



NOvA Test Beam Experiences & Issues

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for the NOvA Test Beam Group

Accelerator Division Coordination Meeting

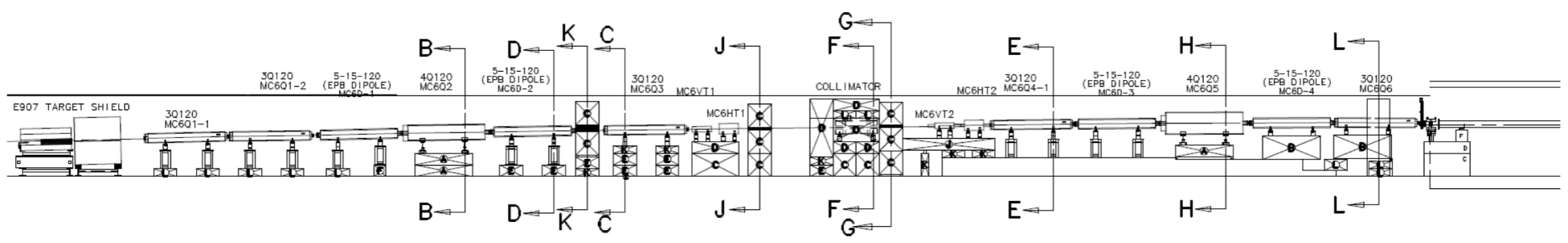
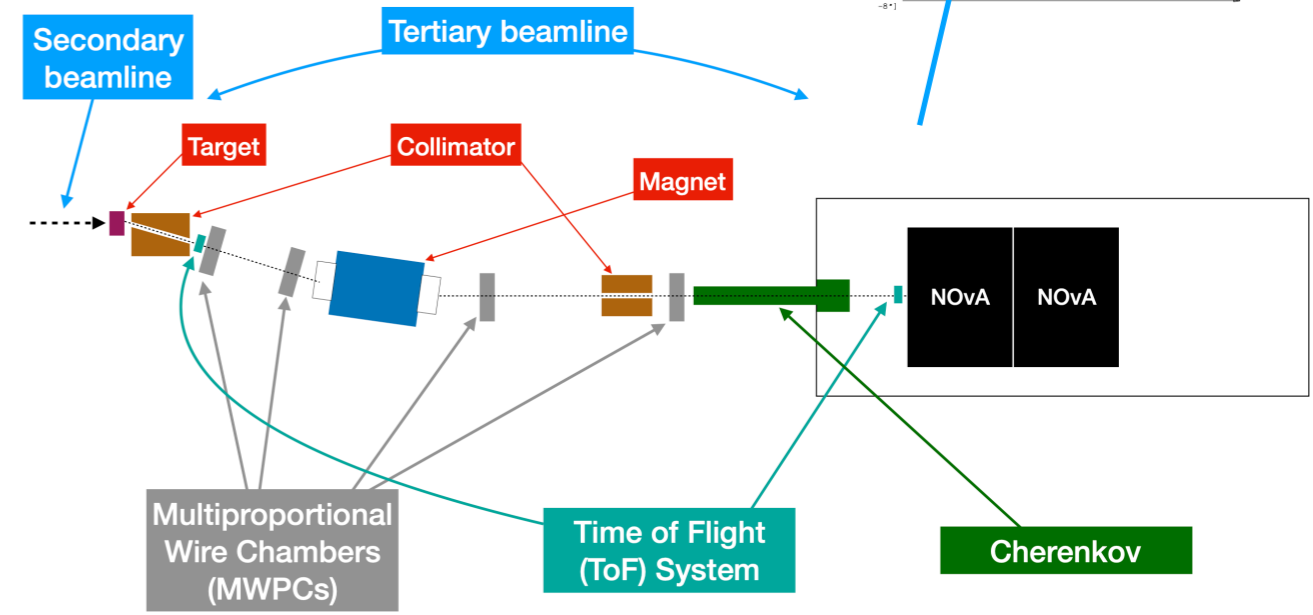
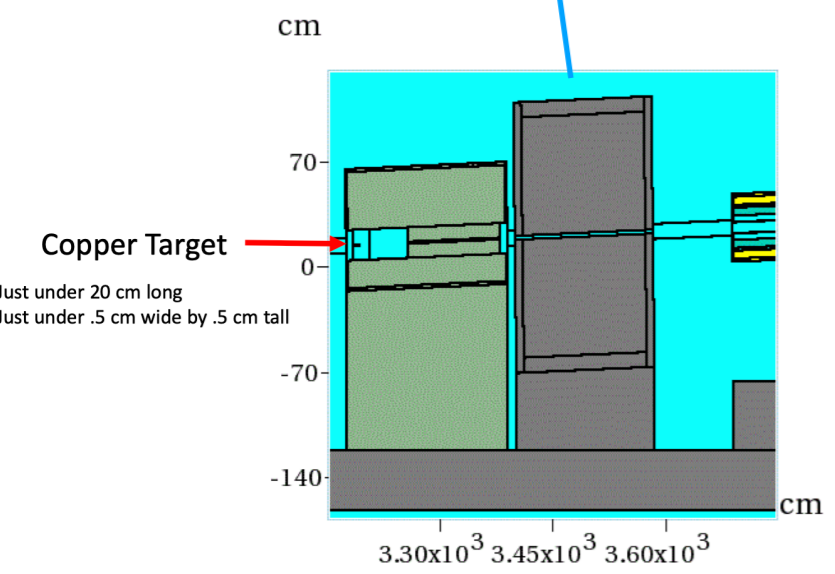
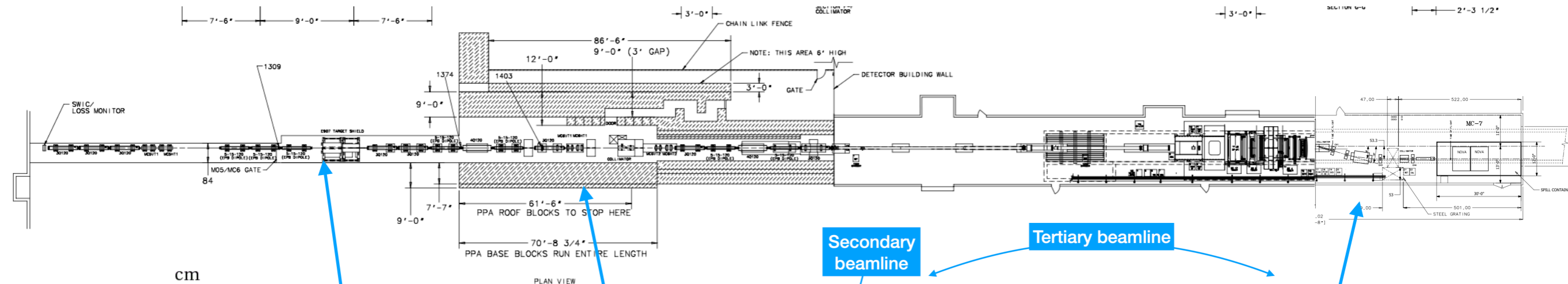
2/26/2020

NOvA Test Beam Program



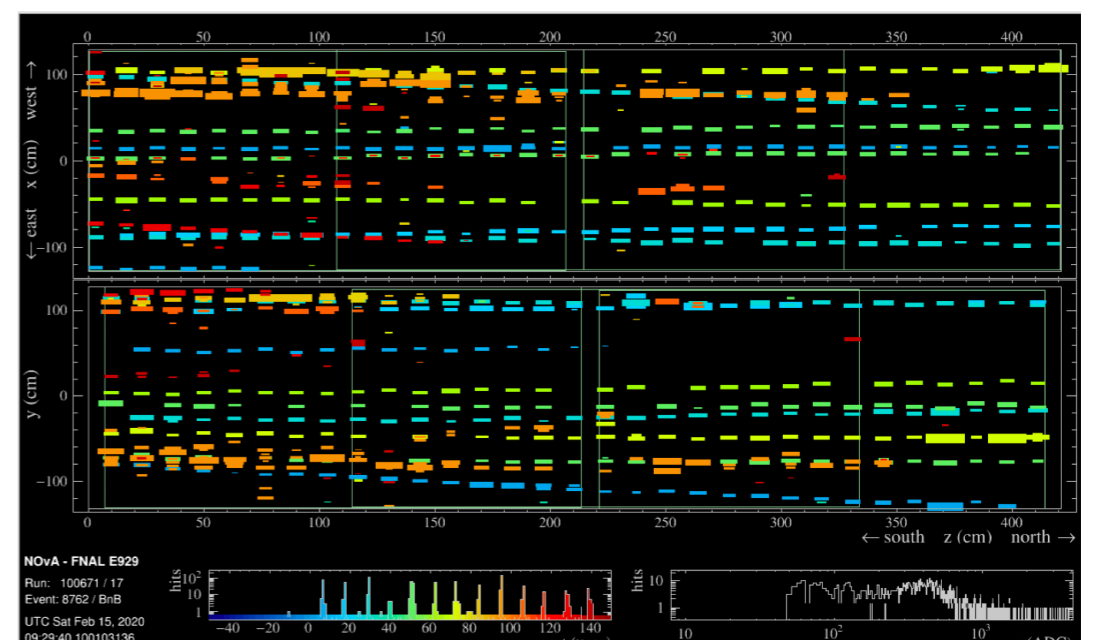
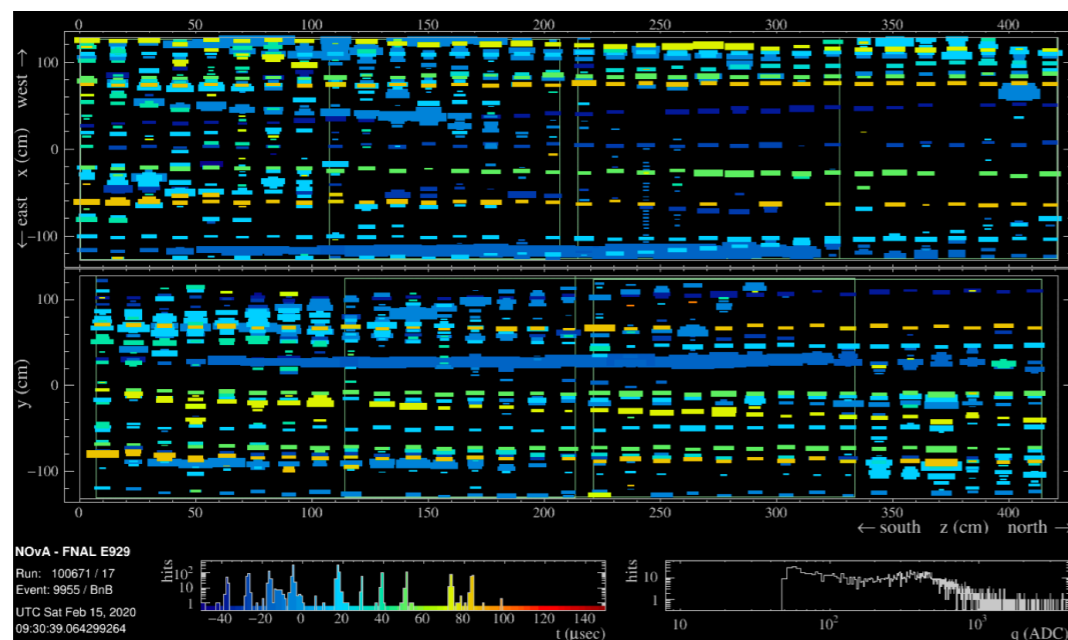
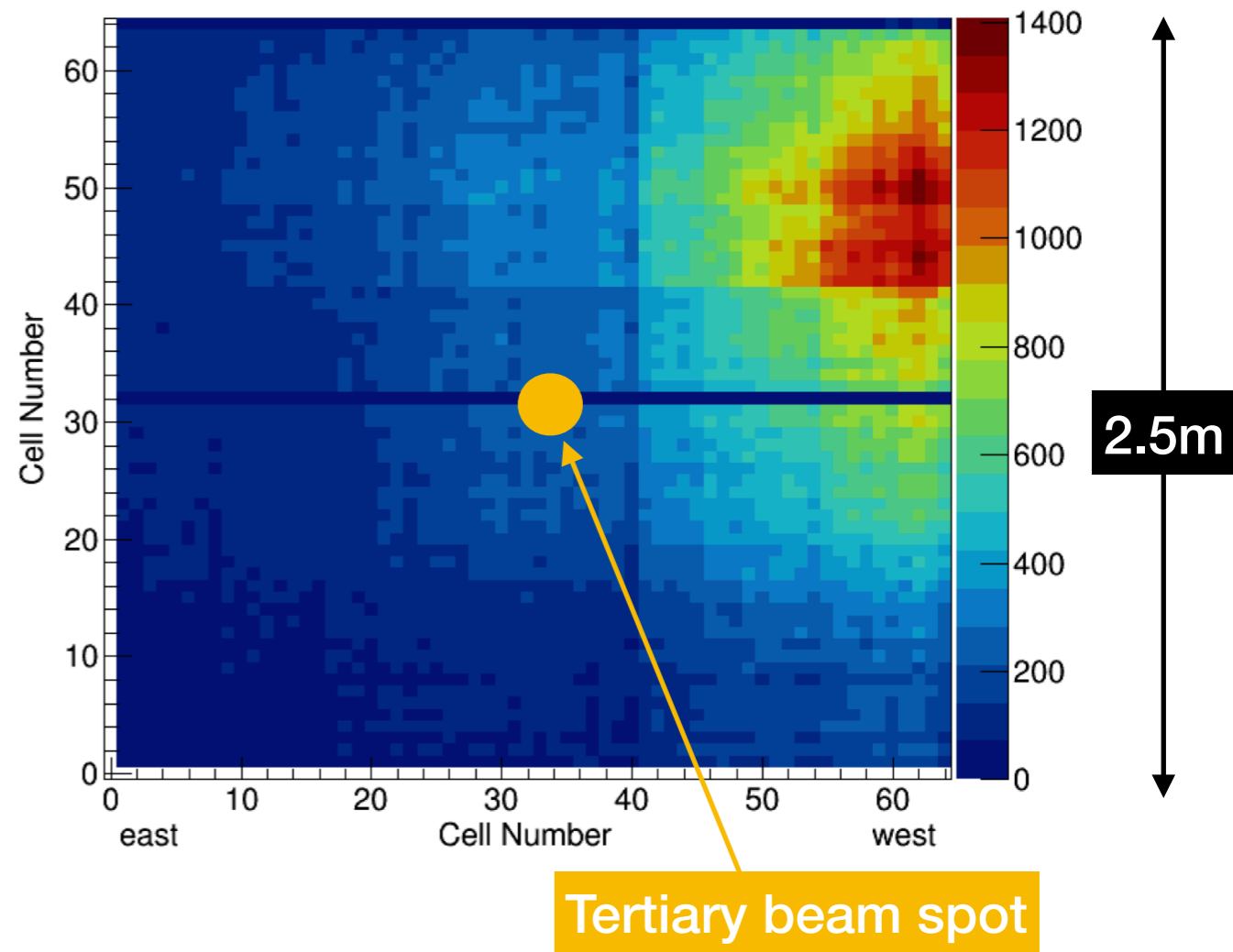
- Collect tagged charged particles (p , π , e , μ , K) in energy range relevant to NOvA neutrino interactions (0.2 — 2 GeV).
- Operating in tertiary beamline at MCenter.
- Expected particle rates: $3e6$ π , $2.6e6$ p , $7.8e4$ e , $3.9e4$ μ , $2.6e4$ K ($\sim 5.6e6$ total).

NOvA Test Beam Beamline



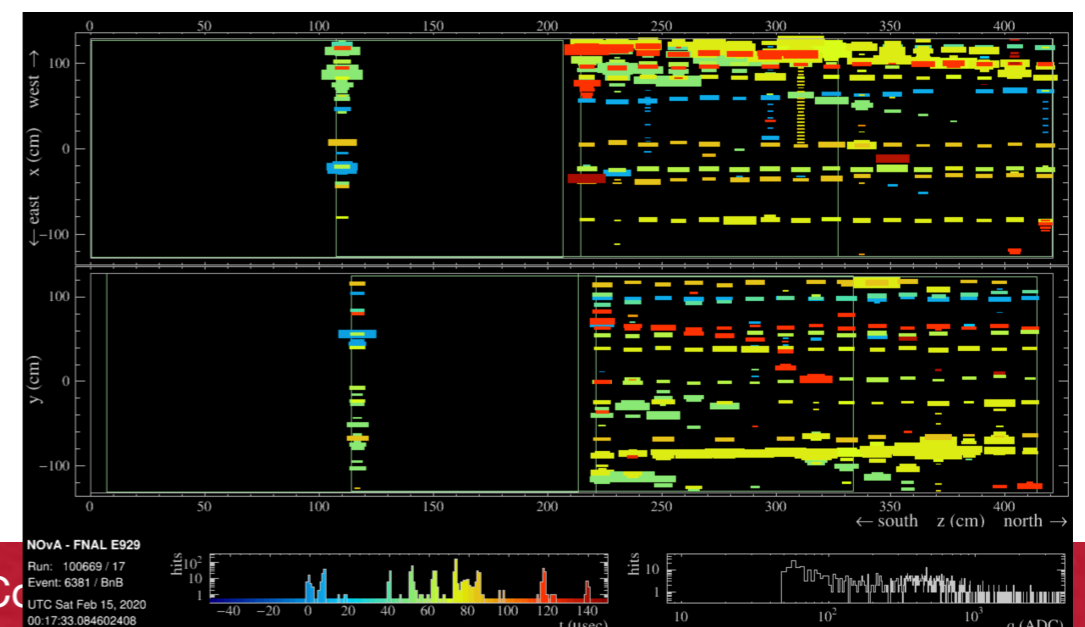
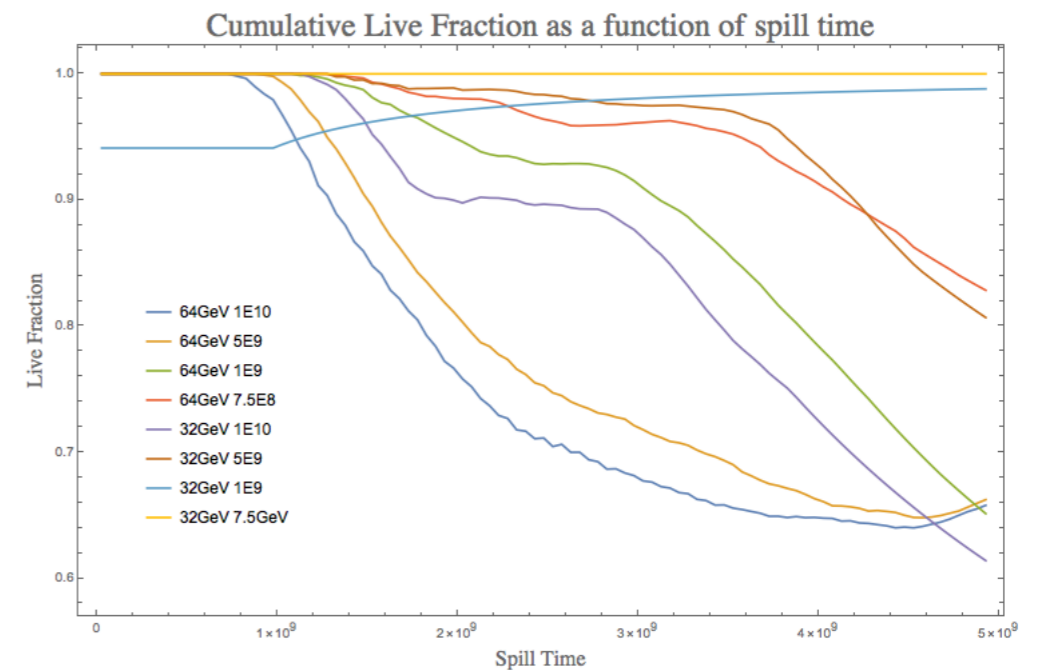
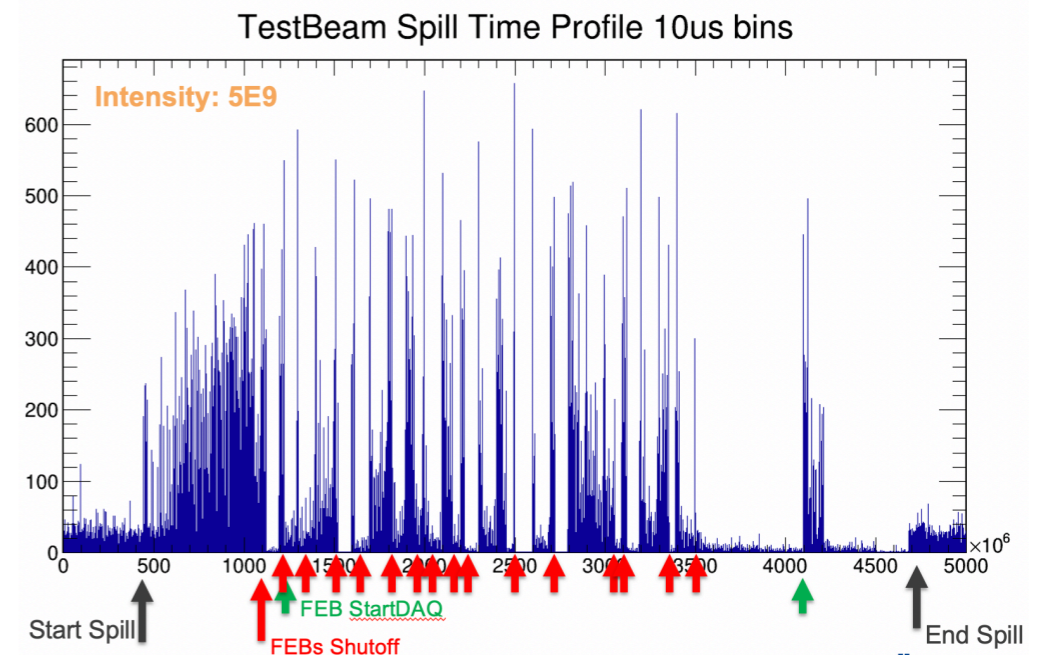
Halo Problems

- Large amounts of high intensity, high energy, off-axis beam halo present in the beamline.
- Swamps the full detector, with a concentration in the Upper West part of the detector (slightly above and to the left when looking down the secondary beam).

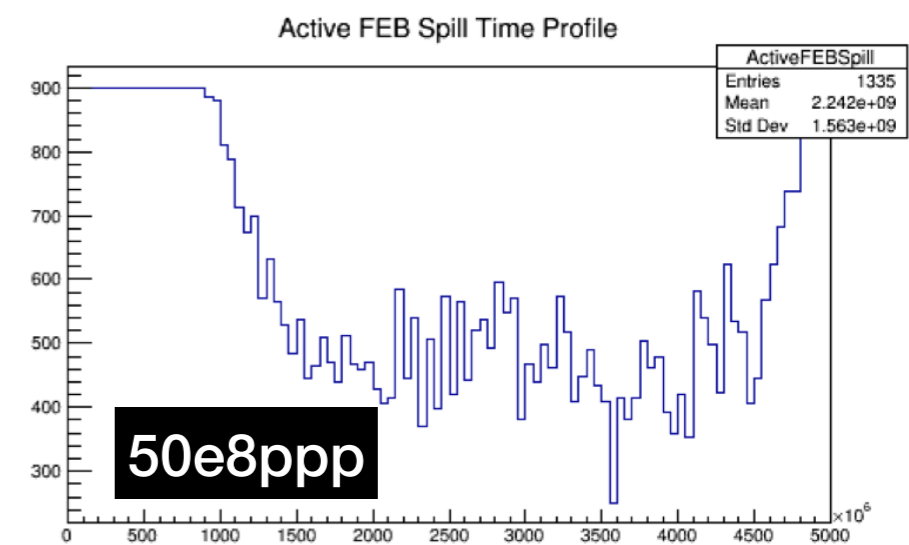
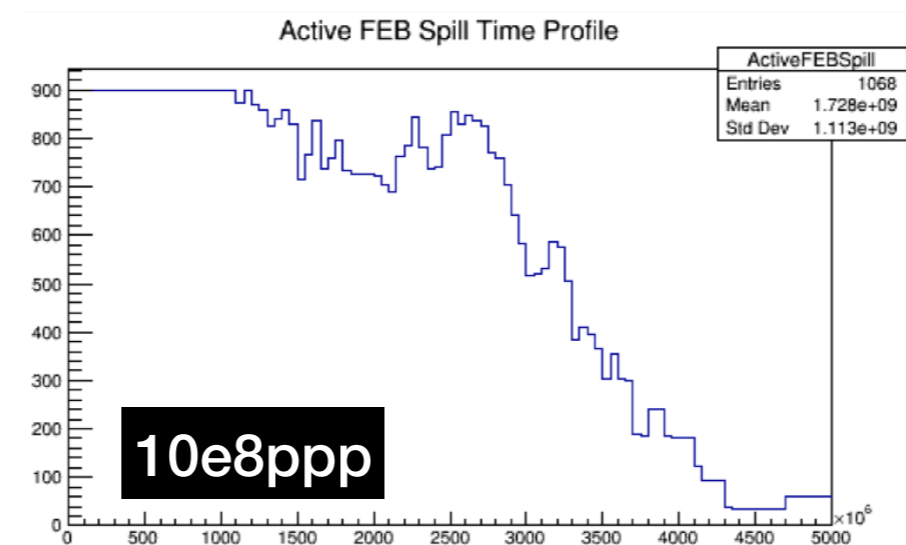
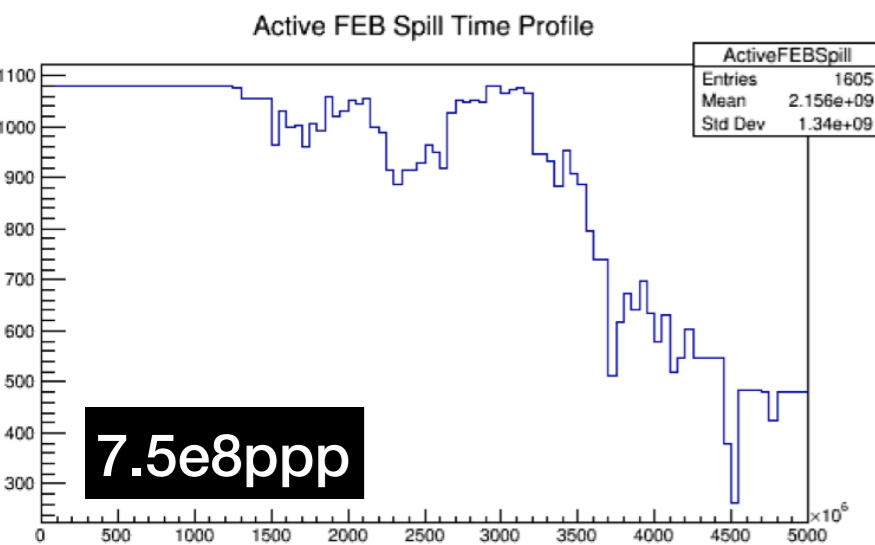
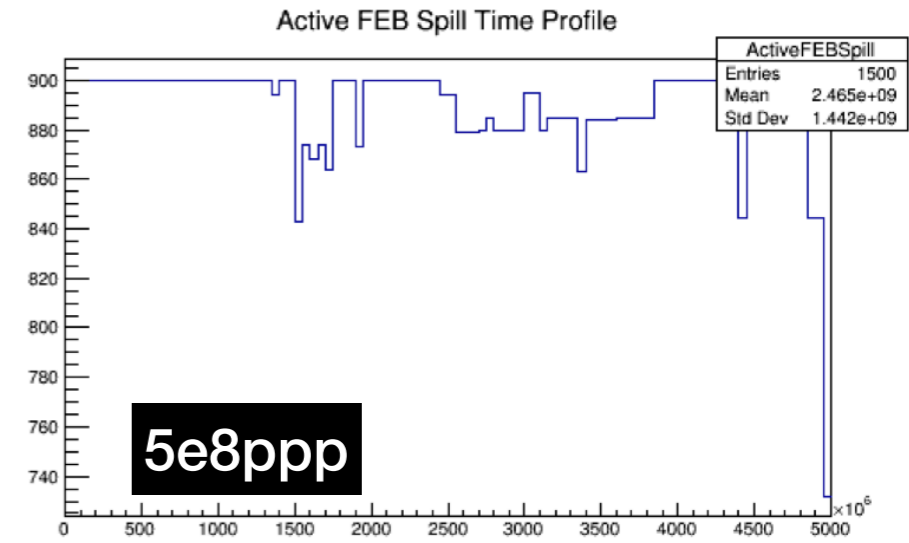
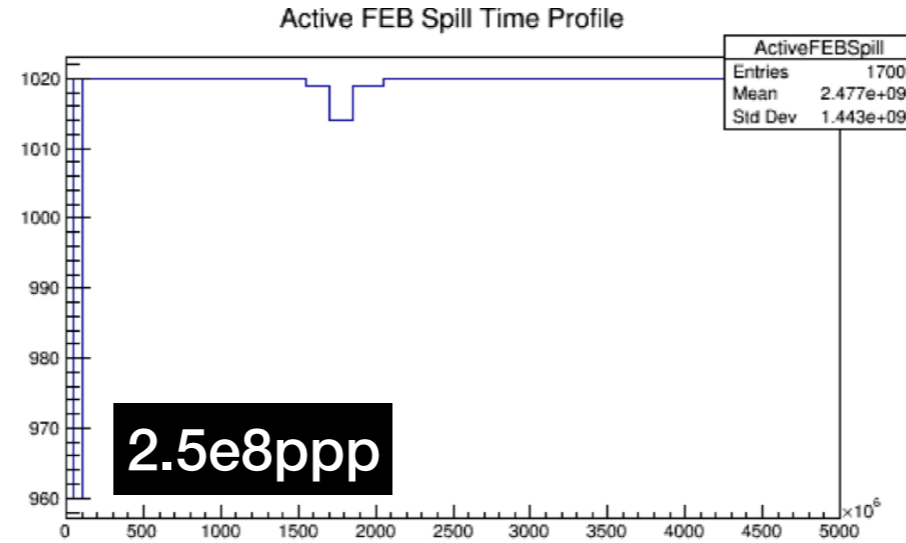
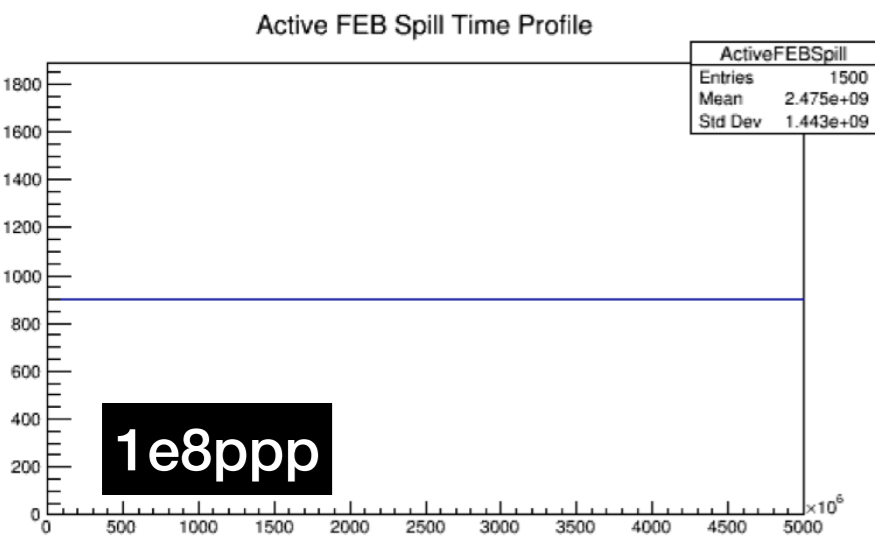


Halo Problems

- Detector front-end electronics (designed for neutrino events) cannot handle pile-up rate; saturate, shut-off during spill. We clear the buffers and reenables data-taking at a rate of 10 Hz. Still miss large amounts of tertiary beam events, resulting in a lot of unusable data for analysis.
- To handle the data rate, we are operating the beam at a significantly lower intensity, and are collecting data at a rate around 2 orders of magnitude lower than expected.



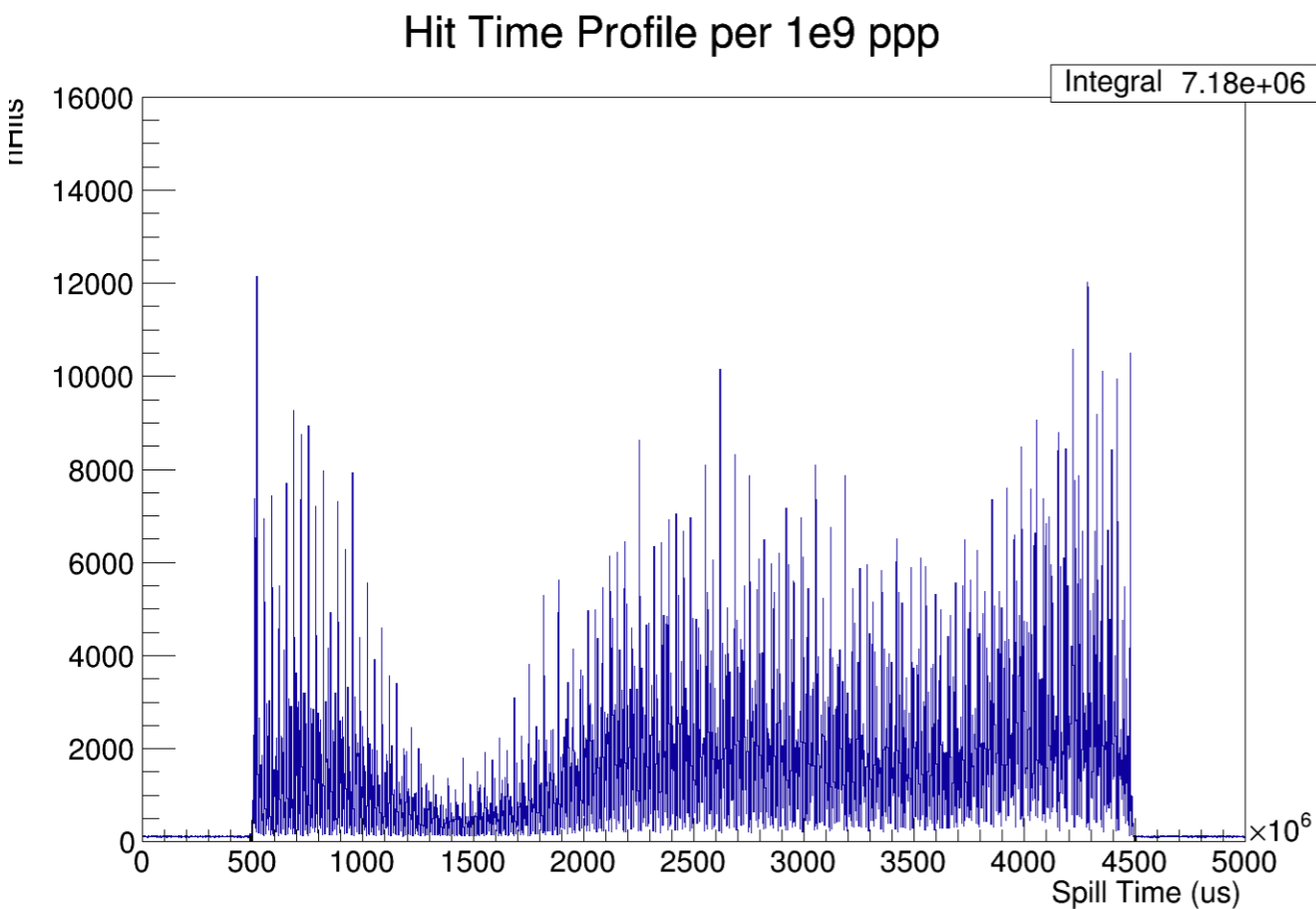
Halo Problems



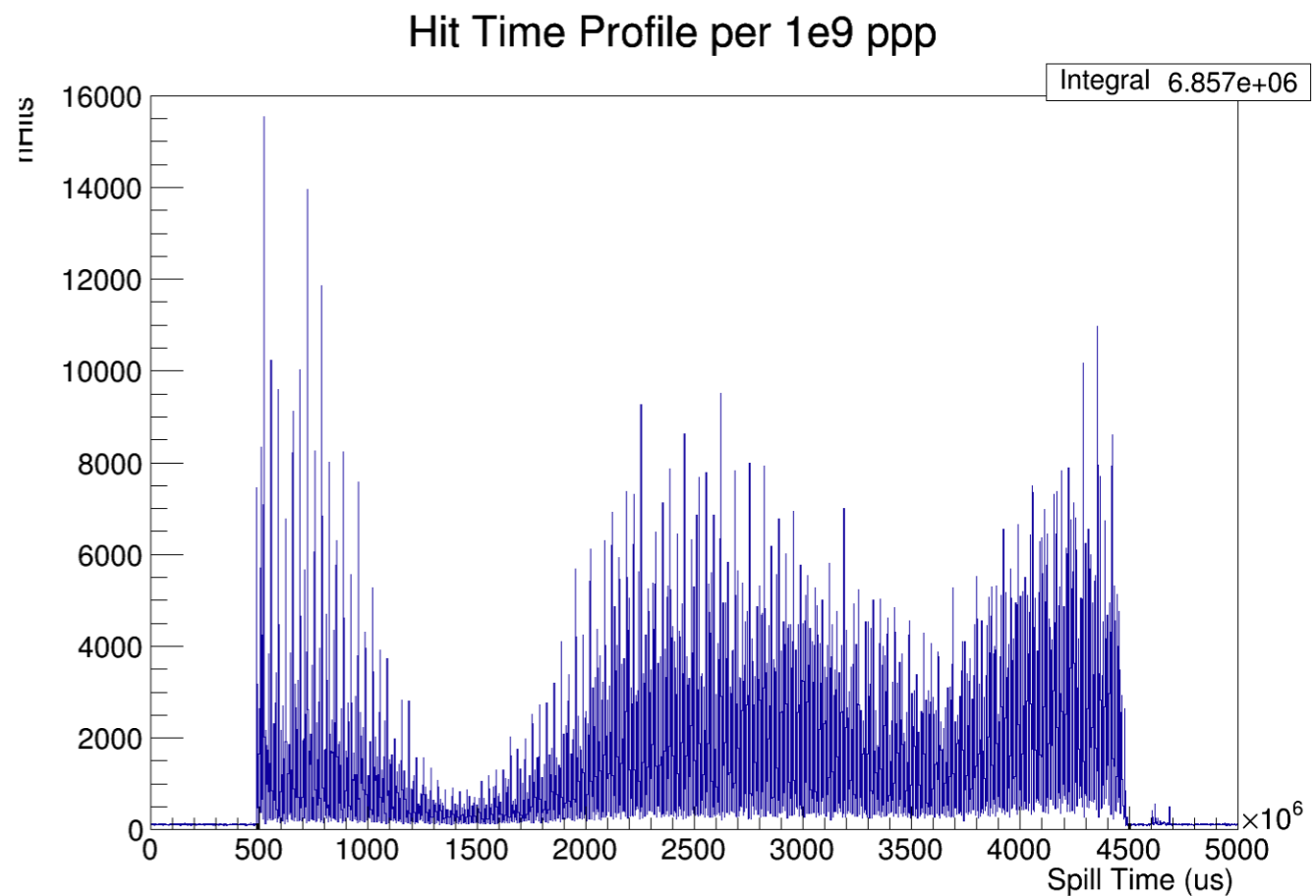
- Fraction of live front-end boards as a function of time in spill.

Spill Structure Problems

- Spill structure as observed by hits in detector, with and without the higher duty factor (~30% improvements) as ran yesterday.
- The initial spike before the dip is troublesome at shutting off our electronics.



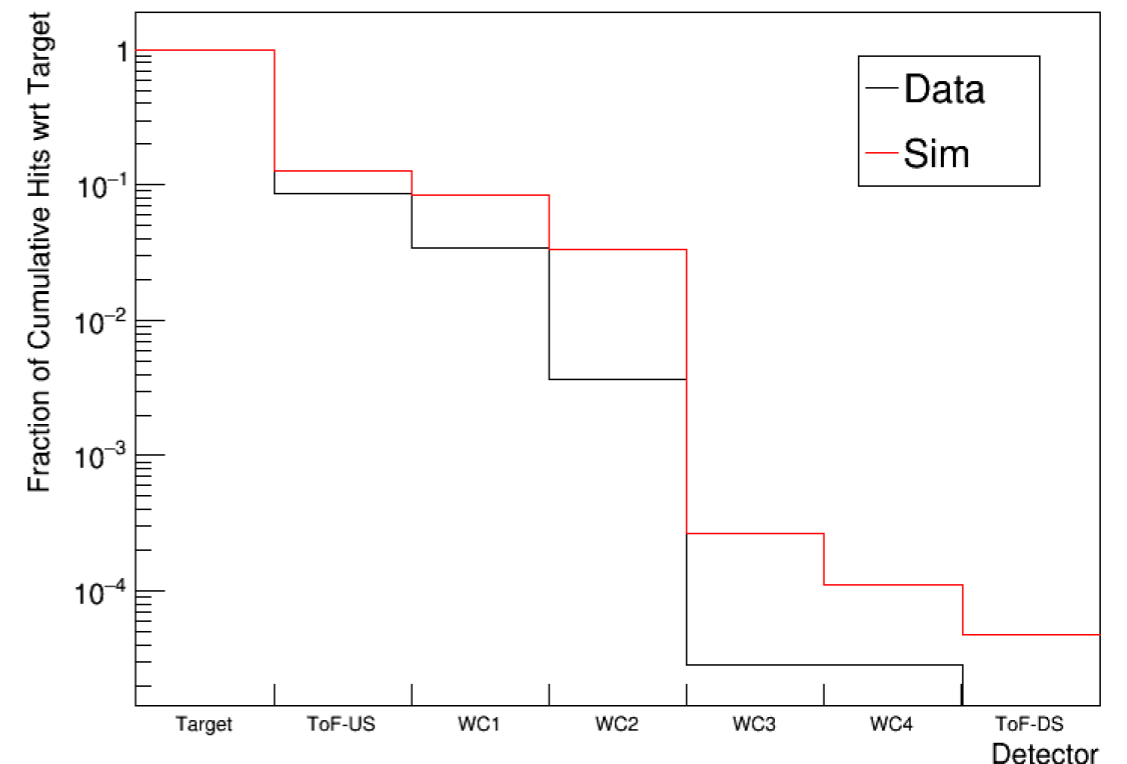
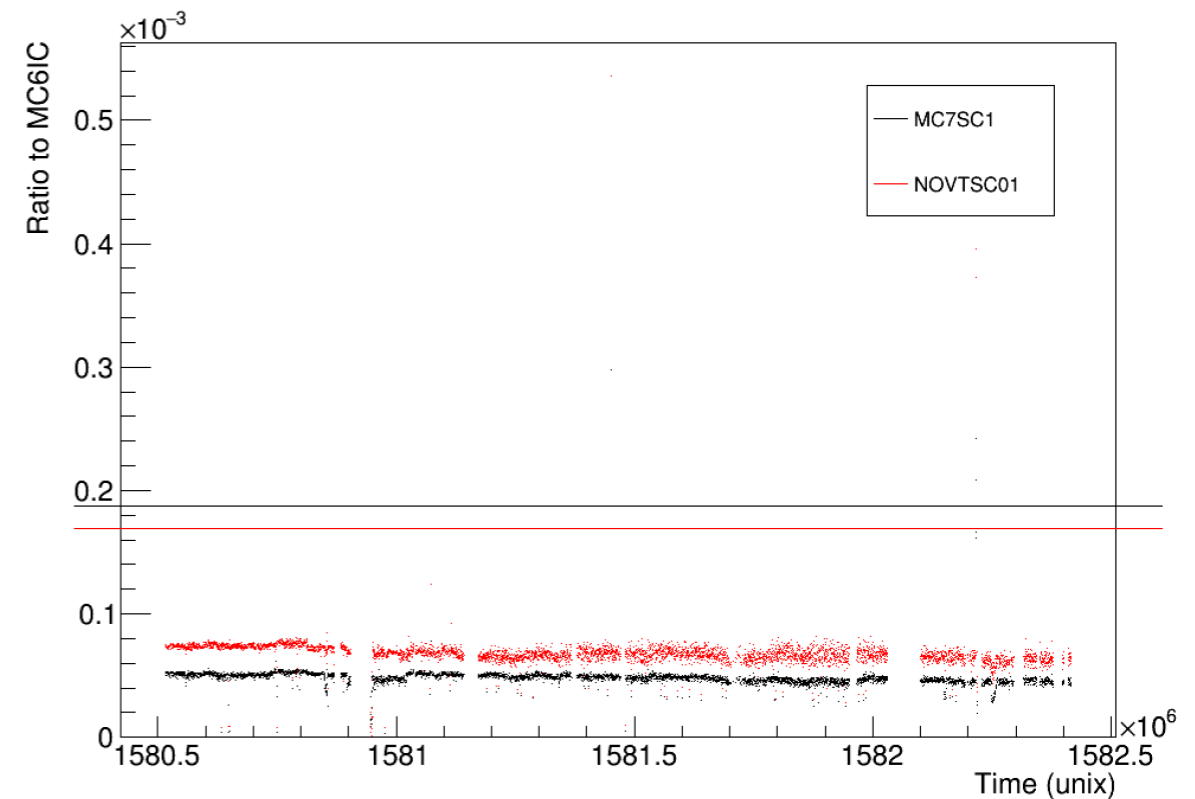
Lower duty factor (~30%)



Higher duty factor (~40%)

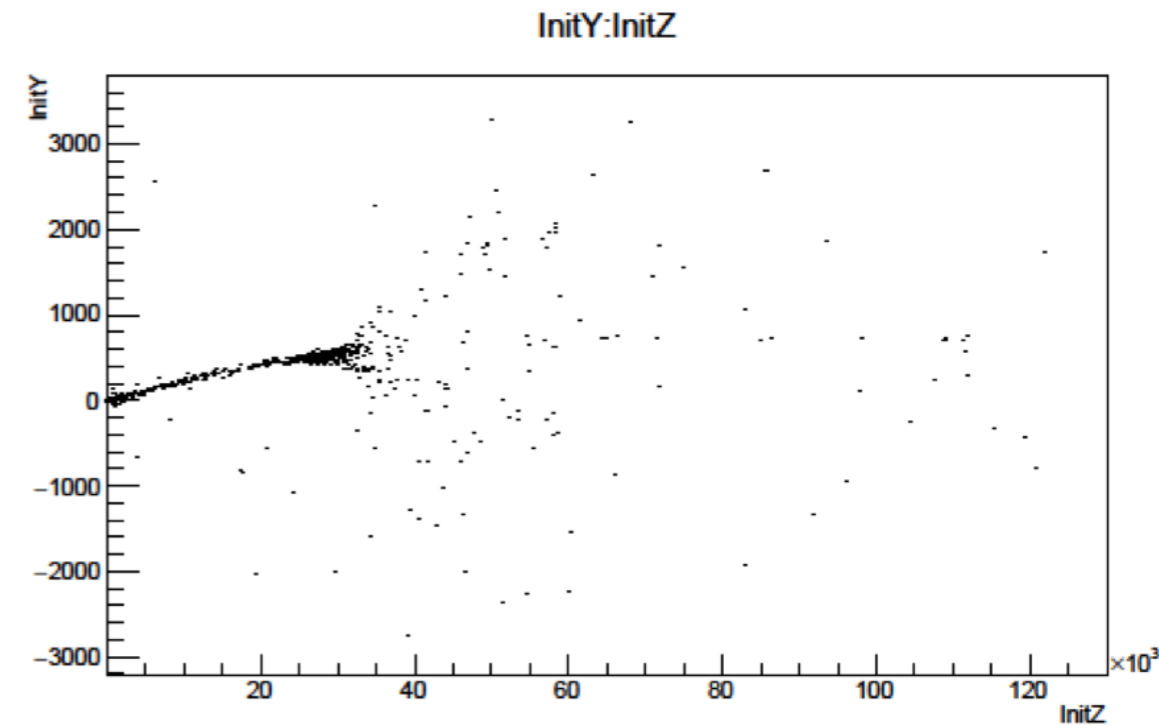
Simulation Problems

- Observe around a factor of 2 fewer hits on counters in secondary beamline than expected from simulation.
- Observe around an order of magnitude fewer hits on our tertiary beamline detectors than expected from simulation.



Understanding Halo Behavior

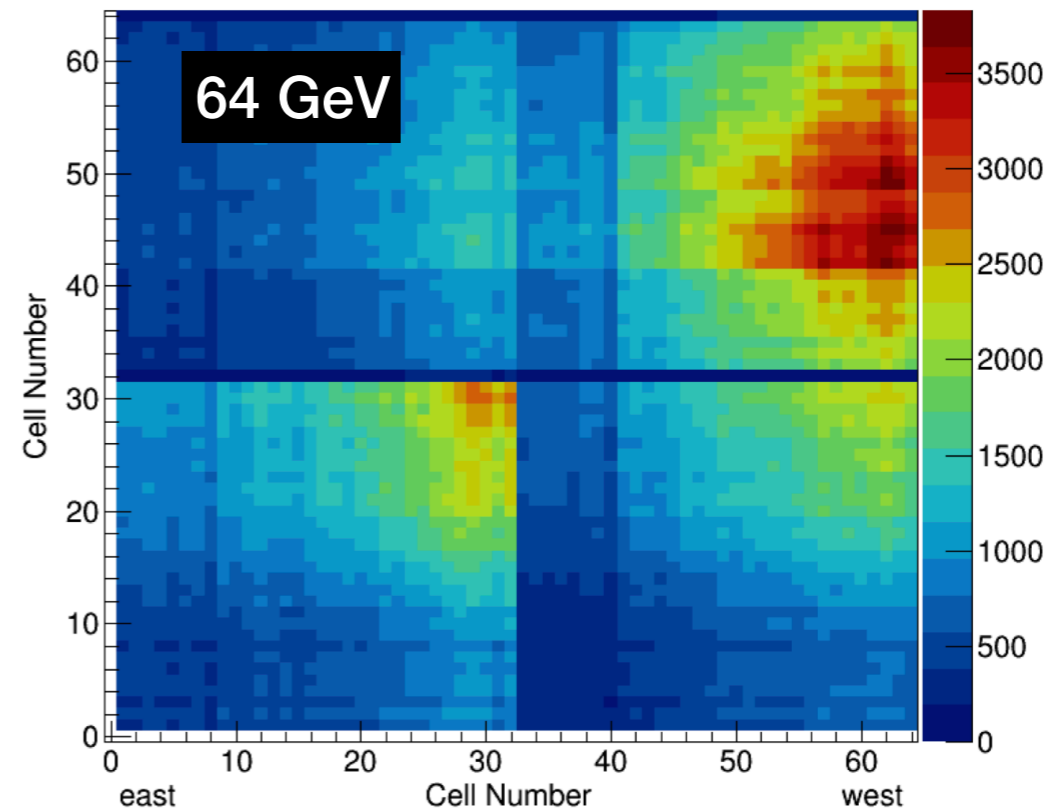
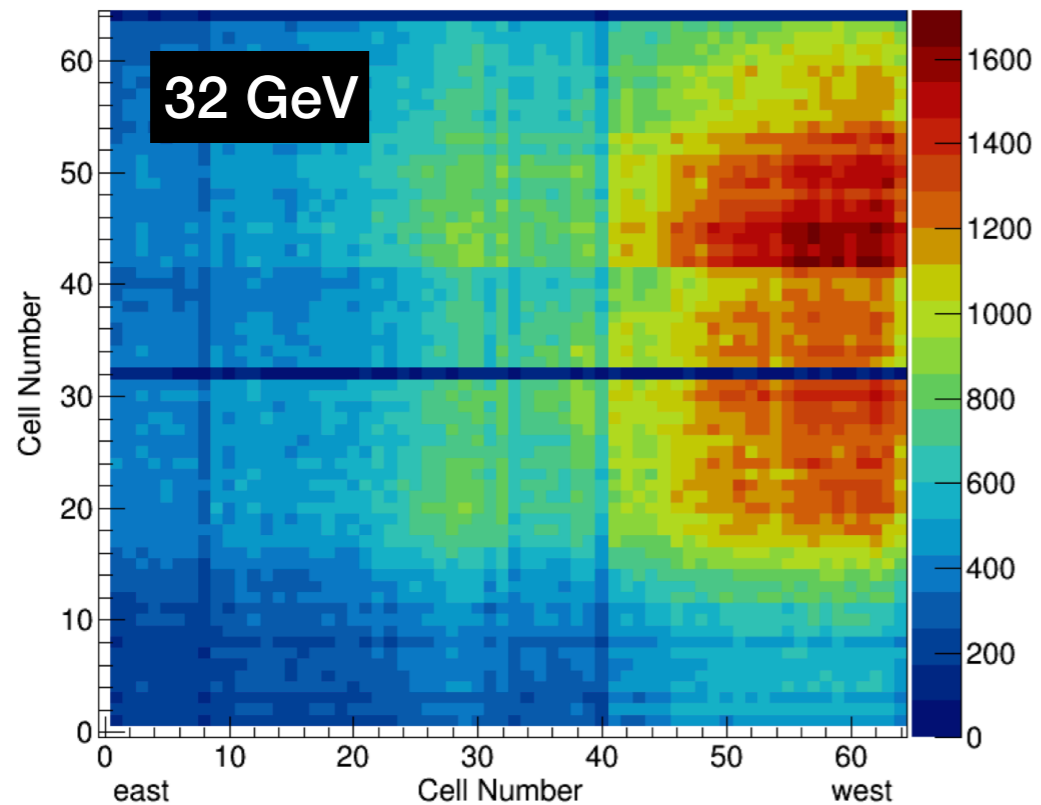
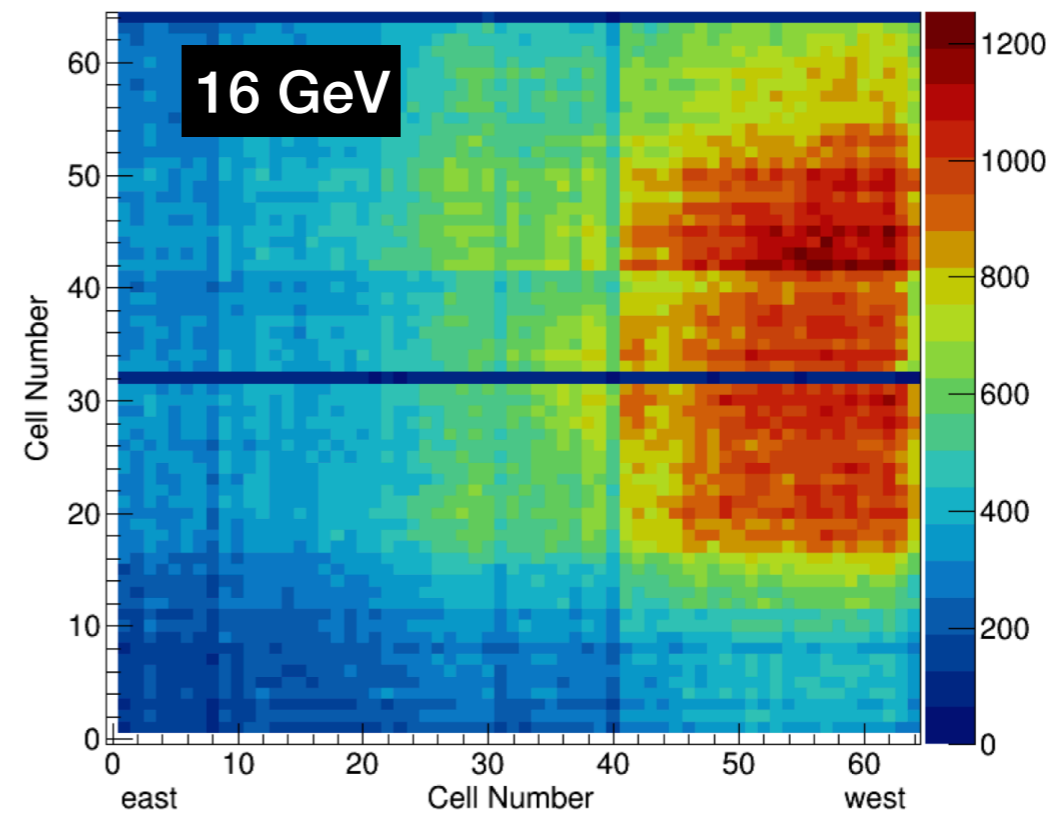
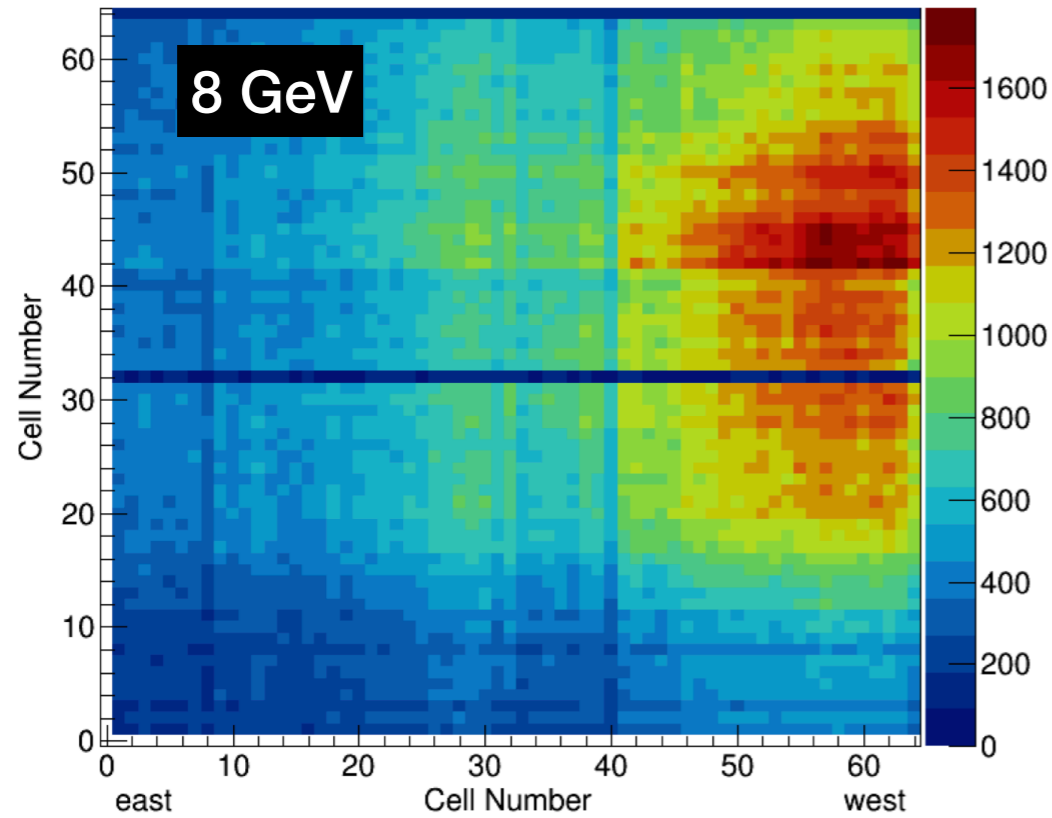
- Using a full combined MC6-MC7 simulation, we have tried to reproduce what we see.
 - Primary target/secondary beam simulation provided by AD, NOvA-built tertiary beam simulation.
- We do produce a lot of muons in the secondary beamline (as Adam has also seen), but they appear to have different characteristics to our halo.
 - Initial position of muons in NOvA detector come from MC6, mostly from first 35m and from inside the beamline.
 - In particular, when closing the collimator in the MC6 beam (MC6CV), we see the halo mostly goes away (along with the rest of our beam), whereas in the simulation this has no effect.



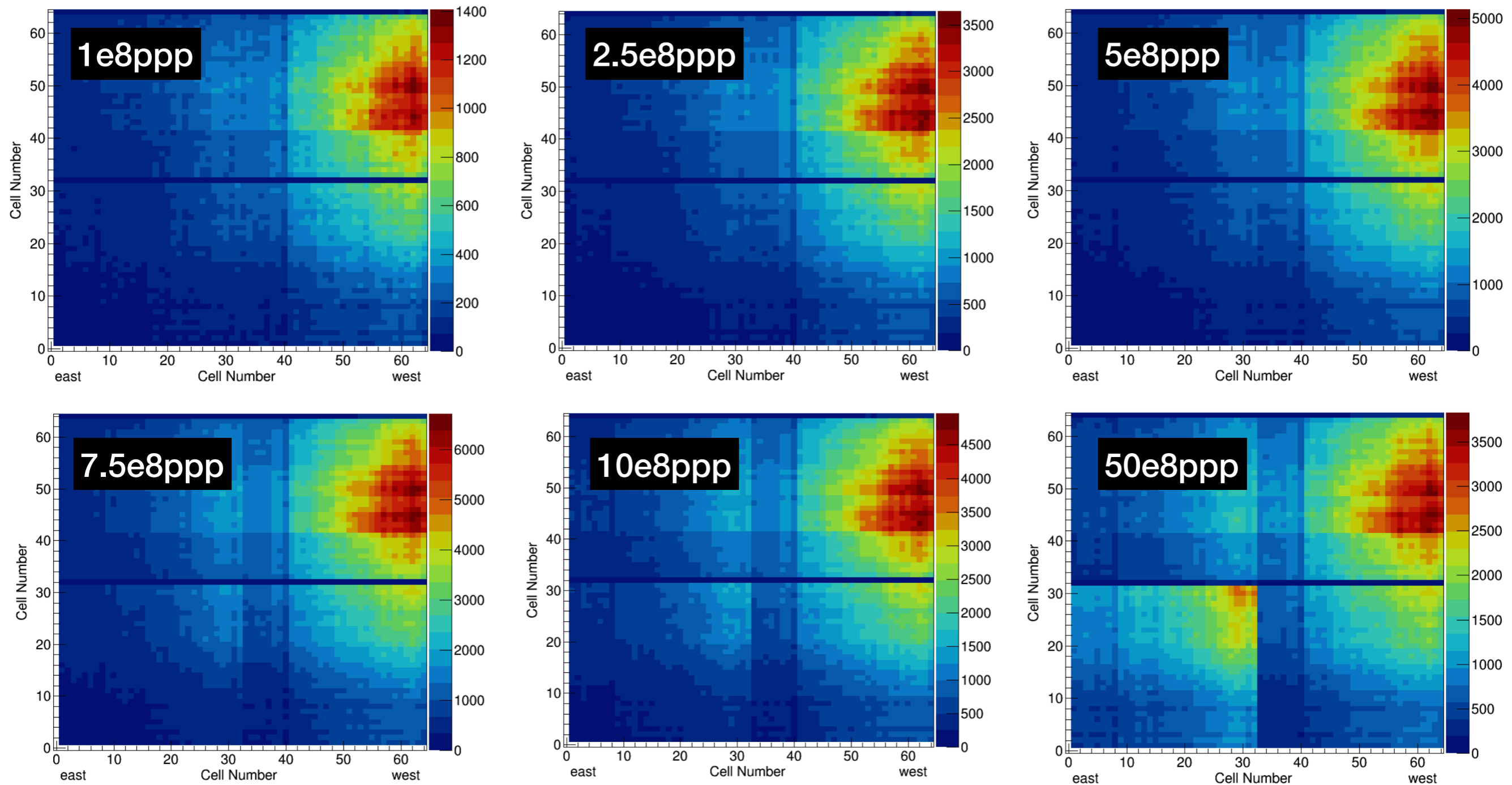
- F:MC6Q4
- ▲ F:MC6H2
- ▲ F:MC6V2
- ▨ F:MC6CV
- ▲ F:MC6H1
- ▲ F:MC6V1
- F:MC6Q3
- △ F:MC6D-2
- F:MC6Q2
- △ F:MC6D-1
- F:MC6Q1 (2)
- MC6TGT

MC6

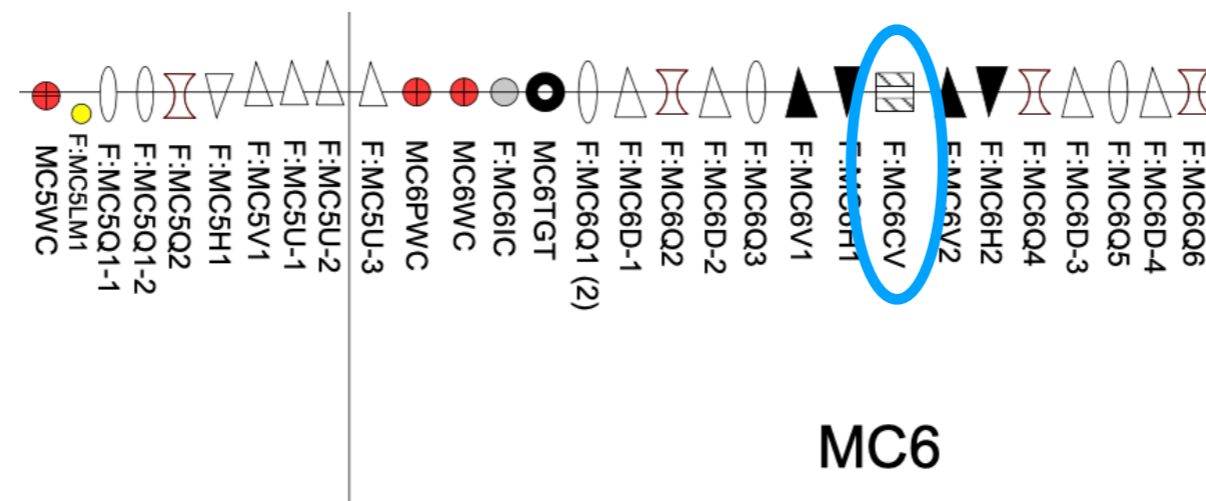
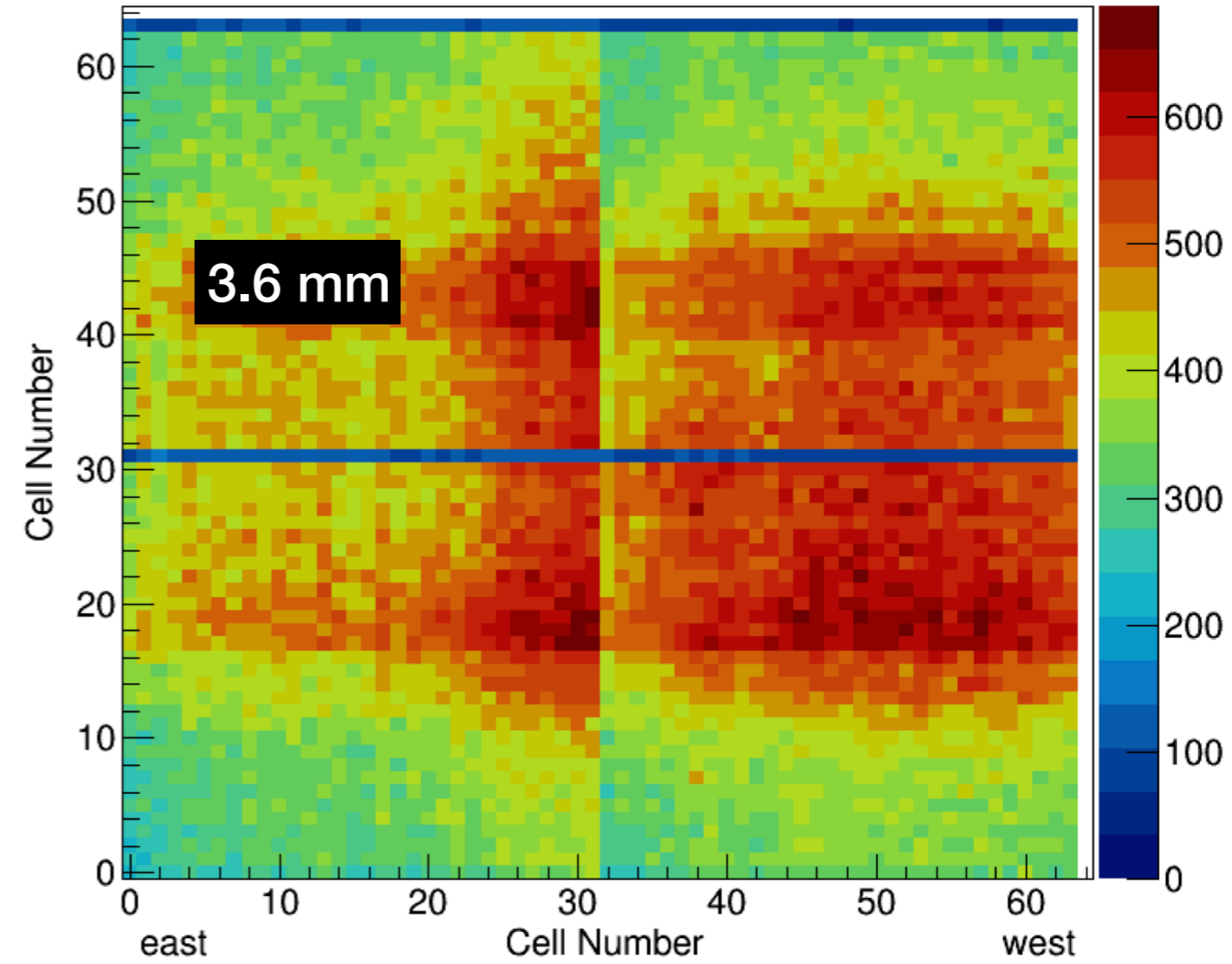
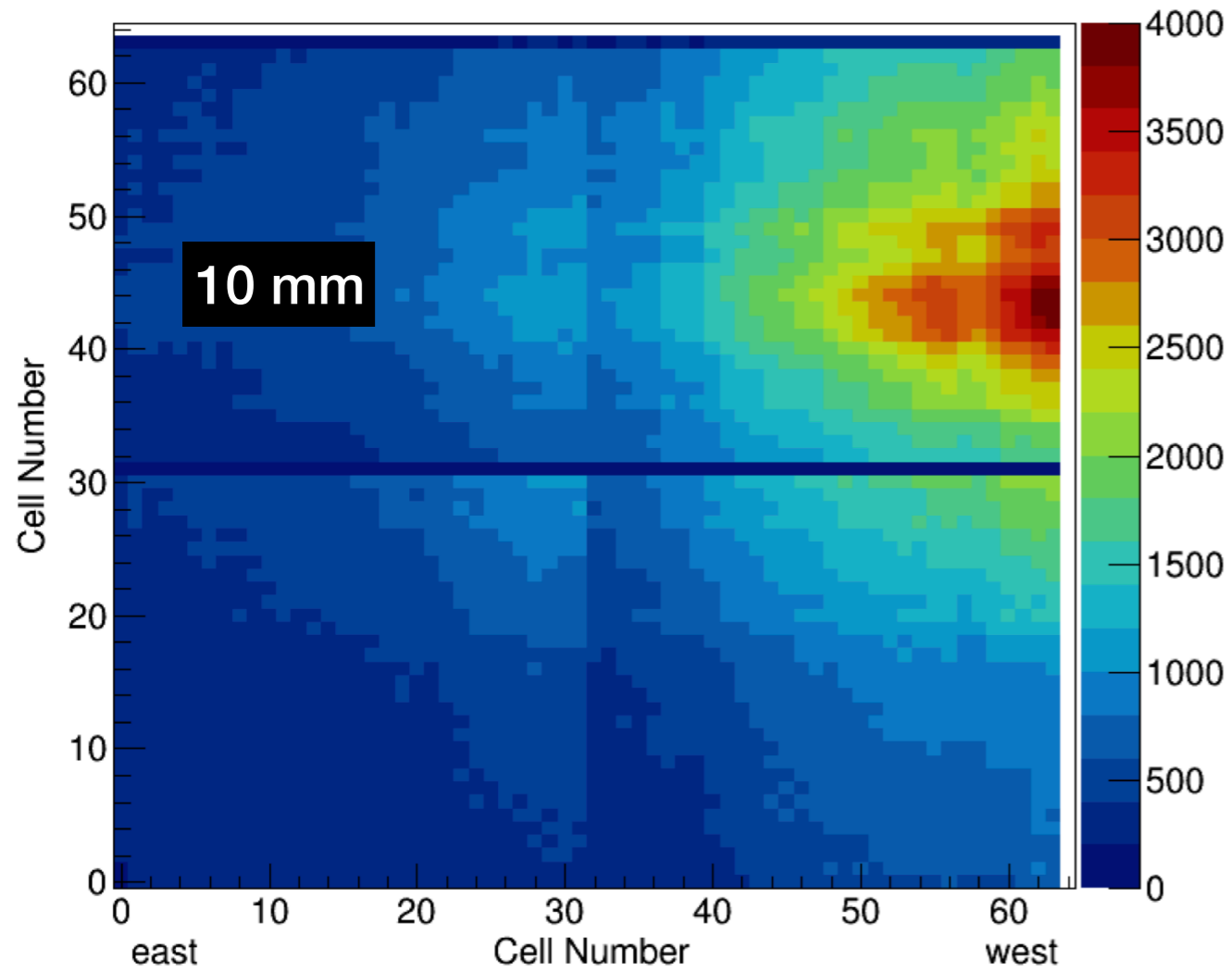
Understanding Halo Behavior



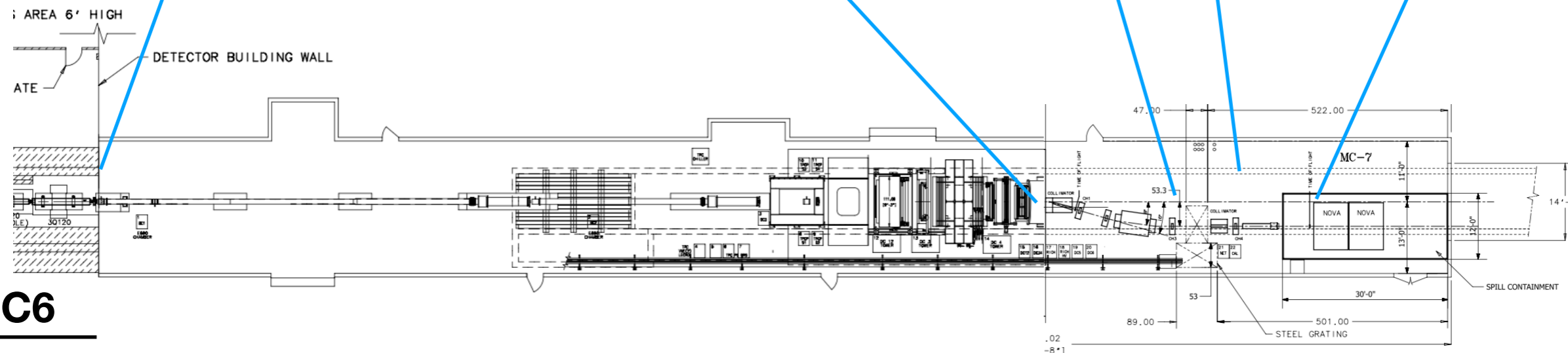
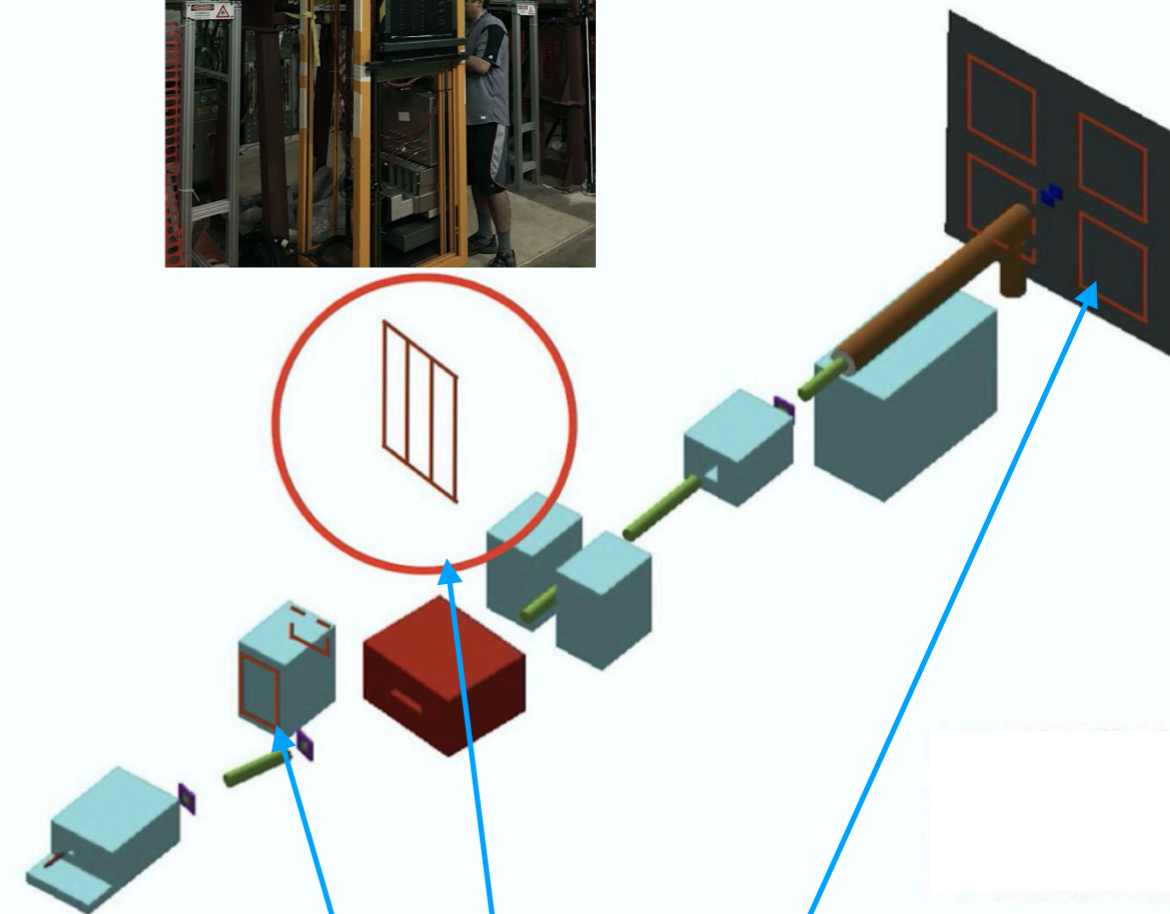
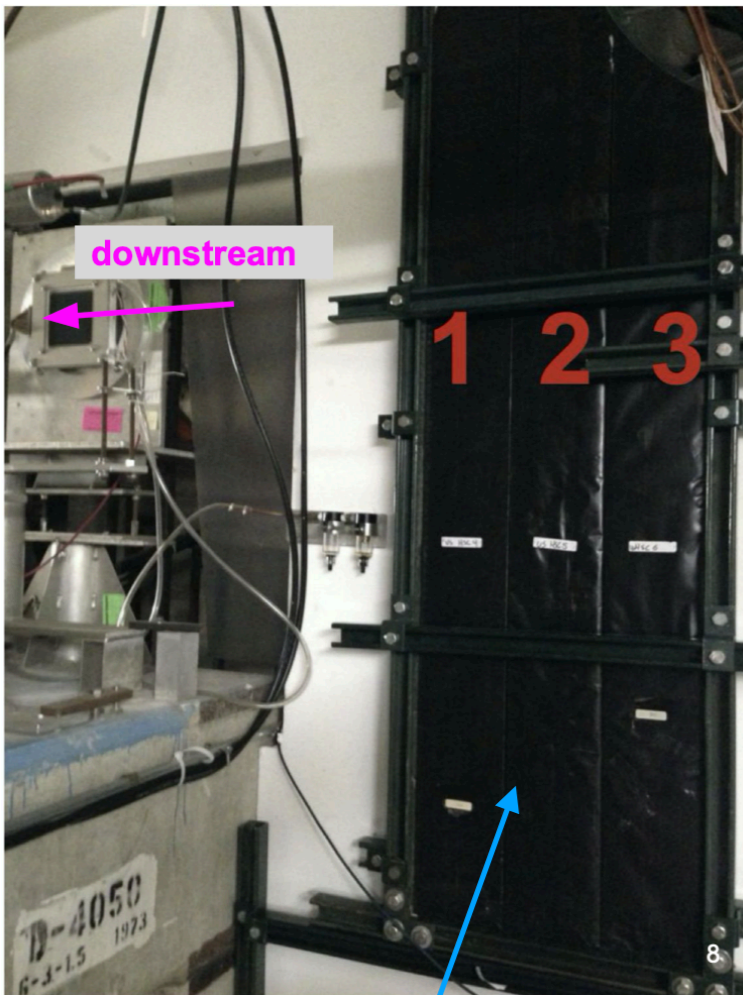
Understanding Halo Behavior



Understanding Halo Behavior



Auxiliary Counters



Auxiliary Counters

- Everything goes into ACNET.

https://cdcvs.fnal.gov/redmine/projects/novatestbeam/wiki/ACNET_Addresses

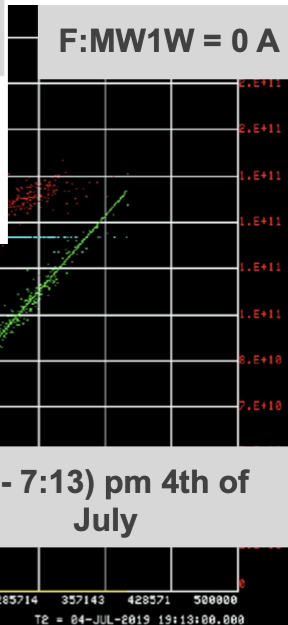
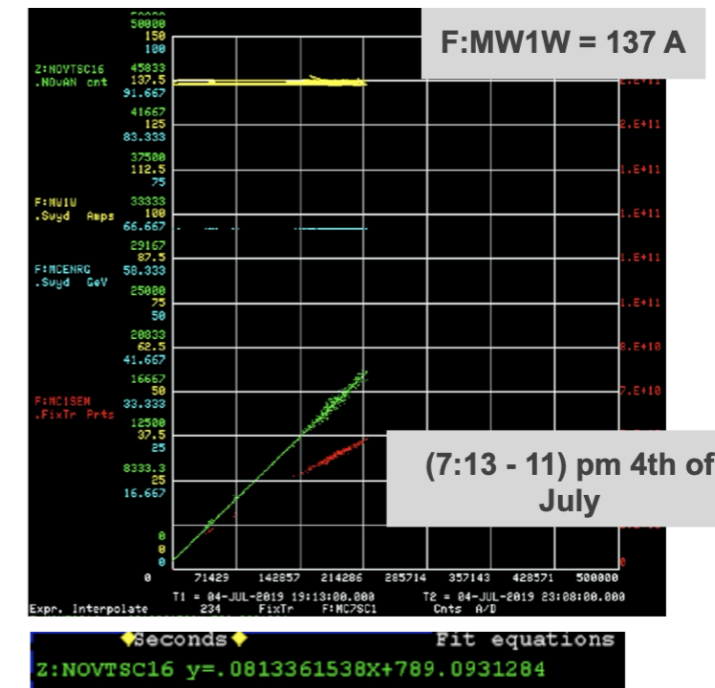
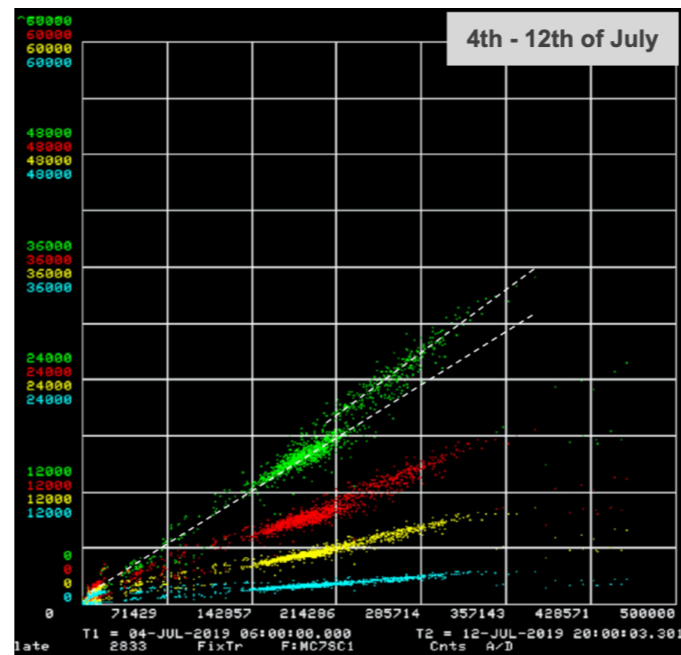
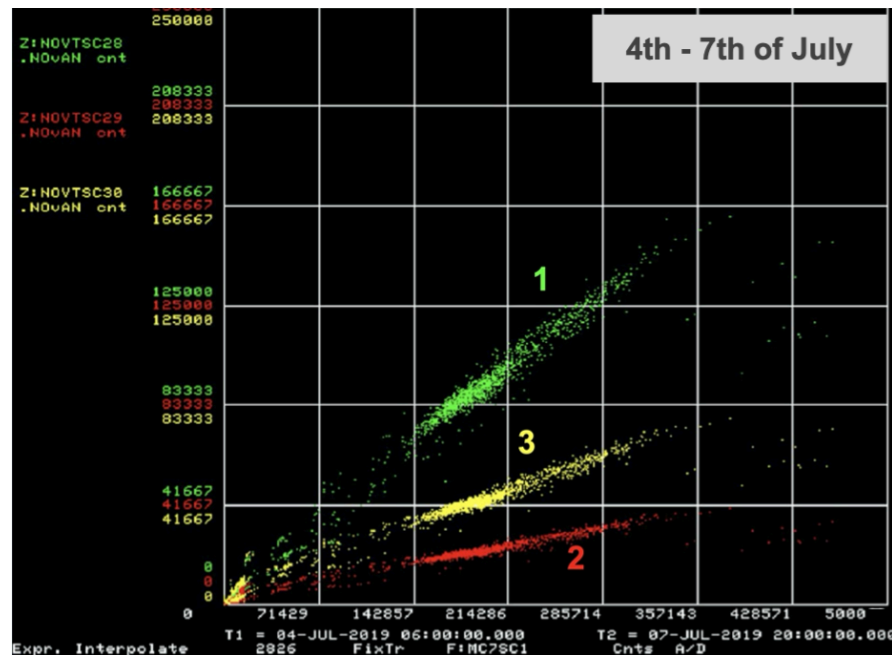
```
All reset every spill.
Z:NOVTSC   - Basic status of SIS 3800 Scaler board
-----
Z:NOVTSC00 - Target scintillators 2-3-4 coincidence
Z:NOVTSC01 - Target scintillator 1
Z:NOVTSC02 - MWPC-1 pulses
Z:NOVTSC03 - MWPC-2 pulses
Z:NOVTSC04 - MWPC-3 pulses
Z:NOVTSC05 - MWPC-4 pulses
Z:NOVTSC06 - Cherenkov PMT pulses
Z:NOVTSC07 - Beamline DAQ trigger

Z:NOVTSC08 - 10.3 Hz counter (Philips pocket pulser) used for the Synoptic "Progress Indicators"
Z:NOVTSC09 - Target wire counter
Z:NOVTSC10 - Paddle-1
Z:NOVTSC11 - Paddle-2
Z:NOVTSC12 - Paddle-3
Z:NOVTSC13 - Paddle-4
Z:NOVTSC14 - Target wire chamber
Z:NOVTSC15 - ToF 3-of-4 DS-SiPM
----- 34 pin Flat Ribbon Cable ----- A
Z:NOVTSC16 - Muon-1 Scintillator
Z:NOVTSC17 - Muon-2 Scintillator
Z:NOVTSC18 - Muon-3 Scintillator
Z:NOVTSC19 - Muon-4 Scintillator
Z:NOVTSC20 - L-1 roaming scintillator
Z:NOVTSC21 - L-2 roaming scintillator
Z:NOVTSC22 - L-3 roaming scintillator
Z:NOVTSC23 - ToF 3-of-4 US

Z:NOVTSC24 - Shield-1 Scintillator
Z:NOVTSC25 - Shield-2 Scintillator
Z:NOVTSC26 - Shield-3 Scintillator
Z:NOVTSC27 - Shield 1&2 Coincidence
Z:NOVTSC28 - Beam-1 Scintillator
Z:NOVTSC29 - Beam-2 Scintillator
Z:NOVTSC30 - Beam-3 Scintillator
Z:NOVTSC31 - ToF 3-of-4 DS
----- 34 pin Flat Ribbon Cable ----- B
```

Understanding Halo Behavior

- All counters downstream of MC7SC1 scale like MC7SC1 during the period where several beamline components changed values. This means that **we never managed to change the halo with respect to the intensity of the secondary beam** (besides changes in MW1W's current).
- The beam scintillators (NOVTSC28-30) show **more halo above than below the beam**.
- The halo on the NOvA testbeam detector diminishes slightly with respect to MC7SC1 **when MW1W changes to a non-zero current and beam is served to MTest**.



Looking downstream, front of NOvA testbeam detector

Around the secondary beam, upstream of NOvA target. 1 above, 2 below, 3 west side

Attempted Solutions

- Running at lower intensity.
 - Still getting FEB shut-offs, compromising the quality and usefulness of the data we collect.
 - Statistics far too low to achieve primary goals of program.

Expected particle rates: $3e6$ π , $2.6e6$ p , $7.8e4$ e , $3.9e4$ μ , $2.6e4$ K ($\sim 5.6e6$ total).

- At this rate (~ 100 particles/day), we're looking at $\mathcal{O}(12,000)$ events total by shutdown
- 2187 events
 - 98 electrons ($ckovadc > 0$ and $40 < toftime < 50$)
 - 826 protons ($ckovadc = 0$ and $toftime > 50$ ns)
 - 1259 other - muons, pions, accidentals ($ckovadc = 0$ and $40 < toftime \leq 50$ ns)

Totals as of Feb 15

- Deployed new versions of the firmware for our front-end boards with a larger buffer (8x and 16x default), to mitigate read-out saturation.
 - See some improvements, at most factor of 2 improvement in useable intensity (optimistic).
- Only solution? Identify the source of the halo and reduce/eliminate/redirect the beam.

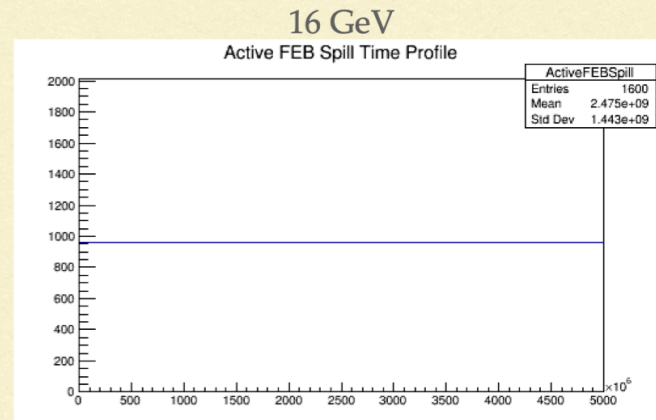
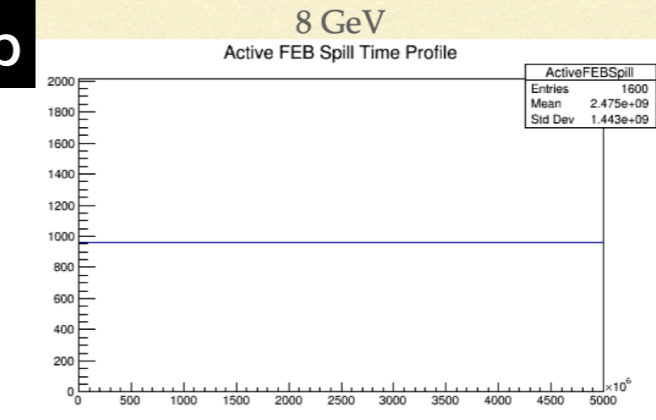
Action Items for Discussion

- Secondary beamline simulation does not describe well what we observe:
 - Cannot reproduce halo;
 - Rates on counters in secondary and tertiary beamline are not in agreement.
 - Walk-through of MC6 to understand the simulation and identify any components not being simulated.
- Ensure beam is correctly hitting targets. Recent scans seem to show this is the case, but Adam is going to double-check when he fixes his splash-back counter on the primary target (this week).
 - Position and angles scans on the target with this in place. Observe any changed behavior of the halo.
- Repeat studies of halo steering.

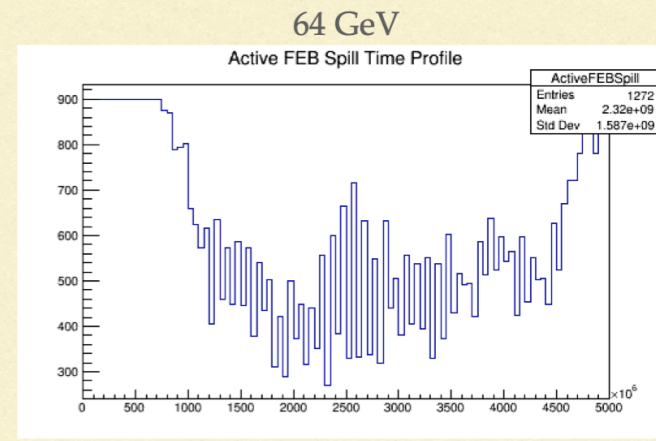
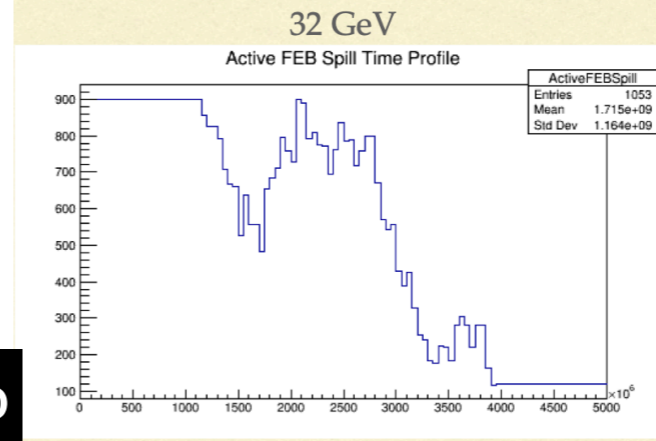
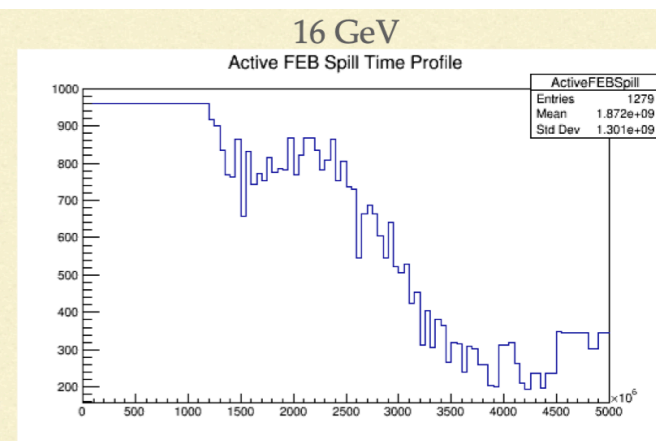
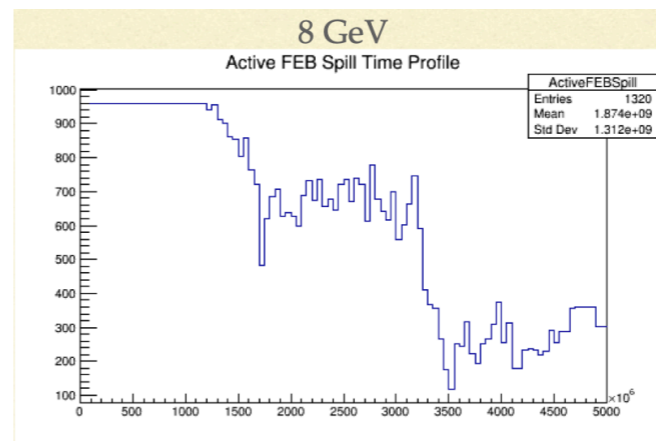
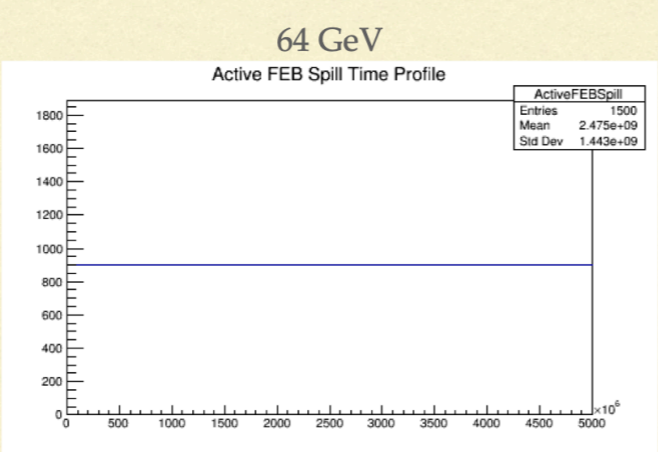
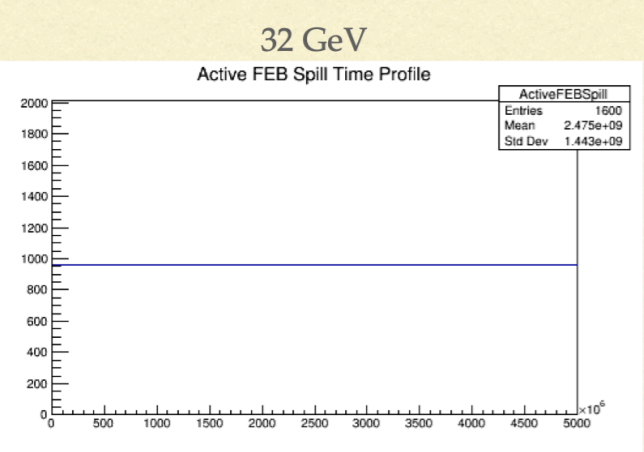
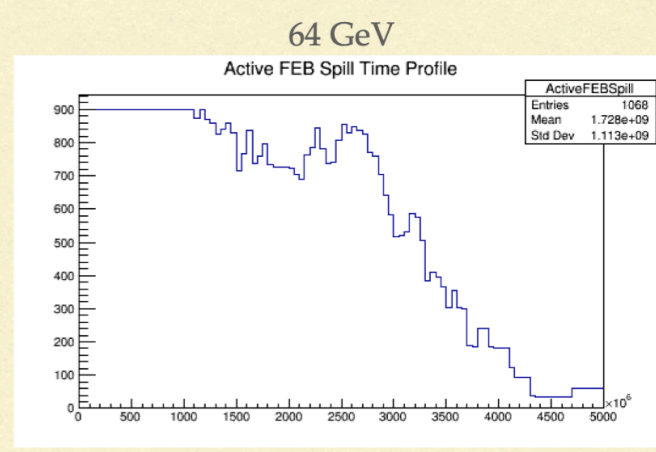
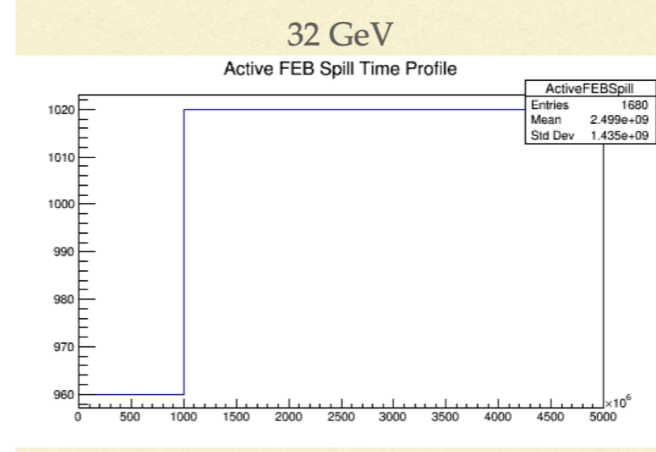
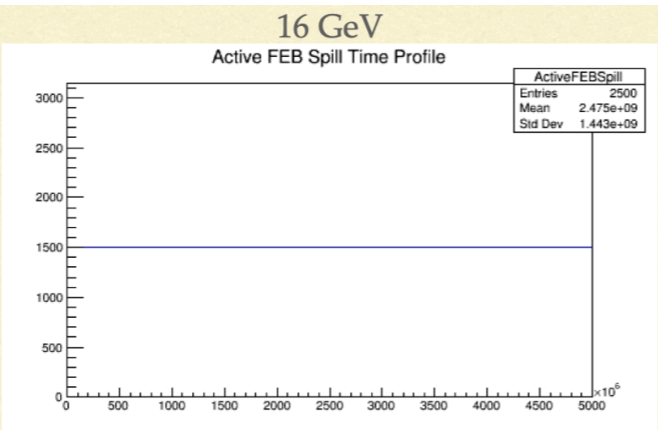
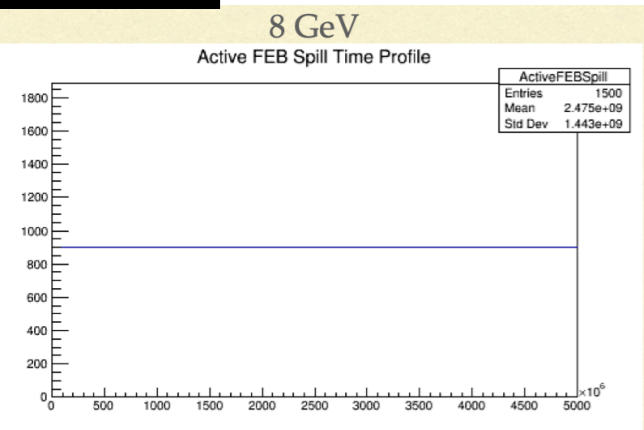
Other Things

The Problems

10e8ppp



1e8ppp

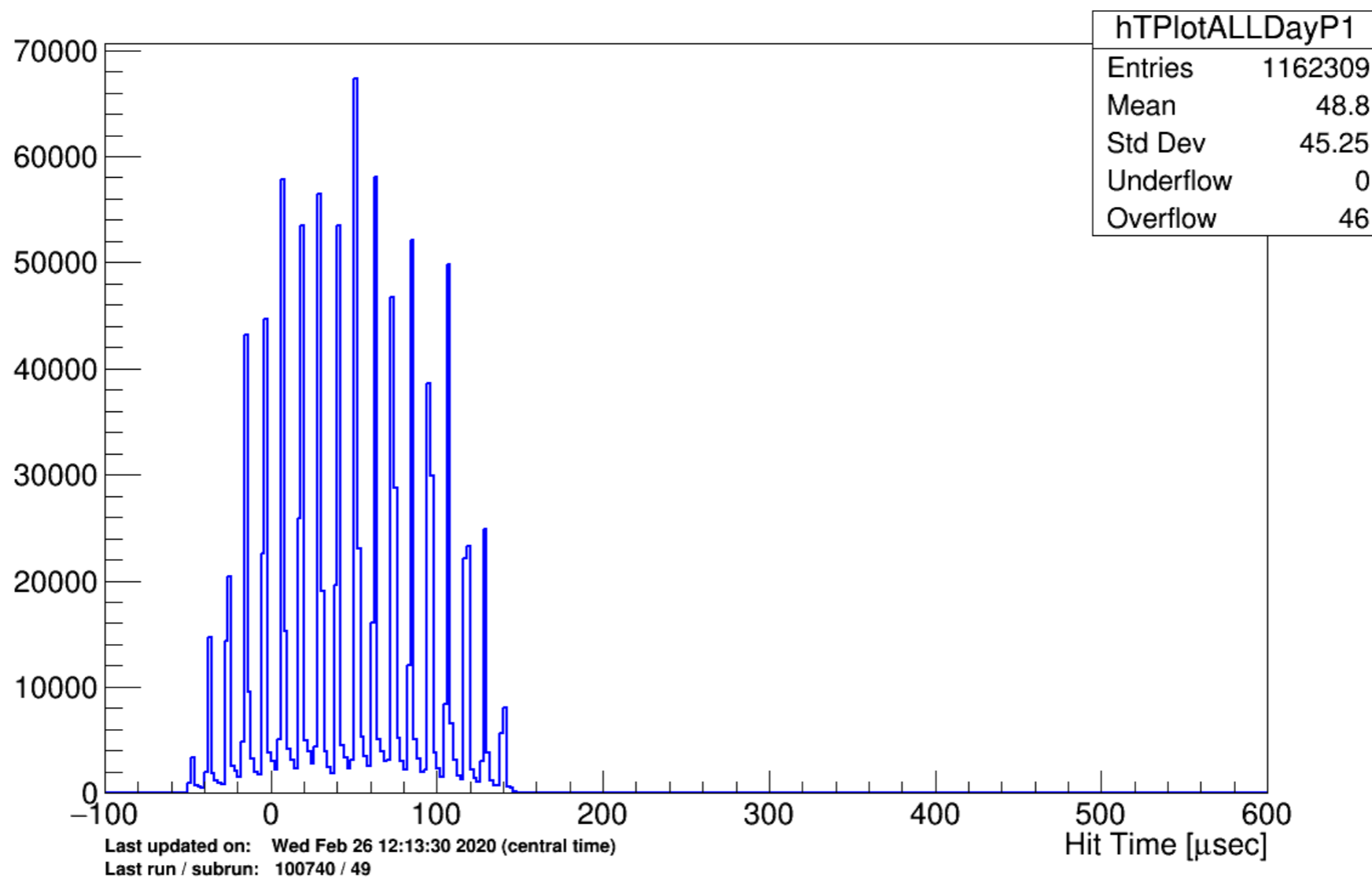


100e8ppp

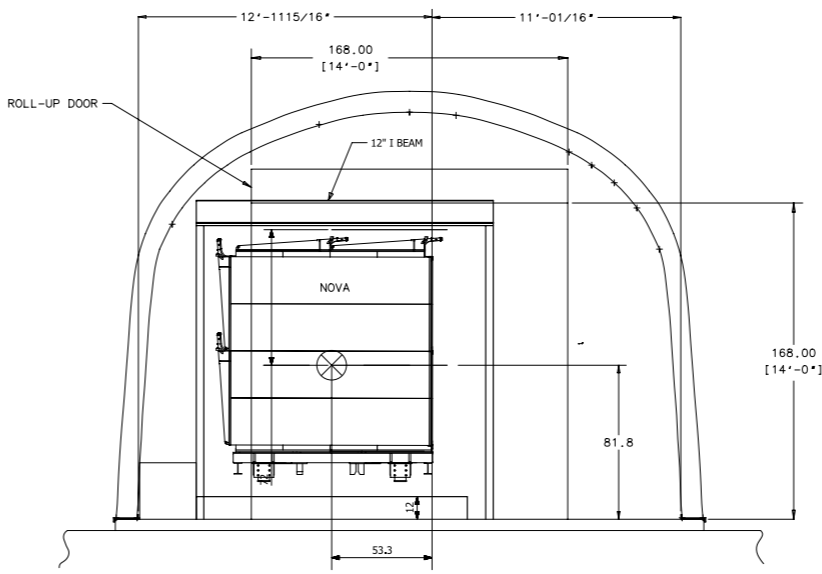
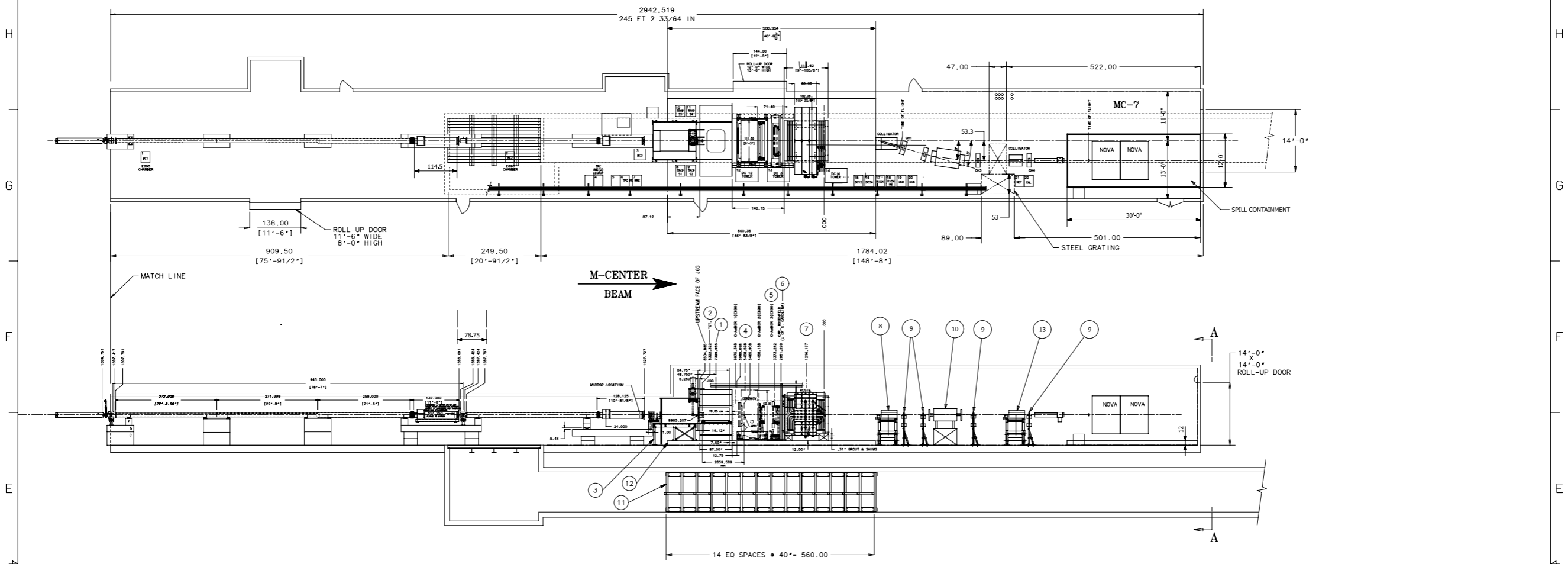
Secondary momentum & Primary intensity scan

Halo Hits

Beamline Time Distribution for All Hits (past 24 hrs.) - partition 1

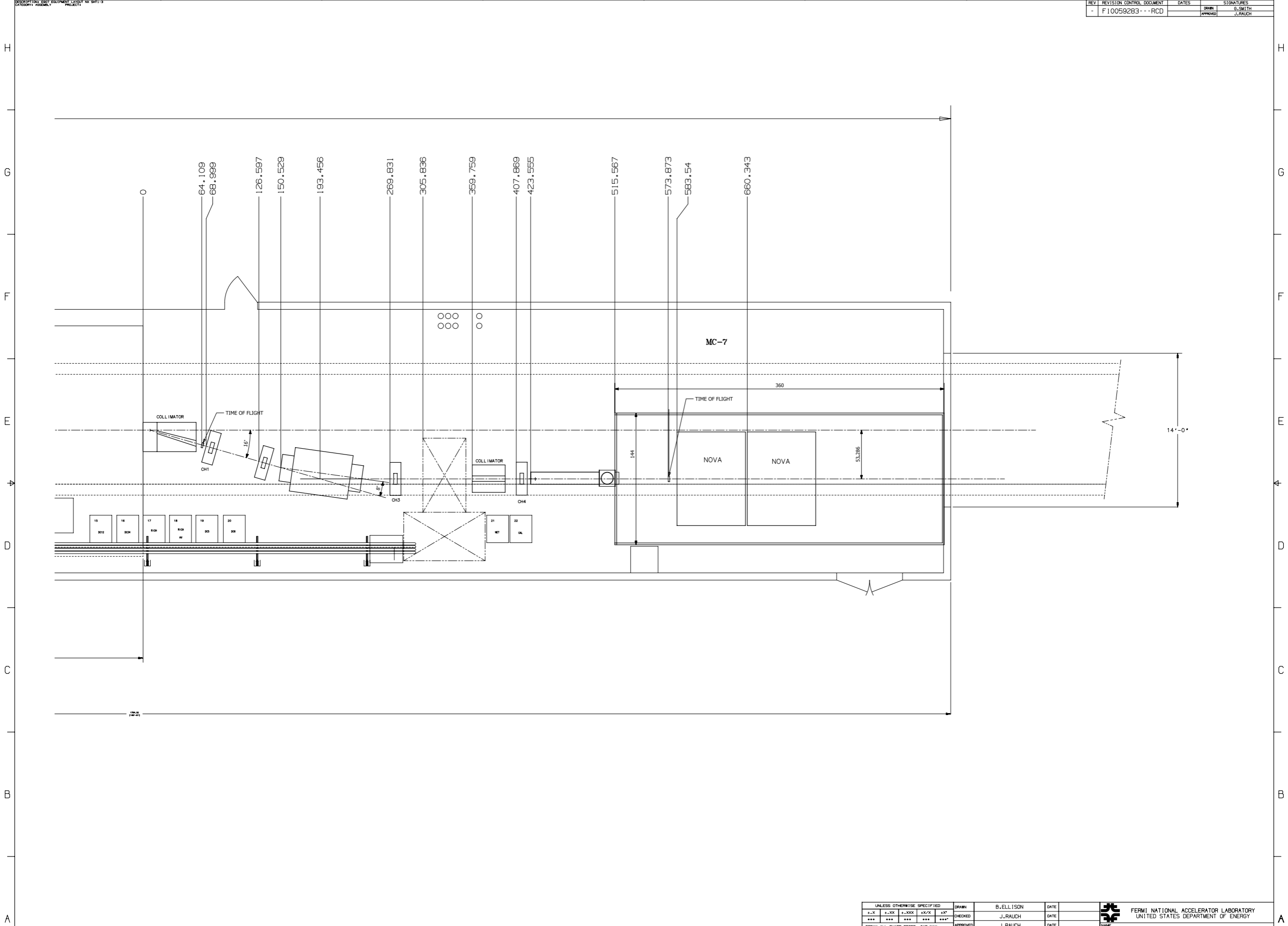


- All hits during spill. DAQ is timed in such that tertiary beam triggers arrive at 50us.



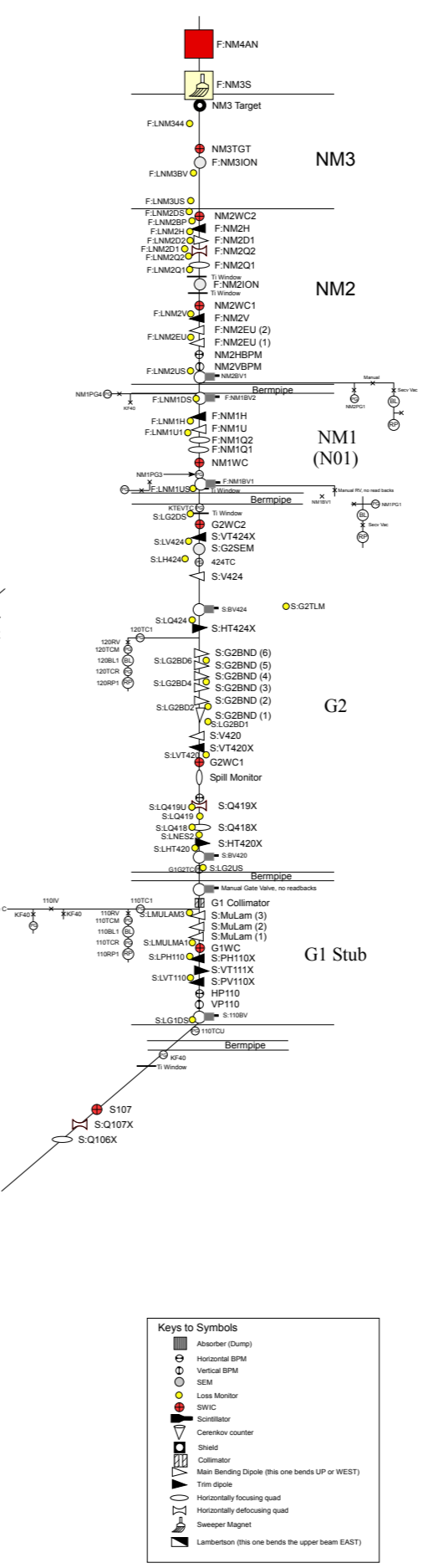
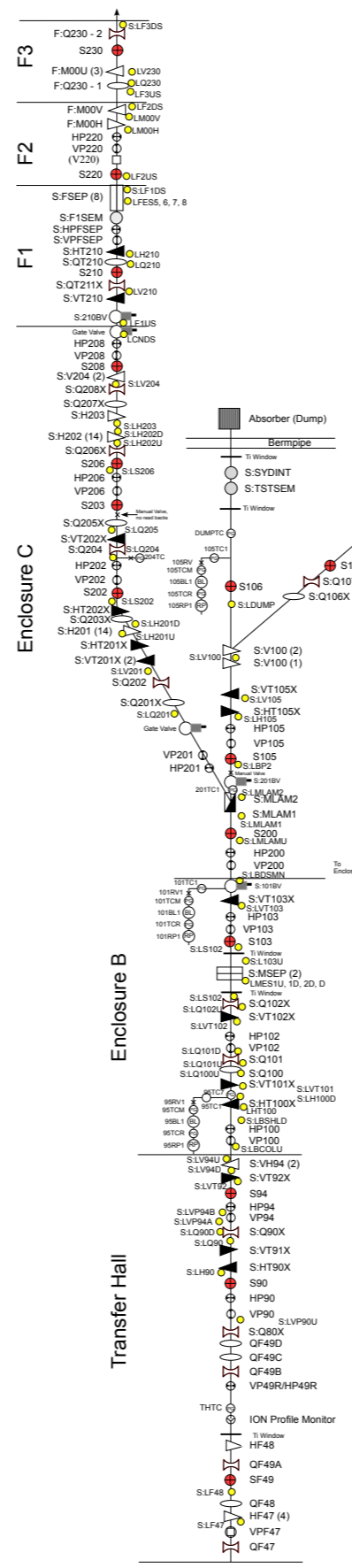
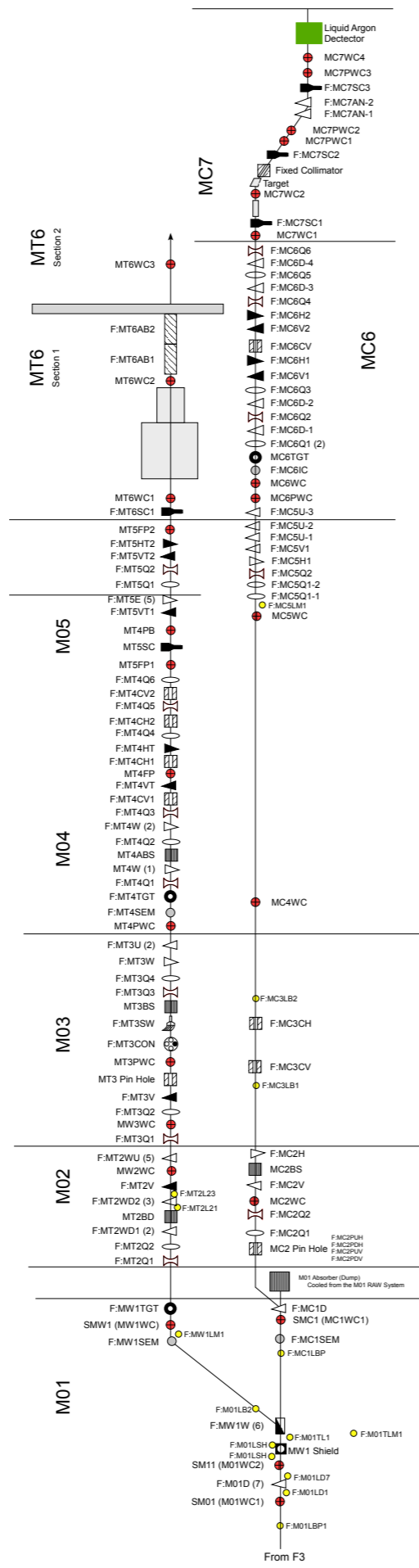
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
13		COLLIMATOR 2	1
12	ME-397567	JGG CONCRETE PAD	1
11	ME-397580	M-BOTTOM STRUCTURAL BRACING LOCATION LAYOUT	1
10	ME-466259	TRIM MAGNETS	1
9	ME-466282	MWPC STAND	4
8	ME-466139	COLLIMATOR	1
7	ME-421025	ROSIE MAGNET	1
6		TOP SYSTEM	1
5	ME-421104	E907 DRIFT CHAMBER 3 (E690)	1
4	ME-421018	E-907 CERENKOV CHAMBER#1 (E690) - CHAMBER#2 (E690)	1
3	ME-421104	E-907 TCP-CART-STAND-JGG	1
2		TARGET	1
1	ME-397657	JOLLY GREEN GIANT MAGNET	1

UNLESS OTHERWISE SPECIFIED					DRAWN	B. ELLISON	DATE	
±.X	±.XX	±.XXX	±.X/X	±"	CHECKED	J. RAUCH	DATE	
***	***	***	***	***	APPROVED	J. RAUCH	DATE	
BREAK ALL SHARP EDGES .015 MAX. DO NOT SCALE DRAWING DIMENSIONS SHOWN BY NUMERICAL VALUE MAX. ALL MACH SURFACES ±.0008 DRAWING UNITS: INCHES					FERMILAB PARTICLES PHYSICS MECHANICAL SUPPORT FERMION NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
E907 EQUIPMENT LAYOUT NX SHT: 3					SCALE	SIZE	DRAWING NUMBER	SHEET
					OR NOTED	E	F10059283	1 of 1



REV	REVISION CONTROL DOCUMENT	DATES	SIGNATURES
-	F10059283--RCD		G. SMITH J. RAUCH

UNLESS OTHERWISE SPECIFIED					DRAWN	B. ELLISON	DATE	 FERMILAB NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
±.X	±.XX	±.XXX	±X/X	±X'	CHECKED	J. RAUCH	DATE				
***	***	***	***	***	APPROVED	J. RAUCH	DATE				
<small>BREAK ALL SHARP EDGES .015 MAX. DO NOT SCALE DRAWING DIMENSIONS GOVERN OVER SIZE MAX. ALL MACH SURFACES ±.005 DRAWING UNITS: INCHES</small>					<small>MATERIAL</small> SEE PARTS LIST <small>NAME Particle Physics Mechanical Support</small>		<small>SCALE</small> 1:1 <small>OR NOTED</small>		<small>SIZE</small> E	<small>DRAWING NUMBER</small> F10059283	<small>SHEET</small> 2 of 2



Keys to Symbols

- Absorber (Dump)
- Horizontal BPM
- Vertical BPM
- SEM
- Loss Monitor
- SWIC
- Scintillator
- Cerenkov counter
- Shield
- Collimator
- Main Bending Dipole (this one bends UP or WEST)
- Trim dipole
- Horizontally focusing quad
- Horizontally defocusing quad
- Sweeper Magnet
- Lambertson (this one bends the upper beam EAST)