Accurate simulation of the ASTRONEU EAS array with HOURS

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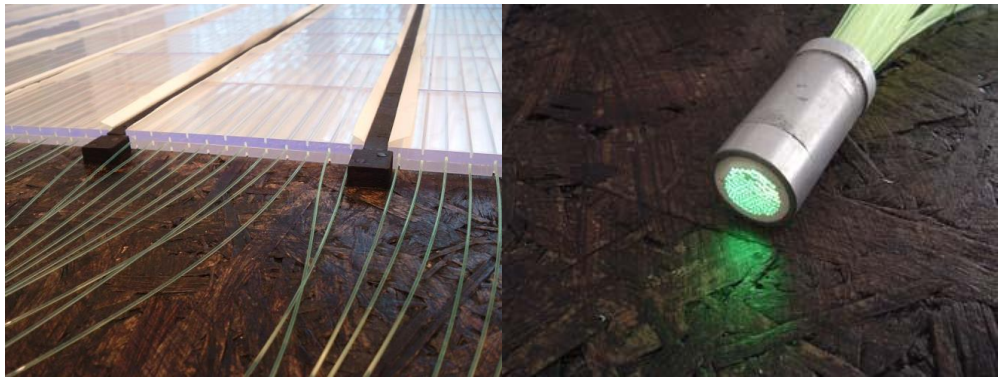
Astroneu EAS Array



WLS fibers: Bicron (BCF-91A) Light attenuation length: 330cm

Scintillators : Protvino (Russia)

Emission spectrum:420 nm

Decay time 2 ns

PMT: Photonis (XP1912)

Rise time : 2 ns

Detectors data acquisition with the Quarknet card

- 4 input channels
- NIM trigger out signal
- USB connection to hosting computer
- Performs time tagging of the crossings of the pulses with one adjustable threshold (set through the acquisition software)
  - 10x amplification of the input signals
  - Time resolution 1.25ns
  - Adjustable trigger criteria (majority, time window)
- External GPS receiver provides the absolute time of the event
- ...

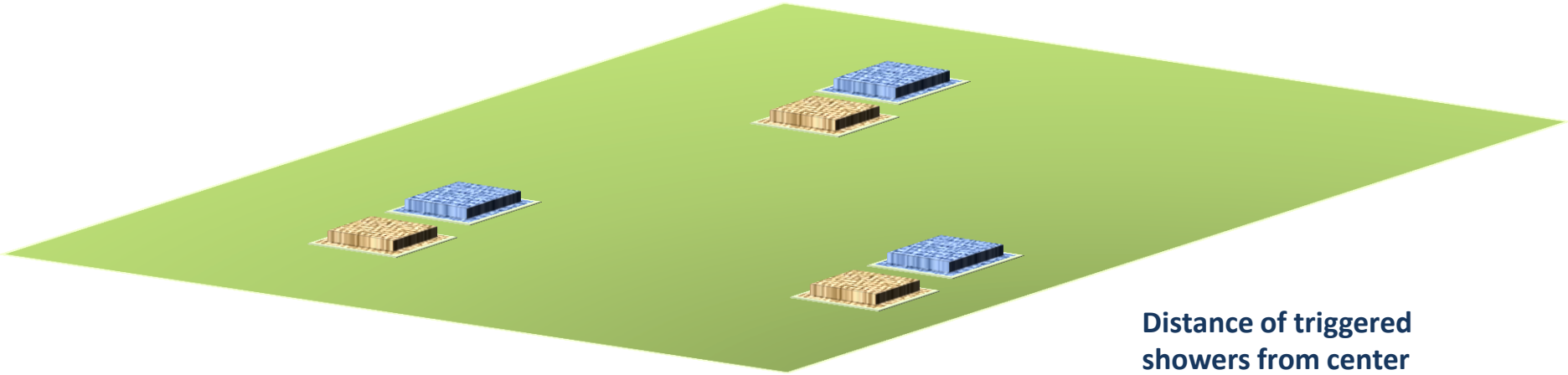
Reference

Detector Operation in HOU Campus (Patras)

Station A (Master Trigger)

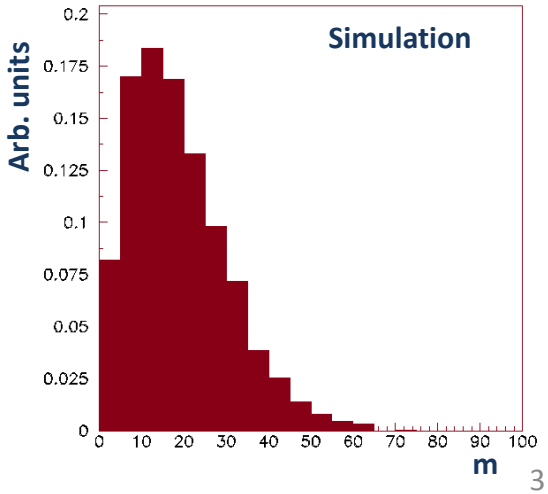
Station B

25 m Average Distance between counters (same station)



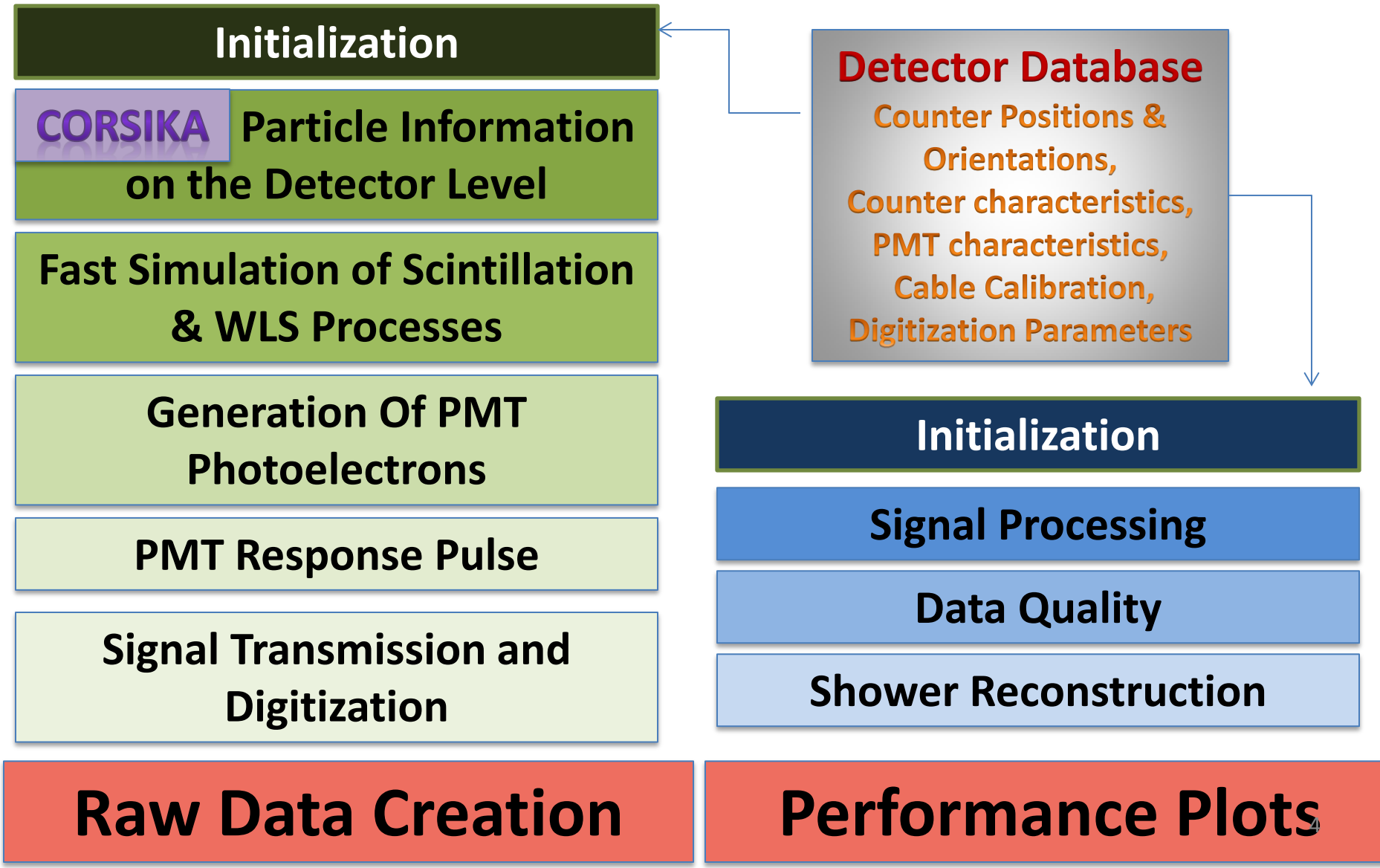
- Response to the same EAS
- Station A : Triple coincidence with 10mV threshold
- Station B : External trigger from station A
- Trigger rate ~ 20/hr

Distance of triggered showers from center



HOURS-EAS

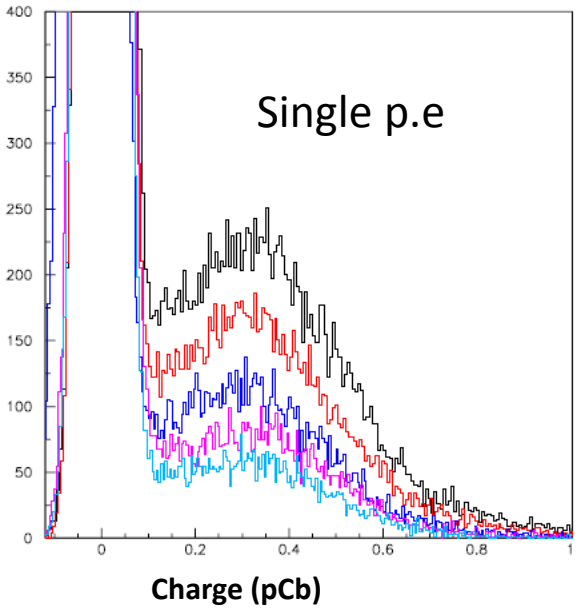
Hellenic Open University Reconstruction and Simulation of Extended Air Showers



Calibration Database

The Photomultiplier Tube:

PH: XP1912



@ “nominal” H.V.

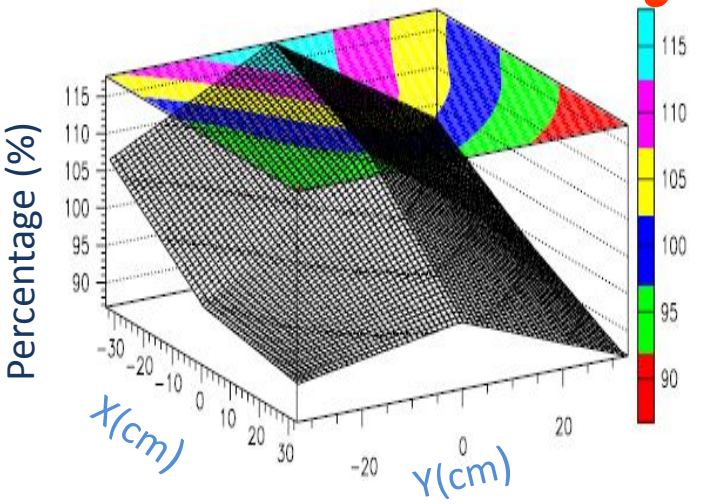
gain: ~ 4 10^5

<charge>/p.e. ~ 0.07pCb

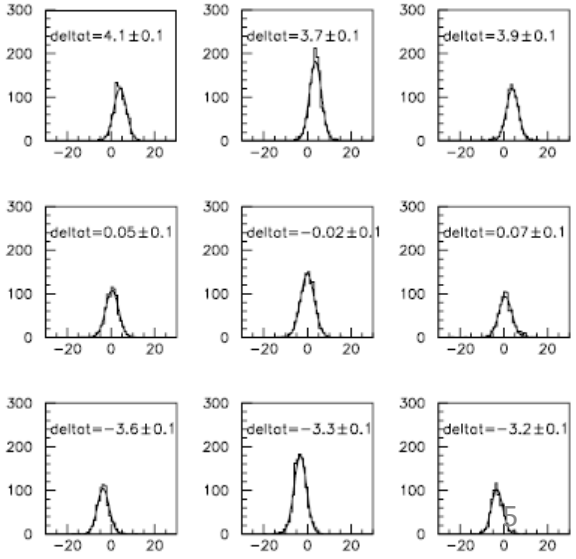
<pulse height>/p.e. ~ 1.05mV

Counter

Detector Uniformity



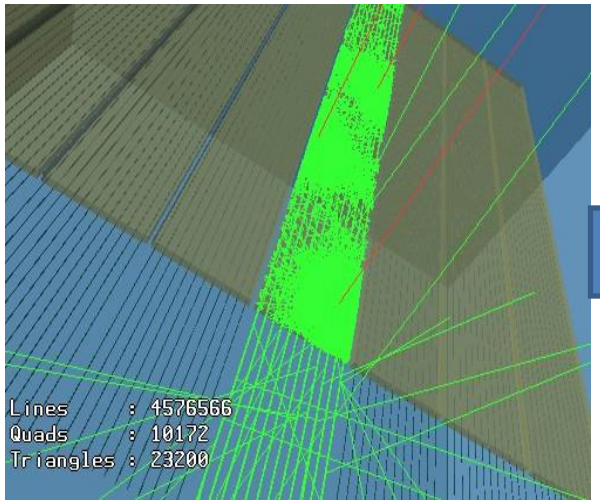
Relative Timing



Each counter and PMT has its own description in the simulation

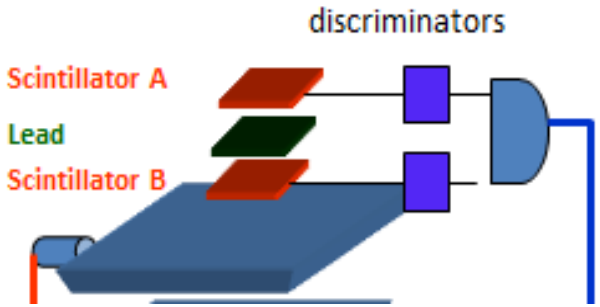
Scintillation Process and WLS

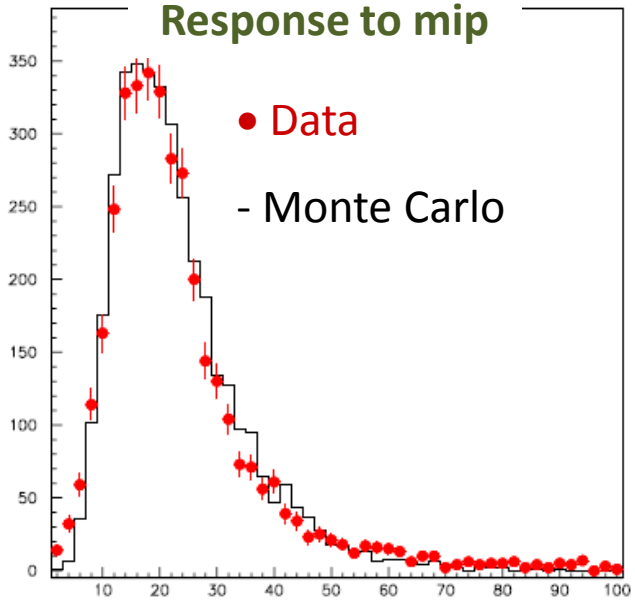
GEANT 4 Simulation



Parameterization of photon generation for:

- **Each particle (e,γ,μ,…)**
- **Momentum direction**
- **Energy**

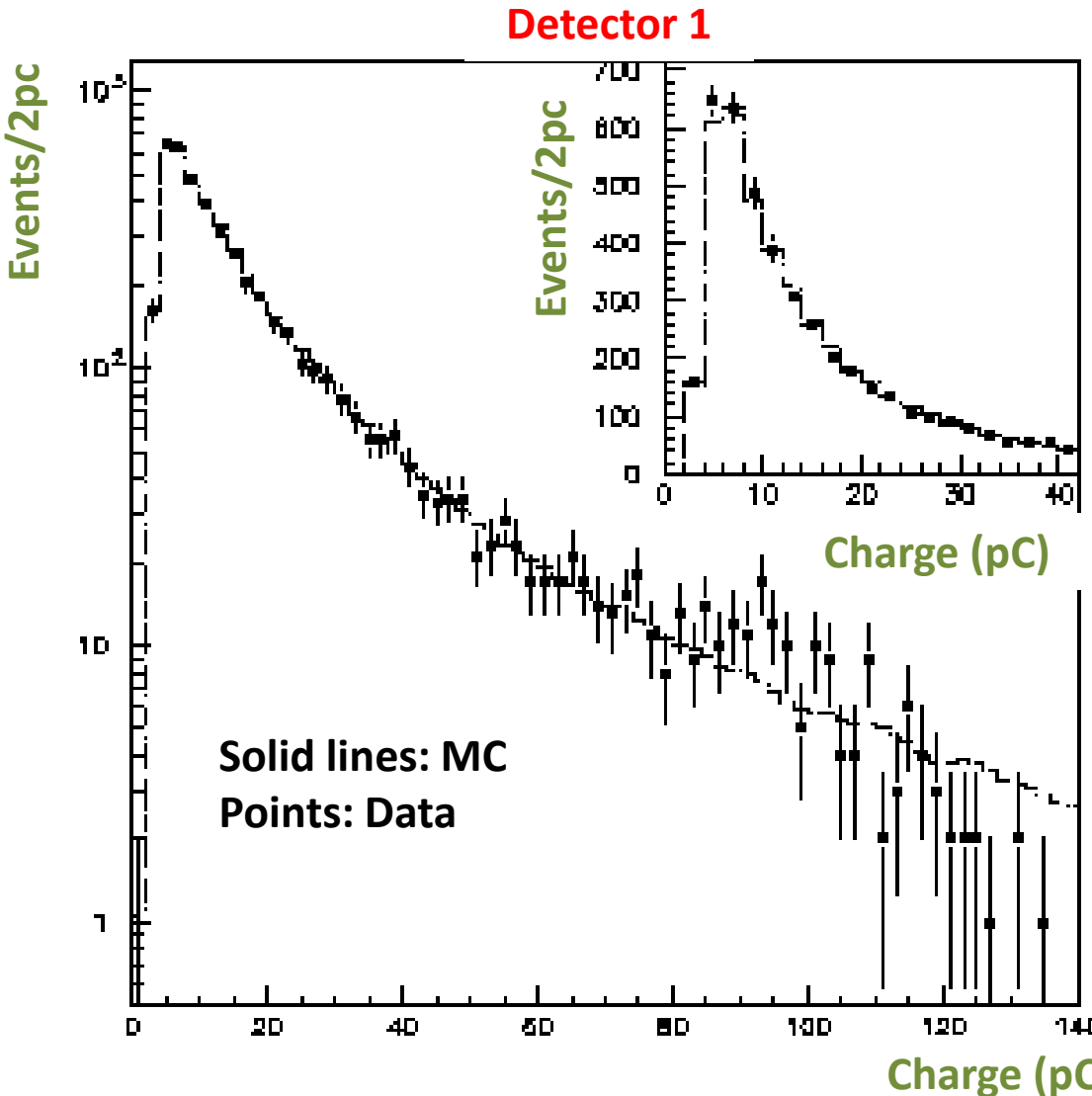




Charge (in units of mean p.e. charge)

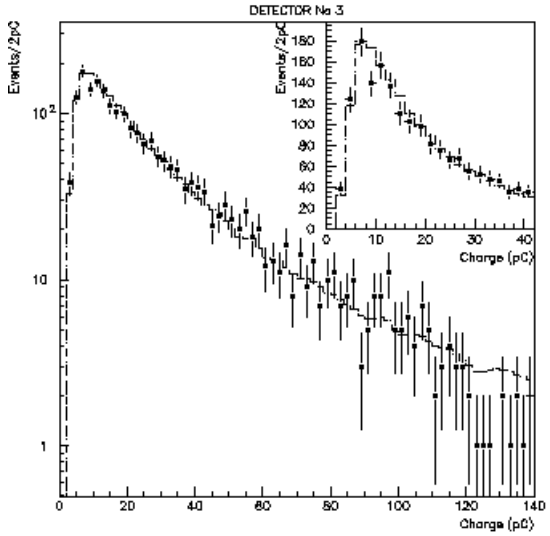
Charge in showers

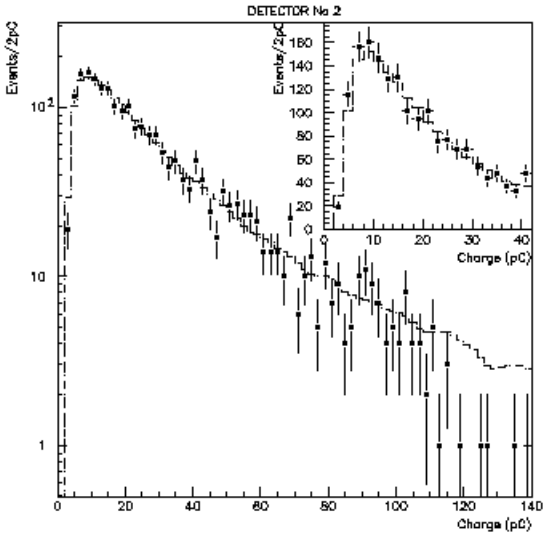
Station A, Trigger triple coincidence with threshold at 10mV

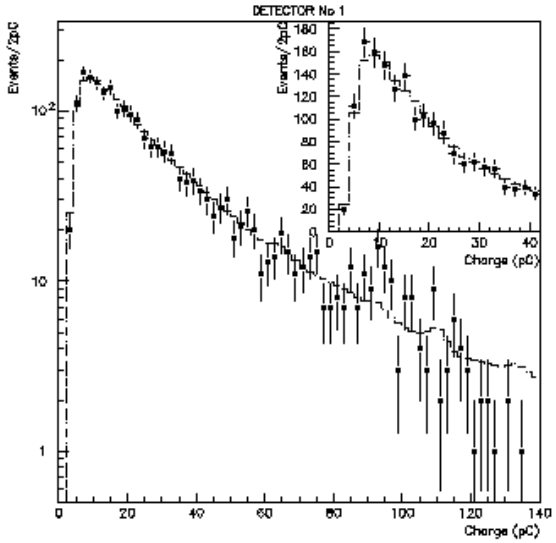


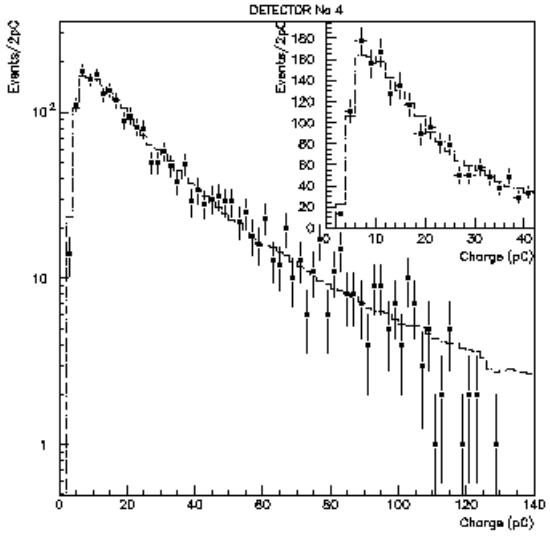
Charge in showers

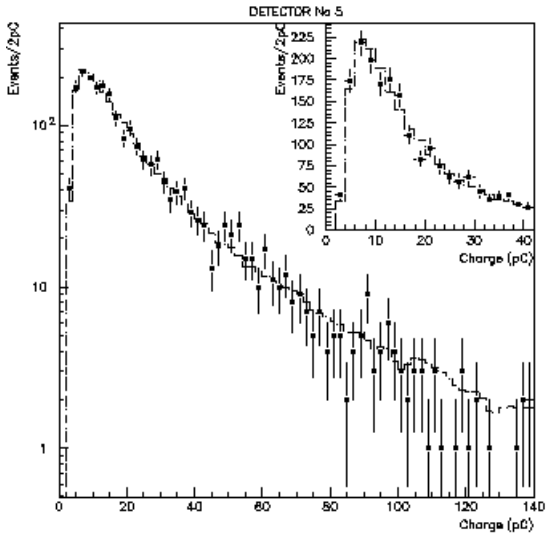
Station A & B, Trigger 6-fold coincidence with threshold at 10mV

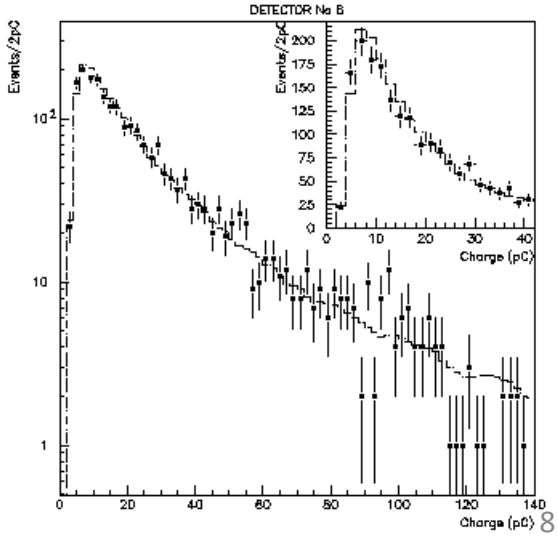






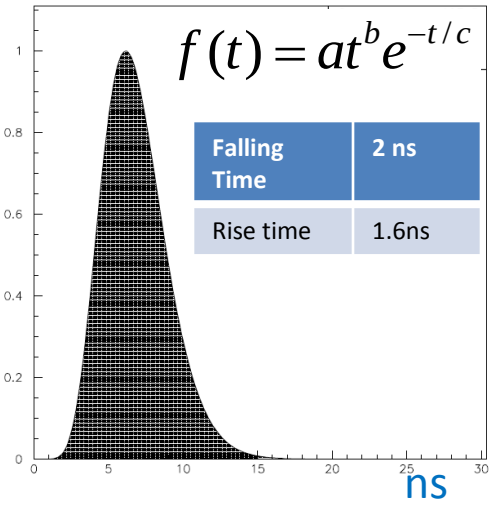






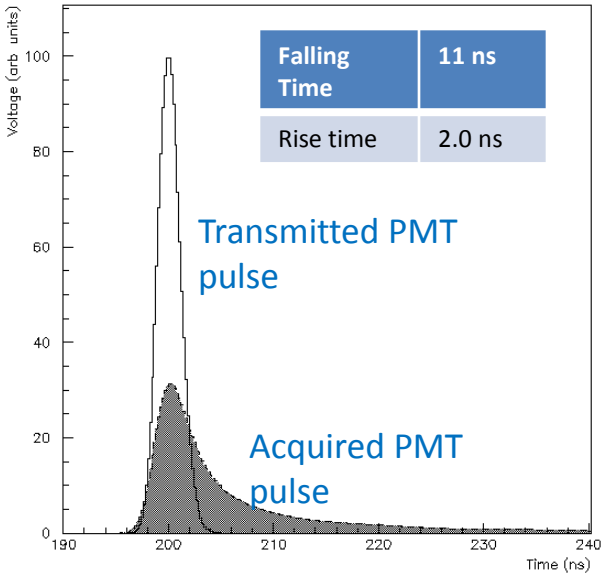
Single pe Pulse Simulation

Single photoelectron wave form



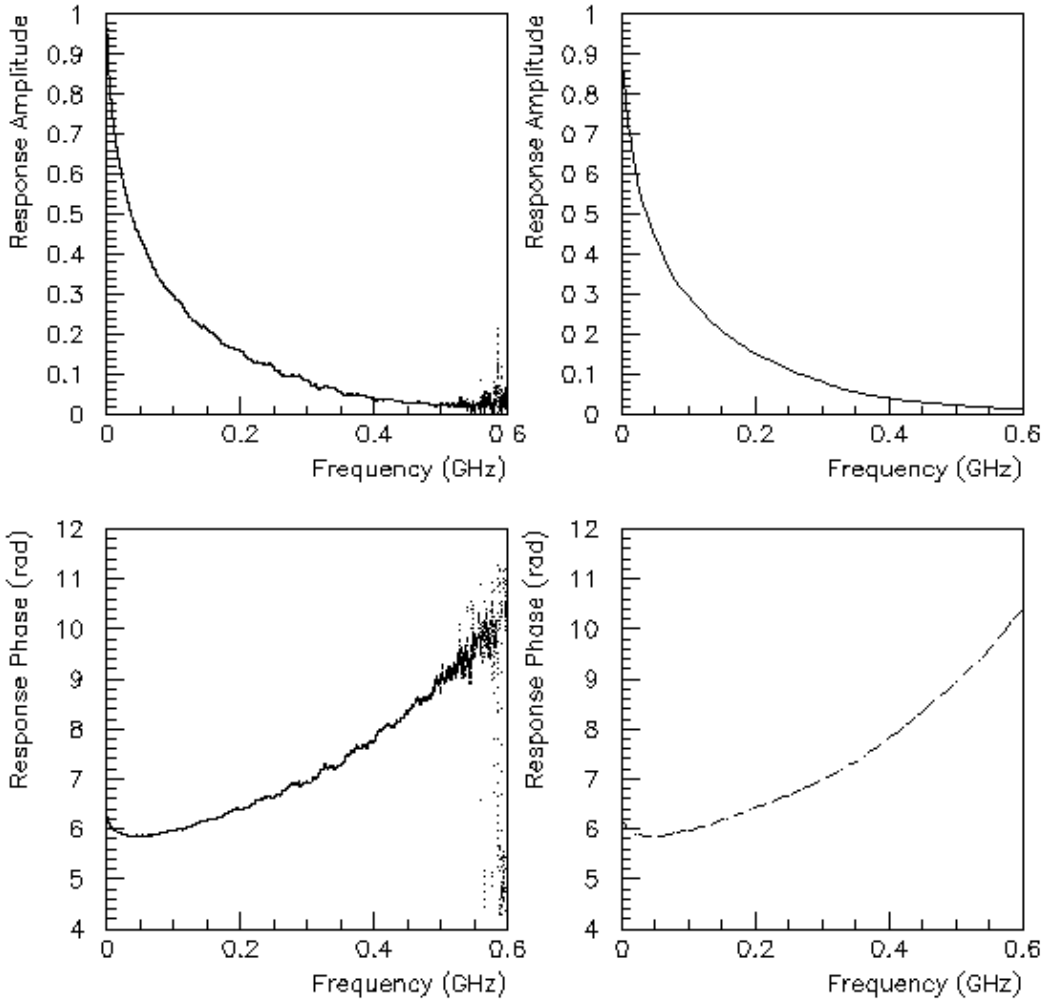
Falling Time	2 ns
Rise time	1.6ns

Pulse Distortion



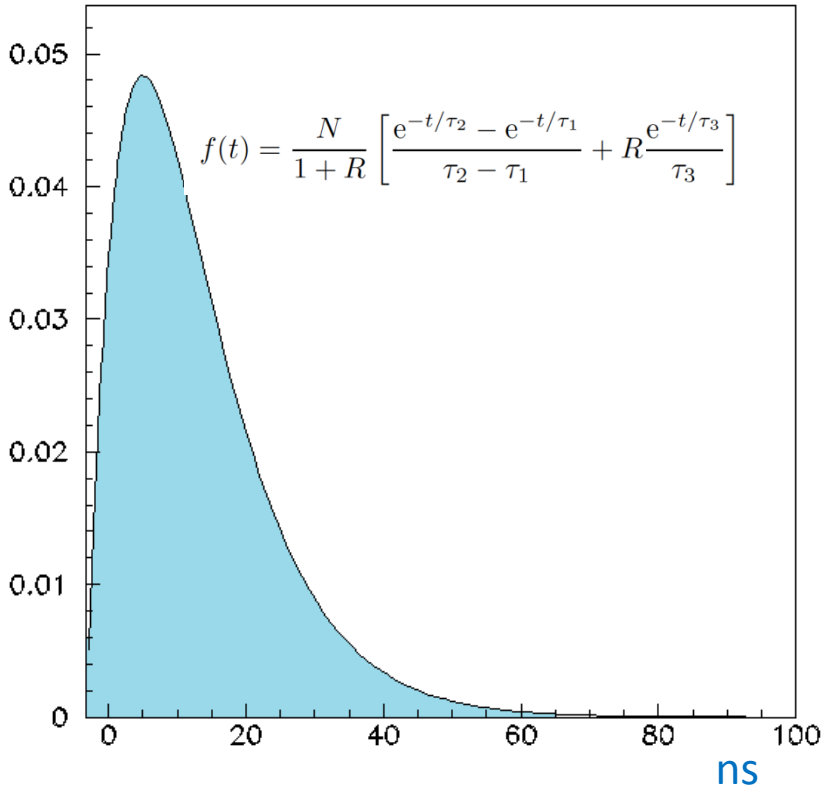
Falling Time	11 ns
Rise time	2.0 ns

Fourier Analysis



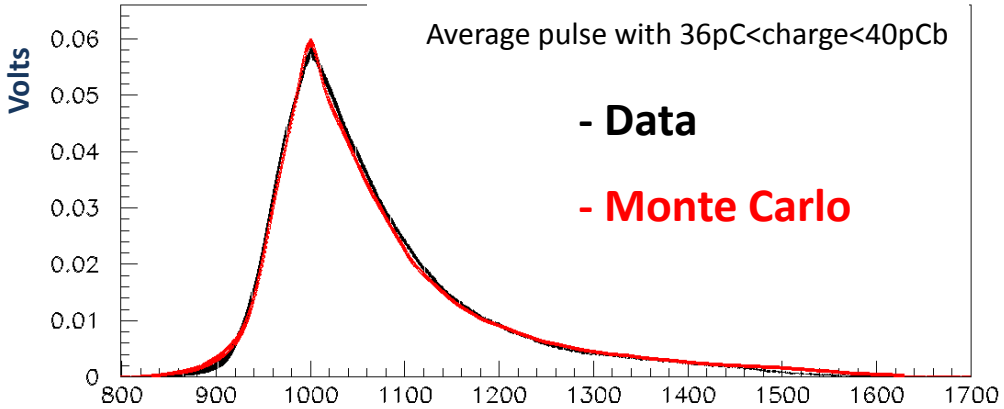
Scintillation Process

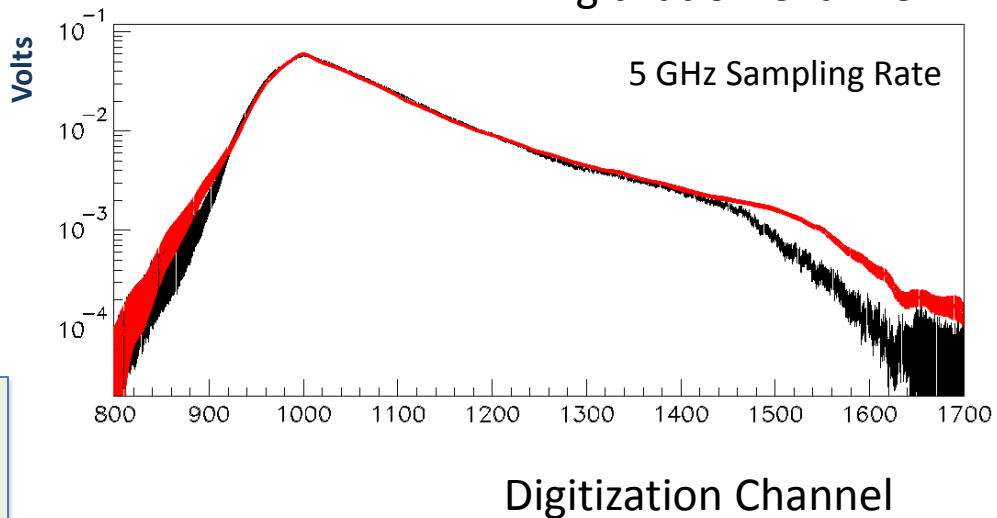
Components of Scintillation Process



WLS Fiber absorption & emission

Shower Pulse Comparison





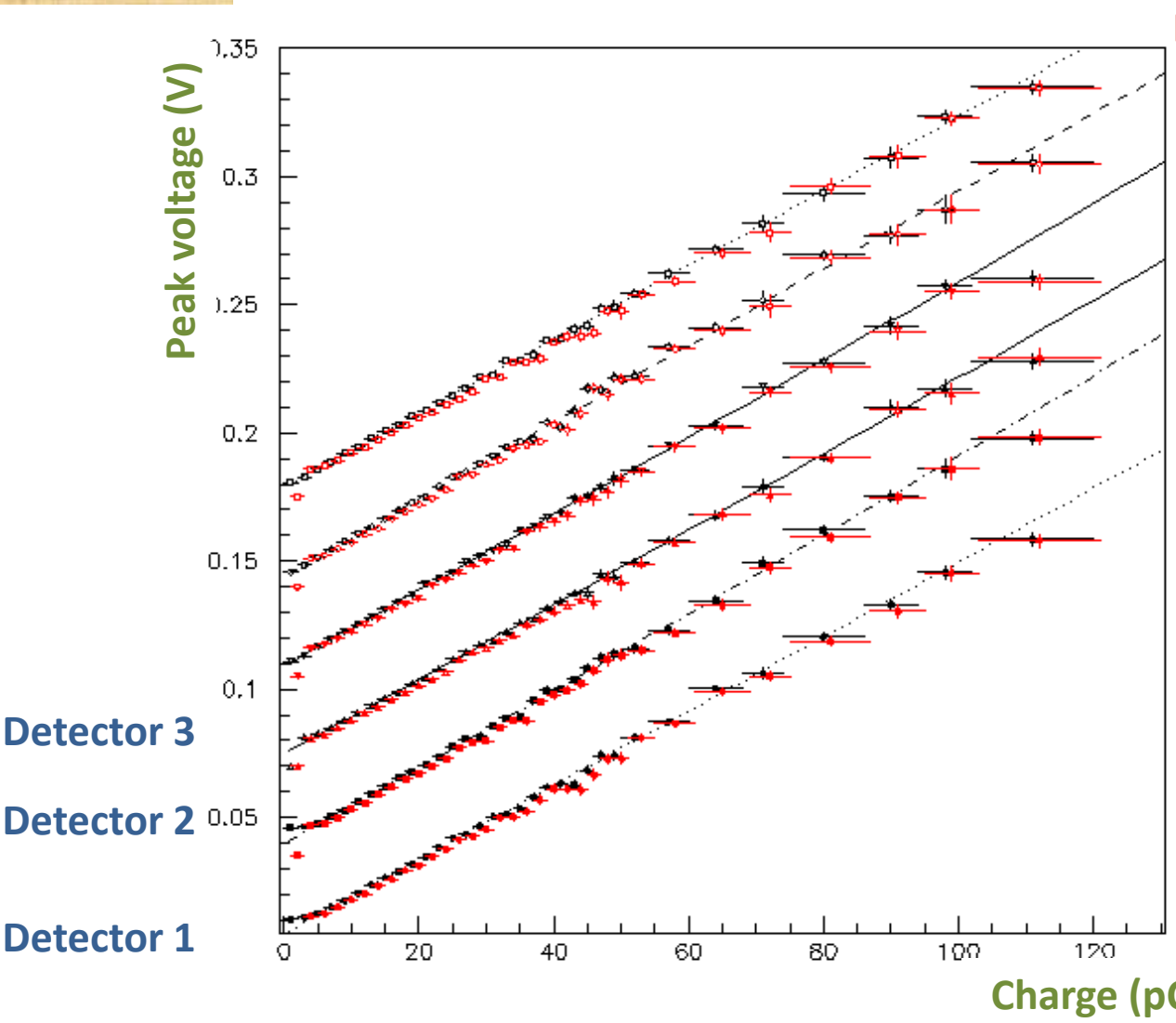
Peak Voltage vs Charge

Station A

Station B

Black points: Trigger triple coincidence on A with threshold at 10mV

Red points: Trigger 6-fold coincidence with threshold at 10mV



Detector 3

Detector 2

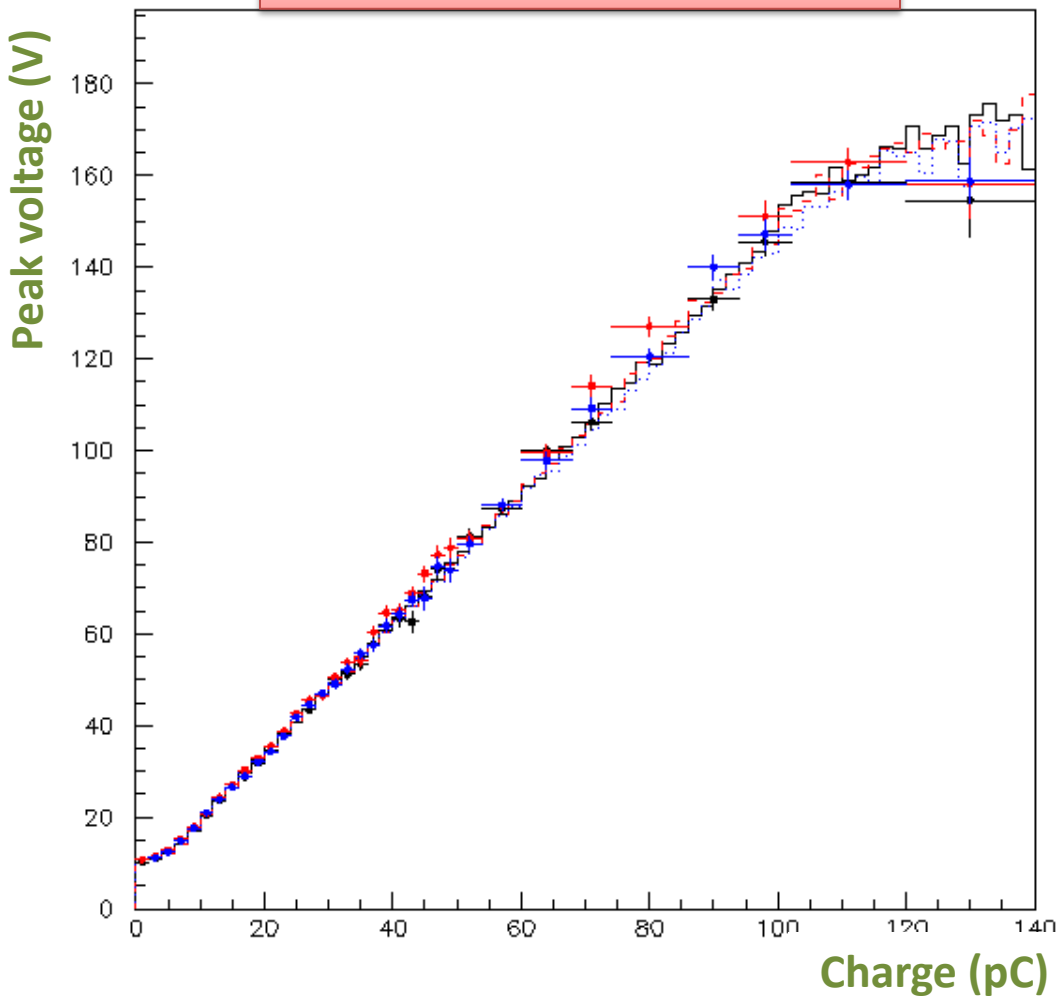
Detector 1

The points (except Detector 1) are parallel shifted by 3.5 mV per detector

Peak Voltage vs Charge

Station A, Trigger triple coincidence with threshold at 10mV

Comparison with Simulation



Points: Data
Detector 1
Detector 2
Detector 3

Solid lines: MC
Detector 1
Detector 2
Detector 3

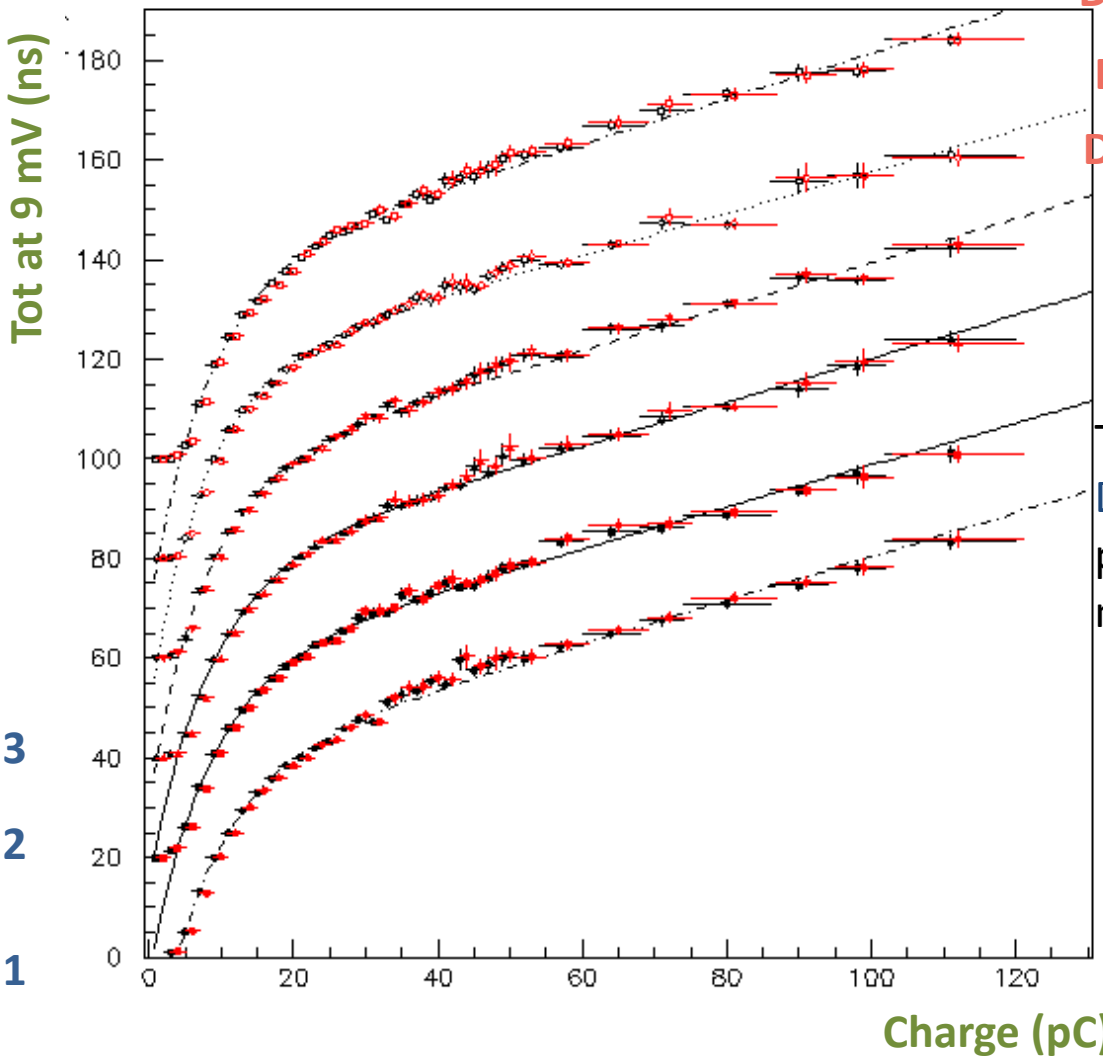
Tot vs Charge

Station A

Station B

Black points: Trigger triple coincidence on A with threshold at 10mV

Red points: Trigger 6-fold coincidence with threshold at 10mV

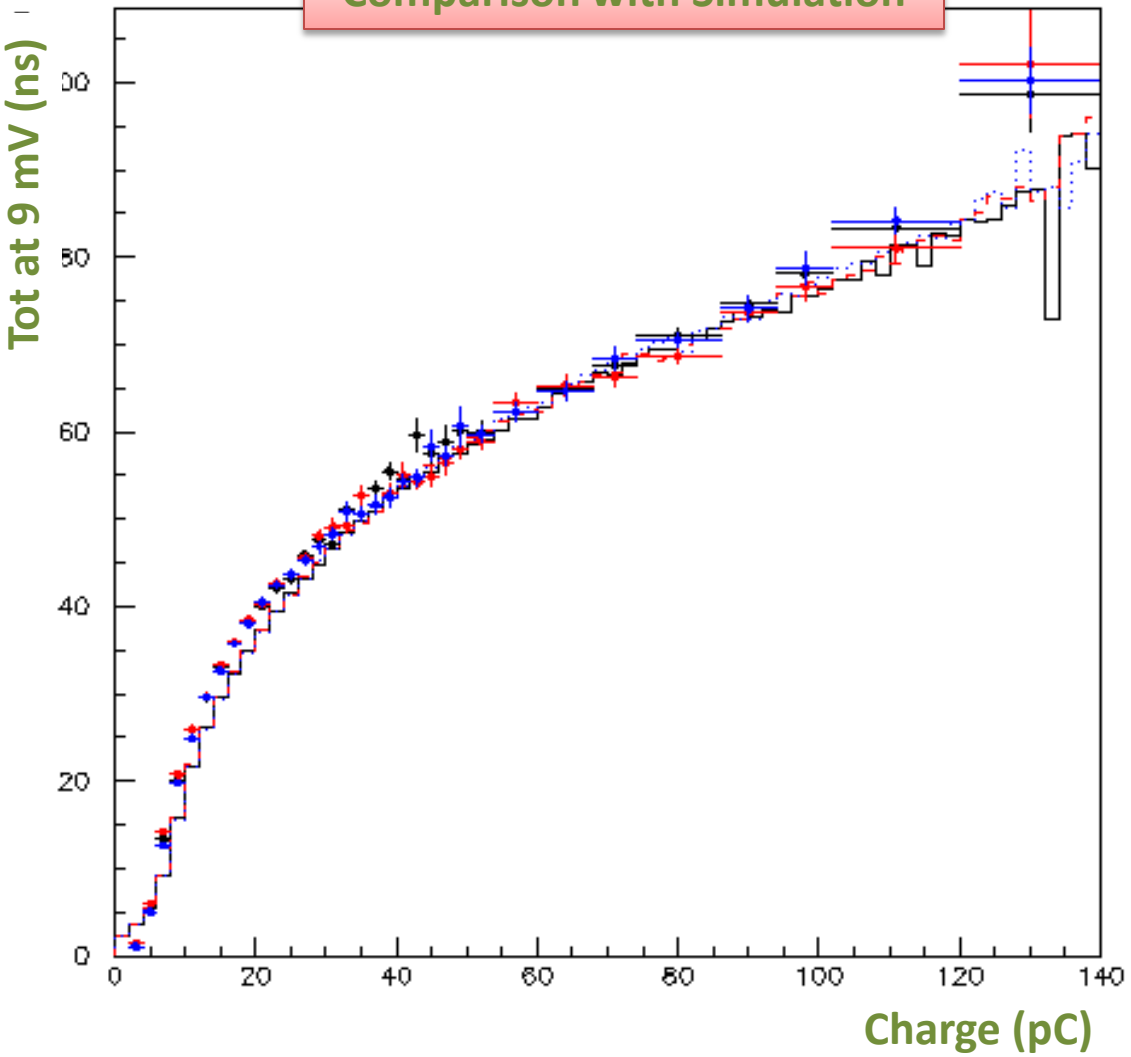


The points (except Detector 1) are parallel shifted by 20 ns per detector

Tot vs Charge

Station A, Trigger triple coincidence with threshold at 10mV

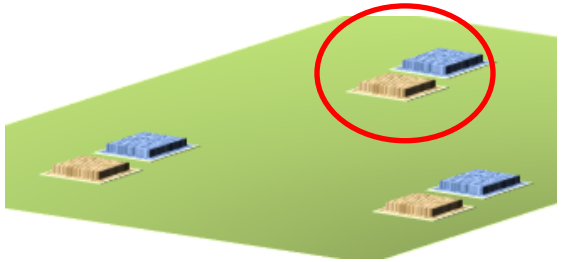
Comparison with Simulation



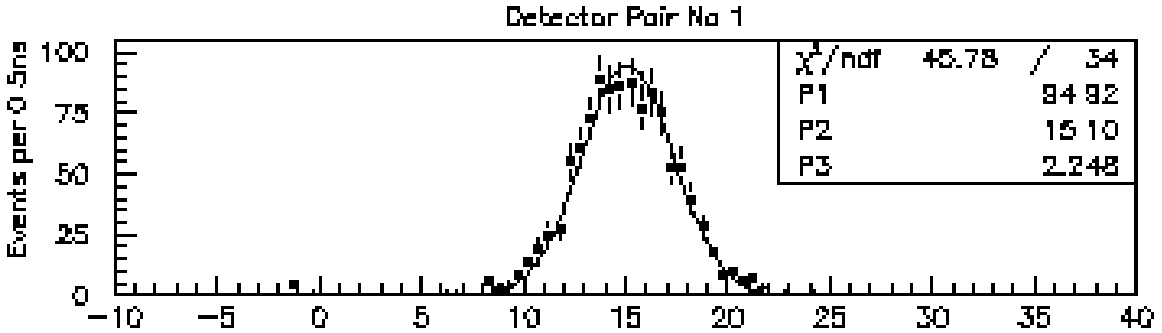
Points: Data
Detector 1
Detector 2
Detector 3

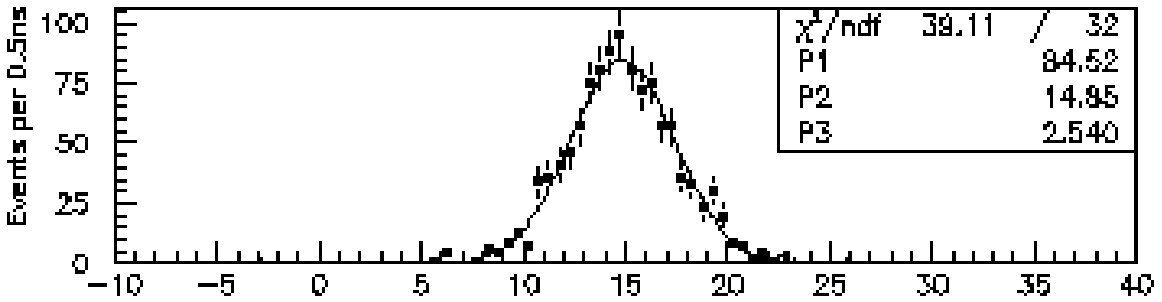
Solid lines: MC
Detector 1
Detector 2
Detector 3

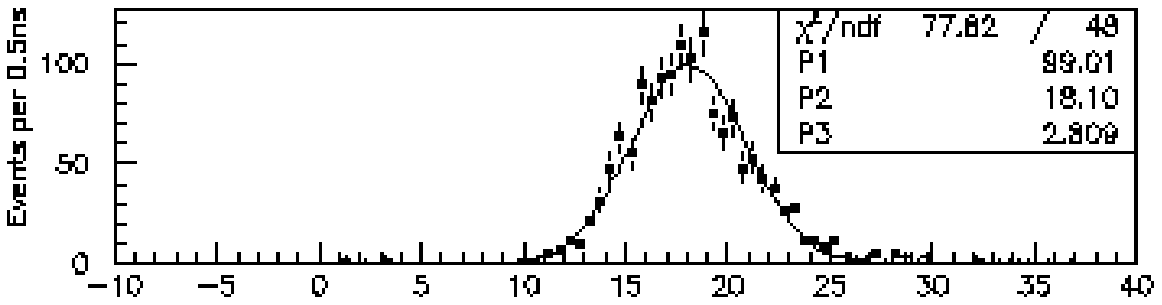
Timing Corrections and Resolution



Use time Resolution in Simulation

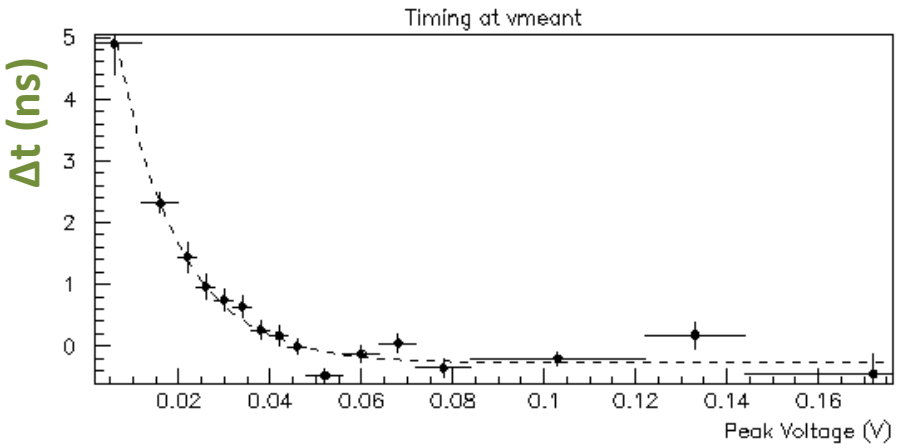


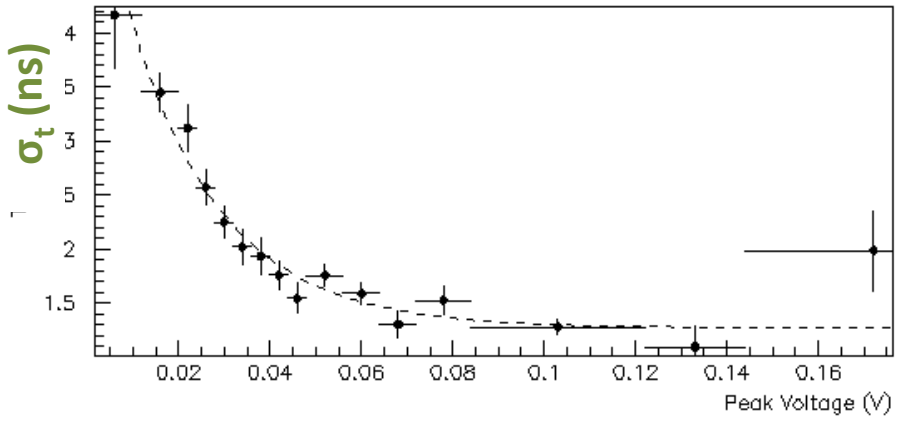




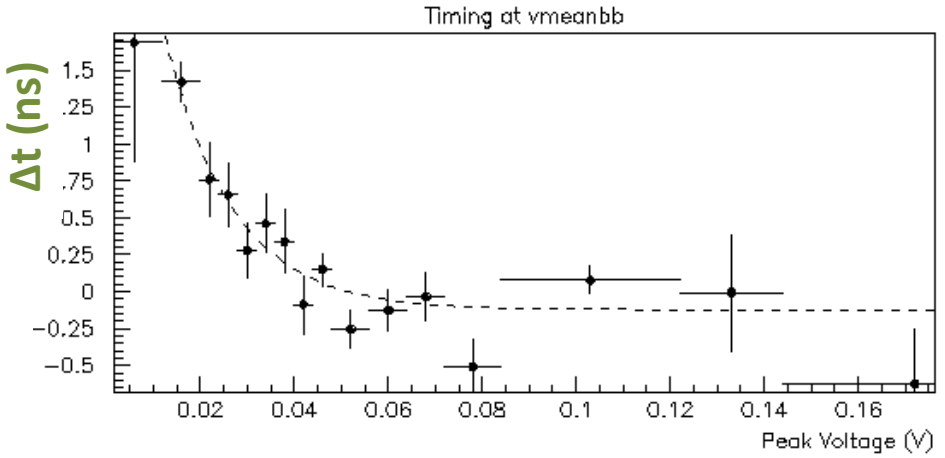
Timing

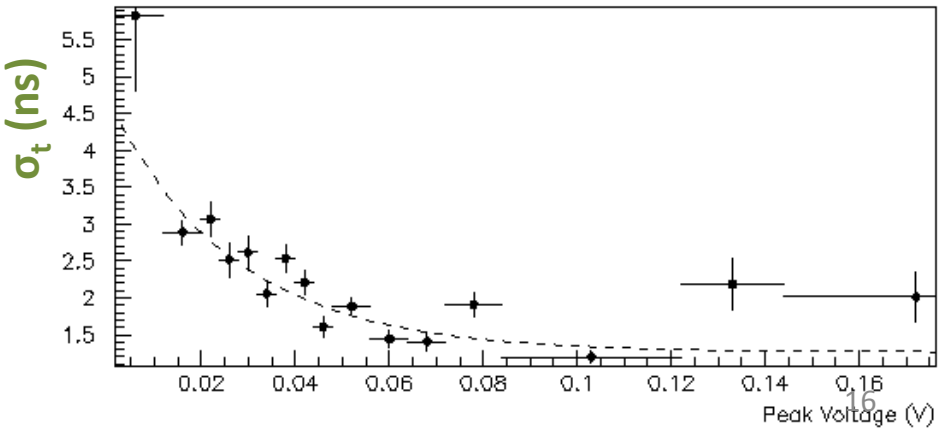
Timing at Threshold 9mV



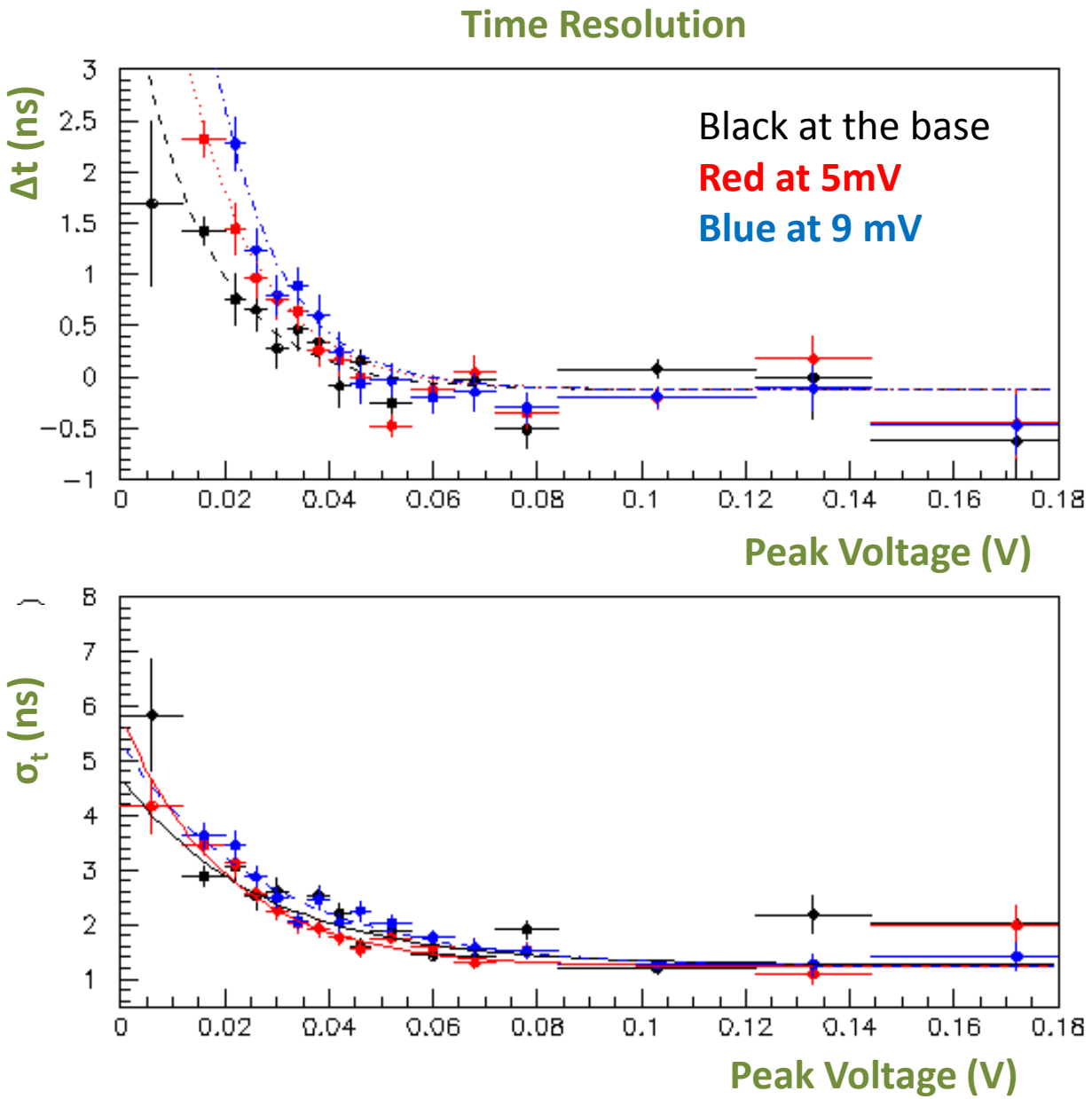


Timing at Base





Timing Corrections and Resolution

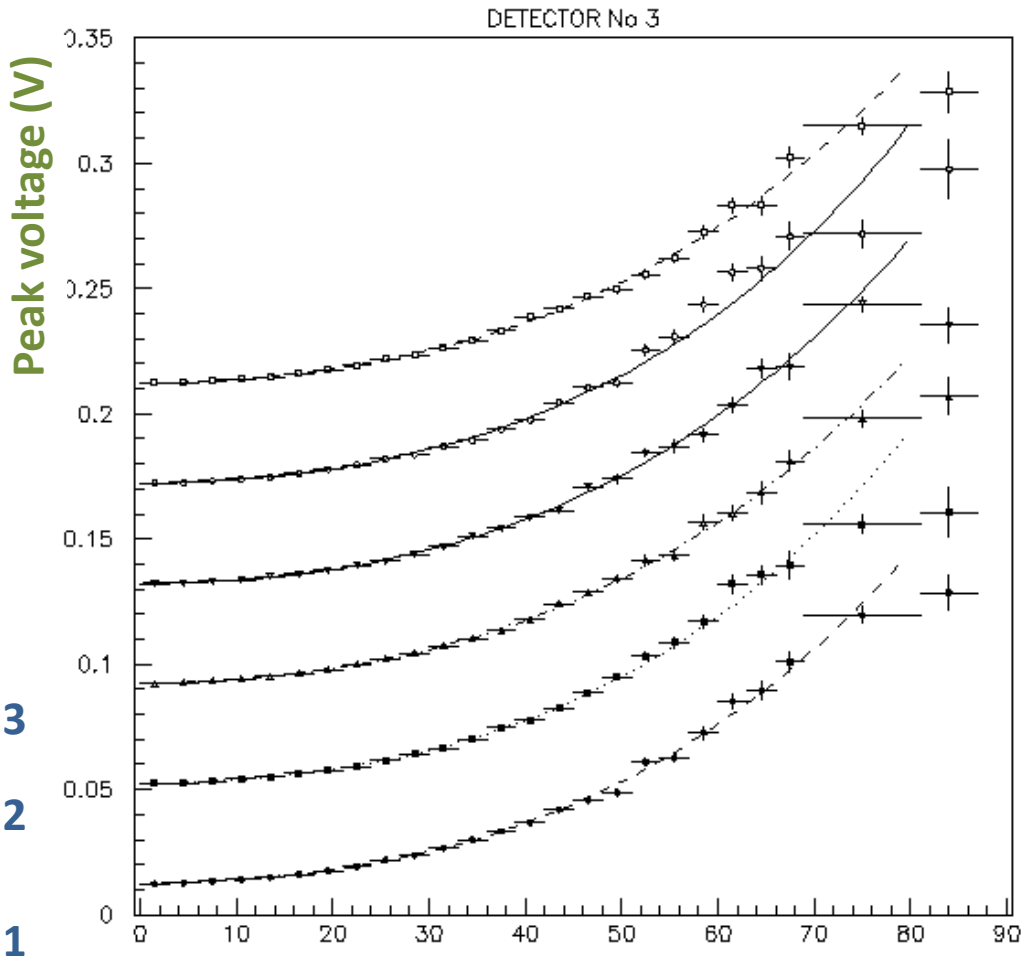


Peak Voltage vs Tot

Station A

Station B

Trigger triple coincidence on A with threshold at 10mV



Detector 3

Detector 2

Detector 1

Detector 3

Detector 2

Detector 1

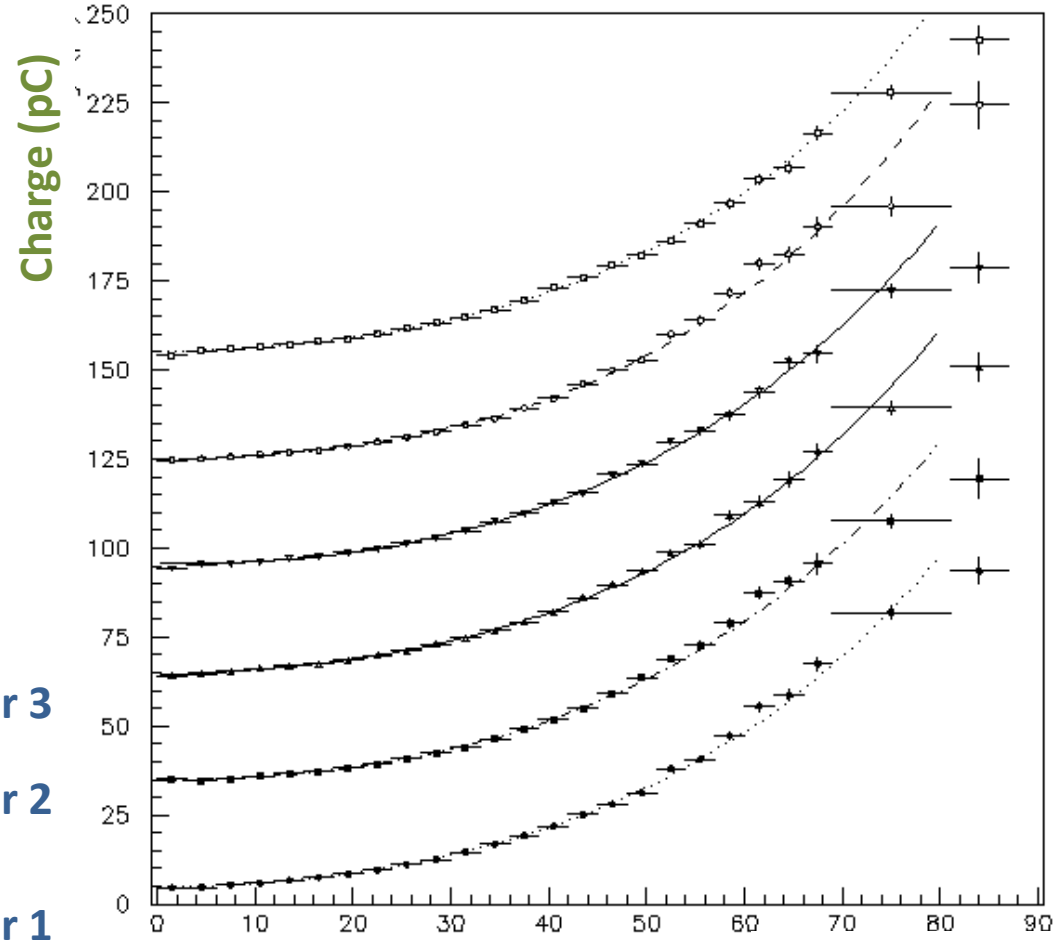
The points (except Detector 1) are parallel shifted by 0.4 mV per detector

Charge vs Tot

Station A

Station B

Trigger triple coincidence on A with threshold at 10mV



Detector 3

Detector 2

Detector 1

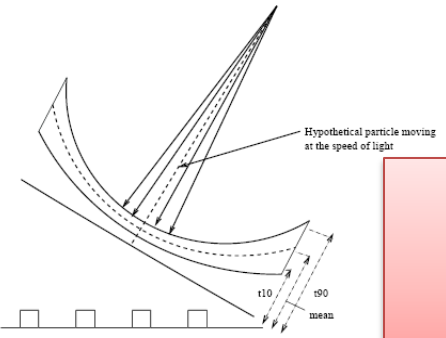
Detector 3

Detector 2

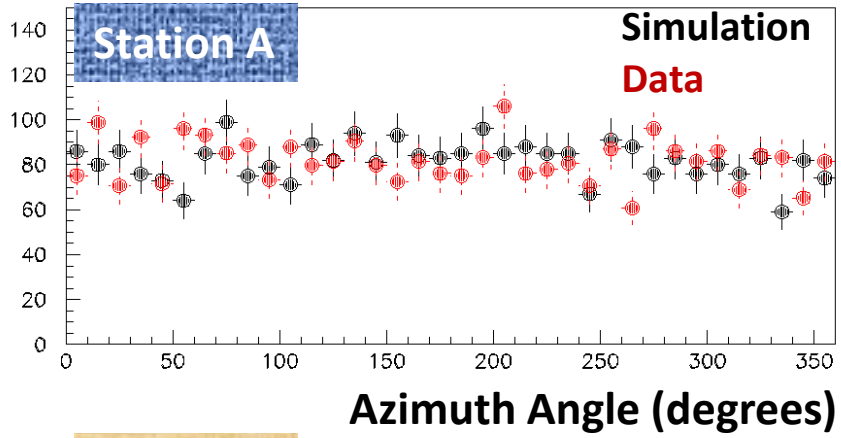
Detector 1

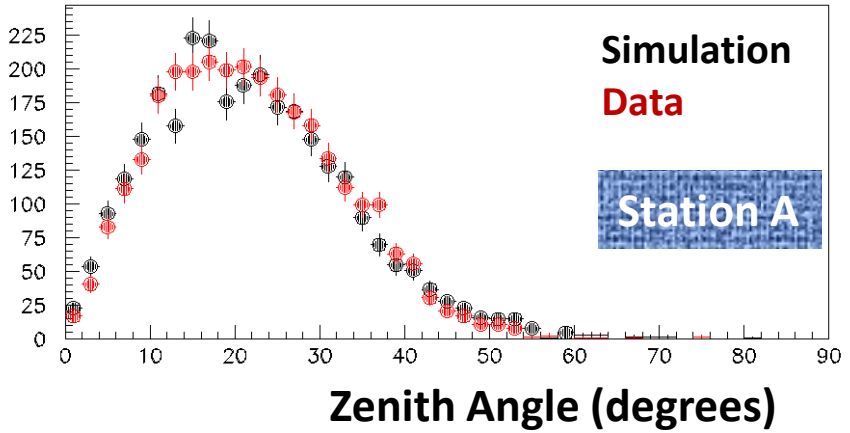
The points (except Detector 1) are parallel shifted by 30 pC per detector

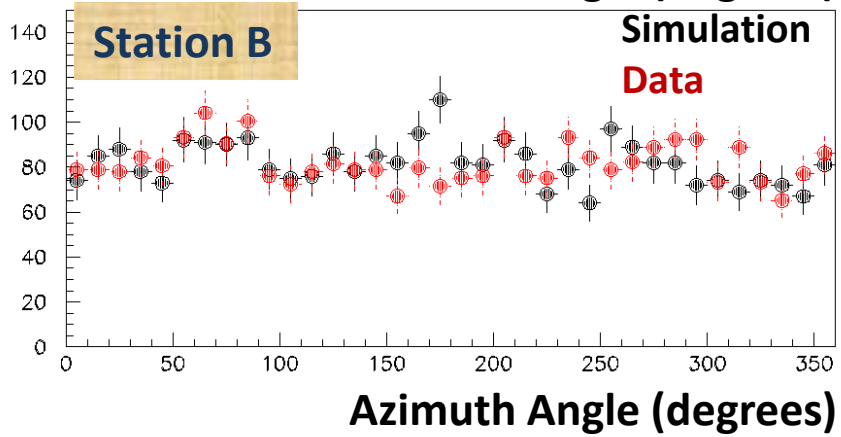
Shower Direction Reconstruction

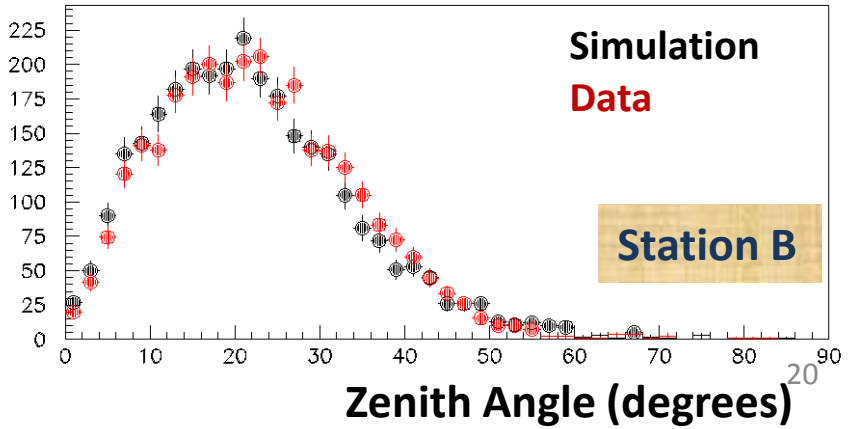


Angular Reconstruction of EAS
Using Triangulation
Comparison with Simulation



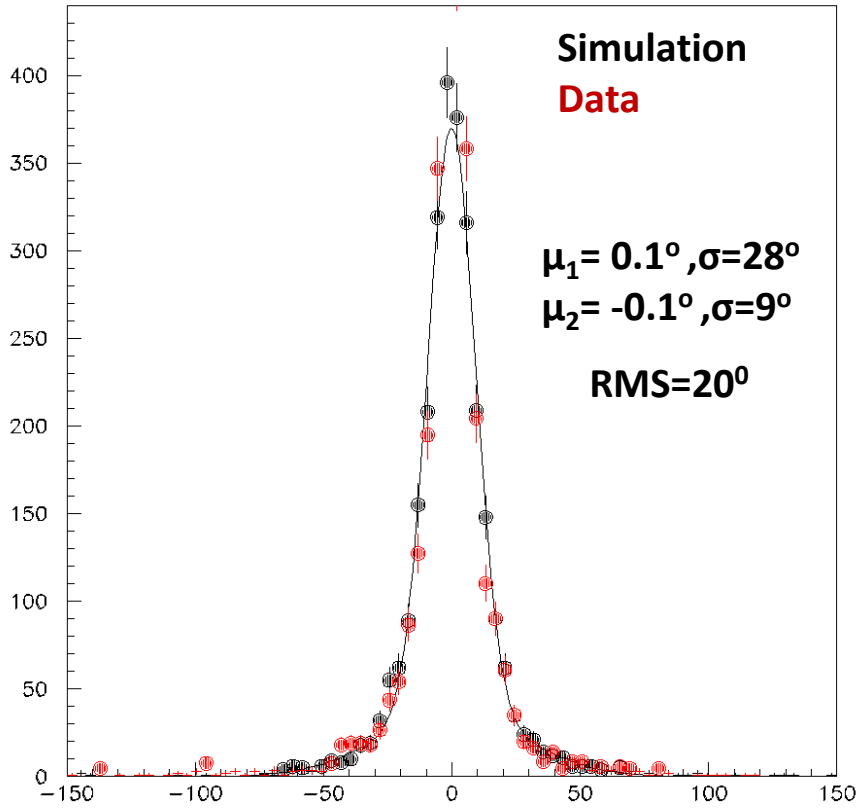




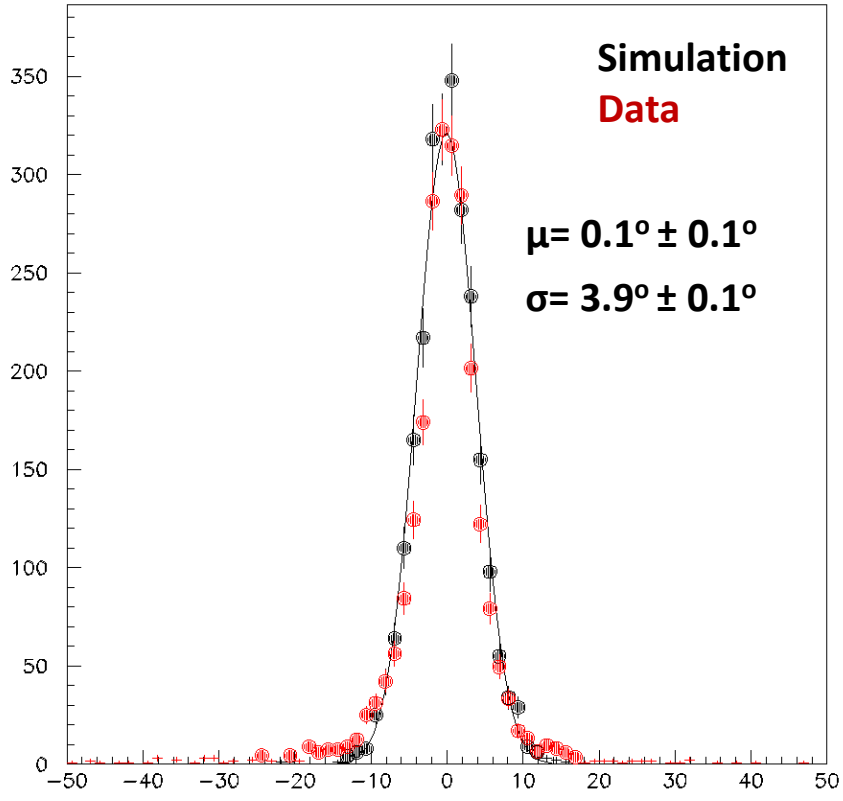


Comparison Between Stations

Showers detected from both stations



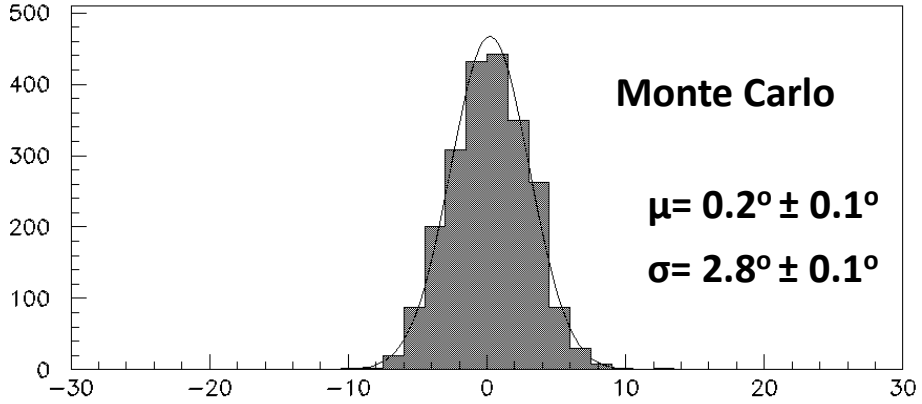
Azimuth Angle Deviation (degrees)

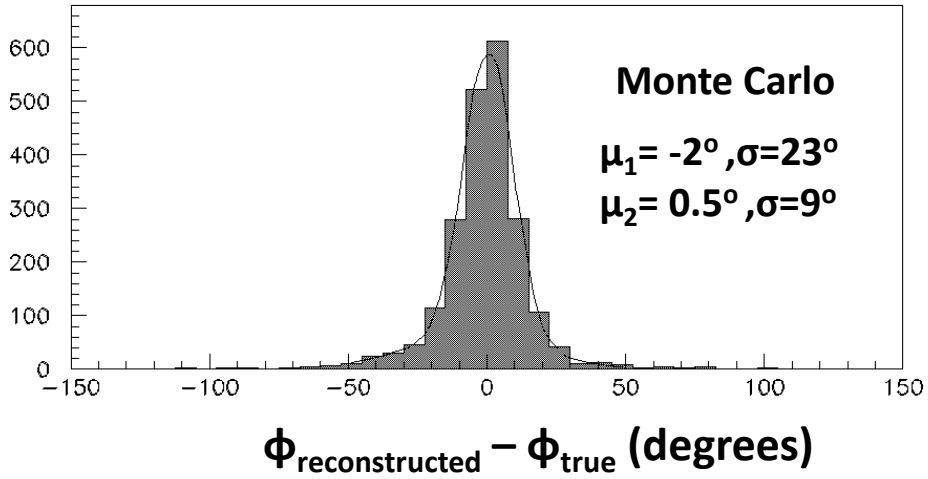


Zenith Angle Deviation (degrees)

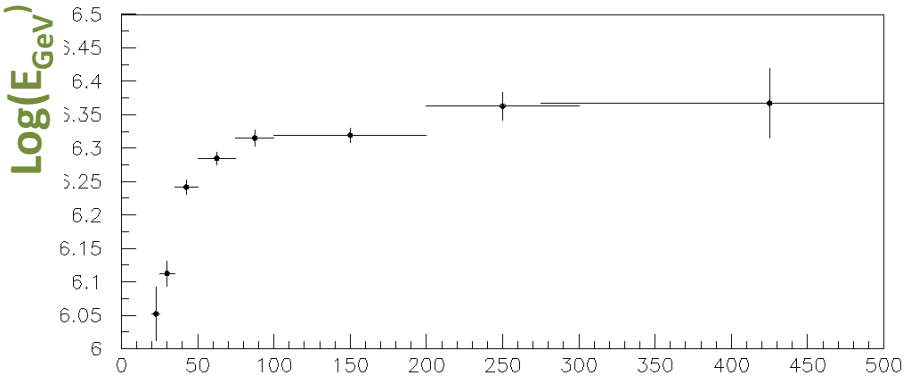
Single Station Performance

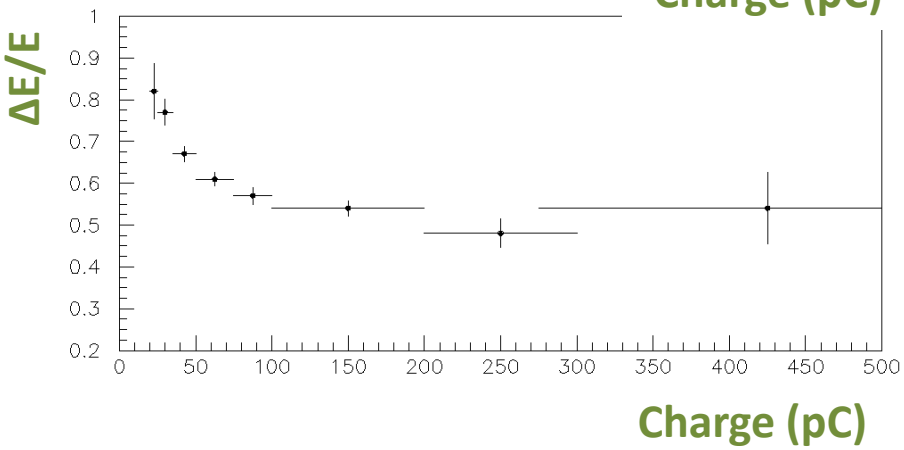
Estimated Angular Resolution





Estimated Energy Resolution





Conclusions and Plans

Conclusions

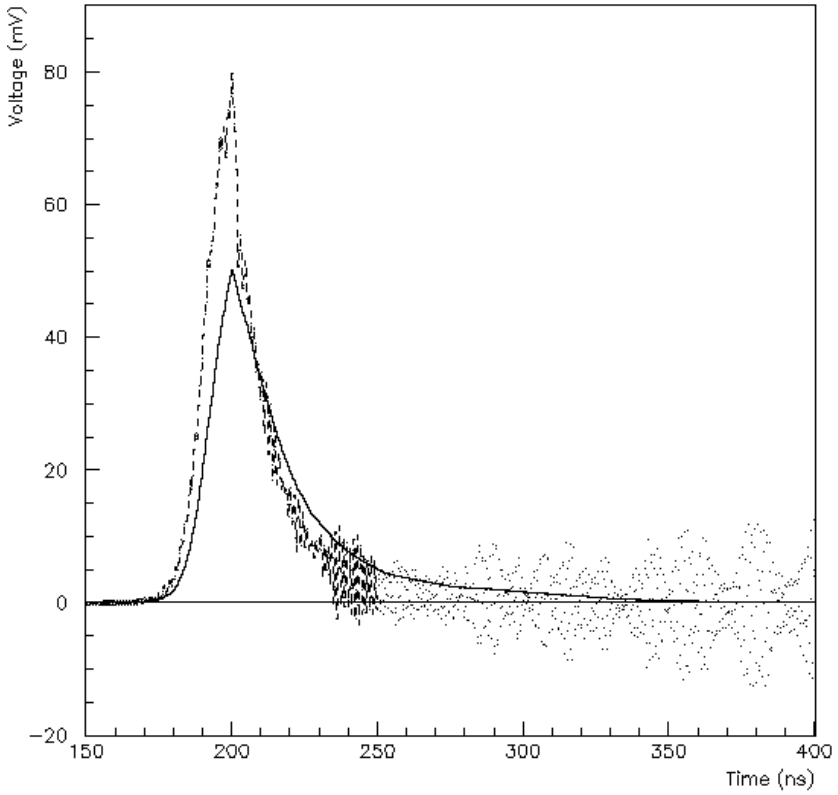
- The Simulation Software agrees very well with the data
  - Charge deposit
  - Peak voltage
  - TOT
  - Pulse shape
  - Response to showers

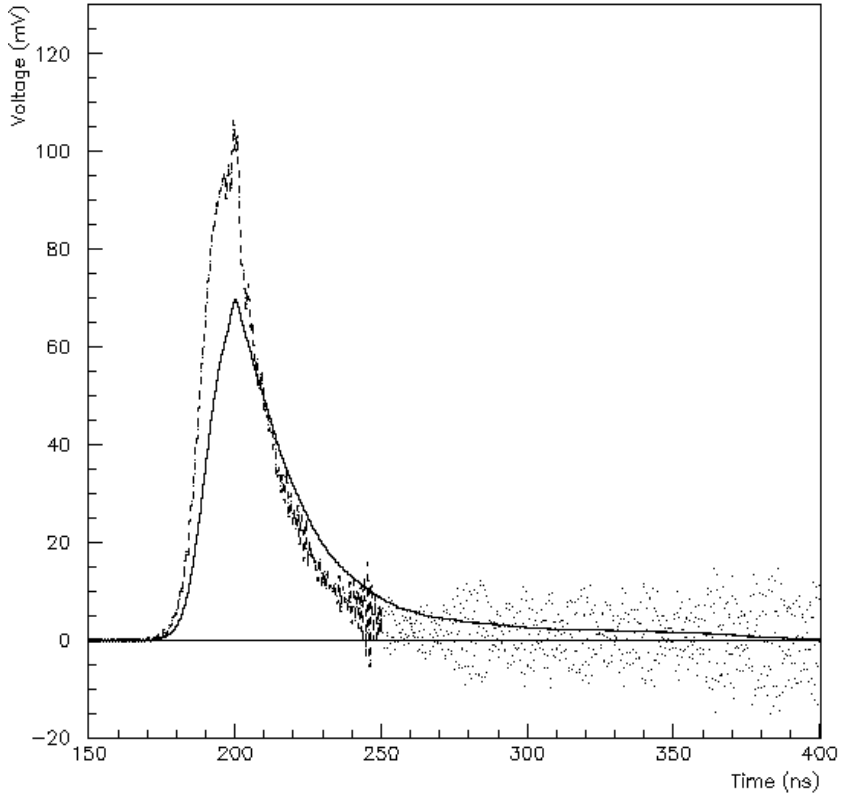
Plans

- Include quarknet functionality & parameterizations of peak voltage and charge vs TOT
- Radio simulation
- Gaseous detectors (MicroMegas)

Signal Transmission

Inverse Fourier Transformation





Pulse Restoration