

# Bremsstrahlung benchmarks

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## Abstract

GEANT4 models for bremsstrahlung were tested versus experimental data and the prediction of the PENELOPE as well as EGS4 packages. The models show good agreement with the experiment for the electron energy interval 1-15 MeV. The new G4SeltzerBerger model improves the description of the data in the range 1-3 MeV for GEANT4 standard electro-magnetic package.

# 1 Outline

1. GEANT4 bremsstrahlung models.
2. Benchmark experimental data.
3. Comparison with experimental data for the bremsstrahlung spectrum at different angles.
4. Conclusions.

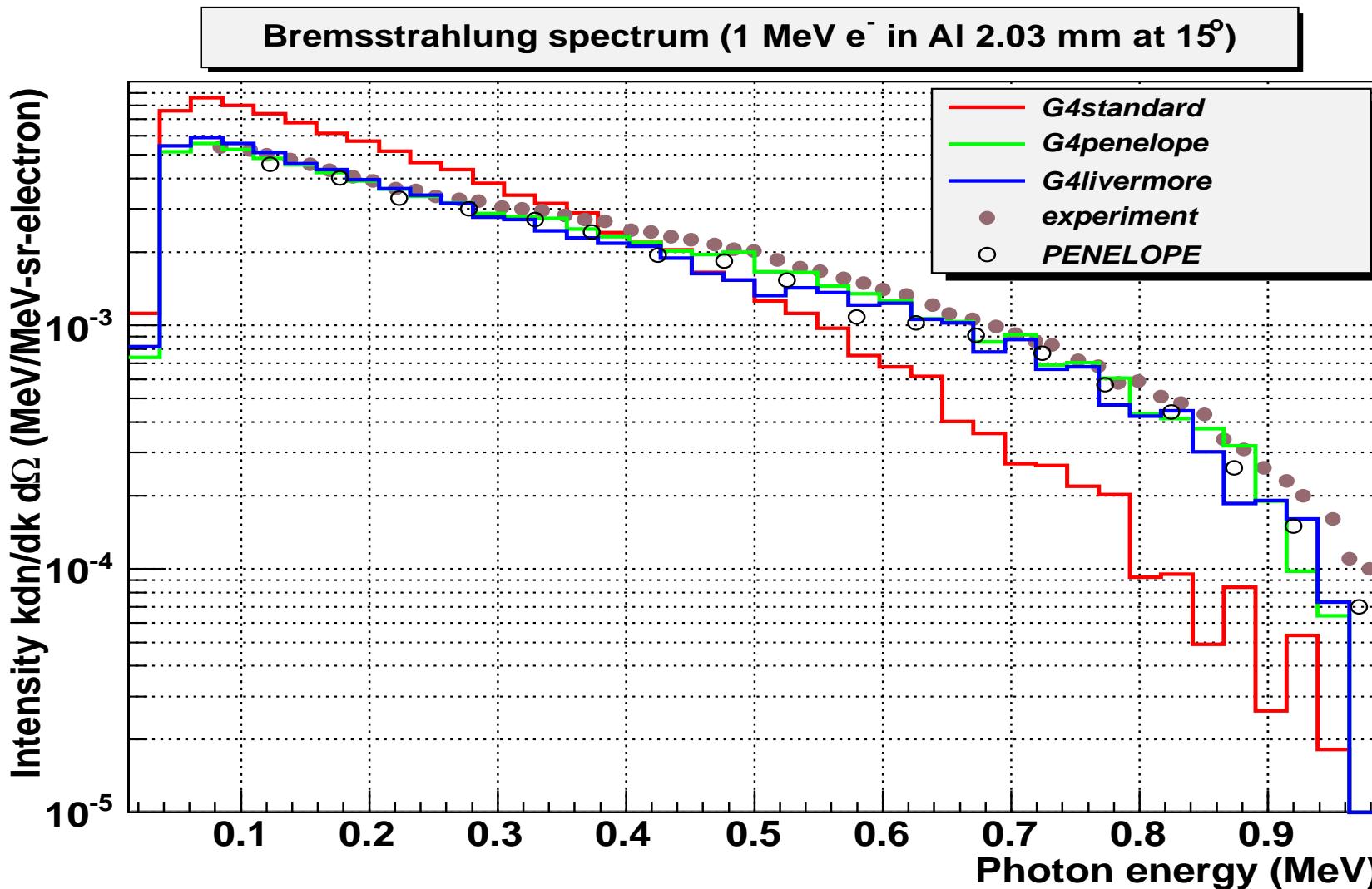
## 2 GEANT4 bremsstrahlung models

1. G4eBremsstrahlungModel in the EM standard package.
2. New G4SeltzerBergerModel in the EM standard package. It utilizes directly the calculations from [1].
3. G4PenelopeBremsstrahlungModel in the EM low energy package.
4. G4LivermoreBremsstrahlungModel in the EM low energy package.

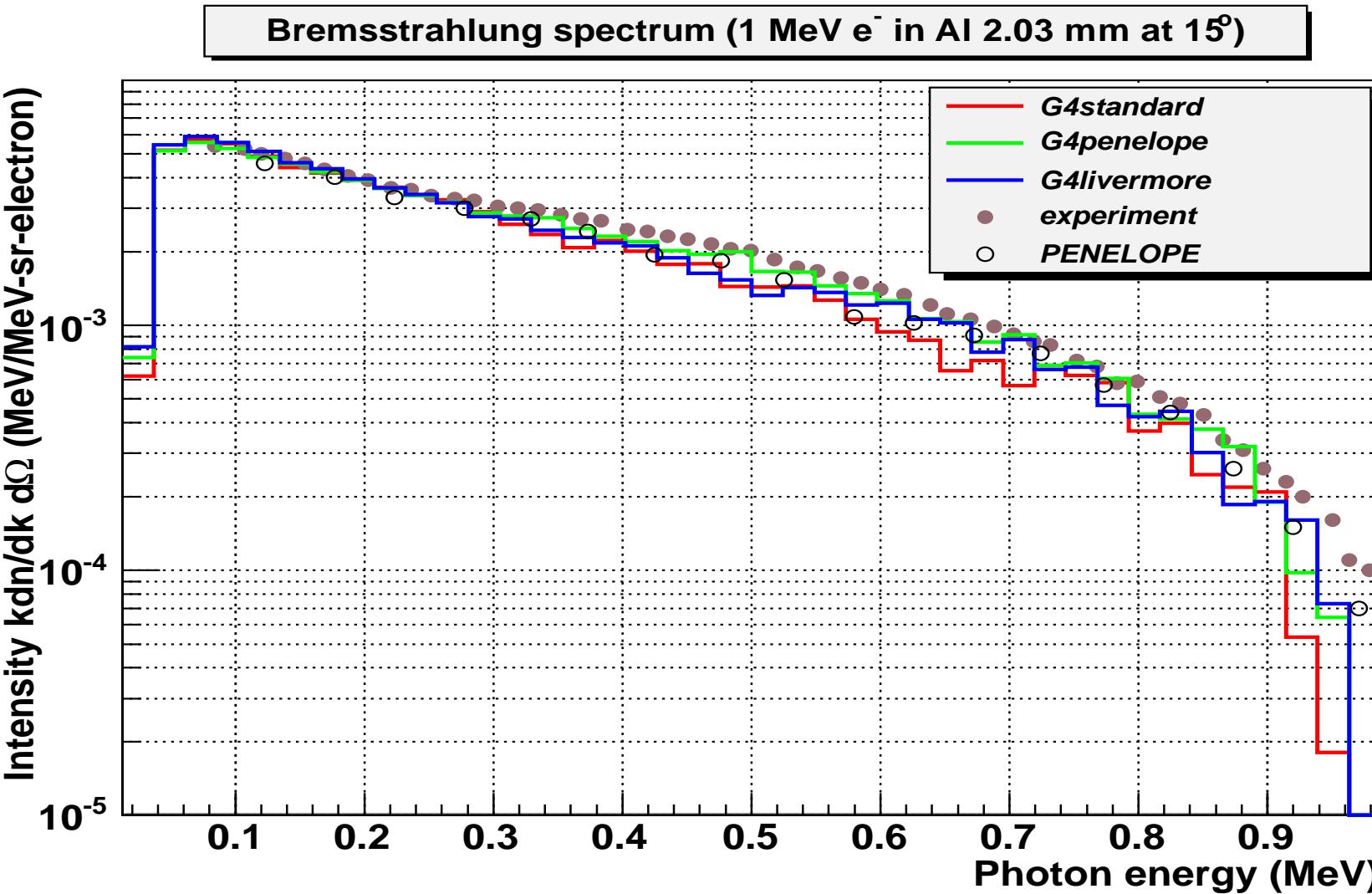
### 3 Bremsstrahlung produced by low energy electrons

Experimental data for Al, from [2, 3] are evaluated versus the GEANT4 models and the prediction of the PENELOPE package [4]. The bremsstrahlung intensity spectrum produced by electrons with the energies 1 and 2.8 MeV was evaluated at the angle of  $15^\circ$  in aluminum with 2.03 and 6.41 mm thicknesses, respectively. The experiment with 15 MeV [5] electrons was evaluated in terms of bremsstrahlung spectrum to compare the GEANT4 model predictions with the results of EGS4 simulation (Al 36.1 mm thick at  $10^\circ$ ).

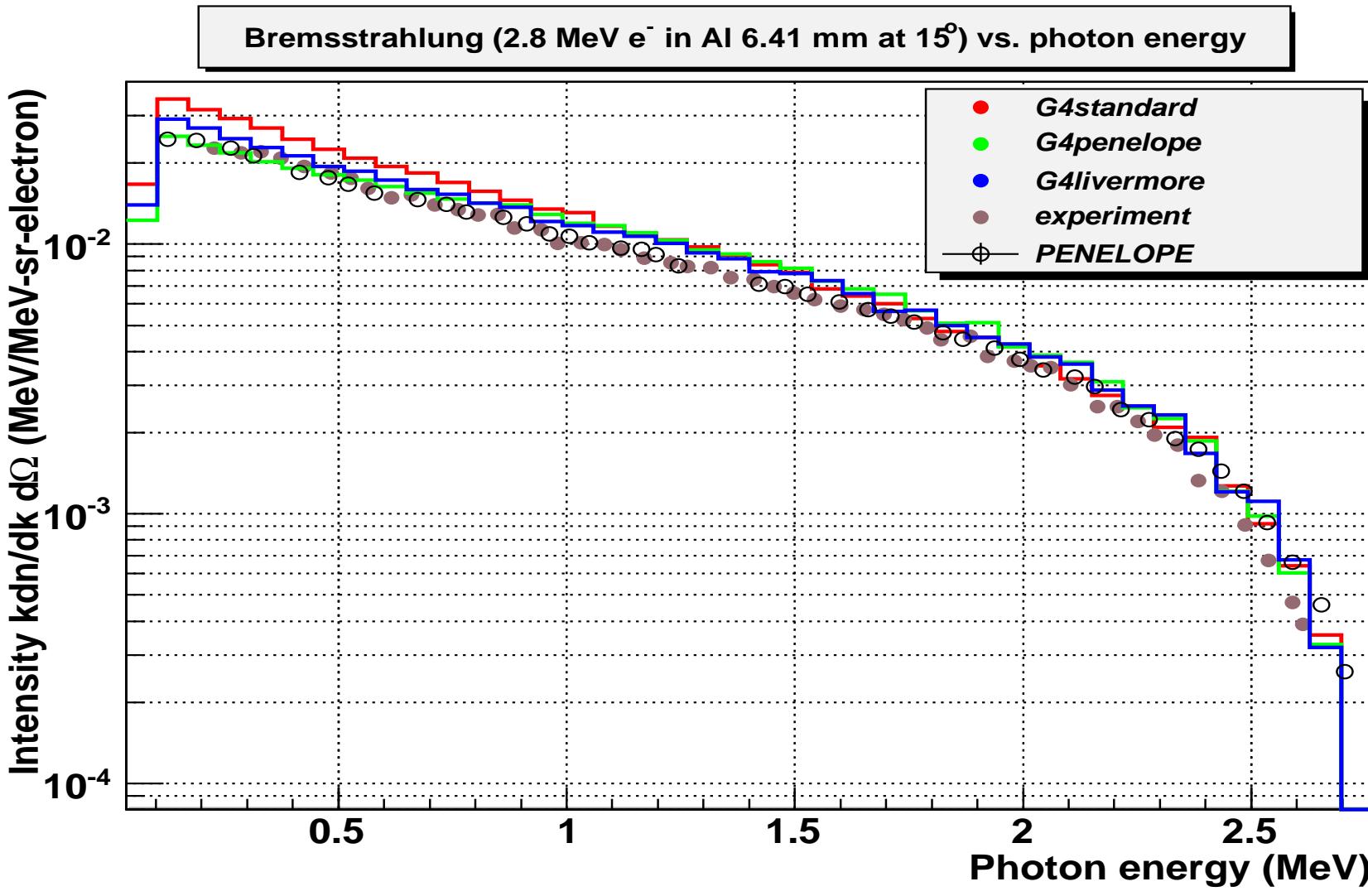
The simulation of bremsstrahlung requires high statistics to get smooth curves corresponding to the experimental measurements. A modern remote cluster of parallel processors was used in the batch mode to perform the simulation of the experimental set-ups.



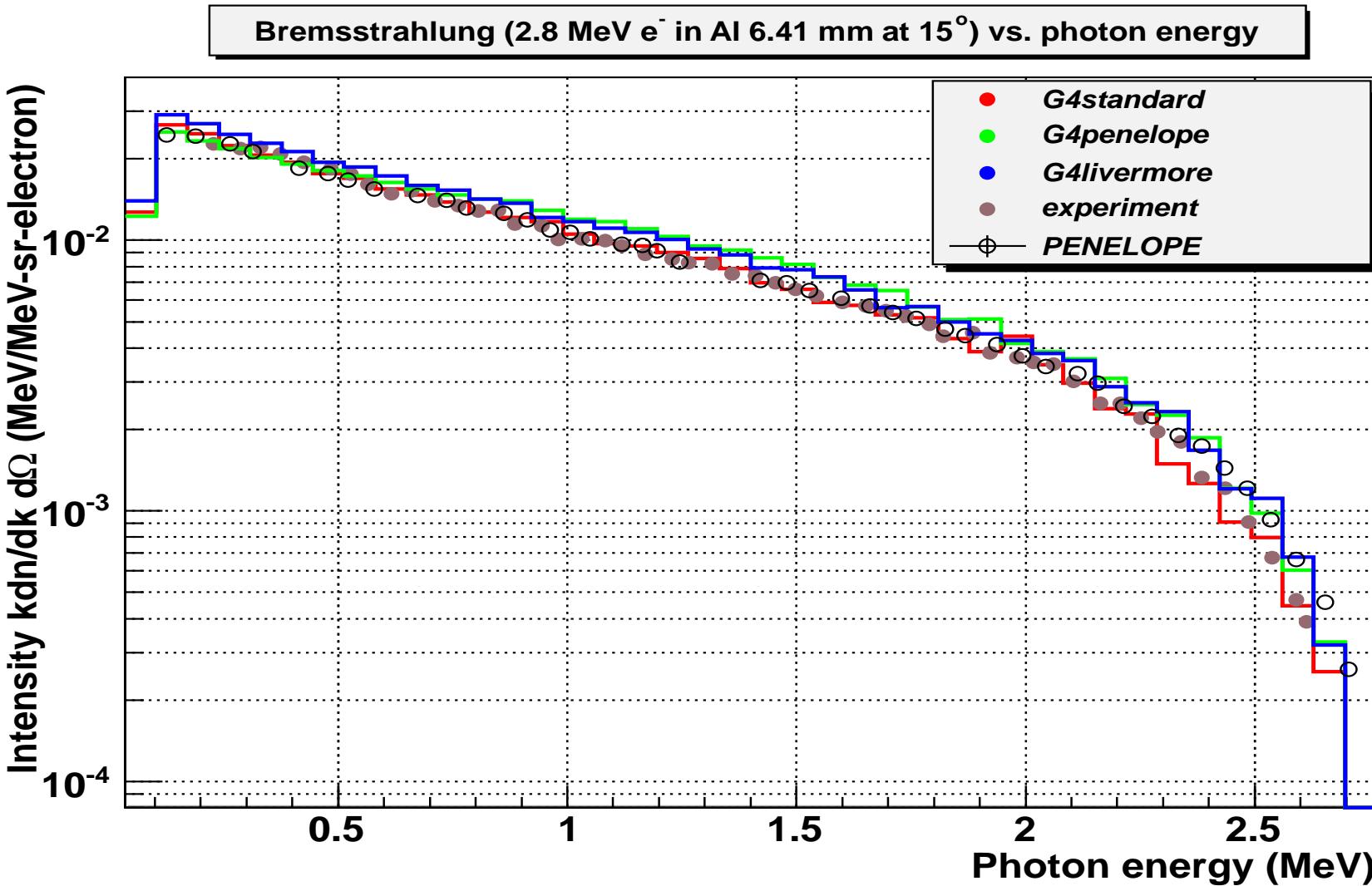
Statistics is  $1 \cdot 10^8$ . The G4eBremsstrahlungModel overestimates the spectrum at low energies and underestimates at high energies.



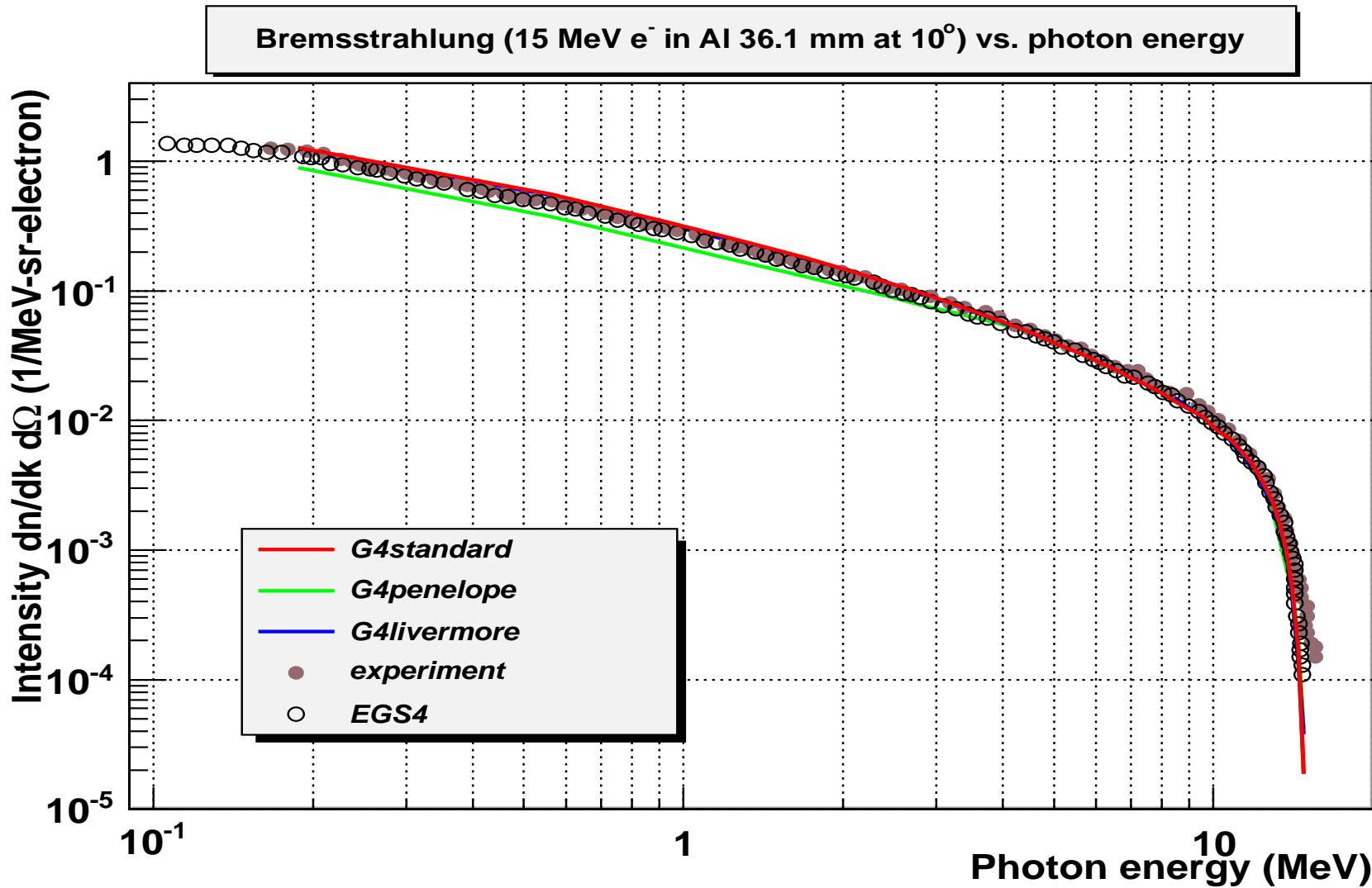
Statistics is  $1 \cdot 10^8$ . The G4SeltzerBergerModel is in good agreement with data.



Statistics is  $1 \cdot 10^8$ .



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Statistics is  $5 \cdot 10^7$ .

## 4 Conclusions

1. The GEANT4 G4PenelopeBremsstrahlungModel, G4LivermoreBremsstrahlungModel and new G4SeltzerBergerModel models are in satisfactory agreement with experimental data and the prediction of PENELOPE and EGS4 packages.
2. The GEANT4 old G4eBremsstrahlungModel model overestimates the bremsstrahlung spectrum at fixed angle for low photon energies with more deep decreasing for high energies. This disagreement with data is more visible for 1 MeV electrons which is close to the border of the model cross section database. The model works much better for the electron energies more than 3 MeV.

## References

- [1] S.M. Seltzer and M.J. Berger, Atomic data and nuclear data tables, 35 (1986) 345.
- [2] W.E. Dance et al., J. of Appl. Phys., 39 (1968) 2881-2889.
- [3] D.H. Rester et al., J. of Appl. Phys., 41 (1970) 2682-2692.
- [4] F. Salvat, J.F Fernandez-Varea, J. Sempau, X. Llovet, Rad. Phys. and Chem., 75 (2006) 1201-1219.
- [5] B.A. Faddegon, C.K. Ross and D.W.O. Rogers, Med. Phys., 18 (1991) 727-739.