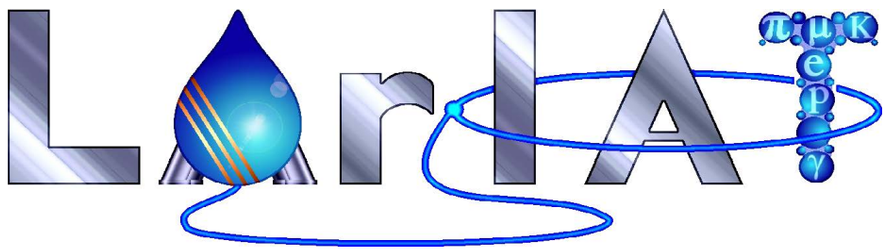


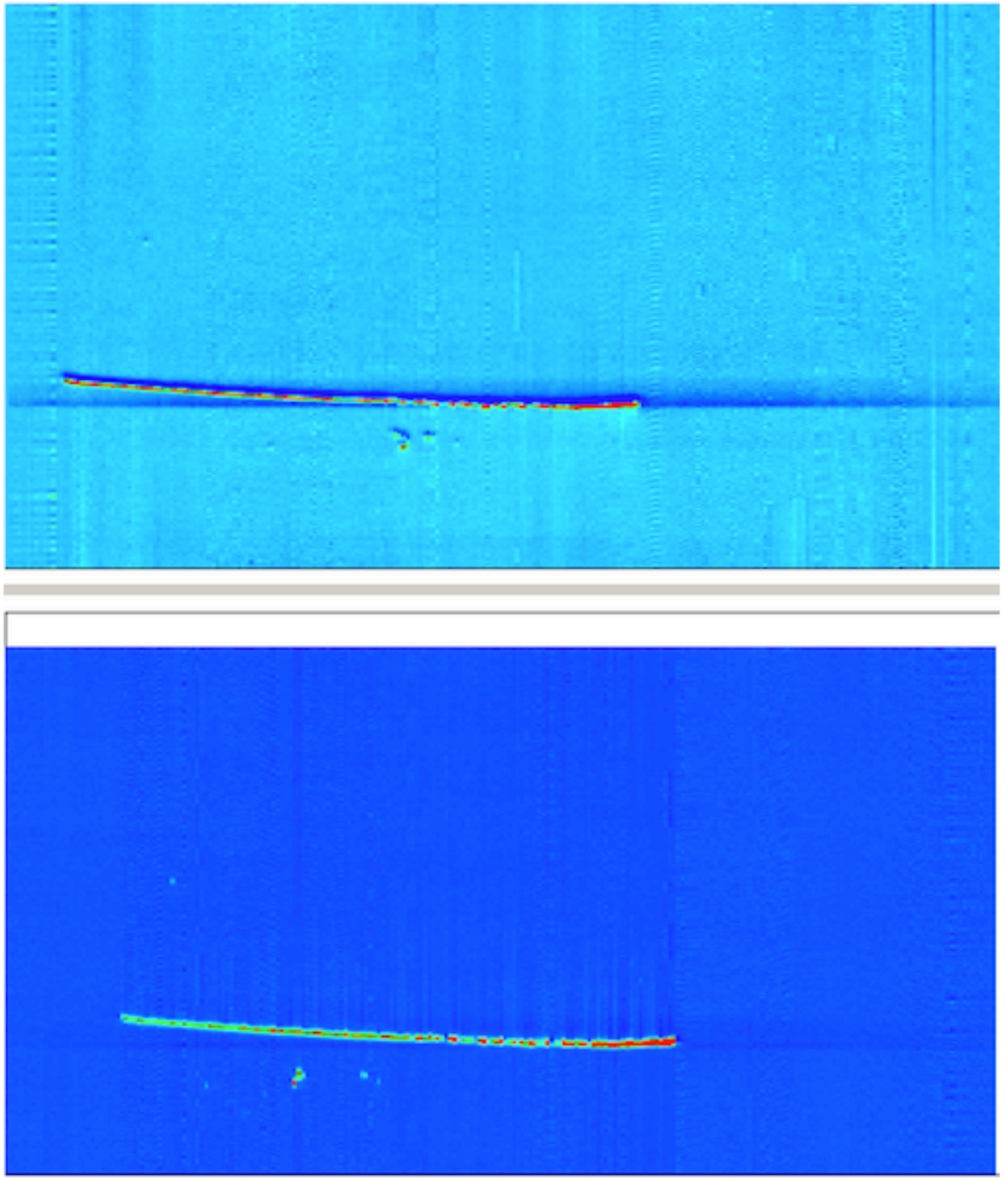
Aerogel Beam Line Cherenkov Detector for the LArIAT Experiment

Brandon Soubasis
Texas State University
Advisors: Jennifer Raaf, Will Flanagan, Karol Lang

August 4, 2015

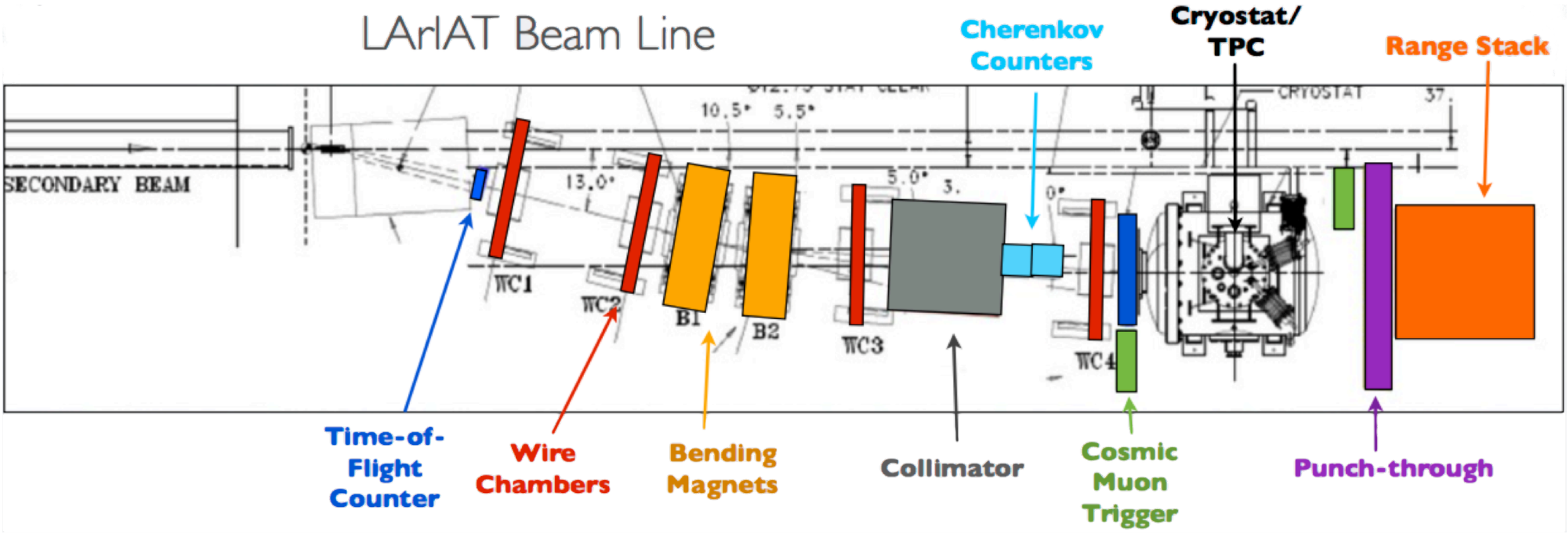
Liquid Argon Time Projection Chambers(LArTPCs)

- LArIAT is a LArTPC at Fermilab Test Beam Facility that provides beams of known energies, selection of different particle types, and controlled environment in which to tune simulations and to develop tools for particle identification (PID), calorimetry, and event reconstruction without relying solely on simulation.



Particle ID

- We currently have 2 time of flight scintillator counters which give discrimination for particles but not for to close in mass such as p/π, but not π/μ.



Particle ID

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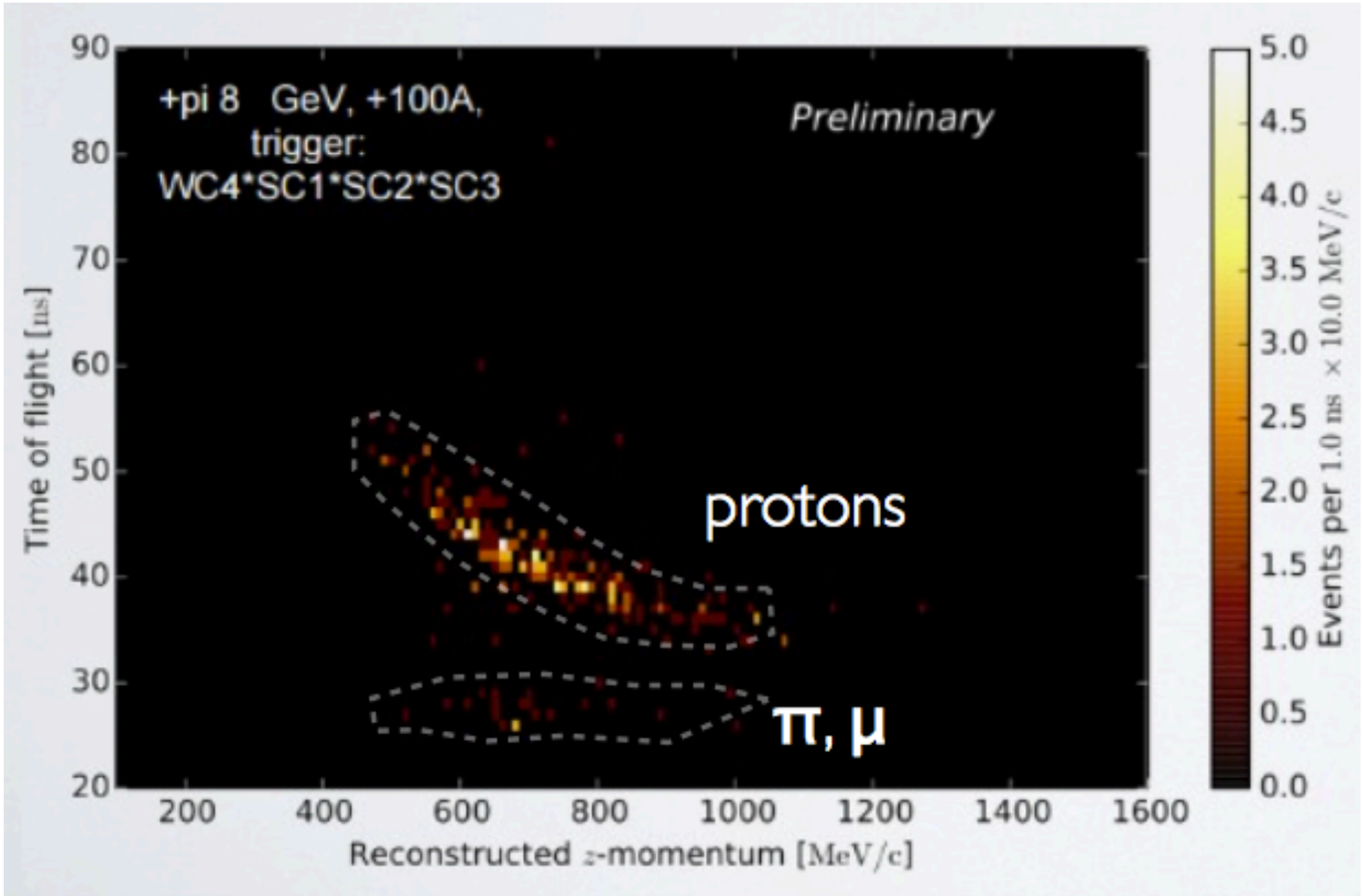
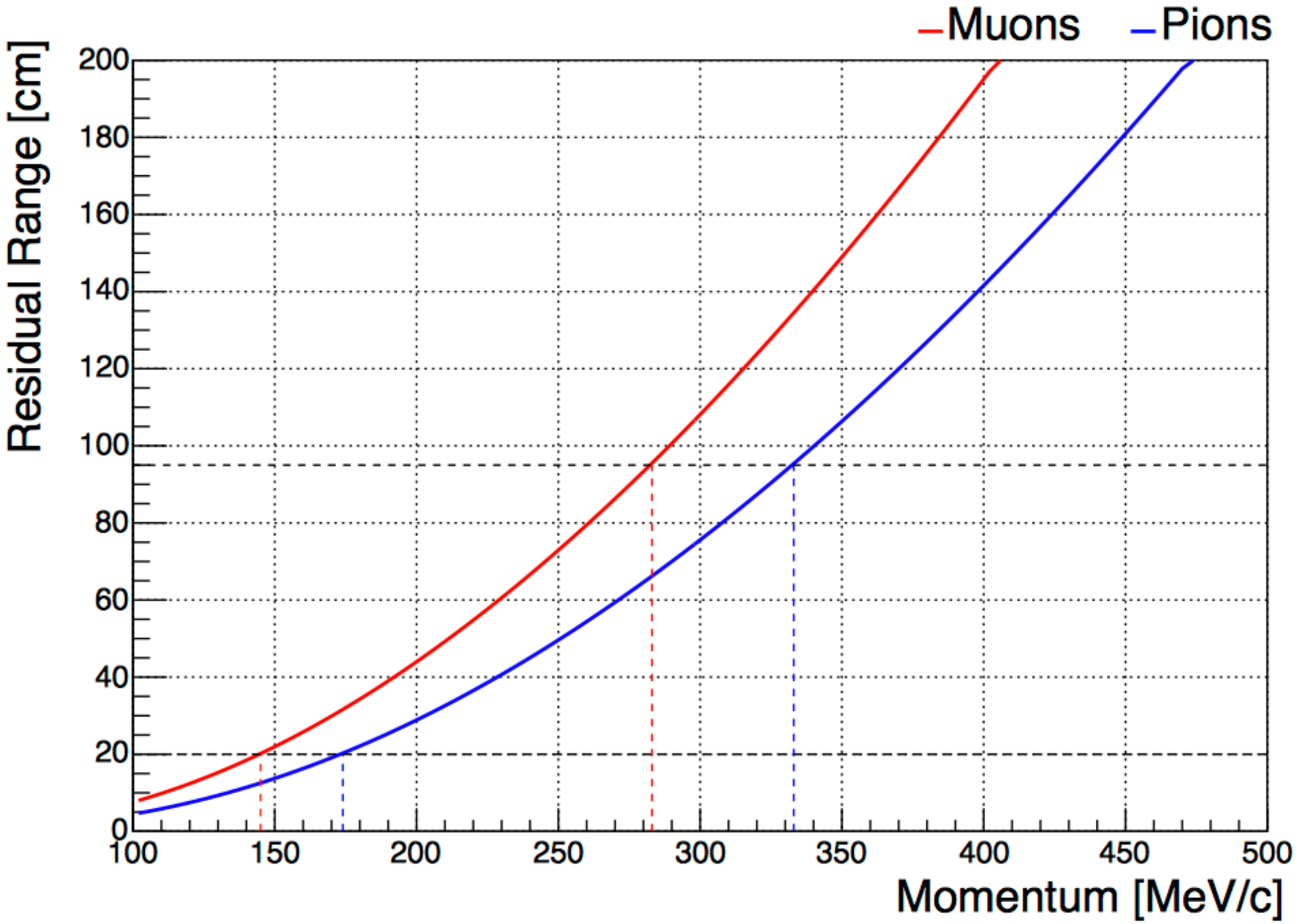


Motivation

➢ How can we measure stopped muons and pions at LArIAT?

- Given simple assumptions, muons should stop within the LAr TPC with p<280 MeV and pions with p<330 MeV.

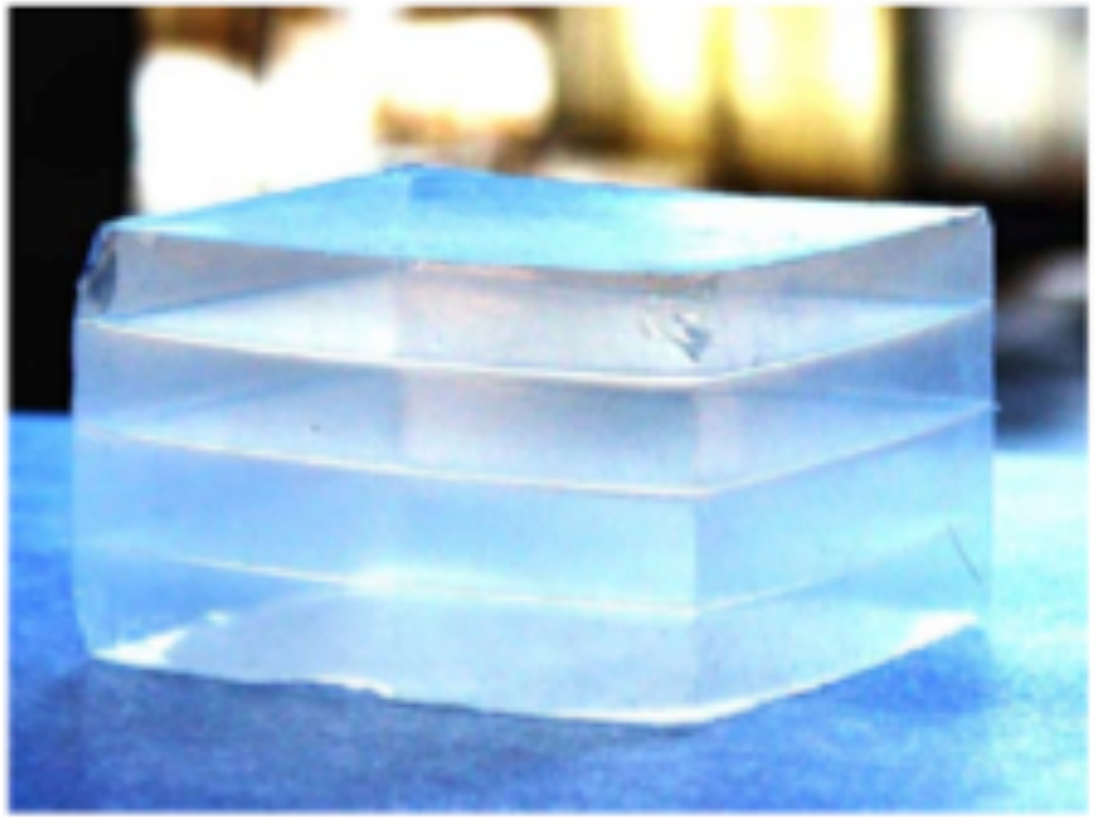


Motivation

➢ How can we seperate stopped muons and pions at LArIAT?

- Can't use a muon range stack since these muons will be stopping in the LAr TPC.
- Time of Flight (ToF) can be difficult since muon and pion masses only differ by 30%

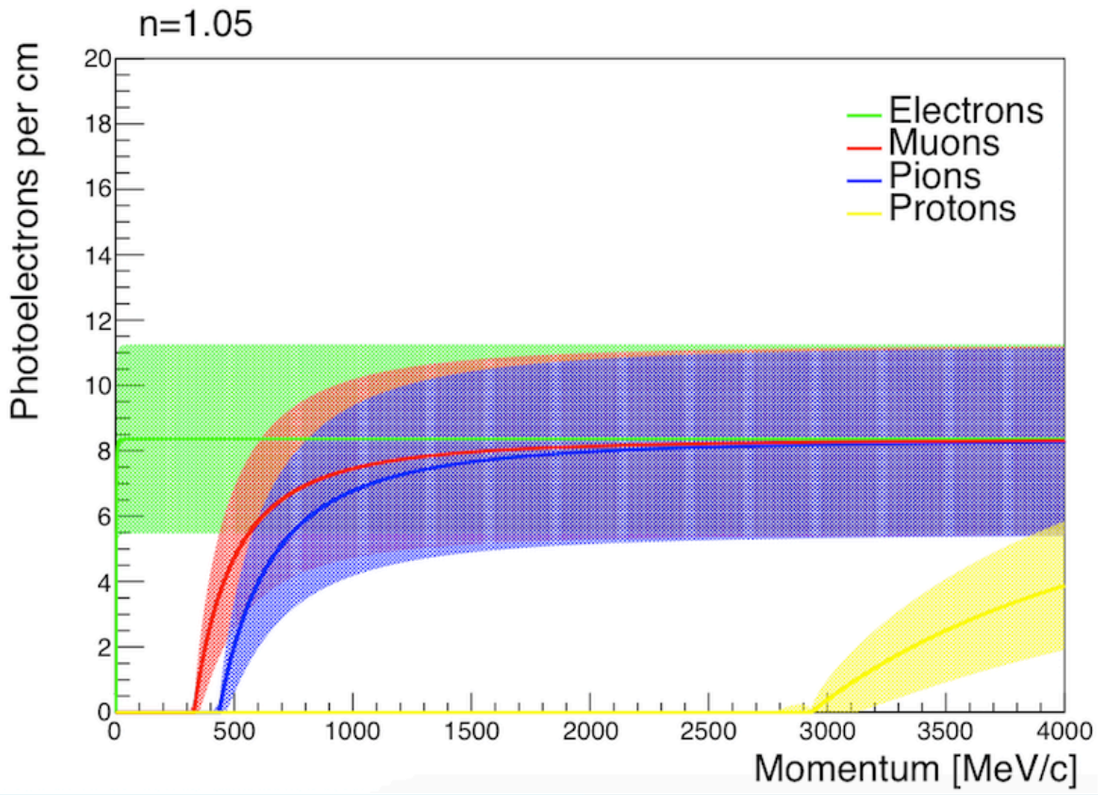
-What about a material with a small index of refraction (Aerogel)?

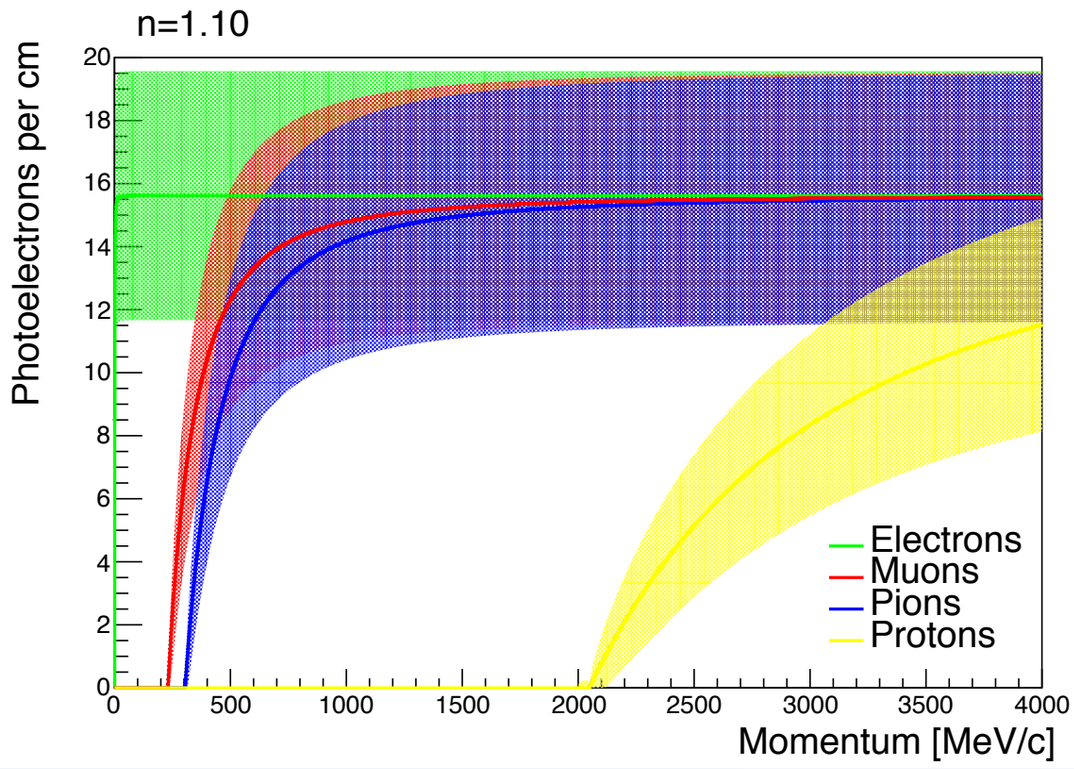


- Aiming to separate muons and pions in a momentum range where muons emit Cherenkov radiation while pions do not.
- Different indices of refraction are sensitive to different momentum ranges.
- The combination of the two aerogel Cherenkov counter, pions and muons can be identified for p<400MeV/c

		n = 1.10	n = 1.05
220<p<285	**μ**	✓	x
	π	x	x
300<p<400	**μ**	✓	✓
	π	✓	x

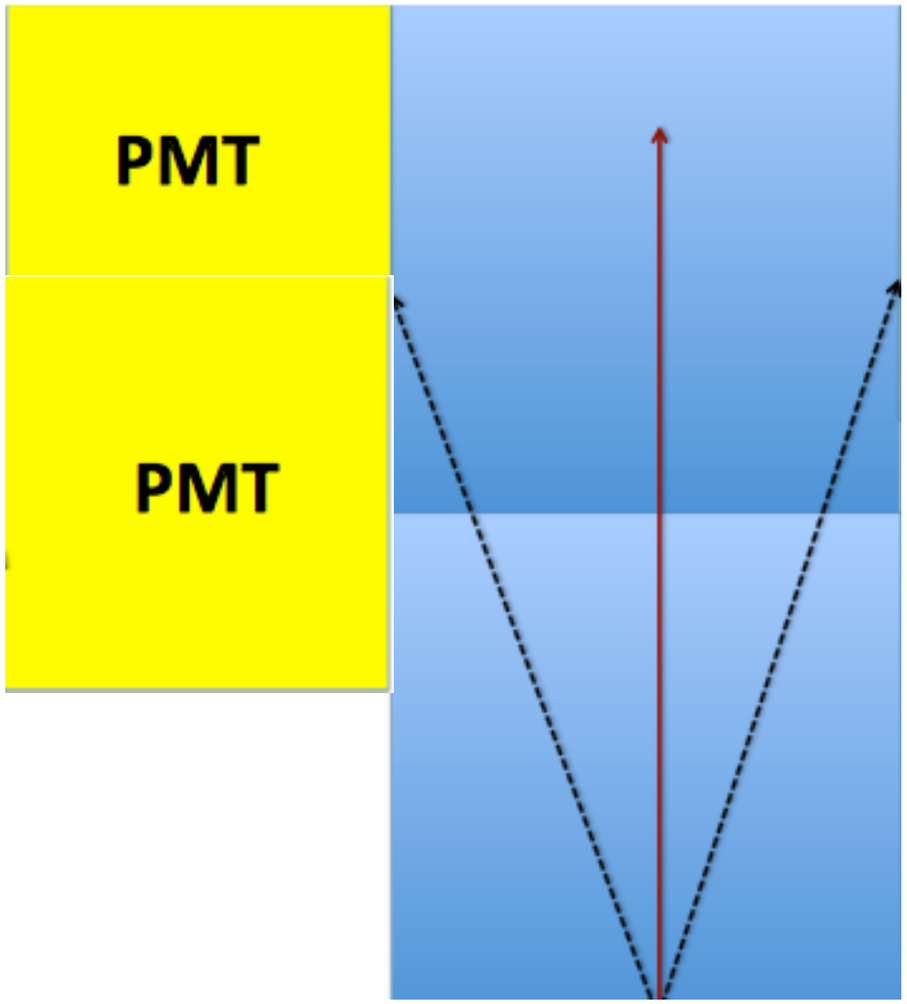
$$N_{PE} \approx 90 \times \sin^2\theta_c \text{ where } \cos\theta_c = \frac{1}{\beta n}$$





Designs

Active

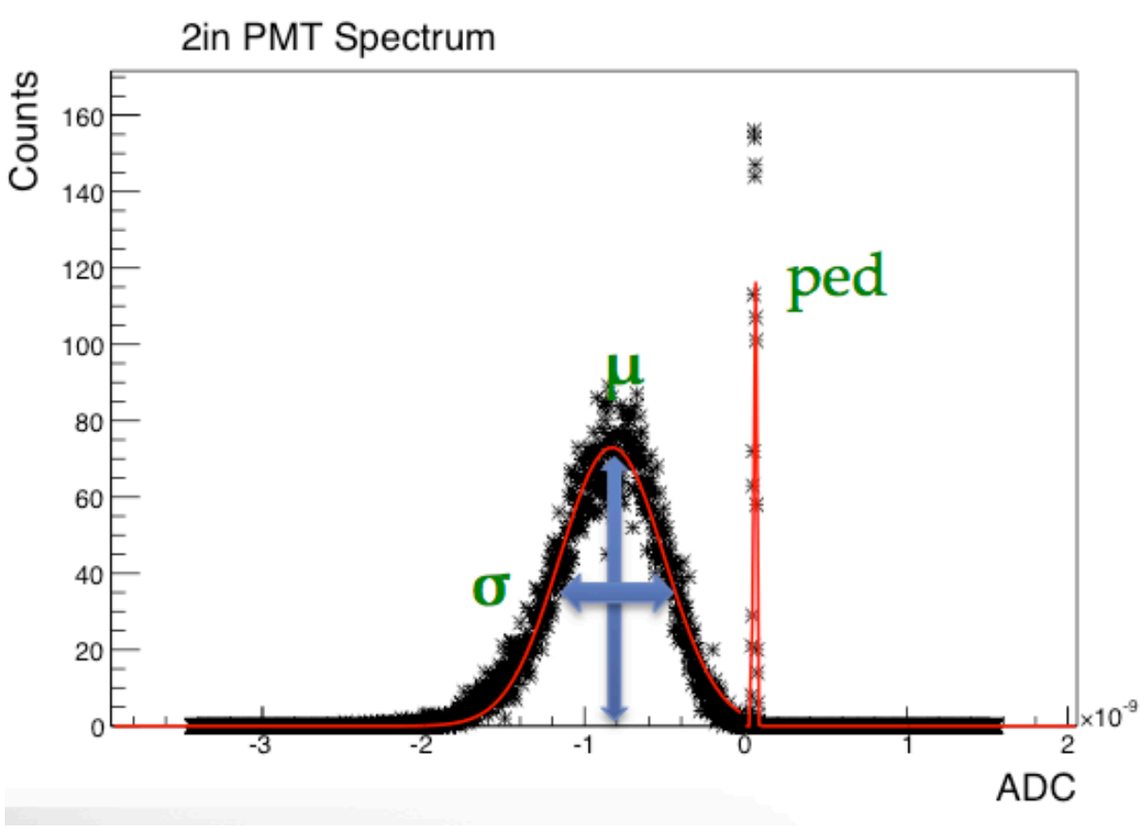


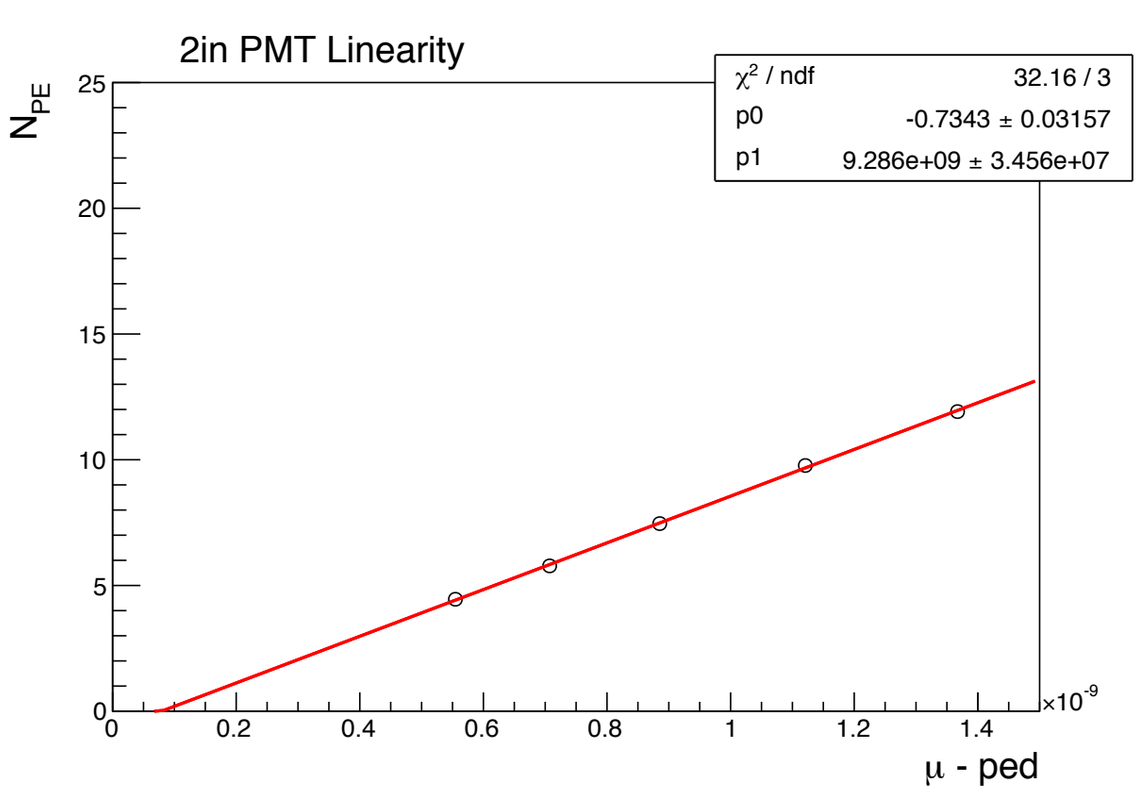
- We have our aerogel tiles horizontal instead of vertical.
- This increases our thickness for particles to pass through from 6.5 to 7.4 inches
- Currently using the EMI 9954B 2” PMT with another 3” PMT.

PMTs

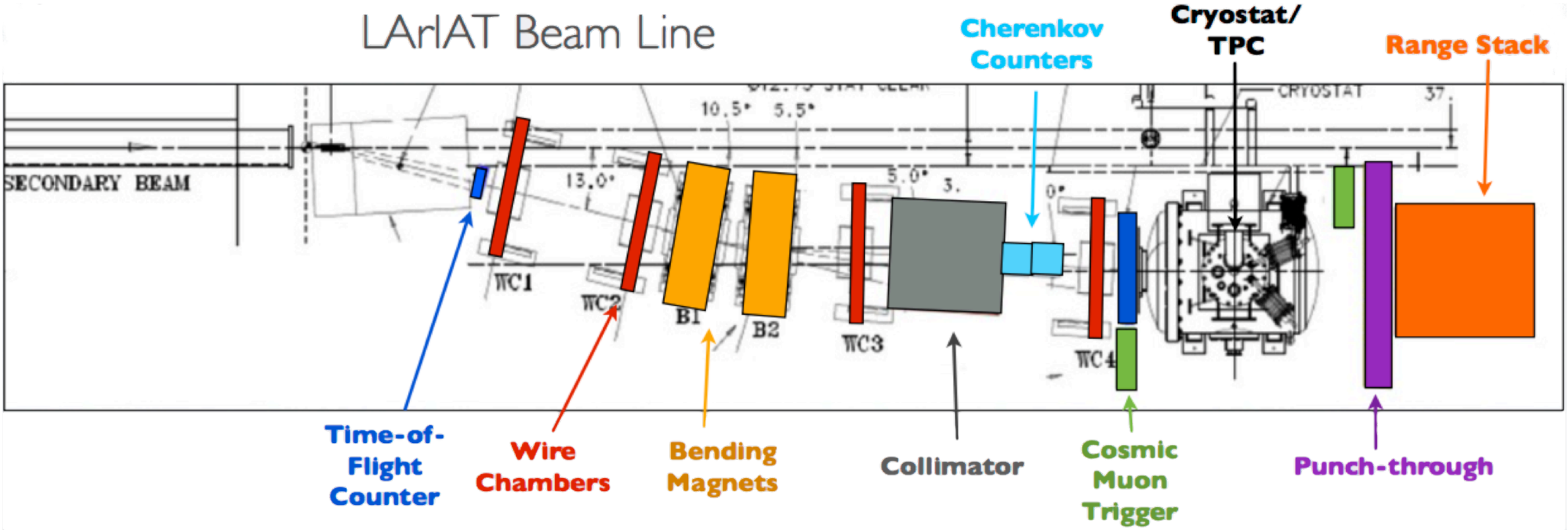
- Calibrated PMTs using LED pulses.
- This allows us to translate from ADC counts to NPE

$$n_0 \sim \left(\frac{\mu - ped}{\sigma_{0m}}\right)^2$$



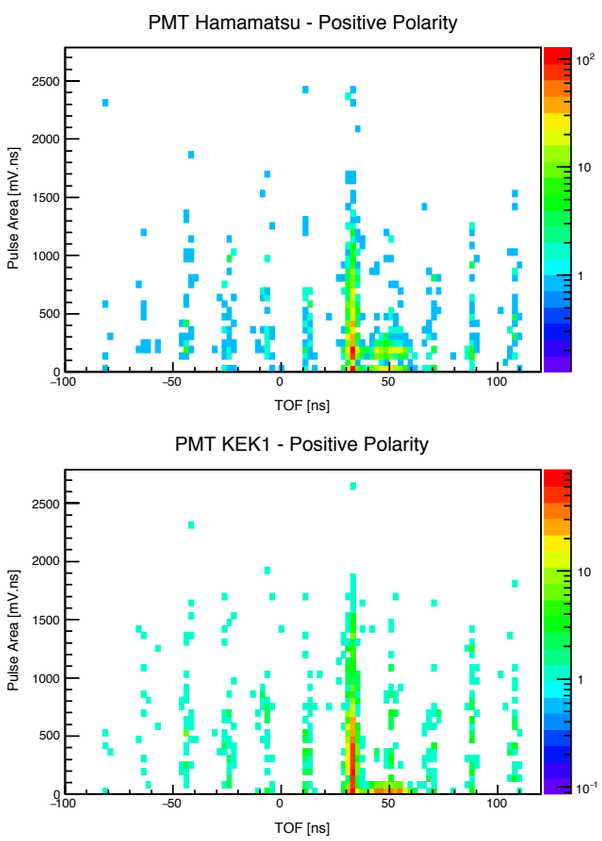


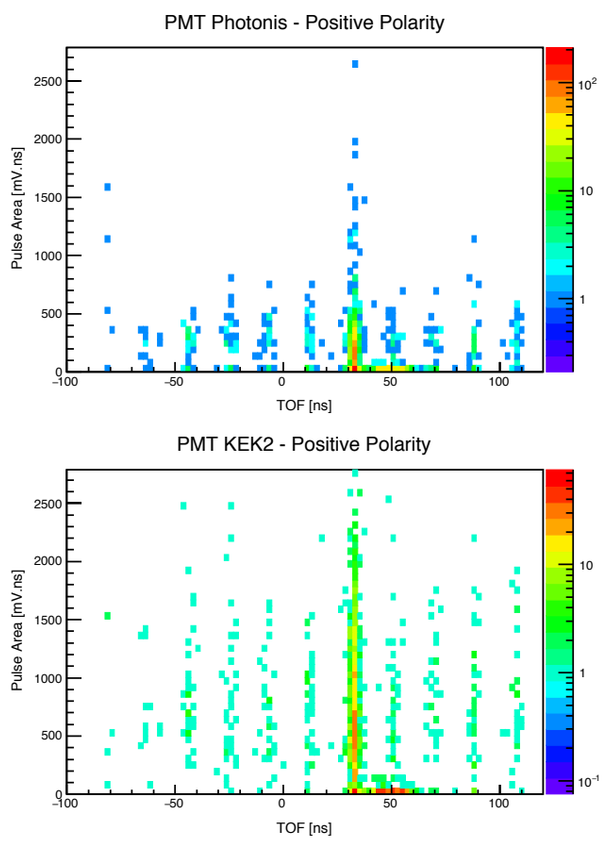
➢ Due to the size of the new design(s), our counter is placed DS just after the KEK counter.



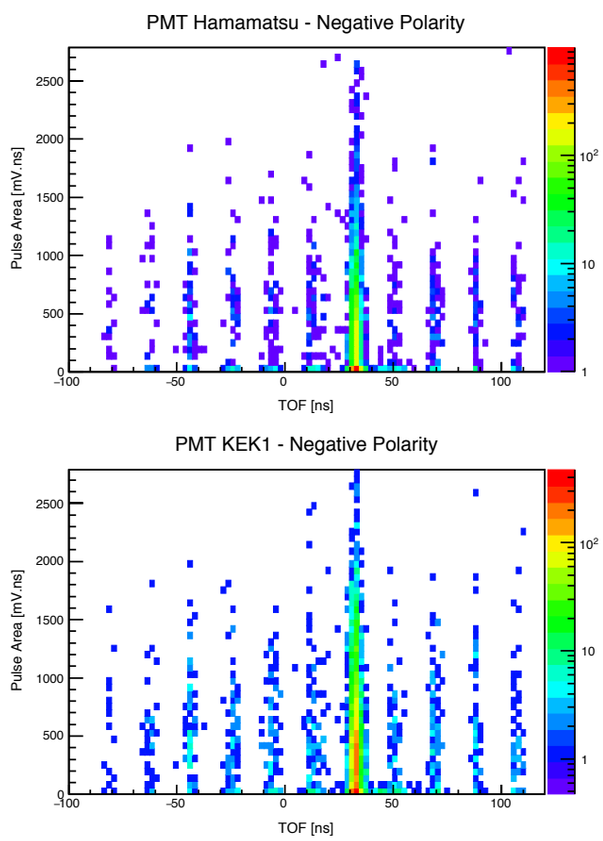
➢ Can better understand our pile up from the aerogel counters?

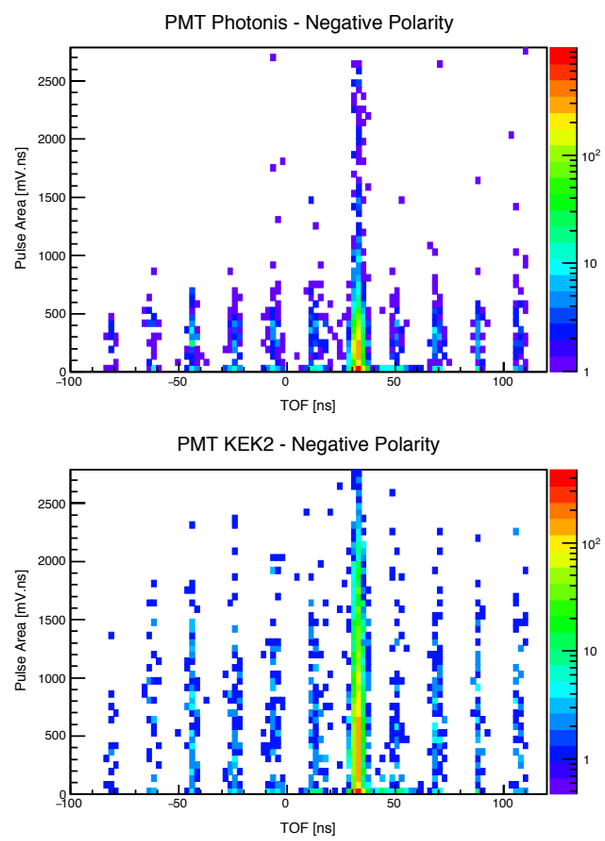
➢ TOF vs Pulse Area – Positive Magnet Polarity Runs - with pile up



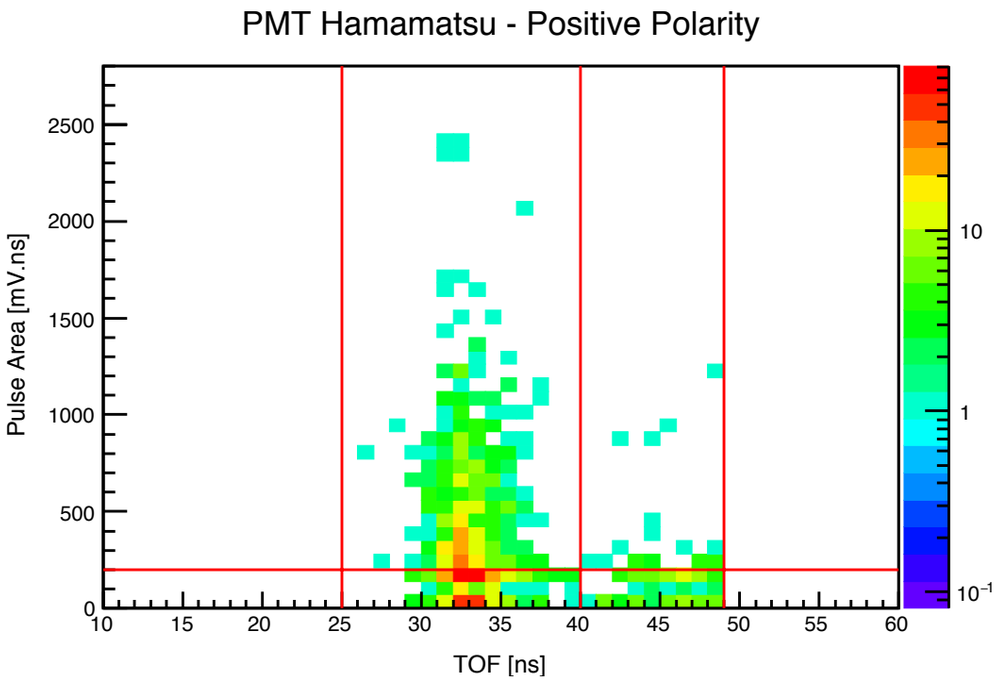


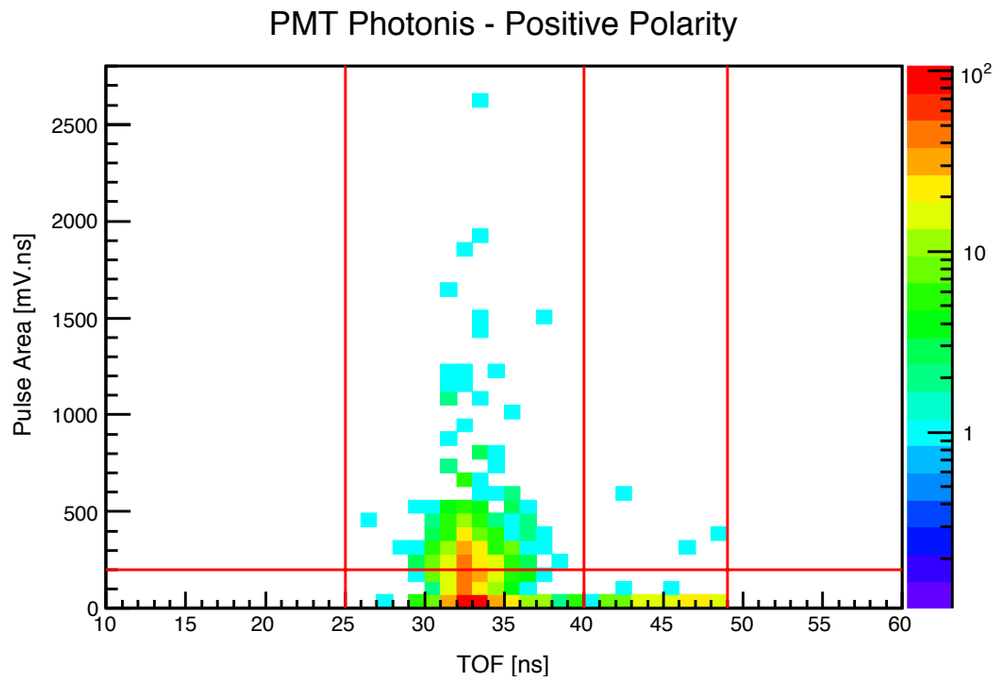
➢ TOF vs Pulse Area – Negative Magnet Polarity Runs - with pile up

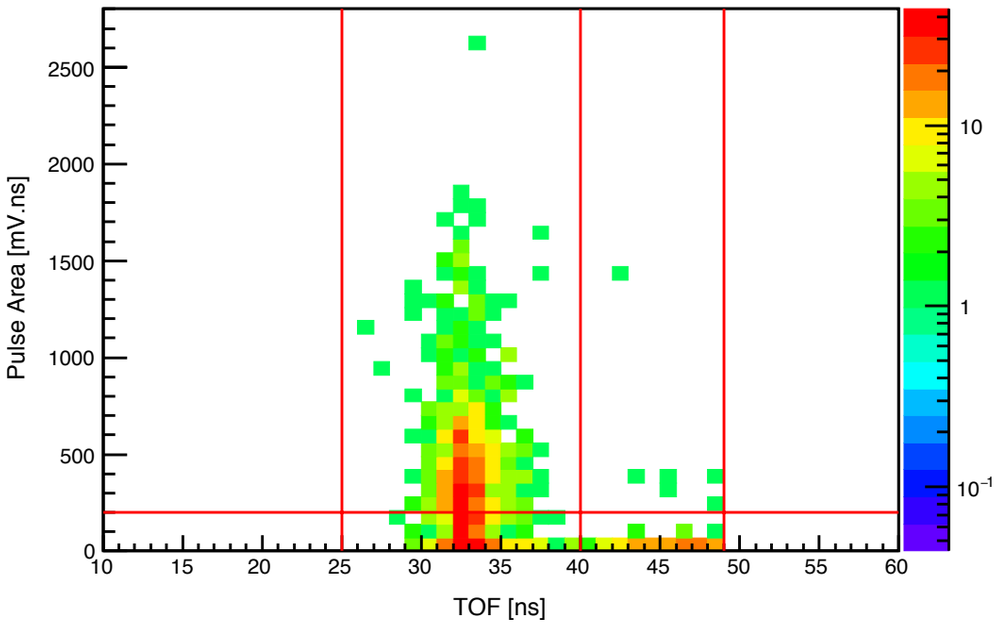


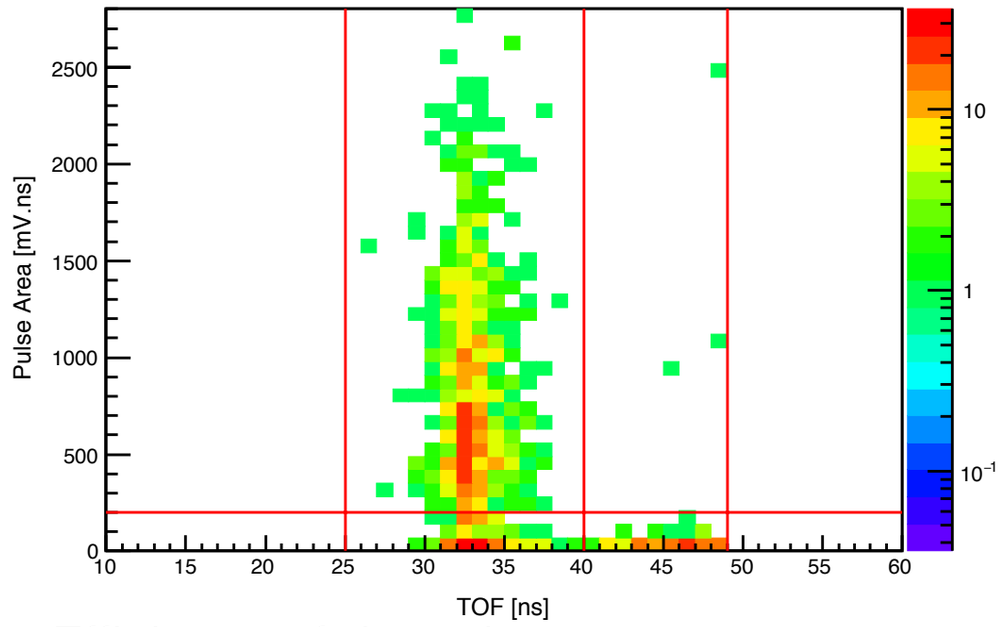


➢ TOF vs Pulse Area – Positive Magnet Polarity Runs





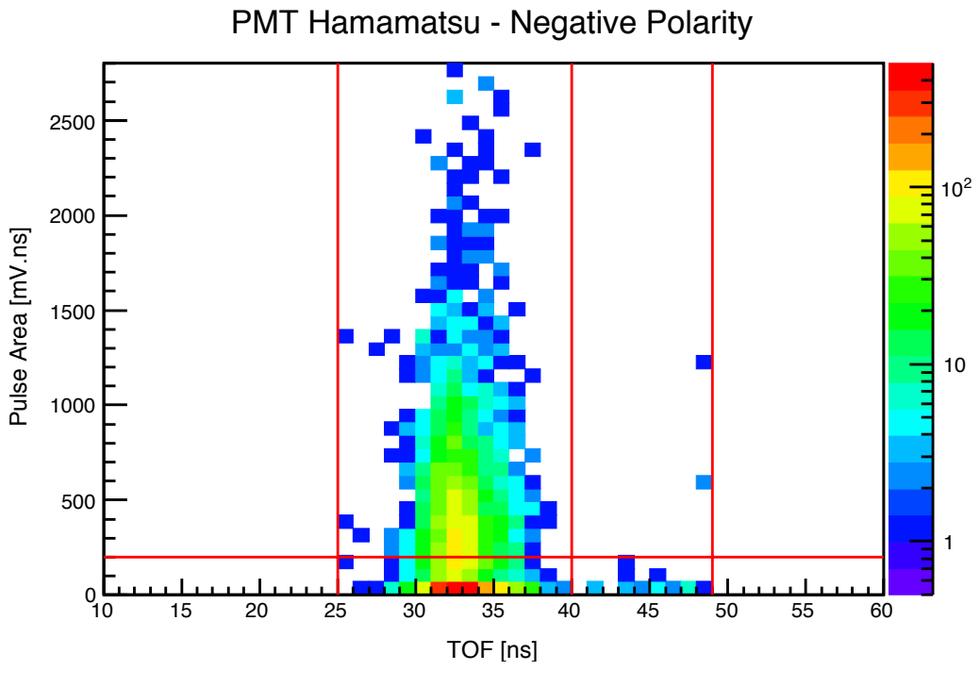


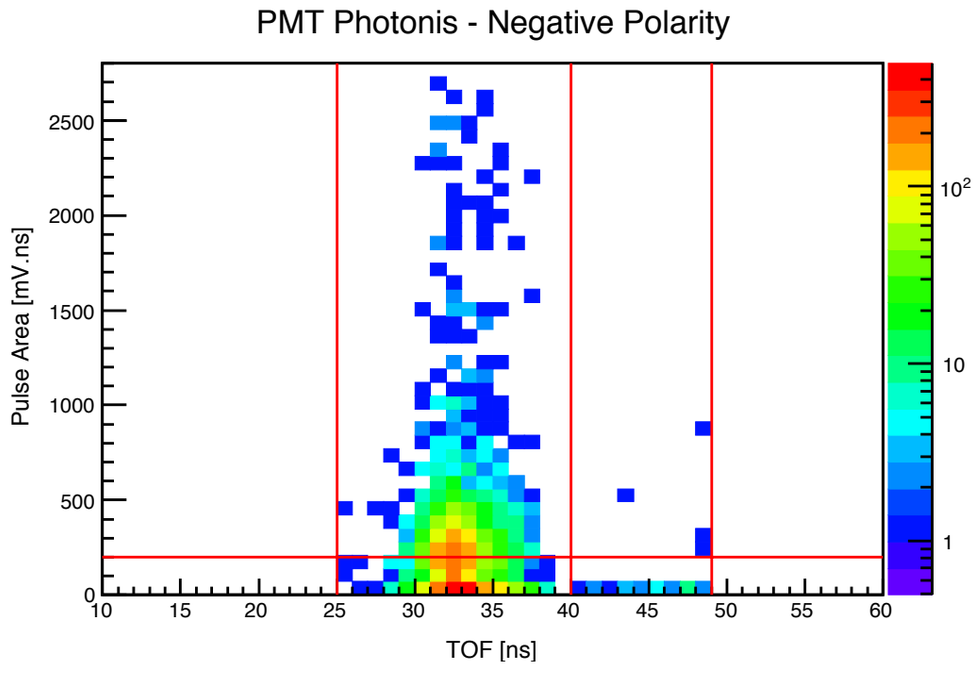


- Efficiency of detecting pion:
  - HMMS PMT: 57%
  - PTN PMT: 41%
  - KEK1 PMT:67%
  - KEK2 PMT: 82%

- Efficiency of detecting proton:
  - HMMS PMT: 22%
  - PTN PMT: 29%
  - KEK1 PMT: 5%
  - KEK2 PMT: 2%

➢ TOF vs Pulse Area – Negative Magnet Polarity Runs





- Efficiency of detecting pion
  - HMMS PMT: 52%
  - PTN PMT: 42%
  - KEK1 PMT: 69%
  - KEK2 PMT: 74%

- Efficiency of detecting proton
  - HMMS PMT10%
  - PTN PMT: 13%
  - KEK1 PMT: 9%
  - KEK2 PMT: 15%

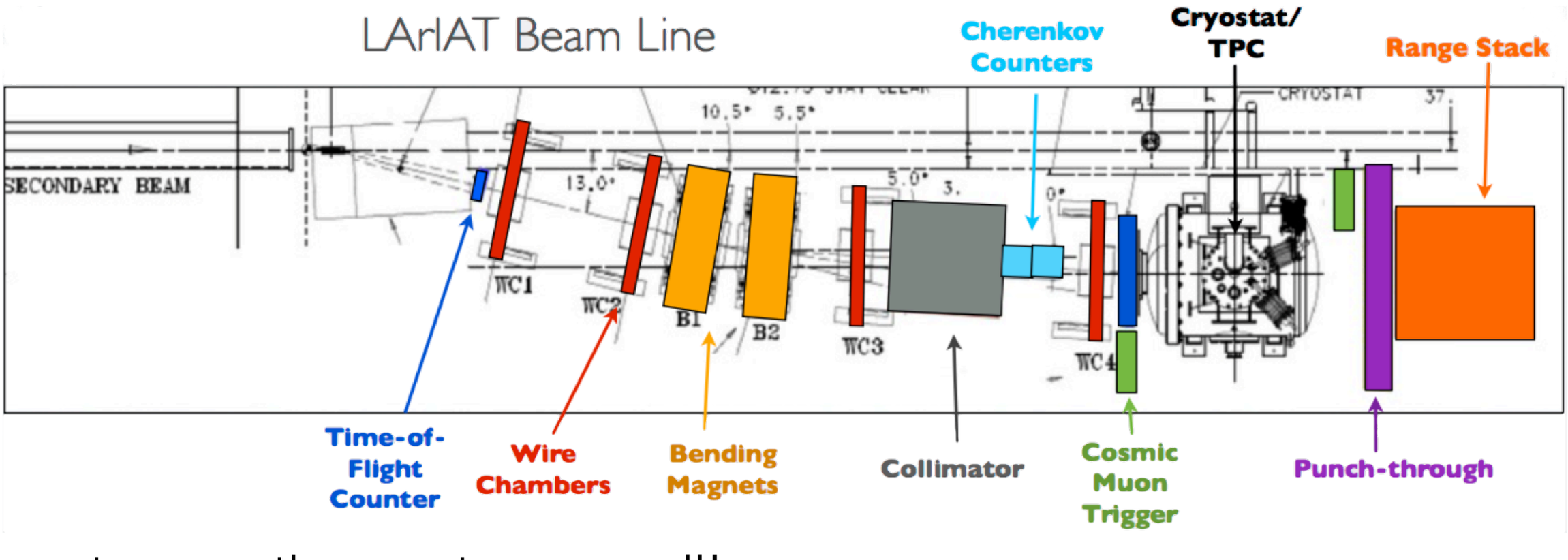
Reference

E.H.Bellamy et al. NIM A339 (1994) 468-476
P.Adamson et al. NuMI-L-661 (2000)
R.Godang et al. MUC-NOT-COOL-EXP-304

Other Involvement here at Fermilab

- US Wall Halo Scintillator Counter(HSC) Installation
  - Modified Collimator Running and simulations
    - Studies with Silicon photomultiplier (SiPMs)

US Wall Halo Scintillator Counter(HSC) Installation



- Counters on the upstream wall!
  - Measure any secondary beam halo.
  - Help understand radiation field of MC7.

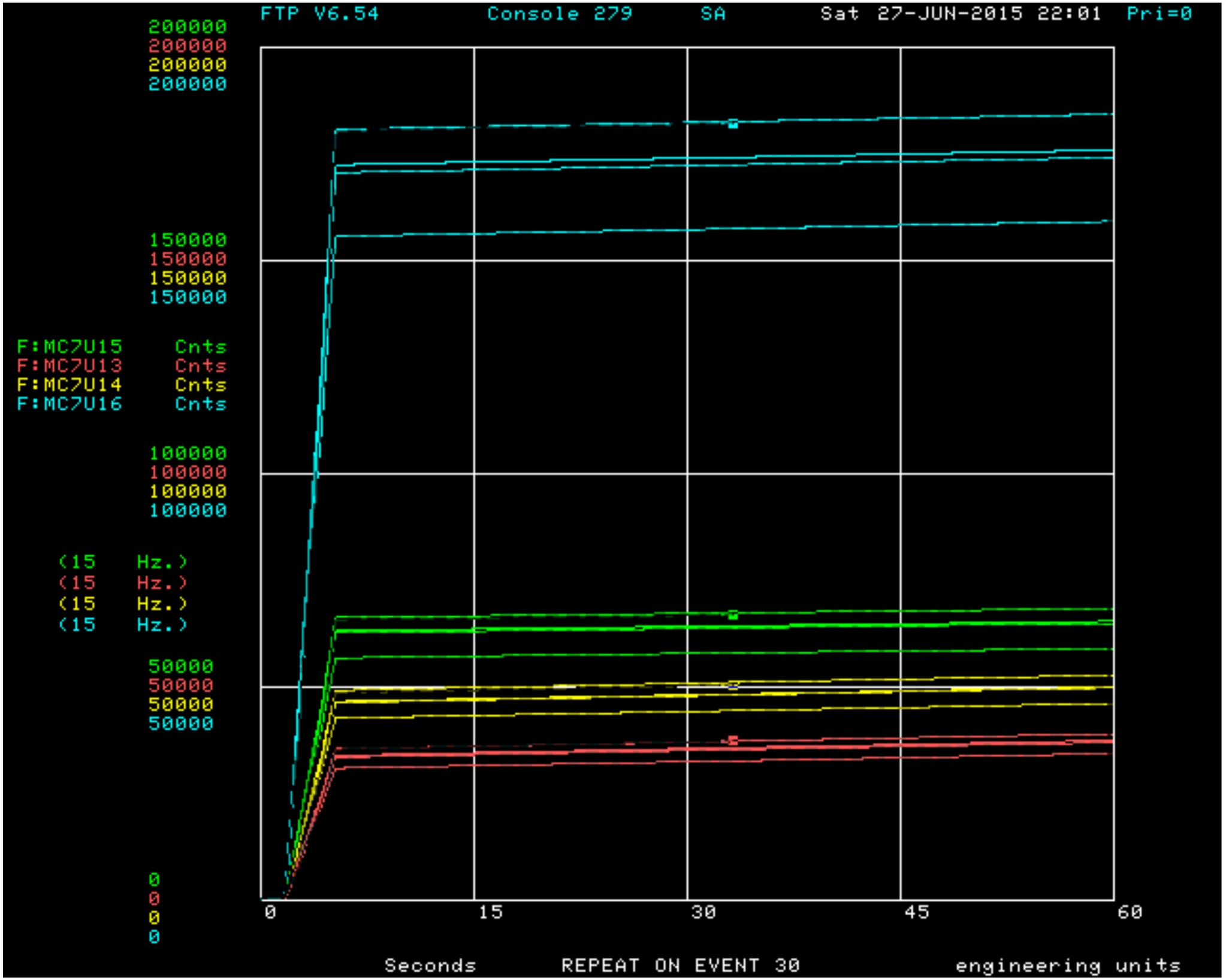
- Counters on the upstream wall!
  - Measure any secondary beam halo.
  - Help understand radiation field of MC7.

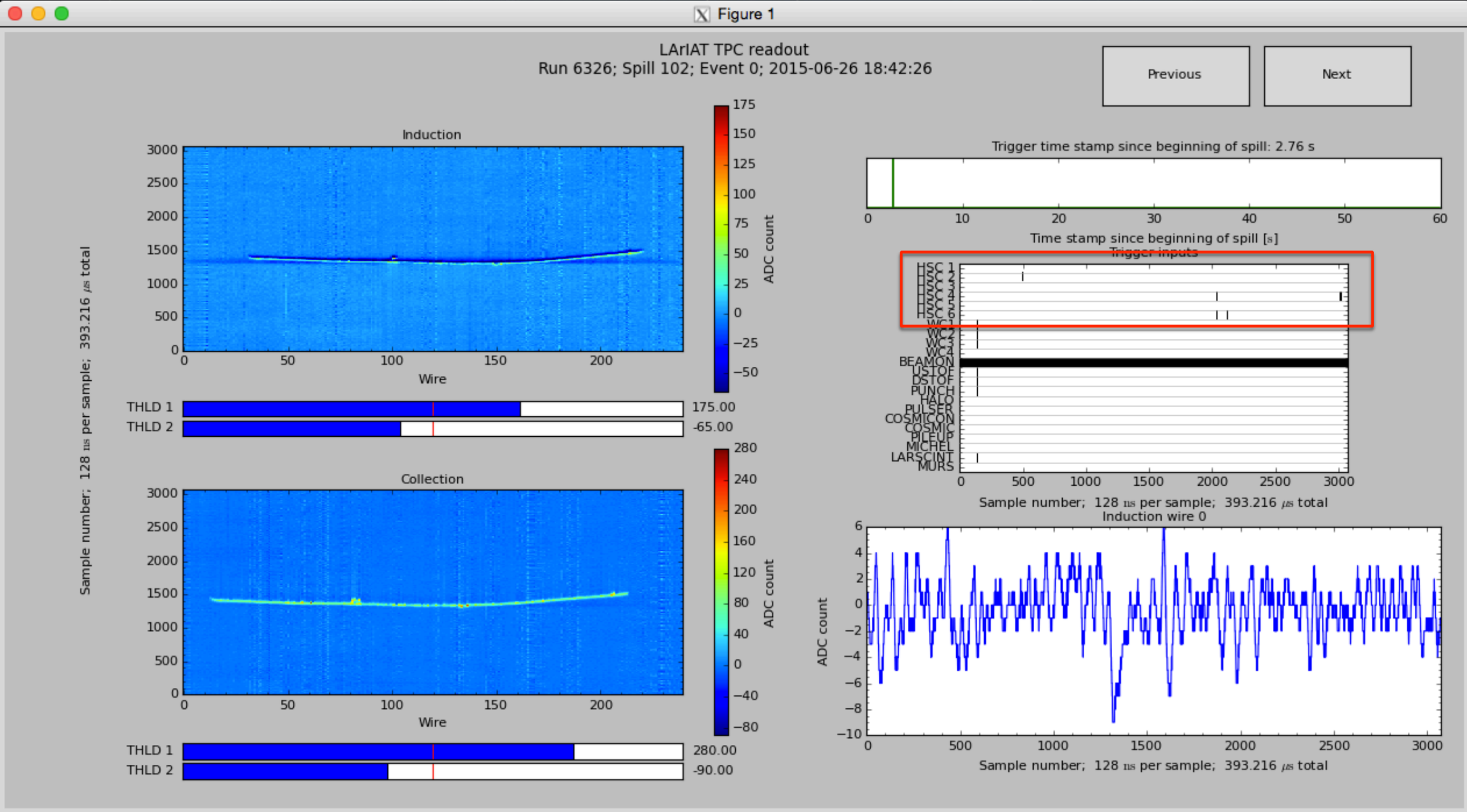
- Wall halo counters are connected into the quad scalar and sent into acnet.
- Plugged into a spare v1740 board.

PB S60 PPD Params<NoSets>

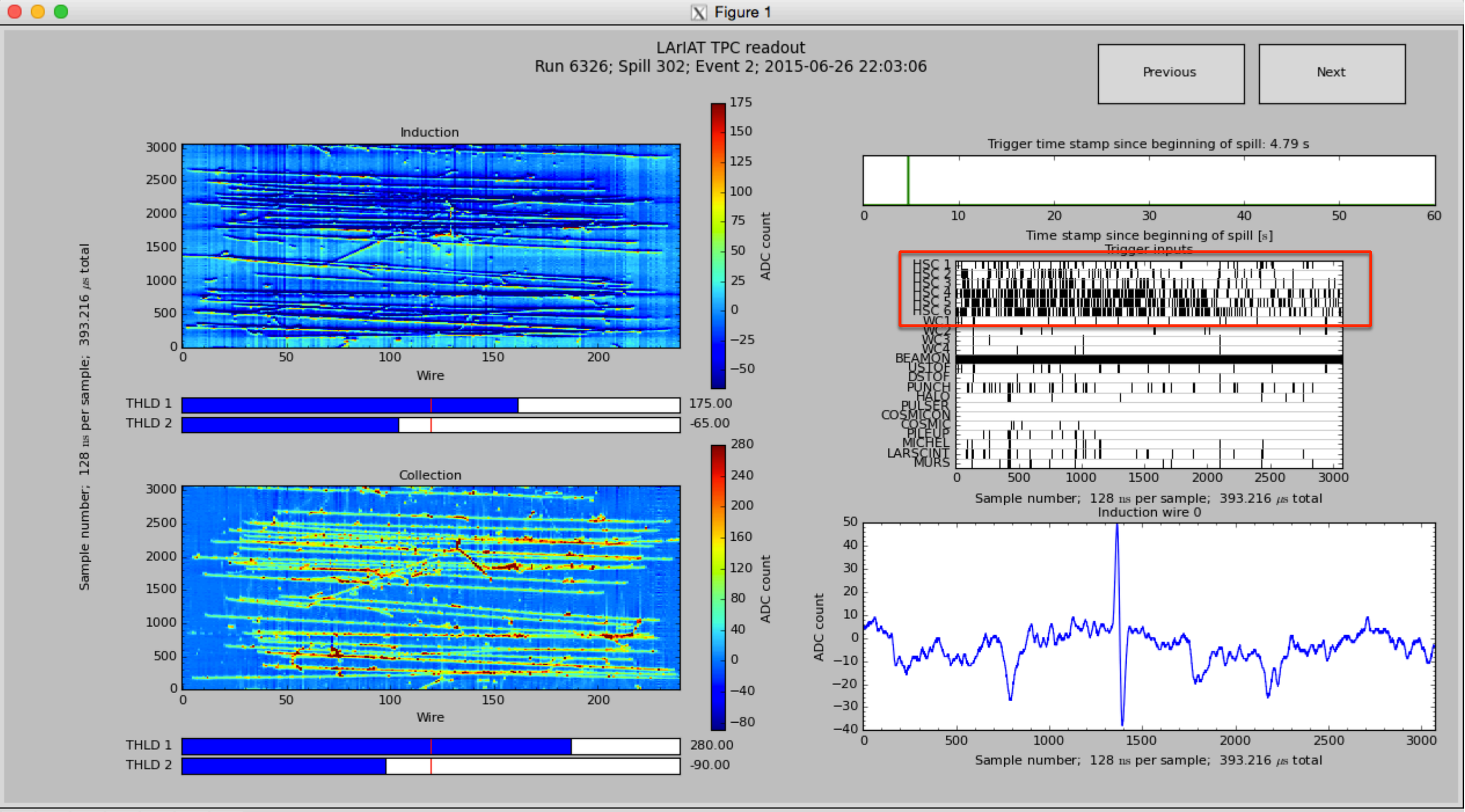
```
S60  User Input Parameters          SET      D/A    A/D   Com-U ◆PTools◆
                                  Fast Time Plot
 *SA◆ X-A/D   X=TIME*40        Y=F:MC7U15     ,F:MC7U13     ,F:MC7U14     ,F:MC7U16
 BL-- Eng-U   I= 0             I= 0           , 0           , 0           , 0
 r_30 AUTO    F= 60            F= 200000      , 200000      , 200000      , 200000
 ◆Save◆  ◆Restore◆                          Return
 F:MC7U01      MC7 Wire Chamber WC1                    7609    Cnts
 F:MC7U02      MC7 Wire Chamber WC2                    6143    Cnts
 F:MC7U03      MC7 Wire Chamber WC3                    3073    Cnts
 F:MC7U04      MC7 Wire Chamber WC4                    2500    Cnts
 F:MC7U05      MC7 Aero Gel AG US E                    3144    Cnts
 F:MC7U06      MC7 Aero Gel AG US W                    184     Cnts
 F:MC7U07      MC7 Aero Gel AG DS E                    44      Cnts
 F:MC7U08      MC7 Aero Gel AG DS W                    70      Cnts
 F:MC7U09      LArIAT Cosmic Accidental                442     Cnts
 F:MC7U10      LArIAT Halo tertiary bm                 6664    Cnts
 F:MC7U11      LArIAT TPC Readout Trig                 40      Cnts
 F:MC7U12      LArIAT Fast Trigger                     42      Cnts
 F:MC7U13      LArIAT Wall Halo 1                      37031   Cnts
 F:MC7U14      LArIAT Wall Halo 2                      50351   Cnts
 F:MC7U15      LArIAT Wall Halo 3                      66338   Cnts
 F:MC7U16      LArIAT Wall Halo 4                      2E+05   Cnts
 F:MC7U17      LArIAT Wall Halo 5                      2E+05   Cnts
 F:MC7U18      LArIAT Wall Halo 6                      2E+05   Cnts
 F:MC7U19      LArIAT Spare Scaler                      0      Cnts
 F:MC7U20      LArIAT Spare Scaler                      0      Cnts
```

- We can see now the Halo Scintillator Counter's reaction to the beam spill.



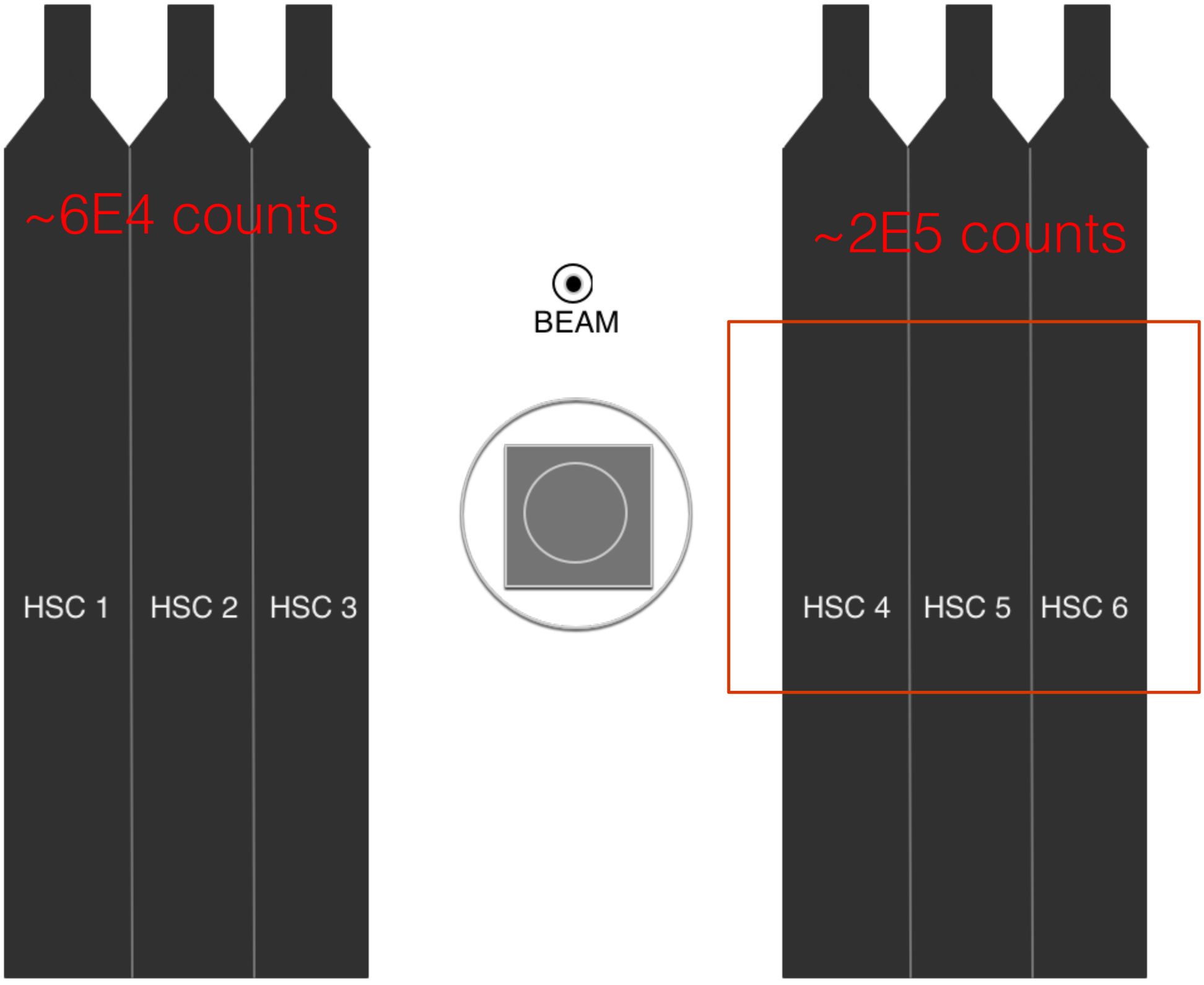


- I have made changes to the event display to output all 6 wall HSCs.
  - Single tracks seem to quiet in the counters



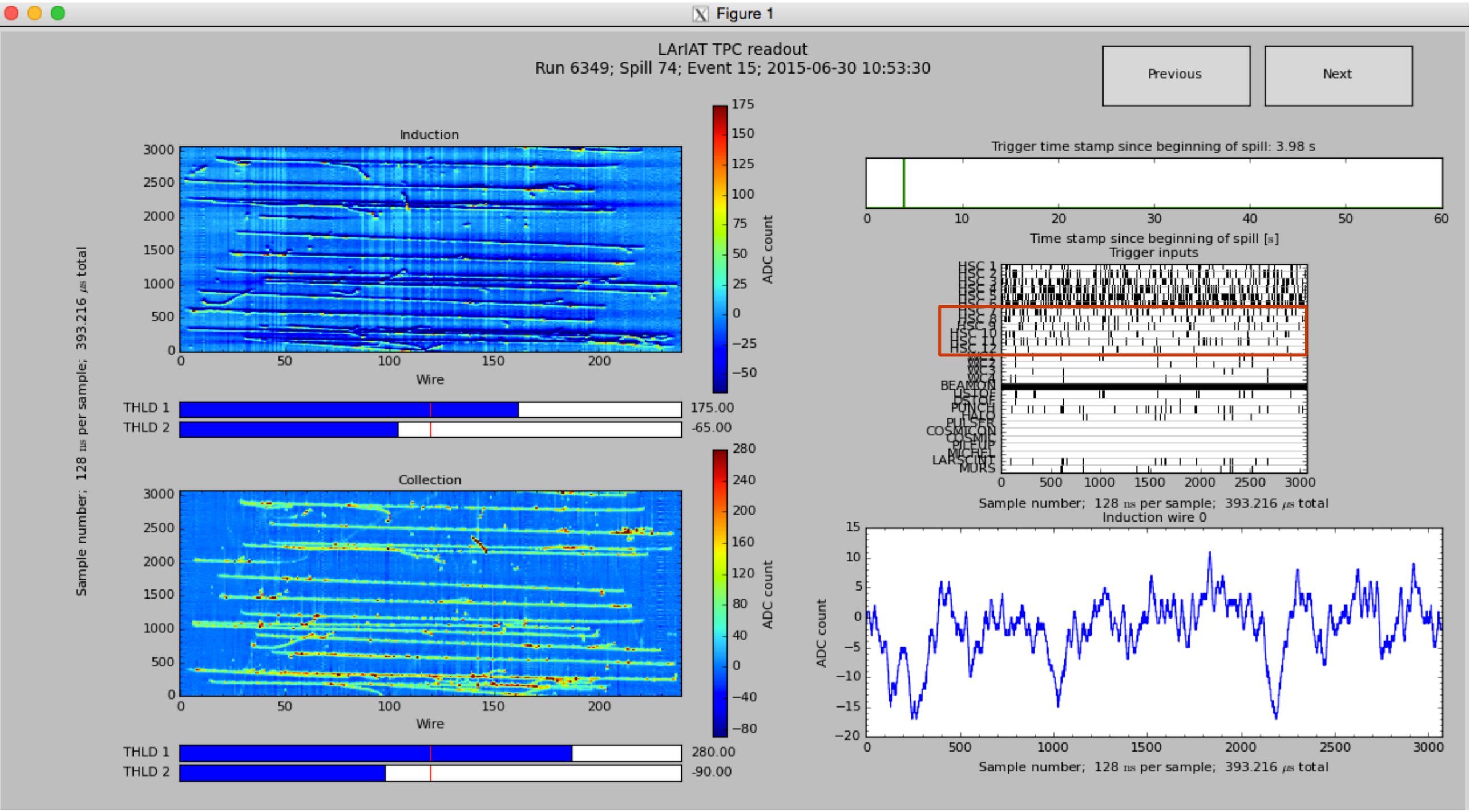
- Notice the wall counter are lighting up when we have a lot of through the LArTPC.
  - Can we veto on the wall HSCs in the v1495.

- We have noticed that HSC 4, HSC 5, and HSC 6 are seeing higher counts then HSC 1, HSC 2, and HSC 3.



- As of June 29th the movable rack has also been installed.

- I have made changes to the event display again adding the movable rack Halo Scintillator Counter's channels.



Modified Collimator Running + Simulations

Proposal for Special LArIAT Runs

- Principal investigators: Will Flanagan, Dung Phan, Brandon Soubasis, James Zhu
- Proposal duration: 4 hours with beam, 4 days without beam

As LArIAT Run I comes to a successful close, we would like to propose three special runs in order to better understand our beam and the capabilities of our experiment.

Date	Time	Run Configuration
7/3	Two Hours*	No Target
7/3	Two Hours*	Modified Collimator
7/4-7/5	All Day	Na-22
7/6	7:30am-3:00pm	Cf-252
beyond 7/6		Source Runs TBD

*This includes installation/controlled access time.

1 Radioactive Source Runs

LArIAT would benefit from obtaining a pure sample of photons and neutrons. A short run with radioactive sources will help us to understand our opportunities and limitations for such measurements. The relevant sources for this run are below.

Isotope	Type	Source ID	Current Activity
Na-22	Gamma (Annihilation Radiation)	22-1.5-1	17.9 microCuries
Cs-137	Gamma (Internal Conversion)	137-3.1-69	725 microCuries
Cf-252	Neutron (Spontaneous Fission)	252-7.2-1	4.2 microCuries

1.1 Gamma Sources

The two relevant gamma sources are now in the Meson Detector Building source box. Dung Phan and Will Flanagan have a key to this source box and are certified to move these sources into place. They will be placed between MC7SC3 and the titanium window of the cryostat. Since Na-22 is an annihilation source, it produces back to back photons with an energy of 0.511 MeV. The Na-22 will be our first choice if we see a reasonable rate of events in the TPC. The trigger condition will be SC3 and LARSCINT.

Cs-137 does not provide simultaneous photons, but we could benefit from the higher rate and higher energy (0.624 MeV) of this source.

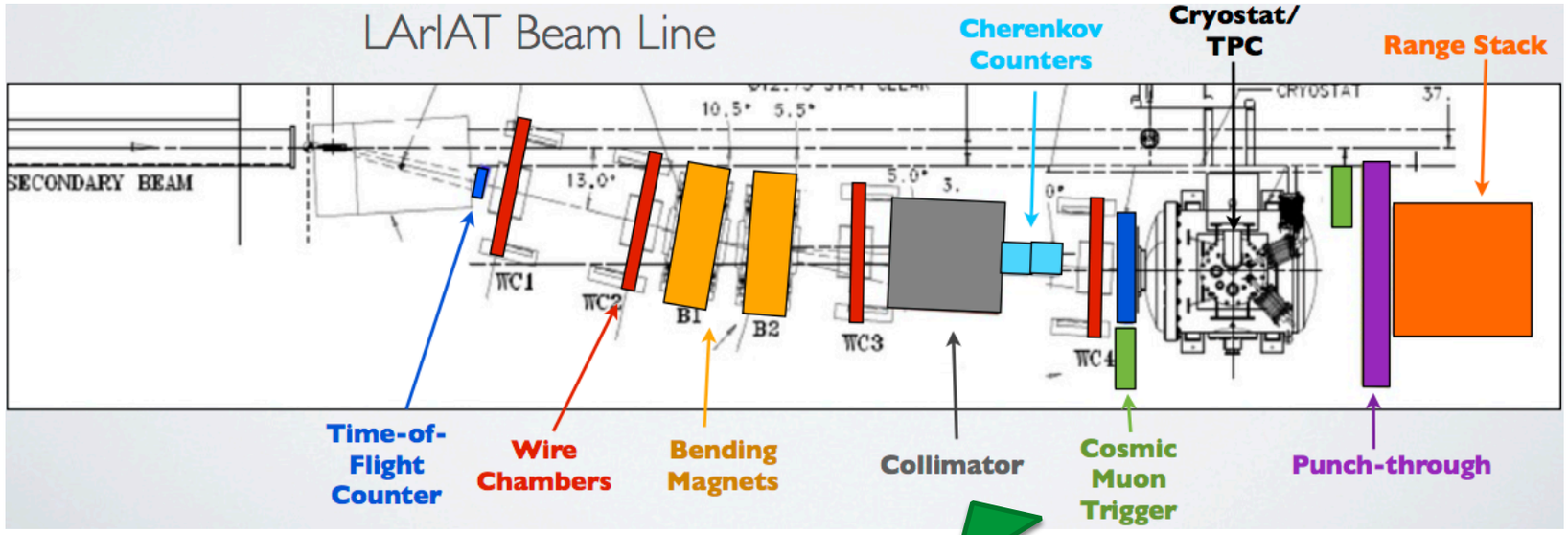
1.2 Neutron Sources

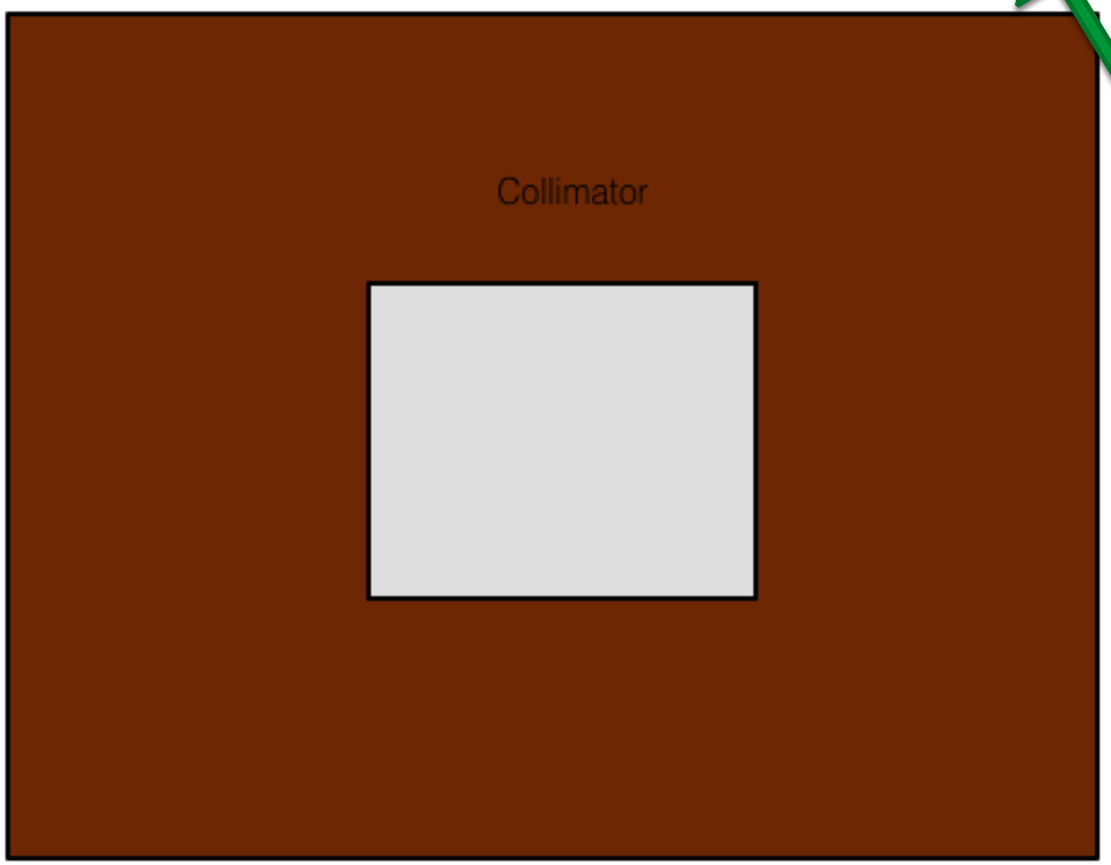
the Cf-252 source must be placed by an approved source technician. The first day of possible neutron source running is July 6. On days of neutron source running, the source will be delivered at 7:30am and picked up at 3:00pm. Kathy Graden is the Source Physicist who is preparing the Radioactive Work Permit.

The trigger condition will be LARSCINT. We have yet to demonstrate that our DQM can handle the high rate of this trigger.

- Prepared steel plates and braces to narrow our downstream
- collimator.
- Been simulating the change in our observed momentum spectrum that these plates would give.
- Observing this change in our momentum spectrum would test both our beamline simulation and momentum reconstruction.

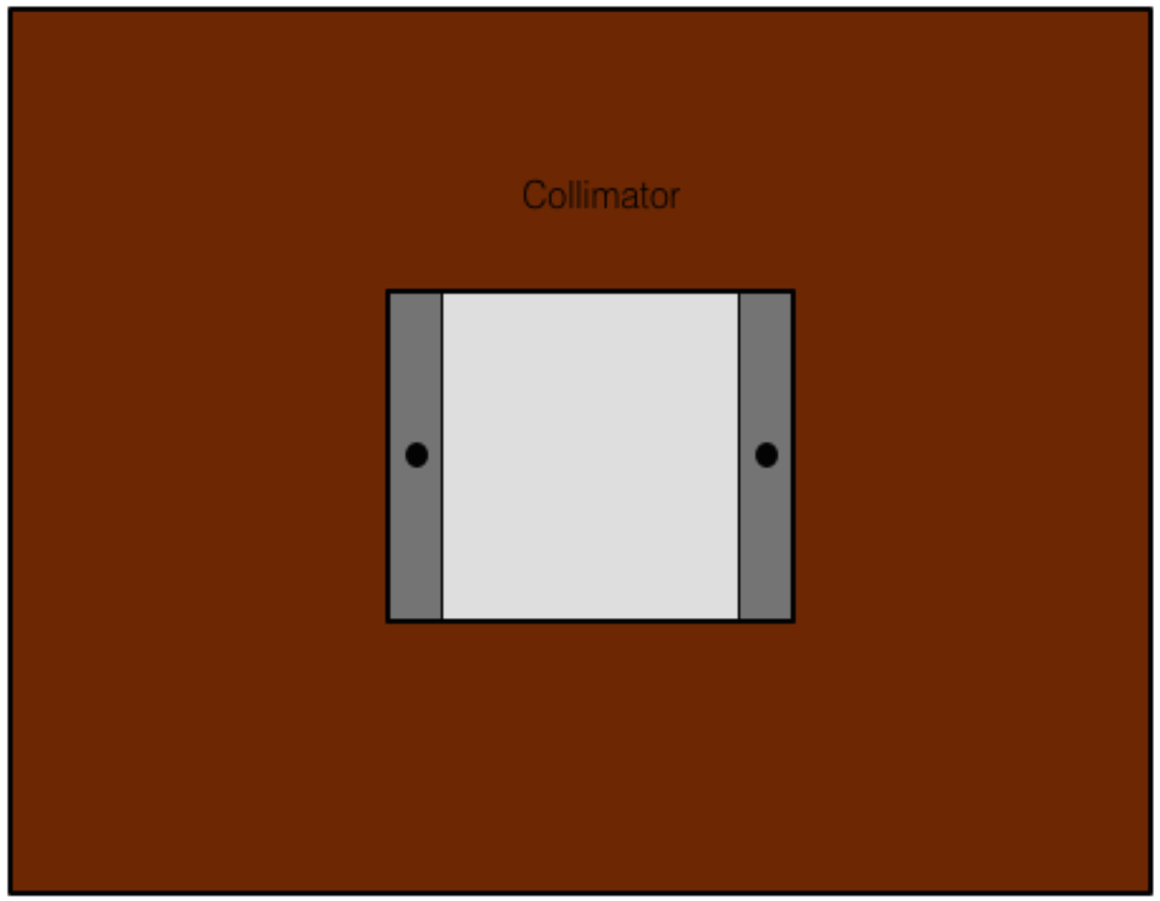
- We have found some steel plates that have been tapped so that they can be placed inside the collimator to have the option of narrowing the beam. This will give us four options for the beam width.

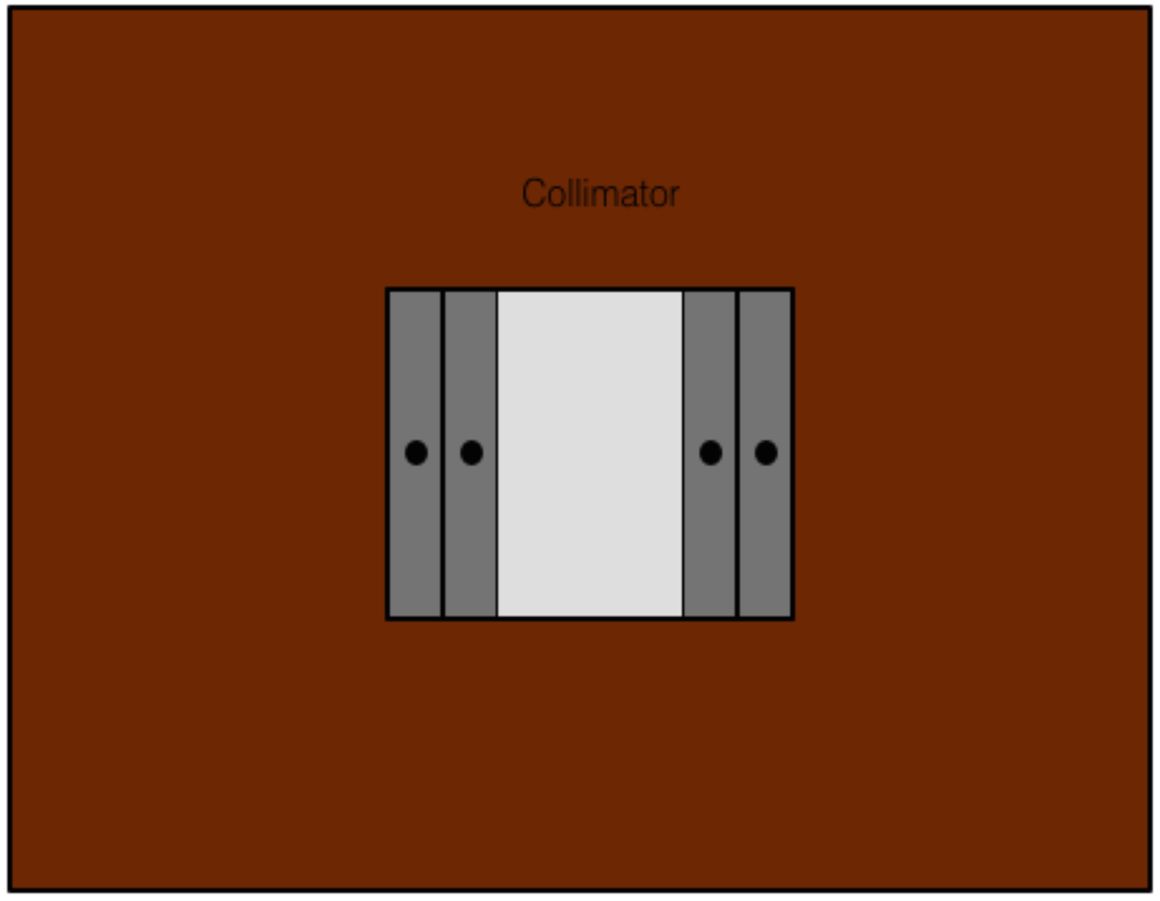




Collimator

- I am working on the beam line simulation of these plates within the collimator


Collimator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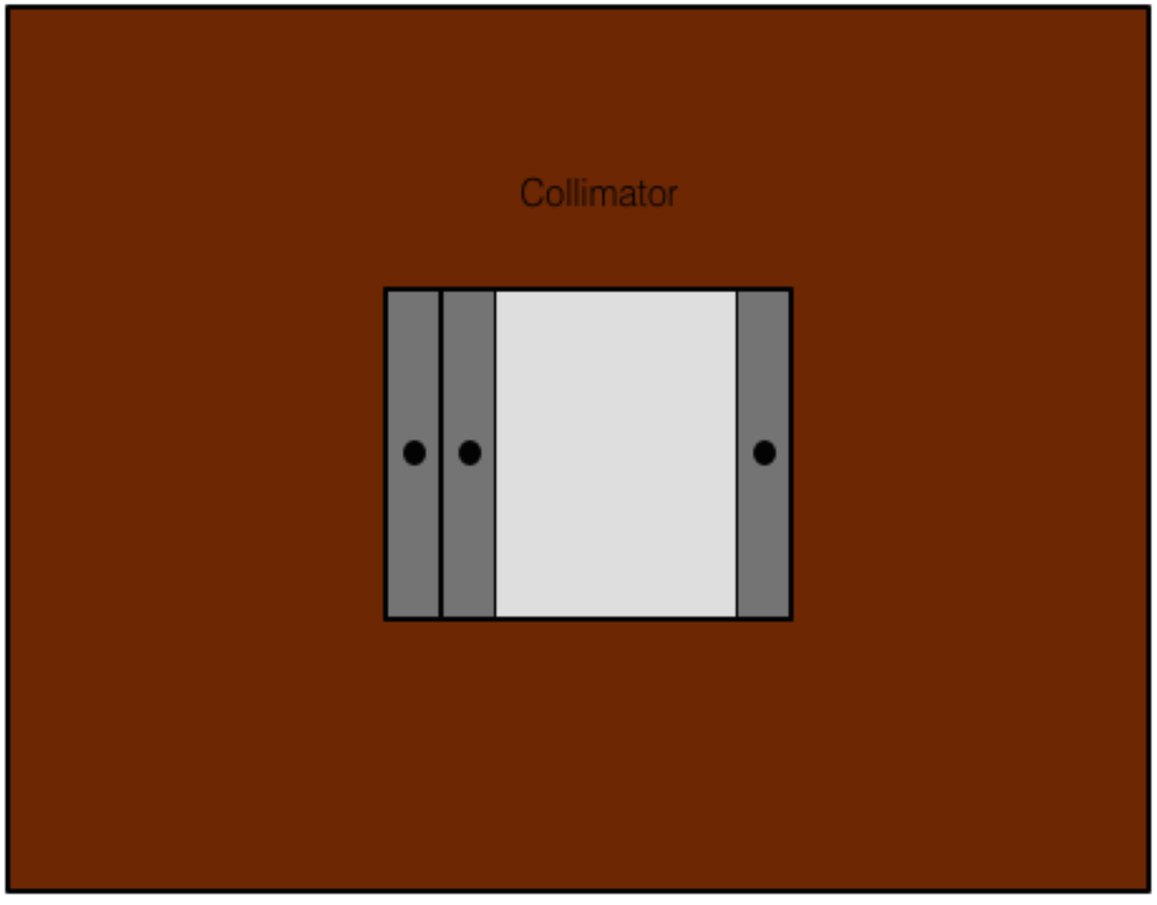
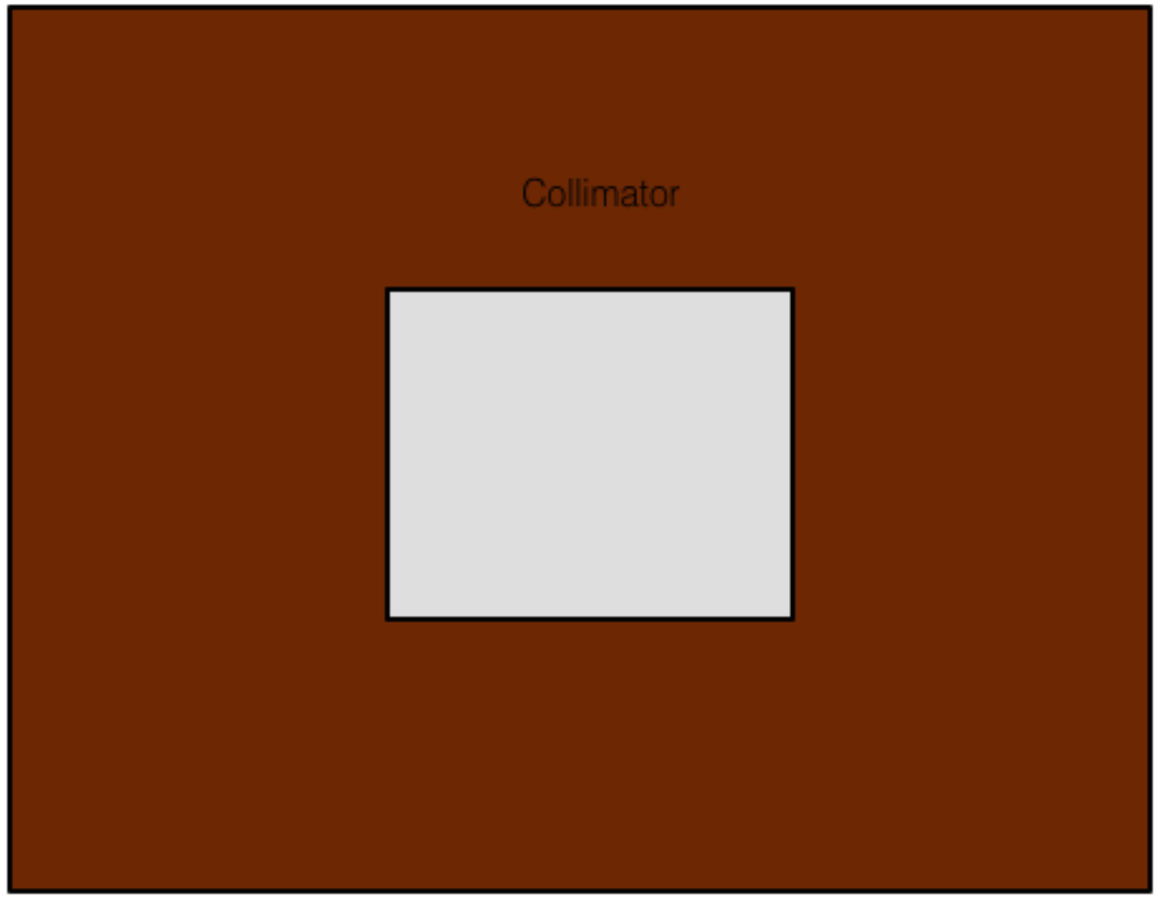
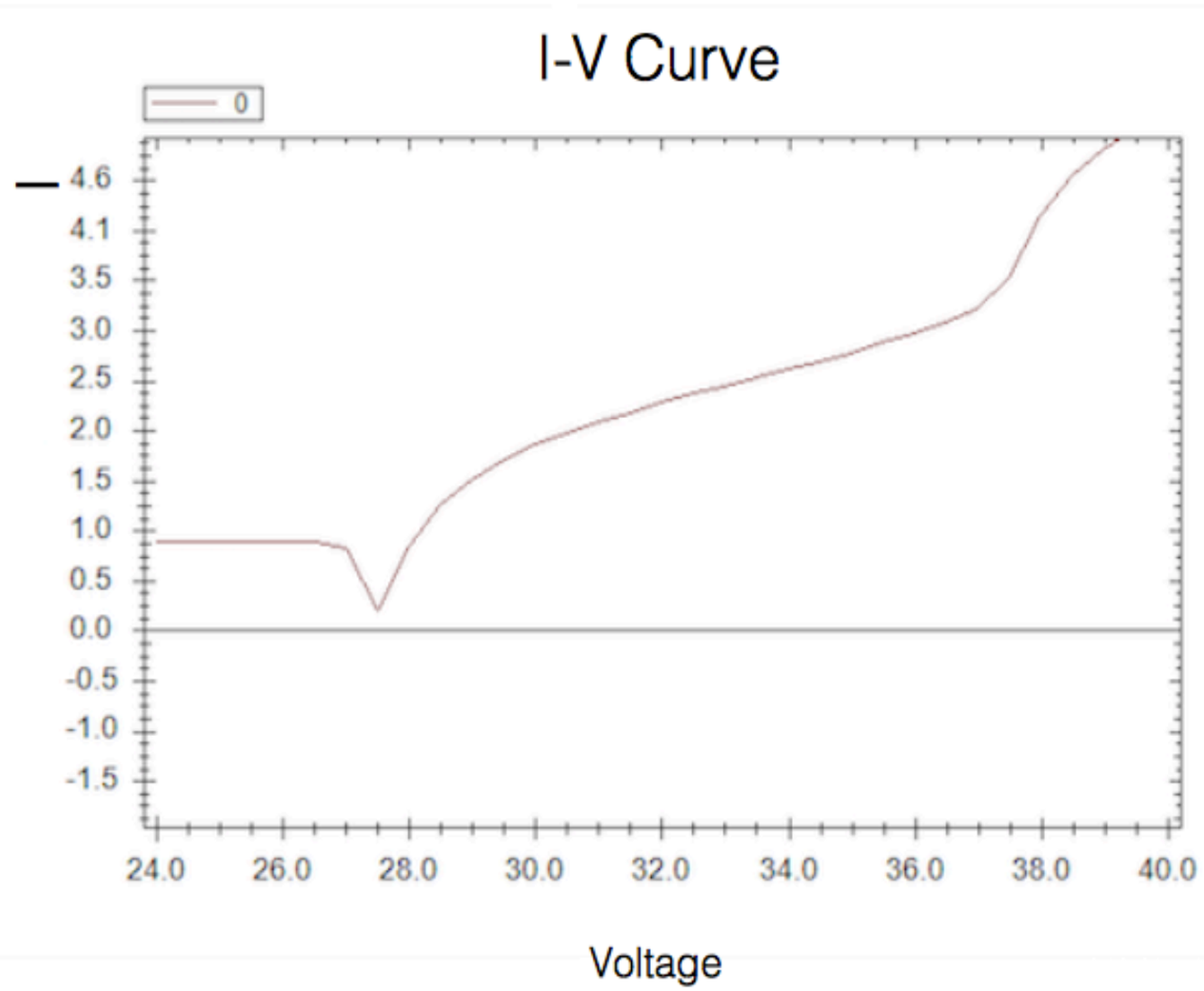
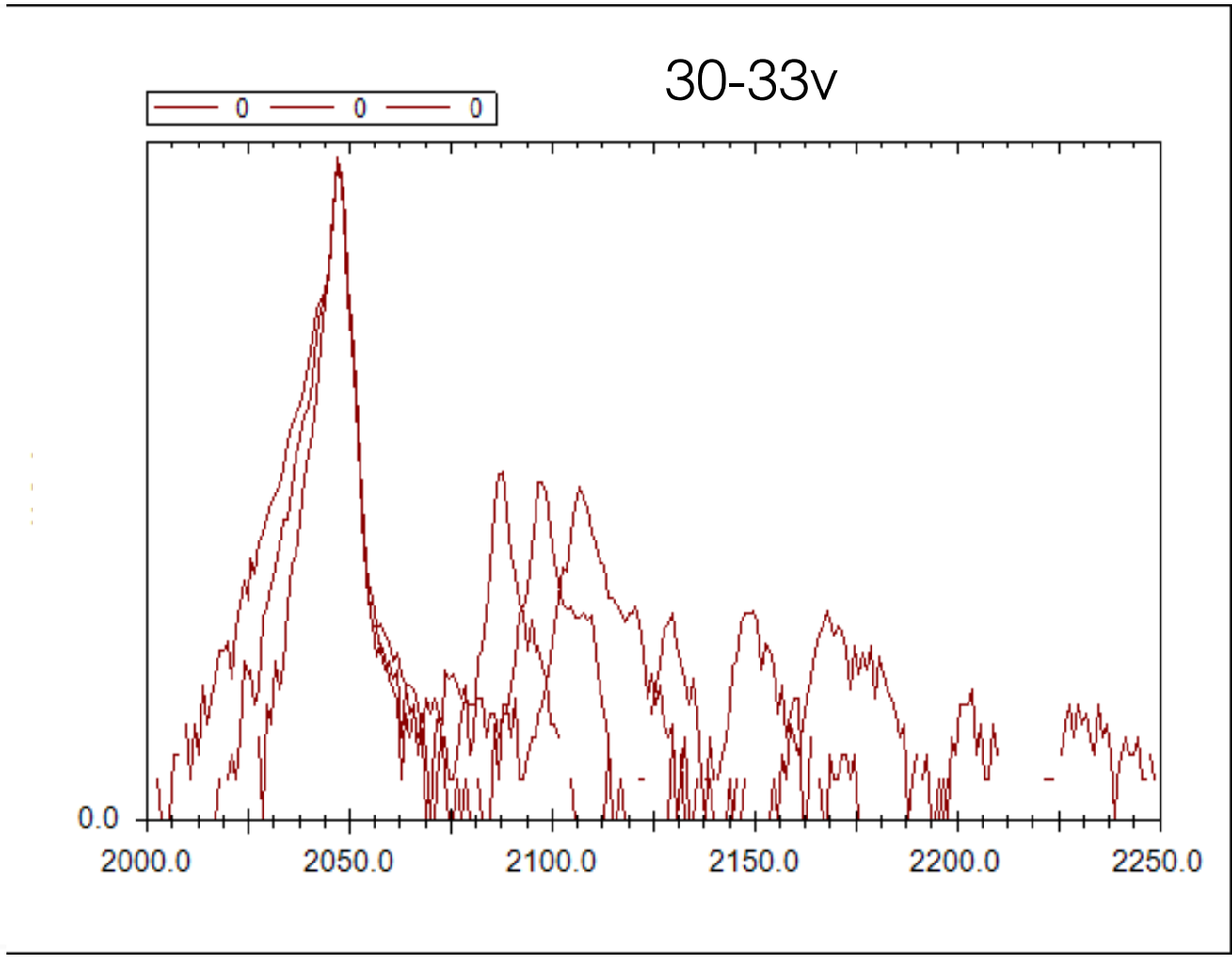

Collimator

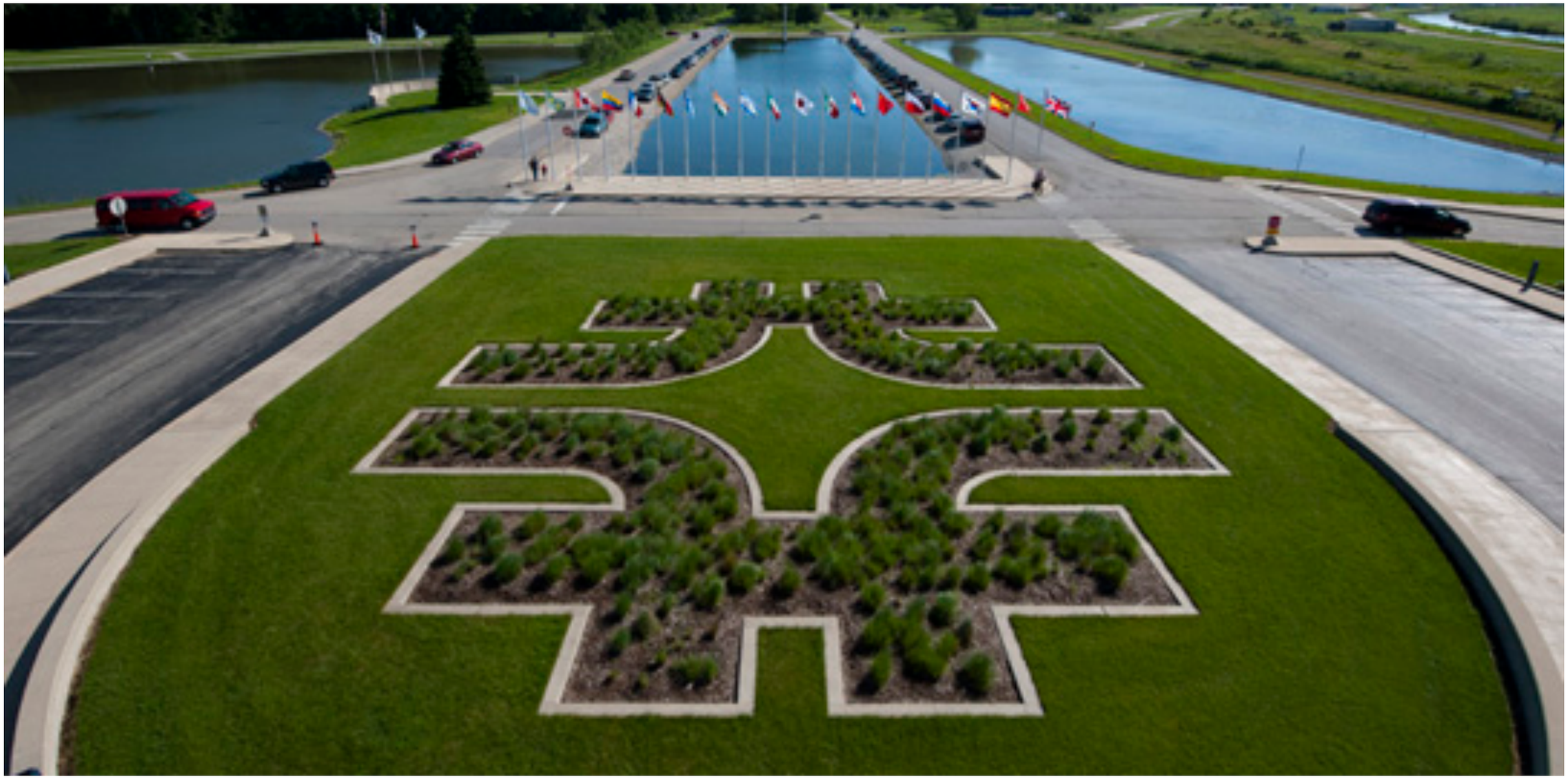

Collimator

Studies with SensL Silicon photomultiplier (SiPM) – 35 - 50μm microcells

- Compact!
- Inexpensive!
- Insensitive to magnetic field !
- Low operating voltage





ACKOWLEDGEMENTS

I would like to thank Jennifer Raaff, Will Flanagan, Dung Phan, Flavio Cavanna,Karol Lang, and the LArIAT collaboration for there time and guidance this summer, and the SIST committee for providing me with the opportunity to continue my research at Fermilab.