

Dual-Readout Calorimeter Simulation

State of the Art

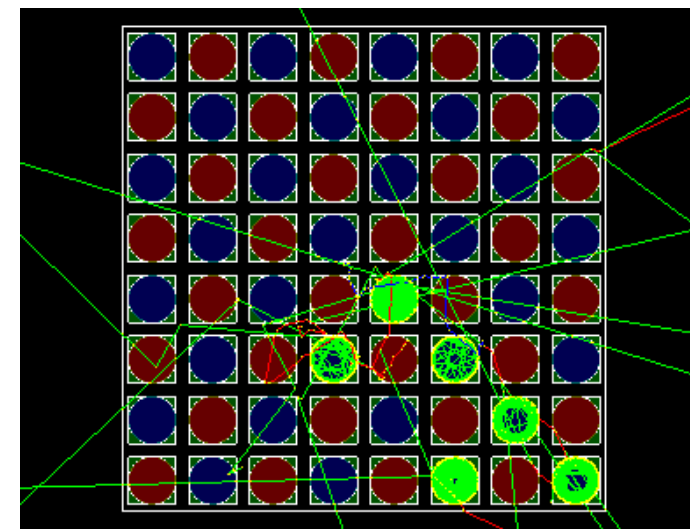
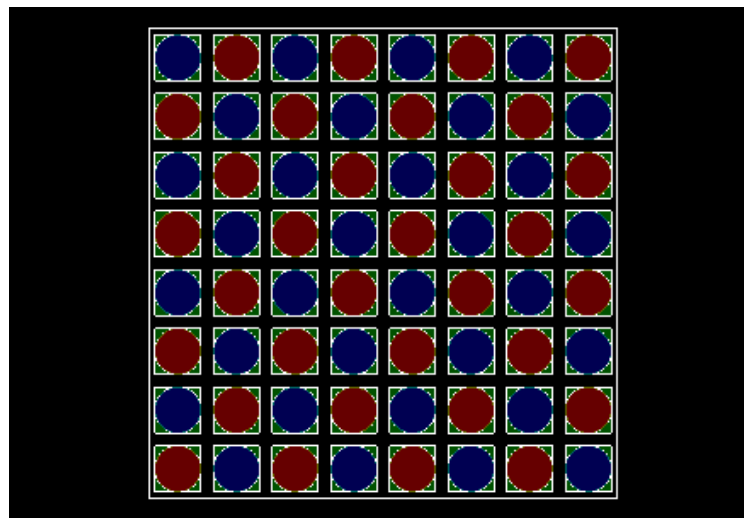
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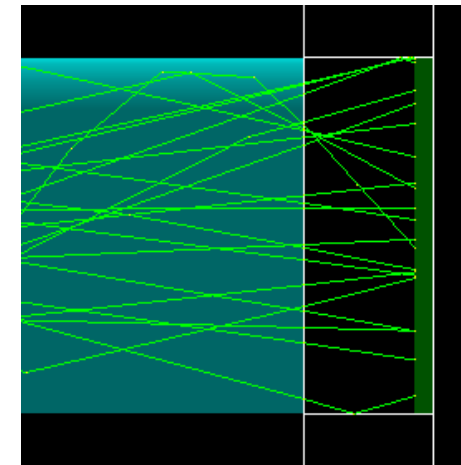
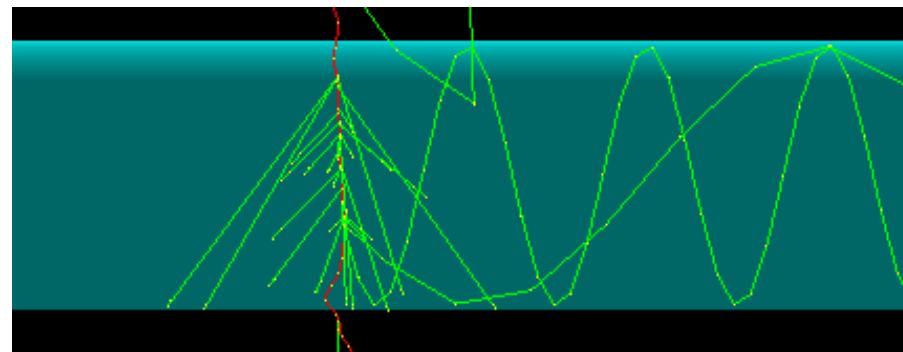
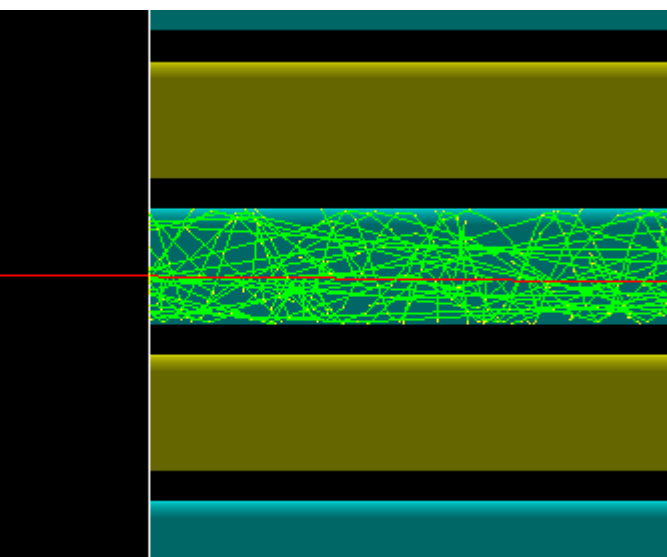
Geometry

- 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



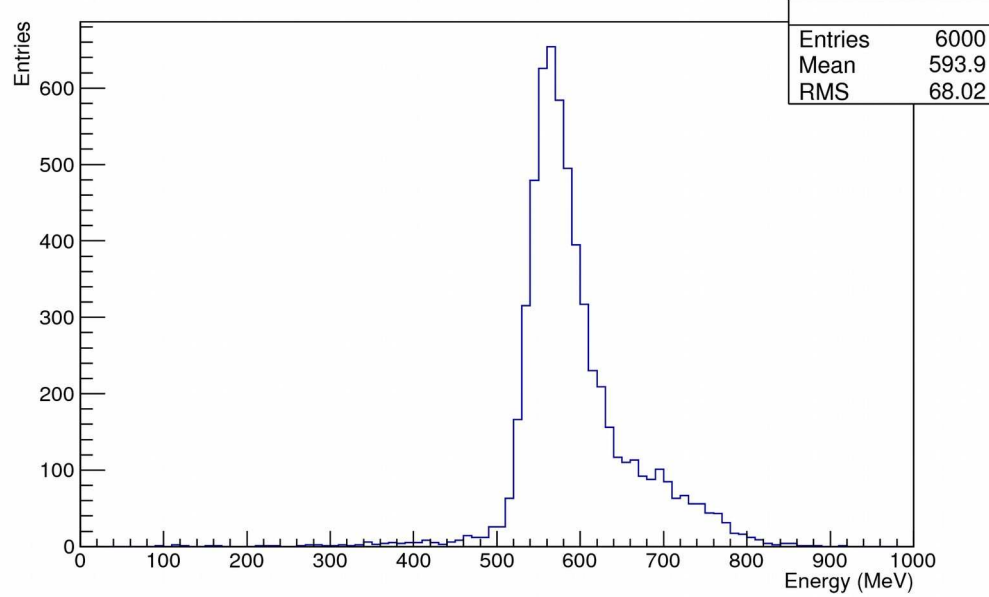
Light production and propagation

- 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

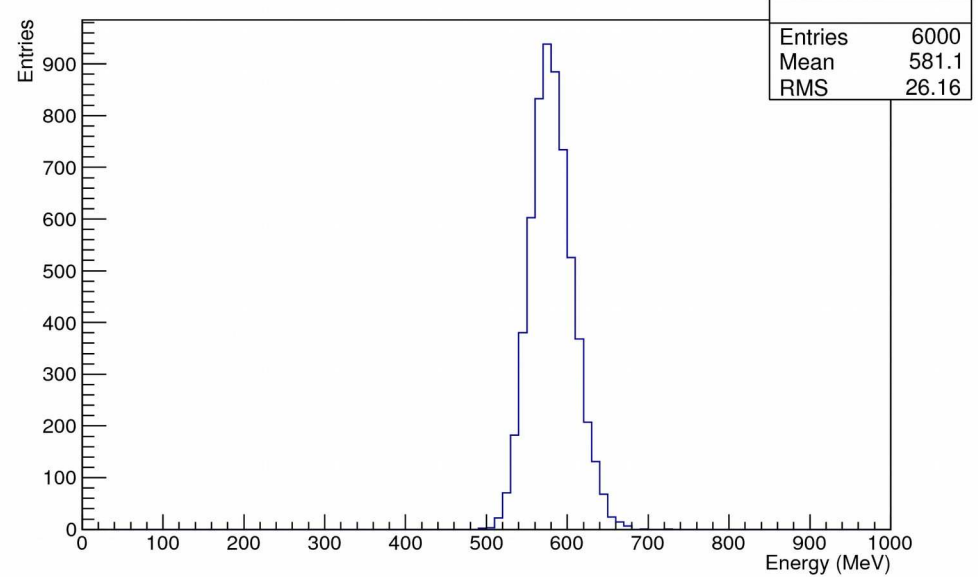


Channeling and fluctuations

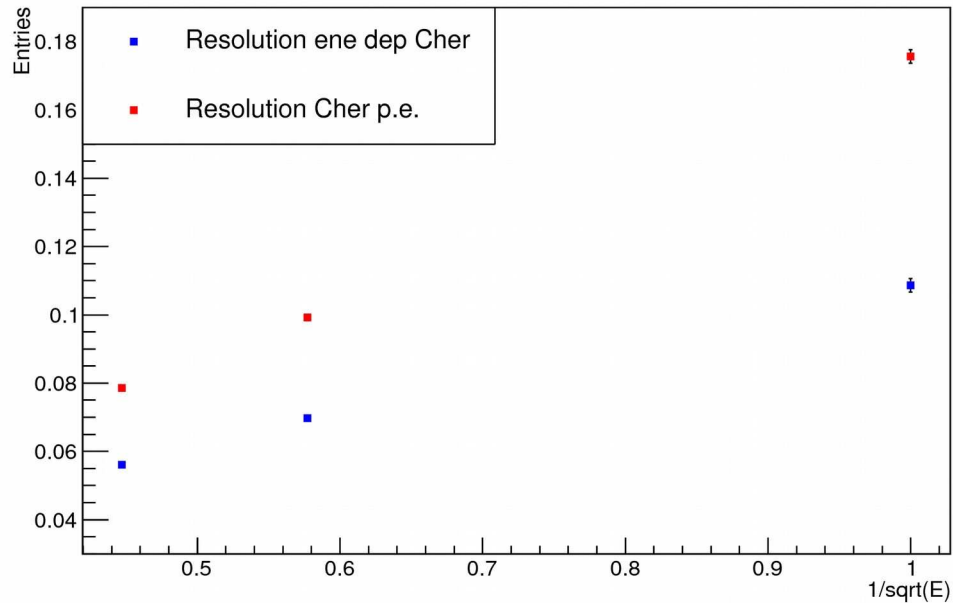
Energy deposited in scin fibres 10 GeV e-



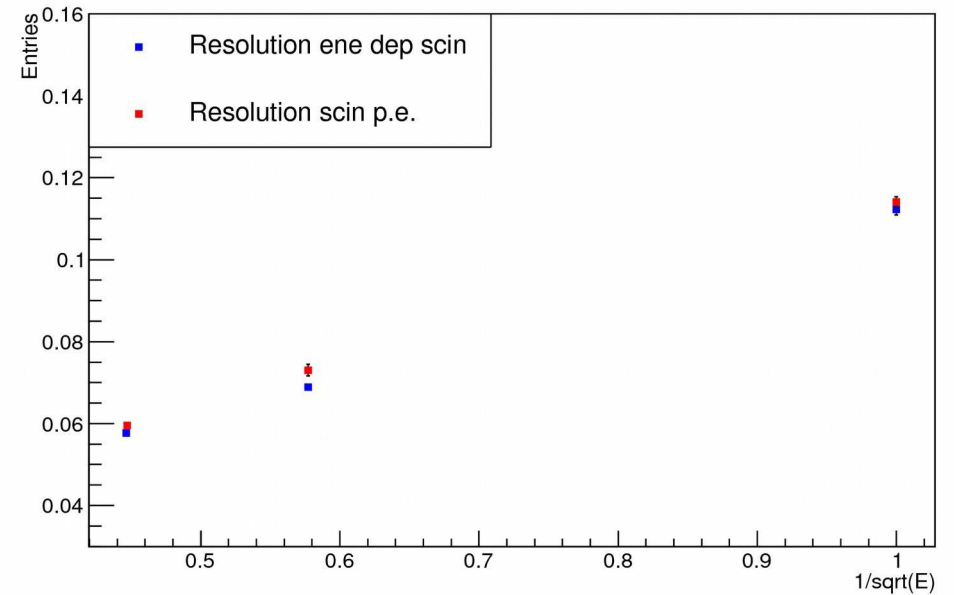
Energy deposited in scin fibres 10 GeV e-



Energy resolutions from Cher signals e-

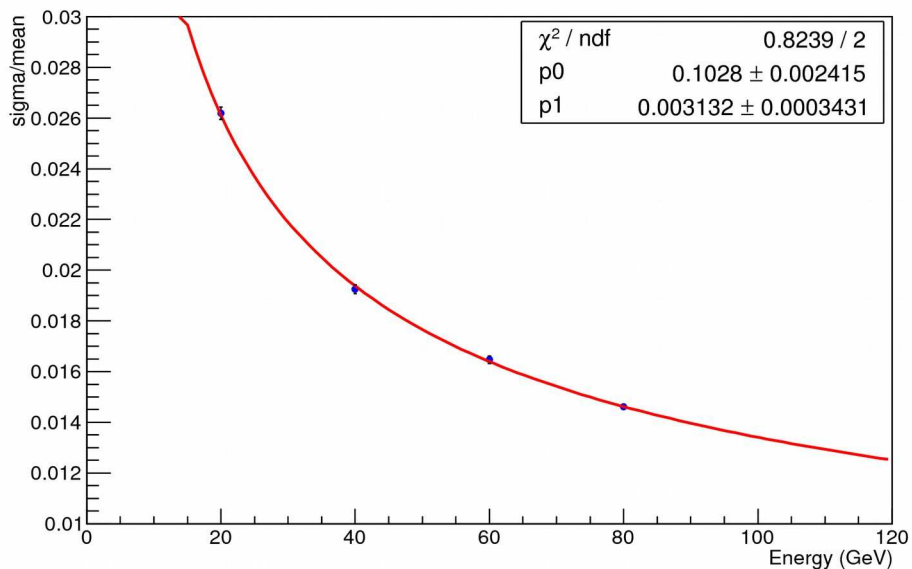


Energy resolutions from scin signals e-

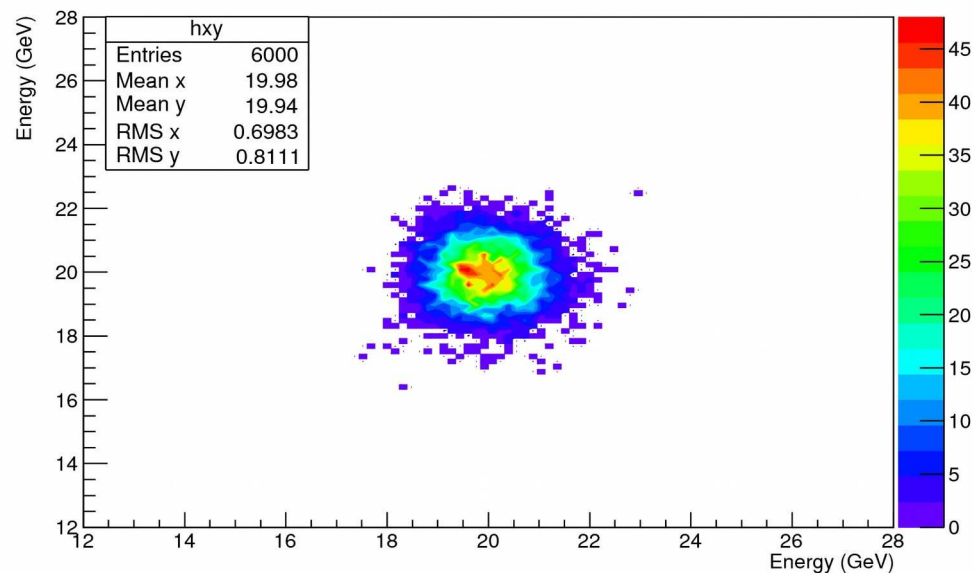


Electromagnetic energy resolution

Combined (cher+scin) energy resolution e-



Energy reconstructed scin - cher signals 20 GeV e-

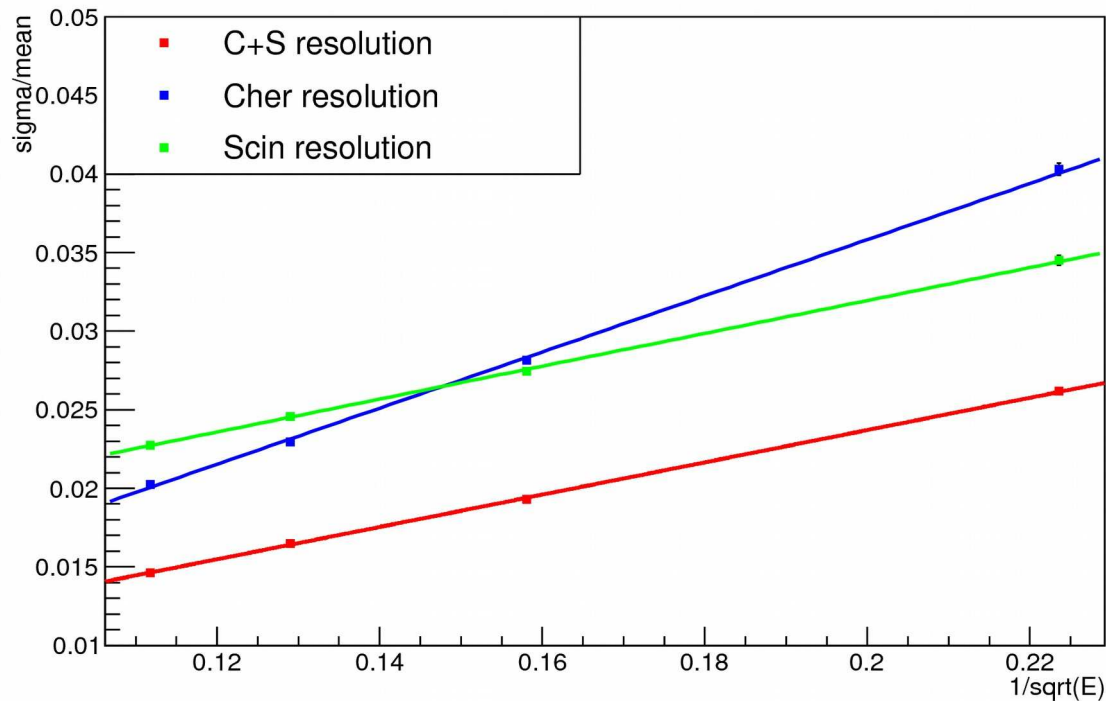


Energy resolutions e-

Cherenkov: $17.9\%/\sqrt{E}$

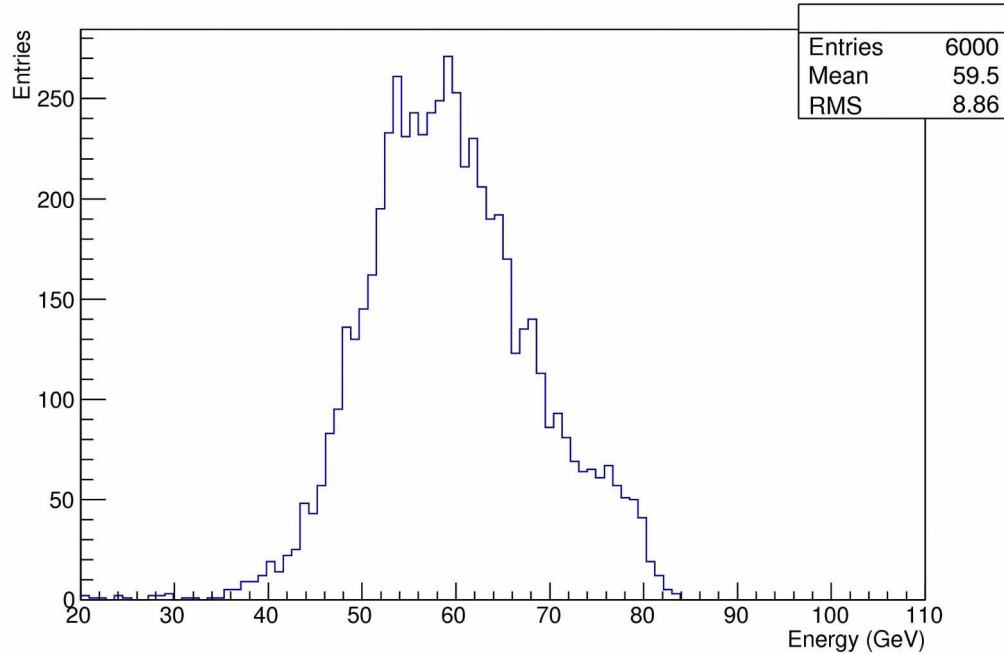
Scintillation:
 $10.5\%/\sqrt{E} + 1.1\%$

C+S: $10.3\%/\sqrt{e} + 0.3\%$

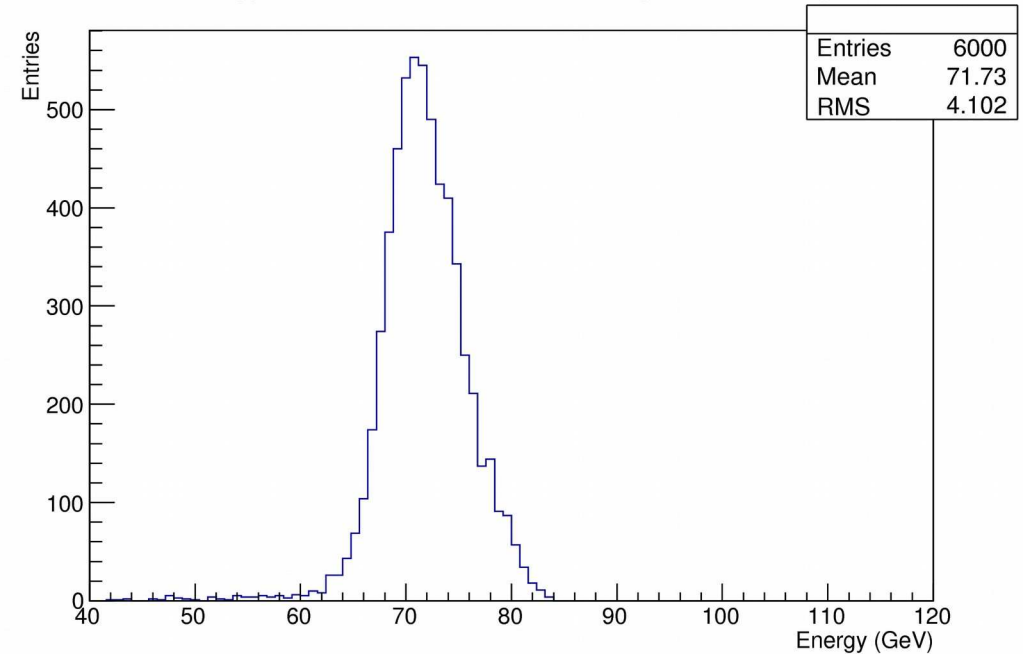


Signals from hadrons

Energy reconstructed from cher signal 80 GeV pi-

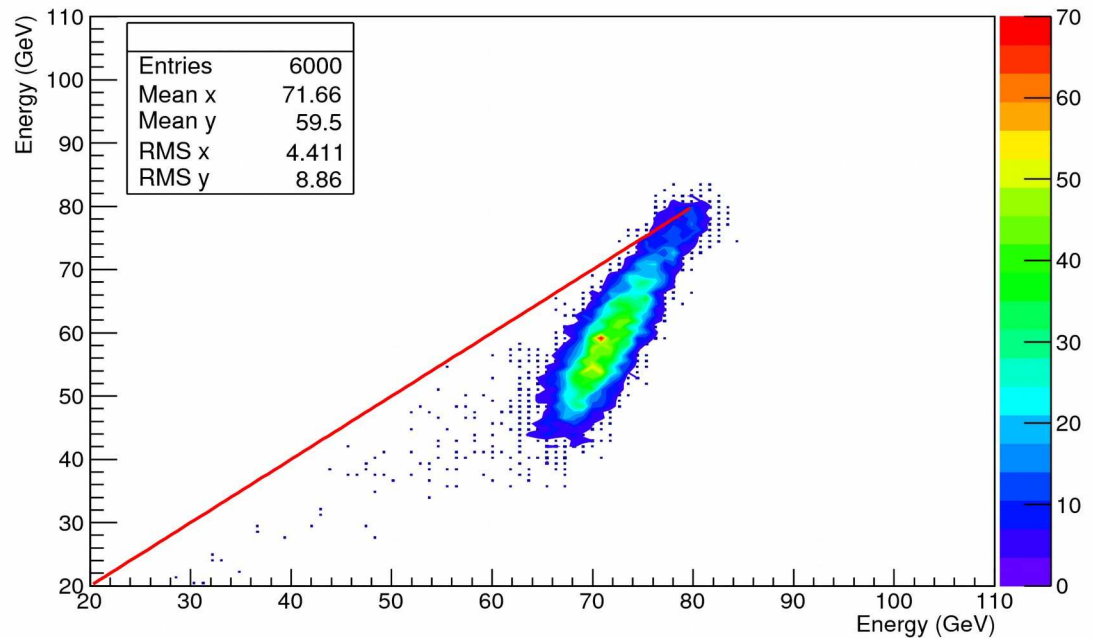


Energy reconstructed from scin signal 80 GeV pi-



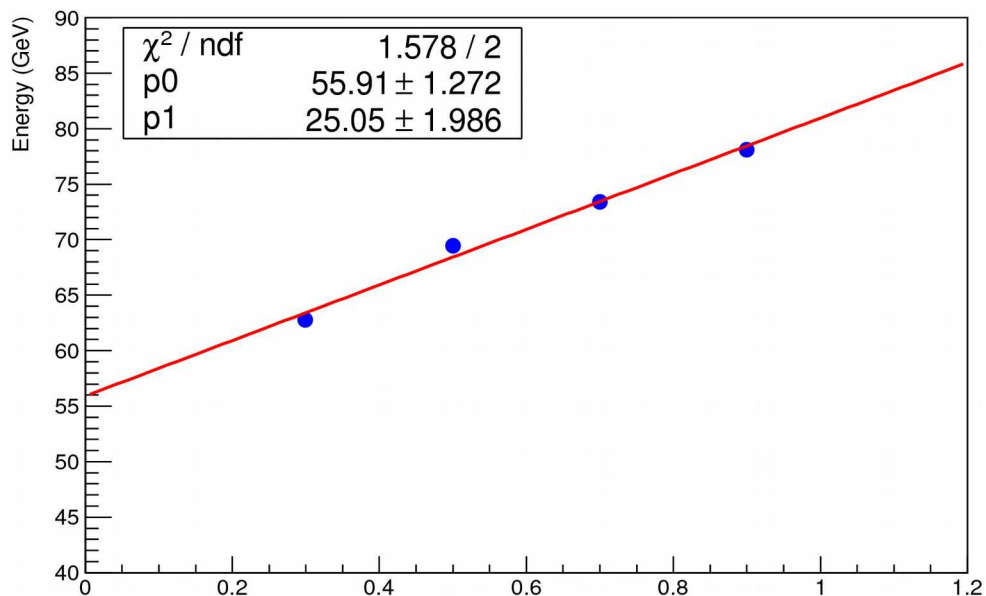
Important to introduce Birk saturation law for scintillating fibres!

Energy reconstructed from cher - scin signals 80 GeV pi-

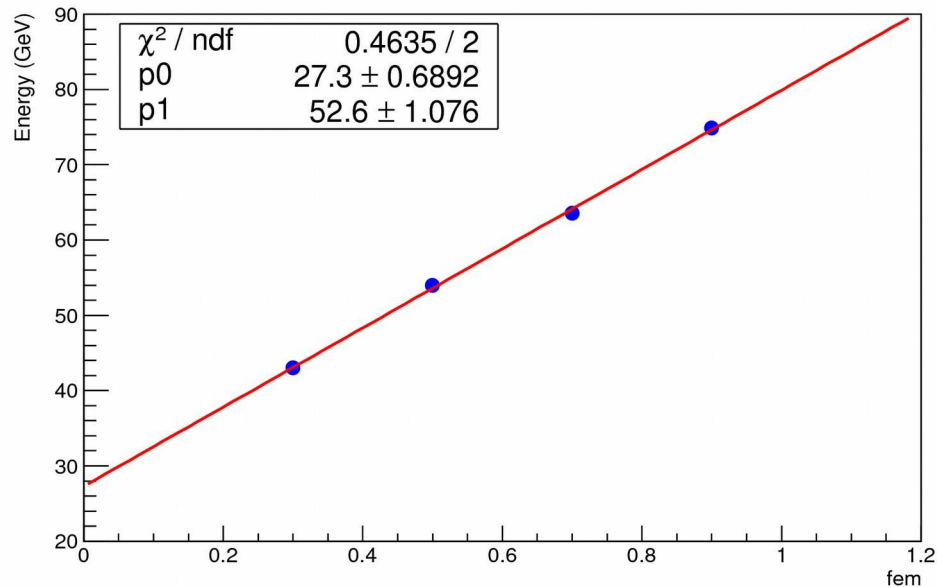


E/H estimation

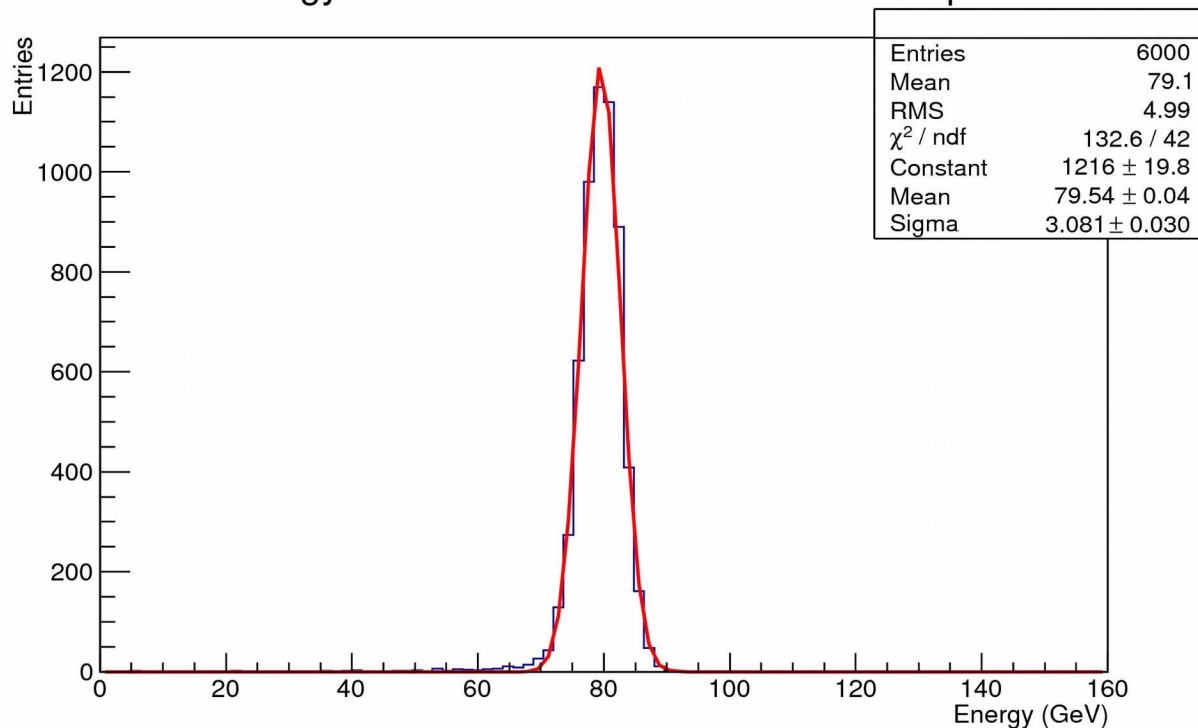
Scintillation signal 80 GeV pi-



Cherenkov signal 80 GeV pi-



Energy reconstructed DR method 80 GeV pi-



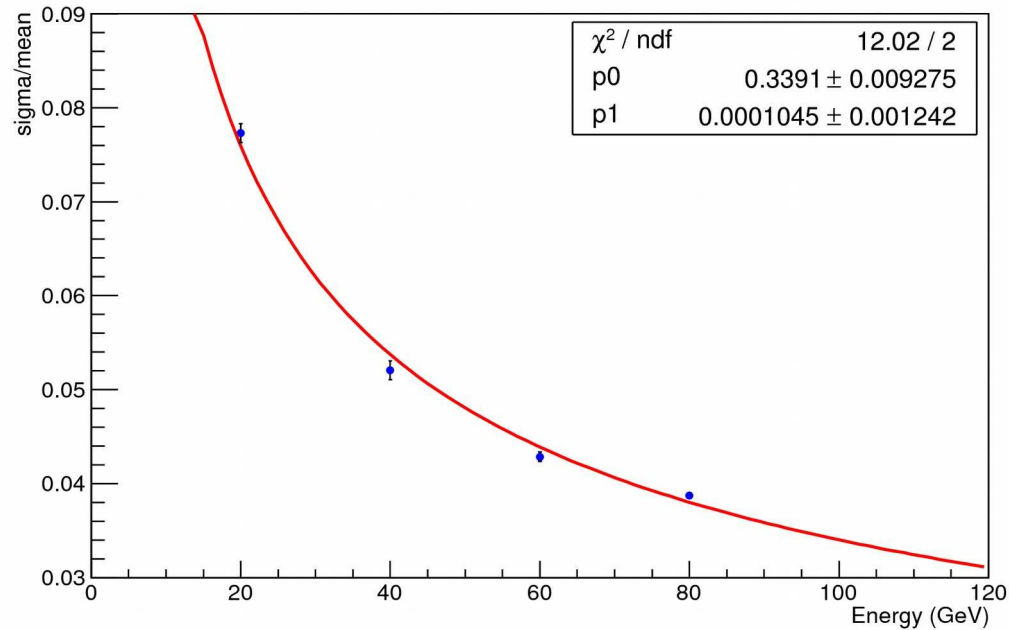
Scintillation: h/e =
0.73

Cherenkov: h/e = 0.29

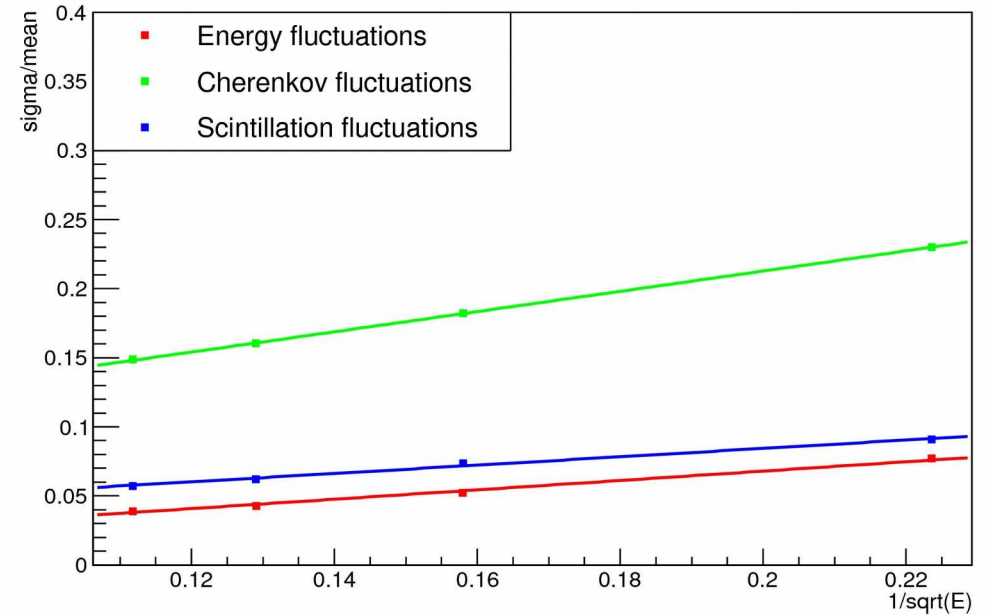
Chi = 0.38

Hadronic energy resolution

Dual readout energy resolution pi-



Energy resolutions pi-



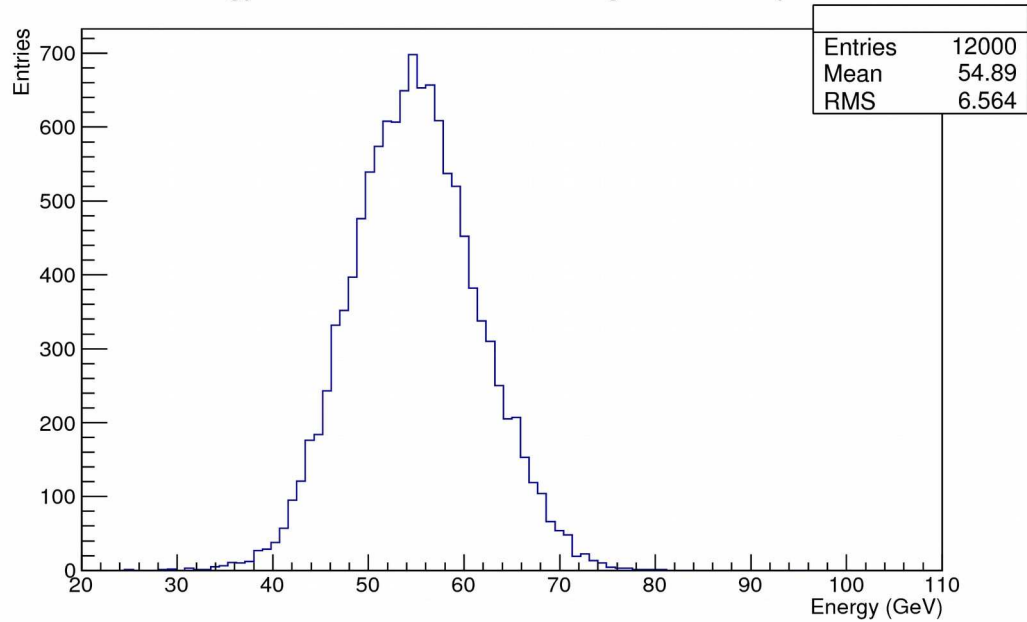
Scintillation: $30\%/\sqrt{E} + 2.4\%$

Cherenkov: $73\%/\sqrt{E} + 6.6\%$

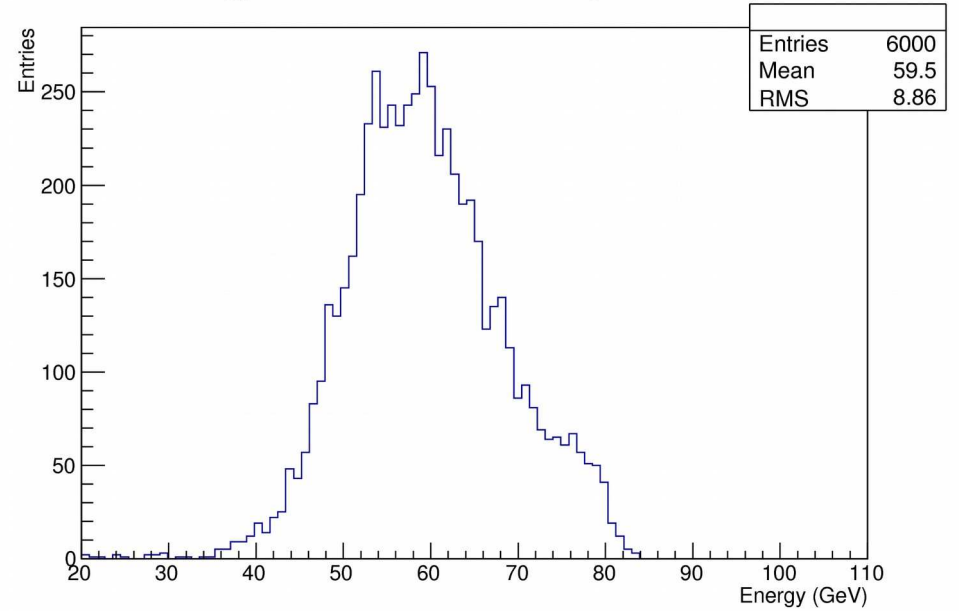
Dual readout method: $34\%/\sqrt{E}$

Proton vs Pions

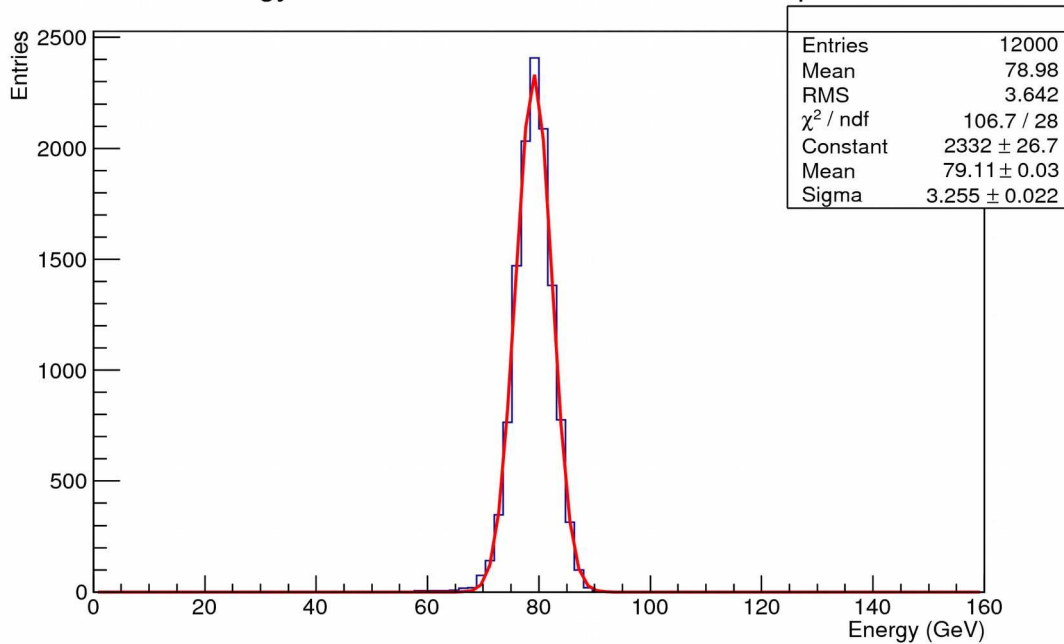
Energy reconstructed from cher signal 80 GeV proton



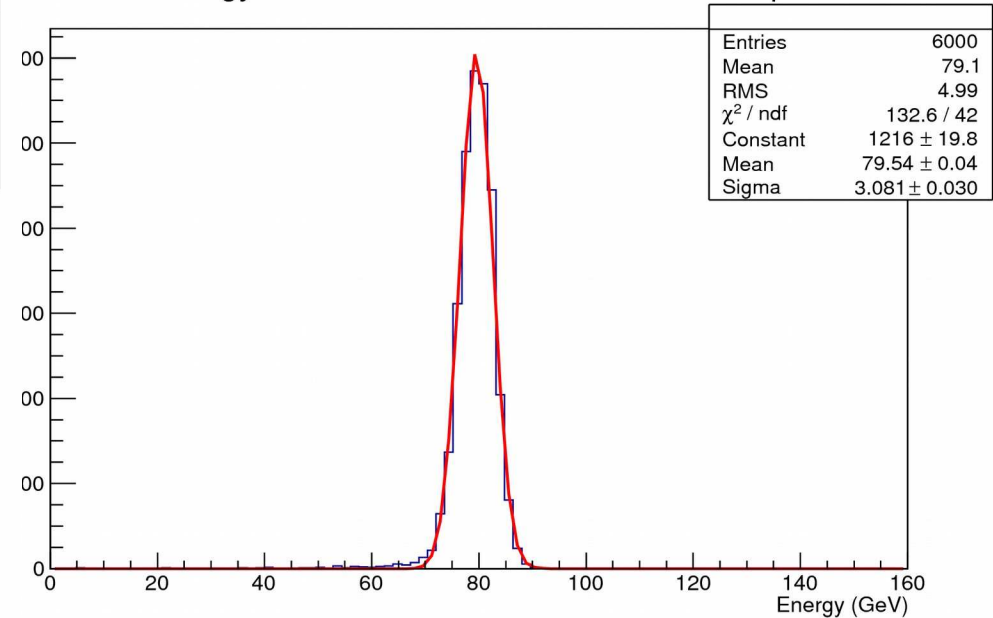
Energy reconstructed from cher signal 80 GeV pi-



Energy reconstructed DR method 80 GeV proton

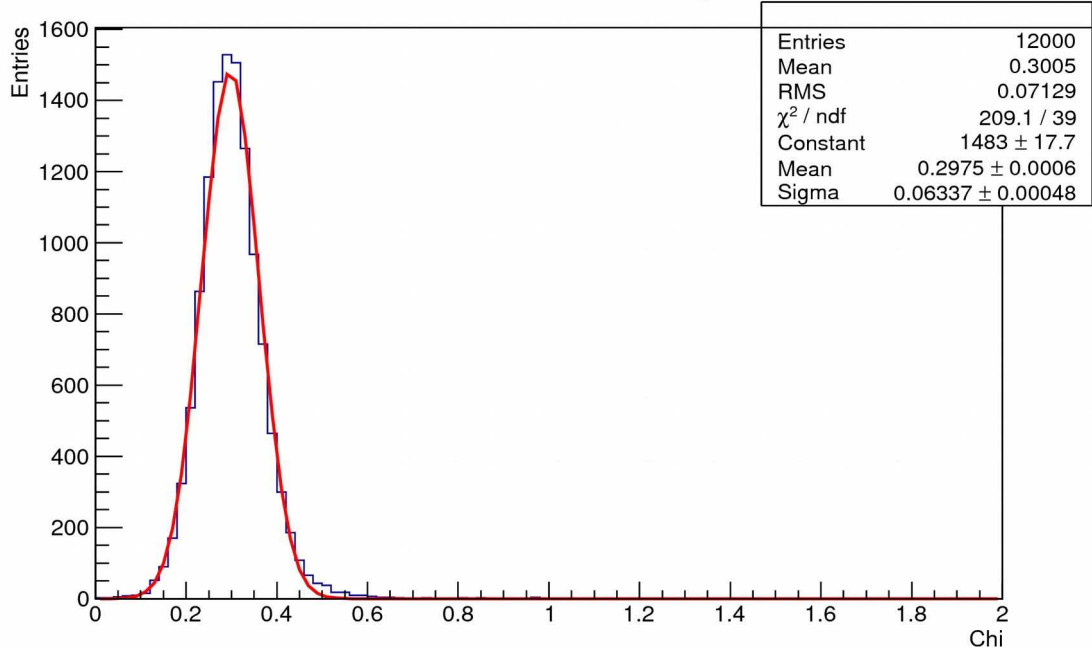


Energy reconstructed DR method 80 GeV pi-



Lead vs Copper: chi factors

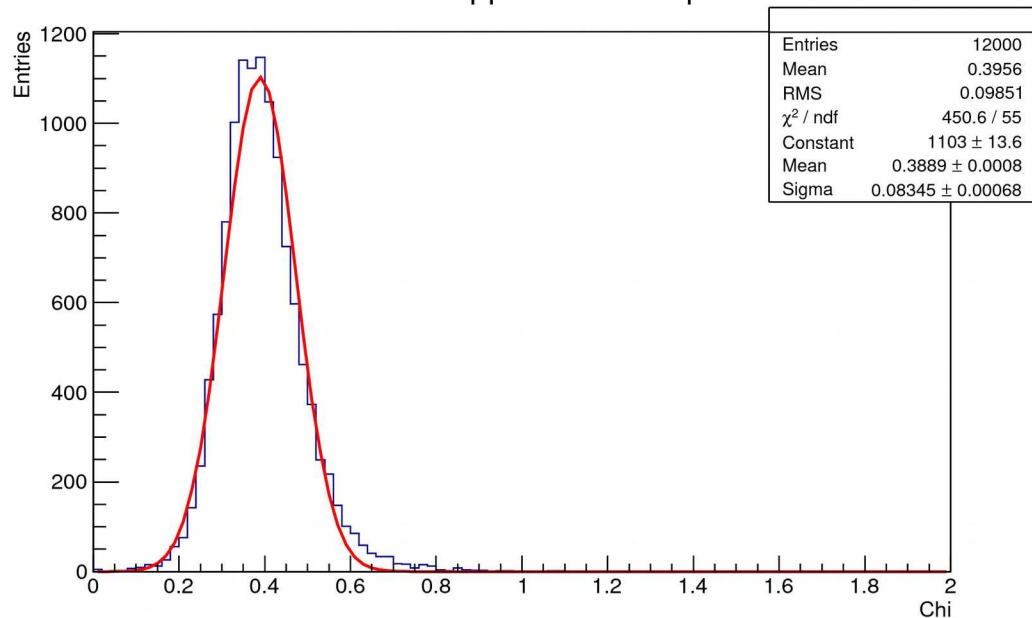
Chi factor - lead - 80 GeV proton



Lead: Chi = 0.3

$$\text{Chi} = (E-S)/(E-C)$$

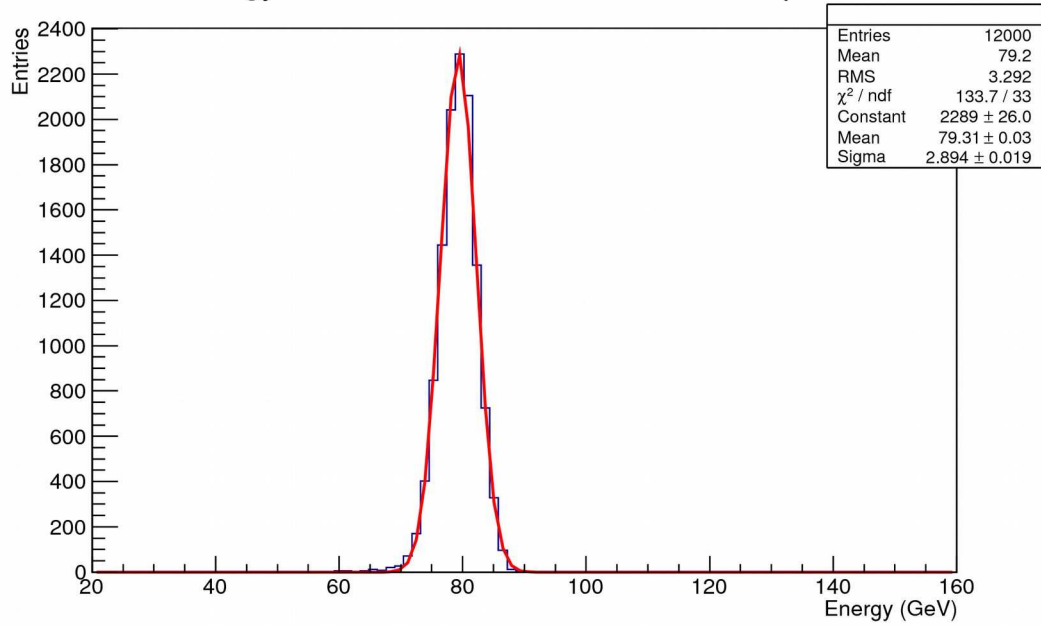
Chi factor - copper - 80 GeV proton



Copper: Chi = 0.38

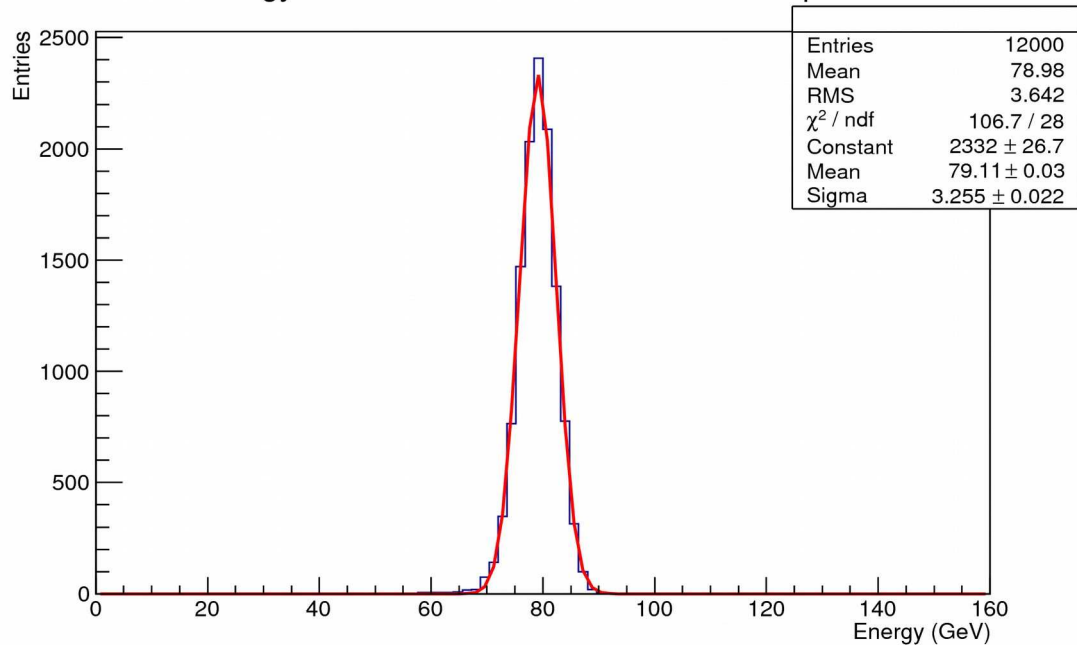
Lead vs copper: energy resolution

Energy reconstructed DR method 80 GeV proton



Lead: mean 79.3 sigma
2.89

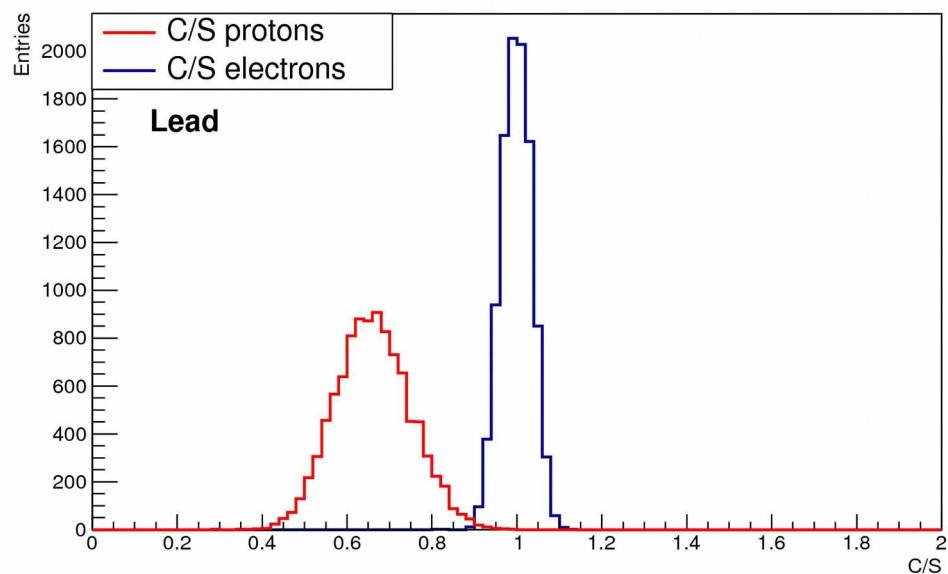
Energy reconstructed DR method 80 GeV proton



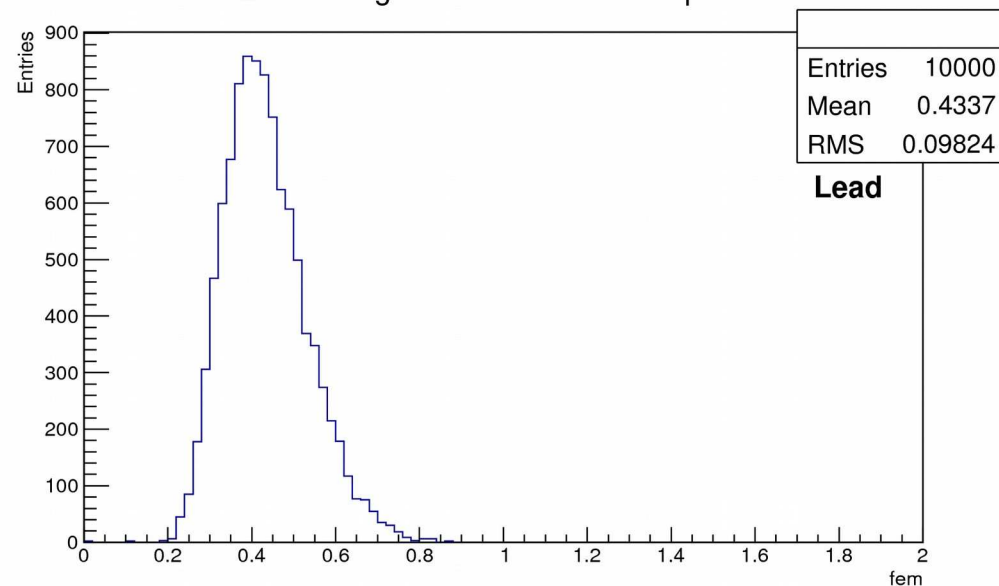
Copper: mean 79.11 sigma
3.25

Lead vs copper: particle identification

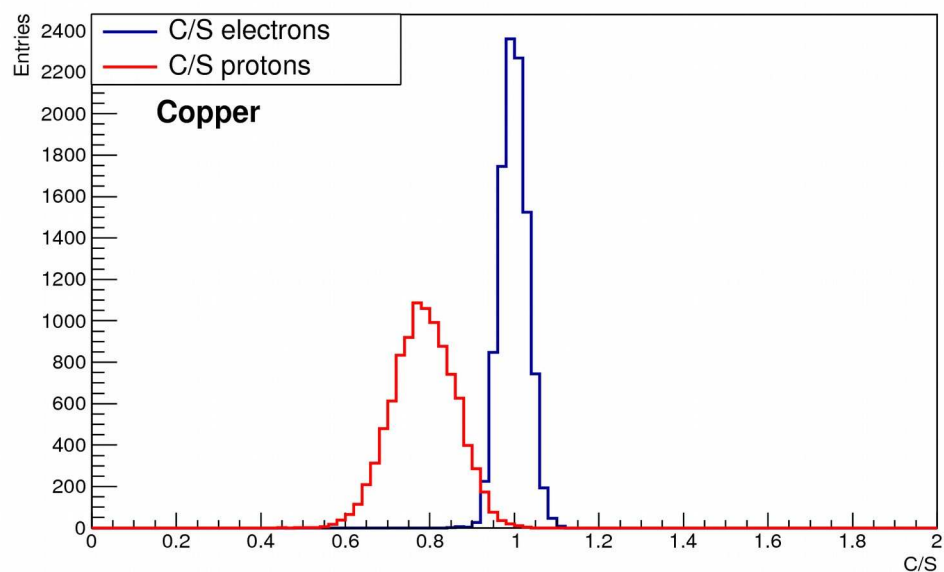
C/S 80 GeV electron - proton



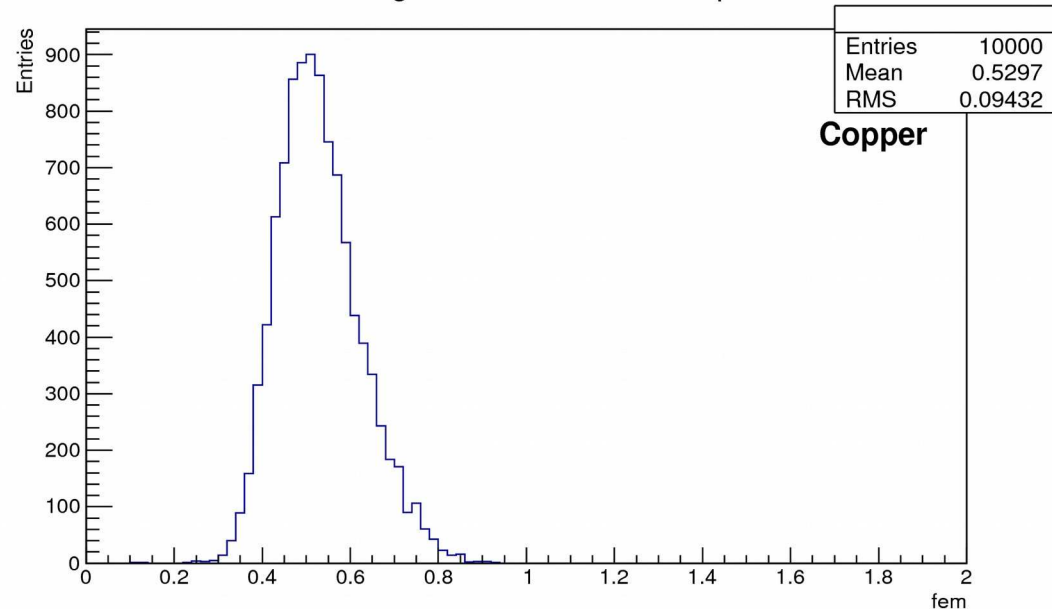
Electromagnetic fraction 80 GeV proton



C/S 80 GeV electron - proton



Electromagnetic fraction 80 GeV proton

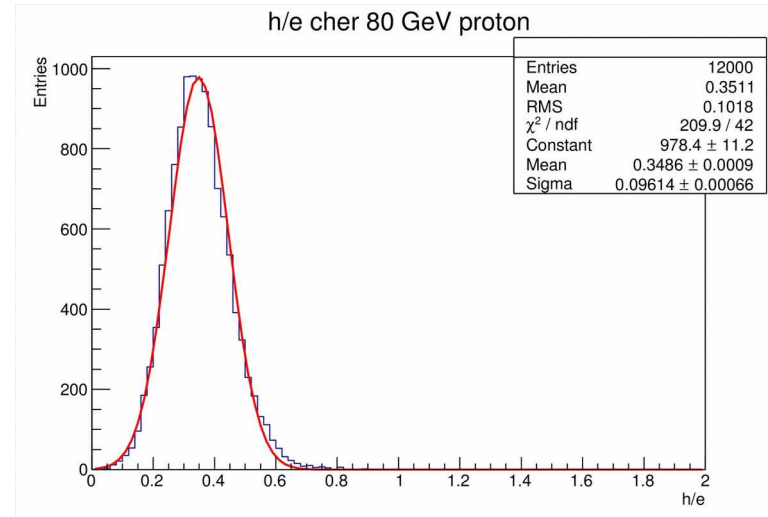
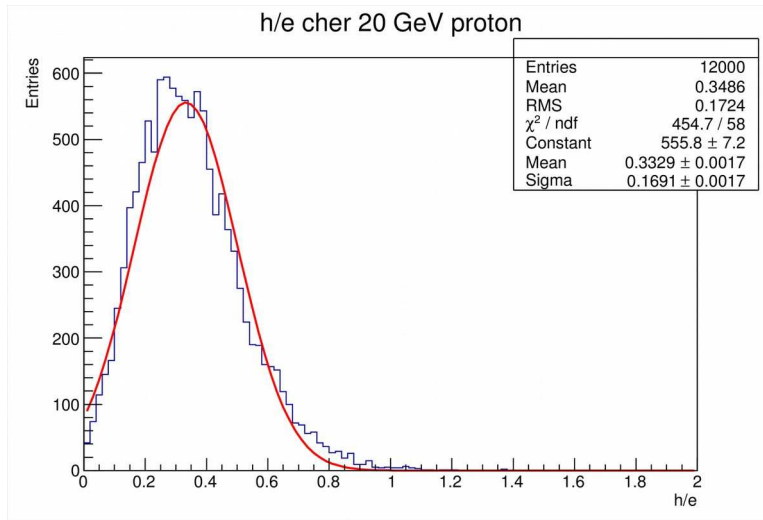


H/E estimation from simulation

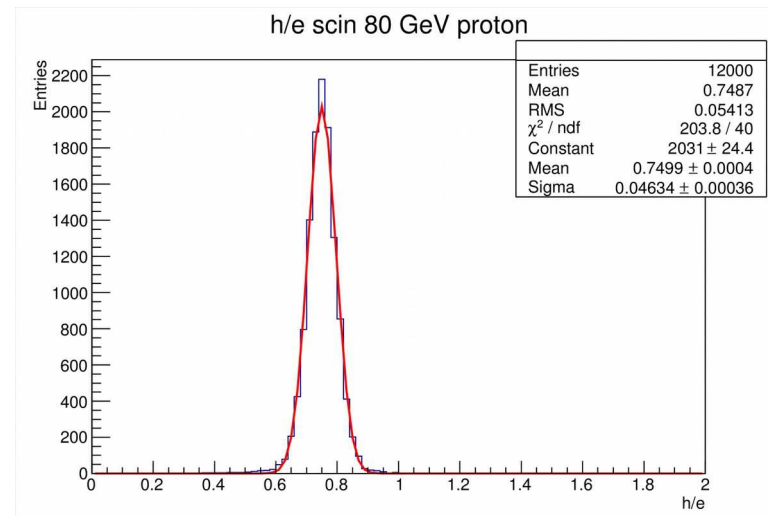
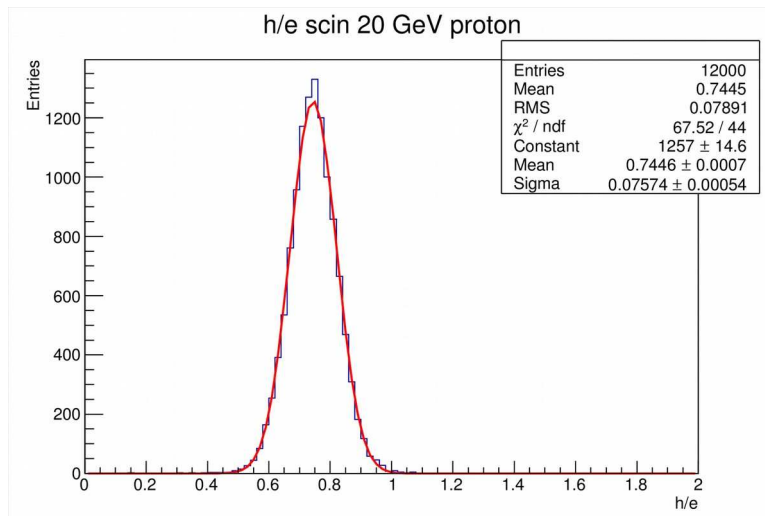
Cherenkov: $h/e = (C/E - fem) / (1-fem)$

Scintillation: $h/e = (S/E - fem) / (1-fem)$

Cu h/e factors – proton 20 & 80 GeV

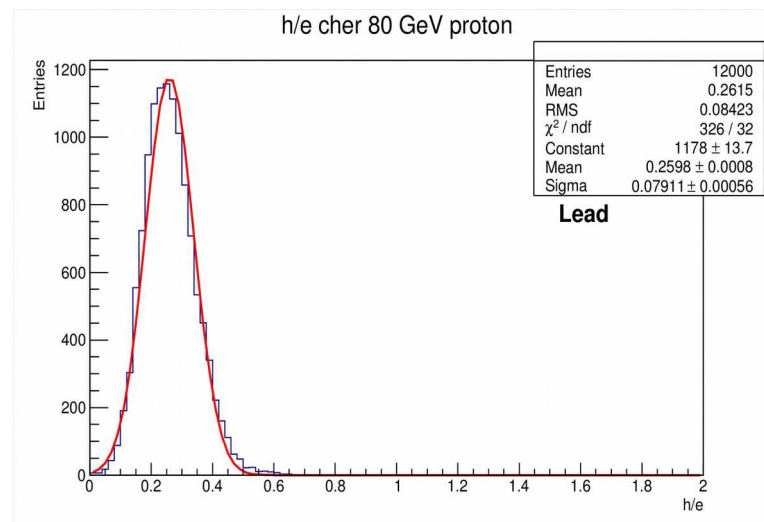
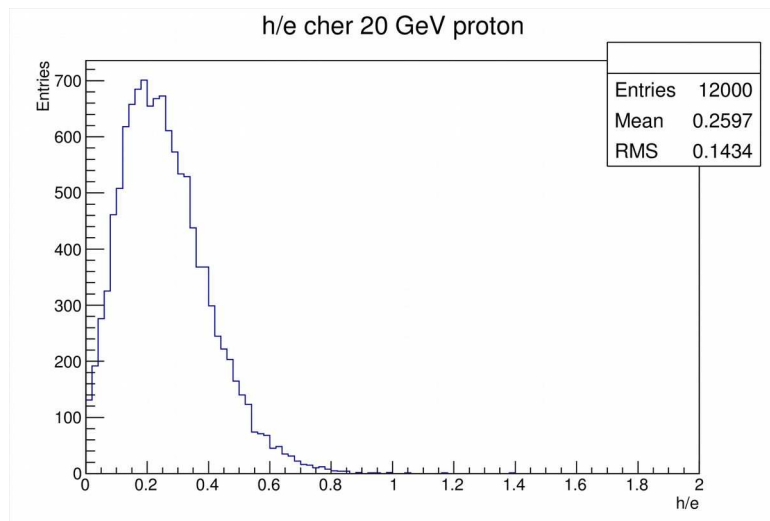


Cher. h/e ≈ 0.35

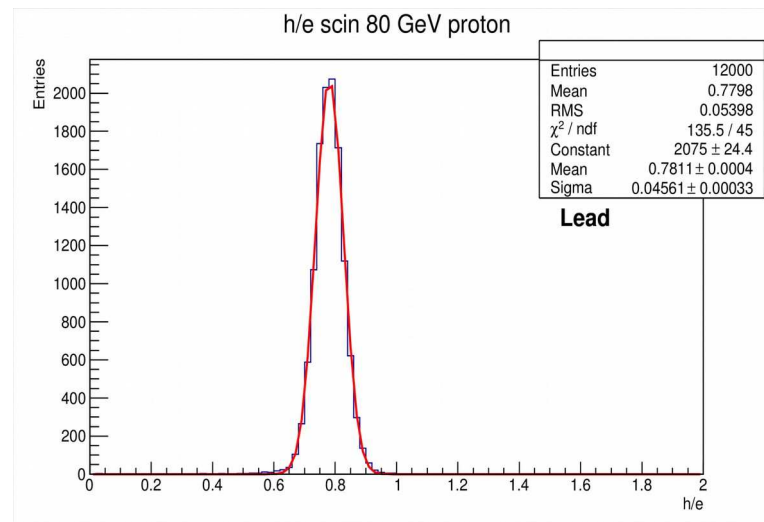
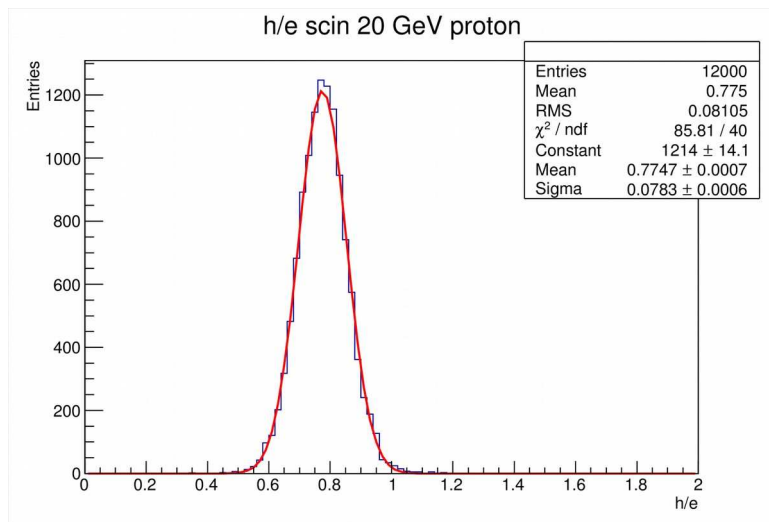


Scint. h/e ≈ 0.75

Pb h/e factors – proton 20 & 80 GeV

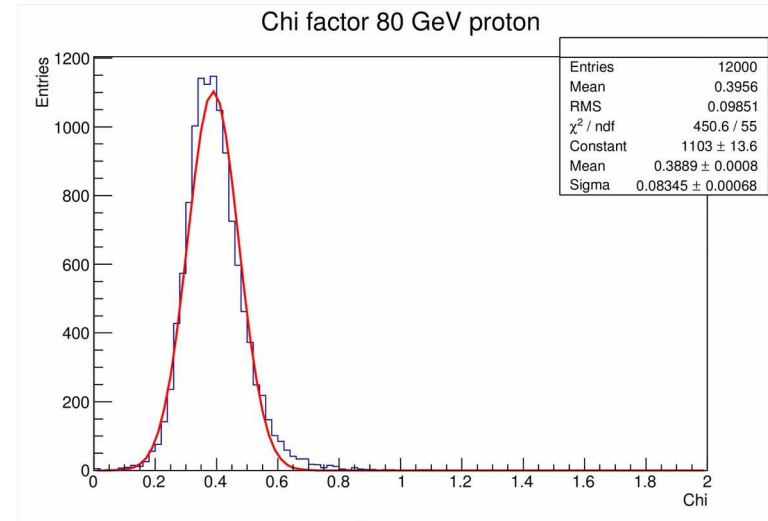
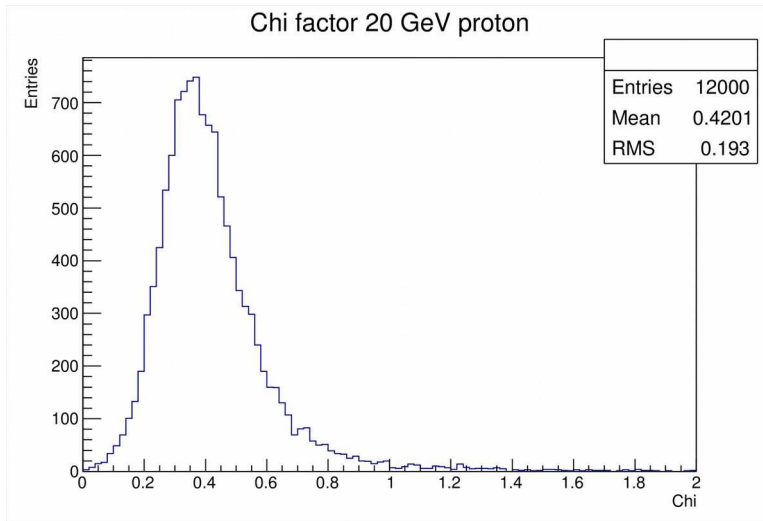


Cher. h/e \approx 0.26

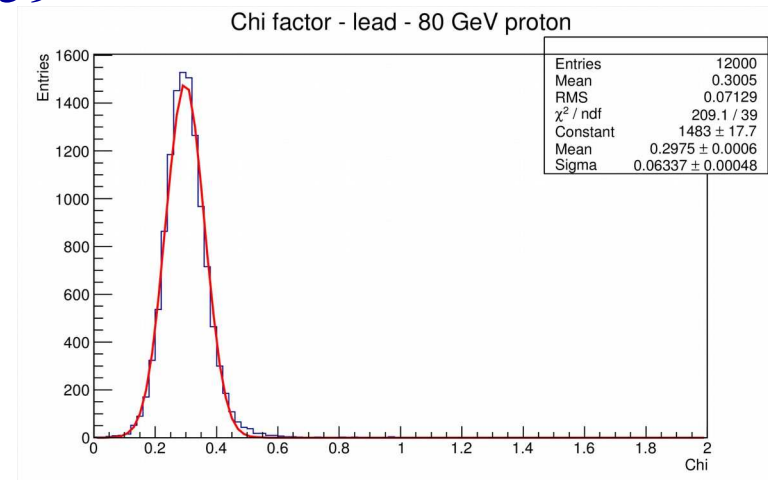
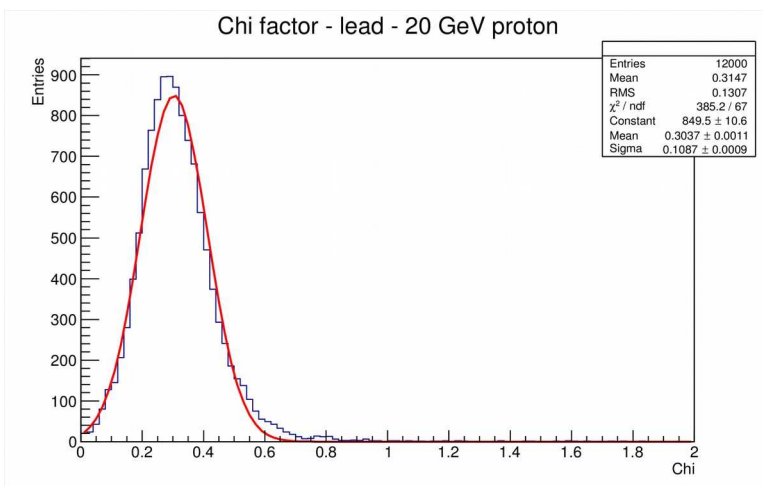


Scint. h/e \approx 0.78

Cu & Pb Chi factors – proton 20 & 80 GeV



Cu $X \approx 0.39$



Pb $X \approx 0.30$