G4 Simulation of LAr Barrel and 2002 testbeam electrons

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Physics Validation of simulation, October 1st, 2003

- DATA: August 2002 testbeam, energy scan at $\eta = 0.687,\ \phi = 0.282$ between 10 and 180 GeV;
- MC: standalone program for LAr Barrel by Gaston Parrour (testbeam configuration) based on Geant4 v4.1; full simulation of showers with 30 μm cutoff;
- Before comparing...
  - caveat on upstream material;
  - energy scales of different samplings need to be intercalibrated in both MC and real data!

Material upstream the module in testbeam

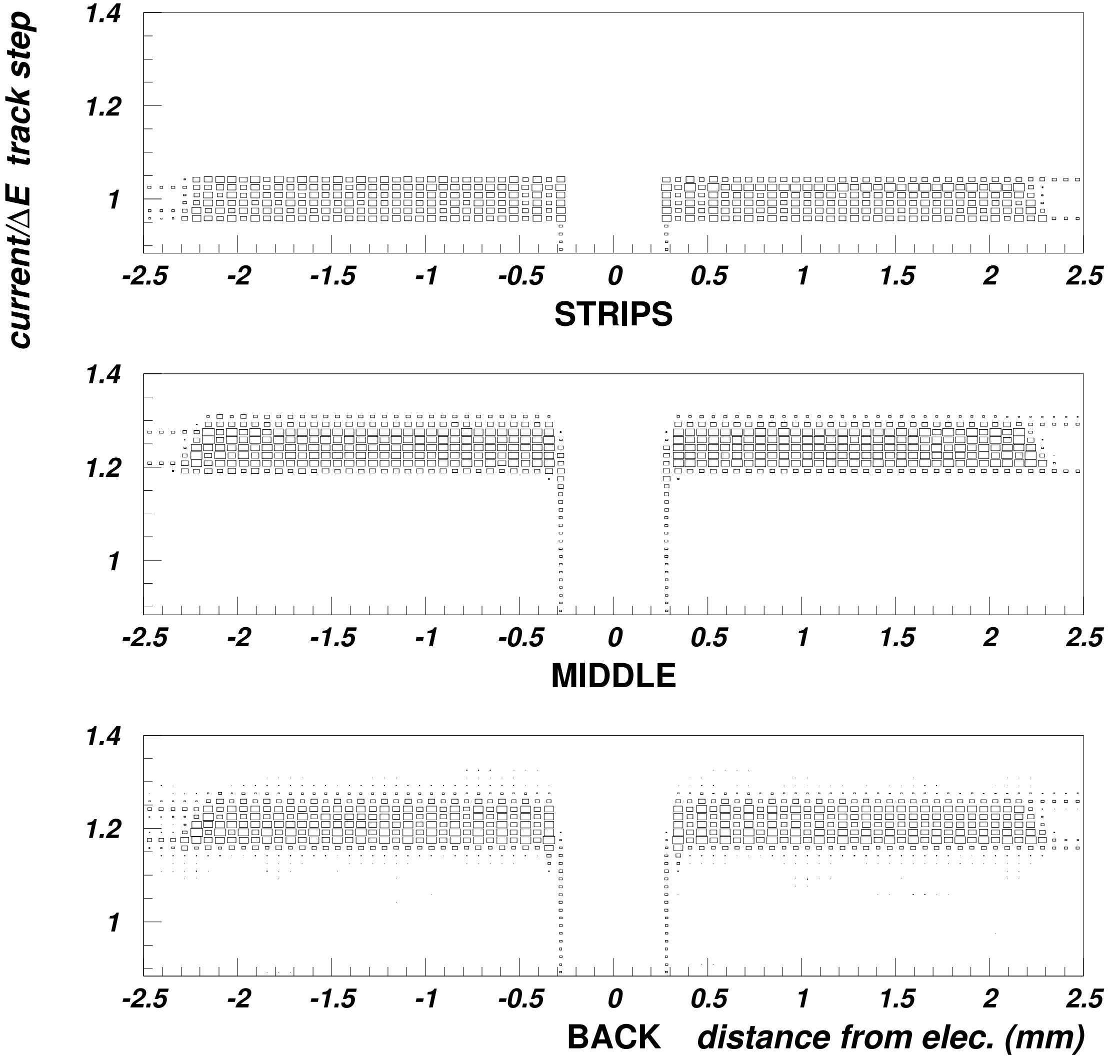
	G4 code		Real		
	cm	X0	cm	X0	
air			950	0.03	
Mylar windows			0.2	0.01	
NA45			667	0.01 – 0.04	
First Cerenkov counter			1176	$\sim$ 0.01	
total "far" material		0		$\sim$ 0.06 – 0.10	
scintillators	1.25	0.03	4.2	0.09	
air	100	0.003	300	0.01	
windows, chambers, $\check{C}$ 2				0.01 – 0.03	
foam (Rohacell)	22	0.03	30	0.04	
LAr before PS	–		0.2 – 0.5?	0.01 – 0.04	
Cryostat walls	9	1.01	8	0.90	(measured 31/7/03)
Total "close" material		1.07		1.05 – 1.10	

- MC data produced before a better evaluation of material along beam line;
- brems. in the "far" material (before last trimming magnets), where the photons are likely lost, is not simulated;
- the amount of "close" material in the simulation is reasonable. . .
- . . . but some uncertainty persist for the material along the beam line and also around the Presampler;

Layer intercalibration on MC data

- use muons;
- equalize the ratio current/energy loss in the straight–electrode region, far from the electrode;
- correction factors are:

PS	1.000
STRIPS	1.000
MIDDLE	0.804
BACK	0.828



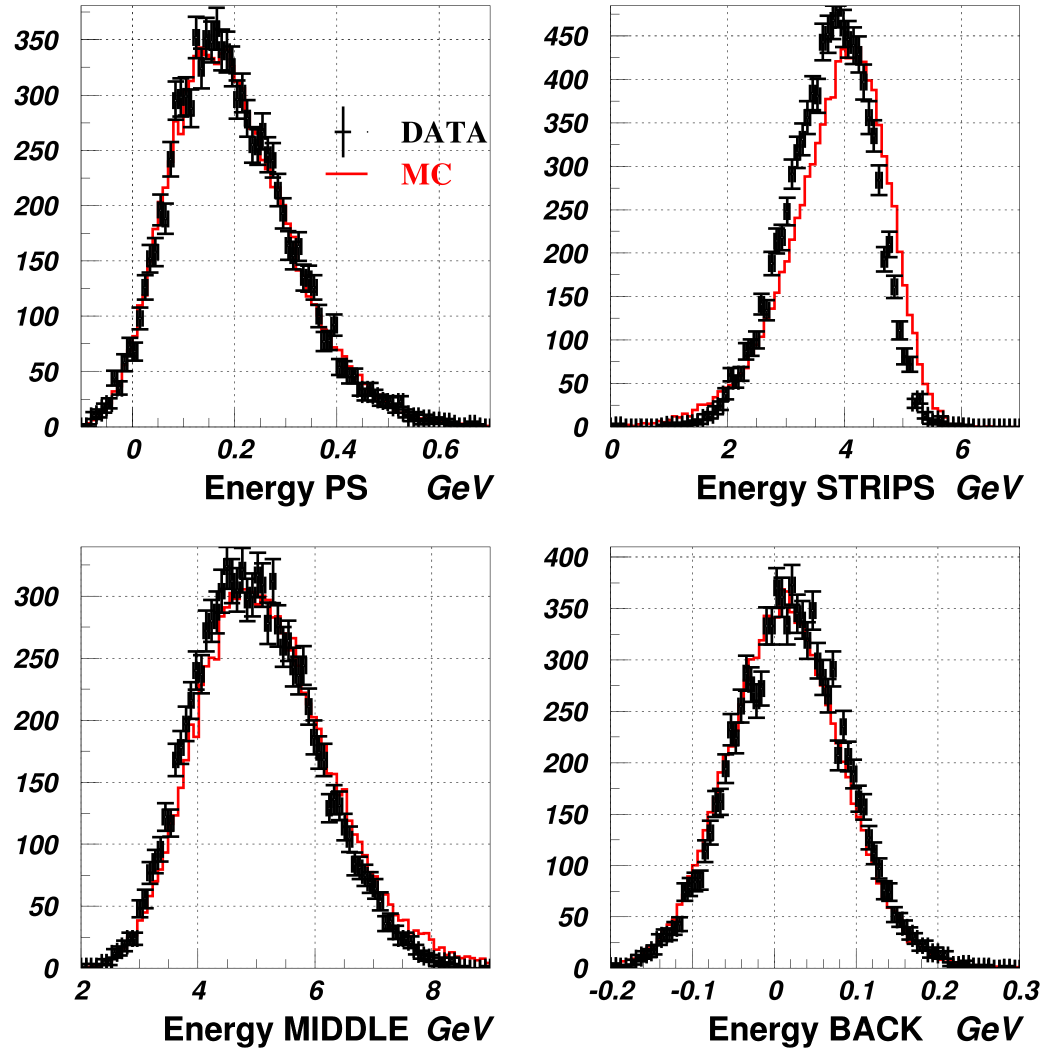
Layer intercalibration on REAL data

- guaranteed in principle by electronic calibration;
- but affected by cross–talk, especially in the STRIPS: calibration data show that 6.5 % of the signal injected in one cell goes to the 2 neighbours cells;
- if this is true also for physics data (not obvious. . .) we expect that the cluster energy is overestimated by the same amount;
- there is also cross–talk among cells of different layers, the most important effect being between MID and BACK;
- waiting for a detailed modeling of cross–talk in the MC, apply two naive corrections:
  - correct the full STRIPS energy by a factor 0.935 ± 0.01;
  - move 0.5 % of MID energy from BACK to MID (tuned on data/mc comparison).

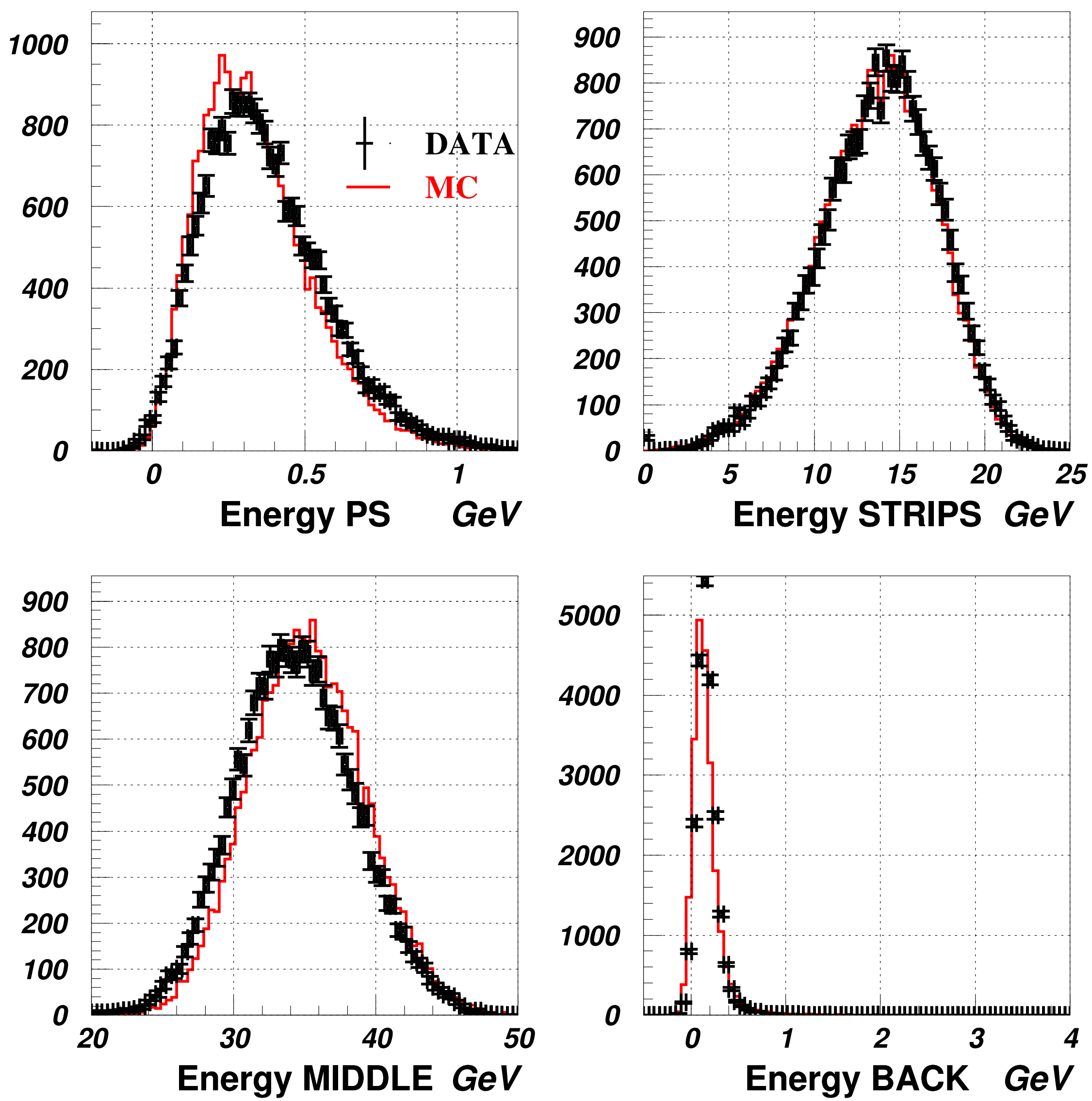
DATA/MC Comparison: Absolute energy

- the global energy scale for data is fixed to agree the MC one at 100 GeV;
- uncorrelated noise, as measured in real random events, is added to MC.

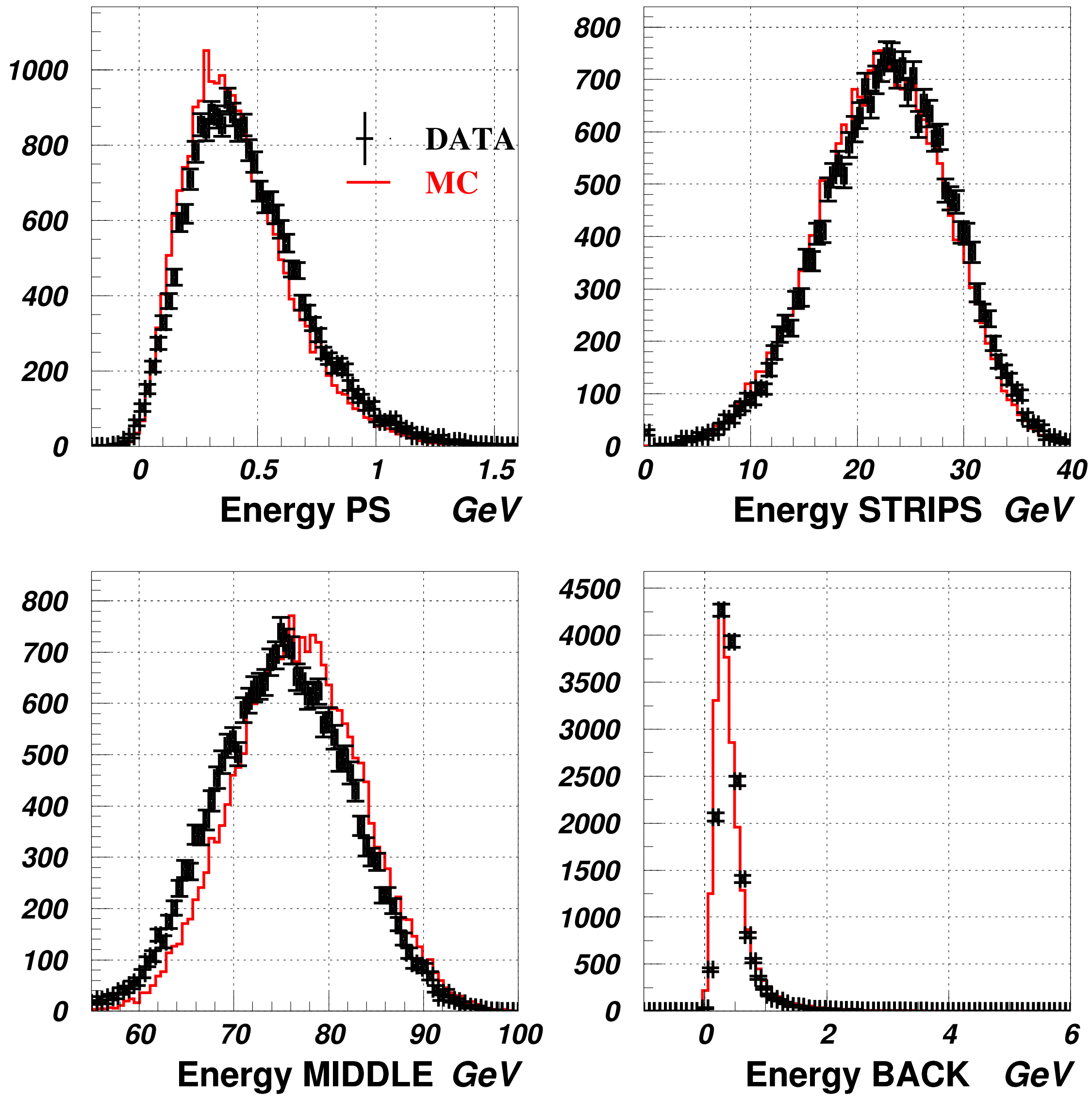
Energy = 10 GeV



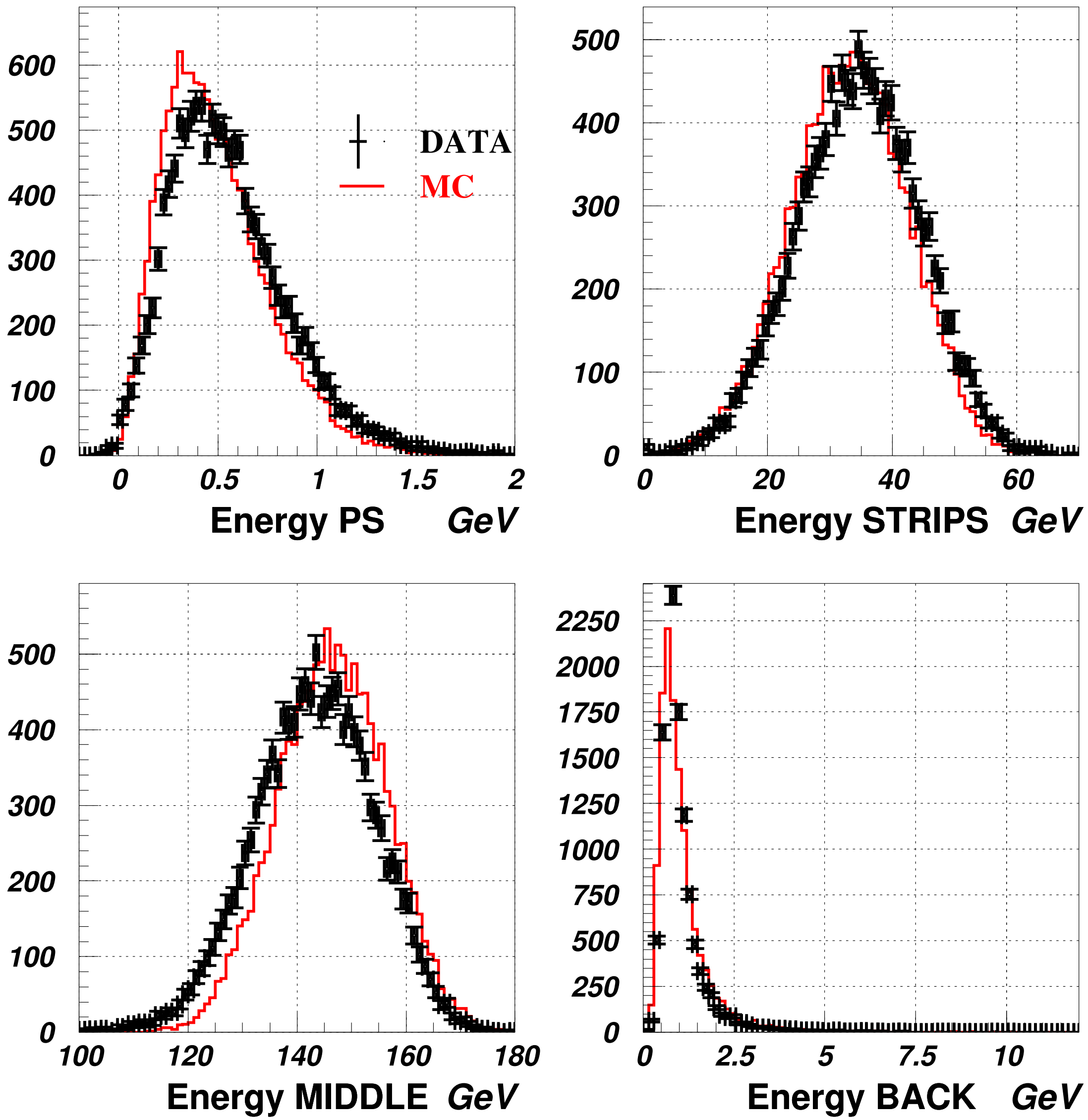
Energy = 50 GeV



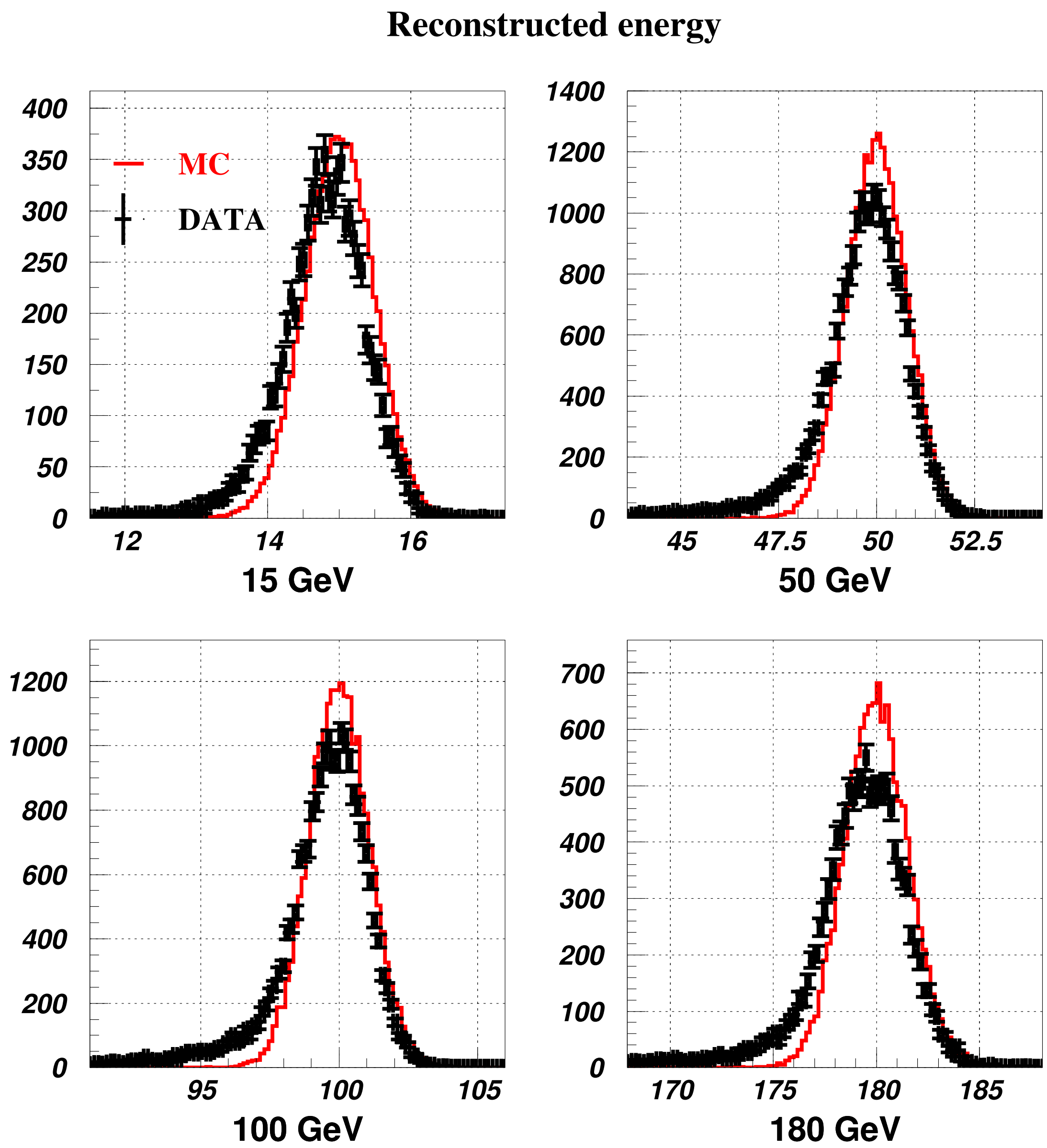
Energy = 100 GeV



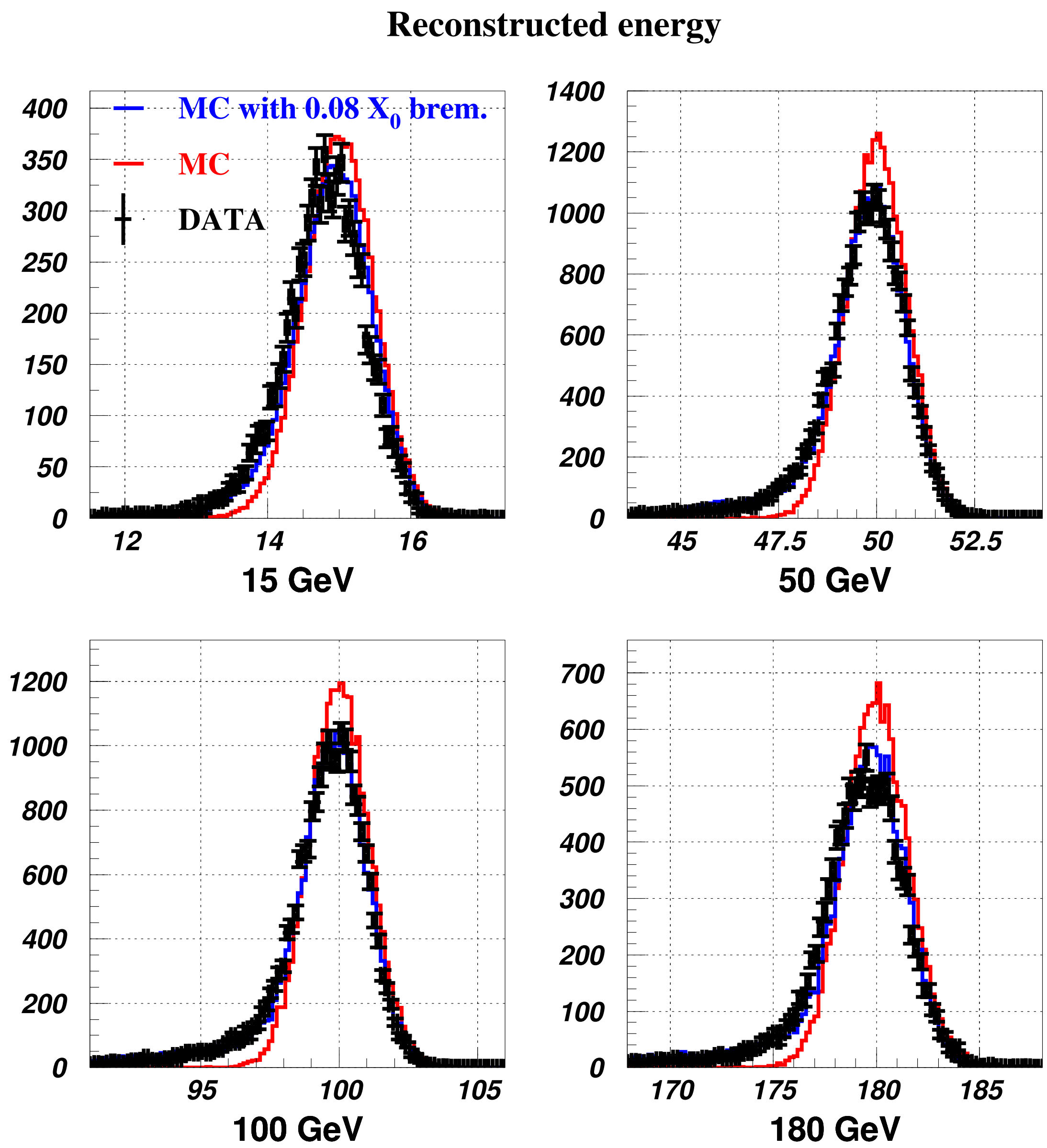
Energy = 180 GeV



- Total energy distribution: an asymmetric tail is clearly present in the real data;
- NOT from π contamination: tight cuts have been applied (based on transverse profile);
- it is likely produced by Brehmsstrahlung in the "far" beam line material

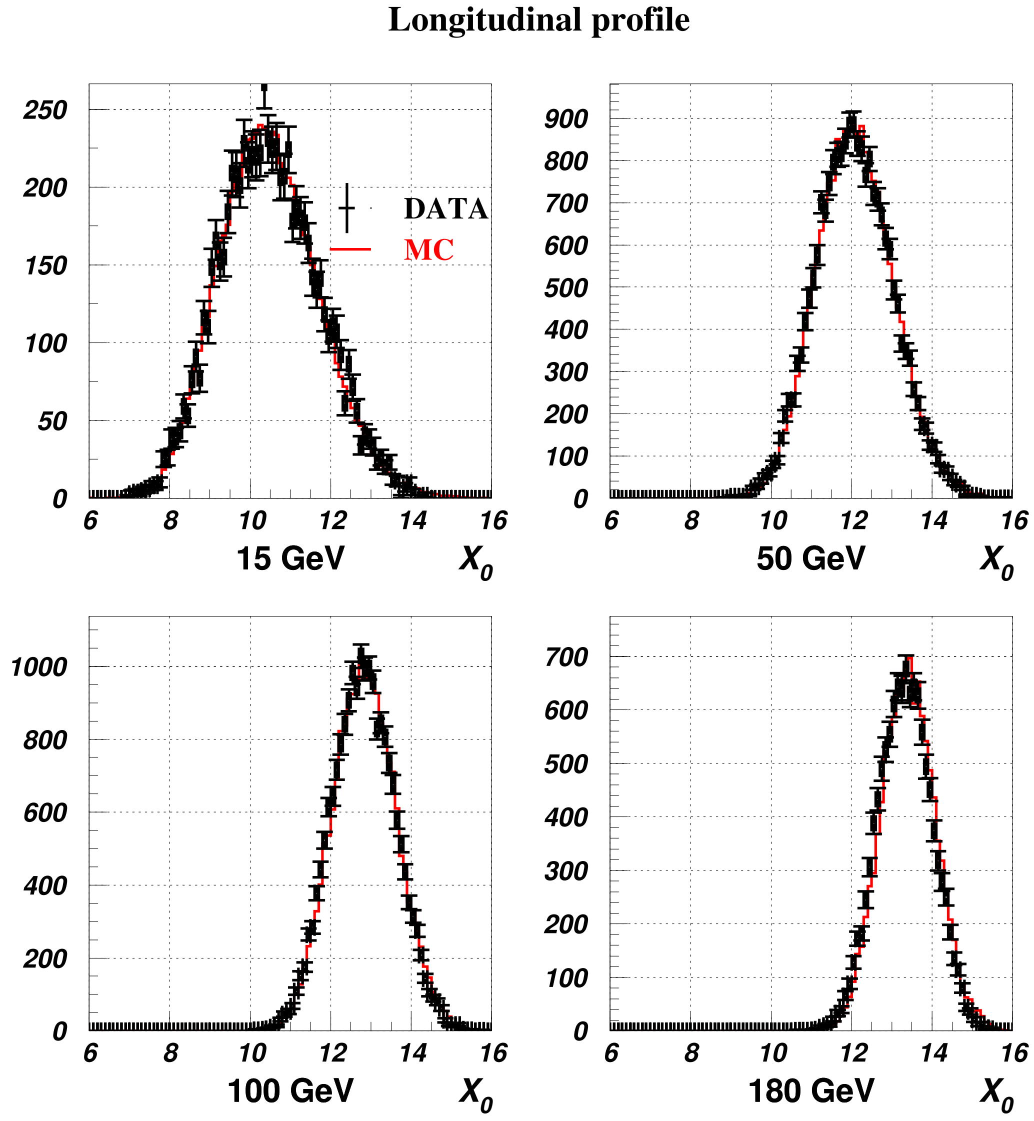


- a toy simulation of the brems. losses reproduce the tails if the quantity of material amounts to 0.08 X_0;
- this is compatible with our knowledge of the beam line



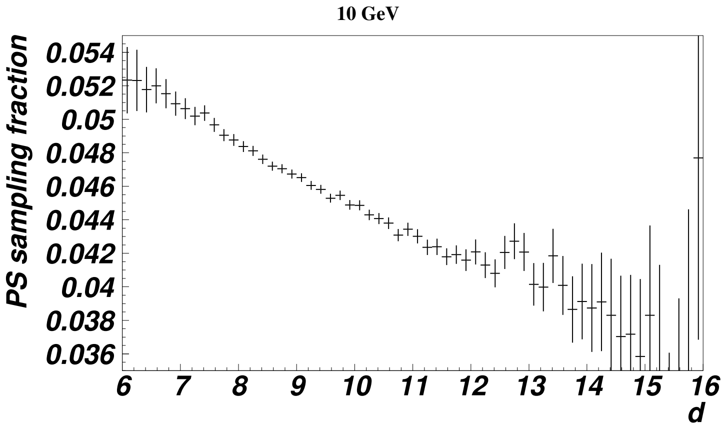
Longitudinal profile

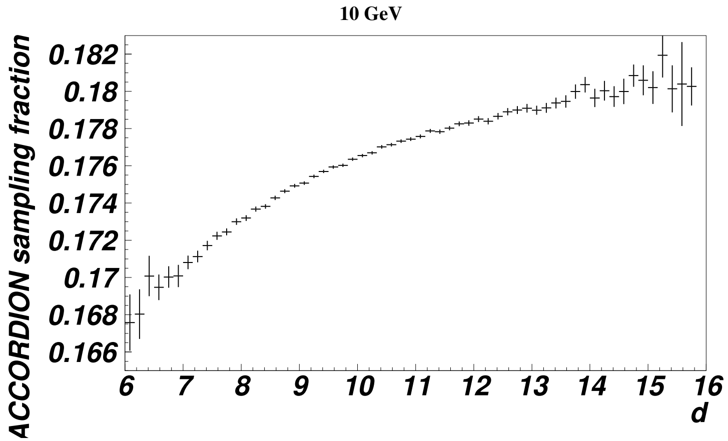
- compare longitudinal barycenter $d = \frac{4 d_{PS} \times E_{PS} + \sum_{\ell=1}^{3} d_\ell \times E_\ell}{4\ E_{PS} + \sum_{\ell=1}^{3} E_\ell}$ where d_ℓ are the depths at the center of each samplings (in X0 units), and the energy of the PS is multiplied by 4 to account for the different sampling fraction.



Energy dependence on shower depth

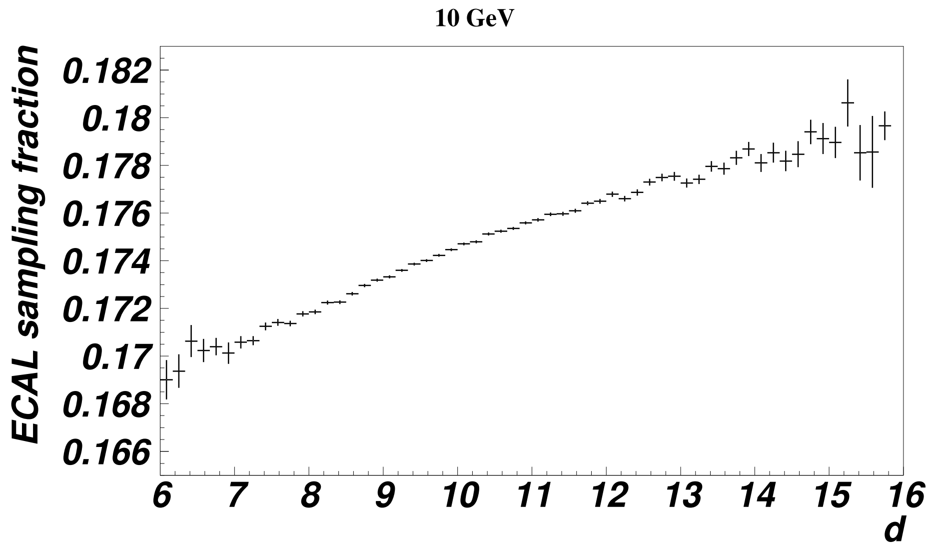
- MC predicts the electron sampling fractions of PS and Accordion to depend on the shower depths for a fixed energy



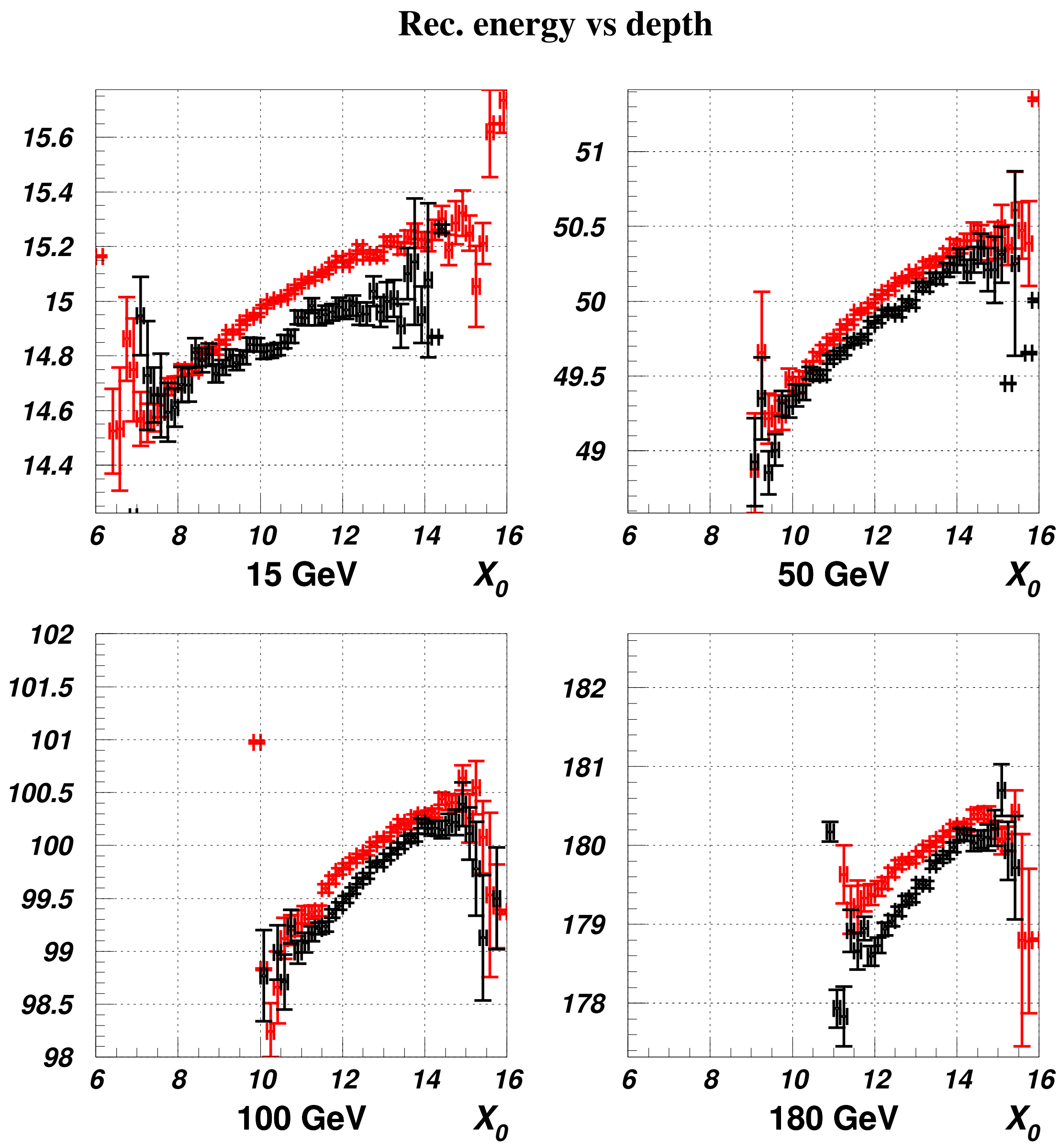


- The effect doesn't compensate when adding the energies as

$$E_{rec} = E_{\text{active–PS}}/(s.f.)_{\text{PS}} + E_{\text{active–acc.}}/(s.f.)_{\text{acc.}}$$



- this non–trivial physical effect, which depend on the lowest energy part of the shower, is confirmed on real data, though the quantitative agreement is not perfect



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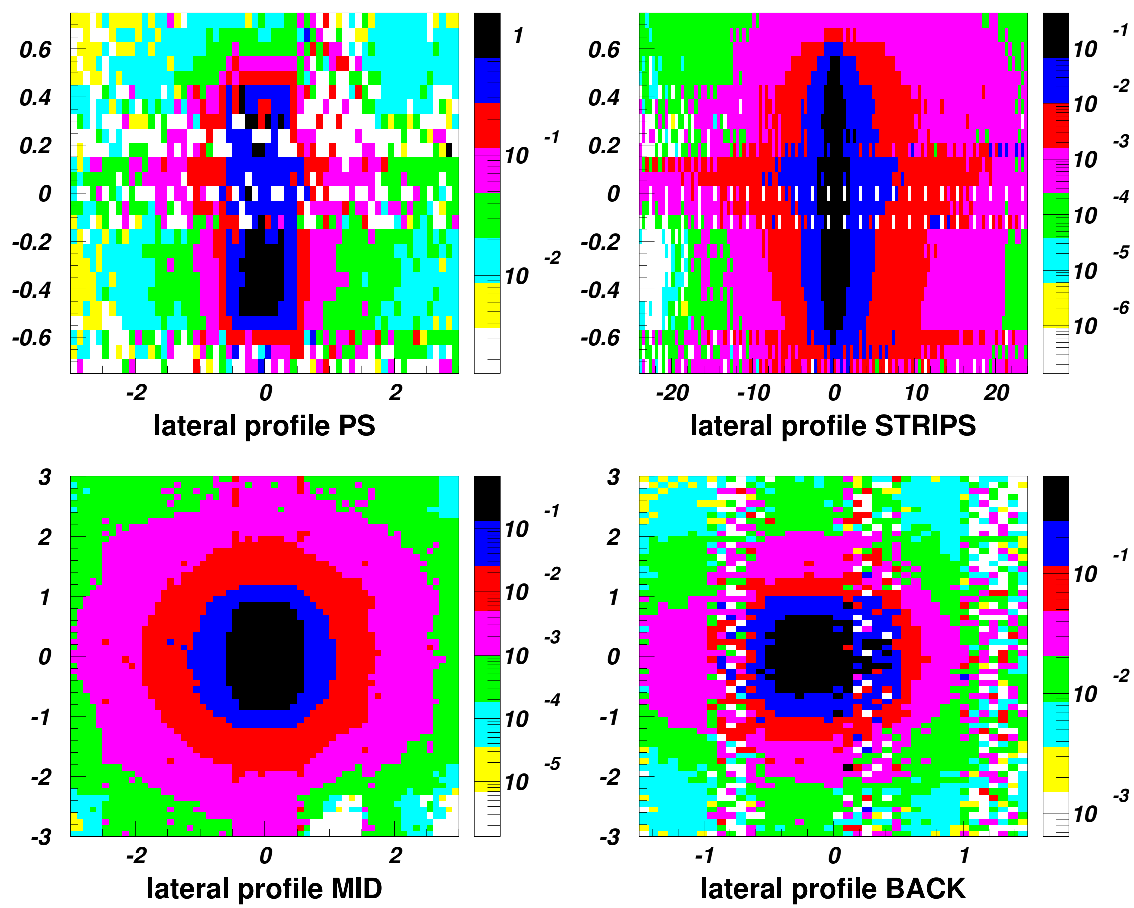
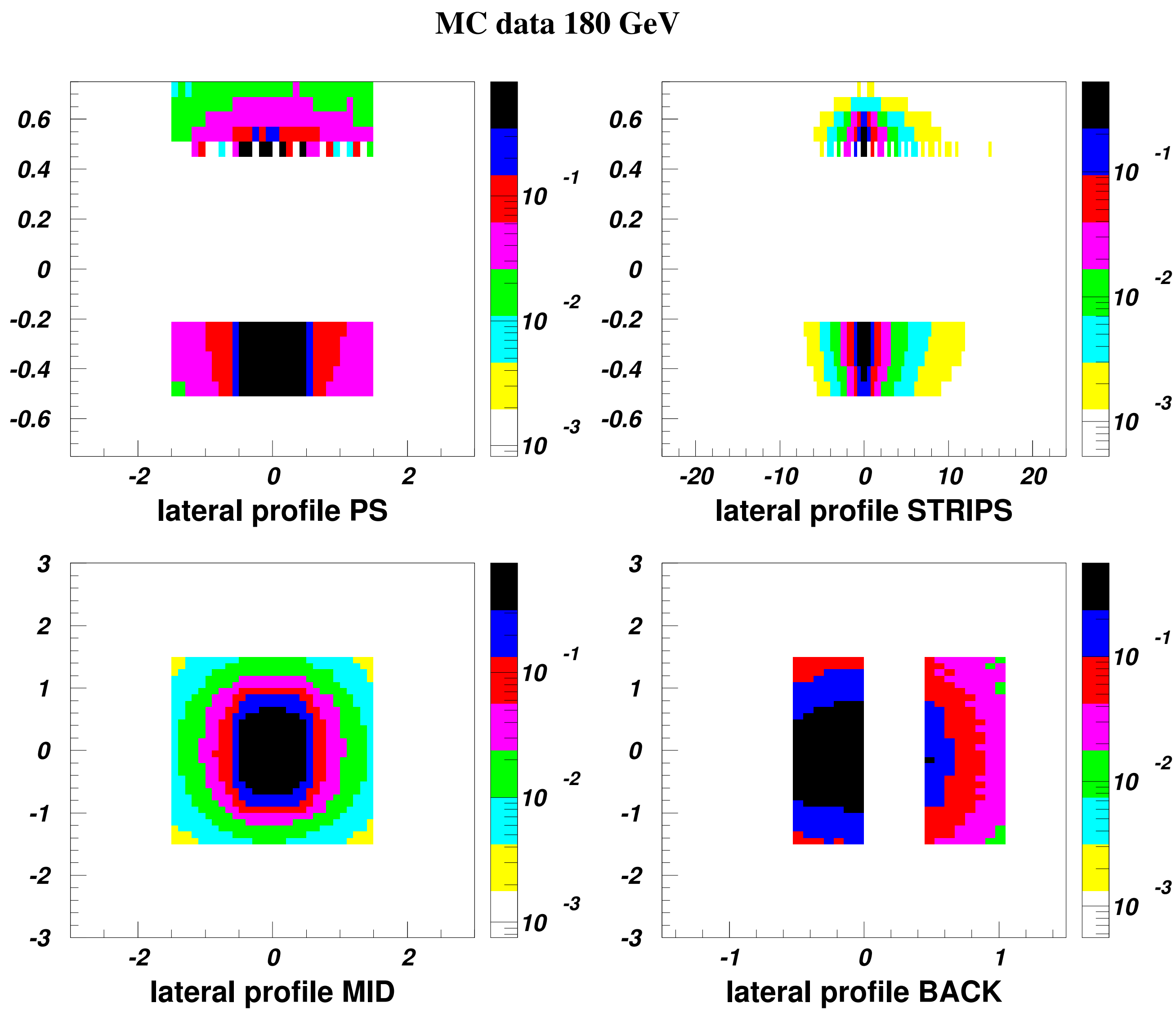
Transverse profile

- for each sampling, compute the energy fraction in a single cell as a function of the distance from the cluster centroid in η and ϕ;
- the centroid position is obtained from the strips (η) and from the middle (ϕ);
- plots are in cell units (the range is
  $\Delta\eta = 0.075$,
  $\Delta\phi = 0.0736$)

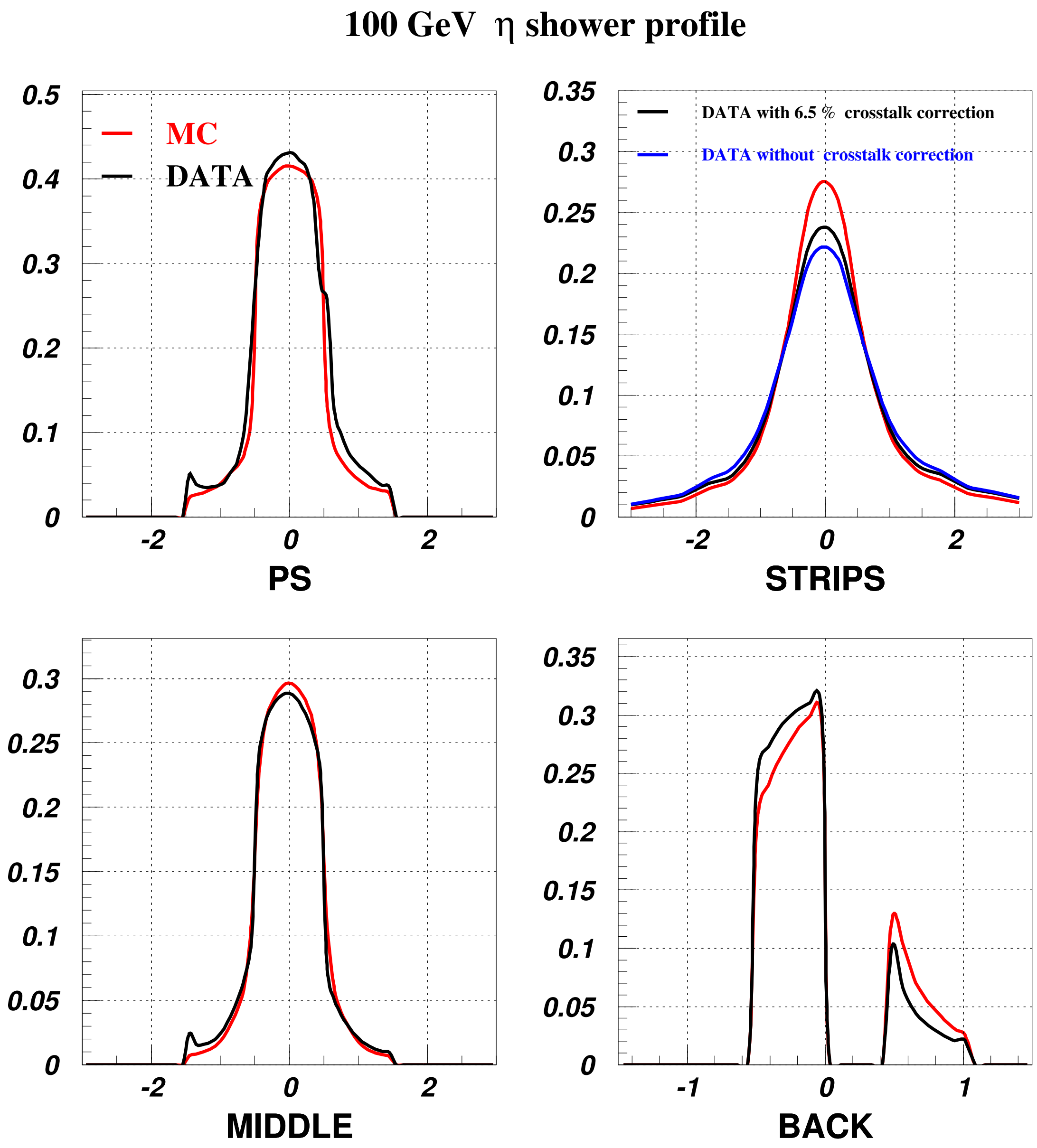
REAL data 180 GeV



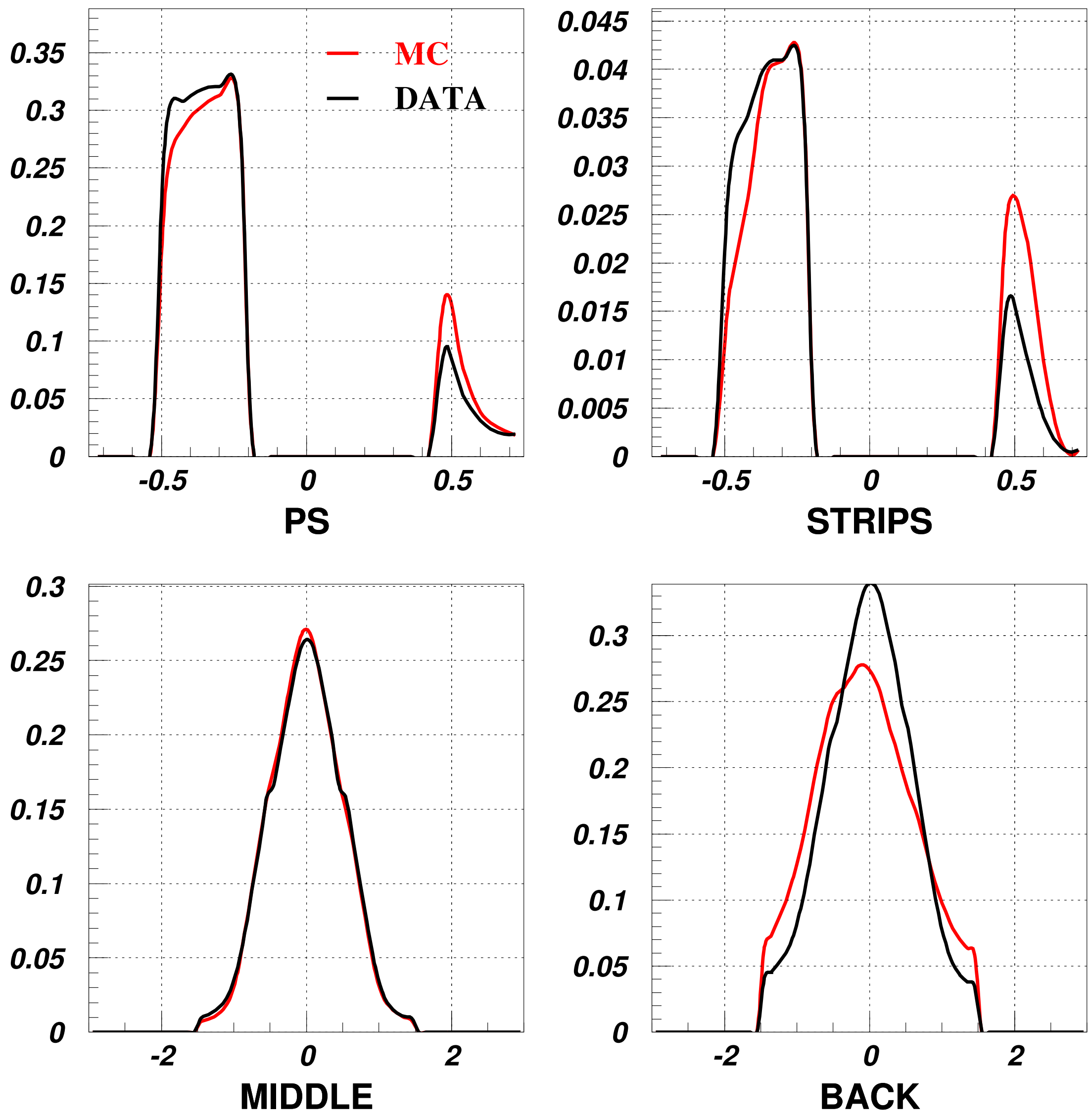
- for MC, available only for the cells inside 3x3 clusters...



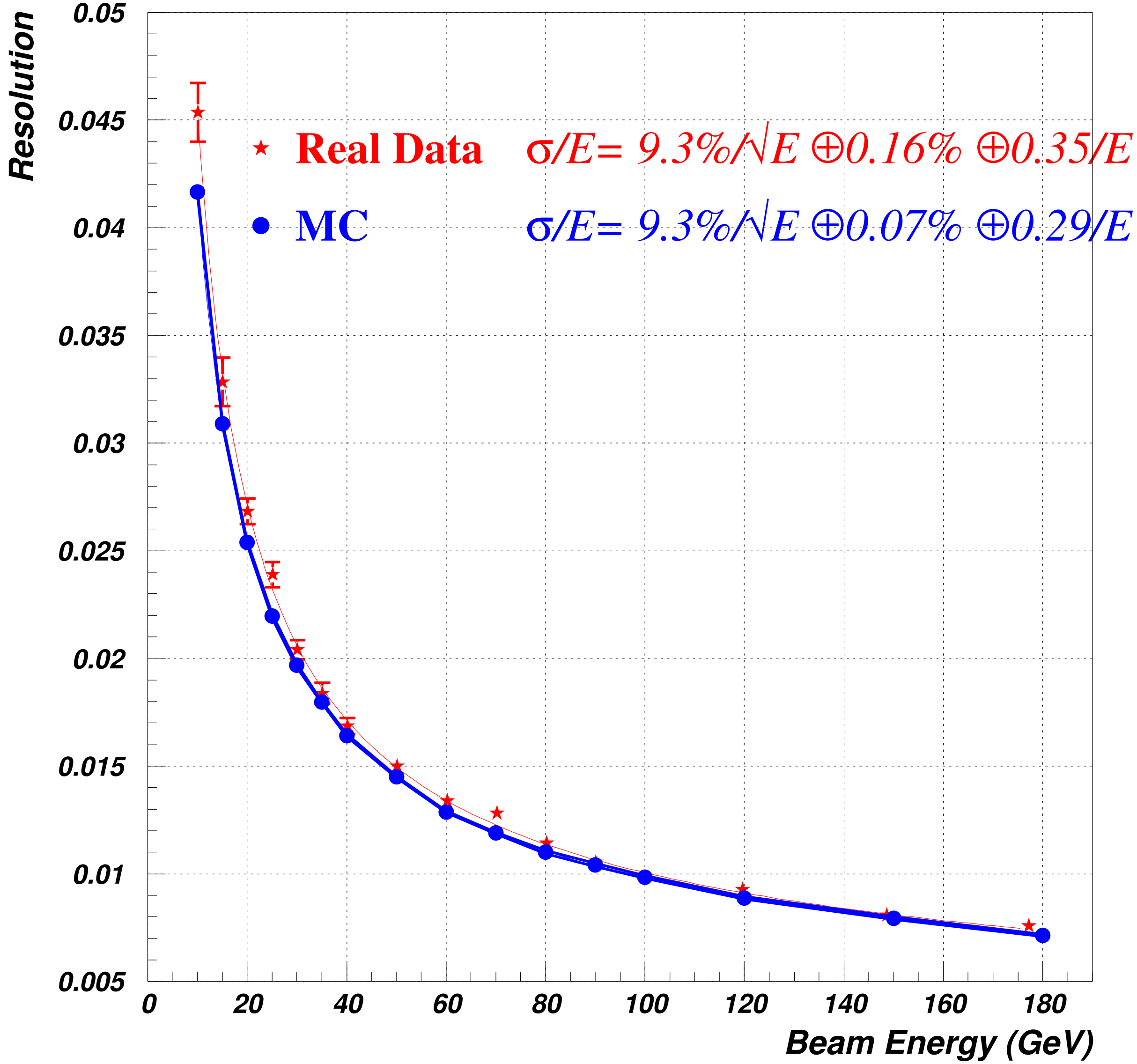
- compare projections for cells in 3x3 clusters;
- for the STRIPS, the cross–talk 10 % correction improves the comparison



100 GeV ϕ shower profile



Energy Resolution



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Conclusions

- Satisfactory overall agreement between G4 simulation and real data;
- reconstructed energies in different samplings, longitudinal and transverse profiles agree at $\sim 1\%$ level ;
- subtle physical effects reproduced;
- no evidence for problems with the G4 code;
- at present the comparison is clearly limited by
  - ➜ simulation of the beam line;
  - ➜ modeling of cross–talk and uncorrelated noise.