Electron-Muon Ranger (EMR)

Digitization and Reconstruction

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On Behalf of the EMR Group

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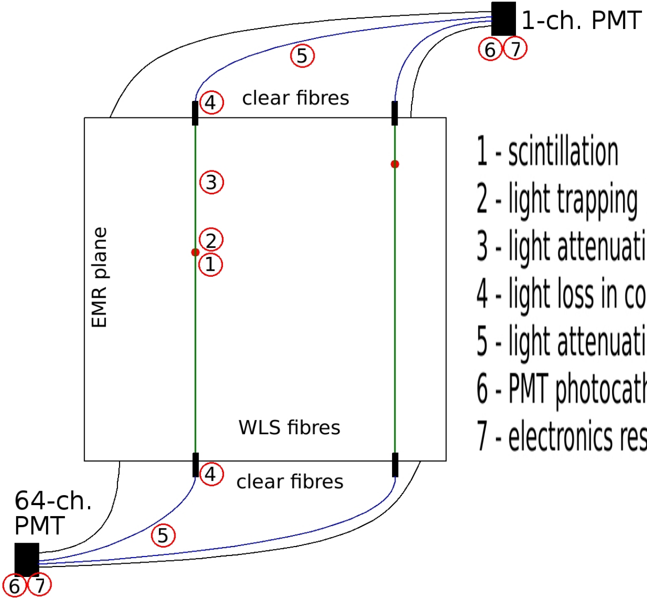
Digitization Scheme



1 - scintillation
2 - light trapping by WLS fibre
3 - light attenuation in WLS fibre
4 - light loss in connector
5 - light attenuation in clear fibre
6 - PMT photocathode
7 - electronics response

Digitization Procedure

All digitization parameters are preliminary

1. convert energy given by Geant4 into the number of scintillation photons (nsph): 2000 photos/MeV
2. sample nsph with Poisson distribution
3. covert nsph to the number of trapped photons (ntph): trapping efficiency 2%
4. sample ntph with Poisson distribution

64-ch. PMT - bar readout

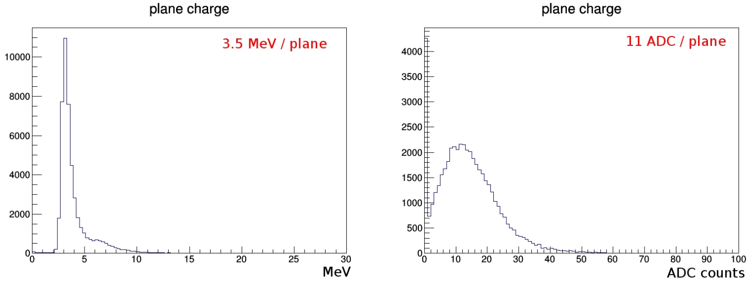
6. reduce ntph according to the length of wavelength shifting fiber (WLSf) and clear fiber (CLf) (naph): WLSf - 2.0 dB/m, CLf - 0.35 dB/m
7. apply channel attenuation map: ight loss in connectors up to 30%
8. sample naph with Poisson distribution
9. convert naph to the number of photoelectrons (npe): PMT quantum efficiency - 20%
10. sample npe with Poisson distribution
11. correct npe for photocathode non-uniformity: up to 40%
12. convert npe to the number of ADC counts: 8 ADC/npe
13. simulate electronics response: gaussian smearing - width 10 ADC
14. convert nADC to TOT: nADC=a+b*log(TOT/c+d)
15. covnert geant4 time to ADC counts (deltaT): 2.5ns/ADC
16. sample deltaT with Gaussian distribution: width - 2 ADC

1-ch. PMT - plane readout

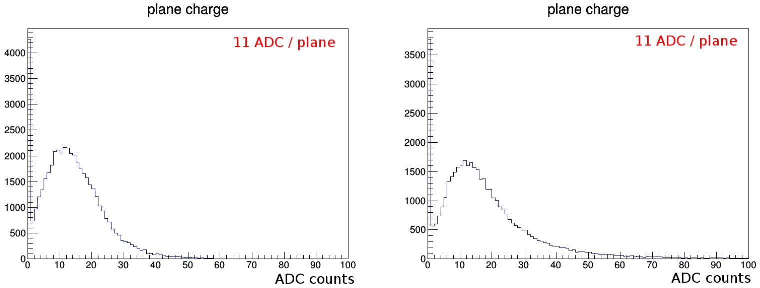
6. reduce ntph according to the length of wavelength shifting fiber (WLSf) and clear fiber (CLf) (naph): WLSf - 2.0 dB/m, CLf - 0.35 dB/m
7. apply channel attenuation map: ight loss in connectors up to 30%
8. sample naph with Poisson distribution
9. convert naph to the number of photoelectrons (npe): PMT quantum efficiency - 14.5%
10. sample npe with Poisson distribution
11. correct npe for photocathode non-uniformity: up to 50%
12. convert npe to the number of ADC counts: 1 ADC/npe
13. simulate electronics response: gaussian smearing - width 6.5 ADC
14. set signal baseline (8bit ADC):$\sim$130 ADC
15. simulate noise level - number of fluctuations within acquisition window: from 0 to 200
16. set noise position: upwards/downwards fluctuations
17. simulate negative voltage pulse with random noise

Digitization: MC Raw → MC Digitized
Total Charge Per Plane

- 3 GeV muons simulated (to be compared with cosmics)
- left plot: energy deposition per plane in MeV
- right plot: digitized energy after electronics conversion - total charge per plane in ADC counts

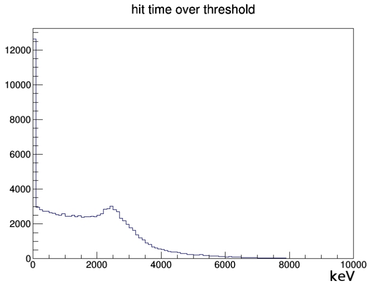


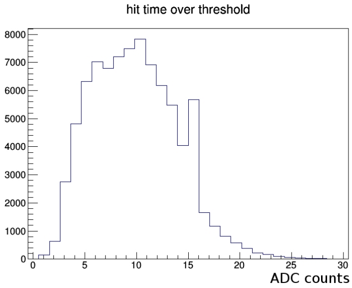
- 3 GeV muons simulated (to be compared with cosmics)
- left plot: digitized energy after electronics conversion - total charge per plane in ADC counts
- right plot: total charge per plane from cosmic muons



- even with peliminary digitization parameters the agreement is very good

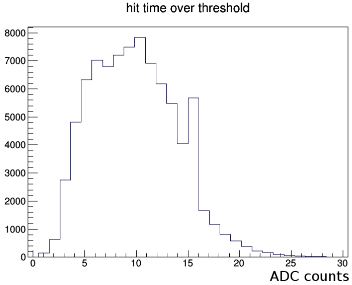
- 3 GeV muons simulated (to be compared with cosmics)
- left plot: energy deposition per bar in MeV
- right plot: digitized energy after electronics conversion - time over threshold measurement per bar in ADC counts

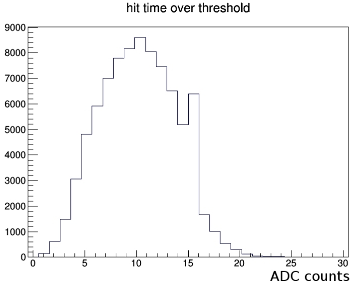




Digitization: MC Digitized → Cosmics
Time Over Threshold

- 3 GeV muons simulated (to be compared with cosmics)
- left plot: digitized energy after electronics conversion - time over threshold measurement per bar in ADC counts
- right plot: time over threshold measurement per bar from cosmic muons

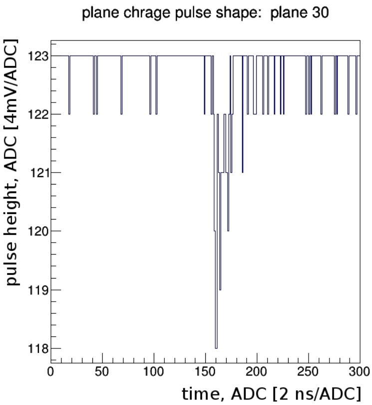


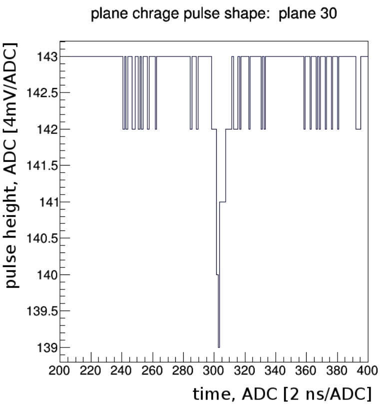


- even with peliminary digitization parameters the agreement is very good
- peak around 15 present in both Monte Carlo and data. no explanation so far

Digitization: MC Digitized → Cosmics
Pulse Shape

- 3 GeV muons simulated (to be compared with cosmics)
- left plot: digitized energy converted into negative voltage (sampled with Landau distribution) pulse with random noise
- right plot: real ADC pulse from cosmics





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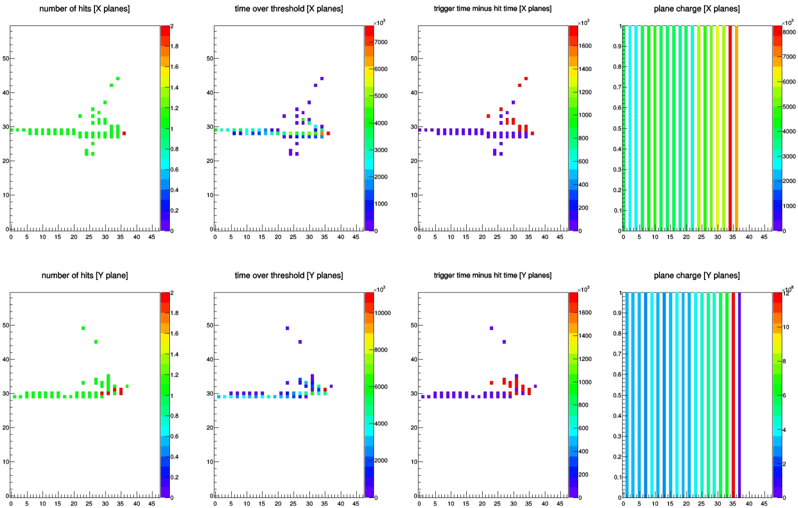
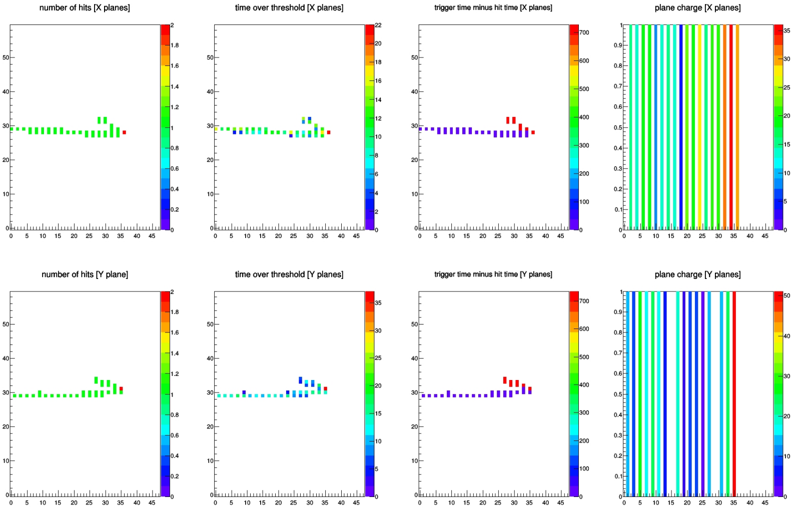
Monte Carlo Raw
260 MeV muon



- all energy depositions are visible

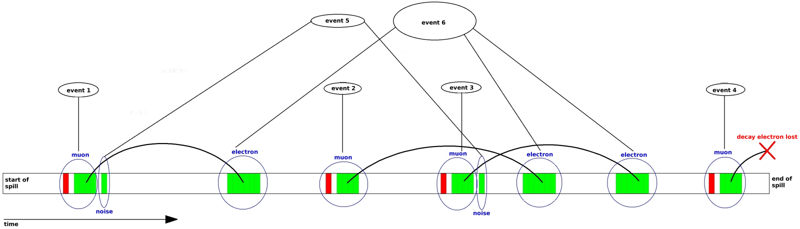
Digitized Monte Carlo
260 MeV muon



- only significant energy depositions are visible
- signals are smeared or even lost sometimes (due to statistical fluctuations)

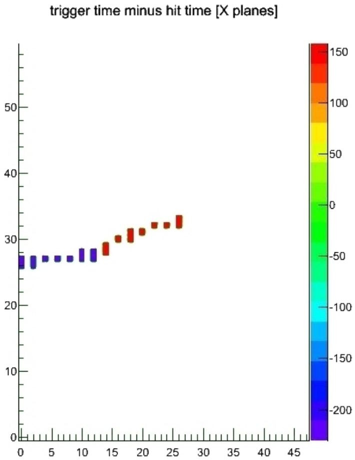
Reconstruction: Timing Analysis

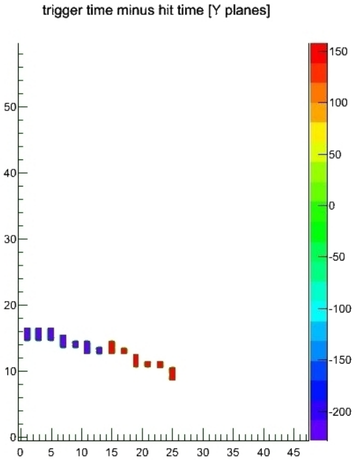
- event cleaning:
  - selection of primary particles (associated to triggers)
  - noise rejection
  - decay particles selection



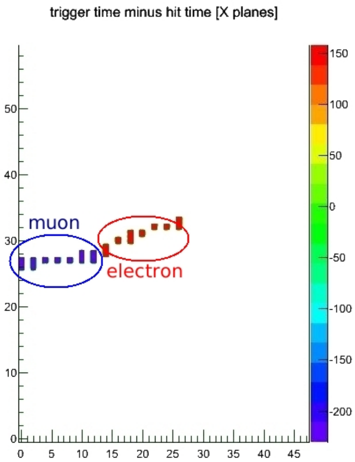
- primary particles are saved in separate events
- noise events are grouped in one event
- all the rest are in the last event:
  - decay particles
  - cosmic muons

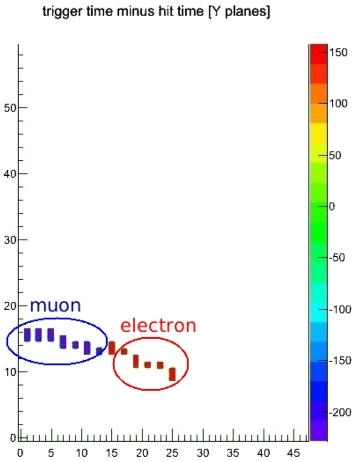
- after cleaning event is ready for track reconstruction

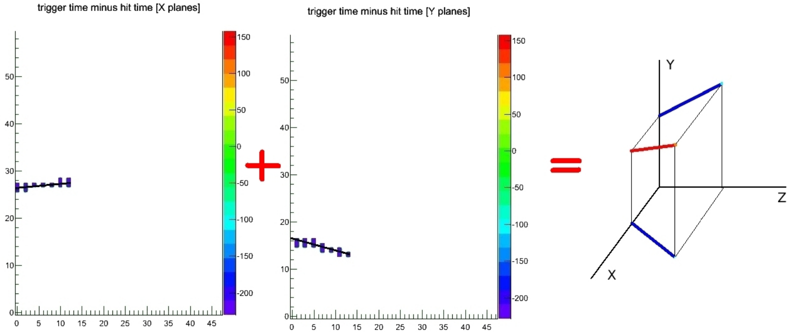




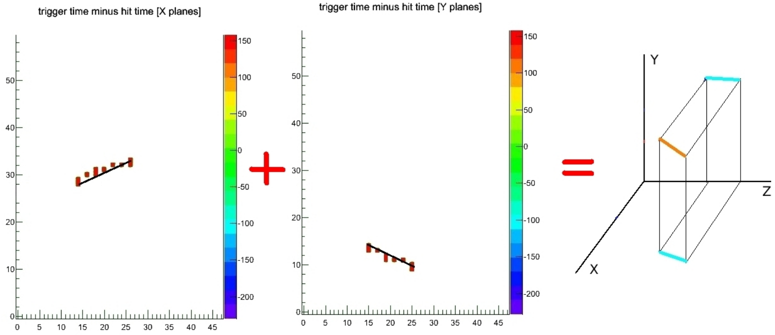
- primary and secondary tracks are easily identified







- track is not a regular line
- fitted with a piecewise linear function
- XZ and YZ projections fitted separatly
- length of 3D track defines a range



- track is not a regular line
- fitted with a piecewise linear function
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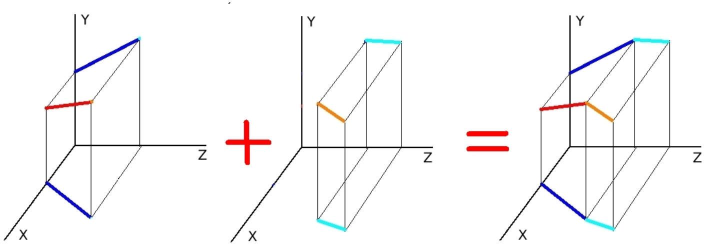
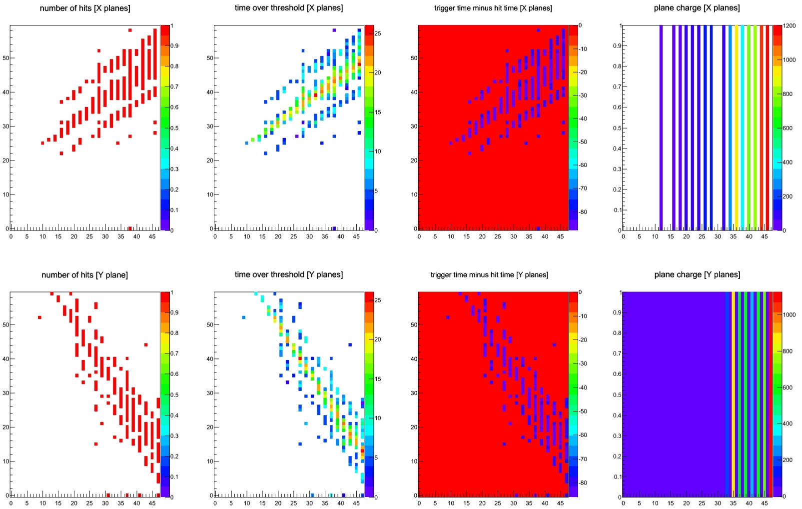
Track Reconstruction
3D Track



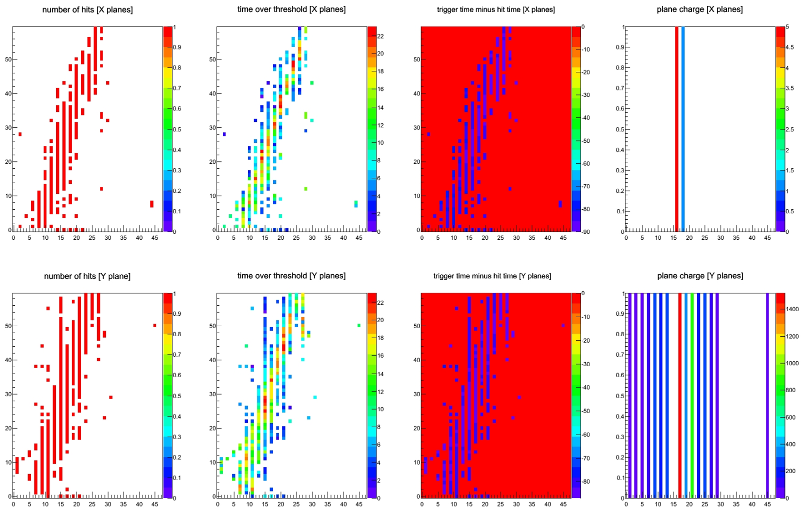
- an end point of the secondary track should match an end point of a primary one
- presence of secondary track is an additional discriminating variable
- reconstructed variables:
  - range (function of momentum)
  - secondary tracks
  - total charge
  - ratio of charge in the second part of the track over the first one (>1 for muons and pions, $\sim$1 for electrons)
- all the above variables contribute to PID and momentum identification

This algorithm is being implemented...

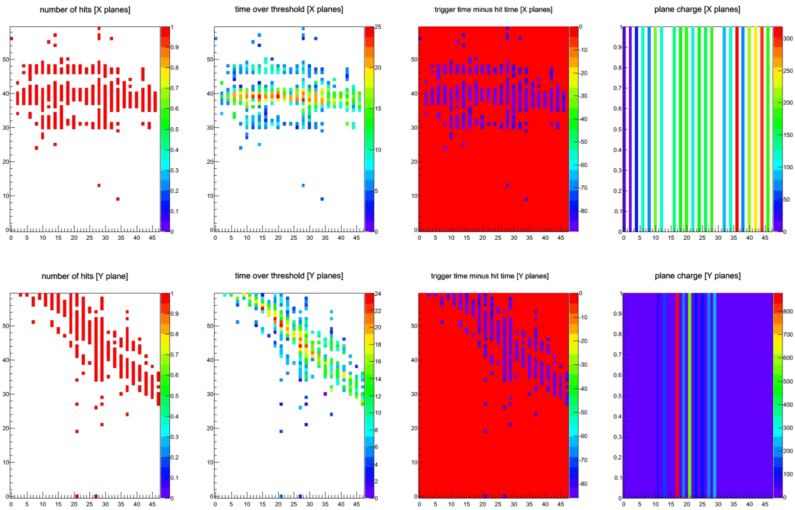
High Energy Cosmics



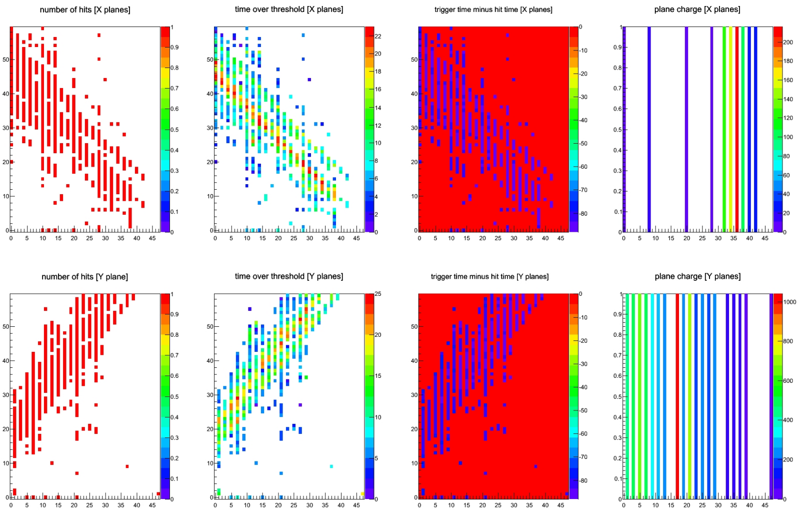
High Energy Cosmics



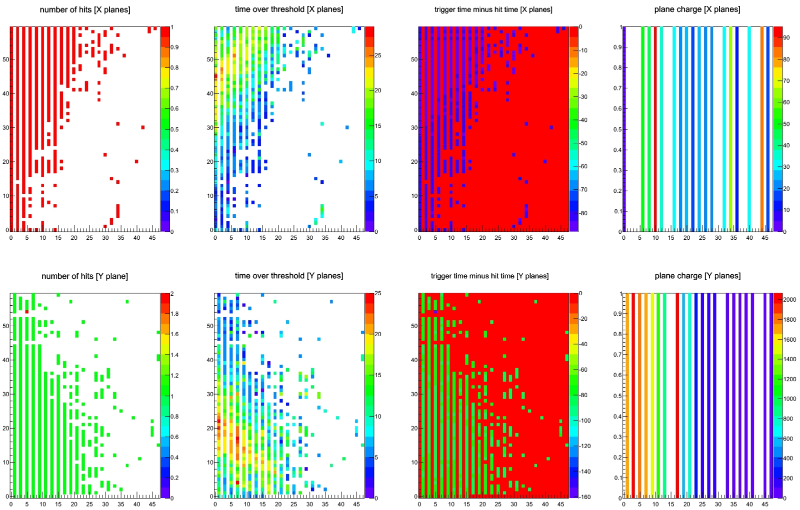
High Energy Cosmics



High Energy Cosmics



High Energy Cosmics



Summary

- digitization of geant4 simulation is implemented
- both electronics chains are simulated (64-ch. and 1-ch. PMT readouts including FEB/DBB and fADC boards)
- even with preliminary digitization parameters an agreement between simulation and data is exceptional
- digitization parameters will be studies/measured/tuned to match real hardware
- reconstruction is being implemented...