Geant4 9.6 Electromagnetic Physics Highlights

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V.N.Ivanchenko for EM physics groups
G4 Associate International, CERN

Introduction

- For complete list of modifications see Release Notes for 9.6 and electromagnetic physics (EM) web pages
- Below we will focus on few major improvements affecting majority of users

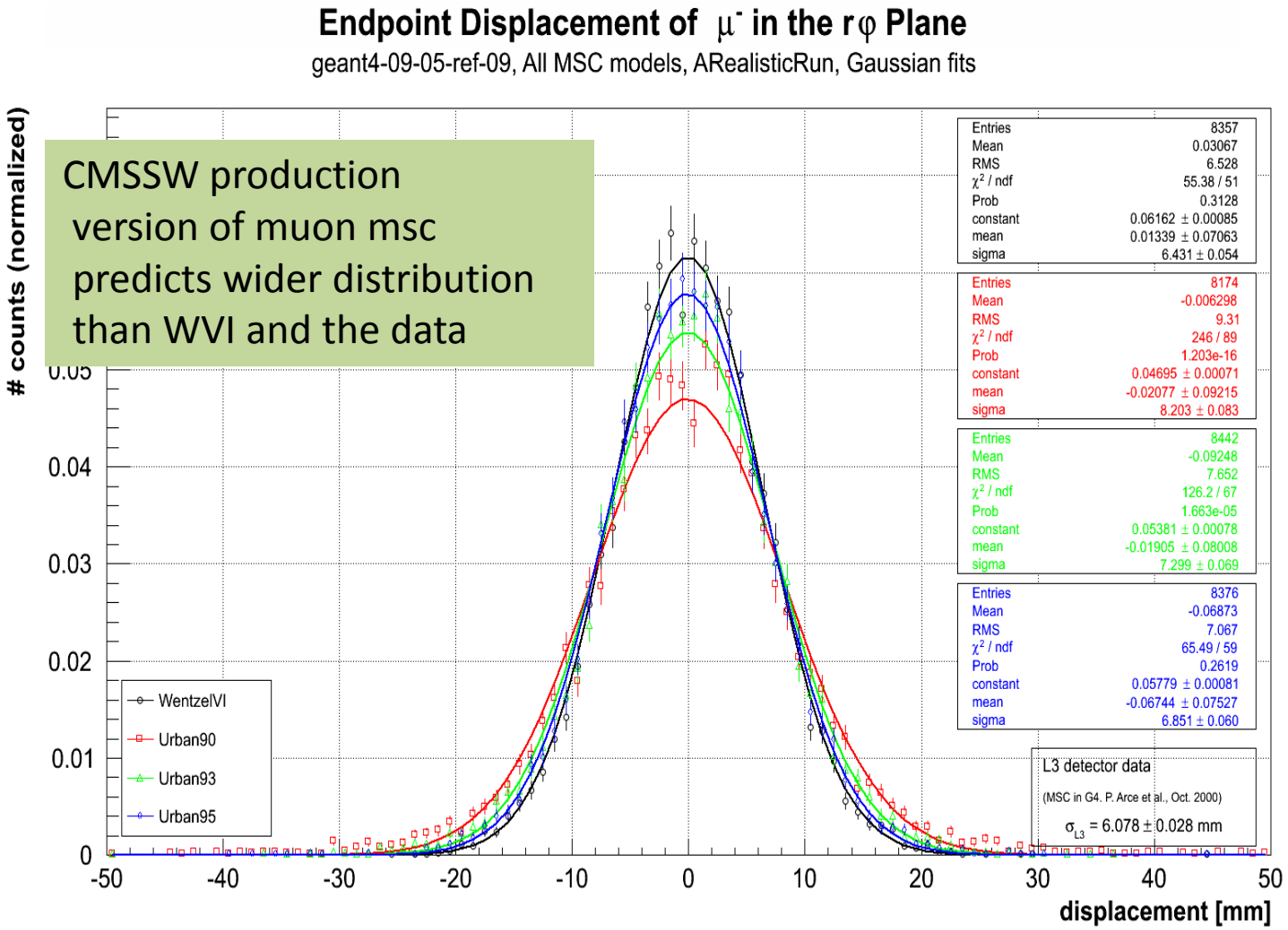
Major modifications require change of an application of Geant4

- EM physics (both standard and low-energy) now require the G4EMLOW 6.32 data files
- Obsolete methods Get/SetModel() have been removed from optical processes
  - removal of such calls in custom physics lists with optical boundary process is mandatory
  - no effects on results, because these methods were dummy
- G4EmStandardPhysics_option4 : new EM physics constructor
  - selects the most accurate models for each EM process
  - combines models both from standard and low-energy sub-packages

Overview of modifications for multiple scattering

- Base material approach is implemented
  - In 9.5 base material approach was introduced forenergy loss and discrete processes only
- Particles and anti-particles share EM process class
  - Reduced size of EM tables
- Physics Tables moved from processes to models
  - Urban and Wentzel models may work in the same Physics List for different energy range
- In all EM builders (except Opt3) Wentzel model is used for all charged particles except e+- below 100MeV
  - Long Reserford tail better simulated by the Wentzel model
  - ATLAS problem of big scattering angles after small step in low dense media is fixed
  - LHCb requirements for tracking in thin and thick media are fulfilled
  - In standard Opt3 builder UrbanMsc95 models is used for for hadrons and ions

Geant4 muons versus L3 data (M.Schenk, CERN summer student)



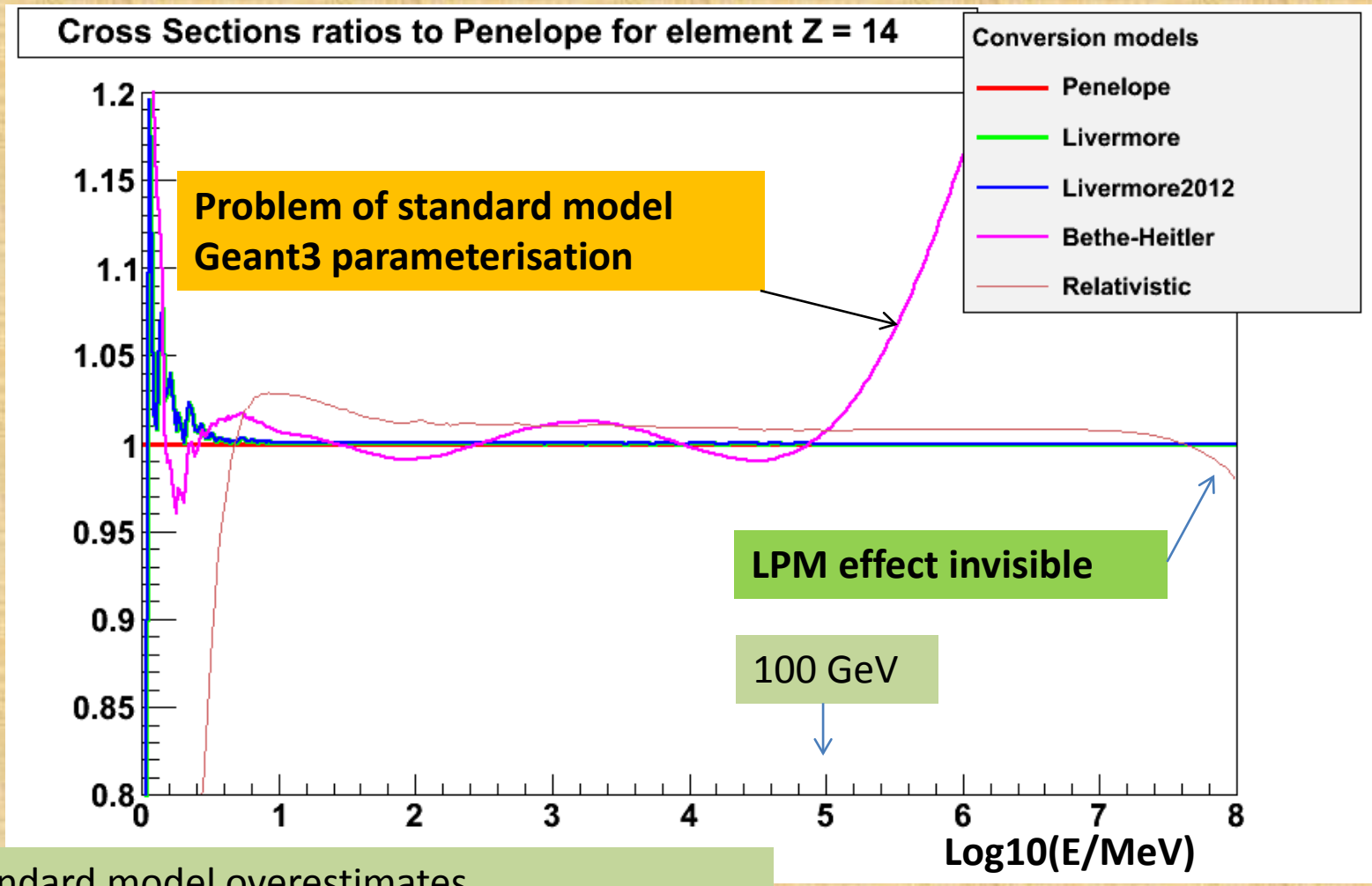
Common for all EM sub-packages

- Established universal interface to angular generator for all models and cleanup angular generators
  - Bremsstrahlung, Rayleigh, photoeffect
- Built-in biasing for EM fixed and extended
  - Bremsstrahlung splitting significantly improved
    - For each extra gamma resampling is performed
  - Weight propagation fixed
  - Range cut option is added
- Added new method
  - G4EmCalculator::ComputeGammaAttenuationLength()

Gamma conversion model review

- Gamma conversion models of Geant4 have been reviewed
  - Cross sections and final states were studied
- It was shown that standard model (derived from Geant3 implementation) has problems
  - Parameterisation was established below 100 GeV
  - Inaccurate cross section above 100 GeV
- Since Geant4 9.4 we have ultra-relativistic gamma conversion model which takes into account LPM effect
  - It was not consideted for LHC because LPM effect is important at higher energies
  - In Geant4 9.6 this model is included in all EM constructors above 80 GeV

Gamma conversion cross section ratio for Silicon between different Geant4 models



Standard model overestimates probability of gamma conversion in tracker

Bremsstrahlung

- Seltzer-Berger model:
  - More detailed grid of Setzer-Berger differential cross sections
    - Geant4 9.5: 31 points for electron energy, 14- for photon energy
    - Geant4 9.6: 52 points for electron energy, 31- for photon energy
  - Updated screening functions
- G4DipBustGenerator for angular distribution is default
- Other angular generators (Tsai, 2BS, 2BN) are verified versus original publications and corresponding improvements are added
  - mainly for backward hemisphere

Selected list of other modifications

- New processes/models
  - For microdosimetry in Silicon for electrons, protons and ions
  - Compton scattering model (G4LowEPComptonModel)
- Model refinments
  - fluctuation model upgrade for gas layers
  - extended energy range of dEdx and other tables for monopoles with large mass
  - Livermore photoeffect, pair production, and Rayleigh scattering models reviewed and improved
    - Significant speedup of sampling of final states
- EM dataset refinments:
  - Removed Penelope2001 data
  - Reviewed and modified ICRU`73 data for ion stopping
  - Added extra data for new low-energy and DNA models

Geant4 9.6: EM Physics builders for HEP

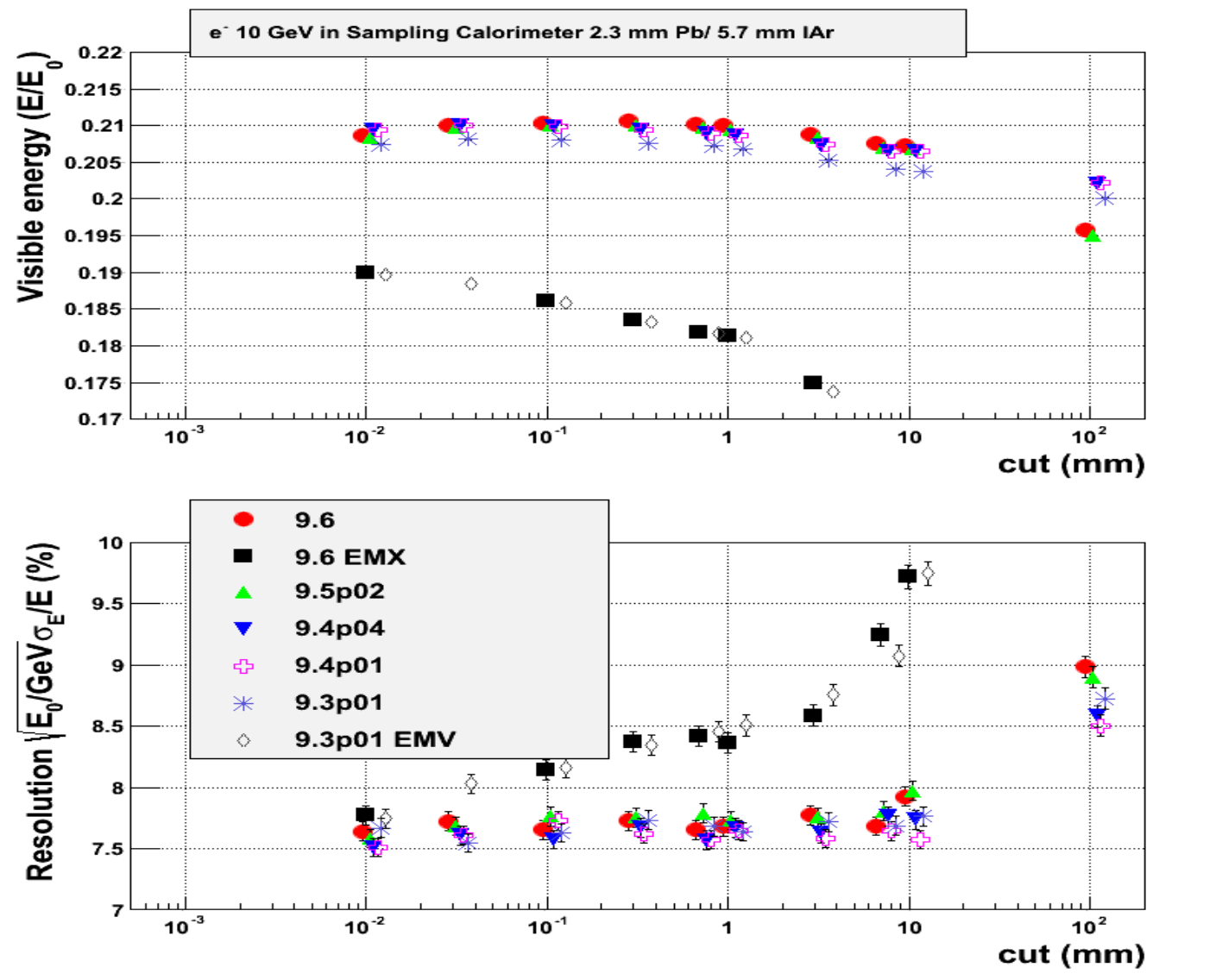
- List of particles: for which EM physics processes are defined
  - γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, p, $\Sigma^{\pm}$, Ξ^{-}, Ω^{-}, anti($\Sigma^{\pm}$, Ξ^{-}, Ω^{-})
  - $\tau^{\pm}$, $B^{\pm}$, $D^{\pm}$, $D_s^{\pm}$, Λ_c^{+}, Σ_c^{+}, Σ_c^{++}, Ξ_c^{+}, anti(Λ_c^{+}, Σ_c^{+}, Σ_c^{++}, Ξ_c^{+})
  - d, t, He3, He4, GenericIon, anti(d, t, He3, He4)

Constructor	Components	Comments
G4EmStandardPhysics	Default (QGSP_BERT, FTFP_BERT…)	ATLAS, and other HEP productions, other applications
G4EmStandardPhysics_option1	Fast due to simple step limitation, cuts used by photon processes (FTFP_BERT_EMV)	Similar to one used by CMS, good for crystals, not good for sampling calorimeters
G4EmStandardPhysics_option2	Experimental: updated photon models and bremsstrahlung on top of Opt1	Similar to one used by LHCb

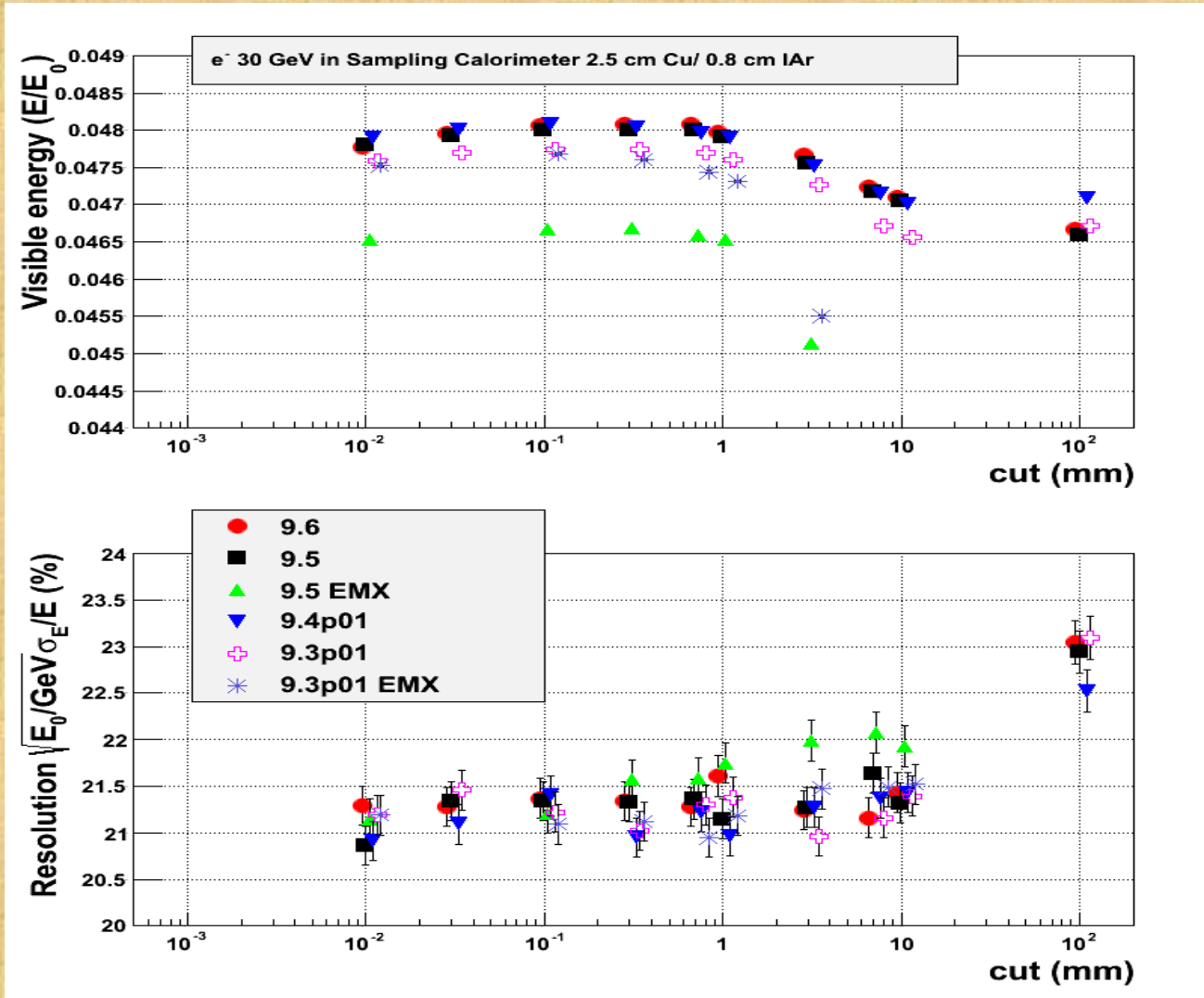
BACKUP: VALIDATION RESULTS

SIMPLIFIED CALORIMETERS

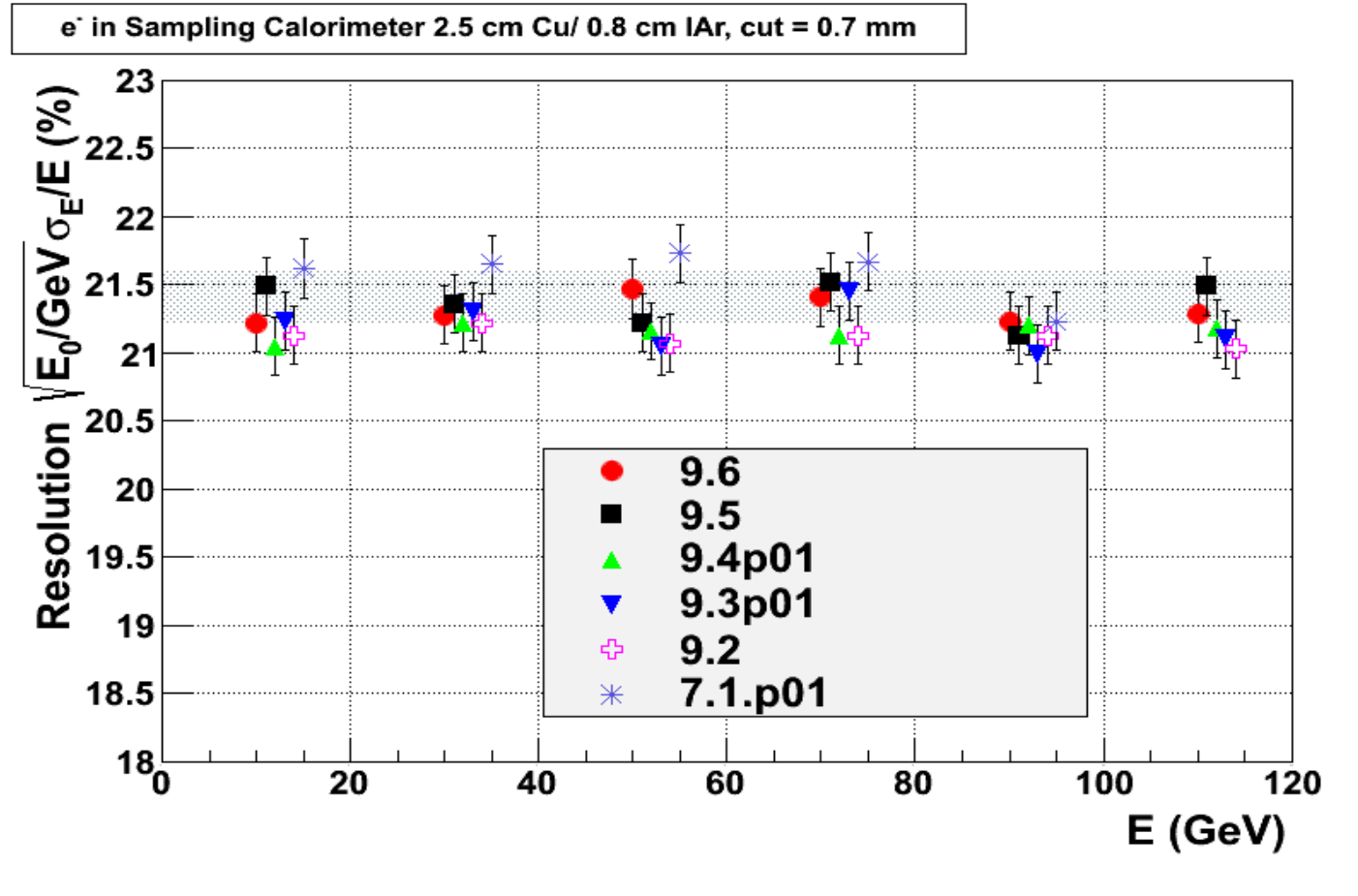
ATLAS Barrel type calorimeter



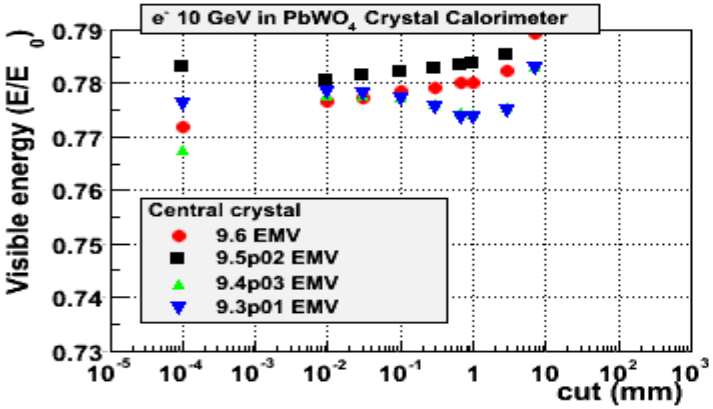
ATLAS HEC type calorimeter

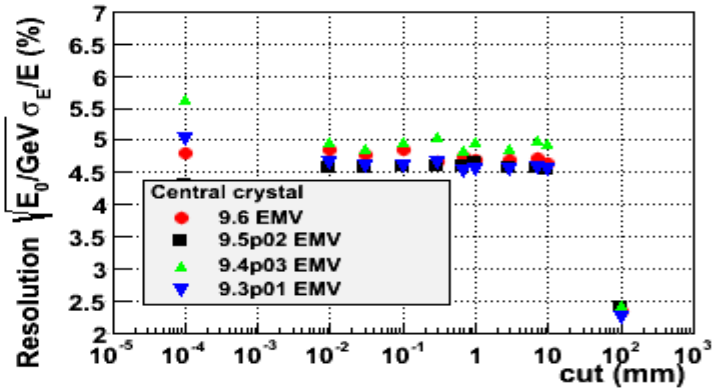


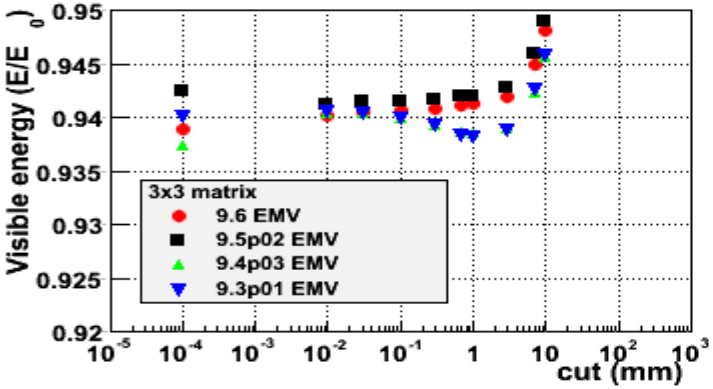
ATLAS HEC type calorimeter

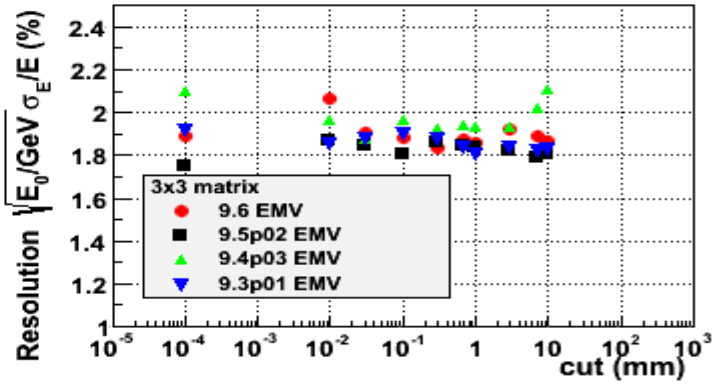


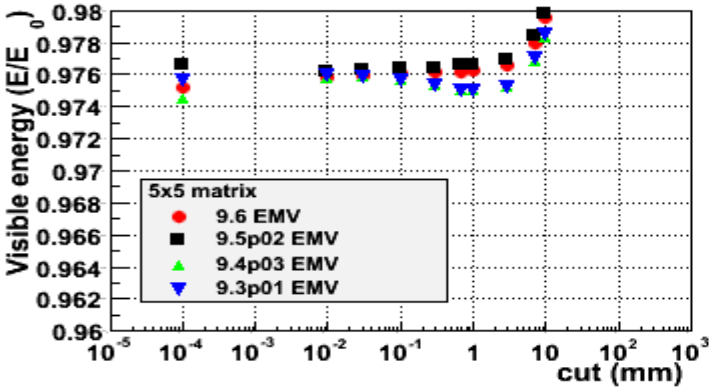
CMS ECAL type calorimeter

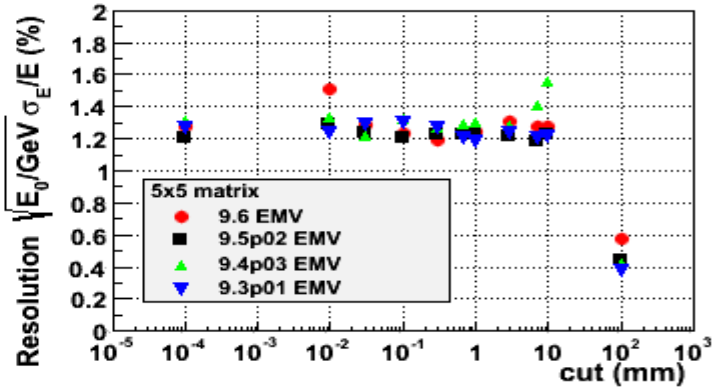




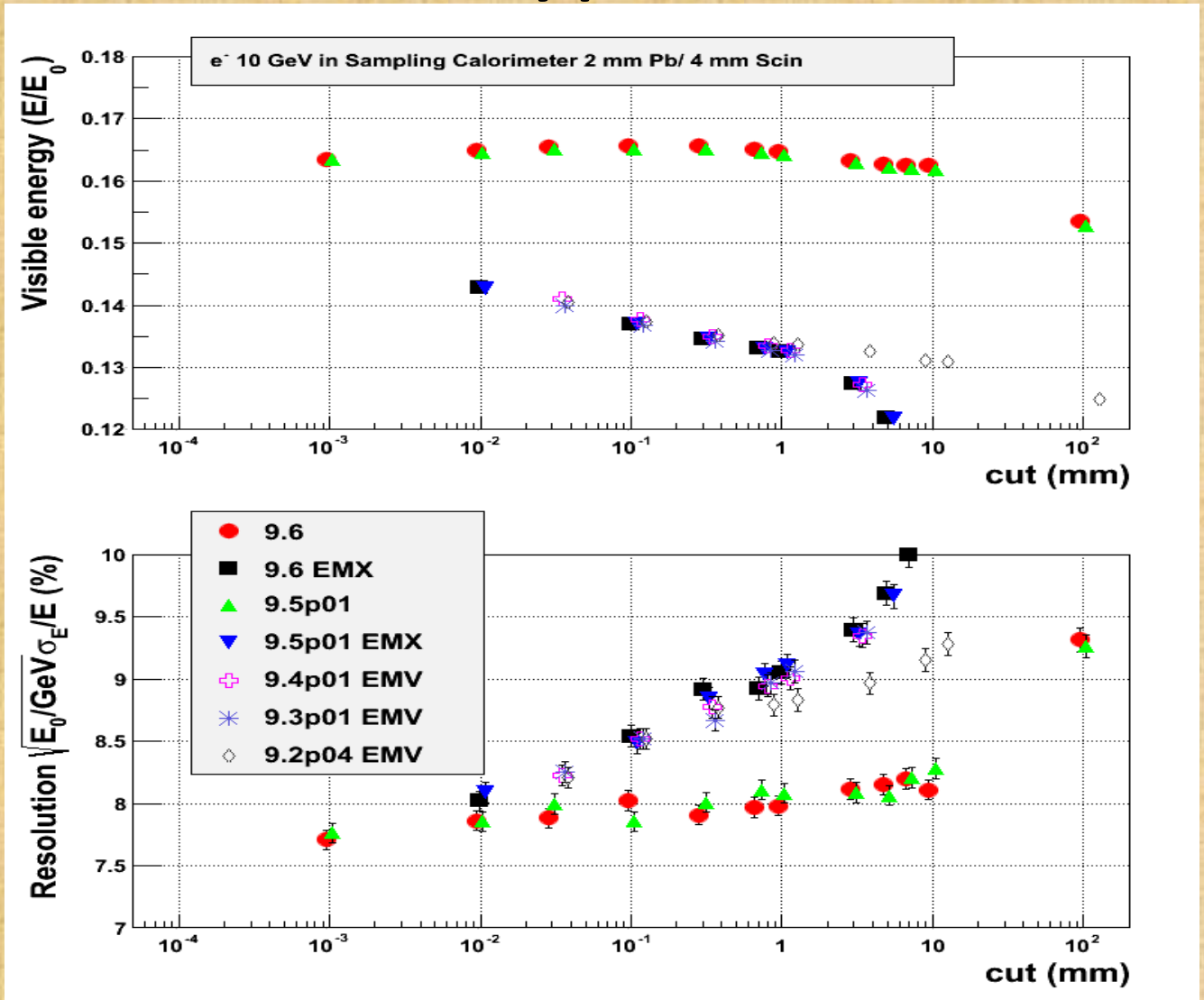




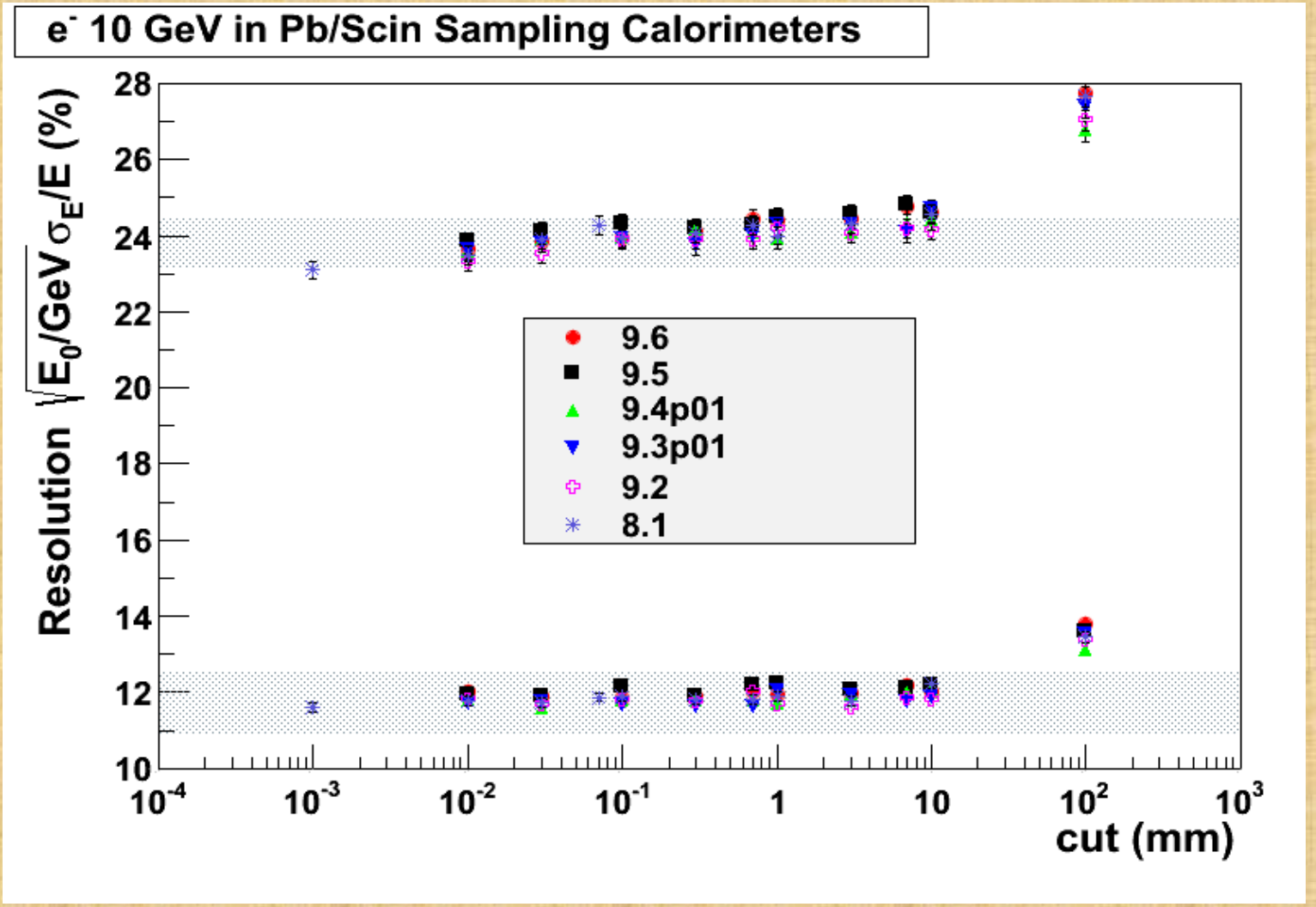




LHCb type calorimeter



ZEUS test-beam calorimeter



MULTIPLE SCATTERING

Fano cavity test case

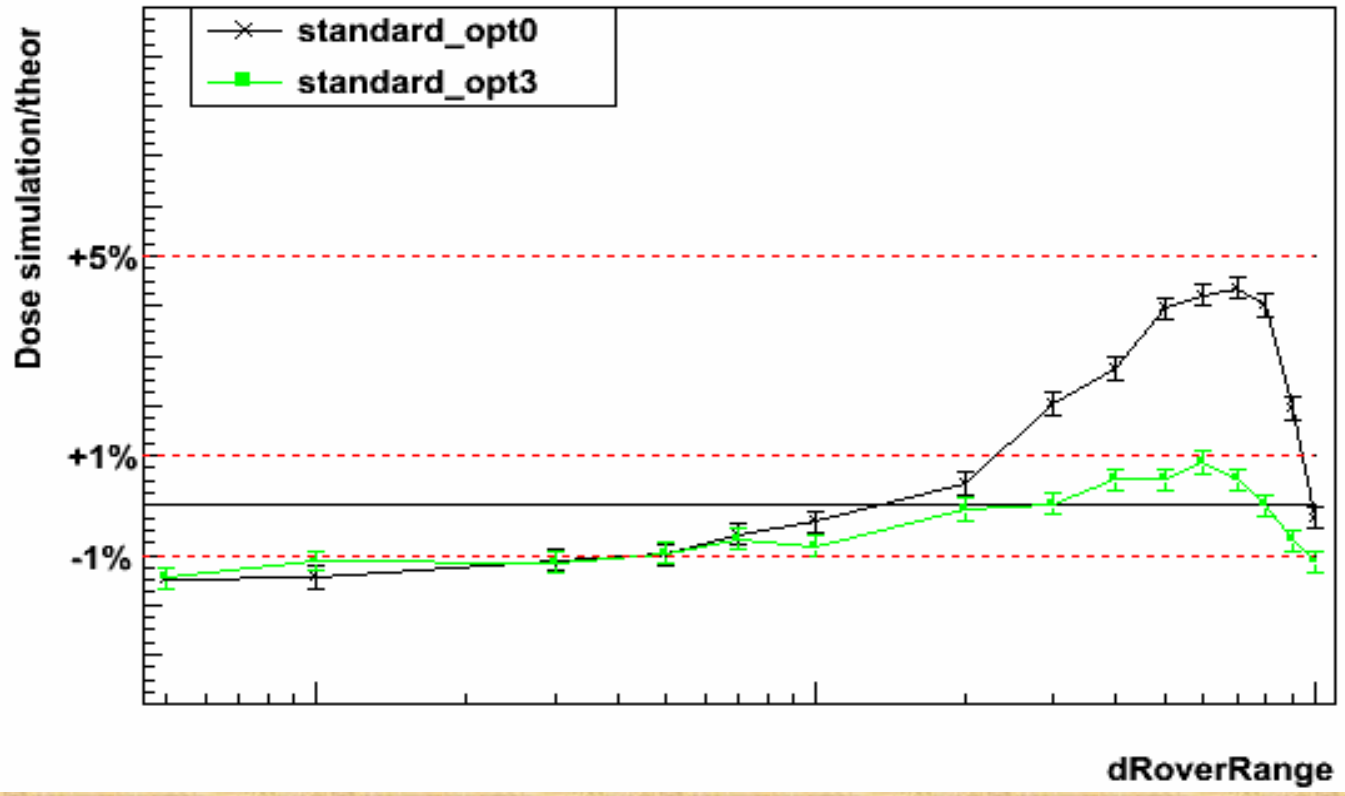
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 09-05-ref-10

Basic test (no fluct, no msc):

standard_opt0 : 0.9976 +/- 0.0002 for dRoverRange = 0.004
standard_opt3 : 1.0006 +/- 0.0002 for dRoverRange = 0.004

Full test (fluct & msc):



Fano cavity test case

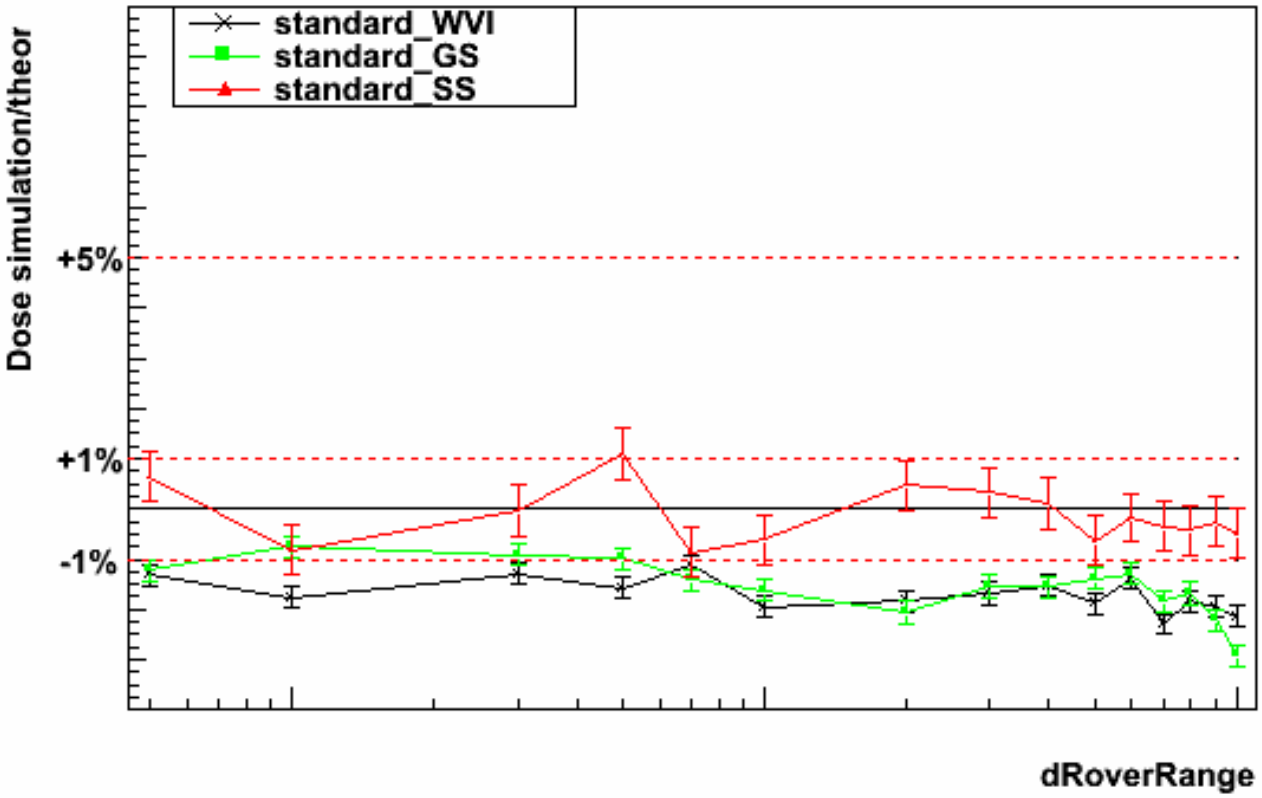
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 09-05-ref-10

Basic test (no fluct, no msc):

standard_WVI : 0.9995 +/- 0.0006 for dRoverRange = 0.004
standard_GS : 1.0006 +/- 0.0002 for dRoverRange = 0.004

Full test (fluct & msc):



Fano2 cavity test case

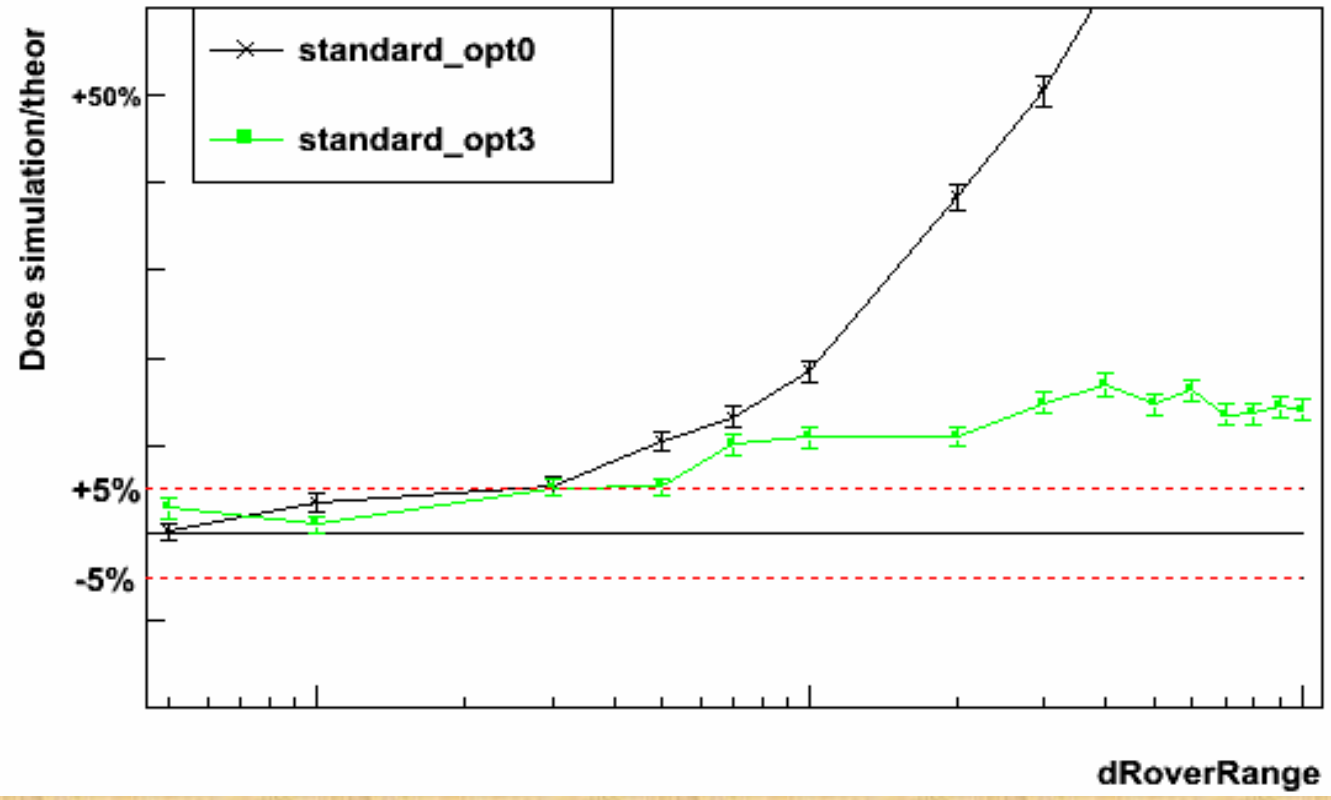
Ratio between simulated and theorical dose deposited by a 1.00 MeV electron beam crossing an infinite radius chamber

Geant4 release : 09-05-ref-10

Basic test (no fluct, no msc):

standard_opt0 : 1.0013 +/- 0.0009 for dRoverRange = 0.004
standard_opt3 : 1.0008 +/- 0.0009 for dRoverRange = 0.004

Full test (fluct & msc):



Fano2 cavity test case

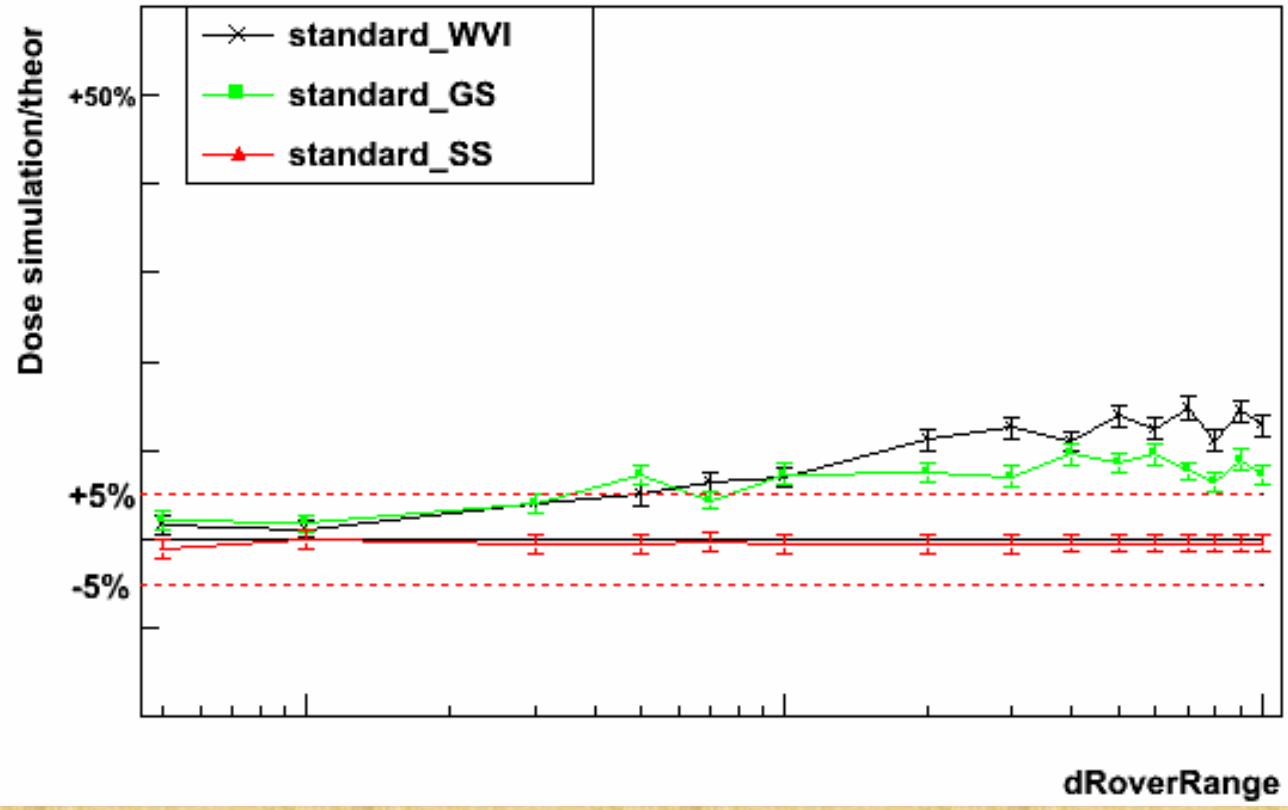
Ratio between simulated and theorical dose deposited by a 1.00 MeV electron beam crossing an infinite radius chamber

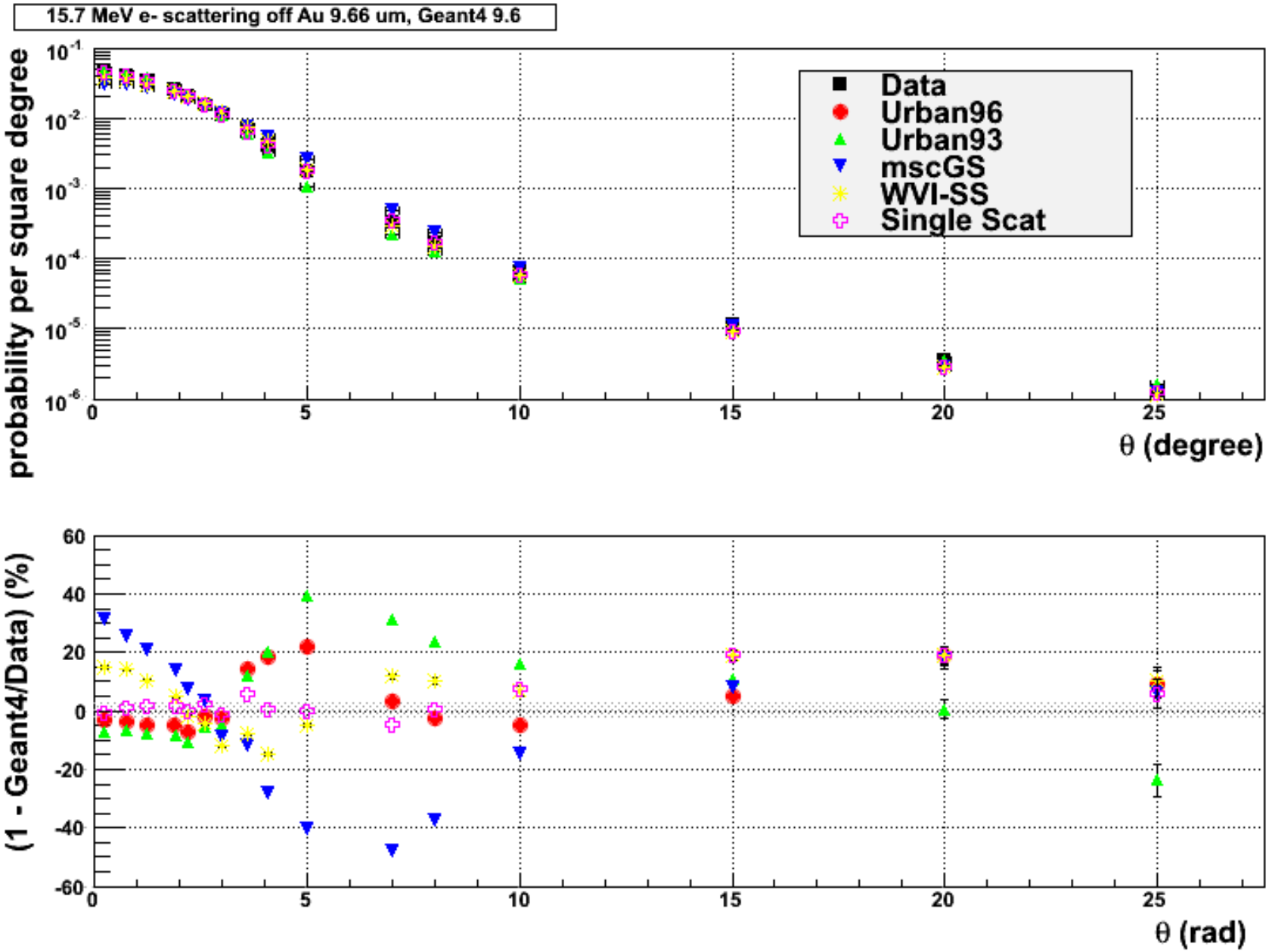
Geant4 release : 09-05-ref-10

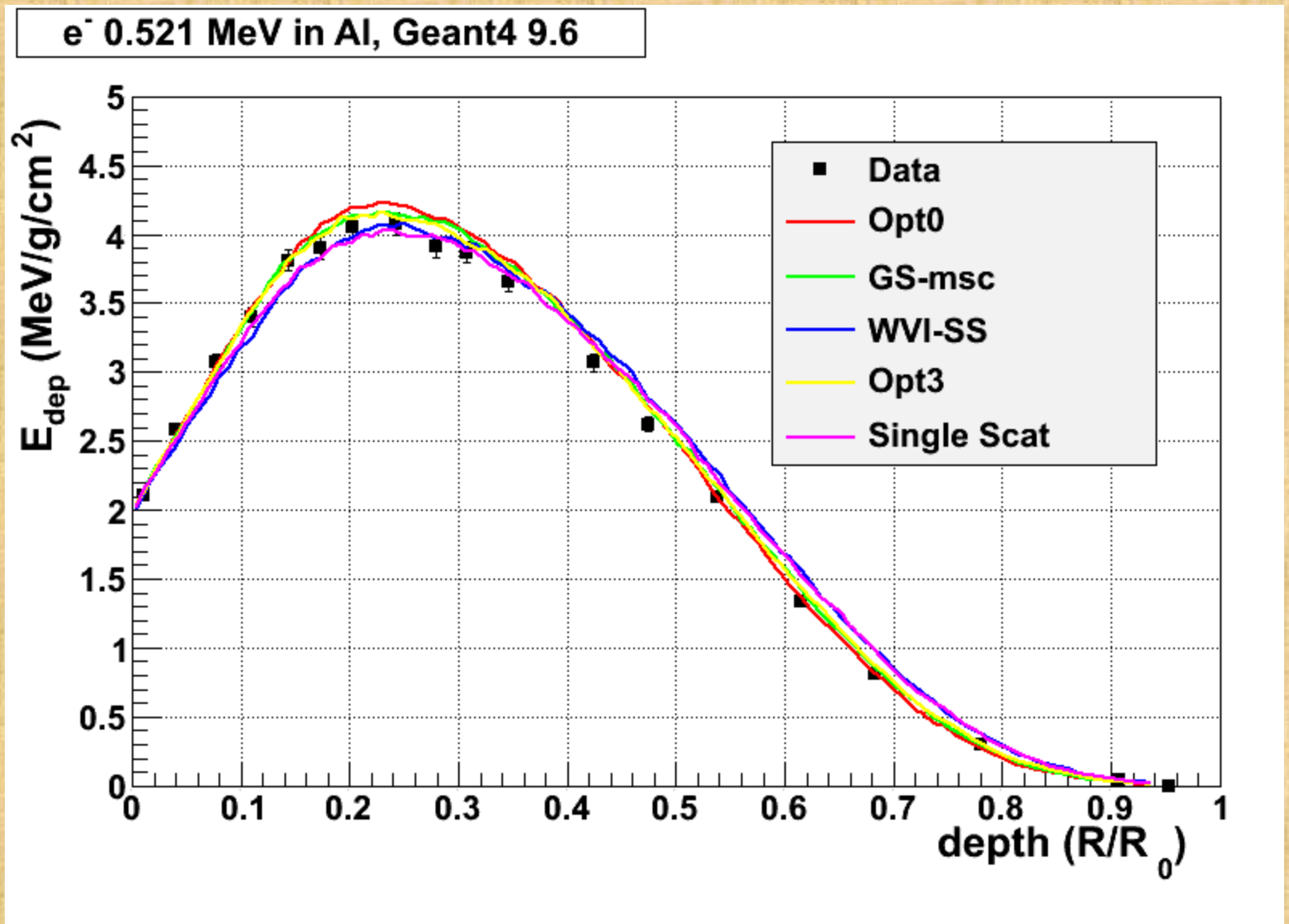
Basic test (no fluct, no msc):

standard_WVI : 1.0089 +/- 0.0035 for dRoverRange = 0.004
standard_GS : 1.0008 +/- 0.0009 for dRoverRange = 0.004

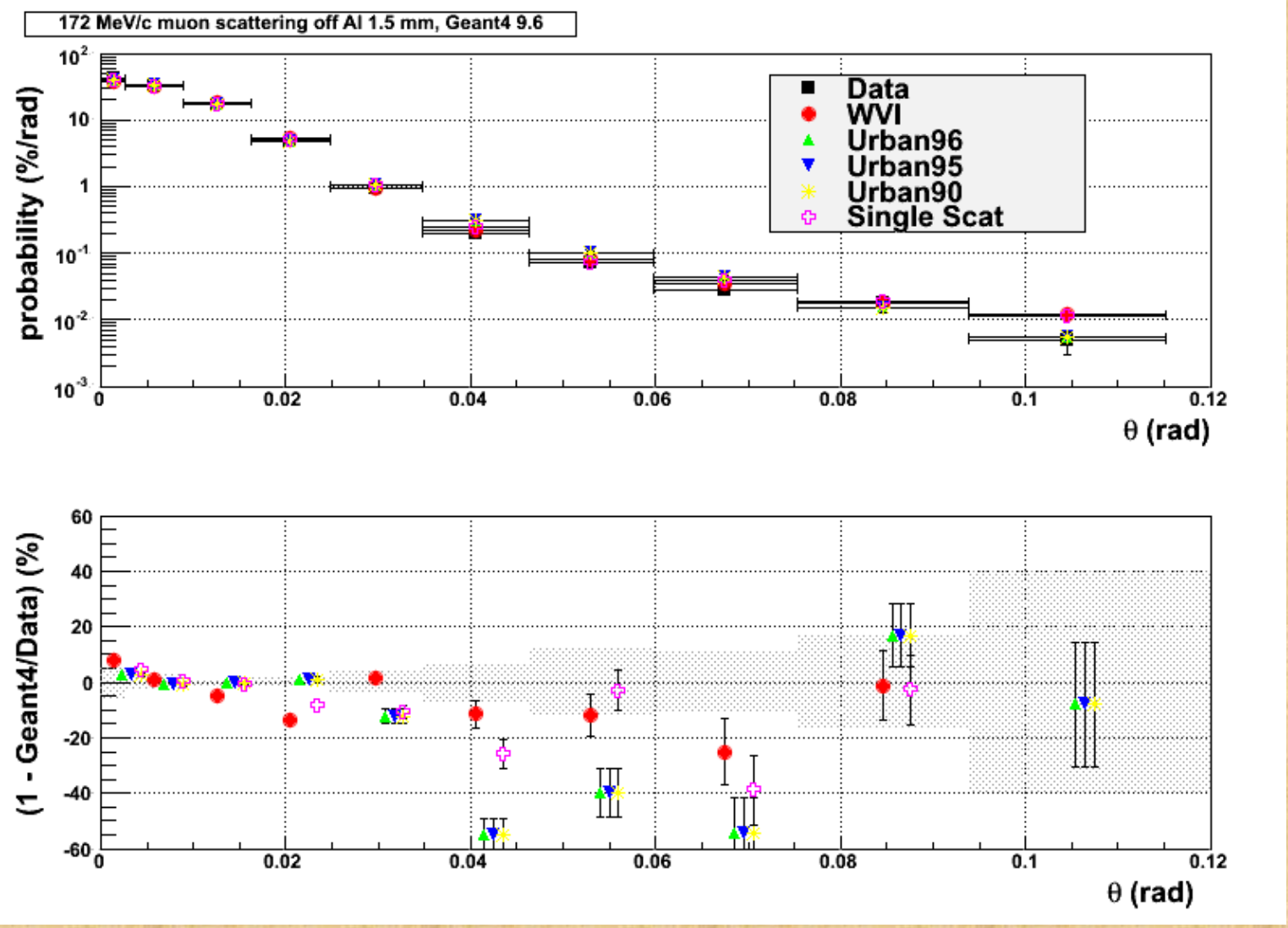
Full test (fluct & msc):



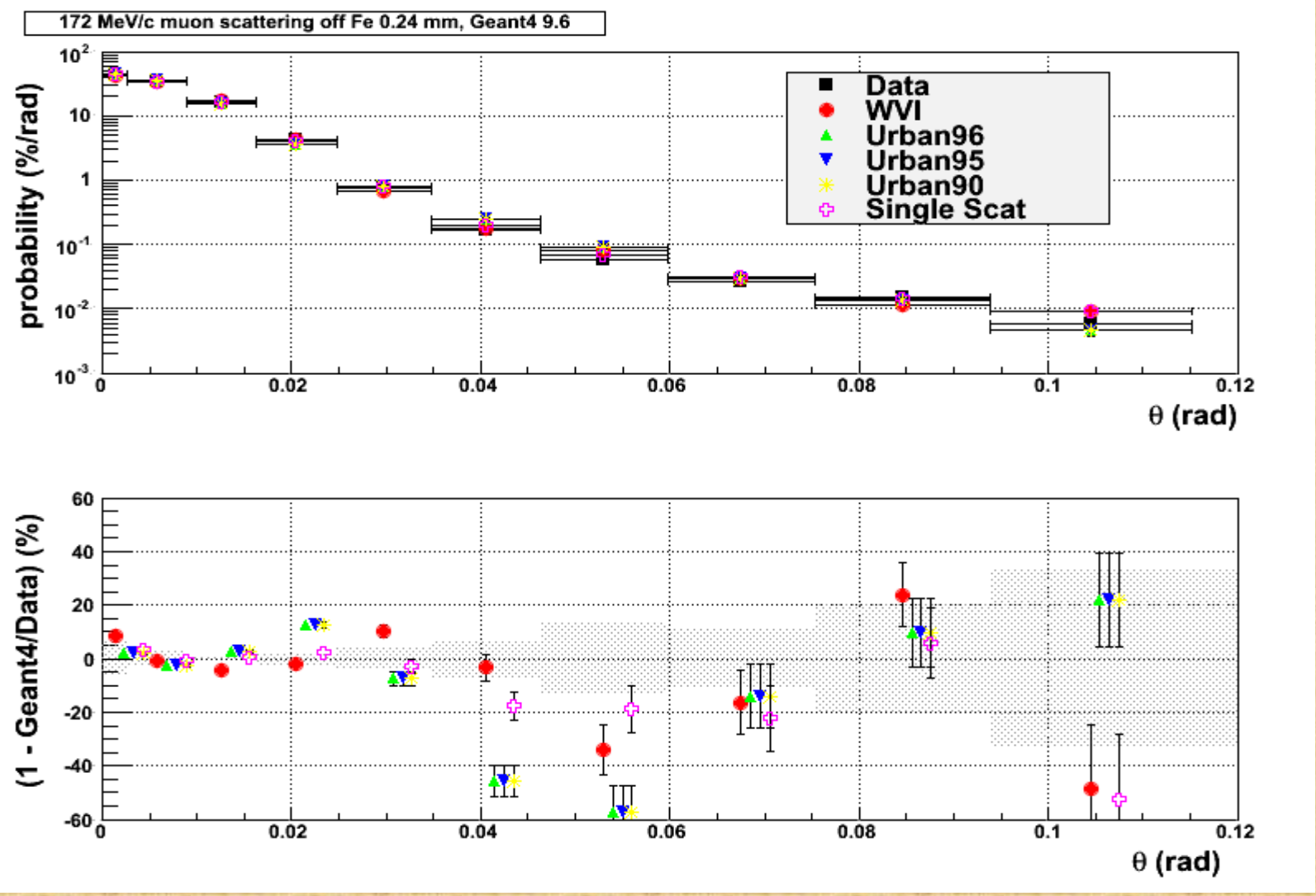

15.7 MeV e- scattering off Au 9.66 um, Geant4 9.6
probability per square degree
θ (degree)
Data
Urban96
Urban93
mscGS
WVI-SS
Single Scat
(1 - Geant4/Data) (%)
θ (rad)


e⁻ 0.521 MeV in Al, Geant4 9.6
E_dep (MeV/g/cm²)
depth (R/R_0)
Data
Opt0
GS-msc
WVI-SS
Opt3
Single Scat
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

MuScat data


172 MeV/c muon scattering off Al 1.5 mm, Geant4 9.6
probability (%/rad)
θ (rad)
Data
WVI
Urban96
Urban95
Urban90
Single Scat
(1 - Geant4/Data) (%)
θ (rad)

MuScat data


172 MeV/c muon scattering off Fe 0.24 mm, Geant4 9.6
probability (%/rad)
Data
WVI
Urban96
Urban95
Urban90
Single Scat
θ (rad)
(1 - Geant4/Data) (%)
θ (rad)

High energy data for muons