12 GeV Upgrade
Future Science at Jefferson Lab

EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

December 2-3, 2016

Overview

1. Cosmic test of GEM+SPD continued at UVa up to end of September. No analysis so far due to GEM tracking code not available (yet).
2. Test of the radiated Preshower is going well (two undergrads working on this). Some preliminary results.
3. Main progress is on the beam test of all detectors: FASPD, LASPD, 3x Preshower, 3x shashlyk (2 from SDU, 1 from THU)
4. LHCb will dismount their preshower in 2019, (this past week) asked us if we are interested.
5. UVa postdoc is leaving in < 1 month
6. I have submitted my DOE renewal and included ½ postdoc as part of the pre R&D request, but did not include equipment/material/prototyping cost.
7. We need to resume discussion on the support structure (Vic moved from U Chicago back to ANL), but have not started regular meeting yet.

Preshower Tile Radiation Hardness

- 8 preshower tiles were placed around Hall A during the spring 2016 run, generally near ion chambers (yellow tube).
- Preshower tiles are from CNCS and Kedi, and previously tested in 2015.
- Each tile was wrapped in tyvek and black tedlar and contained two fibers with 2.5 turns each.
- Radiation hardness website

Irradiated Preshower preliminary results

1. Students: Margaret Doyle, Sam Blum
2. Optical grease is from 2014, expired. We tested the preshower “as is”, after replacing grease, and now are testing them after replacing the fiber. All NPE lower than before radiation but could be partly due to mechanical (not radiational) damage to fiber

Tile #	location in Hall A	Before Radiation	Radiation Dose	With Old Grease “as is”	After replacing grease
Kedi 1	Beam Right lumis	87.1	161-164 kRad	56.6	42.5-56.3*
Kedi 2	Upstream of scattering chamber	85.4	185-189 kRad	57.6 (fiber had a kink)	67.3
Kedi 3	Beamline grider	87	31-38 kRad	66	59*
Kedi 4	Compton chicane	91	9-17 kRad	55(?)*-74 (fiber broken)	63.3*
CNCS 1	beam left lumis	83.4	156-172 kRad	56.2	45.2-47.1
CNCS 2	Beam Right scattering chamber	84.7	43-53 kRad	61.6	71
CNCS 3	Beam Left scattering chamber	81.8	20-24 kRad	62.5	69.3
CNCS 4	Hall A dump	83.4	230-286 kRad	41.2	47.2

* These measurements used a different PMT, with a loose wire connection on the voltage divider and results may not be reliable. This PMT is now removed to ensure our final test (with fresh grease and fiber is reliable.

More background information

1. LHCb tracker upgrade (scifi tracker) reported irradiation test of fibers and 4 models to extend to higher doses. Light loss starts to be visible at 0.5kGy or 50krad, and drops by factor two at roughly 2-3kGy or 200-300krad. These are plastic fibers where radiation damage affects mostly the clarity (attentuation length) and the scintillating efficiency and the two are similar. Thus damage is expected to be more visible for longer fibers. For WLS fibers, there can be additional damage to the WLS dye/fluor that is not applicable to the LHCb scifi tracker.
2. Radiation dose expected for SoLID (see ECal meeting minutes from 3/26/14, maybe outdated), and the run duration corresponding to 200krad dose: SPD 2krad/month (100 months); Preshower 10krad/month (PVDIS?, 20months); Shashlyk 2krad/month (PVDIS?, 100 months).

Beam Tests in Hall A, Fall 2016 run period

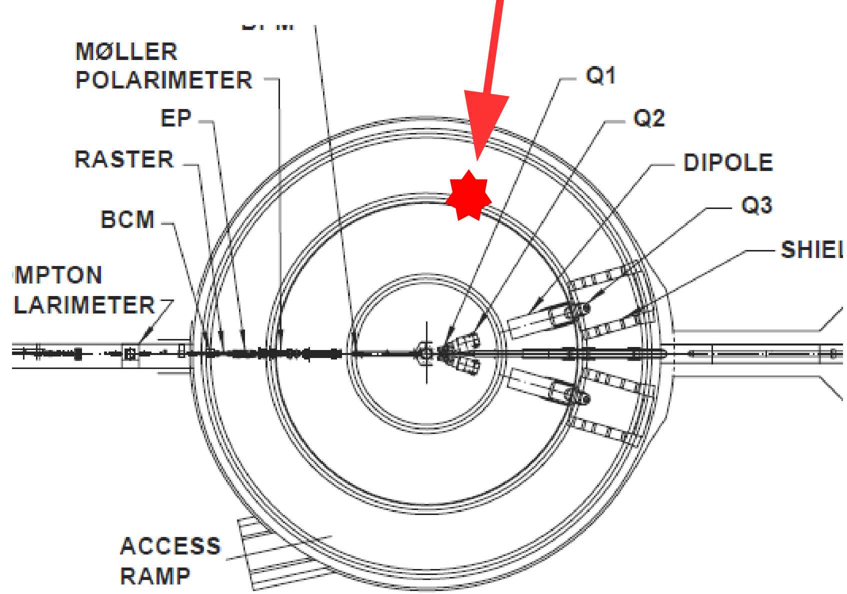
Work done by Ye Tian (SDU), Vince Sulkosky, with help from Mark Jones and Alexandre Camsonne

Detector package platform (same height as beamline)

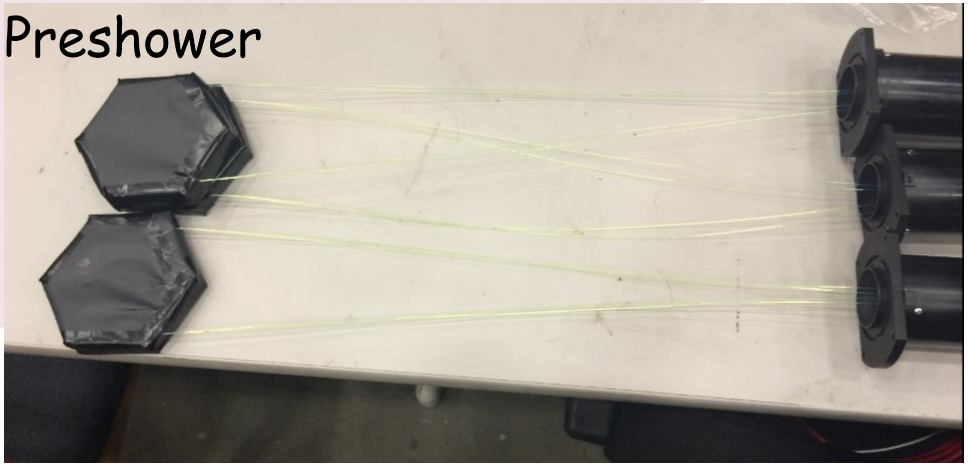
Electronics

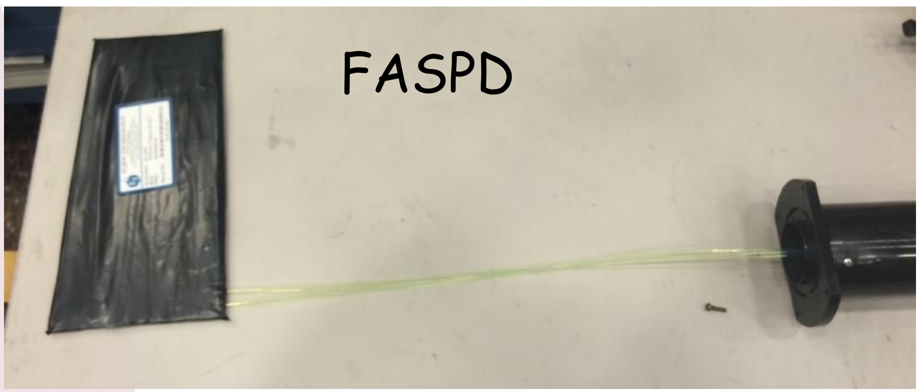
shielding

at about 76 deg

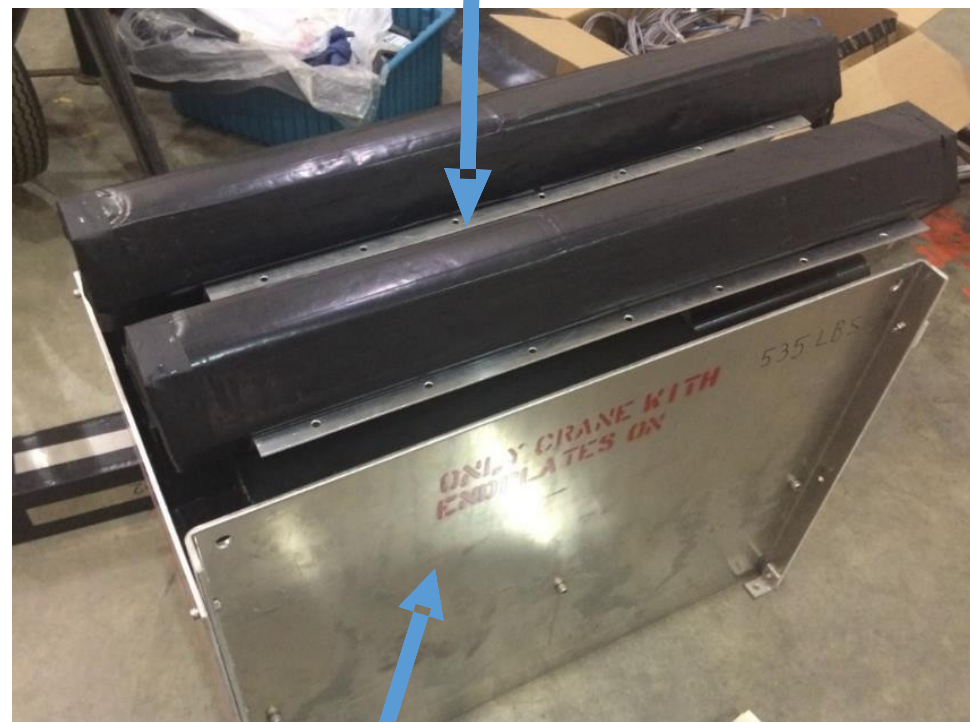


Beam test – detector preparation





shashlyk modules



9x SBS calo modules (square shape)

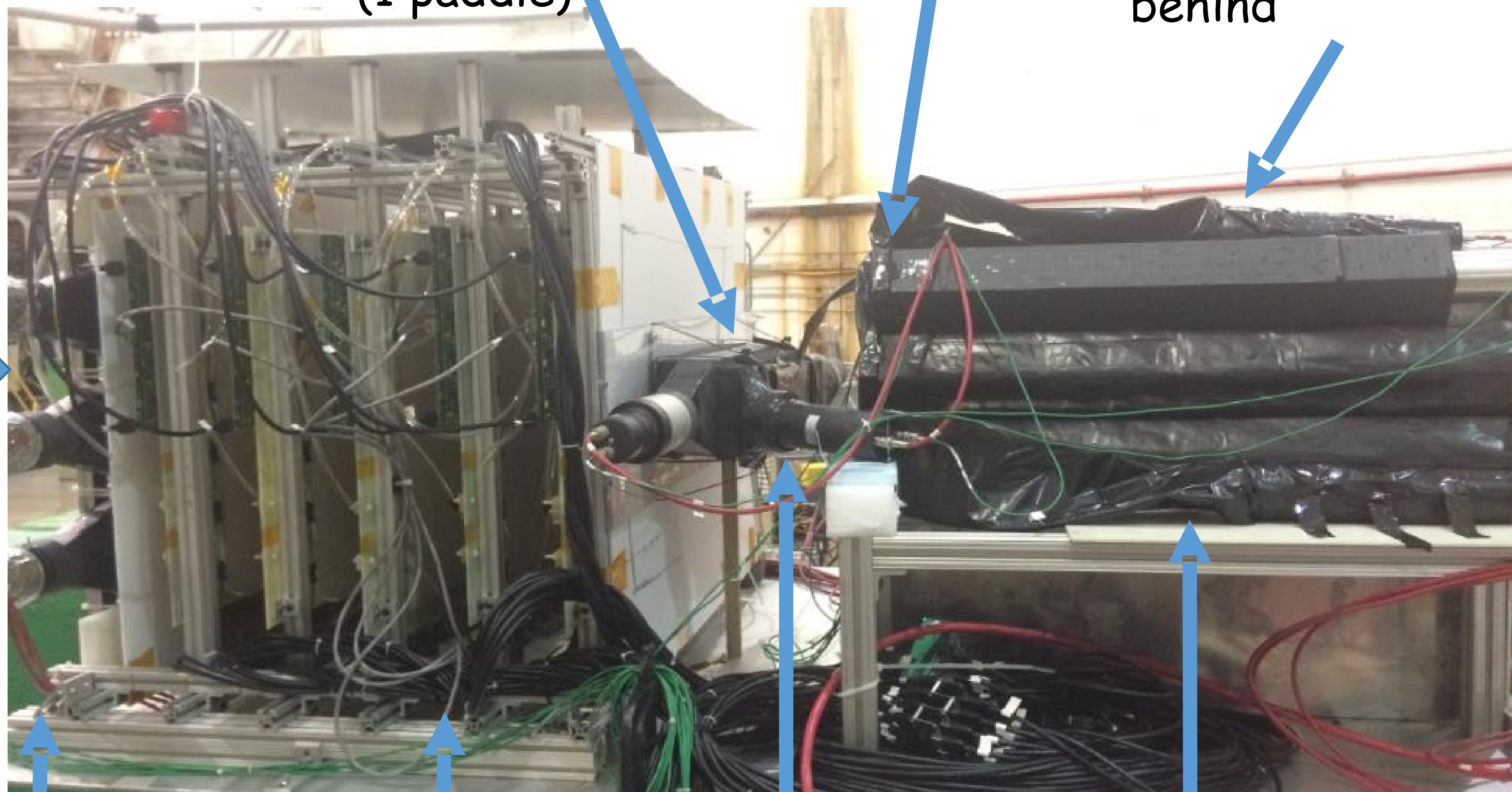
Beam test – detector arrangement

back trigger scintillator (1 paddle)

3x preshower

SBS calorimeters are behind

particles



front trigger scintillators (3 paddles)

5 GEM layers

FASPD
LASPD

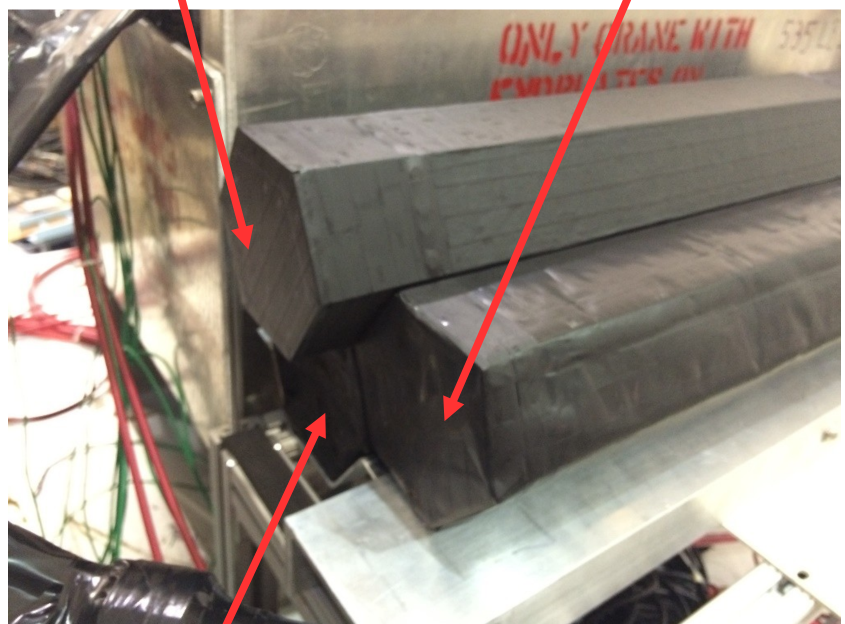
3x shashlyk

Rearrange the setup of SoLID detectors on Thursday 10/27

both FASPD and LASPD are now in front of the shashlyk cluster

THU (fiber sticking out in the front)

SDU#1

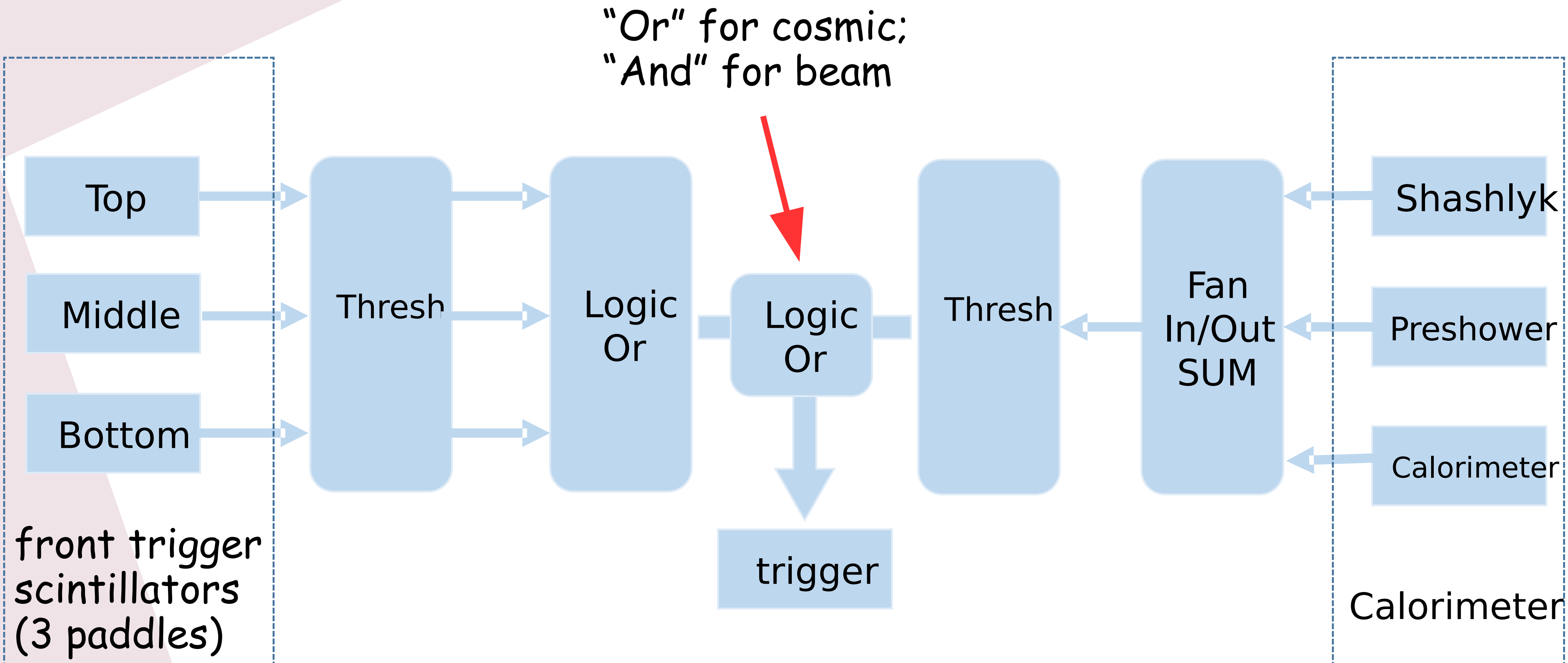


5cm gap between all preshower and shashlyks due to the 5cm longer length of the THU module

SDU#2 (closer to center of triggering scintillators)

Beam test – trigger setup

Trigger setup was changed many times, but roughly is like this:



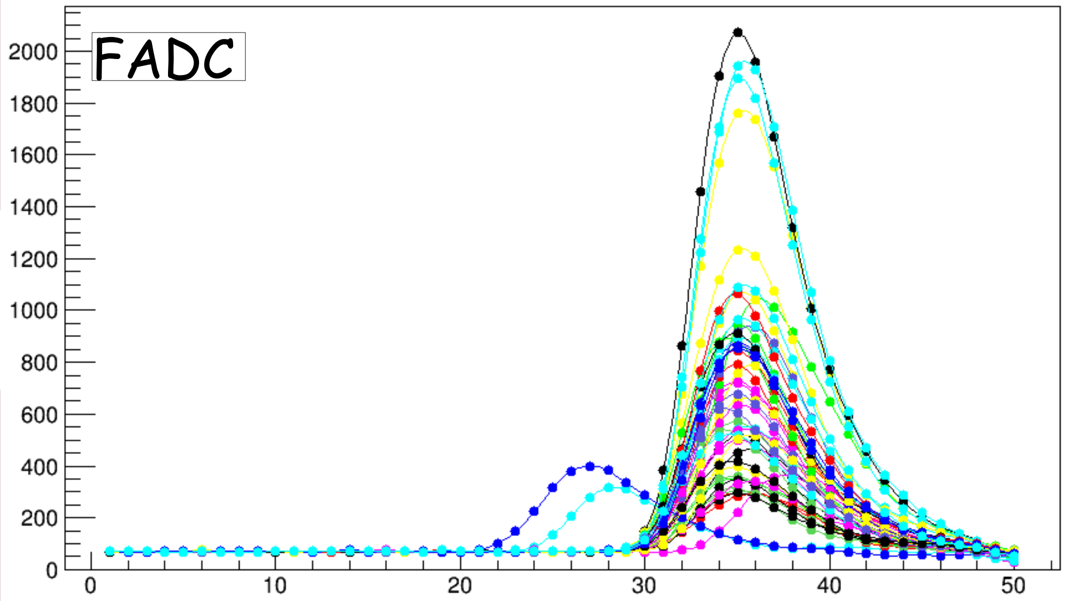
All SoLID detectors in FADC, TDC, and scalers

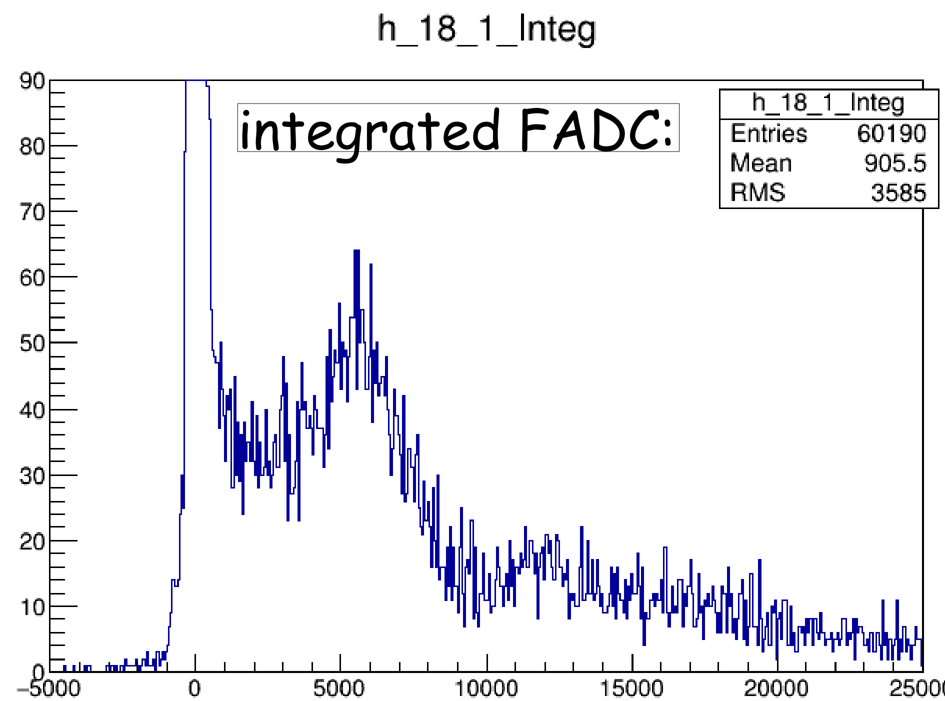
We spent more than a month to adjust HV, trigger setup, setup and debug electronics.

Beam test - Some Spectra

SBS calorimeter

plot dated 11/3



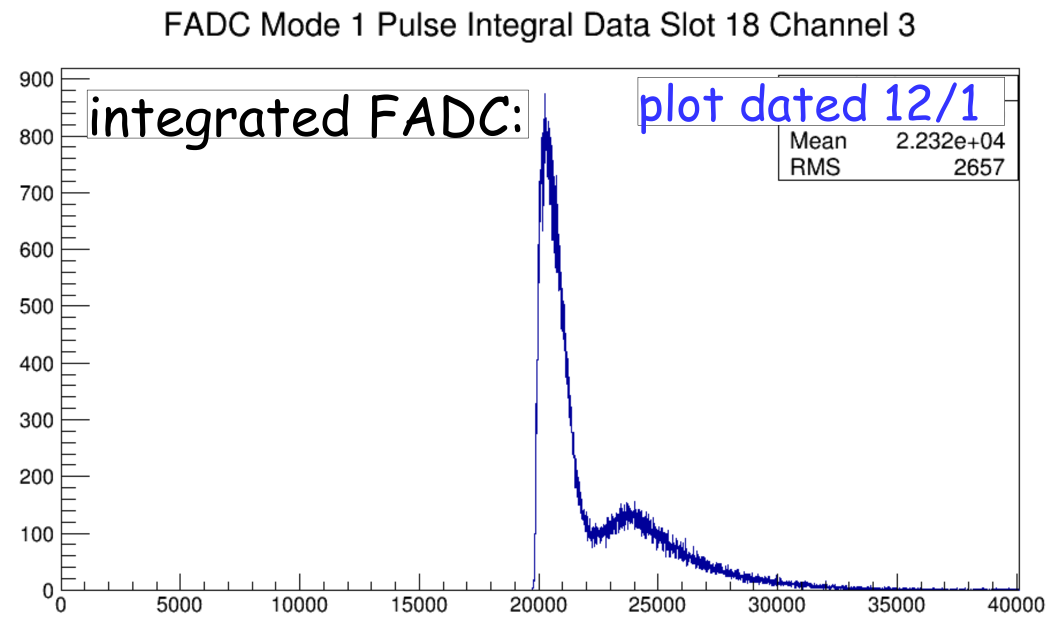


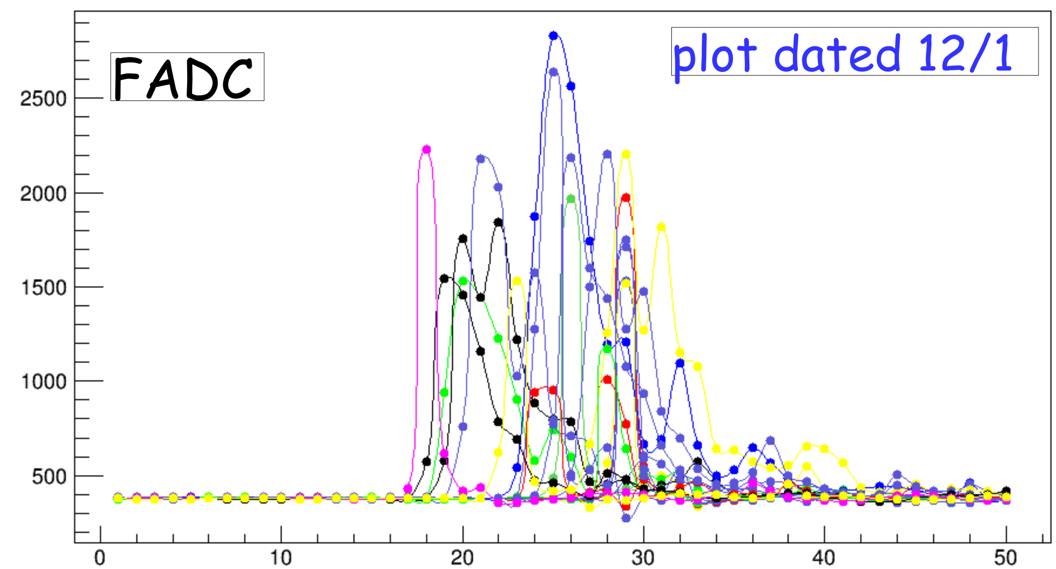
Beam test – Single trigger tests to check HV

"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)

THU shashlyk module

Pedestal is about 19000
Counting rate 300* 2(prescale)

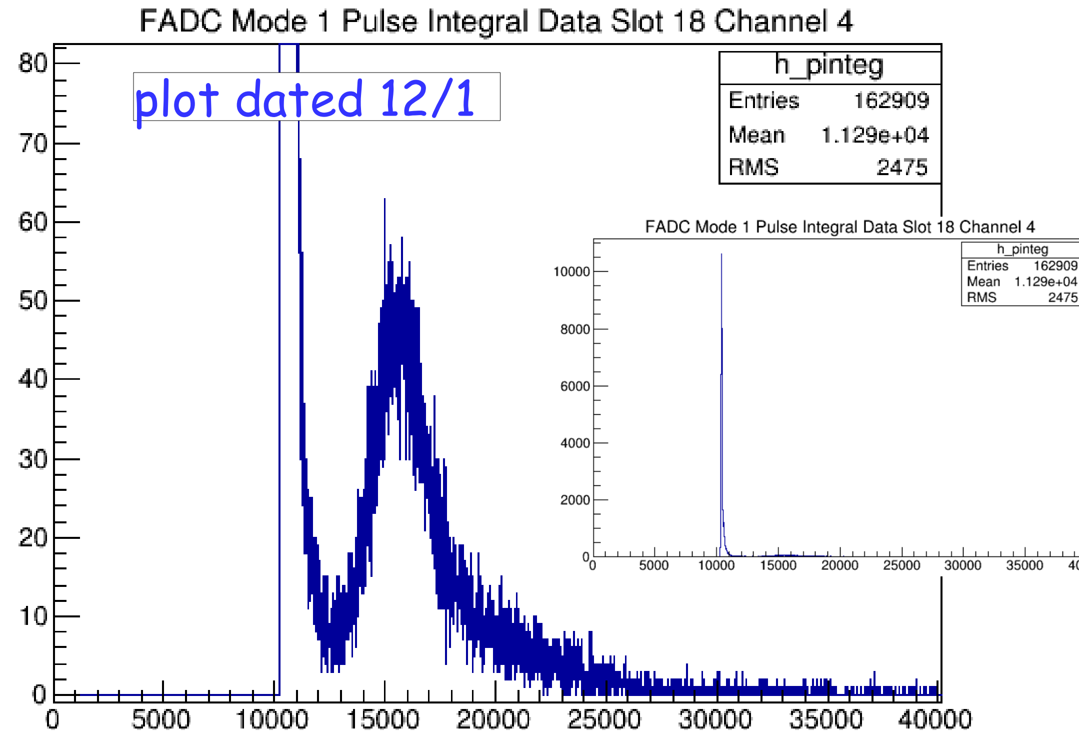


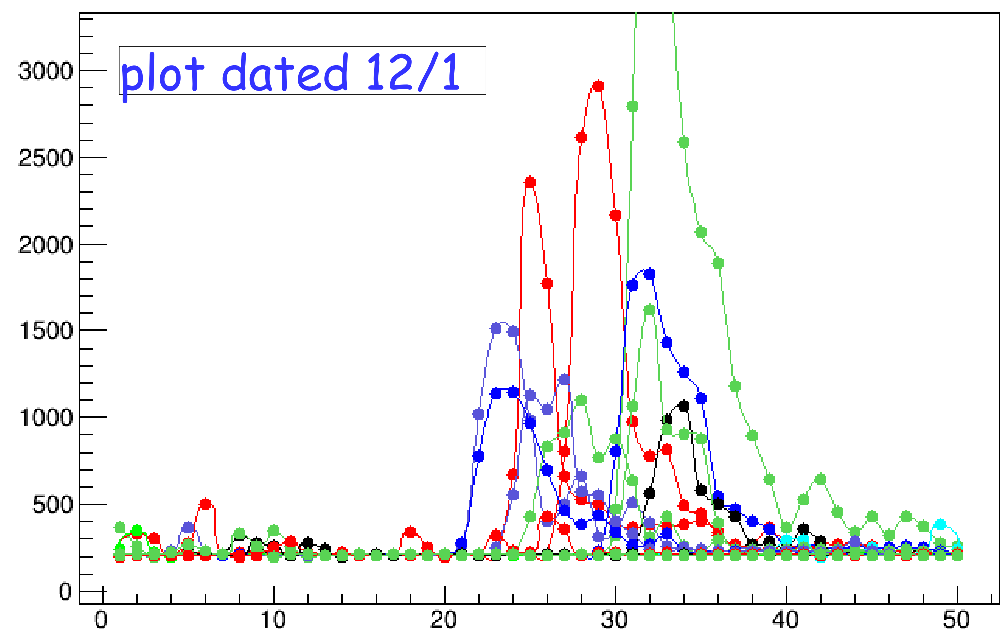


Preshower in front of the THU shashlyk module (CNCS#5)

"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)

Cannot see the single p.e. peak, may be able to use PMT gain to estimate Npe

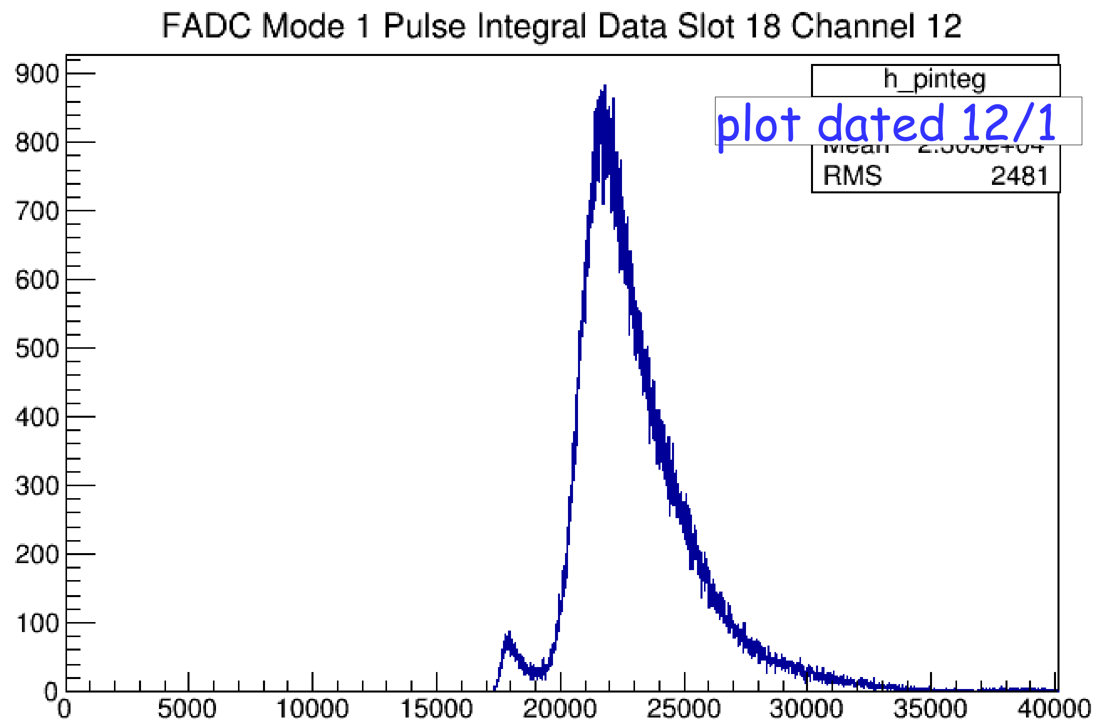


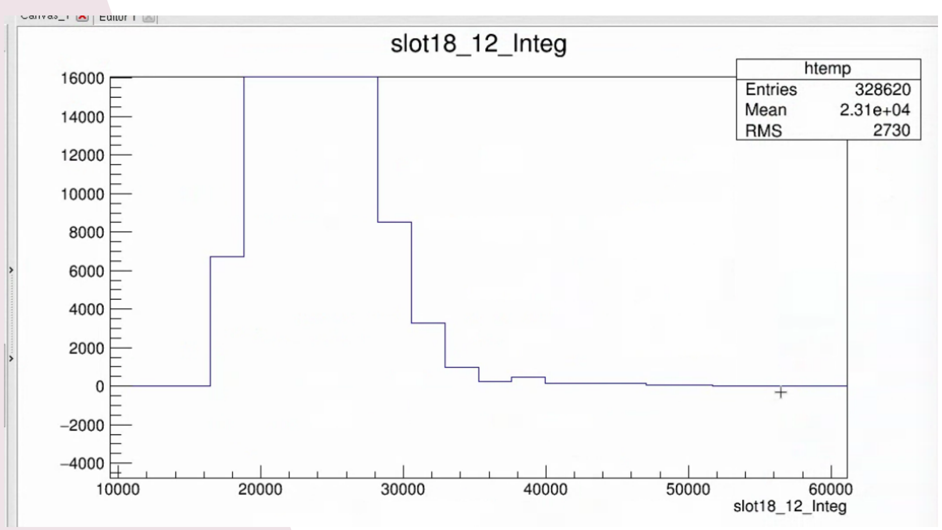


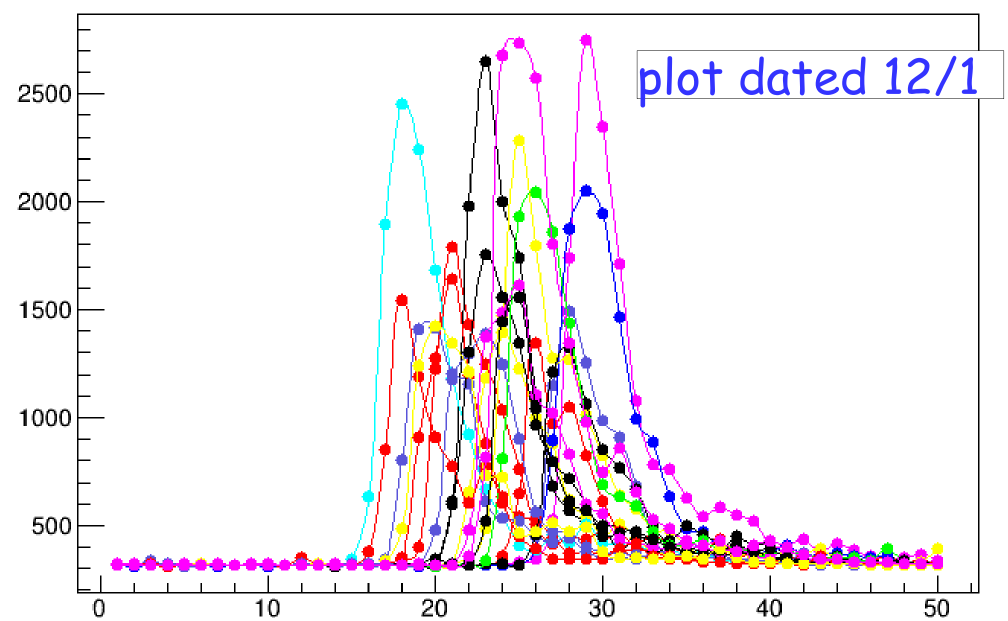
SDU1 shashlyk module

"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)

- Pedestal 15800
- Counting rate 50*2(prescale)

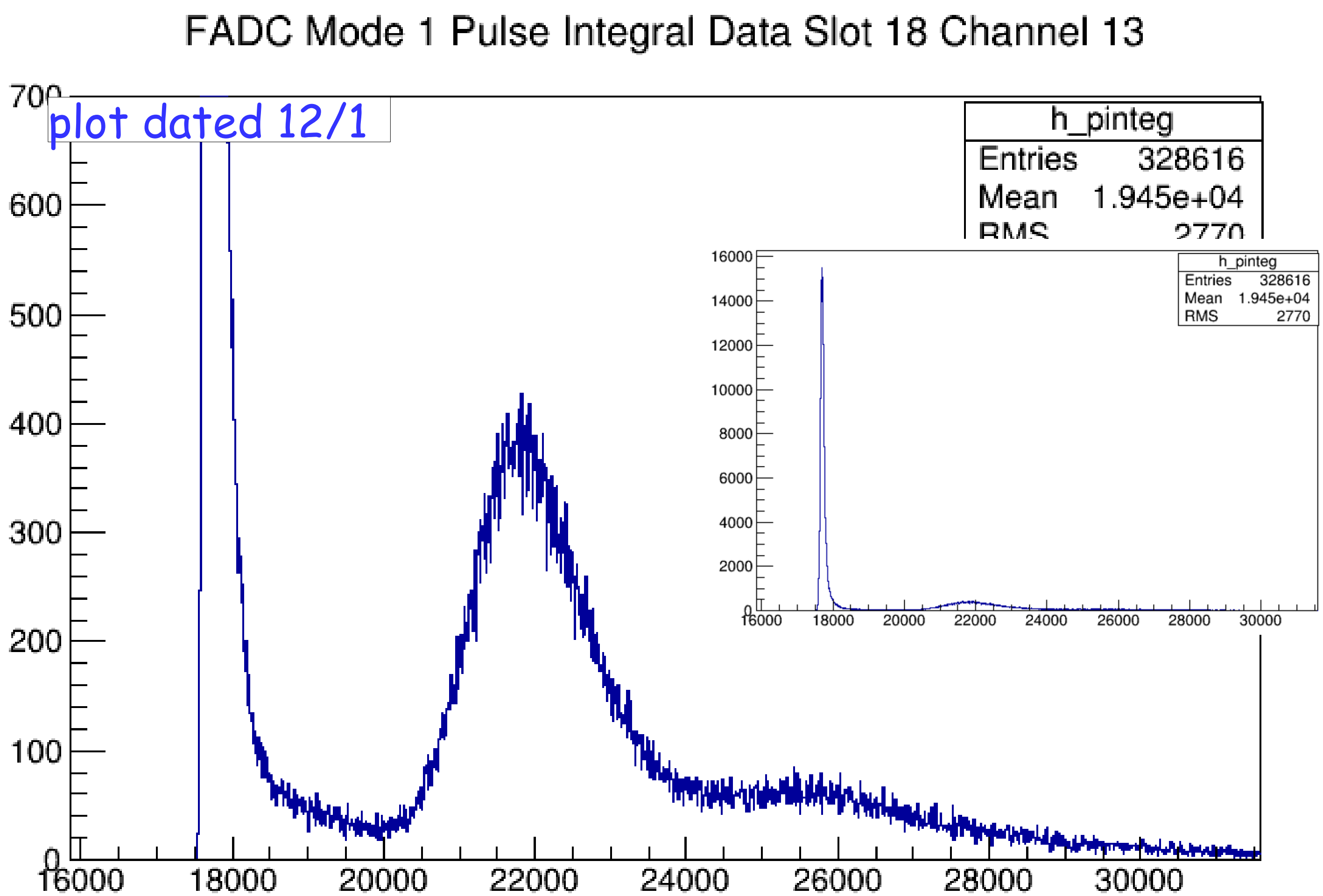






Preshower in front of the SDU1 shashlyk module (CNCS#6)

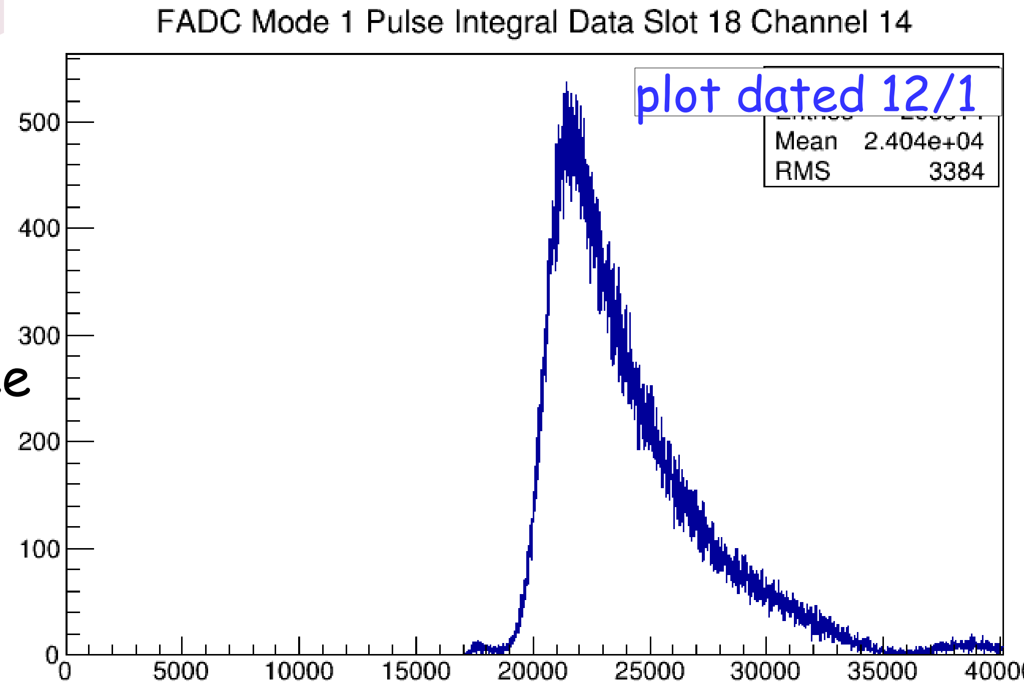
"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)

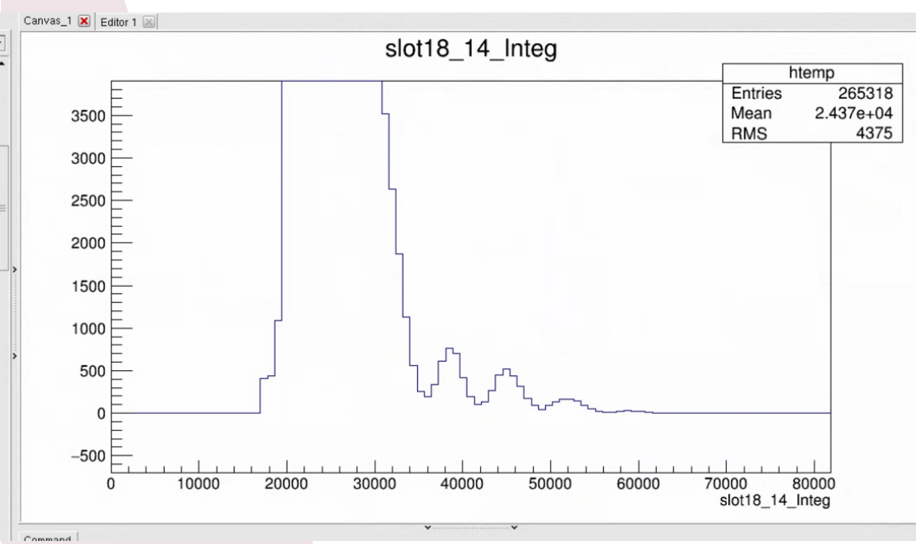


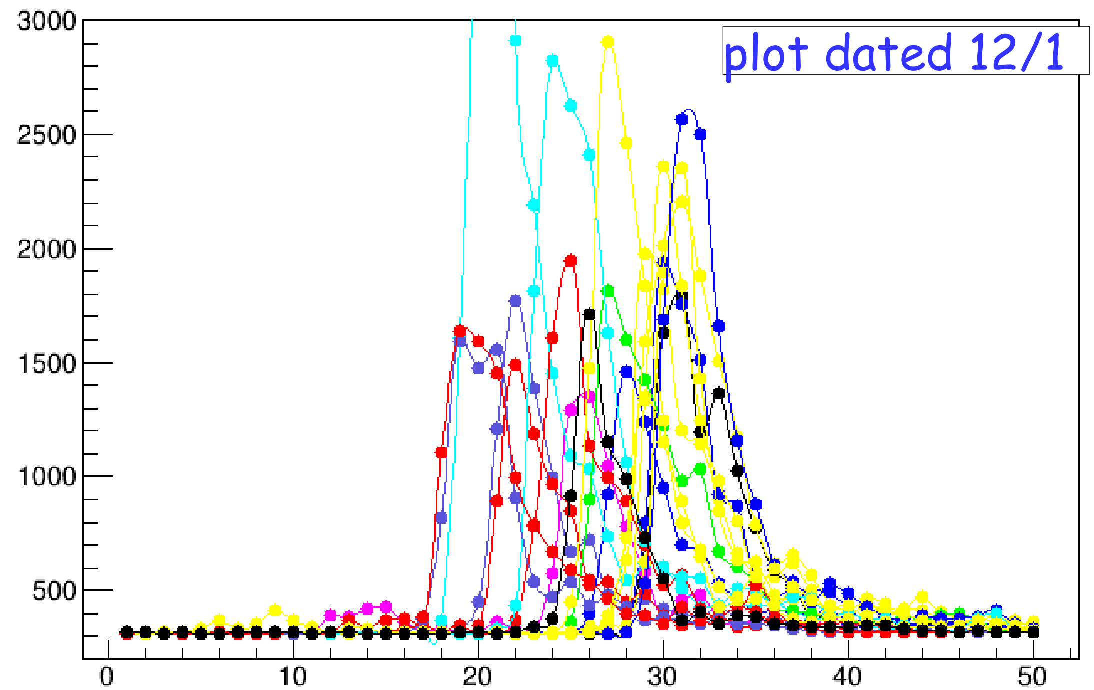
SDU2 shashlyk module

"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)

- Pedestal 15800
- Counting rate 170* 2(prescale)

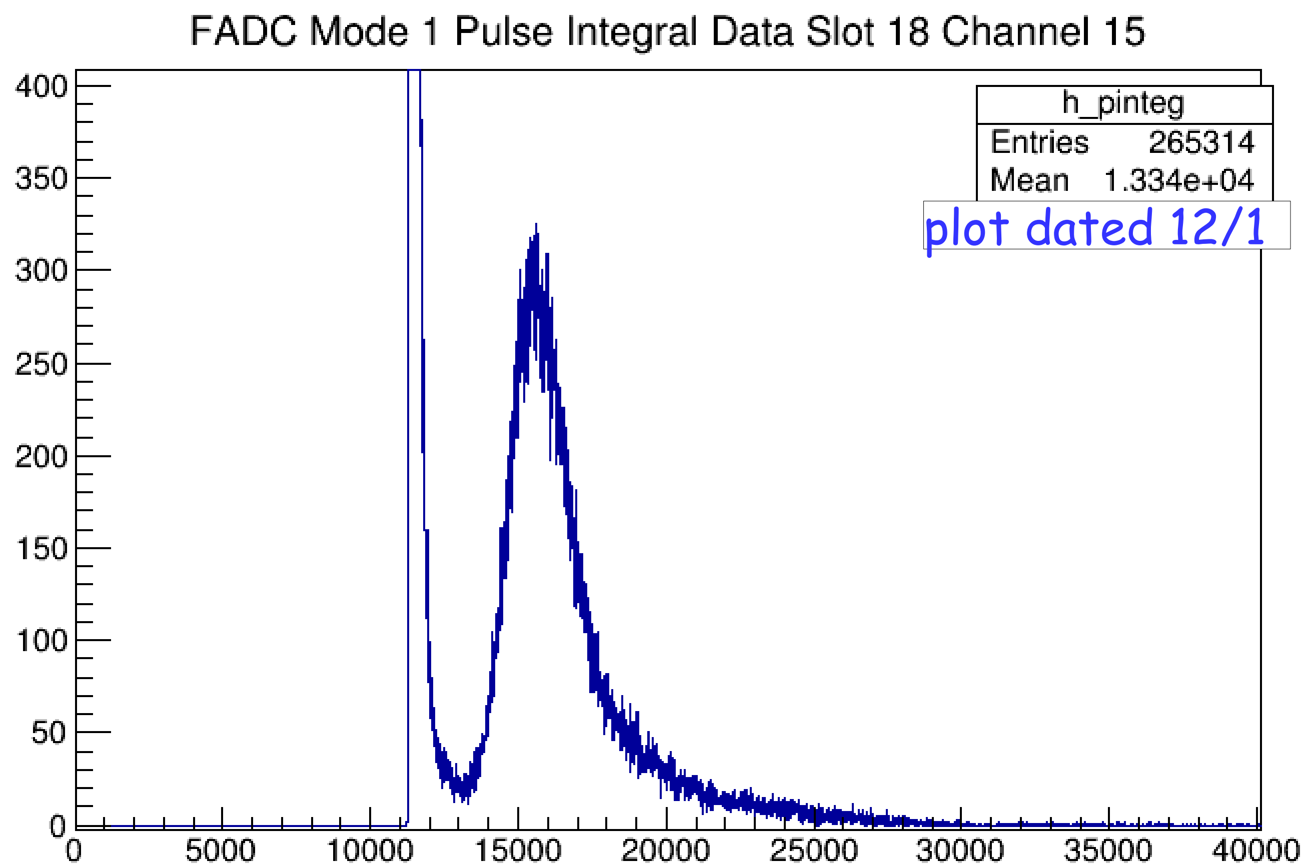






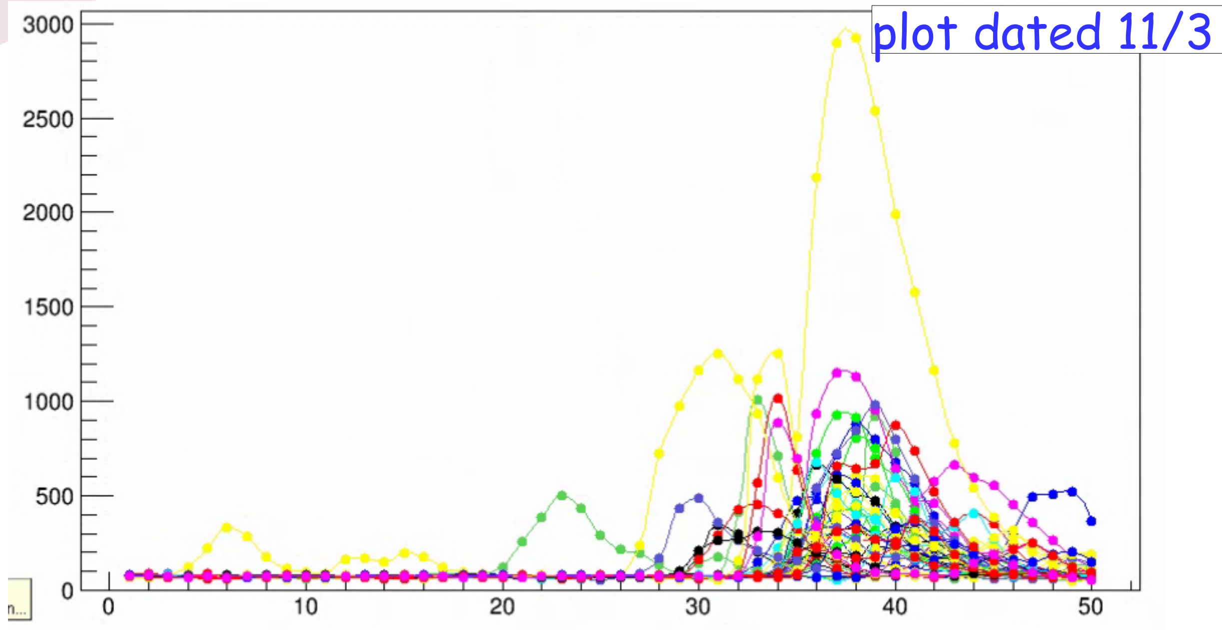
Preshower in front of the SDU2 shashlyk module (Kedi#6)

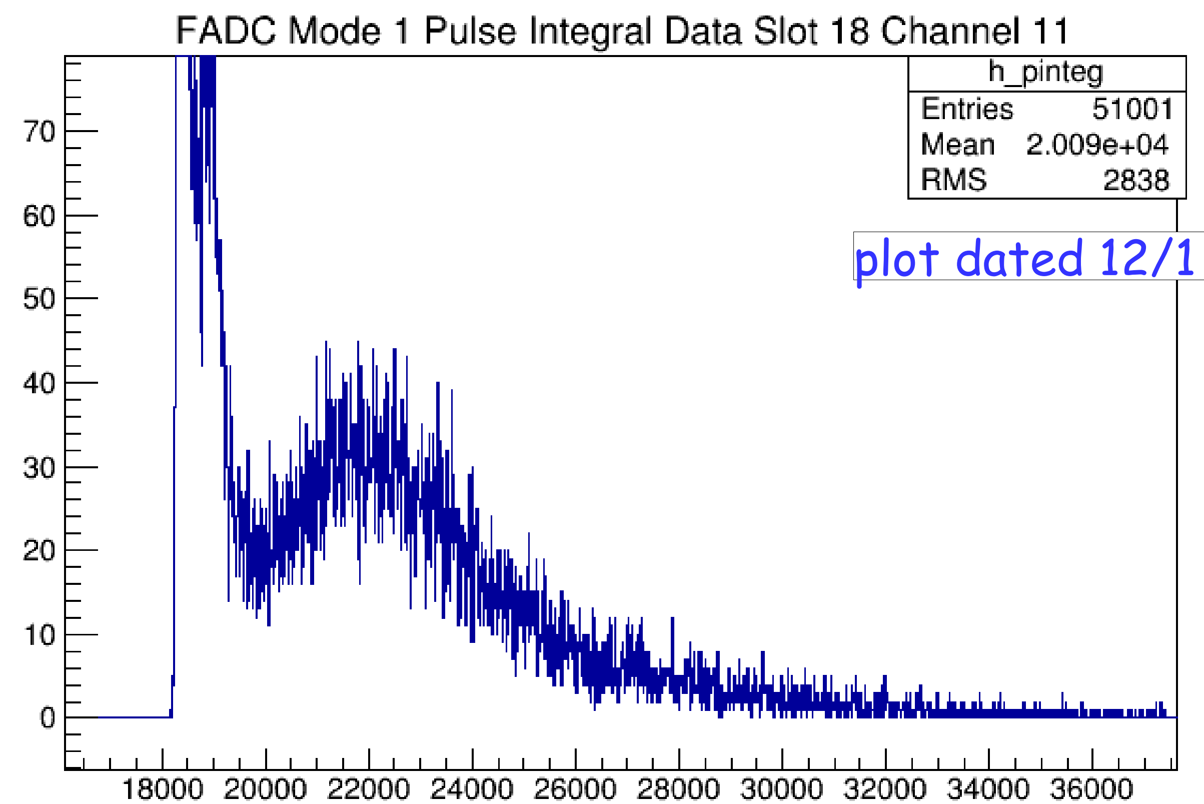
"Single-trigger" test: These plots were made with only one shashlyk module as trigger. All other calo block's HVs were off (so will not see pedestal here)



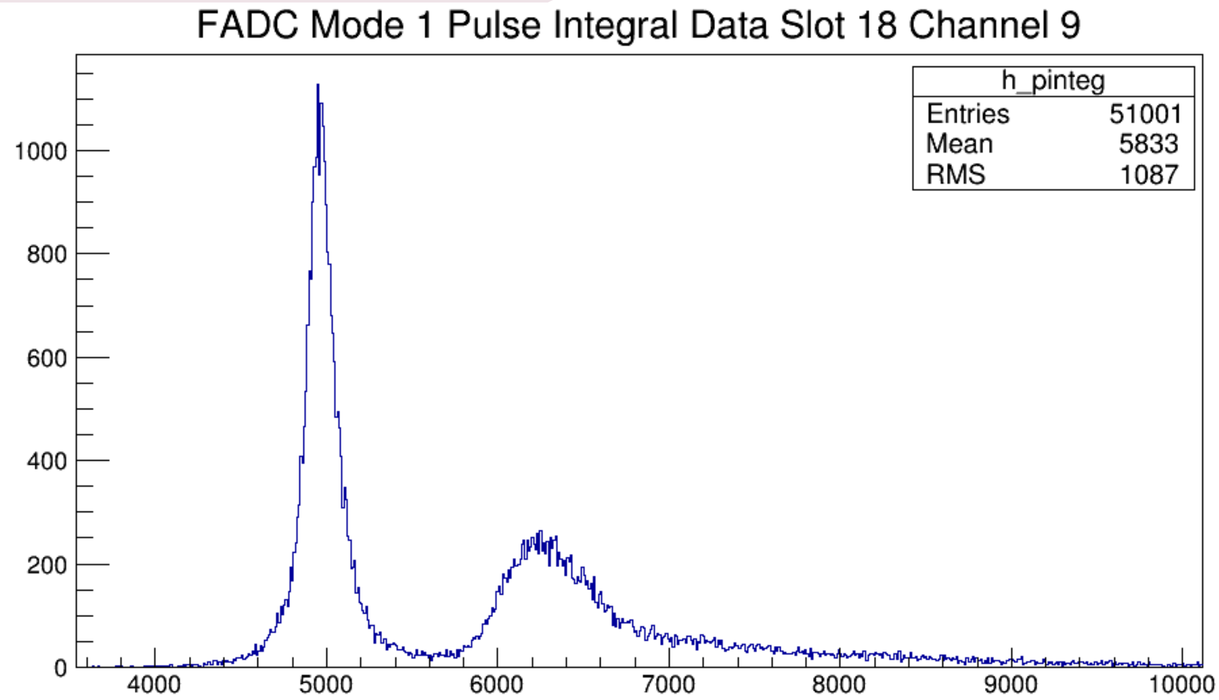
FASPD

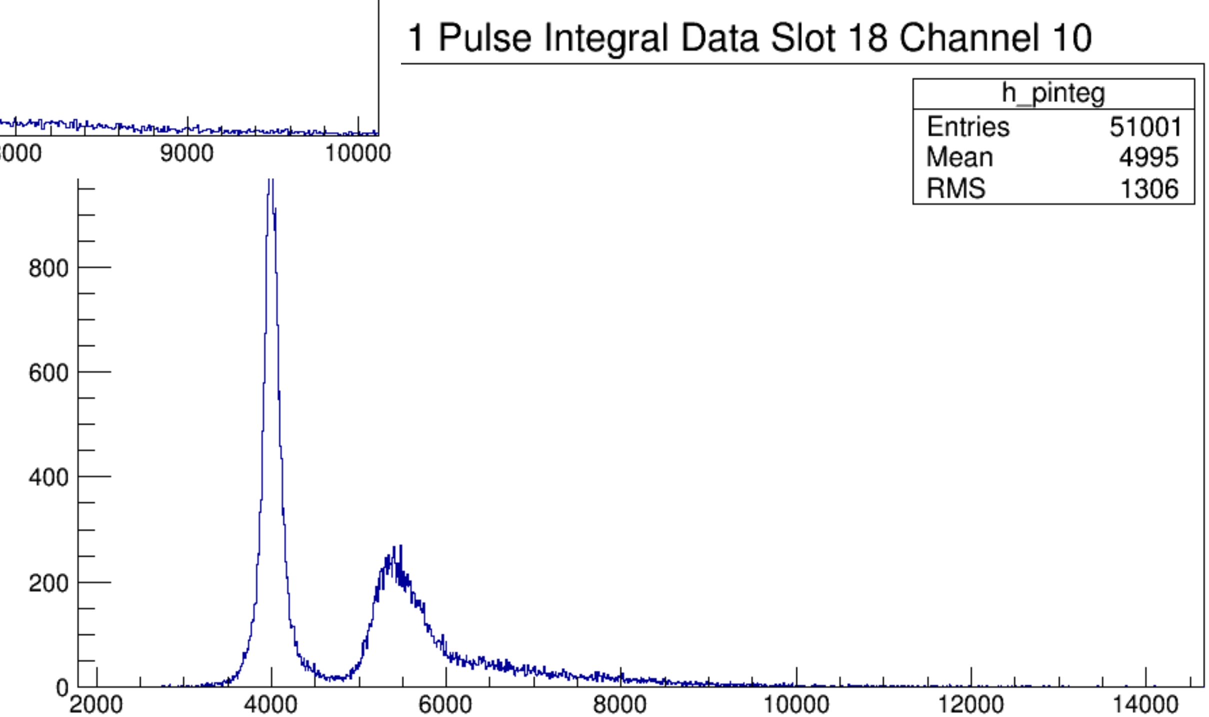
We seem to get Npe~(6.5-7), using 2 fibers now, compare to Npe~(9-11) from UVa test in 2015 with 1 fiber





LASPD left and right PMT





To-Do List

1. Finish irradiated preshower test
2. Beam test seems to be in working shape. Keep collecting data. Need to integrate GEM decoder in the analyzer. Need to keep a detailed run list for future analysis.
3. Beam test analysis may be difficult due to lack of manpower. Main questions to be answered:
   a) What are the p.e. yield of all detectors? (Only FASPD shows single p.e. peak, others need to know PMT gain)
   b) What is the p.e. yield uniformity for FASPD?
   c) What is the timing resolution of LASPD, with GEM tracking information?
   d) Can we combine SPD info with Preshower and Shashlyk, and try to identify MIP and electron peaks in the shashlyk? What is the light yield and what could be the energy resolution?
   e) What other important information we can learn from the beam test and how should we do it? Move the plat form to smaller angle?
4. Chinese groups will continue constructing and improving their prototypes.
5. Do we want some of the LHCb preshowers?

Address Recommendations from Director's Review

Slides copied from August 2016 meeting, no update since

August 2016 slides were based on May 2015 report, with updates

Address Recommendations from Director's Review

Observations: Other experiments have extensive expertise with scintillating fibers and SiPMs in harsh radiation environments, like LHCb.

Recommendations:
The calorimeter group is encouraged to contact other groups (ALICE, LHCb and possibly CMS) to understand the detector design choices these groups have made and resources needed for construction.

Lorenzo's simulation showed neutron background at the location of LASPD readout to be between 6E12 and 1E+13n/cm^2. The simulated condition was 3He target, 15uA, 3000 hours. Lorenzo suggested a factor of 3 buffer

The most relevant info on SiPM is from LHCb tracker upgrade. In summary:

- They need to run at -40C for the SiPM to last the whole duration, at a neutron background of close to 1E12/cm2. So if SoLID is 2E12 neq/cm2, cooling to -50C might work, 4E12-> -60C might work, 8E12-> -70C, 1.6E13 -> -80C, etc. Note that the detector unit must be designed to increase the temperature to 40C for slow annealing or 80C for fast annealing.

- CMS (talked to Brad Cox): CMS calorimeter upgrade will use W (inactive) +LSO (active), very small size (the module is about the size of a finger). The advantage of the small size is the small attenuation in the optical elements, so with radiation damage the damage in the signal is not severe. For readout, the background next to the calo is about 1E14-E15 but the SiPM is located far away, "get down to about 1E12".

- Hall D and EIC experience are all orders of magnitude lower.

Address Recommendations from Director's Review

Findings

• The plan to rely on an outside international laboratory to produce EM calorimeter modules seems risky, considering difficulties with communication observed so far.

Recommendations:

The calorimeter group is encouraged to contact other groups (ALICE, LHCb and possibly CMS) to understand the detector design choices these groups have made and resources needed for construction.

– Prof. Onel from U. of Iowa – supporting emails

– Tom Cormier ORNL (previously Wayne State U.) – phone call. WSU group's Ecal lab was discommissioned long time ago. Equipment loan is possible but they "need to find out who owns the equipment first".

– SDU and THU groups are in direct contact with Central China Normal University (CCNU) group, learning their experience with ALICE module assembly, compression, transportation and storage (no fiber insertion)

– SDU and THU groups have made great progress on module prototyping. Mass production in China possible.

Address Recommendations from Director's Review

2a Findings

• The simulations do not seem to include the support structures and inactive material.

Recommendations:

The collaboration is strongly encouraged to develop an end to-end realistic simulation and reconstruction to further optimize cost and physics reach and derive clear performance requirements for the individual subdetectors.

Answer: We can develop the full-scale simulation including nuts bolts rods and endcaps, but we need manpower – 0.5 postdoc.

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2a Findings
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Backups

Commission, Calibration, and Integration of EC

- Cosmic test, LED test – before beam – this should be good to 10-20%.
- A rough fit based on the fact that the energy deposit should be smooth function of R and should be repetitive in phi – with beam, fast, can be done with only EC running
- Using MIP at very low beam current – If set electron max at 1.5V, MIP peak (60MeV) should be seen at around 40mV with dE/E=20% or +/- 8mV. The FADC full scale is 2 V and 12 bit, so resolution is 2/4096=0.5mV which correspond to +/-16 bins, plenty for a clear identificiation (if we are not messed up by very low-E background) – with beam, not so fast, can be done with only EC running -- could be good to 2-5%;

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Commission, Calibration, and Integration of EC

(continued)

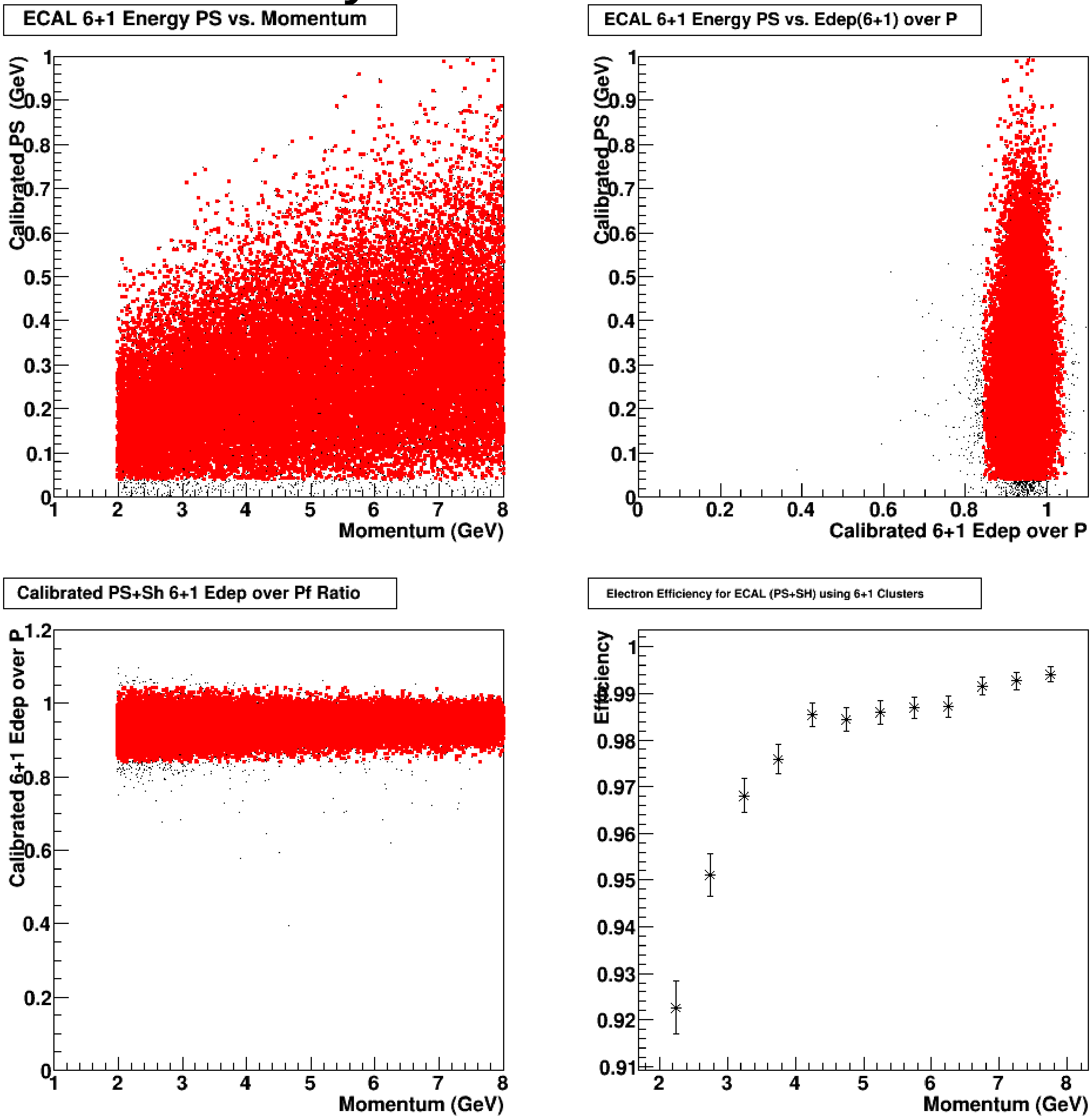
- Using elastic electrons at low beam energy – with beam, commissioning, slow, coverage in momentum and angle won't be large (probably can only use 2.2 GeV beam), precision will be high if done with tracking, can be done with only EC running but precision limited by the knowledge of scattering angle (EC position resolution divided by drift distance, also lack of vertex position);
- Using electrons with known tracking/momentum – with beam, commissioning, slow, must be done with GEM, high precision.
- pi0 reconstruction: need 2-cluster triggers – with beam, can be done with EC only, can be done continuously and non-intrusive, can potentially reach high precision.

Commissioning

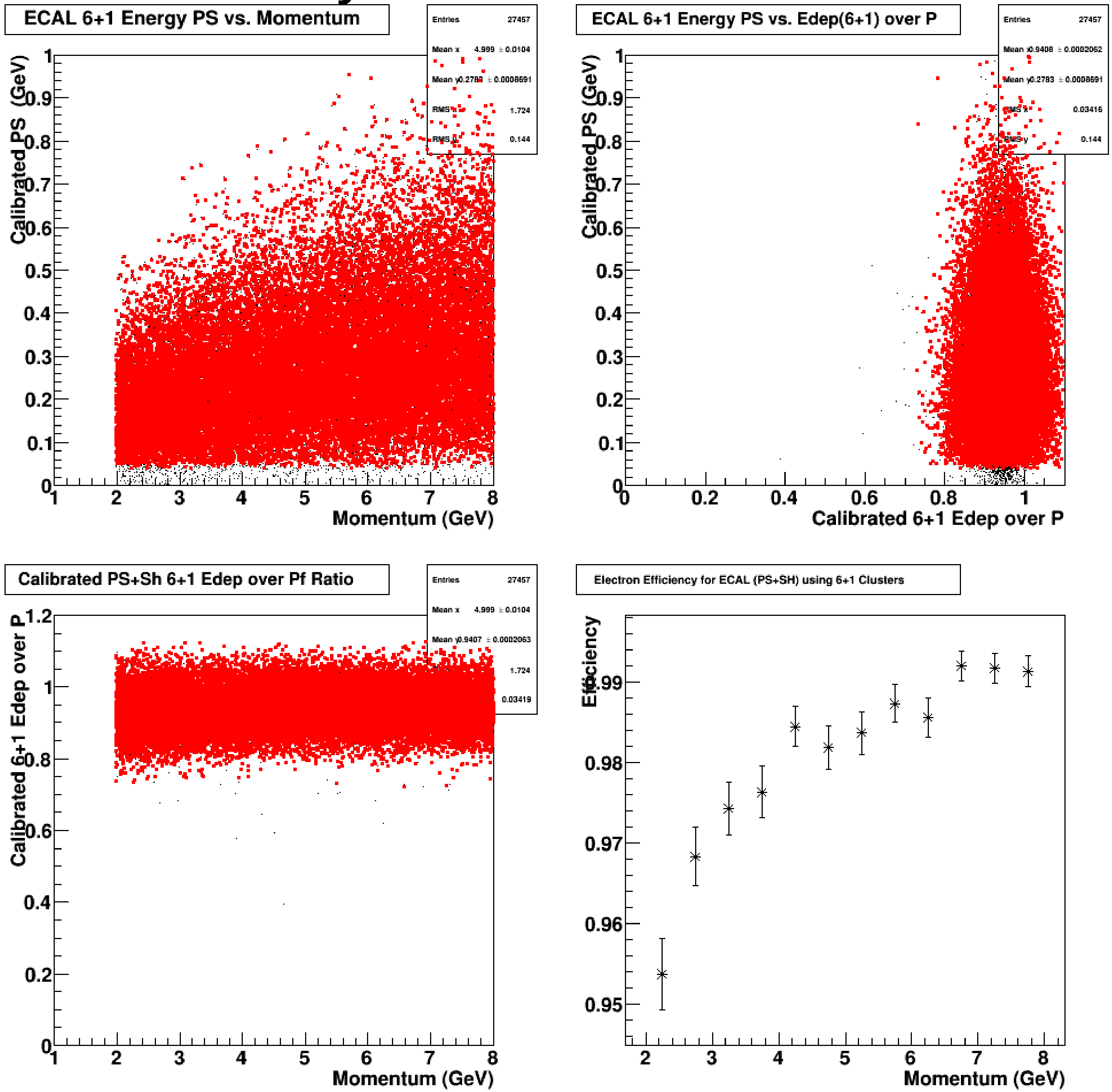
For all components: Preshower, Shower, LASPD, FASPD, two methods to test/calibrate/commissioning in situ (in addition to cosmic):

1. LED system – check on fibers, fiber connections, PMT, DAQ, electronics
2. Using MIP at low luminosity: general calibration of PMT gain.

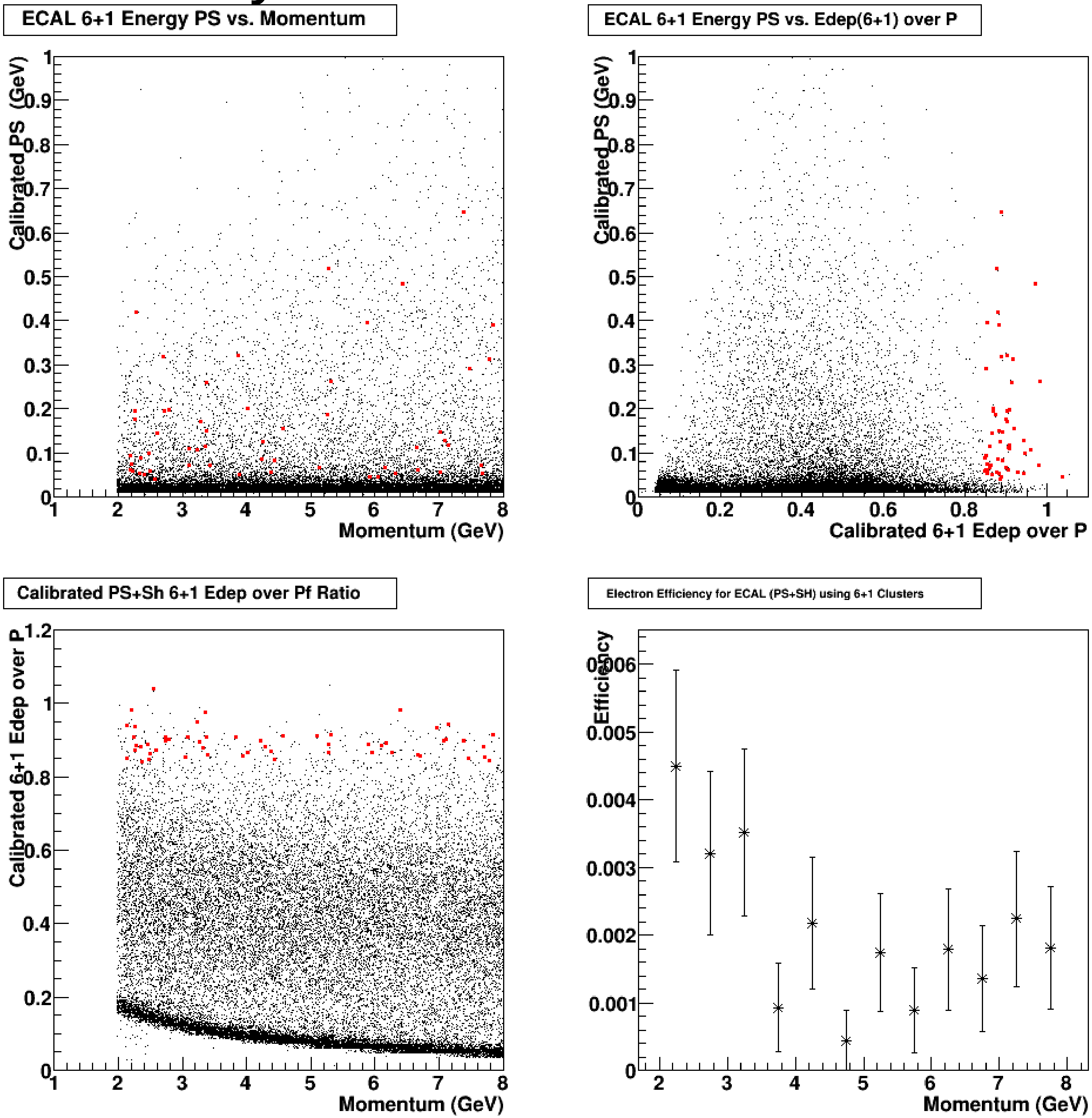
Electron Efficiency: with Birk's Attenuation No PE



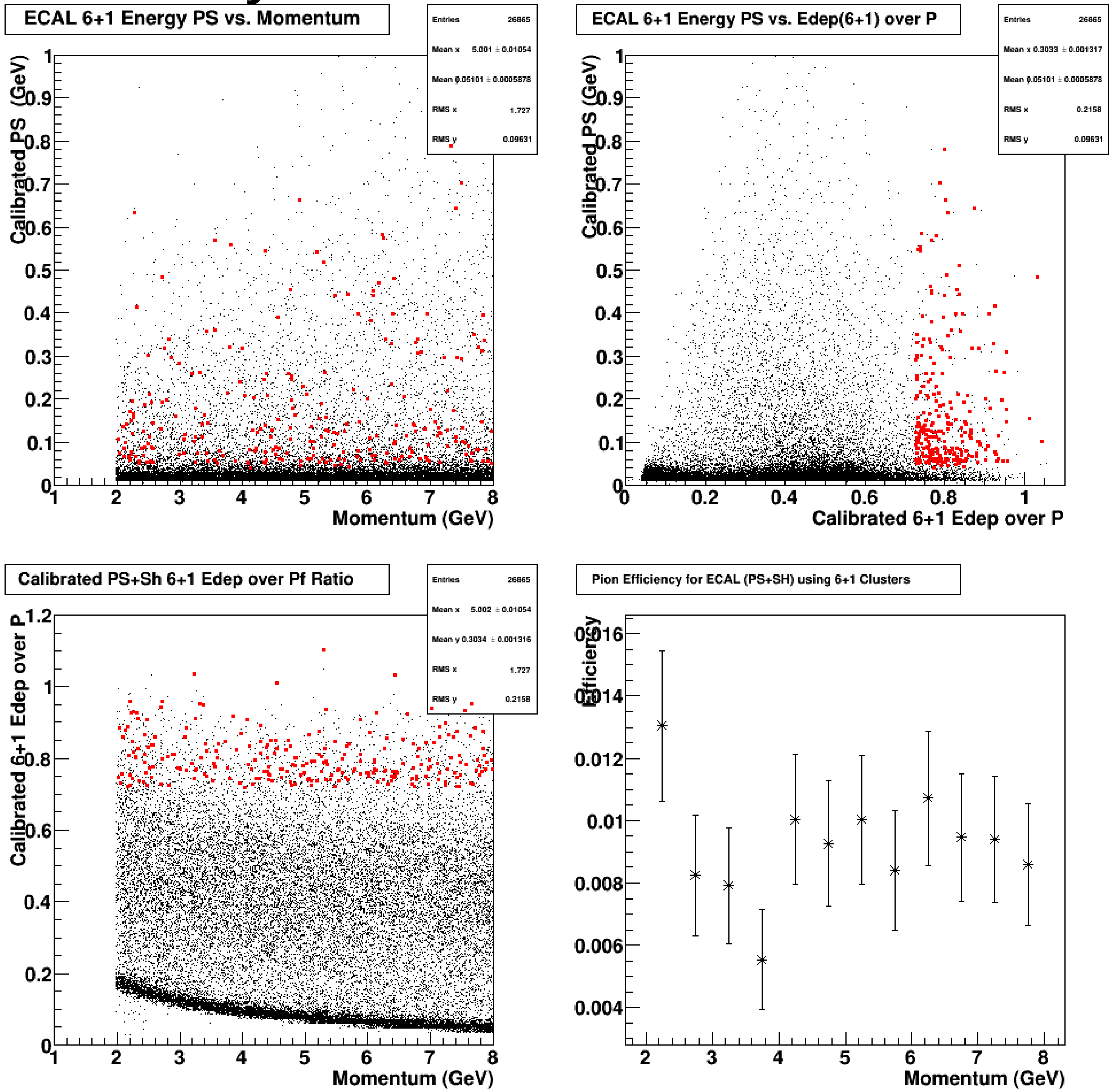
Electron Efficiency: with Birk's Attenuation 400 PE



Pion Efficiency: with Birk's Attenuation No PE



Pion Efficiency: with Birk's Attenuation 400 PE



PID Efficiency : with Birk Effect No PE

	Electron		Pion	
Momentum	Efficiency	Error	Efficiency	Error
2.25	0.923	0.006	0.004	0.001
2.75	0.951	0.004	0.003	0.001
3.25	0.968	0.004	0.004	0.001
3.75	0.976	0.003	0.001	0.001
4.25	0.985	0.002	0.002	0.001
4.75	0.984	0.003	0.0001	0.0001
5.25	0.986	0.002	0.002	0.001
5.75	0.987	0.002	0.001	0.001
6.25	0.987	0.002	0.002	0.001
6.75	0.992	0.002	0.001	0.001
7.25	0.993	0.002	0.002	0.001
7.75	0.994	0.002	0.002	0.001

PID Efficiency : with Birk Effect 400 PE

	Electron		Pion	
Momentum	Efficiency	Error	Efficiency	Error
2.25	0.954	0.004	0.013	0.002
2.75	0.968	0.004	0.008	0.002
3.25	0.974	0.003	0.008	0.002
3.75	0.976	0.003	0.006	0.002
4.25	0.985	0.003	0.01	0.002
4.75	0.982	0.003	0.009	0.002
5.25	0.984	0.003	0.01	0.002
5.75	0.987	0.002	0.008	0.002
6.25	0.986	0.002	0.011	0.002
6.75	0.992	0.002	0.009	0.002
7.25	0.992	0.002	0.009	0.002
7.75	0.991	0.002	0.009	0.002

Note : Shower and PS cuts are relaxed
to keep electron efficiency above 95%

Birk's Effect

- The Birk's effect states that scintillation light output will be saturated if the dE/dx for a given charge particle reaches above certain value.
  - The figure (this is from original Birk's paper) shows how the light yield per path length, dL/dx (in the paper it is called dS/dr but same parameter) varies with dE/dx. See how dL/dx saturates for very large dE/dx.

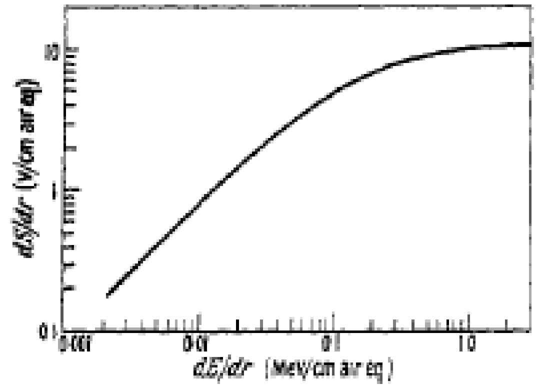


Figure 1. Specific fluorescence dS/dr plotted against specific energy loss dE/dr in anthracene.

Birk's Effect

- The Figure 2 shows light yield per path length variation for different particles
- Figure 3 shows show the total light yield varies for different particles.

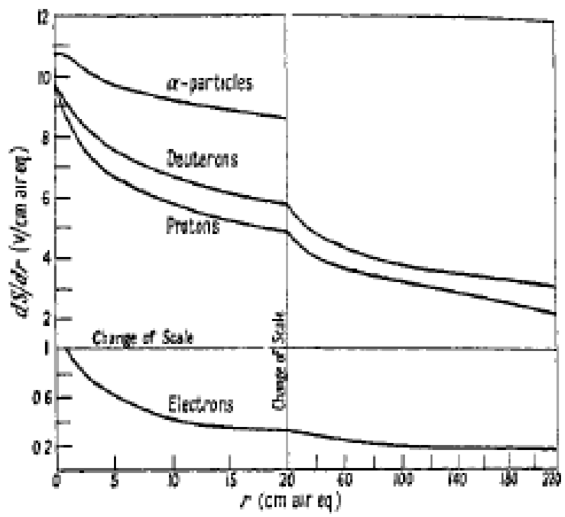


Figure 2. Specific fluorescence dS/dr plotted against residual range r for different particles in anthracene.

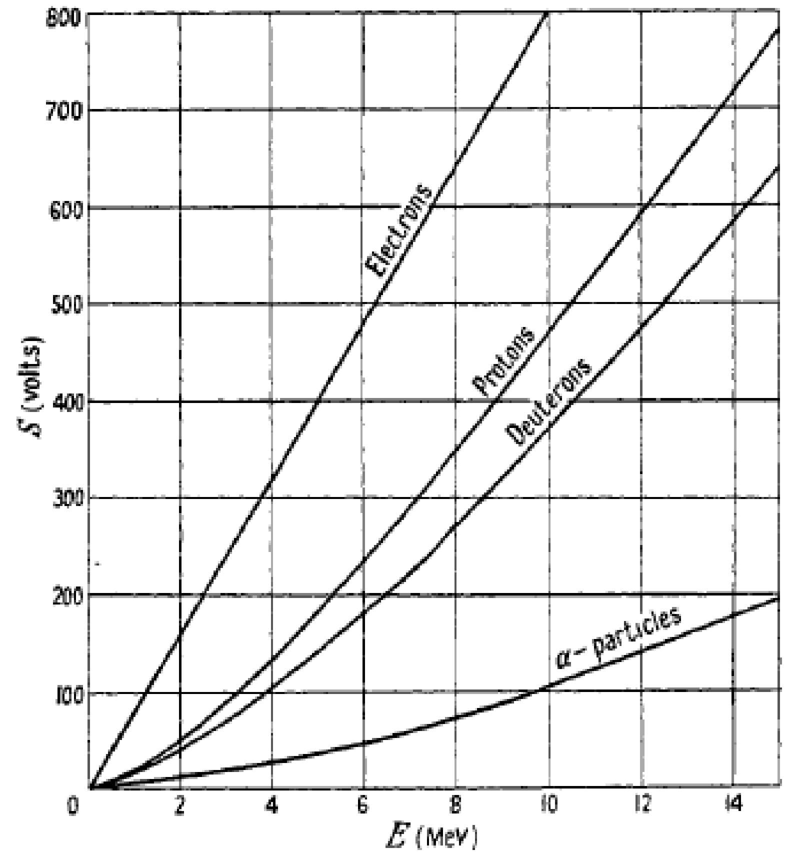


Figure 3. Relative scintillation response S of anthracene to particles of energy E.

Birk's Effect

- Depending on the dE/dx for different charge particles within the scintillation material light output will be different
- dE/dx values are much higher for hadrons compared to electrons
  - suppression of light and non-linear behavior for hadrons.
- Based on the published literature Birk's constant is energy independent for higher energies and it will be different for very low energy charge particles (charge particles in keV range).
- This effect considered to be important only for organic scinitllators based on experimental results.

Birk's Effect

- The Birk's effect takes place during scintillation in the active material
  - Light yield per path length, $dL/dx = S.\, dE/dx /(1 + K_B . dE/dx)$
  - Where dE/dx is the energy loss per path length, S is scint. Efficiency and K_B is Birk's constant
- In simulation it is only considered for the active material and not in the absorber material.