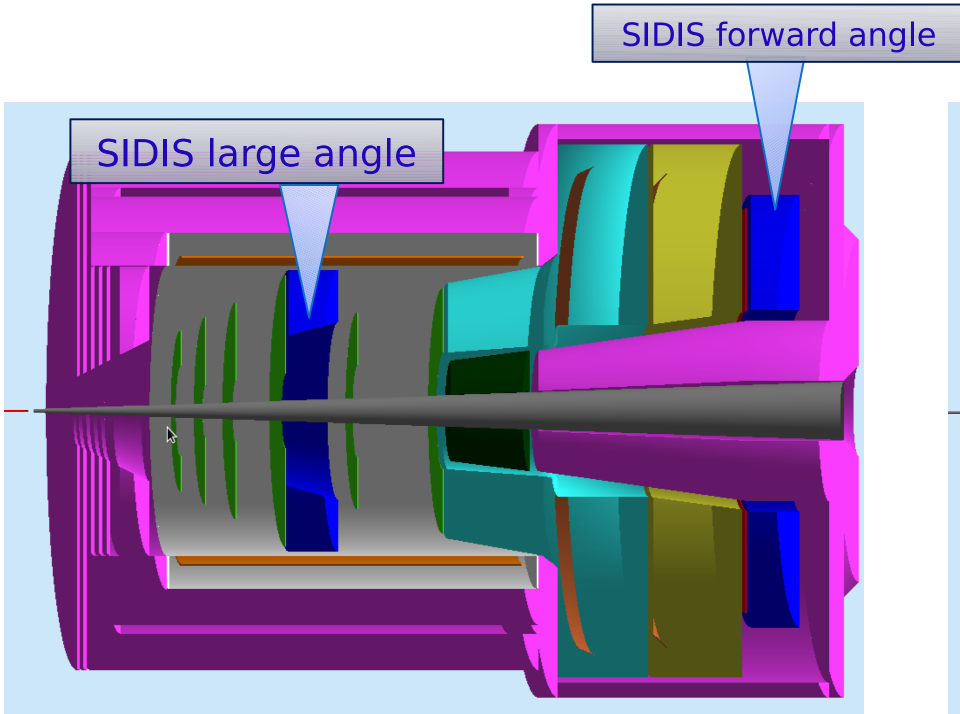
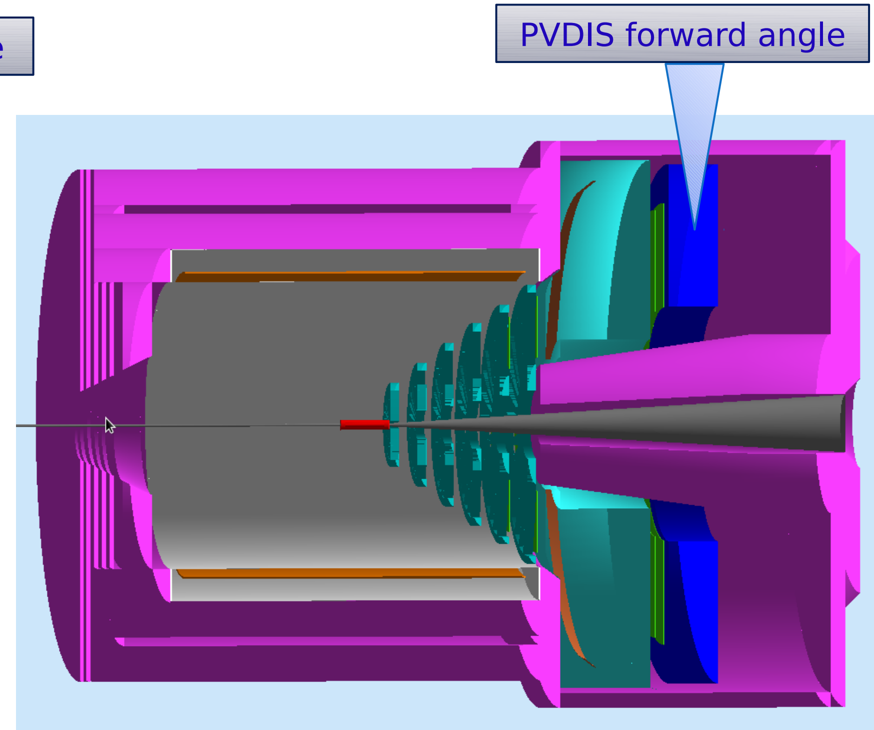
Update on EM Calorimeters

Calorimeter Group

Jefferson Lab

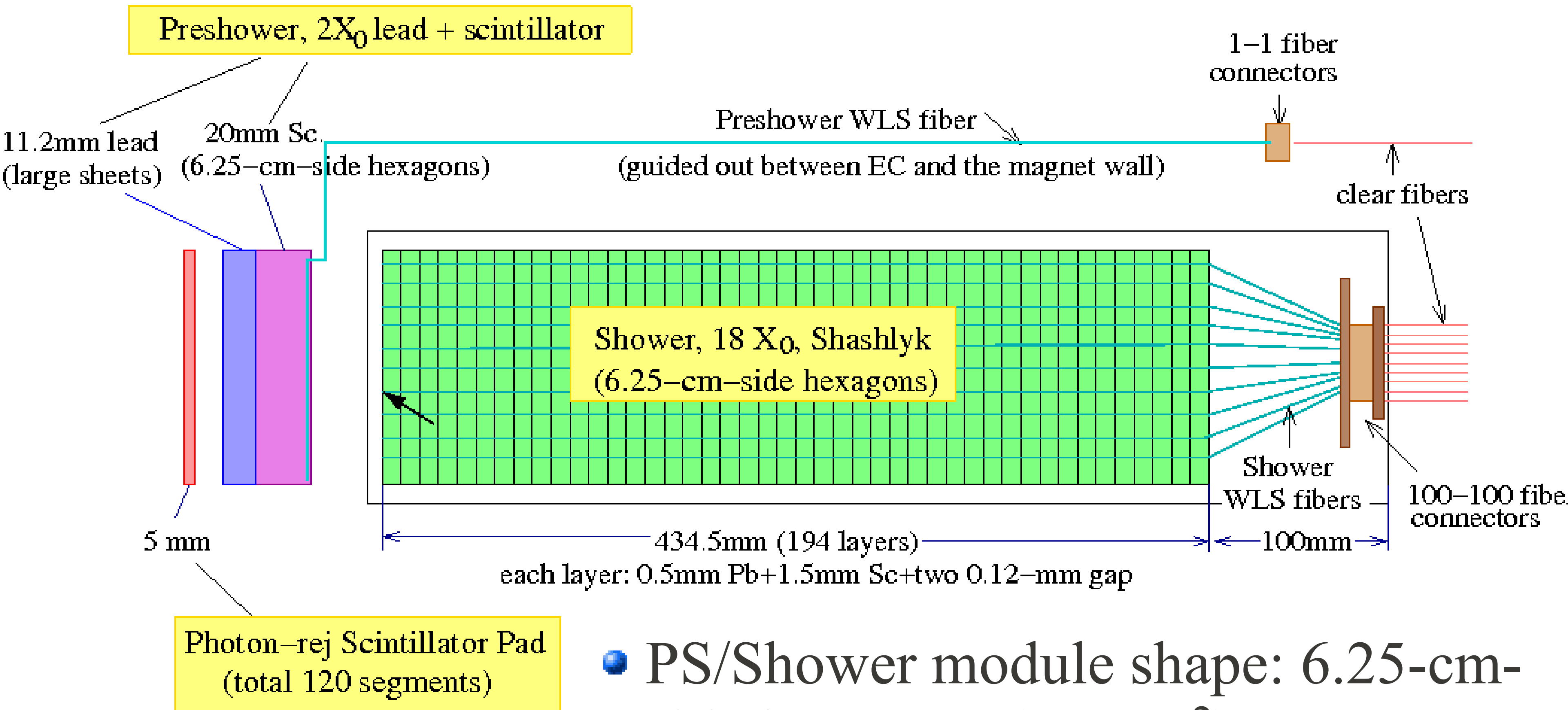
SoLID EM Calorimeter Overview





SoLID EM Calorimeters	Polar Angle (degree)	P (GeV / c)	Max π / e	Cerenkov Coverage	Area (m^2)
PVDIS Forward-Angle	22 - 35	2.3 – 6	~ 200	<3-4 GeV/c	~17
SIDIS Forward-Angle	8-15	1 -7	~ 200	<4.7 GeV/c	~11
SIDIS Large-Angle	17-24	3 - 6	~20	None	~5

Module Design @ last meeting

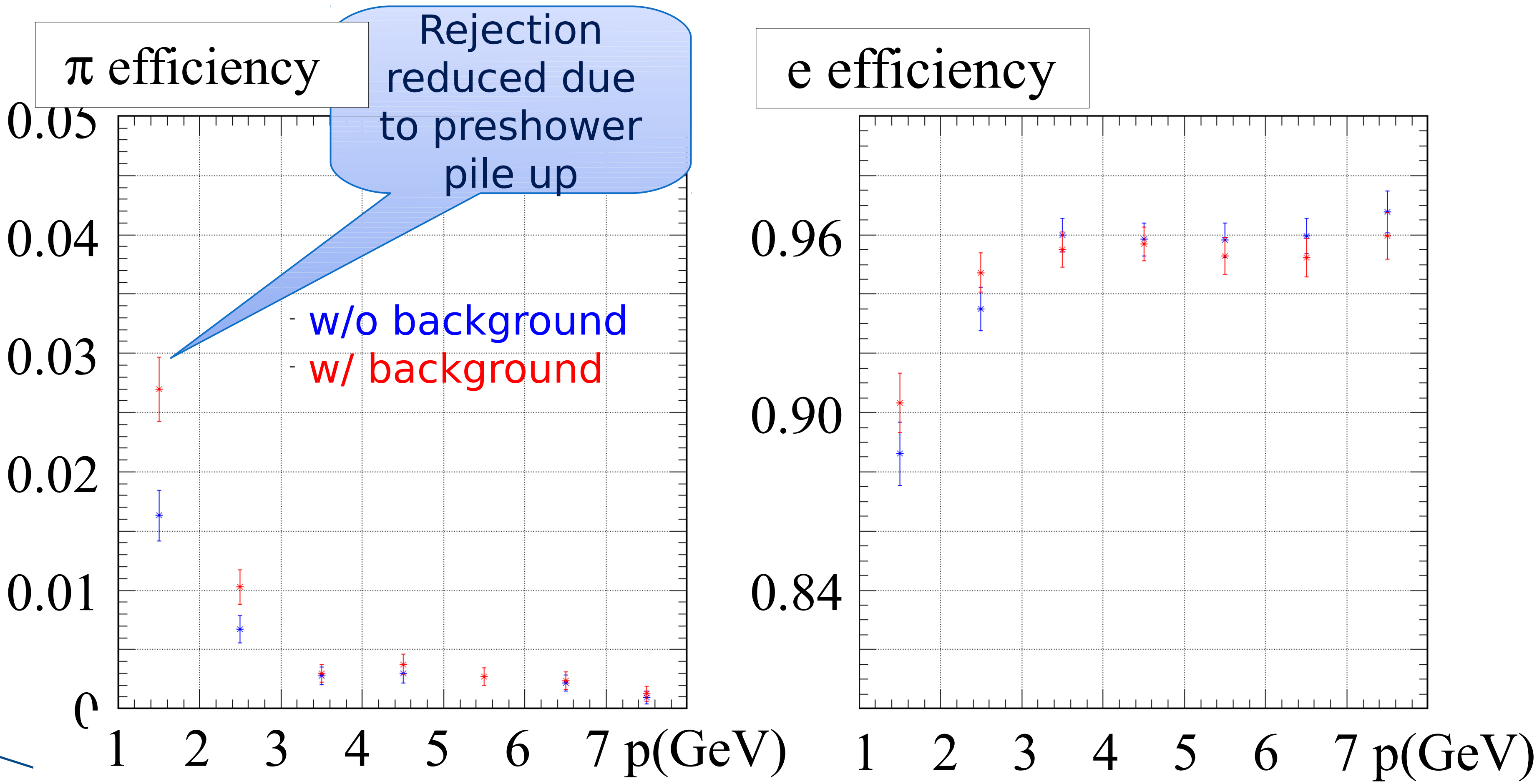


- PS/Shower module shape: 6.25-cm-side hexagons (100cm^2)
- SPD: only basic design for SIDIS LAEC, no detailed segmentation

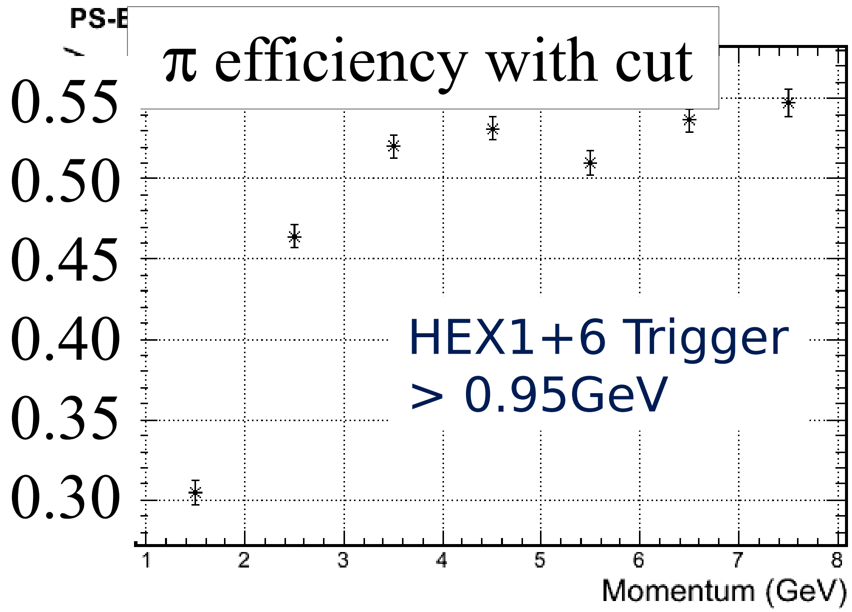
Updates since last meeting

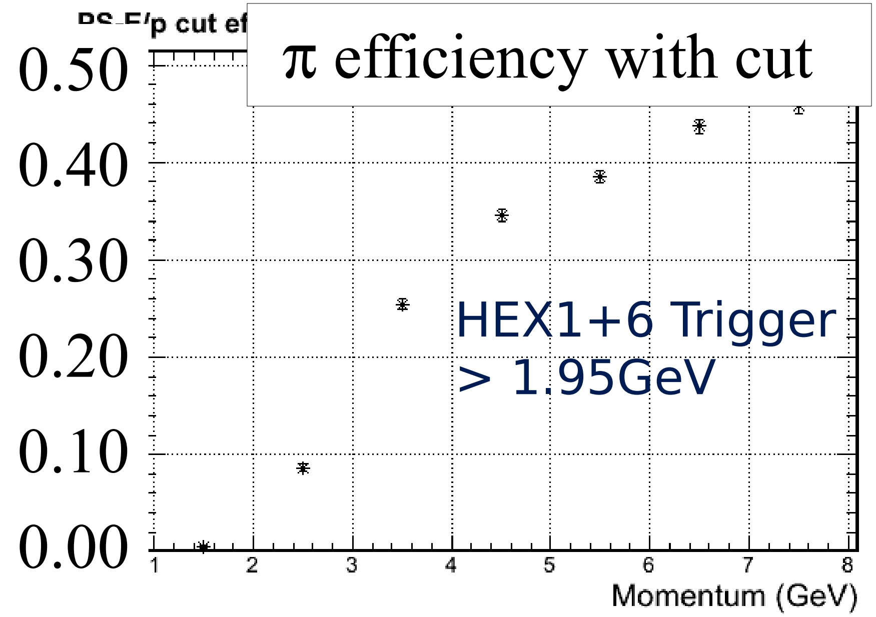
- Last time reported SPD, PID&trigger results for SIDIS FAEC including background. Today:
  - SPD for SIDIS FAEC: 60 azimuthal, 2 radial (85 → 127cm, 127 → 240cm), providing 5:1 γ rej
  - SIDIS LAEC performance w/ SPD;
  - PVDIS: there have been several background updates (see baffle talk), PID and trigger performance with the latest baffle design;
  - PVDIS EC performance impact on DAQ.
- Considering Multi-Anode PMT for Preshower and SPD
- Updates on total EC cost estimate

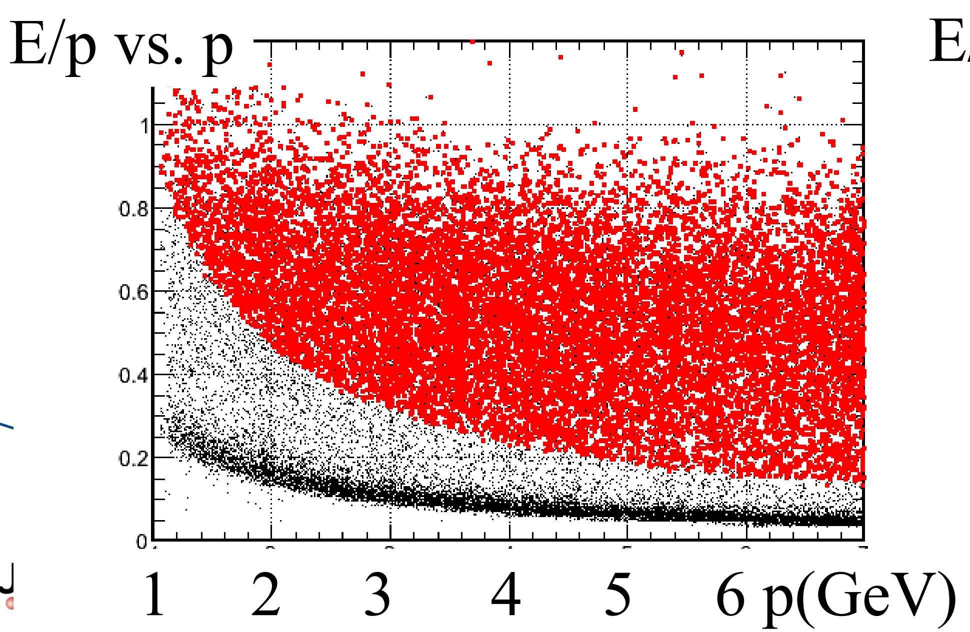
March meeting – SIDIS FAEC PID w/ background

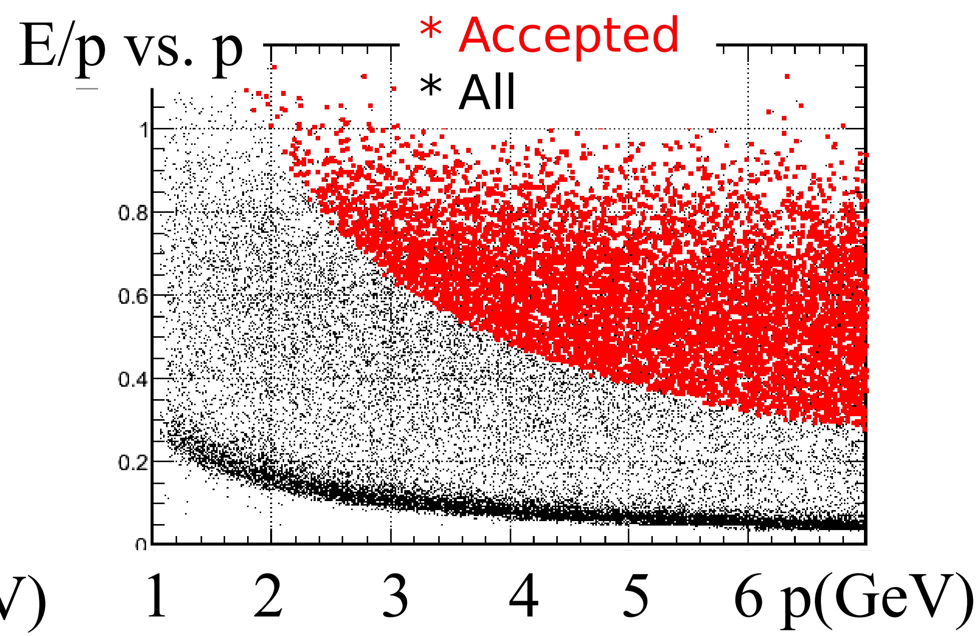


March meeting – SIDIS FAEC Trigger w/ background



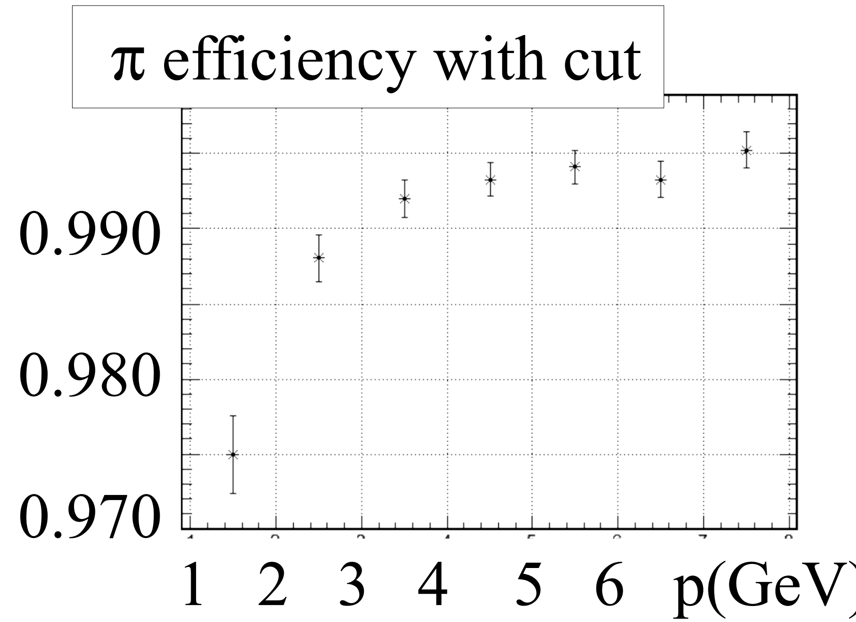


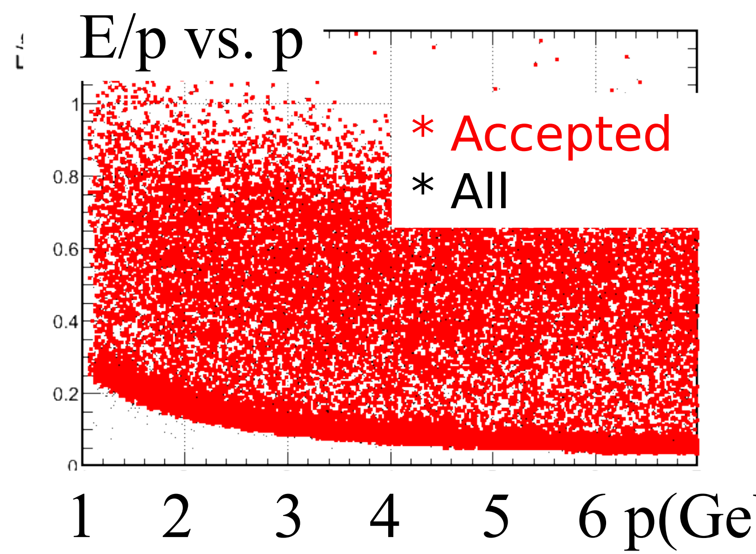




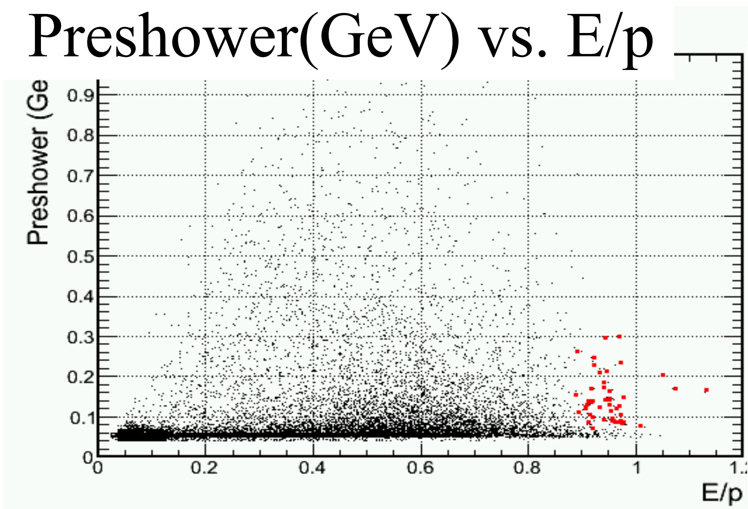
March meeting – Hexagon Calorimeter Pion Trigger Efficiency

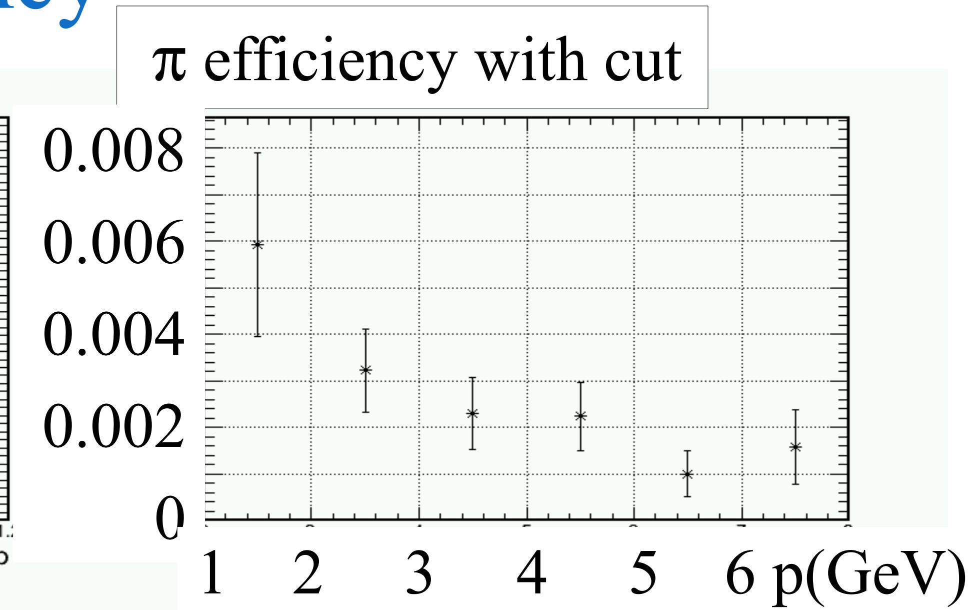
- Trigger cut: HEX1+6 trigger raw signal > 85% MIP (which is MIP – 2σ = 220MeV calibrated)
- Background passes this cut: rate ~20MHz, dominated by photon.
- With a 5:1 photon suppression from SPD, we get ~4MHz total trigger rate, which fit in the DAQ limit (PR12-10-006)
- Will join global DAQ study for final verification

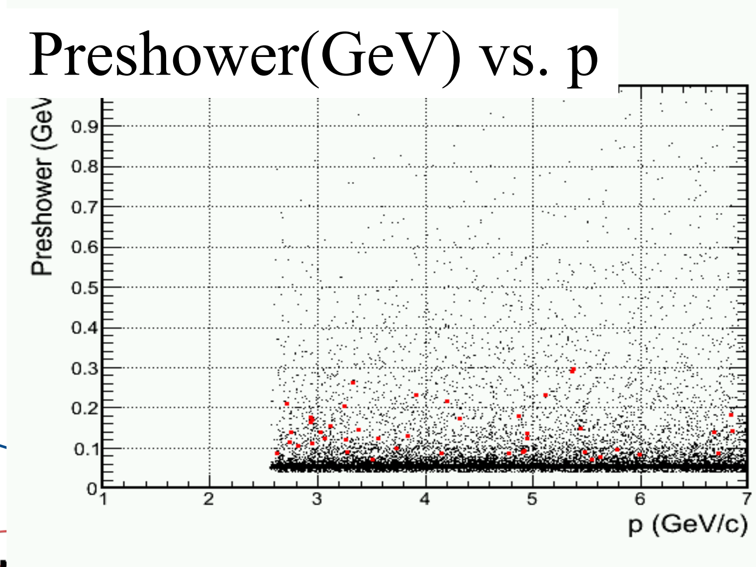


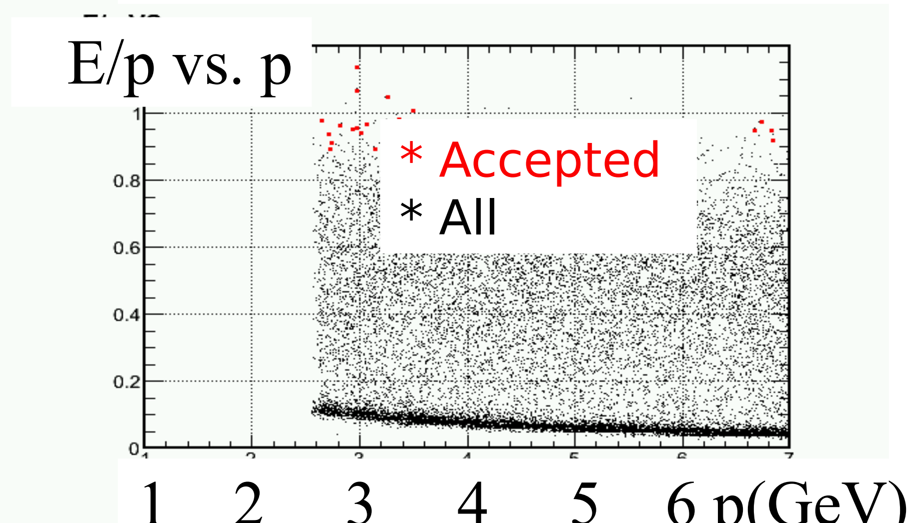


SIDIS LAEC PID without background @ 94% electron efficiency



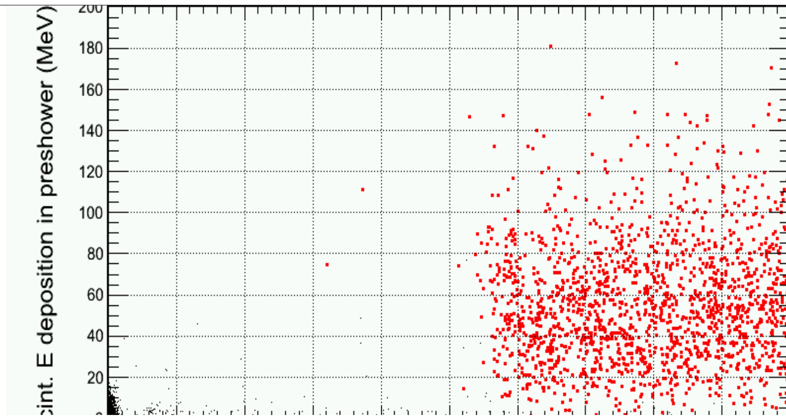






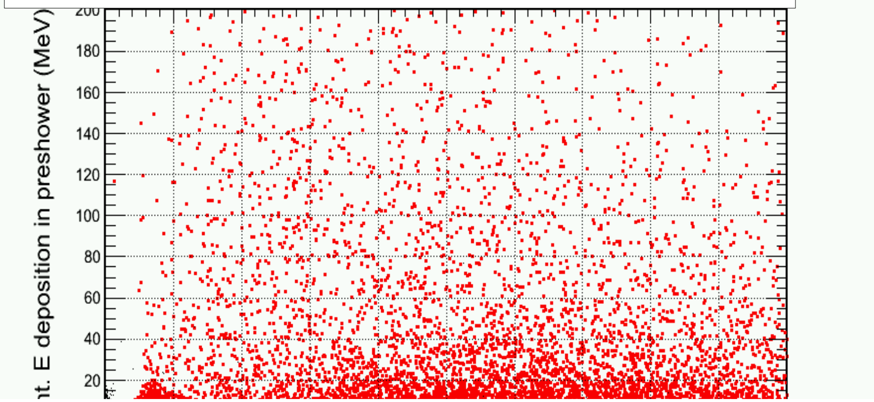
SIDIS LAEC Background Components

Black: background, Red: electrons



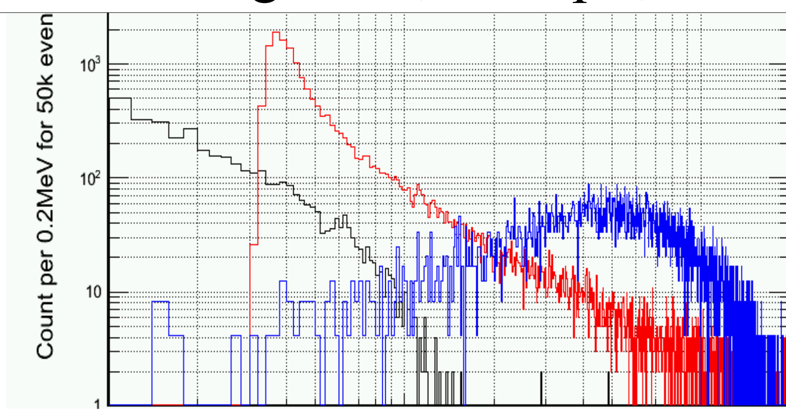
Scintillator energy dep. in Shower (MeV)

Black: background, Red: pi-



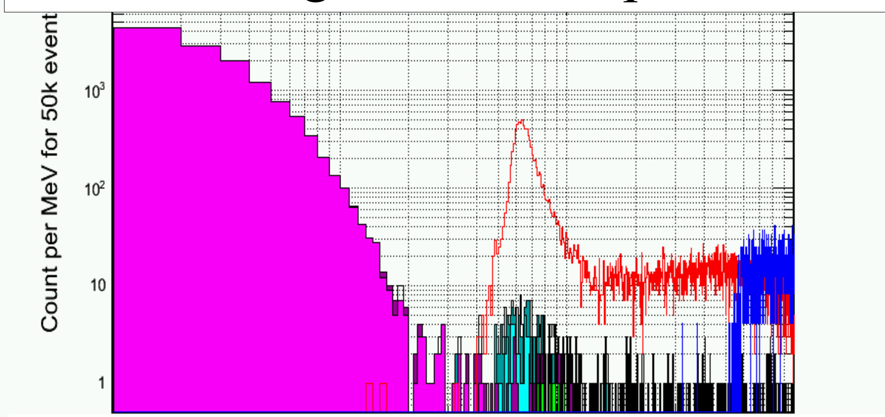
cintillator energy dep. in Shower (MeV)

Black: background, Red: pi-, blue: e-



Scintillator energy dep. in PS (MeV)

Black: background, Red: pi-, blue: e-

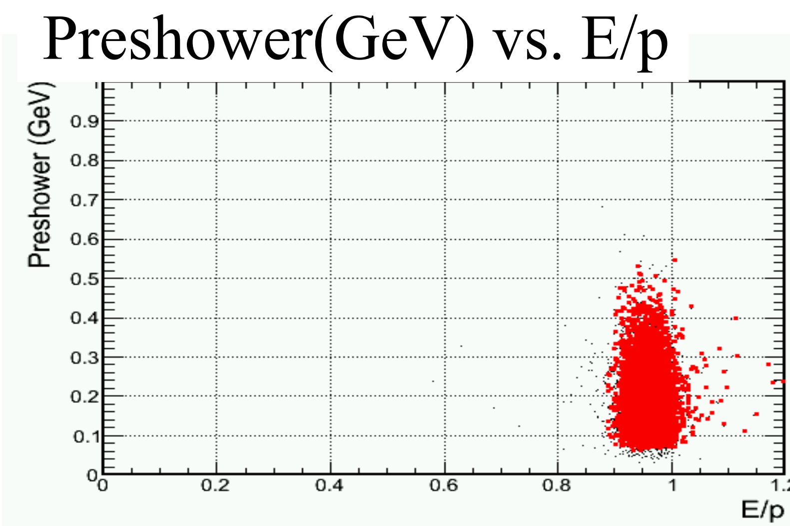


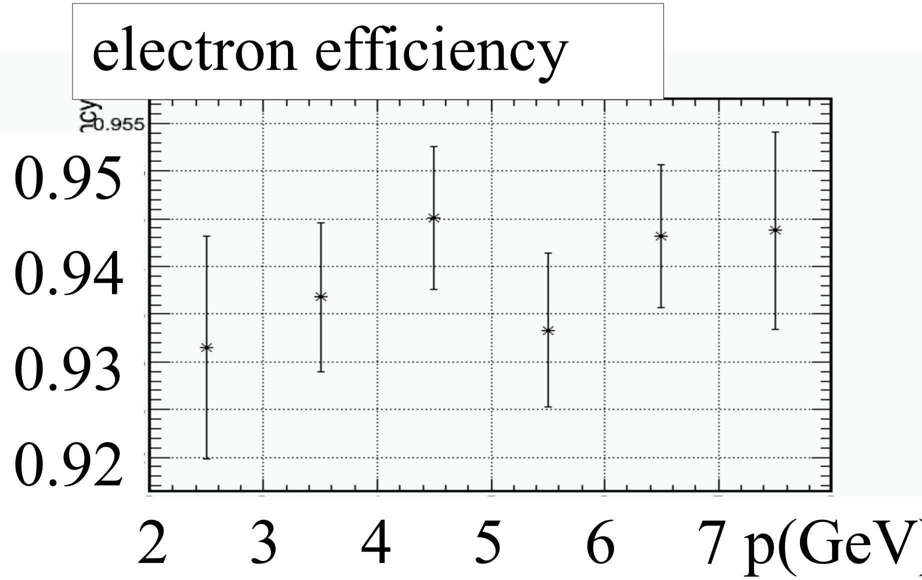
Scintillator energy dep. in Shower (MeV)

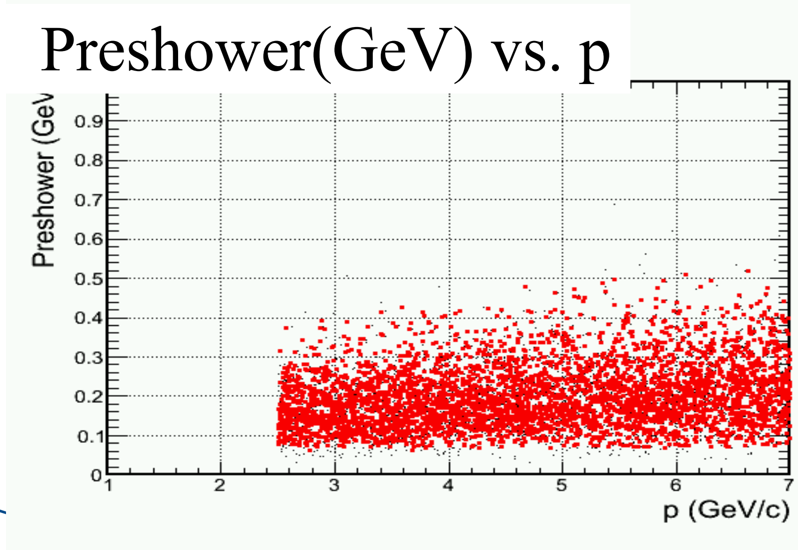
- Photon (6GHz/6+1 Hex cluster) ← dominates
- but well-shielded by the PS lead layer

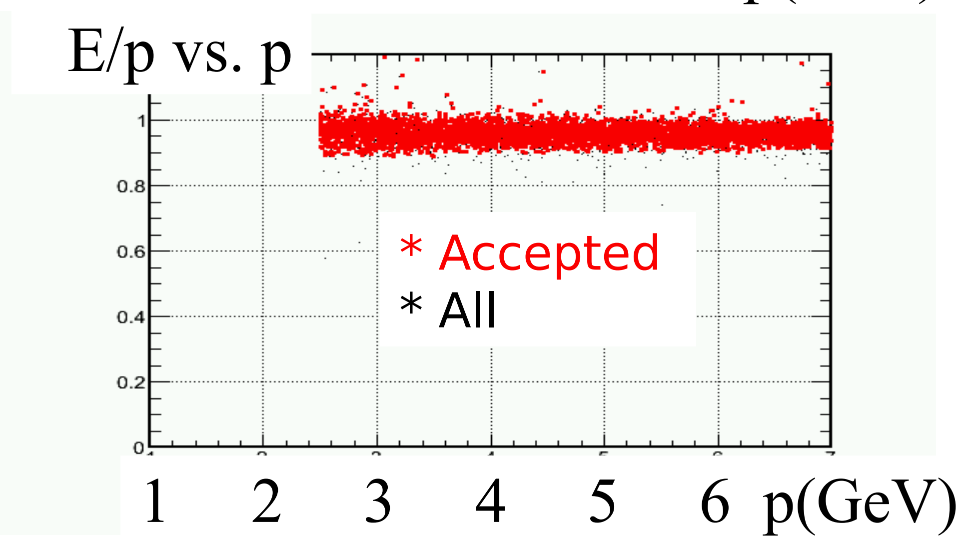
Electron Pion- Pion+ Proton

SIDIS LAEC PID with background, inner R



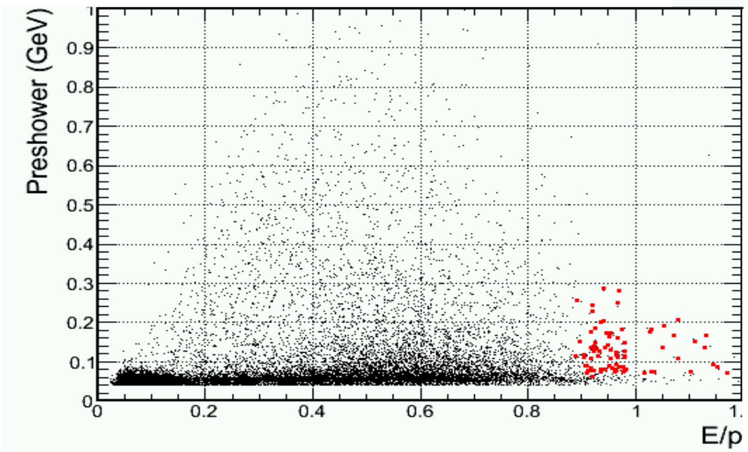




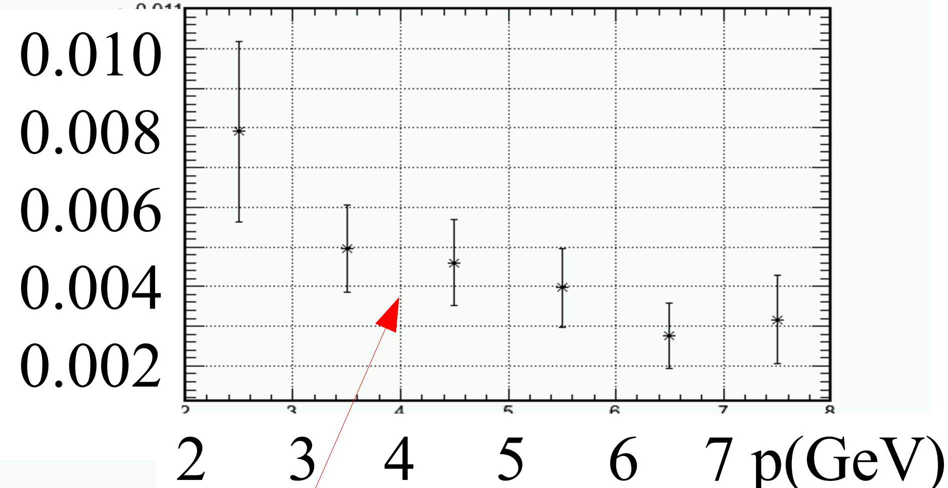


SIDIS LAEC PID with background, inner R

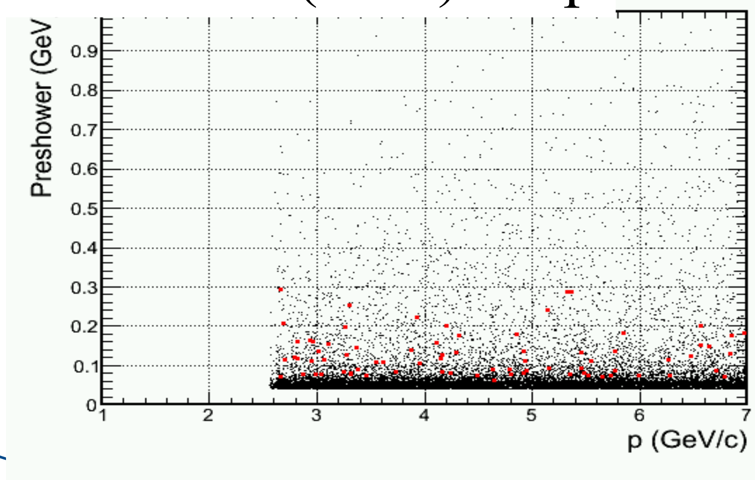
Preshower(GeV) vs. E/p



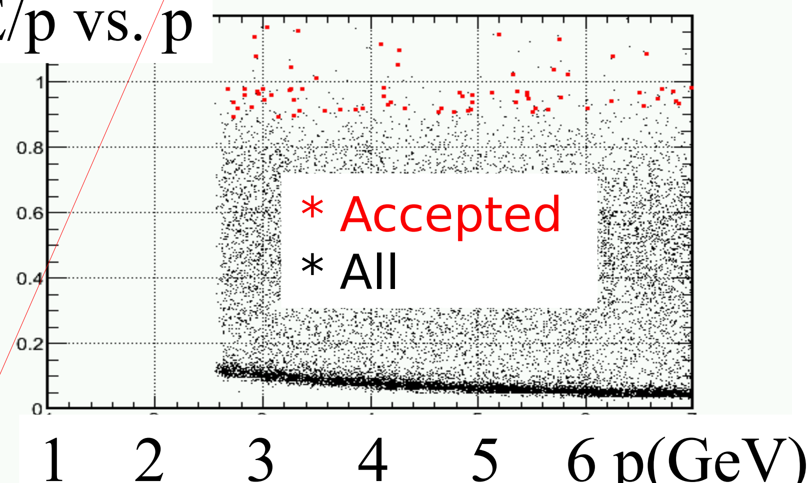
π efficiency with cut



Preshower(GeV) vs. p



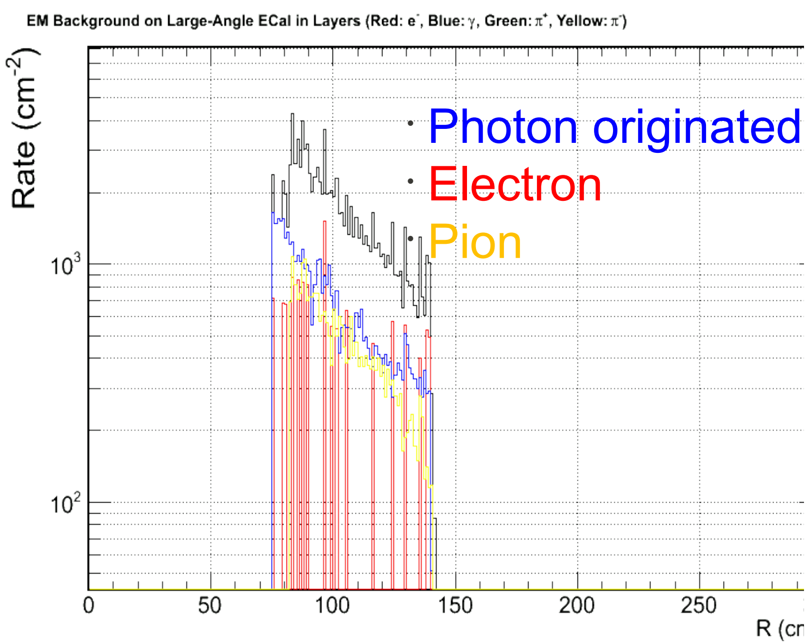
E/p vs. p



- still better than 100:1 @ 94% e eff.

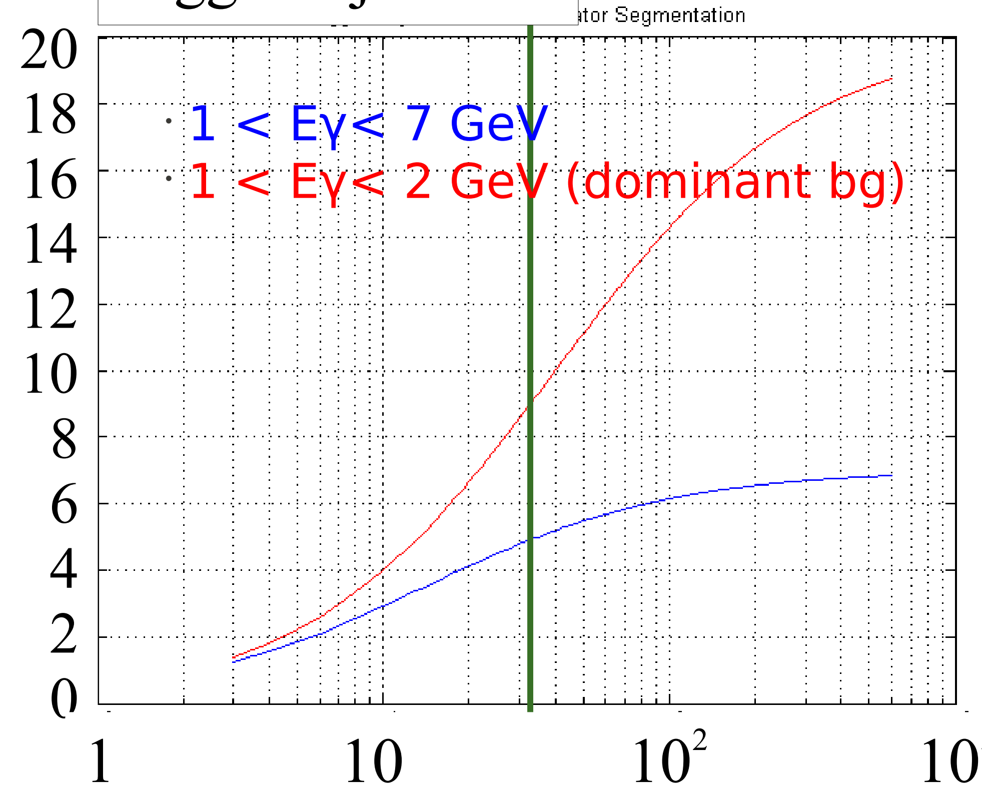
SPD for SIDIS LAEC

Scintillator MIP rate (cm^{-2})



R (cm)

trigger rejection

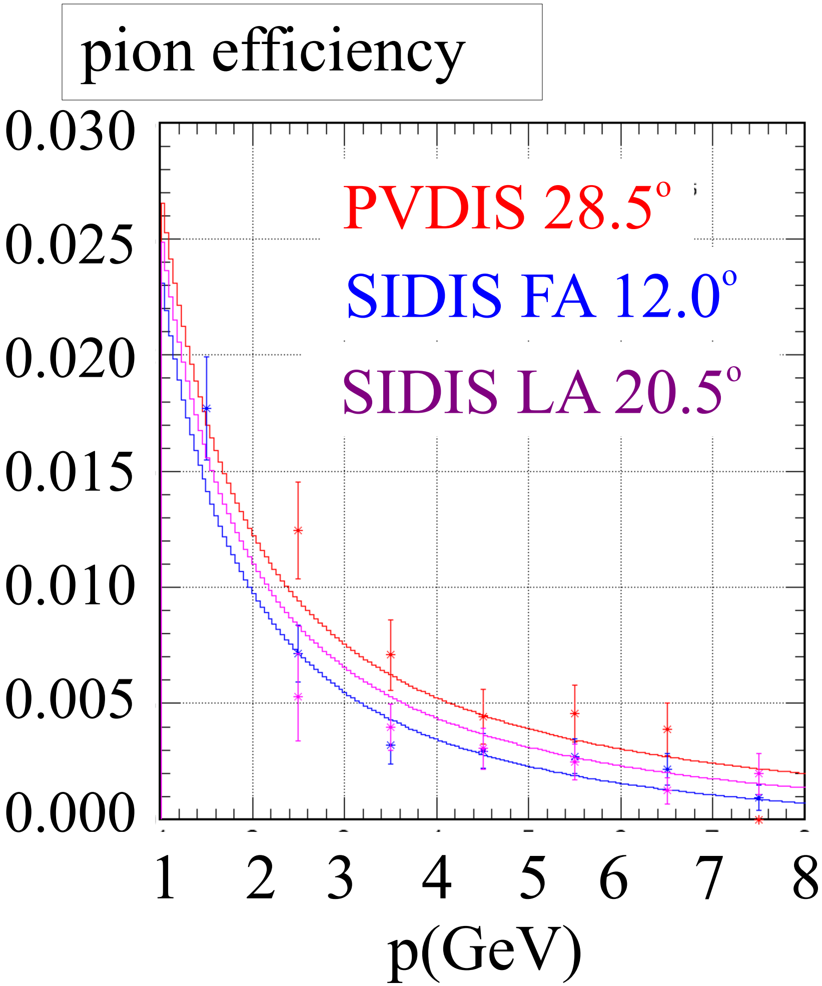


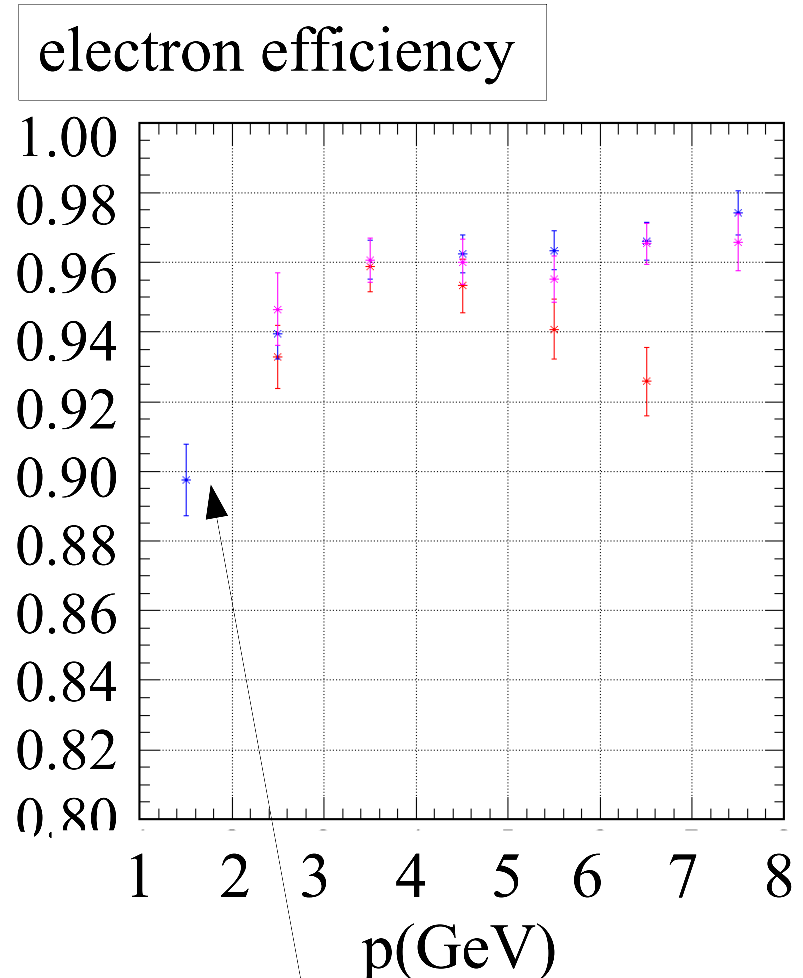
segments

~8:1 rejection
with 30 segments

PVDIS Performance with Background Using the Latest Baffle Design with CLEO Magnet

March meeting – PVDIS PID w/o background

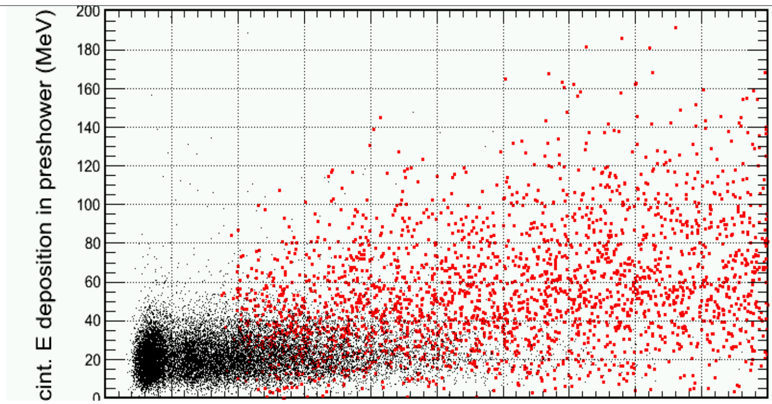




Preshower PID power drop significantly at this bin

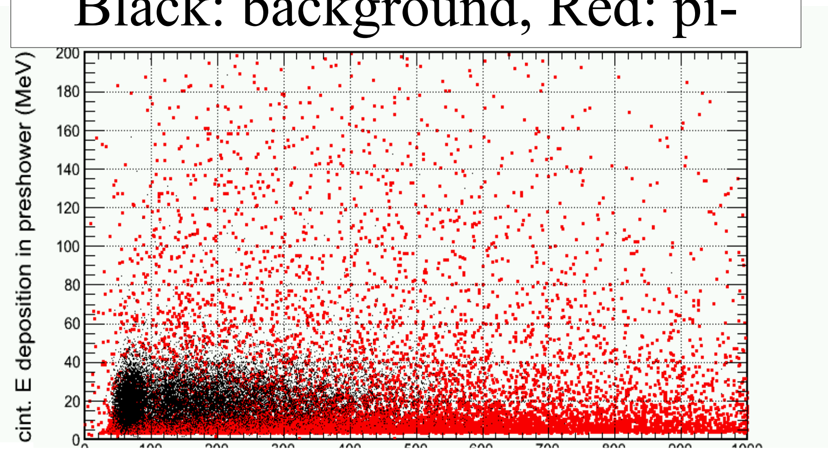
PVDIS background, Mid-R, High-rad ϕ slice

Black: background, Red: electrons



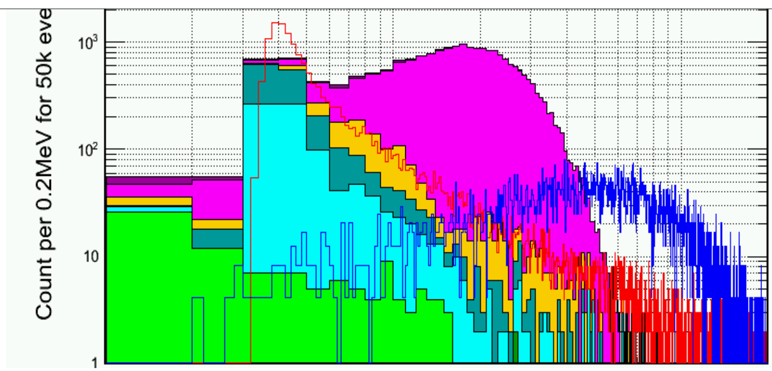
Scintillator energy dep. in Shower (MeV)

Black: background, Red: pi-



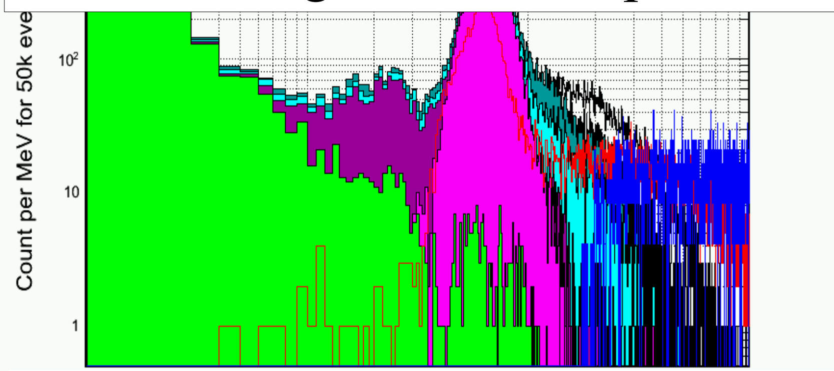
Scintillator energy dep. in Shower (MeV)

Black: background, Red: pi-, blue: e-



Scintillator energy dep. in PS (MeV)

Black: background, Red: pi-, blue: e-



Scintillator energy dep. in Shower (MeV)

- Photon (6GHz/6+1 Hex cluster)
- Electron Pion- Pion+ Proton

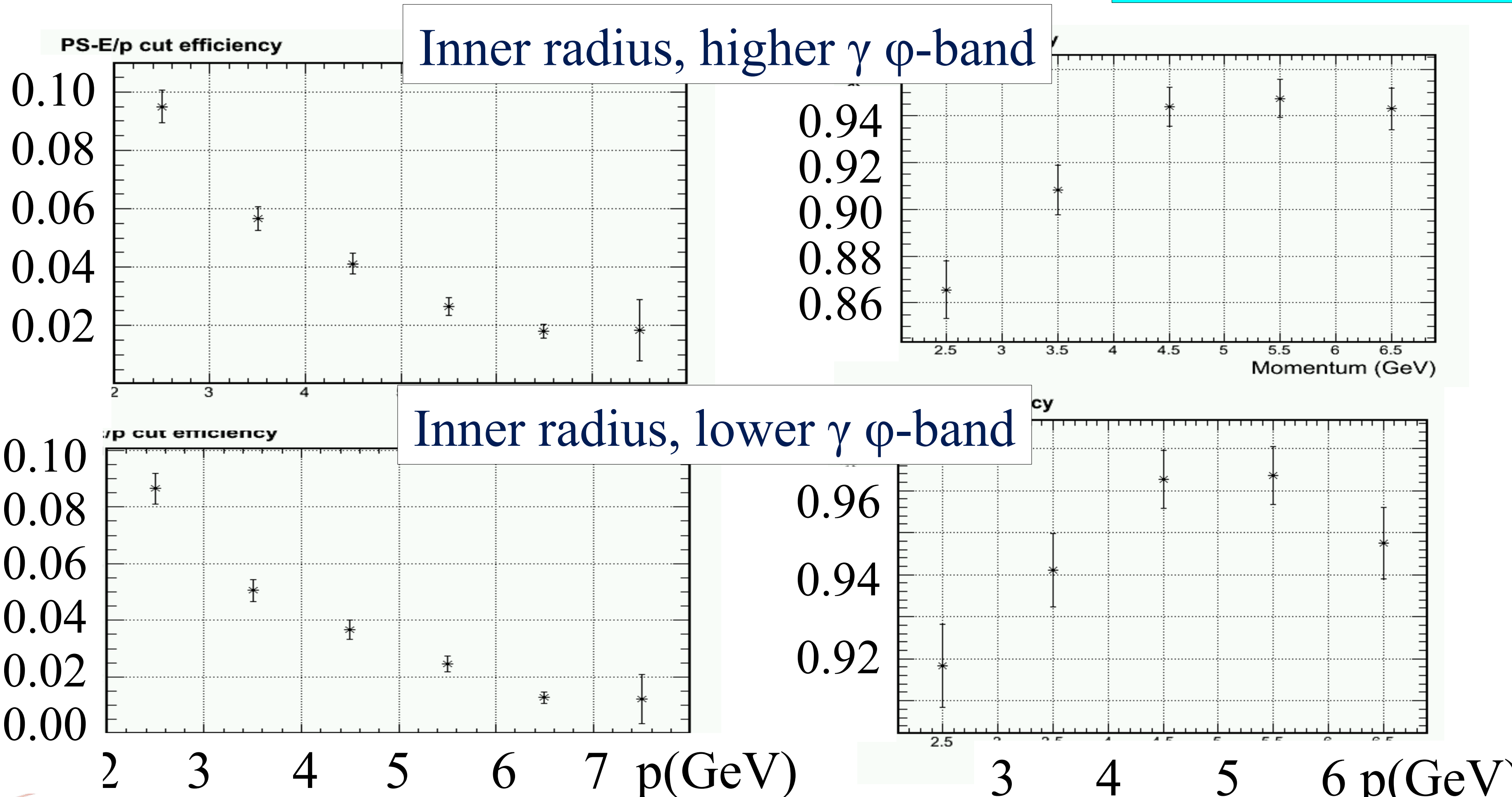
Jefferson Lab

PVDIS PID with background

with DC component removal
PS 6+1 > MIP + Bgd + (2-3) σ
SH 6+1>1.6 GeV

pion efficiency

electron efficiency



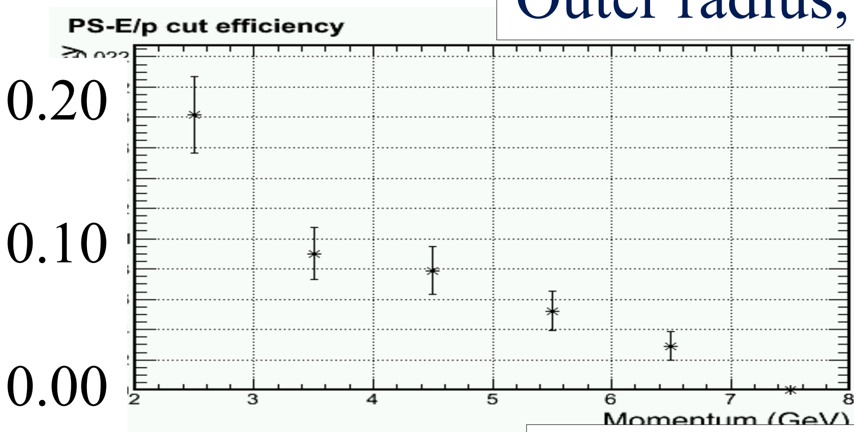
PVDIS PID with background

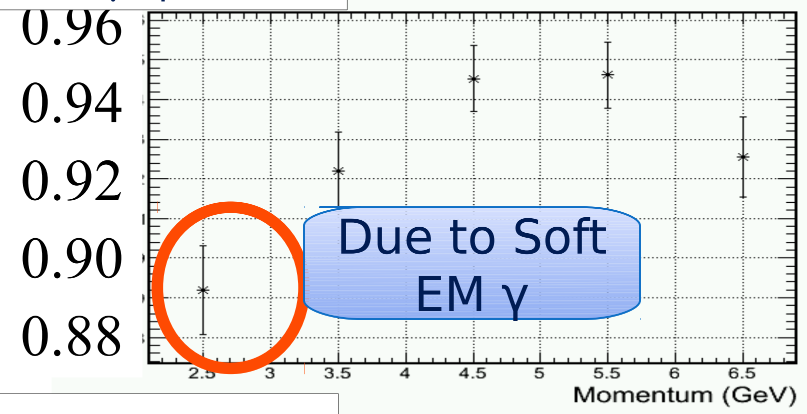
with DC component removal
PS 6+1 > MIP + Bgd + (2-3) σ
SH 6+1>1.6 GeV

pion efficiency

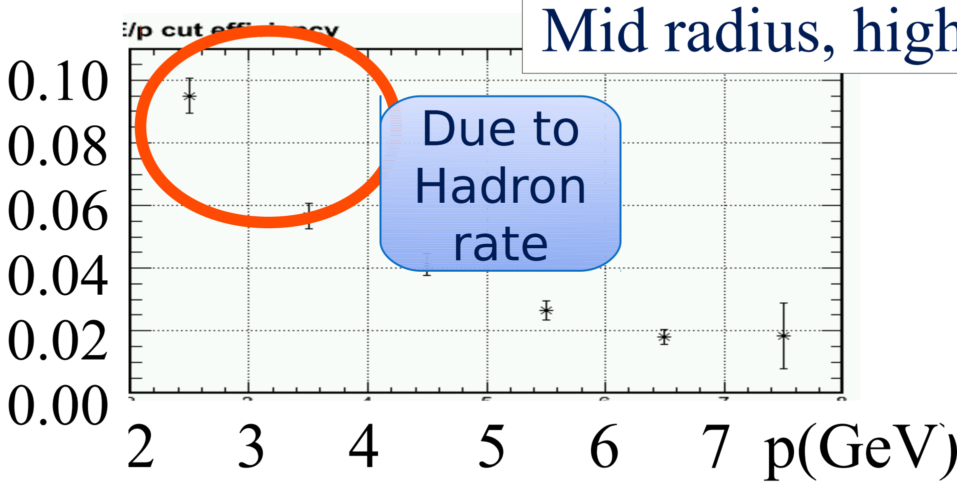
electron efficiency

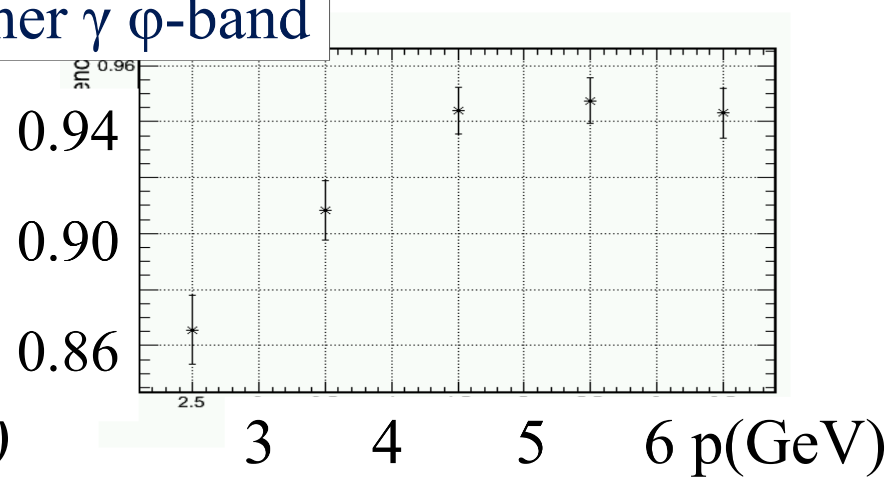
Outer radius, higher γ φ-band





Mid radius, higher γ φ-band





PVDIS PID with background – does it meet the Physics requirement?

- At inner radius, high-rad ϕ region, EC pion rej. varies from 10:1 at 2 GeV to 50:1 at 8 GeV;
- Using March CC talk, at 20deg, 2GeV/c, pi/e=200. CC provides 1000:1 rej w/o bg (worse if w/ bg). If EC provides 10:1 then pion contamination in e- samples would be 2% in offline analysis.
- Main conclusion #1: Using 6+1 cluster sum isn't enough, *must store all FADC waveforms* to improve PID (factor of 10 expected using 4ns vs. 50ns timing);
- Main conclusion #2: Pion asymmetry needed, must have clean pion trigger/events (very low electron contamination). Pion rate needed ~ ¼ of e- rate (estimated using 5% contamination, pion asym measured to 1%, causing 0.05% syst uncertainty in Apv)

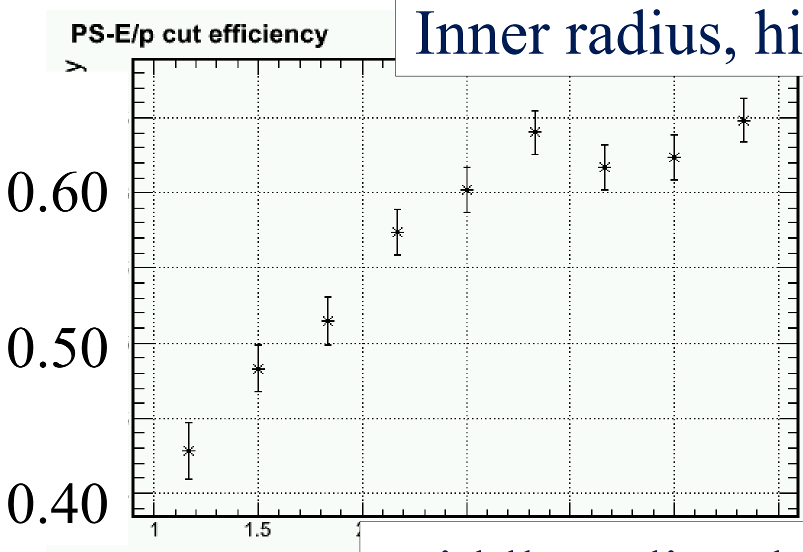
PVDIS Trigger with background

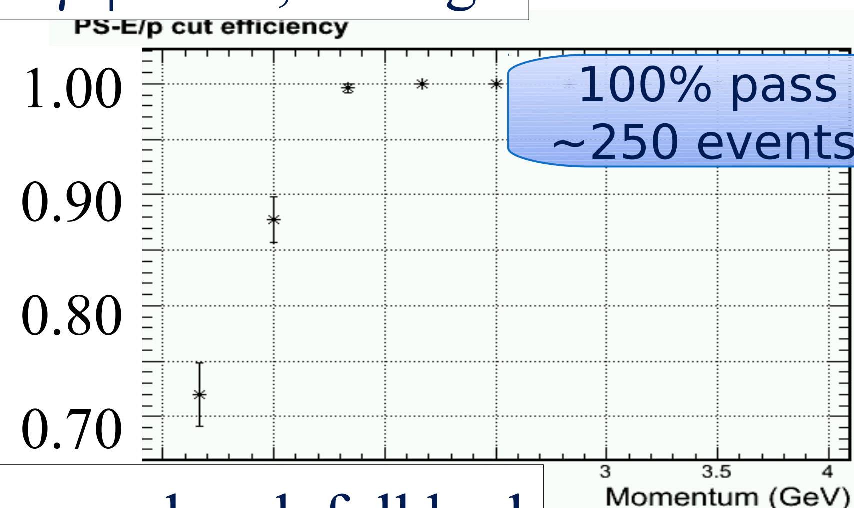
SH 6+1>1.6 GeV (corresponds to 2 GeV electrons)

pion efficiency

electron efficiency

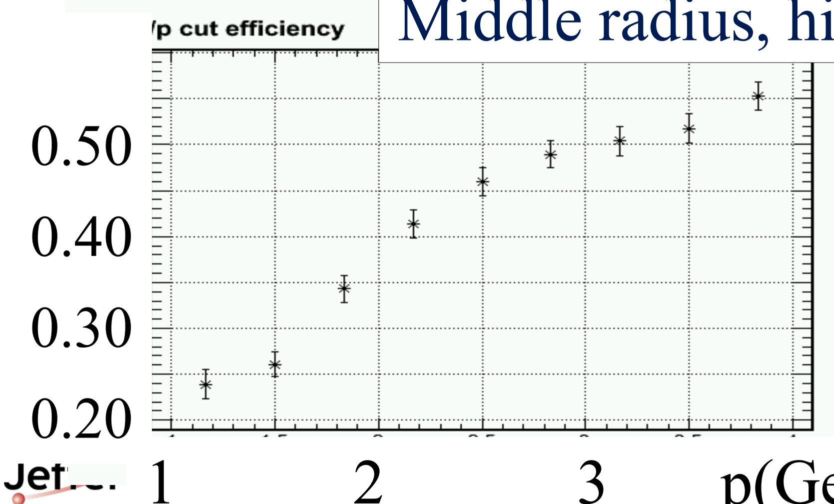
Inner radius, higher γ φ-band, full bgd

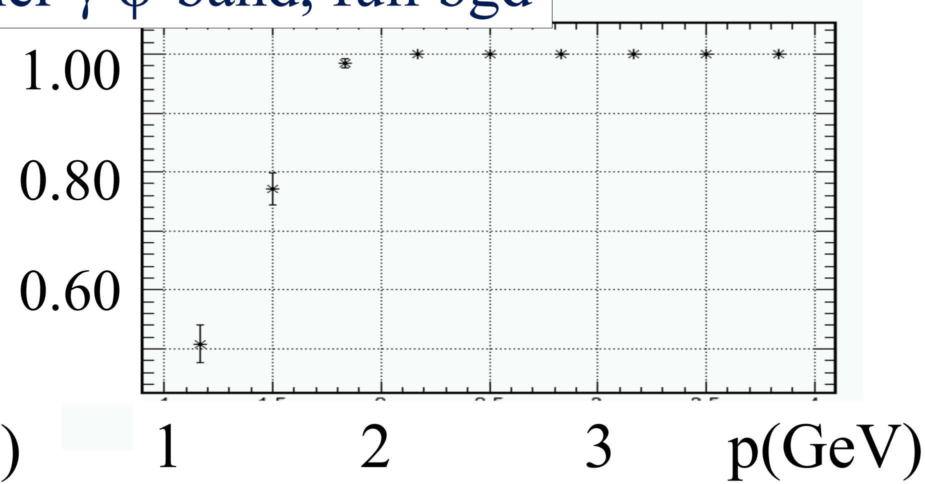




100% pass for ~250 events/bin

Middle radius, higher γ φ-band, full bgd





PVDIS Trigger with background

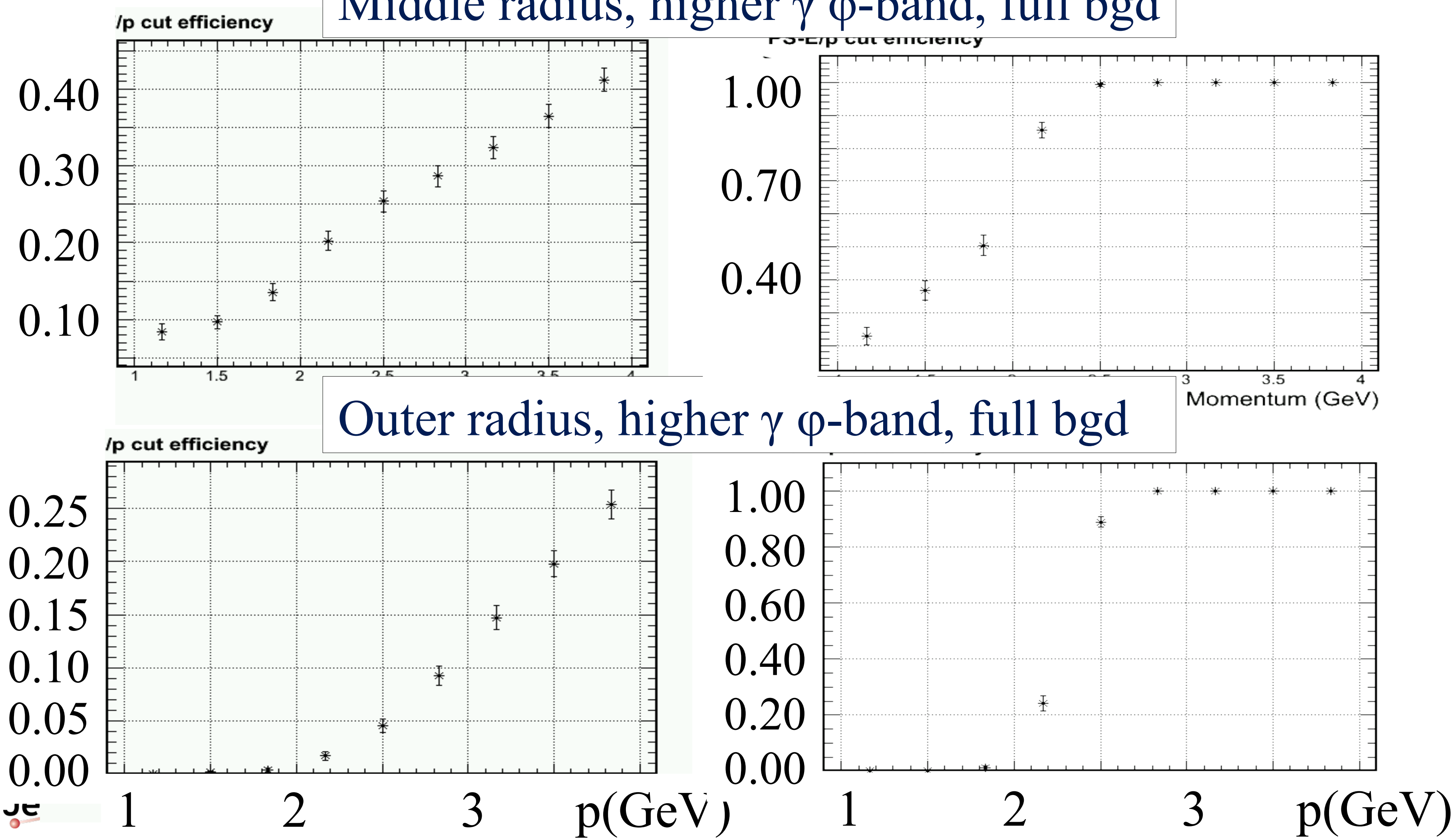
SH 6+1>2.1 GeV (corresponds to 2.5 GeV electrons)

pion efficiency

electron efficiency

Middle radius, higher γ φ-band, full bgd

Outer radius, higher γ φ-band, full bgd



PVDIS Trigger with background – Adding Preshower?

- Shower cut: 6+1 cluster > 1.6 GeV
- Preshower cut: central block > 1 MIP +1σ

p		2 GeV	8 GeV
mid R, high-rad ϕ region	pion rej e- eff.	~10:1 95%	~3:1 ~98%
inner R, high-rad ϕ region	pion rej e- eff.	~10:1 90%	~3:1 ~98%

electron efficiency too low!

→ can't use Preshower in trigger

Current PVDIS Trigger Design

- EC trigger will use Shower cut only: 6+1 cluster>1.6 GeV
- Use EC+CC for electron trigger
- Use EC+$\overline{CC}$ for pion trigger, but must be with prescaling (up to 100), see next page

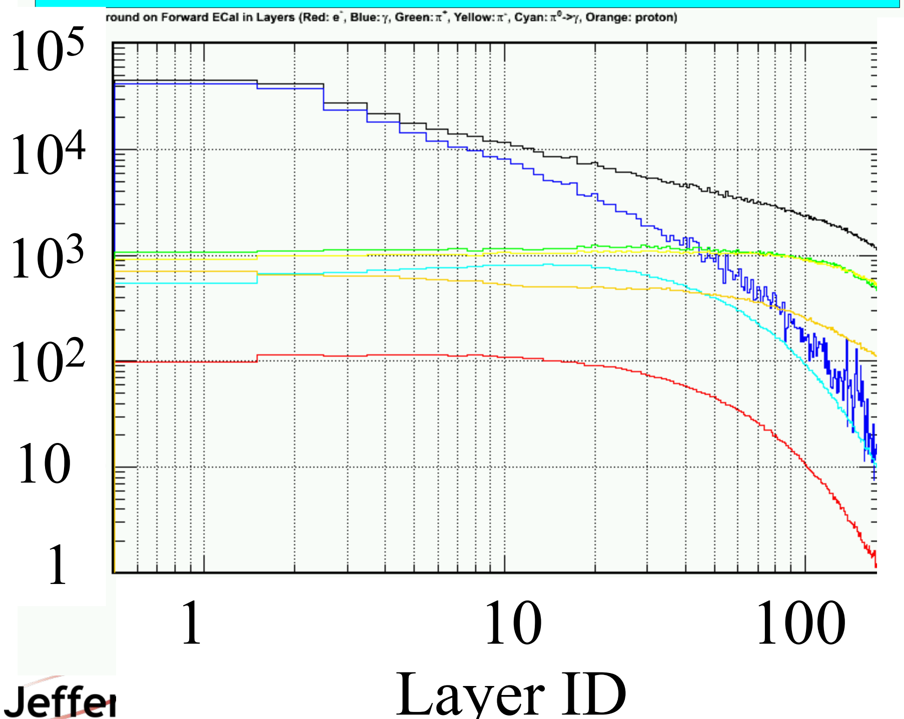
How to Form PVDIS Trigger to meet DAQ Needs?

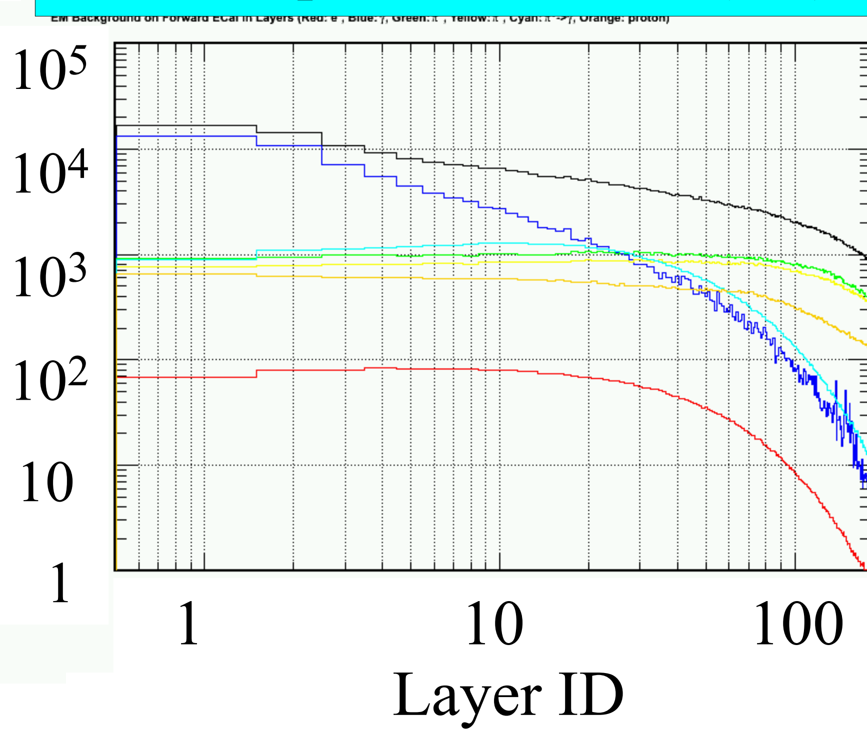
- Trigger rate limit is ~60kHz/sector (total 30 sectors) – from DAQ group
- Our expected DIS e- rate is 4-8kHz/sector, and assuming we need the same pion rate to extract pion asymmetry. This leaves 40kHz of pion contamination in e- trigger.
- Electron trigger: If pi/e=100, pion rejection must be >20:1. Since EC provides only 2:1 (inner radius) to (5-10):1 (outer radius), need CC to provide at least 10:1 rejection – Can CC provide this (with full background) at the trigger level?
- Pion trigger: with 400-800kHz/sector raw pion rate, prescaling of 100 is necessary.

PVDIS Radiation Dose

- Photon (EM) ← dominant!
- Photon (Pi0)
- Electron
- Pion- Pion+ Proton

High radiation ϕ region	Low radiation ϕ region
radiation per PAC month (rad)	radiation per PAC month (rad)





PVDIS Radiation Dose – Impact on fibers?

- Dose expected: (20-40) krad/month
  - (80-160) krad for PVDIS 120 PAC days
  - (240-500) krad for 1 PAC year;
- WLS fibers light loss:
  - Kuraray 10% loss (per meter?) @100krad → 30% @700krad;
  - St. Gobain 15% loss @ 100krad → 50% @ 700krad.
- Assuming 50% light loss, effect on PID is minimal as long as we calibrate the photon yield during running.

WLS Fiber radiation hardness

Table 1
Optical properties of each type of WLS fibers before the irradiation. Average light output at 140 cm and RMS, average attenuation length (L_{att}) and RMS, for ten fibers of each type. The values are normalized to I_{140} of the Y11(200)MSJ fibers

Fiber type	I_{140}	RMS (%)	L_{att} (cm)	RMS (%)
BCF91A MC	0.98	9.6	280	9.5
Y11(200)MSJ	1.00	1.8	280	1.6
S250-100	0.81	5.7	230	5.6

Table 2
Relative light output at $x = 140$ cm, for total doses of 1.16 and 6.93 kGy

Fiber type	$\frac{R(140)}{R(30)}$ for 1.16 kGy			$\frac{R(140)}{R(30)}$ for 6.93 kGy		
	0 days	1 day	10 days	0 days	1 day	10 days
BCF91A MC	0.83	0.86	0.85	0.54	0.56	0.56
Y11(200)MSJ	0.87	0.92	0.91	0.71	0.72	0.74
S250-100	0.60	0.70	0.81	0.52	0.55	0.64

SoLID Collaboration Meeting, May 2013 26

Budget Estimate Update

Budget @ January Meeting

	Per module cost ($)	All module cost (M$)
Module material	700(L)/250(S)	1.26
Module production	800(L)/500(S)	1.49
Clear fiber	260(L)/65(S)	0.46
Fiber connectors	150	0.27
PMTs	600*2	2.34
Labor	5 tech and 5 student years	1.3
Total		7.12
Total+30% contingency		9.26

5.8M, to be compared to next slide

- + Prototyping ~ 0.3 M$
- + Support ~

Budget @ March Meeting

- IHEP (not including fibers) for 1700 PS+SH
  - Preshower: $112k-$120k
  - Shower: $549k-$651k
  - Structure+assembly: $255k-$340k
  - IHEP total: ($1.22-$1.51)M + 24% overhead (2012 rate) = ($1.51-$1.87)M
- Fiber connectors+tubing (Leoni+other): ~$300k
- WLS+clear fibers(?): $703k (S.G.) - $2.47M (Kuraray)
- PMTs: $600x2x(~1900)=$2.28M
- Total from above (no contingency): **($4.8M-$5.2M)** if using S.G.; $(6.6-7.0)M if using Kuraray
- Labor? Shipping? Contingency?

Cost Update – Status

- No quote yet for SPD
- No quote yet for Shower fiber mirrors (IHEP)
- Updated fiber cost with diamond-tool cutting (do not know yet if IHEP can cut the fibers)
- PMT cost with quote

Fiber Cost Update

	March 2013	May 2013 (fiber alone)	May 2013 (diamond-tool cutting)
S.G. WLS	$203k	$203k	$240k
S.G. Clear	$500k	$574k (longer)	$208k
Total	$703k	$777k	$448k
Kuraray WLS	$787k	$573k	
Kurary clear	$1,681k	$1,091k (shorter)	
Total	$2,468k	$1,664k	

$1,225k

PMT Cost Update

- March meeting: $600*2*(~1900)=$2.28M
- Now: $400 PMT + $240 base = $640 *2*(~1900) = $2.43M

Budget Update

- IHEP (not including fibers) for 1700 PS+SH
  - Preshower: \$112k-\$120k
  - Shower: \$549k-\$651k
  - Structure+assembly: \$255k-\$340k
  - IHEP total: (\$1.22-\$1.51)M + 24% overhead (2012 rate) = (\$1.51-\$1.87)M
- Fiber connectors+tubing (Leoni+other): ~\$300k
- WLS+clear fibers: \$777k+\$448k (S.G.) - \$1.66M (Kuraray)
- PMTs: \$640x2x(~1900)=\$2.43M
- Total from above (no contingency): **(\$5.3M-\$5.7M)** if using S.G.
- Labor? Shipping? Contingency?

Plan

- Continue tweaking baffles to reduce background (but no significant change in PID expected)
- LED calibration?
- Reducing cost:
  - MAPMT study, perhaps even small-scale tests – potential saving of ~$800k
  - use CLAS12 cutter to cut fibers ourselves – potential saving of $448k, but need labor to cut ~190,000 fibers
  - Customized PMT bases?
  - Smaller PMTs for Preshower?

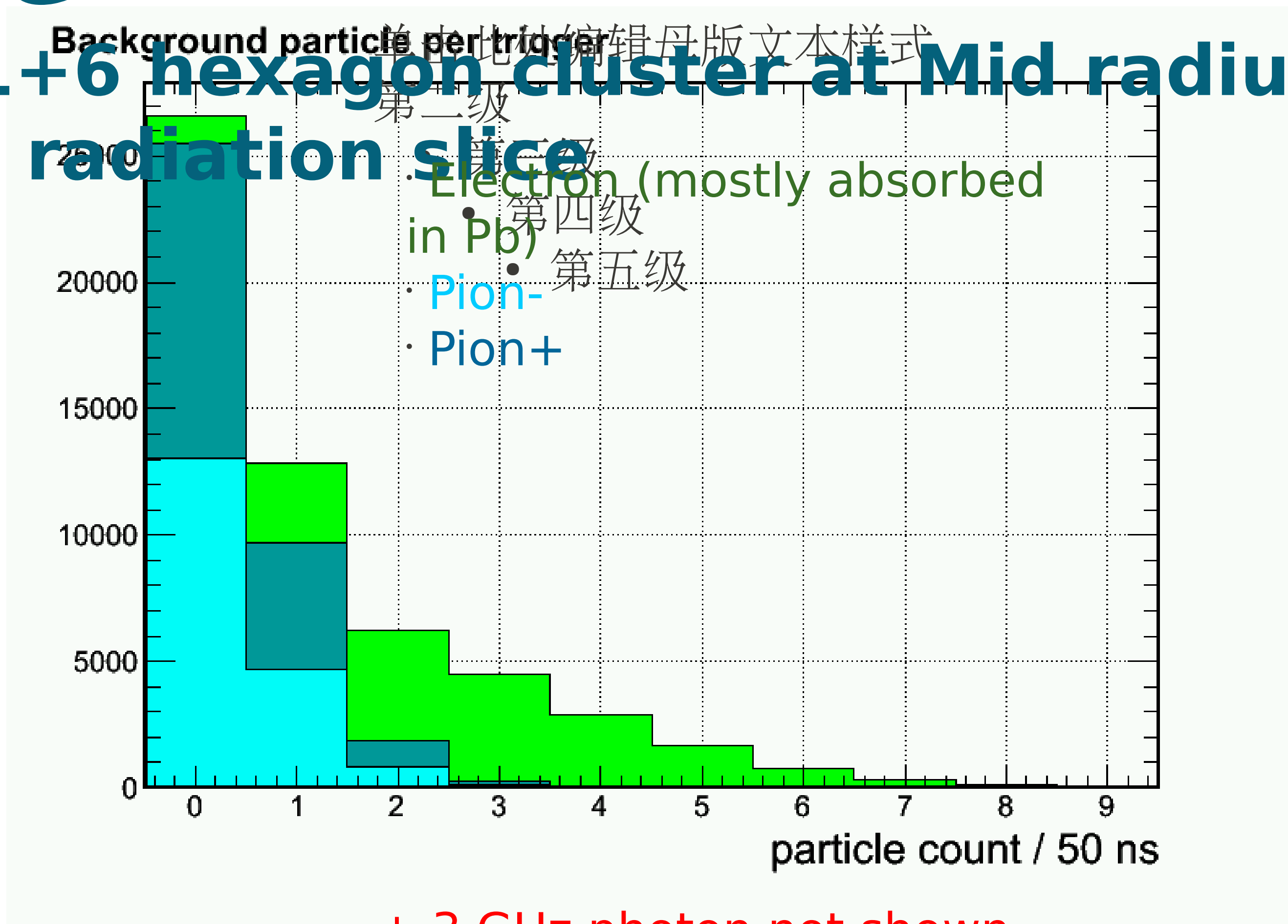
Possible Design Update – Multi-Anode PMTs

- Current Preshower readout: 1 PMT ($600)/module, but each module is read out by only a couple of fibers so we are wasting cross-sectional area of the PMT;
- MAPMT: about $100/channel → potential saving of PS PMT from $1.02M to $200k;
- To be studied: gain-matching between channels of one MAPMT. LHCb used specialized front-end electronic modules to produce digital triggers. We could use FADC directly, no need for FE-electronics.

Backup Slides

Updated: Per-event pion rate

for 1+6 hexagon cluster at Mid radius, high radiation slice

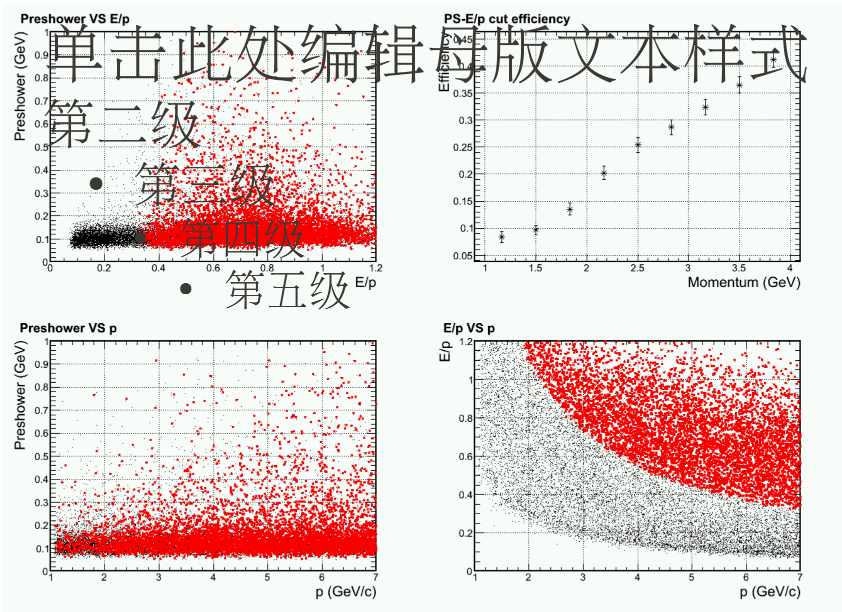


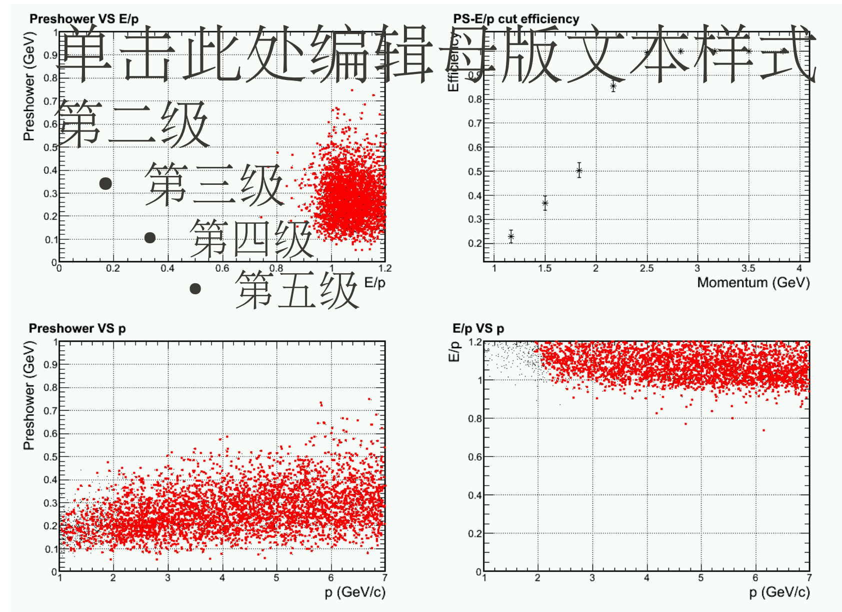
单击此处编辑母版文本样式
第二级
第三级
- Electron (mostly absorbed in Pb)
  - 第四级
    - 第五级
- Pion-
- Pion+

+ 3 GHz photon not shown

More detail in trigger cut

Middle radius, higher γ φ-band, full bgd
Shower Hex 1+6 trigger > 2.1 GeV





Pion Efficiency

Electron Efficiency

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Readout occupancy per shower channel for ~75MeV zero suppression