Update on EM Calorimeters

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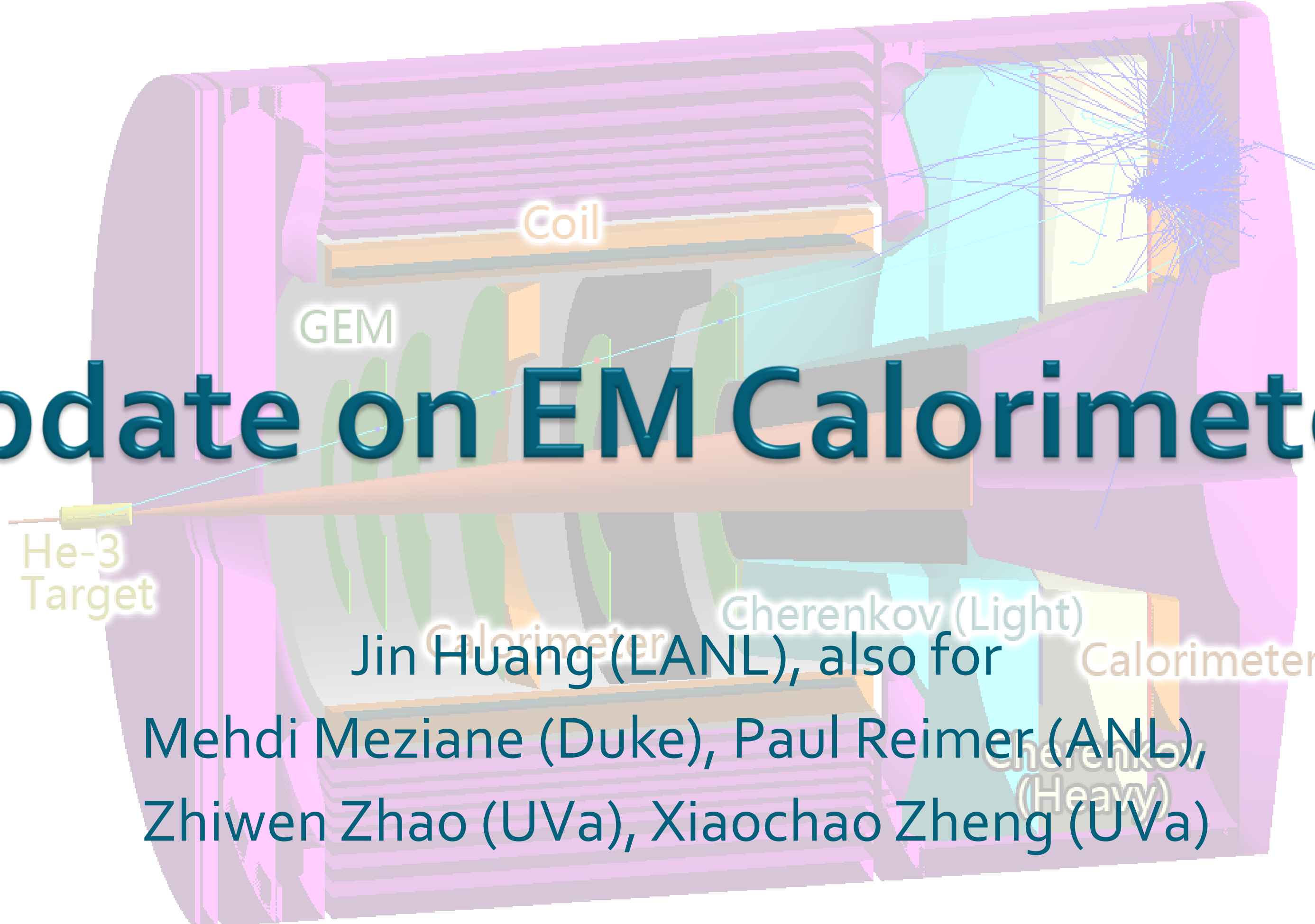
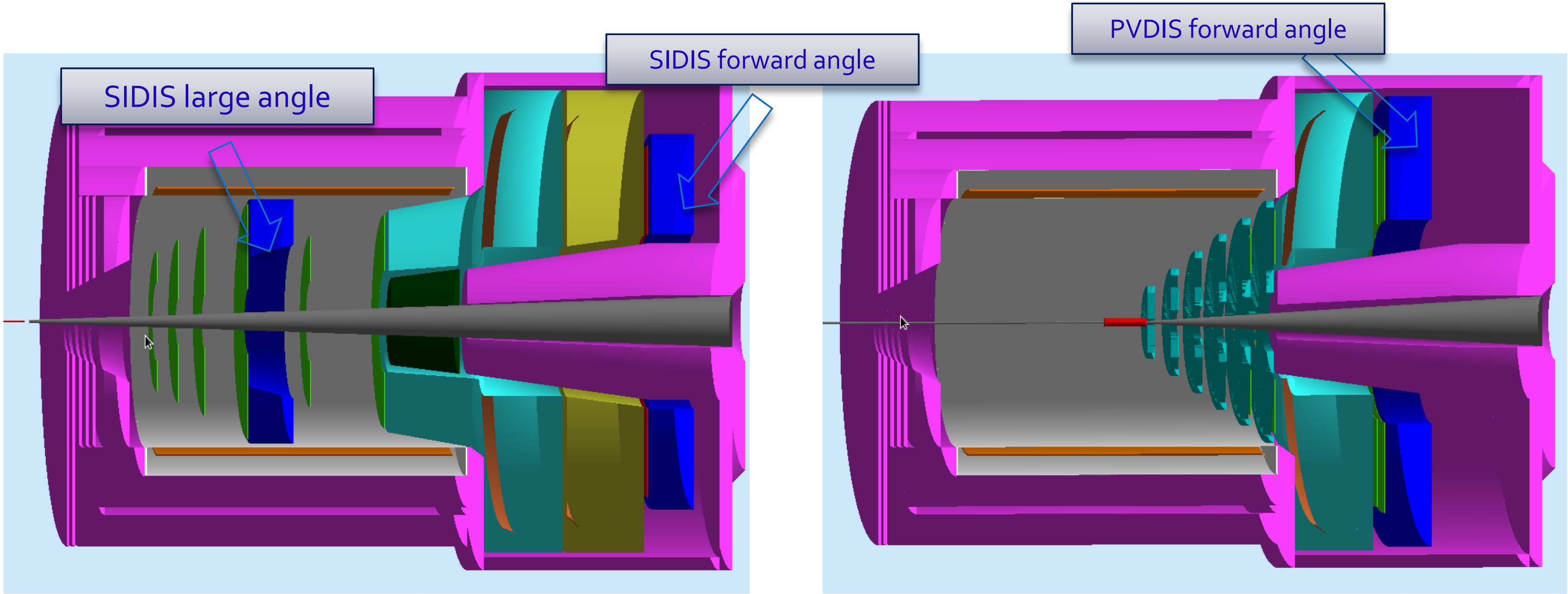


Jefferson Lab

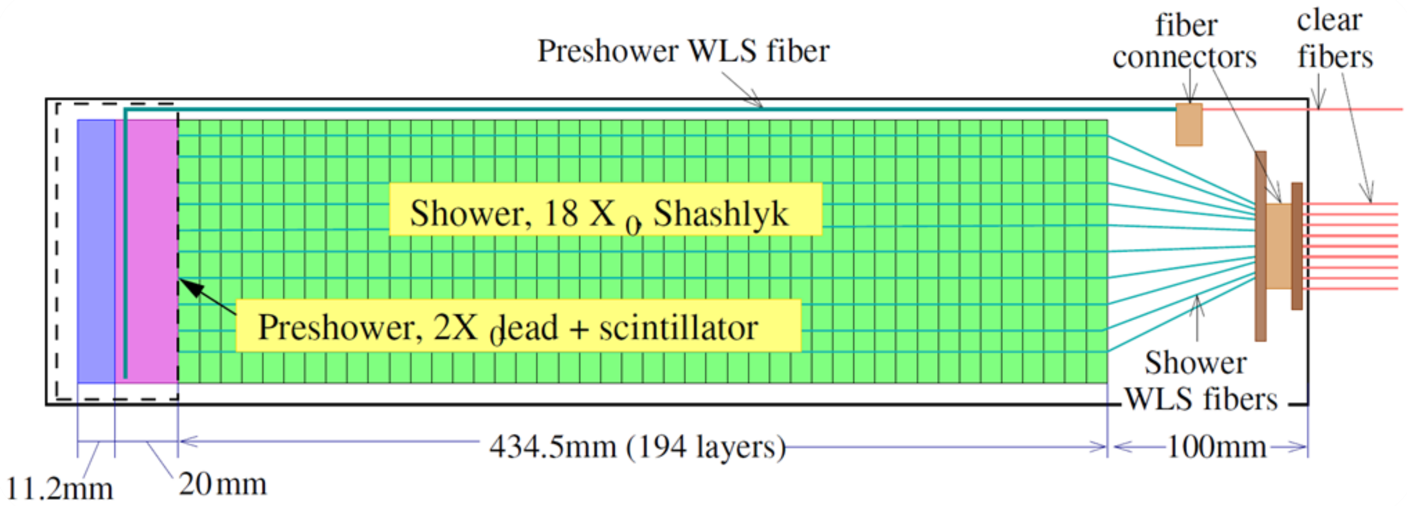
Overview

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

Default design for calorimeter modules



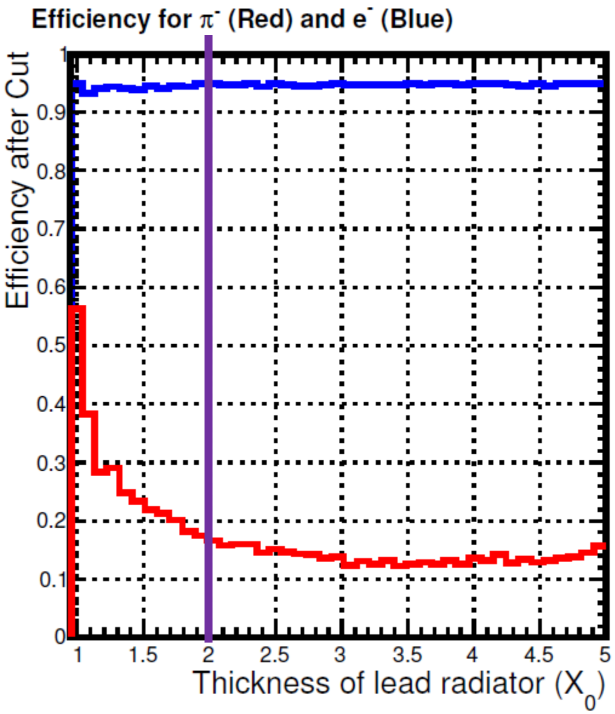
- Preshower
  – HERMES/LHCb style passive radiator + scintillator design
    - 2 Xo lead radiator + 2 cm scintillator tile w/ WLS readout
- Shower
  – COMPASS style Shashlyk calorimeter design
    - Layer structure : 0.5 mm lead + 1.5 mm scintillator + 0.12 mm gap x 2
    - X_o = 24cm, R_M ~ 5 cm, 194 layers, 43 cm in depth

Shower – quick review

- Choice of technology
  - Shashlyk design was chosen based on advantage of radiation resistance + cost + ease of readout
- Features
  - Pb/Scint ratio 1:3 (V) : chosen to reach <5%/√E energy resolution and ~100:1 pion rejection
  - Scintillator thickness of 1.5mm: based past designs to balance sampling fineness VS lateral light transmission loss
  - Total length of 20 X_0 : contain 98% of shower and maximize pion-electron difference
    → MIP = 270 MeV (real) / 320 MeV (reconstructed)
  - Lateral size of 10x10 cm^2: max size allowed (to reduce $$) before position resolution significantly deteriorates (σ~1 cm after cor.)

Preshower – quick review

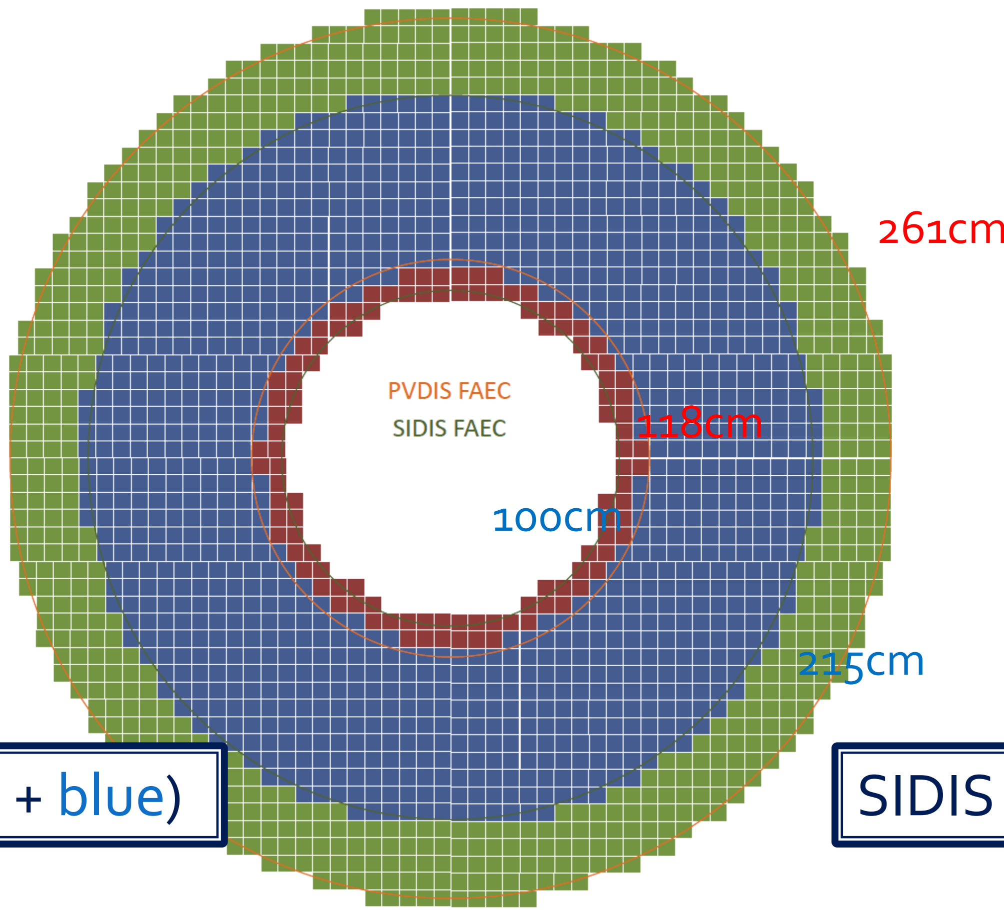
- Choice of technology
  - HERMES/LHCb style VS full Shashlyk design, former is much easier to readout and high in radiation resistance
- Features
  - Absorber of 2 X_0 lead :
    - Thinner – loose preshower rejection
    - Thicker – loose shower resolution
    - Scanned for 1.5, 2 and 3 X_0; 2 X_0 serve SoLID best
  - Scintillator of 2 cm:
    - MIP = 4 MeV, electron cut ~ 3 MIP



Design Updates
- Layout Update

SIDIS and PVDIS FAEC (beam view)

- Both can share supporting structure, only need to move along beam direction to change configuration
- Supporting structure needs to be made from 100cm to 261cm



VDIS FAEC (green + blue)

SIDIS LAEC (blue + red)

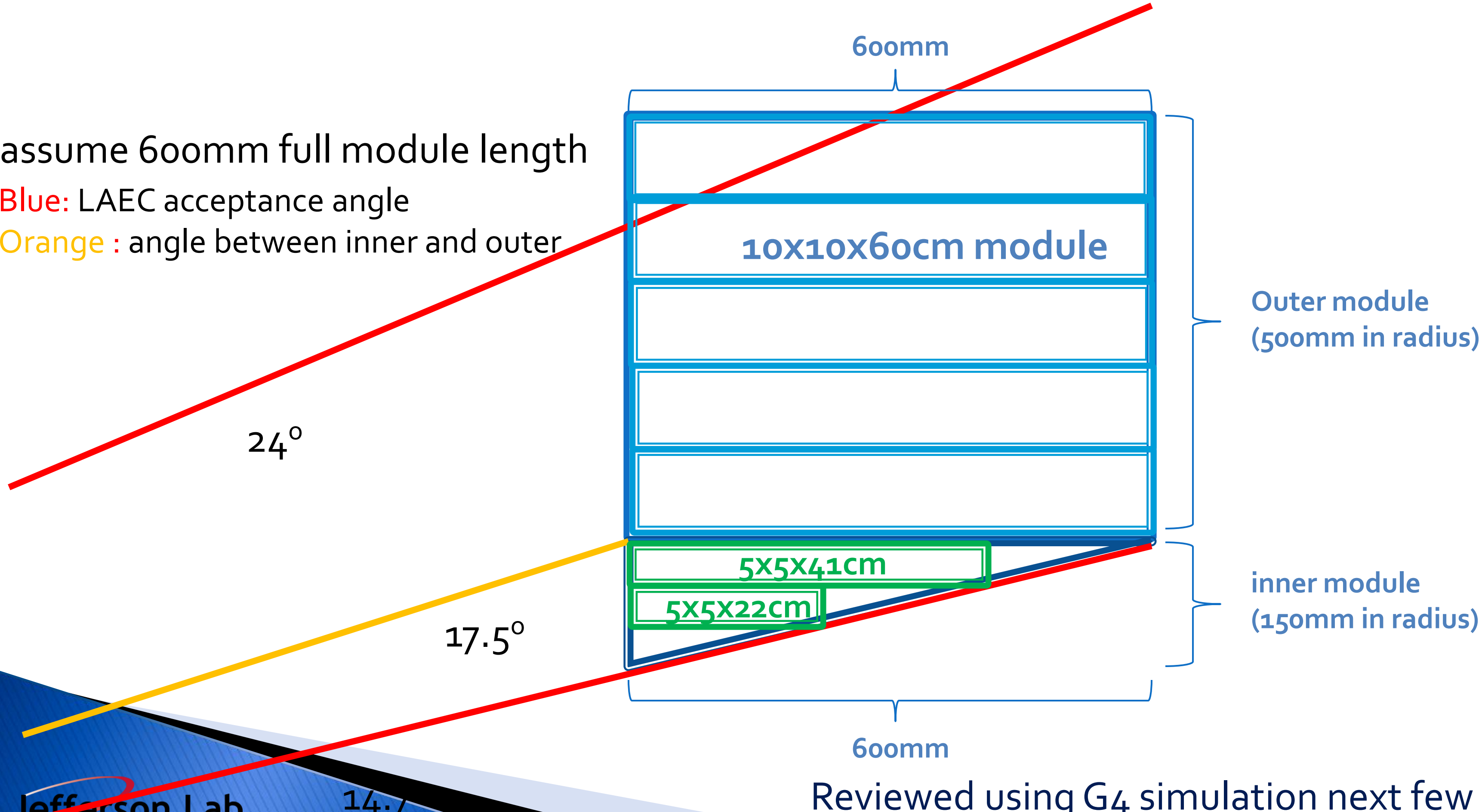
Ideas to minimize SIDIS LAEC Acceptance gap

- We want to cover full azimuthal angle and leave no gap between modules, so module can not be tilted and need to be along Z axis
- Prefer having short outer module so that the outer module area can cover more and inner module area can cover less
- Inner module need to be special shape to avoid blocking acceptance. One way to solve it is to have smaller 5x5cm (like COMPASS) module with various length

assume 600mm full module length

Blue: LAEC acceptance angle

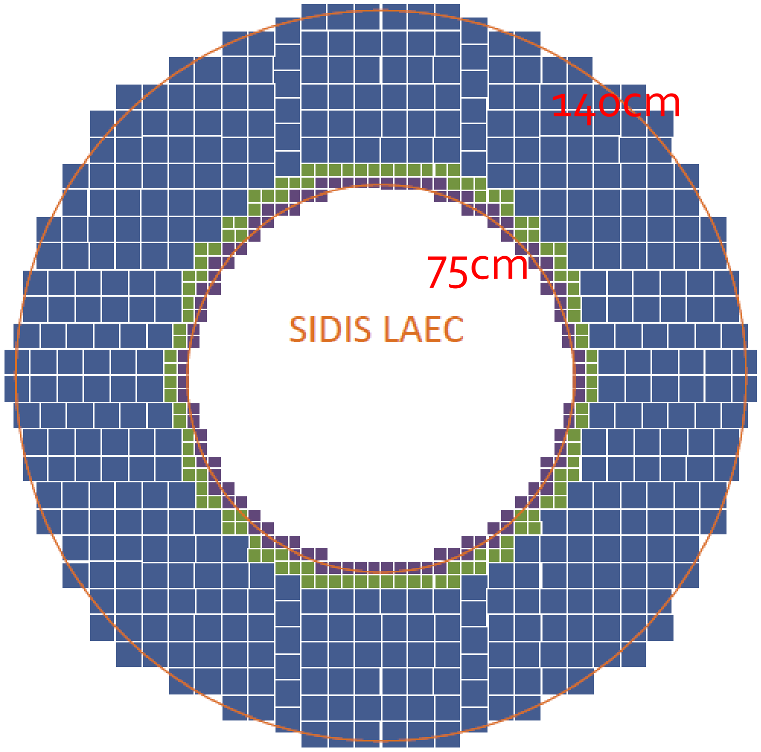
Orange : angle between inner and outer



Reviewed using G4 simulation next few pages

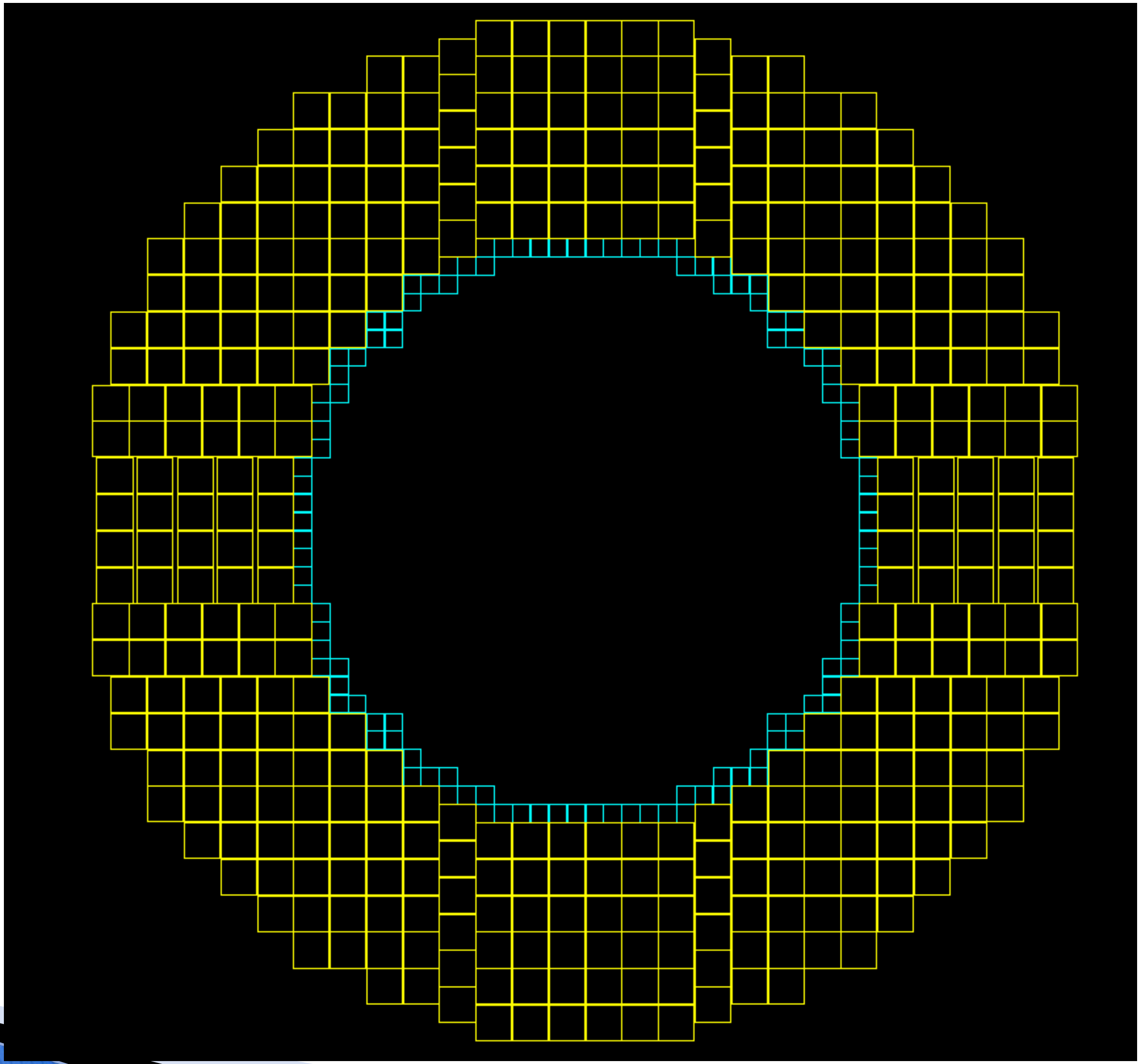
SIDIS LAEC (beam view)

- Type I (10x10cm) module in blue, type II (5x5cm long) module in green, type III (5x5cm short) module in purple.
- Supporting structure needs to be made from 75cm to 140cm

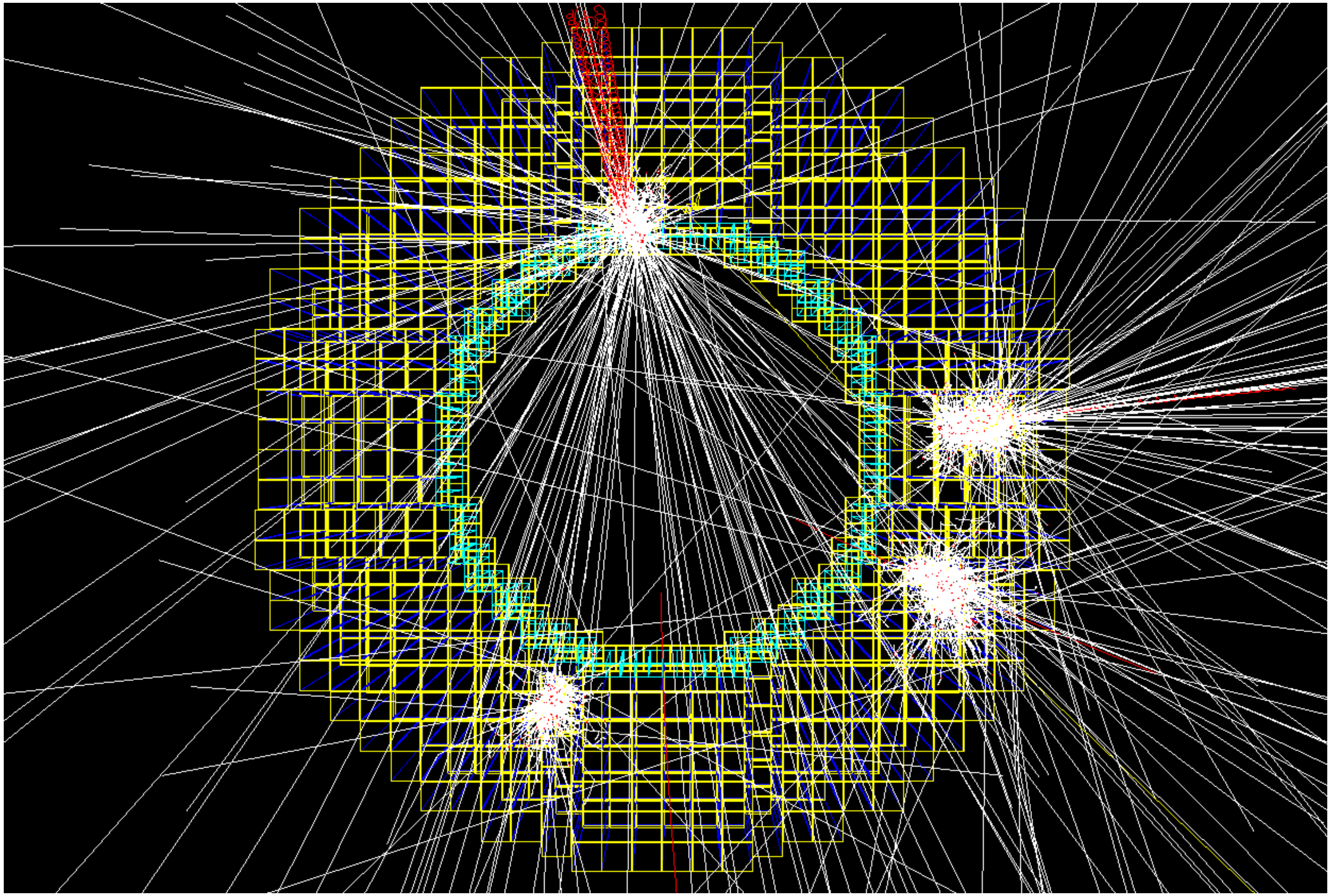


Design Updates
- Edge effects for LAEC

LAEC layout in G4 Simulation

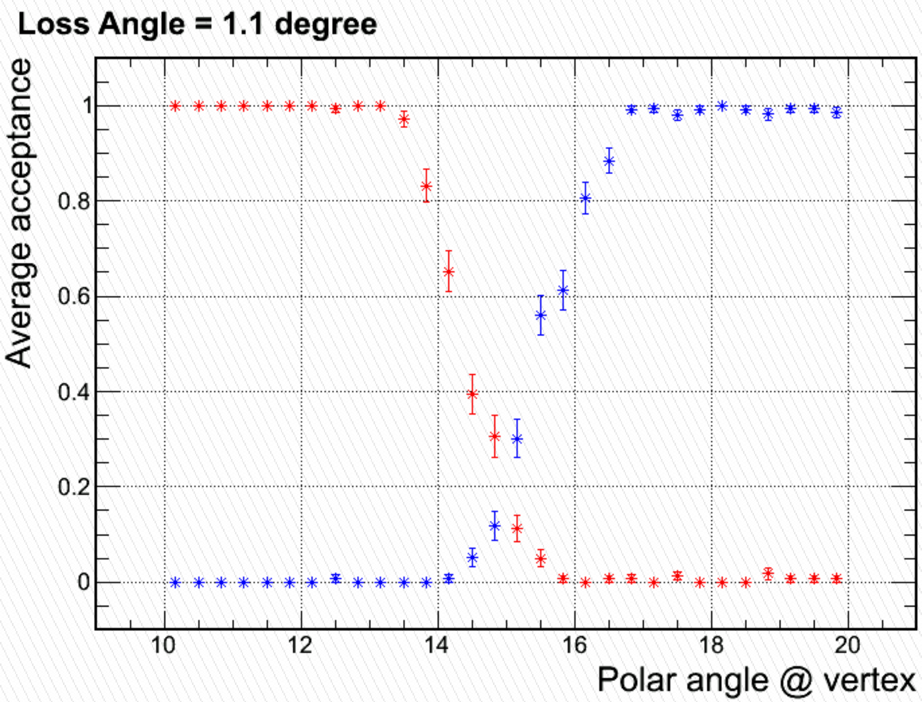


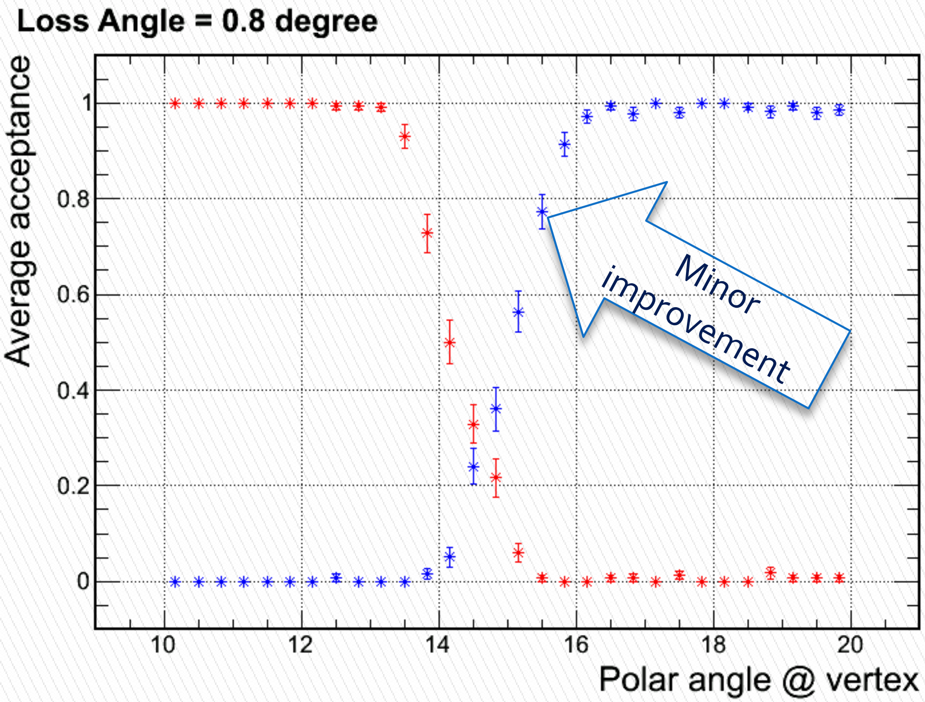
LAEC in full standalone G4 Simulation
Track transportation provided by GEMC, CLEO field



How much does inner modules help?

- LAEC catch 80% of shower
- Go freely to forward acceptance



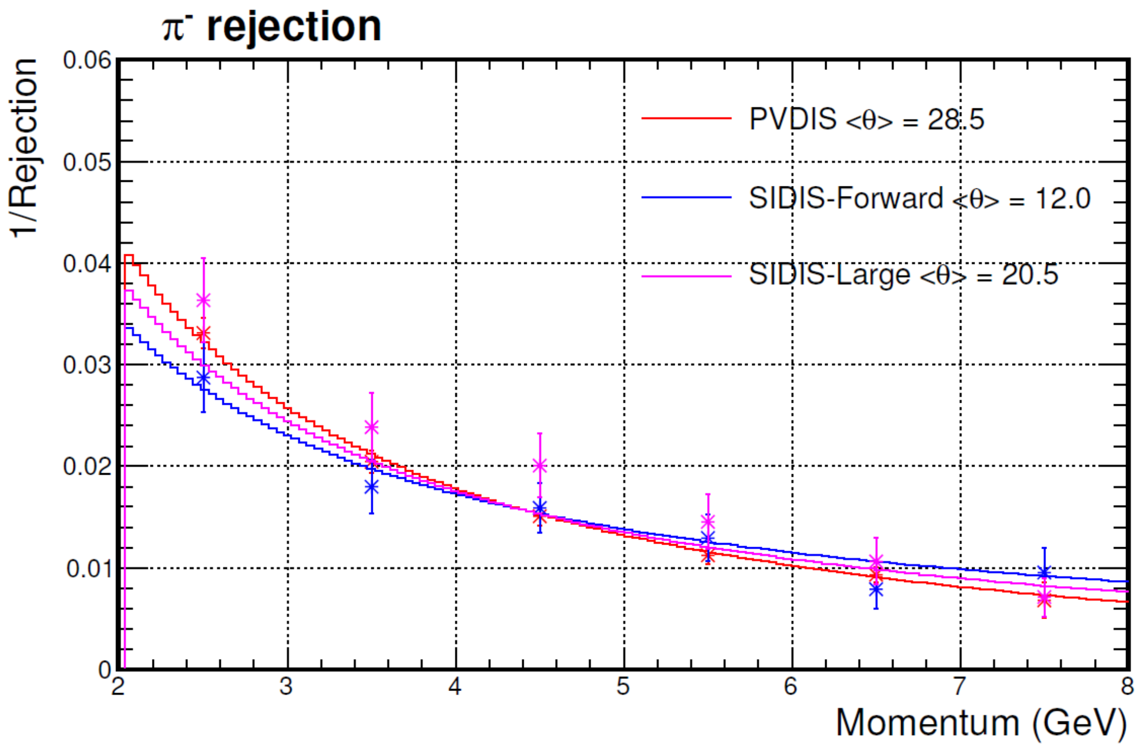


Stand conf. 404 10x10 cm^2 modules

+ 116 5x5 cm^2 inner modules

Design Updates
- Shower cluster size cut

Previously showed pion rejection

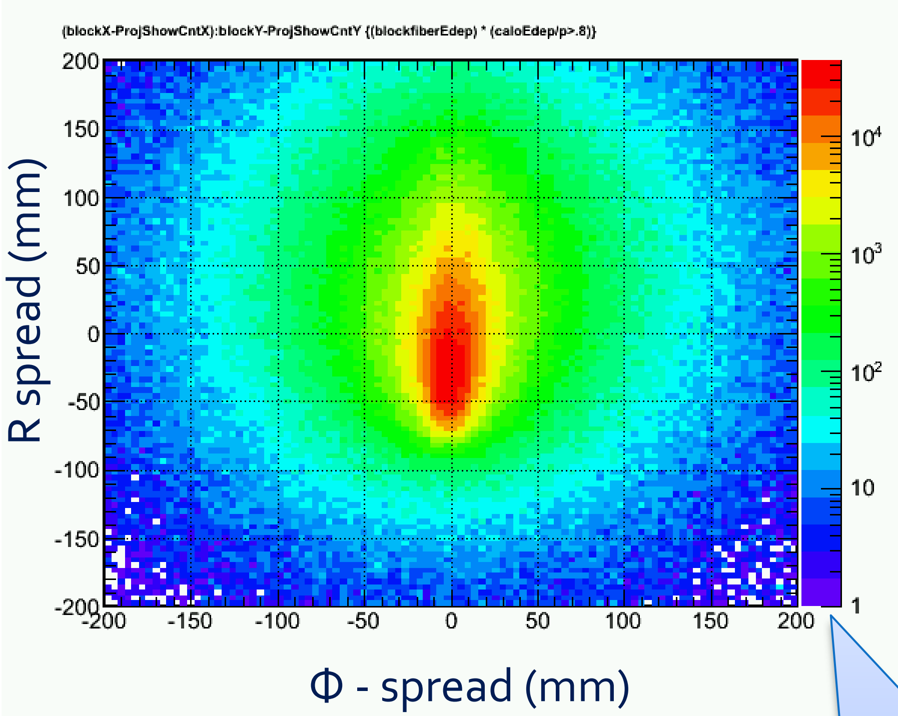


94% electron eff.

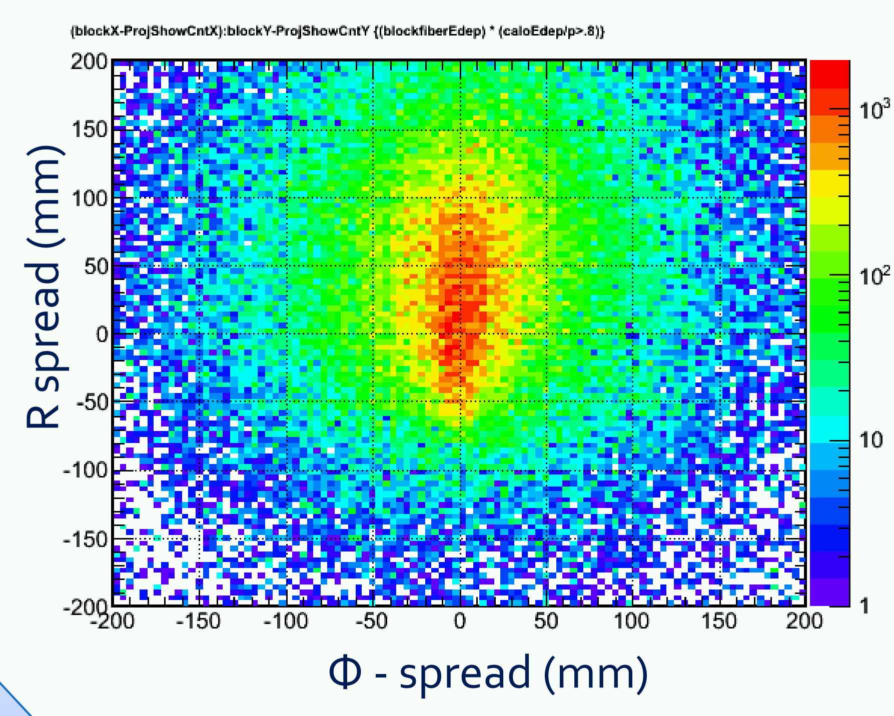
- PID selection used 3-D cut on PS, e/p and momentum
- PS and e information come from sum signal in all non-zero modules
- Enemy here is very specific: almost fully absorbed hadronic shower with high energy deposition

Shower area difference

Electron shower



Hadronic shower (e/p>80%)

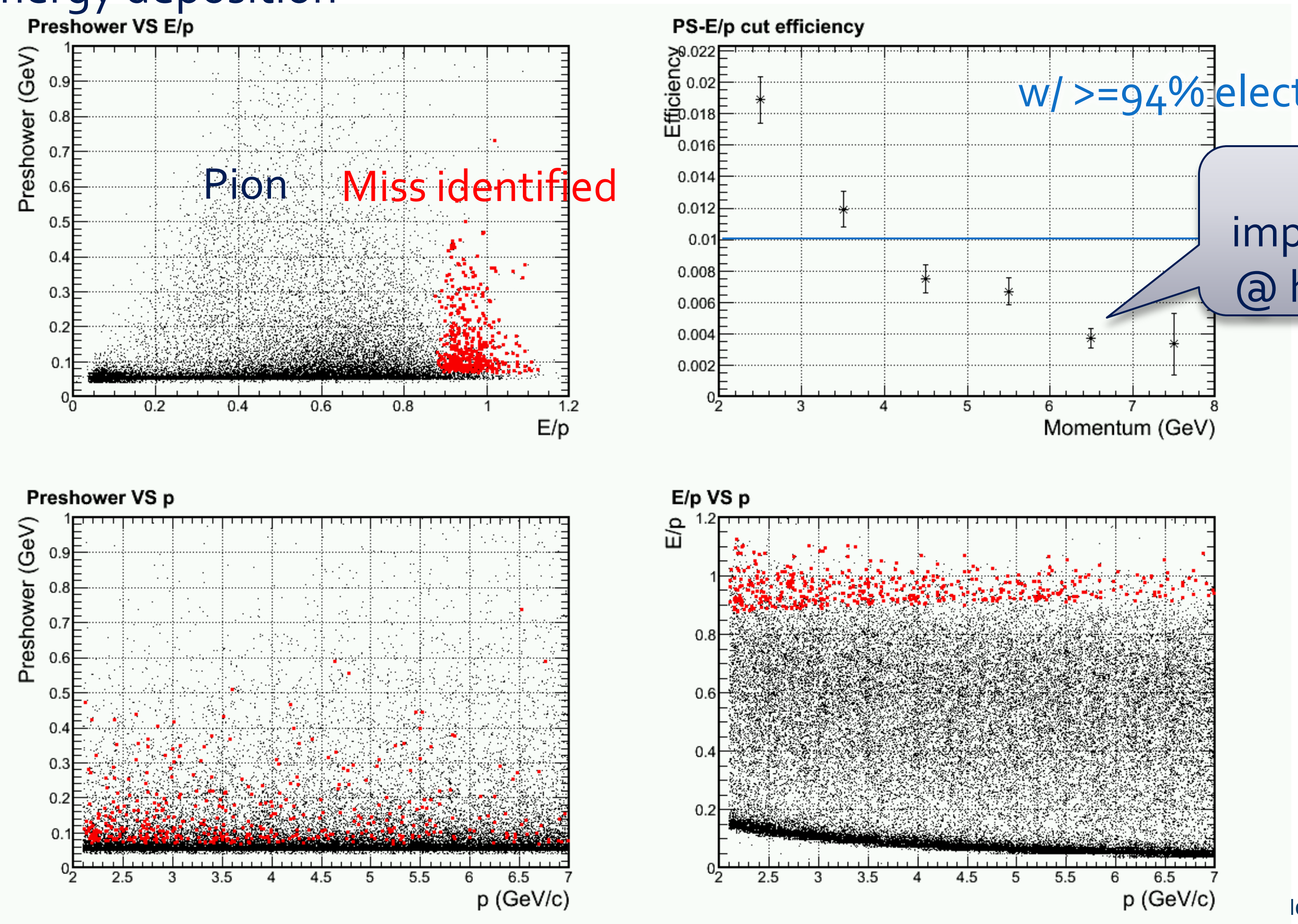


Notice the difference in color scale

Apply additional cut to limit max size of cluster around track projection

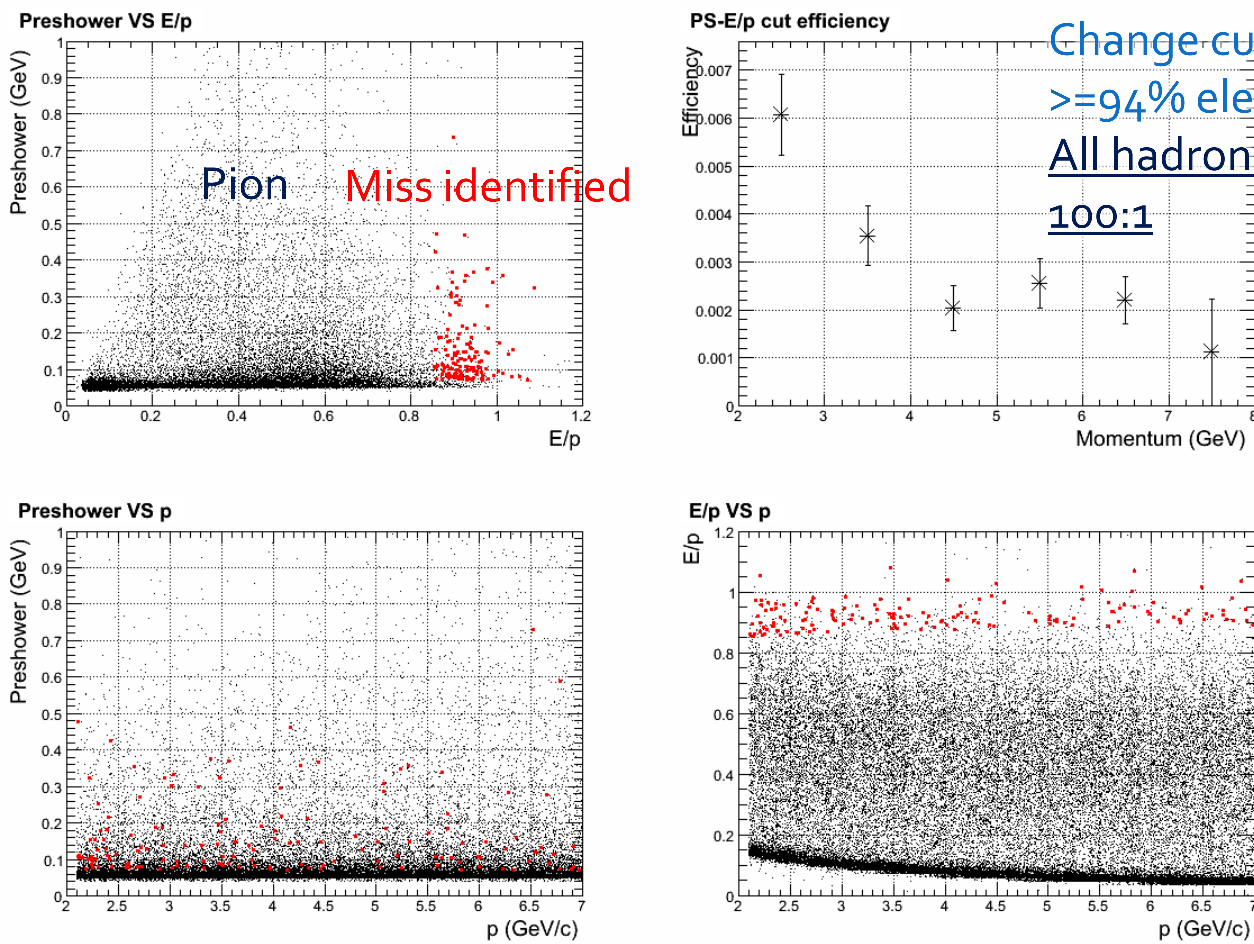
- Limit cluster to be not larger than 3x3 modules around track projection to shower central depth
- Minor cut on EM shower but effectively removed hadronic showers of very high energy deposition

Flat phase space in PVDIS acceptance



Can it be further improved?

- Further limit cluster to be not larger than 2x2 modules around track projection to shower central depth
- Now loose ~5% of EM shower, but hadron shower cuts faster



Change cut and maintain >=94% electron eff.

<u>All hadron rej. better than 100:1</u>

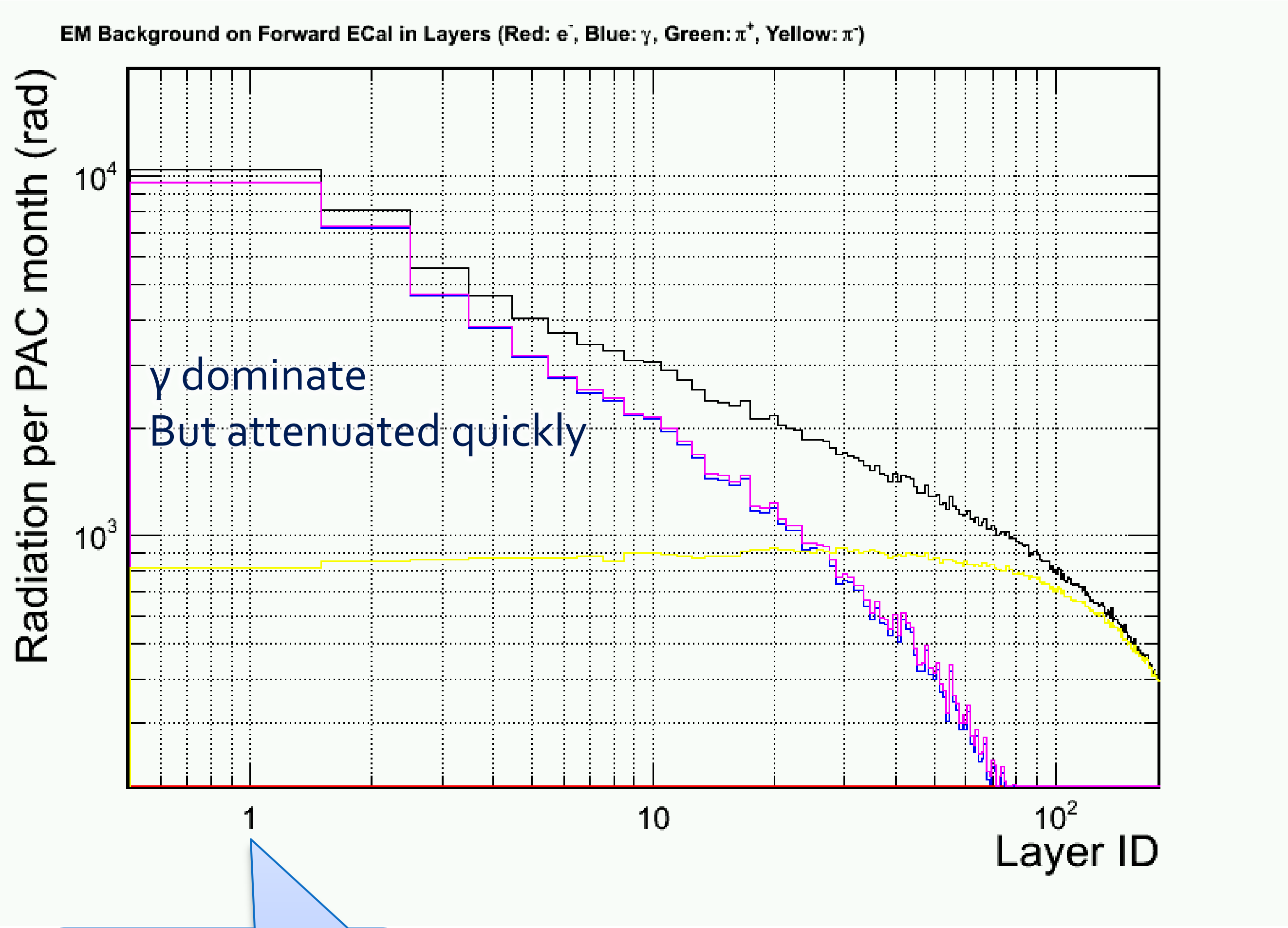
Flat phase space in PVDIS acceptance

Design Updates
- Radiation dose

What's new

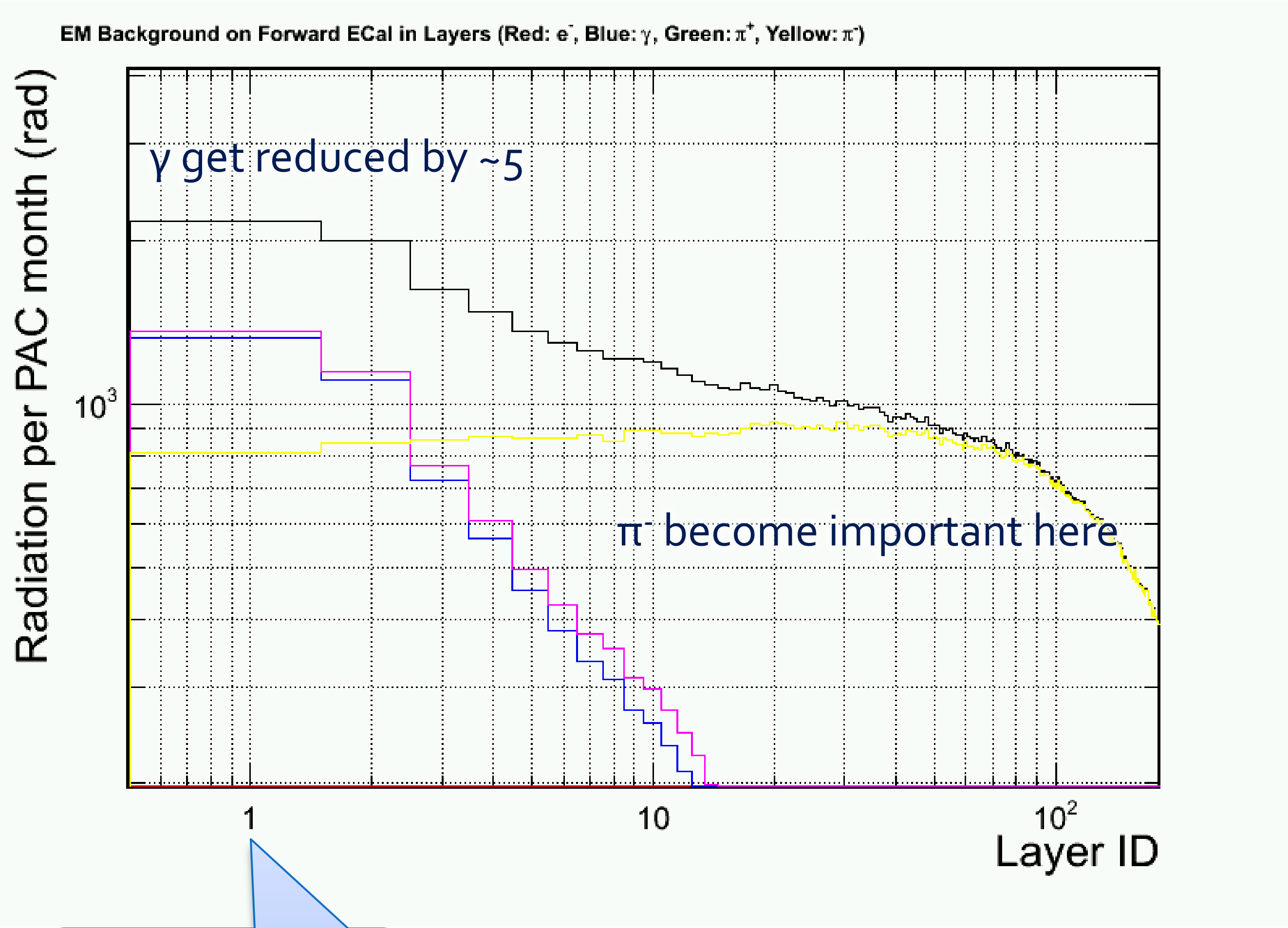
- LHCb/HERMES preshower, instead full Shashlyk preshower
  - As shown before, the preshower scintillator receive most of the radiation, due to the low energy backgrounds
  - This part radiation dose are now absorbed in 2Xo absorber, and we just see its EM tail now
  - Especially, lead absorber effectively kill all low energy electron background
- New background distribution updated by Zhiwen
  - SIDIS:
    - With target collimator (suppress background by 4)
    - First large angle simulation
  - PVDIS: have option to remove direct photon sight (expected to be removed in the final baffle design)
- Dominating background, photons 1-10 MeV
  - After preshower, which attenuate them a lot, they still penetrate ~10 layers in Shashlyk

PVDIS – current baffle (with direct γ)



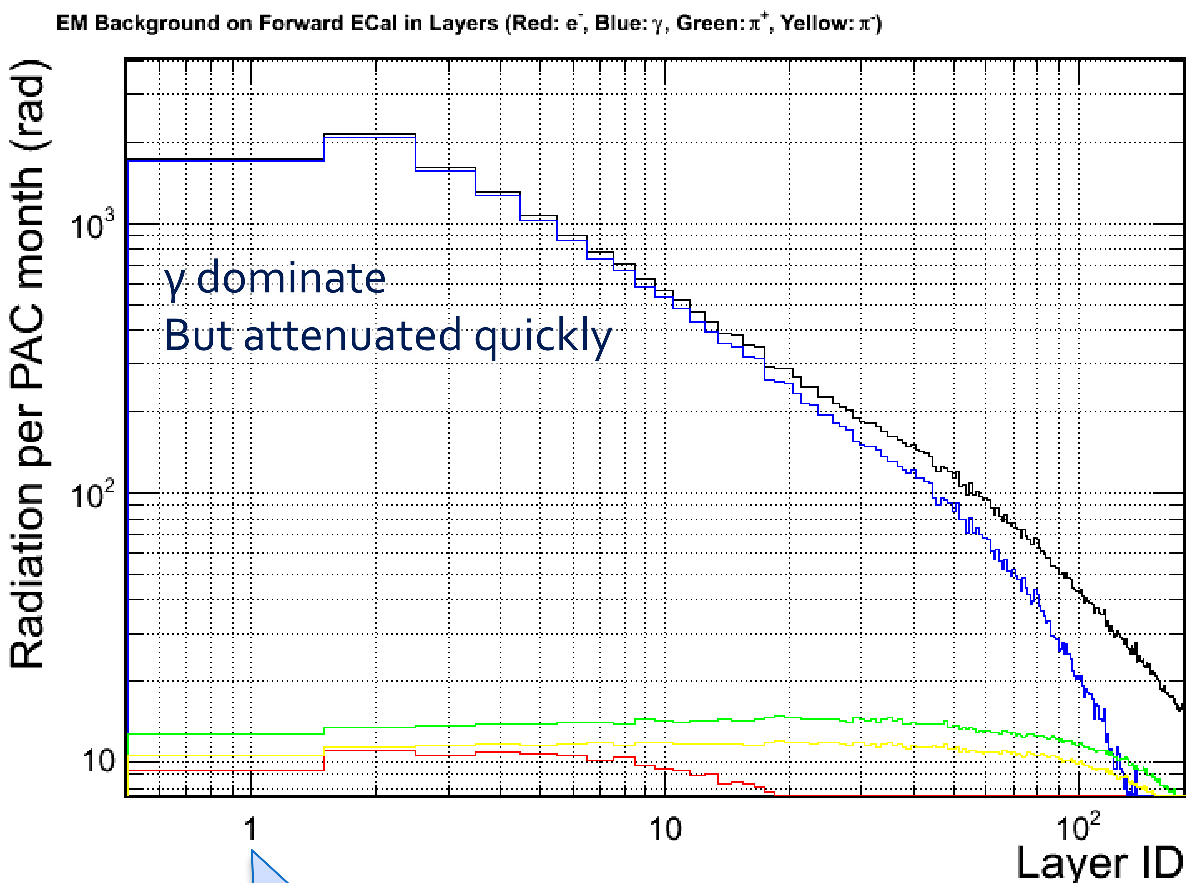
Layer #1 is 2cm preshower scint.

PVDIS – preview for a baffle w/o direct γ



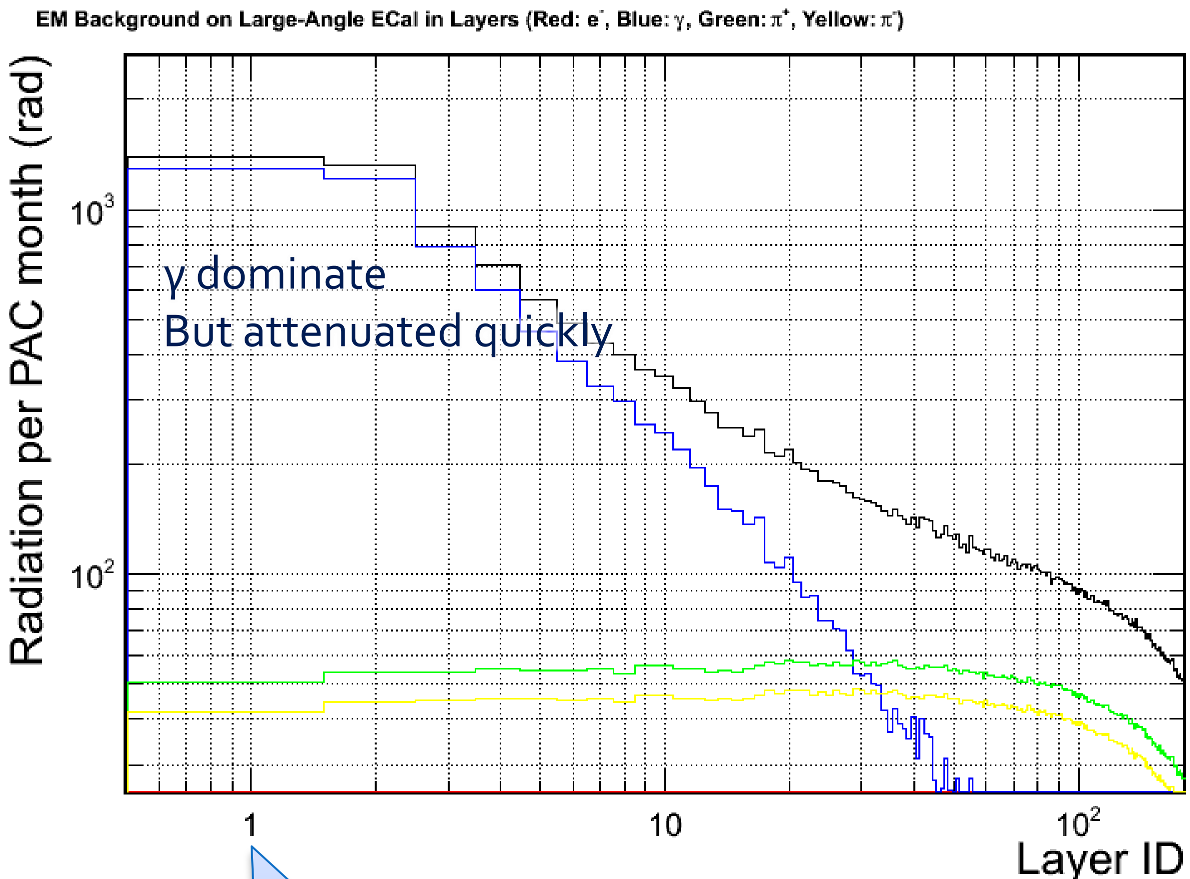
Layer #1 is 2cm preshower scint.

SIDIS – Forward



Layer #1 is 2cm preshower scint.

SIDIS – Large-Angle

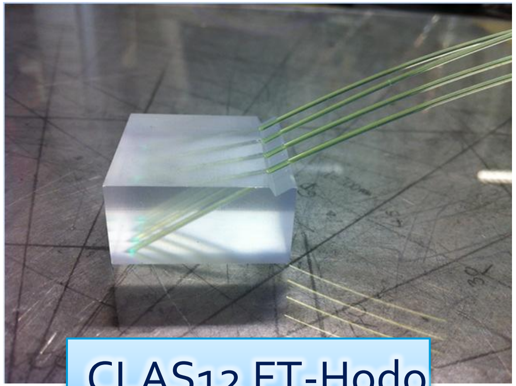


Layer #1 is 2cm preshower scint.

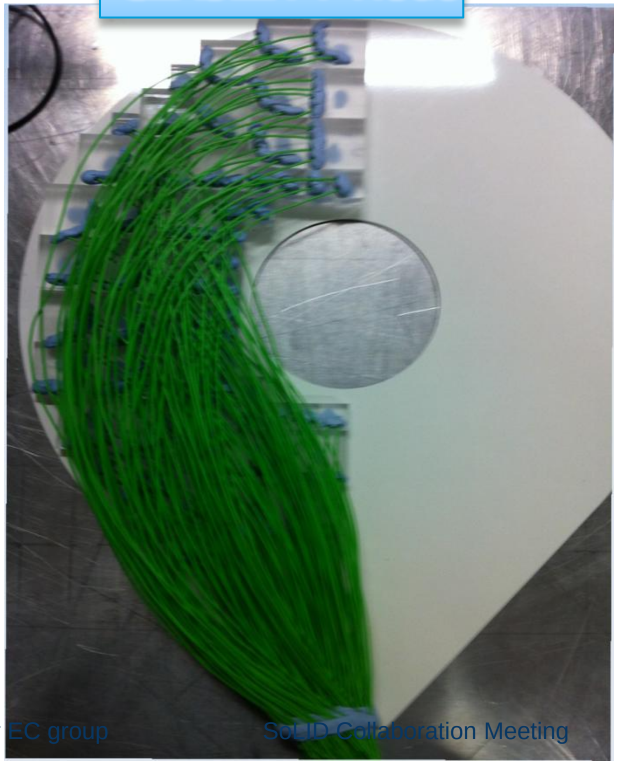
Light Readout

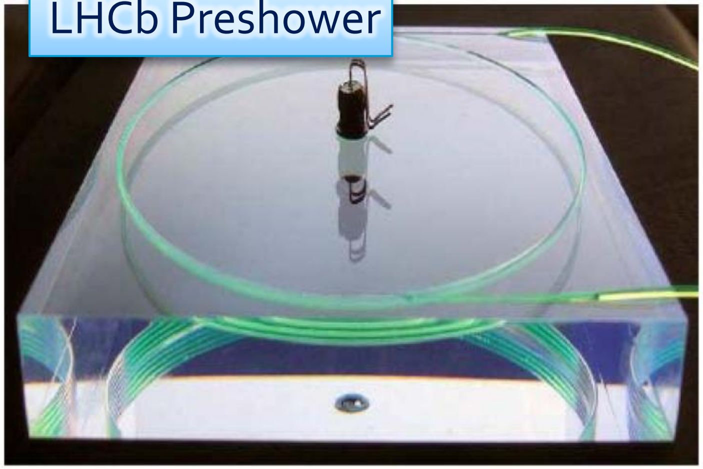
WLS fiber in scintillator pad

- Drill on scintillator and glue WLS in
- Used by LHCb etc.
- Will use by CLAS12 FT-Hodo



CLAS12 FT-Hodo

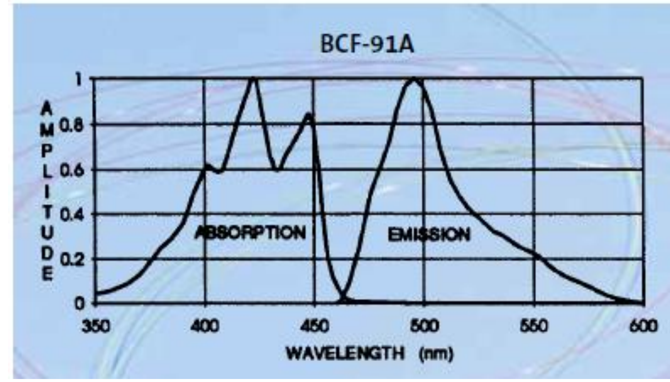


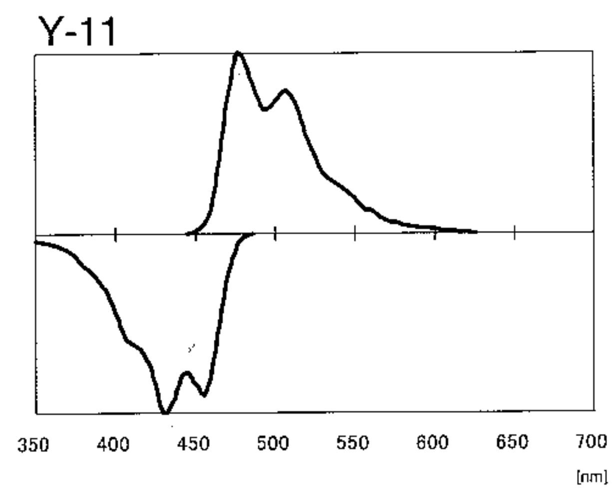


LHCb Preshower

Fiber

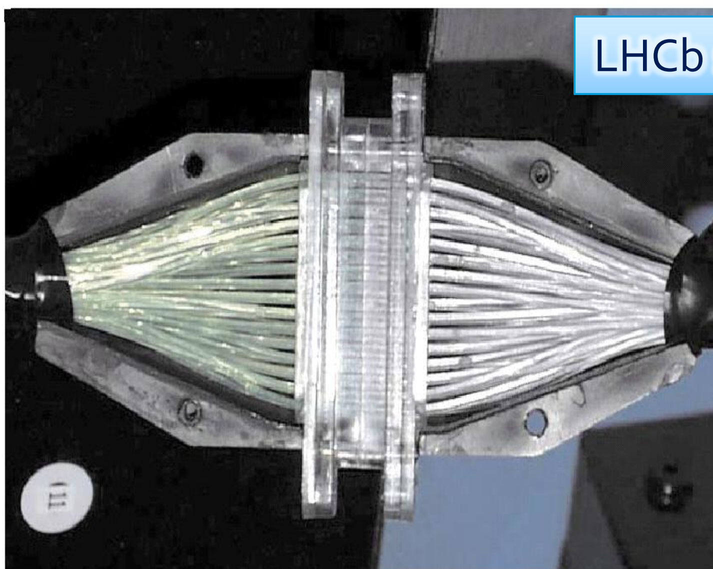
- WSL fiber in shower, 100/module
  - Bicron BCF-91A
    - multi-clad, 1/e length >3.5m
    - 1mmD, bend 20cmD (?)
    - $0.87/m
    - less rad hard
- WLS fiber in preshower pad, 1-2/module
  - KURARAY Y-11(200)MS
    - multi-clad, 1/e length >3.5m
    - 0.5mmD, bend 5cmD
    - $1/m
    - more rad hard
- Clear fiber for both, 101-102/module
  - Bicron BCF-98
    - $1/m





Fiber connection

- Shower will use 1-1 bundle fiber connector.
  Used in previous experiments (LHCb, Minos)
  custom made fiber connector $175/module, quote by LEONI
- Preshower will use comercial 1-1 single fiber connector, a few $ each.



LHCb shower

- fiber bundle to PMT connector, cost estimate $25/module

Readout

- PMT option - Hamamatsu R3998-02
  - 28mmD Bialkali Photocathode
  - $600 each
  - Used by CLAS TPE calorimeter which has COMPASS module
  - As our baseline design
- APD/SiPM option
  - High resistance to magnetic field
  - Need to be careful due to high neutron background
  - Contacting vendor for high radiation resistance designs (sensor + amp.)
  - Estimating neutron background @ photon detectors

Budget Update

Budget table – calorimeter group version

	Per-module cost($)	All-module cost(M$)
Module material	700 (L)/250 (S)	1.26
Module production	800 (L)/500 (S)	1.49
Clear fibers	260 (L)/65 (S)	0.46
Fiber connectors	200	0.39
PMTs	600 x 2	2.34
Labor	5 tech years, 5 student years	0.75
Total	-	6.7
Total+ 30% contingency	-	8.7

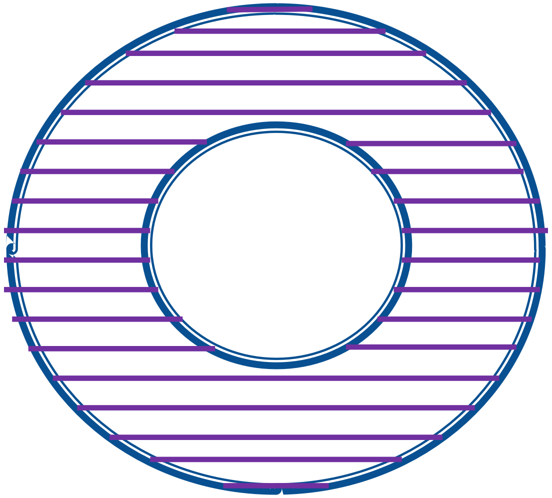
- + Prototyping ~ 0.3 M$
- Lab estimate : 5.7 (base)+3.8 (Labor)
- JP : 6.2 (base) + 1.3 (Labor)

What we need

What we need

- Engineering support (Zhiwen)
  - Support structure
  - How to do maintenance and install it back
- Inquiries
  - IHEP (Xiaochao)
  - Fiber connection (Mehdi)
  - Photon detectors (Zhiwen)
- Background effect (Jin)
  - Event mixing with signal and background simulation
- Prototyping

Support structure ideas



- Overview
  - One support for LAEC, one support for FAEC
  - Only a few cm gap between outer radius of SIDIS LAEC and inner radius of cryo, is it enough?
  - Only a few cm gap between outer radius of FAEC and inner radius of nose cone, is it enough?
  - Need to consider the supporting with overall magnet cryo and yoke structure.
- “super” Modules
  - Group 1-3 row of modules into supermodule
  - shift supermodule’s horizontal position to make layers

backup

WLS 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

Fiber connection (Backup option)

- Fiber splicing
  - Robust connection and excellent transmission (2%)
  - CLAS12 Forward Tagger Hodoscope will fuse WLS and clear fiber. Commercial vendor has been contacted and They are also developing their own method.
  - We will collaborate with them to examine the labor and cost requirement.