Calorimeter Design for SoLID Project

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SoLID Collaboration Meeting

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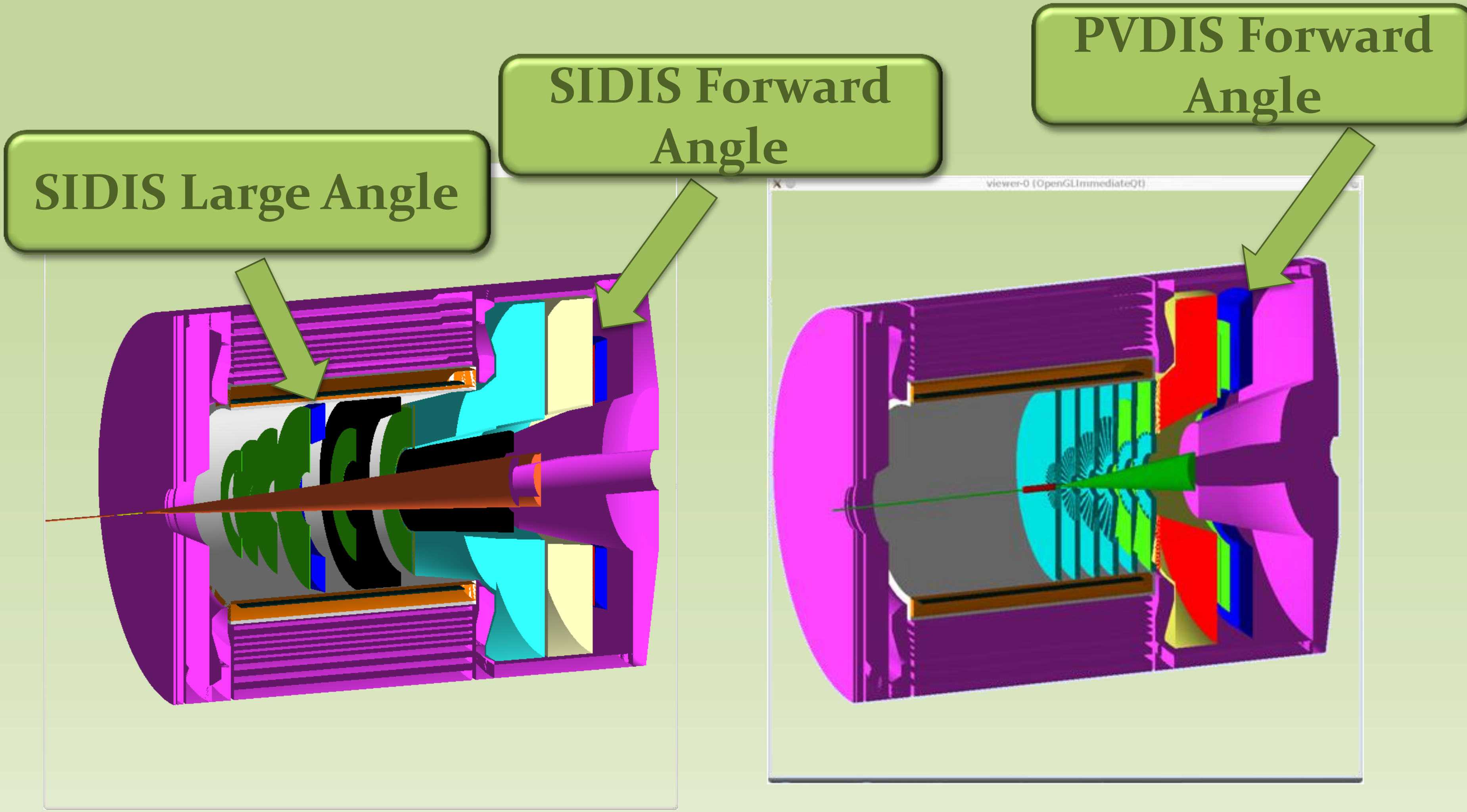
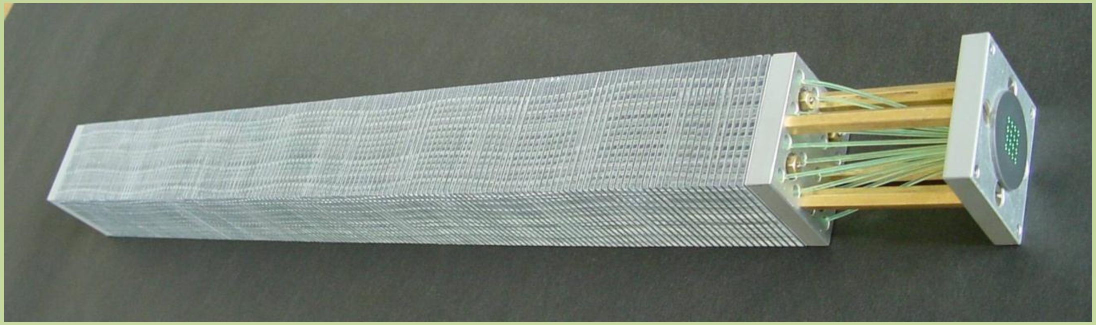
OUTLINE

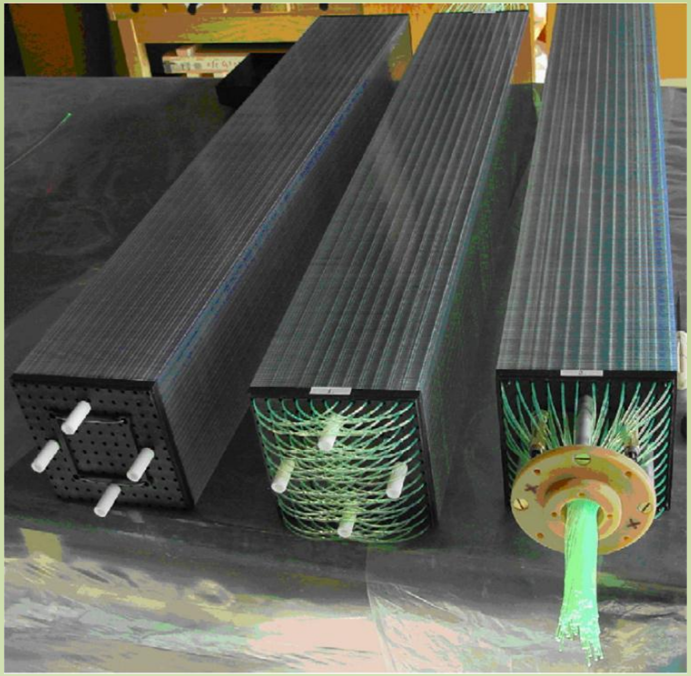
- ❖ Requirements
- ❖ Calorimeter design
  - ➢ Best Option
  - ➢ Tunable design
  - ➢ Layout
  - ➢ Light Readout
- ❖ Budget Estimate
- ❖ Simulation Update
- ❖ Conclusion

SIDIS/PVDIS CONFIGURATIONS



Calorimeter Design: Best Option





- Lead-Scintillator Sampling Calorimeter:
  Shashlyk Calorimeter

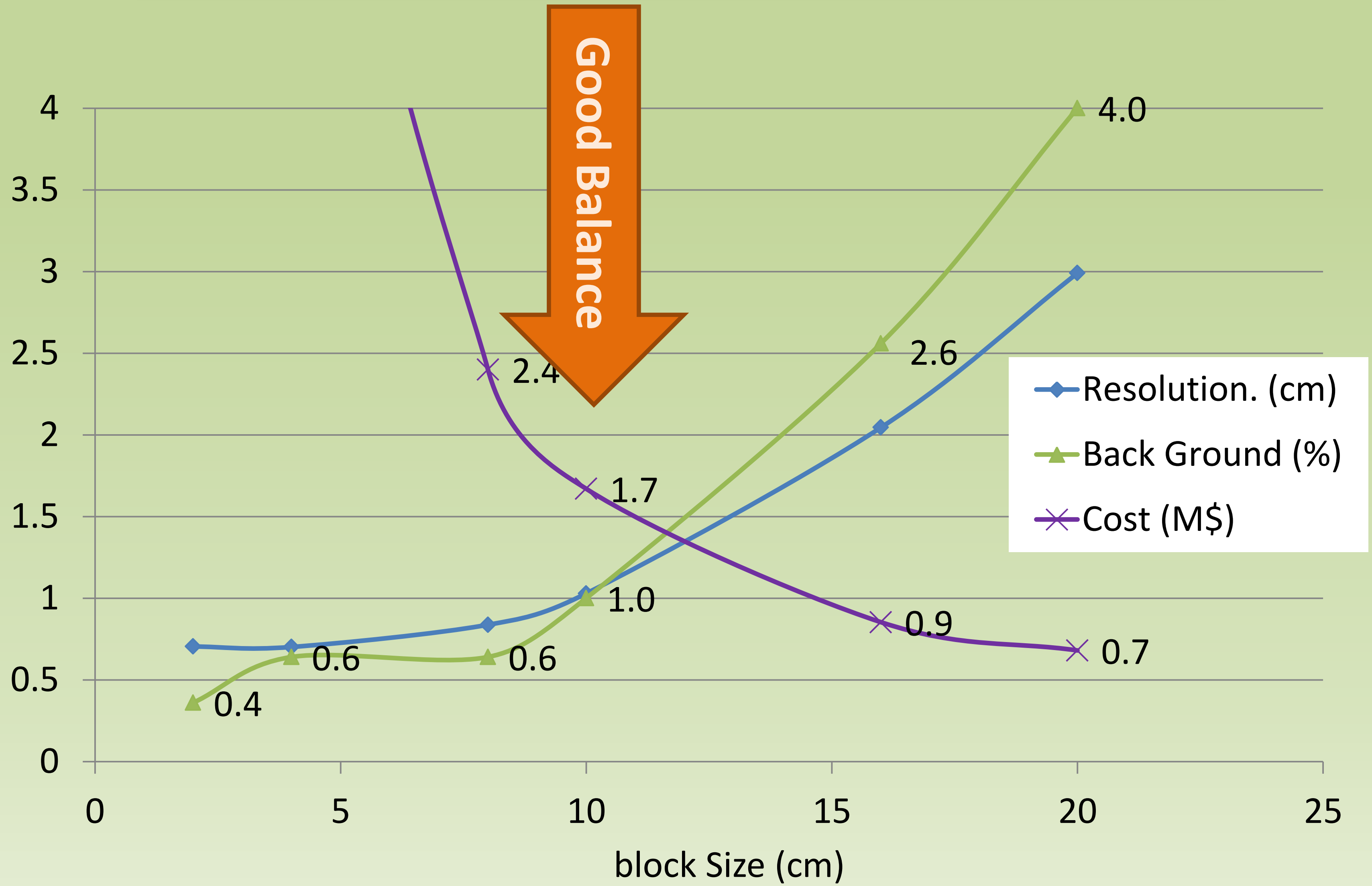
- Fibers collect and read out the light

- Great flexibility, tunable energy resolution: ~ 6%/√E is not a problem

- Good radiation Hardness: ~ 500 krad/year

- Well developed and mature technology: used previously in other experiments

Calorimeter Design: Lateral Size

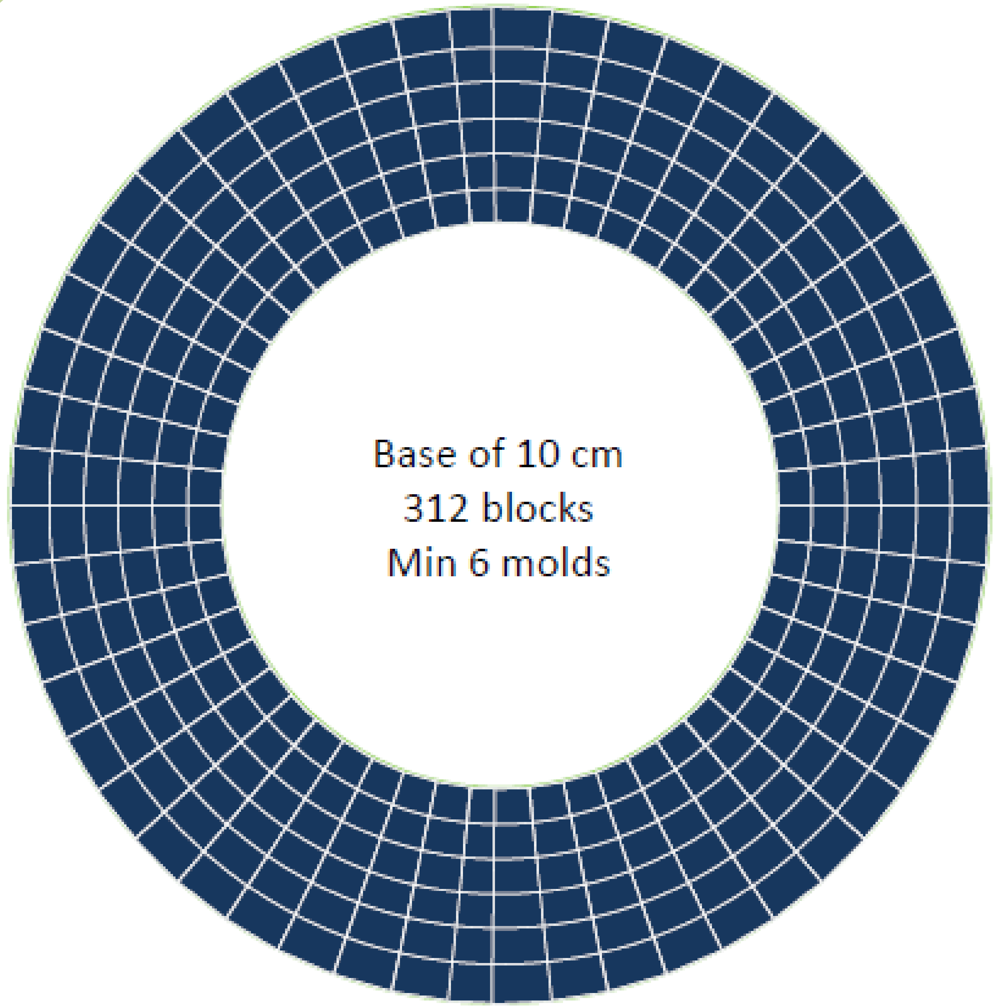


Calorimeter Design: Layout - Ring Sector

❖ Excellent coverage (no edge effect)

❖ Small minimum number of blocks but several molds (~50 k each!)

❖ Block size varies with the radius, so does the position resolution



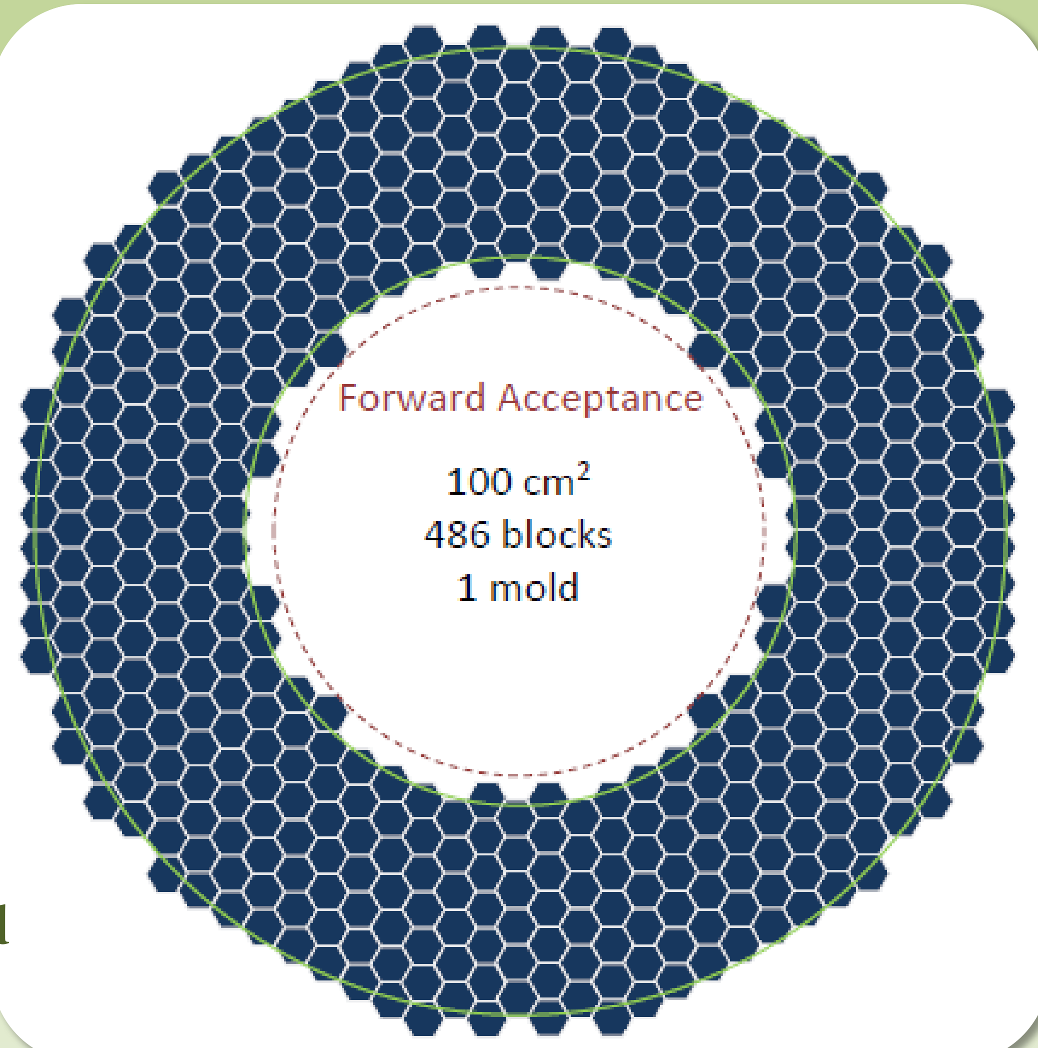
Calorimeter Design: Layout - Hexagon

❖ Possible edge effects

❖ Larger number of blocks but one molds

❖ Same block size

❖ Only six direct neighbors for each block, easier background determination



Calorimeter Design: Layout - Square

- ❖ Possible edge effects
- ❖ ~ Same number of block as the hexagon layout
- ❖ Same block size
- ❖ Easy assembly and mature production

Calorimeter Design: Layout - Summary

	Hexagon		Square		Sector	
	Small	Large	Small	Large	Small	Large
Size (cm)	10	10	10	10	10.5	9.95
Blocks	912	486	908	492	576	312
Molds	Min 1	Min 1	Min 1	Min 1	Min 9	Min 6
Total	1398 blocks 1 mold ~ $1.4M		1400 blocks 1 mold ~ $1.4M		888 blocks 15 molds ~ $1.64M	

❖ Preferred configuration: Square

- Easy assembly
- Mature production
- Greater Flexibility (easier rearrangement)

Calorimeter Design: Light Read-out

❖ Large Angle Calorimeter:

- Preferred option: transport light outside the magnetic field.

- PMT read out outside the magnet is easy to maintain.

❖ Forward Angle Calorimeter:

- Option 1 : transport light outside the endcap, easy access

- Option 2 : in field light readout (<100G).
  Need PMT with mu-metal shielding

Both options are under studies

Calorimeter Design: Fibers

- **Fibers:**
  - **Wave Length Shifting fibers (WLS):**

KURARAY Y11: - good attenuation length (3.5-4m),

- good radiation hardness : <30% loss of light output after a 693 krad irradiation.

- Recovery: few percents after 10 days

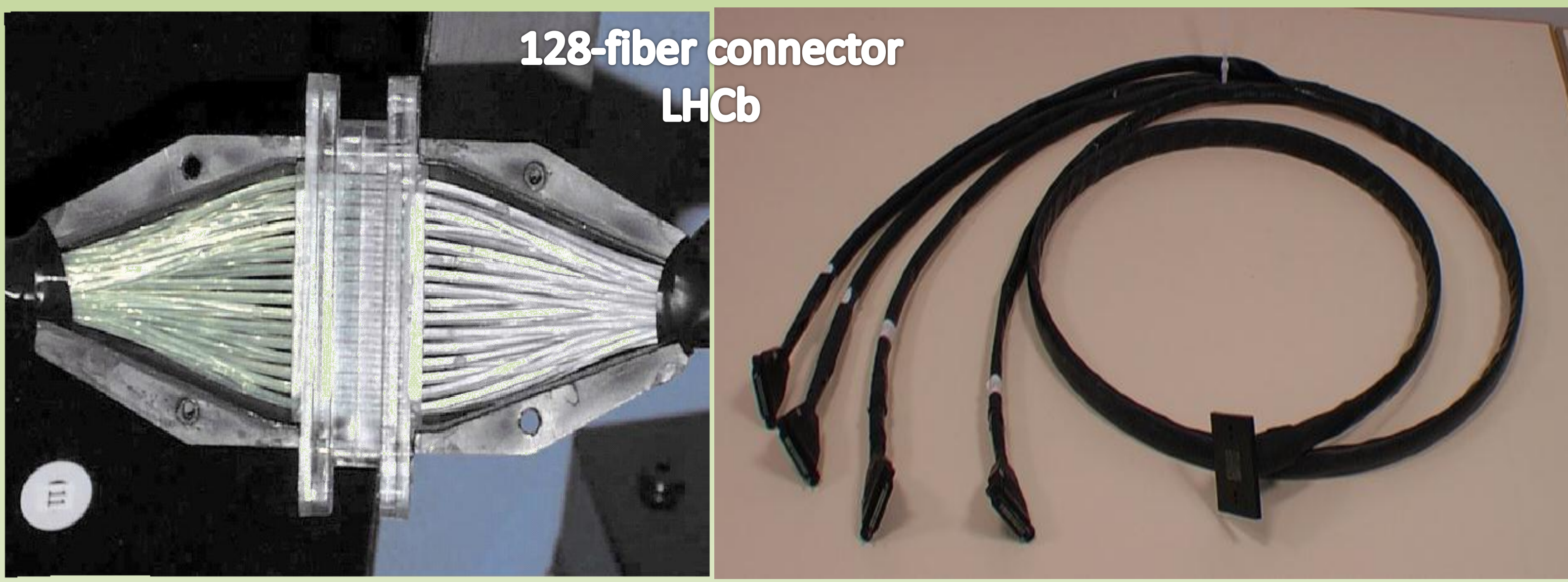
(M.J. Varanda et al. / NIM in Phys. Res. A 453 (2000) 255}258)

- **Clear Fibers:** KURARAY clear PS, Super Eska…, options under study.

Calorimeter Design: Connectors

❖ **Option 1:**

One to one WLS/clear fiber connector,
used in previous experiments (LHCb, Minos)



Calorimeter Design: Connectors

❖ **Option 2:**

Thermal fusion: splice the WLS and clear fiber.

Giorgio Apollinari et al NIM in Phys. Research. A311 (1992) 5211-528

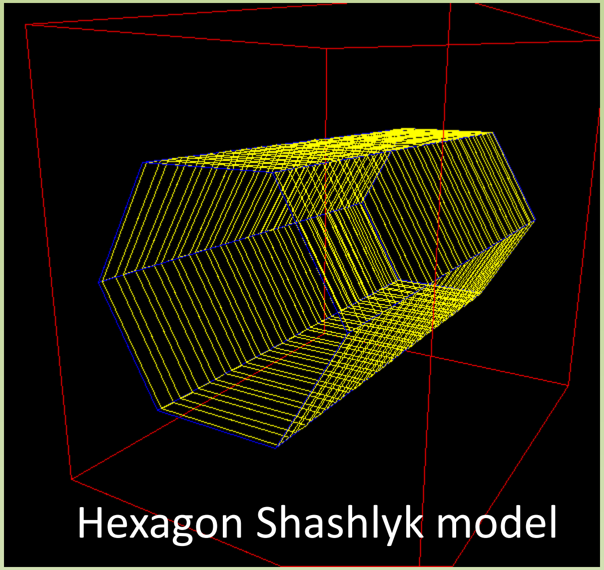
❖ **Option 3:**

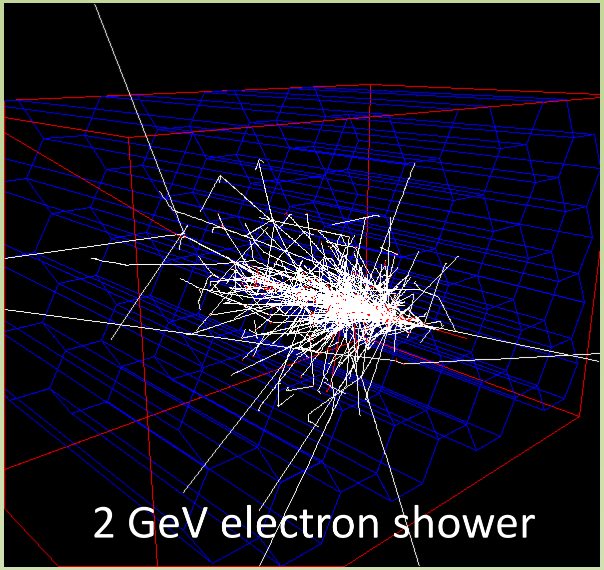
Glue the WLS fibers to a lucite disk coupled to a lucite Rod with optical grease or Si gel "cookie".

Would reduce the cost significantly

Need more R&D to decide what is the best option.

Hexagon Layout Simulation

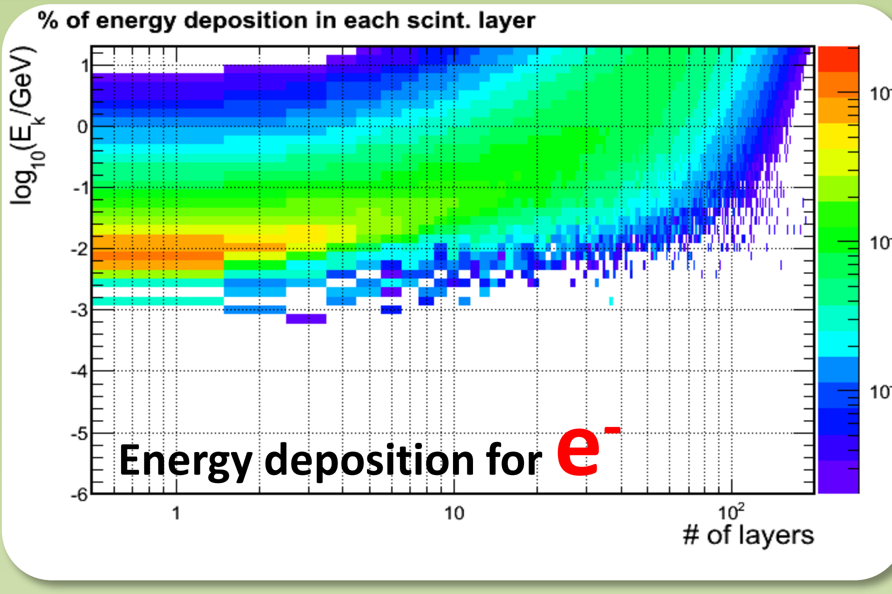


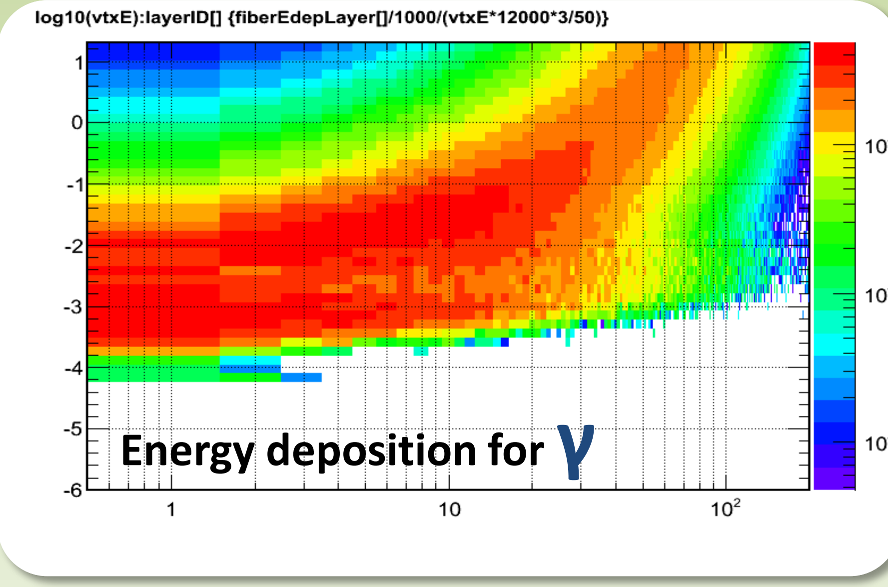


Energy weighted position resolution is about the same as the square layout one: ~1cm

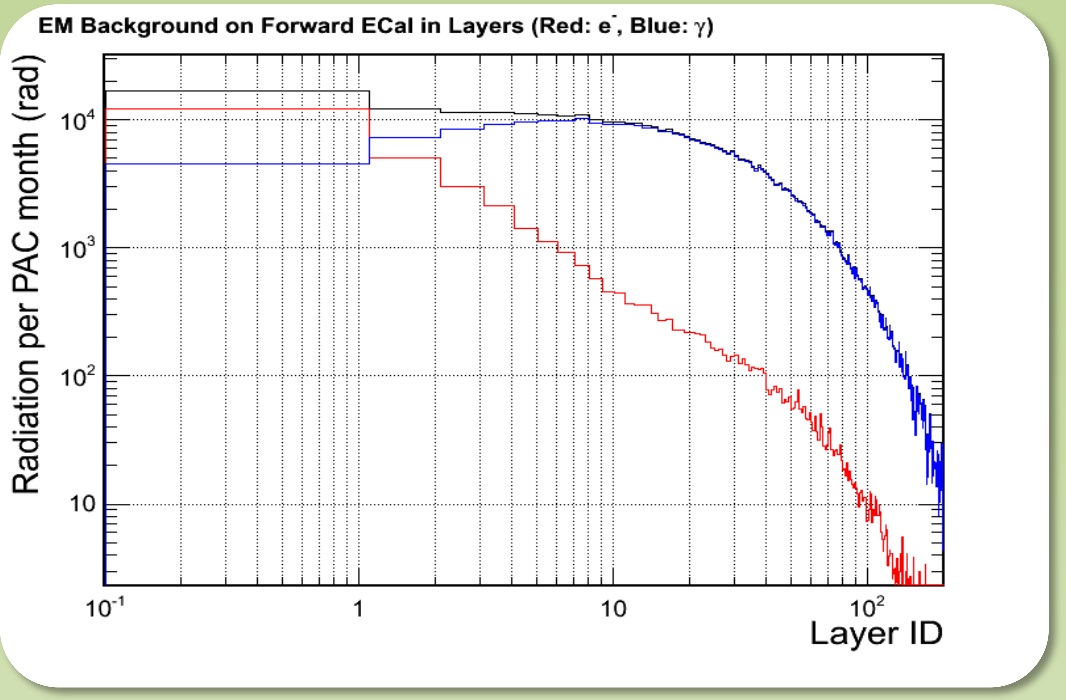
Background Simulation

- The radiation dose for scintillators is 100krad~2Mrad, material dependent.
- Doses on the fibers are similar to the doses on scintillator tiles (both are plastic based).
- Dose = (fraction energy deposition for each layer) *(energy flux)
- (energy flux) is generated by using GEMC and Babar model.
- (fraction energy deposition) is calculated using GEANT 4 simulation for each layer and different incoming particle kinematic energy.





Background Simulation



- The first 10 layers of scintillator have most of the radiation dose. Dominated by γ.
- Not much safety margin to radiation limit for some scintillator. Need to use radiation hard material.
- Can add a front shielding of 1~2mm lead (equivalent to 2~3 layers) to reduce the radiation in the first few layers.
- GEMC background model is being improved.

Budget Estimate

Experiment	Angle (degree)	Radius (cm)	Area(m^2)	Number of modules	Module cost (M$)	Fiber Extension (M$)	PMT+ support (M$)	Total cost
PVDIS (forward angle)	22-35	110-258	~10	1000? ~Baffle design	1.5	0	0.6	2.1
SIDIS (forward angle)	9-15	107-202	11	908				
SIDIS (large angle)	17-24	82-141	5	492	0.8	0.3(?)	0.3	1.4

- **Support structure: 0.2M$ (?)**
- **10x10cm Shashlyk module costs about $1~1.5K each**
- **PVDIS : factor 0.5 reduction due to only covers ~half of azimuthal angle**
- **Rearrangement of modules between PVDIS & SIDIS large angle calorimeters**

TEST of the COMPASS modules

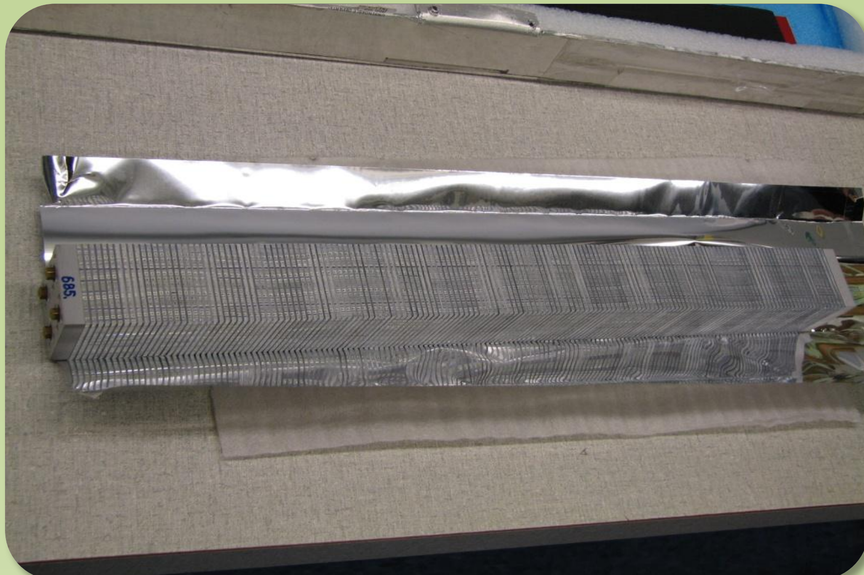
- To gain direct experience with the modules.

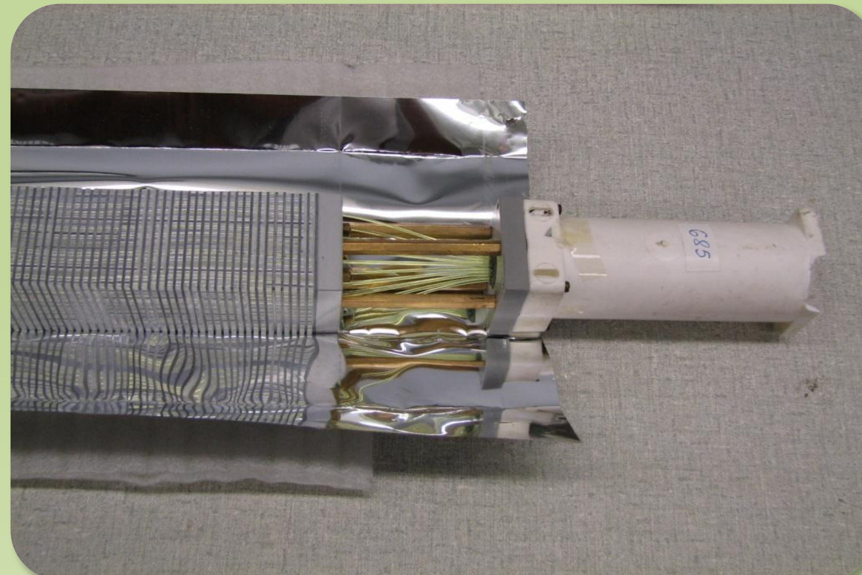
- To help parameterizing the light sampling for WSL fibers and anchor the simulation.

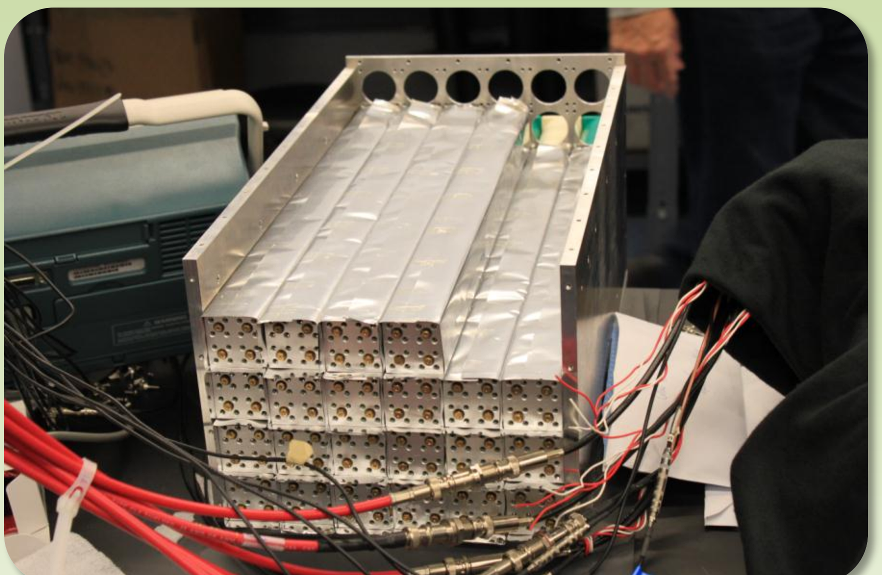
- To study the position resolution at different incoming angles.

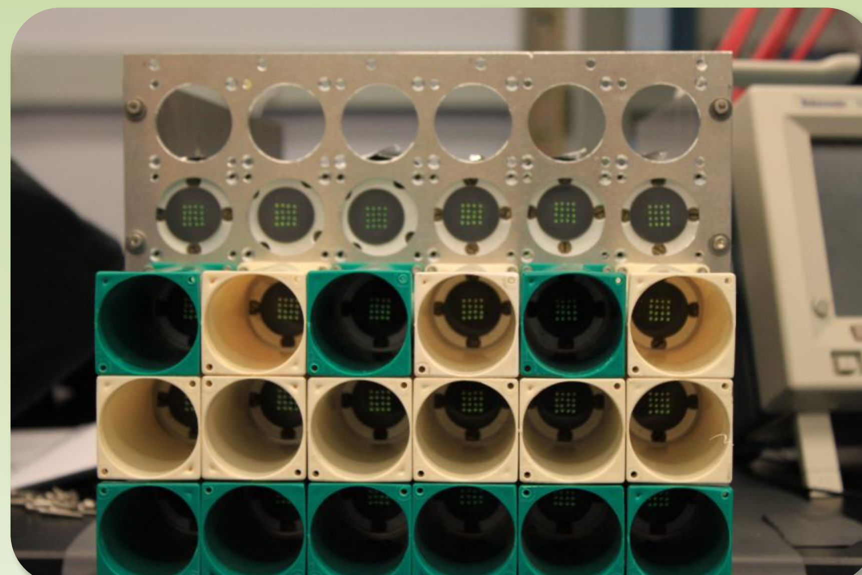
- We will borrow 30(5x6) COMPASS module used for TPE@CLAS, but still need PMT, base and electronics.

COMPASS modules used for TPE@CLAS









Beam Test Plan

- Before the holiday, setup and bench test with cosmic ray for calibration

- After the holiday, beam test in HallA
  - gain balance
  - sampling fraction
  - energy resolution
  - Timing
  - position resolution with angles

Conclusion

- Square Layout preferred over hexagon and ring sector

- Need more R&D on the WLS/clear fibers connection (connectors, fusion, bundle…)

- Background simulation is ongoing

- Budget: $2.1 M for PVDIS + SIDIS large angle
  $1.4 M for SIDIS forward angle

- Plan for a beam test of the COMPASS modules

Backup Slides

REQUIREMENTS

❖ **Electron-hadron separation:**

- ➢ 100:1 pion rejection in electron sample
- ➢ Energy resolution: $\sigma(E)/E \sim 6\%/\sqrt{E}$

❖ **Provide shower Position:**

- ➢ σ ~1cm, for tracking initial seed / suppress background

❖ **Time response:**

- ➢ σ <~ few hundreds ps, provide trigger/identify beam bunch (TOF PID)

Calorimeter Design: Flexibility

- Great design adaptability to match the experimental needs.
- Two experienced providers contacted:
  - IHEP at Protvino for design & production
  - INR at Trozic for design & UNIPLAST for production

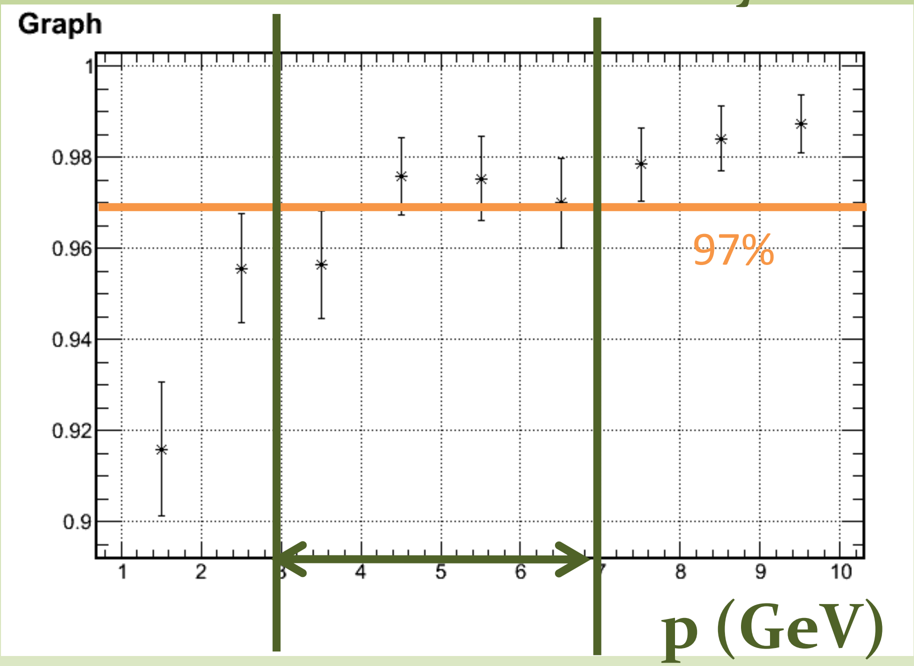
Experiment	COMPASS	PANDA	KIPIO
Pb Thick/ Layer (mm)	0.8	0.3	0.28
Sci Thick/ Layer (mm)	1.5	1.5	1.5
Energy Res. a/sqrt(E)	6.5%	~3%	~3%
Rad. Length, X_0 (mm)	17.5	34	35
Total Rad. Length (X_0)	22.5	20	16
Moliere radius (mm)	36	59	60
Typical Detecting Energy	10^1~10^2GeV?	<10GeV	<1GeV
Trans. Size (cm)	~4x4	11x11	11x11
Active depth(cm)	400	680	555

Calorimeter Design: Lead/Sci Ratio

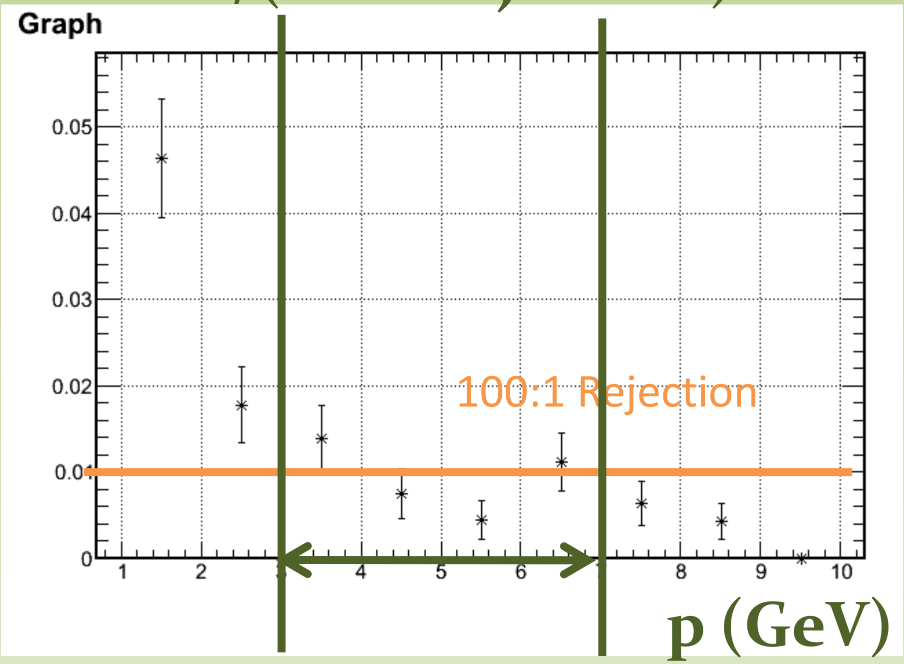
- Tuning of the ratio performed with a dedicated Geant 4 simulation.

↳ Can reach a pion rejection factor of 100/1 with Pb thick. = 0.6 mm /layer

Electron Efficiency



1/(Pion rejection)



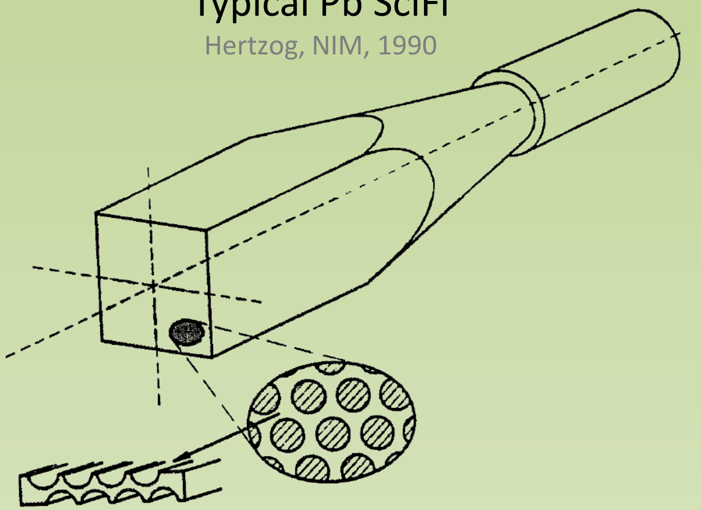
Range of interest: 3~7 GeV

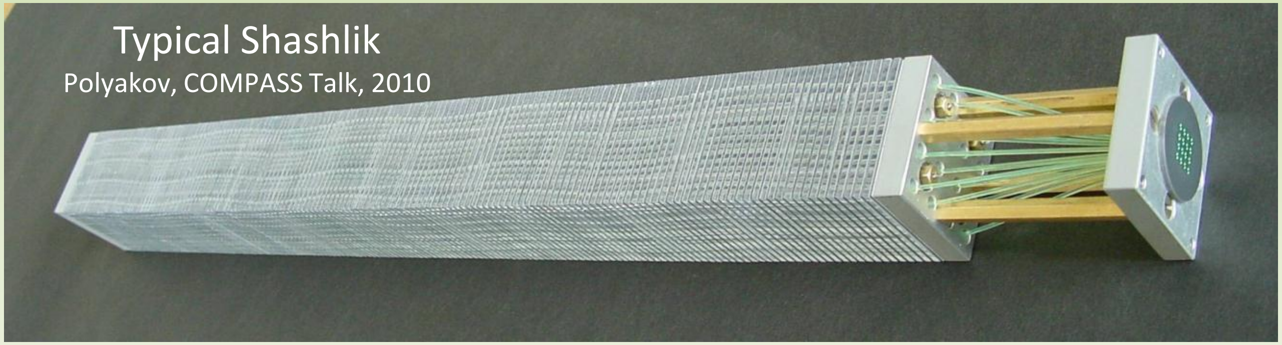
Compare of calorimeter types

A. Shashlik calorimeter
B. SciFi calorimeter – Pb
C. SciFi calorimeter – Fe
   – Combined with end cap

Typical Pb SciFi

Hertzog, NIM, 1990





Compare option A & B

Shashlyk and SciFi-Pb

- Similarity
  - Pb-scintillator based sampling calorimeter
  - Similar in resolution and radiation hardness
  - Both fit the need of SoLID
- Choice : Shashlyk
  - Easier to read out light:
    Photon collection area 100 times smaller than SciFi
  - Matured production

Compare A & C for the forward Calo.
The choice - Shashlik

Reason of choosing Shashlik over Scifi/Fe in endcup

- Shashlik is cheaper.
  - It's production module cost cheaper or similar to SciFi fiber cost alone.
- Shashlik is more mature.
  - SciFi/Fe needs R&D
- Shashlik is easier.
  - several suppliers with good experience are available.