Recent Upgrades and Status of Geant4 Electromagnetic Physics

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

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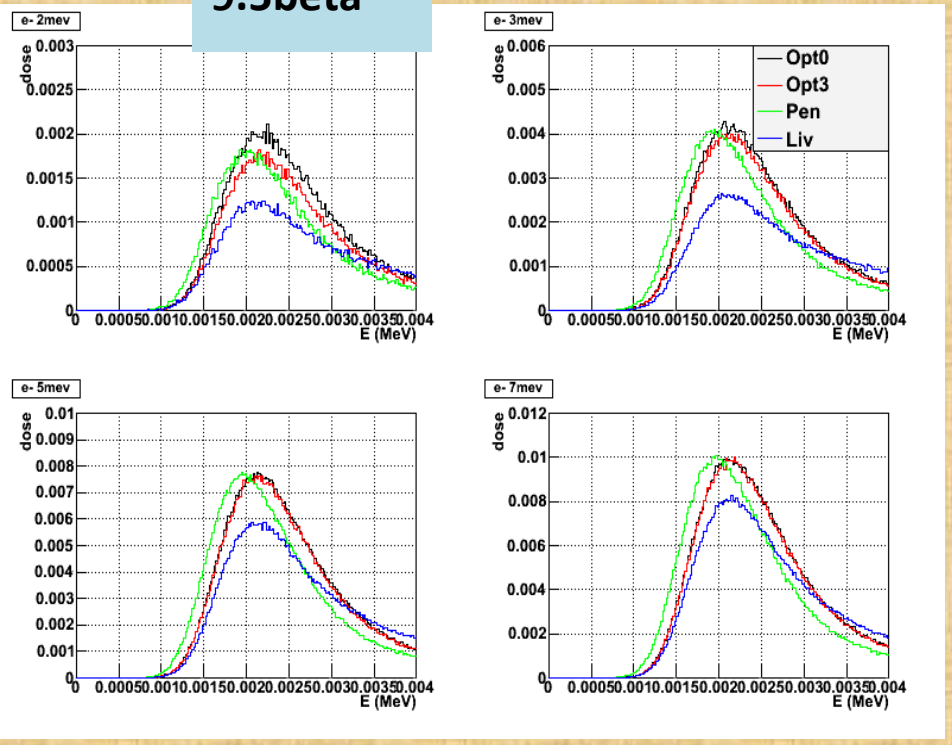
Outline

- Major modification of user interfaces in Geant4 9.6
- Main developments
  - Multiple and single scattering
  - Ionisation
  - Bremsstrahlung
  - Gamma processes
  - EM Physics Lists constructors
- Plans

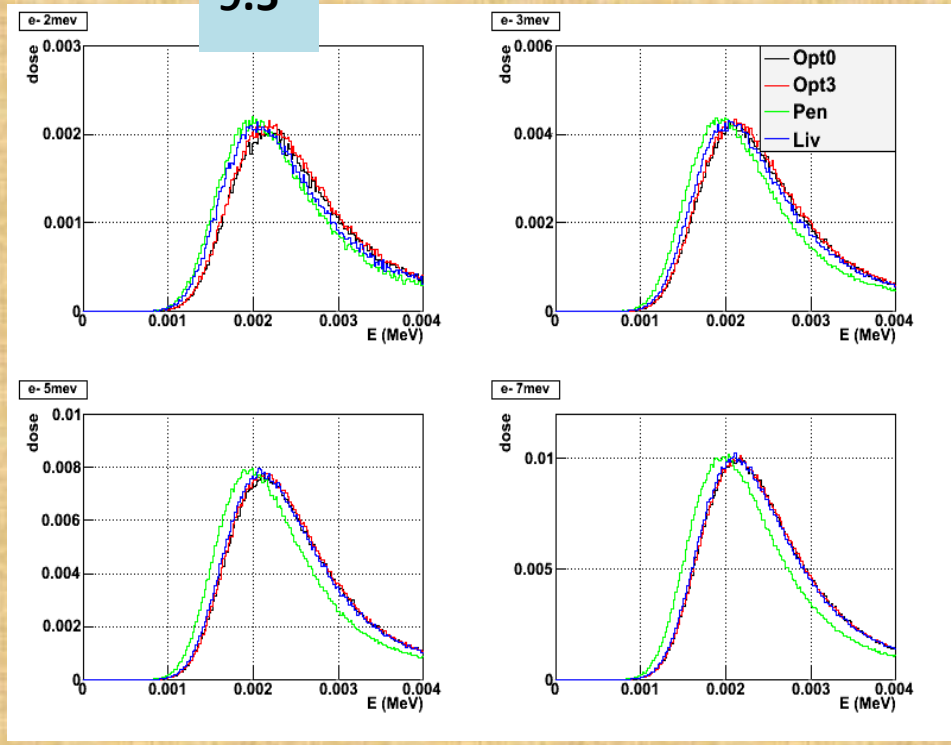
- Remark: a significant progress in several aspects of Geant4 EM physics was achieved recent years with ESA projects ELSHIELD and BIORAD

ELSHIELD 1-D Benchmark

9.5beta



9.5



- Dose deposition in 10 um Si layer by 2, 3, 5, 7 MeV electron beams and 2 mm Al shielding
- Penelope predicts a bit lower peak position – difference in model of fluctuations
- In general all Physics Lists of 9.5 predicts the same dose

New Geant4 version 9.6

- Was released in December, 2012
  - Finelized unification of standard/Livermore/Penelope/DNA models
    - Common approach for angular generators
    - Common de-excitation module in all processes/models
    - Common biasing options
    - Opt4 Physics List
  - Upgraded single/multiple scattering infrastructure
  - Reviewed and updated photon processes
  - Removed old Penelope2001 (Geant4 Penelope coresponds to Penelope2008)
- First patch in February, 2013
  - Fixed tracking in magnetic field
  - Fixed de-excitation for Livermore photoelectric
  - Replaced Compton low-energy model in the new Option4 Physics List
- Known problems (to be fixed in the next patch):
  - New Compton model developed by Monash University group have rare numerical problem
  - Livermore ionisation models has problem required for Opt4 low-energy limit should be increased, to today one needs to apply

  /process/eLoss/minKinEnergy 100 eV

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 for all Geant4 processes
  - «Range cut» biasing option is added
- Added new method
  - G4EmCalculator::ComputeGammaAttenuationLength()
- EM physics (both standard and low-energy) now require the G4EMLOW 6.32 data files

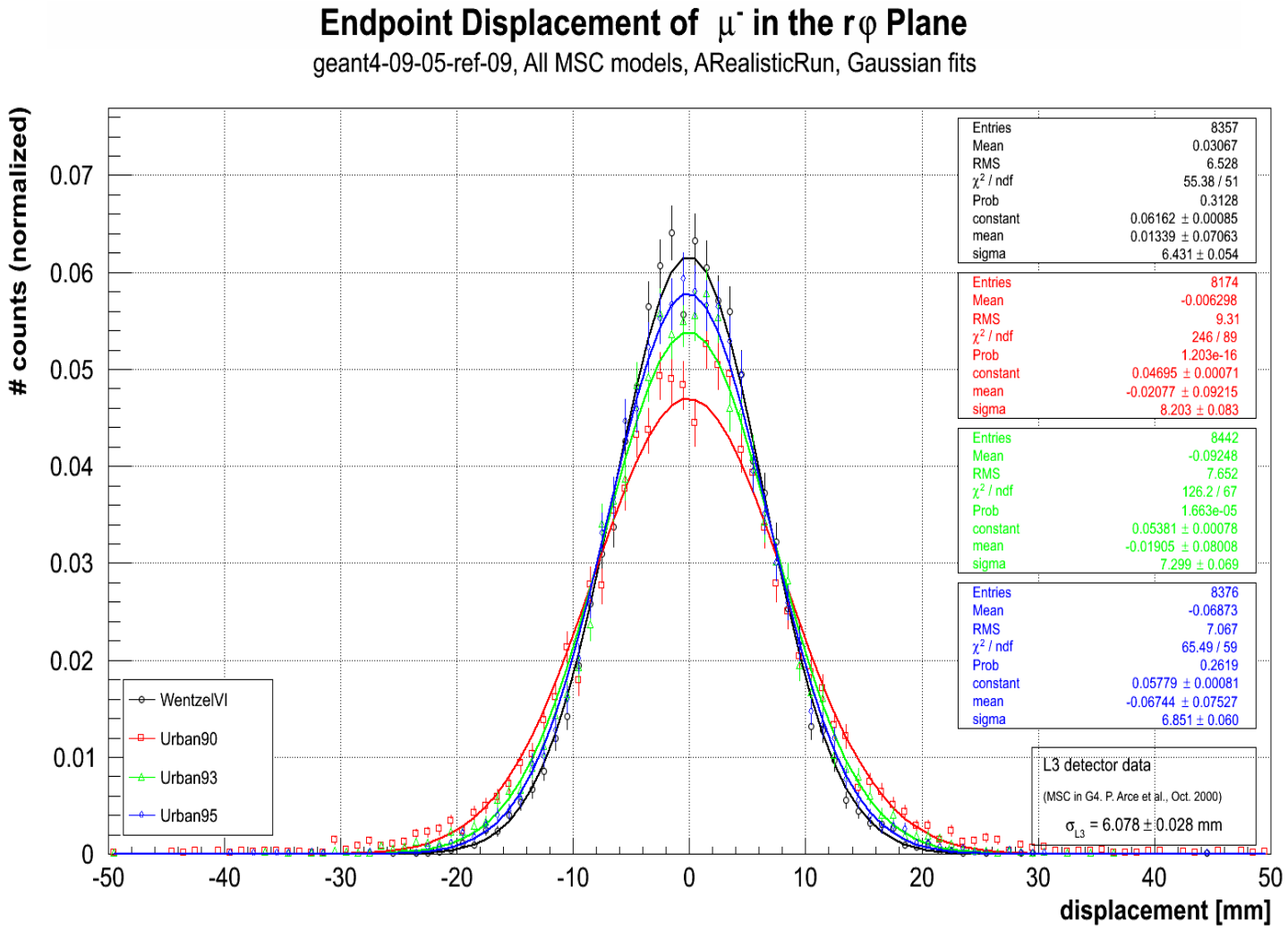
Main Developments and Validation Results

Overview of modifications for multiple scattering

- Base material approach is implemented
  - In 9.5 base material approach was introduced for energy loss and discrete processes only
- Particles and anti-particles may share EM process class
  - Reduced size of EM tables
- Physics Tables moved from msc processes to models
  - Urban, WentzelVI and single scattering models may work in the same Physics List for different energy range
- In all EM builders (except Opt3) WentzelVI model is used for all charged particles except e+- below 100MeV
  - Long Reserford tail better simulated by the WentzelVI 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
- Tunning of G4UrbanMscModel96 have been performed

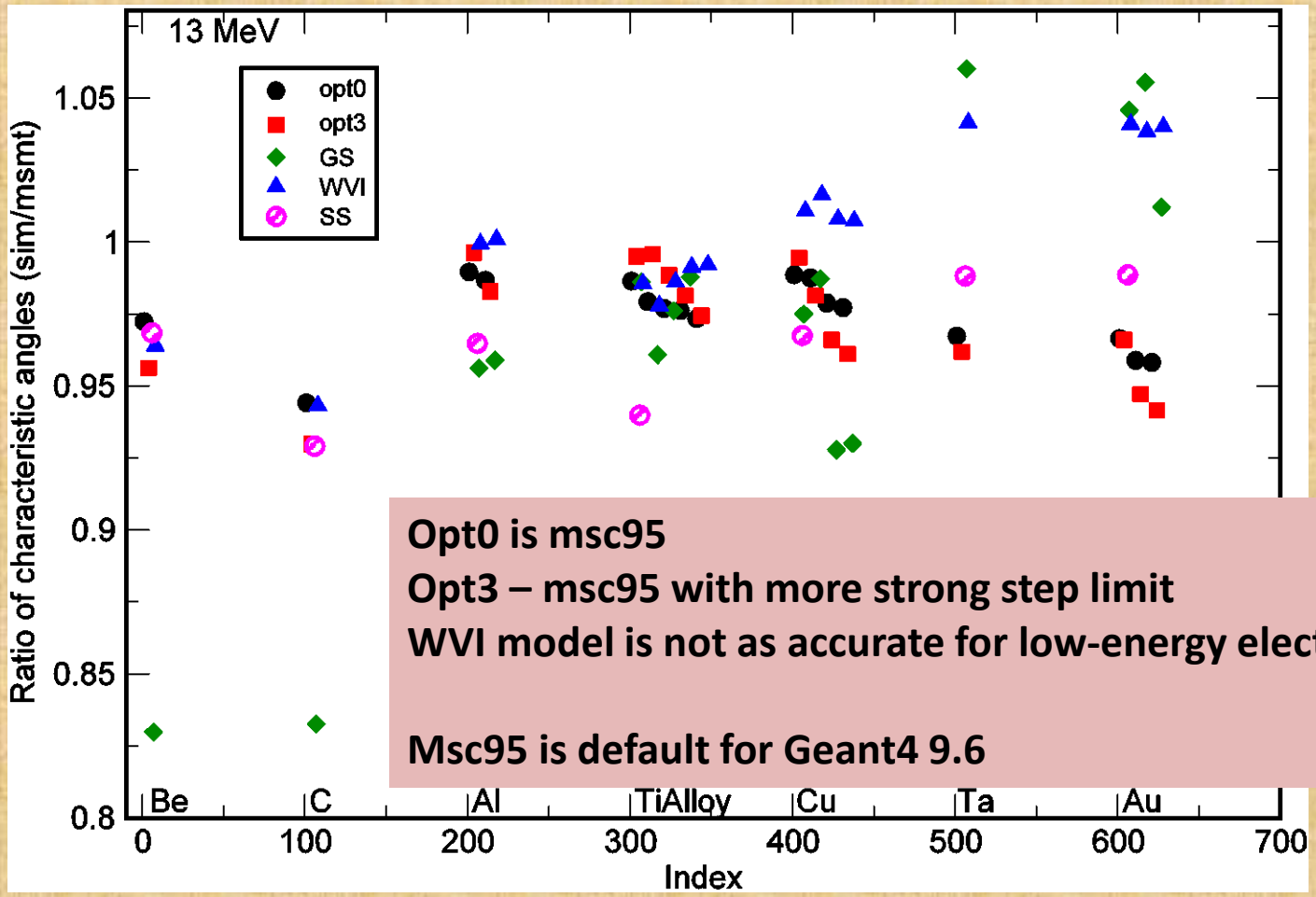
Why WentzelVI for high energy?
Geant4 muons versus L3 data

(M.Schenk, CERN summer student)



Why Urban95 for low-energy? Electron scattering benchmark

(CHEP'12 D. Sawkey)



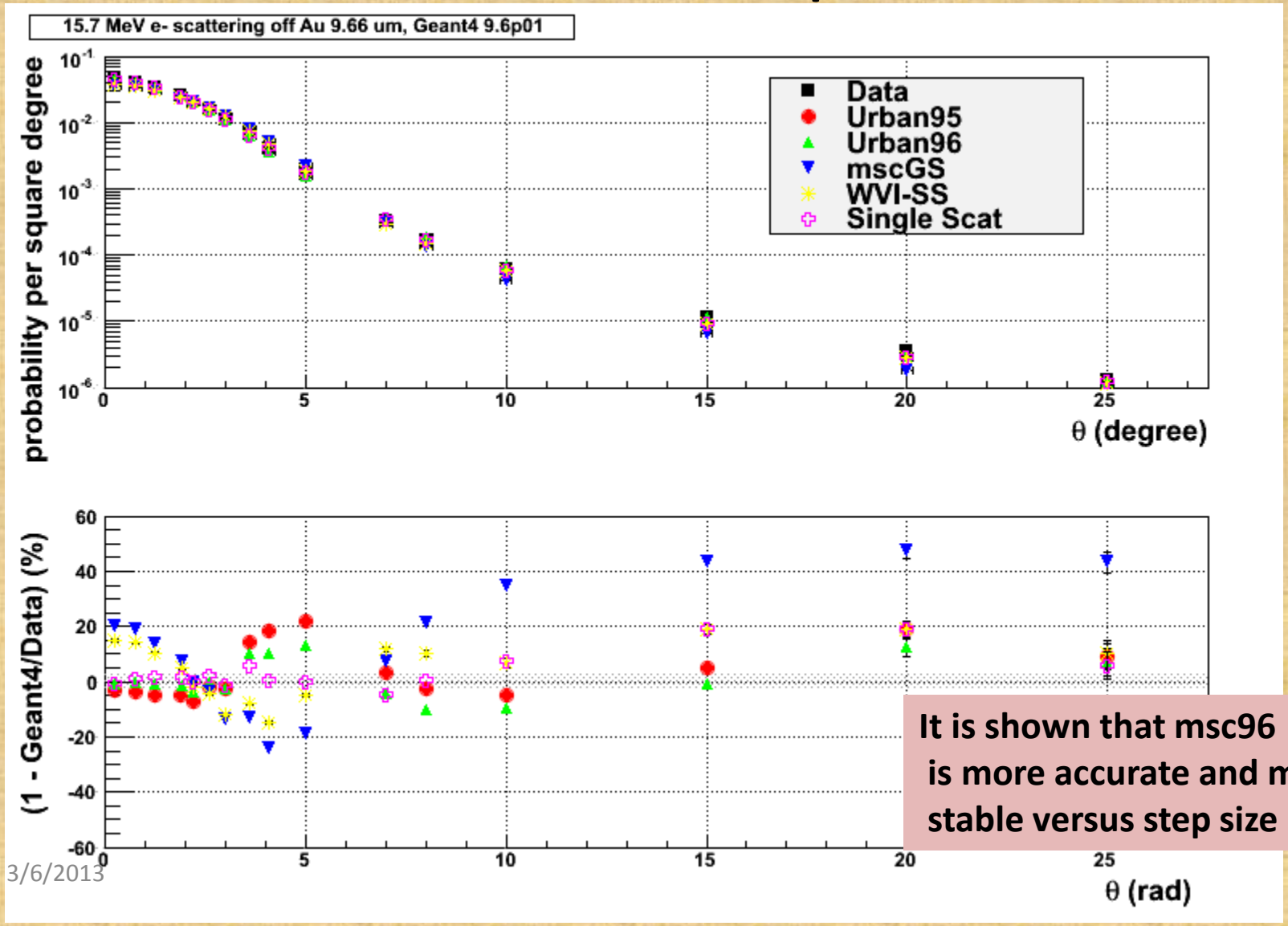
Opt0 is msc95

Opt3 – msc95 with more strong step limit

WVI model is not as accurate for low-energy electrons

Msc95 is default for Geant4 9.6

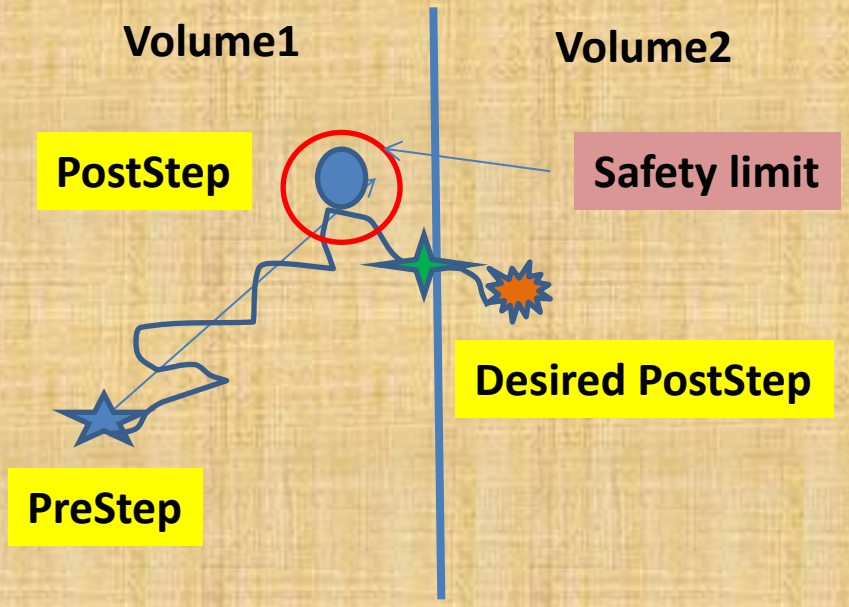
G4UrbanMscModel96 has been tunned for 9.6patch01



It is shown that msc96 is more accurate and more stable versus step size

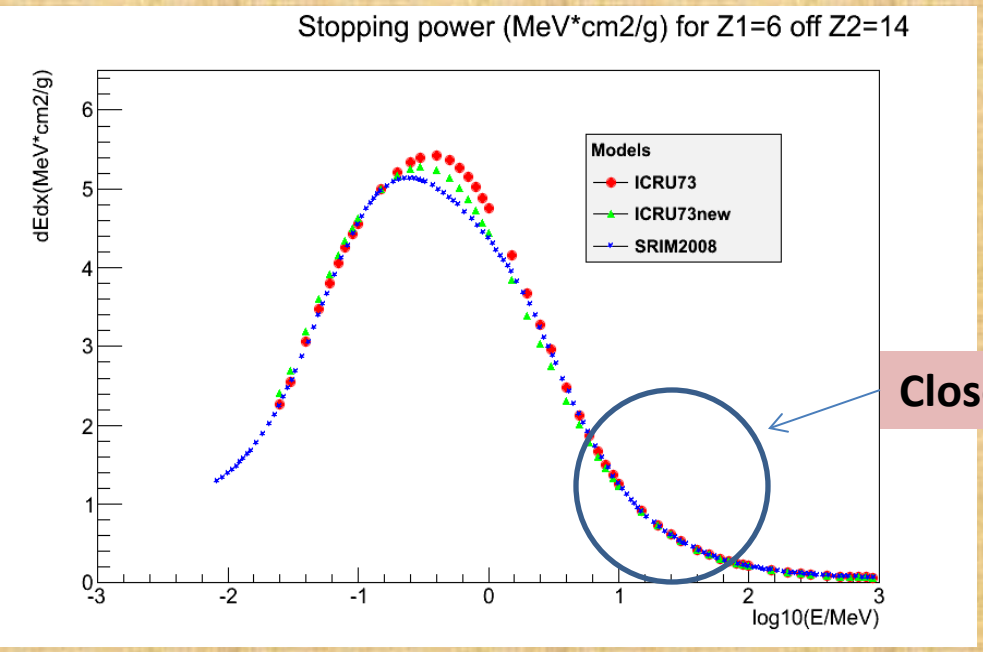
Multiple scattering upgrade

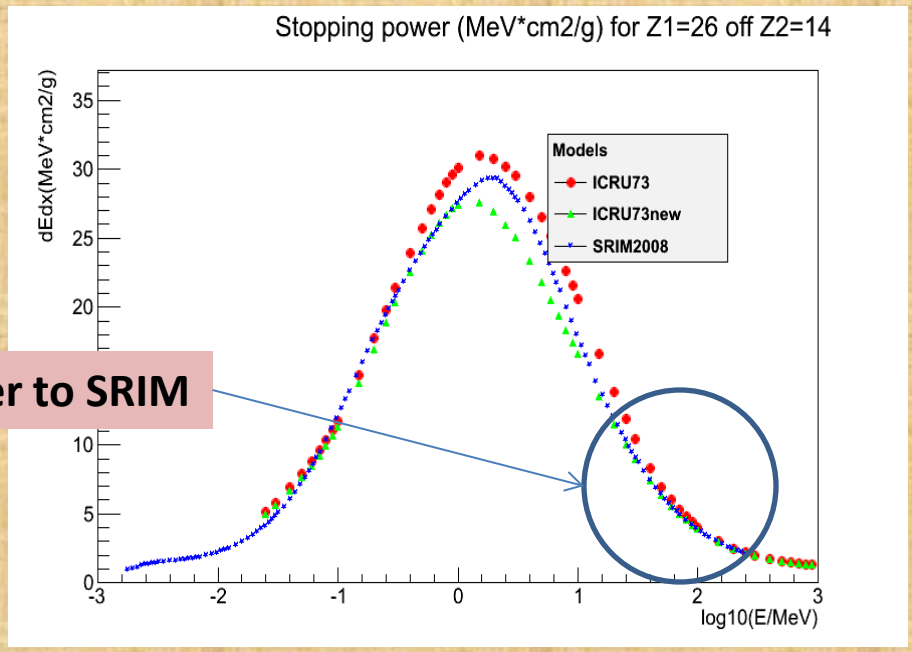
- From ELSHIELD and other studies it is clear that Geant4 msc provides shorter geometry ranges of electrons
- To fix this the main proposal:
  - Migration of msc sampling from PostStep to AlongStep
- 1st step iis done for Geant4 9.6
  - This work for all msc models
- Plan to finelize in version 10
  - We can reduce number of steps if this mecanism will work



- End point should be shifted to geometry boundary
- true step length should be corrected

Ion Stopping Power Upgrade





Closer to SRIM

- Geant4 data set for ion stopping power have been updated using computation from PASS code done in RRMC project
- More smooth dependence of stopping power versus primary ion charge
- More close to SRIM parameterisation

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

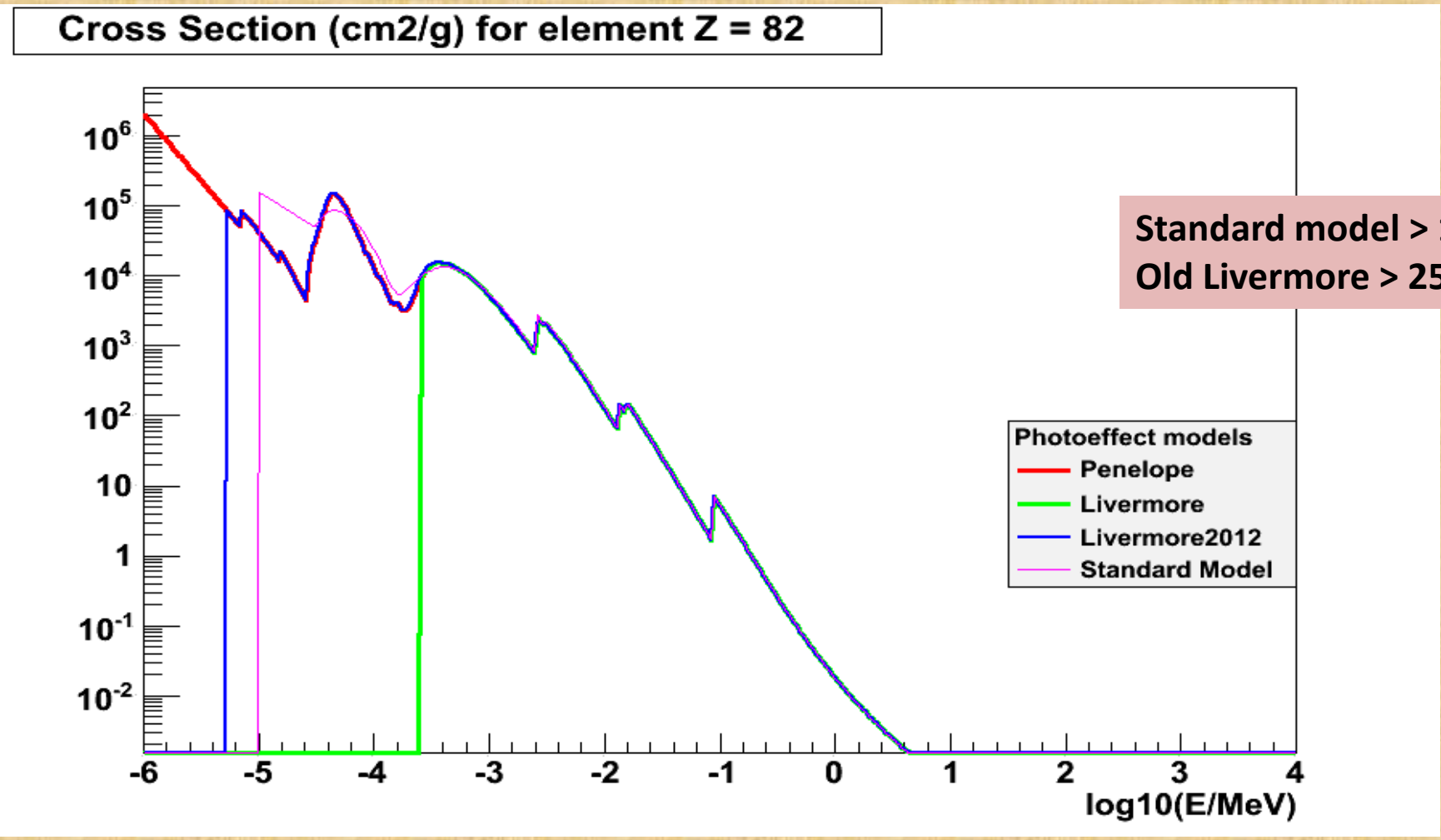
Gamma processes review

- All available gamma processes and models (standard and low-energy) have been reviewed and upgraded
  - Cross sections, energy and angular spectra
  - Number of issues were identified and fixed
  - Livermore model have been updated to speedup simulation
- An example: Rayleigh scattering at 250 keV in Pb:

Model	CPU (s)
Penelope	0.03
Livermore	0.03
Livermore-OLD	6.48

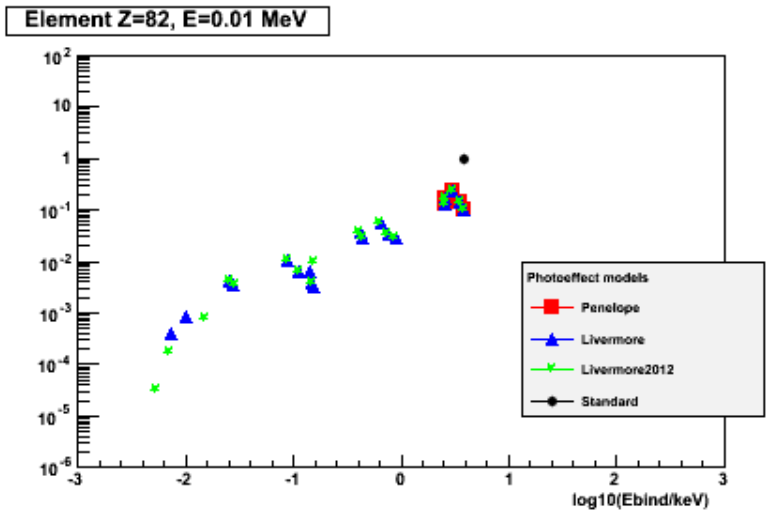
Livermore scattering is now included in Opt3, Opt4, Livermore Physics Lists

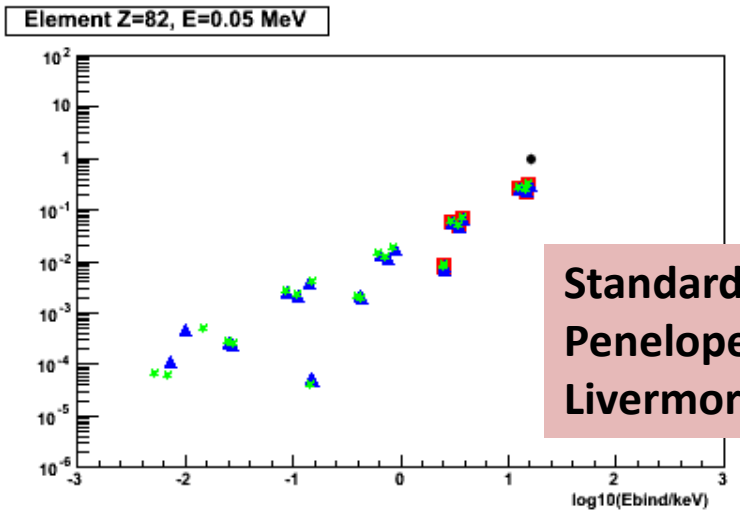
Photo-electric cross sections



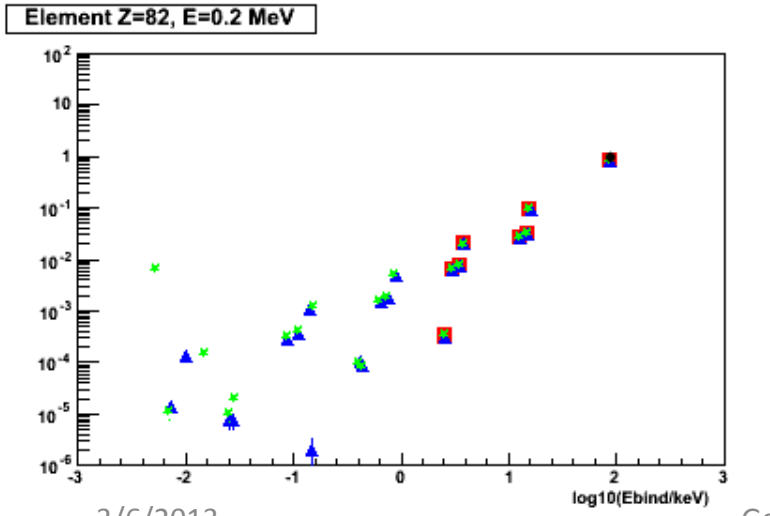
Standard model > 1 keV
Old Livermore > 250 eV

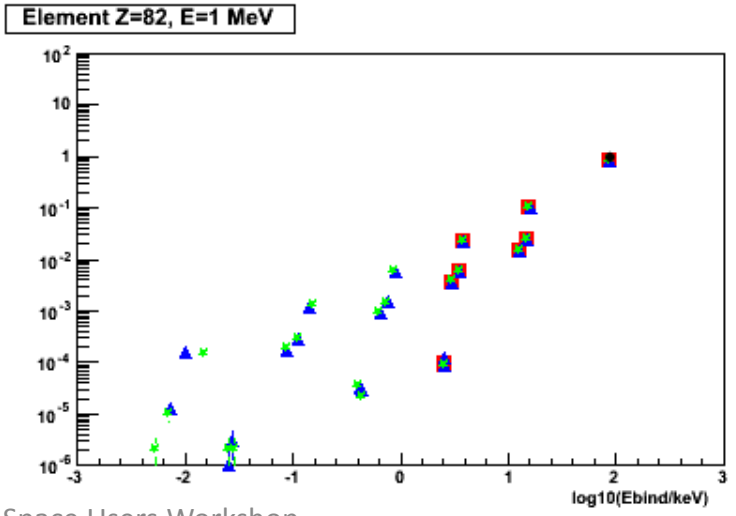
Photoelectric electron energies in Lead 10, 50, 200, 1000 keV



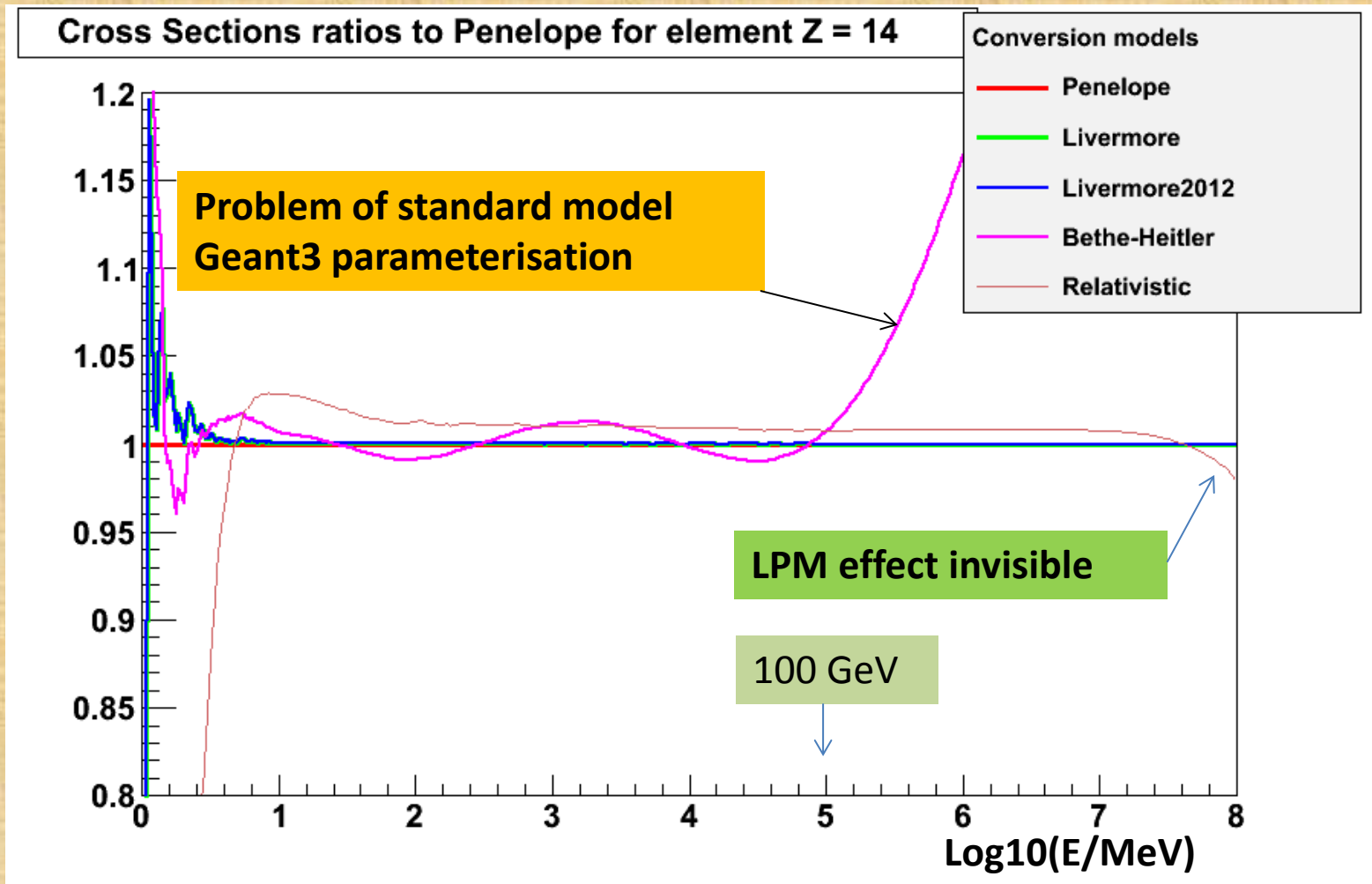


Standard model: K-shell
Penelope: K-, L-, M-
Livermore: all shells





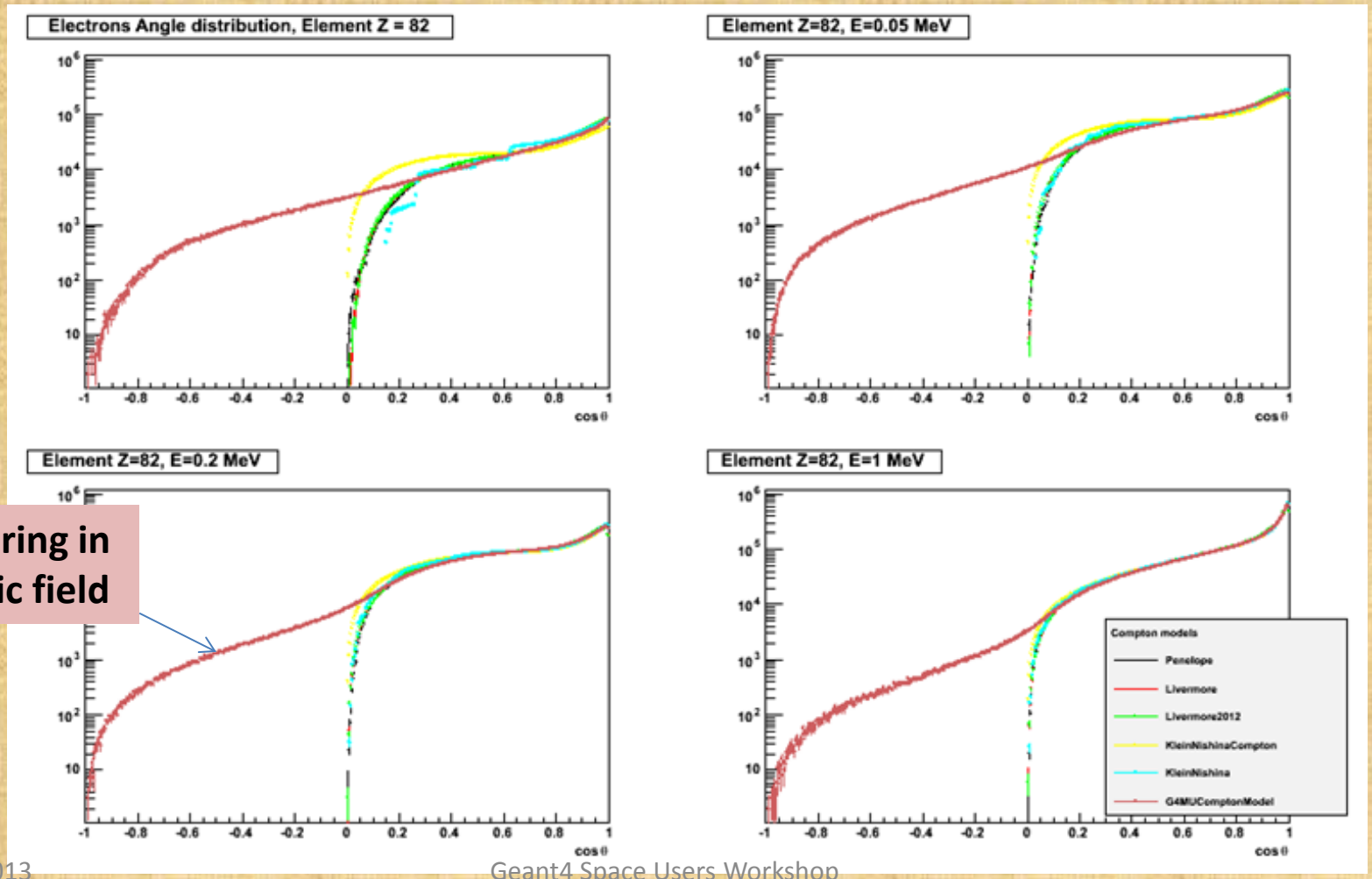
Gamma conversion cross section ratio for Silicon between different Geant4 models
In 9.6 relativistic model is applied above 80 GeV



Anglular distribution of electrons

Compton scattering in Pb (10, 50, 200, 1000 keV)

Monash University model is based on new approach



Scattering in atomic field

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

Geant4 9.6: EM Physics builders for Space and medical applications

Constructor	Components	Comments
G4EmStandardPhysics_option3	Msc95 for prticle types, standard models when applicable	The most accurate standard
G4EmStandardPhysics_option4	WentzelVI at high energy msc95 below 100 MeV, photon models from Livermore and Penelope, Livermore ionisation for e-	The most accurate EM physics
G4EmLivermore	Livermore models when applicable	Livermore
G4EmPenelope	Penelope models when applicable	Penelope
G4EmLivermorePolarized	Polarized models	
G4EmDNA	Example of DNA physics	

Plans for the release 10

- Make EM physics multi-tread capable
  - Standard
  - low-energy
  - DNA
- Complete developments for multiple scattering
  - migration of msc to AlongStep
  - Urban msc model and release only G4UrbanMscModel
- Alternative energy loss fluctuation model for thin layers
- Alternative ion ionisation model
- Establish Opt4 as a production Physics List