Standard Em physics : activities in 2003

Significant developments in 2002-2003

- Multiple scattering (L. Urban)
- Model approach for Ionization and Bremsstrahlung (V. Ivantchenko)
- Ionization for GenericIons (V. Ivantchenko)
- Cut per region
- Ultra relativistic energies (H. Burkhardt, S. Kelner, R. Kokoulin)
- Scintillation process (P. Gumplinger)
- Models of Transition Radiation detectors (V. Grichine)

Photo Electric effect

- Sandia parametrisation of total cross section (100 eV).
- suppression of production cut for photo electron.
- angle of photo electron : Sauter-Gravila distribution.

Still to be implemented :

- atom deexcitation : fluorescent photon or Auger electron, as in Geant3.21

Compton Scattering

- suppression of production cut for Compton electron.

Remember : there is a PolarizedCompton process.

Still to be implemented :

- Rayleigh scattering, as in Geant3.21
- Doppler broadening ?

Gamma Conversion

- suppression of production cut for (e^+, e^-).
- assymetric (e^+, e^-) angular distribution.
- new process : $\gamma \longrightarrow \mu^+ \; \mu^-$ (above 1 TeV)

Still to be implemented :

- generation of triplet state : $e^+ \; e^- \; e^-$?
- LPM effect (above 40 TeV).

e^+ e^- annihilation

- suppression of production cut for $(\gamma\ \gamma)$.
- new process : $e^+\ e^- \longrightarrow \mu^+\ \mu^-$ (high energy)

Still to be implemented :

- annihilation in 1 or 3 gammas ?

Ionization

- hIonisation : model for Bragg's peak
- hIonisation able to handle GenericIon.
- the 'subcutoff' δ-rays generation switched off.
- set function to overwrite the default MeanExcitationEnergy (G4Material, mixtures).

Bremsstrahlung by electron

- 1 keV $\rightarrow$ 10 keV : total cross section parametrised from EEDL.

Multiple scattering

- the model of angular distribution has changed several time.
- implementation of a sampling fonction for the conversion 'true' $\leftrightarrow$ 'geometrical' path length
- implementation of a 'boundary algorithm' (option) : $\rightarrow$ albedo

Still to be implemented :

- split msc in specialized processes : muons, ions.
- step limitation ?

Scintillation

- is a RestDiscreteProcess.
- allows for fast and slow desexcitation components.
- the excitation levels are material and particle dependent.

Model variant : motivations

- decouple Ionization and Bremstrahlung. $\Longrightarrow$ limited number of static objects.
- allows several models of the same process. Models can be defined by region and by energy.

Model variant : specific features for Ions

- `G4ionIonisation`
  - one set of table for all ions
  - specific model for energy loss fluctuations
  - dynamic charge : charge of ion is changed after each step
- `G4MultipleScattering`
  - the msc MeanFreePath is recalculed on fly (ie. cannot be tabuled)

Tutorial

As a consequence of the Slac Tutorial (2001), a substantial training in Electromagnetic Physics, with exercices, is available:

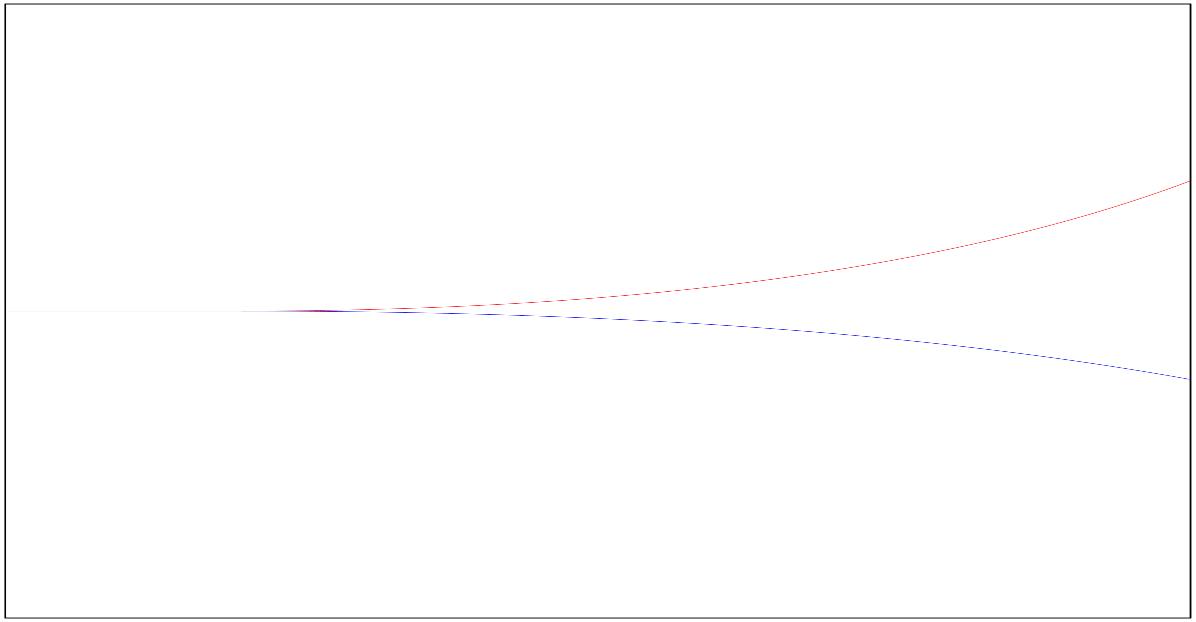
`geant4/documents/training/electromagnetic`

Examples

`geant4/examples/extended/electromagnetic`

- TestEm1 : individual processes.
- TestEm2 : shower profile in homogeneous medium.
- TestEm3 : sampling calorimeter.
- TestEm4 : low energy gamma processes. (the simplest example)
- TestEm5 : mainly dedicaced to the multiple scattering.
- TestEm6 : illustrate $\gamma \longrightarrow \mu^+ \mu^-$ and $e^+e^- \longrightarrow \mu^+ \mu^-$
- TestEm7 : dedicaced to the Bragg peak.
- TestEm8 : dedicaced to Photo Absorption Ionization model.
- TestEm9 : illustrate the concept of region.

γ 100 TeV in 500 m of iron (B 100 tesla)



Standard Em physics : from V5.2 to V6.2

In Geant4 V6.0 there was a major redesign and implementation of some EM(std) processes in order to migrate to the so-called 'model approach', i.e. to allow to have several models of the same process (cf. V.Ivantchenko talks).

This redesign concerns G4VEnergyLoss, its derived classes Bremsstrahlung and Ionization. Also MultipleScattering.

The migration would have been transparent to users. Unfortunatly few bugs have been introduced.

Bugs introduced in V6.0 (1)

not present in V5.2, corrected in V6.1 or V6.1_ref1

- Multiple scattering. The width of the angular distribution became too big by $\simeq 30\%$. It did not affect electrons, only muons and hadrons.
  Corrected in V6.1
- Mu ionization. The total cross section for d-rays production became too small by $\simeq 10\%$ for low energy muons ($< 1 GeV$).
  Corrected in V6.0p1
- Computation of mean dE/dx. Error in retrieving value from table. Affect proton around 1 MeV.
  Corrected in V6.1_ref1

Bugs introduced in V6.0 (2)

- Charged particle stopping in low density gas ($< 10^{-4}\ mg/cm3$).
  An endless loop on the last step of particles trying to stop.
  Final energy : DBL_MIN instead of 0.
  Corrected in V6.1_ref1
- Energy loss fluctuations. Added protection against long loop for the case of small energy deposition but big fluctuations.
  Potential cause of large performance penalty in one known case.
  Corrected in V6.0p1
- Energy loss fluctuations. Reduce domain of applicability of fluctuation model for very small step.
  Corrected in V6.1_ref1

Correction of older bugs: none

Due to the above bugs, we recommend **not to use** V6.0 nor V6.0p1 for massive productions sensitive to muon physics.

Or,at least, with V6.0 modify the PhysicsList for Muon: use G4MultipleScattering52 (see option g4v52 below)

g4v52

For safety, the 'old fashionned' processes, as there were in V5.2-ref-02, have been kept working under names: G4MultipleScattering52 ...etc...

Examples of such backward PhysicsLists can be found in most of the examples located in:

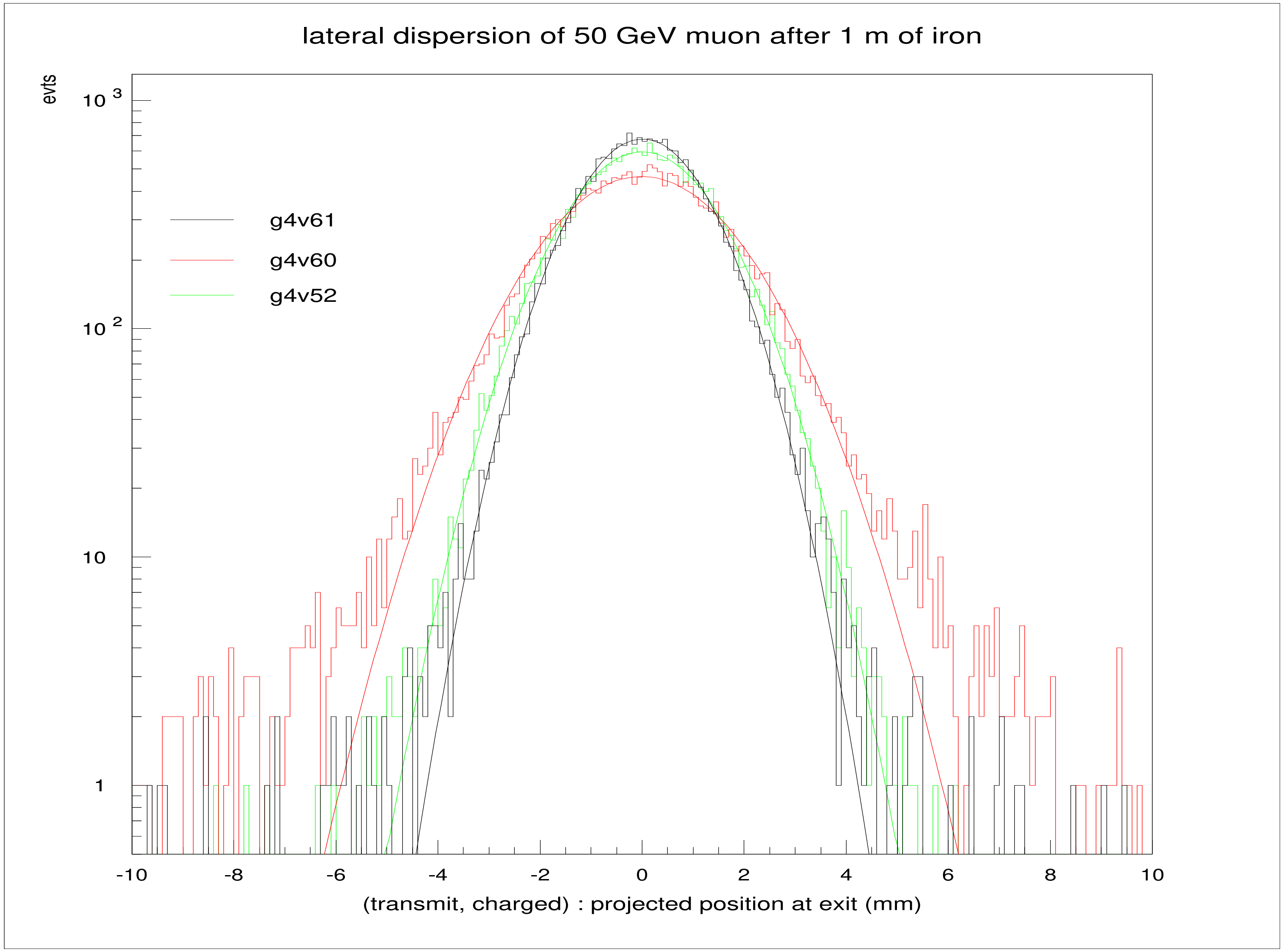
geant4/examples/extended/electromagnetic

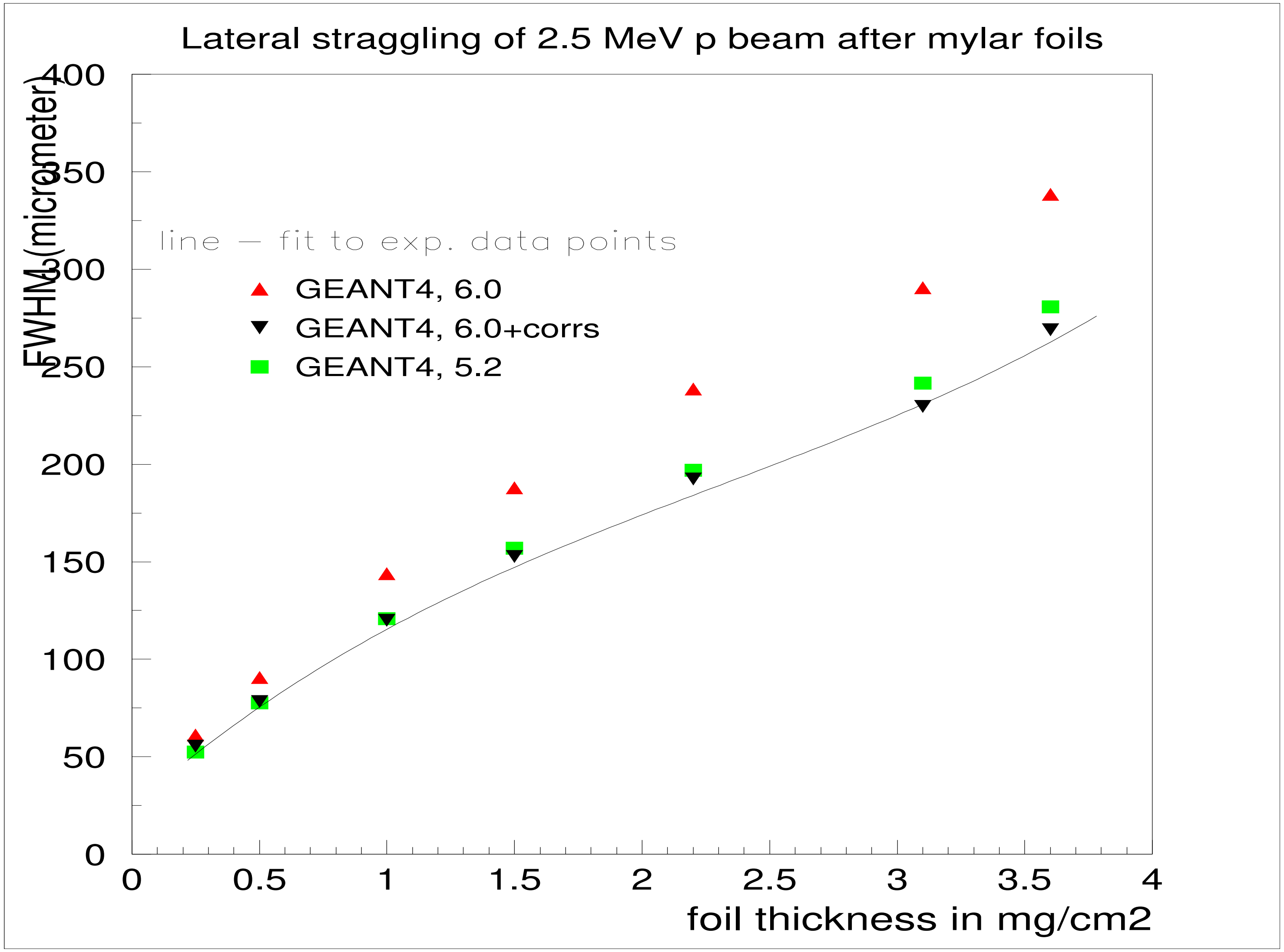
Improvements and new features (1)

- Multiple scattering 1: geom $\Longleftrightarrow$ true transformation. Use 'exact' formula in both direction, with more restrictive definition of small step approximation Introduced in V6.1 + V6.1_ref1
- Multiple scattering 2: angular distribution. Gaussian part: Highland formula for electron (introduced in V6.0). Second order term in Highland formula (introduced in V6.1_ref1).
- General conclusion on multiple scattering : V6.2 $\simeq$ V5.2, except for high energy electron.

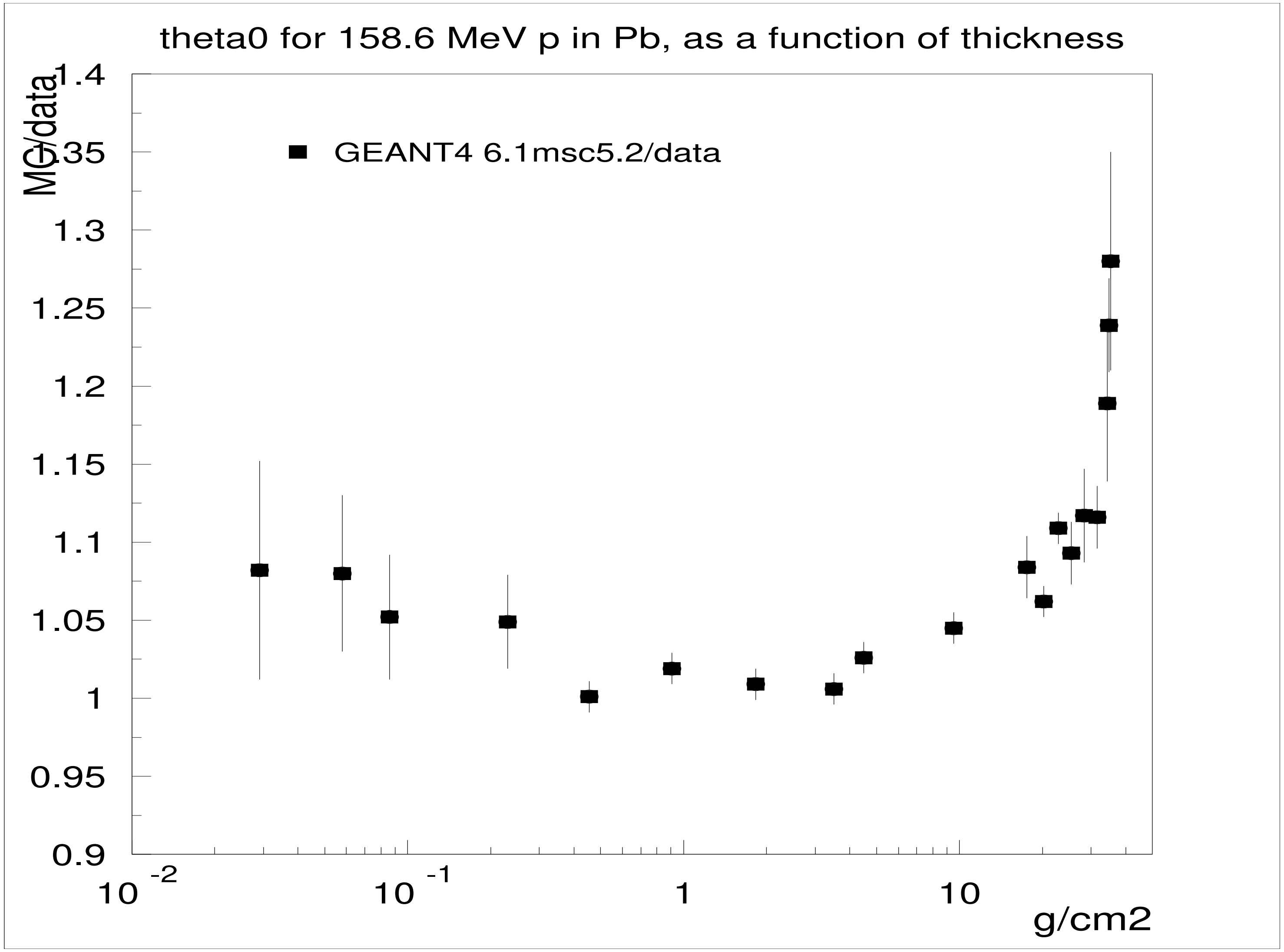
Improvements and new features (2)

- Mu ionization. Take into account radiative corrections caculation in G4MuBetheBlochModel for muon energy above 1 GeV. Accuracy of energy loss of high energy muons improved from 10% to 2%
- Mu pair production. Updated parameterizations in G4MuPairProductionModel for energies over 1 TeV. Precision of differential cross section parameterization is improved from 30% (in the worst case) to 5%
- G4EmProcessOptions. It is a new class to be used in PhysicsLists

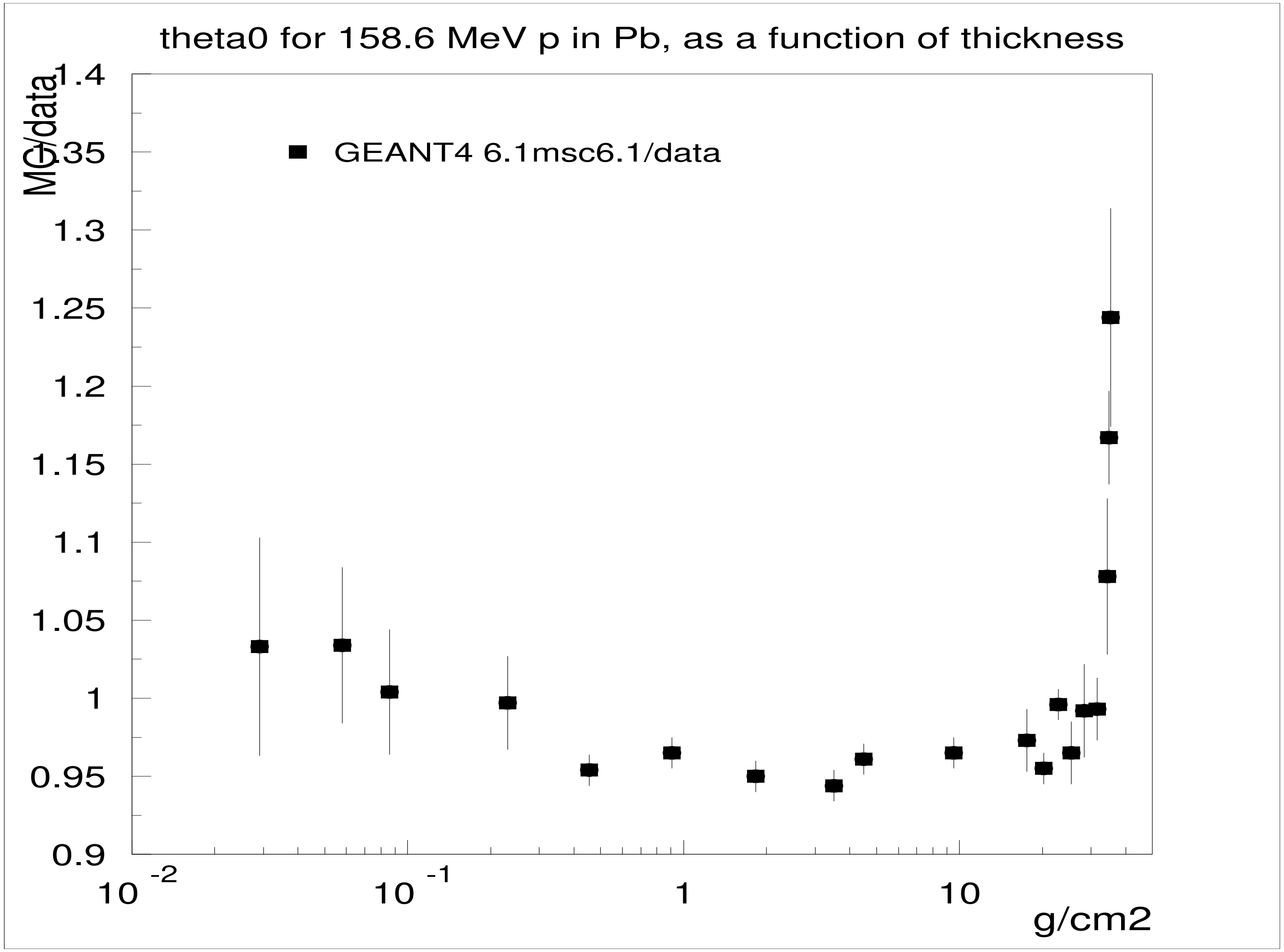

lateral dispersion of 50 GeV muon after 1 m of iron
evts
10^3
10^2
10
1
g4v61
g4v60
g4v52
-10
-8
-6
-4
-2
0
2
4
6
8
10
(transmit, charged) : projected position at exit (mm)


Lateral straggling of 2.5 MeV p beam after mylar foils
FWHM (micrometer)
0
50
100
150
200
250
300
350
400
line — fit to exp. data points
GEANT4, 6.0
GEANT4, 6.0+corrs
GEANT4, 5.2
0
0.5
1
1.5
2
2.5
3
3.5
4
foil thickness in mg/cm2

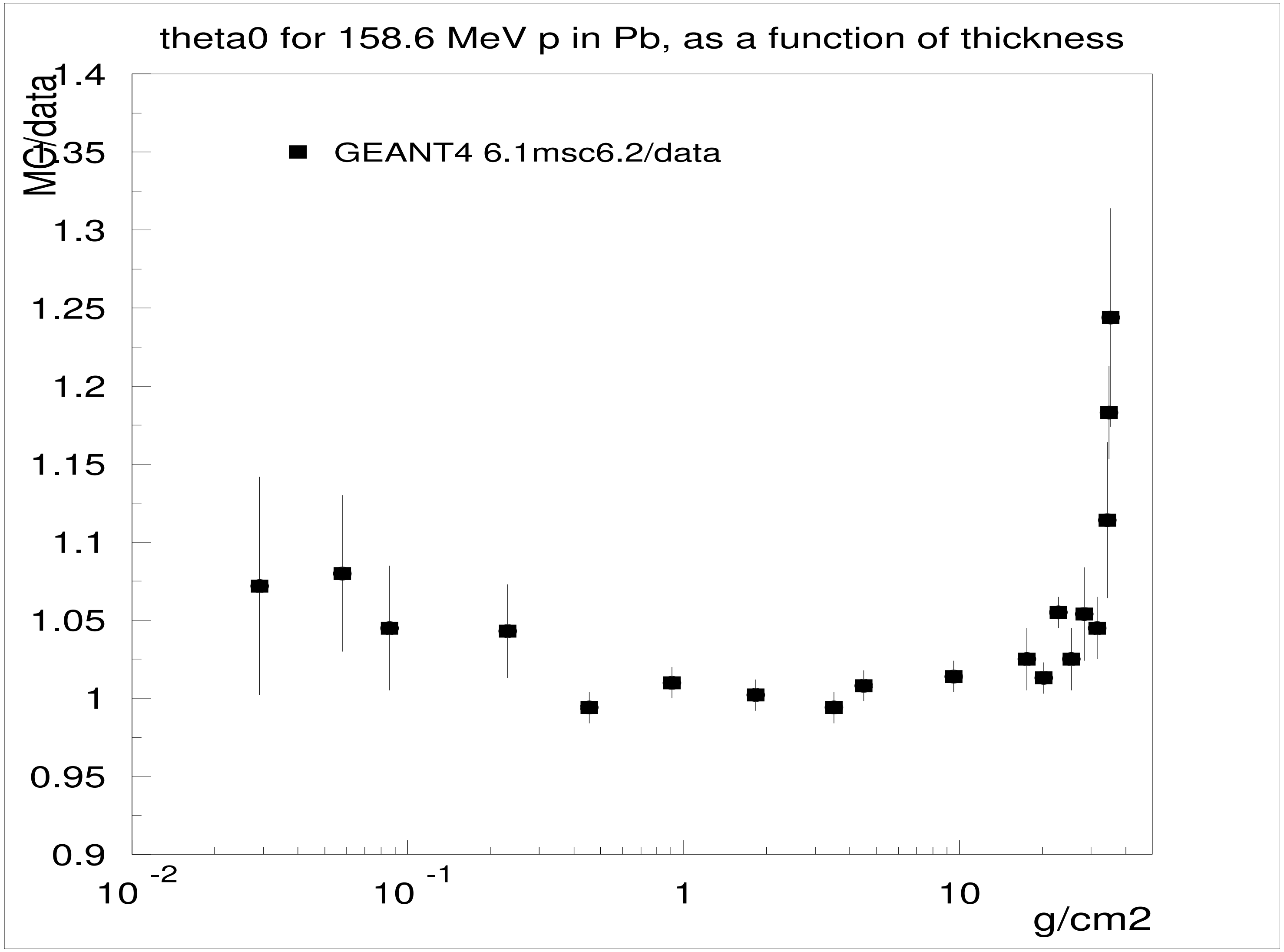
version 5.2


theta0 for 158.6 MeV p in Pb, as a function of thickness
MC/data
GEANT4 6.1msc5.2/data
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
10 -2
10 -1
1
10
g/cm2

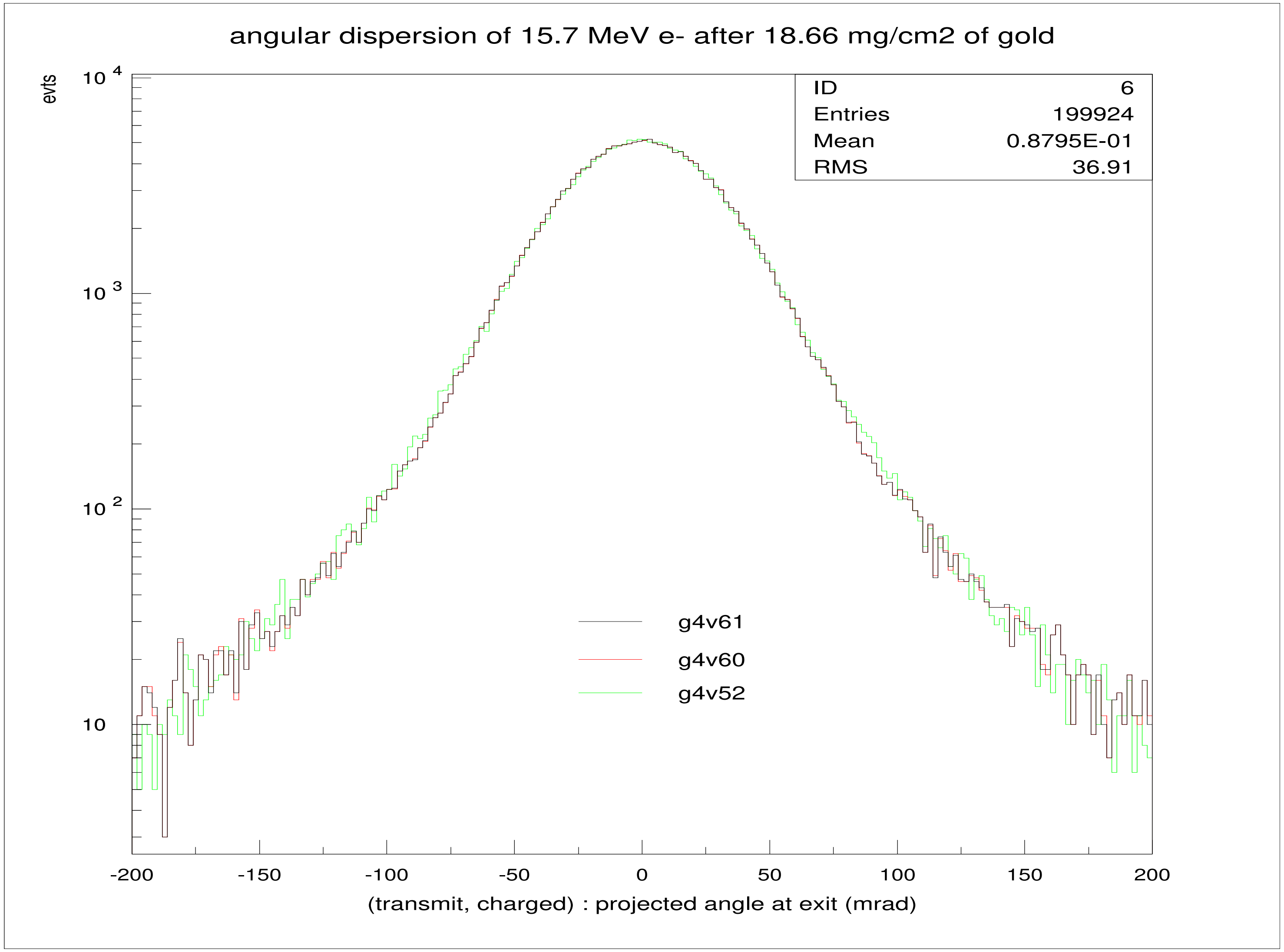
version 6.1


theta0 for 158.6 MeV p in Pb, as a function of thickness
MC/data
GEANT4 6.1msc6.1/data
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
10 -2
10 -1
1
10
g/cm2

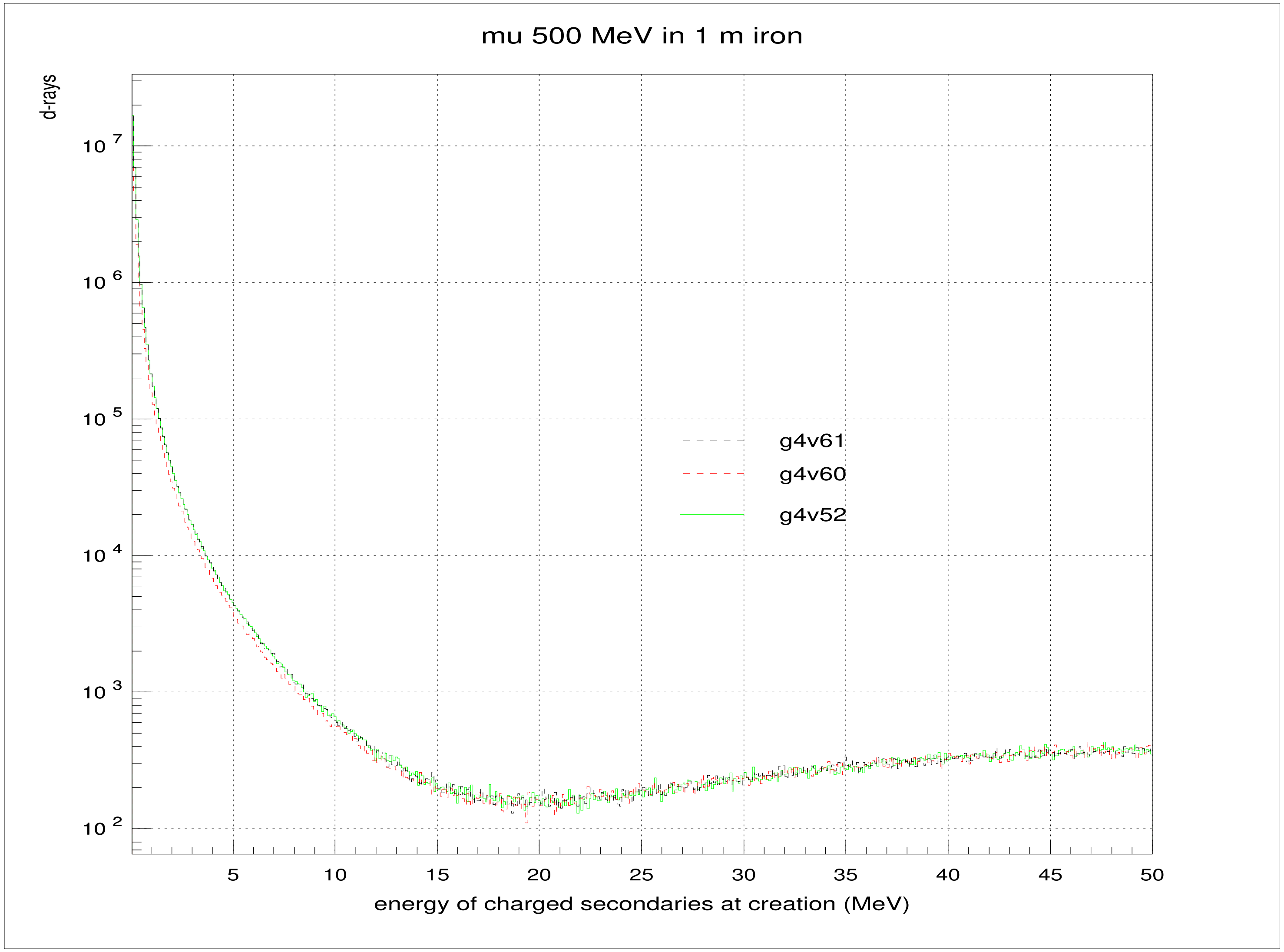
version 6.2


theta0 for 158.6 MeV p in Pb, as a function of thickness
MC/data
GEANT4 6.1msc6.2/data
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
10 -2
10 -1
1
10
g/cm2

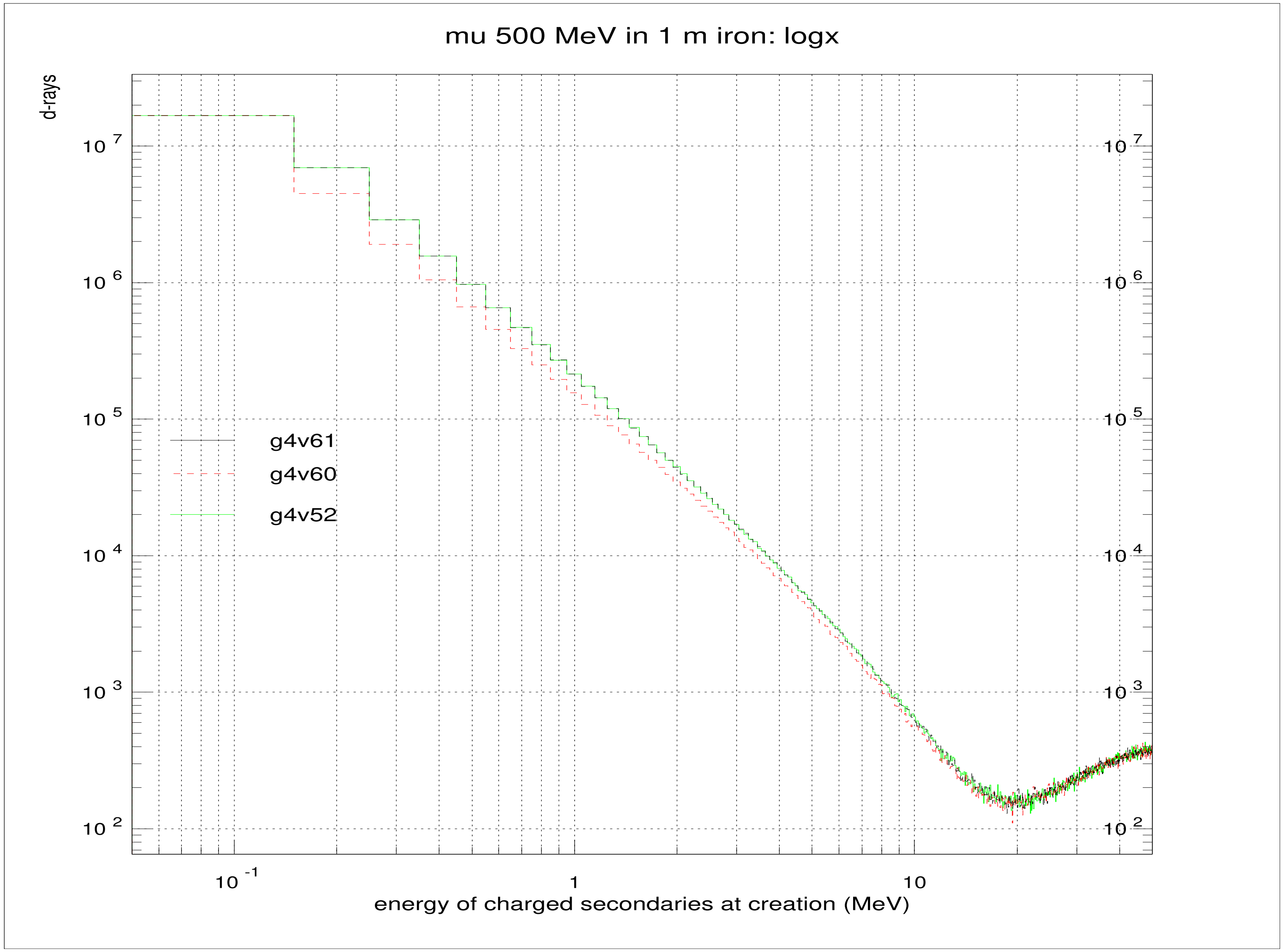
Do not affect electrons ...



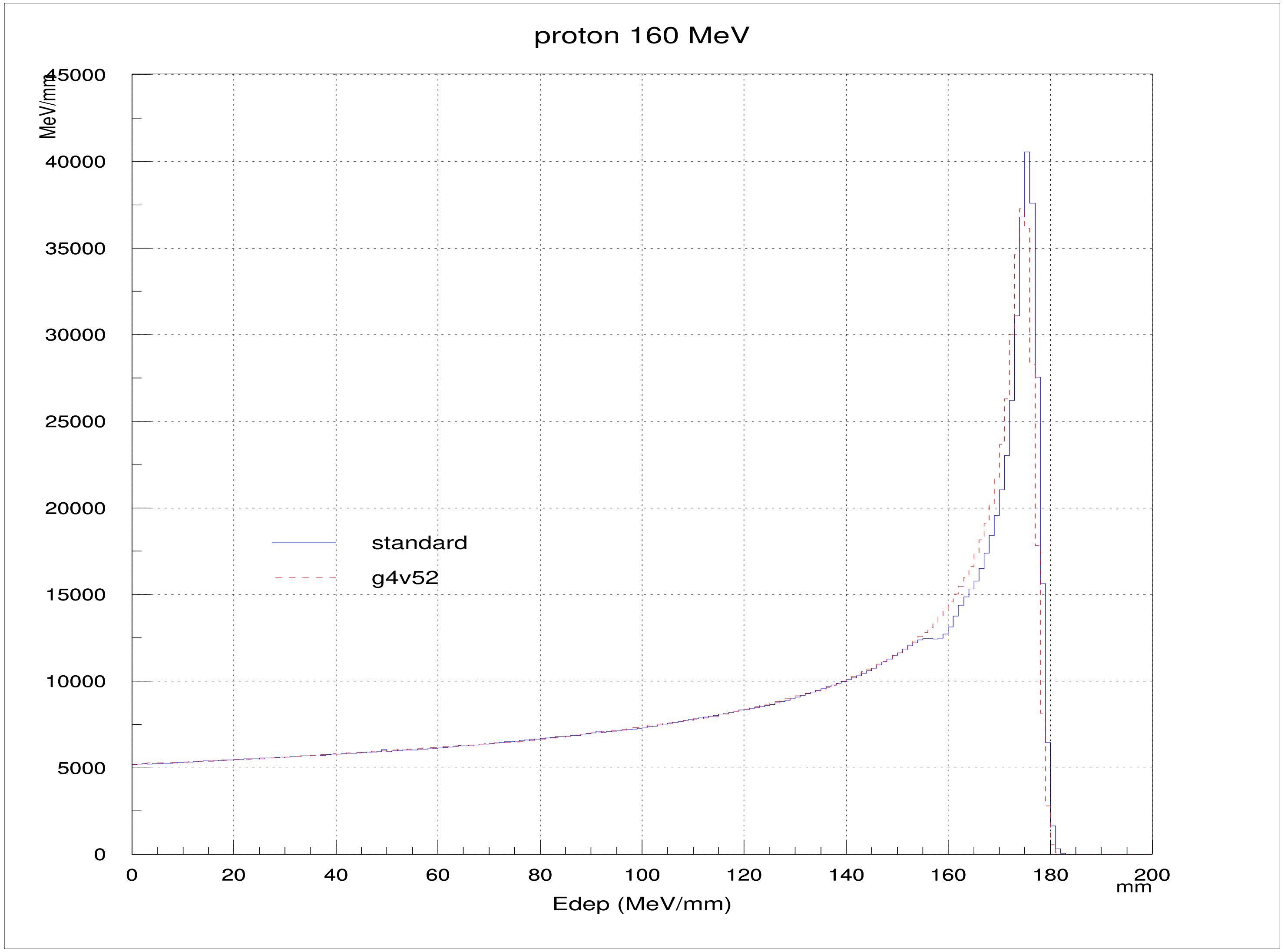
Mu ionization cross section



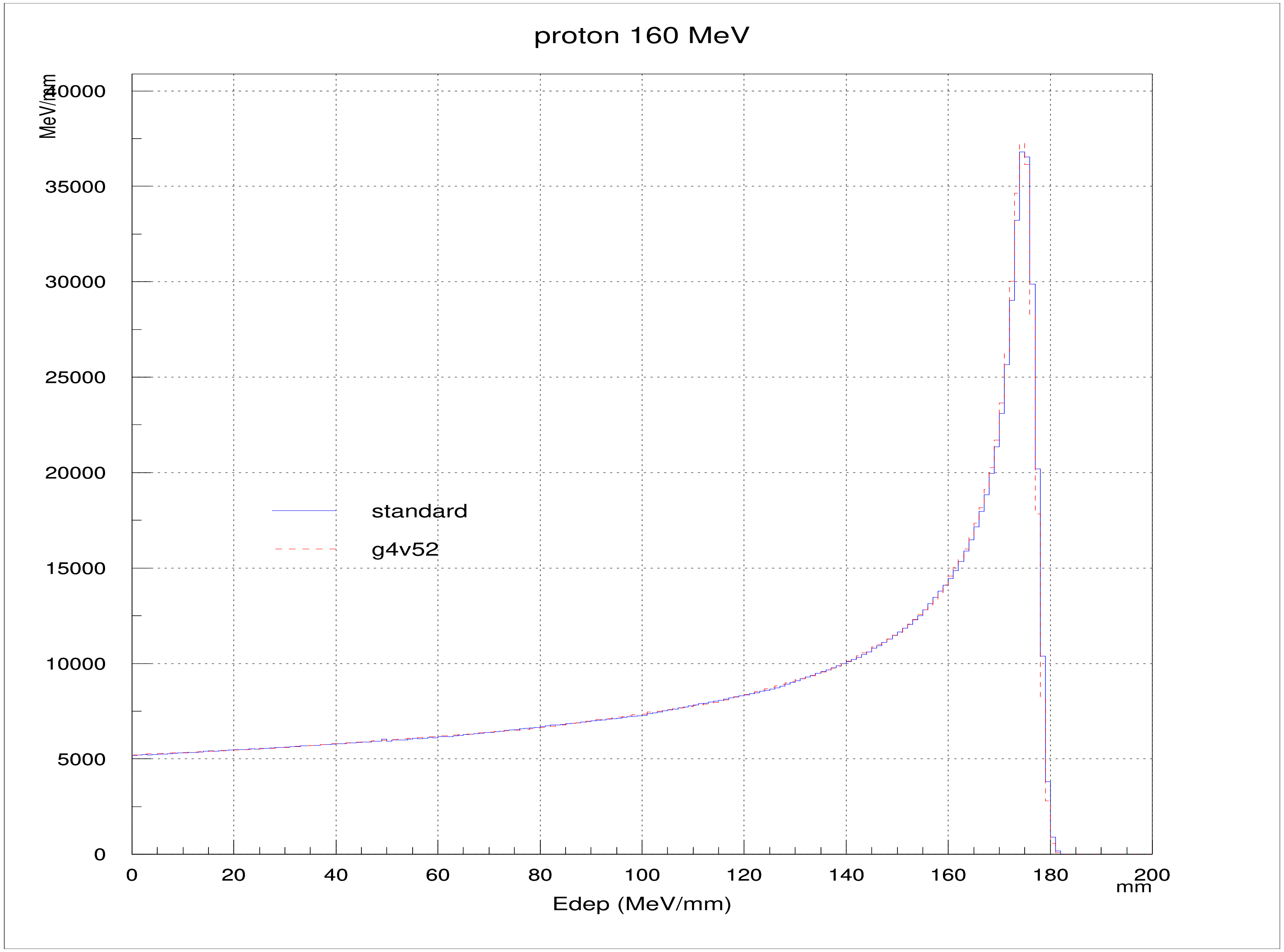
Mu ionization cross section: logx



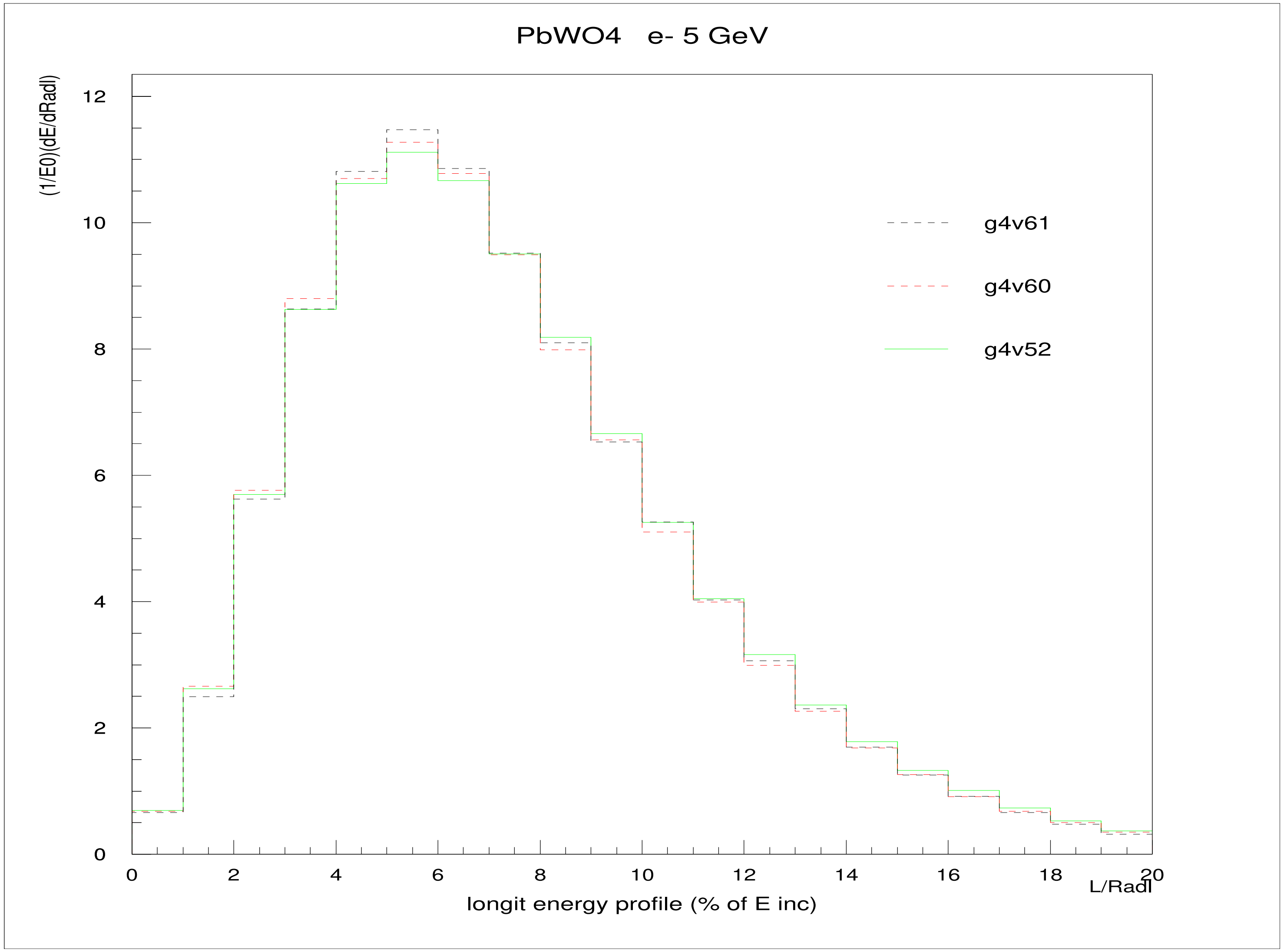
Error in retrieving dE/dx from table : V6.0 versus V5.2



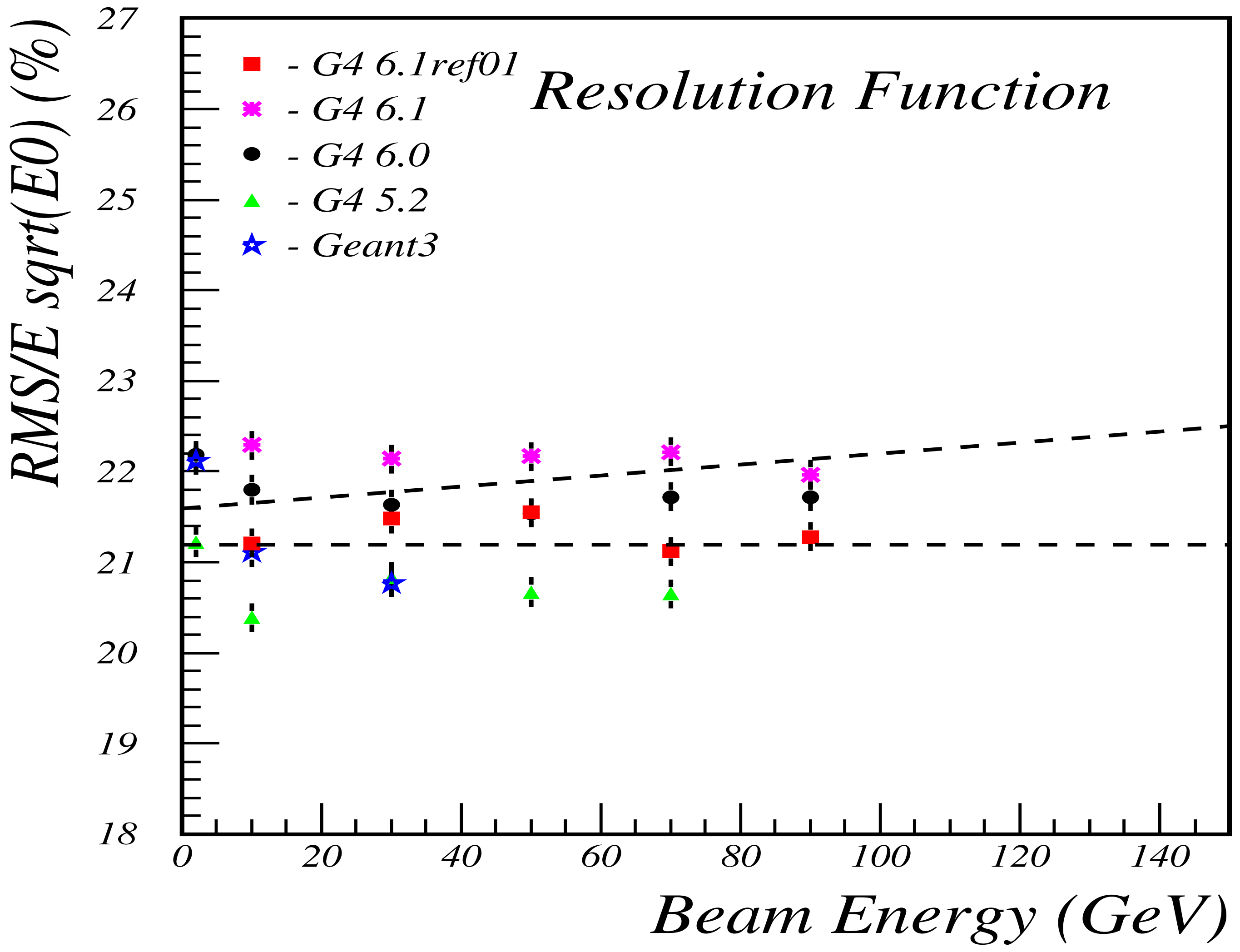
Error in retrieving dE/dx from table : V6.2 versus V5.2



electron shower :longitudinal profile



sampling calorimeter: atlas hec



After V6.2 release

- Examples of modular PhysicsLists using the concept of Em builder
- Start to set up a Validation Suite with Em physics inside