Heavy Photon Search Electromagnetic Calorimeter

Holly Szumila-Vance
On behalf of the Heavy Photon Search Collaboration
Old Dominion University, Department of Physics

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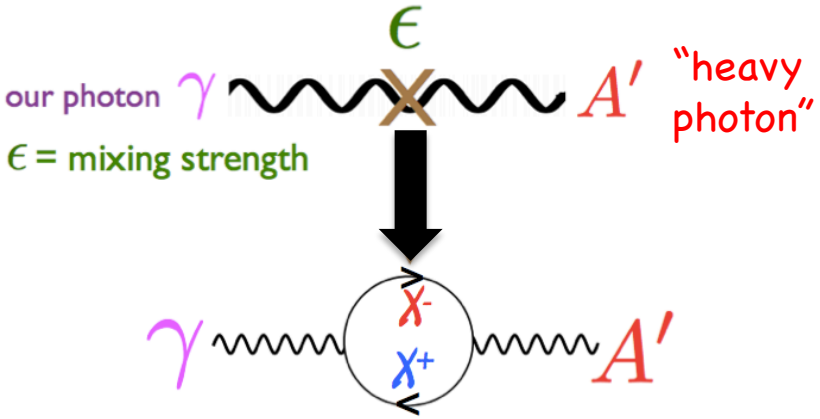
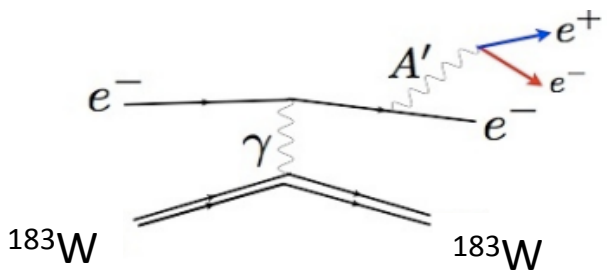
OLD DOMINION
UNIVERSITY

Heavy Photons

Additional U(1) symmetry in nature
-> new gauge boson!

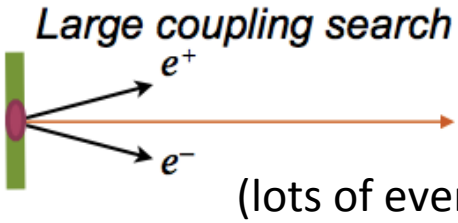


Kinetic mixing could be the leading interaction between the Standard Model and Dark Sector!

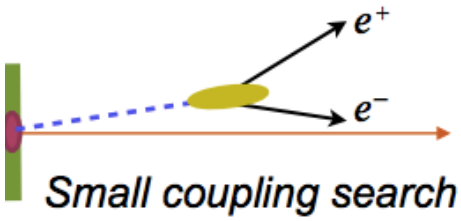


$e^- + {}^{183}W \rightarrow A' + X \rightarrow e^+ + e^- + X$

ϵ (Coupling/mixing parameter)



(lots of events)



(fewer events)

Heavy Photons

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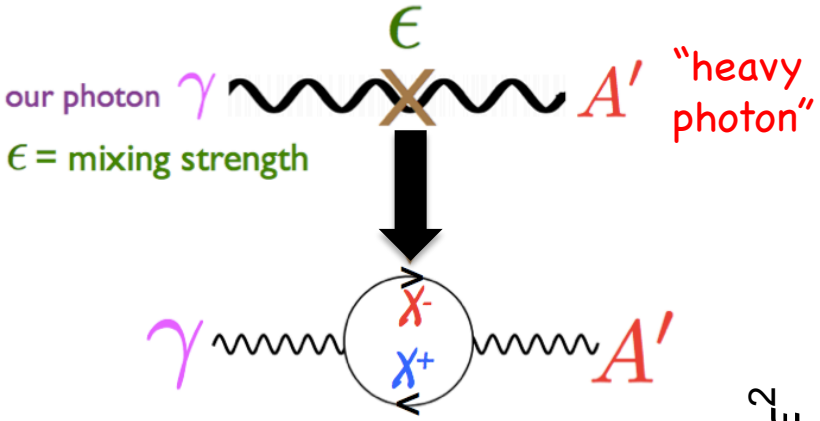
-> new gauge boson!



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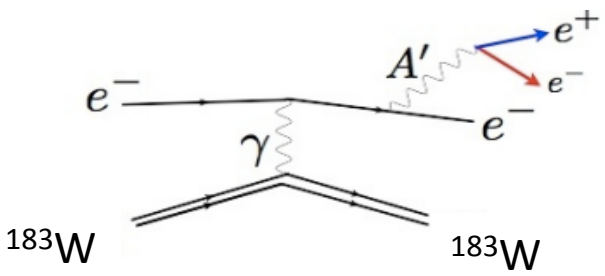

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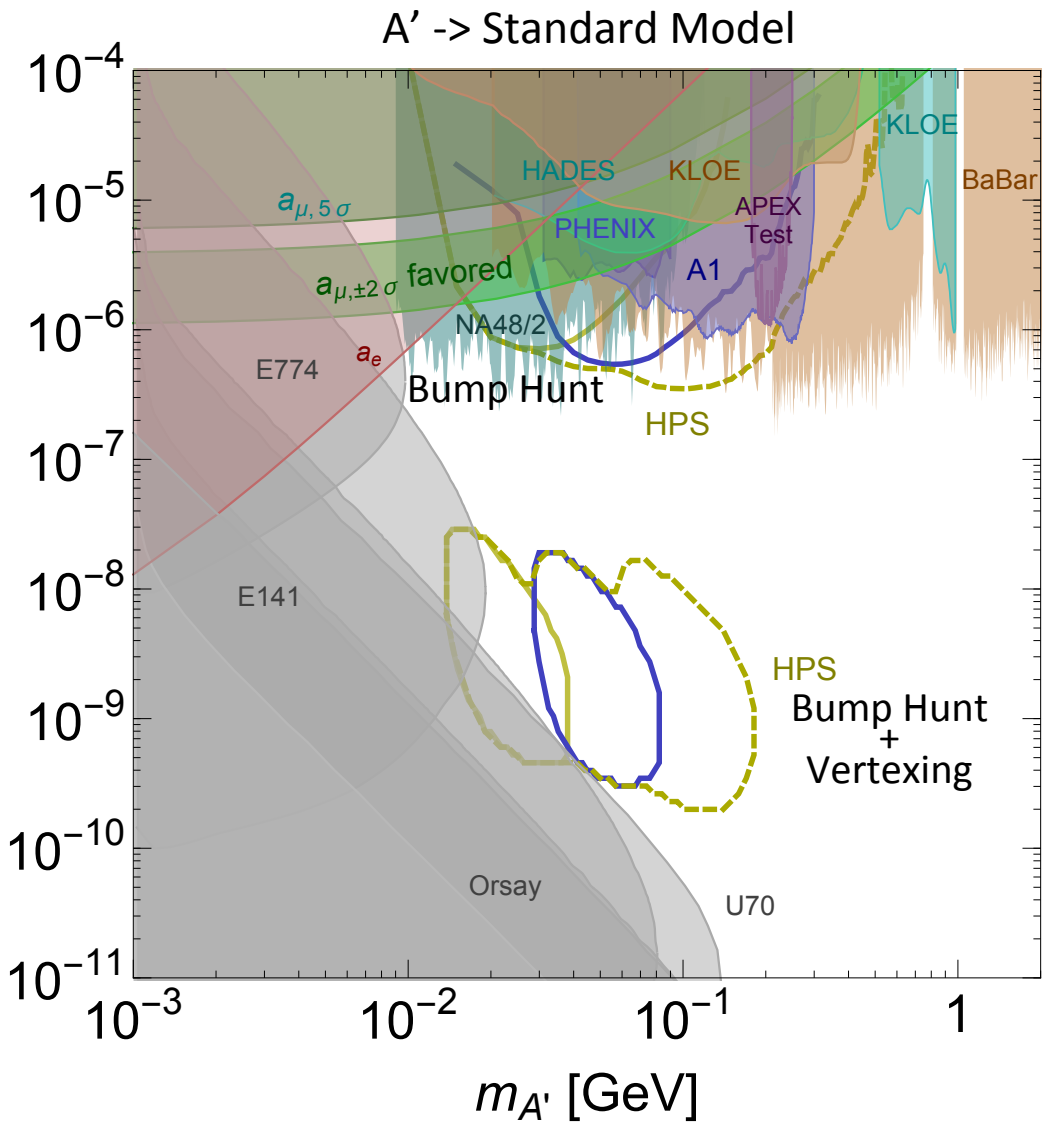
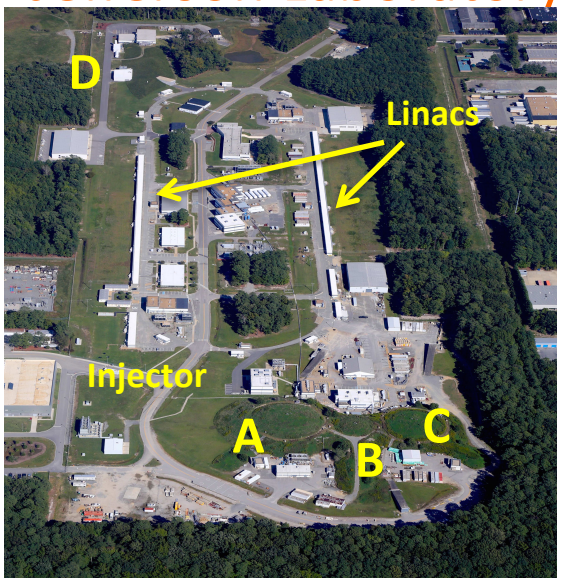
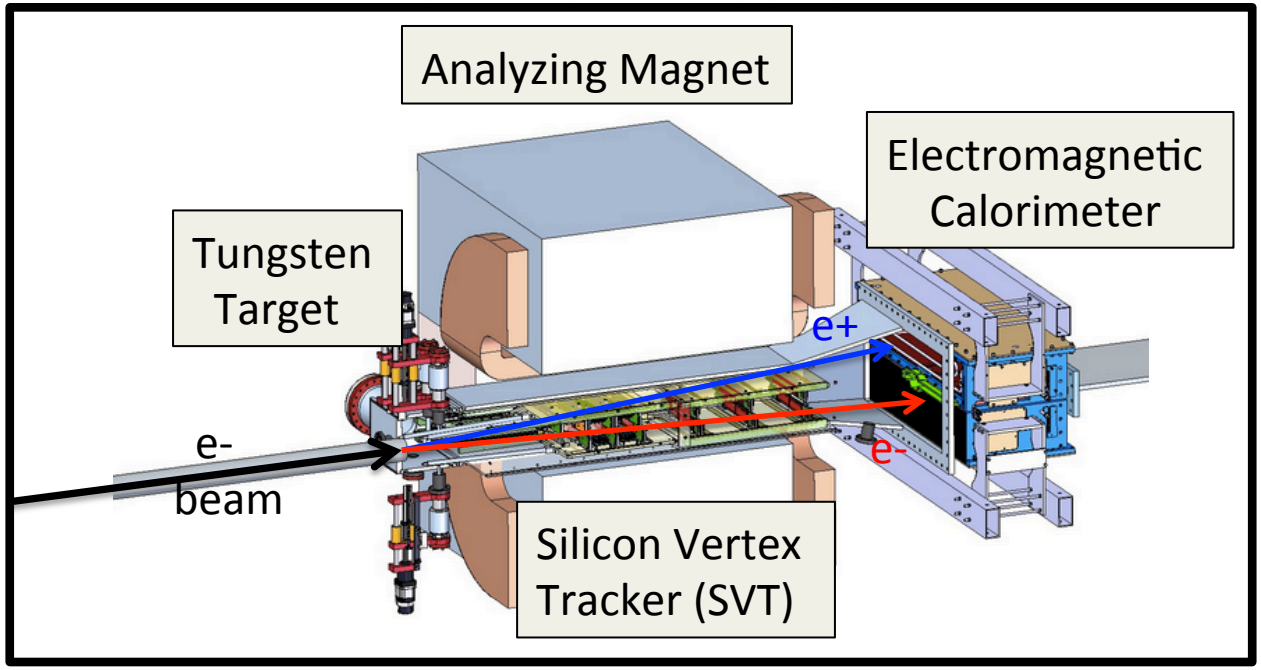


HPS Experiment

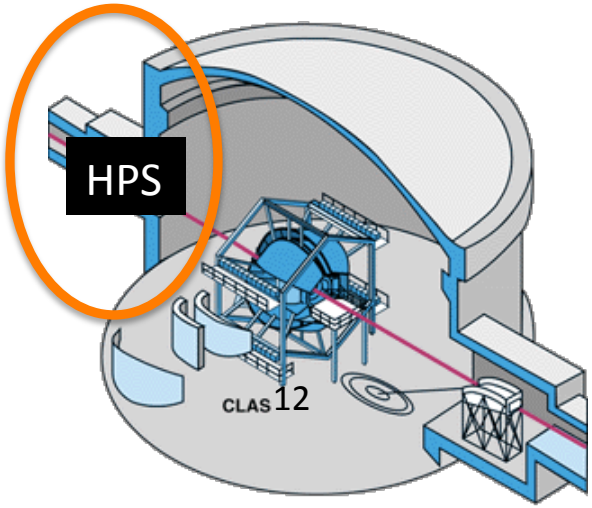
Jefferson Laboratory



HPS in Hall B alcove



Hall B



Detectors:

- SVT: tracks particles, measures momentum and vertex
- ECal: triggers events, measures energy

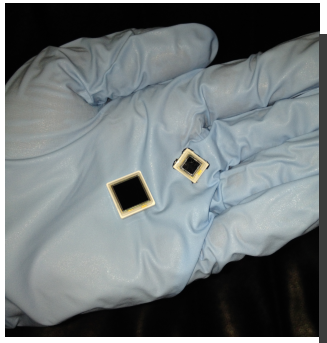
- Magnetic fields bend particles horizontally
- Each detector is separated vertically to avoid "sheet of flame"

Electromagnetic Calorimeter (ECal) Characteristics

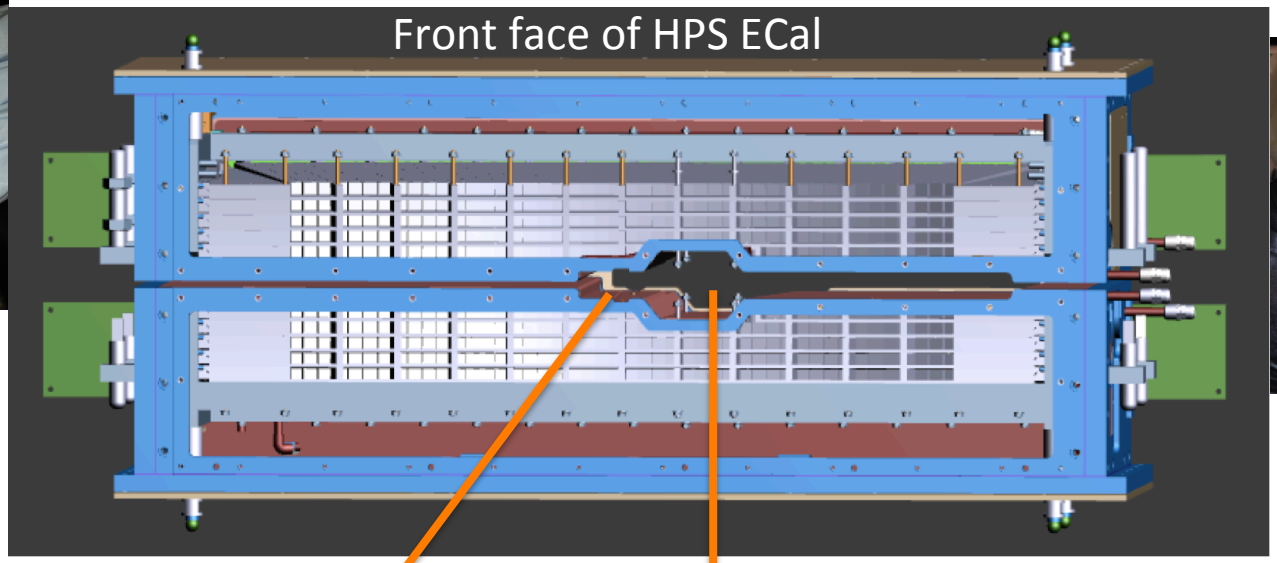
Features:

- 442 $PbWO_4$ scintillating crystals
- Large Area Avalanche Photo Diodes (APD) for readout
- Light Monitoring System (LED)

APD upgrade

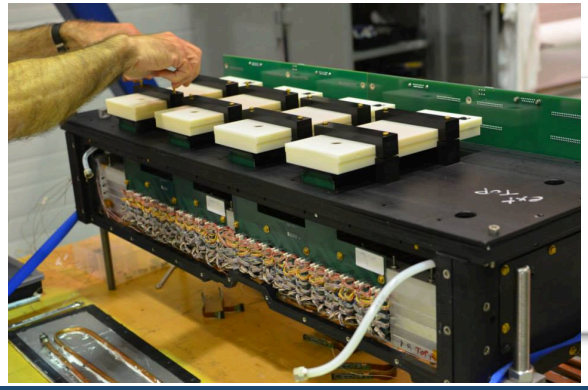


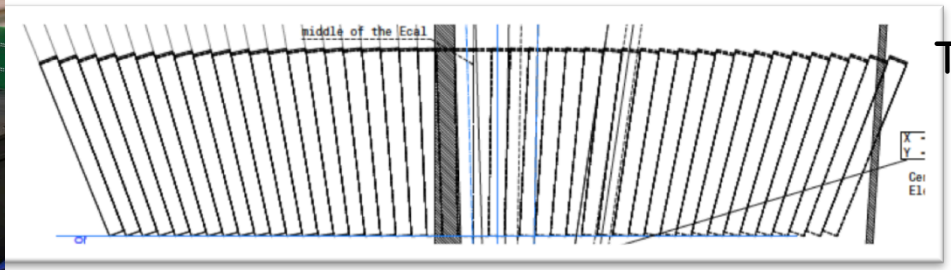
Upgraded from $5x5\ mm^2$ to $10x10\ mm^2$



Single PbWO4 crystal

Crystal face dimensions: $1.3x1.3\ cm^2$





Top view of HPS ECal crystals

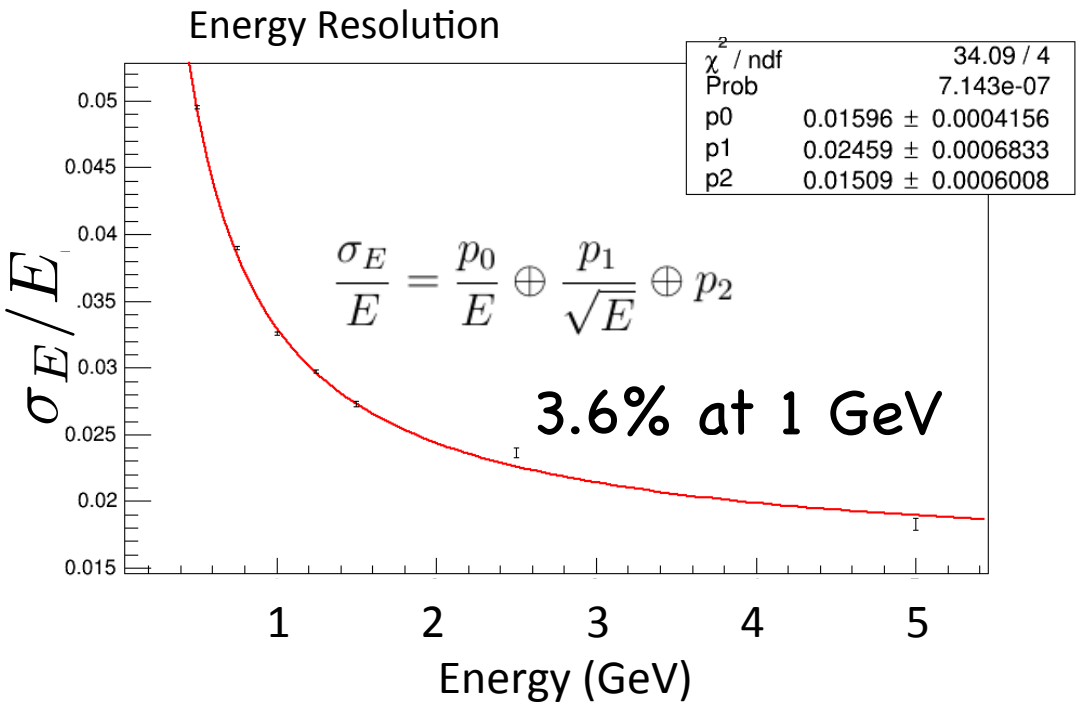
Design and Simulation, Resolution

ECal simulation:

- Energy
- Position
- Opening angle from target

Invariant mass:

$$m^2_{A'} \cong 2E_1E_2(1-\cos\theta)$$



(Excluding 9mm edge)

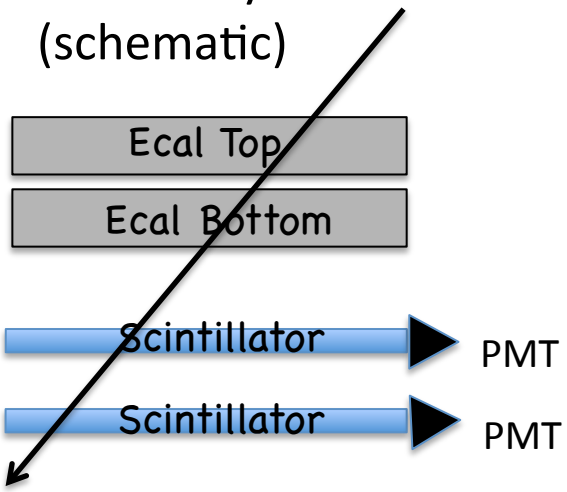
For 100 MeV A' mass and 1 GeV leptons:

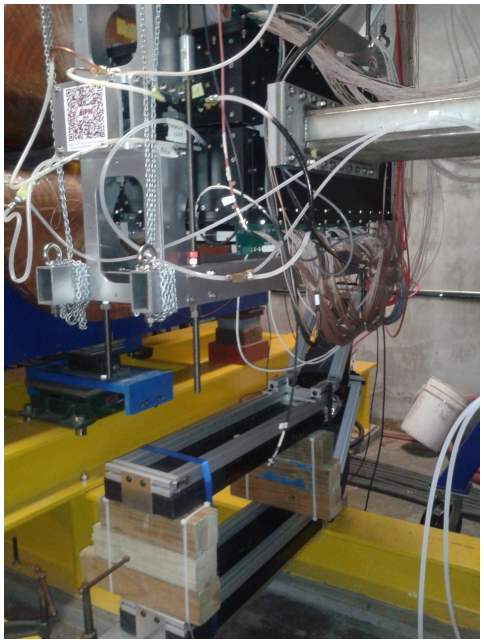
0.5 T B-field

		Mass resolution
ECal alone	$\sigma_E/E = 3.6\%$, $\sigma_\theta \approx 6.3$ mrad	6.5 MeV
SVT alone	$\sigma_p/p \approx 3\%$, $\sigma_\theta \approx 2.5$ mrad	3.7 MeV
ECal and SVT combined	$\sigma_p/p \approx 3\% \oplus \sigma_E/E = 3.6\%$	3.4 MeV

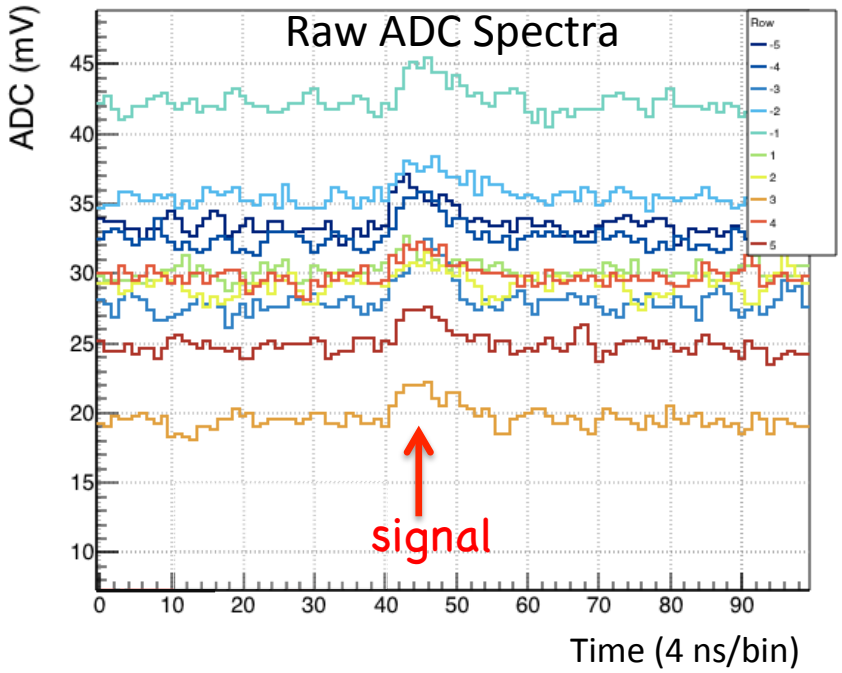
Cosmic Calibration (Low Energy)

Cosmic Layout (schematic)



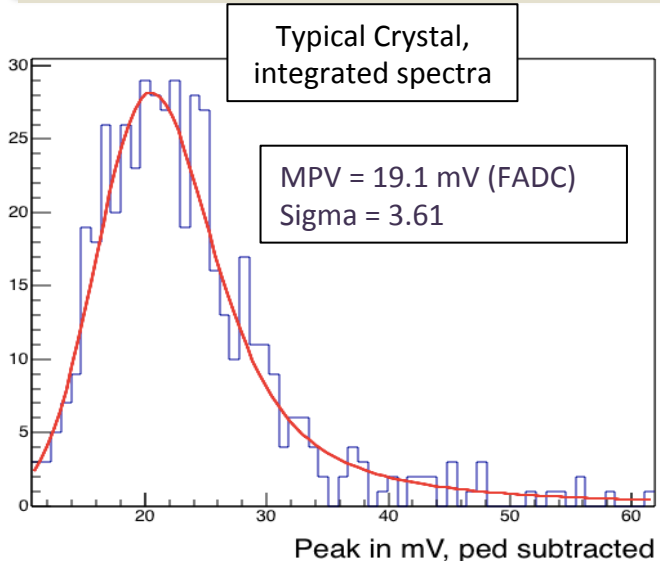


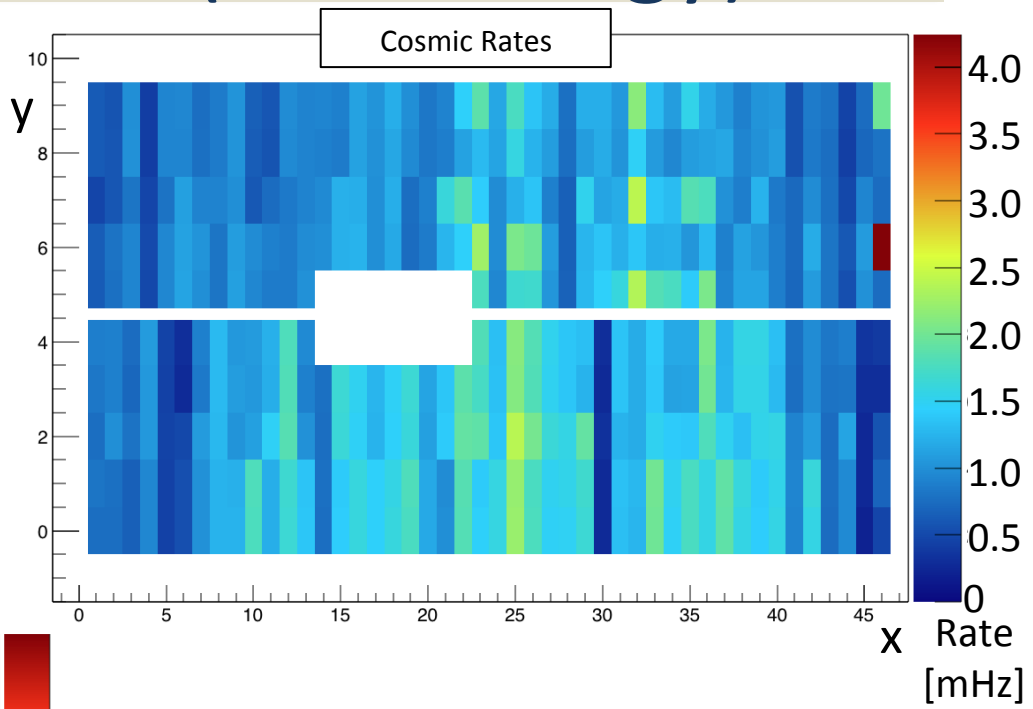
Ecal in Hall B, JLab

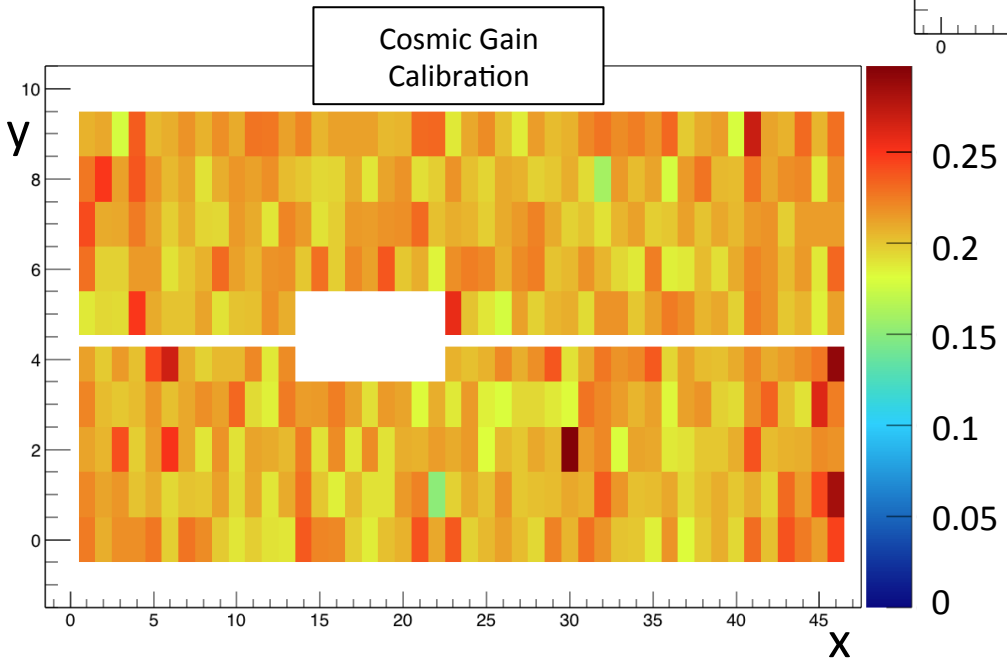


- Data in **raw** FADC mode, integrated over 80 ns window offline
- Energy ≈ 18 MeV/ crystal (simulation)

Cosmic Calibration (Low Energy)





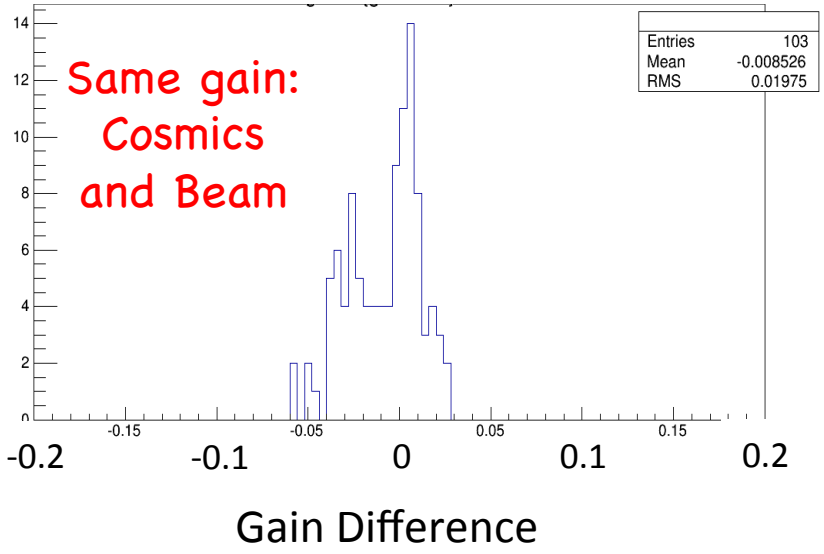


- Fit each crystal's integrated peak with convolution of Landau, Gaussian
- Locate peak of the fit, numerically
- Gain = Energy (MeV)/Peak (FADC)

Beam Energy Calibrations (High Energy)

1) Beam Energy Electrons (1.92 GeV, Dec 2014)

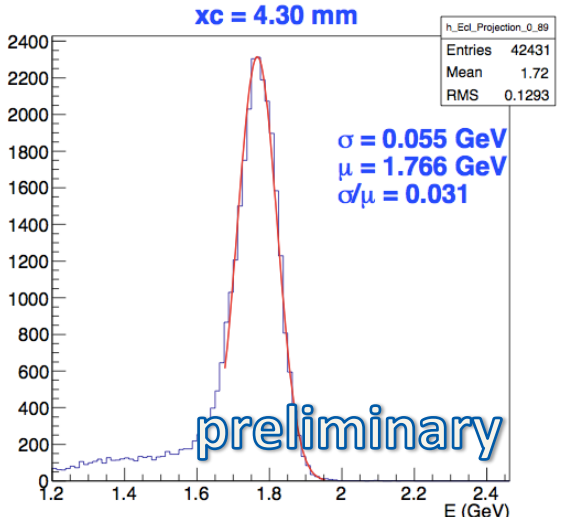
- High energy calibration point
- Limited acceptance
- Agreement with cosmic gains!

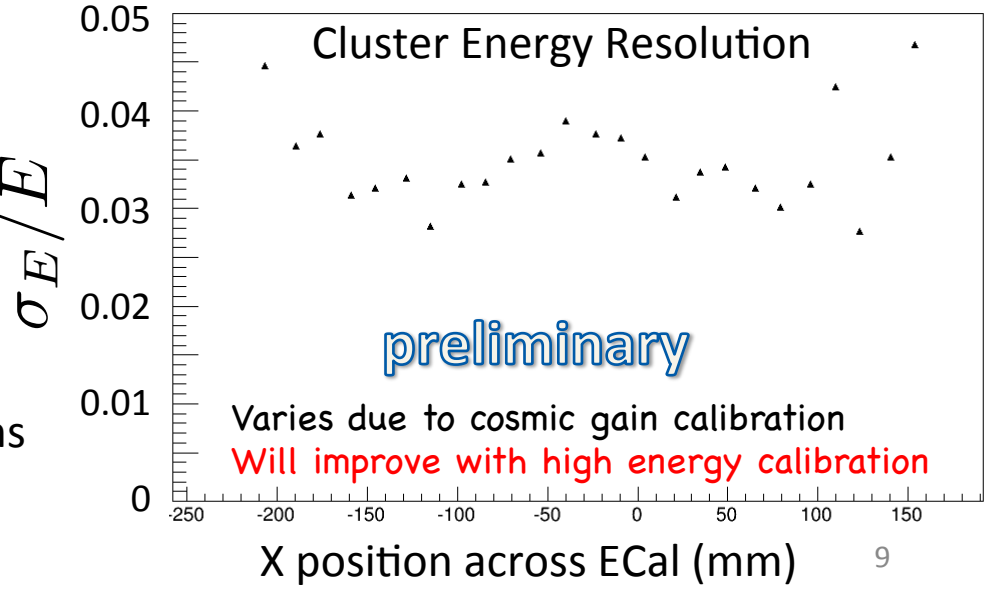


2) Energy calibration using SVT Track momentum

- Covers full range of energies and positions
- Coming soon!! (Spring 2015)

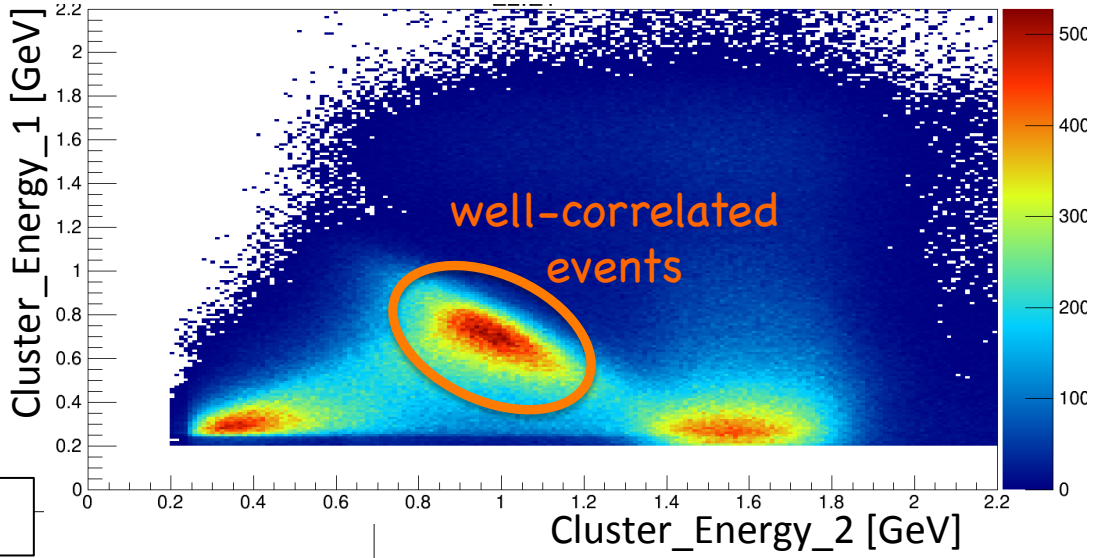
- Cosmic gains used for beam energy electron clusters:

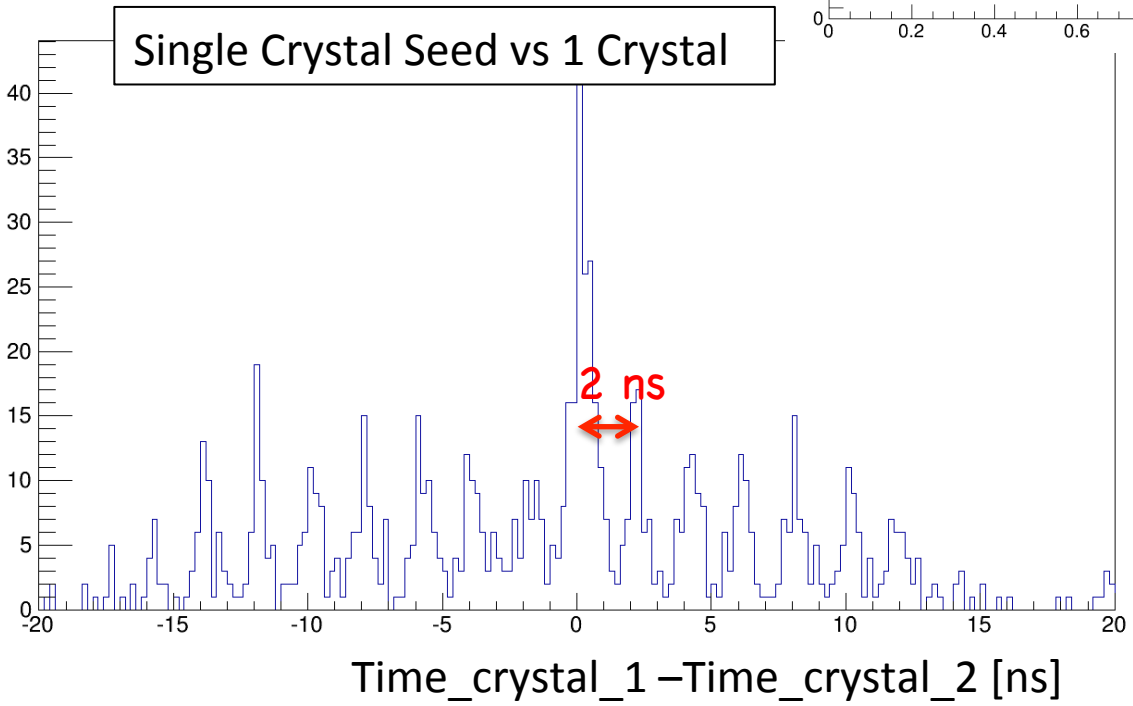




Timing

- Commissioned use of Flash ADCs for signal readout
- Verified time walk corrections
- Two-cluster events (correlated pairs) for resolution and timing studies
- Cluster timing studies





- Beam enters Hall B at 499 MHz
- We can significantly reduce accidentals!

Conclusions

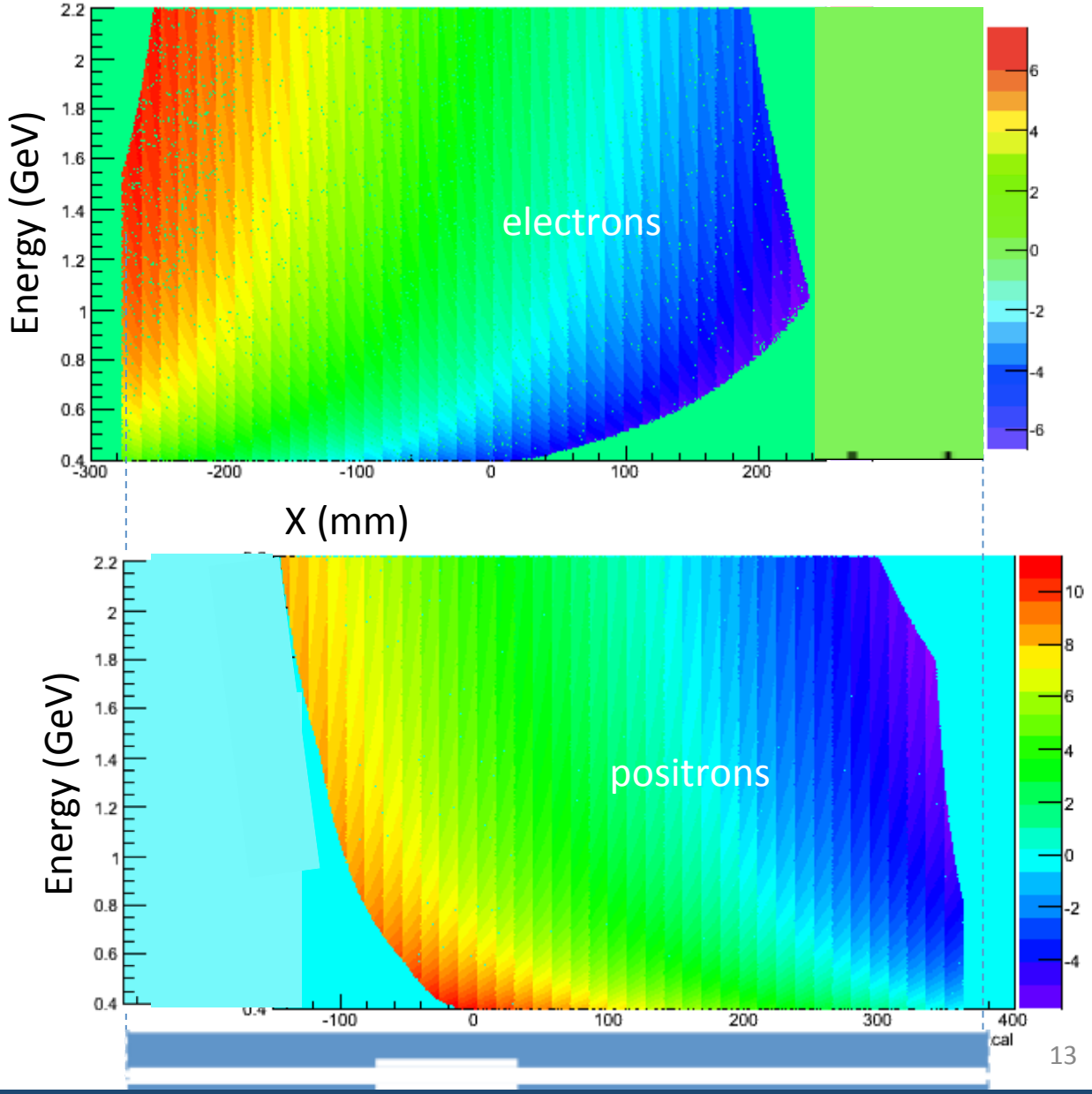
- Electronics upgrades for ECal installed and working
- Allowed trigger to work at start of beam
- Low energy calibration using cosmic ray muons (18 MeV/crystal)
  - Resolved voltage and hardware issues
  - Measured gains, generally uniform
- High energy calibration using beam energy electrons (2 GeV clusters)
  - Gains consistent with cosmic gains within 5%
- Time resolution in 2 cluster events
  - Can be used to reduce accidentals
  - FADC time granularity 4 ns

The ECal is commissioned and ready!

ECal + SVT Acceptance

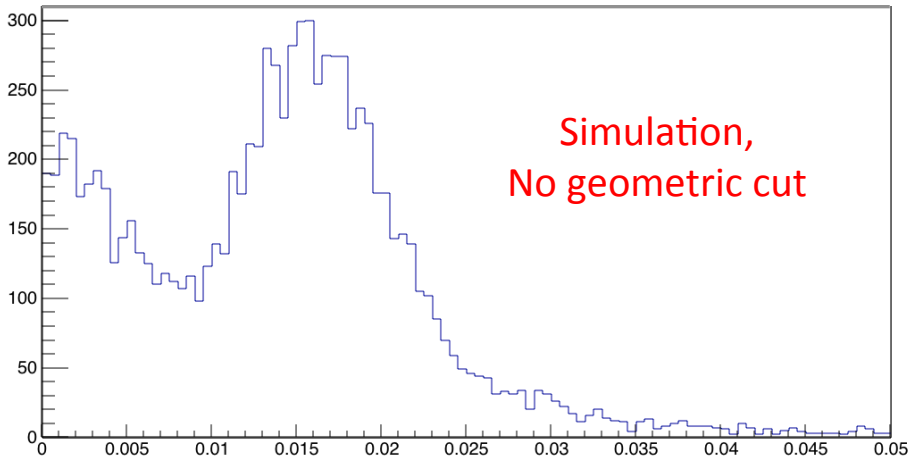
Color corresponds to angle with respect to crystal axis.

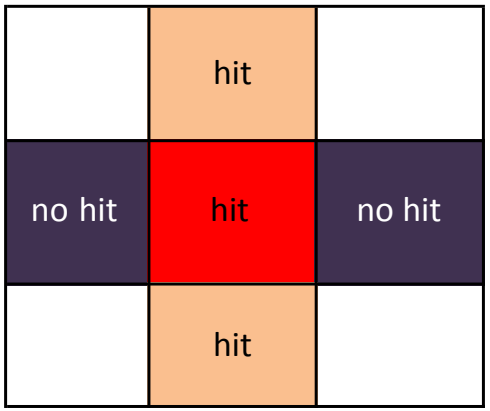
with at least 3 SVT layers hit

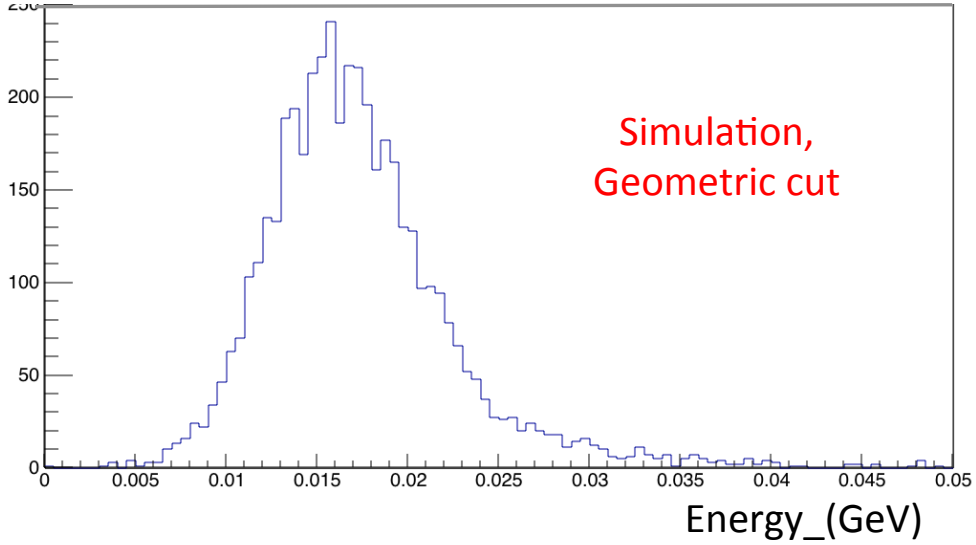


Cosmic Geometry Cut

Energy deposited in single crystal







Rates		
	Simulation	**Actual**
Trigger	4.5 Hz	5-6 Hz
Cuts		MIP energy cut (scintillator) removes 70%
	Geometry cut removes 90%	Geometry cut removes 90%
Per crystal	~9 mHz average, 4 mHz side crystals	~4 mHz average, 2 mHz side crystals