Forward Electromagnetic Calorimeter Calibration Status

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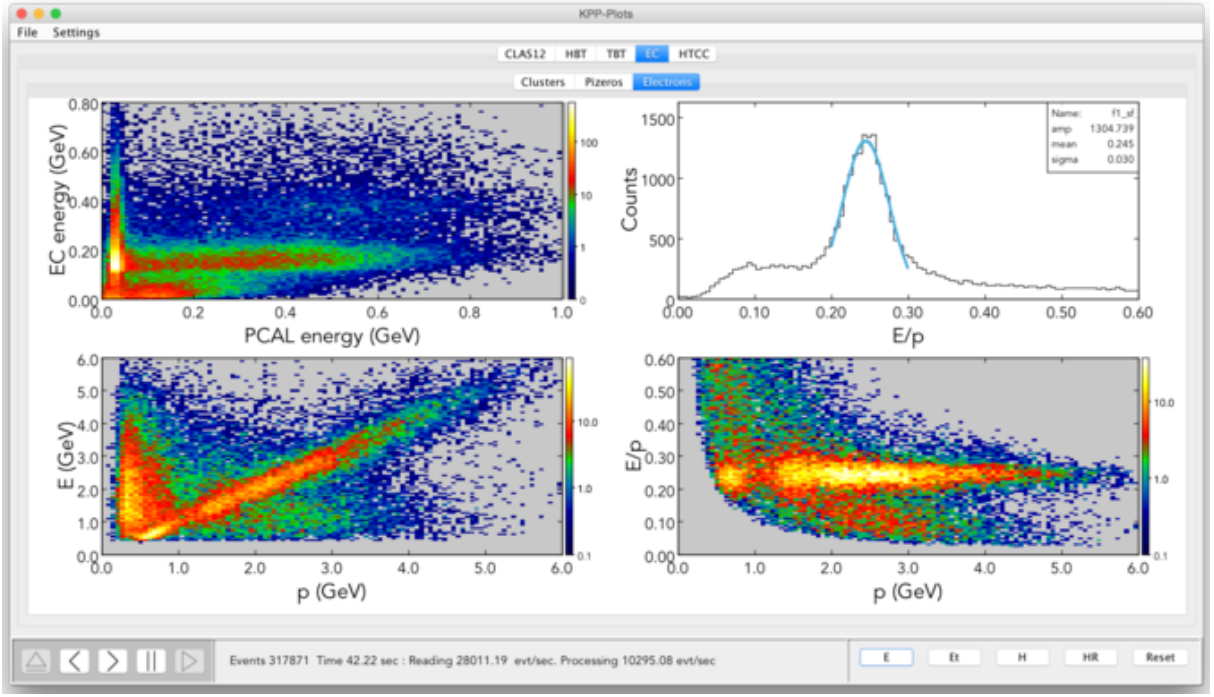
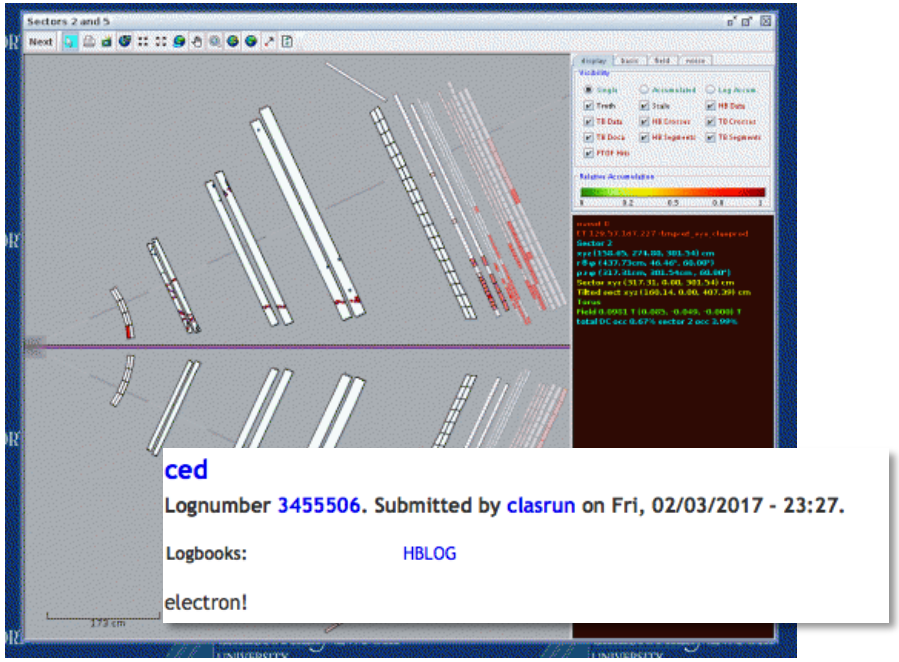
- Using KPP pions and pizeros to evaluate cosmic muon calibrations
- Future plans

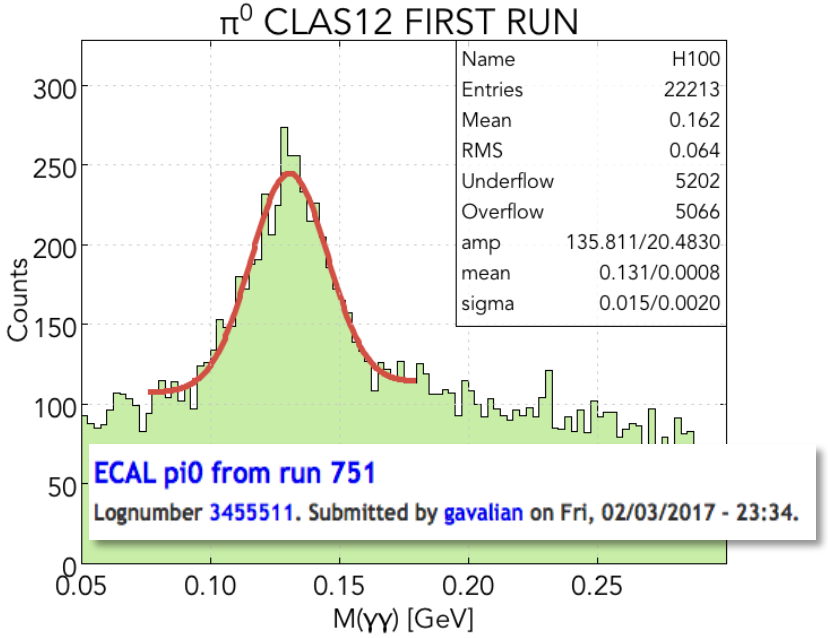


PCAL/EC calibration satisfied KPP requirements.

1. What can KPP data tell us about calibration quality?
   a) Pions vs. muons
   b) Pizero invariant mass
   c) Electron E/P

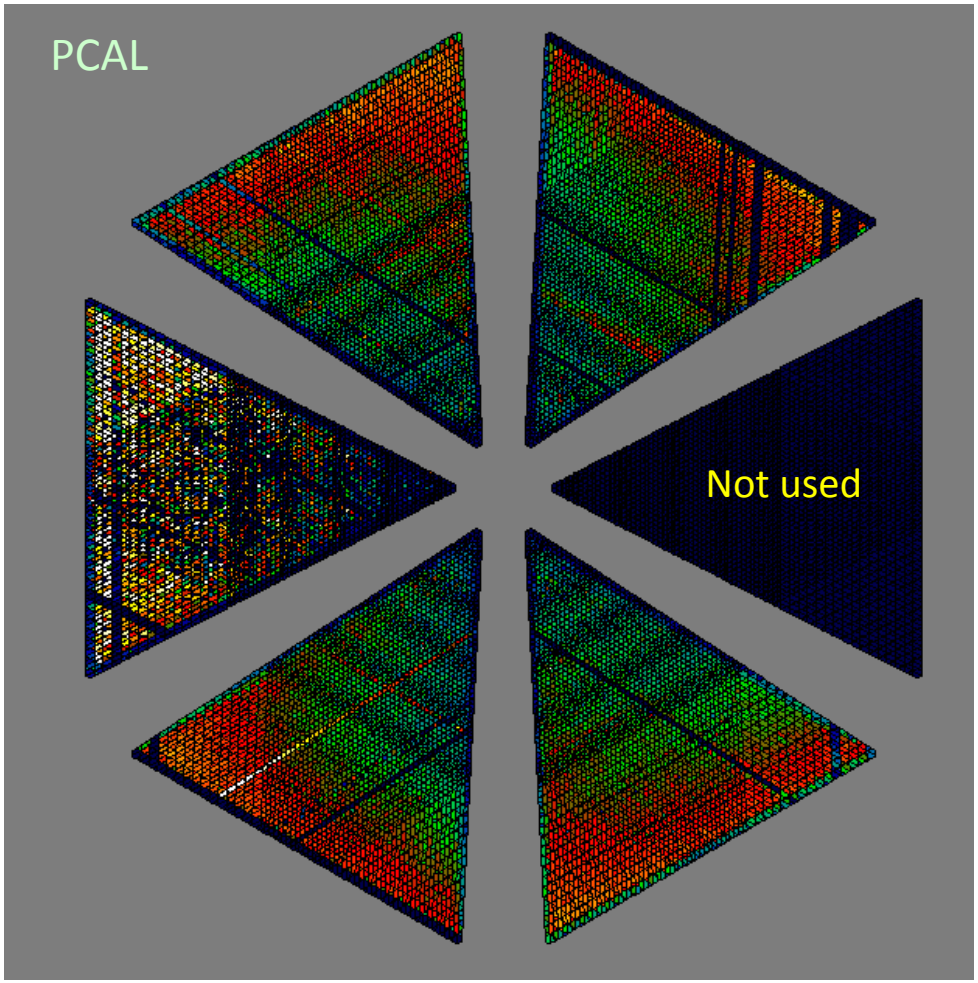
2. What can be done to improve absolute energy calibration and resolution?

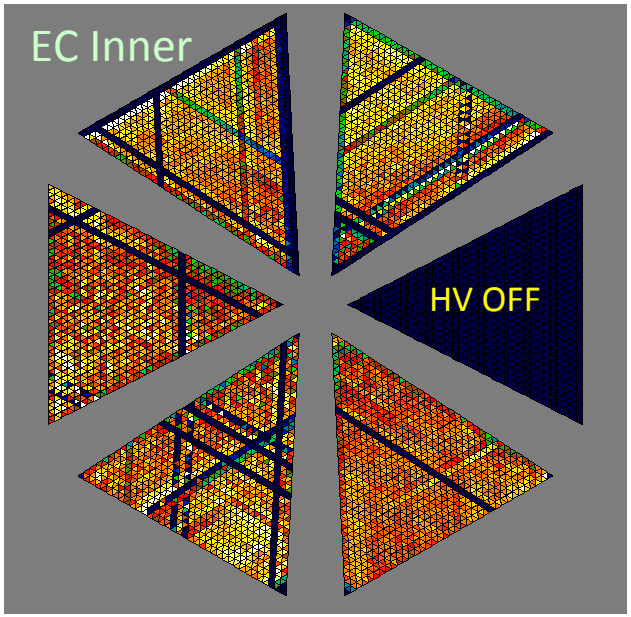


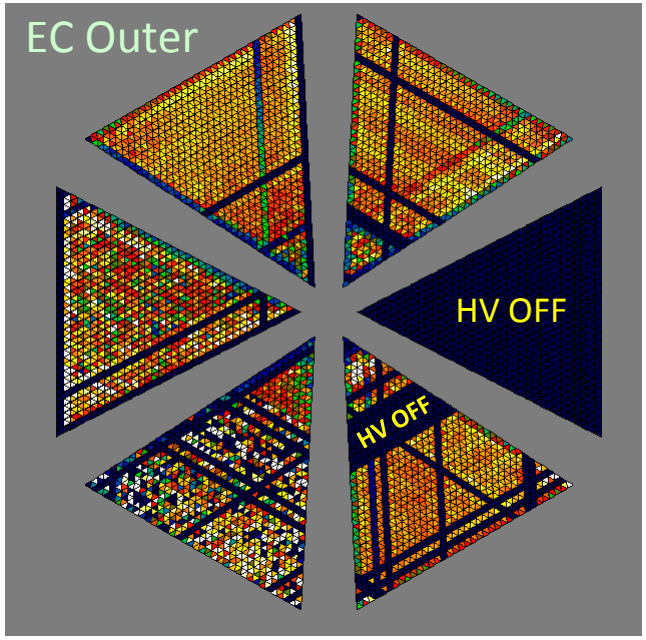


Status of PCAL/EC During KPP

- Strips missing: Kinked cables, BNC/LEMO issues, dead PMTs.
- Strips weak, hot, inefficient: Cable swaps, PMT gains.
- Sector 4 off due to light leaks in EC (except run 809).
- Group of HV cables never installed in EC.Outer.S5 due to obstruction.

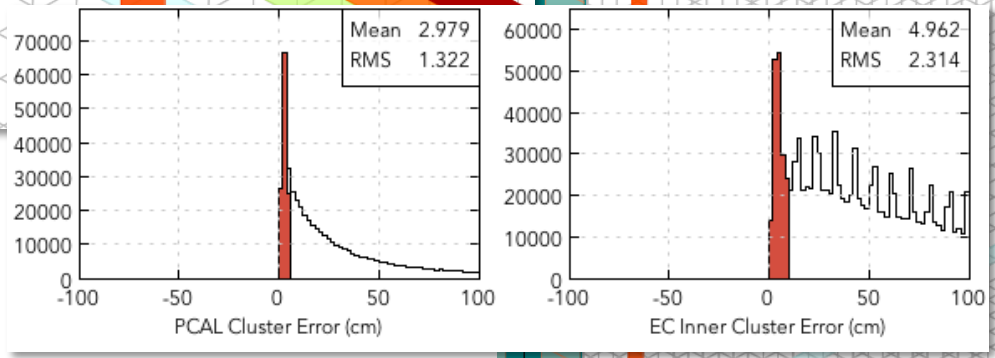






FADC/FPGA trigger: clusters identified using Dalitz rule and energy weighted strip numbers.

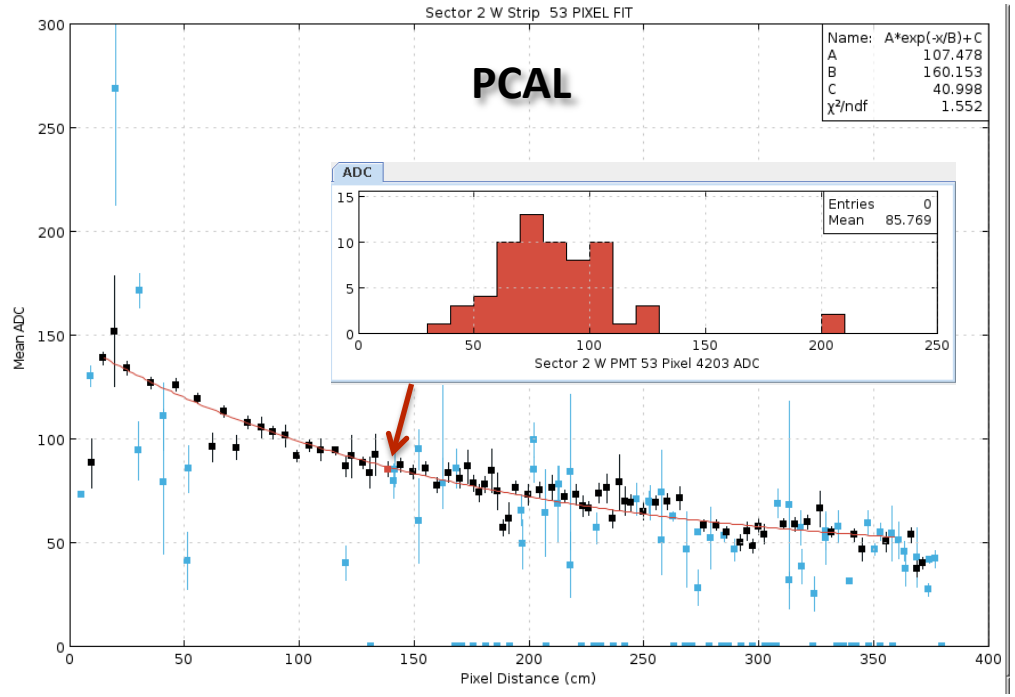
ECEngine: clusters found using geometry database for strips.

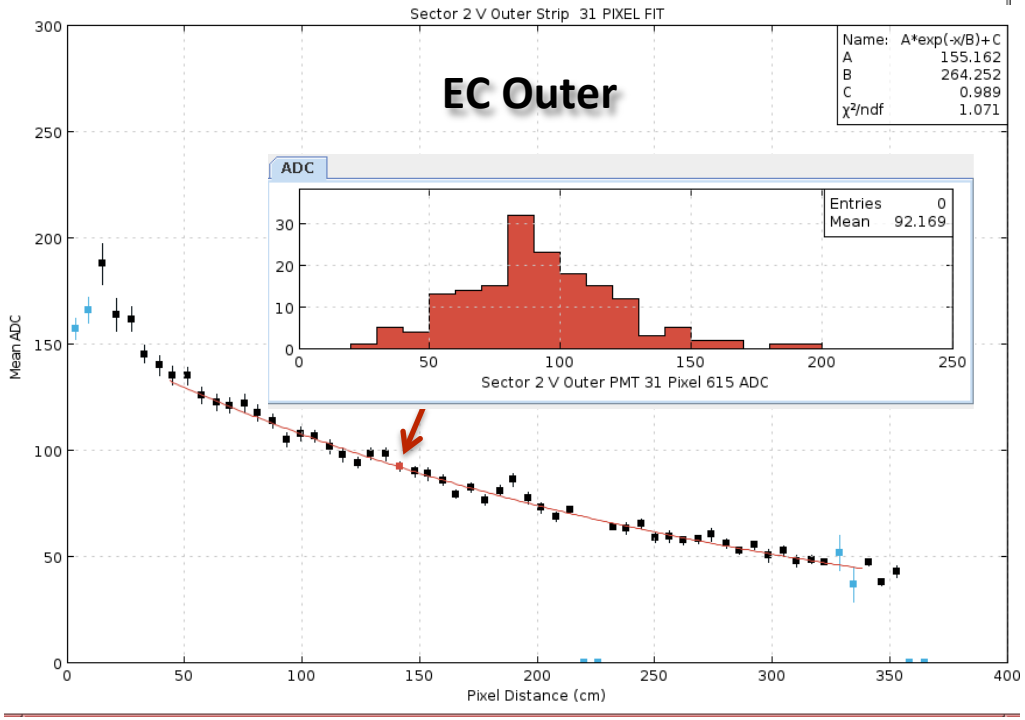


- **Peak:** set of contiguous energy-weighted strips (no gaps).
- **Cluster:** Overlap of 3 peaks.

Pixel: Cluster containing only 3 strips. Used for calibration.

event 10
Hipo File clas12_000761_a00009.hipo
Sector 3
lab xyz (-9.91, 181.45, 694.33) cm
lab ρφ (181.72, 93.13)
sector xyz (162.10, -82.14, 694.33) cm
sector ρφ (181.72, -26.87)
loc xyz (-146.528, -82.139, 0.000) cm





Gain and Attenuation Corrections using Cosmics

ADC CALIBRATION

CLAS 6: 10 ch/MeV
CLAS 12: 150 ch/MeV (PCAL)
100 ch/MeV (EC)
50 ch/MeV (EC Sector 5)

Fit *scaled* mean ADC vs pixel distance *x* from end of scintillator strip using 3-param function:

$$\frac{MeanADC}{scale} = A \times \exp(-x / B) + C$$

CCDB/calibration/ec/gain
10*MIP/[scale*(A+C)]

CCDB/calibration/ec/attenuation
A/(A+C) B C/(A+C)

MIP = 10 MeV (PCAL, EC inner) 16 MeV (EC outer)
scale = 5 (Sector 5) 10 (other sectors)

ECAL::clusters: Reconstructed Position, Energy and Time

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   {"name":"coordW",      "id":18,  "type":"int32",  "info":"W coordinate"}
```

energy: Corrected for PMT gain variations and light attenuation. No S.F. correction.

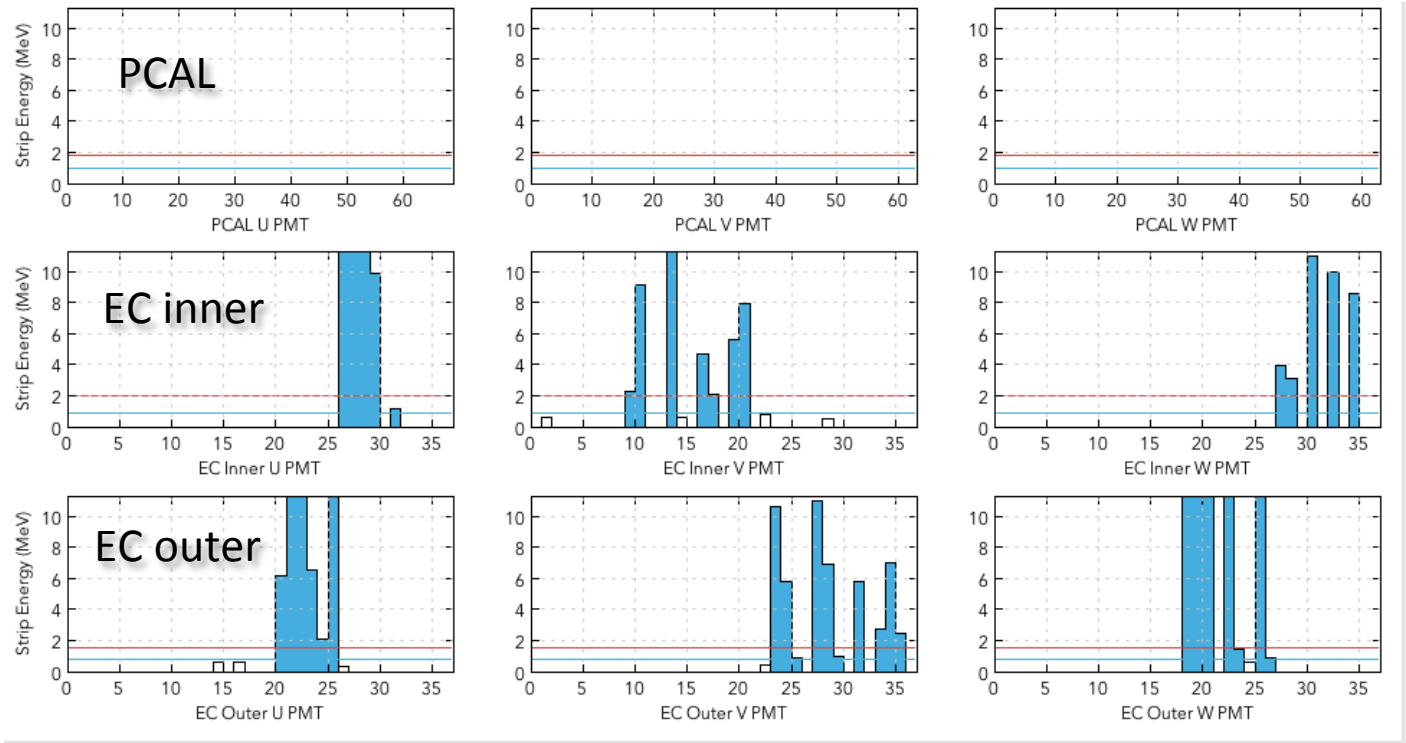
x,y,z: Lab frame coordinates of clusters

- Spatial distribution of PMT gains (x vs. y normalized to MIP energy)
- Pathlength of MIP tracks

coordU,V,W: Effective coordinate of strip with maximum energy in U,V,W peak.

- Used in FADC/VTP trigger reconstruction banks.
- Allow to evaluate cluster energy dependence on individual PMTs.

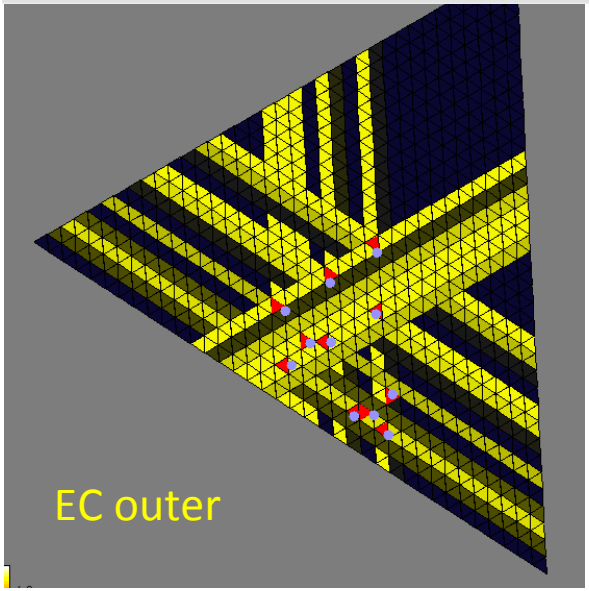
Rejection of Vertical Cosmic Triggers: Cluster Multiplicity Cut



Empty

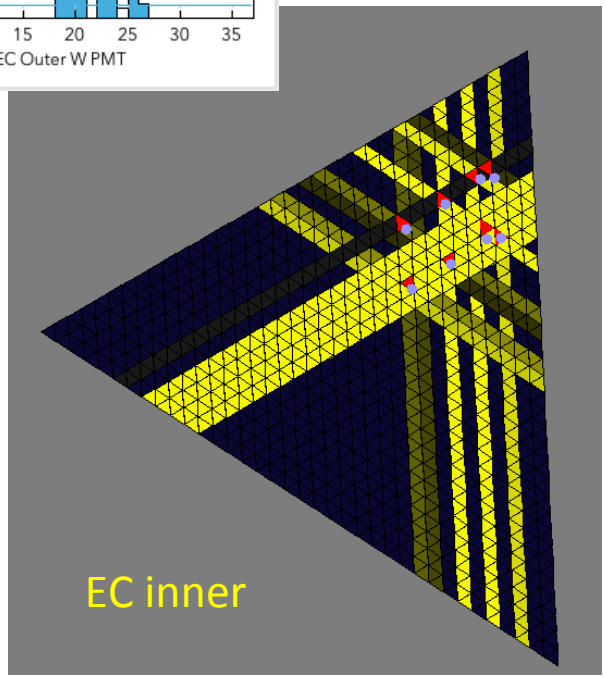
Multiple peaks

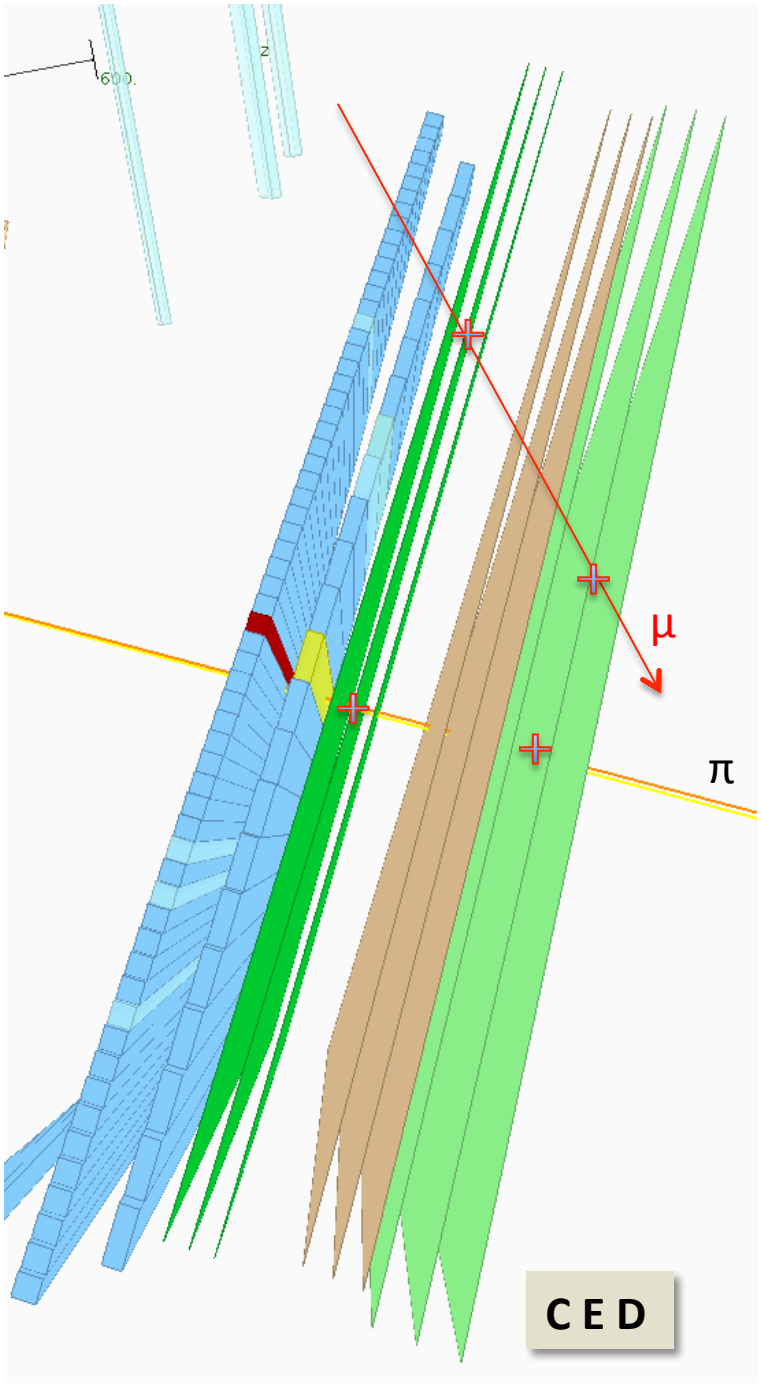
EC inner and EC outer peaks not correlated



Vertical tracks from cosmics produce large number of clusters.

Requiring only 1 cluster per layer rejects these events.

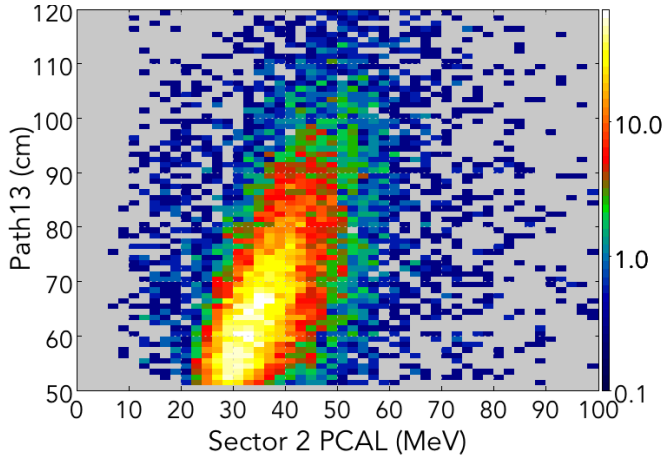




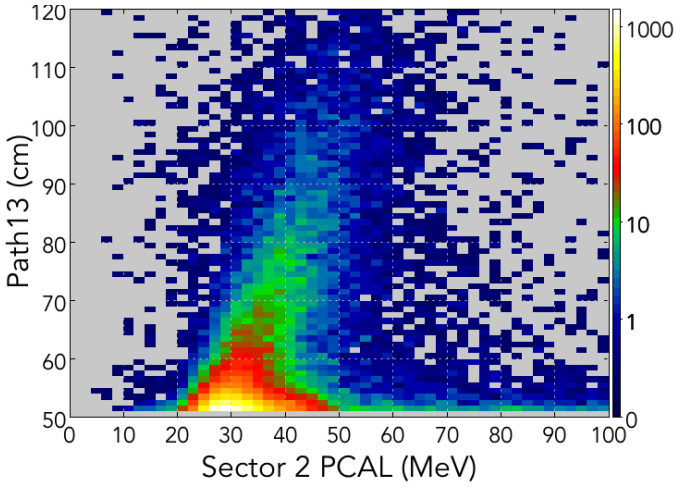
Rejection of cosmic tracks

Tracks which pass cluster multiplicity cut can still be rejected using track path-length:

$$path\,ij = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \quad i,j = 1:PCAL \;\; 2:ECin \;\; 3:ECout$$



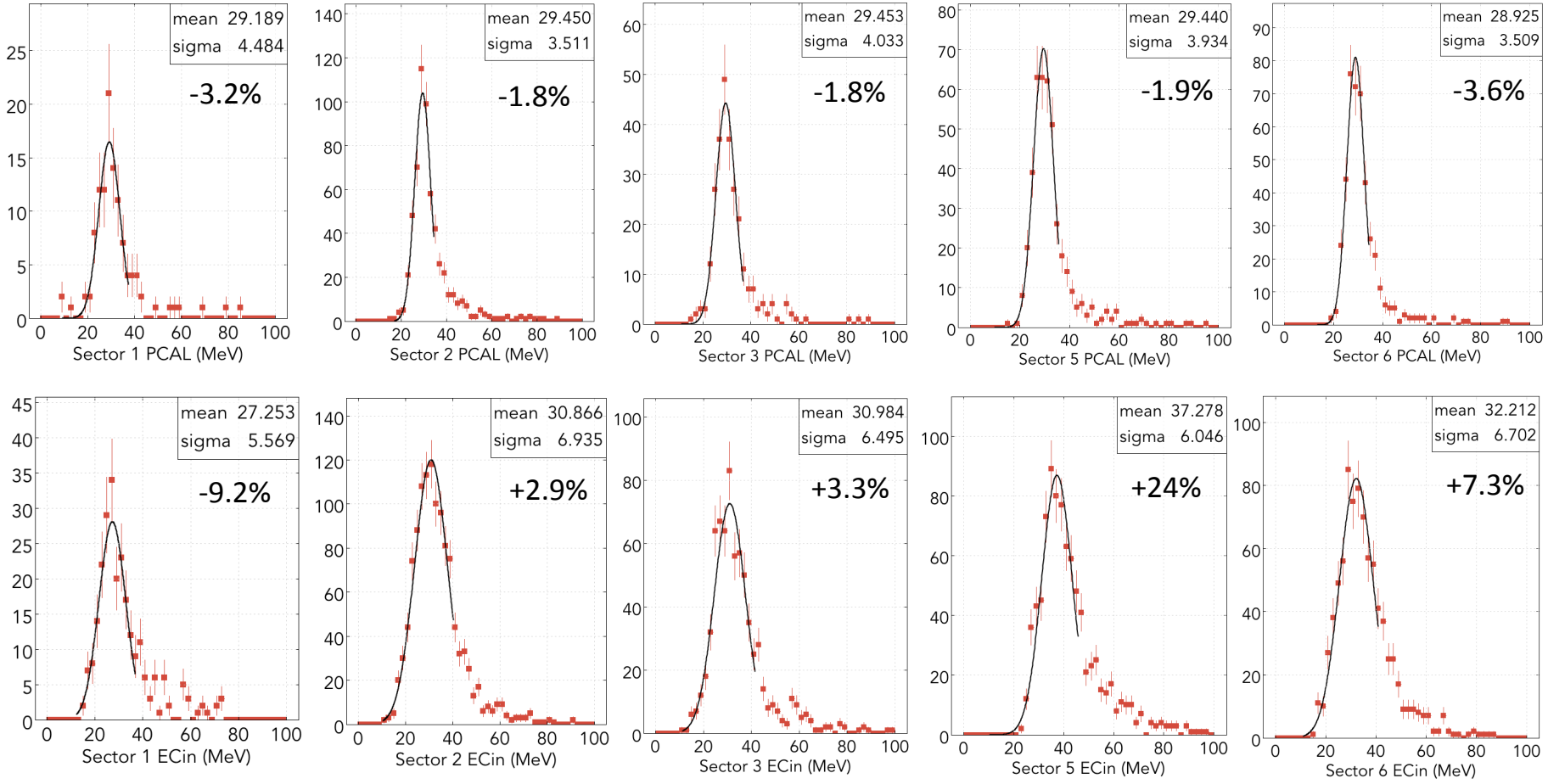
Run 760
Low threshold. Beam off events show pathlength distribution of cosmic triggers.



Run 809
High threshold. Triggers dominated by short pathlengths at MIP energy of 30 MeV.

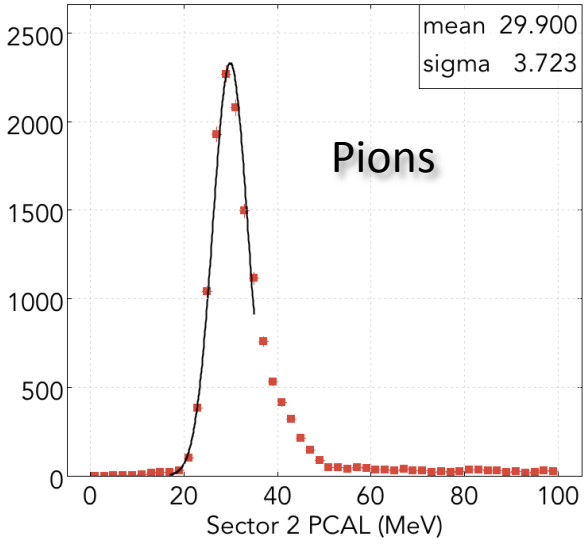
Cosmic Triggers: Reconstructed Muons from KPP Run 760

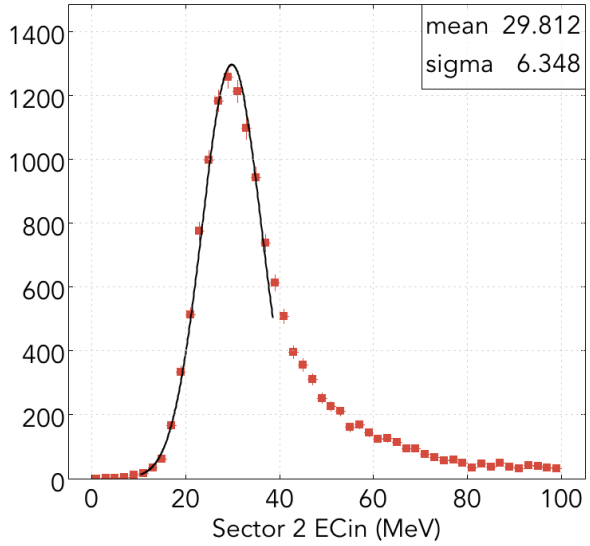
- Pass1 cooking using CCDB constants from post-KPP cosmic run
- Runs 752-767 used low threshold EC Inner cluster six-sector trigger
- Expected MIP cluster energy in PCAL and EC Inner is 30 MeV.
- Cut on **1 cluster per layer** and **path12 < 34 cm**, **path23 < 20 cm** (<10% path variation).

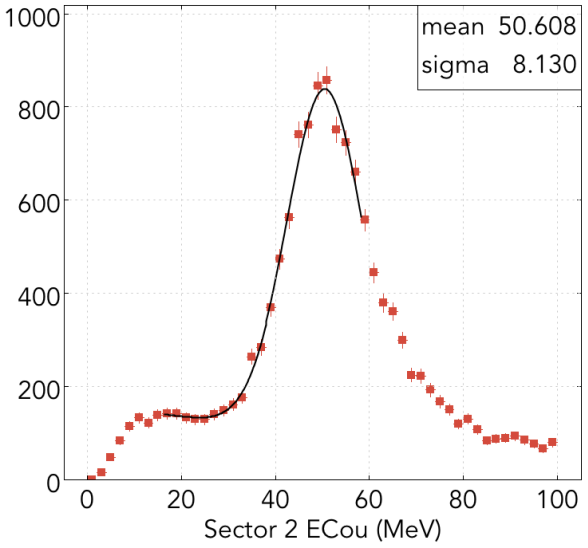


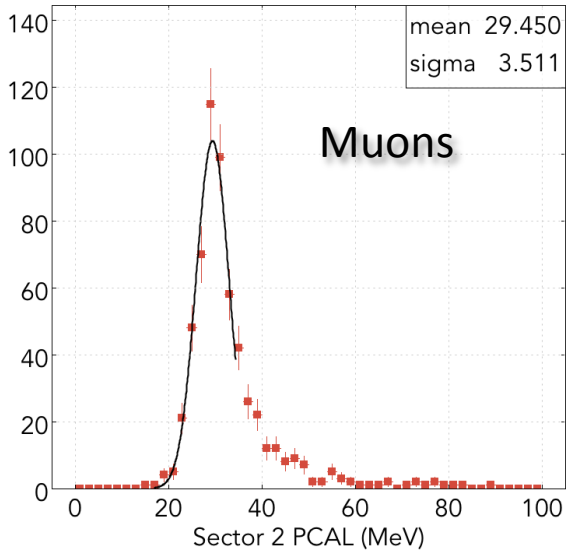
Pion Triggers: Reconstructed Pions Compared to Muons

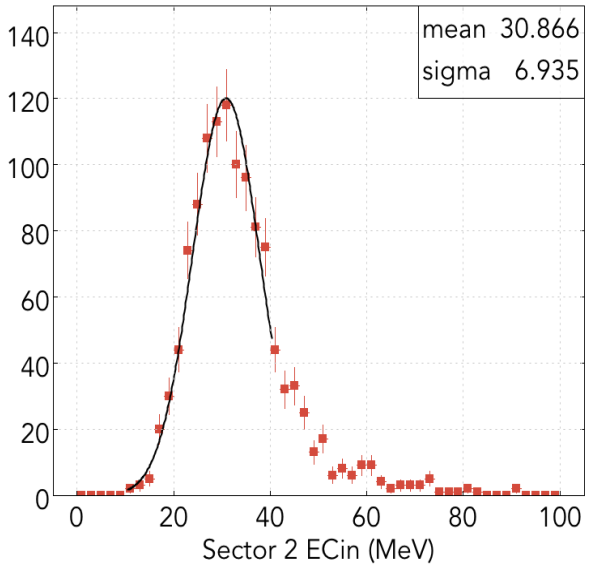
- Identical cuts for both
- Expect 30 MeV for PCAL, EC Inner and 48 MeV for EC Outer.

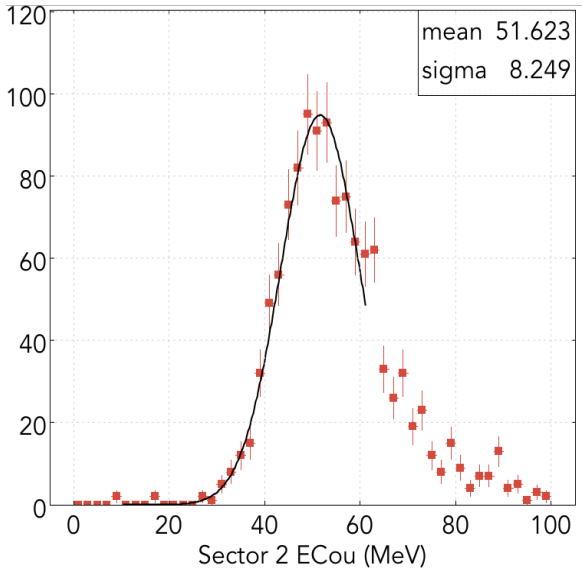




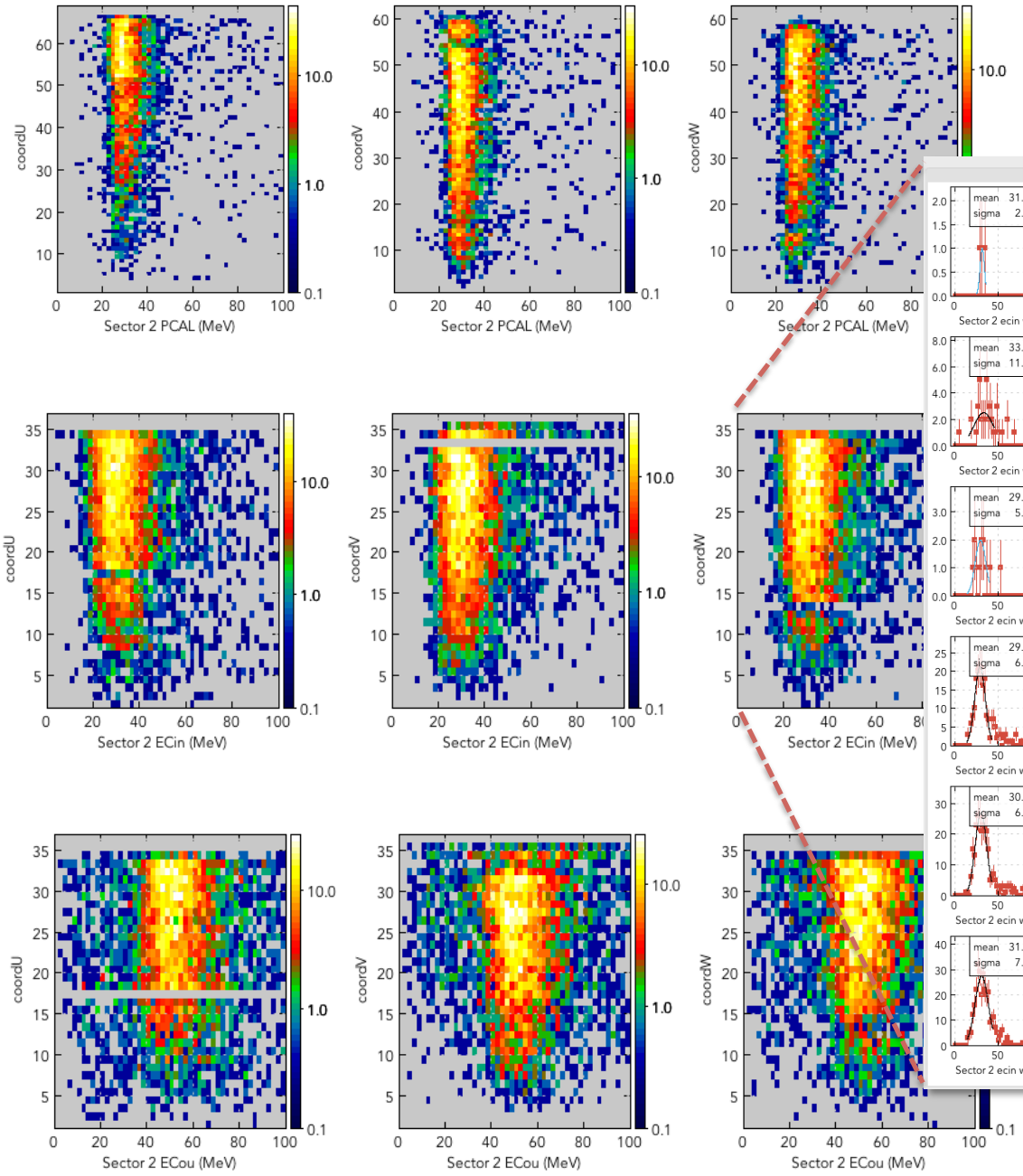








Pion Triggers: Reconstructed Cluster Energy vs. PMT with Largest Peak Energy



ECAL::clusters

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```
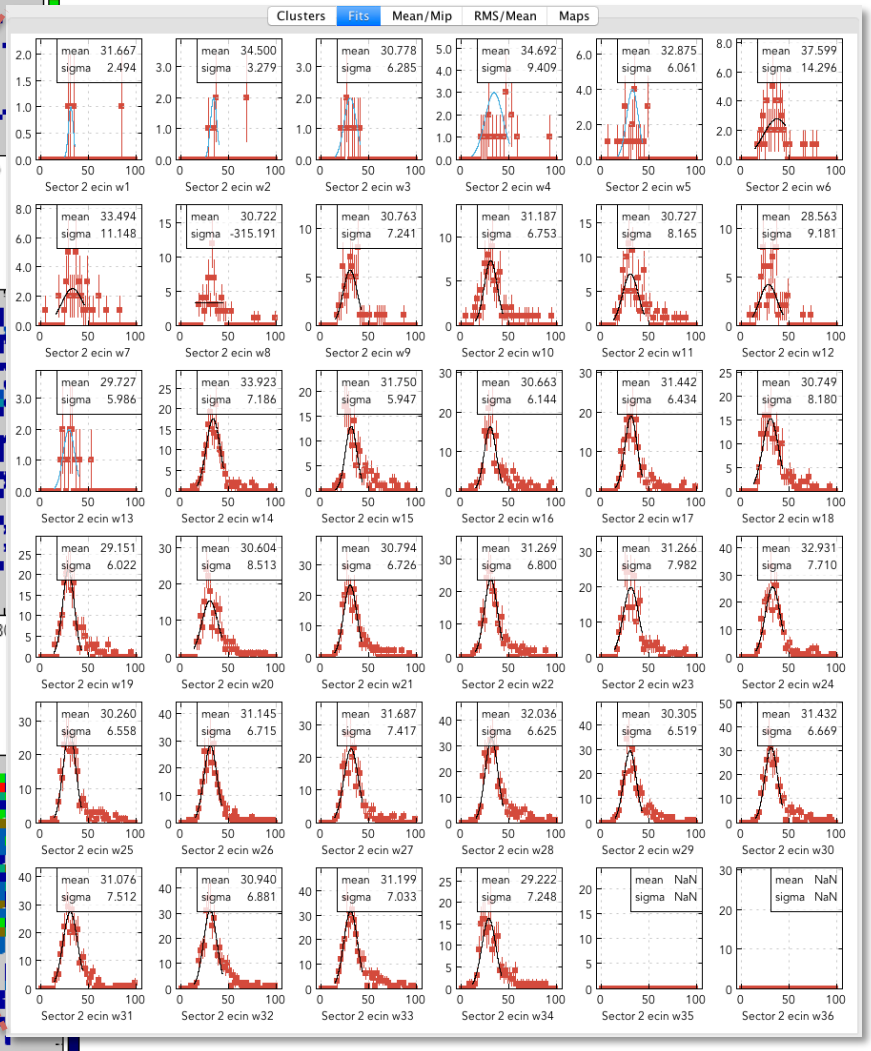

Fits to PMT slices



New ECAL Banks in Pass 2 Cooking

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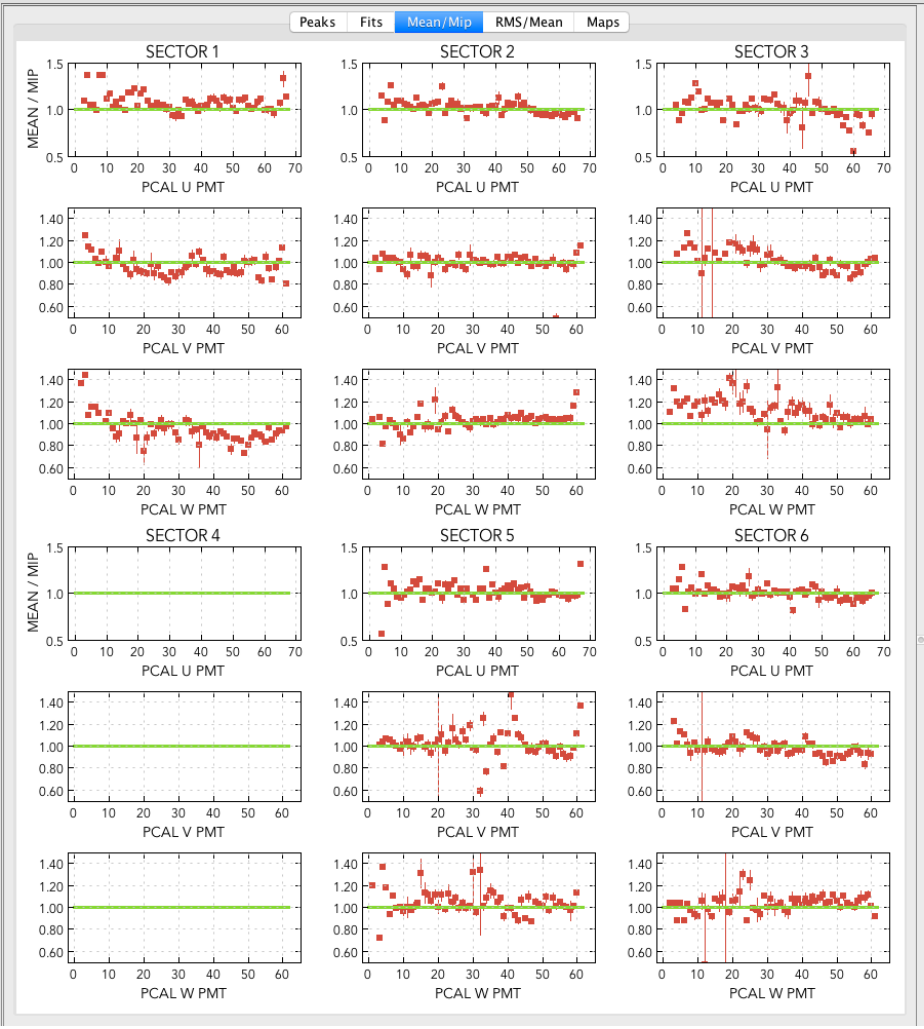
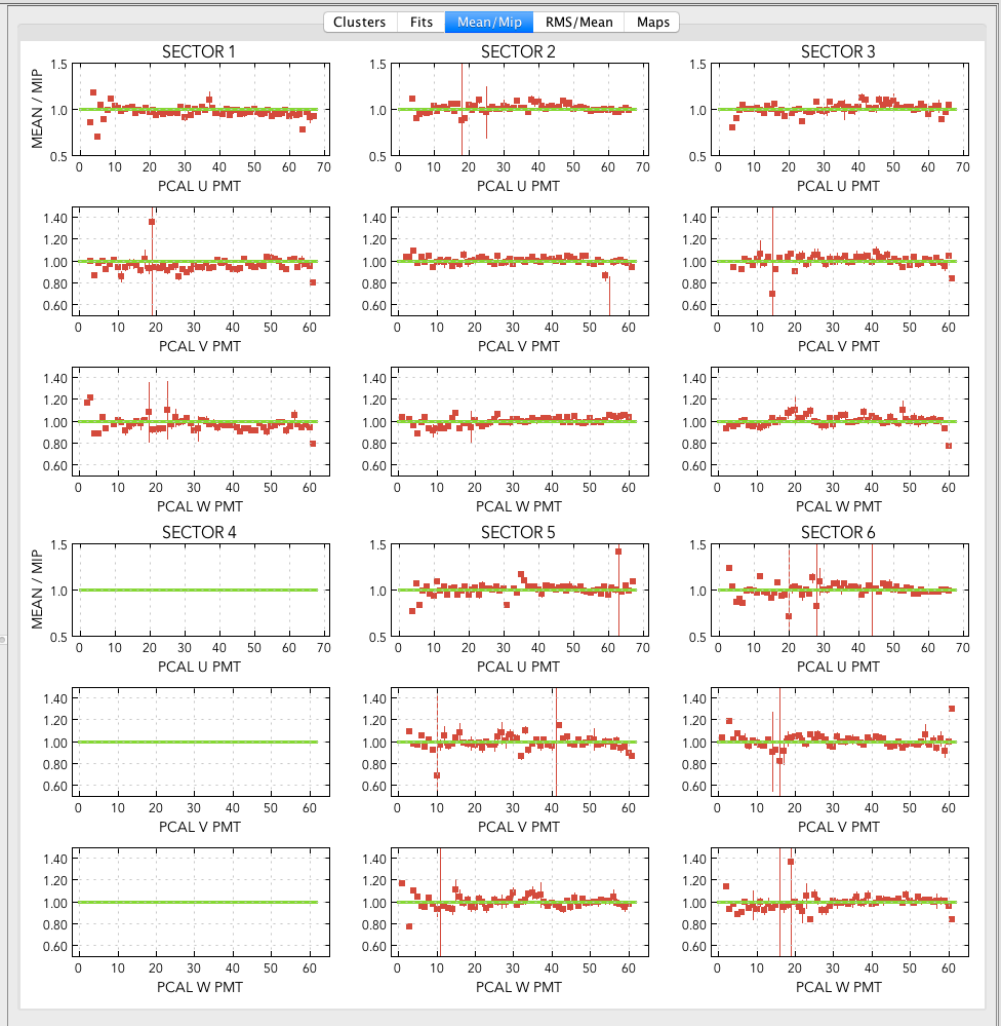
Reconstructed peak energies now available

Pion Triggers: Summary of Reconstructed Peak and Cluster Energies for PCAL

PEAKS



CLUSTERS

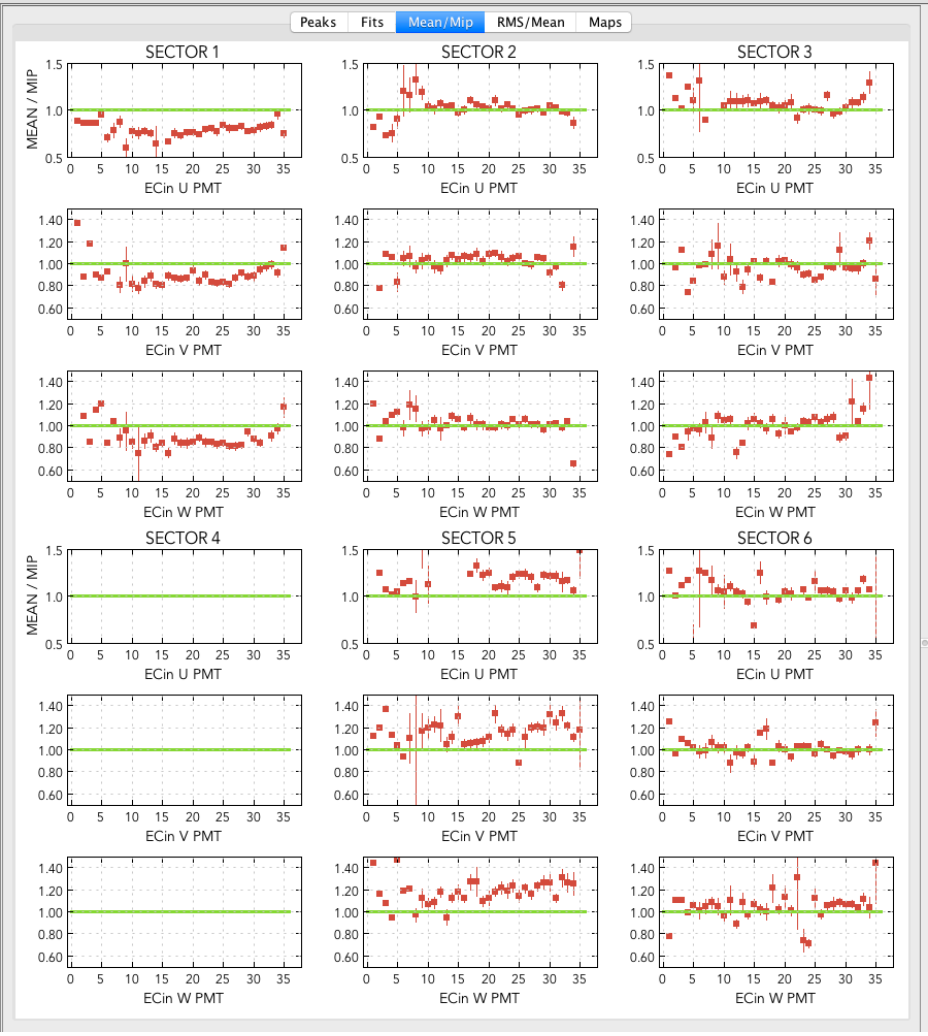


Notes:

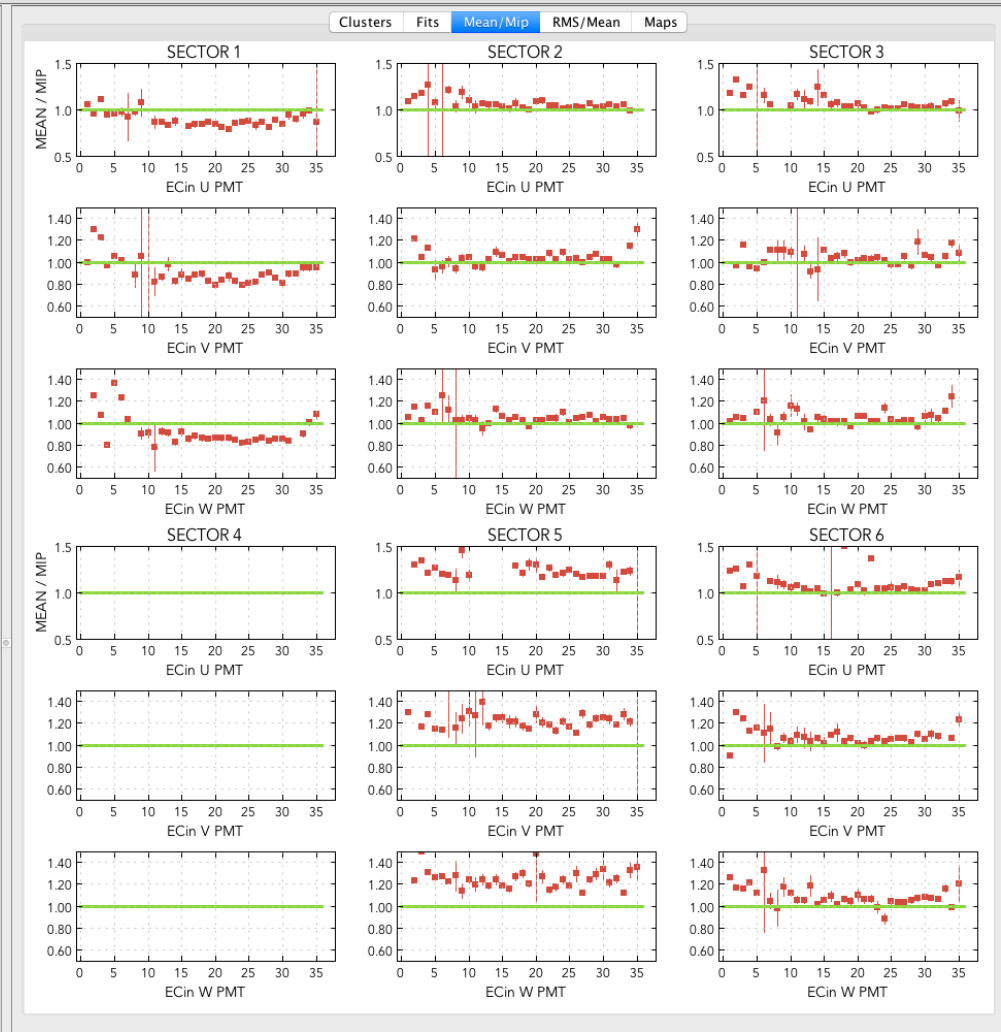
1. Cluster energies close to desired values. Mostly +/- 5% variance.
2. Peak energies show some systematic variance absent in cluster energies.
3. Possibly some geometry issues that cancel out in energy sum?

Pion Triggers: Summary of Reconstructed Peak and Cluster Energies for EC Inner

PEAKS



CLUSTERS

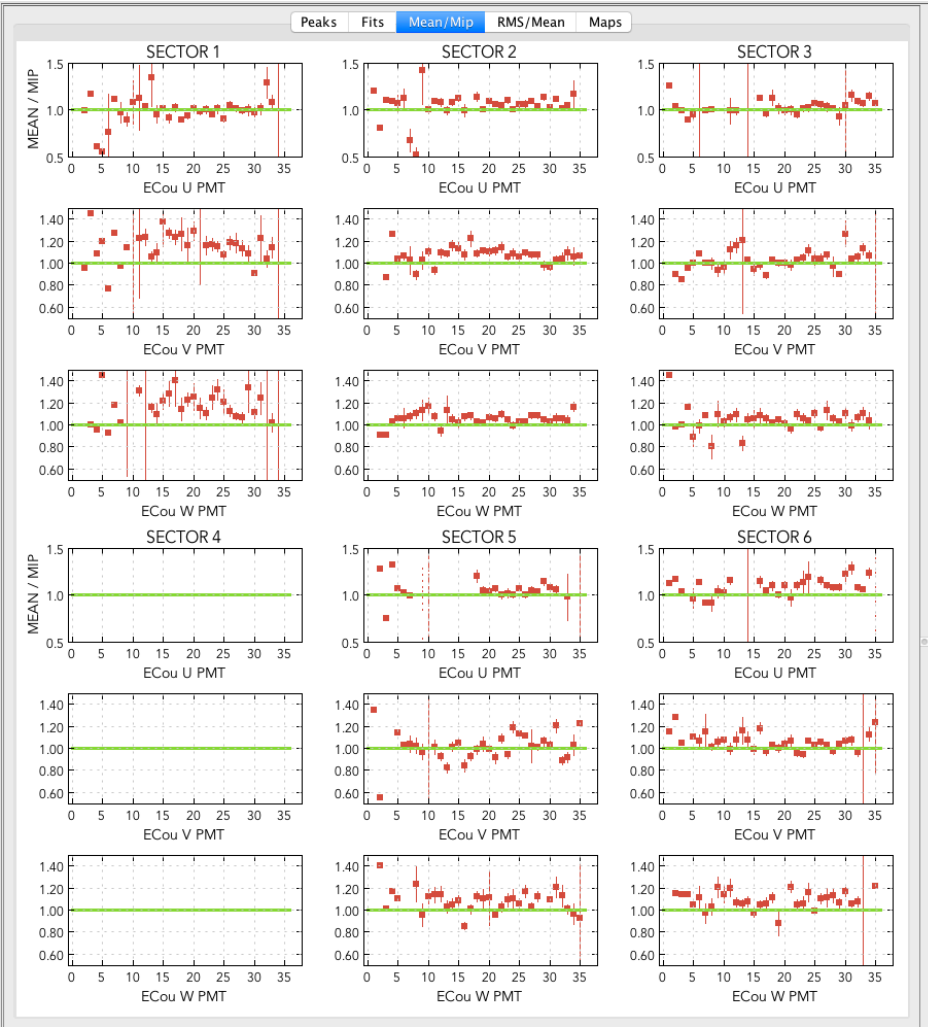


Notes:

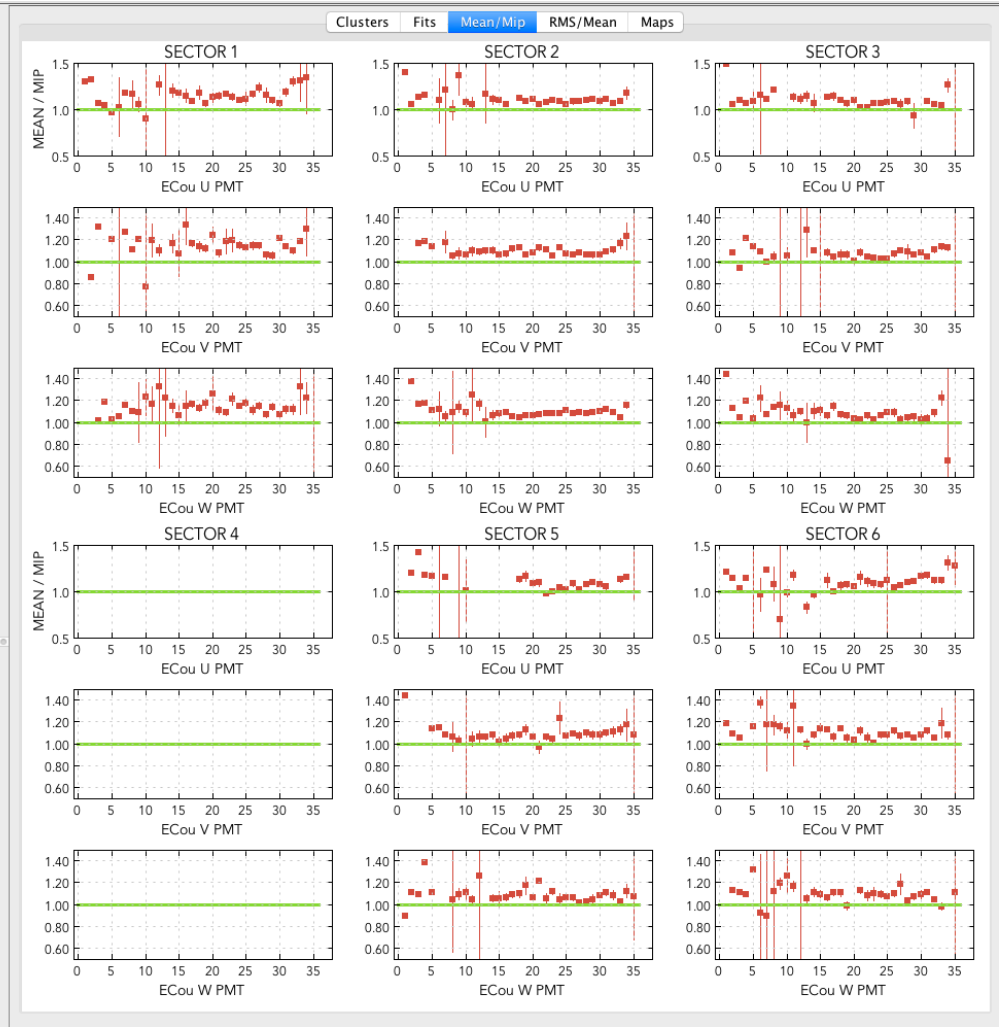
1. Similar variance in gains for peaks and clusters.
2. Sector 1 20% low while Sector 5 20% high. Reason unclear.
3. Gain outliers due mostly to missing strips causing mis-calibration of adjacent strips.

Pion Triggers: Summary of Reconstructed Peak and Cluster Energies for EC Outer

PEAKS



CLUSTERS

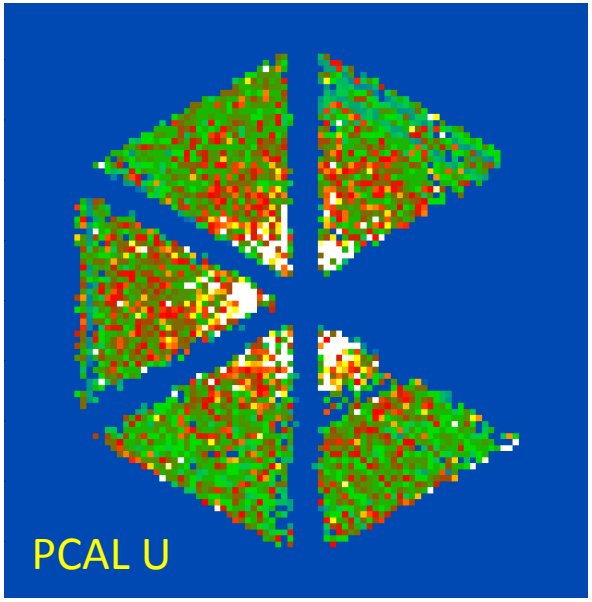


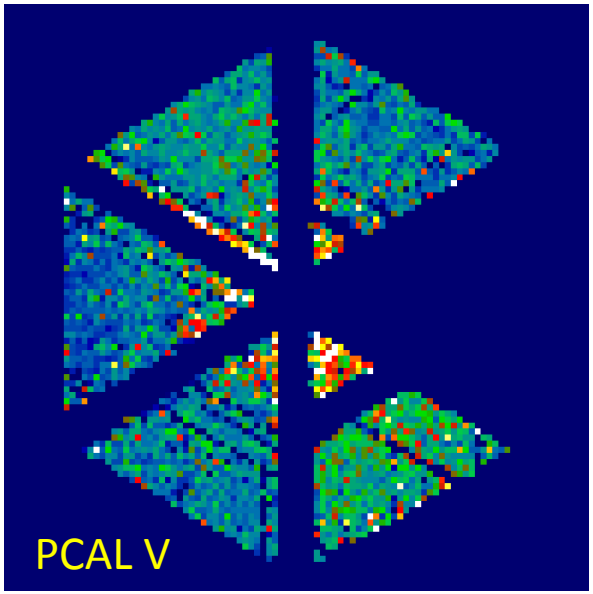
Notes:

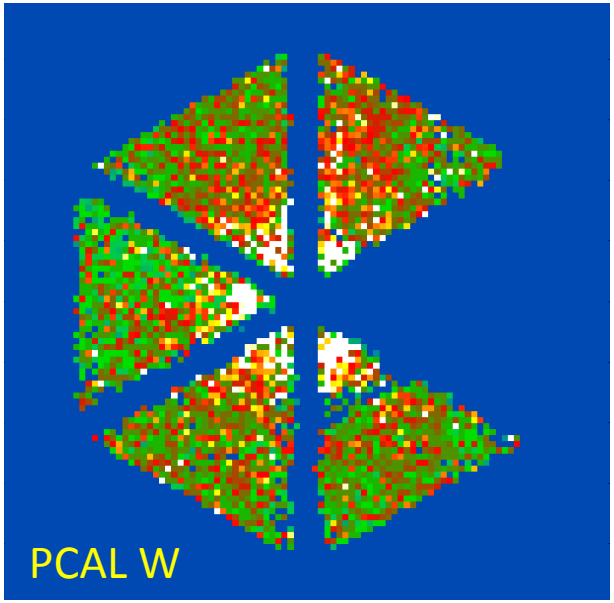
1. Generally larger (5-10%) than expected MIP energy.
2. Could be hadronic interactions. Need to look at muons in all sectors.

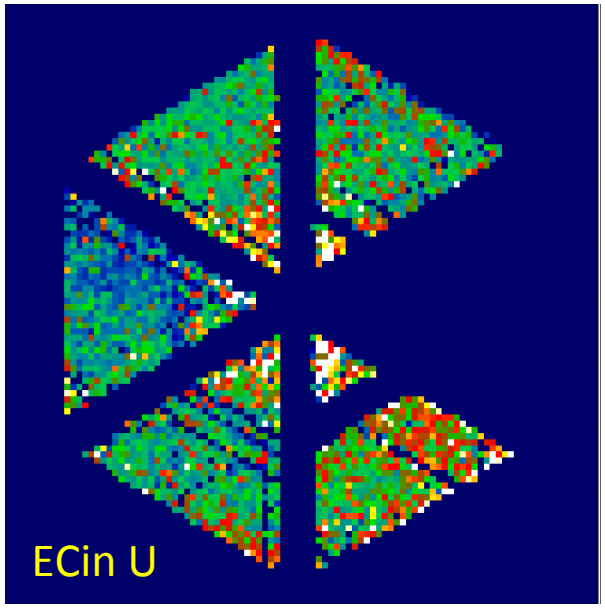
Pion Triggers: Detector Maps of Reconstructed Peak Energy

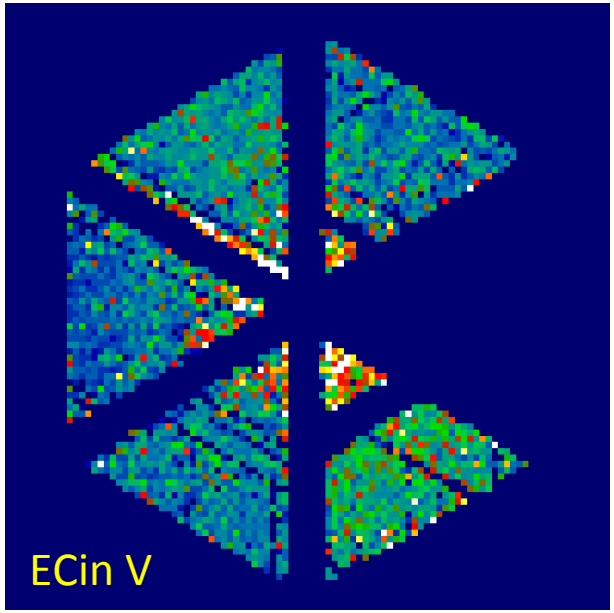
Used for debugging attenuation corrections

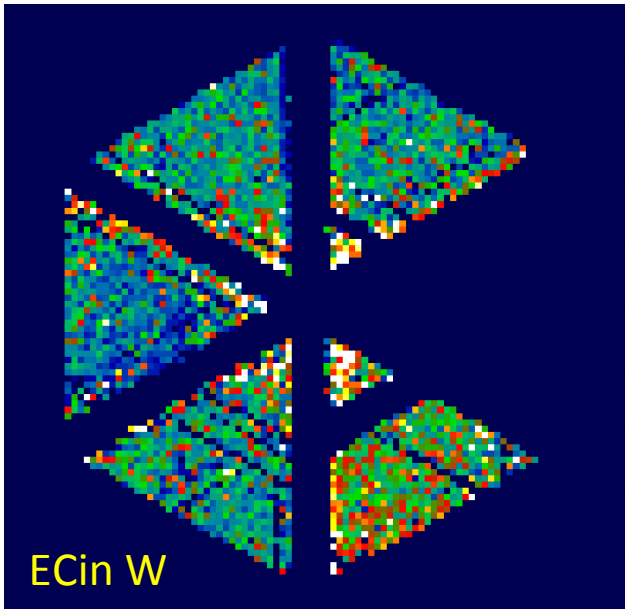




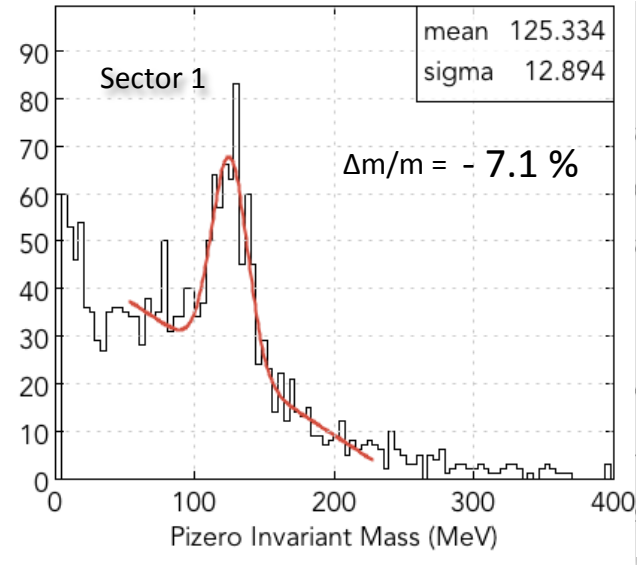


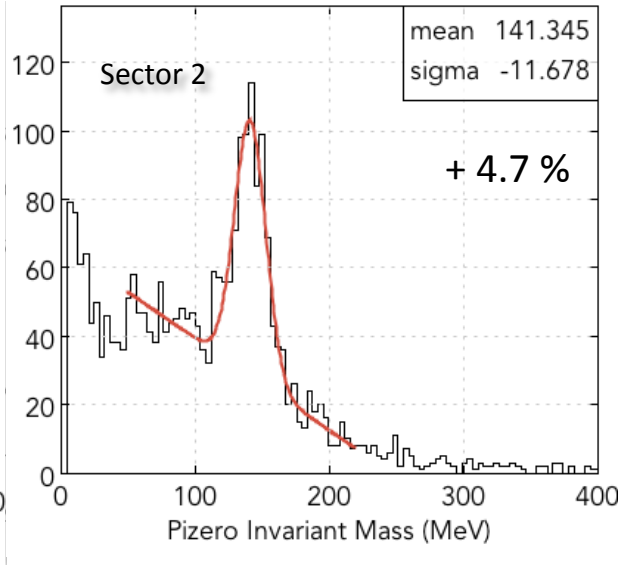


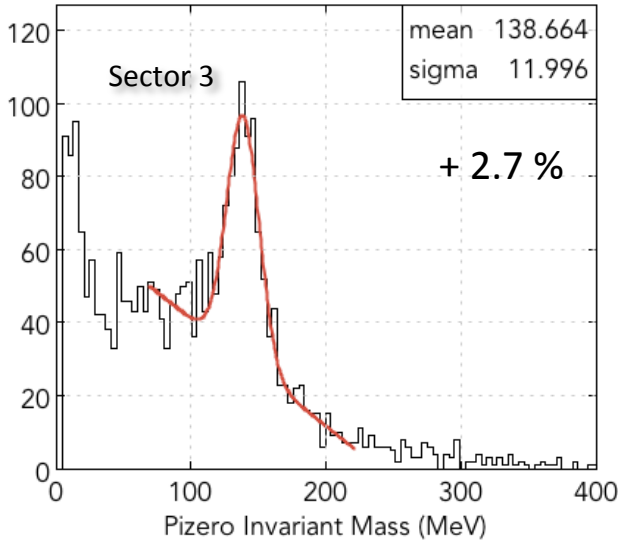


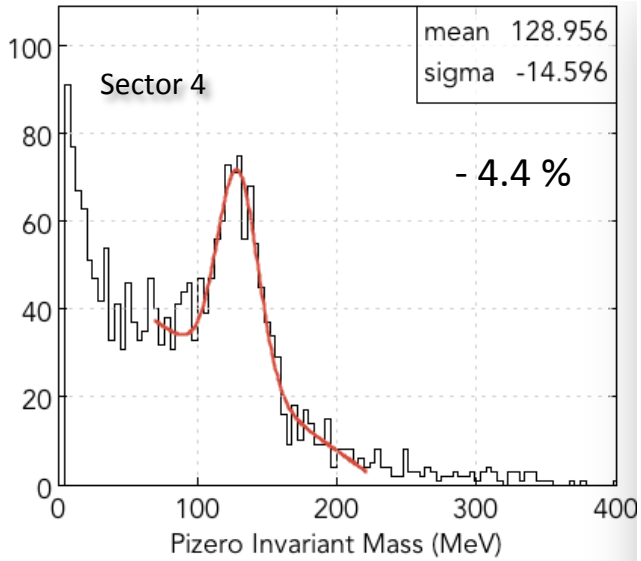


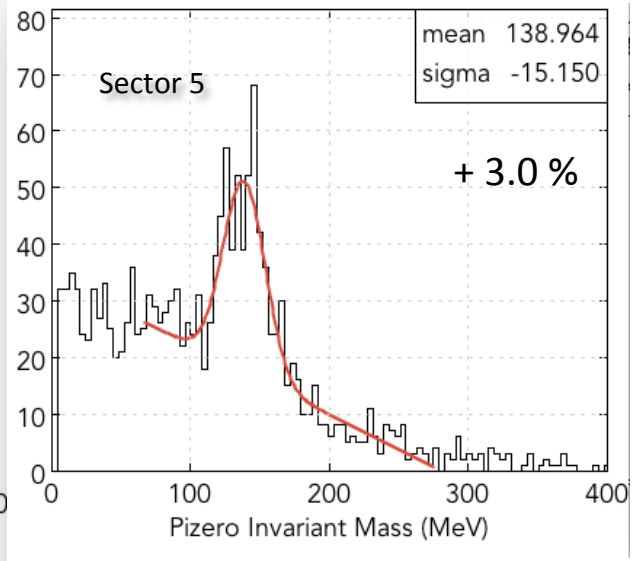
Run 809: High Threshold Six-Sector Trigger – Pizero Invariant Mass from Two-Photon Decay

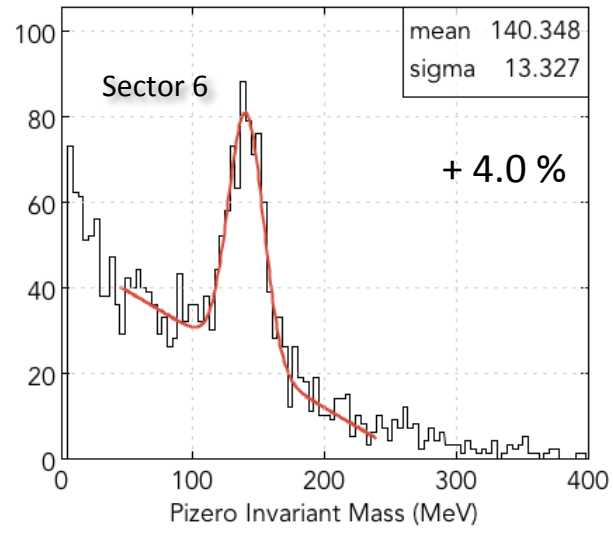












Notes:
1. Lower mass in S1 as expected from Run 760 calibration check
2. Worst resolution in S5 due to variance between PCAL and EC Inner calibration

Summary and Future Work

- Preliminary results show validation of gain and attenuation correction procedures incorporated into calibration suite.
- Full KPP dataset DSTs will be used to study e- E/P and pizero mass resolution in comparison to GEMC predictions.
- Some remaining systematics issues between PCAL and EC response require study.
- Possibility of using pions for full calibration? S1 and S4 PCAL cannot be calibrated on FC with muons. CLAS12 hadronic trigger for calibration and monitoring?

Hardware and Trigger

- Finish repair of PCAL/EC occupancy holes (now until engineering run).
- Begin debugging PCAL VTP trigger (May) B. Raydo, S. Boiarinov.
- Six sector cosmic runs with EC VTP trigger (almost ready).
- Prepare suitably normalized calibration constants to FADC/VTP trigger.

Remaining ECMon calibration suite development (finish by mid-summer)

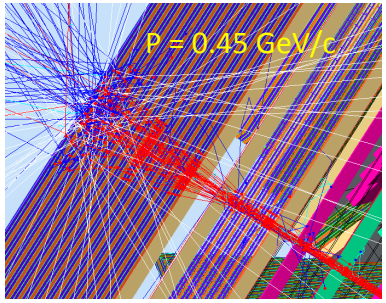
- Timing using (RF, FADC) based corrections (likely borrow from FTOF).
- PCAL/EC relative and absolute alignment using physics and survey data.
- Detector status summary plots.
- Documentation and tutorials.

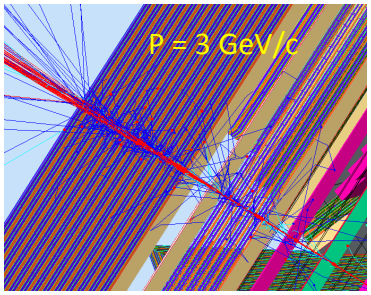
Muons in polyvinyltoluene $[(2\text{-}CH_3C_6H_4CHCH_2)_n]$

$\langle Z/A \rangle$	ρ [g/cm^3]	I [eV]	a	$k = m_s$	x_0	x_1	$\overline{C}$	δ_0
0.54141	1.032	64.7	0.16101	3.2393	0.1464	2.4855	3.1997	0.00

T	p [MeV/c]	Ionization	Brems	Pair prod	Photonucl	Total	CSDA range [g/cm^2]
		[MeV cm^2/g]					
10.0 MeV	4.704×10^1	7.917				7.917	6.971×10^{-1}
14.0 MeV	5.616×10^1	6.171				6.171	1.275×10^0
20.0 MeV	6.802×10^1	4.816				4.816	2.389×10^0
30.0 MeV	8.509×10^1	3.734				3.734	4.780×10^0
40.0 MeV	1.003×10^2	3.187				3.187	7.698×10^0
80.0 MeV	1.527×10^2	2.388				2.388	2.266×10^1
100. MeV	1.764×10^2	2.237				2.237	3.133×10^1
140. MeV	2.218×10^2	2.082				2.082	4.996×10^1
200. MeV	2.868×10^2	1.992				1.992	7.954×10^1
300. MeV	3.917×10^2	1.957			0.000	1.957	1.303×10^2
325. MeV	4.171×10^2	1.956			0.000	1.956	*Minimum ionization*
400. MeV	4.945×10^2	1.962			0.000	1.962	1.814×10^2
800. MeV	8.995×10^2	2.033	0.000		0.000	2.034	3.817×10^2
1.00 GeV	1.101×10^3	2.066	0.000		0.000	2.067	4.792×10^2
1.40 GeV	1.502×10^3	2.120	0.000		0.001	2.121	6.702×10^2
2.00 GeV	2.103×10^3	2.179	0.000	0.000	0.001	2.181	9.489×10^2
3.00 GeV	3.104×10^3	2.246	0.001	0.001	0.001	2.249	1.400×10^3

http://pdg.lbl.gov/2016/AtomicNuclearProperties/MUE/muE_polyvinyltoluene.pdf

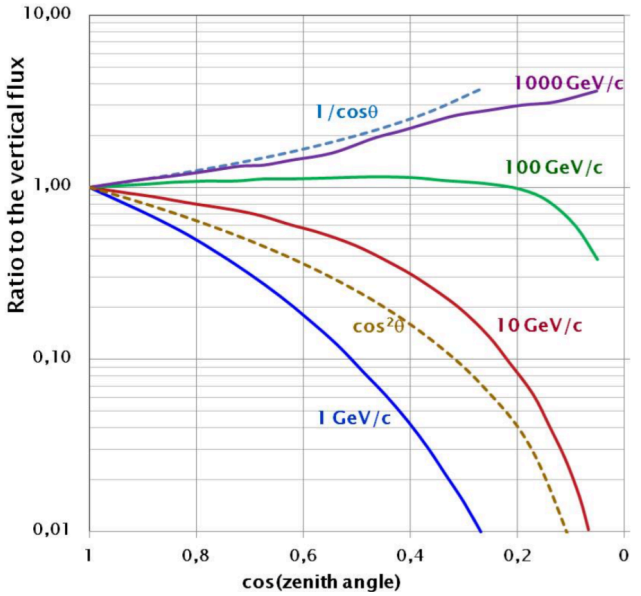


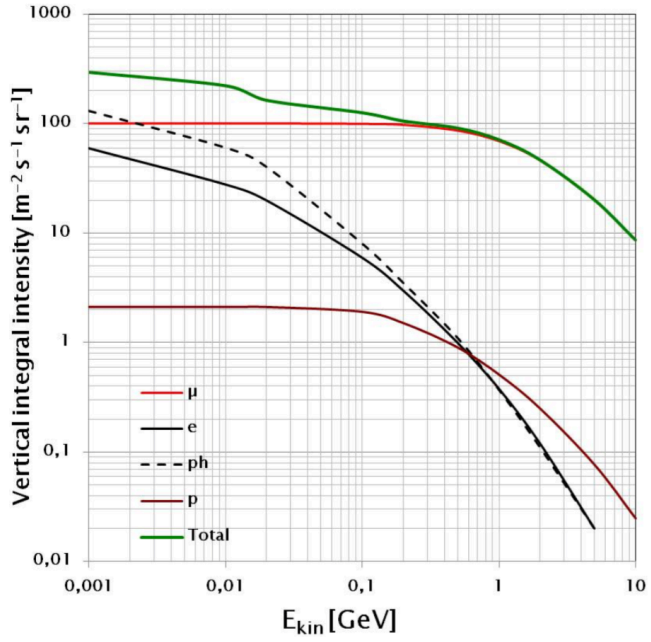


GEMC muons:

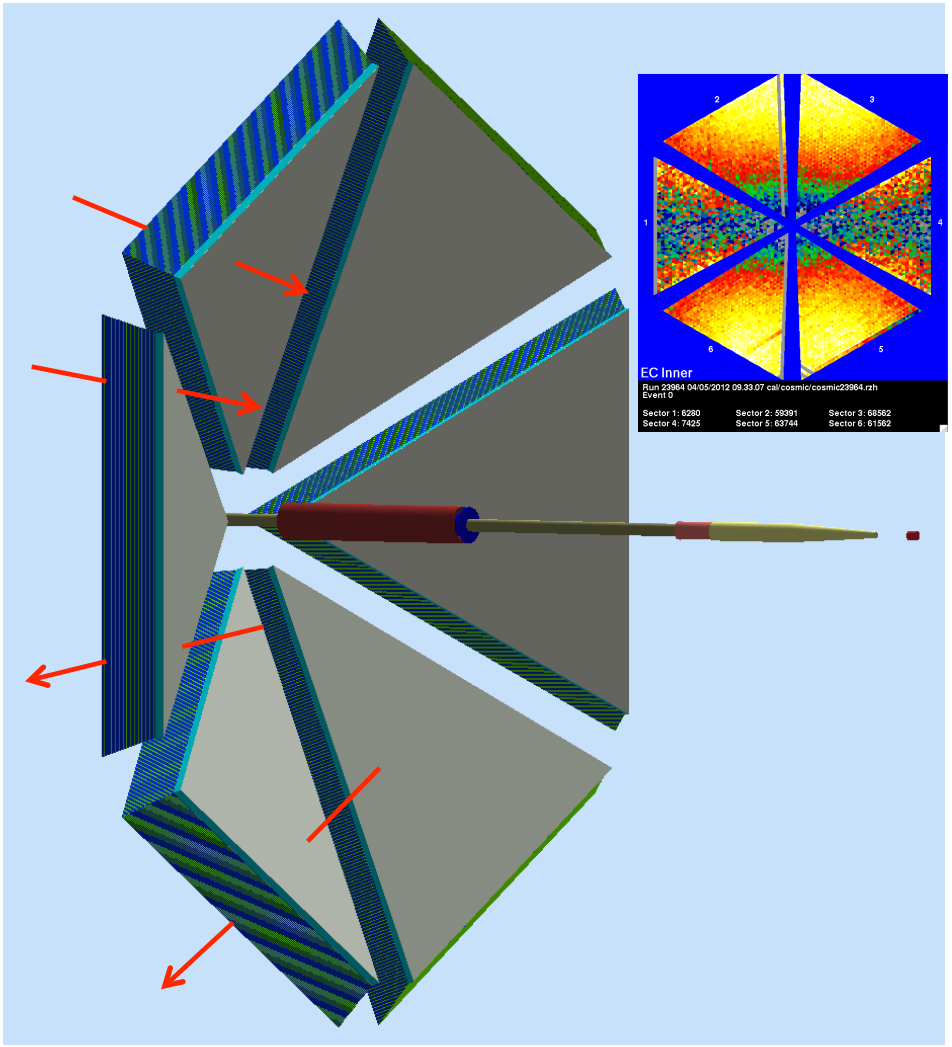
p < 0.10 stop in Panel 1A
p < 0.23 stop at rear of PCAL
p < 0.31 stop between EC inner, EC outer
p > 0.45 exit rear of EC (large multiple scattering)
p = 3 GeV (insignificant multiple scattering)

- Mean incident muon energy depends on zenith angle.
- Mean ionization energy loss depends on coincidence requirements and pixel cuts used to constrain minimum incident energy.

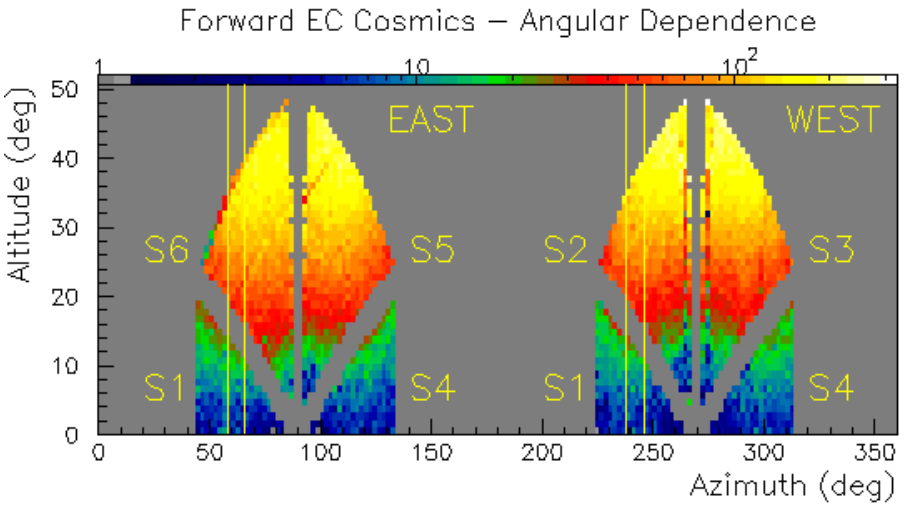


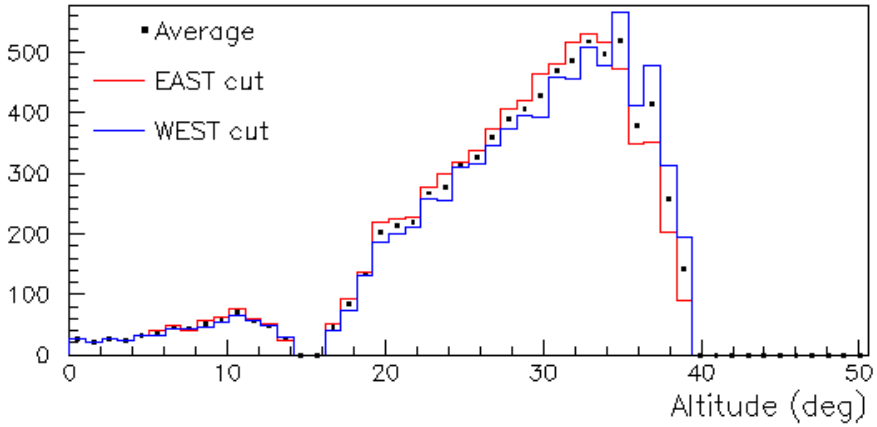


EC is a Cosmic Ray Telescope

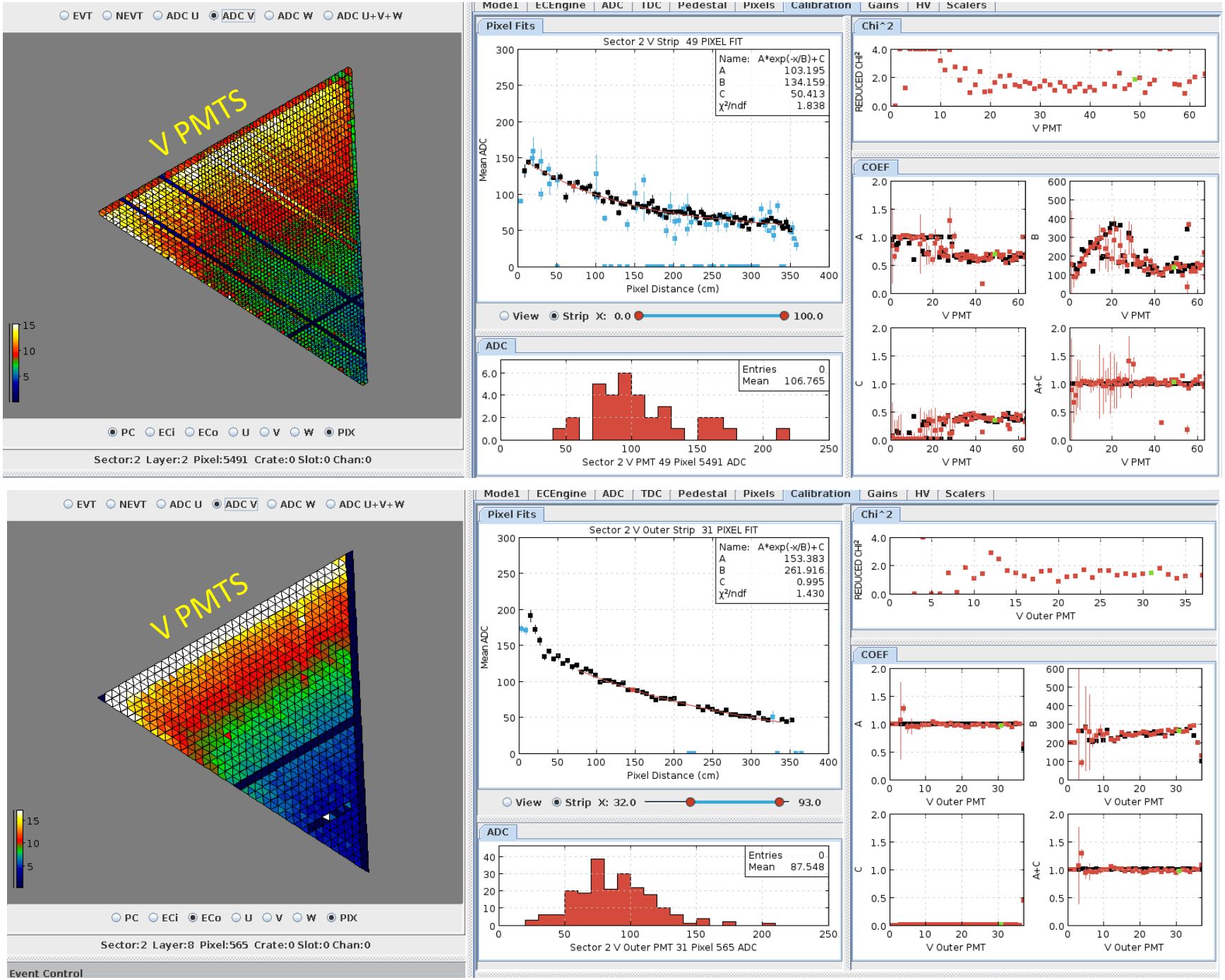


Projective geometry of EC means each pixel points to the target, *and* to a unique point in the sky.





When projected onto sky coordinates, slices in azimuth from East and West can be compared to check detector symmetry.


EVT NEVT ADC U ADC V ADC W ADC U+V+W
V PMTS
15
10
5
PC ECi ECo U V W PIX
Sector:2 Layer:2 Pixel:5491 Crate:0 Slot:0 Chan:0
Model ECEngine ADC TDC Pedestal Pixels Calibration Gains HV Scalers
Pixel Fits
Sector 2 V Strip 49 PIXEL FIT
Name: A*exp(-x/B)+C
A 103.195
B 134.159
C 50.413
χ²/ndf 1.838
Mean ADC
Pixel Distance (cm)
View Strip X: 0.0 100.0
ADC
Entries 0
Mean 106.765
Sector 2 V PMT 49 Pixel 5491 ADC
Chi^2
REDUCED CHI²
V PMT
COEF
A
B
C
A+C
V PMT
EVT NEVT ADC U ADC V ADC W ADC U+V+W
V PMTS
15
10
5
PC ECi ECo U V W PIX
Sector:2 Layer:8 Pixel:565 Crate:0 Slot:0 Chan:0
Event Control
Model ECEngine ADC TDC Pedestal Pixels Calibration Gains HV Scalers
Pixel Fits
Sector 2 V Outer Strip 31 PIXEL FIT
Name: A*exp(-x/B)+C
A 153.383
B 261.916
C 0.995
χ²/ndf 1.430
Mean ADC
Pixel Distance (cm)
View Strip X: 32.0 93.0
ADC
Entries 0
Mean 87.548
Sector 2 V Outer PMT 31 Pixel 565 ADC
Chi^2
REDUCED CHI²
V Outer PMT
COEF
A
B
C
A+C
V Outer PMT