Bremsstrahlung simulation with Geant4

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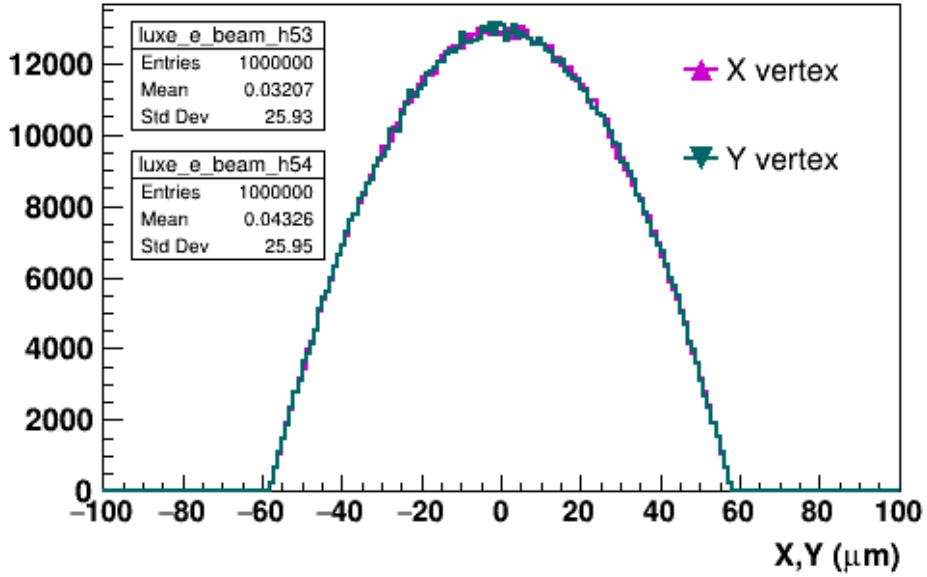
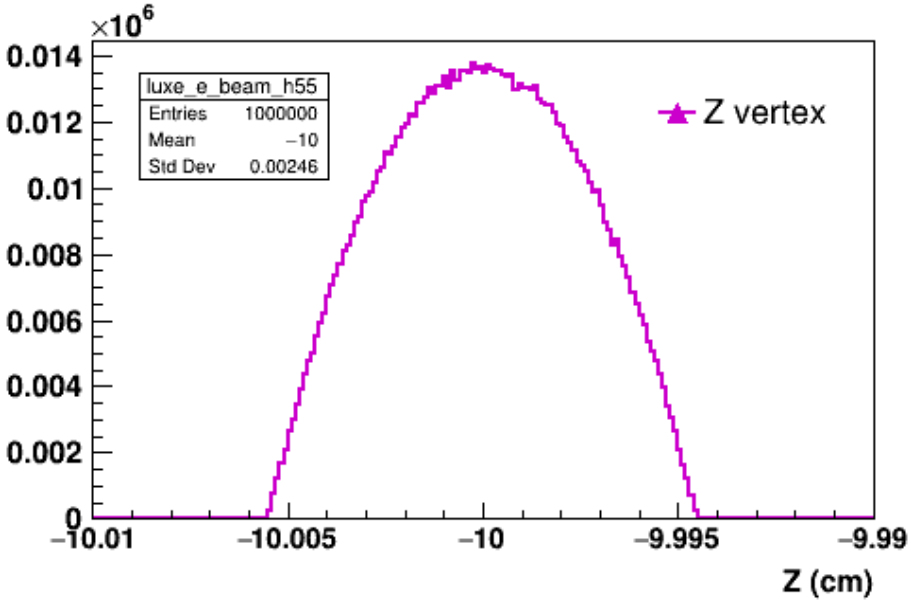
LUXE Meeting
November 5, 2018

Particle Source





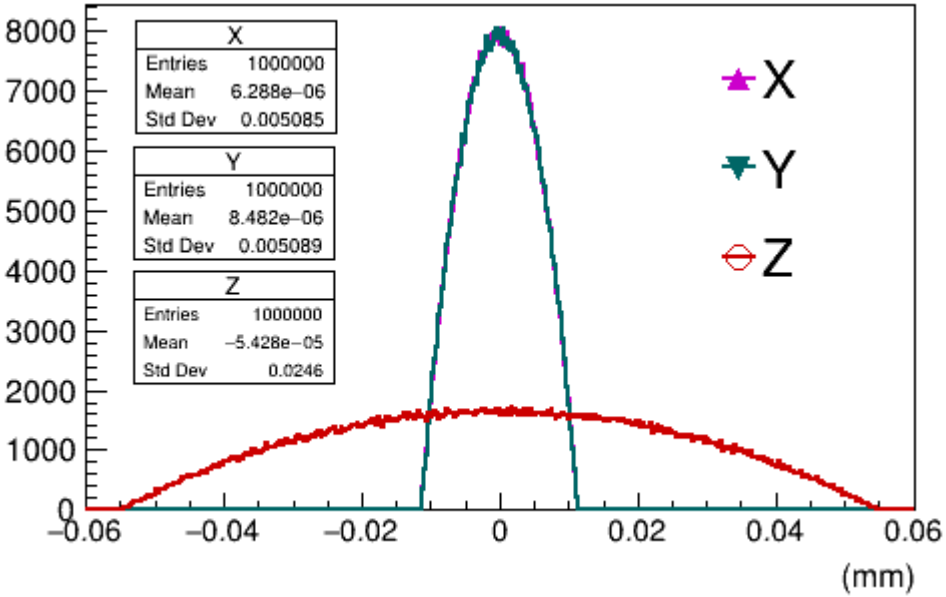
Geant4 General Particle Source:

/gps/particle e-
/gps/energy 17.5 GeV
/gps/position (0.0, 0.0, -10.0) cm
/gps/number 1
/gps/pos/type Volume
/gps/pos/shape Ellipsoid
/gps/pos/centre (0.0, 0.0, -10.0) cm

/gps/pos/halfx 58.0 um
/gps/pos/halfy 58.0 um
/gps/pos/halfz 55.0 um

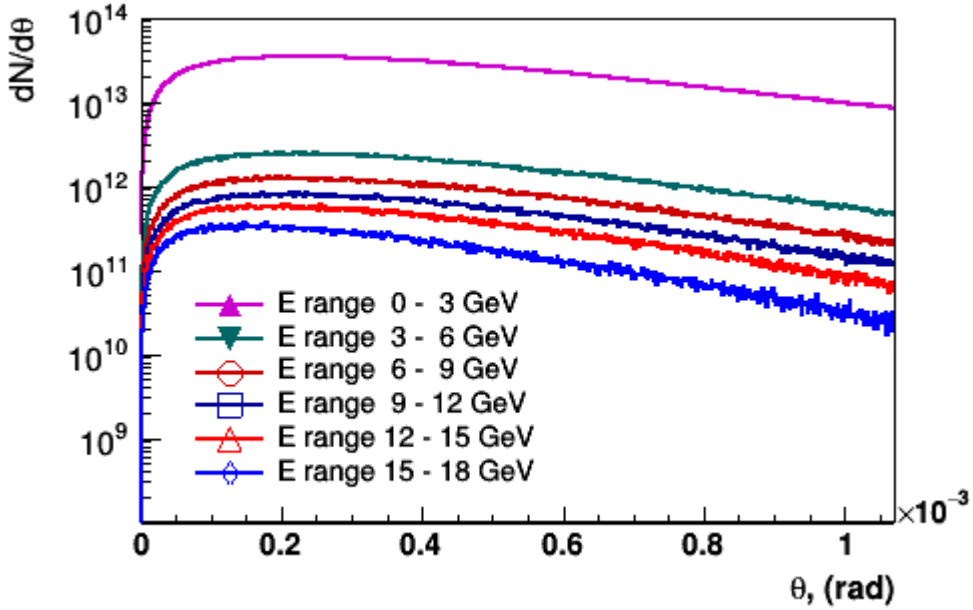
/gps/ang/type focused
/gps/ang/focuspoint (0.0, 0.0, 500.0) cm

Source at IP, Z = 400 cm

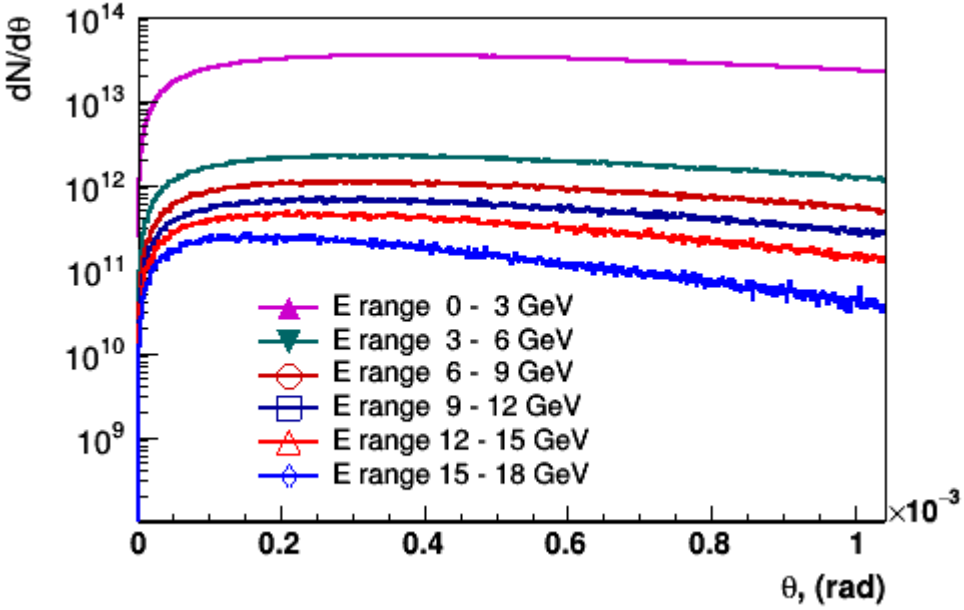


Bremsstrahlung on Al target

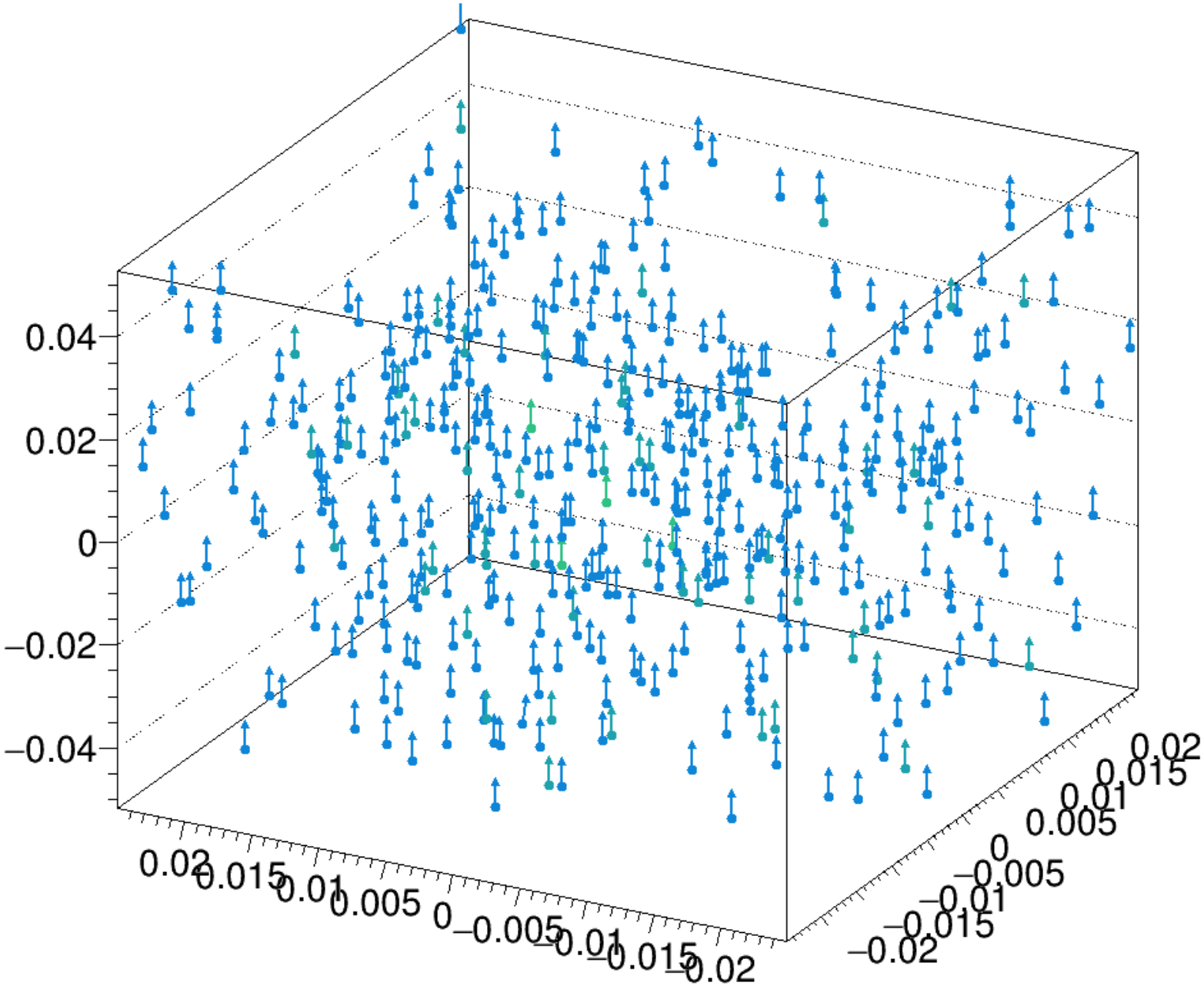
Al, 0.5X0 (44.5 mm)



Al, 1X0 (89 mm)



Photons at IP



Geant4 bremsstrahlung model

Seltzer-Berger bremsstrahlung model

In order to improve accuracy of the model described above a new model *G4SeltzerBergerModel* have been design which implementing cross section based on interpolation of published tables [SB85][SB86]. Single-differential cross section can be written as a sum of a contribution of bremsstrahlung produced in the field of the screened atomic nucleus $d\sigma_n/dk$, and the part $Z\,d\sigma_e/dk$ corresponding to bremsstrahlung produced in the field of the Z atomic electrons,

$$\frac{d\sigma}{dk} = \frac{d\sigma_n}{dk} + Z\frac{d\sigma_e}{dk}\,.$$

.... The angular dependence is contained in the variable $u = E\theta m^{-1}$. For a given value of u the dependence of the shape of the function on Z, E and $\epsilon = k/E$ is very weak. Thus, the distribution can be approximated by a function

$$f(u) = C\left(ue^{-au} + due^{-3au}\right)$$

where

$$C = \frac{9a^2}{9+d} \qquad a = 0.625 \qquad d = 27$$

Angular distribution of Bremsstrahlung photons and of positrons for calculations of terrestrial gamma-ray flashes and positron beams

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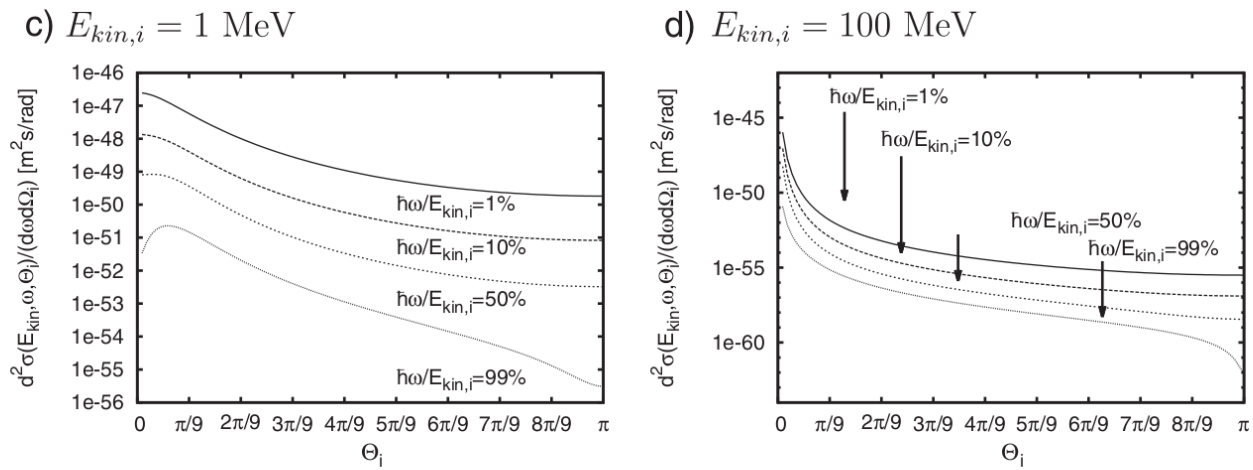


Fig. 3. The doubly differential cross section $d^2\sigma/(d\omega d\Omega_i)(E_{kin,i},\omega,\Theta_i)$ for Bremsstrahlung ($Z = 7$) versus the scattering angle Θ_i between emitted photon and incident electron. The electron energies are a) $E_{kin,i} = 10$ keV, b) $E_{kin,i} = 150$ keV, c) $E_{kin,i} = 1$ MeV and d) $E_{kin,i} = 100$ MeV. In each plot the photon energy $\hbar\omega$ amounts to 1%, 10%, 50% and 95% of the kinetic energy of the incident electron.

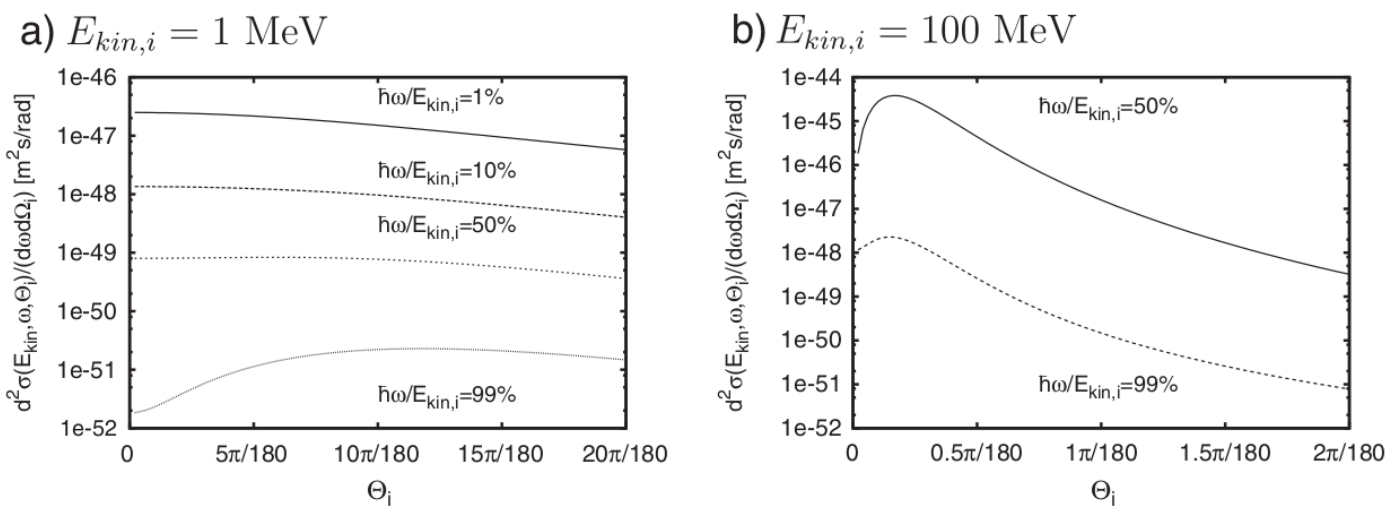
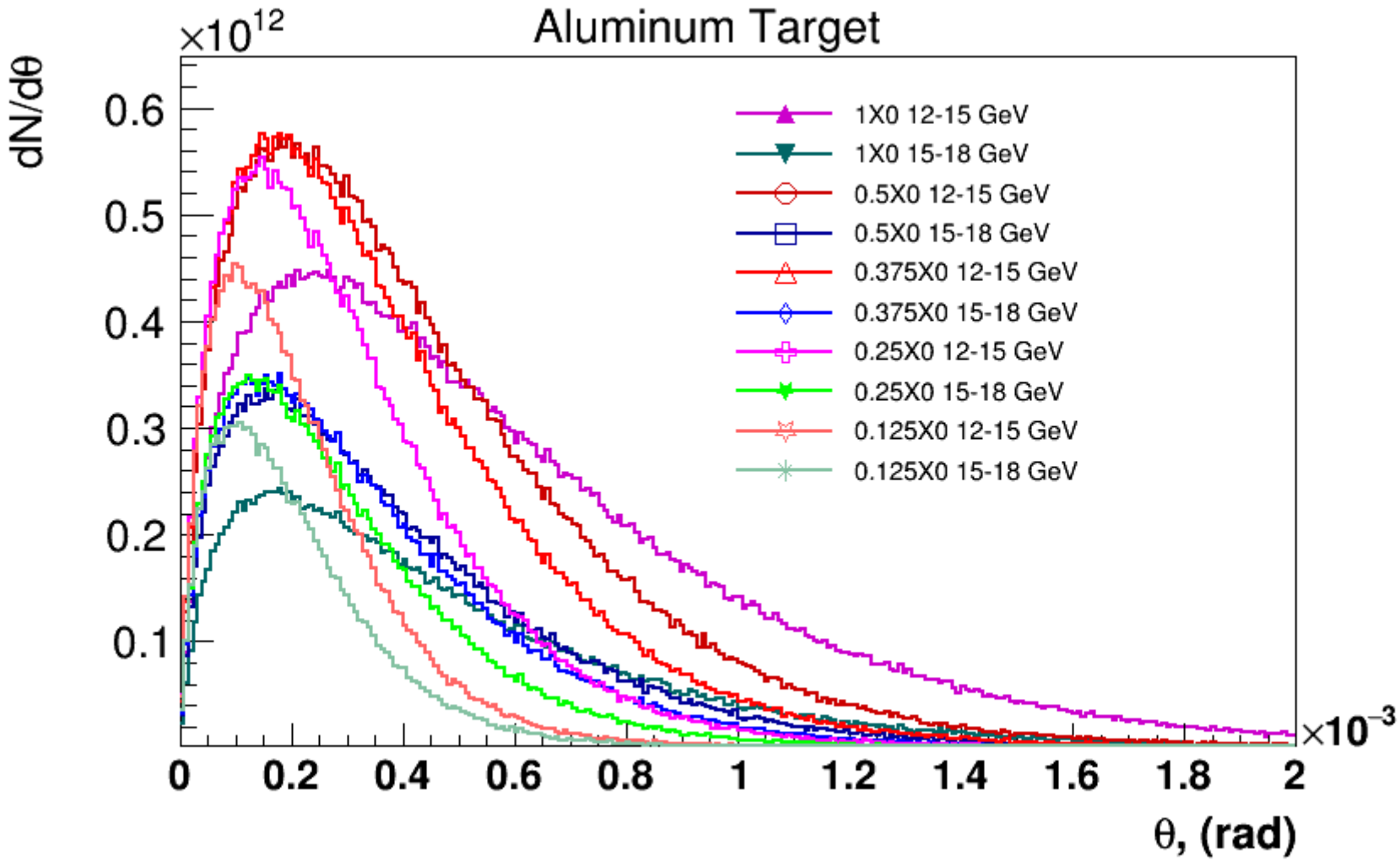


Fig. 4. The doubly differential cross section $d^2\sigma/(d\omega d\Omega_i)$ for Bremsstrahlung as in Fig. 3 for a smaller angular range.

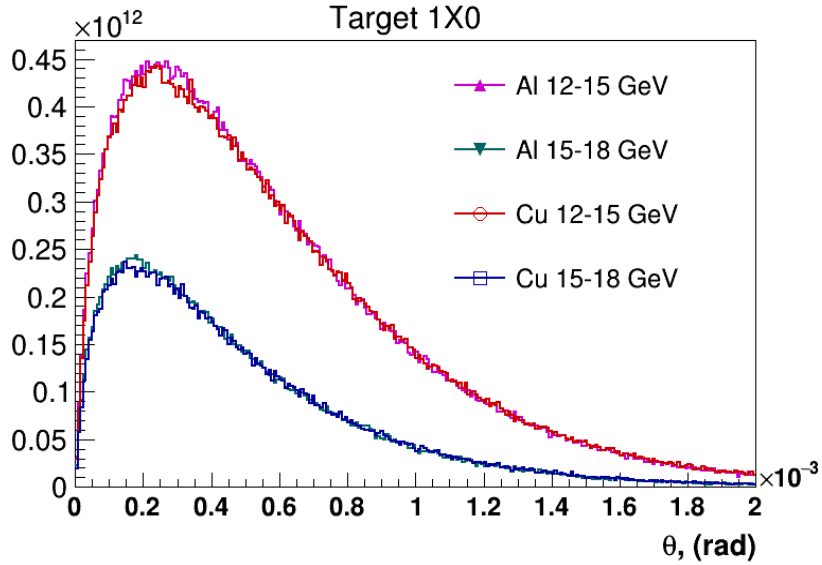
Target thickness

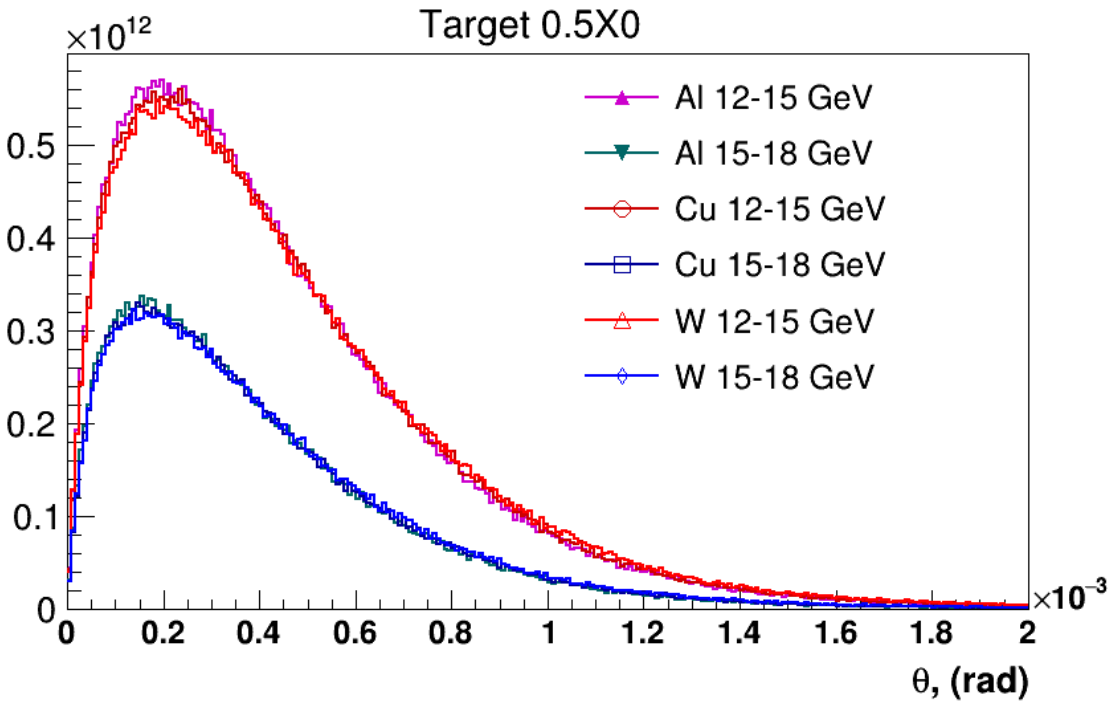
- 17.5 GeV e- beam, generated from single point along Z;
- Detector is 4 m away from the target.

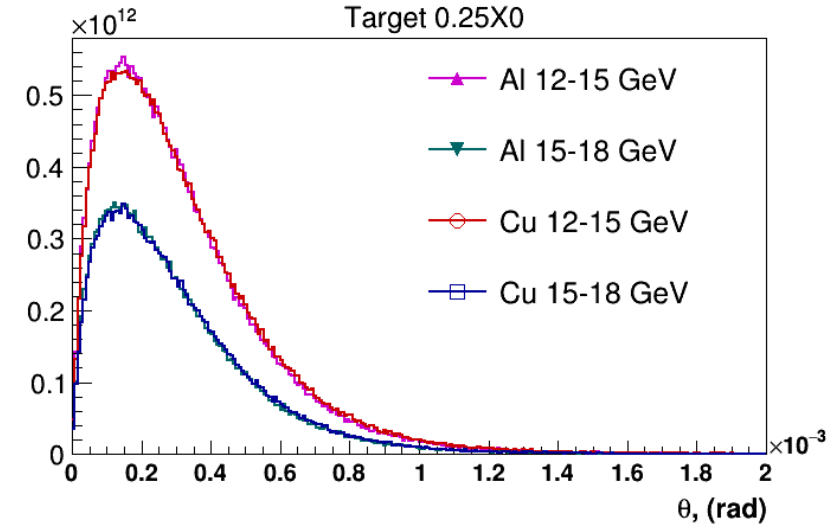


Different target materials

- 17.5 GeV e- beam, generated from single point along Z;
- Detector is 4 m away from the target.







Macroparticles

```
#   E (GeV)      x (um)      y (um)      z(um)      beta_x      beta_y      beta_z      PDG_NUM     MP_Wgt
#-----------------------------------------------------------------------------------------------------------
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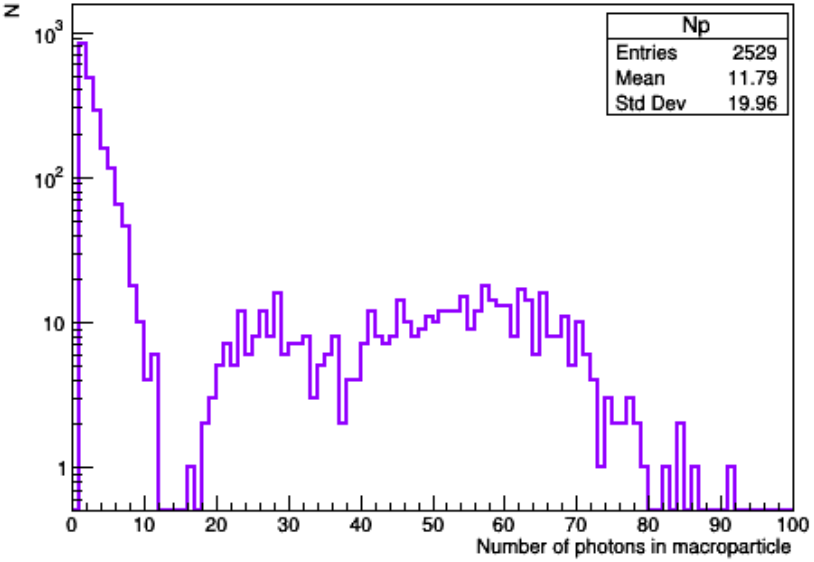
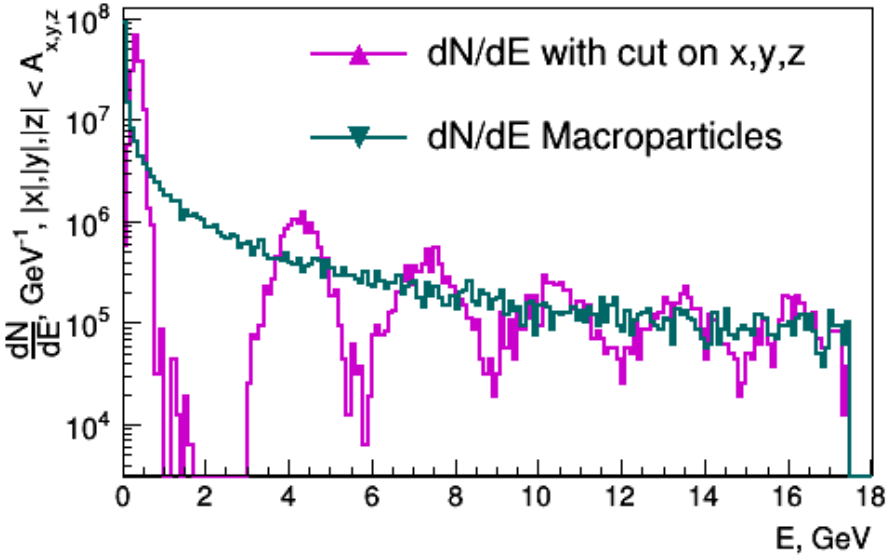
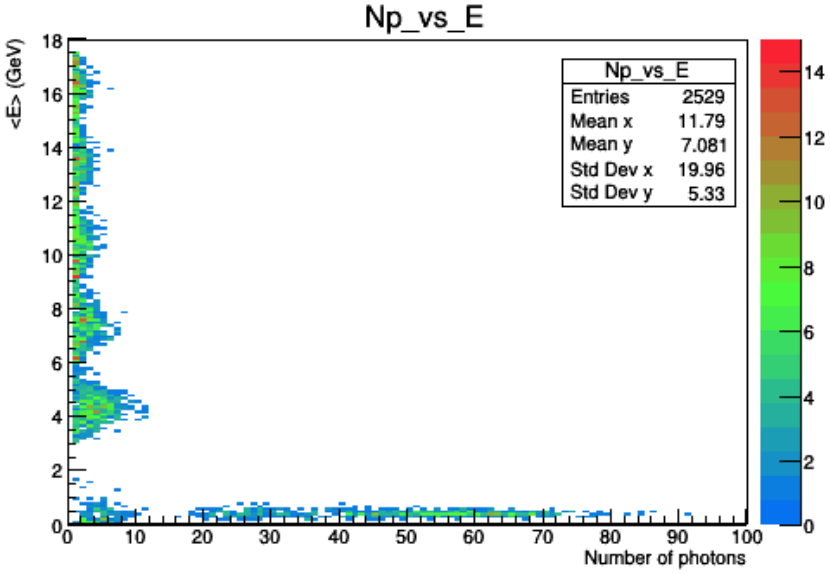
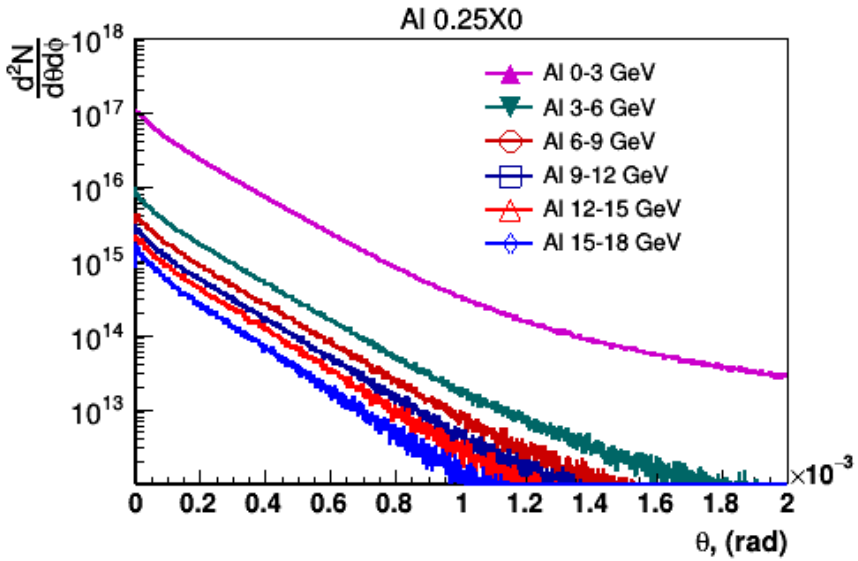
- Beam as on slide 2;
- Target: Al, 0.25X0, (22 mm).
  - 4D space (x, y, z, E) divided into cells;
  - Each cell is converted to macroparticle with X = <x>, … E = <E>;
  - Number of photons in the cell defines the weight.

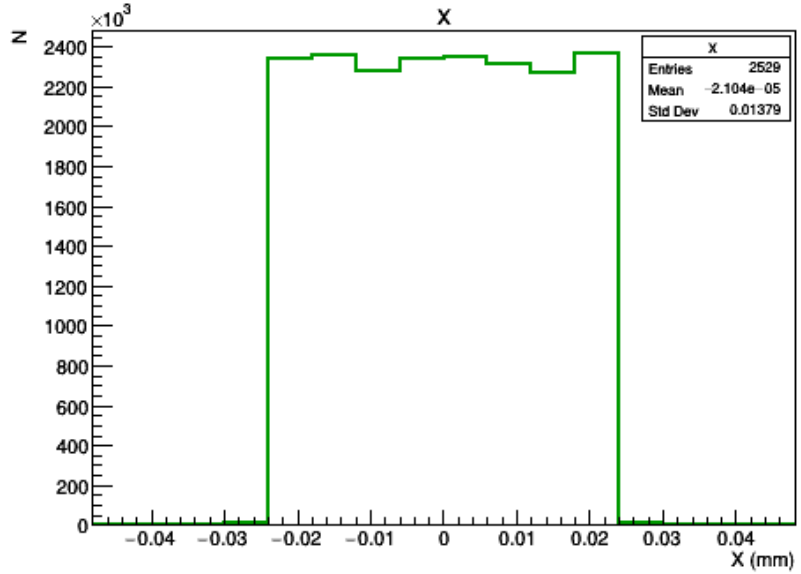


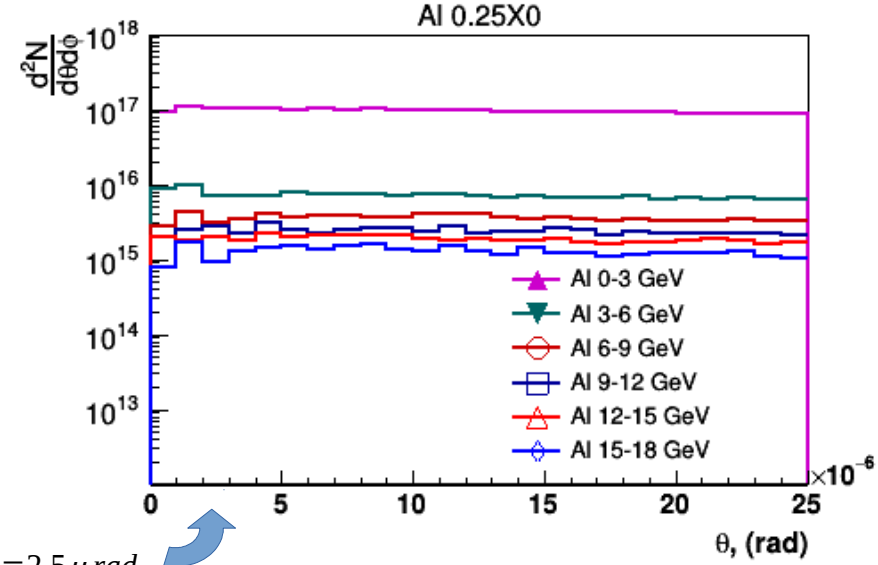


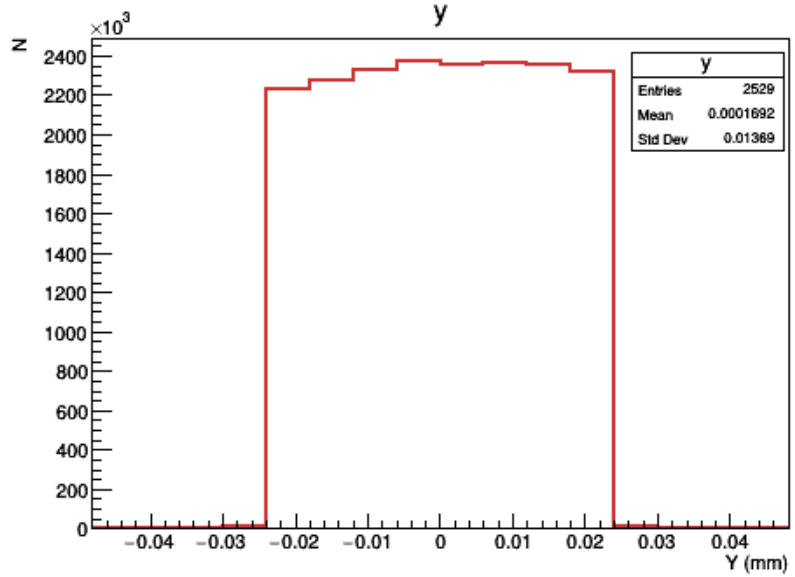


Photon θ and Macroparticle position



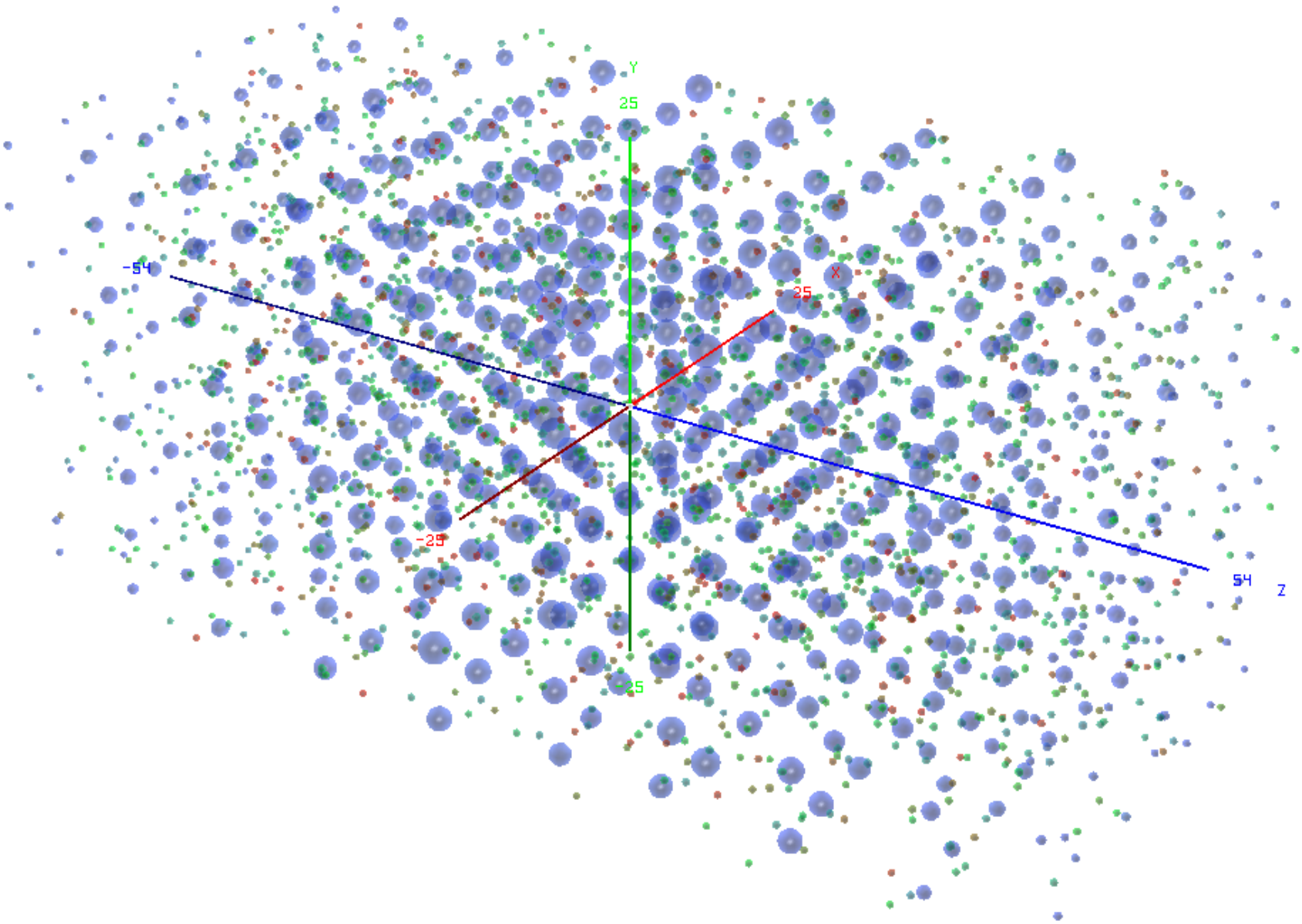




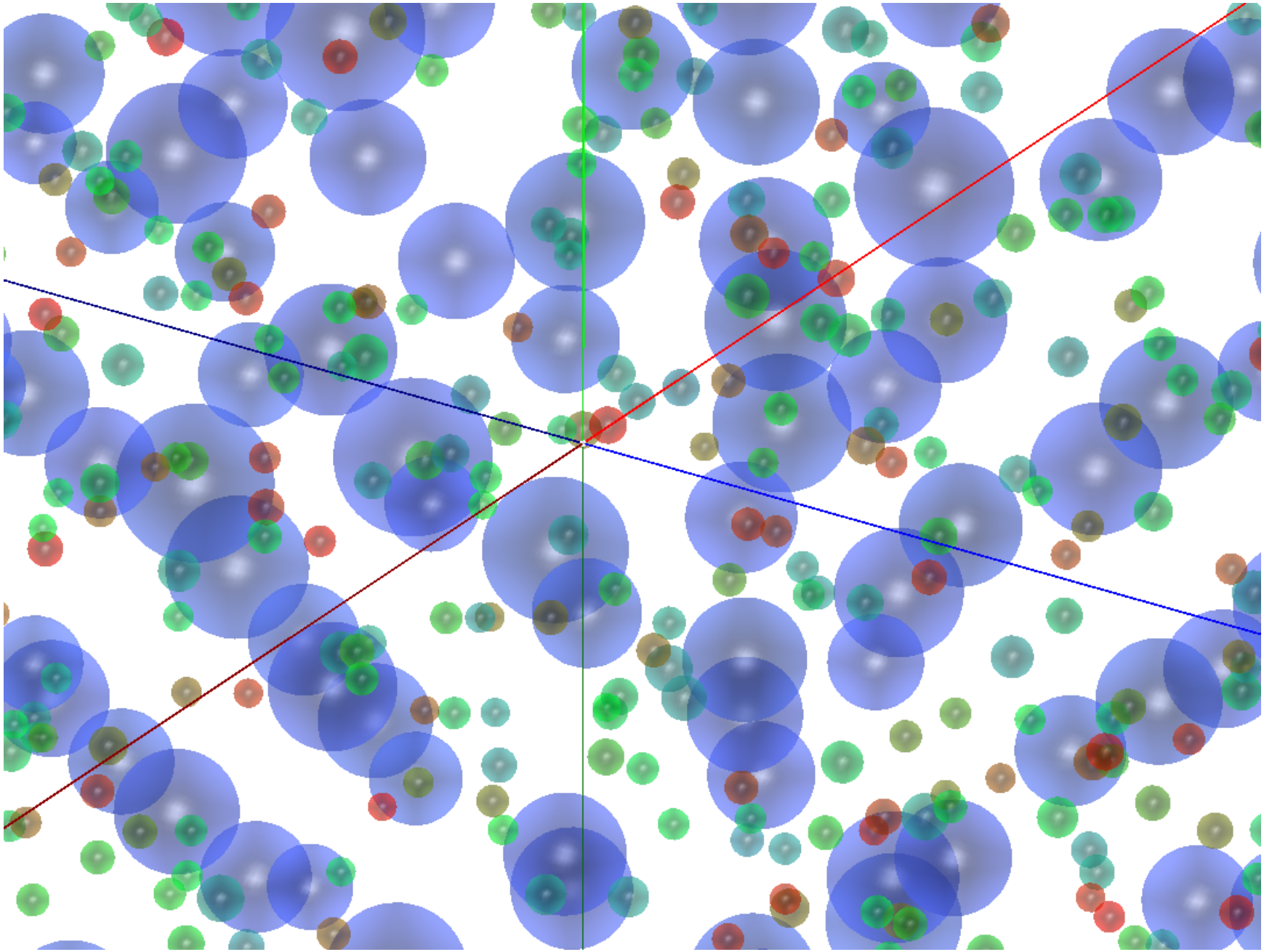


$$\frac{10\,\mu m}{4\,m} = 2.5\,\mu rad$$

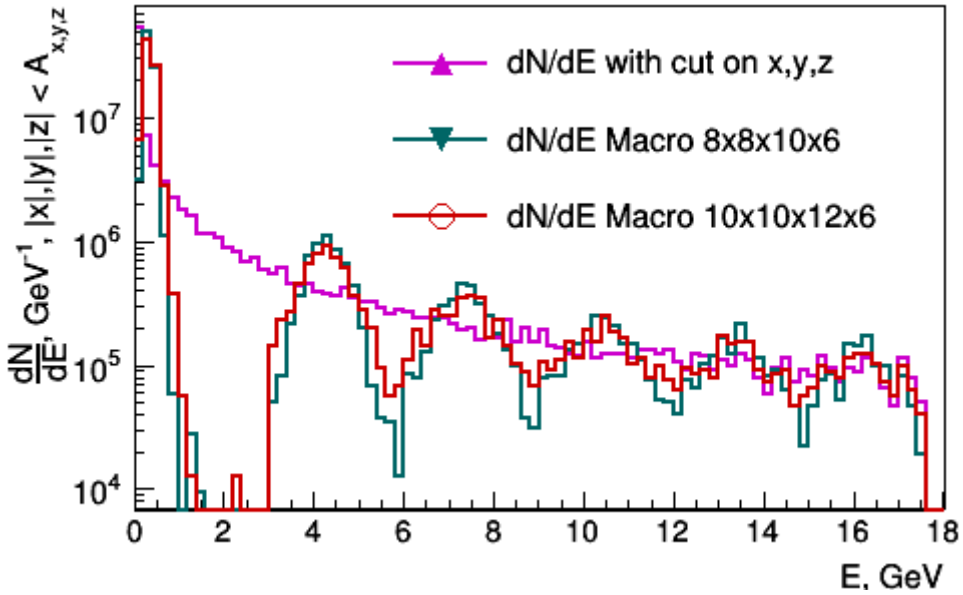
Macro particles Al, 0.25X0.
x/y/z/E: 8/8/10/6

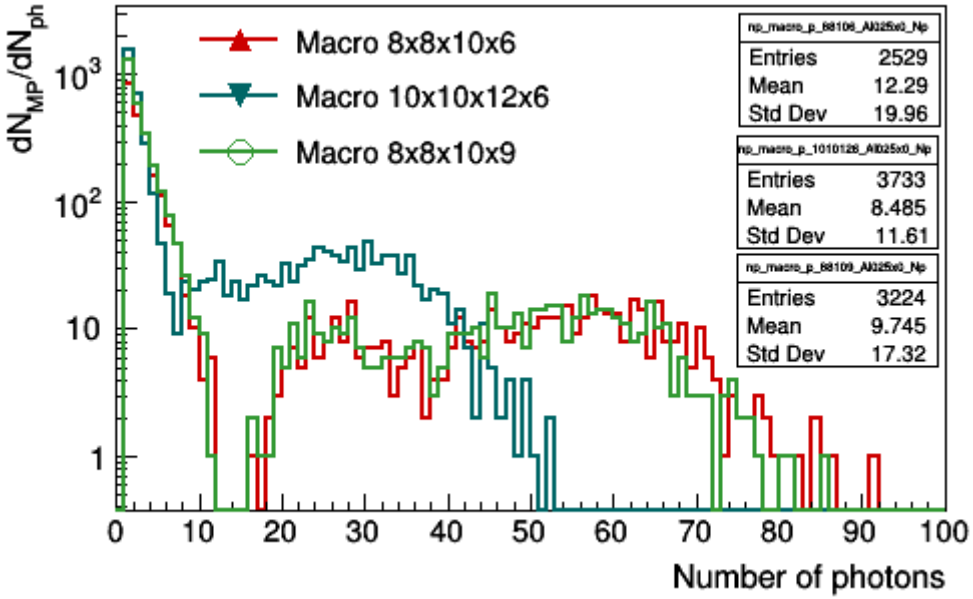


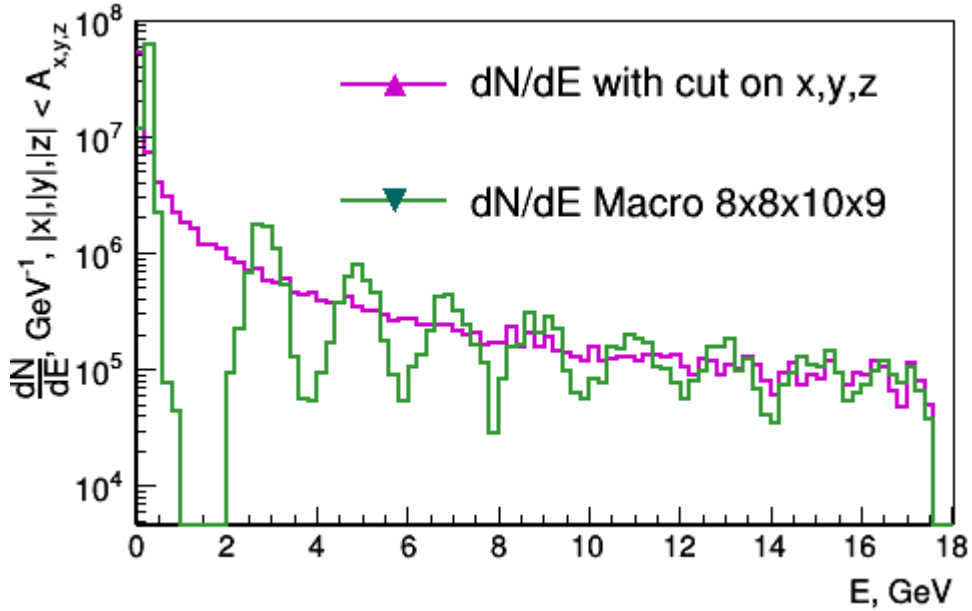
Macro particles Al, 0.25X0.
x/y/z/E: 8/8/10/6



Macroparticles of different size







Macroparticles: Al 0.25X0 and 0.5X0