Directional bremsstrahlung splitting in Geant4

Geant4 Collaboration Meeting, Jefferson Lab

September 25, 2019

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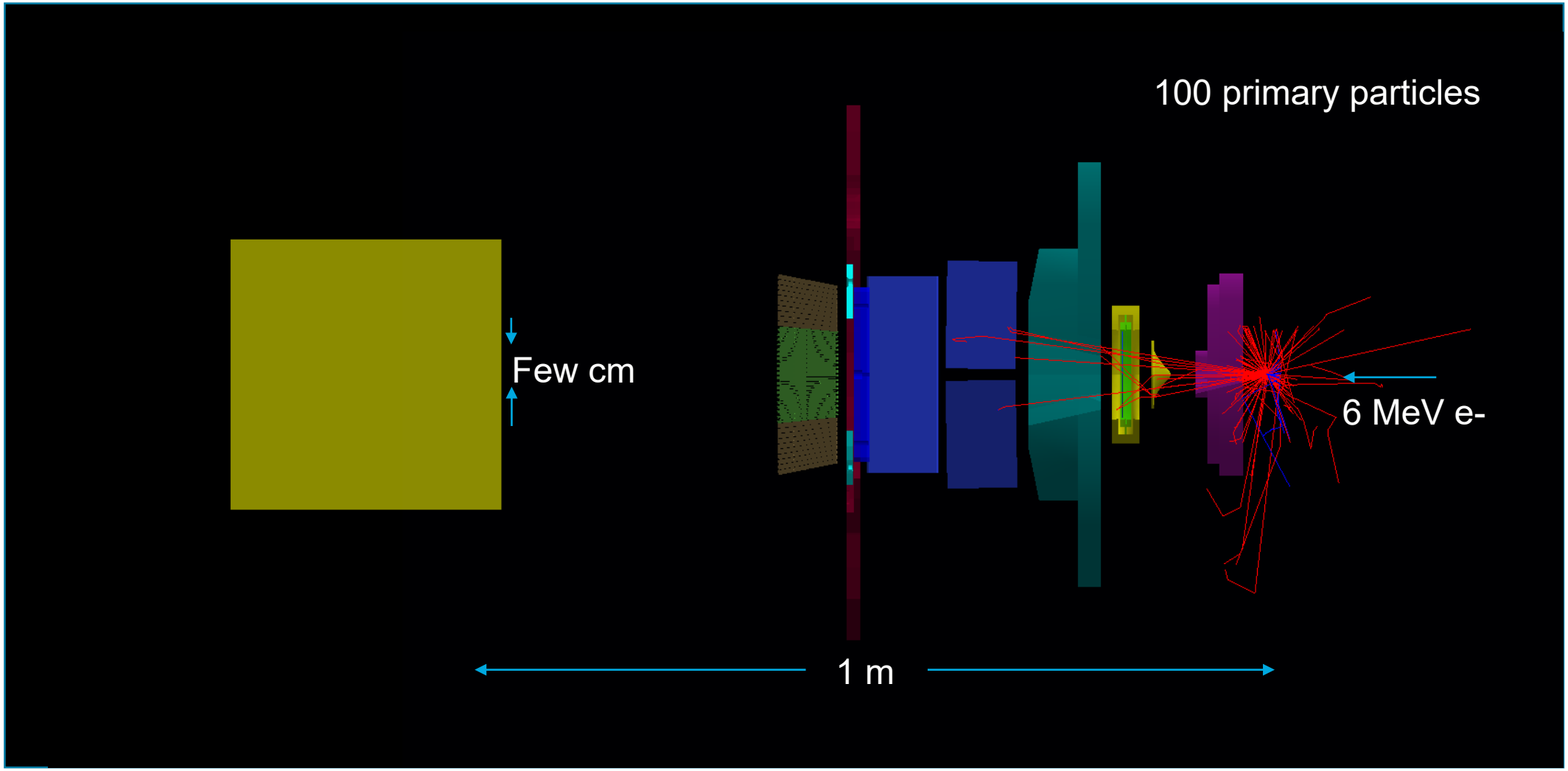
Varian Medical Systems

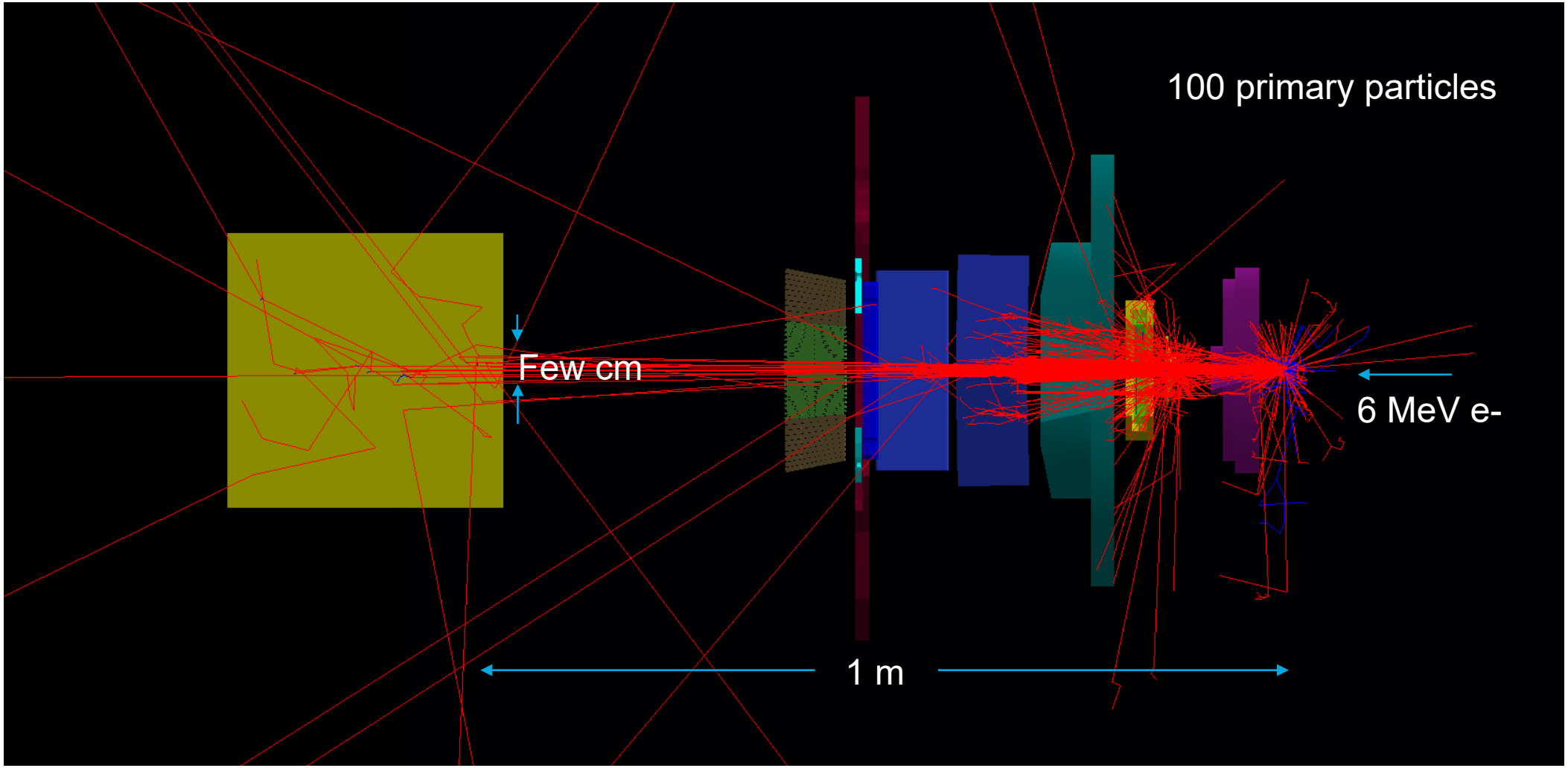
Motivation

- Radiotherapy: calculate dose to patient quickly

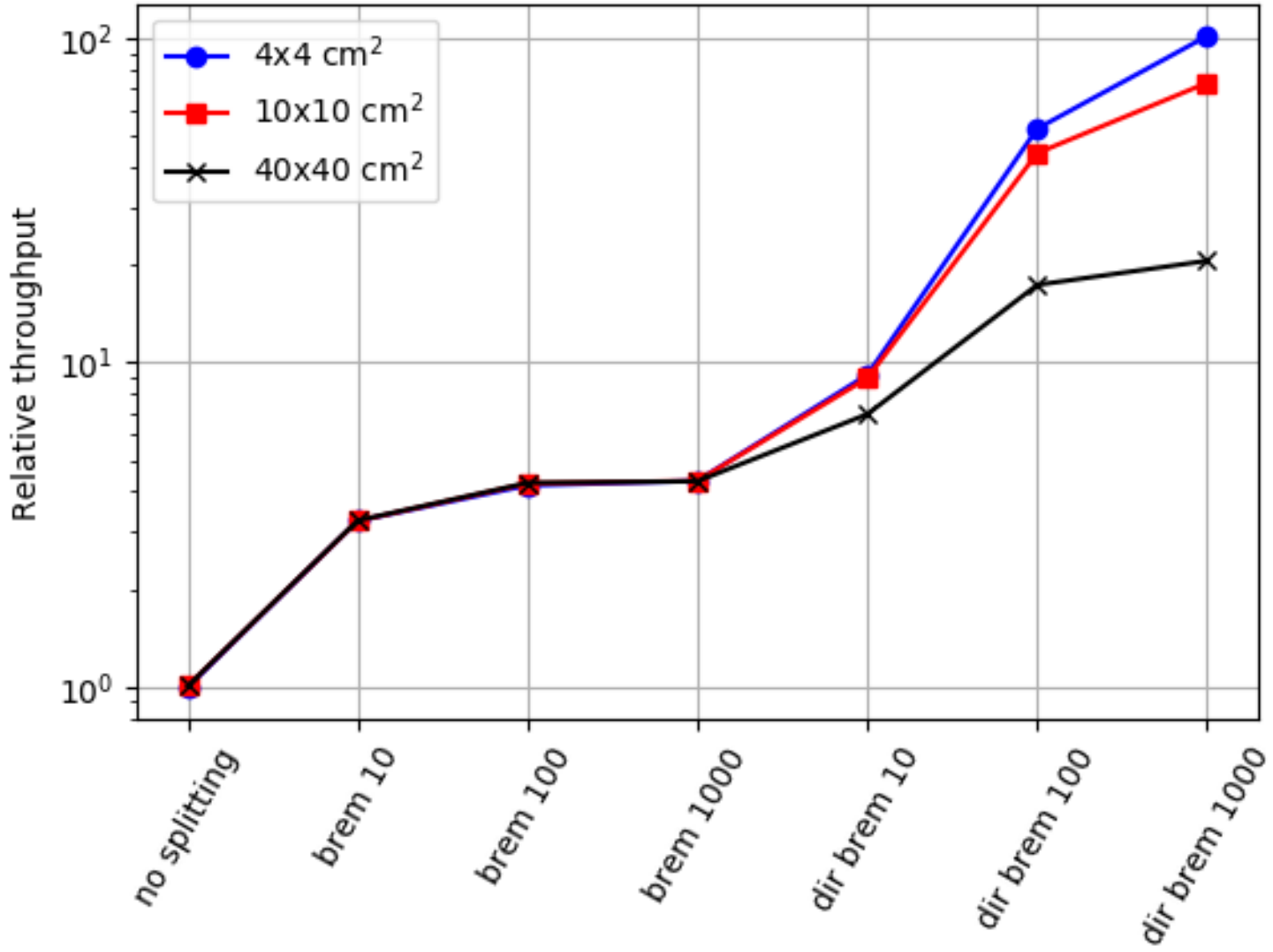
Simulation geometry



Simulation geometry (with directional splitting)



Throughput (full linac simulation)



Method

- For all interactions producing gammas:
- Split N times (new weight 1/N)
- Is the gamma going towards target volume?
  - If yes, keep
  - If no, play Russian Roulette (survival probability 1/N, weight 1)
- All gamma reaching the target volume have weight 1/N

- Compare bremsstrahlung splitting (not directional)

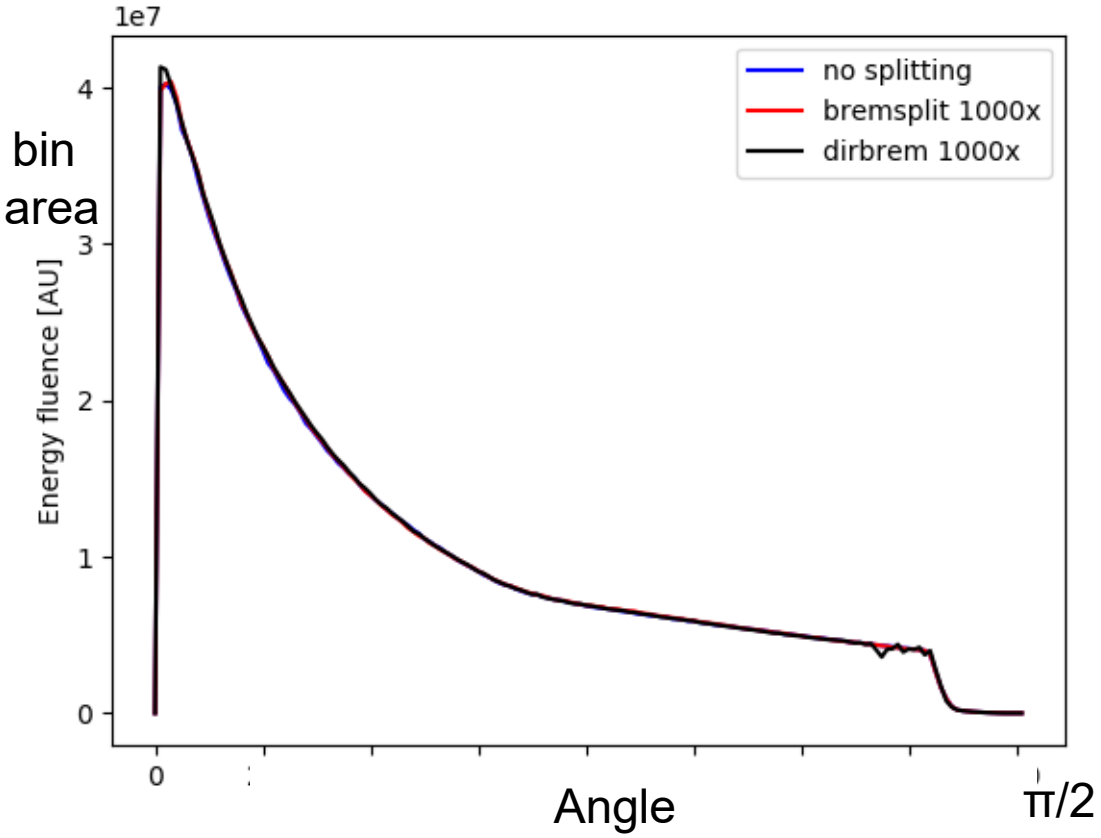
UI commands

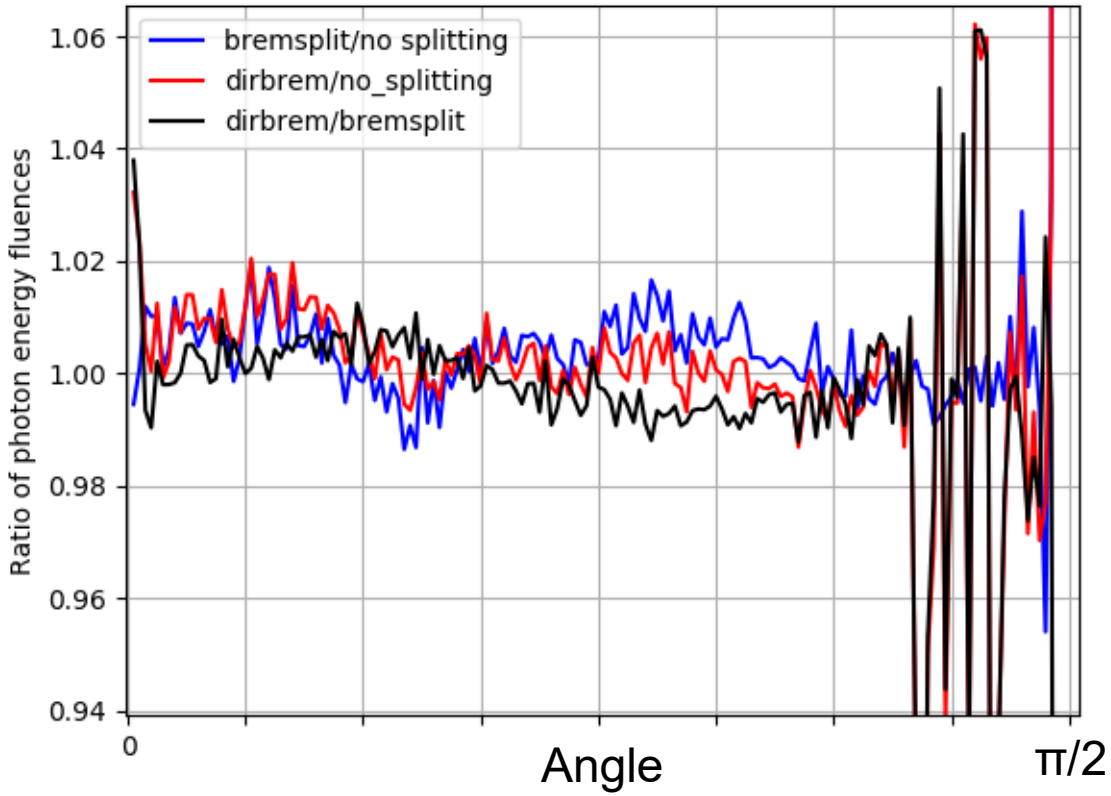
```
/process/em/setDirectionalSplitting true
/process/em/setDirectionalSplittingTarget 0 0 0 mm  # x, y, z components of center
/process/em/setDirectionalSplittingRadius 5 cm
/process/em/setSecBiasing eBrem   world 1000 100 MeV  # region, splitting factor, max energy
/process/em/setSecBiasing Rayl    world 1000 100 MeV
/process/em/setSecBiasing phot    world 1000 100 MeV
/process/em/setSecBiasing compt   world 1000 100 MeV
/process/em/setSecBiasing annihil world 1000 100 MeV
```

Accuracy tests: modified TestEm5

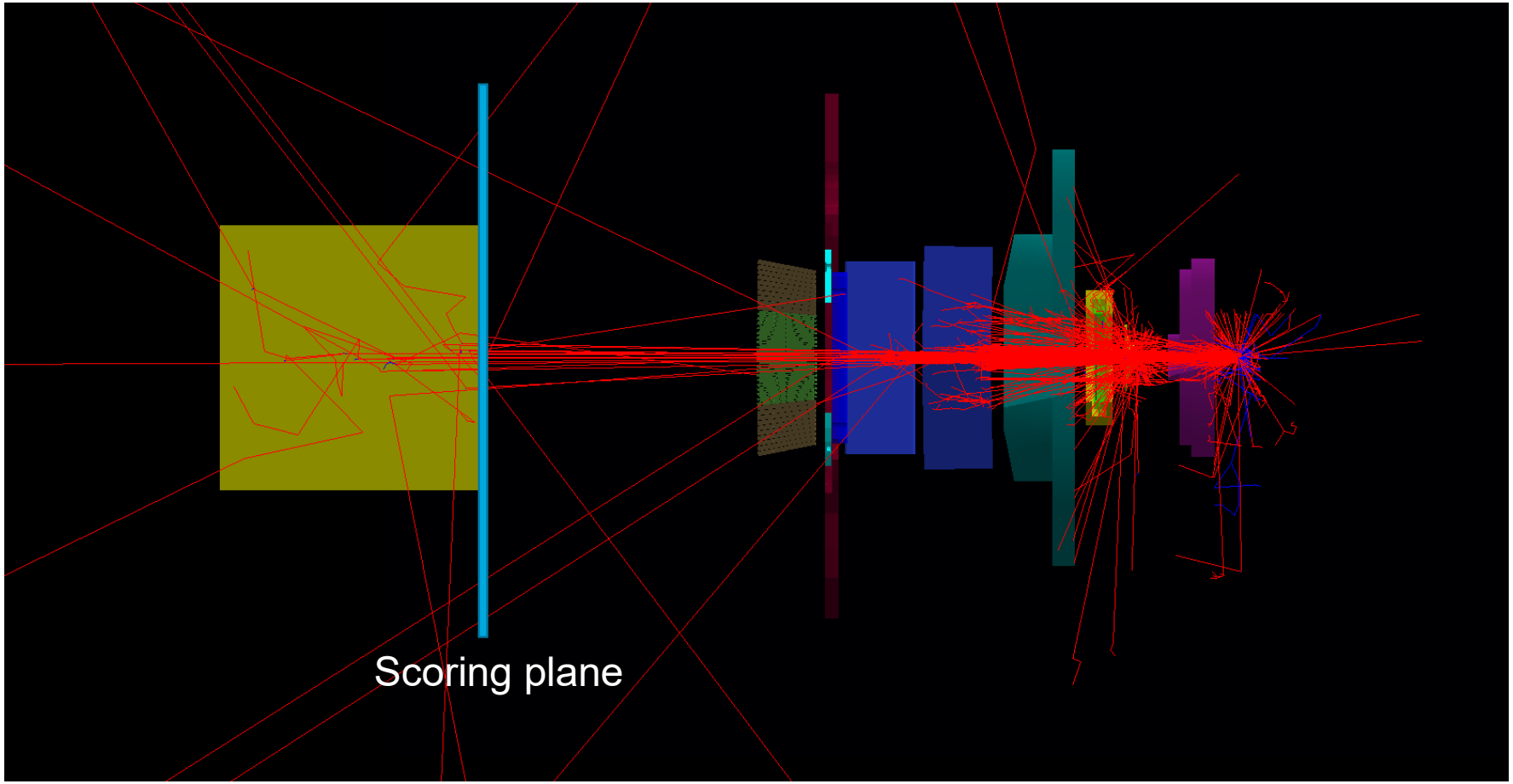
Need to take weight into account

Per bin not area



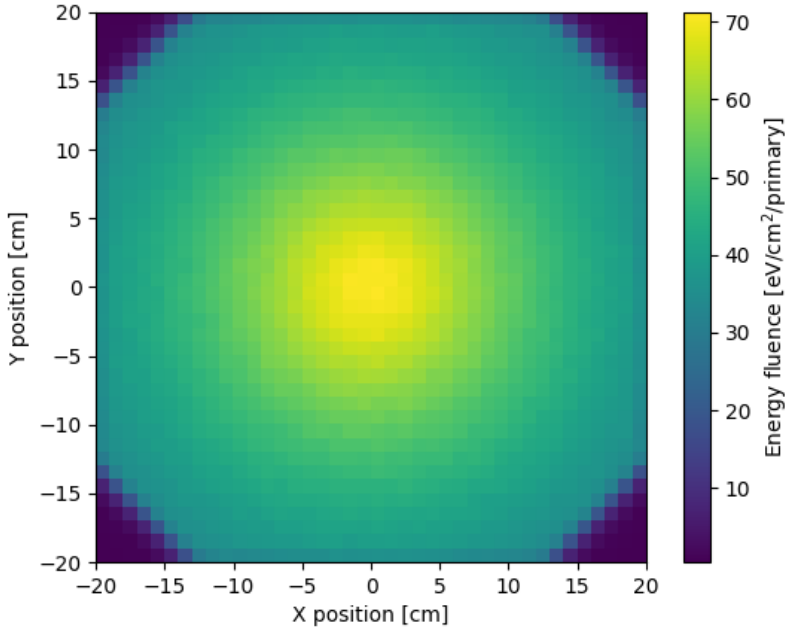


Accuracy: realistic geometry

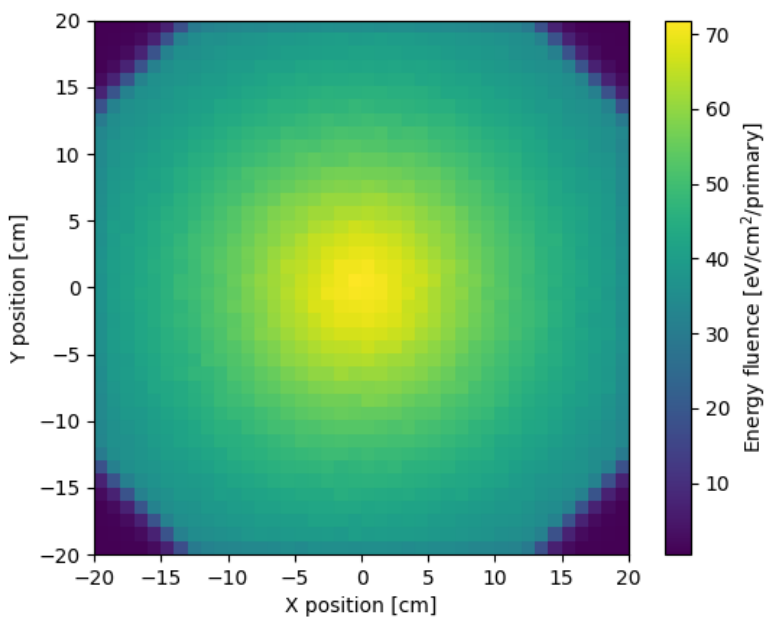


Accuracy: realistic geometry
Energy fluence at patient plane

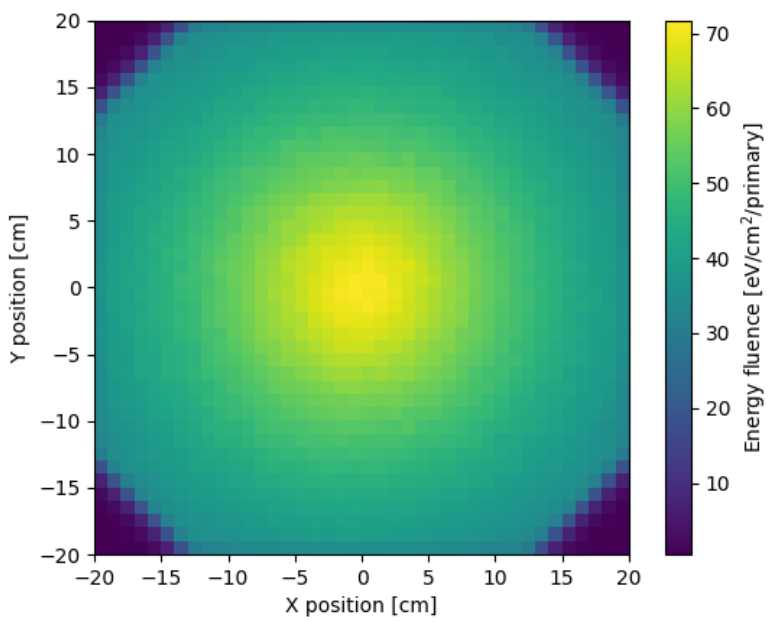
10^9 primary particles (no splitting)



No splitting

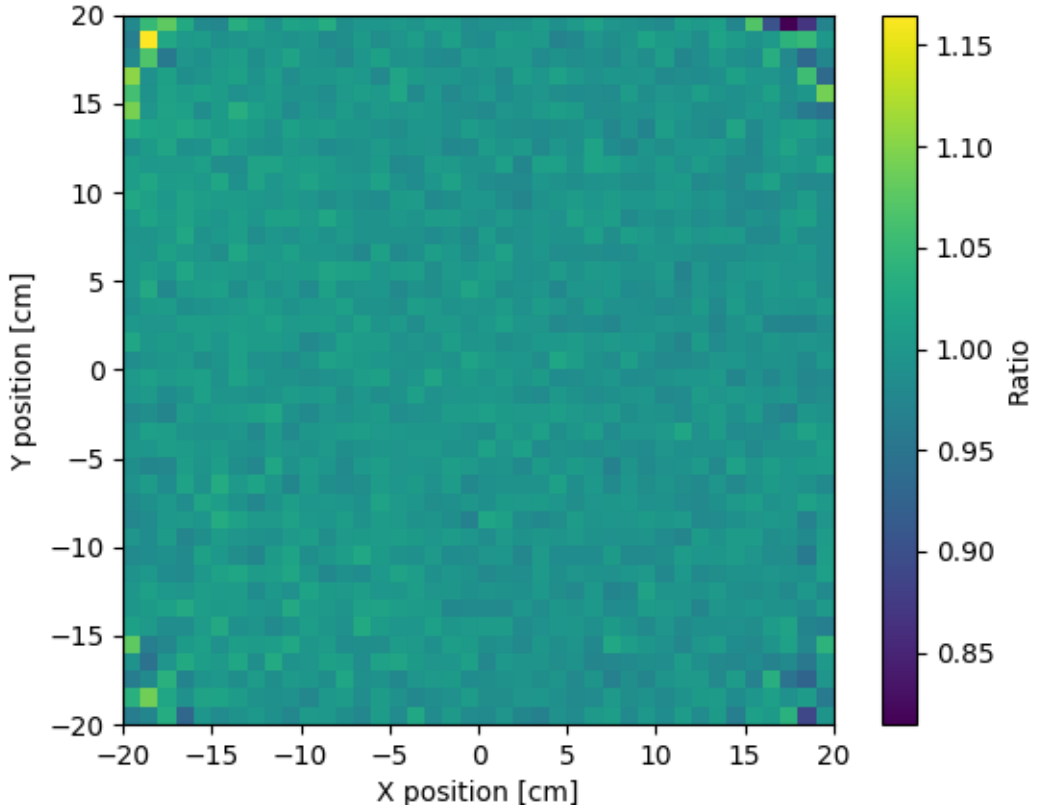


Brem splitting

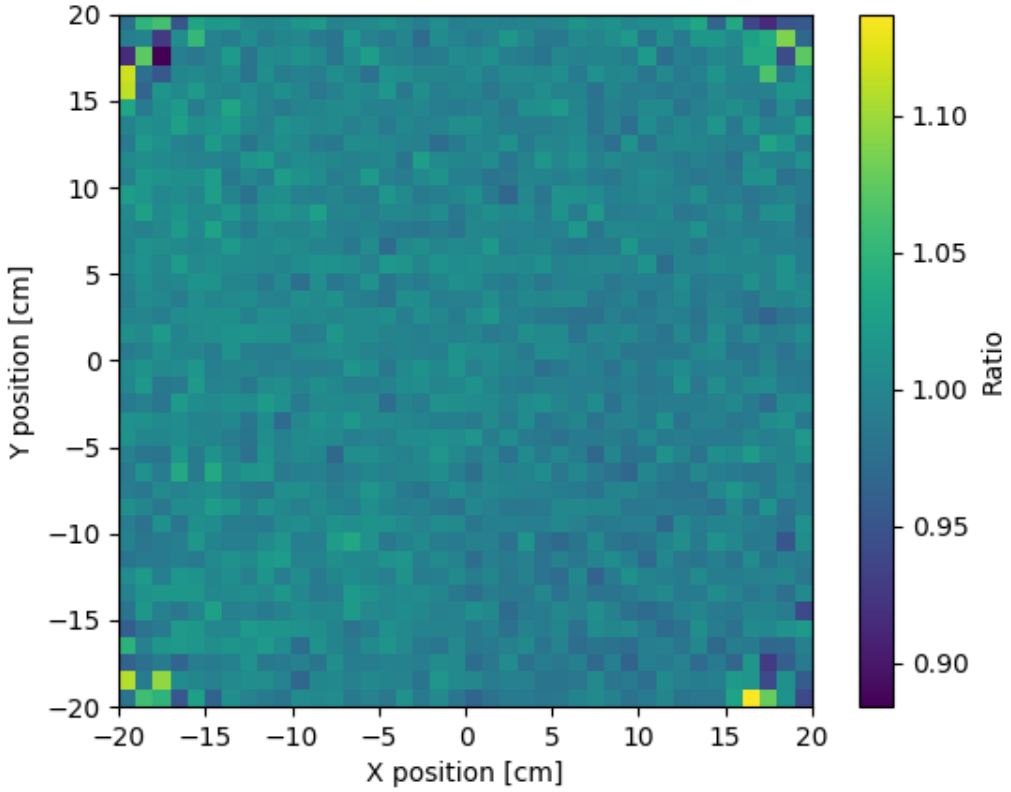


Directional brem splitting

Accuracy: realistic geometry
Ratios of energy fluence at patient plane

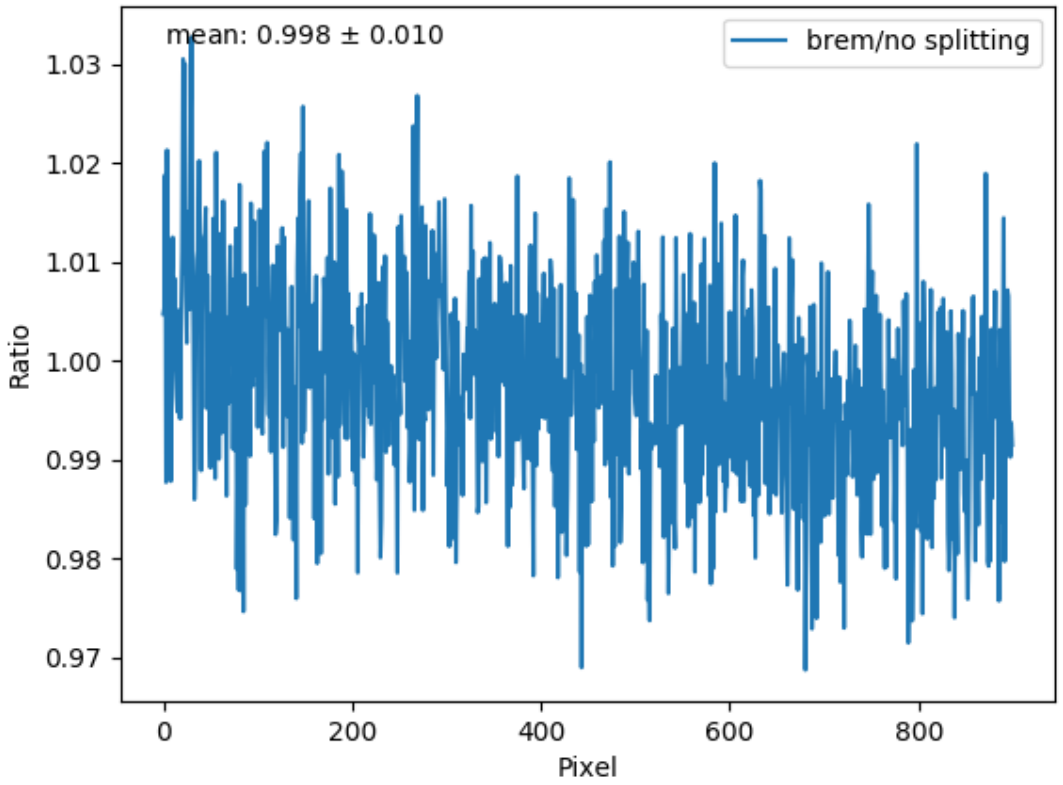


Brem to No splitting

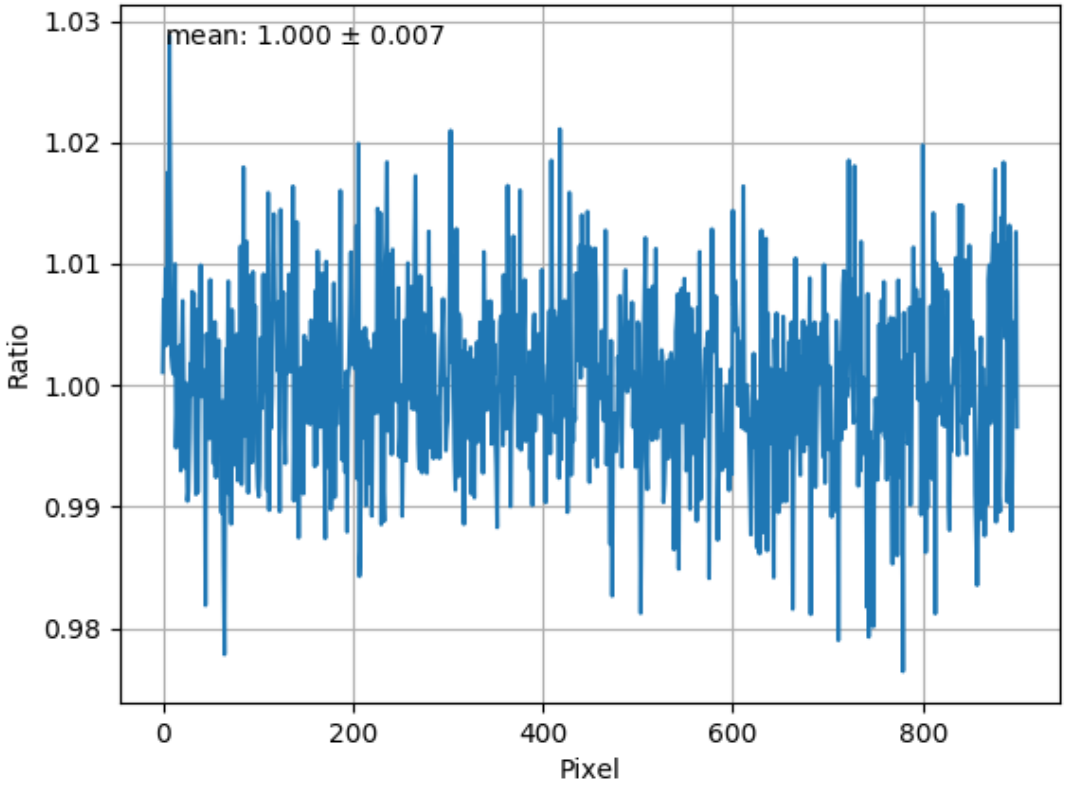


Dir Brem splitting to no splitting

Accuracy: realistic geometry
Ratios of energy fluence at patient plane



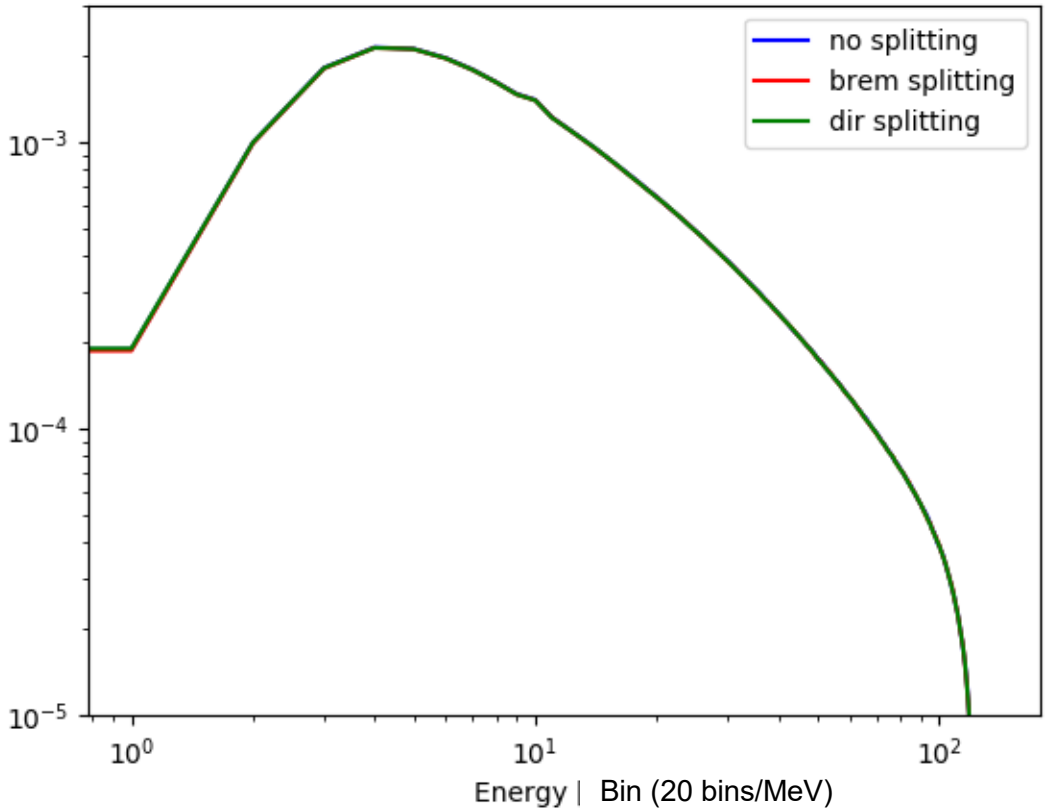
Brem to No splitting

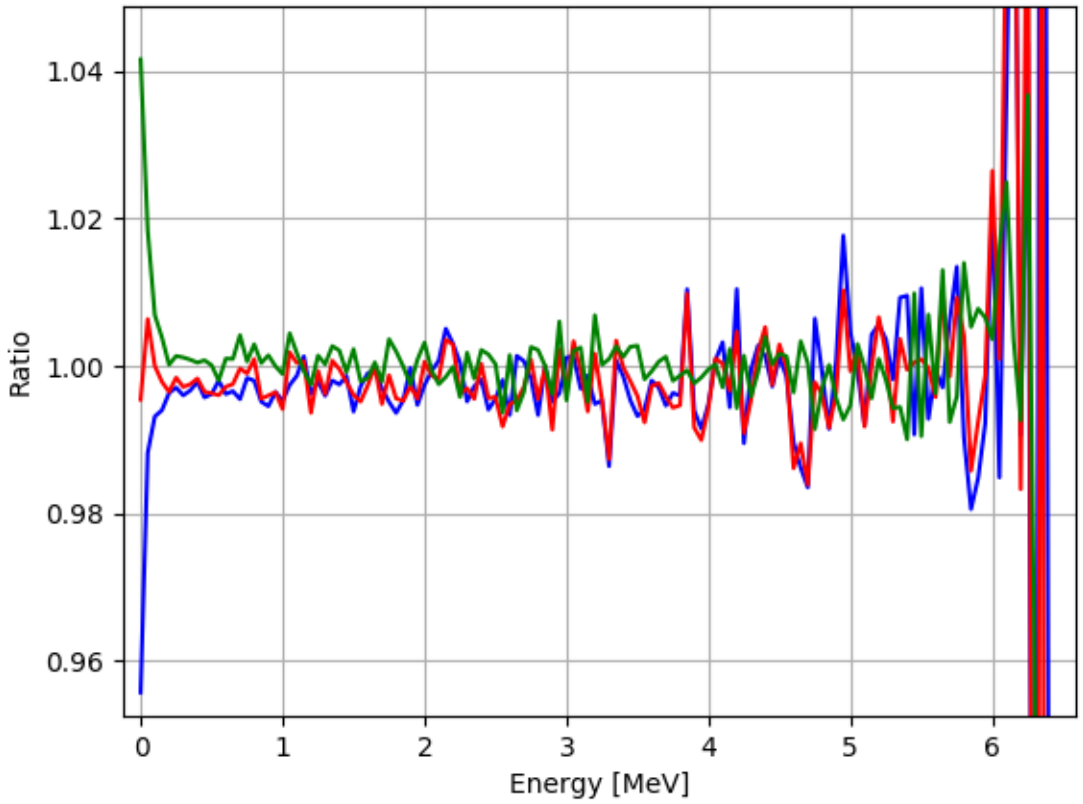


Dir Brem splitting to no splitting

Accuracy: realistic geometry
Spectrum at patient plane

Central 30x30 cm^2





Speed

Fast, accurate photon beam accelerator modeling using BEAMnrc: A systematic investigation of efficiency enhancing methods and cross-section data

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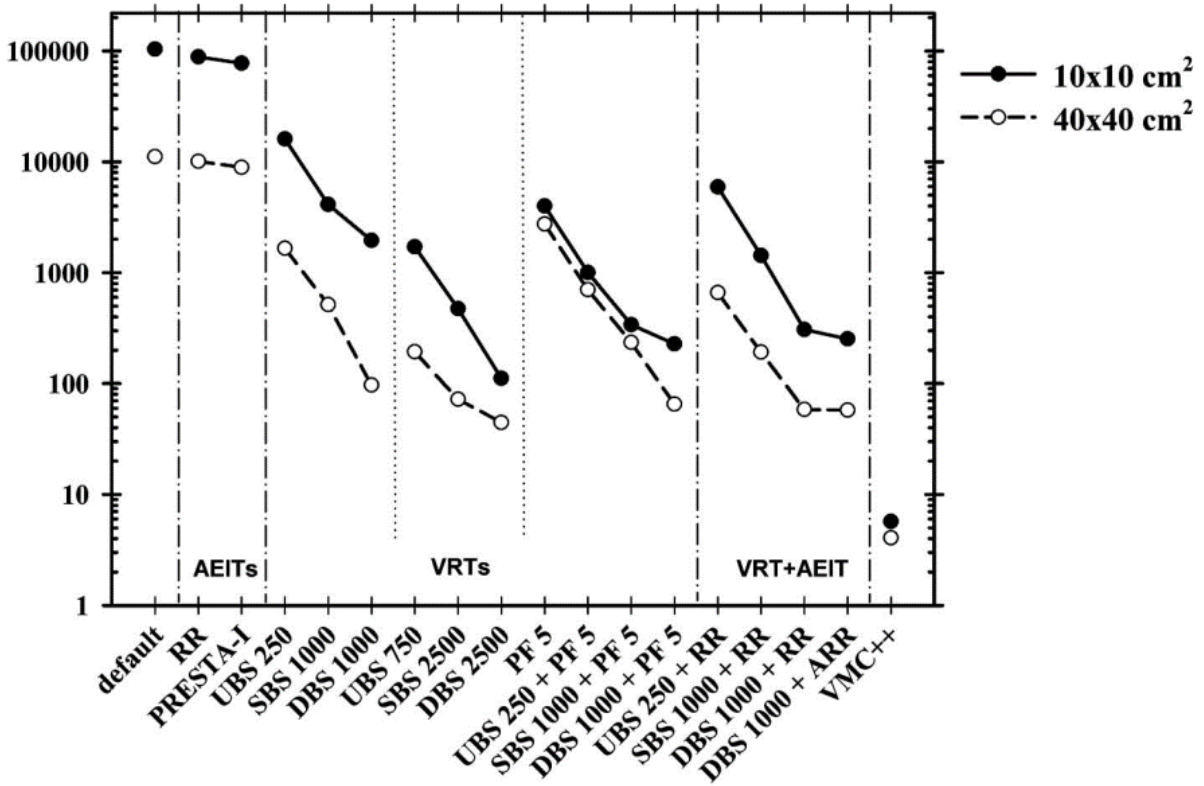
Med. Phys. 36 (12), December 2009



To do

- Two tags not yet committed:
  - Emstand (annihililation weight)
  - Emutils (memory leak)
- Electrons at surface?
- Other processes generating gamma (e.g. fluorescence)
- Next bottlenecks:
  - Gamma transport from voxel to voxel
  - Modifying geometry (collimators and gantry move)
- Example macro

Proposal

- Could G4DynamicParticle store weight?
- Currently store
  - list of secondaries (std::vector<G4DynamicParticle*>)
  - Parallel list of weights std::vector<G4double>