Jefferson Lab
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University of New Hampshire

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

# Positron trigger, hodoscope upgrade

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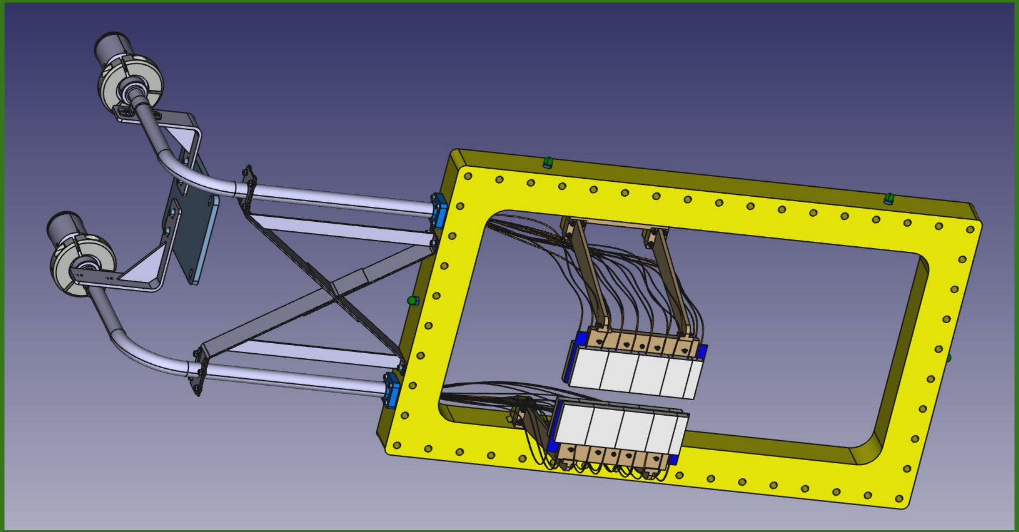
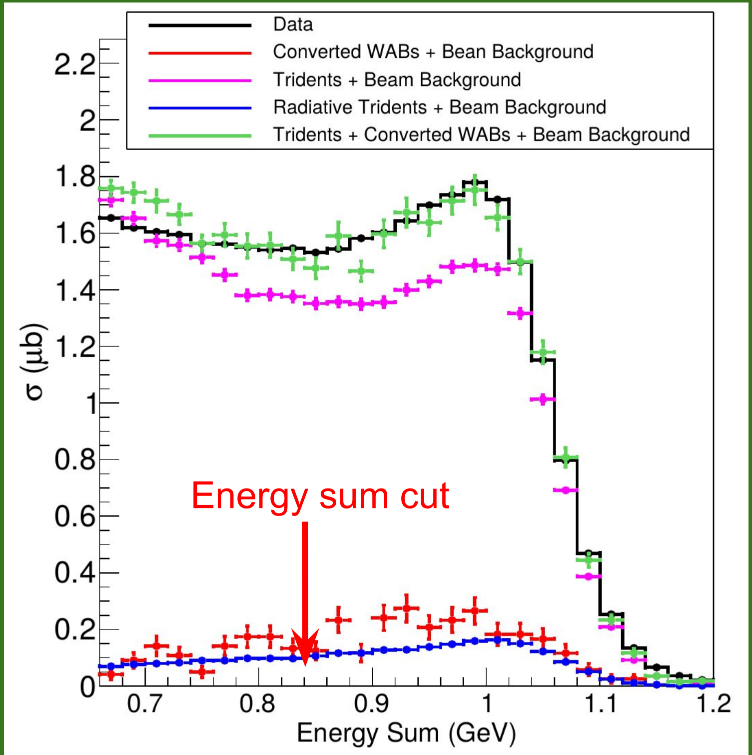
HPS review
SLAC, January 18, 2019

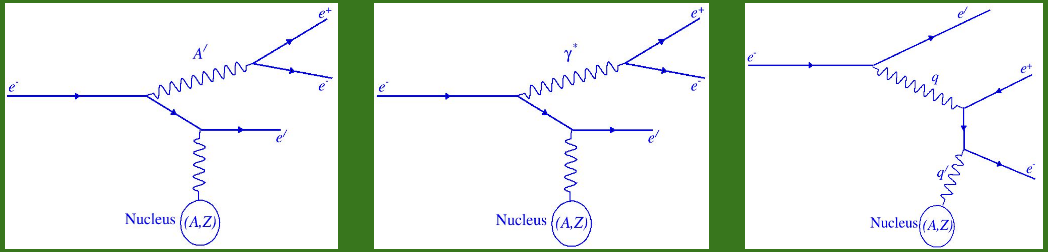


# HPS sensitive region

$$\frac{d\sigma(e^- Z \to e - Z(A' \to l^+ l^-))}{d\sigma(e^- Z \to e - Z(\gamma^* \to l^+ l^-))} = \frac{3\pi\epsilon^2}{2N_{eff}\alpha}\frac{m_{A'}}{\delta m}$$




Signal is proportional to the radiative tridents

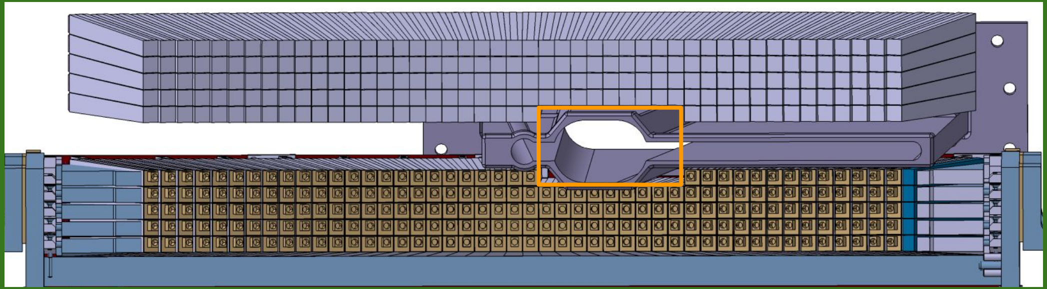



Radiative photon production is kinematically identical to A’ production: peaked at beam energy, and small production angle.

Bethe Heitler (BH) has much larger cross section, and unlike to rad. tridents, BH is peaked at small energies

Maximum signal sensitivity is reached at high Esum region: *Esum > ≈0.8Eb*

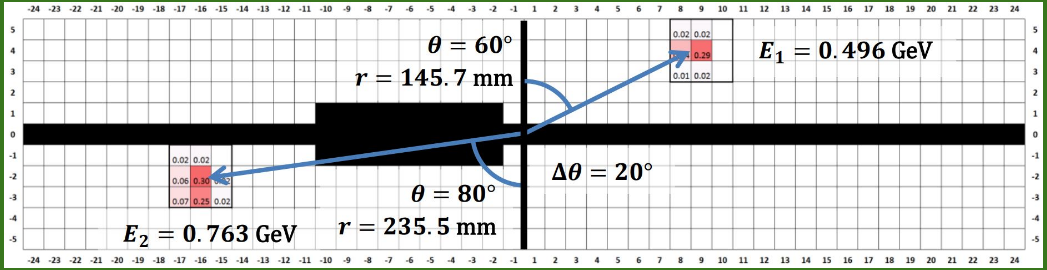
# The trigger that we run in 2015 and 2016



ECal was used for the trigger

221 crystals in each half.

9 too hot crystals are removed from each half. This region is called "*ECal Hole*"




One of $e^-e^+$ pairs from A' decay travels bottom and the other top. In addition, the dipole magnet bends them to opposite directions beam left ($e^+$) beam right ($e^-$)

The production trigger "*pair1*" searches for two clusters in opposite detector halves.

Min and max energy cuts on each crustal
Time coincidence between 2 clusters: 12 ns
Coplanarity cut:  40 deg
Max Energy sum energy cut

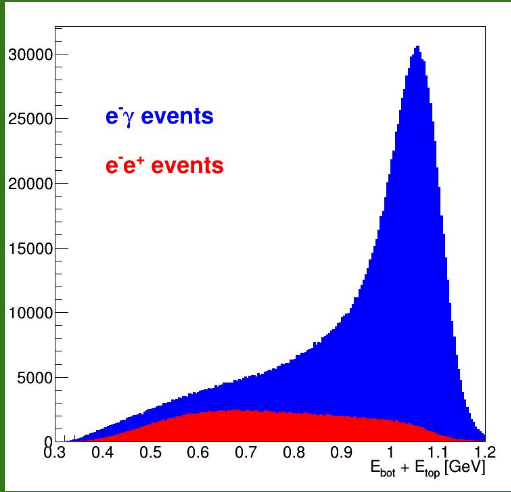
# Analysis of the data

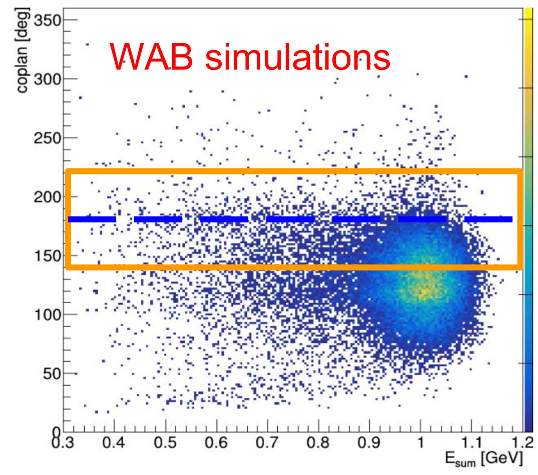
The production trigger worked well, eff. > 95%

However, trigger is dominated by the so called Wide Angle Bremsstrahlung (WAB) events ($\gamma e^-$).
Part of WAB photons passed the coplanarity cut and hence got detected.

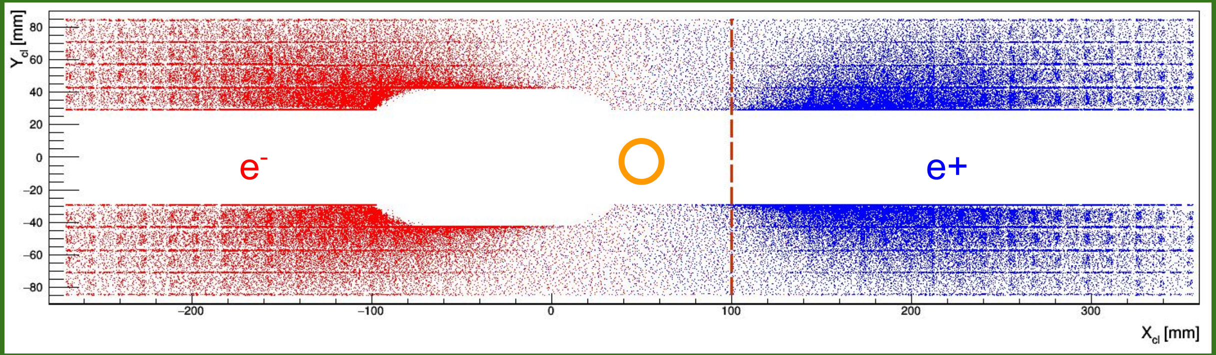
SVT detects tracks going through the region of 9 removed clusters, and we see clear sign of electrons lost in the ECal hole

Events from pair1 trigger

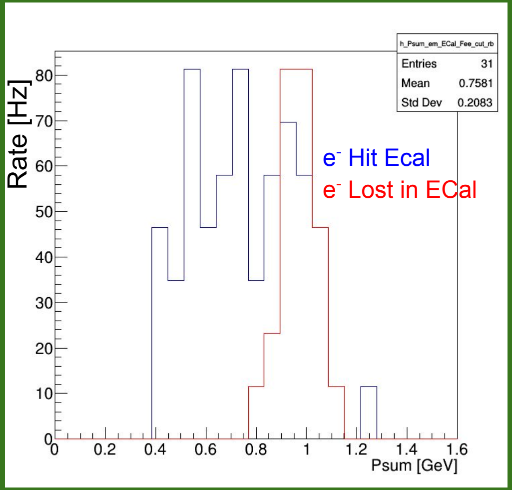



Data: $e^-$ and $e^+$ cluster "Y vs X" for the trident final state



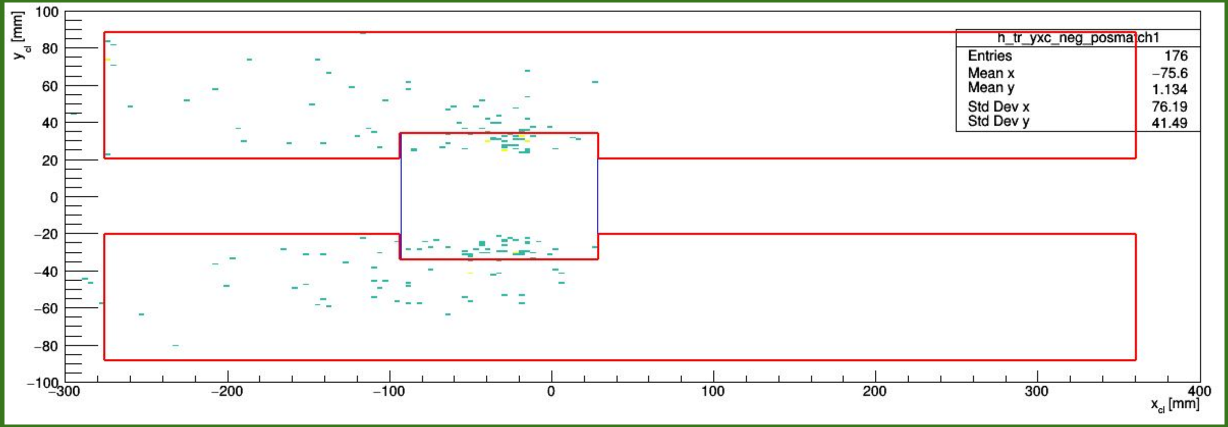
# More on electrons going through the ECal hole



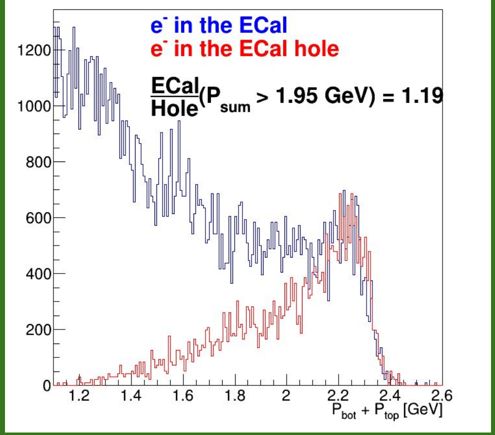

Random trigger data was used to study trident events, where electron is lost in ECal hole.

Events, with 1 pos track matched with the cluster in ECal, and a negative track in the  opposite detector halve, are selected.

Both: simulations and random trigger data show that at high Esum region about half of trident events have electron in the ECal hole




Simulations



# New trigger and scintillation hodoscope

- Hodoscope should suppress the huge WAB background at the trigger level.
- Instead of bot⊗top coincidence, use Hodo⊗ECal (pos side) coincidence. This will allow to record events, where electron miss the ECal.

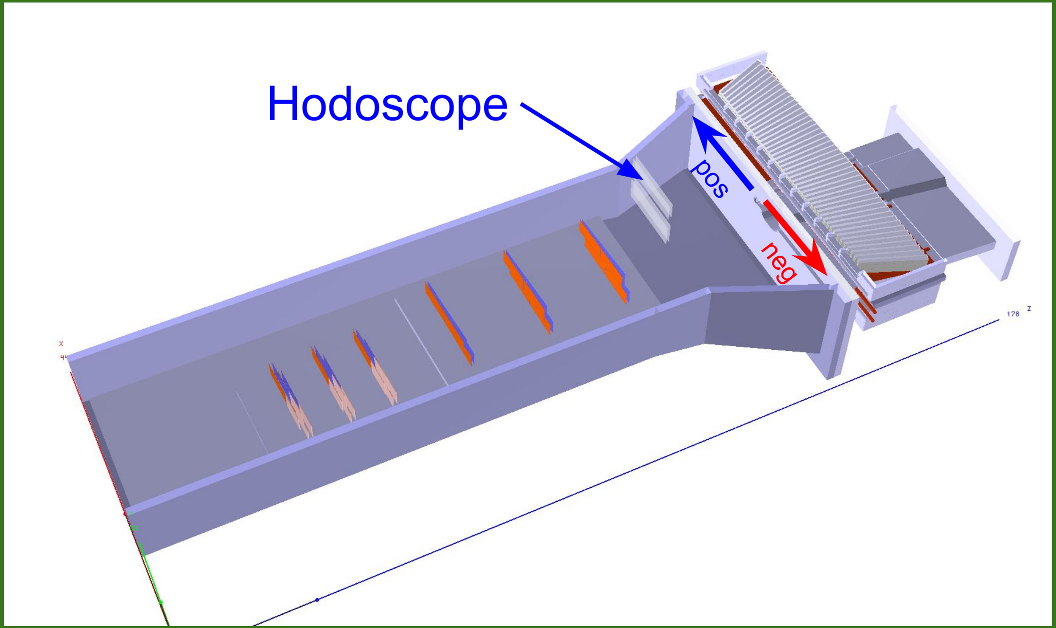
## Design considerations

A. Cover most (close to 100%) of the "Trident" positrons that will have an electron in the SVT

B. Be as compact as possible, without affecting the condition A., to avoid unnecessary rates

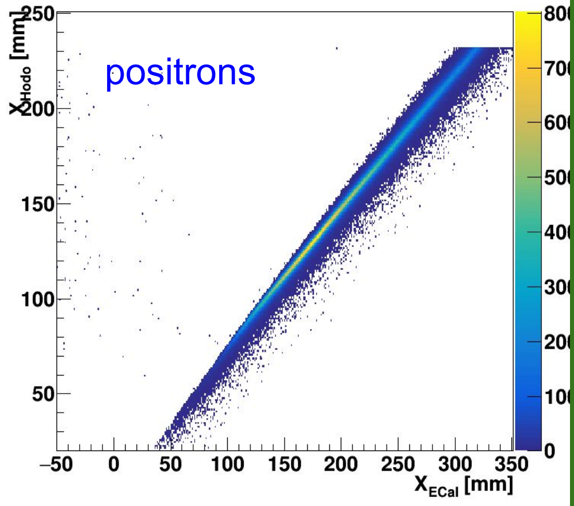
C. Keep rate in individual pixels below 200 kHz

D. Not to be too close to EC, to avoid back splash from the EC

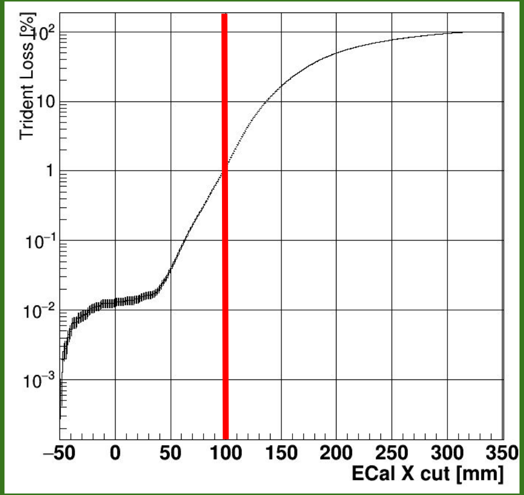


# Hodoscope dimensions

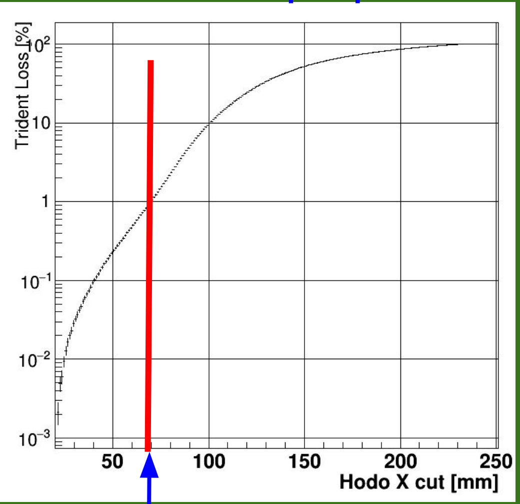
Trident simulations with proper cross section




At ECal




At Hodoscope plane




The edge of the Hodo

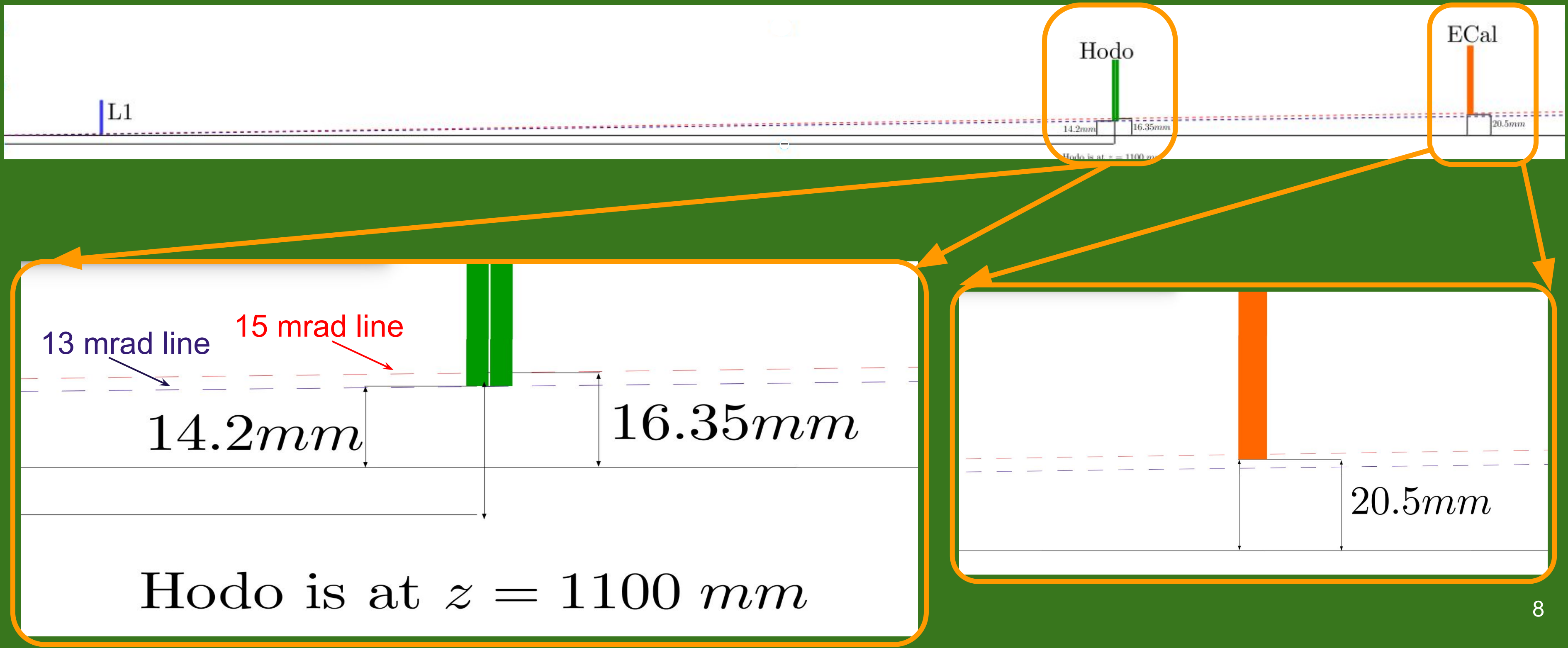
A clear correlation between the hodo coordinates and ECal coordinates

Triggering as a coincidence of hodo hit and ECal cluster > 100 mm, will keep 98-99% of tridents

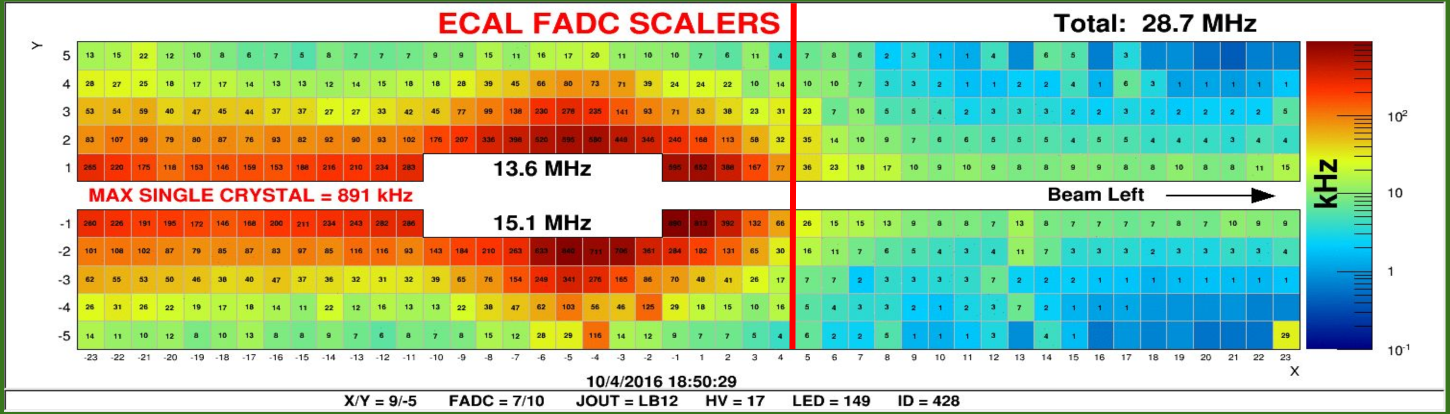
# Vertical positioning of the Hodo

The hodoscope vertically will be placed in a way, to make sure that it covers the SVT and ECal

With the current plan Hodo starts from 13 mrad which is 2mm closer to the beam at the presumed position of the hodoscope than the 15mrad

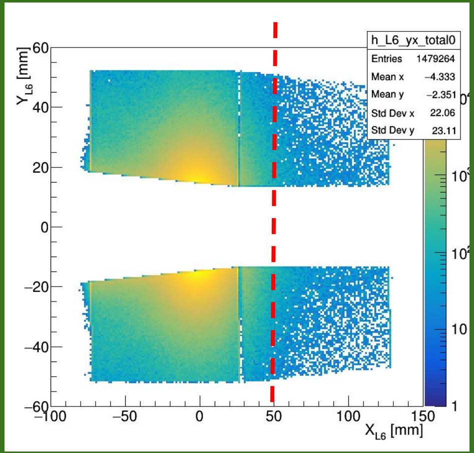


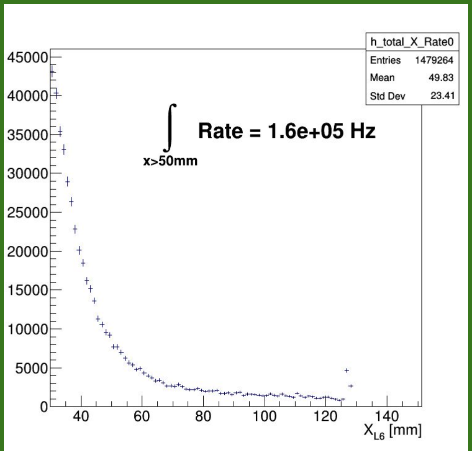
# Estimate of occupancies using data




Singles rates in ECal on the positron side are few 100 kHz

L6 occupancy




As a proxy to Hodo rate, L6 3D hits were used

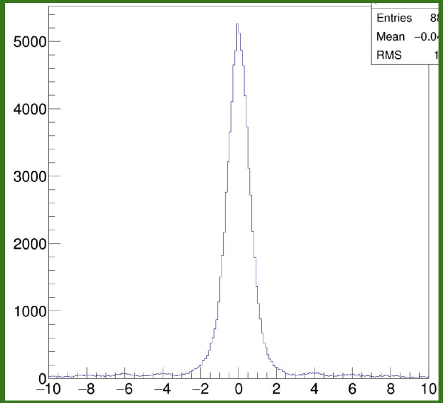
Top and Bottom together gives 160 kHz in the positron region.

In terms of readout these are quite tolerable rates for PMTs

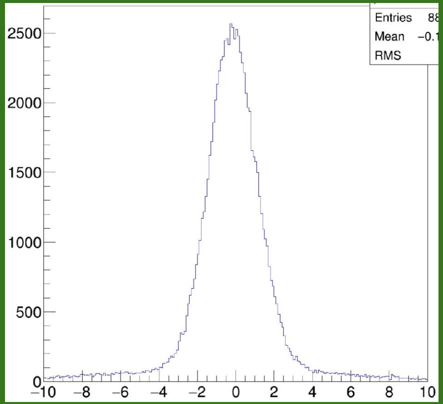
The conclusion is, any pixelation will be ok in terms of readout

# Clust-track time difference

2 cluster time difference




Trk-cluster time difference




The cluster time resolution is better than the track time resolution

The question is how much background will be picked up when one of particles will not have a cluster

To check this, a trident final state selection was performed without requiring a cluster for electron.

Background under 2 cl. Time difference is 1-2%

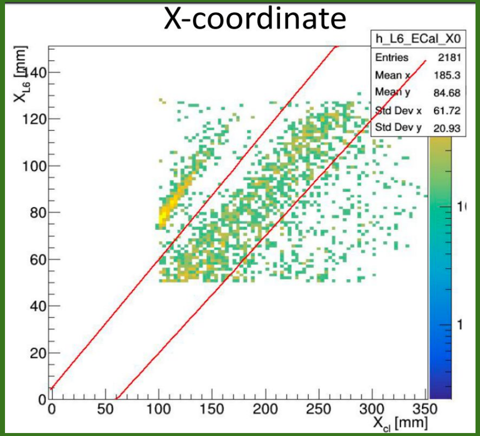
Background under track-cluster time difference is about twice more, but below 5% - 6%.

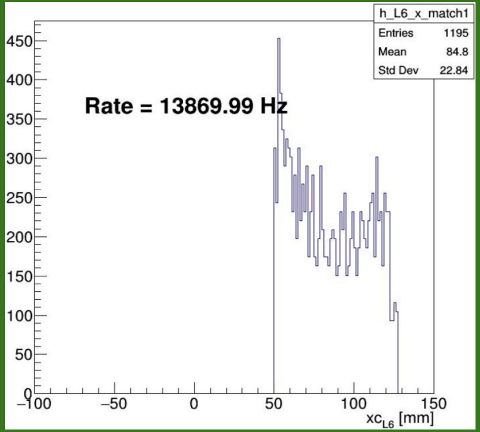
Slight increase of background, but it is not a dramatic effect

# MC simulations and expected rates @ 2.3 GeV

As a proxy to hodoscope expected rates, we have used random trigger data, and we did L6 of "SVT vs ECal" coincidence.

2.3 GeV data gives 14. KHz

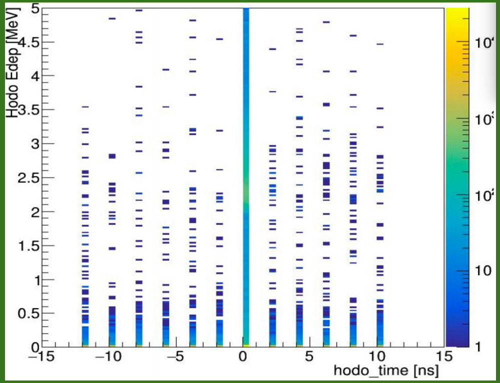


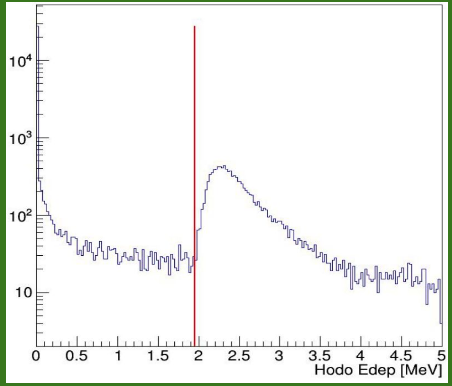




Simulations

X > 100 mm
E_cl (0.3 - 1.4 GeV)

Expected rate is 16.3 KHz



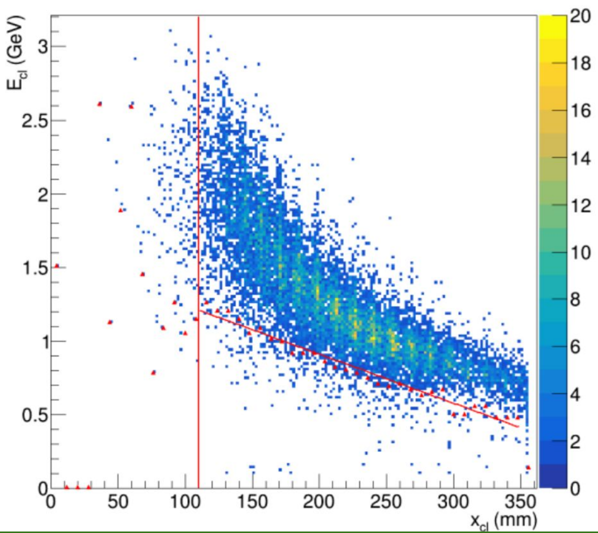



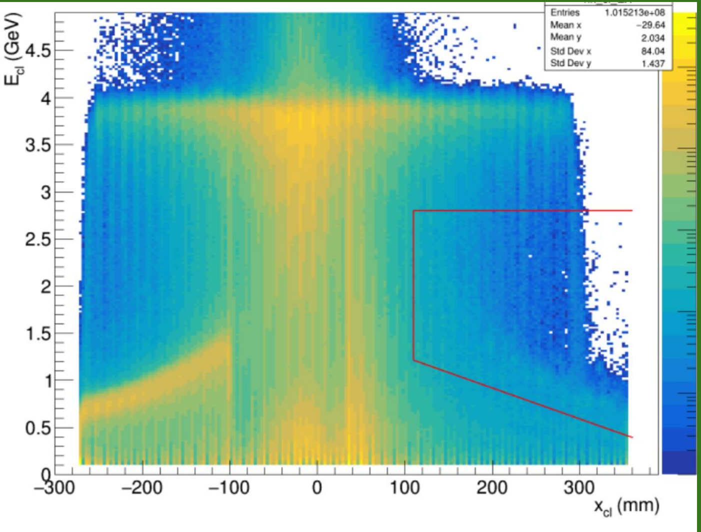
# Additional handle to reduce rates

As a backup plan, if the hodoscope alone will not manage to reduce rates to a tolerable level

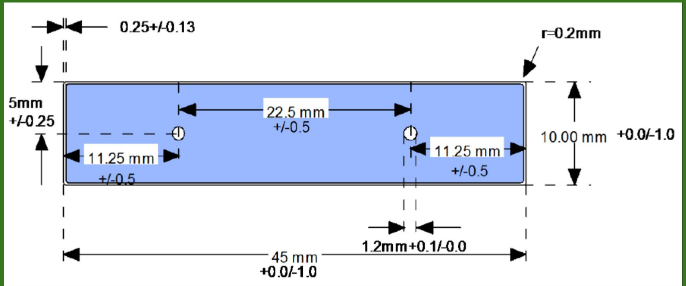
Use correlation of “momentum vs X_cl”, high momentum positrons bend less and therefore hit the ECal at small x, while low momentum bende more and hit the ECal at large x

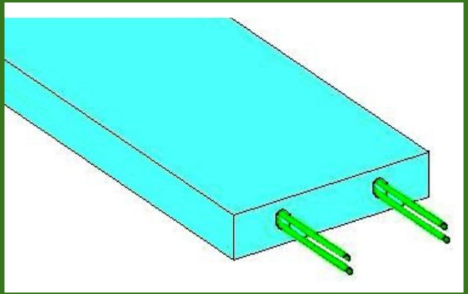
With keeping more than 90% of tridents ECal only is estimated to keep the rate below 20 KHz

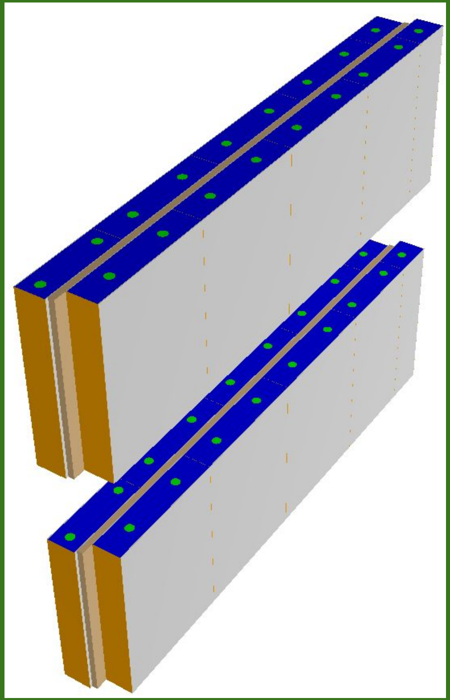


# Hodo dimensions and materials

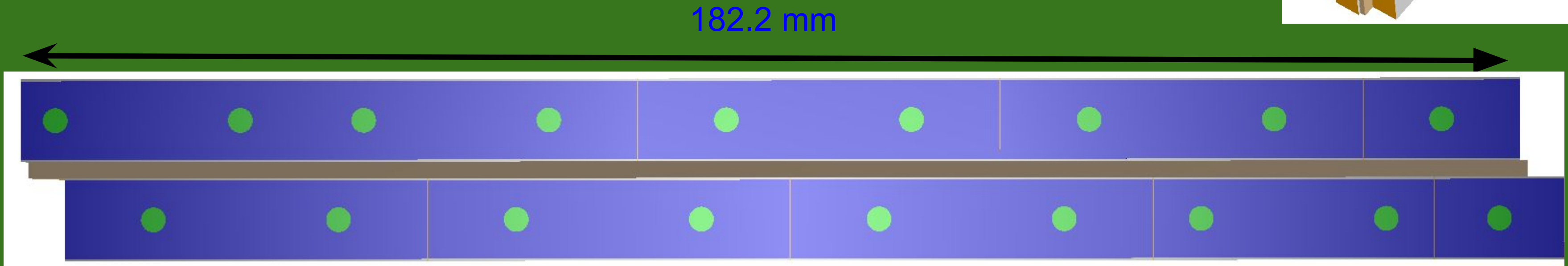




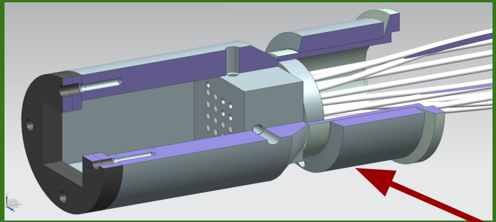
There are enough scintillator and fiber left overs from the CLAS12 PCal project to build the hodoscope (including all kinds of prototyping)

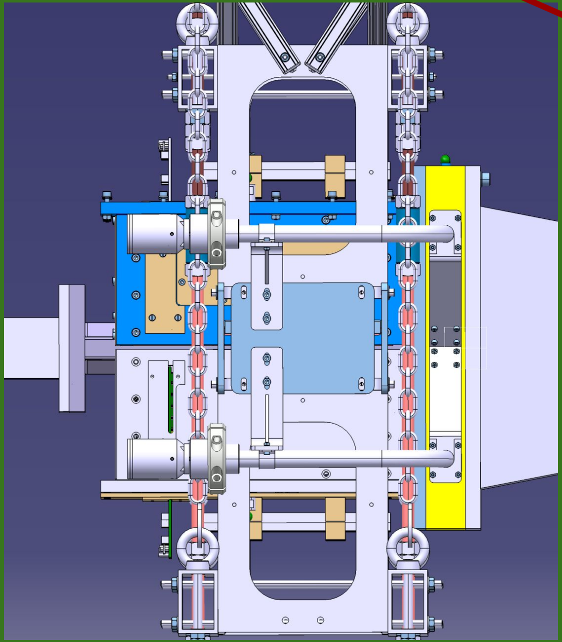
Extruded scintillators with two hole and $TiO_2$ coating
Kuraray Y11 multi-clad 1mm diameter wavelength shifting fibers
Proposed hodoscope design: two layers to reduce the accidental background from the Vacuum chamber walls.



# The Design was approved by EC in December 2017

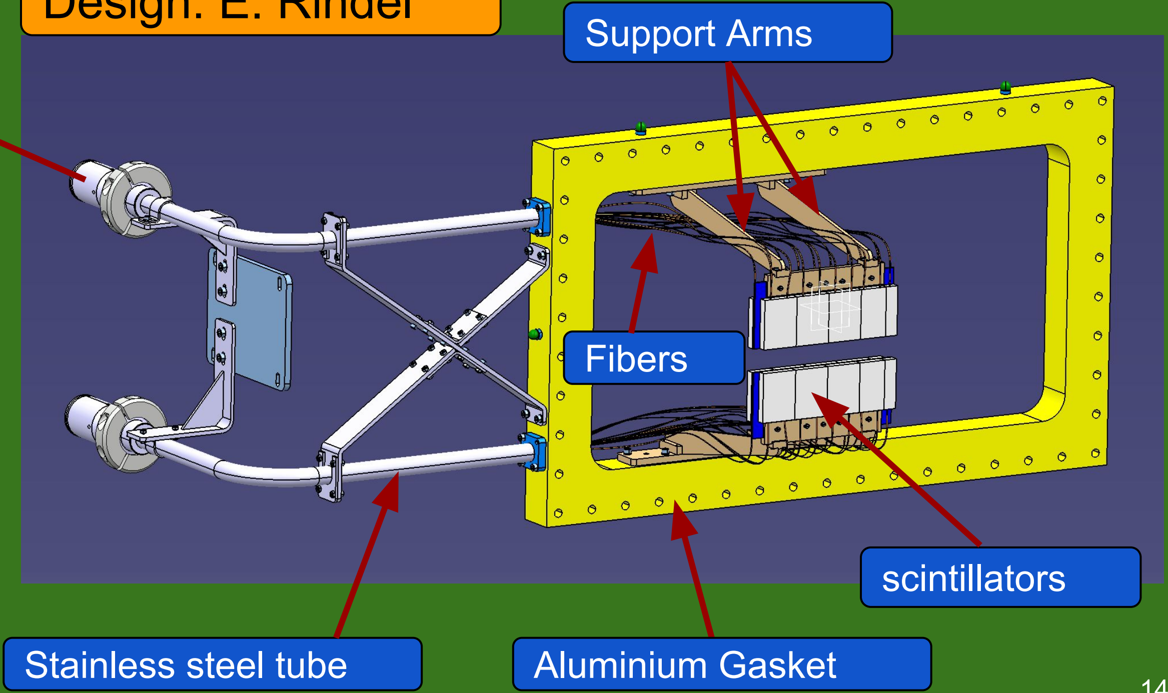
maPMT housing





Engineering design and construction of the support frame is done by Orsay group

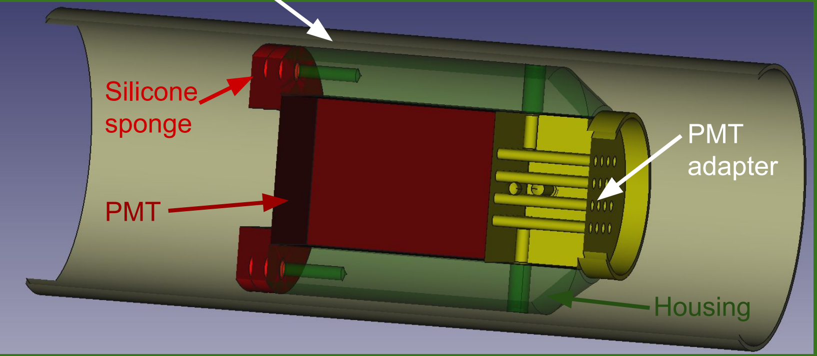
Design: E. Rindel



# Some pictures of parts

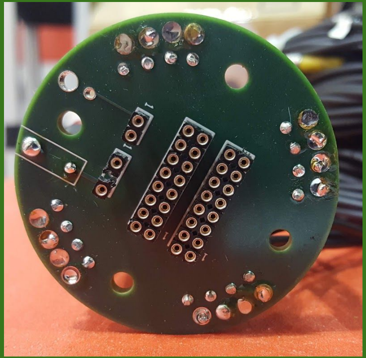
Engineering drawing of the PMT housing w/ mag. shielding

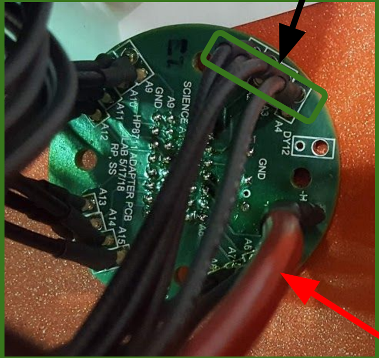
Magn. shield




Readout board

signal






PMT Readout without fibers

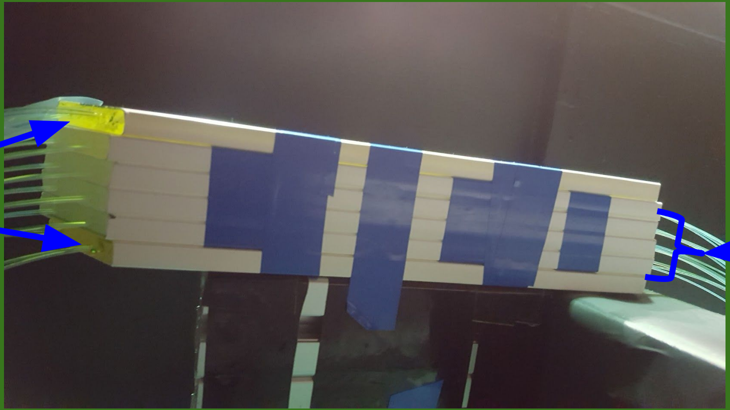


Magnetic shielding will suppress small residual magnetic field from the dipole magnet

All components are in place!

# The test setup

Coincidence scintillators

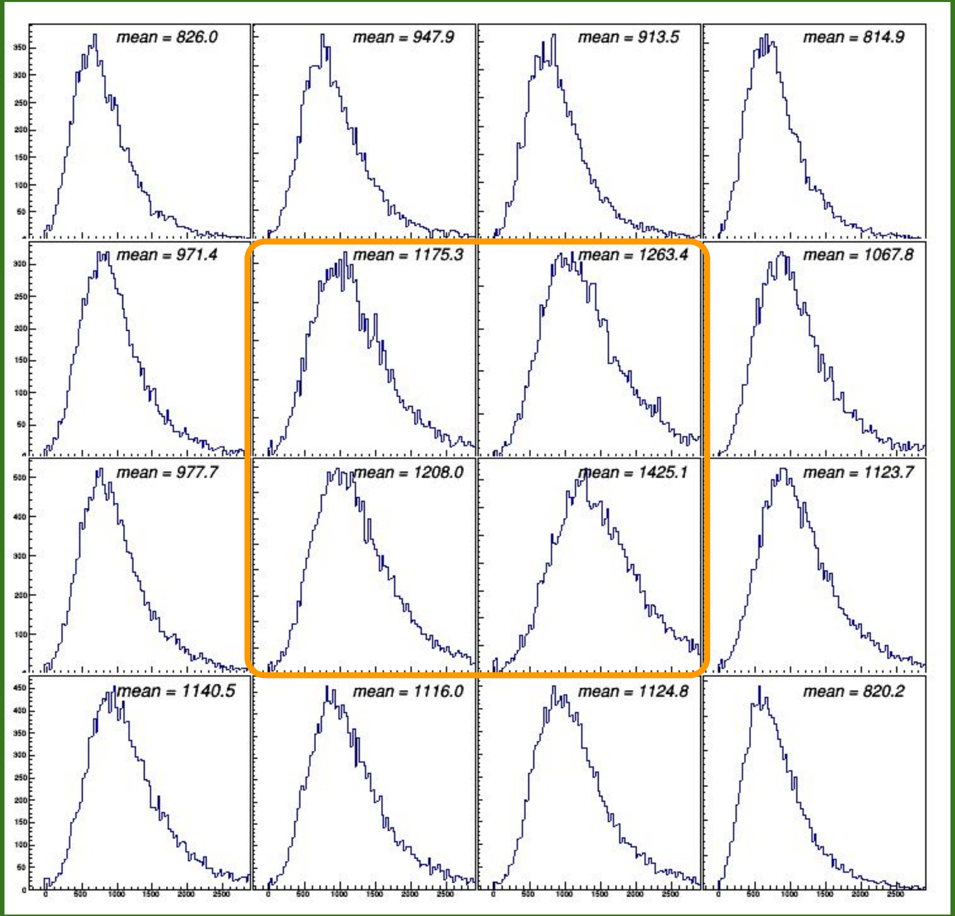


Probe scintillators

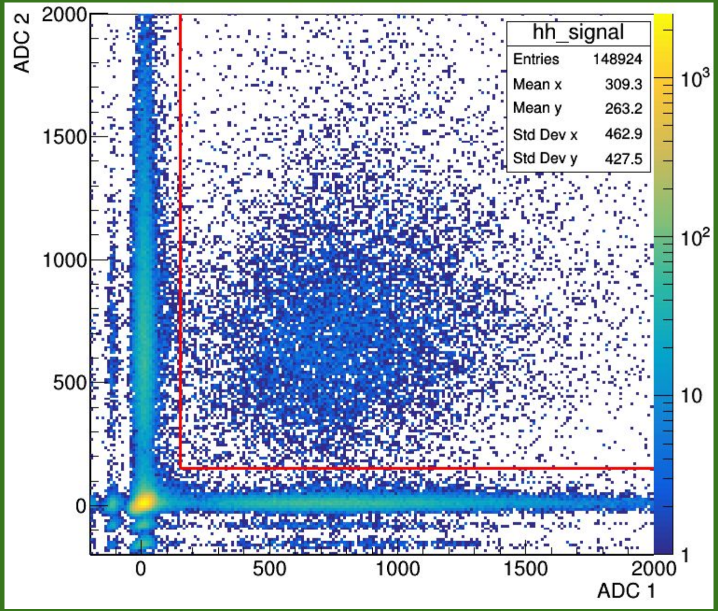
Each scintillator has 2 holes
2 fibers in each hole


- Check for any issues in the readout chain: scintillators, fibers, adapter, PMT, FADC
- Single photoelectron peak for all channels
- Measure the average number of photoelectrons
- Check the uniformity of Gains of all PMT channels
- Measure the level of a cross talk
- Practice glueing fibers in the scintillator

# Signal distributions

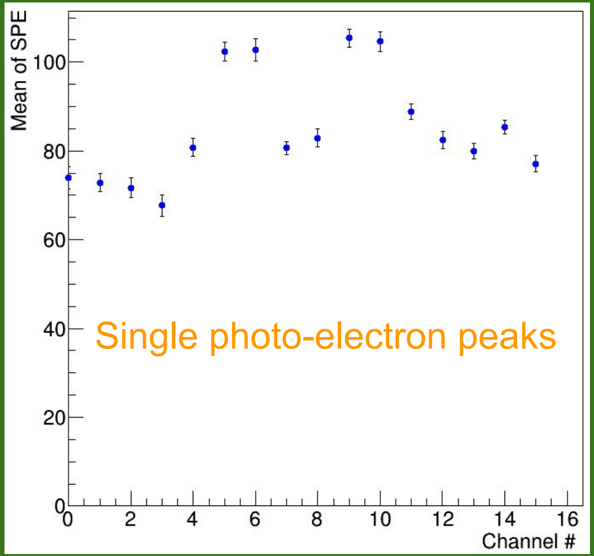


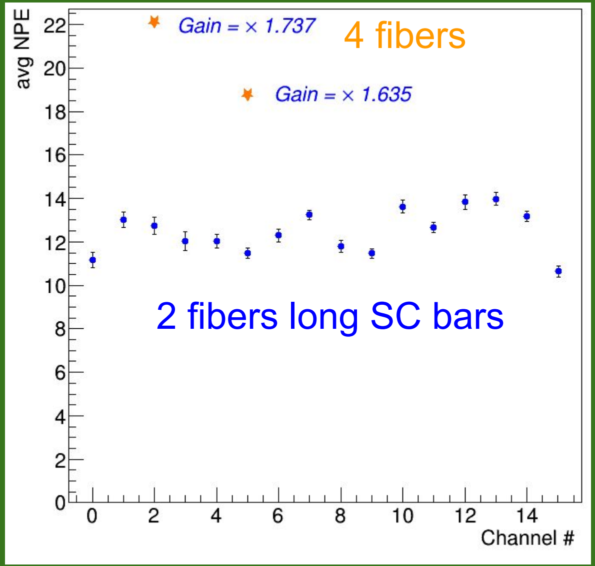

Signals, when both coincidence PMTs have ADC > 150

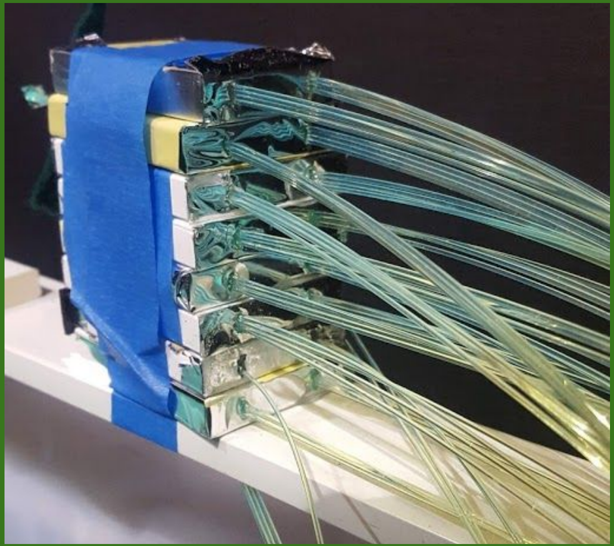



- All channels are functioning :-)
- No dramatic differences between channels
- Channels in the middle have larger gains

# Number of photoelectrons



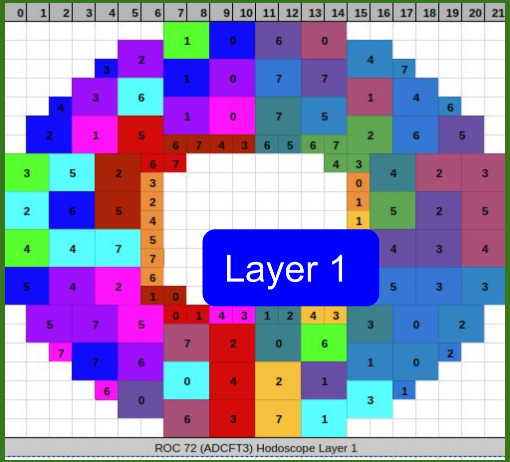



Instead of 2 fibers, we will use 4 fibers without gluing fibers inside SC bars.

We will have about 20 phe per MIP

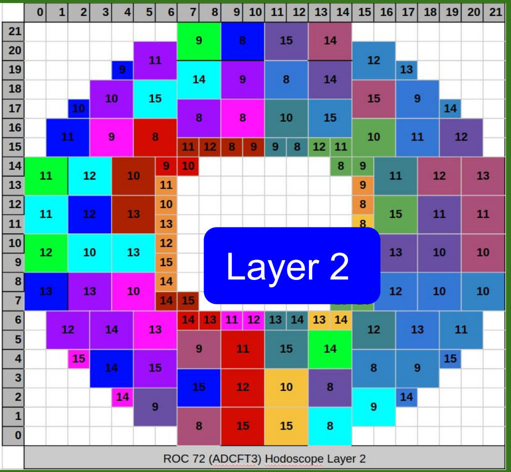
# CLAS12 Forward Tagger trigger

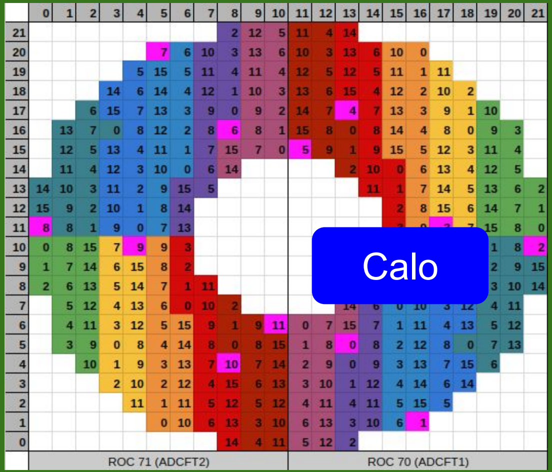



The Positron trigger will be quite similar to the one used in CLAS12 FT

- Coincidence between Hodo layers: L1 and L2 Hodo
- Coincidence between Hodo pixel and Calo cluster
- Emin, Emax for the cluster

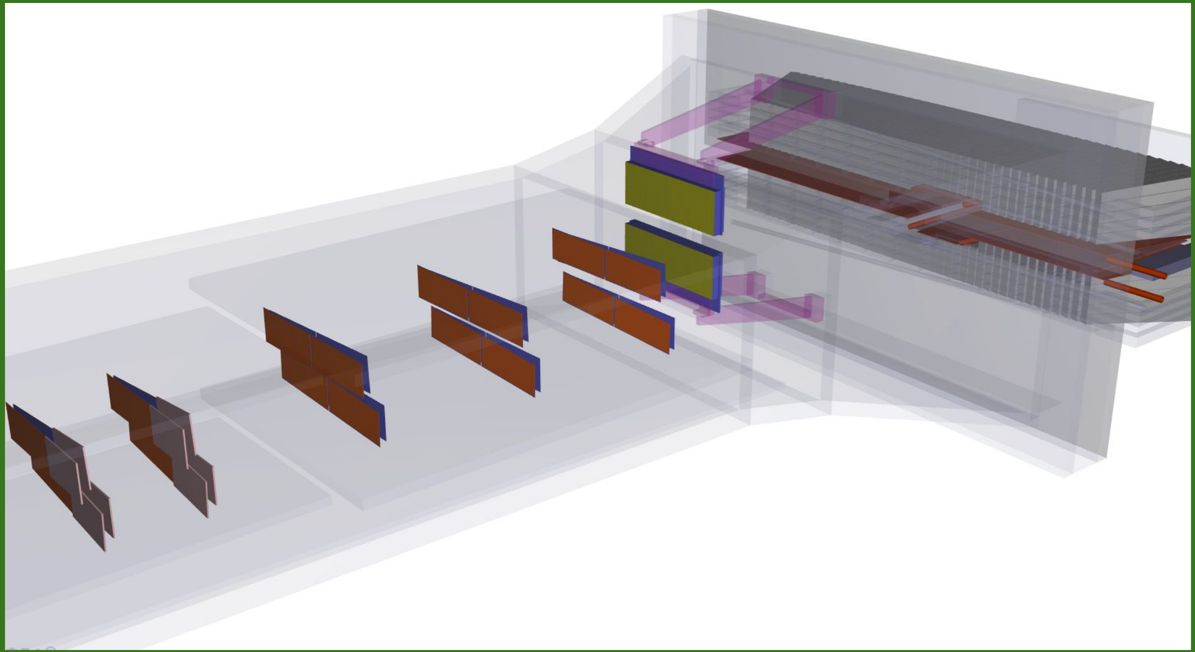
The FT trigger worked well, CLAS12 took data with it.




See S. Boiarinov's talk for Details in the

# Software status



The hodoscope is integrated in the hps detector package.

Energy to pulse conversion and readout is implemented in hps-java. Currently being validated.

The trigger is implemented in the trigger simulation package, and is being validated.

# Resources

*UNH*: student, faculty, postdoc
PMT, housing components for PMTs, magnetic shieldings, consubanles,
Simulations and data analysis, Conceptual design, assembly, tests and prototyping

*IPN*: Staff scientist and engineer
Engineering Design and construction of the hodoscope support frame and fiber feed through tubes.

*College of William & Mary*: Professor
Machining of scintillator strips

*ANSL (YerPhI):* Help with prototyping and testing

*INFN Catania:* Help with the construction of the hodoscope

*JLab*: staff scientists, engineers, technicians
Fibers, Scintillators, FADC boards, Readout electronics for tests, HV main frame,
PMT readout boards. consumables, Implementation of Trigger.

# Schedule

| | |
|---|---|
| The conceptual design is finalized | Aug 2017 |
| The engineering design is finalized | Nov 2017, approved Dec 2017 |
| Optical glues are purchased | Summer 2017 |
| PMTs are ordered | Arrive end of June |
| Hodo support is ready | Arrived early June |
| DarkBox/Electronics/DAQ | Ready at EEL building |
| Machining of strips | Ready, end of July 2018 |
| Other parts: PCB/housing/shielding | July 2018 |
| Prototyping, testing the readout chain, PMT gains, light loss in fibers, etc… | Almost finished (Jan 21) |
| Full assembly (ready to be installed) | 28 Feb, 2018 |
| Installation in the hall | 29 Apr 2019 |
| Trigger firmware should be ready | 06 May 2019 |

# Installation schedule

- Jan 23 - Jan 25: prepare the area in the EEL building for the assembly to start (Occupied by the BAND detector components, which will move out Jan 22)
- Jan 26 - Jan 30: Glue fibers into PMT adapter
- Jan 31 - Feb 6: Glue mylar to sides of scintillators (including polishing of SC bars)
- Feb 7 - Feb 13: Install (glue) SC bars to the hodo support frame
- Feb 14- Feb 15: Prepare the setup for cosmic tests
- Feb 18 - Feb 28: Take cosmic data and make sure all channels are working Properly.

The positron trigger will be ready and tested well before the run begins

# Summary

The hodoscope will allow to increase the rate of “Good” events by about twice

An additional plan: position dependent energy cuts allow to further reduce the trigger rate, and even in case of failure of hodoscope, can keep the trigger rate in a tolerable level

All necessary parts are in place

All prototyping and tests are nearly finished, and we expect construction to start end of January.

The hodoscope should be ready by the end of February waiting to be installed in the hall at the end of April.

# Backup slides

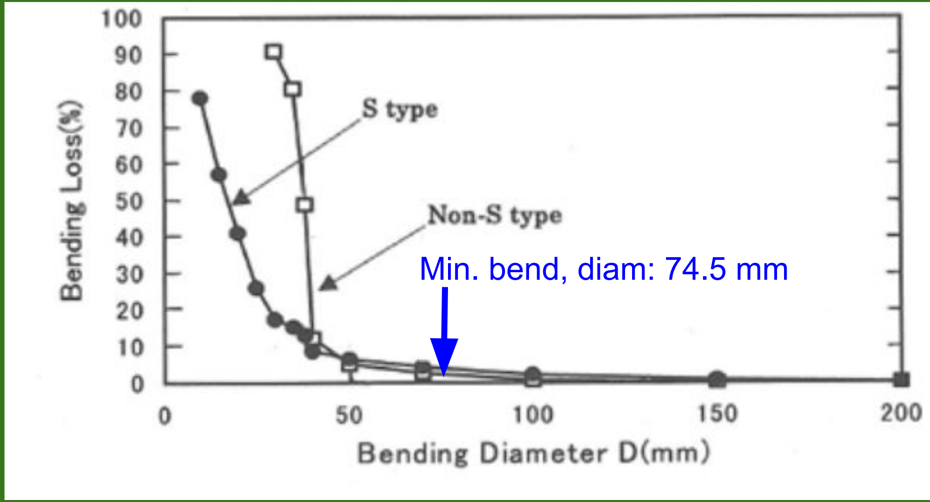
# The budget

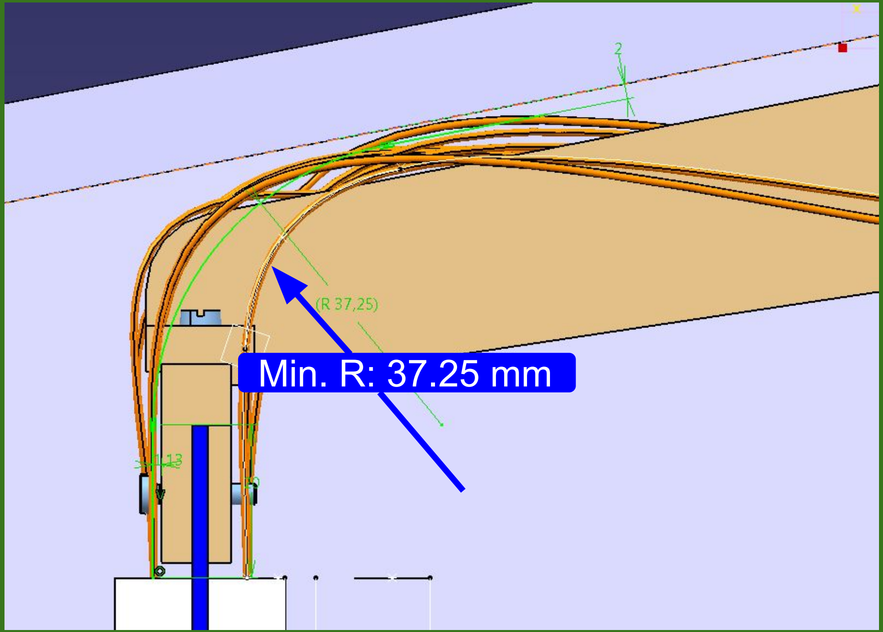
| Item | Cost | Comment |
| --- | --- | --- |
| Scintillators and fibers | - | Leftover from the PCal |
| Machining of strips | $500 | Funds from W&M |
| PMTs | $3422 | Funds from UNH |
| PMT housing | $2721 | Funds from UNH |
| Magnetic shieldings | $444.4 | Funds from UNH |
| PCB boards | $600 | Funds from JLab |
| Hodoscope support (including shipping) | 3983.22€ | Funds, design and fabrication from Orsay |
| Hodoscope assembly | $1,000 | consumables(glue, gloves), JLAB and UNH |
| Total | $8687 + 3983.22€ | |

# Light loss because of fiber bending

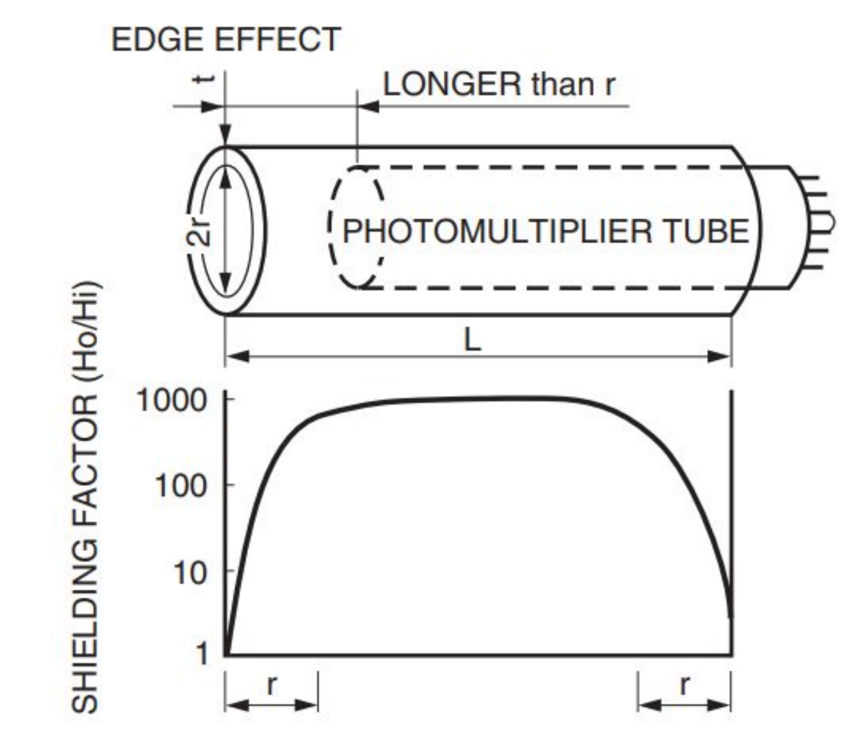
Due to limited workspace, from scintillator tile to PMT, fibers should be bent.
The minimum bending diameter is 74.5 mm (R=37.25 mm)

The light loss because of fiber bending is not more than few %



# Expected reduction of the magnetic field




Expected Magnetic field inside the mu-metal shield is calculated

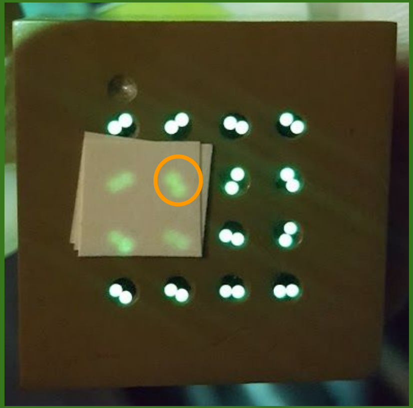
$$H_{in} = H_{out} \frac{4r}{3\mu t}$$

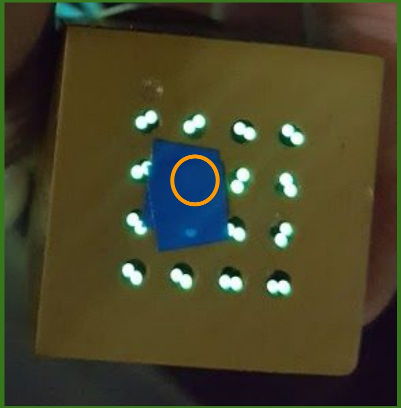
| | |
|---|---|
| Material | Ad-Mu 80 |
| $\mu$ Permeability at 40 Gaus: | 55.000 - 75.000 |
| R (Inner diameter) | 60 mm |
| t (thickness) | 1 mm |

Earth magnetic field ranges from 0.25 - 0.65 Gaus

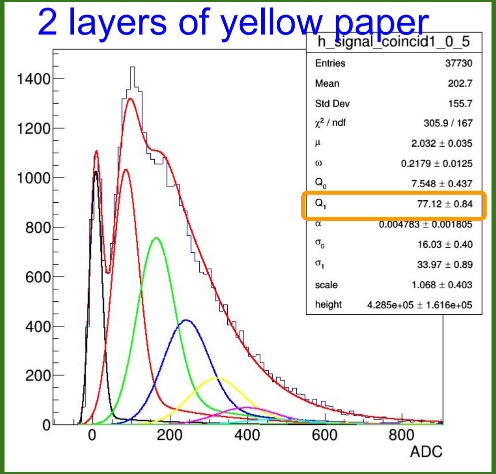
$$H_{in} = H_{out} \frac{4r}{3\mu t} = 30[\mathrm{Gaus}] \frac{4 \cdot 60[mm]}{3 \cdot 55000 \cdot 1[mm]} = 0.04 \text{ Gaus}$$

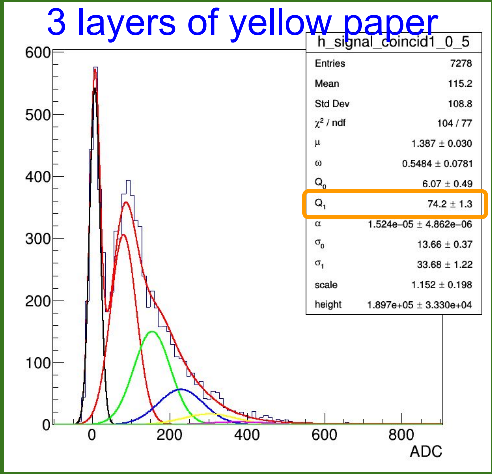
# Single photoelectron peak

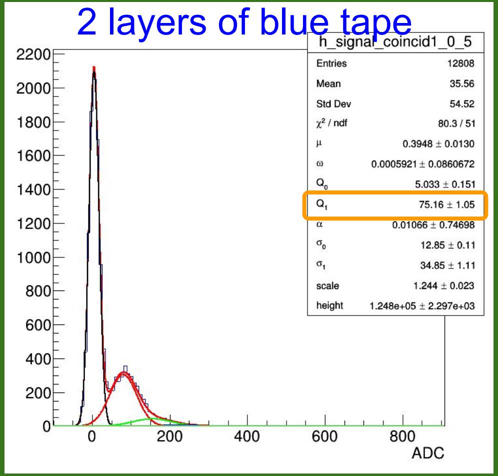




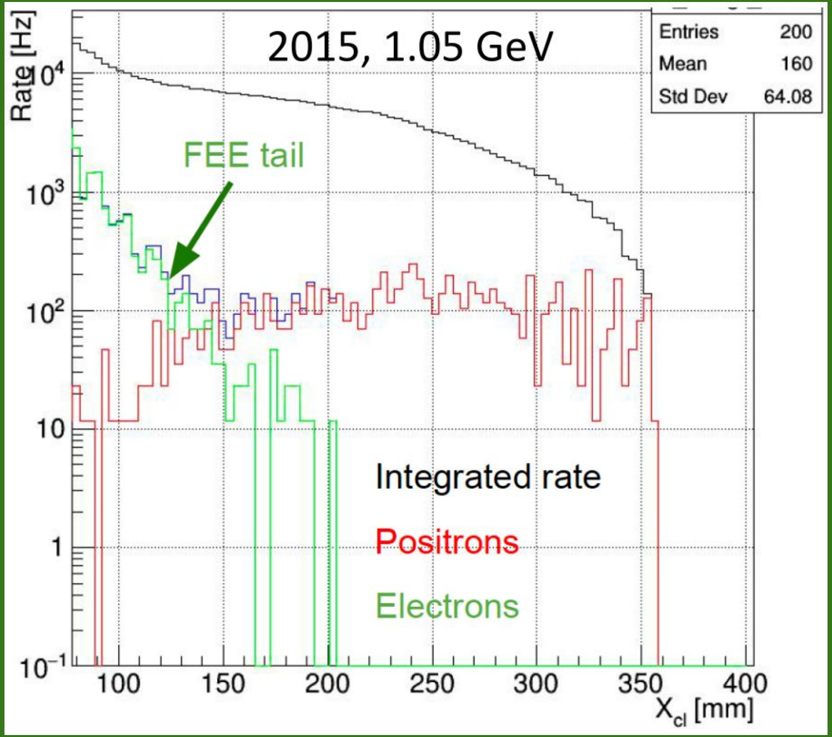
**Fit function: see the paper Nucl.Instrum.Meth. A339 (1994) 468-476**

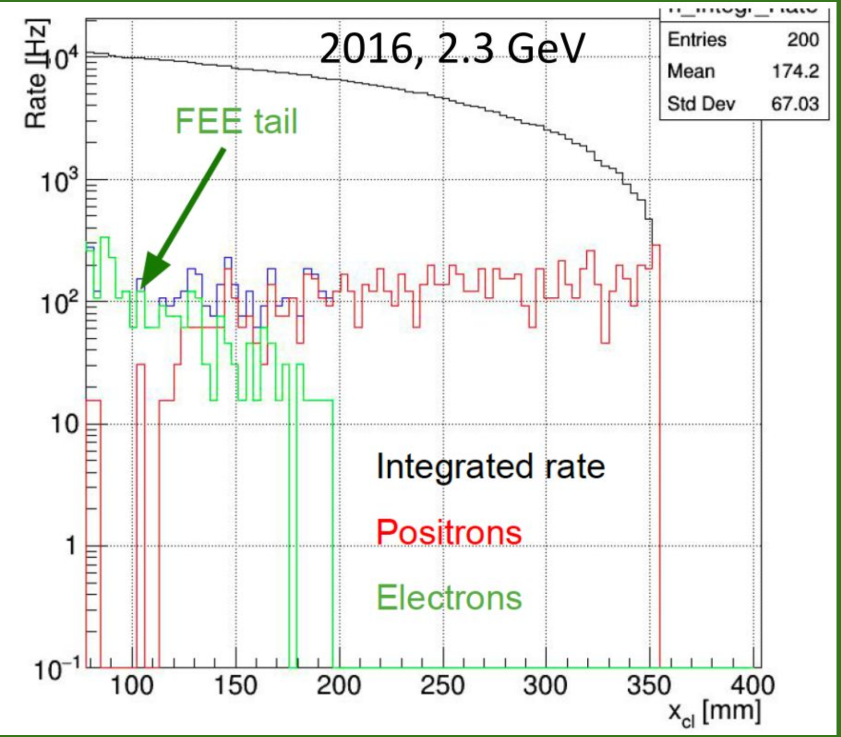


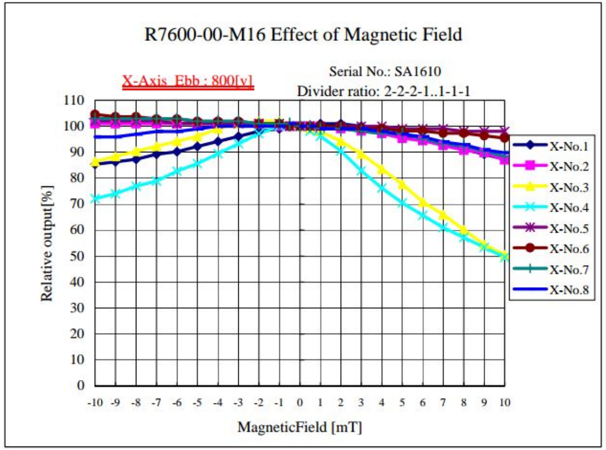
# Rates of positive tracks from Random trigger data

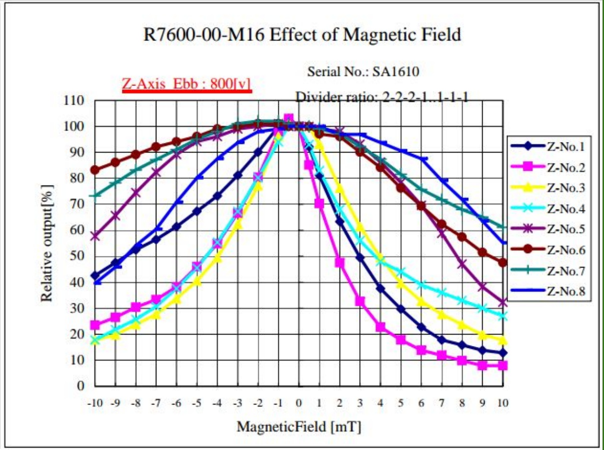


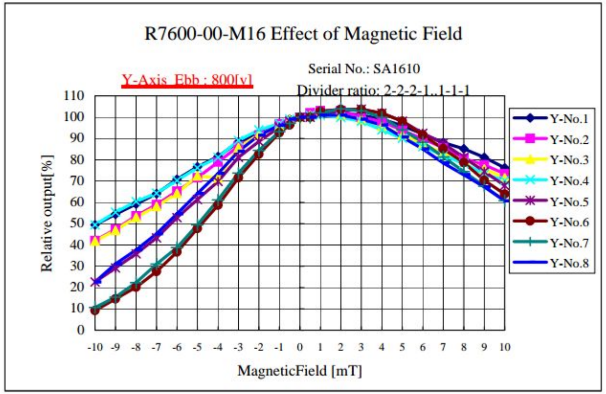



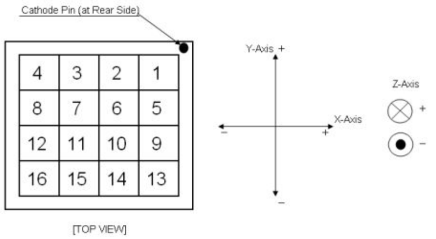
# Effect of the magnetic field to the PMT

The most dramatic effect induces the z component of the field

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Even 10 Gaus "Z" field can reduce the gain by 30%

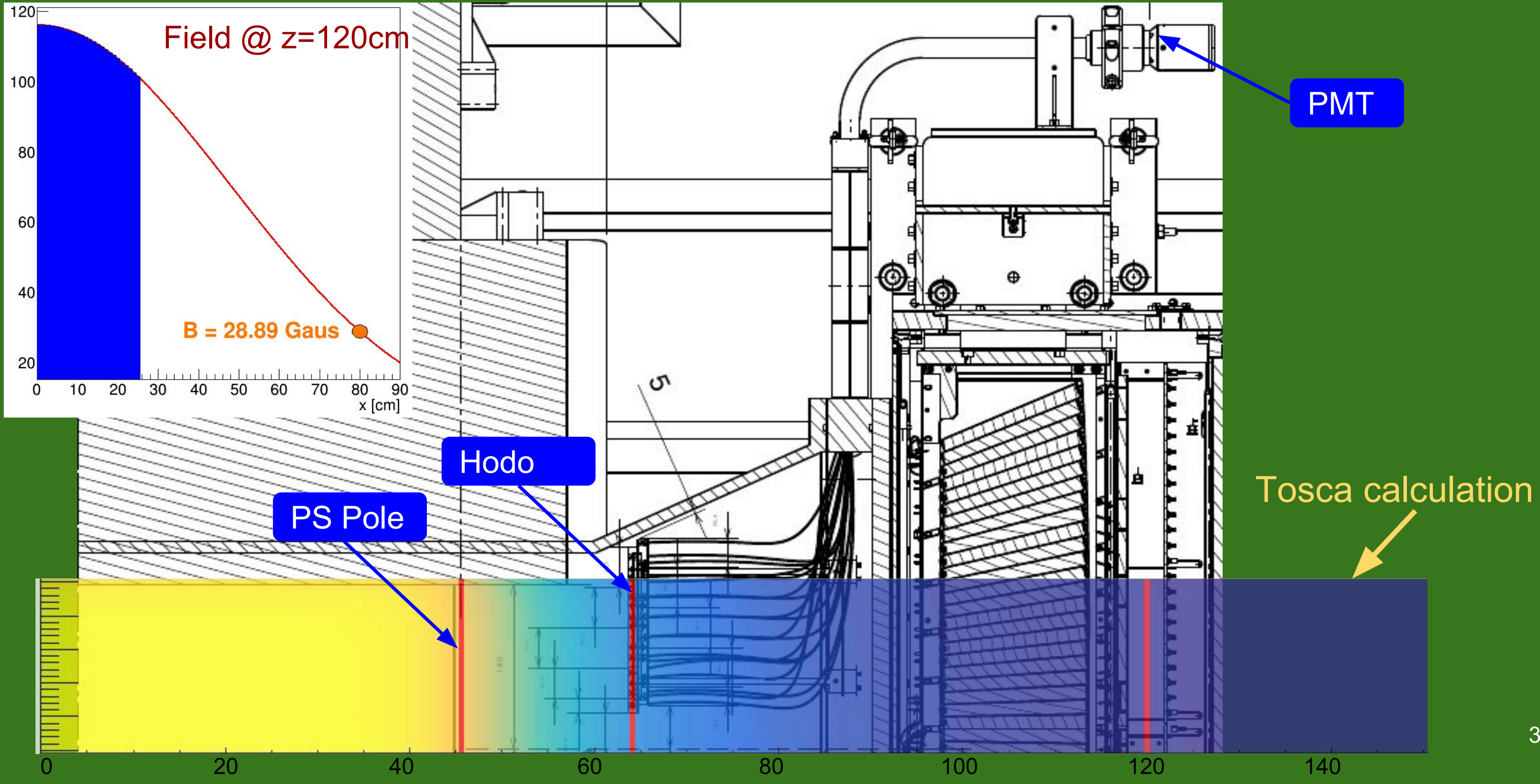
The mildest effect will induce field parallel to the "X" of PMT.

A magnetic shielding is ordered and in place, which will highly suppress the residual magnetic field.

PMT X axis will be placed parallel to the Lab Frame "Y" axis

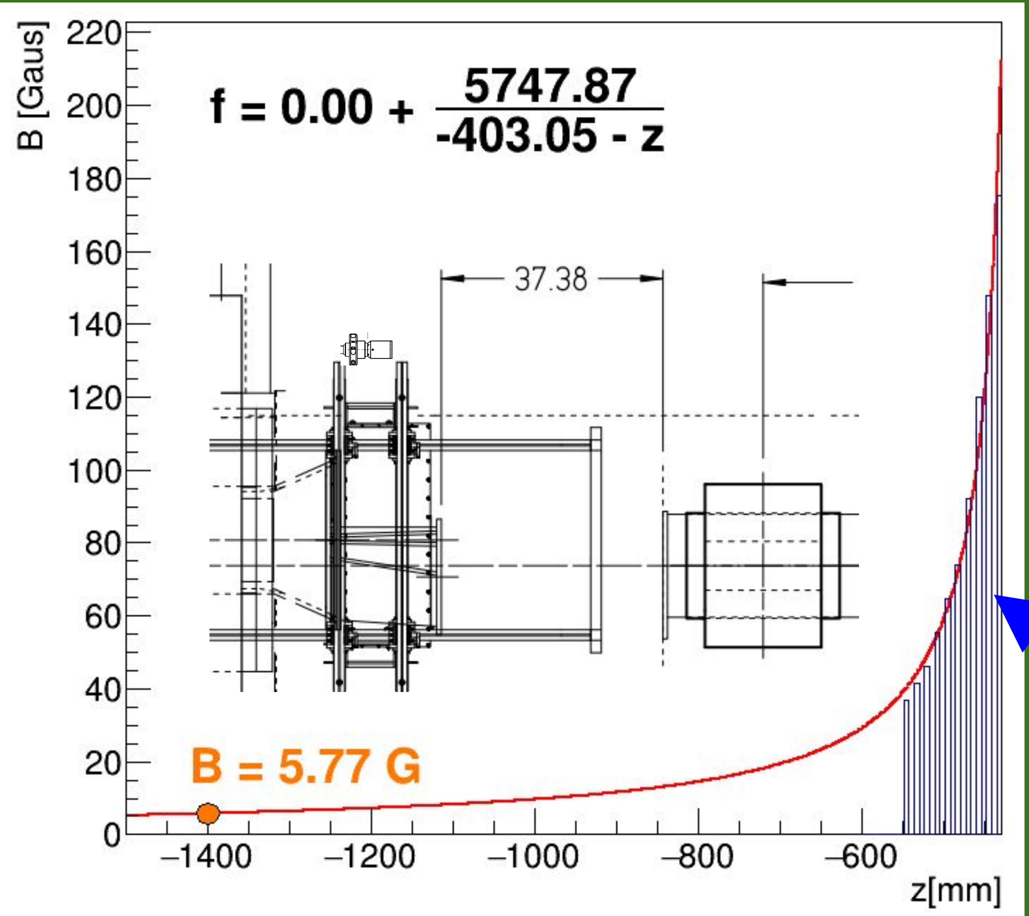
# Estimation of the magnetic field

In the calculated area, field is a Gaussian function of x. Extrapolated up to the PMT x = 80 cm.

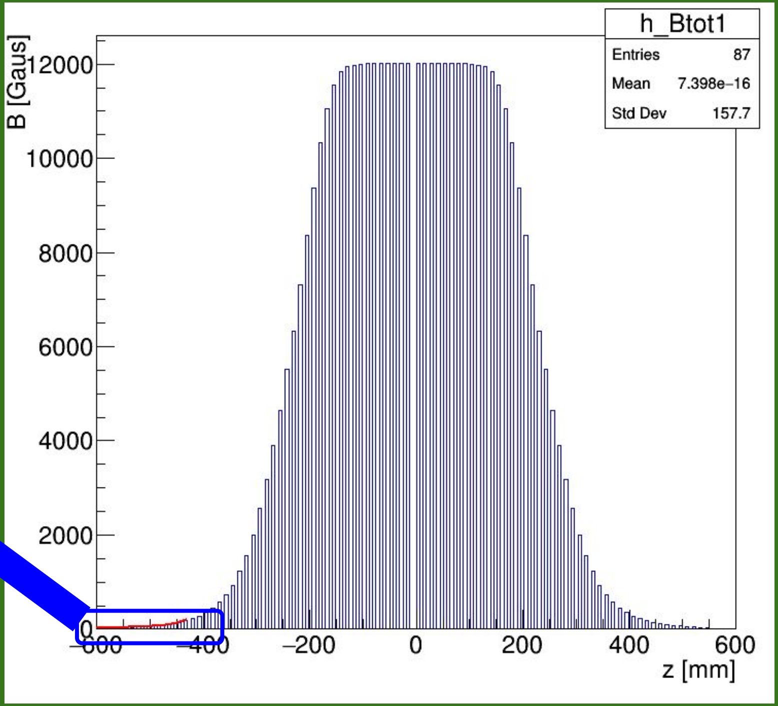


Frascati field is extrapolated to z where PMT is,
PMT is at x=80 => the field at PMT will be even smaller

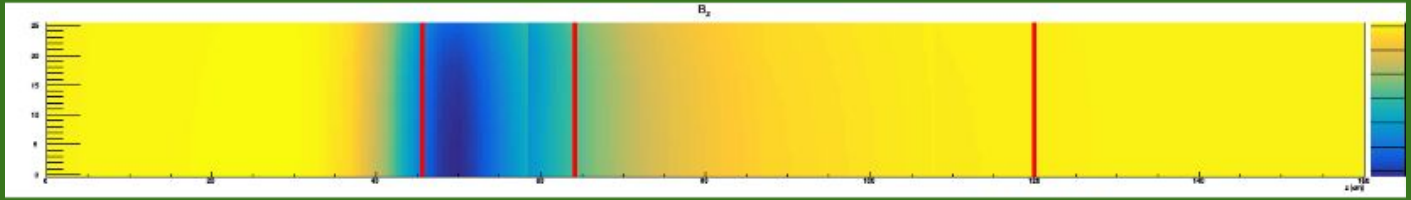
## The frascati field @ PMT is negligible




Frascati field at (x=0, y=0) as a function of z

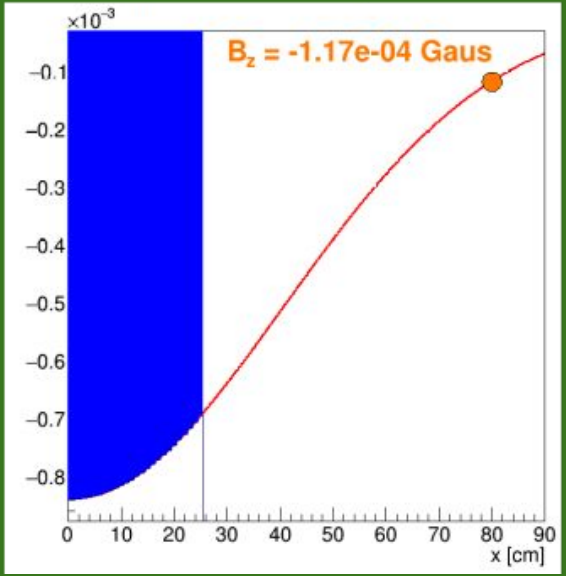


# Z component of the field



Z of PMT

Extrapolated to PMT position




The most sensitive component of the field is the “Z” component (parallel to PMT axis)

The extrapolated magnetic field at PMT location is too small.