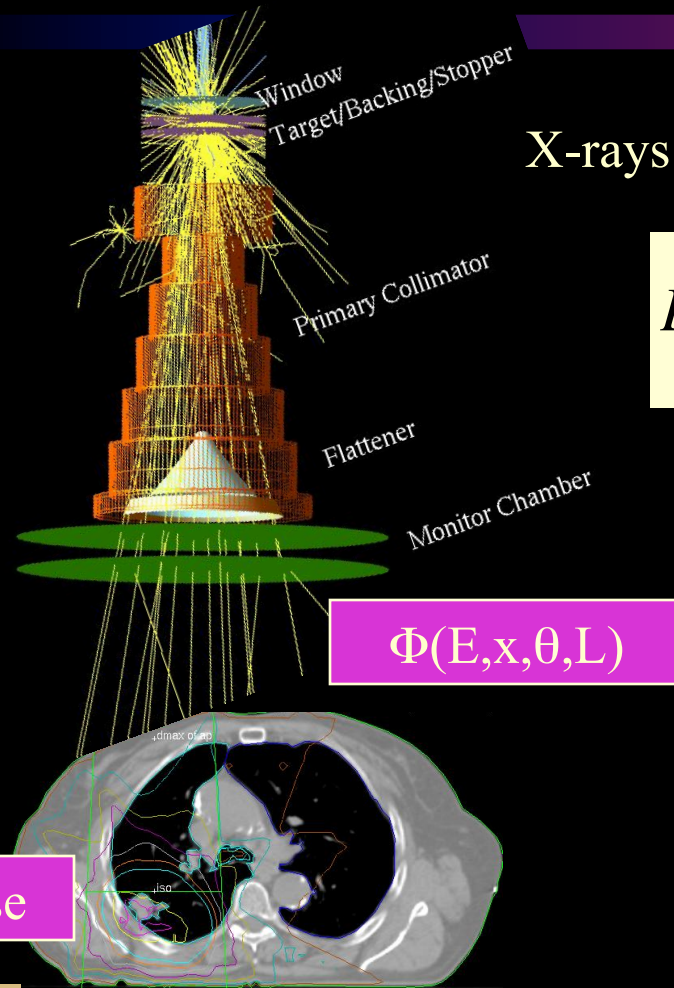# *Bremsstrahlung from thick targets at radiotherapy energies*

Bruce Faddegon and José Ramos-Méndez

University of California San Francisco

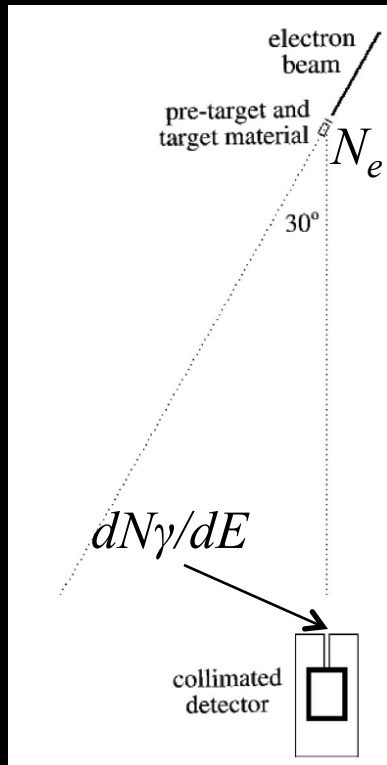# *X-ray benchmark*

Window

Target/Backing/Stopper

X-rays

Primary Collimator

Flattener

Monitor Chamber

$\Phi(E,x,\theta,L)$

Dose

$$D(\theta) \propto K_{coll}(\theta) = \int \Psi(\theta, E) \frac{\mu_{en}(E)}{\rho} dE$$

Benchmark x-ray fluence distributions $\Phi(\theta, E)$ from targets used in radiotherapy

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Thick-target bremsstrahlung from 0-90° at 15 MV

Bremsstrahlung yield

$$\frac{dS}{dE} = \frac{1}{N_e} \frac{d^2 N_\gamma}{dE\, d\Omega}$$

- Photon fluence energy spectrum at 1 meter per incident electron
- Correct for pile-up, bkg, detector response, detector efficiency, and collimator effect

Integrated bremsstrahlung yield

$$S_{E_0} = \int_{E_0}^{E_{max}} \frac{dS}{dE}\, dE = \frac{1}{N_e} \frac{d(N_\gamma)_{E_0}}{d\Omega}$$

electron beam

pre-target and target material N_e

30°

$dN\gamma/dE$

collimated detector

Bruce Faddegon, Carl Ross and Dave W. O. Rogers, "Angular distribution of bremsstrahlung from 15-MeV electrons on thick targets of Be, Al and Pb

Thick-target bremsstrahlung on beam axis at 10, 15, 20, 25 and 30 MV

- Count photons with energy $E > E_o$
- Correct for pile-up, background, detector response, detector efficiency, and collimator effect

+ background
…. pile-up
---- efficiency and attenuation
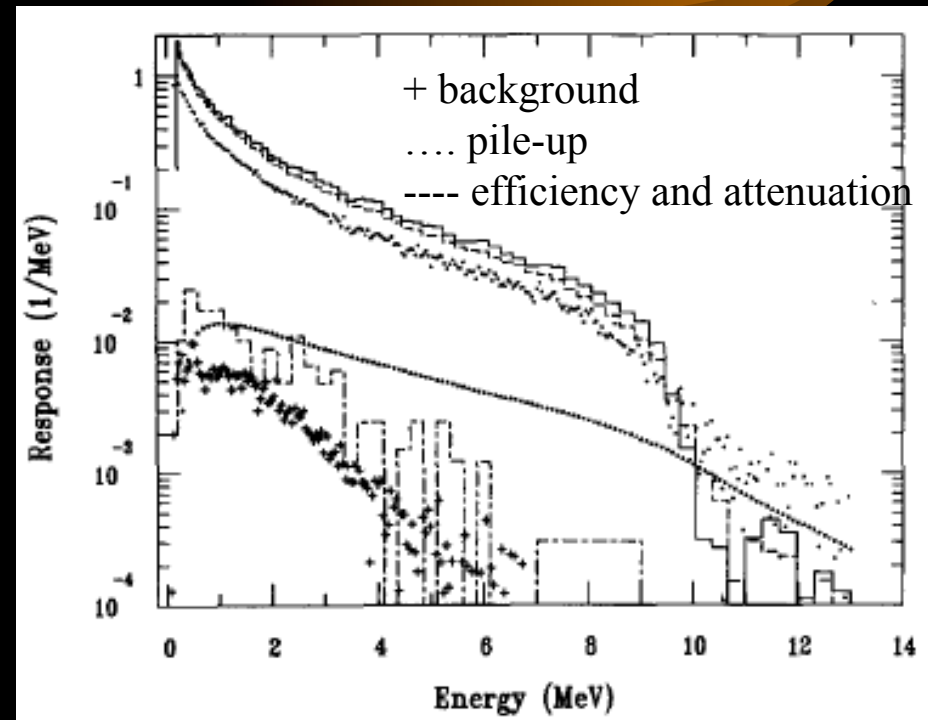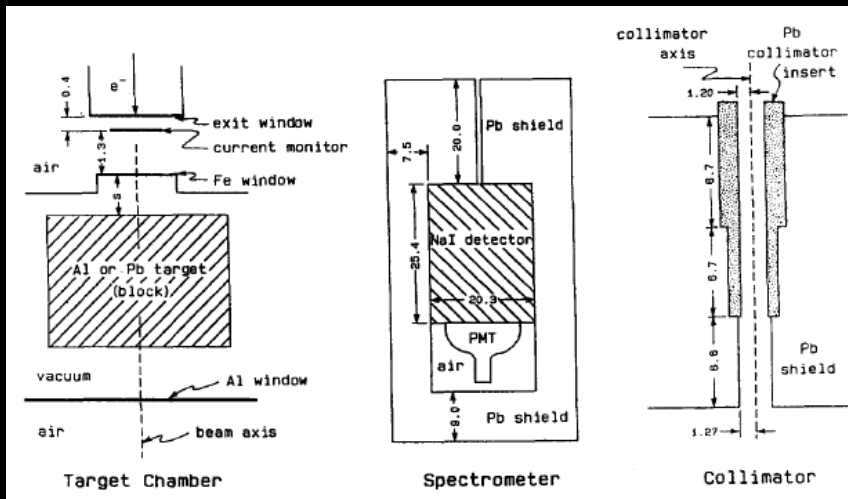
Bruce Faddegon, Carl Ross and Dave W. O. Rogers, "Forward-directed bremsstrahlung of 10- to 30-MeV ellectrons incident on thick target of Al and Pb", Med. Phys. 17:773, 1990

# *Published benchmark of Geant4: 2008*
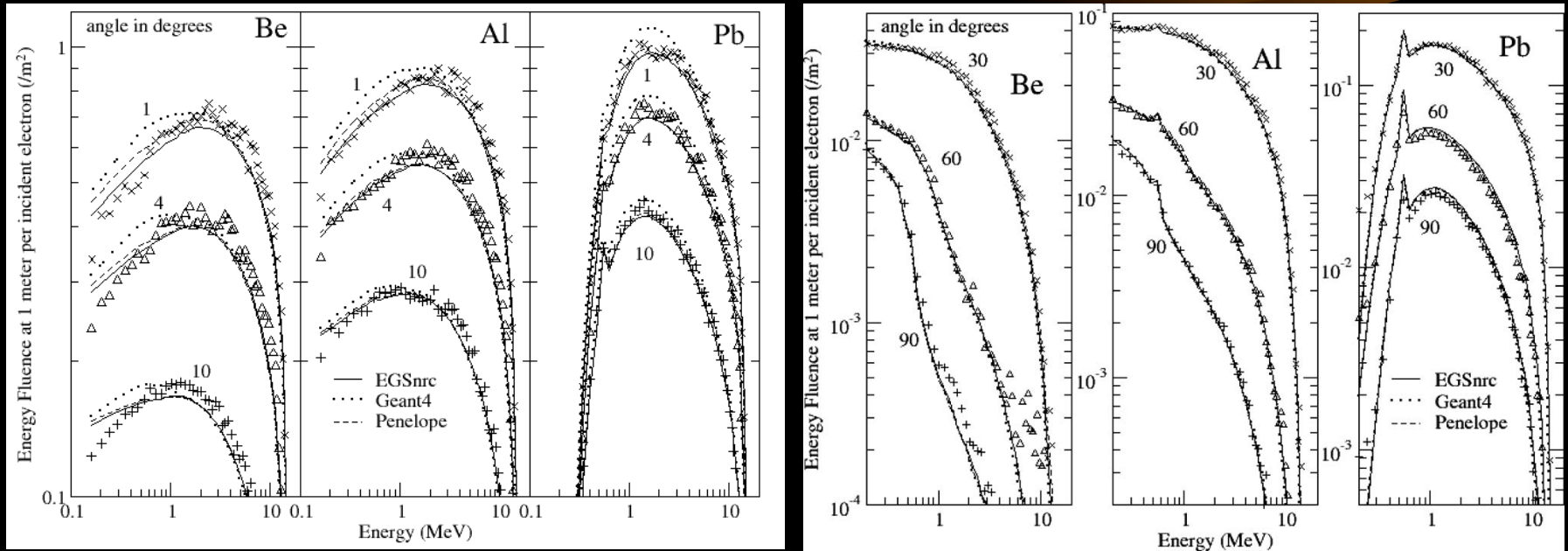
Bruce A Faddegon, Makoto Asai, Joseph Perl, Carl Ross, Josep Sempau, Jane Tinslay, and Francesc Salvat, "Benchmarking of Monte Carlo simulation of bremsstrahlung from thick targets at radiotherapy energies," Med. Phys. 35(10):4308-4317, 2008.

Published benchmark of Geant4: 2008

Points – mst
Lines – Geant4
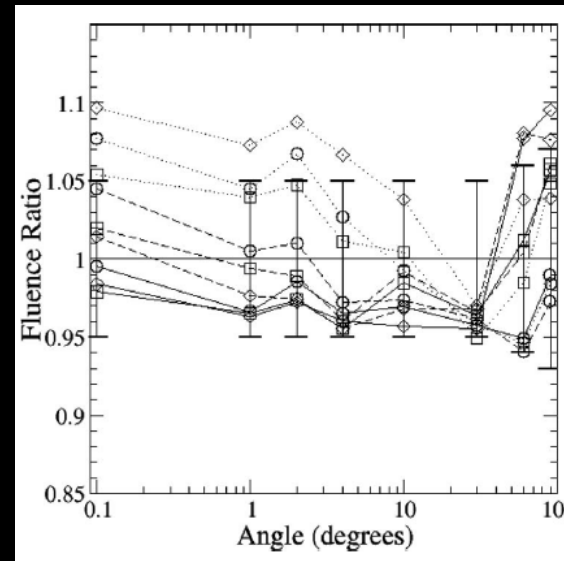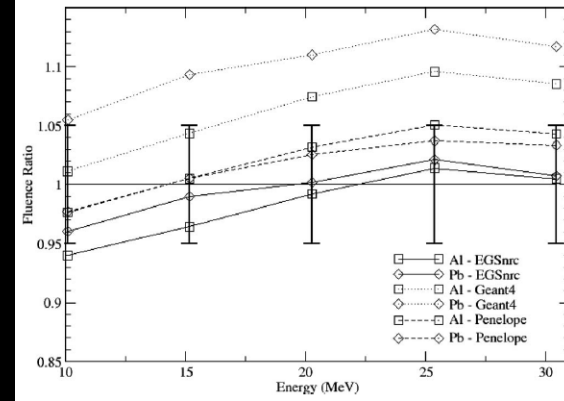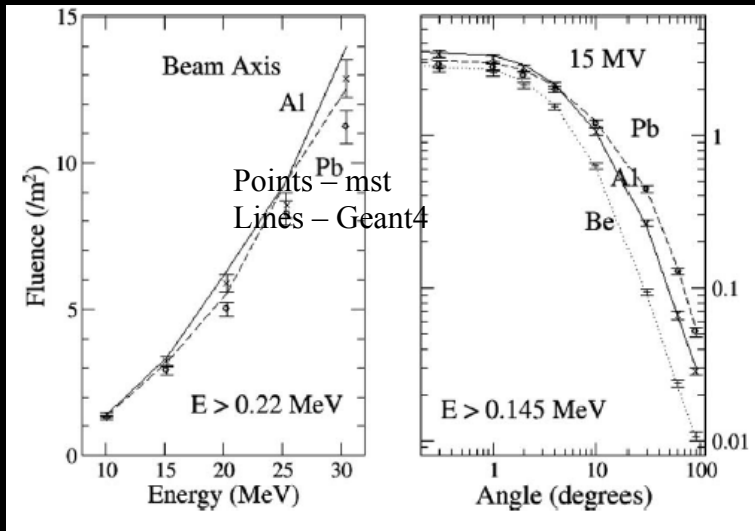
Off-axis ratio (OAR), measured within 3%, agrees with simulation with Geant4 within ~5% – not as good as EGSnrc or Penelope and not good enough!

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Preliminary results of 15 MV bremsstrahlung benchmark
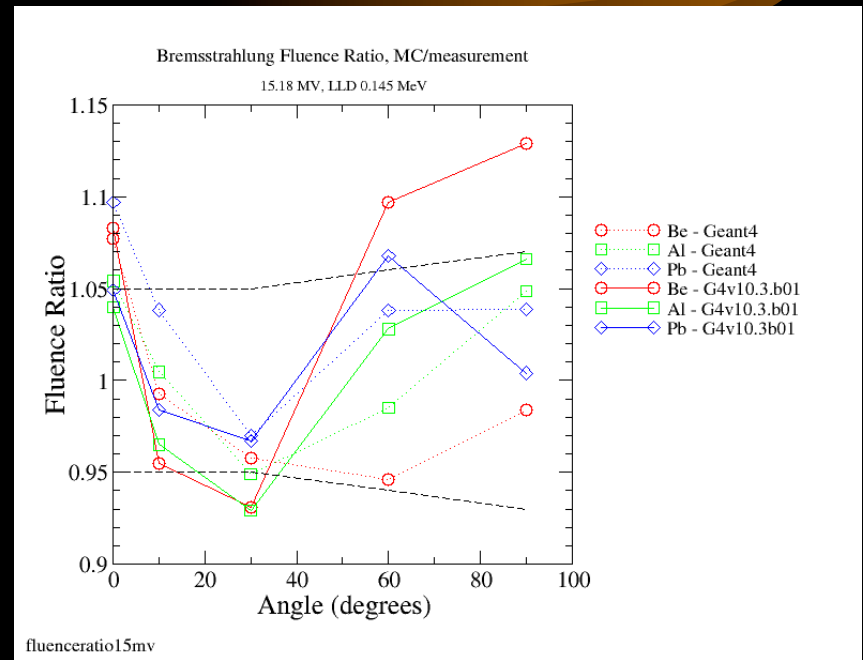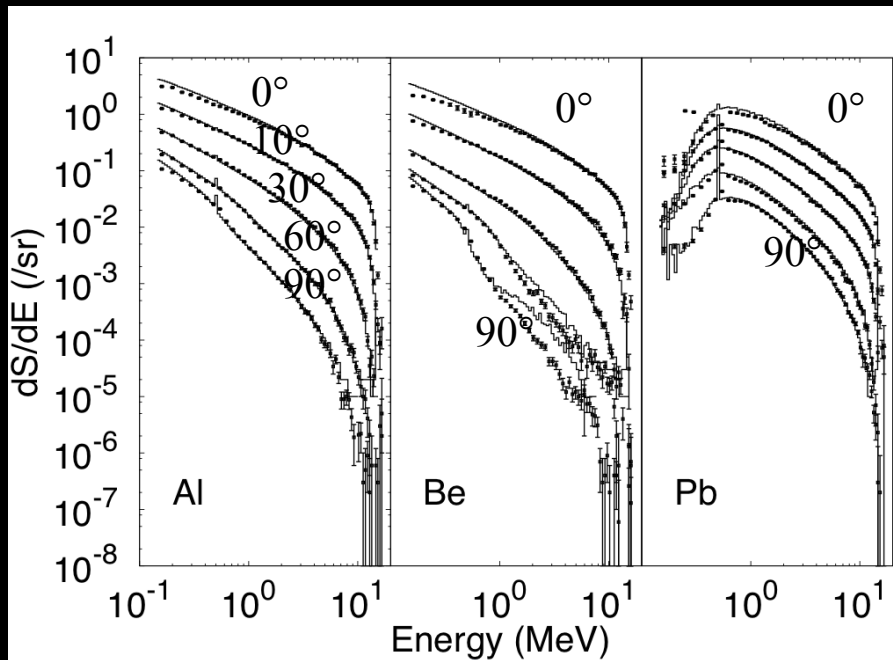
Geant4.10.3.b01: G4EmStandardPhysicsGS (with Goudsmit-Saunderson scattering model for electrons), global production cut for secondary particles of 0.01 mm, dRoverRange 0.05 mm, dFinalRange 0.05 mm.

Conclusions

- Choice of benchmarks from measured sets: 15 MV spectra (fluence per electron) from thick Be, Al and Pb targets at 1, 4, 10, 30, 60 and 90 degrees

- Regression testing tolerance: Verify calculation with new versions of Geant4 has same or higher accuracy (matches measurement better) within 2 standard deviations calculation precision

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