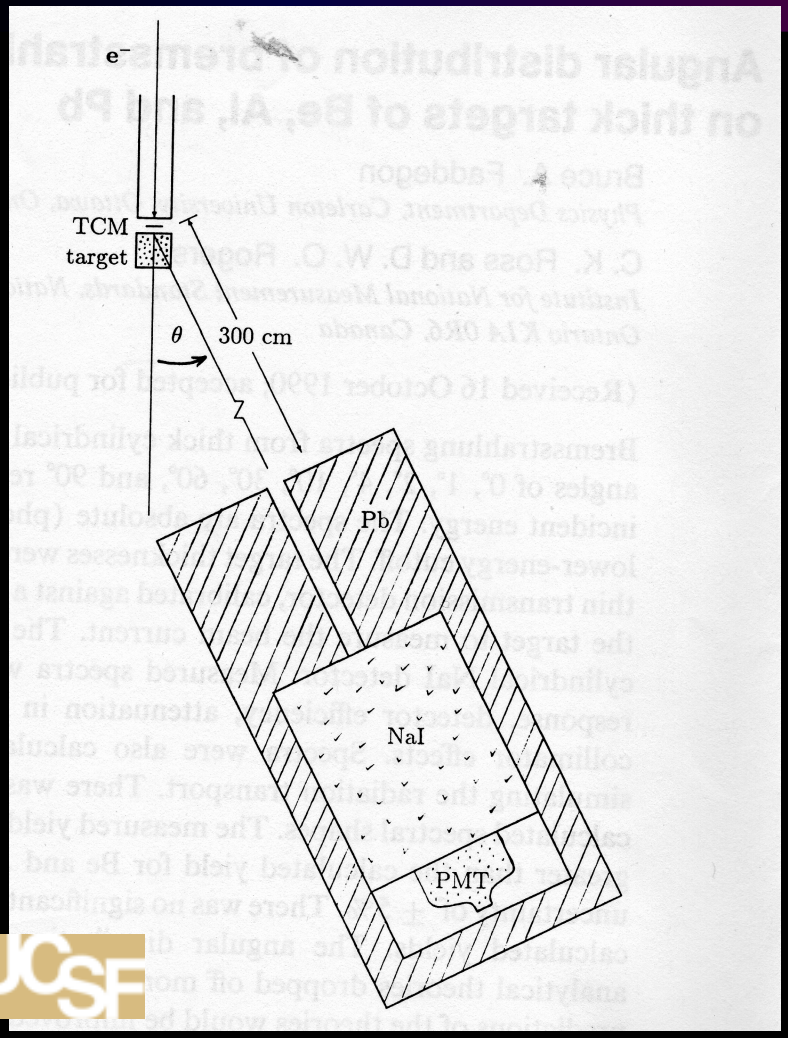
An accurate experimental benchmark of bremsstrahlung for radiotherapy quality beams

Bruce Faddegon, UCSF
Joseph Perl, SLAC
Tsukasa Aso, SLAC
Makoto Asai, SLAC

Outline

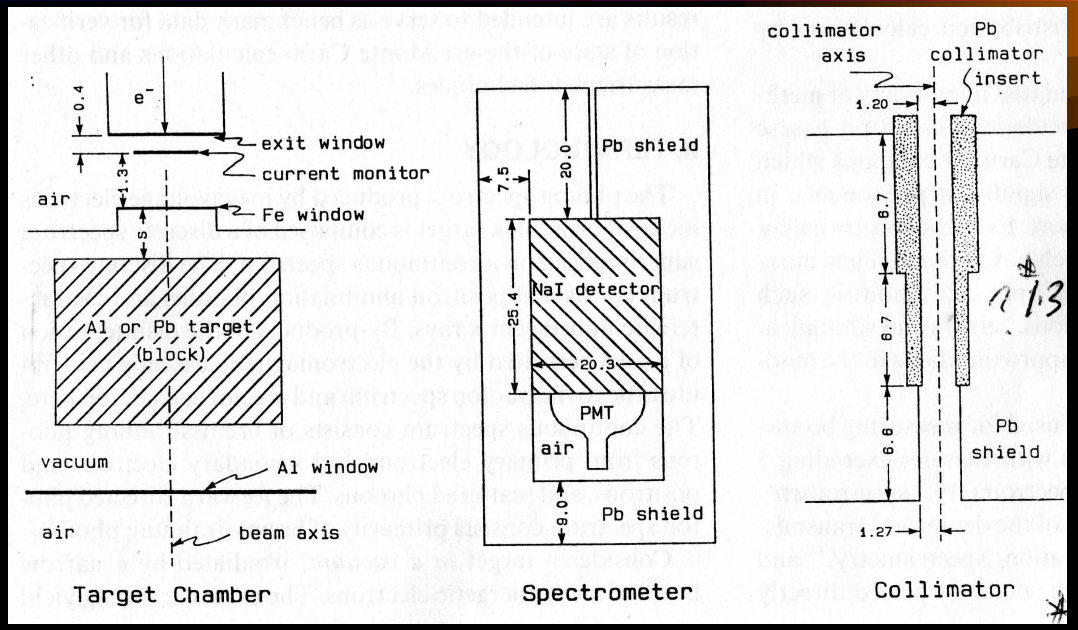
- Experiment
- Monte Carlo geometry
- Results
  - Accuracy
  - Timing
- Conclusions

Thick-target bremsstrahlung measurement at 10-30 MV



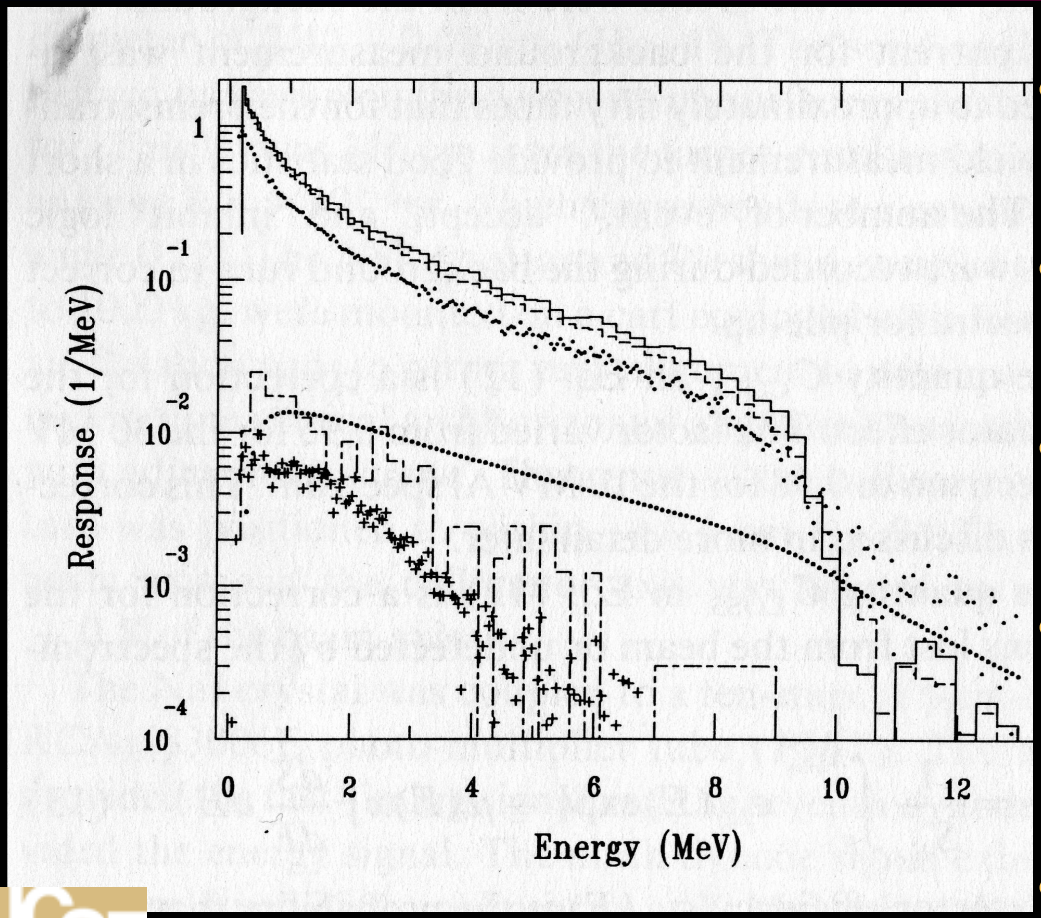
- Bremsstrahlung yield: photons per unit solid angle per unit energy interval
- Targets: Be, Al, Pb, thickness is CSDA range
- Yield on beam axis, Al and Pb, 10, 15, 20, 25 and 30 MV
- Yield at 15 MV, Be, Al and Pb at 0, 1, 2, 4, 10, 30, 60, 90°
- Back angle in progress

Target and detector geometry



- 0.3 cm radius electron beam normally incident on 0.013 cm Ti, 0.01 cm Si TCM, 0.005 cm SS window (≤ 10 °), target BCM
- 8x10” NaI, 1” Pb collimator

Data processing



- Subtract pile-up spectrum and bkg
- Add counts lost to pulse pile-up
- Unfold detector response
- Add counts lost to attenuation and detector efficiency
- Collimator effect

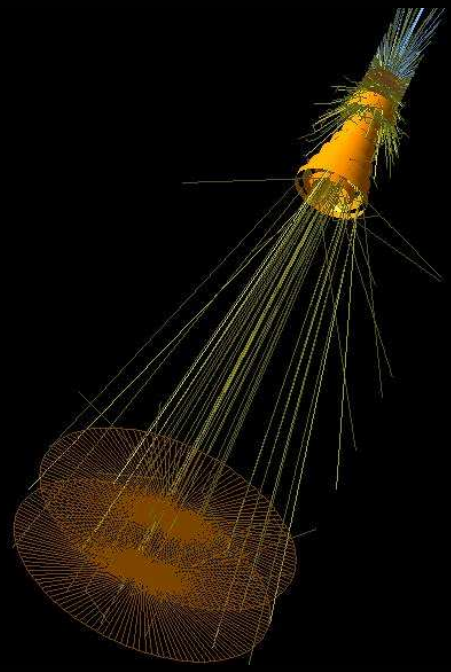
Thick-target bremsstrahlung benchmark measurements

- "Forward-directed bremsstrahlung of 10- to 30-MeV electrons incident on thick targets of Al and Pb", BA Faddegon, CK Ross, DWO Rogers, Medical Physics 17(5):773-785, 1990
- "Angular distribution of bremsstrahlung from 15-MeV electrons incident on thick targets of Be, Al and Pb," BA Faddegon, CK Ross, DWO Rogers, Medical Physics 18(4):727-739, 1991

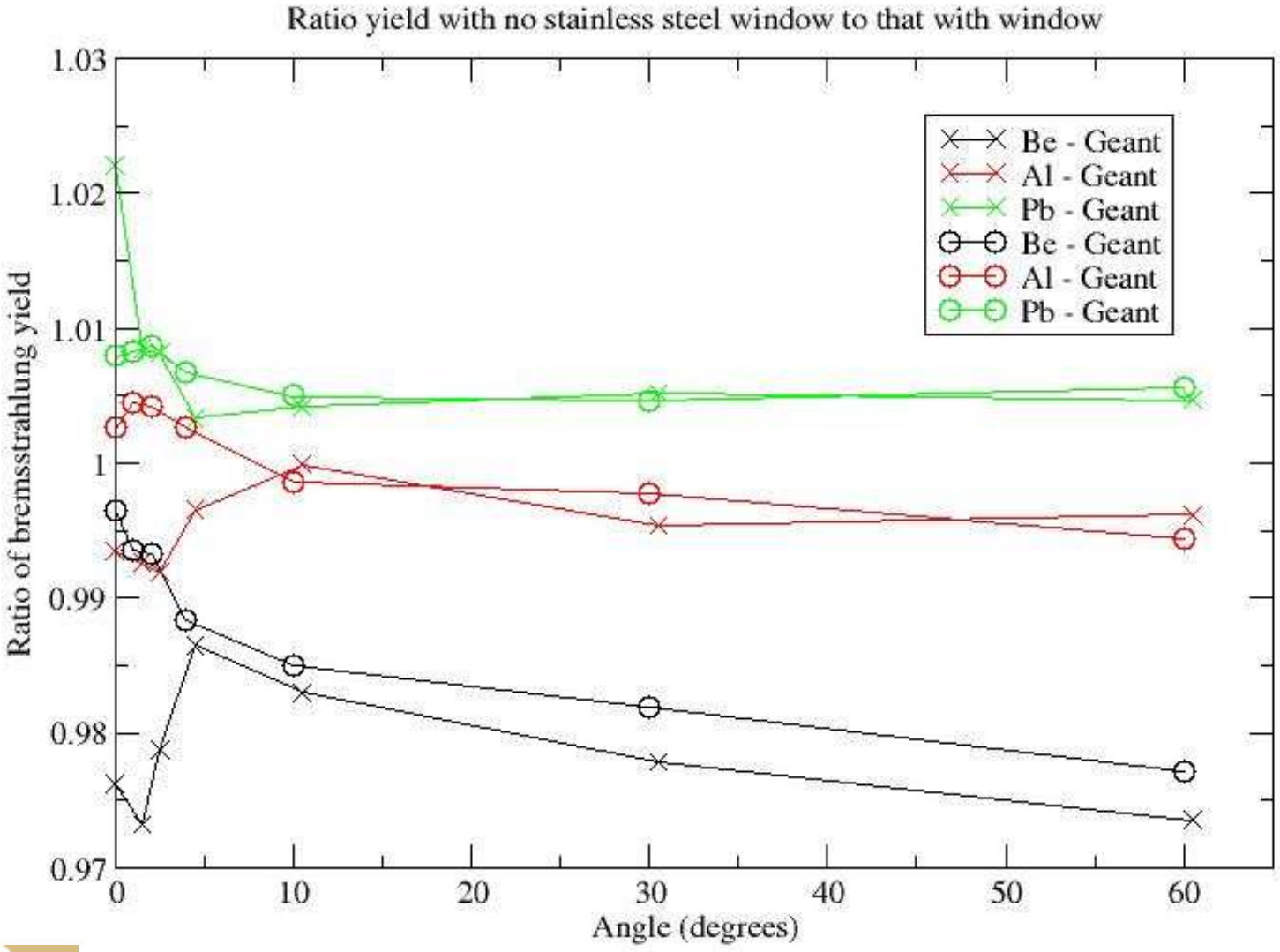
Monte Carlo simulation: 15 MeV electrons on Be/Al/Pb target

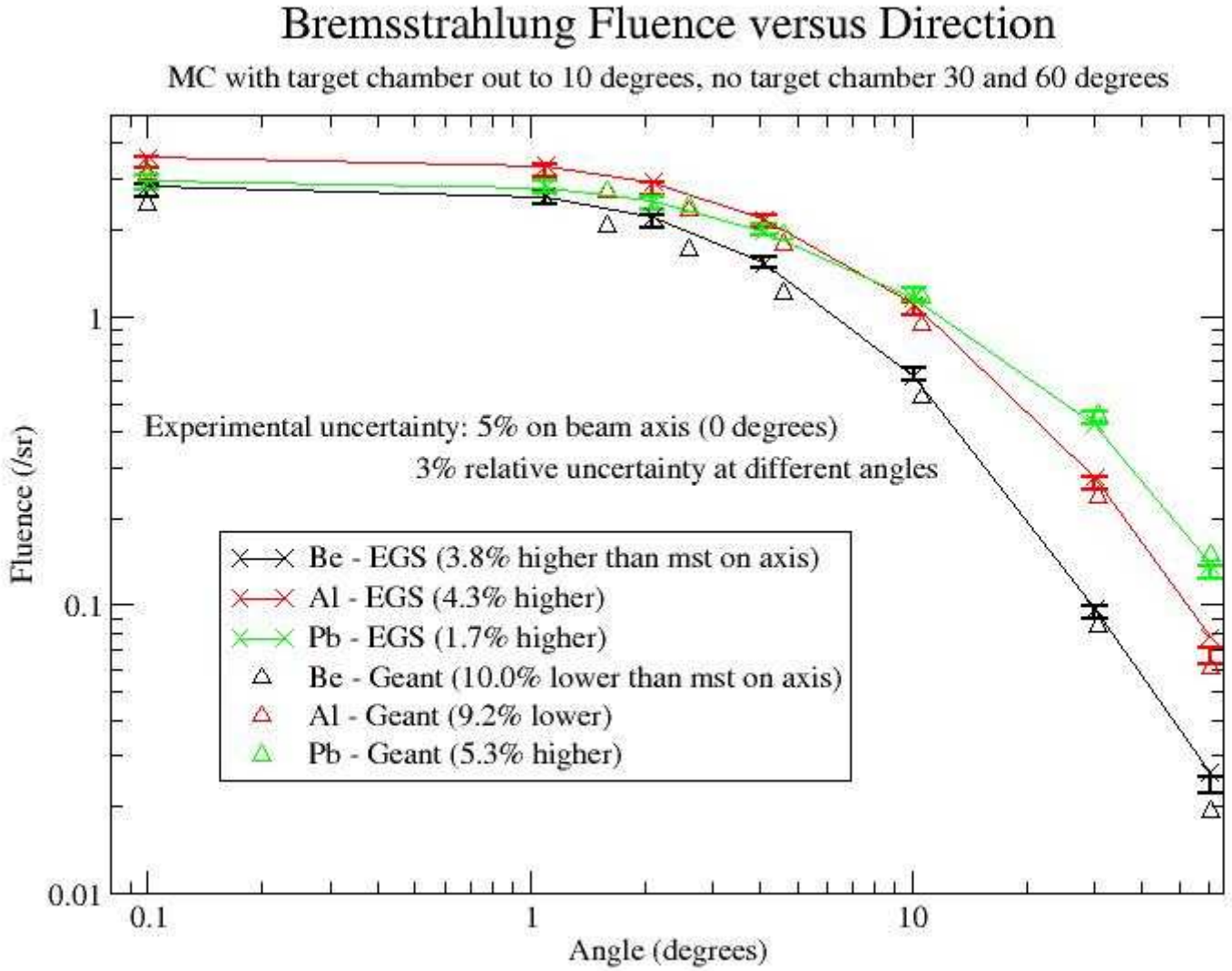
- Geant4
- New geometry: scoring sphere around beamline and target developed by M. Asai
- New scoring developed by T. Aso
- Installation and support by J. Perl

- EGSnrc with BEAM user code from NRCC
- Revised scoring



Effect of target chamber on 15 MV bremsstrahlung yield

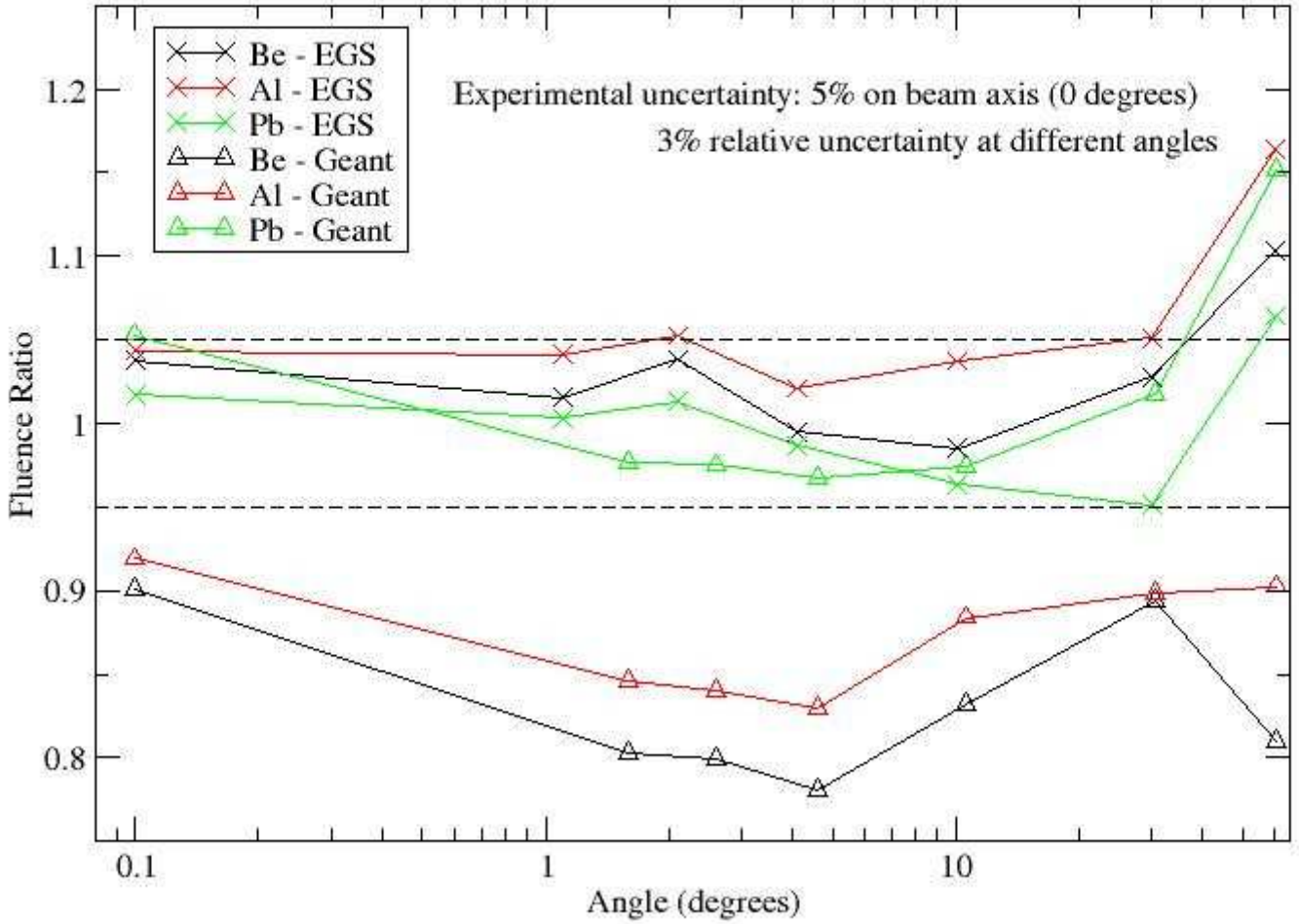



Bremsstrahlung Fluence versus Direction
MC with target chamber out to 10 degrees, no target chamber 30 and 60 degrees
Experimental uncertainty: 5% on beam axis (0 degrees)
3% relative uncertainty at different angles
Be - EGS (3.8% higher than mst on axis)
Al - EGS (4.3% higher)
Pb - EGS (1.7% higher)
Be - Geant (10.0% lower than mst on axis)
Al - Geant (9.2% lower)
Pb - Geant (5.3% higher)
Fluence (/sr)
1
0.1
0.01
0.1
1
10
Angle (degrees)

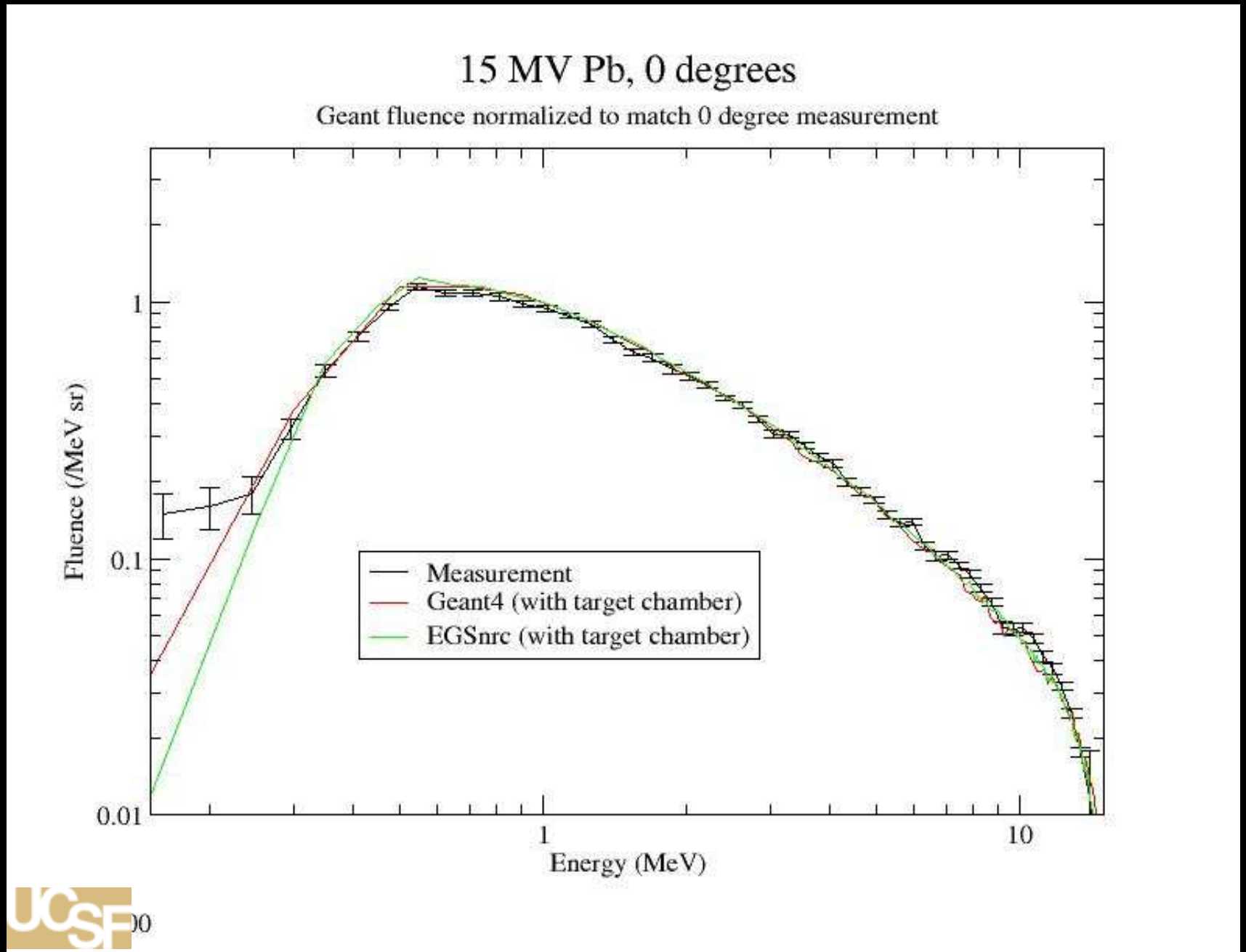
fluence

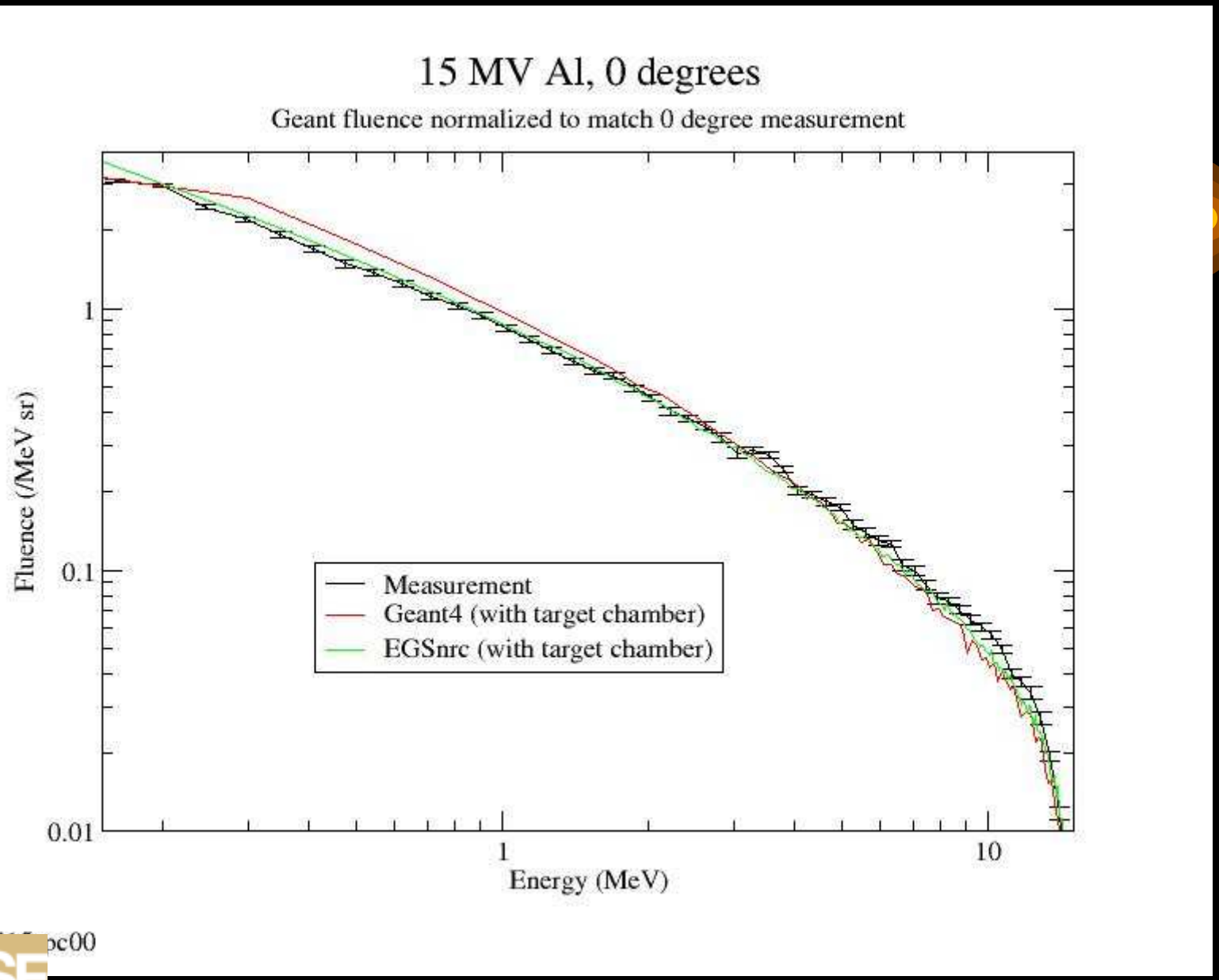
Bremsstrahlung Fluence Ratio, MC/measurement

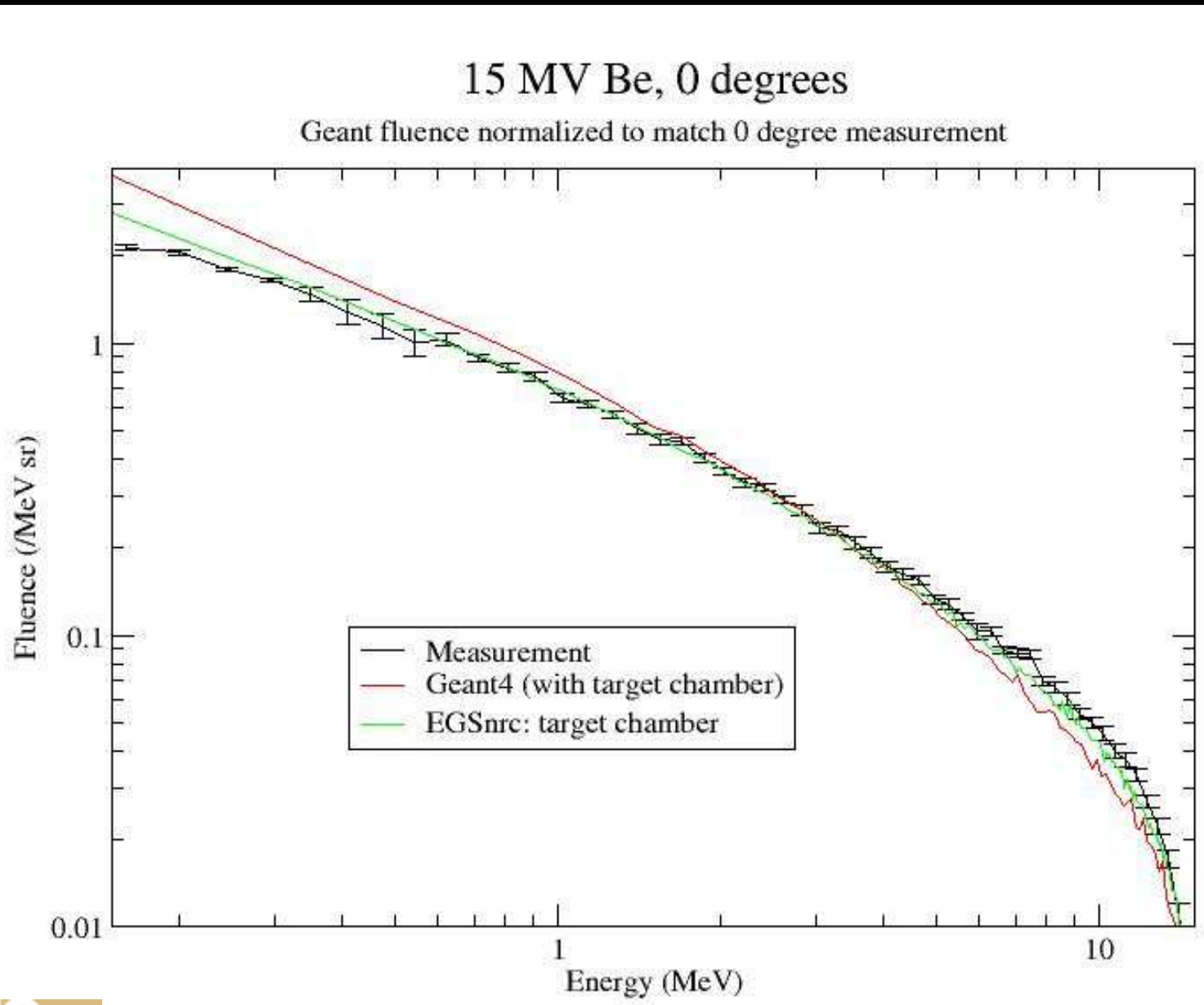
MC with target chamber out to 10 degrees, no target chamber 30 and 60 degrees



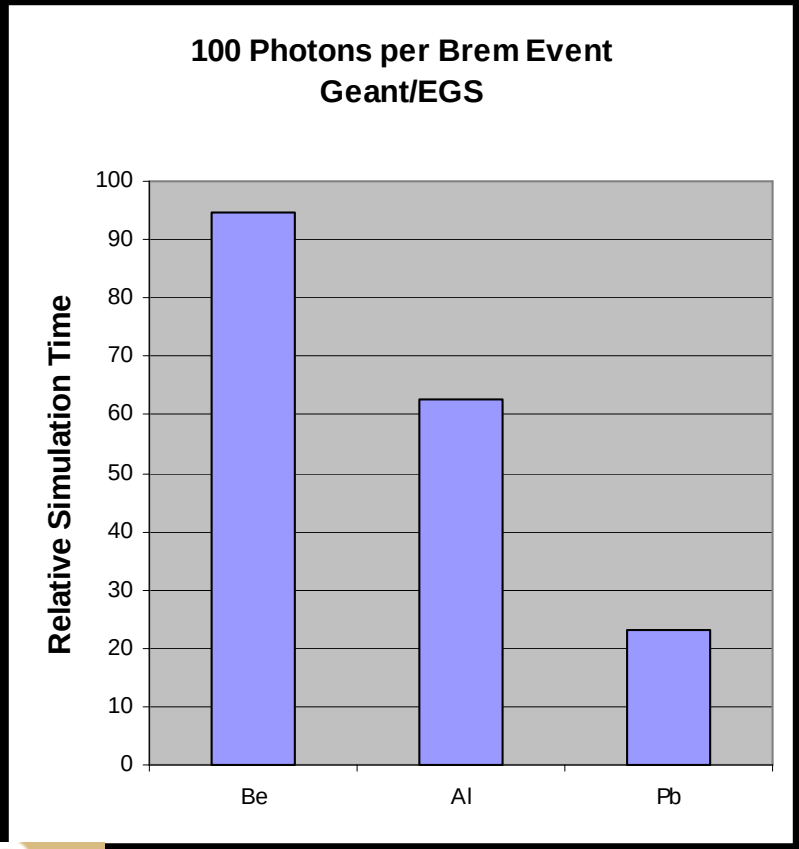
fluenceratio

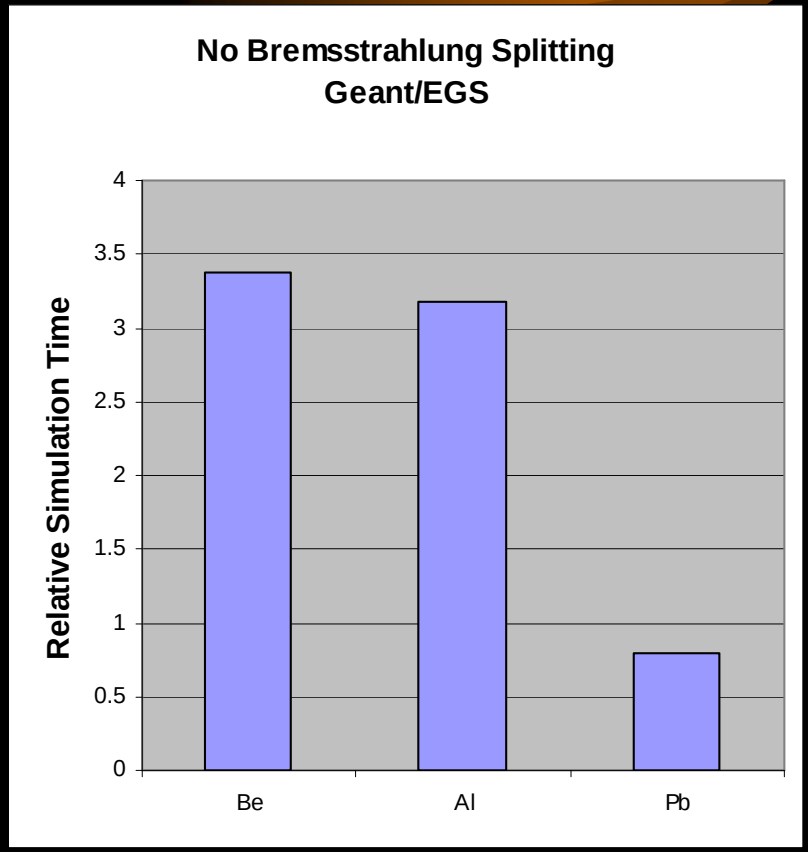

15 MV Pb, 0 degrees
Geant fluence normalized to match 0 degree measurement
Fluence (/MeV sr)
1
0.1
0.01
1
10
Energy (MeV)
Measurement
Geant4 (with target chamber)
EGSnrc (with target chamber)


15 MV Al, 0 degrees
Geant fluence normalized to match 0 degree measurement
Fluence (/MeV sr)
1
0.1
0.01
1
10
Energy (MeV)
Measurement
Geant4 (with target chamber)
EGSnrc (with target chamber)


15 MV Be, 0 degrees
Geant fluence normalized to match 0 degree measurement
Fluence (/MeV sr)
1
0.1
0.01
1
10
Energy (MeV)
Measurement
Geant4 (with target chamber)
EGSnrc: target chamber

Timing Comparison





Conclusions: 15 MV thick-target brem

- Need to improve bremsstrahlung cross-sections
  - Total yield for low-Z targets (10-20%)
  - Energy spectra for low-Z targets, eg, ratio fluence at 1 MeV to 10 MeV is 50% high for Be and Al
  - Angular distribution, eg, ratio fluence on beam axis to 1 degree off axis high by 7-10%, all targets
- Timing should be pretty good with bremsstrahlung splitting employed (under investigation)
  - Slow for low-Z targets by factor of 3