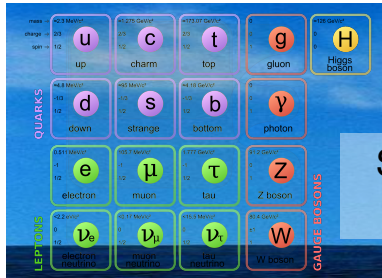
A brief update

Marzio De Napoli – INFN - Catania

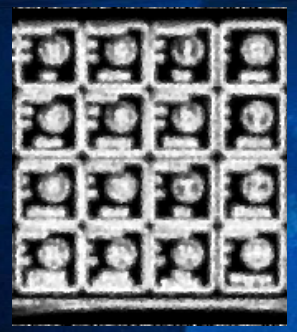
JLAB12 Collaboration Meeting – Rome 17/7/19

Hidden Sector



SM partciles make ~5% of the Universe, why should the Dark Matter world (~24%) be any simpler?

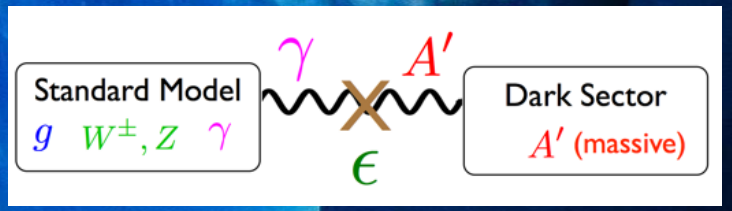
Hidden Sector made by New Particles & New Forces



Light Dark Matter (MeV-GeV) is an attracting DM candidate but requires *a new Force* to achieve the correct thermal relic

DM particles could interact via a new U(1) light vector mediator *Dark/Heavy Photon, A'*

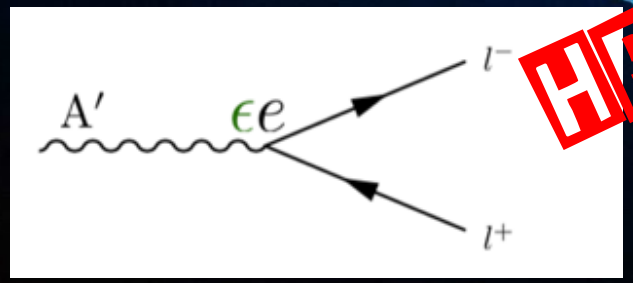
Kinetic mixing between SM photon and Dark photon induces *weak coupling to electric charge*

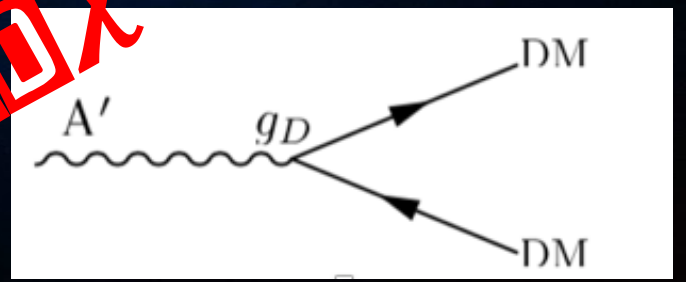


Search scenarios
$m_{A'} \sim m_{DM} \sim MeV \div GeV$

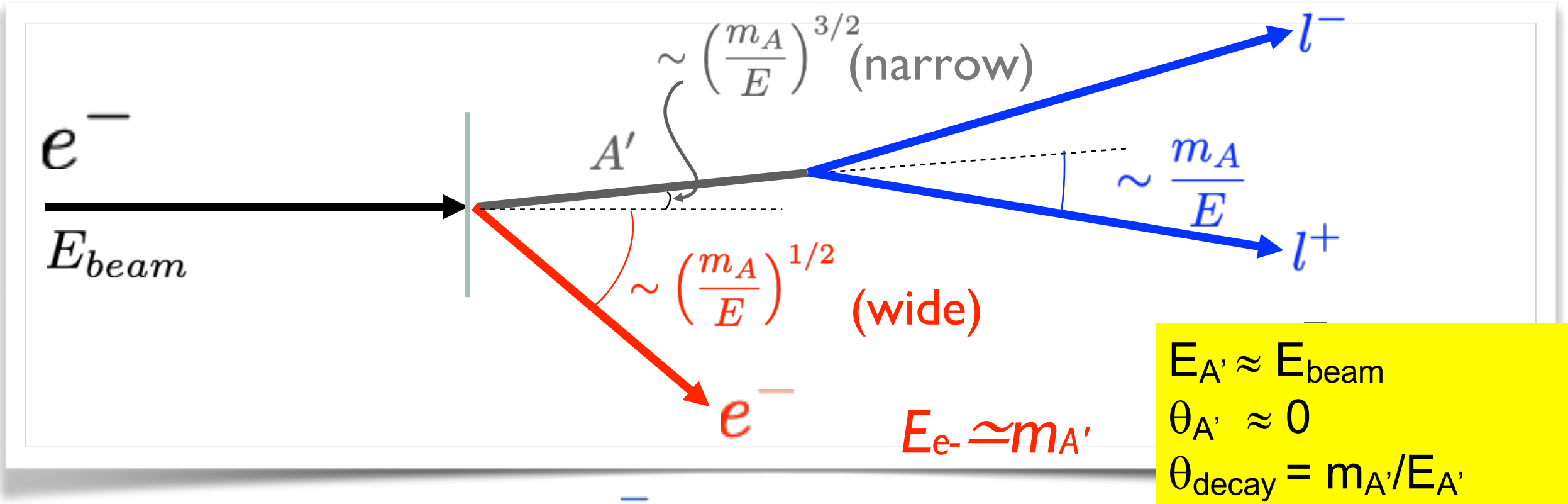
Search for visibly decaying Dark Photons

Search for Light Dark Matter

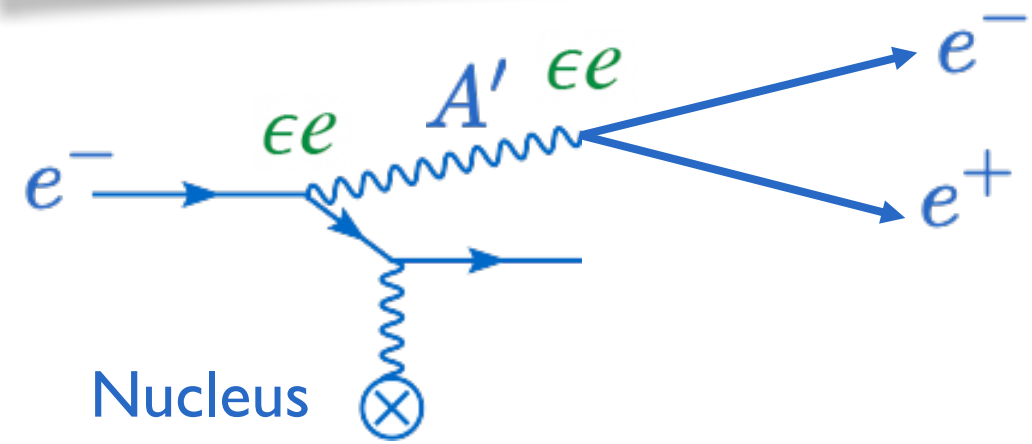




Detecting A’ decays



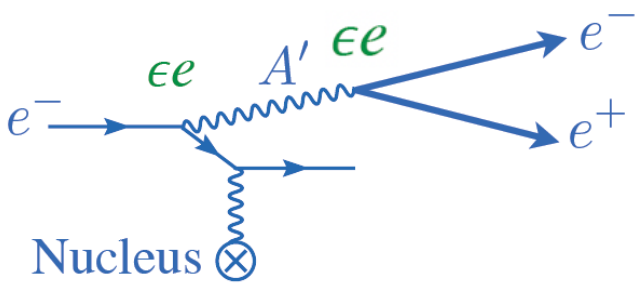
$E_{A'} \approx E_{beam}$
$\theta_{A'} \approx 0$
$\theta_{decay} = m_{A'}/E_{A'}$



Need:

- Small angle detection of e+ e-
- Very high luminosity
- Good invariant mass resolution

HPS Detector



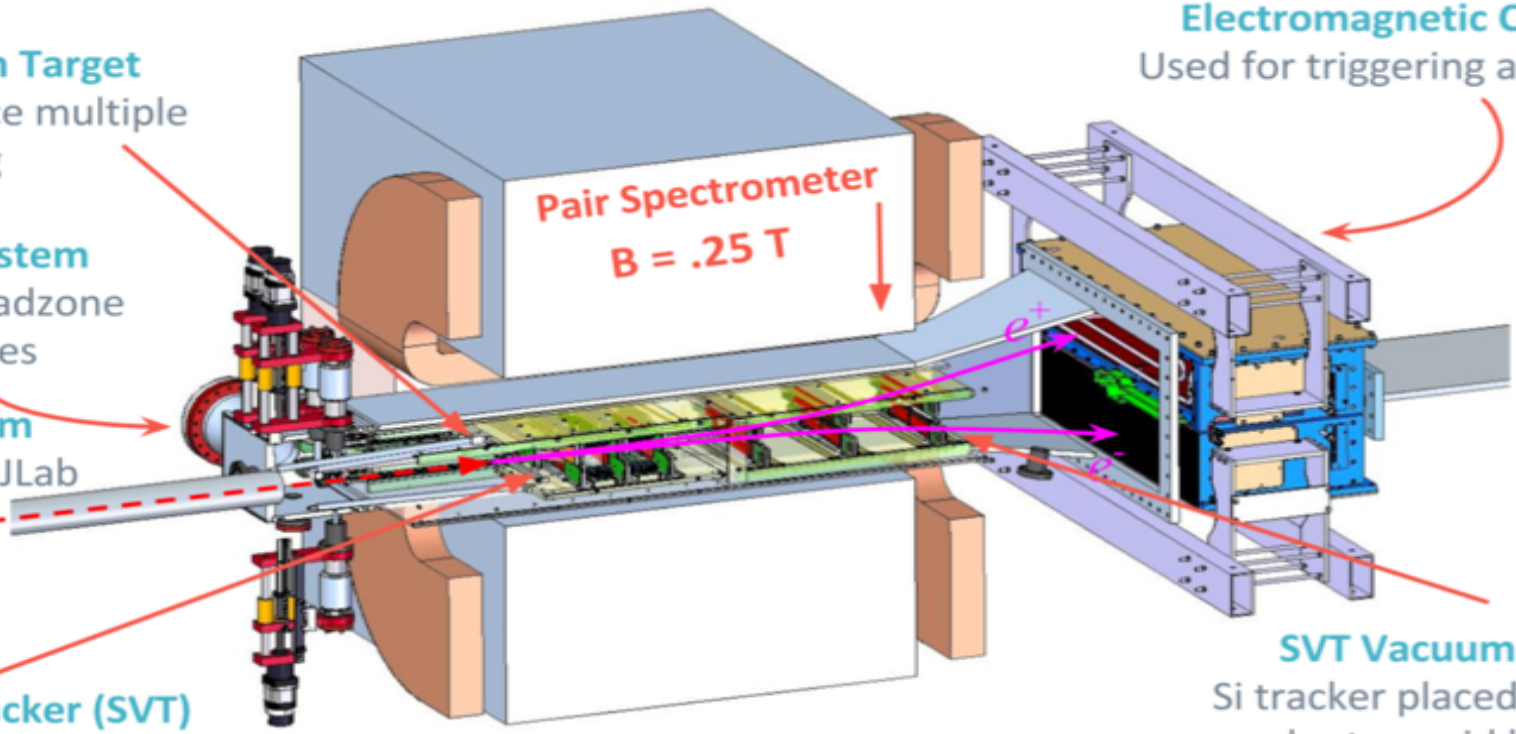
HPS DETECTOR

~10^{-3} X_0 Tungsten Target
Thin target to reduce multiple scattering

Linear Shift Motion System
Allows adjustment of deadzone between SVT volumes

High intesity e^- beam
Courtesy of CEBAF @ JLab

Silicon Vertex Tracker (SVT)
Split into two volumes to avoid intense flux of scattered beam electrons. Used for precise momentum and vertex determination



Electromagnetic Calorimeter
Used for triggering and particle ID

SVT Vacuum Chamber
Si tracker placed in vacuum in order to avoid backgrounds due to beam-gas interactions

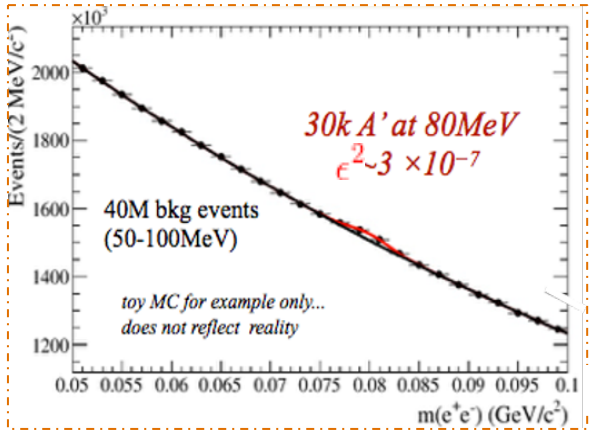
SVT + ECal DAQ capable of 50 kHz

Installed within the Hall B alcove at Jefferson Lab upstream of the CLAS12 detector

Heavy Photon signatures in HPS

"Large" signal, huge QED background

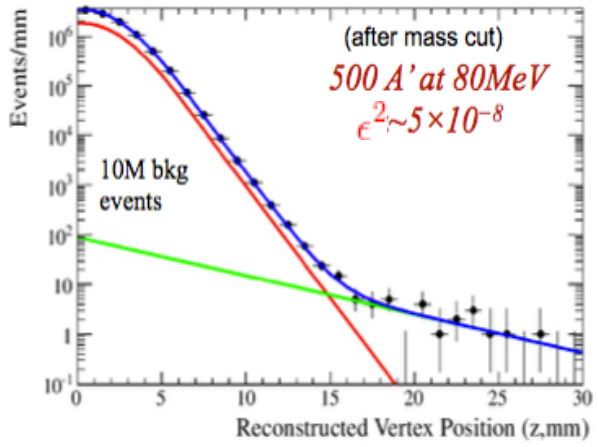
(**resonance search**)



invariant mass [GeV]

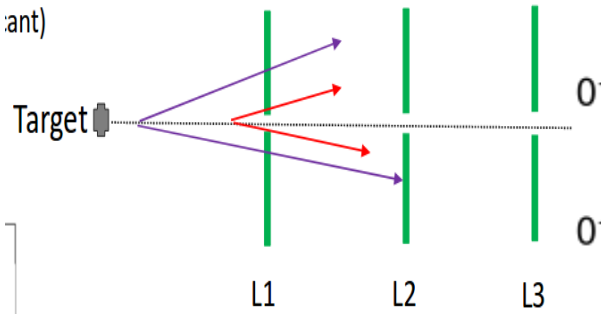
Small signal, very little background

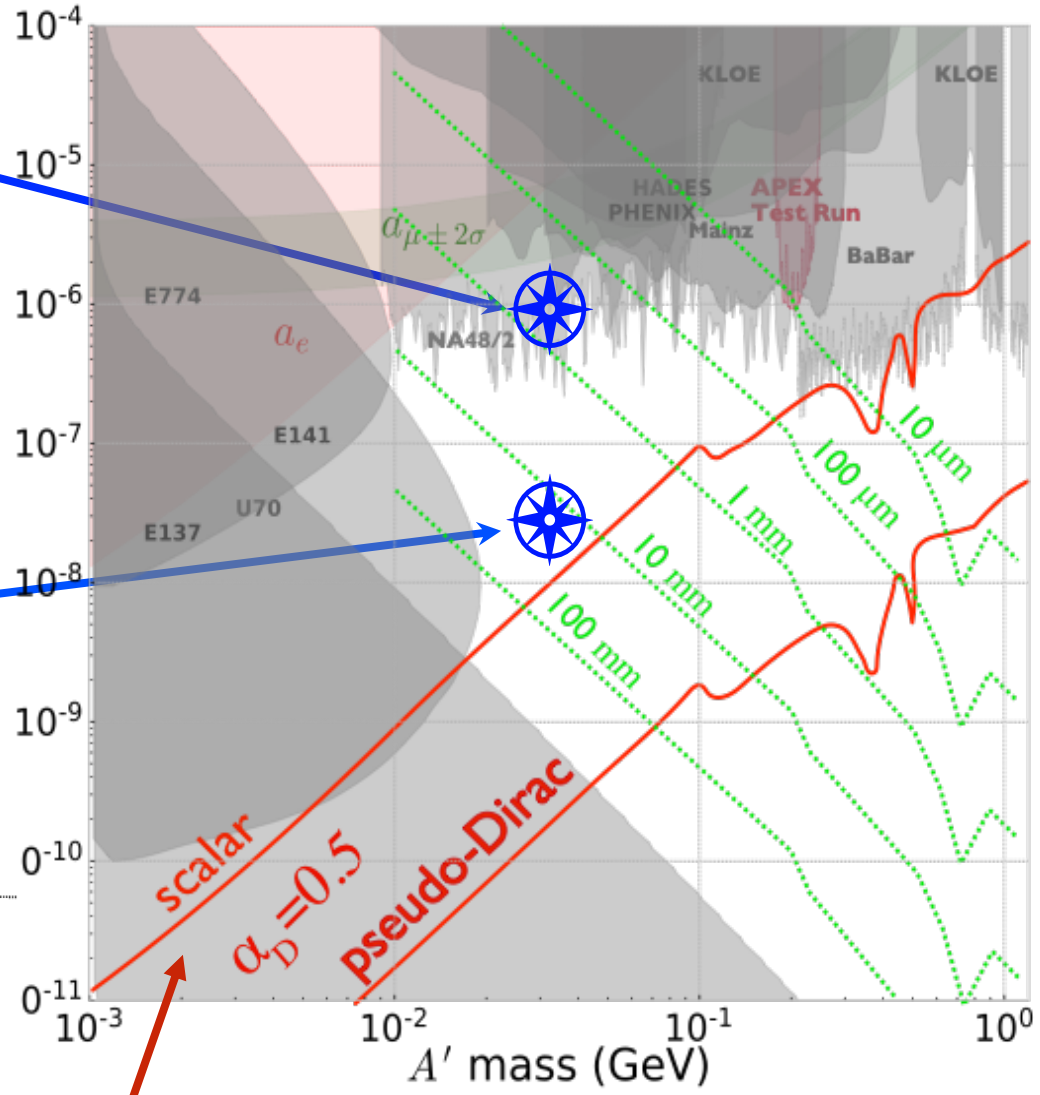
(**detached vertex search**)



reconstructed z vertex [mm]

$$\gamma c\tau \propto \frac{1}{\epsilon^2 m_{A'}^2}$$

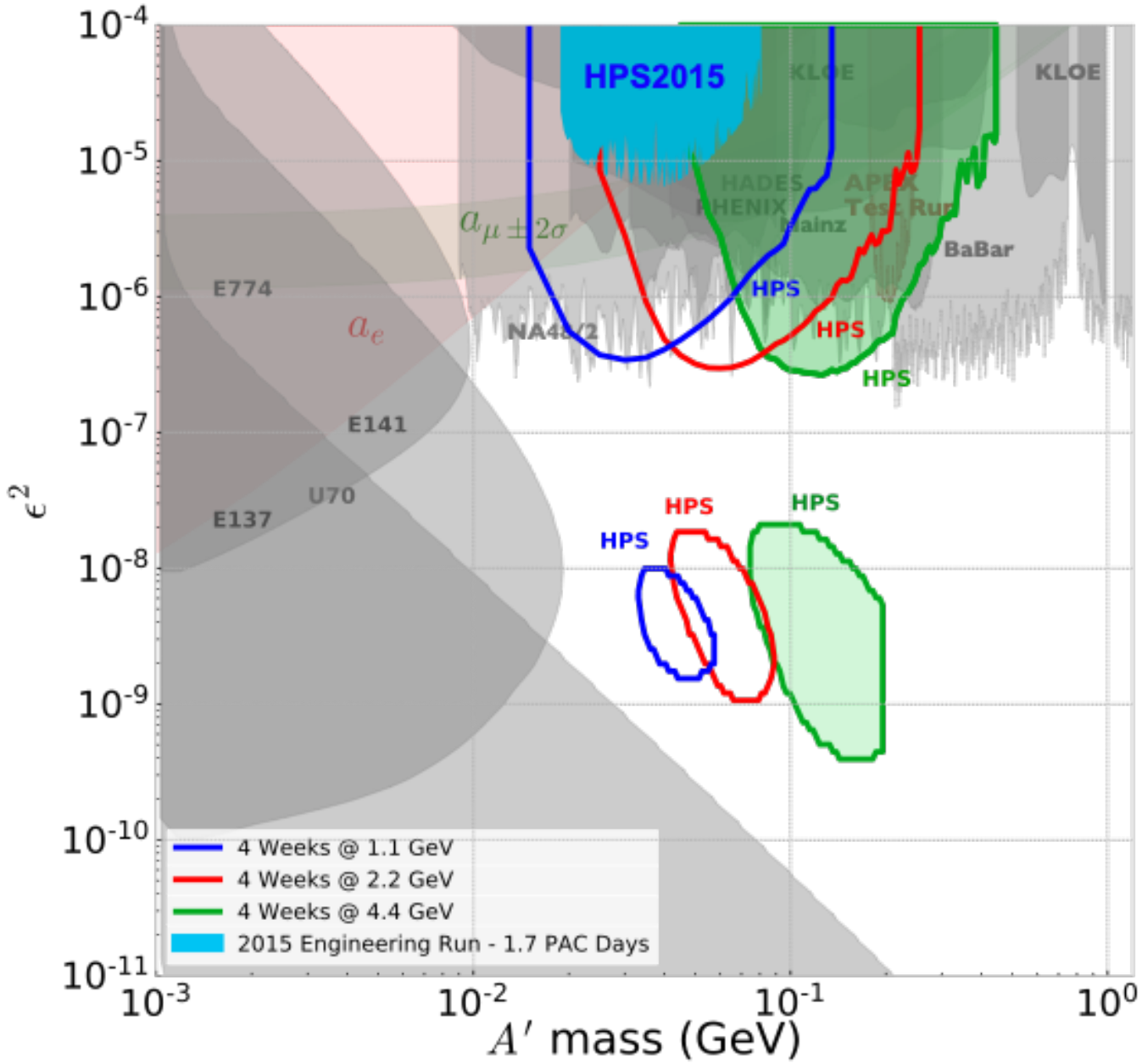




Region motivated by thermal light dark matter.

Cosmic Visions Whitepaper [arXiv:1707.04591]

HPS reach


HPS2015
KLOE
KLOE
HADES
PHENIX
Mainz
BaBar
$a_\mu \pm 2\sigma$
E774
a_e
NA48/2
HPS
HPS
HPS
E141
U70
E137
HPS
HPS
HPS
4 Weeks @ 1.1 GeV
4 Weeks @ 2.2 GeV
4 Weeks @ 4.4 GeV
2015 Engineering Run - 1.7 PAC Days
ϵ^2
A' mass (GeV)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-3}
10^{-2}
10^{-1}
10^{0}

The Engineering Runs ‘15 & ‘16

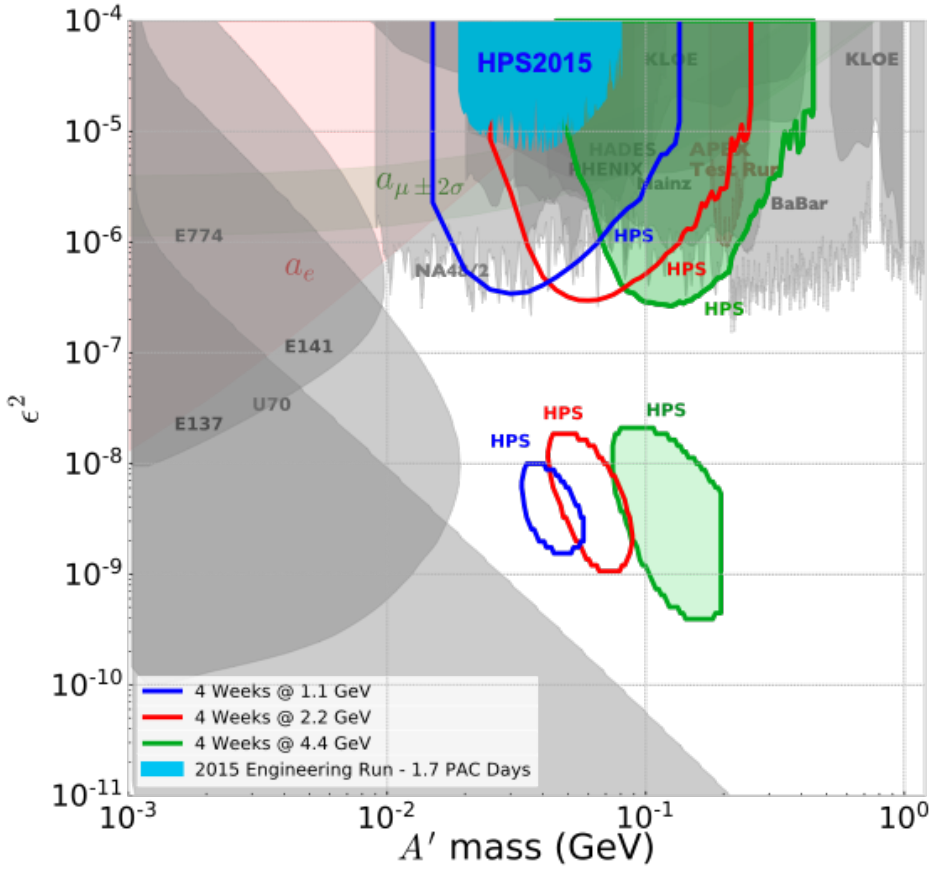
HPS is making use of “opportunistic” running in 2015 & 2016, while the CLAS12 detector is being build in Hall-B.

Spring 2015: Beam time during nights and weekends. (1.7 PAC days)
Beam: 1.05 GeV @ 50 nA on 4 µm W target
Data rate: 20 kHz, 150 MB/sec

Spring 2016: Beam time during weekends only (5.4 PAC days)
Beam: 2.3 GeV @ 200 nA on 4 µm W target
Data rate: 25 kHz (up to 50 kHz), 200 MB/sec

- These are challenging running conditions, with a lot of time spend on beam tuning each startup.
- Excellent support from accelerator division made physics quality data possible.
- Both runs had interruptions due to issues with accelerator (CHL)
- Both runs received extensions from lab management.

HPS first physics publication



PHYSICAL REVIEW D

covering particles, fields, gravitation, and cosmology

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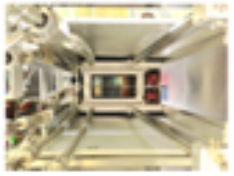
Search for a dark photon in electroproduced e^+e^- pairs with the Heavy Photon Search experiment at JLab

P. H. Adrian *et al.* (Heavy Photon Search Collaboration)

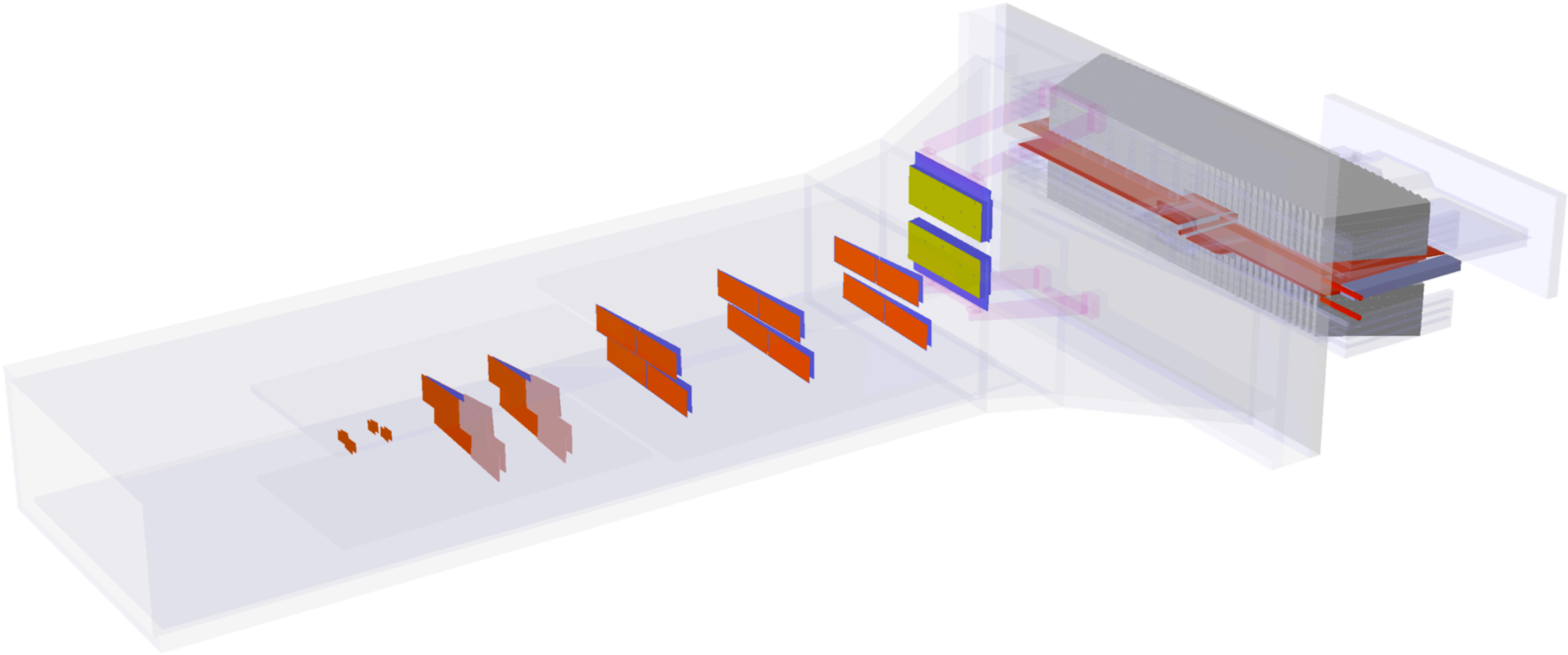
Phys. Rev. D **98**, 091101(R) (2018) – Published 12 November 2018



In a successful engineering run, the Heavy Photon Search Collaboration demonstrates that its upcoming heavy photon search experiment will be able to probe so far unexplored parameter regions in the search for dark photons.

Show Abstract +

2019 : Status of the HPS detector

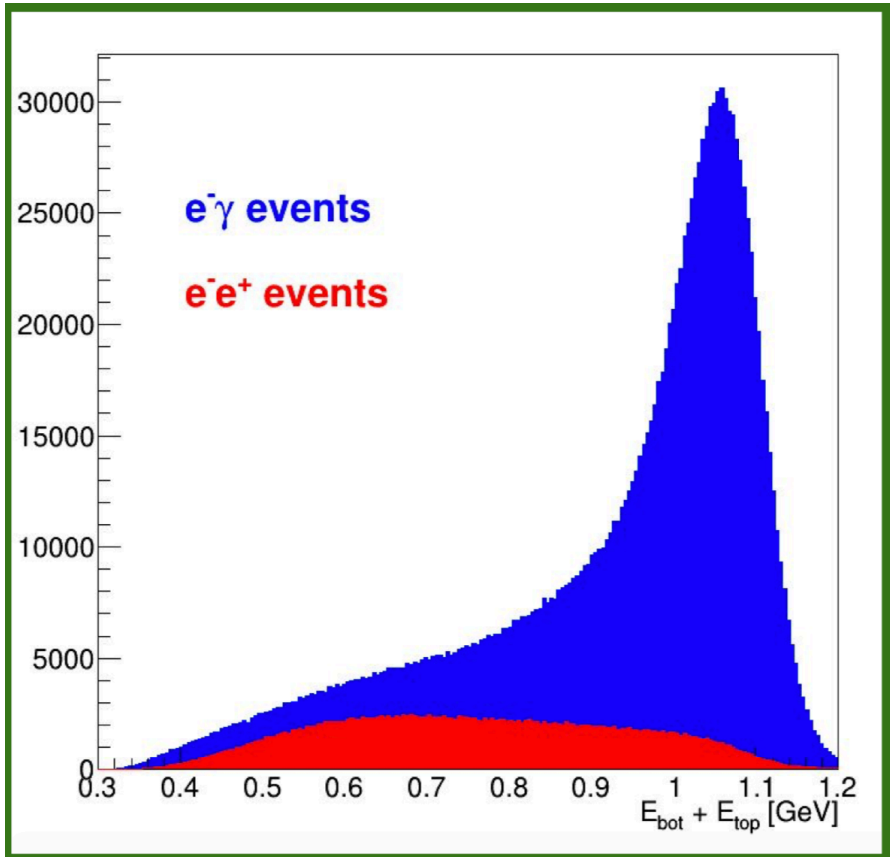


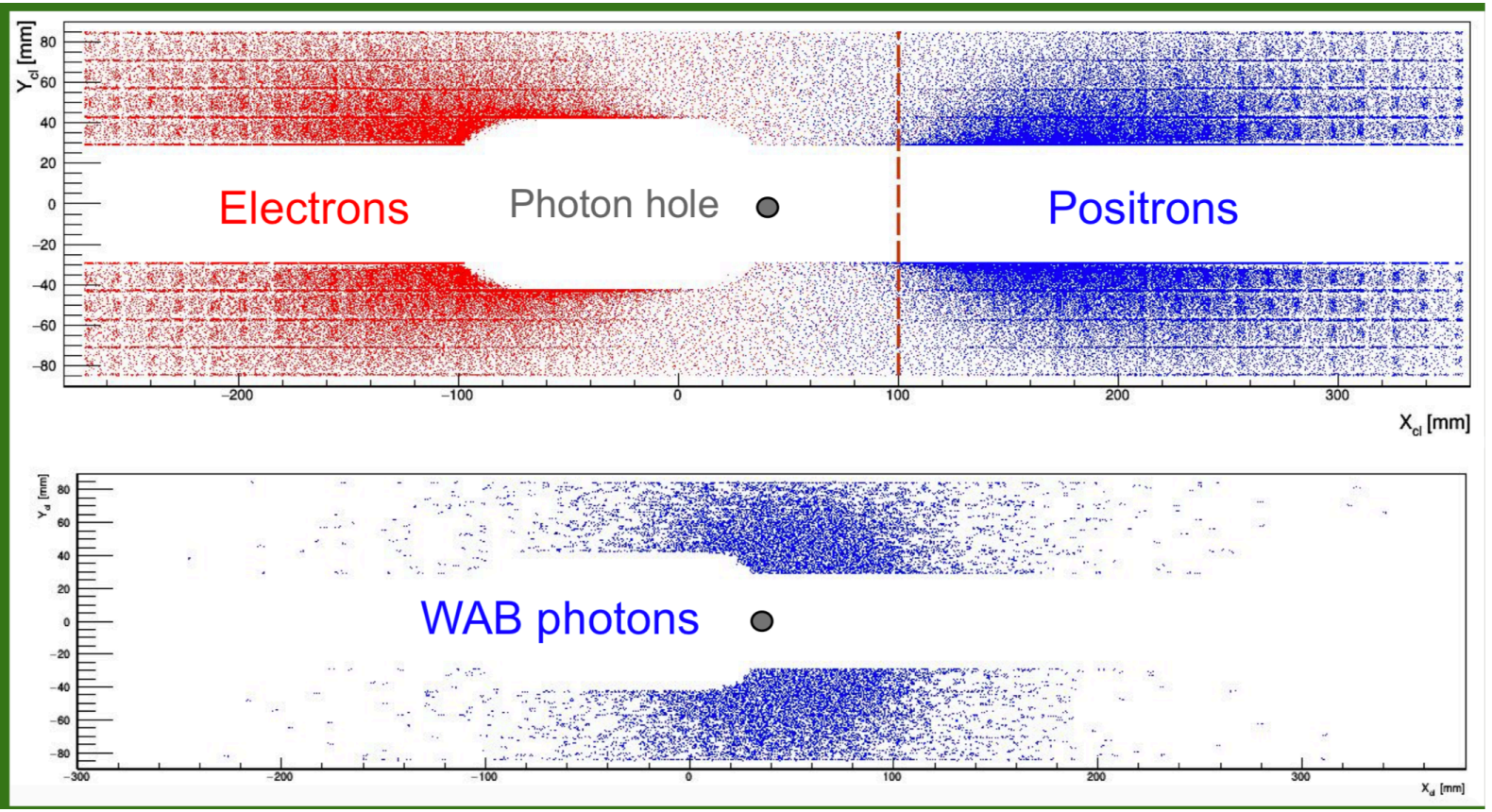
Main Trigger in 2015 and 2016 Runs

Pair1: Two coincident clusters, one in each detector half, and being coplanar

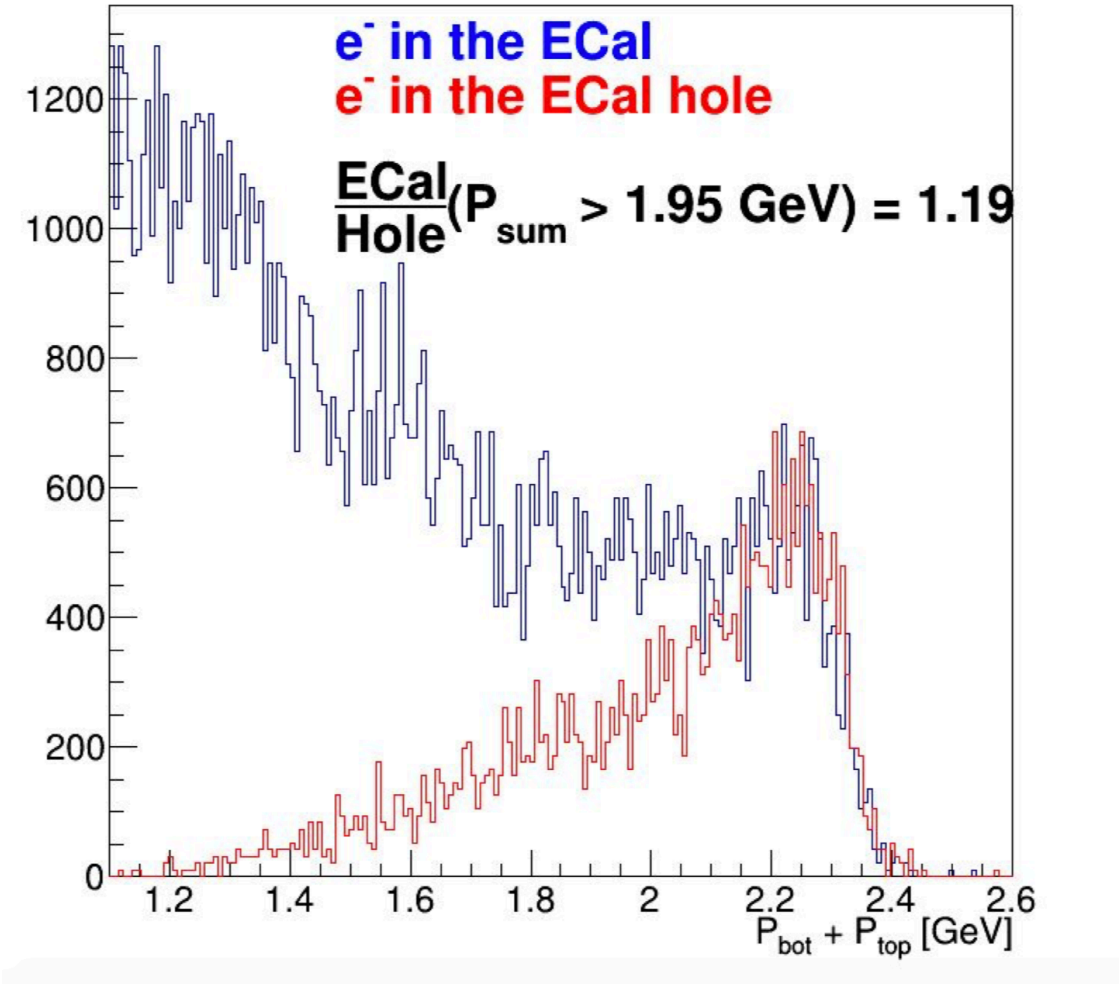
Actual e-e+ pairs are only a small fraction of pair1 triggered events, pair1 is dominated by WABs

Tridents, where electrons passes through to the ECal gap, will be lost





Events with electron in the Ecal hole



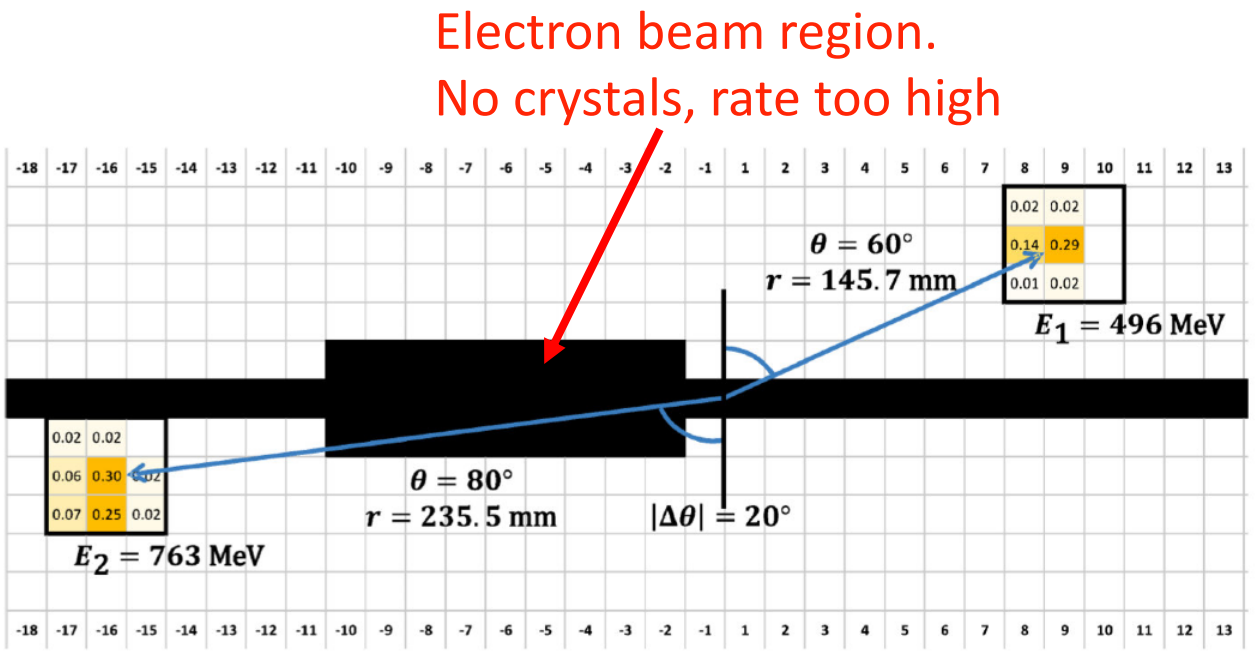
≈ Half of events with Esum >0.85 E_b, have electrons escaped through ECal hole

Triggering only on clusters in the positron side will recover these events, however, just the ECal rate on the positron side is quite large (exceeds DAQ capabilities). This large rate dominated by high energy photons from WABs.

Placing a hodoscope before the Calorimeter will help to suppress photons, and bring the rate down to an acceptable level for the DAQ

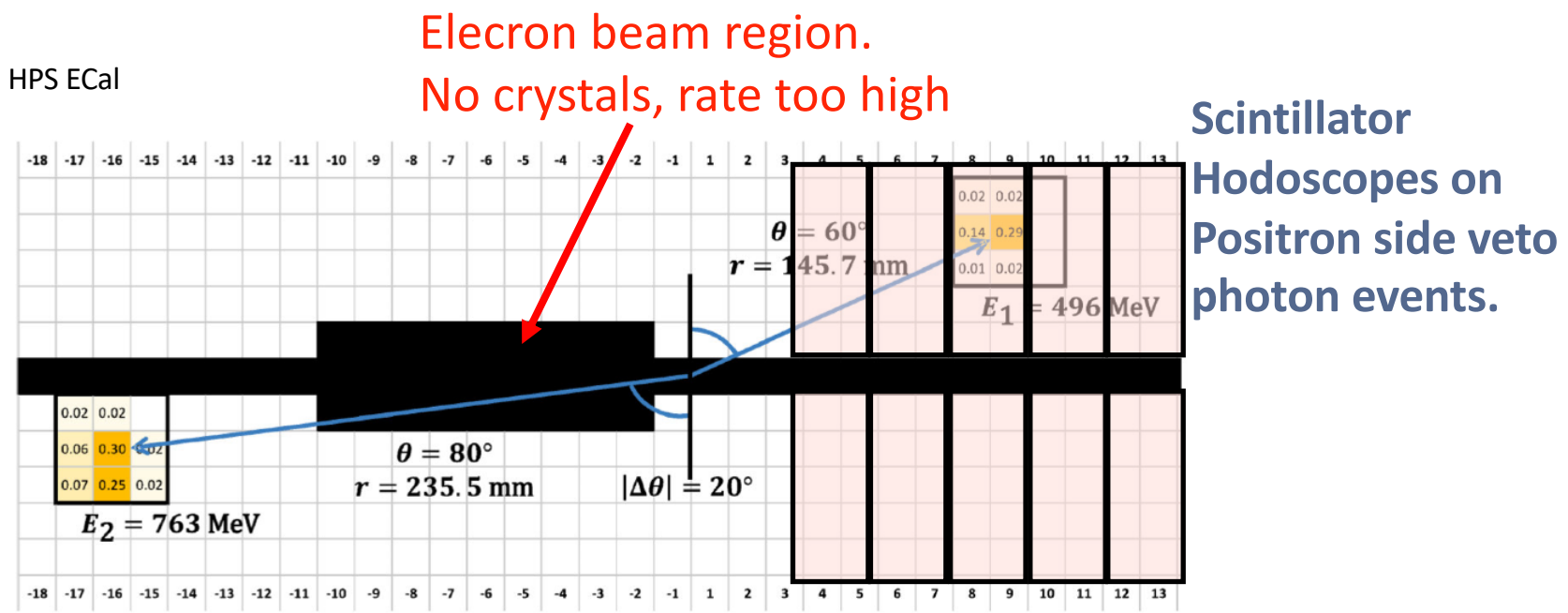
Upgrade: Trigger

- The engineering runs showed that Wide Angle Bremsstrahlung (WAB) events are a major background source in the HPS trigger.

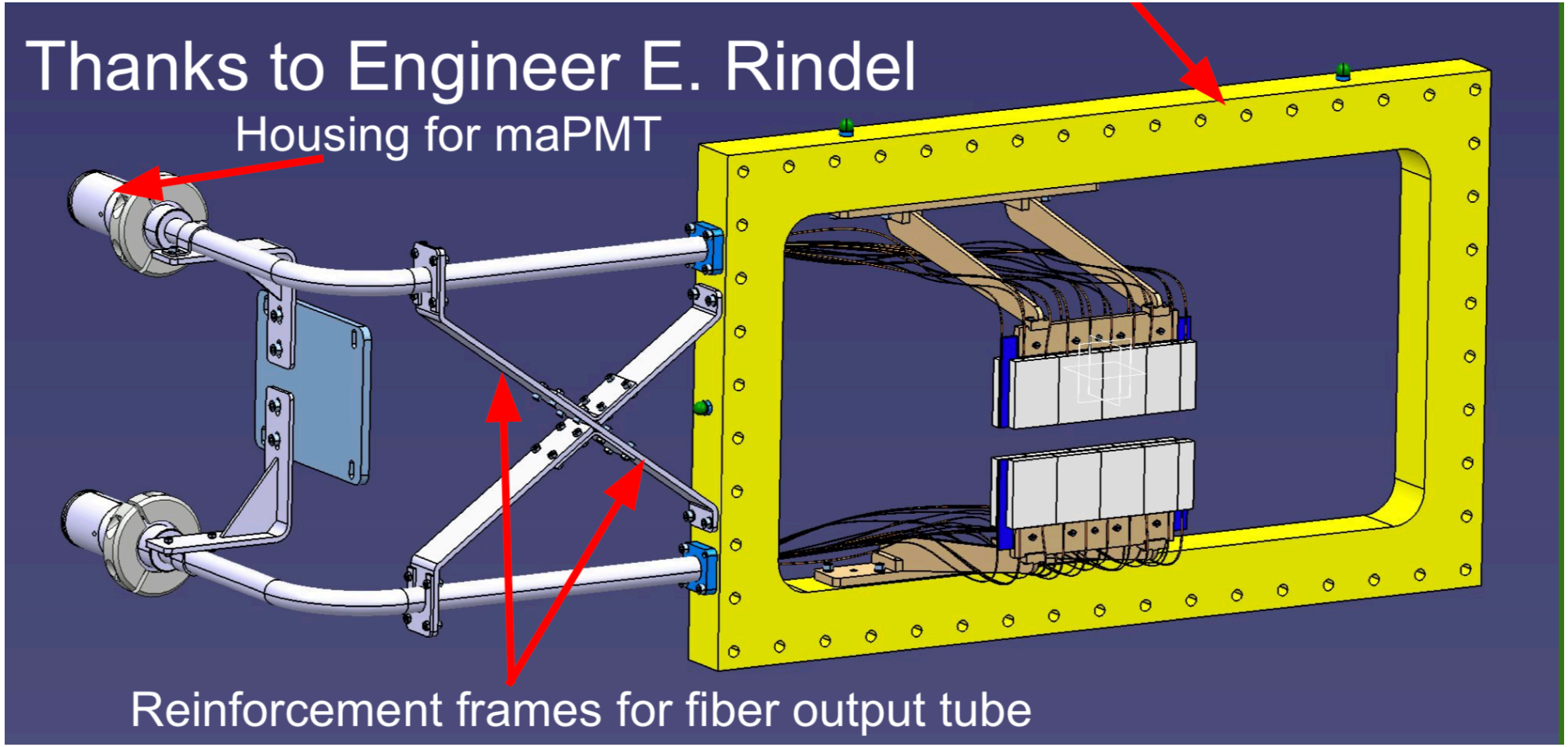


Upgrade: Trigger

- Solution: Add a hodoscope on the e+ side to veto the WAB photons.
- Also: single arm e+ trigger increases small angle acceptance.
- Expect 2x data taking efficiency gain.



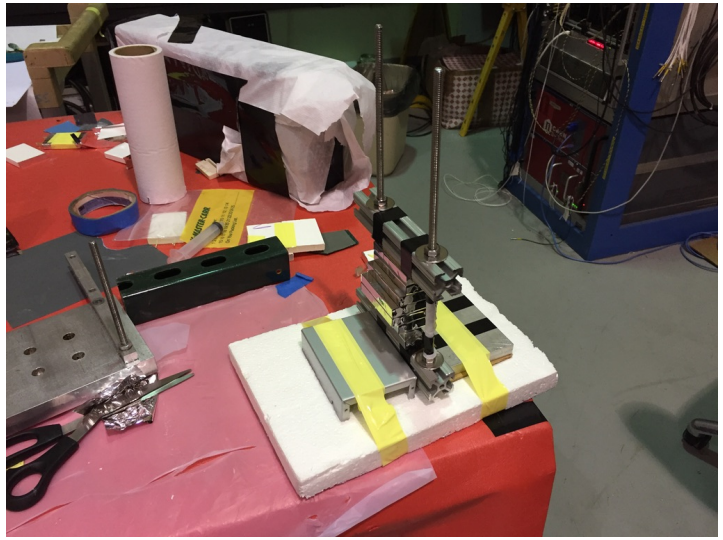
Hodoscope

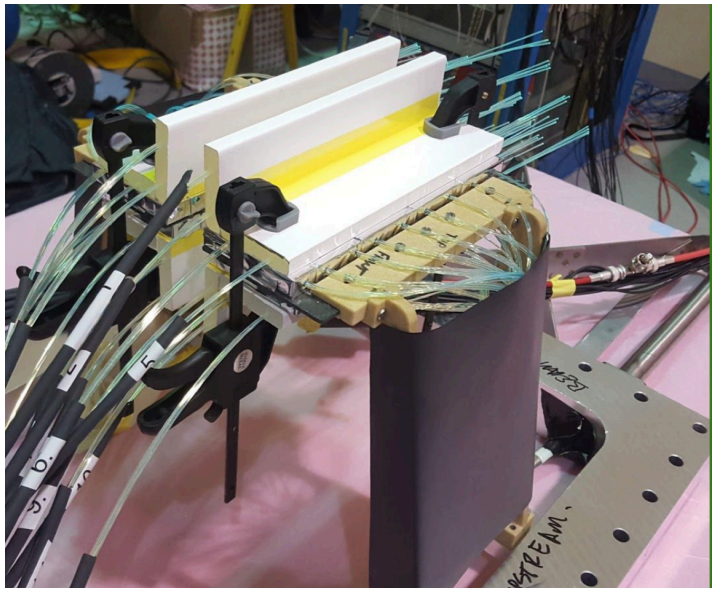


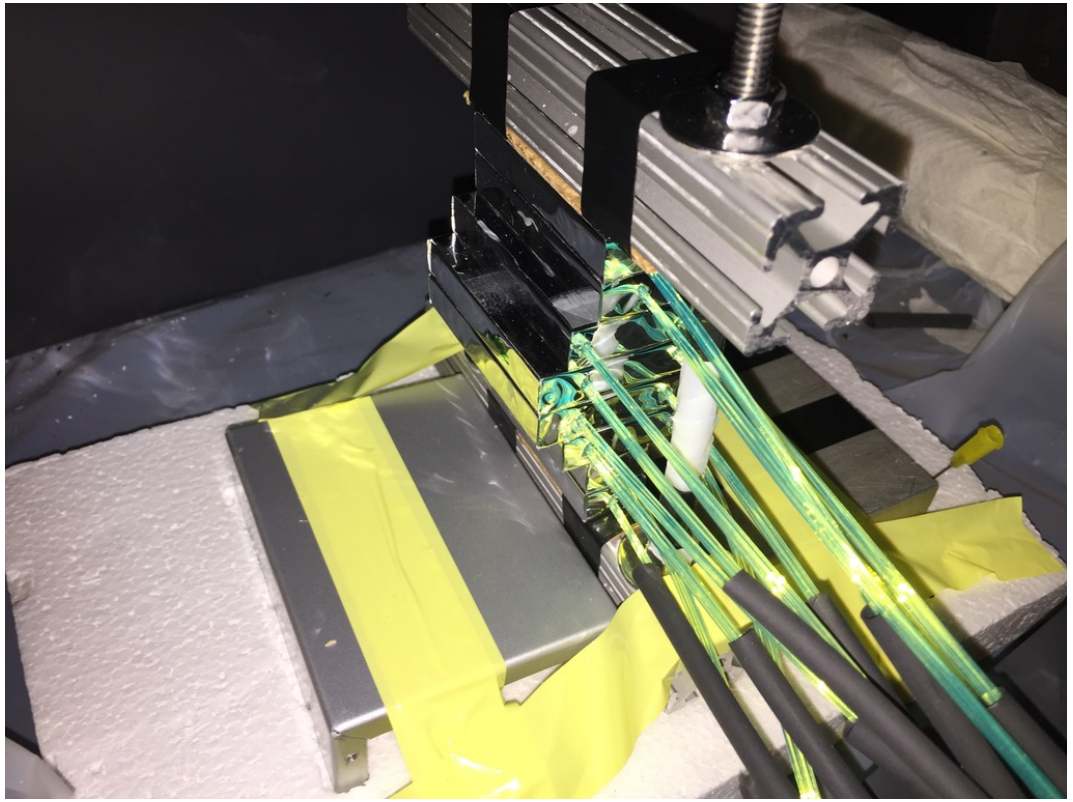
Hodo is placed In between the L6 and the ECal

The ECal with ECal vacuum chamber will be moved downstream by 50 mm

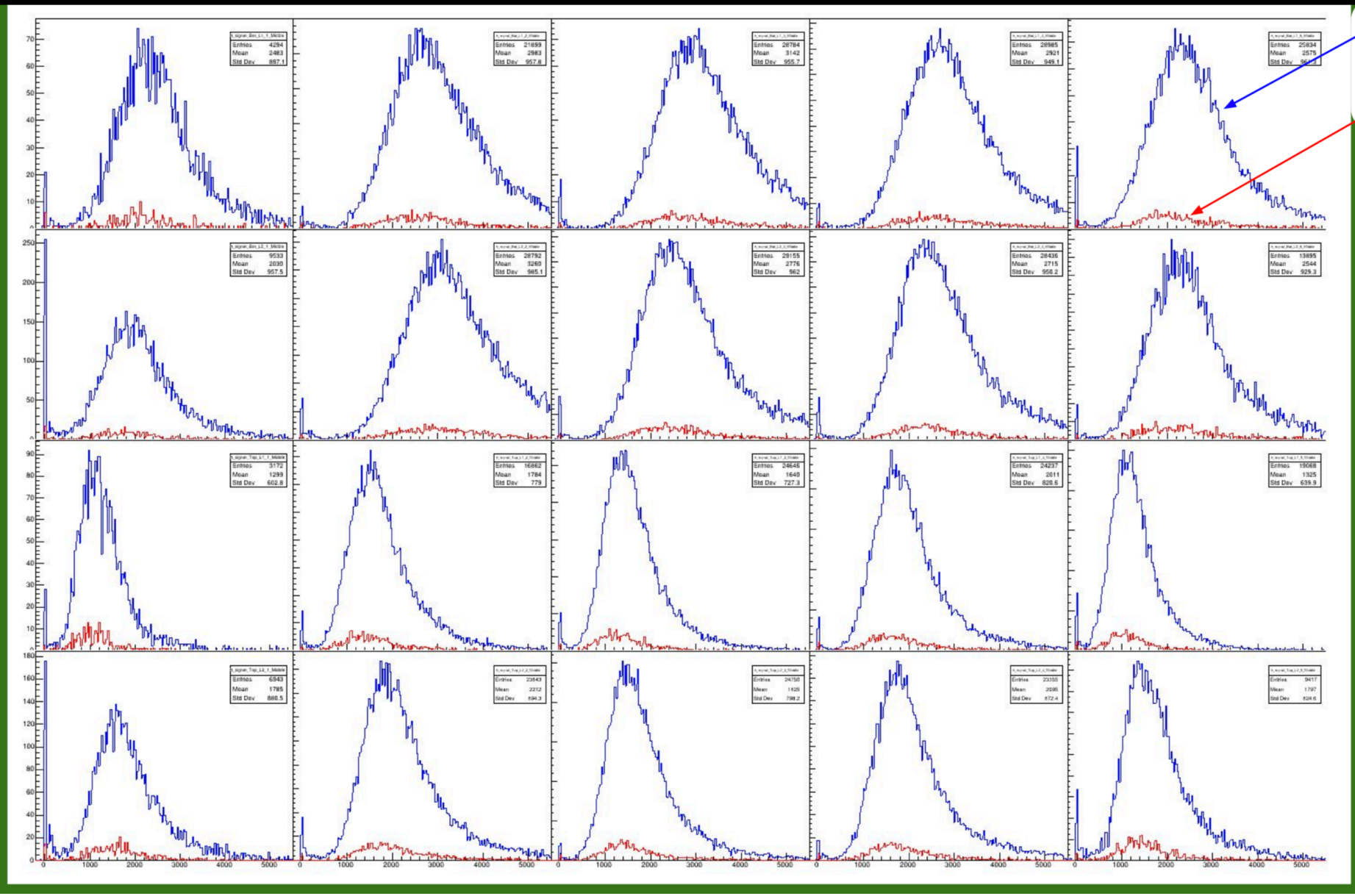
Hodoscope construction



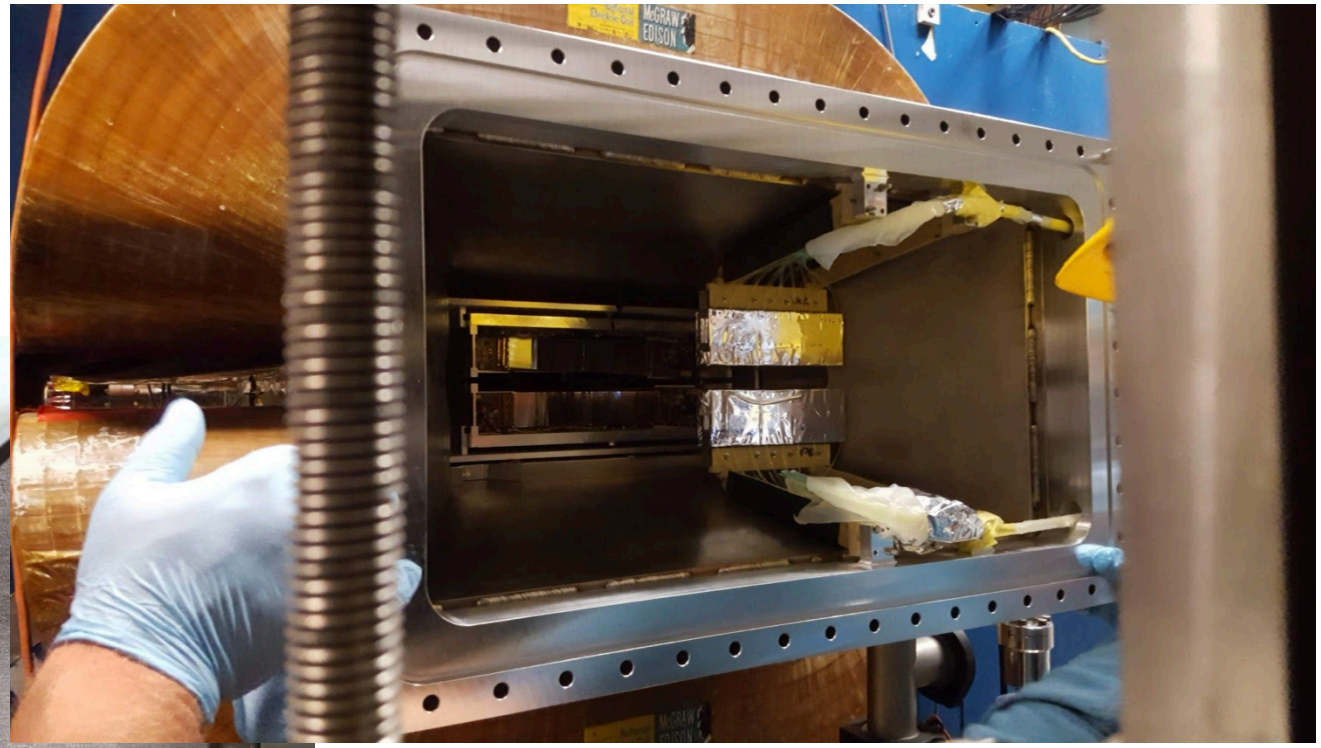


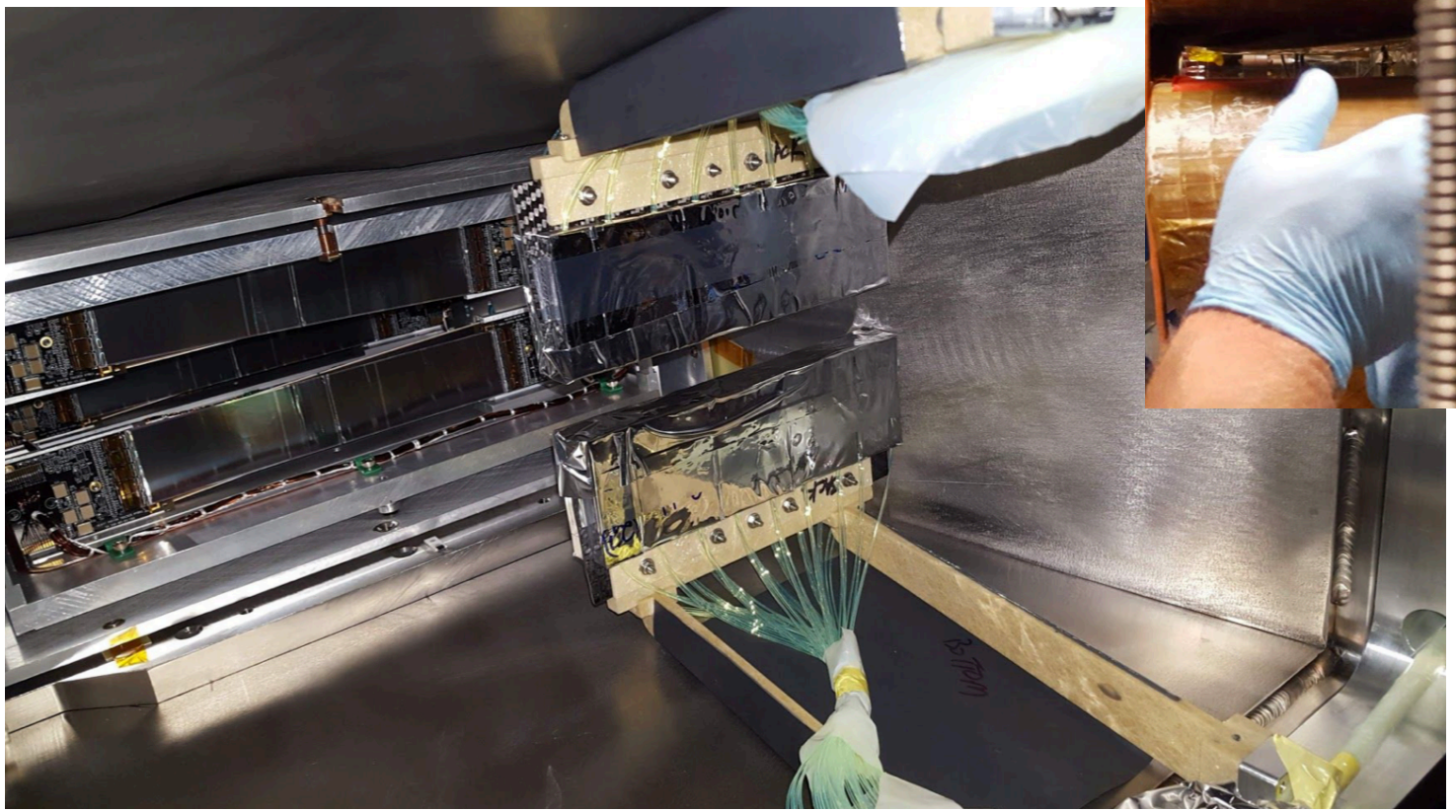


Raw adc signals from all tiles



Hodoscope installed



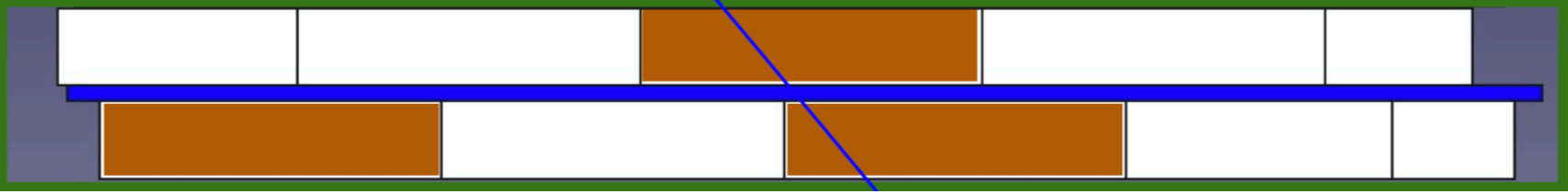


The Trigger

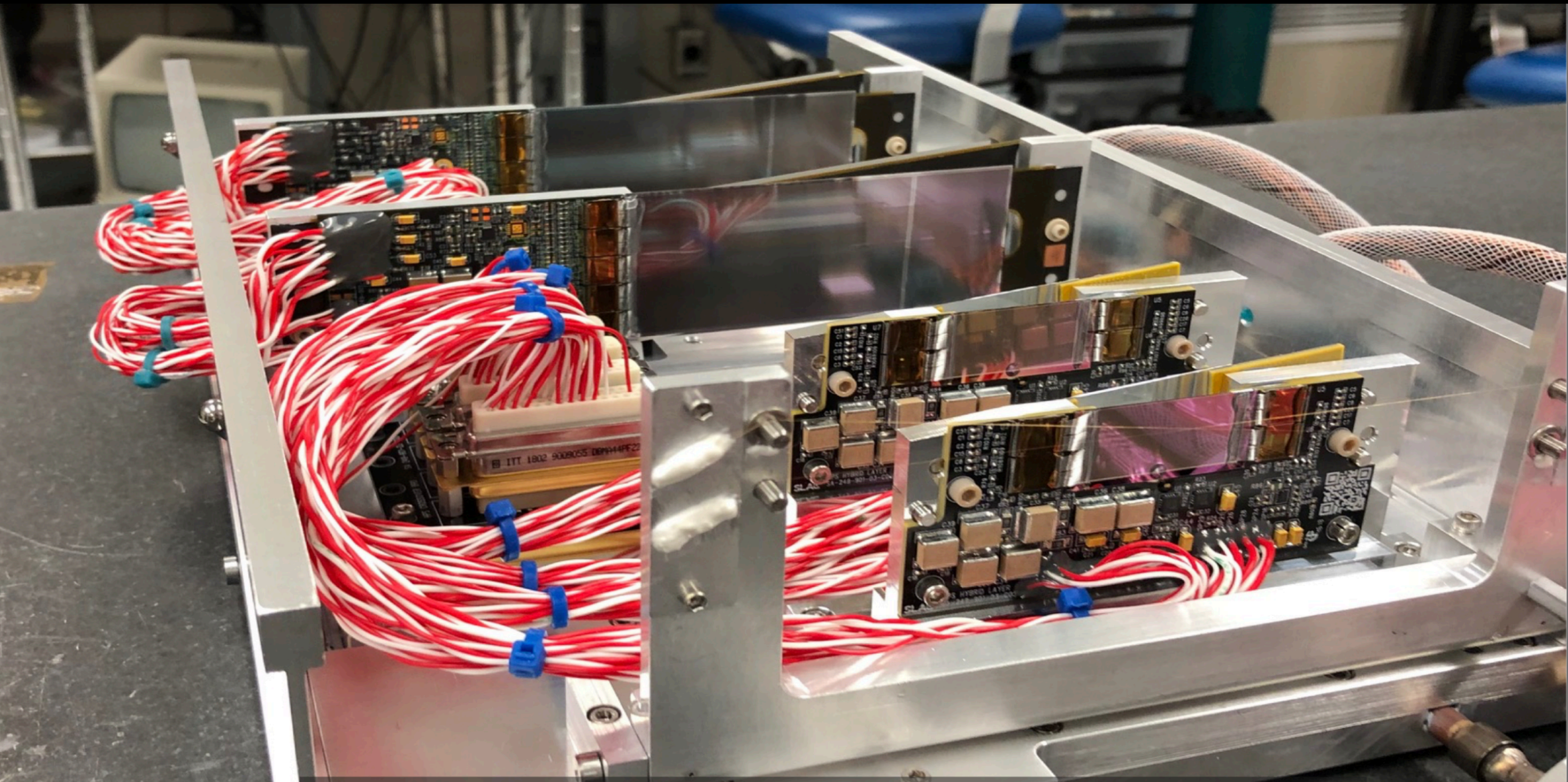
ECal crystal with i_x >= 5

For each L1 Hit there should be L2 hit and ECal cluster in a certain range

L1 x L2 x ECal



SVT Upgrade

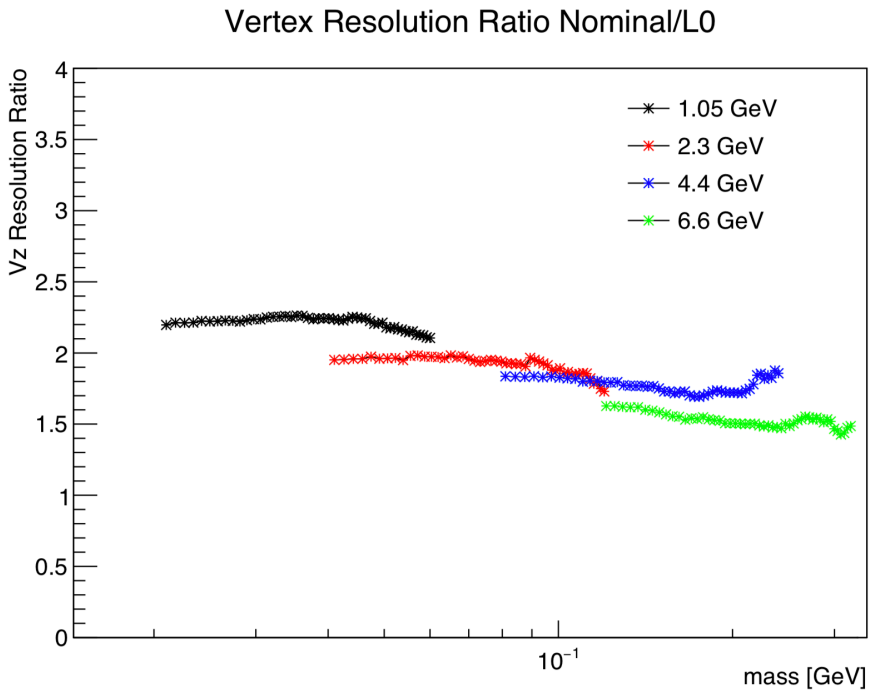


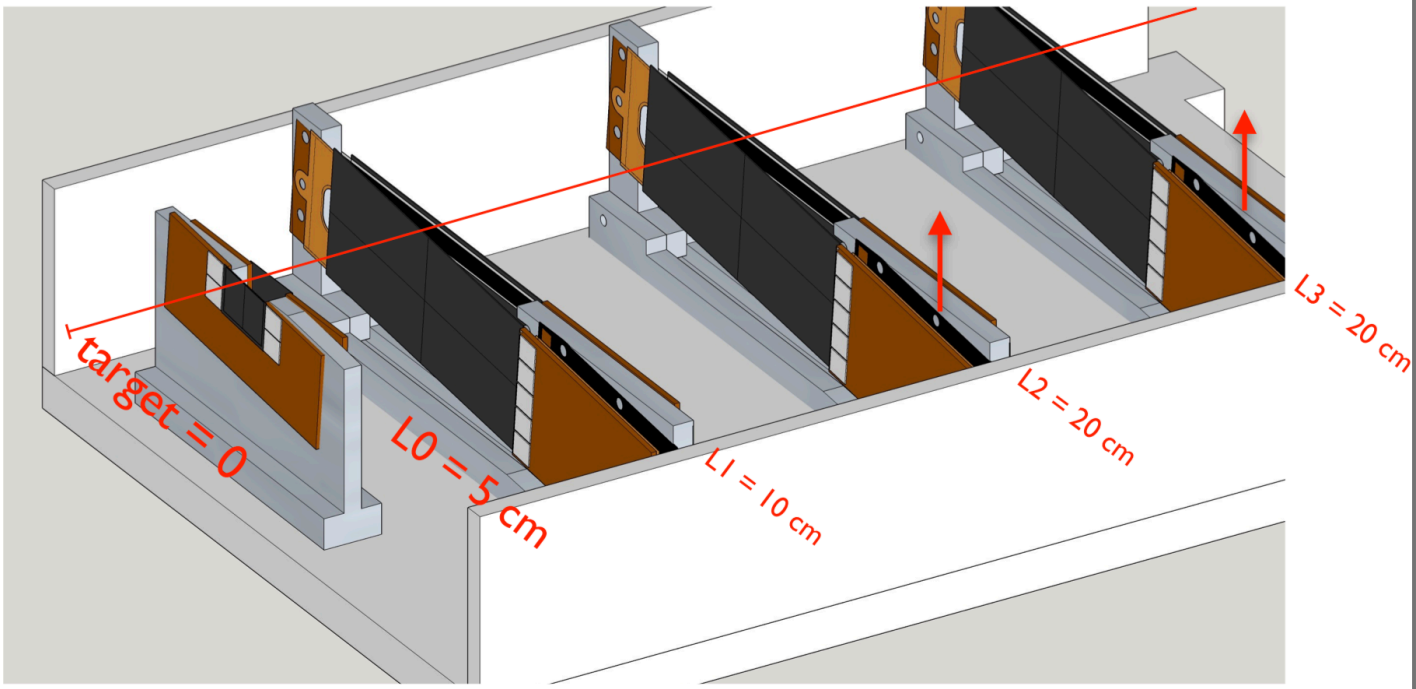
SVT Upgrade

Addition of Layer 0, similar in concept to other layers, but…

half the distance to target (5 cm)

roughly half the material (0.4% X_0)





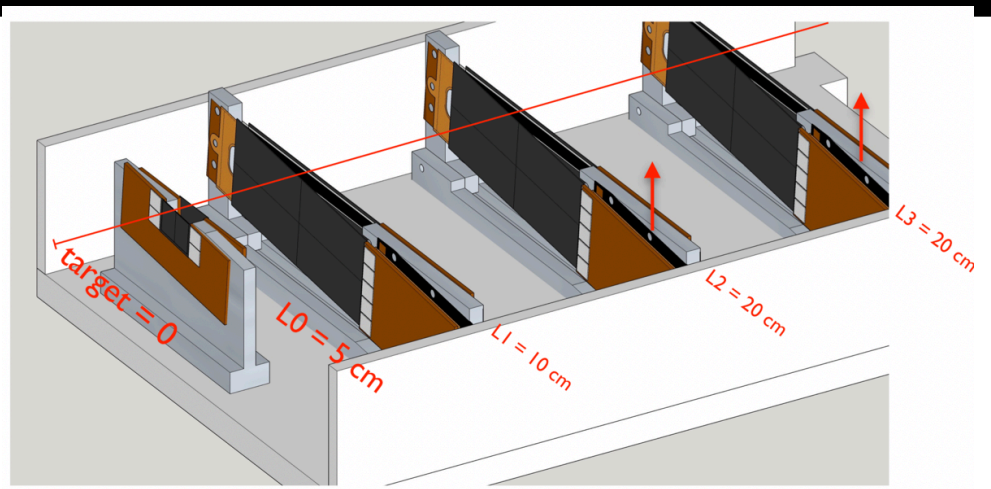
Improve vertex resolution 2x with an additional layer closer to target: L0

Using thinner, “slimmed edge” sensors for L0 and L1

reduce multiple scattering.

SVT Upgrade

Move L2-L3 closer to beam for increased acceptance by1.5x

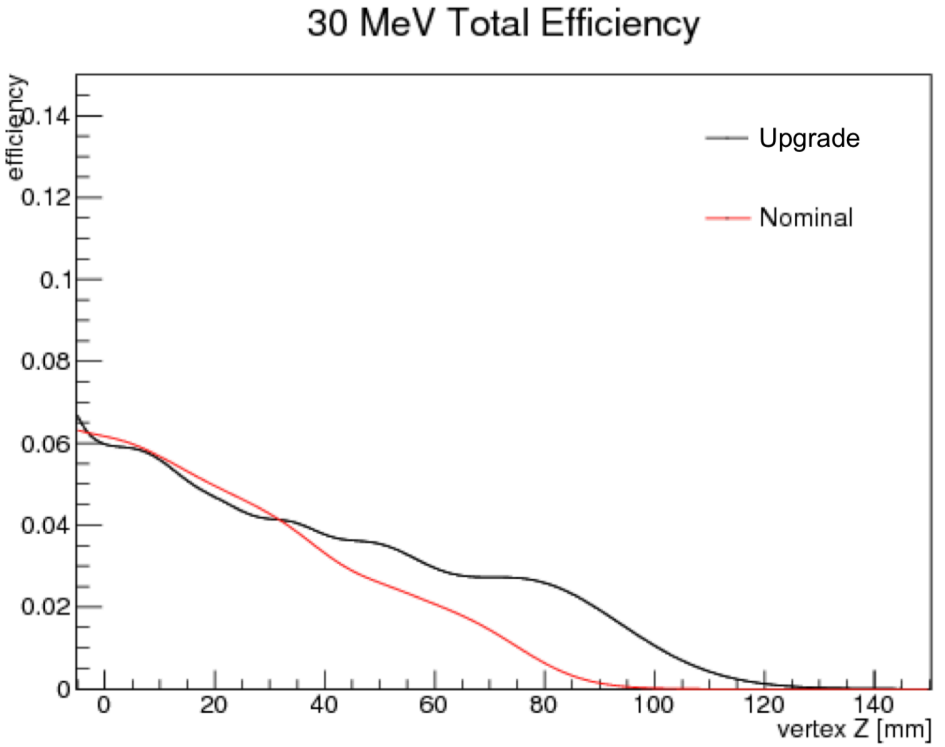


Moving L2 and L3 inward towards beam maximizes acceptance for long-lived A′

Occupancy is acceptable (similar to L1) for 0.7mm move

Easily accomplished with the addition of thin shims under L2, L3 supports

Moving Layers 2 and 3 inwards increases acceptance for long-lived A′ daughters as expected.

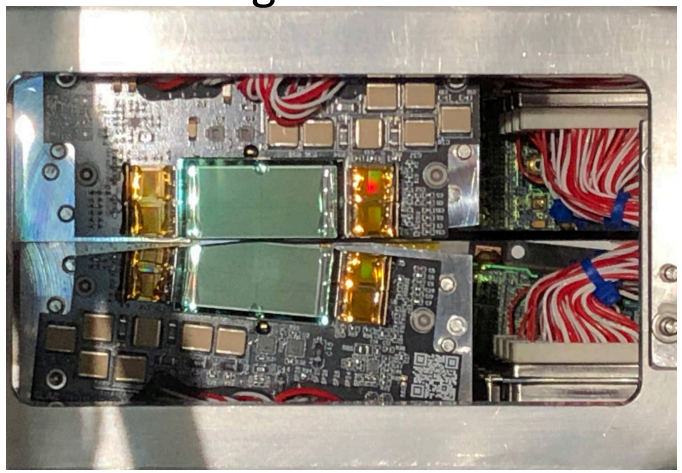


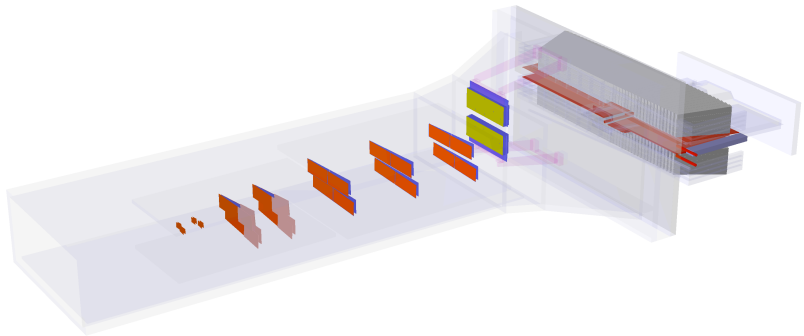
2019 Data Run

- Upgraded detector is installed.
- Run with 4.55 GeV beam on 0.25% Tungsten target.
- Total run time will be 1 week commissioning + 8 weeks data taking = 4.5 PAC weeks.
- Shifts from 13 Jun. to 21 Aug.
- Higher efficiency of the upgraded detector trigger (2x) should translate to at least 10 ~ 12 times the amount of useful data compared to 2016 run
- SVT upgrade will make this data ~3x more efficient for vertex searches, so vertex searches we see 30 times the useful data.

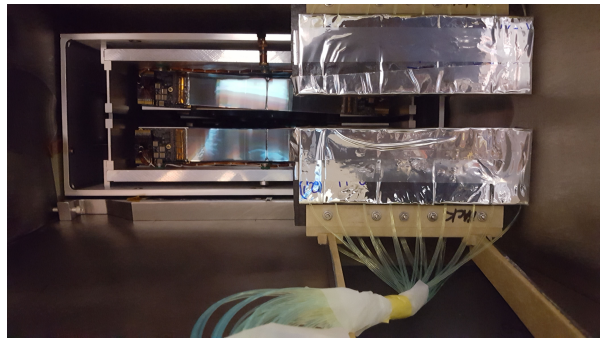
- Major Power outage 1 Jul. -> Machine is straggling to deliver beam for experiments. -> right-now beam on the tagger dump

View from target side of detector.





View from down beam side of detector.



2019 Beam Parameters

Parameter	Value
Beam energy (5 pass)	4.55 GeV
Beam current	up to 450 nA
Current stability	< 10%
Beam bunch Frequency	499 MHz
Beam profile at the target	
σ_x	< 100 μm
σ_y	< 50 μm
Halo	$< 10^{-5}$ @ 5 σ
Beam position stability	
in x	< 50 μm
in y	< 50 μm

JLAB12-collaboration activities on HPS

- SHIFTS (22 blocks over tot: 84) + experts on call
- Ecal re-start, tests, preliminary calibrations, LED system
- Construction and test of the Hodoscope
- Ecal calibrations
- Vertext detector alignment
- Marzio De Napoli (Ct) memeber of the Executive Commettee
- Andrea Celentano (Ge) chair of the Publications and Presentations Commettee

Conclusions

- The 2015 resonance search was published.
- 2016 data analysis in progress
- Data taking at 4.4 GeV this summer
- Upgraded HPS detector improves resonance search 2x and vertex search 6x
- Expect 30x the statistics for resonance search compared to 2015 data set.
- Expect 90x the statistics for vertex search compared to 2015 data set.
- Future runs at ~1.1 GeV and ~2.2 GeV will also cover new reach.
- Next year HPS will undergo Jeopardy process, (i.e.) experiments that remain approved on the books for extended periods of time need to be periodically reevaluated by the PAC.