Validation results from ELSHIELD project

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Outline

- ELSHIELD benchmarks
- Electron scattering (Hanson data)
- Sandia data benchmarks
- Electron ionisation,
- Bremsstrahlung
- 1D benchmark
• ELSHIELD project funded by ESA include extensive model EM standard model developments development in 2010-2011

• In framework of the ELSHIELD project EM benchmarks for the energy 1 keV – 20 MeV have been extended and regular exercised

• Problems in standard models and combined Physics lists have been fixed
## List of ELSHIELD validation benchmarks versus experimental data

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Type</th>
<th>Energy/angle</th>
<th>Material</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron scattering</td>
<td>new</td>
<td>15.6 MeV 0 – 25°</td>
<td>Au</td>
<td>data</td>
</tr>
<tr>
<td>Electron scattering</td>
<td>Existing, update in progress</td>
<td>13, 20 MeV 0 – 12°</td>
<td>Be, C, Al, Ti, Cu, Au, Ta</td>
<td>Data, EGSnrc, Penelope</td>
</tr>
<tr>
<td>Dose profile</td>
<td>Existing</td>
<td>0.5 – 1 MeV</td>
<td>Al, Mo, Ta, TaAl, AlAuAl</td>
<td>Data</td>
</tr>
<tr>
<td>Backscattering</td>
<td>new</td>
<td>0.1 – 1 MeV 0 – 75°</td>
<td>Be, C, Al, Ti, Cu, Mo, Au, Ta, U</td>
<td>Data</td>
</tr>
<tr>
<td>Bremsstrahlung</td>
<td>new</td>
<td>1, 2.8, 15 MeV 0 – 60°</td>
<td>Al, Cu, W</td>
<td>Data, EGSnrc, Penelope</td>
</tr>
<tr>
<td>Dose kernel</td>
<td>Existing</td>
<td>10, 15, 100 keV, 1 MeV</td>
<td>Water</td>
<td>EGSnrc</td>
</tr>
</tbody>
</table>

**Energy interval of interest for the project 1 keV – 20 MeV**
Electron scattering

A. O. Hanson et al., “Measurement of multiple scattering of 15.7-meV electrons,”

15.7 MeV e- scattering off Au 9.66 um, Geant4 9.4ref08

(probability per square degree)

\[ \theta \text{ (degree)} \]

\[ \theta \text{ (rad)} \]

Data
Urban93
WVI-SS
Urban95
mscGS
Single Scat

(1 - Geant4/Data) (%)
MonteCarlo/Data method is one of the most effective
Another point of view on the same data
We need to keep different approaches
This test support Urban95 model to be default
Electron backscattering scattering


New benchmark on electron backscattering using Sandia data (A. Lechner)

- New benchmark have been developed using Sandia data on backscattering and energy deposition in semi-infinite media
- Electron energy 0.1 – 1 MeV
- Beam angles from 0 and 75 degrees
- Be, C, Al, Ti, Cu, Mo, Ag, Ta, Au, U

Optimization of $f_r$ (FactorRange) parameter: default value 0.04 should be reduced to 0.01 to provide stable simulation at low energy
Backscattering as a function of projectile energy (A. Lechner)
Factor-Range and energy profiles for Sandia data (test37)

$F_R = 0.04$ (default)

$F_R = 0.01$

19 September 2011

16th Geant4 Workshop
Other benchmarks

electron stopping powers
bremsstrahlung
Effect of Rayleigh scattering
Electron Ionisation in Aluminum (V. Grichine)

- Standard models (Moller-Bhabha and PAI were extended down in energy)
- Benchmark results show good agreement between models above 10 keV
- Below 10 keV Livermore model is more precise
- Low limit of the tables can be reduced to 10 eV
Bremsstrahlung developments and new benchmark (V. Grichine)

- Three models were benchmarked:
  - Standard
  - Livermore
  - Penelope
- Several angular generators:
  - G4ModifiedTsai
  - G4Generator2BS
  - G4PenelopeBremsstrahlungAngular
  - G4DipBustGenerator

- Angular generators are very similar
- Tsai predicts small backscattering fraction due to scattering off electrons
- Tsai/Urban model is correct theoretically!
Bremsstrahlung energy spectra (V. Grichine)

- Statistics $10^8$ per run
- At 15 MeV Geant4, EGS and data agree each other
- At 1 MeV Standard model far from the data and Penelope predictions
- Below 10 MeV Standard model should be substituted
Rayleigh scattering must be taken into account for keV energy gamma transport
ELSHIELD Project 1D benchmark:
Comparison of different models
Validation of new models and options
Estimation effects of different absorbers
Estimation of effects of cross section uncertainty
1-D benchmark geometry

- **GRAS analysis modules:**
  - Dose analysis in two Si layers 10 um and 300 um
  - Fluencies of gamma and electrons in front of the detector
  - New GRASSiAnalysisModule for dose profile in Si

- **1D and 2D Histograms**

- **Physics Lists:**
  - Opt0 (needed to understand reverse MC precision)
  - Opt3, Livermore, Penelope
  - PIXE option for all
Materials and thicknesses for the 1-D benchmark implemented in GDML files

- Sensitive detector 2 volumes of Si
  - 10x10x0.001; cm³
  - 10x10x0.03 cm³
- Single absorbers (SHIELDOSE standard)
  - Al 0.5, 1, 2, 3, 5, 10, 20 mm
  - Ta 0.081, 0.162, 0.324, 0.486, 0.81, 1.62, 3.24 mm\(\times\)\(\rho\text{(Al)}/\rho\text{(Ta)}\)
- Combined absorbers
  - Al, Au, Al 1.79/0.046/0.03 mm – total mass 2 mm Al
  - Al, Ta, Al 1.79/0.025/0.03 mm \(x\times\rho(x)/y\times\rho(y) = 0.1\)
  - Al, Ag, Al 1.79/0.029/0.03 mm
- Optional structure
  - Al, Au 1.818/0.0467 mm – total mass 2 mm Al
  - Al, Ta 1.818/0.0254 mm \(x\times\rho(x)/y\times\rho(y) = 0.1\)
  - Al, Ag 1.818/0.02945
Dose deposition in 300 um Si layer from high energy electron beams and 2 mm Al or Ta shielding

- All Physics Lists well agree, Opt0 is narrower for Aluminum at 2 MeV
- Tantalum reduces dose in 5 times at 2 MeV and in 2.5 times at 5 MeV
- Statistics $10^6$ events per plot/Physics List
- Results for 9.5beta
Dose deposition in 10 um Si layer from high energy electron beams and 2 mm Al or Ta shielding

- Livermore predicts significantly wider dose with the same peak position
- Penelope predicts a bit smaller peak position
- Tantalum reduces dose in 6 times at 2 MeV and in 2.5 times at 5 MeV
- Statistics $10^6$ events per plot/Physics List
- Results for 9.5beta
Results with Geant4 9.4ref08 10 um Si

Penelope predicts a bit lower peak position
Results with Geant4 9.4ref08 for 0.3 mm Si

Ideal agreement between models with ref08
Dose deposition in 300 um Si layer from low energy electron beams and 2 mm Al shielding

- Livermore and Penelope dose is lower than Opt0 or Opt3
- More absorption?
- Statistics $4 \times 10^7$ events per plot/Physics List

19 September 2011
Mean energy deposition as a function of electron energy

Energy deposition in 10 um Si

Energy deposition in 0.3 mm Si
Effect of shielding material

• Electron spectrum $1/E$ in the interval of energy 1 keV – 10 MeV

• Ta layer absorb more e- due to multiple scattering?

• Mass of shielding is the same
Conclusions

• Thanks to ESA funding a significant models development and validation have been carried out
• We confirm that Urban95model should be default
• With ref08 we have achieve more close results for different Physics Lists