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NESTOR

SIMULATION TOOLS AND METHODS

Vlvnt Workhop

- Physics Simulation
- Cherenkov light emition and propagation
- OM response

GEANT4

- PMT Waveform generation (signal)
- Trigger & Electronics Response

HOME MADE

Raw Data Format

Physical Processes

- **Neutrino interaction, vertex simulation**
- μ and e interactions into the water
  - Cherenkov Emition
  - Multiple scattering
  - Bremsstrallung
  - Ionisation (delta rays)
  - pair production
  - Muon nucleus interaction
  - Electromagnetic and Hadronic Showers
  - etc

Cherenkov photon generation & interactions

Primary or Secondary Particle Tracking

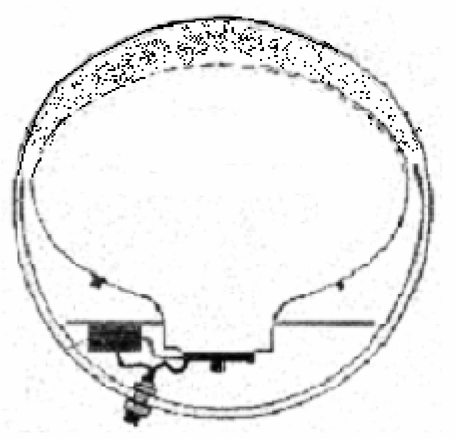
Generation of Cherenkov photons

Optical photon Tracking

- Absorption in water
- Boundary processes & scattering

Optical Module description

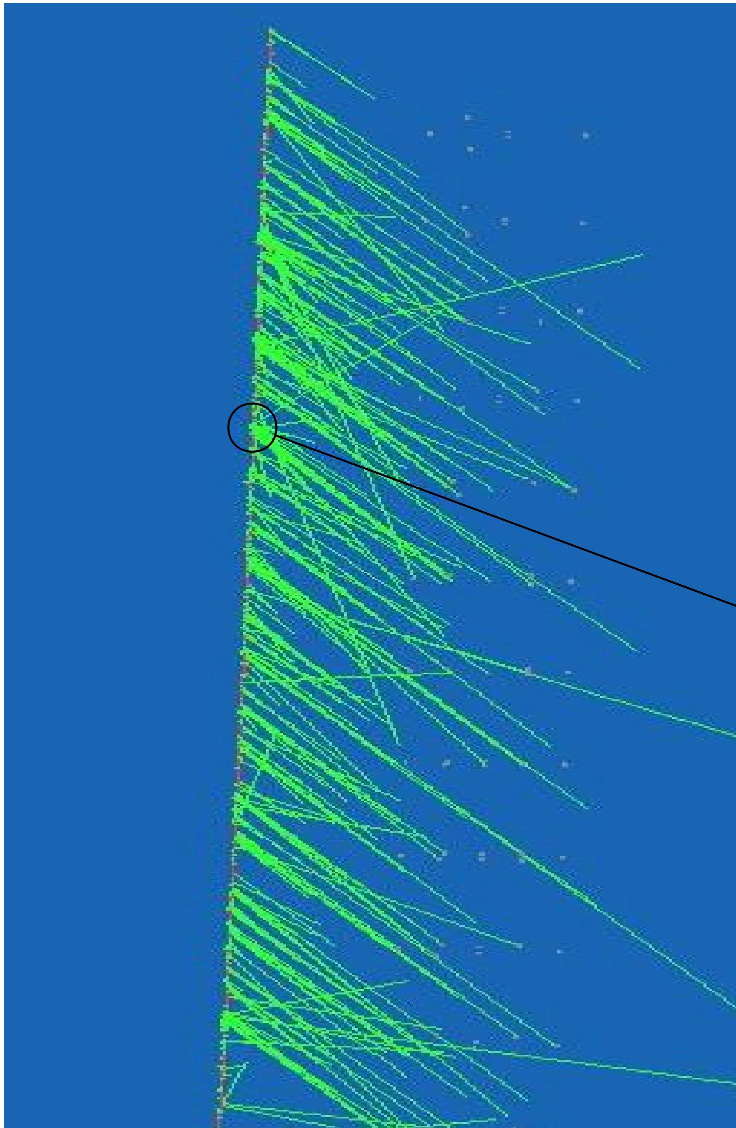
- Detailed geometrical description



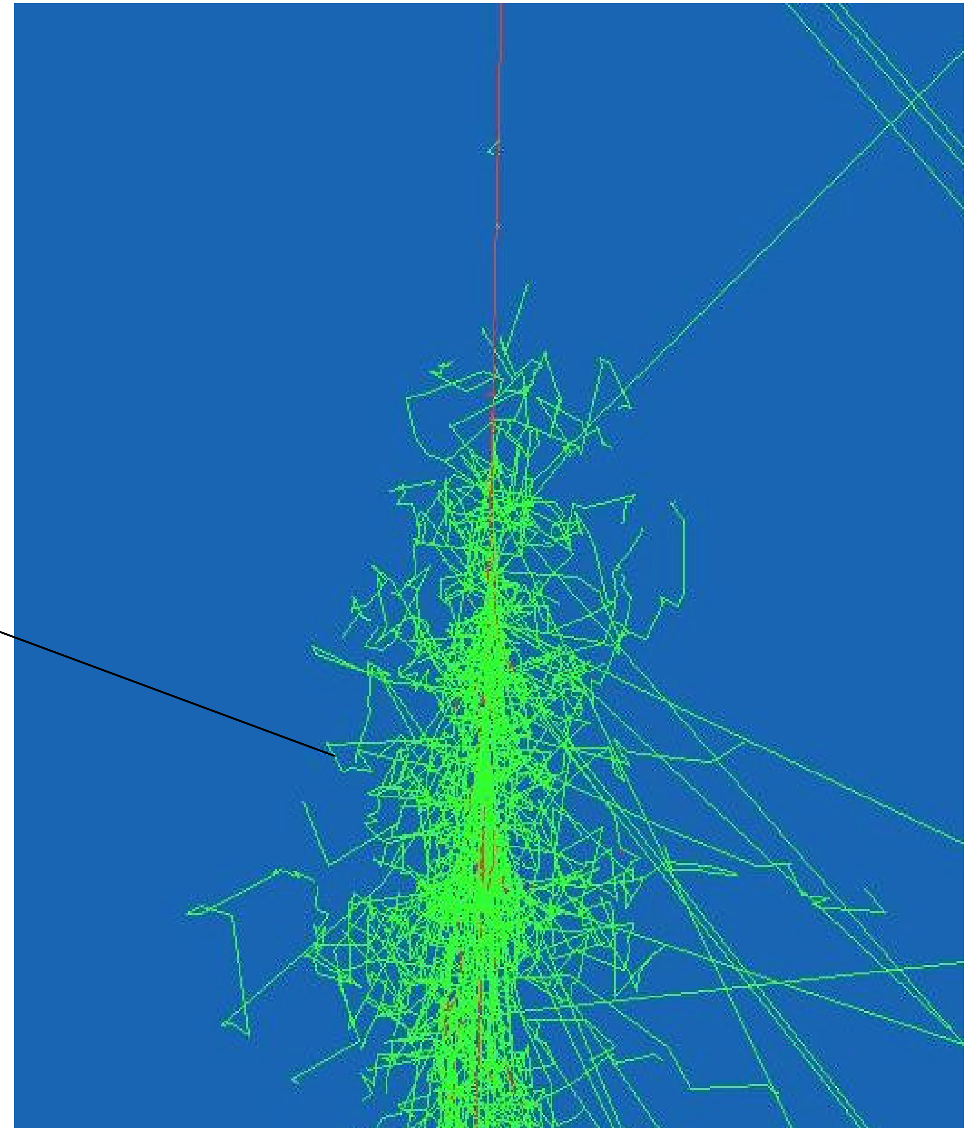
- Material Description (absorption, refraction index)

Example of GEANT4 full simulation

A muon track (100 GeV)



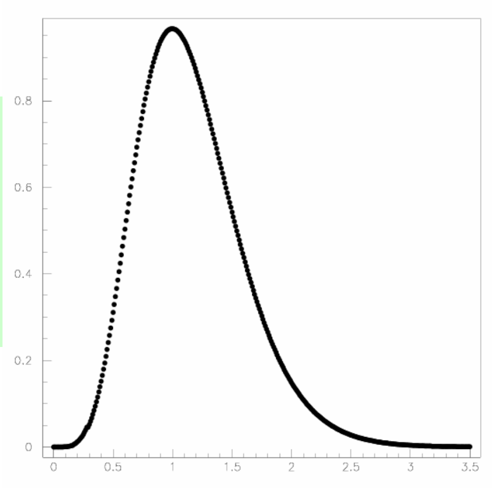
Shower Development



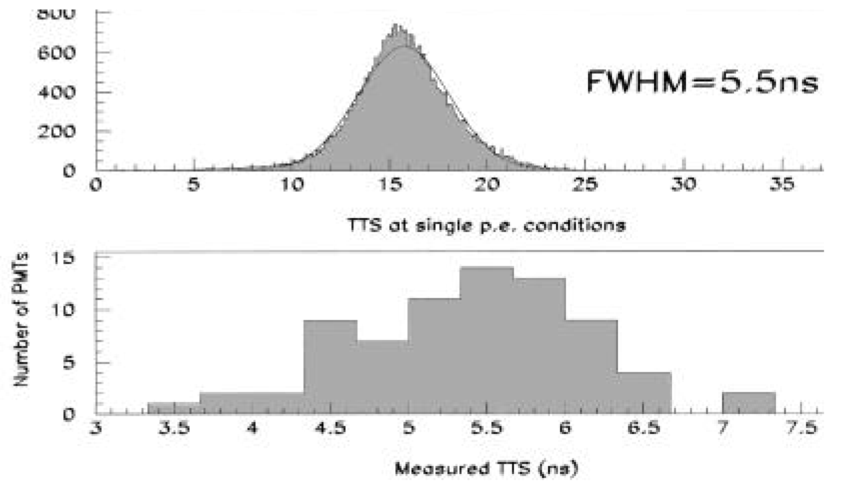
Waveform generation (a)

Treat independently each pe produced during the GEANT4 Simulation

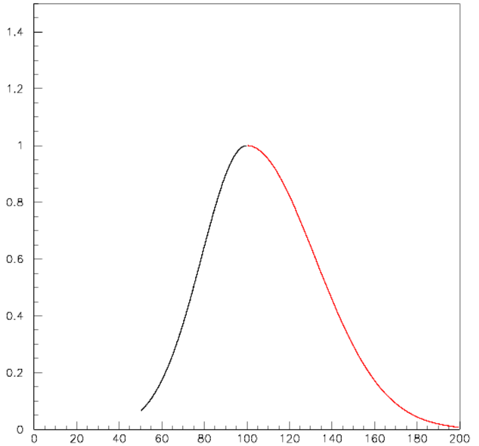
Pulse height distribution for one pe (measured)



Transition Time distribution for one pe



Pulse Shape



Waveform generation (b)

Add Background pulses due to thermionic noise and the K40 radioactivity.

• The pulse height distribution of the thermionic noise has been measured at the Lab.

• The K40 background pulses follow the characteristic pulse height distribution of a single pe.

• The arrival time of the background pulses is random

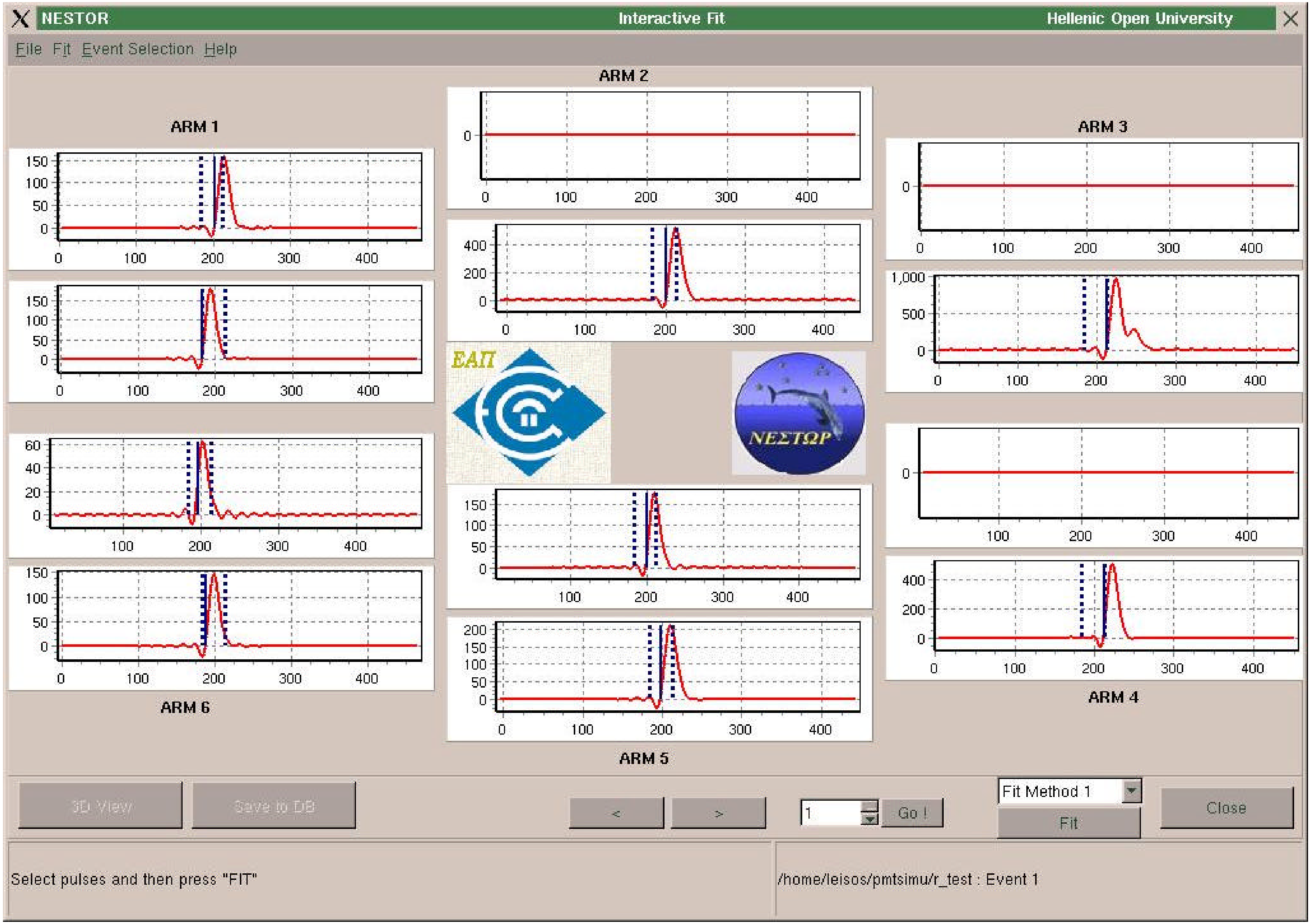
The linear sum of the simulated response to each pe generates the PMT Waveform.

Electronics response

Detailed simulation of :

- PMT Pulse Attenuation & Delay (see A. Tsirigotis talk)
- PMT Pulse Digitization in the ATWDs
- Trigger formation
- Data Formatting (using the raw data protocol)

Example of MC Simulation



Parameterization of the expected PMT Response (a)

Because we have to use the Collected PMT Charge in the Fitting Procedure…

Compare the deposited charge at each PMT with the expected value for each candidate track !?

Parameterization of:

- the Expected Mean Number of Photons at each PMT

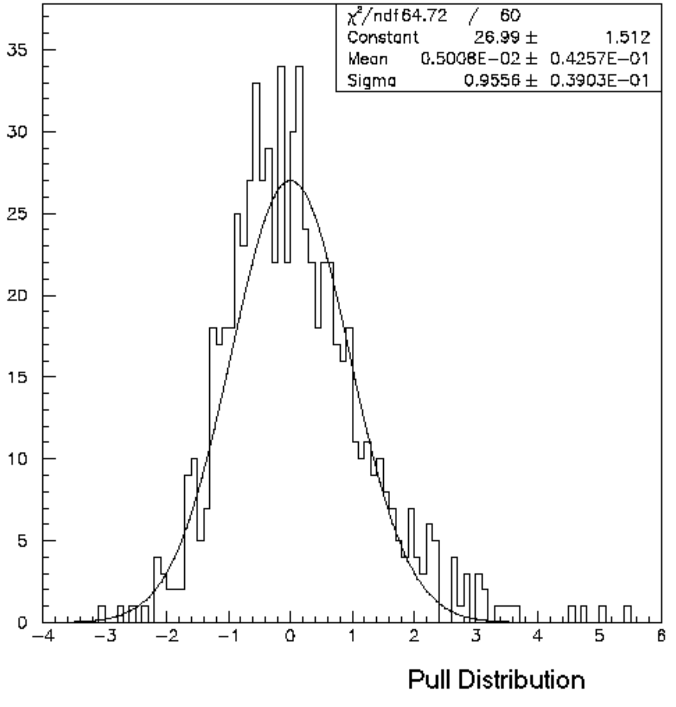
as a function of the track direction and distance form the PMT

- the Variance of the Distribution of the Expected Number of Photons at each PMT

as a function of the track direction and distance form the PMT

Parameterization of the expected PMT Response (b)

Compare the Geant4 Full Simulation of the Detector with the Parameterization of Mean Number and Variance of the Deposited PEs ?



Pull :

(Deposited Charge$_{GEANT}$-Expected charge)/Error

Comparison of the MC Estimations with the Data Sample

Data from a depth of 4000 m

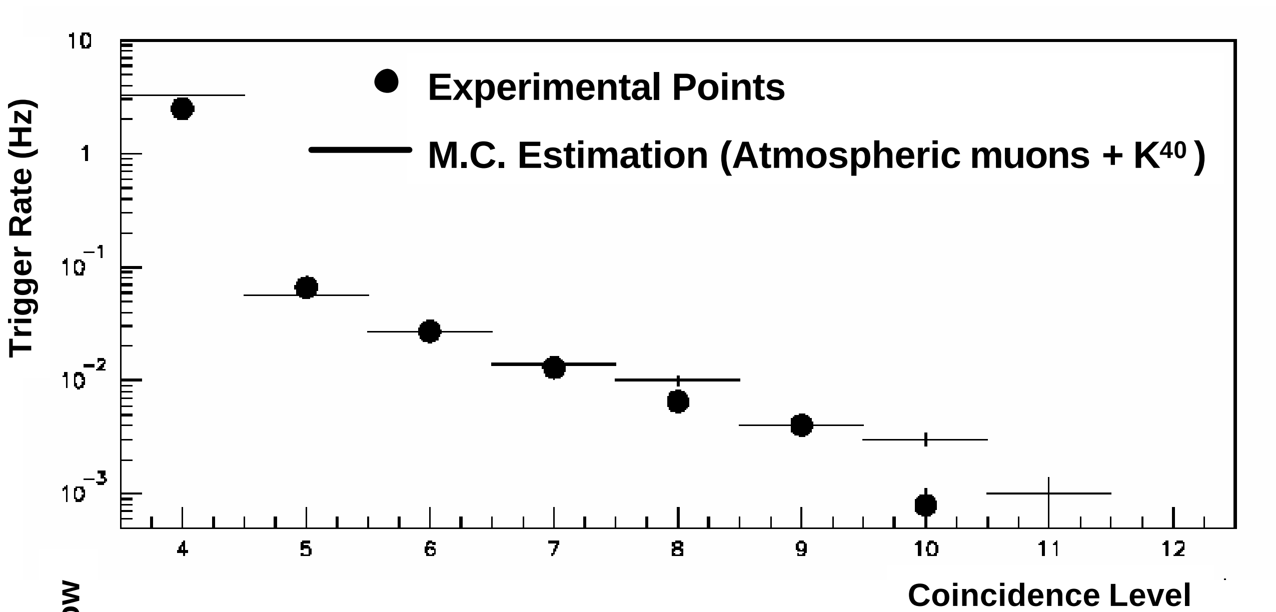
Trigger Studies

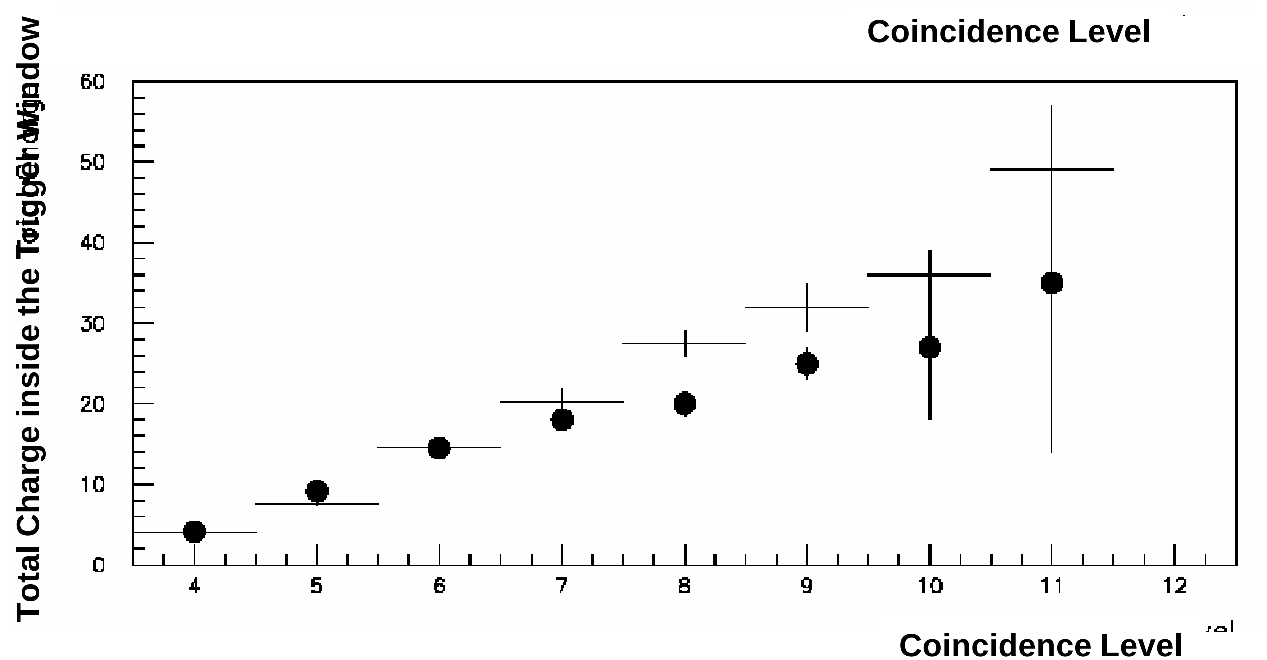
Data Collected with

4fold Majority Trigger

Thresholds at 30mV

(1/4 P.E.)





Comparison of the MC Estimations with the Data Sample

Data from a depth of 4000 m

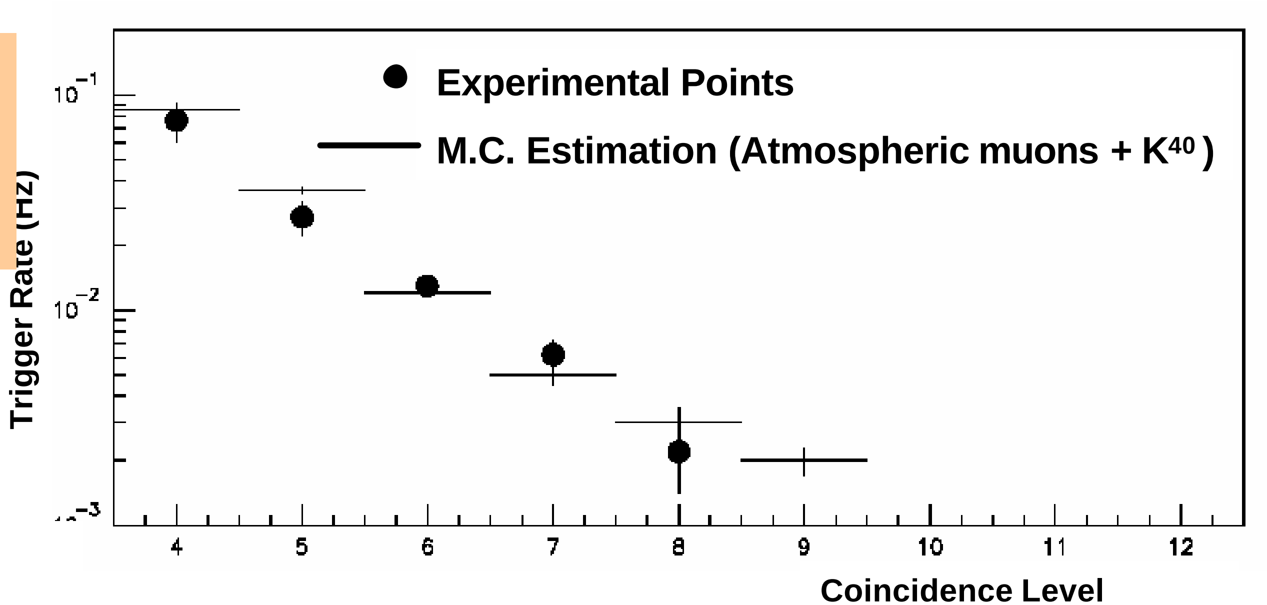
Trigger Studies

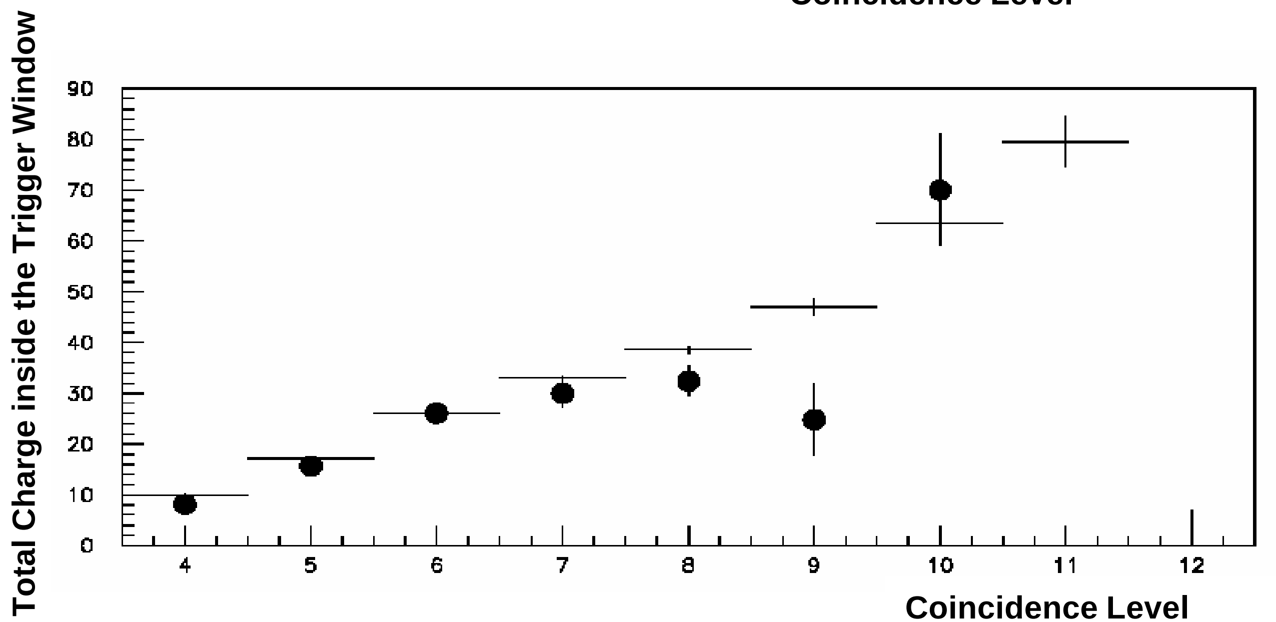
Data Collected with

4fold Majority Trigger

Thresholds at 120mV

(1 P.E.)





Comparison of the MC Estimations with the Data Sample

Data Collected with

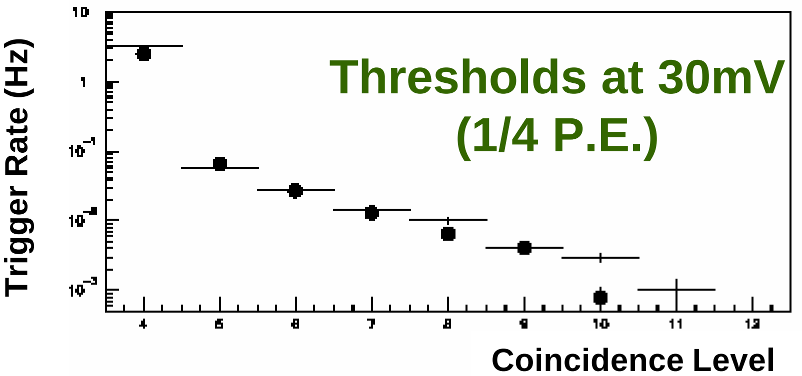
4fold Majority Coincidence Trigger

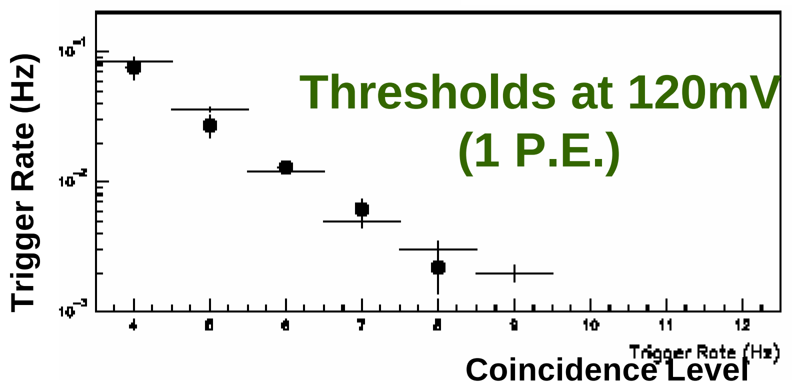
(greater or equal to 4fold)

	Thresholds at 30 mV	Thresholds at 120 mV
Measured Total Trigger Rates	2.61 ± 0.02 Hz	0.12 ± 0.01 Hz
M.C. Prediction (atmospheric muons only)	0.141 ± 0.005 Hz	0.12 ± 0.01 Hz

● **Experimental Points**

—— **M.C. Estimation** (Atmospheric muons + K^{40})





Fast Simulation

A <u>good</u> approximation for the majority of the effects we study

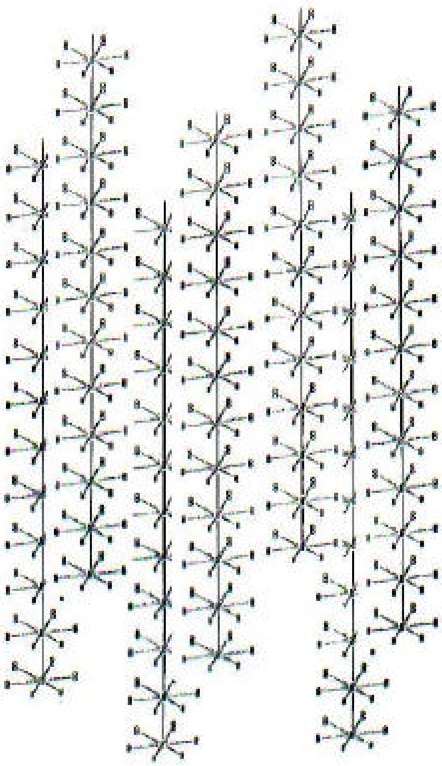
- point like shower
- generation of flux of photons

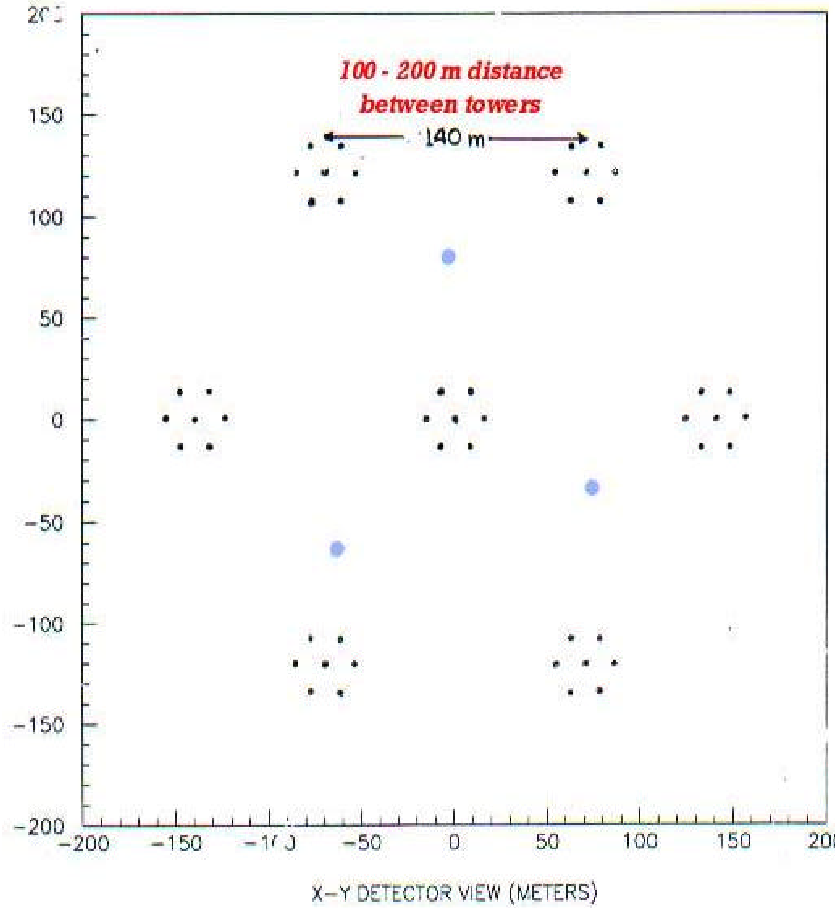
(does not treat each photon separately)

- parameterization of PMT response
- The simulation of the electronics is an approximation of the real process
- The energy losses equivalent to GEANT4

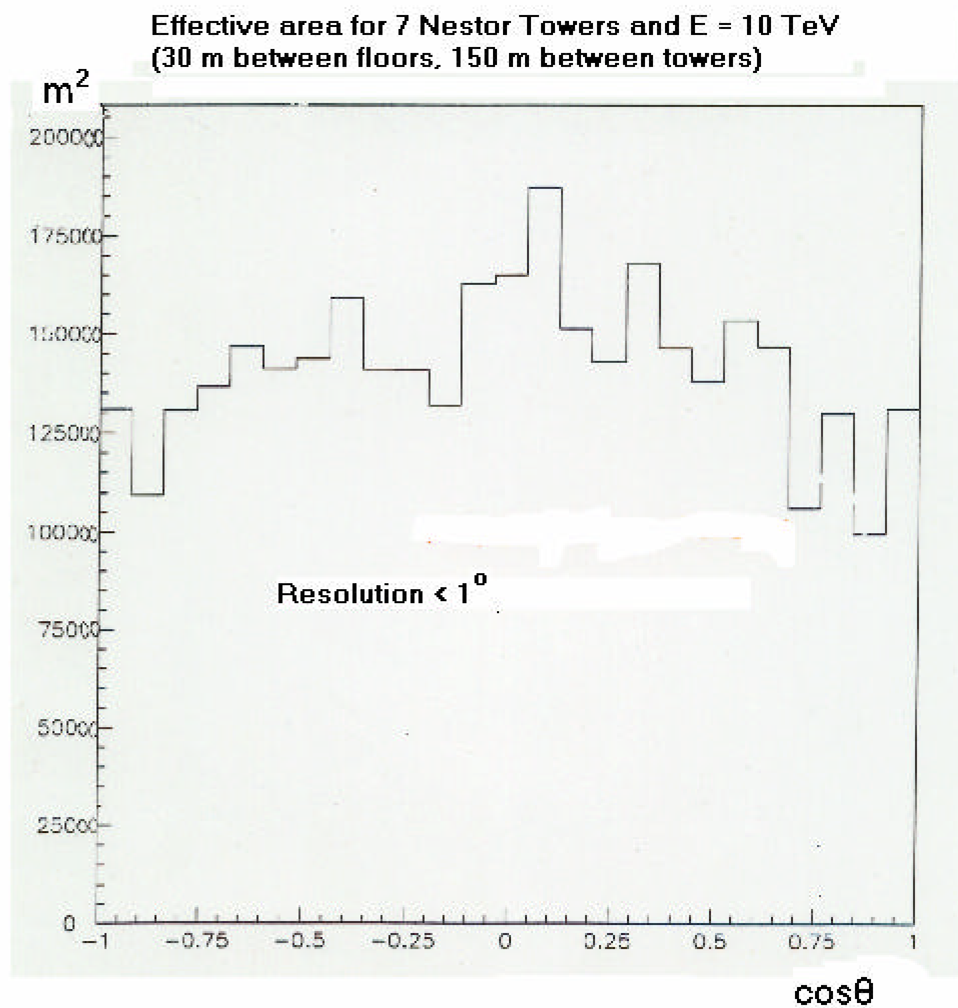
Example: Eff Area Calculation (a)

15% of a Km^2 NESTOR Detector

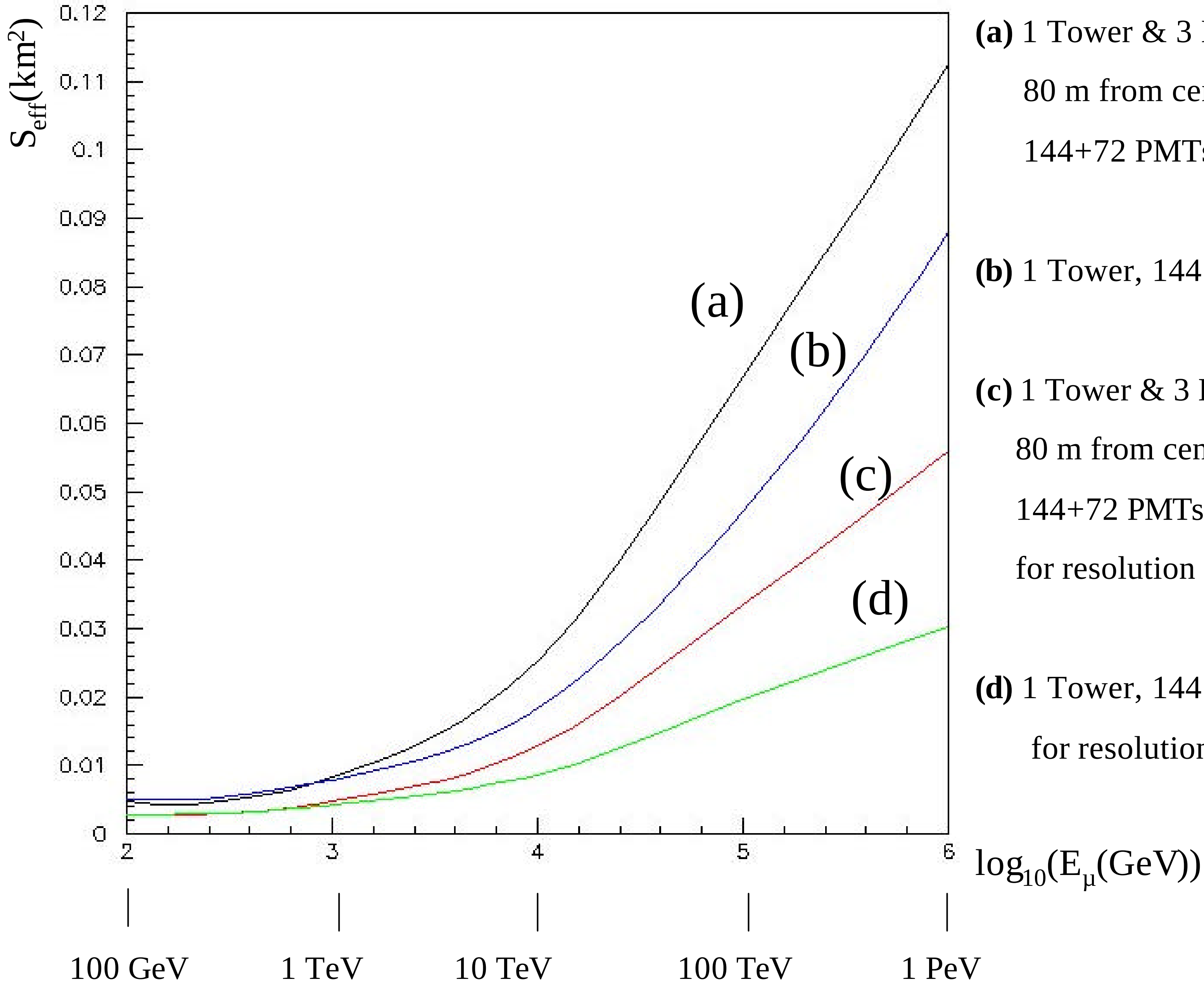




Example: Eff Area Calculation (b)



Example: Eff Area Calculation (c)



(a) 1 Tower & 3 DUMAND strings,
80 m from center of Tower,
144+72 PMTs (15”)

(b) 1 Tower, 144 PMTs (15”)

(c) 1 Tower & 3 DUMAND strings,
80 m from center of Tower,
144+72 PMTs (15”),
for resolution <5°

(d) 1 Tower, 144 PMTs (15”)
for resolution <5°