Validation results from ELSHIELD project

Contract 22839/10/NL/AT

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Outline

- ELSHIELD benchmarks
- Electron scattering (Hanson data)
- Sandia data benchmarks
- Electron ionisation,
- Bremsstrahlung
- 1D benchmark

Introduction

- ELSHIELD project funded by ESA include extensive model EM standard model developments development in 2010-2011
- In framework of the ELSHIELD project EM benchmarks for the energy 1 keV – 20 MeV have been extended and regular exercised
- Problems in standard models and combined Physics lists have been fixed

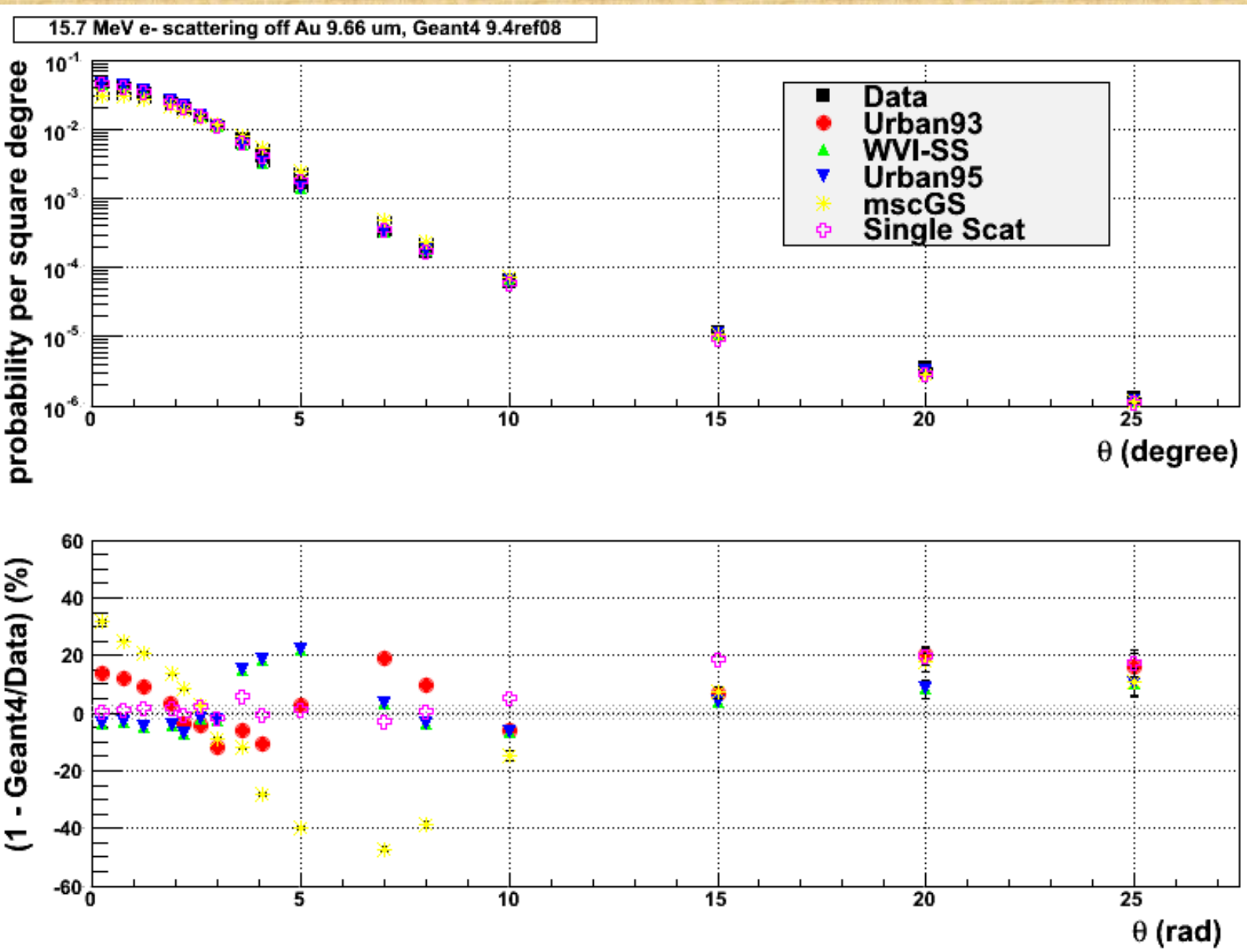
List of ELSHIELD validation benchmarks versus experimental data

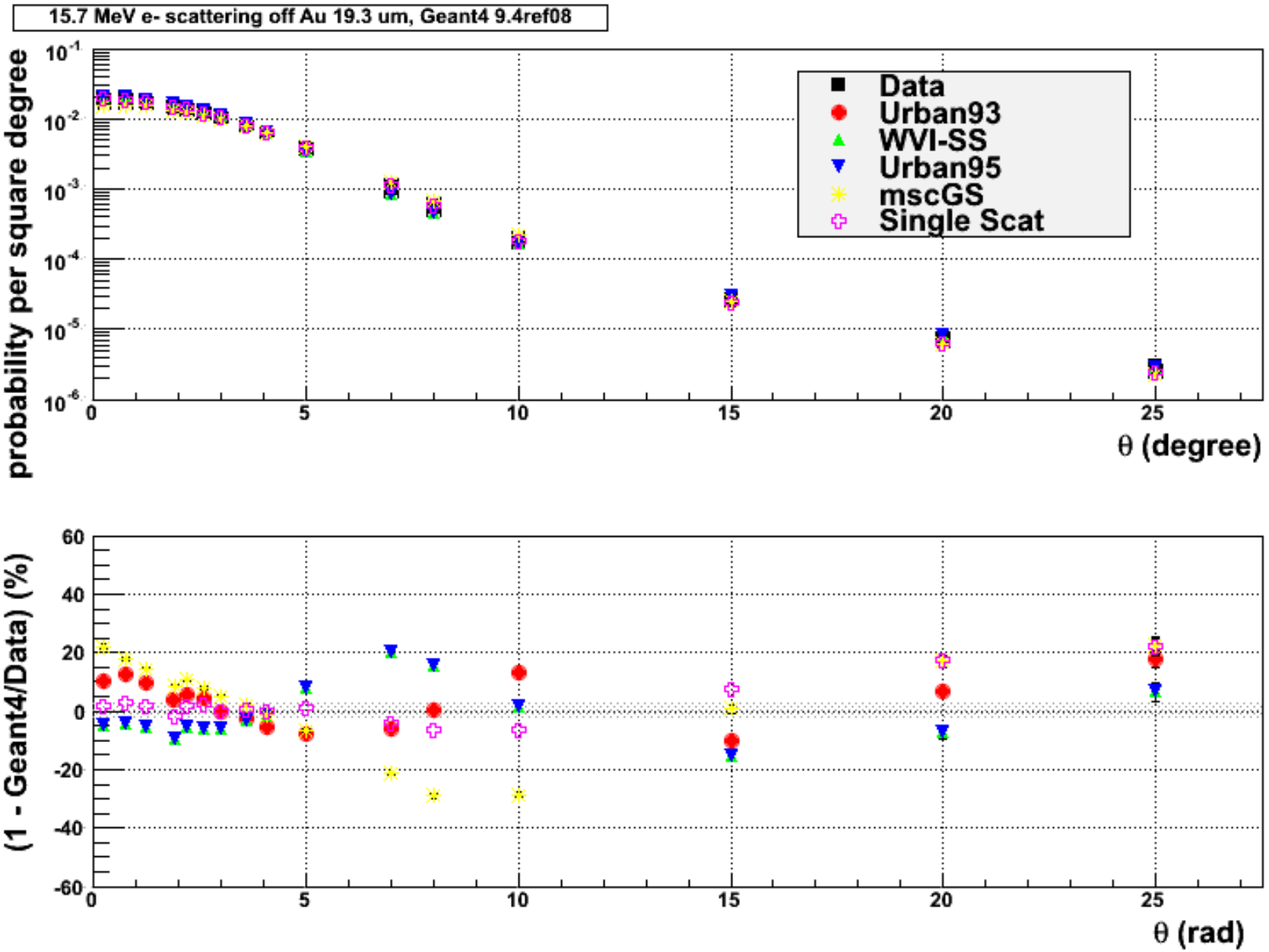
Benchmark	Type	Energy/angle	Material	Test
Electron scattering	new	15.6 MeV $0 – 25^0$	Au	data
Electron scattering	Existing, update in progress	13, 20 MeV $0 – 12^0$	Be, C, Al, Ti, Cu, Au, Ta	Data, EGSnrc, Penelope
Dose profile	Existing	0.5 – 1 MeV	Al, Mo, Ta, TaAl, AlAuAl	Data
Backscattering	new	0.1 – 1 MeV $0 – 75^0$	Be, C, Al, Ti, Cu, Mo, Au, Ta, U	Data
Bremsstrahlung	new	1, 2.8, 15 MeV $0 – 60^0$	Al, Cu, W	Data, EGSnrc, Penelope
Dose kernel	Existing	10, 15, 100 keV 1 MeV	Water	EGSnrc

Energy interval of interest for the project 1 keV – 20 MeV

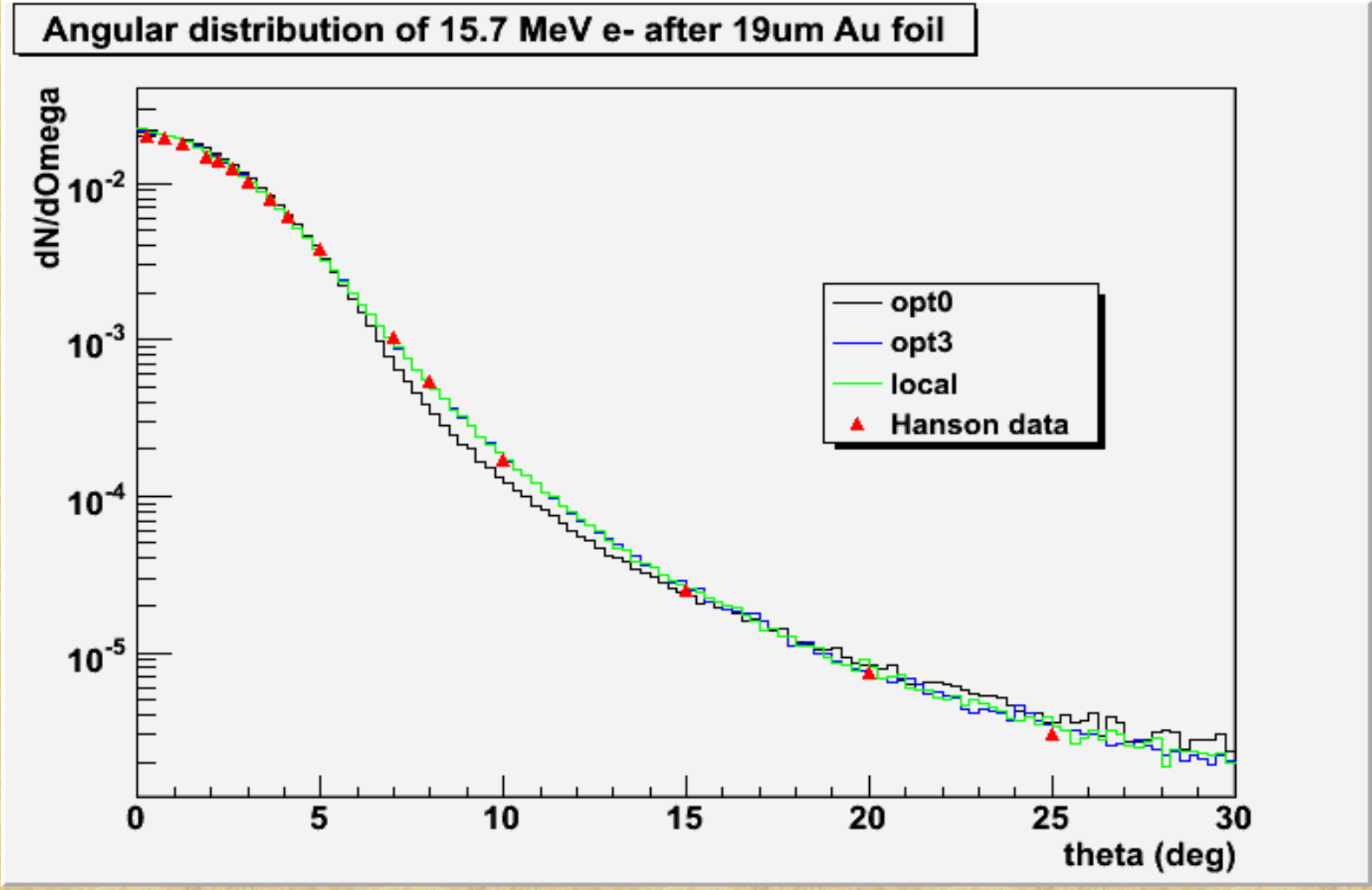
Electron scattering

A. O. Hanson et al., “Measurement of multiple scattering of 15.7-meV electrons,” *Phys. Rev.* 84, p. 634-637, 1951.


15.7 MeV e- scattering off Au 9.66 um, Geant4 9.4ref08
probability per square degree
θ (degree)
Data
Urban93
WVI-SS
Urban95
mscGS
Single Scat
(1 - Geant4/Data) (%)
θ (rad)


15.7 MeV e- scattering off Au 19.3 um, Geant4 9.4ref08
probability per square degree
θ (degree)
Data
Urban93
WVI-SS
Urban95
mscGS
Single Scat
(1 - Geant4/Data) (%)
θ (rad)

Em5.Hanson test 9.4ref07 (M.Maire)



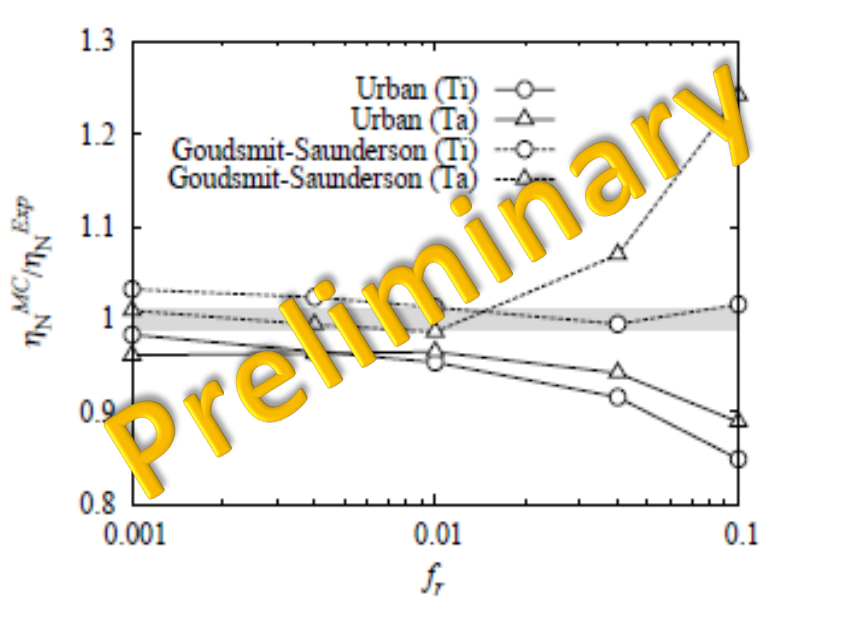
- MonteCarlo/Data method is one of the most effective
- Another point of view on the same data
- We need to keep different approaches
- This test support Urban95 model to be default

Electron backscattering scattering

G. J. Lochwood et al., “Calorimetric measurement of electron energy deposition in extended media - theory vs experiment,” *Technical Report SAND79-0414 UC-34a*, 1979.

G. J. Lockwood, G. H. Miller, J. A. Halbleib, Simultaneous integral measurement of electron energy and charge albedos, IEEE Trans. Nucl. Sci. 22 (1975) 2537–2542.

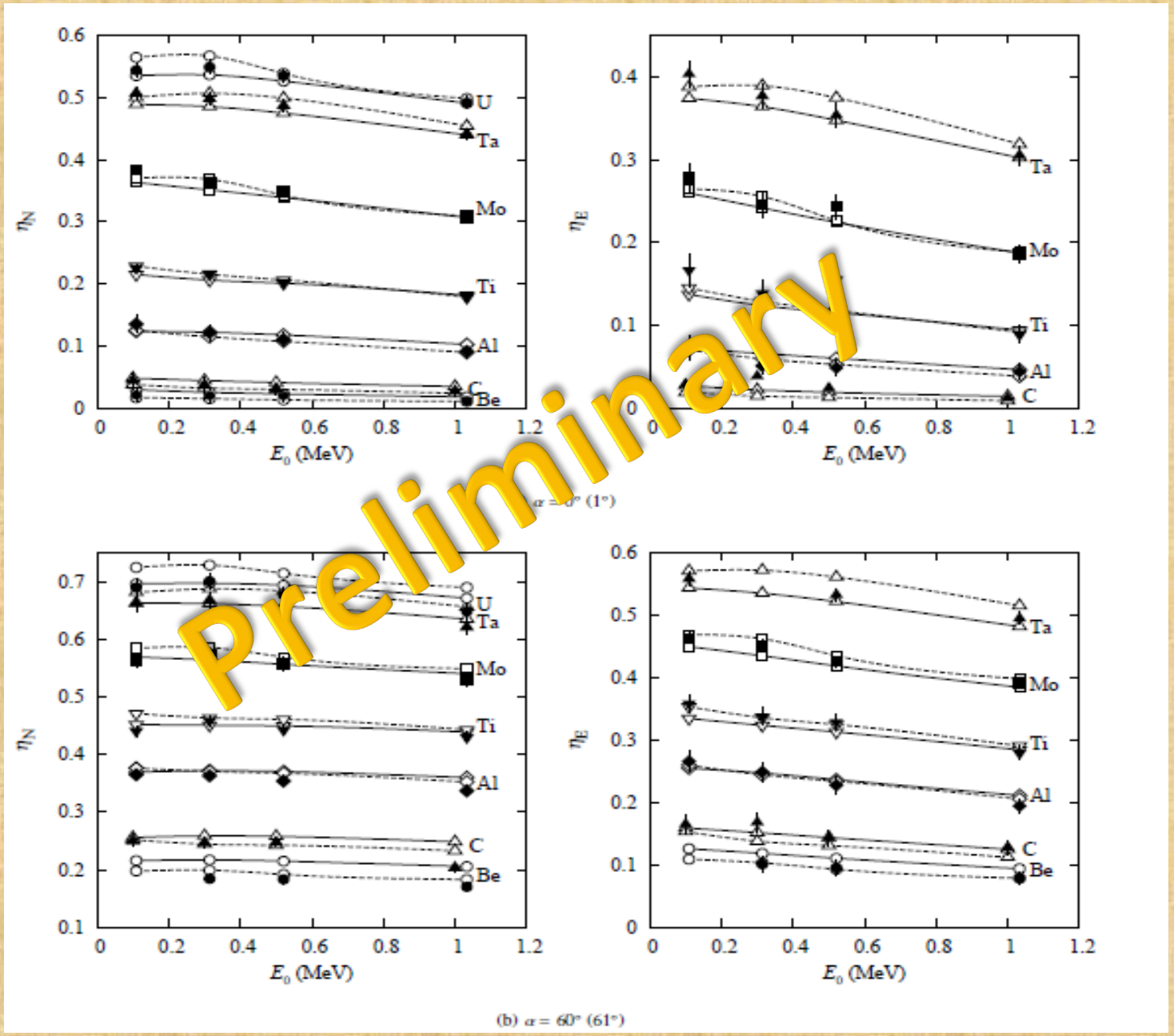
New benchmark on electron backscattering using Sandia data (A.Lechner)



Optimization of f_r (FactorRange) parameter: default value 0.04 should be reduced to 0.01 to provide stable simulation at low energy

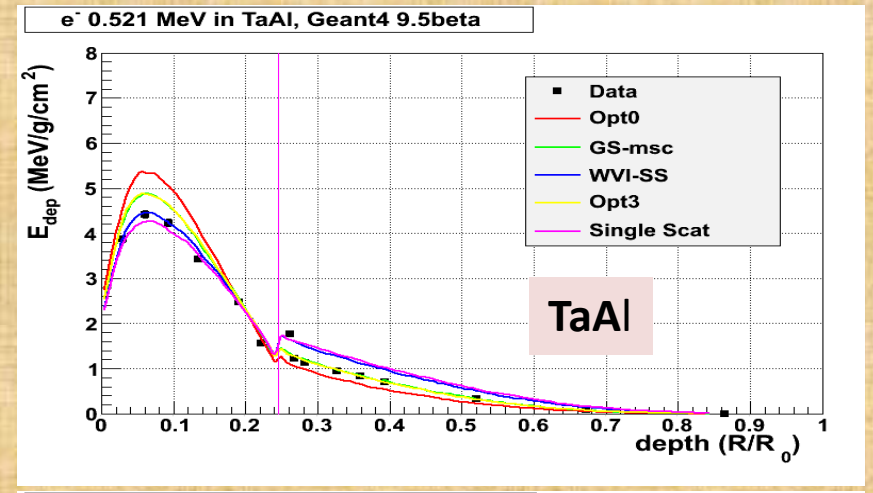
- New benchmark have been developed using Sandia data on backscattering and energy deposition in semi-infinite media
- Electron energy 0.1 – 1 MeV
- Beam angles from 0 and 75 degrees
- Be, C, Al, Ti, Cu, Mo, Ag, Ta, Au, U

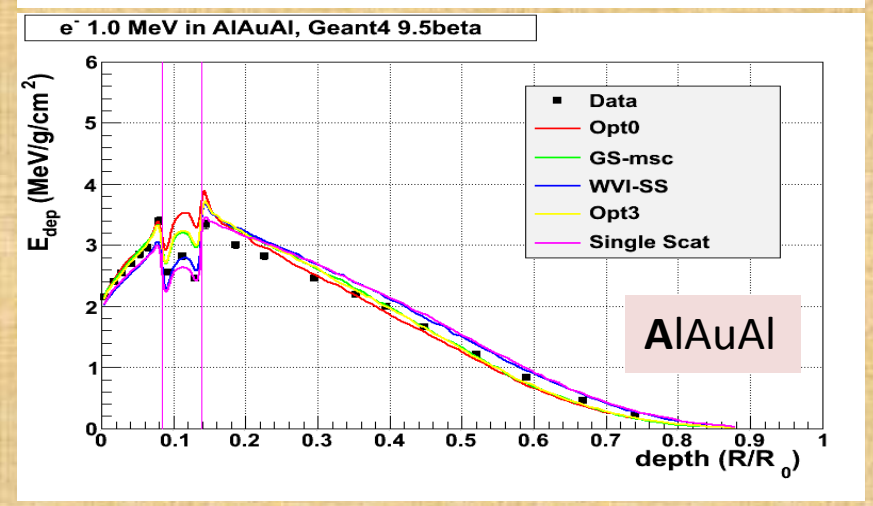
Backscattering as a function of projectile energy (A.Lechner)



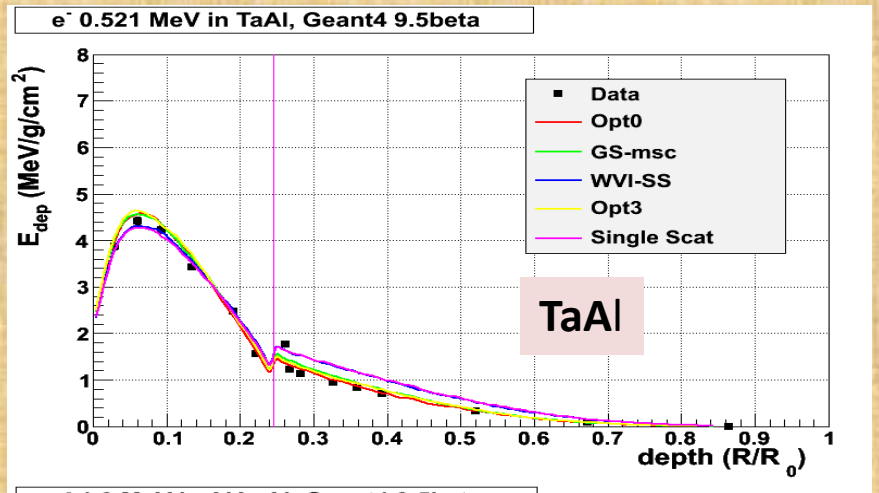
Factor-Range and energy profiles for Sandia data (test37)

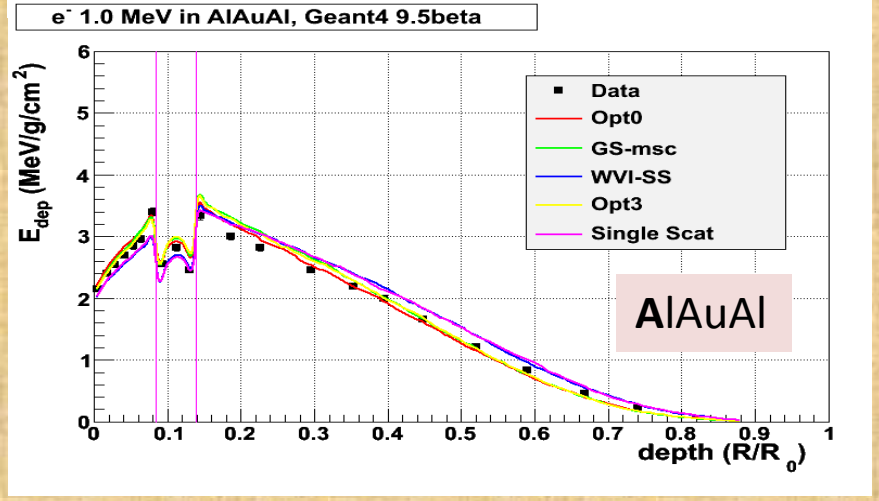
F_R = 0.04 (default)





F_R = 0.01





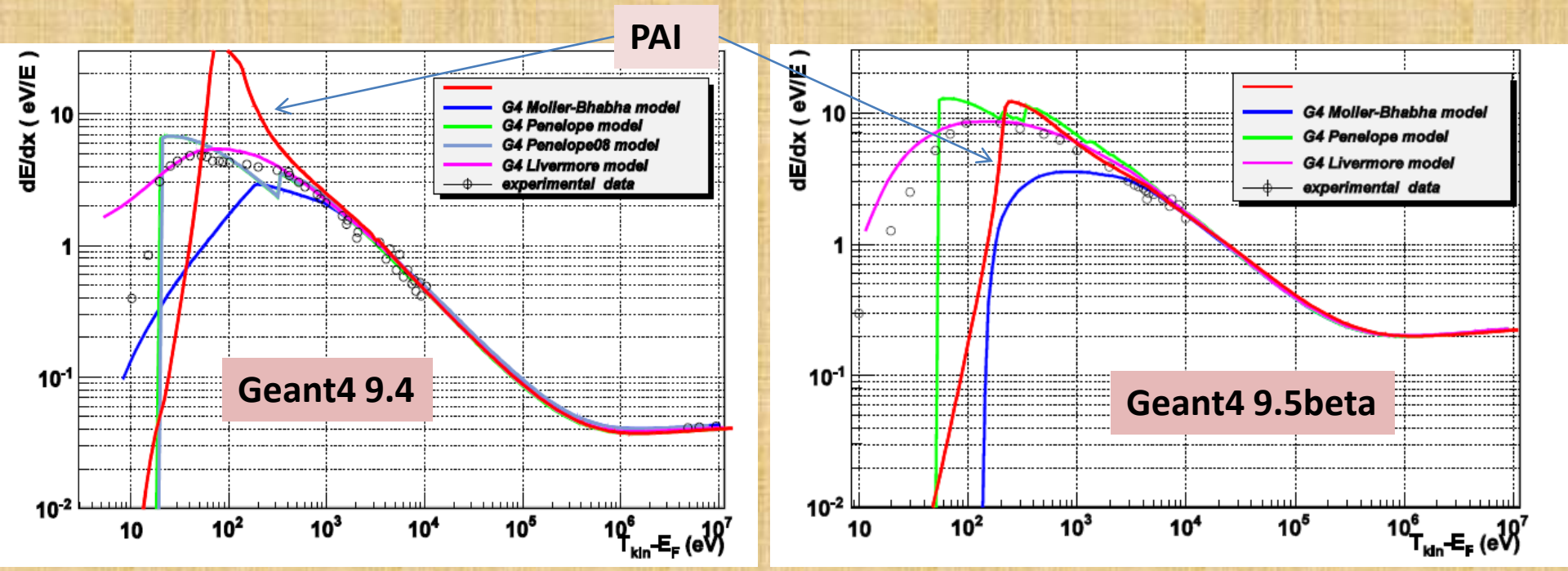
Other benchmarks

electron stopping powers

bremsstrahlung

Effect of Rayleigh scattering

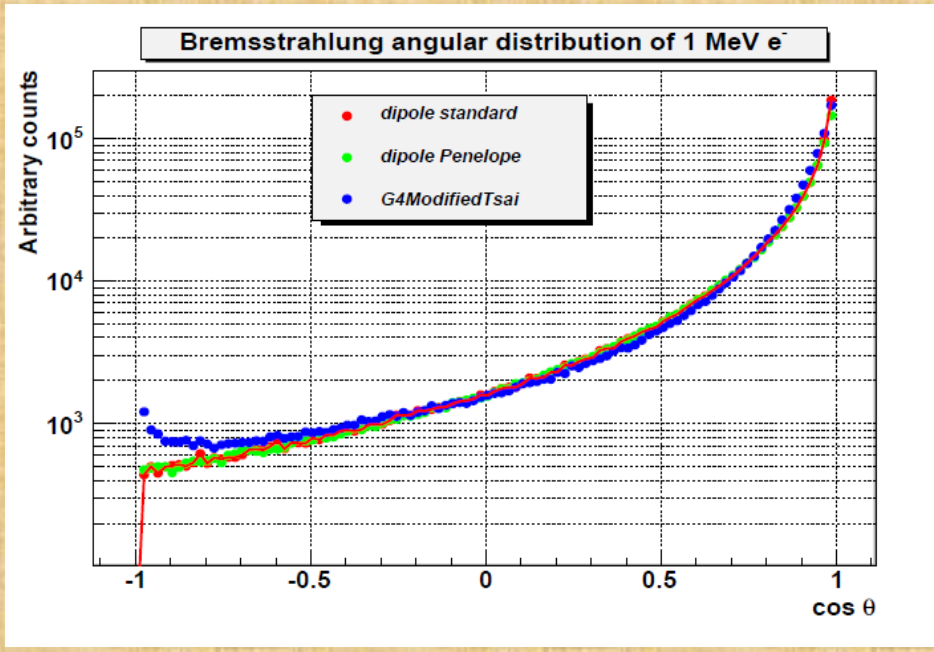
Electron Ionisation in Aluminum (V.Grichine)



- Standard models (Moller-Bhabha and PAI were extended down in energy
- Benchmark results show good agreement between models above 10 keV
- Below 10 keV Livermore model is more precise
- Low limit of the tables can be reduced to 10 eV

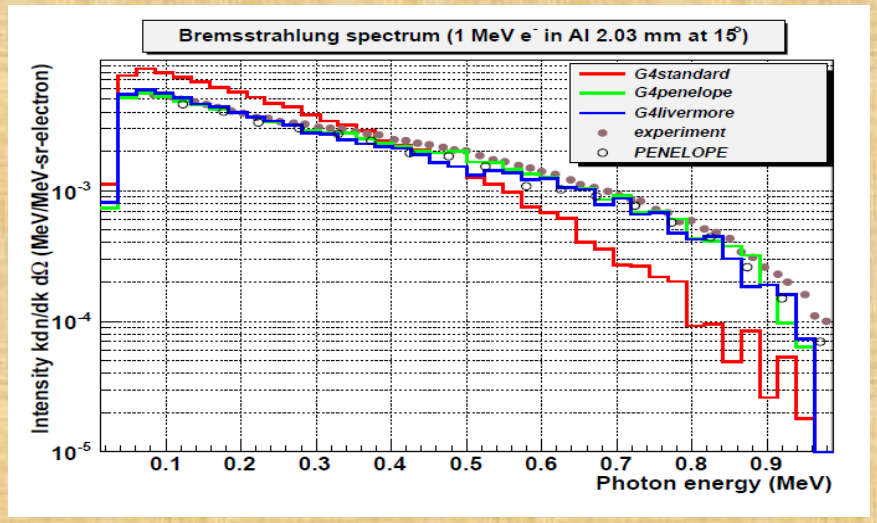
Bremsstrahlung developments and new benchmark (V.Grichine)

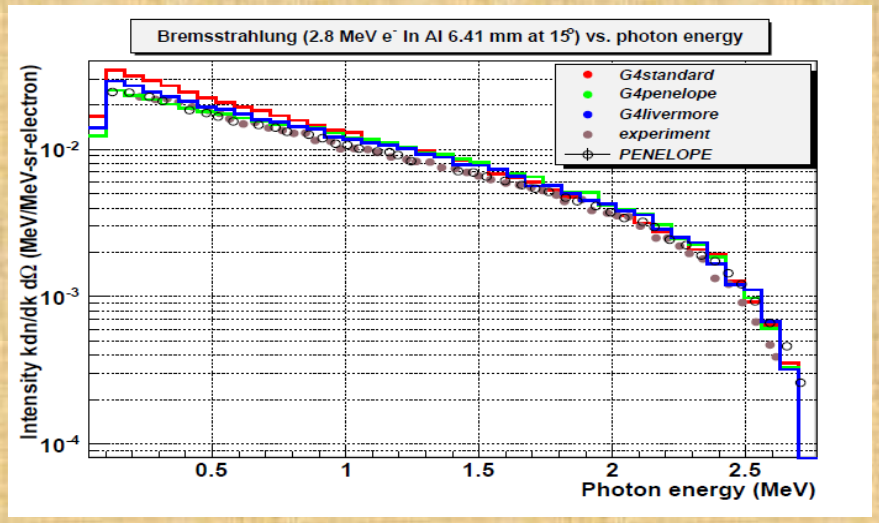
- Three models were benchmarked:
  - Standard
  - Livermore
  - Penelope
- Several angular generators:
  - G4ModifiedTsai
  - G4Generator2BS
  - G4PenelopeBremsstrahlungAngular
  - G4DipBustGenerator

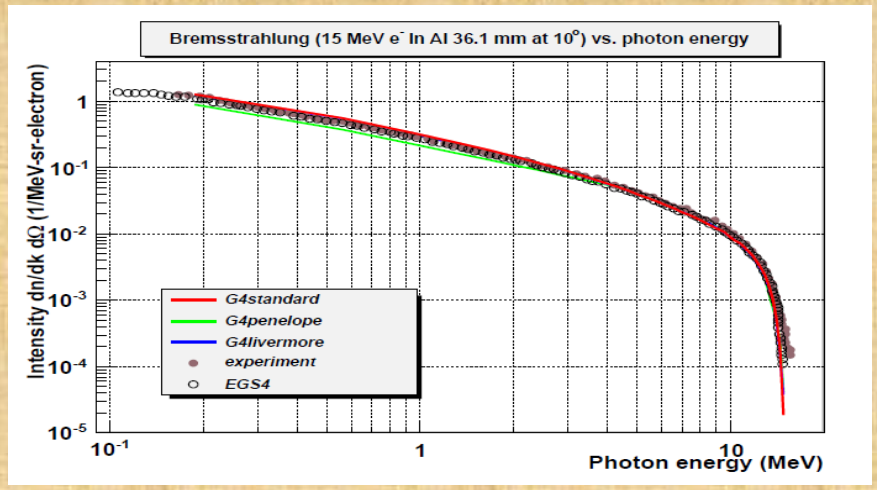


- Angular generators are very similar
- Tsai predicts small backscattering fraction due to scattering off electrons
- Tsai/Urban model is correct theoretically!

Bremsstrahlung energy spectra (V.Grichine)

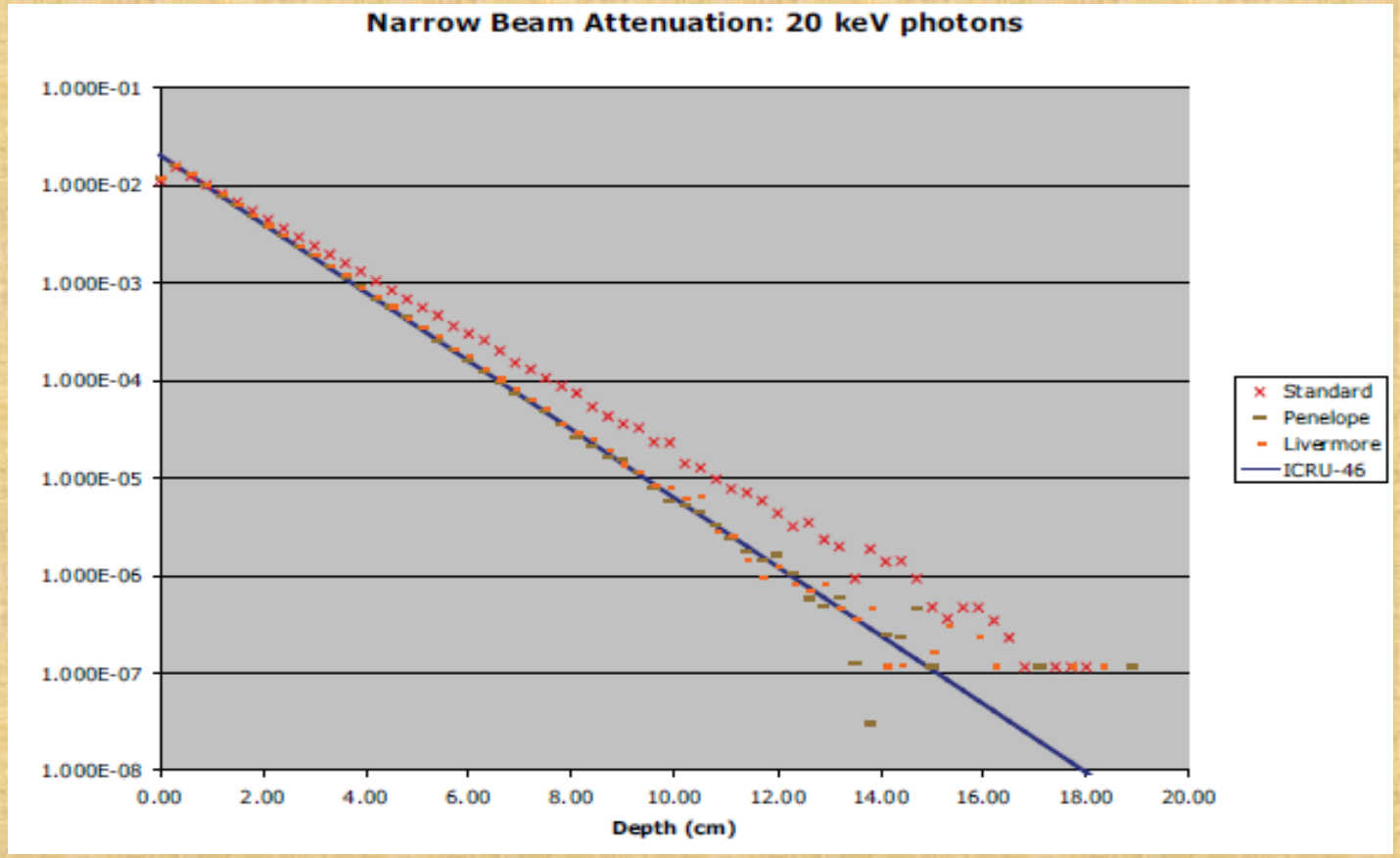






- Statistics 10^8 per run
- At 15 MeV Geant4, EGS and data agree each other
- At 1 MeV Standard model far from the data and Penelope predictions
- Below 10 MeV Standard model should be substituted

Gamma Absorption Geant4/EGSnrc 1st Australian Geant4 Workshop



- Rayleigh scattering must be taken into account for keV energy gamma transport

ELSHIELD Project 1D benchmark:

Comparison of different models

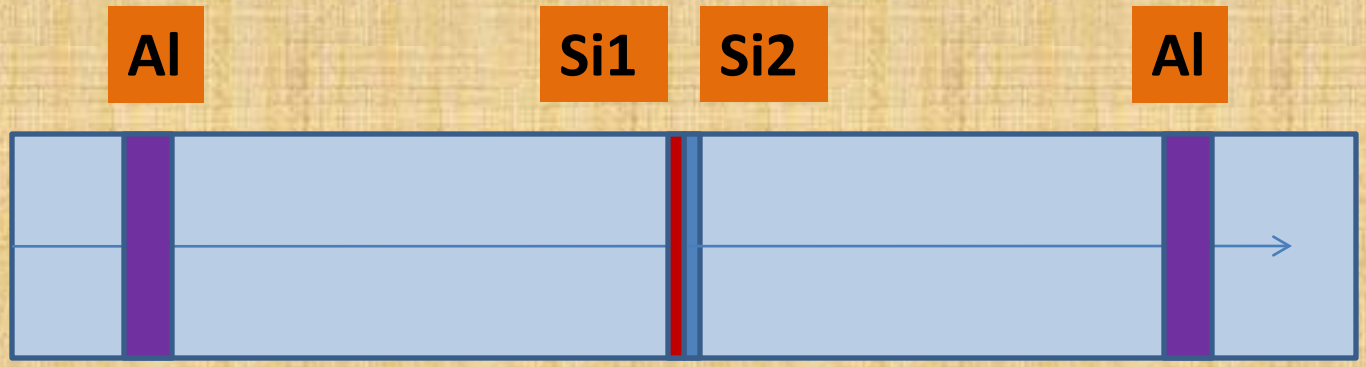
Validation of new models and options

Estimation effects of different absorbers

Estimation of effects of cross section uncertainty

1-D benchmark geometry

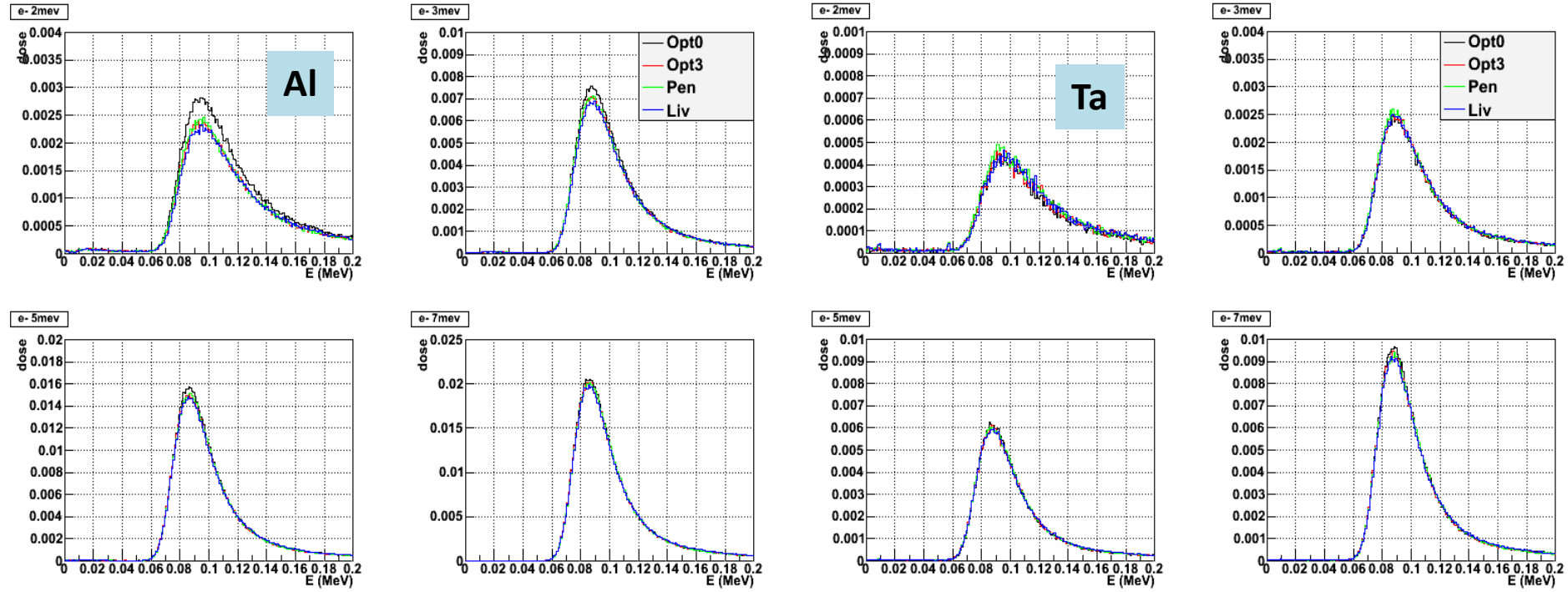
- GRAS analysis modules:
  - Dose analysis in two Si layers 10 um and 300 um
  - Fluencies of gamma and electrons in front of the detector
  - New GRASSiAnalysisModule for dose profile in Si
- 1D and 2D Histograms
- Physics Lists:
  - Opt0 (needed to understand reverse MC precision)
  - Opt3, Livermore, Penelope
  - PIXE option for all



Materials and thicknesses for the 1-D benchmark implemented in GDML files

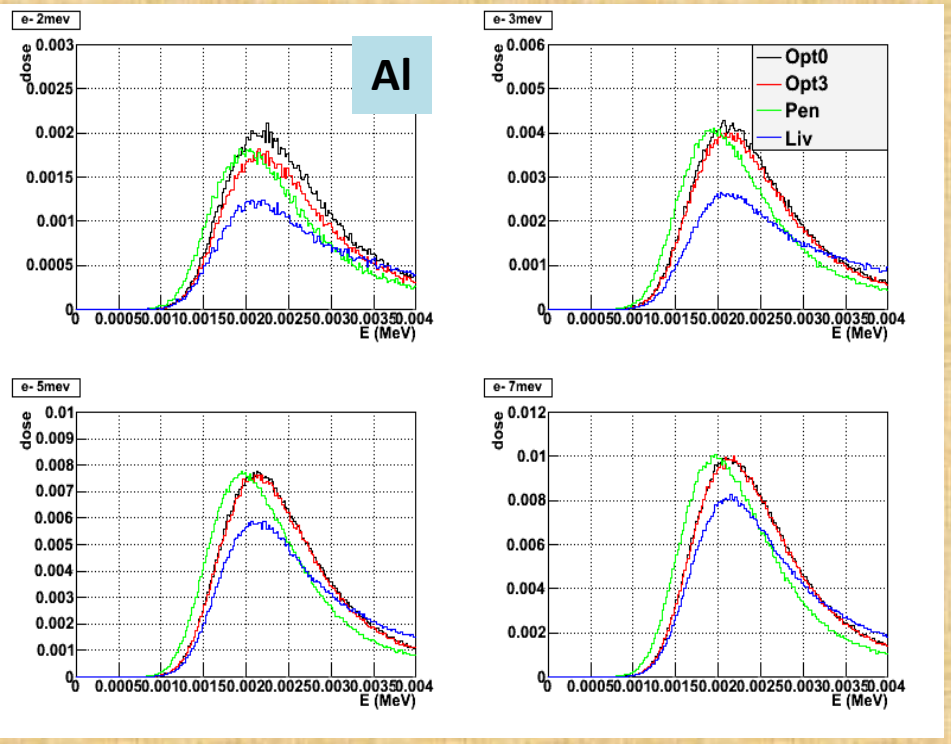
- Sensitive detector 2 volumes of Si
  - 10x10x0.001; cm^3
  - 10x10x0.03 cm^3
- Single absorbers (SHIELDOSE standard)
  - Al 0.5, 1, 2, 3, 5, 10, 20 mm
  - Ta 0.081, 0.162, 0.324, 0.486, 0.81, 1.62, 3.24 mm*Rho(Al)/Rho(Ta)
- Combined absorbers
  - Al, Au, Al 1.79/0.046/ 0.03 mm – total mass 2 mm Al
  - Al, Ta, Al 1.79/0.025/0.03 mm x*Rho(x)/y*Rho(y) = 0.1
  - Al, Ag, Al 1.79/0.029/0.03 mm
- Optional structure
  - Al, Au 1.818/0.0467 mm – total mass 2 mm Al
  - Al, Ta 1.818/0.0254 mm x*Rho(x)/y*Rho(y) = 0.1
  - Al, Ag 1.818/0.02945

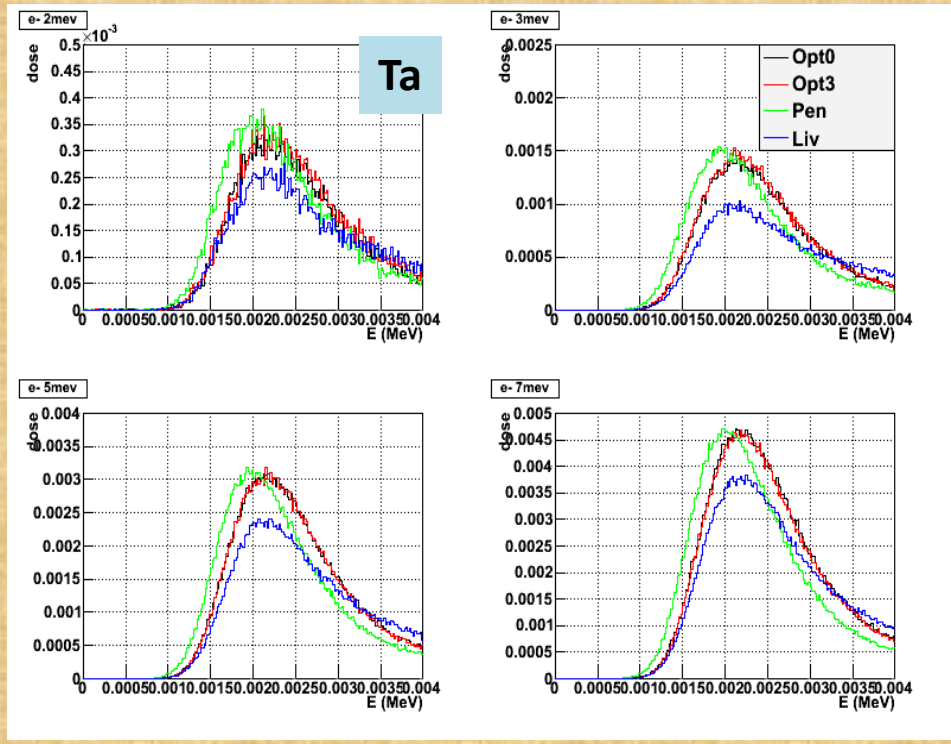
Dose deposition in 300 um Si layer from high energy electron beams and 2 mm Al or Ta shielding



- All Physics Lists well agree, Opt0 is narrower for Aluminum at 2 MeV
- Tantalum reduces dose in 5 times at 2 MeV and in 2.5 times at 5 MeV
- Statistics 10^6 events per plot/Physics List
- Results for 9.5beta

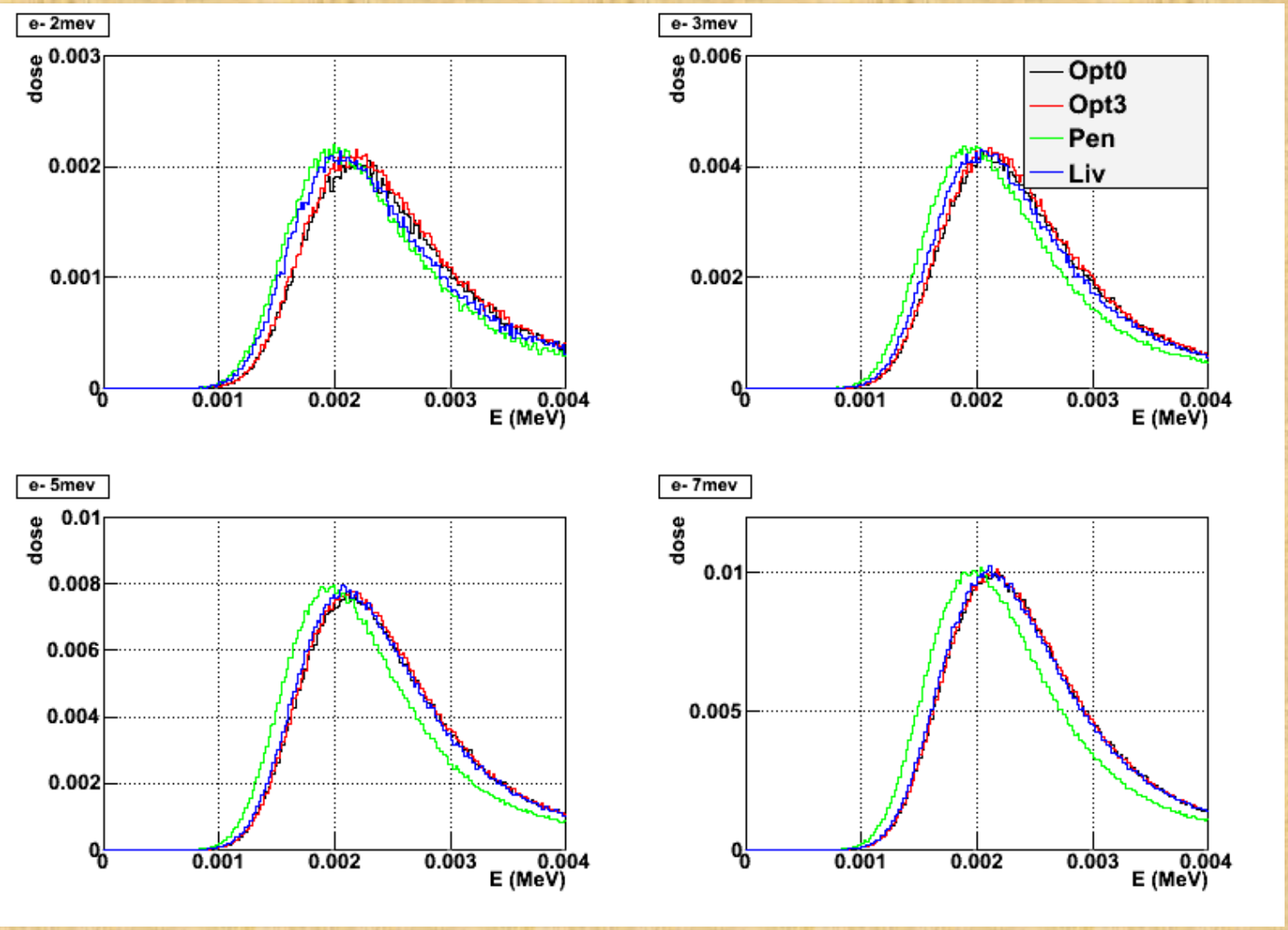
Dose deposition in 10 um Si layer from high energy electron beams and 2 mm Al or Ta shielding





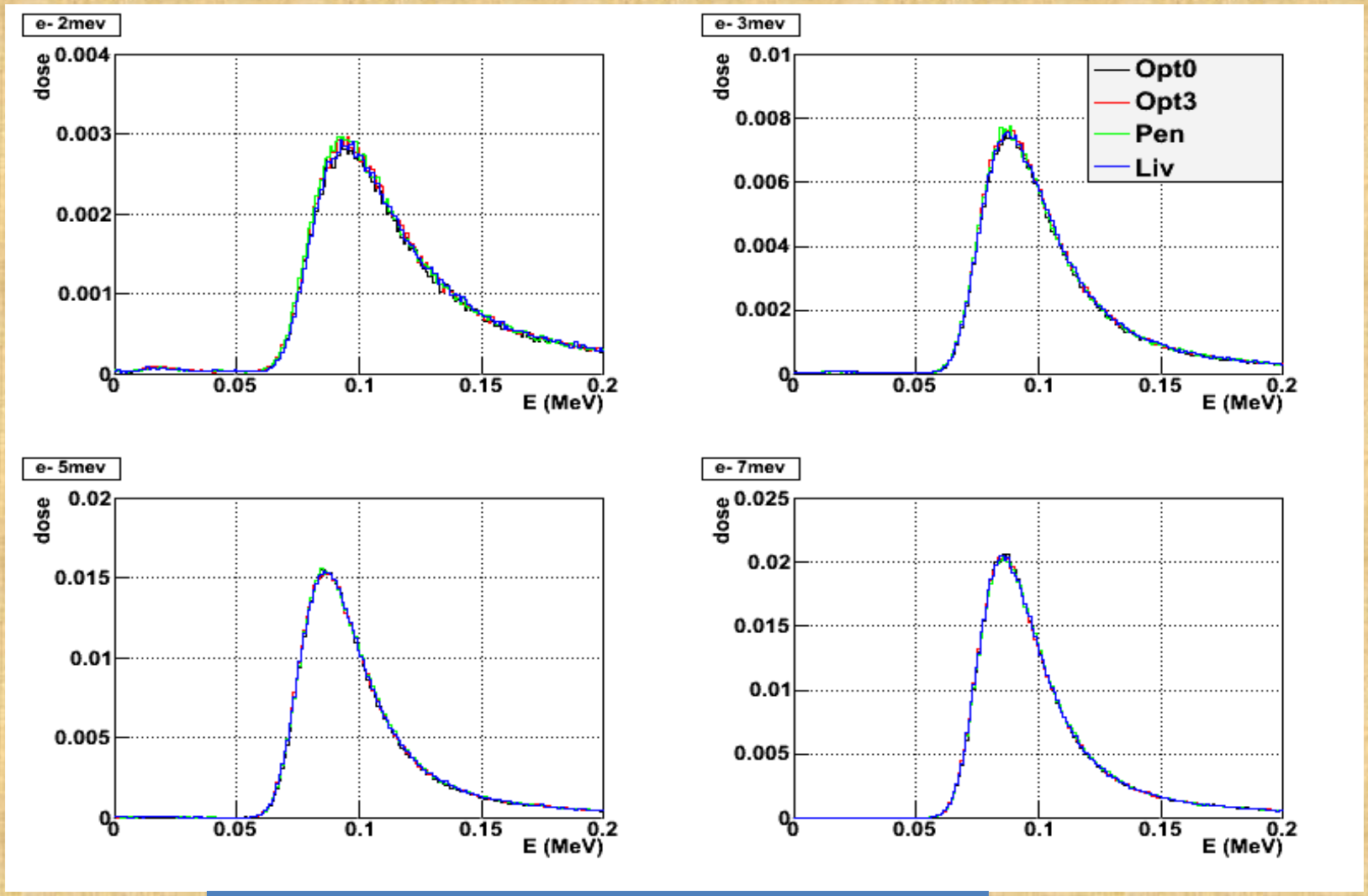
- Livermore predicts significantly wider dose with the same peak position
- Penelope predicts a bit smaller peak position
- Tantalum reduces dose in 6 times at 2 MeV and in 2.5 times at 5 MeV
- Statistics 10^6 events per plot/Physics List
- Results for 9.5beta

Results with Geant4 9.4ref08 10 um Si



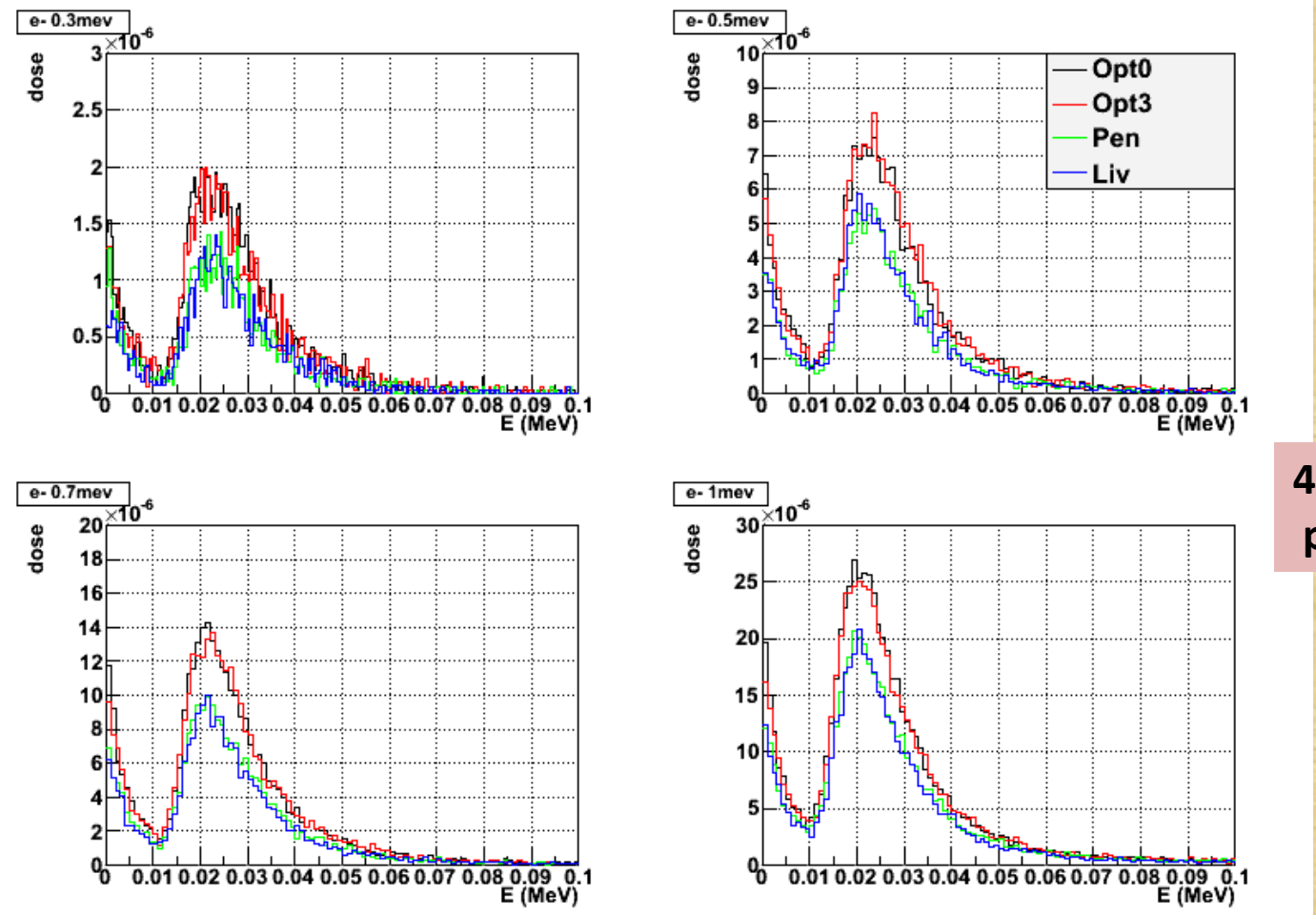
Penelope predicts a bit lower peak position

Results with Geant4 9.4ref08 for 0.3 mm Si



Ideal agreement between models with ref08

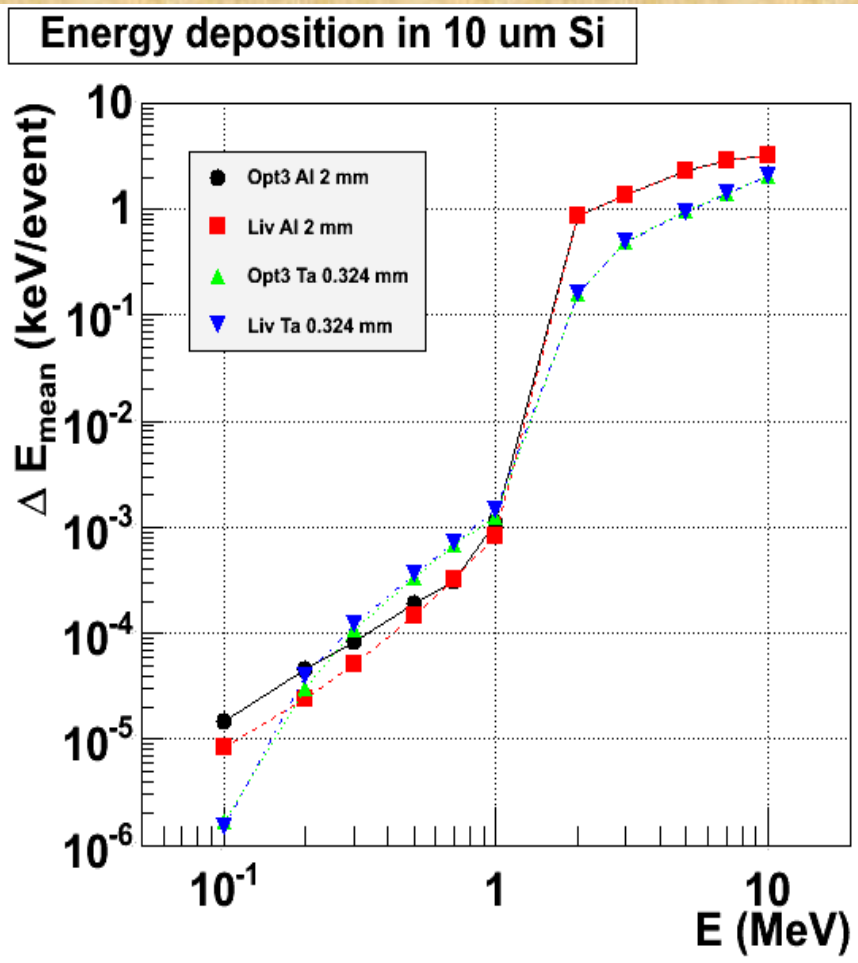
Dose deposition in 300 um Si layer from low energy electron beams and 2 mm Al shielding

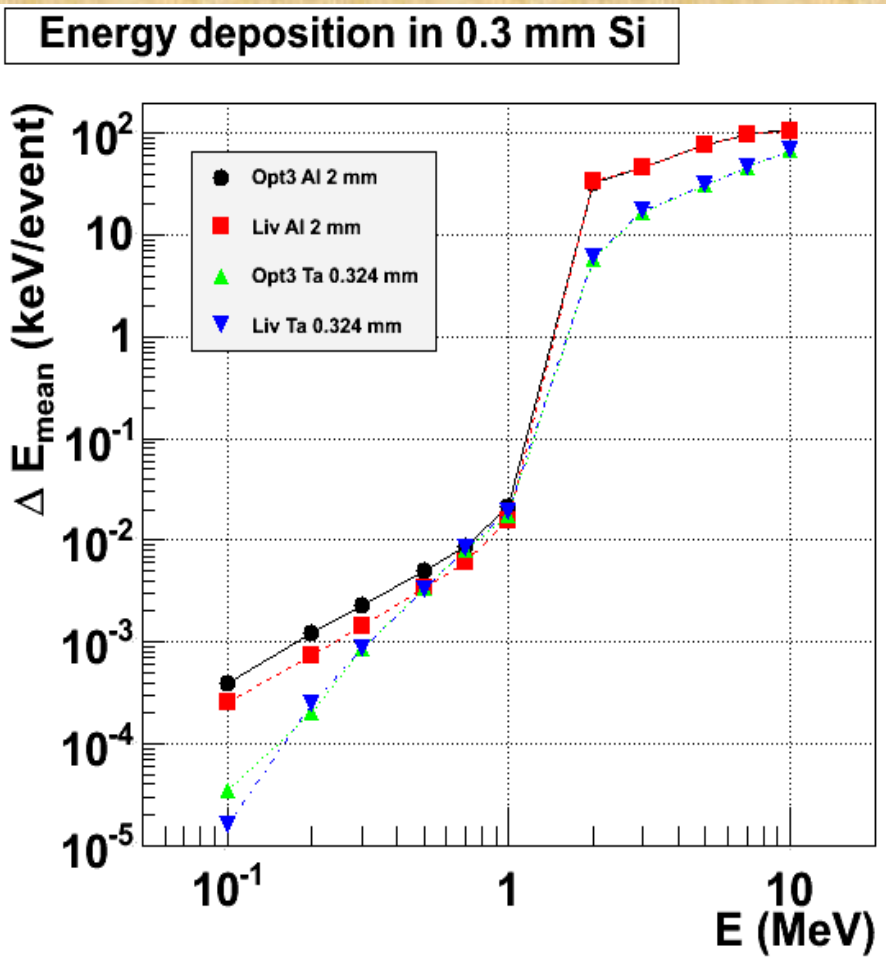


4x10^7 events per run

- Livermore and Penelope dose is lower than Otp0 or Opt3
- More absorttion?
- Statistics 4x10^7 events per plot/Physics List

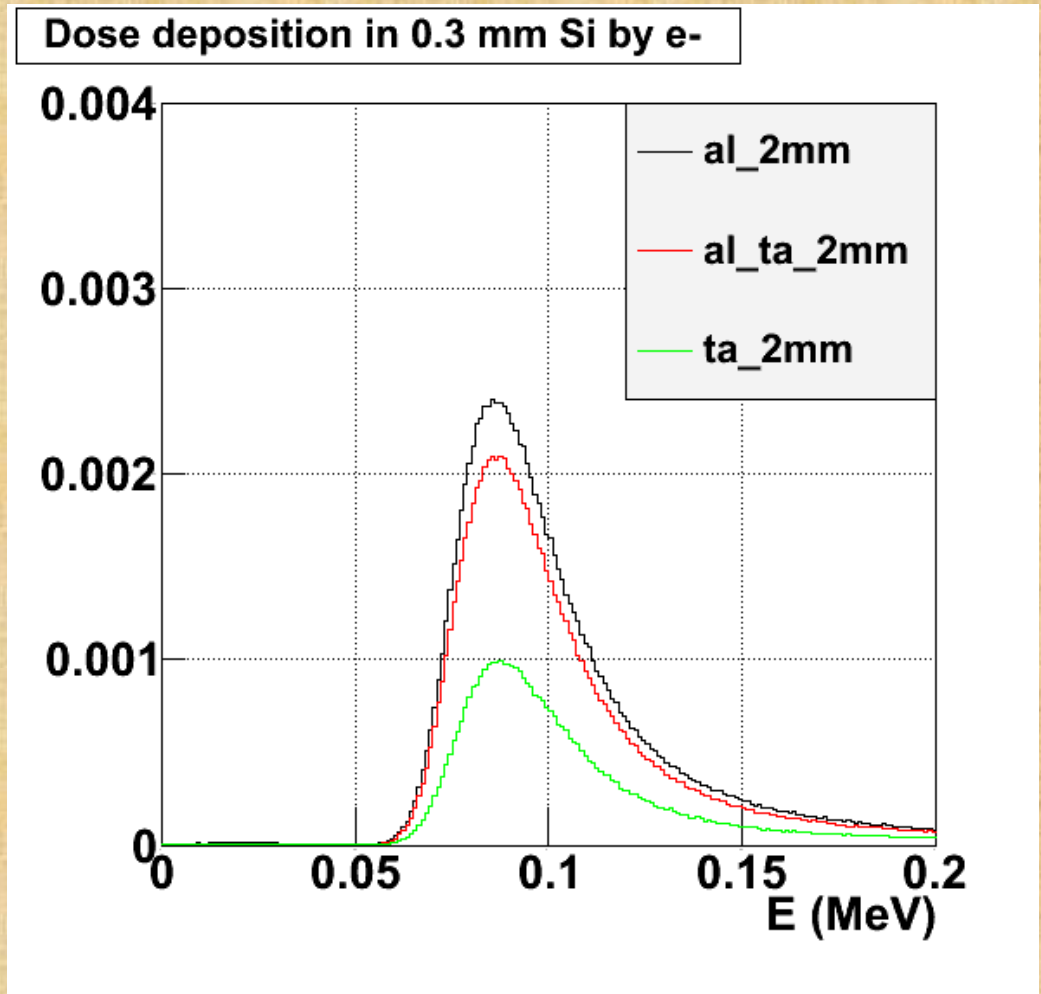
Mean energy deposition as a function of electron energy





Effect of shielding material

- Electron spectrum 1/E in the interval of energy 1 keV – 10 MeV
- Ta layer absorb more e- due to multiple scattering?
- Mass of shielding is the same



Conclusions

- Thanks to ESA funding a significant models development and validation have been carried out
- We confirm that Urban95model should be default
- With ref08 we have achieve more close results for different Physics Lists