2020	12/28/2020
Muon Campus	1/11/2021	12/28/2020
SwitchYard Primary	12/11/2020	1/15/2021
Meson (Primary, Test & Center)	12/11/2020	1/15/2021
FAST	n/a – beam currently not operational due to machine instrumentation issues	n/a – beam currently not operational due to machine instrumentation issues
Neutrino Muon	n/a – beam currently not operational during experiment reconfiguration	n/a – beam currently not operational during experiment reconfiguration
Proton	n/a – machine in “standby” state and not running beam	n/a – machine in “standby” state and not running beam
Tevatron (TeV)	n/a – machine in “standby” state and not running beam	n/a – machine in “standby” state and not running beam

Table 2. Beam Intensity Comparison

Machine	Beam Intensity for Beam-On Survey	Operating Limit Beam Intensity	Operating Limit Beam Energy
Linac	1.2E17 protons/hr	3.54E17 protons/hr	400 MeV
MTA	2.8E14 protons/hr	2.7E15 protons/hr	400 MeV
Booster	1.2E17 protons/hr	2.70E17 protons/hr	8 GeV
8 GeV	1.8E17 protons/hr	2.84E17 protons/hr	8 GeV
Booster Neutrino Beam (BNB)	2.95E16 protons/hr	1.62E17 protons/hr	8 GeV
Main Injector (MI) / Recycler (RR)	--	--	--
- Main Injector	4.1E16 protons/hr	2.93E17 protons/hr	8 GeV
		2.93E17 protons/hr	120 GeV
		2.34E17 protons/hr	150 GeV
- Recycler	2.5E16 protons/hr	2.25E17 protons/hr	8 GeV
NuMI	2.9E16 protons/hr	2.25E17 protons/hr	120 GeV
F Sector (shared beamlines for SY and Muon Campus)	--	--	--
- P1-P2 Line to Muon Campus	1E16 protons/hr	6.5E16 protons/hr	8 GeV
- P1-P2 Line to SwitchYard	1.3E13 protons/hr	3.60E13 protons/hr	120 GeV
Muon Campus	--	--	--
- On Target	1E16 protons/hr	4.32E16 protons/hr	8 GeV
- Off Target	n/a – running On Target	3.60E13 protons/hr	8 GeV
SwitchYard Primary	3.7E13 protons/hr	6.00E14 protons/hr	120 GeV
Meson (Primary, Test & Center)	--	--	--
- Primary	1.4E13 protons/hr	1.68E14 protons/hr	120 GeV
- Test	6.5E12 protons/hr	1.20E13 protons/hr	120 GeV
- Center	2.5E10 protons/hr	1.02E12 protons/hr	120 GeV
FAST	n/a – beam currently not operational due to machine instrumentation issues		
NM	n/a – beam currently not operational during experiment reconfiguration		

Results

Survey location points were approved by the assigned RSO, RPO Department Head, and/or the SRSO prior to conducting any surveys.

RCTs performed all surveys, background and beam-on, at the prescribed locations. Background surveys were performed prior to that machine starting up, or during a down-day if already operational. Beam-on surveys were performed after that machine was operational and running stable beam. After the Linac background survey for both gamma and neutron, it was determined that with the beam off there is no other potential source for neutrons, so no additional neutron background measurements were taken at each survey location. Instead, three sixty-minute background sample measurements were taken, and the average of these measurements was taken to be the background value for all locations.

Gamma Results

Gamma survey results for both background and beam-on measurements were initially reported in cpm. The difference between the two was found to show the net beam-on count rate due to gammas from beam operations of that machine. Locations with net results greater than 1000 cpm were identified, as shown in Table 6. Standard deviation for all results was calculated, $\sigma_{N_S} = \sqrt{N_T + N_B}$, where N_S is the net value, N_T is the gross sample (i.e., beam-on) value, and N_B is the background value.[4]

In order to ensure the bicron surveys did not produce unacceptable false positive or false negative results, critical levels, L_C , and minimum detectable limits, N_D , were calculated, based on the direct cpm measurements. In order to ensure no larger than 5% rate of false positive results, the critical level was found to be $L_C = 2.326\sigma_{N_B}$ or $L_C = 2.326\sqrt{N_B}$,[5] and any net result, N_S , greater than L_C was flagged for confirming counts present above background. In order to ensure appropriate instrumentation was used, a minimum detectable limit (from the sample result), was found to be $N_D = 4.653\sigma_{N_B} + 2.706$ or $N_D = 4.653\sqrt{N_B} + 2.706$. [6]

Results of the gamma radiation surveys, net calculation, and standard deviation calculation were then converted to exposure rate, mR/hr, where 200,000 cpm is roughly equivalent to 1 mR/hr.[2] Results are shown to three decimal places, and rounded to zero for any negative net results. Locations with net exposure rates greater than 0.05 mR/hr, which is the threshold for unlimited occupancy, were identified, as shown in Table 3. Locations with net exposure rates between 0.025-0.05 mR/hr were identified, as shown in Table 4. Table 5 contains a list of machines that do not have any locations with net beam-on exposure rates of greater than 0.025 mR/hr. Table 6 lists locations with net counts > 1,000 cpm but net exposure rates < 0.025 mR/hr. In order to further ensure that appropriate instrumentation was used when considering results converted to dose rates, a minimum detectable limit for dose, D_D , was found by taking the minimum detectable limit for counts and converting units: $D_D =$

$$N_D \times \frac{1 \text{ mR/hr}}{200,000 \text{ cpm}}$$

One (1) location was found to have dose rates > 0.05 mR/hr. No locations were found in the 0.025-0.05 mR/hr range. Nine (9) additional locations were found to have count rates > 1000 cpm.

Table 3. Location of Net Beam-On Exposure Rates Greater Than 0.05 mR/hr

Machine	Survey Location #	Geographical Location	Net Beam-On (mR/hr)	Comments
Muon Campus	7	APO Service Building parking lot.	0.054	Elevated count rates here expected due to stored activated material and RAW water skid operations. This building is not accessible to the public, roads leading to this building have "Authorized Personnel Only Beyond This Point" signage. This building is posted as a Radiation Area. Area monitors have already been installed in the north and south vestibules and have been added to the routine area monitoring program. Additional area monitor(s) will need to be added in the center of the building, in the parking lot to continue monitoring that location as well. Based on area monitoring results, additional postings to limit occupancy in the area may be needed.

Table 4. Locations of Net Beam-On Exposure Rates Greater Than 0.025 mR/hr

Machine	Survey Location #	Geographical Location	Net Beam-On (mR/hr)	Comments
none				

Table 5. List of Machines with No Locations of Net Beam-On Exposure Rates Greater than 0.025 mR/hr

Linac
MTA
Booster
8 GeV
Booster Neutrino Beam (BNB)
Main Injector (MI) / Recycler (RR)
NuMI
F Sector (shared beamlines for SY and Muon Campus)
SwitchYard Primary
Meson (Primary, Test & Center)

Table 6. Additional Information For Locations with > 1000 cpm Net Beam-On Count Rates (continued onto next page)

Machine	Survey Location #(s)	Geographical Location	Comments
Booster	8	Short 6 (S6) region, near the Booster collimators.	Documented higher dose rates in Long 6 (L6) and S6 region, see previous area monitor readings. This area will continue to be part of the routine area monitoring program.
8 GeV/BNB	16	MI-12 Service Building	May have higher counts due to BNB targeting and the 1,000 cfm fan unit. Monthly dose rate surveys are performed on the fan unit as part of the routine "snoop" survey program, and an area monitor badge has been added to this location and will be added to the routine area monitoring program.
MI/RR	15	MI-30 Parking Lot	This location was only reading a net of 992 cpm, but still included here. This higher reading is due to the LCW DI bottle located in the MI-30 LCW room. This bottle can at times produce a Radiation Area within the LCW room, so this is expected from LCW cooling of the collimator region components. Area monitors have been added in the LCW room, in the parking lot, and across the road near the pond and will be added to the routine area monitoring program.

Machine	Survey Location #(s)	Geographical Location	Comments
MI/RR	43, 44	Kautz Rd, near AP-0 Service Building	Elevated count rates expected here due to Muon Campus targeting operations, RAW system, and stored radioactive material. This building is posted as a Radiation Area. Area monitors have been installed in the north and south vestibules and will be added to the routine area monitoring program.
MI/RR	46	MI-8 Service Building Parking Lot	Elevated count rates due to LCW piping running through the building. LCW water comes from the MI8 collimator region, to a cooling and polishing loop in the MI-8 Service Building. Area monitors have been installed in the LCW room and the adjacent work area and will be added to the routine area monitoring program.
F Sector	6, 7	Main Ring Rd, North of AP-0 Service Building, near F23 Power Supply Building and F2 Service Building (same as positions 5 & 6 for Muon Campus)	Elevated count rates expected here due to Muon Campus targeting operations. The nearby F2 Refrigerator Building already contains an area monitor as part of the routine area monitoring program.
Muon Campus	5, 6	Main Ring Rd, North of AP-0 Service Building, near F23 Power Supply Building and F2 Service Building (same as positions 6 & 7 for F Sector)	Elevated count rates expected here due to Muon Campus targeting operations. The nearby F2 Refrigerator Building already contains an area monitor as part of the routine area monitoring program.
Muon Campus	8	West (downstream) of AP-0 Service Building on the road	Elevated count rates possible from nearby AP-0 Service Building and Muon Campus targeting operations.

Neutron Results

Neutron survey results for beam-on measurements were initially reported in mrem, using one-minute integration time.

Three sixty-minute background sample measurements were taken, and the average of these measurements, \bar{x} , was found using: $\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$. A sample standard deviation, s , was then found

using: $s = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2}$. The average background sample measurement and sample standard deviation were then converted into mrem/min and mrem/hr and applied to all survey locations.

The difference between the average background and gross beam-on measurements, when converted into mrem/min and mrem/hr, was found to show the net beam-on dose rate due to neutrons from beam operations of that machine. Results are shown to three decimal places, and rounded to zero for any negative net results. Locations with any net dose rate due to neutrons were identified, as shown in Table 7. Table 8 contains a list of machines that do not have any locations with any net beam-on dose rates due to neutrons.

In order to ensure neutron readings, converted to mrem/hr, did not produce unacceptable false positive or false negative results, critical levels, $L_{C,N}$, and minimal detectable dose $D_{D,N}$, were calculated, based on the direct mrem measurements. Similar to calculating the gamma critical level, L_C , the critical level for neutron, $L_{C,N}$ was found to be $L_{C,N} = 2.326s$, [5] and any net result greater than this critical level was flagged for confirming readings present above background. All locations were found to be below the critical level, $L_{C,N}$. In order to ensure appropriate instrumentation was used, a minimum detectable limit for neutron dose, $D_{D,N}$, was found to be $D_{D,N} = 4.653s$. [7]

Table 7. Locations of Neutron Dose Rates Found.

Machine	Survey Location #	Geographical Location	Net Beam-On (mrem/hr)	Comments
Muon Campus	10	On Indian Creek Road, above the end of the Transport DS enclosure and start of the Delivery Ring enclosure.	0.115	Above where the M3 line bends to go into the Delivery Ring, but before injection. This location is not accessible to the public, roads leading to this location have "Authorized Personnel Only Beyond This Point" signage. Will need additional follow-up.

Table 8. List of Machines with No Neutron Dose Rates Found.

Linac
MTA
Booster
8 GeV
Booster Neutrino Beam (BNB)
Main Injector (MI) / Recycler (RR)
NuMI
F Sector (shared beamlines for SY and Muon Campus)
SwitchYard Primary
Meson (Primary, Test & Center)

Scaling, Occupancy Time, Public Accessibility & Interlocked Detectors

At the core of the FSO concern about potential dose to the public, we were asked to identify locations that are publicly accessible where public dose restrictions could be exceeded if not for occupancy adjustment. Visitors to Fermilab are limited to 100 mrem in a year.[8] Fermilab radiological design criteria, and therefore dose rate and posting standards, rely on the standard 2,000 hour working-year.[9] For the purpose of this study, potential dose, in mrem, at both the standard 2,000 hour working-year and 24/7/365 occupancies were calculated based on the calculated gamma and/or neutron dose rates.

In order to be conservative in calculating potential dose at both occupancies, the exposure and/or dose rates determined based on beam intensity at the time of the survey was scaled to approved Operating Limit beam intensities.[3] From there, potential dose was calculated for each occupancy, shown in Table 10, with the following assumptions:

- 1 mR/hr is equivalent to 1 mrem/hr
- Occupancy is either the standard 2,000 hr working-year, or 24/7/365. However, since beam is not operational 24/7/365, the dose calculated for this occupancy takes into account annual % beam up-time for the machine (or upstream/limiting machines) noted in the shielding assessment[10][11][12][13], as shown in Table 9.
- Assuming interlocked radiation detectors are not in use
 - *Interlocked radiation detectors are in place and set to trip limits based on the Shielding Assessment for that machine*

Table 9. Annual % Beam Up-Time

	# Weeks Operational	Efficiency	Annual % Beam Up-Time
Linac[10] ¹	52	100%	100%
MTA	Use upstream machine - Linac		
Booster[11] ²	52	100%	100%
8 GeV	Use upstream machine - Booster		
BNB	Use upstream machine - Booster		
MI[12]	44	80%	67.7%
RR[13] ³	52	99%	99%
F Sector	Use upstream machine - MI		
Muon Campus	Use upstream machine - MI		
Switchyard	Use upstream machine - MI		
Meson	Use upstream machine - MI		

¹The Linac Shielding Assessment doesn't specify annual beam up-time. For the purpose of this report it will be taken as 100%.

²Booster Shielding Assessment assumed 100% efficiency in order to provide as much beam as possible in order to accommodate for downstream inefficiency, but doesn't specify number of weeks operational. For the purpose of this report it will be taken as 52 weeks.

³The Recycler Shielding Assessment specifies that the machine runs at 99% efficiency, but doesn't specify number of weeks operational. For the purpose of this report it will be taken as 52 weeks.

Fourteen (14) locations would exceed 100 mrem in a year at the Operating Limit intensity, assuming 24/7/365 occupancy and annual beam up-time. None of which are publicly accessible.[14] Only seven (7) locations would exceed 100 mrem in a year at the Operating Limit intensity, assuming the standard 2,000 hour working-year. None of which are publicly accessible.[14] Additionally, all locations are in normally not-occupied locations (i.e., roads and parking lots). Figure 1 shows an overlay of these locations on the Fermilab Site Map.

Finally, it is noted that interlocked radiation detectors are utilized to ensure dose rates do not reach certain levels based on that locations posting & occupancy.[8] Table 10 also indicates interlocked radiation detector trip levels that are used for that location.

Table 10. Locations > 100 mrem in a year at Operating Limit Intensities for either 2,000 hr or 24/7/365 Occupancy. (continued on next several pages)

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
8 GeV/BNB								
16	MI-12 Service Building	20.000	87.600	109.831	481.058	Table 6 > 1,000 cpm	No	3 chipmunks set to trip at 5 mrem/hr and 4 chipmunks set to trip at 1 mrem/hr in and around the MI-12 Service Building
MI/RR								
15	Indian Creed Rd near MI-30 Service Building	10.000	43.800	71.463 ¹	211.884 ¹	Table 6 > 1,000 cpm	No	MI-30 Service Building LCW room has chipmunk set to trip at 2.5 mrem/hr
				54.878 ²	237.962 ²			
41	Kautz Rd, South of MI-62 Service Building	4.000	17.520	28.585 ¹	84.753 ¹	Elevated count rates possible here due to close proximity to the MI/RR, NuMI and Muon Campus Beamlines.	No	MI-62 Service Building LCW room has chipmunk set to trip at 2.5 mrem/hr
				36.000 ²	156.103 ²			
42	Kautz Rd, North of MI-62 Service Building	4.000	17.520	28.585 ¹	84.753 ¹	Elevated count rates possible here due to close proximity to the MI/RR, NuMI and Muon Campus Beamlines.	No	MI-62 Service Building LCW room has chipmunk set to trip at 2.5 mrem/hr
				36.000 ²	156.103 ²			

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
MI/RR								
43	Kautz Rd, near AP-0 Service Building	38.000	166.440	271.561 ¹	805.157 ¹	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
				342.000 ²	1482.980 ²			
44	Kautz Rd, near AP-0 Service Building	30.000	131.400	214.390 ¹	635.651 ¹	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
				270.000 ²	1170.774 ²			
45	Kautz Rd, just north of the front/North MI-8 Service Building parking lot	4.000	17.520	28.585 ¹	84.753 ¹	< 1,000 net cpm Bicon survey, but since intensity at the time of the survey was 1 order of magnitude lower than the Op. Limit intensity, any non-zero cpm scales to larger dose rates at the Op. Limit and therefore larger dose values assuming 24/7/365 occupancy.	No	None required – potential dose at standard 2,000 hr working-year less than 100 mrem. Area monitors have been added to the MI-8 Service Building.
				36.000 ²	156.103 ²			

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
MI/RR								
46	Indian Creek Rd, just past the back/South MI-8 Service Building parking lot	10.000	43.800	71.463 ¹	211.884 ¹	Table 6 > 1,000 cpm	No	None required – potential dose at standard 2,000 hr working-year less than 100 mrem. Area monitors have been added to the MI-8 Service Building.
				90.000 ²	390.258 ²			
F Sector								
6*	Main Ring Rd, North of AP-0 Service Building, near F23 Power Supply Building (same as location 5 for Muon Campus)	28	122.640	182.000 ³	539.616 ³	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
				77.538 ⁴	229.896 ⁴			
7 [†]	Main Ring Rd, North of AP-0 Service Building, near F2 Service Building (same as location 6 for Muon Campus)	20.000	87.600	130.000 ³	385.440 ³	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
				55.385 ⁴	164.211 ⁴			

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
F Sector								
8	Main Ring Rd, near F27 Power Supply Building	6.000	26.280	39.000 ³	115.632 ³	Elevated count rates expected here due to Muon Campus targeting operations. The nearby F2 Refrigerator Building already contains an area monitor as part of the routine area monitoring program.	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
				16.615 ⁴	49.263 ⁴			
Muon Campus								
5*	Main Ring Rd, North of AP-0 Service Building, near F23 Power Supply Building (same as location 6 for F Sector)	28	122.640	120.960	358.637	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
Muon Campus								
6 ⁺	Main Ring Rd, North of AP-0 Service Building, near F2 Service Building (same as location 7 for F Sector)	24	105.120	103.680	307.403	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
7	AP0 Service Building parking lot.	108	473.040	466.560	1383.315	Table 3 > 0.05 mR/hr	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr
8	Kautz Rd, North of AP-0 Service Building & South of MI-8 Service Building	18.000	78.840	77.760	230.552	Table 6 > 1,000 cpm	No	AP-0 Service Building has two chipmunks set to trip at 5 mrem/hr and 15 mrem/hr

Machine & Survey Location	Geographic Location	At Survey Intensity		Scaled to Op. Limit		Comments	Public Accessibility	Interlocked Radiation Detectors
		2,000 hr working-year (mrem)	24/7/365	2,000 hr working-year (mrem)	24/7/365			
Muon Campus								
10 ^N	On Indian Creek Road, above the end of the Transport DS enclosure and start of the Delivery Ring enclosure.	217.34	1,008.364	869.789	2578.857	Table 7 neutron dose	No	Several chipmunks in APO Service Building set to trip at either 15 mrem/hr or 5 mrem/hr and AP-10 Service Building set to trip at 2.5 mrem/hr. Also a chipmunk at the Transport DS/Delivery Ring gate in the enclosure set to trip at rate of 5 mrem/hr when Delivery Ring is in access.

^N due to neutron dose (all others due to gamma dose)

¹ scaled to MI Operating Limit intensity

² scaled to RR Operating Limit intensity

³ scaled to P1-P2 Line to Muon Campus Operating Limit intensity

⁴ scaled to P1-P2 Line to Switchyard Operating Limit intensity

* same physical location surveyed in two machine surveys, counted as one location

† same physical location surveyed in two machine surveys, counted as one location

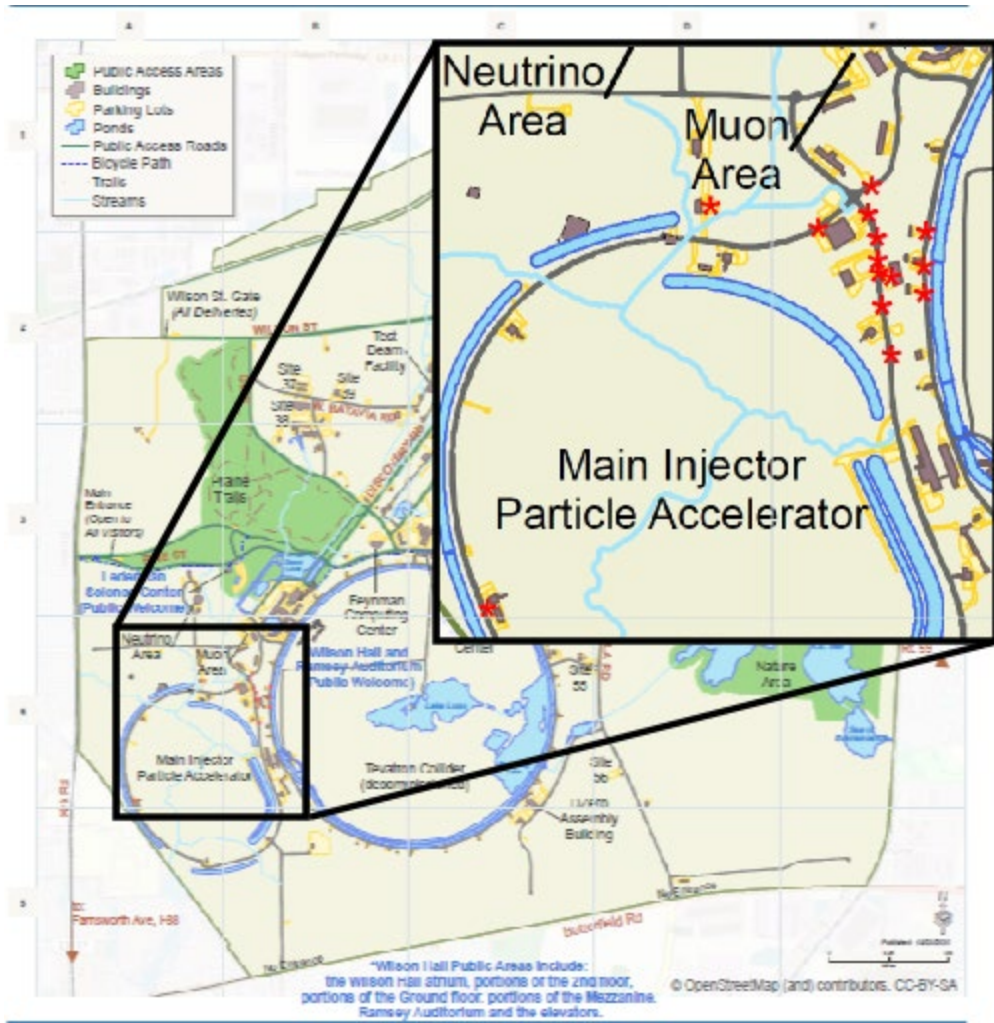


Figure 1. Map of Locations > 100 mrem/year for 24/7/365 Occupancy Overlaid on the Fermilab Public Area Map

Interlocked Radiation Detectors – From Running Conditions

BNB Interlocked Detectors

MUX	Type	Location	QF	R/I Mode	Trip Level	CDC	Device(s) Tripped
1-150	Chipmunk	MI-12 Serv. Bldg Upstairs Stripline Pen.	5	Integrate	5 mrem/hr	E:BNECRD	E:HV860 & BS860
1-148	Chipmunk	MI-12B Shield Blocks	5	Integrate	5 mrem/hr	E:BNECRD	E:HV860 & BS860
1-147	Chipmunk	MI-12 Service Building Downstream	5	Integrate	5 mrem/hr	E:BNECRD	E:HV860 & BS860
1-146	Chipmunk	MimiBooNE Berm US of MI-12	5	Integrate	1 mrem/hr	E:BNECRD	E:HV860 & BS860
1-145	Chipmunk	MimiBooNE Berm Indian Creek Culvert	5	Integrate	1 mrem/hr	E:BNECRD	E:HV860 & BS860
1-144	Chipmunk	MimiBooNE Indian Creek Road	5	Integrate	1 mrem/hr	E:BNECRD	E:HV860 & BS860
1-137	Chipmunk	MI-12A Upstream Berm	5	Integrate	1 mrem/hr	E:BNECRD	E:HV860 & BS860

MI/RR Interlocked Detectors

MUX	Type	Location	QF	R/I Mode	Trip Level	CDC	Device(s) Tripped
1-136	Chipmunk	MI-10 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-160	Chipmunk	MI-20 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-169	Chipmunk	MI-30 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-186	Chipmunk	MI-40 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-192	Chipmunk	MI-50 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-200	Chipmunk	MI-52 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-216	Chipmunk	MI-62 SB LCW	1	Integrate	2.5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-208	Chipmunk	MI-60 S Room 117 Pipe & BUS Pen.	5	Integrate	5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-209	Chipmunk	MI-60 S Room 110 LCW Pens RF Gal	5	Integrate	5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-210	Chipmunk	MI-60 N Room 110 LCW Pens RF Gal	5	Integrate	5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-211	Chipmunk	MI-60 N Room 118 LCW Pen	5	Integrate	5 mrem/hr	I:MICRD	I:LAM10 & BS10
1-212	Chipmunk	MI-60 N Room 118 Pen	5	Integrate	5 mrem/hr	I:MICRD	I:LAM10 & BS10

F-Sector (P1-P2 Line) Interlocked Detectors

MUX	Type	Location	QF	R/I Mode	Trip Level	CDC	Device(s) Tripped
2-244	Chipmunk	F1 Refrigerator Building	5	Integrate	50 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-228	Chipmunk	F0 Service Building Penetration #1	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-229	Chipmunk	F0 Service Building Penetration #2	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-230	Chipmunk	F0 Service Building Penetration #3	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-231	Chipmunk	F0 Service Building Penetration #4	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-232	Chipmunk	F0 Service Building Penetration #5	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-233	Chipmunk	F0 Service Building Penetration #6	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-234	Chipmunk	F0 Service Building Penetration #7	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701
2-235	Chipmunk	F0 Service Building Penetration #8	5	Rate	5 mrem/hr	I:P1CRD	R:LAM52, R:V703, I:LAM52, I:V701

Muon Campus Interlocked Detectors for both On- and Off-Target Modes

MUX	Type	Location	QF	R/I Mode	Trip Level	CDC	Device(s) Tripped
2-071	TLM	Muon Campus Prevault		Integrate	3000 nC/min	D:MICDC	I:F17B3 & M:HV100
2-065	Chipmunk	AP-1 Entrance - PreTarget Access Hutch	5	Integrate	5 mrem/hr	D:MICDC	I:F17B3 & M:HV100
2-069	Chipmunk	AP0 South Vault Wall	5	Integrate	15 mrem/hr	D:MICDC	I:F17B3 & M:HV100
2-064	Chipmunk	AP0 South Building Wall	5	Integrate	5 mrem/hr	D:MICDC	I:F17B3 & M:HV100
2-075	Chipmunk	Transport DS/Delivery Ring Gate	5	Rate	5 mrem/hr	D:MICDC	I:F17B3 & M:HV100
2-080	Chipmunk	AP-10 North Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-081	Chipmunk	AP-10 A17R05	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-082	Chipmunk	AP-10 A16R07	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-083	Chipmunk	AP-10 A16R03	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-084	Chipmunk	AP-10 D:QS	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-085	Chipmunk	AP-10 D:QD	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-086	Chipmunk	AP-10 A14R03	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-087	Chipmunk	AP-10 A14R0Y	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-088	Chipmunk	AP-10 MCR SW Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-089	Chipmunk	AP-10 Bay A13 South	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-090	Chipmunk	AP-10 Bay A12 North	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-091	Chipmunk	AP-10 A2R01	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-092	Chipmunk	AP-10 SW Rollup Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-093	Chipmunk	AP-10 South Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-096	Chipmunk	AP-30 South Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-097	Chipmunk	AP-30 S Rollup Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-098	Chipmunk	AP-30 D:H744	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-099	Chipmunk	AP-30 D:QT303	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-100	Chipmunk	AP-30 A35R07	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-101	Chipmunk	AP-30 A35R01	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-102	Chipmunk	AP-30 D:ISEP	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-103	Chipmunk	AP-30 A34R03	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-104	Chipmunk	AP-30 A33R07	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-105	Chipmunk	AP-30 A33R01	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-106	Chipmunk	AP-30 D:ELAM	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-107	Chipmunk	AP-30 D:V906	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-108	Chipmunk	AP-30 NE Rollup Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-109	Chipmunk	AP-30 North Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-112	Chipmunk	AP-50 West Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-113	Chipmunk	AP-50 A57R07	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-114	Chipmunk	AP-50 A57R01	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-115	Chipmunk	AP-50 A56R04	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-116	Chipmunk	AP-50 A55R08	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-117	Chipmunk	AP-50 A55R02 RFPA	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-118	Chipmunk	AP-50 D:SEXFV	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-119	Chipmunk	AP-50 D:VA03	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-120	Chipmunk	AP-50 A53R07	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-121	Chipmunk	AP-50 A53R01	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-122	Chipmunk	AP-50 Abort Kicker	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-123	Chipmunk	AP-50 D:ASEP	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-124	Chipmunk	AP-50 East Rollup Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707
2-125	Chipmunk	AP-50 East Door	5	Integrate	2.5 mrem/hr	D:DELCDC	D:H812 (g-2) or D:H700 (Mu2e) & BS707

Muon Campus Additional Interlocked Detectors when in On-Target Mode

1-001	Chipmunk	MC-1 DS of Q023	5	Integrate	2.5 mrem/hr	D:MC1CDC	D:V003 & D:H005
1-002	Chipmunk	MC-1 g-2 Ring Center	5	Integrate	2.0 mrem/hr	D:MC1CDC	D:V003 & D:H005

Muon Campus Additional Interlocked Detectors when in Off-Target Mode

1-019	Chipmunk	M4 7 foot drop Gate	5	Integrate	1.0 mrem/hr	D:M4CDC	D:H910
1-003	Chipmunk	MC-1 Hall Extraction Stub Gate	5	Rate	2.5 mrem/hr	D:M4CDC	D:H910

Conclusion

The purpose of this initial qualitative survey was to identify areas that warrant further investigation and focus. These surveys identified no locations that are accessible to the public that could exceed the dose limit to members of the public assuming the standard 2,000 hour working-year occupancy, and no locations that are accessible to the public that could exceed the dose limit to members of the public assuming 24/7/365 occupancy and standard beam up-time. Additionally, this survey identified a few locations that warrant additional area monitor dosimeters to be deployed for continuous monitoring through the routine area monitoring program, as well as locations that warrant follow-up survey.

- One (1) location with gamma dose rates > 0.05 mR/hr.
 - This building is not accessible to the public.
 - Area monitors have already been added to the adjacent north & south vestibules and have been added to the routine monitoring program. Additional area monitor(s) will need to be added in the center of the building, in the parking lot to continue monitoring that location as well. (Recommendation 1) Based on area monitoring results, additional postings to limit occupancy in the area may be needed.
 - This location will need to be posted as a Controlled Area, as required by FRCM Chapter 2.[8] (Recommendation 2)
- Nine (9) locations with elevated count rates, but with dose rates < 0.025 mR/hr.
 - These locations are not accessible to the public.
 - These locations will continue to be monitored through the routine area monitoring program. No additional area monitors needed.
- One (1) location with non-zero neutron dose rates.
 - This location is not accessible to the public
 - It is suspected that this reading may have been due to user error (i.e., bumping the instrument during the survey), or within the error bars for background readings. Repeat REM500 surveys should be conducted to determine. (Recommendation 3)
 - Pending results of repeat REM500 surveys, this location may warrant additional investigation, such as repeat neutron measurements, review of previous chipmunk studies, and/or review of the shielding assessment. In particular, special attention should be given to this areas as plans progress to increase beam intensity for Mu2e operations. Based on the results of this additional investigation, postings may need to be applied.

Ongoing monitoring of locations will be handled through the routine area monitoring program, which will capture dose throughout the quarter including if/when intensities increase.

Attached at the end of the report, the following information is provided for each machine survey:

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Recommendations

1. Additional area monitor dosimeters should be placed at the following locations:
 - a. AP-0 Service Building Parking Lot, between the service building and the parking lot (Muon Campus Location 7)
 - b. AP-0 Service Building Parking Lot, between the parking lot and the road
 - c. Near Indian Creek Road, over Muon Campus beamline (Muon Campus Location 10)
2. Controlled Area postings should be placed around the AP-0 Parking Lot.
3. Repeat REM500 neutron survey measurements should be taken at Muon Campus Location 10 to determine if the original measurement was inaccurate due to user error or is statistically indistinguishable from background.
 - Completed 2/8/2021 – still showing neutron results. Recommend installing area monitors to continue monitoring and evaluation. (Added to Recommendation 1)
4. Confirm that sufficient signage is in place in the field to indicate areas where public is not permitted (i.e., all potential entrances to a side road off of Discovery Rd, potential “non-routine” routes that may be taken, etc.).

References

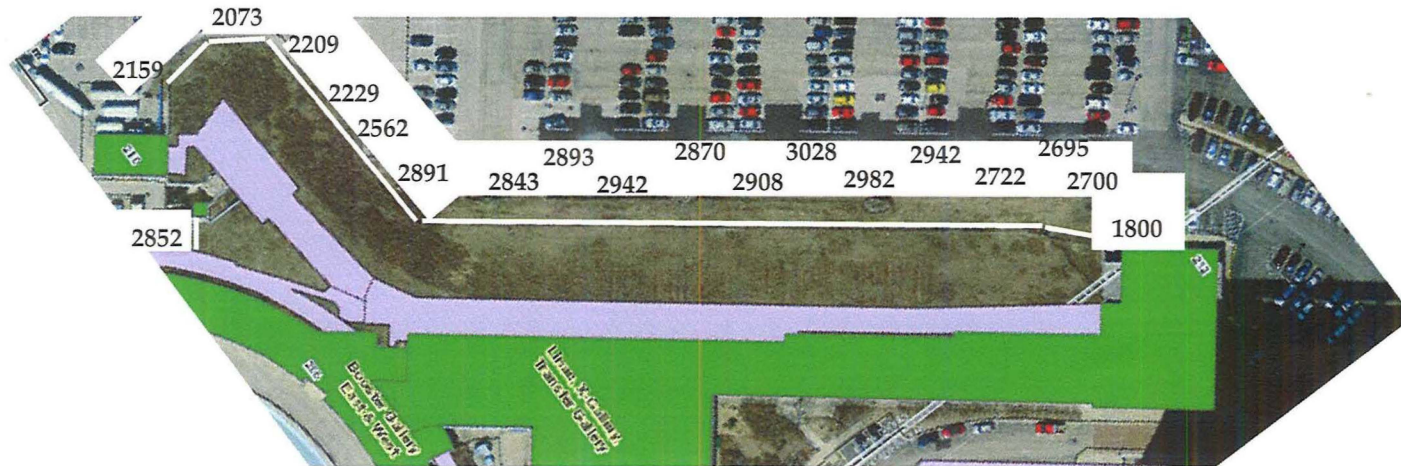
- [1] iTrack Review 53446: 400 MeV Test Area (MTA) Accelerator Readiness Review (ARR).
https://www-esh.fnal.gov/pls/apex/f?p=127:21:1014210002915:::P21_ID,PO_RETURN_PAGE_REVIEW,PO_REVIEW_ID:53446,20,53446&cs=3LMb67mxcsV1wMXzWjuAvVqfN8hGZg-KFo0QeCq6YPXnegnxnnBbrB5B_WPwKB7Lg3dBWj3F6z7POOxRbO4gU0w
- [2] R.P. Note 109 *Radioactivity Release Criteria for Materials, Equipment and Waste*. Rev. 1. May 2013. <https://esh-docdb.fnal.gov/cgi-bin/sso/ShowDocument?docid=2202>
- [3] ADAP-11-0003 *Approved Accelerator Beam Intensity Operating Limits*. Rev. 11. August 25, 2020. <https://beamdocs.fnal.gov/AD-private/DocDB/ShowDocument?docid=4977>
- [4] Knoll, G. F. (2000). *Radiation Detection and Measurement, 3rd Edition*. Equations 3.38, 3.58 & 3.59.
- [5] Knoll, G. F. (2000). *Radiation Detection and Measurement, 3rd Edition*. Equation 3.61.
- [6] Knoll, G. F. (2000). *Radiation Detection and Measurement, 3rd Edition*. Equation 3.67.
- [7] Knoll, G. F. (2000). *Radiation Detection and Measurement, 3rd Edition*. Equation 3.64.
- [8] Fermilab Radiological Control Manual (FRCM) Chapter 2, *Radiological Standards*. <https://esh-docdb.fnal.gov/cgi-bin/ShowDocument?docid=444>
- [9] Title 10 Code of Federal Regulations (CFR) Part 835 *Occupational Radiation Protection*, Section 1002 "Facility design and modifications".
- [10] Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning. September 21, 1993.
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- [11] Booster Shielding Assessment. Version 6, January 17, 2017.
<https://fermipoint.fnal.gov/org/eshq/sa/Shared%20Documents/Booster%20Shielding%20Assessment/Booster%20Shielding%20Assessment%20v6%20011717.pdf>
- [12] Main Injector 1500 kW Incremental Shielding Assessment. May 23, 2018.
<https://fermipoint.fnal.gov/org/eshq/sa/Shared%20Documents/Main%20Injector%201500%20kW%20Incremental%20Shielding%20Assessment/MI%201500%20kW%20ISA%20v1.5.pdf>
- [13] Recycler Ring Incremental Shielding Assessment 2.25e17 protons/hour. October 3, 2012.
<https://fermipoint.fnal.gov/org/eshq/sa/Shared%20Documents/Recycler%20Ring%202.25E17%20Shielding%20Assessment/Recycler%20ISA%2010-03-12.pdf>
- [14] Fermilab Security Designations map. <https://news.fnal.gov/wp-content/uploads/site-map.pdf>

Attachment 1 – Linac

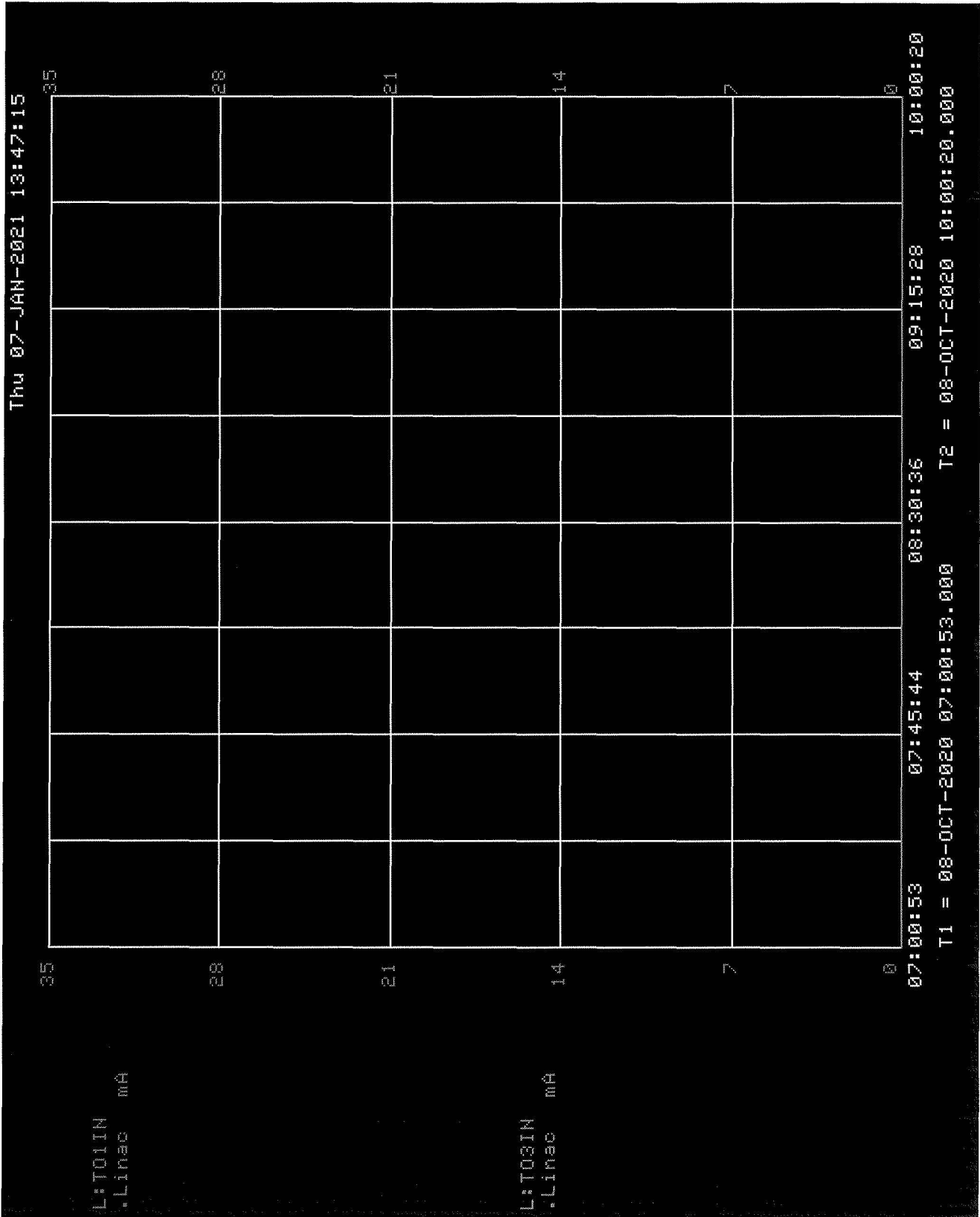
- Background survey including beam intensity plot printout via ACNET
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- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Linac Beam On Survey

Created Oct 7, 2020



All Areas <_NA__ mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u> NA </u> mR/hr@1foot			
Radiation Instruments Used			Comments: Base line survey with beam off. No neutrons dose recorded. Reading were 1 minute Analyst scaler readings			
Inst Type: Analyst	REM500				Bkgd _____ cpm	
Inst No: 33	1				Wipe #	Reading
Batt/Source Chk: Sat	Sat				_____	_____ ccpm
Cal. Due Date: 8/21	10/21				_____	_____ ccpm
Background: See map			_____	_____ ccpm		
LEGEND			Surveyed By: <u>Fulgham/ Delao</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>			
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (R) - Radioactive Material Wipe (#) - Wipe (F) - Floor Wipe			Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.13 16:28:09 -0800			



Linac Beam On Survey

Created Oct 7, 2020

SURVEY POINTS

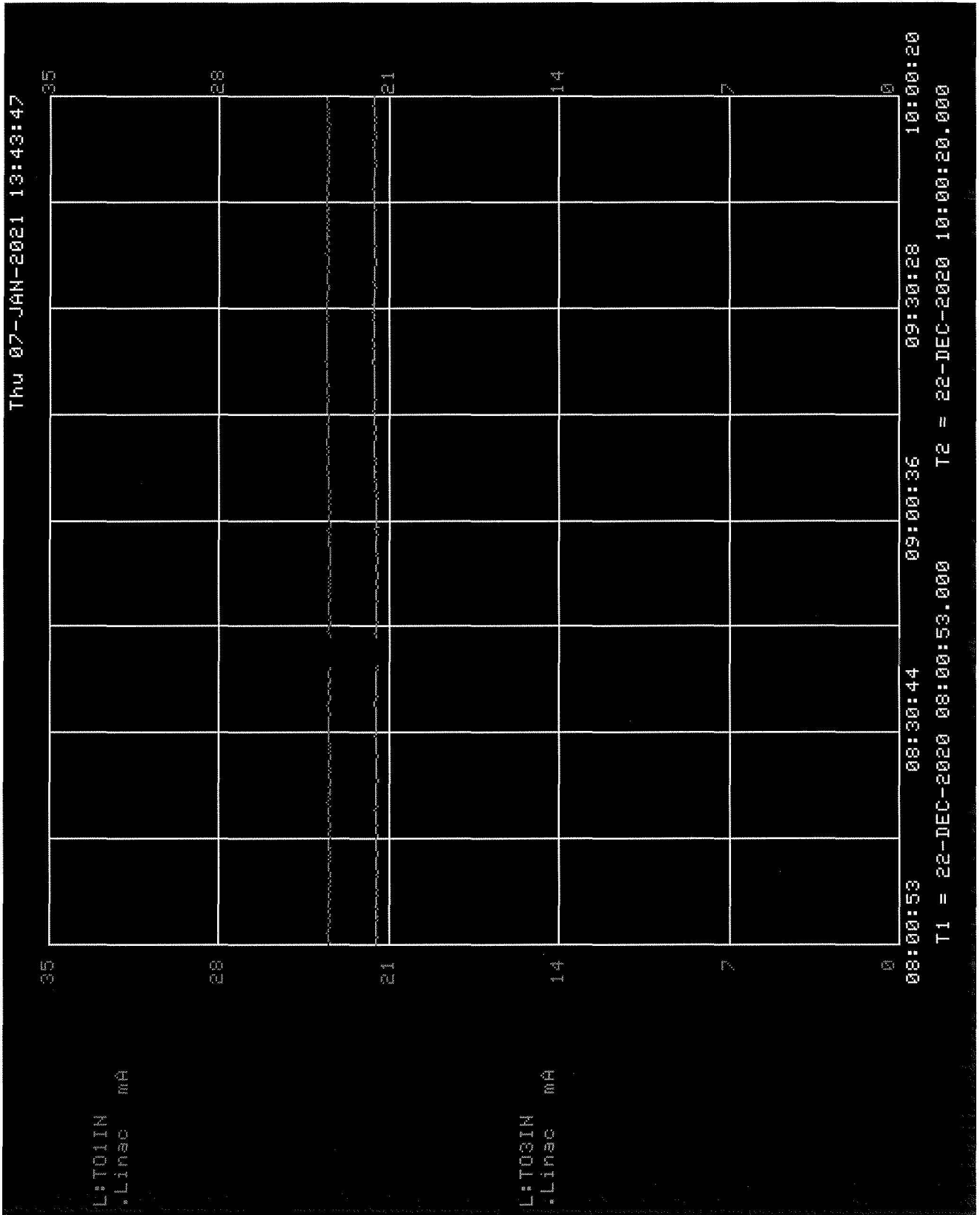
SURVEY POINT #1:	2,525
SURVEY POINT #2:	2,558
SURVEY POINT #3:	2,743
SURVEY POINT #4:	2,724
SURVEY POINT #5:	3,011
SURVEY POINT #6:	2,913
SURVEY POINT #7:	2,844
SURVEY POINT #8:	2,873
SURVEY POINT #9:	2,905
SURVEY POINT #10:	2,906
SURVEY POINT #11:	2,730
SURVEY POINT #12:	2,965
SURVEY POINT #13:	2,374
SURVEY POINT #14:	2,484
SURVEY POINT #15:	2,572
SURVEY POINT #16:	2,159
SURVEY POINT #17:	2,738
SURVEY POINT #18:	3,009



● = "Radiation Area" sign location

Start: 0900 Stop: 0945

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot																									
Radiation Instruments Used			Bkgd _____ cpm																									
Inst Type: <u>Bicron Analyst</u>	<u>REM 500</u>	N/A	Comments:																									
Inst No: <u>#35</u>	<u>#1</u>		A Beam "ON" survey was performed at the perimeter of the Linac berm.																									
Batt/Source Chk: <u>Sat/Sat</u>	<u>Sat/Sat</u>		Beam intensity in Linac was 21 mA.																									
Cal. Due Date: <u>Oct. / 2021</u>	<u>Oct. / 2021</u>		Nothing was detected using the REM 500 instrument.																									
Background: <u>See Map</u>	<u>See Map</u>		<u>Readings were done at one minute integrations using the Bicron instrument scaler.</u>																									
LEGEND			Surveyed By: <u>Jose De La O #4175</u>																									
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material			Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <small>Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.15 16:28:36 -0600</small>																									
Ⓡ - Radioactive Material Wipe Ⓢ - Wipe ⓈF - Floor Wipe																												
			<table border="1"> <tr> <td>Wipe #</td> <td>Reading</td> <td>Wipe #</td> <td>Reading</td> </tr> <tr> <td>_____</td> <td>_____ ccpm</td> <td>_____</td> <td>_____ ccpm</td> </tr> <tr> <td>_____</td> <td>_____ ccpm</td> <td>_____</td> <td>_____ ccpm</td> </tr> <tr> <td>_____</td> <td>_____ ccpm</td> <td>_____</td> <td>_____ ccpm</td> </tr> <tr> <td>_____</td> <td>_____ ccpm</td> <td>_____</td> <td>_____ ccpm</td> </tr> <tr> <td>_____</td> <td>_____ ccpm</td> <td>_____</td> <td>_____ ccpm</td> </tr> </table>		Wipe #	Reading	Wipe #	Reading	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm	_____	_____ ccpm
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Linac

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	2700	2525	-175	72.28	-175 ± 72.28	120.863	244.483
2	2695	2558	-137	72.48	-137 ± 72.48	120.751	244.259
3	2722	2743	21	73.93	21 ± 73.93	121.354	245.466
4	2942	2724	-218	75.27	-218 ± 75.27	126.163	255.086
5	2982	3011	29	77.41	29 ± 77.41	127.017	256.796
6	3028	2913	-115	77.08	-115 ± 77.08	127.993	258.748
7	2908	2844	-64	75.84	-64 ± 75.84	125.432	253.623
8	2870	2873	3	75.78	3 ± 75.78	124.609	251.978
9	2942	2905	-37	76.47	-37 ± 76.47	126.163	255.086
10	2893	2906	13	76.15	13 ± 76.15	125.108	252.975
11	2843	2730	-113	74.65	-113 ± 74.65	124.022	250.803
12	2891	2965	74	76.52	74 ± 76.52	125.064	252.889
13	2562	2374	-188	70.26	-188 ± 70.26	117.733	238.223
14	2229	2484	255	68.65	255 ± 68.65	109.816	222.385
15	2209	2572	363	69.14	363 ± 69.14	109.322	221.397
16	2073	2159	86	65.05	86 ± 65.05	105.903	214.558
17	2159	2738	579	69.98	579 ± 69.98	108.078	218.908
18	2852	3009	157	76.56	157 ± 76.56	124.218	251.195

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.014	0.013	0.000	0.0004	0 ± 0.0004	0.001
0.013	0.013	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.015	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.015	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.015	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.015	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.015	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.013	0.012	0.000	0.0004	0 ± 0.0004	0.001
0.011	0.012	0.001	0.0003	0.001 ± 0.0003	0.001
0.011	0.013	0.002	0.0003	0.002 ± 0.0003	0.001
0.010	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.011	0.014	0.003	0.0003	0.003 ± 0.0003	0.001
0.014	0.015	0.001	0.0004	0.001 ± 0.0004	0.001

Linac

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
17	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
18	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

Linac

Scaling Dose Rates to Linac Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time			Neutron		
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.000	0.000	0	0	0.000	0	0	0
2	0.000	0.000	0	0	0.000	0	0	0
3	0.000	0.000	0	0	0.000	0	0	0
4	0.000	0.000	0	0	0.000	0	0	0
5	0.000	0.000	0	0	0.000	0	0	0
6	0.000	0.000	0	0	0.000	0	0	0
7	0.000	0.000	0	0	0.000	0	0	0
8	0.000	0.000	0	0	0.000	0	0	0
9	0.000	0.000	0	0	0.000	0	0	0
10	0.000	0.000	0	0	0.000	0	0	0
11	0.000	0.000	0	0	0.000	0	0	0
12	0.000	0.000	0	0	0.000	0	0	0
13	0.000	0.000	0	0	0.000	0	0	0
14	0.001	0.000	0.00295	5.9	25.842	0	0	0
15	0.002	0.000	0.0059	11.8	51.684	0	0	0
16	0.000	0.000	0	0	0.000	0	0	0
17	0.003	0.000	0.00885	17.7	77.526	0	0	0
18	0.001	0.000	0.00295	5.9	25.842	0	0	0

Intensities (protons/hr)

Survey Op. Limit

1.20E+17 3.54E+17

Beam Up-Time

Weeks 52
Efficiency 100%

100.0%

Attachment 2 – MeV Test Area (MTA)

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

MTA Beam On Survey

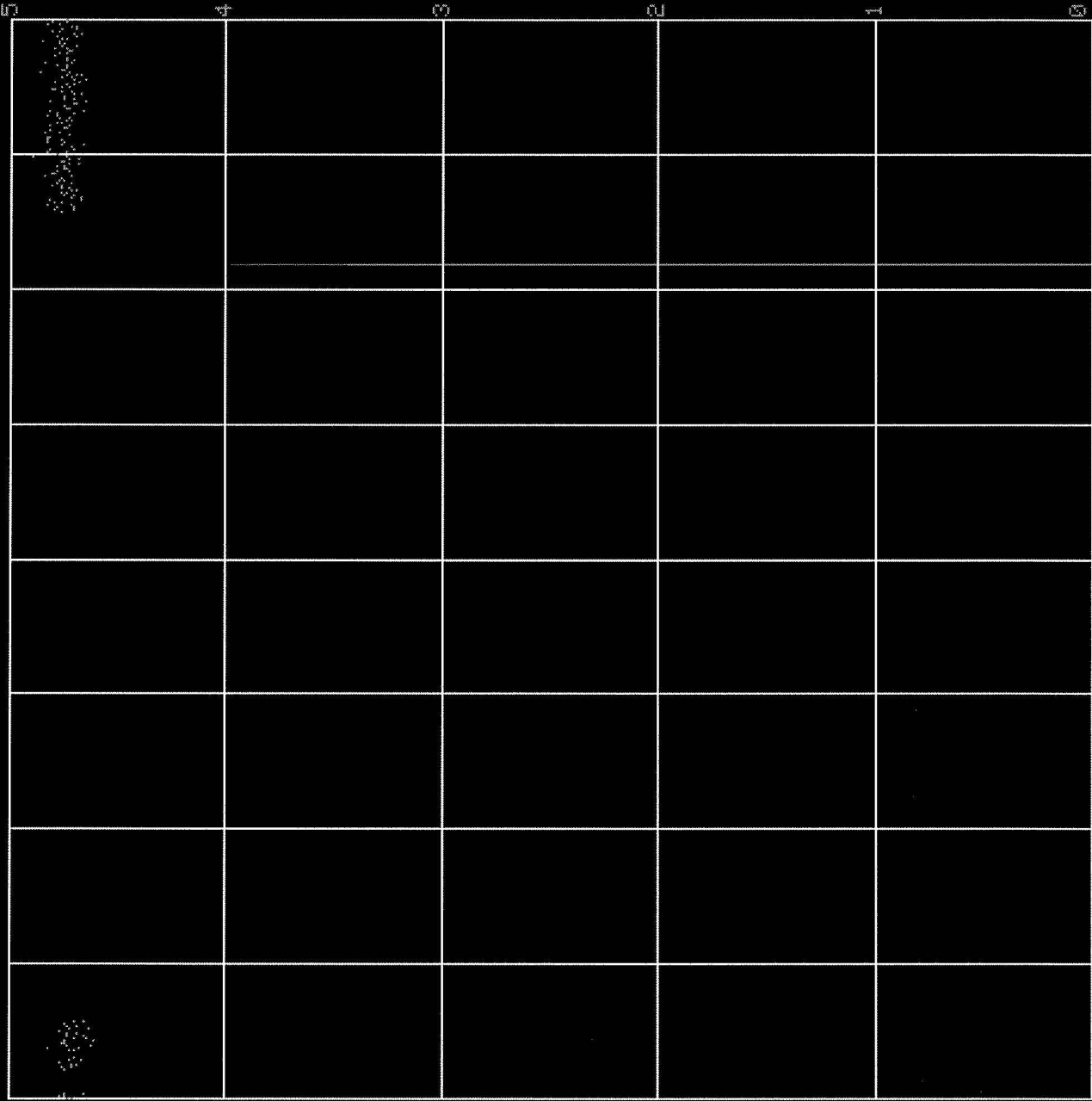
Created Oct 7, 2020

location	Gamma cpm	Neutron mrem/min
1	2903	0
2	2615	0
3	2216	0
4	2254	0
5	2121	0
6	2113	0
7	2793	0



All Areas <_NA___ mR/hr@1foot (Unless otherwise indicated)		Highest Dose Rate Found: _NA___ mR/hr@1foot	
Radiation Instruments Used		Comments: Base line survey with beam off. No neutrons dose recorded. Reading were 1 minute Analyst scaler readings	
Inst Type: <u>Analyst</u>	REM500		
Inst No: <u>26</u>	1		
Batt/Source Chk: <u>Sat</u>	Sat		
Cal. Due Date: <u>5/21</u>	10/21	Surveved By: <u>Fulgham</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>	
Background: <u>See map</u>			
LEGEND		Bkgd _____ cpm	
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material		Wipe # Reading Wipe # Reading _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____	
#R - Radioactive Material Wipe # - Wipe #F - Floor Wipe		Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.02.05 14:31:52 -0600	

Thu 04-FEB-2021 10:44:23



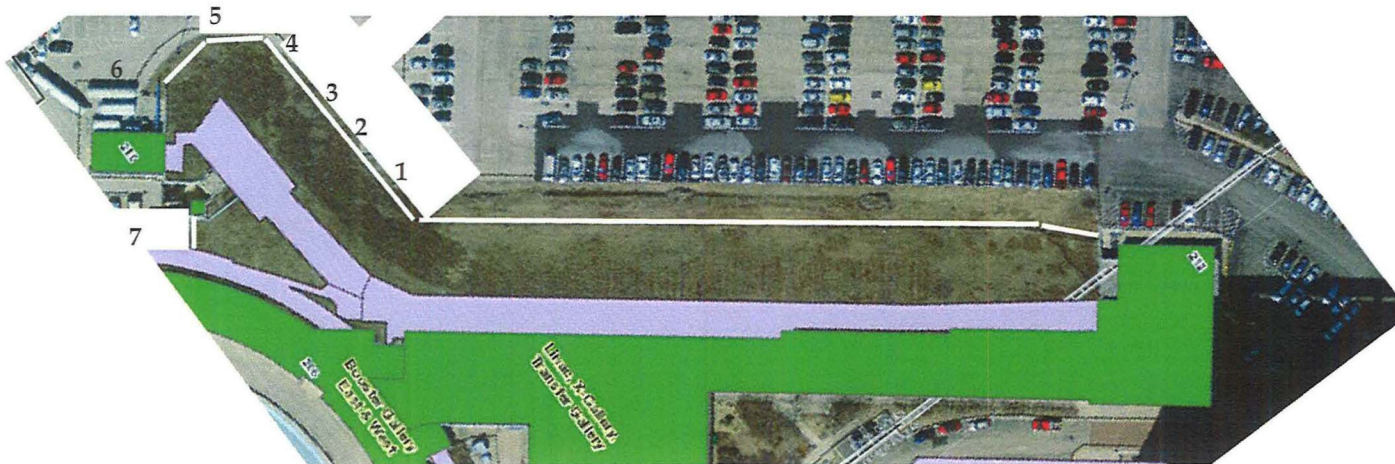
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T1 = 03-FEB-2021 05:00:33.000 T2 = 03-FEB-2021 20:00:33.000

E:UTR01 E12
.MTA

MTA Beam On Survey

Created Oct 7, 2020

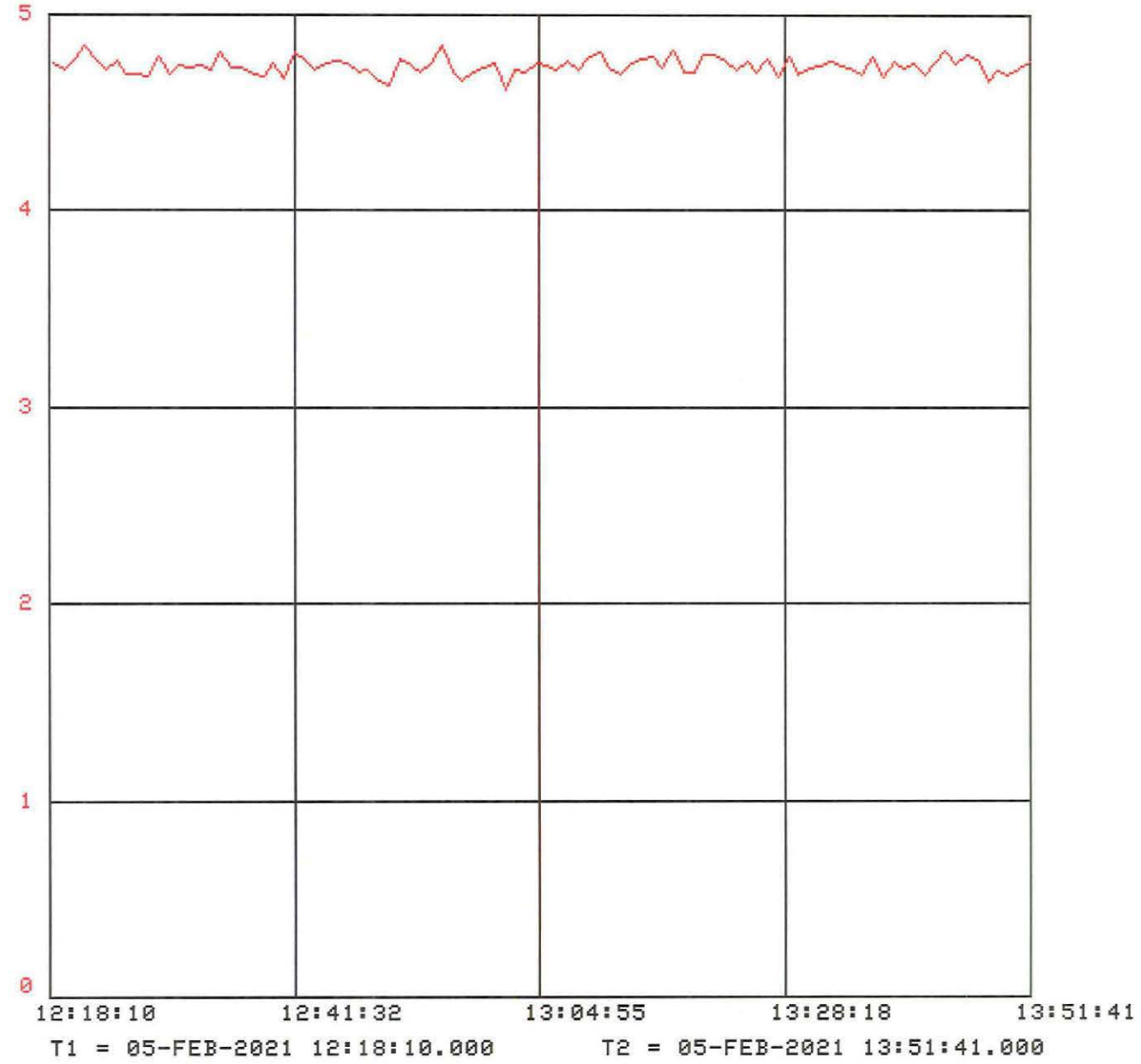
location	Gamma cpm	Neutron mrem/min
1	2606	0
2	2633	0
3	2247	0
4	2194	0
5	2149	0
6	2132	0
7	2697	0



All Areas < <u>NA</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>NA</u> mR/hr@1foot		
Radiation Instruments Used			Comments: Reading were 1 minute integrations readings. Surveyed By: <u>Fulgham</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <div style="font-size: 8px; float: right;">Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.02.05 15:31:10 -06'00'</div>		
Inst Type: <u>Analyst</u>	<u>REM500</u>				
Inst No: <u>26</u>	<u>1</u>				
Batt/Source Chk: <u>Sat</u>	<u>Sat</u>				
Cal. Due Date: <u>5/21</u>	<u>10/21</u>				
Background: <u>See map</u>					
LEGEND			Bkgd _____ cpm Wipe # Reading Wipe # Reading _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm		
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (#R) - Radioactive Material Wipe (#) - Wipe (#F) - Floor Wipe					

Fri 05-FEB-2021 13:52:08

E:UTR01
.MTA E12



MeV Test Area (MTA)

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	2903	2606	-297	74.22	-297 ± 74.22	125.324	253.407
2	2615	2633	18	72.44	18 ± 72.44	118.945	240.647
3	2216	2247	31	66.81	31 ± 66.81	109.495	221.743
4	2254	2194	-60	66.69	-60 ± 66.69	110.430	223.613
5	2121	2149	28	65.35	28 ± 65.35	107.122	216.997
6	2113	2132	19	65.15	19 ± 65.15	106.920	216.592
7	2793	2697	-96	74.09	-96 ± 74.09	122.926	248.612

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.015	0.013	0.000	0.0004	0 ± 0.0004	0.001
0.013	0.013	0.000	0.0004	0 ± 0.0004	0.001
0.011	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.011	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.011	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.011	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.014	0.013	0.000	0.0004	0 ± 0.0004	0.001

MeV Test Area (MTA)

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	$L_{C,N}$	$D_{D,N}$
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

MeV Test Area (MTA)

Scaling Dose Rates to MTA Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	Gamma	Neutron	Gamma			Neutron		
	Net Beam-On (mR/hr)	Net Beam-On (mrem/hr)	Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
1	0.000	0.000	0	0	0.000	0	0	0
2	0.000	0.000	0	0	0.000	0	0	0
3	0.000	0.000	0	0	0.000	0	0	0
4	0.000	0.000	0	0	0.000	0	0	0
5	0.000	0.000	0	0	0.000	0	0	0
6	0.000	0.000	0	0	0.000	0	0	0
7	0.000	0.000	0	0	0.000	0	0	0

Intensities (protons/hr)

Survey Op. Limit

2.80E+14 2.70E+15

Beam Up-Time

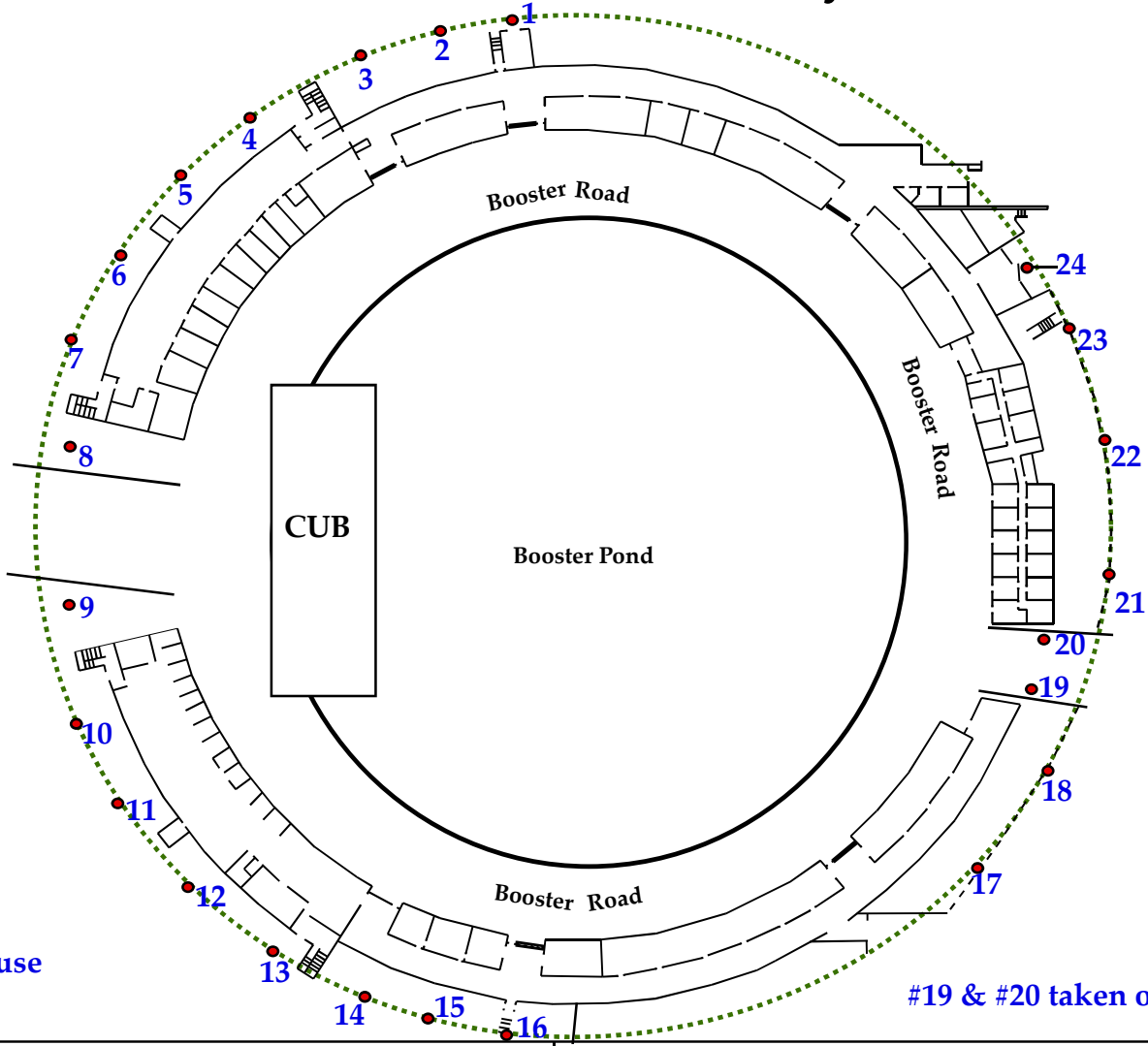
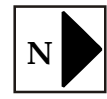
Weeks 52
Efficiency 100%

100.0%

Attachment 3 – Booster

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Booster Beam- On Survey



SURVEY POINTS

SURVEY POINT #1:	1,508
SURVEY POINT #2:	1,207
SURVEY POINT #3:	1,214
SURVEY POINT #4:	2,867
SURVEY POINT #5:	3,055
SURVEY POINT #6:	2,747
SURVEY POINT #7:	2,605
SURVEY POINT #8:	2,319
SURVEY POINT #9:	2,648
SURVEY POINT #10:	2,535
SURVEY POINT #11:	2,503
SURVEY POINT #12:	2,654

SURVEY POINTS

SURVEY POINT #13:	2438
SURVEY POINT #14:	1,588
SURVEY POINT #15:	1,502
SURVEY POINT #16:	1,799
SURVEY POINT #17:	1,699
SURVEY POINT #18:	1,687
SURVEY POINT #19:	1,433
SURVEY POINT #20:	1,380
SURVEY POINT #21:	1,874
SURVEY POINT #22:	1,996
SURVEY POINT #23:	1,796
SURVEY POINT #24:	1,317

#8 & #9 Location of Doghouse

#19 & #20 taken on center of road asphalt

All Areas < NA mR/hr@1foot (Unless otherwise indicated) Highest Dose Rate Found: NA mR/hr@1foot

Radiation Instruments Used			
Inst Type:	Bicron Analyst		
Inst No:	#68		
Batt/Source Chk:	Sat/Sat	N/A	N/A
Cal. Due Date:	Sept. / 2021		
Background:	See Map		

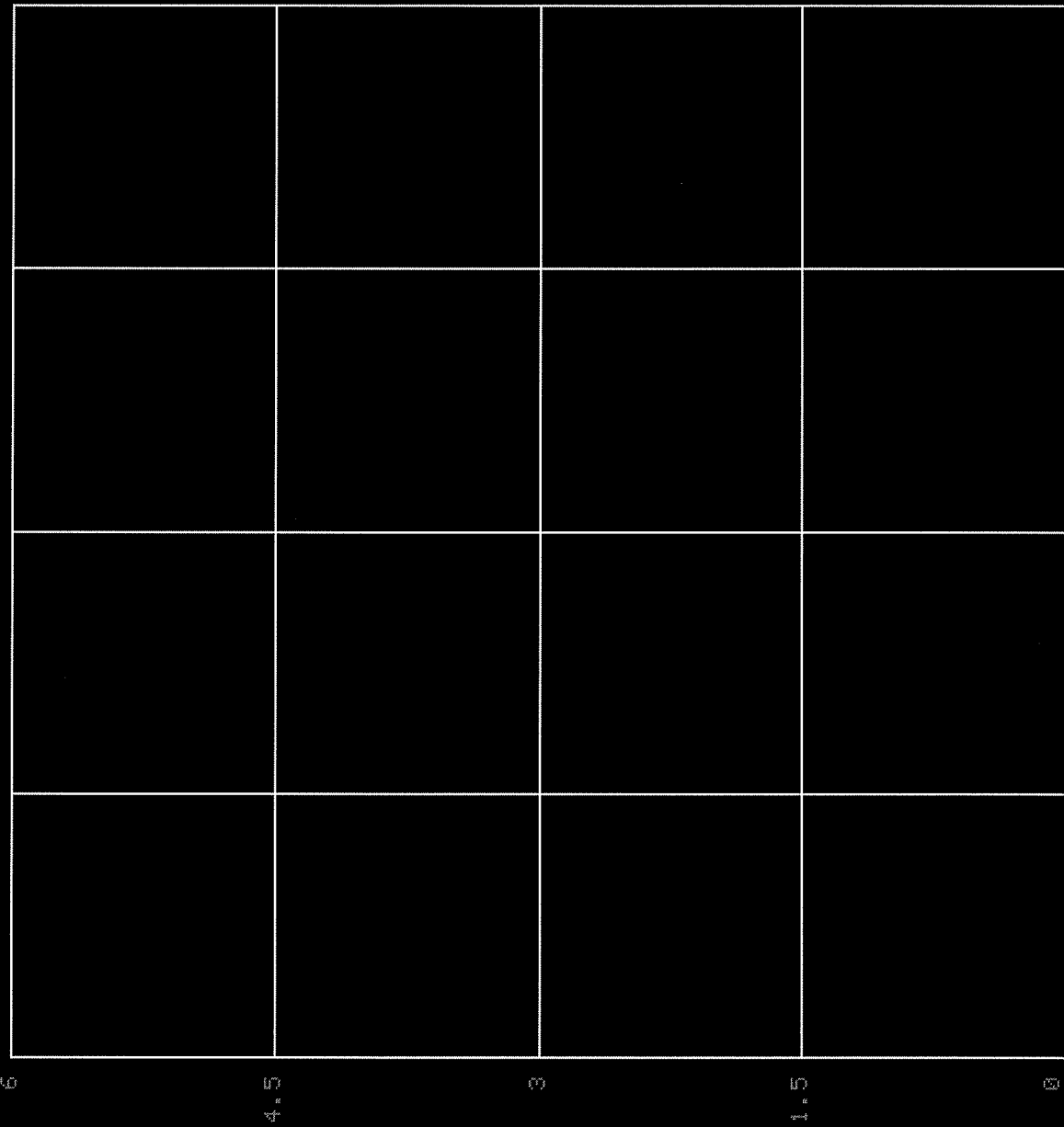
Bkgd _____ cpm			
Wipe #	Reading	Wipe #	Reading
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm

Comments:
 Background survey with beam off. The survey points were taken at roughly the edge of the perimeter (~ 10 feet off the wall) of the Booster Ring building.
 Readings are 1 minute integration using the Analyst scaler
 No neutron background taken due to no neutron source from the beam.

LEGEND
 # - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material
 (R) - Radioactive Material Wipe (W) - Wipe (F) - Floor Wipe

Surveyed By: Jose De La O #4175
 Reviewed By: Maddie Schoell, UID:maddiew
Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.02.02 11:05:59 -06'00'

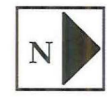
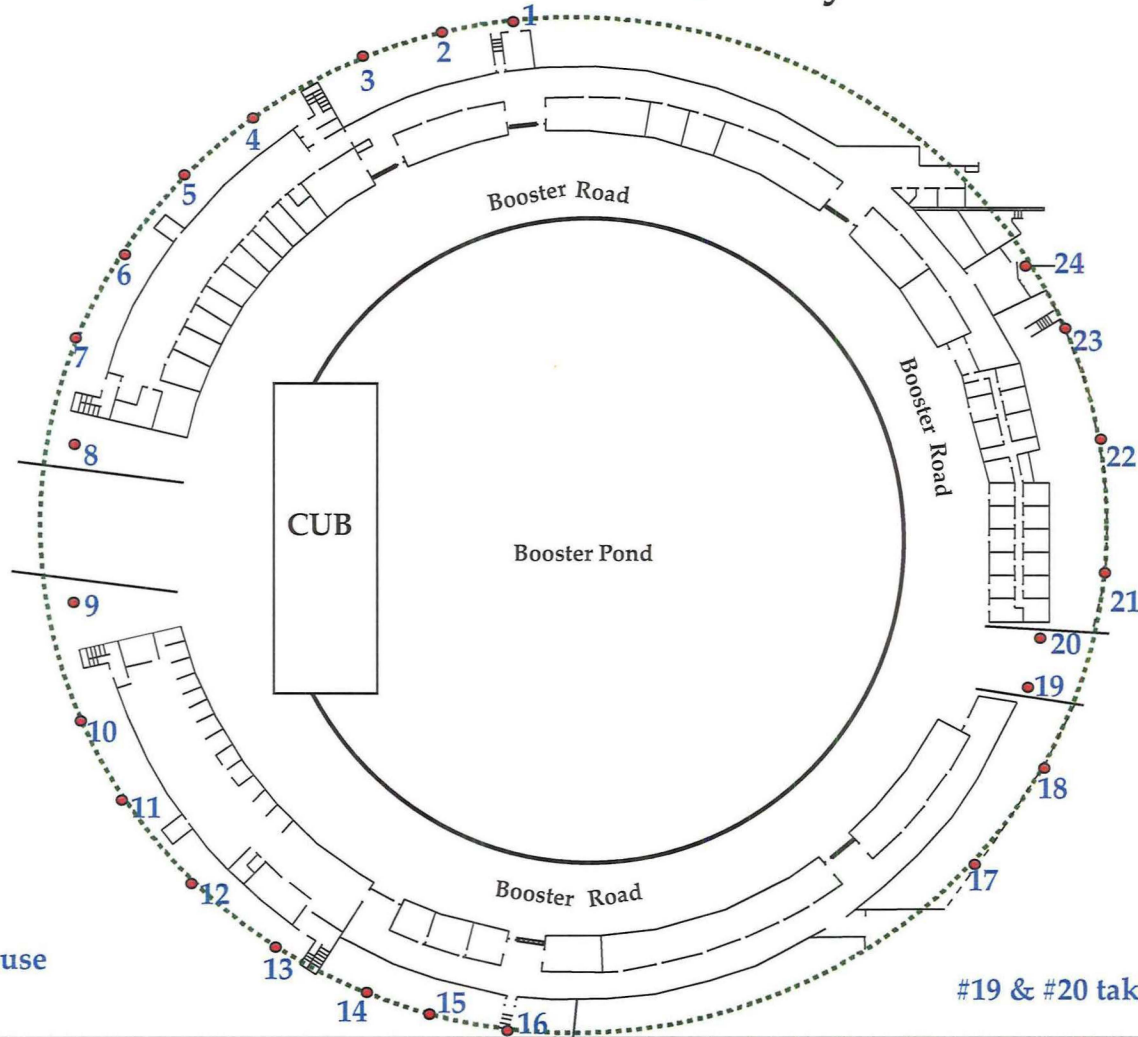
Thu 07-JAN-2021 14:03:29



B:CHGBBM
Dsafty E12

12:00:53 12:45:44 13:30:36 14:15:28 15:00:20
T1 = 09-OCT-2020 12:00:53.000 T2 = 09-OCT-2020 15:00:20.000

Booster Beam- On Survey



SURVEY POINTS	
SURVEY POINT #1:	1,555
SURVEY POINT #2:	1,500
SURVEY POINT #3:	1,544
SURVEY POINT #4:	3,226
SURVEY POINT #5:	2,973
SURVEY POINT #6:	3,092
SURVEY POINT #7:	2,760
SURVEY POINT #8:	3,328
SURVEY POINT #9:	2,701
SURVEY POINT #10:	2,703
SURVEY POINT #11:	3,030
SURVEY POINT #12:	3,463

SURVEY POINTS	
SURVEY POINT #13:	2,812
SURVEY POINT #14:	1,601
SURVEY POINT #15:	1,626
SURVEY POINT #16:	1,879
SURVEY POINT #17:	2,174
SURVEY POINT #18:	2,456
SURVEY POINT #19:	1,587
SURVEY POINT #20:	1,698
SURVEY POINT #21:	2,414
SURVEY POINT #22:	2,498
SURVEY POINT #23:	2,473
SURVEY POINT #24:	1,442

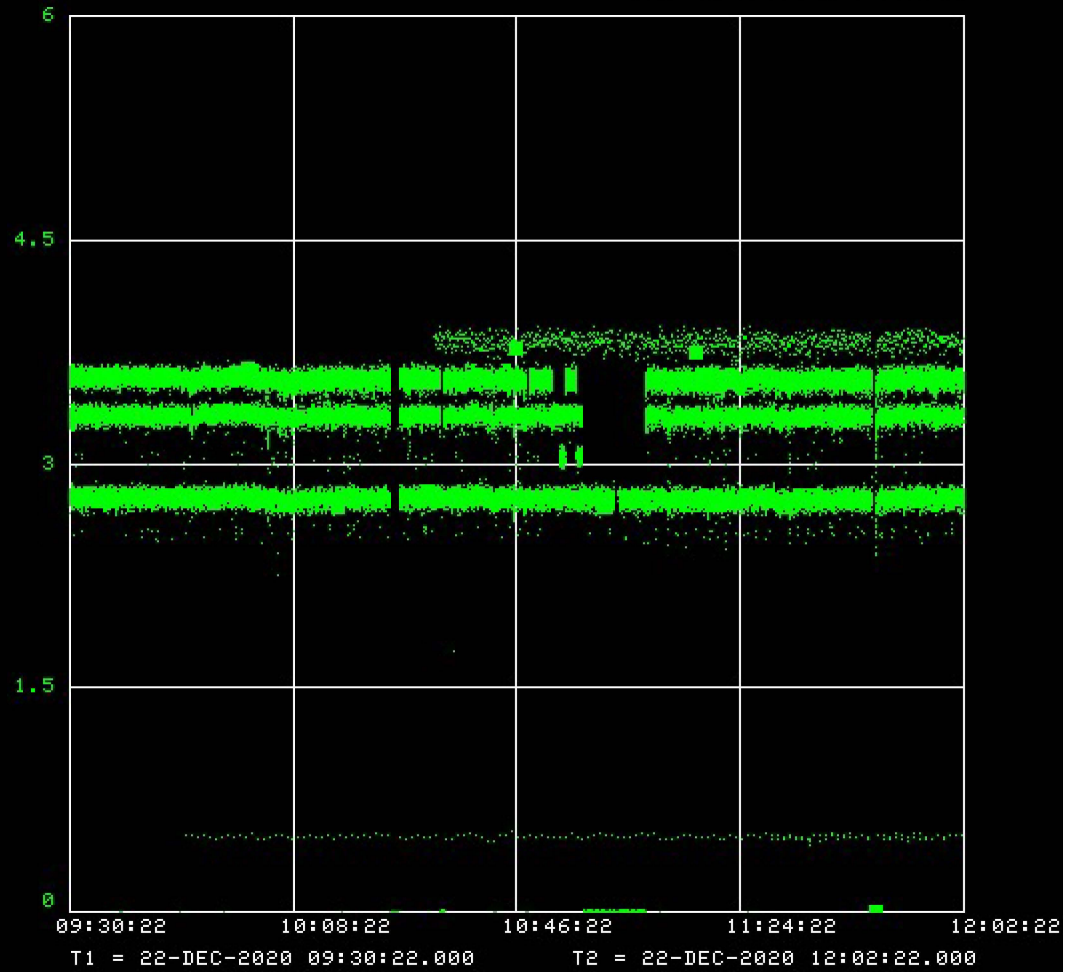
#8 & #9 Location of Doghouse

#19 & #20 taken on center of road asphalt

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot			
Radiation Instruments Used			Bkgd _____ cpm			
Inst Type: <u>Bicron Analyst</u>	<u>REM 500</u>	N/A	Wipe #	Reading	Wipe #	Reading
Inst No: <u>#35</u>	<u>#1</u>		_____	_____	_____	_____
Batt/Source Chk: <u>Sat/Sat</u>	<u>Sat/Sat</u>		_____	_____	_____	_____
Cal. Due Date: <u>Oct. / 2021</u>	<u>Oct. / 2021</u>		_____	_____	_____	_____
Background: <u>See Map</u>	<u>See Map</u>		_____	_____	_____	_____
LEGEND			Comments:			
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material			A Beam "ON" survey was performed at the perimeter Booster ring			
Ⓡ - Radioactive Material Wipe Ⓢ - Wipe ⓈF - Floor Wipe			Beam intensity in Linac was 21 mA. Nothing was detected using the REM 500 meter.			
			Readings were taken at one minute integrations using the Bicron instrument scaler and 1 minute reading with the Rem 500.			
			Surveyed By: <u>Jose De La O #4175</u>			
			Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <small>Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.19 16:52:21 -0600</small>			

Wed 20-JAN-2021 07:09:46

B:CHGBBM
DInst1 E12



Booster

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1508	1555	47	55.34	47 ± 55.34	90.326	183.396
2	1207	1500	293	52.03	293 ± 52.03	80.810 !	164.360
3	1214	1544	330	52.52	330 ± 52.52	81.044 !	164.828
4	2876	3226	350	78.12	350 ± 78.12	124.740 !	252.239
5	3055	2973	-82	77.64	-82 ± 77.64	128.563	259.887
6	2747	3092	345	76.41	345 ± 76.41	121.910 !	246.578
7	2605	2760	155	73.25	155 ± 73.25	118.717 !	240.191
8	2319	3328	1009	75.15	1009 ± 75.15	112.011 !	226.776
9	2684	2701	17	73.38	17 ± 73.38	120.504	243.766
10	2535	2703	168	72.37	168 ± 72.37	117.111 !	236.979
11	2503	3030	527	74.38	527 ± 74.38	116.370 !	235.496
12	2654	3463	809	78.21	809 ± 78.21	119.829 !	242.415
13	2438	2812	374	72.46	374 ± 72.46	114.849 !	232.453
14	1588	1601	13	56.47	13 ± 56.47	92.690	188.127
15	1502	1626	124	55.93	124 ± 55.93	90.146 !	183.036
16	1799	1879	80	60.65	80 ± 60.65	98.656	200.061
17	1699	2174	475	62.23	475 ± 62.23	95.875 !	194.498
18	1687	2456	769	64.37	769 ± 64.37	95.536 !	193.819
19	1433	1587	154	54.95	154 ± 54.95	88.051 !	178.845
20	1380	1698	318	55.48	318 ± 55.48	86.407 !	175.557
21	1874	2414	540	65.48	540 ± 65.48	100.692 !	204.133
22	1996	2498	502	67.04	502 ± 67.04	103.918 !	210.586
23	1796	2473	677	65.34	677 ± 65.34	98.574 !	199.897
24	1317	1442	125	52.53	125 ± 52.53	84.412 !	171.566

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.008	0.008	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.006	0.008	0.002	0.0003	0.002 ± 0.0003	0.001
0.014	0.016	0.002	0.0004	0.002 ± 0.0004	0.001
0.015	0.015	0.000	0.0004	0 ± 0.0004	0.001
0.014	0.015	0.002	0.0004	0.002 ± 0.0004	0.001
0.013	0.014	0.001	0.0004	0.001 ± 0.0004	0.001
0.012	0.017	0.005	0.0004	0.005 ± 0.0004	0.001
0.013	0.014	0.000	0.0004	0 ± 0.0004	0.001
0.013	0.014	0.001	0.0004	0.001 ± 0.0004	0.001
0.013	0.015	0.003	0.0004	0.003 ± 0.0004	0.001
0.013	0.017	0.004	0.0004	0.004 ± 0.0004	0.001
0.012	0.014	0.002	0.0004	0.002 ± 0.0004	0.001
0.008	0.008	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.009	0.009	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.011	0.002	0.0003	0.002 ± 0.0003	0.001
0.008	0.012	0.004	0.0003	0.004 ± 0.0003	0.001
0.007	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.007	0.008	0.002	0.0003	0.002 ± 0.0003	0.001
0.009	0.012	0.003	0.0003	0.003 ± 0.0003	0.001
0.010	0.012	0.003	0.0003	0.003 ± 0.0003	0.001
0.009	0.012	0.003	0.0003	0.003 ± 0.0003	0.001
0.007	0.007	0.001	0.0003	0.001 ± 0.0003	0.001

Booster

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net ± St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
17	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
18	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
19	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
20	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
21	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
22	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
23	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
24	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04

Booster

Scaling Dose Rates to Booster Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0.000	0	0
2	0.001	0.000	0.002	4.500	19.710	0.000	0	0
3	0.002	0.000	0.005	9.000	39.420	0.000	0	0
4	0.002	0.000	0.005	9.000	39.420	0.000	0	0
5	0.000	0.000	0.000	0.000	0.000	0.000	0	0
6	0.002	0.000	0.005	9.000	39.420	0.000	0	0
7	0.001	0.000	0.002	4.500	19.710	0.000	0	0
8	0.005	0.000	0.011	22.500	98.550	0.000	0	0
9	0.000	0.000	0.000	0.000	0.000	0.000	0	0
10	0.001	0.000	0.002	4.500	19.710	0.000	0	0
11	0.003	0.000	0.007	13.500	59.130	0.000	0	0
12	0.004	0.000	0.009	18.000	78.840	0.000	0	0
13	0.002	0.000	0.005	9.000	39.420	0.000	0	0
14	0.000	0.000	0.000	0.000	0.000	0.000	0	0
15	0.001	0.000	0.002	4.500	19.710	0.000	0	0
16	0.000	0.000	0.000	0.000	0.000	0.000	0	0
17	0.002	0.000	0.005	9.000	39.420	0.000	0	0
18	0.004	0.000	0.009	18.000	78.840	0.000	0	0
19	0.001	0.000	0.002	4.500	19.710	0.000	0	0
20	0.002	0.000	0.005	9.000	39.420	0.000	0	0
21	0.003	0.000	0.007	13.500	59.130	0.000	0	0
22	0.003	0.000	0.007	13.500	59.130	0.000	0	0
23	0.003	0.000	0.007	13.500	59.130	0.000	0	0
24	0.001	0.000	0.002	4.500	19.710	0.000	0	0

Intensities (protons/hr)		Beam Up-Time	
Survey	Op. Limit	# Weeks	Efficiency
1.20E+17	2.70E+17	52	100%
		100.0%	

Attachment 4 – 8 GeV, Including Booster Neutrino Beam (BNB)

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

8 GeV/MI12 Lines Beam On Survey

Created Oct 23, 2020



location	Gamma cpm	Neutron mrem/min
1	1180	N/A
2	1436	
3	1284	
4	1251	
5	1311	
6	1333	
7	1290	
8	1325	
9	911	
10	967	
11	1199	
12	1298	
13	1030	
14	1340	
15	1303	
16	1039	

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)				Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot			
Radiation Instruments Used				Bkgd _____ cpm			
Inst Type: <u>Analyst</u>				Wipe #		Reading	
Inst No: <u>26</u>				_____		_____ ccpm	
Batt/Source Chk: <u>SAT</u>				_____		_____ ccpm	
Cal. Due Date: <u>5-21</u>				_____		_____ ccpm	
Background: <u>N/A</u>				_____		_____ ccpm	
LEGEND							
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material							
#R - Radioactive Material Wipe		# - Wipe		#F - Floor Wipe			
				Comments: <u>Survey done using 1min integration on Analyst Scatter</u> <u>No neutron background taken due to no source from the beam</u>			
				Surveyed By: <u>Fulham</u>			
				Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <small>Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.25.14:19:10 -0600</small>			

Thu 07-JAN-2021 14:49:20

1.E+17

7.E+16

5.E+16

2.E+16

0

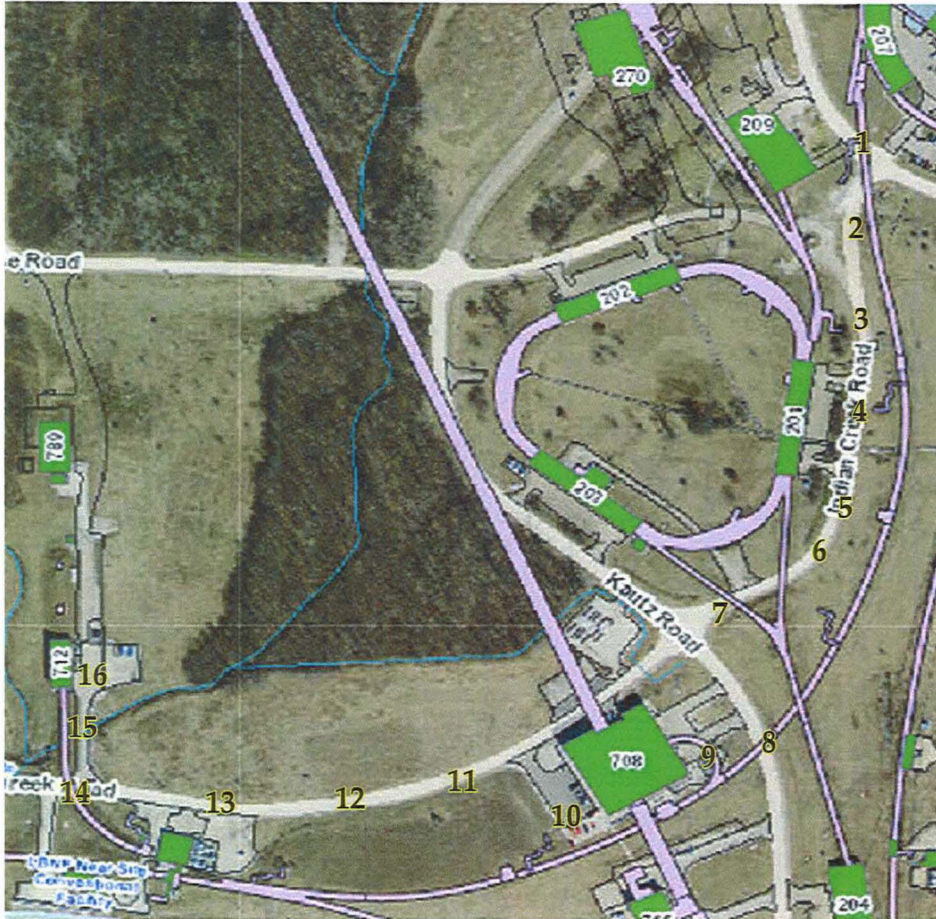
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T1 = 17-NOV-2020 12:00:30.000 T2 = 17-NOV-2020 15:00:53.000

E:MBRATE
.MBoon p/hr

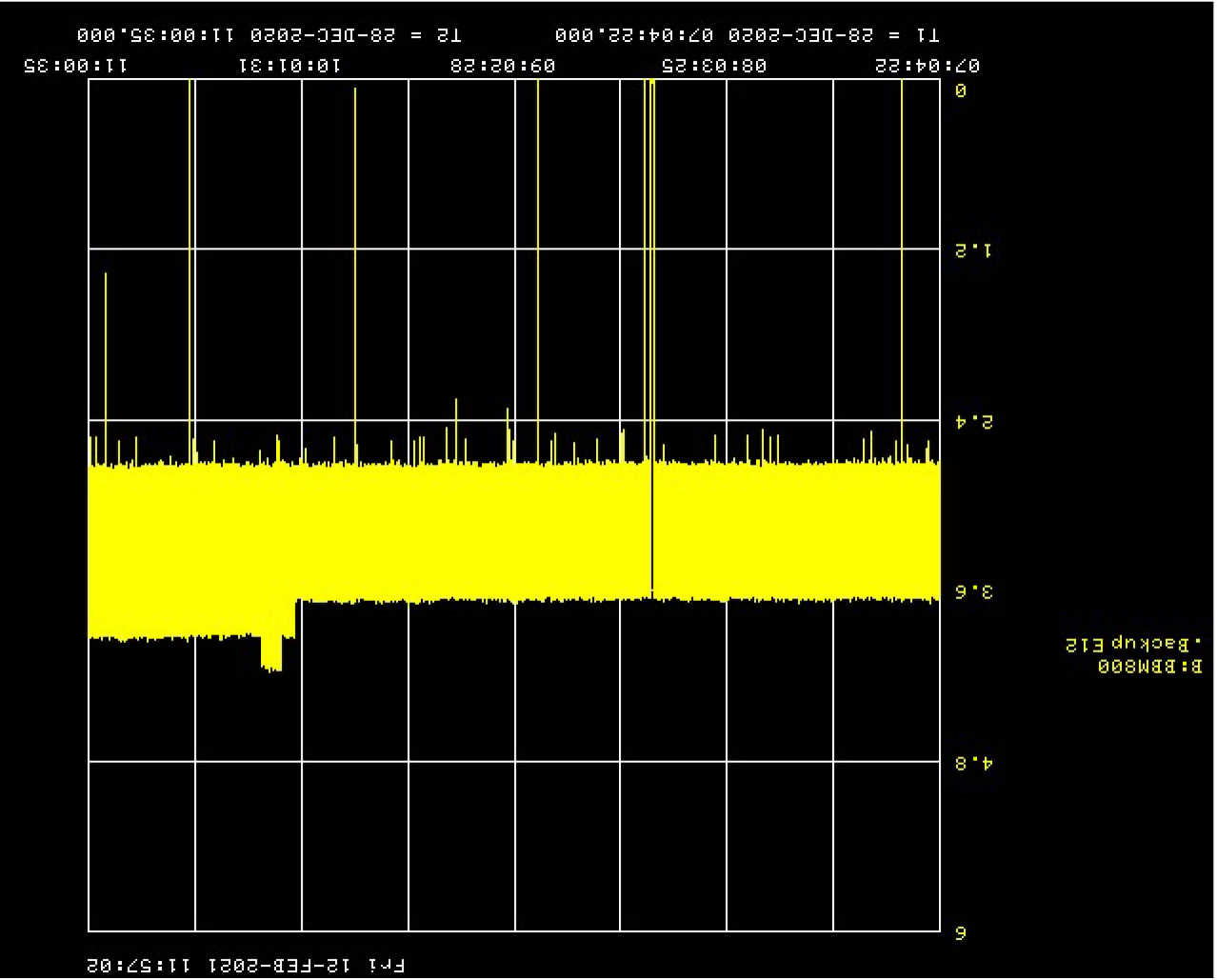
8 GeV/MI12 Lines Beam On Survey

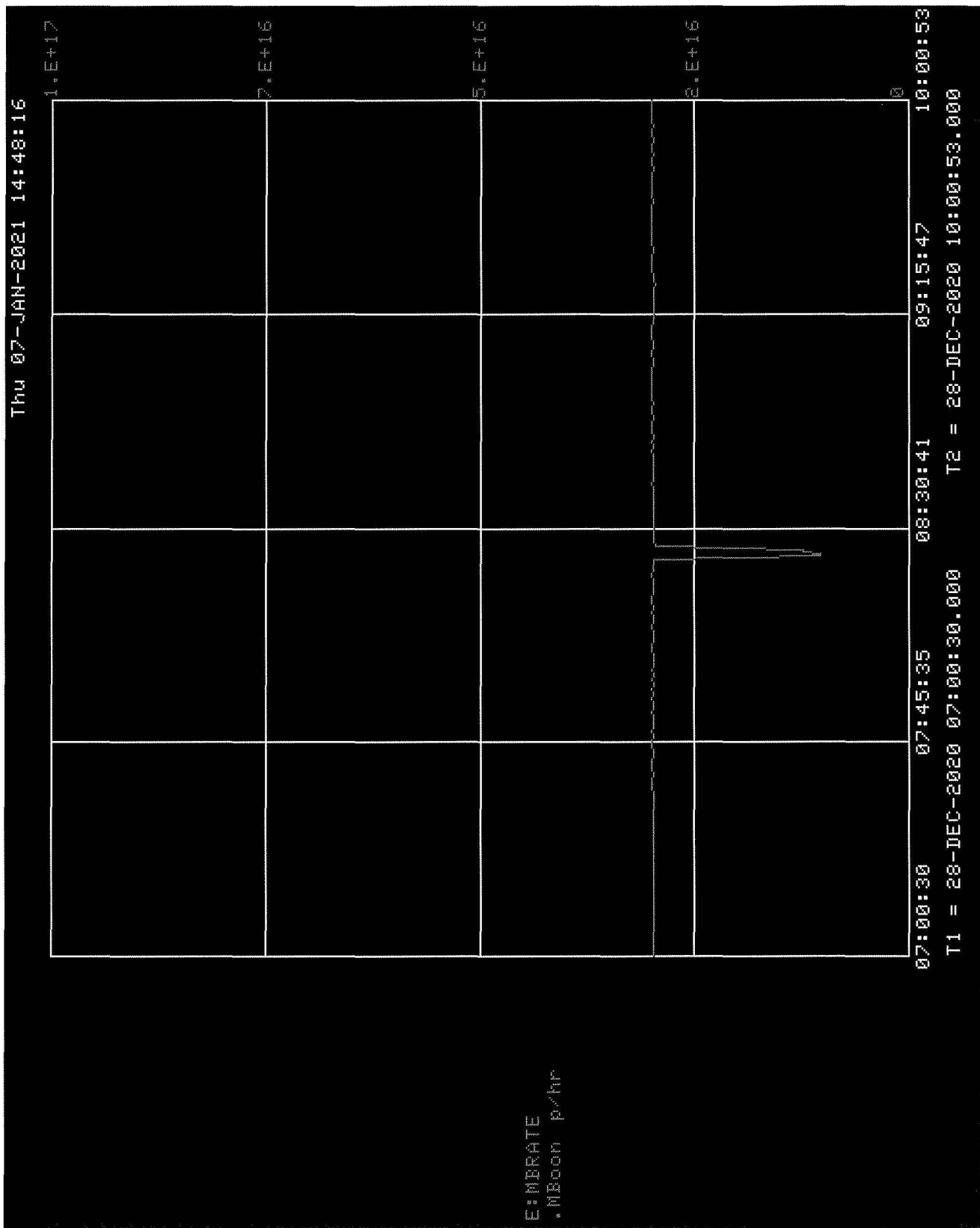
Created Oct 23, 2020



location	Gamma cpm	Neutron mrem/min
1	1110	0
2	1083	0
3	1120	0
4	1147	0
5	1166	0
6	1231	0
7	1275	0
8	1810	0
9	1433	0
10	1192	0
11	1189	0
12	1129	0
13	1201	0
14	1266	0
15	1279	0
16	3054	0

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot		
Radiation Instruments Used			Bkgd _____ cpm Comments: Survey completed using 1min integration Analyst scaler and the REM 500		
Inst Type: <u>Analyst</u>	<u>REM 500</u>				
Inst No: <u>26</u>	<u>1</u>				
Batt/Source Chk: <u>SAT</u>	<u>SAT</u>				
Cal. Due Date: <u>5-21</u>	<u>10-21</u>				
Background: <u>N/A</u>	<u>N/A</u>				
Wipe Tests			Wipe # Reading Wipe # Reading _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm		
LEGEND			Surveyed By: <u>Fulgiam</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>		
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (R) - Radioactive Material Wipe (#) - Wipe (F) - Floor Wipe					





8 GeV Line

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1180	1110	-70	47.85	-70 ± 47.85	79.901	162.542
2	1436	1083	-353	50.19	-353 ± 50.19	88.143	179.030
3	1284	1120	-164	49.03	-164 ± 49.03	83.347	169.437
4	1251	1147	-104	48.97	-104 ± 48.97	82.269	167.280
5	1311	1166	-145	49.77	-145 ± 49.77	84.219	171.181
6	1333	1231	-102	50.64	-102 ± 50.64	84.923	172.588
7	1290	1275	-15	50.65	-15 ± 50.65	83.542	169.826
8	1325	1810	485	55.99	485 ± 55.99	84.668 !	172.078
9	911	1433	522	48.41	522 ± 48.41	70.205 !	143.146
10	967	1192	225	46.47	225 ± 46.47	72.331 !	147.399
11	1199	1189	-10	48.87	-10 ± 48.87	80.541	163.823
12	1298	1129	-169	49.26	-169 ± 49.26	83.801	170.343
13	1030	1201	171	47.23	171 ± 47.23	74.650 !	152.038
14	1340	1266	-74	51.05	-74 ± 51.05	85.146	173.034
15	1303	1279	-24	50.81	-24 ± 50.81	83.962	170.666
16	1039	3054	2015	63.98	2015 ± 63.98	74.975 !	152.689

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.005	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.009	0.002	0.0003	0.002 ± 0.0003	0.001
0.005	0.007	0.003	0.0002	0.003 ± 0.0002	0.001
0.005	0.006	0.001	0.0002	0.001 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.006	0.001	0.0002	0.001 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.005	0.015	0.010	0.0003	0.01 ± 0.0003	0.001

8 GeV Line

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

8 GeV Line - 8 GeV Locations

Scaling Dose Rates to 8 GeV Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma			Neutron		
			Net Beam- On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam- On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.000	0.000	0.000	0.000	0.000	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.000	0.000	0.000	0.000	0.000	0	0	0
7	0.000	0.000	0.000	0.000	0.000	0	0	0
8	0.002	0.000	0.003	6.311	27.643	0	0	0
9	0.003	0.000	0.005	9.467	41.464	0	0	0
10	0.001	0.000	0.002	3.156	13.821	0	0	0
11	0.000	0.000	0.000	0.000	0.000	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.001	0.000	0.002	3.156	13.821	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
1.80E+17	2.84E+17

Beam Up-Time	
# Weeks	52
Efficiency	100%
100.0%	

8 GeV Line - Booster Neutrino Beam (BNB Locations)

Scaling Dose Rates to BNB Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
13	0.001	0.000	0.005	10.983	48.106	0	0	0
14	0.000	0.000	0.000	0.000	0.000	0	0	0
15	0.000	0.000	0.000	0.000	0.000	0	0	0
16	0.010	0.000	0.055	109.831	481.058	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
2.95E+16	1.62E+17

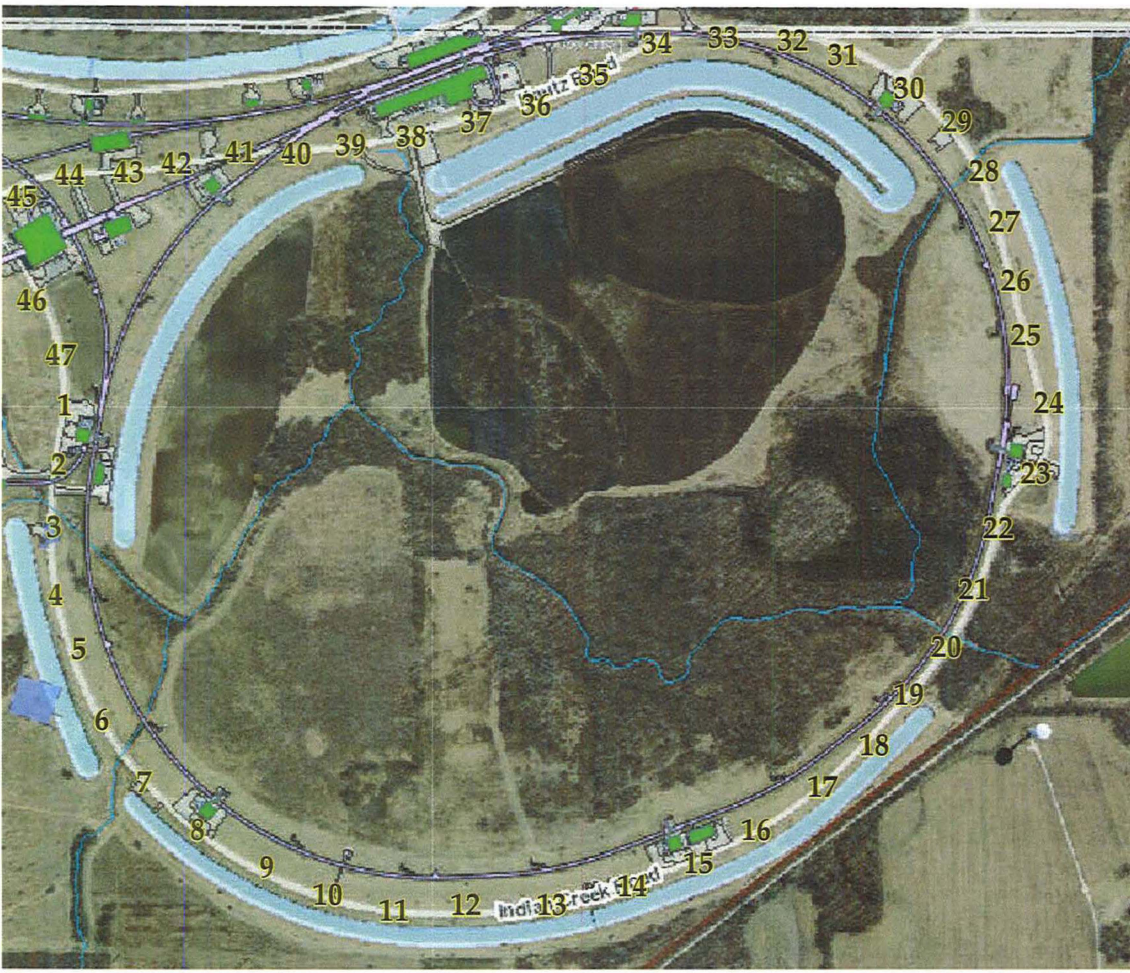
Beam Up-Time	
# Weeks	52
Efficiency	100%
100.0%	

Attachment 5 – Main Injector (MI) & Recycler (RR), Including NuMI

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Mn Inj Beam On Survey

Created Oct 23, 2020



location	Gamma cpm	Neutron mrem/min	location	Gamma cpm	Neutron mrem/min
1	1030	N/A	26	1221	N/A
2	1340		27	1217	
3	closed construction		28	1153	
4			29	1172	
5			30	1050	
6			31	1142	
7			32	1063	
8			33	1043	
9	1501		34	1049	
10	1465		35	1136	
11	1323		36	1145	
12	1350		37	1097	
13	1440		38	1212	
14	1331		39	1269	
15	1158		40	1157	
16	1208		41	1138	
17	1349		42	1268	
18	1251		43	1135	
19	1351		44	1146	
20	1299		45	911	
21	1270		46	1119	
22	1210		47	1298	
23	1019				
24	1218				
25	1207				

All Areas < N/A mR/hr@1foot (Unless otherwise indicated)

Highest Dose Rate Found: N/A mR/hr@1foot

Radiation Instruments Used		
Inst Type:	Analyst	Analyst
Inst No:	26	68
Batt/Source Chk:	SAT	SAT
Cal. Due Date:	5-21	5-21
Background:	N/A	N/A

Bkgd _____ cpm			
Wipe #	Reading	Wipe #	Reading
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm
_____	_____ ccpm	_____	_____ ccpm

Comments:
 survey complete using 1 min integration on the Analyst scater
 No neutron background taken due to no source from the beam

LEGEND
 # - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material
 (R) - Radioactive Material Wipe (#) - Wipe (F) - Floor Wipe

Surveyed By: Fulgheri/Deloo
 Reviewed By: Maddie Schoell, UID:maddiew
Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.25 14:25:38 -0600

Thu 07-JAN-2021 15:13:25

12:00:30 12:53:05 13:45:41 14:38:17 15:30:53

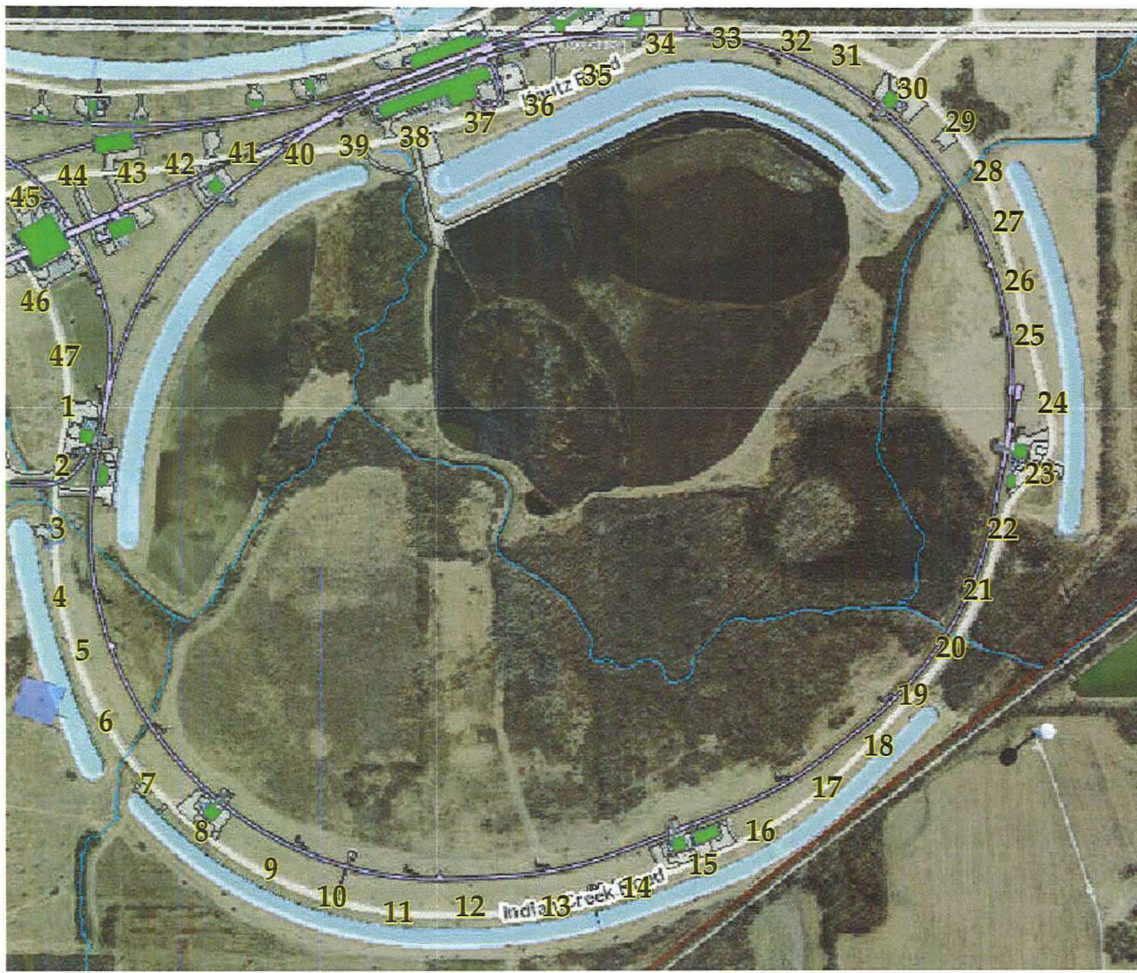
T1 = 17-NOV-2020 12:00:30.000 T2 = 17-NOV-2020 15:30:53.000

R:TOR003
*BOLK E12

R:TOR003
*BOLK E12

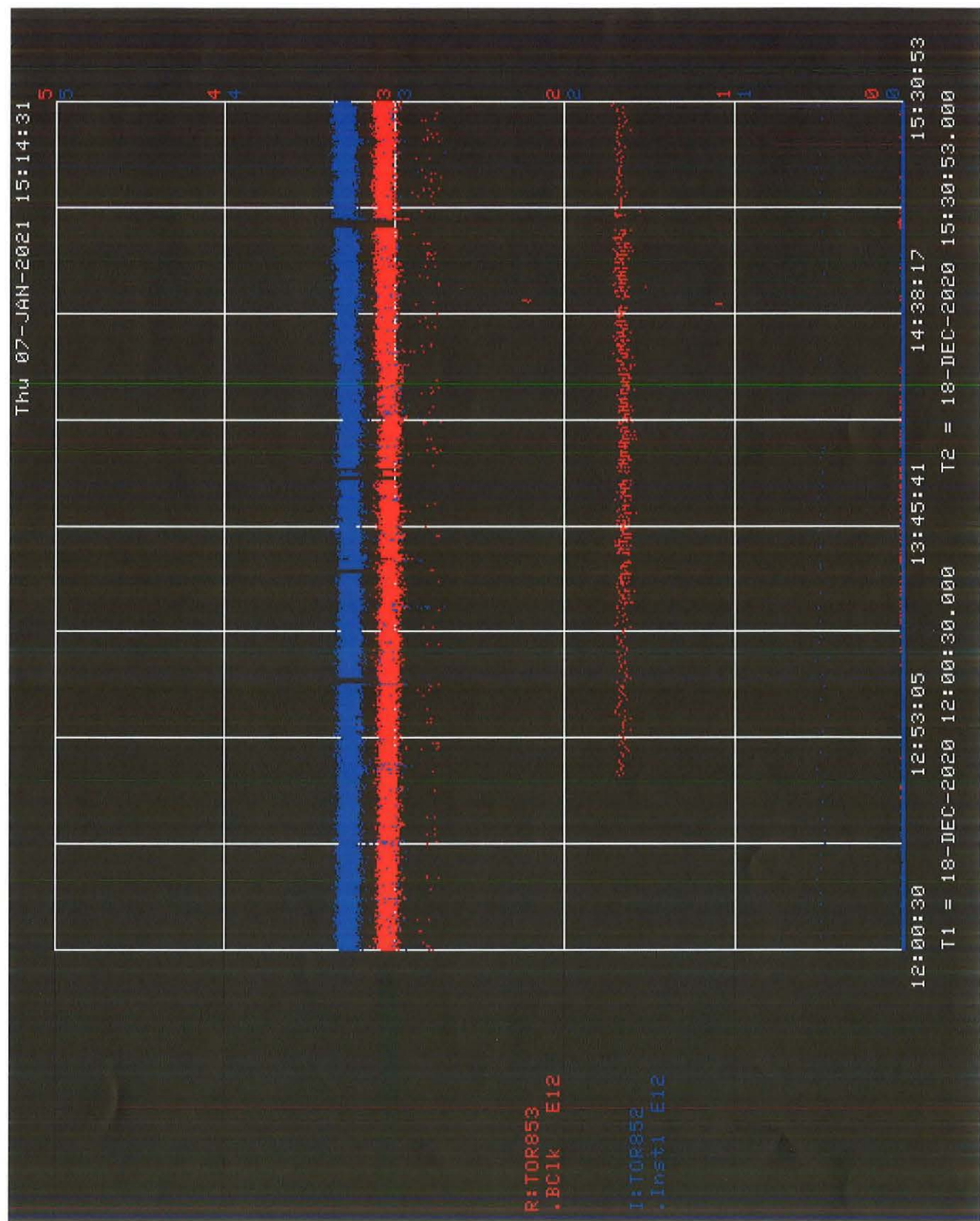
Mn Inj Beam On Survey

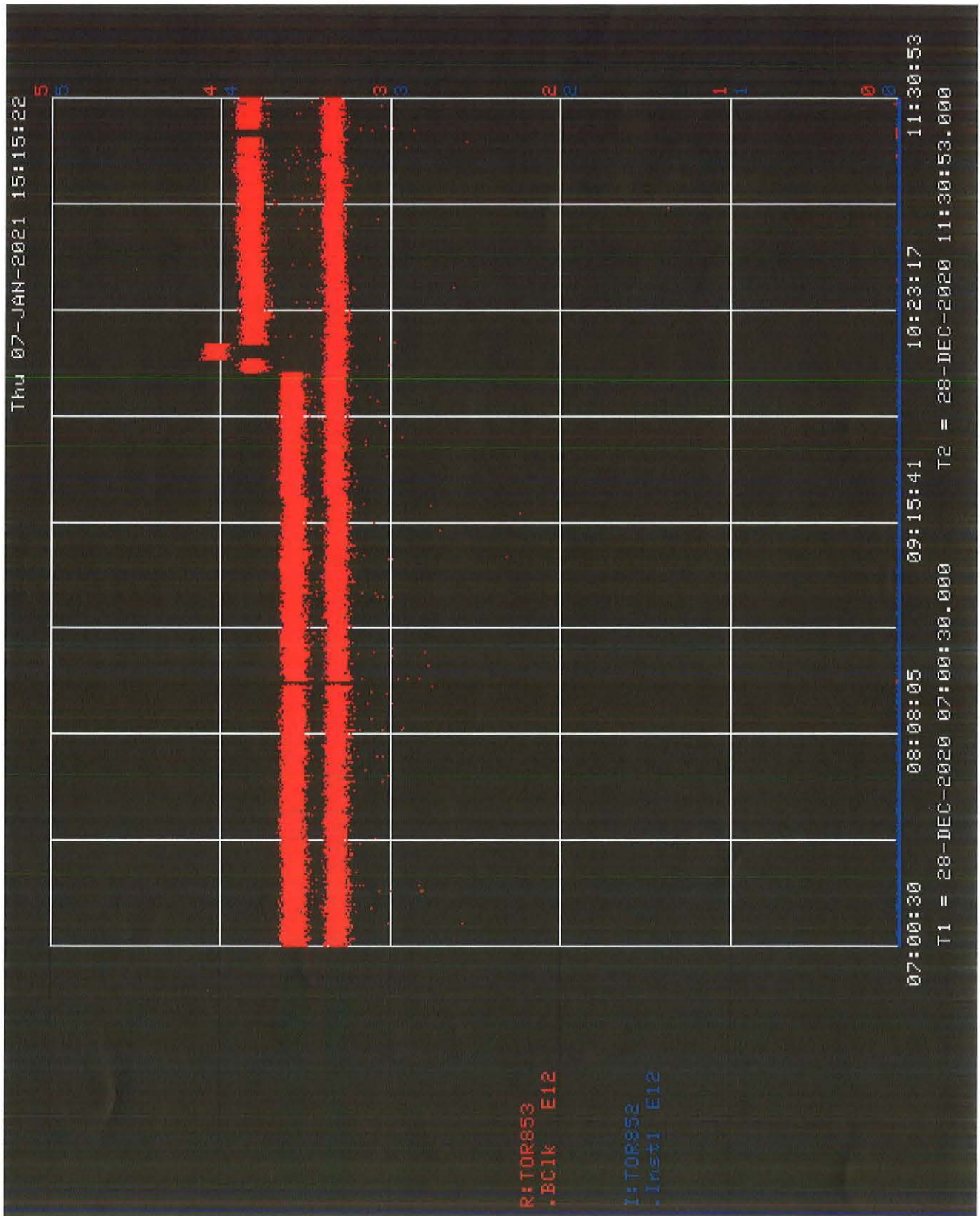
Created Oct 23, 2020



location	Gamma cpm	Neutron mrem/min	location	Gamma cpm	Neutron mrem/min
1	1219	0	26	1091	0
2	1129	0	27	1108	0
3	1135	0	28	1120	0
4	1100	0	29	1071	0
5	1182	0	30	1006	0
6	1039	0	31	1088	0
7	1140	0	32	1028	0
8	1067	0	33	965	0
9	1117	0	34	982	0
10	1117	0	35	938	0
11	1093	0	36	1012	0
12	1106	0	37	908	0
13	972	0	38	1112	0
14	1004	0	39	1149	0
15	2150	0	40	1265	0
16	966	0	41	1469	0
17	979	0	42	1756	0
18	1059	0	43	4991	0
19	1009	0	44	4093	0
20	968	0	45	1306	0
21	1015	0	46	1203	0
22	1010	0	47	1230	0
23	1179	0			
24	1136	0			
25	1278	0			

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot		
Radiation Instruments Used			Bkgd _____ cpm Wipe # Reading Wipe # Reading _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm		
Inst Type: <u>Analyst</u>	<u>Rem 500</u>				
Inst No: <u>26</u>	<u>1</u>				
Batt/Source Chk: <u>SAT</u>	<u>SAT</u>				
Cal. Due Date: <u>5-21</u>	<u>10-21</u>				
Background: <u>N/A</u>	<u>N/A</u>				
LEGEND			Comments: 1-23, 45-47 completed 12-18-20 24-44 completed 12-28-20 Readings are 1 minute integrations		
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (R) - Radioactive Material Wipe (F) - Floor Wipe					
			Surveyed By: <u>Edgeman</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>		





Main Injector (MI) / Recycler (RR)

Gamma Survey Results (continued)

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
29	1172	1071	-101	47.36	-101 ± 47.36	79.629	161.999
30	1050	1006	-44	45.34	-44 ± 45.34	75.371	153.480
31	1142	1088	-54	47.22	-54 ± 47.22	78.604	159.947
32	1063	1028	-35	45.73	-35 ± 45.73	75.836	154.411
33	1043	965	-78	44.81	-78 ± 44.81	75.119	152.977
34	1049	982	-67	45.07	-67 ± 45.07	75.335	153.409
35	1136	938	-198	45.54	-198 ± 45.54	78.397	159.533
36	1145	1012	-133	46.44	-133 ± 46.44	78.707	160.154
37	1097	908	-189	44.78	-189 ± 44.78	77.039	156.818
38	1212	1112	-100	48.21	-100 ± 48.21	80.977	164.695
39	1269	1149	-120	49.17	-120 ± 49.17	82.859	168.460
40	1157	1265	108	49.21	108 ± 49.21	79.118 !	160.976
41	1138	1469	331	51.06	331 ± 51.06	78.466 !	159.671
42	1268	1756	488	54.99	488 ± 54.99	82.827 !	168.395
43	1135	4991	3856	78.27	3856 ± 78.27	78.362 !	159.464
44	1146	4093	2947	72.38	2947 ± 72.38	78.741 !	160.222
45	911	1306	395	47.09	395 ± 47.09	70.205 !	143.146
46	119	1203	1084	36.36	1084 ± 36.36	25.374 !	53.464
47	1298	1230	-68	50.28	-68 ± 50.28	83.801	170.343

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.001	0.0002	0.001 ± 0.0002	0.001
0.006	0.007	0.002	0.0003	0.002 ± 0.0003	0.001
0.006	0.009	0.002	0.0003	0.002 ± 0.0003	0.001
0.006	0.025	0.019	0.0004	0.019 ± 0.0004	0.001
0.006	0.020	0.015	0.0004	0.015 ± 0.0004	0.001
0.005	0.007	0.002	0.0002	0.002 ± 0.0002	0.001
0.001	0.006	0.005	0.0002	0.005 ± 0.0002	0.000
0.006	0.006	0.000	0.0003	0 ± 0.0003	0.001

*The road for locations 3-8 was closed due to LBNF site-prep construction during the background survey. The road was open for beam-on survey, with readings being consistent with other near-background measurements. For these locations, the background readings were taken to be the average of the other 41 background measurements.

Main Injector (MI) / Recycler (RR)

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
17	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
18	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
19	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
20	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
21	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
22	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
23	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
24	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
25	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
26	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
27	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
28	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
29	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

Main Injector (MI) / Recycler (RR)

Neutron Survey Results (continued)

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
30	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
31	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
32	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
33	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
34	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
35	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
36	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
37	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
38	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
39	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
40	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
41	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
42	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
43	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
44	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
45	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
46	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
47	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

Main Injector (MI) / Recycler (RR)

Scaling Dose Rates to MI Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time			Scaled to Operating Limit Intensity at Standard Beam Up-Time		
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.001	0.000	0.007	14.293	42.377	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.000	0.000	0.000	0.000	0.000	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.000	0.000	0.000	0.000	0.000	0	0	0
7	0.000	0.000	0.000	0.000	0.000	0	0	0
8	0.000	0.000	0.000	0.000	0.000	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.000	0.000	0.000	0.000	0.000	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.000	0.000	0.000	0.000	0.000	0	0	0
14	0.000	0.000	0.000	0.000	0.000	0	0	0
15	0.005	0.000	0.036	71.463	211.884	0	0	0
16	0.000	0.000	0.000	0.000	0.000	0	0	0
17	0.000	0.000	0.000	0.000	0.000	0	0	0
18	0.000	0.000	0.000	0.000	0.000	0	0	0
19	0.000	0.000	0.000	0.000	0.000	0	0	0
20	0.000	0.000	0.000	0.000	0.000	0	0	0
21	0.000	0.000	0.000	0.000	0.000	0	0	0
22	0.000	0.000	0.000	0.000	0.000	0	0	0
23	0.001	0.000	0.007	14.293	42.377	0	0	0
24	0.000	0.000	0.000	0.000	0.000	0	0	0
25	0.000	0.000	0.000	0.000	0.000	0	0	0
26	0.000	0.000	0.000	0.000	0.000	0	0	0
27	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
4.10E+16	2.93E+17

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

Main Injector (MI) / Recycler (RR) (continued)

Scaling Dose Rates to MI Operating Limit Intensity & Calculate Annual Dose (continued)

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
28	0.000	0.000	0.000	0.000	0.000	0	0	0
29	0.000	0.000	0.000	0.000	0.000	0	0	0
30	0.000	0.000	0.000	0.000	0.000	0	0	0
31	0.000	0.000	0.000	0.000	0.000	0	0	0
32	0.000	0.000	0.000	0.000	0.000	0	0	0
33	0.000	0.000	0.000	0.000	0.000	0	0	0
34	0.000	0.000	0.000	0.000	0.000	0	0	0
35	0.000	0.000	0.000	0.000	0.000	0	0	0
36	0.000	0.000	0.000	0.000	0.000	0	0	0
37	0.000	0.000	0.000	0.000	0.000	0	0	0
38	0.000	0.000	0.000	0.000	0.000	0	0	0
39	0.000	0.000	0.000	0.000	0.000	0	0	0
40	0.001	0.000	0.007	14.293	42.377	0	0	0
41	0.002	0.000	0.014	28.585	84.753	0	0	0
42	0.002	0.000	0.014	28.585	84.753	0	0	0
43	0.019	0.000	0.136	271.561	805.157	0	0	0
44	0.015	0.000	0.107	214.390	635.651	0	0	0
45	0.002	0.000	0.014	28.585	84.753	0	0	0
46	0.005	0.000	0.036	71.463	211.884	0	0	0
47	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
4.10E+16	2.93E+17

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

Main Injector (MI) / Recycler (RR)

Scaling Dose Rates to RR Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time			Scaled to Operating Limit Intensity at Standard Beam Up-Time		
	Gamma Net Beam-On (mR/hr)	Neutron Net Beam-On (mrem/hr)	Gamma Net Beam-On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam-On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.001	0.000	0.005	10.976	47.592	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.000	0.000	0.000	0.000	0.000	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.000	0.000	0.000	0.000	0.000	0	0	0
7	0.000	0.000	0.000	0.000	0.000	0	0	0
8	0.000	0.000	0.000	0.000	0.000	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.000	0.000	0.000	0.000	0.000	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.000	0.000	0.000	0.000	0.000	0	0	0
14	0.000	0.000	0.000	0.000	0.000	0	0	0
15	0.005	0.000	0.027	54.878	237.962	0	0	0
16	0.000	0.000	0.000	0.000	0.000	0	0	0
17	0.000	0.000	0.000	0.000	0.000	0	0	0
18	0.000	0.000	0.000	0.000	0.000	0	0	0
19	0.000	0.000	0.000	0.000	0.000	0	0	0
20	0.000	0.000	0.000	0.000	0.000	0	0	0
21	0.000	0.000	0.000	0.000	0.000	0	0	0
22	0.000	0.000	0.000	0.000	0.000	0	0	0
23	0.001	0.000	0.005	10.976	47.592	0	0	0
24	0.000	0.000	0.000	0.000	0.000	0	0	0
25	0.000	0.000	0.000	0.000	0.000	0	0	0
26	0.000	0.000	0.000	0.000	0.000	0	0	0
27	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
2.50E+16	2.25E+17

Beam Up-Time	
# Weeks	52
Efficiency	99%
99.0%	

Main Injector (MI) / Recycler (RR) (continued)

Scaling Dose Rates to RR Operating Limit Intensity & Calculate Annual Dose (continued)

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma	Neutron	Gamma			Neutron		
	Net Beam-On (mR/hr)	Net Beam-On (mrem/hr)	Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
28	0.000	0.000	0.000	0.000	0.000	0	0	0
29	0.000	0.000	0	0.000	0.000	0	0	0
30	0.000	0.000	0	0.000	0.000	0	0	0
31	0.000	0.000	0	0.000	0.000	0	0	0
32	0.000	0.000	0	0.000	0.000	0	0	0
33	0.000	0.000	0	0.000	0.000	0	0	0
34	0.000	0.000	0	0.000	0.000	0	0	0
35	0.000	0.000	0	0.000	0.000	0	0	0
36	0.000	0.000	0	0.000	0.000	0	0	0
37	0.000	0.000	0	0.000	0.000	0	0	0
38	0.000	0.000	0	0.000	0.000	0	0	0
39	0.000	0.000	0	0.000	0.000	0	0	0
40	0.001	0.000	0.009	18.000	78.052	0	0	0
41	0.002	0.000	0.018	36.000	156.103	0	0	0
42	0.002	0.000	0.018	36.000	156.103	0	0	0
43	0.019	0.000	0.171	342.000	1482.980	0	0	0
44	0.015	0.000	0.135	270.000	1170.774	0	0	0
45	0.002	0.000	0.018	36.000	156.103	0	0	0
46	0.005	0.000	0.045	90.000	390.258	0	0	0
47	0.000	0.000	0	0.000	0.000	0	0	0

Intensities (protons/hr)		Beam Up-Time	
Survey	Op. Limit	# Weeks Efficiency	52 99%
2.50E+16	2.25E+17	99.0%	

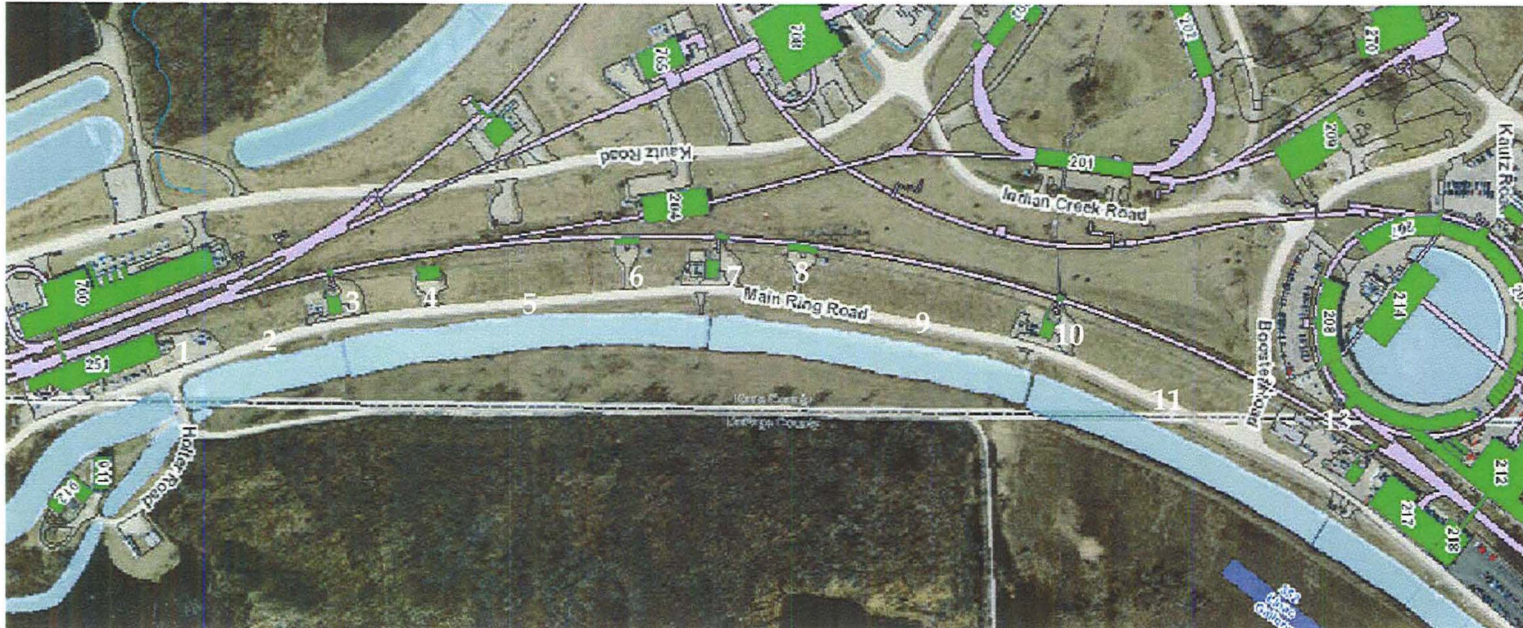
Attachment 6 – F Sector

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

DATE: 12/11/20 TIME: 1300 PURPOSE: BACKGROUND SURVEY

F-Sector Beam On Survey

Created Dec 8, 2020

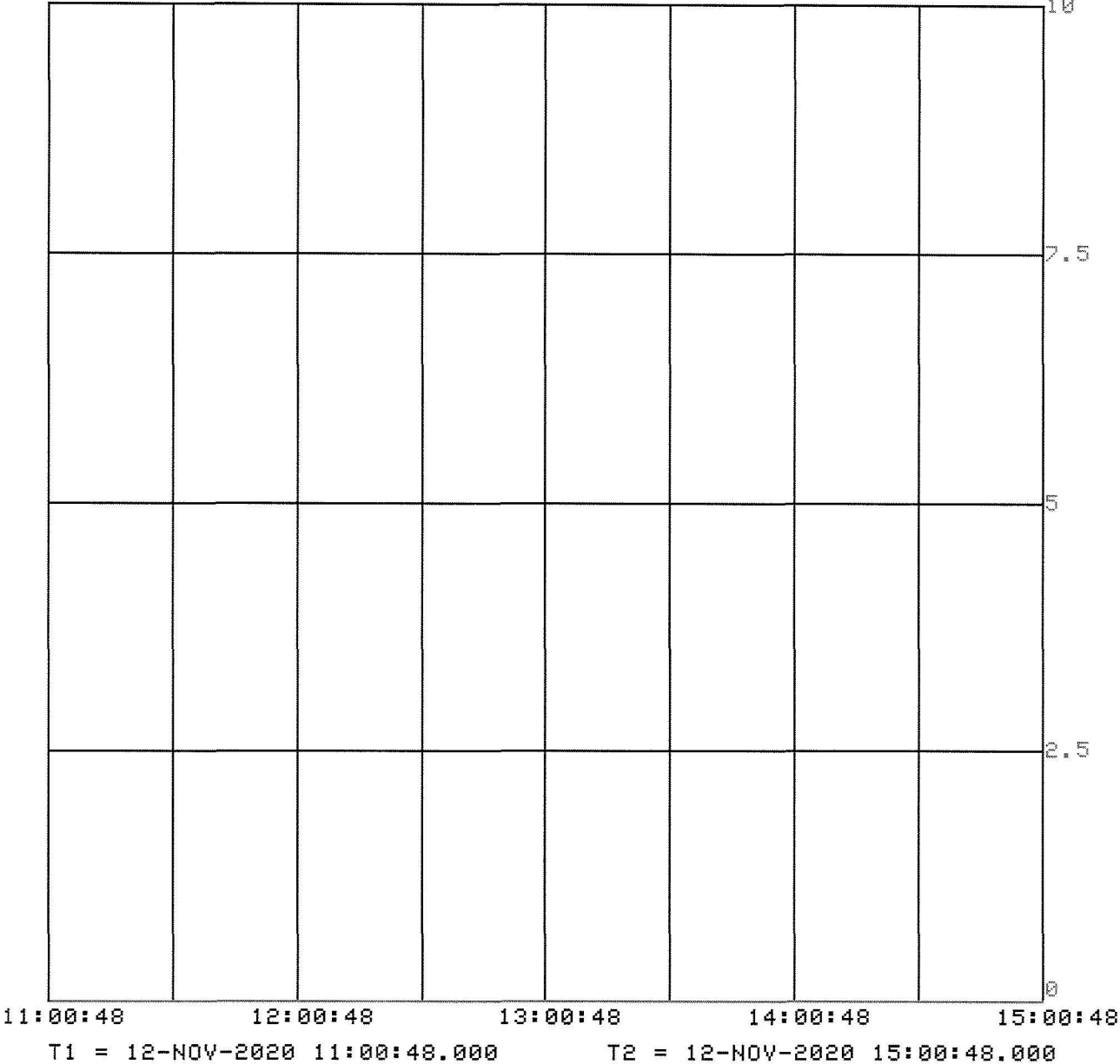


location	Gamma cpm	Neutron mrem/min
1	1176	N/A
2	1339	
3	1247	
4	1295	
5	1349	
6	1357	
7	1487	
8	1399	
9	1427	
10	1391	
11	1432	
12	1194	
13	1248	

All Areas < N/A mR/hr@1foot (Unless otherwise indicated)		Highest Dose Rate Found: N/A mR/hr@1foot	
Radiation Instruments Used		Bkgd _____ cpm	
Inst Type: <u>BICHSEL ANALYST</u>	<div style="border: 1px solid black; height: 100px; width: 100%;"></div>	Wipe #	Reading
Inst No: <u>#33</u>			
Batt/Source Chk: <u>SAT/SAT</u>		_____	_____
Cal. Due Date: <u>Nov/2021</u>		_____	_____
Background: <u>SEE ABOVE</u>		_____	_____
LEGEND		_____	_____
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material		_____	_____
(#R) - Radioactive Material Wipe (#) - Wipe (#F) - Floor Wipe		_____	_____
		Comments: READINGs ARE 1 MINUTE INTEGRATIONS. No neutron background taken due to no source from beam	
		Surveyed By: <u>[Signature]</u>	
		Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <small>Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.01.25 14:23:14 -0600</small>	

Fri 08-JAN-2021 08:34:55

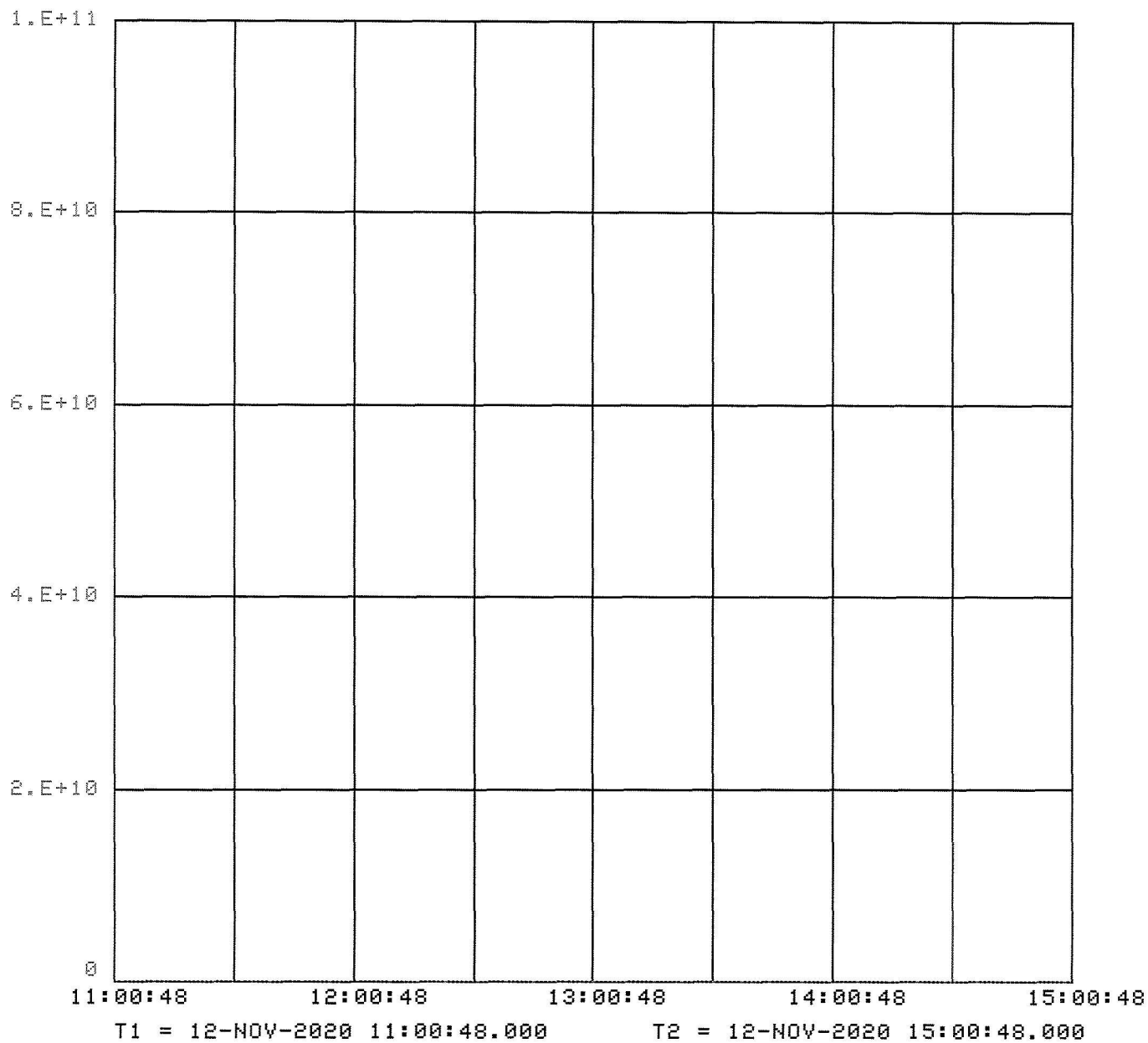
Console Location 151, 08-JAN-21 08:35:04
NuMI shift plot #4



D:POTMIN
.Muon4 E14

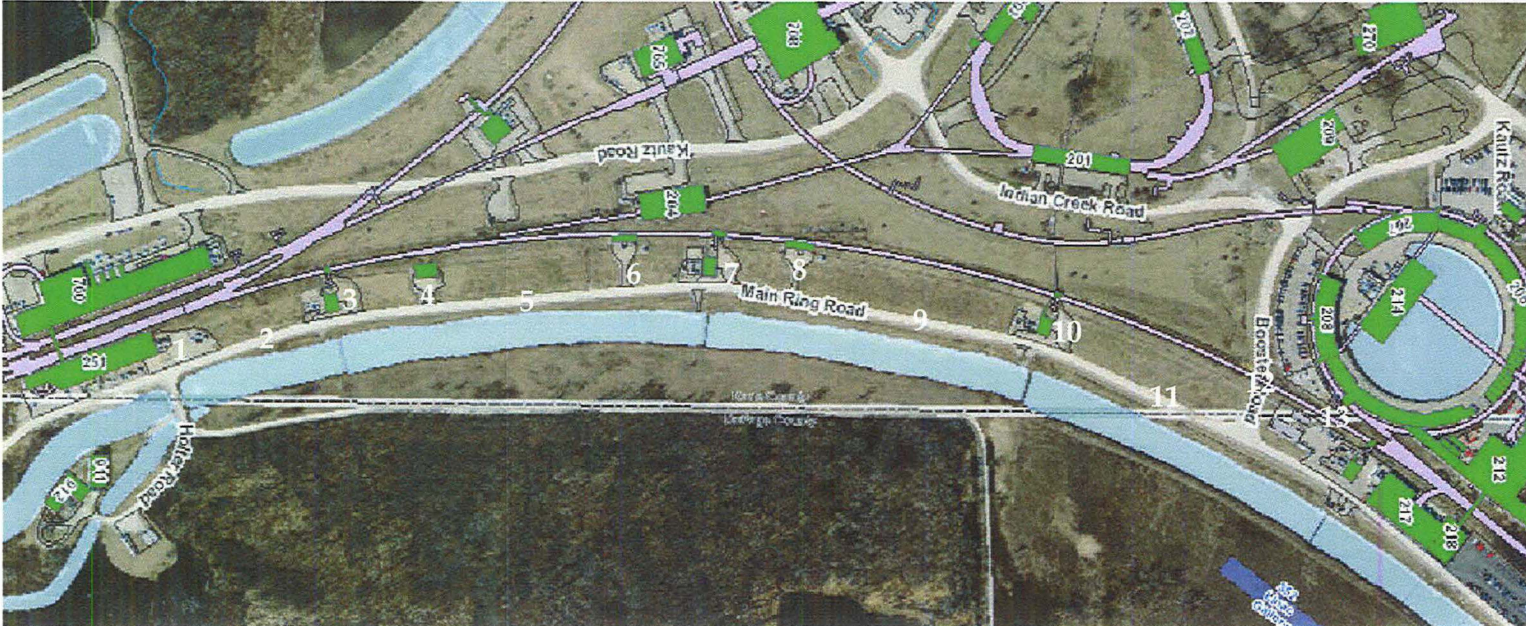
Fri 08-JAN-2021 08:35:37

F:MWISEM
.FixTr2 ppp



F-Sector Beam On Survey

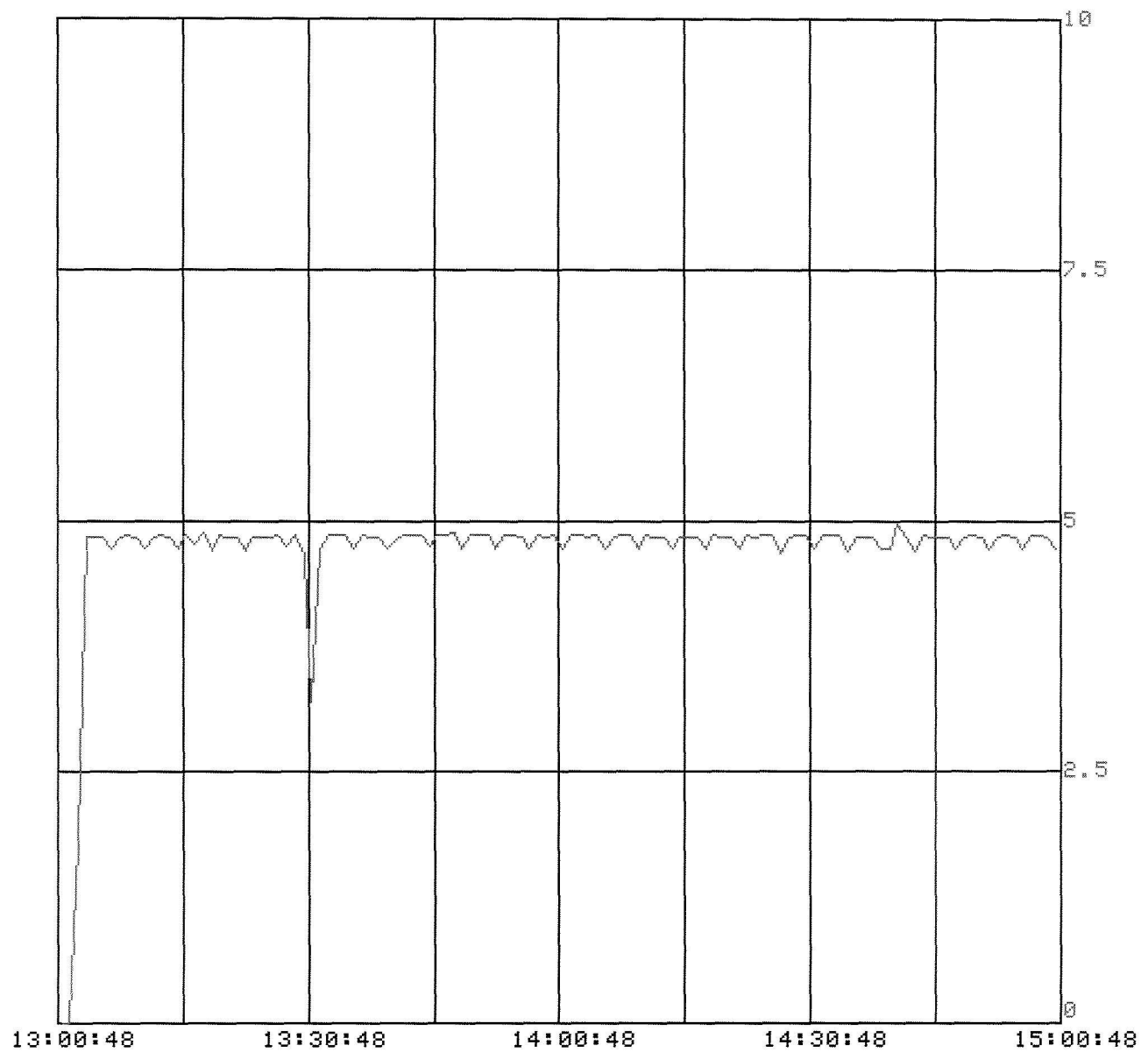
Created Dec 8, 2020



location	Gamma cpm	Neutron mrem/min
1	1041	0
2	1076	0
3	1410	0
4	1352	0
5	1423	0
6	4064	0
7	3549	0
8	1931	0
9	1339	0
10	1124	0
11	1140	0
12	986	0
13	934	0

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)				Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot	
Radiation Instruments Used				Comments: <i>readings are 1 minute integrations</i>	
Inst Type: <u>Analyst</u>	<u>REM 500</u>	Bkgd _____ cpm			
Inst No: <u>26</u>	<u>1</u>	Wipe #	Reading		
Batt/Source Chk: <u>SAT</u>	<u>SAT</u>	_____	_____ ccpm		
Cal. Due Date: <u>5-21</u>	<u>10-21</u>	_____	_____ ccpm		
Background: <u>N/A</u>	<u>N/A</u>	_____	_____ ccpm		
LEGEND				Surveyed By: <u>Fulgham</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>	
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material					
(R) - Radioactive Material Wipe (W) - Wipe (F) - Floor Wipe					

Fri 08-JAN-2021 08:30:57

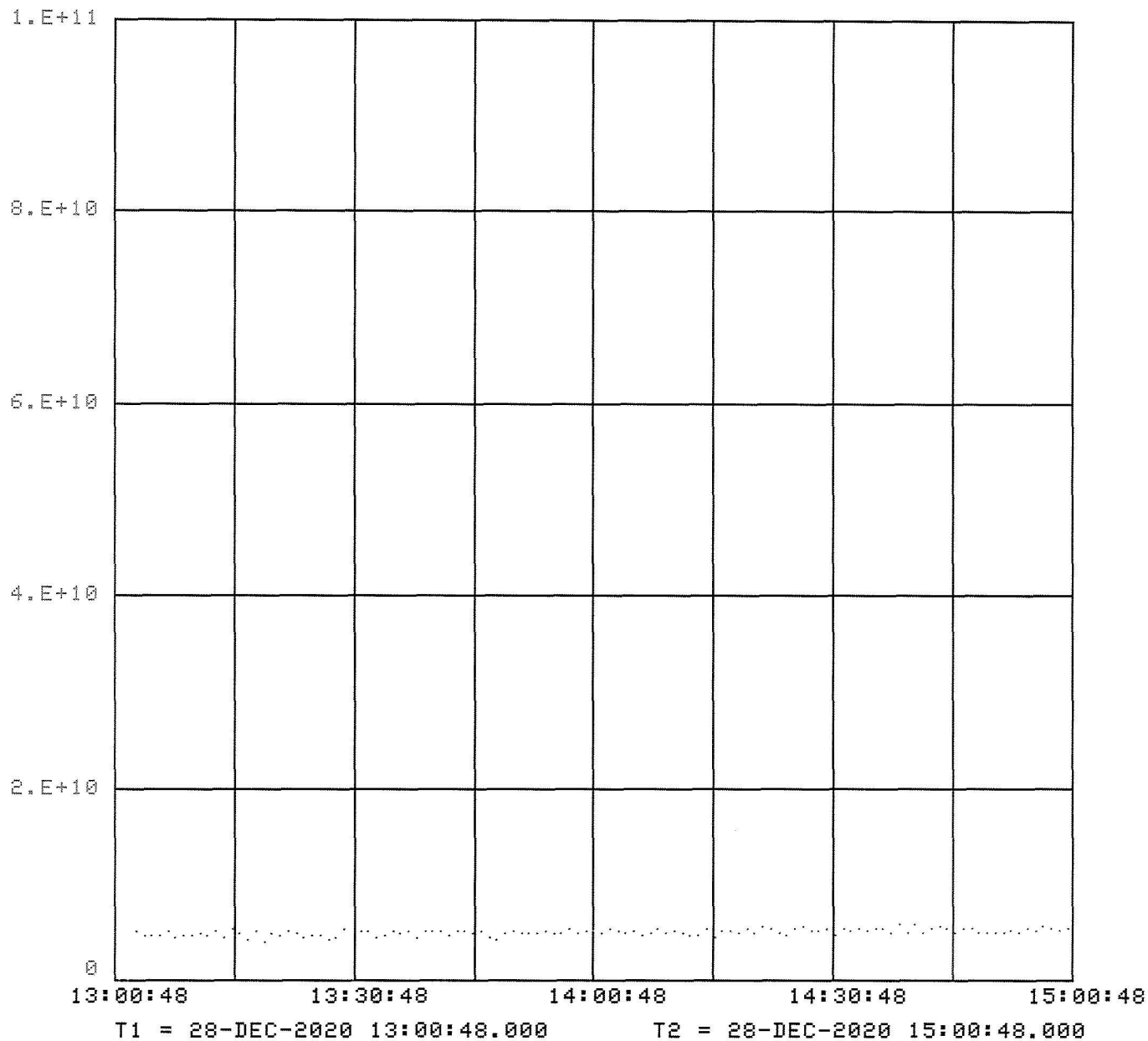


D:POTMIN
.Muon4 E14

T1 = 28-DEC-2020 13:00:48.000 T2 = 28-DEC-2020 15:00:48.000

Fri 08-JAN-2021 08:37:12

F:MWISEM
.FixTr2 ppp



F Sector

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1176	1041	-135	47.09	-135 ± 47.09	79.765	162.271
2	1339	1076	-263	49.14	-263 ± 49.14	85.114	172.970
3	1247	1410	163	51.55	163 ± 51.55	82.138 !	167.017
4	1295	1352	57	51.45	57 ± 51.45	83.704	170.149
5	1349	1423	74	52.65	74 ± 52.65	85.431	173.605
6	1357	4064	2707	73.63	2707 ± 73.63	85.684 !	174.111
7	1487	3549	2062	70.96	2062 ± 70.96	89.694 !	182.133
8	1399	1931	532	57.71	532 ± 57.71	87.000 !	176.743
9	1427	1339	-88	52.59	-88 ± 52.59	87.866	178.476
10	1391	1124	-267	50.15	-267 ± 50.15	86.751	176.245
11	1432	1140	-292	50.71	-292 ± 50.71	88.020	178.784
12	1194	986	-208	46.69	-208 ± 46.69	80.373	163.487
13	1248	934	-314	46.71	-314 ± 46.71	82.171	167.083

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.007	0.001	0.0003	0.001 ± 0.0003	0.001
0.006	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.020	0.014	0.0004	0.014 ± 0.0004	0.001
0.007	0.018	0.010	0.0004	0.01 ± 0.0004	0.001
0.007	0.010	0.003	0.0003	0.003 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001

F Sector

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

F Sector

Scaling Dose Rates to P1-P2 Line to Muon Campus Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time			Scaled to Operating Limit Intensity at Standard Beam Up-Time		
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.001	0.000	0.007	13.000	38.544	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.014	0.000	0.091	182.000	539.616	0	0	0
7	0.010	0.000	0.065	130.000	385.440	0	0	0
8	0.003	0.000	0.020	39.000	115.632	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.000	0.000	0.000	0.000	0.000	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
1.00E+16	6.50E+16

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

F Sector

Scaling Dose Rates to P1-P2 Line to Switchyard Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time			Scaled to Operating Limit Intensity at Standard Beam Up-Time		
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.001	0.000	0.003	5.538	16.421	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.014	0.000	0.039	77.538	229.896	0	0	0
7	0.010	0.000	0.028	55.385	164.211	0	0	0
8	0.003	0.000	0.008	16.615	49.263	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.000	0.000	0.000	0.000	0.000	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
1.30E+13	3.60E+13

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

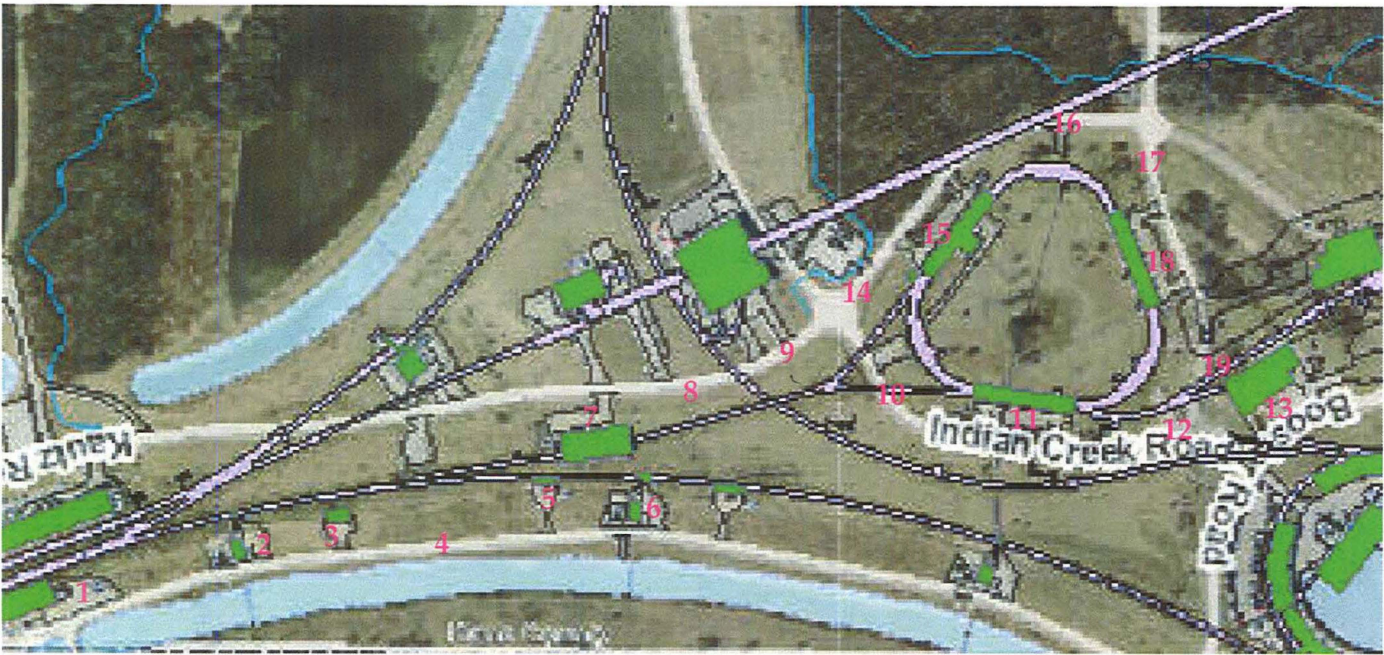
Attachment 7 – Muon Campus

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
 - Repeat neutron surveys also included
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Muon Campus Beam On Survey

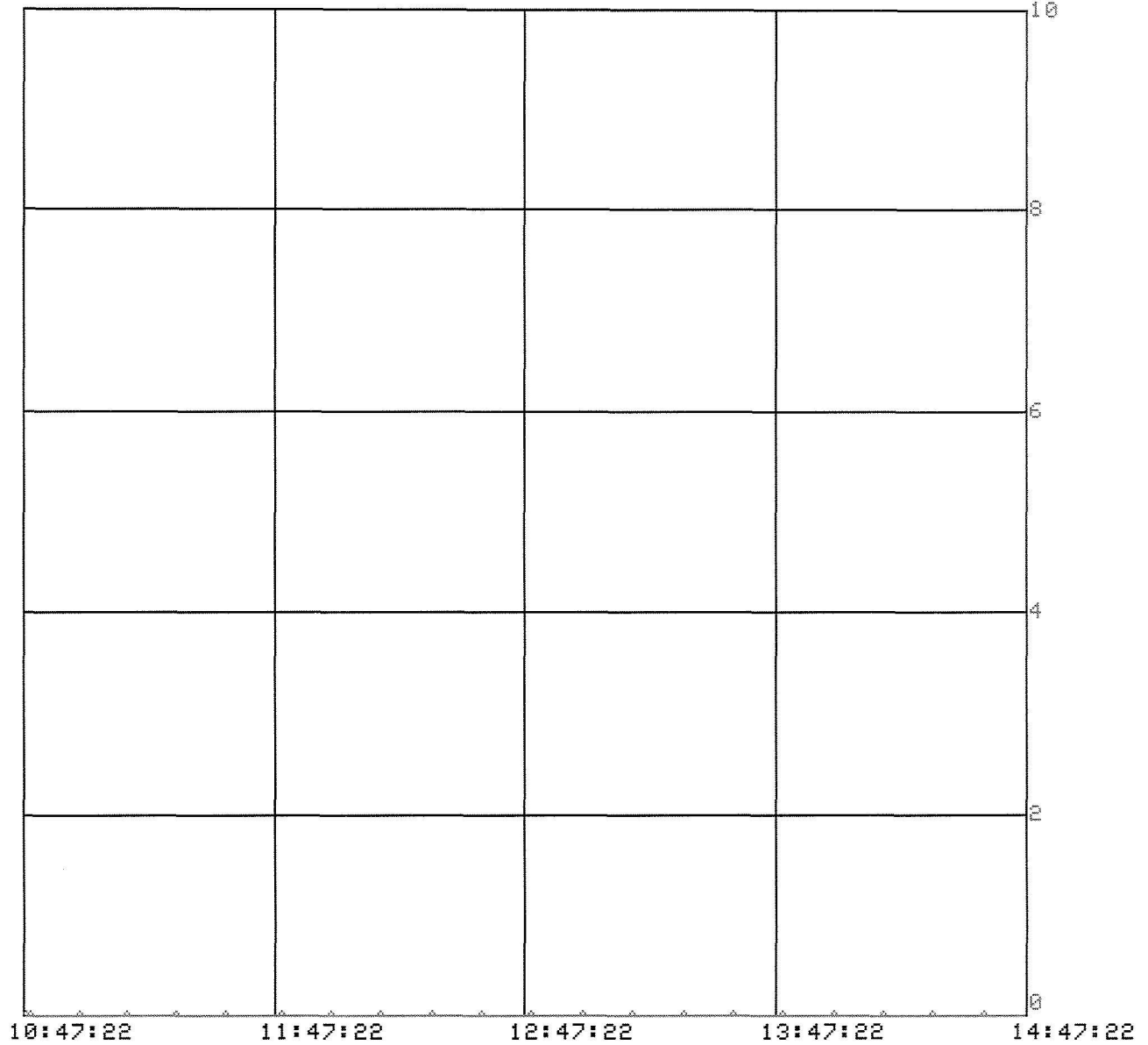
Created Dec 12, 2020

Location	Gamma cpm	Neutron mrem/min
1	1001	N/A
2	1146	
3	1221	
4	1326	
5	1286	
6	1228	
7	1308	
8	1337	
9	1349	
10	1308	
11	1343	
12	1393	
13	1082	
14	1243	
15	1207	
16	1272	
17	1314	
18	1243	
19	1107	



All Areas < N/A mR/hr@1foot (Unless otherwise indicated)		Highest Dose Rate Found: N/A mR/hr@1foot	
Radiation Instruments Used Inst Type: <u>BICM100051</u> Inst No: <u>33</u> Batt/Source Chk: <u>SW/FAT</u> Cal. Due Date: <u>Aug 2021</u> Background: <u>See Note</u>		Bkgd _____ cpm Wipe # Reading Wipe # Reading _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm	
LEGEND # - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (#R) - Radioactive Material Wipe (#) - Wipe (#F) - Floor Wipe		Comments: <u>READINGS ARE 1 MINUTE INTEGRATIONS</u> <u>No neutron background taken due to no source from beam</u> Surveyed By: <u>[Signature]</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>	

Mon 11-JAN-2021 14:47:35



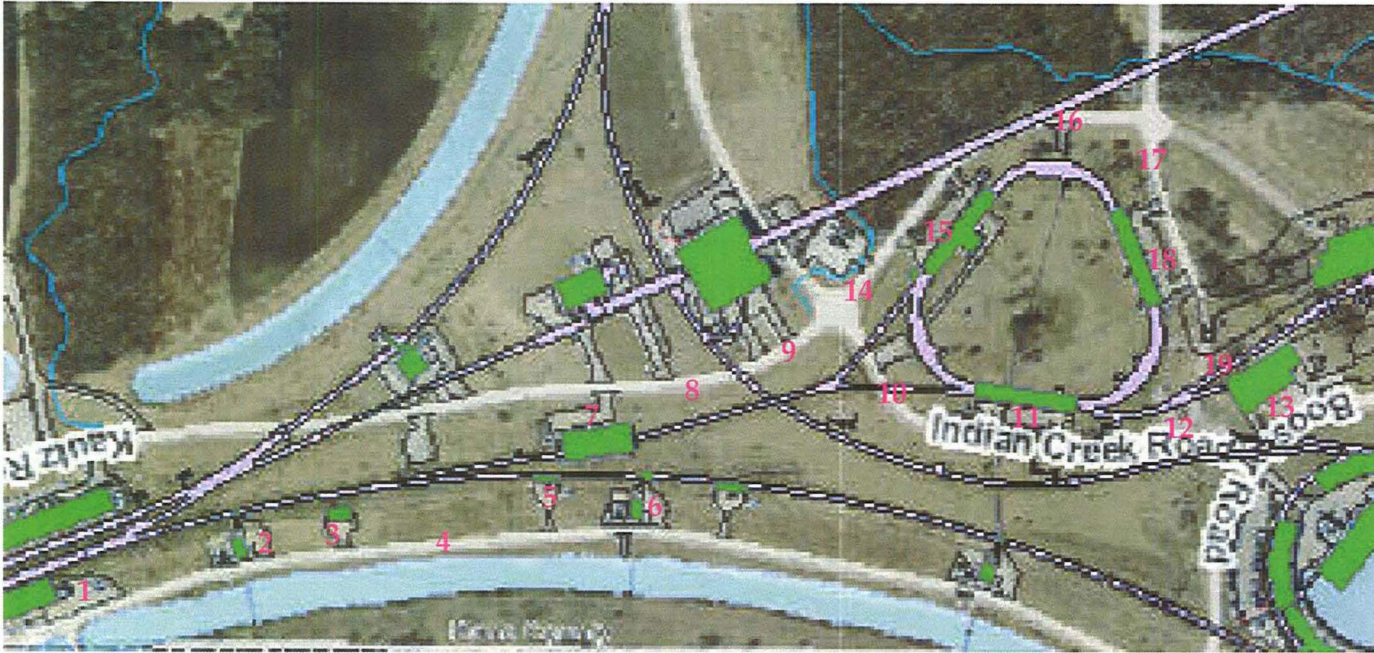
D:POTMIN
*Muon4 E14

T1 = 11-JAN-2021 10:47:22.000

T2 = 11-JAN-2021 14:47:22.000

Muon Campus Beam On Survey

Created Dec 12, 2020

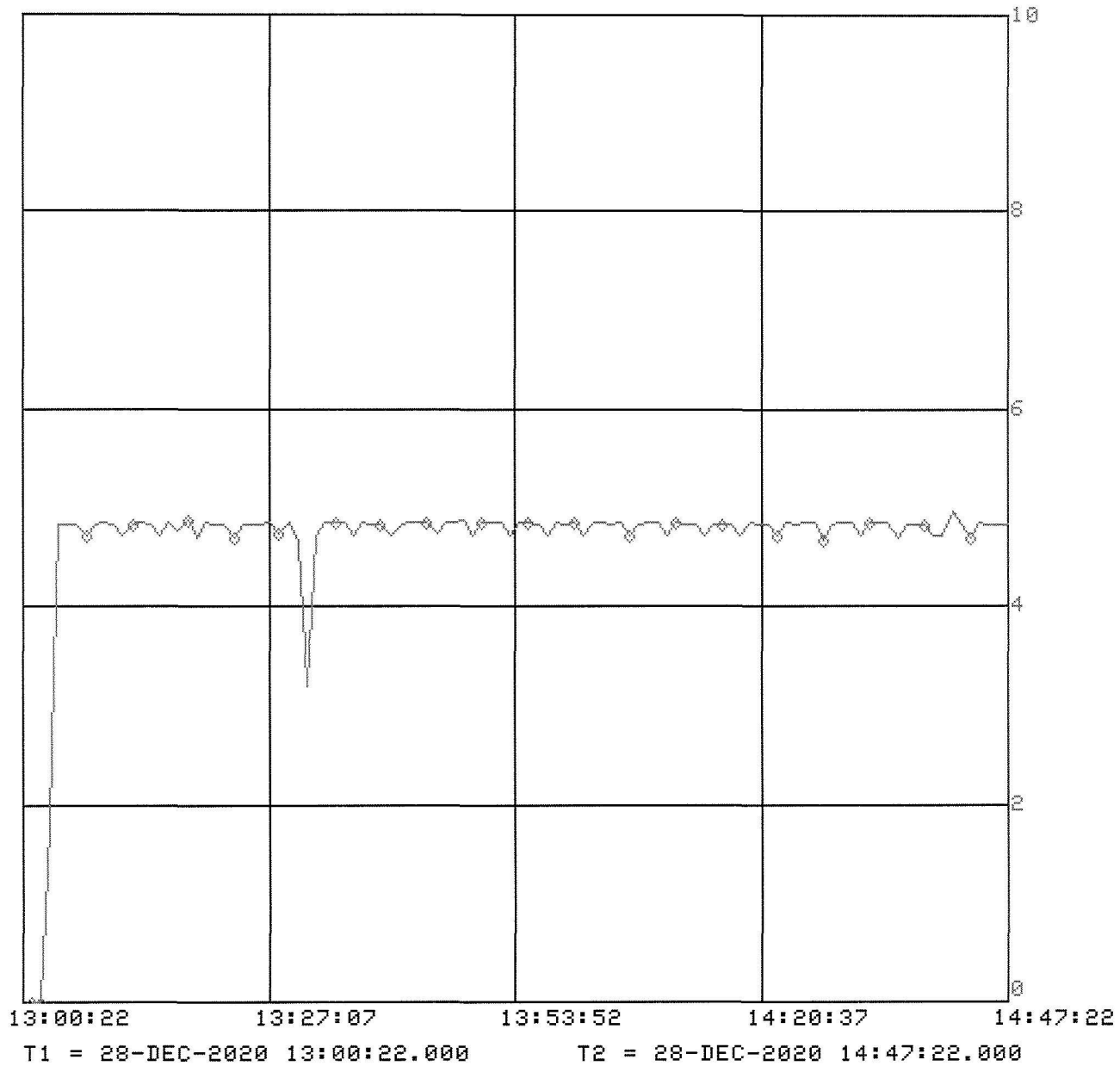


location	Gamma cpm	Neutron mrem/min
1	1041	0
2	1410	0
3	1352	0
4	1423	0
5	4064	0
6	3549	0
7	12180	0
8	3208	0
9	1542	0
10	1240	0.002
11	1080	0
12	1181	0
13	999	0
14	1212	0
15	938	0
16	1120	0
17	1188	0
18	1296	0
19	1019	0

All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)				Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot						
Radiation Instruments Used				Comments:						
Inst Type:	<u>Analyt</u>	<u>Rem 500</u>						Bkgd _____ cpm		
Inst No:	<u>26</u>	<u>1</u>						Wipe # Reading Wipe # Reading		
Batt/Source Chk:	<u>SAT</u>	<u>SAT</u>	_____					_____	_____	_____
Cal. Due Date:	<u>5-21</u>	<u>10-21</u>	_____					_____	_____	_____
Background:	<u>N/A</u>	<u>N/A</u>	_____					_____	_____	_____
LEGEND # - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material #R - Radioactive Material Wipe # - Wipe #F - Floor Wipe				Surveyed By: <u>Fulgum</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>						

Digitally signed by Maddie Schoell, UID:maddiew
Date: 2021.01.21 12:09:18 -0500

Mon 11-JAN-2021 14:49:24



D:POTMIN
+Muon4 E14

Muon Campus

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1001	1041	40	45.19	40 ± 45.19	73.591	149.920
2	1146	1410	264	50.56	264 ± 50.56	78.741 !	160.222
3	1221	1352	131	50.72	131 ± 50.72	81.277 !	165.295
4	1326	1423	97	52.43	97 ± 52.43	84.700 !	172.142
5	1286	4064	2778	73.14	2778 ± 73.14	83.412 !	169.566
6	1228	3549	2321	69.12	2321 ± 69.12	81.510 !	165.760
7	1308	12180	10872	116.14	10872 ± 116.14	84.123 !	170.988
8	1337	3208	1871	67.42	1871 ± 67.42	85.050 !	172.843
9	1349	1542	193	53.77	193 ± 53.77	85.431 !	173.605
10	1308	1240	-68	50.48	-68 ± 50.48	84.123	170.988
11	1343	1080	-263	49.22	-263 ± 49.22	85.241	173.224
12	1393	1181	-212	50.73	-212 ± 50.73	86.813	176.370
13	1082	999	-83	45.62	-83 ± 45.62	76.511	155.761
14	1243	1212	-31	49.55	-31 ± 49.55	82.006	166.753
15	1207	938	-269	46.31	-269 ± 46.31	80.810	164.360
16	1272	1120	-152	48.91	-152 ± 48.91	82.957	168.656
17	1314	1188	-126	50.02	-126 ± 50.02	84.315	171.373
18	1243	1296	53	50.39	53 ± 50.39	82.006	166.753
19	1107	1019	-88	46.11	-88 ± 46.11	77.390	157.519

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.007	0.001	0.0003	0.001 ± 0.0003	0.001
0.006	0.007	0.001	0.0003	0.001 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.020	0.014	0.0004	0.014 ± 0.0004	0.001
0.006	0.018	0.012	0.0003	0.012 ± 0.0003	0.001
0.007	0.061	0.054	0.0006	0.054 ± 0.0006	0.001
0.007	0.016	0.009	0.0003	0.009 ± 0.0003	0.001
0.007	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001

Muon Campus

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net ± St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.120	0.101	1.08E-04	0.101 ± 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
17	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
18	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
19	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04

Muon Campus

Scaling Dose Rates to Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma Net Beam- On (mR/hr)	Gamma 2,000 hr Working Year (mrem)	Gamma 24/7/365 (mrem)	Neutron Net Beam- On (mrem/hr)	Neutron 2,000 hr Working Year (mrem)	Neutron 24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
2	0.001	0.000	0.004	8.640	25.617	0.000	0.000	0
3	0.001	0.000	0.004	8.640	25.617	0.000	0.000	0
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
5	0.014	0.000	0.060	120.960	358.637	0.000	0.000	0
6	0.012	0.000	0.052	103.680	307.403	0.000	0.000	0
7	0.054	0.000	0.233	466.560	1383.315	0.000	0.000	0
8	0.009	0.000	0.039	77.760	230.552	0.000	0.000	0
9	0.001	0.000	0.004	8.640	25.617	0.000	0.000	0
10	0.000	0.101	0.000	0.000	0.000	0.435	869.789	2578.857
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0

Intensities (protons/hr)	
Survey	Op. Limit
1.00E+16	4.32E+16

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

Muon Campus - Location 10 Repeat Survey

Repeat Muon Campus Location 10 Neutron Survey

Time	Count Time (min)	Dose (mrem)	Dose Rate (mrem/min)	Average Gross (mrem/min)	Average Gross (mrem/hr)	Sample Std. Dev. (mrem)	Sample Std. Dev. (mrem/min)	Sample Std. Dev (mrem/hr)
2/8/2021 13:29	1	0.000	0.000	0.010	0.6012	0.00017445	0.000174452	0.0104671
2/8/2021 13:29	2	0.023	0.012					
2/8/2021 13:32	1	0.032	0.032					
2/8/2021 13:33	5	0.033	0.007					
2/8/2021 13:38	10	0.000	0.000					

Muon Campus

Updated Neutron Survey Results for Location 10

Location	Average Background (mrem)	Average Background (mrem/hr)	Average Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
10	0.01933	0.01933	0.601	0.582	1.05E-02	0.5819 \pm 0.010	2.43E-02	4.87E-02

Muon Campus - Location 10 Repeat Survey

Scaling Dose Rates to Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam-On (mR/hr)	Neutron Net Beam-On (mrem/hr)	Gamma			Neutron		
			Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
10	0.000	0.582	0.000	0.000	0.000	2.514	5027.357	14905.726

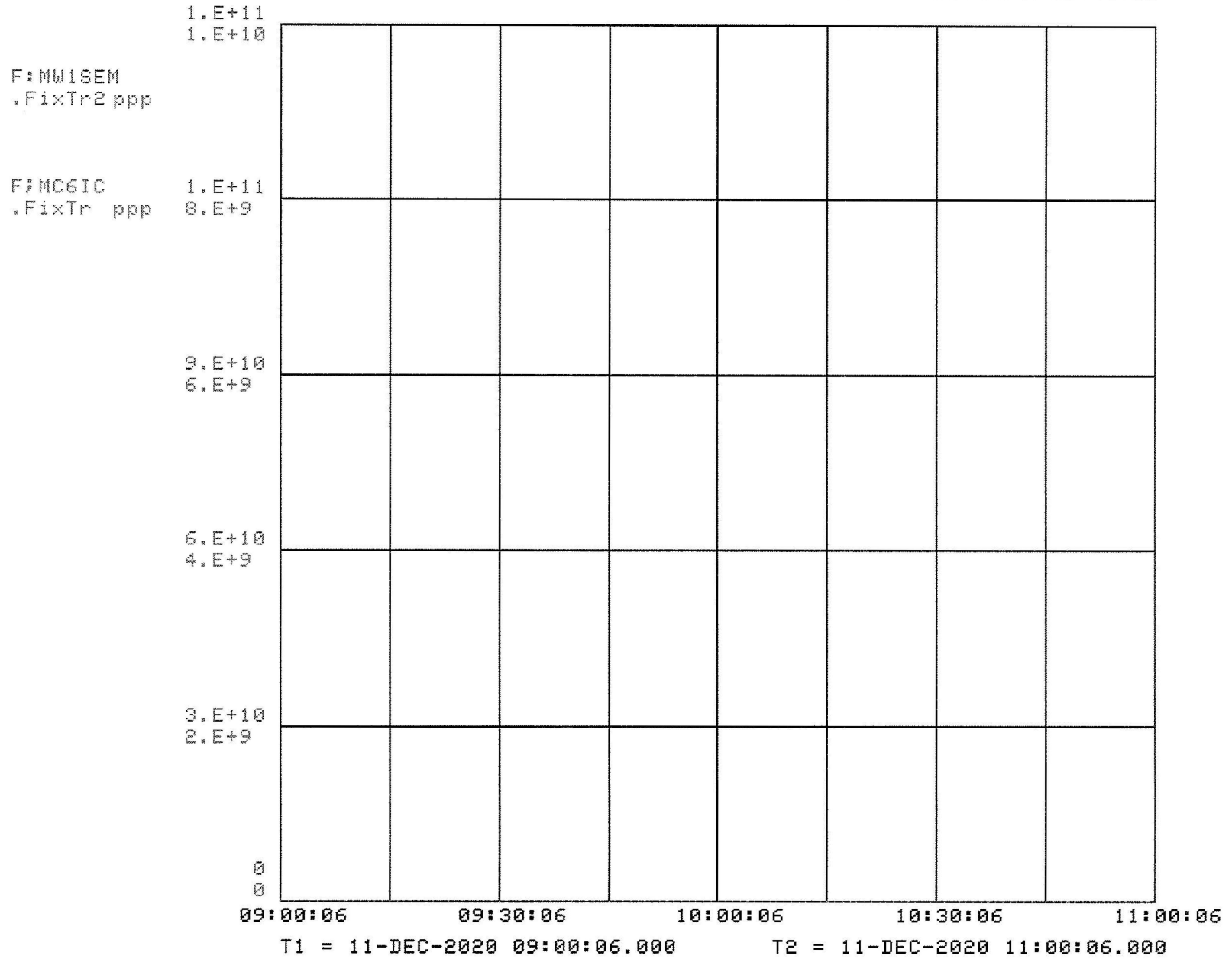
Intensities (protons/hr)	
Survey	Op. Limit
1.00E+16	4.32E+16

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

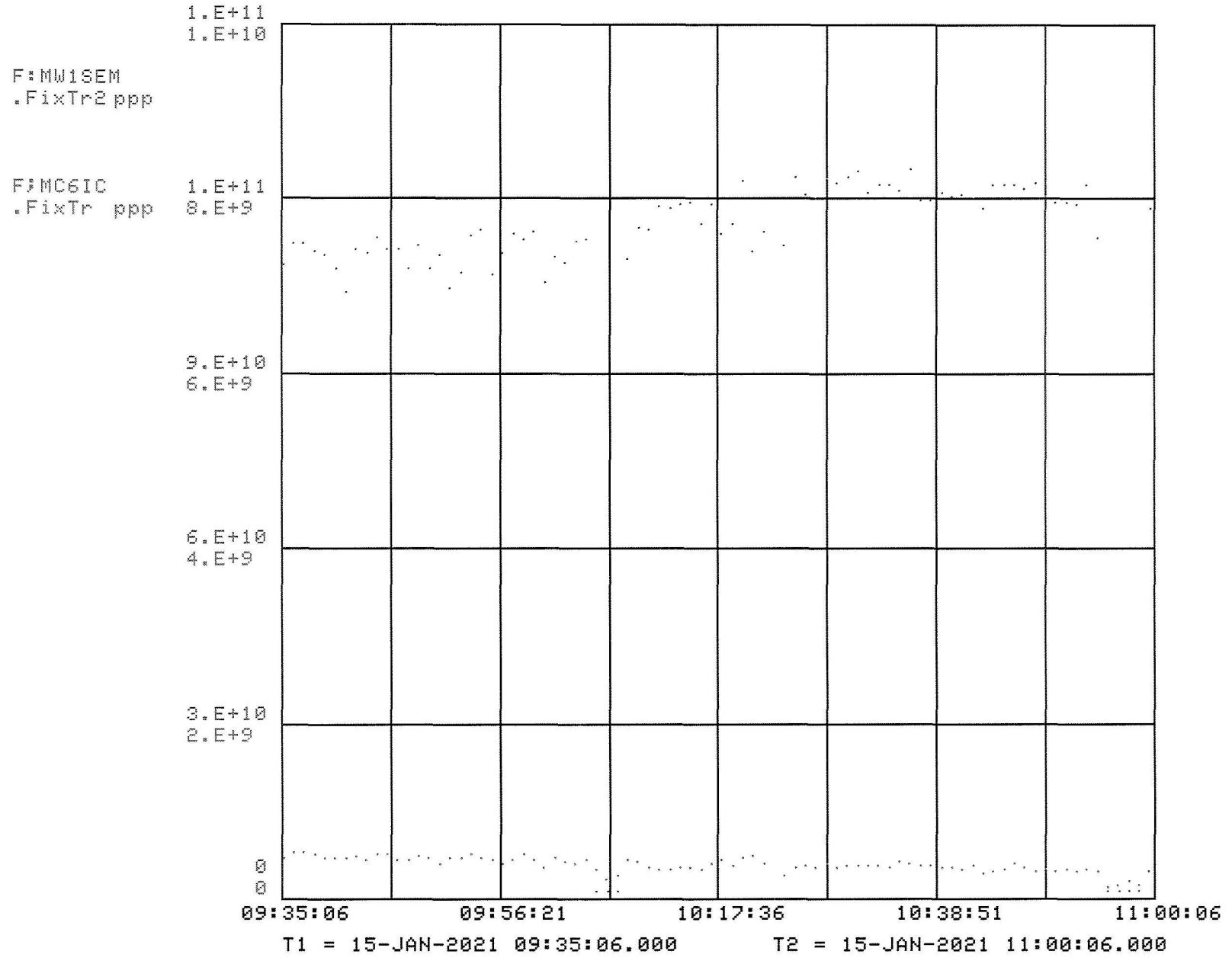
Attachment 8 – Switchyard

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Fri 15-JAN-2021 12:48:06



Fri 15-JAN-2021 11:43:26



SwitchYard Primary

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1201	934	-267	46.21	-267 ± 46.21	80.609	163.958
2	1048	1179	131	47.19	131 ± 47.19	75.299 !	153.337
3	1044	1106	62	46.37	62 ± 46.37	75.155	153.049
4	2224	2180	-44	66.36	-44 ± 66.36	109.693	222.138
5	2069	2080	11	64.41	11 ± 64.41	105.801	214.354
6	1560	1627	67	56.45	67 ± 56.45	91.870	186.485
7	1085	1162	77	47.40	77 ± 47.4	76.617 !	155.973
8	1316	1388	72	52.00	72 ± 52	84.380	171.502
9	1368	1289	-79	51.55	-79 ± 51.55	86.031	174.804
10	1464	1411	-53	53.62	-53 ± 53.62	88.998	180.740
11	1247	1546	299	52.85	299 ± 52.85	82.138 !	167.017
12	1500	1375	-125	53.62	-125 ± 53.62	90.086	182.916

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.006	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.006	0.001	0.0002	0.001 ± 0.0002	0.001
0.005	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.011	0.011	0.000	0.0003	0 ± 0.0003	0.001
0.010	0.010	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.008	0.000	0.0003	0 ± 0.0003	0.001
0.005	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.008	0.007	0.000	0.0003	0 ± 0.0003	0.001

SwitchYard Primary

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net \pm St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 \pm 0.000108	2.52E-04	5.04E-04

SwitchYard Primary

Scaling Dose Rates to Operating Limit Intensity & Calculate Annual Dose

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma	Neutron	Gamma			Neutron		
	Net Beam-On (mR/hr)	Net Beam-On (mrem/hr)	Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0	0.000	0
2	0.001	0.000	0.016	32.432	96.160	0	0	0
3	0.000	0.000	0.000	0.000	0.000	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.000	0.000	0.000	0.000	0.000	0	0	0
7	0.000	0.000	0.000	0.000	0.000	0	0	0
8	0.000	0.000	0.000	0.000	0.000	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.001	0.000	0.016	32.432	96.160	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
3.70E+13	6.00E+14

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

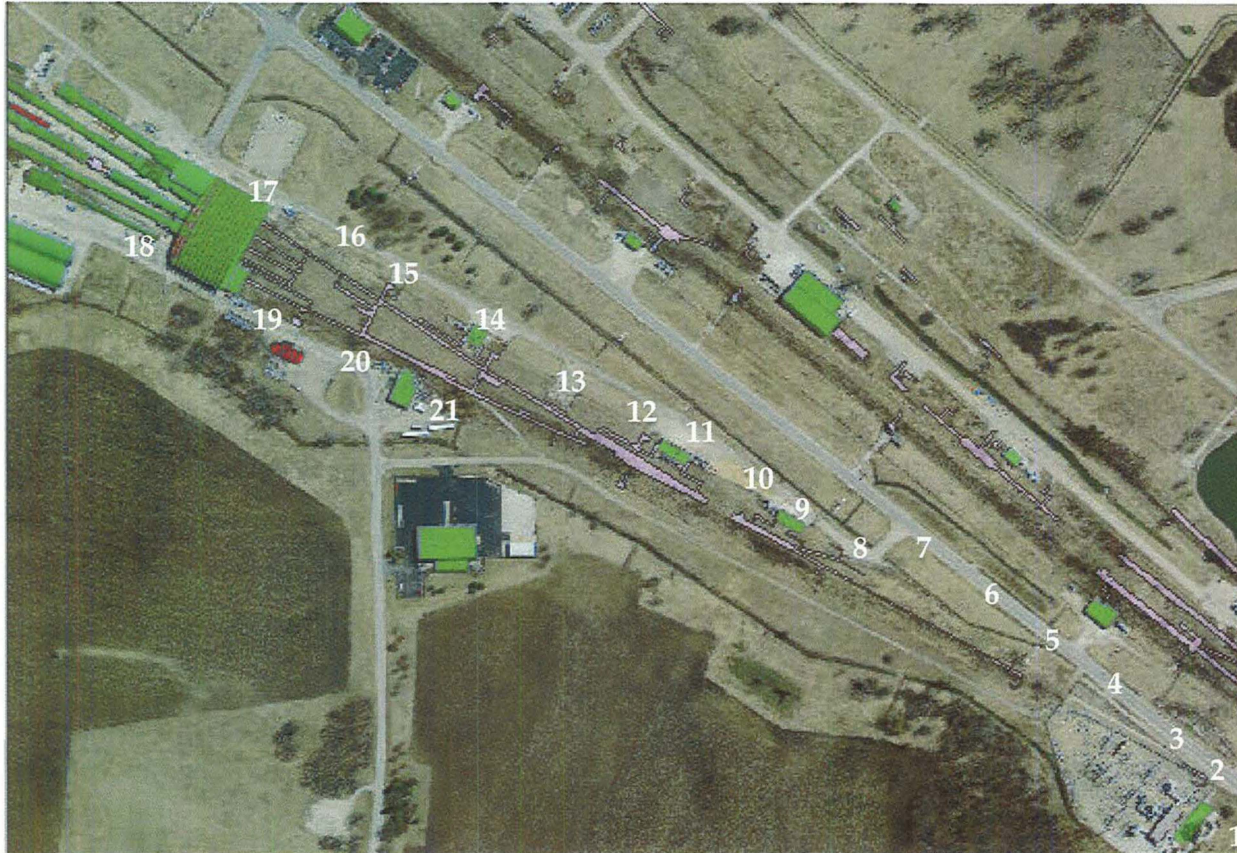
Attachment 9 – Meson, Including Meson Primary, Meson Test & Meson Center

- Background survey including beam intensity plot printout via ACNET
- Beam-on survey including beam intensity plot printout via ACNET
- Gamma & Neutron results table
- Results scaled from survey intensity to Operating Limit intensity and calculations for annual dose, assuming standard beam up-time when looking at 24/7/365 occupancy

Meson Beam On Survey

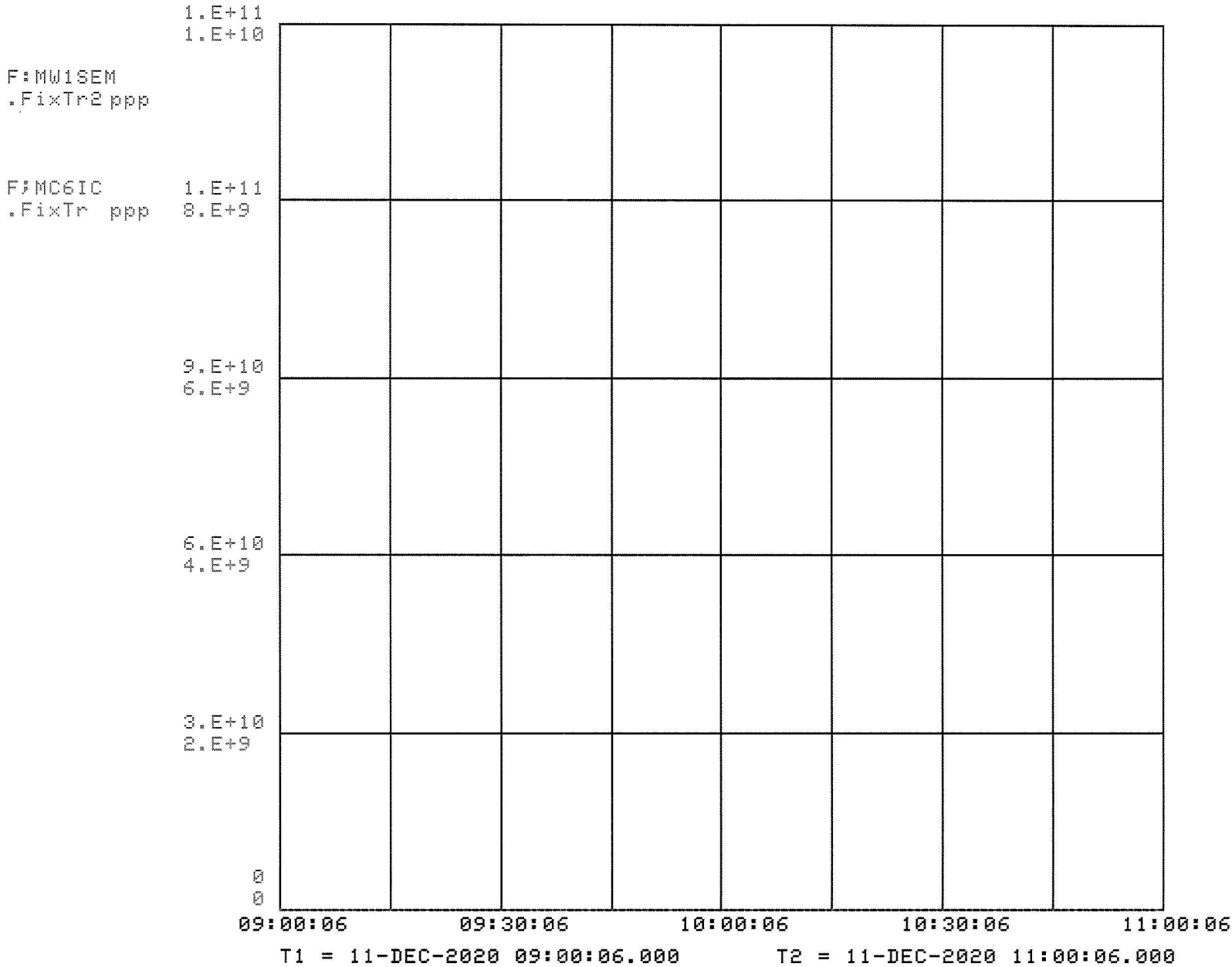
Created Dec 8, 2020

location	Gamma cpm	Neutron mrem
1	1383	
2	1100	
3	1096	
4	1103	
5	1422	
6	1536	
7	1423	
8	1455	
9	1344	
10	1510	
11	1337	
12	1595	
13	1473	
14	1422	
15	1436	
16	1438	
17	1040	
18	1144	
19	1333	
20	1280	
21	1640	
22		
23		
24		
25		



All Areas < <u>N/A</u> mR/hr@1foot (Unless otherwise indicated)		Highest Dose Rate Found: <u>N/A</u> mR/hr@1foot	
Radiation Instruments Used			
Inst Type: <u>DICORON ANALYST</u>		Bkgd _____ cpm Comments: readings are 1 minute integration No neutron background taken due to no source from beam.	
Inst No: <u>#33</u>			
Batt/Source Chk: <u>SAT/SAT</u>			
Cal. Due Date: <u>AUG 2021</u>			
Background: <u>SEE ABOVE</u>			
LEGEND		Wipe # Reading Wipe # Reading _____ _____ _____ _____ ccpm ccpm ccpm ccpm ccpm ccpm ccpm ccpm ccpm ccpm	
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (R) - Radioactive Material Wipe (H) - Wipe (F) - Floor Wipe		Surveyed By: <u>[Signature]</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u> <small>Digitally signed by Maddie Schoell, UID:maddiew Date: 2021.02.02 11:15:26 -0600</small>	

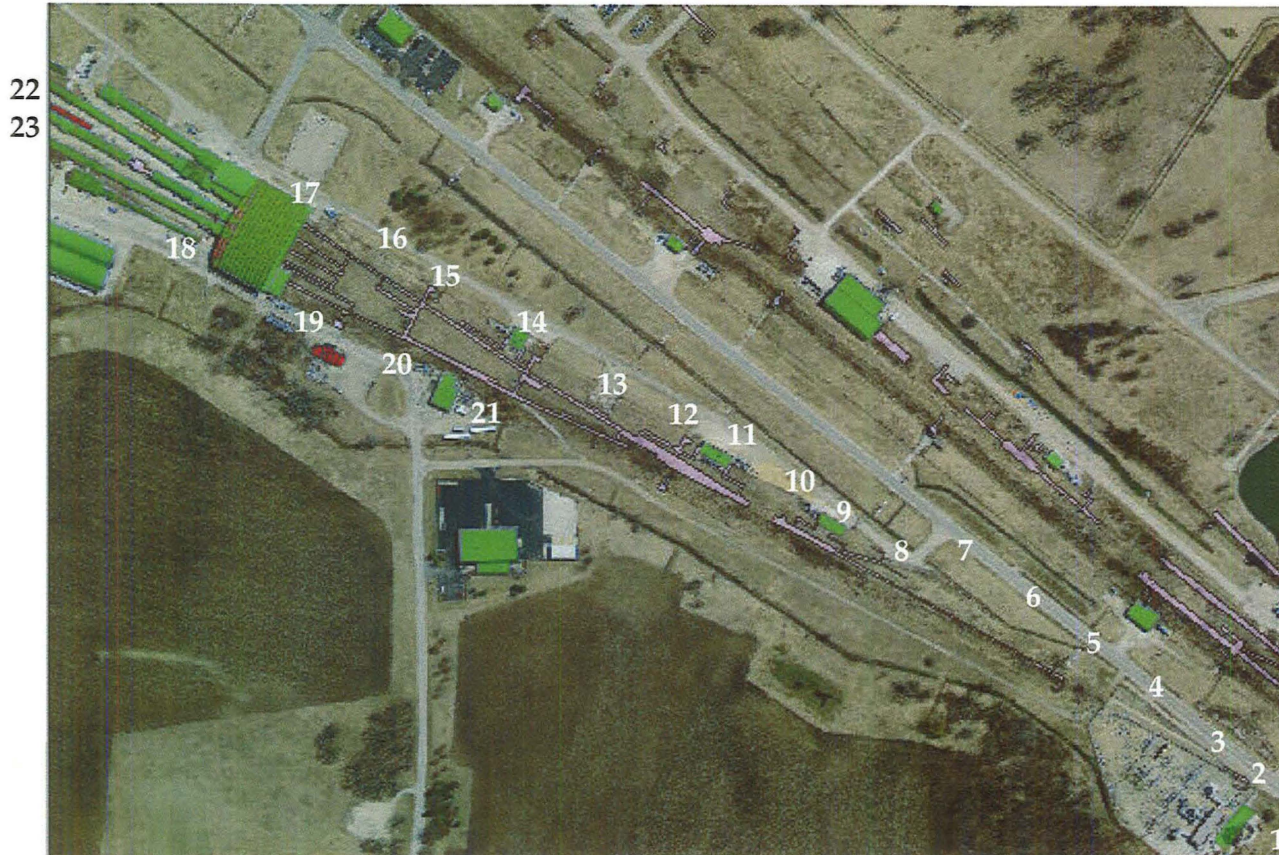
Fri 15-JAN-2021 12:48:06



Console Location 148, 15-JAN-21 12:48:34
Shots to Recycler

Meson Beam On Survey

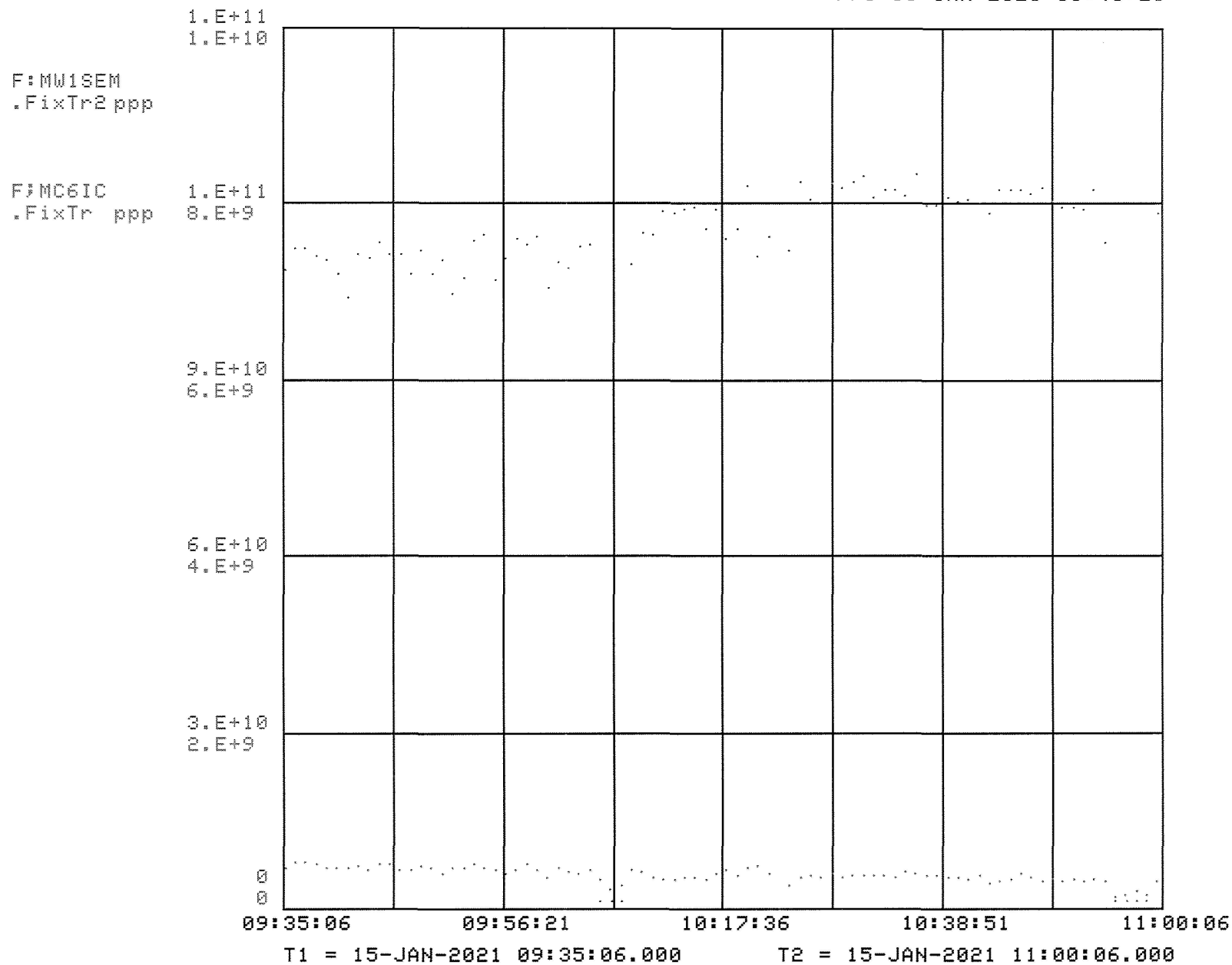
Created Dec 8, 2020



location	Gamma cpm	Neutron mrem
1	1162	0
2	1115	0
3	1200	0
4	1182	0
5	1202	0
6	1260	0
7	1309	0
8	1465	0
9	1371	0
10	1411	0
11	1546	0
12	1375	0
13	1285	0
14	1316	0
15	1286	0
16	1295	0
17	1065	0
18	1186	0
19	1241	0
20	1374	0
21	1398	0
22	1206	0
23	1434	0
24		
25		

All Areas < <u>NA</u> mR/hr@1foot (Unless otherwise indicated)			Highest Dose Rate Found: <u>NA</u> mR/hr@1foot	
Radiation Instruments Used			Bkgd _____ cpm	
Inst Type: <u>Analyst</u>	<u>Rom 500</u>			
Inst No: <u>26</u>	<u>1</u>		Comments: readings are 1 minute integration	
Batt/Source Chk: <u>SAT</u>	<u>SAT</u>			
Cal. Due Date: <u>4-21</u>	<u>10-21</u>			
Background: <u>NA</u>				
LEGEND			Wipe # Reading Wipe # Reading _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm _____ ccpm	
# - Dose Rate in mR/hr @ 1 ft. * - Unlabeled Radioactive Material (#R) - Radioactive Material Wipe (#) - Wipe (#F) - Floor Wipe			Surveyed By: <u>F. Lyden</u> Reviewed By: <u>Maddie Schoell, UID:maddiew</u>	

Fri 15-JAN-2021 11:43:26



Meson (Primary, Test & Center)

Gamma Survey Results

Bicron Results

Location	Background (cpm)	Gross Beam-On (cpm)	Net Beam-On (cpm)	Standard Deviation	Net ± St. Dev.	L _c	N _D
1	1383	1162	-221	50.45	-221 ± 50.45	86.501	175.745
2	1100	1115	15	47.06	15 ± 47.06	77.145	157.029
3	1096	1200	104	47.92	104 ± 47.92	77.004 !	156.748
4	1103	1182	79	47.80	79 ± 47.8	77.250 !	157.239
5	1422	1202	-220	51.22	-220 ± 51.22	87.712	178.168
6	1536	1260	-276	52.88	-276 ± 52.88	91.160	185.066
7	1423	1309	-114	52.27	-114 ± 52.27	87.743	178.230
8	1455	1465	10	54.04	10 ± 54.04	88.724	180.192
9	1344	1371	27	52.11	27 ± 52.11	85.273	173.288
10	1510	1411	-99	54.05	-99 ± 54.05	90.385	183.516
11	1337	1546	209	53.69	209 ± 53.69	85.050 !	172.843
12	1595	1375	-220	54.50	-220 ± 54.5	92.895	188.535
13	1473	1285	-188	52.52	-188 ± 52.52	89.271	181.287
14	1422	1316	-106	52.33	-106 ± 52.33	87.712	178.168
15	1436	1286	-150	52.17	-150 ± 52.17	88.143	179.030
16	1438	1295	-143	52.28	-143 ± 52.28	88.204	179.152
17	1040	1065	25	45.88	25 ± 45.88	75.011	152.761
18	1144	1186	42	48.27	42 ± 48.27	78.672	160.085
19	1333	1241	-92	50.73	-92 ± 50.73	84.923	172.588
20	1280	1374	94	51.52	94 ± 51.52	83.218 !	169.177
21	1640	1298	-342	54.20	-342 ± 54.2	94.196	191.138
22*	1358	1206	-152	50.64	-152 ± 50.64	85.716	174.174
23*	1358	1434	76	52.84	76 ± 52.84	85.716	174.174

Converted to mR/hr

Background (mR/hr)	Gross Beam-On (mR/hr)	Net Beam-On (mR/hr)	Standard Deviation	Net ± St. Dev.	D _D
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.005	0.006	0.001	0.0002	0.001 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.008	0.001	0.0003	0.001 ± 0.0003	0.001
0.008	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.005	0.005	0.000	0.0002	0 ± 0.0002	0.001
0.006	0.006	0.000	0.0002	0 ± 0.0002	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.006	0.007	0.000	0.0003	0 ± 0.0003	0.001
0.008	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.006	0.000	0.0003	0 ± 0.0003	0.001
0.007	0.007	0.000	0.0003	0 ± 0.0003	0.001

*When original background measurements were taken, only MTest & MPrimary were planned to be operational for the beam-on survey, so locations 22 and 23 weren't included. MCenter was approved to run prior to the beam-on survey, locations 22 and 23 added. Beam-on readings were consistent with other near-background measurements. Background taken to be the average of the other 21 background measurements.

Meson (Primary, Test & Center)

Neutron Survey Results

Location	Average Background (mrem)	Average Background (mrem/hr)	Gross Beam-On (mrem/hr)	Net Beam-On (mrem/hr)	Sample Standard Deviation (mrem/hr)	Net ± St. Dev. (mrem/hr)	L _{C,N}	D _{D,N}
1	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
2	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
3	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
4	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
5	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
6	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
7	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
8	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
9	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
10	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
11	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
12	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
13	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
14	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
15	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
16	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
17	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
18	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
19	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
20	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
21	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
22	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04
23	0.01933	0.01933	0.000	0.000	1.08E-04	0 ± 0.000108	2.52E-04	5.04E-04

Meson (Primary, Test & Center) - Meson Primary Locations

Scaling Dose Rates to Meson Primary Operating Limit Intensity & Calculate Annual Dose

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma	Neutron	Gamma			Neutron		
	Net Beam-On (mR/hr)	Net Beam-On (mrem/hr)	Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
1	0.000	0.000	0.000	0.000	0.000	0	0	0
2	0.000	0.000	0.000	0.000	0.000	0	0	0
3	0.001	0.000	0.012	24.000	71.158	0	0	0
4	0.000	0.000	0.000	0.000	0.000	0	0	0
5	0.000	0.000	0.000	0.000	0.000	0	0	0
6	0.000	0.000	0.000	0.000	0.000	0	0	0
7	0.000	0.000	0.000	0.000	0.000	0	0	0
8	0.000	0.000	0.000	0.000	0.000	0	0	0
9	0.000	0.000	0.000	0.000	0.000	0	0	0
10	0.000	0.000	0.000	0.000	0.000	0	0	0
11	0.001	0.000	0.012	24.000	71.158	0	0	0
12	0.000	0.000	0.000	0.000	0.000	0	0	0
13	0.000	0.000	0.000	0.000	0.000	0	0	0
14	0.000	0.000	0.000	0.000	0.000	0	0	0
15	0.000	0.000	0.000	0.000	0.000	0	0	0
16	0.000	0.000	0.000	0.000	0.000	0	0	0
19	0.000	0.000	0.000	0.000	0.000	0	0	0
20	0.000	0.000	0.000	0.000	0.000	0	0	0
21	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)		Beam Up-Time	
Survey	Op. Limit	# Weeks	Efficiency
1.40E+13	1.68E+14	44	80%
		67.7%	

Meson (Primary, Test & Center) - Meson Test Locations

Scaling Dose Rates to Meson Test Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	Gamma	Neutron	Gamma			Neutron		
	Net Beam-On (mR/hr)	Net Beam-On (mrem/hr)	Net Beam-On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam-On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
16	0.000	0.000	0.000	0.000	0.000	0	0	0
17	0.000	0.000	0.000	0.000	0.000	0	0	0
18	0.000	0.000	0.000	0.000	0.000	0	0	0
19	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
6.50E+12	1.20E+13

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	

Meson (Primary, Test & Center) - Meson Center Locations

Scaling Dose Rates to Meson Center Operating Limit Intensity & Calculate Annual Dose

At Survey Intensity

Scaled to Operating Limit Intensity at Standard Beam Up-Time

Location	At Survey Intensity		Scaled to Operating Limit Intensity at Standard Beam Up-Time					
	Gamma Net Beam- On (mR/hr)	Neutron Net Beam- On (mrem/hr)	Gamma			Neutron		
			Net Beam- On (mR/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)	Net Beam- On (mrem/hr)	2,000 hr Working Year (mrem)	24/7/365 (mrem)
16	0.000	0.000	0.000	0.000	0.000	0	0	0
17	0.000	0.000	0.000	0.000	0.000	0	0	0
19	0.000	0.000	0.000	0.000	0.000	0	0	0
22	0.000	0.000	0.000	0.000	0.000	0	0	0
23	0.000	0.000	0.000	0.000	0.000	0	0	0

Intensities (protons/hr)	
Survey	Op. Limit
2.50E+10	1.02E+12

Beam Up-Time	
# Weeks	44
Efficiency	80%
67.7%	