HPS Trigger Upgrade

S. Stepanyan (JLAB)

HPS Upgrade ERR

June 12, 2017, Jefferson Lab

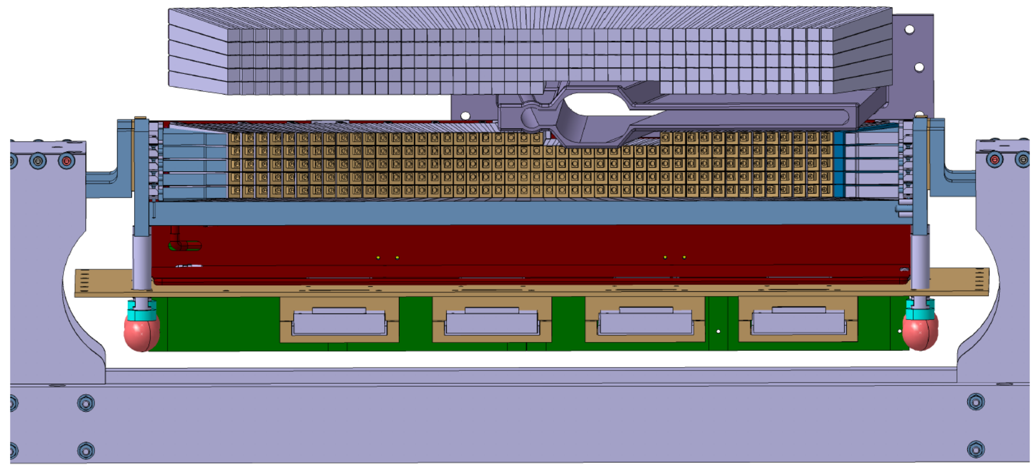
OFFICE OF SCIENCE
Jefferson Lab
Thomas Jefferson National Accelerator Facility
JSA

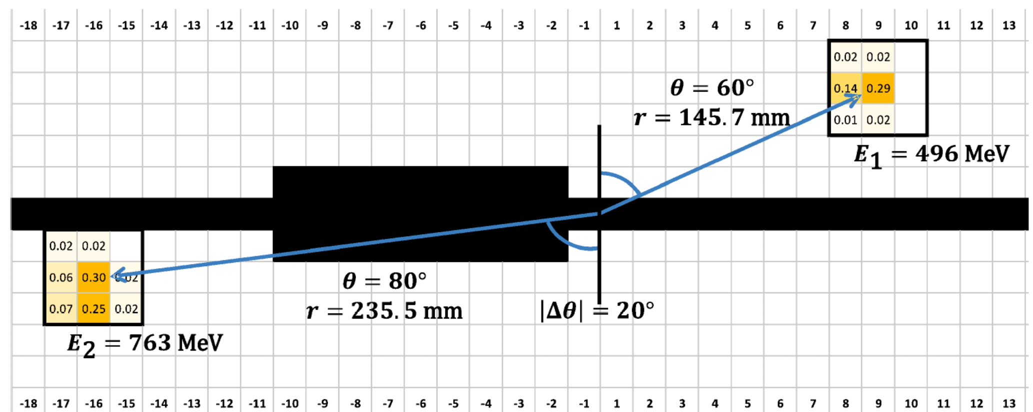
Outline

- HPS Ecal, pair trigger and reconstruction of e^+e^- pairs
- Analysis of random trigger data
- Single arm e^+ trigger rates
- Simulations
- Concept of a scintillation hodoscope
- Resources
- Schedule, and cost estimate
- Risks and mitigations
- Summary

HPS Ecal and the trigger

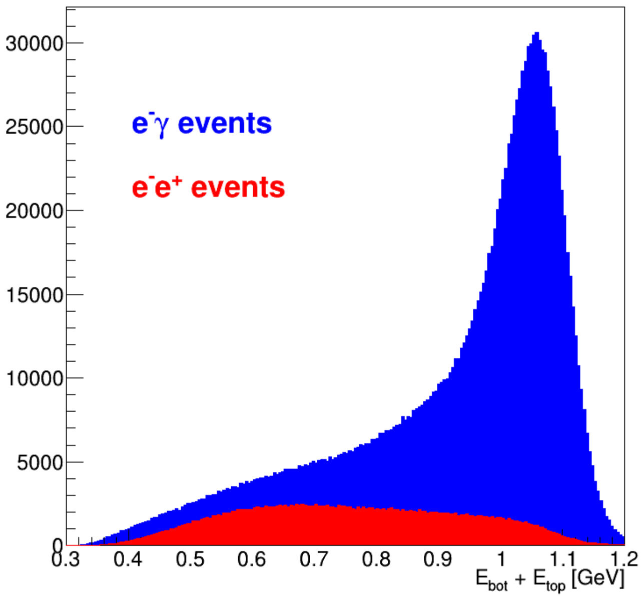
- A homogeneous calorimeter made of 442 (221 per sector) lead tungstate ($PbWO_4$) crystals readout with 10x10 APDs.
- Rectangular formation of modules in each sector with 9-modules removed from closest to the beam row.
- The analog signal from each Ecal channel is continuously sampled by the FADC every 4 ns.
- Modules with energy above threshold are processed for the trigger.
- Energy and position cuts are applied to define cluster pair trigger.



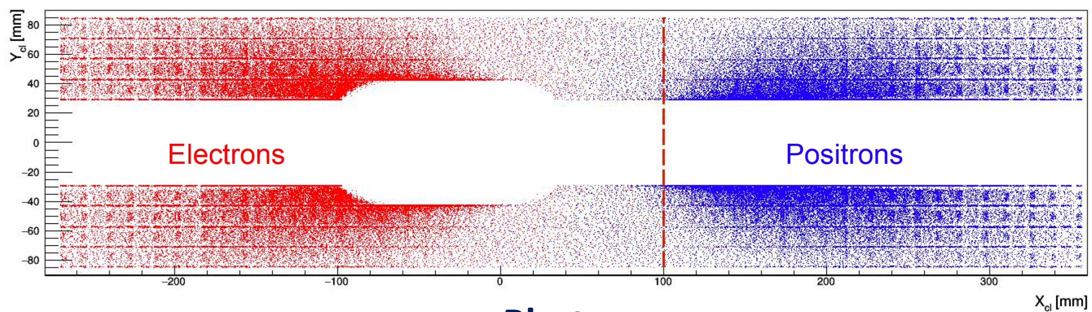


Cluster pairs and tridents

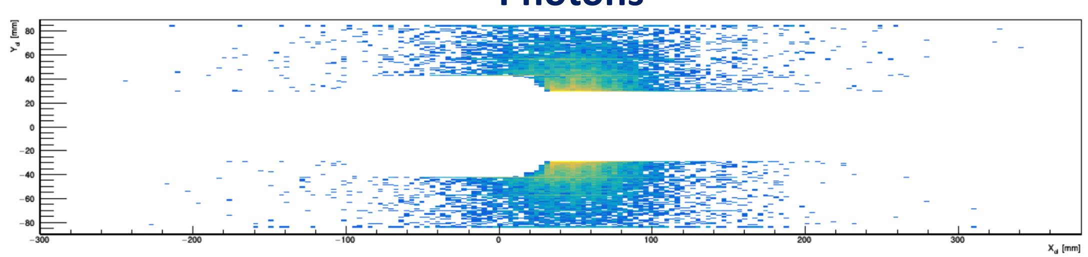
- Cluster pair trigger worked well, efficiency >95%, DAQ rates ~20 kHz at LT≈95%
- However, as it was found from data analysis and comparison with MC, there were two issues that effected HPS physics output:
  - Pair trigger requires electron to be detected in Ecal. Not all electrons reconstructed in SVT will have a hit in Ecal due to the Ecal “hole” for beam to go though (removed modules)
  - the cluster trigger wont differentiate between neutral and charged particles. The large fraction of HPS triggers came from wide angle bremsstrahlung (WAB) events ($e^- \gamma$).



Electrons and positrons from Trident events

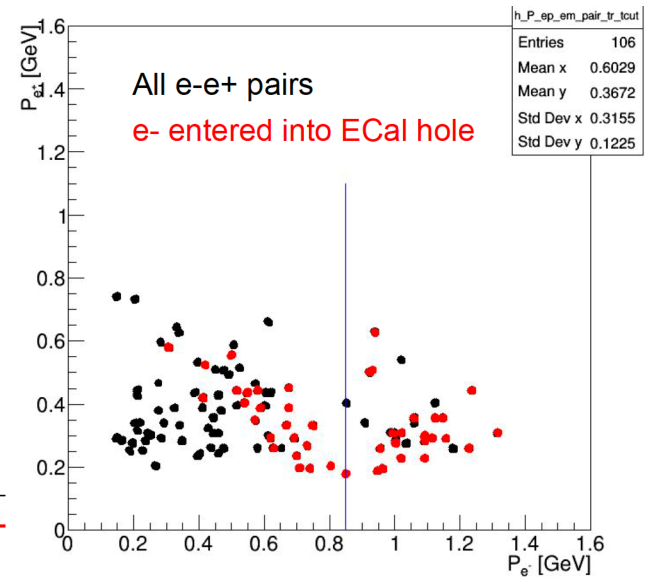


Photons

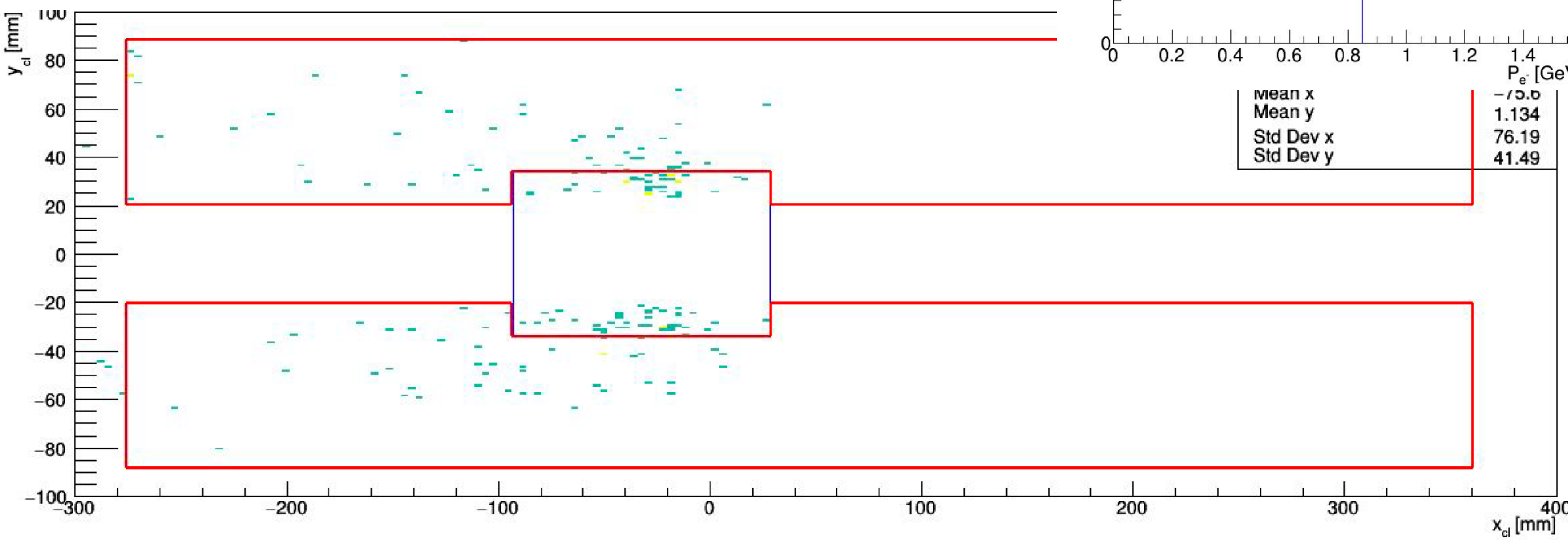


Random Pulser Trigger Data

- Two track events, positively charged track matched with a cluster in Ecal.
- No requirement for negatively charged track – Ecal cluster match
- Half of electrons in e^+e^- trident events end up in the calorimeter hole



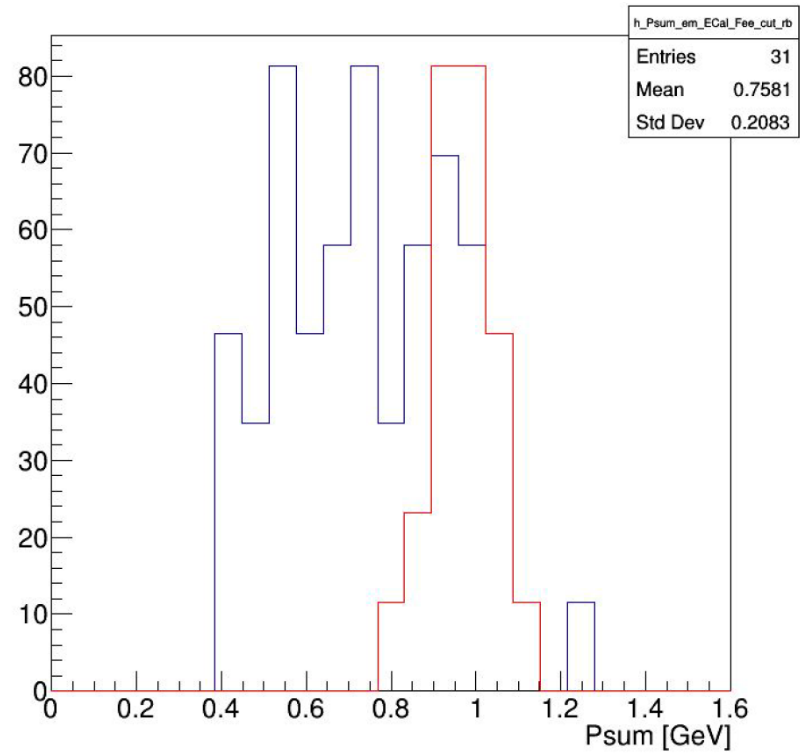
Position of electron at ECal

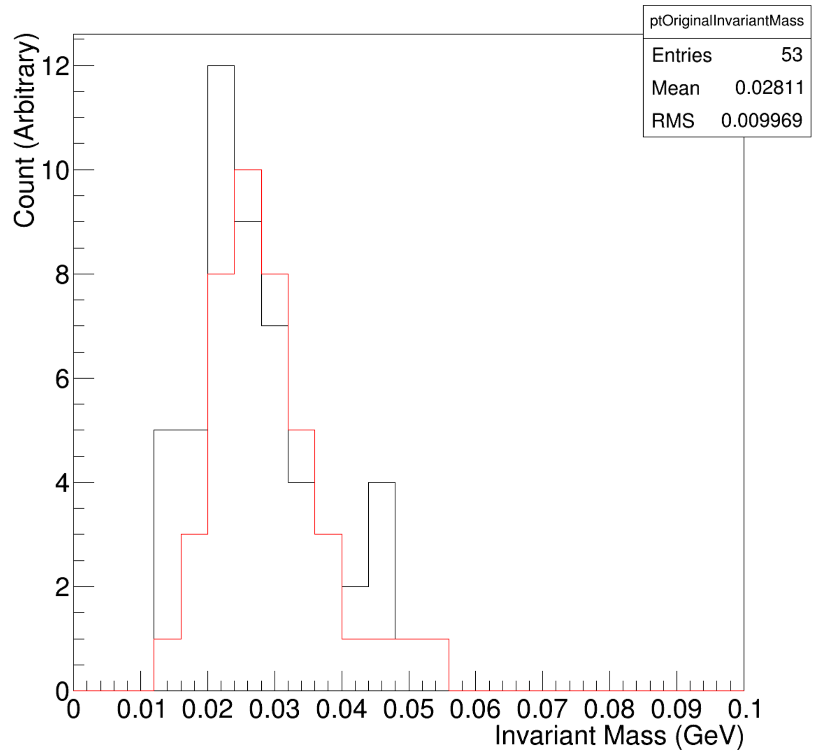


Pairs With e+ Track – Ecal Cluster Match

Data (2015), random pulser trigger

Almost half of e- from reconstructed e+e- tracks with p_{sum}>0.8E_0 are lost in the Ecal hole

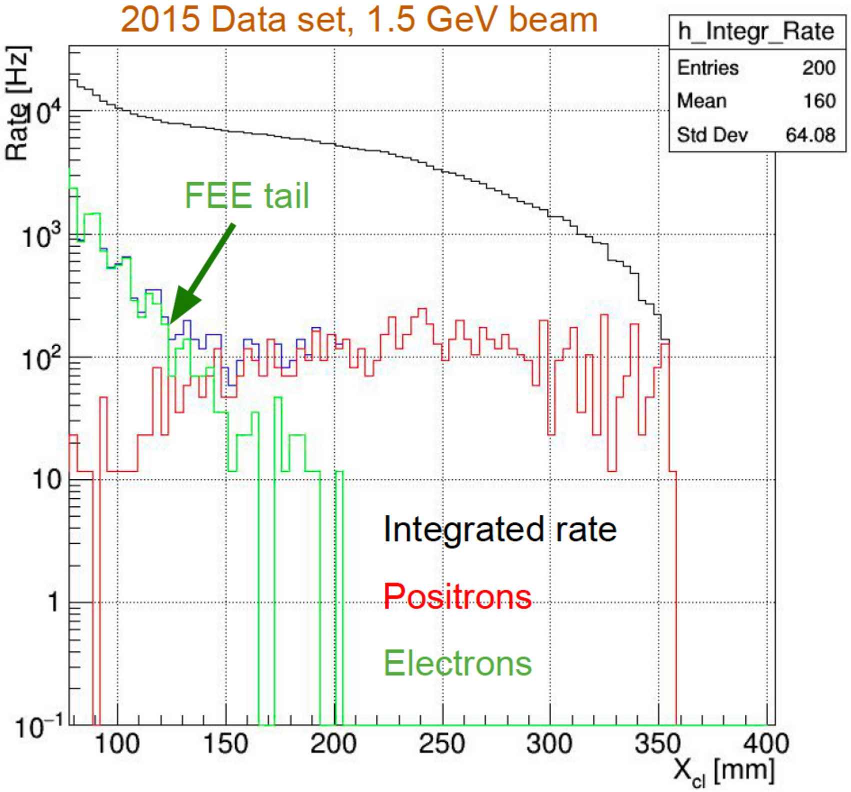


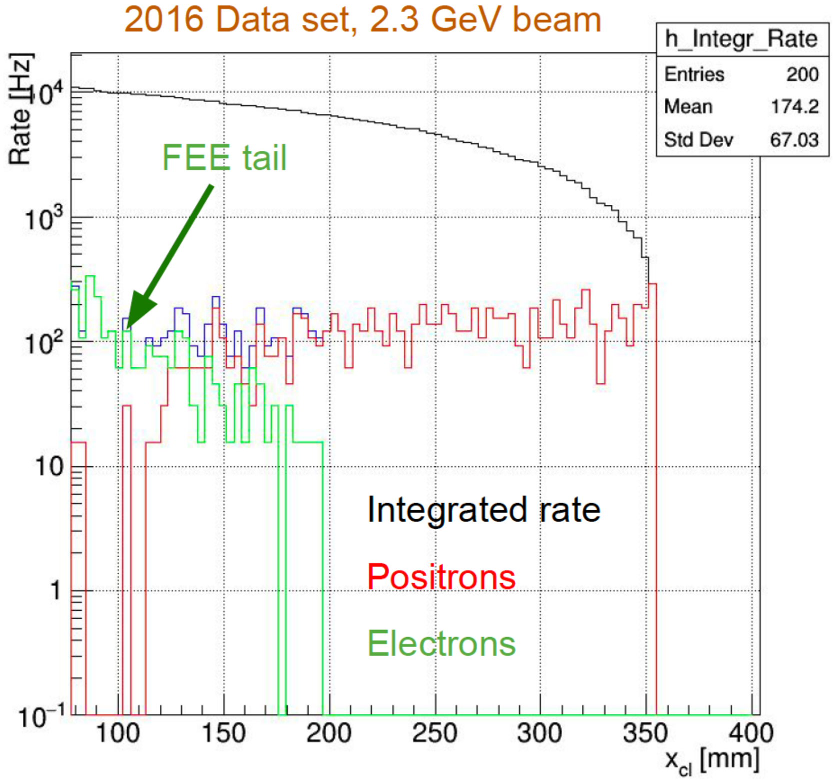


Proposed Trigger Upgrade

Triggering on positrons alone (single arm trigger) will fix the issue with the lost electrons and eliminates high WAB content in the data

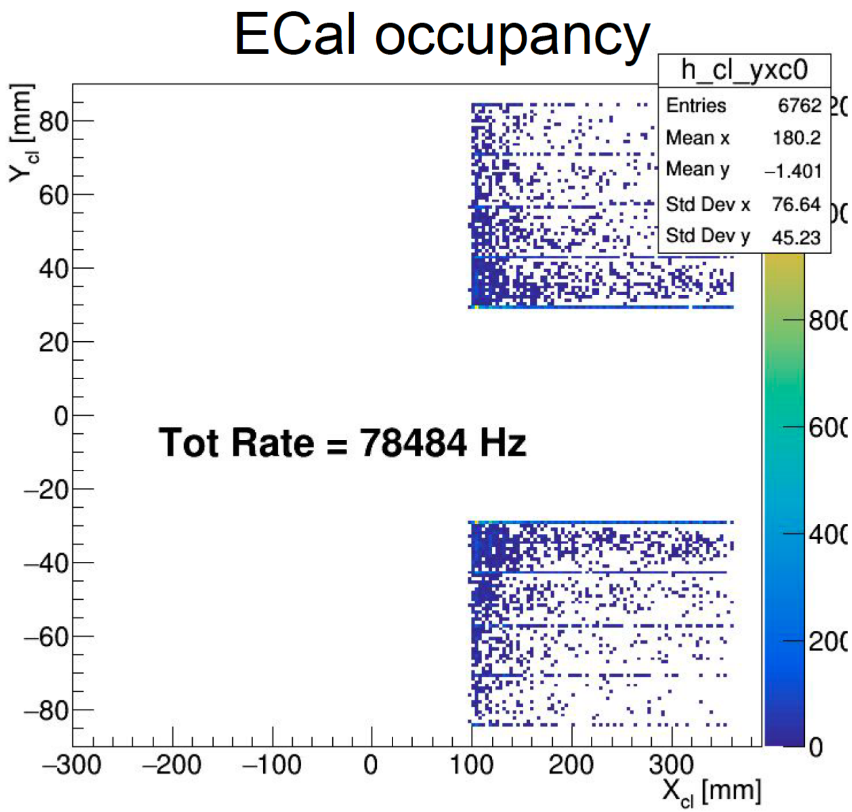
- Positrons from trident events (e^+e^-) end up in the x>100 cm region in ECal
- Rate of clusters in "positron" region (x>100 cm) matched with tracks is ~12 kHz

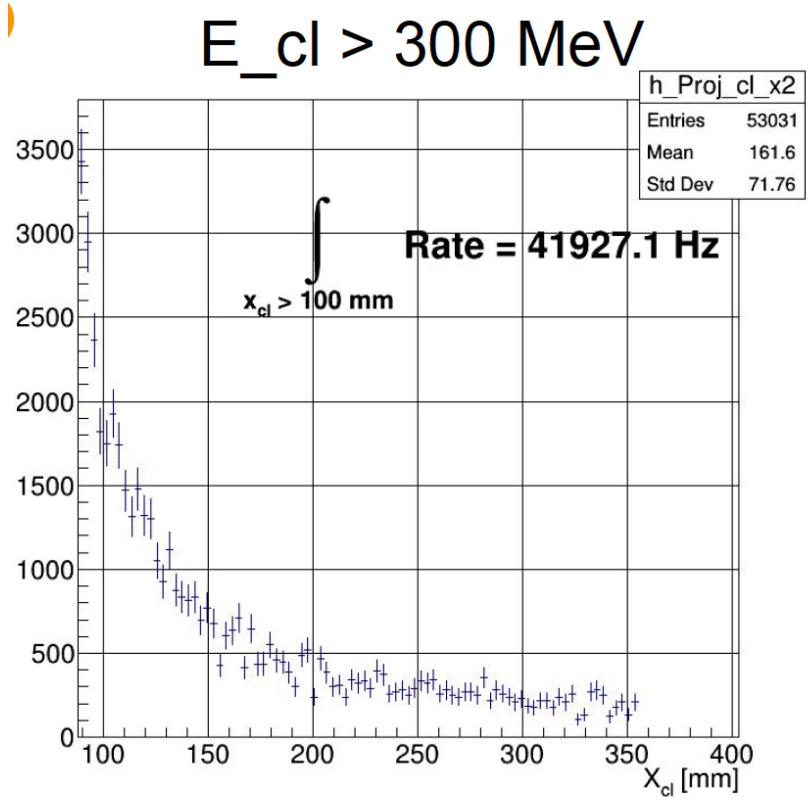




Cluster Rates with x>100 cm

- The rate of a single cluster trigger on the positron side is too high (> 40 kHz) due to WAB photons (Ecal does not differentiate between photon and positron showers)
- WAB photons can be excluded from the trigger by a coincidence of the ECal cluster with a fast charge particle detector in the trigger

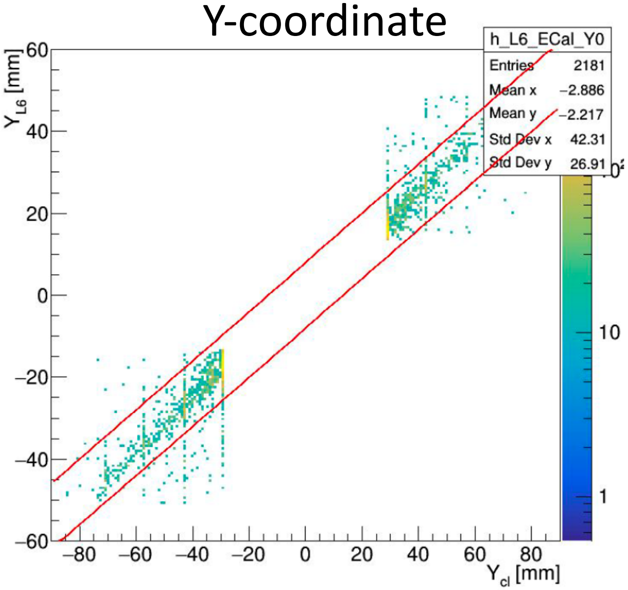




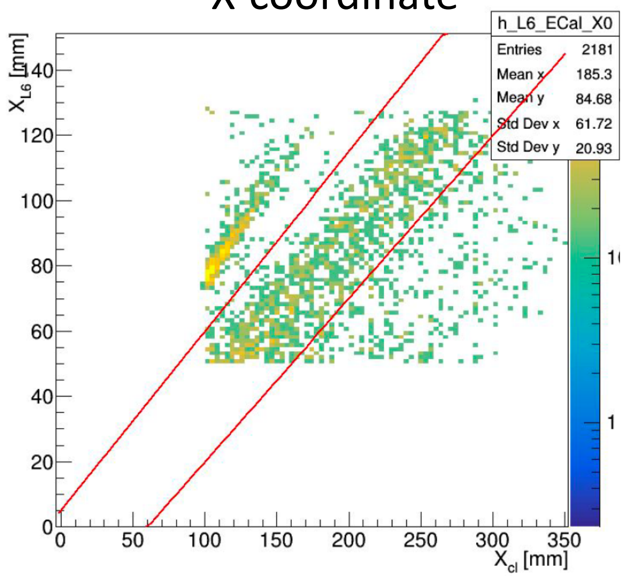
Ecal Cluster – L6 Hits

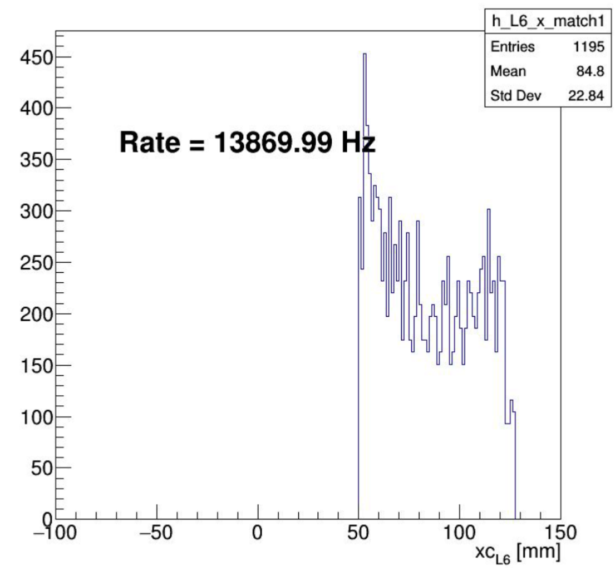
- SVT Layer-6 was used as proxy for a charged particle detector in order to understand rates.
- SVT 3D hits on Layer-6 were used in coincidence with clusters in the Ecal
- Position correlations are used to make geometric coincidence between a hit in L6 and a cluster in ECal

Y-coordinate



X-coordinate

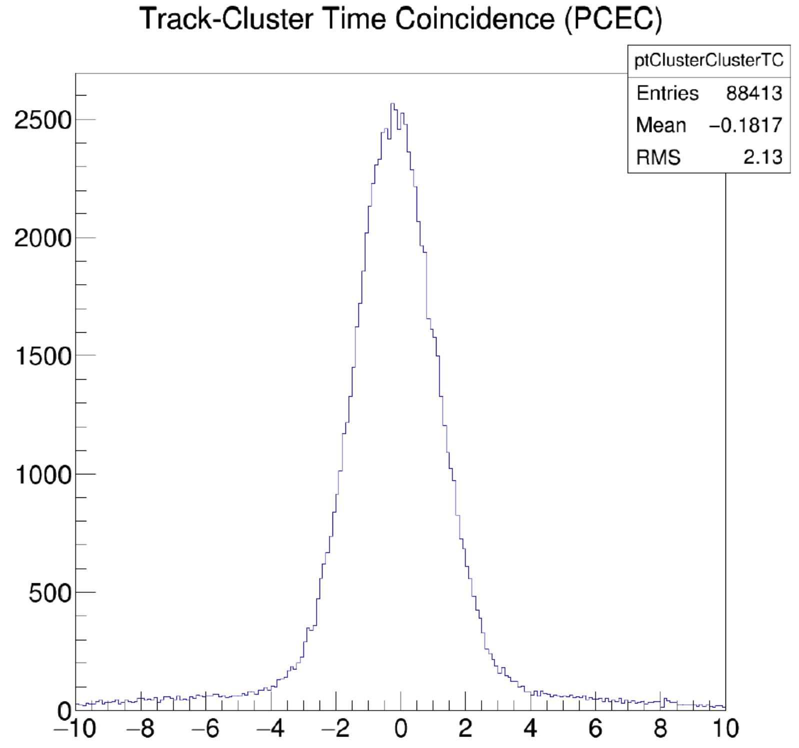


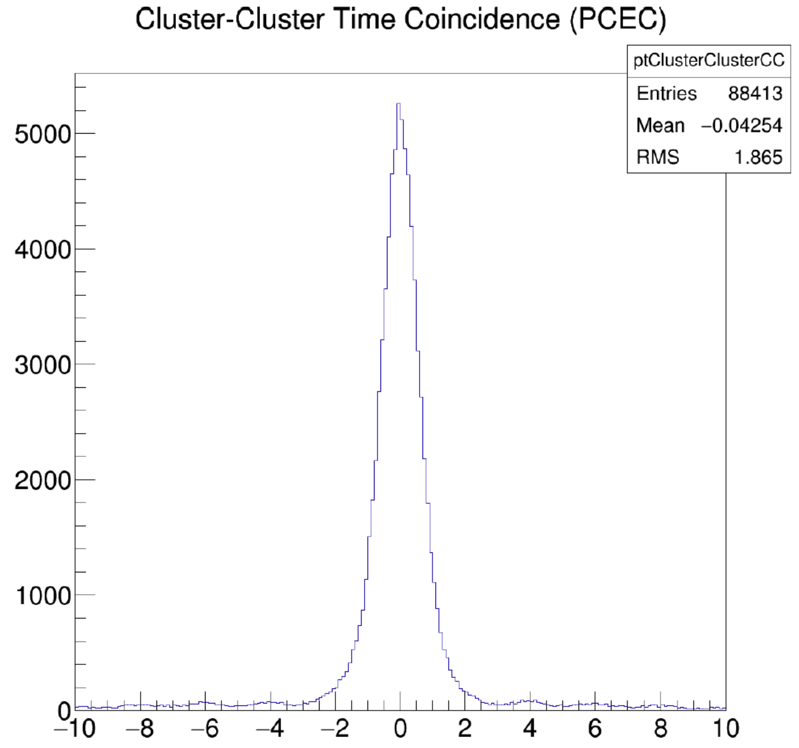


Coincidence rate between matched L6 hit and Ecal cluster (red lines) is ~14 kHz. Without matching rate is ~24 kHz (still manageable)

Reconstruction of two track events with one cluster match

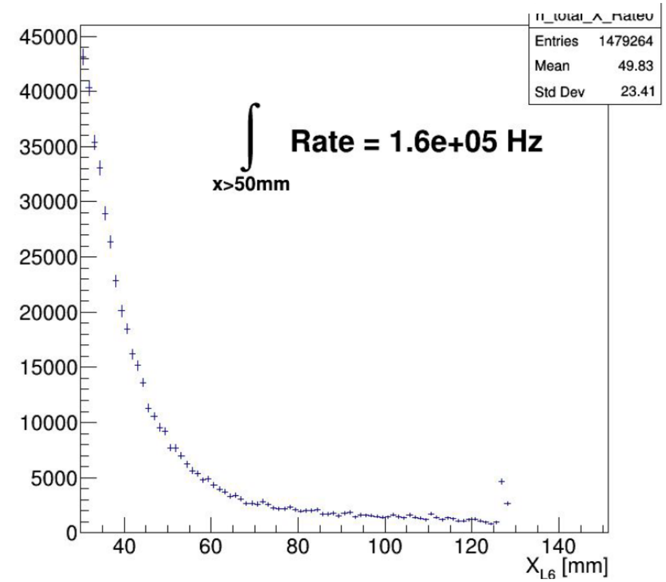
- In the current analysis two cluster time difference is used to eliminate accidentals.
- When only one of tracks is matched with a cluster in Ecal, Ecal cluster and the second track time difference can be used to clean up events

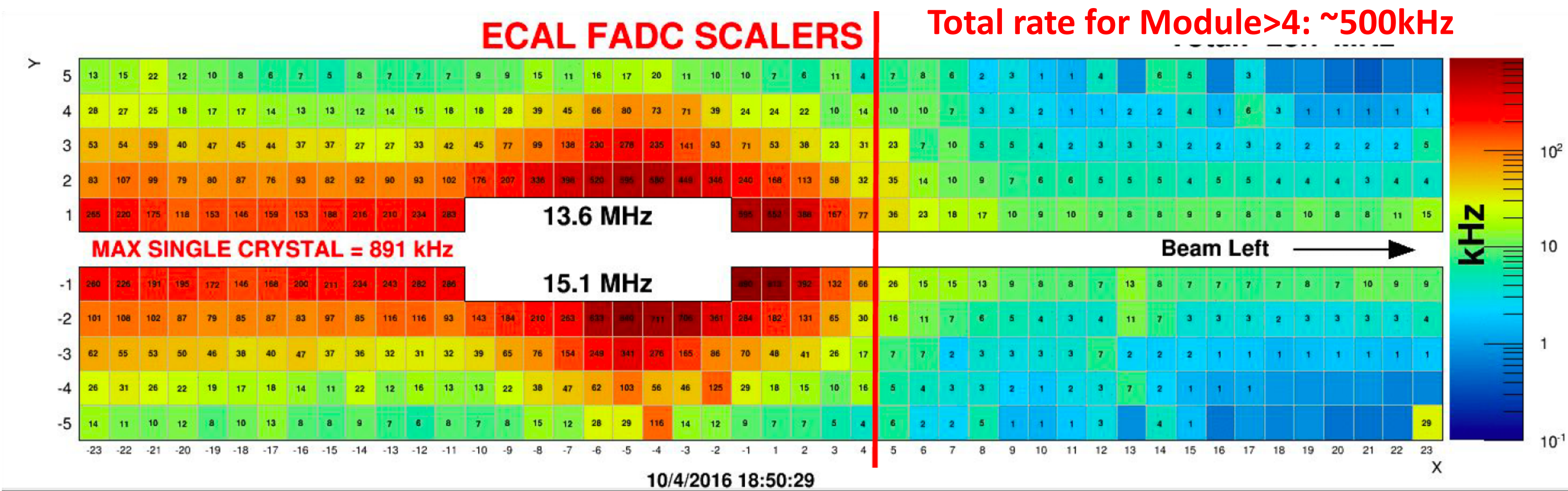




Rates in L6 and ECal

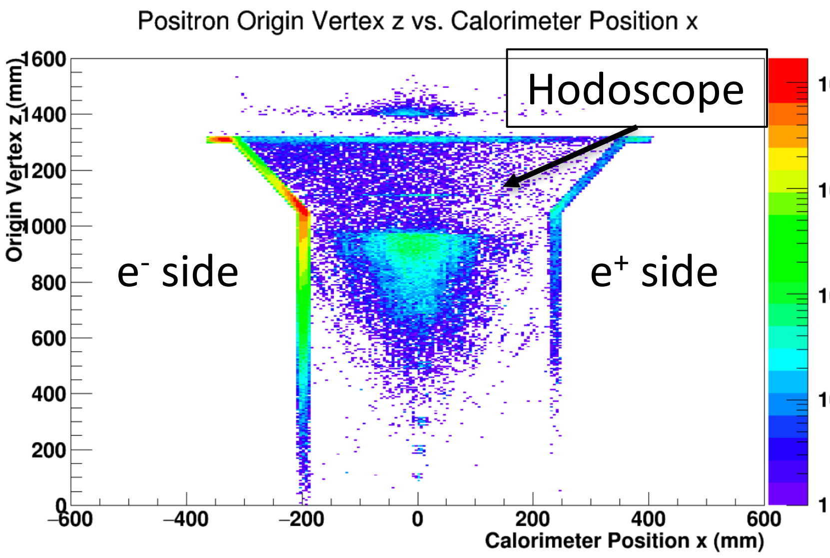
- Rate of L6 hits with x > 50 cm (the region that corresponds to the ”positron” side of Ecal) is 160 kHz
- Ecal singles rate with x > 100 cm ~500 kHz
- The singles rate in Ecal is due to showers and includes WAB photons
- Single hit rate on a plane between SVT L6 and the Ecal, on the “positron” side, is expected to be low, close to the rate of L6 3D hits, quite manageable for a scintillation counter

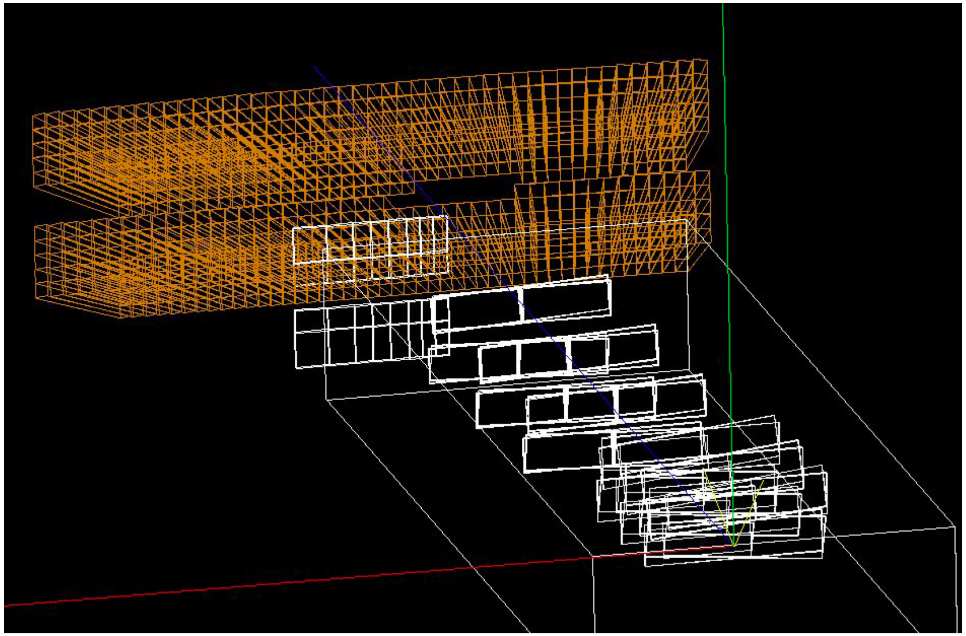




Simulation with Scintillation Hodoscope

- Hodoscope was inserted into HPS GEANT-4 model as a 1cm thick scintillator plane
- Full physics model was used to estimate trigger rates and backgrounds
- Most of background comes from interactions of electrons and photons with vacuum chamber walls (1/2 inch SS) and can be eliminated by timing and energy deposition cuts





Simulations with Hodoscope

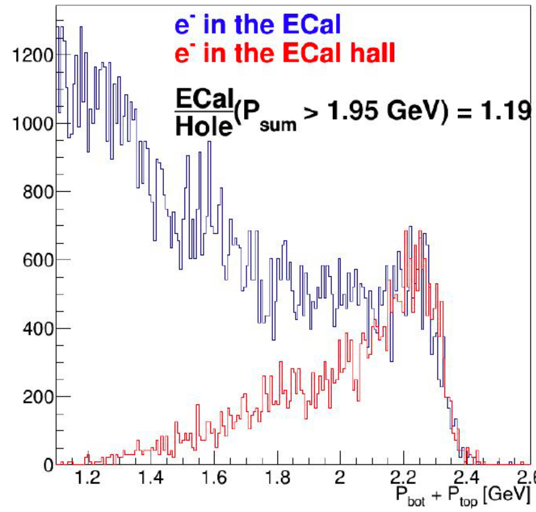
Full MC with 2.3 GeV beam energy, agrees with data, lost electrons are high momentum and are half of the trident events with $p_{sum}>0.8E_0$

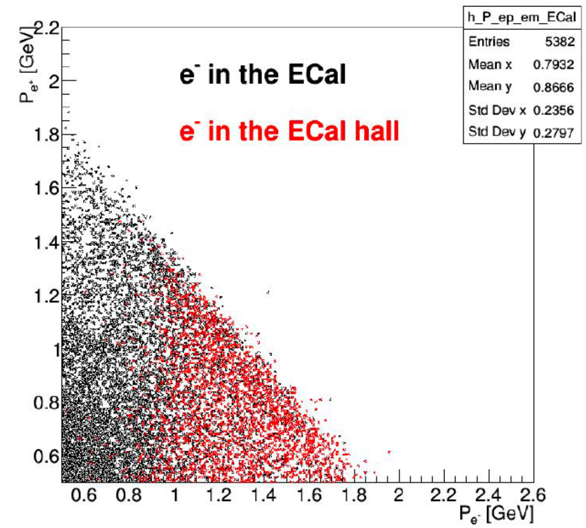
With cuts:

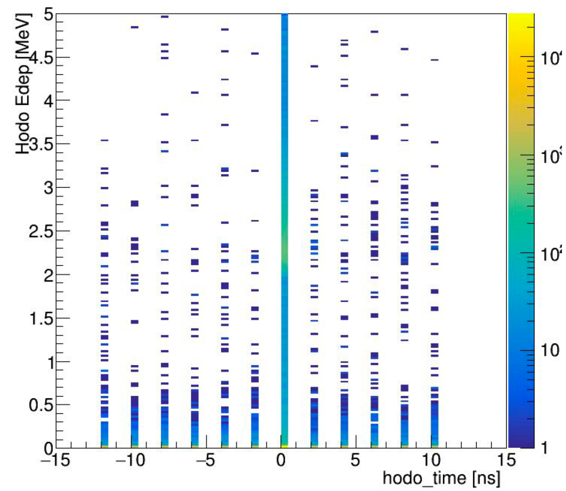
- x_{cl} > 100 mm,
- 0.3 GeV < E_{cl} < 1.4 GeV
- E_{dep} > 1.95 MeV

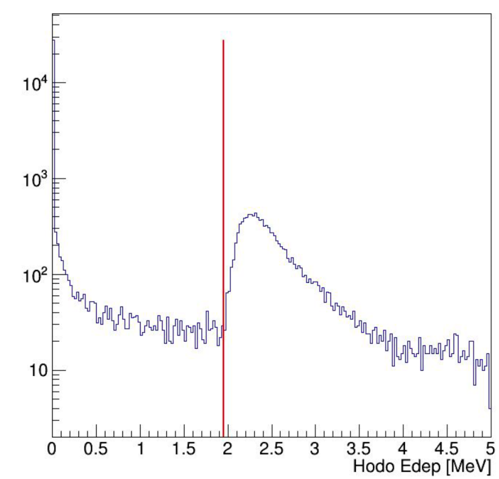
the expected trigger rate composed of a coincidence between Ecal cluster and a hit in hodoscope **~16 kHz**

(this should be compared with 14 kHz from L6xECal studies from data)

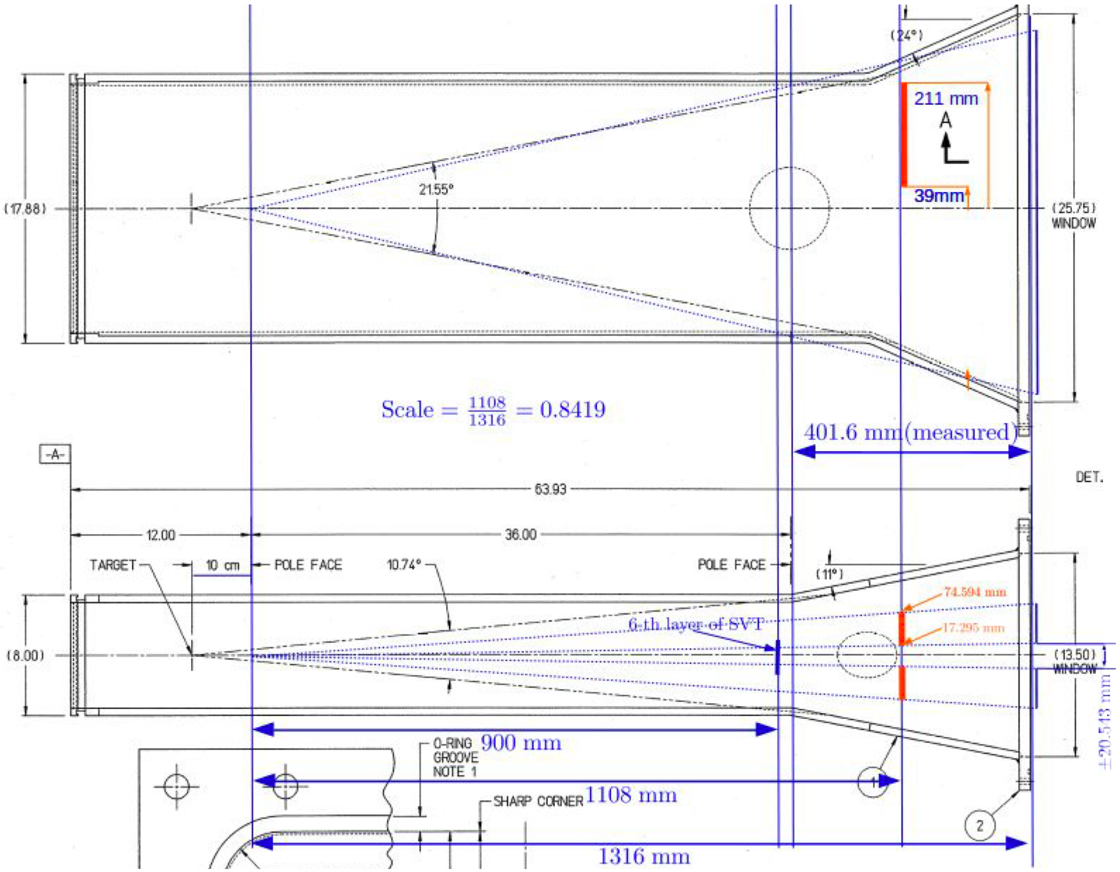








HPS Scintillation Hodoscope



Mounted inside the vacuum chamber, half a way between SVT L6 and the exit flange.

Two rectangular shape modules:

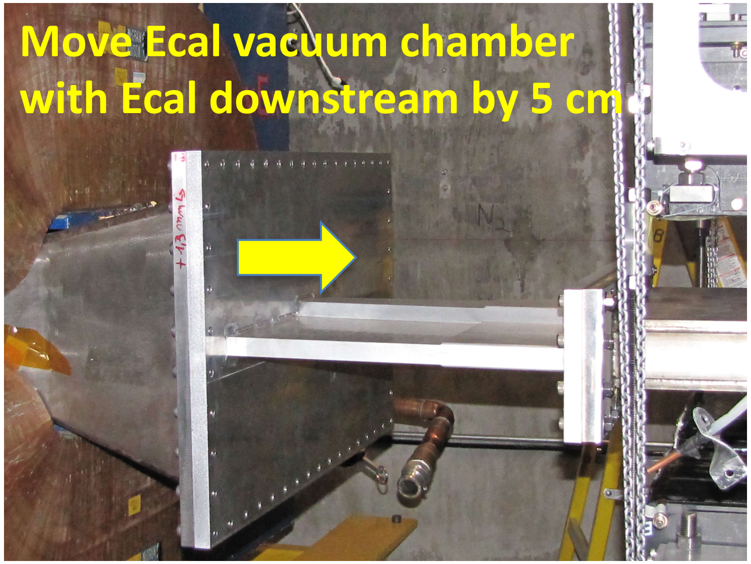
$$\Delta X = 180\ mm;\ \Delta Y = 60\ mm$$

$\boldsymbol{\delta}$=15 mm to 30 mm wide vertical strips with embedded wave-length shifting fibers.

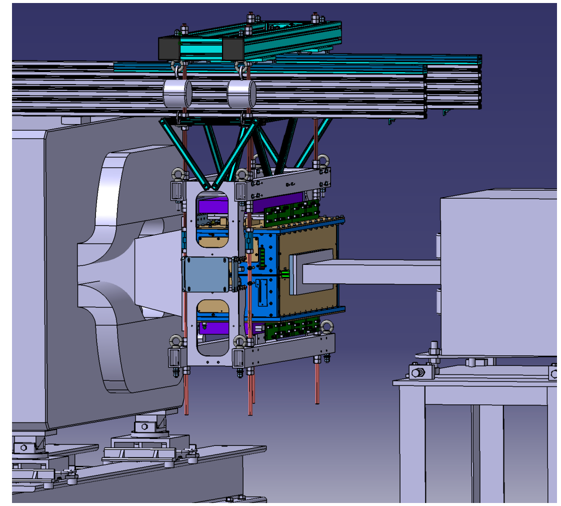
Readout with multi-anode PMT (Hamamatsu H7811, 16 channels).

Scintillator strips and fibers from CLAS12 PCAL leftovers, backing foam for scintillator support (as for CLAS-DVCS hodoscope), fiber-PMT transition (vacuum feedthrough) and the PMT housing the same as for CLAS12 BOM, PMT readout with FADC250.

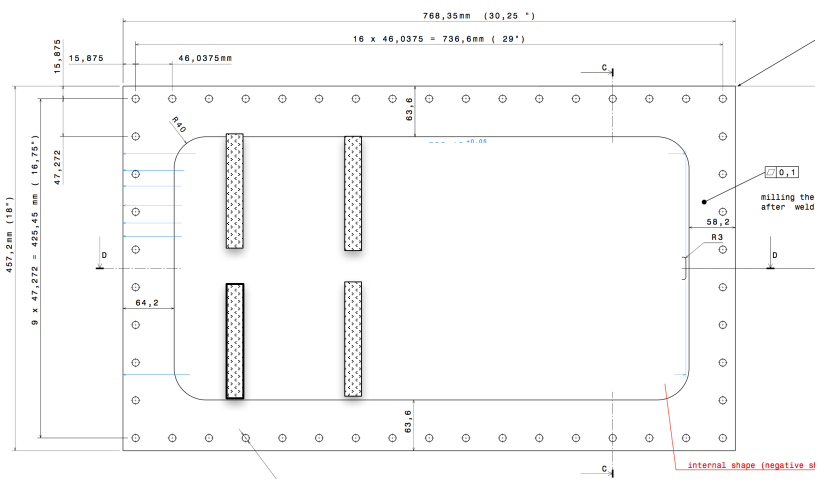
Hodoscope Mounting System (conceptual)

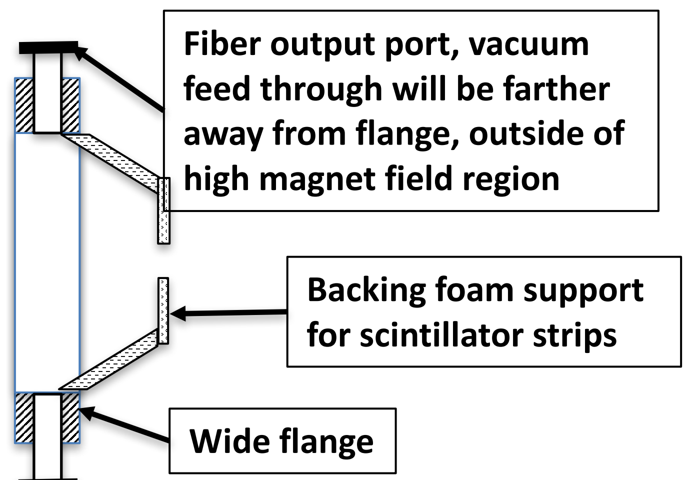


Ecal mounting system



Add 5 cm wide flange between analyzing magnet and Ecal vacuum chambers





Hodoscope Concept

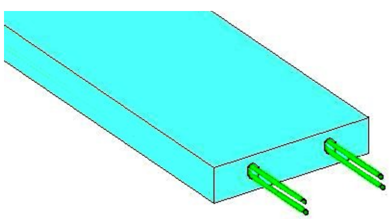
Use already tested, proven technics:

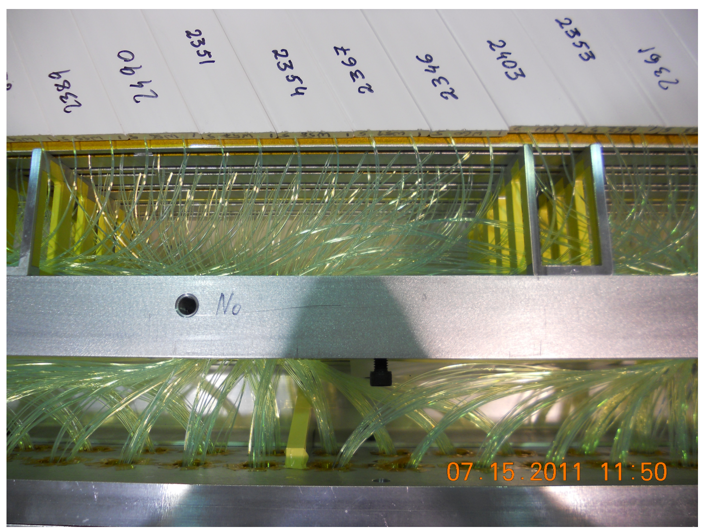
- extruded scintillator strips from PCAL
- Kuraray Y11 wave-length shifting fibers from PCAL
- maPMT, Hamamatsu H8711 as in CLAS-BOM)
- Housing and readout from CLAS-BOM

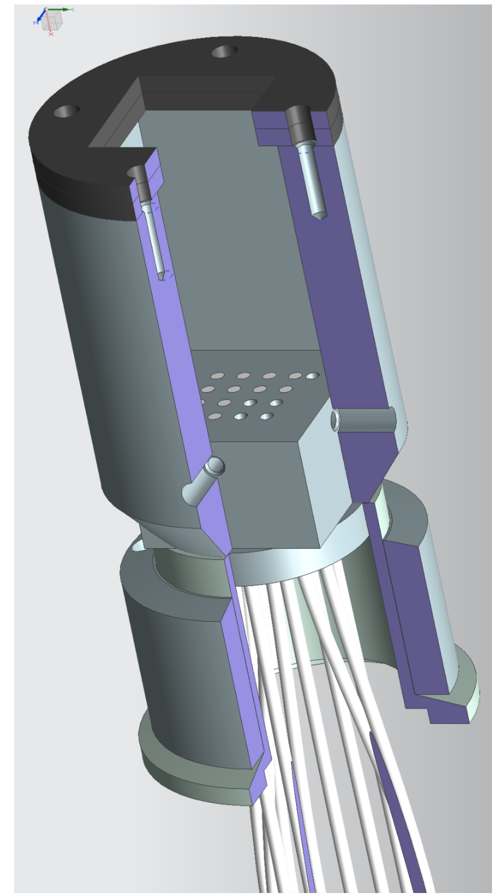
Experience with PCAL – unglued 4-fibers produce 12 p.e./MeV. Gluing fibers will increase light by x2 (from PCAL R&D).

We expect ~50 p.e./e^+ from the hodoscope

BOM maPMT housing and fiber feedthrough







Resources

- Project is user driven and will be lead by three institutions.
- University of New Hampshire (a postdoc and a grad. student):
  - Simulation and data analysis
  - Purchase of PMTs and dividers purchase (<10 k$)
  - assembly of the hodoscope at JLAB
  - commissioning

Currently UNH has two grad students and a postdoc on HPS involved in data analysis, trigger development, MC production, and PI leads HPS software group

- IPN Orsay (engineer, designer, and technician):
  - Design and fabrication of the flange and hodoscope support

Orsay played key role in the design and fabrication of the ECal and Ecal vacuum chamber, has a grad. student on HPS, PI leads HPS Ecal group

- JLAB:
  - Space for assembly
  - PMT housing and readout design (will use the design from BOM)
  - two fADC boards (can be barrowed)
  - general support in installation

Schedule and Cost

Item	Cost	Comments
Scintillator and fibers	-	Leftovers from CLAS12 PCAL project
Machining of strips	$1000	
PMTs and dividers	$6600	JLAB design, funds from UNH
Hodoscope support	-	Designed and fabricated at Orsay
PMT housing, fiber feedthrough	$1000	The same as for CLAS BOM
Horoscope assembly	$1000	Consumables (glue, gloves …)
Total	$9600	

Item	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Complete MC	■							
Design of flange and supports		■	■	■				
Fabrication and delivery of support				■	■	■		
Assembly of the hodoscope							■	■
Commissioning with cosmics								■
Ready to install								■

Risks and Mitigation

The HPS trigger upgrade that requires fabrication and installation of a scintillation hodoscope inside the vacuum chamber of the HPS setup is a very low risk project:

- Schedule – there is a 3 months contingency. However, if for some reason hodoscope will not be ready, HPS can run with Ecal cluster pair trigger as during the engineering runs. No changes to the detector will be made.
- Cost – the main cost driver is the PMT purchase, there are two used PMTs on hands (from old CLAS profiler).
- Technical – the proposed hodoscope design is simple and uses scintillator fiber readout system that has been used in many detectors in Hall-B. The readout with maPMT is not new either. The support and mounting are simple, Orsay group has extensive experience in designing and fabricating such components (the whole Ecal design and fabrication of most of parts have been done by this group).
- Performance – if hodoscope is installed but will not perform as required, HPS still can run with the trigger setup used in engineering run. Hodoscope will add <20% more dead material in front of Ecal to what already exist.

Summary

- HPS engineering runs and subsequent data analysis showed that a significant number of e^+e^- events, where both particles are reconstructed by SVT tracking, were lost due to electrons ending up in the Ecal “hole” made by removing 18 modules around the beam
- These events were not recorded since the main trigger, pair of clusters, requires to have both particles to be detected in ECal
- The solution to recover these lost events is not to trigger on electrons. A single arm positron trigger will work
- Most of clusters in the “positron” side of the Ecal are from high energy photons and Ecal only trigger has too high rates
- We proposed to upgrade to the trigger system to include a charged particle detector in it, a scintillation hodoscope, located half a way between SVT L6 and the flange in front of ECal
- Proposed detector is simple, uses well tested technologies, will cost <10k$ for materials and will be ready for HPS 2018 run