Simulation studies on a combined calorimeter and magnetic spectrometer set-up

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Idea of the study

Define the next generation of R&D experiments for ILC detector

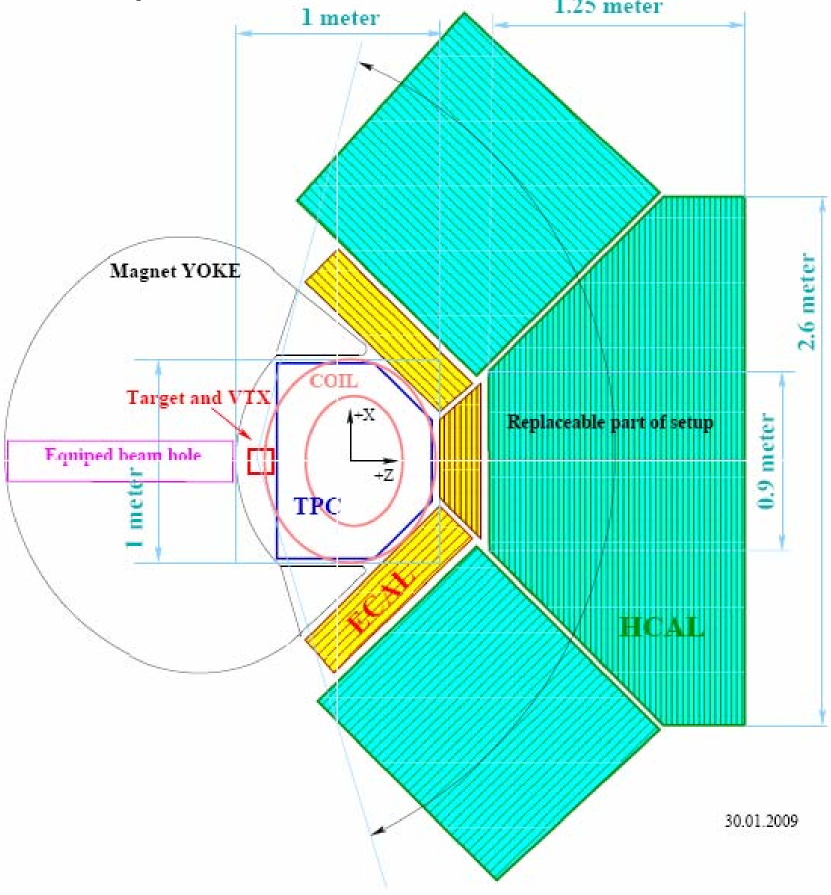
Option A: combine whole chain of ILD detectors at test beam

Project aim:

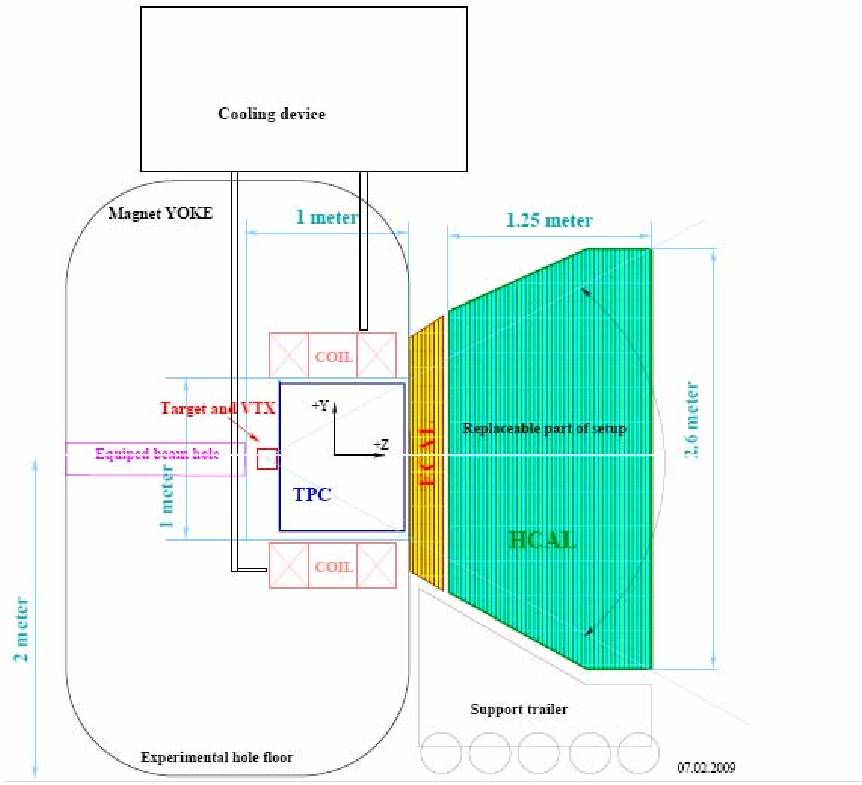
1. Experimental proof of Particle Flow Algorithm using pseudo–jets
2. Test full detector chain / DAQ / combined data analysis

Toy model geometry

Top view



Side view



Vertical magnetic field in about one cubic meter volume.

Feasibility analysis

Key question:

is the expected pseudo-jet energy resolution of this experiment sufficient to validate PFLOW ?

Simulate the energy spread and particle multiplicity at various stages:

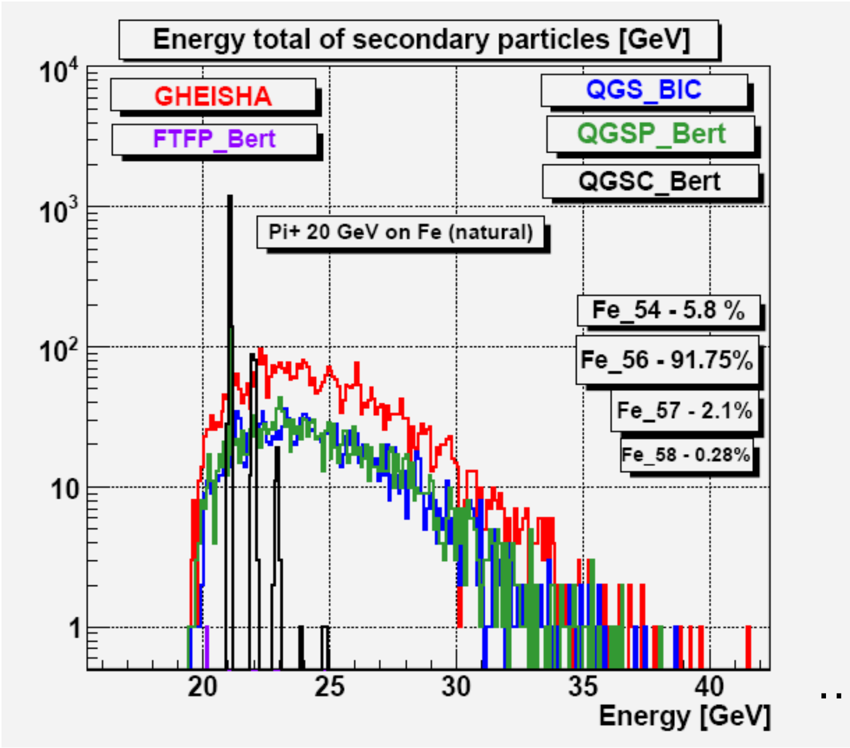
- after the first nuclear interaction in the target
- leaving the target
- at the calorimeter front
- of the reconstructed PFLOW objects (PFO)

After first interaction

Sum of total energy after first interaction of 20 GeV π on Fe (natural=4 isotopes)
- expected E_{sum} = 20 + 56 GeV
- visible effect of various isotopes - binding energy

Including residual nucleus

zoom in the kin. energy range



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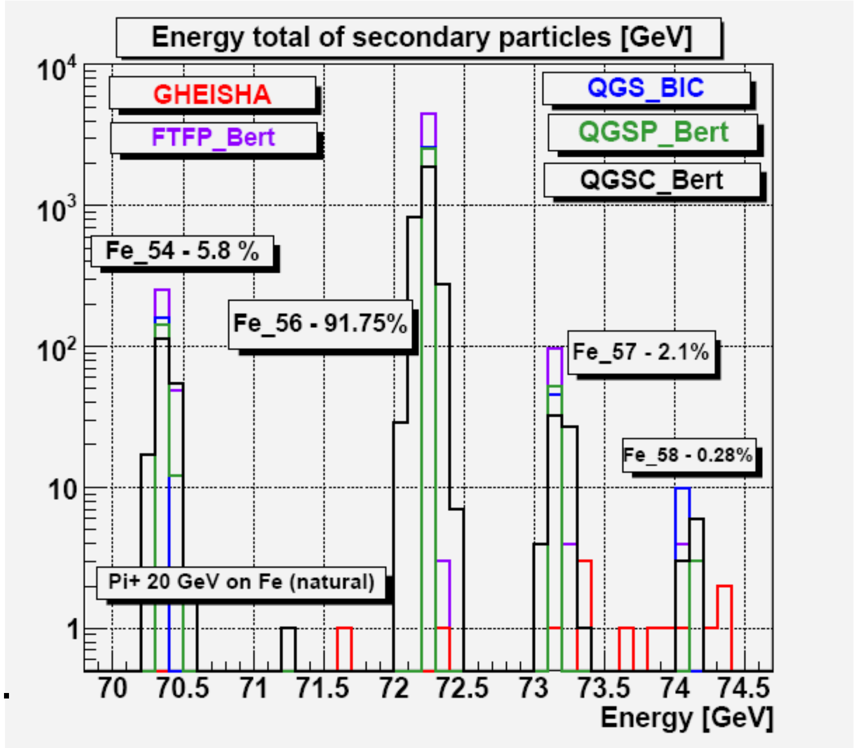
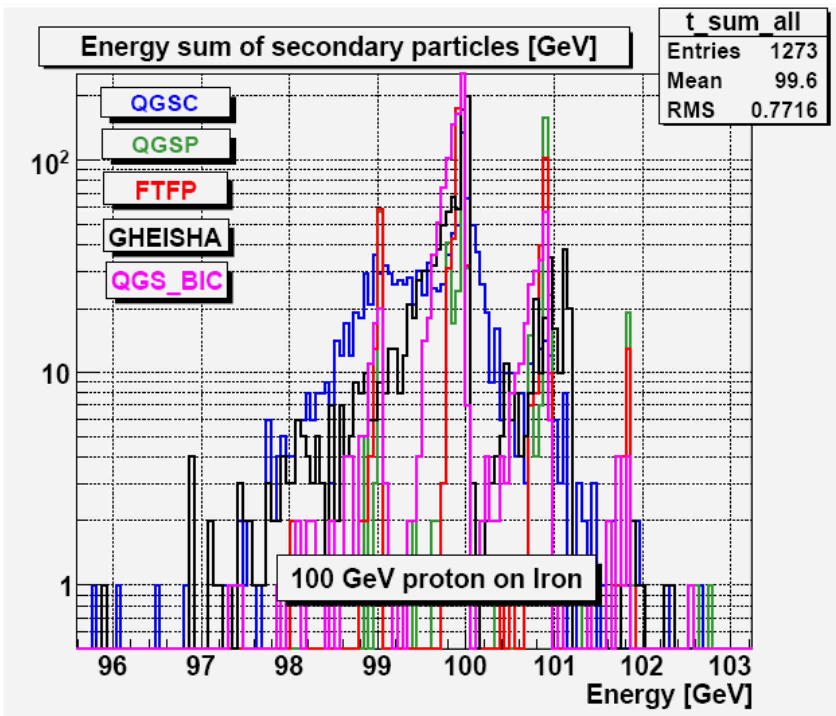
zoom in the total energy range

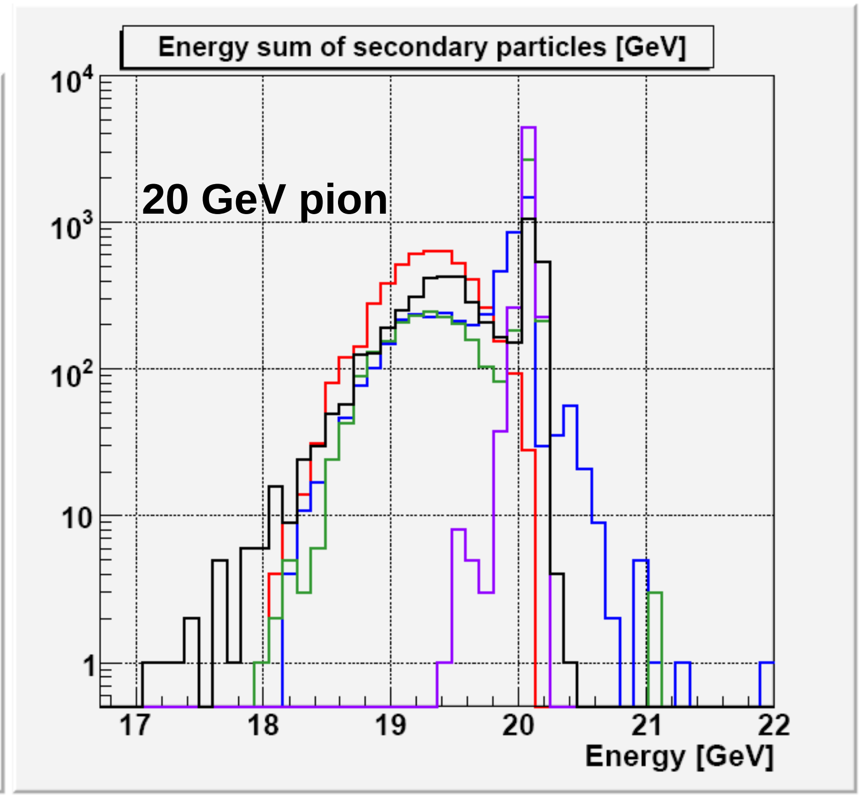


After a thin target

Thin target: Fe; radius = 5 mm; length = 10 mm
Thin target = ~1 nuclear interaction in target (minimum particle multiplicity)

Excluding residual nucleus

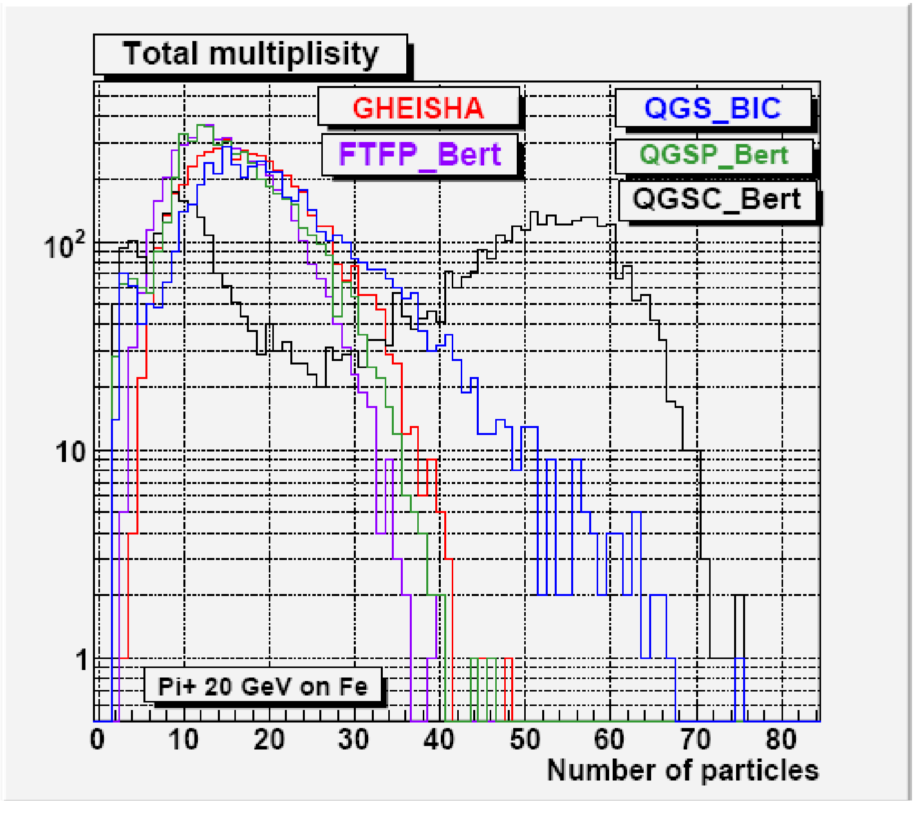


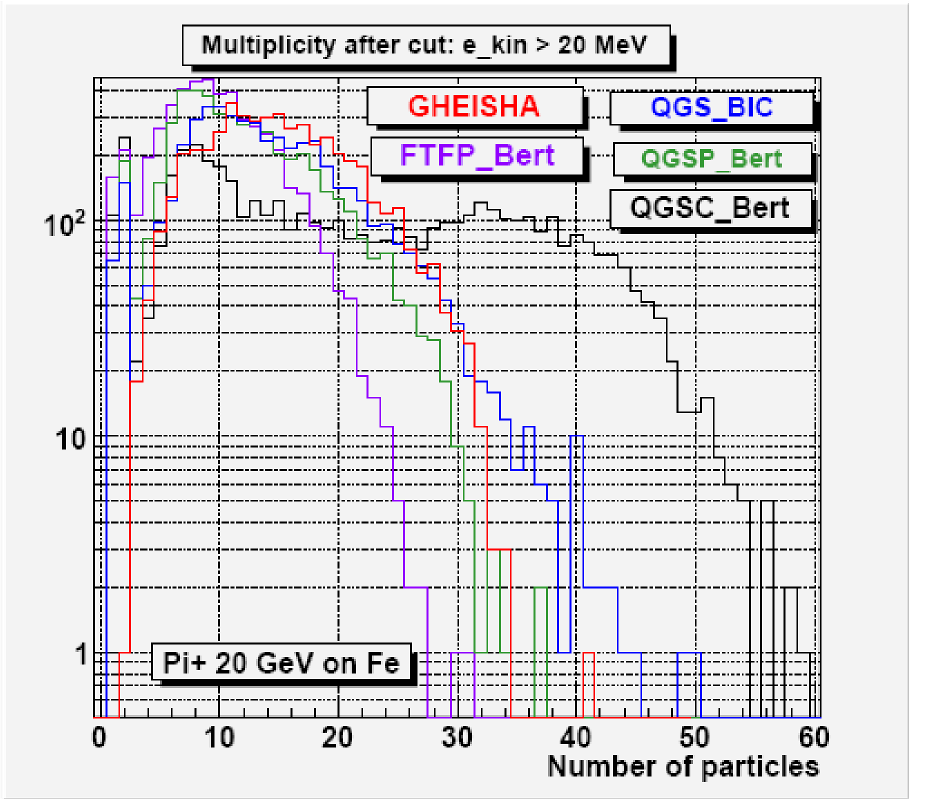


Different target isotopes give different initial (pseudo-jet) energy after target

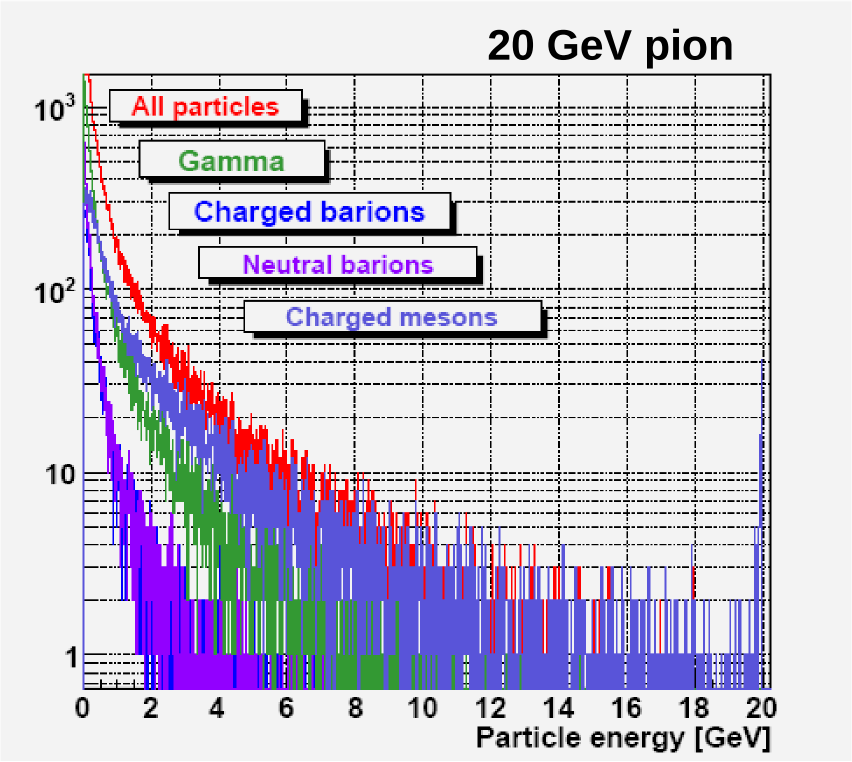
Multiplicity after a thin target

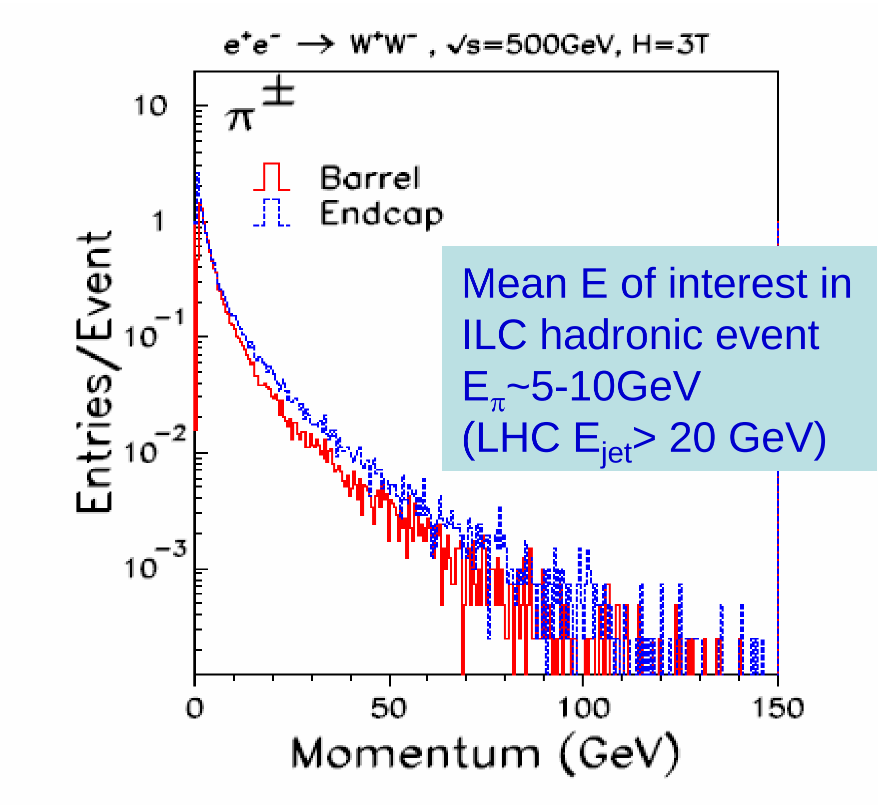
Different physic lists lead to very different predictions
➔ Hard to define pseudo-jet properties





Particle energy spectrum after thin target





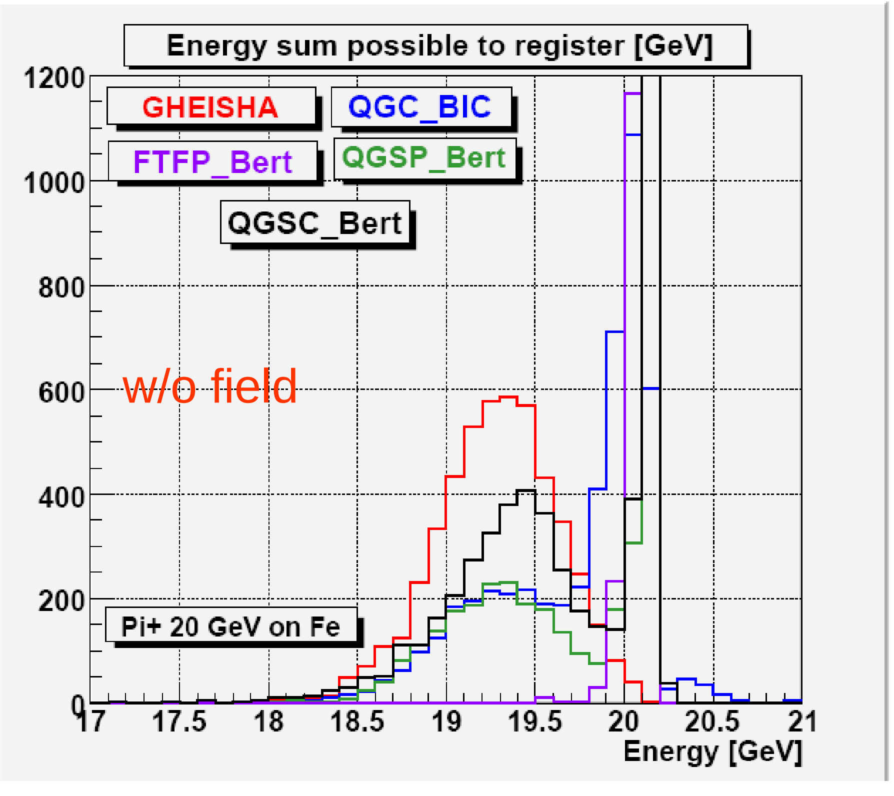
The pseudo-jet has to mimic a ILC event

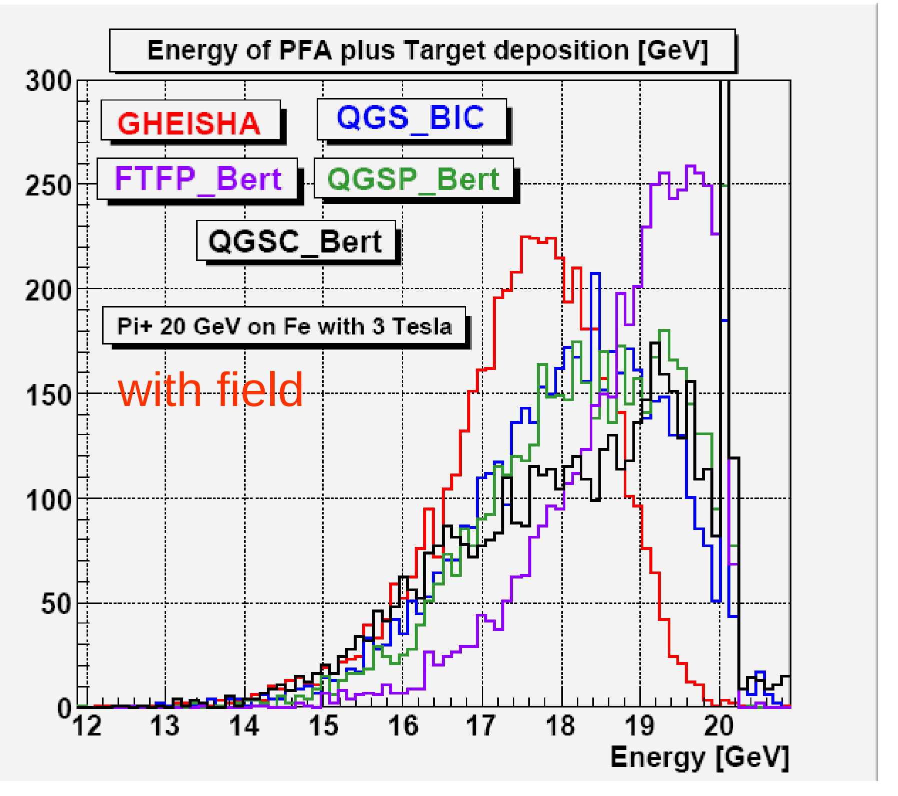
High bean energy will be needed to have average particle energy in pseudo-jet ~5-10 GeV

Energy at the calorimeter front face

Energy that can be measured by this experiment

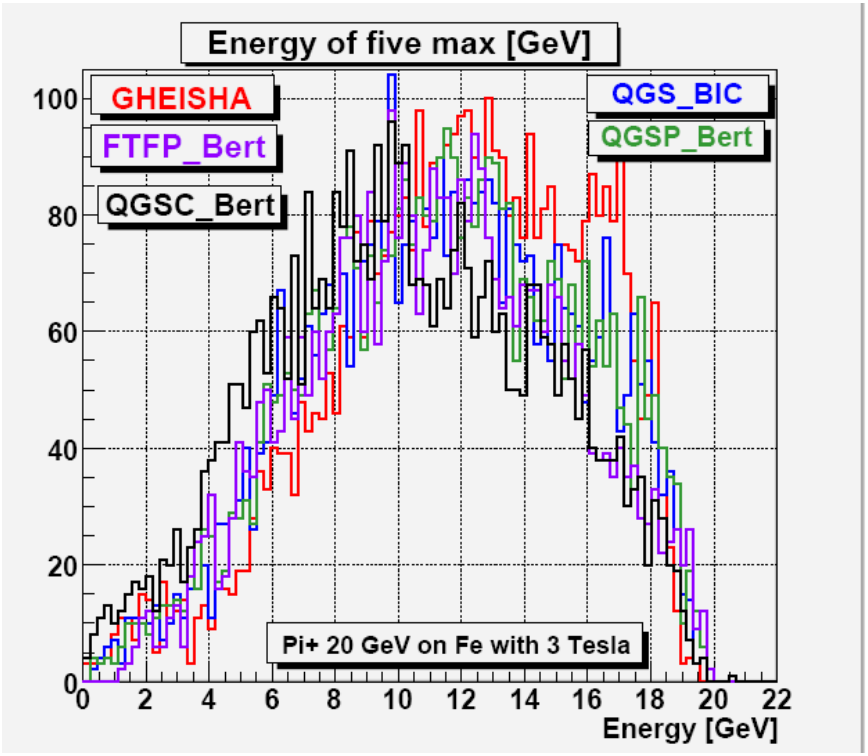
~ 1 GeV coverage inefficiency @ 20 GeV
Large spread in energy (1.5 – 3 GeV) , different for various models

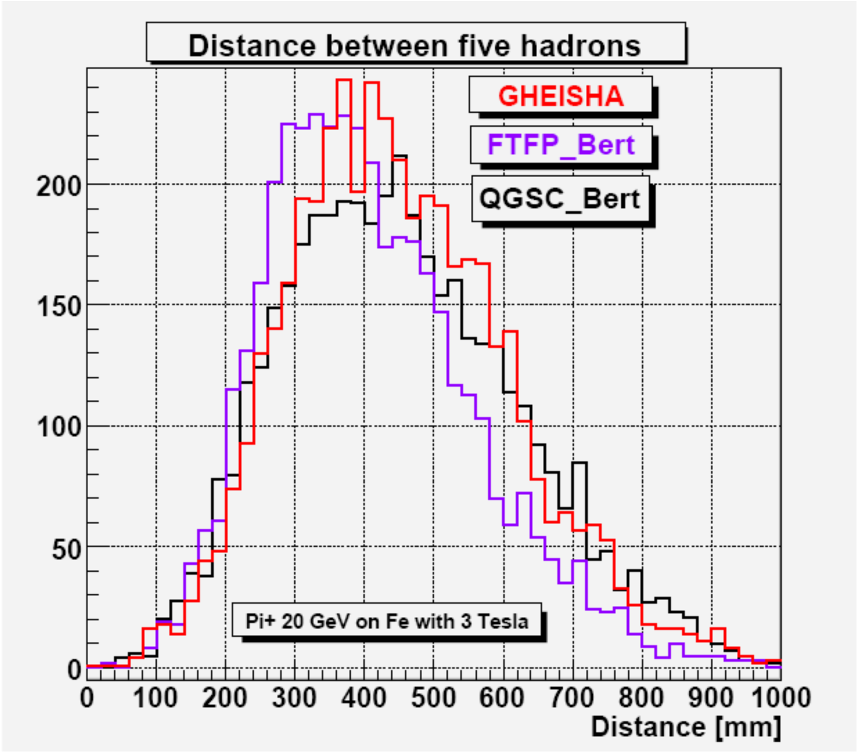




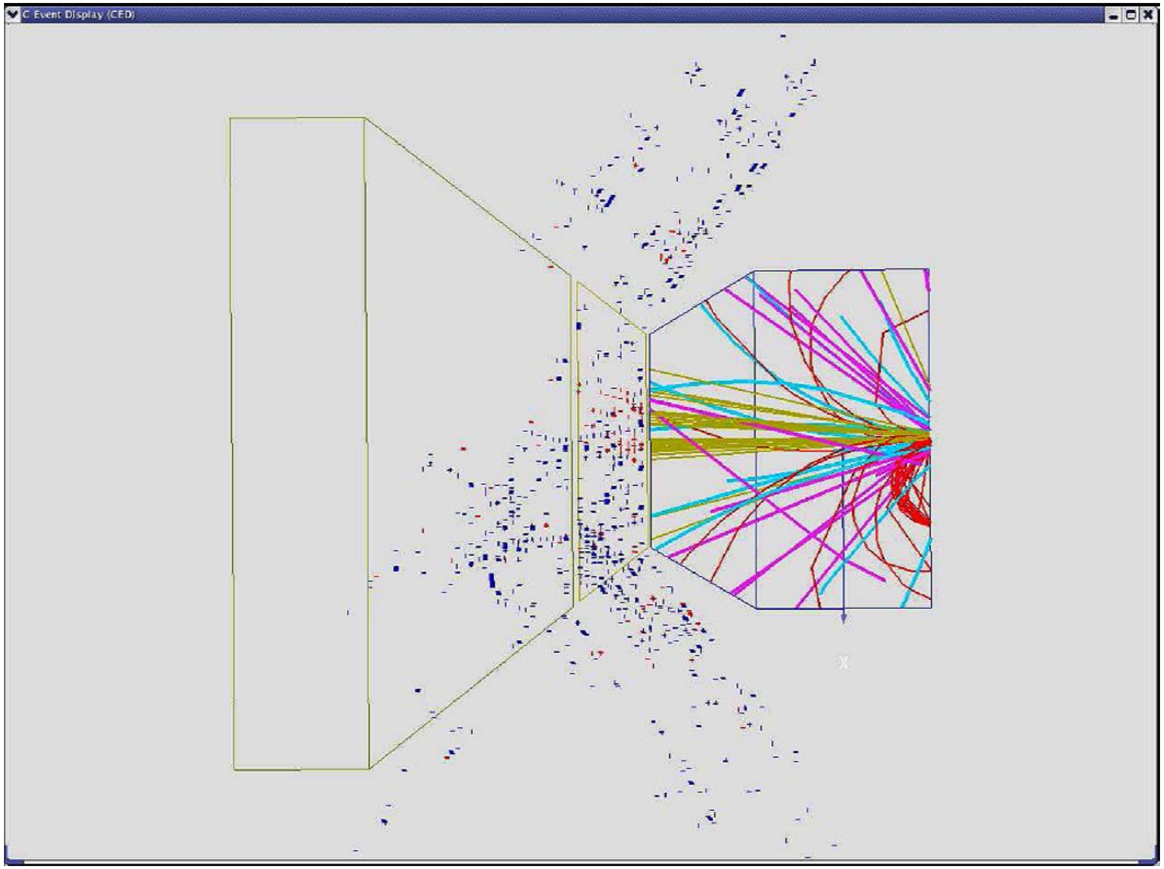
Five most energetic particles

Some good news:
Spectra and angular distributions of the most energetic particles are in a rather good agreement for all GEANT4 physics lists



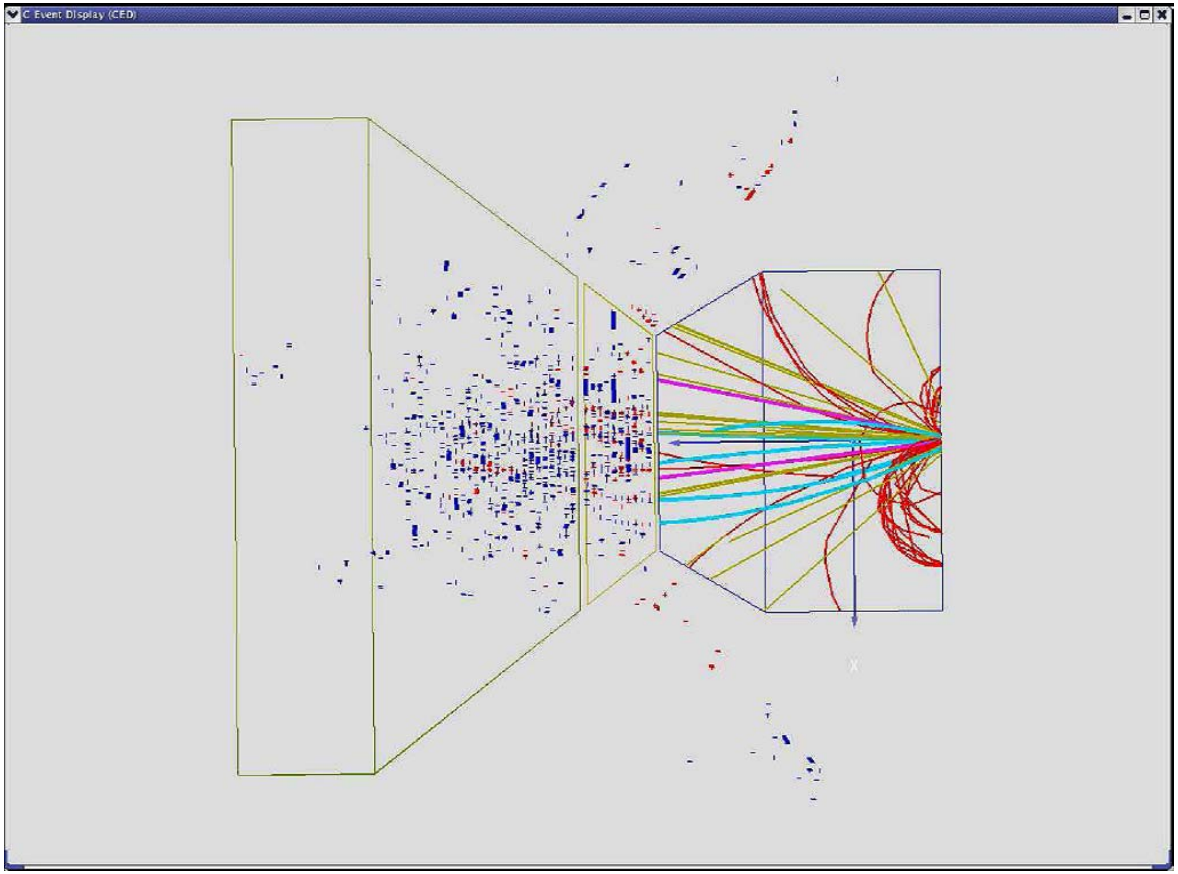


Simulated events



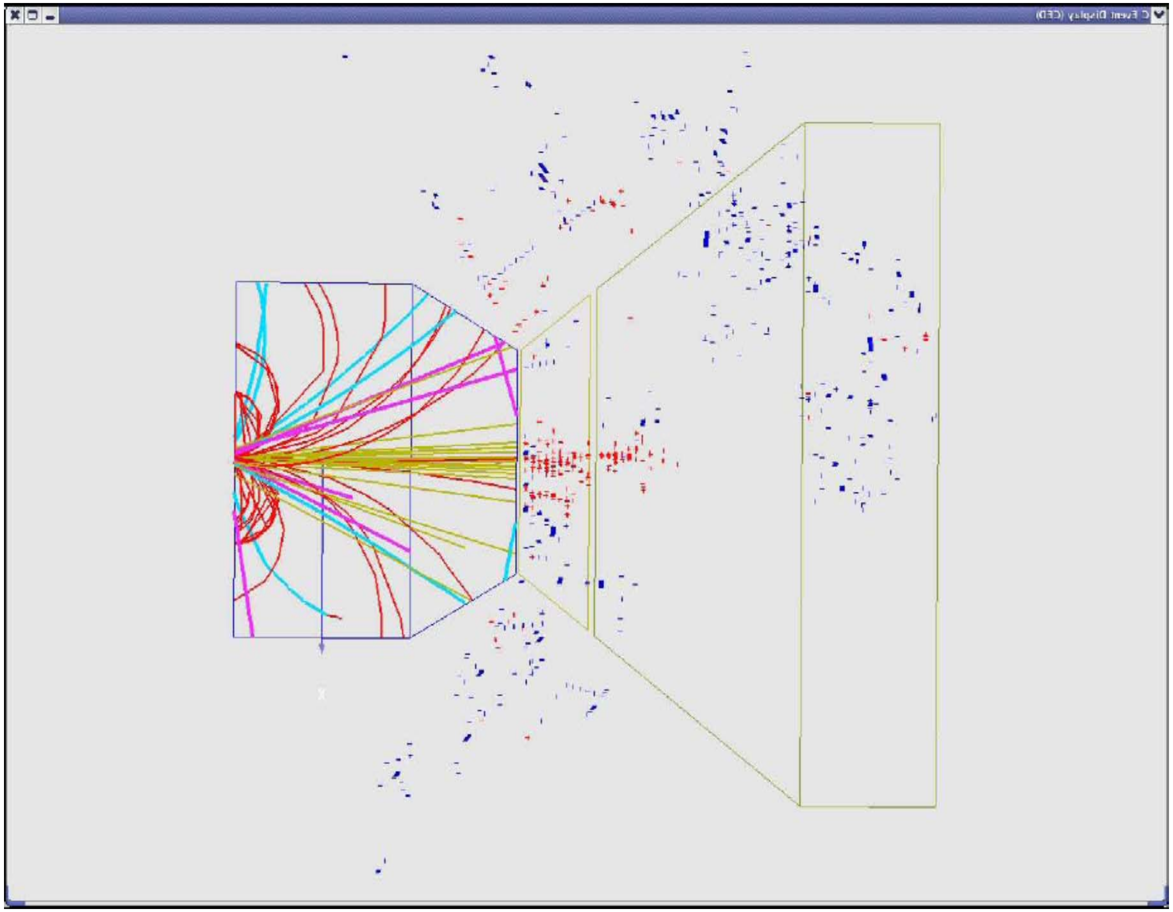
Pion+; 20 GeV; 0.8 Tesla; Thin target.

Simulated events



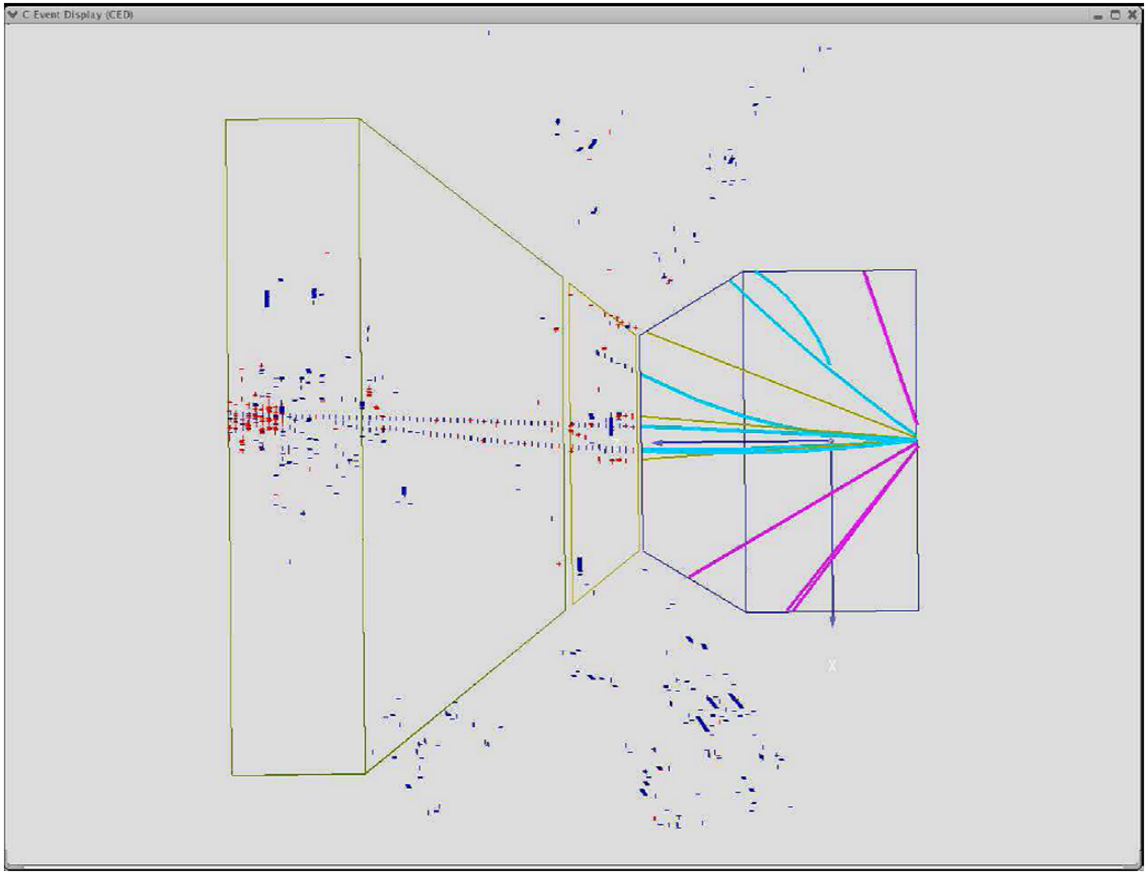
Pion+; 20 [GeV]; 0.8 Tesla; Thin target.
Energy lost in target = 1.818 [GeV]; Sum = 18.74 [GeV];
Sum of PFO energies = 16.93 [GeV]; E calo = 14.33 [GeV]

Simulated events



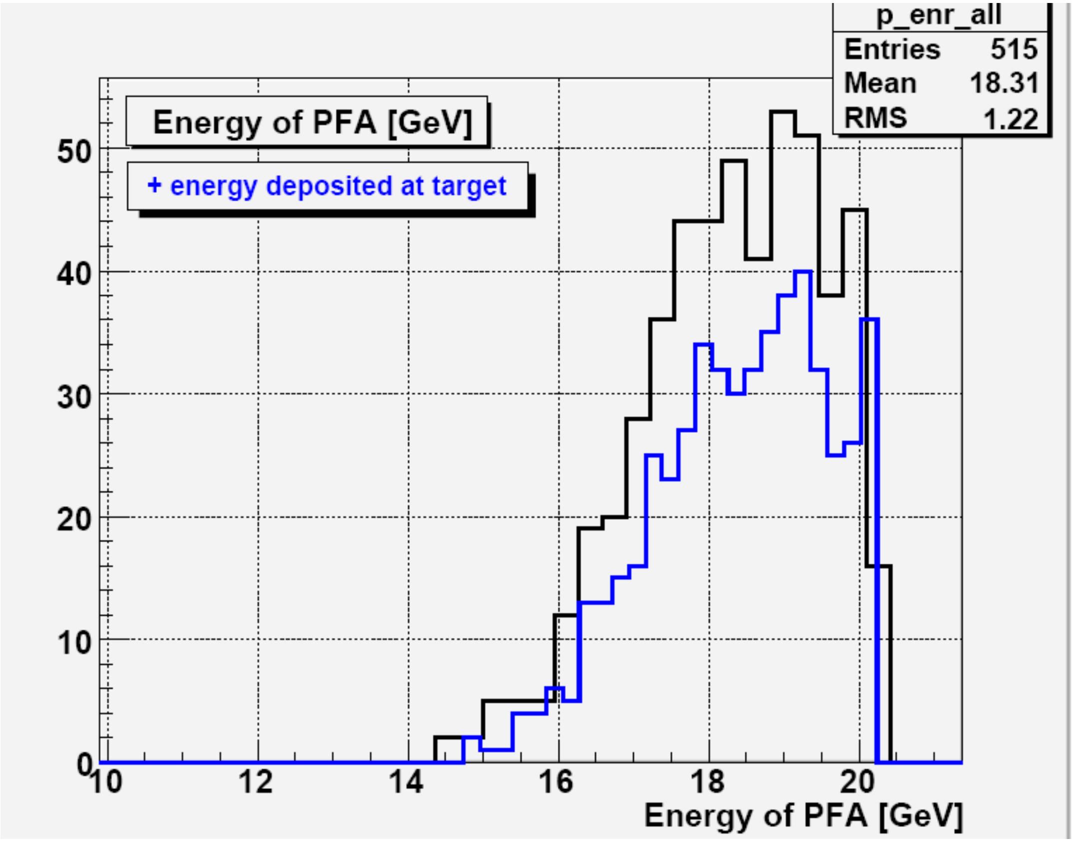
Pion+; 20 [GeV]; 0.8 Tesla; Thin target.
Energy lost in target = 3.042 [GeV]; Sum = 19.85 [GeV];
Sum of PFO energies = 16.81 [GeV]; E calo = 14.18 [GeV]

Simulated events



Pion+; 20 [GeV]; 0.8 Tesla; Thin target.
Energy lost in target = 0.3148 [GeV]; Sum = 19.64 [GeV];
Sum of PFO energies = 19.32 [GeV]; E calo = 13.49 [GeV]

Reconstructed PFLOW energy

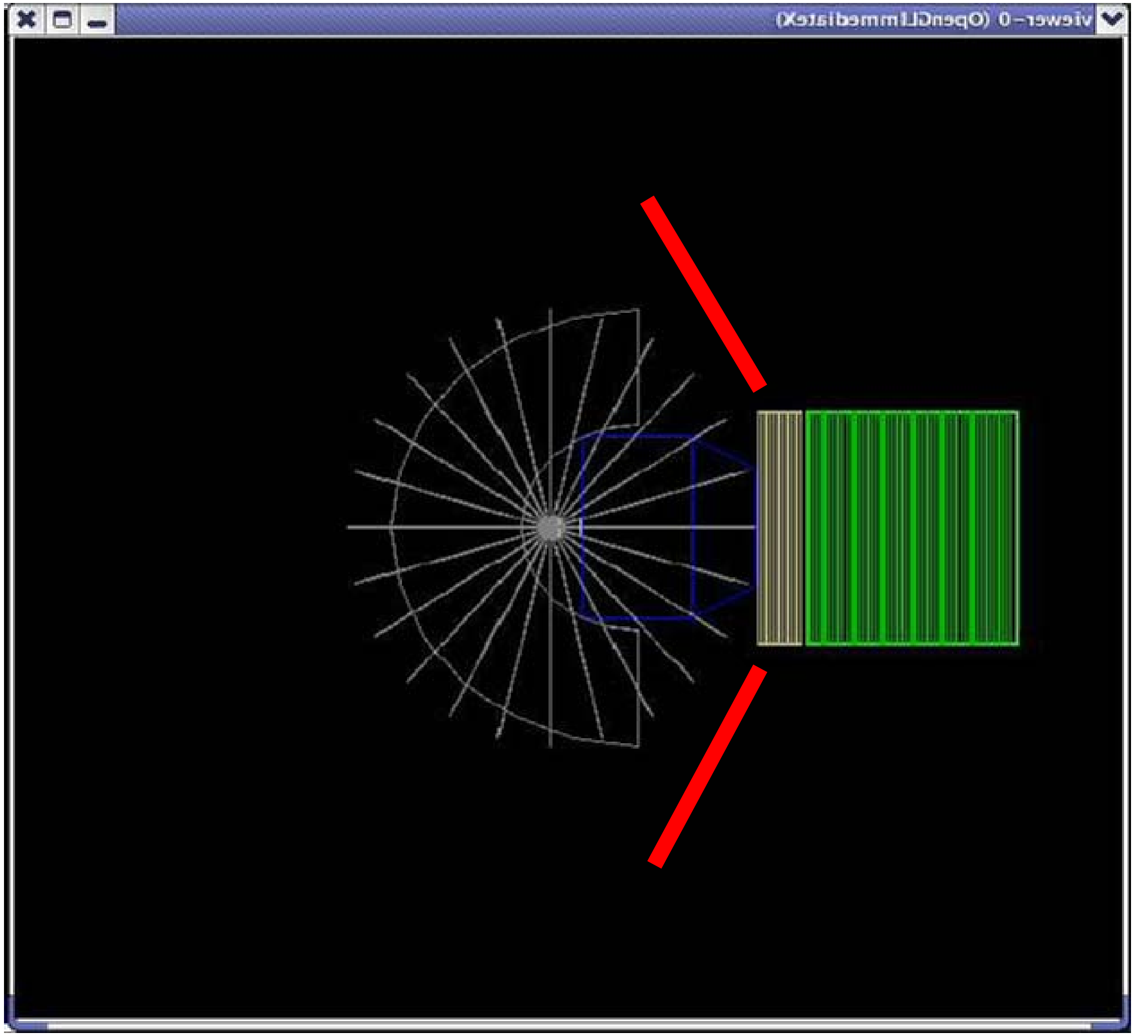


Assuming:
$\sigma(E)/E=30\%/\mathrm{sqrt}(E)$

$\sigma(20\ \mathrm{GeV}) = 0.33/4.5*20$
$= 1.3$ GeV

Expected PFA resolution for 20 GeV is about 1.3 GeV that is comparable with energy spread of pseudo–jet
➔This experiment could provide a test for PFA
BUT: remember large spread in model predictions !!!

Realistic experiment

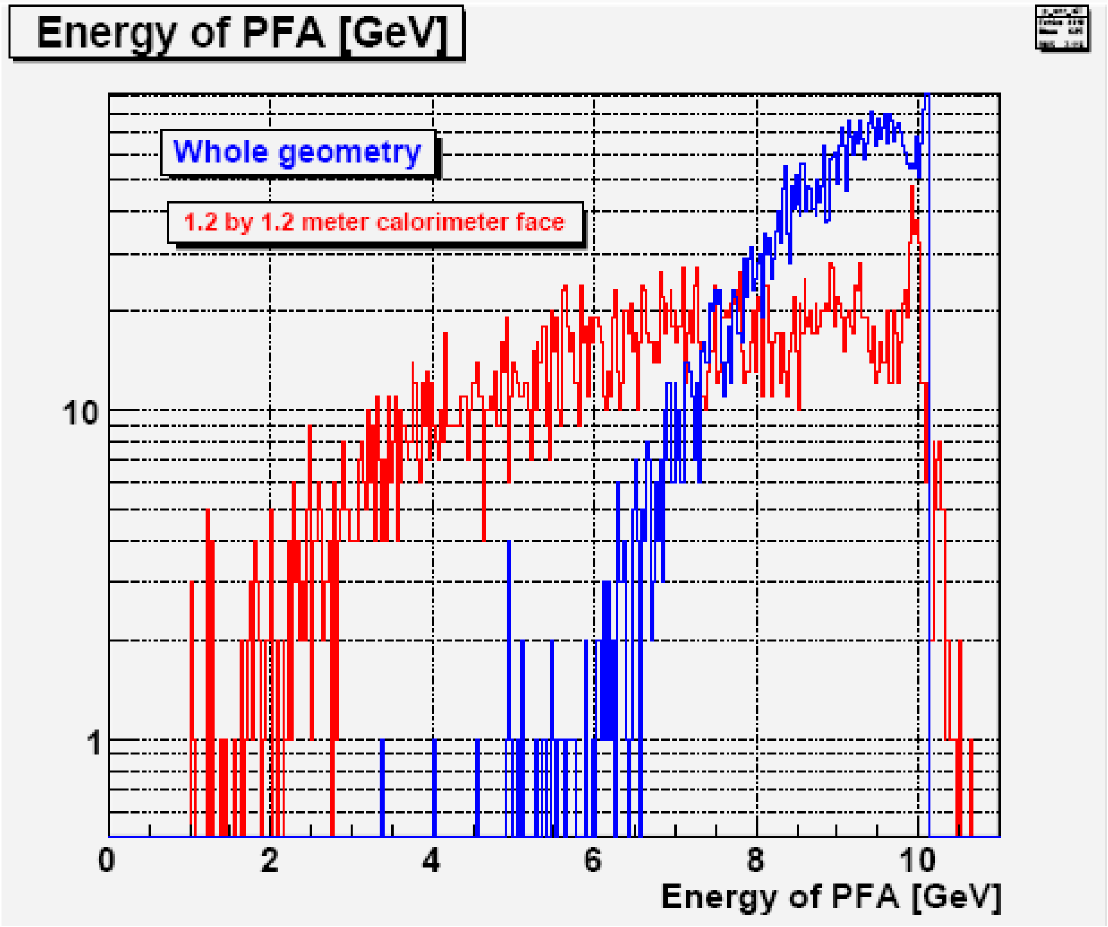


The detector shown
(~ eight times CALICE HCAL)
is too large and much too expensive

Realistic option:
CALICE like calorimeter with
1.2 x 1.2 m^2 size

Maybe add veto counters to
replace calo shoulders
to tag only forward pseudo-jets

Reconstructed energy with reduced geometry



Transversal leakage become too large for PFA
Expected PFA resolution for 10 GeV is of about 1 GeV
Pseudo-jet energy spread > 4 GeV ➔ hopeless

Conclusion

A combined calorimeter-spectrometer project is too large and too expensive to be realistic

Such a project will have a small running time because it needs small statistics to prove PFA

A device with smaller calorimeter will not be able to prove PFA

Some open issues for optimization studies could be:

- replace large tracker with more compact silicon tracker
- add shoulder veto counters to simulation

In the end one has to unfold the "jet energy spread“ by simulations

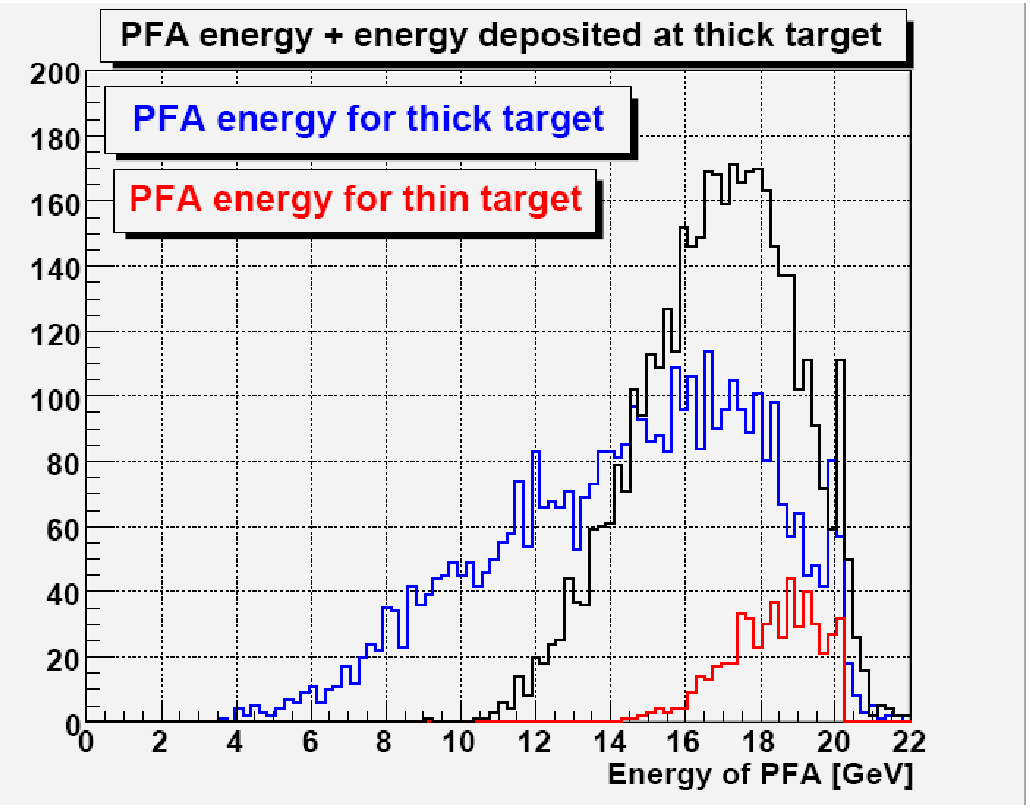
➔ Only indirect test of PFlow possible

The real problem of this type of physics is to measure inelastic exclusive hadron cross–sections on nuclei for intermediate energy range

➔ Better design an ad hoc nuclear physics experiment

Backup slides

Thin vs thick targets



"Thin": 5 mm diameter 10 mm length

"Thick" here is 50 mm diameter 100 mm length

Energy loses in thick target could be "compensate" using sensitive targets
Number of interactions in thin target much less compared to thick one