Validation Activities at SLAC of Relevance to Medical Users

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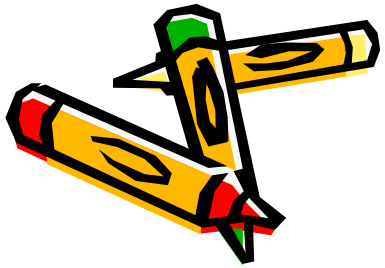
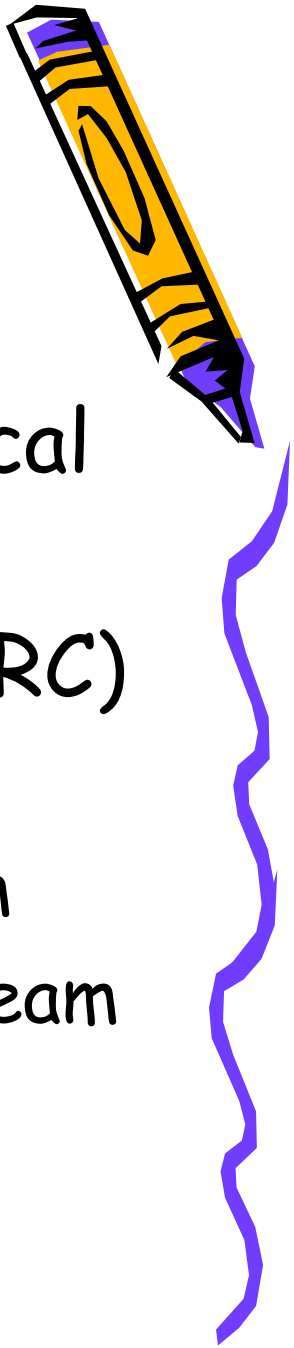
SLAC/SCCS

G4NAMU meeting March 6th, 2006

We regularly check Geant4 performances and provides results for inside and outside users of SLAC. From such our efforts, I pick up several validations which have relations in the medical fields

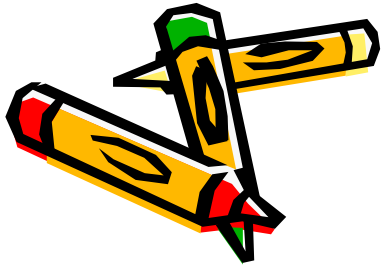


Medical use case validations



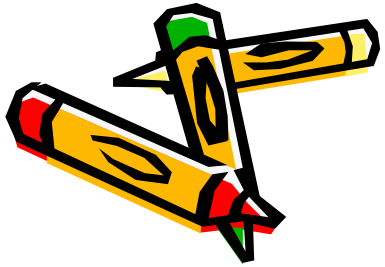
- "Questions for comparison of clinical Monte Carlo codes"

  (D. W. O. Roger, Author of EGS-NRC)
  - Speed test
  - Accuracy test for 18MV photon beam
  - Accuracy test for 20MeV electron beam

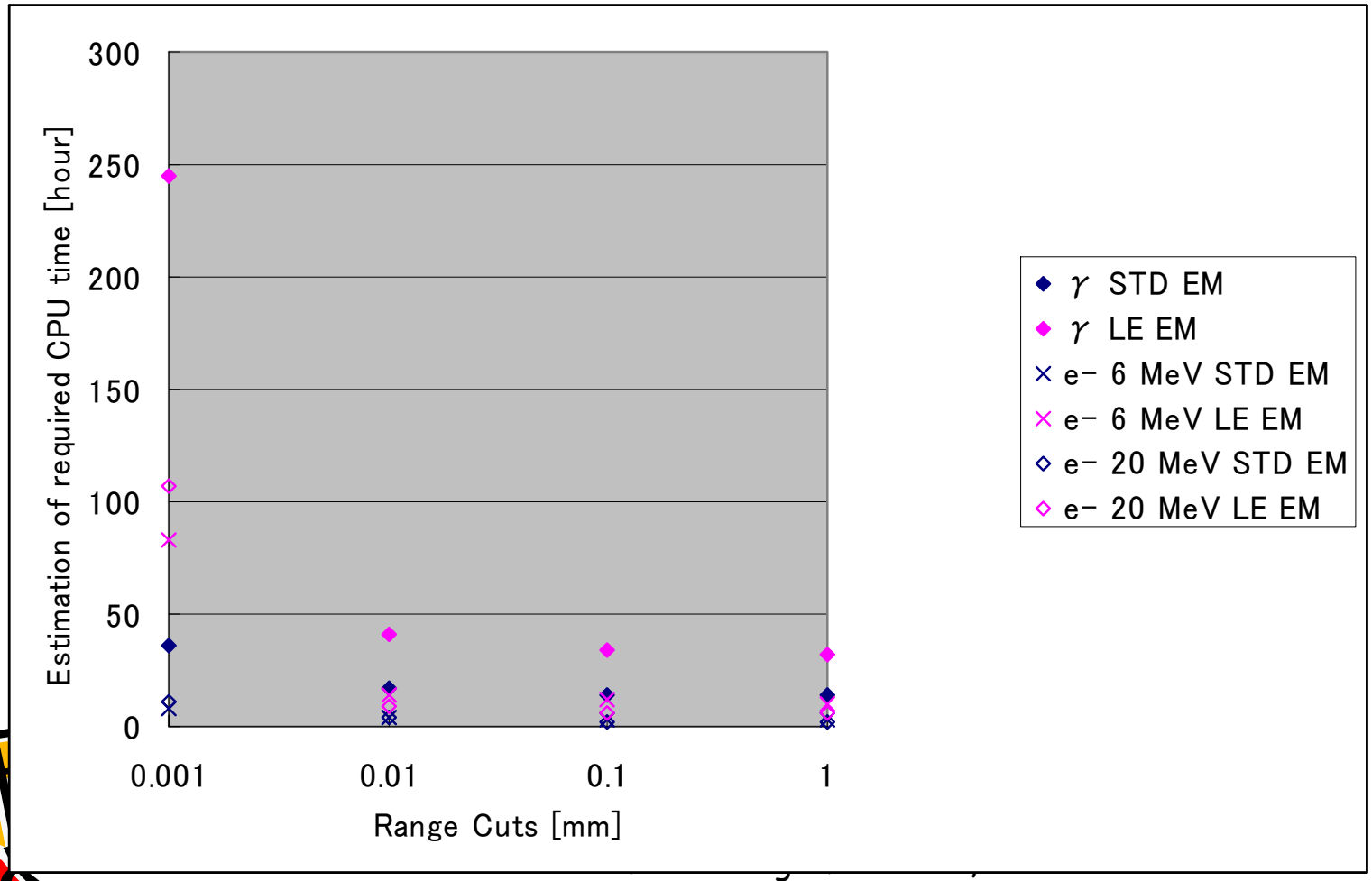


Speed of photon & electron calculations

- Geometry
  - The phantom is 30.5 cm x 39.5 cm x30 cm deep and filled with 5 mm^3 voxels.
  - The voxels are to be filled randomly with one of 4 materials (water, aluminum, lung (ICRU, ρ =0.26 g/cm^3) and graphite)
- Incident beams
  - photon 6 MV spectrum (calculated and given)
  - Electron 6MeV and 20 MeV
  - a point source at 100 cm SSD and collimated to 10x10 cm^2 at the phantom surface.
- Statistical Uncertainties to be achieved
  - an average relative statistical uncertainty on voxels with a dose greater than Dmax/2 of 0.02 or less.



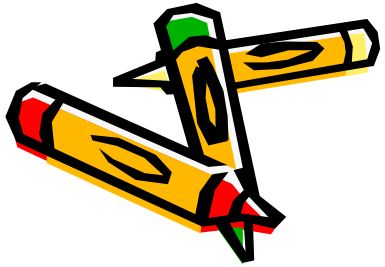
Results
geant4 v8.0.p01

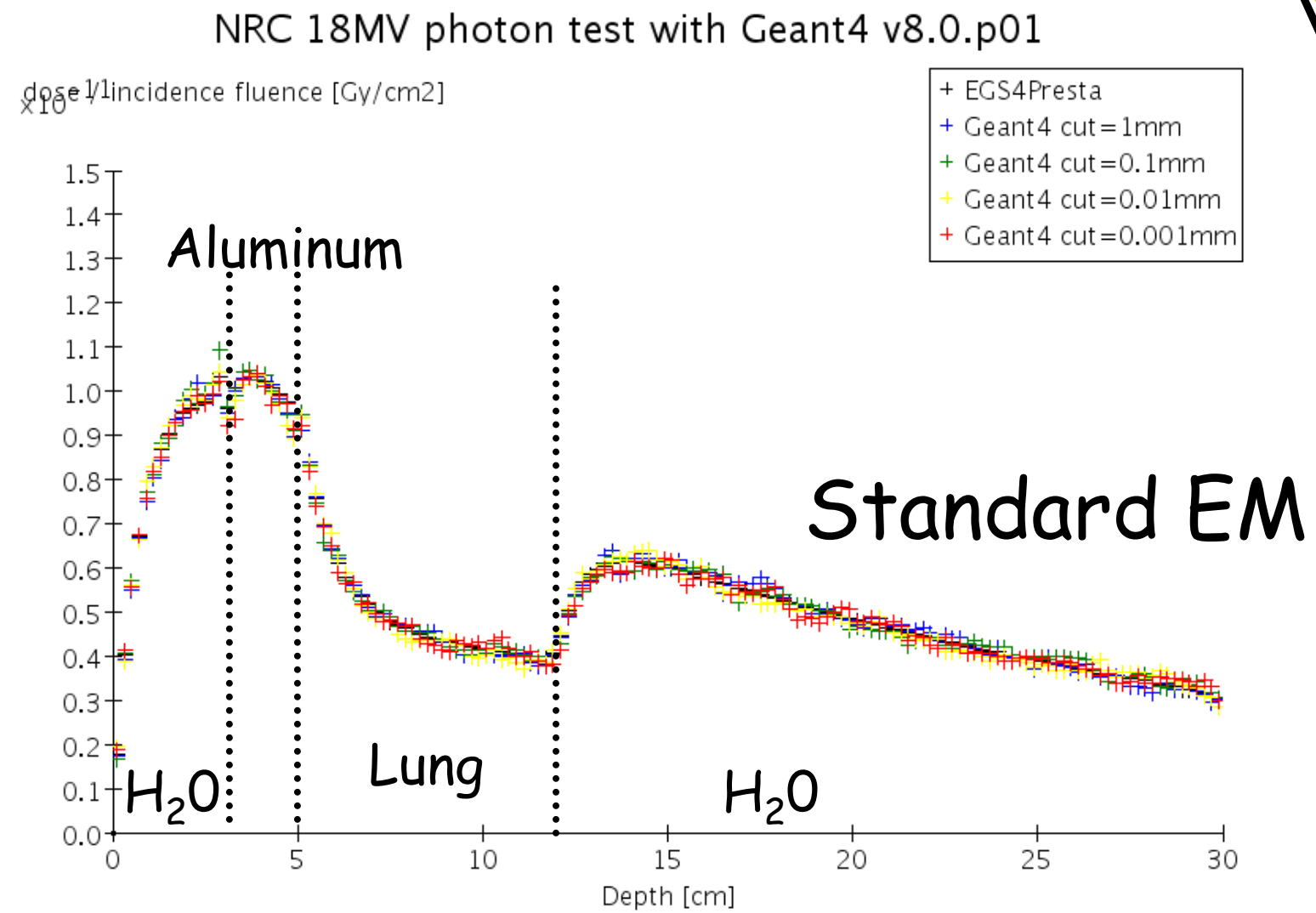


Accuracy test
Photon case

- Geometry
  - Similar to the previous, however material and voxel size are different.
  - From 0 to 3 cm is water, 3 to 5 cm is aluminum, 5 to 12 cm is lung and 12 to 30 cm is water.
  - The voxels are 5 mm^2 in the x-y directions but only 2 mm deep to increase the resolution.

    (beams come from z direction)
- Incident beams
  - a uniform 18MV beam from a realistic clinical accelerator as calculated at NRC using the BEAM code (given)





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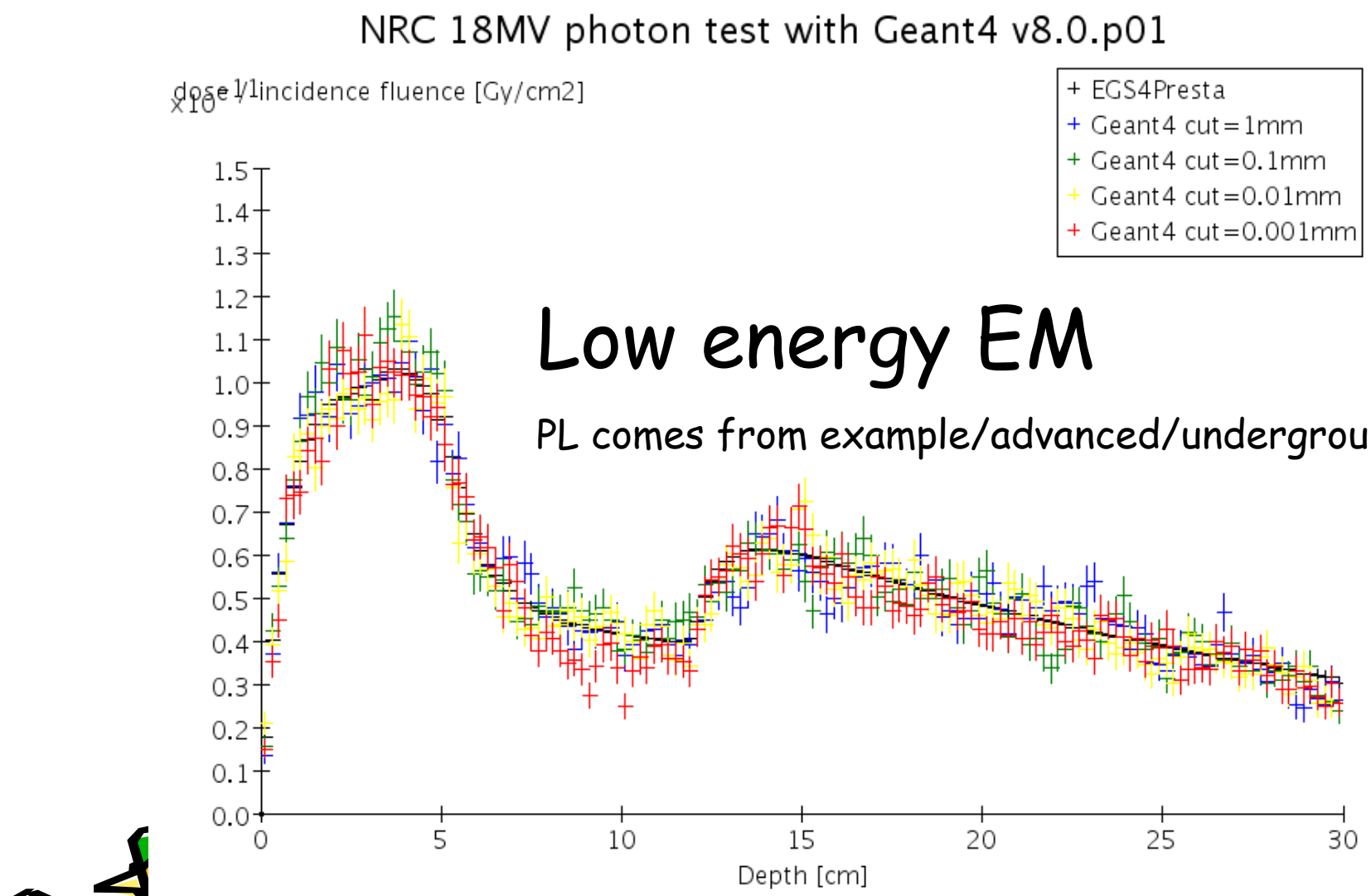
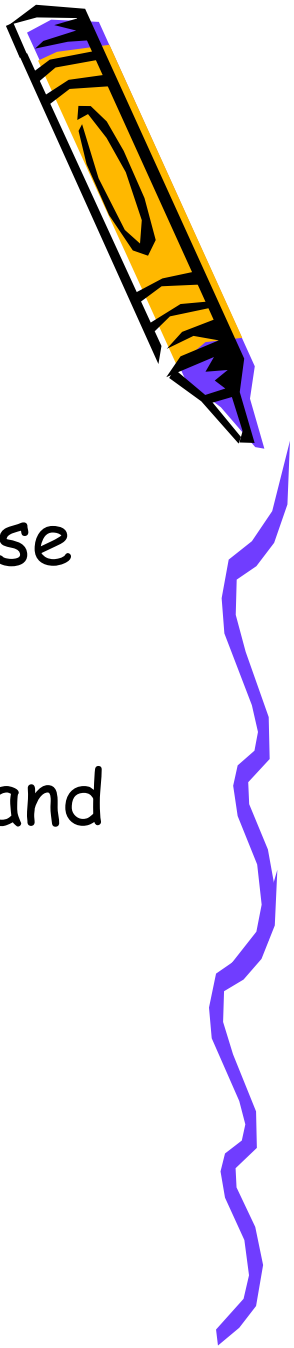


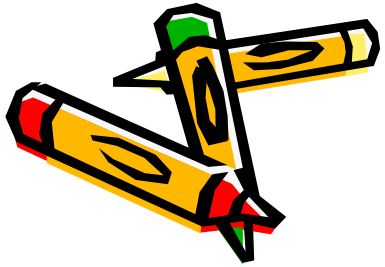
Low energy EM

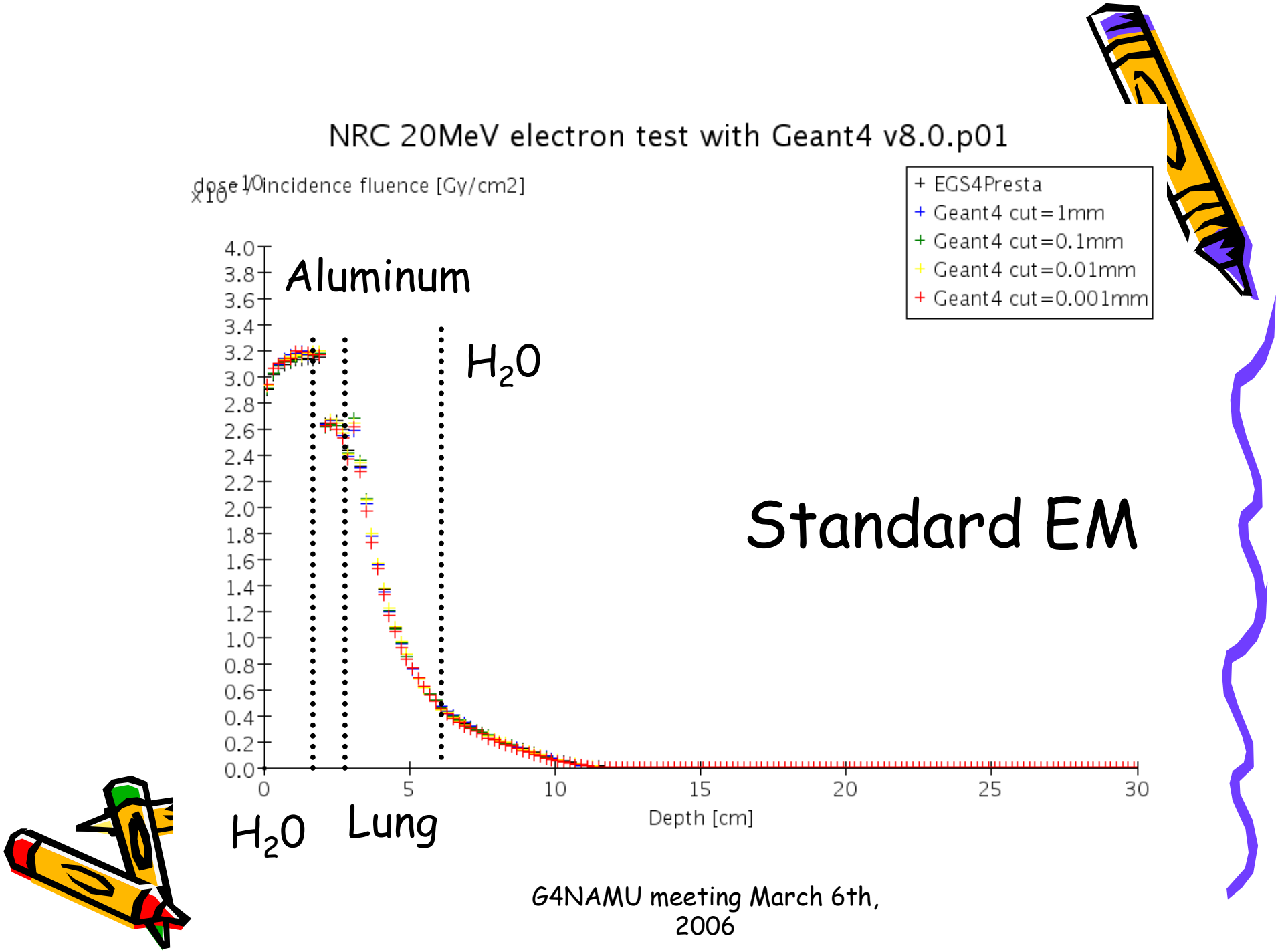
PL comes from example/advanced/underground

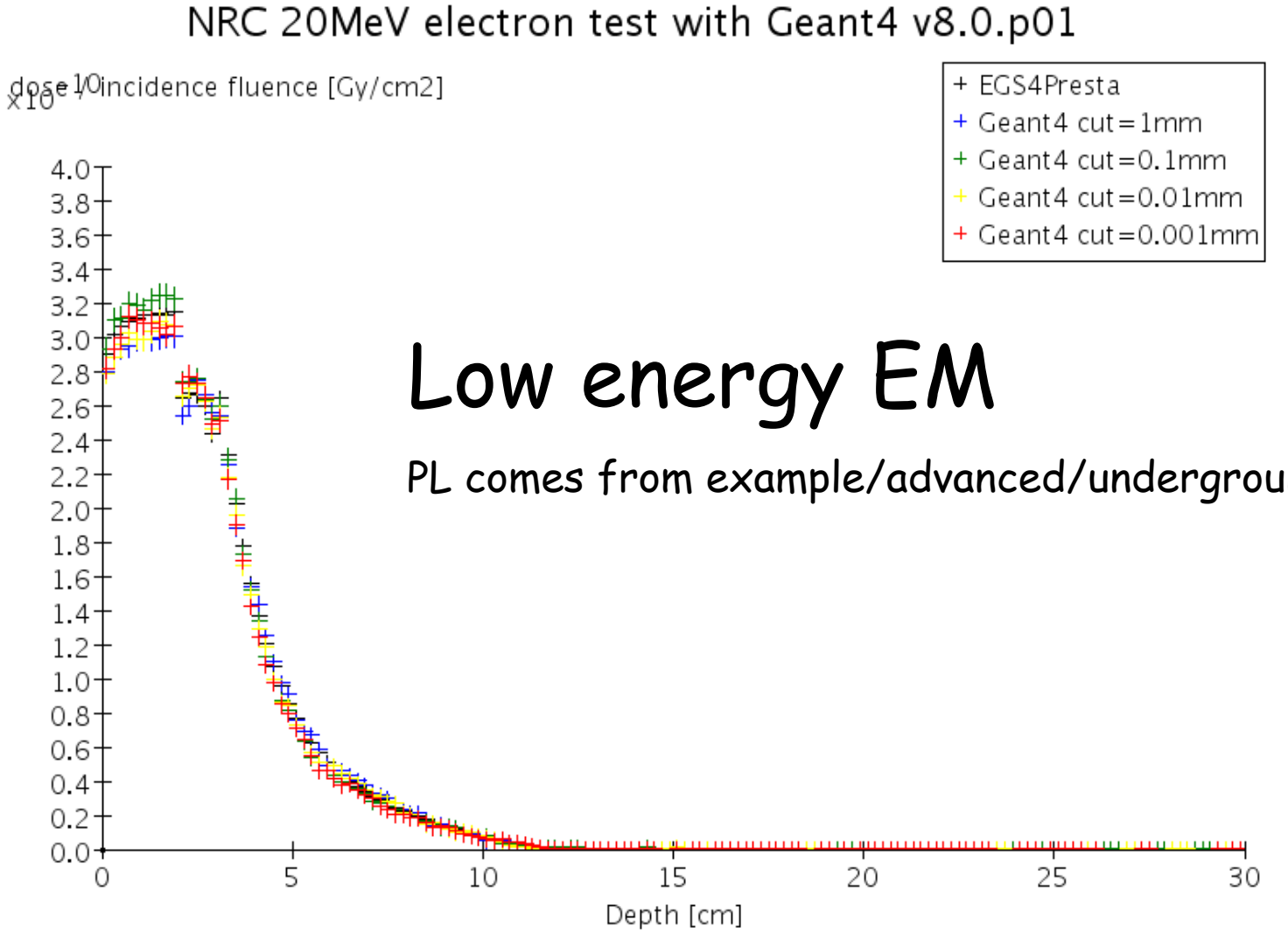
Accuracy test
Electron case



- Geometry
  - The phantoms are very similar to those for photon beams
  - From 1 to 2 cm is water, 2 to 3 cm is aluminium, 3 to 6 cm is lung material and 6 to 30 cm is water.
- Incinde beams
  - 20 MeV mono energetic electrons




NRC 20MeV electron test with Geant4 v8.0.p01
dose incidence fluence [Gy/cm2]
x10^-10
EGS4Presta
Geant4 cut=1mm
Geant4 cut=0.1mm
Geant4 cut=0.01mm
Geant4 cut=0.001mm
Aluminum
H2O
H2O
Lung
Depth [cm]
Standard EM



Low energy EM

PL comes from example/advanced/underground

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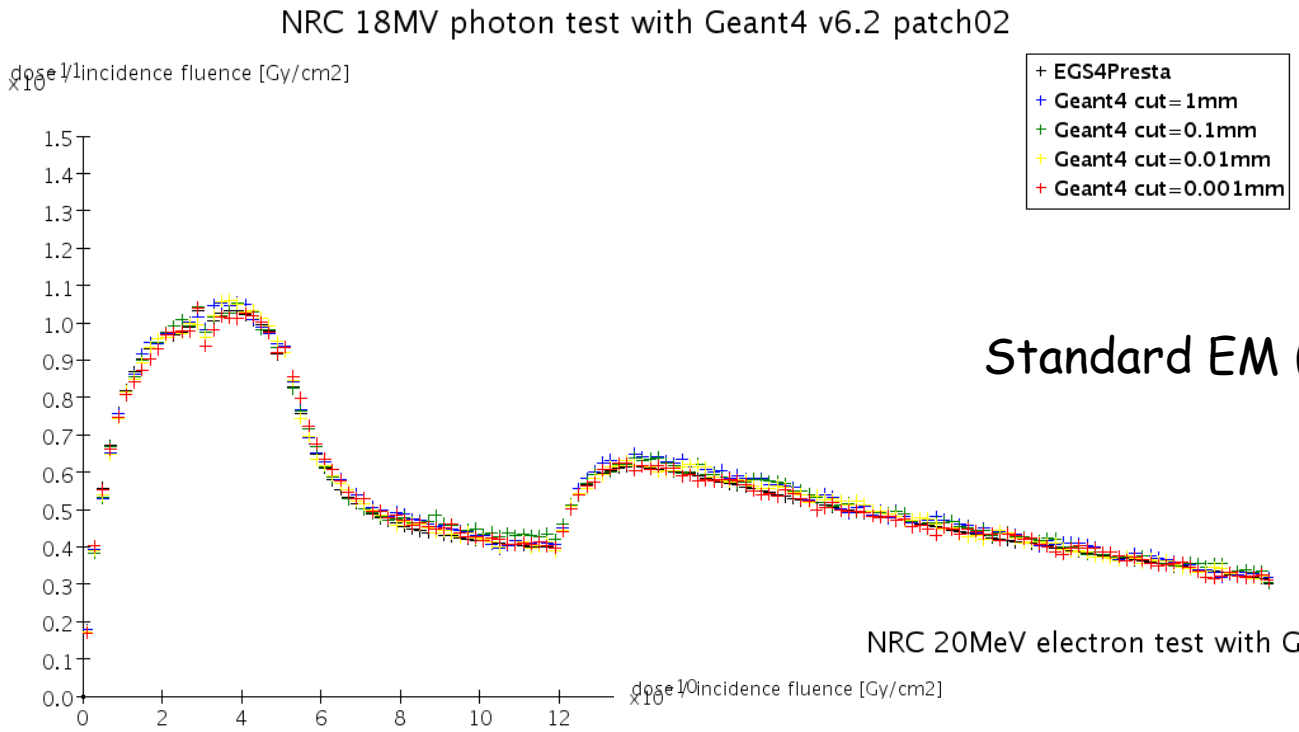
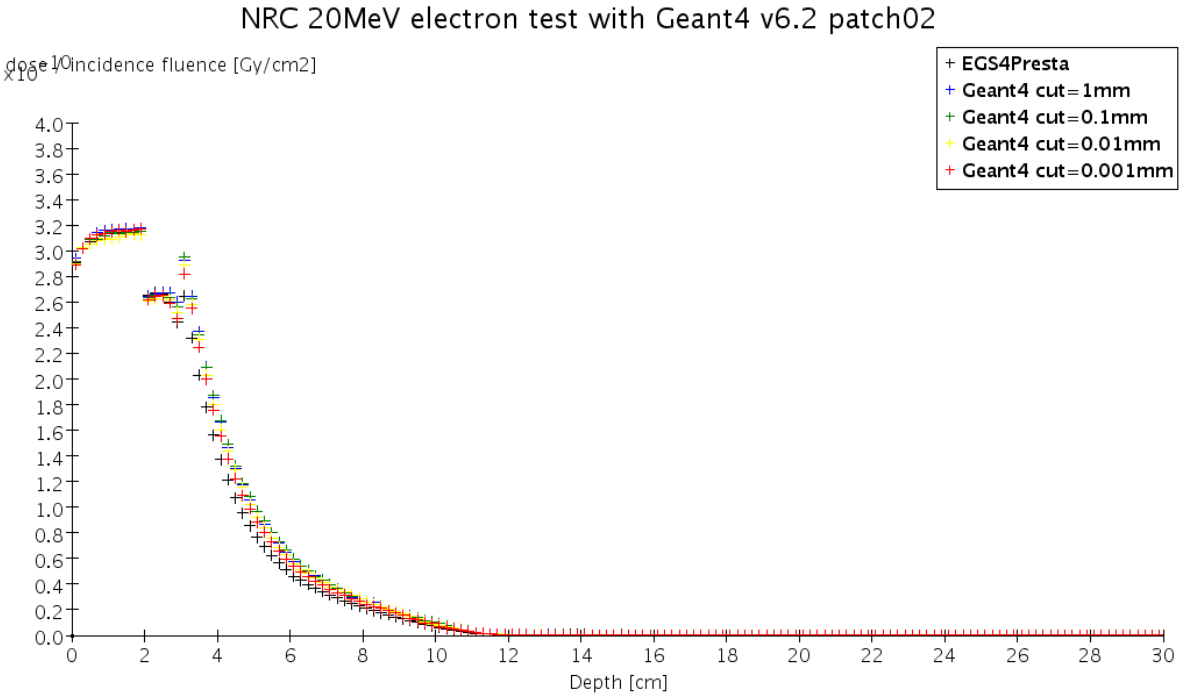
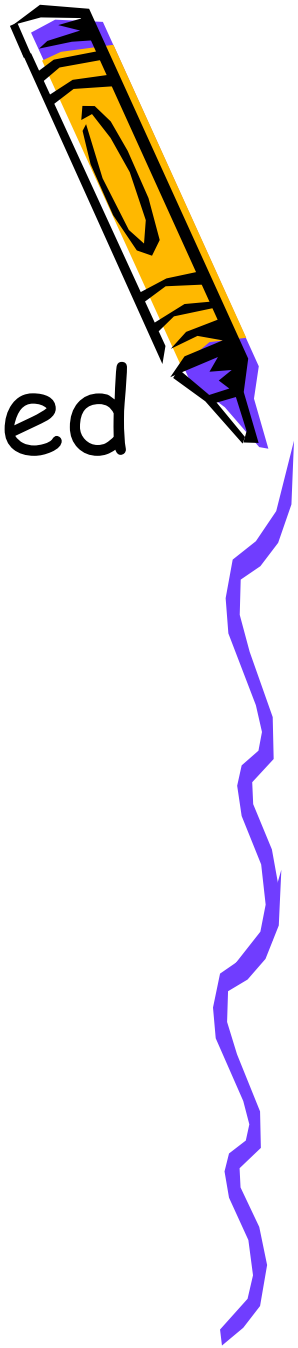


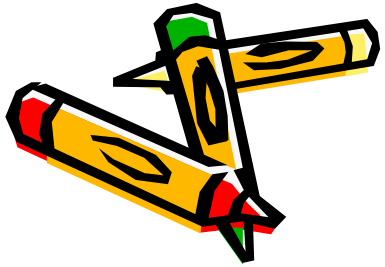
Standard EM (ExN03PhysicsList)



We also tests
Low energy EM
(DMXPhysicsList)



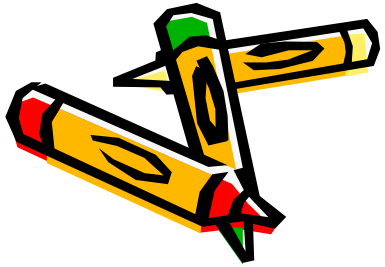
These validations are carried out for each release of Geant4.



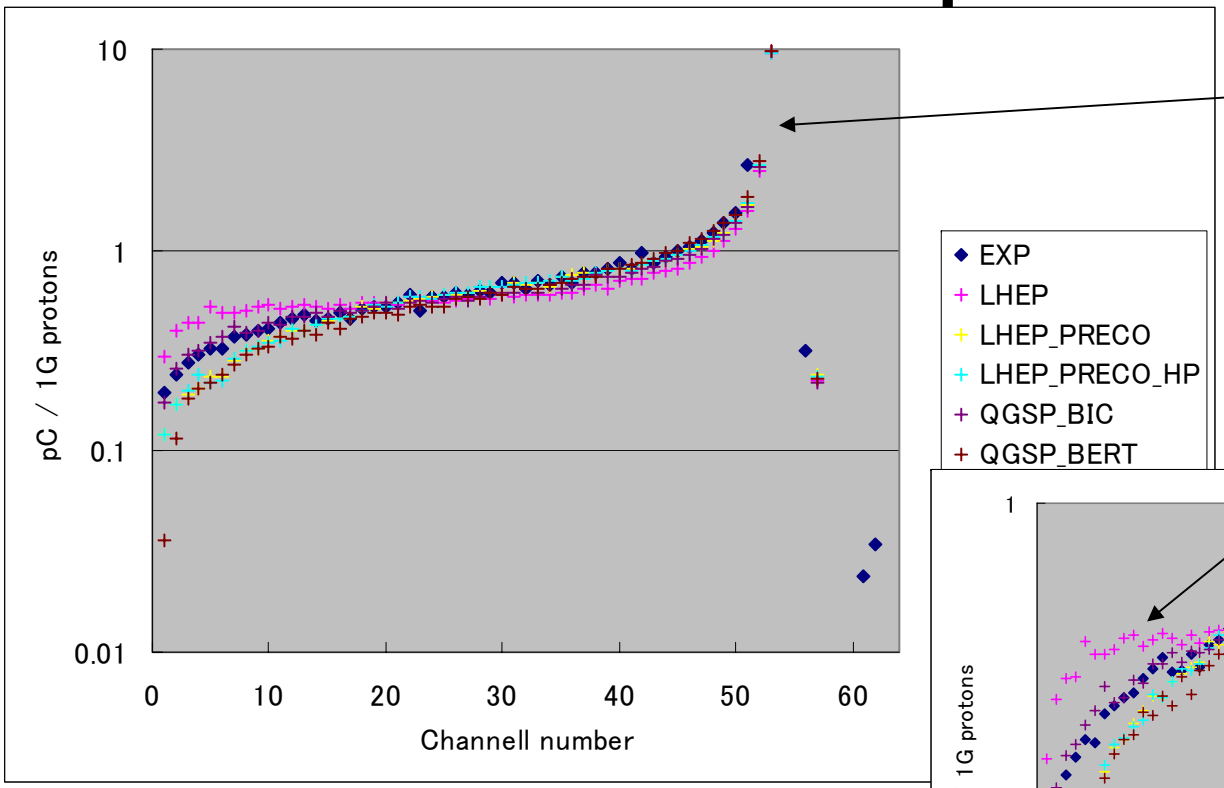
Nuclear interactions of 160 MeV protons stopping in copper: A test of Monte Carlo nuclear models

Bernard Gottschalk, Rachel Platais, and Harald Paganetti
pp. 2597-2601 Med. Phys 26-12 (1999)

- The longitudinal charge distribution left by 160 MeV protons stopping in a multilayer Faraday cup (MLFC) was measured
- The distribution consists of two regions
  - build-up region attributable entirely to nuclear interactions
  - sharp peak attributable entirely to protons stopping by EM interactions



Multi Layers Faraday Cups ~160MeV protons

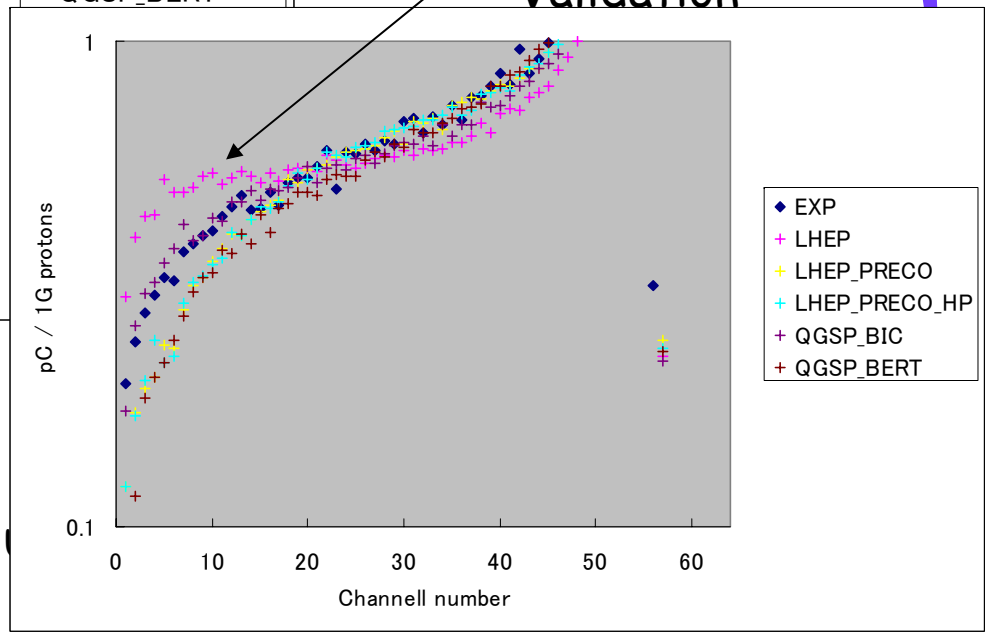


sharp peak

EM Physics Validation

build-up region

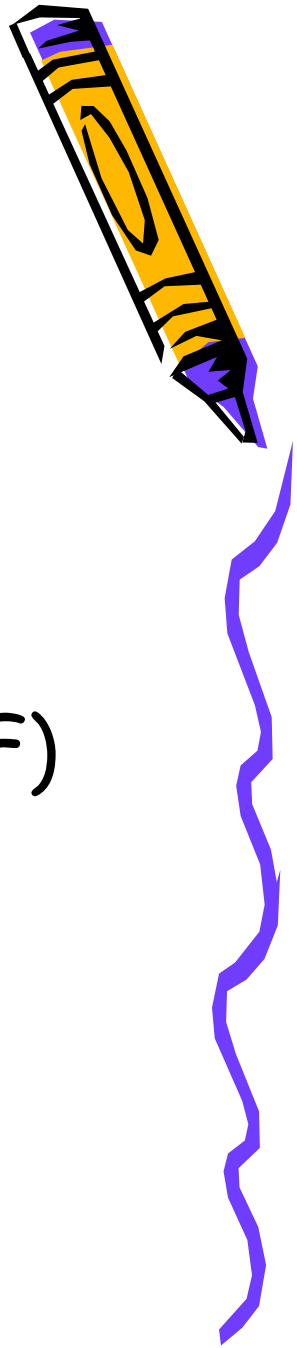
Hadron Physics Validation



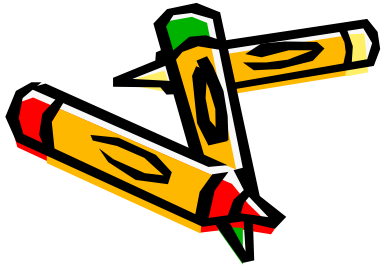
Kapton-Cu layers

Nuclear interactions of 160 MeV protons stopping in copper: A test of Monte Carlo nuclear models
Bernard Gottschalk, Rachel Platais, and Harald Paganetti
pp. 2597-2601 Med. Phys 26-12 (1999)

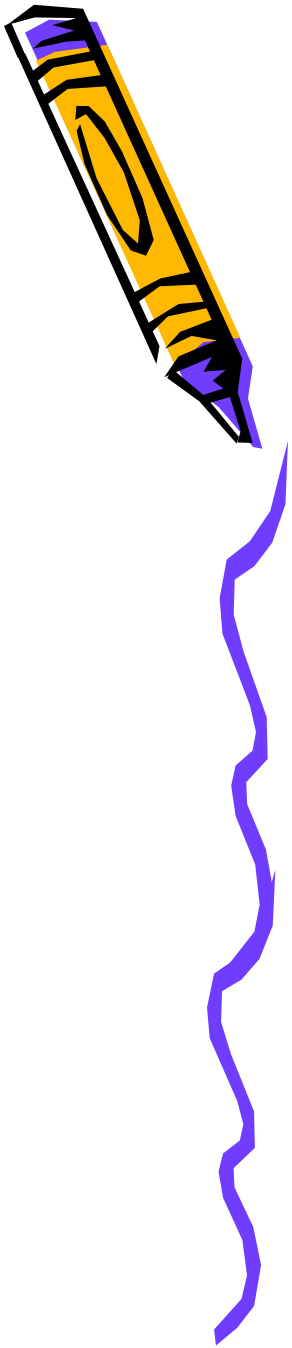
Verification of High Precision Neutron models



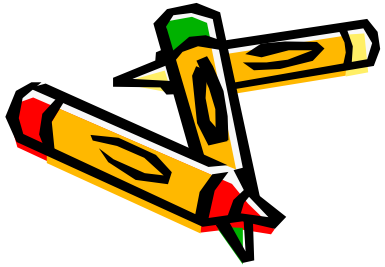
- Checking Cross Sections and Final State Products of High Precision Neutron models of Geant4 with Evaluated Nuclear Data File (ENDF) libraries
- MCNPs depend on ENDF libraries
  - at least data driven parts of its



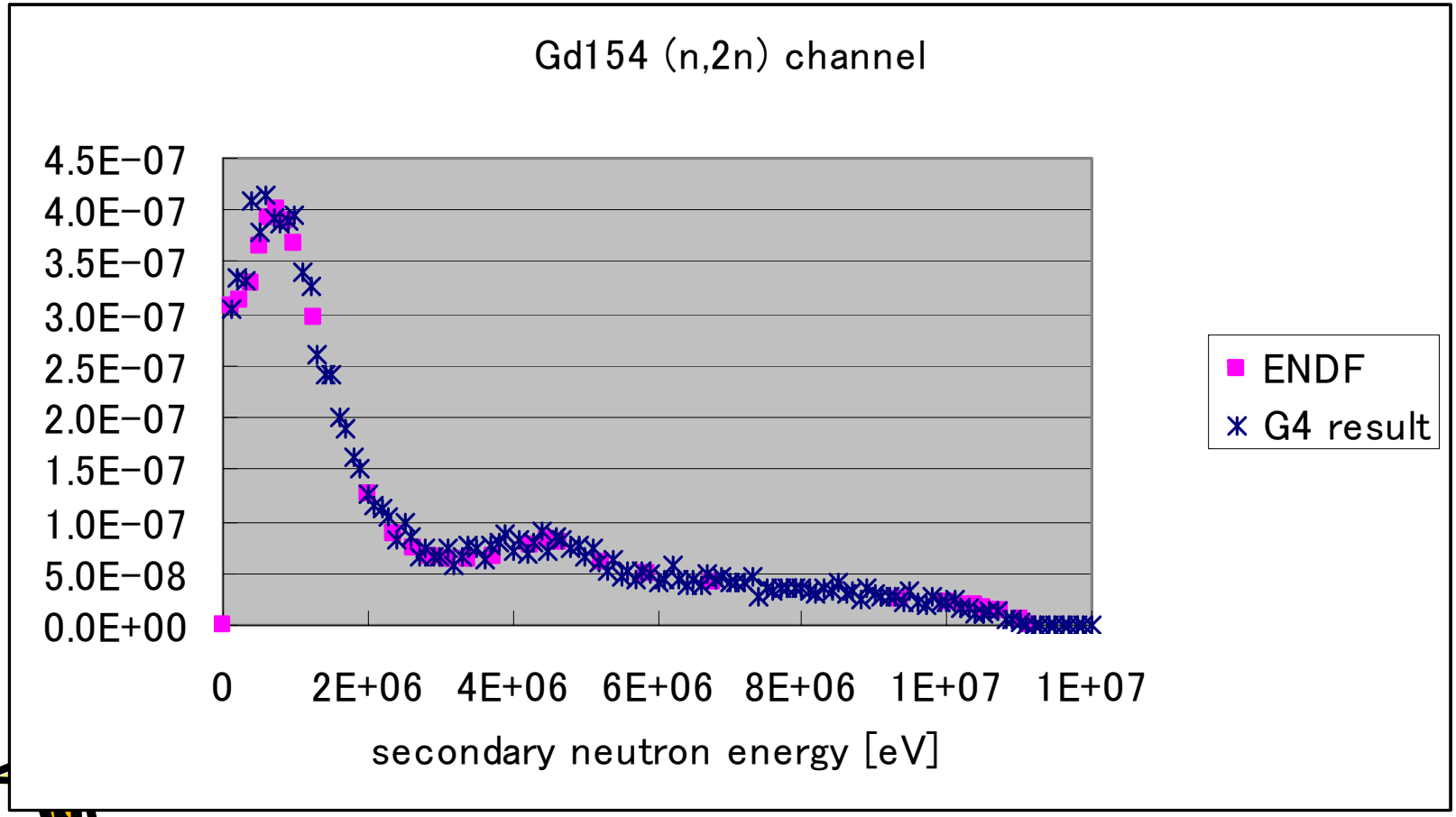
Verification of High Precision Neutron models
Channel Cross Sections
20MeV neutron on Gd157



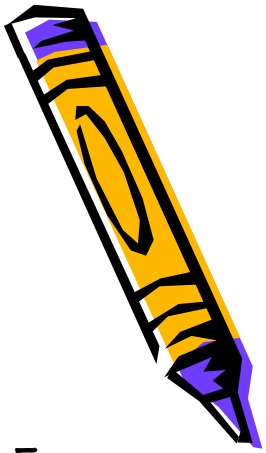
Geant4 results	ENDF data
• Ela XS 3.7104216 [barn]	• 3.708710+0 [barn]
• Inela XS 1.2508858	
• Inela XS F01 0.99179298	• 9.940940E-1
• Inela XS F04 0.18413539	• 1.836200E-1
• Inela XS F06 0.020973994	• 2.126800E-2
• Inela XS F10 0.041302787	• 4.064300E-2
• Inela XS F23 0.009658162	• 9.717300E-3
• Inela XS F27 0.0030225183	• 3.306100E-3
• Cap XS 0.0017767842	• 1.646330E-3



Verification of High Precision Neutron models
Energy Spectrum of Secondary Particles



Comparison of Computing Speed and Memory consume among deferent implementation of Simple Voxelized Geometries.



Geometry: Phantom 30x30x30 cubic cm.

Fill this Phantom by 216k voxels which have size of 0.5x0.5x0.5 cubic cm.

Incidence particle: 50MeV electron

Vertical incidence to a surface of Phantom
Uniform incidence to the surface.

Implementation of Phantom

1, All voxels are place by G4Placement. (216k voxels)

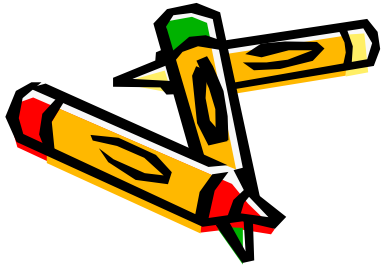
2, Configured a rod from voxels and placed these rods. (3.6k rods)

3, Configured a disk from rods and placed these disks. (60disks)

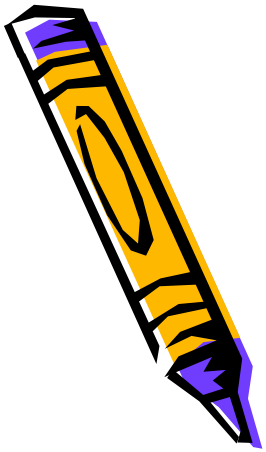
4, Using G4VPVParameterisation

with kXAxis

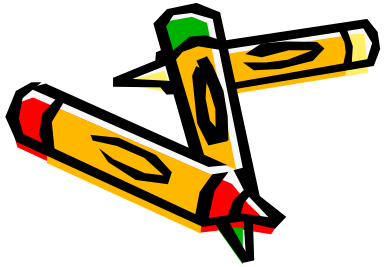
with kUndefined



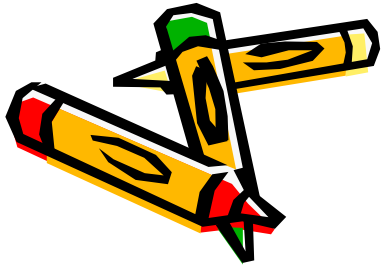
Results

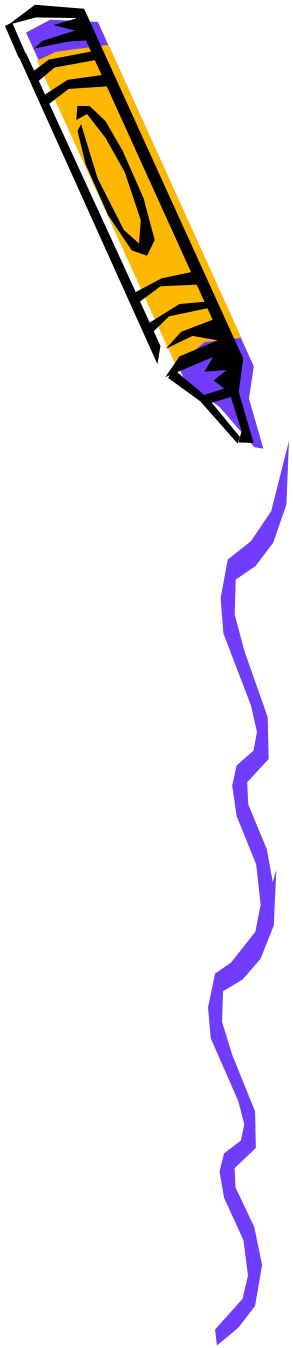


- Memory consume
  1,47830k
  2, 572k
  3,   2k
  4,42250k with kUndefined
    4k with kXAxis
- Computing Speed
  100k electrons incidence
  1, 433.99sec
  2, 410.69sec
  3, 427.97sec
  4, 446.85sec with kUndefined
  44685 sec with kXAxis (estimated from 1k electrons)
- Order of magnitude differences appeared in both memory consume and CPU performances.
- Please take care geometry implementations, even it's a simple voxelized one.



Other validation activities at SLAC

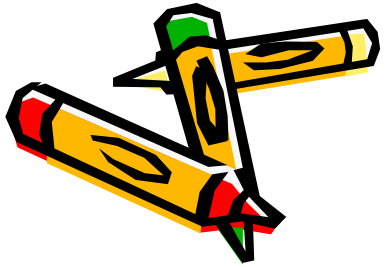




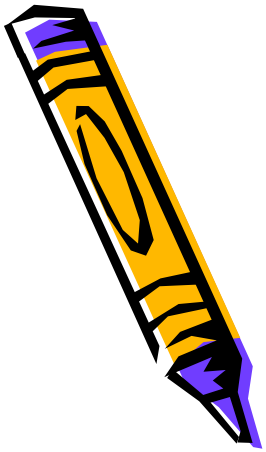
G4NAMU meeting March 6th, 2006

Hadron interaction validation

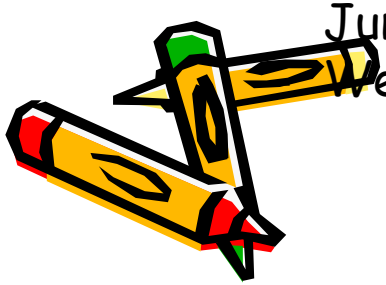
- For all major hadronic physics lists (Ex LHEP, QGSP, FTFP etc)
  - Gamma, Pion, and Kaon production spectra
  - Mean multiplicity distributions
    - Gazdzicki, M. and Roehrich D., Z. Phys. C65 215 (1995)
    - Dermer, Apj 307 47-59 (1986)
  - Charged multiplicity distributions
    - Brick, D. et al., Phys. Rev. D25, 2794 (1982)
    - Adamus, M. et al., Z. Phys. C32 475 (1986)
    - Ammar, R. et al., Phys. Lett. B178, 124-128 (1986)

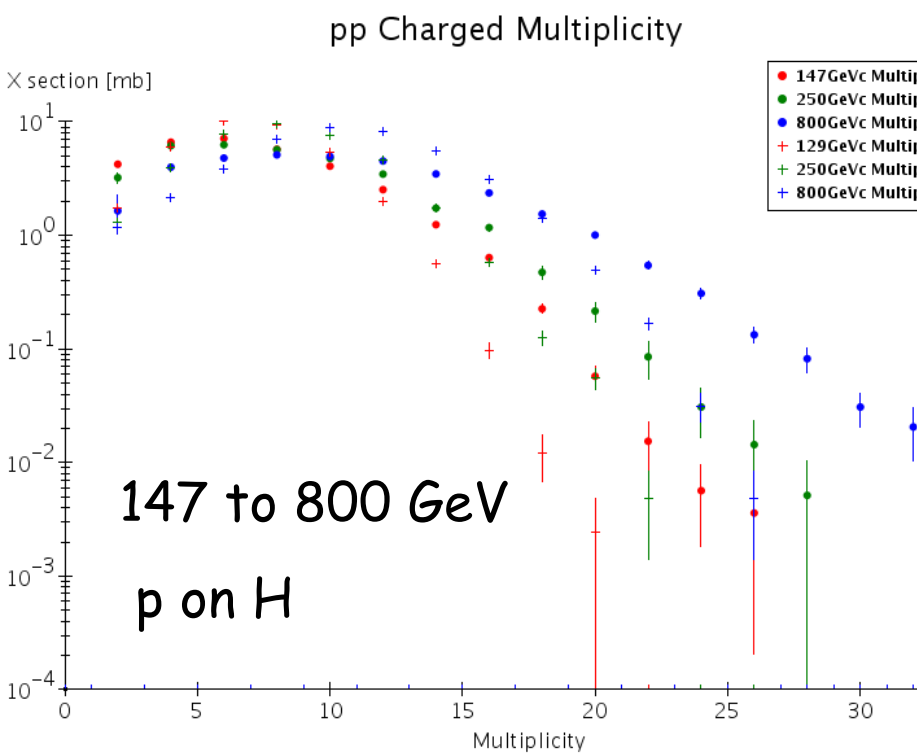


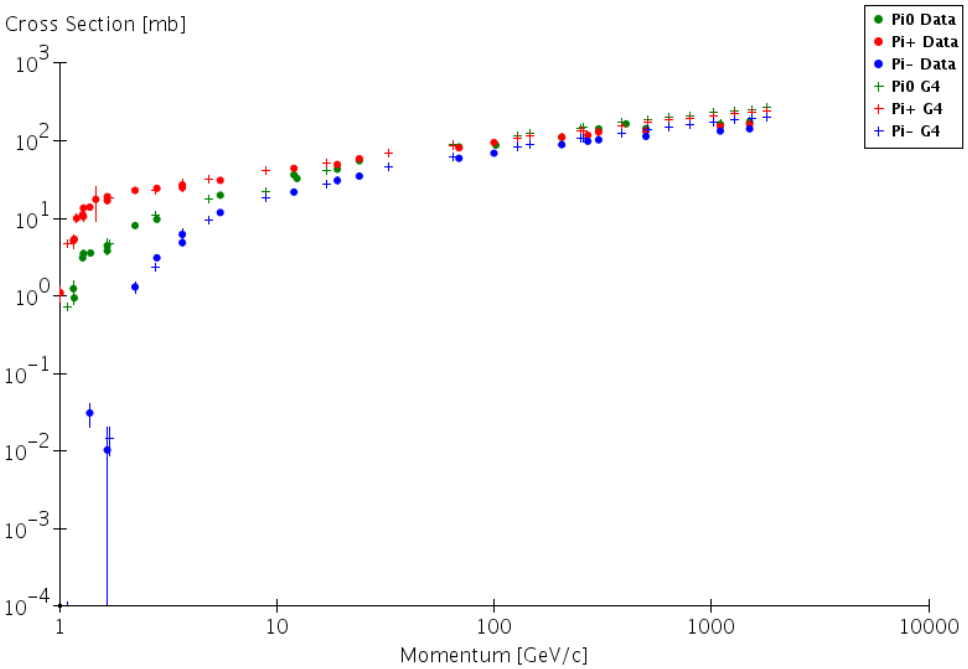
Ion interaction validations



- Neutron double differential production cross sections
  - Iwata et al.,*Phys. Rev.* **C64** pp. 05460901(2001)
- Pion double differential production cross sections
  - J. Papp, LBL-3633, May 1975. 202pp
- Neutron Yield from Thick Target
  - T. Kurosawa et al., *Phys. Rev.* **C62** pp. 04461501 (2000)
- Fragment particle production cross sections
  - F. Flesch et al., J, RM, 31, 533, 1999
  - F. Flesch et al., J, RM, 34, 237, 2001
  - Webber, W. R. et al., Phys. Rev.C: Nucl. Phys., vol. 41, no. 2, Feb. 1990,
  - V.D.AKSINENKO et al. J, NP/A, 348, 518, 1980
  - Bertulani, C. A. and B. Gerhard, Phys. Rep., vol. 163, nos. 5 & 6, June 1988, pp. 299-408.
  - Westfall, G. D. et al., Phys. Rev. C, vol. 19, no. 4, Apr. 1979,

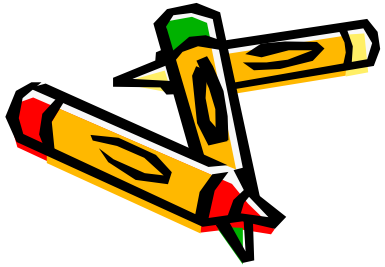




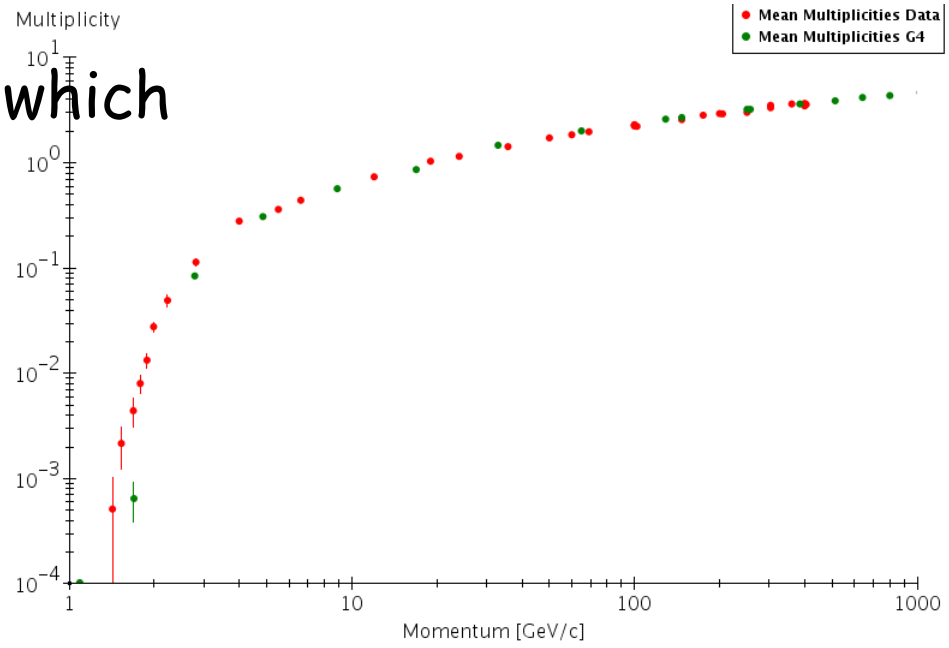


Validation of LC Physics Lists which SLAC provided

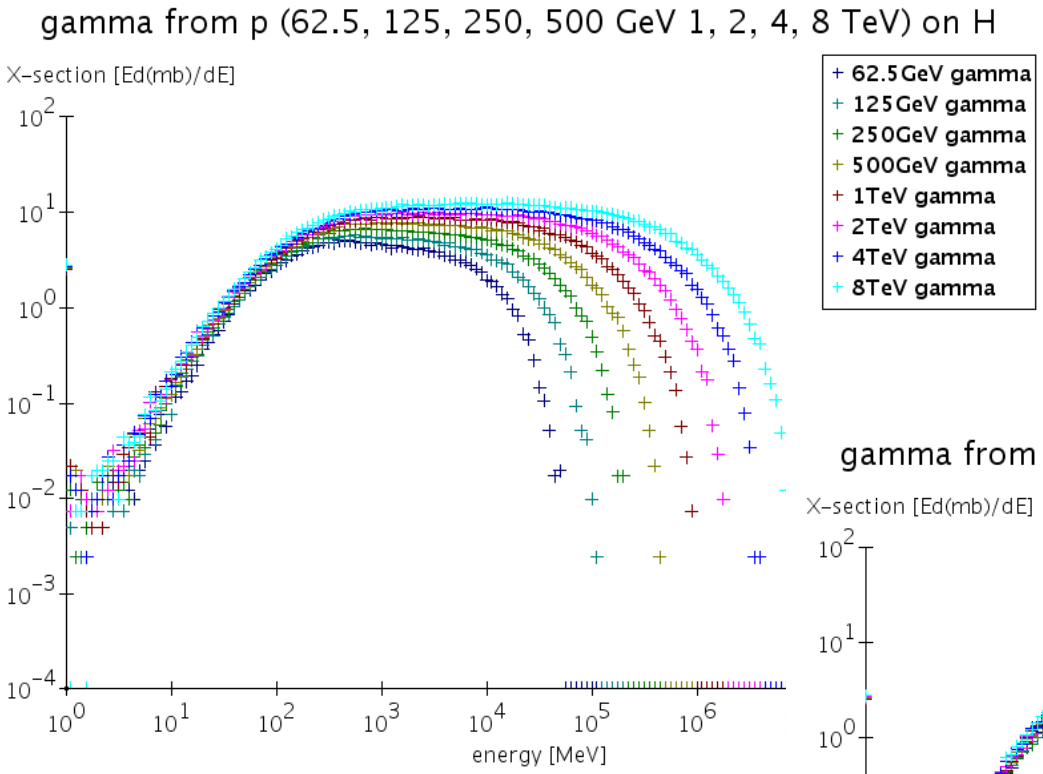
Geant4 v7.0.p01



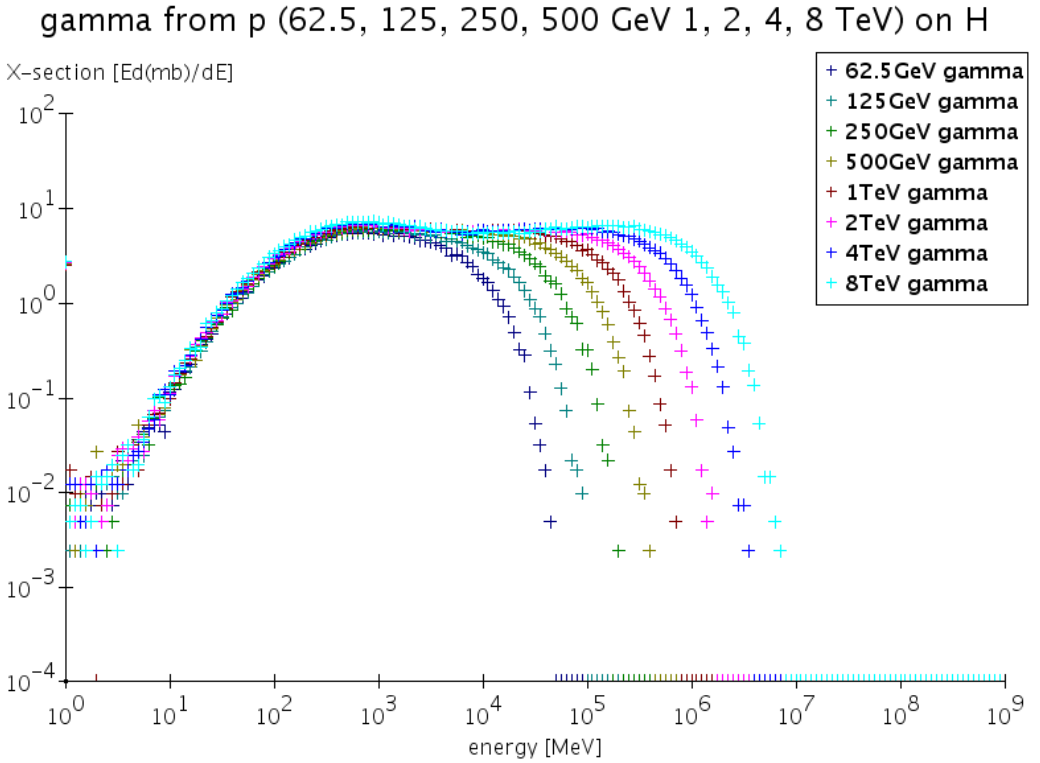
G4NAMU



QGSP

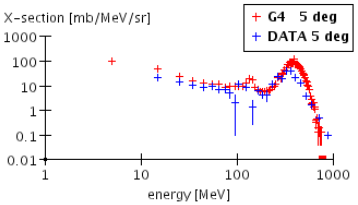


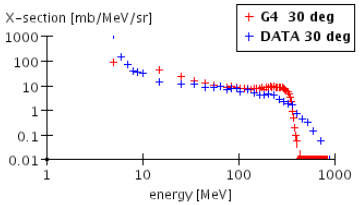
FTFP

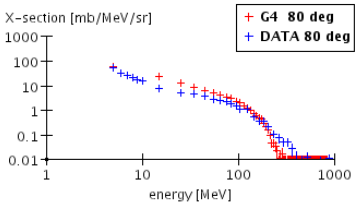


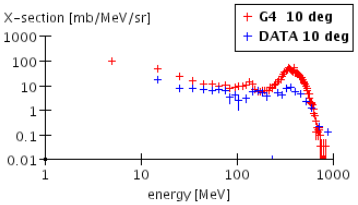
Geant4 v7.1.p01
Hadronic List PACK 2.5

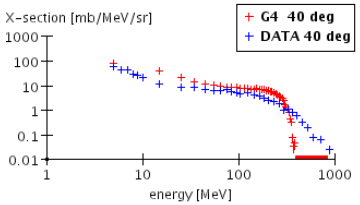
Neutron Production
400 MeV/n Carbon on Copper

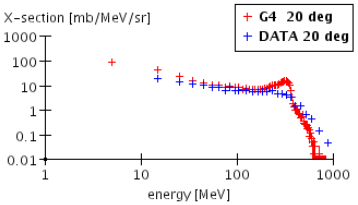


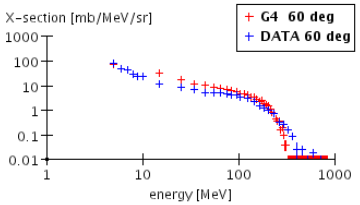




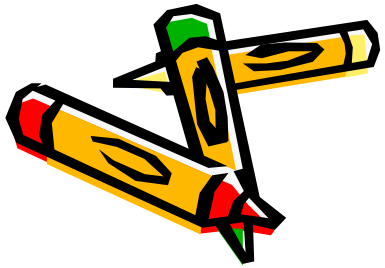






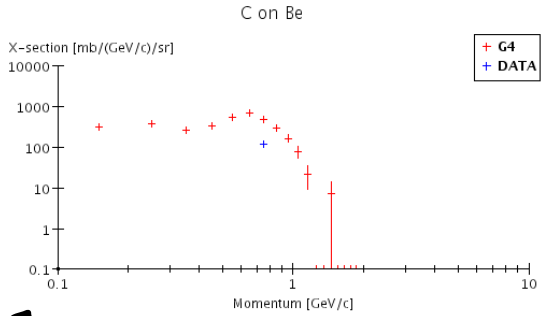


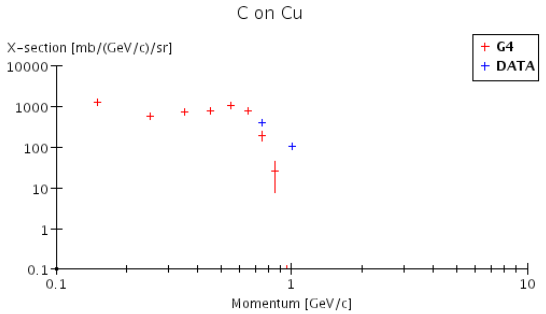
Geant4 6.2.p02
Binary Cascade Light Ions

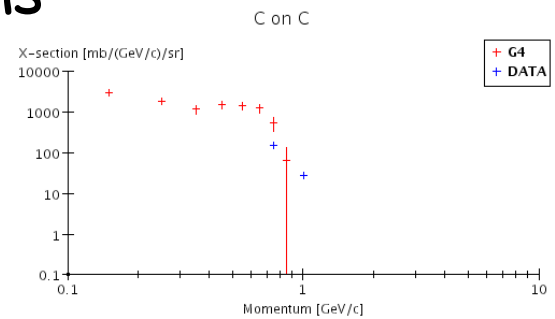


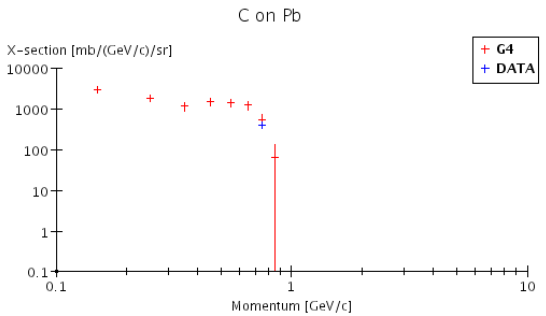
Pion Production

1 GeV/c/n Carbon on Be, C, Cu and Pn

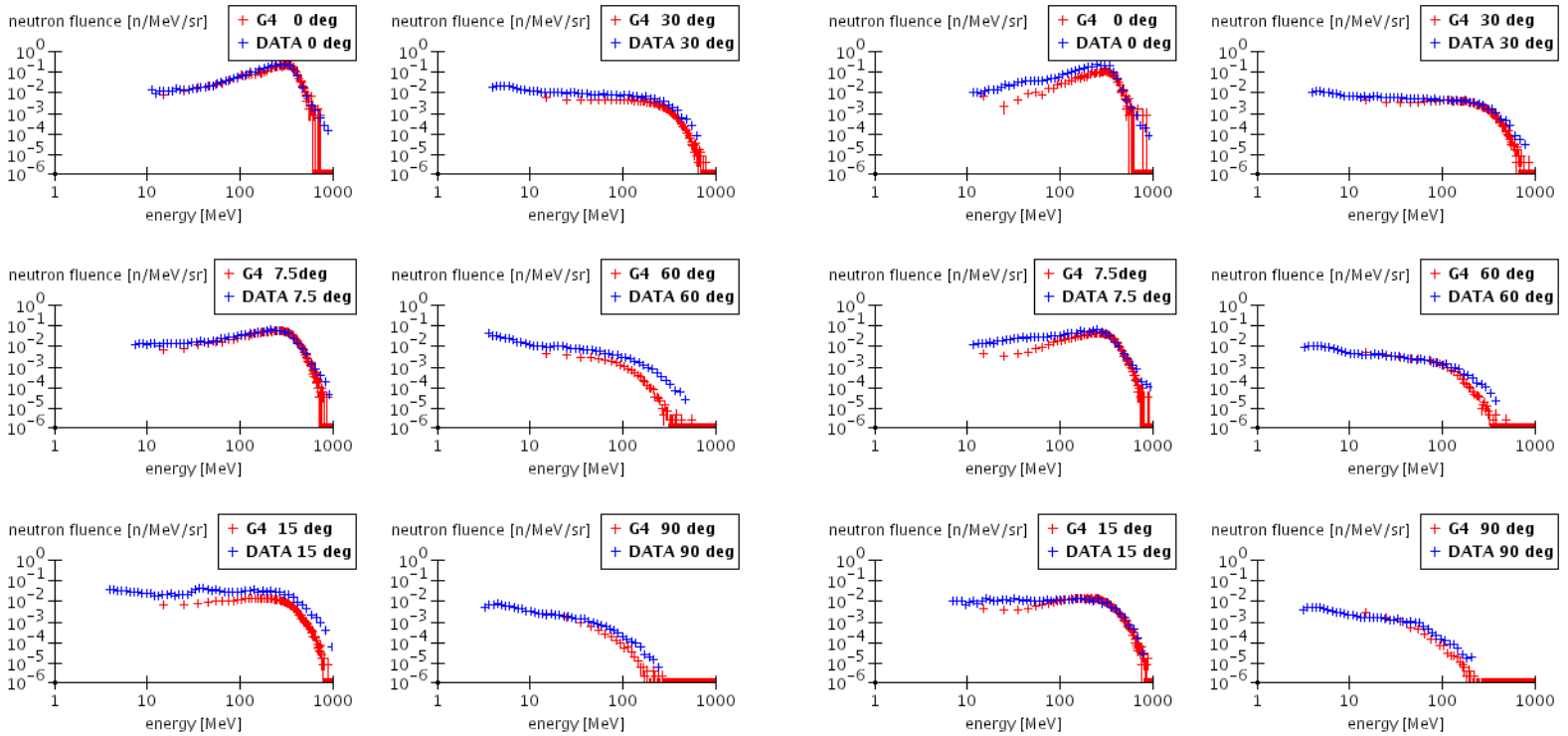








Neutron Yield
Fe 400 MeV/n beams



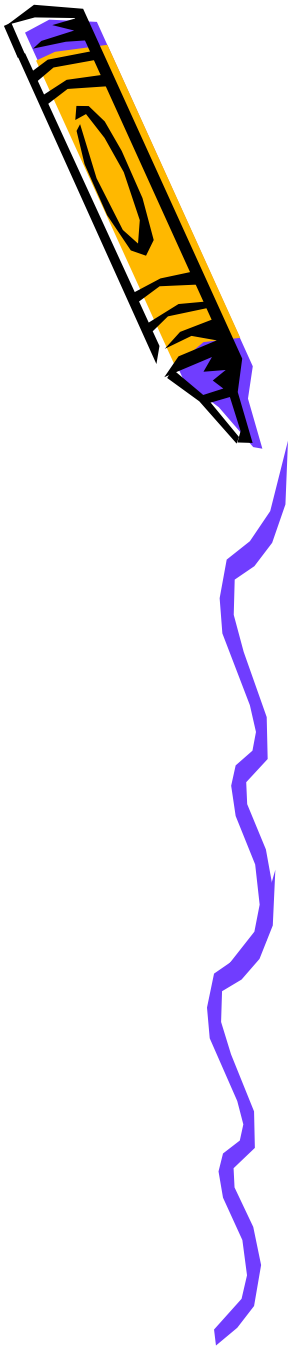
CarbonThick Target

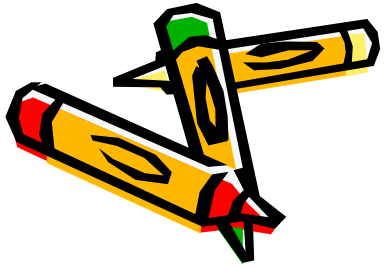
Aluminum Thick Target

G4NAMU meeting March 6th, 2006

T. Kurosawa et al., *Phys. Rev.* **C62** pp. 04461501 (2000)

And so on,





Summary

- Several validations which related to medical use cases are already run regularly at SLAC.
- We have a plan of expansion of validations
  - Comparison requests with reference of data are welcome.