The simulation of the reactions induced by the cosmic-ray protons is based on GHEISHA, which strictly speaking is an event generator.

How realistic is it, with respect to the physical parameters measured by the LAT (trajectory pattern in Tkr and energy-deposition in Cal)?

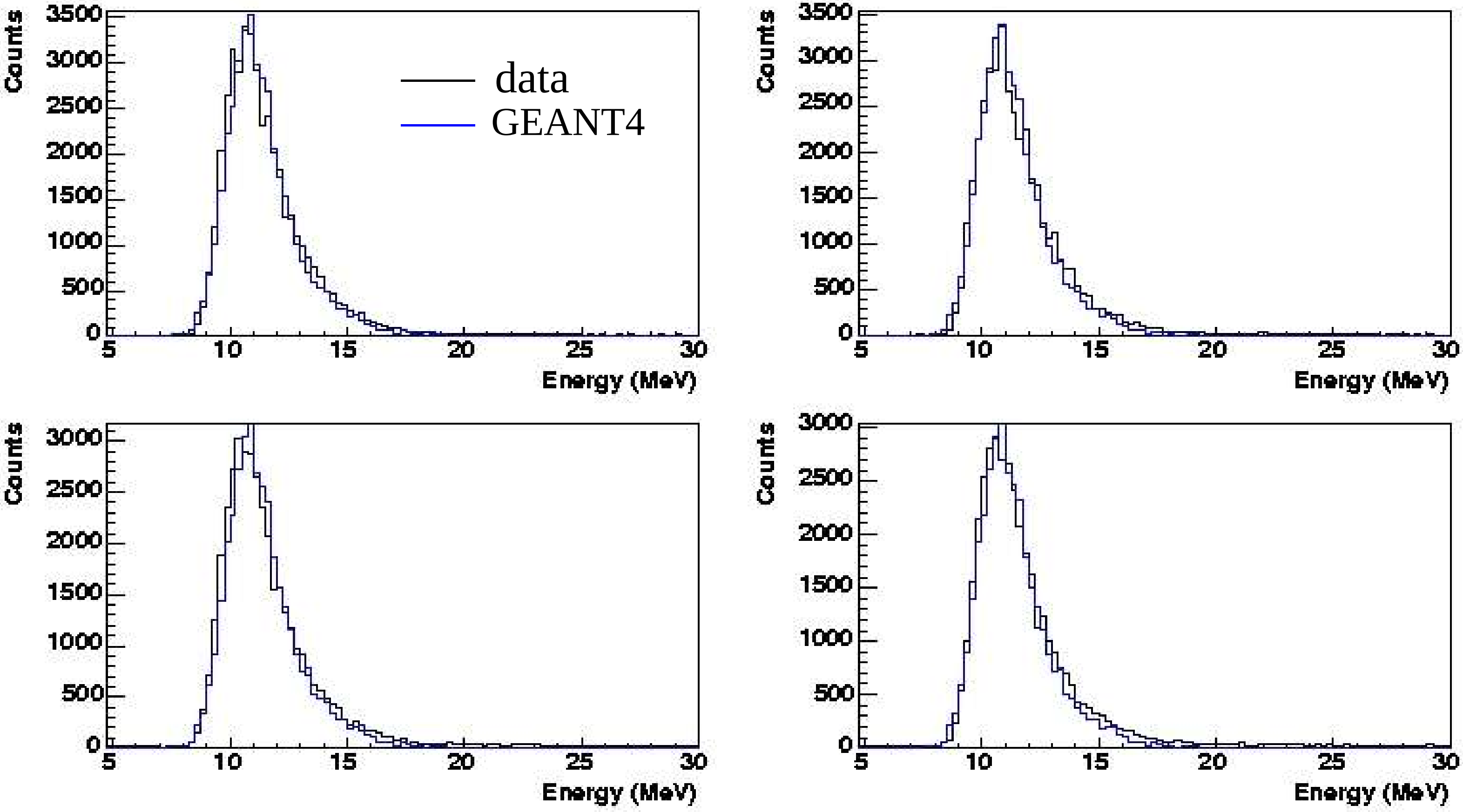
2 sets of data are available, which are essentially by-products of calibration runs with MIPs

at CERN: 20 GeV/c mixed beam of protons, π, electrons and muons;

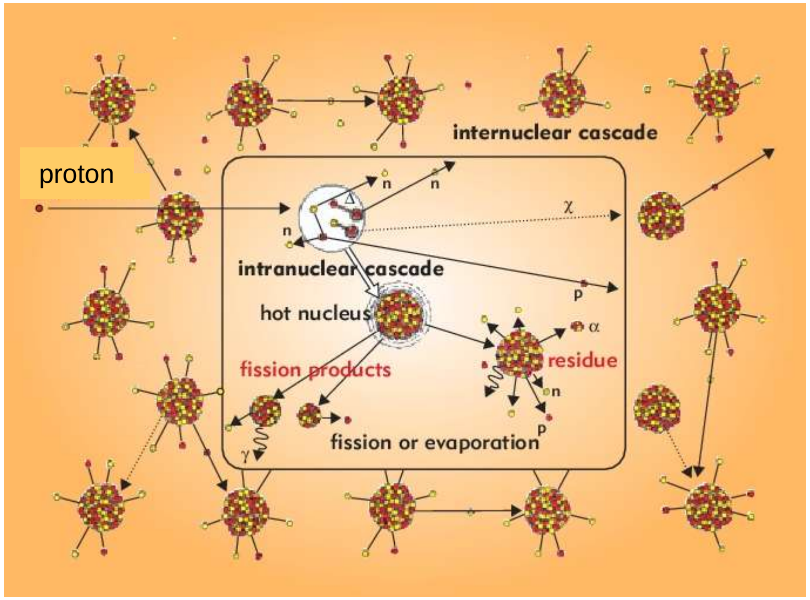
at GSI: 1.7 GeV protons, 3.4 GeV deuterons (not shown).

Most of the results presented here were obtained by Johan Bregeon.

GSI calibration with 1.7 GeV proton



Simulation of nuclear reactions at relativistic energies



(Example: Bertini's cascade)

In reactions at a few GeV/nucleon, two stages must be modeled separately:
- the intranuclear cascade: the Broglie wavelength (h/p) being much shorter than the internucleon distance, the incident proton interacts incoherently with individual nucleons (in contrast with the case at low energy, where it interacts with the « mean field », the potential created collectively by the nucleons).
- the statistical decay (« cooling») of the excited nucleus.

The secondary particles may again interact with other nuclei (internuclear cascade).

Simulating nuclear reactions properly requires fine-tuning many parameters (nuclear equation of state, « in-medium » cross sections, level density parameter, fission widths…).

GHEISHA

(H. Fesefeldt)

http://www.physik.rwth-aachen.de/~harm/geant/gheisha/index.html

It is a "parametric model" , i.e. it uses parametrisations of cross sections.

In the GHEISHA code high energy hadron nucleus interactions are simulated by sampling distributions functions of

- the combined multiplicity $w(\mathbf{a},n_1,n_2,...,n_i,...)$ for all particles i, i = π^+, π^-, π^0, p, n,..... including the correlations between them;
- the additive quantum numbers (energy E, charge Q, strangeness S and baryon number B) in the whole phase space region;
- evaporation and nuclear fission.

A universal function $f(\mathbf{b},x/pT,mT)$ is used for the distribution of the additive quantum numbers, with Feynman variable x, the transverse momentum pT and transverse mass mT. **a** and **b** are parameter vectors, which depend on the particle type of the incoming beam and the atomic number A of the target.

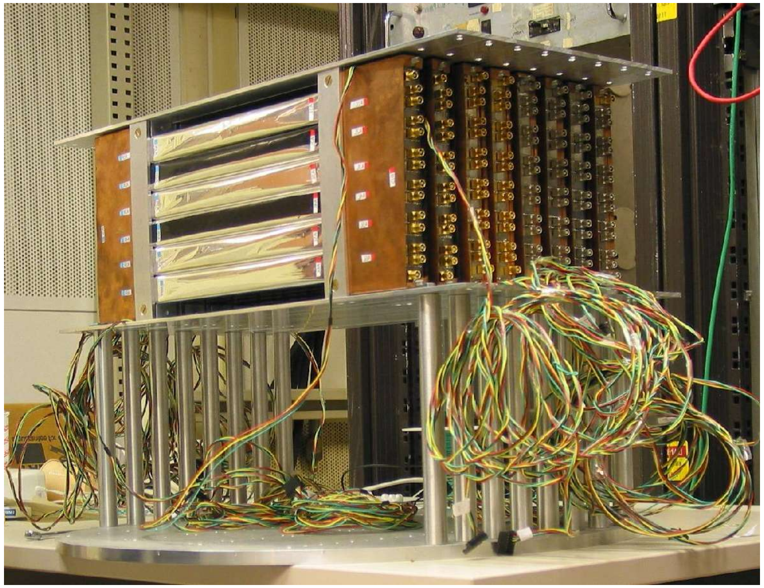
Note 1: Neither charge nor mass is conserved…

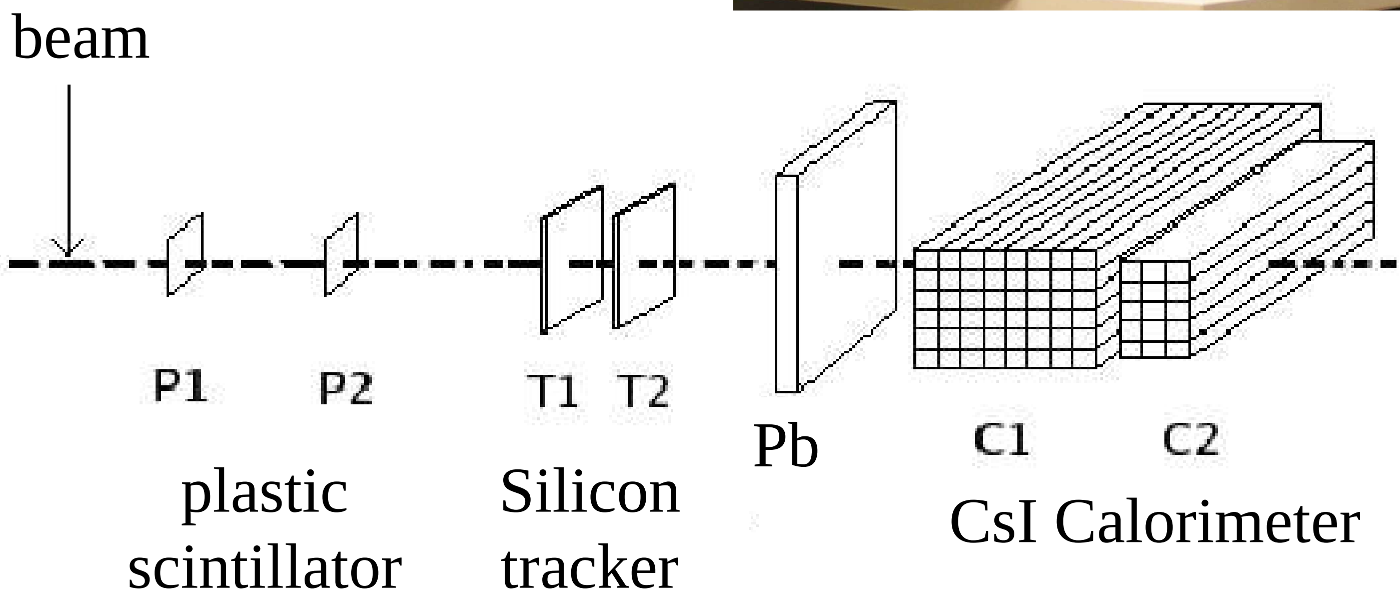
Note 2: There is only little alternative to gheisha between 3 GeV/c and 25 GeV/c in GEANT4.

Note 3: Strictly speaking, the Cal measures the light produced by the CsI scintillator traversed by particles. This light is proportional to energy for electromagnetic showers, and for protons, muons (ionisation energy loss), But not for the heavier particles generated in nuclear reactions («quenching »). So it is not totally legitimate to compare "deposited energy" predicted by simulations with "measured energy" (aka light) for hadronic reactions.

CERN setup

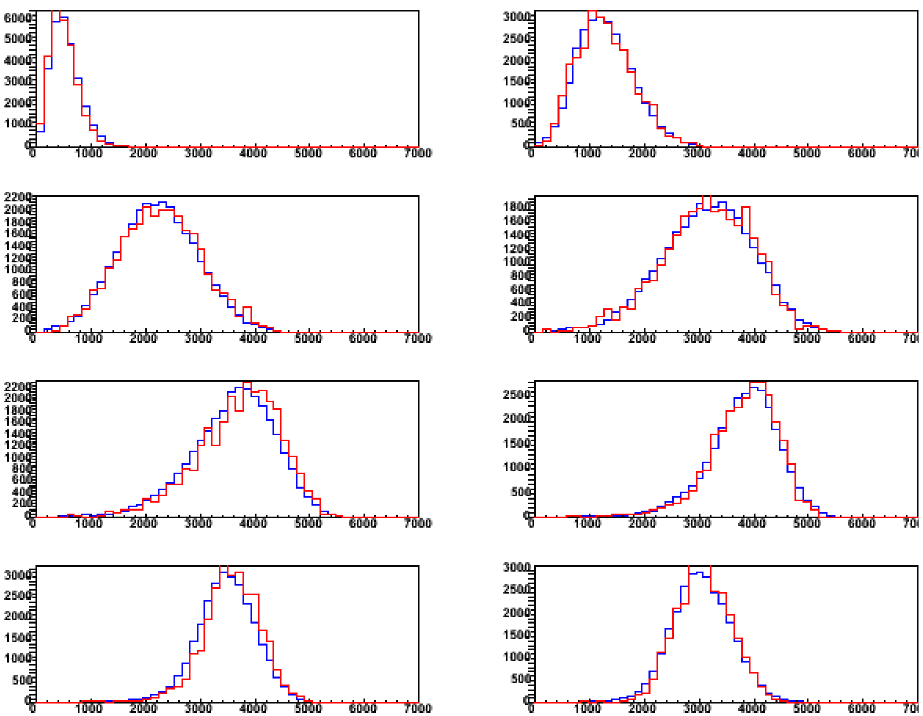
« minical »: 8 layers of 6 crystals
home-made electronics





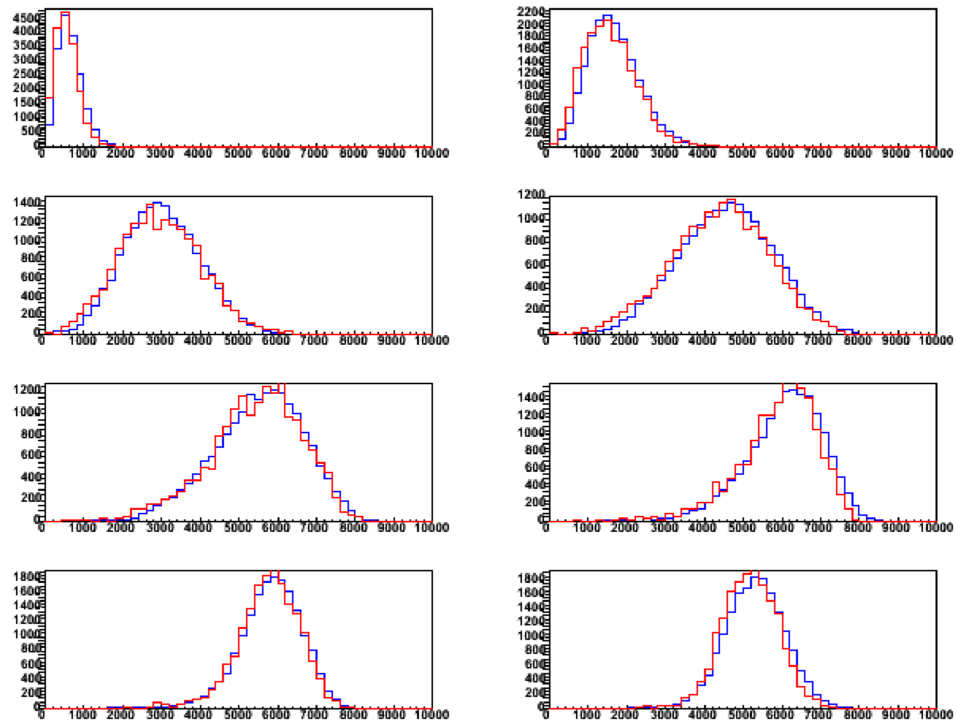
Electromagnetic showers

50 GeV e^+ 1.5 X_0



deposited energy (MeV)

80 GeV e^+ 1.5 X_0

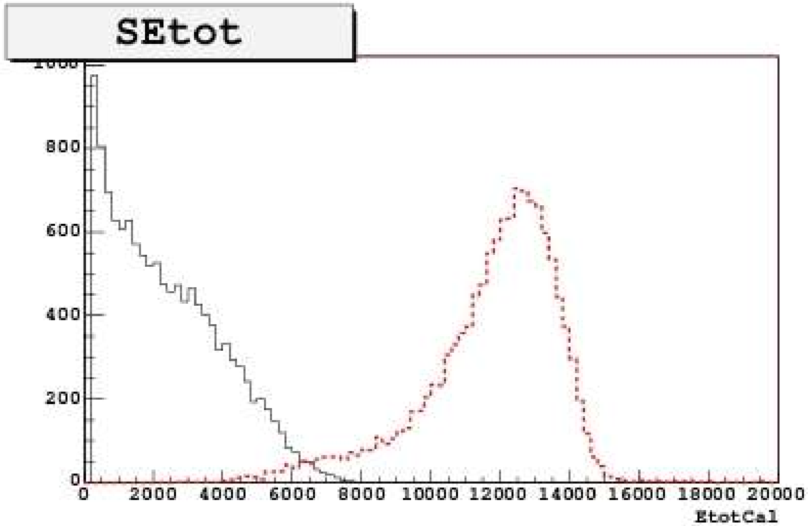


deposited energy (MeV)

blue: data red: Geant4

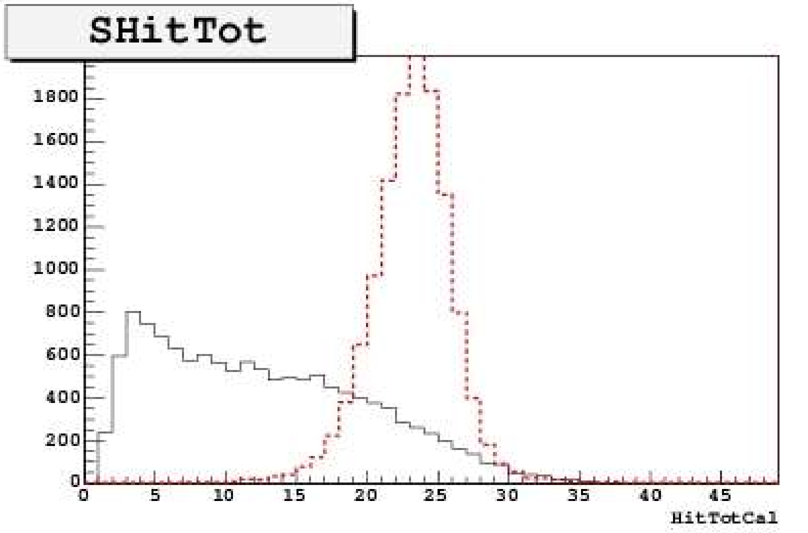
20 GeV/c beam

total deposited energy



hadrons
electrons

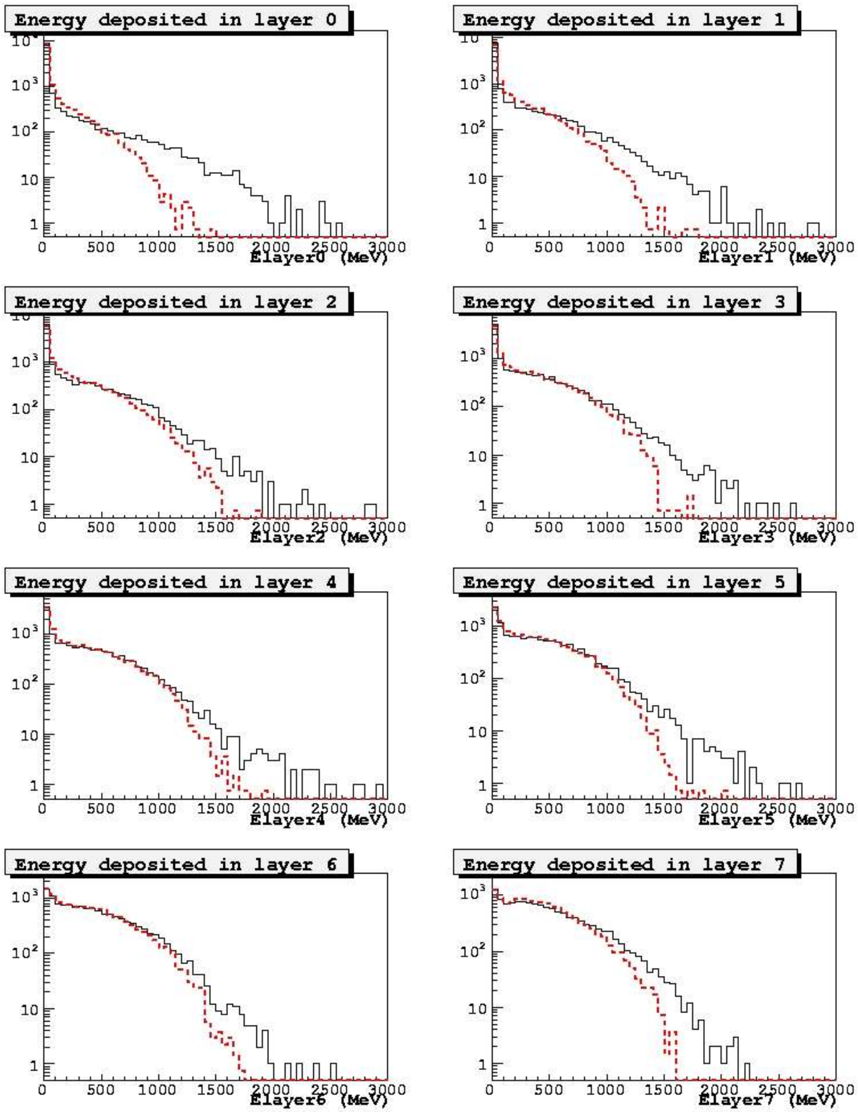
total hit multiplicity



——— data

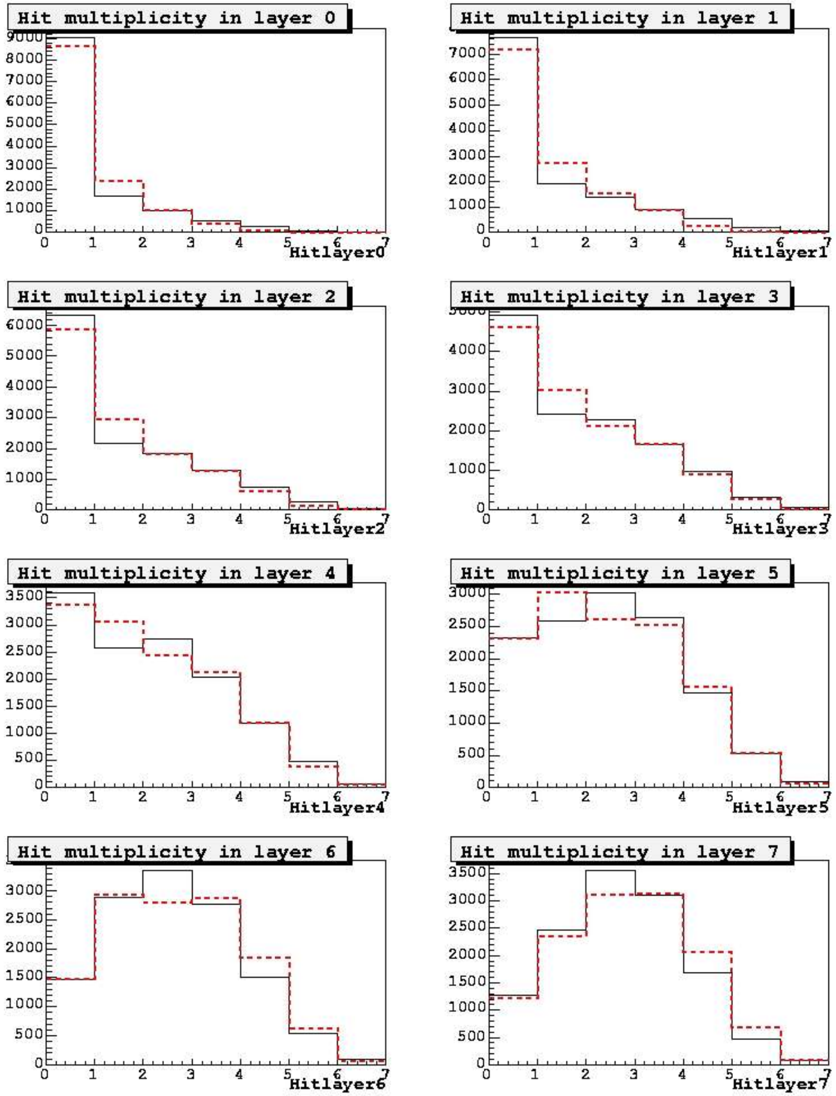
- - - - - gheisha

deposited energy

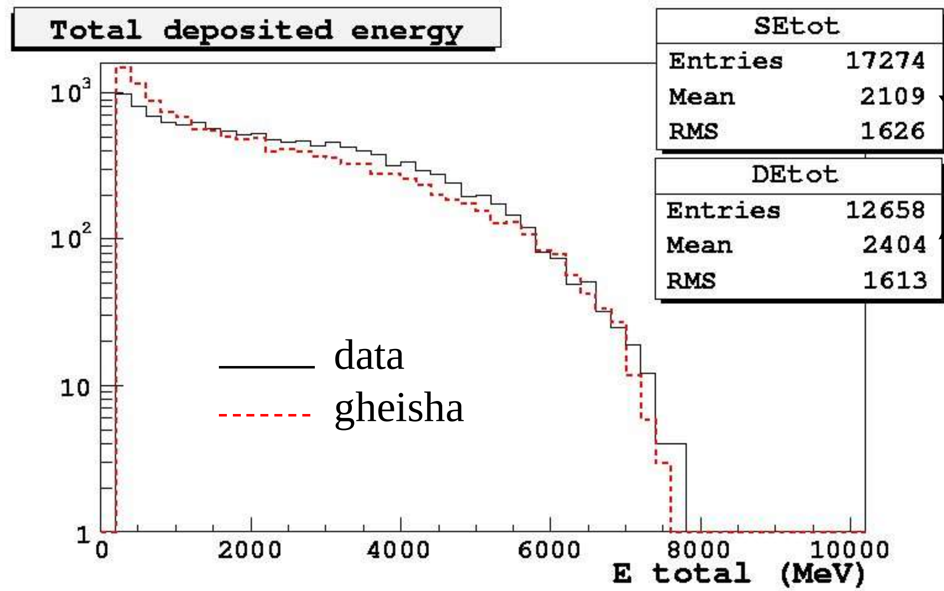


hit multiplicity

(E>50 MeV)

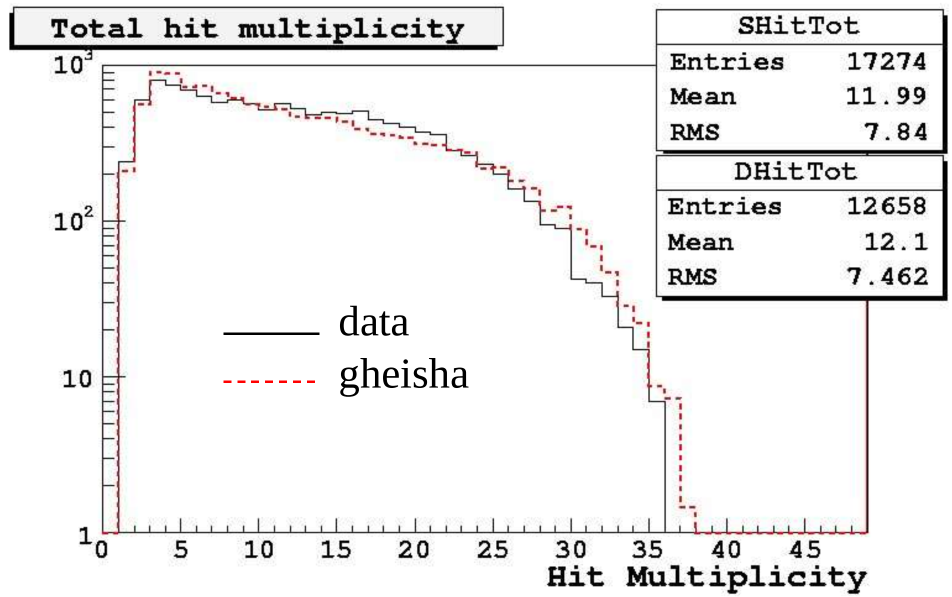


total deposited energy

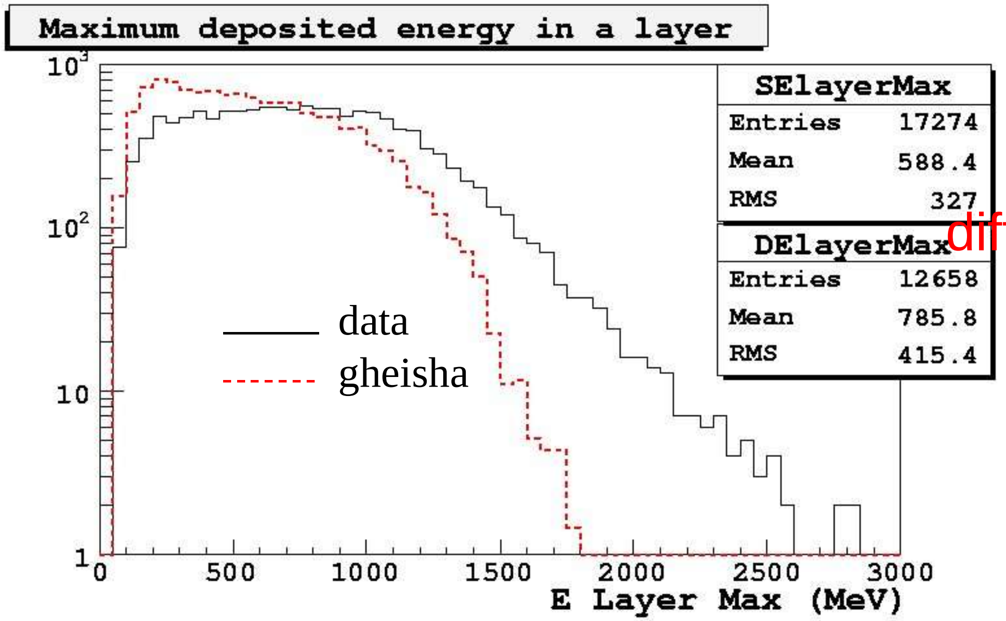


15% difference

total hit multiplicity (E> 50 MeV)



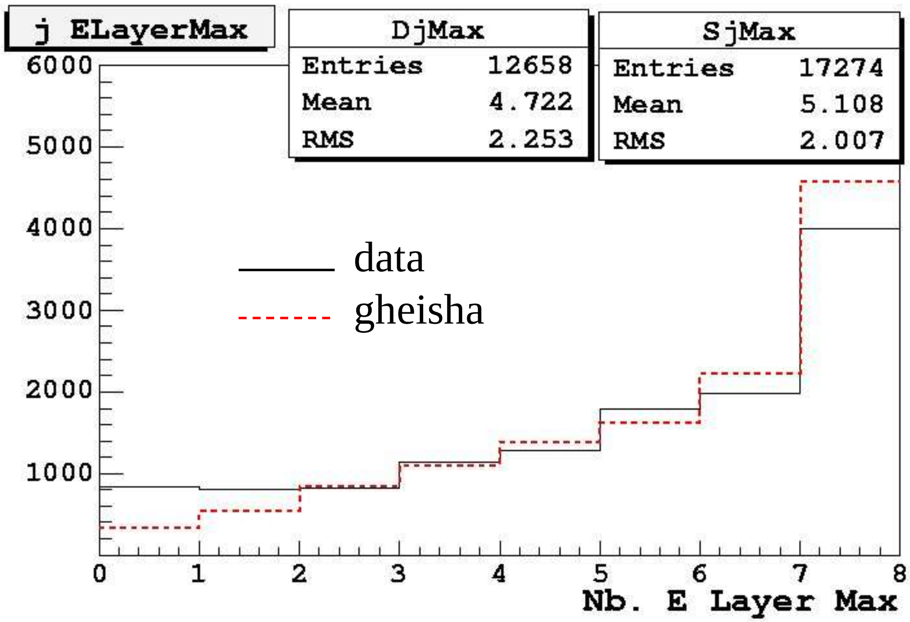
Maximum deposited energy in a layer

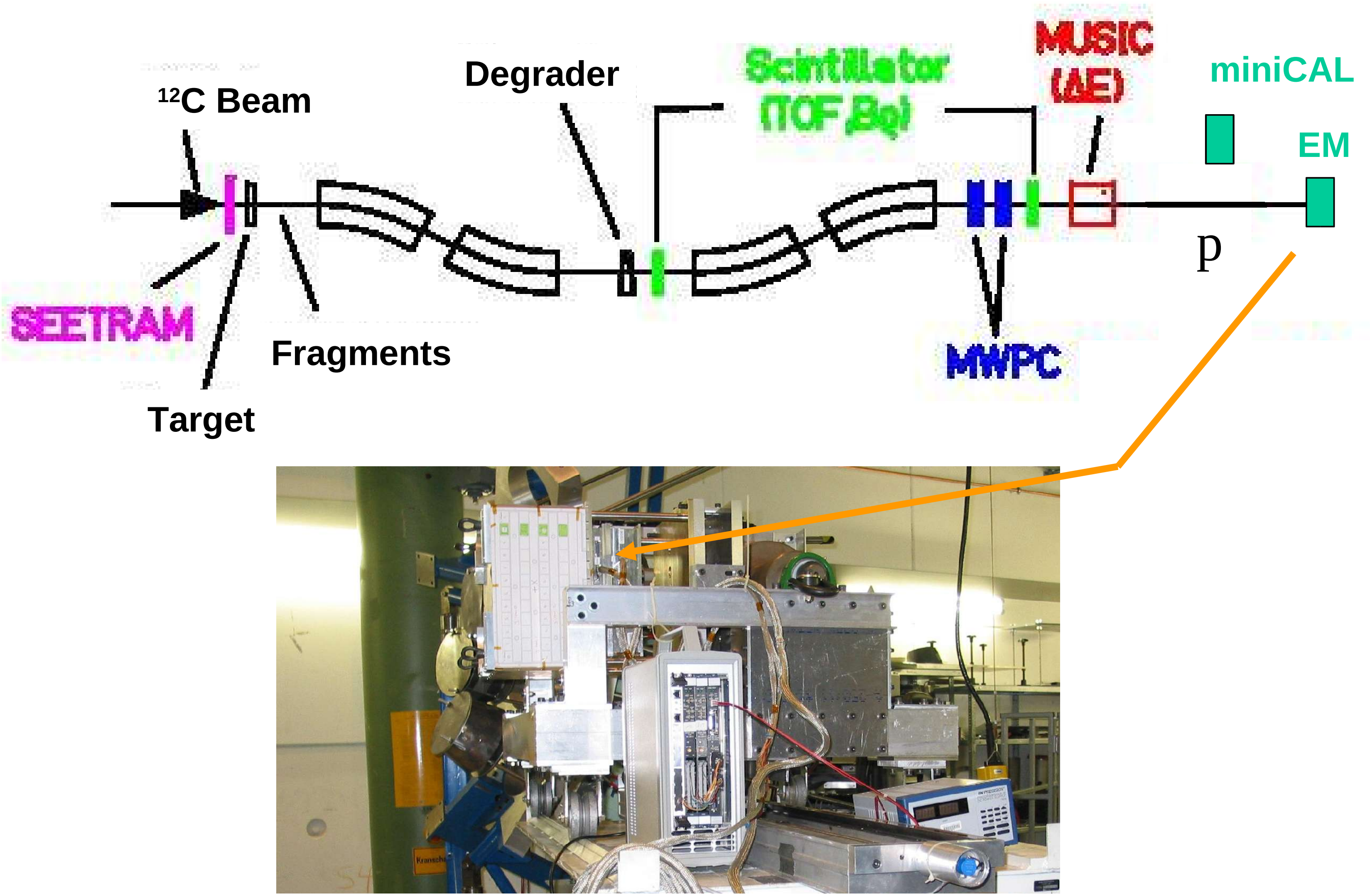


29% difference

Layer with maximum deposited energy

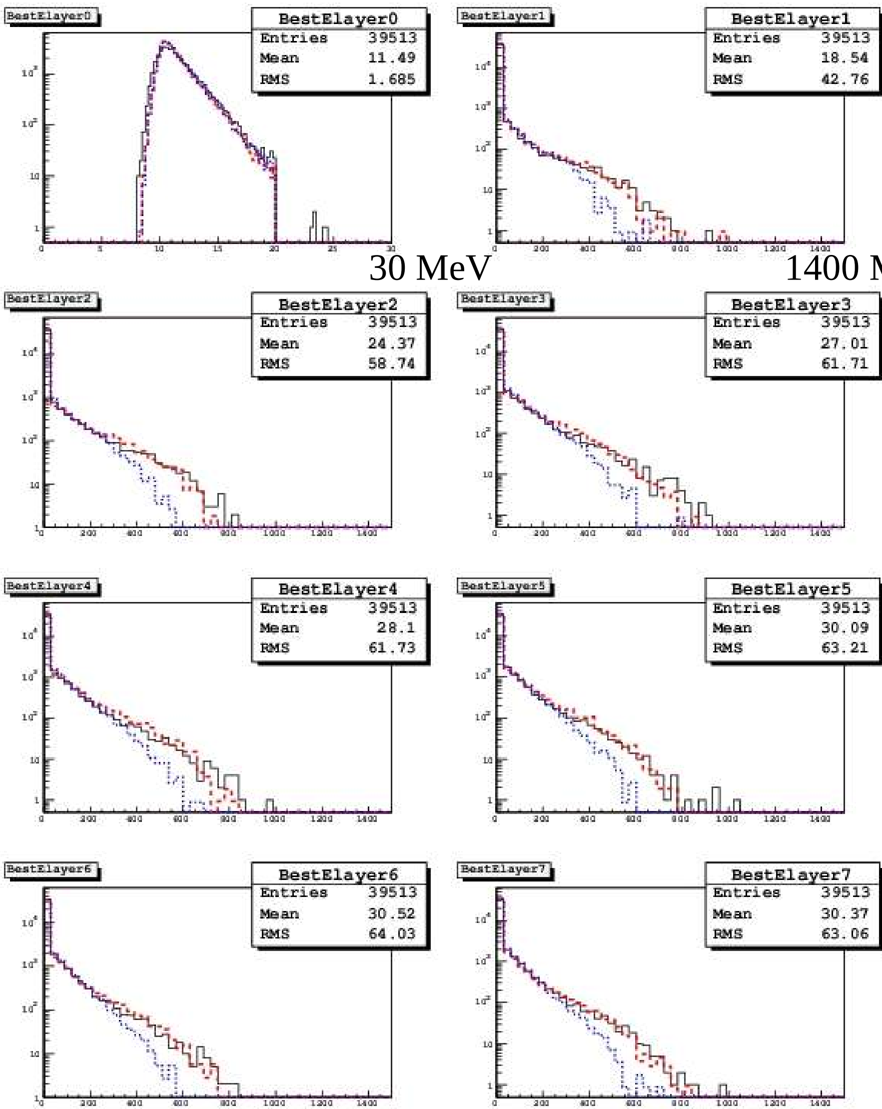
(Etot >200 MeV)




Degrader
Scintillator
(TOF Bρ)
MUSIC
(ΔE)
miniCAL
12C Beam
EM
p
SEETRAM
Fragments
MWPC
Target

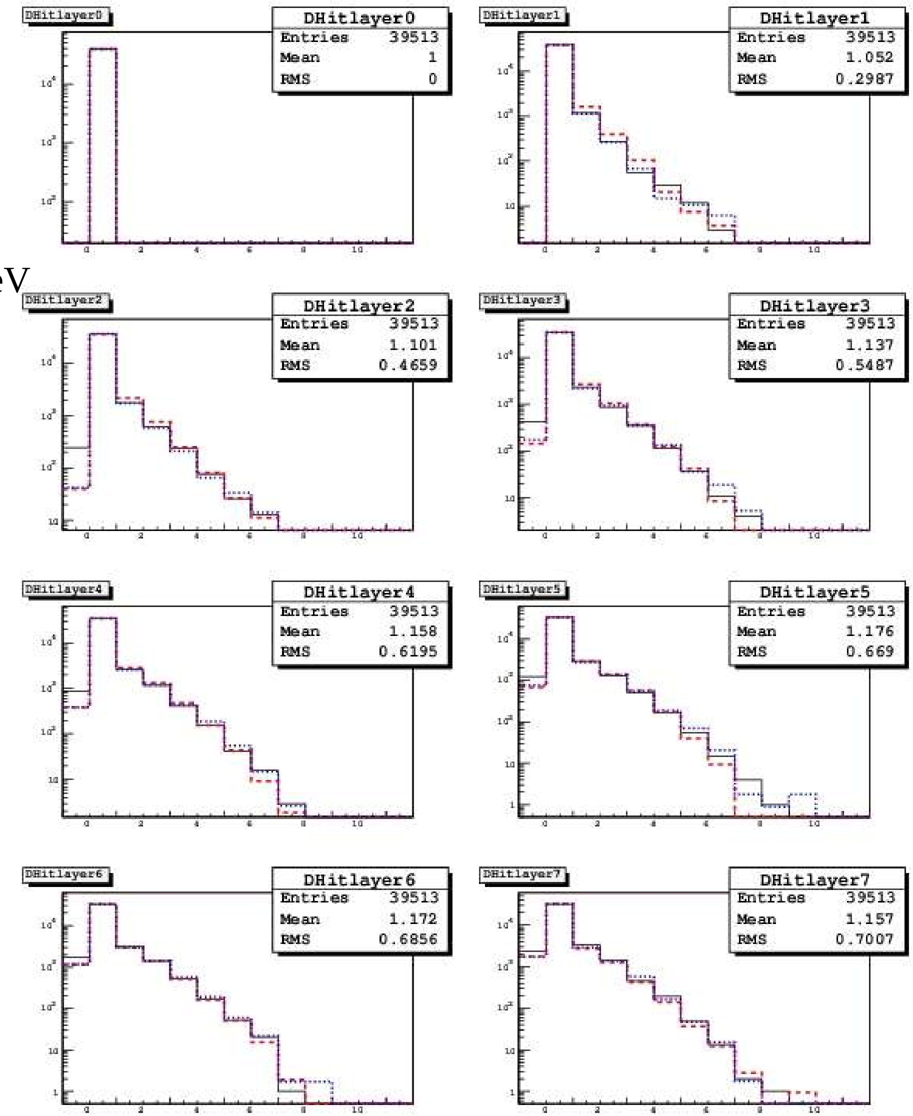
data
gheisha
bert-inc

deposited energy distributions



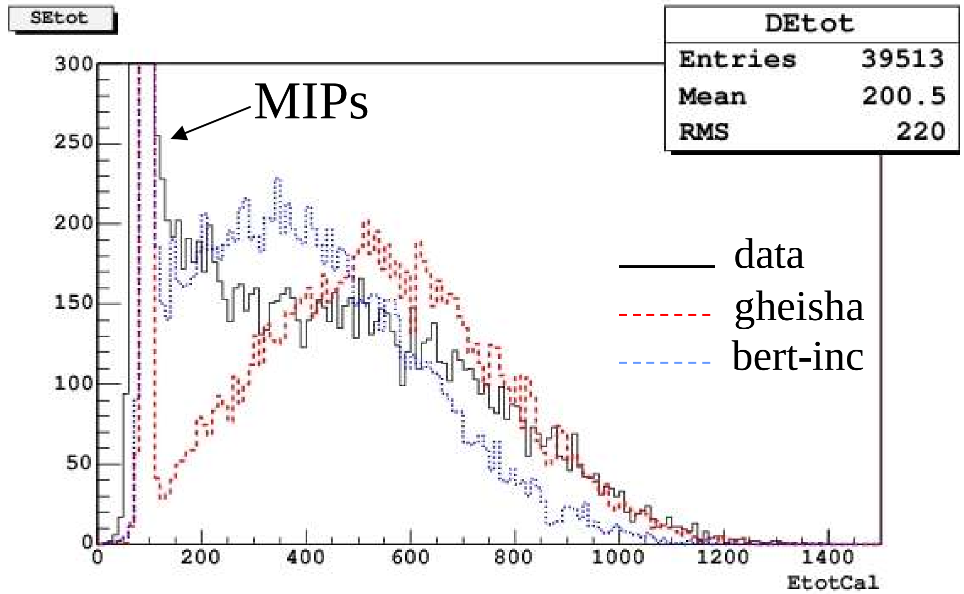
energy (MeV)

hit distributions

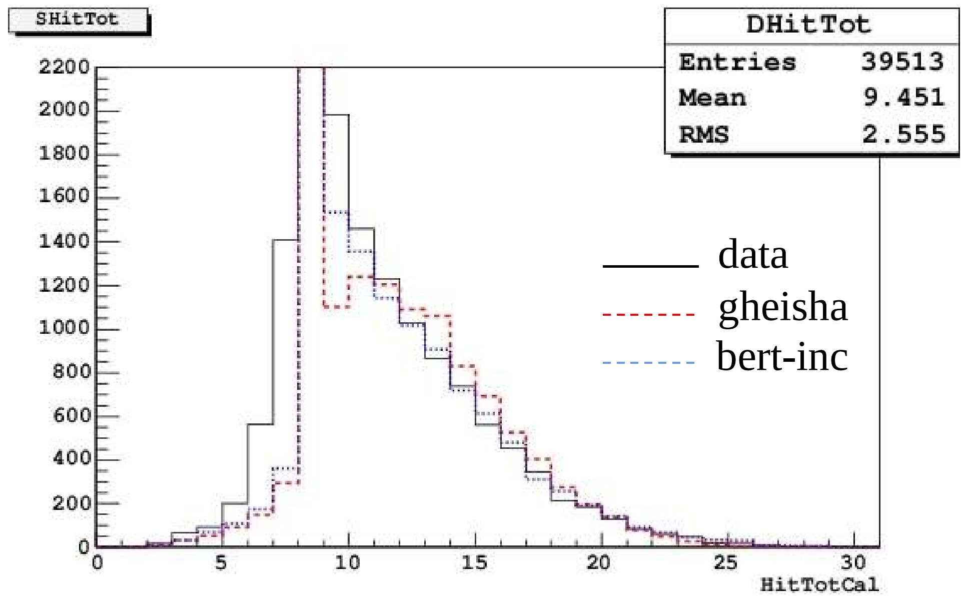


hit number

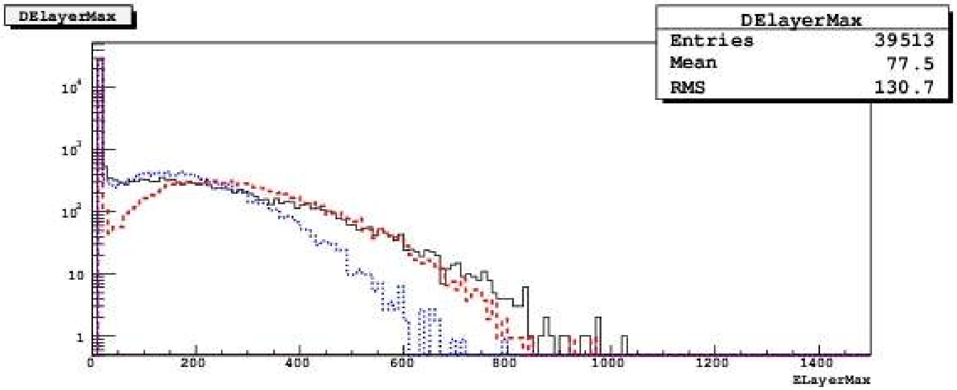
total deposited energy



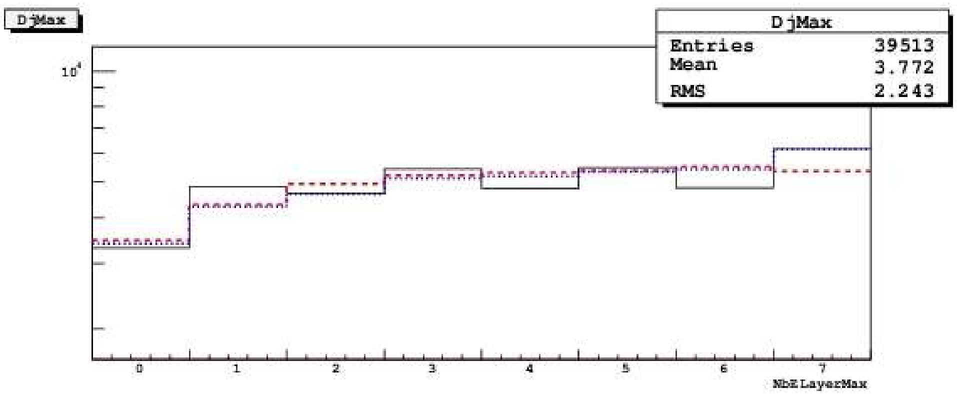
total hit multiplicity



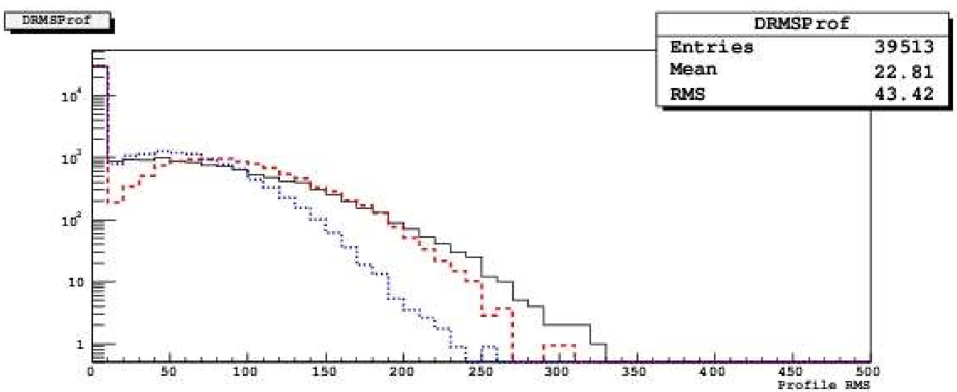
maximum deposited energy



layer with maximum deposited energy



RMS of deposited energies



data
gheisha
bert-inc

Conclusion

Reasonable overall agreement observed at 20 GeV/c.

At low energy, better agreement with Bertini's INC than with Gheisha.

Prospects:

GLAST is a « recognized experiment » at CERN.

This status was extended for three more years in 2004.

Experiment at SPS in 2006 considered by the CAL group

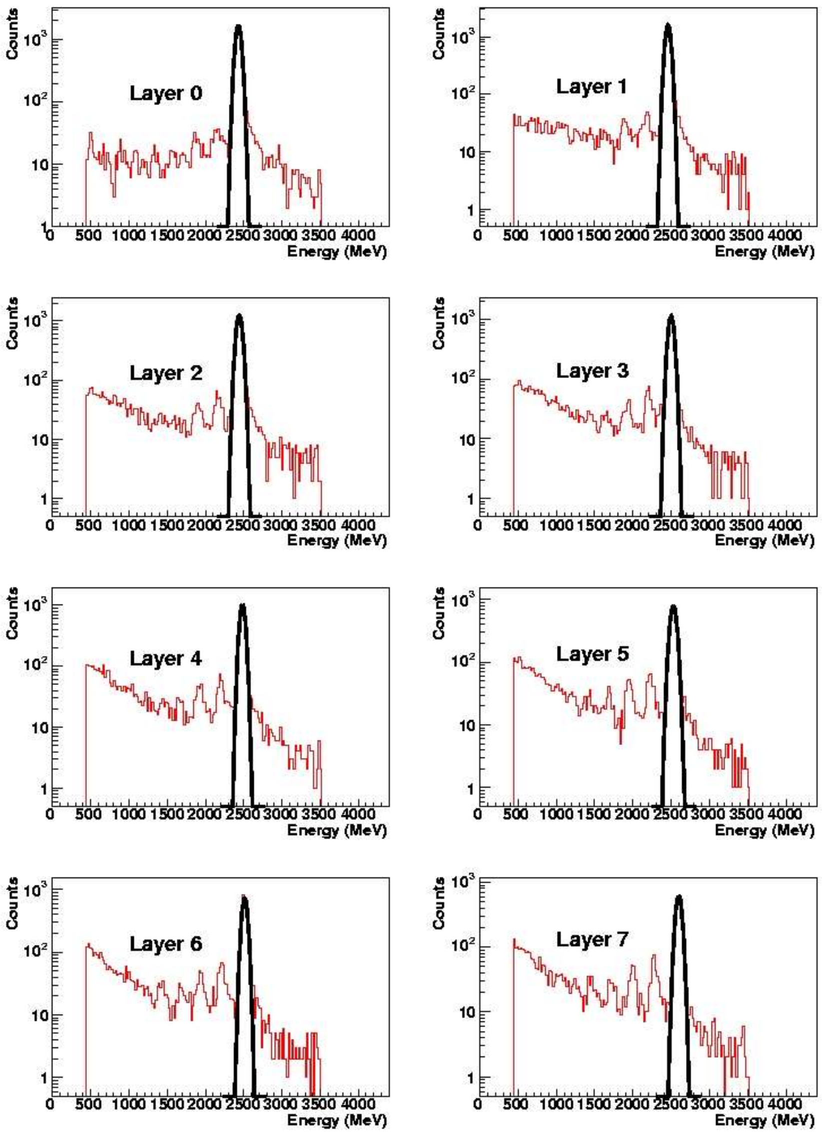
with the EM fitted with flight electronics.

Experiment at PS?

secondary beam: 1 GeV/c $< p <$ 3.5 GeV/c

Heavy ions

data (1.7 GeV/nucleon Si)



simutation results