Validation of Electromagnetic Physics

Daren Sawkey
on behalf of the Electromagnetic Physics working group

VARIAN medical systems

Geant4 Collaboration Meeting
Fermilab
Sept 30, 2015

Overview

process level (unit)

- gamma
  - cross sections self-consistent
  - comparison to NIST
- bremsstrahlung
- multiple scattering (pure)
  - electron 13 to 20 MeV
  - proton 160 MeV
  - muon 172 MeV
  - muon 45 GeV
- multiple scattering ( )
  - dose deposition vs depth (Sandia)
  - Fano cavity
- fluctuations
  - ALICE TPC
  - silicon

integrated (system)

- calorimetry (Vladimir)
- Bragg peak
- medical linac

EM benhcmarks

Validation of Geant4 Electromagnetic packages is based on Geant4 extended electromagnetic and medical examples. Validation is performed versus published data and/or between Geant4 versions. The list of dedicated tests for standard electromagnetic physics is shown below.

Multiple scattering

Test	Responsible	Coverage	Purpose
Hanson data	VI	e- of 15.6 MeV off Au targets	Thin targets
Electron benchmark	DS	13 and 20 MeV e- off Be, C, Al, Ti, Ta, Au targets	Thin targets
MuScat data	VI	96.2 MeV mu+ off lqH, Li, Be, C, CH2, Al, Fe	This targets
High energy data	VI	mu+ 7.2, 11.6 GeV off Cu; pi, K, p at 75, 125, 175 GeV in Be, C, Al, Cu, Sn, Pb	This targets
Model comparisons	VI	e- off Si	This targets
Sandia data	OK	e- of 0.5 MeV in semi-infinite media of Al, Mo, Ta, TaAl, AlAuAl	Dose profile
Fano theorem	SE	gamma of 1 MeV in water	Radiation dose inside cavity
Fano theorem	SE	e- of 1 MeV in water	Radiation dose inside cavity
Dose kernel	SI	e- of 1, 10, 15, 100, 1000 keV in water	Dose profile

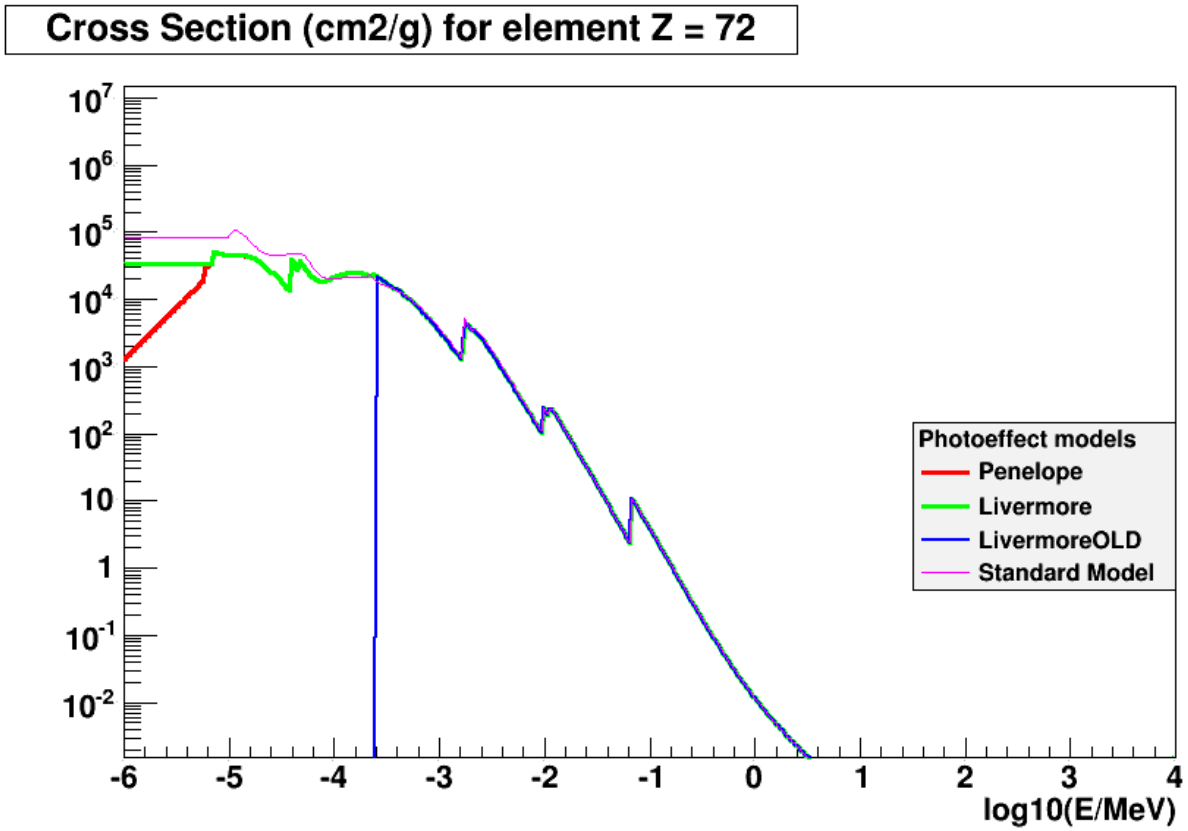
Calorimeter tests

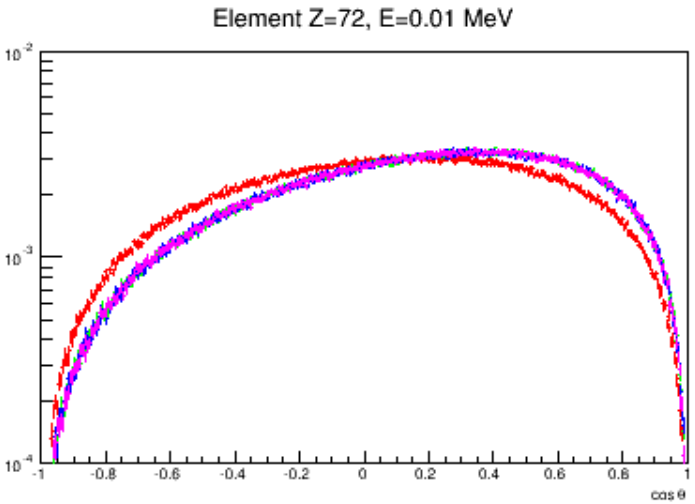
Test	Responsible	Coverage	Purpose
ATLAS barrel	VI	e- of 10 GeV in Ar/Pb sampling calorimeter	Calorimeter response
ATLAS HEC	VI	e- of 10,30, 50, 70, 90, 110 GeV in Ar/Cu sampling calorimeter	Calorimeter response
LHCb	VI	e- of 10 GeV in Sc/Pb sampling calorimeter	Calorimeter response
ATLAS Tile	VI	e-, mu- of 20 GeV in Sc/Fe sampling calorimeter	Calorimeter response
ZEUS testbeam data	VI	e- of 10 GeV in Sc/Pb sampling calorimeter	Calorimeter response
CMS ECAL	VI	e- of 10 GeV in PbWO4 crystal calorimeter	Calorimeter response
CMS combined	VI	e-, gamma in CMS ECAL + HCAL	Calorimeter response

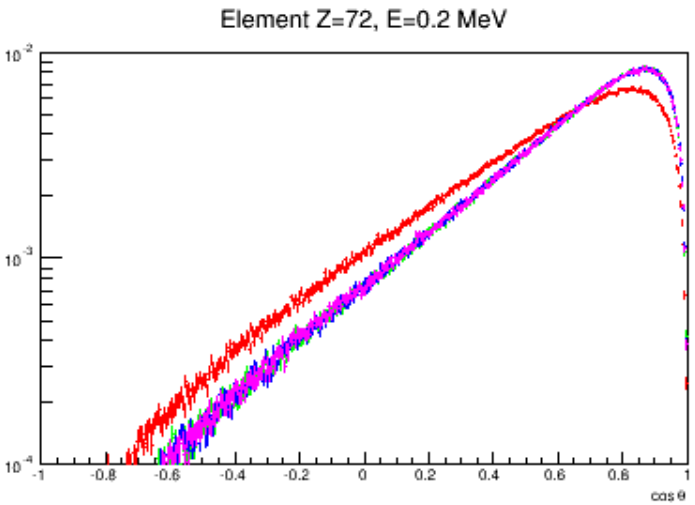
http://www.geant4.org/geant4/collaboration/working_groups/electromagnetic/benchmarks.shtml

Cross section comparisons

between models

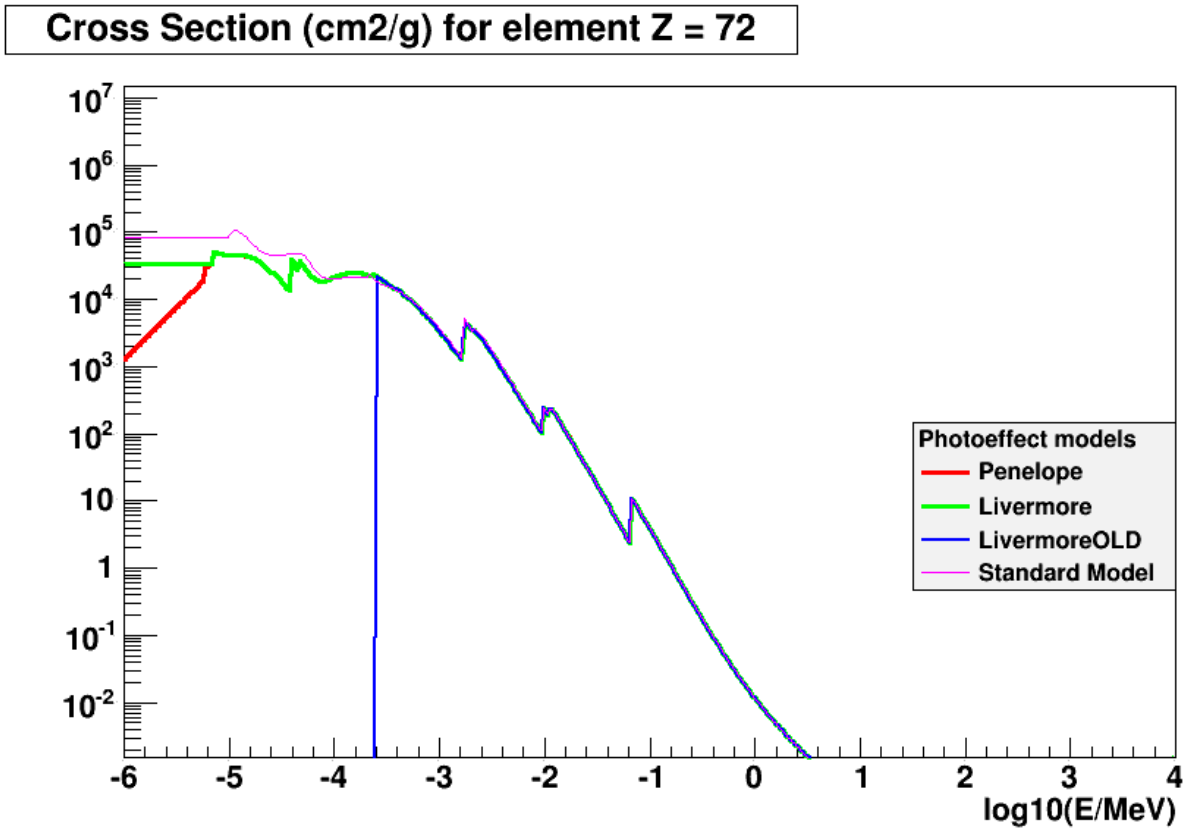


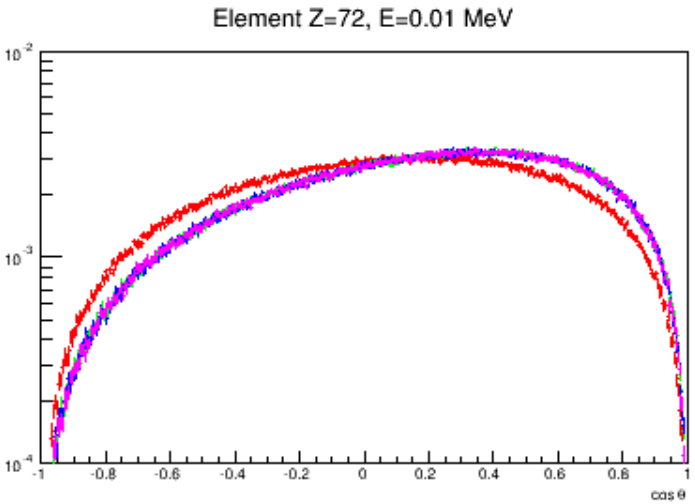


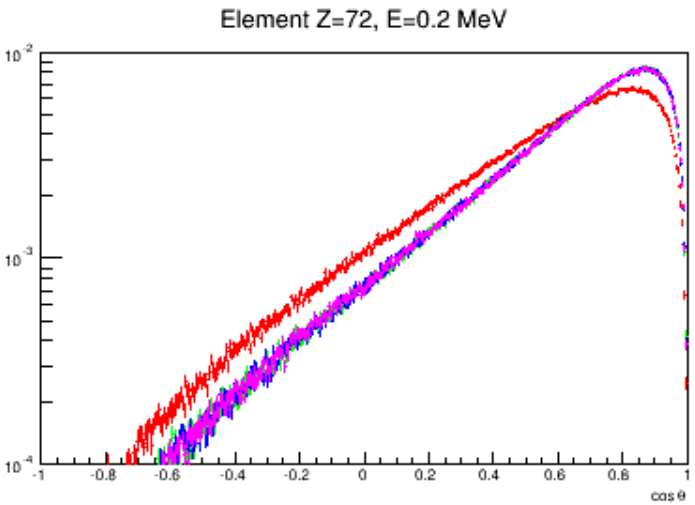


Cross section comparisons

between models



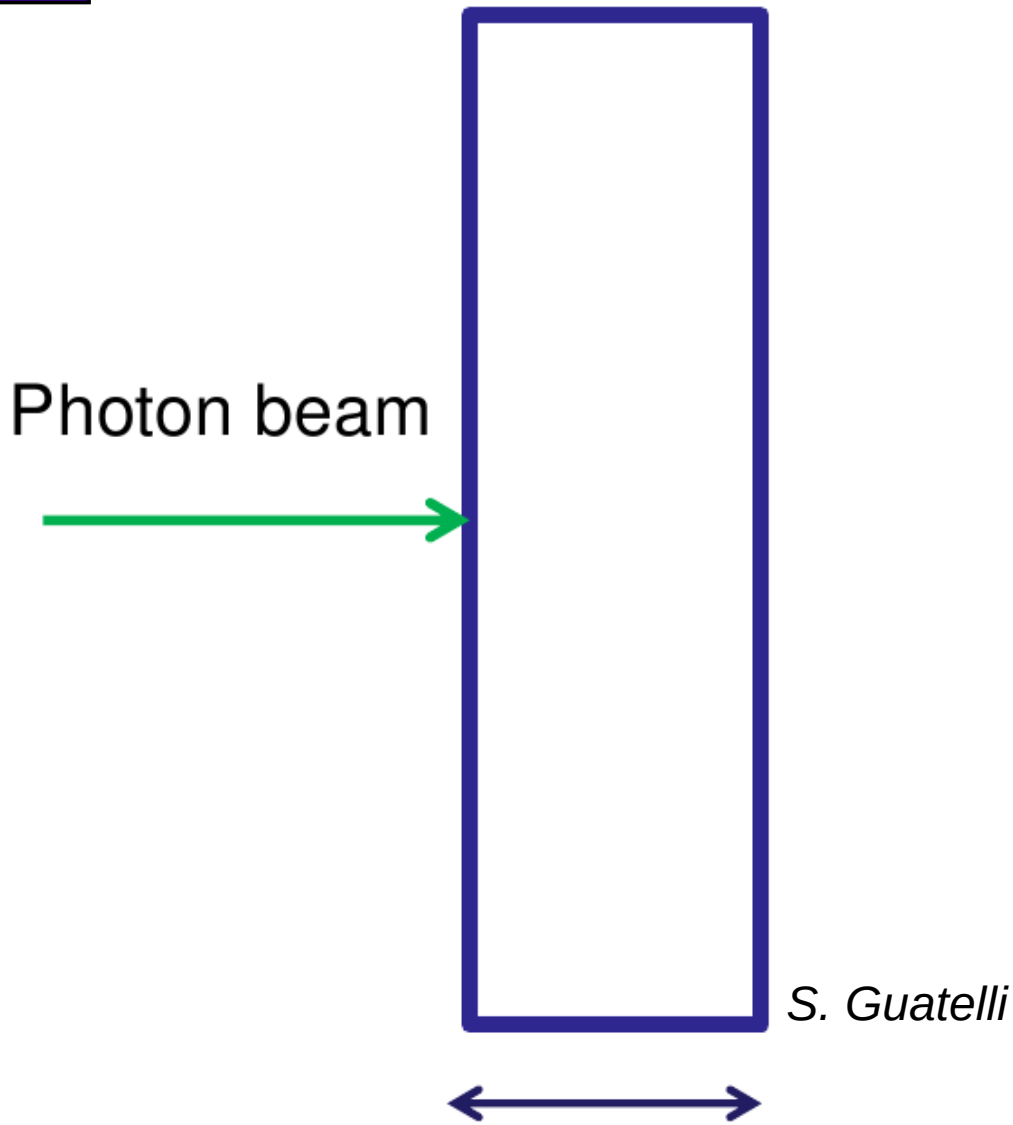




Cross section comparisons

to NIST data

talk of Susanna Guatelli
in parallel session



S. Guatelli

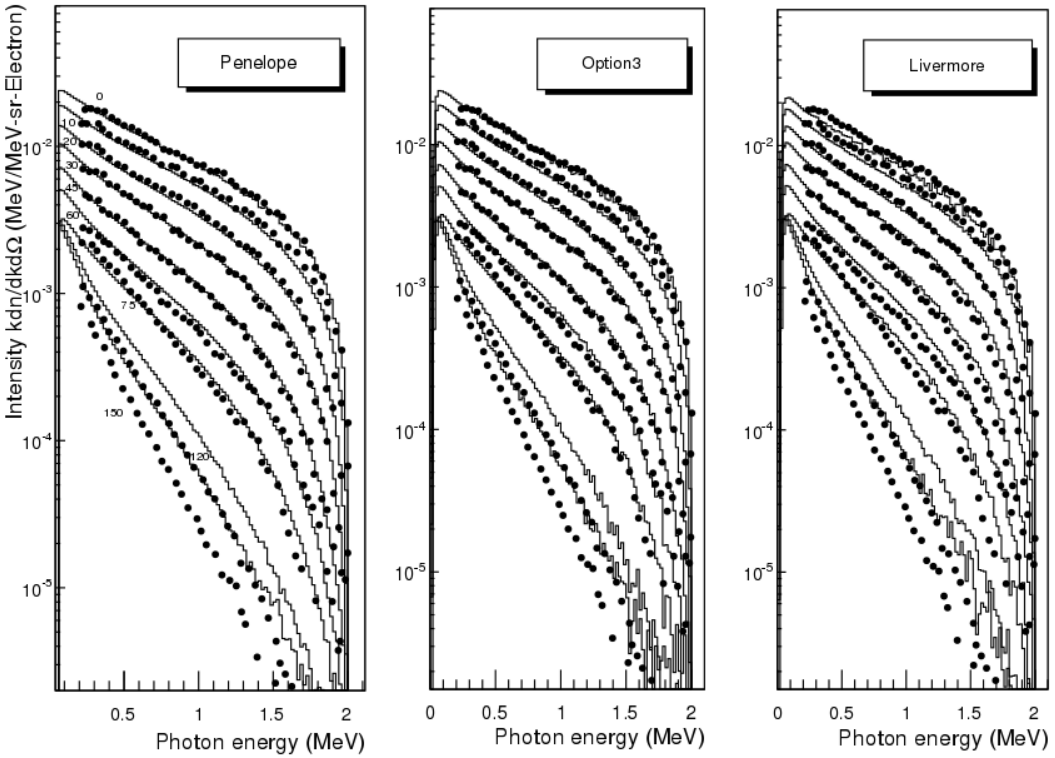
$$N = N_0 e^{-\mu x}$$

Bremsstrahlung

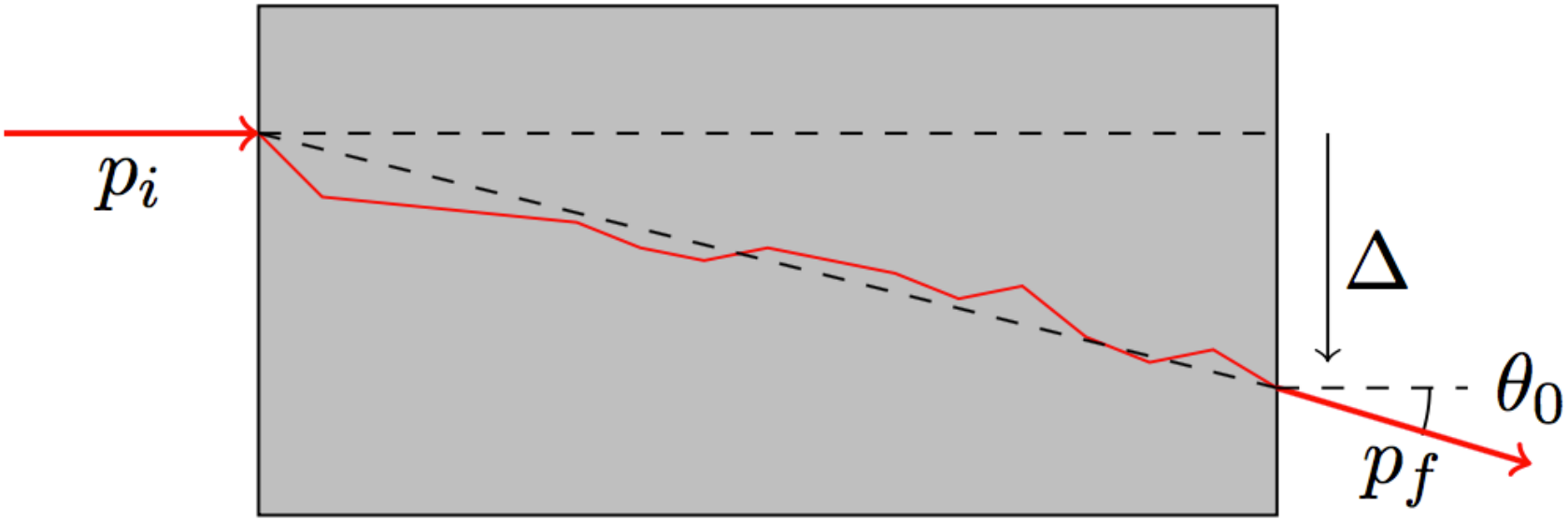
Validation of the Geant4 simulation of bremsstrahlung from thick targets below 3 MeV

L. Pandola[a,b], C. Andenna[c], B. Caccia[d]

Also Faddegon et al. (2008) for 10 – 30 MeV



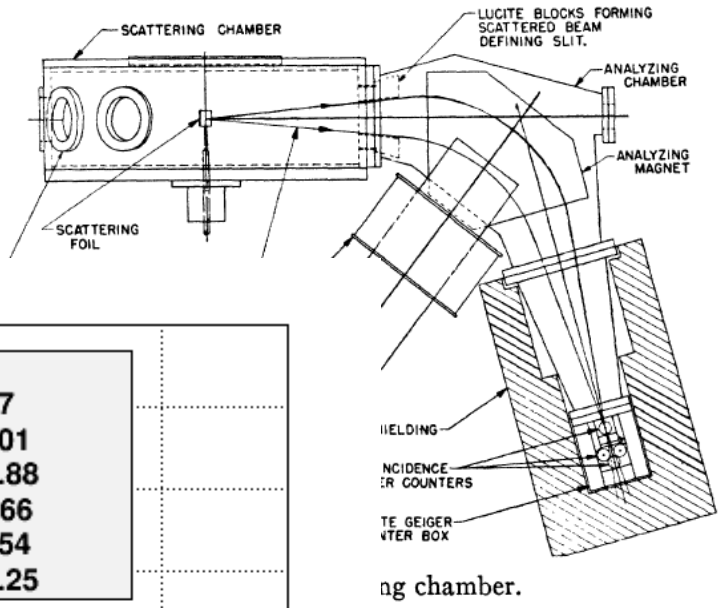
Multiple scattering



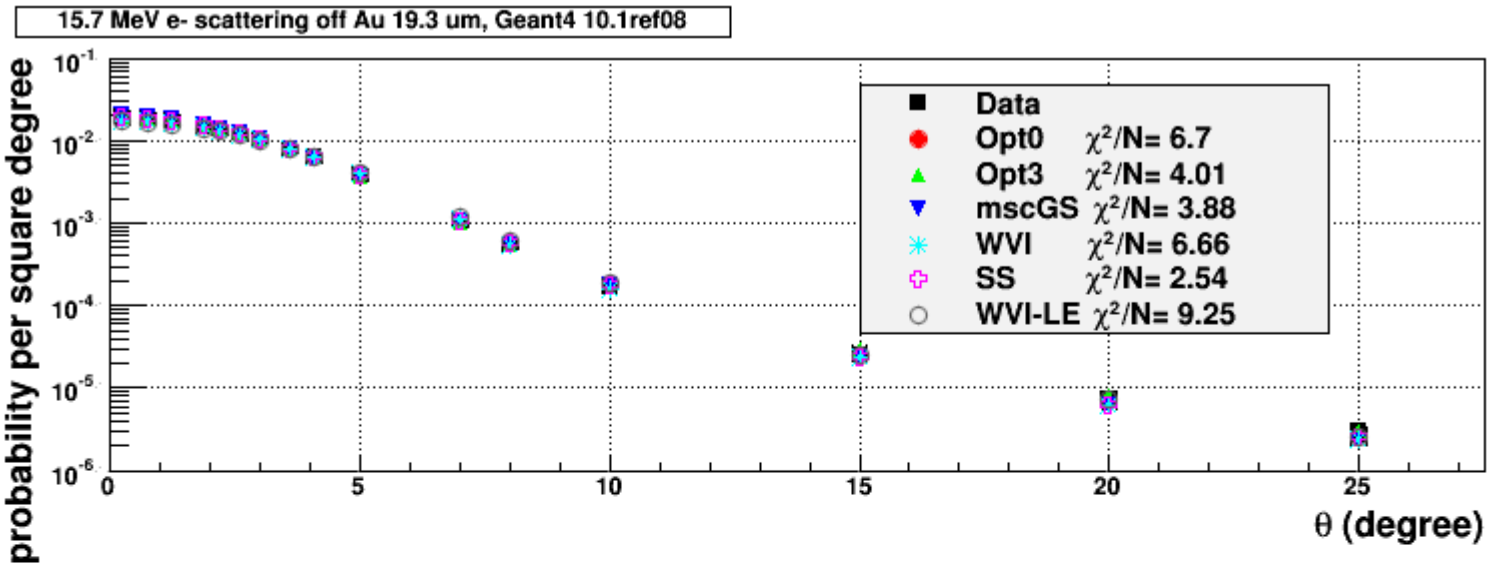
ref

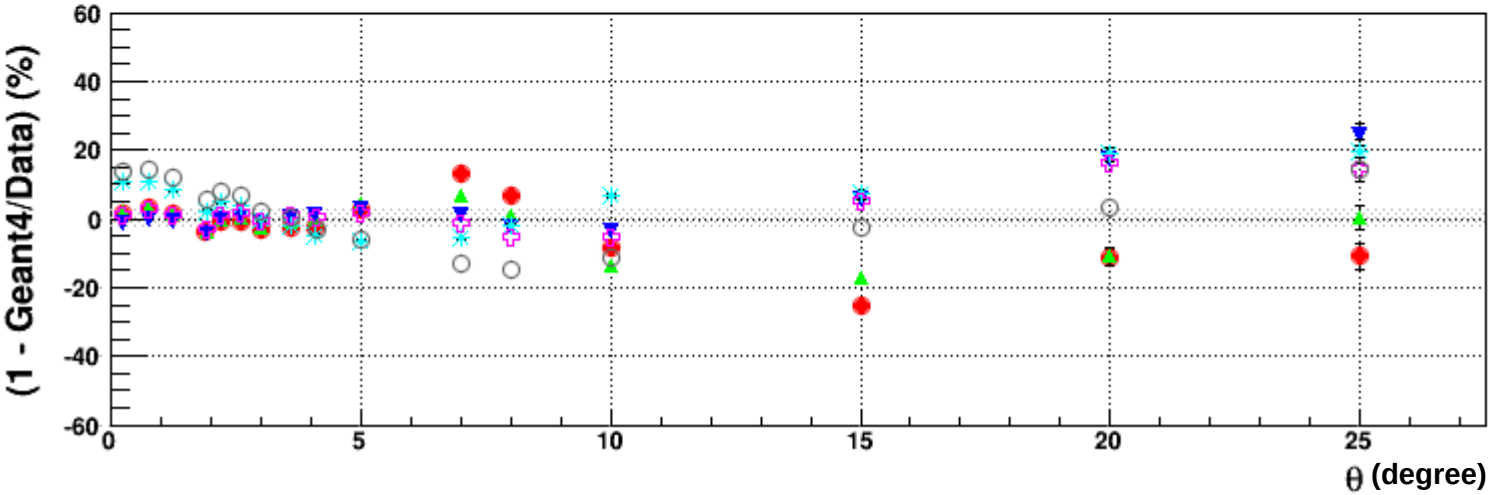
Multiple scattering

Hanson: 15.7 MeV e-, Au



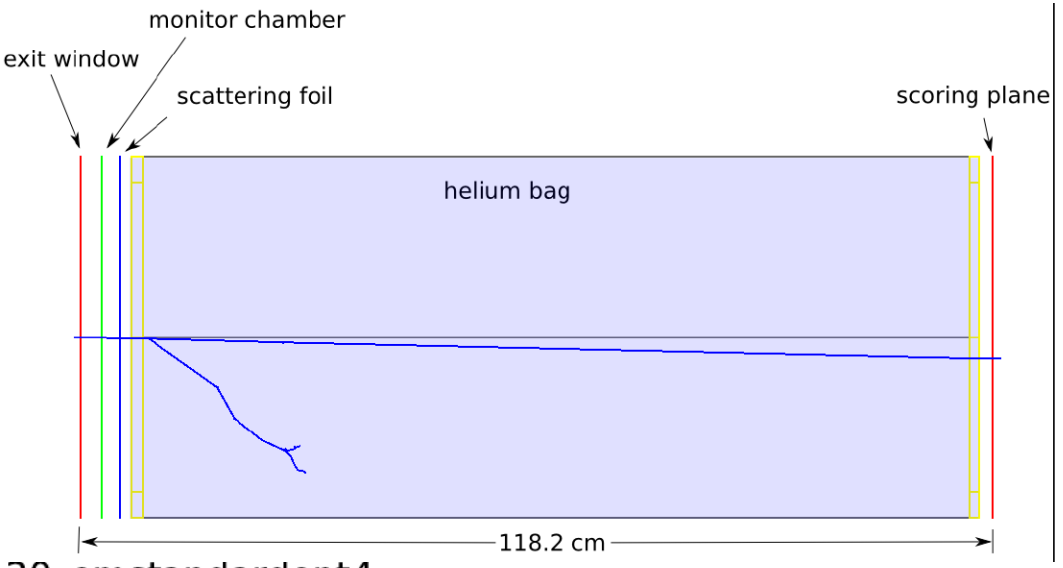
ng chamber.

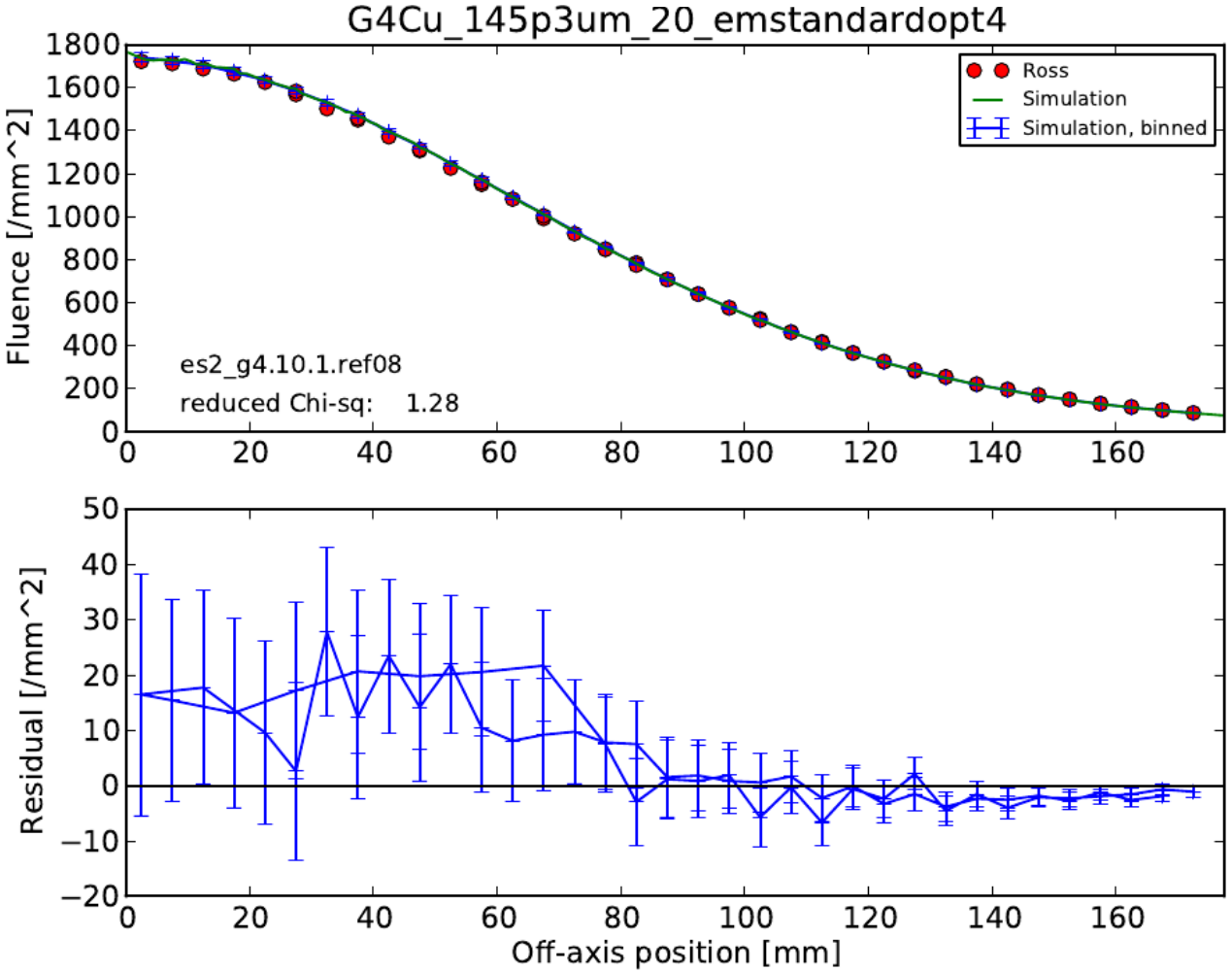




Multiple scattering

Ross et al.
13 and 20 MeV
7 materials of various thicknesses
(37 foil/energy combinations)





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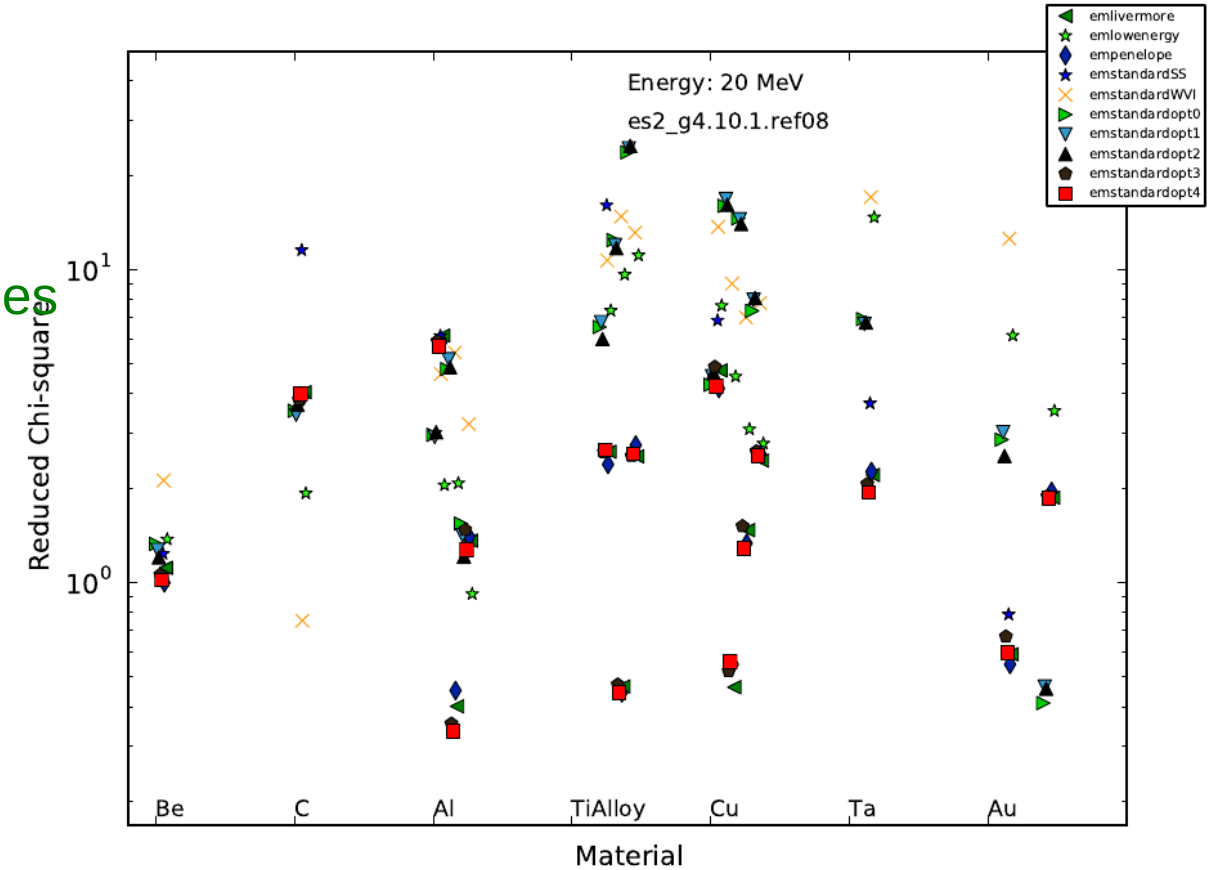

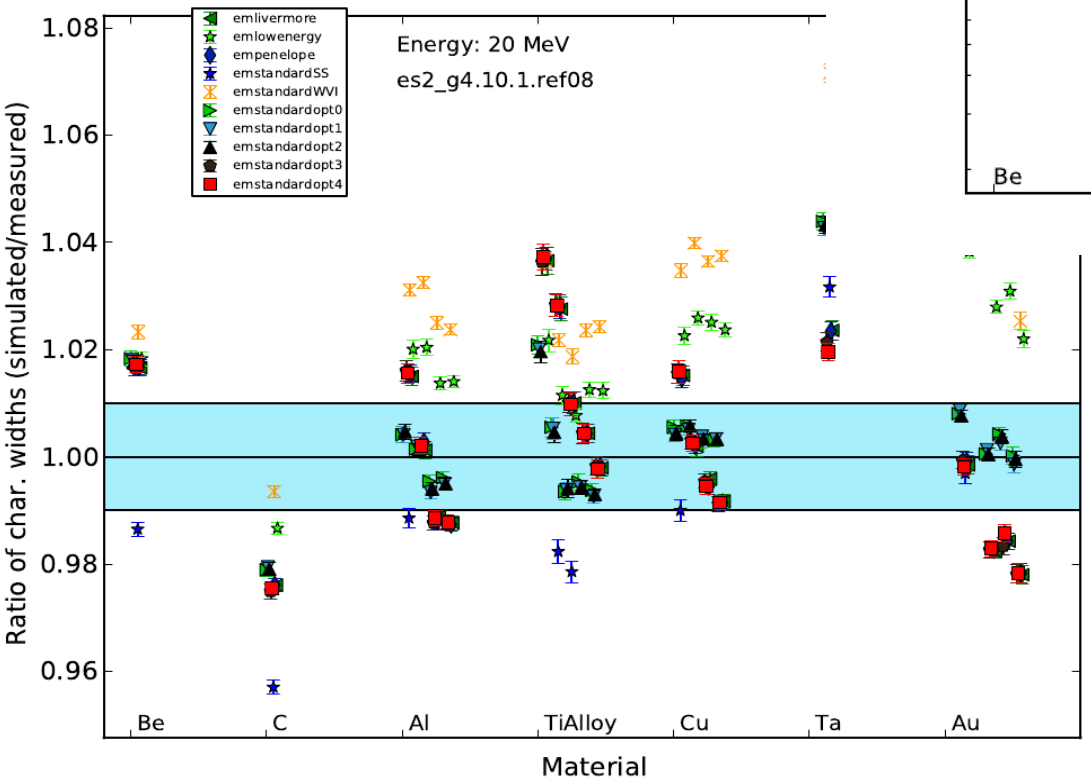

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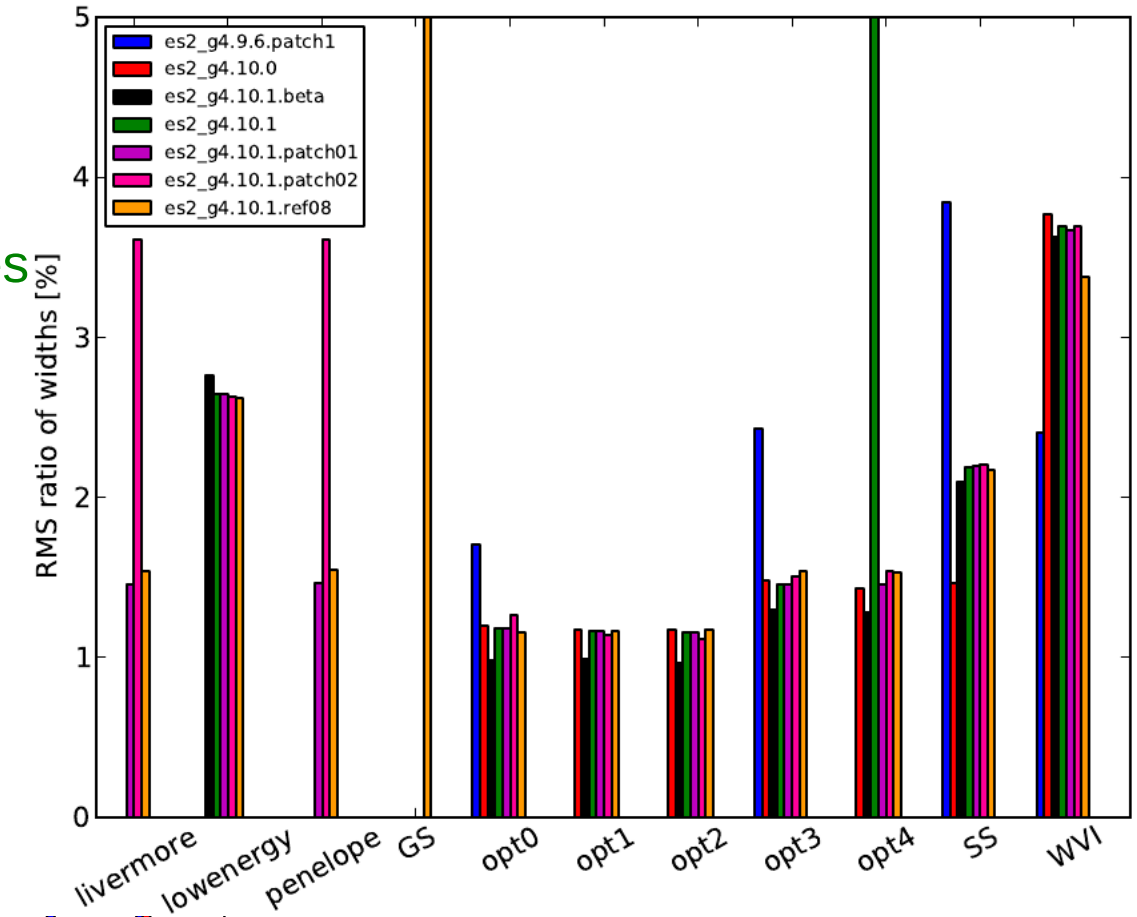
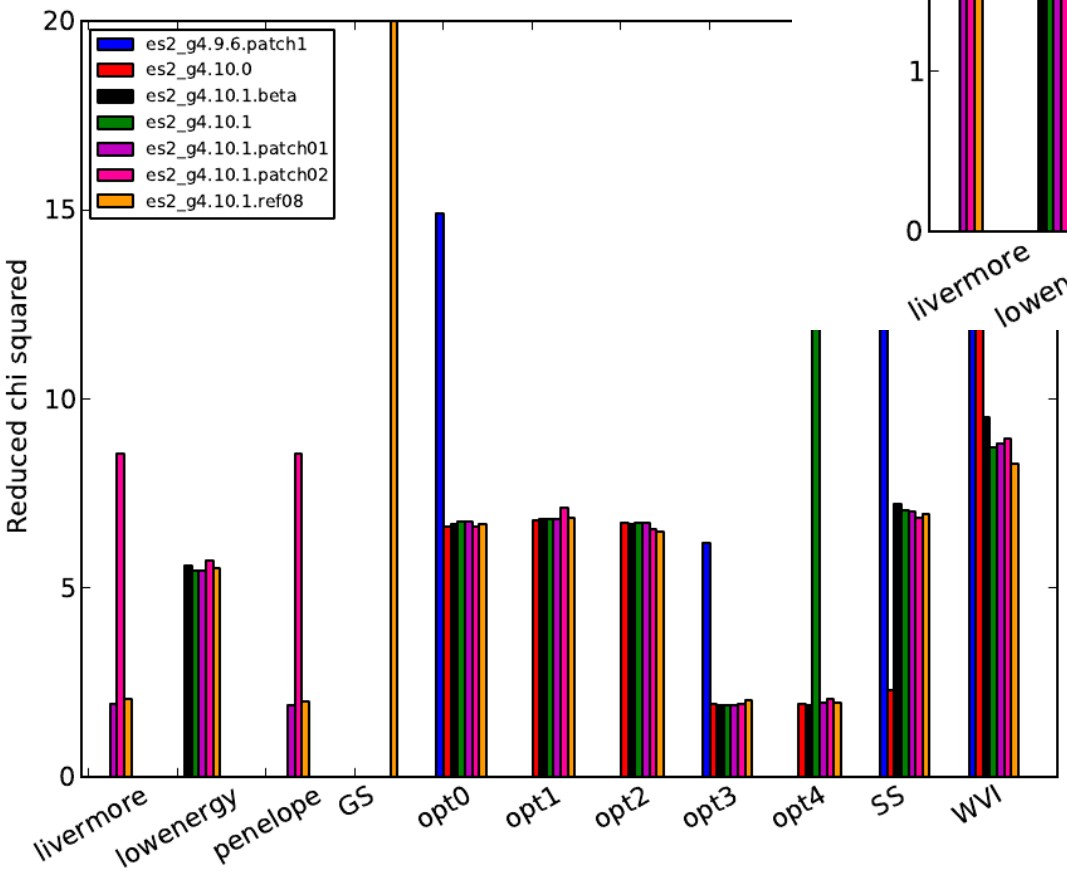
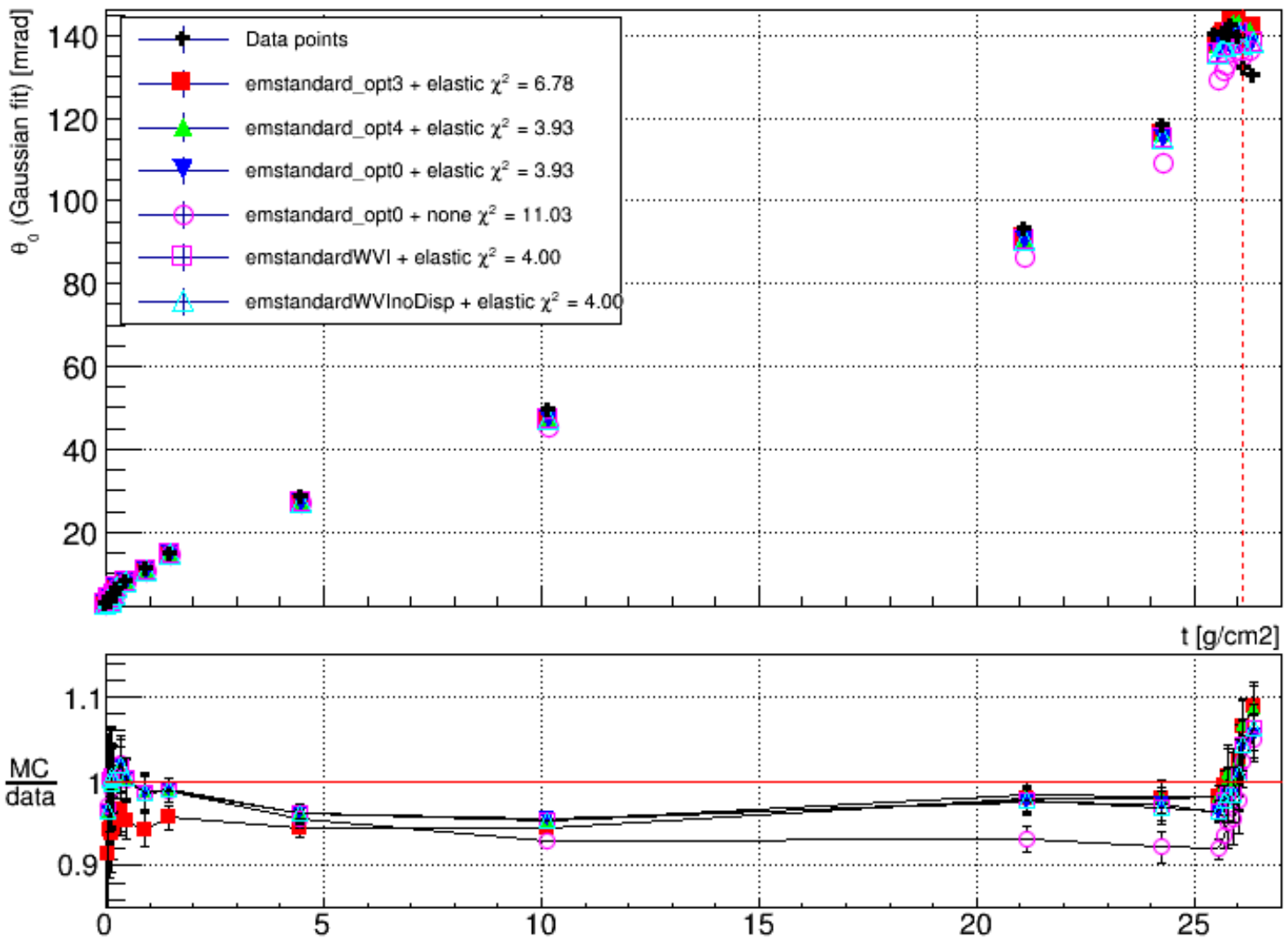




Multiple scattering

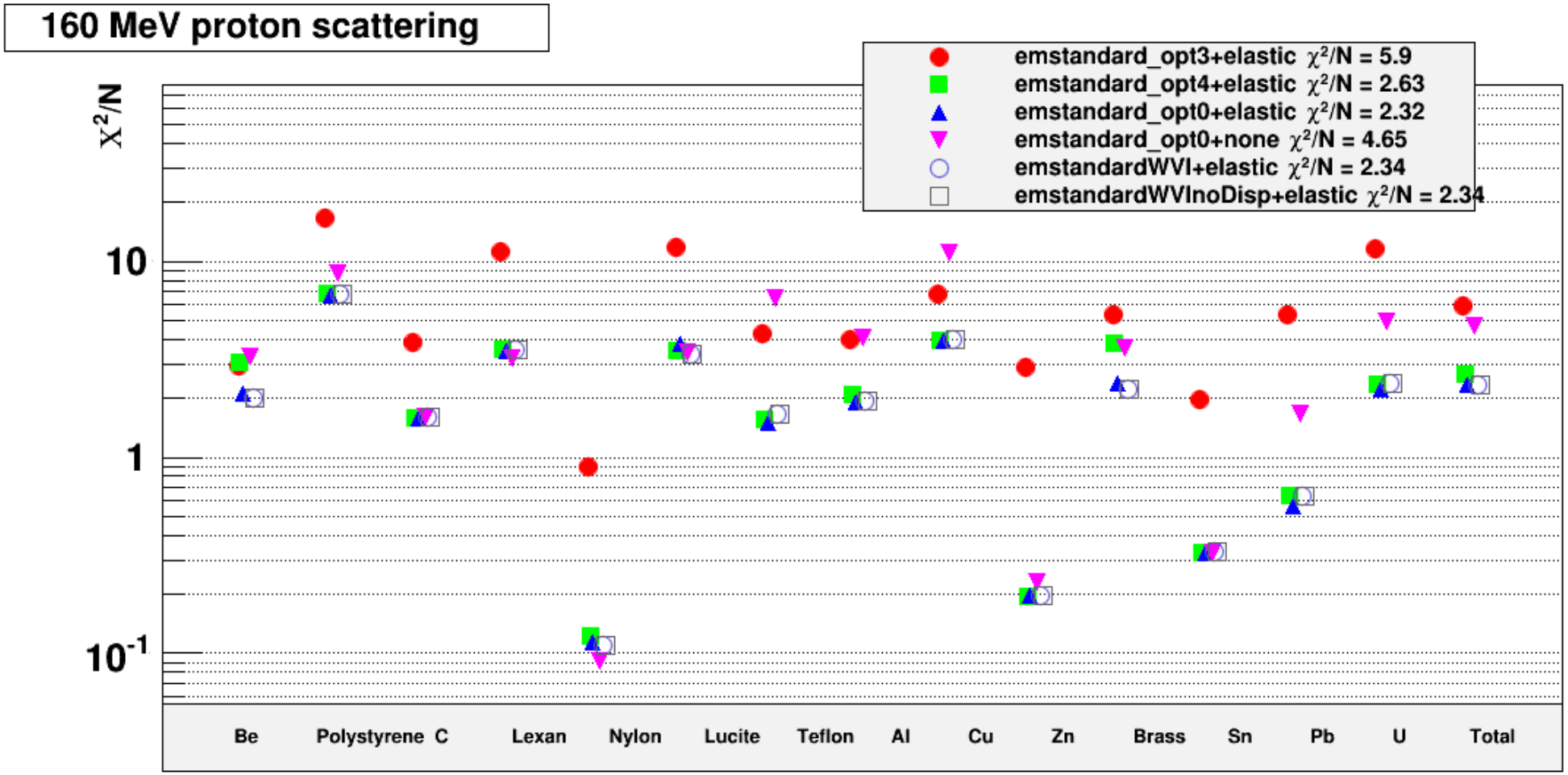
160 MeV protons

Characteristic Angle Distribution for Copper



Multiple scattering

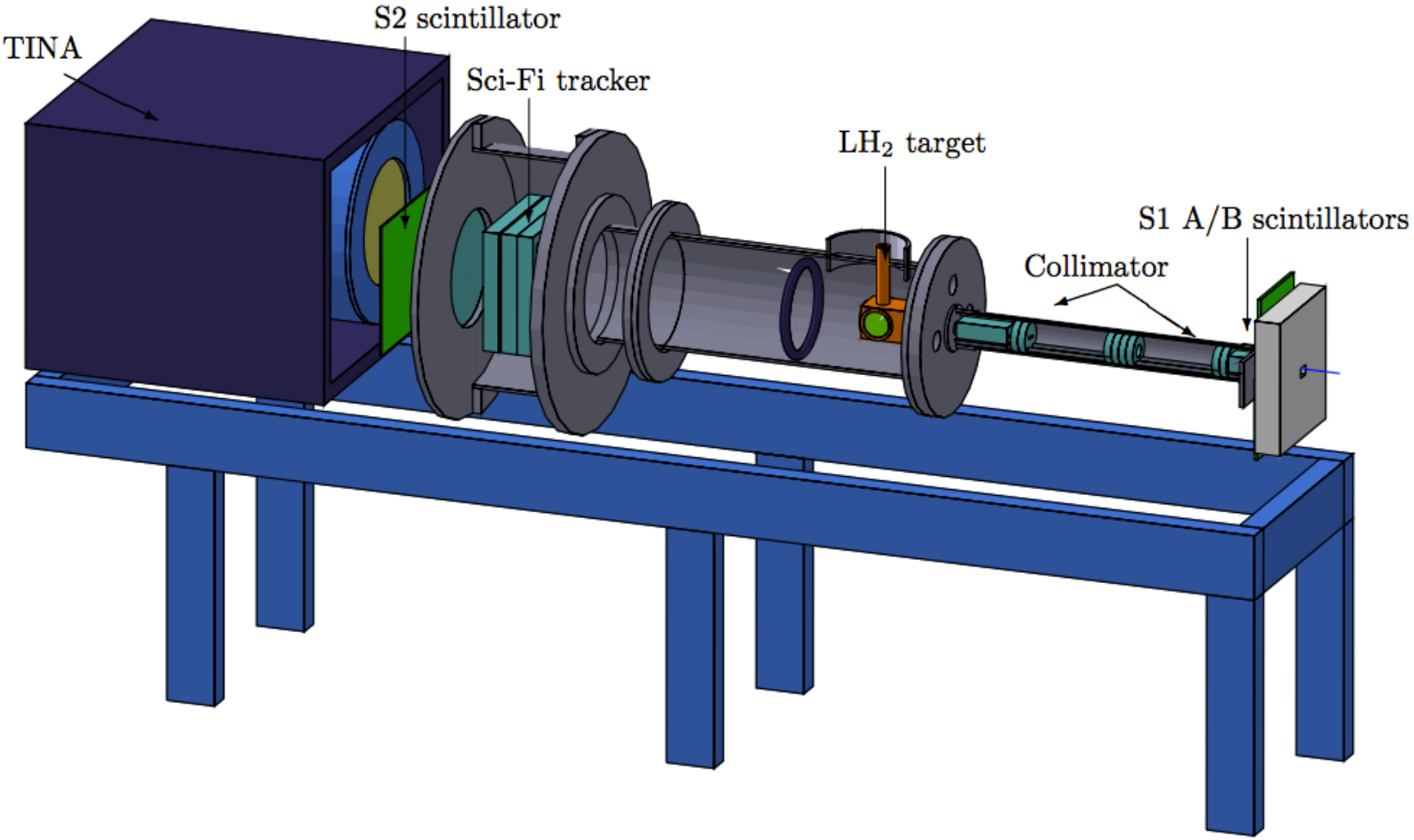
160 MeV protons



Multiple scattering

172 MeV/c muons in thin,
low Z materials

100 W.J. Murray / Nuclear Physics B (Proc. Suppl.) 149 (2005) 99–103



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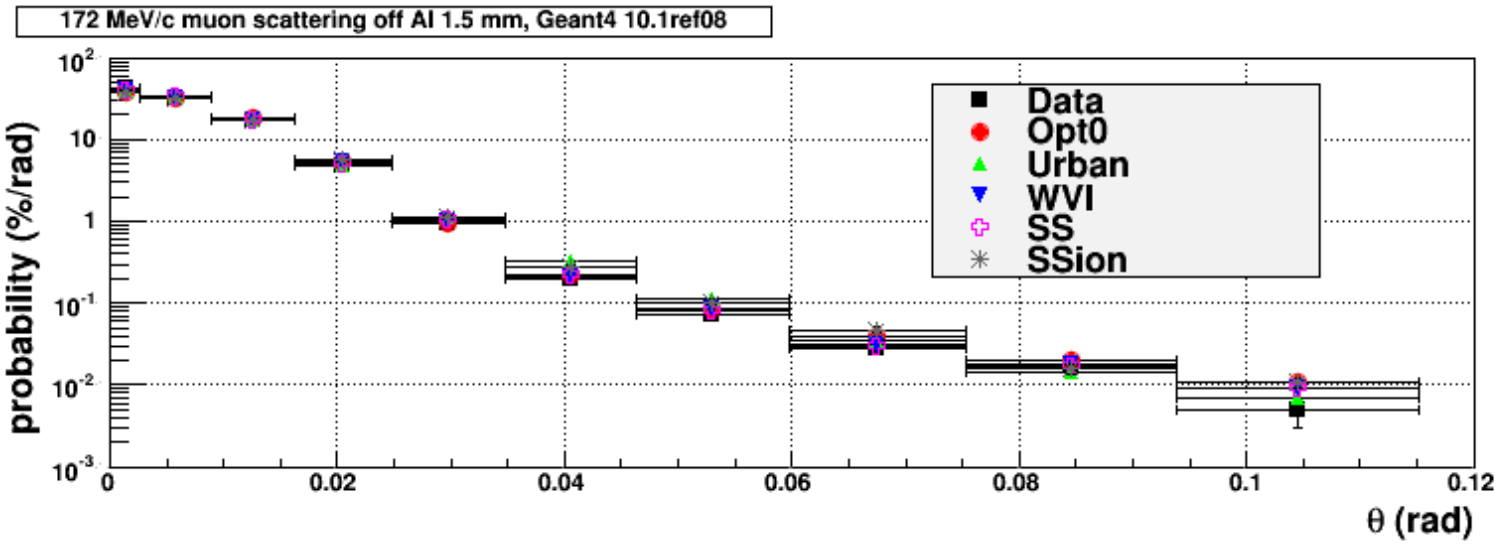

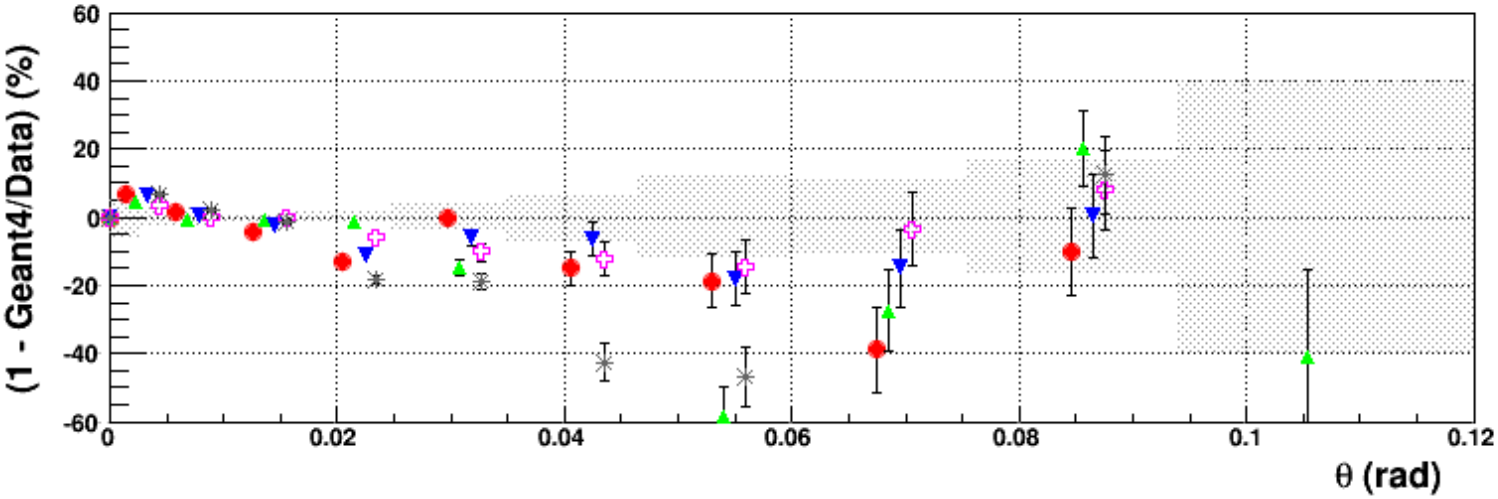

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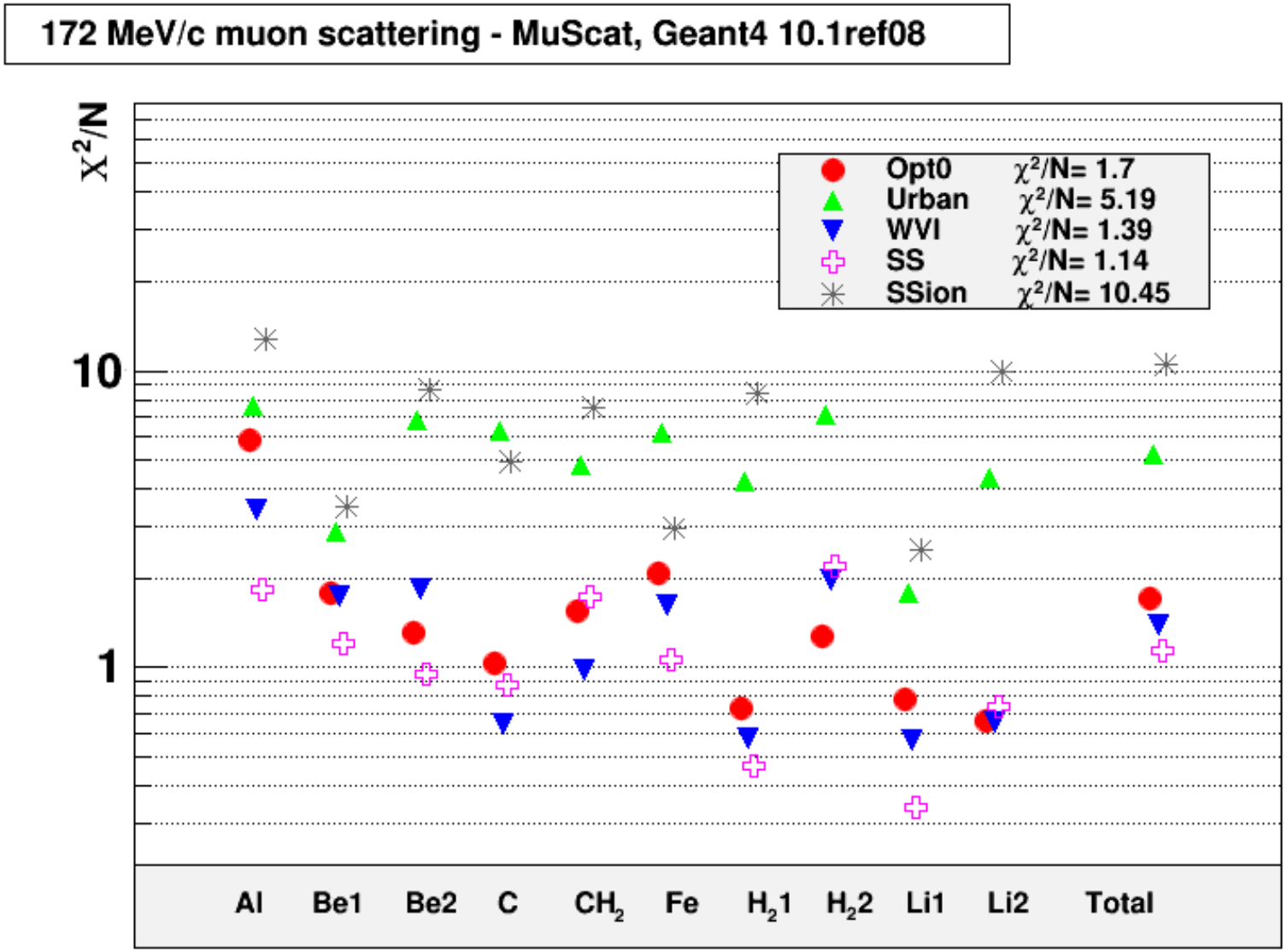
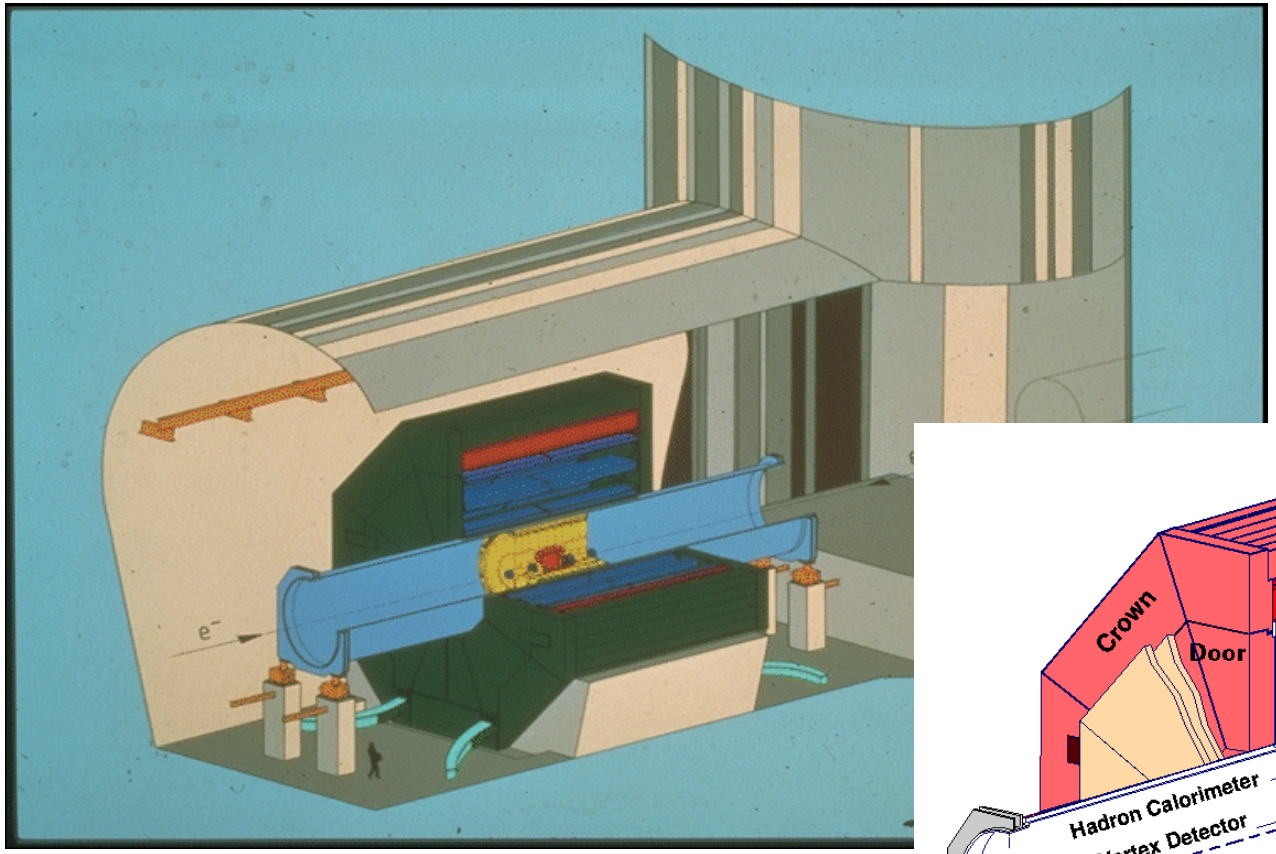
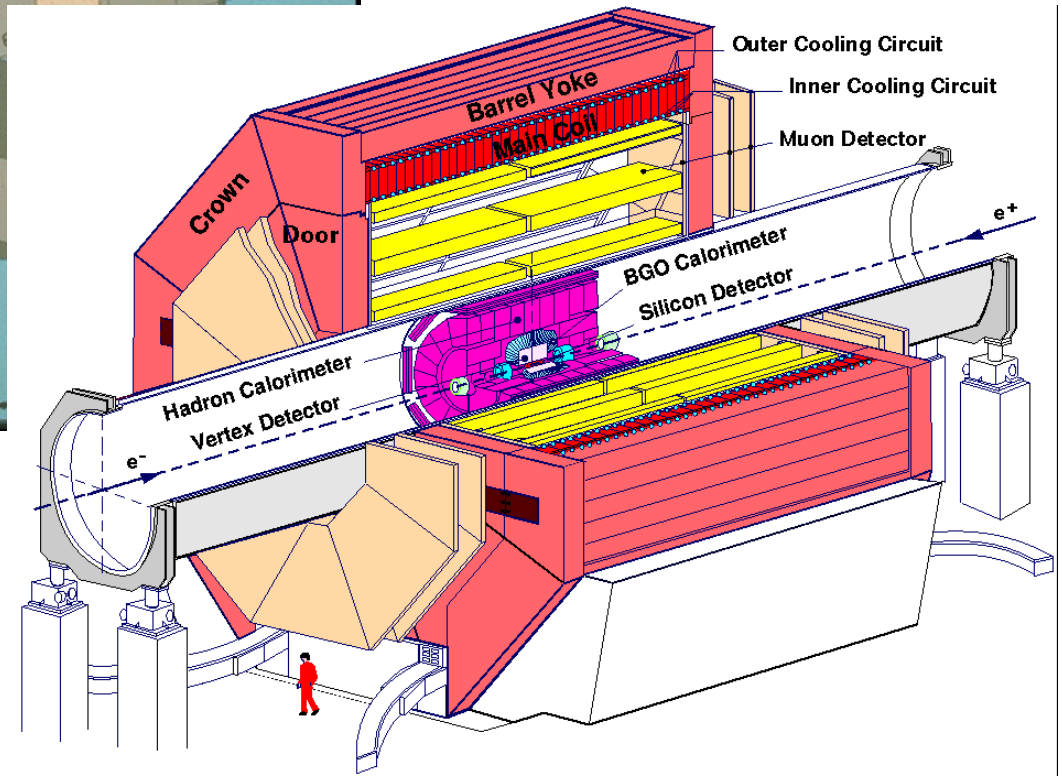


Multiple scattering

L3 45 GeV muons





Multiple scattering

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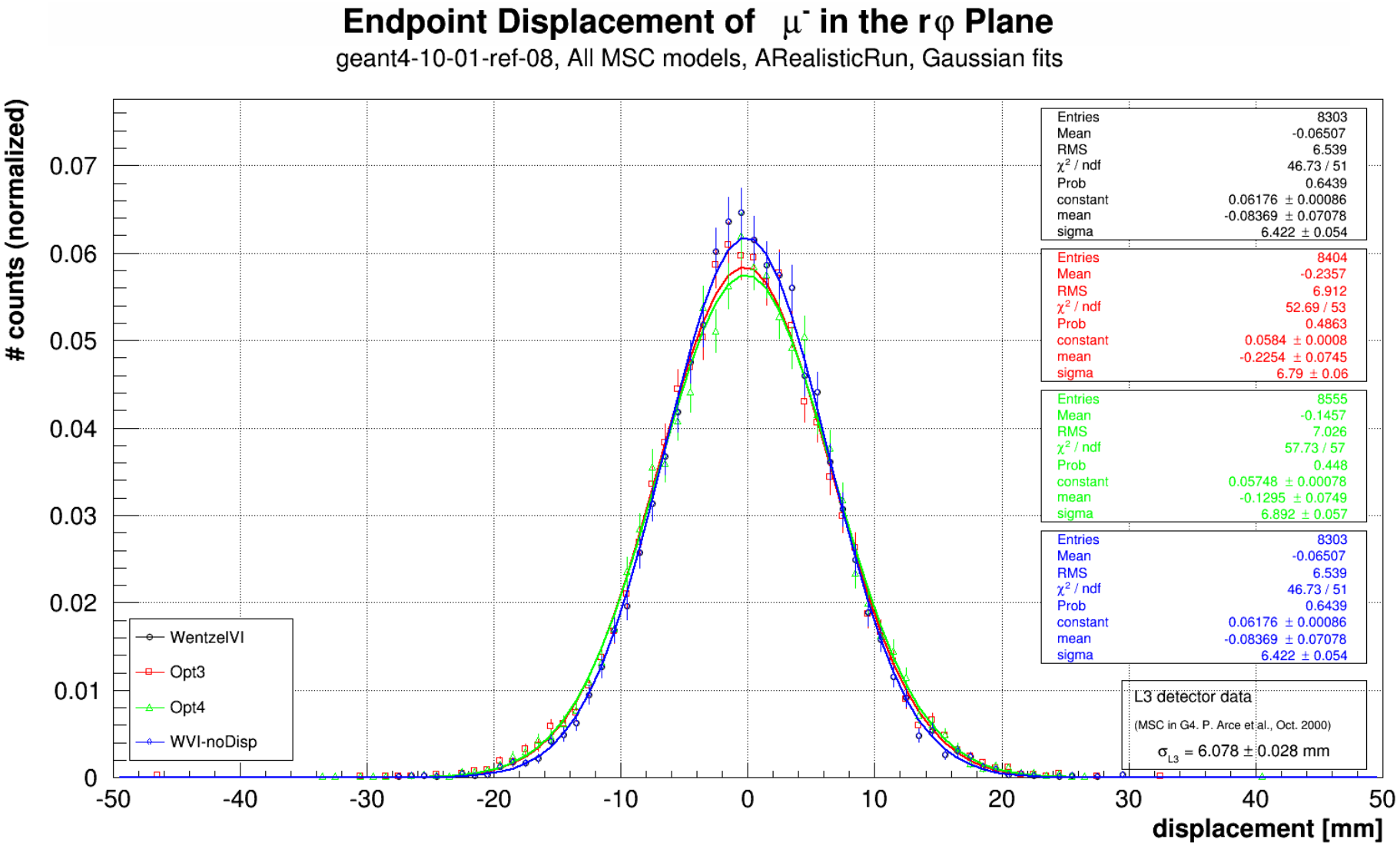
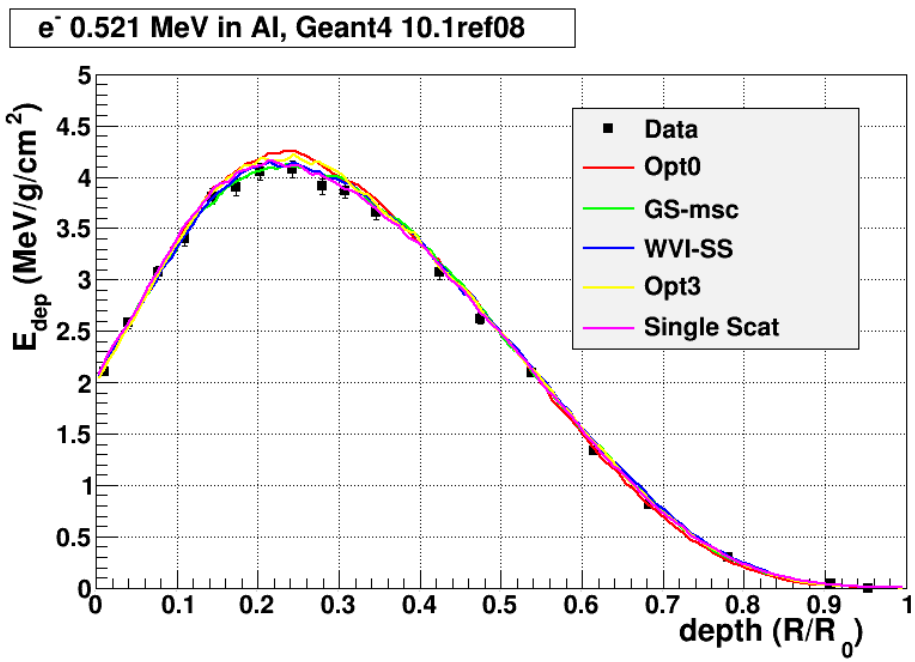
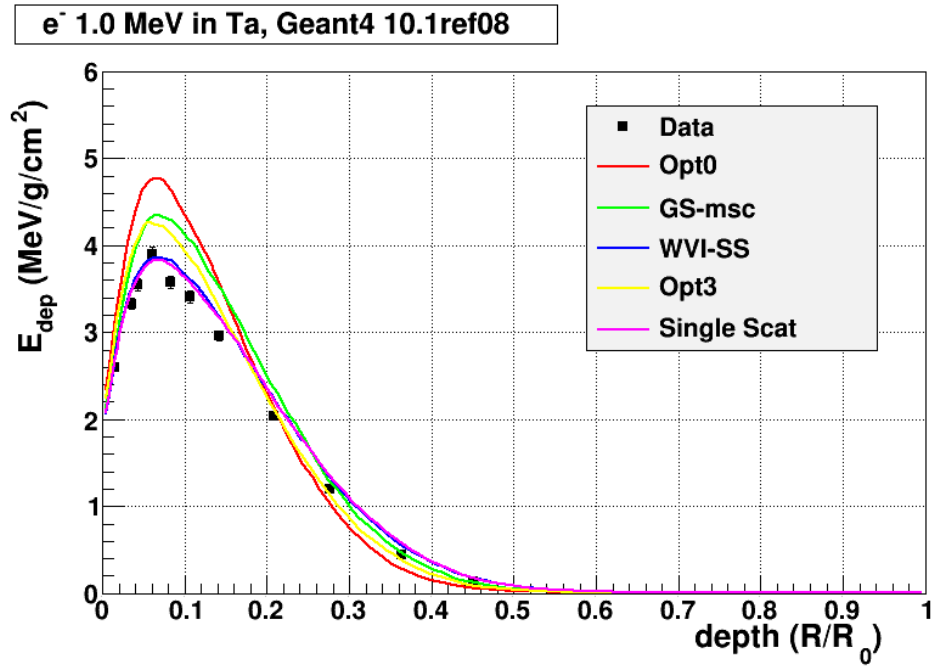
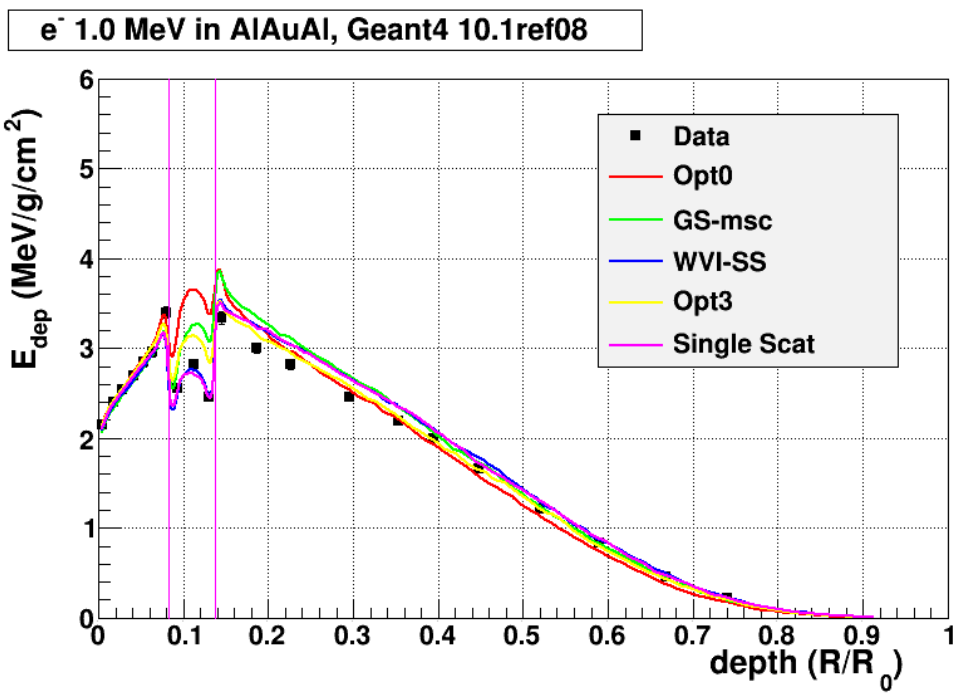
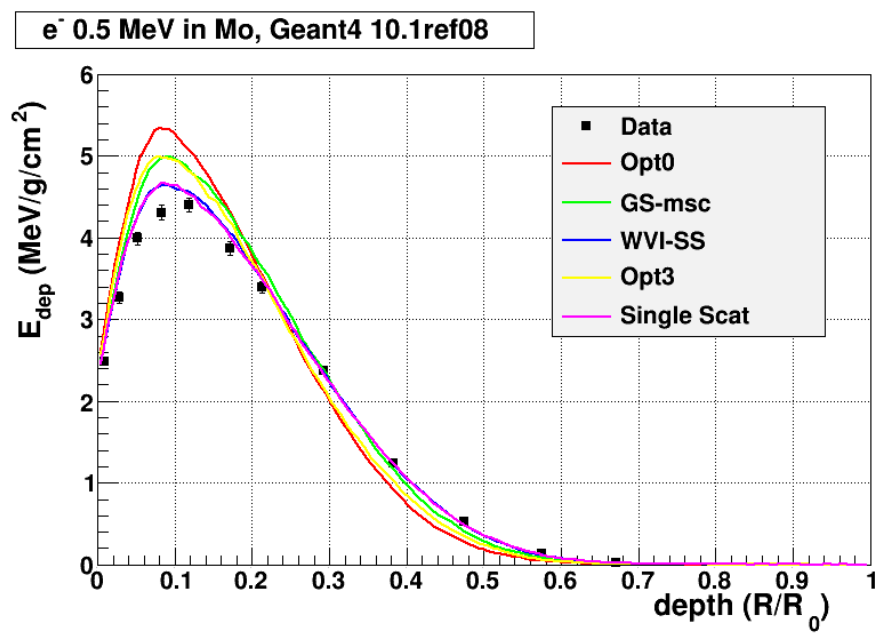


Dose deposition vs. depth (Sandia data)





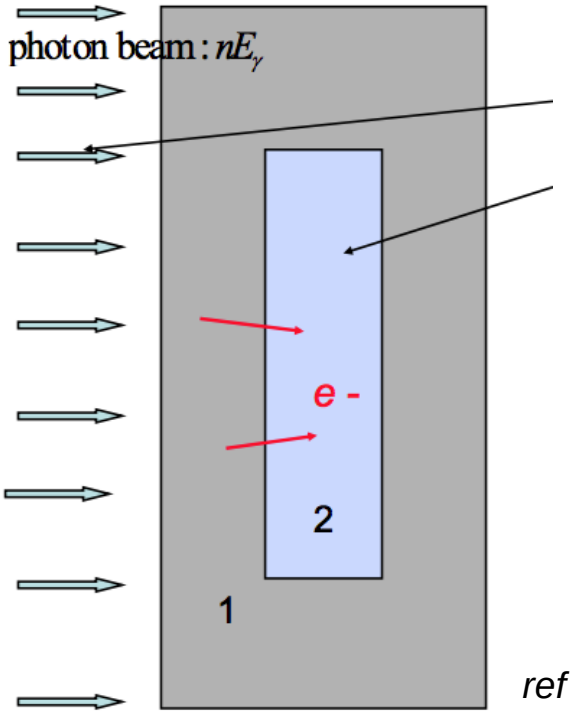


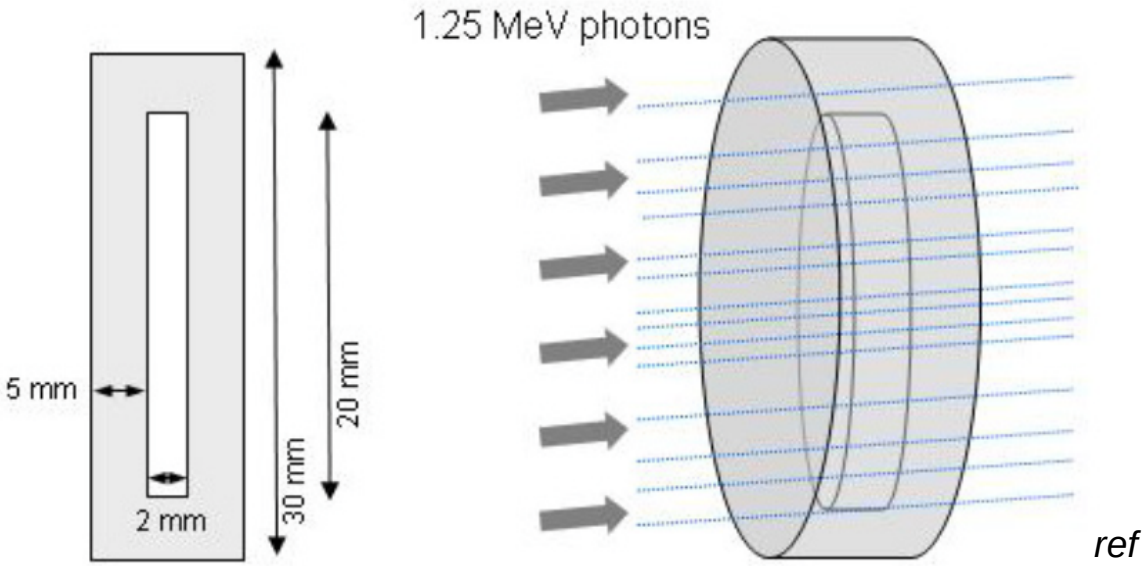


Fano Cavity

One material with two densities

Dose is independent of density





Fano Cavity

Fano cavity test case

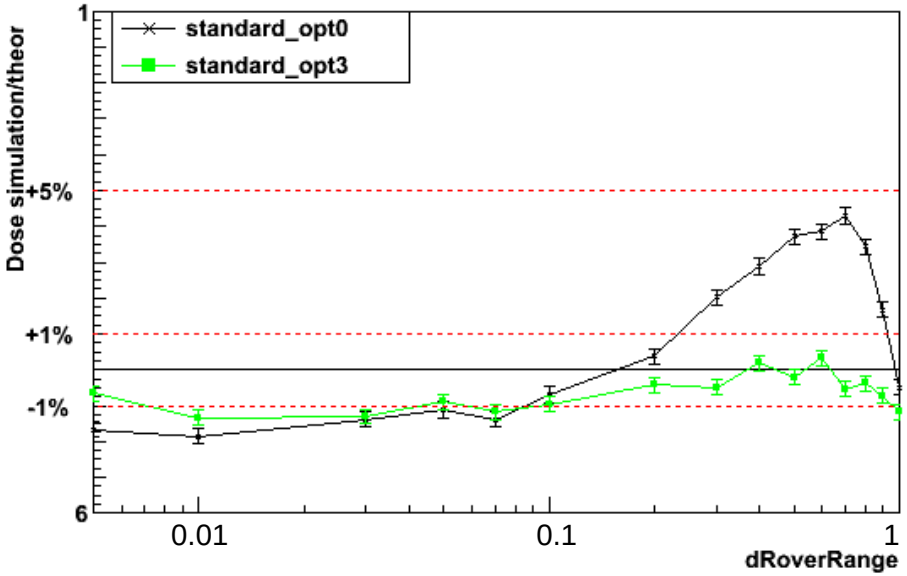
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 10-01-ref-07

Basic test (no fluct, no msc):

standard_opt0 : 0.9946 +/- 0.0002 for dRoverRange = 0.004
standard_opt3 : 0.9977 +/- 0.0002 for dRoverRange = 0.004

Full test (fluct & msc):



Fano cavity test case

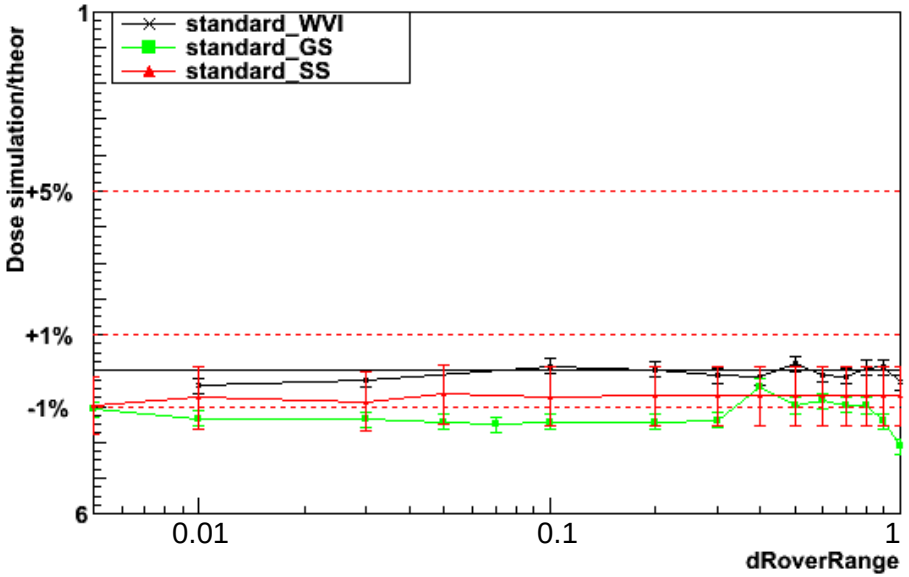
Ratio between simulated and theorical dose deposited by a 1.25 MeV photon beam crossing an ionization chamber

Geant4 release : 10-01-ref-07

Basic test (no fluct, no msc):

standard_WVI : 0.9993 +/- 0.0006 for dRoverRange = 0.004
standard_GS : 0.9977 +/- 0.0002 for dRoverRange = 0.004

Full test (fluct & msc):



Fano Cavity

Fano2 cavity test case

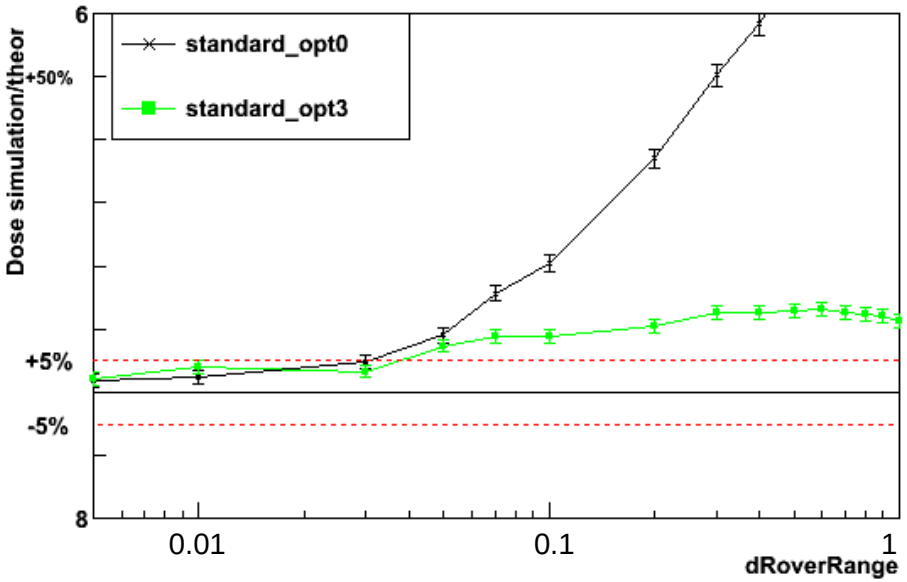
Ratio between simulated and theorical dose deposited by a 1.00 MeV electron beam crossing an infinite radius chamber

Geant4 release : 10-01-ref-07

Basic test (no fluct, no msc):

standard_opt0 : 1.0008 +/- 0.0009 for dRoverRange = 0.004
standard_opt3 : 0.9999 +/- 0.0009 for dRoverRange = 0.004

Full test (fluct & msc):



Fano2 cavity test case

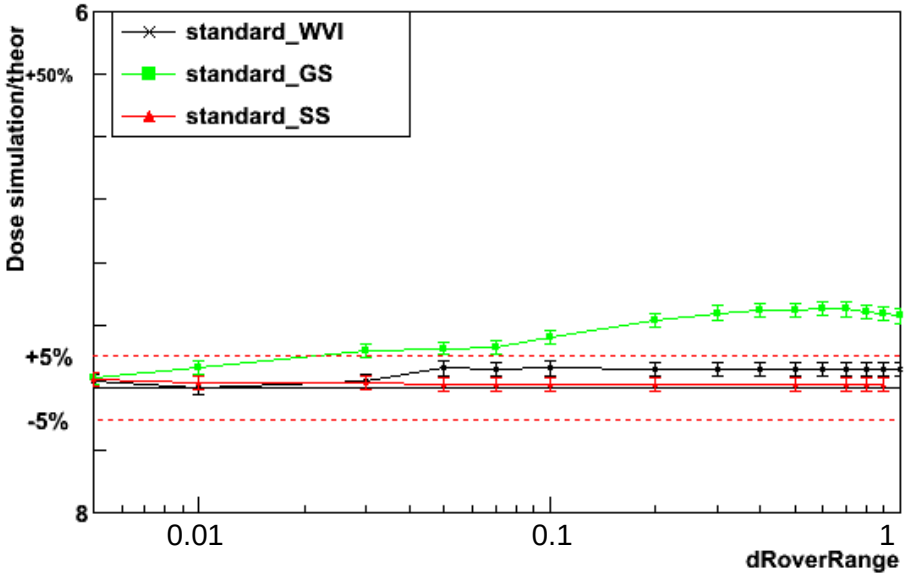
Ratio between simulated and theorical dose deposited by a 1.00 MeV electron beam crossing an infinite radius chamber

Geant4 release : 10-01-ref-07

Basic test (no fluct, no msc):

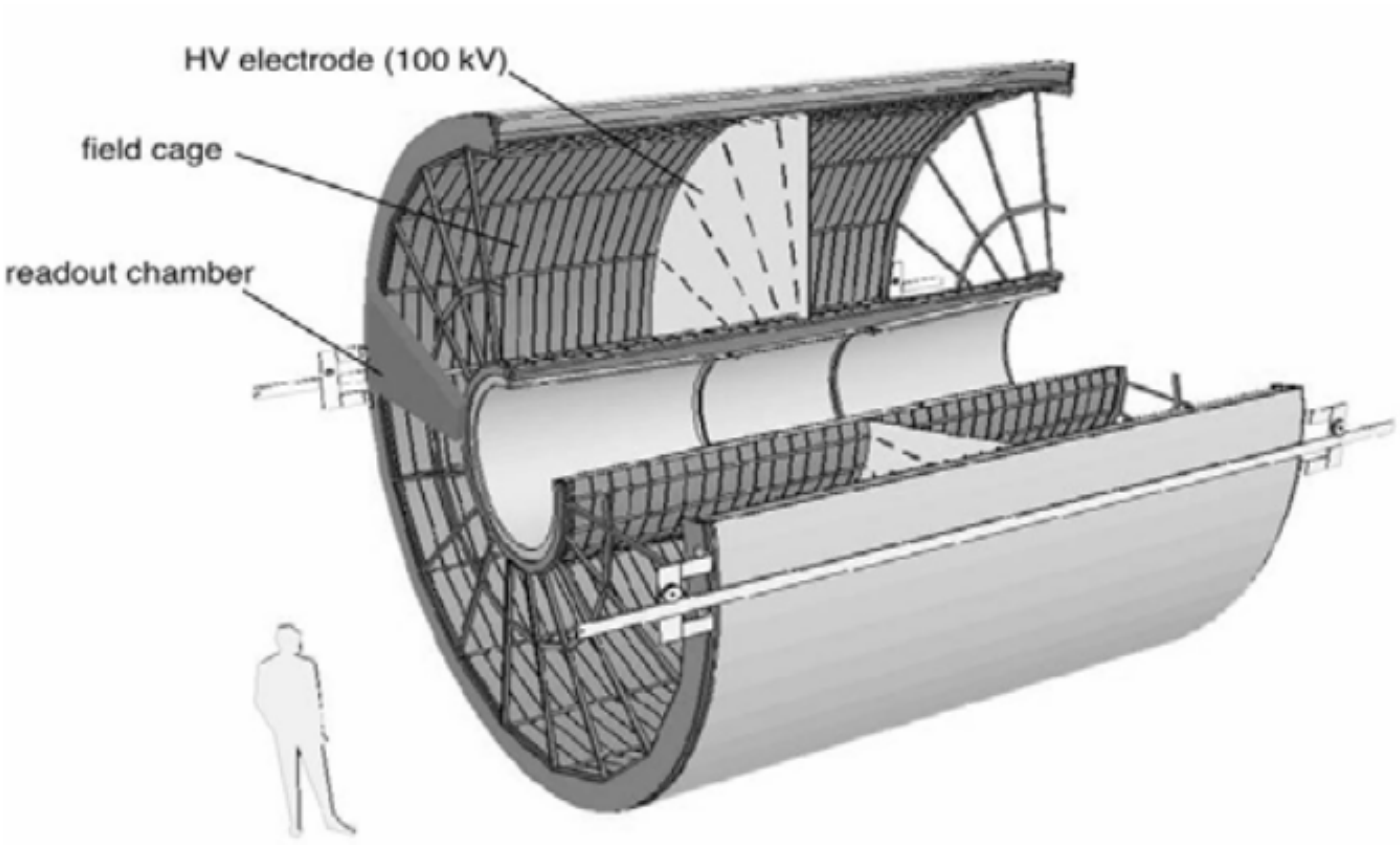
standard_WVI : 0.9981 +/- 0.0033 for dRoverRange = 0.004
standard_GS : 0.9999 +/- 0.0009 for dRoverRange = 0.004

Full test (fluct & msc):



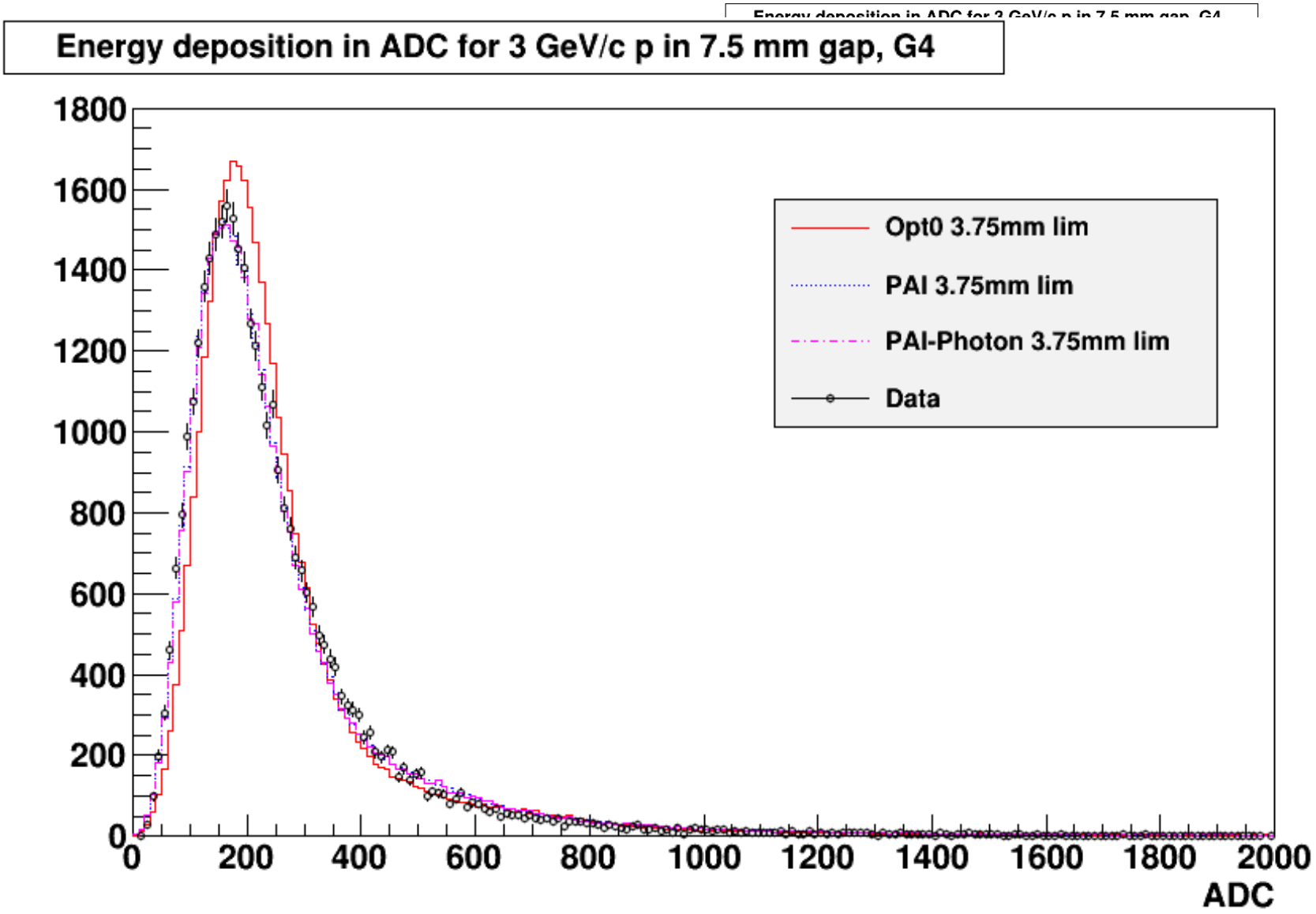
Fluctuations

(ALICE Time Projection Chamber)



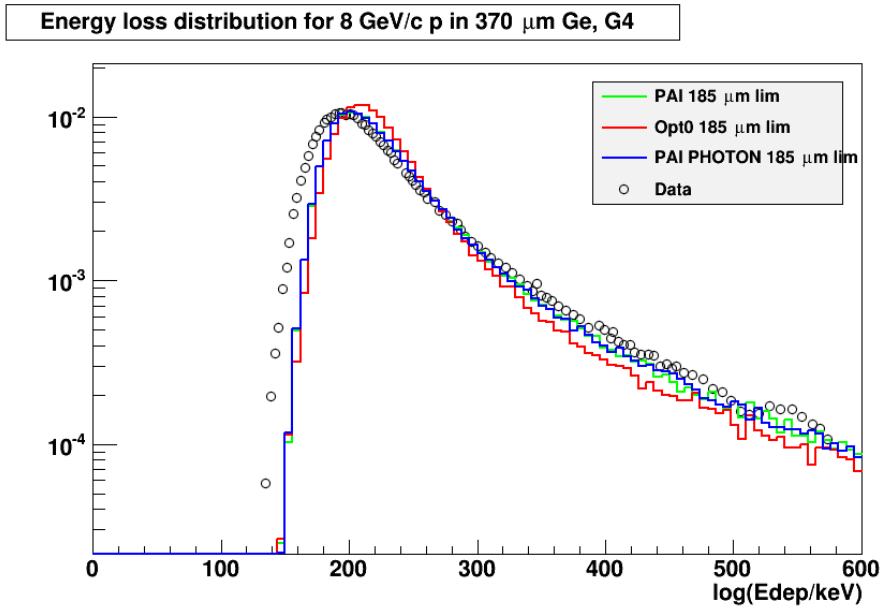
Fluctuations

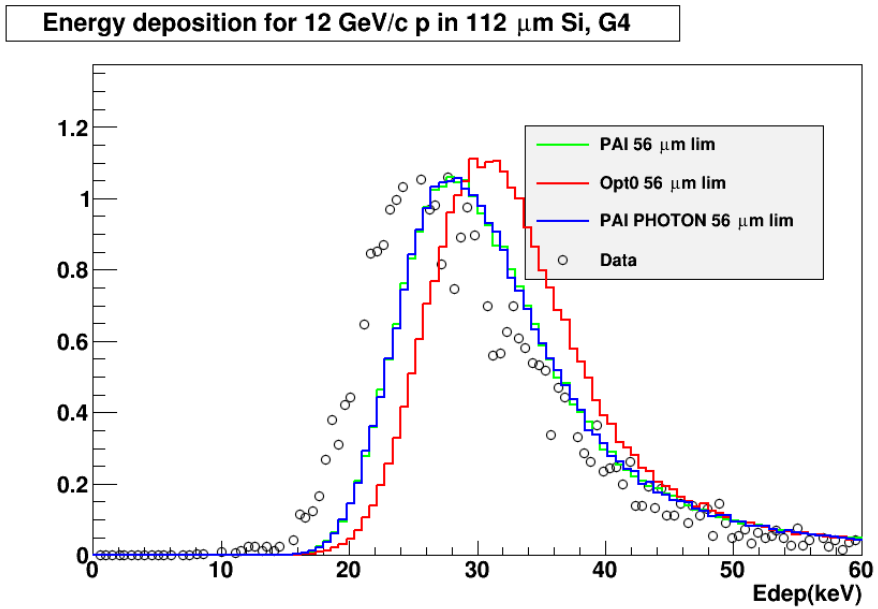
(ALICE Time Projection Chamber)

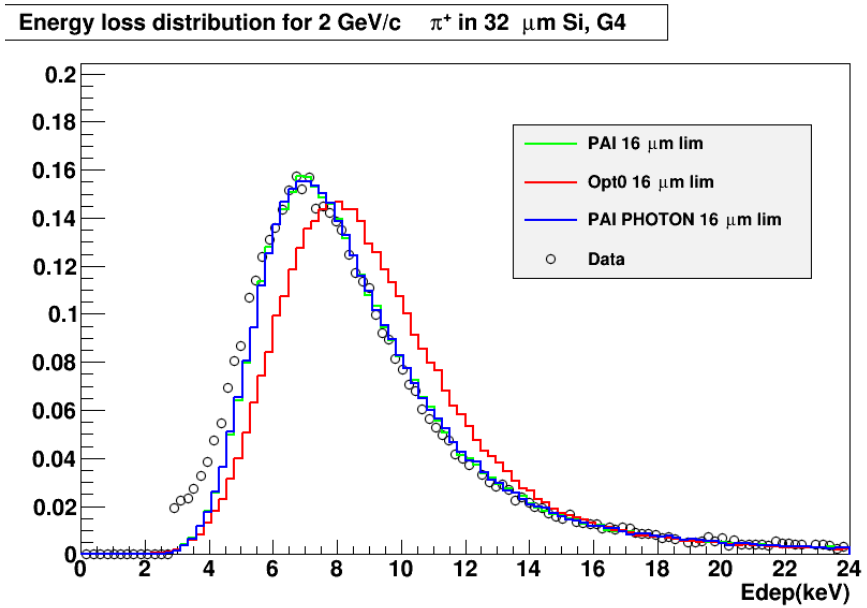


Fluctuations

(semiconductors)

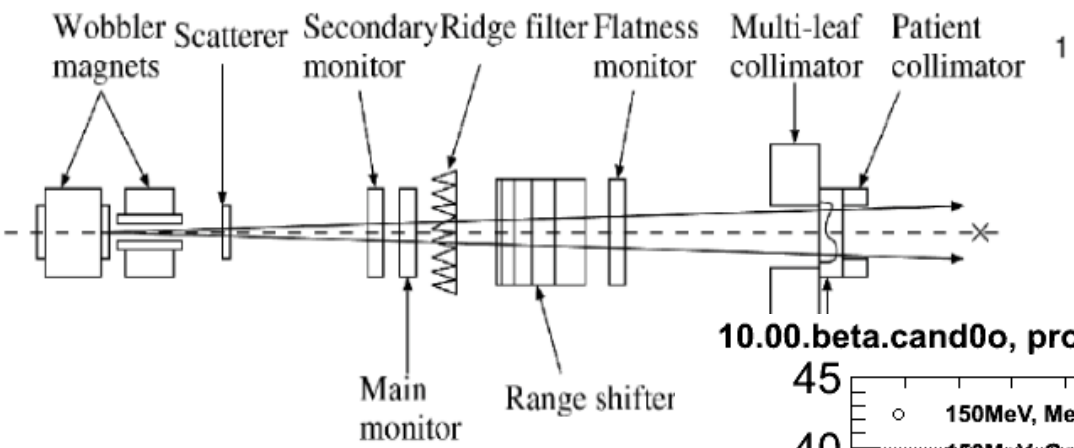


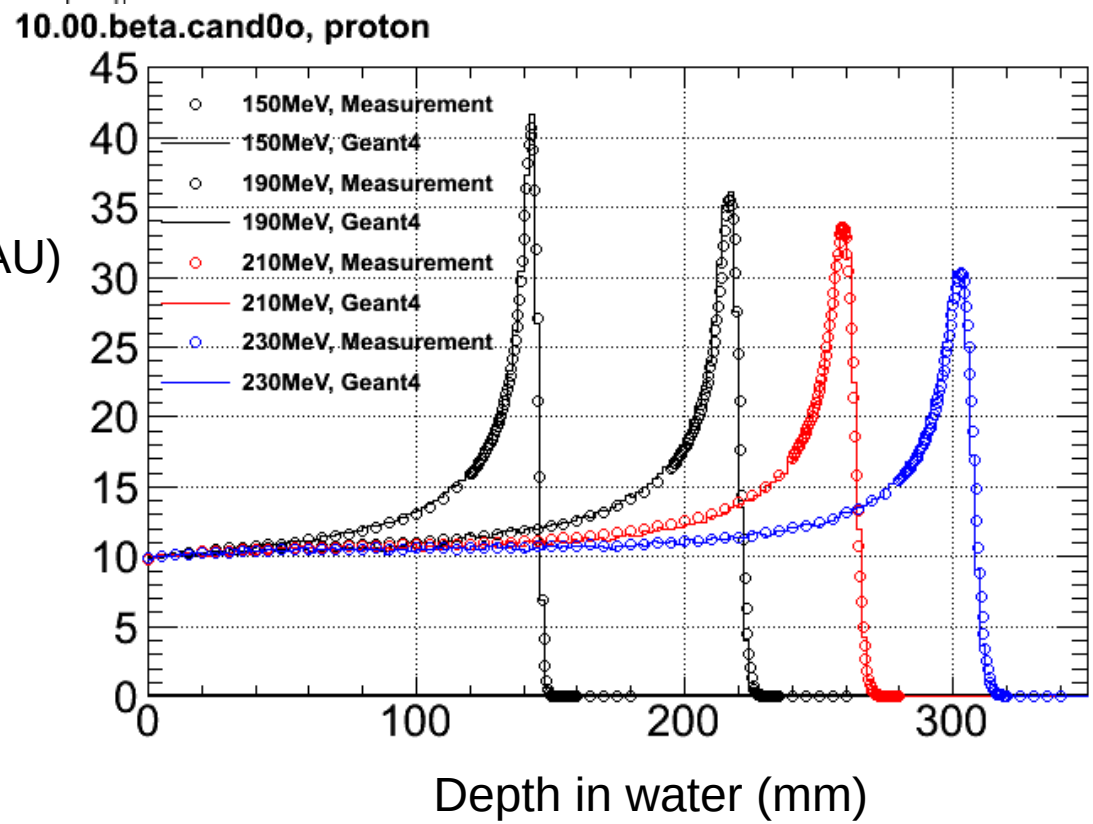




Bragg peak

proton Bragg peak in water (HIBMC, Japan)



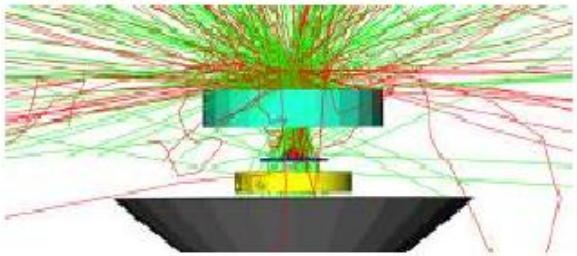


Also: He-4;
C (Guatelli, parallel session)
ions (Santin; parallel session)

Medical Linac

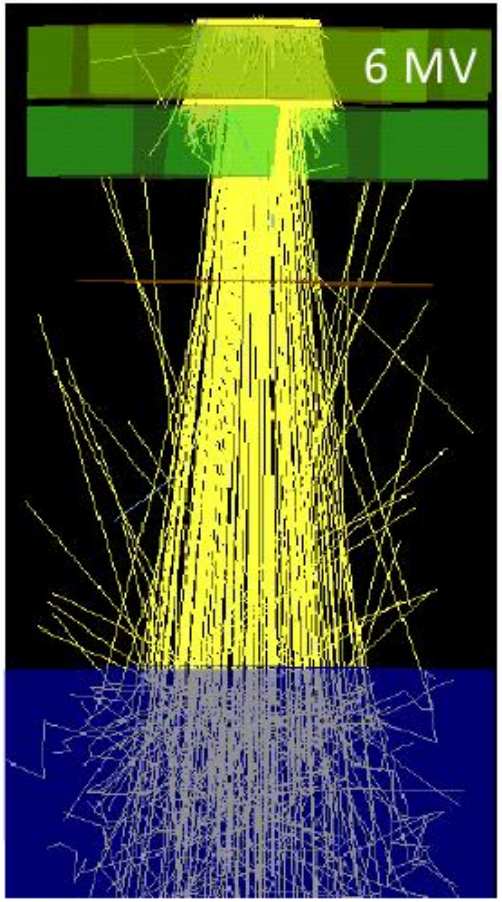
photons: brem, Compton, msc

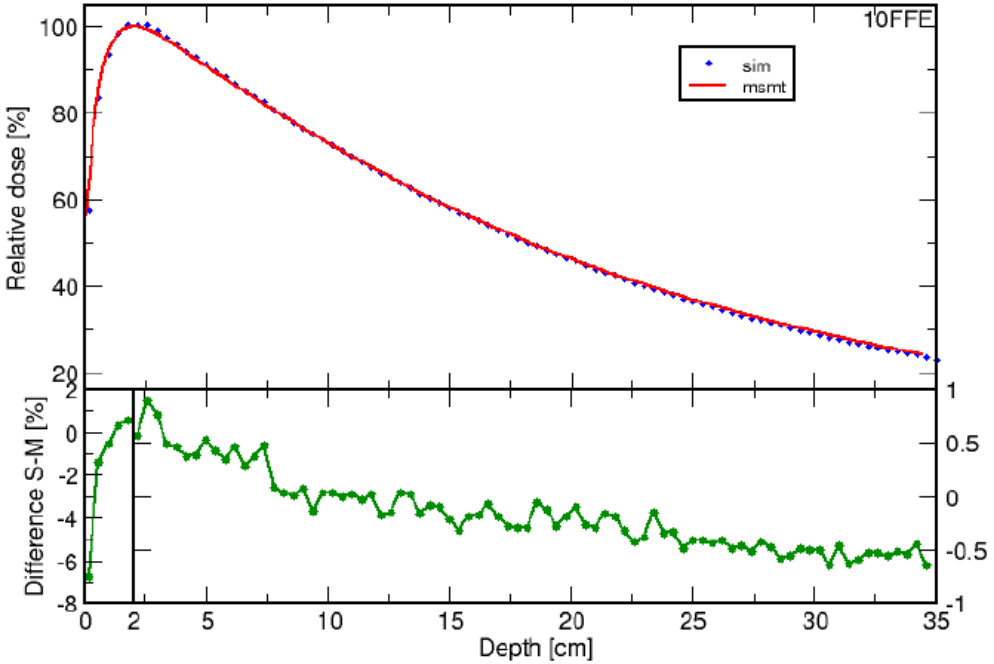
Virtualinac – Geant4

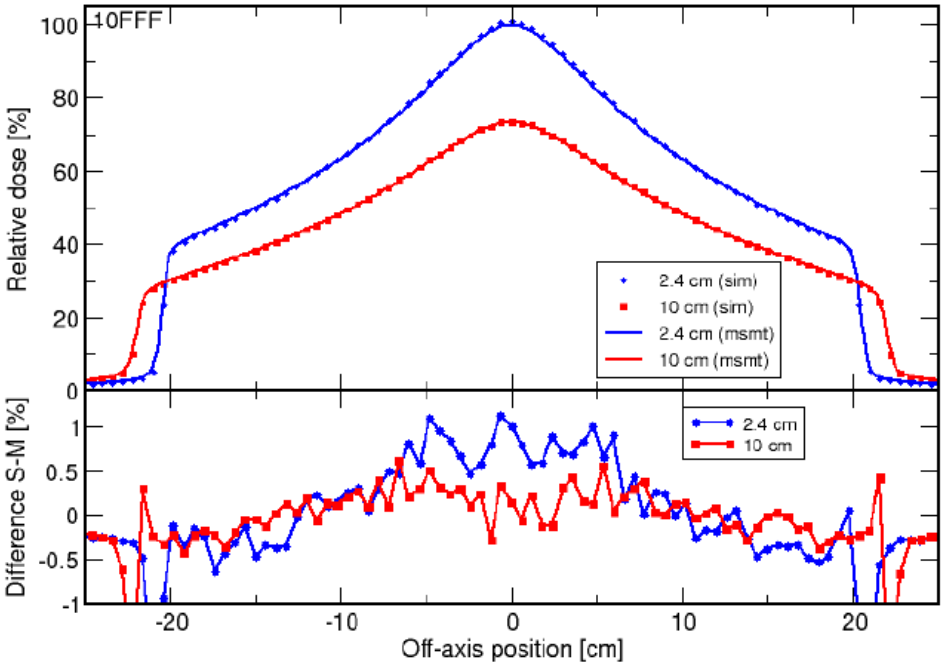


IAEA Phase Space

BEAMnrc



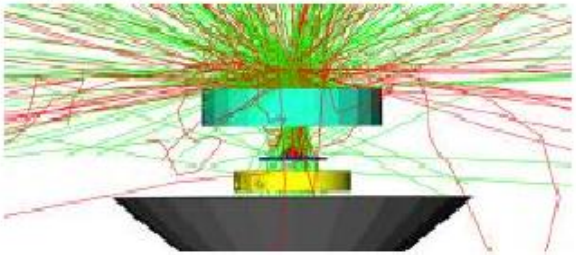




Medical Linac

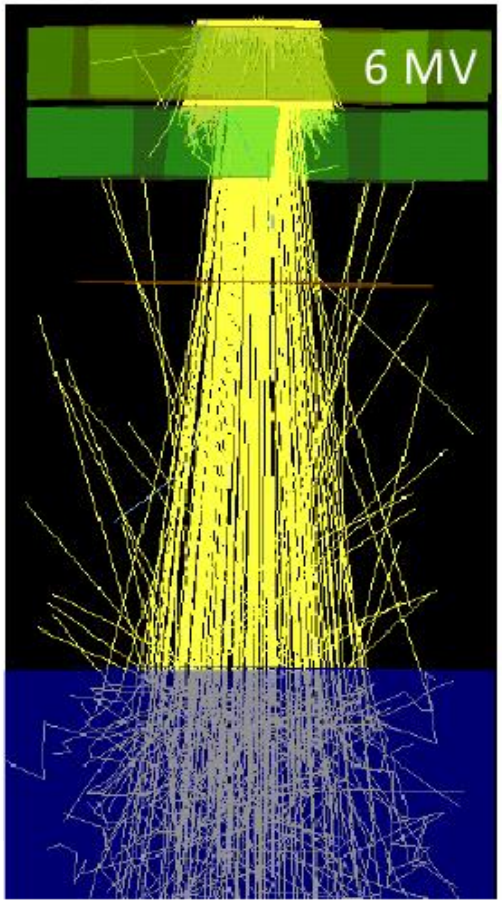
electrons: msc, stopping power

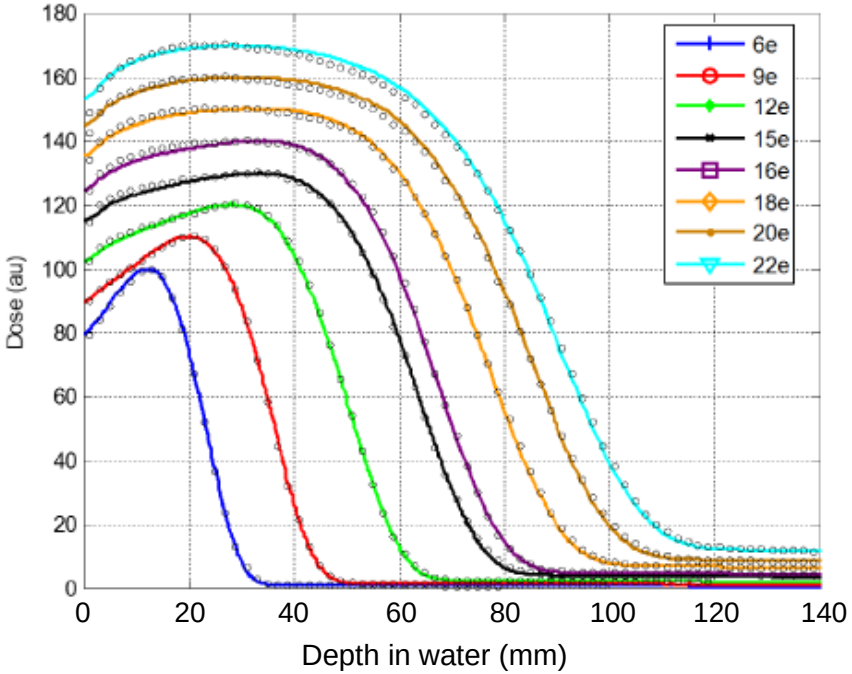
Virtualinac – Geant4

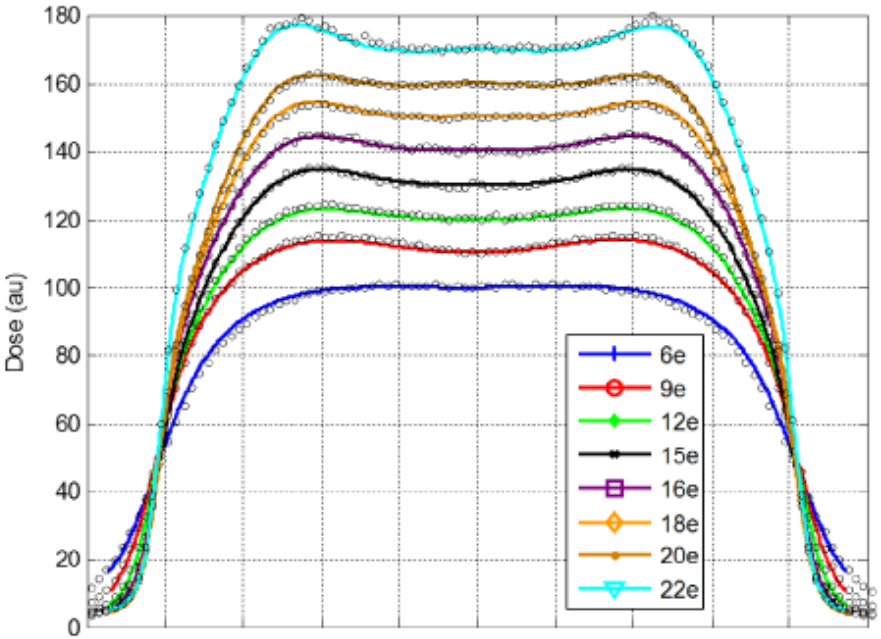


IAEA Phase Space

BEAMnrc







Two problems

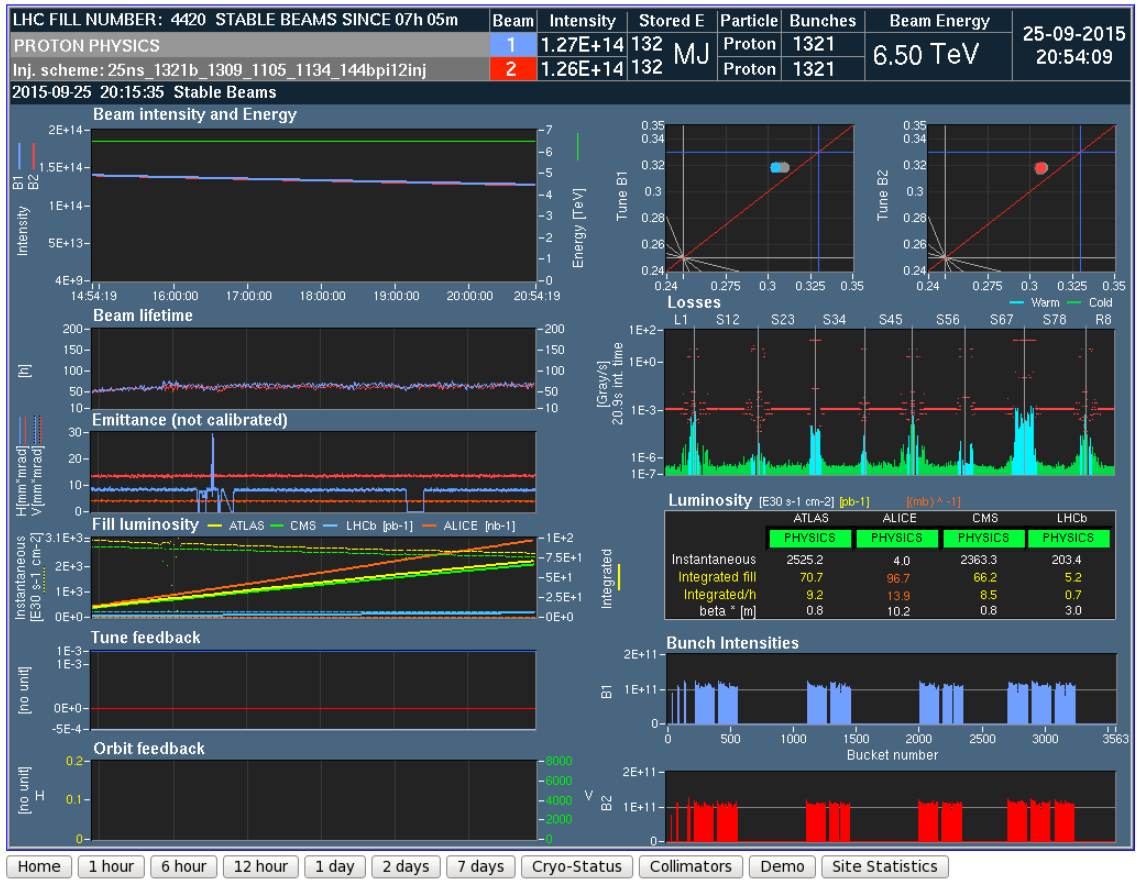
Two problems

1. Not enough data

Two problems

1. Not enough data

2. Too much data


LHC FILL NUMBER: 4420 STABLE BEAMS SINCE 07h 05m
PROTON PHYSICS
Inj. scheme: 25ns_1321b_1309_1105_1134_144bpi12inj
Beam
Intensity
Stored E
Particle
Bunches
Beam Energy
1 1.27E+14 132 MJ Proton 1321
2 1.26E+14 132 Proton 1321
6.50 TeV
25-09-2015 20:54:09
2015-09-25 20:15:35 Stable Beams
Beam intensity and Energy
Beam lifetime
Emittance (not calibrated)
Fill luminosity
Tune feedback
Orbit feedback
Tune B1
Tune B2
Losses
Luminosity
Bunch Intensities
Bucket number
Home
1 hour
6 hour
12 hour
1 day
2 days
7 days
Cryo-Status
Collimators
Demo
Site Statistics