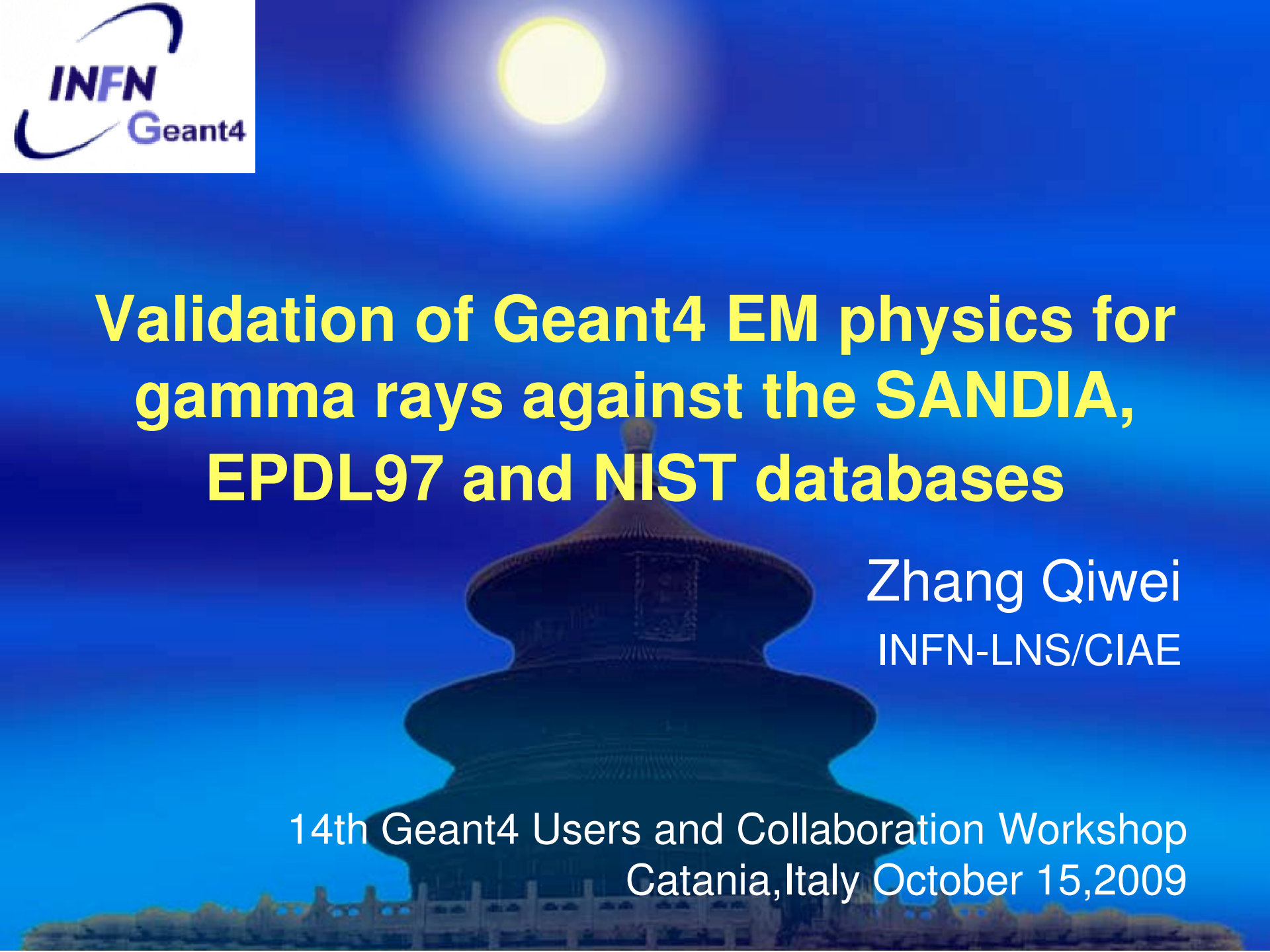


Validation of Geant4 EM physics for gamma rays against the SANDIA, EPDL97 and NIST databases

Zhang Qiwei
INFN-LNS/CIAE

14th Geant4 Users and Collaboration Workshop
Catania,Italy October 15,2009

Outline

- Verification before of validation
  a) Verification for migrated processes (migrated vs non migrated) for Livermore & Penelope
  b) Verification for migrated processes: comparison with Standard physics processes
- Identification of data libraries for validation

  SANDIA EPDL97 NIST
- Validation of the Geant4 photon processes with respect to the data libraries

Migration of low energy EM processes

- From version 9.2 of Geant4, the low energy EM processes and models (Livermore & Penelope) have been migrated to standard EM software design
- A physical process can be simulated according to several models

G4PhotoElectricEffect
- G4PhotoElectricEffect (standard default)
- G4LivermorePhotoElectricModel
- G4PenelopePhotoElectricModel

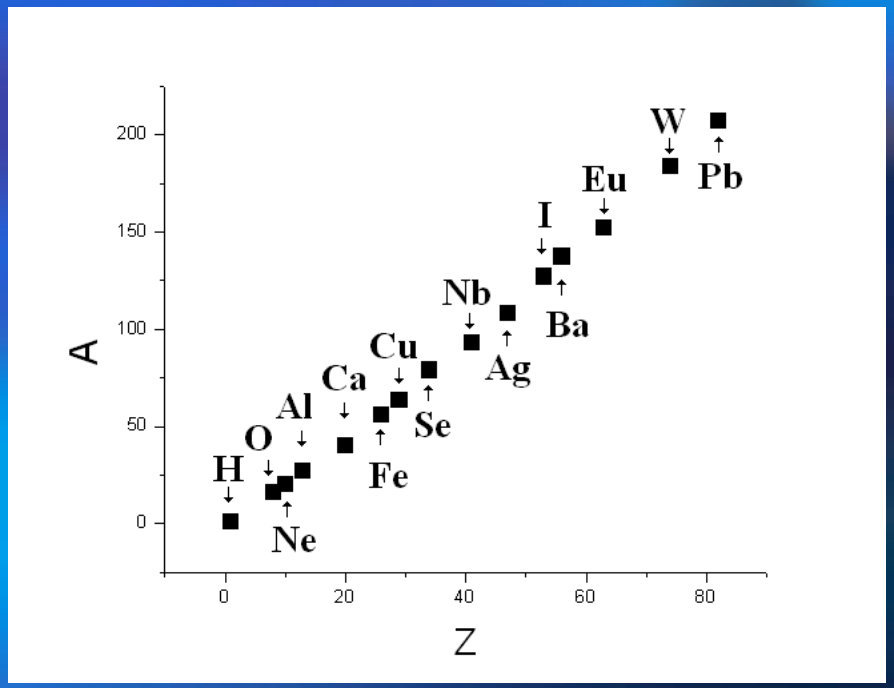
- models can be alternative and/or complementary on certain energy ranges

- Photon processes:
  - Photoelectric effect
  - Compton scattering
  - Gamma conversion

    (pair production +triplet production)
  - Rayleigh scattering
- Material:

elements (15) ⟶

compounds : Air Water NaI



Verification for migrated processes (a)

Comparison of Mean Free Path (MFP)
for the migrated processes: G4EmCaculator object

- G4LivermoreXxxModel.cc
- G4PenelopeXxxModel.cc

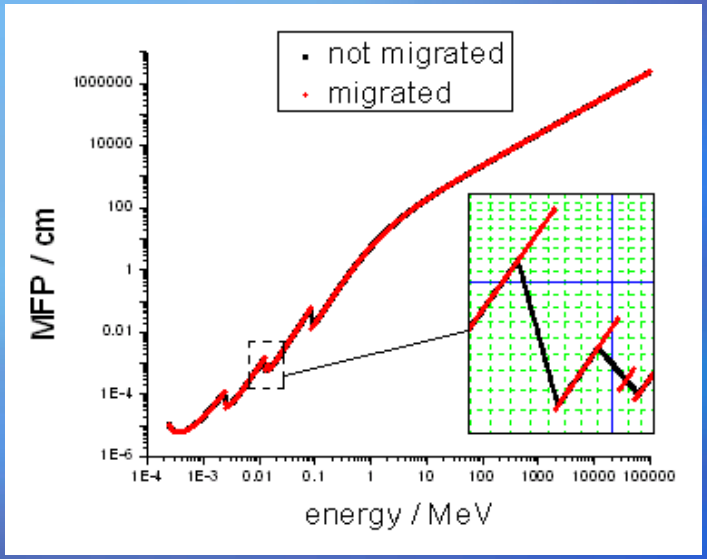
vs

for non migrated processes: Changed the Geant4 code

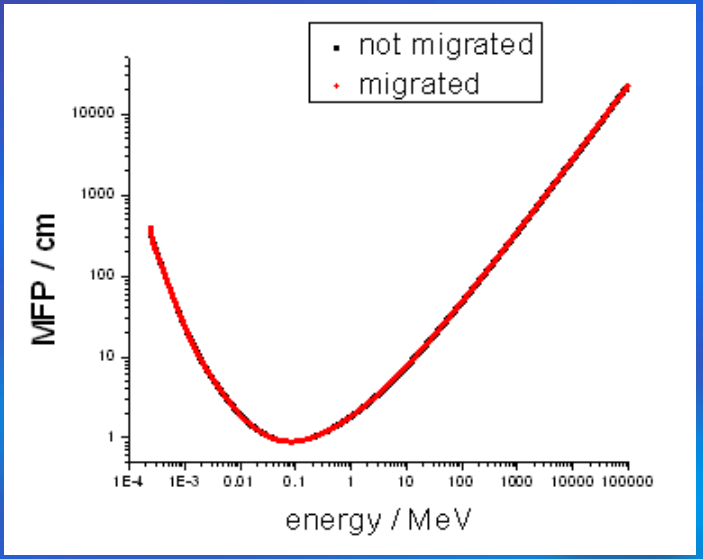
- G4LowEnergyXxx.cc
- G4PenelopeXxx.cc

Comparison of MFP for Livermore model (Pb)

photoelectric

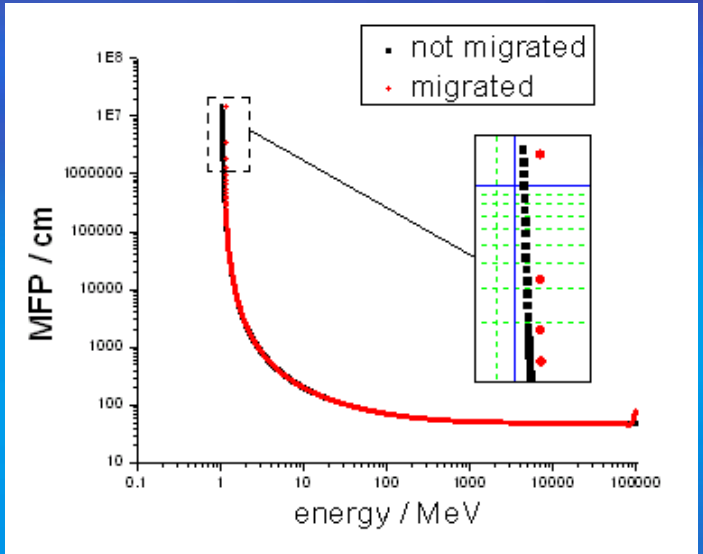


compton

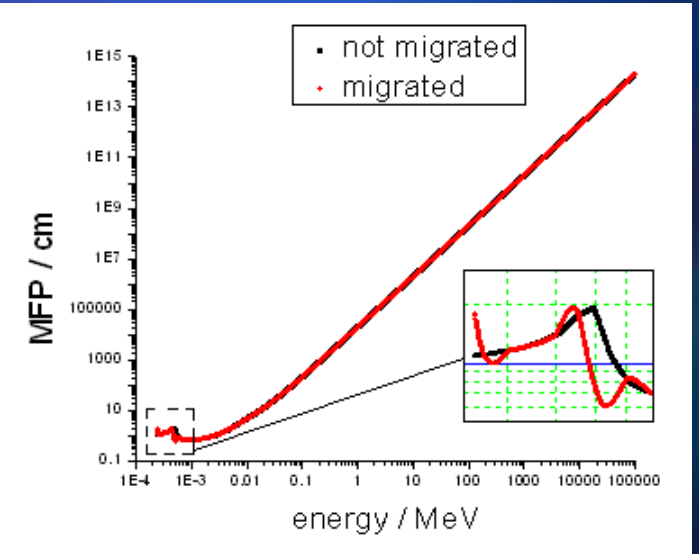


Comparison of MFP for Livermore model (Water)

gamma conversion

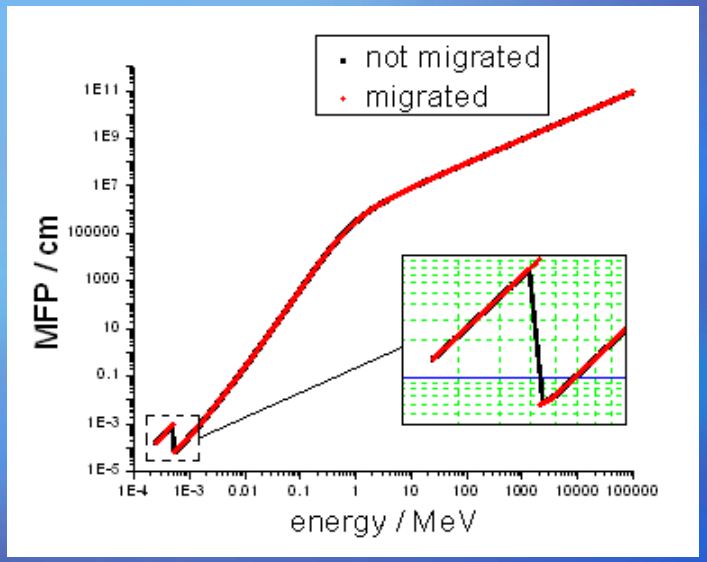


rayleigh

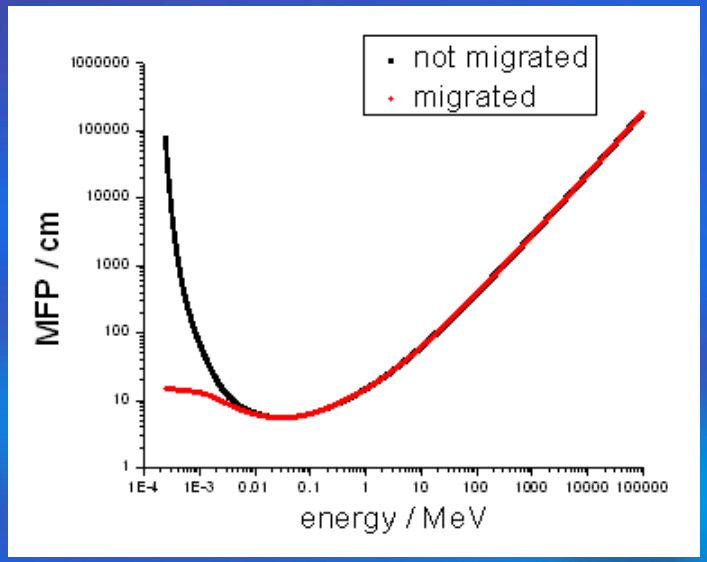


Comparison of MFP for Penelope model (Water)

photoelectric

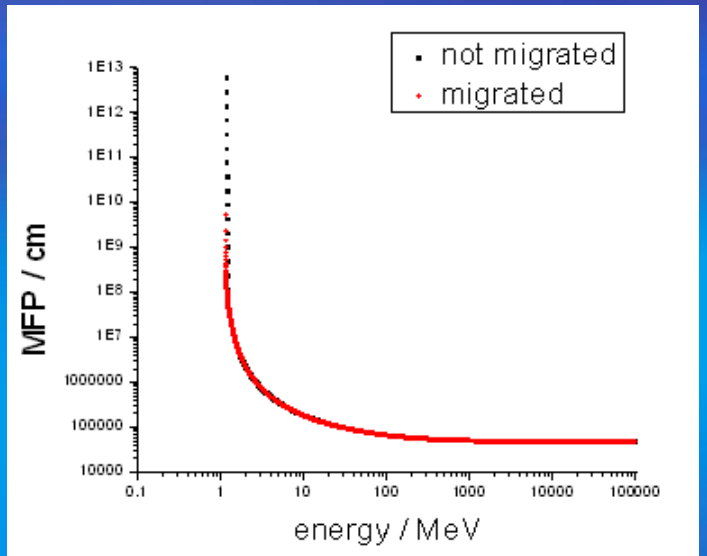


compton

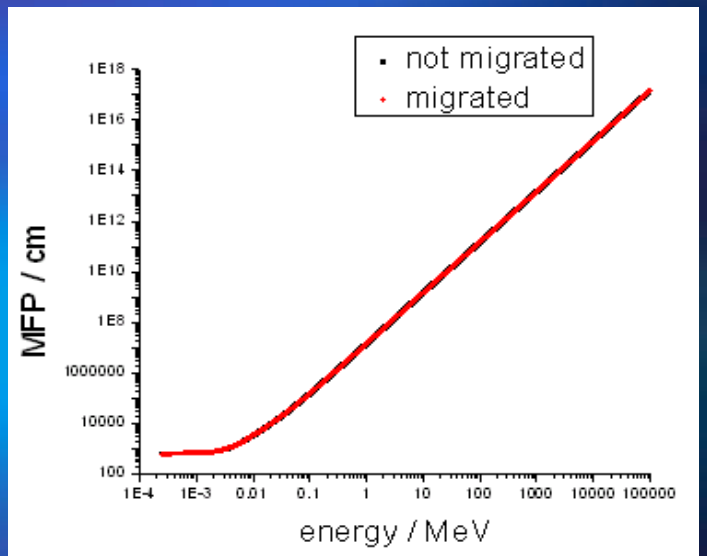


Comparison of MFP for Penelope model (Ne)

gamma conversion



rayleigh



Verification for migrated processes (b)

Comparison of Mean Free Path (MFP)
for the migrated processes: G4EmCaculator object

- G4LivermoreXxxModel.cc
- G4PenelopeXxxModel.cc

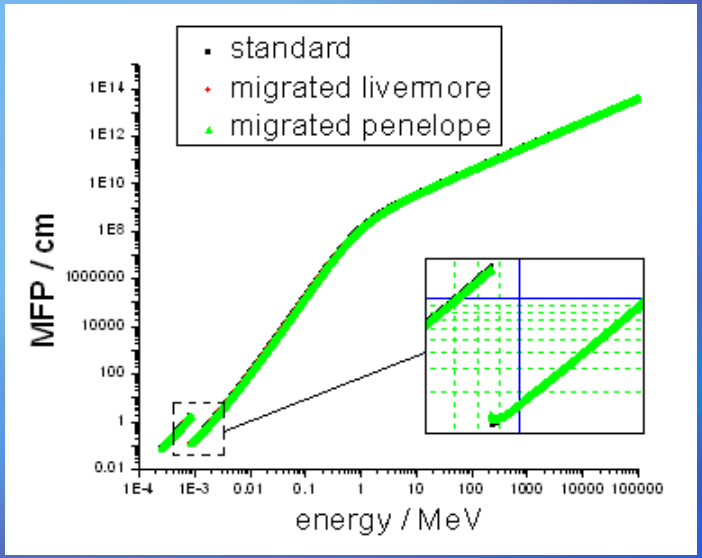
vs

for Standard processes: G4EmCaculator object

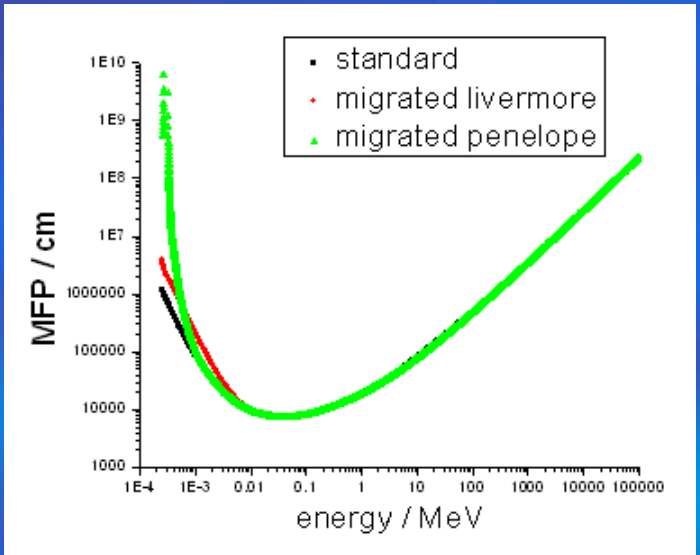
- G4Xxx.cc

Comparison with Standard physics processes (Ne)

photoelectric

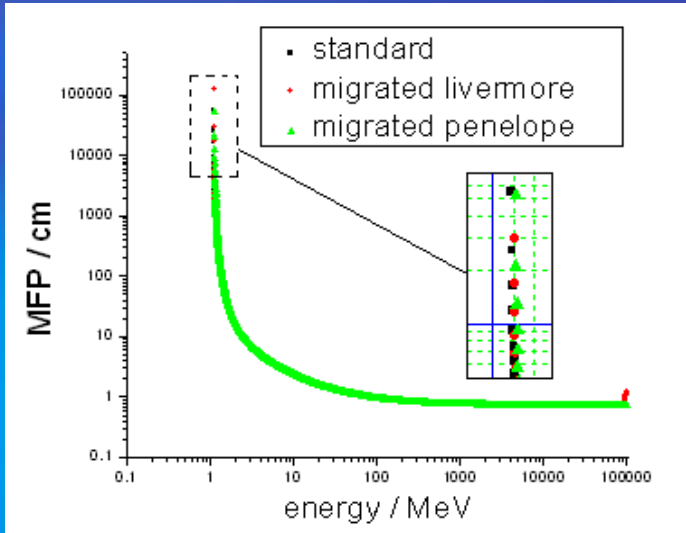


compton

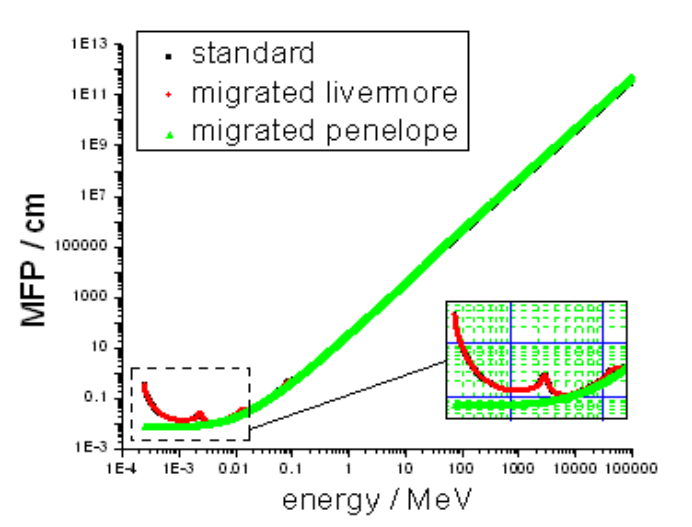


Comparison with Standard physics processes (Pb)

gamma conversion



rayleigh



Identification of data libraries for validation

- **SANIA** National Laboratories provide analytical approximations to cross sections for both photoelectric absorption of photons by atoms and incoherent scattering of photons by atoms
- Analytical Approximations for X-Ray Cross Section III

Standard processes

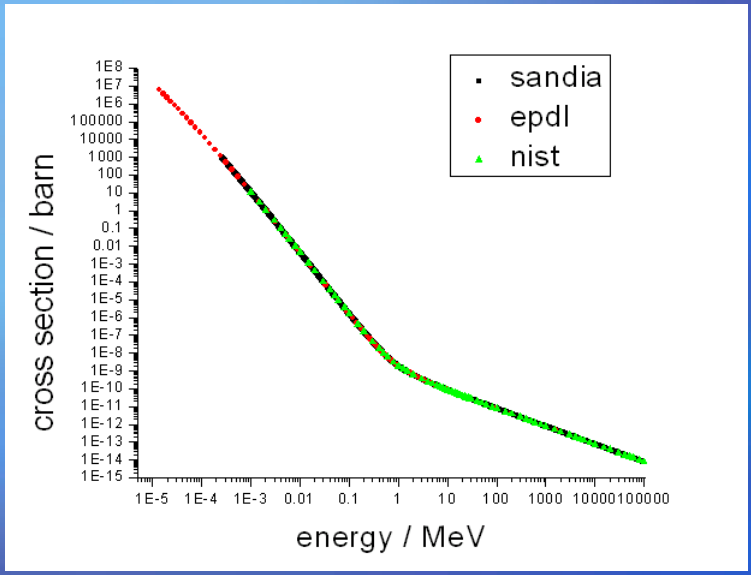
- **EPDL97** (Evaluated Photon Interaction Data Library) designed to meet the needs of users at Lawrence Livermore National Laboratory for use in photon transport calculations
- http://www-nds.iaea.org/epdl97/

Livermore processes

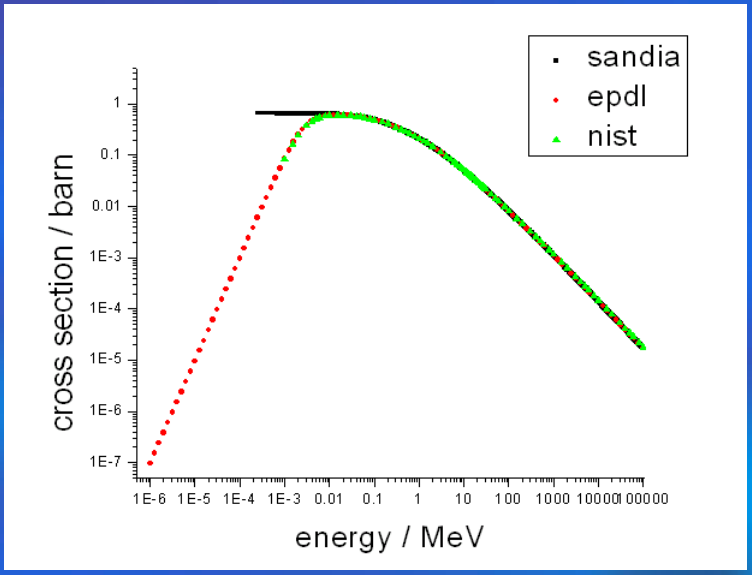
- The National Institute of Standards and Technology (**NIST**) maintains a large number of databases about photon-atom interactions (Form Factors, Attenuation & Scattering Tables, NIST X-Ray and Gamma-Ray Attenuation Coefficients and Cross Section)
- http://physics.nist.gov/PhysRefData/contents.html

Comparison of experimental libraries (H)

photoelectric

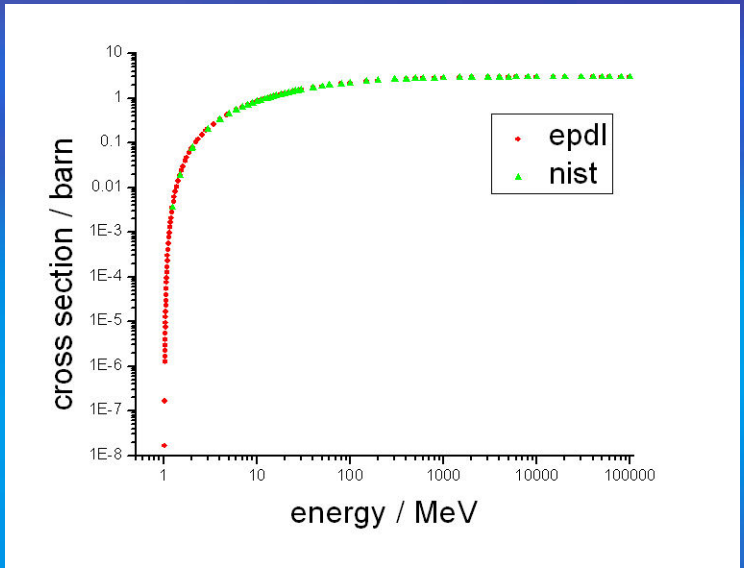


compton

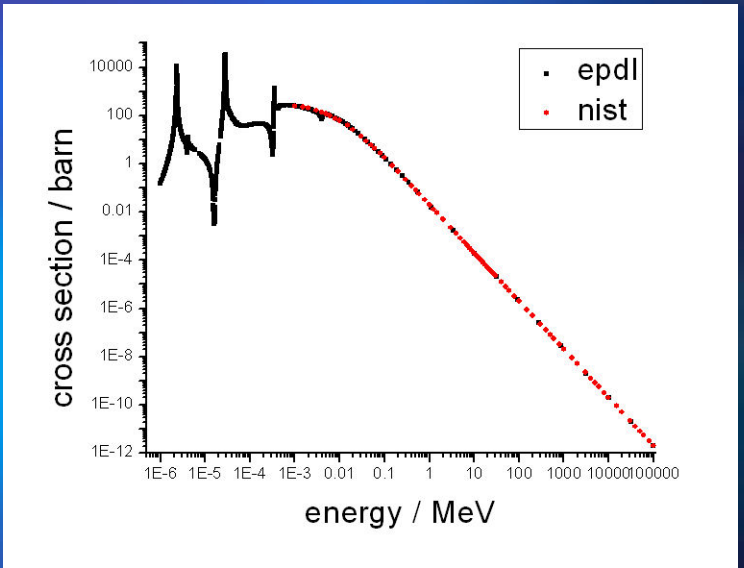


Comparison of experimental libraries (Ca)

gamma conversion

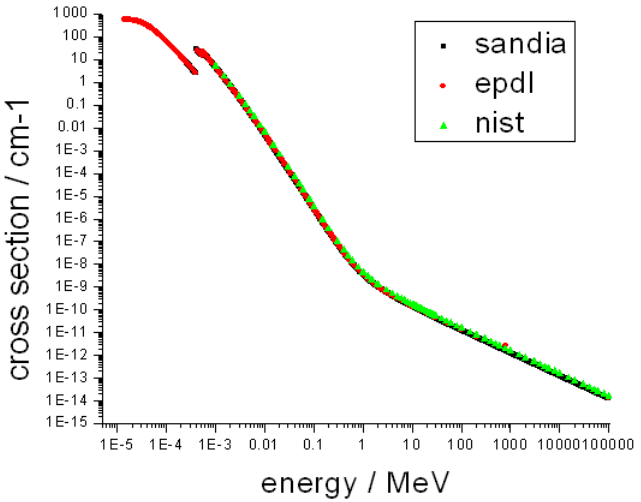


rayleigh

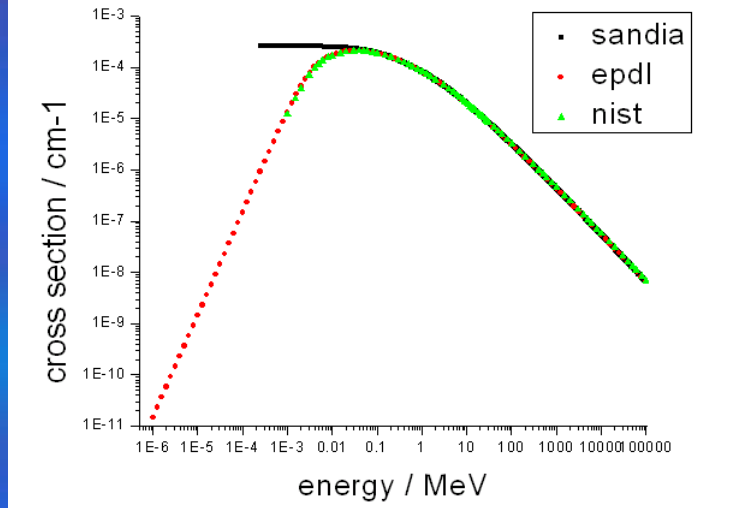


Comparison of experimental libraries (Air)

photoelectric

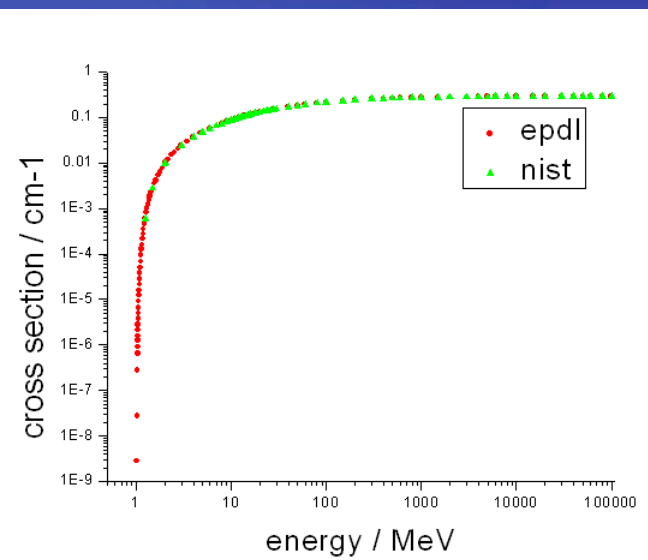


compton

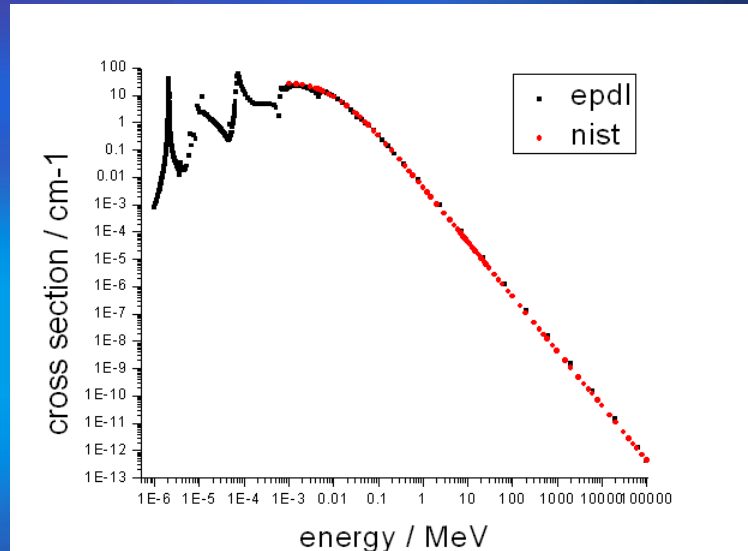


Comparison of experimental libraries (NaI)

gamma conversion



rayleigh



Validation of the Geant4 photon processes with respect to the libraries based on experimental data

- SANDIA
- EPDL97
- NIST

Retrieve the cross section : G4EmCalculator object

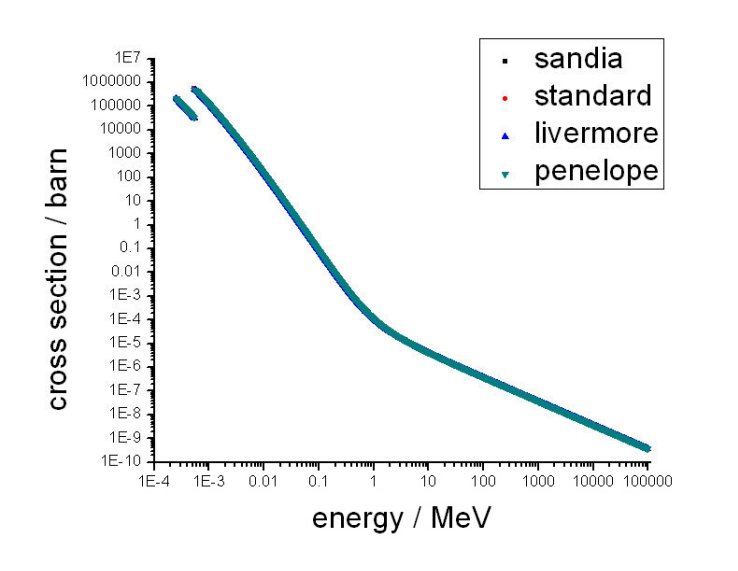
G4EmCalculator emCal
emCal.ComputeCrossSectionPerAtom
(energy,gamma,emName,Z,A,cut)

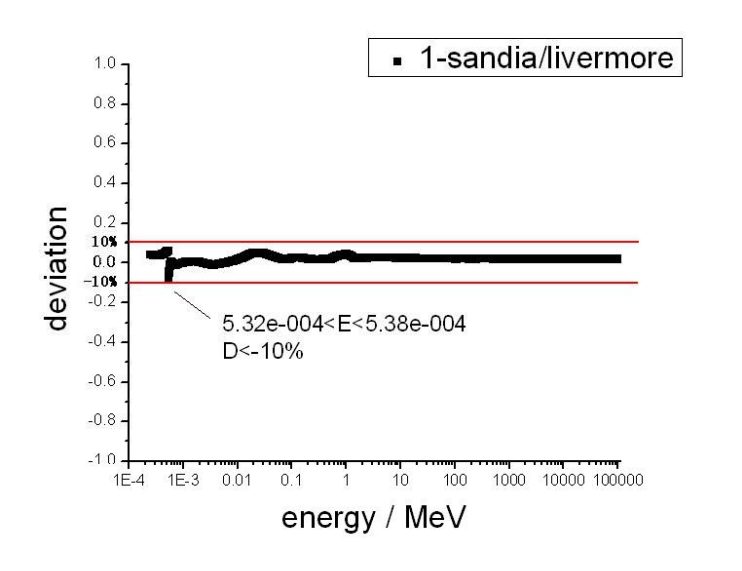
Or

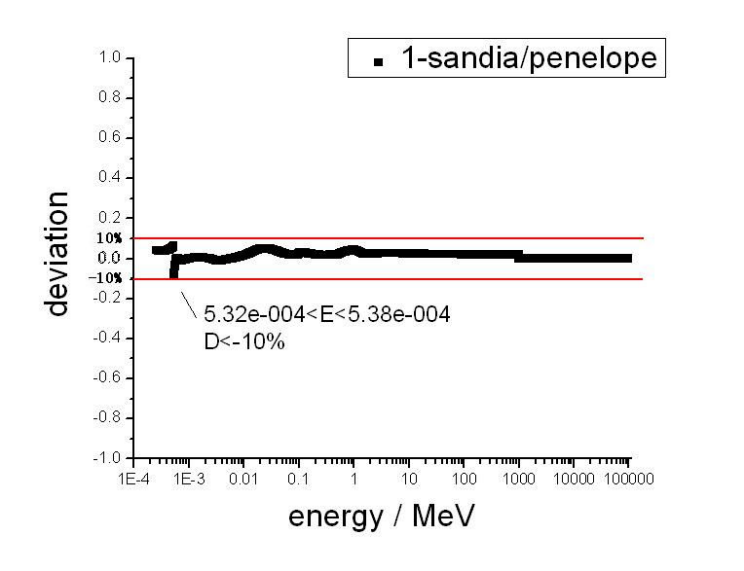
emCal.ComputeCrossSectionPerVolume
(energy,gamma,emName,material,cut)

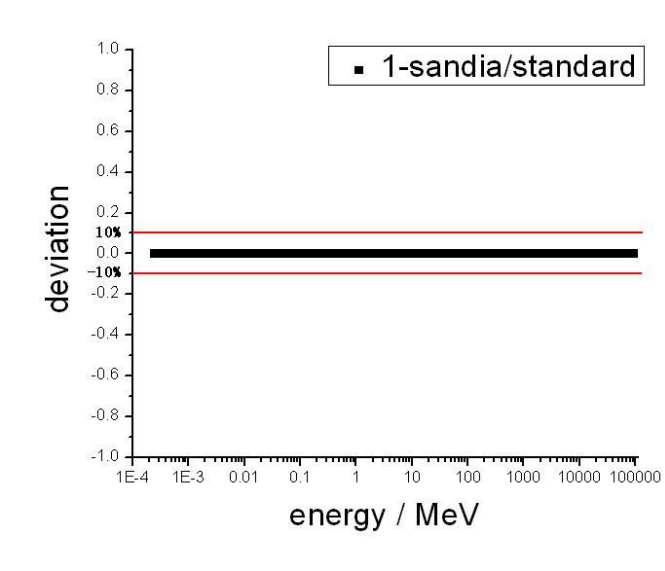
$$\text{deviation} = 1 - \frac{\text{libraries}}{\text{model}}$$

Comparison of XS per Atom between SANDIA and Geant4 (O photoelectric)

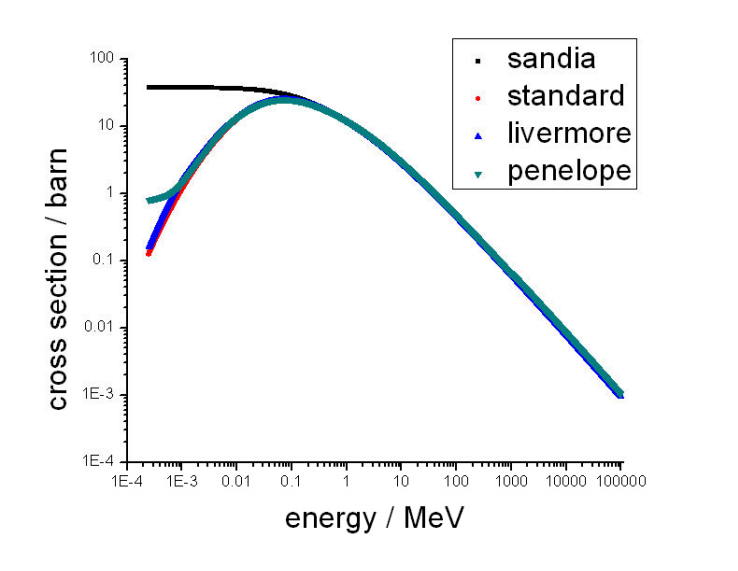


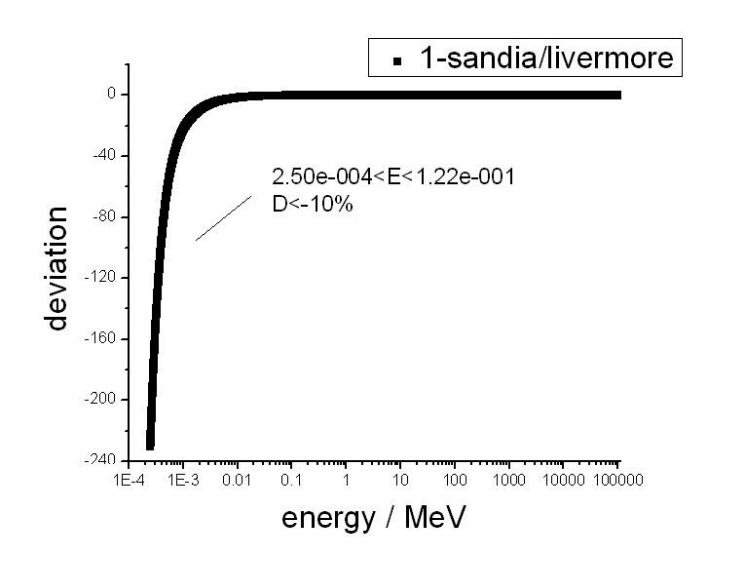


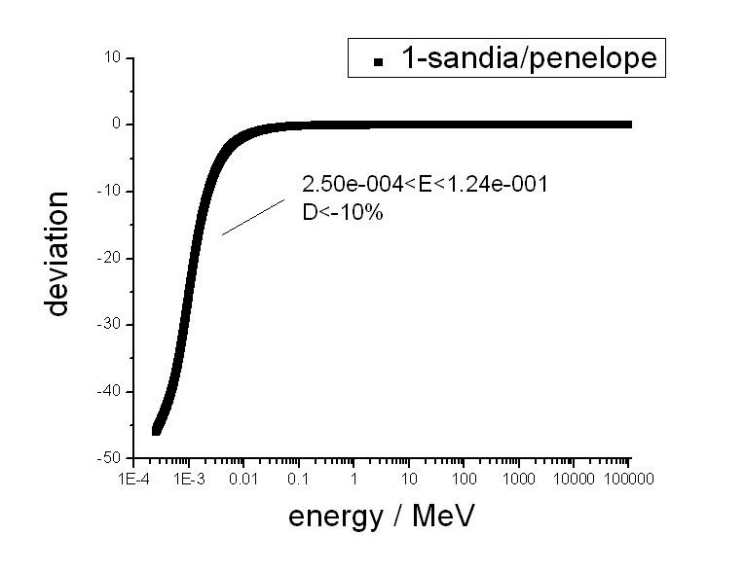


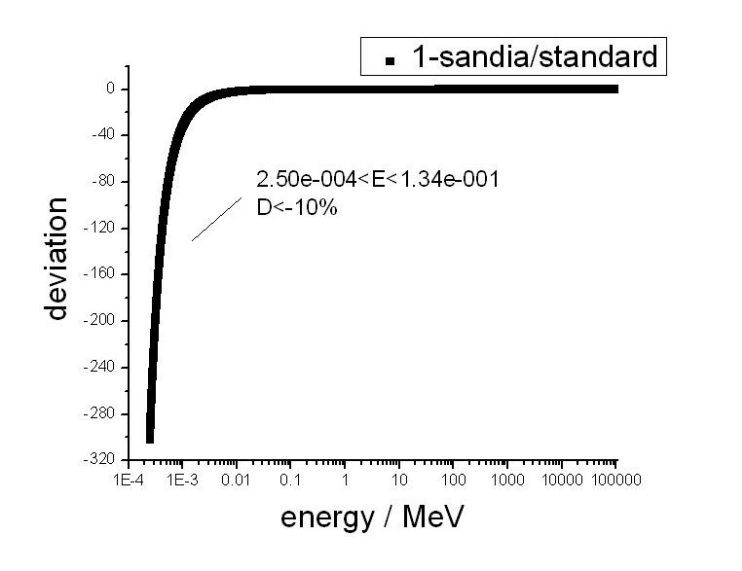


Comparison of XS per Atom between SANDIA and Geant4 (Ba compton)

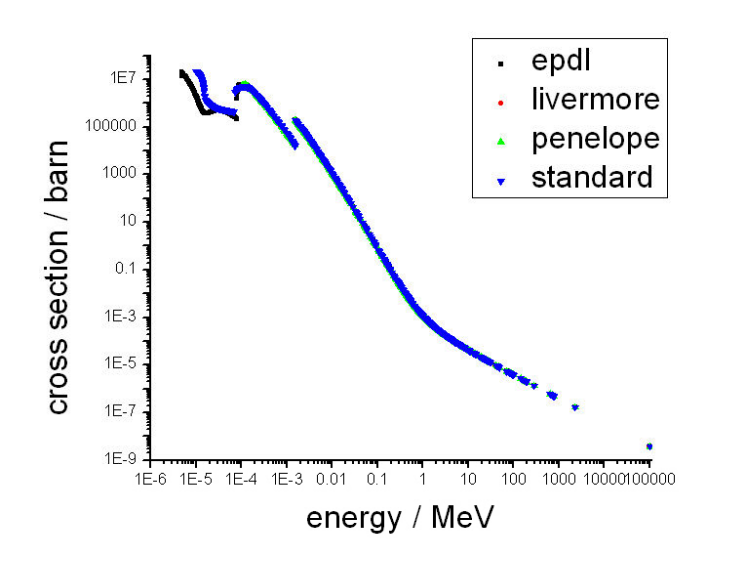


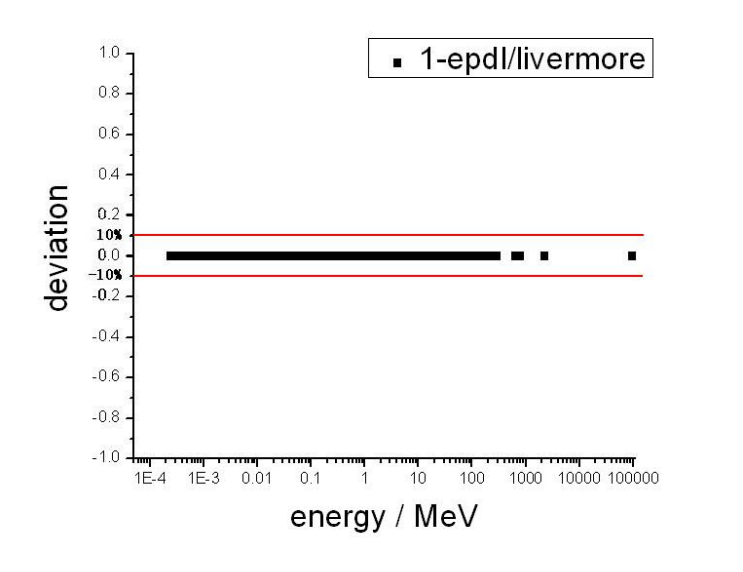


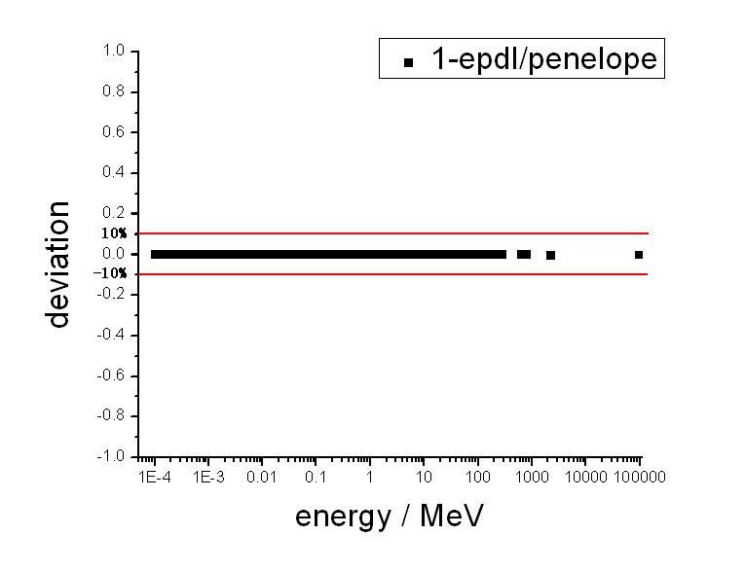


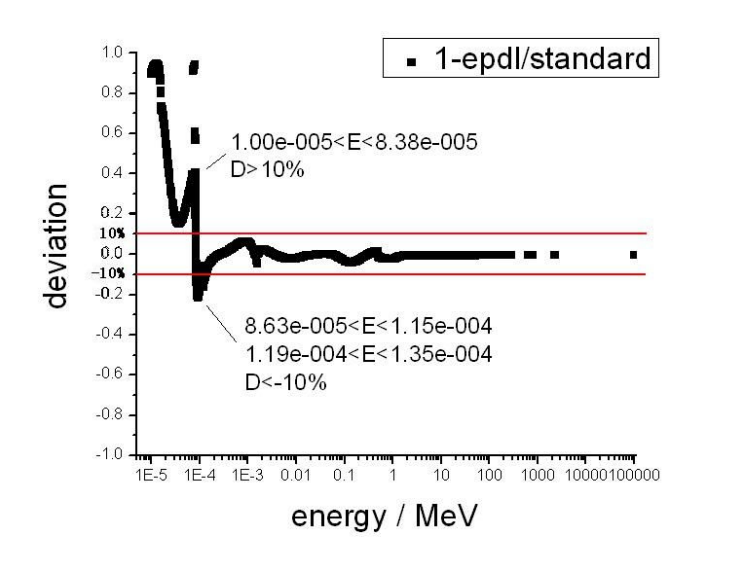


Comparison of XS per Atom between EPDL97 and Geant4 (Al photoelectric)

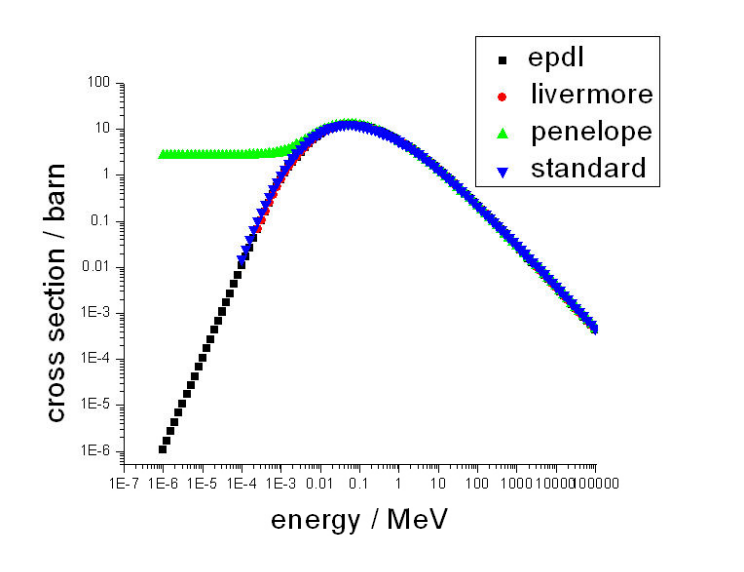


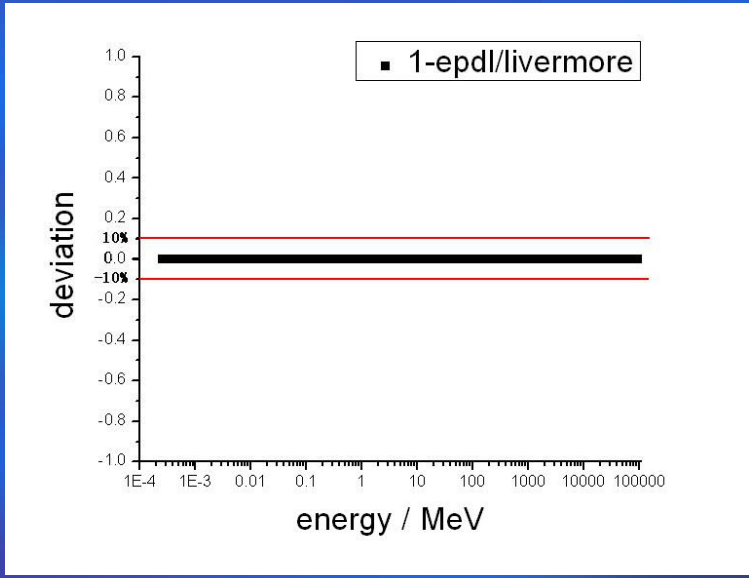


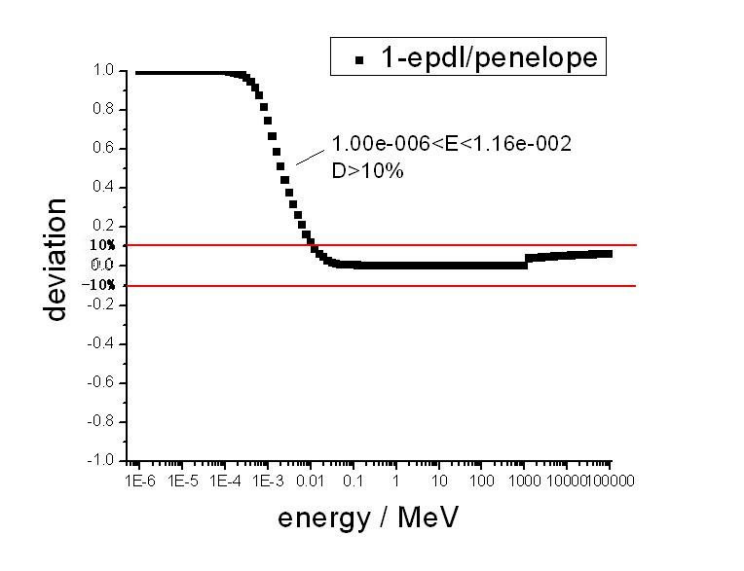


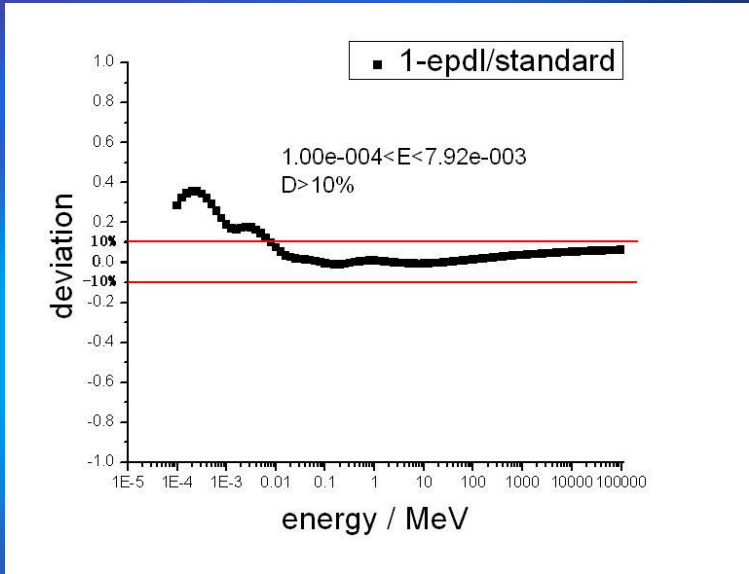


Comparison of XS per Atom between EPDL97 and Geant4 (Fe compton)

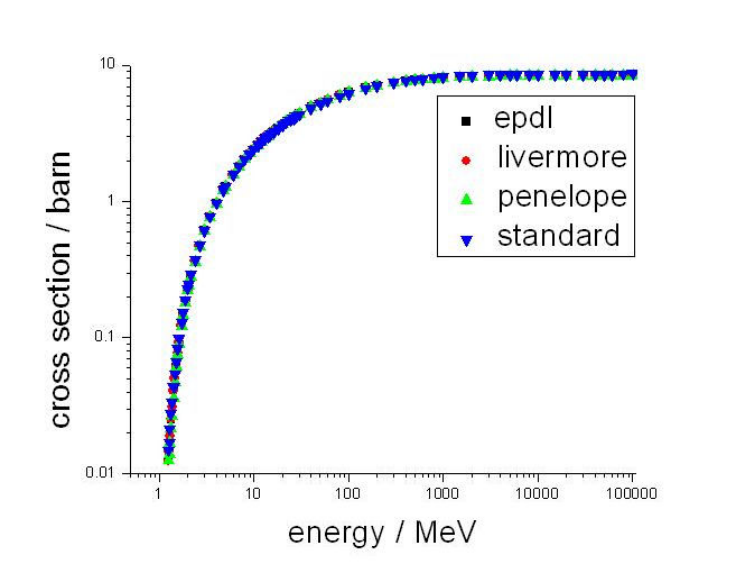


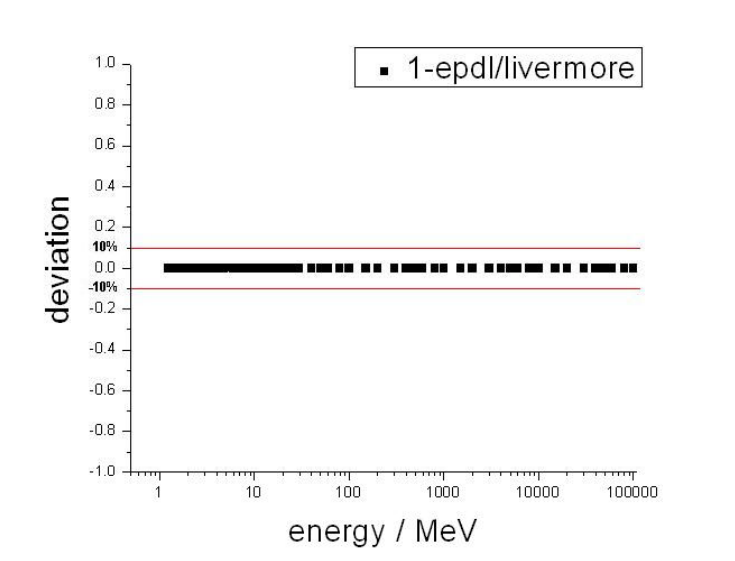


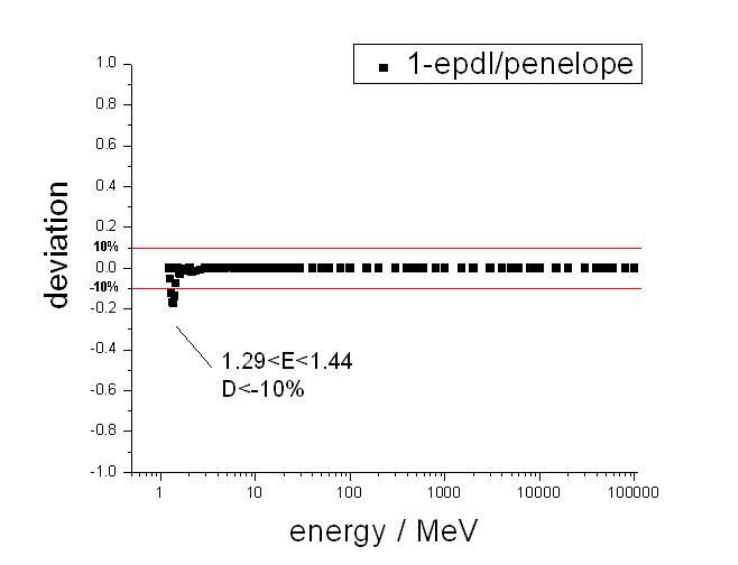


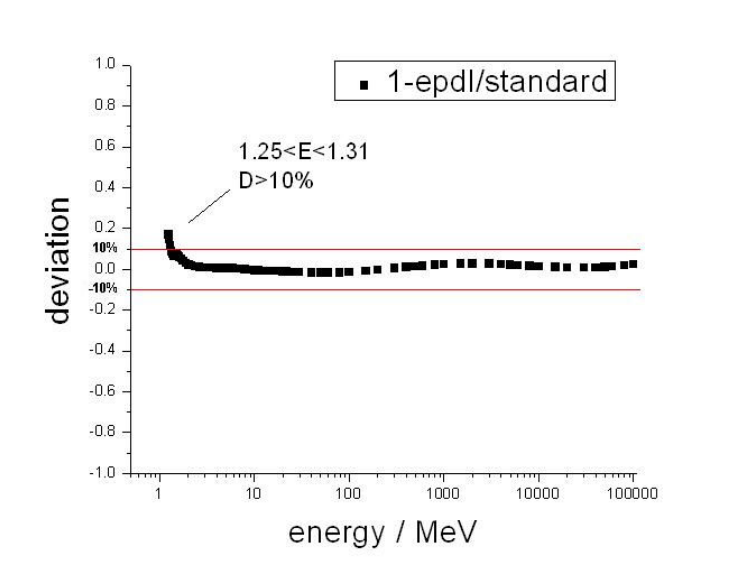


Comparison of XS per Atom between EPDL97 and Geant4 (Se gamma conversion)

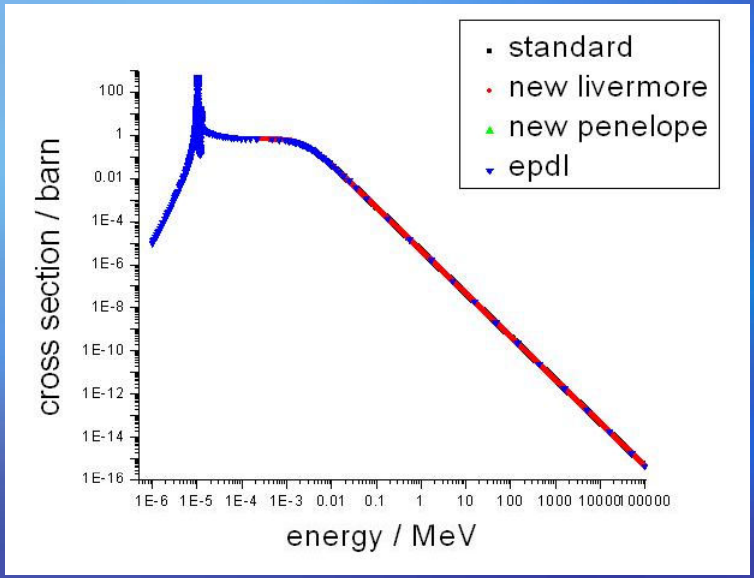


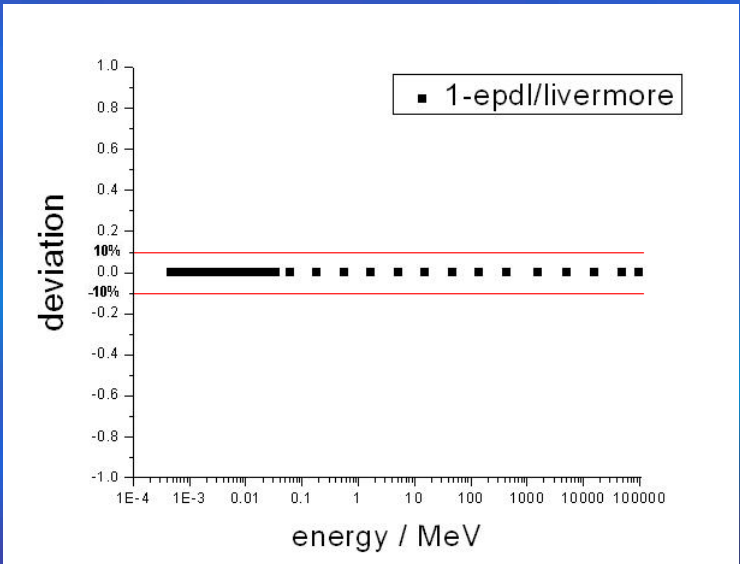


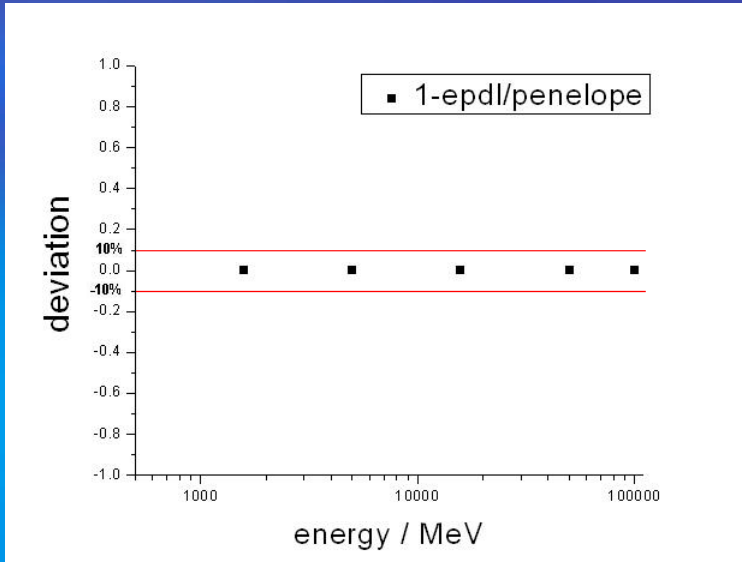


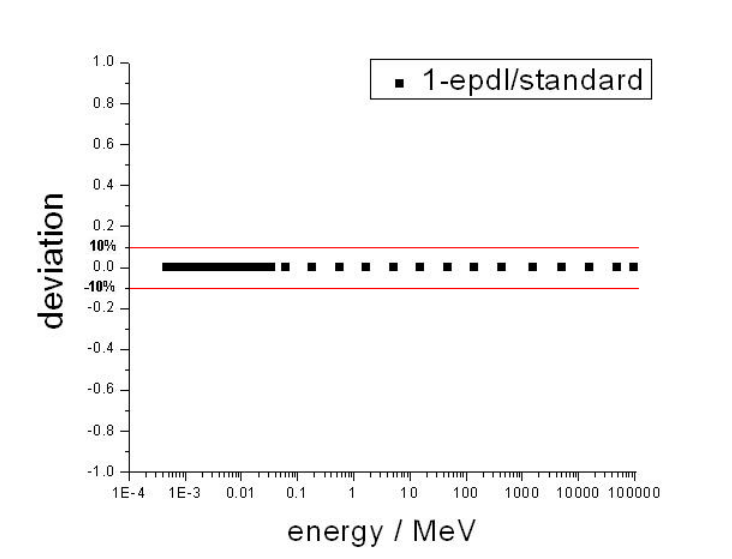


Comparison of XS per Atom between EPDL97 and Geant4 (H rayleigh)

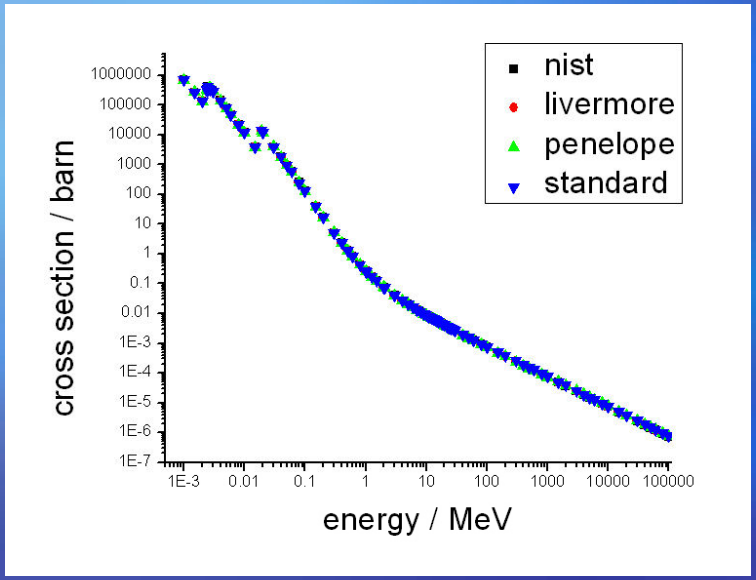


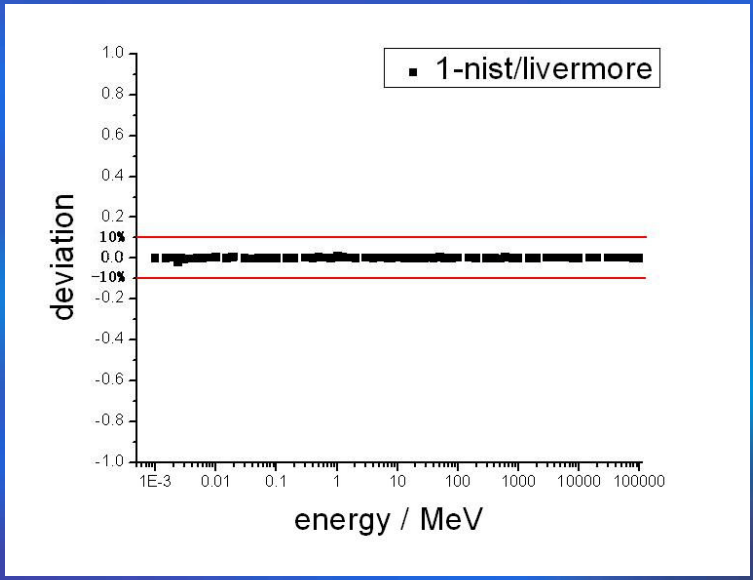


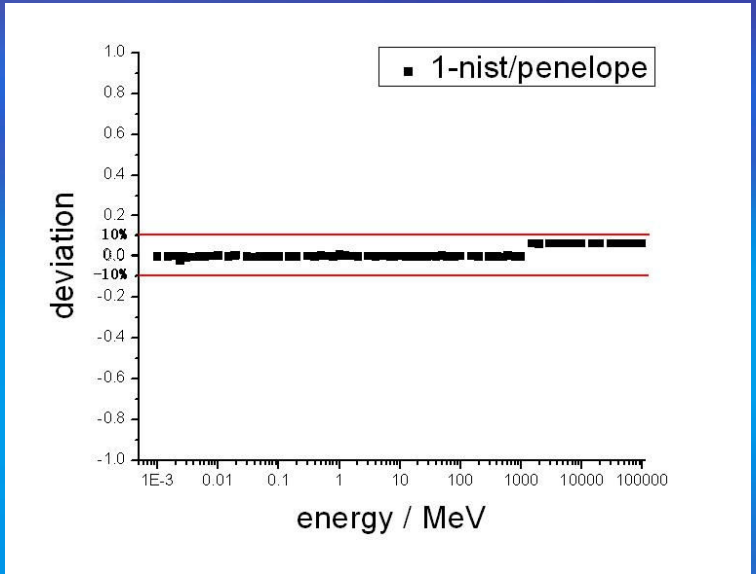


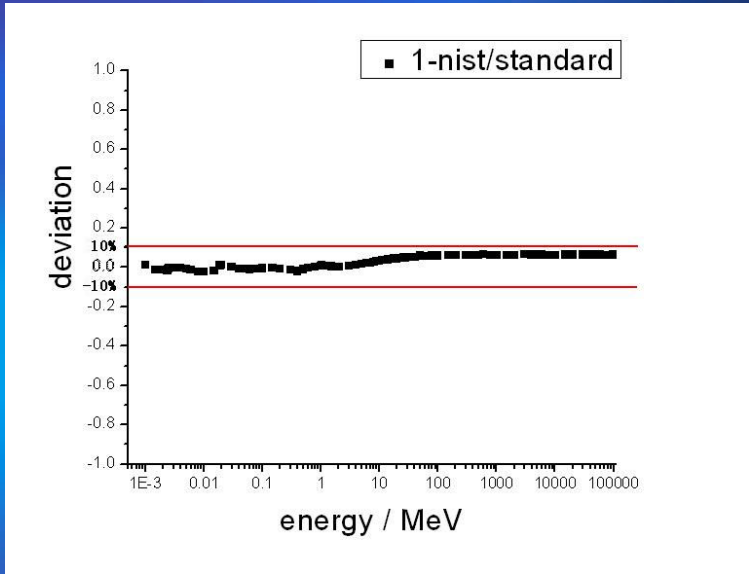


Comparison of XS per Atom between NIST and Geant4 (Nb photoelectric)

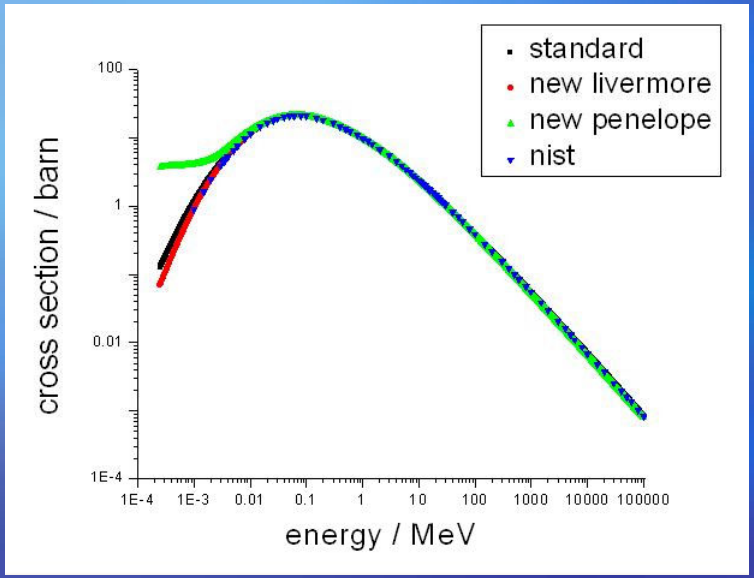


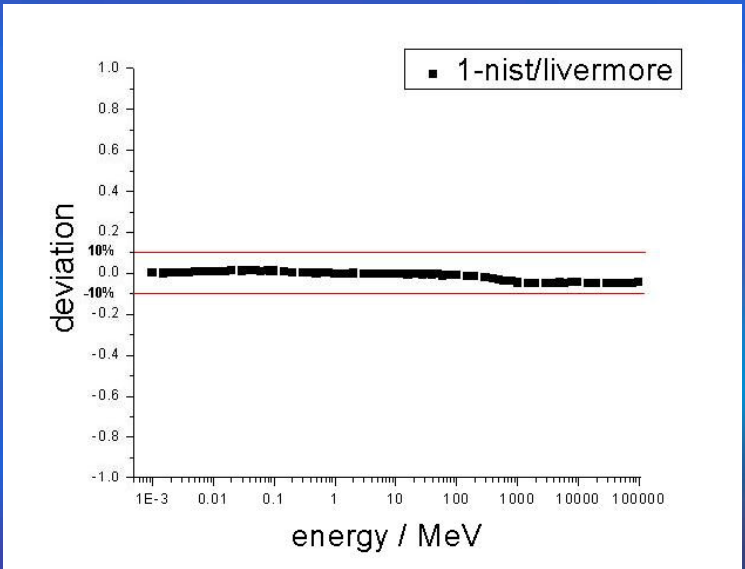


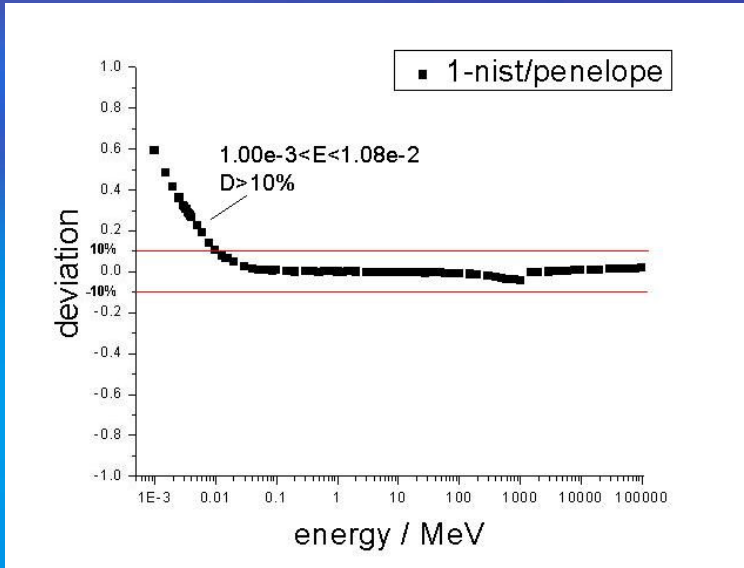


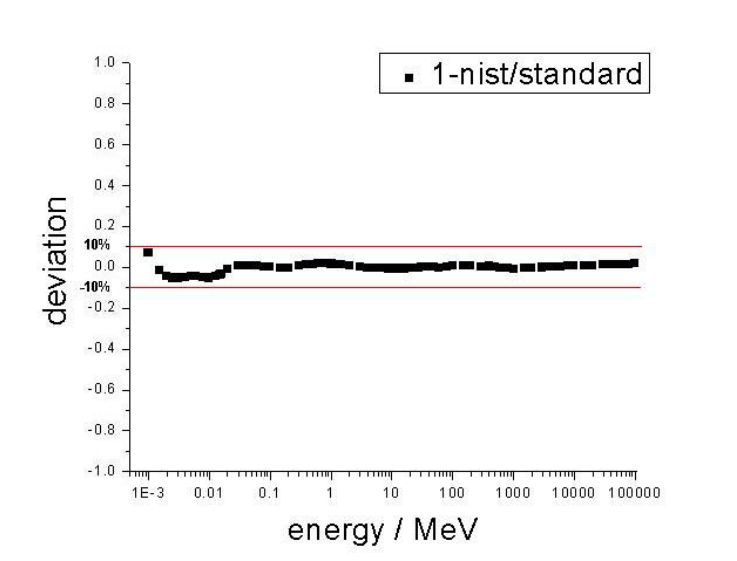


Comparison of XS per Atom between NIST and Geant4 (Ag compton)

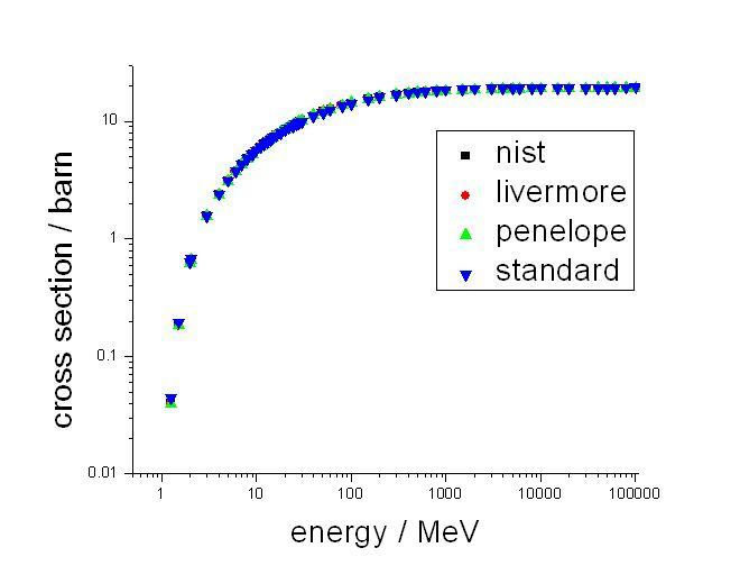


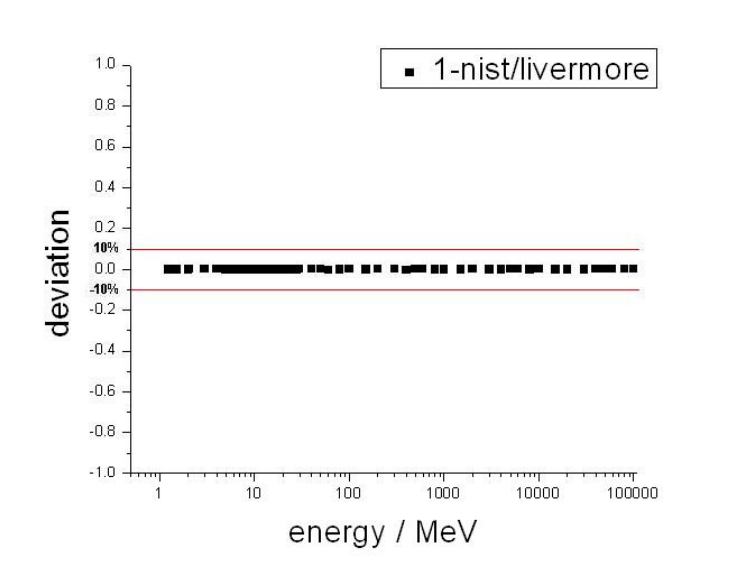


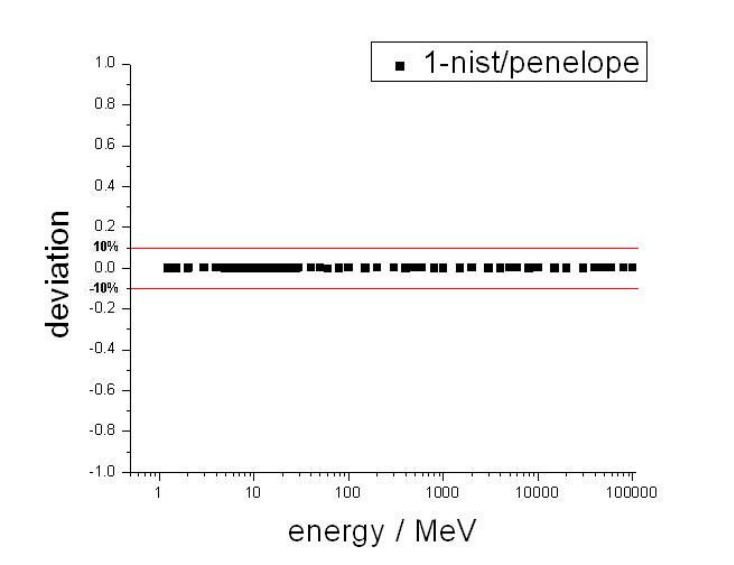


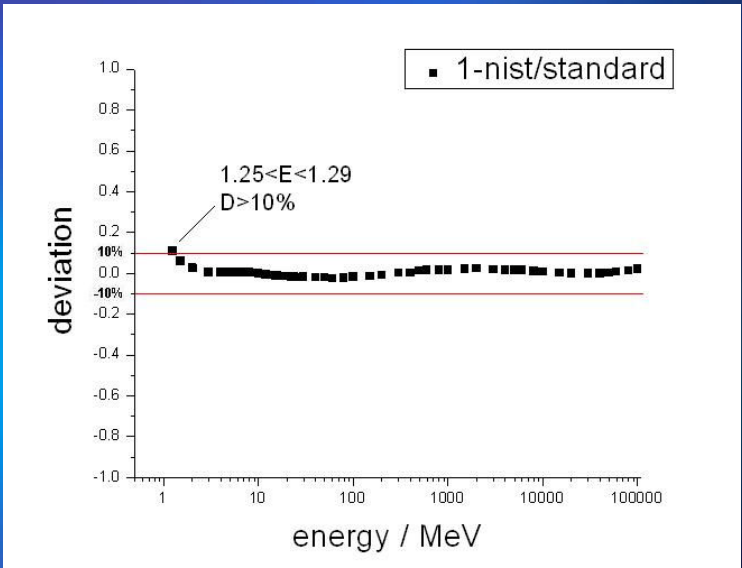


Comparison of XS per Atom between NIST and Geant4 (I gamma conversion)

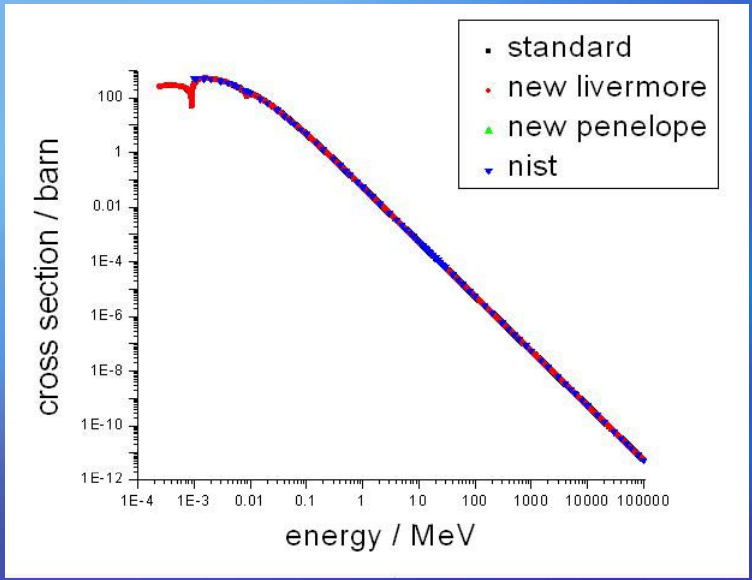


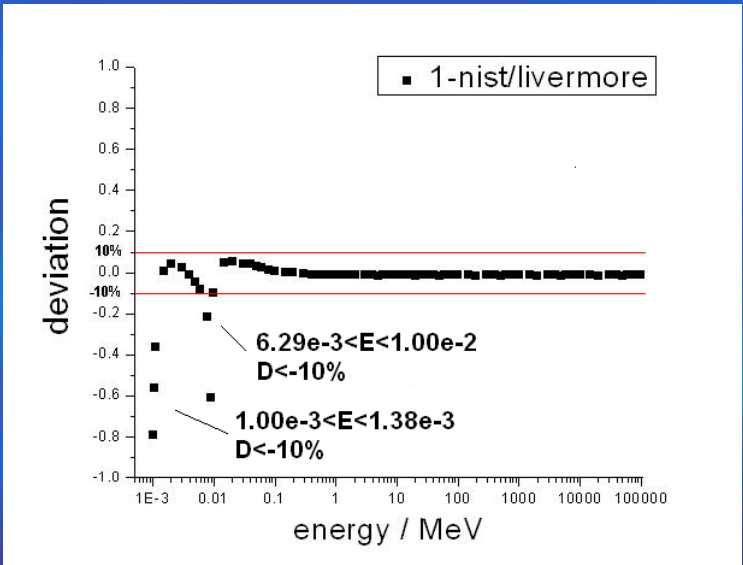


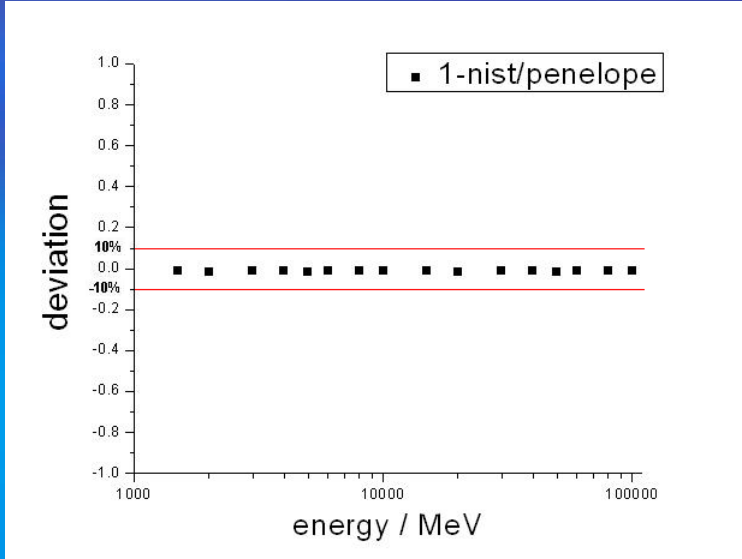


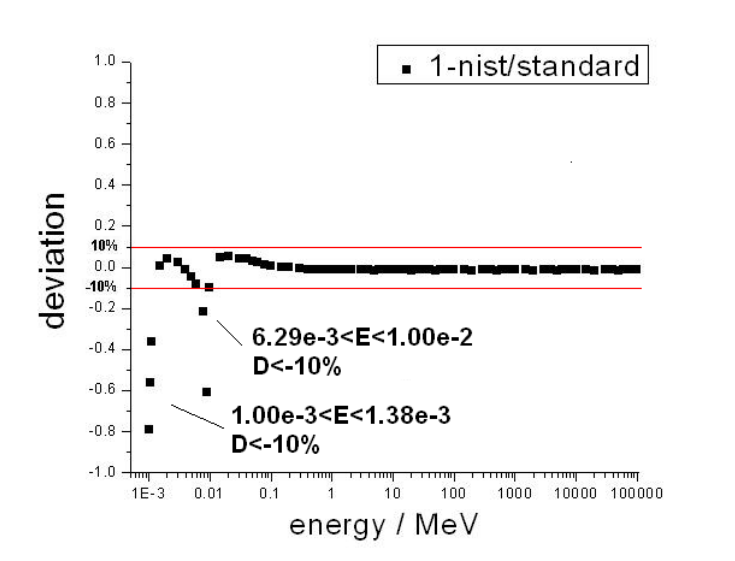


Comparison of XS per Atom between NIST and Geant4 (Cu rayleigh)









- The result in detail:

https://twiki.cern.ch/twiki/bin/view/Geant4/LoweValidation

- In Penelope Rayleigh Model,G4EmCalculator object just can retrieve the XS per Atom (energy > 1GeV)

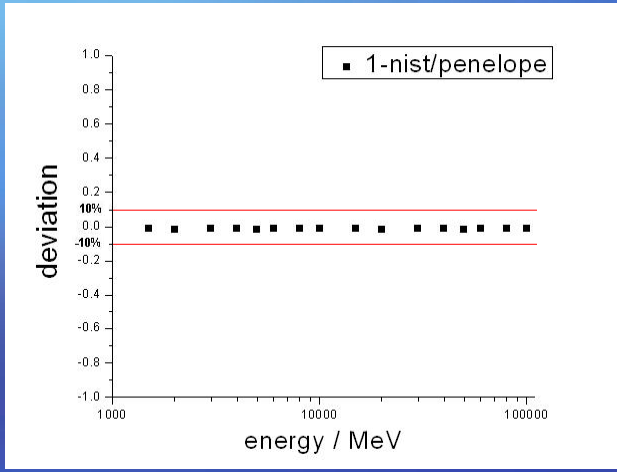
- Retrieve the XS directly with the model's methods

```
G4PenelopeRayleighModel* ray =
                        new G4PenelopeRayleighModel();
xs = ray->CrossSectionPerVolume
                        (material,gamma,energy,cut);
```

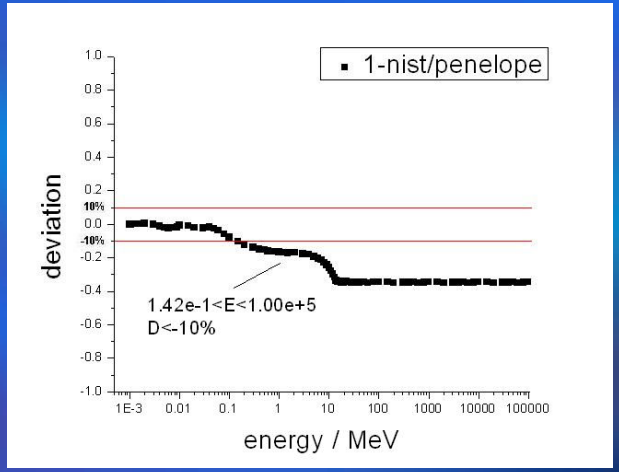
Comparison of XS per Atom between NIST and Penelope Model (rayleigh)

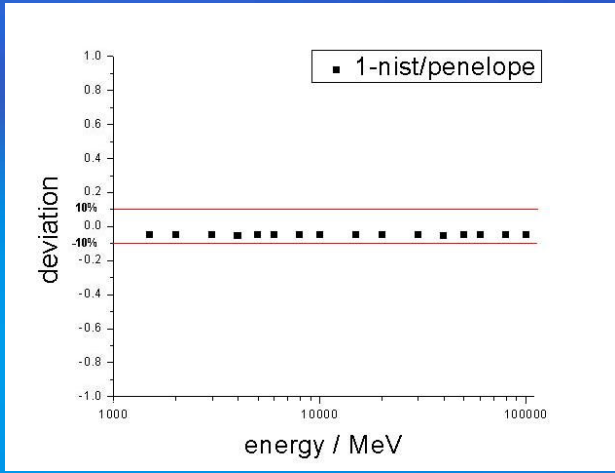
G4EmCalculator object

Direct methods

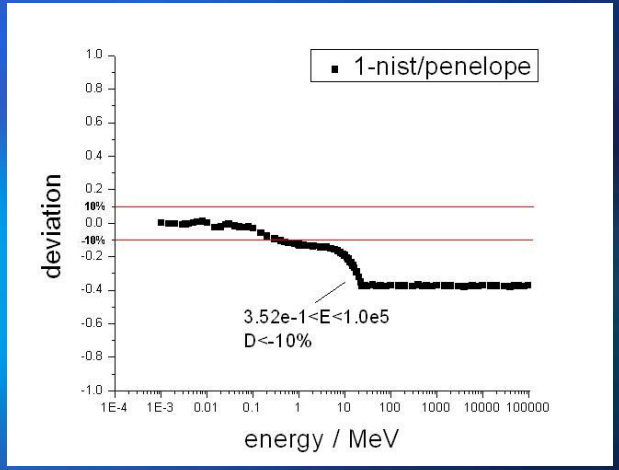


Cu





Ag



conclusions

- The Standard model cross sections originate from SANDIA, their differences are small;
- In the similar case,the Livermore model cross sections are in good agreement with EPDL97;
- The cross sections of most photon models agree with NIST within 10% except Penelope rayleigh model;
- The results of two methods (G4EmCalculator object and direct methods) are agreement except Penelope rayleigh model;

  It looks like Penelop rayleigh calculations by the G4EmCalculator are performed only above 1 GeV, namely outside the Penelope range. It is probably a limit/problem of the G4EmCalculator

Thank you !