Shower Models for Calorimeter

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Motivation

- Update the ElectroMagnetic Shower Models
- Update the Hadronic Shower Models

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- Use the same setup as our previous prototype
  - Calibrate the absorbed energy
    - Compare the energy resolution
    - Check the Energy Compensation
    - Check the Missing Energy
  - Suggest the best Shower models for Jupiter

EM Shower Models

- LCIonPhysics, LCBosonPhysics, LCLeptonPhysics, LCDecayPhysics
  - Date: 7 July 2004
  - Author: *D.H. Wright (SLAC)*
  - http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/ilc/physlistdoc.html
- Standard electromagnetic process
  - Default in the physics_lists in GEANT4 7.0.p1

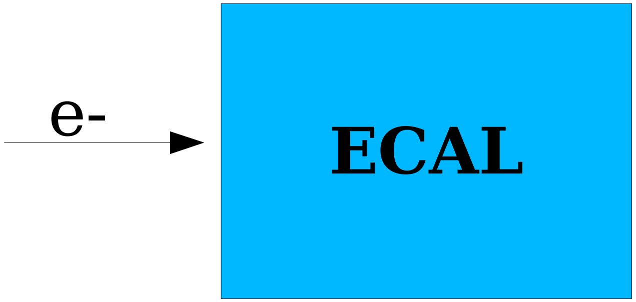
Standard EM Processes

- Processes of gamma, electron, and positron interactions with media was traditionally called Electromagnetic Process (EM)
- Hadron interaction with atomic electrons are also EM

- Gamma
  - Photo-electric effect
  - Compton scattering
  - e+e- pair production
  - μ+μ- pair production
- Electron and positron
  - Ionization
  - Bremsstrahlung
  - Positron annihilation
- Muons
  - Ionization
  - Bremsstrahlung
  - e+e- pair production
- Hadrons
  - Ionization
- Ions
  - Ionization
- Multiple scattering

Standalone Setup

Setup the same lead/plastic scintillator sampling calorimeter written in **<u>NIMA 487 (2002) 291-307</u>**
lead thickness is 8mm; scintillator thickness is 2 mm



18 layers
$\sim 27\ \chi_0$

We compare the energy resolution between:

- Data
- MC (GEANT4 <u>Standard</u> EM Process)
- MC (LC[<u>Ion,Boson,Lepton,Decay</u>] Physics +GEANT4 Standard EM Process)

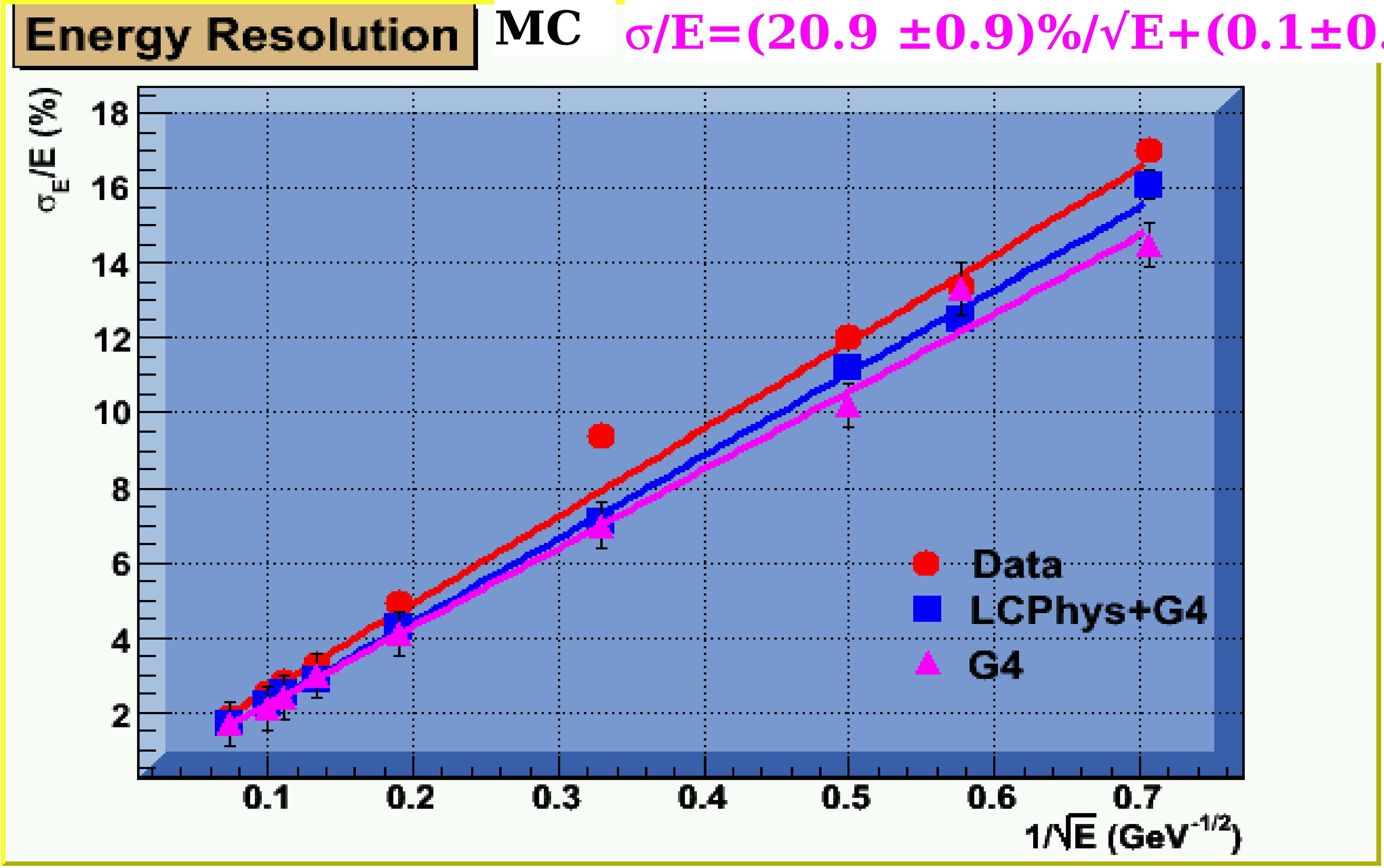
Check Point: Data and MC results should be close enough

Details: Geant4 7.0.p1; max step length = 1 mm (save CPU Time); range cut = 10 micron (save secondary particles)

Compare the MC & Data (e-)

Data $\sigma/E=(22.1 \pm 0.4)\%/\sqrt{E}+(0.0\pm 0.1)\%$

MC $\sigma/E=(20.9 \pm 0.9)\%/\sqrt{E}+(0.1\pm 0.3)\%$



Hadronic Shower Models

- **LCHadronPhysics** *(2004 by D.H. Wright, SLAC)*
  - *http://www.slac.stanford.edu/comp/physics/geant4/slac_physics_lists/ilc/physlistdoc.html*
- **In GEANT4 PhysicsList**
  - **QGSP 2.8** *(2002 by J.P. Wellisch)*
  - **LHEP 3.7** *(2002 by J.P. Wellisch)*
  - **FTFP 2.8** *(2002 by J.P. Wellisch)*
  - **QGSC 2.9** *(2002 by J.P. Wellisch)*

Packaging 2.4 *(2005 by G. Cosmo)*

http://cmsdoc.cern.ch/~hpw/GHAD/HomePage/geant4.6.1/calorimetry/index.html

Hadronic Shower Models

- **LHEP**, is the fastest, when it comes to CPU. It uses the LEP and HEP parametrized models for inelastic scattering.
- **QGSP**, theory driven modeling. It employs quark gluon string model for the 'punch-through' interactions of the projectile with a nucleus, the string excitation cross-sections being calculated in quasi-eikonal approximation.
- **QGSC**, is as QGSP for the initial reaction, but uses chiral invariant phase-space decay (multi-quasmon fragmentation) to model the behavior of the system's fragmentation.
- **FTFP**, is similar to QGSP for the treatment of the fragmentation, but the string excitation/fragmentation is changed from quark-gluon string model to a diffractive string excitation.

Standalone Setup

Setup the same lead/plastic scintillator sampling calorimeter written in **NIMA 487 (2002) 291-307**
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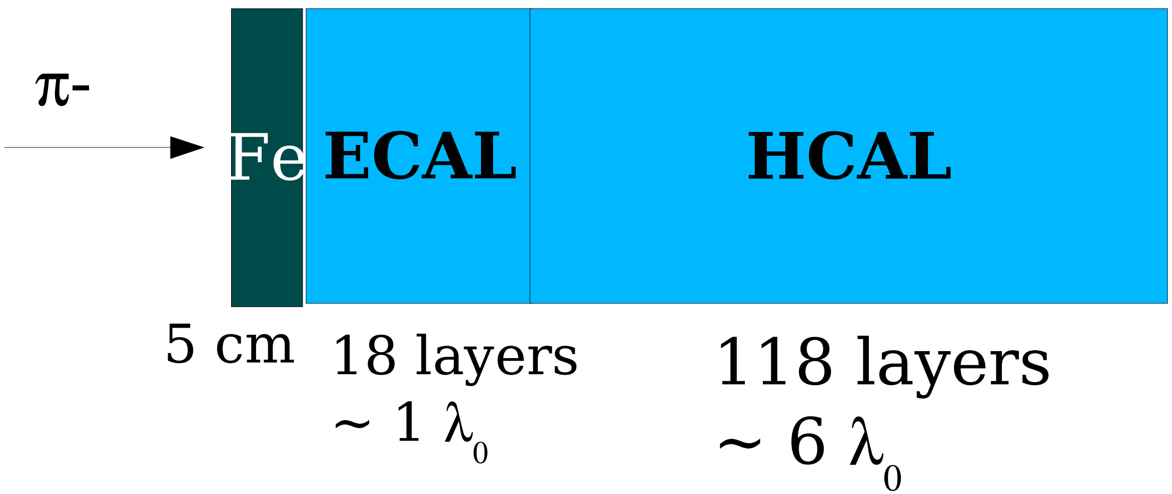


(energy higher than 10 GeV setup)

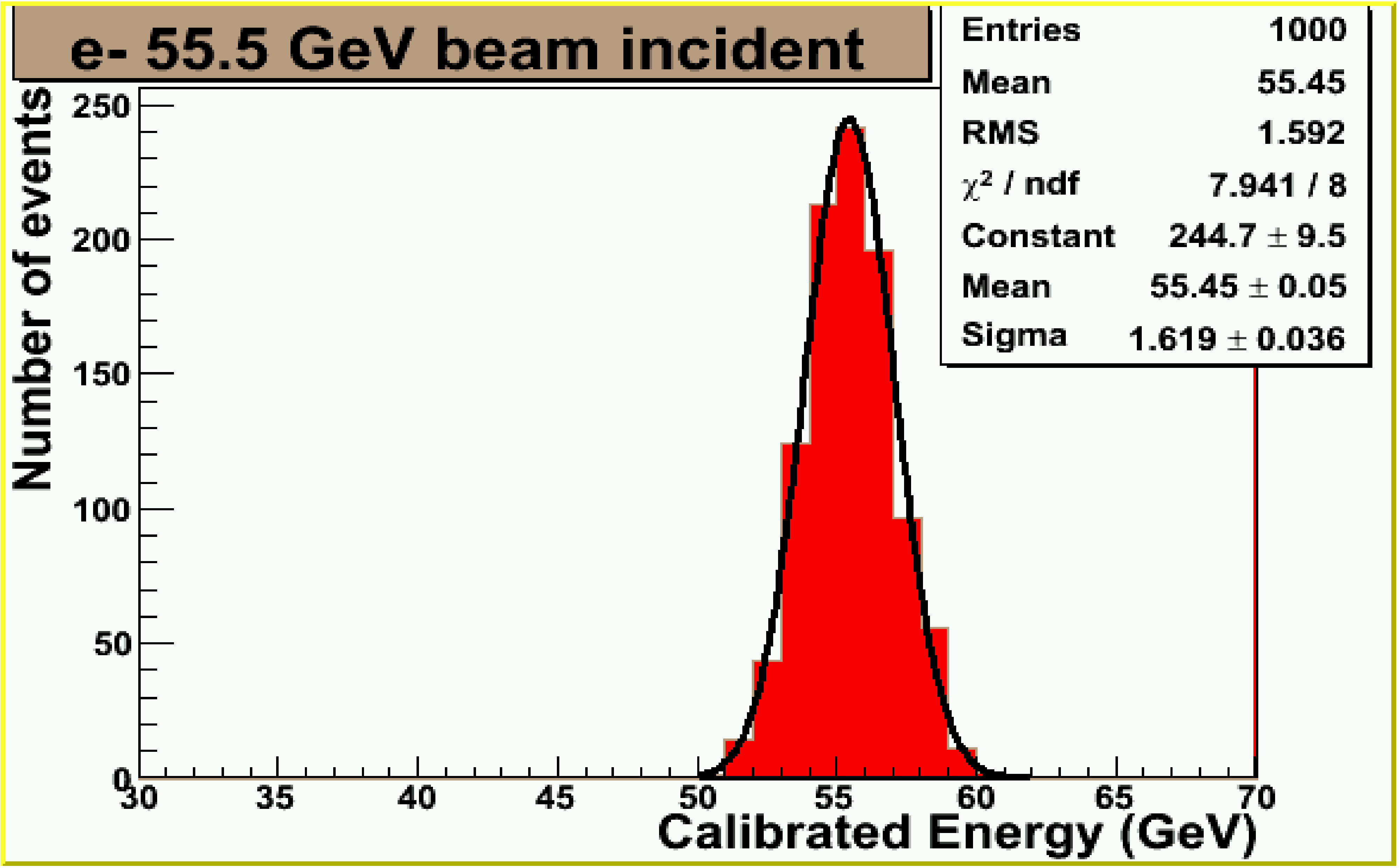
We compare the energy resolution between:

- Data
- LCHadronPhysics
- QGSP
- LHEP
- FTFP
- QGSC

Check Point: Data and MC results should be close enough

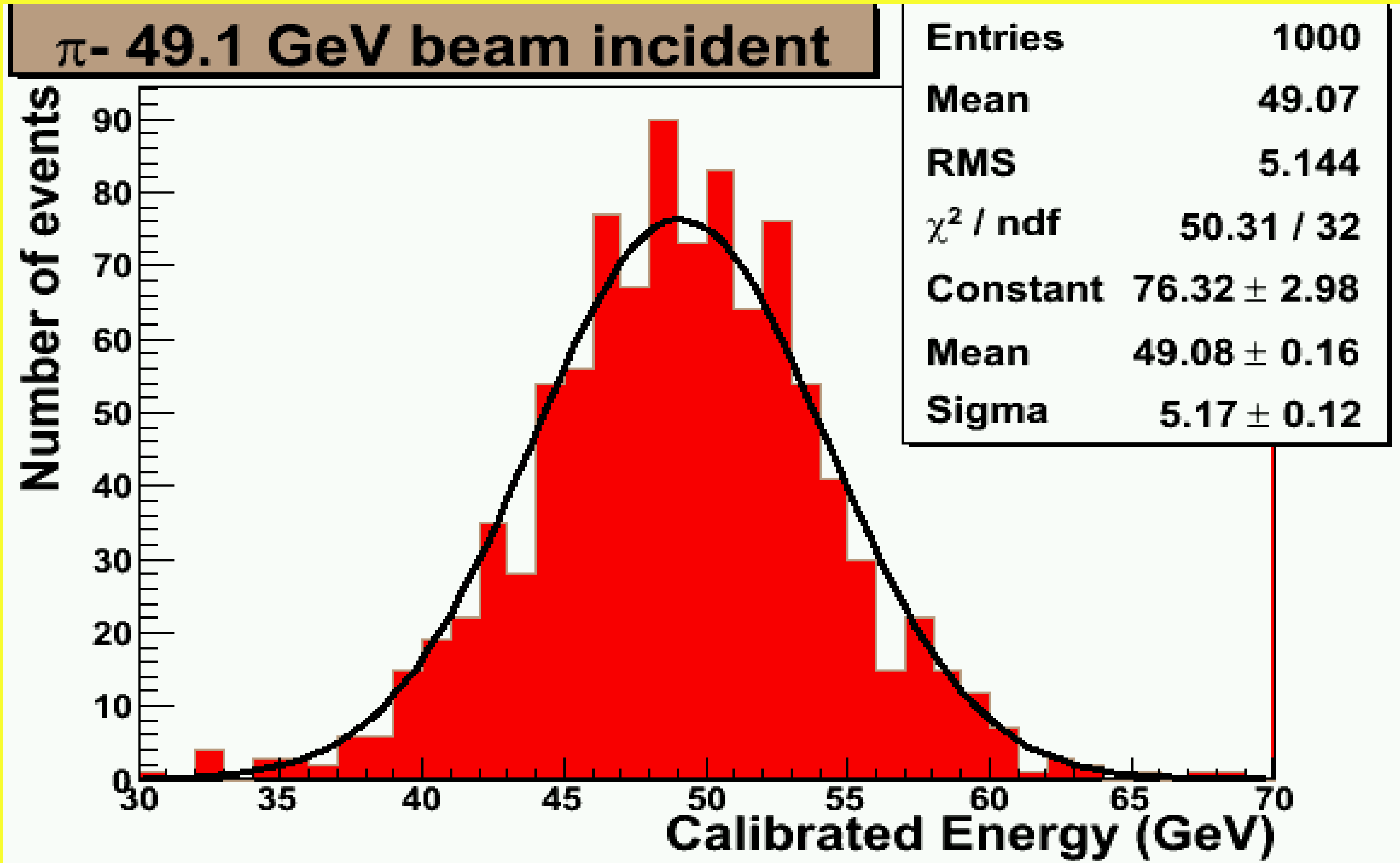
Details: Geant4 7.0.p1; max step length = 1 mm (save CPU Time); range cut = 10 micron (save secondary particles); energy lower than 10 GeV case, there will be no Fe block in front of the ECAL.

Energy Calibration (e-)

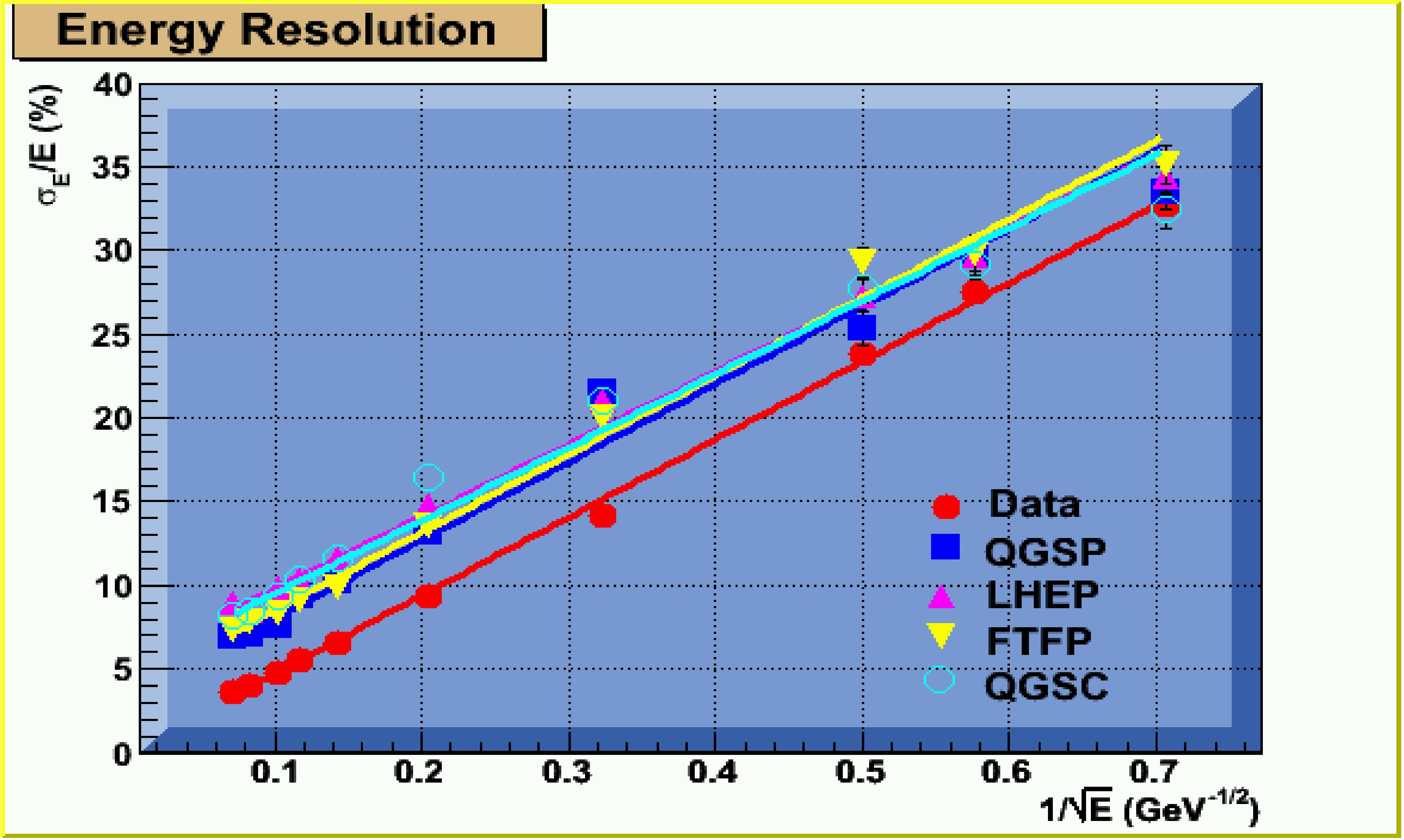


Energy Calibration (π-)

QGSP



Compare the MC & Data (π-)



Compare the MC & Data (π-)

Data		$\sigma/E = (46.6 \pm 0.4)\%/\sqrt{E} + (0.1 \pm 0.1)\%$
MC	**QGSP**	$\sigma/E = (46.5 \pm 1.0)\%/\sqrt{E} + (3.4 \pm 0.2)\%$
	FTFP	$\sigma/E = (46.8 \pm 1.0)\%/\sqrt{E} + (3.8 \pm 0.2)\%$
	QGSC	$\sigma/E = (43.7 \pm 1.0)\%/\sqrt{E} + (5.1 \pm 0.2)\%$
	LHEP	$\sigma/E = (43.3 \pm 1.0)\%/\sqrt{E} + (5.4 \pm 0.2)\%$

- **LCHadronPhysics** (sometimes it makes GEANT4 crash, especially when the energy is higher than 100 GeV)
- We prefer to use the **QGSP** model as our Hadronic shower model.
- We don't know why the fitting **constant** term can't fit the data well.

Error Message (LCHadronPhysics)

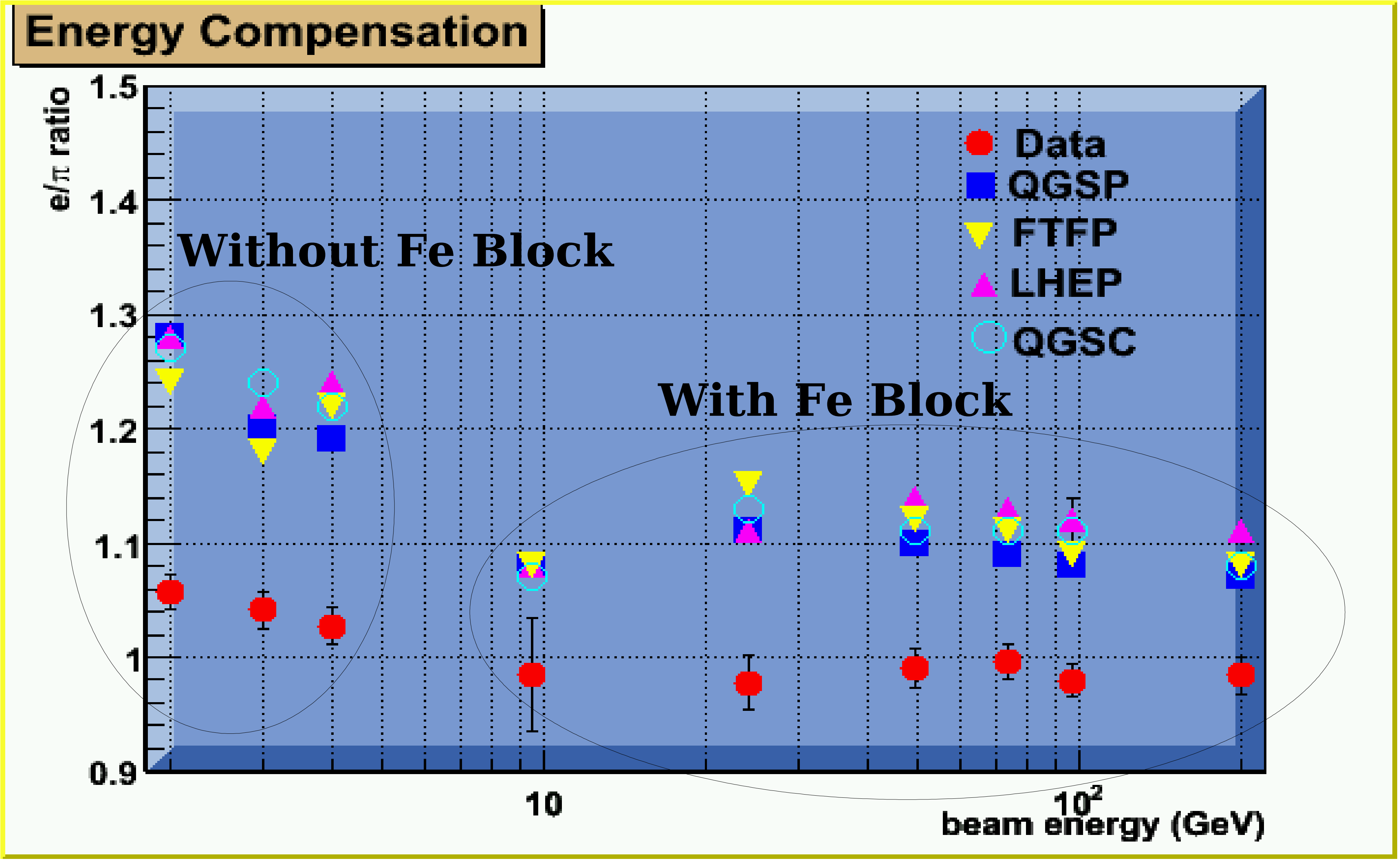
```
*** G4Exception : 007
      issued by : G4HadronicProcess
ChooseHadronicInteraction failed.
*** Fatal Exception *** core dump ***

*** G4Exception: Aborting execution ***
```

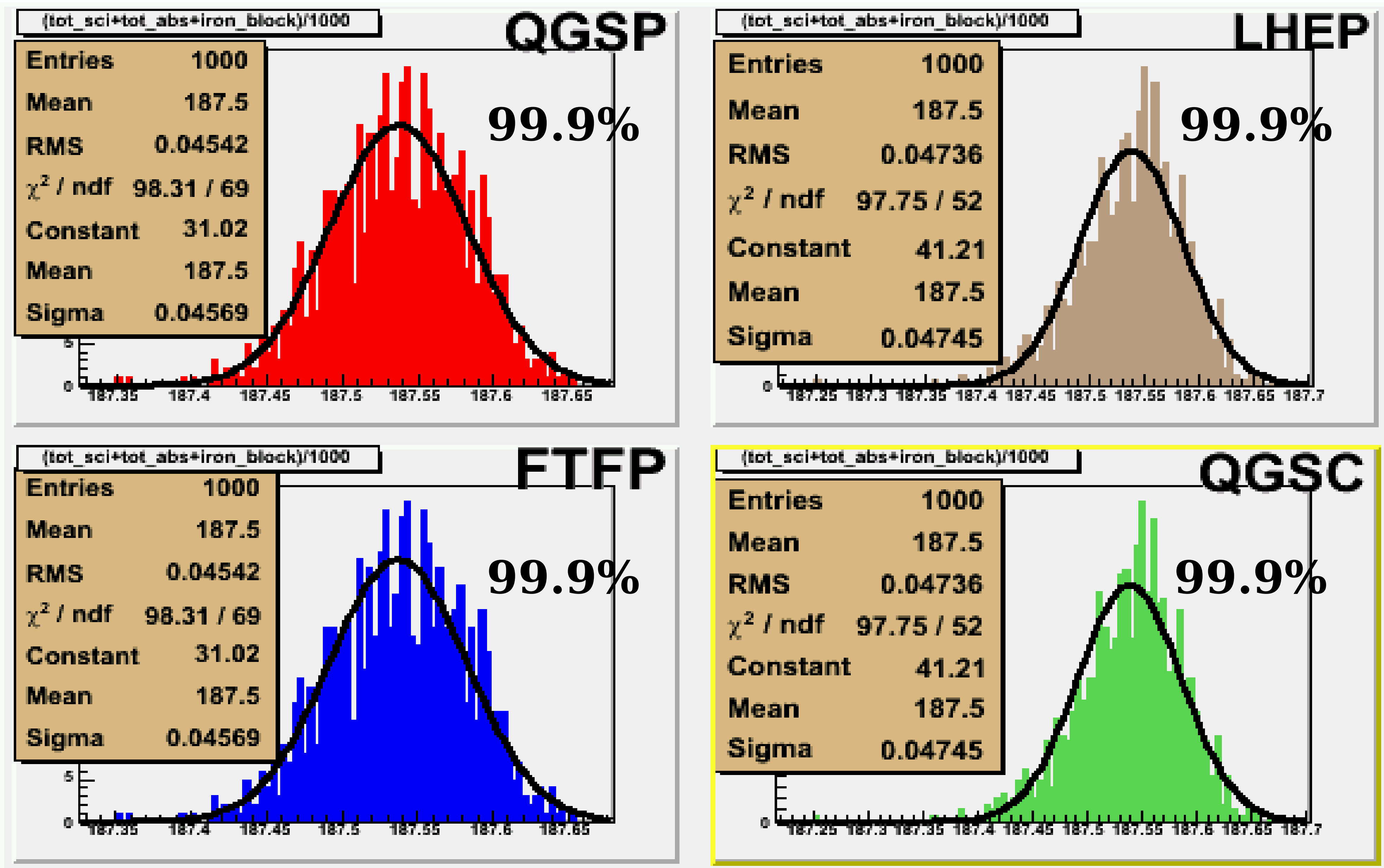
In src/G4EnergyRangeManager.cc, line 118:
===> GetHadronicInteraction: Energy ranges of two models fully overlapping
Unrecoverable error for:
- Particle energy[GeV] = 47.417756
- Material = Lead
- Particle type = proton

In src/G4EnergyRangeManager.cc, line 110:
===> GetHadronicInteraction: No Model found
Unrecoverable error for:
- Particle energy[GeV] = 48.65899
- Material = Lead
- Particle type = gamma

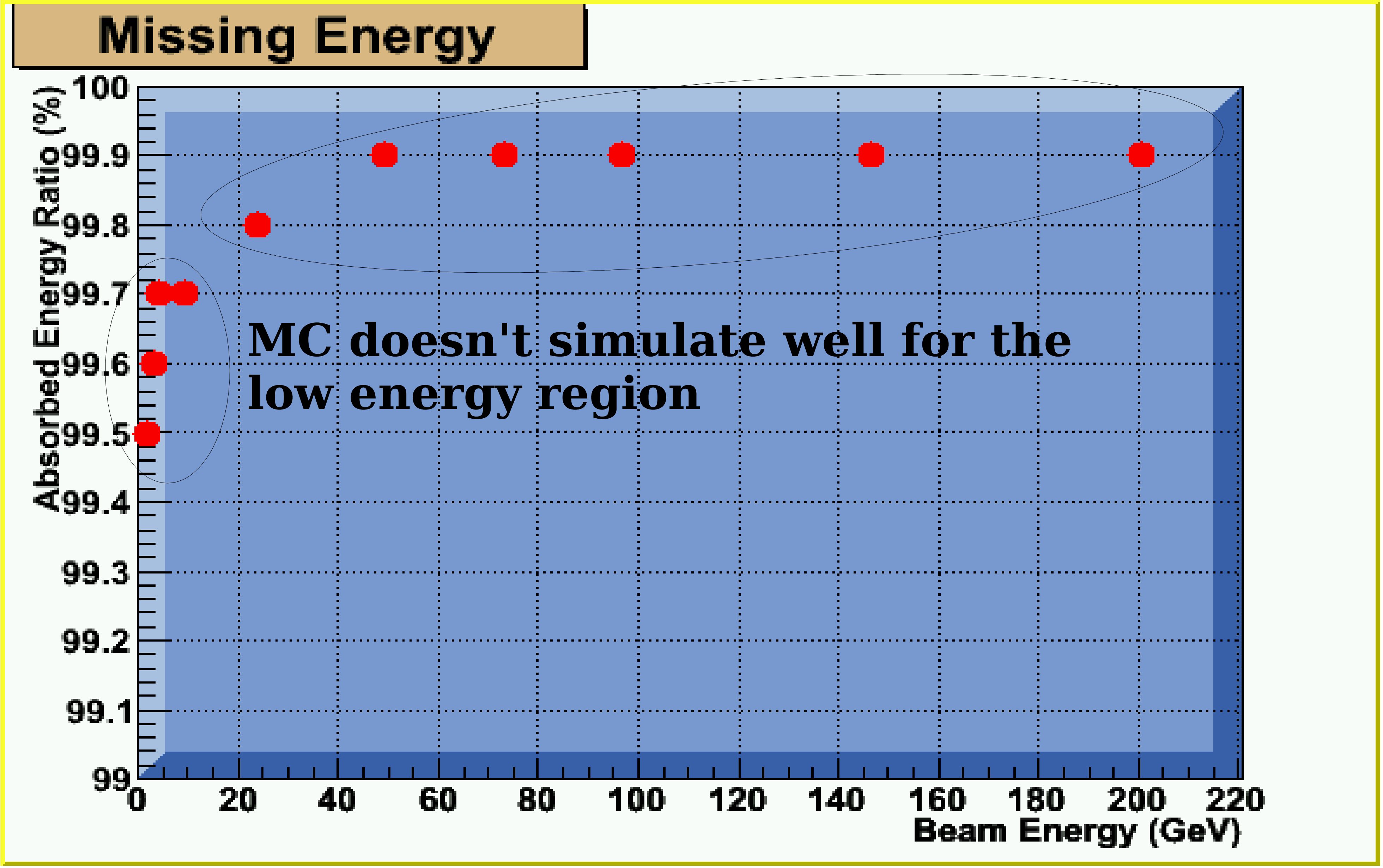
Energy Compensation



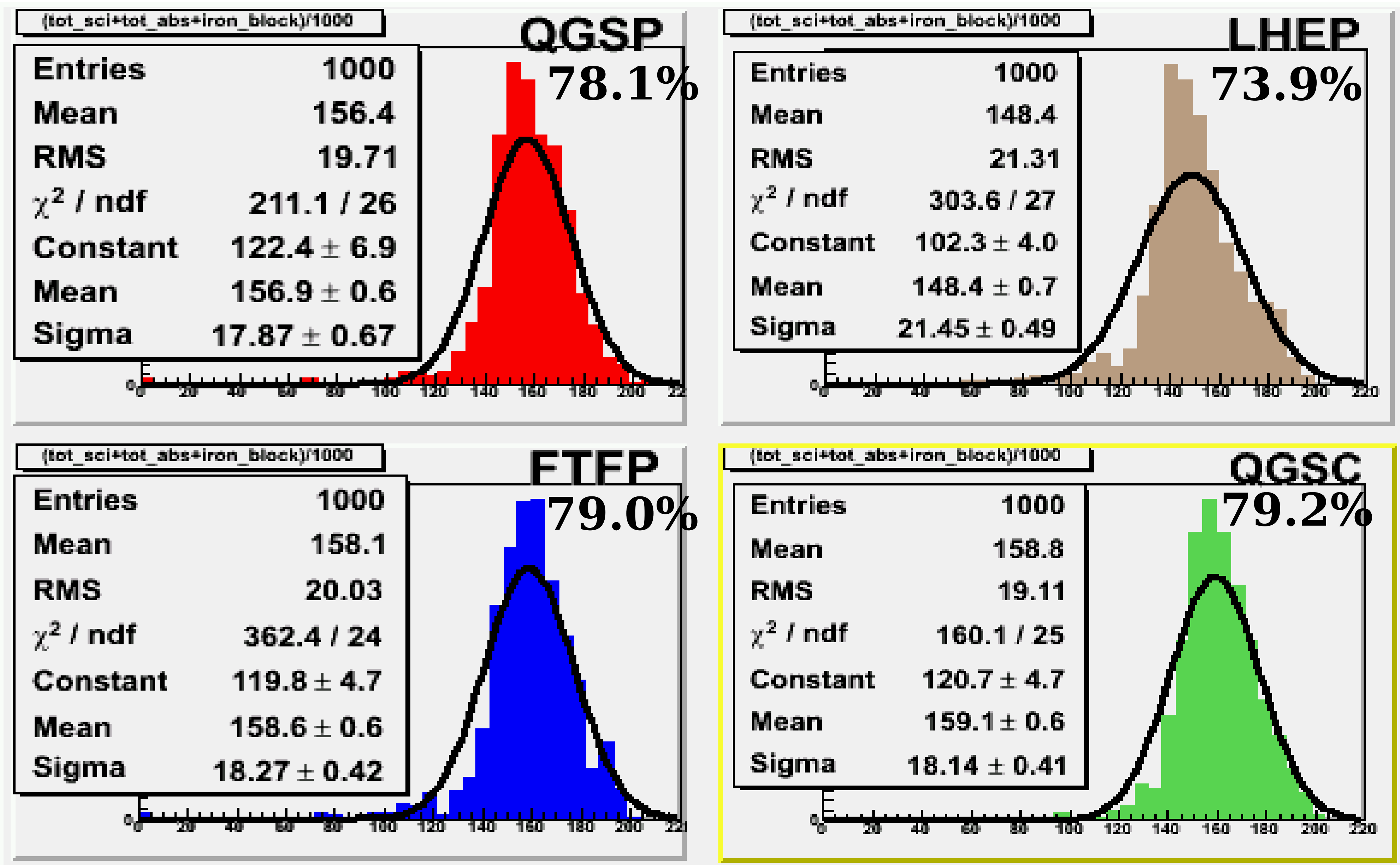
Missing Energy (e-) 187.7 GeV



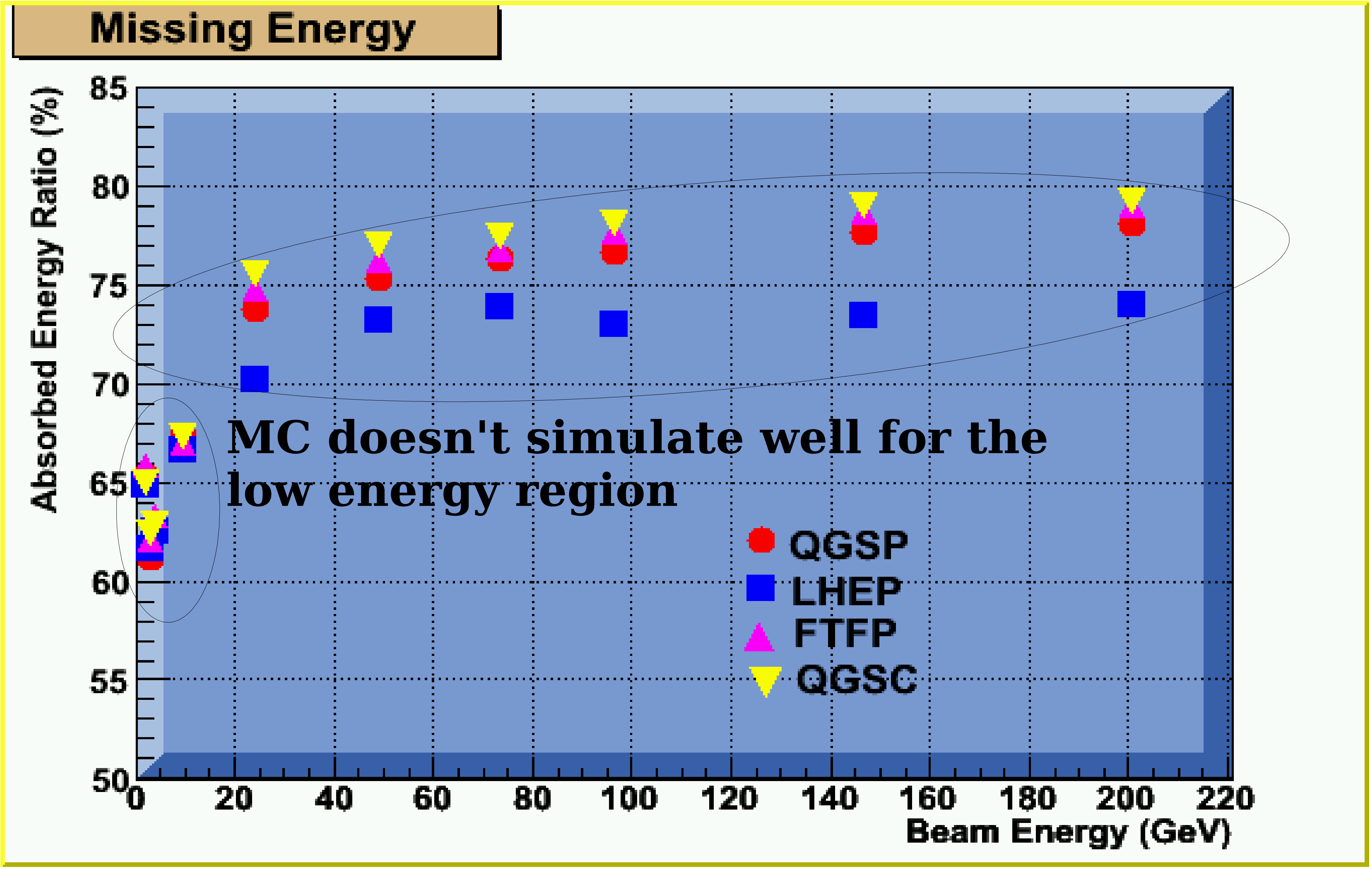
Missing Energy (e-)



Missing Energy (π-) 200.8 GeV



Missing Energy (π-)



Conclusion

- **The EM and Hadron shower models are updated.**
  - **EM: Energy resolution of Data and MC are well fitted.**
  - **HD: Energy resolution of π-, using QGSP model, fits data better than the others.**
- **Geometry settings for the Calorimeter**
  - **Seven interaction length for Calorimeter is long enough, corresponding missing energy is ~ 25%.**
  - **Missing Energy is larger in the lower energy region – improvement may be needed. (newly updated GEANT4 7.1 was just released 12 days ago)**
  - **Energy Compensation (e/π ratio) is close to 1 in the current sampling ratio.**

Backup

Asia Simulation Tools

Last Update: 2005/May/03

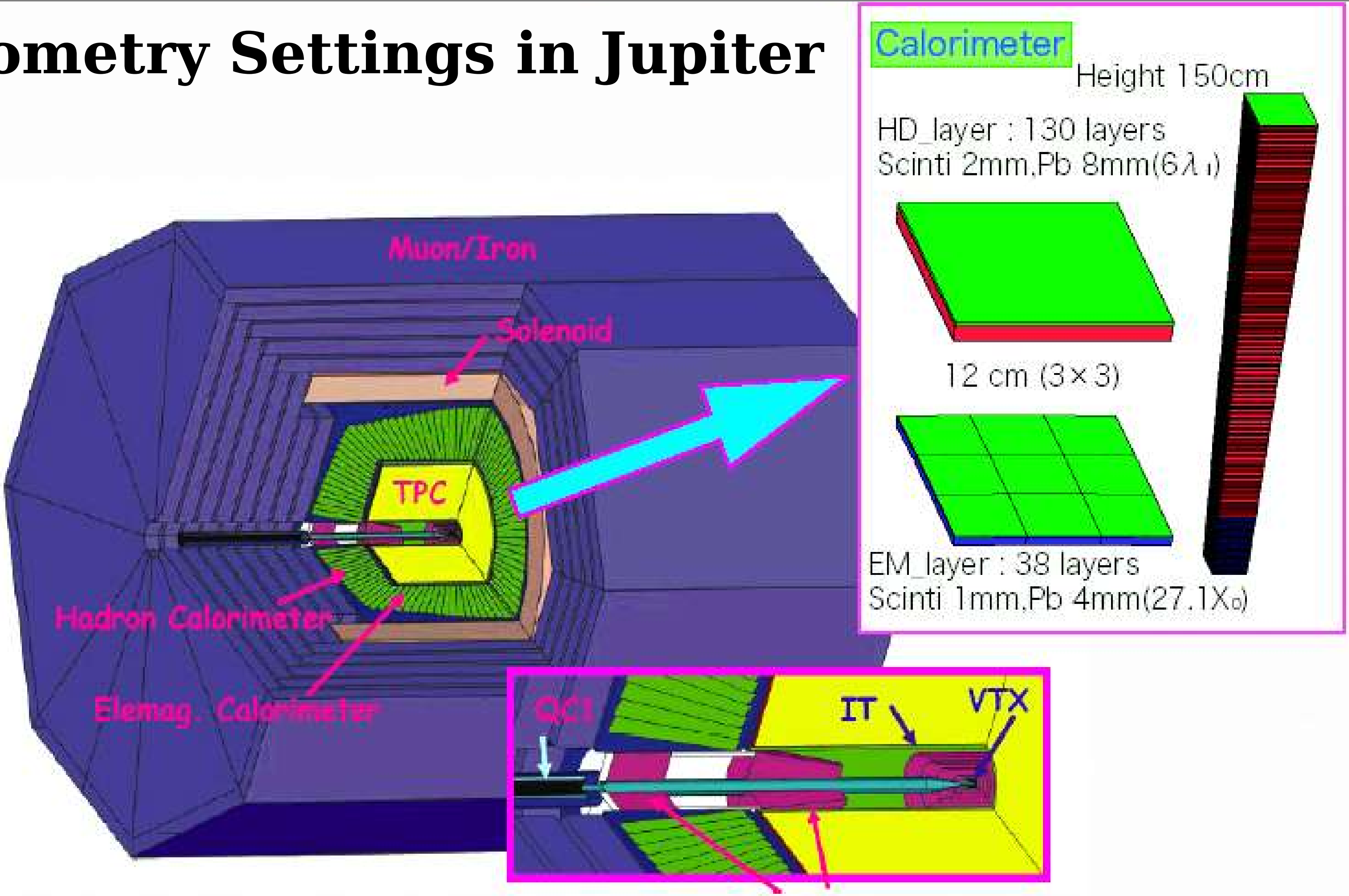
http://acfahep.kek.jp/subg/sim/simtools/index.html

Download

- **SimTools-1-01-bin.tar.gz**
  Collections of pre-compiled binaries, documents, and examples.
- **SimTools-1-01-src.tar.gz**
  Source files correcponding to SimTools-1-01-bin.tar.gz

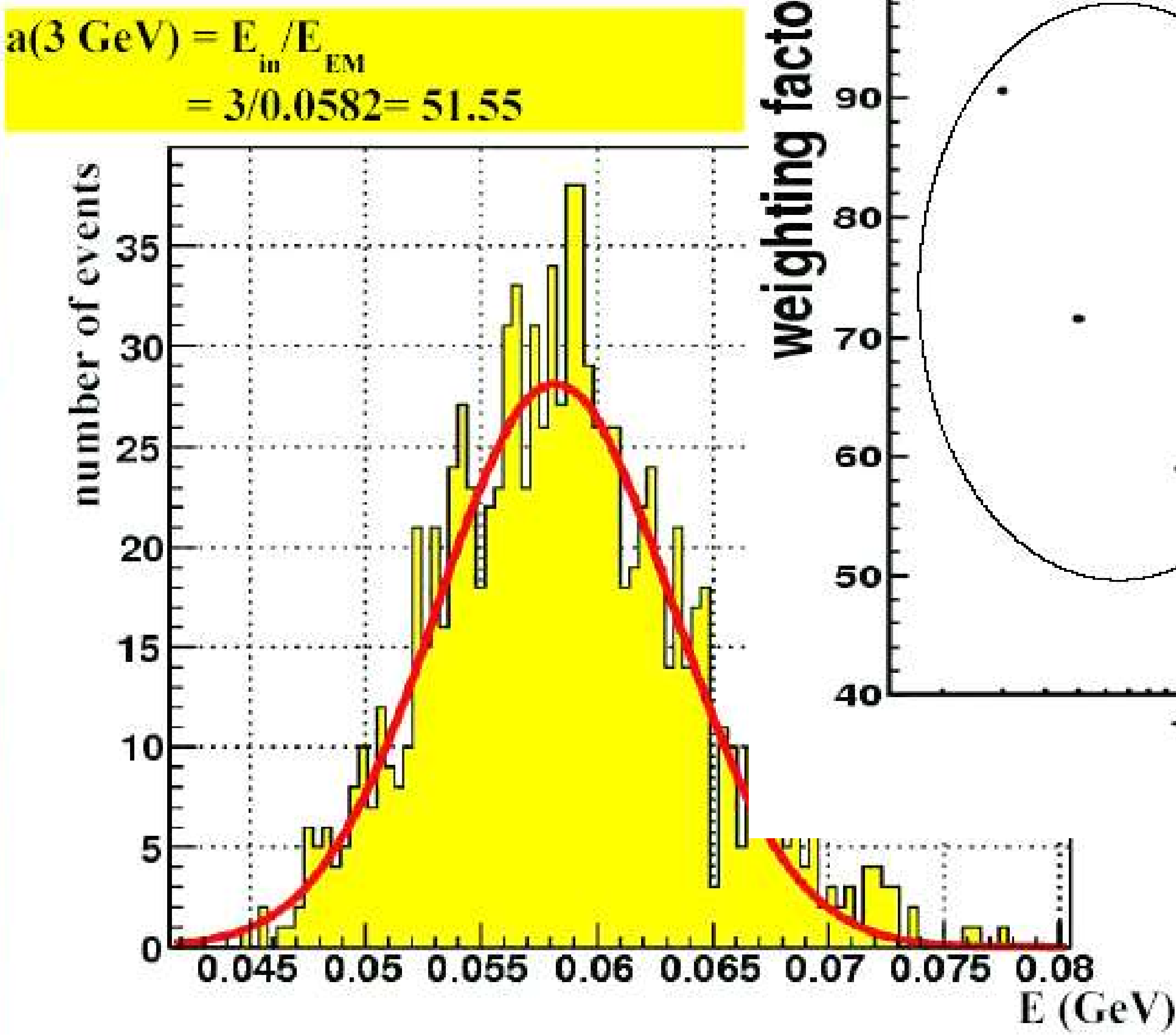
Backup

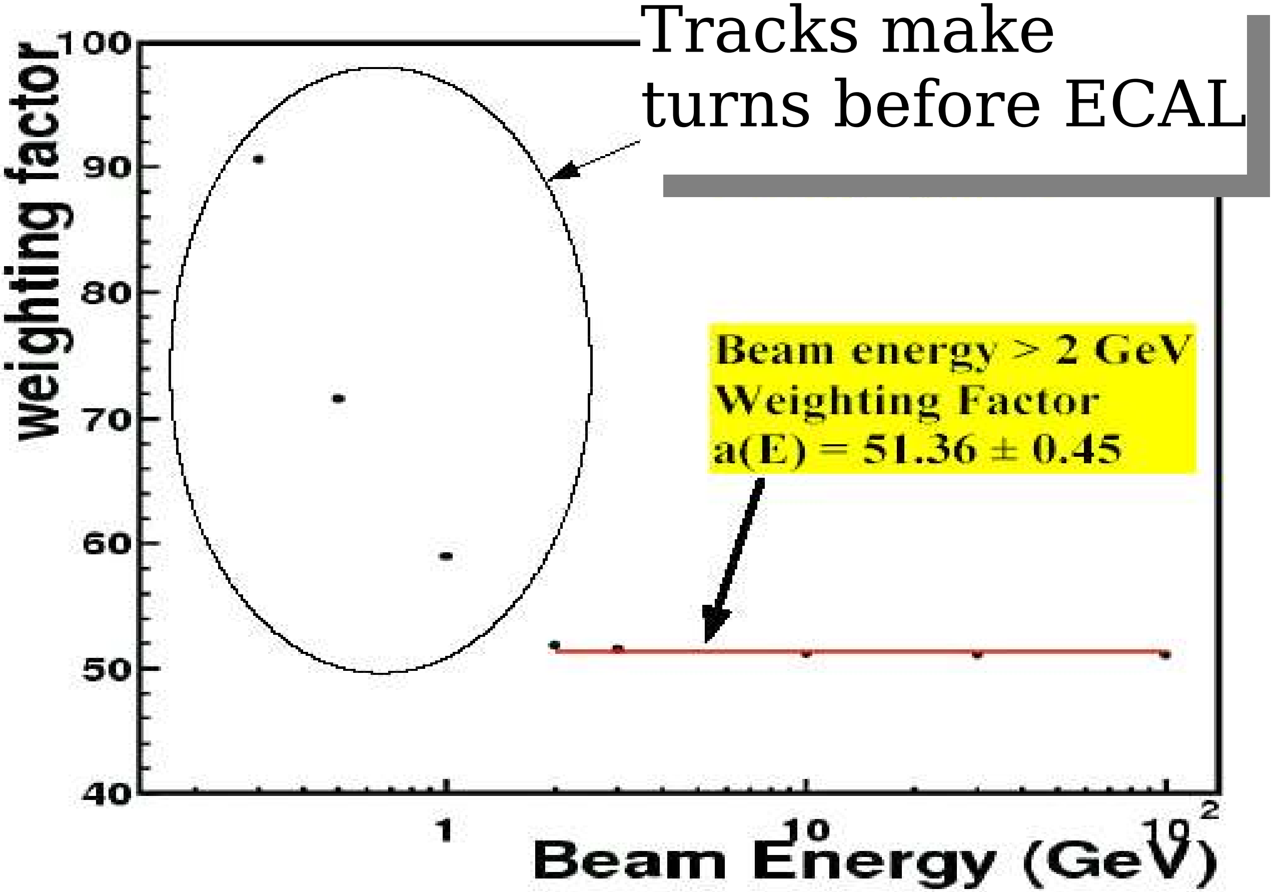
Geometry Settings in Jupiter



Backup

In Jupiter, Energy Calibration: electron





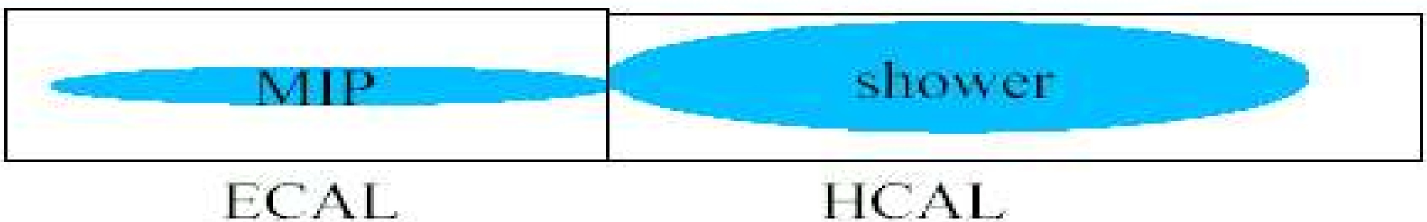
Backup

With QGSP (Jupiter): e/π ratio

Counted by the average values

$$\frac{a(E) = 51.36 \pm 0.45}{a(E) = 51.51 \pm 0.45} = 1.00 \pm 0.01$$

Keep MIPs in ECAL only



Counted by the average values

$$\frac{a(E) = 51.36 \pm 0.45}{a(E) = 46.22 \pm 0.45} = 1.11 \pm 0.02$$

All energy obtained in ECAL scintillator