Geant4 simulation of the DREAM $PbWO_4$ single crystal: preliminary results

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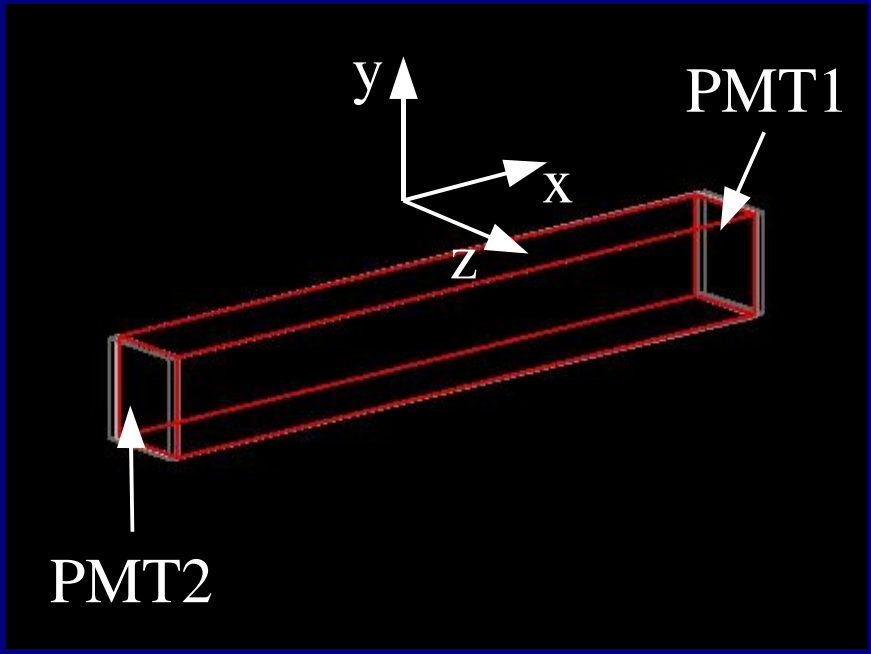
Outline

- Geometry and material description
- Physics processes
- Scintillation light yield
- Cerenkov light yield
- Simulation/data comparison
- Conclusion and plans

Geometry and material (1)

- A $PbWO_4$ single crystal $(2.2 \times 2.2 \times 18)cm^3$
  - wrapped with aluminized mylar sheet of 100μm thickness
- 1mm silicone cookies between single crystal and PMT windows
- Borosilicate glass PMT windows as sensitive detectors
  - a hit is a optical photon
  - 100% efficiency is assumed

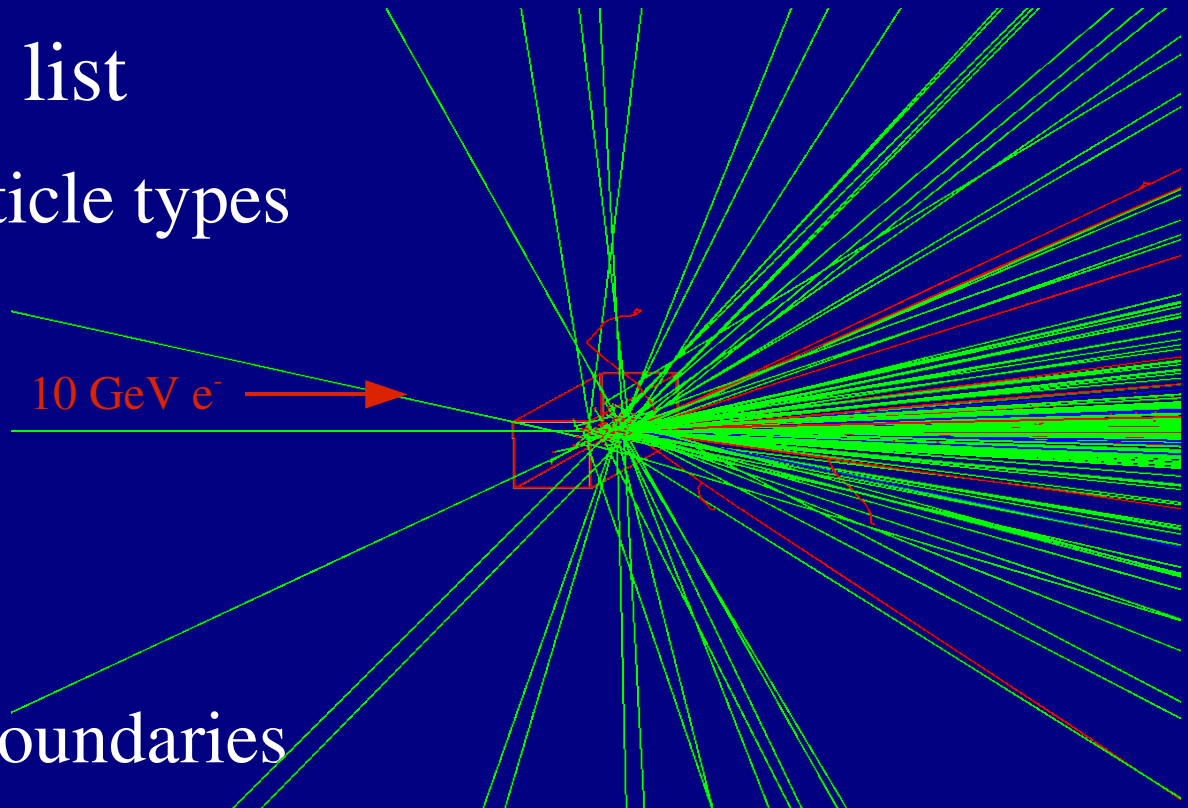


Geometry and material (2)

- Optical properties of PbWO
  - refractive index: 2.16
  - scintillation light yield: 150γ/MeV
  - scintillation fast component: 440nm (5ns) 55%
  - scintillation slow component: 530 nm (15ns) 45%
  - references: NIM A 365 (1995) 291-298, Rev. Mod. Phys 75 (2003) 1243-1286
- silicone refractive index 1.43
- PMT window refractive index 1.473
- surface between crystal and mylar wrapping with 80% reflectivity
  - specular reflection is assumed

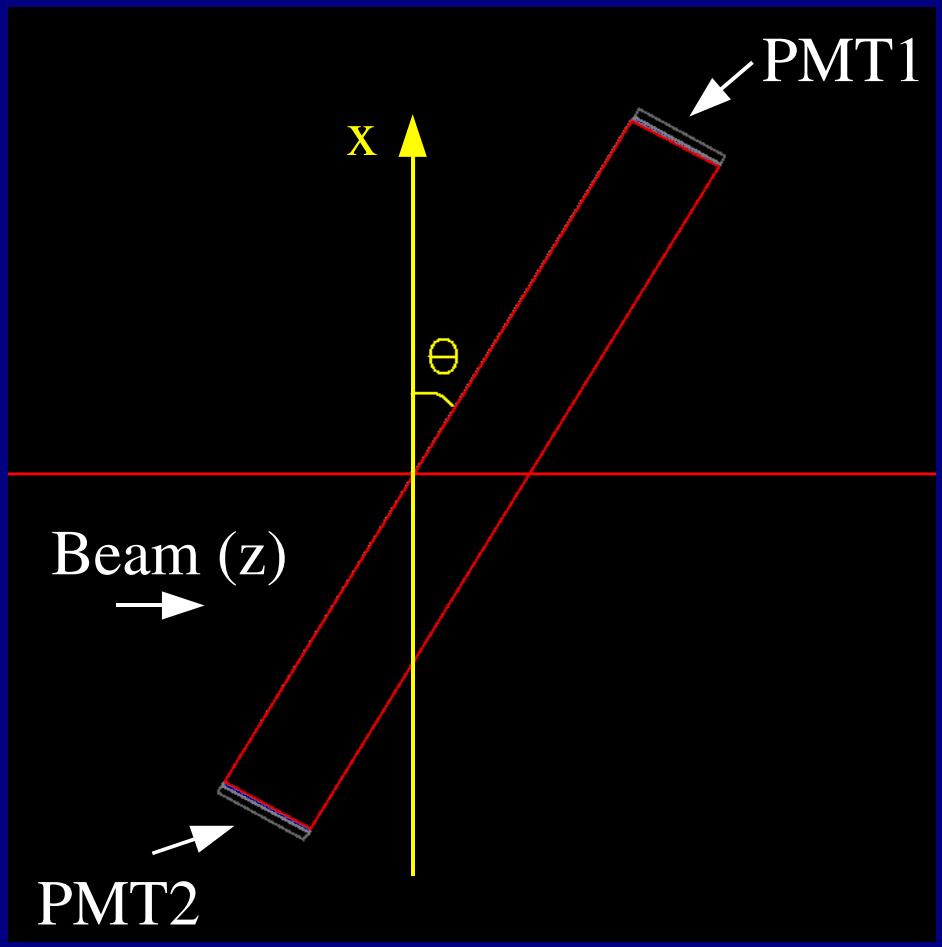
Physics list

- Standard EM Physics list
  - default cut for all particle types
- Optical processes
  - photon production
    - scintillation
    - Cerenkov
  - photon processes at boundaries
  - only optical photons with wavelength in 300-800 nm are taken into account for tracking according to the whole sensitivity range of the PMT photocathode

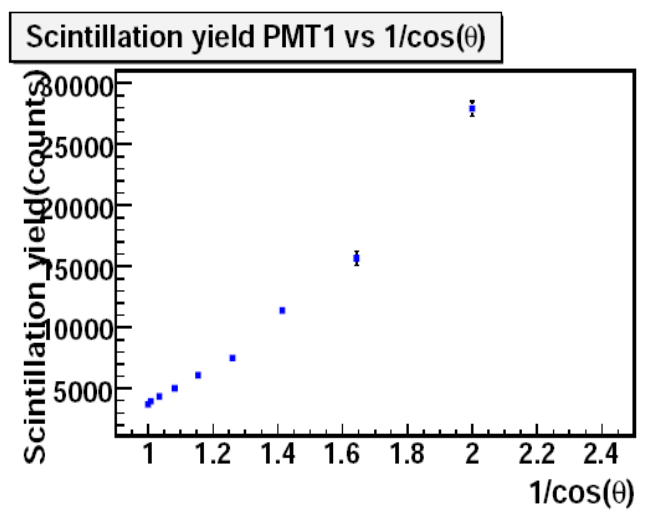


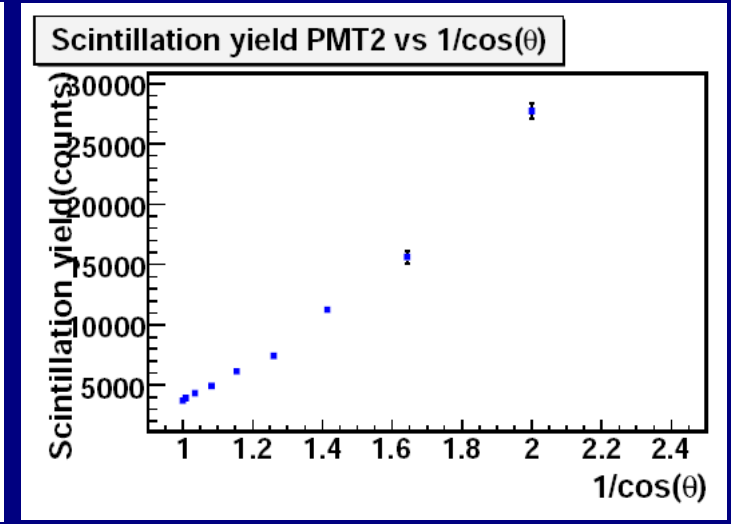
Data sample

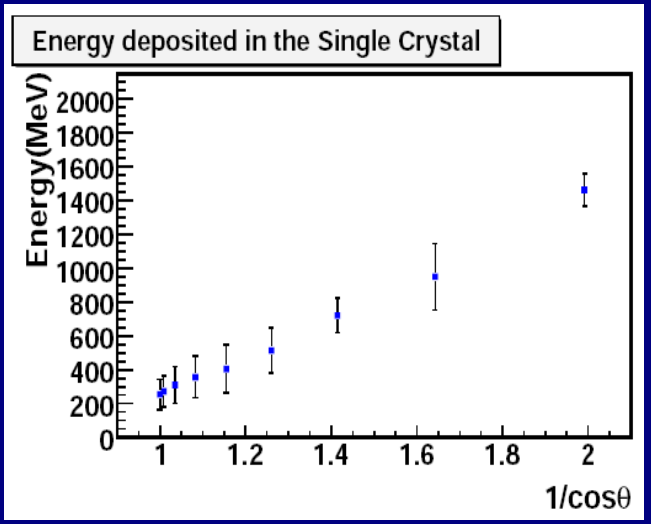
- 1000 events for each value of the angle between the crystal and the beam (z) axis have been simulated with 10 GeV electron beam: 0, 7.5, 15, 22.5... up to 60 degrees
- no beam spread has been introduced



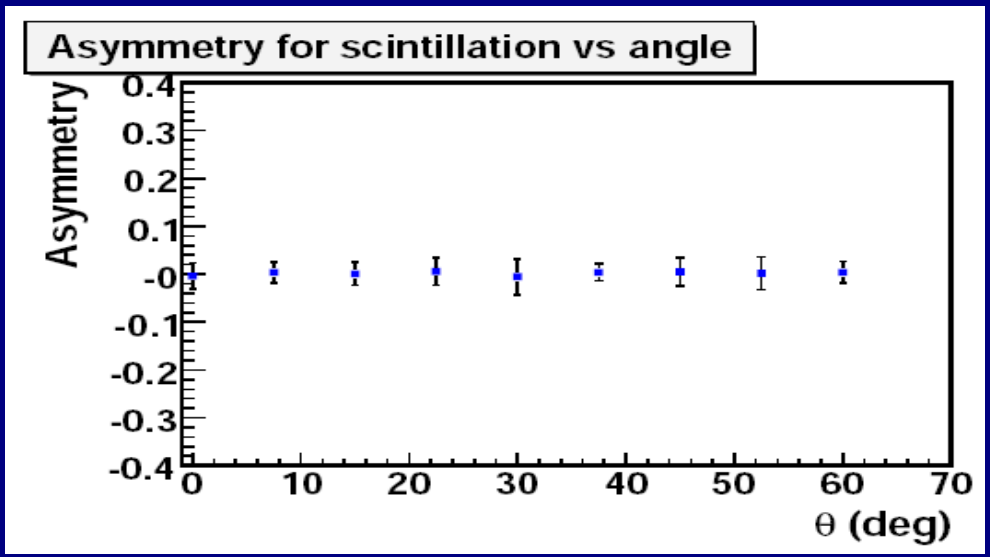
Scintillation light



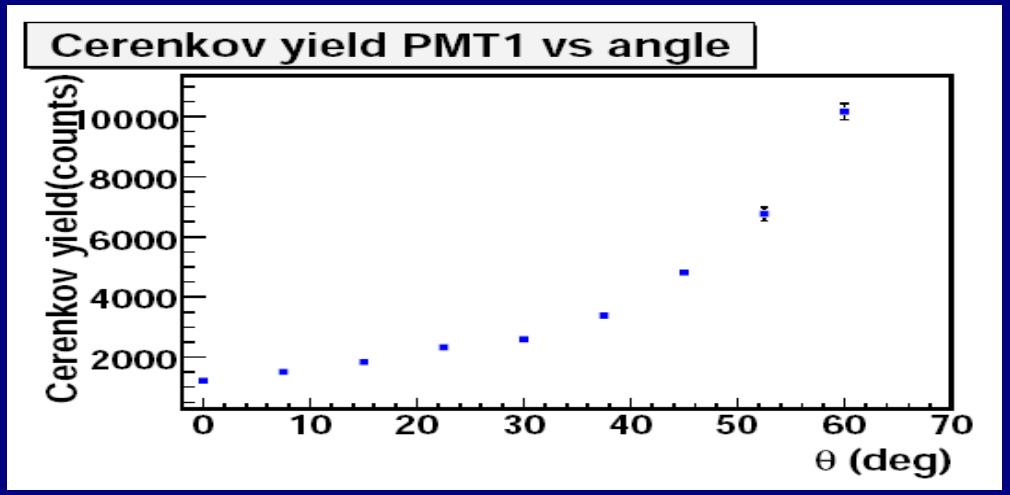


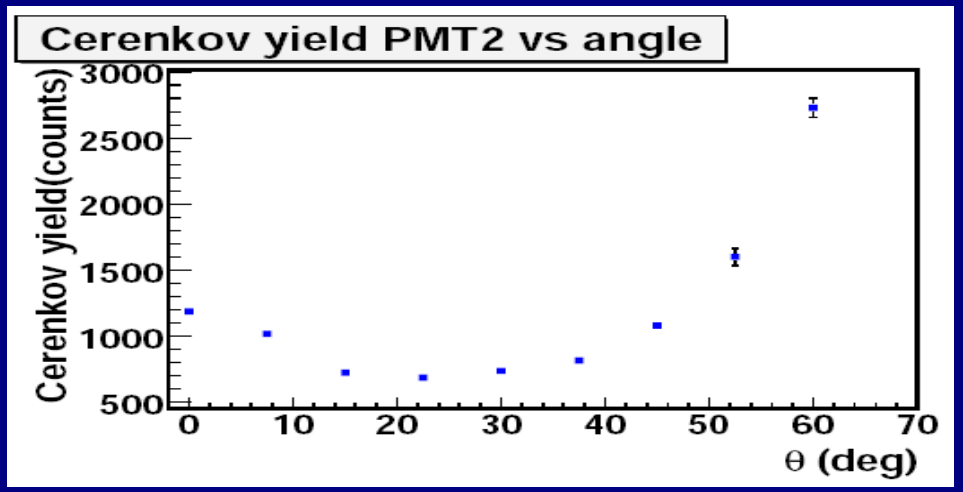


- scintillation light for both the PMTs: the scintillation increases linearly with the crystal length crossed by the primary electrons as the energy deposited in the crystal
- asymmetry due to scintillation photons is zero according to expectation

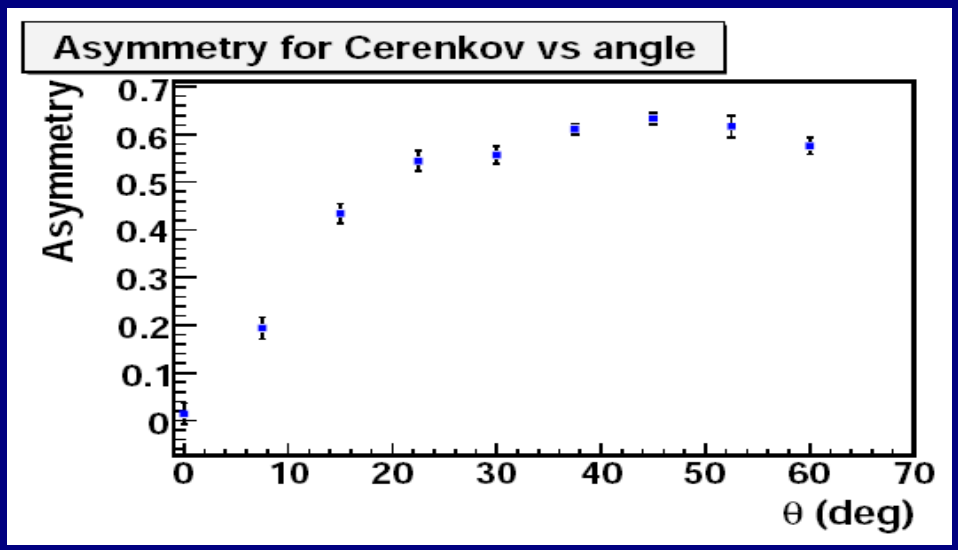


Cerenkov light



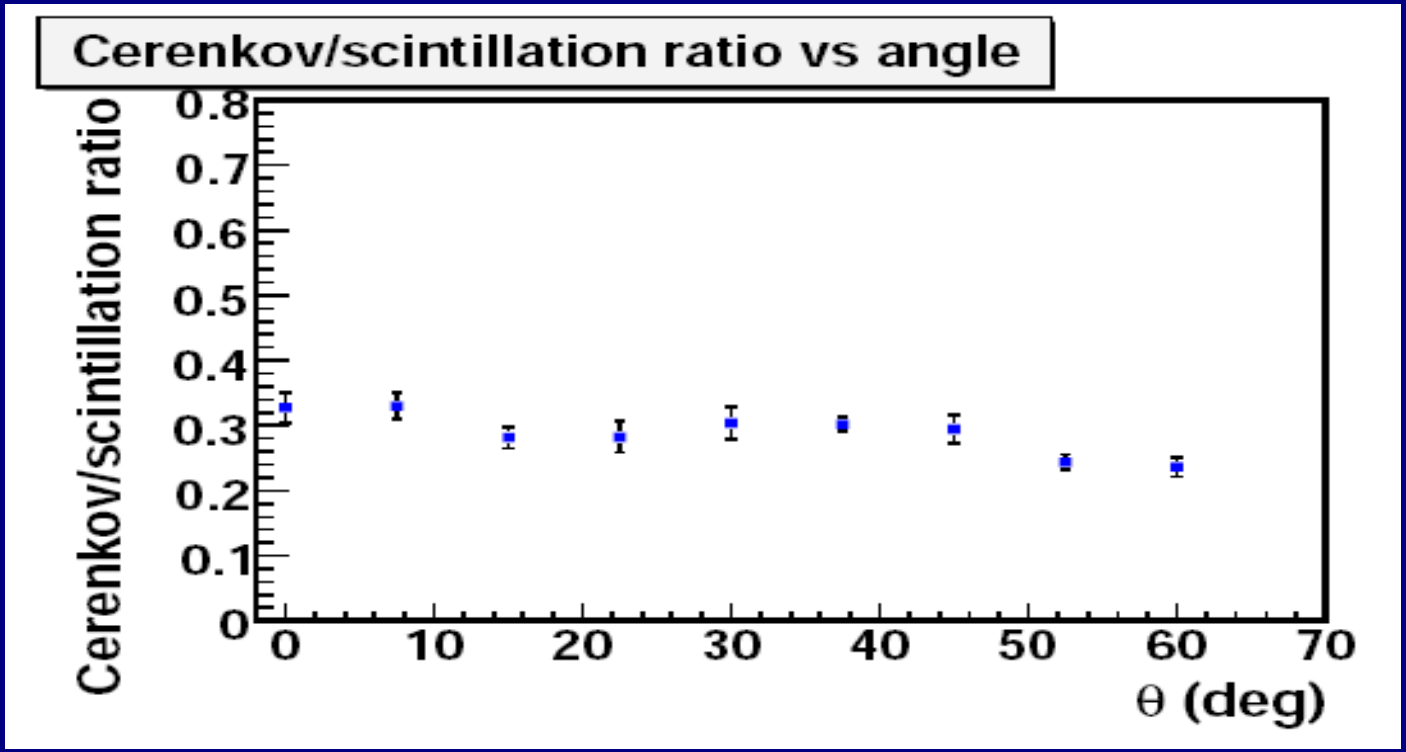


- Cerenkov light for both the PMTs and asymmetry



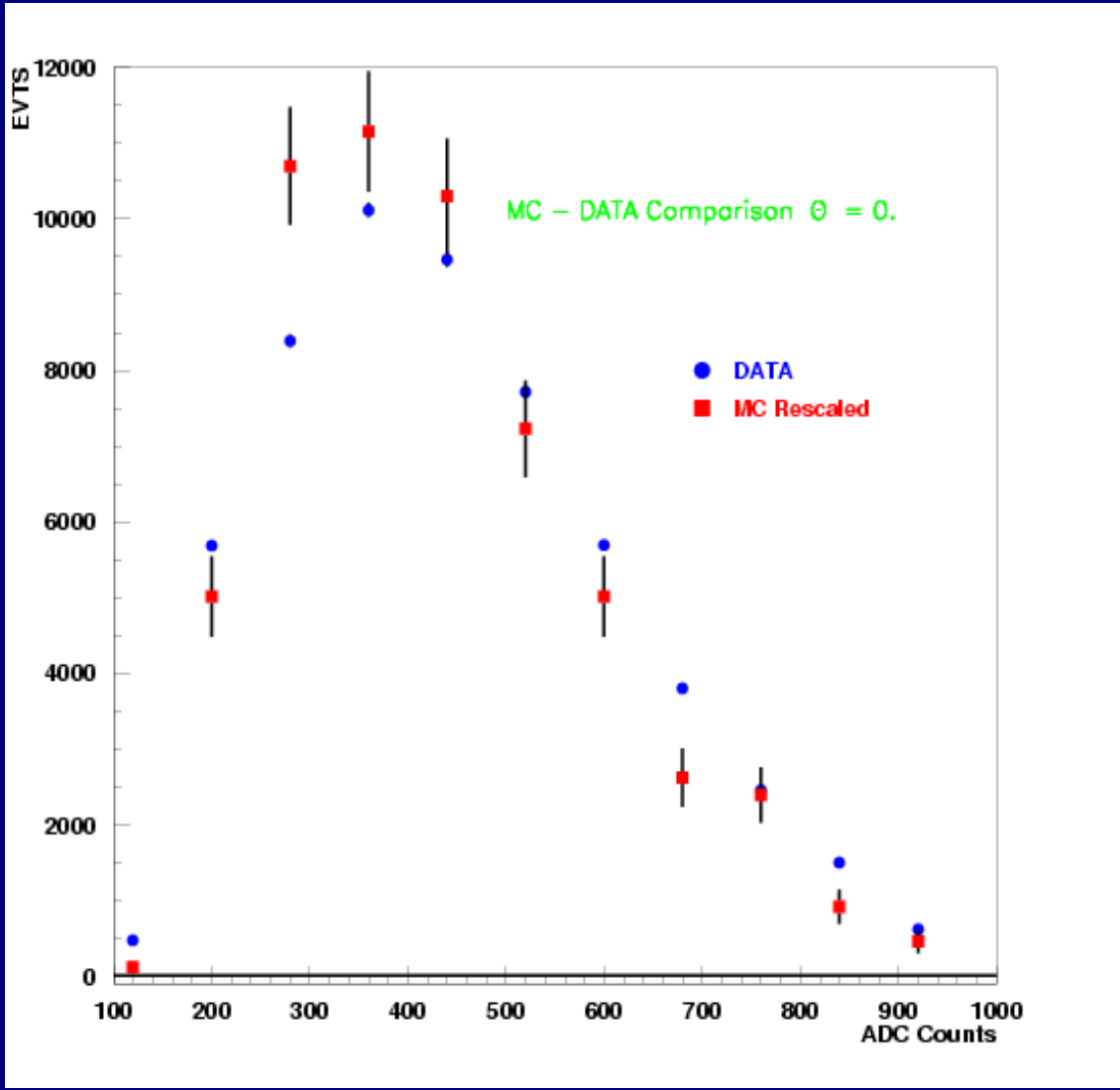
Cerenkov/scintillation ratio

- the total (PMT1+PMT2 yield) Cerenkov/scintillation ratio has been found stable around 0.3



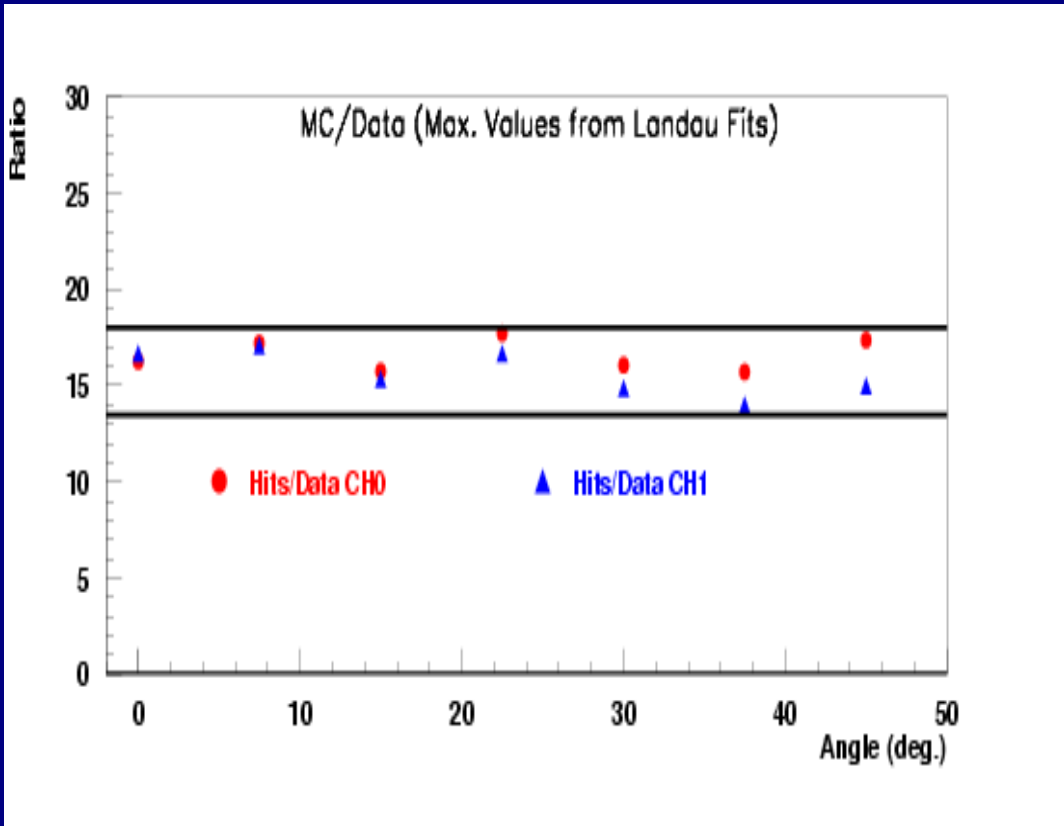
Simulation/data comparison (1)

- MonteCarlo hit distribution rescaled to ADC distribution at θ=0 for PMT1
  - the peak of the MonteCarlo distribution has to match with the peak of the ADC distribution and the hit distribution has to be divided by a scale factor
- data distribution is slightly wider than MC one



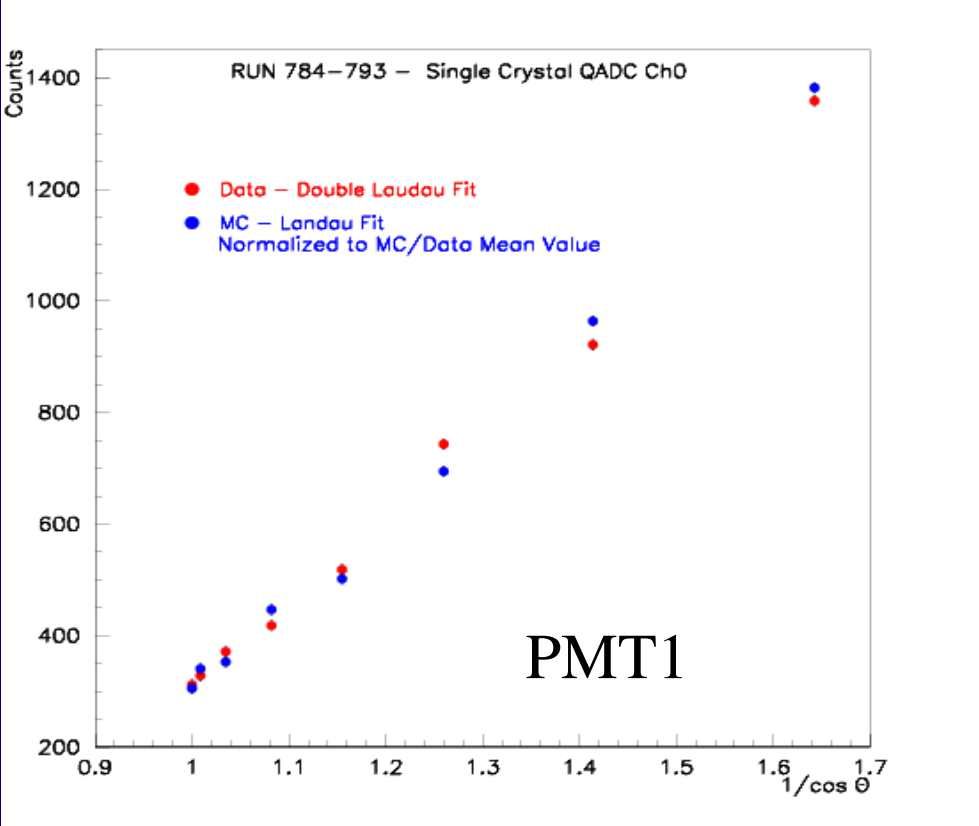
Simulation/data comparison (2)

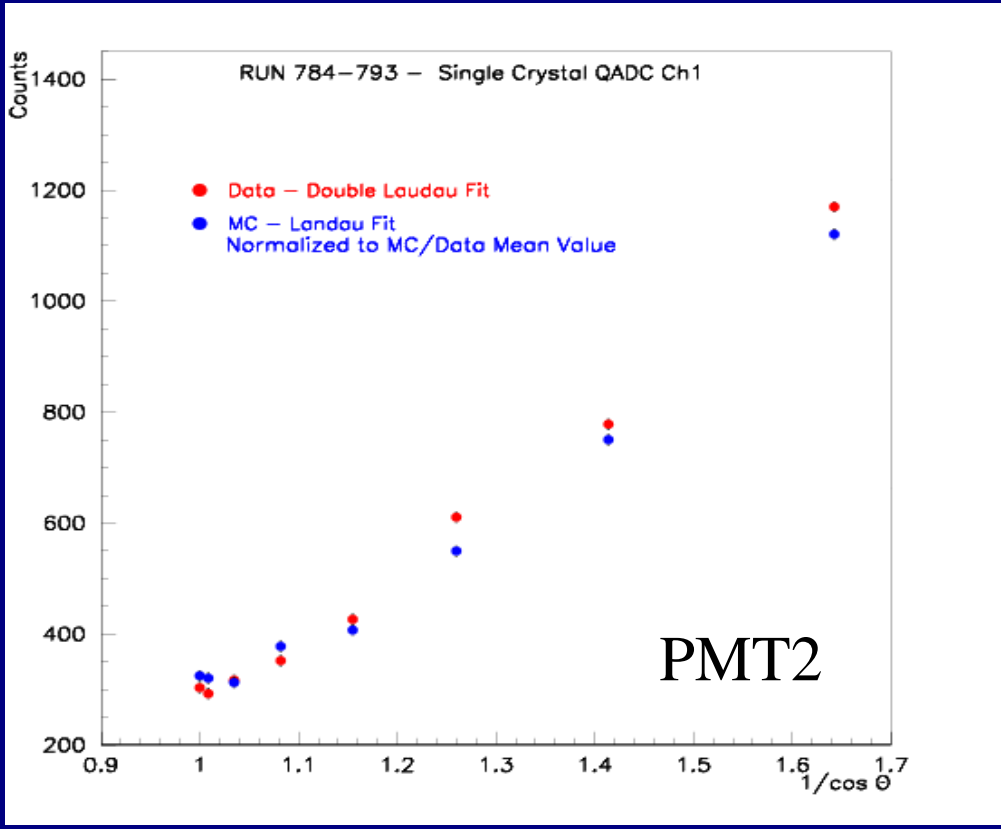
- Ratio between the peak of the MonteCarlo hit distribution and the peak of the ADC distribution for PMT1 and PMT2
  - MC hit distributions have been fitted with a Landau function
  - ADC distributions have been fitted with a double Landau function



Simulation/data comparison (3)

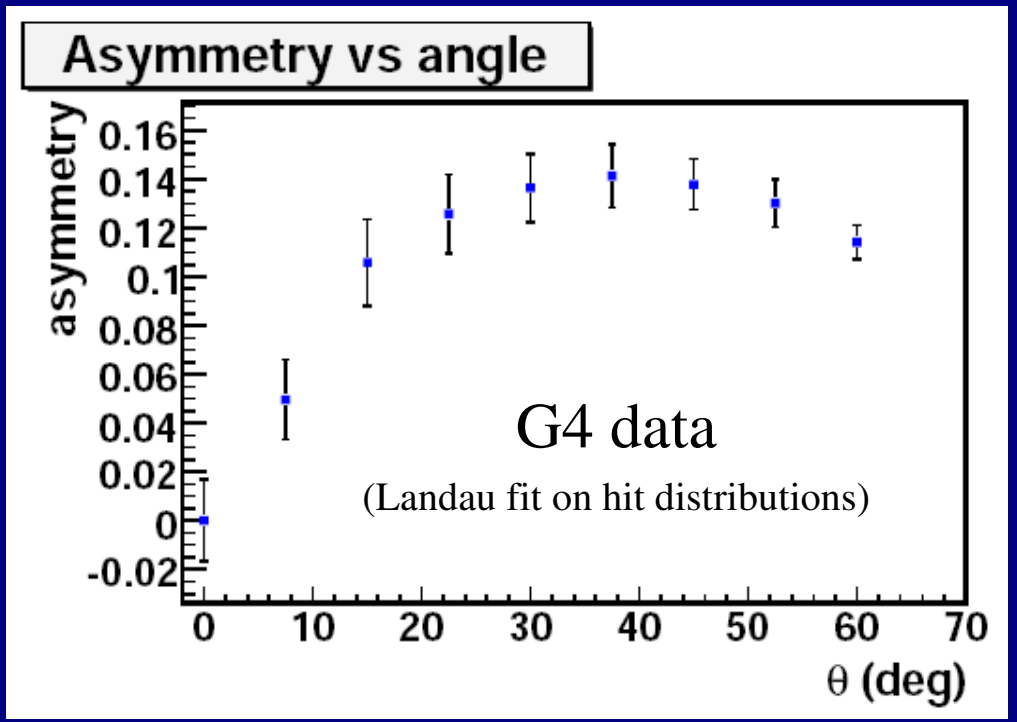
- Peak of the MonteCarlo hit distributions and peak of the ADC distributions normalized to the mean value of the MC/data ratio (shown in the previous slide)

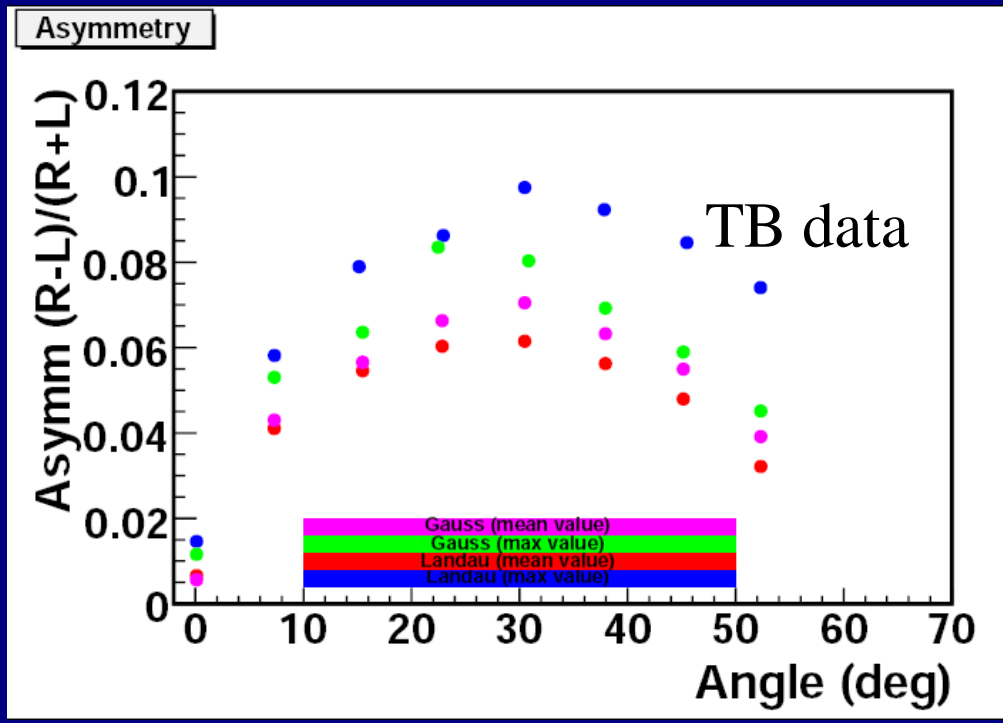




Asymmetry between the two PMTs

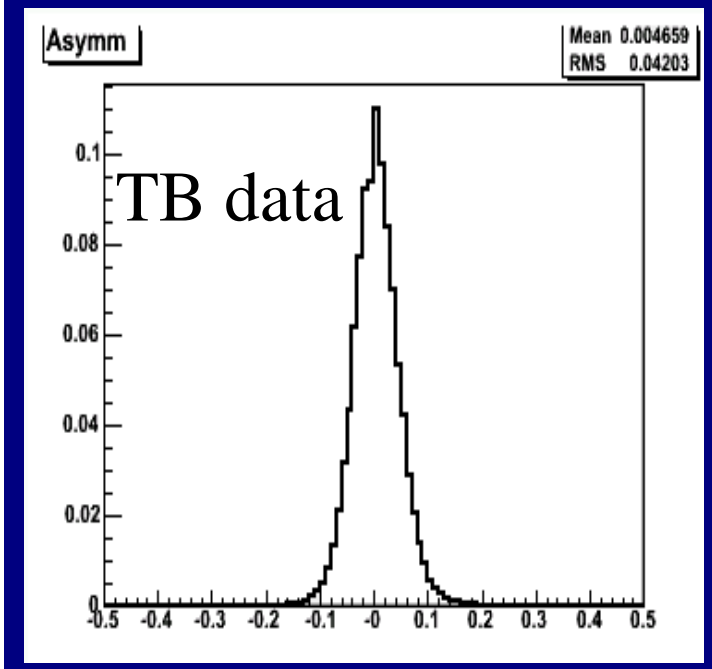
- asymmetry between the two PMTs: comparison between experimental data and simulation
  - in experimental data asymmetry reach its maximum for a ~30° angle, in simulation for a ~37° angle
  - also asymmetry absolute values are different

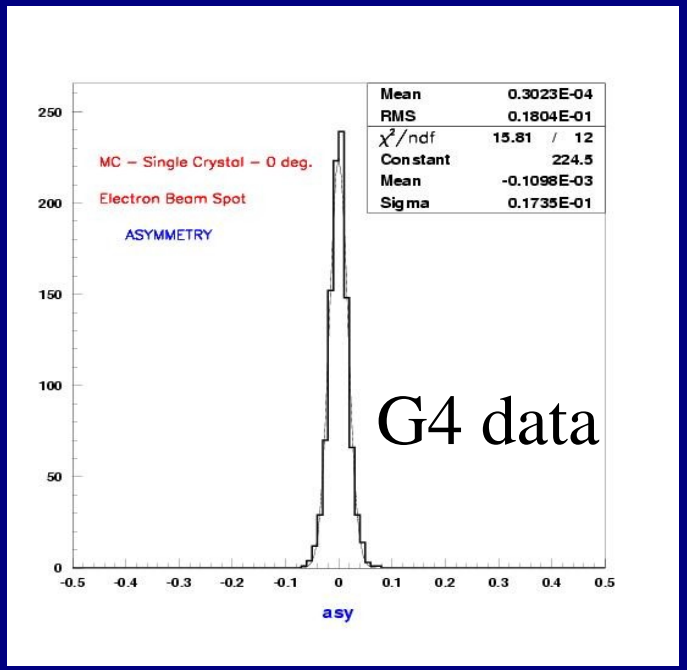


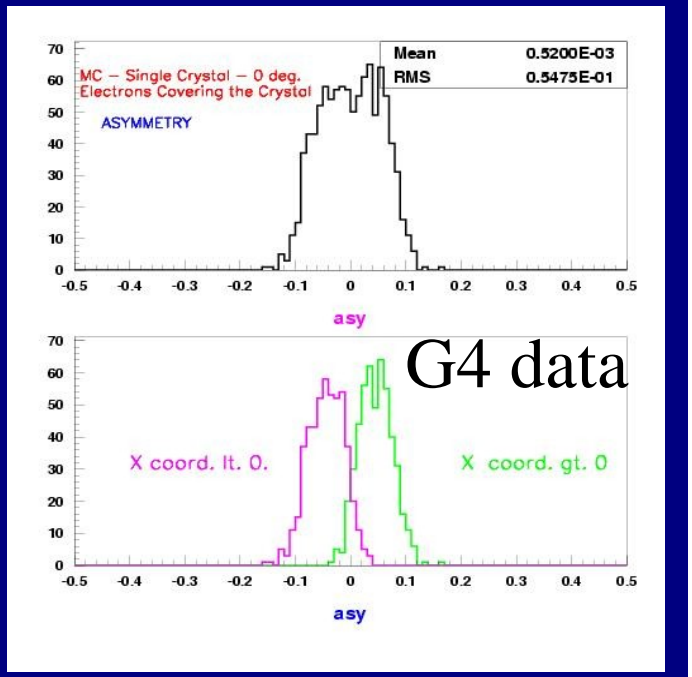


Asymmetry event by event at θ=0

- event by event asymmetry depends on track position
  - in experimental data RMS=0.04
  - in G4 simulation with an electron spot RMS=0.018
  - in G4 simulation with an electron beam covering the whole crystal RMS=0.055
- need to tune the simulation on experimental data introducing a beam spread







Conclusions and outlook

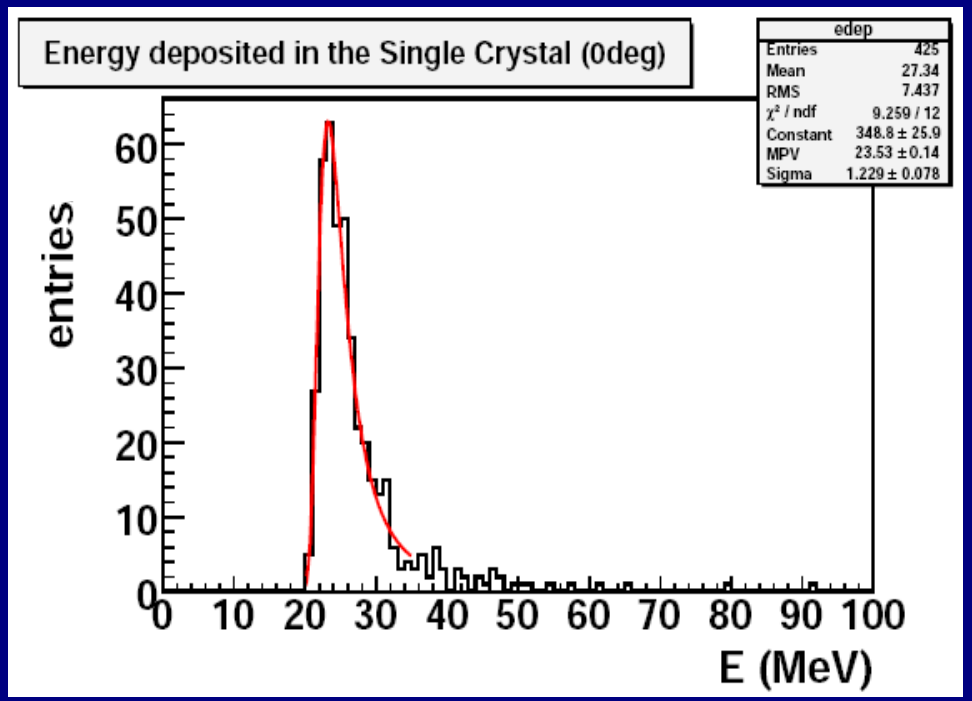
- A Geant4 MC code is ready for single crystal simulation
  - parametrization of the PMT response
  - refine the tuning of the simulation on experimental data
    - simulation of a beam spread similar to experimental conditions
    - varying the reflectivity of the aluminized mylar surface
- We are planning a lot of studies
  - increase MC statistic
  - reproduce Bob and Alessandro results
  - more quantitative comparison between data and simulation for a better MC tuning
  - simulation of muon events

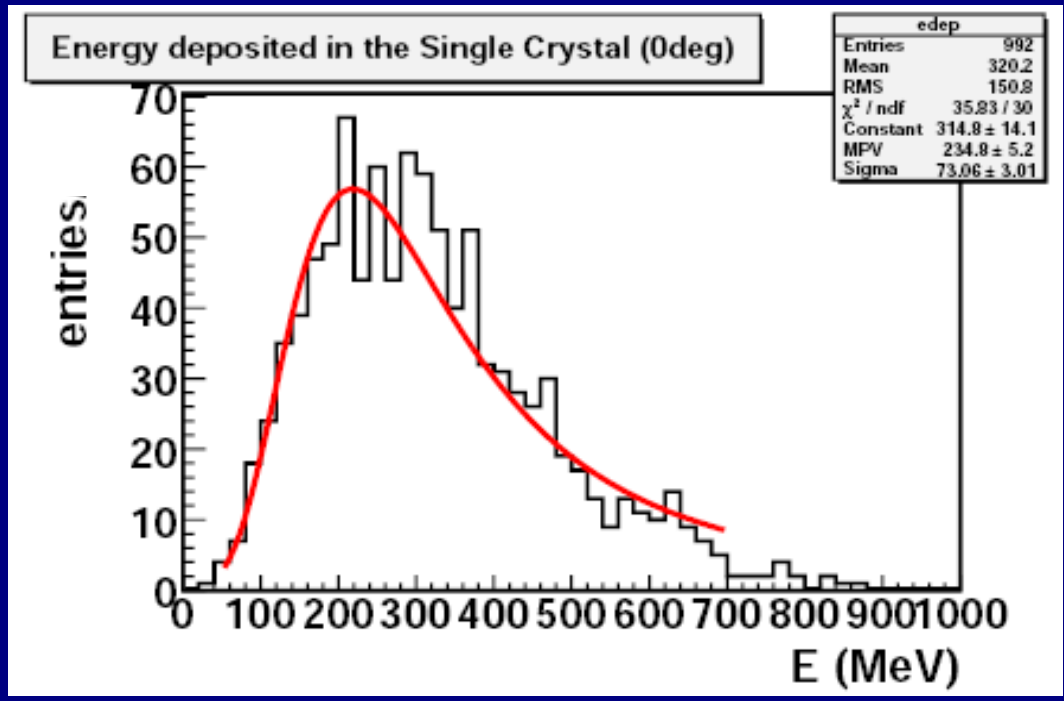
Backup slides

Energy deposited at θ=0

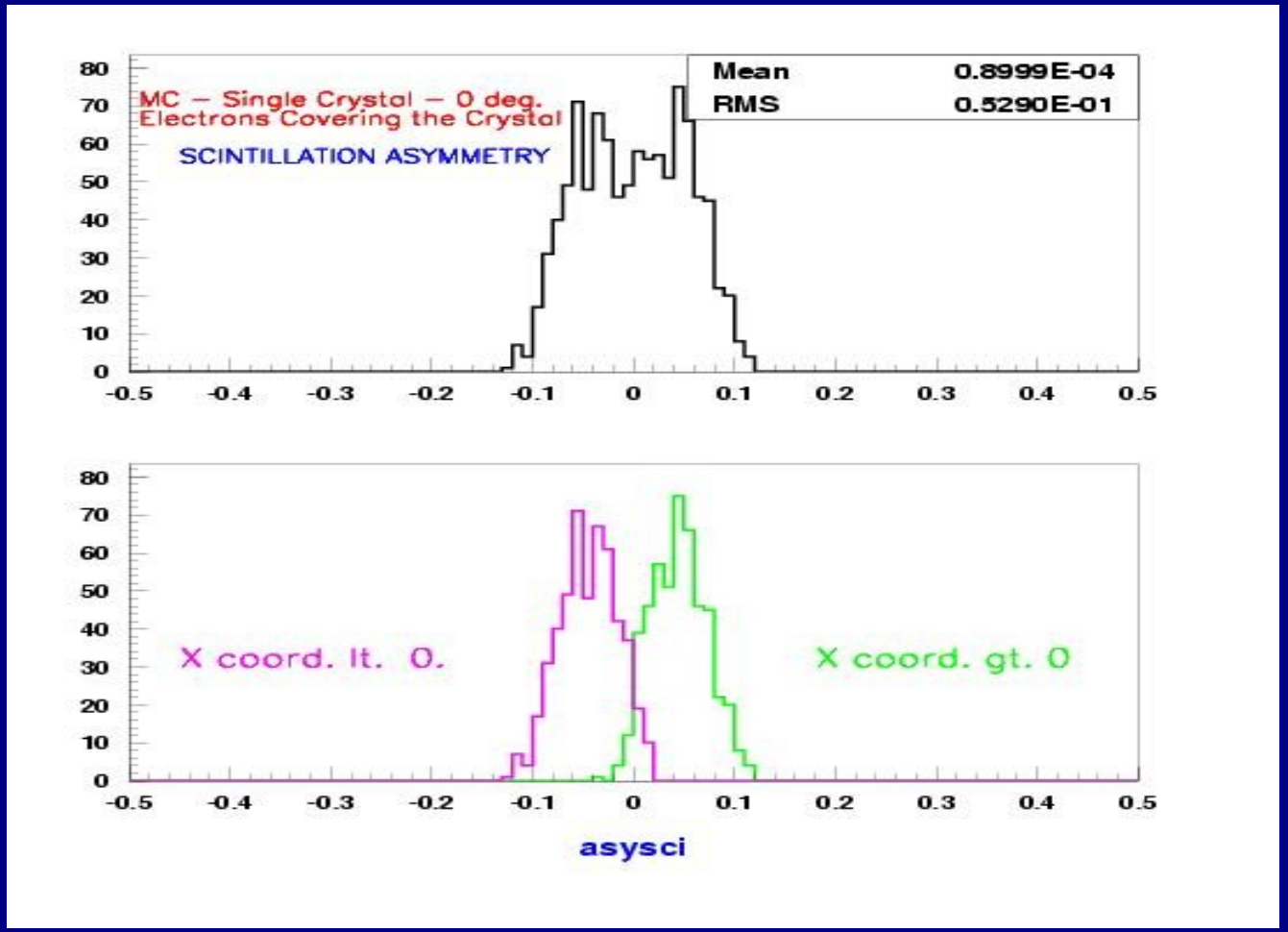
- energy deposited by 10GeV muons (right) and 10GeV electrons (left)
  - the mean value of the energy deposited by muons is in agreement with the energy deposited by a m.i.p. in 2.2 cm of $PbWO_4$:

    $\Delta E = 1.5 MeV/g/cm^2 \times 8.28 g/cm^3 \times 2.2 cm = 27.3 MeV$





asymmetry for scintillation



asymmetry for Cerenkov