

Geant 4

Test & Analysis Project



Statistical Testing

Physics Testing

<http://www.ge.infn.it/geant4/analysis/TandA>



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on behalf of the T&A team



Geant4 Workshop, TRIUMF, September 2003

Physics Testing Project

Electromagnetic Physics

Process

- Iterative and incremental, RUP-based
- Vision
 - start with an initial set of basic electromagnetic tests
 - use GoF component of HEP statistics
 - produce meaningful physics results
 - role in physics and regression testing
- First cycle
 - geant4/tests/test50
 - simple design (design iteration foreseen in near future)
 - first set of meaningful results

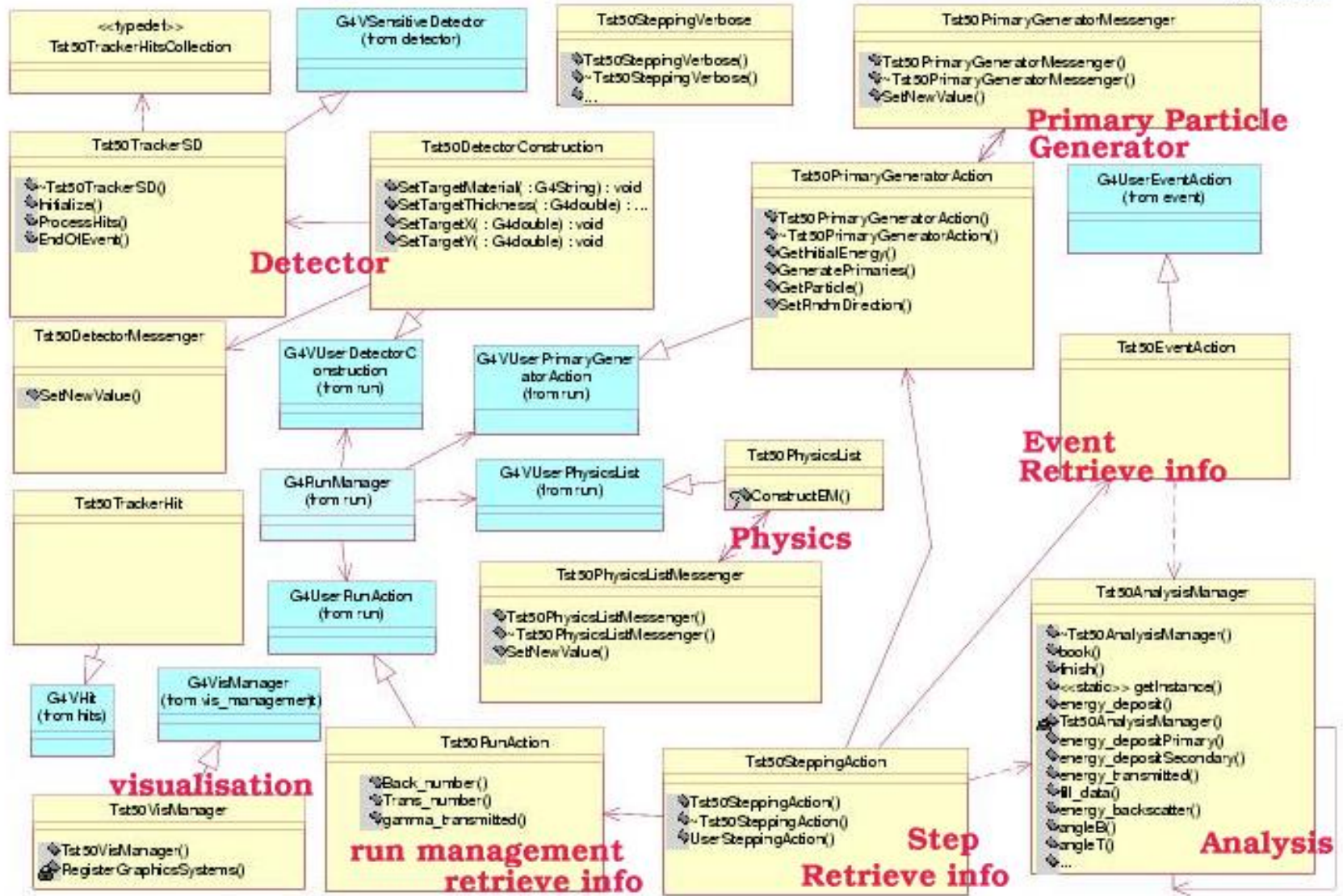
Main User Requirements

- The test produces typical distributions of physical quantities of interest for testing a set of physical processes.
- The user shall be able to define electrons, positrons, antiprotons, pions, photons, ions.
- The experimental set-up (e.g. absorber size and material) can be changed by the user.
- The user shall be able to define position, direction, energy of primary particles.
- The user shall be able to define electromagnetic and hadronic processes.
- The user shall be able to choose different e.m. G4 Packages (Standard, LowE, Penelope)
- The user shall be able to switch on/off the individual physics processes.

URD in <http://www.ge.infn.it/geant4/analysis/test>

General test design

S. Guatelli
10/3/2003



Physics Tests

Electromagnetic physics Standard, LowE, Penelope

- Particle CSDA range
- Particle Stopping Power
- Transmission coefficient
- Backscattering coefficient
- Photon Attenuation coefficient
- Cross sections
- Particle range
- Bremsstrahlung energy spectrum
- Multiple scattering distributions
- Energy deposit in absorber
- Bragg peak (including hadronic interactions)
- etc.

Hadronic physics

- ?

Test results

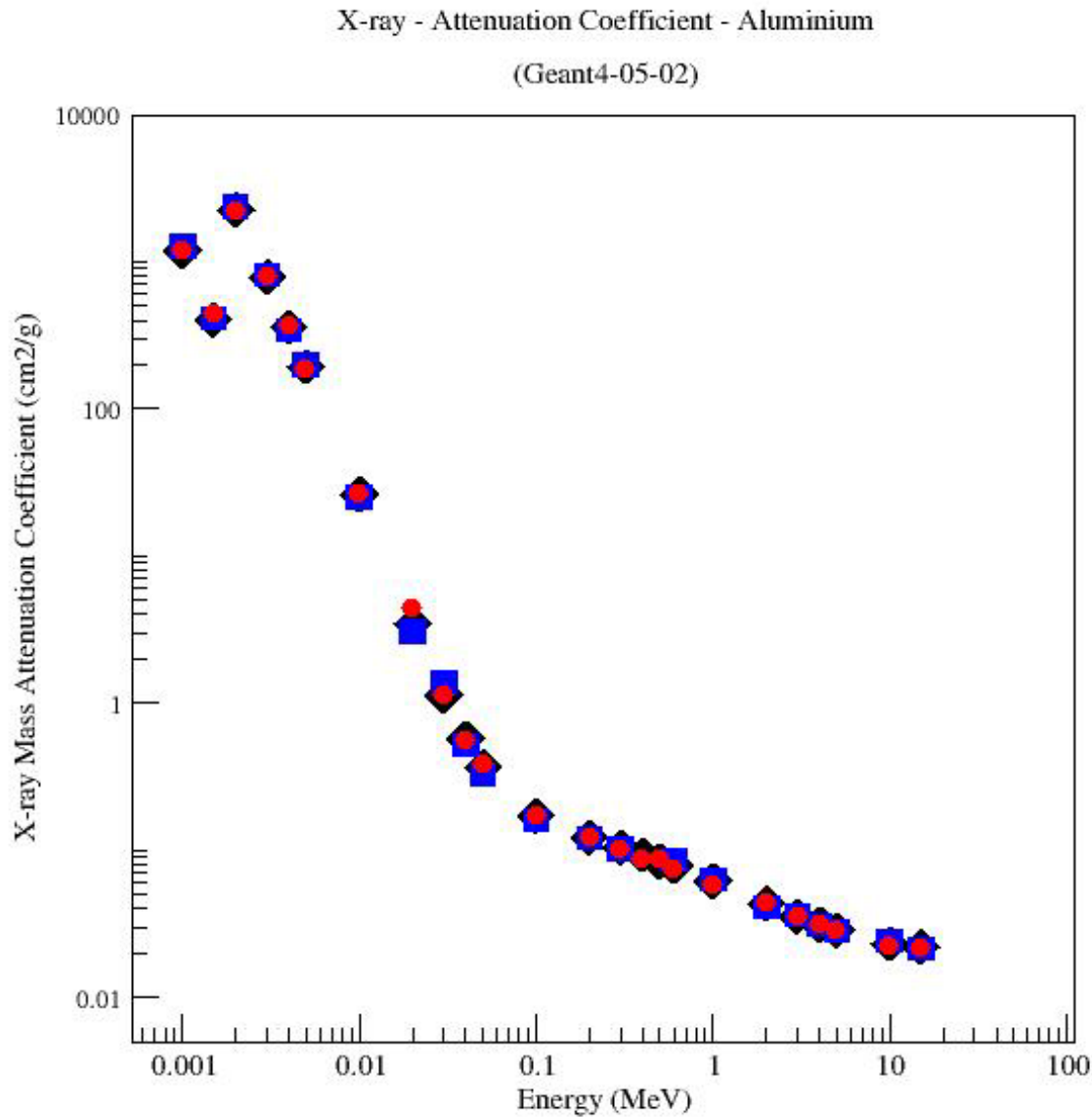
Photon attenuation coefficient

$-\ln \left(\frac{\text{gammaTransmittedFraction}}{\text{targetThickness} * \text{absorberDensity}} \right)$

Absorber Materials:

Be, Al, Si, Ge, Fe, Cs, Au, Pb, U

X-ray Attenuation Coefficient - Al



$$\chi^2_{N-L}=13.1 - \nu=20 - p=0.87$$

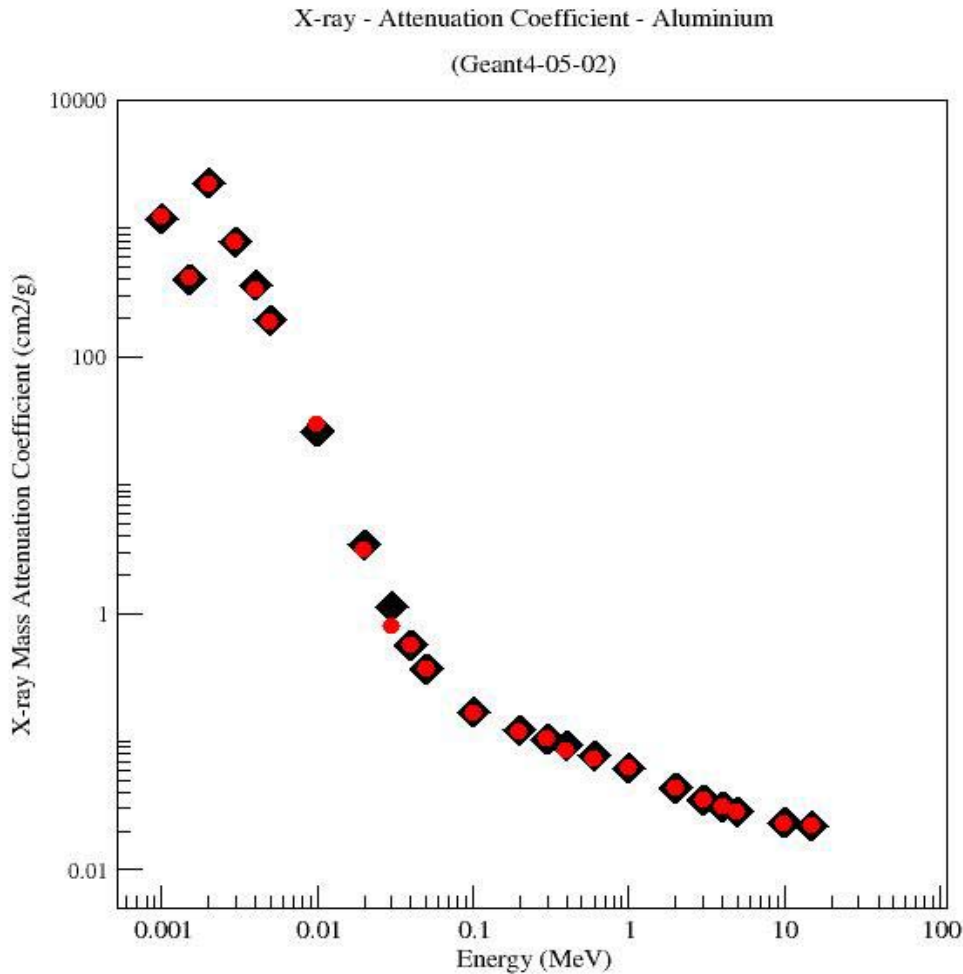
$$\chi^2_{N-S}=23.2 - \nu=15 - p=0.08$$

◆ NIST-XCOM

■ G4 Standard

● G4 LowE

X-ray Attenuation Coefficient - Al



$$\chi^2_{N-P}=15.9 - \nu=19 \quad p=0.66$$

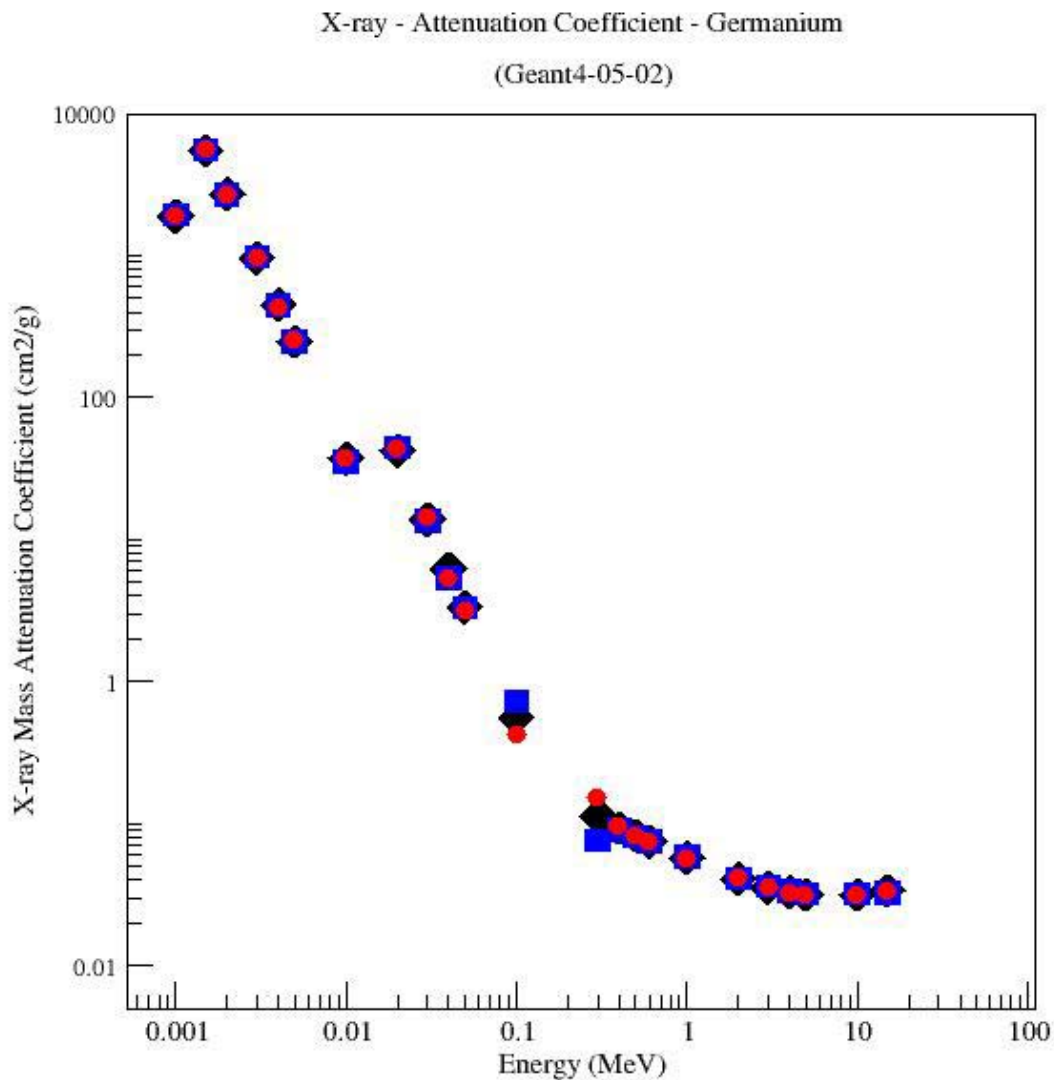


NIST-XCOM



G4 LowE Penelope

X-ray Attenuation Coefficient - Ge



$$\chi^2_{N-L} = 26.3 - \nu = 23 - p = 0.29$$

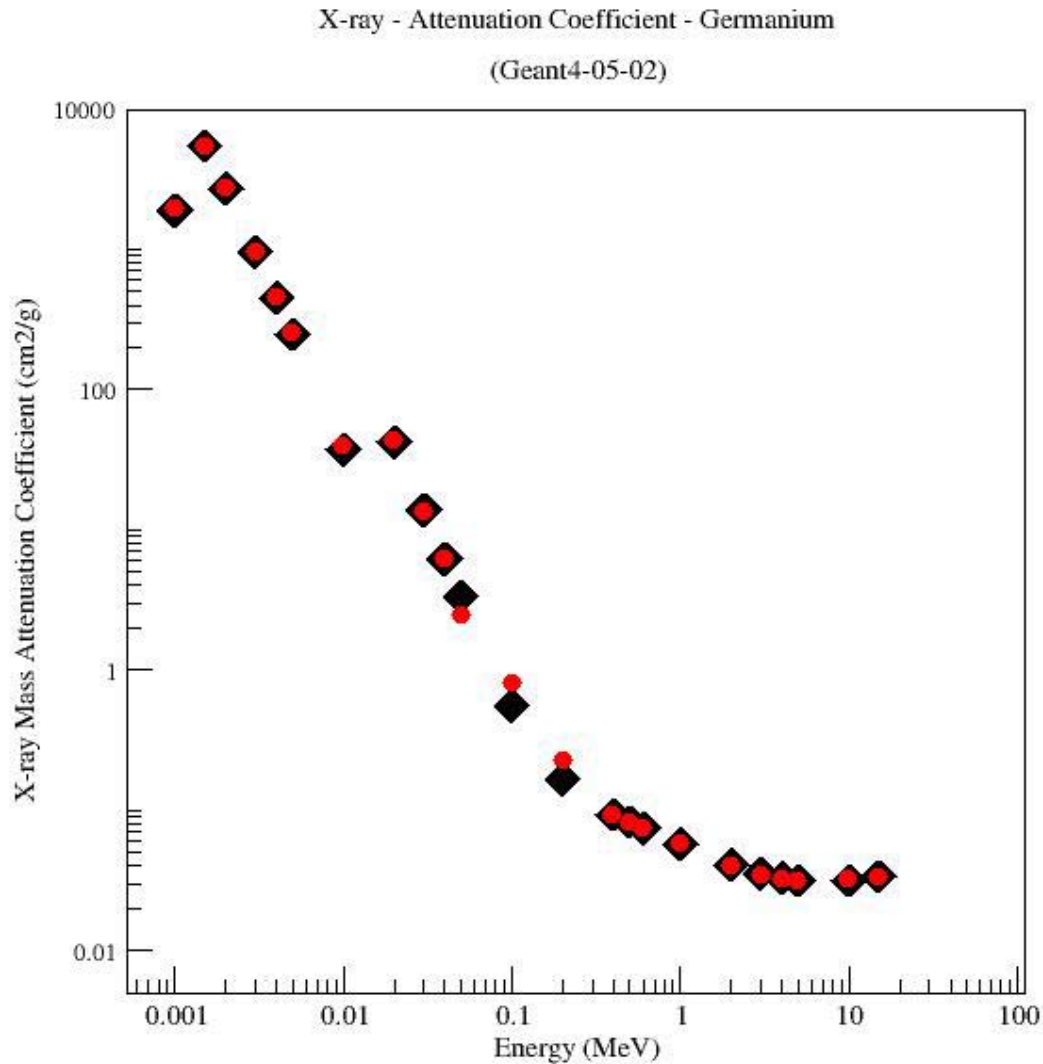
$$\chi^2_{N-S} = 27.9 - \nu = 23 - p = 0.22$$

◆ NIST-XCOM

■ G4 Standard

● G4 LowE

X-ray Attenuation Coefficient - Ge



$$\chi^2_{N-P}=10.1 - \nu=21 - p=0.98$$

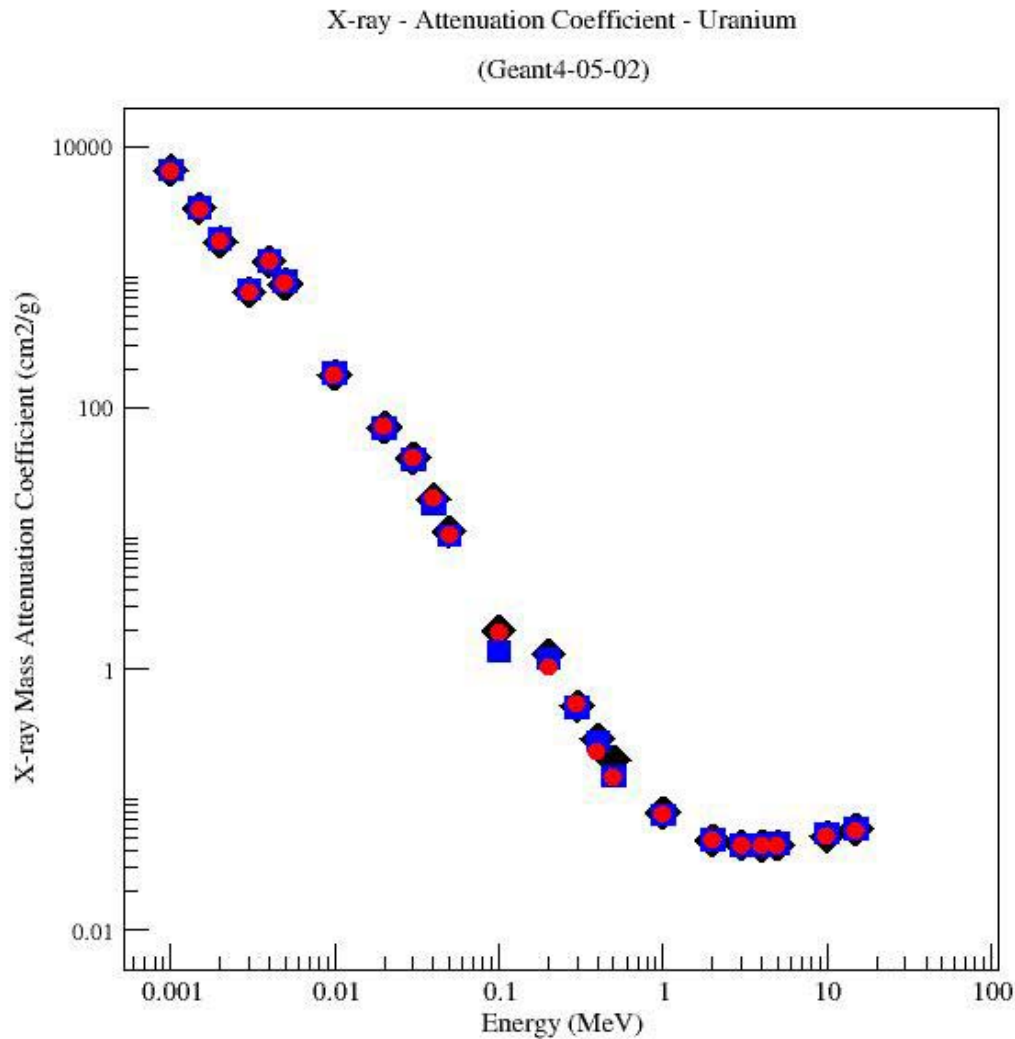


NIST-XCOM



G4 LowE Penelope

X-ray Attenuation Coefficient - U



$$\chi^2_{N-L}=6.6 - \nu=20 - p=0.99$$

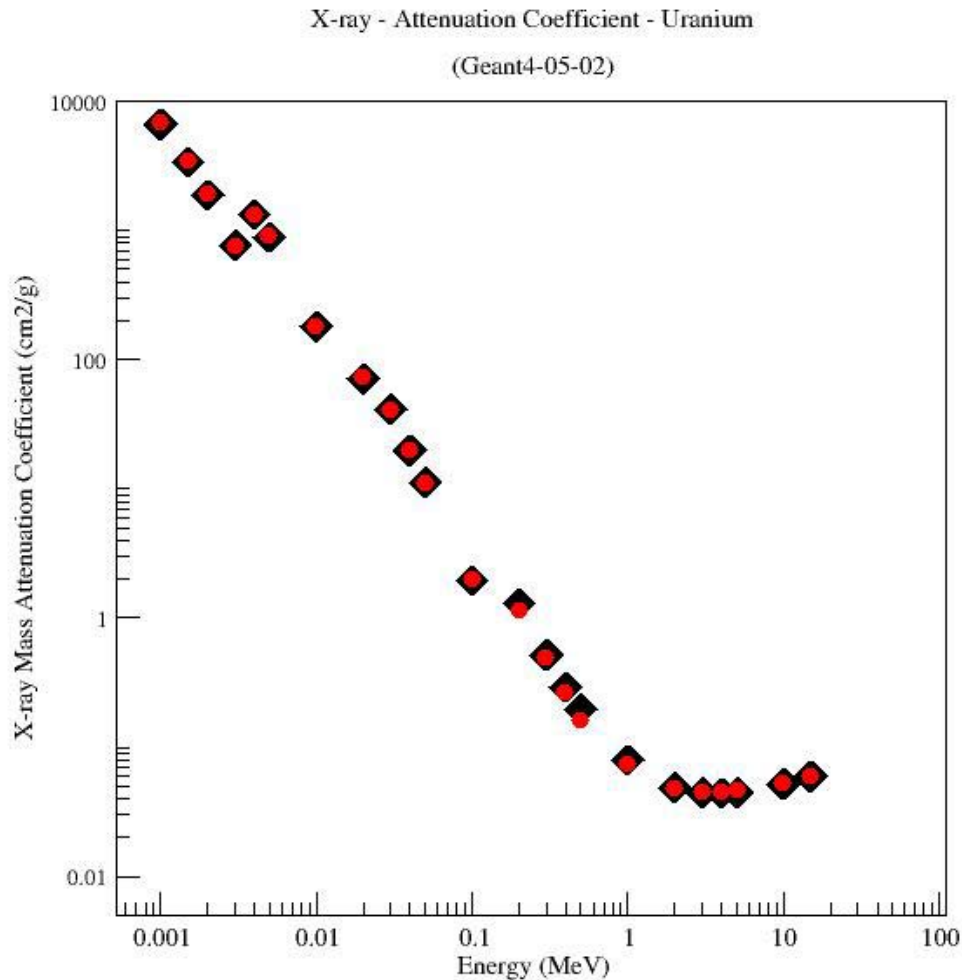
$$\chi^2_{N-S}=14.7 - \nu=20 - p=0.80$$

◆ NIST-XCOM

■ G4 Standard

● G4 LowE

X-ray Attenuation Coefficient - U



$$\chi^2_{N-P}=19.3 - \nu=22 - p=0.63$$



NIST-XCOM



G4 LowE Penelope

Test results

Photon cross sections

attenuation coefficients with only one process activated

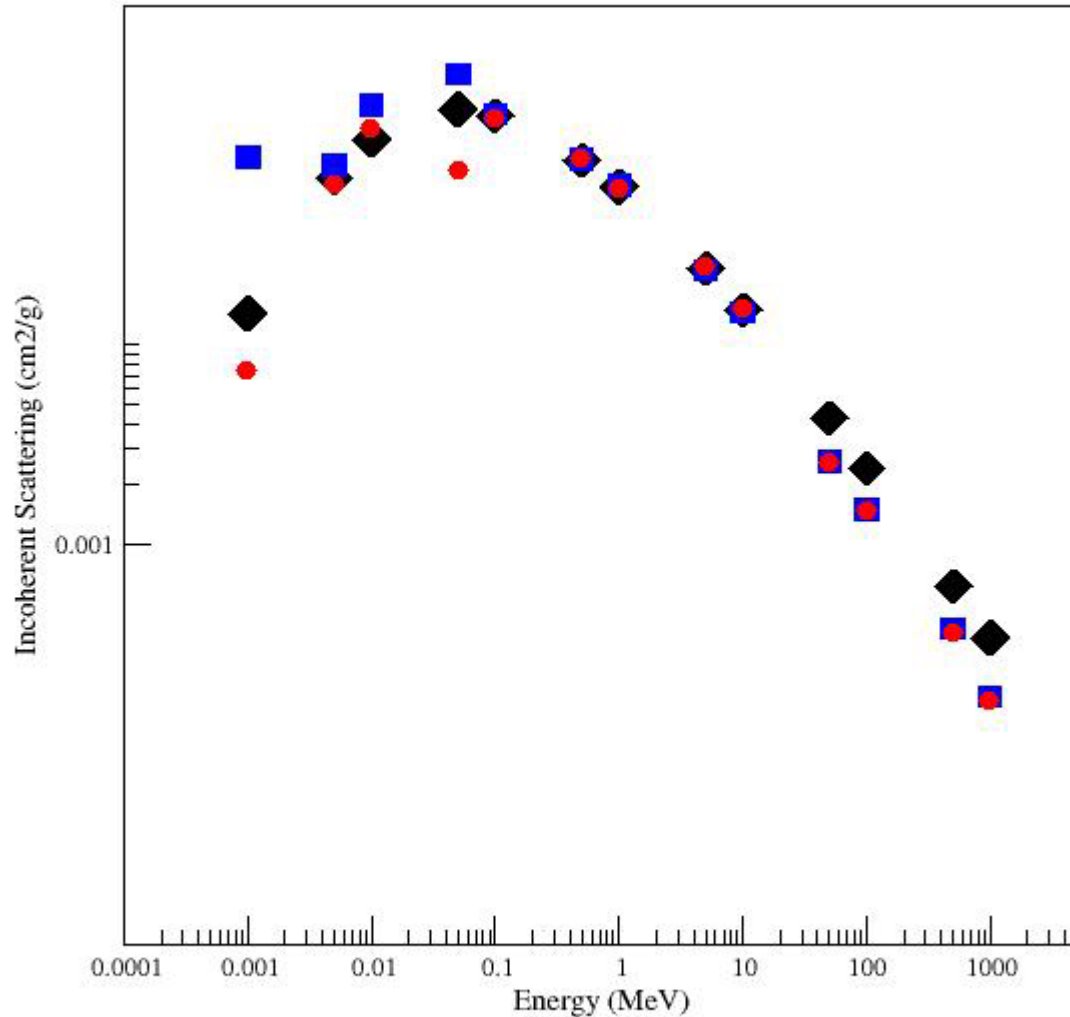
Absorber Materials:

Be, Al, Si, Ge, Fe, Cs, Au, Pb, U

Compton Scattering - Al

Photons - Incoherent Scattering - Aluminium

(Geant4-05-02)



$$\chi^2_{N-L} = 12.9 - \nu=8 - p=0.12$$

$$\chi^2_{N-S} = 8.7 - \nu=6 - p=0.19$$

◆ NIST-XCOM

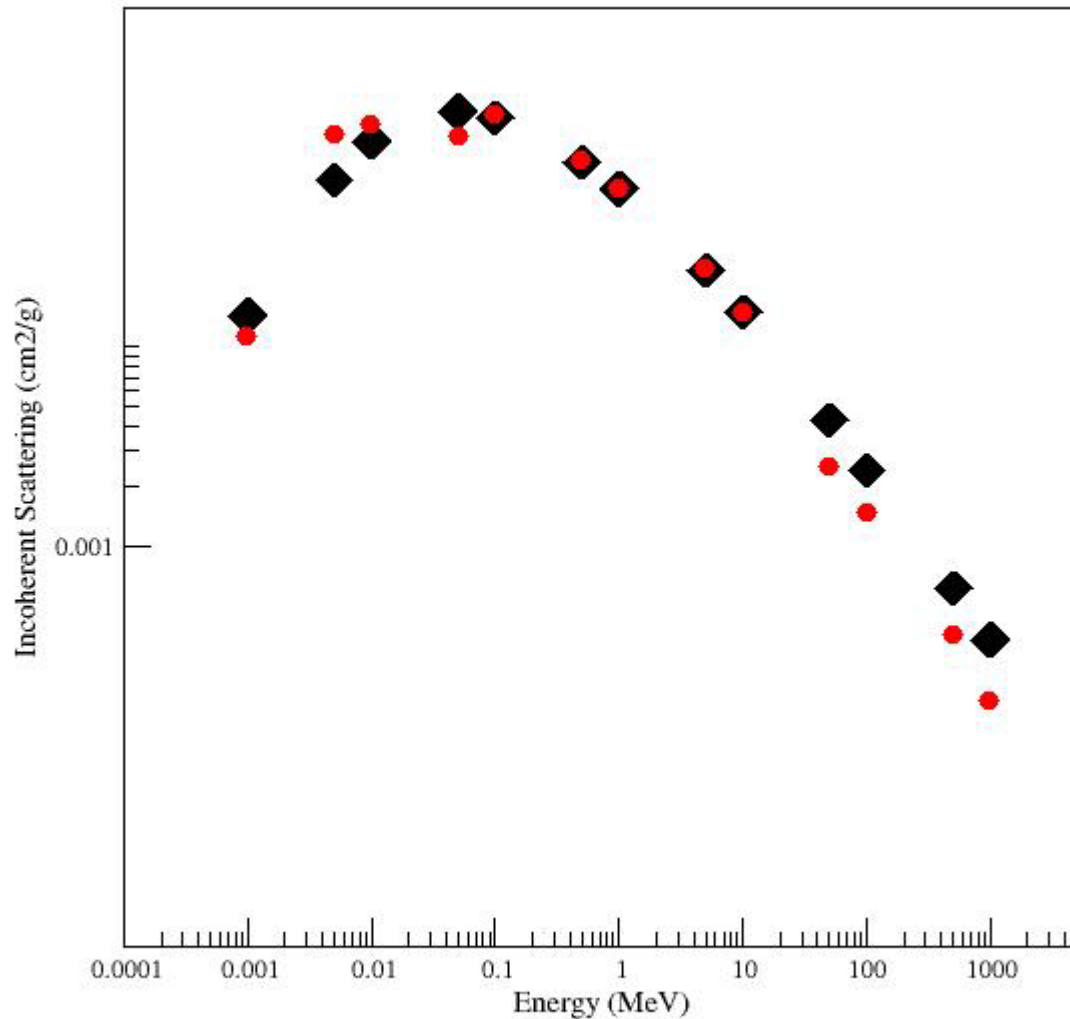
■ G4 Standard

● G4 LowE

Compton Scattering - Al

Photons - Incoherent Scattering - Aluminium

(Geant4-05-02)



NIST-XCOM



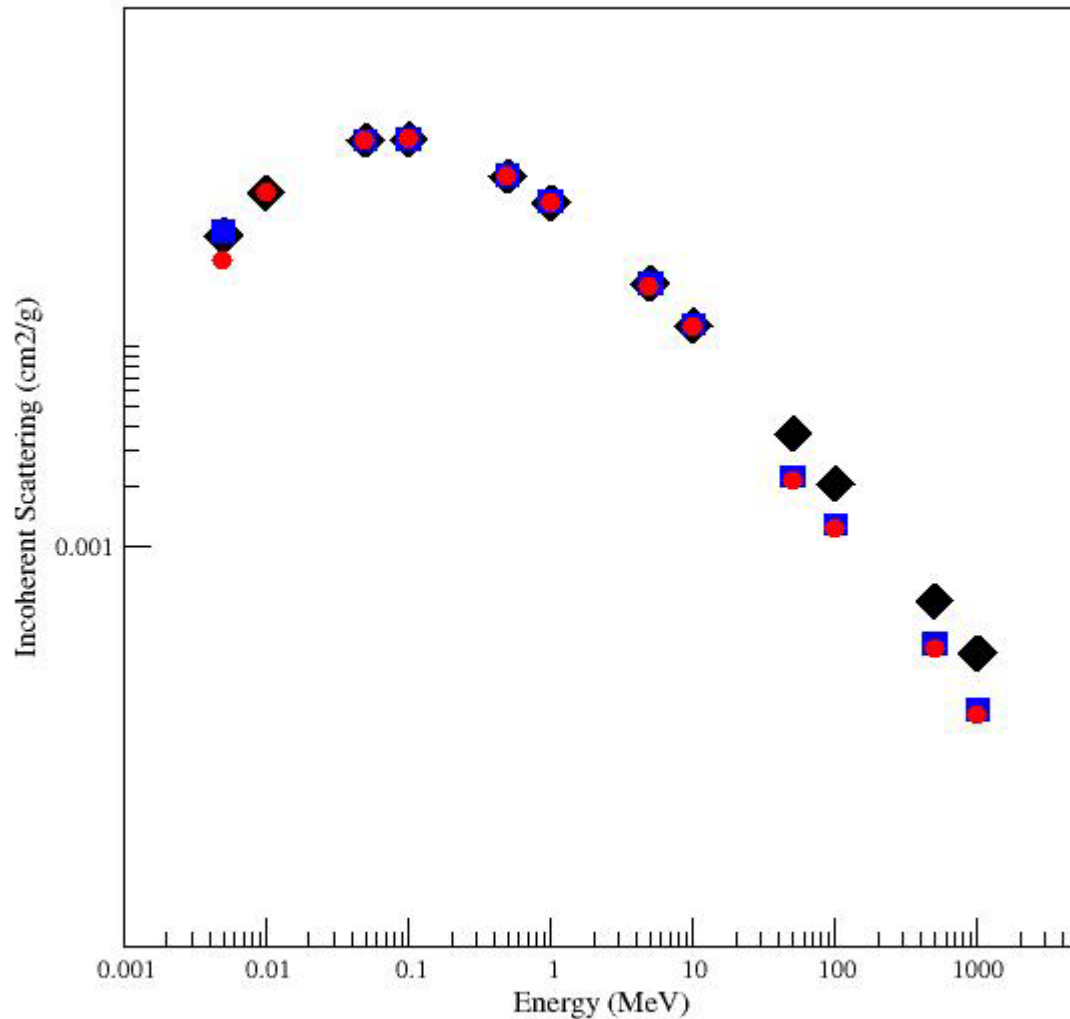
G4 LowE Penelope

$$\chi^2_{N-P}=2.5 - \nu=6 - p=0.87$$

Compton Scattering - Cs

Photons - Incoherent Scattering - Cesium

(Geant4-05-02)



$$\chi^2_{N-L}=4.6 - \nu=8 - p=0.80$$

$$\chi^2_{N-S}=1.8 - \nu=8 - p=0.99$$

◆ NIST-XCOM

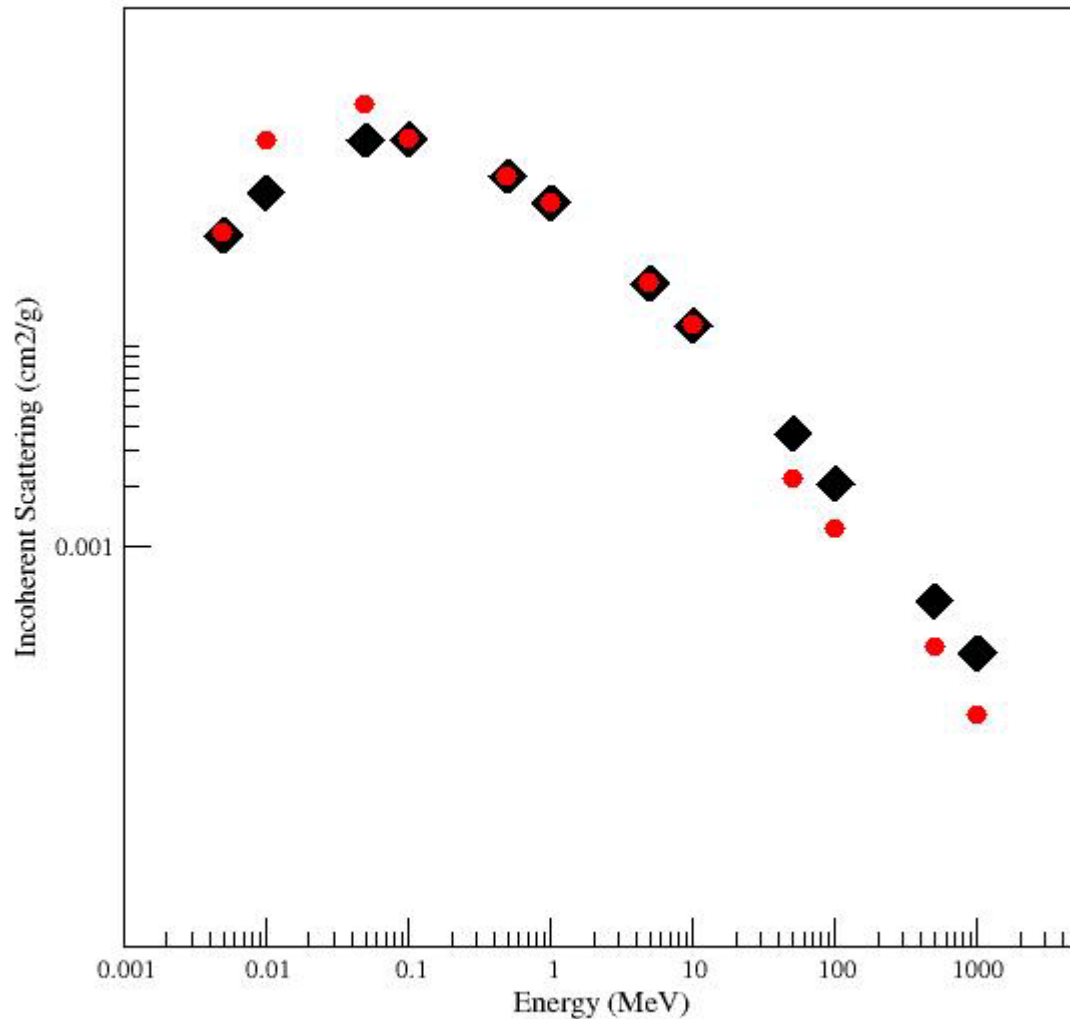
■ G4 Standard

● G4 LowE

Compton Scattering - Cs

Photons - Incoherent Scattering - Cesium

(Geant4-05-02)



NIST-XCOM



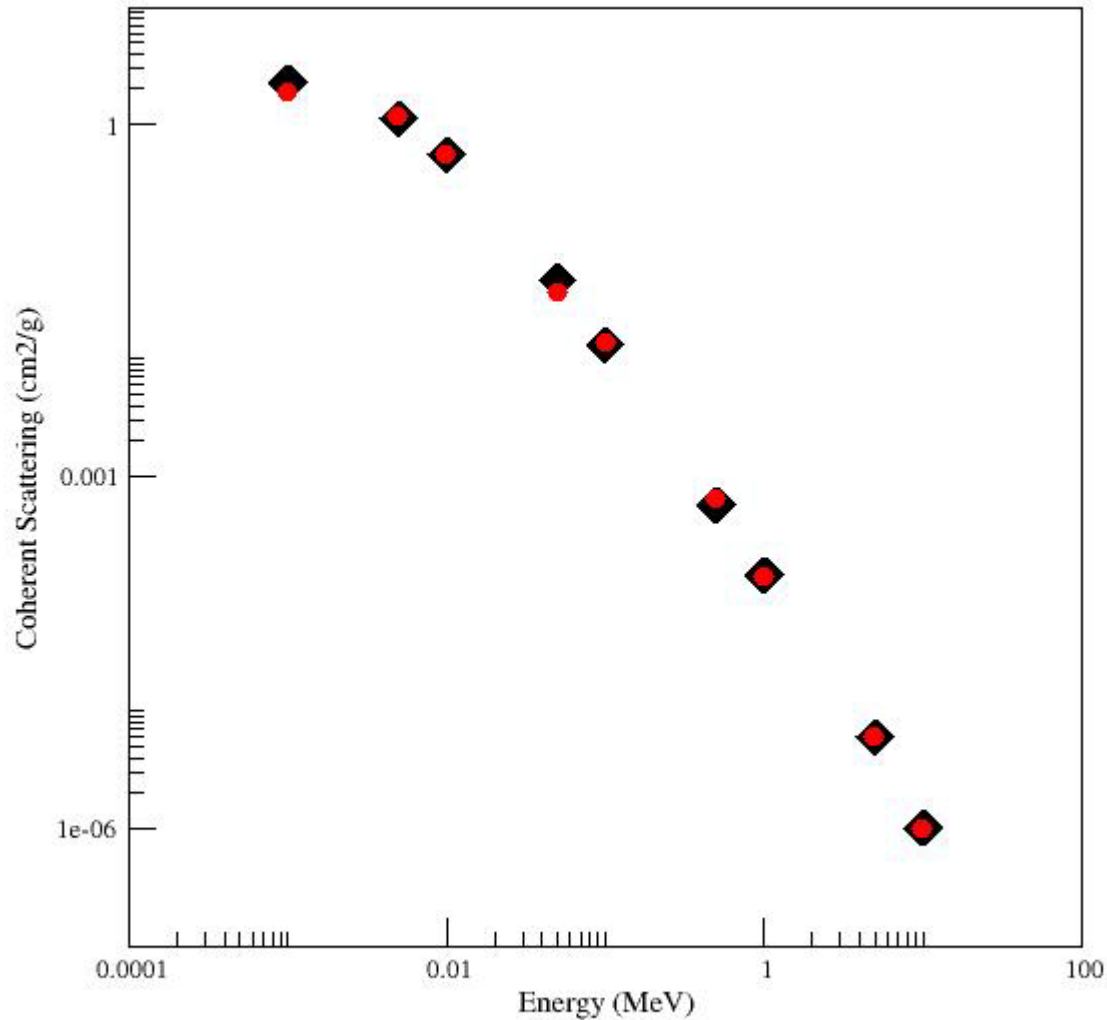
G4 LowE Penelope

$$\chi^2_{N-P} = 4.6 - \nu = 8 - p = 0.80$$

Rayleigh Scattering - Al

Photons - Coherent Scattering - Aluminium

(Geant4-05-02)



$$\chi^2_{N-L} = 13.6 - \nu = 11 - p = 0.26$$



NIST-XCOM

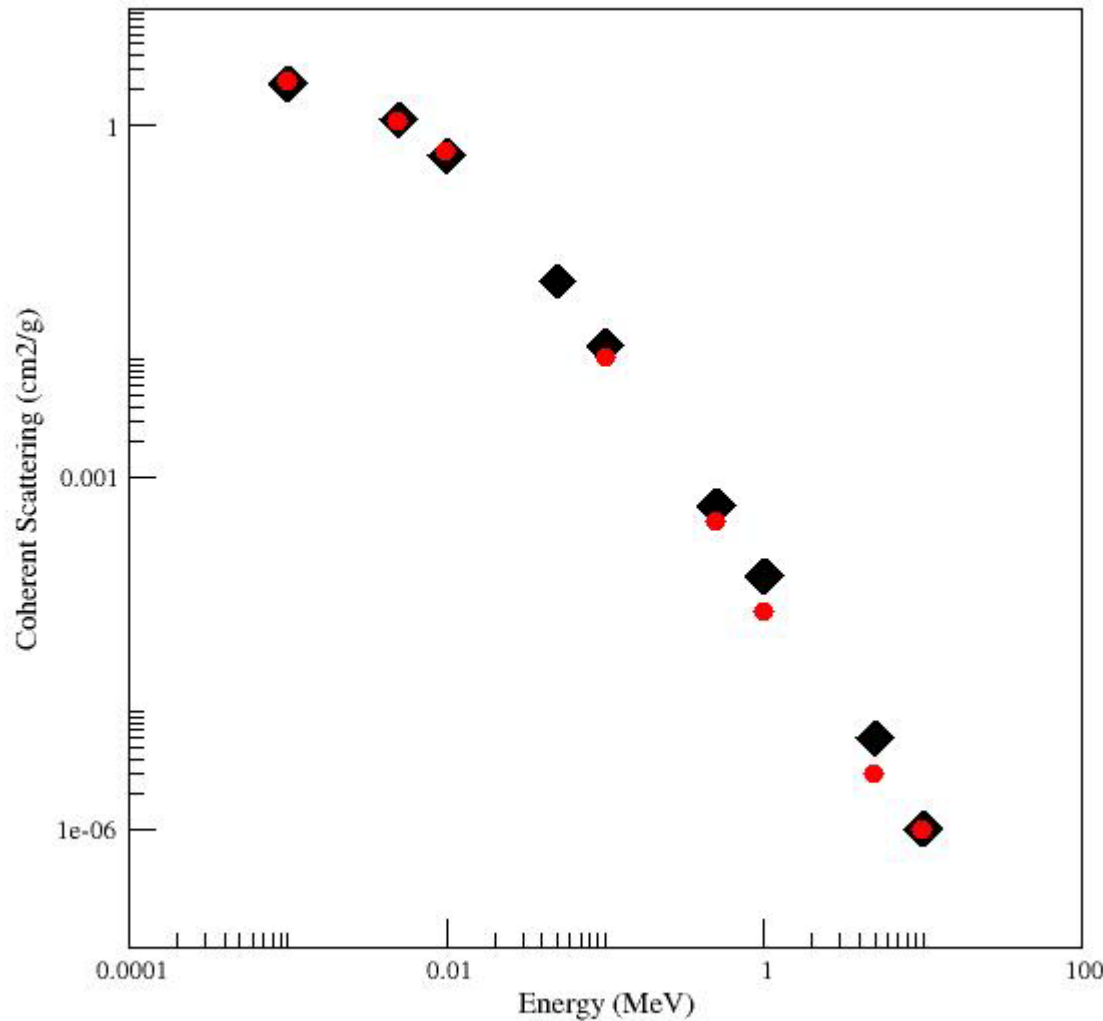


G4 LowE

Rayleigh Scattering - Al

Photons - Coherent Scattering - Aluminium

(Geant4-05-02)



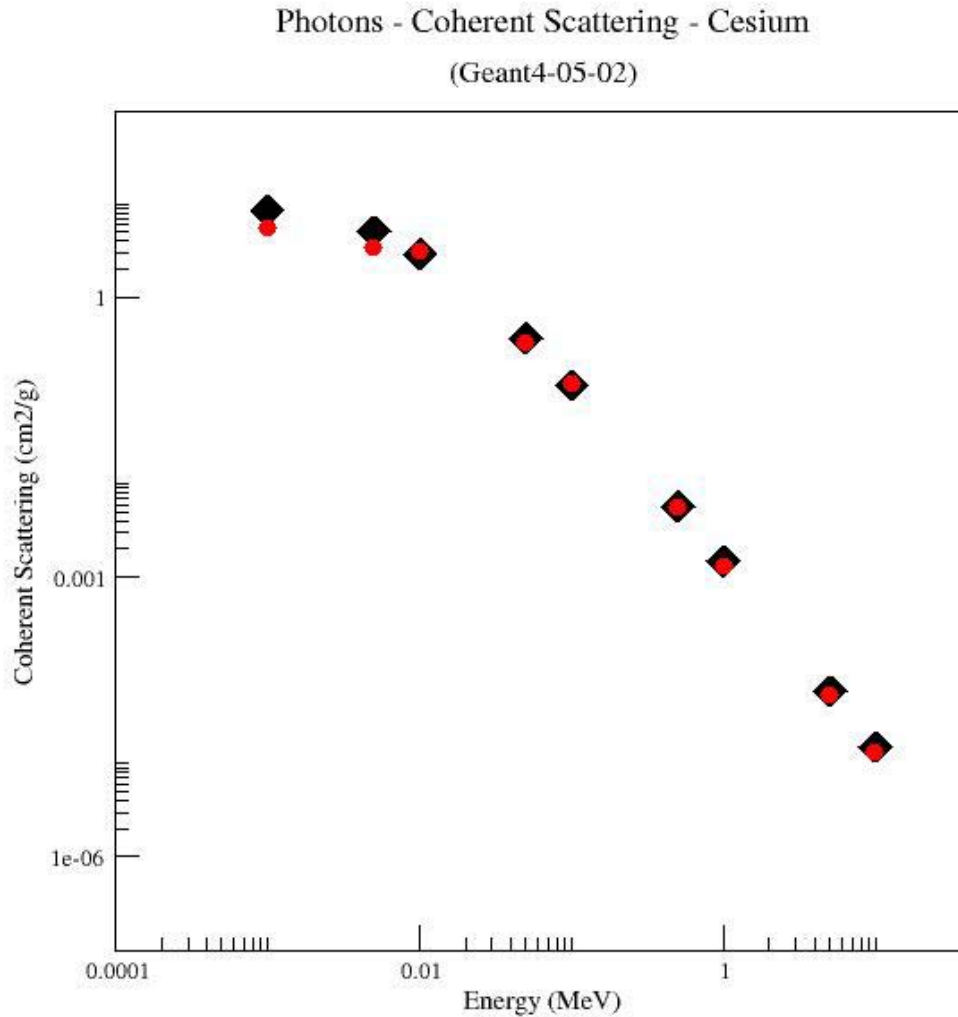
NIST-XCOM



G4 LowE Penelope

$$\chi^2_{N-P}=7.2 - \nu=8 - p=0.52$$

Rayleigh Scattering - Cs

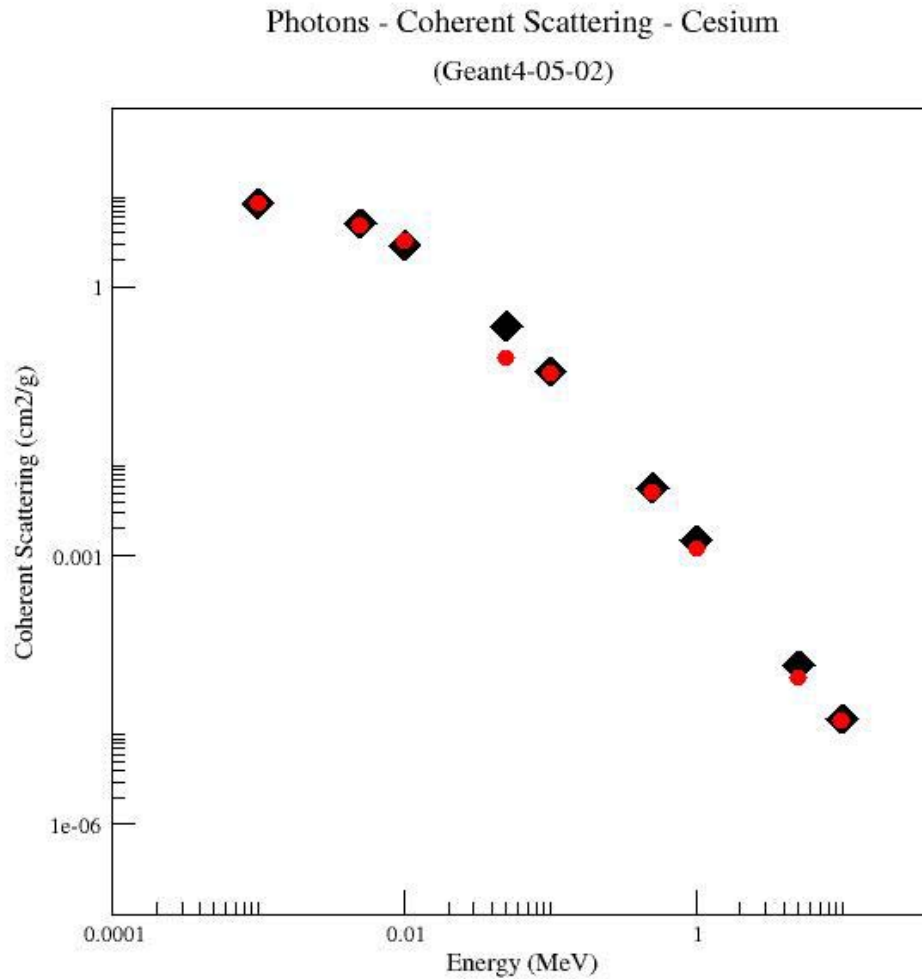


NIST-XCOM



G4 LowE

Raleygh Scattering - Cs



NIST-XCOM

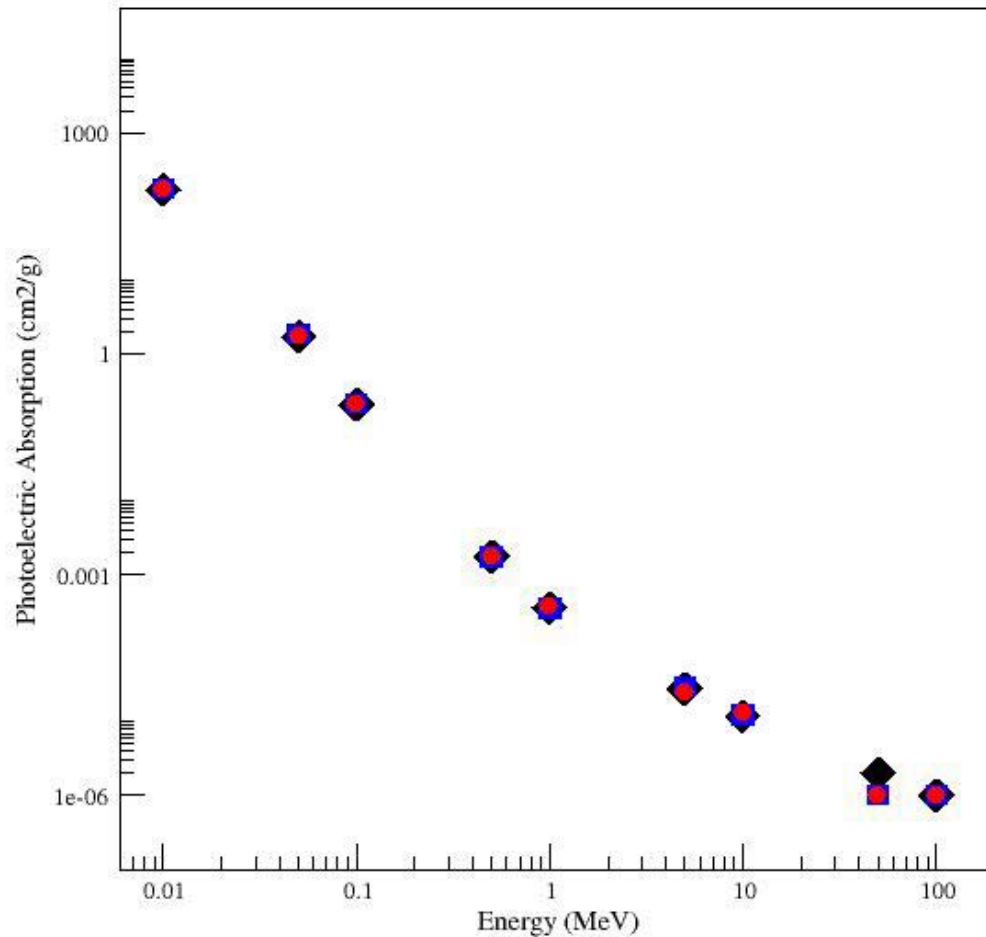


G4 LowE Penelope

Photoelectric Effect - Fe

Photons - Photoelectric Absorption - Iron

(Geant4-05-02)



NIST-XCOM

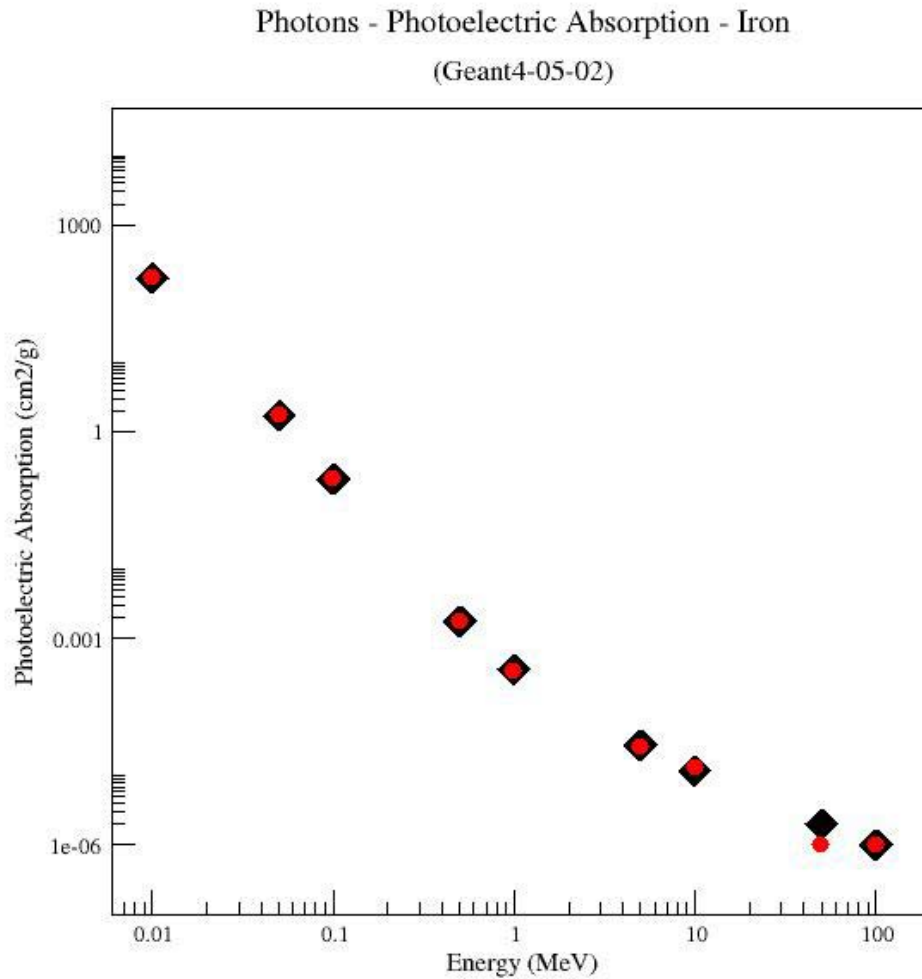


G4 Standard



G4 LowE

Photoelectric effect - Fe

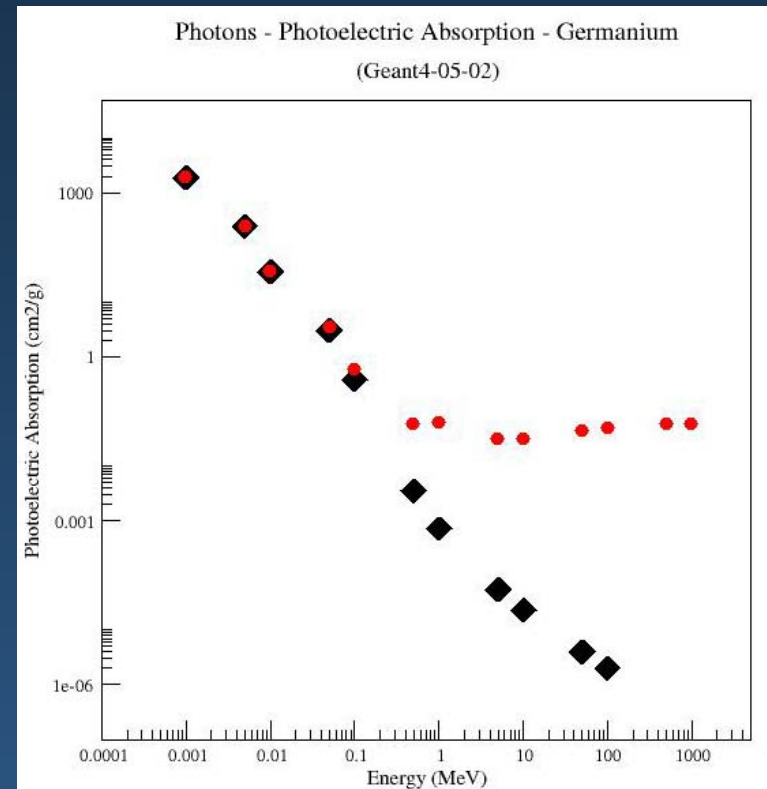
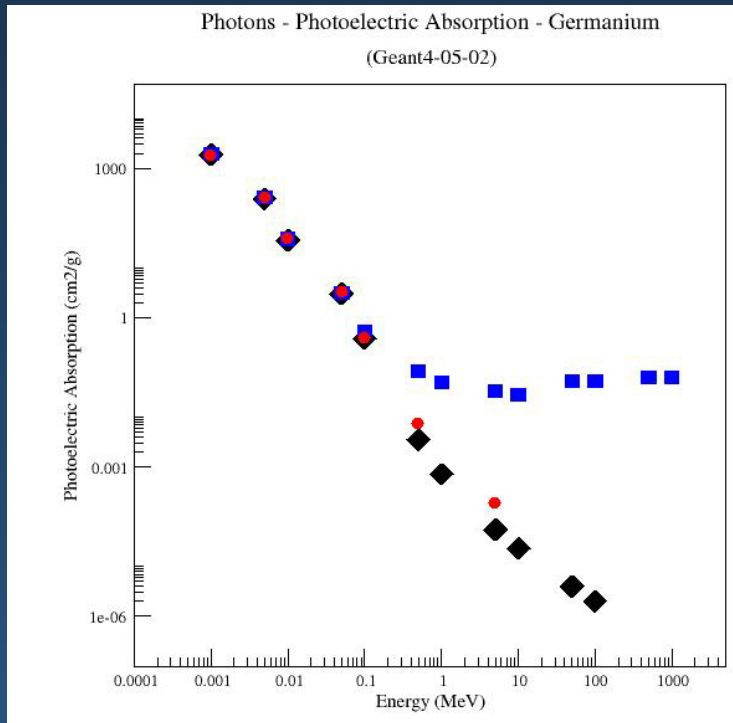


NIST-XCOM



G4 LowE Penelope

Photoelectric Absorption - Ge



◆ NIST-XCOM

■ G4 Standard

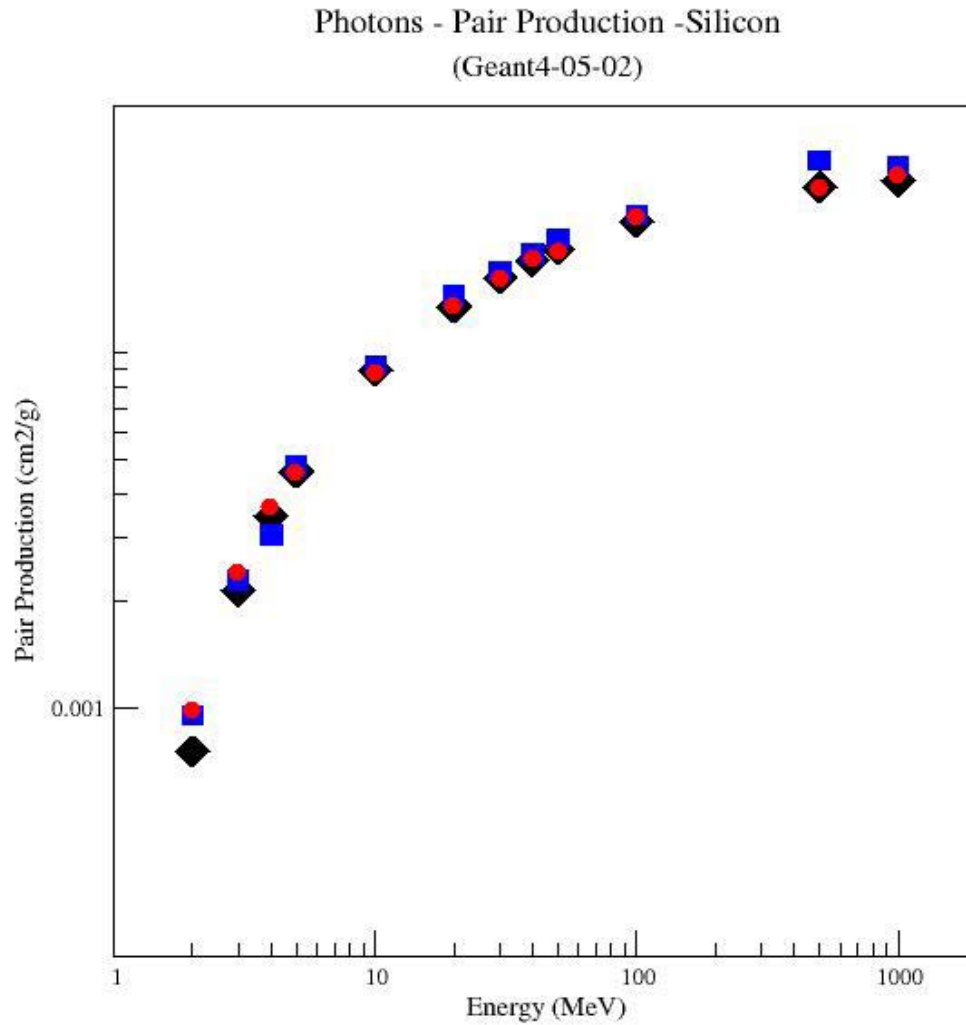
● G4 LowE

◆ NIST-XCOM

● G4 LowE Penelope

2 compatible Monte Carlo
are not necessarily the Truth!

Pair Production - Si

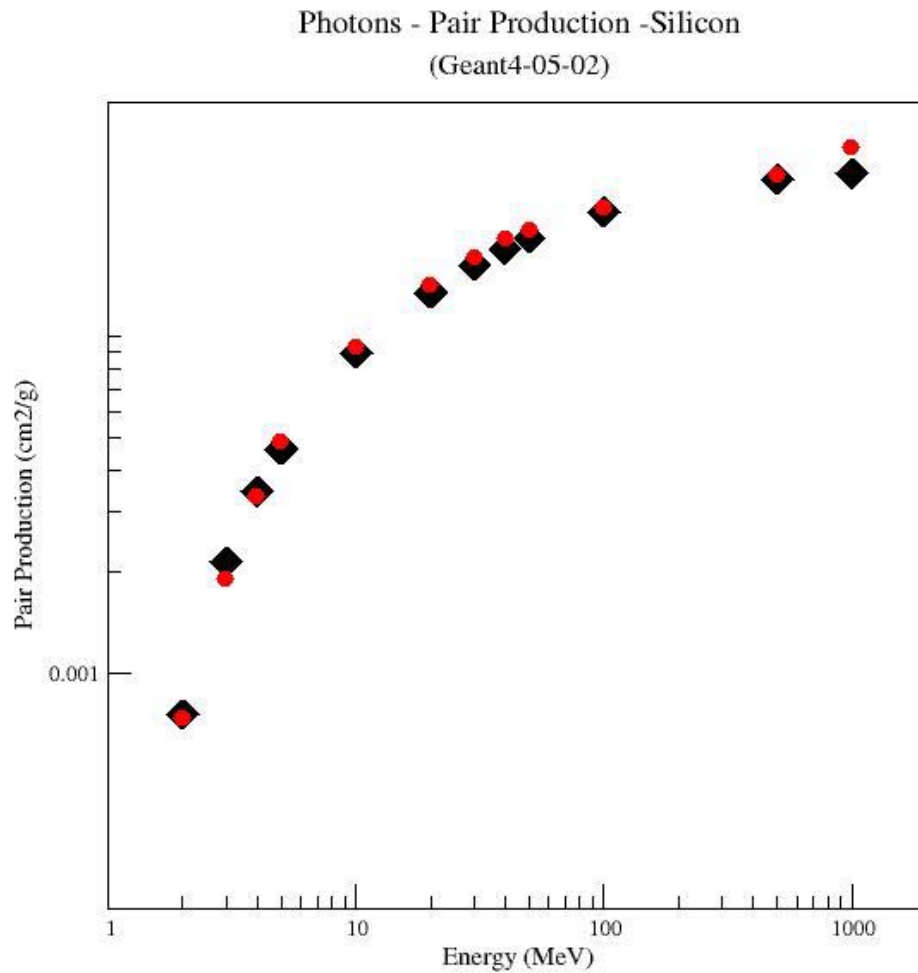


◆ NIST-XCOM

■ G4 Standard

● G4 LowE

Pair Production - Si



NIST-XCOM



G4 LowE Penelope

Test results

CSDA range and Stopping Power for electrons

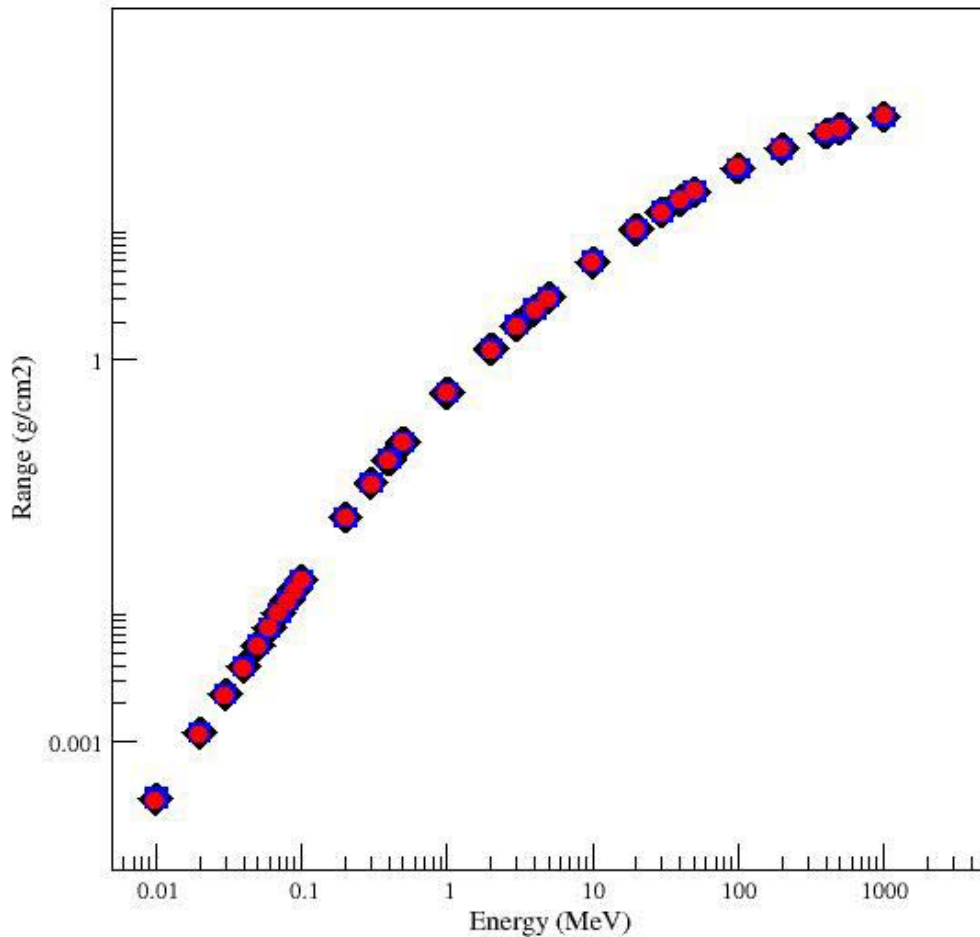
- no multiple scattering
- no energy fluctuations

Absorber Materials:

Be, Al, Si, Ge, Fe, Cs, Au, Pb, U

CSDA Range - Al

Electrons - CSDA Range - Aluminium
(Geant4-05-02)



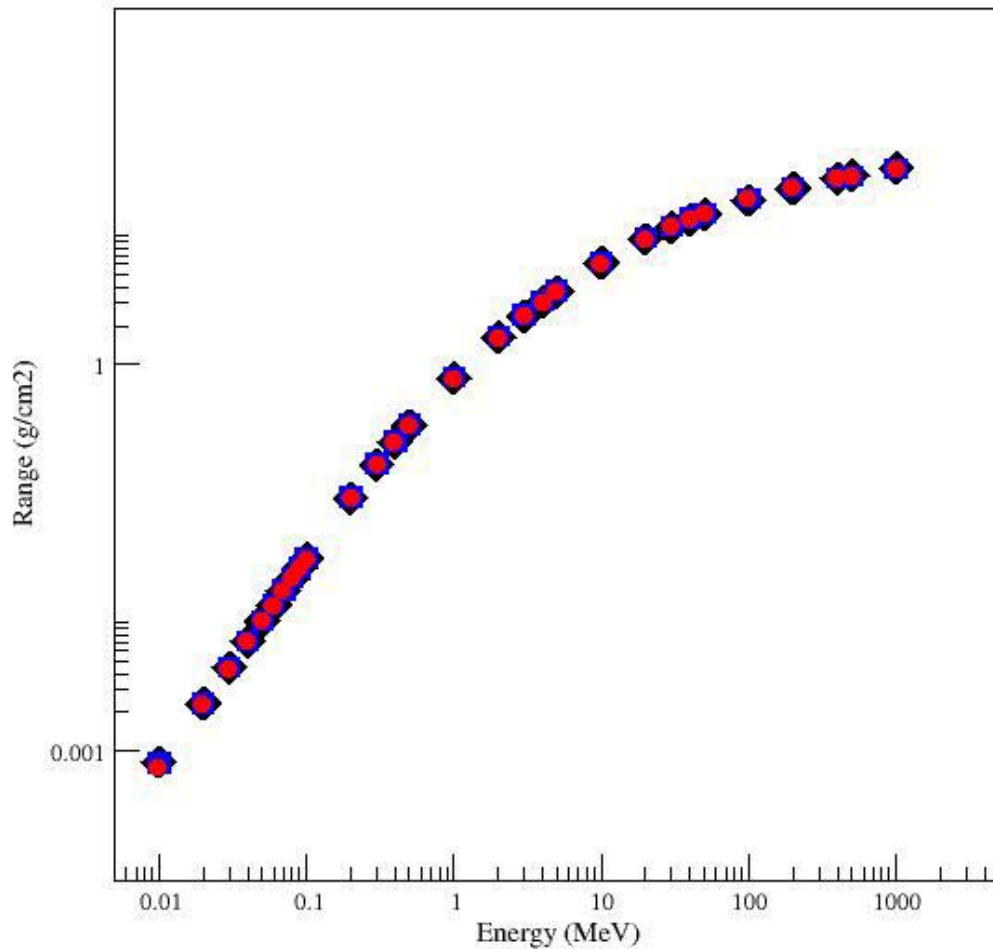
◆ NIST-ESTAR

■ G4 Standard

● G4 LowE

CSDA Range - Pb

Electrons - CSDA Range - Lead
(Geant4-05-02)



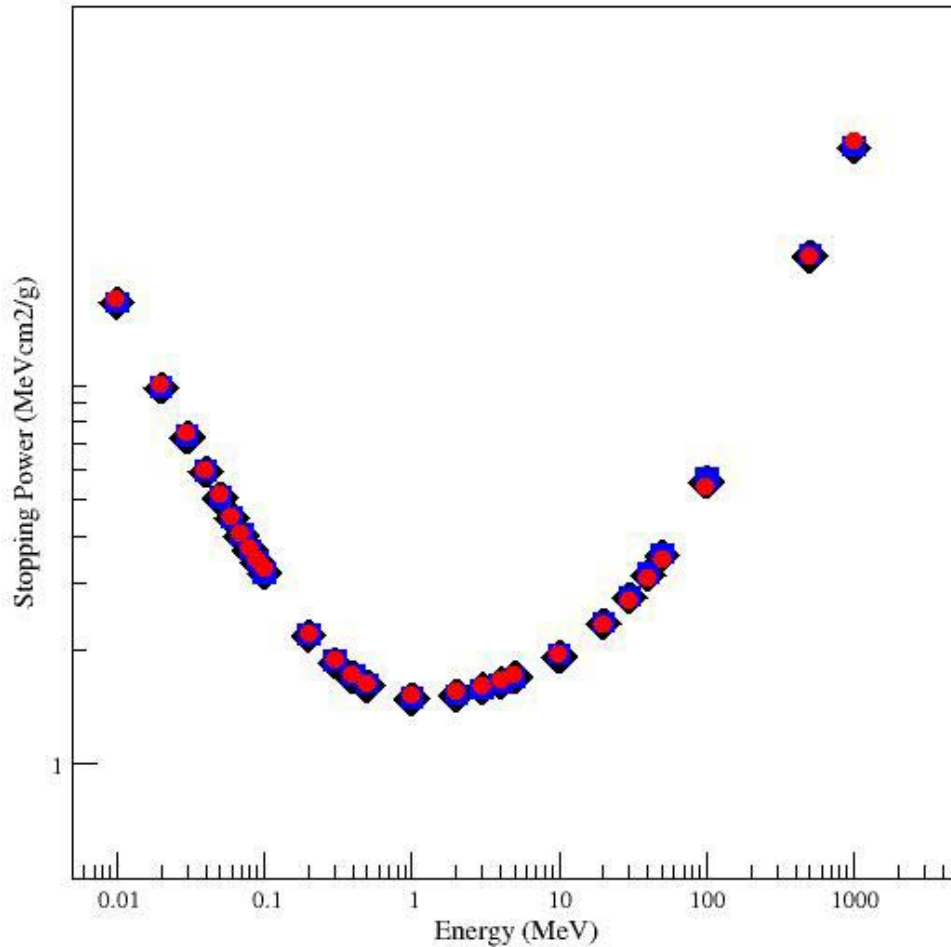
◆ NIST-ESTAR

■ G4 Standard

● G4 LowE

Stopping Power - Al

Electrons - Stopping Power - Aluminium
(Geant4-05-02)



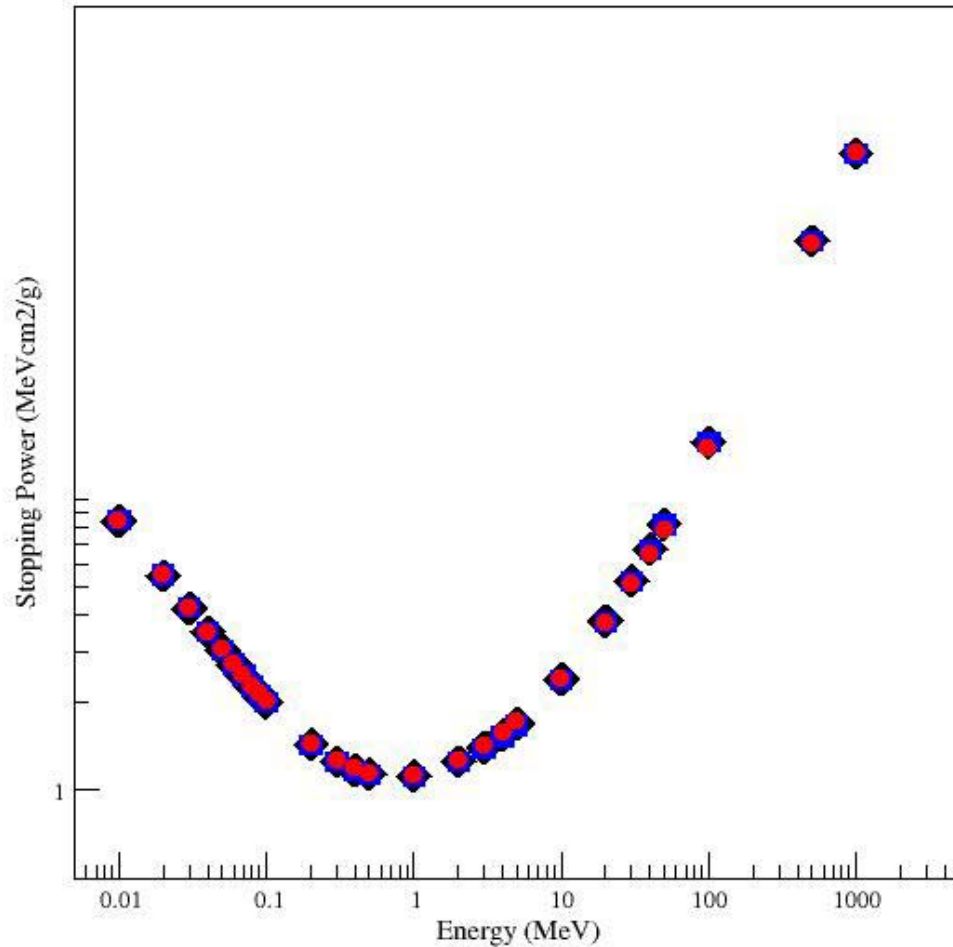
◆ NIST-ESTAR

■ G4 Standard

● G4 LowE

Stopping Power - Pb

Electrons - Stopping Power - Lead
(Geant4-05-02)



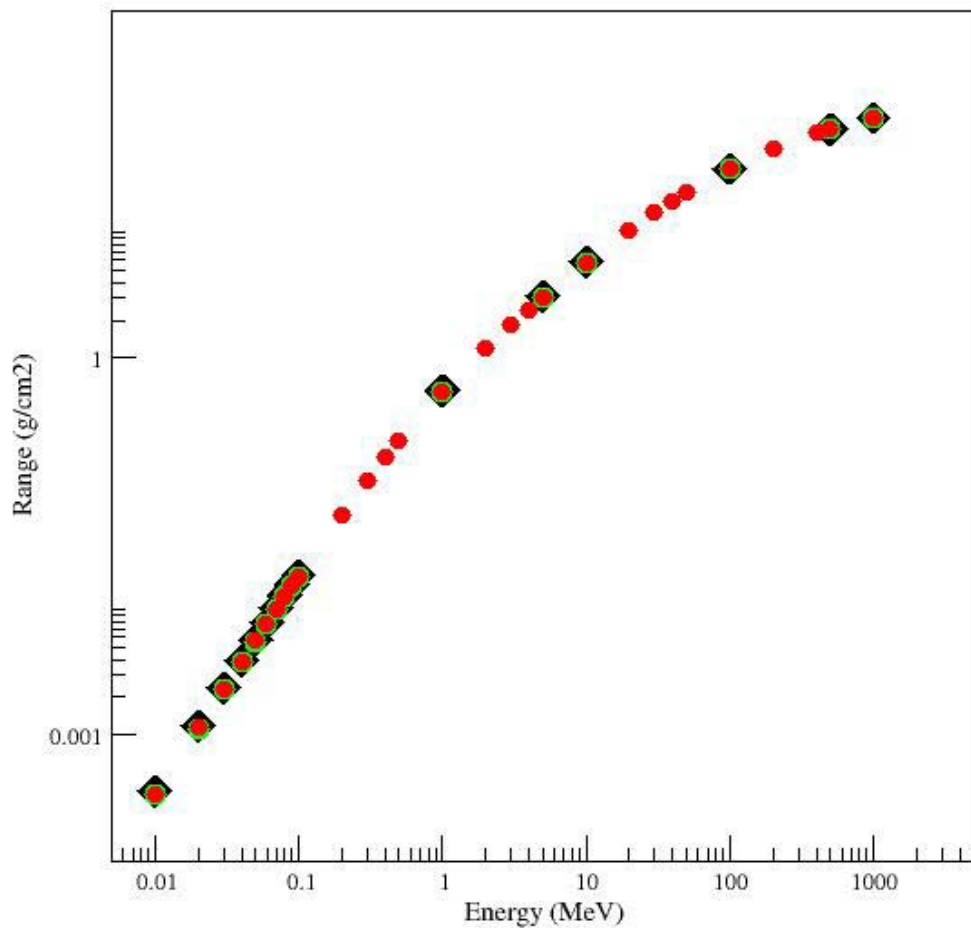
◆ NIST-ESTAR

■ G4 Standard

● G4 LowE

CSDA Range - Al - G4LowE

Electrons - CSDA Range - Aluminium
Regression Testing - G4LowE



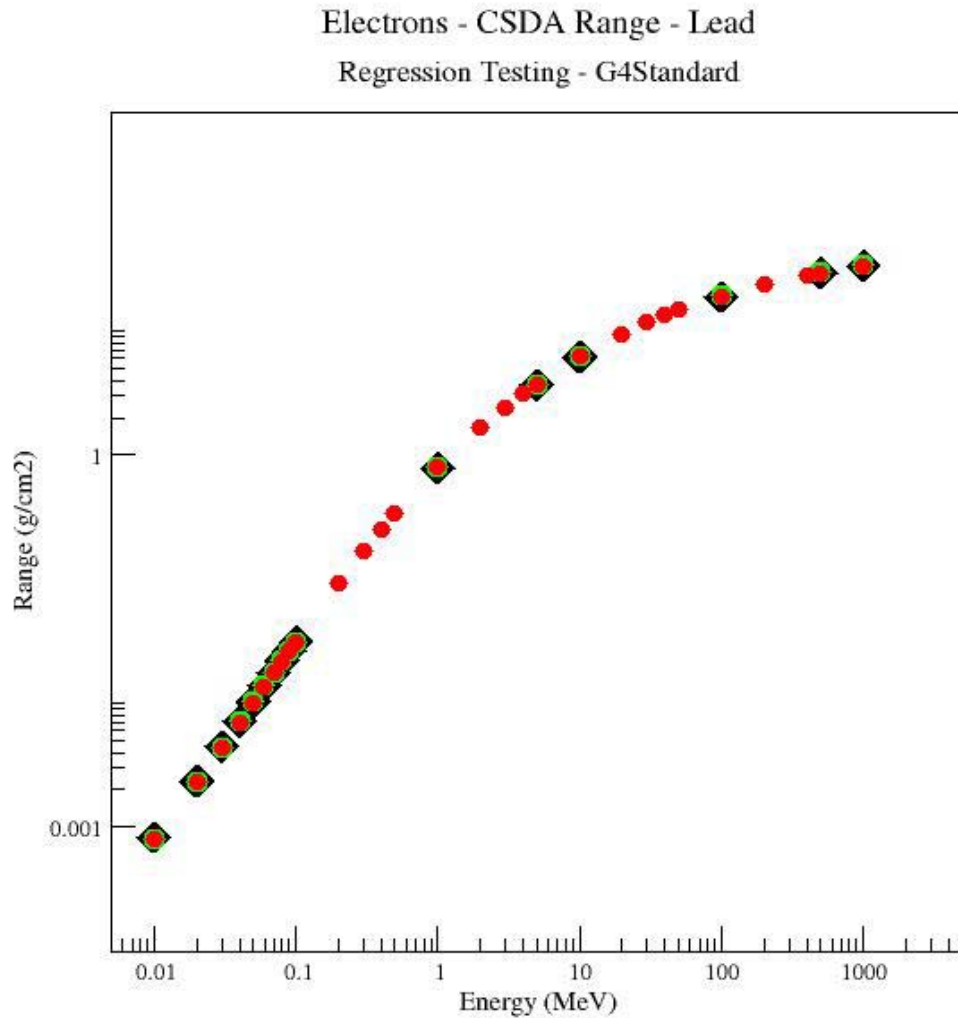
Regression testing

◆ NIST-ESTAR

● Geant4-05-00

● Geant4-05-02

CSDA Range - Pb -G4Standard



Regression
testing



NIST-ESTAR



Geant4-05-00



Geant4-05-02

Test results

CSDA range and Stopping Power for protons

- no multiple scattering
- no energy fluctuations

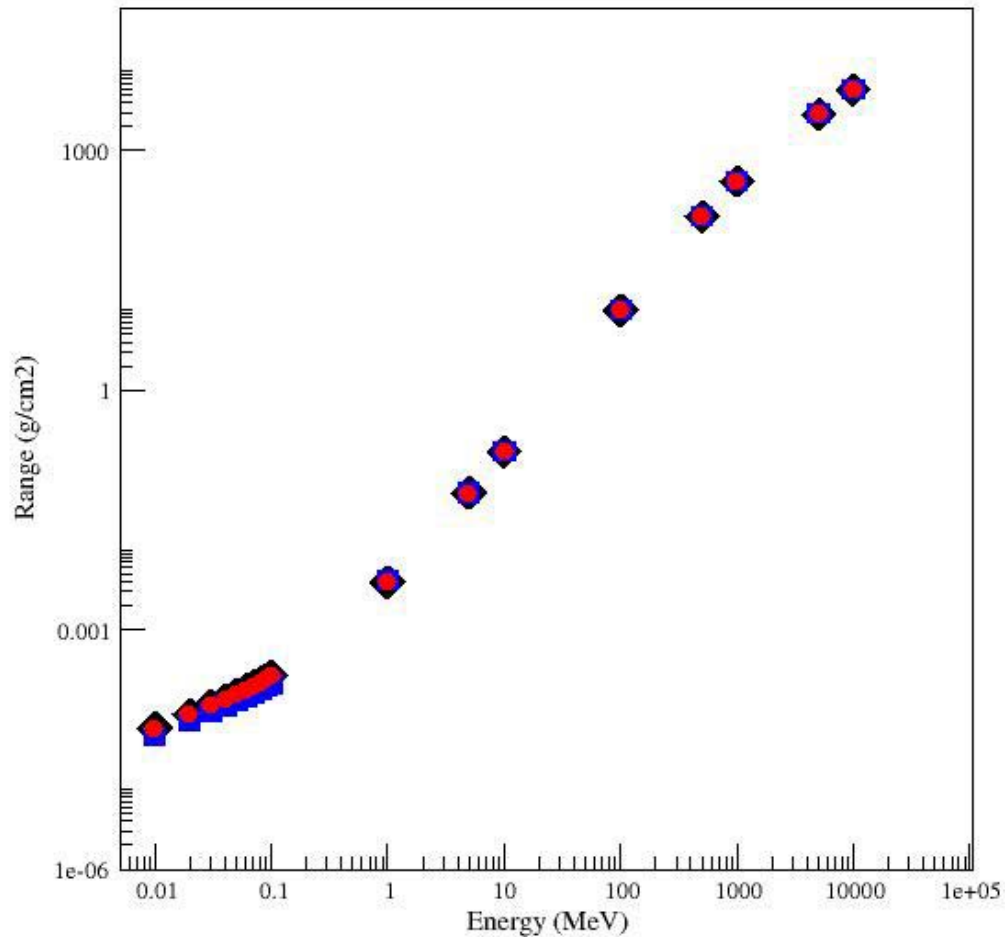
Absorber Materials:

Be, Al, Si, Ge, Fe, Cs, Au, Pb, U

CSDA Range Al

Protons - CSDA Range - Aluminium

(Geant4-05-02)



NIST-PSTAR



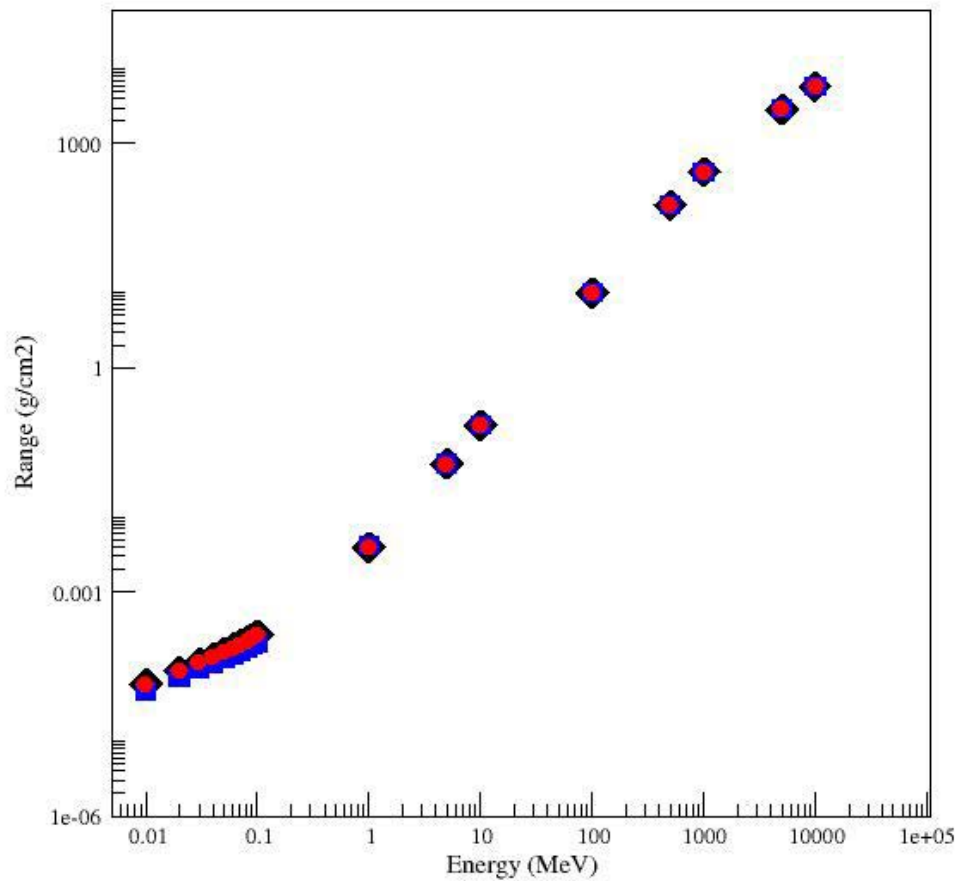
G4 Standard



G4 LowE

CSDA Range Al

Protons - CSDA Range - Aluminium
(Geant4-05-02)



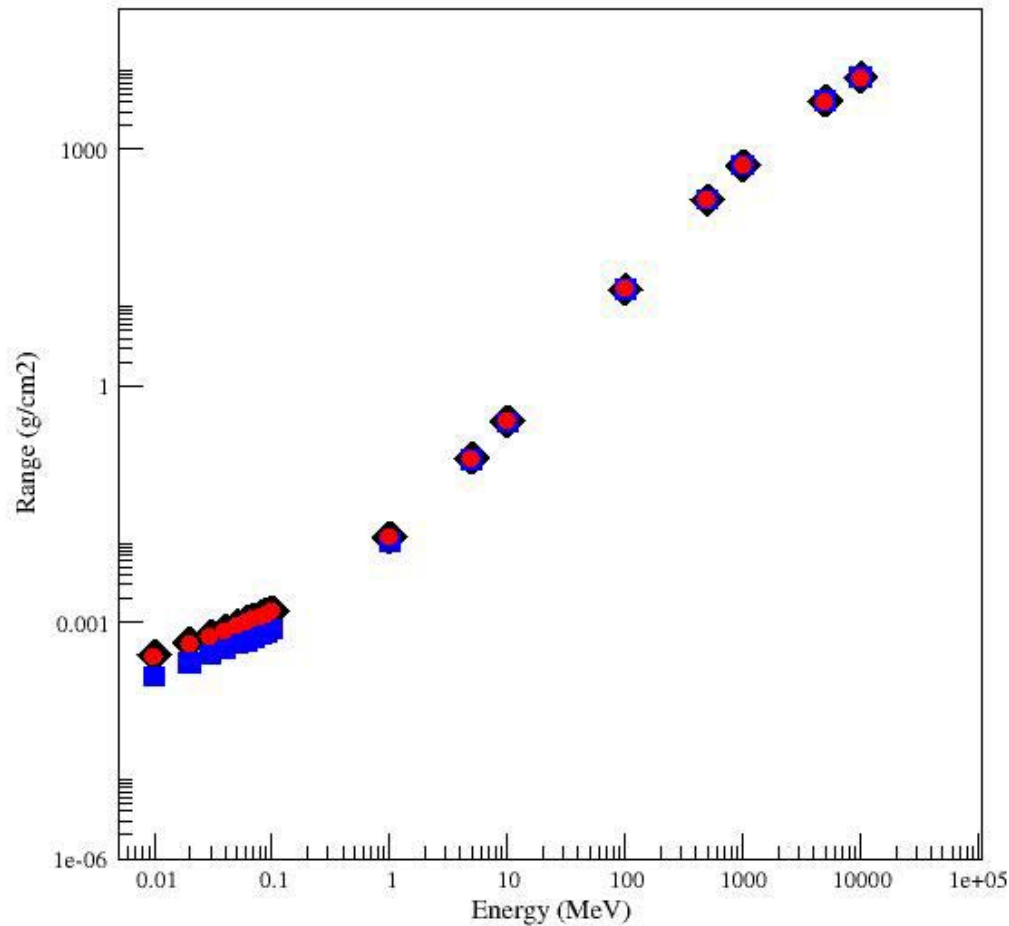
◆ NIST-PSTAR

■ G4 Standard

● G4 LowE

CSDA Range Pb

Protons - CSDA Range - Lead
(Geant4-05-02)



NIST-PSTAR

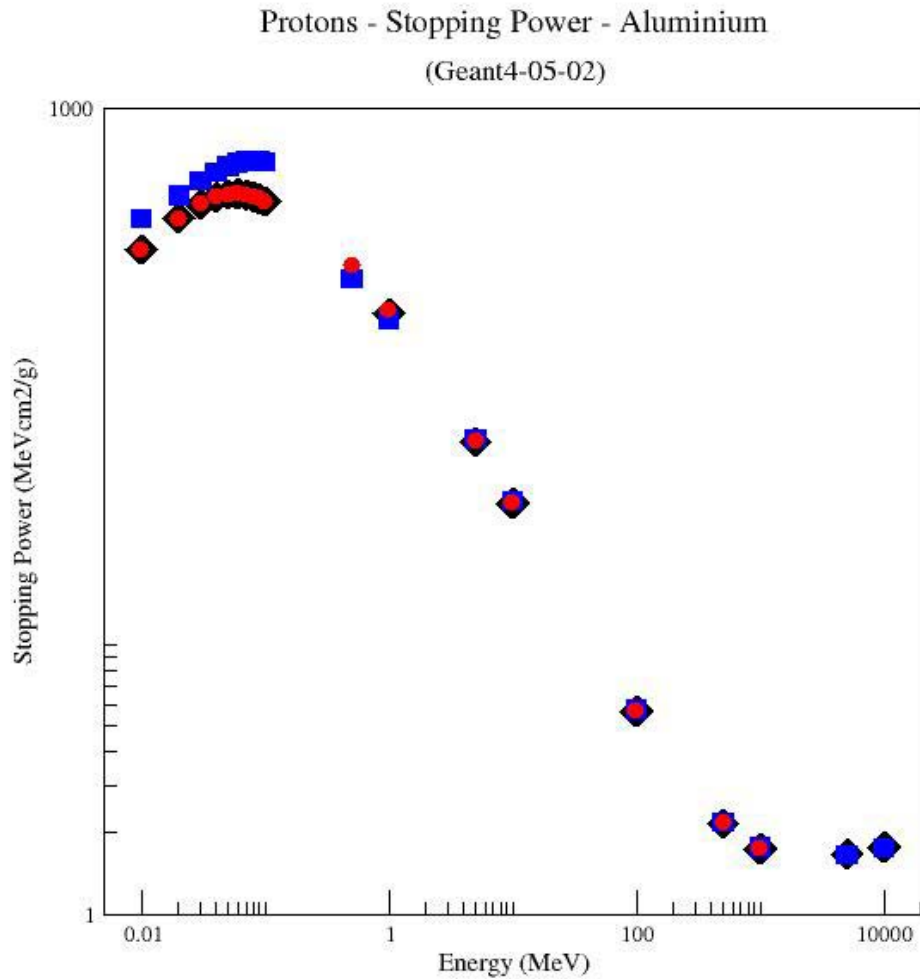


G4 Standard



G4 LowE

Stopping Power Al



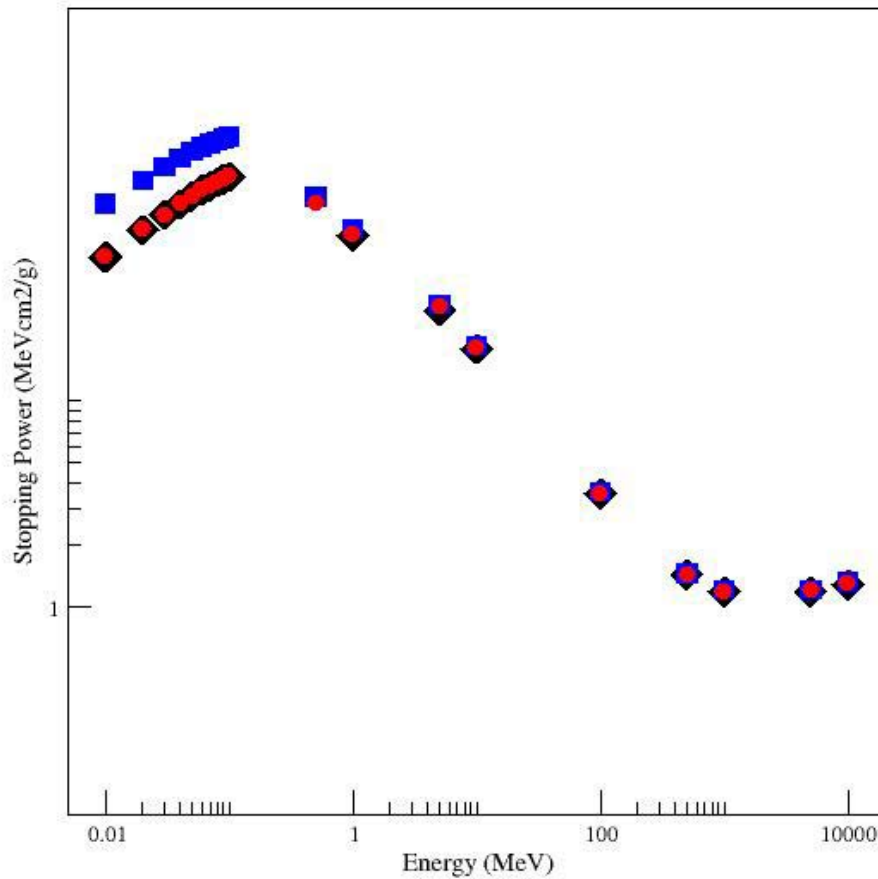
◆ NIST-PSTAR

■ G4 Standard

● G4 LowE Ziegler

Stopping Power Pb

Protons - Stopping Power - Lead
(Geant4-05-02)

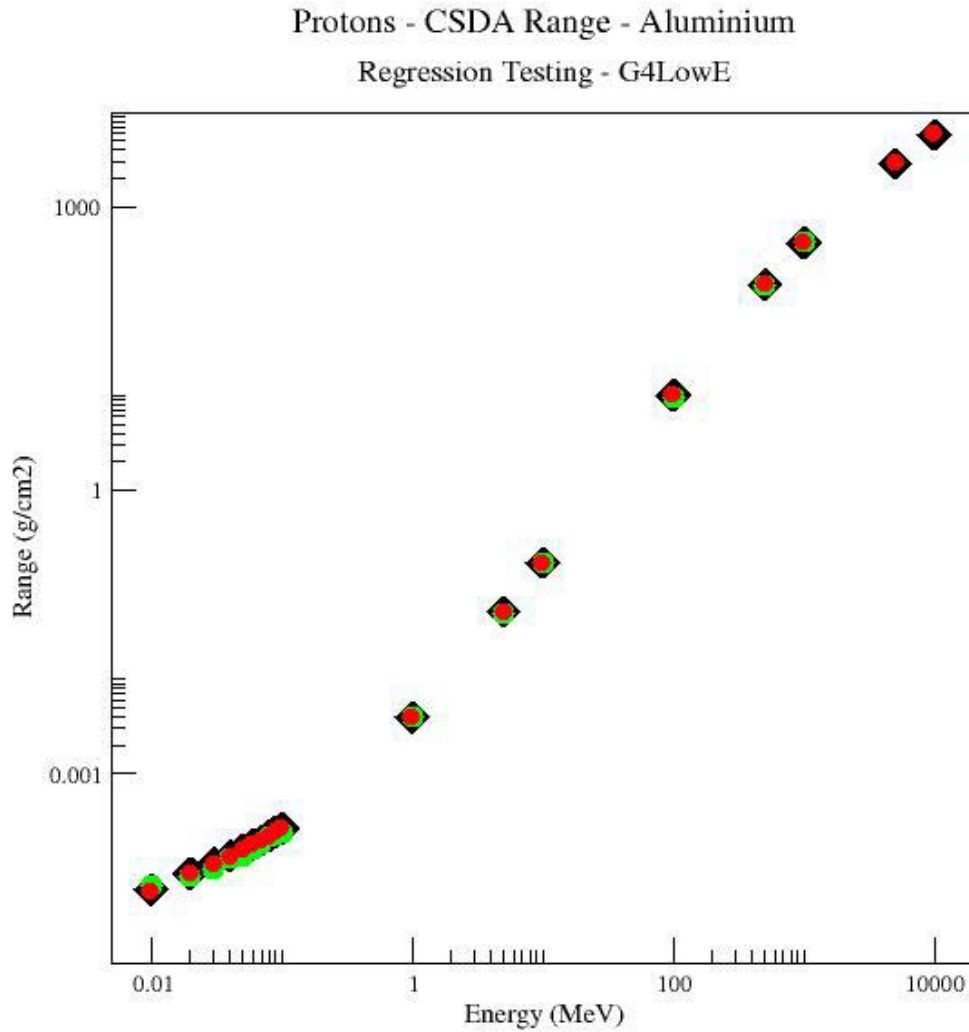


◆ NIST-PSTAR

■ G4 Standard

● G4 LowE

CSDA Range - Al - G4LowE



Regression
testing



NIST-PSTAR

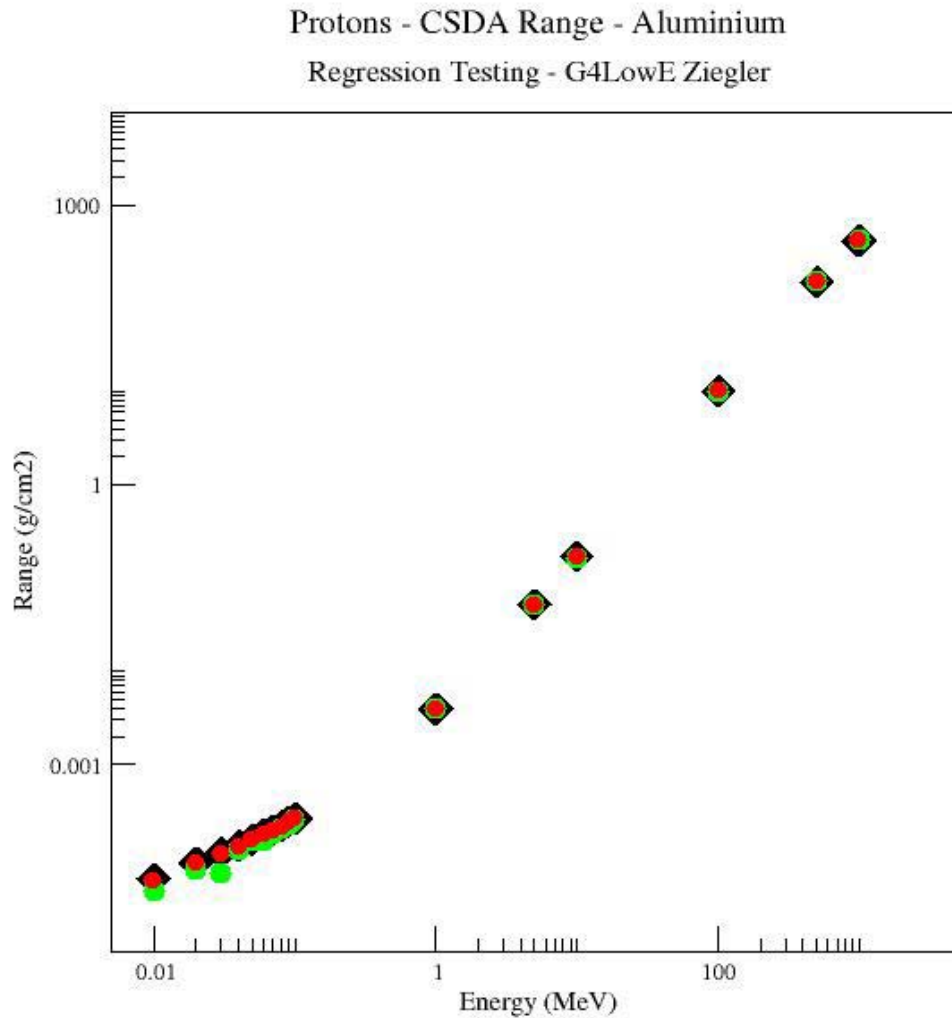


Geant4-05-00



Geant4-05-02

CSDA Range - Al - G4LowE Ziegler



Regression
testing



NIST-PSTAR

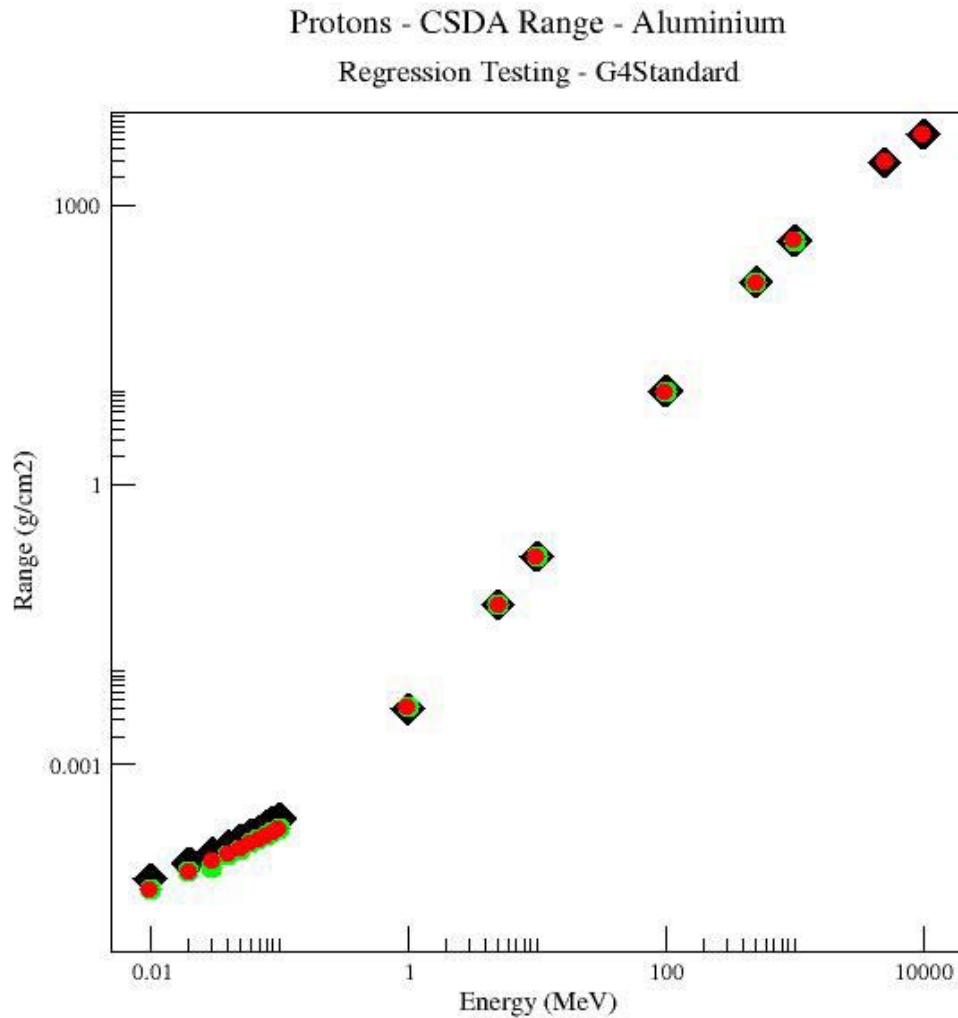


Geant4-05-00



Geant4-05-02

CSDA Range - Al - G4Standard



Regression
testing



NIST-PSTAR

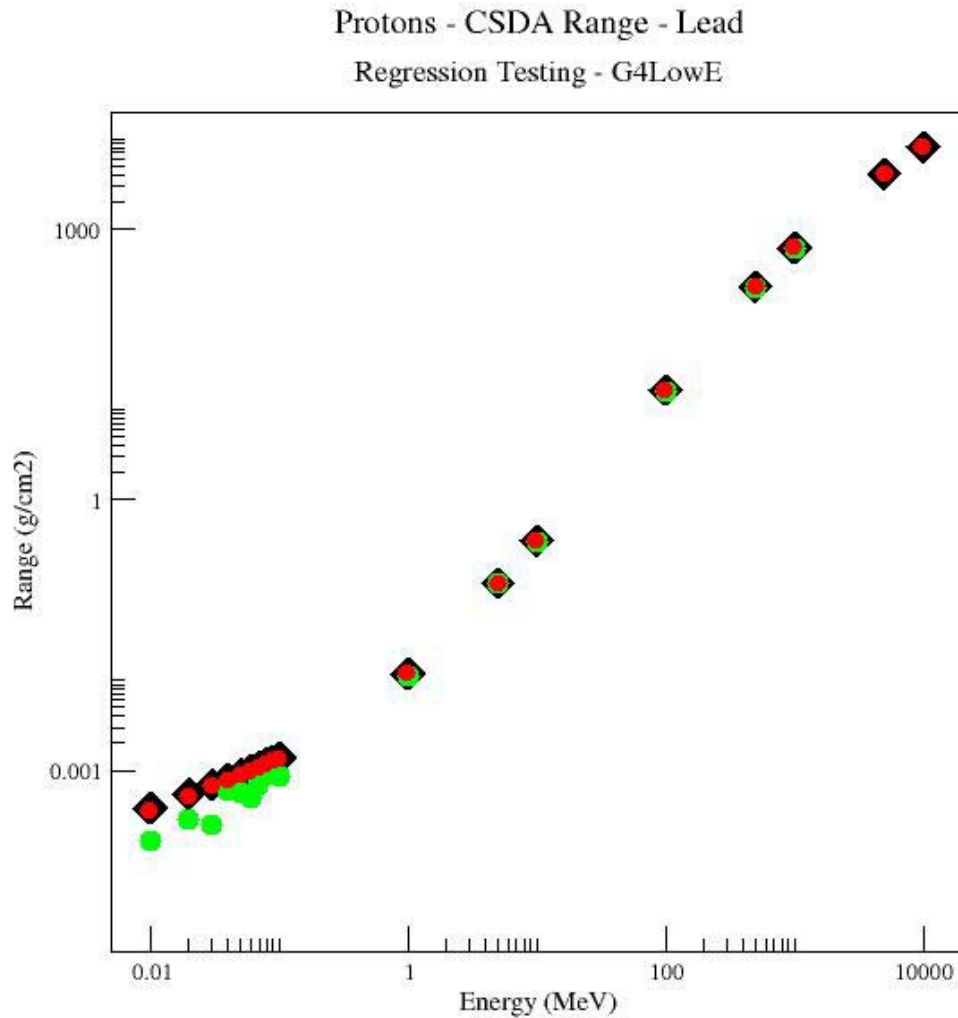


Geant4-05-00



Geant4-05-02

CSDA Range - Pb - G4LowE



Regression
testing



NIST-PSTAR

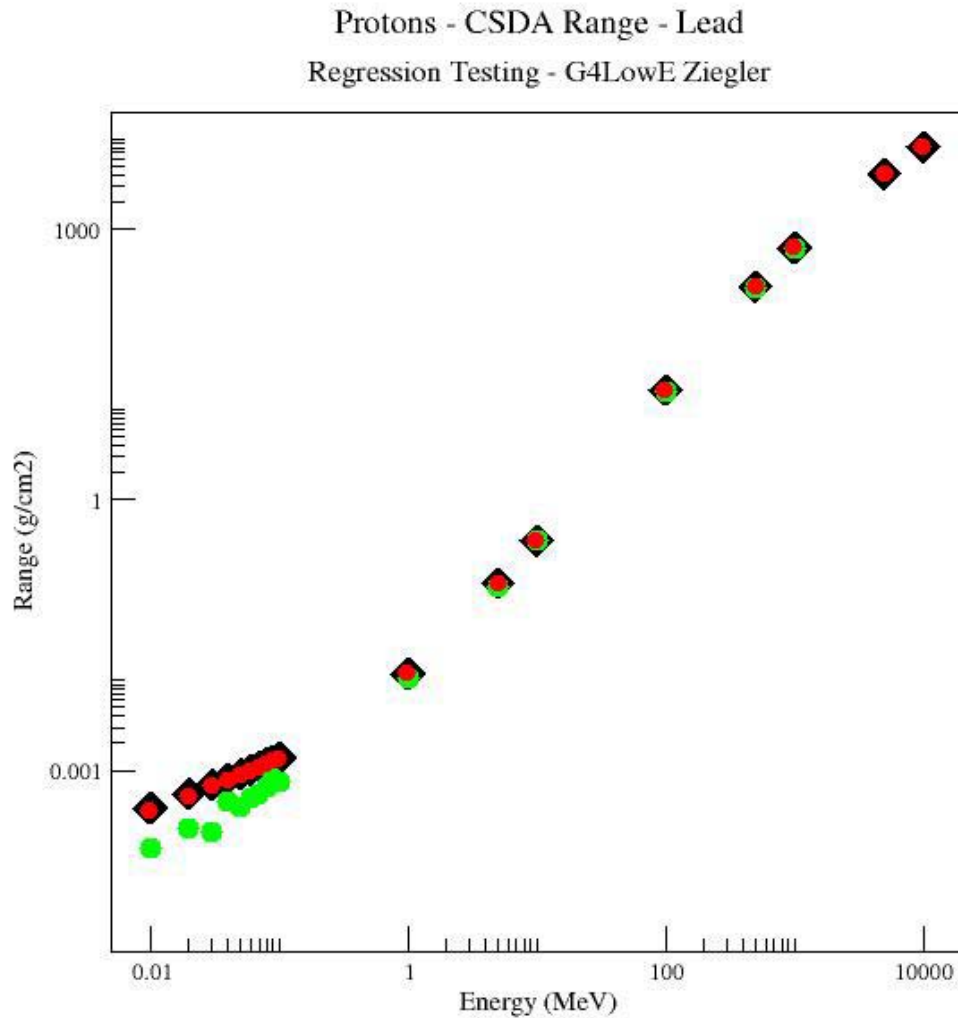


Geant4-05-00



Geant4-05-02

CSDA Range - Pb - G4LowE Ziegler



Regression
testing



NIST-PSTAR

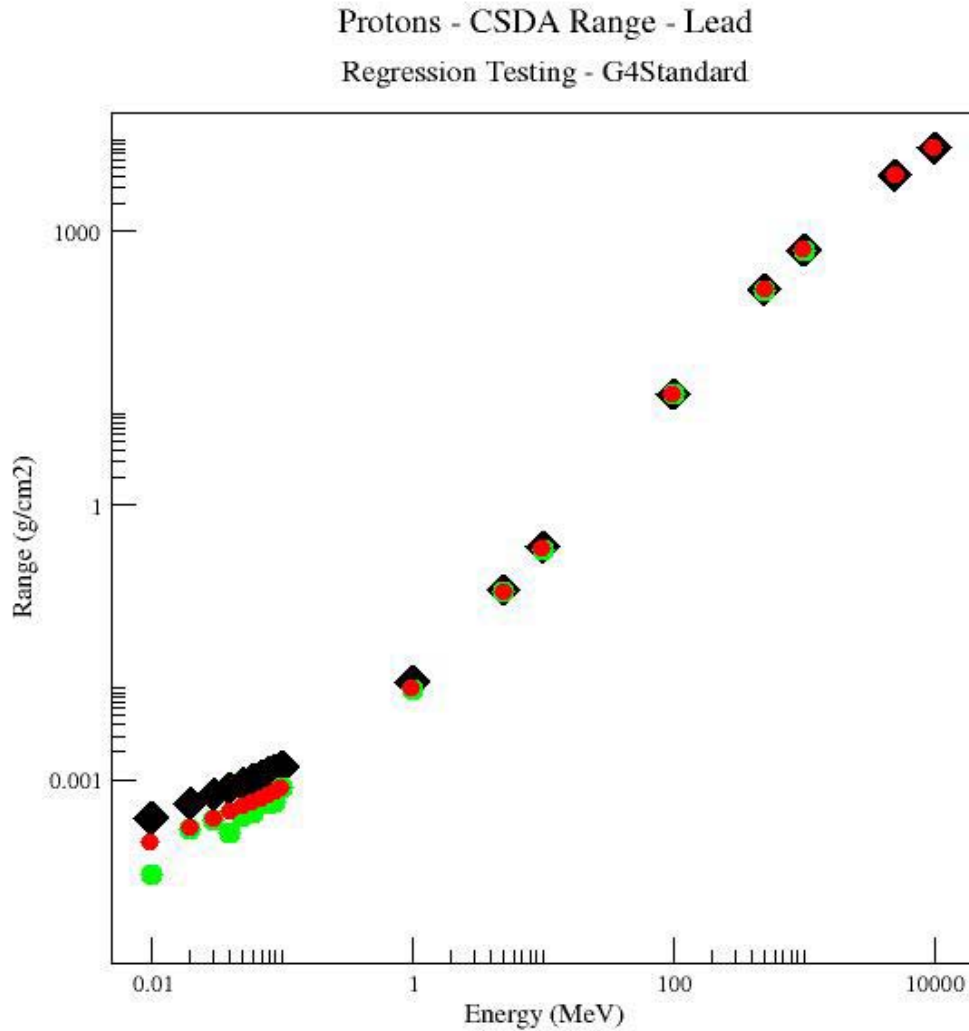


Geant4-05-00



Geant4-05-02

CSDA Range - Pb - G4Standard



Regression
testing



NIST-PSTAR



Geant4-05-00

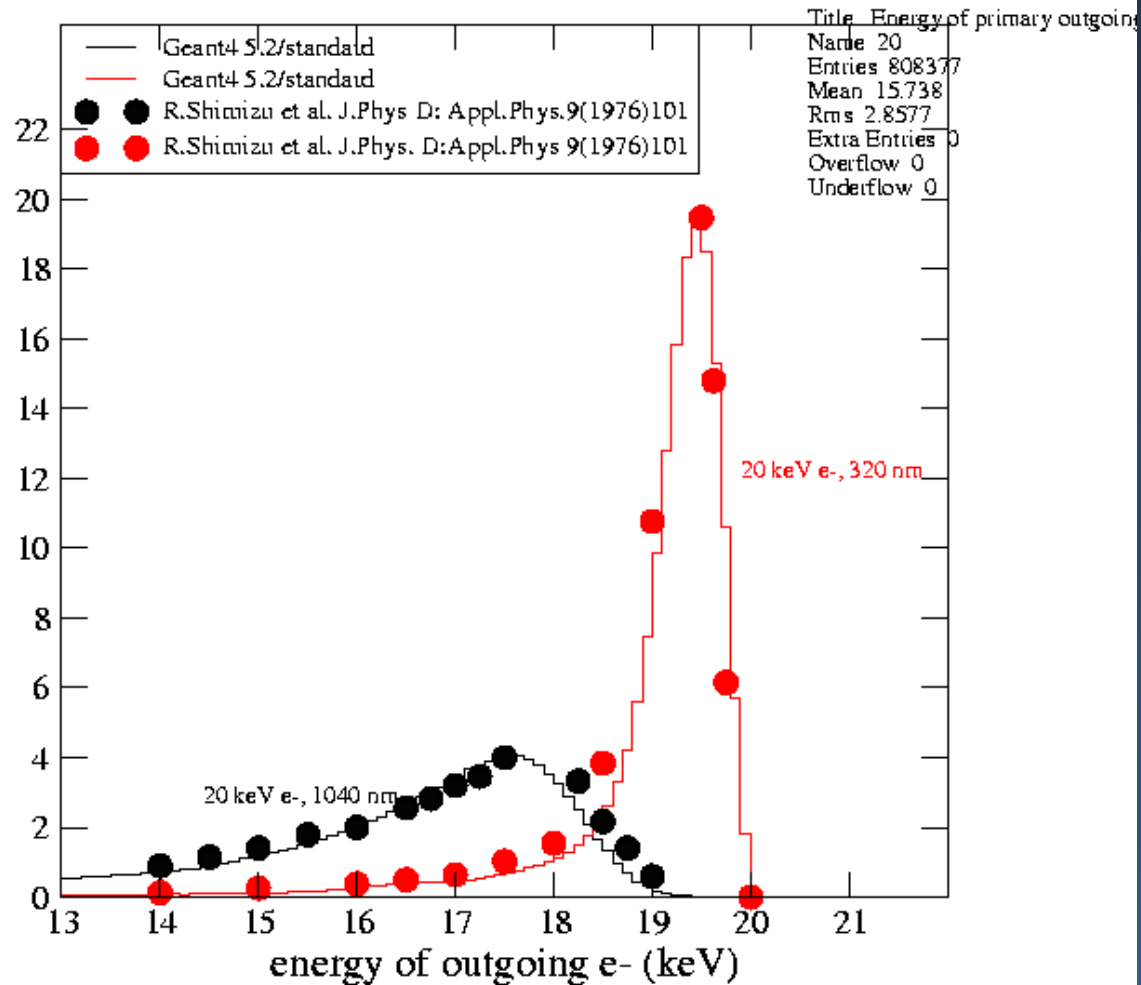


Geant4-05-02

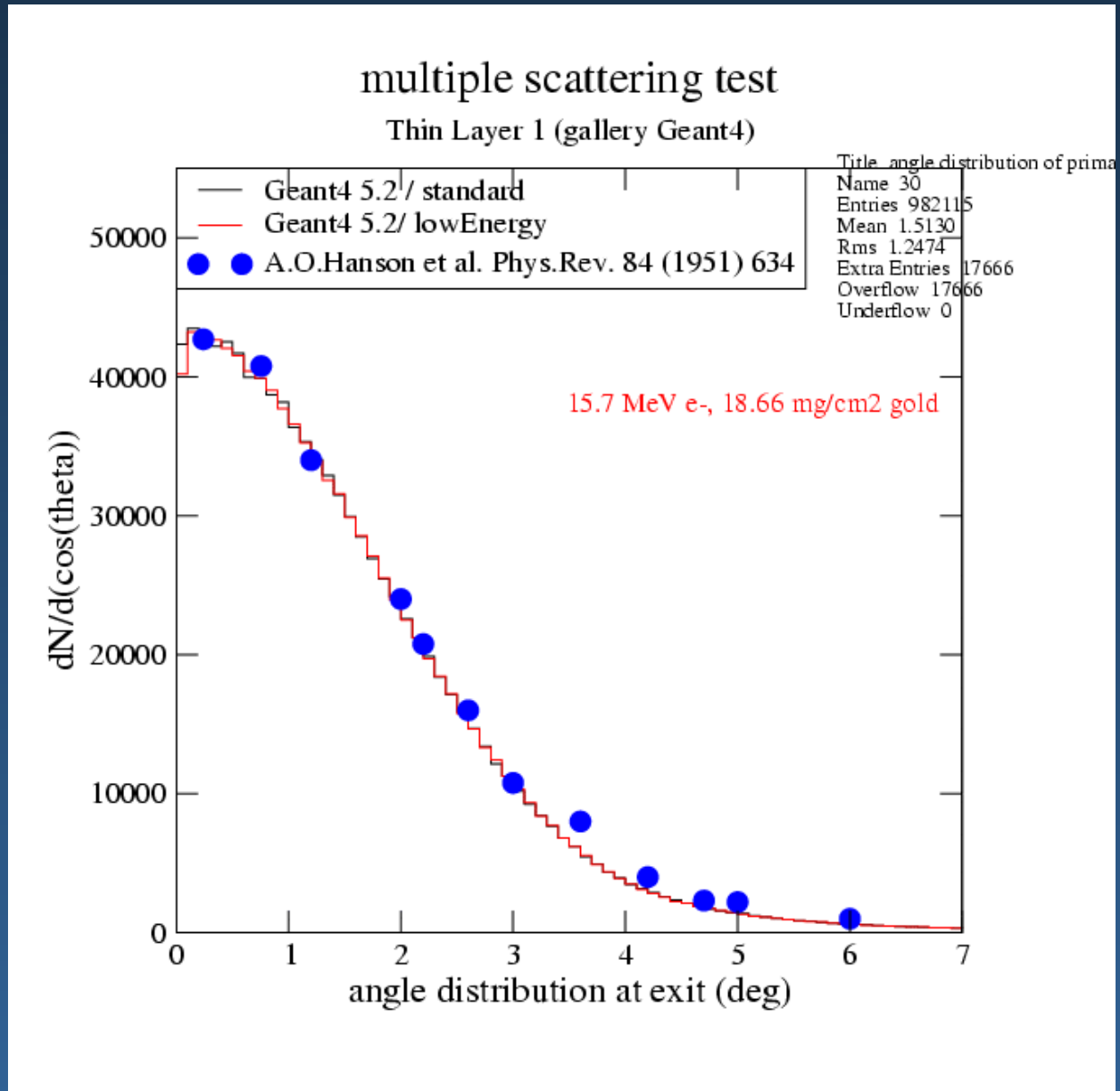
Test results

Transmission

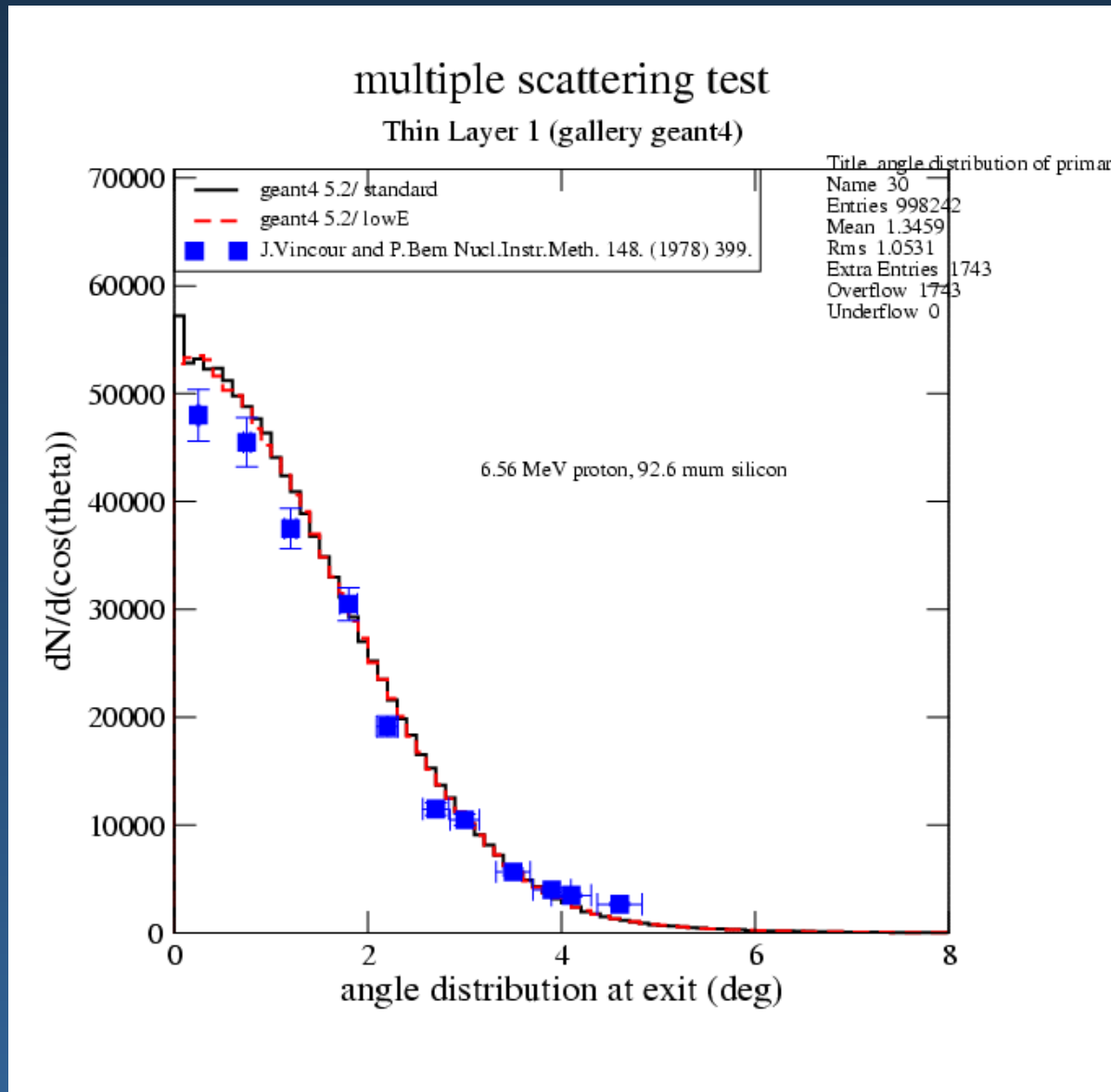
Energy distributions of transmitted e- on Al



Angular distribution of transmitted electrons



Angular distribution of transmitted protons



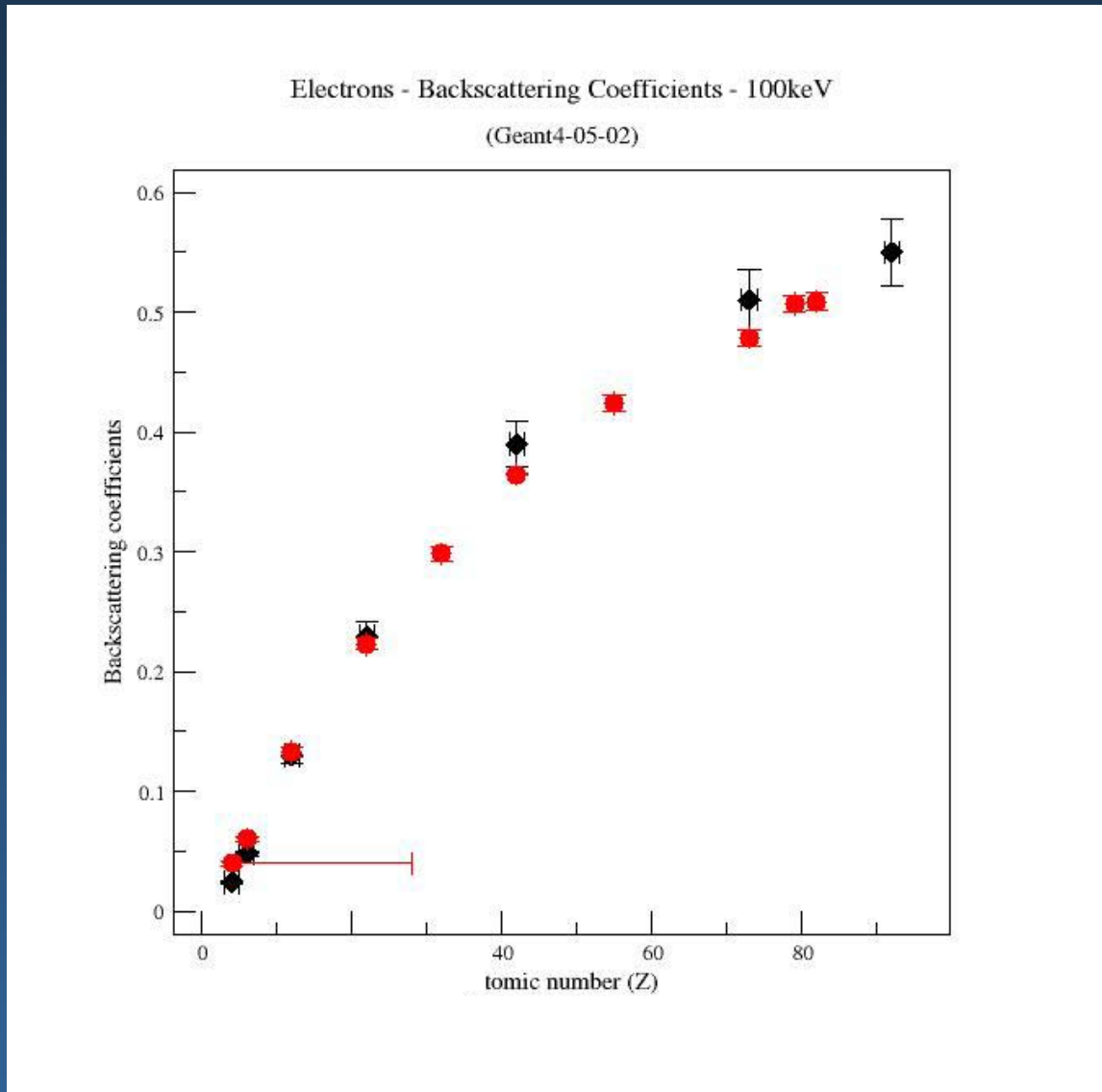
Test results

Backscattering for electrons and positrons

Absorber Materials:

Be, Al, Si, Ge, Fe, Mg, Ag, Au

Backscattering coefficient - $E=100\text{keV}$



Angle of incidence (with respect to the normal to the sample surface) = 0°

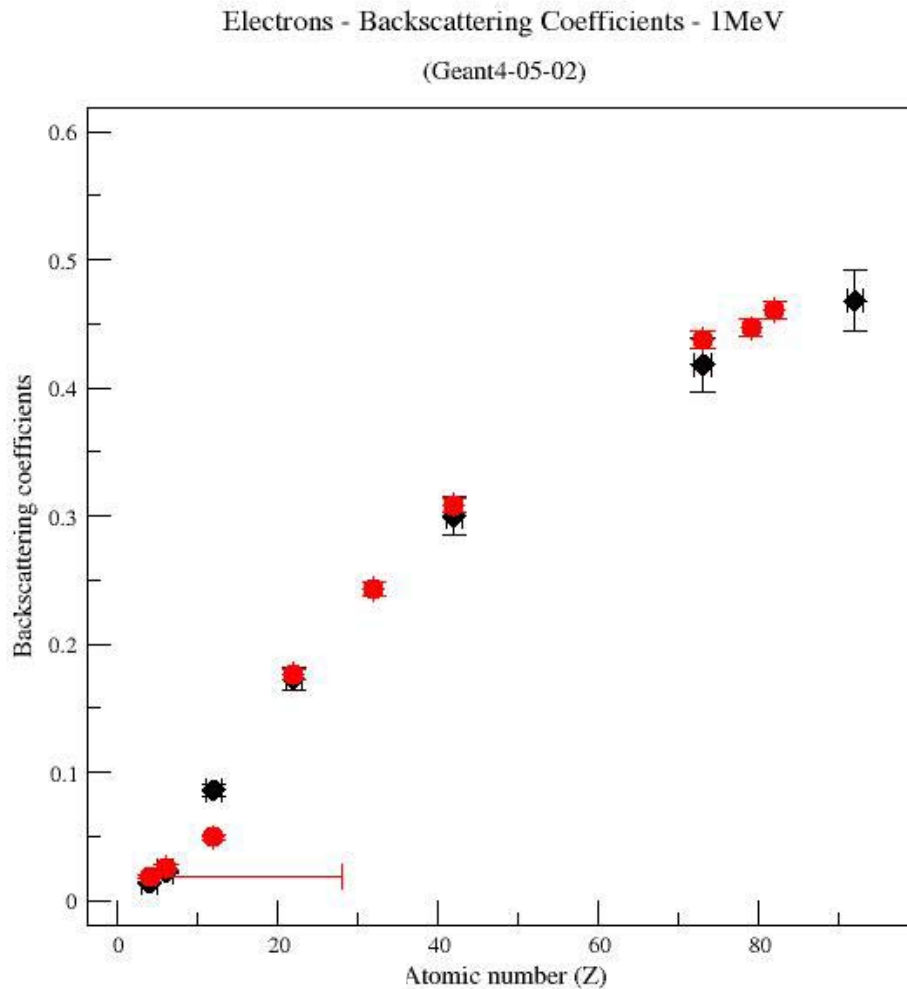


Lockwood et al. (1981)



G4 LowE

Backscattering coefficient - $E=1\text{MeV}$



Angle of incidence (with respect to the normal to the sample surface) = 0°



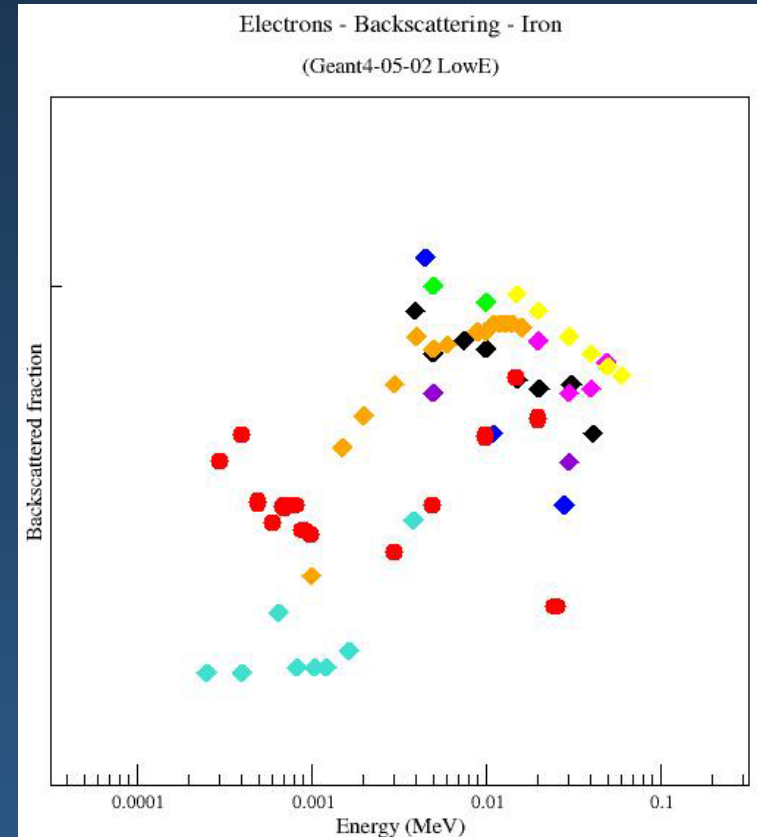
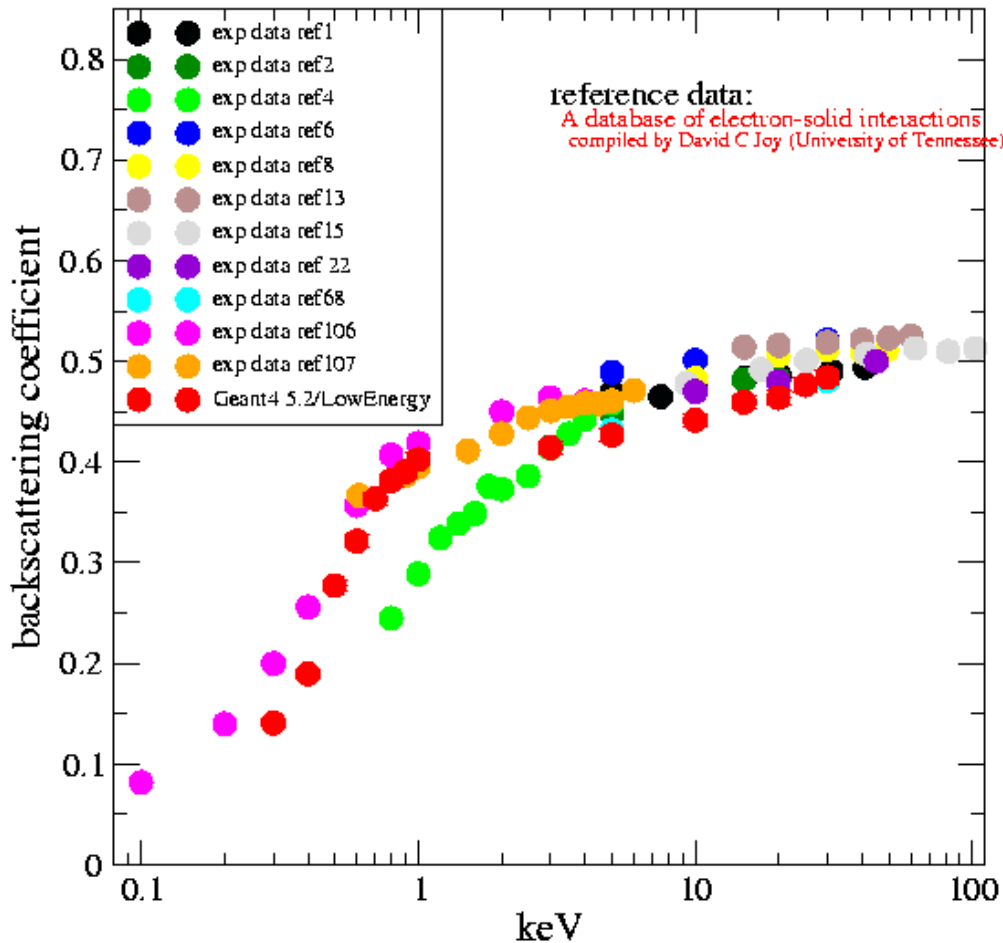
Lockwood et al. (1981)



G4 LowE

Backscattering low energies - Au

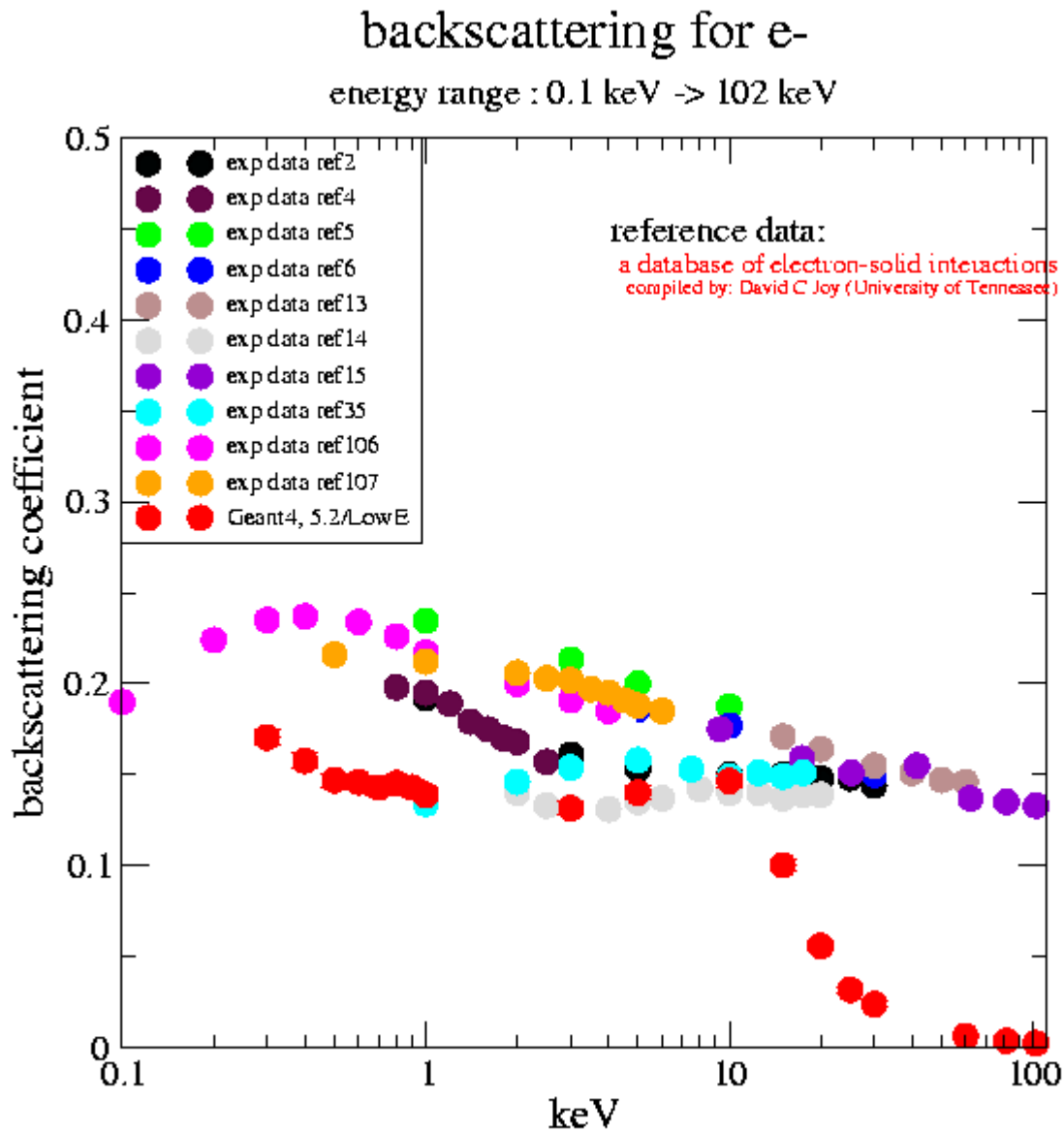
backscattering for e-
e- energy range: 0.1 keV -> 102. keV



Note:

experimental data often exhibit large differences!

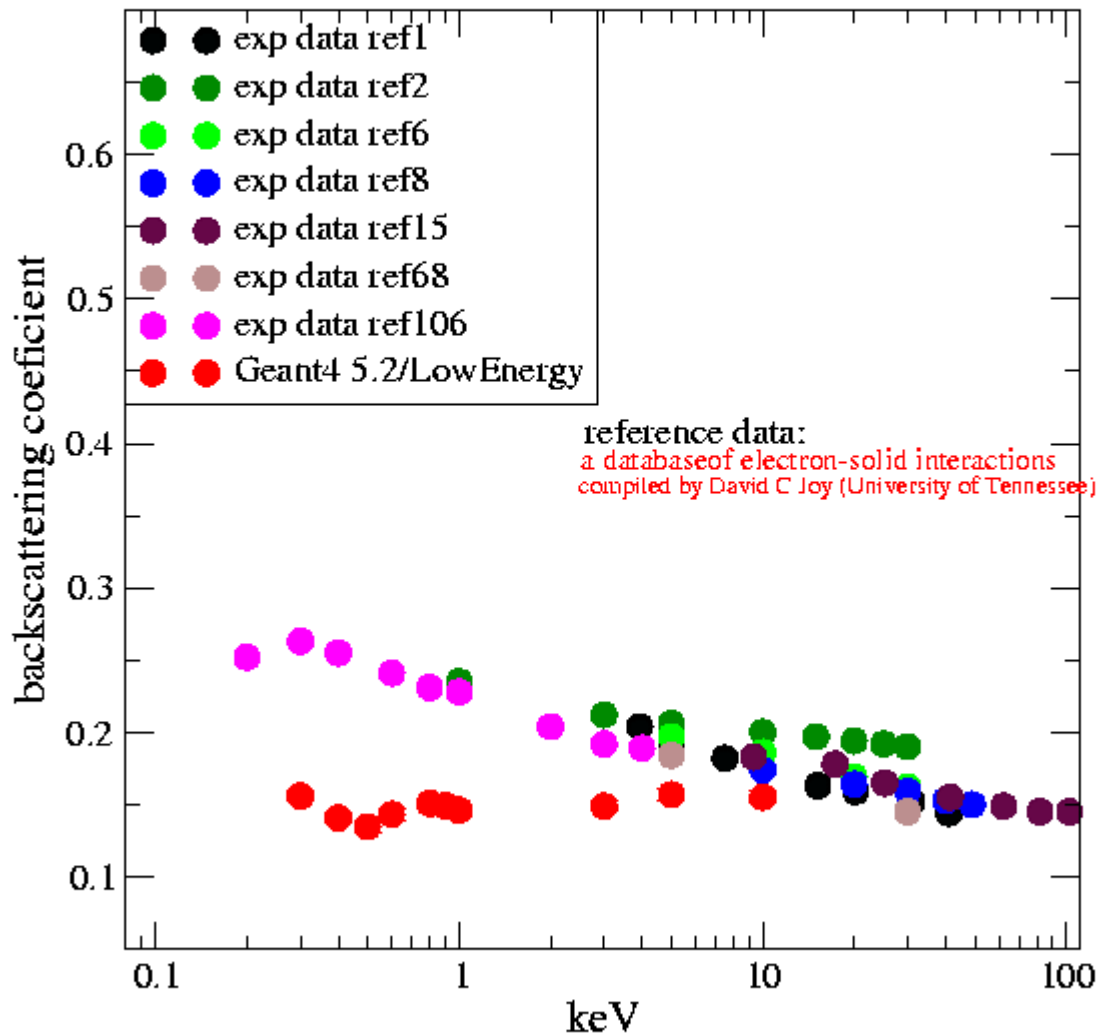
Backscattering low energies - Al



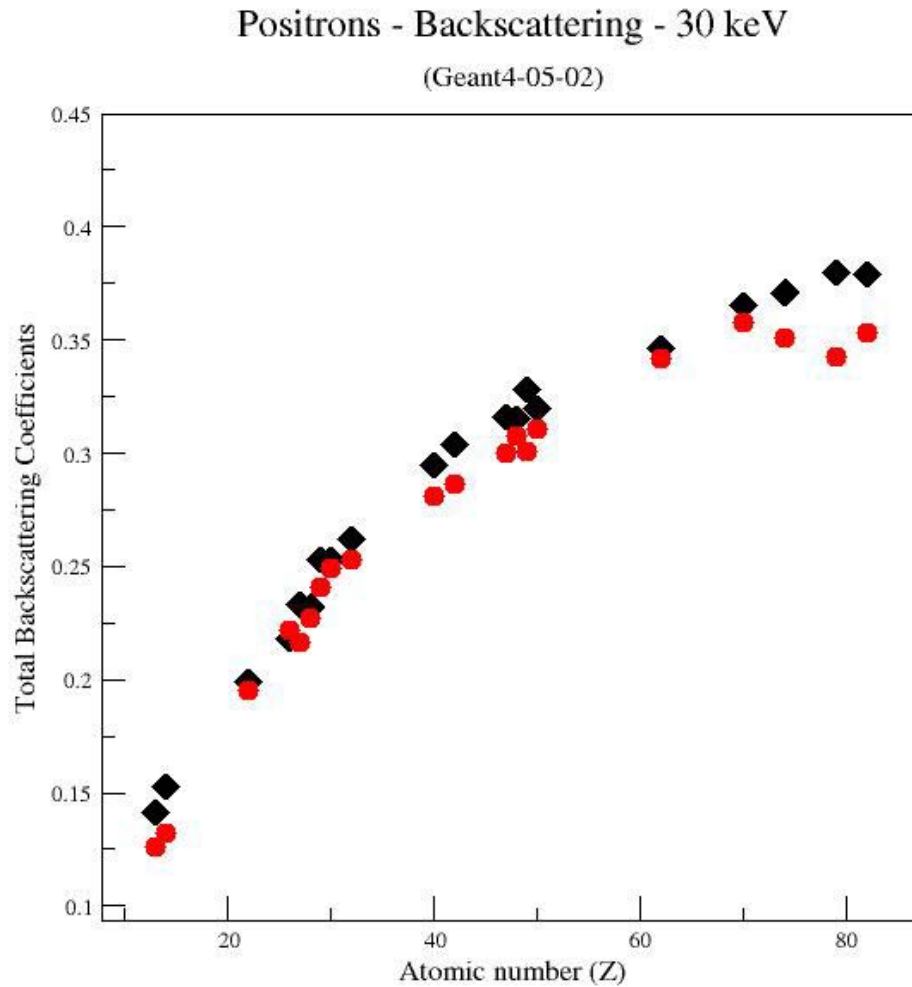
Backscattering low energies - Si

e- backscattering on Si

e- energy range: 0.1 keV -> 102. keV



Backscattering coefficient - 30keV

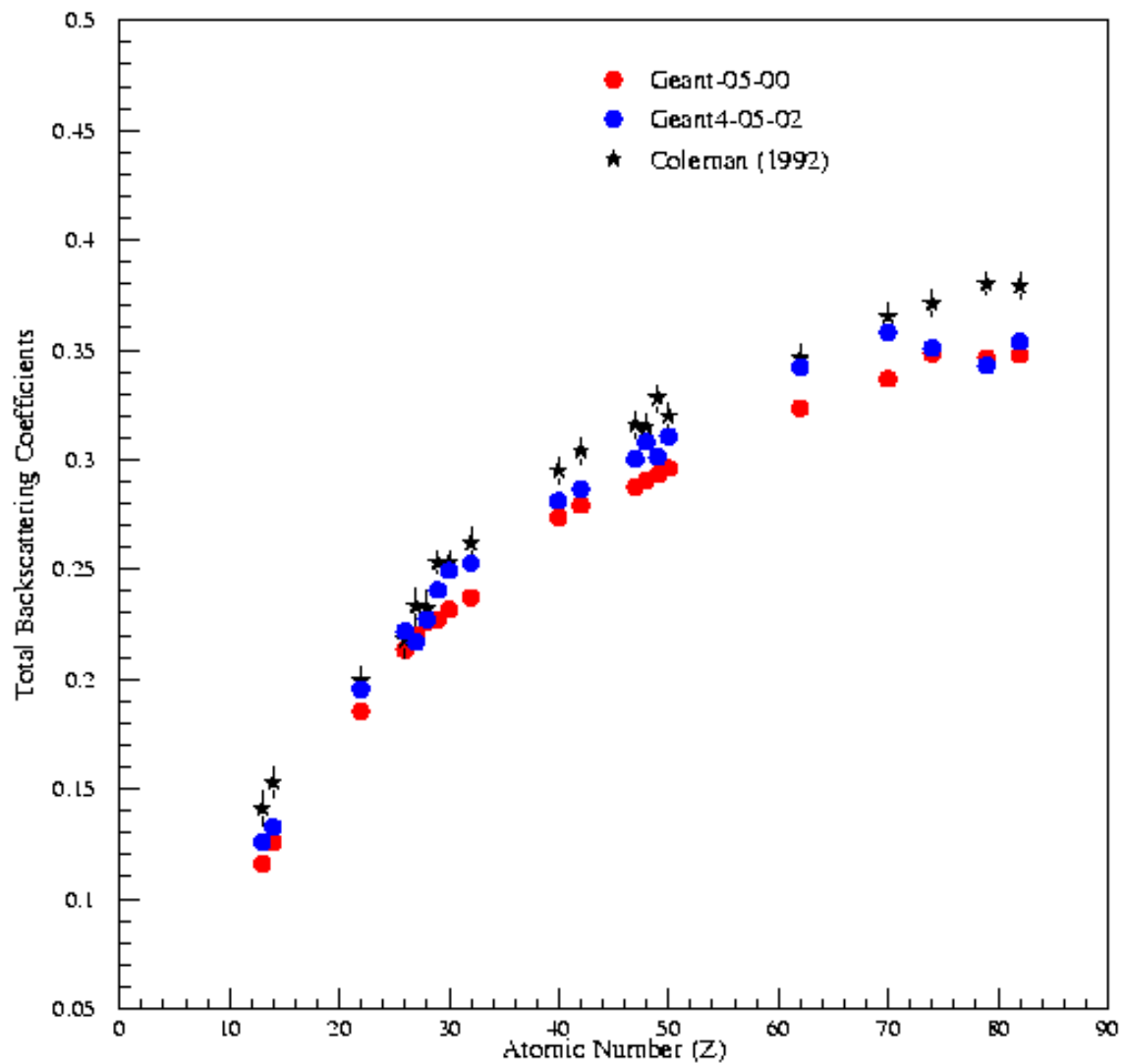


Coleman (1992)



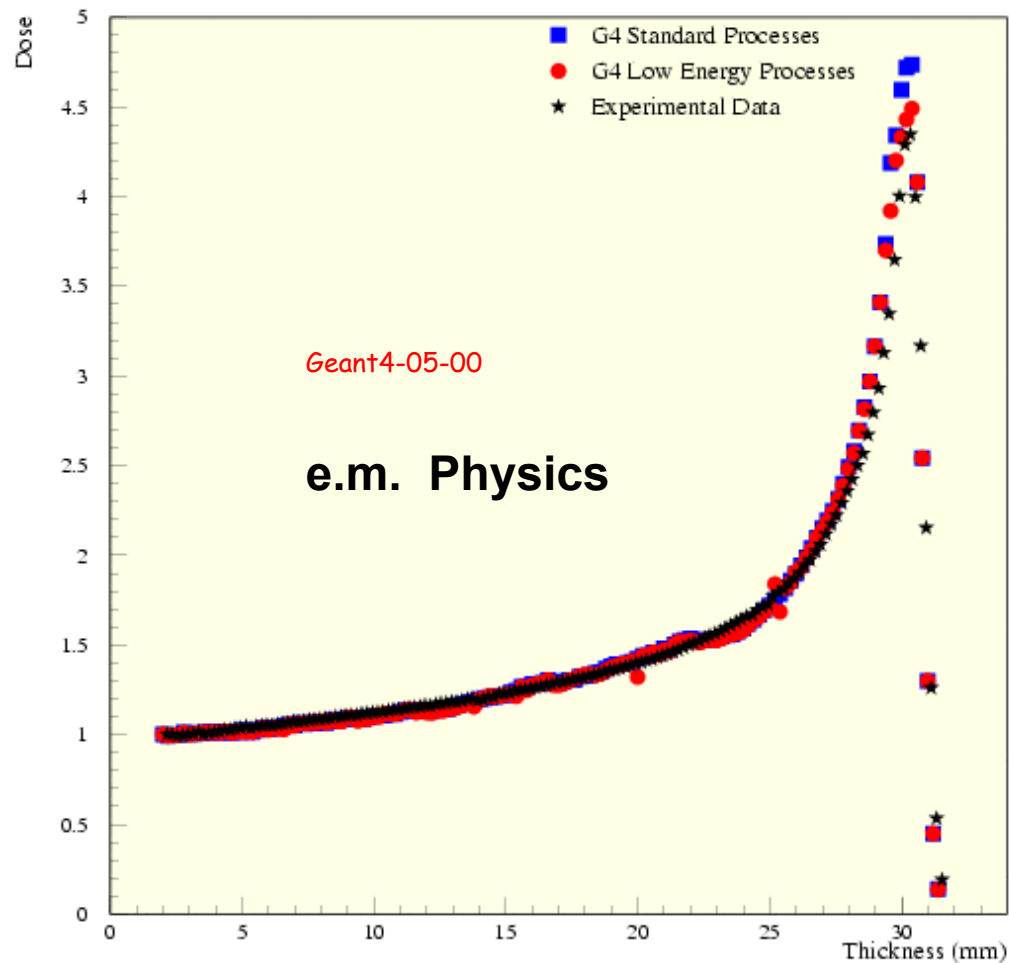
G4 LowE

Positrons - Backscattering - 30keV - Regression Testing



Test results: Bragg peak, protons

Protons - Bragg Peak - Water



Absorber Material: water

Comparison with experimental data from INFN, LNS Catania

Status and plans

Present situation

- A set of basic e.m. tests and results is available
 - CSDA range, stopping power, transmission, backscattering, Bragg Peak, angular distributions etc.
- Regression tests
 - already done twice
- Evaluation of the computing resources needed
 - see Sandra's talk in parallel session

Plans

- Integration in the Geant4 general system testing
- Design iteration
- Complete test automation
- Extend test coverage
 - e.m processes for ions, muons, atomic relaxation, add other e.m. physics distributions...
 - hadronic physics
- Use more sophisticated algorithms of the GoF component

Conclusions

- A lot of progress since last year's workshop...
 - a lot of work, but also a lot of fun!
- A group of bright, enthusiastic, hard-working young collaborators...
- Ground for Geant4 Physics Book



<http://www.nss-mic.org/2003>

Nuclear Science Symposium

Medical Imaging Conference

13th International Workshop on Room-Temperature
Semiconductor X- and Gamma-Ray Detectors



2003

Radiation Detectors and Electronics:
Applications in Physics, Industry, Space, Biology, Genetics and Medicine
Physics, Engineering and Mathematical Aspects of Medical Imaging

Plenary Sessions
Oral Presentations
Poster Sessions
Satellite Workshops
Short Courses
Industrial Exhibits
Companion Program

Abstract Submission Deadlines:
NSS & MIC: May 16, 2003
RTSD Workshop: June 27, 2003

**October 19-25, 2003
Portland, Oregon, USA**

DoubleTree Hotel – Hayden Island Complex

More at **IEEE-NSS,**

Portland, 19-25 October 2003

B. Mascialino et al.,

A Toolkit for statistical data analysis

L. Pandola et al.,

**Precision validation of Geant4
electromagnetic physics**