Geant4 electromagnetic physics for the LHC and other HEP applications

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on behalf of the Geant4 EM Working Groups

DESY, Zeuthen

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Outline

Introduction

Geant4

is a toolkit for the simulation of the passage of particles through matter.

EM physics processes

- interactions of $e^{\pm}$ and γ
- electromagnetic interactions of muons, hadrons and ions
- x-ray processes and processes with optical photons
- ...

Application area

- HEP, medical, space, ...

dedicated models exist for different use cases

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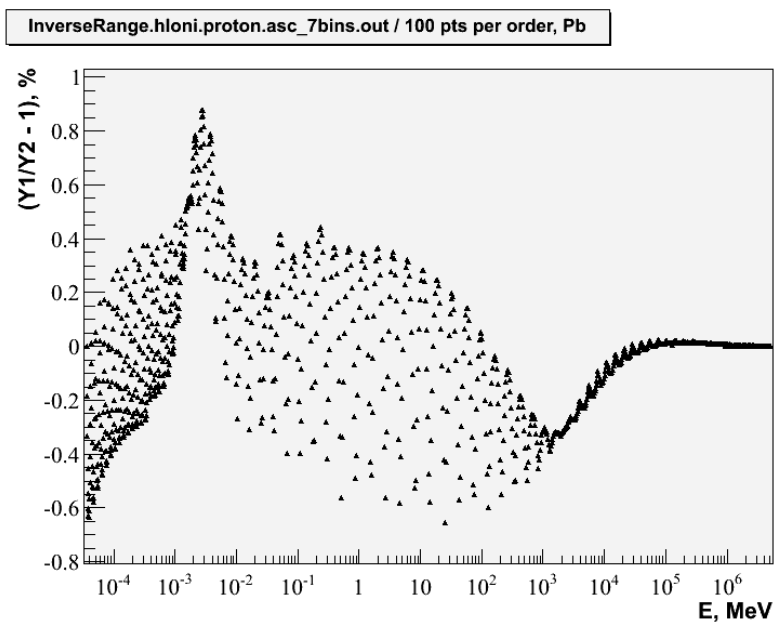
dedicated models exist for different use cases

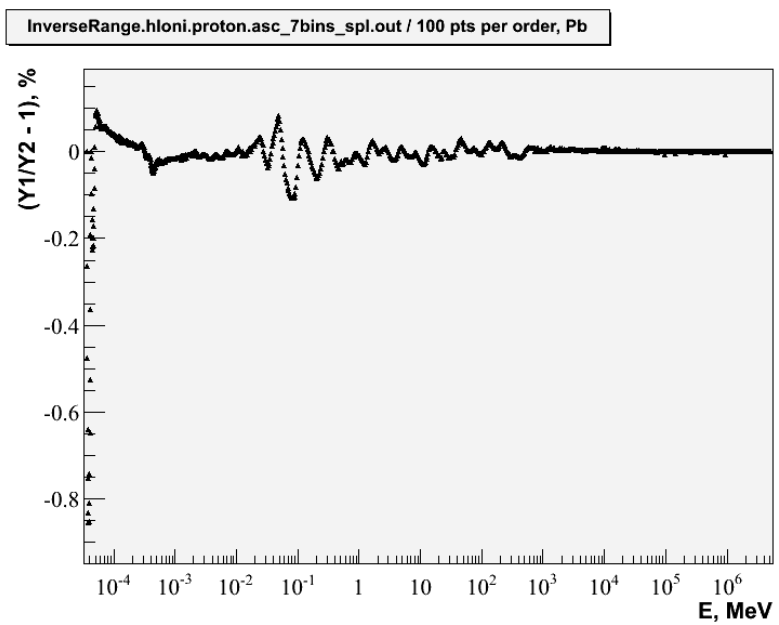
Infrastructure upgrades

Common software design by EM Standard and Low-Energy

- available since G4 version 9.3
- use higher level tools (e.g. spline interpolation in physics tables)
- allows combination of different models for different energy regions in one process

$\Rightarrow$ new components for physics lists (Builder)





Infrastructure upgrades

Improvements in CPU performance

- G4 9.3 default energy interval 1 keV-10 TeV
- Number of bins reduced to 70 ($\sim$20% memory saving)
- significant improvement of start-up time for application with many materials (e.g. LHC experiments)
- Revised converter of cut in range to production thresholds
- Revised of physics vector classes
- Cleaned up standard EM initialization

Geant4 version	amd 32-bit	amd 64 bit
G4 9.2	147 s	179 s
G4 9.3	51 s	56 s

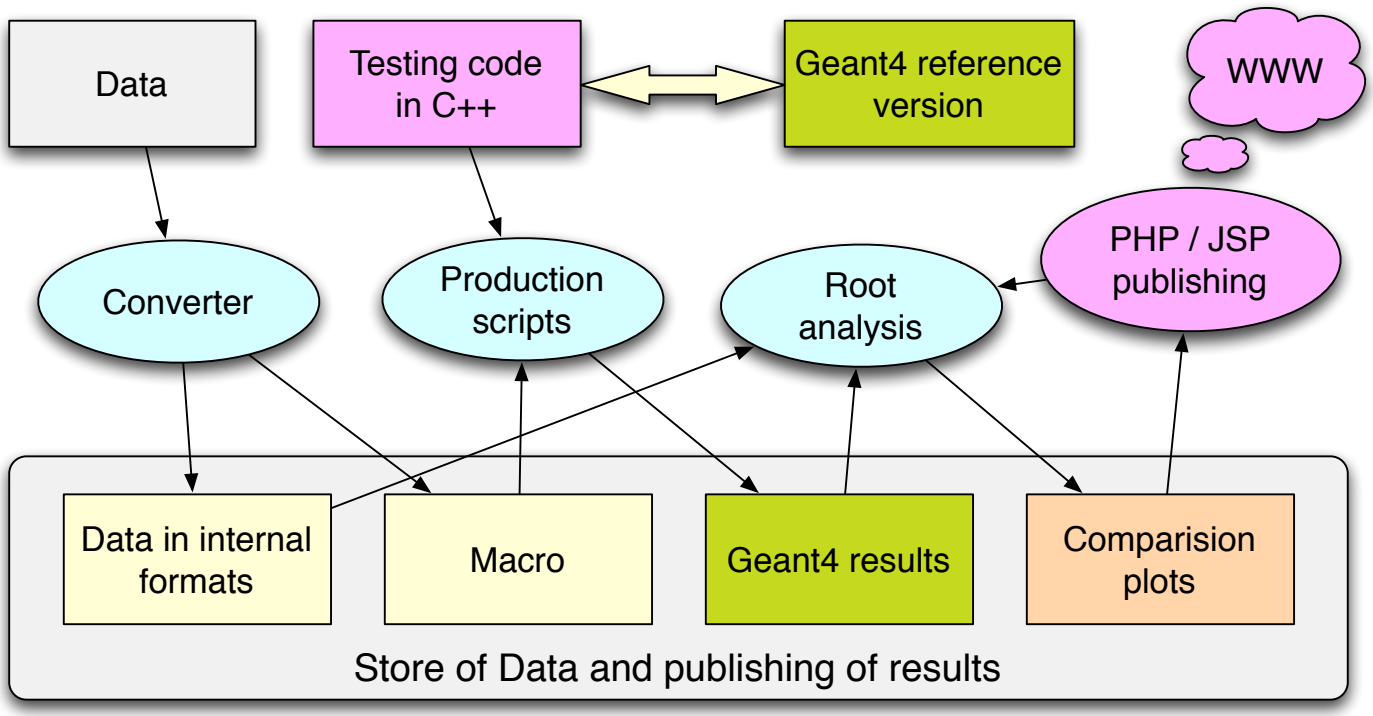
Physics validation - Framework

Two stage test approach

- low-statistics test run regularly by STT
- high-statistics test run using LxBatch, etc.

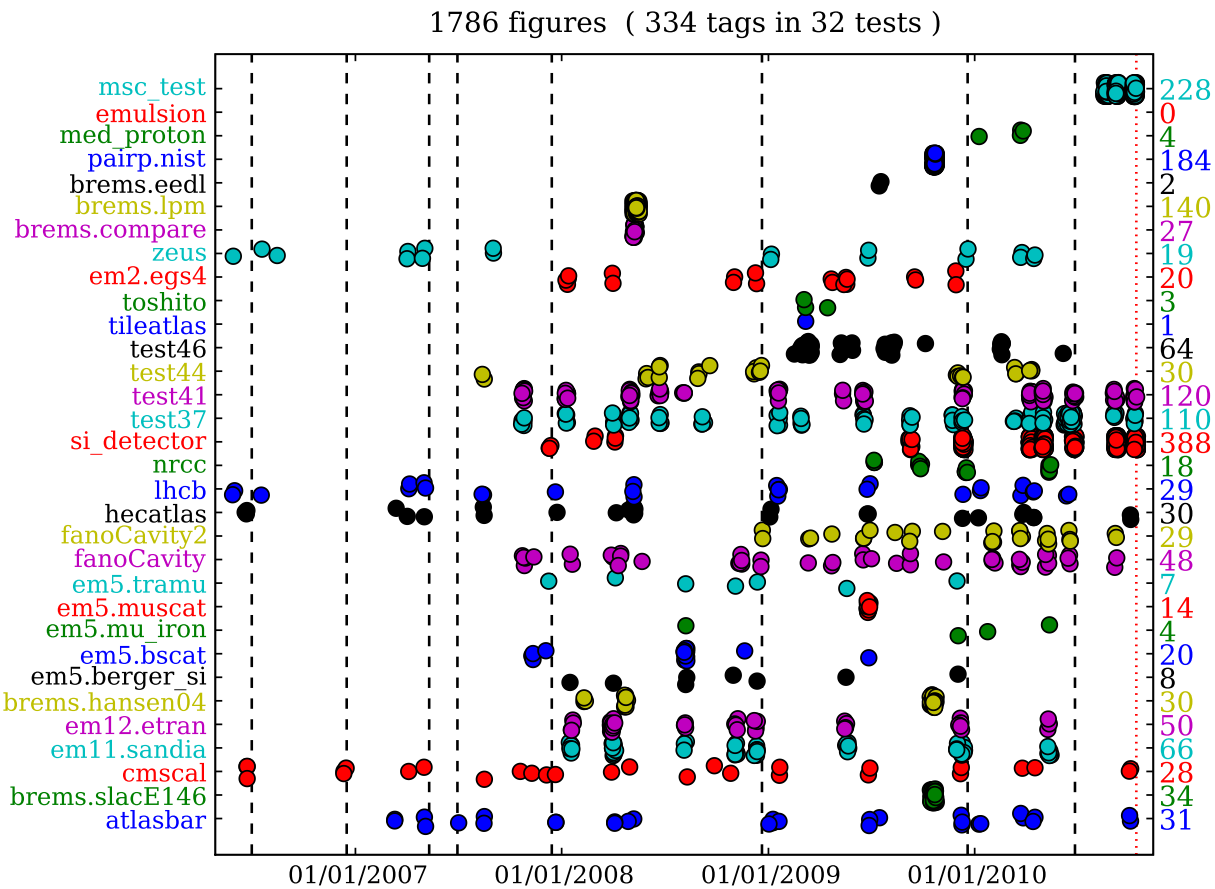
Procedure

- semi-automatic run of jobs
- results generated by scripts
- comparison plots available on the Web



Physics validation - Framework

- PHP based Web interface: http://www-zeuthen.desy.de/geant4
- new JSP based system in development (collaboration with G4 hadronic WG)

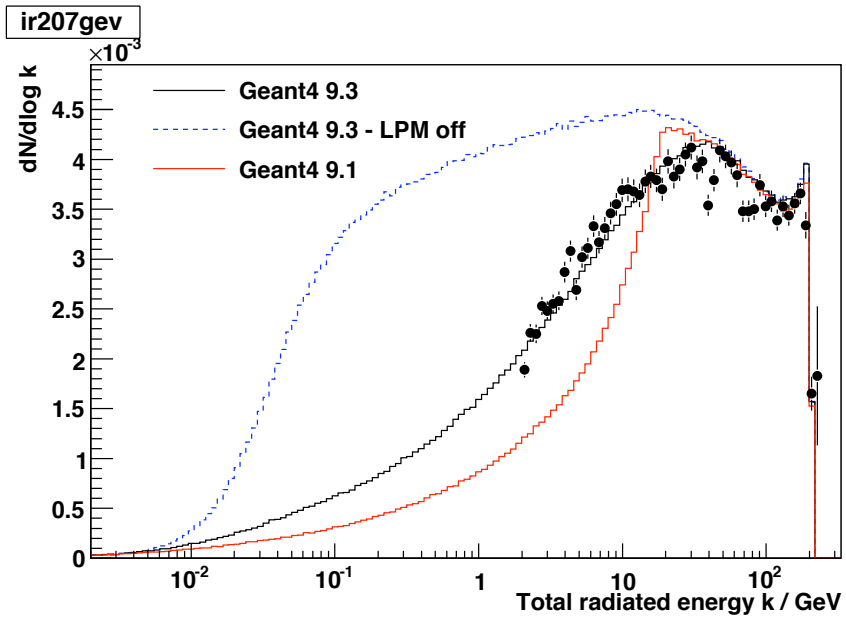


Physics validation - Bremsstrahlung & Pair production

New relativistic bremsstrahlung model

- Bethe-Heitler formula with corrections
- complete screening (valid $E > 1$ GeV)
- includes density and LPM effect

  and consistent combination
  a'la Ter-Mikaelian
- available since Geant4 version 9.2



New relativistic pair production model

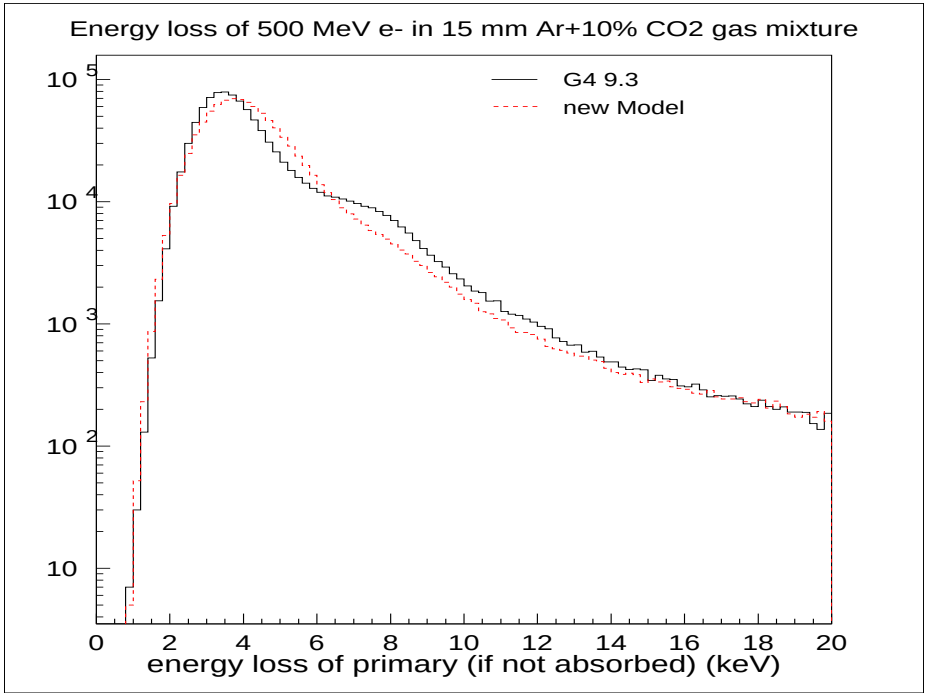
- includes LPM effect
- important only for $E > 1 - 10$ TeV
- available since Geant4 version 9.3

Data: H.D. Hansen et al., Phys.Rev.D 69, 032001 (2004)

Physics validation - Multiple scattering & Fluctuation

revised Urban multiple scattering model

- better description
  esp. for low Z materials
- available since G4 9.3
- will be default in G4 9.4



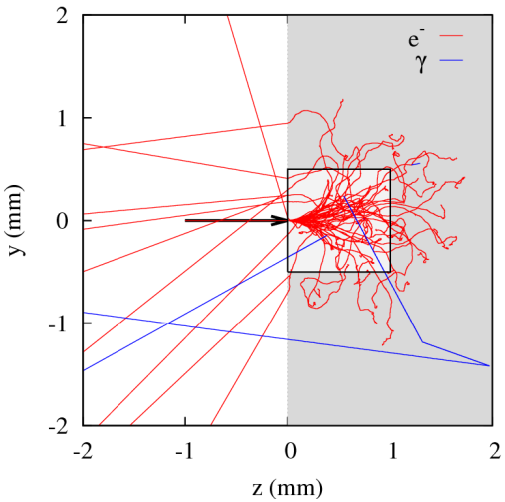
new fluctuation model

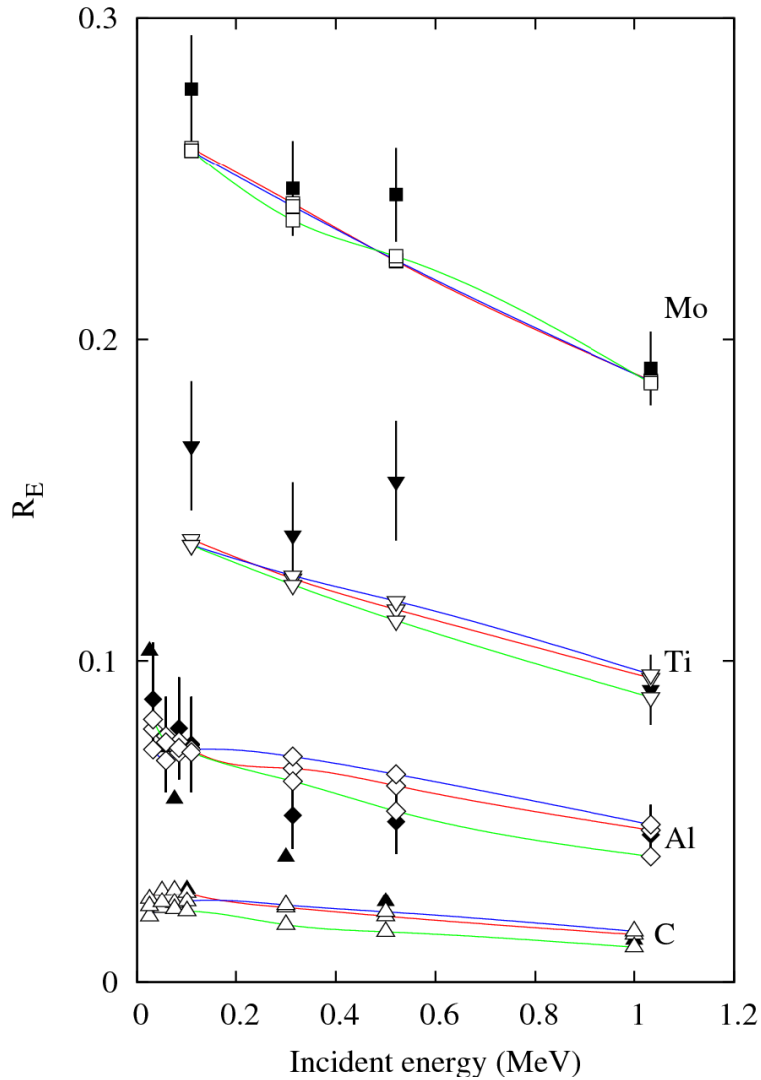
- fixes unphysical behavior
  for low density materials
- results become less cut dependent
- included in G4 9.4

Physics validation - Multiple scattering

Backscattering of electrons

- new test for electron MSC
- energy 0.1 - 1 MeV
- targets: Be, C, Al, Ti, Mo
- Urban MSC model with improved parameters gives good results





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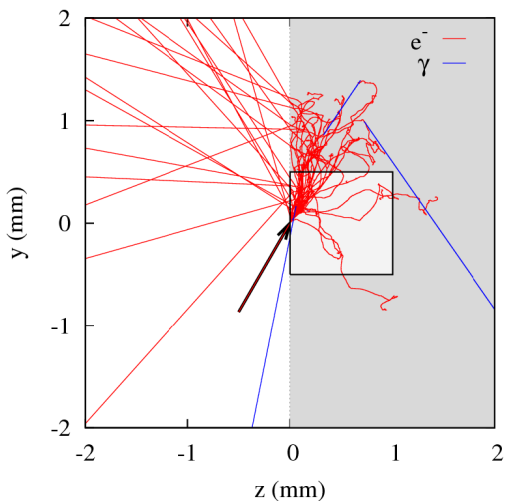

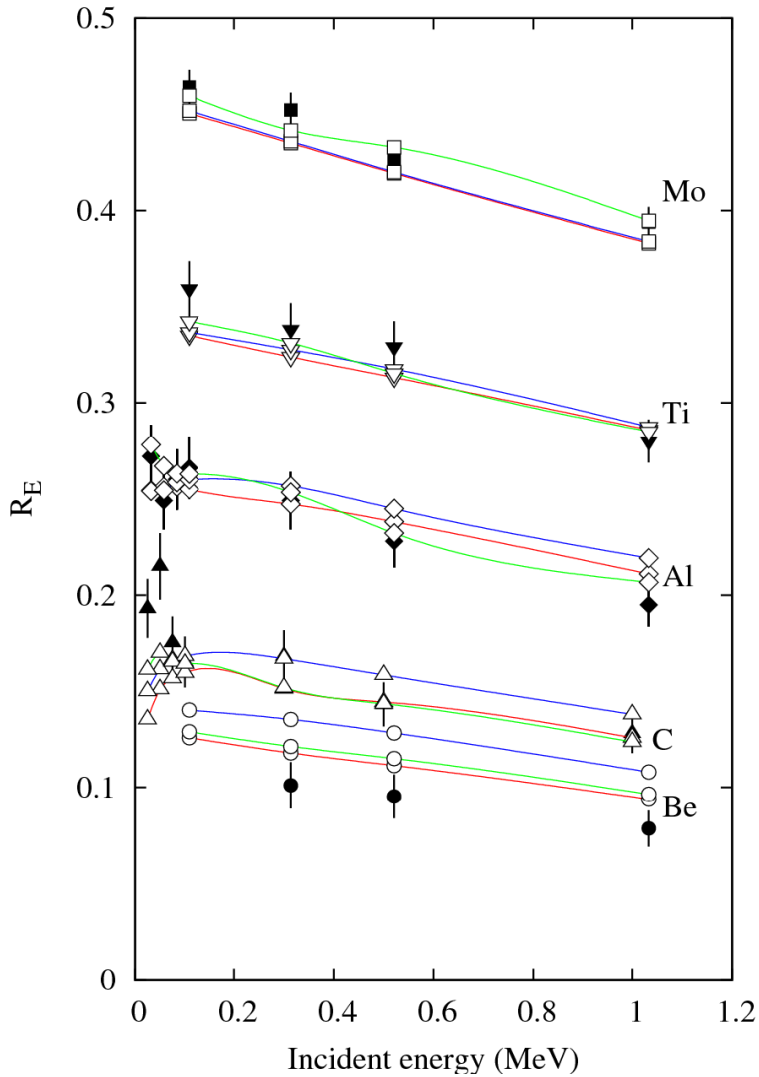

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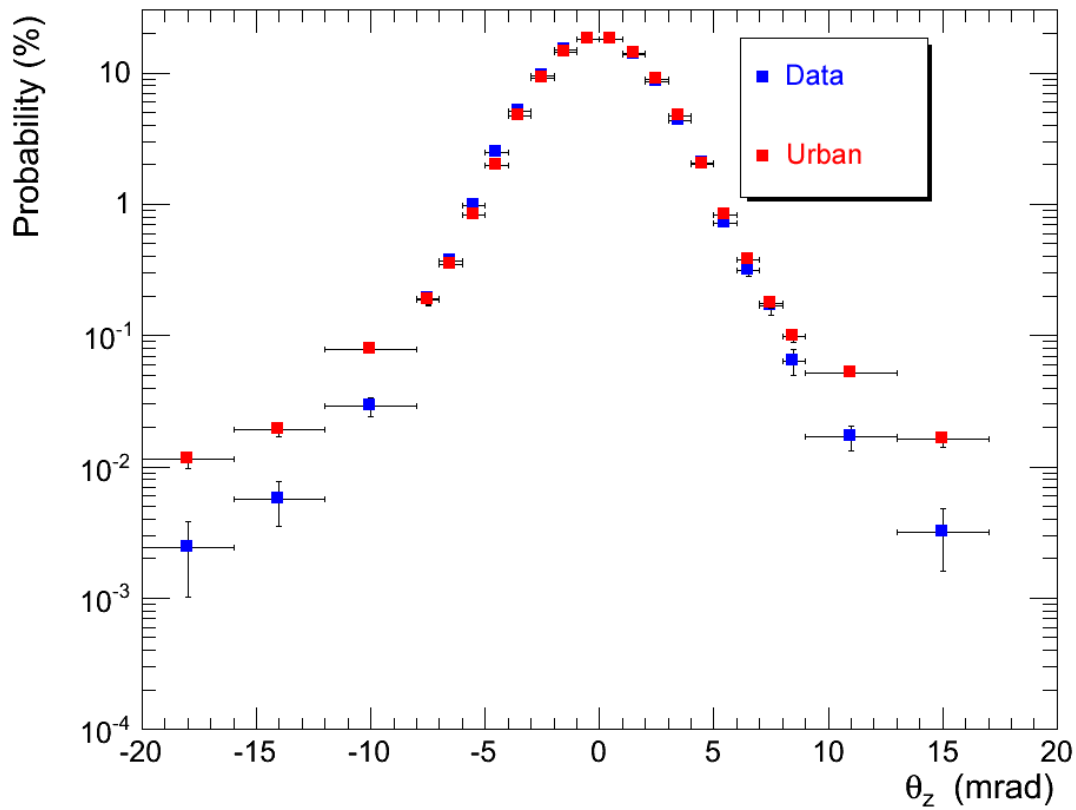
Physics validation - Multiple scattering

Multiple scattering of muons

- 7.3 Gev/c muon on Copper
- default model (Urban) gives good description of core
- deviation at large angles

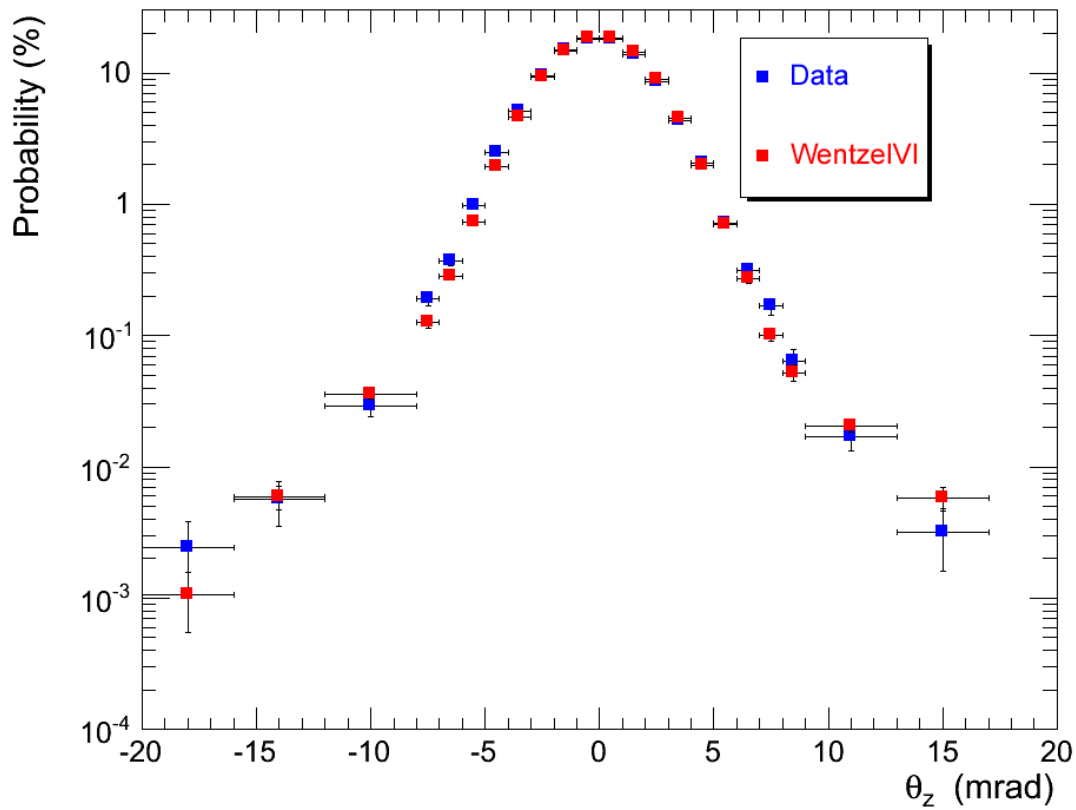


Data: S.A. Akimenko et al., NIM A 234, 518 (1986)

Physics validation - Multiple scattering

Multiple scattering of muons

- 7.3 Gev/c muon on Copper
- default model (Urban) gives good description of core
- deviation at large angles
- new model (WentzelVI) even better
- will be default for muons in G4 9.4



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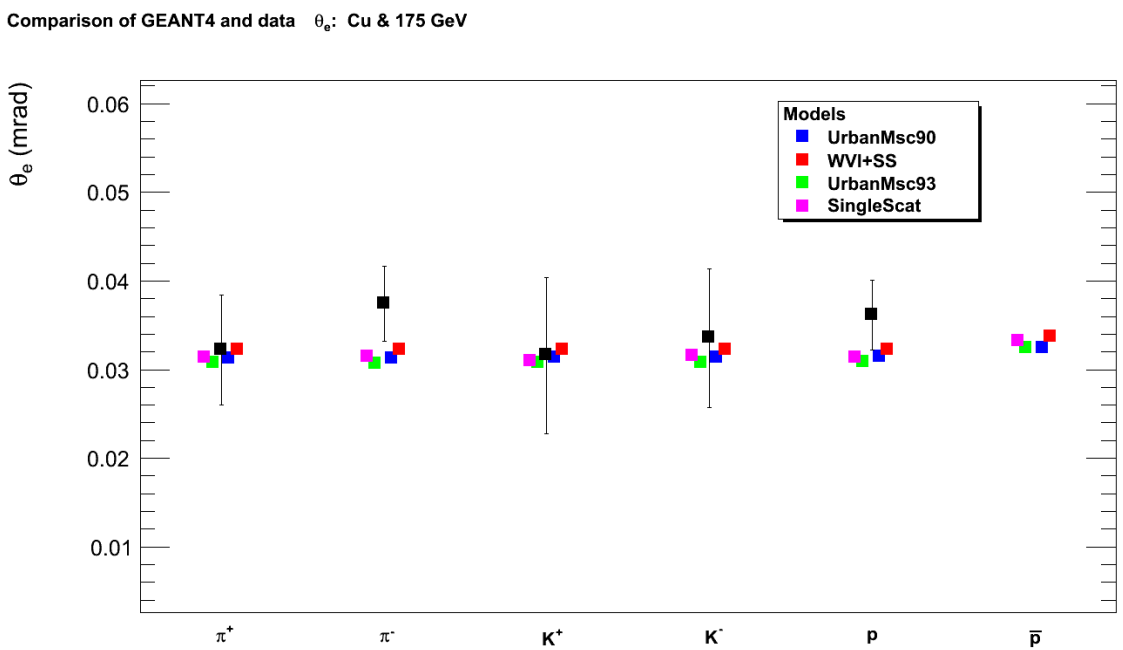
Multiple scattering of hadrons

- 50 - 200 GeV/c
- various targets from Hydrogen to Lead
- comparison with data and Moliere theory



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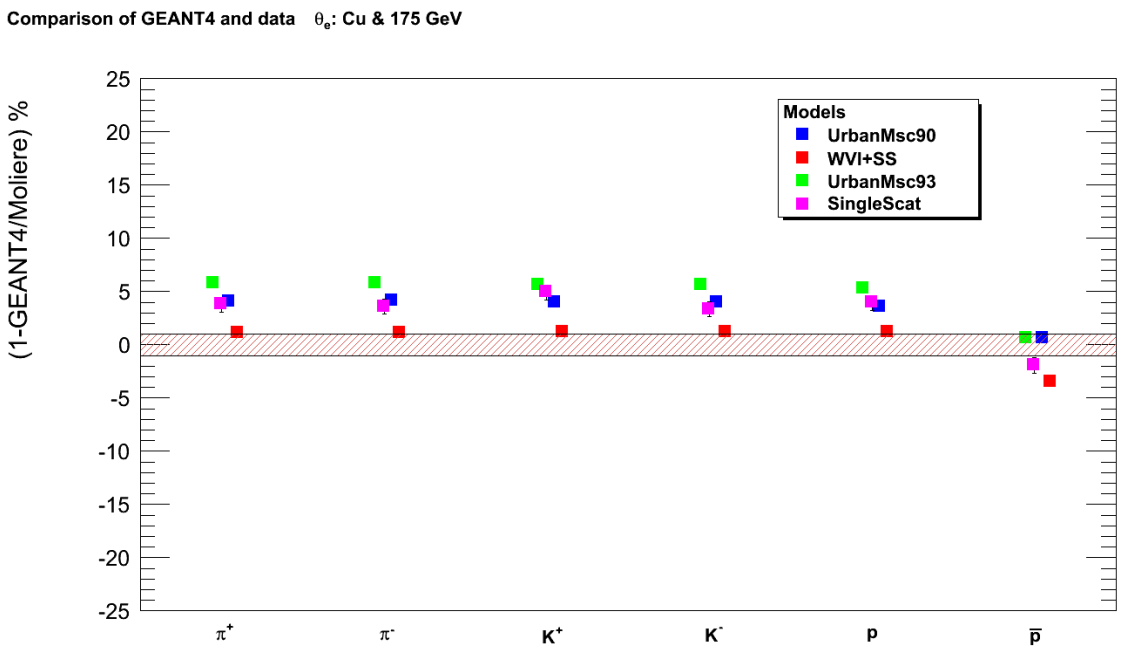

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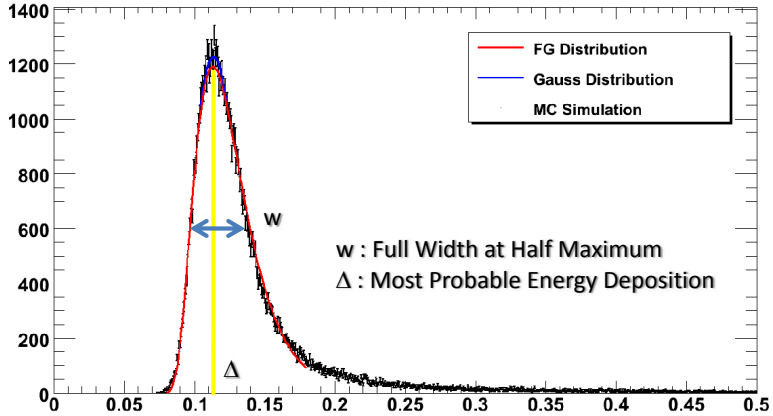
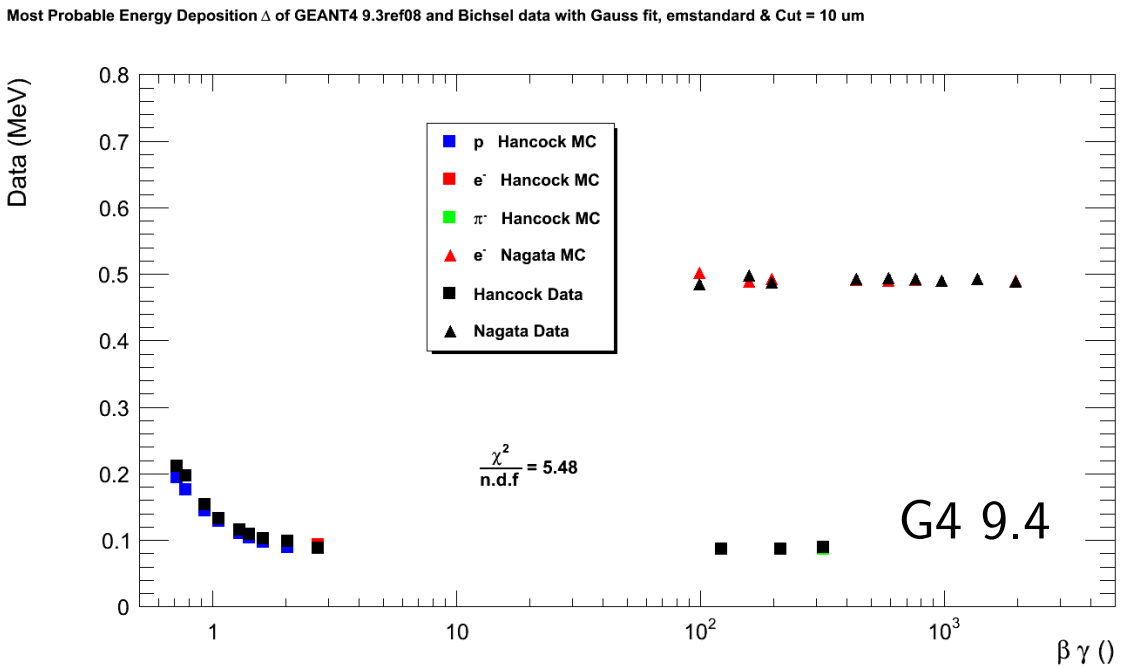
Physics validation - Fluctuation model

- energy deposition spectrum characterized by
  - Most Probable energy deposition
  - Full Width at Half Maximum
- Thin Silicon layer of :
  300 um (Hancock) , 1565 um (Nagata)





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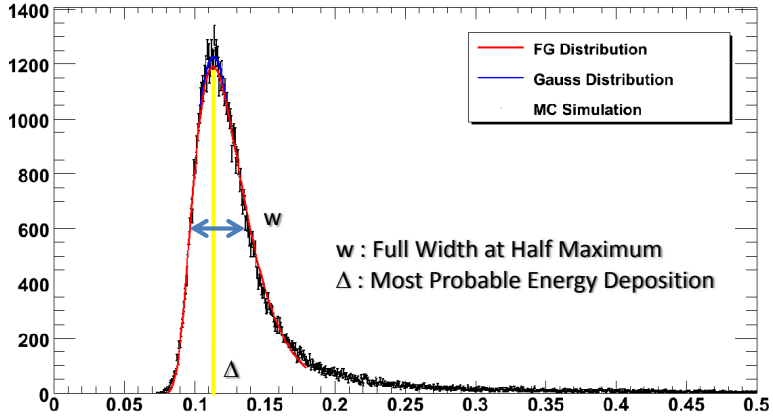

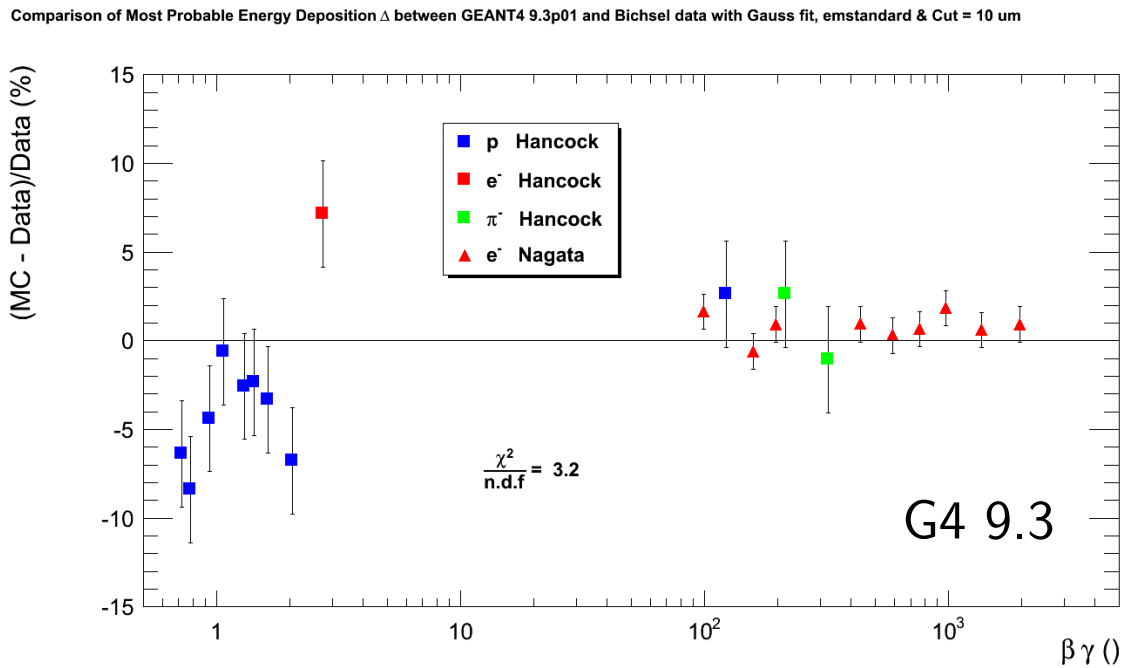

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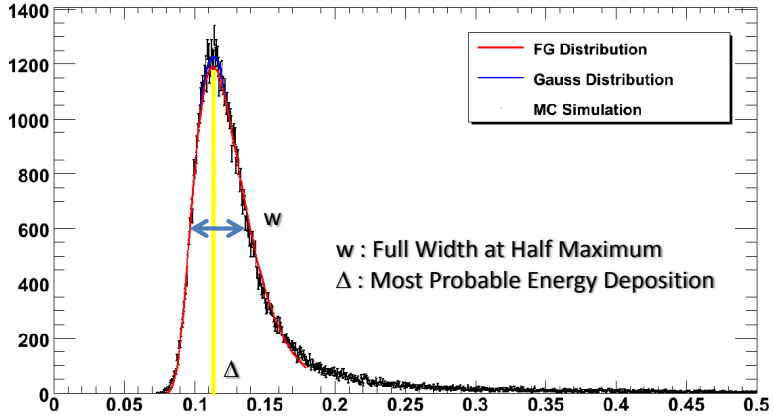

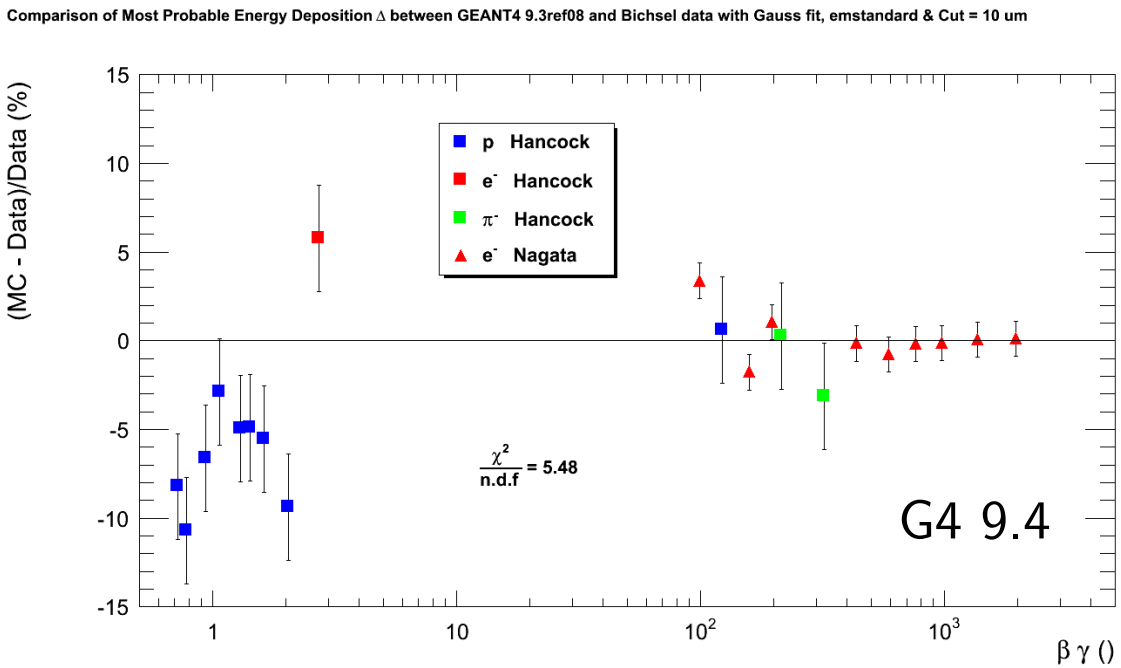

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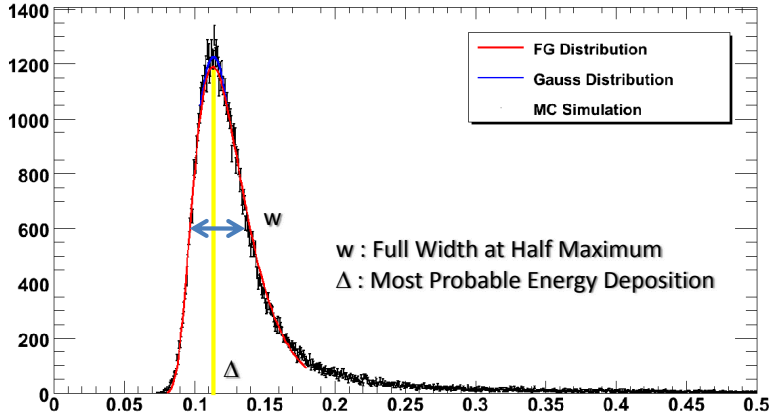

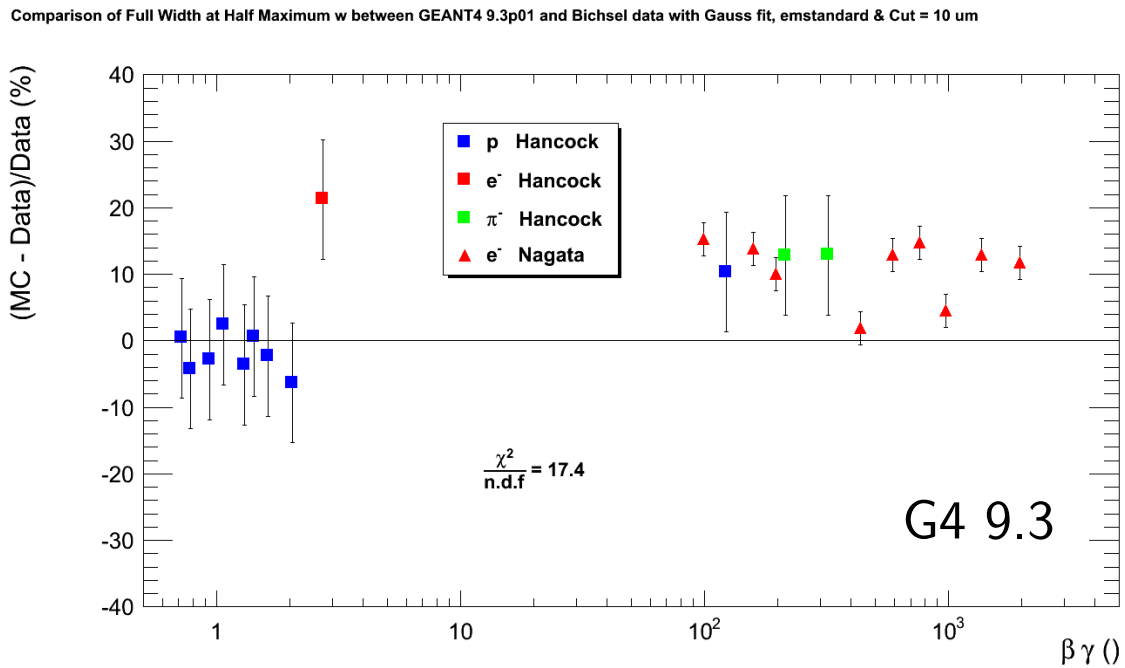

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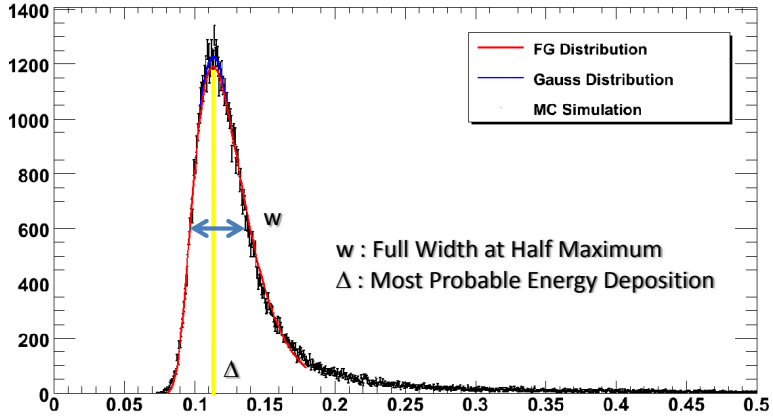

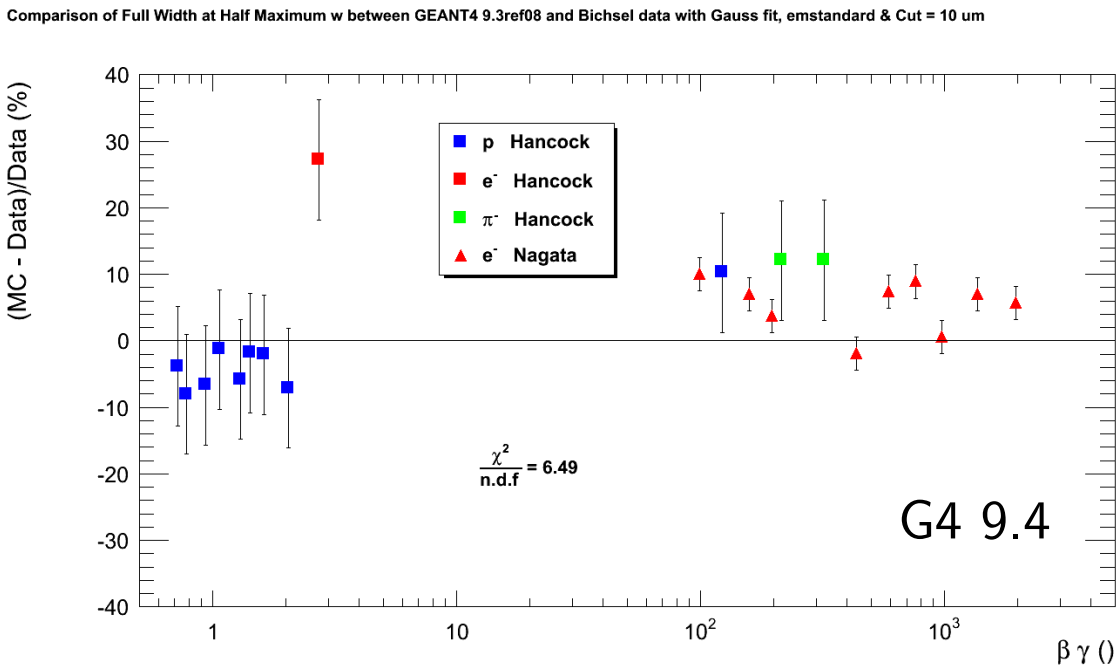

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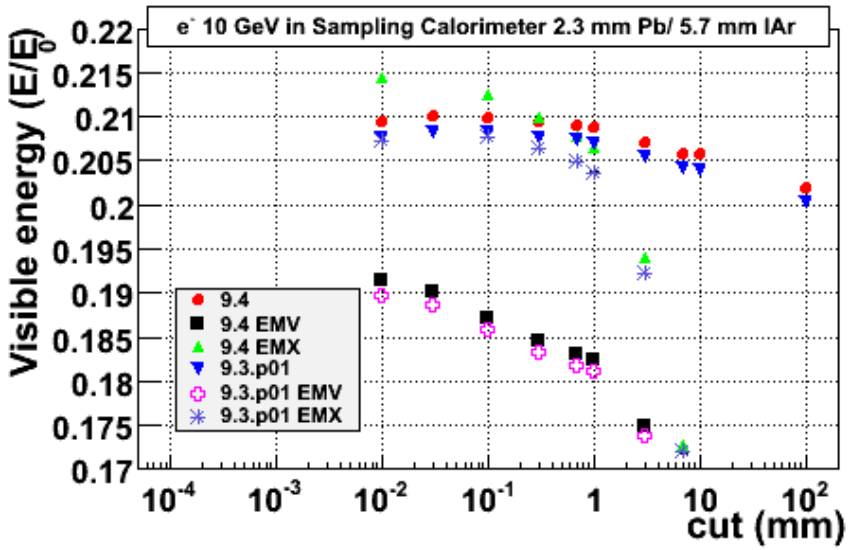
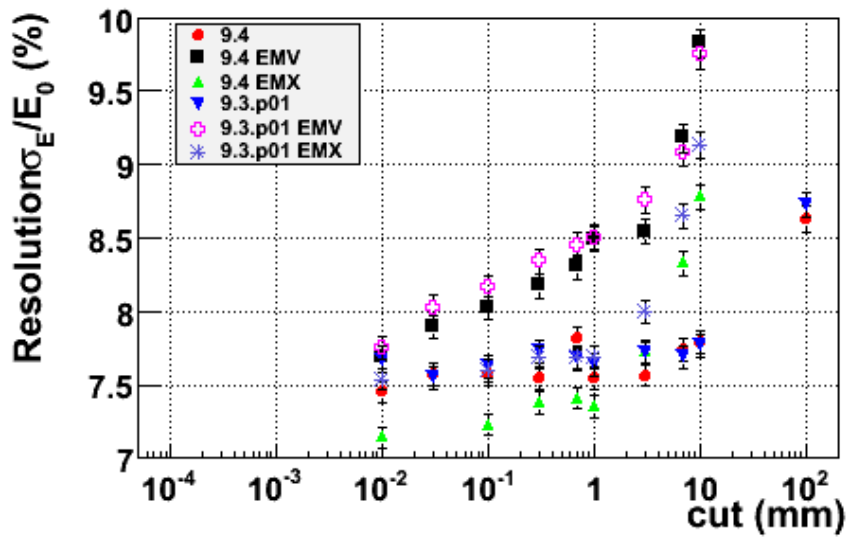
Physics validation - LHC type calorimeter response

Sampling Calorimeter

- Example Atlas EM calo
- simplified setup
- 2.3 mm Pb, 5.7 mm lAr
- test visible energy fraction and resolution
- in general results very stable
- G4 version 9.4 gives
  0.5% increased response
  relative resolution not changed





Summary

EM performance and infrastructure improvements

- common design with low energy processes
- new physics builder cover wider energy range by using different models in different energy regions
- sizable CPU performance increase during initialization stage

EM physics improvements

- LPM effect consistent in Bremsstrahlung and Pair production
- revised fluctuation and MSC models
- extended validation suite with tests of MSC of electrons, muons and hadrons
- visible impact of LHC calorimeter response
- validation results accessible via new Web interface