Comparison of Muon Data with G4 ?

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Original idea:
Muon signal is well known → as a absolute calibration signal possible ?

Results from thesis of G. Schlager (TU Wien)
Copy available…

Here:
Comparisons of Data and G4.7

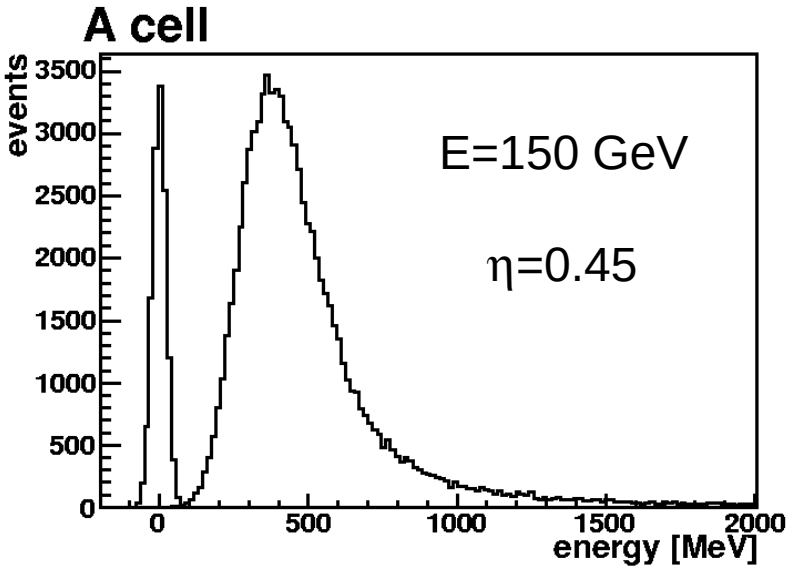
Data Set

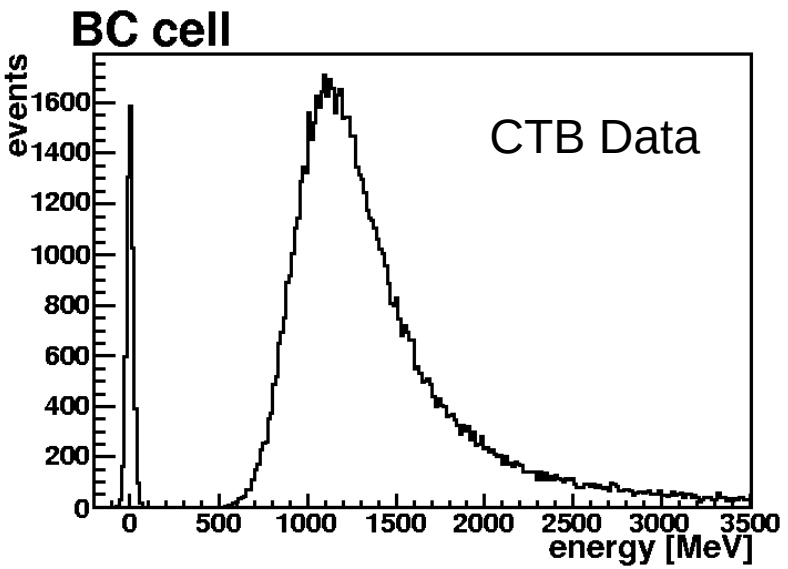
- Atlas Combined Test-beam 2004
- Muon selected with Muon Tag (scintillator located downstream) >490 Cts

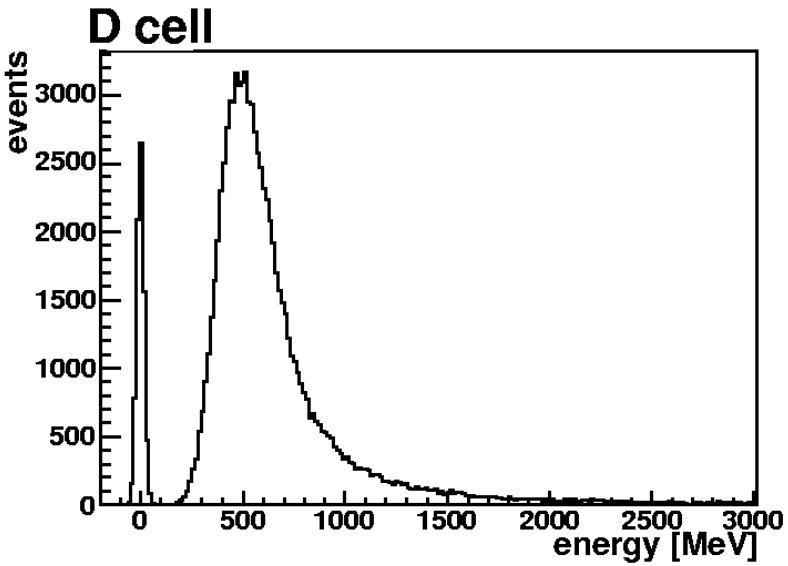
run	Energy (GeV)	η impact	Beam type	events	muons
2102396	20	0.45	Pion	51300	1936
2102347	50	0.45	Pion	118672	6406
2102355	100	0.45	Pion	72553	11722
2102435	150	0.45	muon	88711	87127
2102733	350	0.55	muon	83360	83103

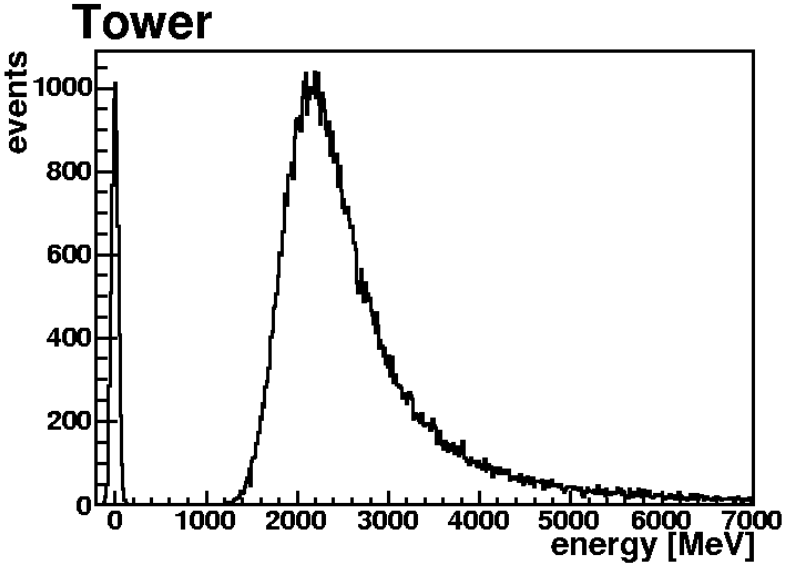
Note: muon from pion decays have rather low trigger acceptance (S1)
i.e. muon contamination in pion beam from muon at beam energy is reasonable assumption

Data Signal in Tile





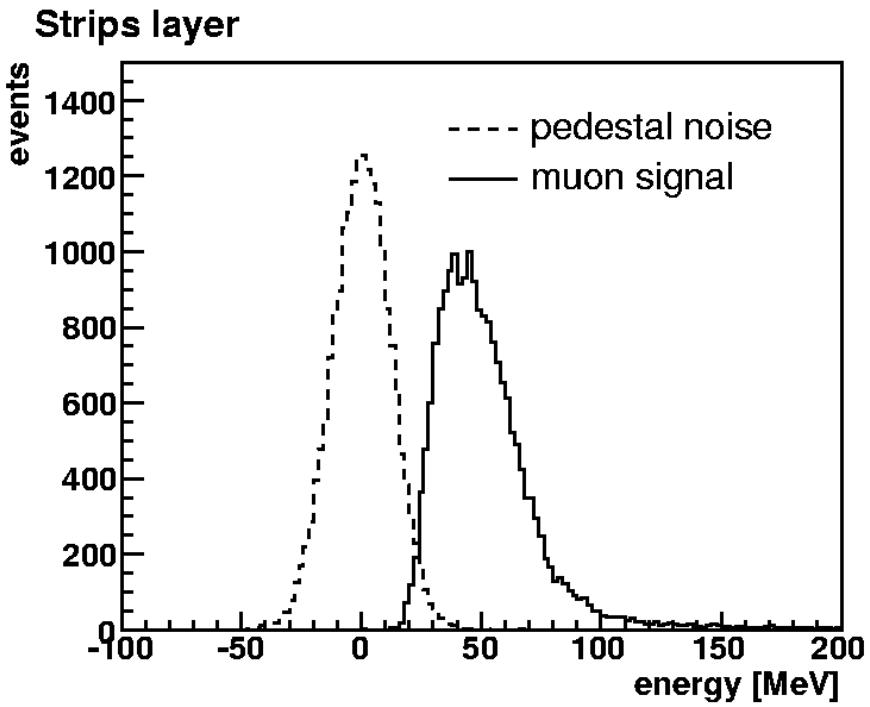


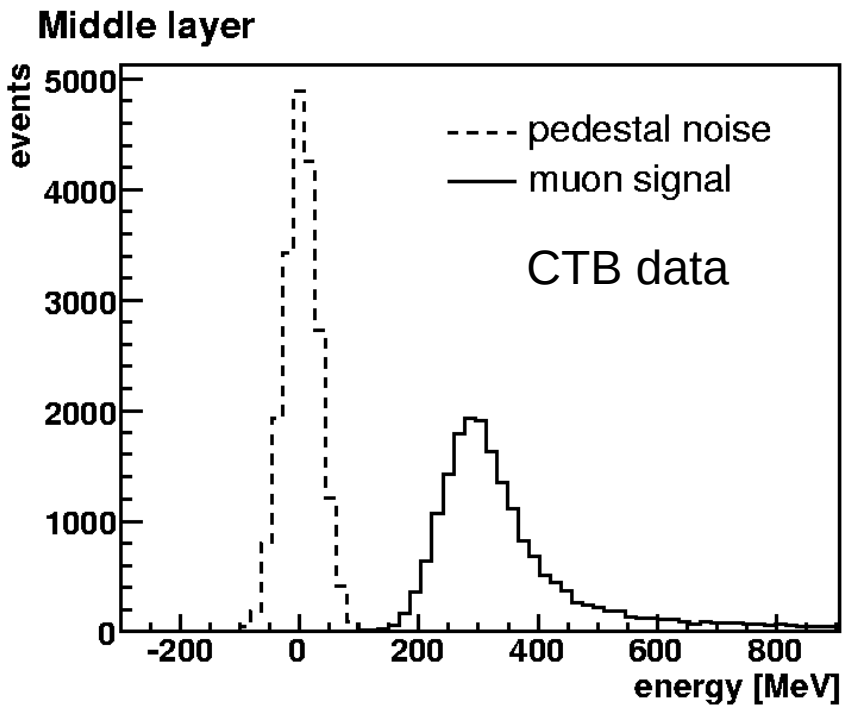


In Tile: cell with maximum energy is taken

S/N=15 in A-cell, S/N=55 for BC-cell and S/N=26 for D-cells

Data Signal in LAr

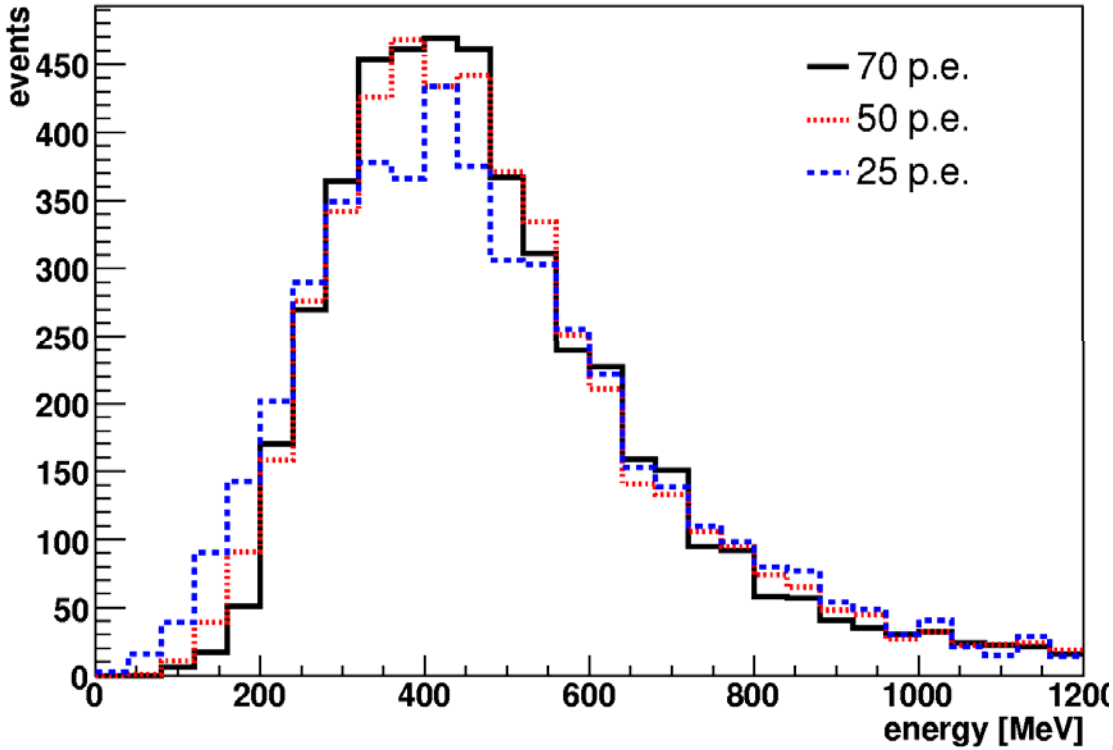




In Middle: cell with maximum E is taken and Phi-neighbour with highest E is added
(muon cluster contains 2 cells)
In strip: cell with maximum E is taken
S/N=4 in strips, S/N=9 for middle

Comment: To optimise the signal to noise, the muon cluster has to be small
This causes problem at high muon energy, since the muon cluster is not large enough to contain e.m. showers (see later)

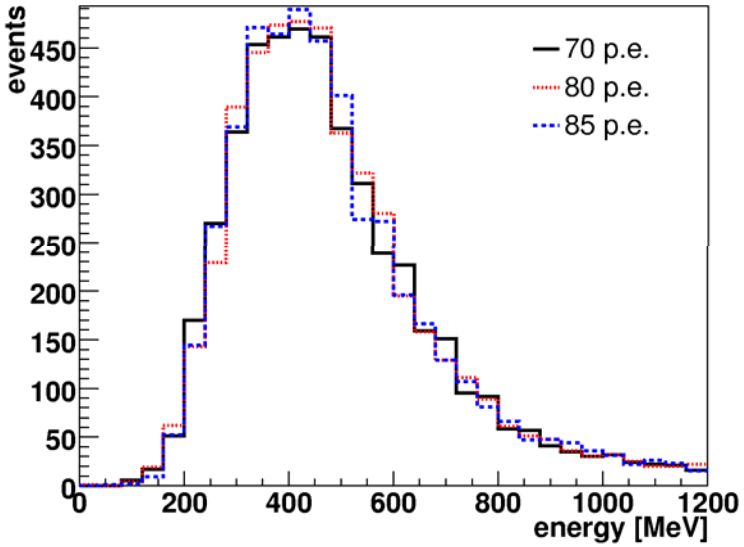
Photostatistics in Tile



The number of photons arriving at the PMT is Poisson distributed

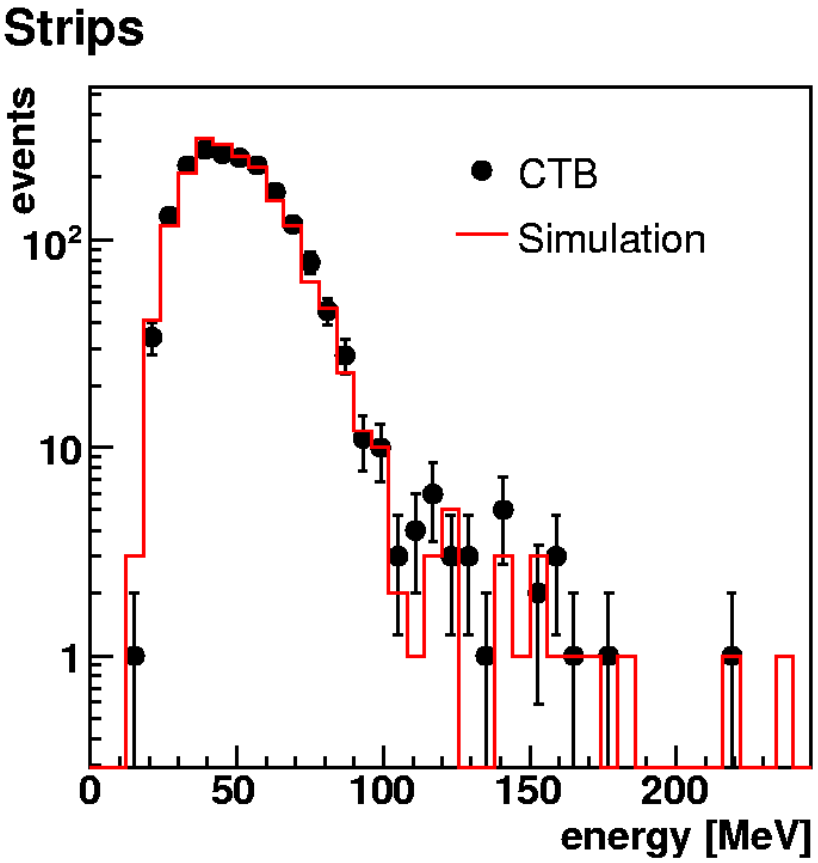
→For low signals, the signal is wider

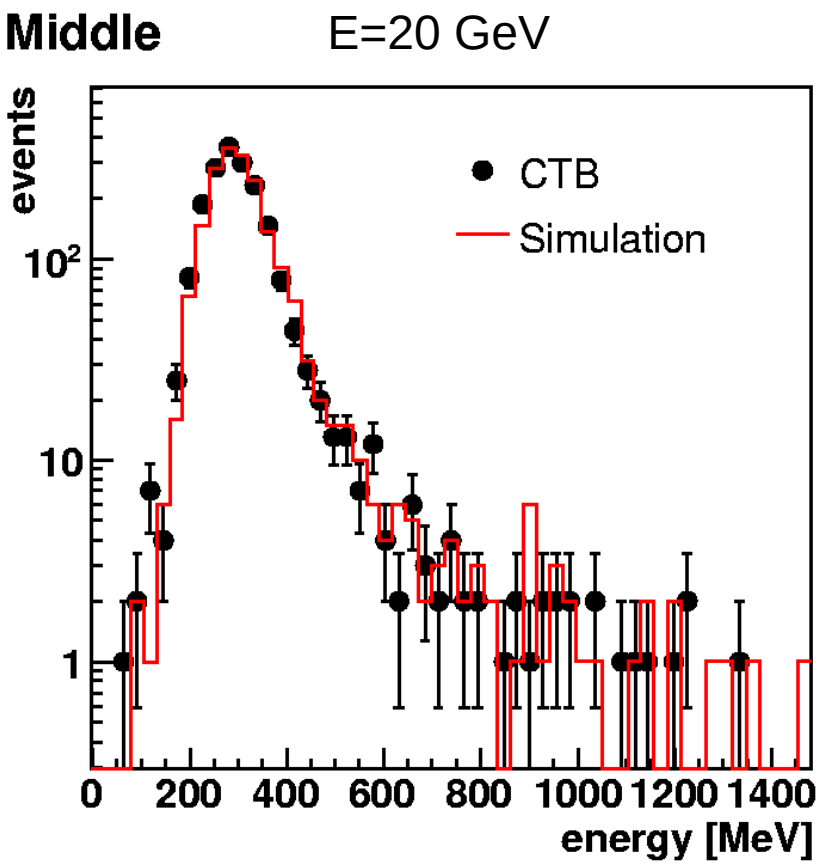
70 pe/GeV from data/MC comparisons and recent light yield study



Data/MC Energy Distribution Shape - LAr

Here, distributions are shifted such that peaks agree



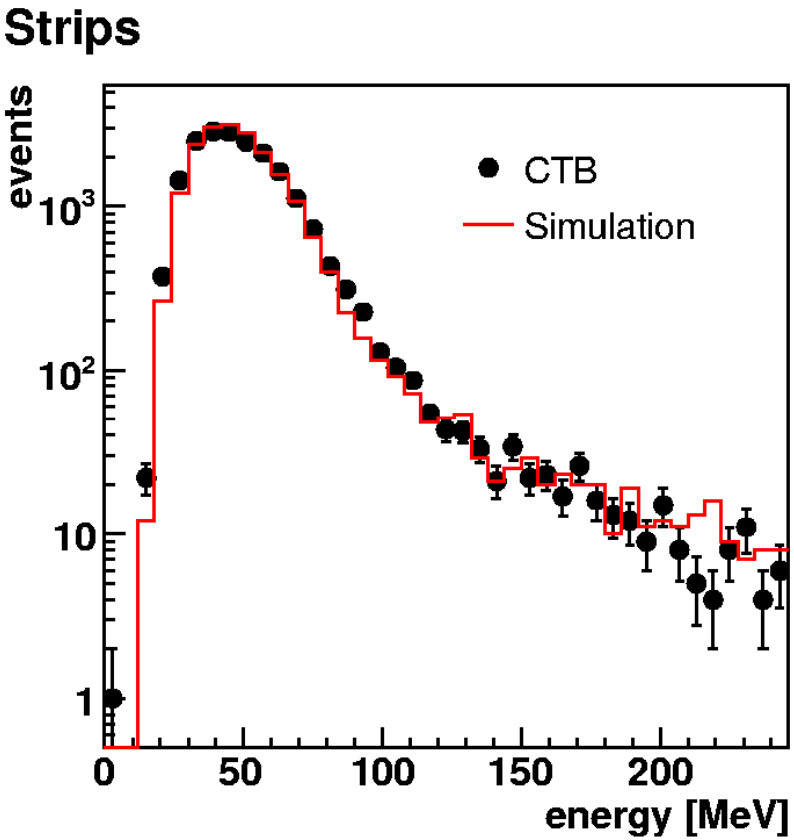


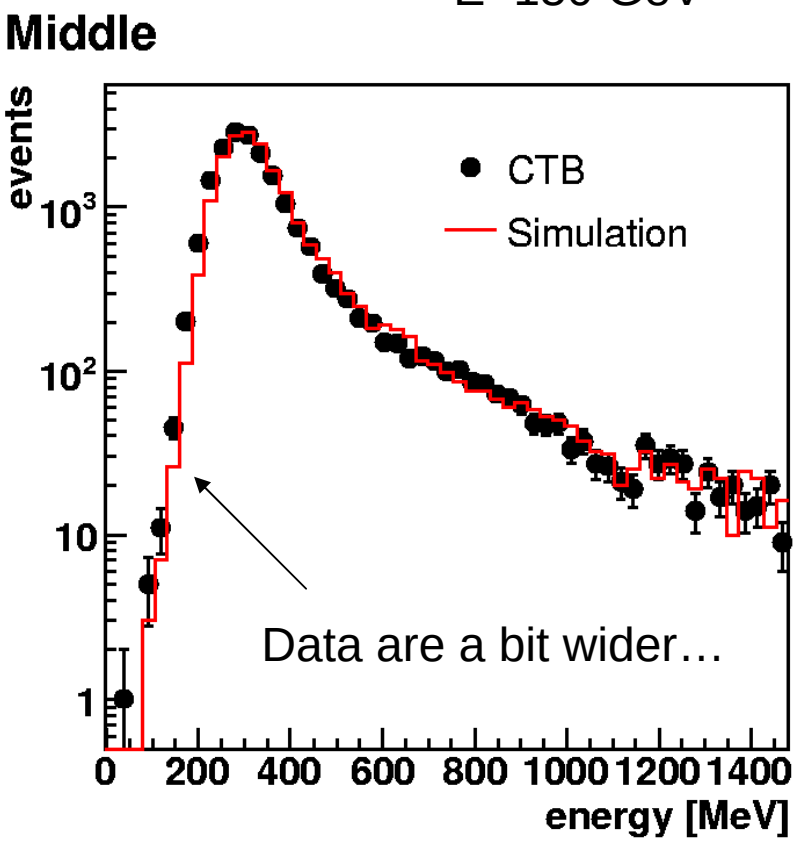
Data/MC agreement in peak region 10-20%

Data/MC Energy Distribution Shape - LAr

Here, distributions are shifted such that peaks agree

E=150 GeV

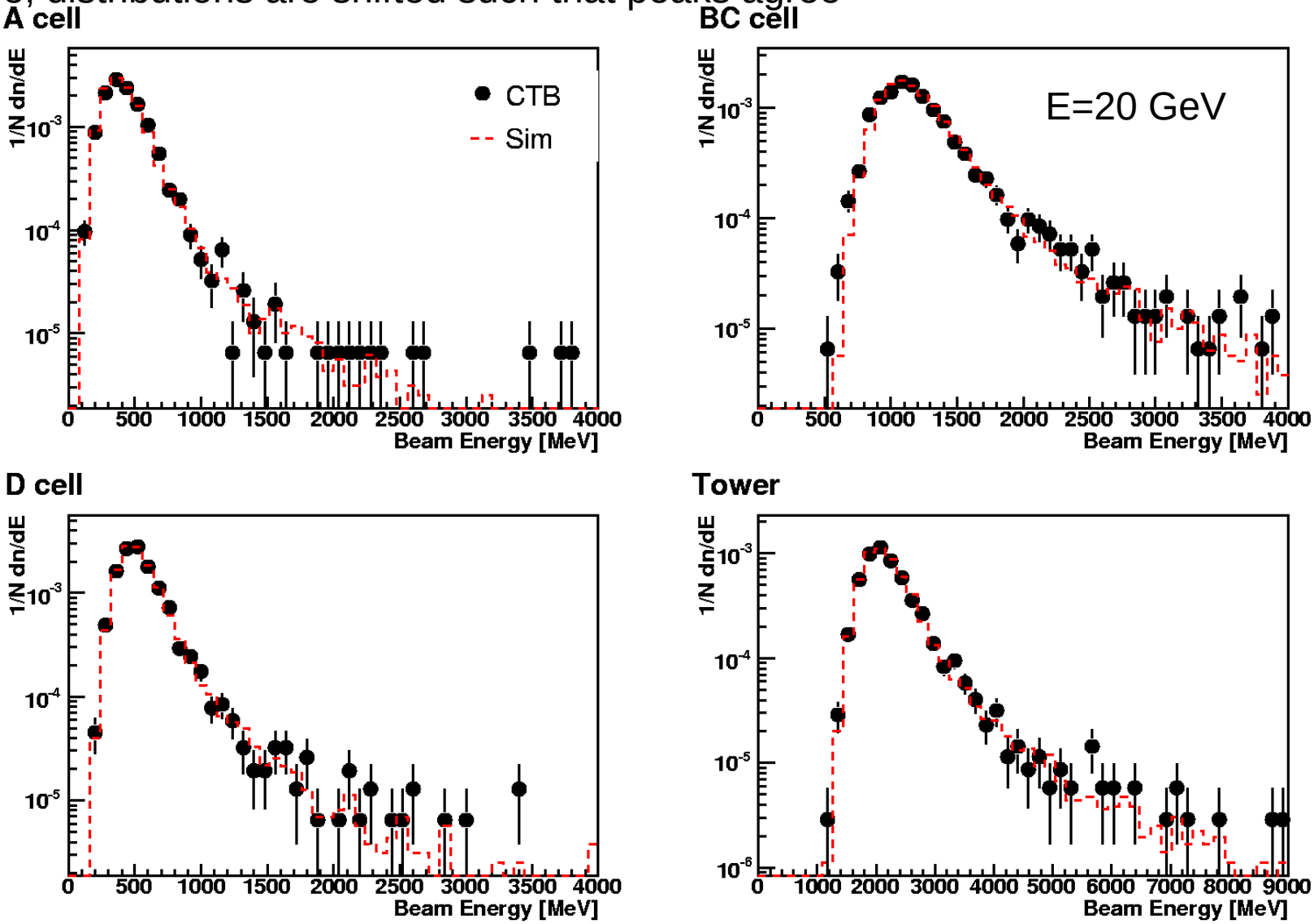




Data/MC agreement in peak region 10% in strips, and 5% in middle layer

Data/MC Energy Distribution Shape – Tile Peak

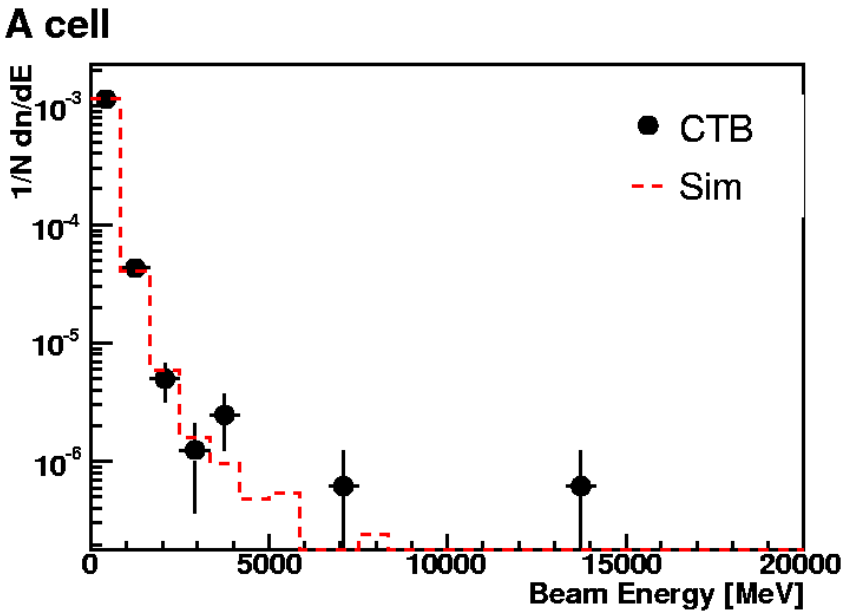
Here, distributions are shifted such that peaks agree

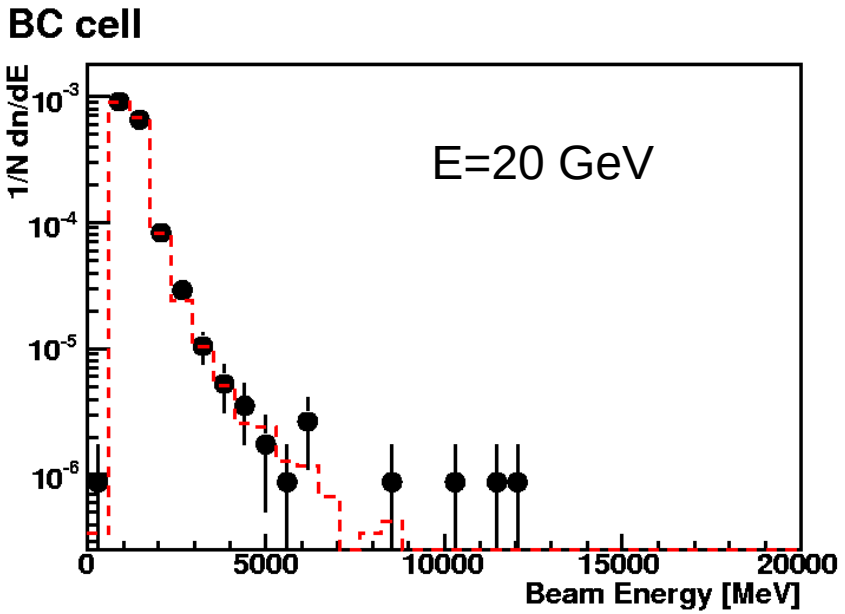


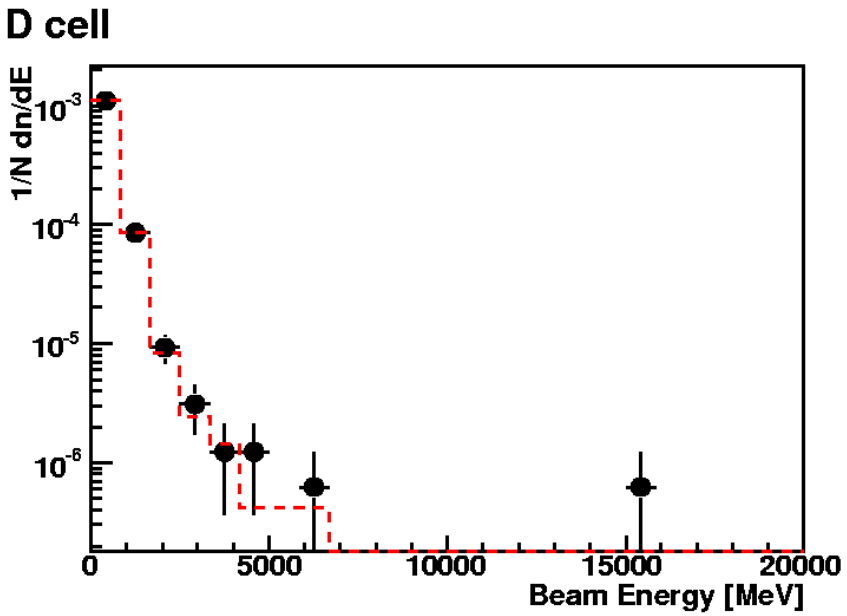
Data/MC agreement in peak region 15%, simulation a bit narrower
(might be instrumental effect due to Tile row non-uniformity, fibres etc.)

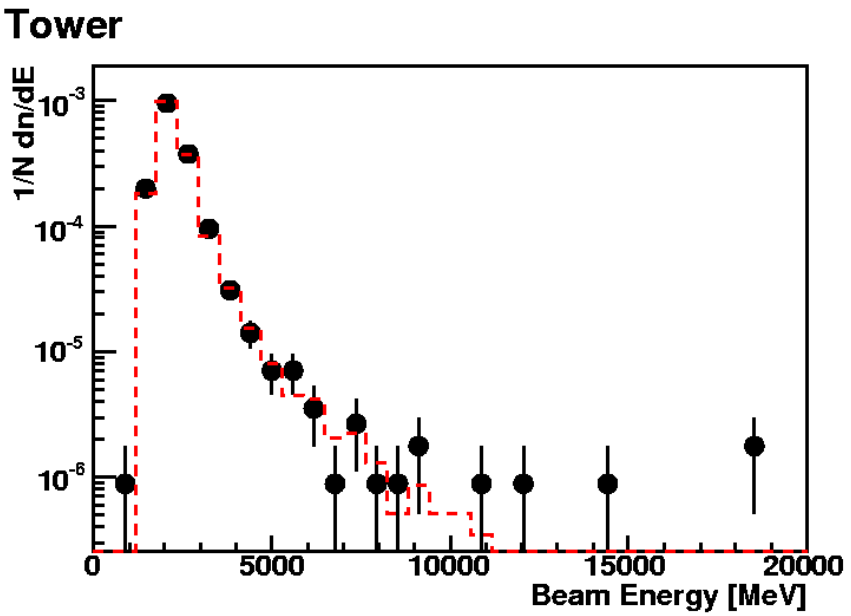
Data/MC Energy Distribution Shape – Tile Tail

Here, distributions are shifted such that peaks agree









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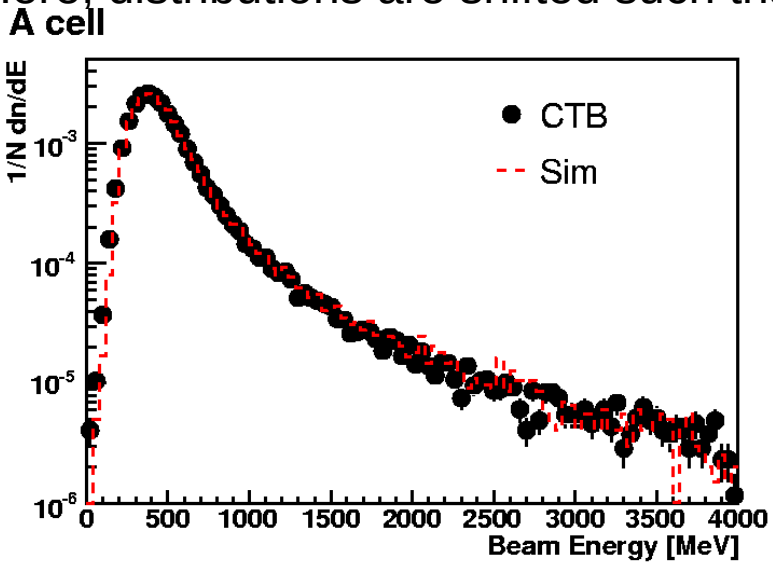
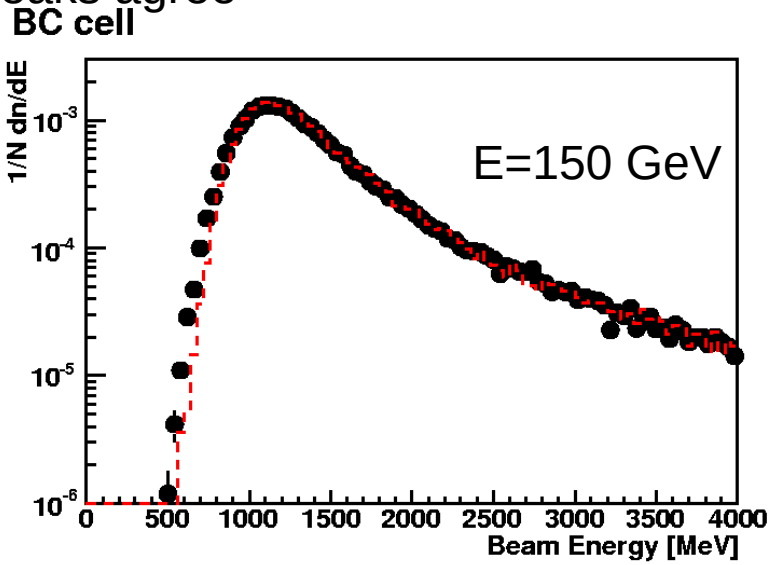
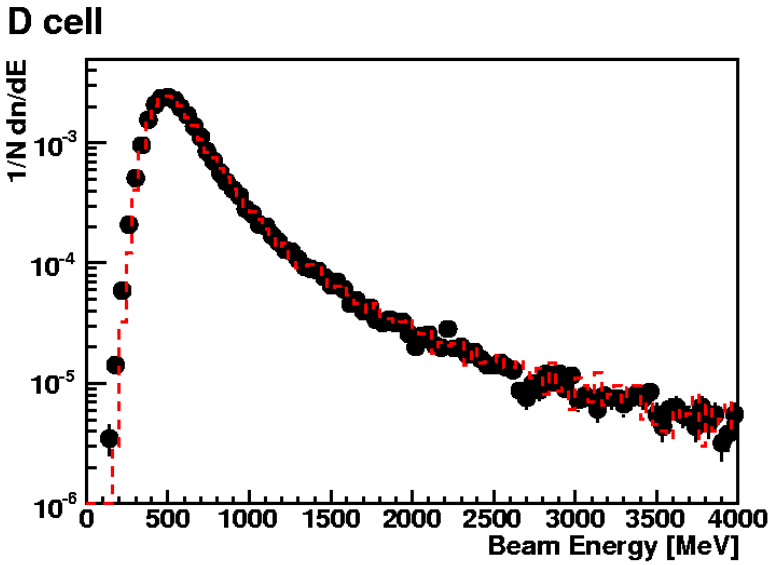
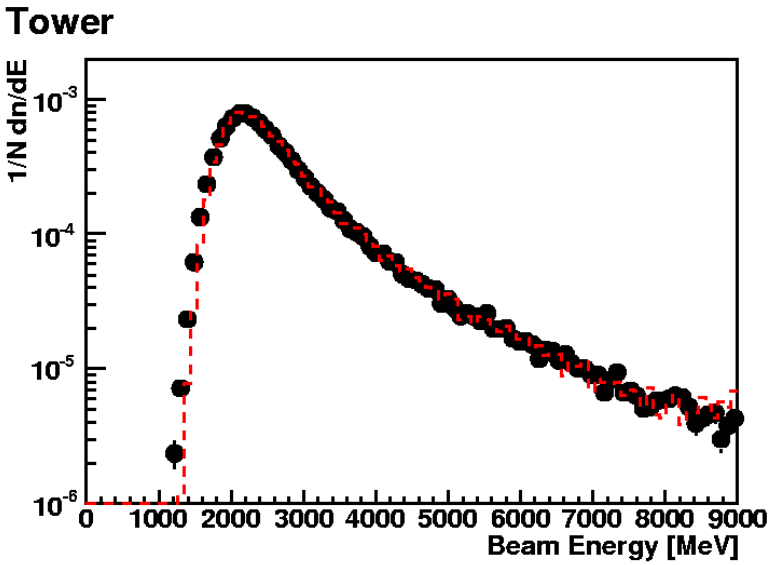






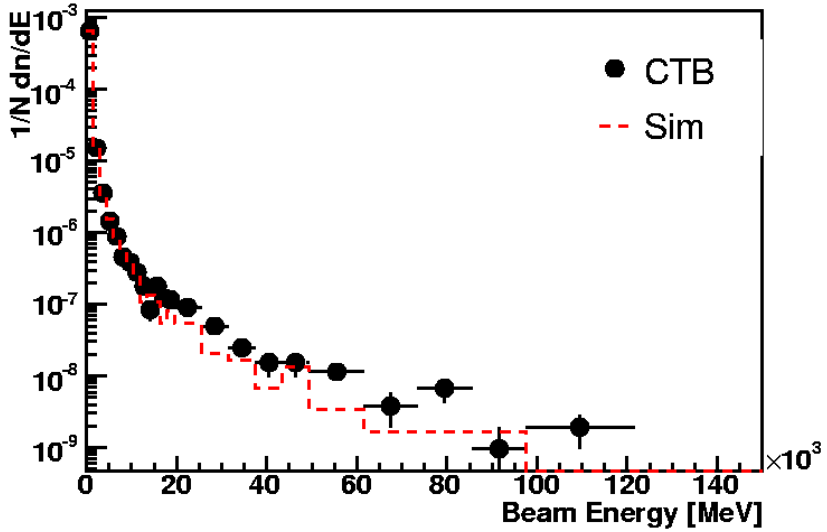


Data/MC agreement in peak region 15%, simulation a bit narrower
(might be instrumental effect due to Tile row non-uniformity, fibres etc.)

Data/MC Energy Distribution Shape – Tile Tail

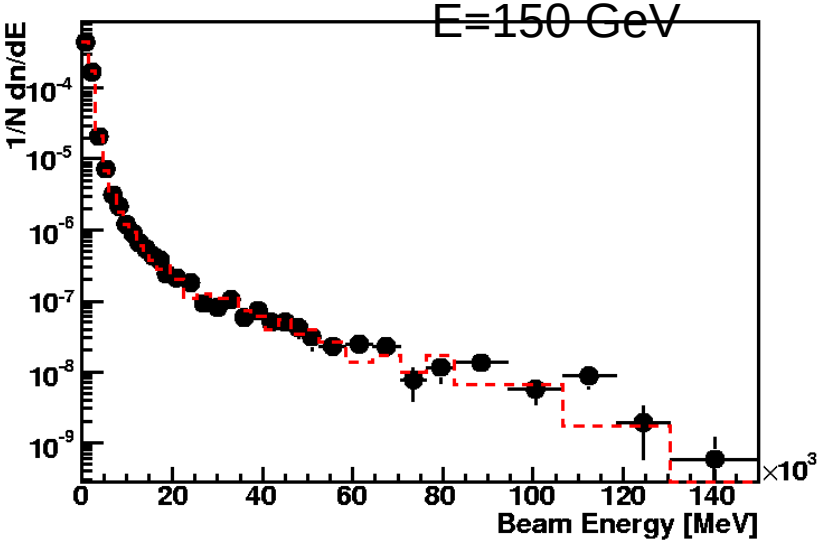
Here, distributions are shifted such that peaks agree

A cell

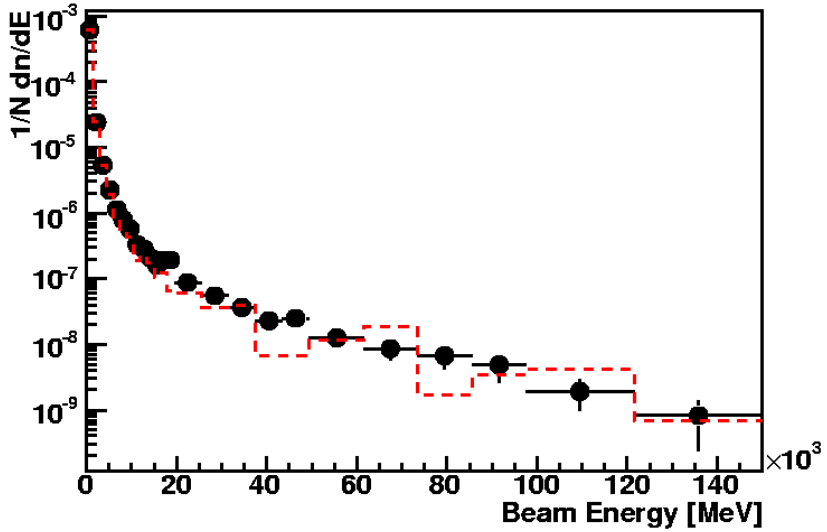


BC cell

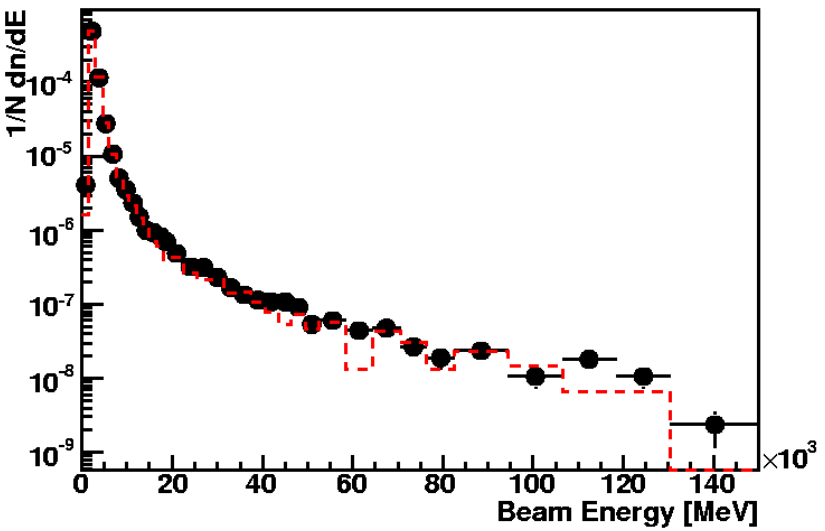
E=150 GeV



D cell



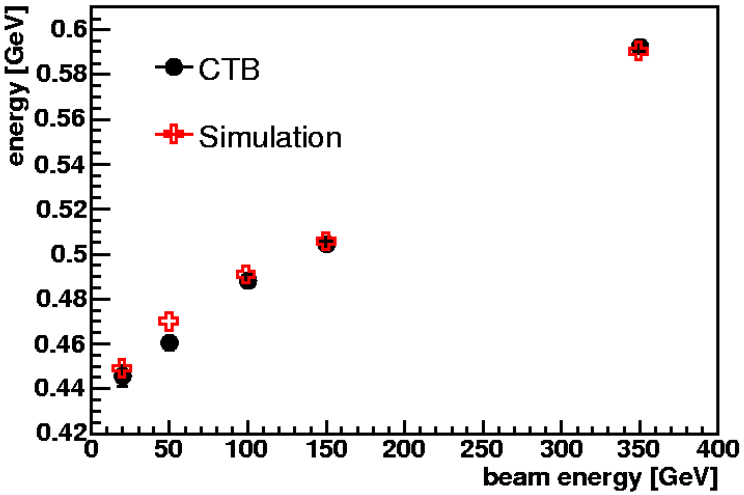
Tower



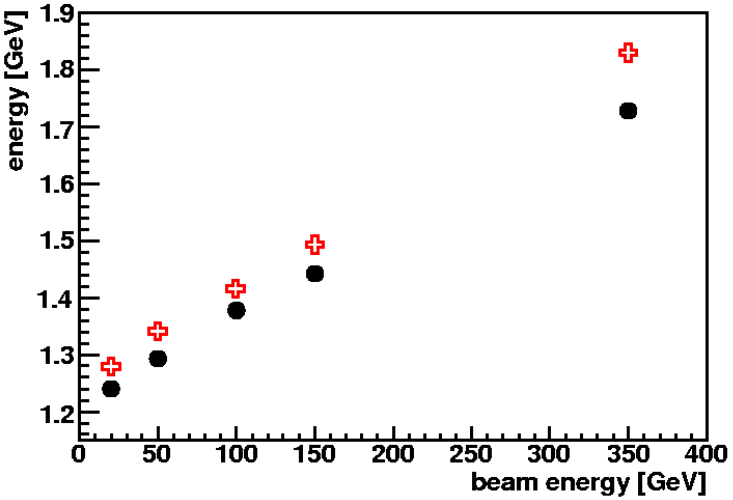
Tile Mean Energy vs Muon Energy

Mean in range: $(E_{mop} - FWHM) < E < (E_{mop} - 5 * FWHM)$ after fit of Landau convoluted with Gauss

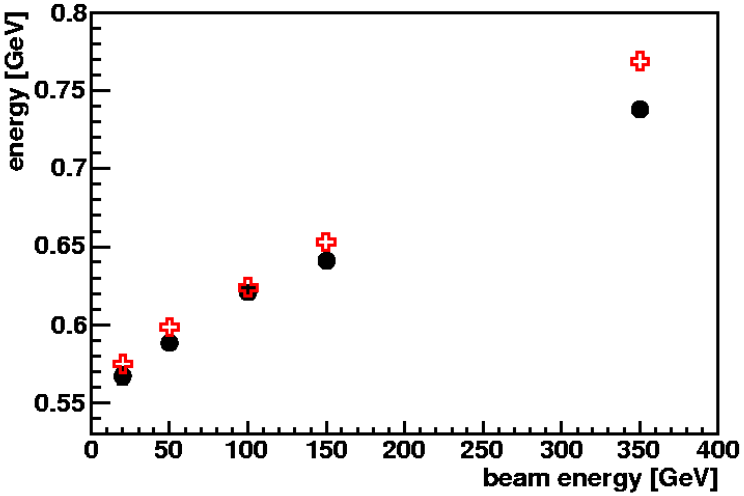
A cell



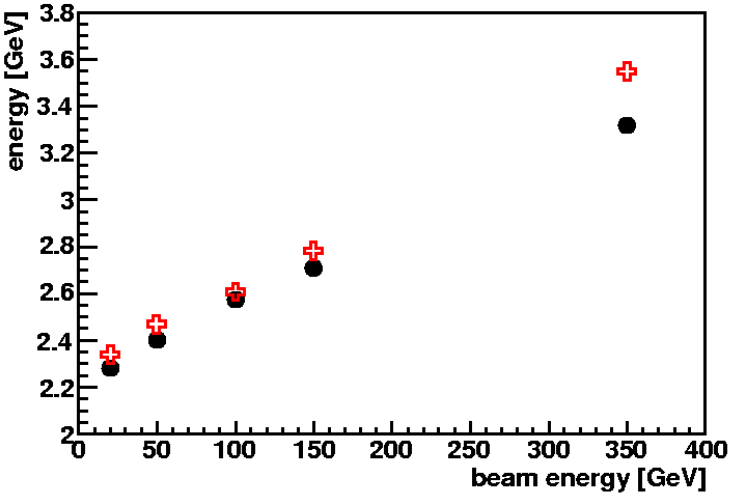
BC cell



D cell

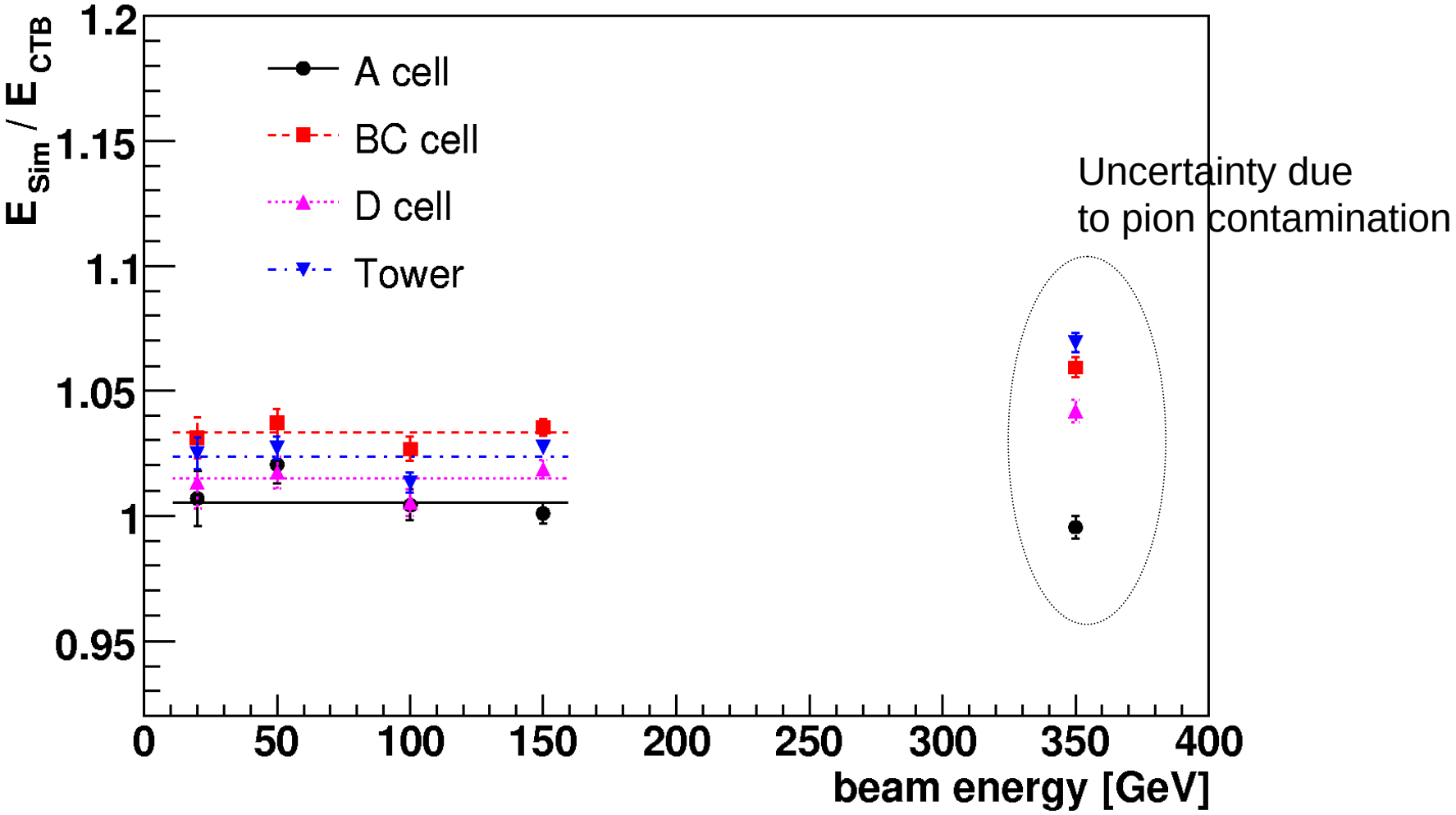


Tower



Slope well described by simulation

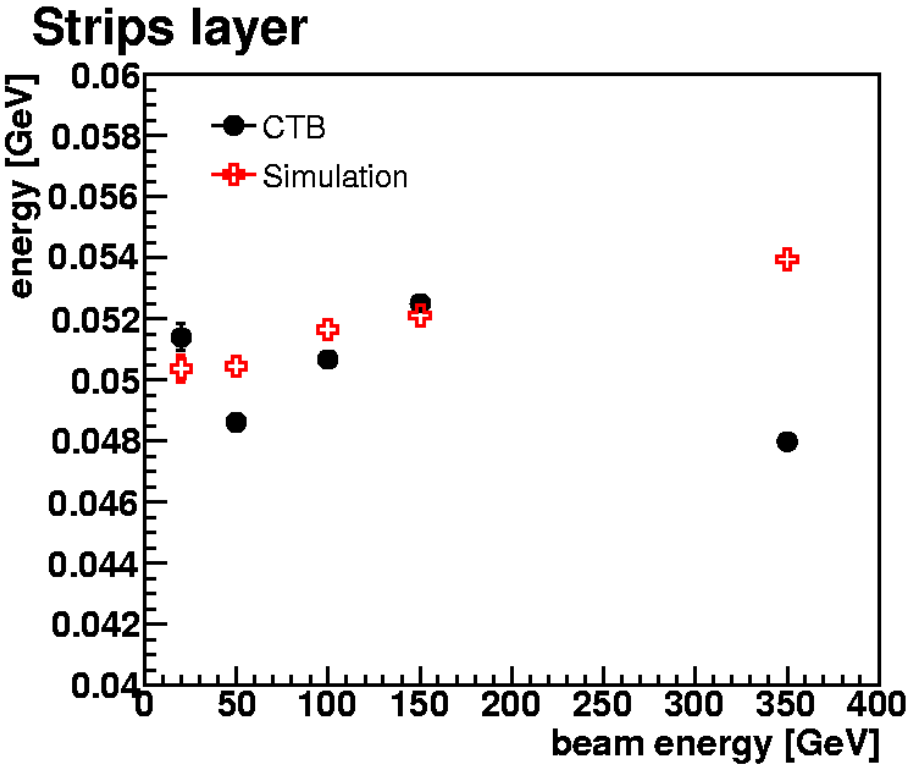
MC/Data Ratio Deposited vs Muon Energy

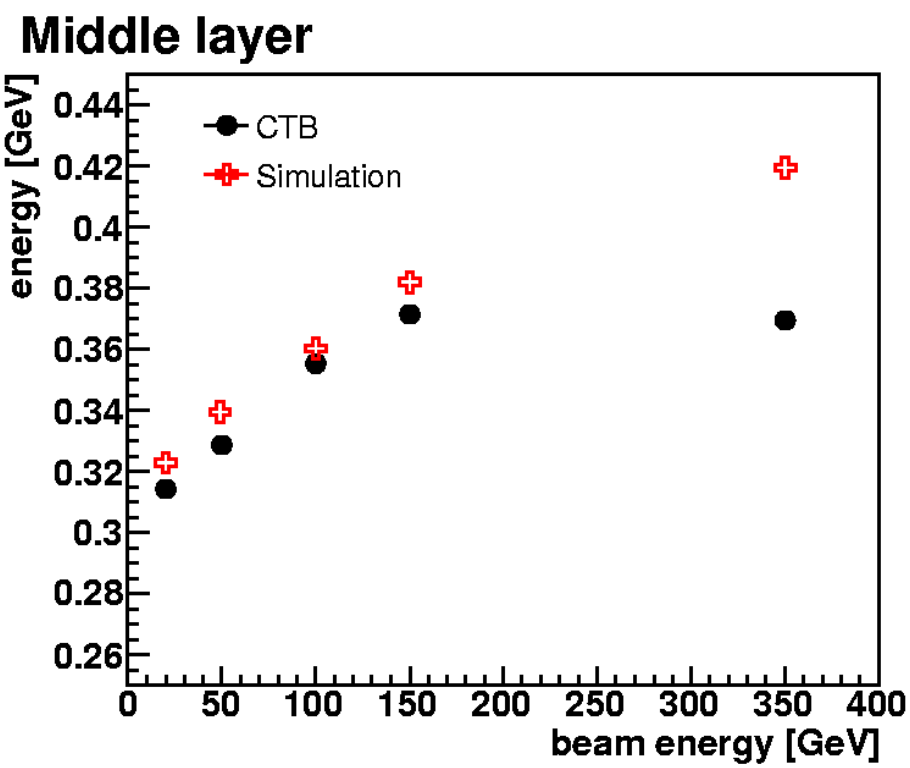


- Systematic layer dependence: in BC largest deviation 3.3%, in A cell smallest: 0.6% spread between layers 1.2% (excluding 350 GeV point)
- no energy dependence, spread between beam energies 0.5%

→On average simulation 2% higher
(can be explained by many effects: e.g. Tile light attenuation)

LAr Mean Energy vs Muon Energy

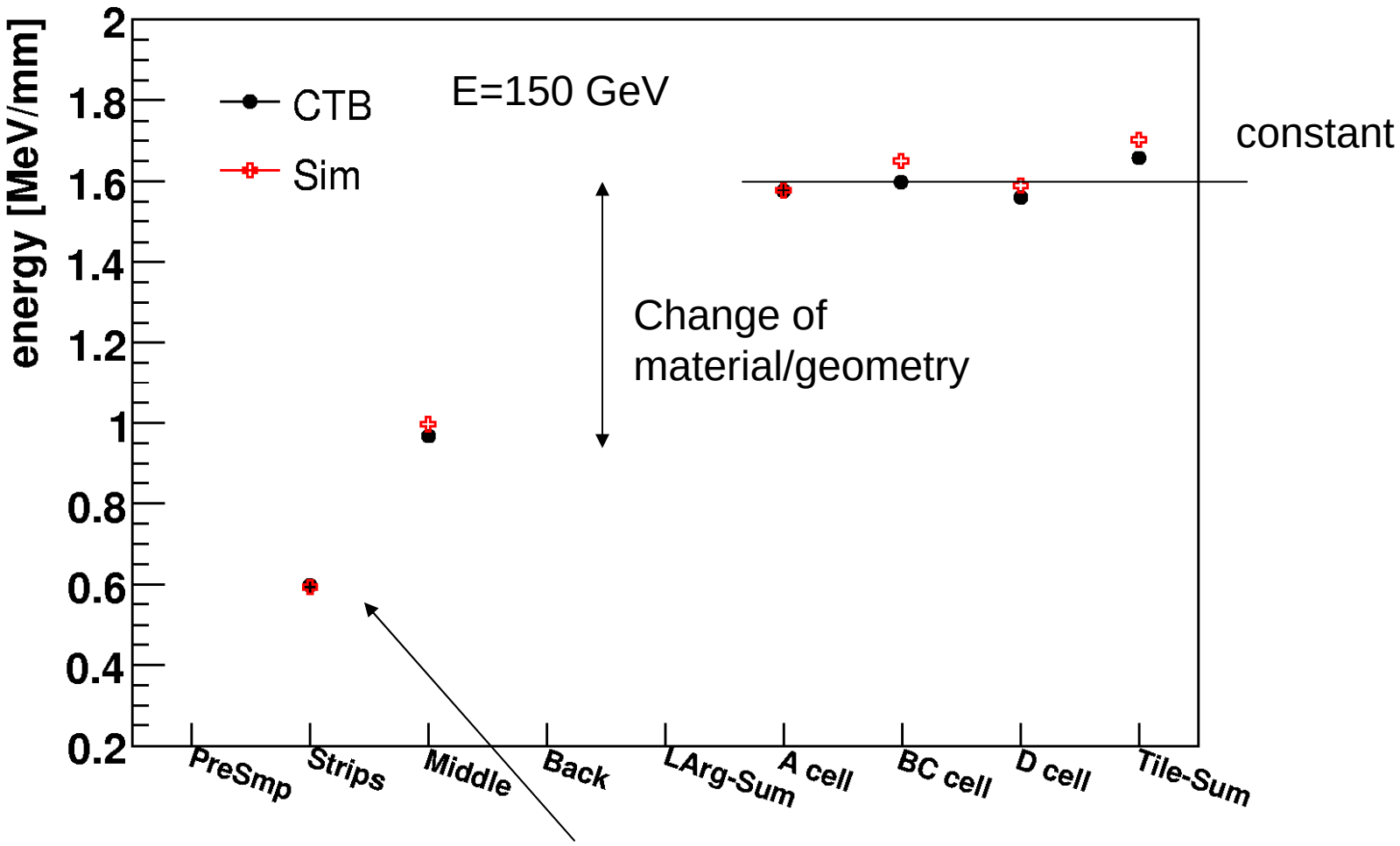




In strips large variations:
Increase with beam energy seen (in data less clear because of fluctuations)

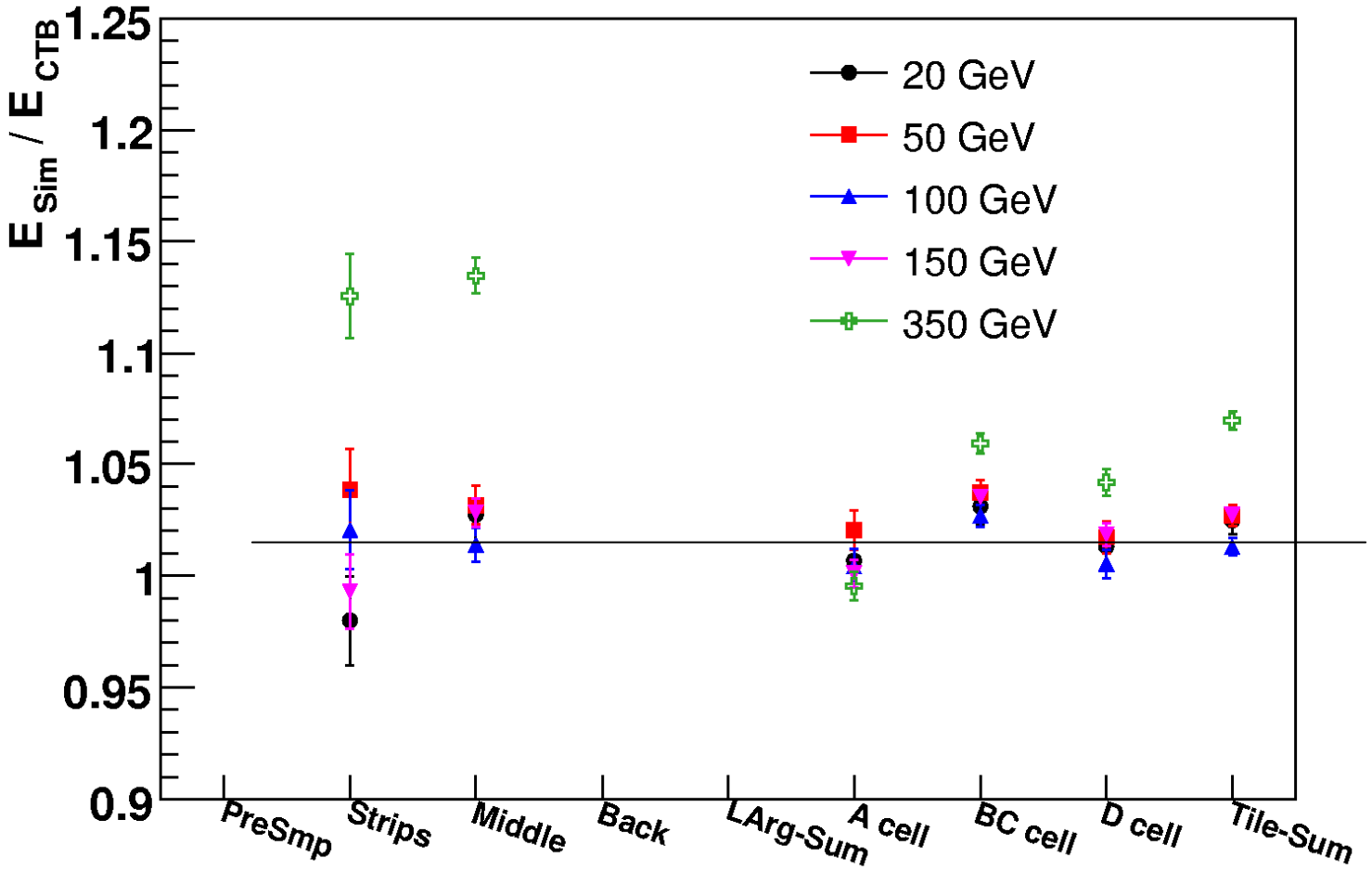
In LAr increase with beam energy less visible:
Increase caused by radiative processes, but e.m. showers not contained by one cell
In particular strip cells are very small → mainly ionisation signal

Mean Energy per path length



Lower signal in strips than middle, since energy migrates out of strip cell
This effect is well described by the simulation

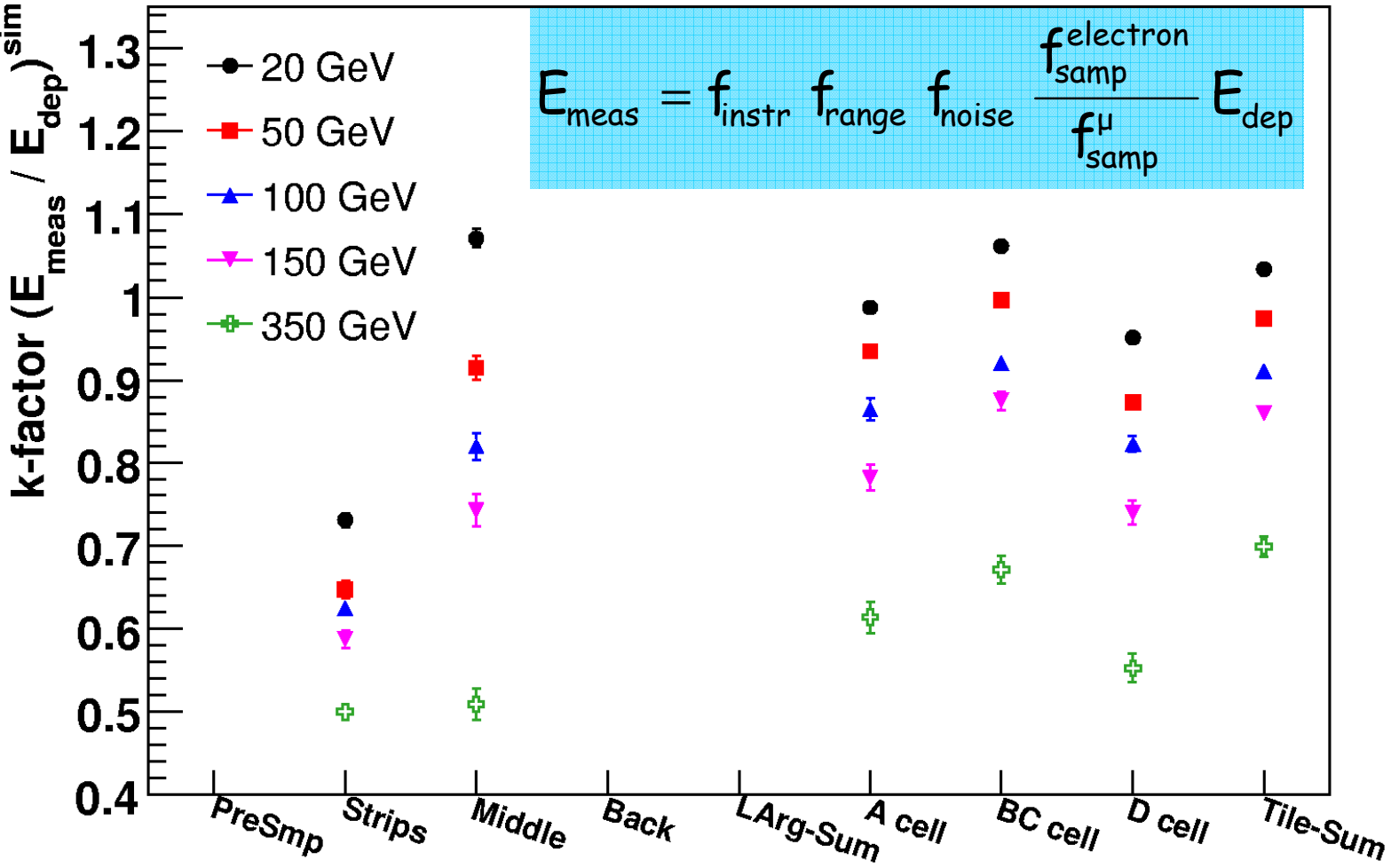
Ratio MC/Data Mean Energy per path length



Achieved precision ~2% !

On average, MC higher than data by about 2% in both LAr and Tile
A spread of 1.4% between the muon energies and the layers (systematics)
For the strips the spread is higher than for the other layers
At 350 GeV, pion contamination prohibits precision comparisons
No clear trend in energy dependence

Correction Factor: Measured/Deposited Energy

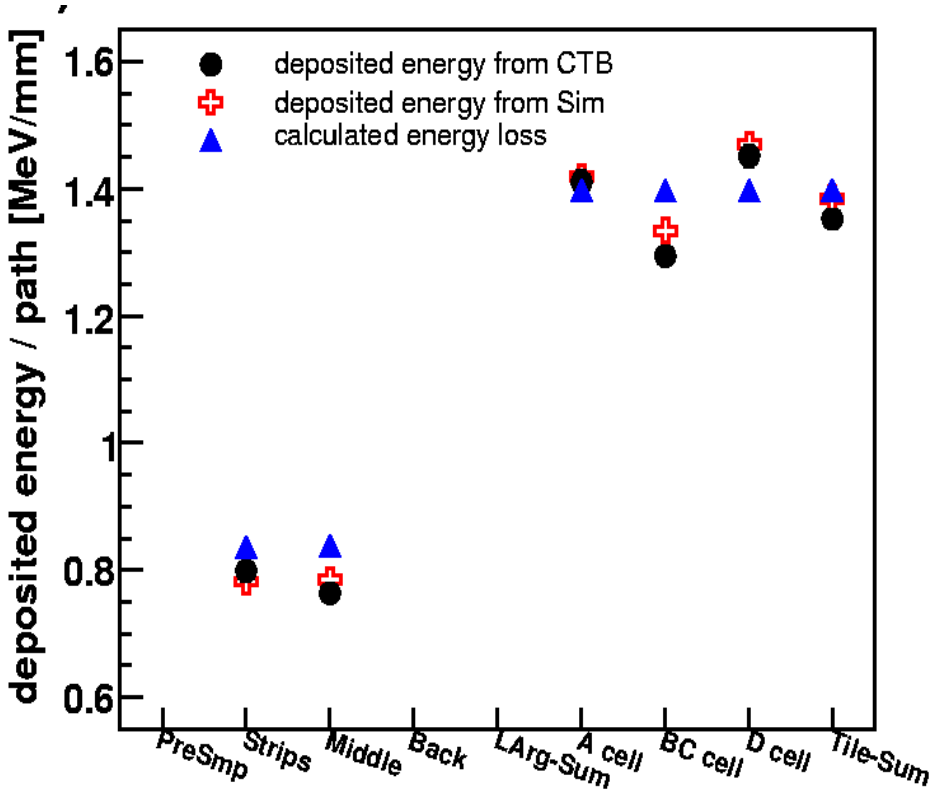


Measured not equal deposited muon energy:
Saturation effects, photostatistics, light attenuation, out-of-cell losses, Lar recombinatio
Basic calibration to electrons not muons: e/μ factor
Mean defined up to 5 FWHM, not full range

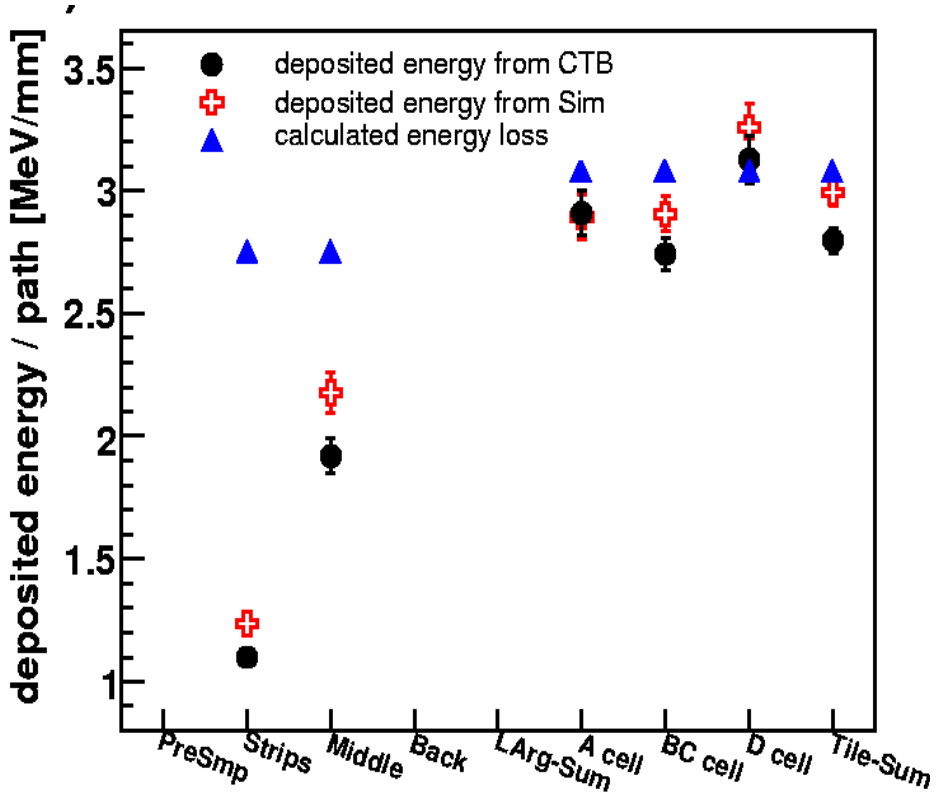
Mean Deposited Energy per path length

Calculated energy loss from first principle calculation: Lohman et al., CERN 85-03

E=20 GeV



E=350 GeV



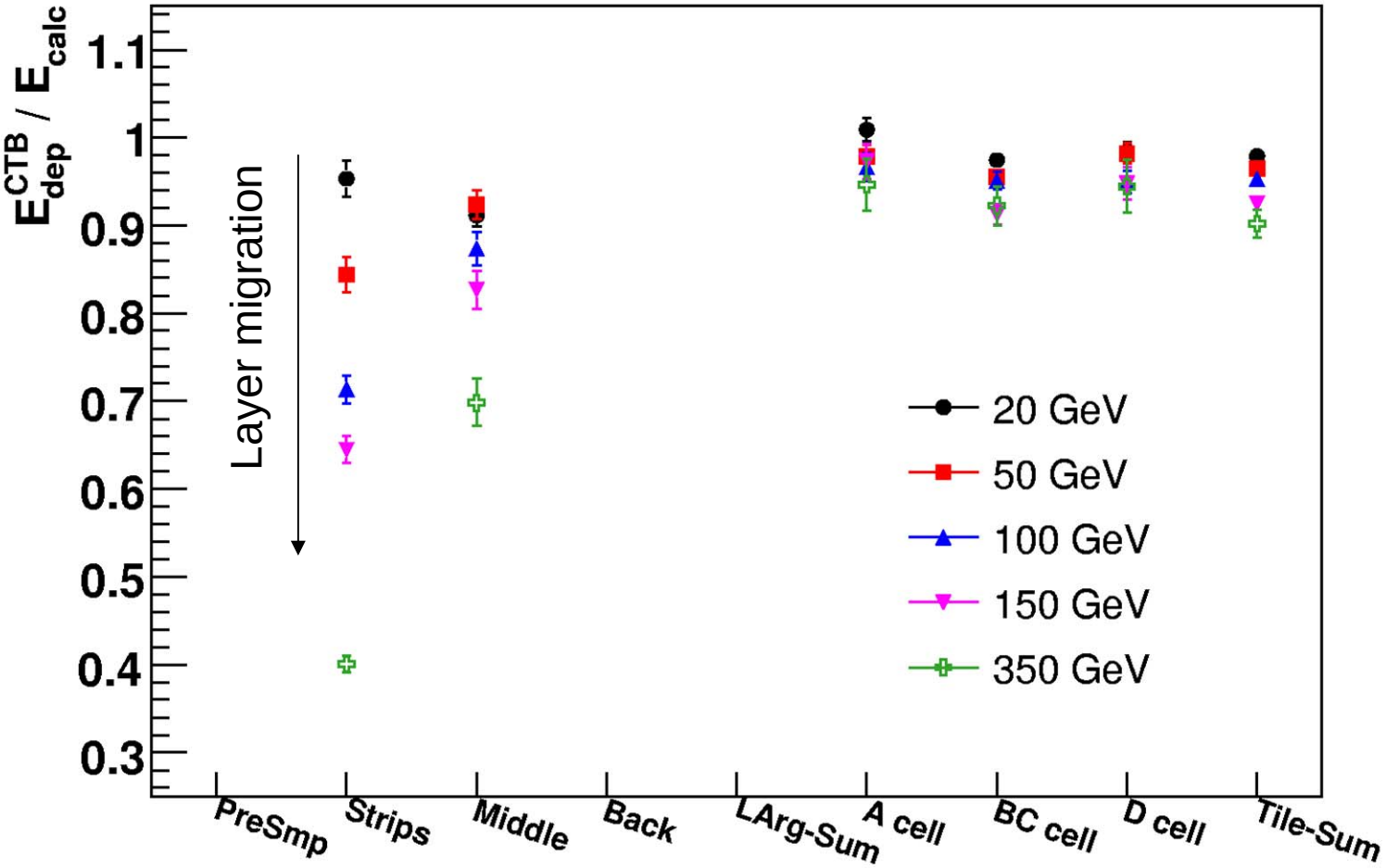
Generally good agreement

Signal from BC higher, since muons traverse more active material (highest f_{samp})

At 350 GeV: lost energy not equal deposited energy (migration in between layers)

Ratio Data/Calculation for Mean Deposited Energy per path length

Here correction for change in sampling fraction between Tile layers



Cross-checks entire analysis Chain to within ~5% in Tile ~10% in Lar

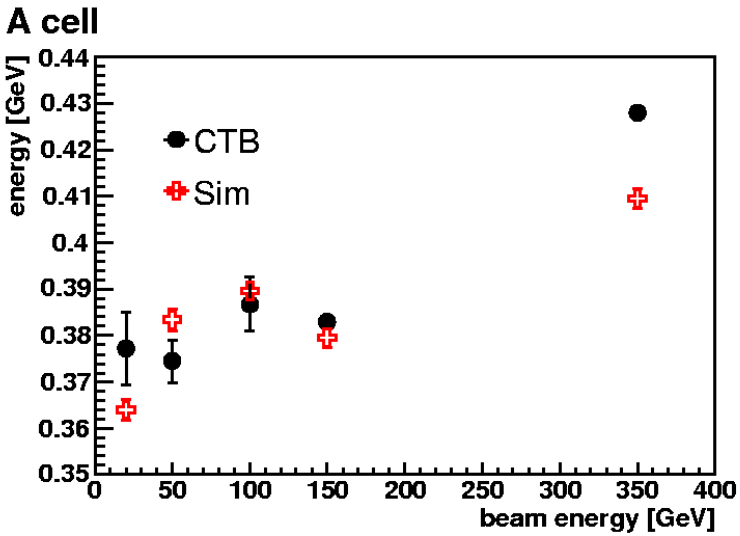
Tile: calculated energy loss 3.7% higher than deposited energy in data
(Due to losses out-side analysed module ?, simplified geometry in calculation?)
Spread: 2.3% due to systematic energy dependence, low energy in better agreement

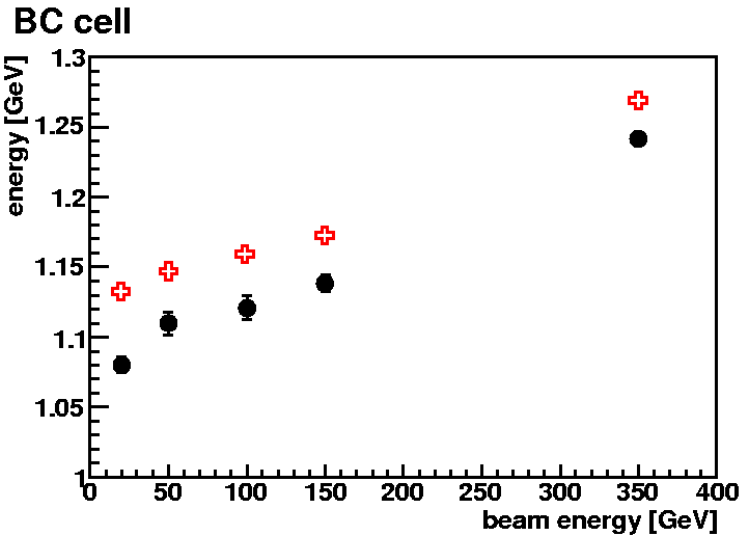
Conclusion

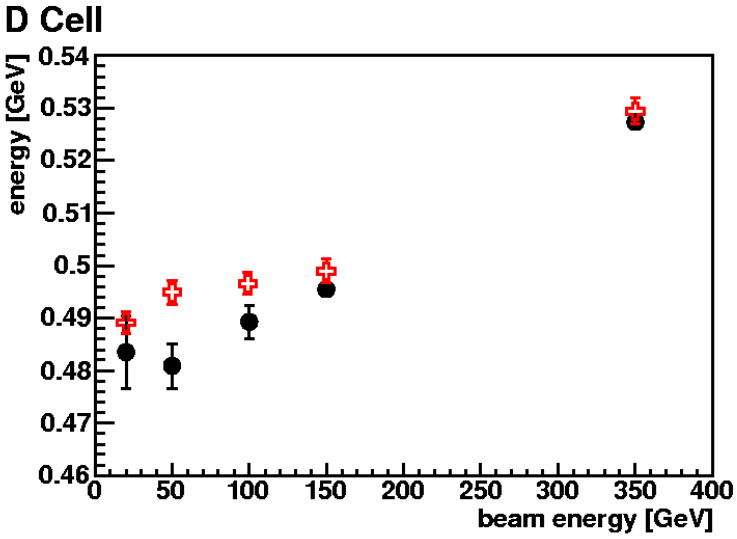
- Muons can be used to calibrate the calorimeter to within a few %
  (absolute energy scale)
- The simulation has to be used as reference signal
- The G4 MC describes the measured signal to ~ 2% with an uncertainty of ~1.5%

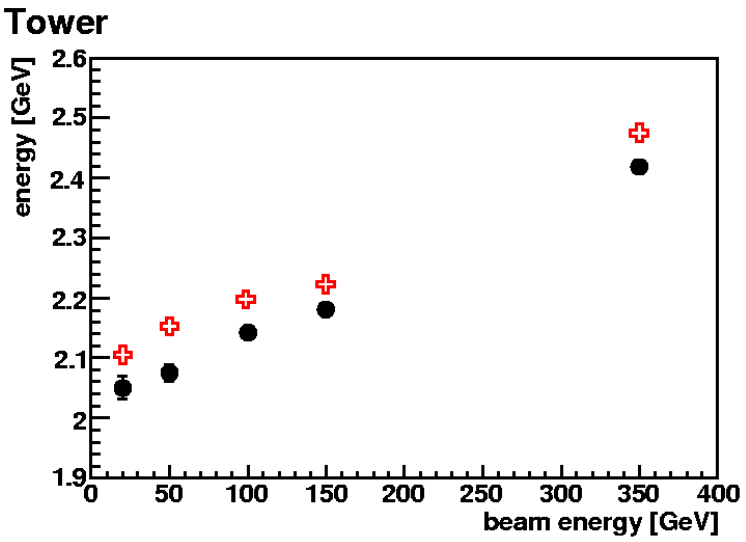
- An overall agreement with a first principle calculation of the muon energy loss
  within 5% for TileCal is found
  In Lar: migrations between layers become strong.
  At low energy the agreement is about 10%

Tile MOP Energy vs Muon Energy

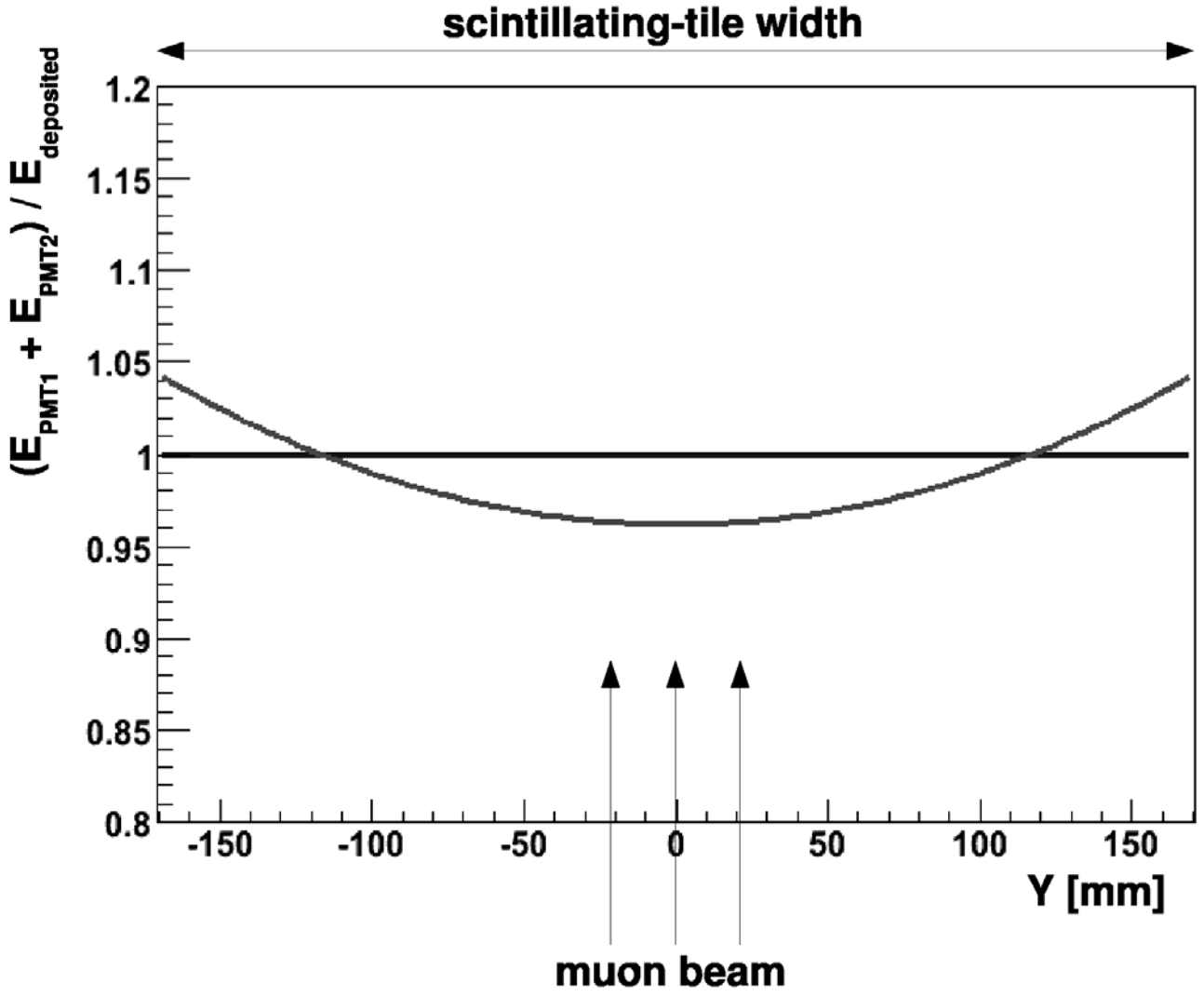








Light Attenuation in Tile



Effect of Birks Law