

# Geant 4



## Updates on Electromagnetic Physics for Geant4 9.4

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# Geant 4



## Outline

- ▶ Main activities of EM standard physics working group in 2010
- ▶ **EM standard modifications for Geant4 9.4**
  - Models of ionisation
  - Multiple scattering
  - Physics Lists
  - Helper classes
- ▶ **Draft plan for 2011**

# Main activities for Electromagnetic Physics in 2010

## ▶ Ionisation

- Improved parameterization of density effect
- Addition of anti-deuteron, anti-triton, anti-He3, anti-alpha
- Addition of the new model for low-energy ionization of negatively charged particles
- Improved models of ionization for monopoles and heavy exotic objects
- Upgraded model of fluctuations of energy loss

## ▶ Bremsstrahlung

- Alternative angular distribution (SLAC request)

## ▶ Multiple scattering

- Urban93 model substitute Urban92 for  $e^\pm$
- WentzelVI model of multiple scattering for muons
- New tests for multiple scattering of high energy particles

## ▶ Infrastructure upgrades

- Physics Lists
- Helper classes

## ▶ Regular activity on validation

- Testing suite run for each reference tag and any significant change of software
- CPU performance profiling

# Geant 4



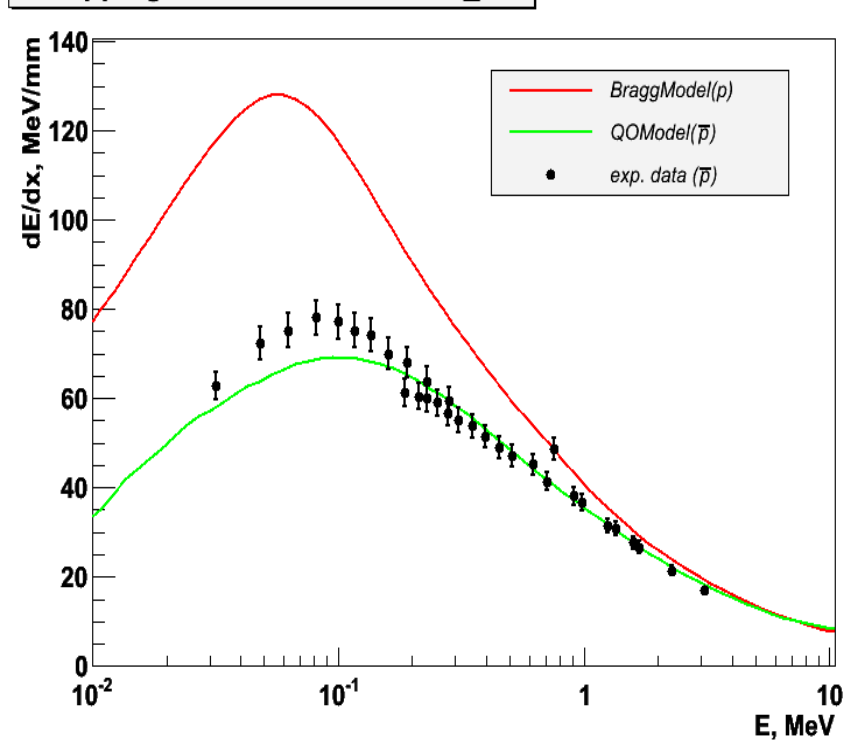
## Ionisation models

# Main Improvements

- ▶ **Upgraded of parameterisations (A.Bagulia)**
  - Density effect
  - Shell Correction
  - Barkas Corrections
- ▶ **Ionisation of magnetic monopole**
  - Transportation of monopoles in field is added (J.Apostolakis, B.Bozsogi, V.Grichine)
  - Delta-electron production is added
- ▶ **Ionisation of heavy highly charged objects**
  - Fixed low-energy behaviors (ATLAS request)

# New Model for Low-energy Negatively Charged Particles (A.Bagulia)

Stopping Powers Models in G4\_Si

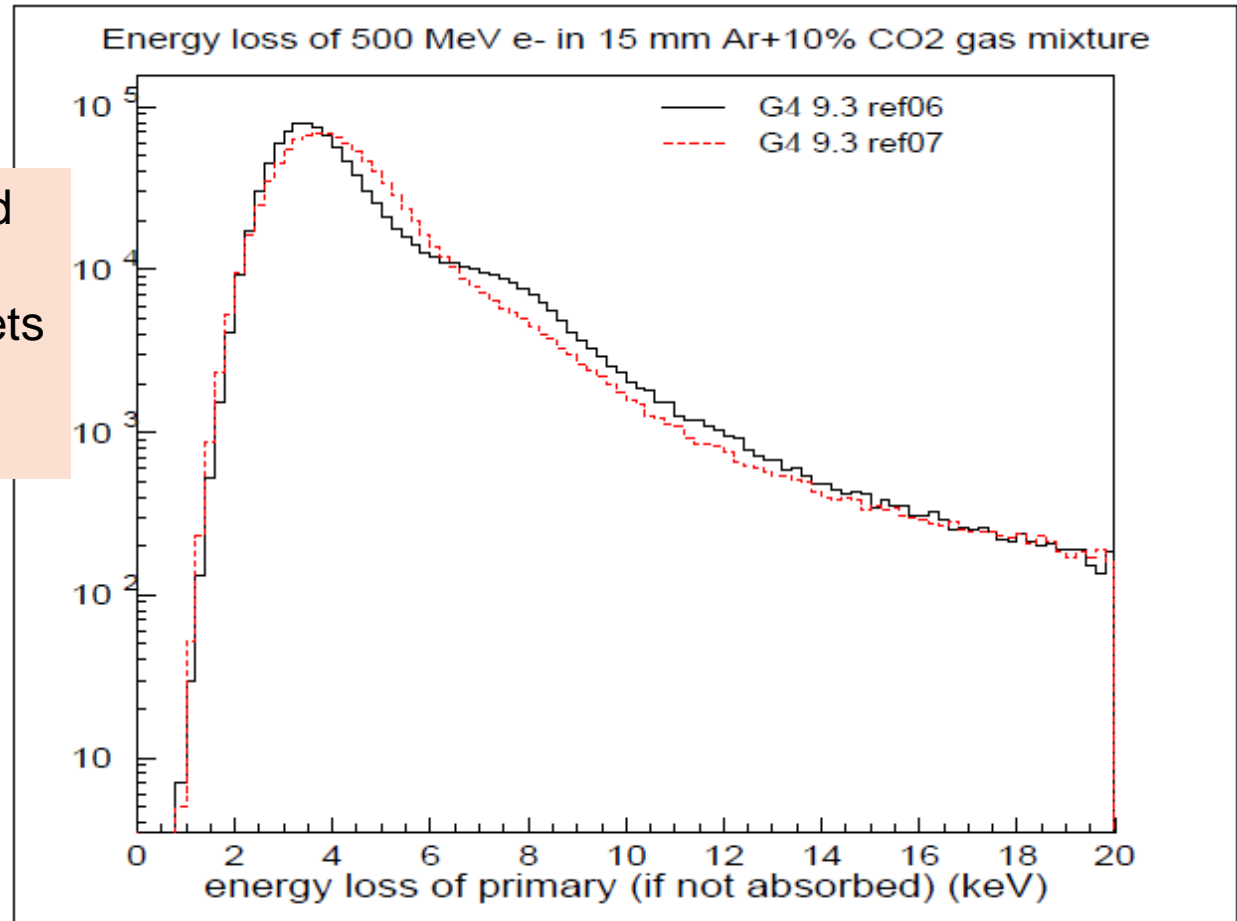


- ▶ Calculation of the stopping power by regarding the target atom as an assemble of quantum harmonic oscillators
- ▶ **ICRU'73 data for oscillator strengths**
- ▶ **Used for new anti-particles and other particles with negative charge**

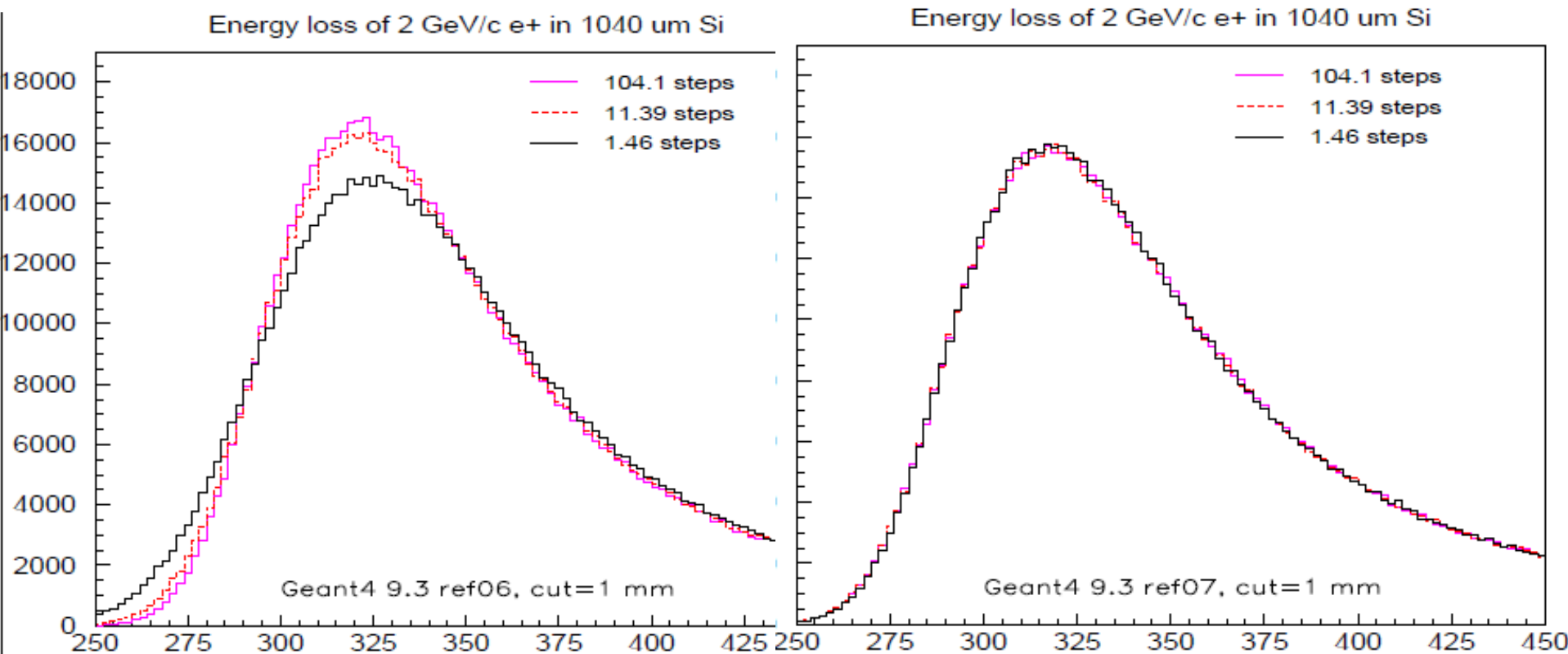
# Upgrade of the Model of Fluctuations (L.Urban)

Problem was observed for tail of energy deposition in thin targets

- gaseous detectors
- Si trackers



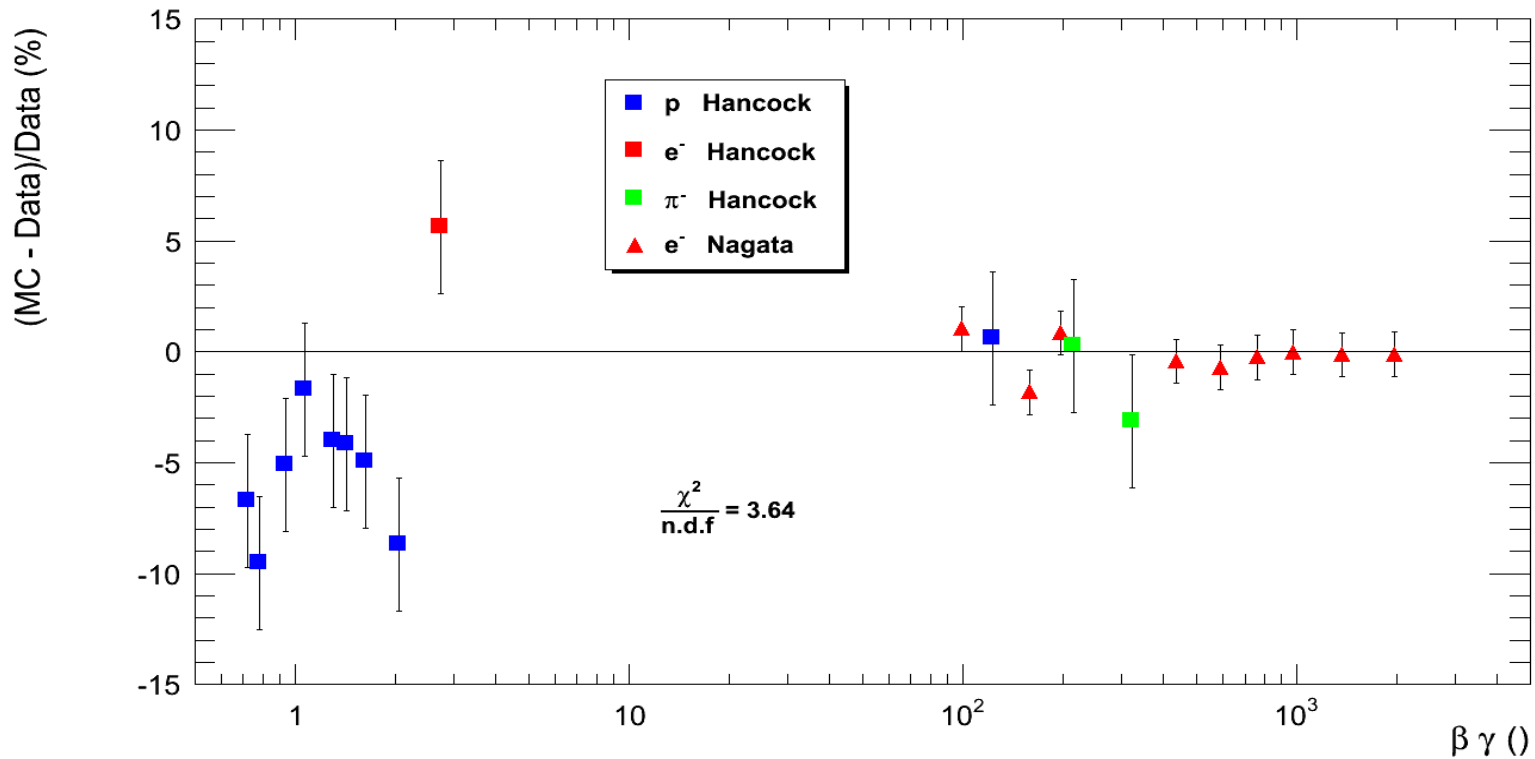
# Stability of the upgraded fluctuation model versus step limit





# Accuracy of simulation of peak of energy deposition in 0.3 mm Silicon for 9.4

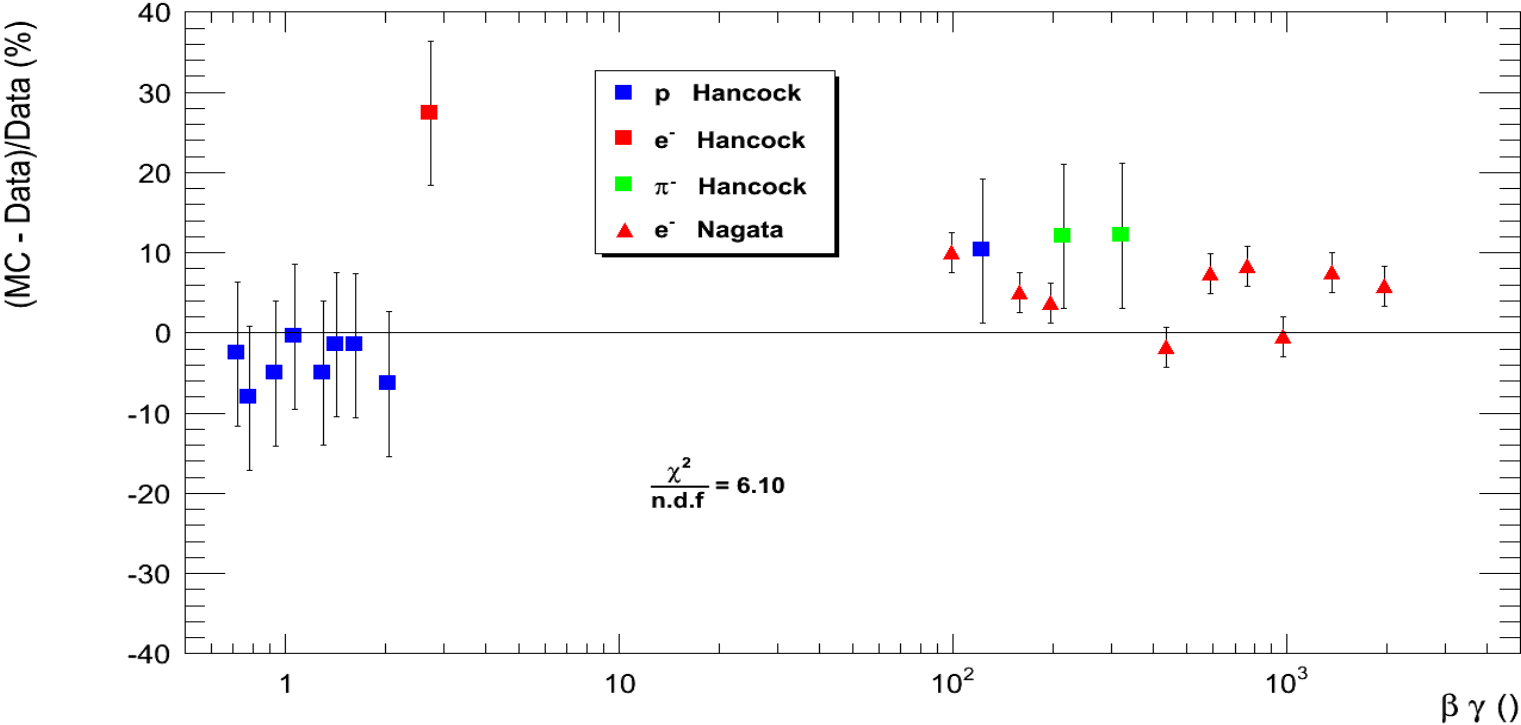
Comparison of Most Probable Energy Deposition  $\Delta$  between GEANT4 9.4 and Bichsel data with Gauss fit, emstandard & Cut = 10  $\mu\text{m}$



In 9.3  $\chi^2$  was 3.2

# Accuracy of simulation of FWHM of energy deposition in 0.3 mm Silicon for 9.4

Comparison of Full Width at Half Maximum w between GEANT4 9.4 and Bichsel data with Gauss fit, emstandard & Cut = 10 um



In 9.3  $\chi^2$  was 17.4

# Geant 4



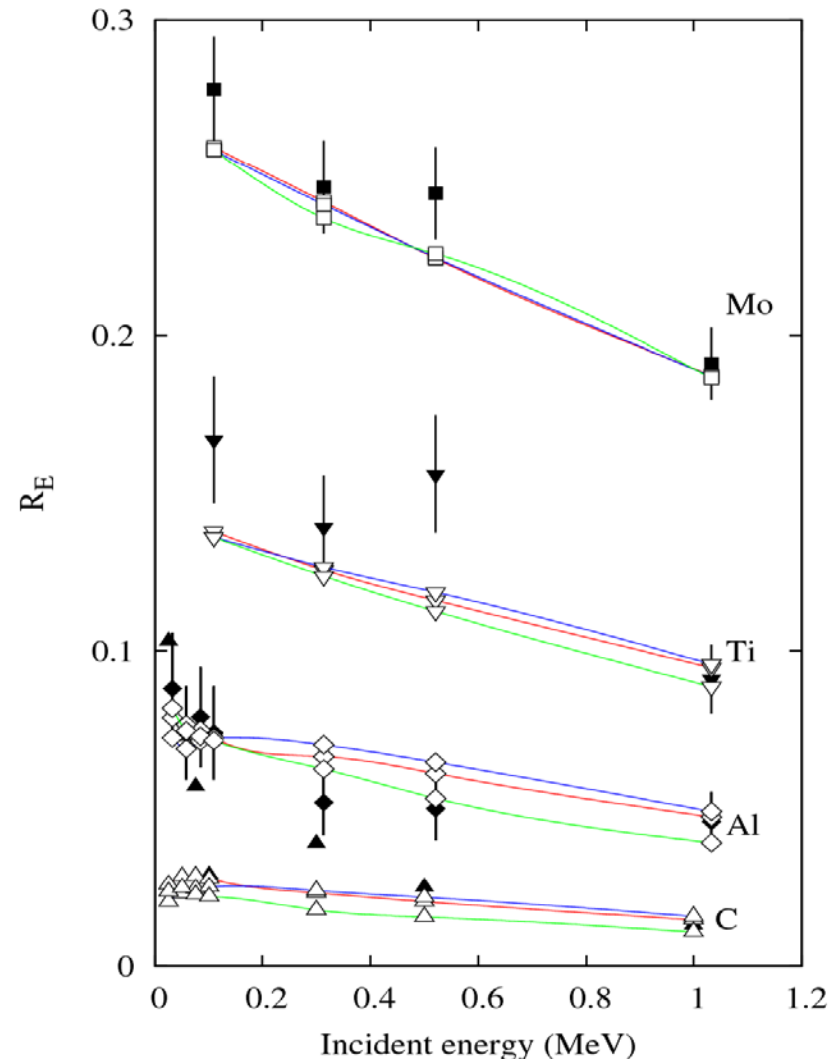
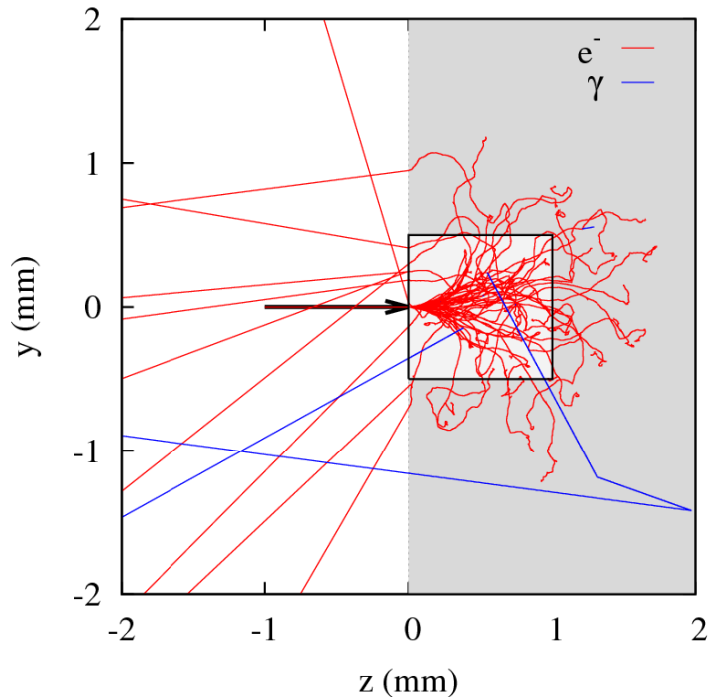
## Multiple scattering models

# Main modifications for 9.4

- ▶ Several validation of **electron scattering** confirms that Urban93 model is more precise
  - Urban92 is default for 9.2 and 9.3
  - Urban93 model become the default for 9.4
    - Optimized for electrons and positrons
- ▶ All tests for muons/hadrons confirm that WentzelVI model is precise for **muons**
  - Urban90 is default for muons and hadrons since 9.0
  - WentzelVI become the default for muons in 9.4

# New Backscattering simulation with L.Urban model (A.Lechner)

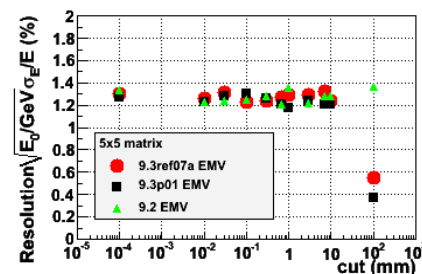
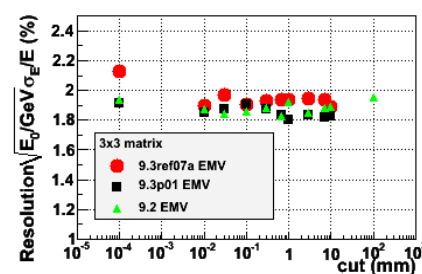
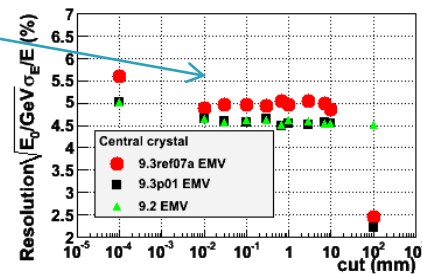
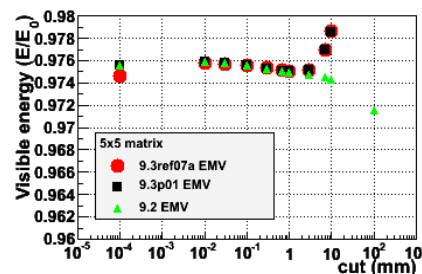
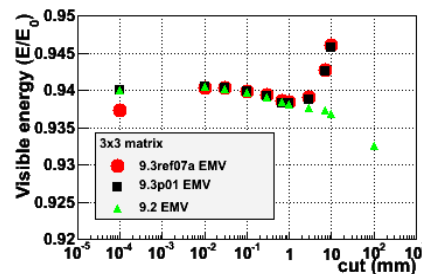
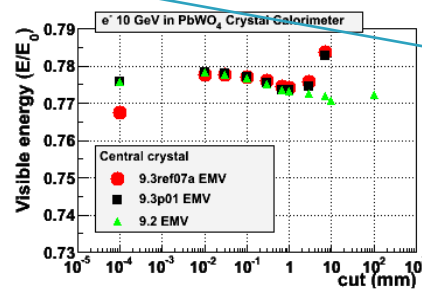
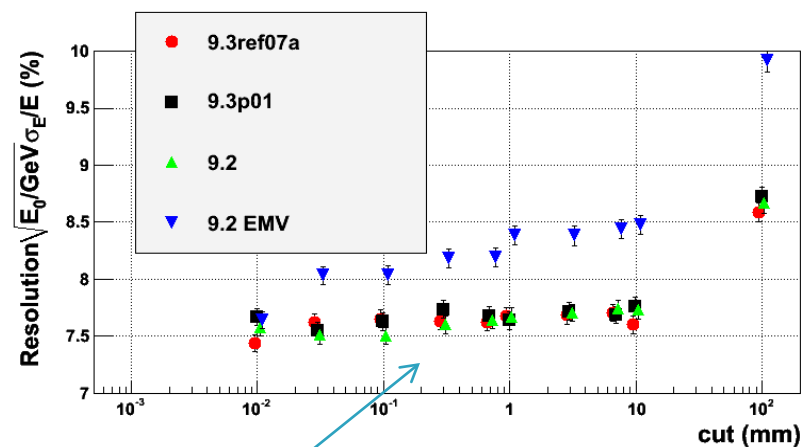
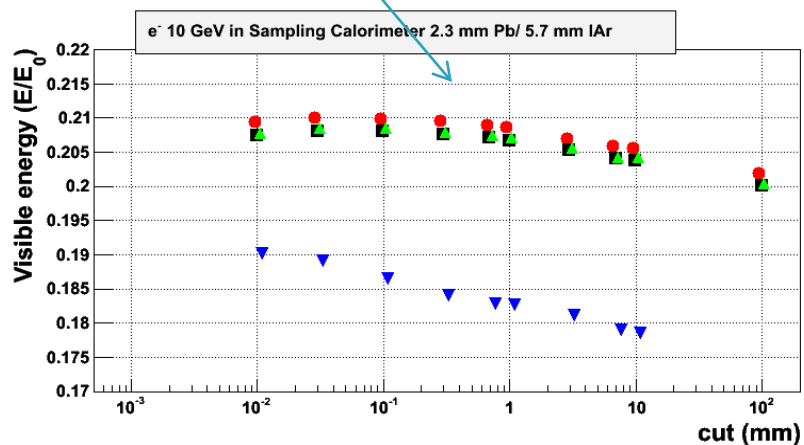
- Electron Energy and Charge Albedos  
SANDIA Report SAND80-0573 (1984)
- Electron energy 0.1 – 1 MeV



# Calorimeter response

Effect of MSC

ATLAS barrel



Resolution is stable

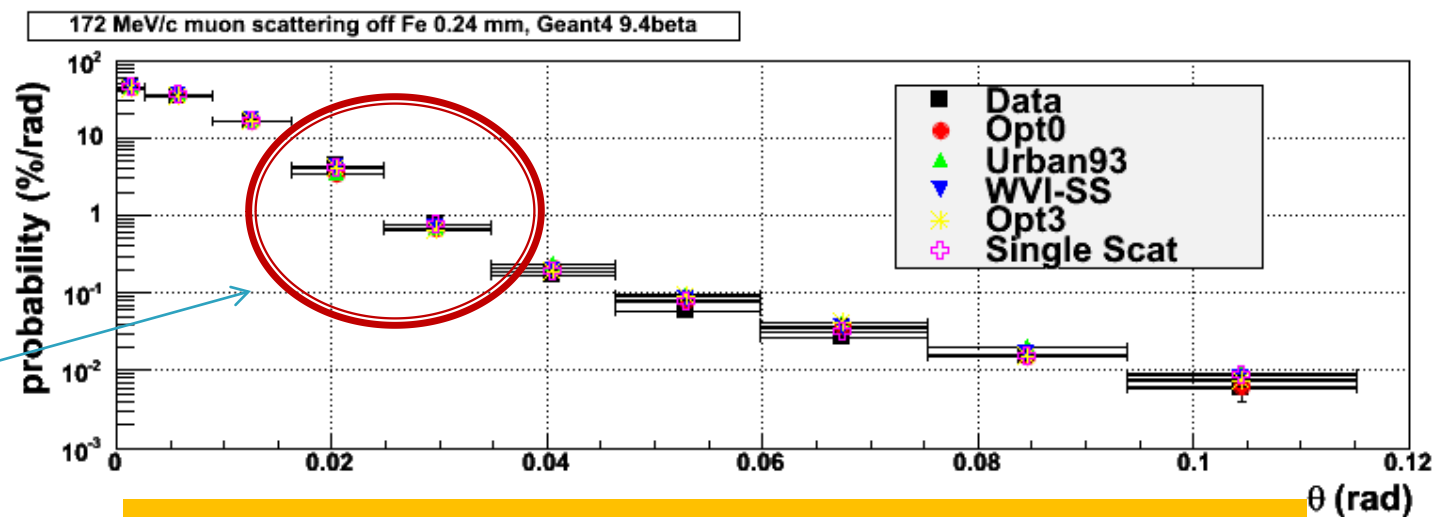
CMS ECAL

# New WentzelVI model

*J. Phys: Conf. Ser. 219 (2010) 032045*

- ▶ **Theory based**
  - Wentzel differential cross section with mass, spin and form-factor corrections
  - Original step limitation
    - Limit step of high energy particles in extended media (LHCb request)
- ▶ **Angular limit** between the single and multiple scattering is selected **dynamically**, depending on momentum and step size
  - **May be applied for transportation in vacuum or low-density media**
  - Can be used together with the hadron elastic scattering process (plan to 2011)

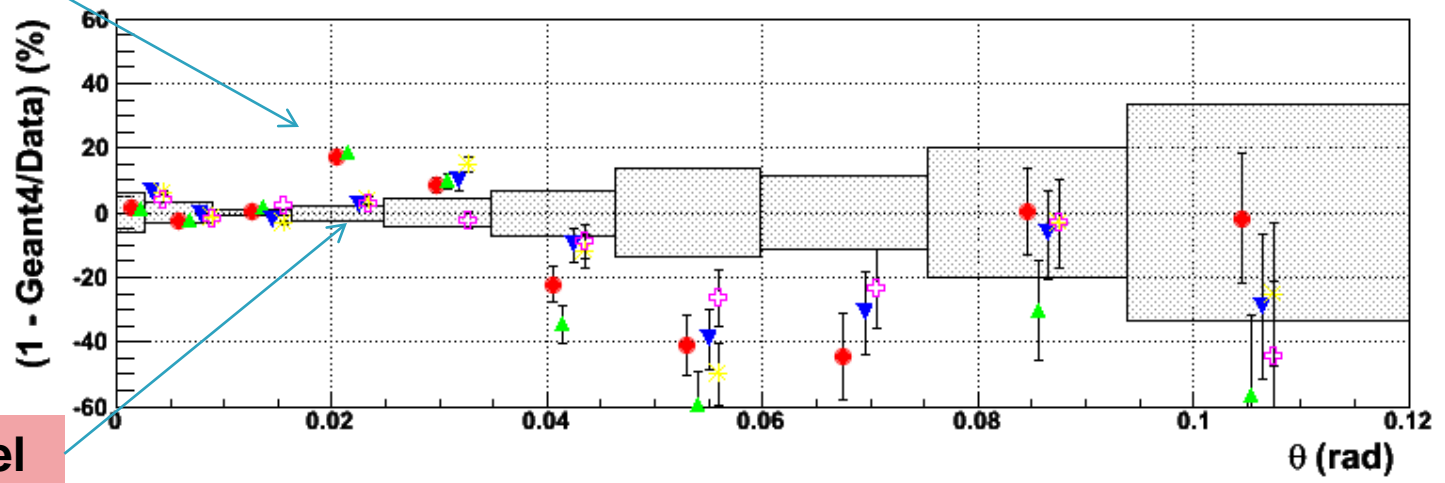
# MuScat Test Results 172 MeV/c



Improved area

Urban model

MuScat data D.Attwood et al., NIM B251 (2006) 41

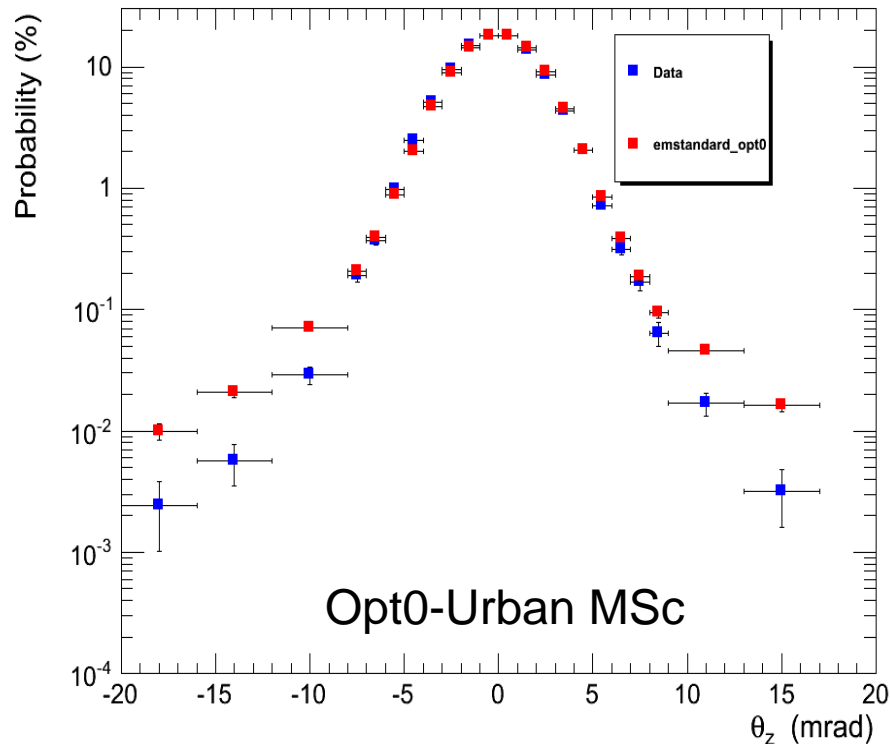


WentzelVI model

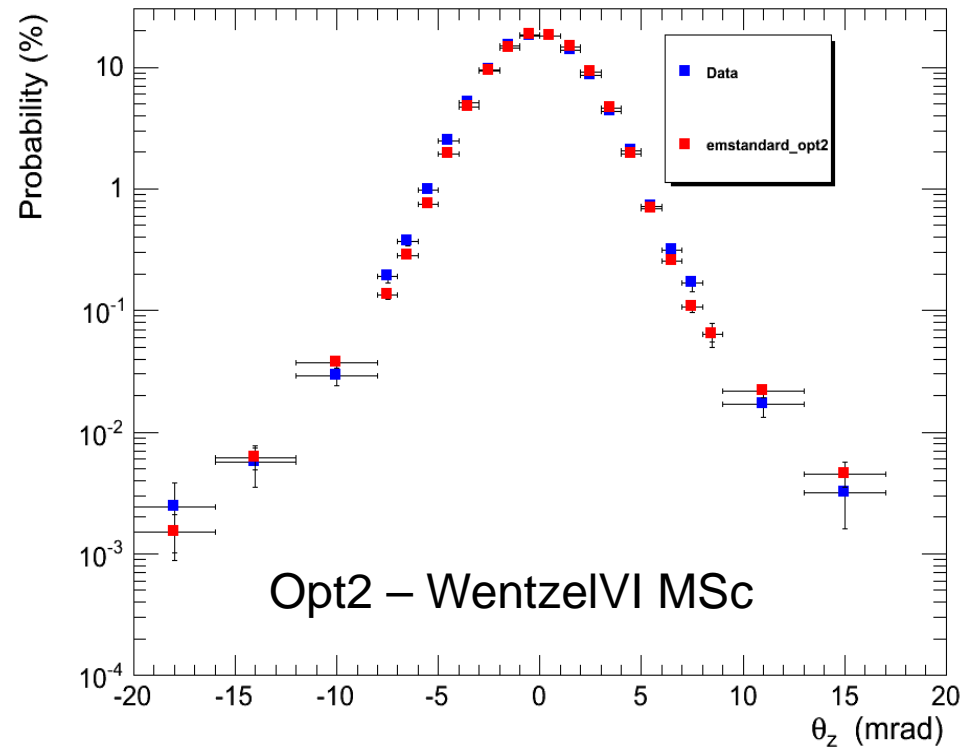


# New test of high energy MSC CERN summer student (O.Dale)

Probability for plane scattering angle  $\theta_z$ : 7.195 GeV & emstandard\_opt0



Probability for plane scattering angle  $\theta_z$ : 7.195 GeV & emstandard\_opt2

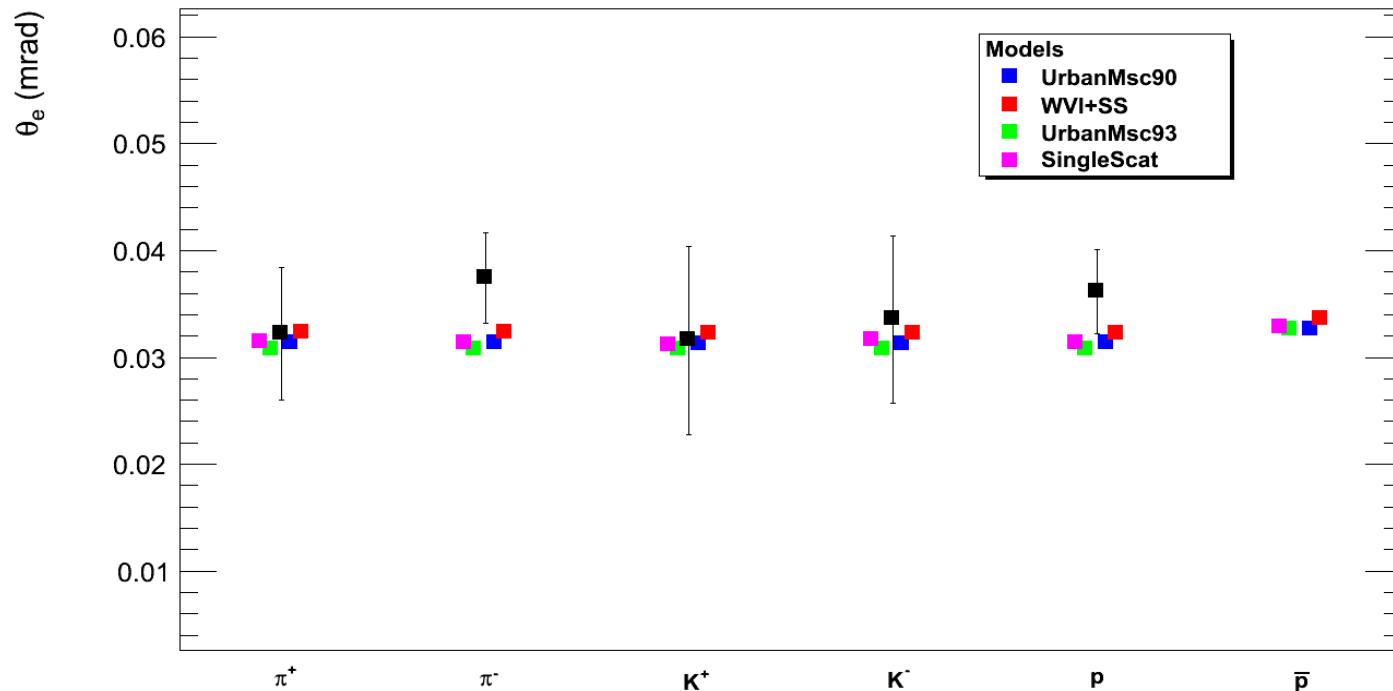


7.195 GeV

- ▶ Urban model overestimates tail
- ▶ WentzelVI and single Coulomb scattering models fit the data

# High energy multiple scattering: 175 GeV beams off Cu target (O.Dale)

Comparison of GEANT4 and data  $\theta_e$ : Cu & 175 GeV



- ▶ Central part of distribution reproduced by all models within data uncertainty and agree with Moliere theory
- ▶ Data available for 50 - 200 GeV for various targets (Be, Al, Cu, Sn, Pb)
- ▶ G.Shen et al., Phys. Rev. D20 1584 (1979)

# Geant 4



## User Interfaces

# EM HEP Physics List constructors for 9.4

Constructor	Components	Comments
G4EmStandardPhysics	Default (QGSP_BERT, FTFP_BERT...)	ATLAS and other HEP productions, other applications
G4EmStandardPhysics_option1	Fast due to simple msc step limitation, cuts used by photon processes (QGSP_BERT_EMV, ...)	CMS and LHCb production, good for crystals not good for sampling EM calorimeters
G4EmStandardPhysics_option2	Experimental: WentzelVI model for hadron msc, BS angular distribution for bremsstahlung (QBBC, ...)	Used for testing of new models

- ▶ Main user interface
- ▶ Used by Geant4 validation suites
  - Are robust due to intensive tests by Geant4 team
- ▶ **Oriented on HEP applications**
- ▶ We have Opt3 and combined constructors for other applications

# Helper classes in 9.4

- ▶ **G4EmCalculator** – easy access to cross sections and stopping powers (TestEm0)
- ▶ **G4EmProcessOptions** – C++ interface to EM options alternative to UI commands
- ▶ **G4EmSaturation** – Birks effect
- ▶ **G4ElectronIonPair** – sampling of ionisation clusters in gaseous or silicon detectors
- ▶ **G4EmConfigurator** – add models per energy range and geometry region

# Geant 4

## Draft plan for 2011

### ▶ Ionisation

- Finalize tuning of ionisation for anti-nuclei model
- Improve ionisation for highly charged exotics and high energy ions
- Improve sampling of fluctuations by specialization of the fluctuation model for electrons and positrons (trackers)

### ▶ Multiple scattering

- Provide combined model for hadrons where Coulomb and strong scattering amplitudes are taken into account consistently

### ▶ Bremsstrahlung

- Increase precision of computation of total cross section (below 1 GeV)
- Improve sampling (including angular distributions)

### ▶ Pair production

- Add triple final state (may affect tracker response)
- Improve angular distribution

### ▶ Polarisation

- Implement spin precession in field using Stokes vector formalism (ILC)

### ▶ Validation

- Regular run existing testing suite
- Extend testing suite for additional thin target data
- Support existing and new experiments
  - LHC - first priority
  - CALICE, ILC,...