HPS Trigger Upgrade

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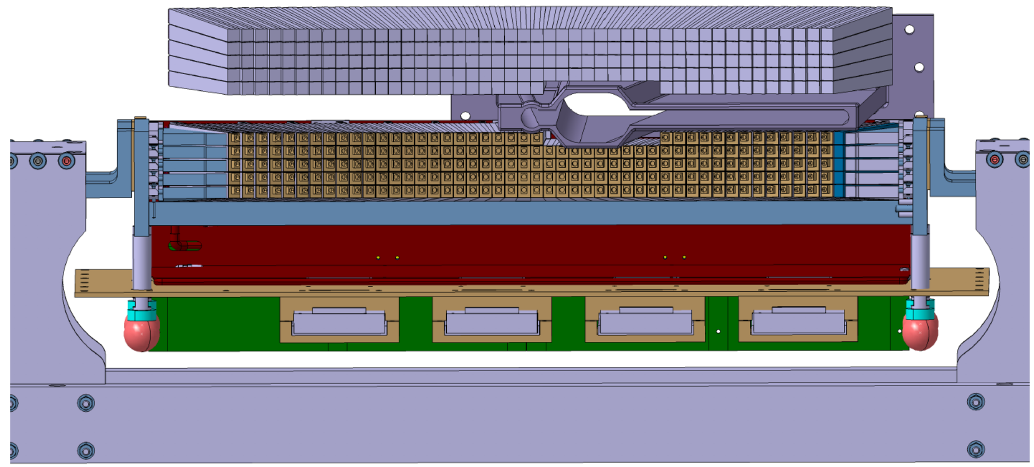
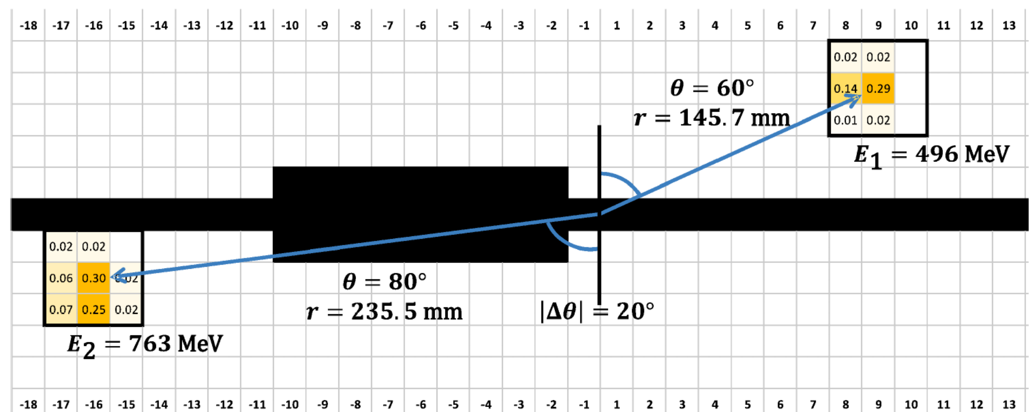
Outline

- HPS ECal and the trigger
- Pair trigger and reconstruction of e+e-
- Analysis of random trigger data
- Single arm e+ trigger rates
- Simulations
- Concept of a scintillation hodoscope
- Resources, schedule, and cost estimate
- Summary

HPS Ecal and the trigger

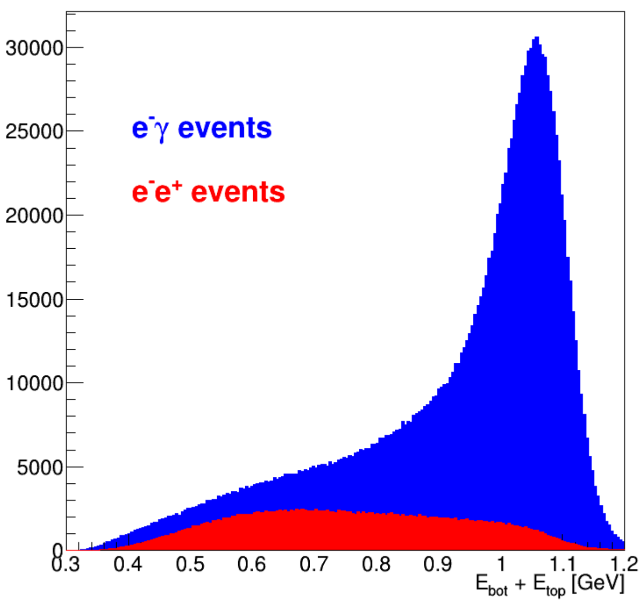
- A homogeneous calorimeter made of 442 (221 per sector) lead tungstate ($PbWO_4$) crystals readout with 10x10 APDs.
- Rectangular formation of modules in each sector with 9-modules removed from closest to the beam row.
- The analog signal from each Ecal channel is continuously sampled by the FADC every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



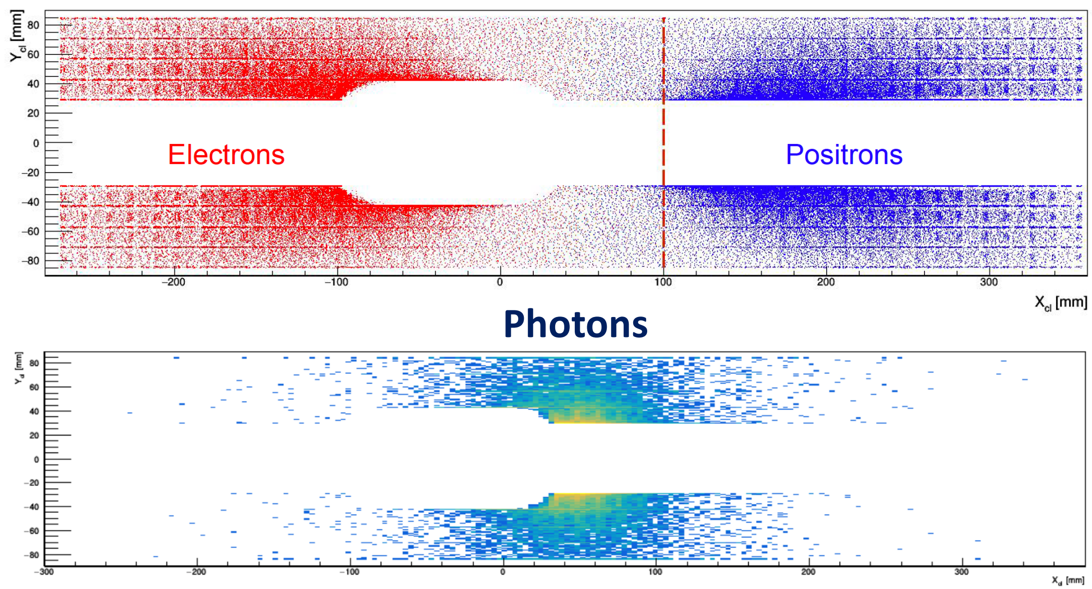


Cluster pairs and tridents

- 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 matching hit Ecal due to the Ecal hole for beam go though (removed modules)
  - the cluster trigger wont differentiate between neutral and charged particles. It turned out that large fraction of HPS triggers came from wide angle bremsstrahlung (WAB) events ($e^-\gamma$).

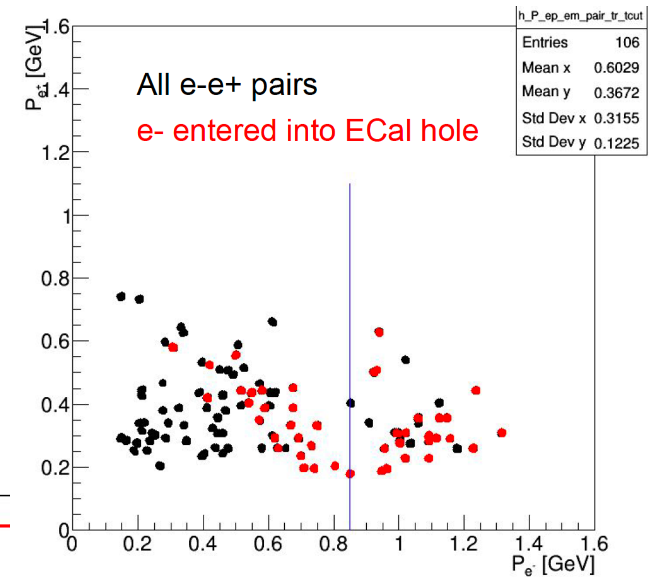


Electrons and positrons from Trident events

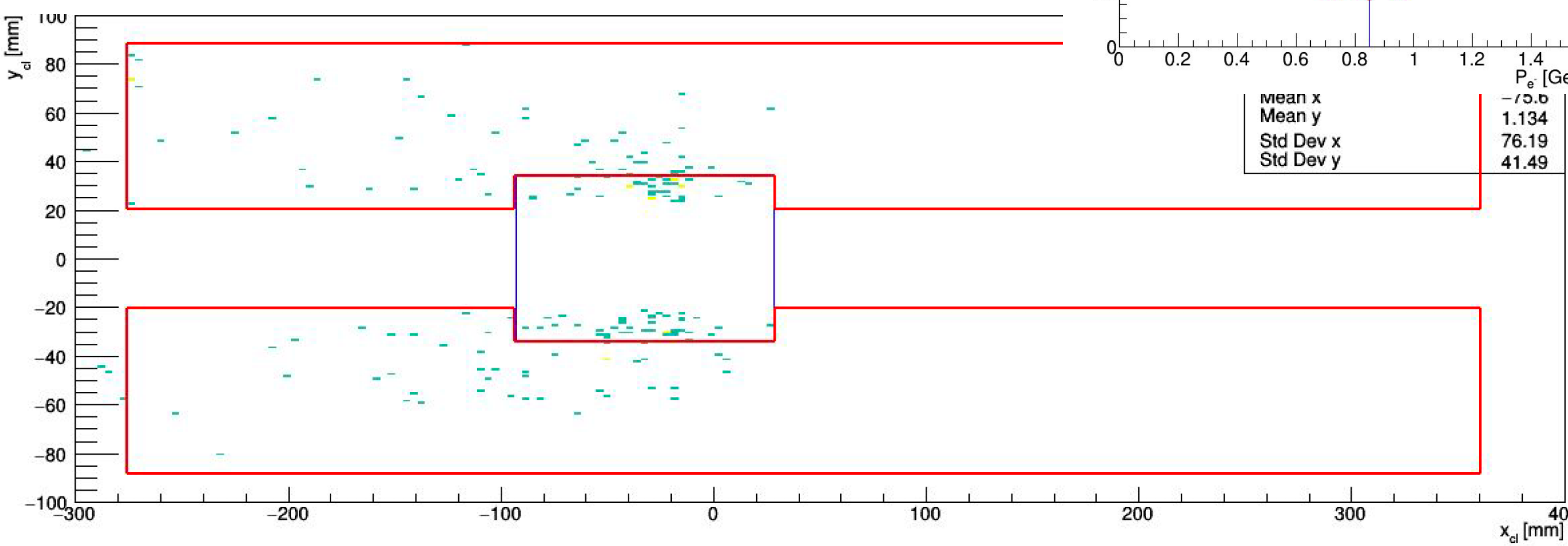


Random Pulser Trigger Data

- 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



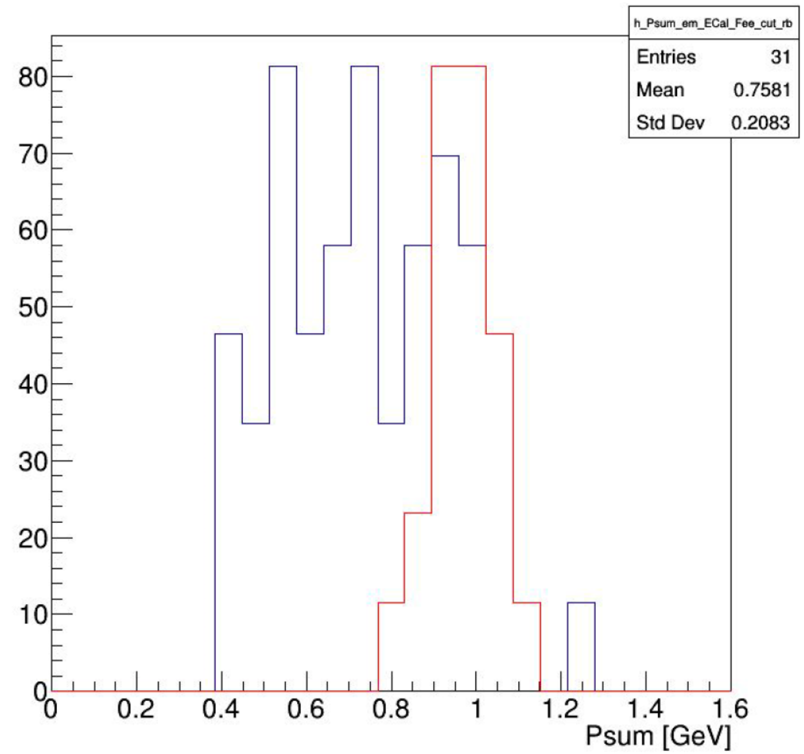
Position of electron at ECal

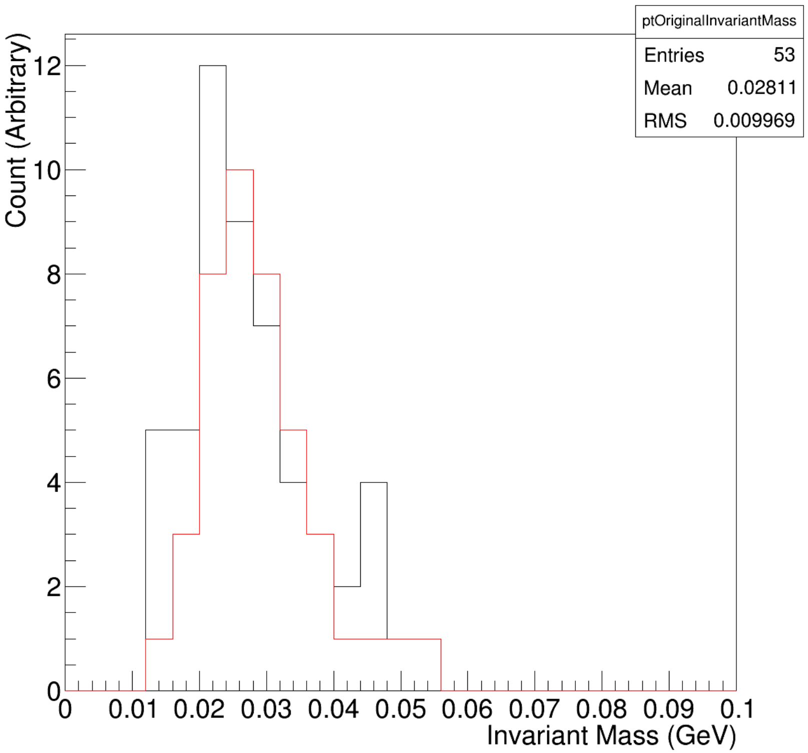


Pairs With e^+ Track – Ecal Cluster Match

Data (2015), random pulser trigger

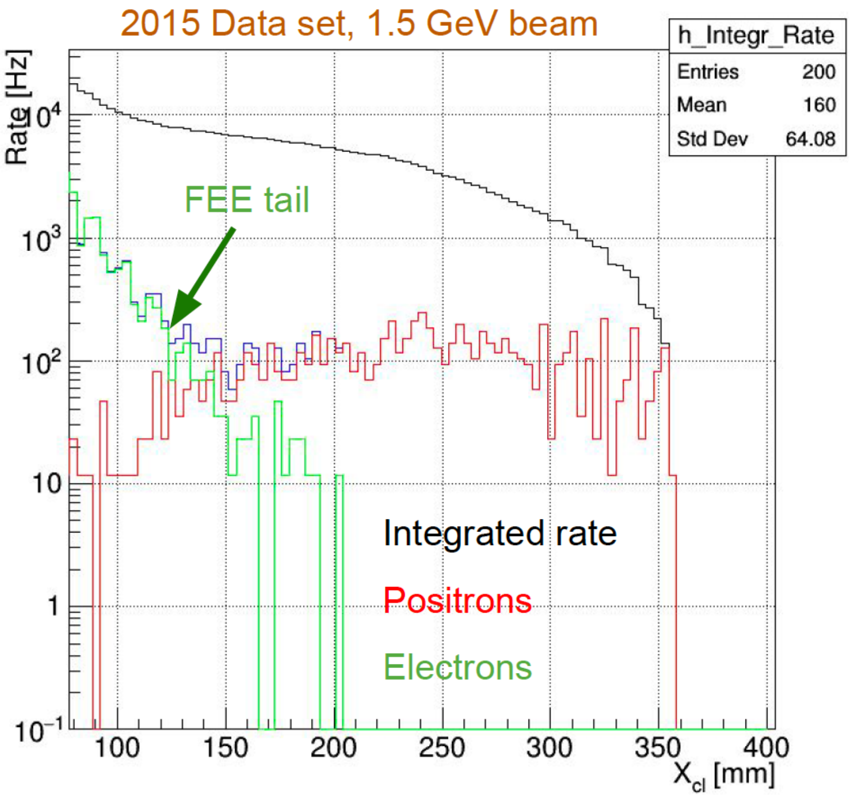
Almost half of e^- from reconstructed e^+e^- tracks with p_{sum}>0.8E_0 are lost in the Ecal hole

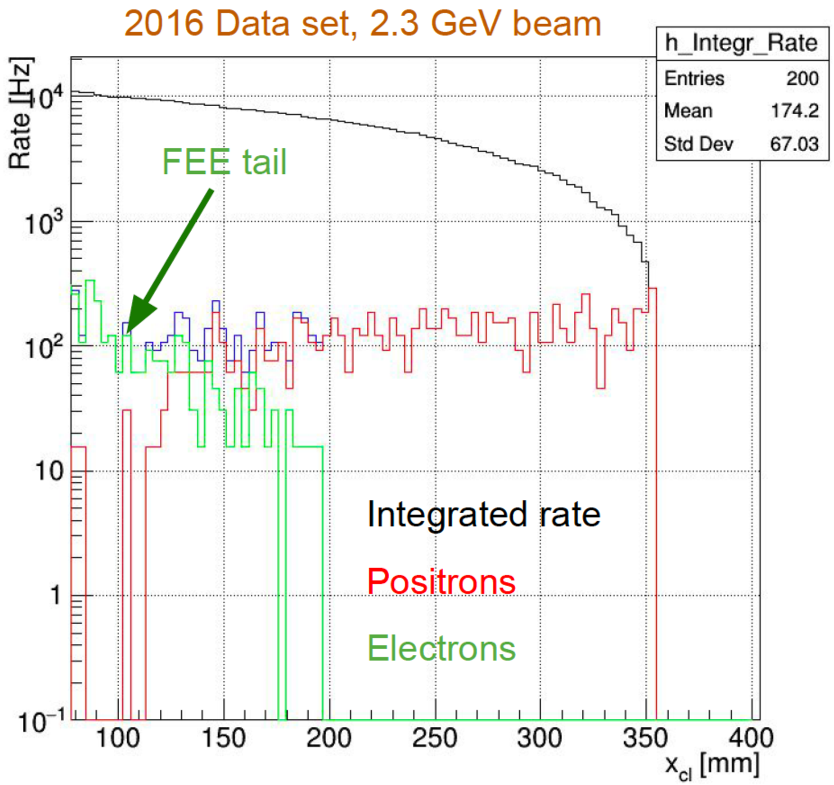




e^+ Cluster Rates

- 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 wit htracks is ~12 kHz

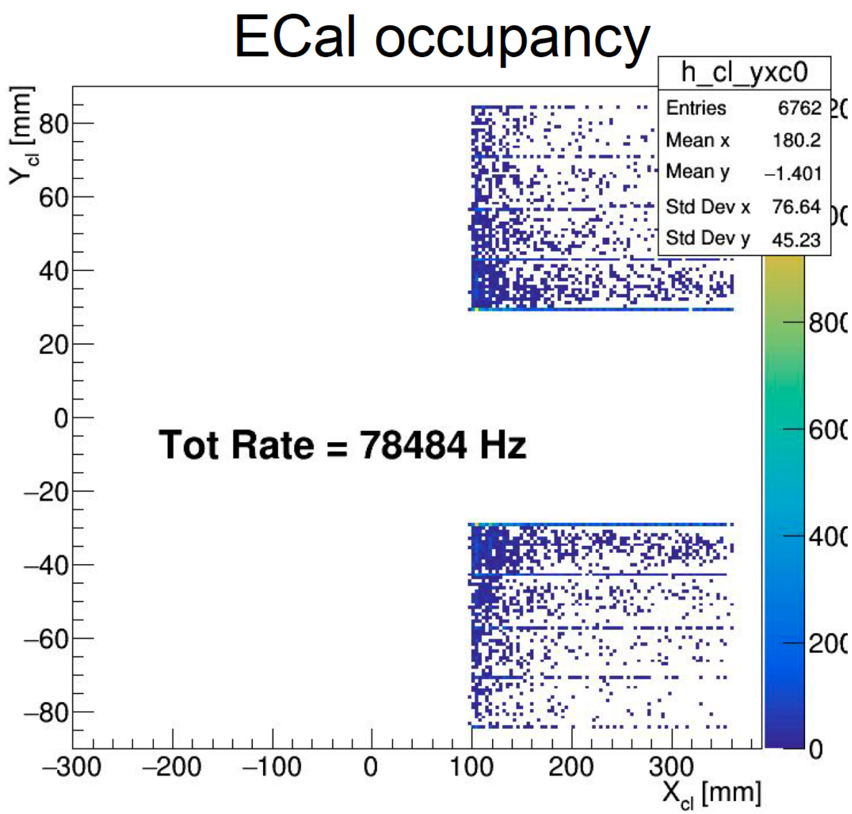


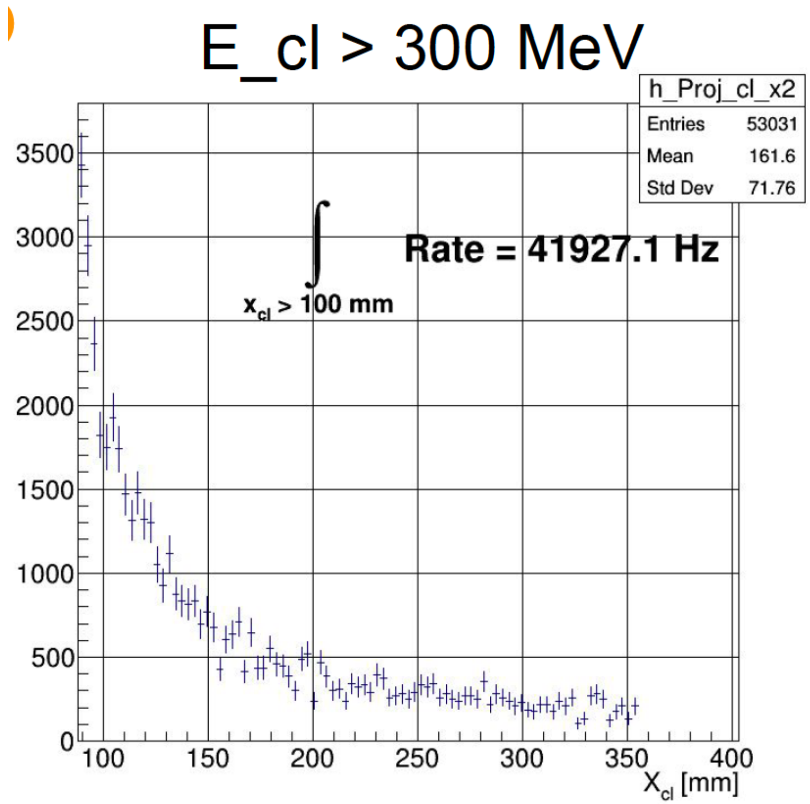


Triggering on positrons alone (single arm trigger) will fix the issue with the lost electrons and eliminates high WAB content in the data

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
- WAB photons can be excluded from the trigger by a coincidence of a fast charge particle detector with ECal in the trigger

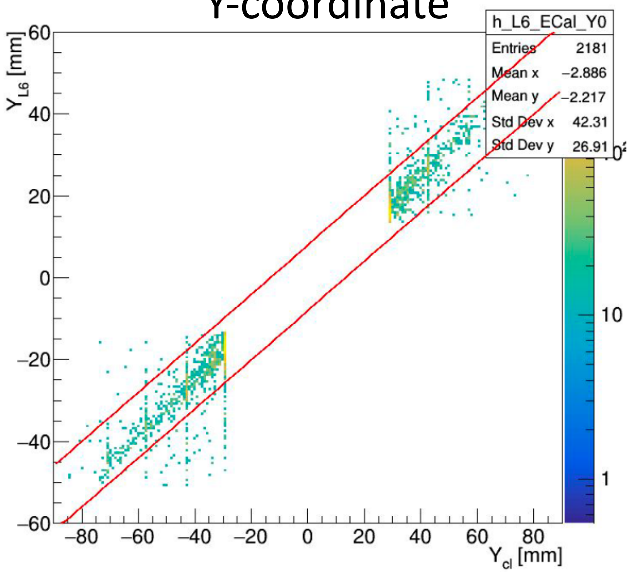




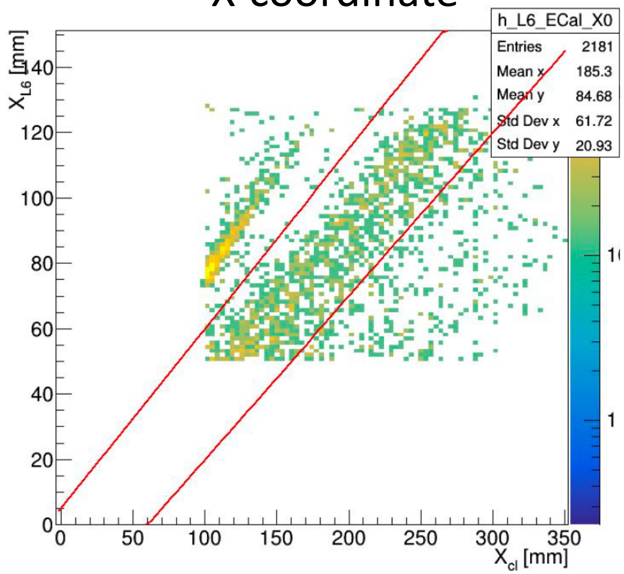
Ecal Cluster – L6 Hits

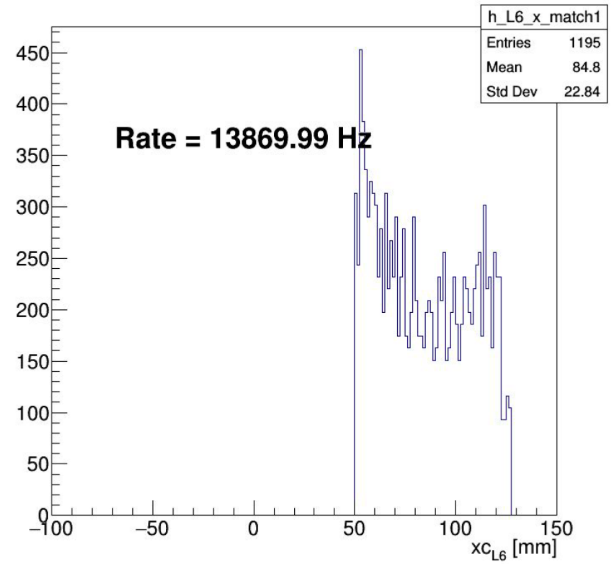
- SVT Layer-6 was used as proxy for a charged particle detector in order to understand rates.
- SVT 3D hits on Layer-6 were used in coincidence with clusters in the Ecal
- Position correlations are used to make geometric coincidence between a hit in L6 and a cluster in ECal

Y-coordinate



X-coordinate

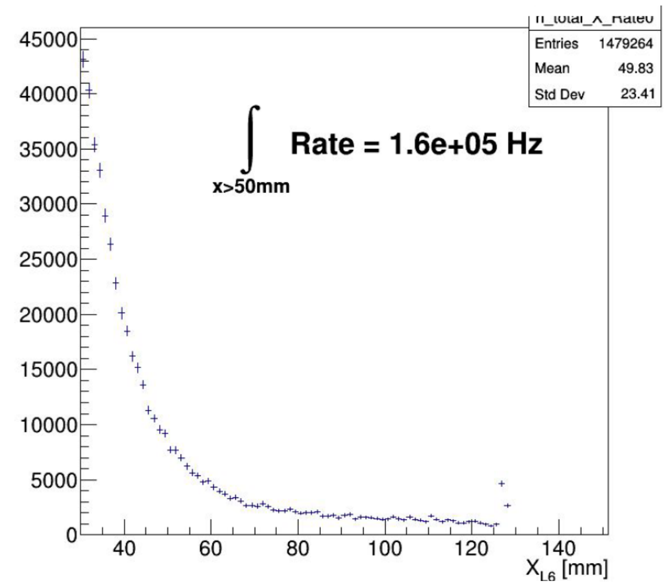


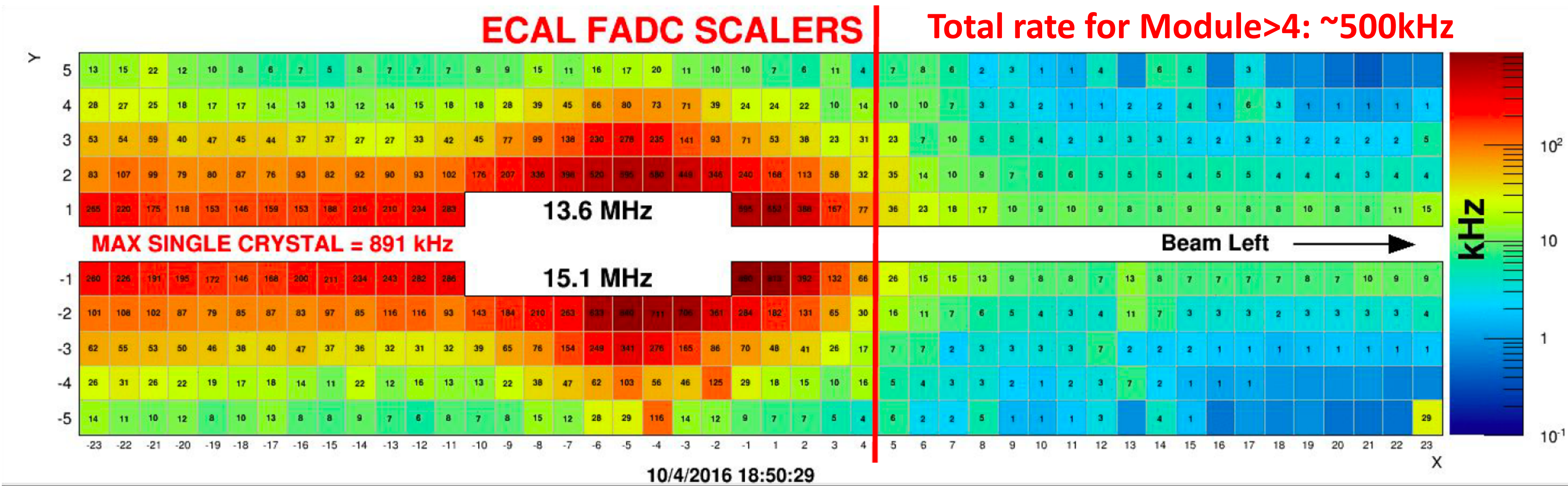


Coincidence rate between L6 hit and Ecal cluster ~14 kHz

Rates in L6 and ECal

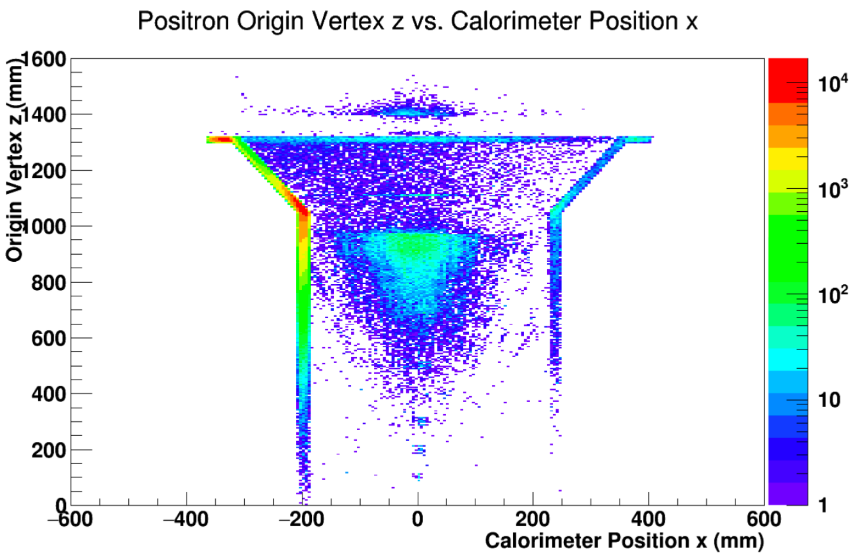
- Rate of L6 hits with x > 50 cm is 160 kHz
- Ecal singles rate with x > 100 cm ~500 kHz
- The rate in Ecal is due to showers and include photons from WABs
- Single hit rate on a plane between SVT L6 and Ecal, on the "positron" side is expected to be low, close to the rate of L6 3D hits, quite manageable for a scintillator counter

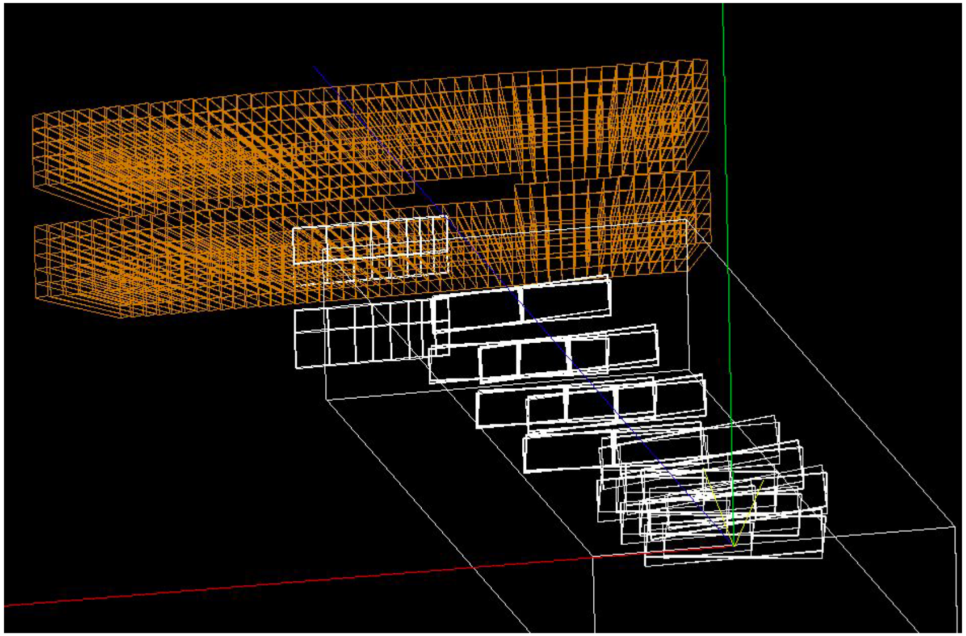




Simulations

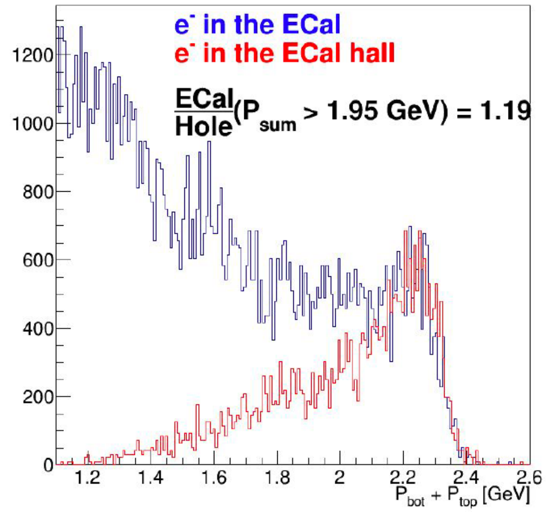
- Hodoscope was inserted into HPS GEANT-4 model as a 1cm thick scintillator plane
- Full physics model was used to estimate trigger rates and backgrounds
- Most of background comes from interactions of electrons and photons with vacuum chamber walls (1/2 inch SS) and can be eliminated by timing and energy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

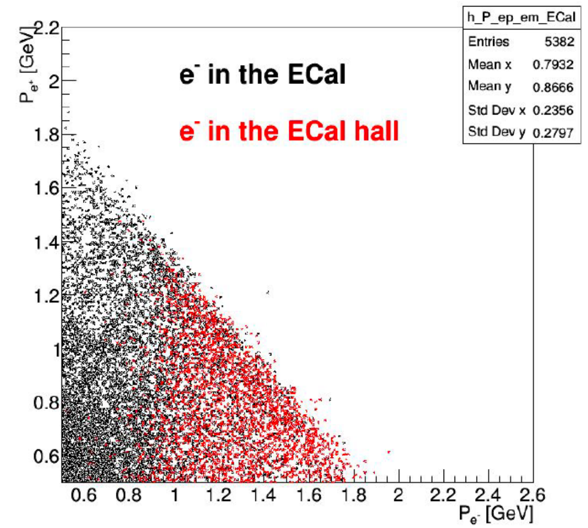




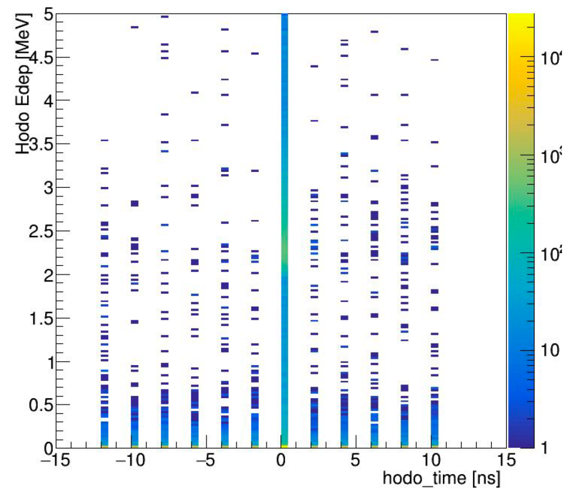
Simulations with Hodoscope

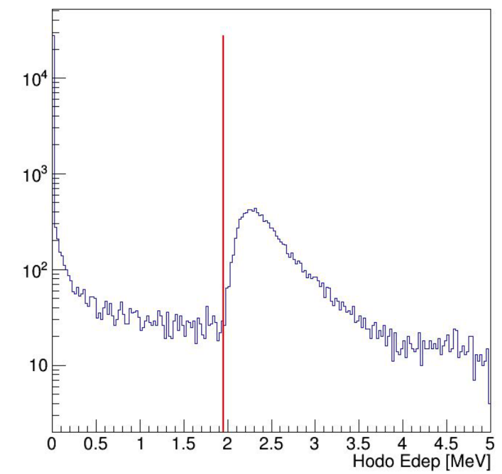
MC 2.3 GeV, the same as from data, lost electrons are high momentum and are half of trident events with $p_{sum}>0.8E_0$



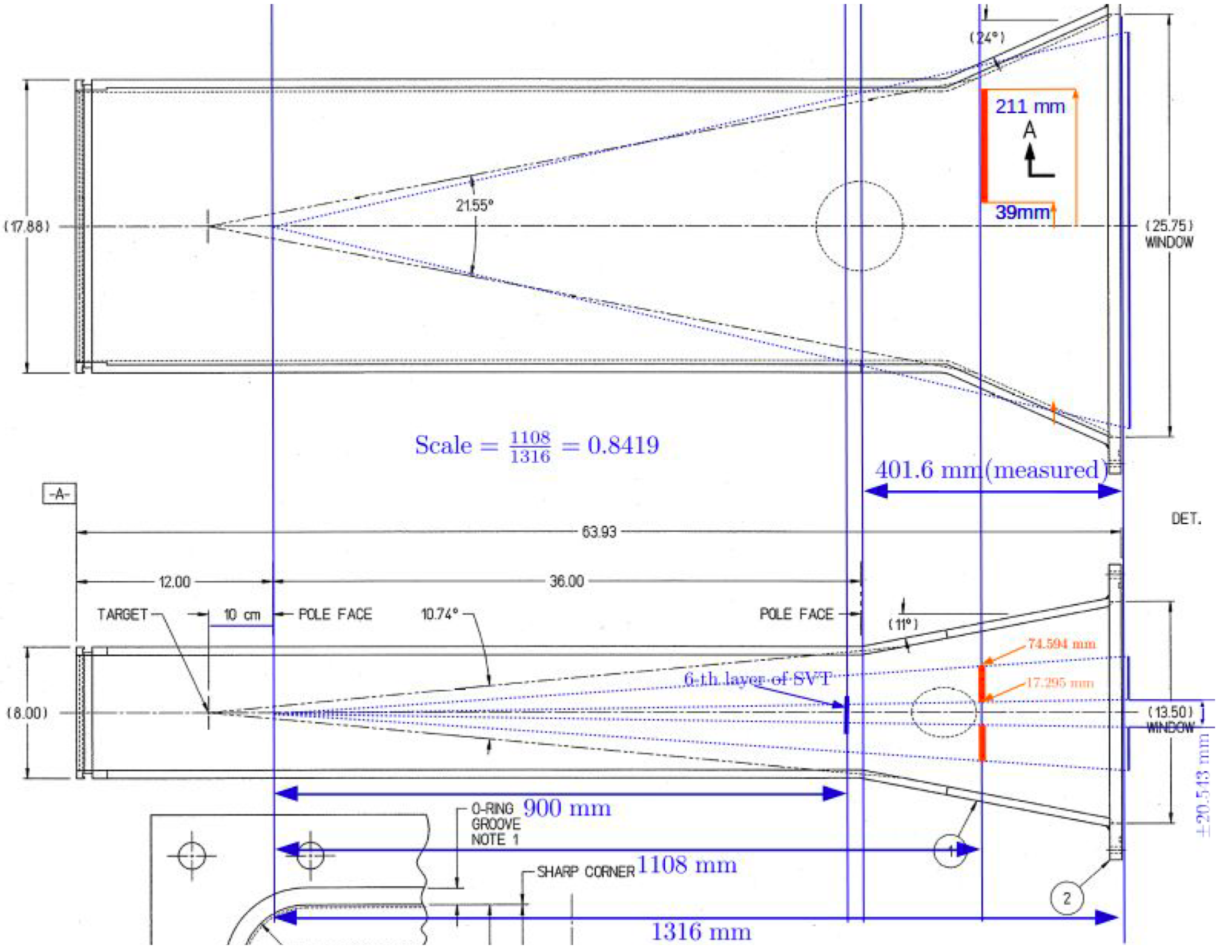


With cuts:
$x_{cl} > 100$ mm,
0.3 GeV < E_{cl} < 1.4 GeV
Hodo_hit_Edep > 1.95 MeV
the expected trigger rate composed of a coincidence between Ecal cluster and a hit in hodoscope ~16 kHz





HPS Scintillation Hodoscope



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

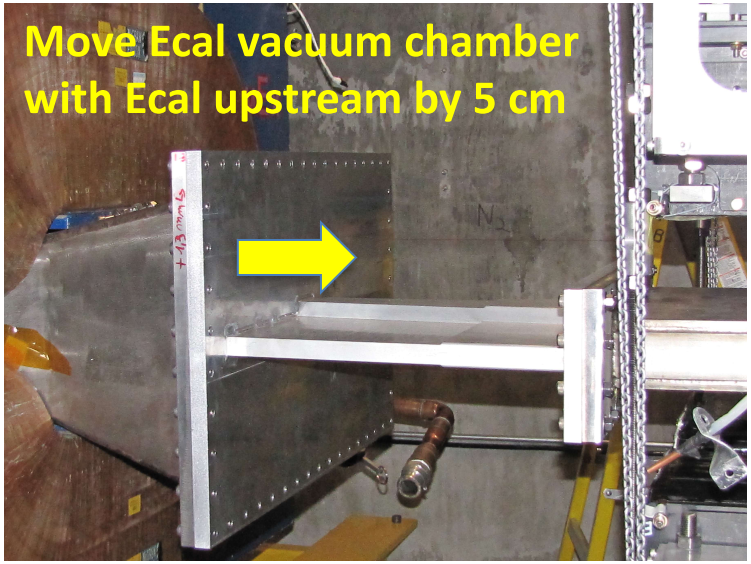
Two rectangular shape modules:
$\Delta X = 180\ mm;\ \Delta Y = 60\ mm$

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

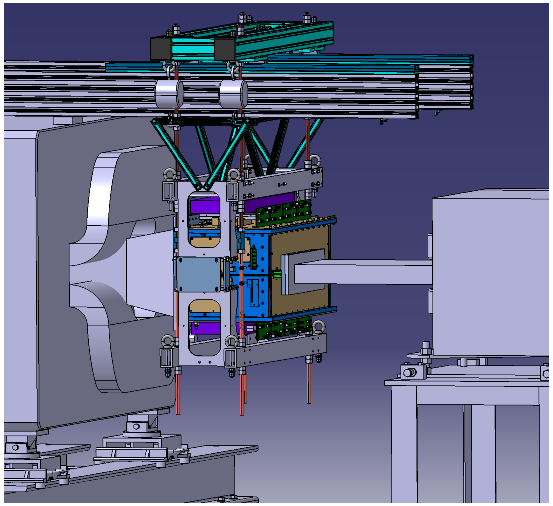
Readout with multi-anode PMT (Hamamatsu H7811, 16 channels).

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.

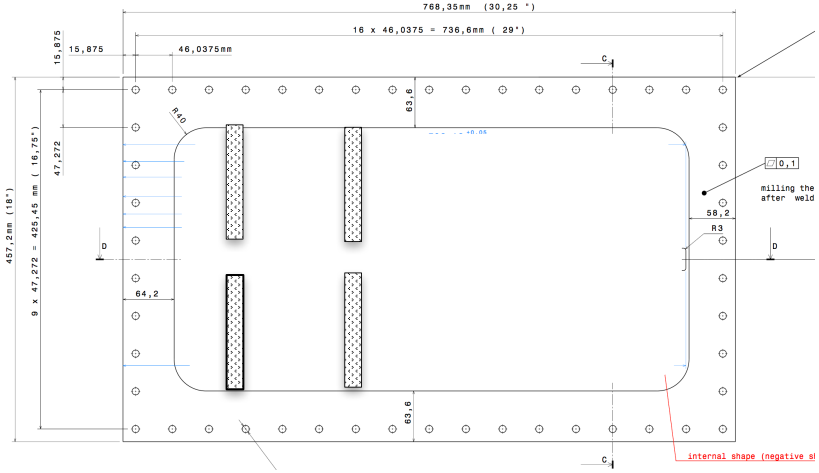
Hodoscope Mounting System (conceptual)

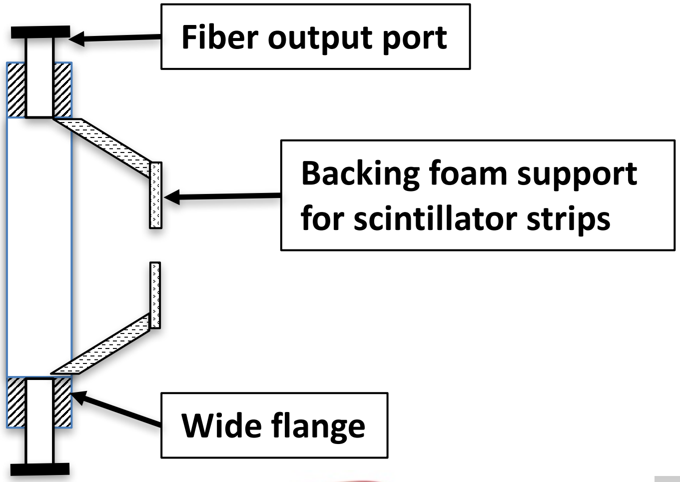


Ecal mounting system



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

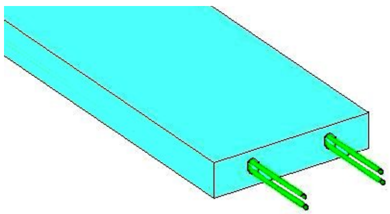


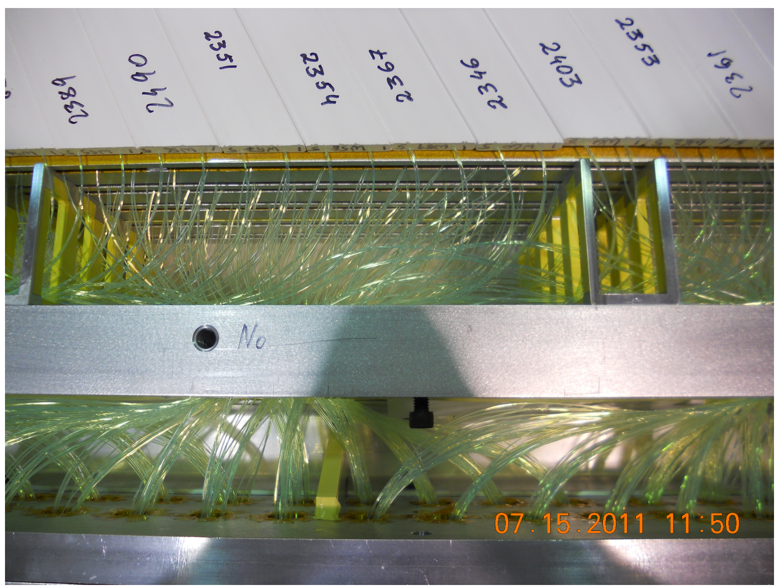


Hodoscope Concept

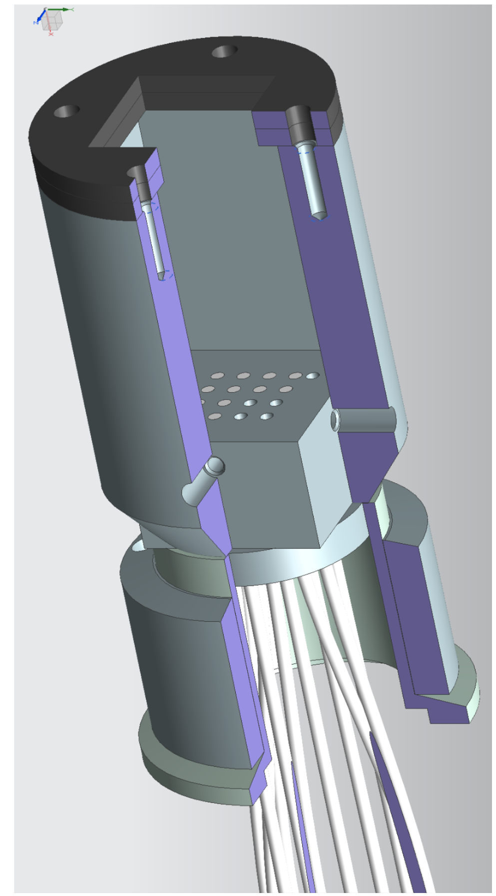
Use already tested, proven technics:

- 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





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 gard. student)
  - Simulation and data analysis
  - Purchase of PMTs and dividers purchase (<10 k$)
  - assembly of the hodoscope at JLAB
  - commissioning
- IPN Orsay (engineer, designer, and technician):
  - Design and fabrication of the flange and hodoscope support
- 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,
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								■

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 9 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, however
- The rate of single clusters, even on the side of the ECal where positrons are detected is too high. Most of clusters in the "positron" side are from high energy photons
- We proposed to upgrade to the trigger system to include a charged particle detector in it, a scintillation hodoscope,
- Proposed detector is simple, uses well tested technologies, will cost <10k$ for materials and will be ready for HPS 2018 run

Track-Ecal timing