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Fermilab Irradiation Test Area

Petra Merkel

Muon PMG/AEM

3 October 2019

Recent Recommendations from DOE Reviewers

- HL LHC CMS CD-1 Director's Review -- Outer Tracker Recommendation:

1. The review committee recommends that Fermilab work with the DOE to establish a proton irradiation facility at Fermilab. This is particularly important during LS2 when the CERN PS facility will be down. This is critical not only for the CMS Outer Barrel but also for all the HL-LHC projects.

- HL LHC CMS CD-1 Review, Outer Tracker Comments:

The Committee encouraged FNAL to establish a proton irradiation facility. This will be of great use for the upgrade program and beyond. In case this facility will not be realized or not be available in time, an alternative needs to be developed. An analysis that supports the preferred alternative needs to be performed.

- HL LHC ATLAS CD-1 Review, Pixel Recommendations:

3. Work with DOE to pursue a dedicated proton irradiation facility in the U.S., e.g. by supporting the proposed irradiation facility at FNAL.

Other users beyond CMS/ATLAS

- We distributed a survey to potential users
 - Not comprehensive but indicative of extent of the need for this type of beam facility
 - https://www.dropbox.com/s/z4lfshhl7b2lrqw/Responses_All_180522.pdf?dl=0
- The need is strong enough to support a variety of radiation testing areas, world-wide:
 - CMS, ATLAS, Mu2e-II, DUNE, LHC-B, sPHENIX, TOTEM, RD50, RD53, CubeSats
- Need within aeronautics industries:
 - Boeing used 2000 hours of beam time at Indiana cyclotron until that facility closed

Existing Facilities

	Particle Type	Beam Energy	Beam Size	Time to $2 \times 10^{16}/\text{cm}^2$	SEE Tests	Availability
CERN	protons	24 GeV	0.5-1.5 cm	111h	yes	LS2 shutdown
Birmingham	protons	40 MeV	1 cm	1h	yes	
Louvain	heavy ions	100s MeV		not feasible	yes	Being built
Ljubljana	neutrons	-	-	1.4h	no	
KIT (operated by ZAG company)	protons	23.5 MeV	0.5 cm	1.5h	(yes) too expensive	4h/week 6 week turnaround
Rhode Island	neutrons	-	-		no	limited
ANL (LEAF)	electrons neutrons	55 MeV 0.5 MeV		7h		Might be planned
BNL (BLIP)	protons+ neutrons	65-200 MeV		20h	no	Might be planned
TRIUMF	protons	5-500 MeV	0.5-1 cm	not feasible	yes	
FSU	protons	17 MeV				limited
LANL	protons	800 MeV		72h	no	2x/year
FNAL ITA	protons	400 MeV	1-7 cm	0.7h	yes	40x/year

Beam extraction in Fermilab LINAC

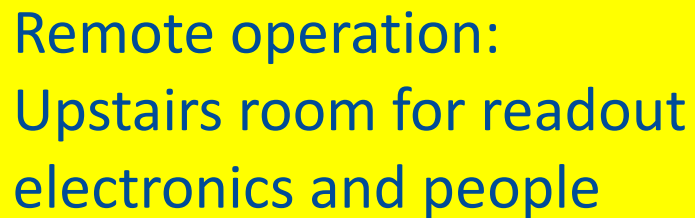
- “Pulses” from the LINAC can be extracted during the 6 second flattop of the SY120 spill and thus have minimal effect on Neutrino pulses
- By running the Irradiation Test Area simultaneously with FTBF, we have no impact on the rest of the program:
 - NuMI requires the Main Injector, as does FTBF.
 - G-2 and FTBF share a common section of beamline, and cannot run simultaneously.
 - BNB is rate limited.
 - Conservative estimate is 40 pulses available.
- A “standard” we have been using consists of
 - Single pulse of 5×10^{12} protons per LINAC batch, 400 MeV
 - Nominally 15 Hz
 - 12 hours availability one day per week
 - A typical run would have beam impacting on 4.7 cm of Si ($10\% \Delta$)
 - Cooldown period of 1 day
 - One user per week.
 - 40 weeks/year

Table 1: Beam parameters to be expected at the DUT (Device Under Test)

Beam Specifications	Min	Max
Beam Size ($\pm 3\sigma$) at DUT	1 cm	5-7 cm
Beam Divergence ($\pm 3\sigma$) at DUT	0.1 <u>mr</u>	1 <u>mr</u>
Number of Proton/pulse	0.3×10^{12}	7.5×10^{12}
Pulse Duration	2 μ s	50 μ s

10/1/18

The Cave



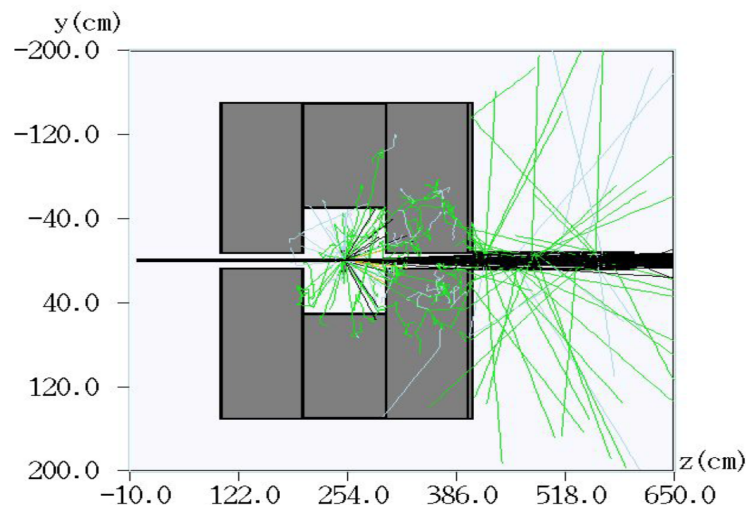
Residual activation of outside (of cave) surfaces

Outside Surfaces after 1 day	10% X_0 (0.9 cm Si)	10% λ (4.7 cm Si)	Worst Case (45 cm Fe)
Upstream wall	0.06	0.12	1.16
Side walls	0.96	0.97	5.00

mRem/hour

(for comparison: Radiation Area at Fermilab: 5-100 mRem/hr)

Table 2. Results from MARS calculation. [4] Predicted residual activation in mrem/hour of the outer surfaces of the shielding cave blocks following twelve hours of irradiation by 400 MeV protons at 5×10^{12} protons/second and one day of cool-down time. [5]



Work at MTA

- Clean up from MAP (muon cooling) finished
- Next 3 months:
 - Rebuilding MTA beam line
 - Reconfiguration and instrumentation
 - Electron stripping station
 - New vacuum window
 - Repair of sprinkler pipes
 - Fill in ODH fan penetration to improve shielding
 - Construction of shielding cave for devices under test
 - Finalize and approve shielding assessment
- 4-6 weeks commissioning
- Aim to be ready for first silicon irradiations end of February 2020
- Operations: ~1FTE from AD + ~1FTE from PPD (test beam group + ES&H)
- Next shutdown: Upgrade to move, cool and readout DUTs for SEU studies and heavier materials



Summary

- Received broad HEP community support for ITA at Fermilab
- Identified MTA hall at end of Linac as appropriate
- Cleaned up muon cooling experiment remnants with left-over MAP funds
- Received construction funds from DOE in September
- Started construction (~3 months), followed by commissioning and operations (AD+PPD)
- Further improvements planned for next year's shutdown

BACKUP

US-CMS Needs

- Outer Tracker upgrade: $\sim 1/3$ of tracker modules are built in US
 - Silicon sensor and module QA/QC through irradiation crucial
 - Neutron and proton irradiation planned between 2019-2024
 - QA during prototyping (2019) \rightarrow decision on sensor design
 - QC on each batch of sensors throughout production (2020-24)
 - One batch every 3 months x 3 sensor types
- Similar needs in HGCal, MIP Timing Detector, Inner Tracker
 - Prototyping of sensors and Fermilab ASICs

Letter of Support from CMS Upgrade Coordinator



KIT | EKP | Hermann-von-Helmholtz-Platz 1 | 76344 Egg-Leopoldshafen, Germany

Fermilab Directorate

Letter of support for the Irradiation Test Area

With the upcoming HL-LHC, the general need for reliable facilities enable design and prototype evaluation. The irradiation campaigns of all material during the procurement experiments, meaning continuously until 2026. With the closure of the LHC beams during the long shutdown LS2, we lost access to any facility able to provide the correct dose/fluence ratio for the innermost LANSCE could be another option but access and availability are not adequate. We are therefore counting on the Fermilab ITA to be able to complete the High Granularity Calorimeter (HGC) for the full fluence ATLAS which faces the same limitations. CMS often uses the KIT facility but, with the relatively correct fluence without destroying the chips due to too high flux is key to success. Also, the ability to fluxes is very difficult to achieve elsewhere. This is a HGC, Tracker and the MTD (MIP Timing Detector) sensor I am not exaggerating in saying, we cannot finish these

I also see a very big advantage to have the irradiation achieve adequately fast feedback on irradiated sensors annealing of DUTs during shipment, which otherwise

The ability to also study SEU and SEL at the same facility

I also recommend establishing a good dosimetry to minimize

I very strongly support the installation of the ITA. Without it, we cannot complete our R&D nor can we be excited about this new facility and are looking forward to

Frank Hartmann
CMS Upgrade Project Coordinator

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Dr. Frank Hartmann

Letter of support for the Irradiation Test Area “ITA” at Fermi National Laboratory

With the upcoming HL-LHC, the general need for reliable irradiation facilities is increasing. These facilities enable design and prototype evaluation. They are also vital for long term Quality Assurance irradiation campaigns of all material during the procurement and assembly stages of the HL-LHC experiments, meaning continuously until 2026.

With the closure of the LHC beams during the long shutdown LS2, we lost access to any facility able to provide the correct dose/fluence ratio for the innermost radii of the tracker and forward detectors. LANSCE could be another option but access and availability are not adequate. We are therefore counting on the Fermilab ITA to be able to complete the required studies for the CMS inner tracker and High Granularity Calorimeter (HGC) for the full fluence range. Many studies are conducted together with ATLAS which faces the same limitations.

CMS often uses the KIT facility but, with the relatively low available energy, it is impossible to reach the correct fluence without destroying the chips due to too high TID. The high energy at ITA in combination with the high flux is key to success. Also, the ability to irradiate large areas (full sensors/modules) at high fluxes is very difficult to achieve elsewhere. This is a mandatory requirement for the irradiation of the HGC, Tracker and the MTD (MIP Timing Detector) sensor/modules.

I am not exaggerating in saying, we cannot finish these studies without the ITA.

I also see a very big advantage to have the irradiation on site of the major contributing CMS institute to achieve adequately fast feedback on irradiated sensors/electronics and to be able to avoid uncontrolled annealing of DUTs during shipment, which otherwise always adds large uncertainties to the results.

The ability to also study SEU and SEL at the same facility seems unique and will open new possibilities.

I also recommend establishing a good dosimetry to minimize uncertainties on the applied fluence/dose.

I very strongly support the installation of the ITA.

Without it, we cannot complete our R&D nor can we evaluate our prototypes correctly. We are very excited about this new facility and are looking forward to extensively use it.

10/1/18

Letter of Support from the US-ATLAS Project Manager

From: "Kotcher, Jonathan" <kotcher@bnl.gov>

Subject: Radiation testing

Date: September 28, 2018 at 3:41:47 PM CDT

To: Vivian O'Dell <odell@fnal.gov>

Dear Vivian:

The U.S. ATLAS institutions participating in the High Luminosity LHC (HL-LHC) Upgrade Project are developing many different devices that require verification of radiation tolerance to significant levels. The Application-Specific Readout Circuits (ASICs) for the ATLAS inner trackers and calorimeters are good examples of this. Currently operating facilities that can reach the required fluences have limited availability, which often leads to prohibitively long wait times (up to 1 year). Such wait times can have a significant impact on the overall construction schedules. Access to a facility that can meet the highest radiation tolerance test levels required with high availability would significantly reduce the risks associated with ensuring that our designs meet the radiation tolerance specifications. Such a facility available at Fermilab will enhance our ability to meet our international obligations.

If there are any additional details we can provide, please don't hesitate to let us know.

Sincerely,

Dr. Jonathan Kotcher
Senior Scientist
Brookhaven National Laboratory
Project Manager, U.S. ATLAS HL-LHC Upgrade Project

Professor Gustaaf Brooijmans
Professor of Physics
Columbia University
Deputy Project Manager, U.S. ATLAS HL-LHC Upgrade Project

Professor Harold Evans
Professor of Physics
Indiana University
Deputy Project Manager, U.S. ATLAS HL-LHC Upgrade Project

Professor Michael Tuts
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Letter of Support from sPHENIX Group at BNL



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managed by Brookhaven Science Associates
for the U.S. Department of Energy

October 15, 2018

Dr Joe Lykken

I am writing to you to express my support for a proton irradiation facility at Fermilab. One of the many challenges facing the experimental heavy-ion and nuclear physics programs is designing detectors and electronics that can operate in the radiation environments that are present in the experimental areas. While the effects of ionizing radiation can be studied using radioactive sources such as ^{60}Co , it is also important to understand the effects from charged hadrons on the electronics. A facility at Fermilab that would allow the performance of electronics in a controlled radiation environment to be studied would be extremely beneficial to the community. The ability to monitor the operation of prototype boards, and characterize the degradation of the performance as a result of irradiation would allow for optimization of component selection and board design. In addition to electronics, studies of the effects of radiation on materials used in detector construction (e.g. glues, plastics) will also be of value. These combined studies will result in improved detector designs that will enhance the physics programs in heavy-ion and nuclear physics.

Should Fermilab pursue implementing a proton irradiation facility in the coming year, the sPHENIX calorimeter electronics group would be interested in conducting tests on electronics that has been design for the sPHENIX calorimeters to understand the long term effects on the the electronics.

Sincerely,

A handwritten signature in dark ink, appearing to read "E. Mannel", written in a cursive style.

Eric J. Mannel, Ph.D.
PHENIX Group
Physics Department
Brookhaven National Laboratory