ZDC-h simulation

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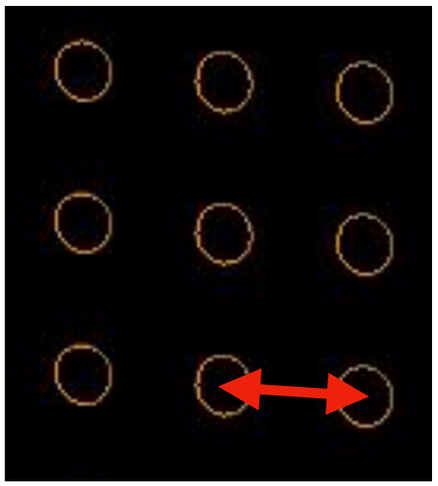
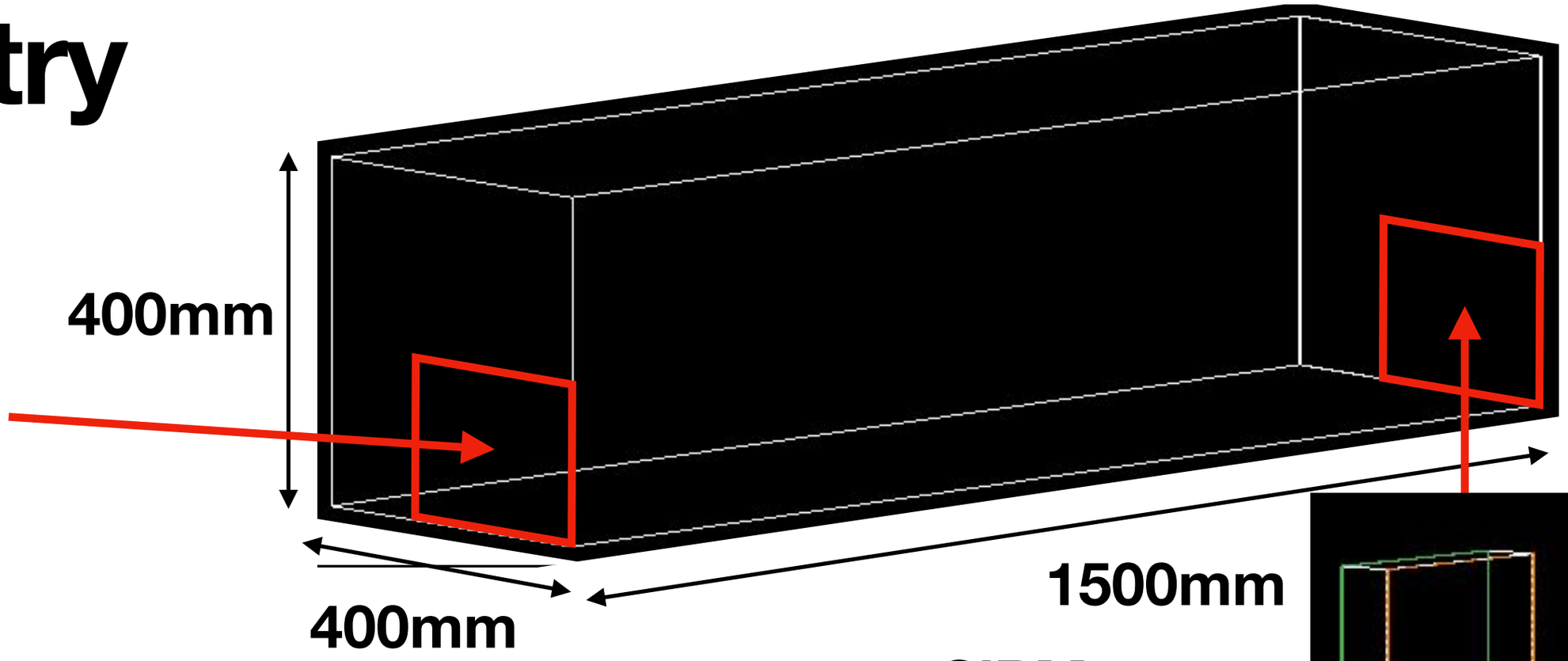
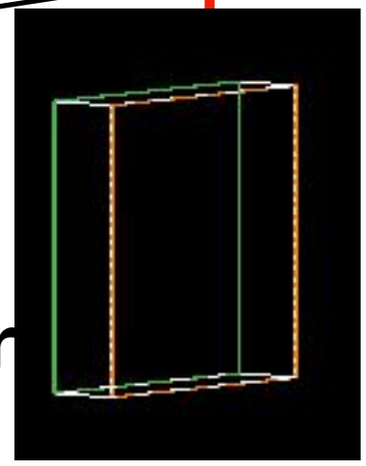
Outline

- We studied the response of hadronic calorimeter for neutron
- Simulation was done a standalone GEANT4 simulation, based on the dual read-out calorimeter package
- The goal of this study is to optimize the parameters for ZDC-h
  - Fiber size and spacing
  - Absorber structure: Capillary or fully filled
  - Material: Cu? Pb? Or what?
  - Detector dimension
  - Fiber species: Scintillating? Quartz? Or both?

Geometry



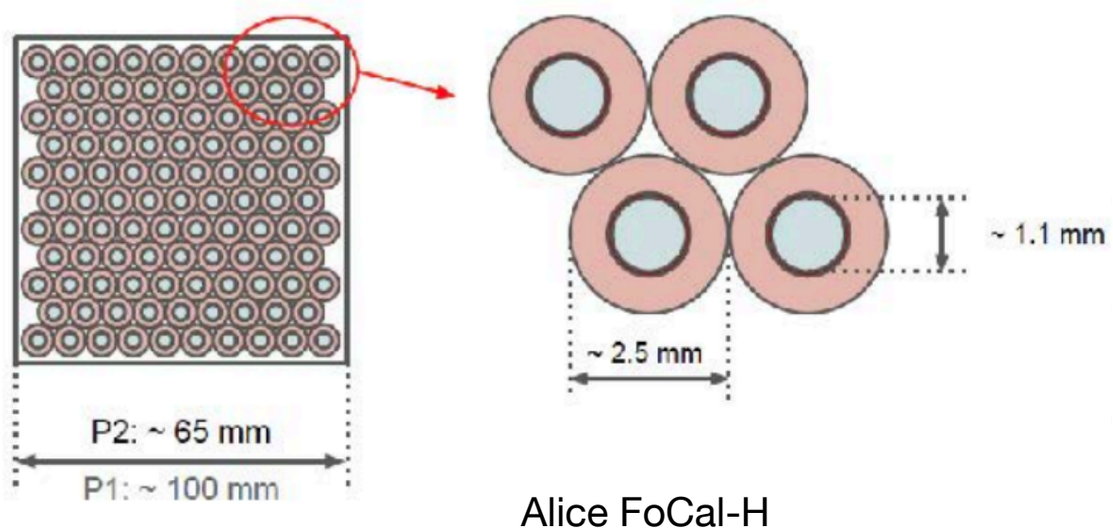




SiPM+

Filter for scintillator

One SiPM by one fiber

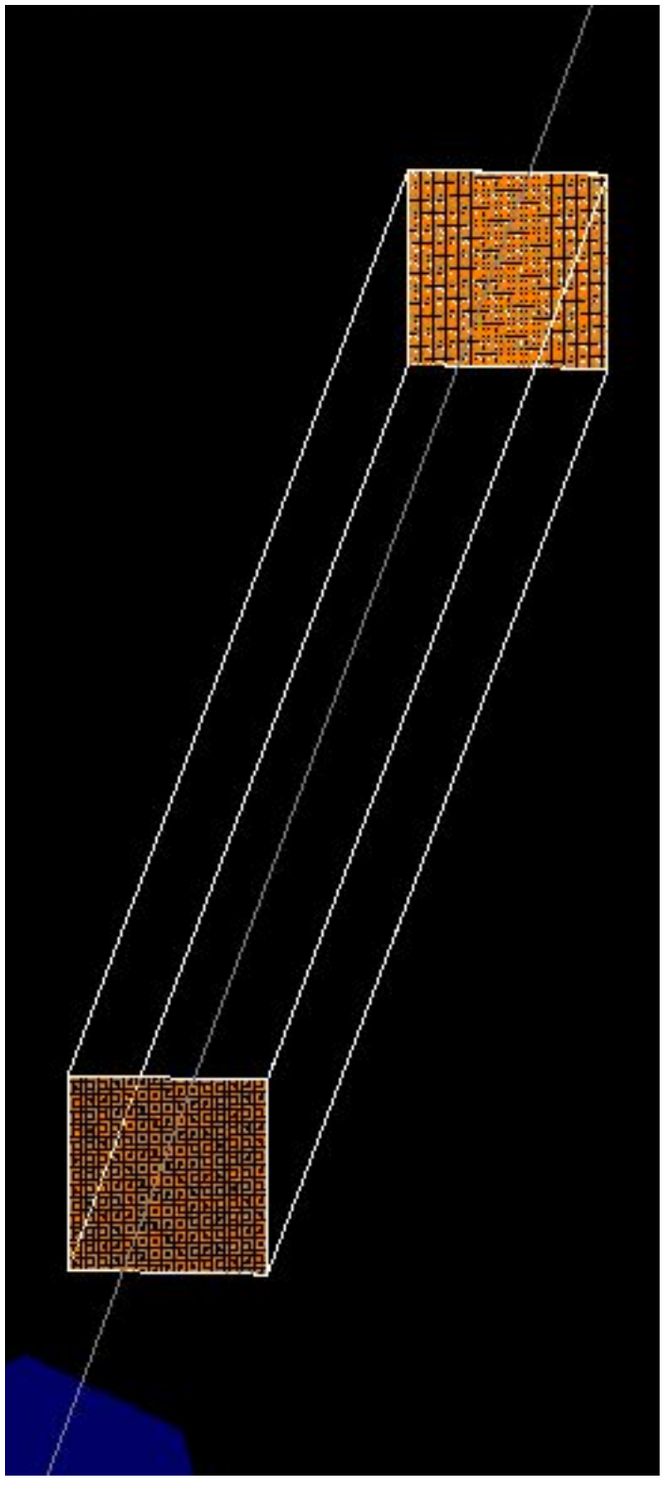


Alice FoCal-H

Alice Focal-h as the reference

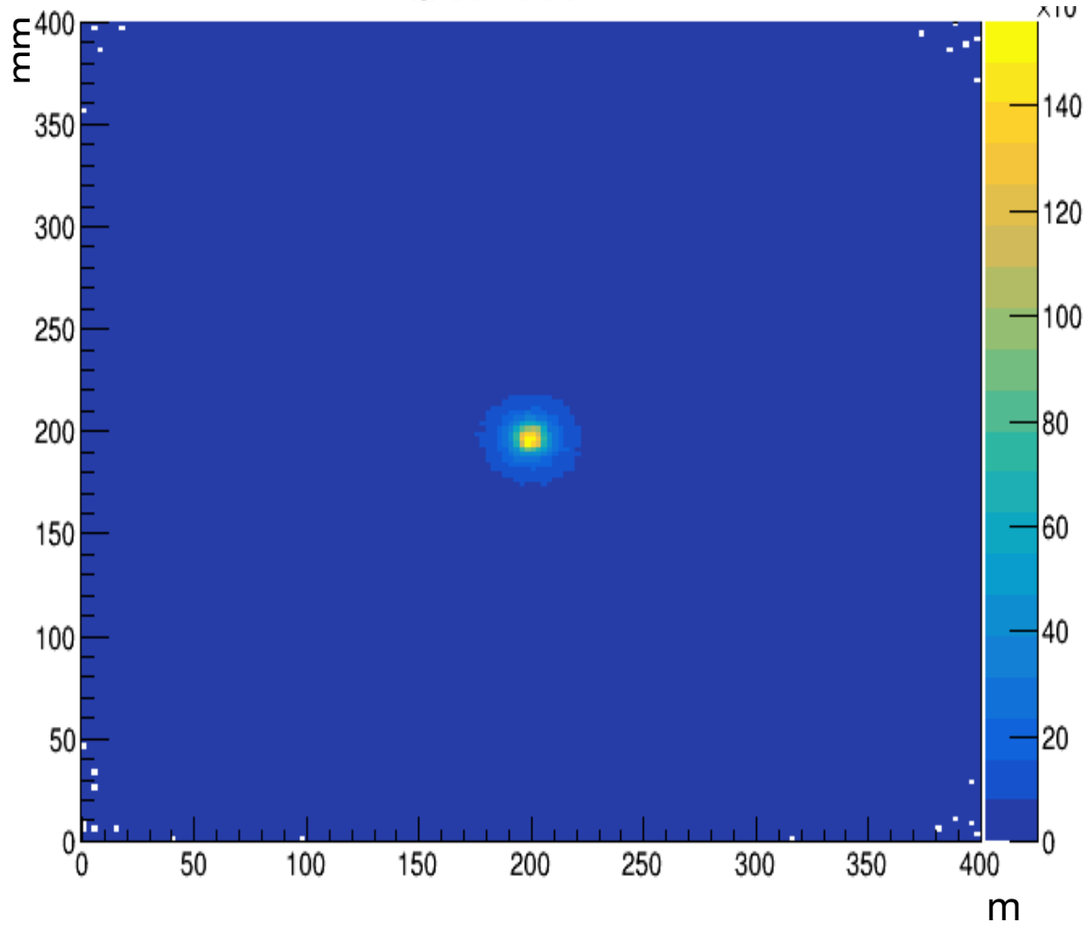
- Fiber spacing = 2.5mm
- Number of fiber $160^2 = 25600$
- All fibers are scintillating fibers

Neutron Beam



Simulated 10 - 150 GeV neutron beams

- Normal angle: 4m rad (arbitrary,)
- Caveat: no ZDC-e ahead in this study yet

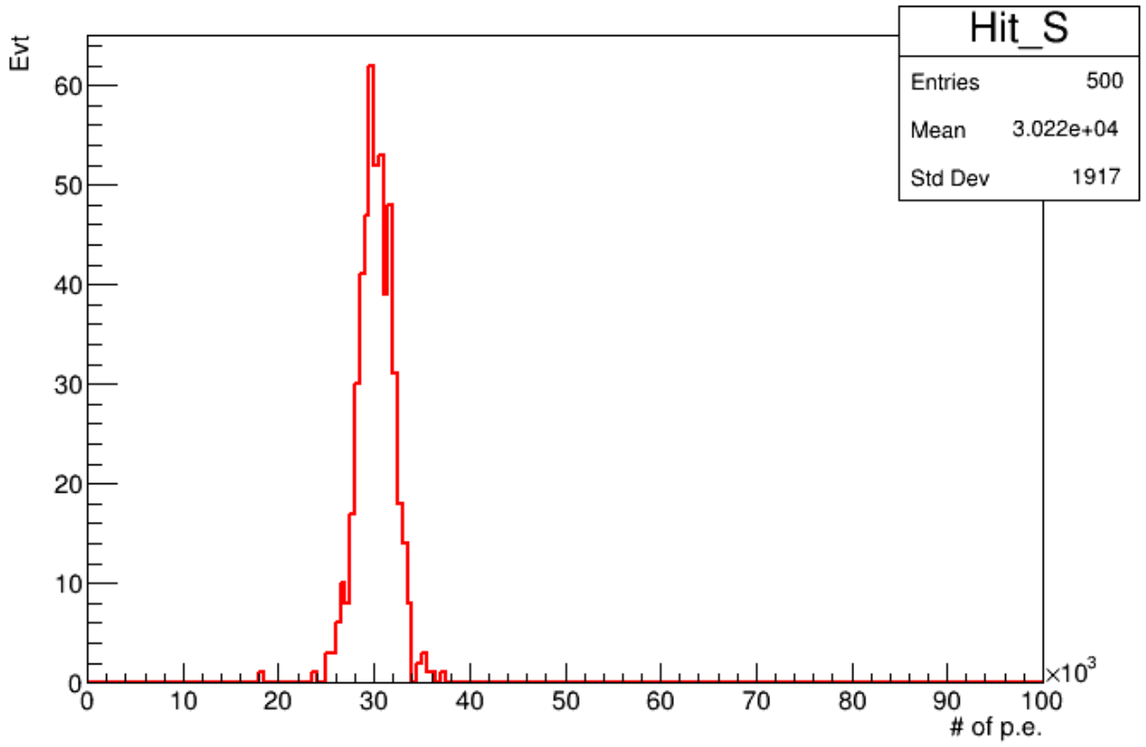


Event display for a 50 GeV neutron

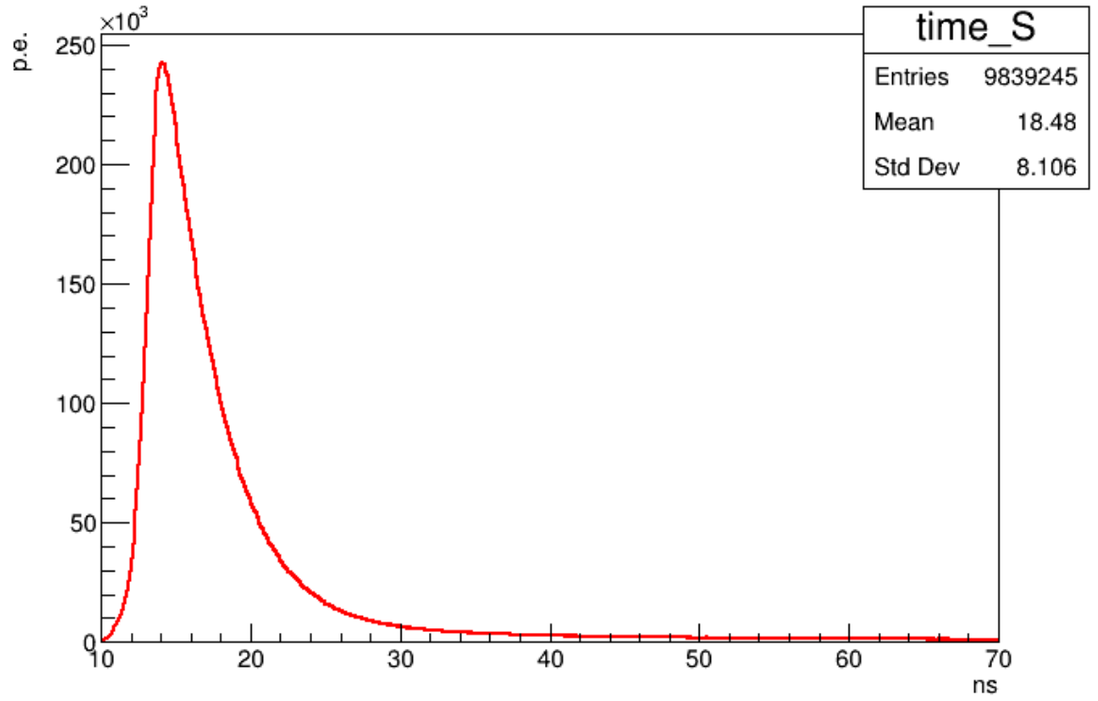
Ex) 80 x 80 x 1500 module particle: geantino

Performance plots

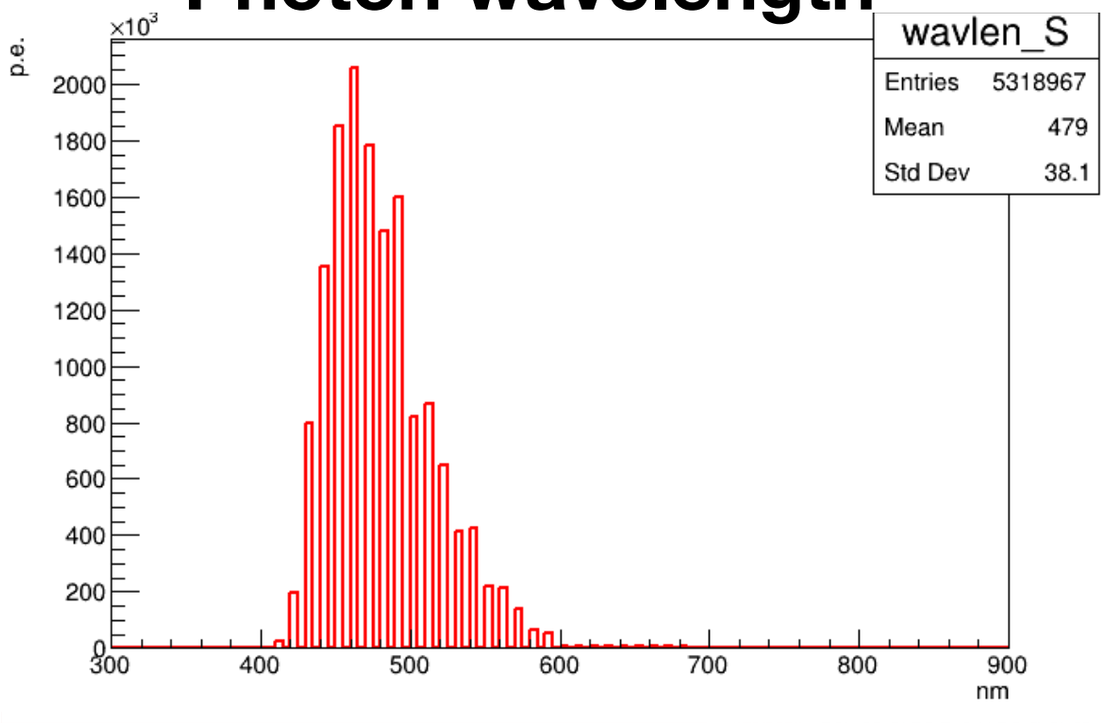
Photon counts by SiPM



Photon's arrival time to reach SiPM



Photon wavelength



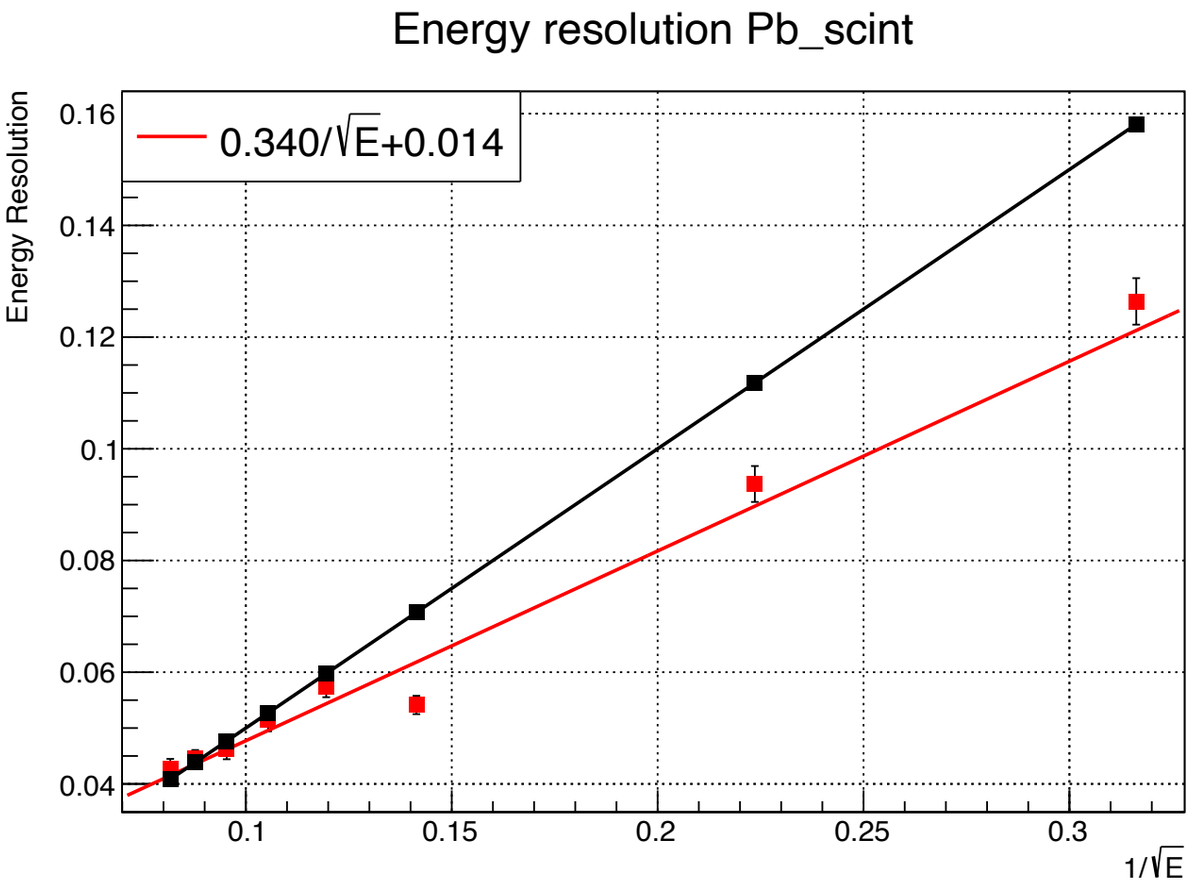
Response to 50 GeV neutron

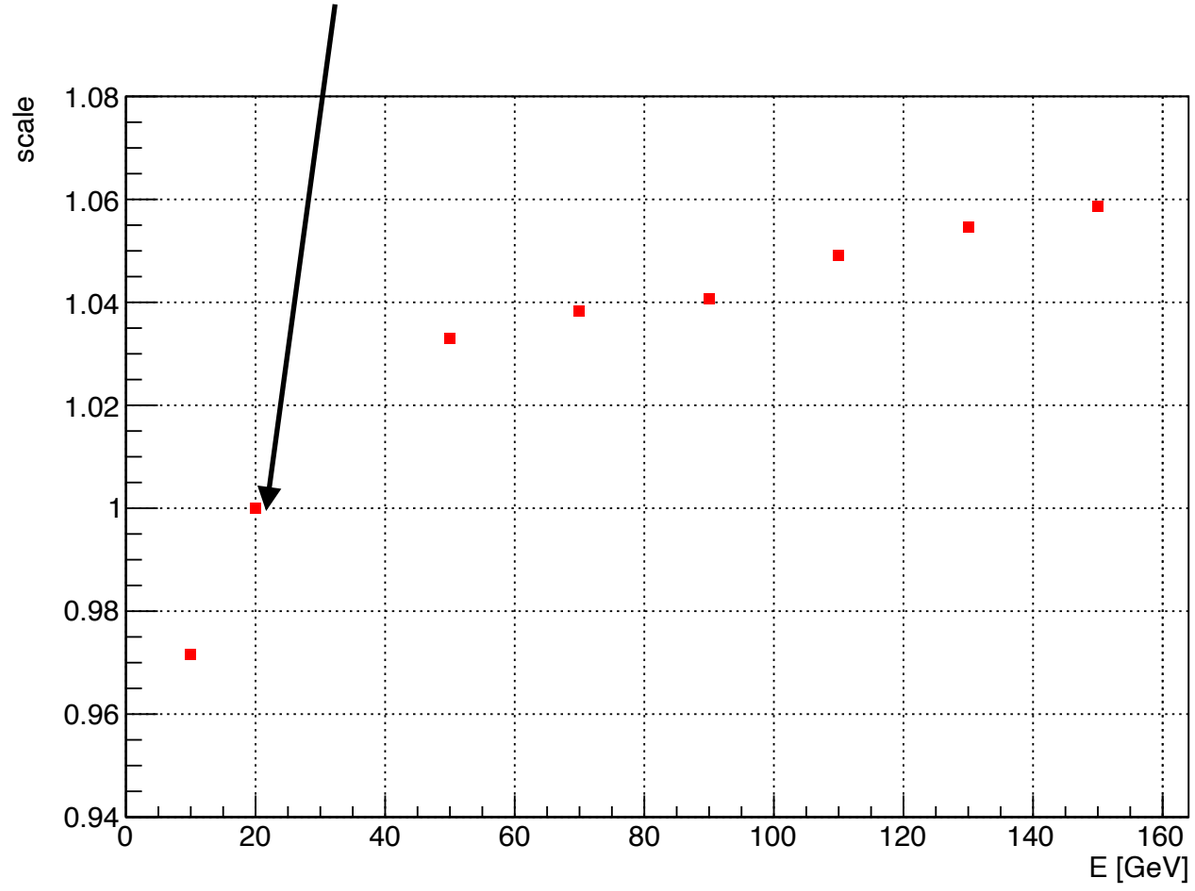
- ΔE/E = 6.3%
- Caveat: Quantum efficiency for readout is not considered, thus resolution is overestimated

Energy Scale and Resolution

Simulated 8 different neutron energy
10, 20, 50, 70, 90, 110, 130, 150 GeV

[# of photons]/[$E_{neutron}$] ratio is fixed here





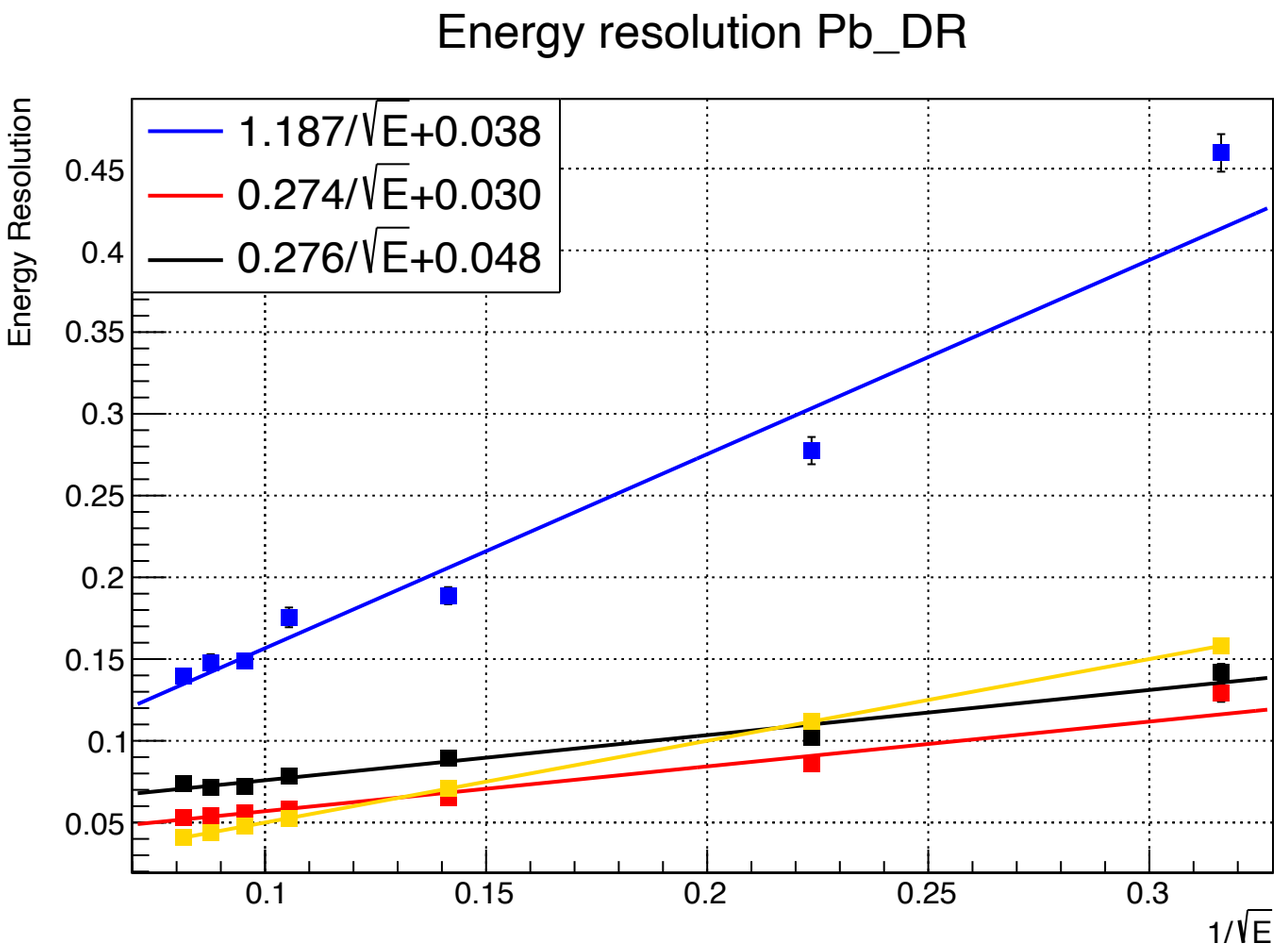
Yellow report number = $\dfrac{50\,\%}{\sqrt{E}}$

$\dfrac{50\,\%}{\sqrt{150GeV}} = 4.08$ 4.28% (MC)

$\dfrac{50\,\%}{\sqrt{10GeV}} = 15.8$ 12.6% (MC)

Dual readout case

Simulated 7 different neutron energy
10, 20, 50, 90, 110, 130, 150 GeV



Cherenkov fiber only

Yellow report number $\frac{50\,\%}{\sqrt{E}}$

Dual fibers combined

Scintillating fiber only

- Quartz fiber: radiation hard, but resolution is too bad by itself
- The use of scintillating fiber is necessary to obtain expected resolution
- The resolution would be even worse if we account readout effect

Plan

- Two (important) missing items
  - Addition of ZDC-e ahead the ZDC-h simulation
  - Reproduce the quantum efficiency for SiPM
    - Any suggestion for this?
- Once these are deployed, we will vary the fiber size, spacing, and bundle numbers in the simulation to find the best parameters

Back ups

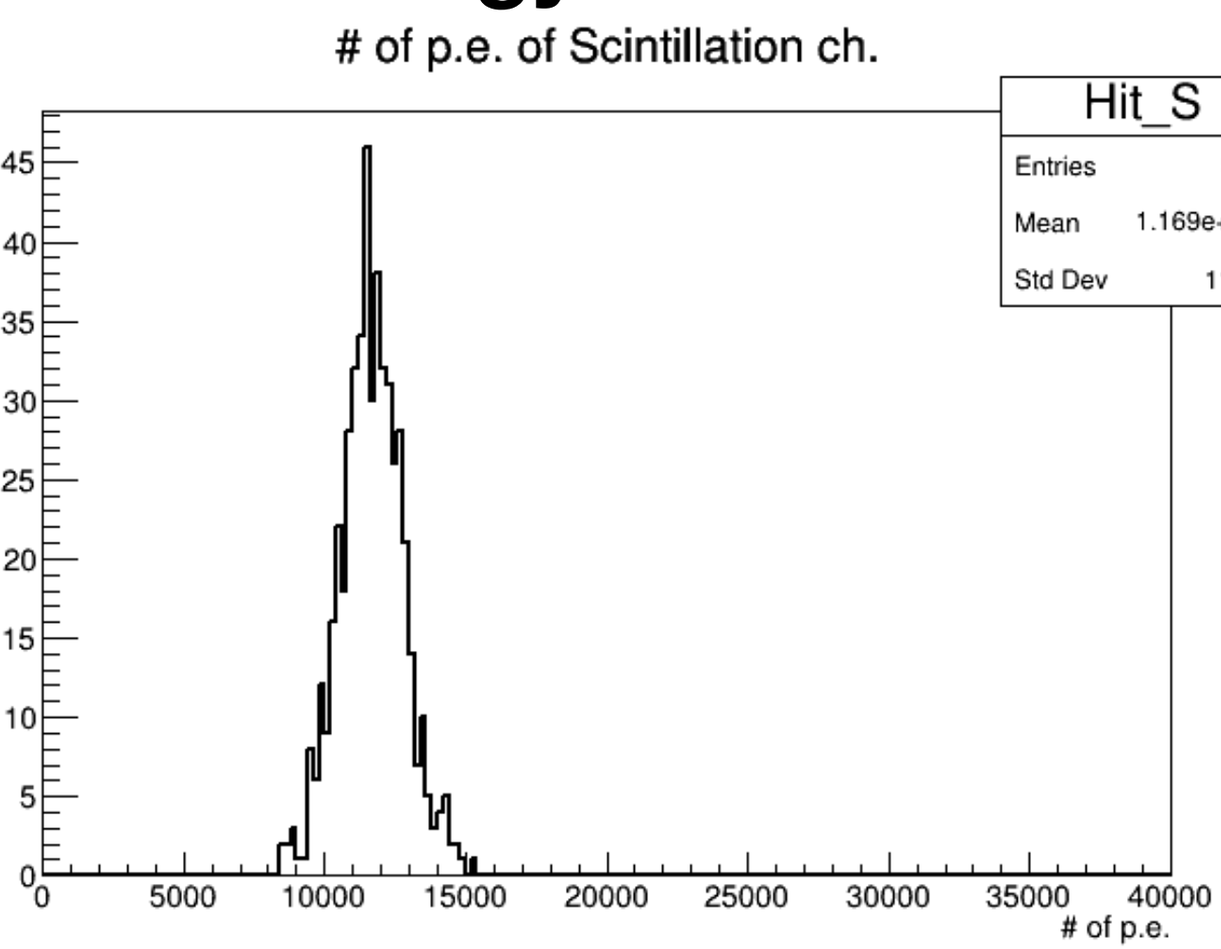
Calibration Based on 20 GeV neutron

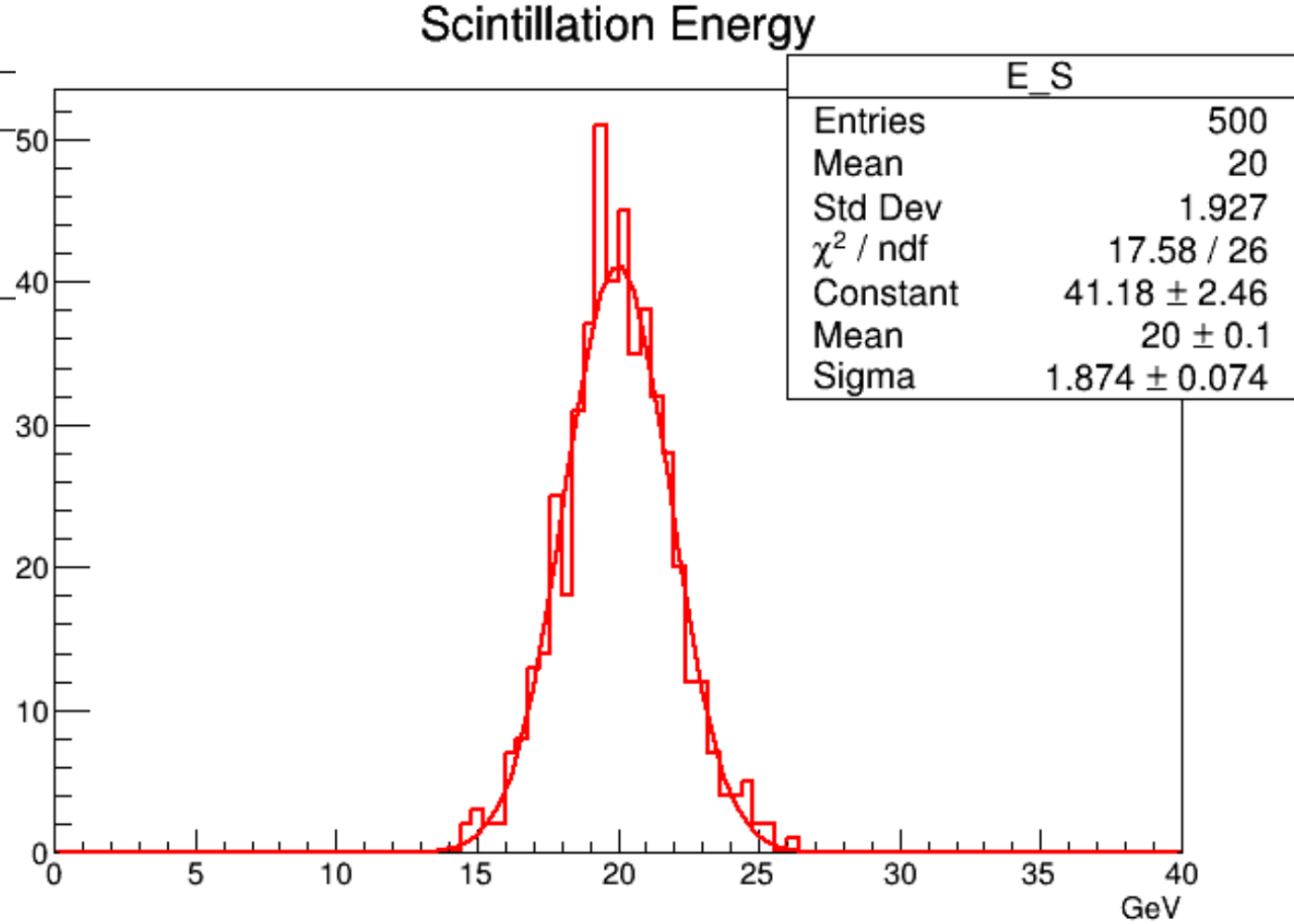
- Energy is proportional to the number of photo-electrons
- Simulation is used to obtain in the scale factors

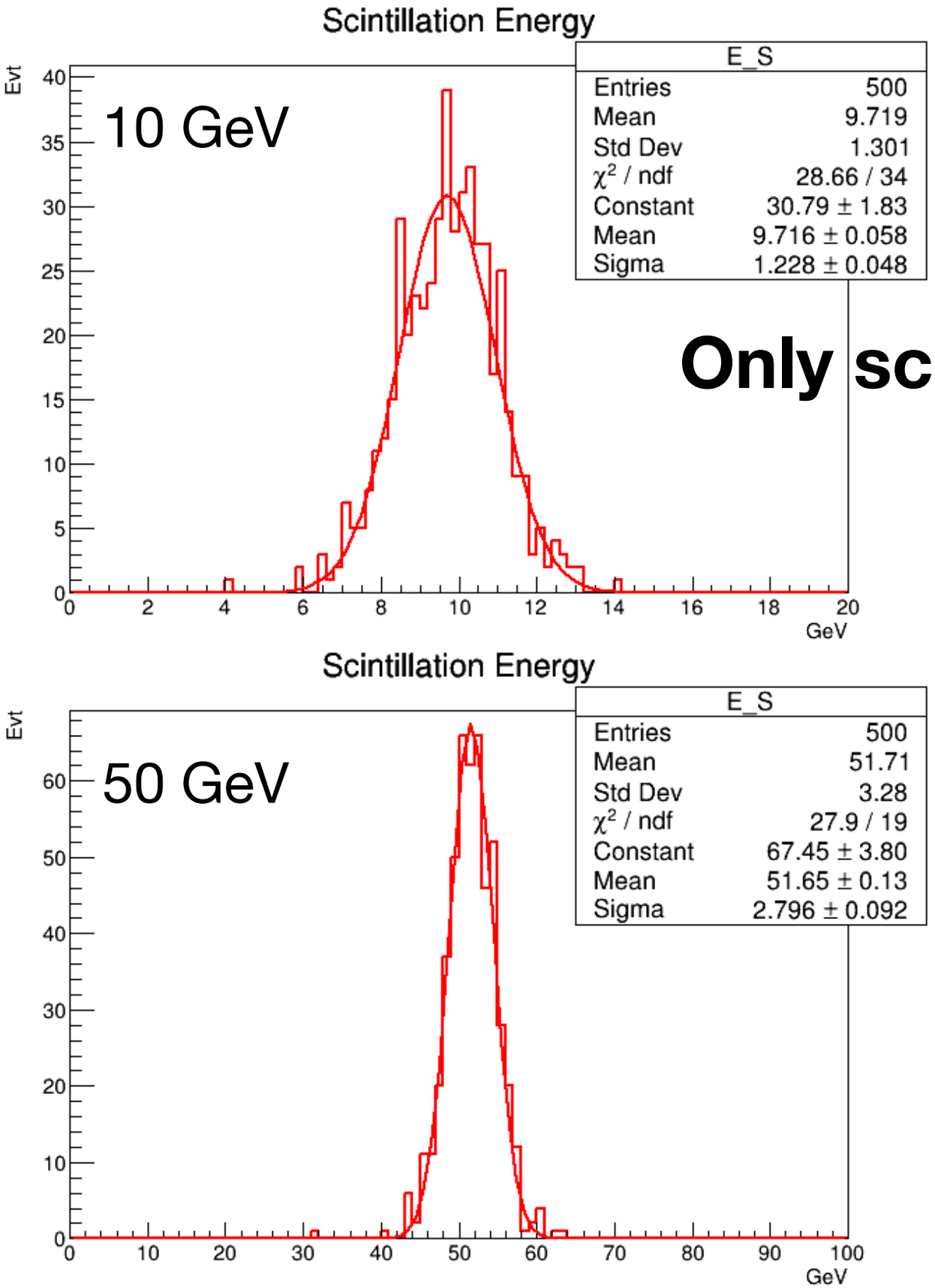
# of photon = 11690

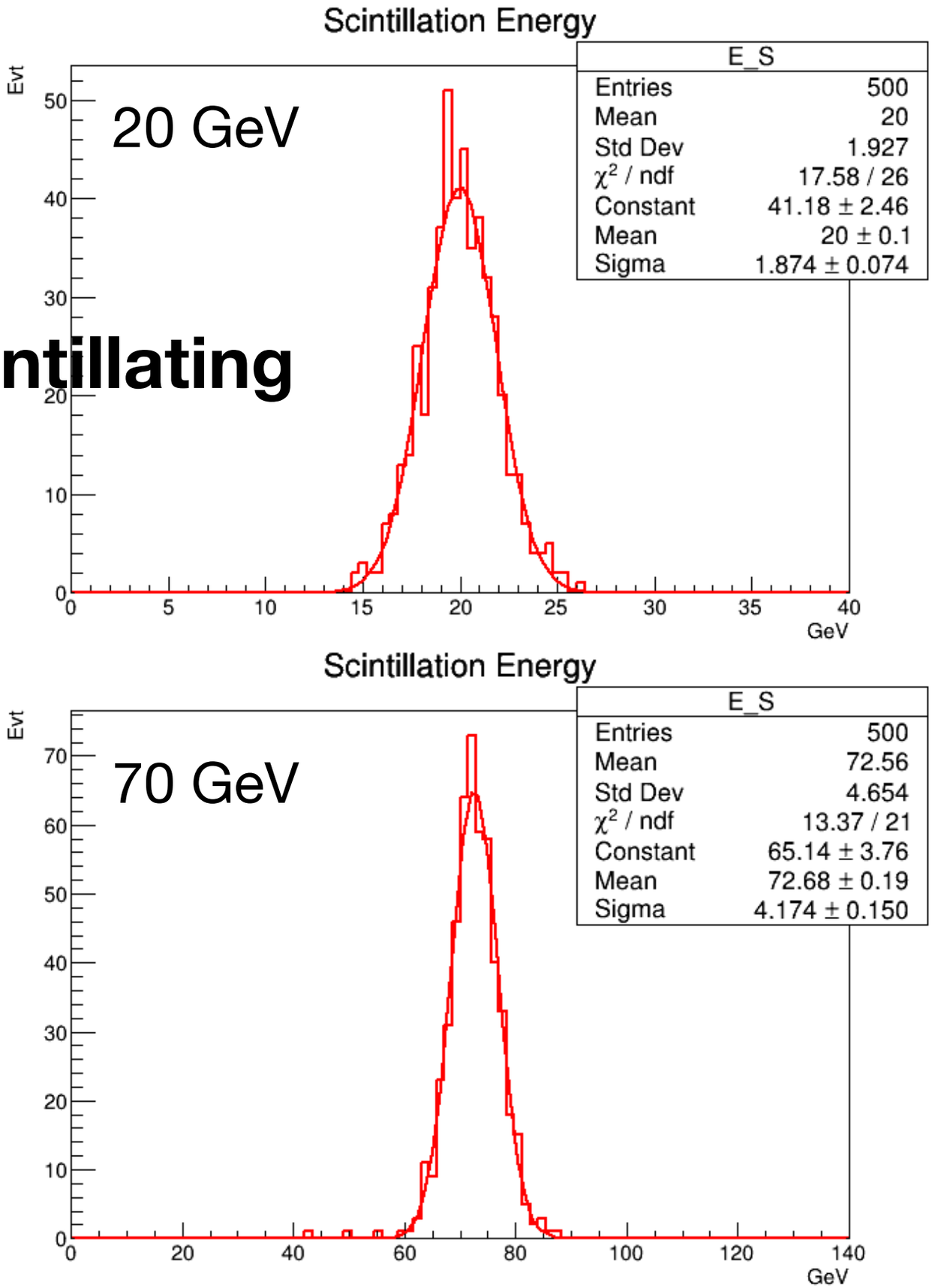
Energy = 20GeV

Scale factor = 20/11690

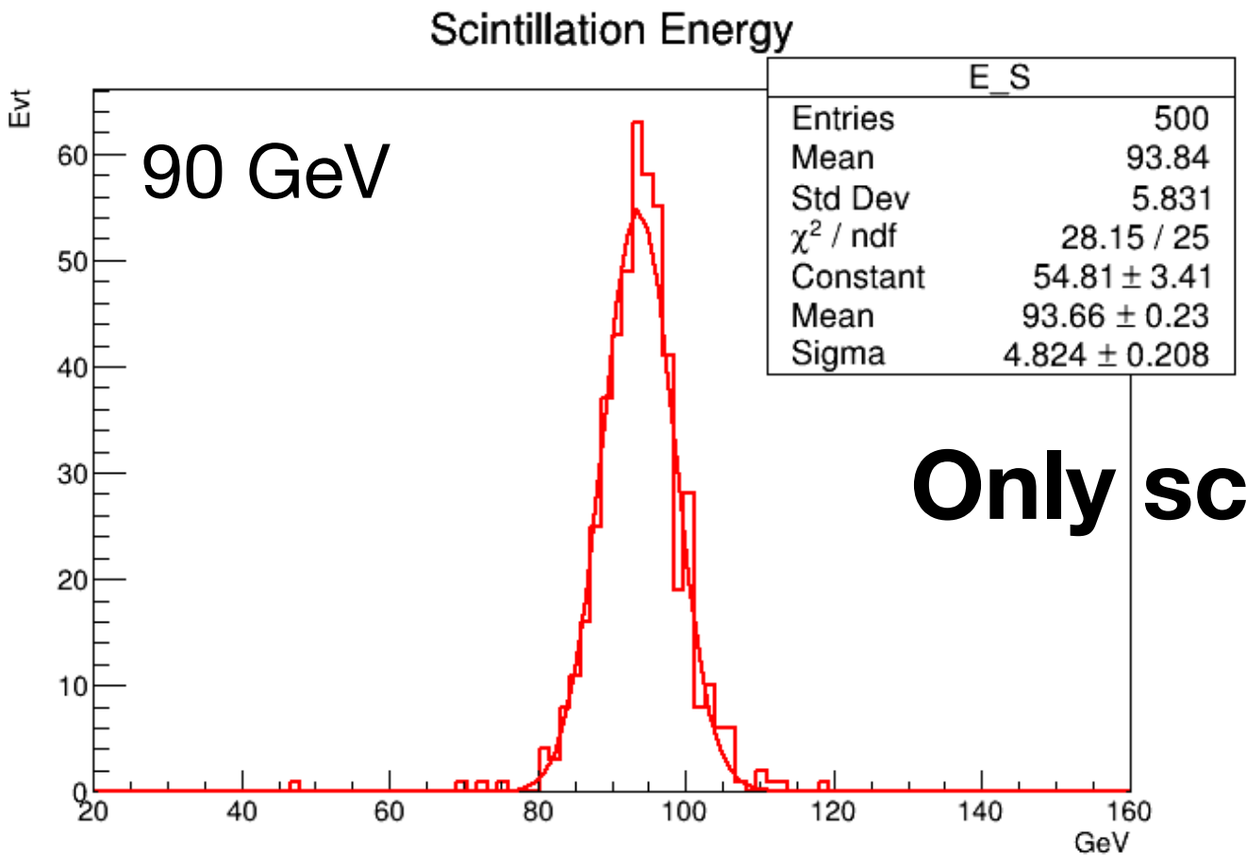


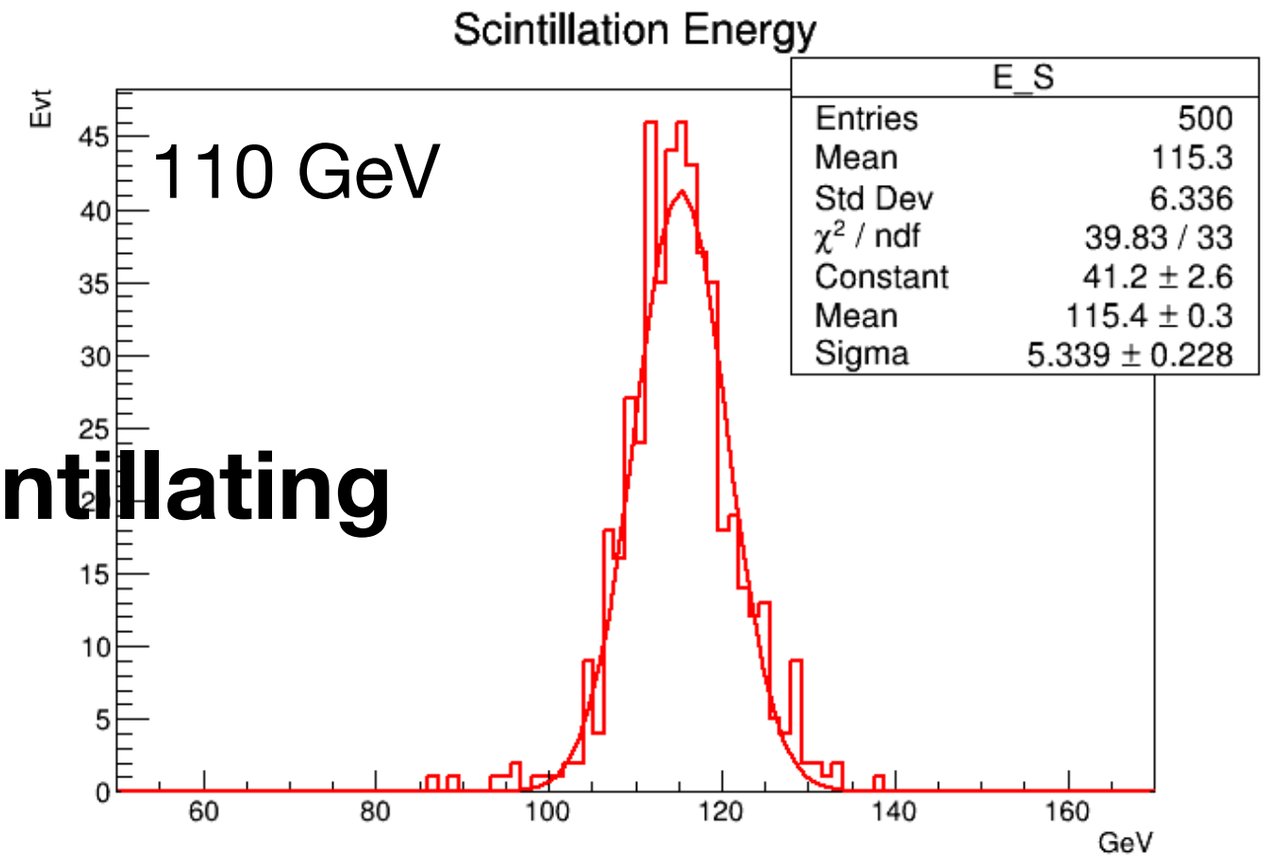




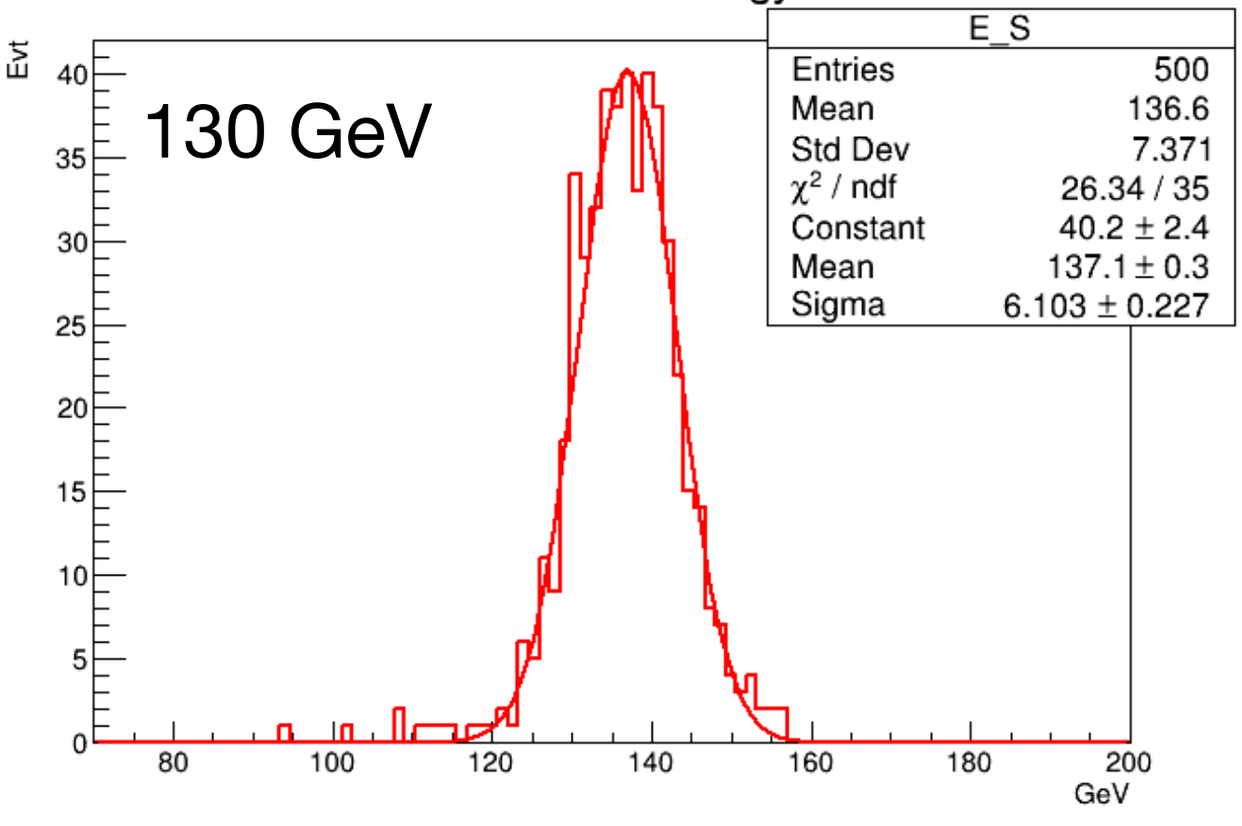


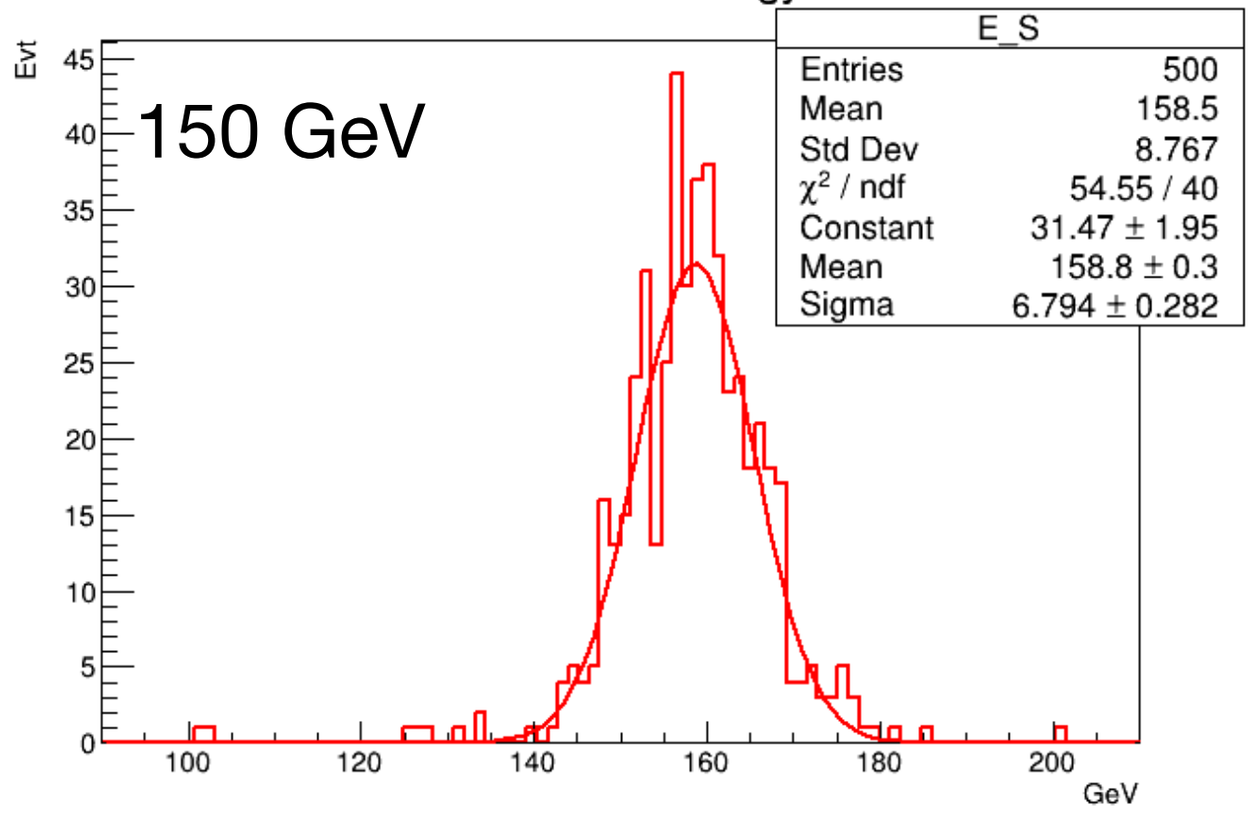
Only scintillating





Only scintillating





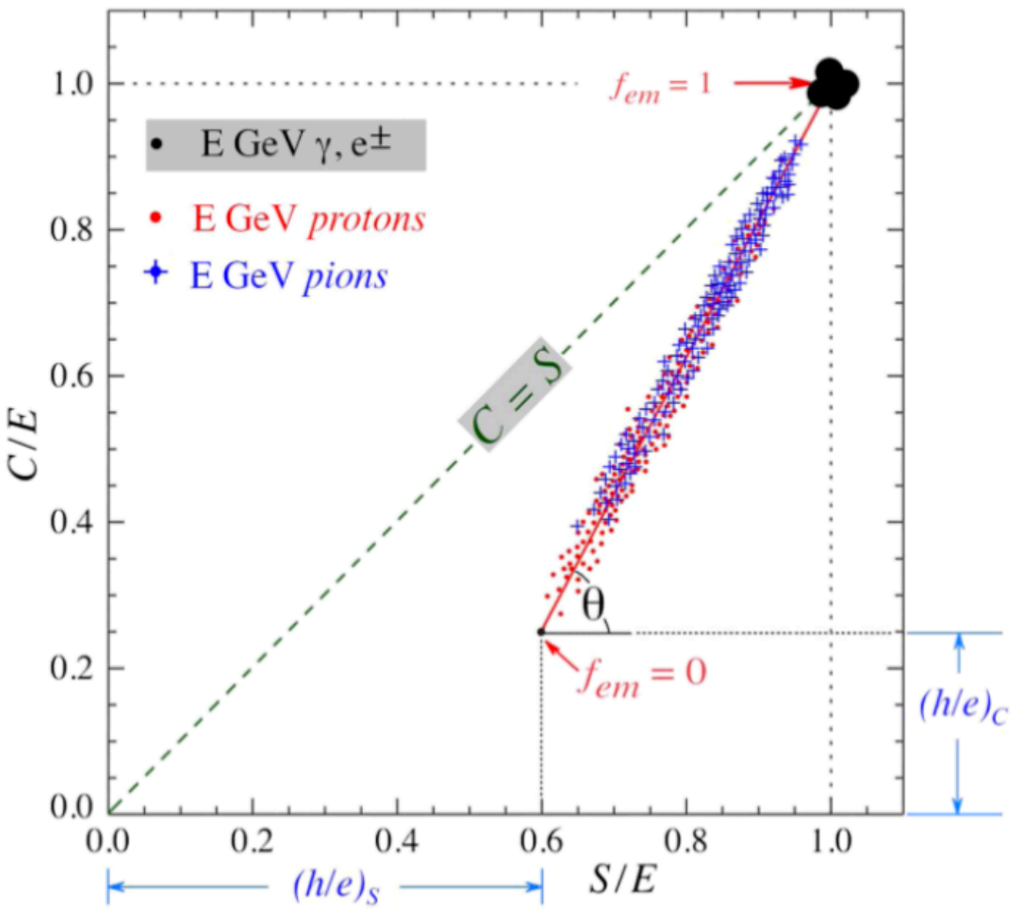
Dual-readout calorimeter

Fiber - scintillating : cherenkov

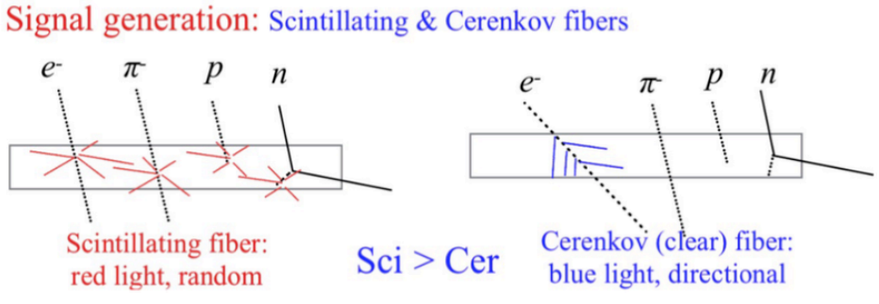
50 : 50

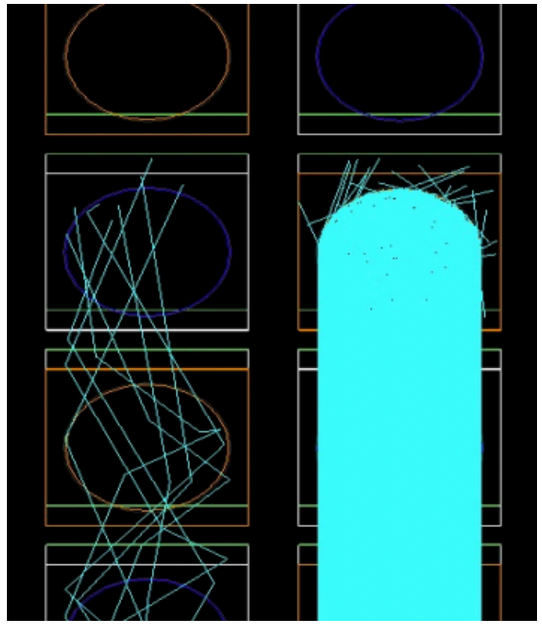
The major difficulty of measuring energy of hadronic showers comes from the fluctuation of EM fraction of a shower, f_em

f_em can be measured by implementing two different Channels with different h/e response in a calorimeter



Energy measured from scintillation channel vs Čerenkov channel for EM particle, π & p





$$S = E[f_{em} + (\frac{h}{e})_S (1 - f_{em})],$$

$$C = E[f_{em} + (\frac{h}{e})_C (1 - f_{em})]$$

$$f_{em} = \frac{(h/e)_C - (C/S)(h/e)_S}{(C/S)[1-(h/e)_S] - [1-(h/e)_C]}$$

$$\cot\theta = \frac{1-(h/e)_S}{1-(h/e)_C} \equiv \chi,$$

$$E = \frac{S - \chi C}{1 - \chi}$$

Resolution table

Energy Resolution	10 GeV	20 GeV	50 GeV	90 GeV	110 GeV	130 GeV	150 GeV
Only scint	12.6%	9.37%	5.41%	5.15%	4.63%	4.45%	4.28%
S & C Dual-readout	14.2%	10.2%	8.92%	7.82%	7.21%	7.12%	7.40%

- We will use **10 - 150 GeV neutrons** in the MC