Bremsstrahlung simulation with Geant4

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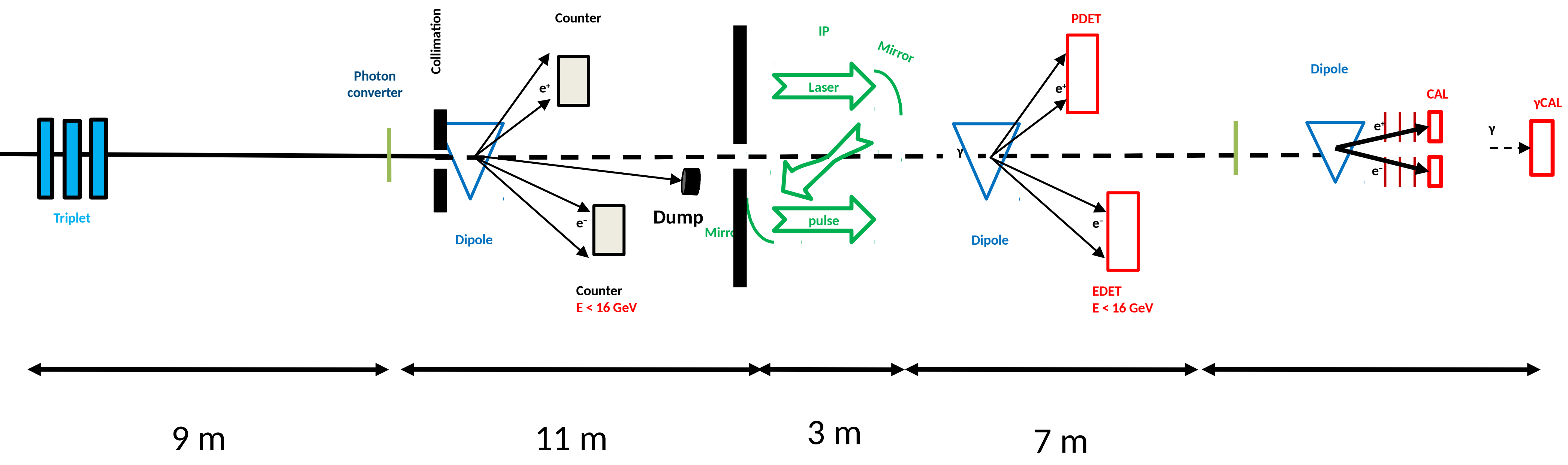
LUXE Meeting
January 28, 2019

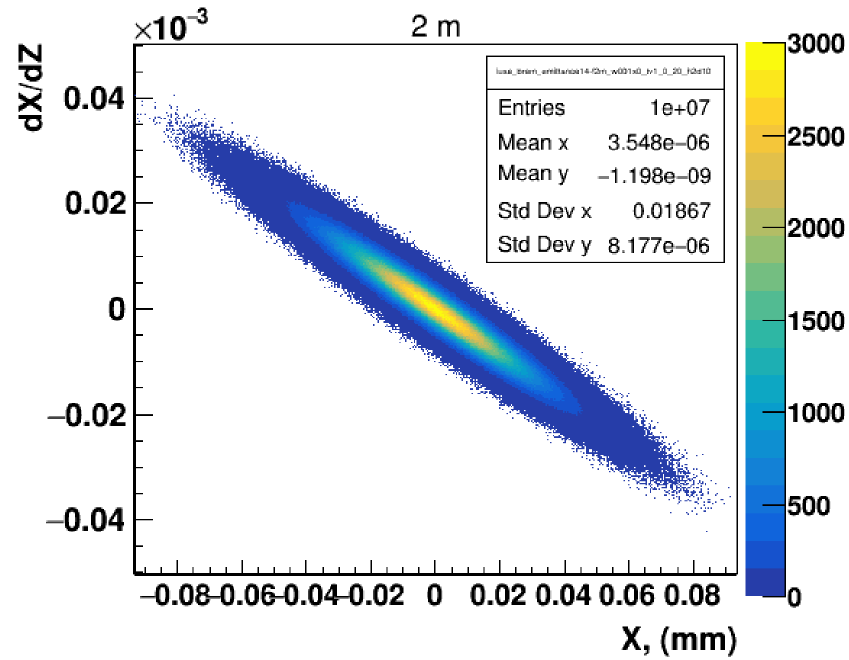
Photon-Photon collisions at LUXE

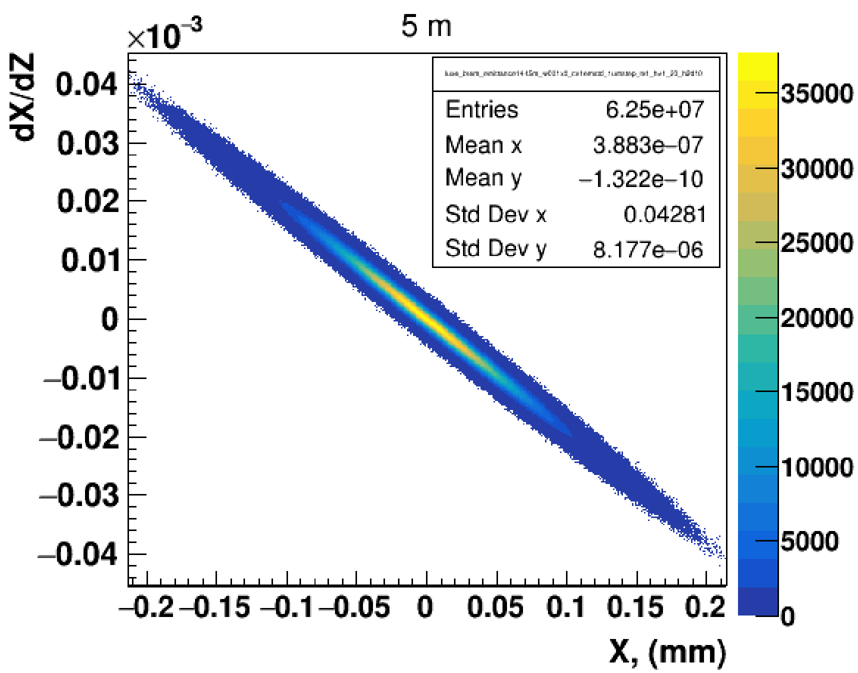


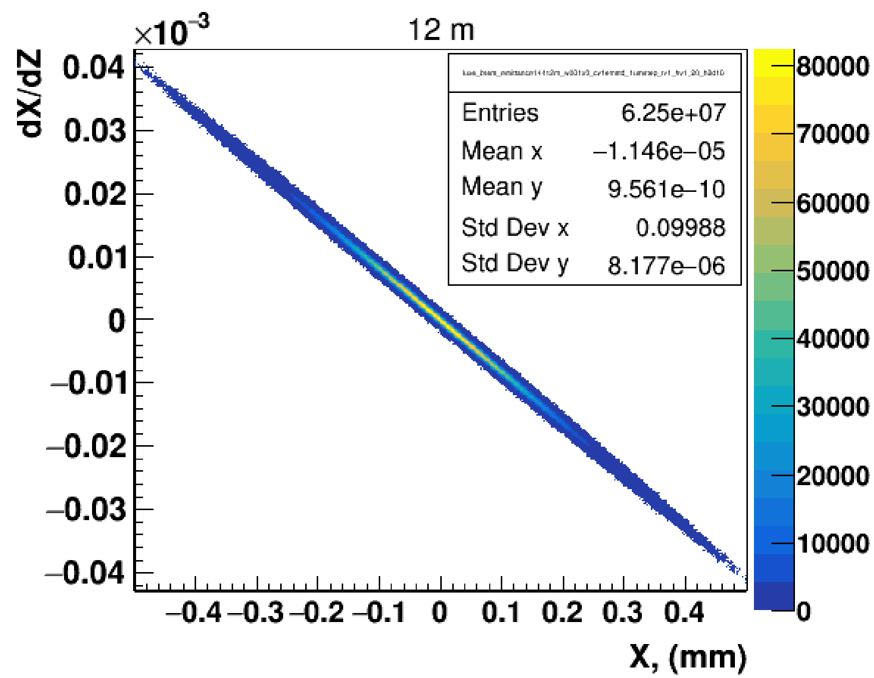
Preliminary estimates!

Target 2 m, 5 m and 12 m upstream of IP

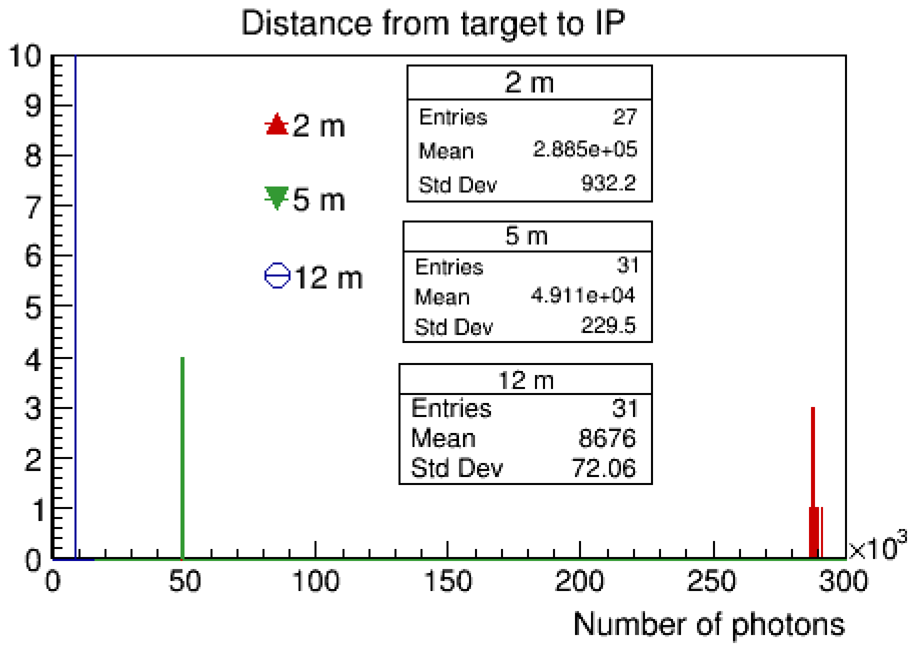
- 2 m: σx = 19 μm;
- 5 m: σx = 43 μm;
- 12 m: σx = 100 μm;







Number of photons



$$N \sim \frac{1}{l^2}$$

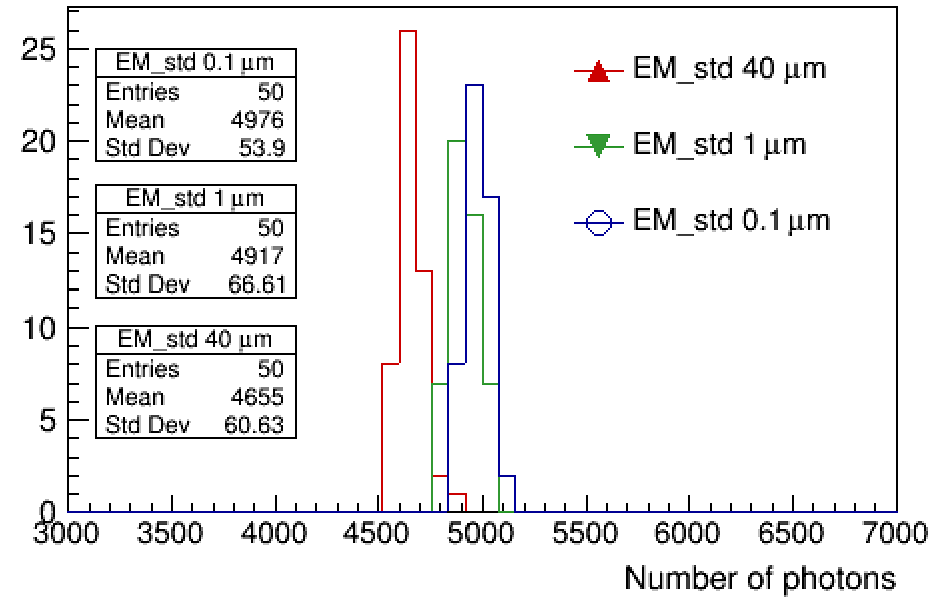
Z, (m)	Z^2	N_Gamma	Z1^2 / Z2^2	N2 / N1		Z1^2 / Z2^2	N2 / N1	
2	4	2.89E+05	6.25E+00	5.8746	0.94	36	33.2565	0.924
5	25	4.91E+04	5.76E+00	5.6611	0.983			
12	144	8675						

Geant4 simulation with different step, different physics lists, different beam

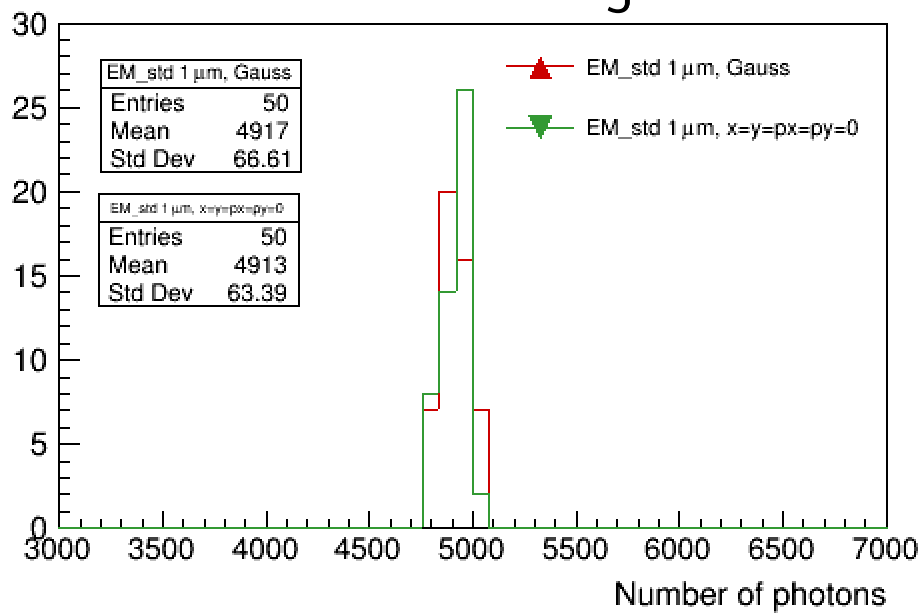
- Gaussian beam, focused on IP;
- Tungsten target 1%X0 (35um) thickness
- 5 m from IP;
- 6.25 M electrons (BX/1000);
- Production cut: 1 µm.

Number of photons inside
|x|<25um and
|y|<25um;

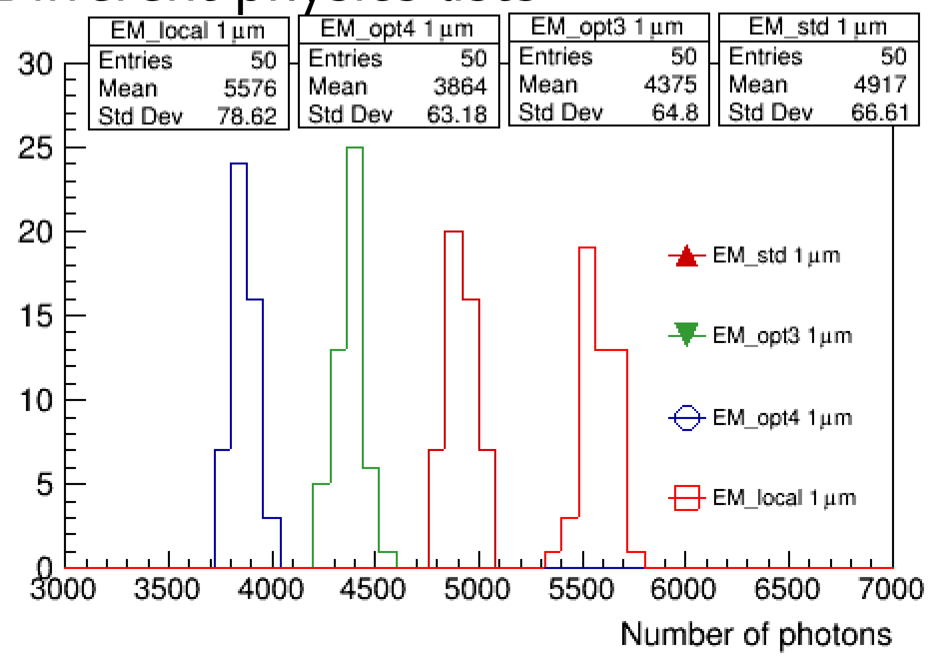
Different step



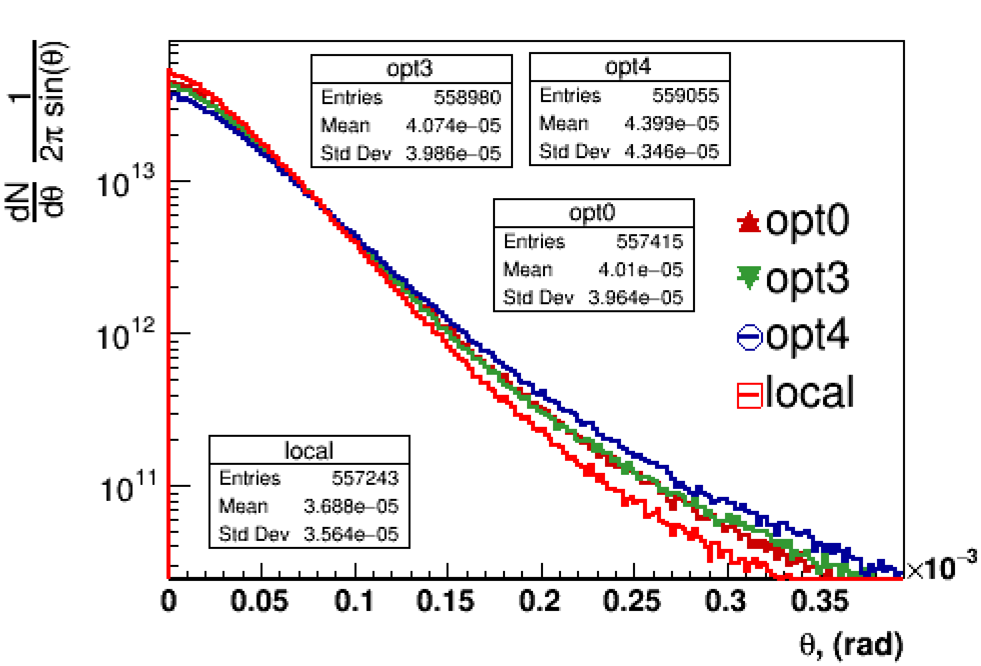
Different beam settings

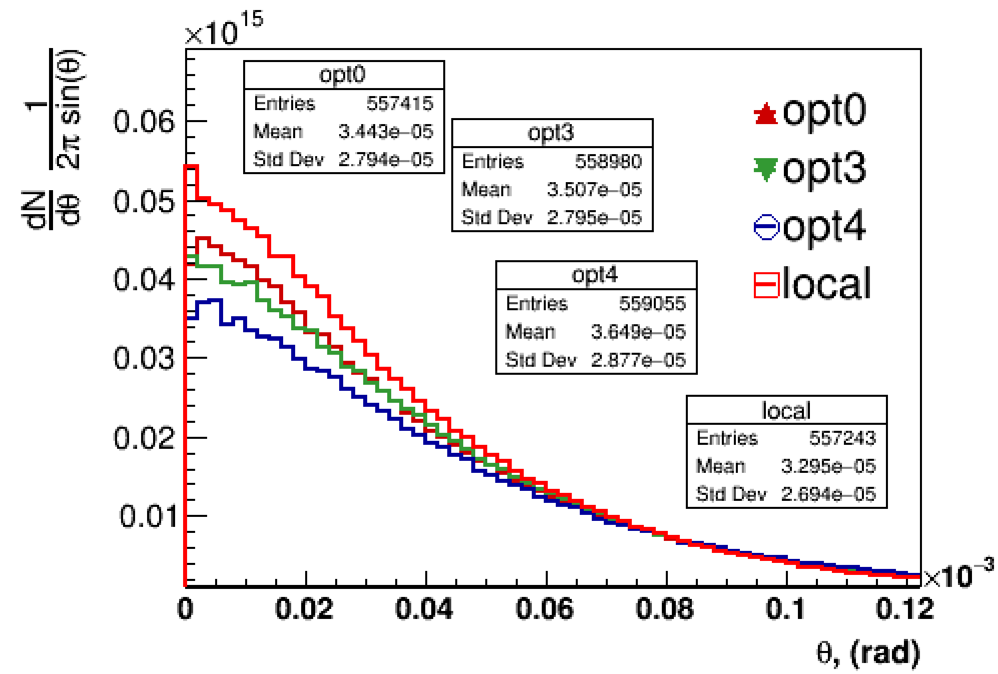


Different physics lists



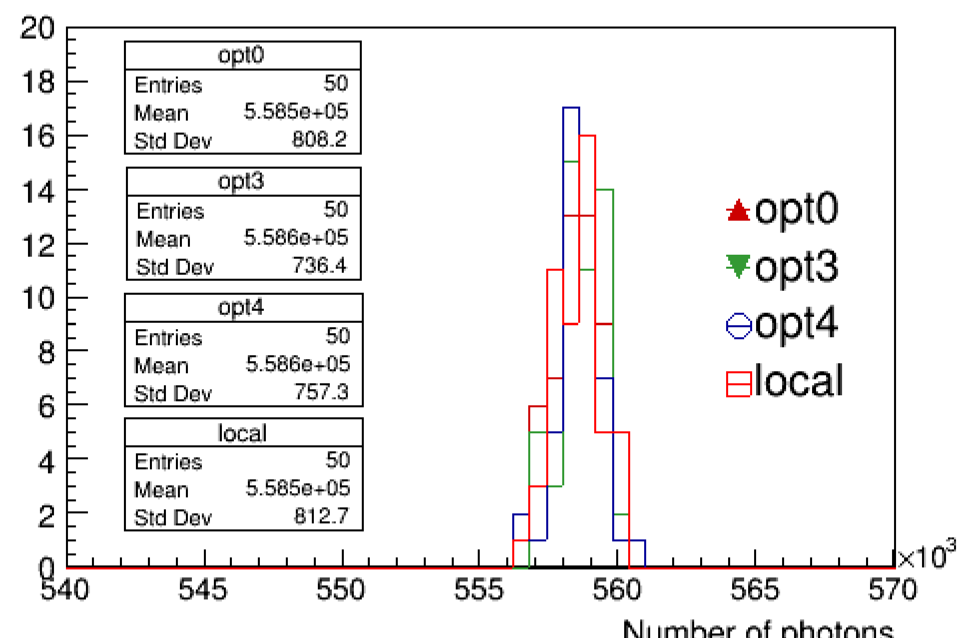
γ angular distribution for different physics lists





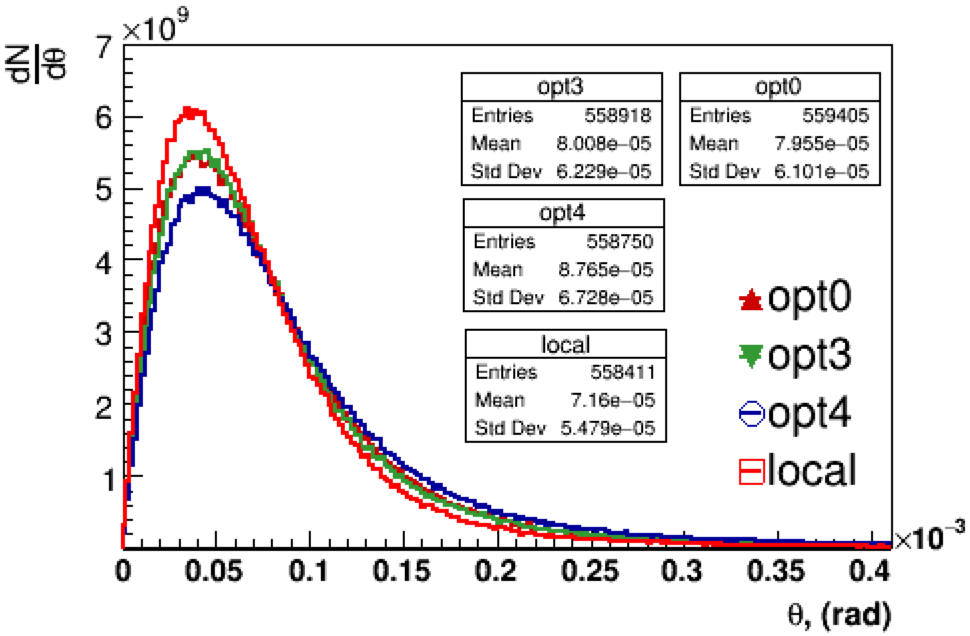
- Angular distribution is the widest for option_4 physics list and the narrowest for the local one.
- Angular distribution explains bottom right plot on previous slide.
- Total number of photons in forward region is identical for all physics lists.

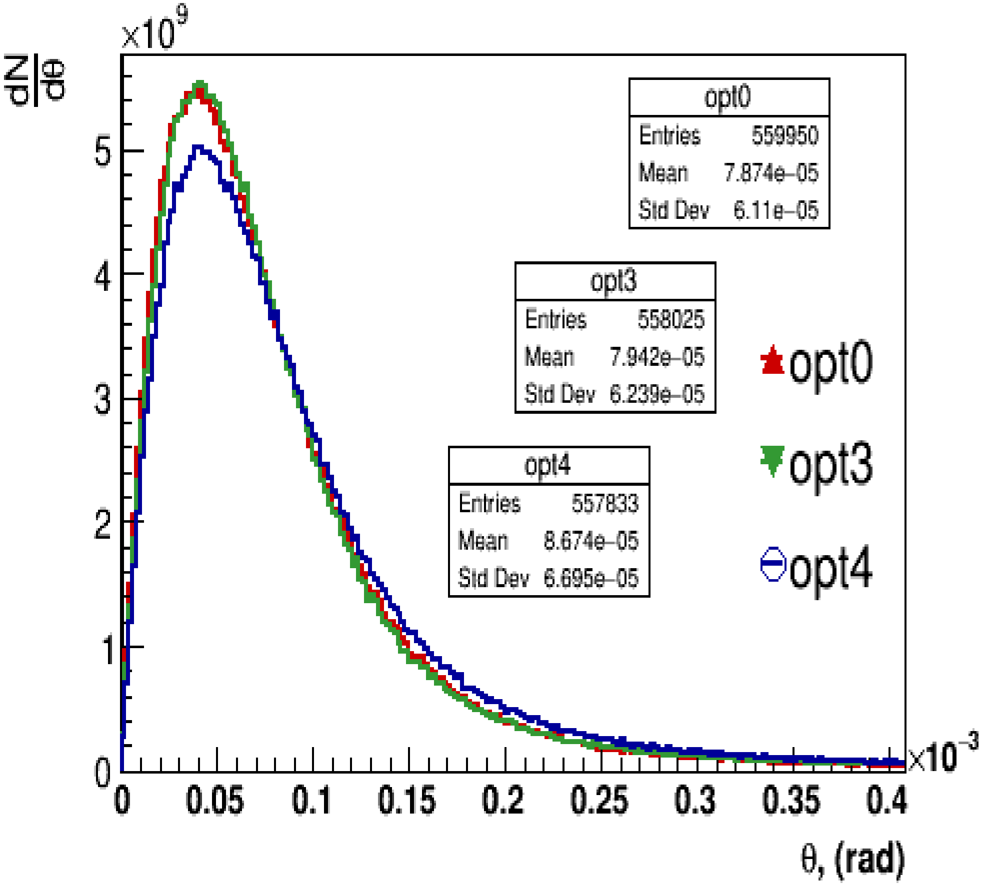
Number of photons inside
|x|<1.5 m and
|y|<1.5 m



Polar angle distribution

Unidirectional beam:
x=y=px=py=0

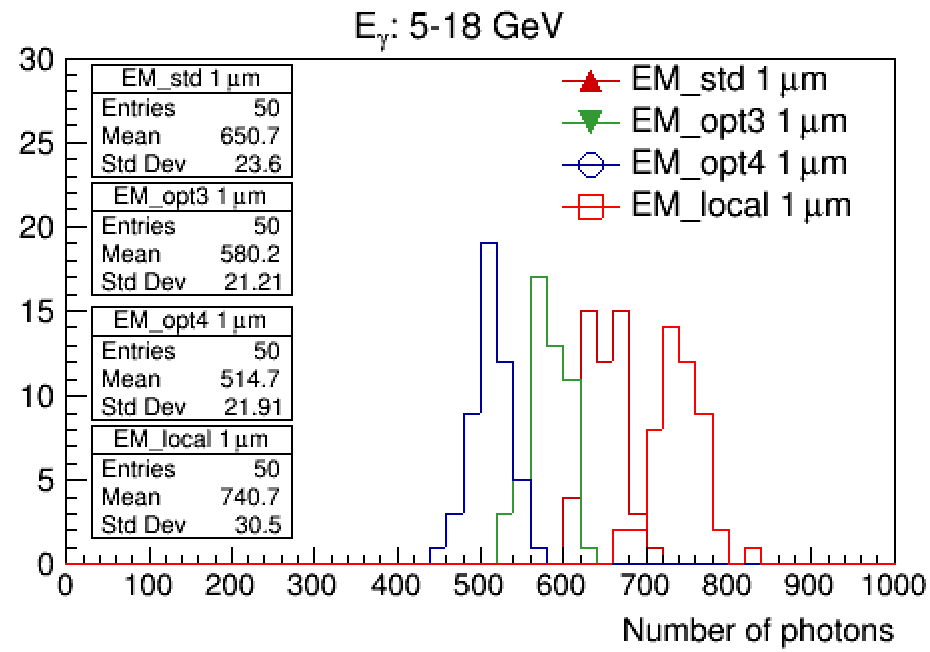




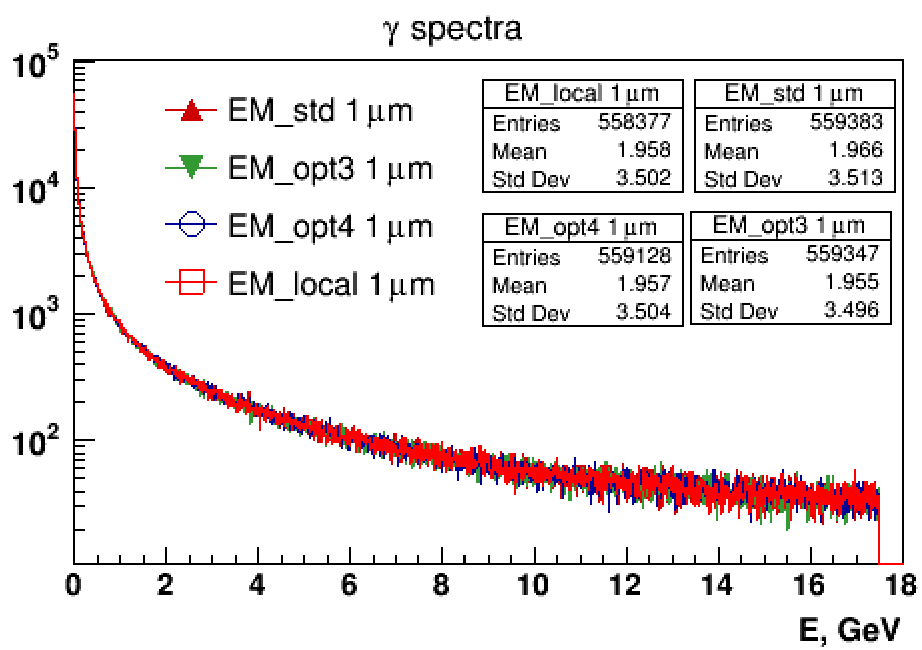
Spectra for different physics lists

- Gaussian beam, focused on IP;
- Tungsten target 1%X0 (35um) thickness
- 5 m from IP;
- 6.25 M electrons (BX/1000);
- Production cut: 1 µm.

Number of photons inside
|x|<25um and
|y|<25um and
5GeV < Eγ < 18GeV;




```
root [1] 4917.0/3864.0
(double) 1.27252
root [2] 650.0/514.0
(double) 1.26459
```



Geant4 reference physics lists

- EM physics for simulation with high accuracy due to "UseDistanceToBoundary" multiple scattering step limitation and usage of `G4UrbanMscModel` for all charged particles, reduced *finalRange* parameter of stepping function optimized per particle type, alternative model `G4KleinNishinaModel` for Compton scattering, enabled fluorescence, enabled nuclear stopping, `G4Generator2BS` angular generator for bremsstrahlung, `G4IonParameterisedLossModel` for ion ionisation, `G4ePairProduction` for electron/positron, 20 bins energy decade of physics tables, and 10 eV low-energy limit for tables (class name `G4EmStandardPhysics_option3`)
- Combination of EM models for simulation with high accuracy includes multiple scattering with "UseSafetyPlus" type of step limitation by combined `G4WentzelVIModel` and `G4eCoulombScatteringModel` for all particle types, for of e+- below 100 MeV `G4GoudsmitSaundersonMscModel` is used, `RangeFactor = 0.2`, `Scin = 3` (error free stepping near geometry boundaries), reduced *finalRange* parameter of stepping function optimized per particle type, enabled fluorescence, enabled nuclear stopping, enable accurate angular generator for ionisation models, `G4LowEPComptonModel` below 20 MeV, `G4PenelopeGammaConversionModel` below 1 GeV, `G4LivermoreIonisationModel` for electrons and positrons below 100 keV, `G4IonParameterisedLossModel` for ion ionisation, `G4Generator2BS` angular generator for bremsstrahlung, `G4ePairProduction` for electron/positron, and 20 bins per energy decade of physics tables, (class name `G4EmStandardPhysics_option4`)

Physics list comparison

Option 3

```
msc:   for e-    SubType= 10
      RangeFactor= 0.04, stepLimitType: 3, latDisplacement: 1, skin= 1, geomFactor= 2.5
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
            UrbanMsc :  Emin=        0 eV    Emax=       10 TeV  Table with 220 bins Emin=    100 eV    Emax=     10 TeV
```

```
eIoni:   for  e-    SubType= 2
      dE/dx and range tables from 10 eV  to 10 TeV in 240 bins
      Lambda tables from threshold to 10 TeV, 20 bins per decade, spline: 1
      finalRange(mm)= 0.1, dRoverRange= 0.2, integral: 1, fluct: 1, linLossLimit= 0.01
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
        MollerBhabha :  Emin=        0 eV    Emax=       10 TeV
```

Option 4

```
msc:   for e-    SubType= 10
      RangeFactor= 0.02, stepLimitType: 3, latDisplacement: 1, skin= 1, geomFactor= 2.5
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
            UrbanMsc :  Emin=        0 eV    Emax=      100 MeV  Table with 120 bins Emin=    100 eV    Emax=    100 MeV
        WentzelVIUni :  Emin=      100 MeV   Emax=       10 TeV  Table with 100 bins Emin=    100 MeV   Emax=     10 TeV
```

```
eIoni:   for  e-    SubType= 2
      dE/dx and range tables from 100 eV  to 10 TeV in 220 bins
      Lambda tables from threshold to 10 TeV, 20 bins per decade, spline: 1
      finalRange(mm)= 0.1, dRoverRange= 0.2, integral: 1, fluct: 1, linLossLimit= 0.01
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
             PenIoni :  Emin=        0 eV    Emax=        1 MeV
        MollerBhabha :  Emin=        1 MeV   Emax=       10 TeV   deltaVI
```

```
CoulombScat:   for  e-, integral: 1     SubType= 1  BuildTable= 1
      Lambda table from 100 MeV to 10 TeV, 20 bins per decade, spline: 1
      180 < Theta(degree) < 180; pLimit(GeV^1)= 0.139531
      ===== EM models for the G4Region  DefaultRegionForTheWorld ======
  eCoulombScattering :  Emin=      100 MeV   Emax=       10 TeV
```

Multiple scattering studies

Nuclear Inst, and Methods in Physics Research B 425 (2018) 18–25

Electron backscattering simulation in Geant4

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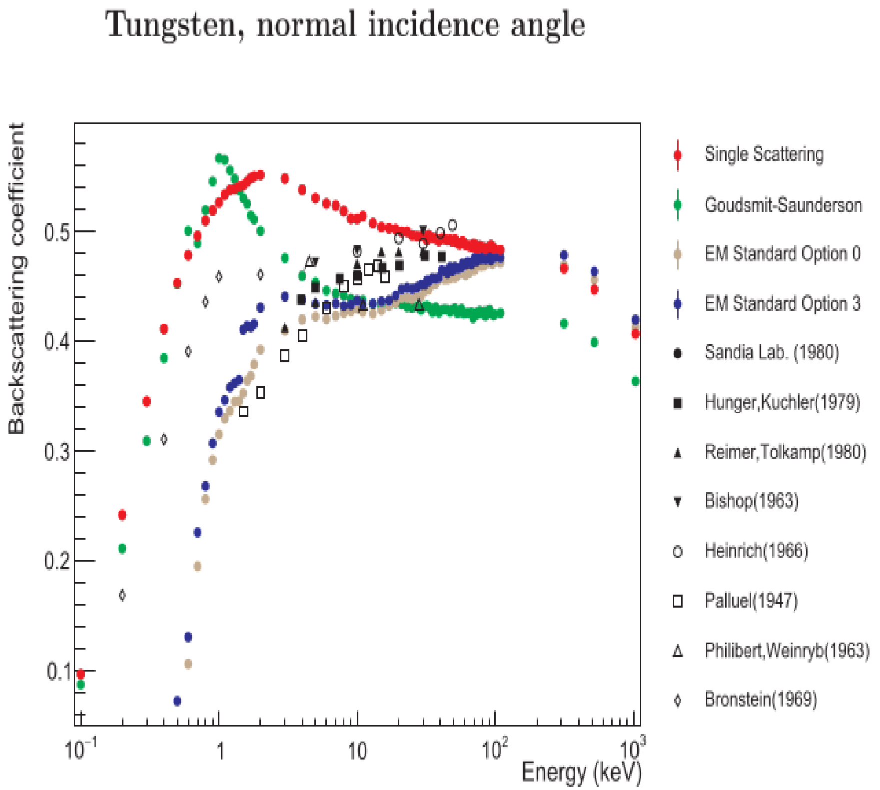

Fig. 8. Geant4 simulations using different standard electromagnetic physics lists are compared with respect to the experimental datasets reported in Table 1 at normal incidence angle using Si (upper figure), and Tungsten (lower figure) as a target. The lowest electron energy was set to 50 eV.

Multiple scattering studies

Nuclear Instruments and Methods in Physics Research B73 (1993) 447–473
North-Holland

NIM B
Beam Interactions with Materials & Atoms

On the theory and simulation of multiple elastic scattering of electrons

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We shall consider mixed simulation procedures in which "hard" collisions, with scattering angle χ larger than a given value χ_S, are individually simulated and soft collisions (with $\chi < \chi_S$) are described by means of a multiple scattering approach. It is clear that, by selecting a conveniently large value for the cutoff angle χ_S, the number of hard collisions per electron track can be made small enough to allow their detailed simulation. As the fluctuations in the spatial displacement after a path length s are mainly due to hard collisions, a mixed procedure (with a suitably small value of χ_S) will yield spatial distributions that are considerably more accurate than those from a conventional condensed simulation. Although

Test of tracks end points

Distribution of track end points