VALIDATION OF GAMMA PROCESSES

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Under ESA technology research programm
Support G4AI and University of Bardeuax I

GOALS OF THE WORK

- New tests were created for 4 main gamma processes
  - Tests of all Geant4 models at all energies and elements
  - Cross sections, secondary energy spectra and angular distributions
  - *http://www.cern.ch/antoni/results*
- Creation of new Livermore gamma models
  - Based on G4PhysicsVector data handling
  - Use optimal algorithms of sampling of final state
  - Download data only for elements used in geometry
- Results are collected for g4.9.5.ref07 (August 2012)

RAYLEGH SCATTERING

UNDER ESA TECHNOLOGY RESEARCH PROGRAM

WORK DONE

- Creation of the new test
- Development of new classes G4LivermoreRayleighModel and G4RayleighAngularGenerator classes
  - Transforming cross sections data from old to the new format
  - Parametrization atomic form factors
  - Implementation of some efficient algorithm of sampling of Rayleigh angular distributions
- Validation of the new model versus Penelope, old Livermore and new standard model of V.Grichine

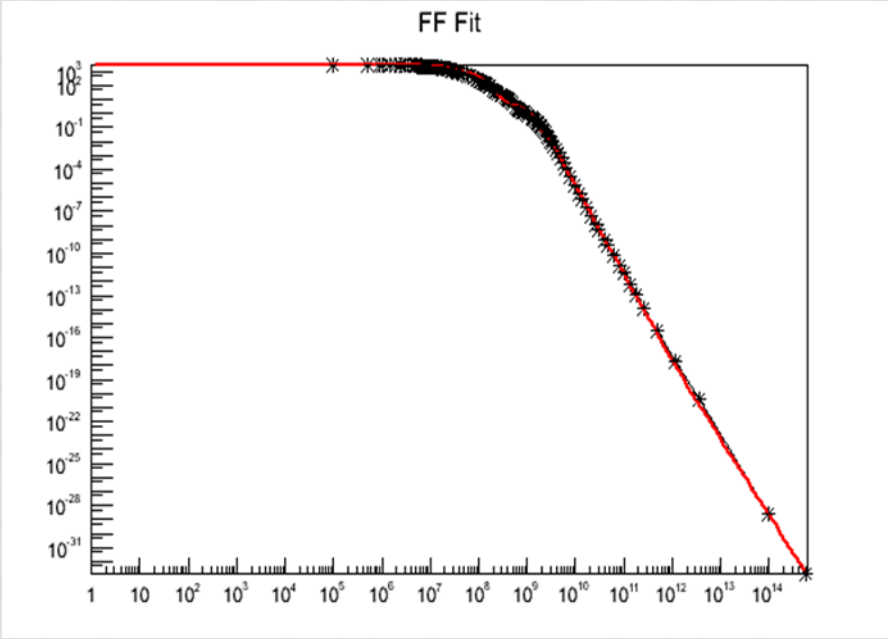
NEW LIVERMORE ANGULAR GENERATOR

- In the old Livermore model atomic form-factors were used in tabulate form, the sampling algorithm was very ineffective.
- In this work the form-factors for all atoms with Z=1 – 100 have been fitted by analytical formula.
- This empirical formula was initially taken from Dermott E. Cullen (Nucl. Instrum. Meth. Phys. Res. B 101, (4), p.499-510)

FIT

- The modified empirical formula for form factors:

$$FF(E, cos)^2 = \sum_{i=0}^{3} \frac{A_i}{(1 + B_i x^2)^{N_i}}$$

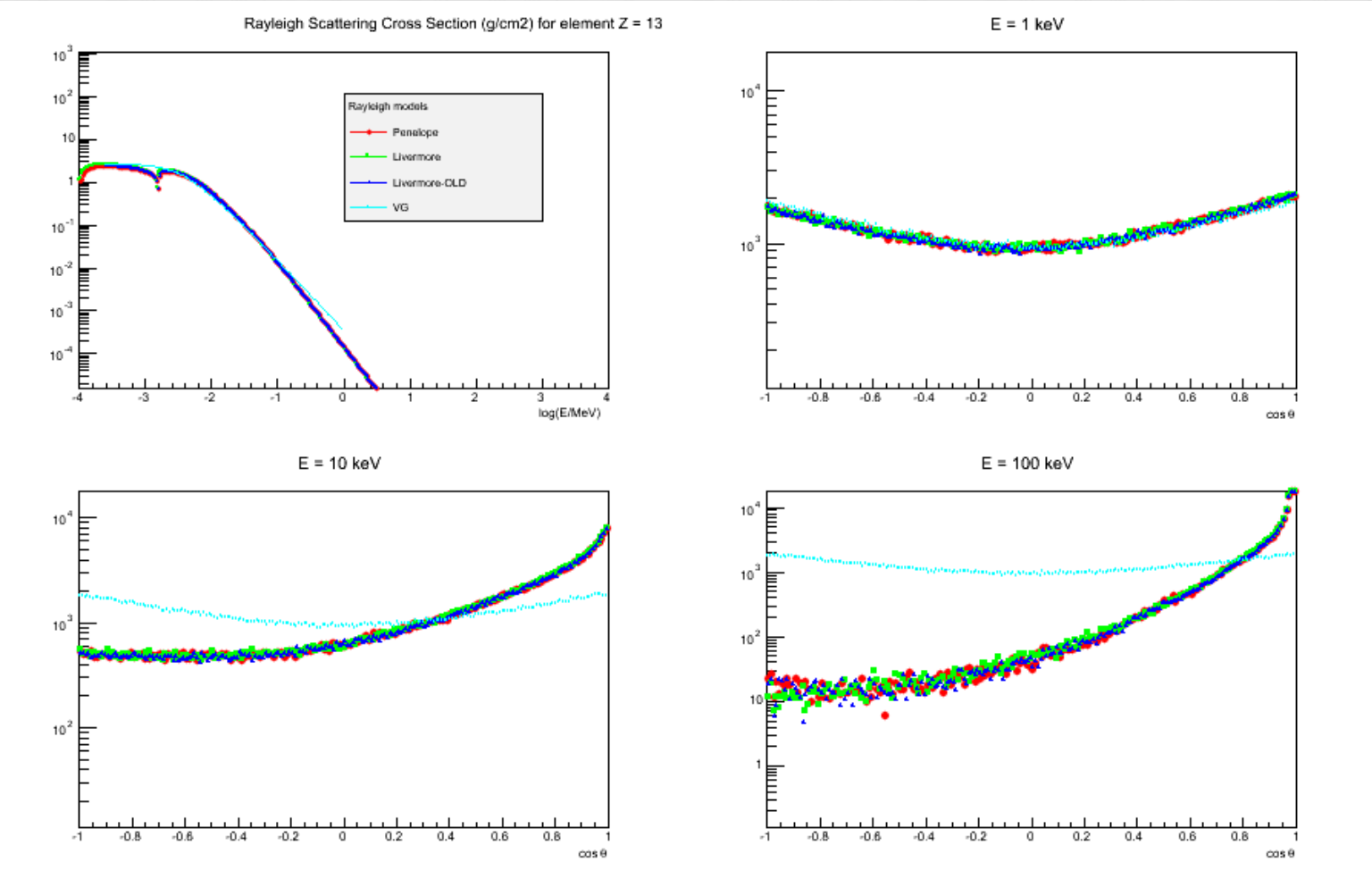


MODELS AVAILABLE

- G4PenelopeRayleighModel
- G4LivermoreRayleighModel
- G4LivermoreRayleighModelOLD
- G4XRayRayleighModel

New test Rayleigh has been created in verification repository (CERN SVN)

COMPARISON RAYLEIGH MODELS 1, 10, 100 KEV GAMMA IN ALUMINUM



CPU COMPARISON (PB, 250 KEV, 20000 EVENTS)

Model	CPU (s)
Penelope	0.03
Livermore	0.03
Livermore-OLD	6.48
V.Grishine	0.01

- Conclusions:
  - New Livermore model provides identical results with Penelope and old Livermore models
  - Old Livermore model is extremely slow
  - V.Grichine model is under development

GAMMA CONVERSION

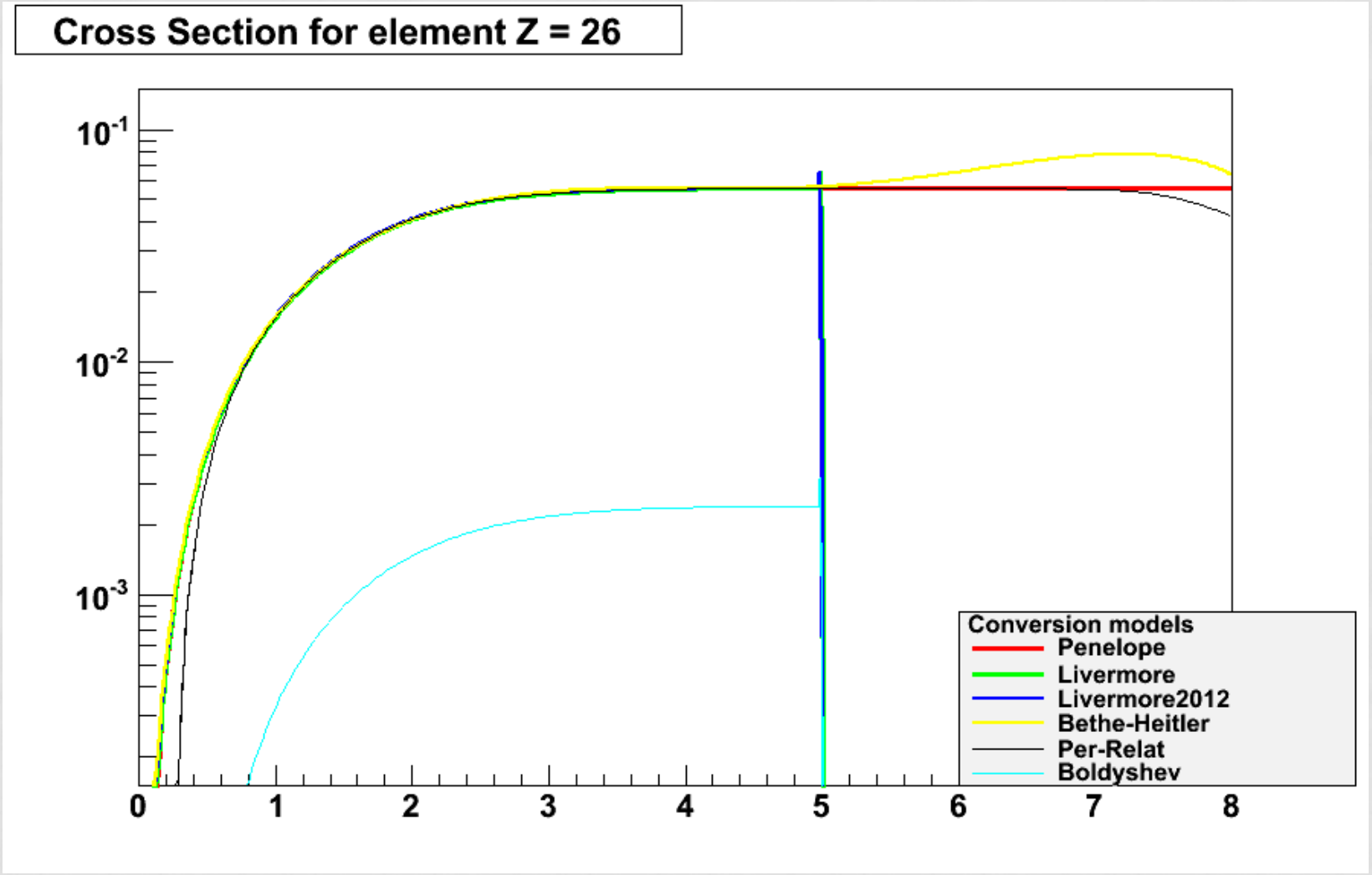
UNDER ESA TECHNOLOGY RESEARCH PROGRAMM

MODELS AVAILABLE

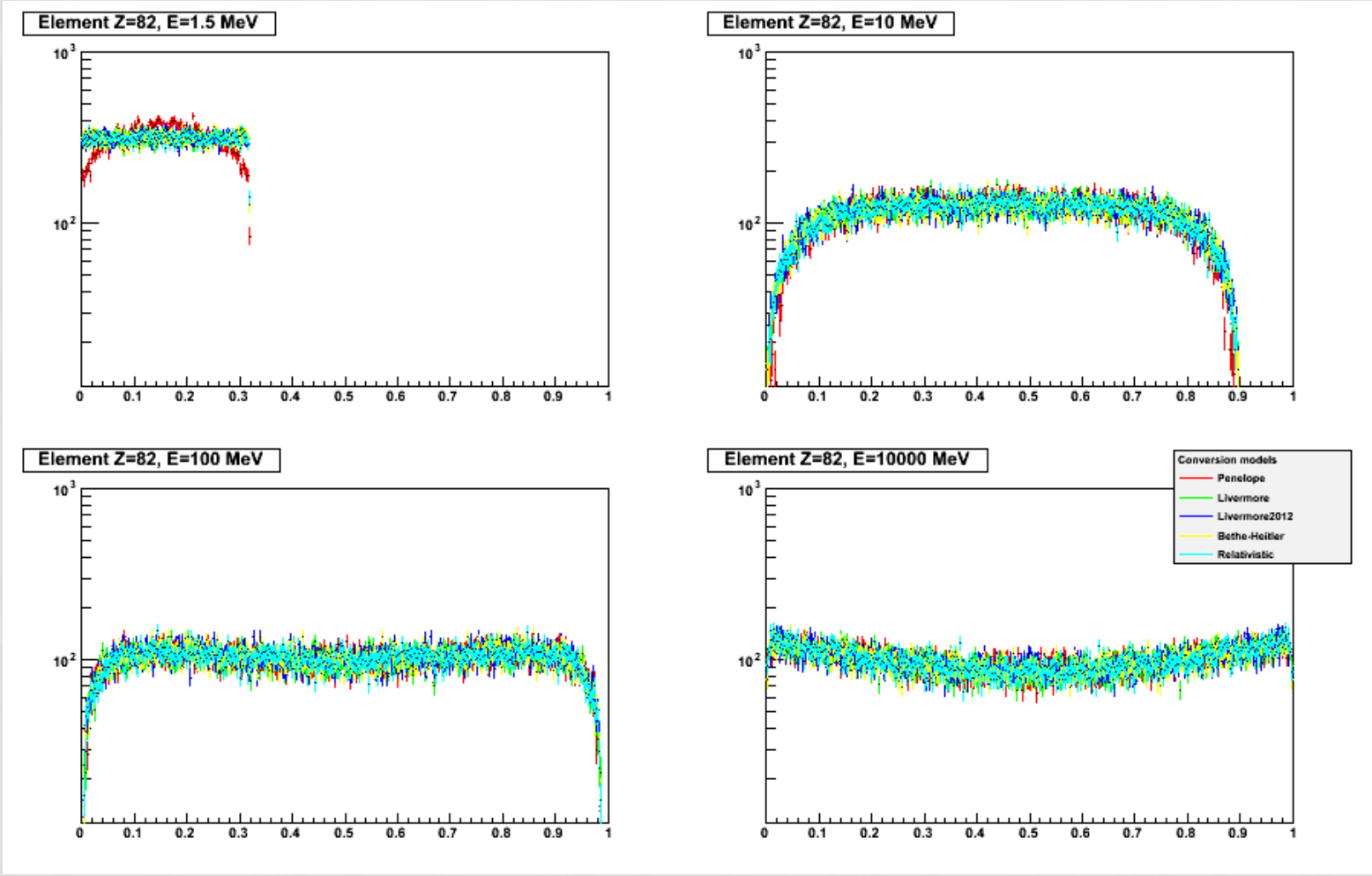
- G4PenelopeGammaConversionModel
- G4LivermoreGammaConversionModel
- G4LivermoreGammaConversionModelOLD
- G4BoldyshevTripletModel (scattering off electrons)
- G4BetheHeitlerModel
- G4PairProductionRelModel

New test Conversion has been created in verification repository (CERN SVN)

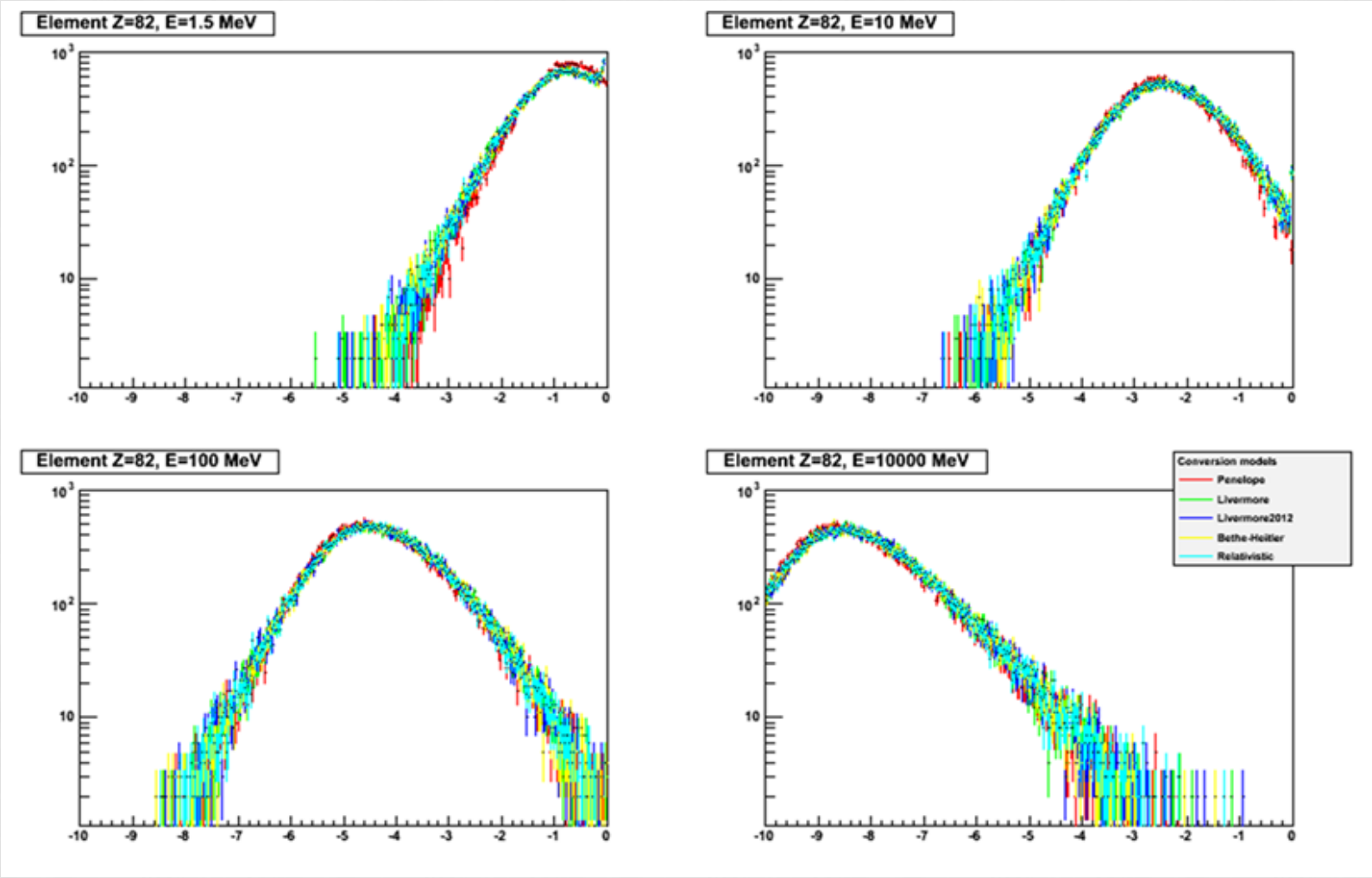
COMPARISON CROSS SECTIONS



ENERGY DISTRIBUTION OF OUTGOING ELECTRONS, PB (1.5, 10, 100, 10^5 MEV)



ANGLES DISTRIBUTION OF OUTGOING ELECTRONS, PB (1.5, 10, 100, 10^5 MEV)



CPU COMPARISON (PB, 100 MEV, 20000 EVENTS)

Model	CPU (s)
Penelope	0.04
Livermore	0.02
Livermore-OLD	0.02
Bethe-Heitler	0.02
Pre-relativistic	0.02

- **Conclusions:**
  - Standard model fail above 100 GeV
  - Relativistic model should be used above 100 GeV
  - Below 100 GeV all models provide identical results with similar CPU performance
  - Penelope model has different energy distribution at threshold from all other models

PHOTOEFFECT

UNDER ESA TECHNOLOGY RESEARCH PROGRAMM

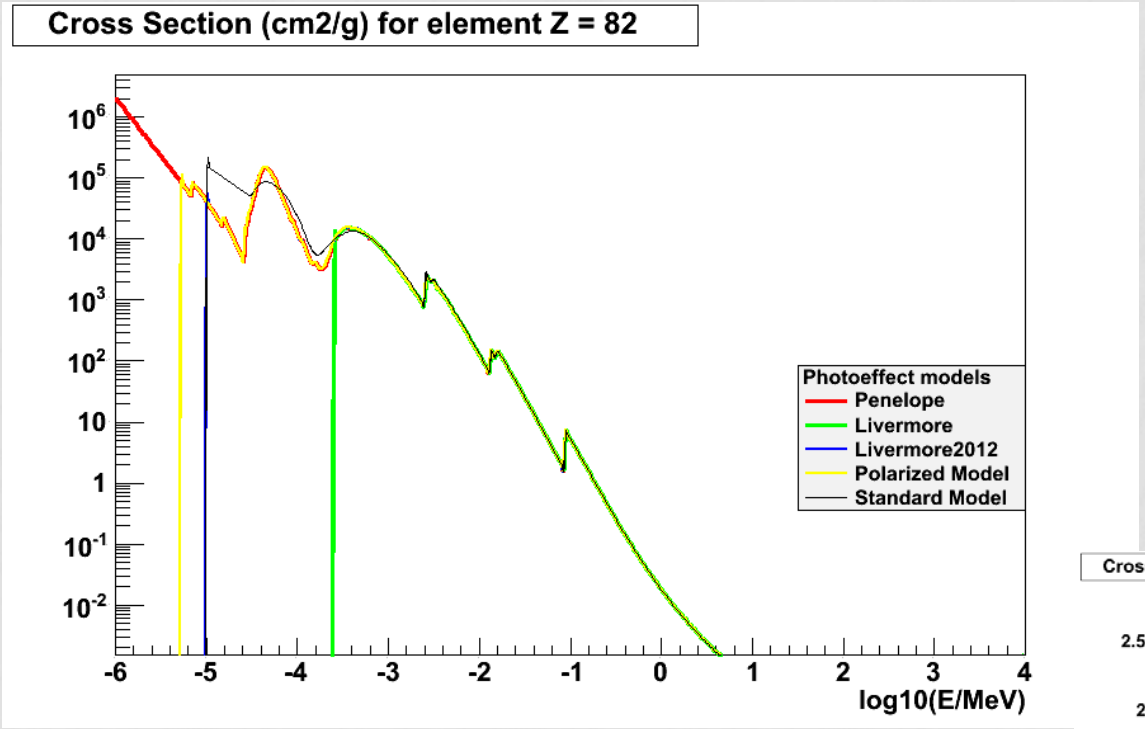
MODELS AND TESTS AVAILABLE

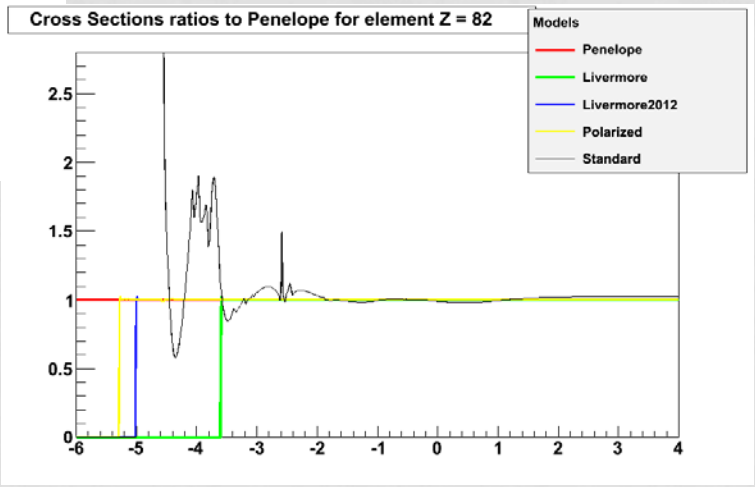
- G4LivermorePhotoElectricModel
- G4Livermore2012PhotoElectricModel
- G4PenelopePhotoElectricModel
- G4PEEffectFluoModel

- G4LivermorePolarizedPhotoElectricModel had some problems and for today it is not included in validation.

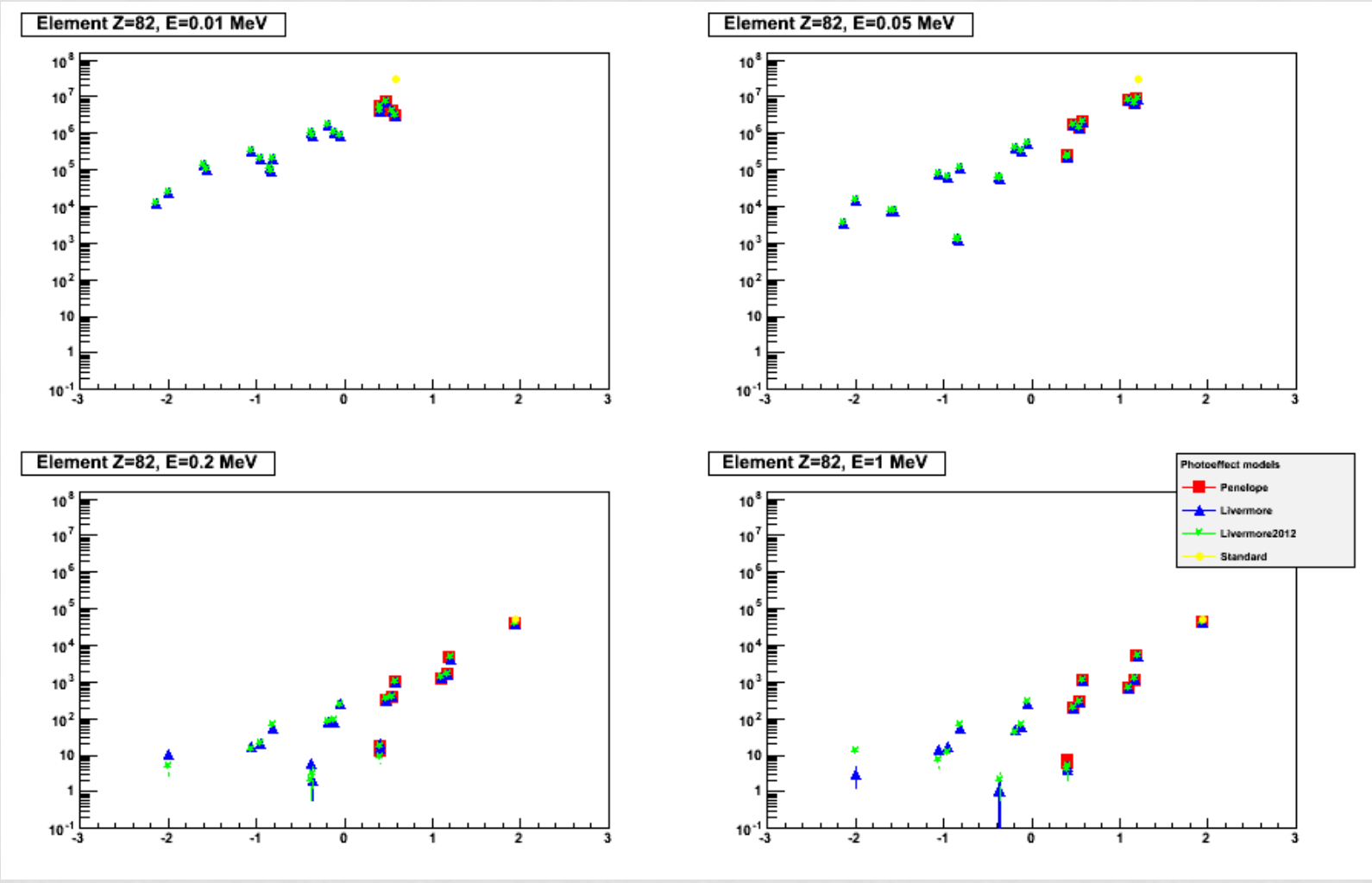
New test Photoeffect has been created in verification repository (CERN SVN)

COMPARISON CROSS SECTIONS

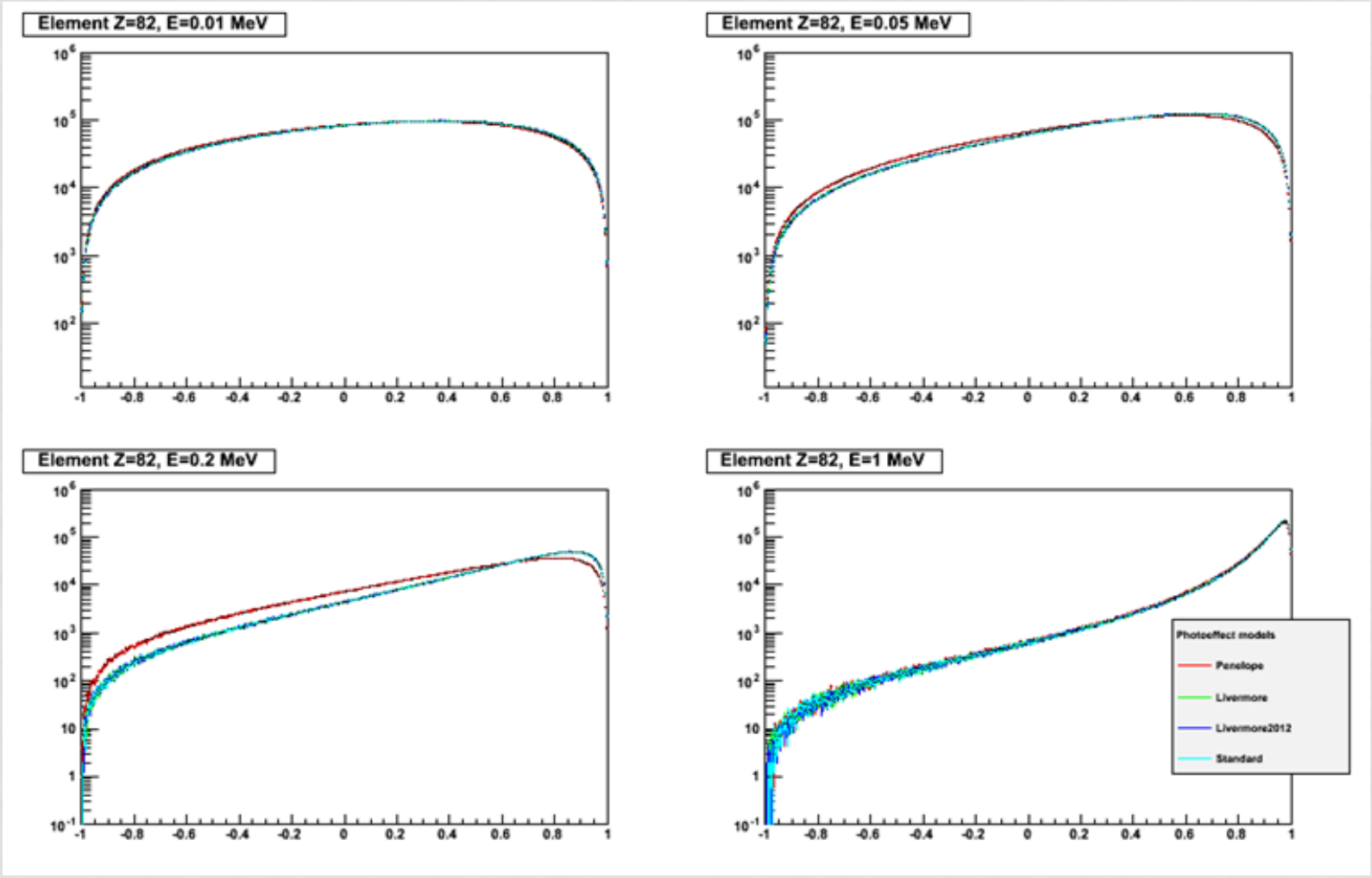




ENERGY DISTRIBUTION OF OUTGOING ELECTRONS , PB (10, 50, 200, 1000 KEV)



ANGLE DISTRIBUTION OF OUTGOING ELECTRONS, PB (10, 50, 200, 1000 KEV)



CPU COMPARISON (PB, 1 MEV, 50000 EVENTS)

Model	CPU (s)
Penelope	0.01
Livermore	0.36
Livermore-OLD	0.37
Standard Model	0.04

- **Conclusions:**
  - Above 1 keV all cross sections for all elements are identical
  - Angular distributions are identical
  - Standard models provide approximate cross sections below 1 keV
  - Standard model generate only nearest level (basically K-shell)
  - OLD Livermore has artifitial break at 250 keV
  - Livermore models are very CPU non-effective, new model should be updated to overcome this problem
  - Penelope is the fastest but it is generating only K-, L-, M-shells

COMPTON EFFECT

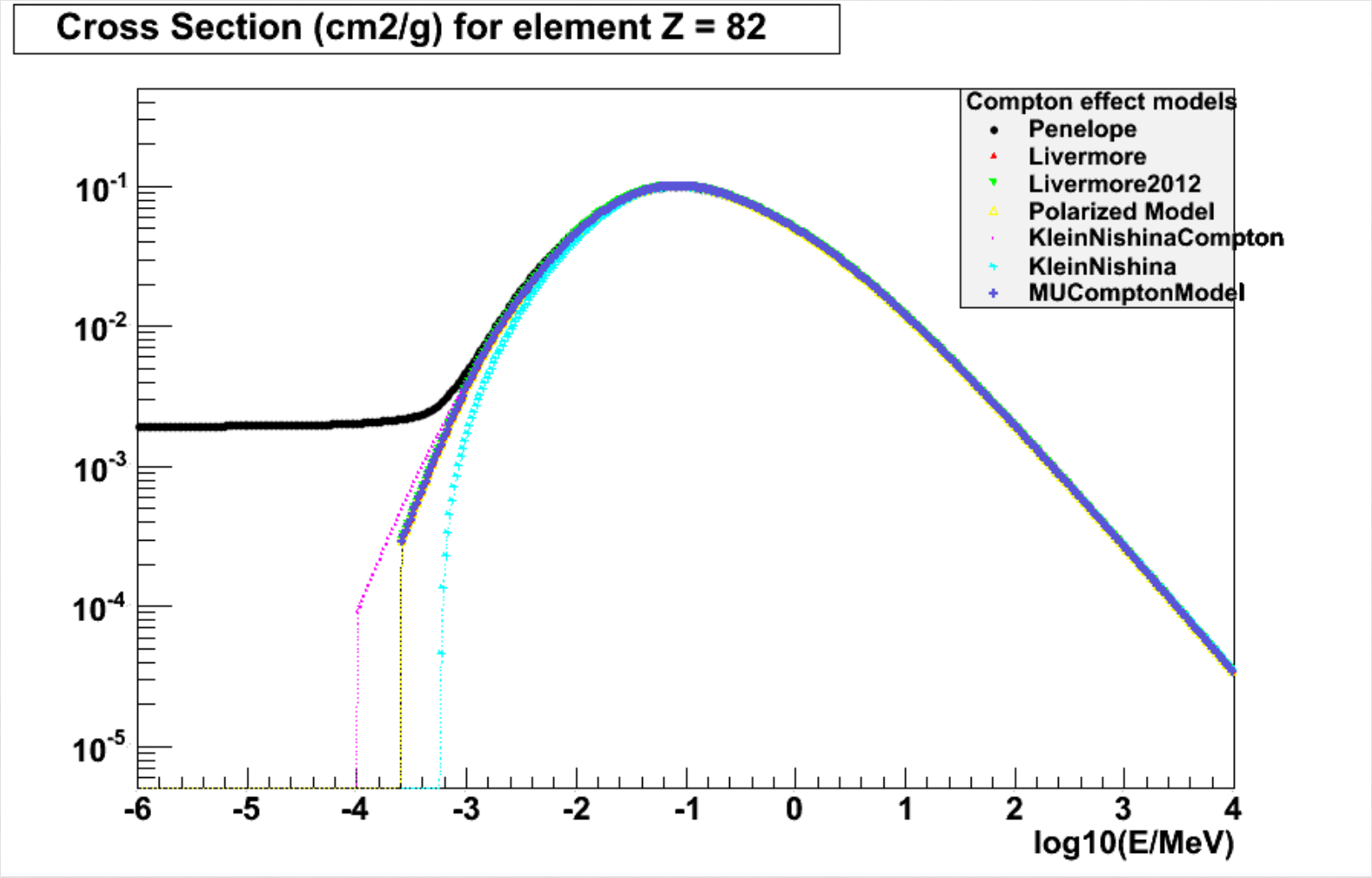
UNDER ESA TECHNOLOGY RESEARCH PROGRAMM

MODELS AND TESTS AVAILABLE

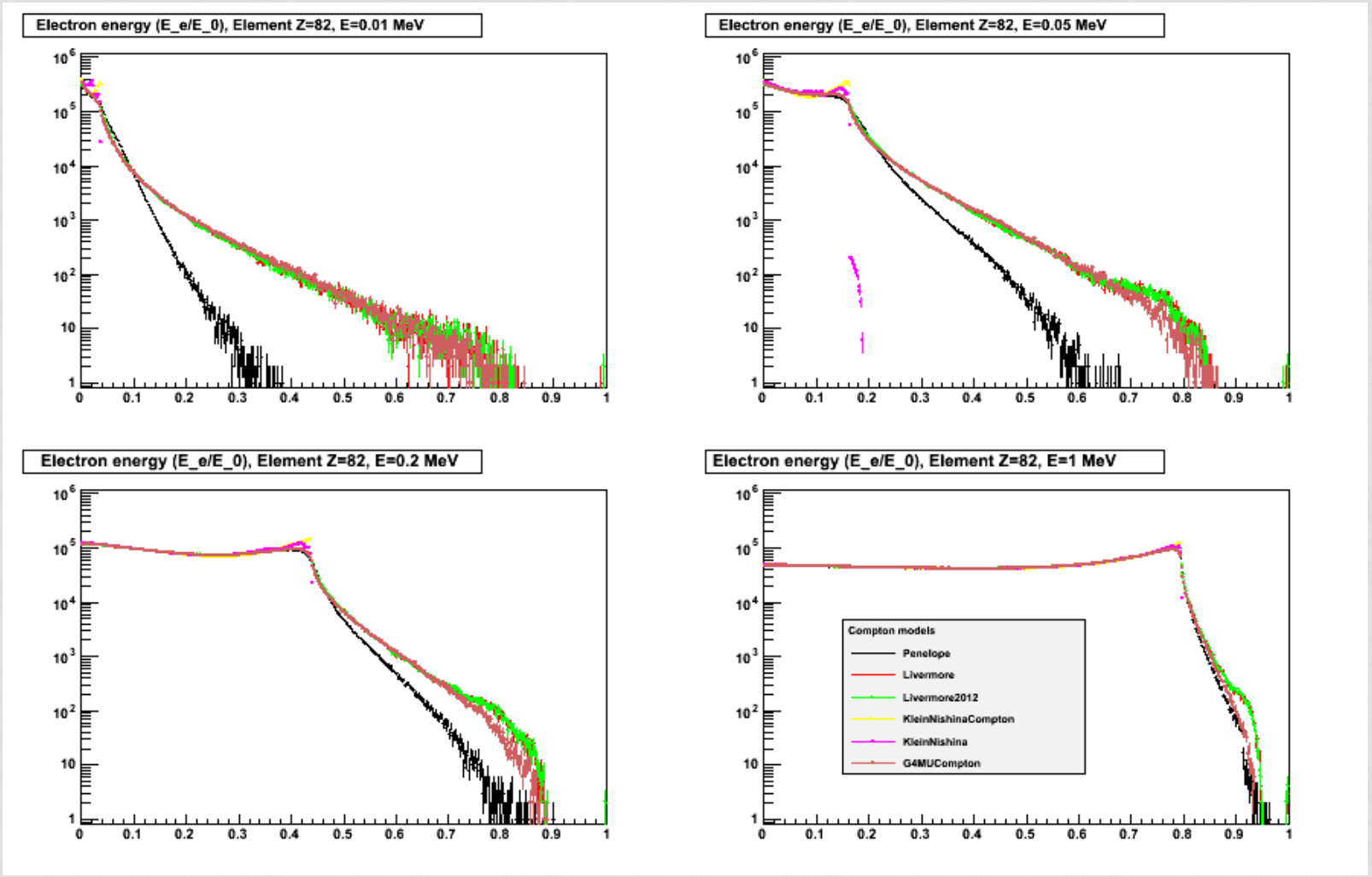
- G4KleinNishinaCompton
- G4KleinNishinaModel
- G4MUComptonModel
- G4LivermoreComptonModel
- G4LivermorePolarizedComptonModel
- G4PenelopeComptonModel

New test ComptonM has been created in verification repository (CERN SVN)

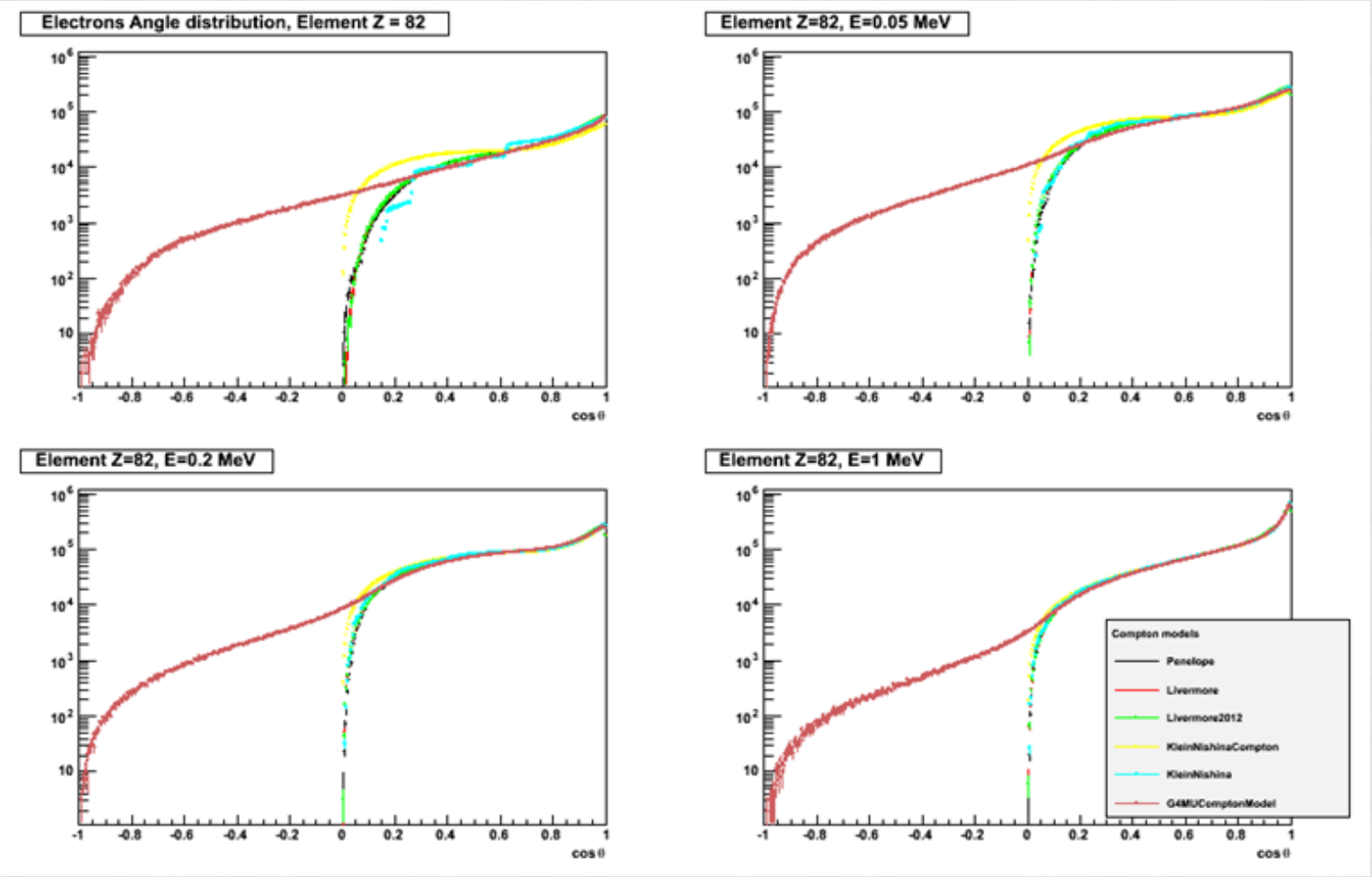
COMPARISON CROSS SECTIONS



ENERGY DISTRIBUTION OF OUTGOING ELECTRONS, PB (10, 50, 200, 1000 KEV)



ANGLE DISTRIBUTION OF OUTGOING ELECTRONS, PB (10, 50, 200, 1000 KEV)



CPU COMPARISON (PB, 1 MEV, 20000 EVENTS)

Model	CPU (s)
Livermore	0.04
Livermore 2012	0.04
Penelope	0.08
KleinNishinaCompton	0.01
KleinNishinaModel	0.03
MUComptonModel	0.05

- **Conclusions:**
  - Models have similar cross sections above 10 keV
  - Below 10 keV there is significant difference between models
  - Angular and energy distributions show different behaviors
  - Performance of models are compatible
  - KleinNishinaModel requires fixes
  - MUComptonModel has advance description of electron angular distribition