Backscattering test results for Geant4 10.1 and beyond

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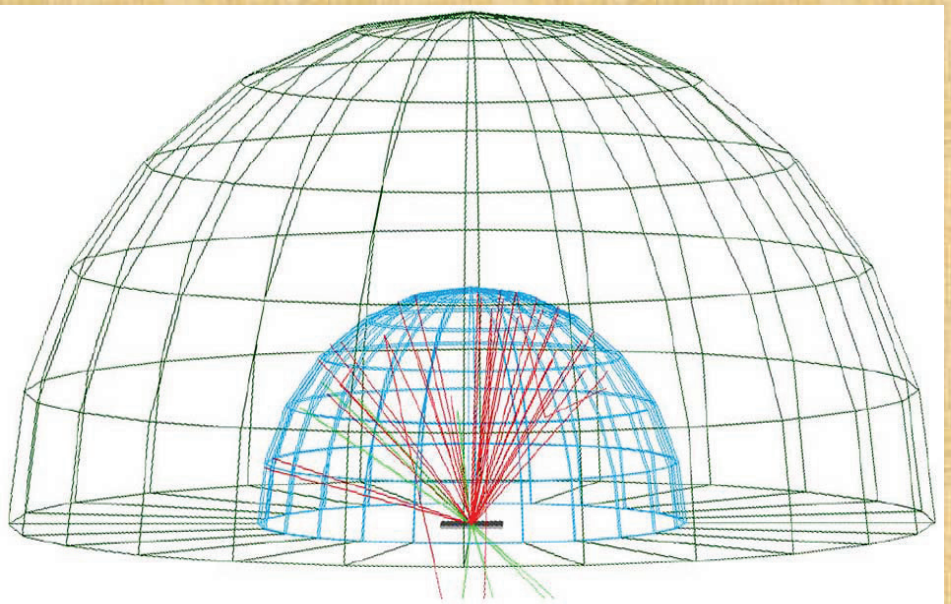
2 June 2015

Introduction

- Backscattering validation results of M.G.Pia were discussed in December after release 10.1
  https://indico.cern.ch/event/348078/session/0/contribution/4/material/slides/0.pdf
- In January there was a discussion on the report at SFT Simulation meeting
  - We confirmed configuration problem in the new WVI Physics constructor and GS multiple scattering model
  - The fixes for WVI and GS were provided for 10.1p01
- Later a paper has been published:
  - IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 62, NO. 2, APRIL 2015
  - In the paper basically the same conclusion and information were published as was reported in December Sim group meeting
- Below we will discuss backscattering test results
  - Initial software were obtained from the git repository provided by M.G.Pia

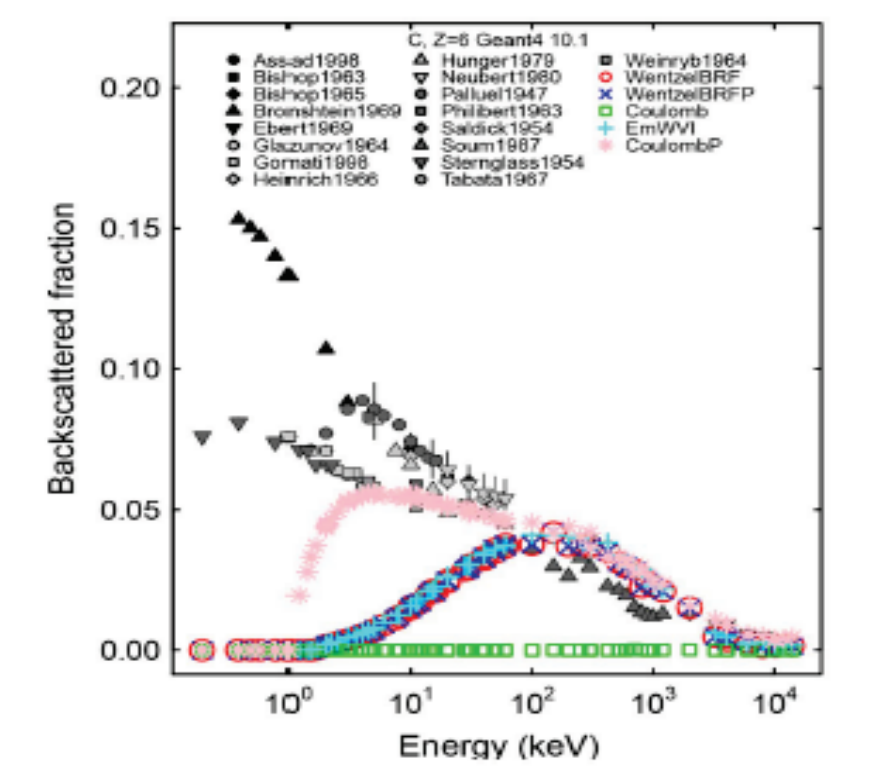
Simulation setup

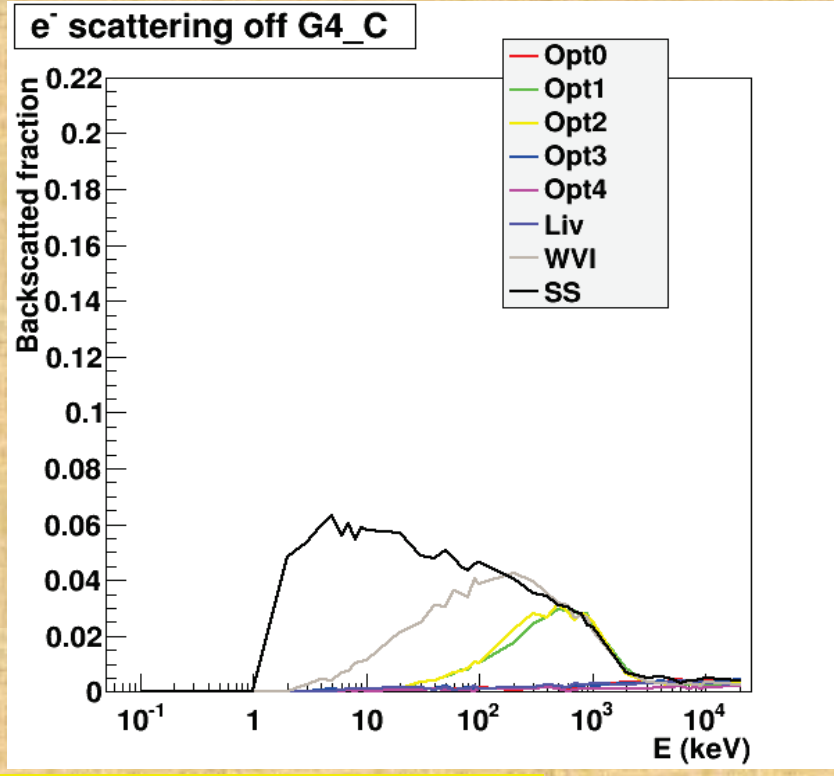
Plot from IEEE Transaction paper



- Target with the default sizes 25x25x1 mm^3 is located below XY plane
- Semi-sherical layers are used for scoring of backscattered electrons
- Primary source is located at the origine of the wold volume on boundary of the target and of the scoring sphere
  - It is sphere centrum
- Bssim application was taken without any modification except one: few lines of code were added to dump backscattering fraction value to a file
  - No parameter tuning forPhysics Lists
- In all computations cut in range was set to 1 um and geometry of the target was default

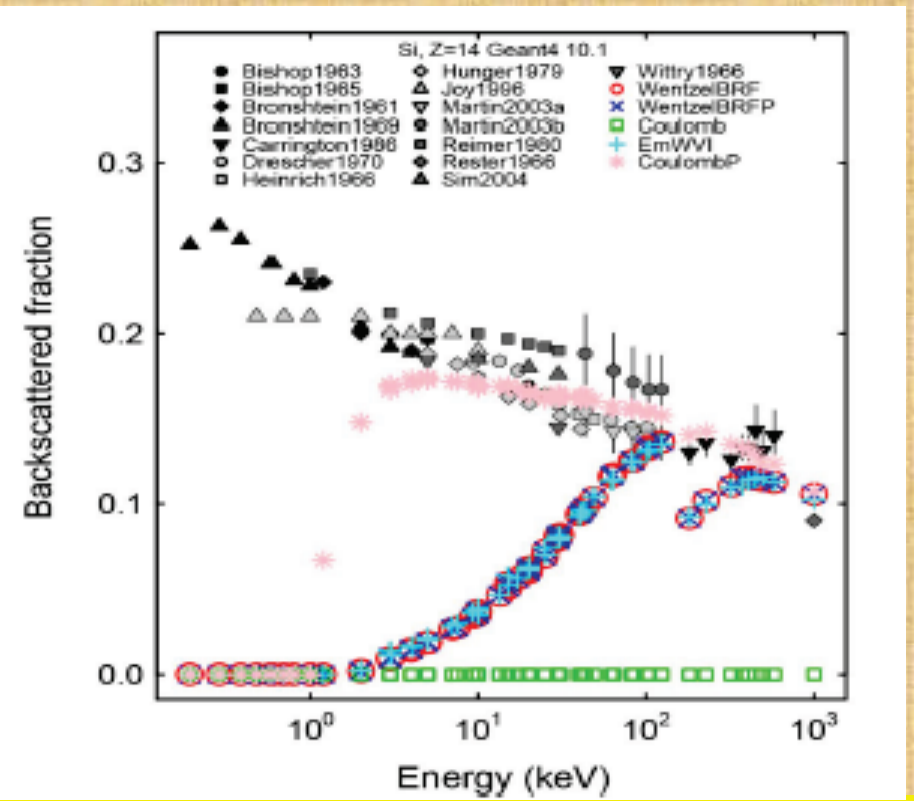
Results for the Carbon target for Geant4 10.1 and plot from IEEE Transaction

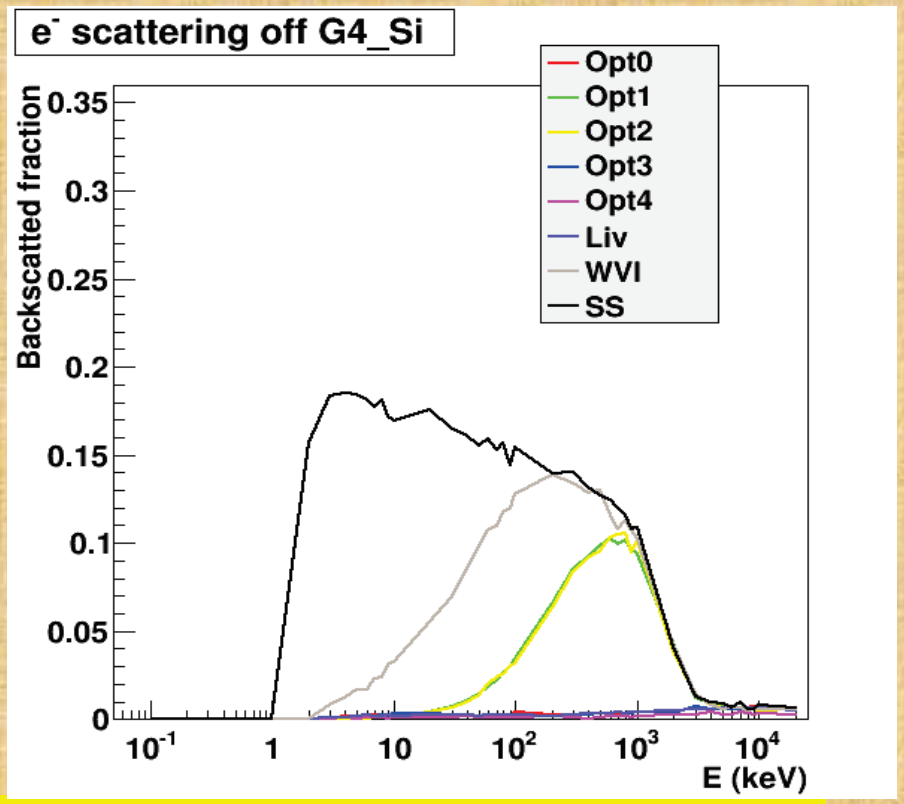




Opt3, Opt4, livermore Physics lists provide zero backscattering
SS above few keV follow the data
WVI above 200 keV follow the data
Opt1, Opt2 follow the data above 0.5 MeV
Results of the paper and bssim are the same

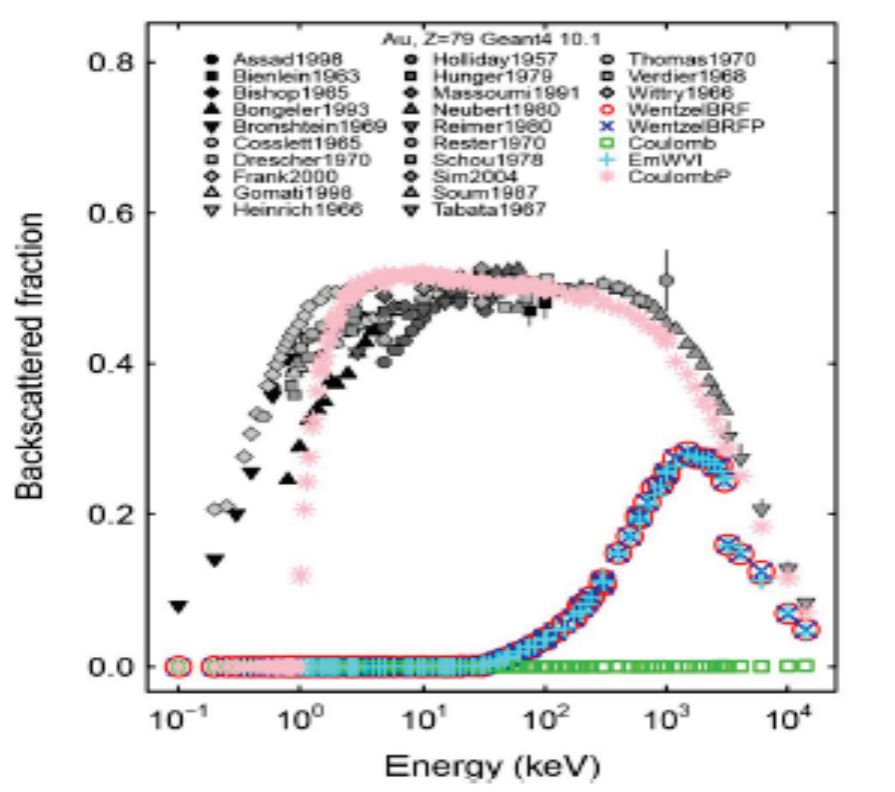
Results for the Silicon target for Geant4 10.1 and plot from IEEE Transaction

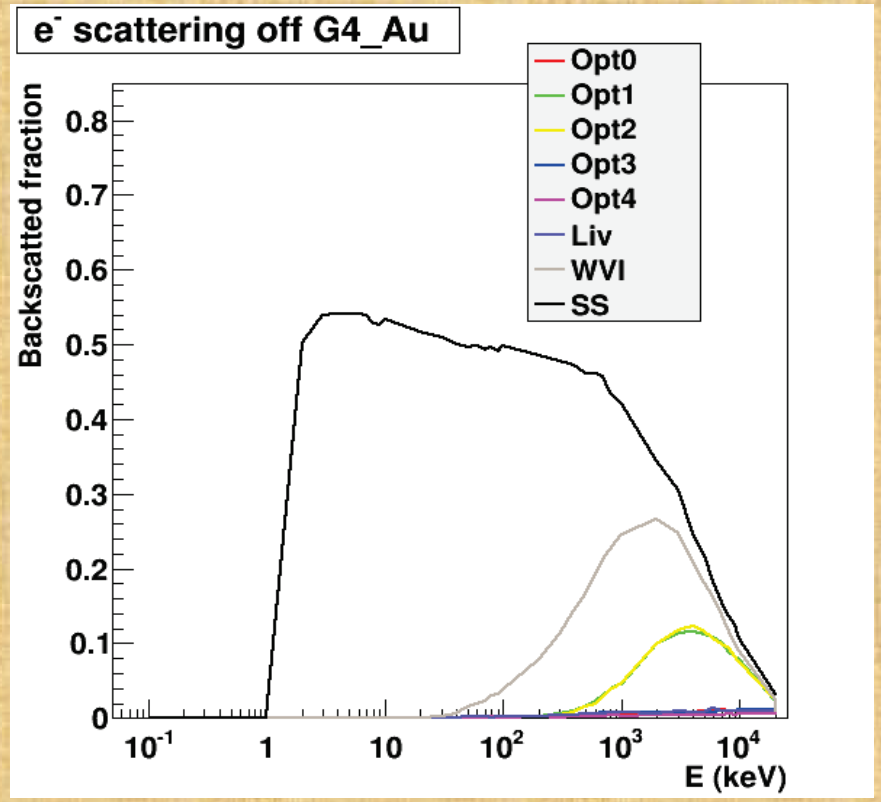




Opt3, Opt4, livermore Physics lists provide zero backscattering E <1 MeV
SS for E > 3 keV follow the data
WVI for E > 200 keV follow the data
Opt1, Opt2 follow the data E > 0.5 MeV
Results of the paper and bssim are the same

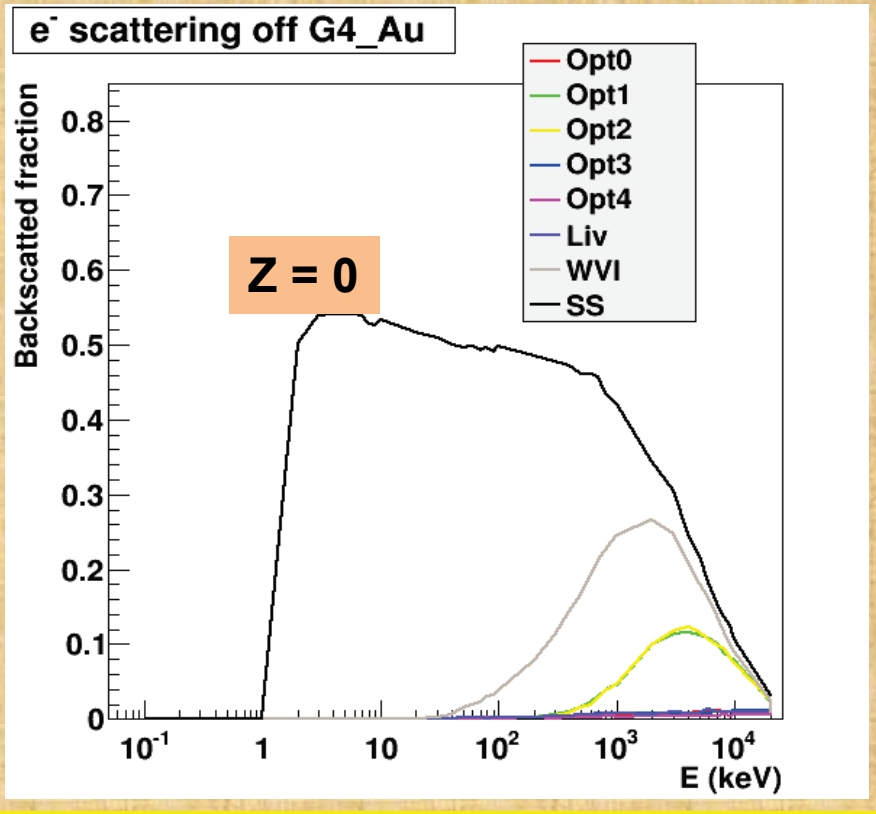
Results for the Gold target for Geant4 10.1 and plot from IEEE Transaction

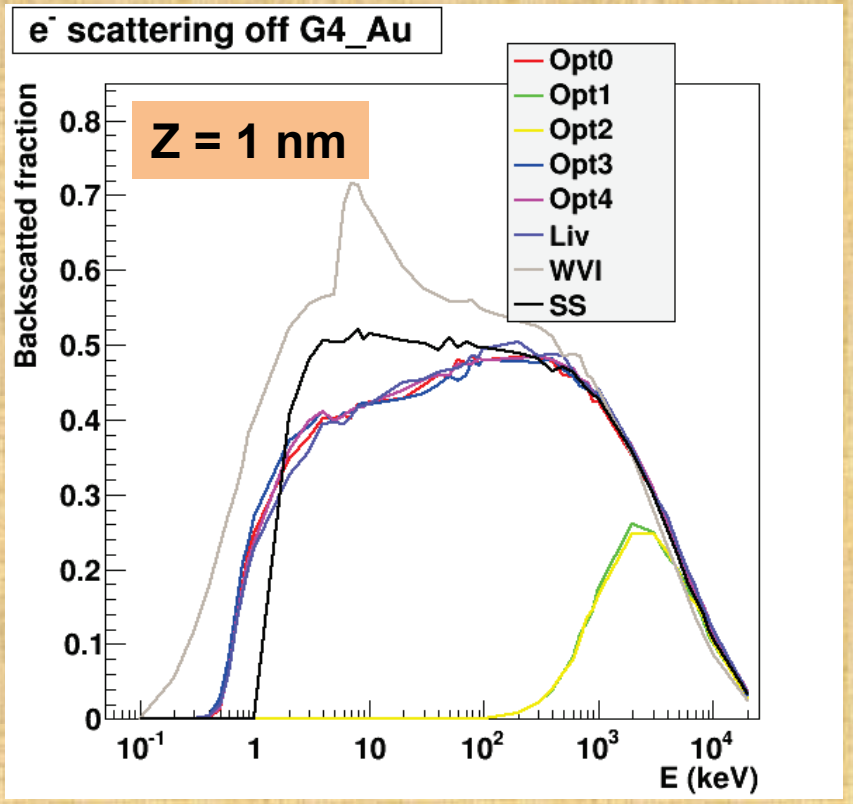




Opt3, Opt4, livermore Physics lists provide zero backscattering E <1 MeV
SS for E > 3 keV follow the data
Opt1, Opt2, WVI follow the data E > 3 MeV
Results of the paper and bssim are the same

Effect of shift of the beam for 1 nm for Geant4 10.1



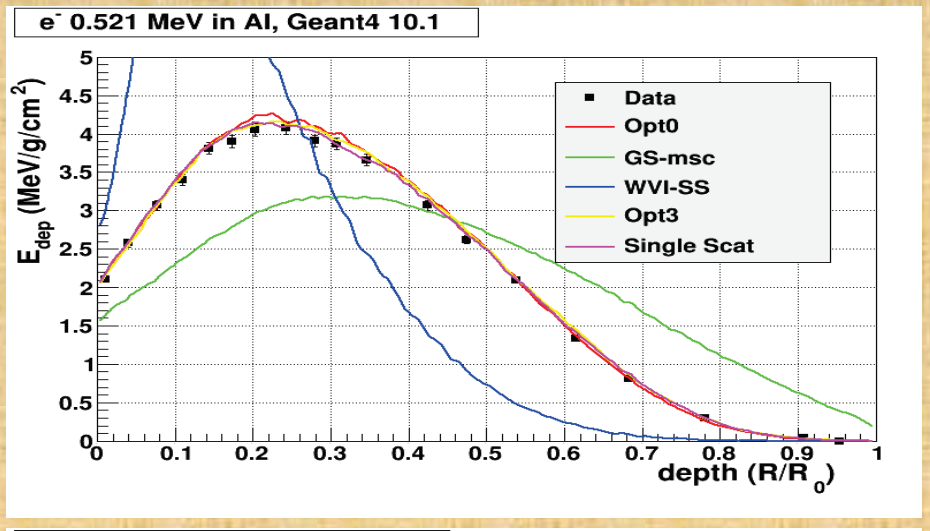


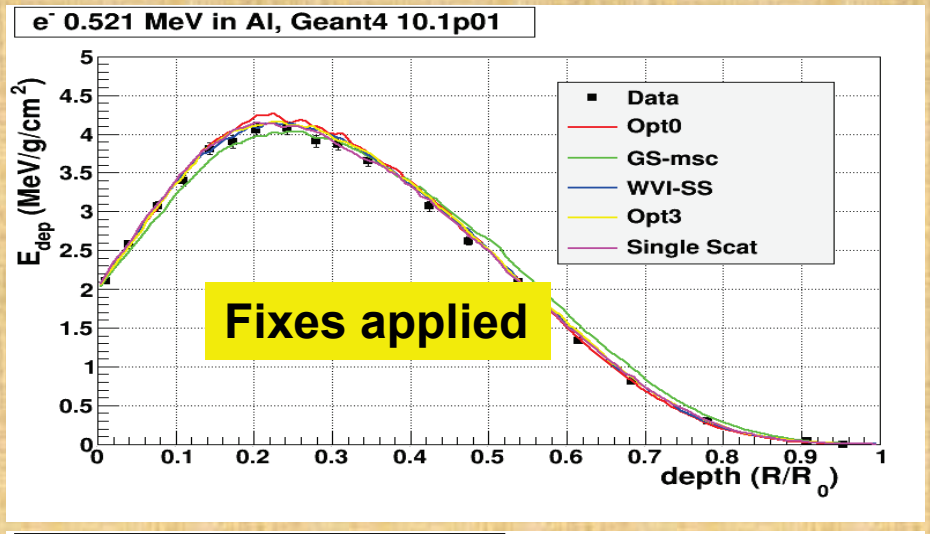
Opt3, Opt4, livermore Physics lists fit the data for E > 0.1 MeV
Opt3, Op4 are qualitatively close to the data 1 keV < E < 0.1 MeV
SS for E scattering > 3 keV follow the data (result is not sensitive to Z)
WVI for E > 500 keV follow the data (below overestimates)
Opt1, Opt2 follow the data E > 0.5 MeV
The problem may be fixed by a sfift of the beam for 1 nm

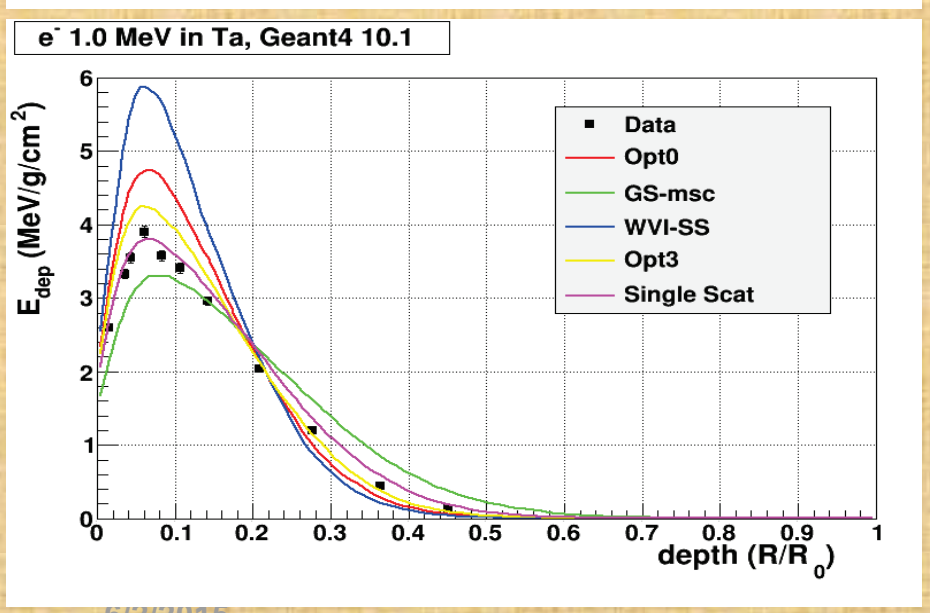
Geant4 10.1patch01

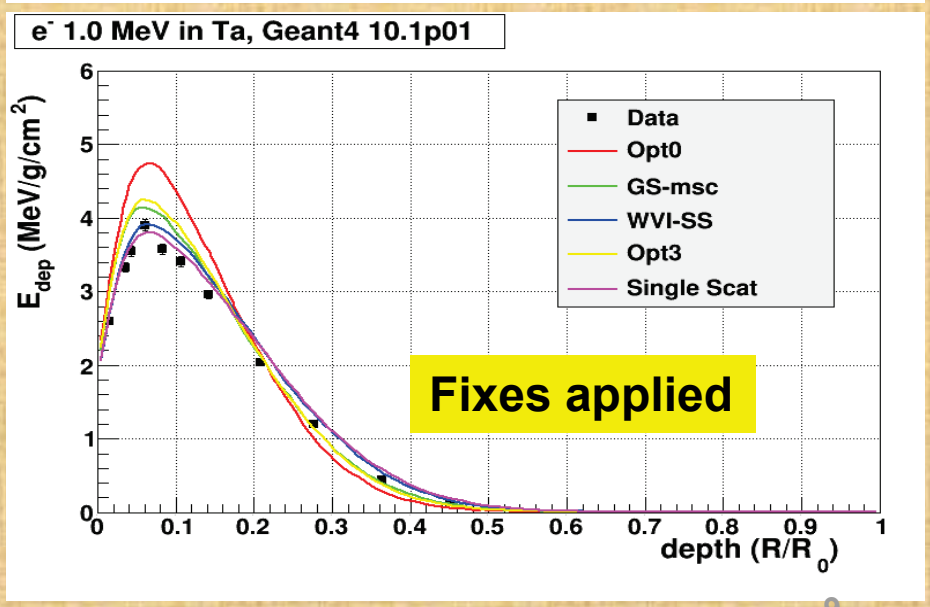
- Problem in bssim application has been confirmed
  - Results practically the same for any target material
  - Std, Opt3, Opt4 return to normal if the beam is shifted for 1 nm
- Also problems are seen in test37
- In the 10.1patch01 the two fixes related to backscattering were applied:
  - Fixed G4GoudsmithSoundersonModel
  - Fixed configuration of scattering models in G4EmStandardPhysicsWVI physics constructors
  - Scattering is back to normal for WVI and GS

Sandia data – problems in WVI and GS results of January

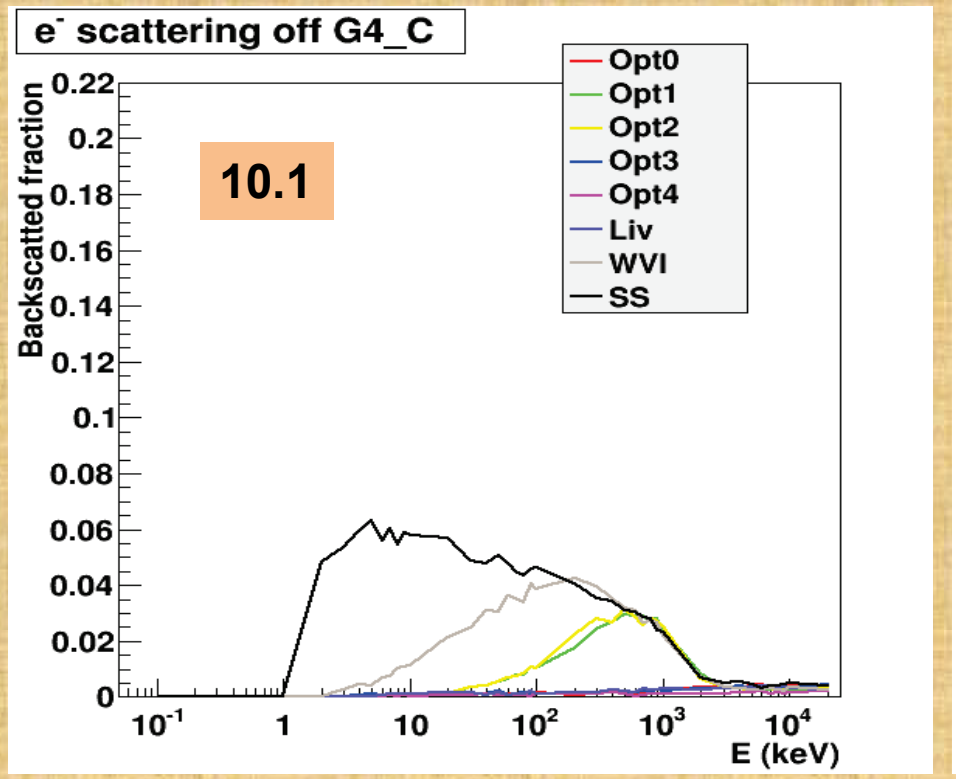


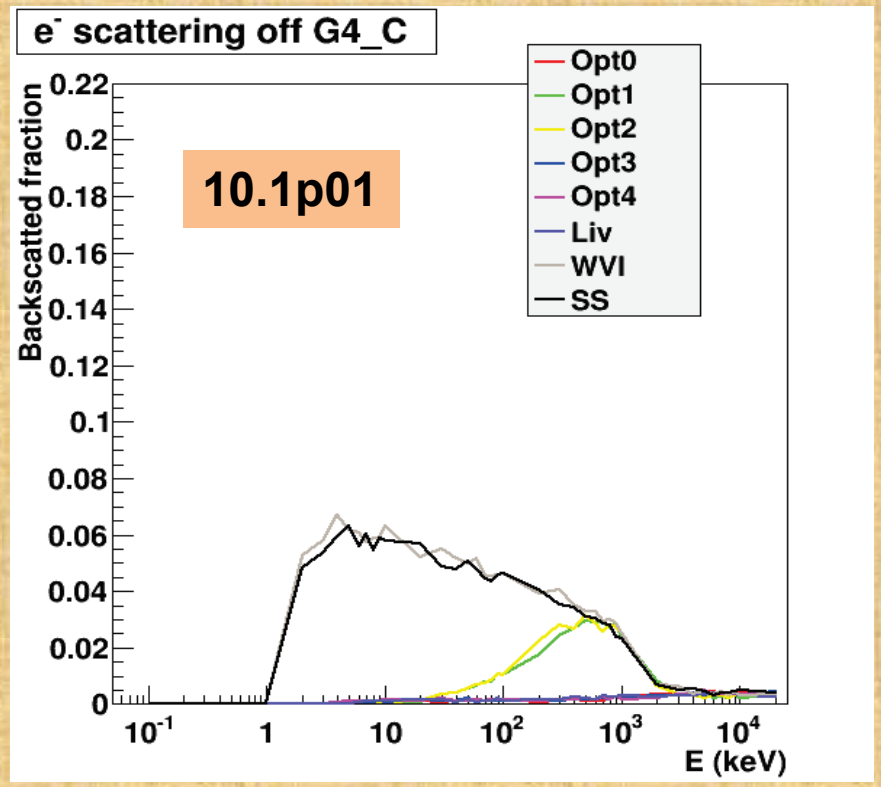






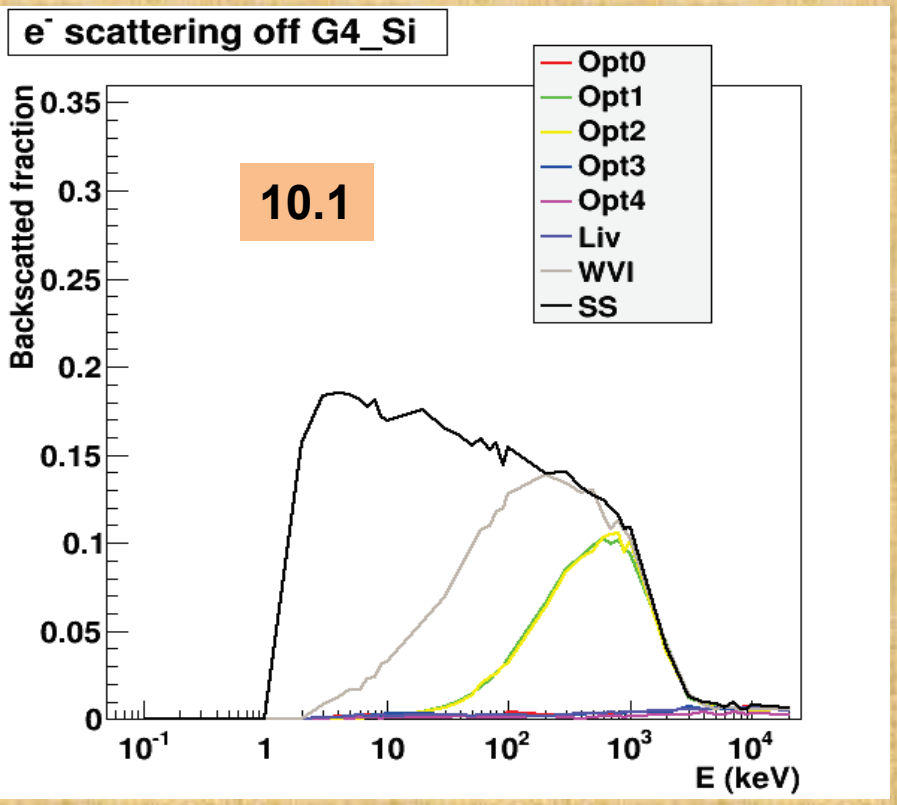
Results for the Carbon target for Geant4 10.1p01 versus 10.1p01

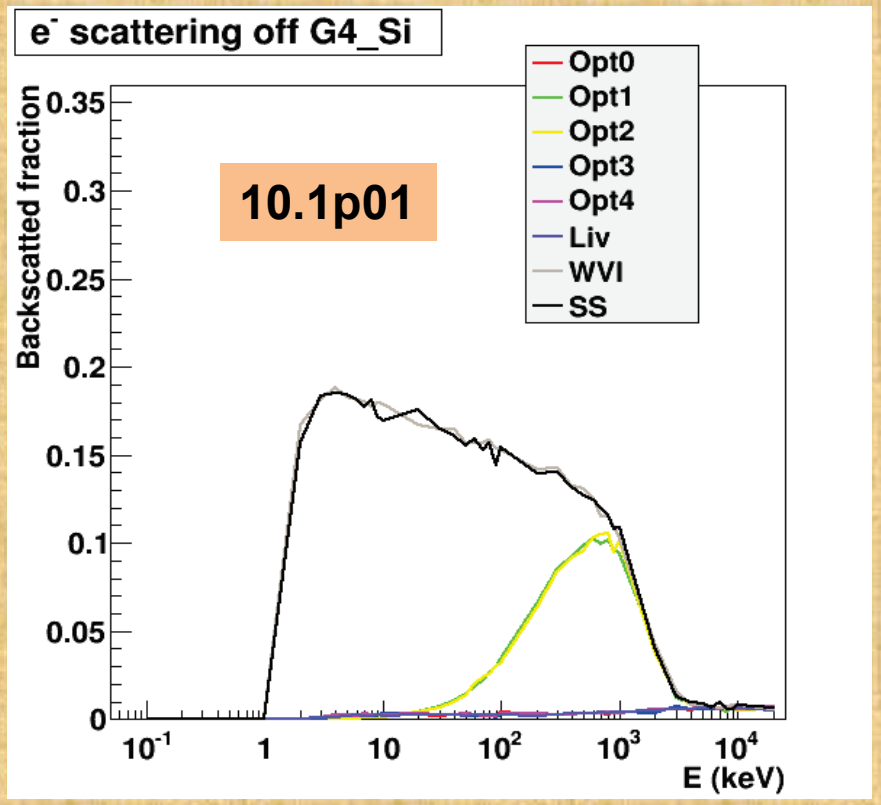




Opt3, Opt4, livermore Physics lists provide zero backscattering
SS, WVI above few keV follow the data
Opt1, Opt2 follow the data above 0.5 MeV

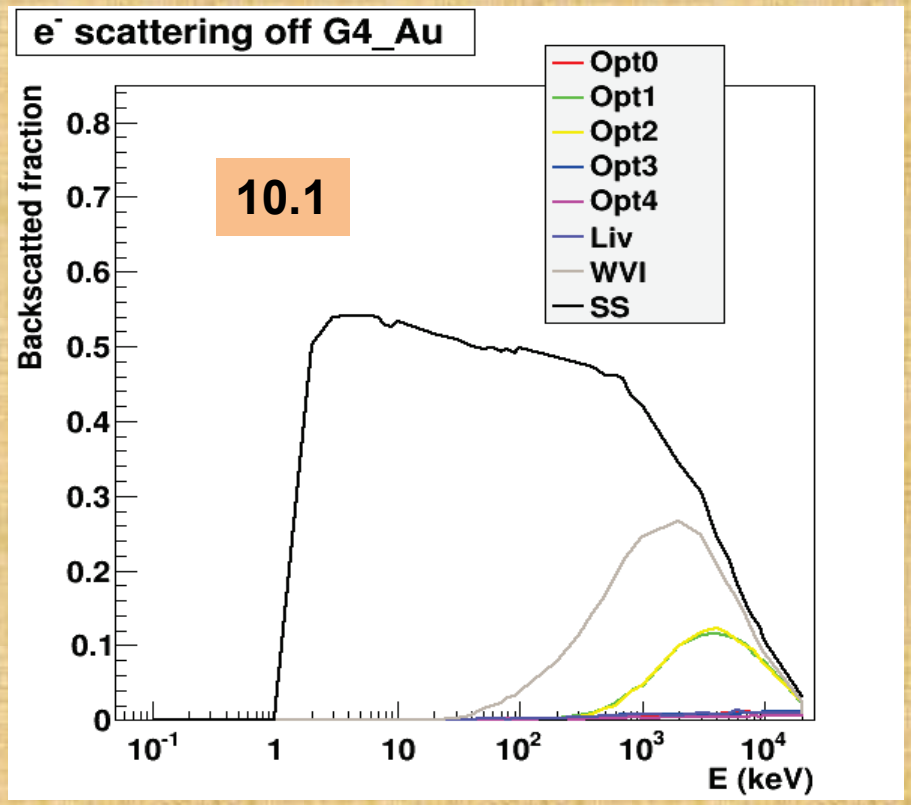
Results for the Silicon target for Geant4 10.1p01 versus 10.1

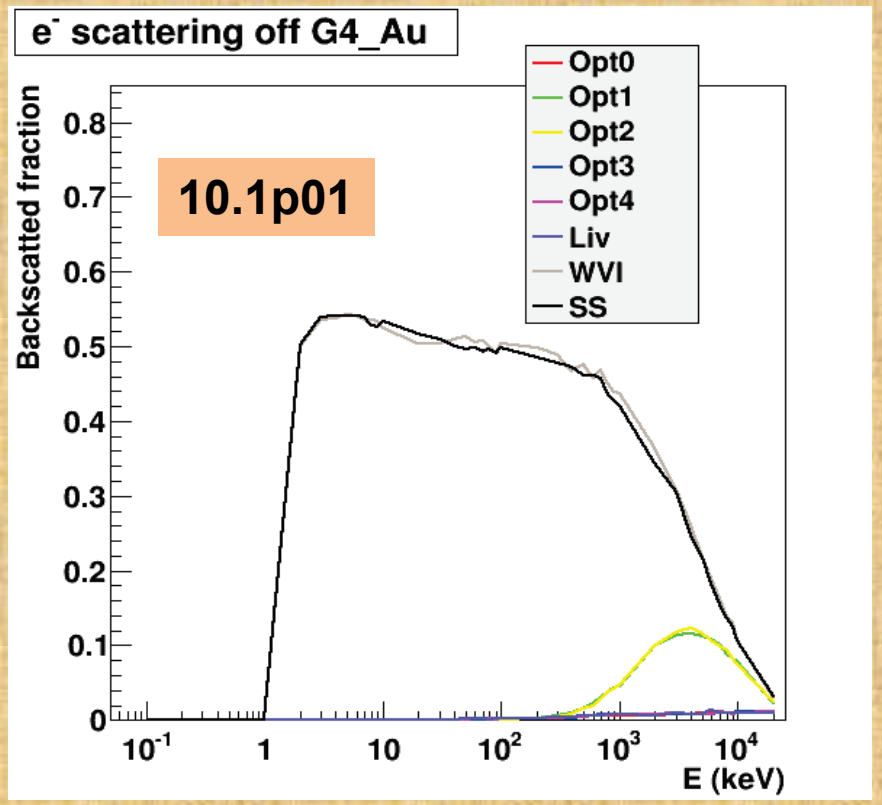




Opt3, Opt4, livermore Physics lists provide zero backscattering E <1 MeV
SS, WVI for E > 3 keV follow the data
Opt1, Opt2 follow the data E > 0.5 MeV

Results for the Gold target for Geant4 10.1p01 versus 10.1





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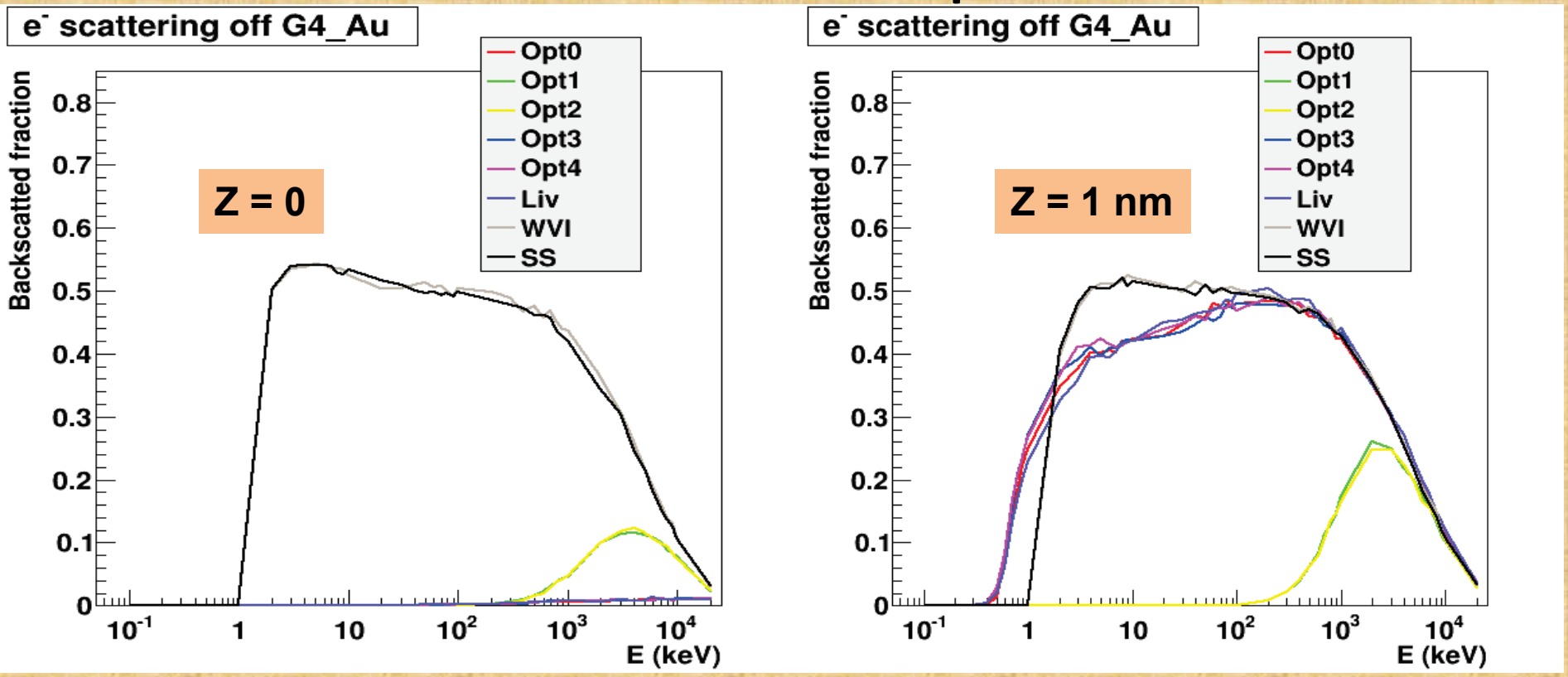
Opt1, Opt2 follow the data E > 3 MeV

Effect of shift of the beam for 1 nm Geant4 10.1p01



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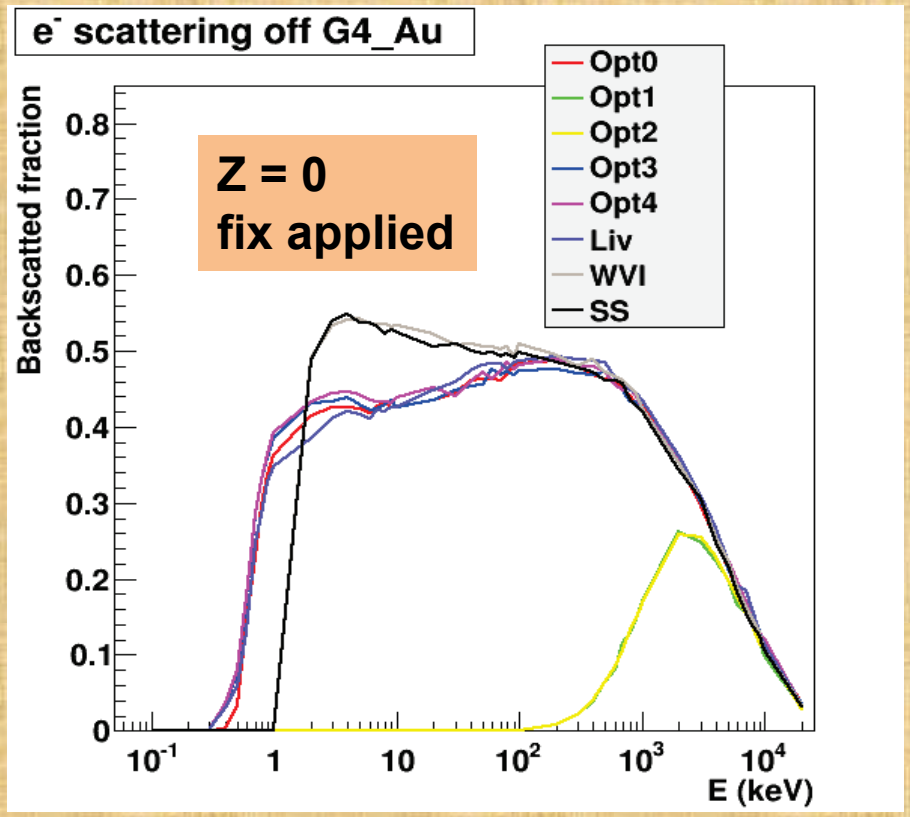
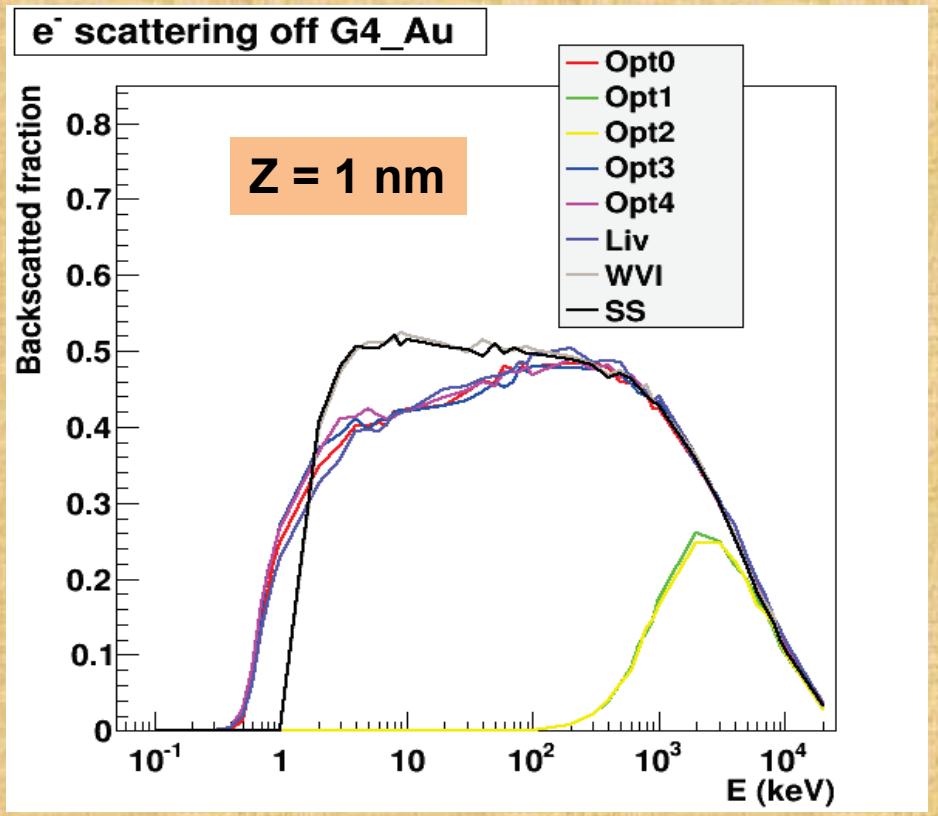
SS, WVI for E > 3 keV follow the data (result is not sensitive to Z)
Opt1, Opt2 follow the data E > 0.5 MeV
The problem may be fixed by a tiny sfift of the beam

Problem in geometry

- It was identified that G4Sphere class has a problem to compute safety when the point is exactly located in the its origine (0, 0, 0)
  - The problem happens only is theta section of the sphere is used
  - Value of safety become arbitrary and multiple scattering model use short cut (R < safety) to sample scattering
- This problem has been fixed and will be available in the 10.2beta release of Geant4 and in the next patch to 10.1

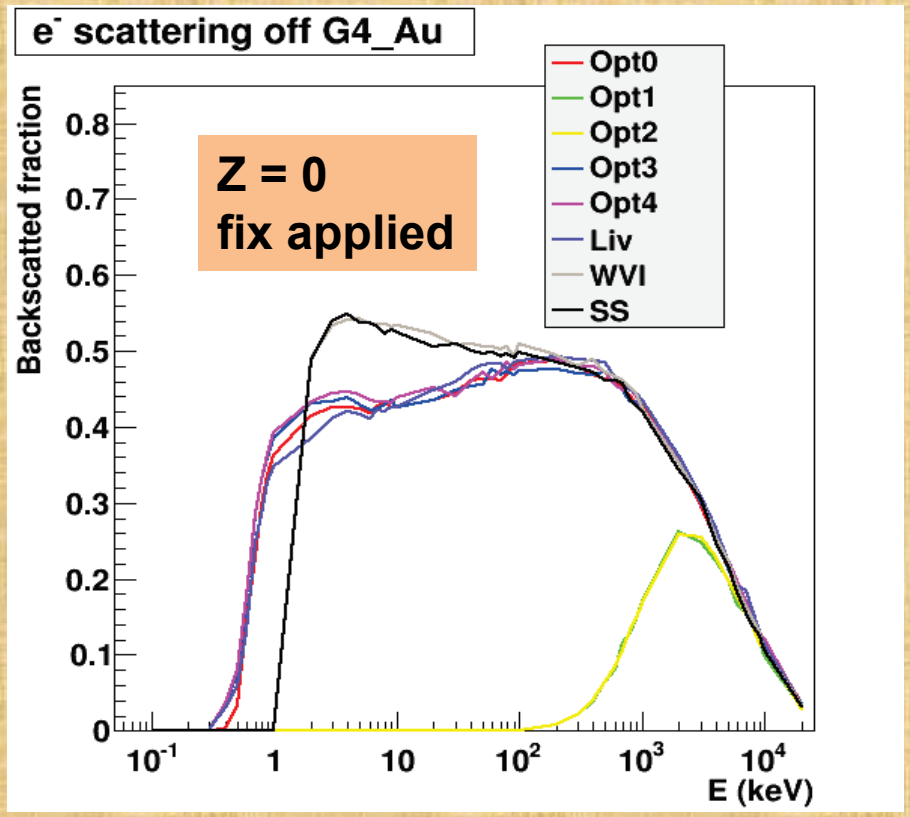
Effect of the fix of G4Sphere code on top of 10.1p01

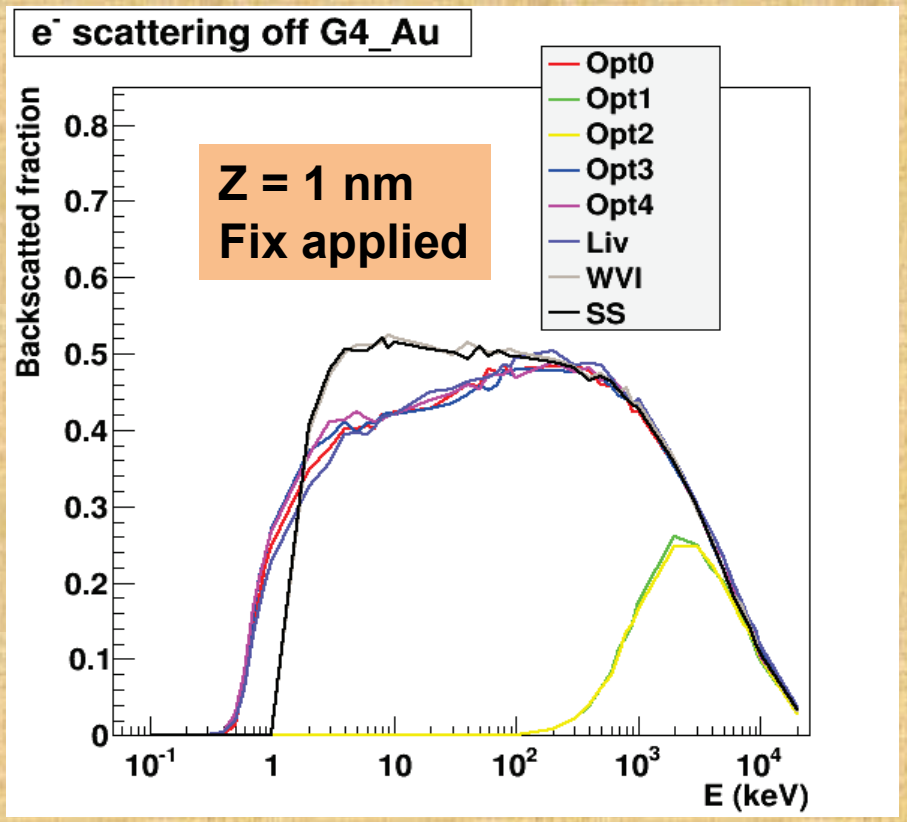




After the fix results for Z=0 and Z=1 nm without the fix are very similar
Results are not fully identical due to statistics

Effect of the fix of G4Sphere code on top of 10.1p01





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Conclusions

- With bssim application results of the paper in IEEE Transaction are reproduced in general
- In Geant4 10.1p01
  - SS and WVI Physics Lists provide results following the data above few keV
  - Opt3 and Opt4 results have a problem of absence of backscattering
- With the shift of the beam position for 1 nm the problem is fixed
- After the fix of G4Sphere the beam position shift is not needed anymore
- Discovered problem does not affect majority of applications because it is practically impossible to get particle position exactly in the sphere centrum except the case when the beam is defined in such point
  - The bug happens only in the case of theta section of the sphere
- The fix of G4Sphere will be included in next patches