EM Standard Status

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For EM Standard Working Group

18th Geant4 Collaboration Workshop
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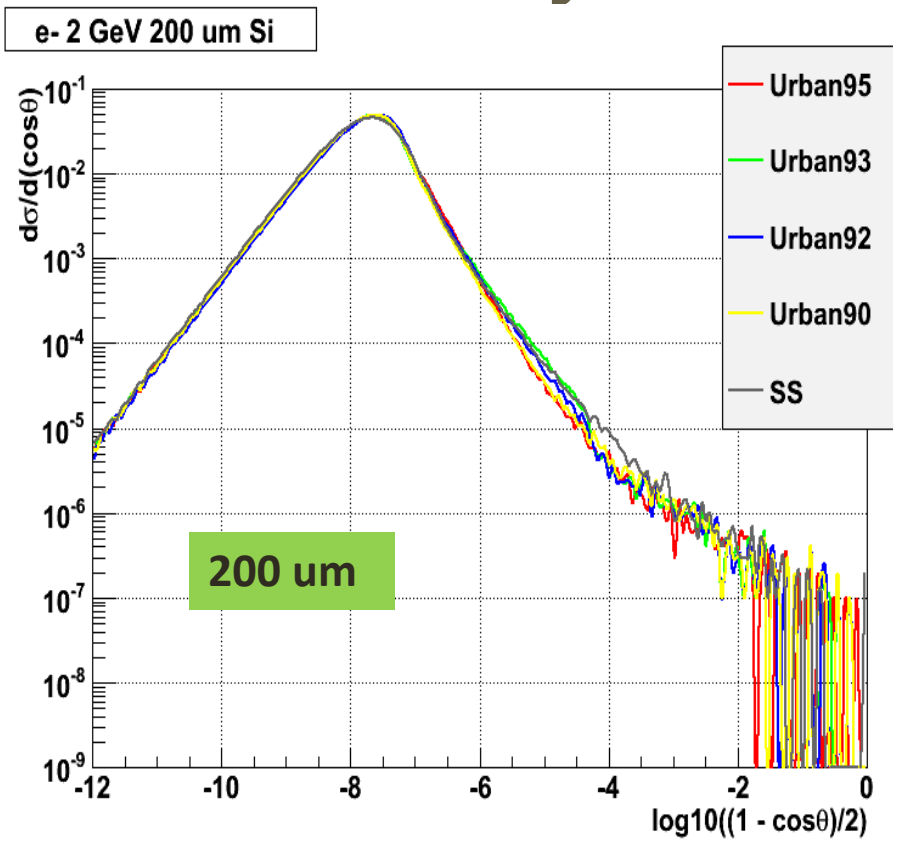
Outline

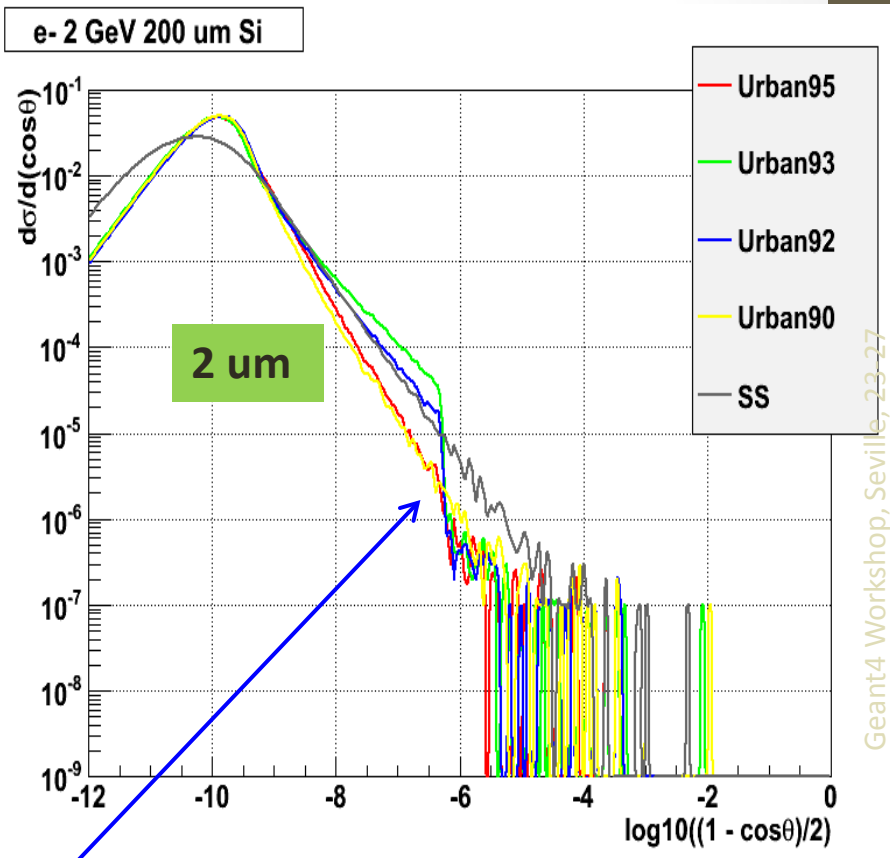
- Develoment and fixes for Geant4 9.6
- Development for the release 10.0
  - Migration of EM code to MT
  - PAI and Fluctuation model evolution
  - Muon processes
  - Multiple scattering
  - What else for release 10?
- Selected validation results
- Summary

Multiple scattering

- Fixed bug #1403: trajectory in magnetic field is incorrect if material is not galactic vacuum
  - The bug was connected with migration of multiple scattering actions from PostStep to AlongStep
  - The fix was done inside G4VMultipleScattering classes G4VMscModel: corrected signature of method SampleScattering().
  - Correction was propagated to all msc models
  - A new validation test Tracker has been created
    - It may be potentially used in CDASH physics validations
- Fixed problem reported by ATLAS of G4UrbanMscModel93
  - In 2012 a fast fix (protection) was introduced to address ATLAS report on rare bad scattering in tracker of high energy electrons
    - A cut have been added into sampling of the tail of distribution
    - It was a suspect that EM shower shape was slightly affected
    - There were problems to reproduce the problem in a simple setup
  - For 9.6p01 the problem was fully understood and fixed
    - Thanks to ATLAS team efforts for analysis of the problem and test productions

Effect of Urban93 protection in thin Silicon layers (Geant4 9.5p01)





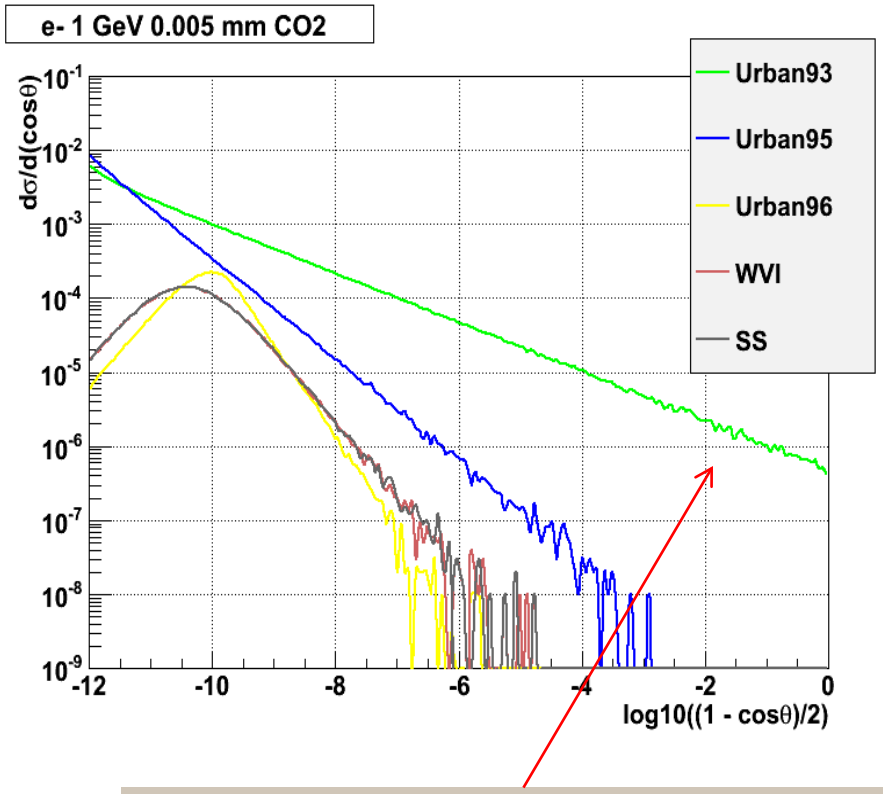
Effect is not visible for larger step size

Protection is Cut to reduce the excessive tail of Urban 93

Side effect on electron line shape tail on per mille level

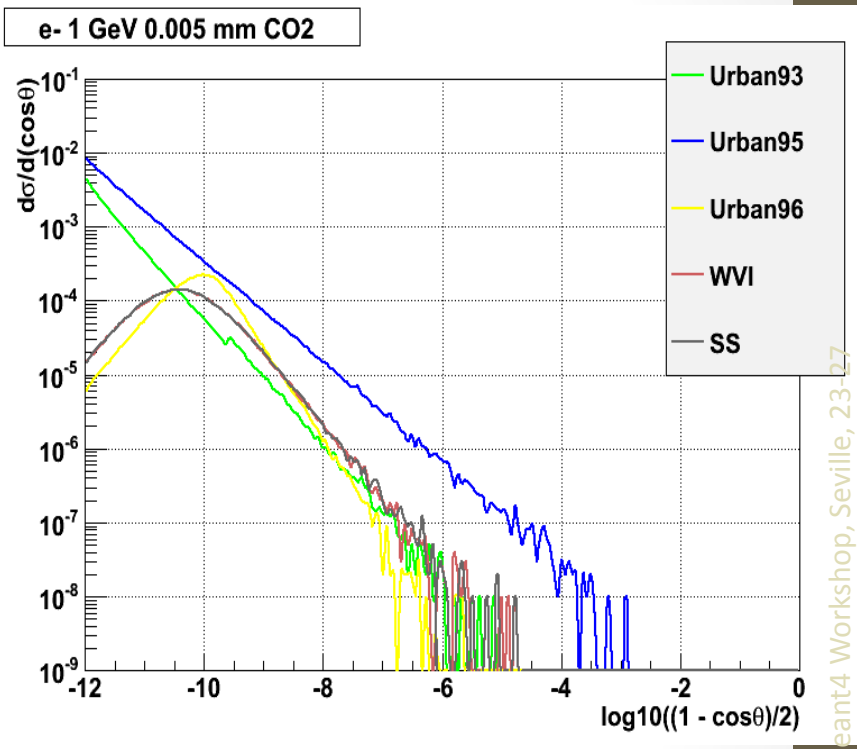
Demonstration of the problem: 5 µm step in CO_2

Msc93 no fix



Msc93 tail is too big
It is the main problem of the Msc93 model, no such problem in other Urban models

Msc93 fix (29 Jan 2013)



Msc93 tail similar to single scattering
The recent version msc96 is fully coincide with single scattering

Lessons from multiple scattering saga

- Approximated theory always better than accuratly tunned approximation if the approximation is tuned to the data with limited application range
- Probalem was not seen in simple benchmarks
- We fully understand and fix this problem when ATLAS peopoles contrubuted to running several variants of simuation with statistics about 1M ATLAS events
- Extra test has been designed and added to the testing suite
- Prompt protection done in 2012 was practically correct
  - ATLAS confirmed that with prompt protection and the real fix both provide the same EM shower shape
- ATLAS still has disagreement Data/MC on level of 10^{-3}
  - Detector and material model is not known enough to reach desired accuracy

EM problems fixed in 9.6p02

- Fixed problem report #1471: rare bug at initialisation of muon models – division by zero
- Wentzel cross section: use different parameterisations for screening function for e+e- and other particles
- In all Urban msc models (93/95/96) disable sampleZ option – removed zero steps and decays of e+ exactly at boundaries between volumes
  - A minor change of sampling calorimeter response (+0.1%)
- G4EmStandardPhysics_option4 low-energylimit is shifted from 10 eV to 100 eV due to problem in G4LivermoreIonisationModel
- What is pending for possibe patch03 (implemented and tested for the development version):
  - extra protection against division by zero inside muon models
  - protection on low-energy limit for secondary production threashold problem report #1481

MIGRATION TO MT

Migration to MT for 10.0beta

- Material cathegory was modified to have in run time only const interfaces
  - Material/element/isotope properties are read-only
  - The most modifications were done for G4SandiaTable
- Initialisation of energy loss processes and multiple scattering were done in different methods
  - First implementation by Xin Dong
  - Master :Prepare/BuildPhysicsTables
  - Worker: PrepareSlave/BuildSlavePhysicsTables
- Significant cleanup of the code of base classes G4VEnergLossProcess, G4VMultipleScattering

Migration to MT for 10.0

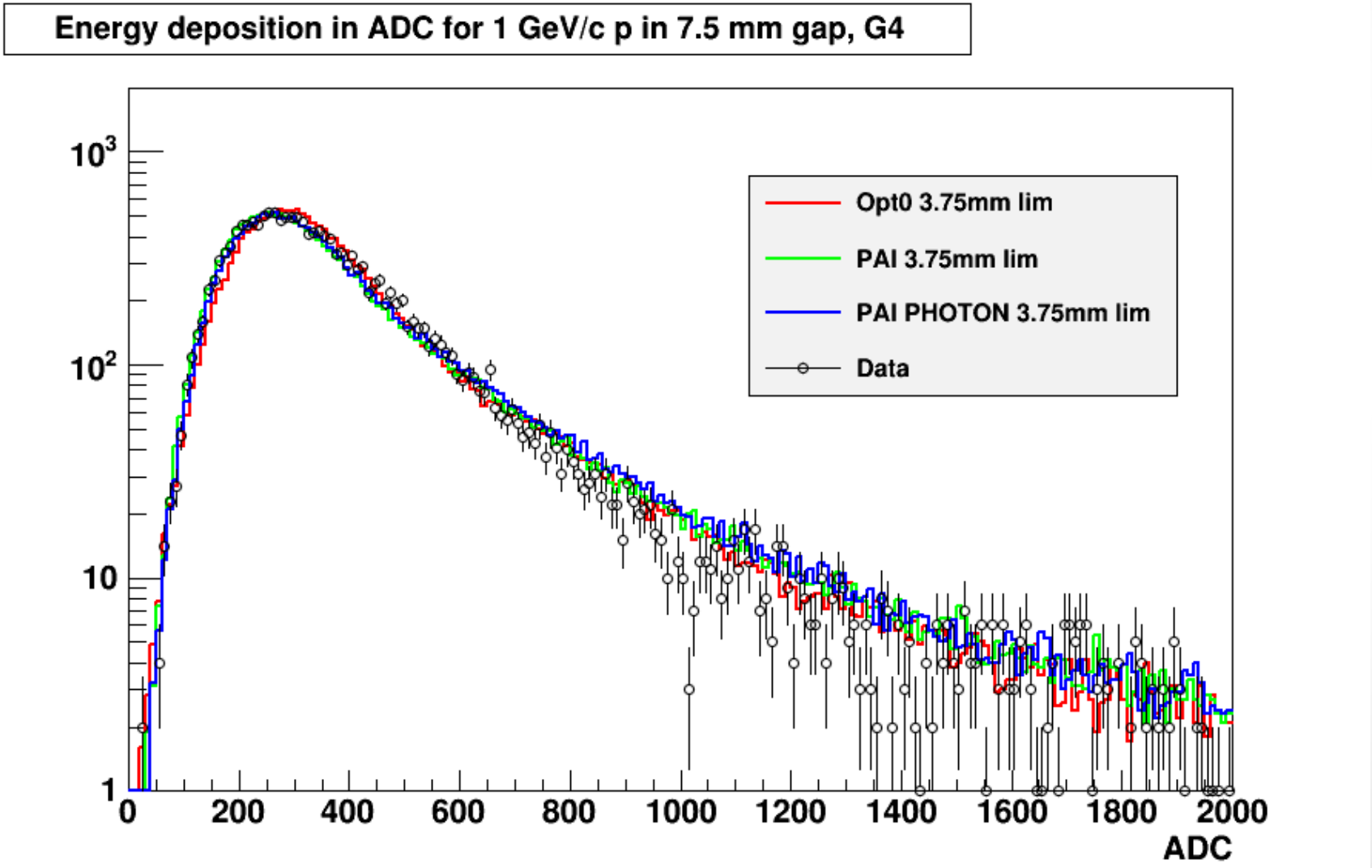
- Data tables belong not only processes class by also model classes
- In order to migrate EM to MT fully some modifications in kernel interfaces were done by Makoto and Andrea Dotti
- As a result all EM processes following G4VEmProcess interface were migrated to MT
  - tables which belong to the base class are shared between threads
  - For G4VEnergLossProcess and G4VMultipleScattering «Slave» metods were removed
- For EM models extra interfaces are added for initialisation allowing to share internal tables between threads
  - Following migration should be performed n model by model base
  - Big data structures are in PAI model and in the model of e+e- pair production by muons and hadrons
    - Sharing of the data has been implemented for these models

PAI AND FLUCTUATION MODEL EVOLUTION

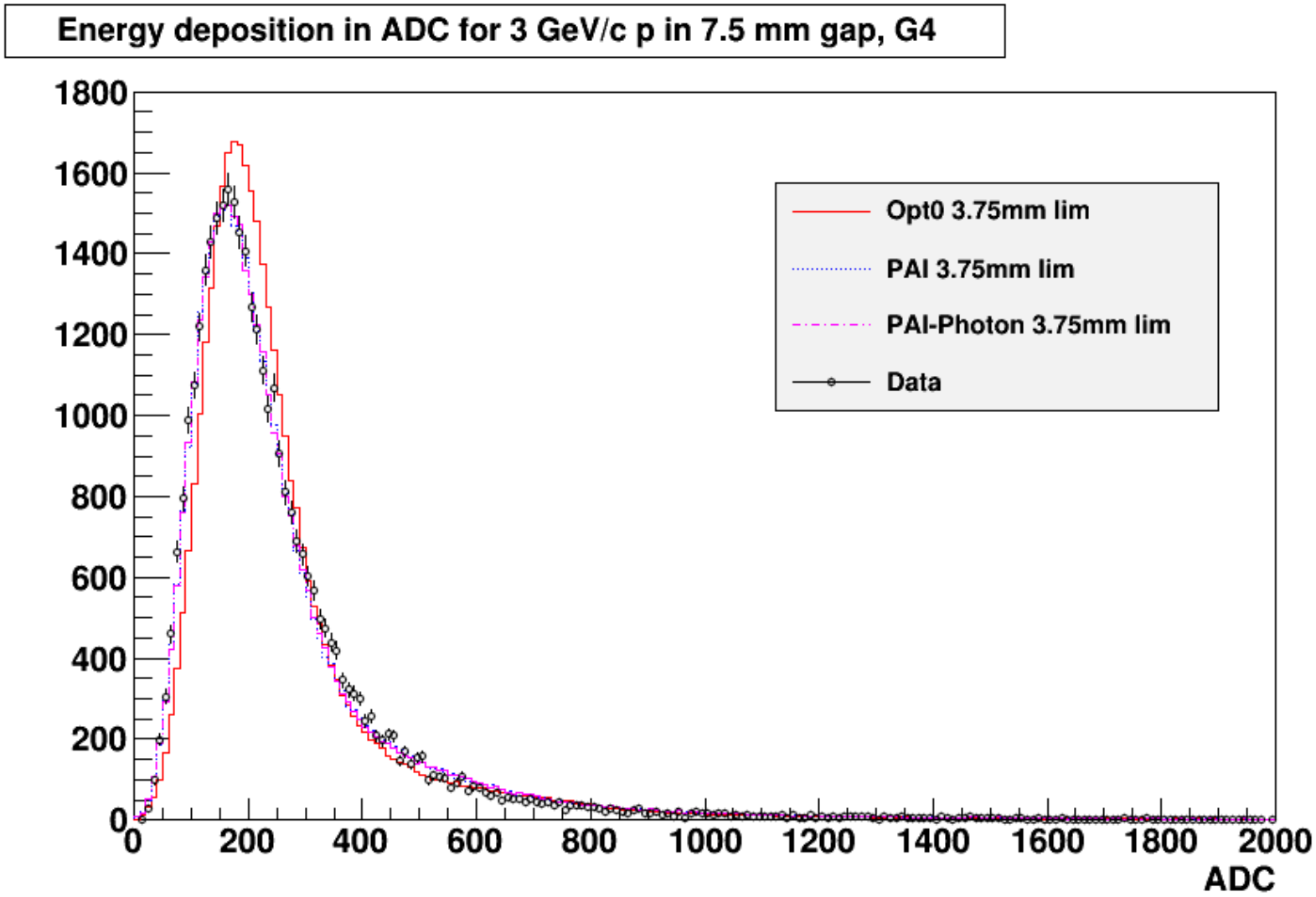
Geant4 fluctuation models

- Since long time Geant4 has two main models of energy loss fluctutions:
  - G4UniversalFluctuations (L. Urban) – default
    - Based on empirical parameterisation
  - G4PAIModel, G4PAIPhotonModel (V. Grichine)
    - Based on theory and photoabsorption cross section provided by Sandia Table
- We have studied physics performance of both models for tracking detectors (V.Grichine, A.Bagulya)
  - This work was activated by requirements of ALICE
- A new test of fluctuation models versus data FlucTest has been created by A. Bagulya
- V.Grichine continue work on more fast variants of PAI model

Energy deposition in ALICE TPC Geant4 9.6ref09 (A.Bagulya, V.Grichine) – log scale

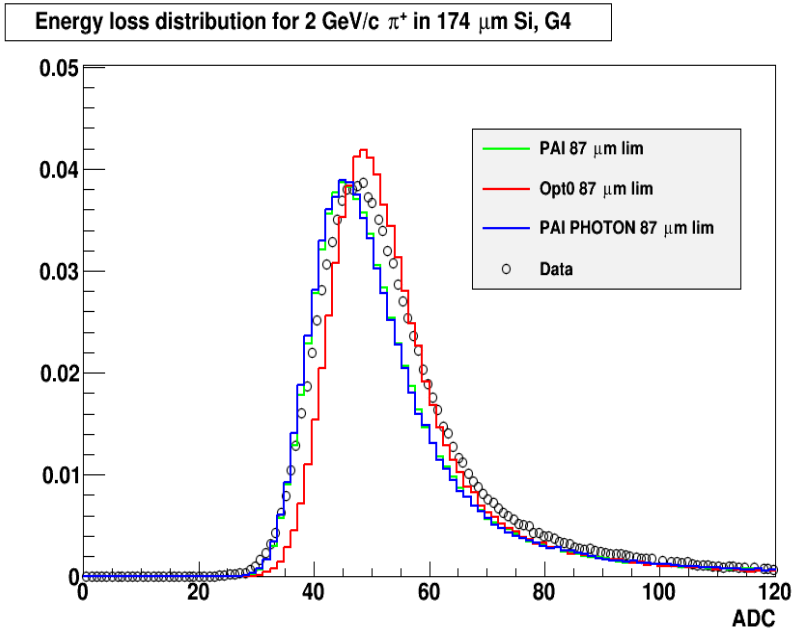


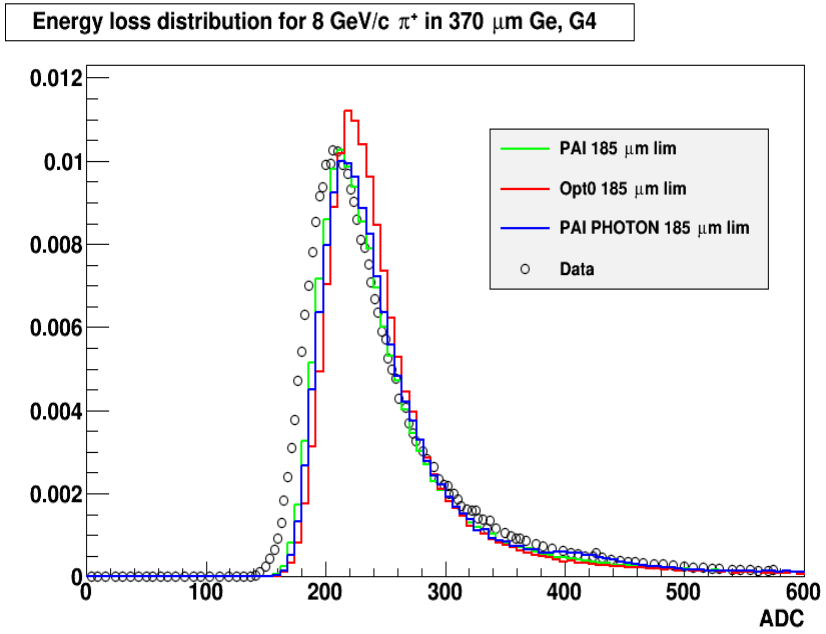
Energy deposition in ALICE TPC Geant4 9.6ref09 (A.Bagulya, V.Grichine) – lin scale



Performance of Fluctuation models

- Results for this targets well reproduced by PAI model without any tuning and independently on step size
- The default model is sensitive to the step limitation
  - Our recommendation – to set step be about half of pad size of TPC and about half size of sensitive layer of a Silicon detector
- PAI model may be configured per G4Regionto be applied only for sensitive volumes



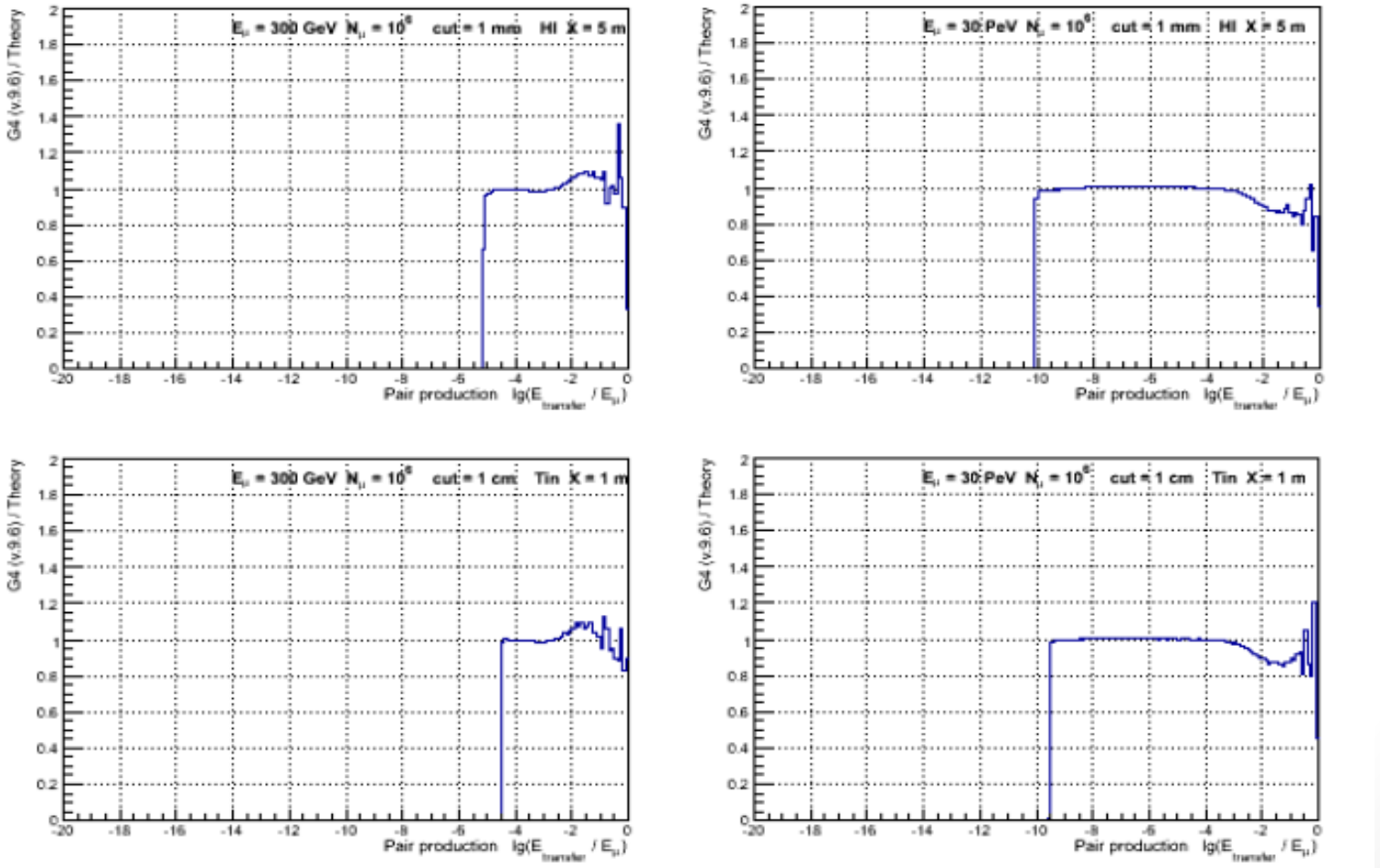


Further refinment of the PAI model

- In order to improve angular distribution of delta-electrons produced by PAI and other models a new angular generator has been created G4DeltaAngle
  - Electron density function is taken into account
  - For MeV electrons delta-production angle become not peaked and have a broad distribution
  - This generator may be used for other cases (delta electron production in the Bragg peak for hadron therapy)
- PAI model has 2 G4PhysicsTable and 2 G4PhysicsVectors
- In order to migrate to MT all data were incopsulated into G4PAIData class which is shared between threads

MUON/HADRON RADIATIVE PROCESSES

The problem for the e+e- pair production model in Geant4 9.6 – validation versus theory (A.Bogdanov)

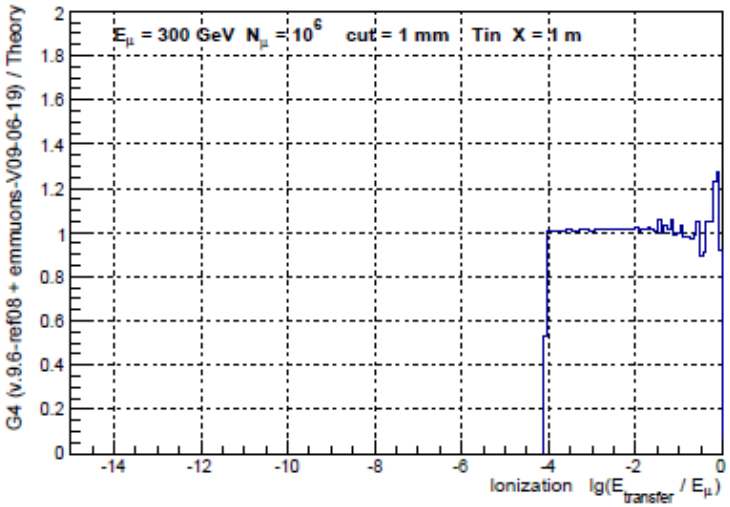


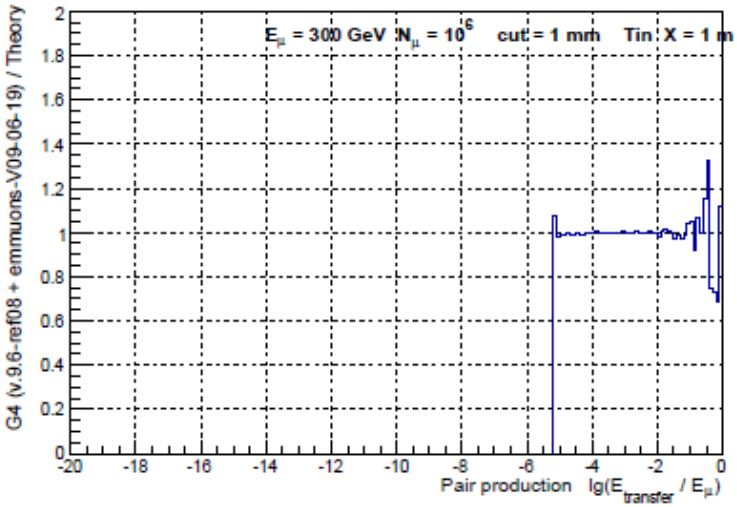
The ratio of simulated (G4) and theoretical distributions in the relative energy transfers for the pair production; muon energies 300 GeV (left) and 30 PeV (right): target HI, cut = 1 mm (up) and Sn, cut = 1 cm (down)

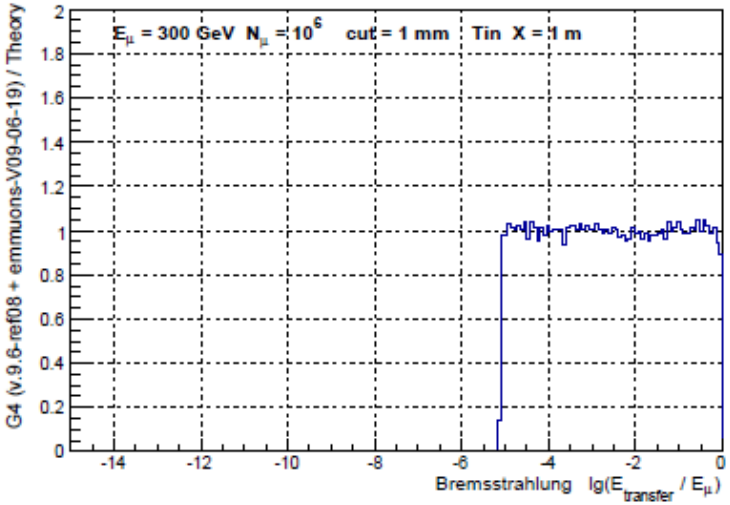
Problems of models of e+e- production by muons and hadrons

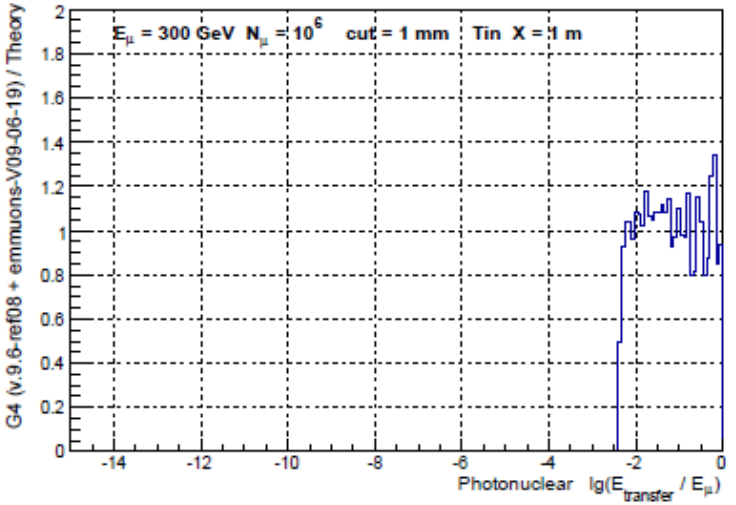
- Observed deviation from the theory is only because of a relativly small size of 2-D internal tables
  - In 9.6 it was 8 x 1000
- The problem was fully fixed by A.Bogdanov by introducing more detailed grid 40 x 4000
  - This update killled CDASH continues due to timeout
- Optimisation of binning was introduced
  - Number of bins in muon energy now depend on max energy
  - Number of bins for secondary energy is returned to 1000
- Size of the internal tables for muons and hadrons is significant
  - about 25% of all EM tables for the standard Physics List
- For MT these internal tables should be shared between threads
  - For that data structure and initialisation of the model were rewritten
    - G4ElementData and G4Physics2DVector are used

Validation of muon processes versus theory 9.6ref09 (A.Bogdanov)









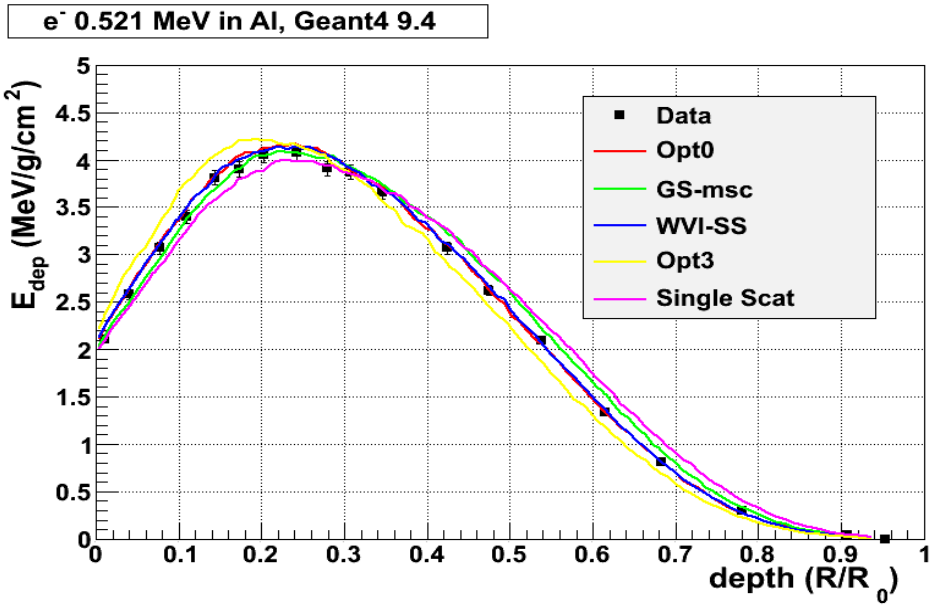
MULTIPLE SCATTERING VALIDATION FOR 10.0BETA AND 9.6REF09

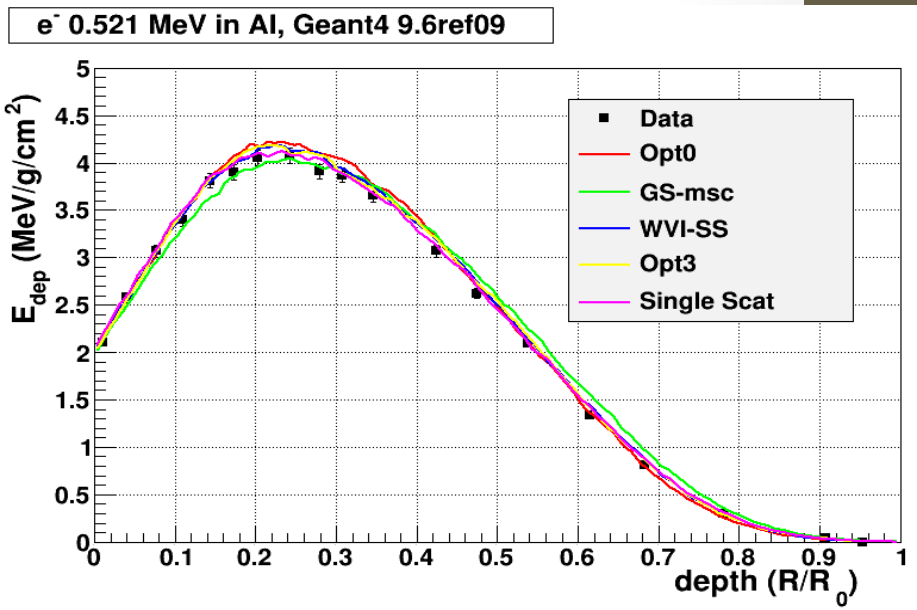
Energy profiles for Sandia data and UrbanMsc/UrbanMsc93

9.4

F_R = 0.04 (default)

9.6ref09



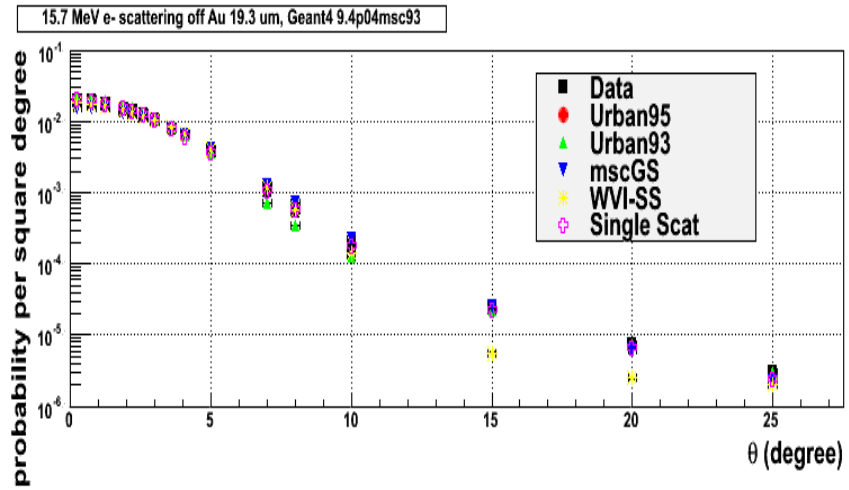


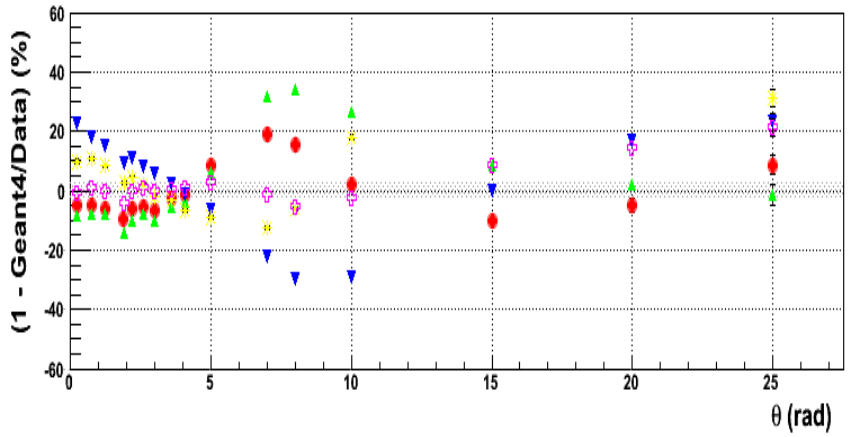
Agrement between different Geant4 multiple scattering models and Sandia data was improved in Geant4 9.6 ref09 versus 9.4

The most significant effect for Opt3

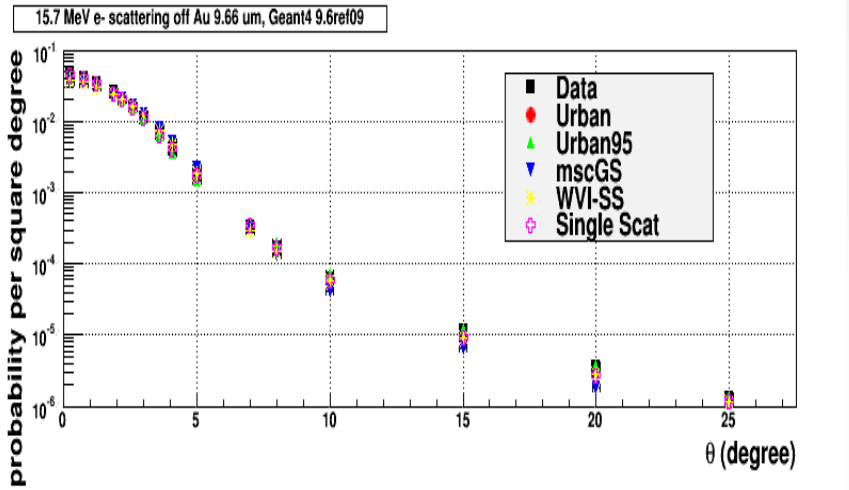
15.6 MeV electrons in thin Au target

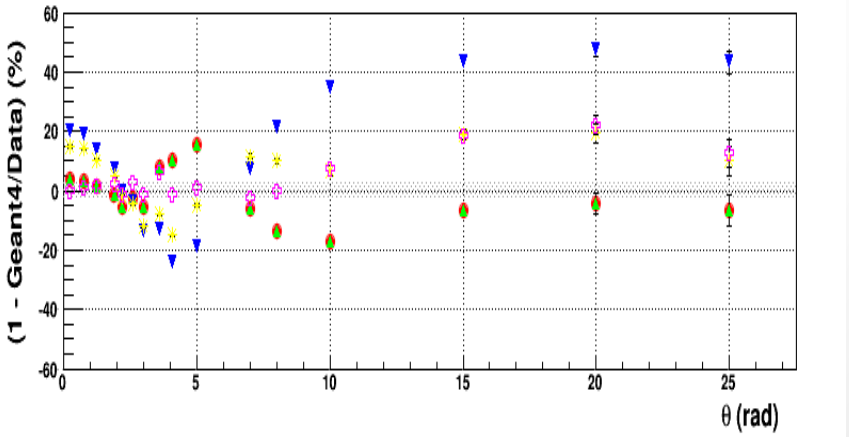
9.4





9.6ref09





1 MeV gamma energy in a cavity (S.Elles)

9.4

Fano cavity test case

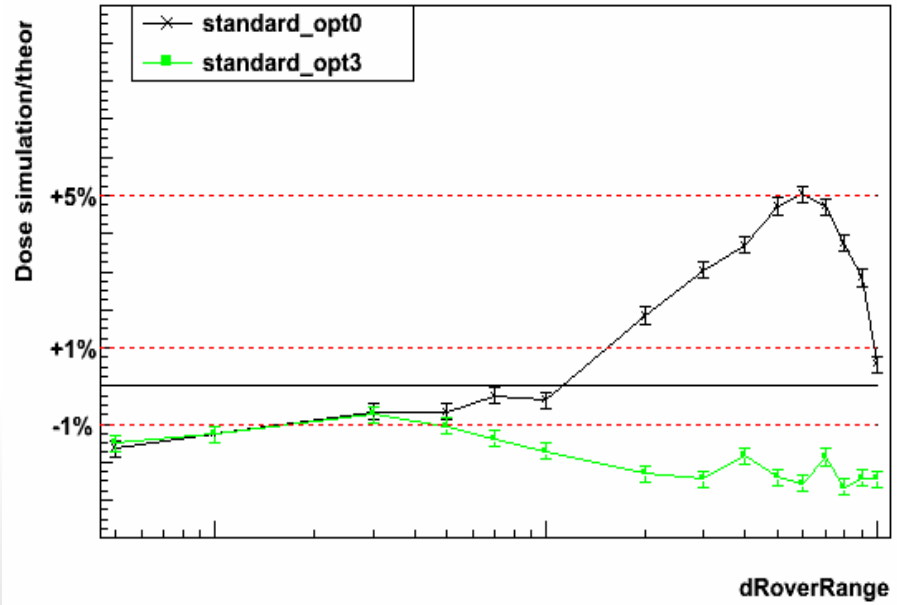
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 09-04-ref-02

Basic test (no fluct, no msc):

standard_opt0 : 0.9983 +/- 0.0002 for dRoverRange = 0.004
standard_opt3 : 1.0007 +/- 0.0002 for dRoverRange = 0.004

Full test (fluct & msc):



9.6

Fano cavity test case

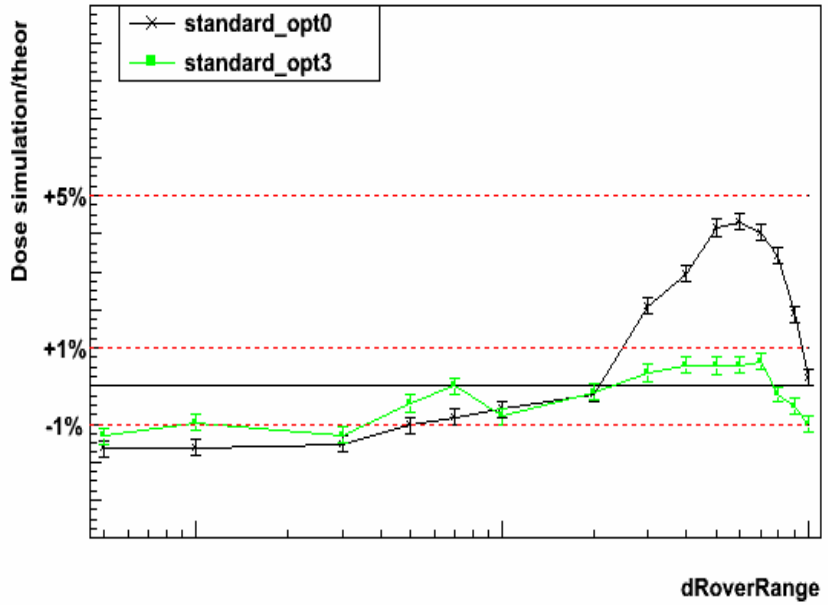
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 09-06-ref-01

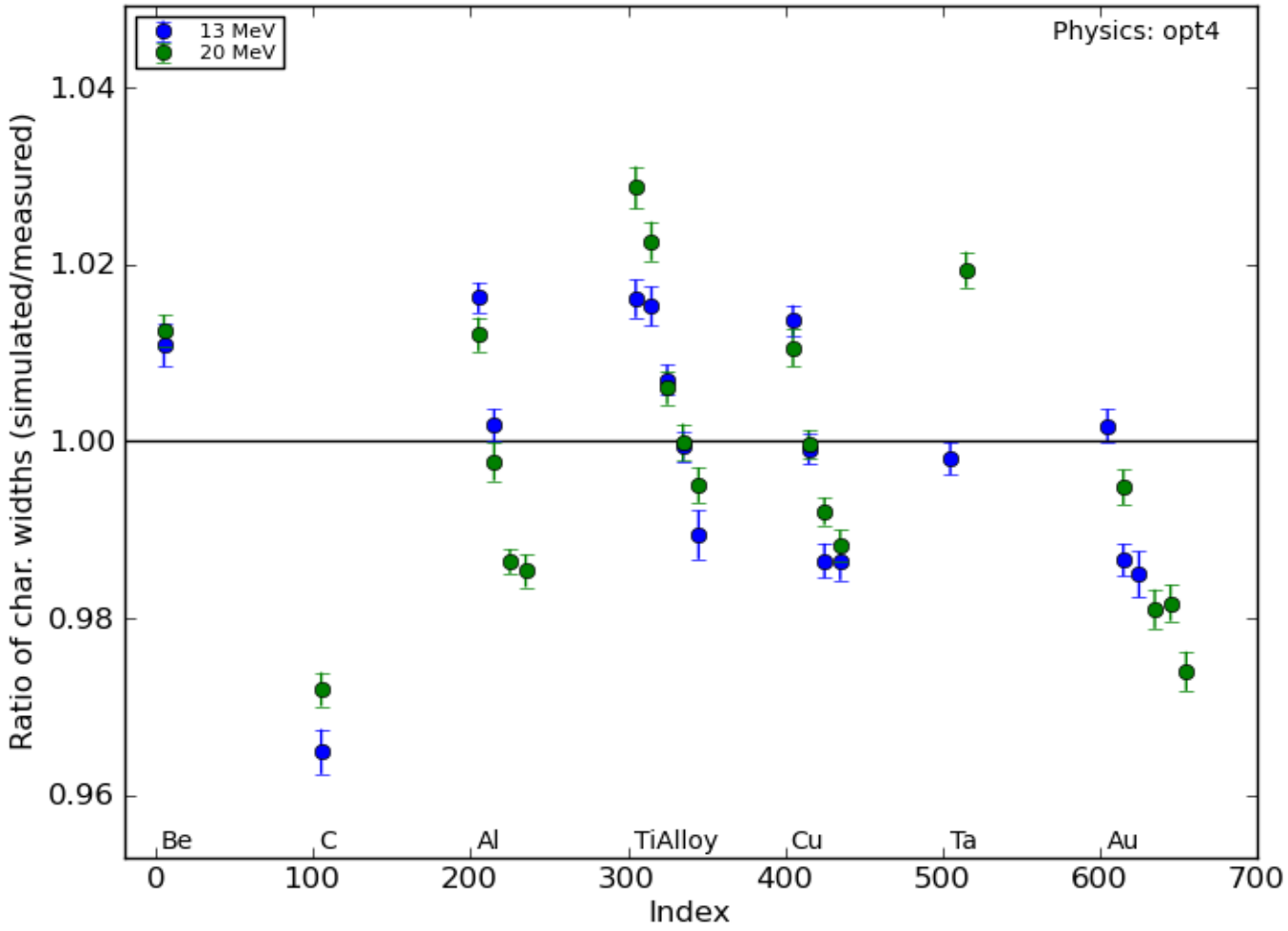
Basic test (no fluct, no msc):

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

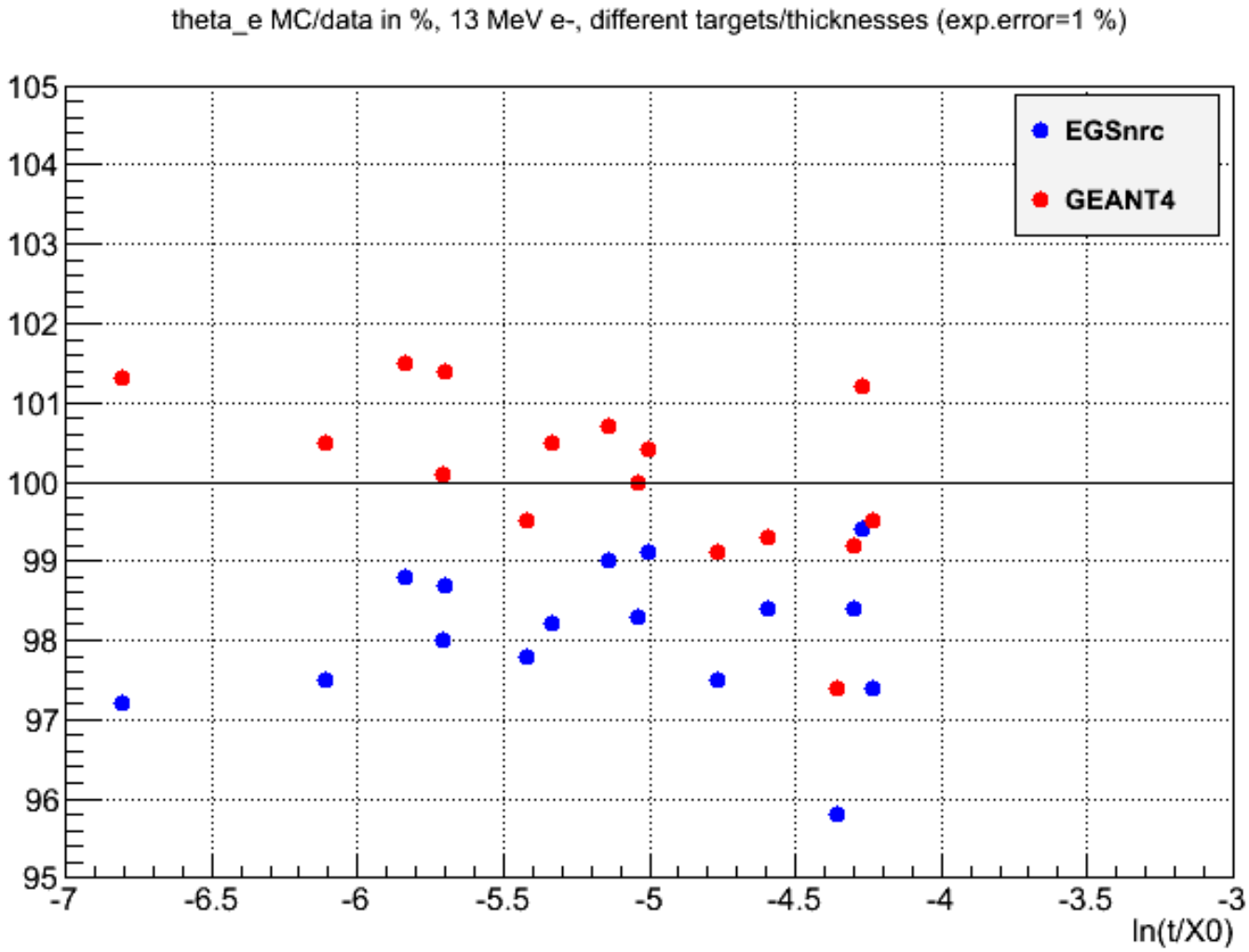
Full test (fluct & msc):



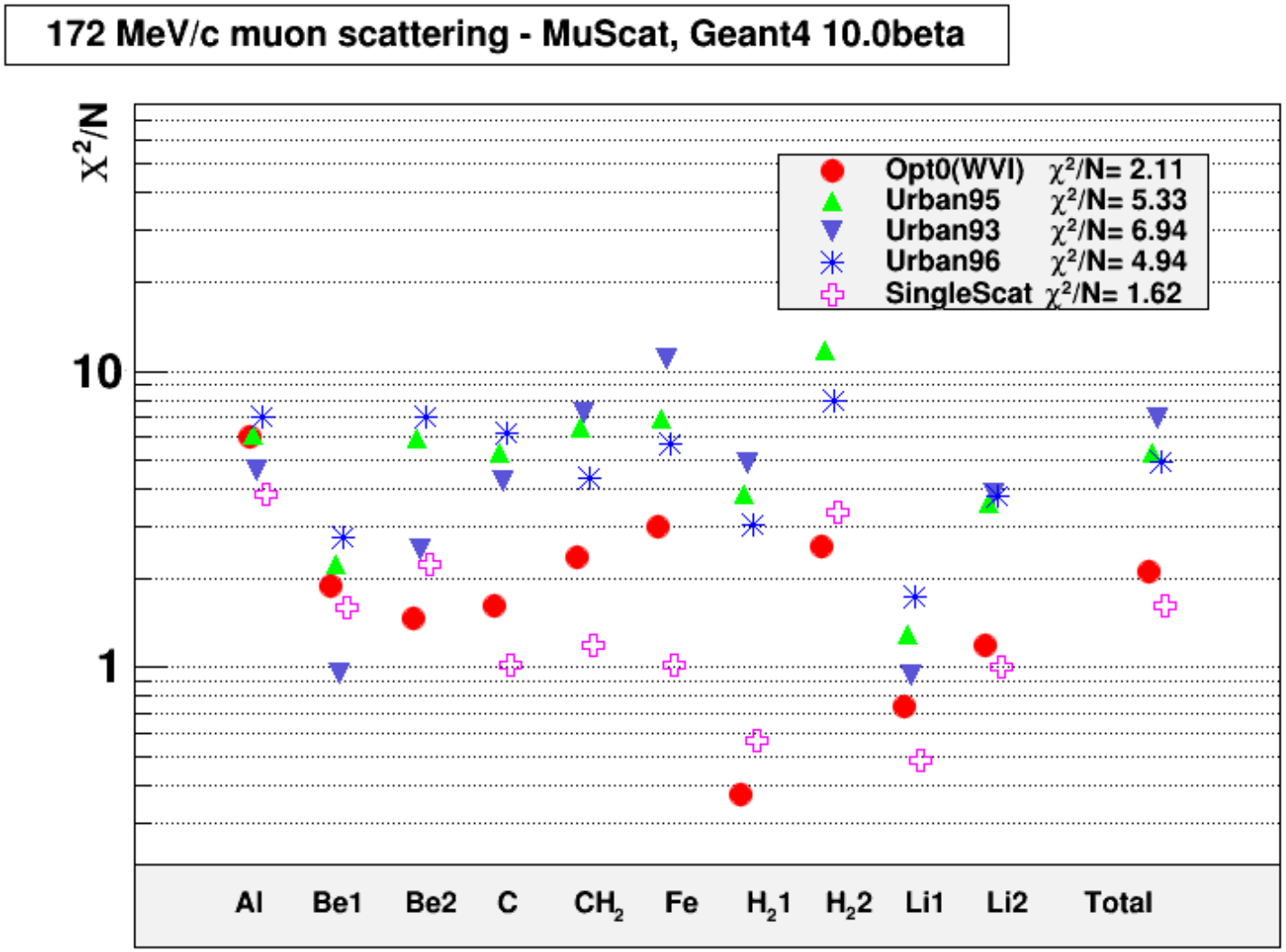
Electron scattering benchmark
(D.Sawkey, see also talk at parallel session)



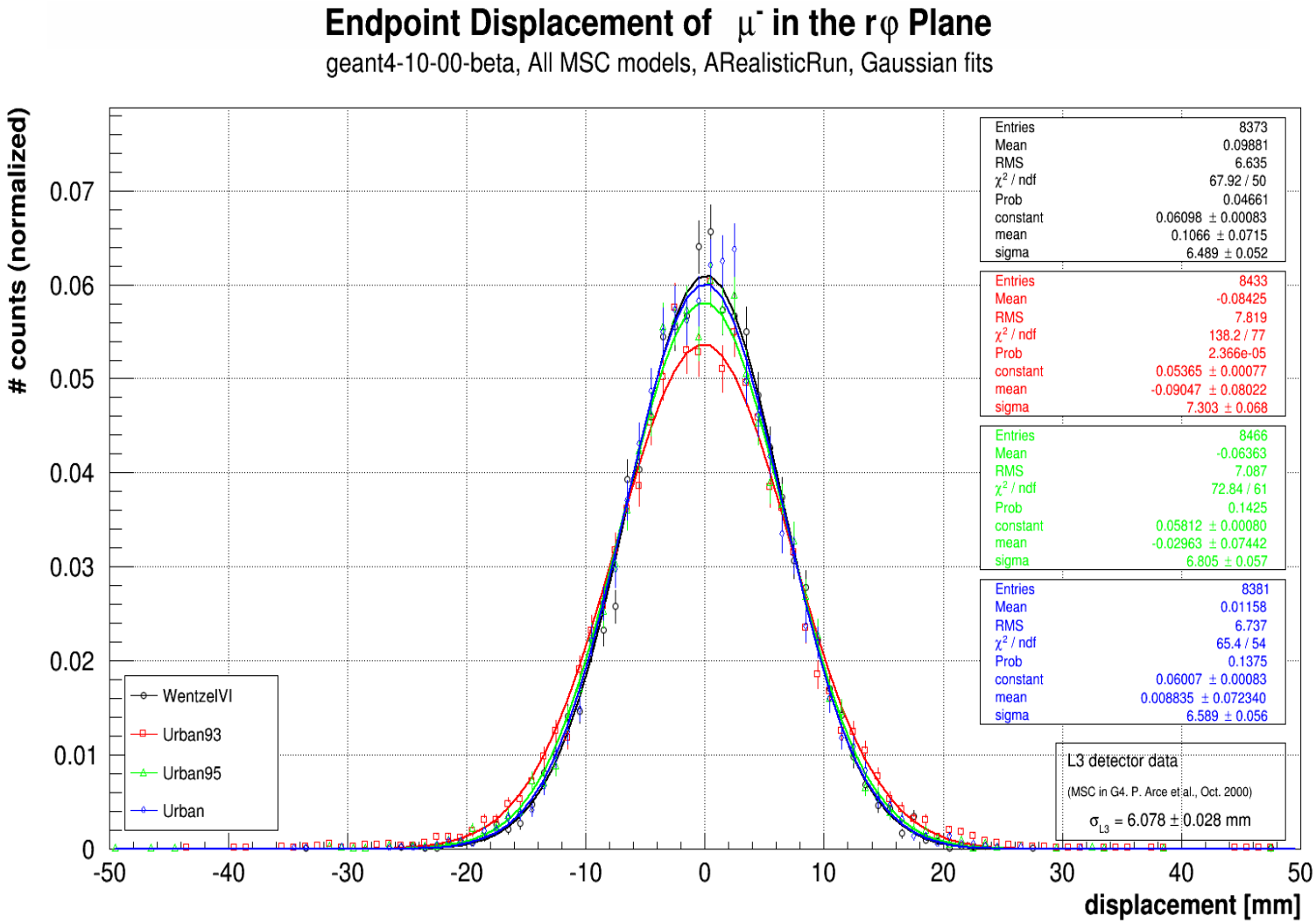
Electron benchmark Geant4/EGS (L.Urban)



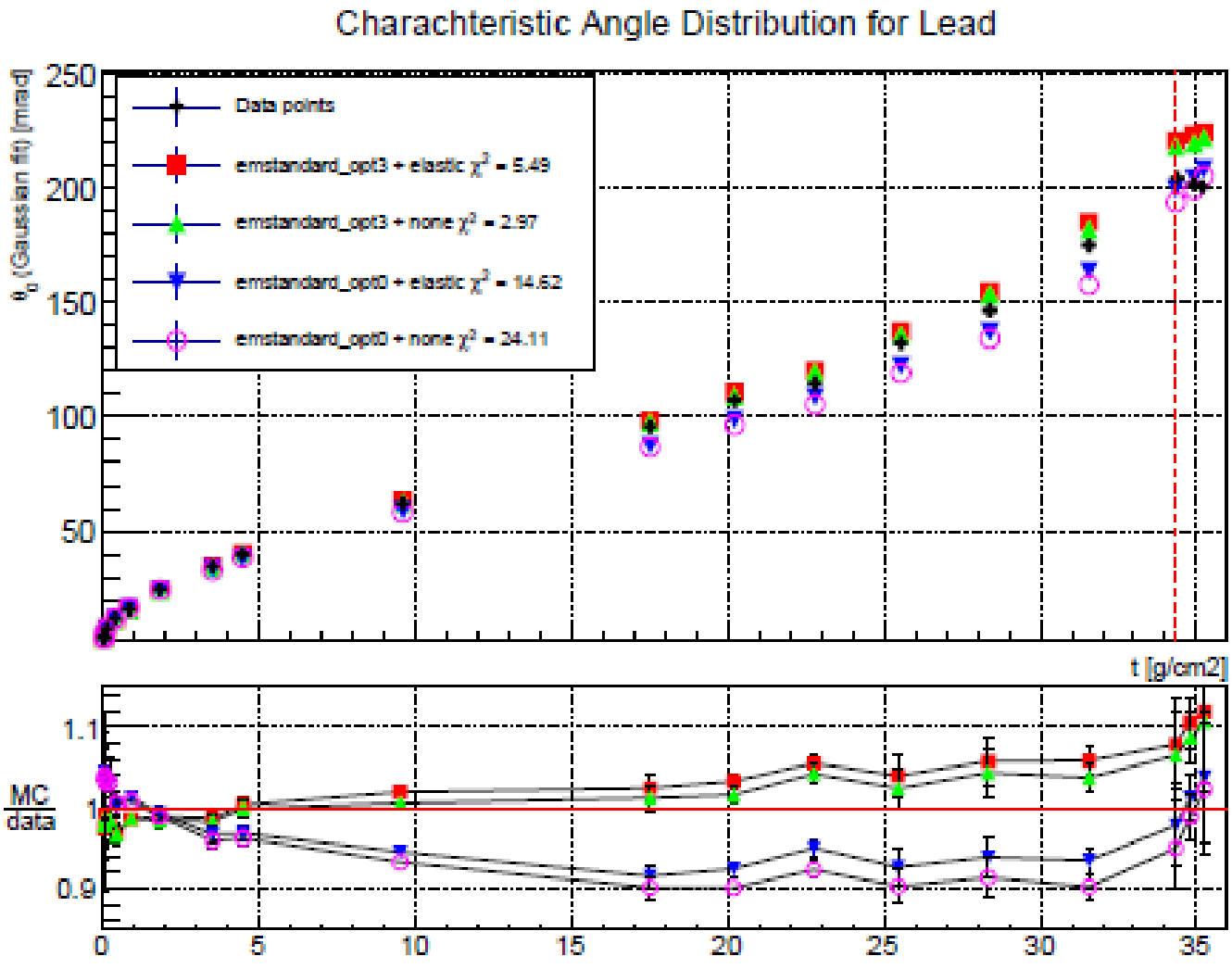
MuScat data for muon scattering



L3 muon displacement



New proton scattering benchmark (S. Schwarz, see details at parallel session)

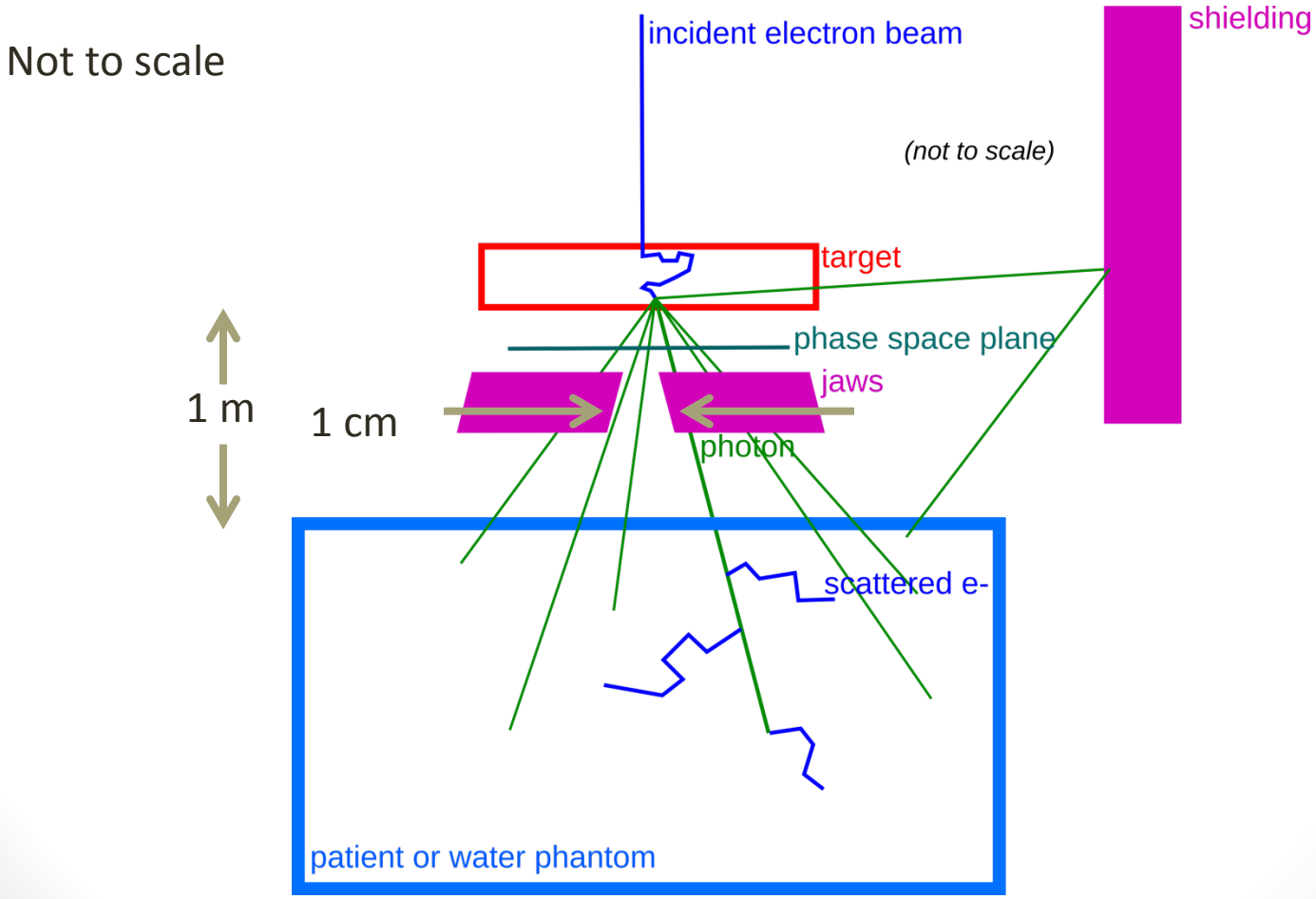


Where we are with multiple scattering?

- The ATLAS problem was fully understood and fixed
- The results with themost recent version of Urban model are the best for all particle types and all benchmarks
- Since ref-09 G4UrbanMscModel is the only one Urban model left in Geant4 distribution
- What should be done:
  - We do not yet fully migrated multiple scattering to AlongStep
    - There is a problem in Transportation
  - Gouldsmith-Saunderson model not fully deploied
  - WentzelVI model may be improved

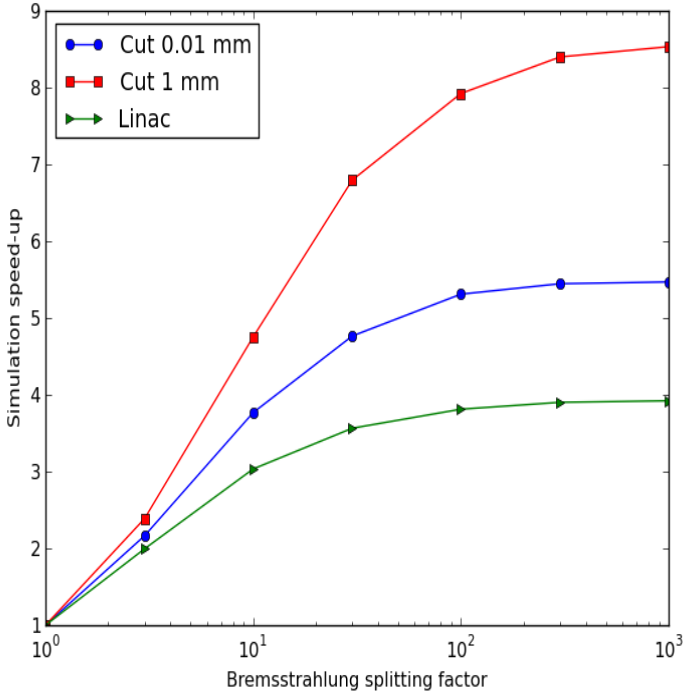
EM BIASING OPTIONS

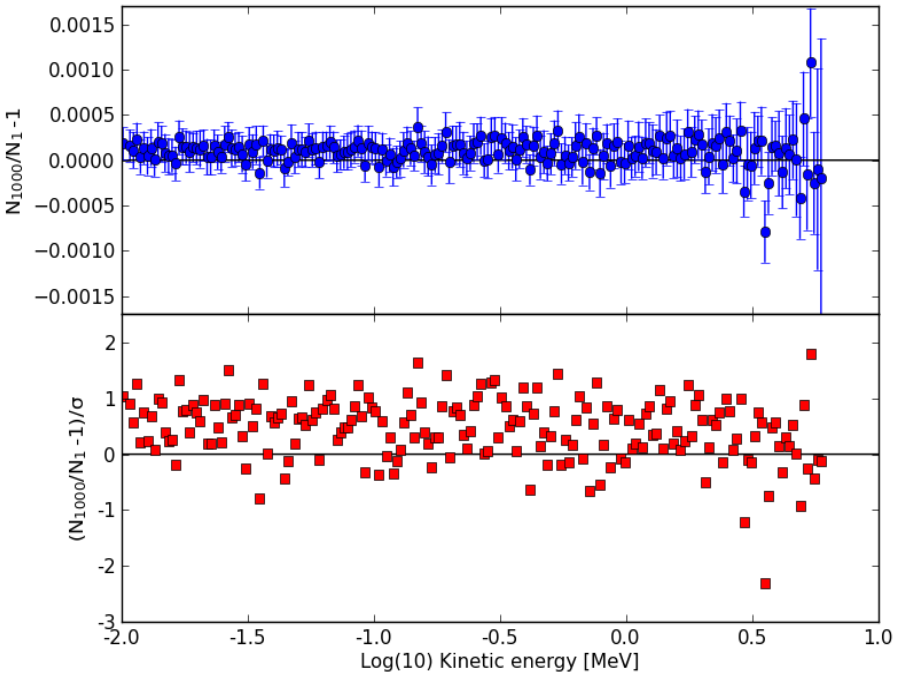
Brem splitting for medical linac (D. Sawkey)



Brem splitting for medical linac (D. Sawkey)

Number of splitted gamma N=1000





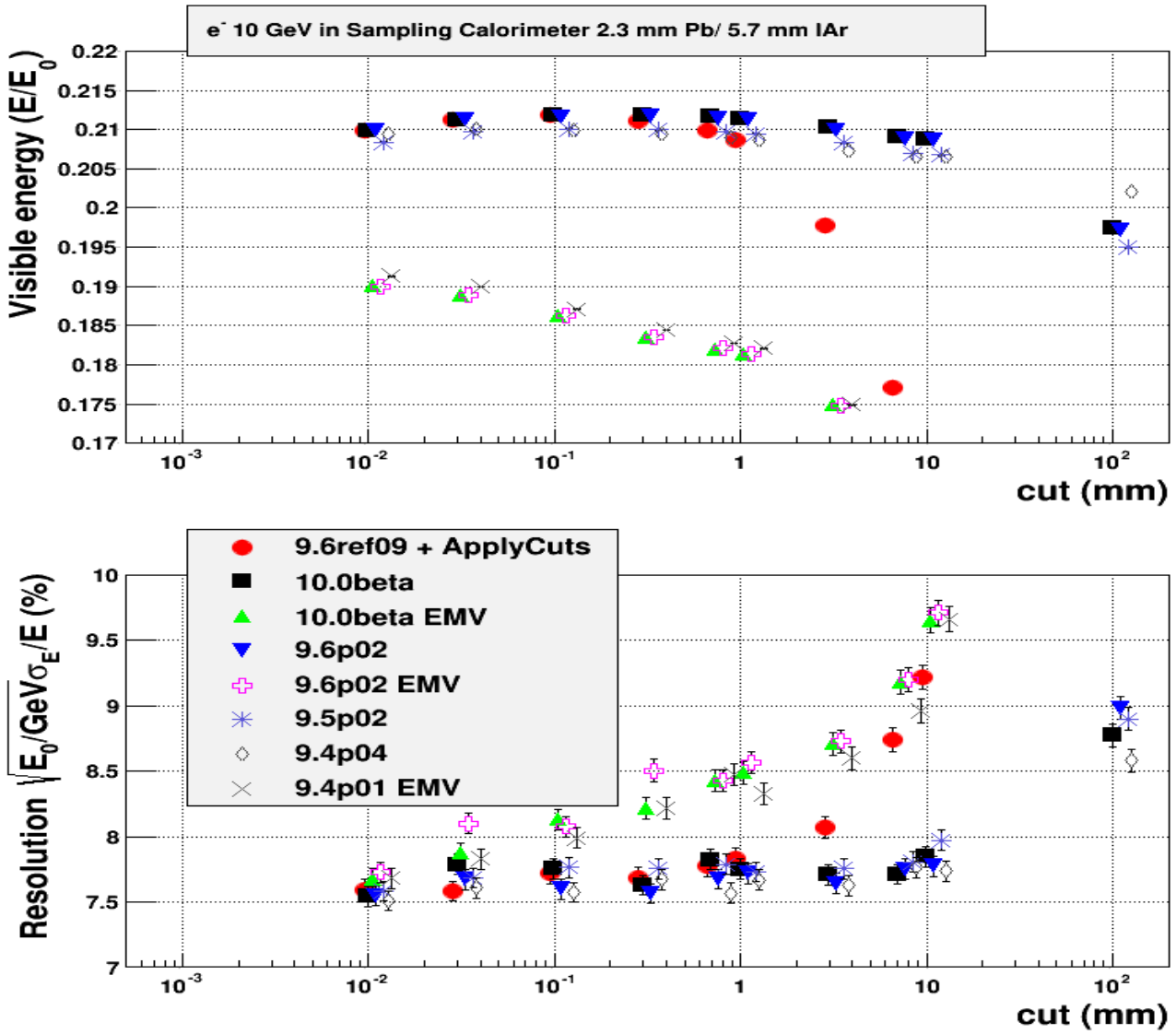
- Speedup depends on cuts and geometry
- Energy spectrum is reproduced with high accuracy

What else for the release 10.0?

- There are a small problem in e+e- pair production by muons which should be fixed (A.Bogdanov)
- Cleanup of G4PAIPhotonModel (V.Grichine)
- Introduce G4Exp and G4Log into sensitive places
- Inspired by this workshop:
  - Addition of UI command /process/em/workerVerbose 0
  - Addition of similar C++ interface
  - Further cleanup of G4PhysicsVector:
    - remove virtuality
    - add std::low_bound for bin location (thanks to K.Genser talks)
- We would like more EM examples to be migrated to MT

CALORIMETER TEST RESULTS FOR 9.6REF09 – PHYICS LIST MODIFIED

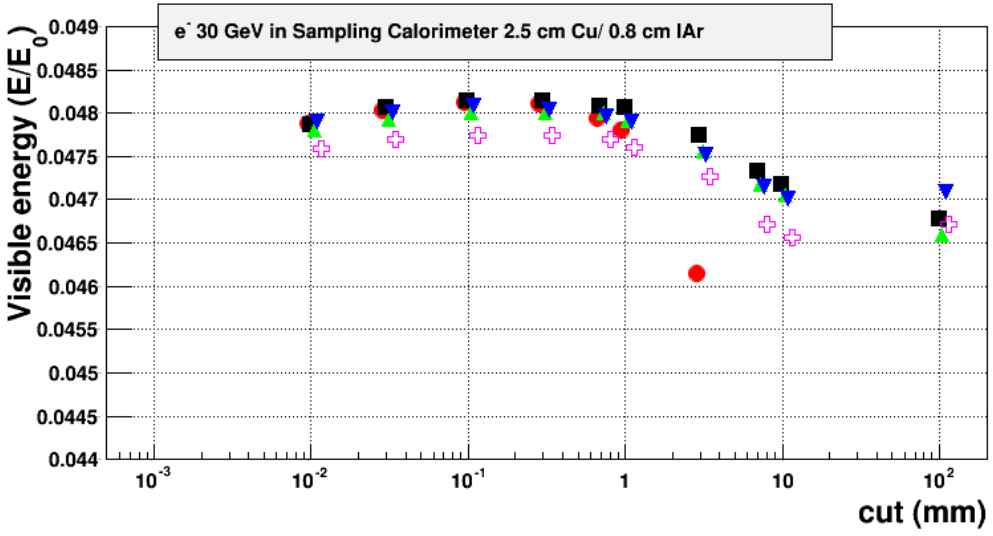
ATLAS-barrel type calorimeter

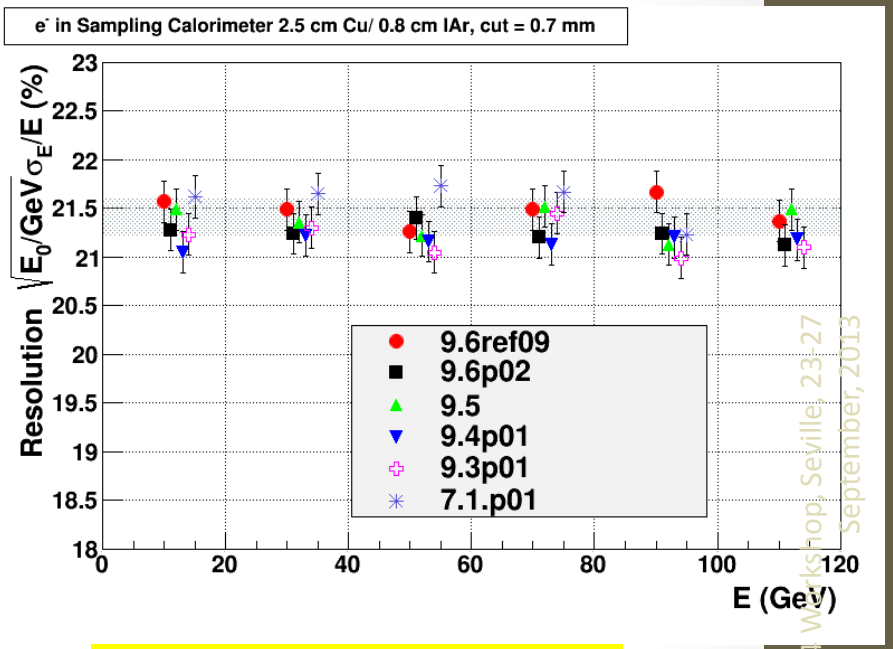


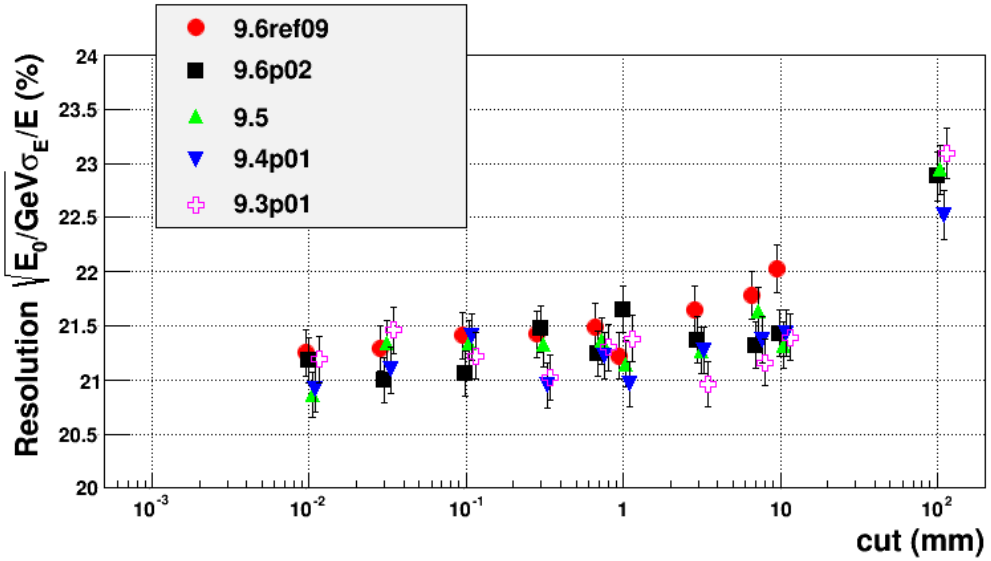
Working point of ATLAS is 1 mm
Using «Apply cuts» as a default provides 10.0/9.6 visible energy to be close to one of 9.4

Give 30% EM speedup for sampling calorimeter

ATLAS-HEC type calorimeter

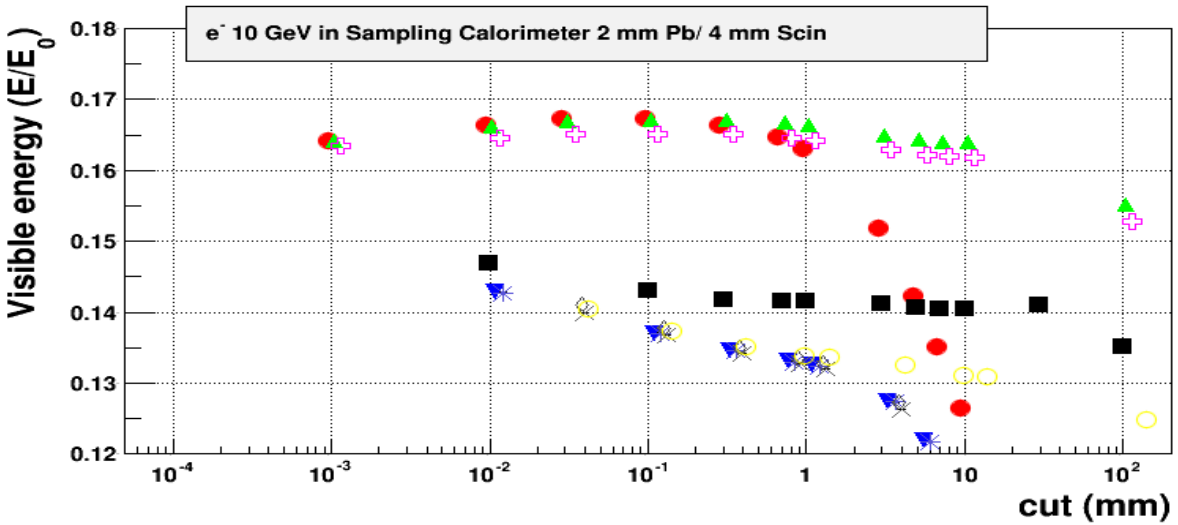


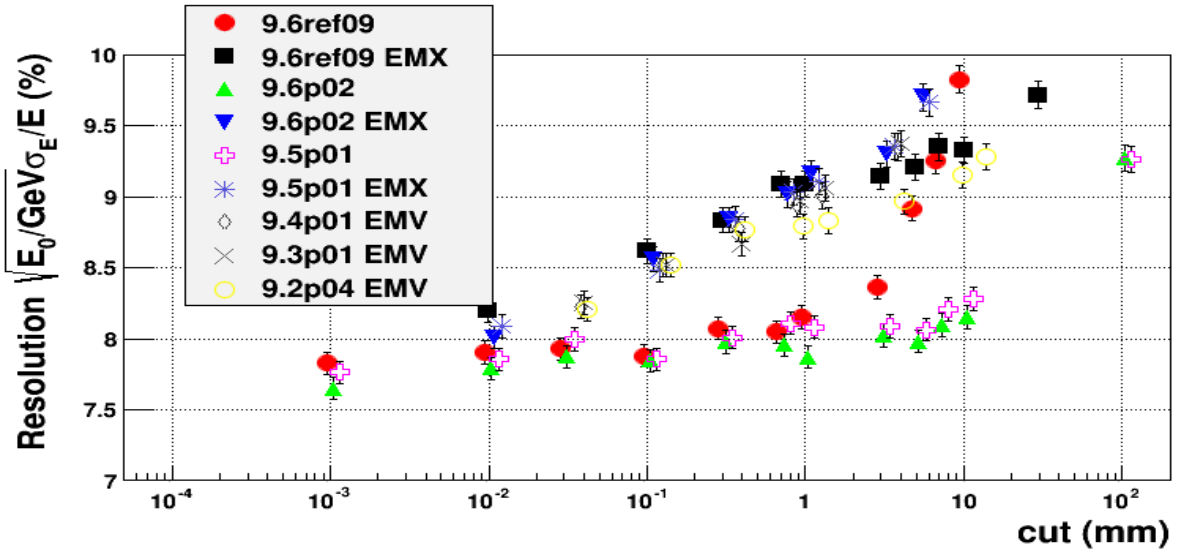




Working point of ATLAS is 1 mm
Using «Apply cuts» as a default provides 10.0/9.6 visible energy to be close to one of 9.4

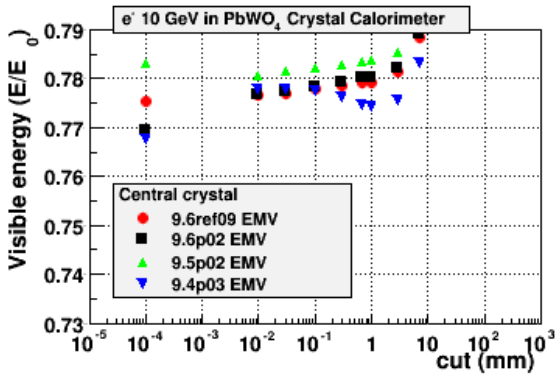
LHCb type calorimeter

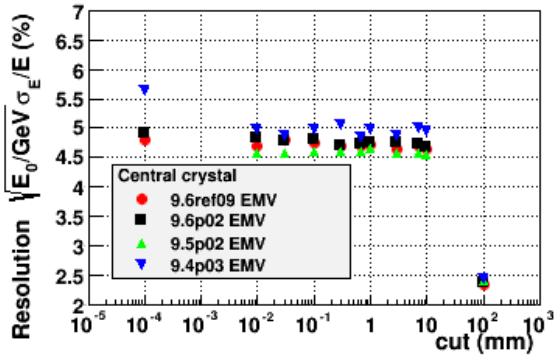


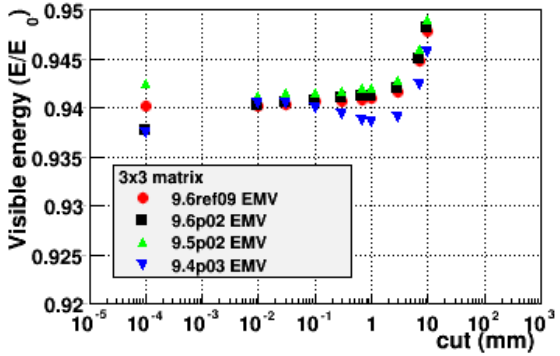


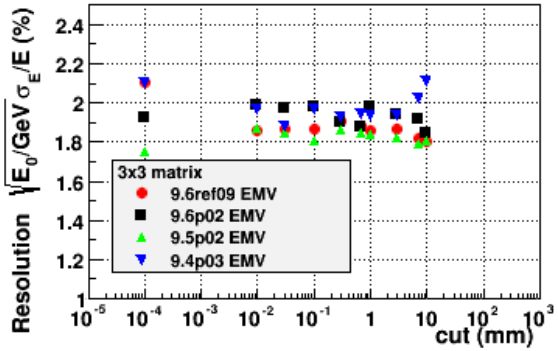
Disabling «Apply cuts» provides const response versus cut value for EMX

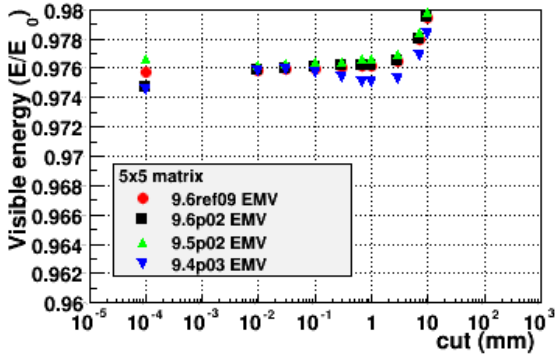
CMS type calorimeter

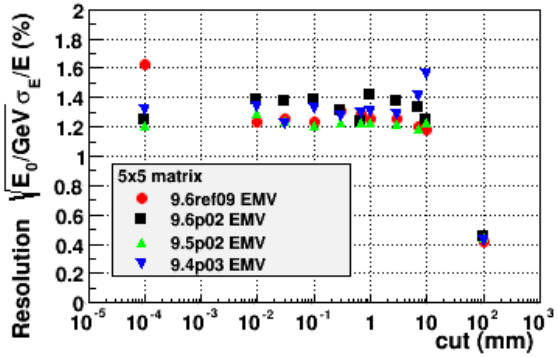












Phyiscs Lists for 10.0

- Please comment the proposal for major changings:
  - For the default Physics List to enable «ApplyCuts» option
  - Suggestion from LHCb is needed how to configure option2 (EMX)
  - Muon-nuclear process enable in all HEP Physics Lists

Summary

- Materials are read-only in run time
- Standard EM physics is fully MT capable for 10.0
  - Due to migration to MT part of development goals for 2013 will not be achieved
- Progress was achieved for
  - PAI model
  - Muon/hadron radiative processes
  - Multiple scattering models consolidation
  - Built-in EM biasing
  - Validations
- There are several pending problems to be resolved before the release (see slide #34)