12 GeV Upgrade
Future Science at Jefferson Lab

EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

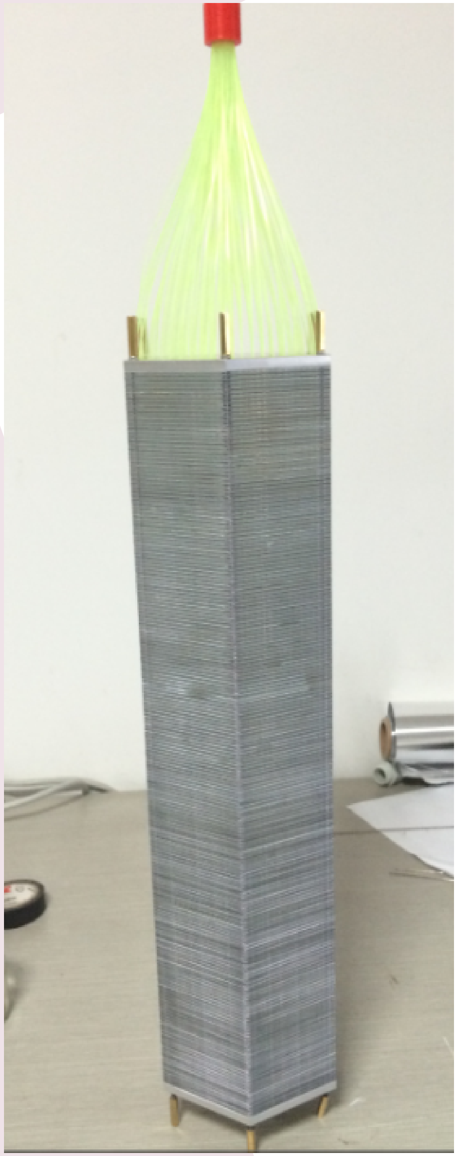
August 26-27, 2016

Overview

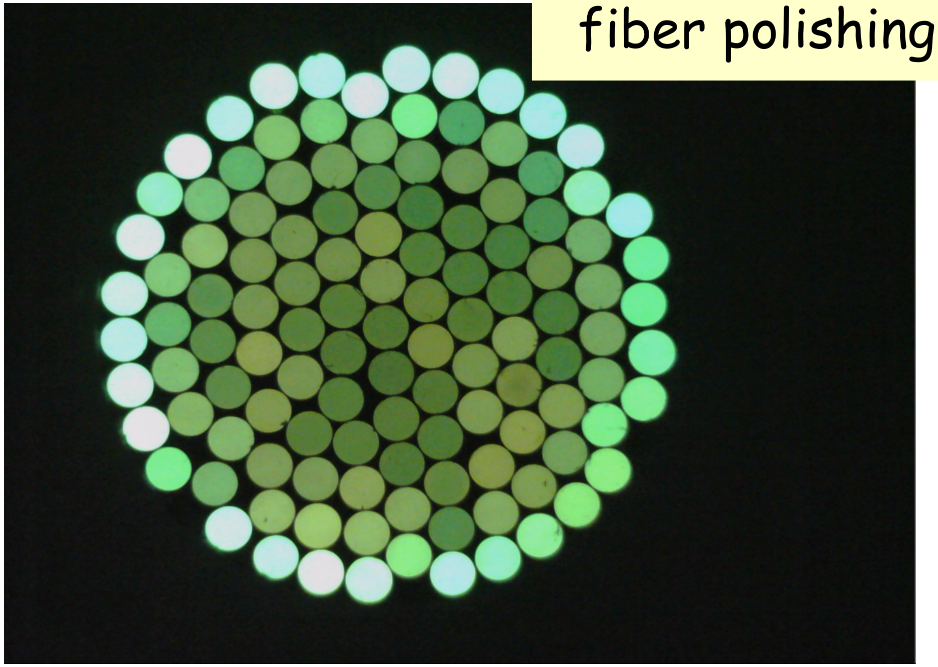
1. At UVa, have been working on FA- and LASPD+GEM test for timing resolution and light yield uniformity. Lot of difficulties .
2. Test of the radiated PReshower is on hold, but expect to make some progress (two undergrads this term to help).
3. Lot of progress on the SDU/THU side

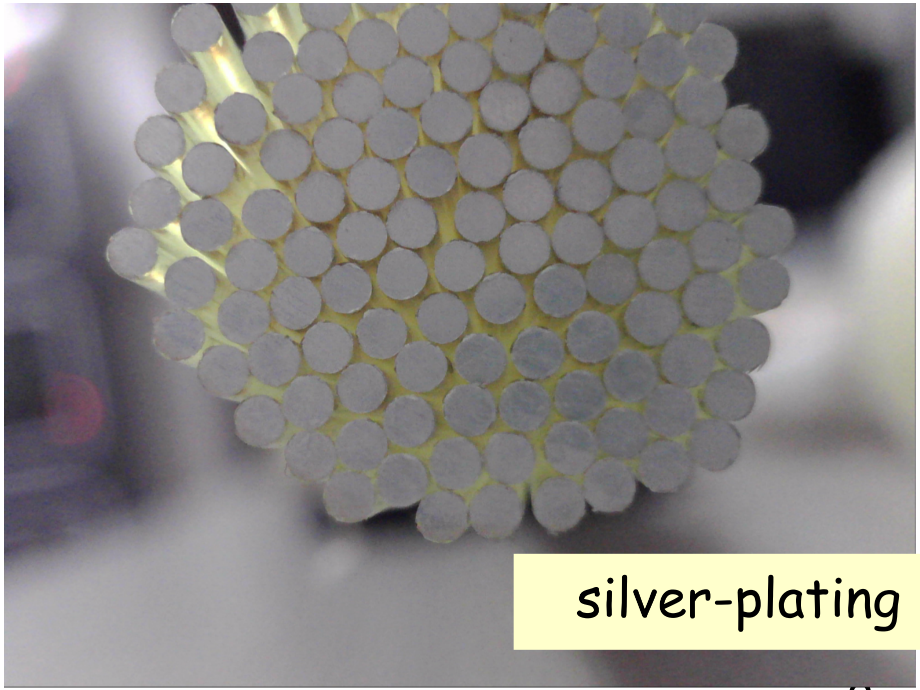
SDU Prototyping Update (Ye, Jianbin, Cunfeng)

practing fiber insertion



fiber polishing

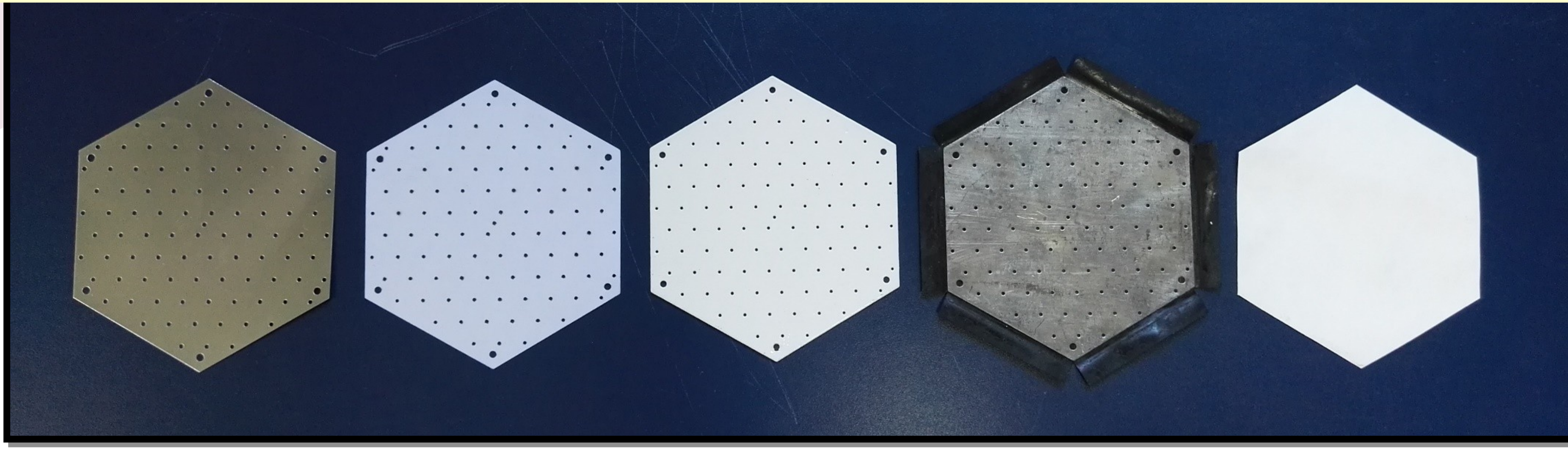




silver-plating

THU Prototyping Update (Chendi, Yi)

test of reflective materials, also practicing fiber insertion and painting fiber end with silver.



PVC (expensive)	Print paper (useless)	Powder paint	none	TYVEK (difficult to cut)

We have 4 kind of material, PVC, print paper, powder paint and TYVEK.
Specially, I want to introduce a new way, Powder paint, to reflect the light.
For painting use electrostatic coating. Polymer powder keeping on surface Pb plate by force of electrostatic attraction. Polymer powder are polymerized at 160-180C during 10-20 min in thermo camera.

Preliminary results: Tyvek, powder paint, and PVC seem to provide the highest light yield

Light Yield Update

1. Last time we reported that UVa test using 5 shashlyk layers showed MIP~1.5p.e. per layer at best

2. SDU group conducted cosmic test using two prototypes:

Light Yield Update

1. Last time we reported that UVa test using 5 shashlyk layers showed MIP~1.5p.e. per layer at best

2. SDU group conducted cosmic test using two prototypes, results are between 1 p.e. and 2 p.e. per layer.

Module No.	WLS fiber	Scintillator	Lead layer	Fiber end	Reflective layer	Front plate	vertical test Npe	horizontal test Npe
SDU #1	BCF91	Kedi (original)	From US	No mirror	Print paper		48	224
SDU #2	BCF91	Kedi (new)	From China	Silver mirror	Print paper	No holes	78	426

using 2 p.e./layer, SoLID running condition would be 2*600(MIP→Shower)*0.5(fiber connector + clear fiber loss) =600, or 4.1%/sqrt(E) from photoelectron statistics. Using TiO2 paint on the side, Tyvek, and Y11 fiber can further improve Npe.

Simulation Updates (Rakitha)

Uniform electrons and Pions distributions incident on ECAL

Photo-electron (PE) yield added to the shower

- 400 PE per GeV and no PE fluctuations in PS
- **PS and shower cuts are relaxed to improve electron efficiency**

Started implementing light yield for scintillator material

- Birk's attenuation : The quenching effect in scintillators where light output saturates when the energy loss density is large
- For the scintillator used for ECAL : Birk's constant is 0.126 mm/MeV

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
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PID Efficiency : with Birk Effect 400 PE

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

To-Do List

1. UVa → SDU enough Y11 fibers and Tyvek sheets to construct a 3rd module.
2. SDU will paint the existing 2 module sides with TiO2 and are looking into shipping the modules to JLab
3. UVa: Continue cosmic GEM/SPD test until mid September
4. Mid September: move FASPD, LASPD, preshower (not radiated) and Chinese shower prototypes to Hall A for parasitic testing. (working on the test documents now).
5. September-Nov: parasitic testing at JLab + Testing radiated preshowers at UVa. Chinese groups continue constructing and improving their prototypes.

Address Recommendations from Director's Review

Slides 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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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)

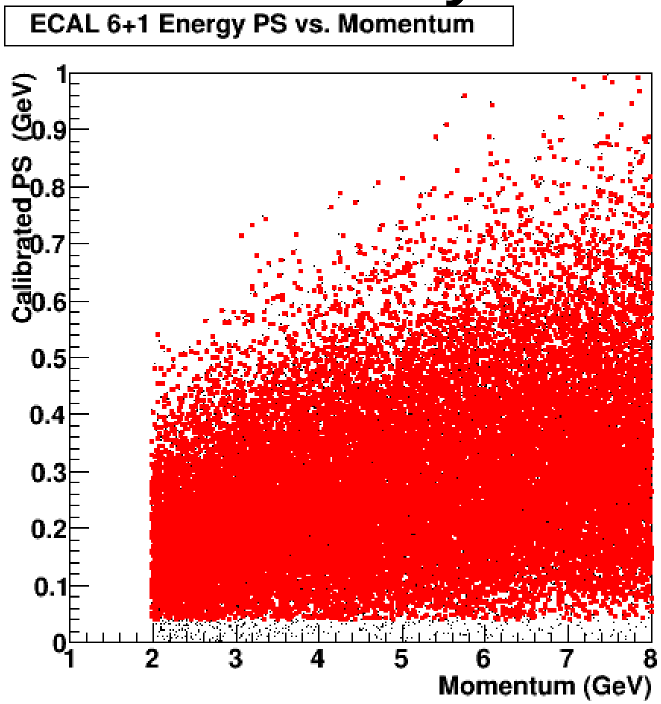
- Using elastic electrons at low beam energy – with beam, commissioning, slow, coverage in momentum and angle won't be large (probably can only use 2.2 GeV beam), precision will be high if done with tracking, can be done with only EC running but precision limited by the knowledge of scattering angle (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.

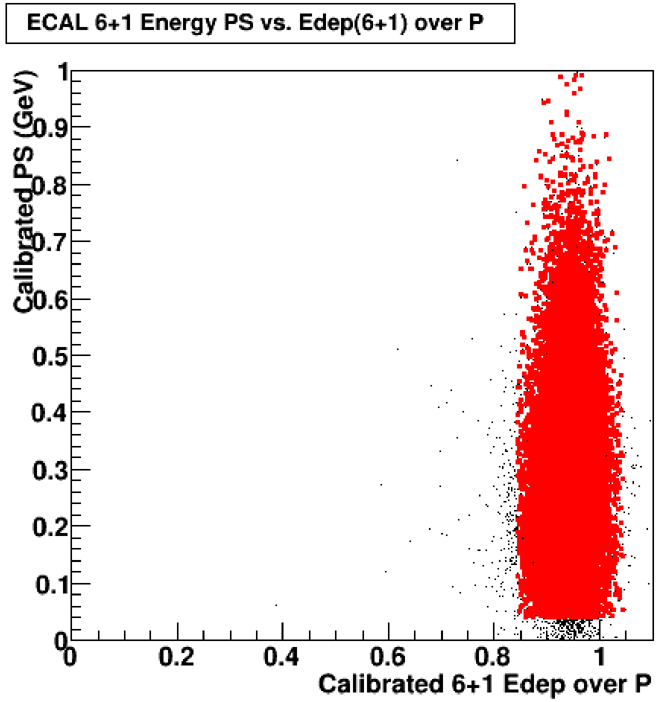
Commissioning

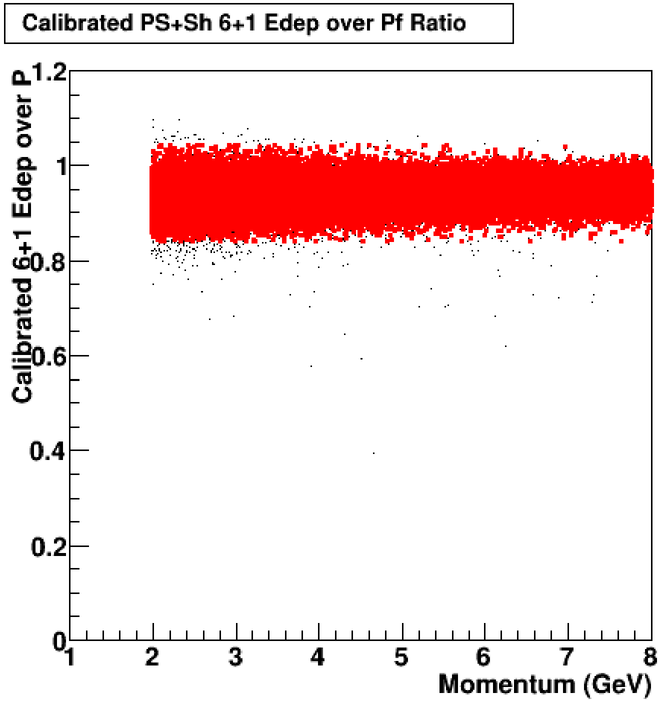
For all components: Preshower, Shower, LASPD, FASPD, two methods to test/calibrate/commissioning in situ (in addition to cosmic):

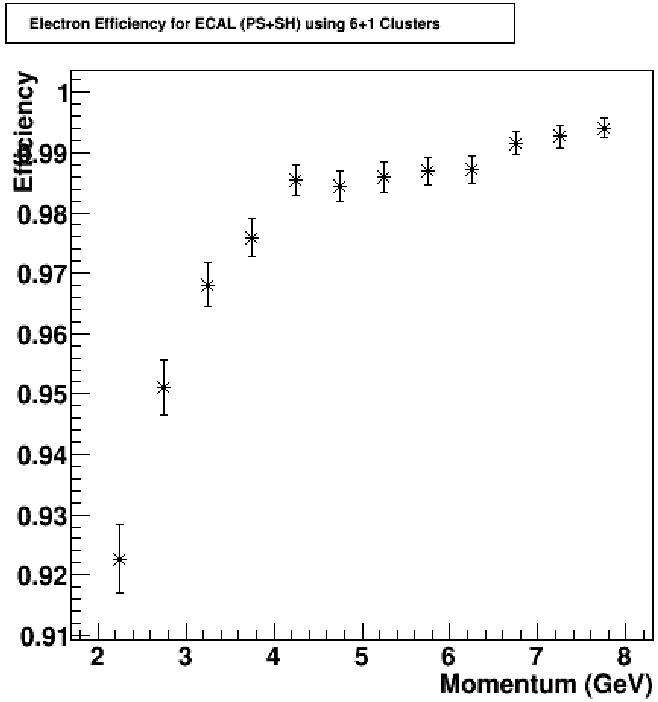
1. LED system – check on fibers, fiber connections, PMT, DAQ, electronics
2. Using MIP at low luminosity: general calibration of PMT gain.

Electron Efficiency: with Birk's Attenuation No PE









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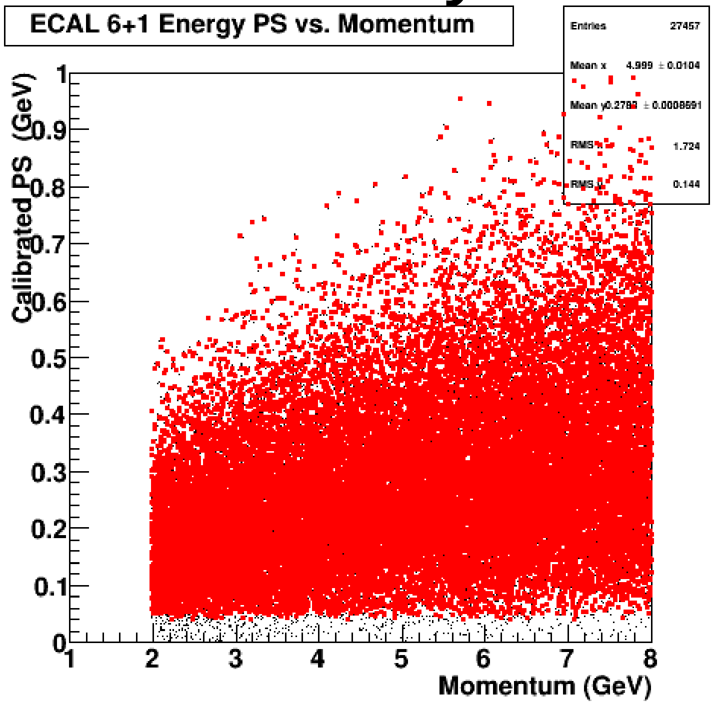
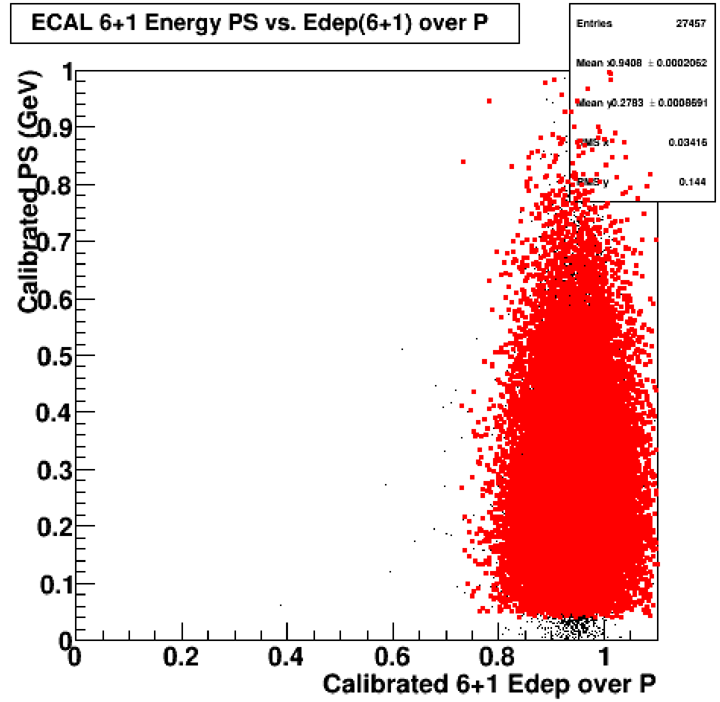
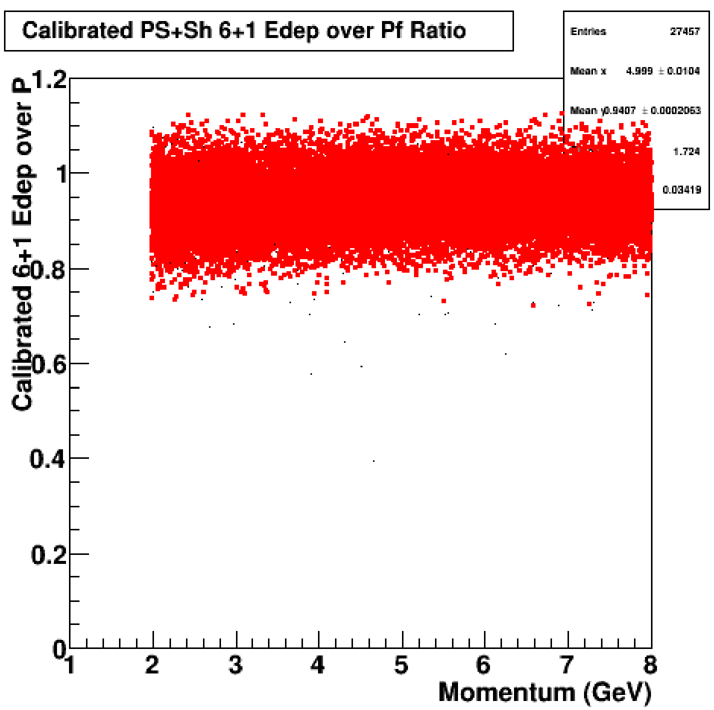
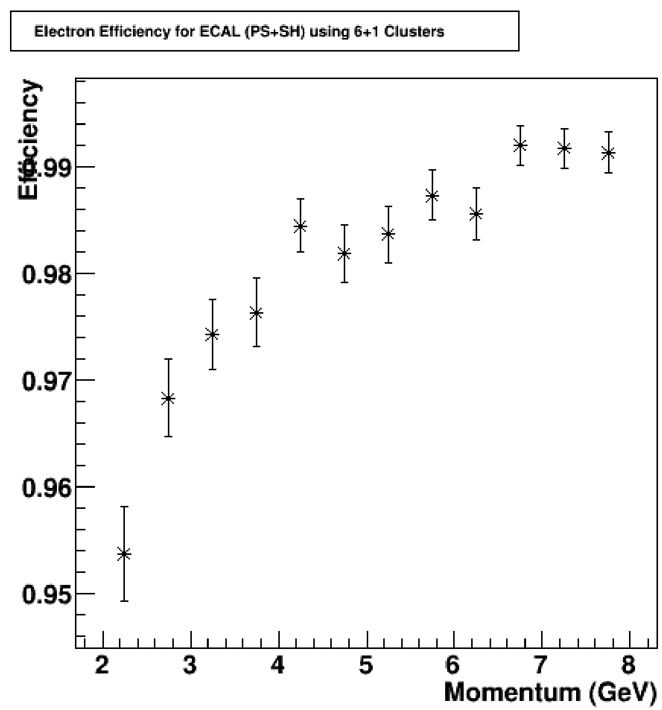
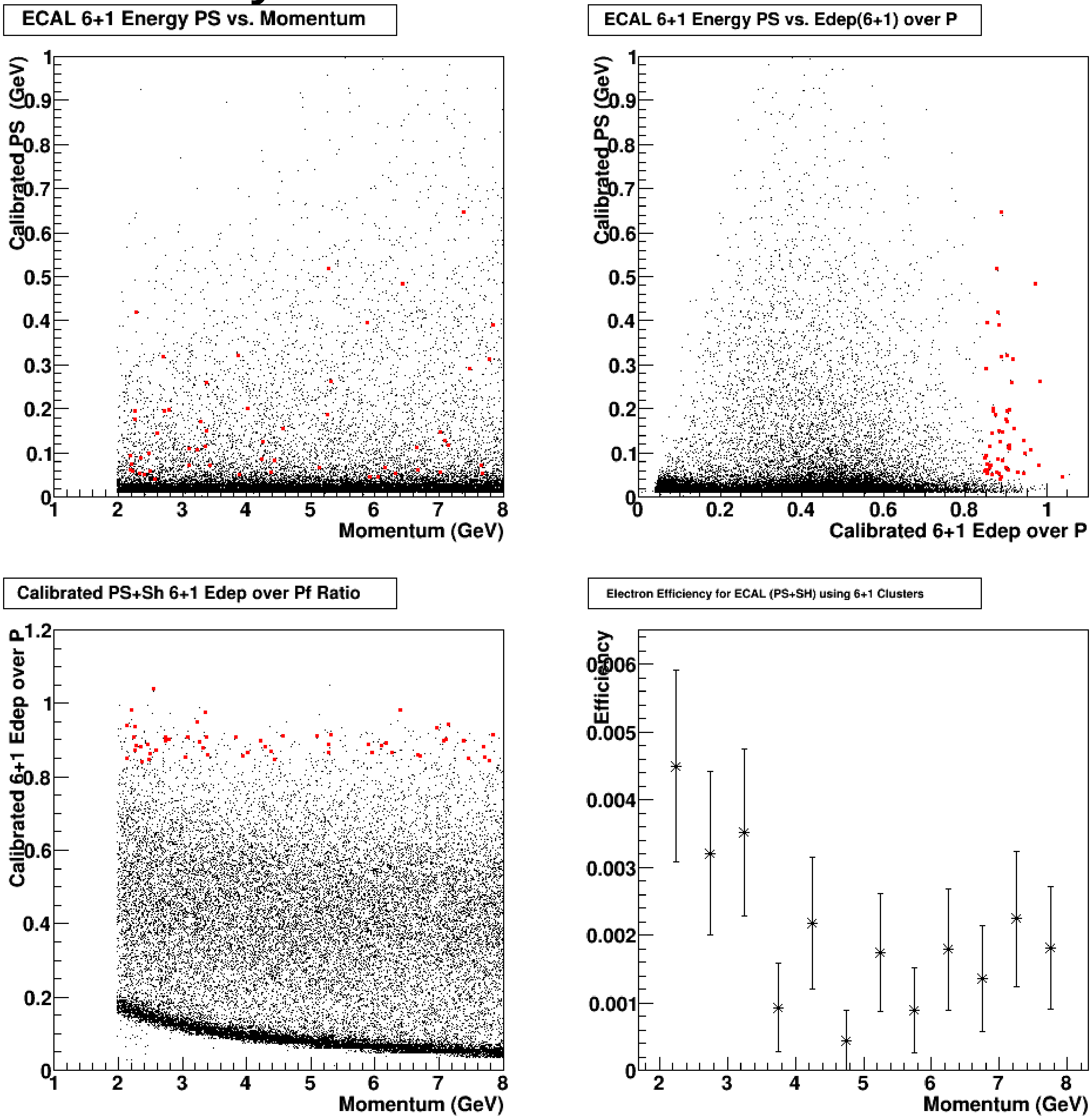








Pion Efficiency: with Birk's Attenuation No PE



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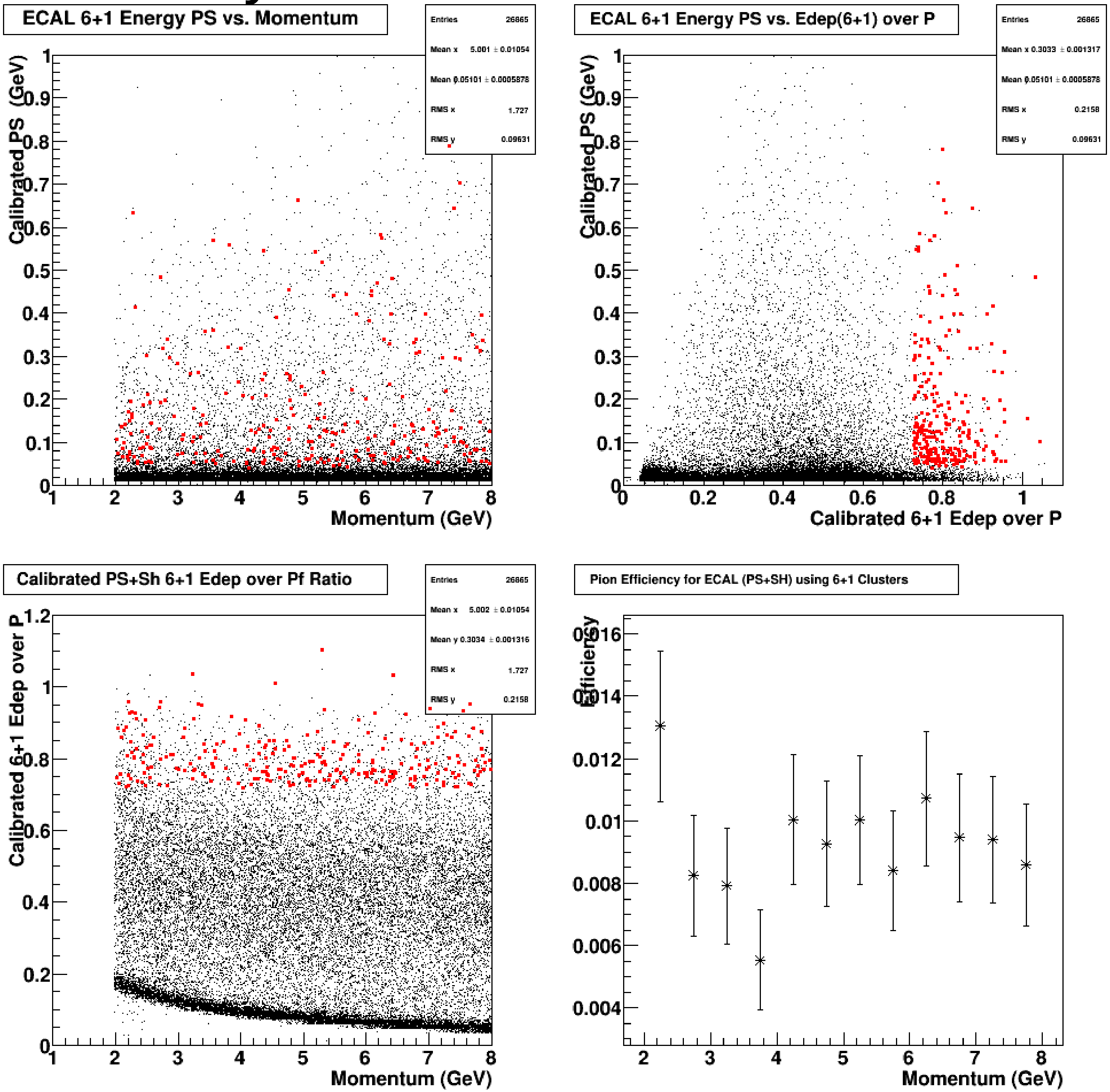

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Birk's Effect

- 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.

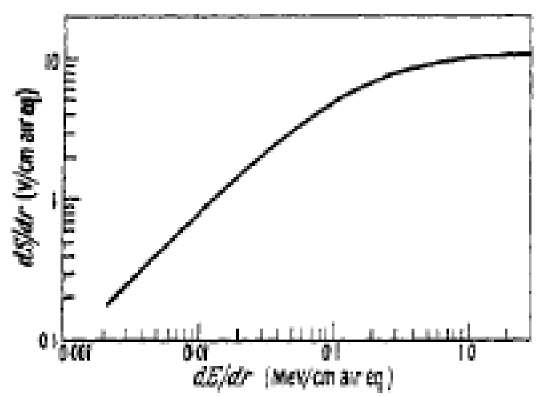

Figure 1. Specific fluorescence dS/dr plotted against specific energy loss dE/dr in anthracene.

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.

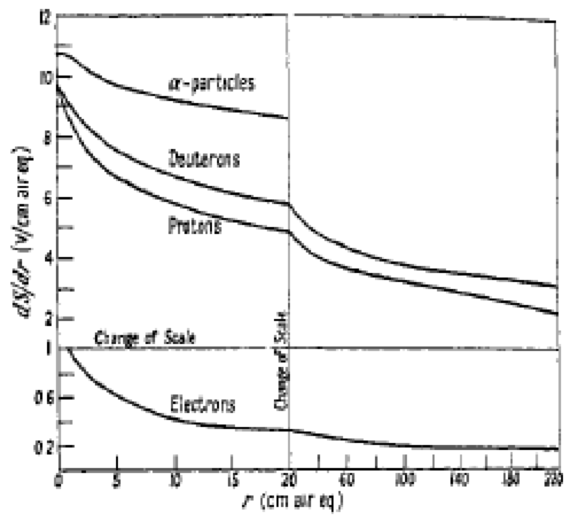

Figure 2. Specific fluorescence dS/dr plotted against residual range r for different particles in anthracene.

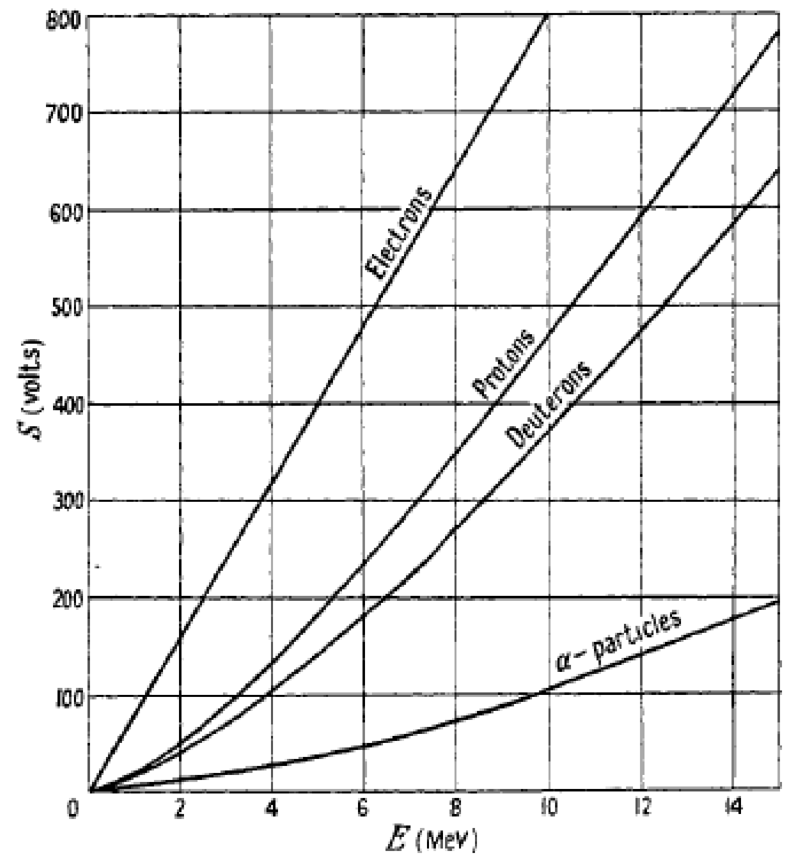

Figure 3. Relative scintillation response S of anthracene to particles of energy E.

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.