Dual-Readout Calorimeter Simulation

State of the Art and Work Plan

RD_FA Collaboration Meeting

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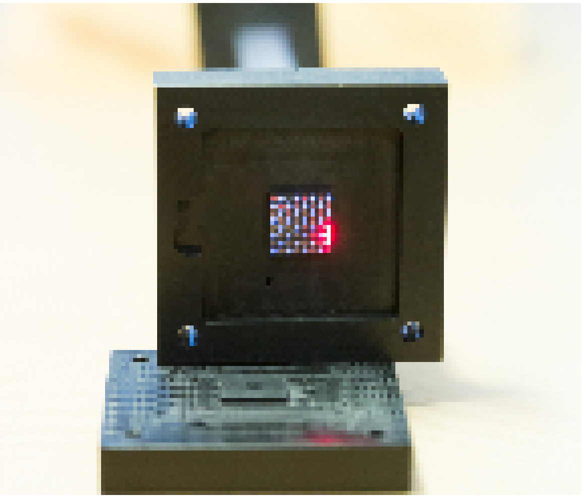
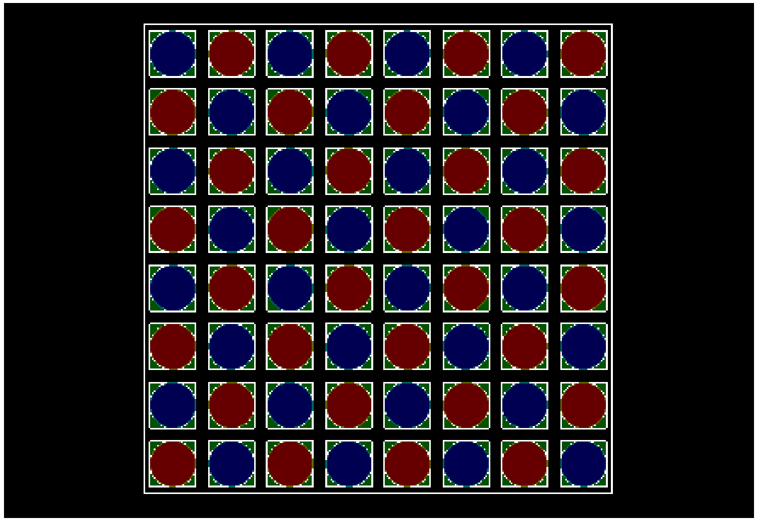
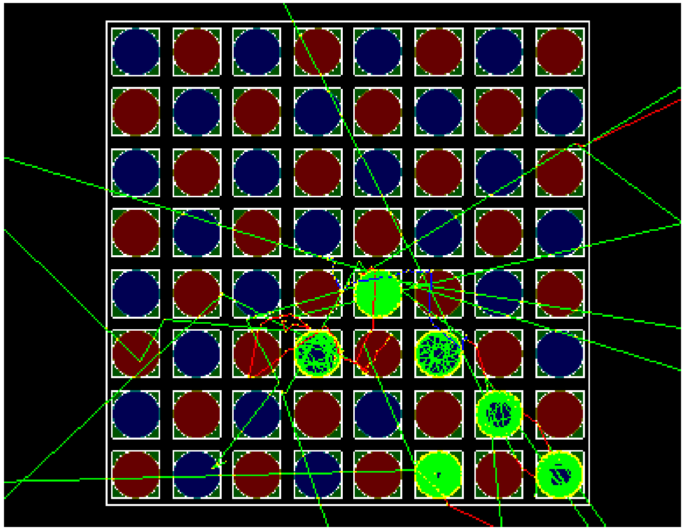
Geometry

- Geant4 code to simulate the module built in Como: about 1 cm x 1 cm x 1 m copper module with 64 (clear and scintillating) fibres readout with SiPMs
- Compile with two latest versions of Geant4: 10.02.p01-10.03.p01
- The possibility to change materials, to add more modules in a matrix to simulate a full containment calorimeter and to rotate the calorimeter is already implemented
- Physics List: FTFP_BERT_HP



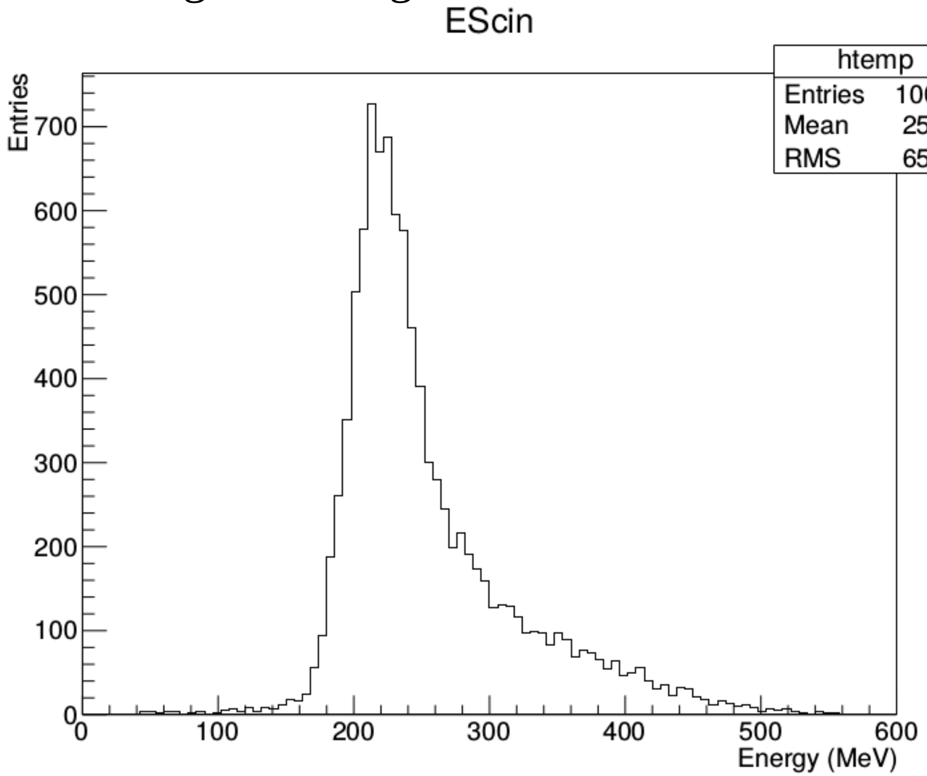




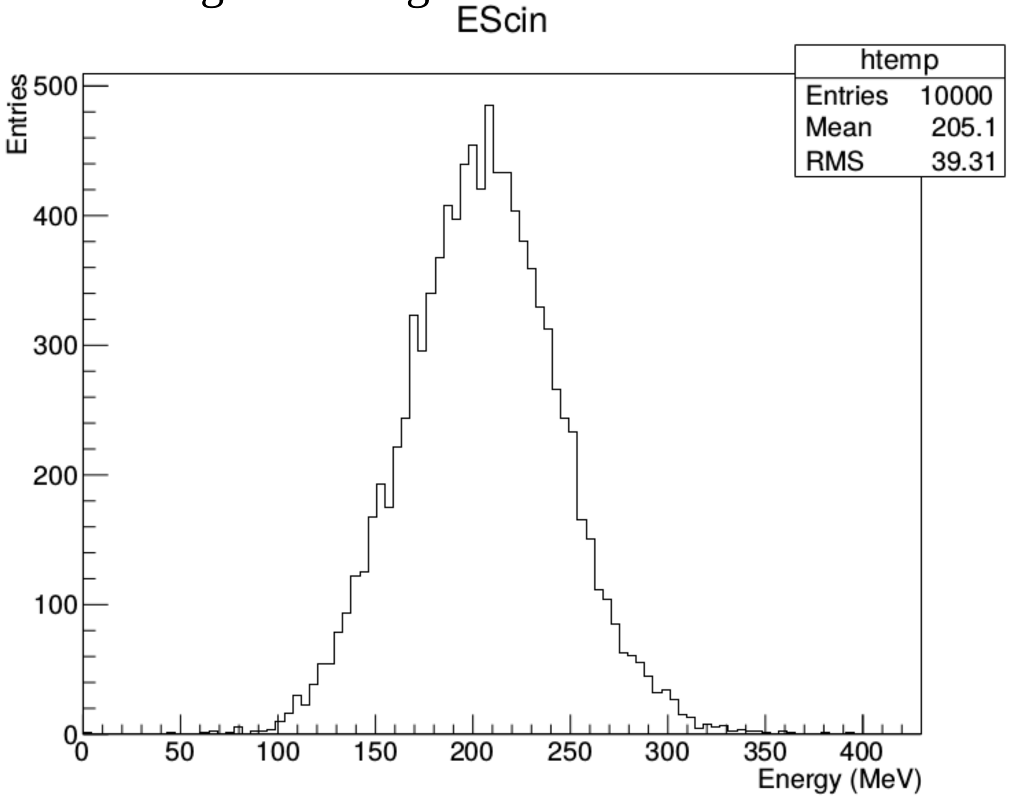
First results with electrons

- The energy deposited in fibres critically depends on the impact angle: if electrons move parallel to fibres they may be significantly oversampled in a single fibre (long tail distribution)
- This problem is immediately solved by giving a small tilt angle to the calorimeter respect to beam particles or giving an angular distribution to primary particles (I use G4GeneralParticleSource)

0 degree tilt angle – 5 GeV electrons

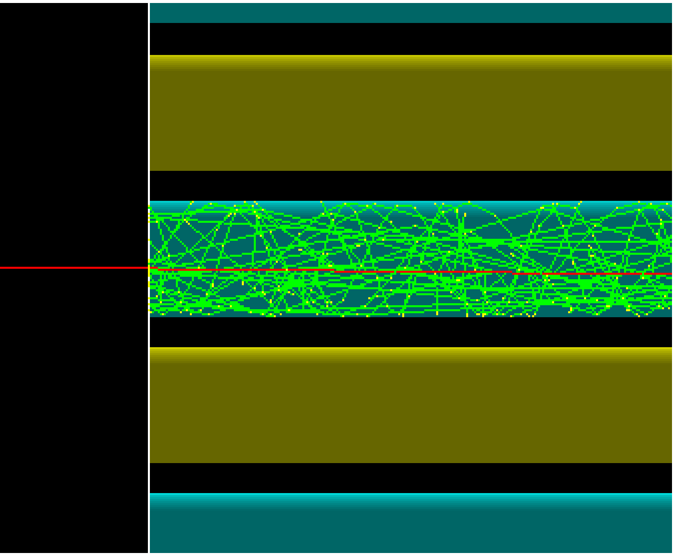


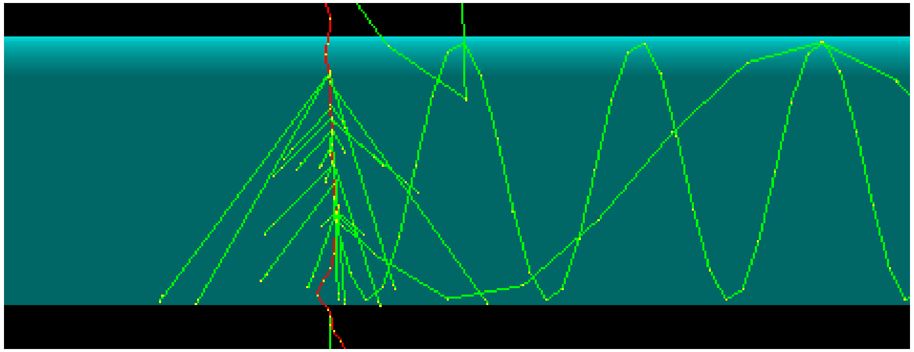
0.5 degree tilt angle – 5 GeV electrons

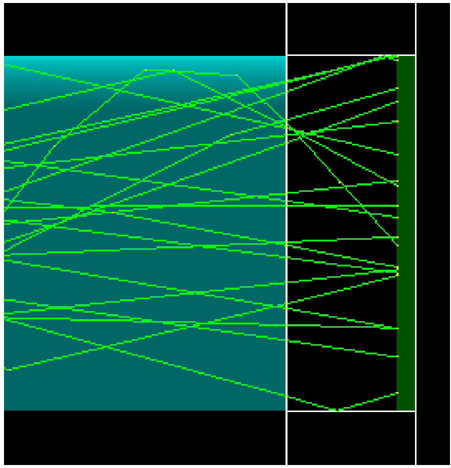


Light production and propagation

- We already have all the optical properties included in our simulation code: scintillation yield, light emission spectrum, refractive indices, attenuation lengths, and SiPM photon detection efficiency (PDE)
- We can produce and transport both photons from Cherenkov and scintillation processes → extremely time consuming!
- Need to parameterize light production and transportation → need to know exactly how light propagates in real fibres
- First parameterization: scintillation yield 1000 photons/MeV, 3% of them propagates towards SiPMs, attenuation length 5 m and 40% PDE



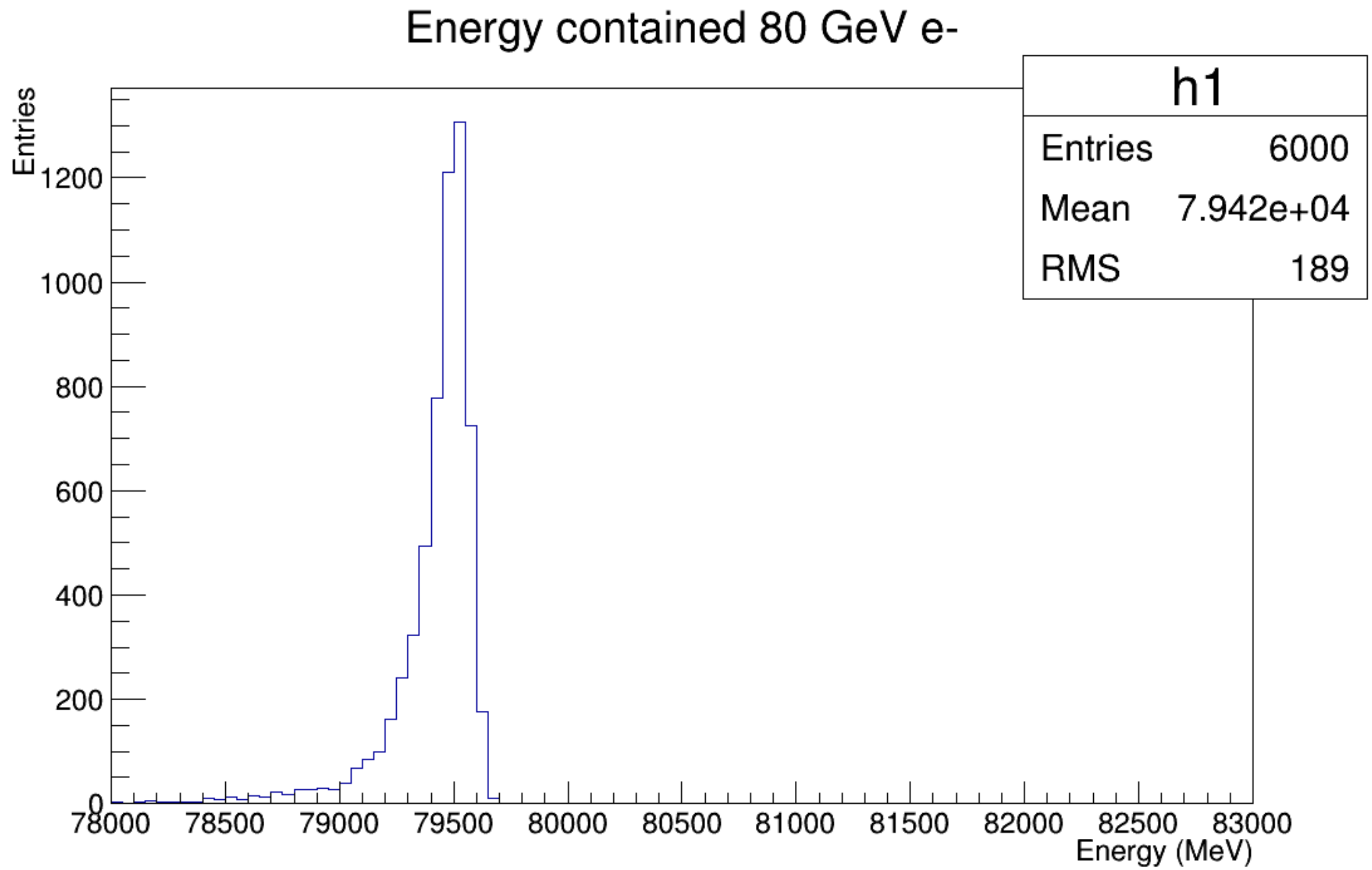




Preliminary results - electrons

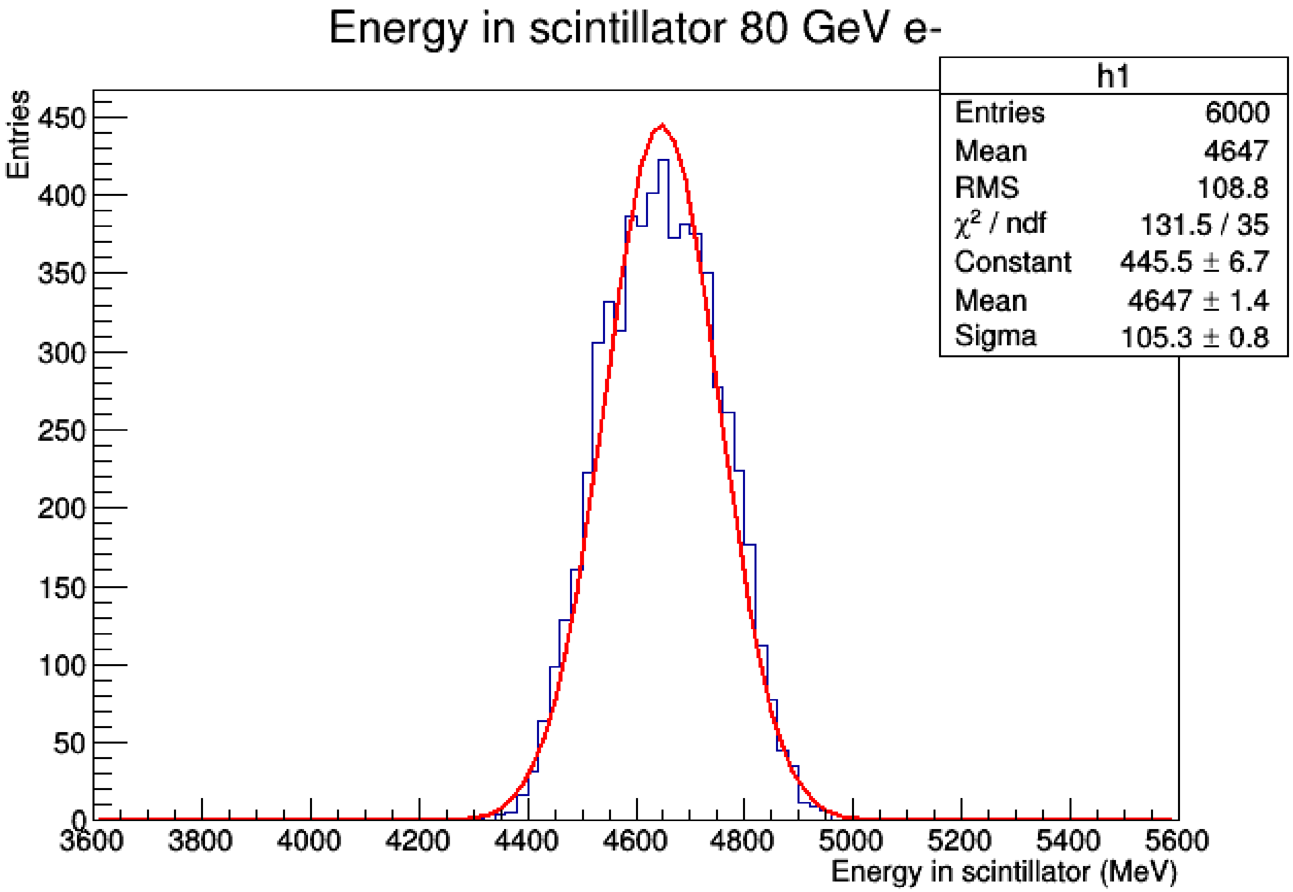
- Calorimeter: 31 cm x 31 cm x 1 m → 99.3% electromagnetic energy containment, 0.75-1.0 deg tilt angles
- Primary particles: electrons 20, 40, 60, 80, 90, 100 GeV
- Beam: uniform distribution over a 1 cm radius circle, 0.1 deg angular distribution

Energy deposited in the calorimeter: Geant4 results



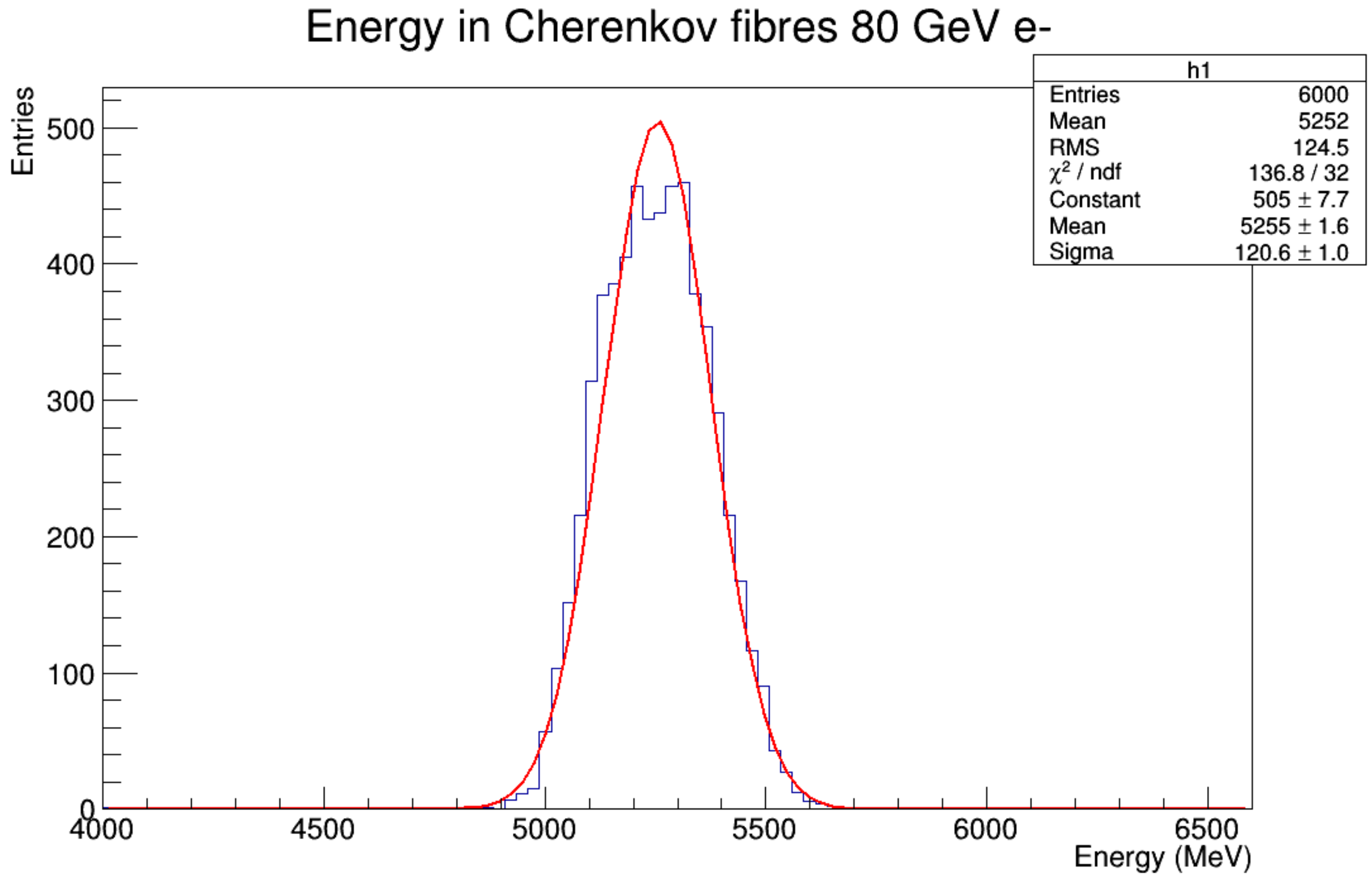
Preliminary results - electrons

- Percentual density difference between PMMA (clear fibres) and polystirene (scintillating fibres) is 12%, yet we see a percentual difference on the energy deposited in clear and scintillating fibres of 12%
- 80 GeV electrons: energy deposited in scintillating fibres 4647 MeV → sampling fraction 5.8%



Preliminary Results - electrons

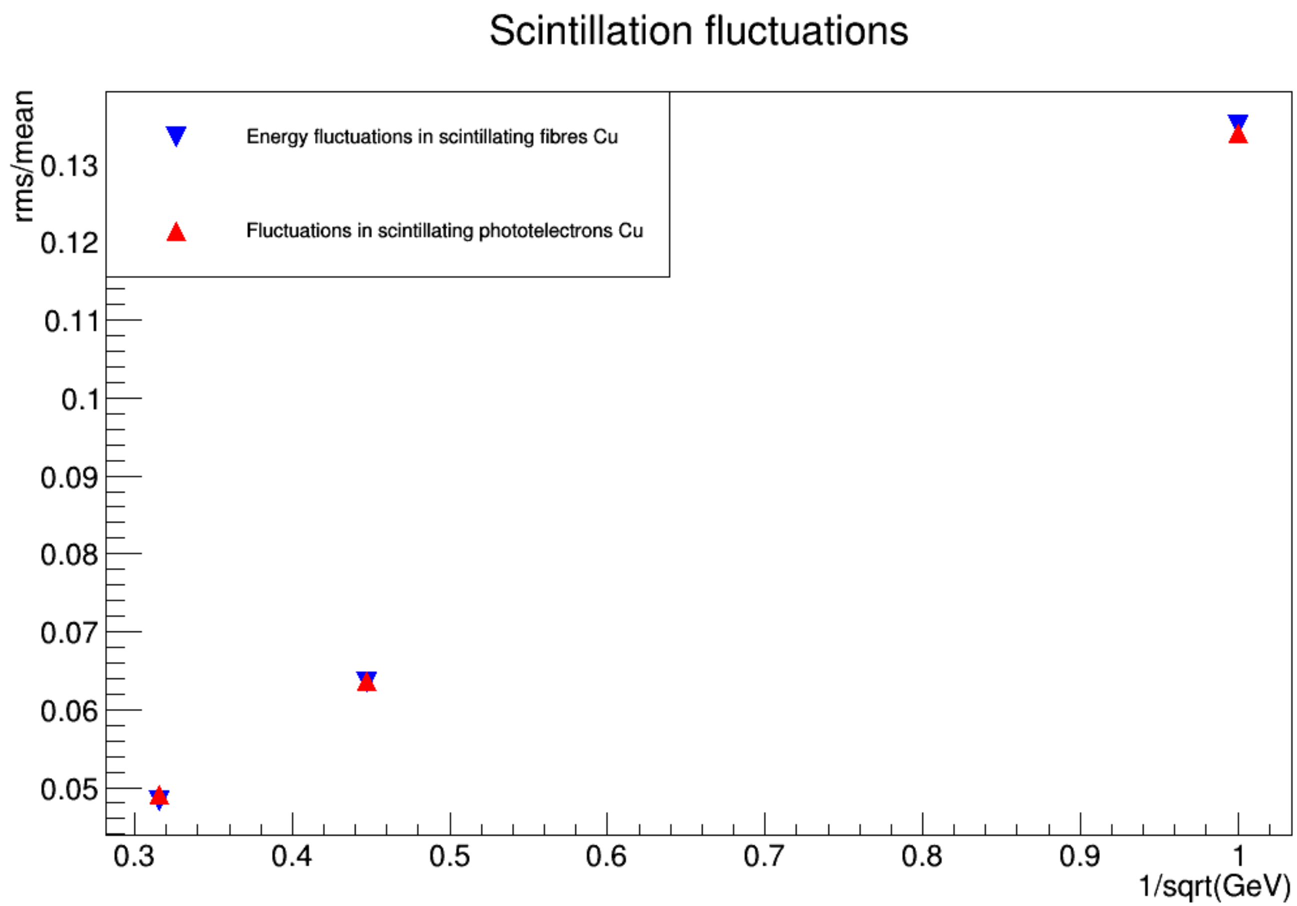
- 80 GeV electrons: energy deposited in Cherenkov fibres 5252 MeV → sampling fraction 6.5%
- Percentual difference: 12%



Parameterized Signals

- We count how many photons are trapped inside fibres and apply an exponetial decay for light attenuation and a binomial probability for detection (PDE 0.4%)
- Scintillation: sampling fraction 5.8%, scintillation yield 10000 photons/MeV, 3% trapped and propagates in forward direction, attenuation length 5 m → 5500 photoelectrons/GeV

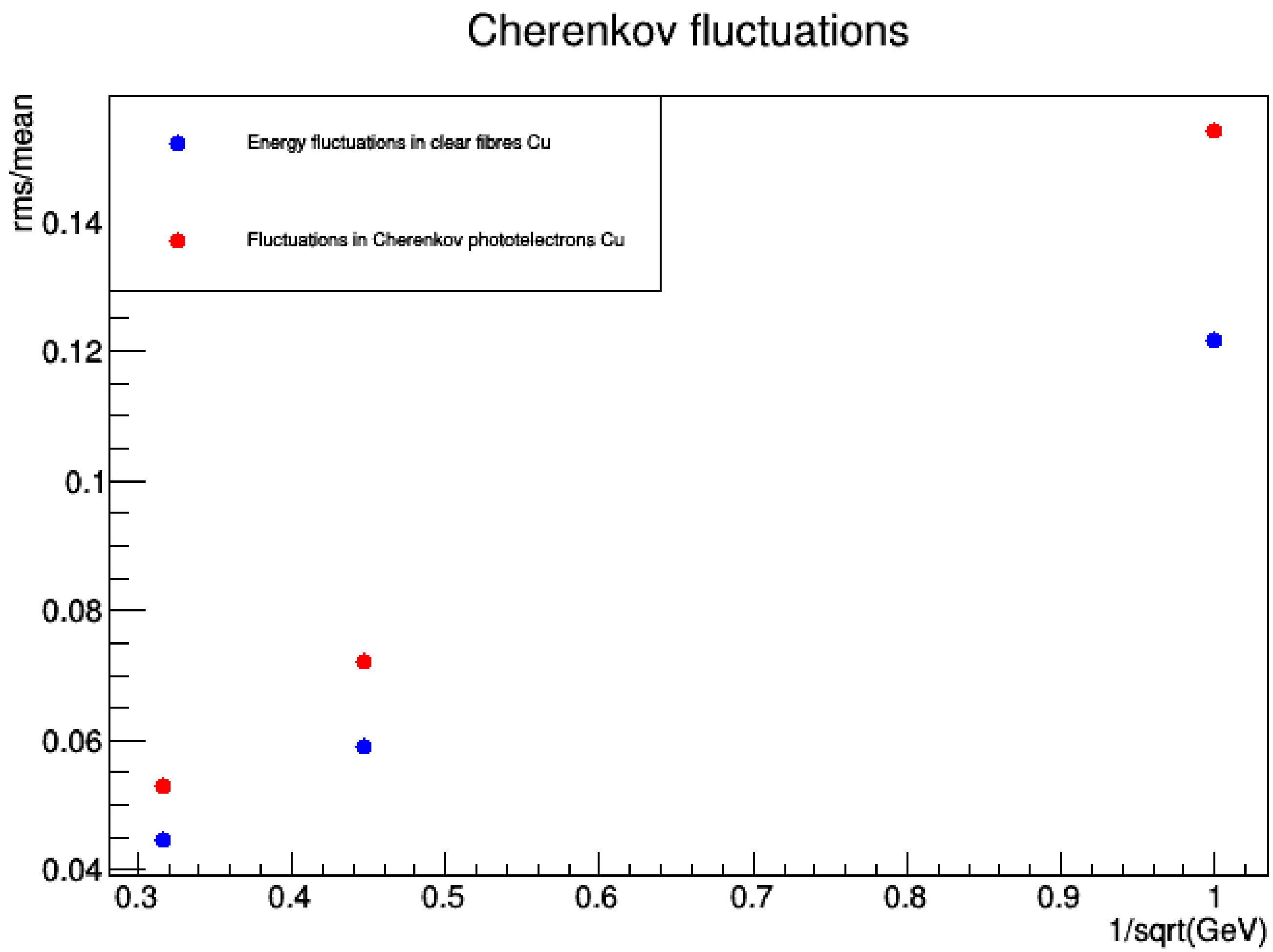
Fluctuation in scintillation photoelectrons are dominated by fluctuations in energy deposited in scintillating fibres → do not need to produce photons!
1,5,10 GeV electrons



Parameterized Signals

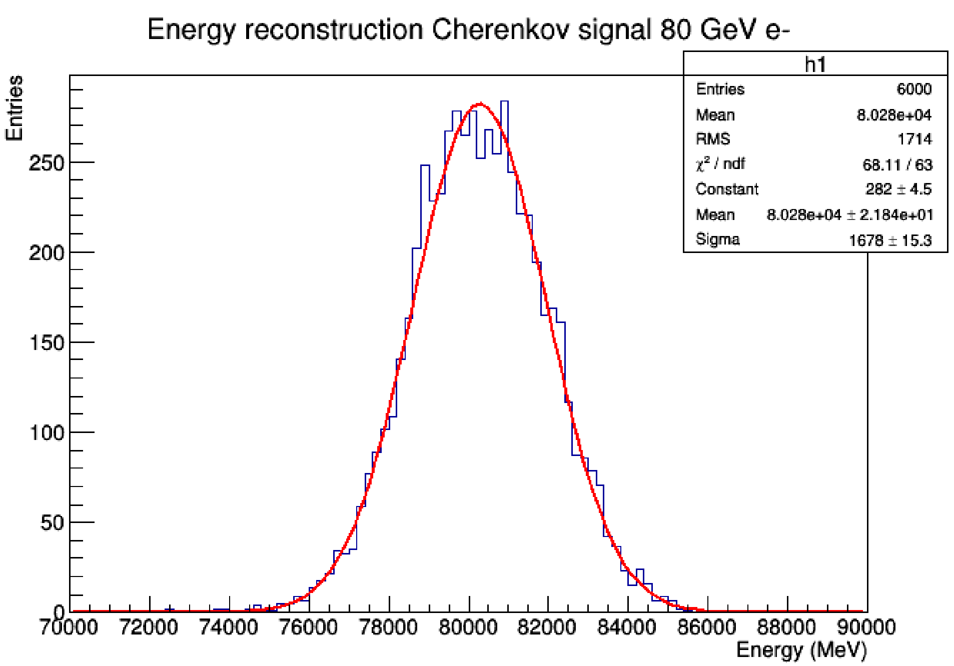
- Cherenkov photoelectrons: 108 photoelectrons/GeV
  Scintillation p.e./Cherenkov p.e. is around 50
- Fluctuations in Cherenkov photoelectrons are not dominated by fluctuations in energy deposited in Cherenkov fibres → need to produce photons!

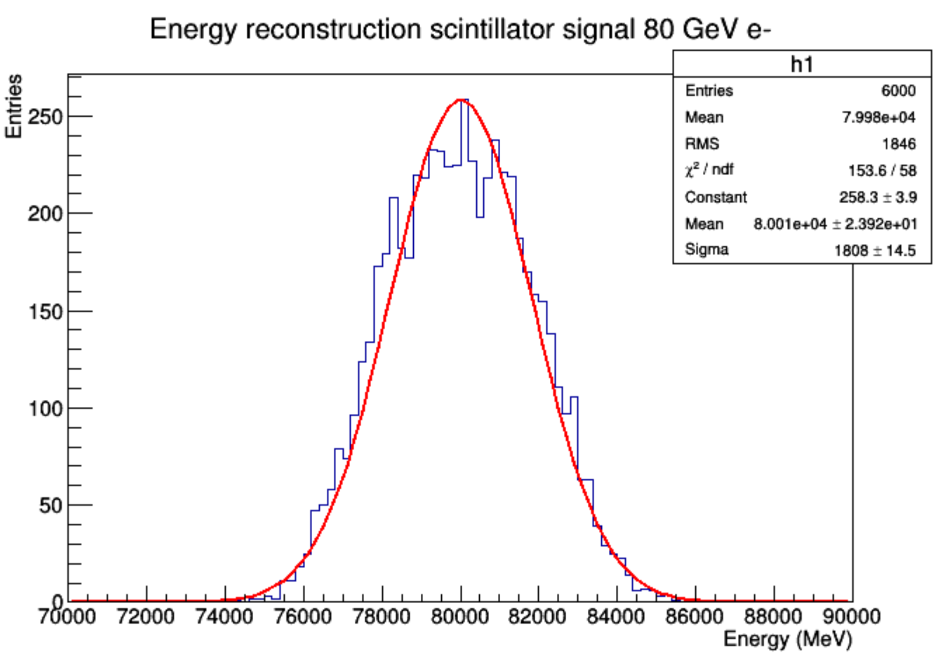
1,5,10
GeV
electrons



Preliminary results - electrons

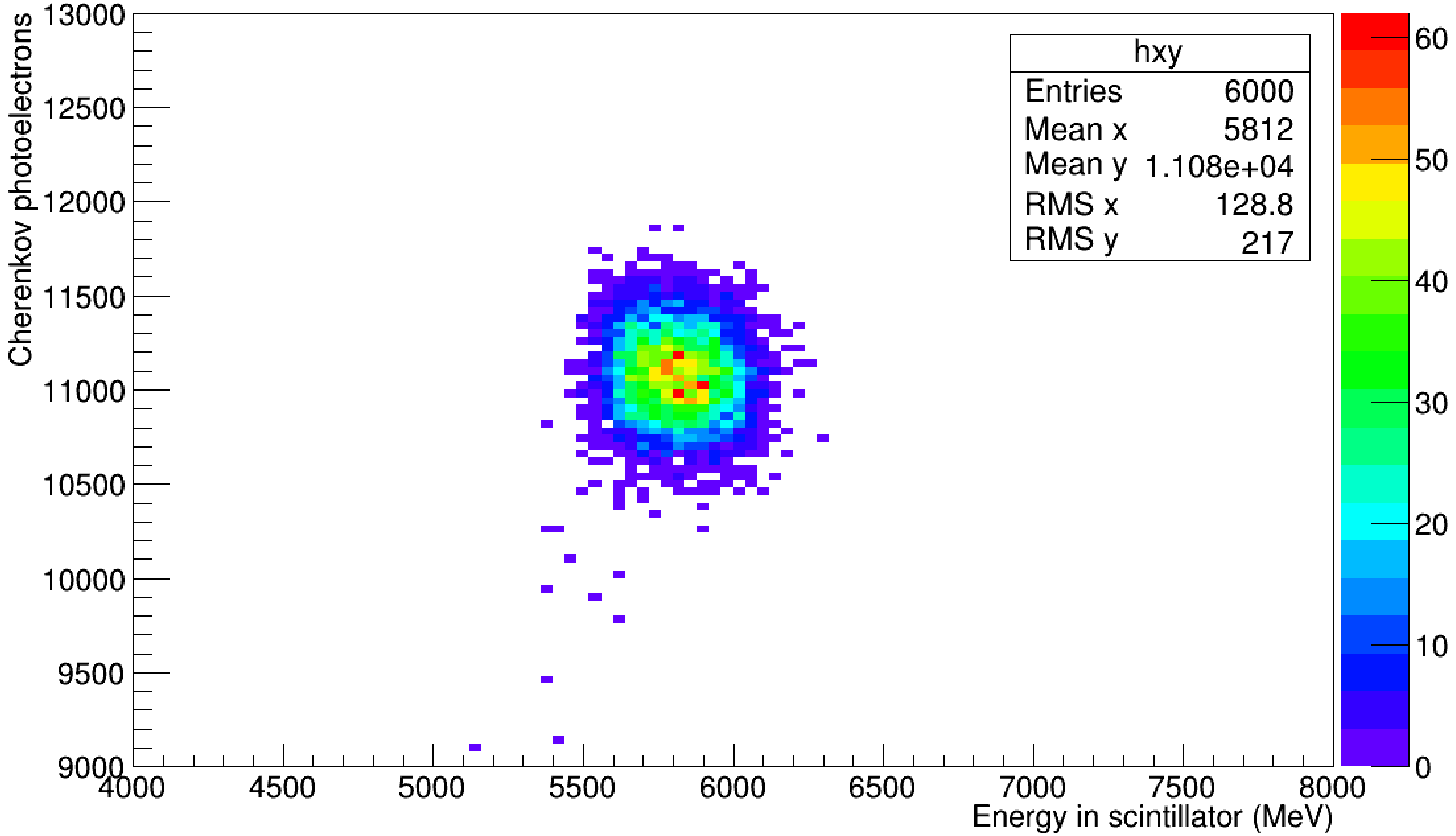
- We calibrated the calorimeter with 40 GeV electrons and reconstructed the energy deposited at other energies from both signals (Cherenkov and scintillator)
- Signal from scintillation: energy deposited in scintillating fibres (light emission is isotropic)
  Signal from Cherenkov: Cherenkov photoelectrons (parameterized)
- 80 GeV electrons: - Cherenkov: mean 80280 MeV sigma 1678 MeV
  - Scintillator: mean 80010 MeV sigma 1808 MeV





Preliminary results - electrons

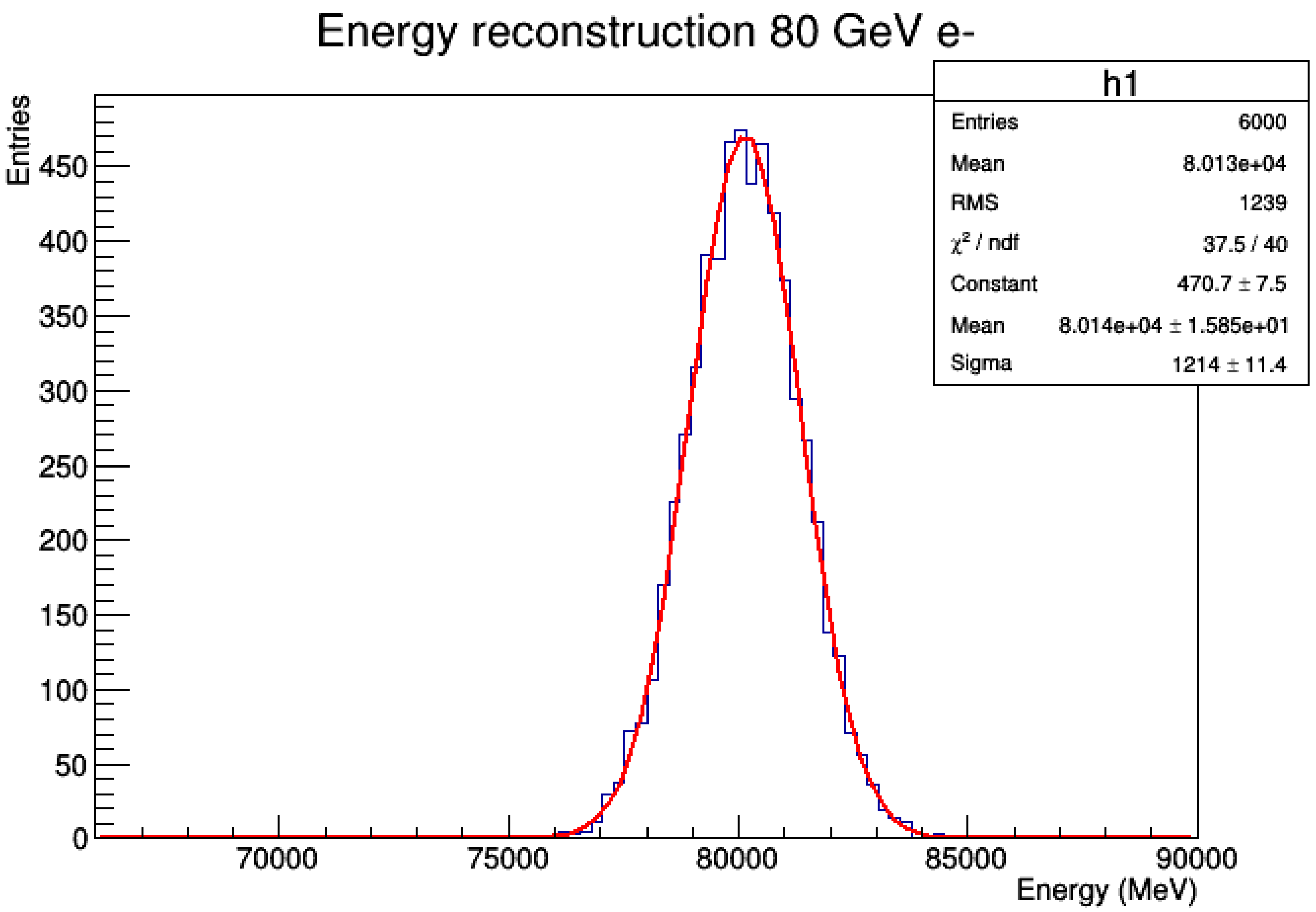
- As we expected we don't observe correlations among scintillation and Cherenkov signals: result obtained with 100 GeV electrons
- The two signals are idependent samplings of the shower: the combination of the two gives a better energy resolution



Preliminary results - electrons

- 80 GeV electrons:

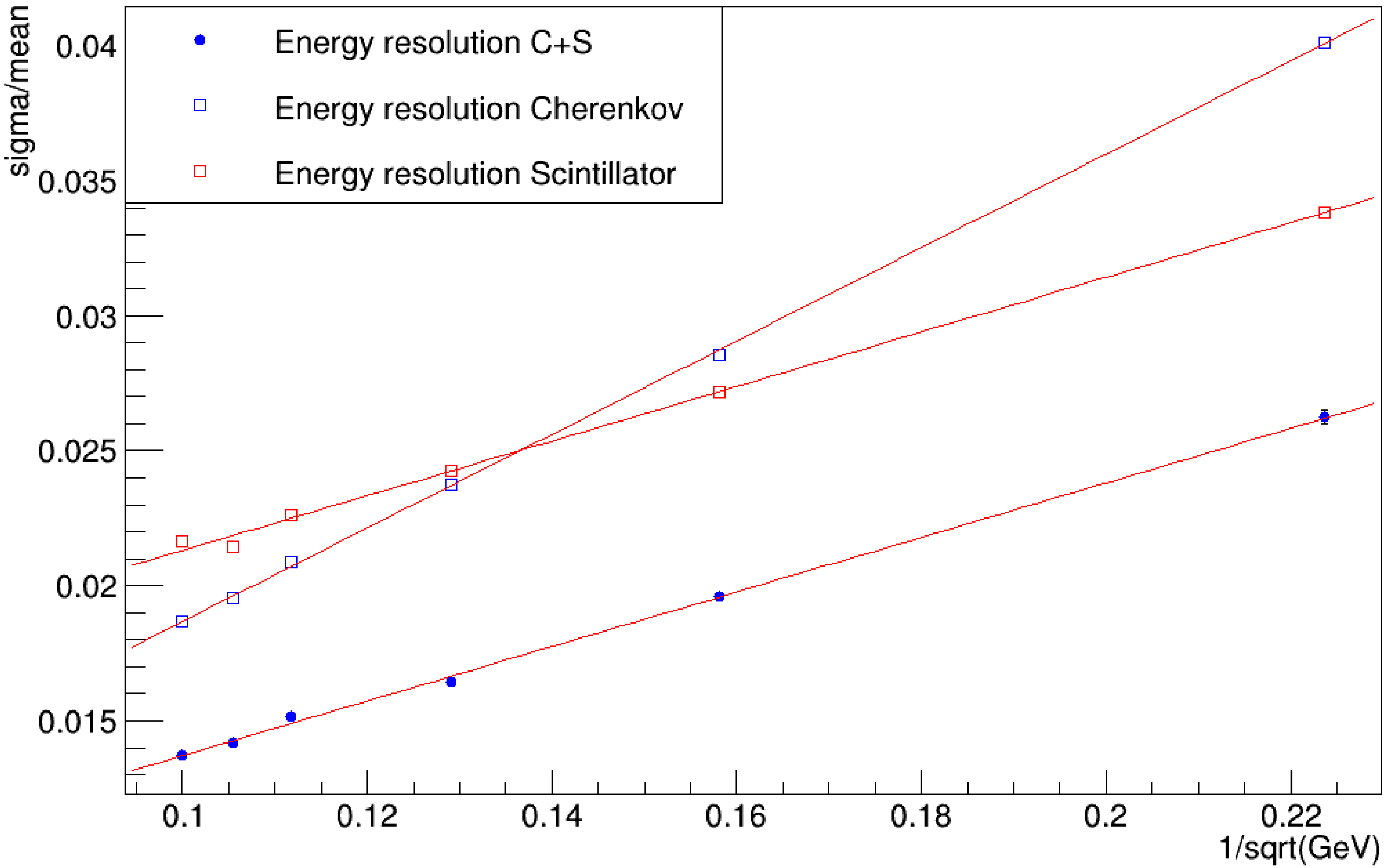
  - Cherenkov + Scintillator: mean 80140 MeV sigma 1214 MeV



Electromagnetic energy resolution

- We estimate an electromagnetic energy resolution of:

Scintillation: 10.1%/sqrt(E)+1.1%   Cherenkov: 17.3%+0.1%
Cherenkov+Scintillation: 10.1%/sqrt(E)+0.4%



CPU - time

- Results obtained with 2.0 GHz processor in single thread mode:

  - We produce and parameterize only Cherenkov photons while the scintillation signal is the energy deposited in scintillating fibres

Energy	Time per event
40 GeV	11.3 s
90 GeV	24.9 s
250 GeV	71.8 s

Work Plan

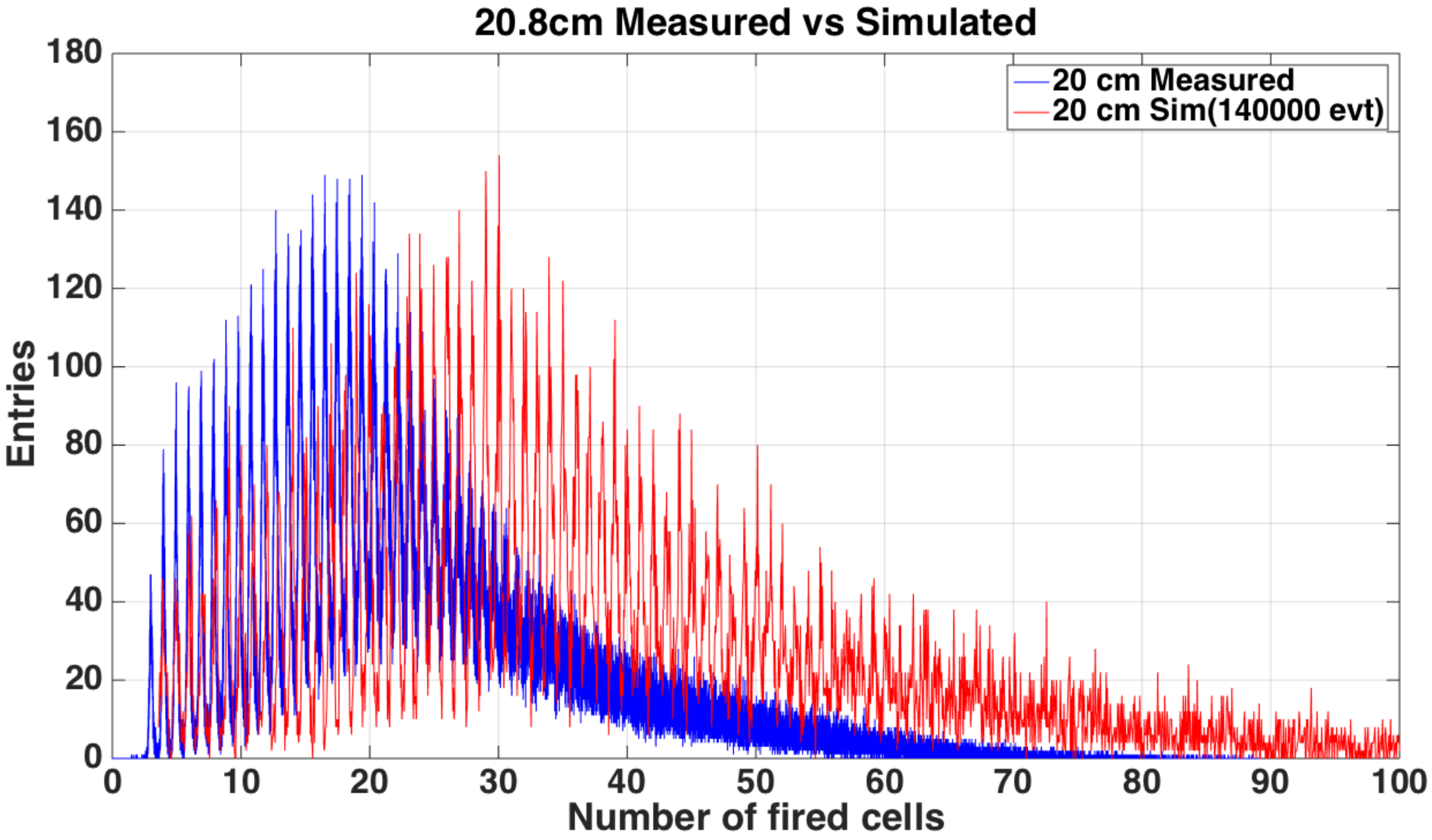
Next three months:

- Single particle resolution (e-, gamma, muon, tau, proton, pion) → need to estimate e/h value for Cherenkov and scintillation signals
- Validate our simulations with results of RD-52 2015 test beam. Code to simulate that geometry in preparation
- Already have a code to simulate SiPM response: we may want to merge the two codes to have the digitization of the signal
- Particle Identification: - Study the effect of 1-2 radiation lengths in front of the calorimeter
  - The effect of a preshower
- Interface Geant4 with phytia to study jet resolution

Work Plan

- Validate our parameterization of light production and transport by simulating a single scintillating fibre stimulated by a Sr/Yr radioactive source and comparing simulations with data

A first attempt already showed a good agreement between data and simulations → multiphoton spectrum



Work Plan

Next six months:

- Merge this code with the geometry simulated for a 4pi experiment (CEPC collegues already working on this)

- Study W,Z,H mass resolution: - Z,W → 2jet
  - H → 4jet, 4lepton, 2g, 2gamma
  - H → 2tau (possible collaboration with Mogens Dam)

- Study calorimeter response inside a full detector (inner tracker and magnets)