# SoLID EC beamtest

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HallB weekly meeting
2012/02/13

Jefferson Lab

12 GeV Upgrade
Future Science at Jefferson Lab

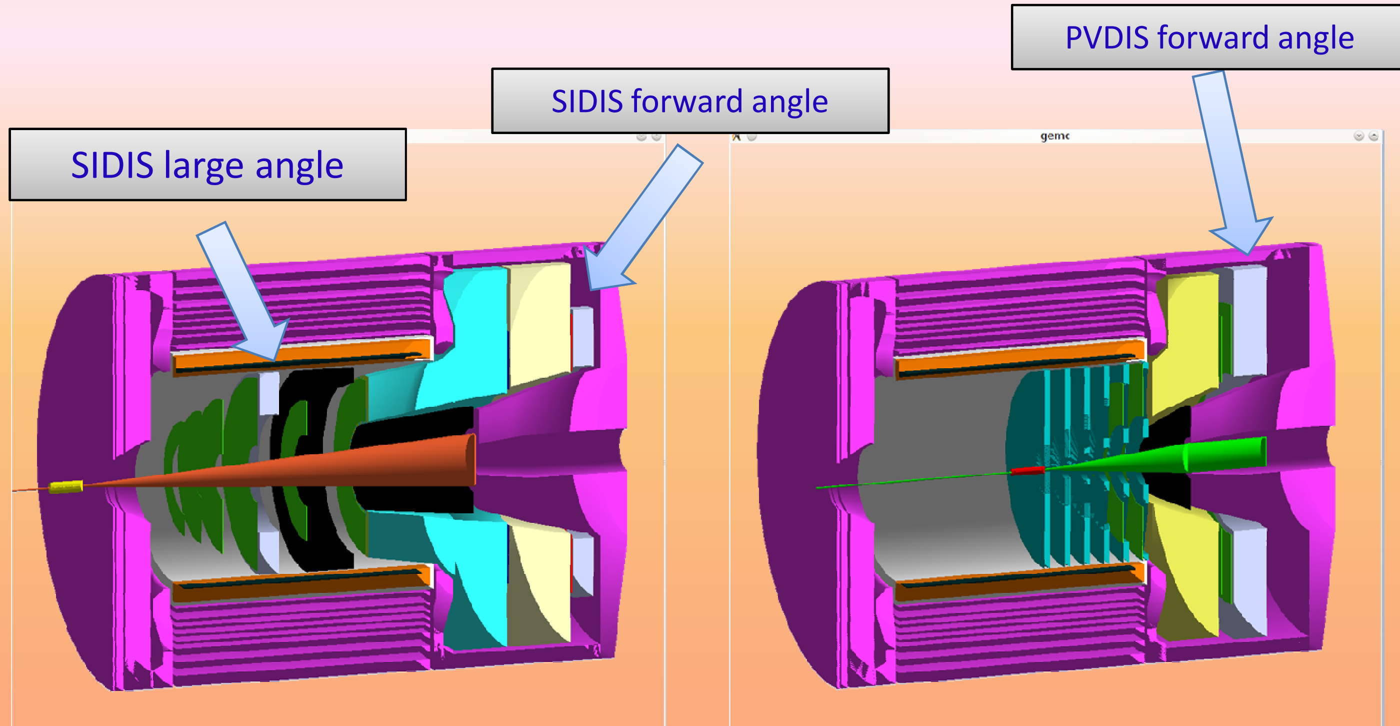
# SoLID - Solenoidal Large Intensity Device

- One of three major new equipments of Hall A 12GeV upgrade besides SuperBigBite and Moller
- General purpose device.

  *proposals:*

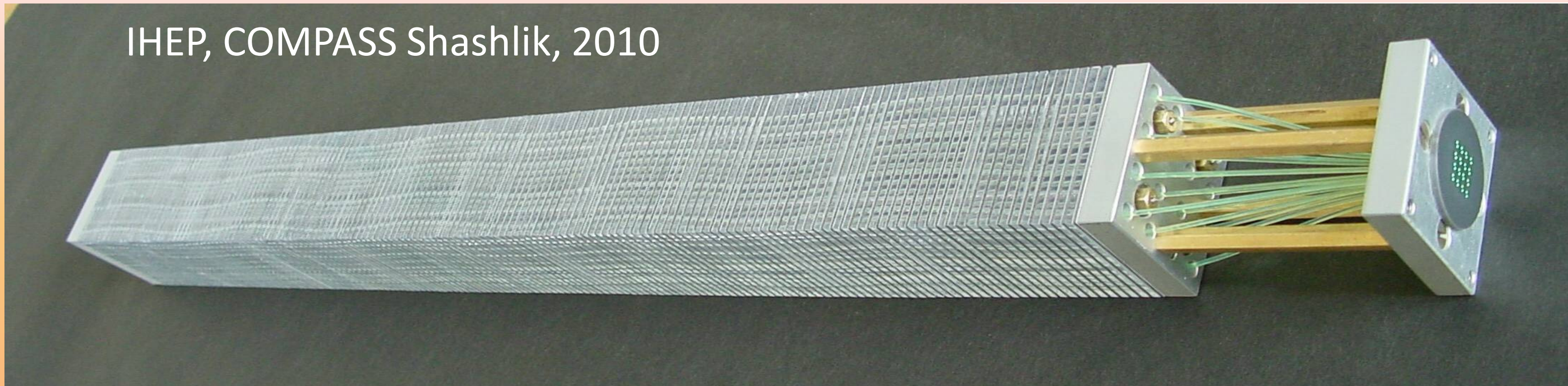
  1. PVDIS (rate A, 169 days)
  2. SIDIS with Transversely Polarized 3He (rate A, 90 days)
  3. SIDIS with Longitudinally Polarized 3He (rate A, 35 days)
  4. SIDIS with Transversely Polarized Proton (conditional approval)

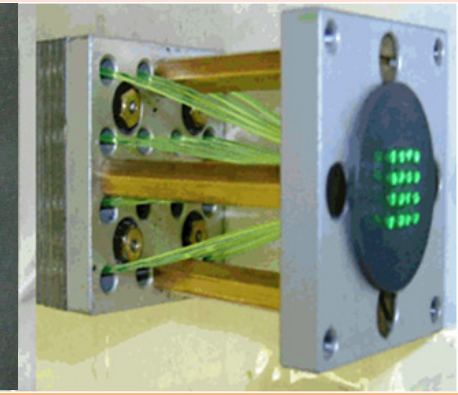
# SoLID Calorimeter Overview

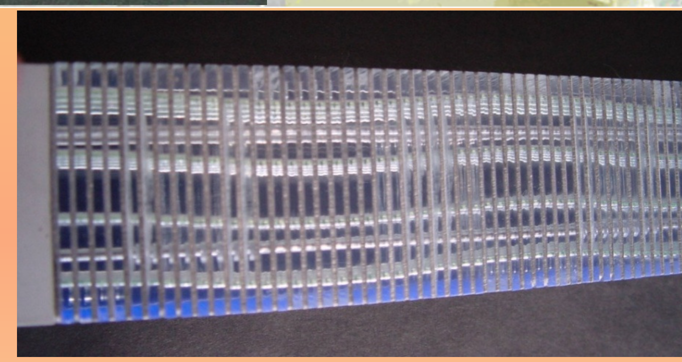



- Electron-hadron separation
  - 100:1 pion rejection in electron sample
  - Energy resolution: σ(E)/E ~ 5%/√E
- Provide shower Position
  - σ ~ 1 cm, for tracking initial seed / suppress background
- Time response
  - σ <~ few hundreds ps
  - provide trigger/identify beam bunch (TOF PID)

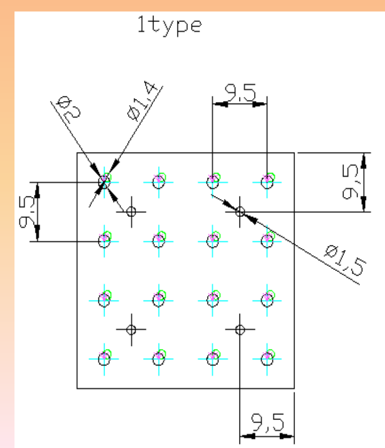
# Best option: Shashlyk Calorimeter



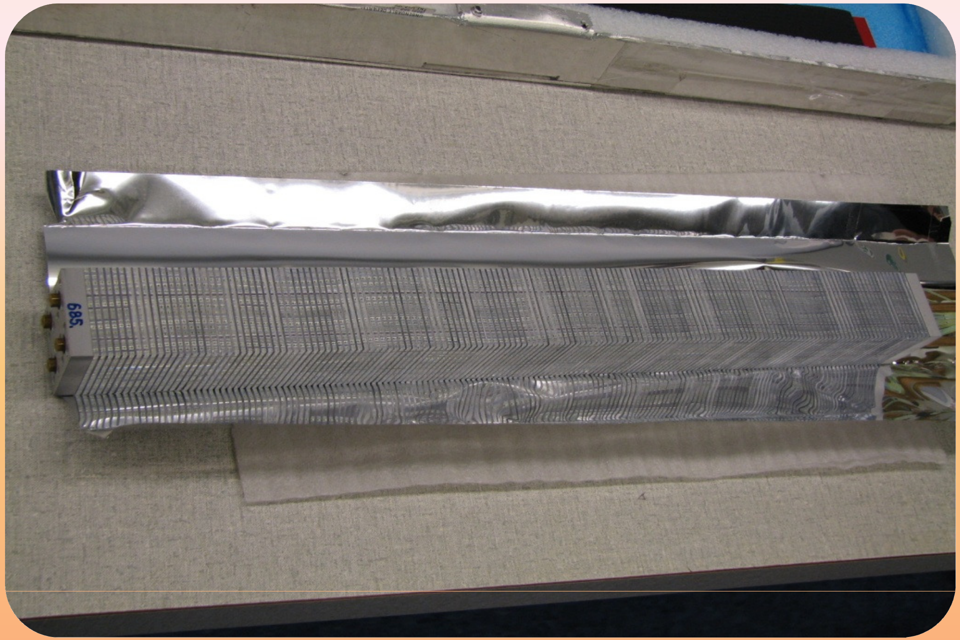



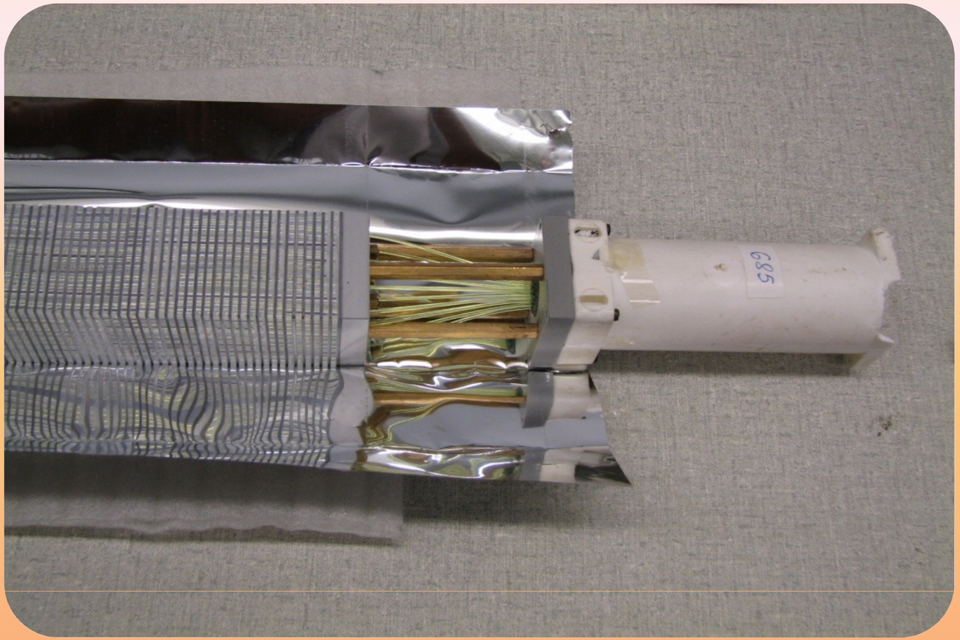


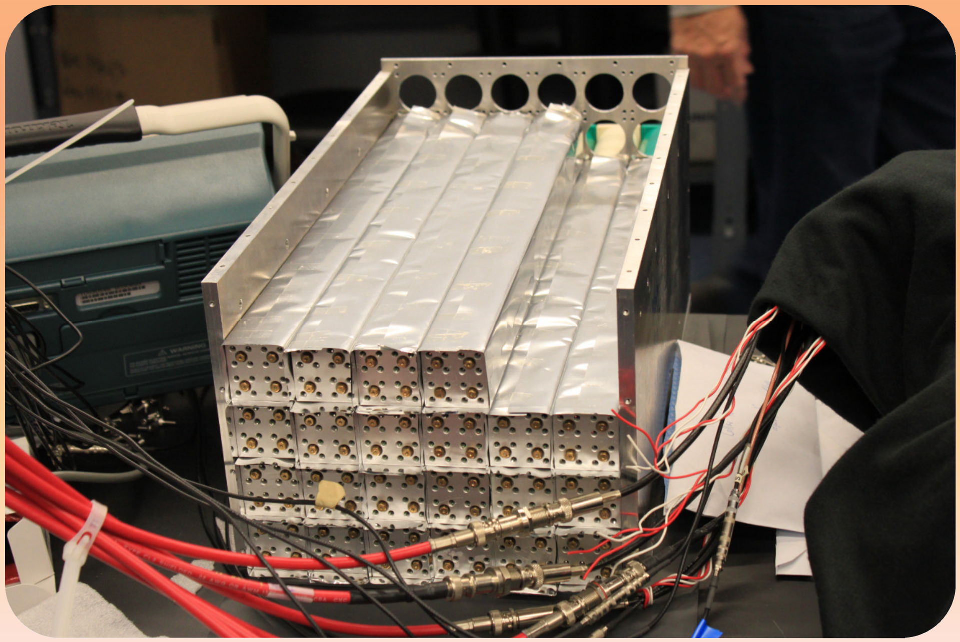
- Shashlyk calorimeter
  - Lead-scintillator sampling calorimeter
  - WLS Fiber collects and reads out light
- Satisfy the SoLID requirement
  - Good energy resolution (tunable)
  - transverse size can be customized
  - Radiation hardness ~ 500kRad (improvable)
- Easier to collect and read out the light
- Well developed technology, used by many experiments
- IHEP production rate about 200 per month

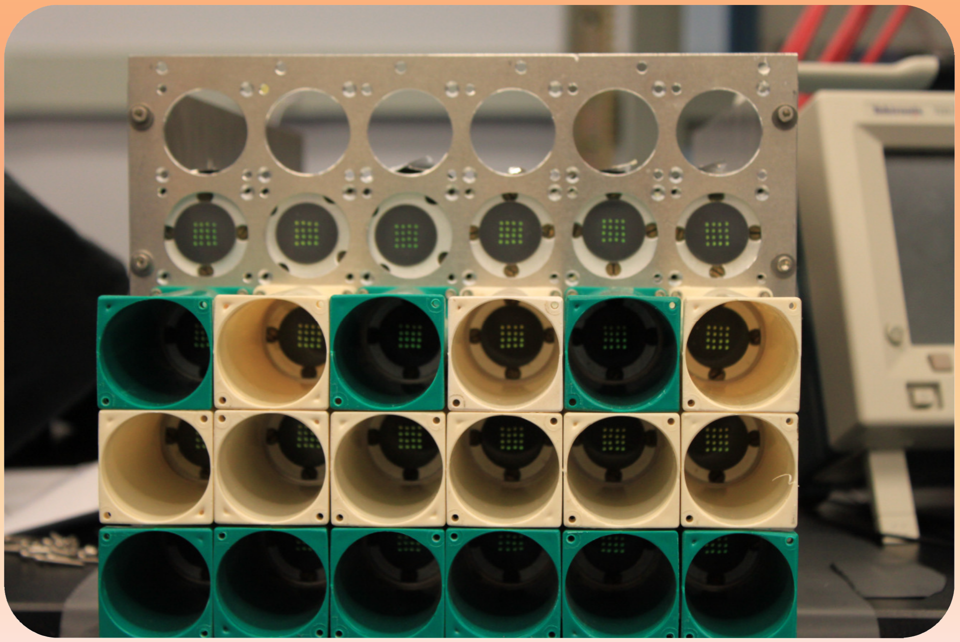


# COMPASS modules used for TPE@CLAS



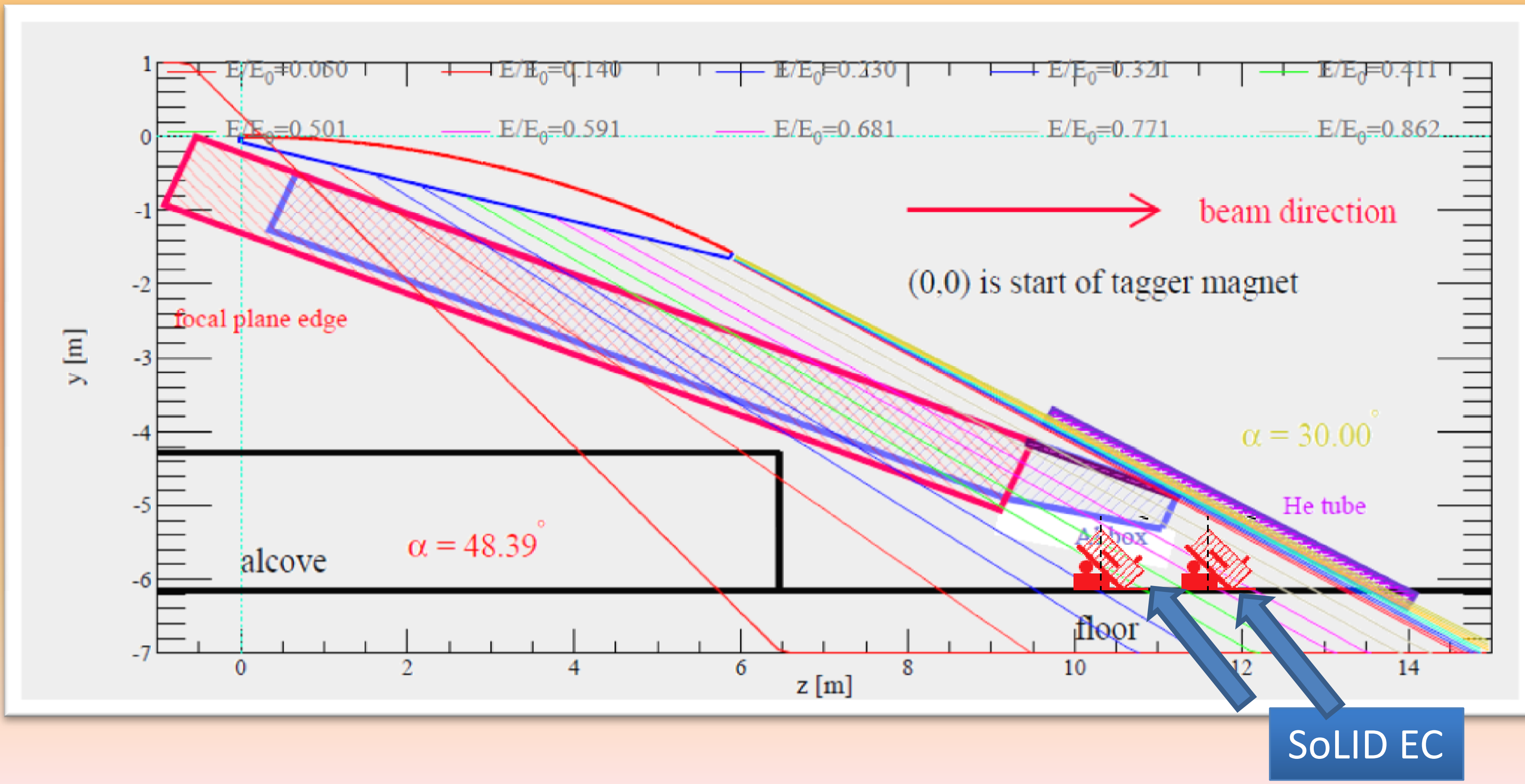





# Main goal of the beamtest

## under CLAS tagger during g14 photon run

- Gain direct experience with the modules.
- Test energy and position resolution at different location (30%-80% of beam energy) and different incoming angles (0-40 degree).
- Use test results to anchor the simulation.

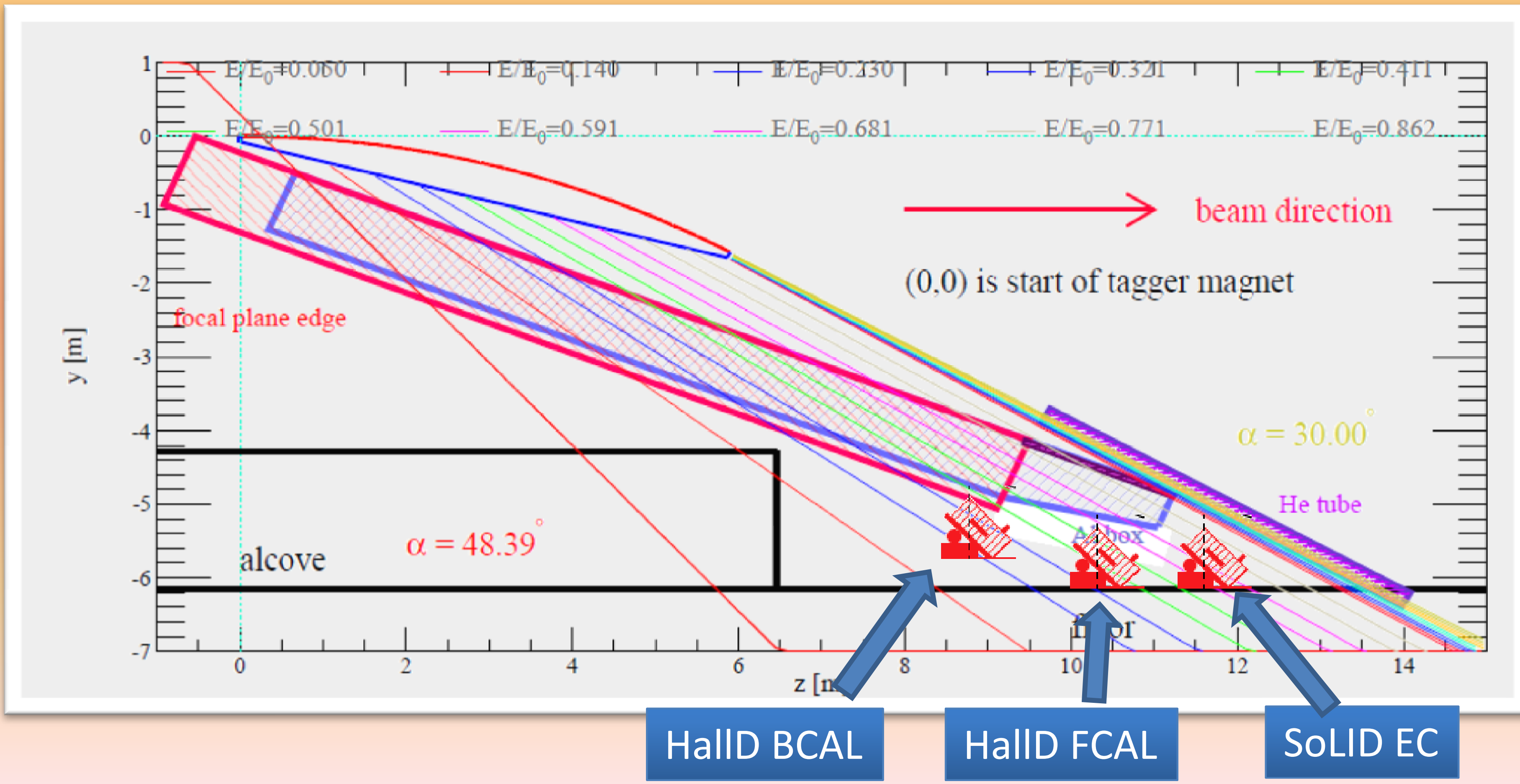


# Details of the plan

1. Test Module
- Use TPE 5x6 array of 3.8x3.8cm modules. PMT readout with mu metal shielding.
2. Trigger and DAQ
- Independent DAQ, non-invasive to CLAS.
- Use a small scintillator in front of a module for trigger.
- May use another small scintillator at upstream for coincidence trigger to help determine trajectory and thus the electron energy and impact angle.
- May use T-counter input for coincidence.
3. Test plan
- Stay at different locations and tilt at different angles depending on time allowed.
- Would love to have short special tagger runs if the g14 run plan allows.
4. Timeline
- Preparation and bench test in Feb.
- Move into HallB 3/3-6 or 3/11-14, and stay until May.

# other tests under CLAS Tagger

- CLAS12 Forward Tagger Calorimeter may move out around end of Feb?
- HallD BCAL test will stay at more forward location for ~1GeV electrons.
- HallD FCAL test and SoLID EC test will stay at higher energies and share locations.



# backup

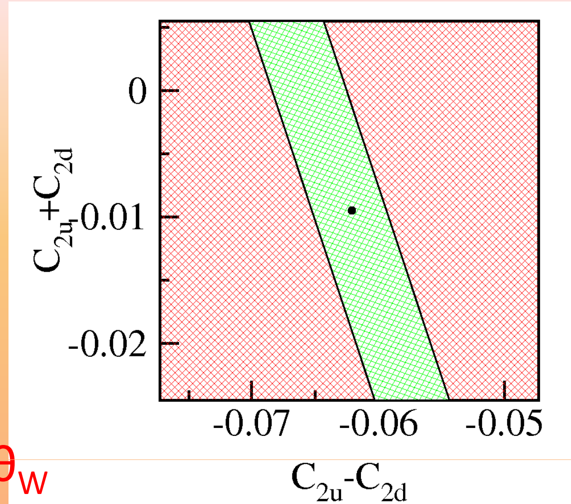
# Motivation for PVDIS

$$A_{PV} = \frac{G_F Q^2}{\sqrt{2}\pi\alpha}\left[\mathbf{a}(x) + Y(y)\,\mathbf{b}(x)\right]$$

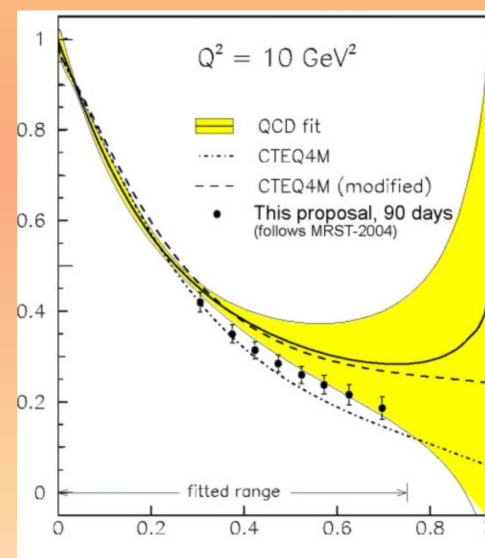
## Standard Model

$$b(x) = \frac{\sum_i C_{2i} Q_i f_i^-(x)}{\sum_i Q_i^2 f_i^+(x)}$$

No $\sin^2\theta_W$




## d/u for Hydrogen



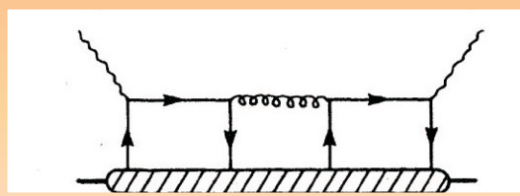

## CSV at Quark Level

$$\delta u(x) = u^p(x) - d^n(x)$$

$$\delta d(x) = d^p(x) - u^n(x)$$

$$R_{CSV} = \frac{\delta A_{PV}(x)}{A_{PV}(x)} = 0.28\,\frac{\delta u(x) - \delta d(x)}{u(x) + d(x)}$$

## Di-quarks in the nucleon ($Q^2$ Dependence)



# All Leading Twist  TMDs

→ Nucleon Spin

→ Quark Spin

| | | Quark polarization | | |
|---|---|---|---|---|
| | | Un-Polarized | Longitudinally Polarized | Transversely Polarized |
| Nucleon Polarization | U | $f_1$ = | | $h_1^{\perp}$ = − <br>Boer-Mulder |
| | L | | $g_1$ = − <br>Helicity | $h_{1L}^{\perp}$ = − |
| | T | $f_{1T}^{\perp}$ = − <br>Sivers | $g_{1T}^{\perp}$ = − | $h_{1T}$ = − <br>Transversity<br>$h_{1T}^{\perp}$ = − <br>Pretzelosity |

# Physics Requirement

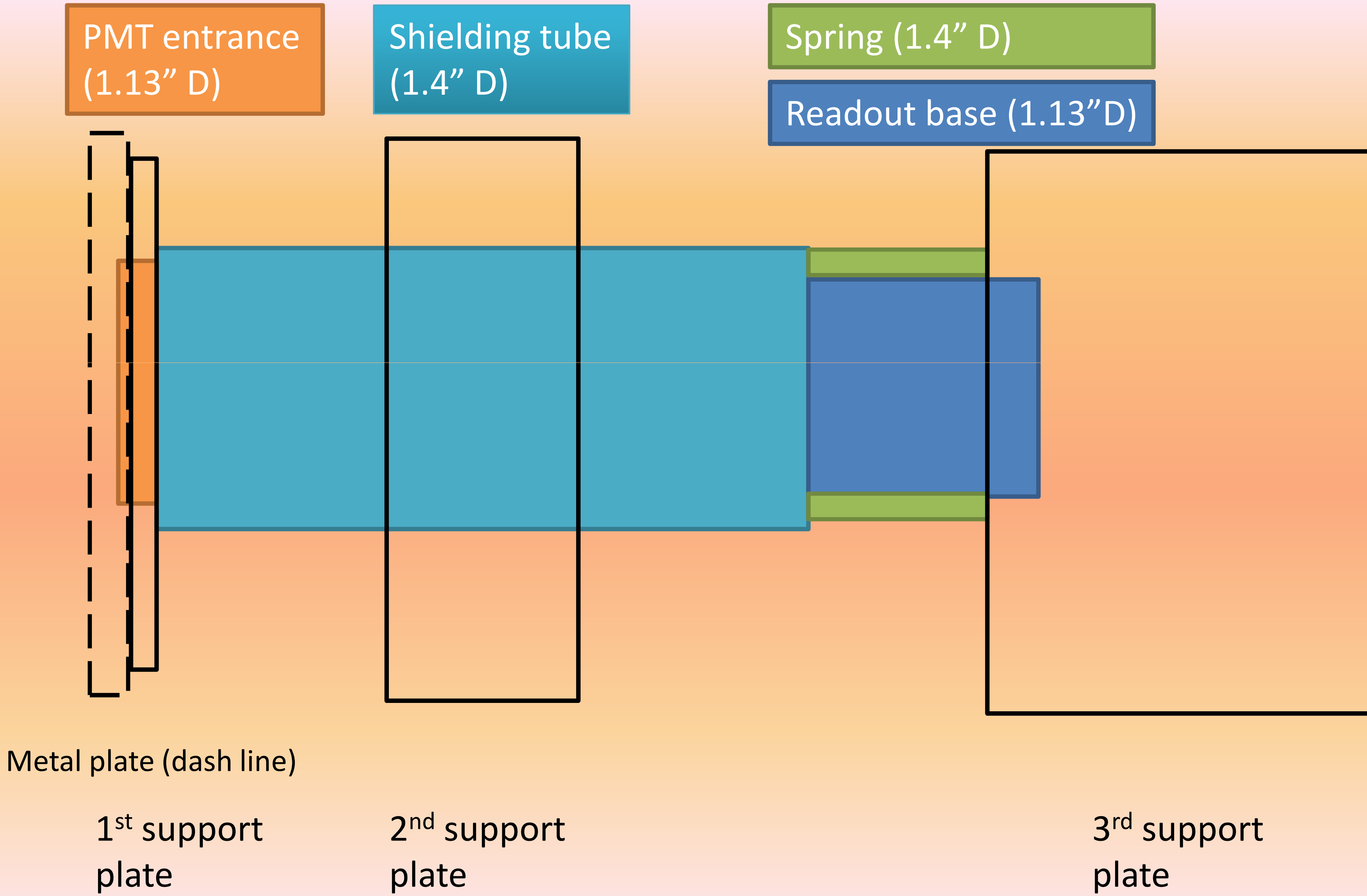
- Electron-hadron separation
  - 100:1 pion rejection in electron sample
  - Energy resolution: $\sigma(E)/E \sim 5\%/\sqrt{E}$
- Provide shower Position
  - $\sigma \sim$ 1 cm, for tracking initial seed / suppress background
- Time response
  - $\sigma$ <~ few hundreds ps
  - provide trigger/identify beam bunch (TOF PID)
- Radiation resistant
  - PVDIS forward angle
    - EM <=2k GeV/cm$^2$/s + pion (GeV/cm$^2$/s), total ~<60 krad/year
  - SIDIS forward angle
    - EM <=5k GeV/cm$^2$/s + pion , total, total ~<100 krad/year
  - SIDIS large angle
    - EM <=20k GeV/cm$^2$/s + pion, total, total ~<400 krad/year

# EM calorimeters with optical readout

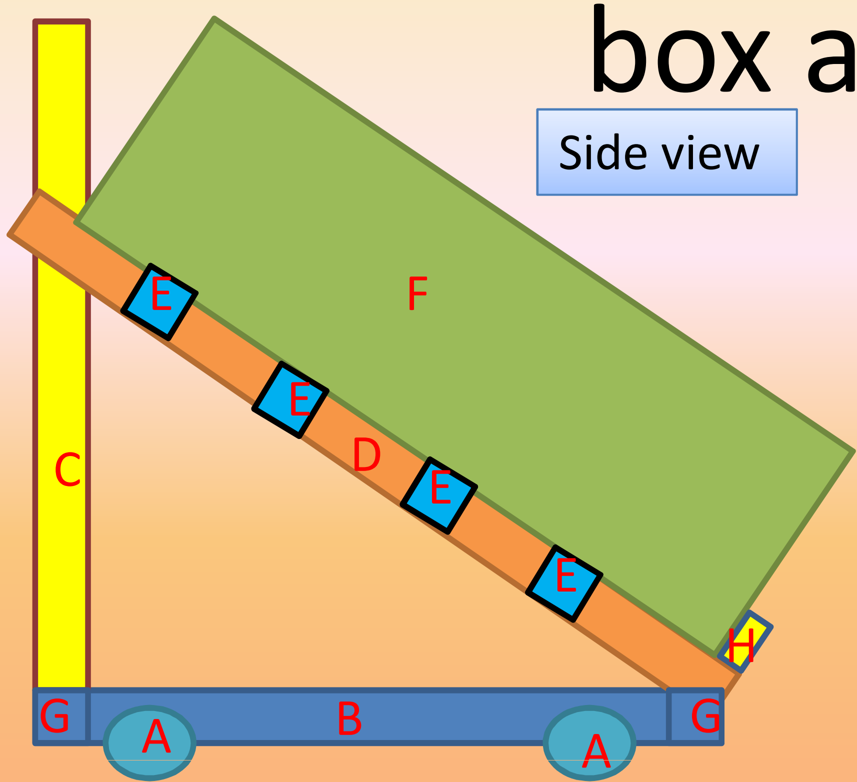
| Material | Density $g/cm^3$ | $X_0$ $cm$ | $R_M$ $cm$ | $\lambda_I$ $cm$ | Refr. index | $\tau$ $ns$ | Peak $\lambda$ $nm$ | Light yield | $\frac{N_{p.e.}}{GeV}$ | rad | $\frac{\sigma E}{E}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Crystals | | | | | | |
| NaI(Tl)** | 3.67 | 2.59 | 4.5 | 41.4 | 1.85 | 250 | 410 | 1.00 | $10^6$ | $10^2$ | $1.5\%/E^{1/4}$ |
| CsI * | 4.53 | 1.85 | 3.8 | 36.5 | 1.80 | 30 | 420 | 0.05 | $10^4$ | $10^4$ | $2.0\%/E^{1/2}$ |
| CsI(Tl)* | 4.53 | 1.85 | 3.8 | 36.5 | 1.80 | 1200 | 550 | 0.40 | $10^6$ | $10^3$ | $1.5\%/E^{1/2}$ |
| BGO | 7.13 | 1.12 | 2.4 | 22.0 | 2.20 | 300 | 480 | 0.15 | $10^5$ | $10^3$ | $2.\%/E^{1/2}$ |
| $PbWO_4$ | 8.28 | 0.89 | 2.2 | 22.4 | 2.30 | 5/39% | 420 | 0.013 | $10^4$ | $10^6$ | $2.0\%/E^{1/2}$ |
| | | | | | | 15/60% | 440 | | | | |
| | | | | | | 100/01% | | | | | |
| LSO | 7.40 | 1.14 | 2.3 | | 1.81 | 40 | 440 | 0.7 | $10^6$ | $10^6$ | $1.5\%/E^{1/2}$ |
| $PbF_2$ | 7.77 | 0.93 | 2.2 | | 1.82 | Cher | Cher | 0.001 | $10^3$ | $10^6$ | $3.5\%/E^{1/2}$ |
| | | | | | Lead glass | | | | | | |
| TF1 | 3.86 | 2.74 | 4.7 | | 1.647 | Cher | Cher | 0.001 | $10^3$ | $10^3$ | $5.0\%/E^{1/2}$ |
| SF-5 | 4.08 | 2.54 | 4.3 | 21.4 | 1.673 | Cher | Cher | 0.001 | $10^3$ | $10^3$ | $5.0\%/E^{1/2}$ |
| SF57 | 5.51 | 1.54 | 2.6 | | 1.89 | Cher | Cher | 0.001 | $10^3$ | $10^3$ | $5.0\%/E^{1/2}$ |
| | | | | | Sampling: lead/scintillator | | | | | | |
| SPACAL | 5.0 | 1.6 | | | | 5 | 425 | 0.3 | $2\cdot10^4$ | $10^6$ | $6.0\%/E^{1/2}$ |
| Shashlyk | 5.0 | 1.6 | | | | 5 | 425 | 0.3 | $10^3$ | $10^6$ | $10.\%/E^{1/2}$ |
| Shashlyk(K) | 2.8 | 3.5 | 6.0 | | | 5 | 425 | 0.3 | $4\cdot10^5$ | $10^5$ | $3.5\%/E^{1/2}$ |

$*$ - hygroscopic

# module to readout connection

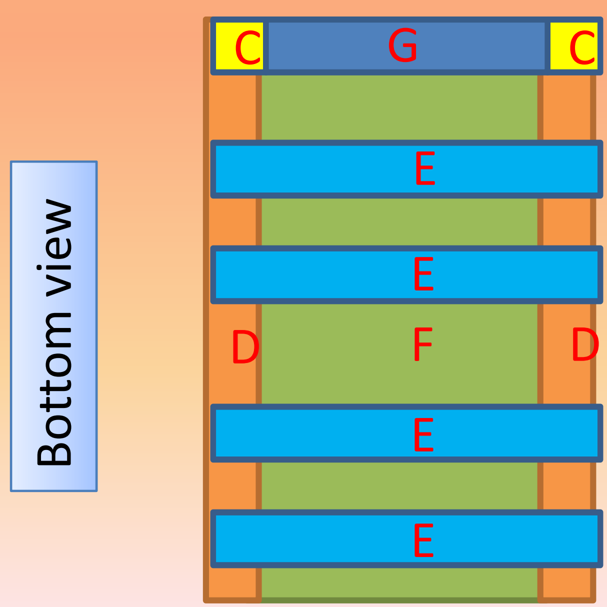


# box and support




A: 4 wheels to move all direction
B: 2 long bars for bottom support
G: 2 short bars for bottom support
C:  2 bars for vertical support
D: 2 bars to lift the box
E:  4 bars to connect the box
F:  the box
H: stopper (2 pieces at both ends or 1 bar across)

Features of the box:
weight about 250lb , height 25cm, width 21cm, length 80cm. At the bottom, 8 threaded holes with 0.22” diameter 0.39” depth for connection.

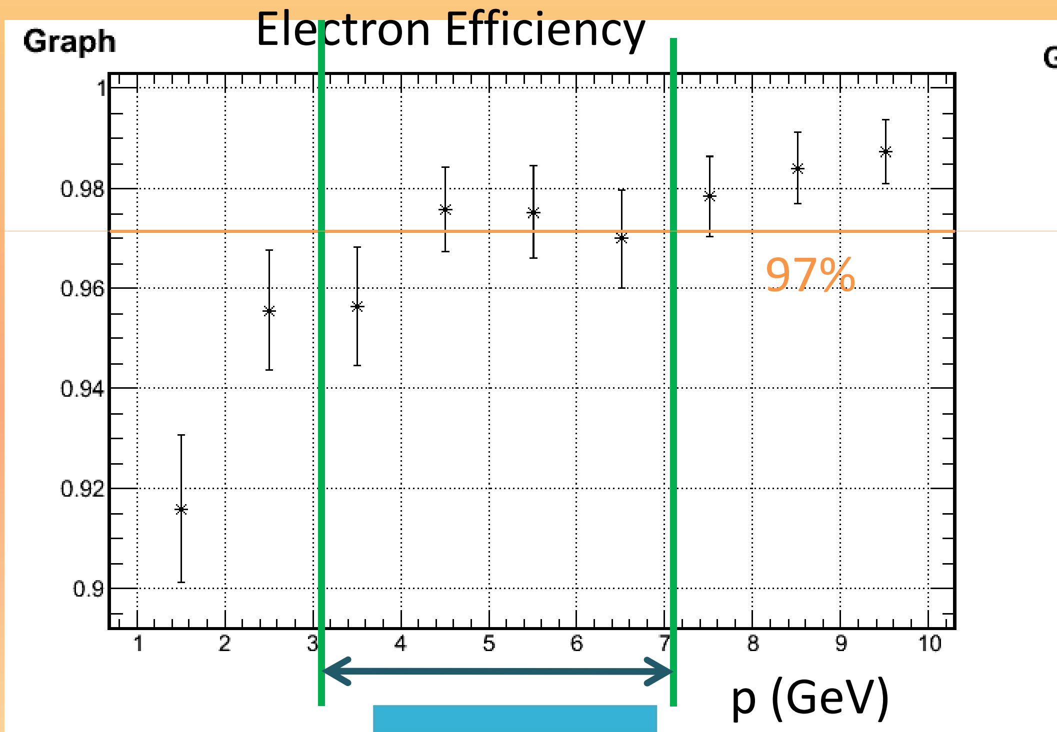


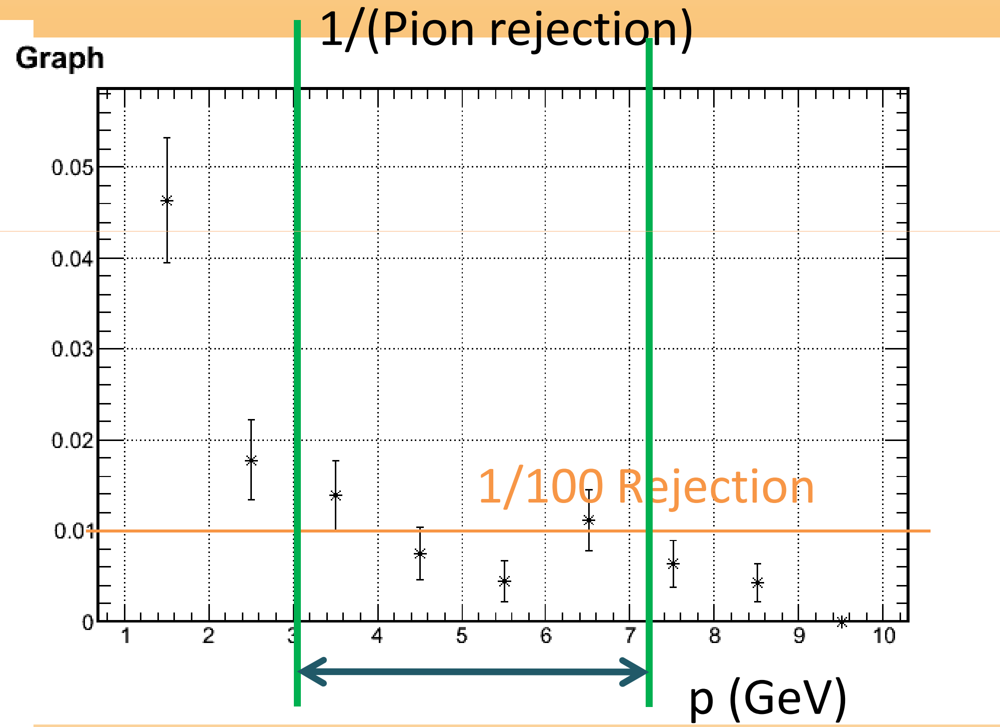

Features of the support:

1. It can support the box and be stable. Other pieces could be added to make it work.
2. D can move along C with some gears so the box can be easily tilted at angles from 0 to 40 degree
3. As compact as possible. the bottom of module to floor need to be less than 15cm, so that at largest angle 40 degree, it won’t go over the vertical clearance about 85cm.

# Pion rejections leads the design

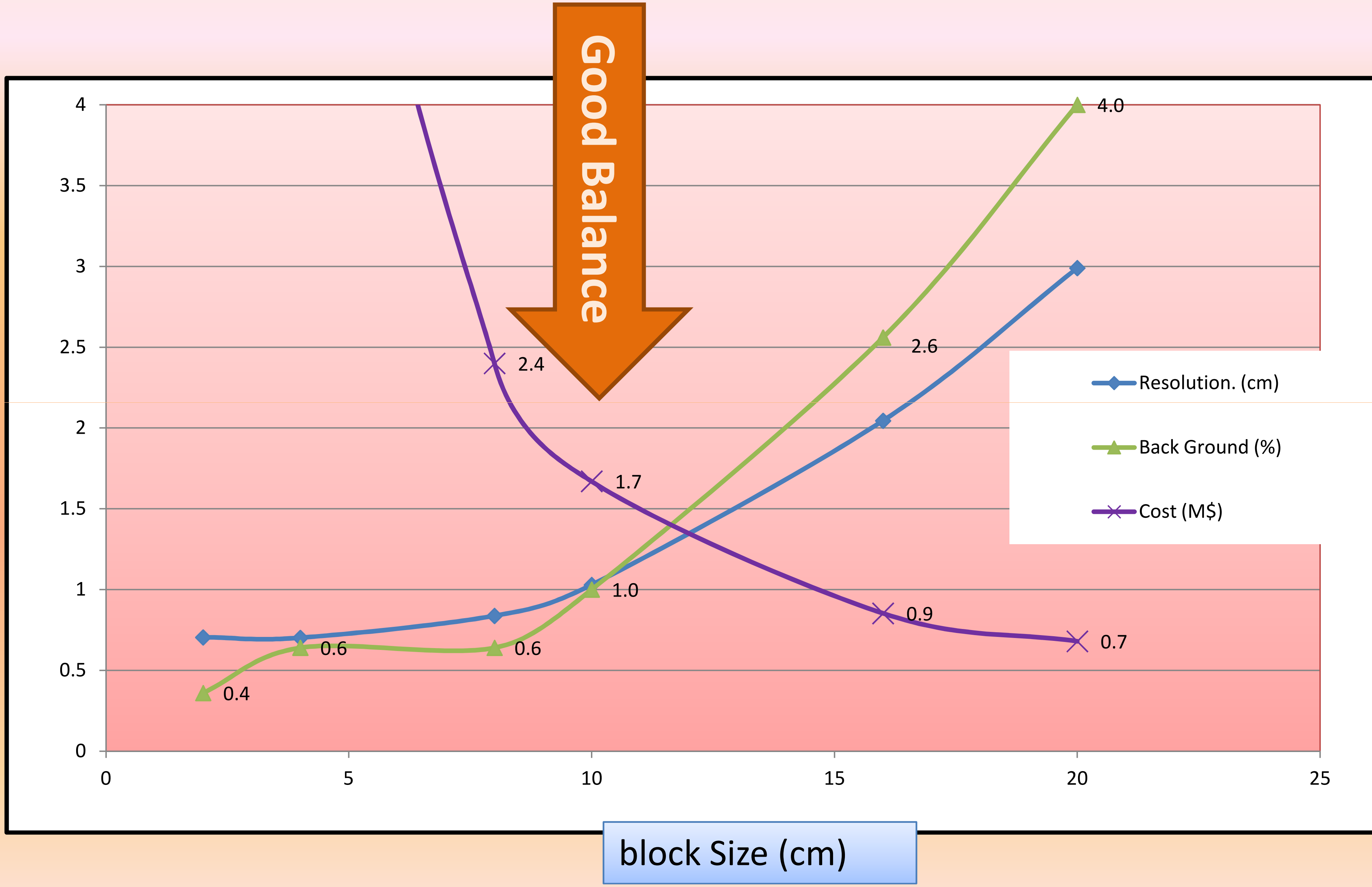
- Reach 100:1 pion rejection
- 0.6mm lead/1.5mm scintillator
  200 layers, 42cm in length (20 $X_0$)



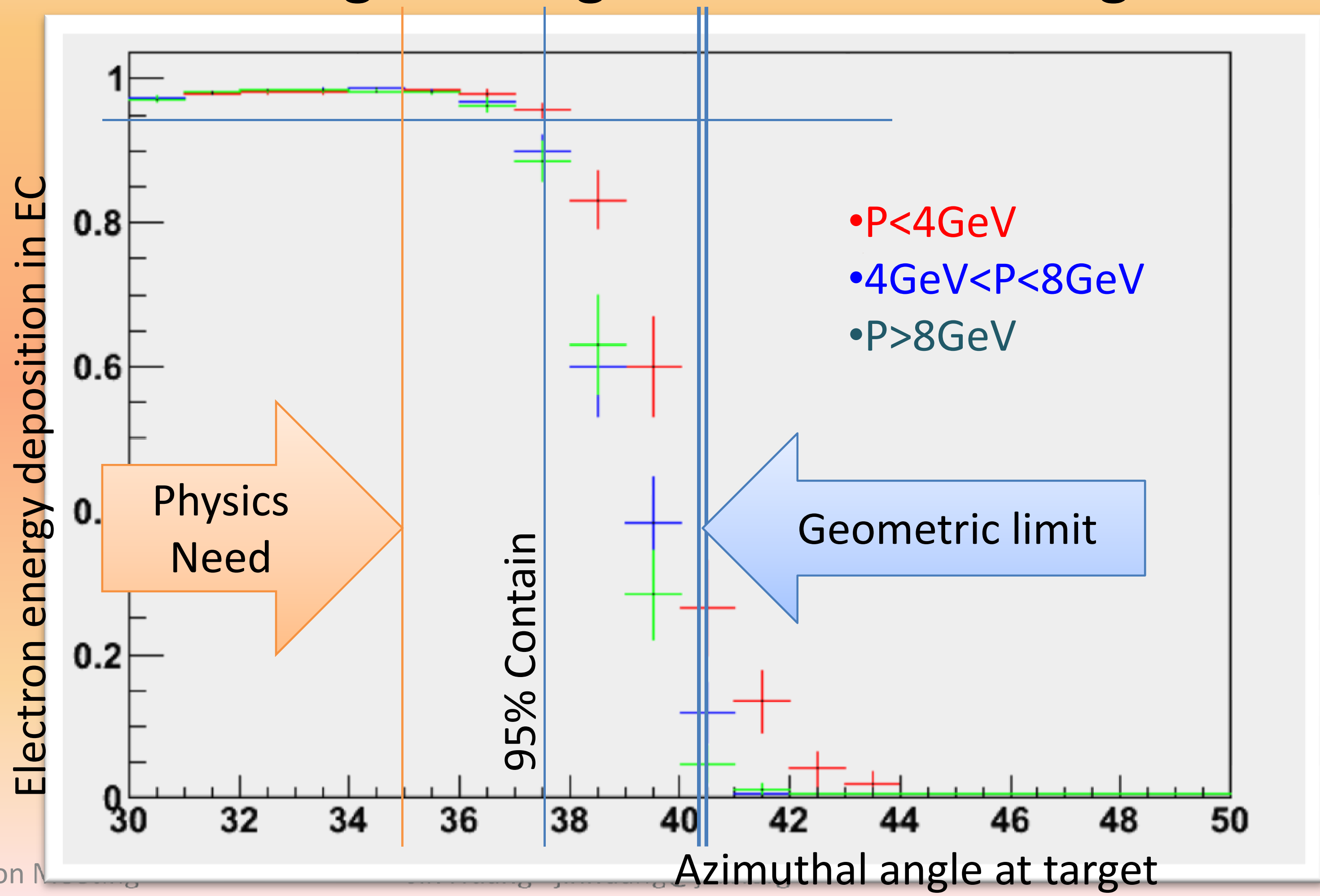

Active:
3~7 GeV

# ECAL Design: Lateral Size



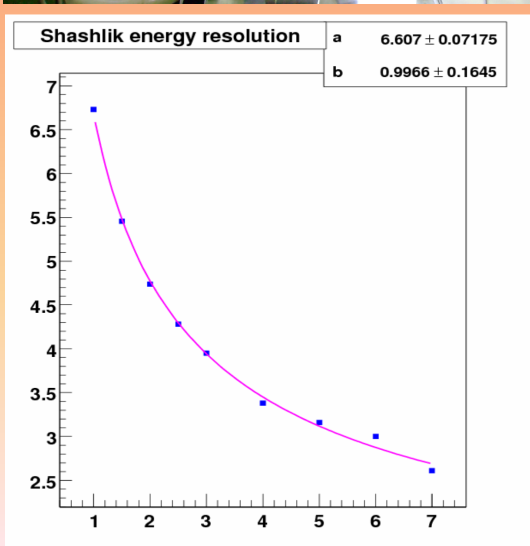
# The edge effect - PVDIS

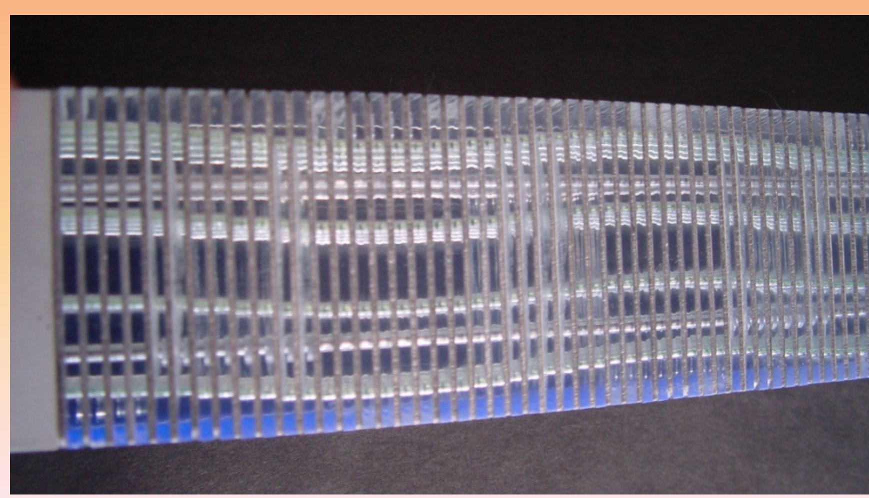
- Have largest indenting angle
  - Calorimeter edge to target center -> 40 degree

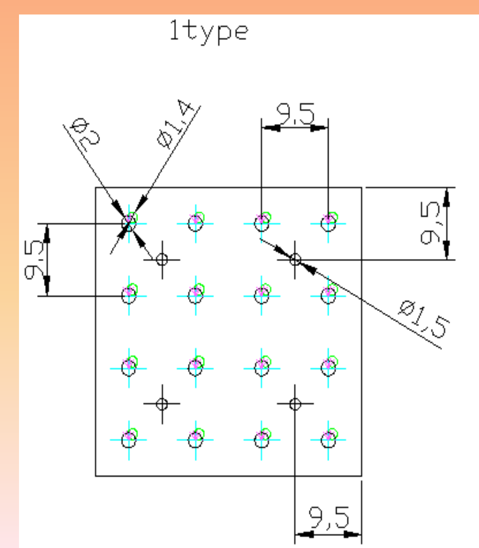


# ECAL Shashlik


- Dimensions 38.2x38.2 $mm^2$
- Radiation length 17.5mm
- Moliere radius 36mm
- Radiation thickness 22.5 $X_0$
- Scintillator thickness 1.5mm
- Lead thickness 0.8mm
- Radiation hardness 500 krad
- Energy resolution 6.5%/√E   1%





# IHEP Scintillator Fasilities

www.ihep.ru/scint/index-e.htm