12 GeV Upgrade
Future Science at Jefferson Lab

EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

March 5-6, 2016

Overview

1. Cosmic test of GEM+SPD at UVa – No analysis so far due to GEM tracking code not available (and not sure if it will ever be).
2. Finished preshower irradiation test.
3. No postdoc (UVa) from Dec until June 2017.
4. Beam test of FASPD, LASPD, 3x preshower and 3xshashlyk completed in December.
   - ✔ No electron signal, MIP signals consistent with cosmic test's light yield;
   - ✔ light yield of preshowers lower than UVa's best result, may be due to wrapping quality;
   - ✔ light yield of FASPD slightly lower than (but consistent with) UVa's best result.
   - ✔ THU module signals are not normal, SDU1 and SDU2 are fine.
   - ✔ Quick look at LASPD data showed poor timing resolution (400ps), also timing resolution of trigger not characterized during the test → cosmic test at JLab needed

In progress

5. Simulation of shashlyk including Birk's effect and photoelectron statistics
6. Simulation for photon collection in scintillators
7. Resumed discussion on the support of ECal.

Irradiated Preshower Results

1. Students: Margaret Doyle, Sam Blum
2. Optical grease is from 2014, expired. We tested the preshower "as is", after replacing grease, and 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 (krad)	With Old Grease "as is"	After replacing grease	After replacing fiber
Kedi 1	Beam Right lumis	87.1	161-164	56.6	74.4	73.3
Kedi 2	Upstream of scattering chamber	85.4	185-189	57.6 (fiber had a kink)	67.3	68.0
Kedi 3	Beamline grider	87	31-38	66	69.7	77.3
Kedi 4	Compton chicane	91	9-17	55(?)*-74 (fiber broken)	86.5	
CNCS 1	beam left lumis	83.4	156-172	56.2	49.7	70.0
CNCS 2	Beam Right scattering chamber	84.7	43-53	61.6	71.0	74.5
CNCS 3	Beam Left scattering chamber	81.8	20-24	62.5	69.3	
CNCS 4	Hall A dump	83.4	230-286	41.2	47.2	54.0

Green numbers are updated results after replacing a loose-wire PMT
Red numbers were performed with a PMT that behaved inconsistently.

http://hallaweb.jlab.org/experiment/PVDIS/SoLID/EC/meetings/2014-test/2016-test/Documents/PSH_rad_tests_02Jan2017.pdf

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 (attenuation 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

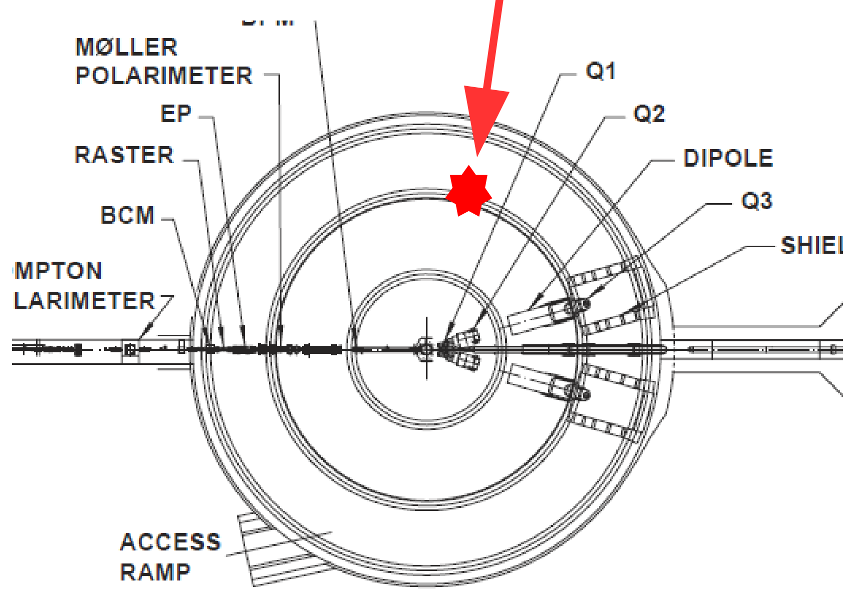
Work done by Ye Tian (SDU), Vince Sulkosky, with help from Mark Jones and Alexandre Camsonne

Detector package platform (same height as beamline)

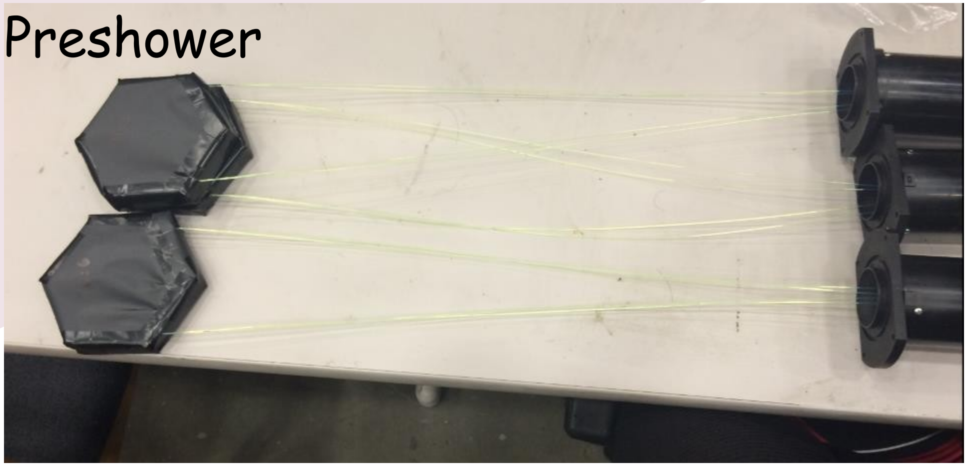
Electronics

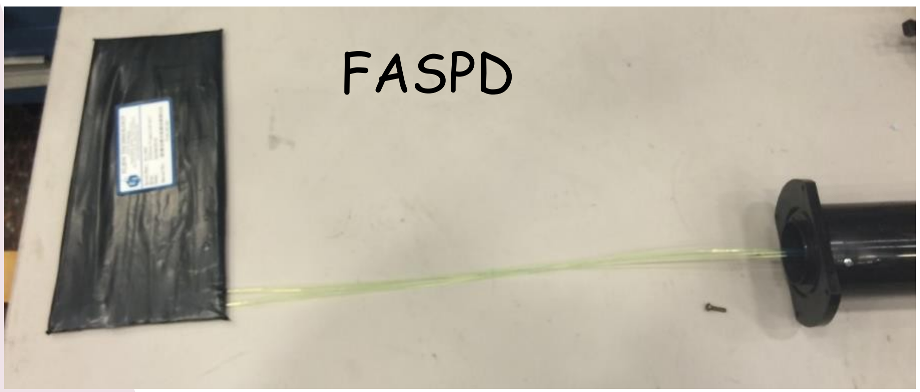
shielding

at about 76 deg

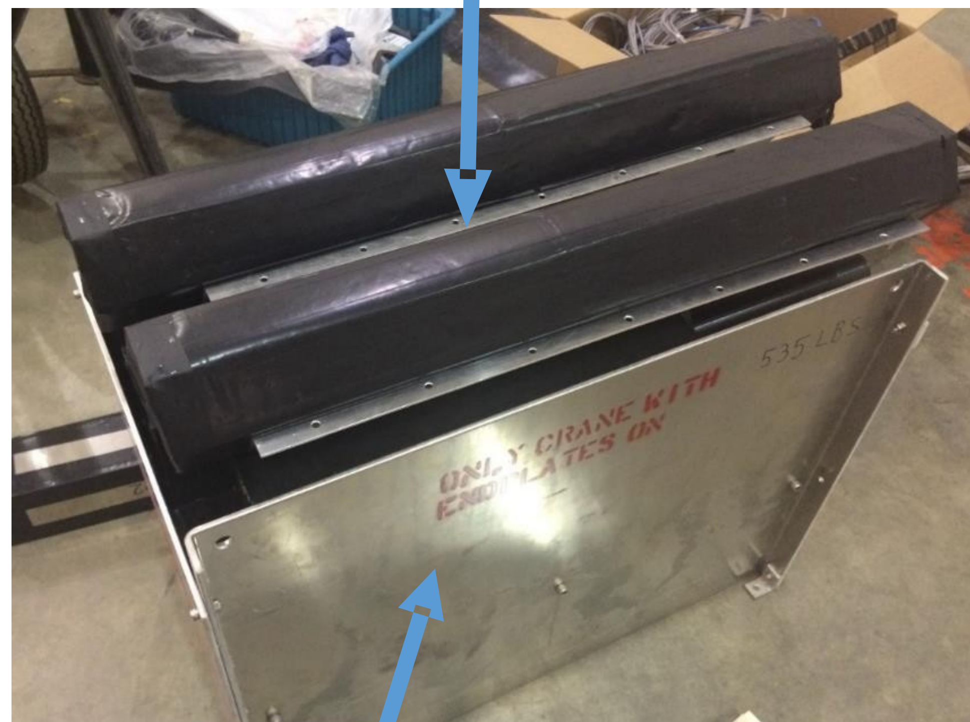


Beam test - detector preparation



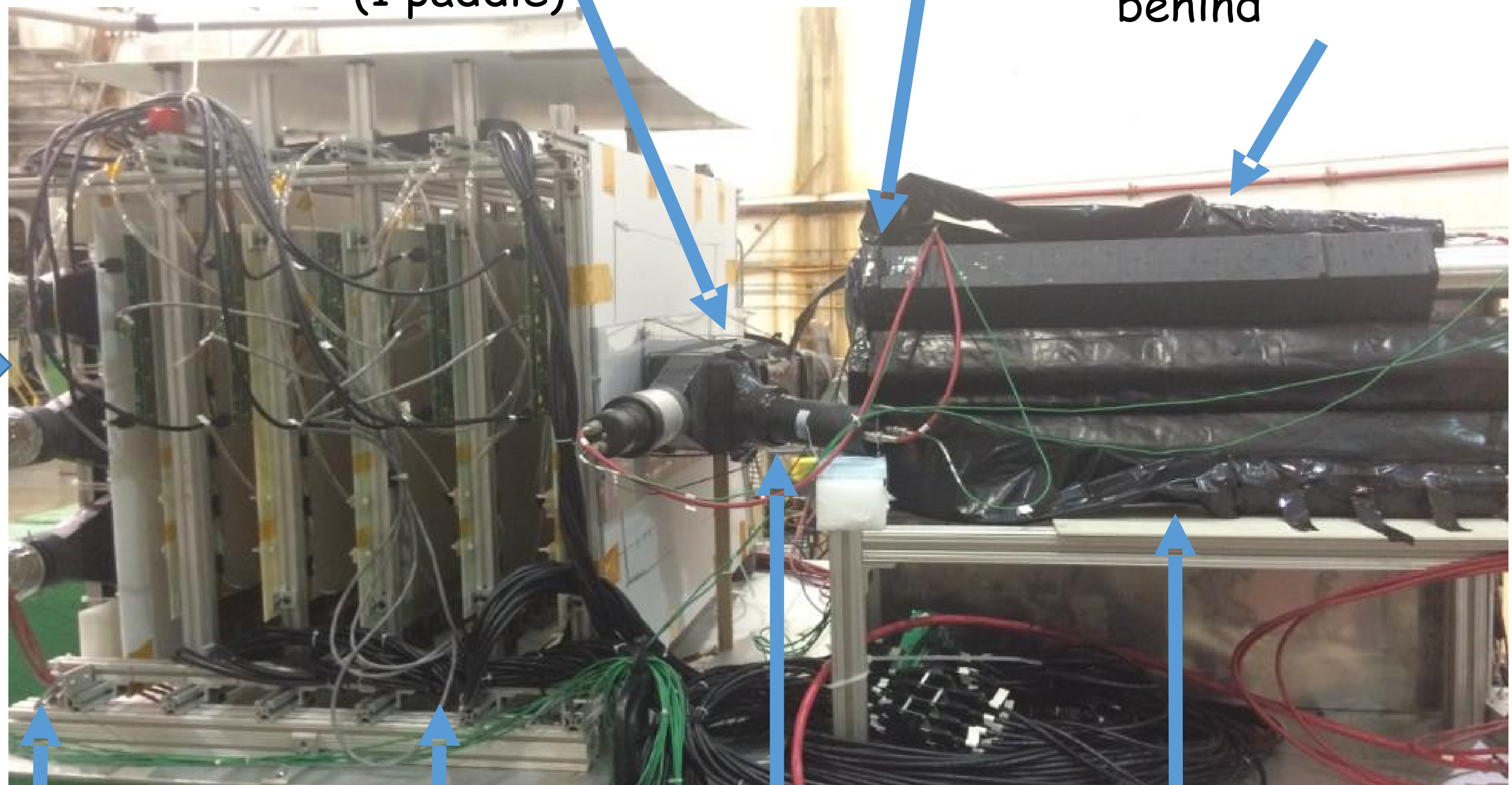


shashlyk modules



9x SBS calo modules (square shape)

Beam test – detector arrangement



Shashlyk prototype and light yield overview

Prototype	scintillator	lead	reflective layer	WLS fiber	WLS fiber end	module side	cosmic vertical test Npe	cosmic horizontal test Npe
SDU1	Kedi original	US	printer paper	BCF91A	none	Tyvek → TiO2	224 → 254	48 → N/A**
SDU2	Kedi new	Chn	printer paper	BCF91A	Chn silver-plating	Tyvek → TiO2*	427 → 383*	83 → N/A**
SDU3	Kedi new	US	printer paper	Y11	Chn silver-plating	TiO2+glue (1/1)	491	107
THU1	Kedi original	Chn	mirror mylar	Y11	Italian silver shine	TiO2 (Kedi)	430-470	96
THU2 (not finished yet)	Kedi new	83.4	powder paint (喷塑)	suggest BCF91A	Italian silver shine			

* TiO2 side-paint was not as good as SDU1
** could not finish before shipping to JLab
[red box] Yields 400/200 layers for MIP → 1333 p.e./GeV electron, factor 2-3 lower than LHCb or ALICE → 666 p.e./GeV if using clear fibers → 4% in δE/E due to photoelectron statistics

Simulation – Birk's effect and photoelectron statistics

- Birk's effect states that scintillation light output will be saturated if the dE/dx for a given charge particle reaches above certain value.
  - Figure 1 (from original Birk's paper) shows how the light yield per path length, dL/dx (in the paper it is called dS/d but same parameter) varies with dE/dx. See how dL/dx saturates for very large dE/dx.

Birk's Effect

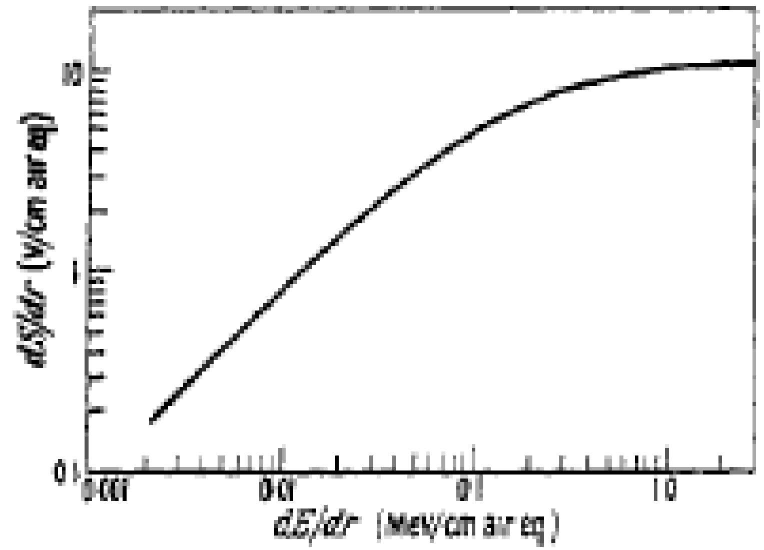


Figure 1. Specific fluorescence dS/dr plotted against specific energy loss dE/dr in anthracene.

Simulation – Birk's effect and photoelectron statistics

Birk's Effect

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

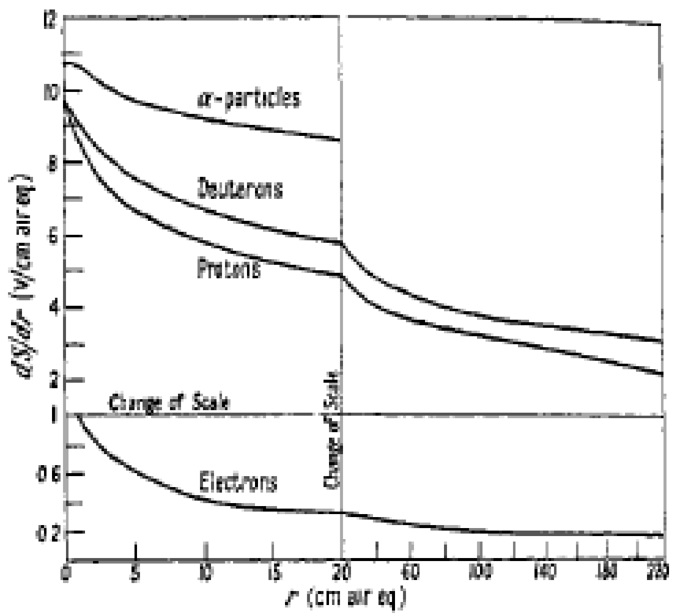


Figure 2. Specific fluorescence dS/dr plotted against residual range r for different particles in anthracene.

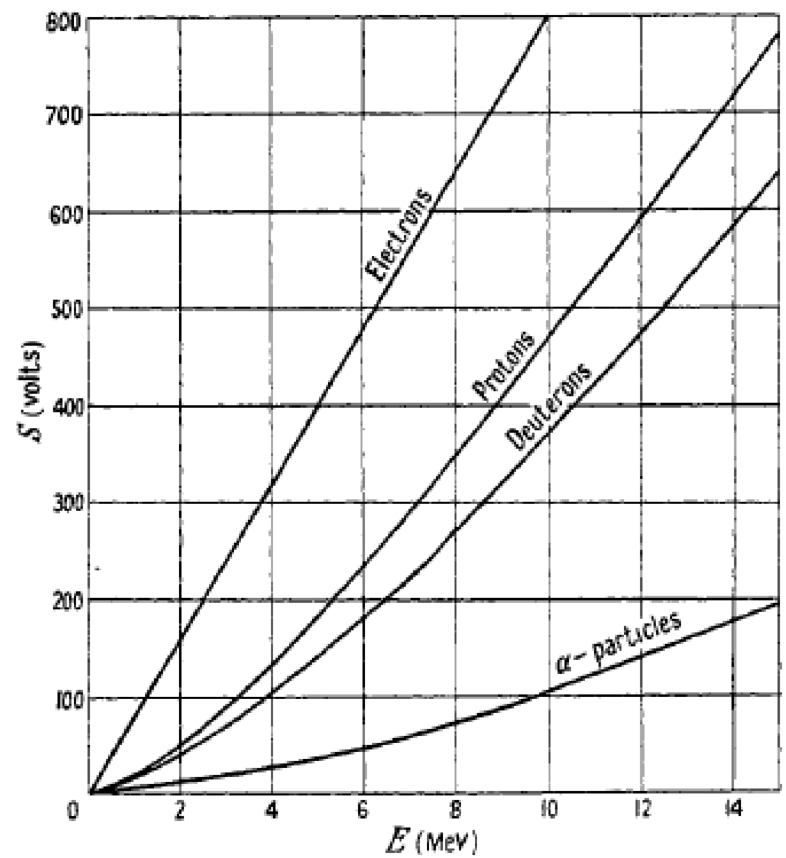


Figure 3. Relative scintillation response S of anthracene to particles of energy E.

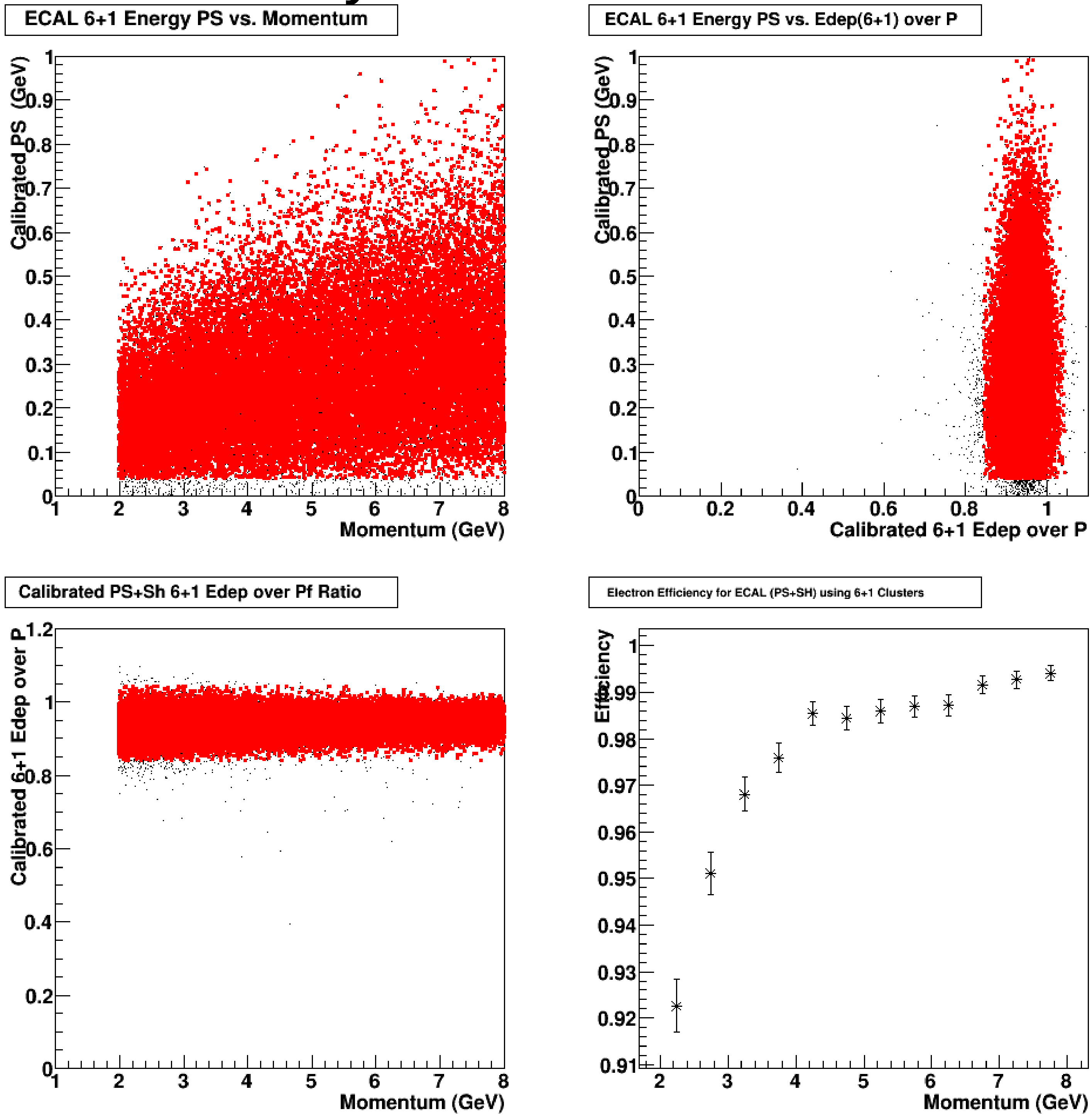
Birk's Effect

- 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.

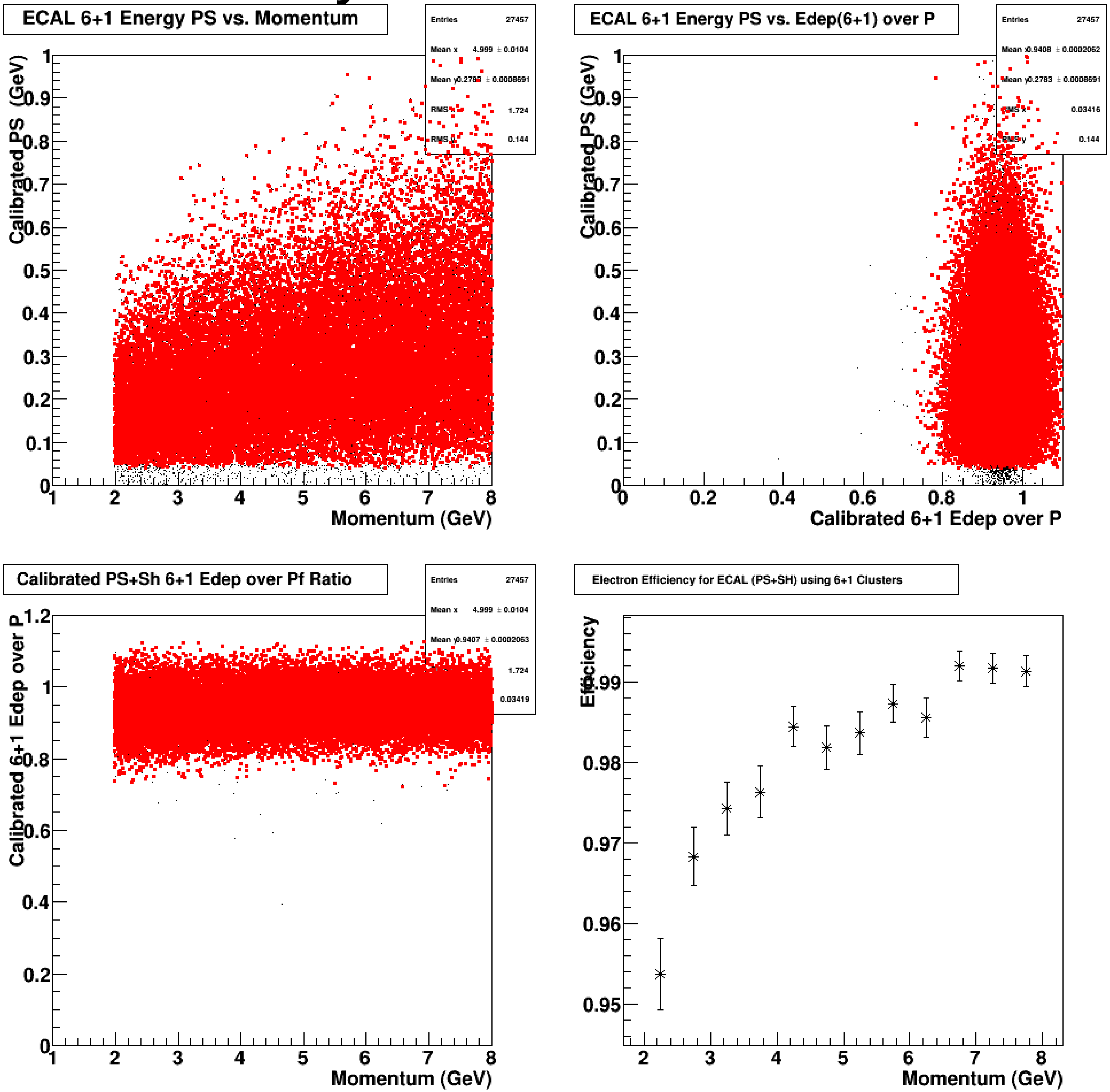
Birk's Effect

- 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.

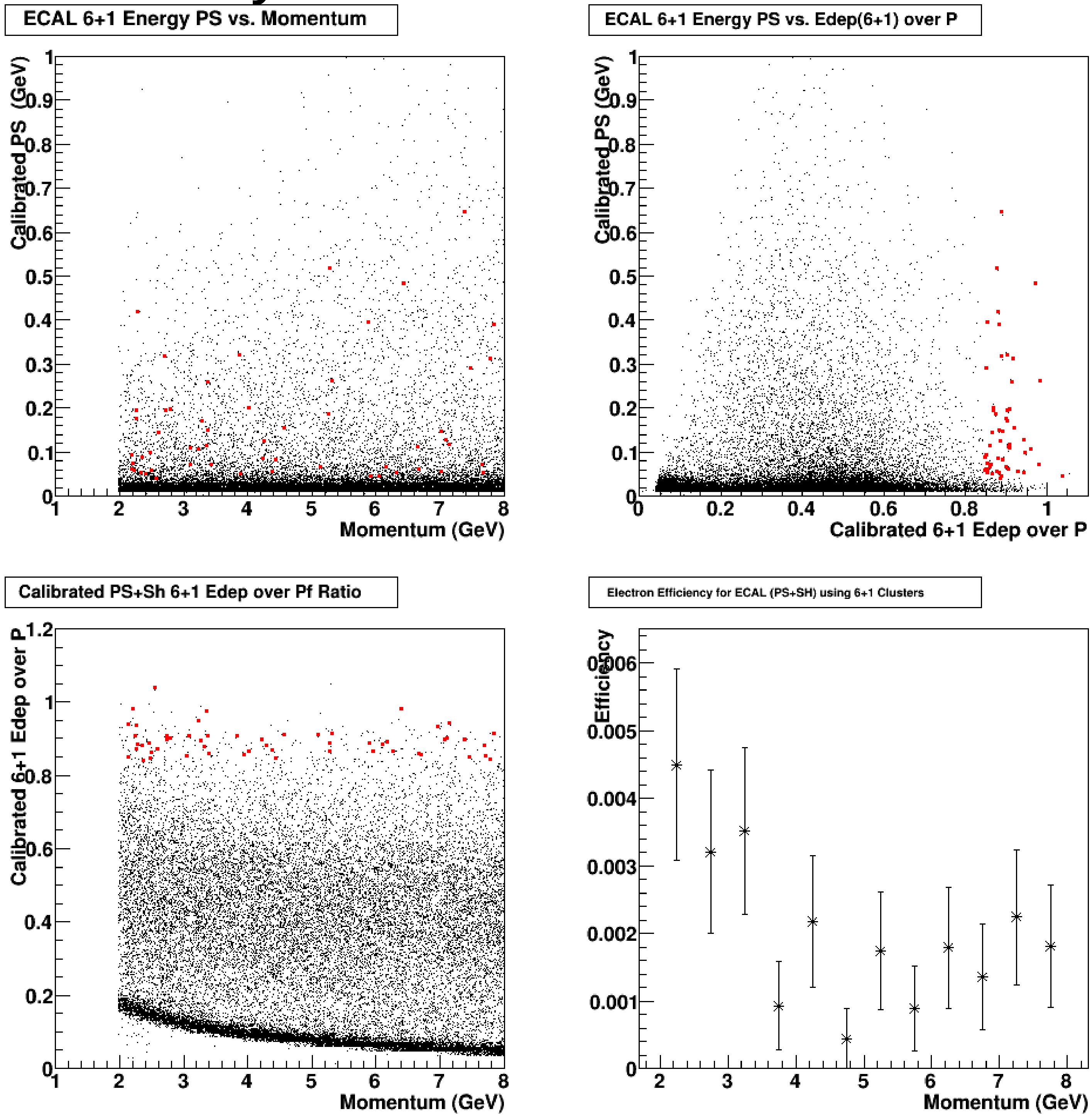
Electron Efficiency: with Birk's Attenuation No PE



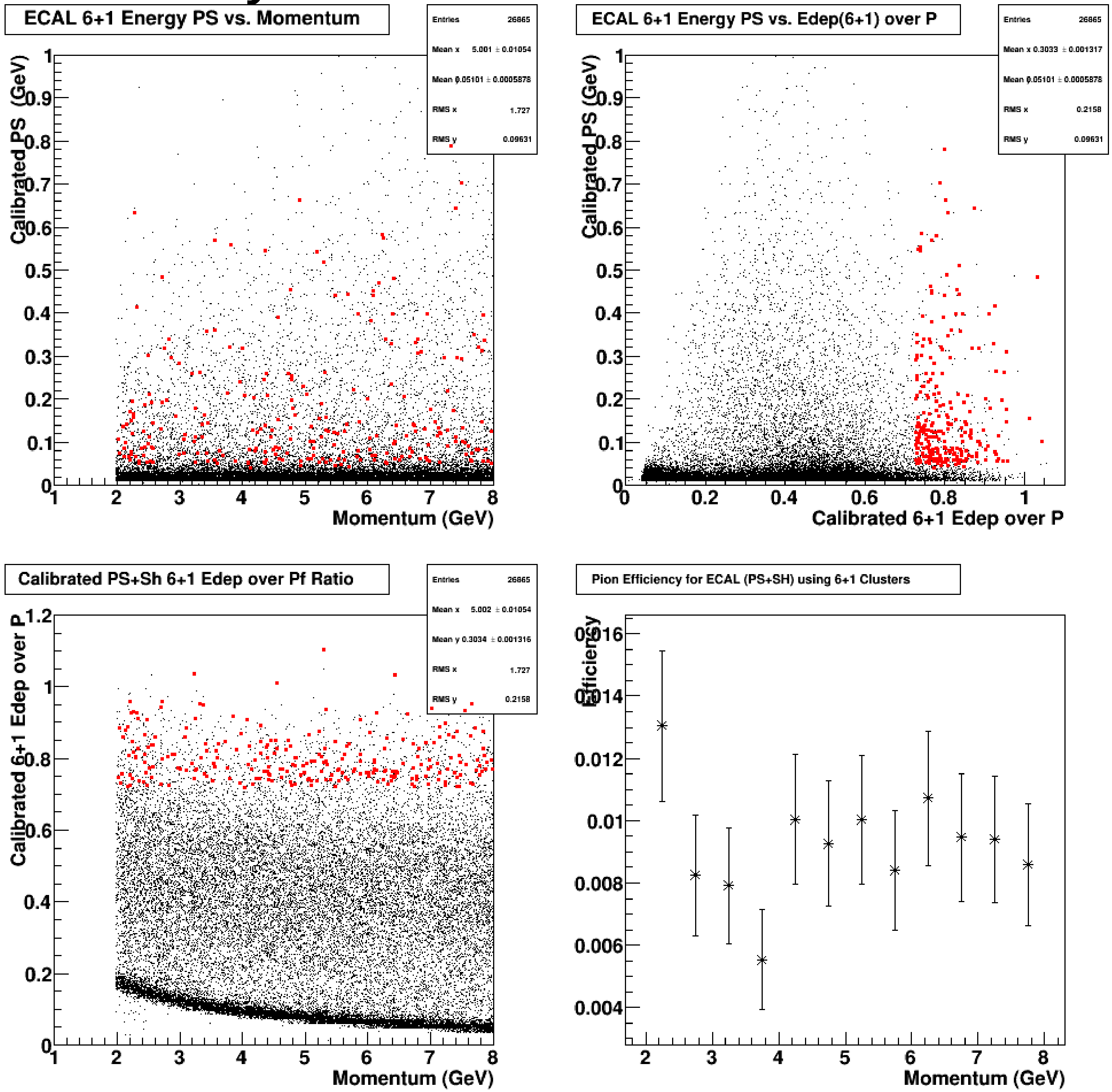
Electron Efficiency: with Birk's Attenuation 400 PE



Pion Efficiency: with Birk's Attenuation No PE



Pion Efficiency: with Birk's Attenuation 400 PE



Simulation – Birk's effect and photoelectron statistics

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

Simulation – Birk's effect and photoelectron statistics

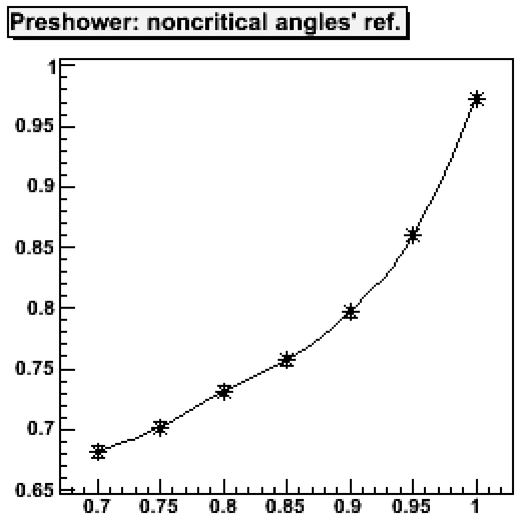
PID Efficiency : with Birk Effect 400 PE

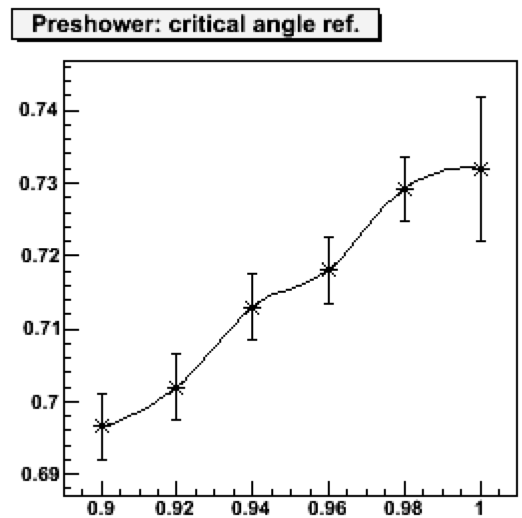
	Electron		Pion	
Momentum	Efficiency	Error	Efficiency	Error
2.25	0.954	0.004	0.013	0.002
2.75	0.968	0.004	0.008	0.002
3.25	0.974	0.003	0.008	0.002
3.75	0.976	0.003	0.006	0.002
4.25	0.985	0.003	0.01	0.002
4.75	0.982	0.003	0.009	0.002
5.25	0.984	0.003	0.01	0.002
5.75	0.987	0.002	0.008	0.002
6.25	0.986	0.002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

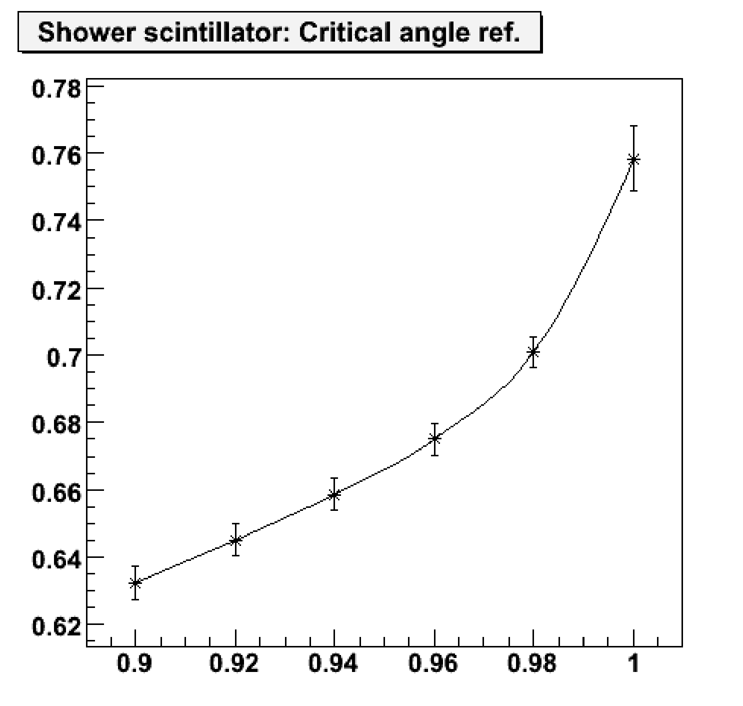
Note : Shower and PS cuts are relaxed to keep electron efficiency above 95%

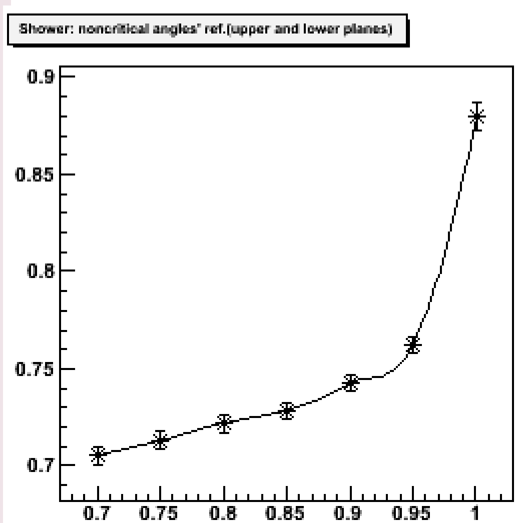
Simulation – photon collection

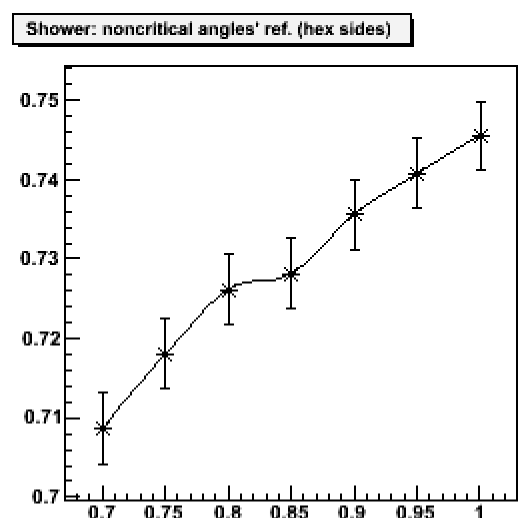
1. C-based simulation by E. Rhett Cheek (UVa, Fall 2016 + Spring 2017)
2. generate photons at random position and angle inside the scintillator → simulate its reflection until it's either lost or absorbed by the WLS fiber;
3. Variable parameters: loss probability for total-internal reflection (nominal 99%), and for non-total-internal reflection (nominal 80%) → help us to understand the effect of improved reflective material or painting on the final light yield
4. To do: a) adding attenuation length of the scintillator; b) Preshower uniformity; c) LASPD simulation (?)











ECal + SPD cost estimate

Item	2014	2017
Shashlyk	$2,997,657 (1800 modules Russian IHEP)	China using 0.1454USD/Y: $3,460,567 (1800 modules); $3,630,323 (5% extra)
Preshower	$280,800 (1800 modules Russian IHEP)	
SPD (Eljen)	FA: $54,900; LA: $34,680	waiting, maybe higher due to deeper grooves for FA (4.5mm vs. 3mm)
HV/CAEN	$1,026,624	$365,015 (newer, lower cost modules)
PMT/Hamamatsu	$885,600 (5% spare incl., MAPMT overestimated); FMPMT not quoted; plus MAPMT base/preamp	$797,510 (5% spare included), plus MAPMT base/preamp → $825k?
Fiber (Saint Gobain)	$700k (~$1/m, 200kmWLS, 520km clear)	~$2.3/m!!! (still checking)
Fiber (Kuraray)	$64k ($2/m 23.5km clear, $3.2/m 6800m WLS)	WLS 200km is $2.6/m; clear still $2.15/m
Fiber connectors	$365k	$420k (incl. 5% spare)
Total	$6,411k	-$240k not incl. fibers

To-Do List

1. Draft MIE (Ecal and SPD) → this week
   (a) include Rakitha's work on Birk effect and photoelectron statistics
   (b) update SPD segmentation using Zhihong's simulation (Sanghwa is following up on this)
   (c) add photon collection simulation
   (d) add preliminary support design
   (e) update cost estimate
2. Beam test analysis – combine GEM with FASPD for light yield uniformity
3. Assist cosmic test at JLab (Ye Tian and Ye Tian) – goal is to get LASPD timing
4. Followup on simulations (Rakitha and Sanghwa)
5. Continue simulation for photon collection (Rhett Cheek)
6. LHCb will dismount their preshower in 2019, (in Dec 2016) asked us if we are interested.
7. Continue working on the support of ECal.

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%;

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.