



Precision Validation of Geant4 Electromagnetic Physics



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

on behalf of Geant4 Low Energy and Standard Electromagnetic Groups



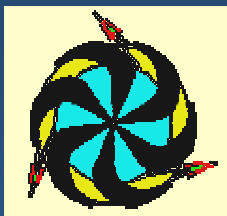
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P. Nieminen (ESA)

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L. Pandola, S. Parlati (INFN LNGS)

G.A.P. Cirrone, G. Cuttone (INFN LNS)



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V. Grichine, V. Ivanchenko (CERN)

M. Maire (LAPP)

P. Gumplinger (TRIUMF)



CHEP 2003, San Diego (CA), 24-28 March 2003

Validating Geant4 Physics

- ...not a new process
 - it started in 1994, at the same time as Geant4 development in RD44
 - continuous, on-going process in all Geant4 physics groups
 - various conference presentations, papers, web Gallery etc.
 - contributions from Geant4 users in many experimental domains
- ...but a new approach
 - Geant4 is a mature product, extensively used in many diverse fields
 - many test results have been produced, but are dispersed
 - mostly “qualitative” validation



Systematic, quantitative test of
Geant4 Electromagnetic Physics

Systematic test

- Testing the “building blocks” of Geant4 Electromagnetic Physics
 - microscopic process quantities
 - cross sections, spectral lines etc.
 - basic process elements
 - stopping powers, angular distributions etc.
- Comparison with respect to well established references (wherever they exist...)
 - reference databases (i.e. NIST, ICRU etc.)
 - reference publications on refereed journals, preferably with several data sets from different experiments
- For a large set of elements and common materials, on a wide energy range
 - a huge amount of work...
 - what presented here is just a set of preliminary results, more coming...

Quantitative test

- Statistical analysis, using Goodness-Of-Fit tests, for a quantitative evaluation of the comparison between simulated and experimental data distributions
 - see A Toolkit for Statistical Data Comparison, this conference
- Work in progress
 - to determine the right test for each set of distributions, among the many GoF tests available
 - to apply it sensibly and correctly
- Preliminary quantitative results will be presented in the following slides

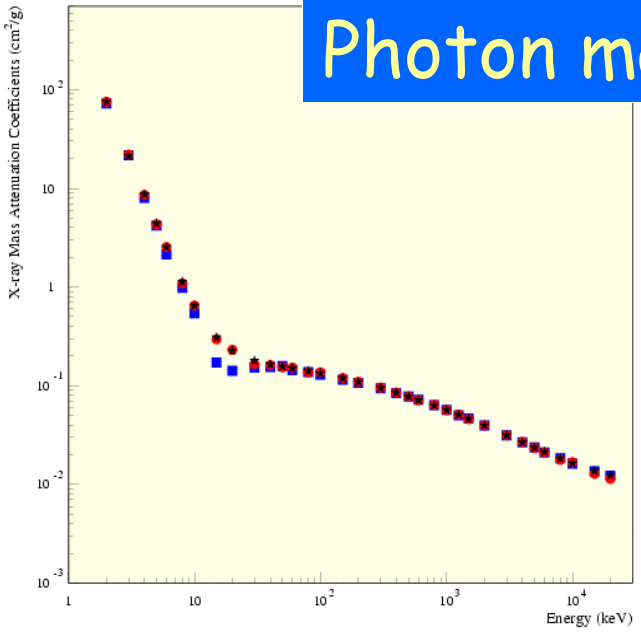
Rigorous software process

- Modelled on the USDP/RUP
- Agreed and documented Vision of the project
- User Requirements collected, specified, analysed and documented
- Requirements traceability
 - traceability items: requirements, design, implementation, test, results, documentation
- Documented OOAD
- etc...

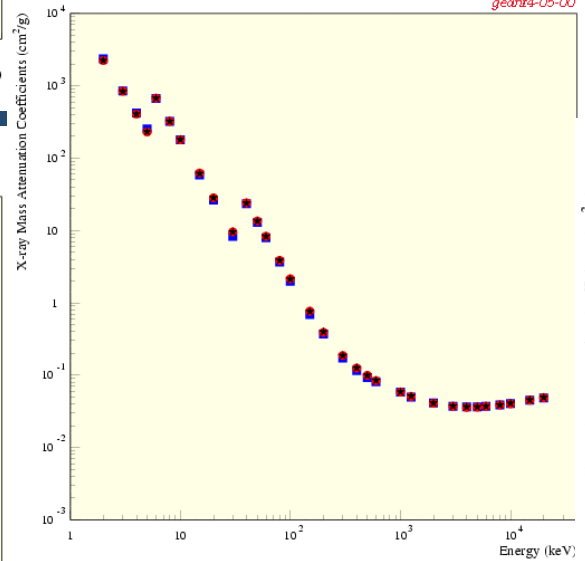
- Process documents available at <http://www.ge.infn.it/geant4/analysis/test>

Photon mass attenuation coefficient

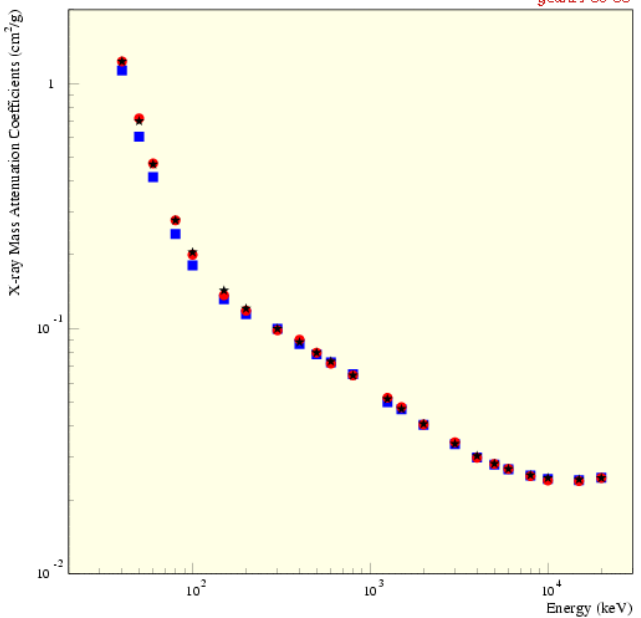
G4 Standard
G4 LowE-EPDL
NIST



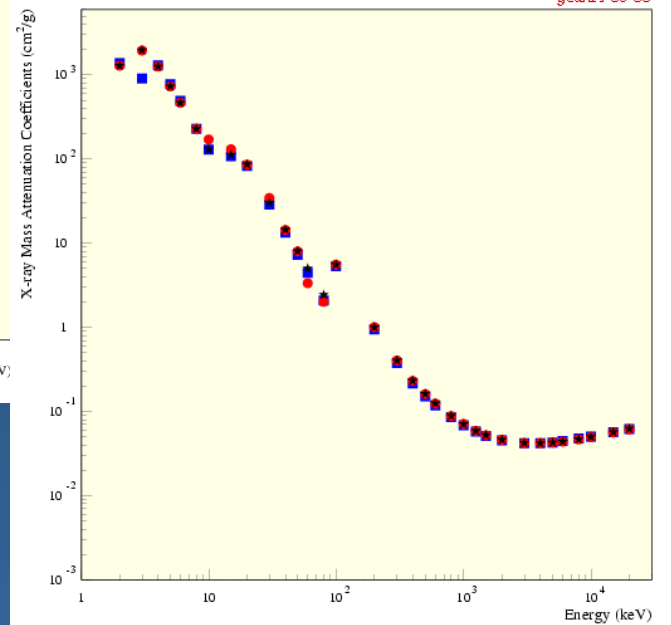
X-ray Attenuation Coefficient - Cesium



X-ray Attenuation Coefficient - liquid Argon

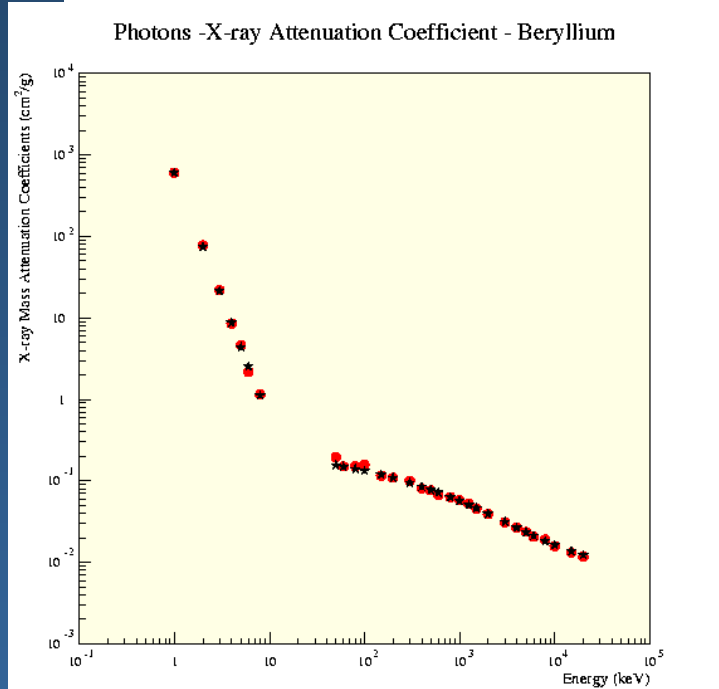
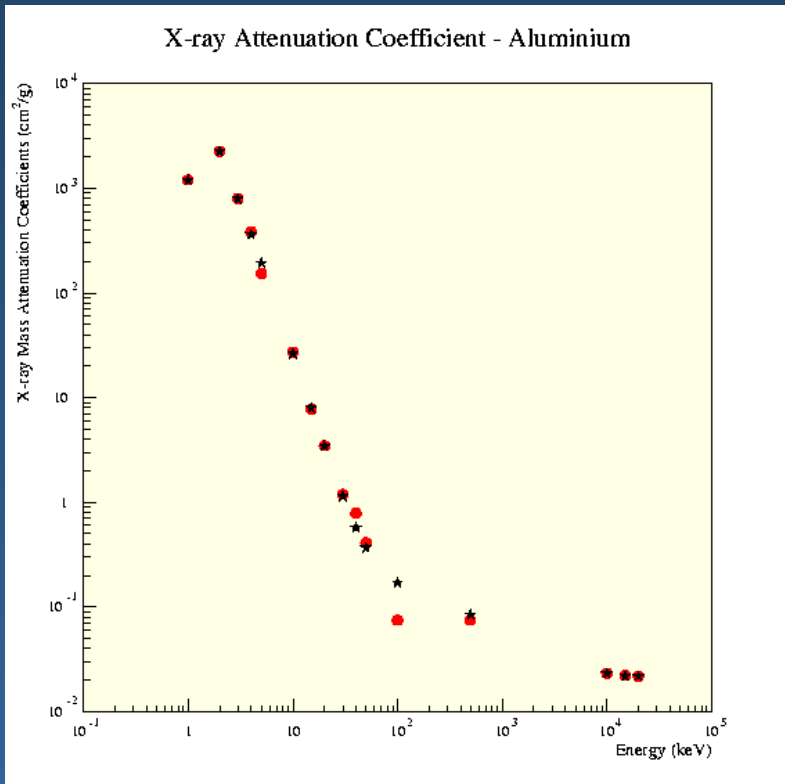
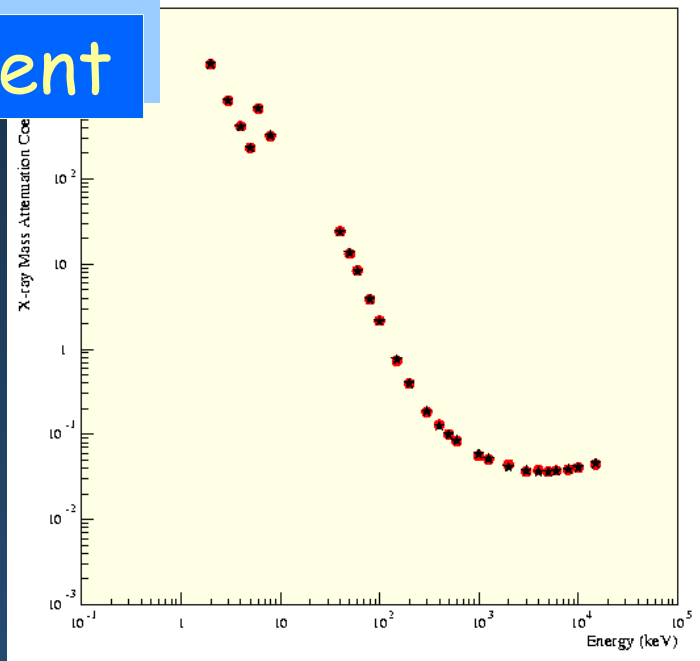


X-ray Attenuation Coefficient - Lead

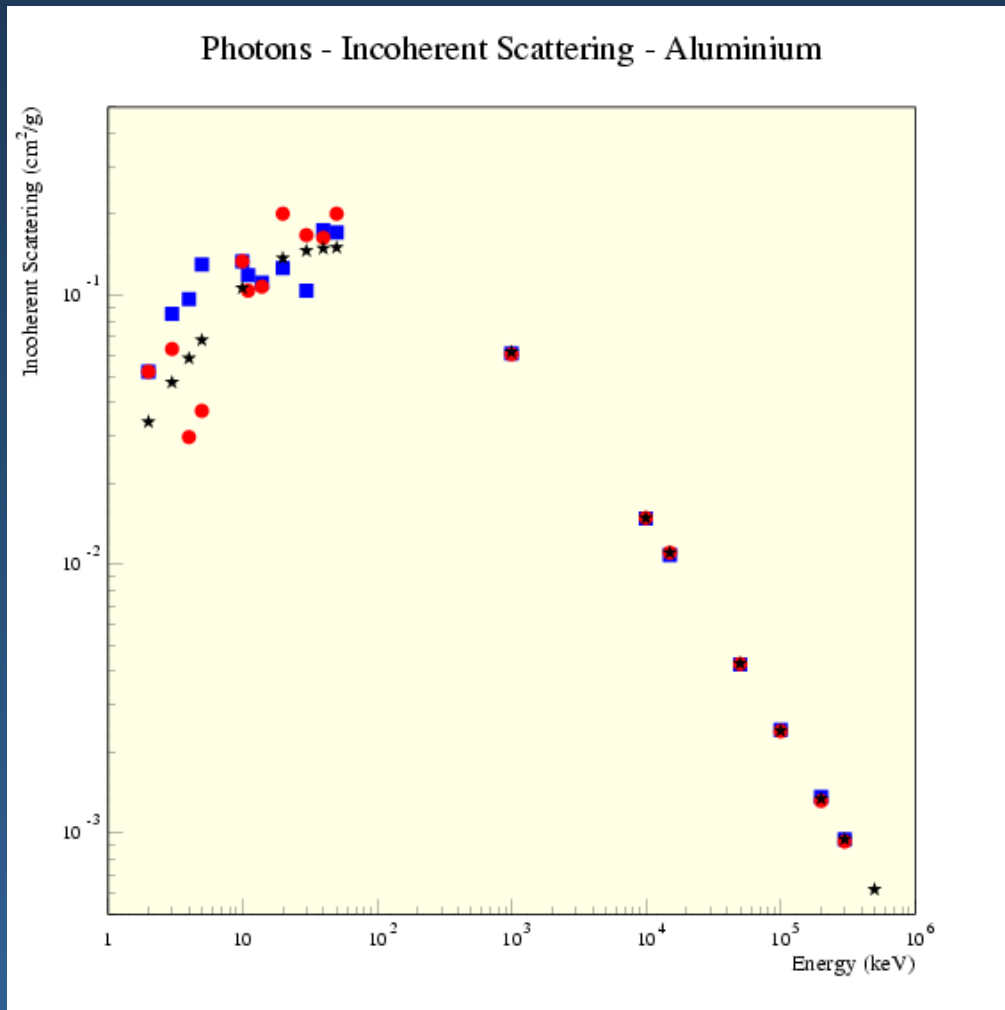


Photon mass attenuation coefficient

G4 LowE-Penelope
(new set of physics models in Geant4!)
NIST

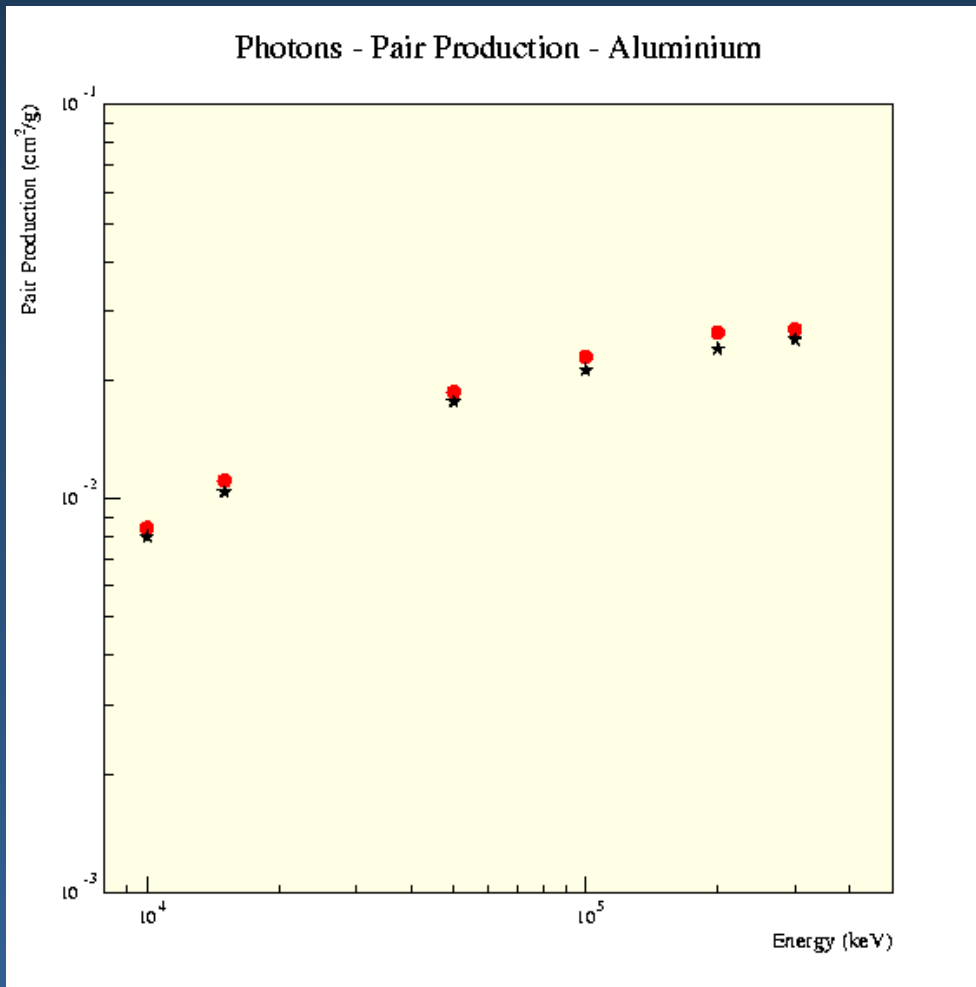


Compton cross sections



G4 Standard
G4 LowE-EPDL
NIST

Pair production cross sections



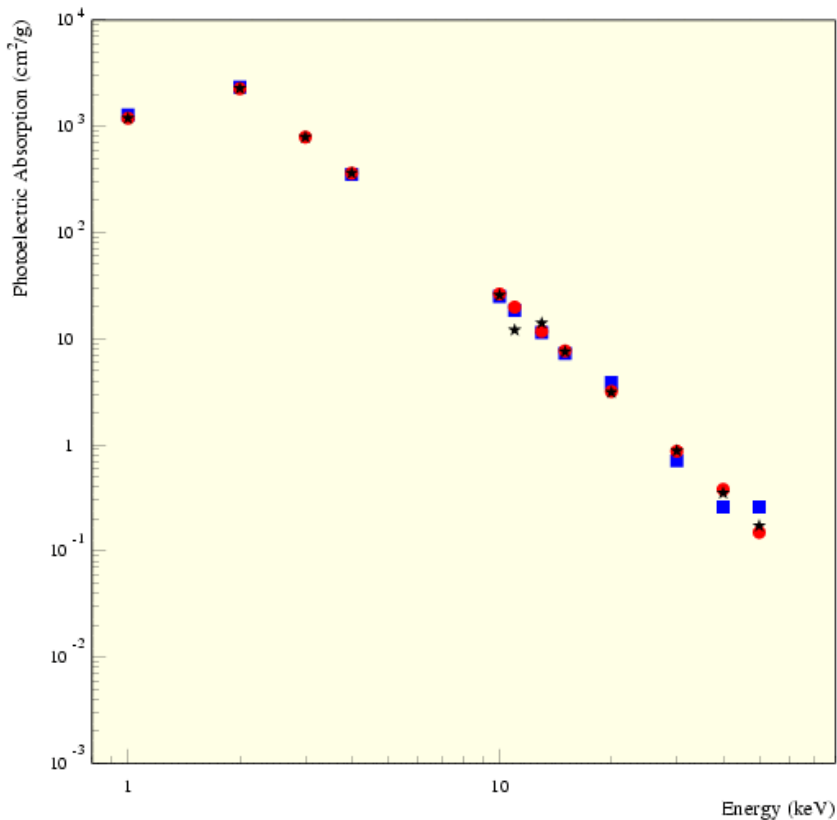
G4 Standard
G4 LowE-EPDL
NIST

Photoelectric cross sections

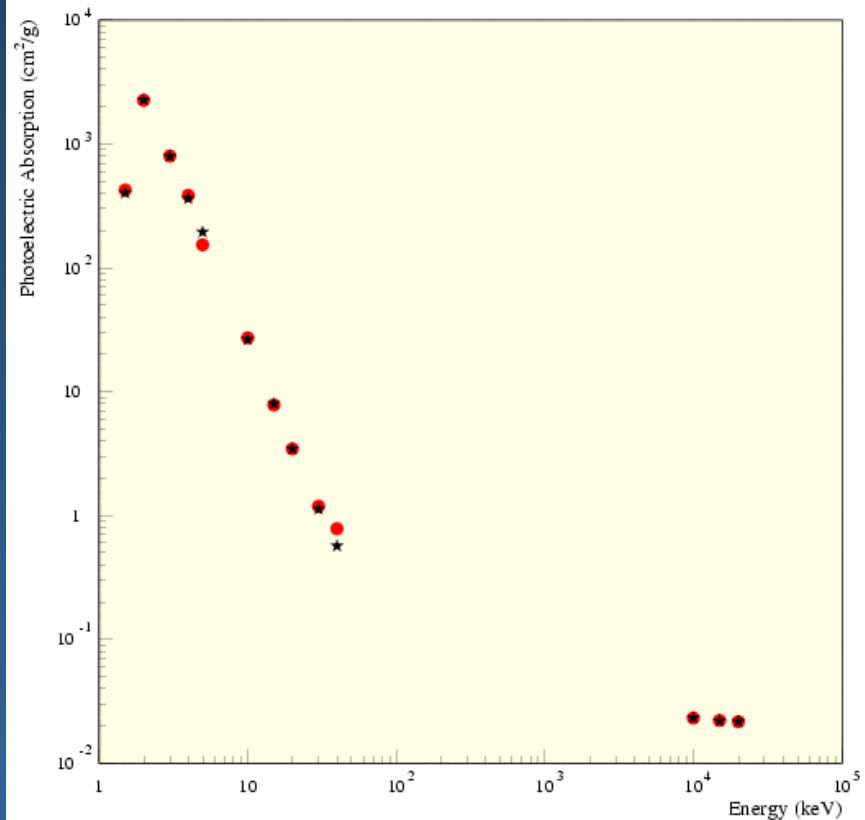
G4 Standard
G4 LowE-EPDL
NIST

G4 LowE-Penelope
NIST

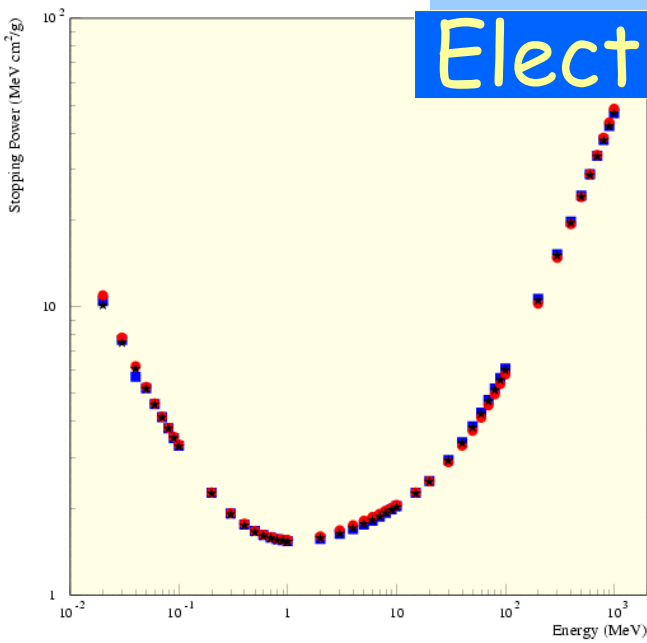
Photons - Photoelectric Absorption - Aluminium



Photons - Photoelectric Absorption - Aluminium



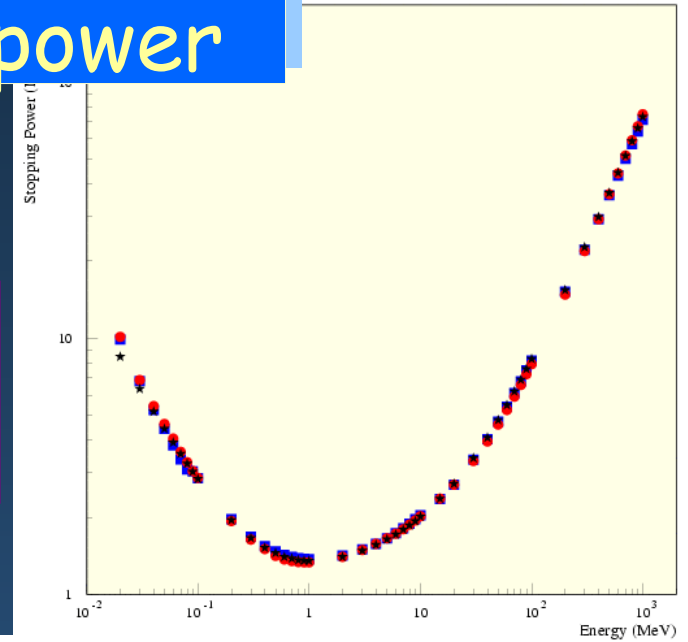
Electrons - Stopping Power - Silicon



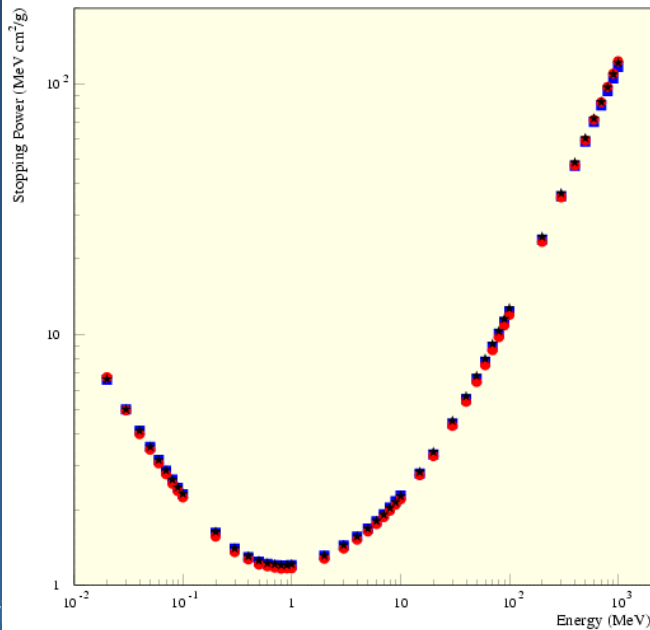
Electron stopping power

G4 Standard
G4 LowE-EEDL
NIST

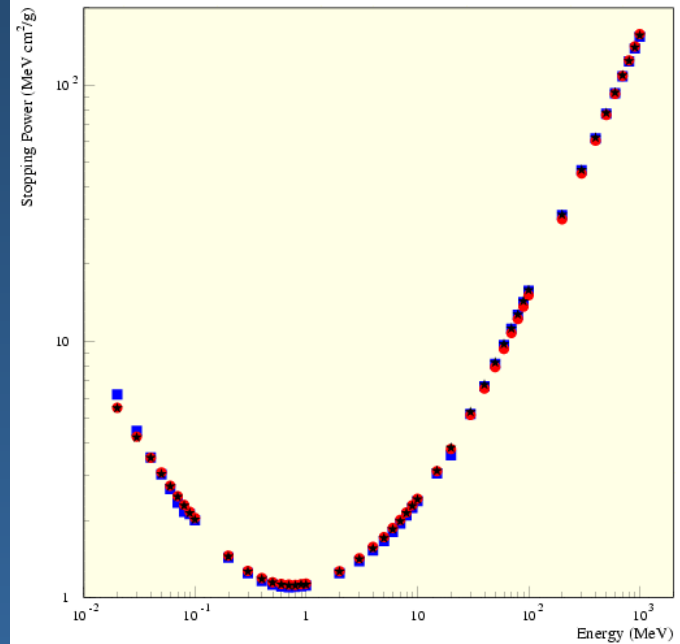
Electrons - Stopping Power - Iron



Electrons - Stopping Power - Cesium

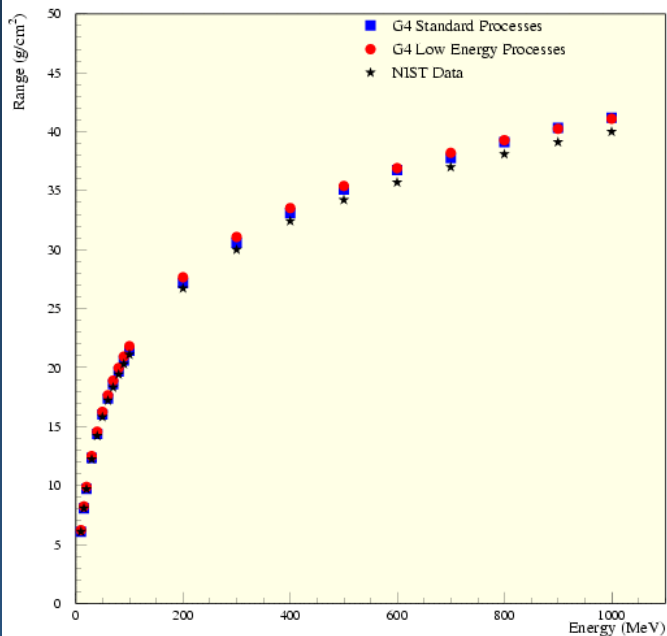


Electrons - Stopping Power - Lead

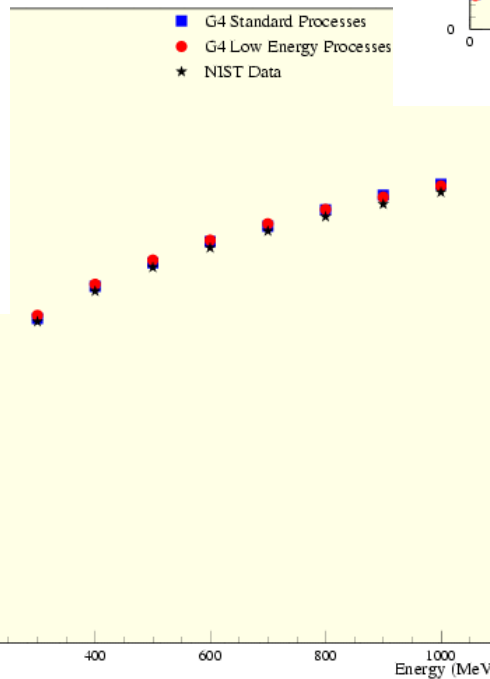


Electron range

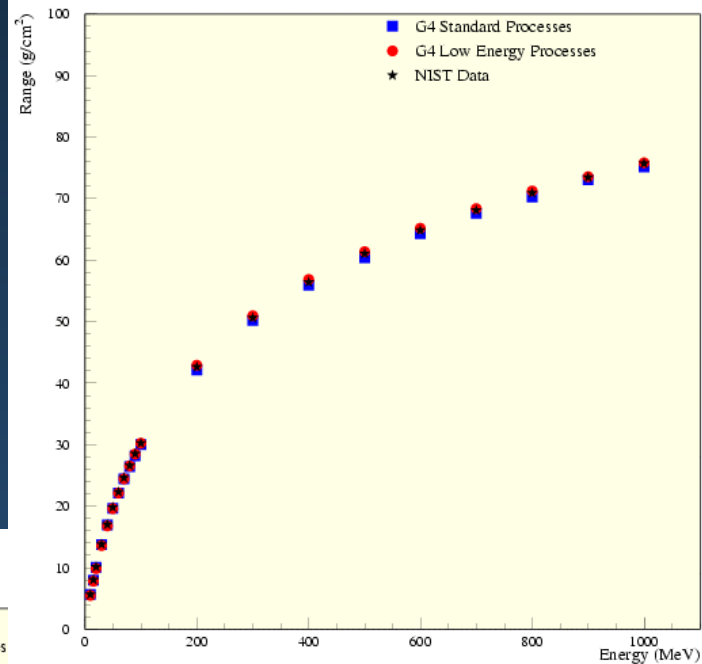
Electrons - Range - Cesium



Electrons - Range - Iron

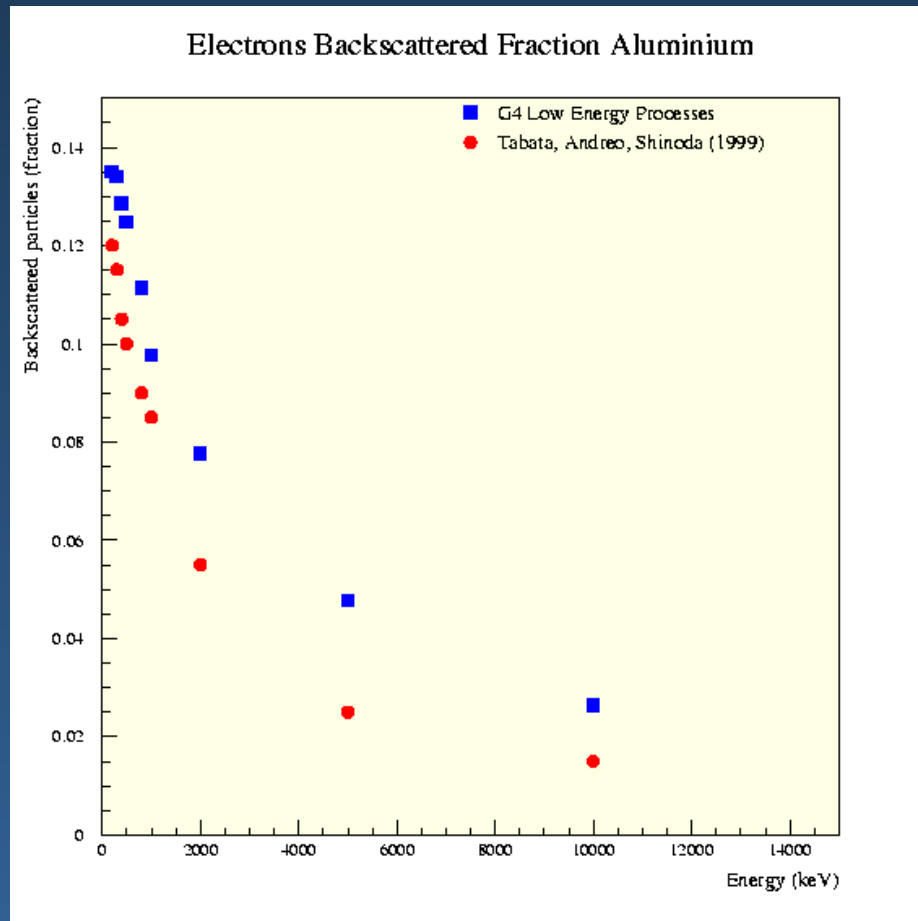


Electrons - Range - Silicon



G4 Standard
G4 LowE-EEDL
NIST

Electrons, backscattered fraction

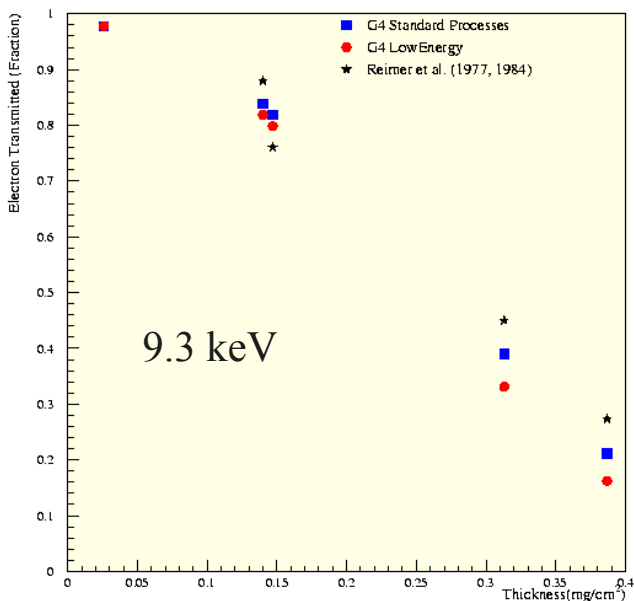


T. Tabata, P. Andreo, K. Shinoda,
Radiat. Phys. Chem. 54 (1999) 11

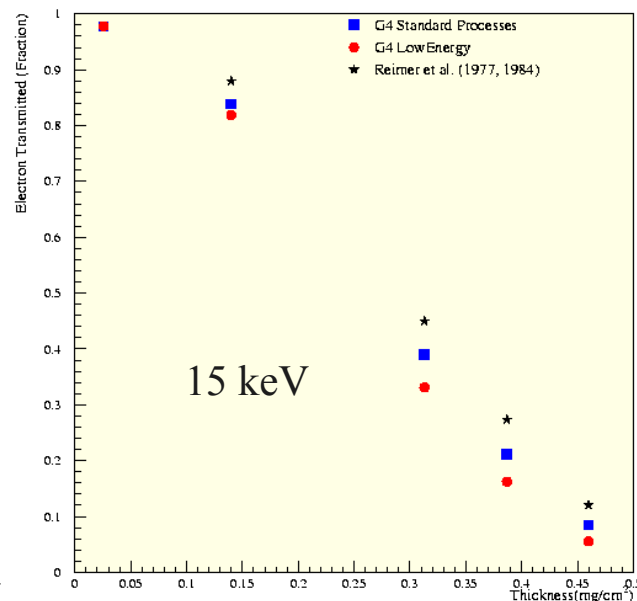
Work in progress, to tune
multiple scattering parameters
available in Geant4

Electrons, transmitted fraction

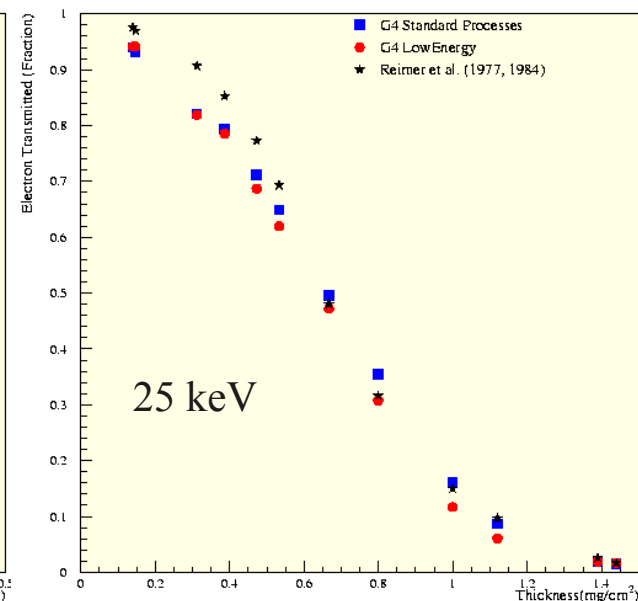
e⁻ Thin Layer Transmission Aluminium



e⁻ Thin Layer Transmission Al



e⁻ Thin Layer Transmission Al



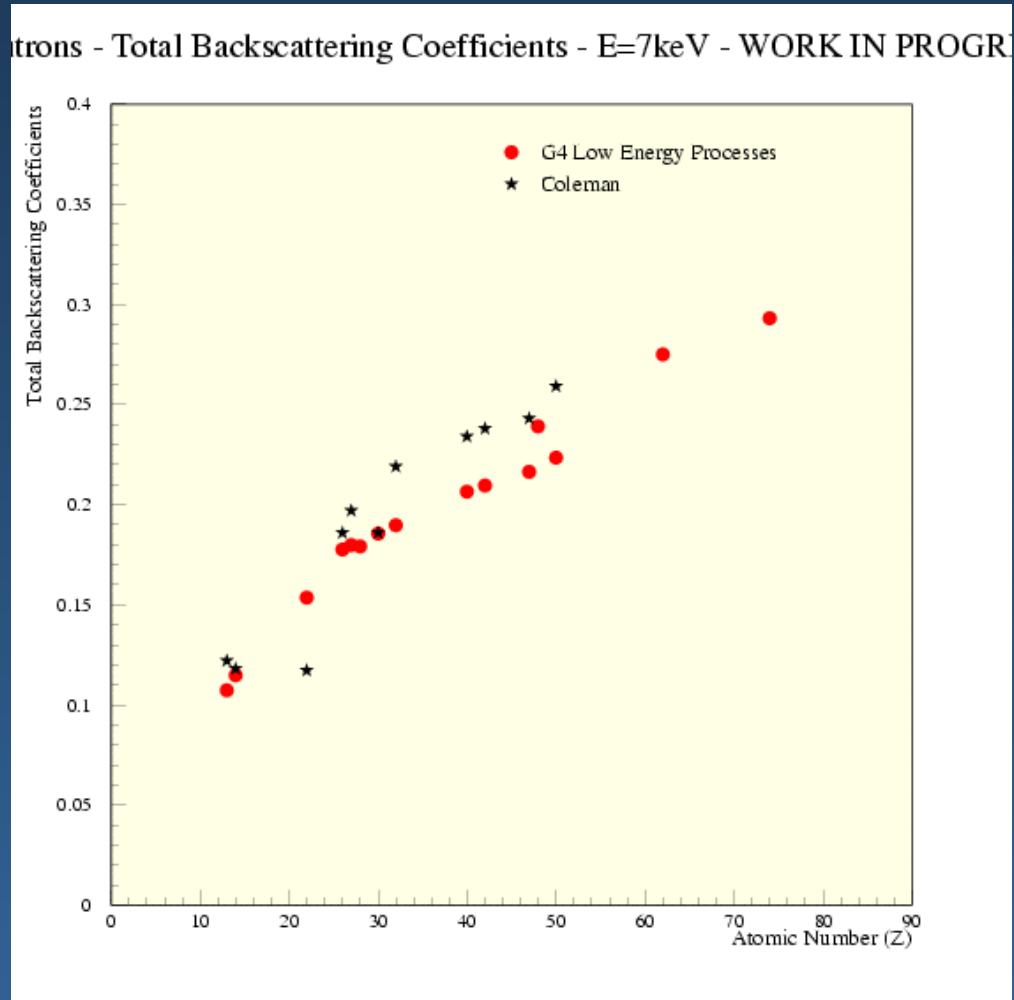
G4 Standard
G4 LowE-EEDL
Reference

L. Reimer, H. Drescher, J. Phys. 10 (1977) 805

G. Neubert, S. Rogaschewski, J. Phys. D: Appl. Phys. 17 (1984) 2439

H.H. Seliger, Phys.Rev. Vol.100 (4) (1955) 1029

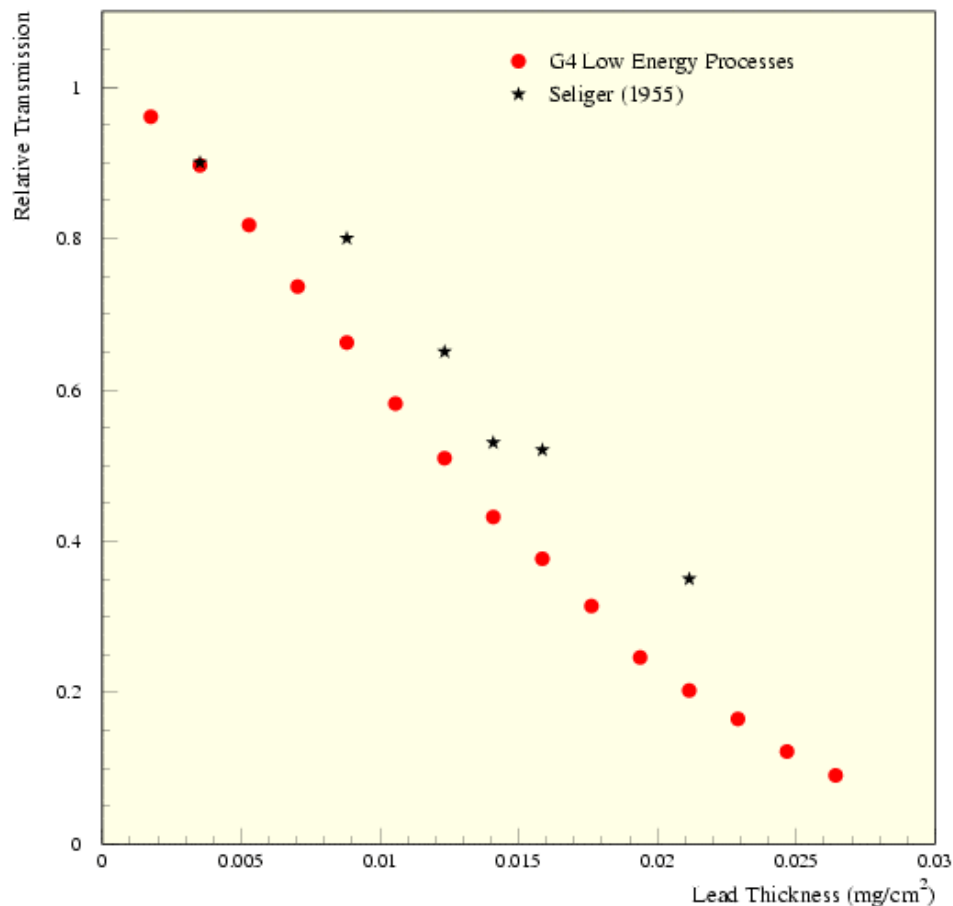
Positrons, backscattered fraction



J. Coleman et al., J. Phys.
Condens. Matter. 4 (1992) 10311

Positrons, transmitted fraction

Positrons ($E=0.96\text{MeV}$) - Relative Transmission in Lead

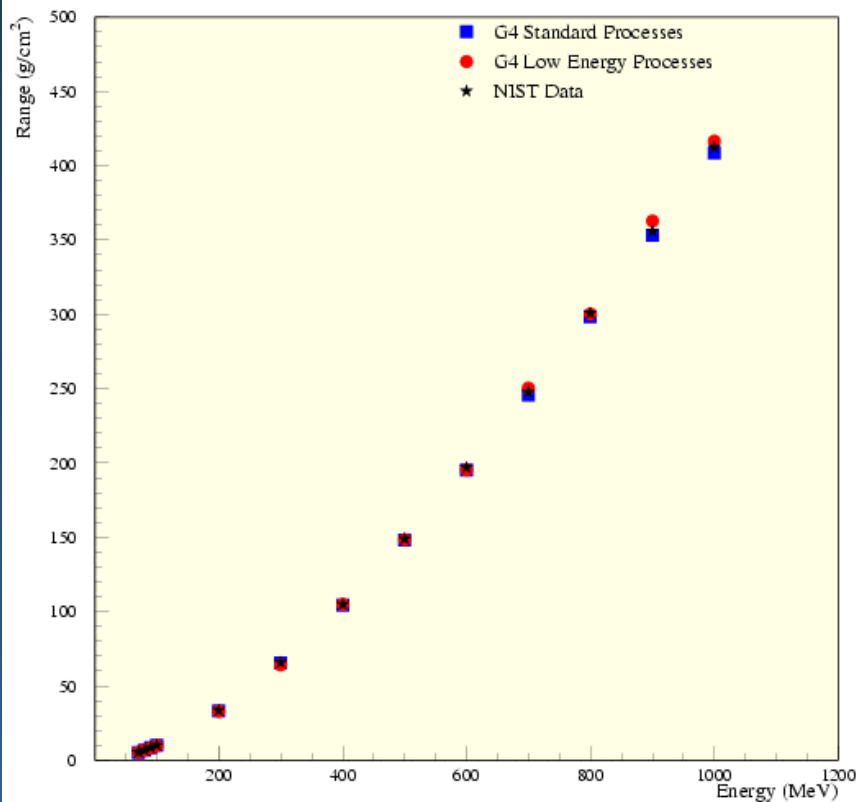


H.H. Seliger, Phys.Rev.
Vol.100 (4) (1955) 1029

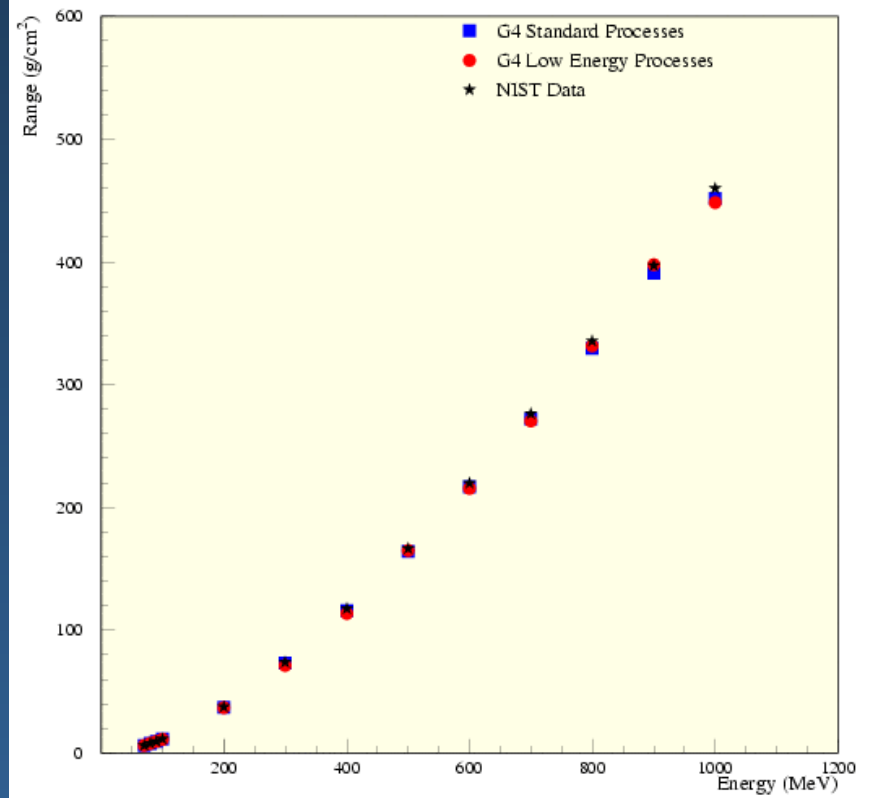
NOTE: Backscattering and transmission distributions are mainly related to multiple scattering model and parameters; work is in progress to optimize the value of these parameters

Protons, stopping power

Protons - Range - Aluminium



Protons - Range - Iron

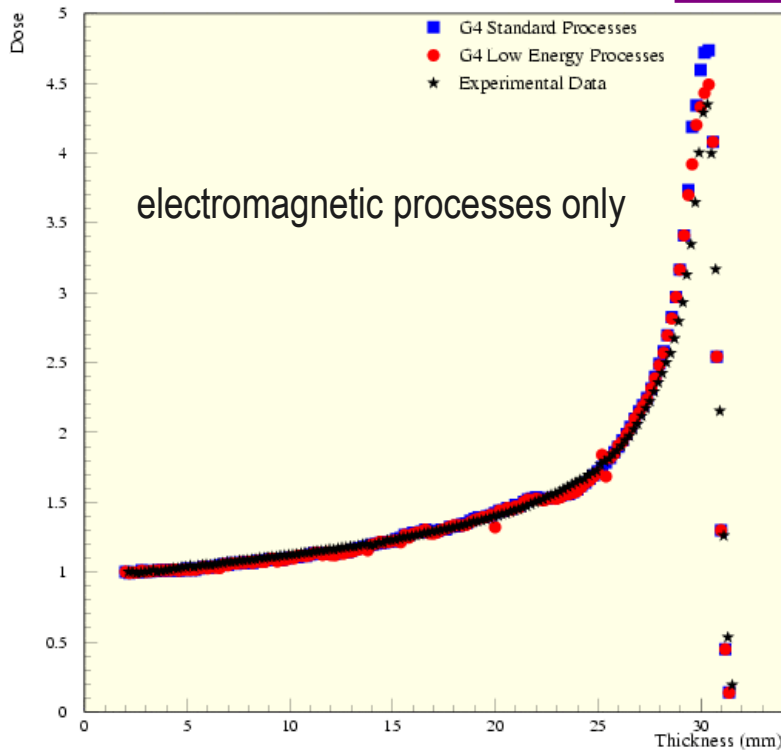


Protons, Bragg peak

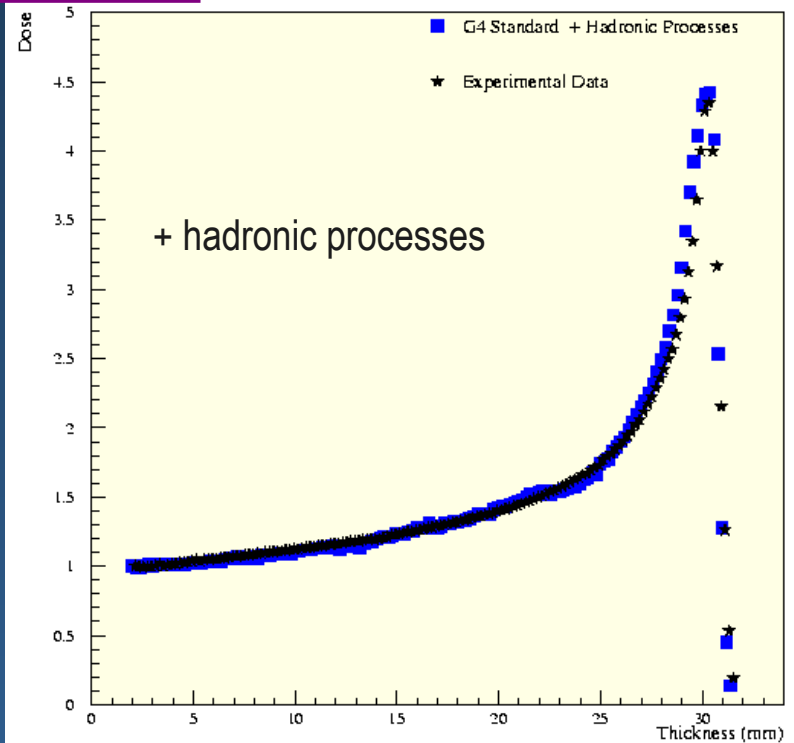
G4 Standard
G4 LowE
Reference

work in progress

Protons - Bragg Peak - Water



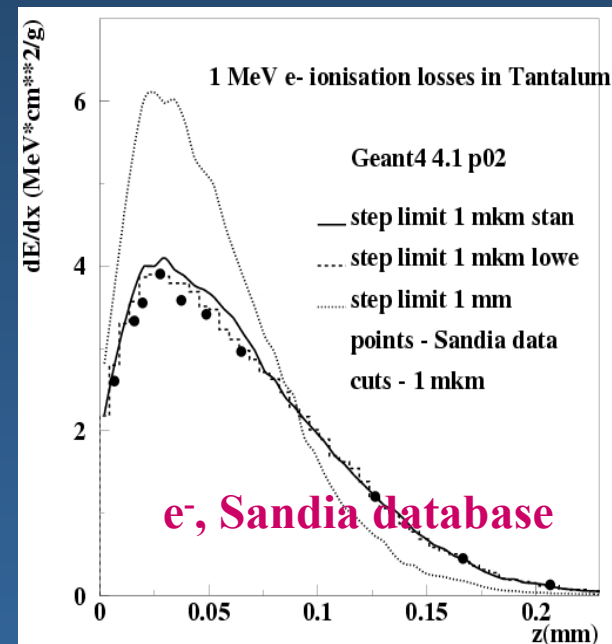
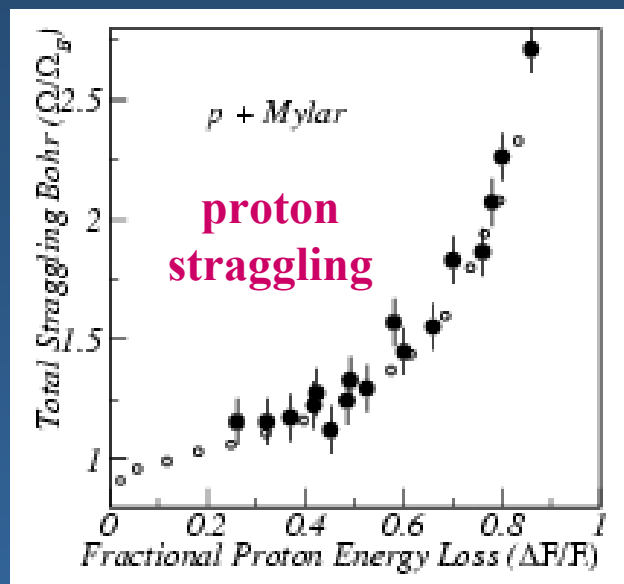
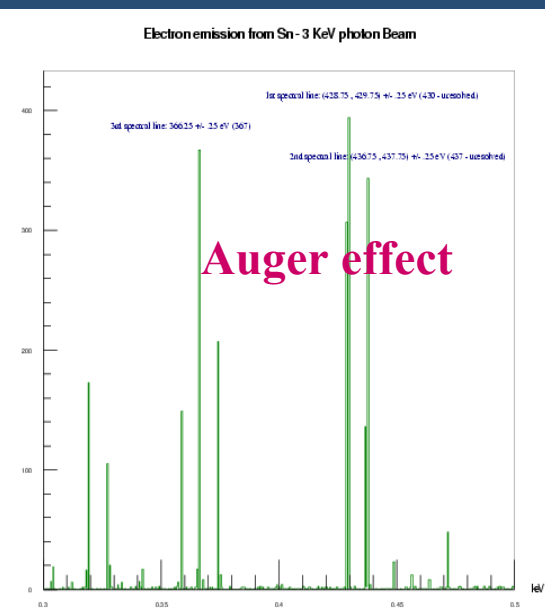
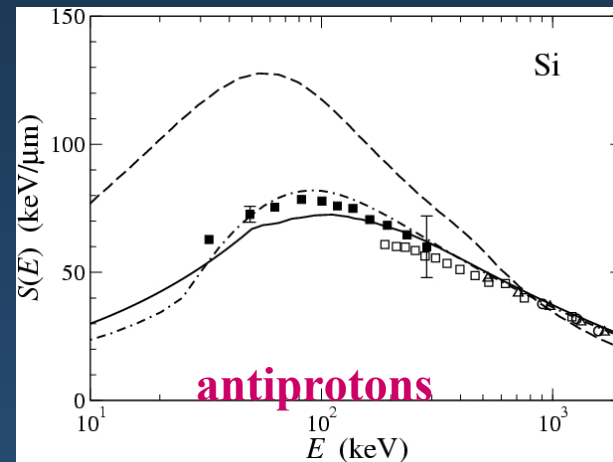
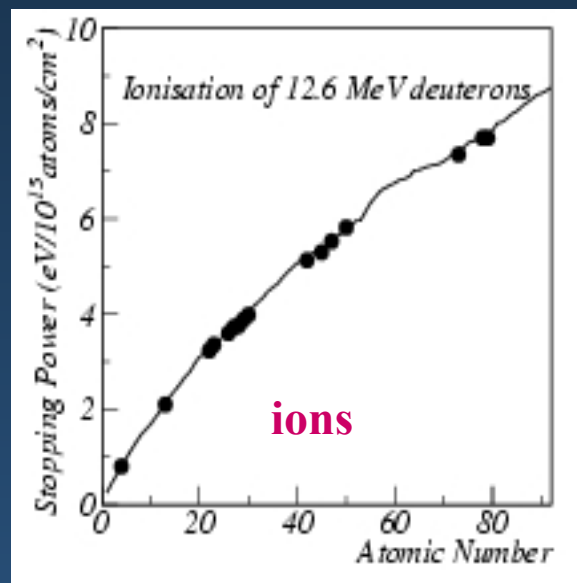
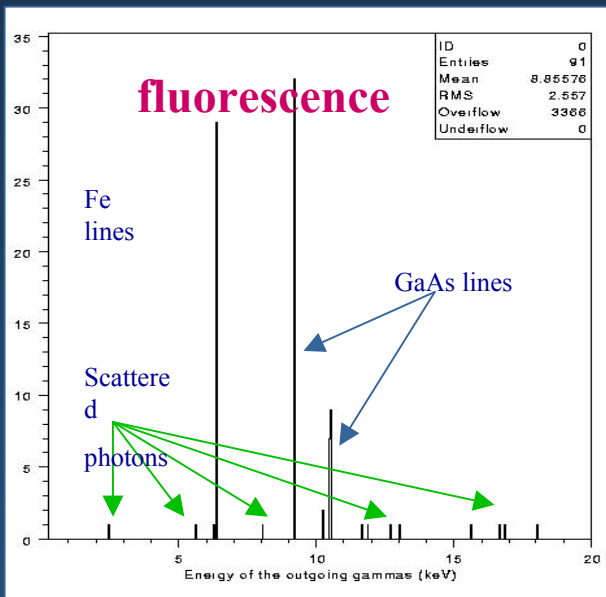
Protons - Bragg Peak - Water



Data: courtesy of CATANA Collaboration, INFN LNS, Catania

Maria Grazia Pia, *INFN Genova*

Much more available or in progress...



Conclusions

- A project is in progress in the Geant4 Collaboration for a **systematic, quantitative** validation of Geant4 Electromagnetic Physics
- Extensive set of preliminary results already available
 - only a small sample shown here
 - already consolidated results in some areas
 - optimization in progress in some areas
- More coming...
- Major effort involving several people, production sites and collaborating groups/projects
- <http://www.ge.infn.it/geant4/analysis/test>