12 GeV Upgrade
Future Science at Jefferson Lab

EC and SPD Updates

The SoLID EC Working Group

SoLID Collaboration Meeting

October 13-14, 2017

Outline

1. Prototype shashlyk module overview, problem with PMT gain.
2. Cosmic test preliminary results on LASPD timing resolution
3. Progress on reproducing the Ecal simulation, mostly on pre-lead thickness (Ye/Syracuse); Note: from March and June meetings: Birk's effect and photoelectron statistics (March meeting) have to wait.
4. Brief progress on LASPD segmentation simulation
5. Not much progress to report this time on testing clear fiber attenuation (Chendi/THU) and fiber reflective coating ongoing (Chendi/THU + Cunfeng+Ang/SDU)
6. Preparation for CD0, CD1?

Shashlyk prototype and light yield overview

Proto-type	scintillator	lead	reflective layer	WLS fiber	WLS fiber end	module side	cosmic vertical test Npe	cosmic horizontal test Npe	PMT gain method
SDU1	Kedi original	US	printer paper	BCF91A	none	Tyvek → TiO2	224 → 254	48 → N/A**	SPE/SDU
SDU2	Kedi new	Chn	printer paper	BCF91A	Chn silver-plating	Tyvek → TiO2*	427 → 383*	83 → N/A**	SPE/SDU
SDU3	Kedi new	US	printer paper	Y11	Chn silver-plating	TiO2+glue (1/1)	491	107	SPE/SDU
THU1	Kedi original	Chn	mirror mylar (reflective)	Y11	Italian silver shine	TiO2 (Kedi)	430-470	96	not measured
THU2	Kedi new	Chn	powder paint (喷塑) (diffusive)	BCF91A	Italian silver shine	Tyvek wrapping (now)	748	90-103	SK/SP (Beijing Hamamatsu)

* TiO2 side-paint was not as good as SDU1 ** could not finish before shipping to JLab

Yields 500/200 layers for MIP → 1666 p.e./GeV electron, factor 2-3 lower than LHCb or ALICE → 833 p.e./GeV if using clear fibers → 3.5% in δE/E due to photoelectron statistics

SDU is planning to construct SDU4.

PMT Gain Puzzles

PMT gain method:

1) SPE/SDU: SPE determined at high HV, then use current to project to low HV – should be the most reliable (SDU PMT also have manufacturer's SK/SP data but not sure what base was used).

2) THU SK/SP: measured at Beijing Hamamatsu with the SK/SP ratio, base changed but was told base is "identical to" the one used for testing at THU.

3) THU took their PMT to Beijing IHEP and measured the SPE at high HV (with the same base), then calculate gain at low HV – found gain to be 2/3 of the SK/SP method. This means the vertical yield for SDU2 is ~1000 instead of 750 – factor two difference between SDU and THU for similar material construction

Ongoing effort:

1) SDU will take their PMT to Beijing IHEP for comparison of the two SPE facilities;

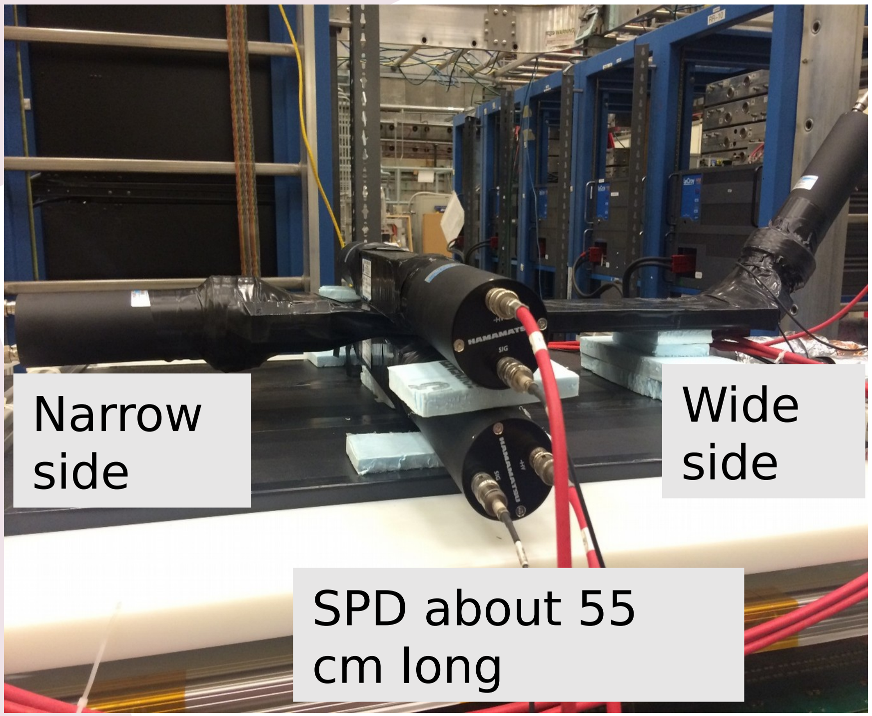
2) THU will take their PMT to SDU for comparison of the two SPE facilities;

3) Both need to do a thorough uncertainty analysis;

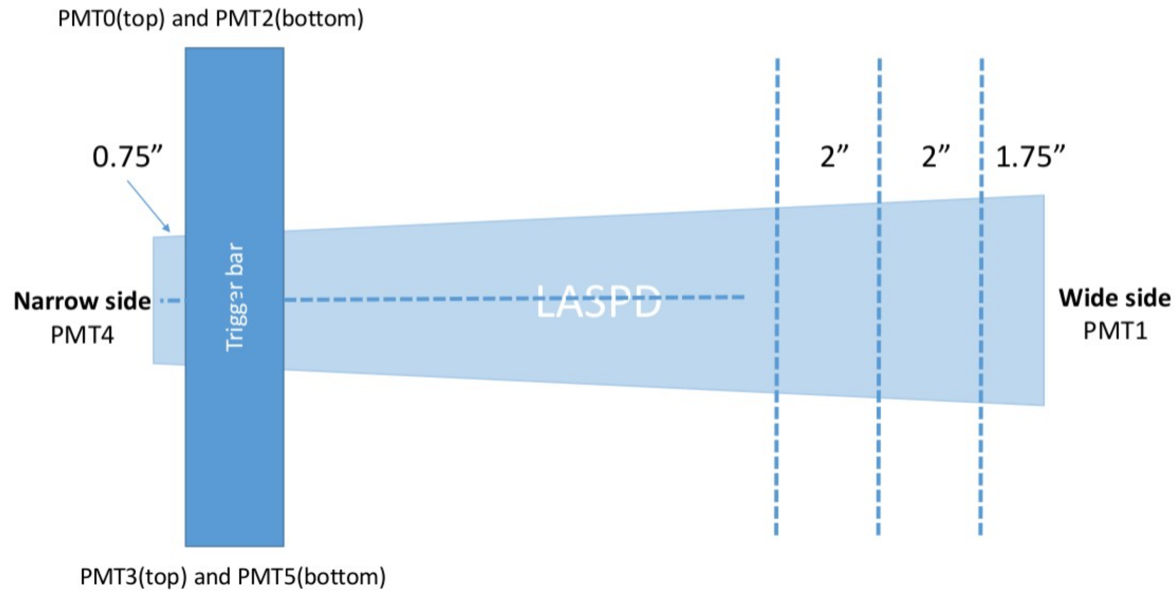
4) Would be good to see both SPE and main peak (horizontal test) but both SDU and THU do not have the proper PMT.

JLab Test Lab Cosmic Runs (Ye Tian/SDU + Jixie/UVa)

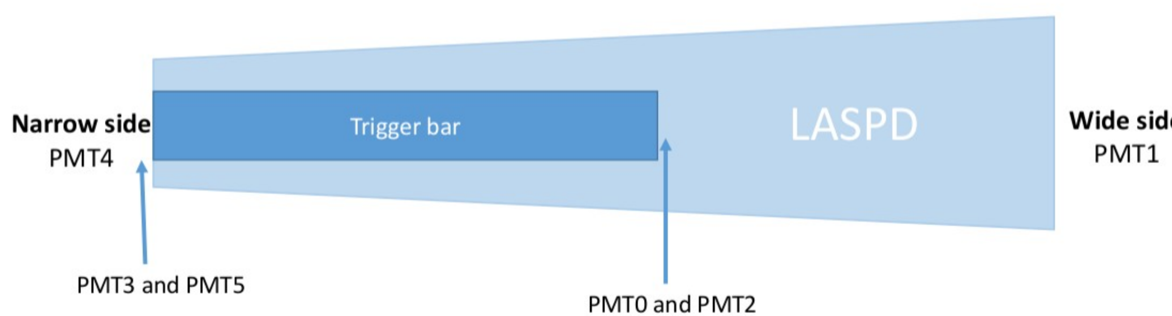
LASPD time resolution test



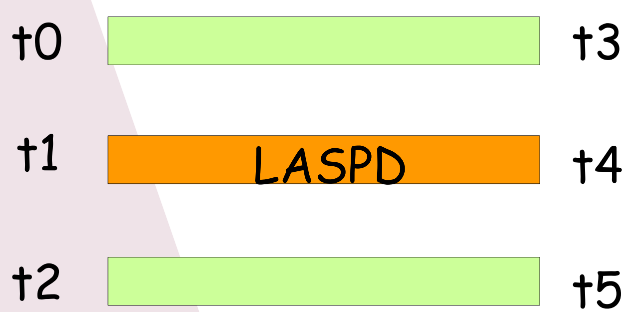
Test setup



Parallel test setup



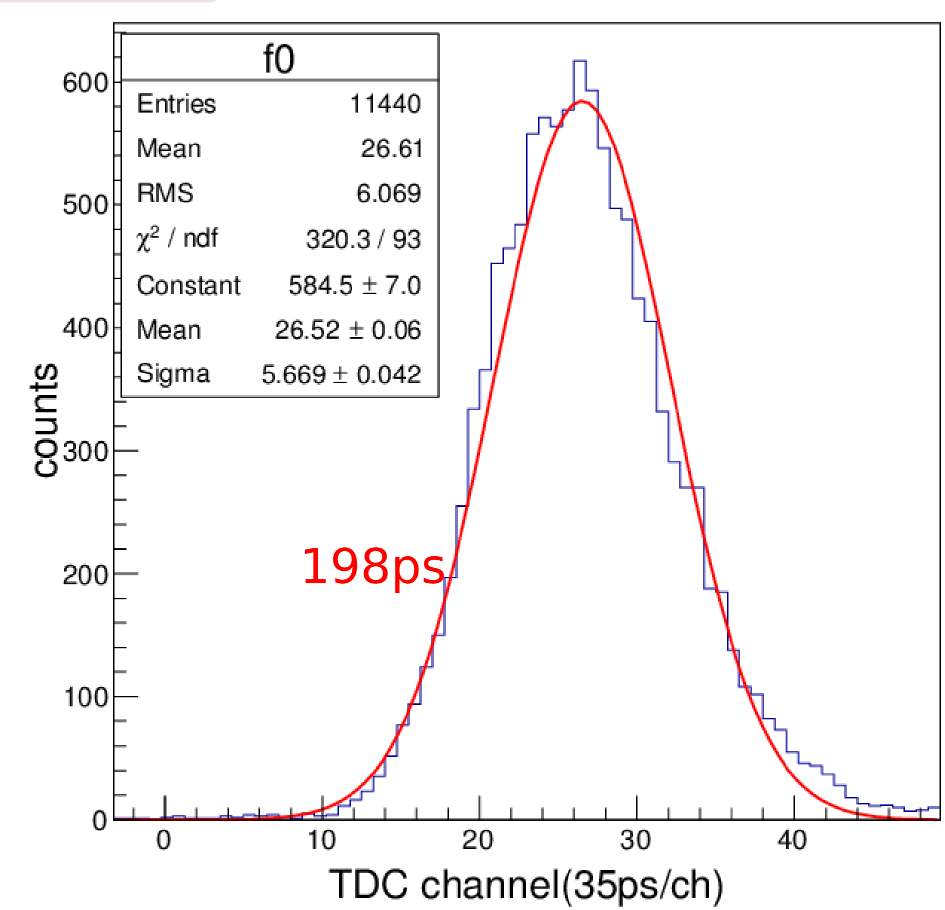
PMT labeling:



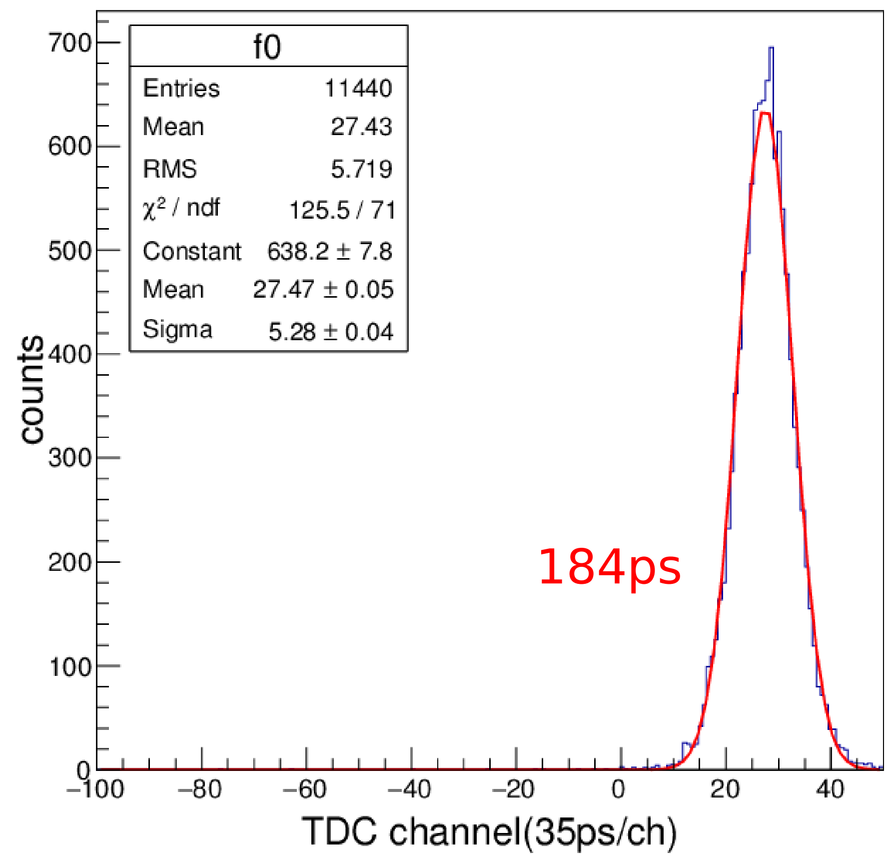
June meeting

No correction from GEM hit position yet. Trigger bars are 5cm wide

Readout from only the wide side:

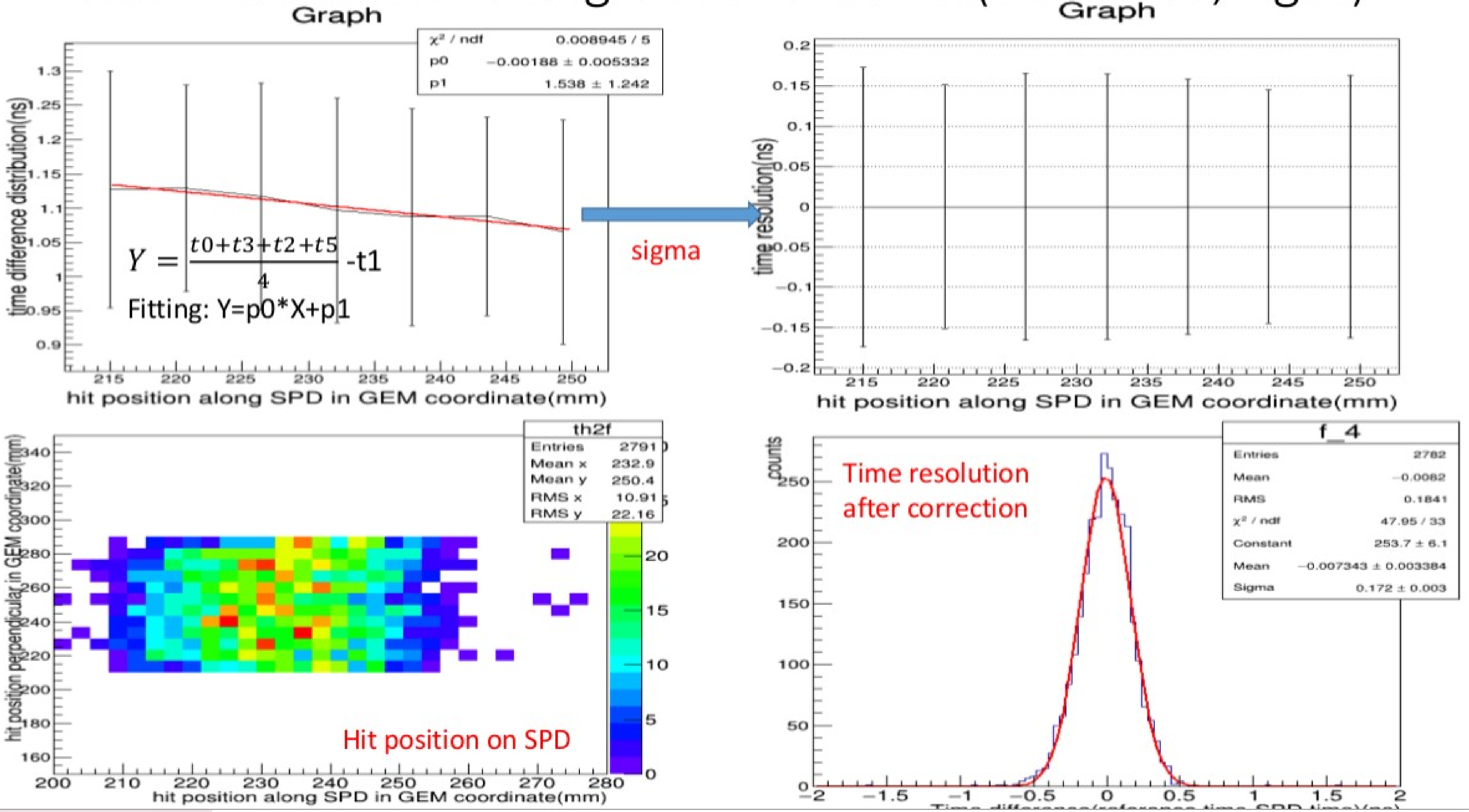


Readout from only the narrow side:



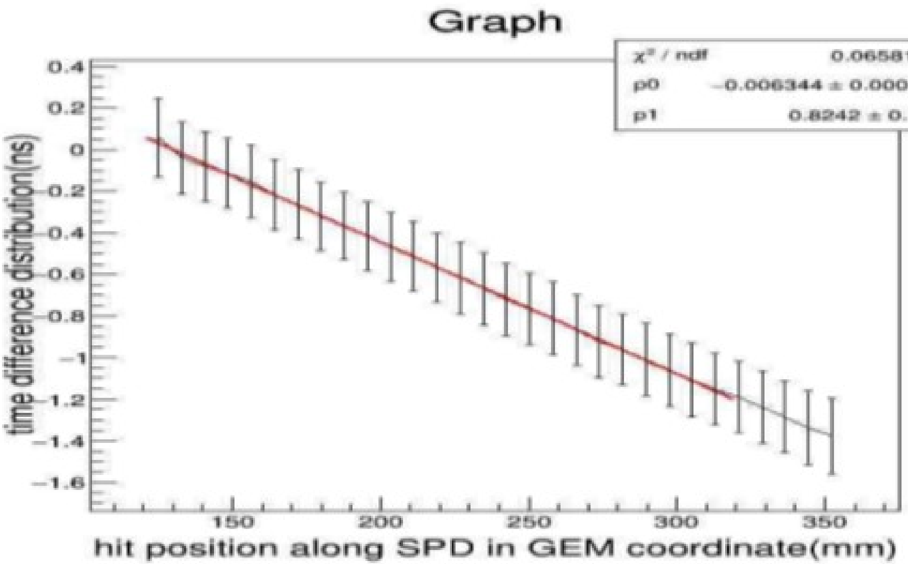
Now, with GEM x-binning and correction

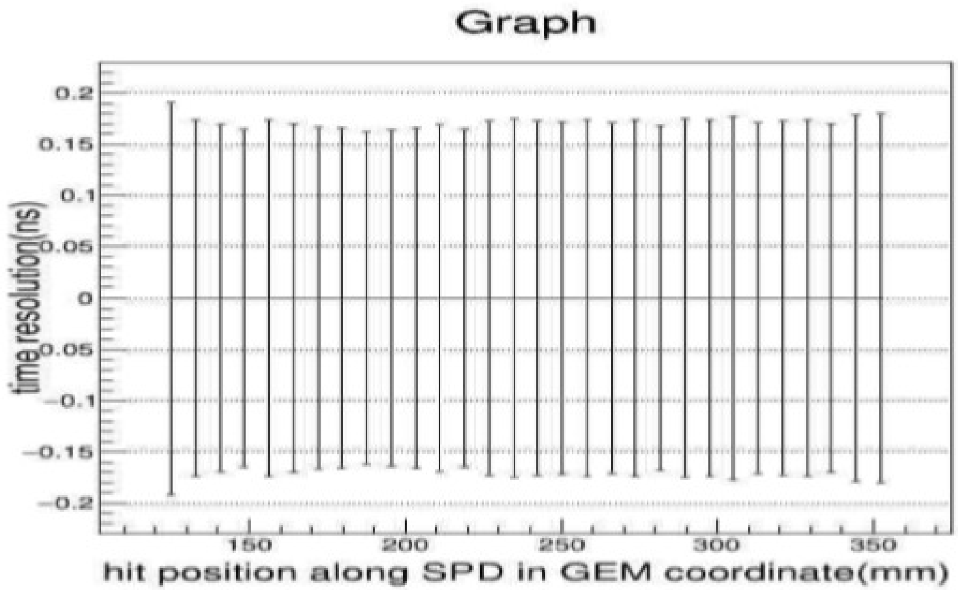
Time resolution of single PMT readout(wide side, right)

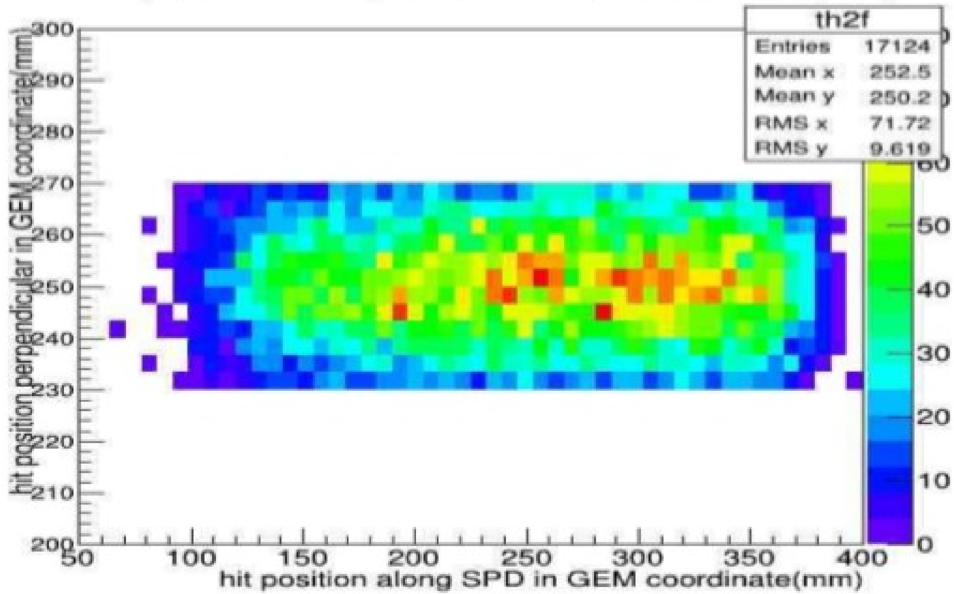


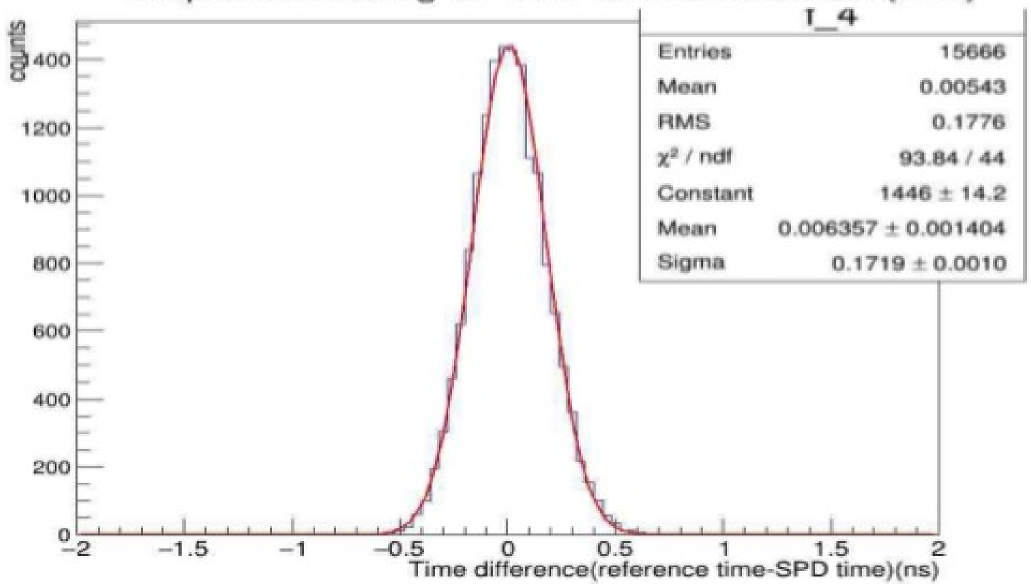
Now, with GEM x-binning and correction

Time resolution of single PMT readout(wide side)









JLab Test Lab Cosmic Runs (Ye Tian/SDU + Jixie/UVa)

- The timing resolution (t0+t3+t2+t5)/4-t4 was measured to be 184ps (see previous two slides) when reading out from the wide side with the event hitting the left-most side (similar to the SoLID condition). We take out the resolution of the trigger bars (82ps for each of the t0,t3,t2 and t5), the resolution for t4 is 170ps. Eventually this dominates the TOF for the LA particles (since the other timing for the coincidence is from MRPC which has a 60-80ps resolution depending on the rate, and is still been improved on) – note: SIDIS requires 150ps.

- More timing analysis is still going on. It was found cutting on y position may improve timing.

- Also need to determine/check THU1 light yield for the horizontal position, with SDU's PMT (for which gain was determined with the SDU/SPE method).

- Will be good to measure LASPD's light yield, but this also need to know the PMT gain and thus the SDU PMT.

ECal Simulation

- Last meeting (June), found huge effect of prelead thickness on energy resolution. What's the effect on PID?

ECAL Energy Resolution Dependence Table

e^- beam no field	polar angle (o)	1GeV σE/E (σ/μ)%	2GeV σE/E(σ/μ)%	5GeV σE/E (σ/μ) %
1748 modules pre-lead+Al 2 X_0	0	5.87±0.046	3.74±0.028	2.19±0.017
	10	5.96±0.046	3.77±0.030	2.24±0.017
	20	6.11±0.048	3.85±0.03	2.25±0.017
	35	7.38±0.058	4.70±0.039	2.56±0.019
1748 modules no pre-lead (PVDIS)	0	3.98±0.029	2.91±0.021	1.94±0.022
	10	4.00±0.029	2.90±0.025	1.95±0.021
	20	3.98±0.029	2.87±0.021	1.93±0.015
	35	4.03±0.029	2.89±0.020	1.92±0.014

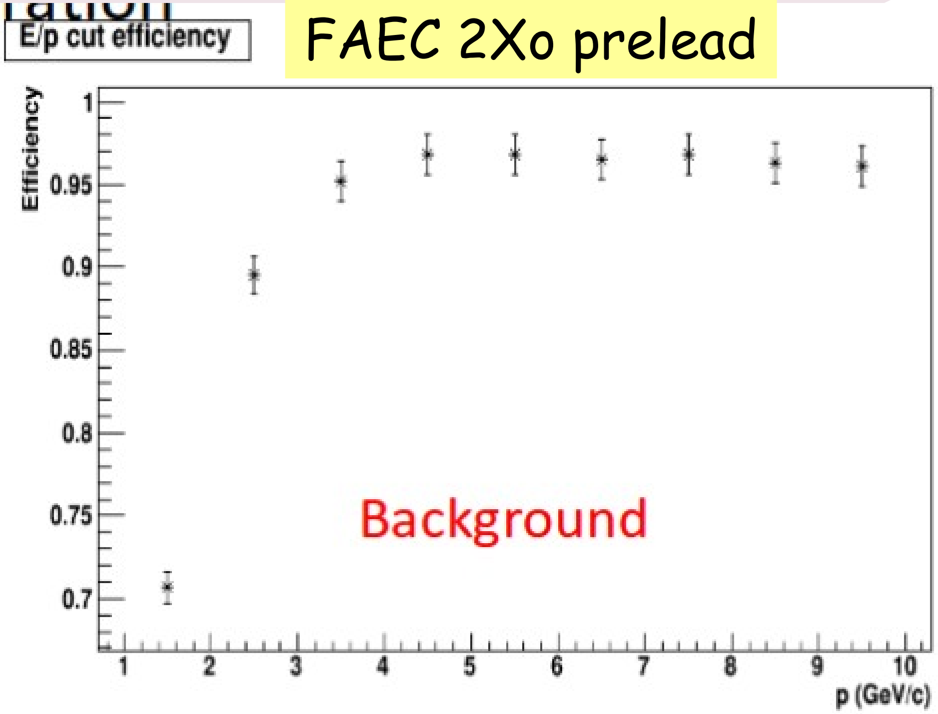
26% worse

- Without the pre-lead, the ECAL energy resolution is independent of the beam polar angle. With $2X_0$ pre-lead, the energy resolution is worse for larger polar angle.

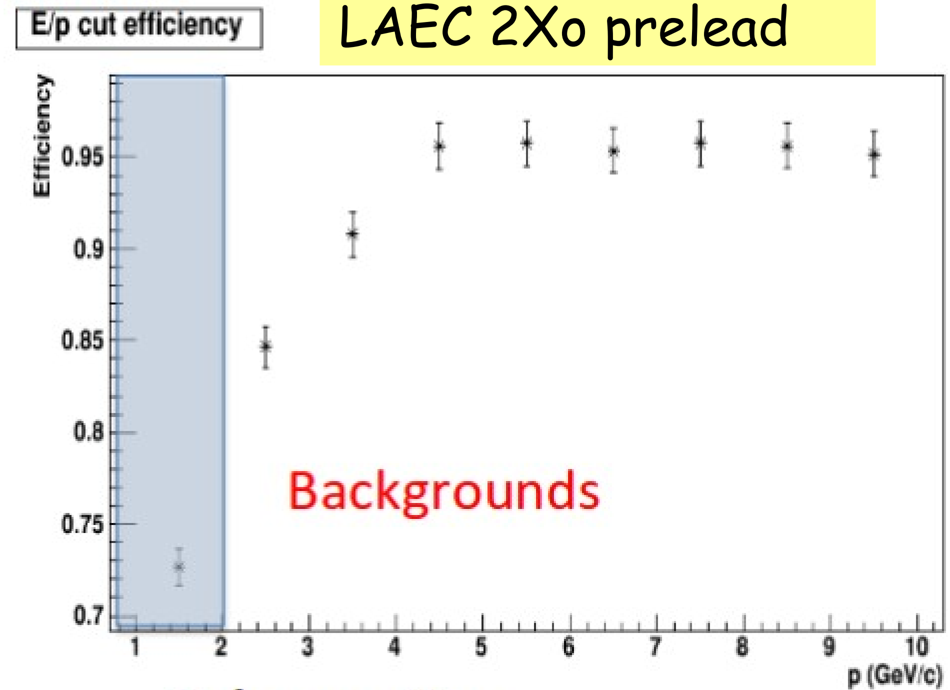
e^- beam no field	Polar angle (o)	1GeV $\sigma E/E$ (σ/μ)%	2GeV $\sigma E/E(\sigma/\mu)$%	5GeV $\sigma E/E$ (σ/μ) %
1748 modules pr-elead $1.5X_0$	0	4.83±0.036	3.21±0.024	1.99±0.015
	10	4.88±0.038	3.29±0.024	2.03±0.015
	20	5.09±0.038	3.33±0.024	2.04±0.016
	35	5.84±0.044	3.74±0.028	2.16±0.016
1748 modules pre-lead $1.0\ X_0$	0	4.33±0.031	3.03±0.023	1.92±0.015
	10	4.34±0.032	3.05±0.023	1.928±0.015
	20	4.43±0.033	3.03±0.023	1.93±0.014
	35	4.68±0.036	3.19±0.024	1.96±0.014
1748 modules pre-lead $0.5X_0$	0	4.09±0.030	2.94±0.024	1.93±0.015
	10	4.15±0.031	2.95±0.023	1.94±0.022
	20	4.15±0.031	2.94±0.022	1.94±0.022
	35	4.29±0.031	3.00±0.022	1.95±0.015

- Simulate pre-lead width $0.5X_0$, $1.0X_0$, $1.5X_0$, and $2.0X_0$, the ECAL energy resolution is worse for the large polar angle, which is more pronounced by increasing the pre-lead width especially in the low energy region (1 GeV).

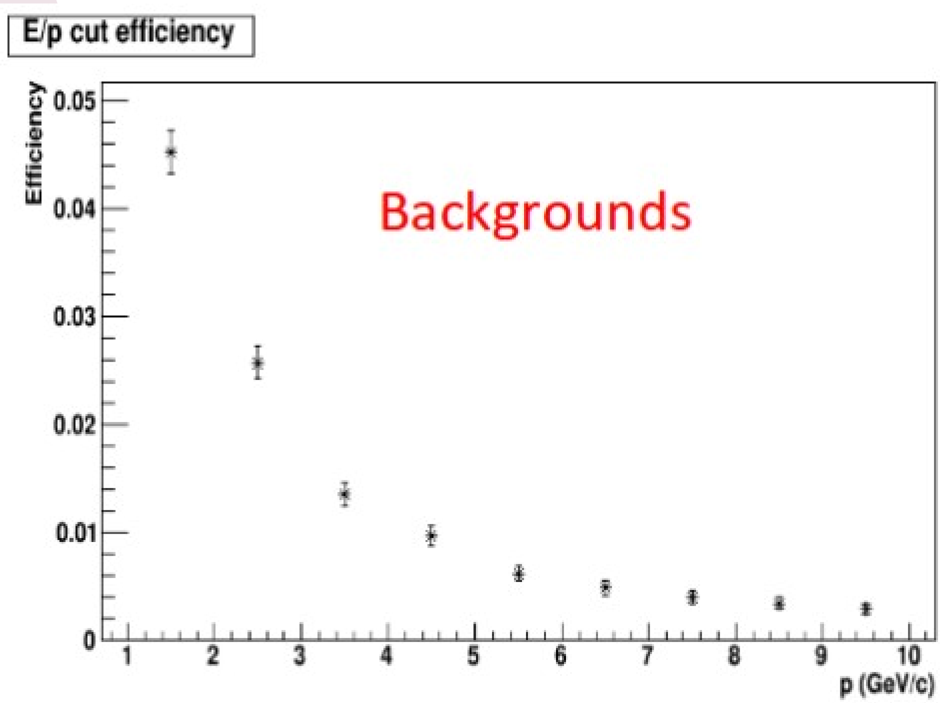
FAEC 2Xo prelead

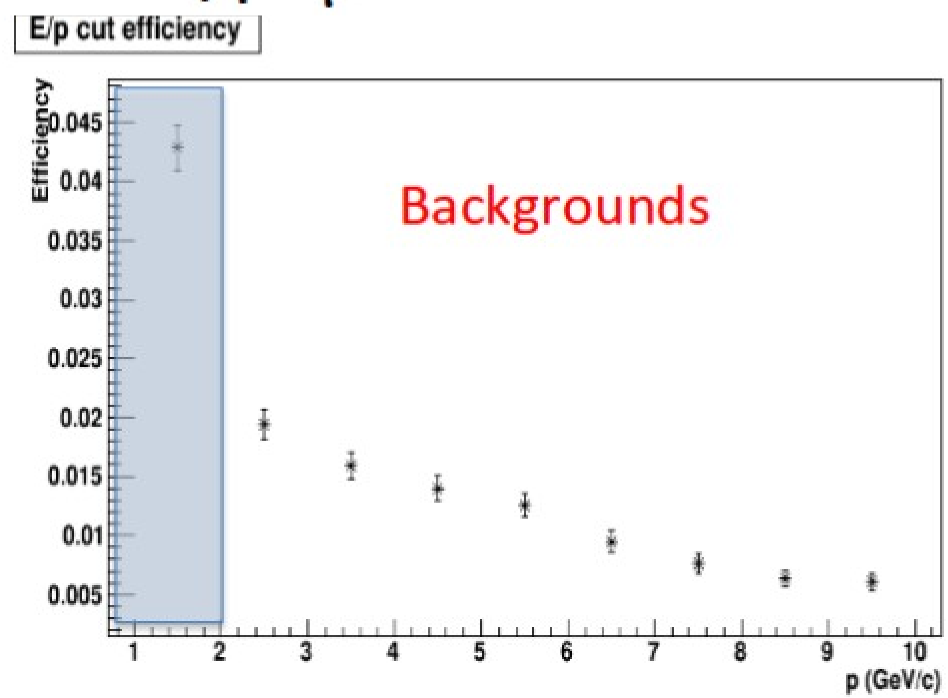


LAEC 2Xo prelead



$E/p>\mu-3\sigma$





PID Performance Summary

- Without background contribution, PID performance (e/π− separation) from both FAEC and LAEC are little better than the PrecDR results (by ignoring the edge effect)

- By including the edge effect, the PID performance will be 10%-15% worse than that without the edge effect.

- With background contribution, PID performance from both FAEC and LAEC are worse than PrecDR results.

  >50:1 π- rejection at 95% e efficiency for p>2GeV/C (FAEC)
  22:1 π- rejection at 70% e efficiency for 1<p<2 GeV/C (FAEC)
  >50:1 π- rejection at 96% e efficiency for p>4GeV/C and 85%-90% for 2GeV<p<4GeV (LAEC $\theta[18^o,22^o]$)

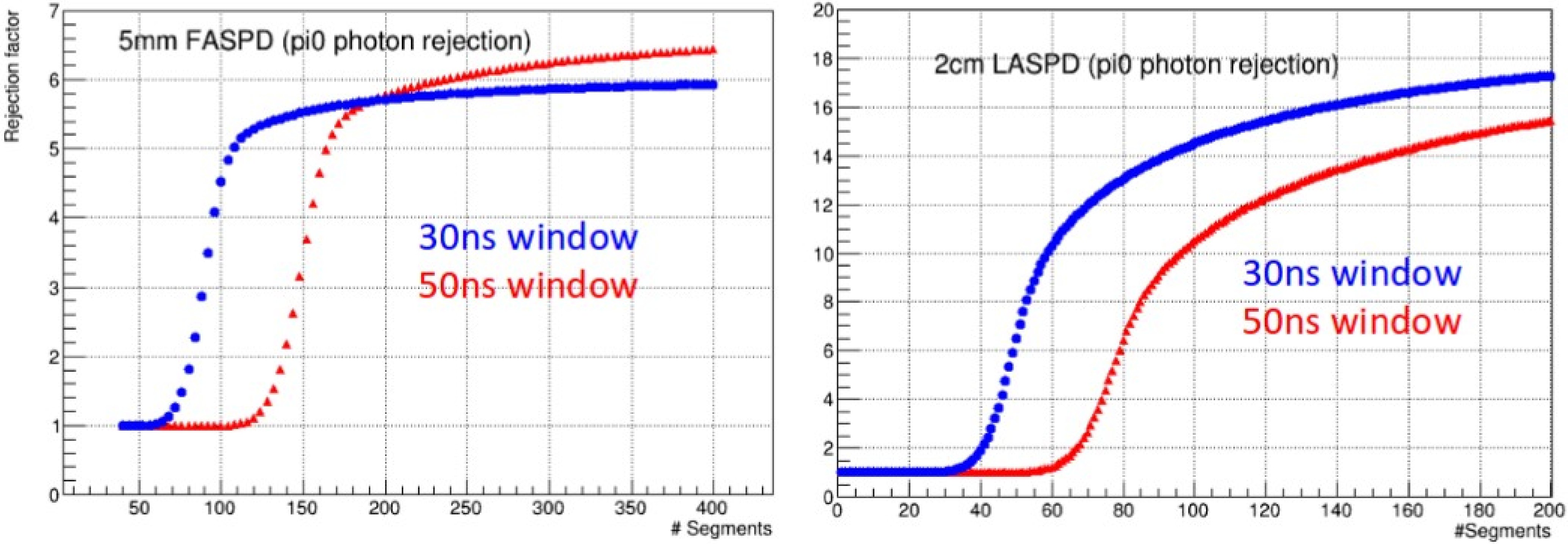
Background study is ongoing !

1. Now doing trigger simulation with backgrounds
2. Should we do PVDIS PID simulation?
3. still need to add Birk effect, Nphe statistics, etc. Will Birk effect improve pion PID?

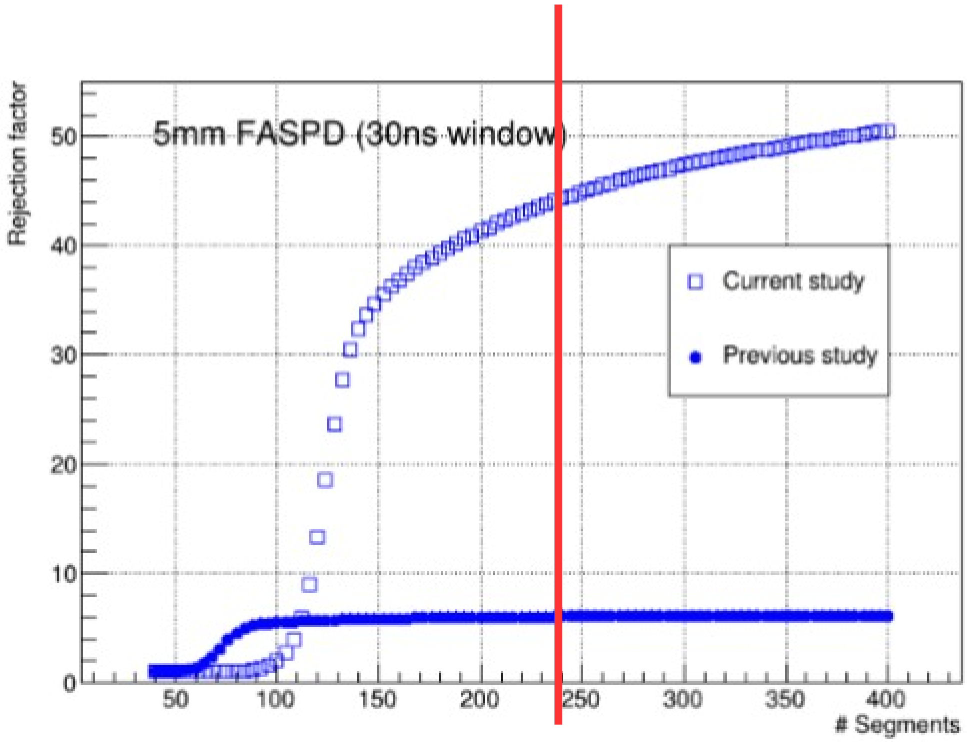
LASPD Simulation

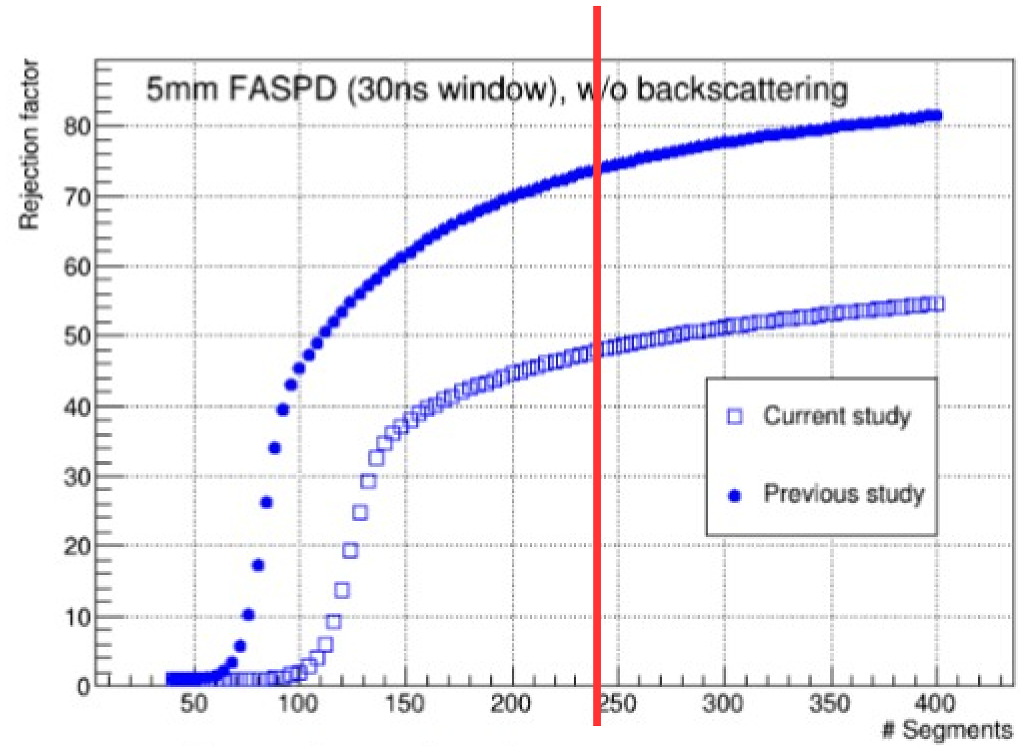
Zhihong's scan result

- plot using text output files from Zhihong's study
- Rejection factor = Total events / (total Edep> cut)



FASPD (30ns), Cut=0.86/2





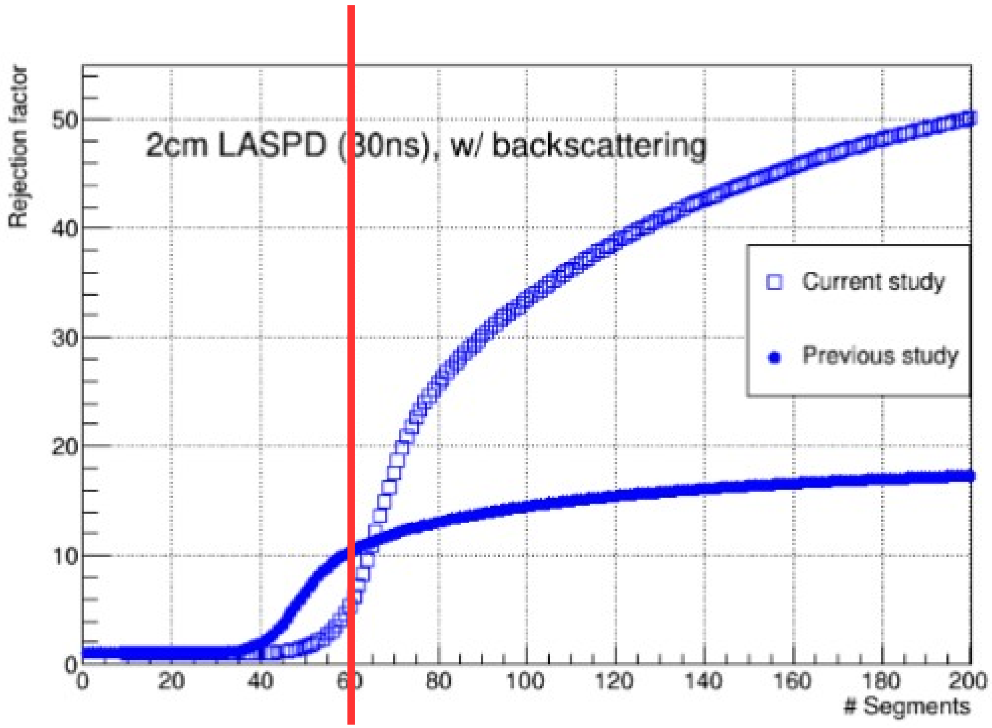
↑ with backscattering contribution added.

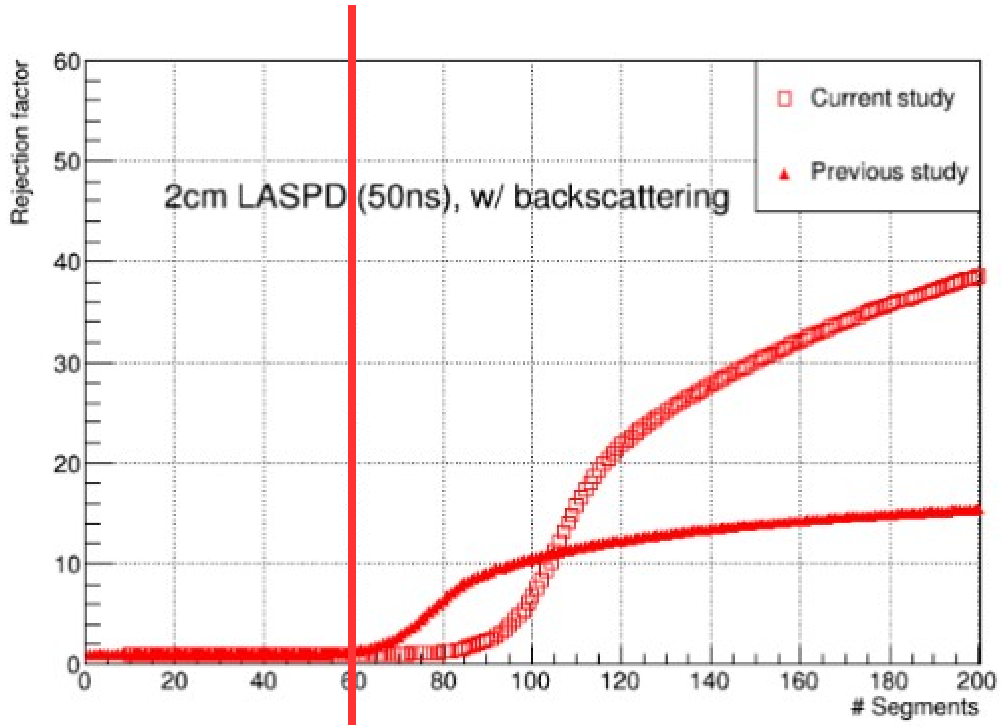
↑ without backscattering contribution added.

total Edep = Edep_forward + EMBG/#Segments + Edep_back

turn-on point is also quite different

LASPD, Cut = 3.82/2





1. Looks like x60 azimuthal segmentation is no longer good enough. We need 120 segmentations. – challenges: higher cost; smaller side for readout (lower light yield?); very tight room if doubling need of light guides and FMPMTs.

Preparation for CD0 and CD1

1. Continue shashlyk prototyping (SDU, THU), figure out the gain puzzle.
2. Continue cosmic test and analysis – finalize LASPD timing data; determine light yield of LASPD; determine relative yield of THU1 module;
3. Continue LASPD simulation, if confirming more segmentation is needed, need to test new prototype.

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4. Continue clear fiber test – previously only THU, but SDU will also start;
5. Continue simulation on triggering, then proceed to other aspects (Birk effect, photon statistics, photon collection, etc.)
6. Need to fully understand shashlyk data from Hall A test, then plan for a full-cluster beam test (Fermilab or Beijing)
7. Support design from ANL has been suspended for a while due to budget issues

(From March meeting: LHCb will dismount their preshower in 2019, (in Dec 2016) asked us if we are interested.)

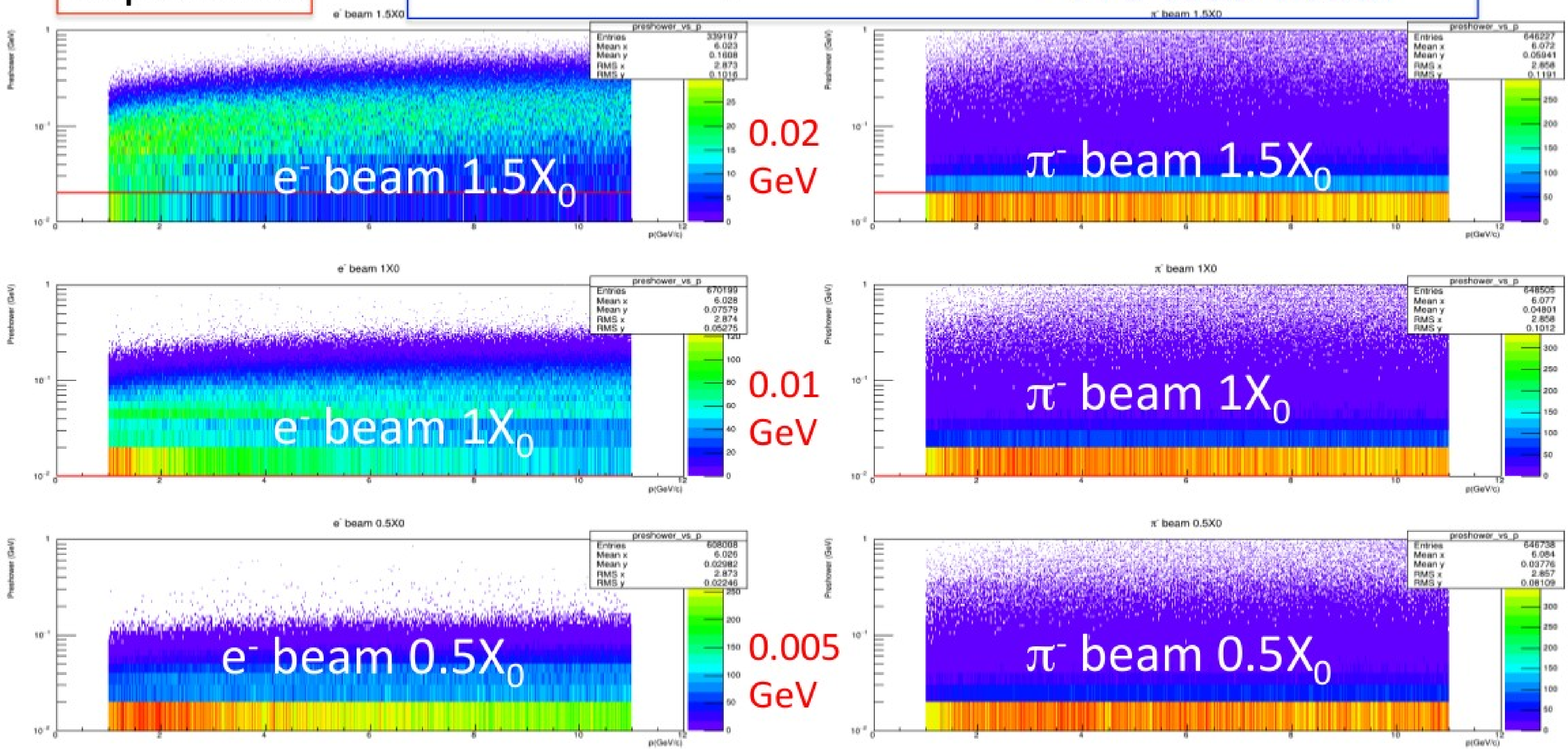
ECal + SPD cost estimate (June 2017)

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) +US $40k lead (material only)
Preshower	$280,800 (1800 modules Russian IHEP)	
SPD (Eljen)	FA: $54,900; LA: $34,680	FA: $58,620 LA: $37,440
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 128 units of MAPMT base/preamp at $200 each(?) → $825k?
Fiber (Saint Gobain)	$700k (~$1/m, 200kmWLS, 520km clear)	$996.5k ($1.8/m WLS 192km, $1.25m clear 520km)
Fiber (Kuraray)	$64k ($2/m 23.5km clear, $3.2/m 6800m WLS)	$82,281 ($4.67/m WLS 6.8km; $2.15/m clear 23.5km)
Fiber connectors	$365k	$420k (incl. 5% spare)
Total	$6,411k	$6,455k

SIDIS PID performance with pre-lead width

e^-/π^- separation

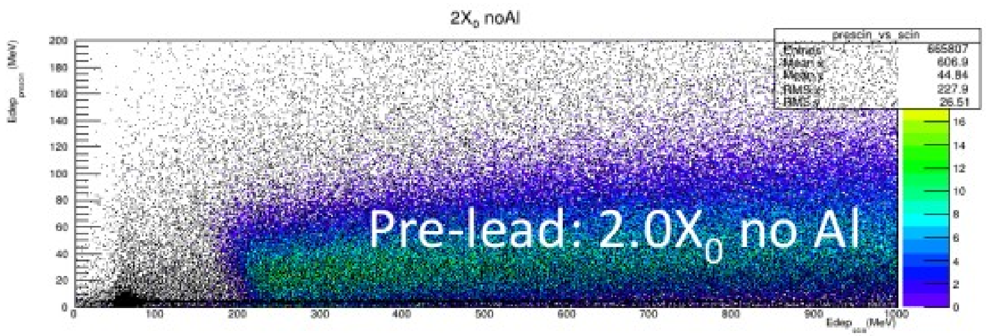
- E_{total}/p cut
- Preshower deposit E cut → Pre-lead width

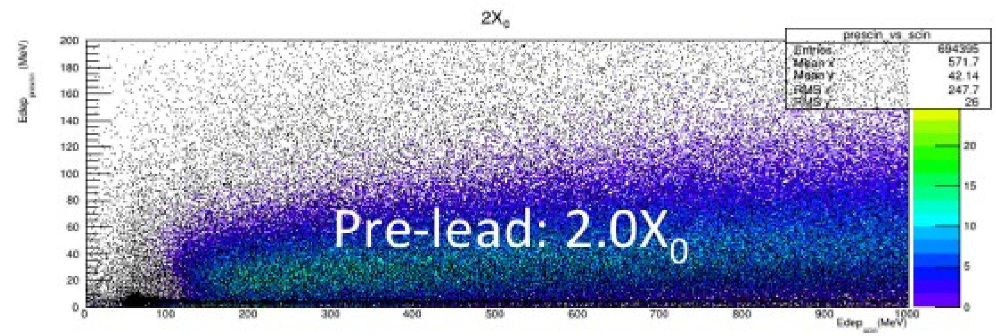


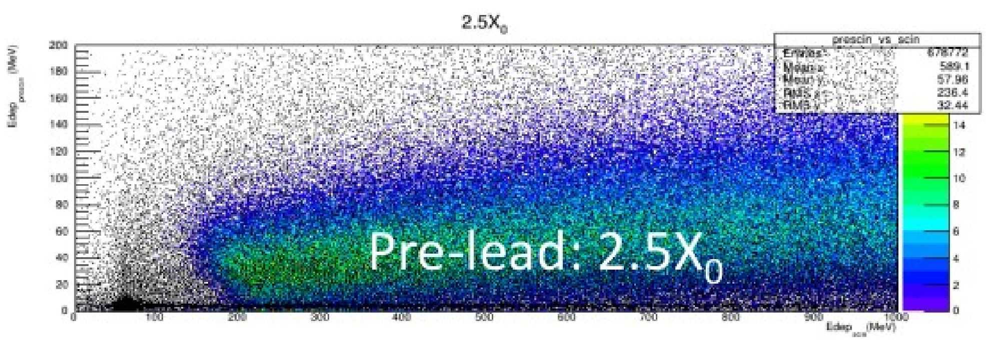
0-11 GeV e- beam, θe [7.5°,14.85°] Calibrated preshower deposit energy Cuts

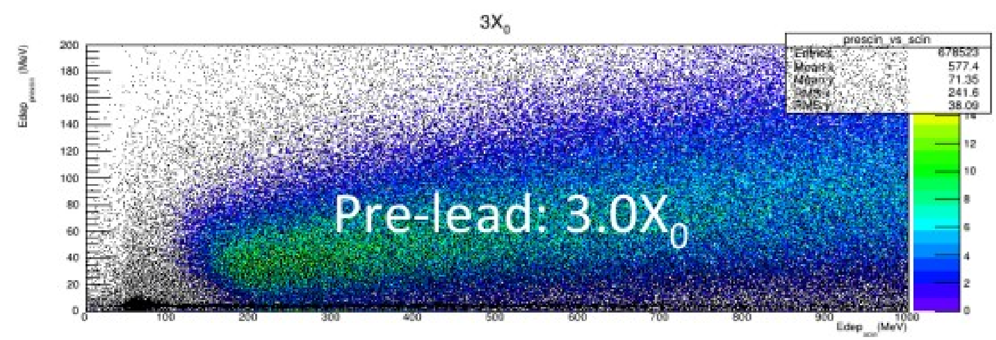
In order to maximize π^- rejection, the pre-lead width should be $>1.5X_0$ to get better e^-/π^-separation with the off-line PID cuts.

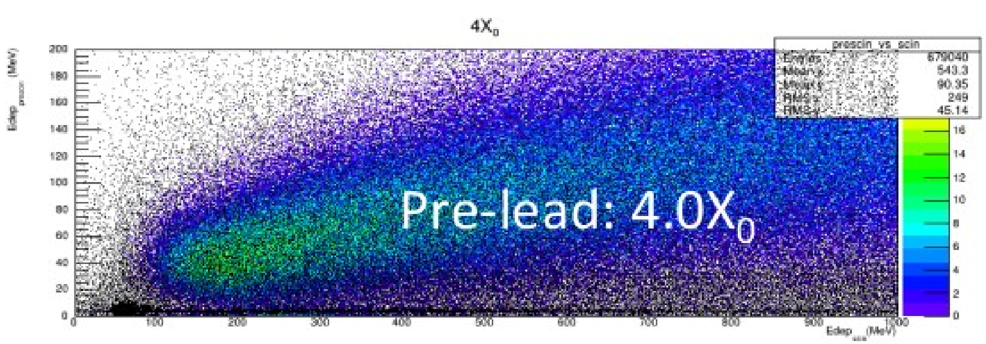
- In order to study the dependence of π^- rejection on the pre-lead width, $2.0X_0$, $2.5X_0$, $3.0X_0$, and $4X_0$ pre-lead width with SIDIS configuration are simulated. For low momentum bins (1-3 GeV), by keeping the e^- efficiency to be >95%, the goal of π^- rejection 1:50 can not be achieved even by increasing the pre-lead width to $4X_0$. So pre-leads width $2.0X_0$ is the compromise selection.











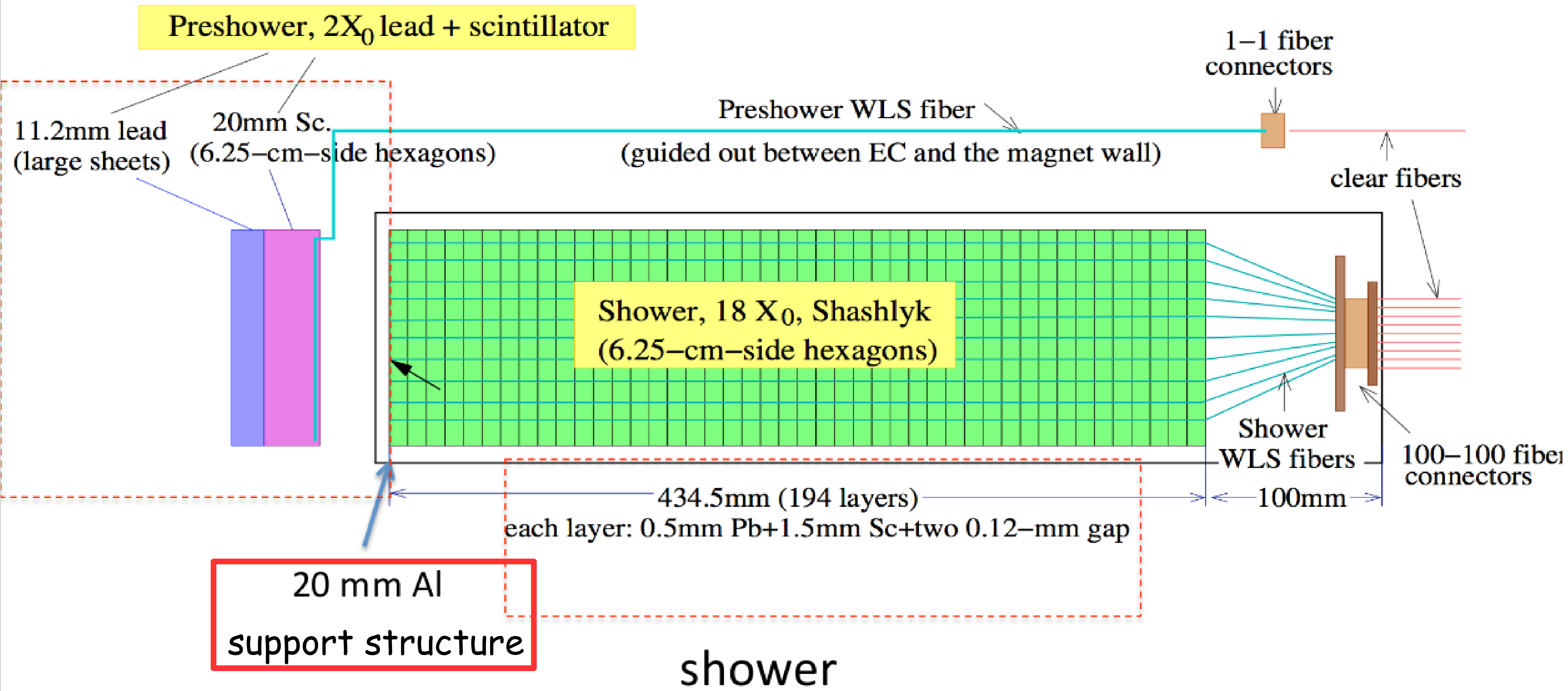
Y: Preshower scintillator deposited energy

X: Shower scintillator deposited energy

Black: π^- Color: e^-

Ecal Simulation (Ye Tian/Syracuse)

Preshower+ Al



1. Ye is using the following function to fit simulation: $\frac{\delta E}{E} = \frac{p_0}{\sqrt{E}} \oplus p_1 \oplus \frac{p_2}{E}$