Possible Luxe studies with Test Beam

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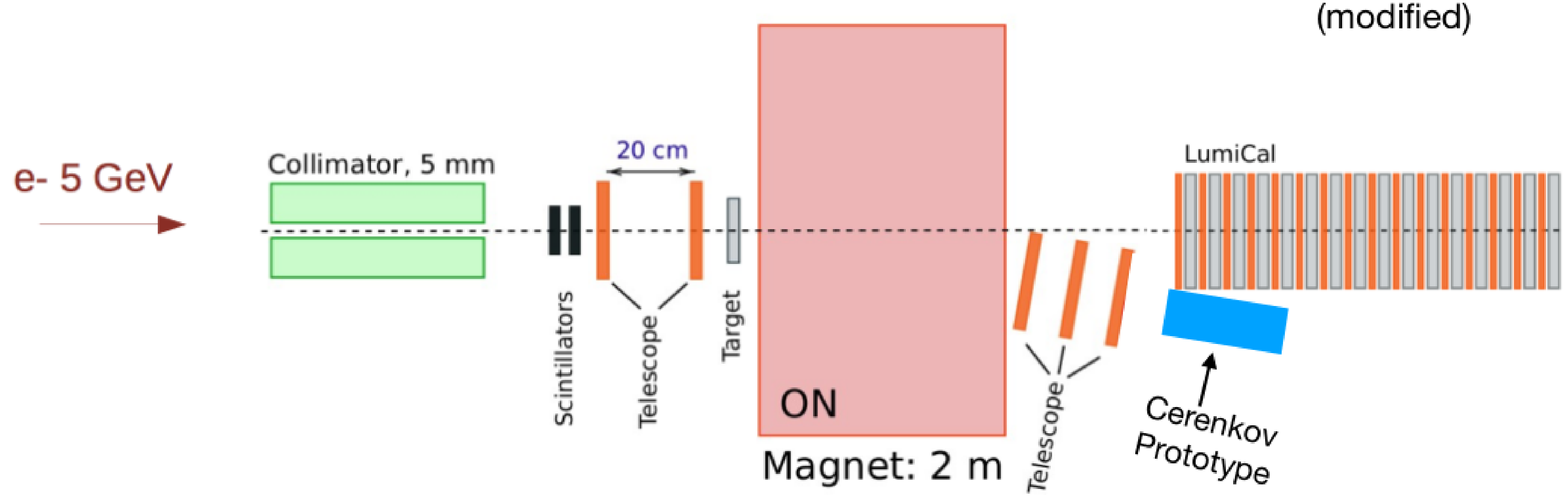
Outline

- Introduction
- Possible LUXE study with FCAL TB:
  - Cherenkov detector;
  - Inclined tracks;
  - Photons.

Chrencov Detector Test as Presented by Ruth Jacobs at 43-th HW meeting (11.12.19)

Proposed TB setup

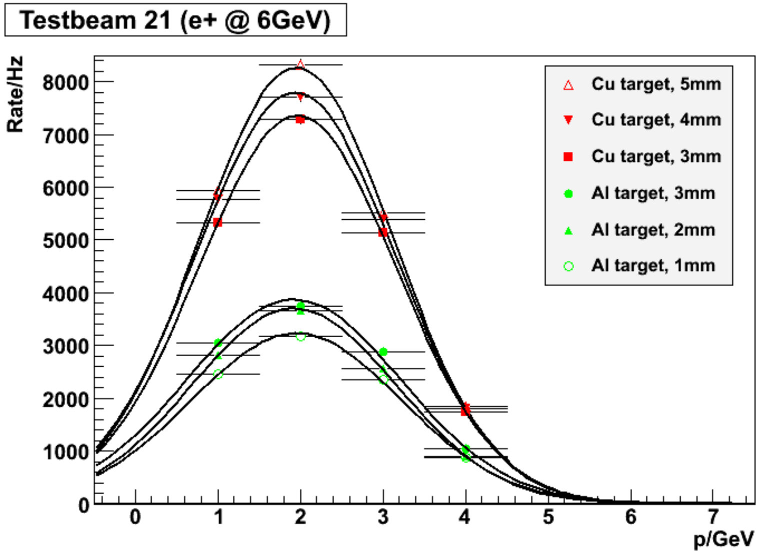


- when LumiCal is measuring photons, could measure electrons
- place prototype behind Alpide telescope and synchronize
  → high-resolution spatial information from telescope,
  study detector response as function of electron position and angle
- interesting electron energy range: anything above 10MeV (gas threshold) works
- prototype: two channels of 8.5x8.5 mm^2 , total acceptance: 17x8.5 mm^2
  → expected electron energy range covered: $\Delta E \sim 1.1$ GeV

DESY.

Test beam line T21

- The rate when taking data with ALPIDE telescope in tb2019 was about 800 Hz for 5 GeV;
- ~20 minutes for 1M events;
- It was probably limited by the beam rate;
- For lower energies (3GeV), which are also good for Cherenkov test, the rate can be higher;
- ALPIDE designed for 200kHz p-p collisions at LHC;
- Few hours would be enough to collect substantial data for Cherenkov prototype when running with just the telescope;
- Simple setup with just two subsystems.



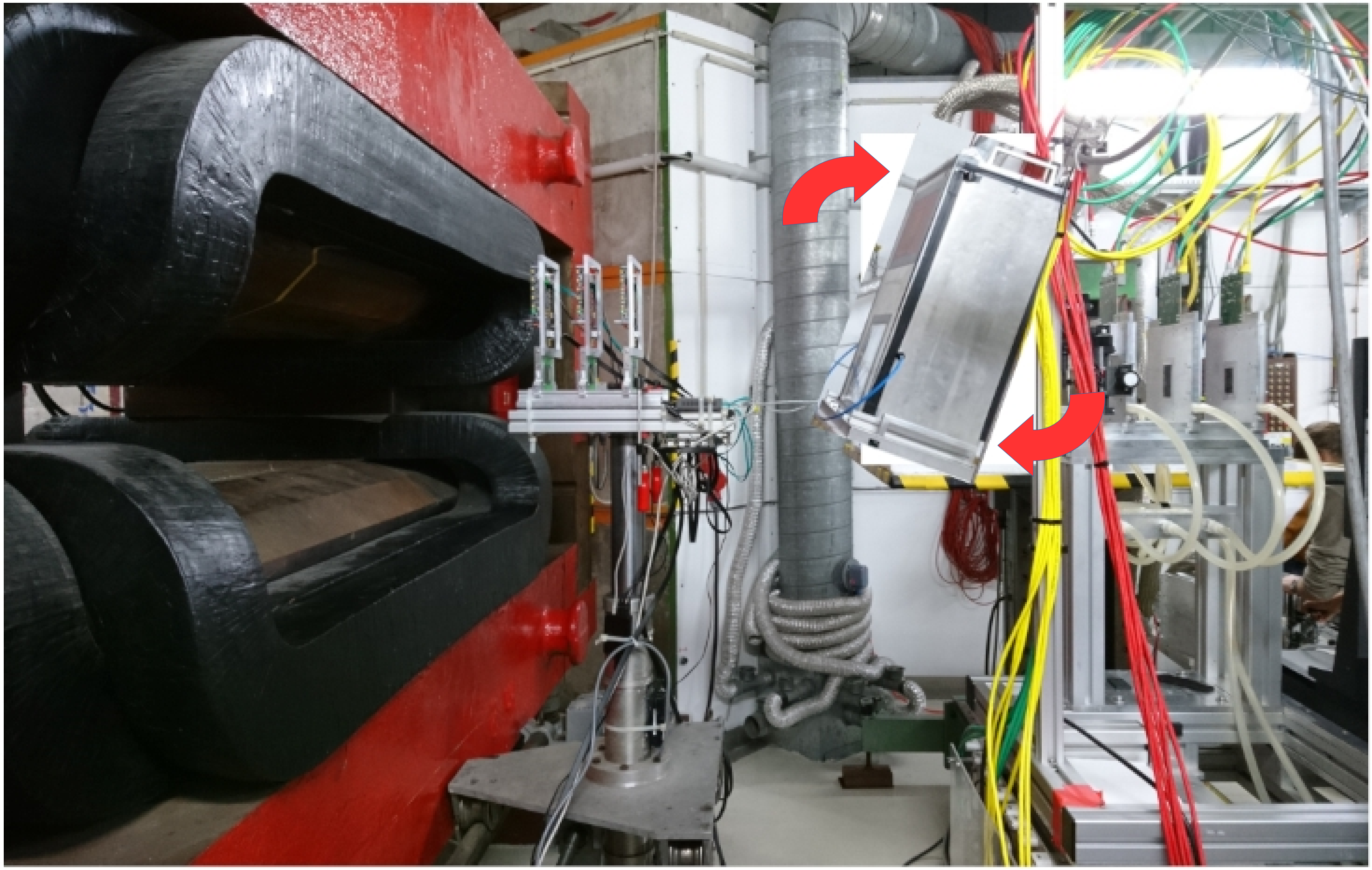
The rates vs momentum

Estimated Rates

Rates	Target 1	Target 2
Energy	3mm Cu	1mm Cu
1 GeV	~3 kHz	~1 kHz
2 GeV	~5 kHz	~1.5 kHz
3 GeV	~4.5 kHz	~1.2 kHz
5 GeV	~15Hz (6GeV in DESY II) - 600 Hz (7GeV in DESY II)	~3Hz (6GeV in DESY II) - 200 Hz (7GeV in DESY II)
6 GeV	~3 Hz (7GeV in DESY II)	~1 Hz (7GeV in DESY II)

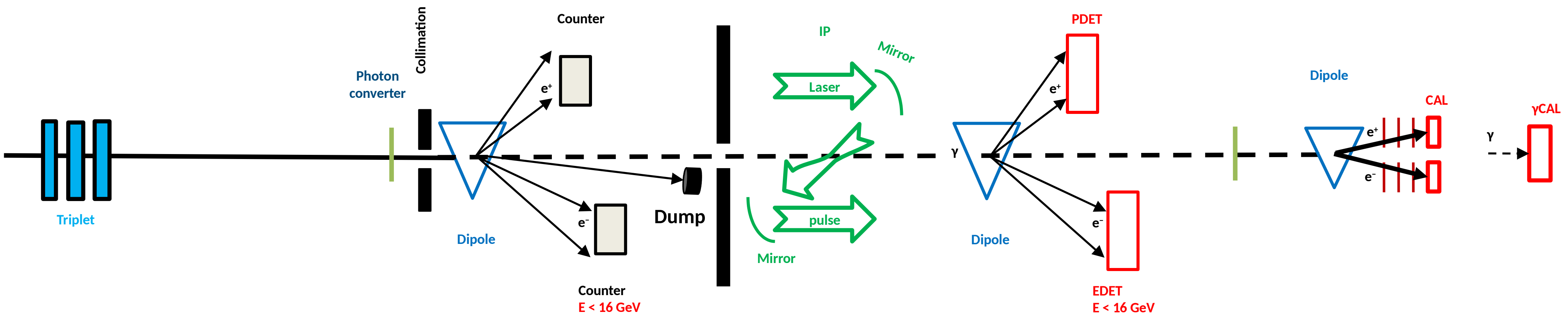
Inclined Tracks in LumiCal

- Test position reconstruction with inclined tracks ?
- Rotate LumiCal around X axis;
- Might be interesting both for LUXE (tracks after the magnet) and for ILD.



LUXE Setup for Photon Laser collisions

Photon-Photon collisions at LUXE



$$\gamma + n\omega \rightarrow e^+e^-$$

One photon pair production (OPPP) at ultra high intensity - non-perturbative physics

<u>European XFEL electron beam:</u>

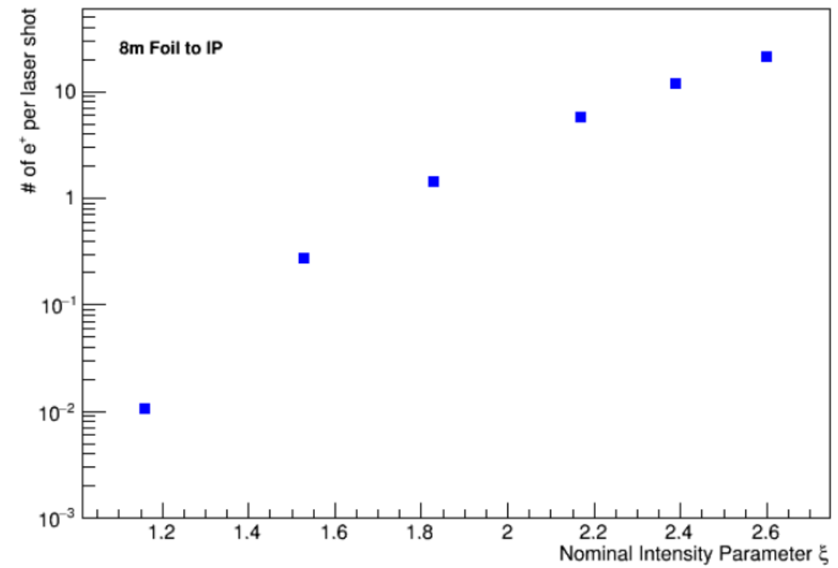
- Energy 17.5 GeV (also possible 10 GeV and 14 GeV);
- Normalized emittance 1.4 mm mrad;
- Repetition rate 10 Hz.

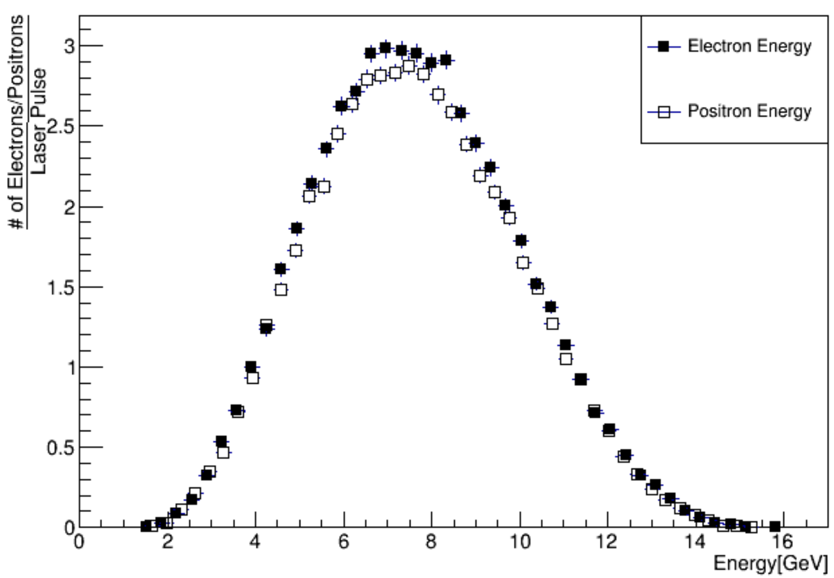
<u>Photons are produced by collisions of XFEL electron beam with tungsten target</u>

One Photon Pair Production in MC

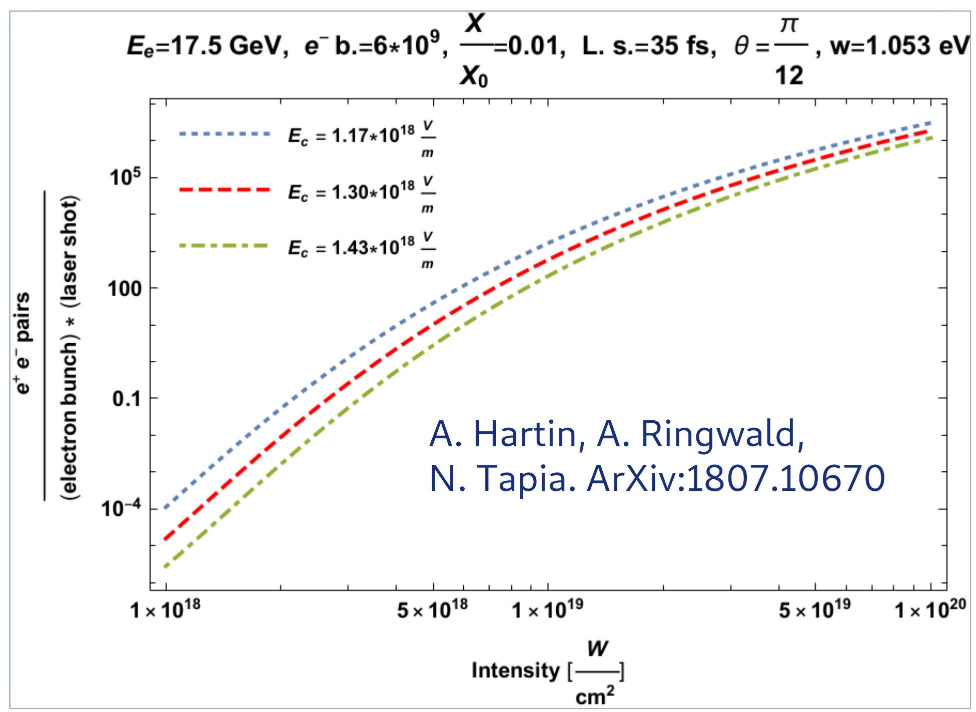
- The rate is up to ~100 e-e+ pairs per one bunch-laser interaction;
- The energy spectra peak at 7 GeV;
- Spectrometer:
  - 1.4T magnet of 1m length;
  - Pixel detector (100 x 100 μm^2 pixel) located 1m away from the magnet;
  - Detection efficiency ~99%.
- **Background and energy resolution to be studied !**

OPPP rate





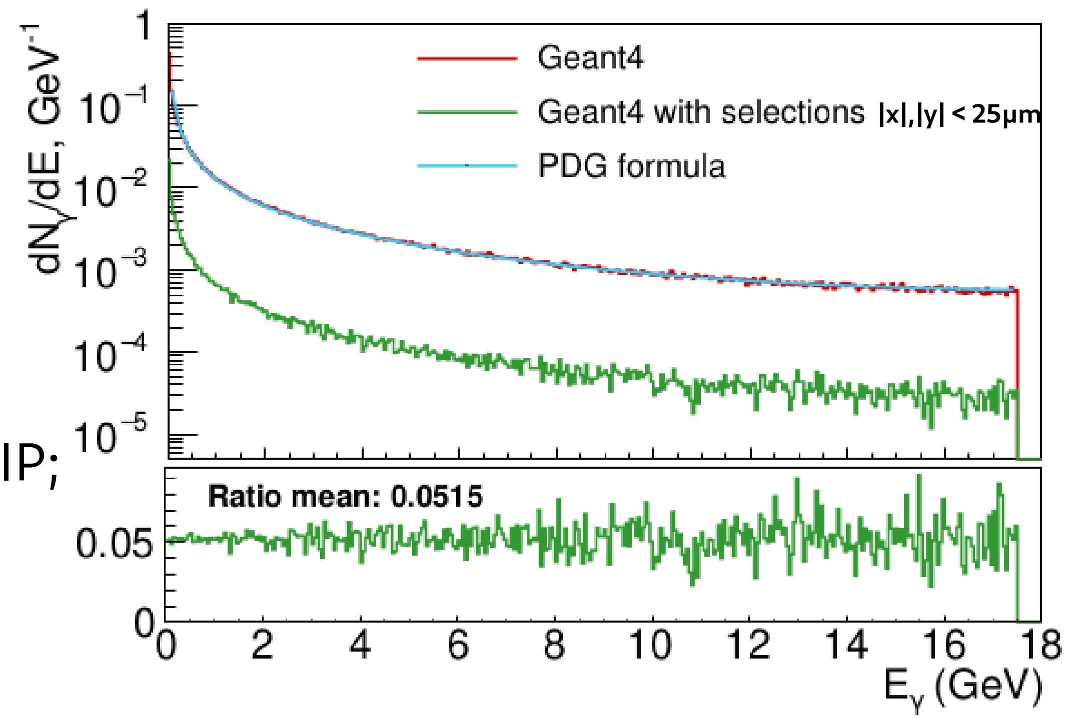
OPPP e-, e+ spectra



Bremsstrahlung Production in Simulation

Bremsstrahlung production
(complete screening, thin target):

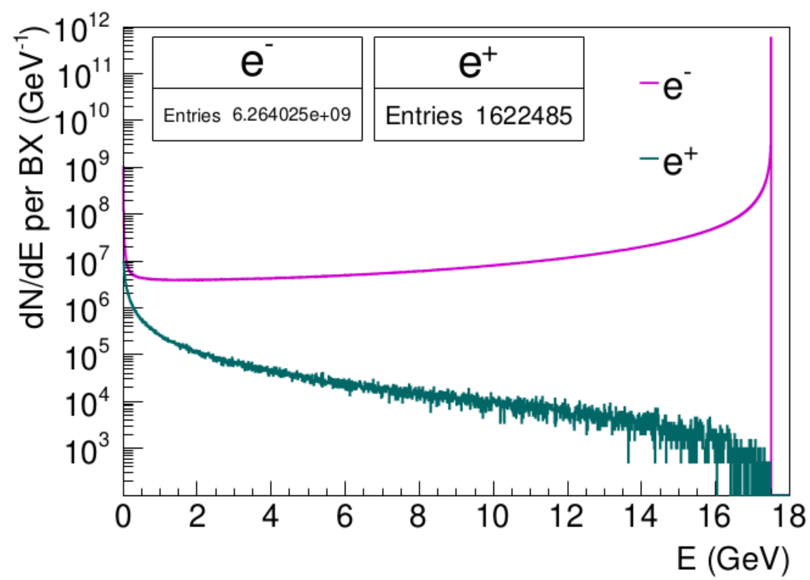
$$\omega_i \frac{\mathrm{d}N_\gamma}{\mathrm{d}\omega_i} \approx \left[\frac{4}{3} - \frac{4}{3}\left(\frac{\omega_i}{E_e}\right) + \left(\frac{\omega_i}{E_e}\right)^2\right]\frac{X}{X_0}$$



- Gaussian beam;
- Tungsten target 1%X0 (35μm), 2m from IP;
- Two histograms are compared:
  - |x| < 1mm and |y| < 1mm (read);
  - |x| < 25μm and |y| < 25μm (green).

- Electrons and positrons observed in forward area behind the target (θ<17°) for one BX.

N e-	6.26E+09
N e-, < 16 GeV	1.80E+08
N e+	1.62E+06



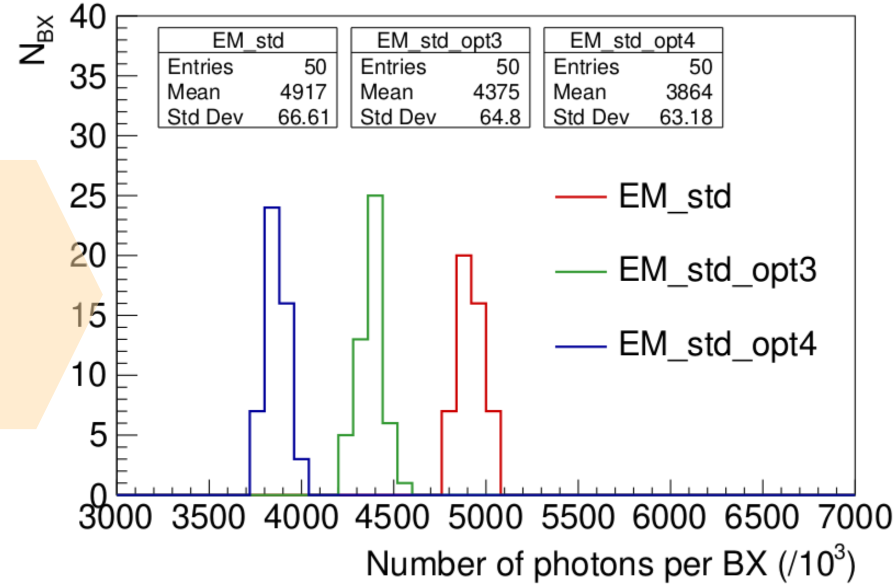
- Can be measured to monitor number of photons.

Geant4 simulation with 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.

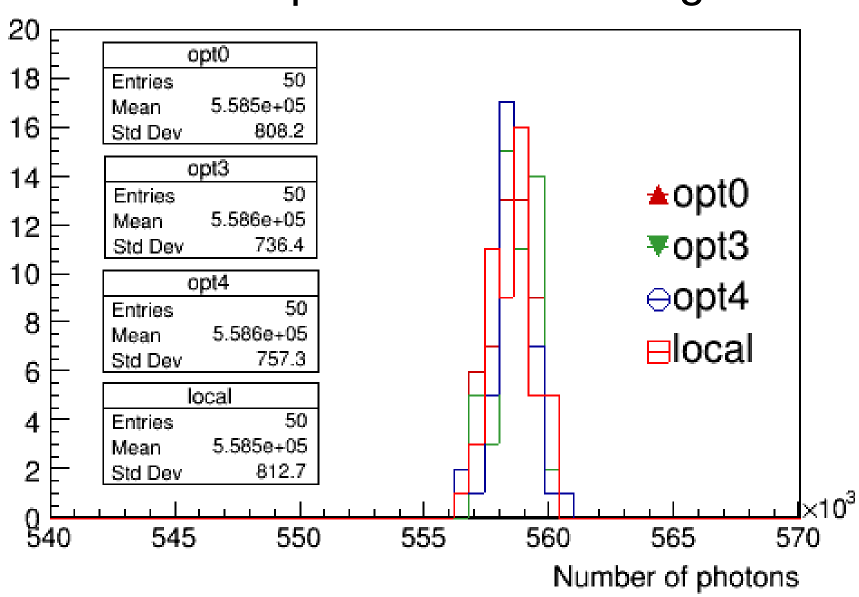
Different physics lists

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

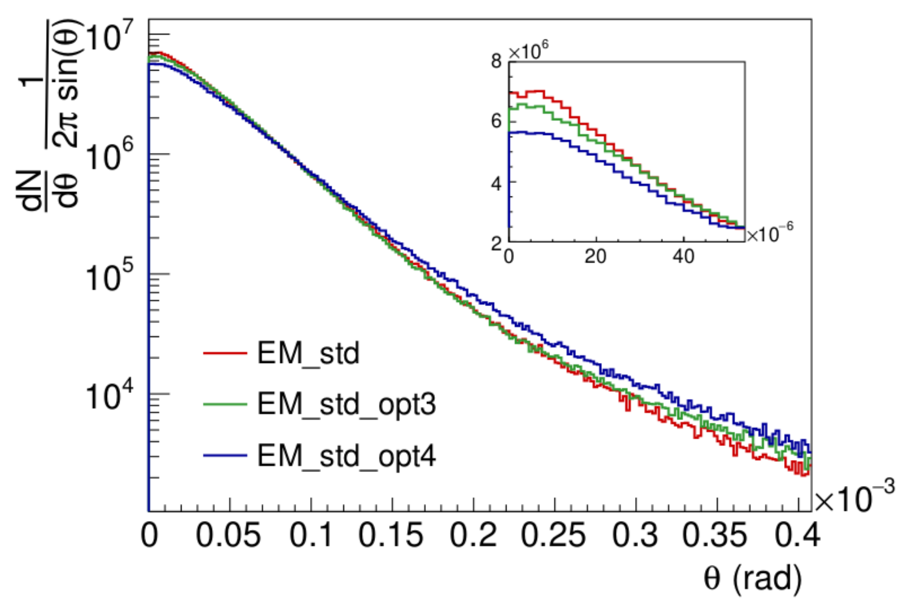


- Angular distribution is the widest for option_4 physics list and the narrowest for option_0.
- Total number of photons in forward region is identical for all physics lists.

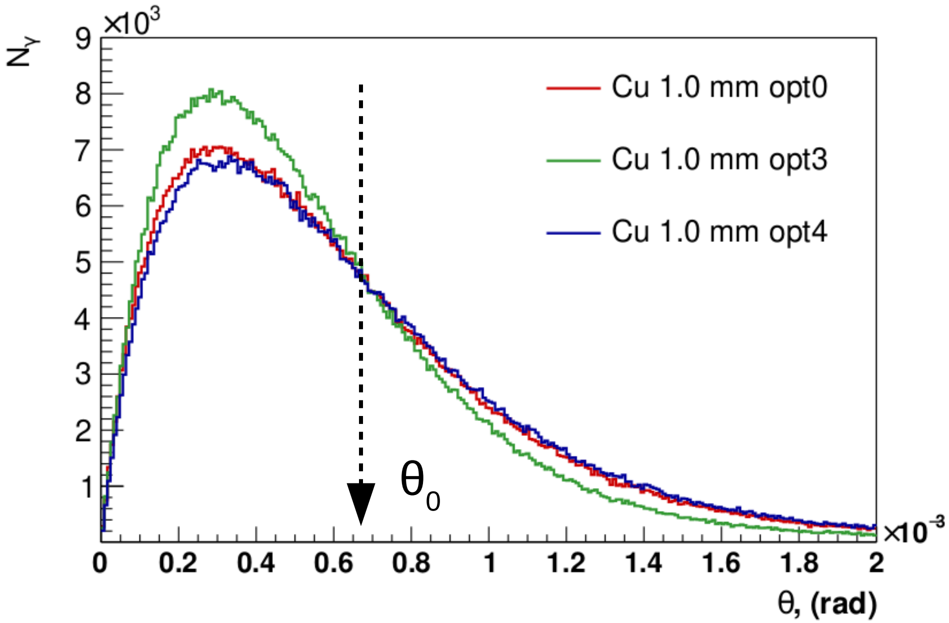
Number of photons in wide rage of θ

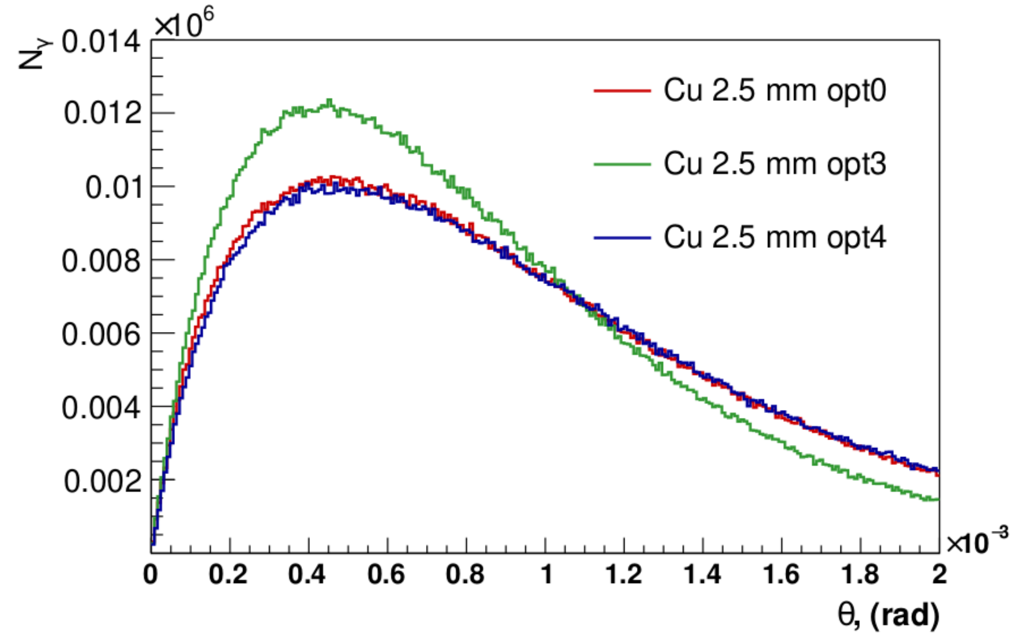


Angular distribution of photons



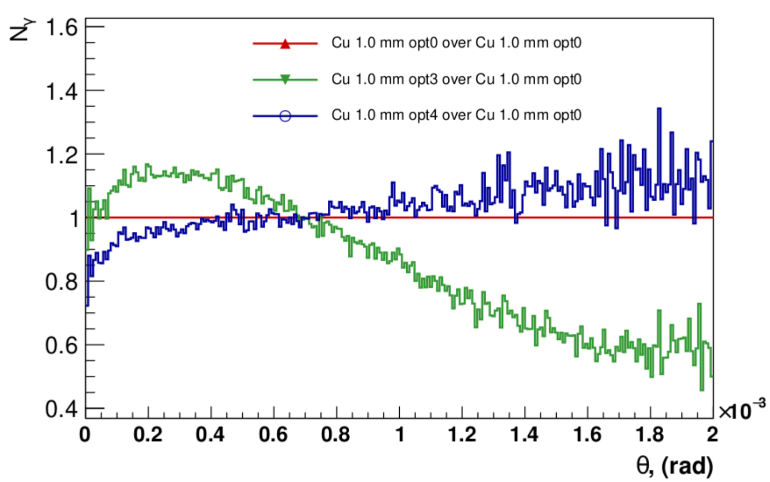
Copper targets 1 mm and 2.5 mm. Photons

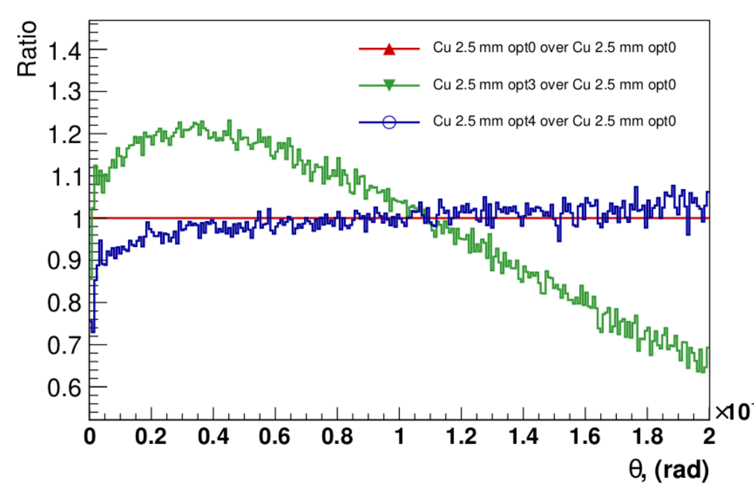




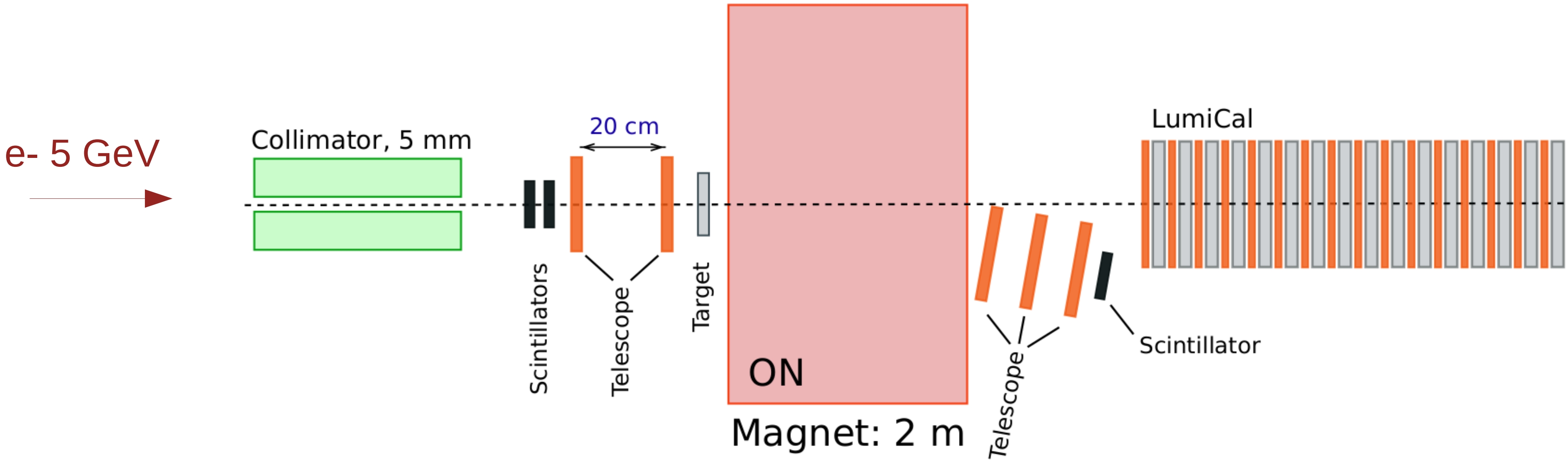
$$\frac{\int_{0} N(\theta)\,d\theta}{\int_{\theta_0}^{1.8\times10^{-3}} N(\theta)\,d\theta}$$

Test the ratio





Setup



- Target: tungsten 0.1 mm (3%X0) or Copper
- Measure bremsstruhlung photon angular distribution;
- Measure bremsstruhlung spectrum;
- Telescope sensor (size 30 x 15 mm^2) covers electron range ~2 GeV;

Number of secondaries per event

Material	Thickness (mm)	Gammas	electrons	positrons	rms proj angle (mrad)
W	0.1	0.3275	0.9524	0.001826	0.4152
W	0.2	0.6722	1.986	0.007265	0.6171
W	0.3	1.029	3.081	0.01666	0.7801
Cu	1	0.9346	11.54	0.01125	0.6802
Cu	1.5	1.403	17.82	0.02469	0.864
Cu	2.5	2.458	31.34	0.06611	1.171

Summary

- Consider the possibility to test the Cherenkov prototype separately when LumiCal will be disassembled in the end or in the very beginning.
- Test position reconstruction for inclined tracks?
- Bremsstrahlung photons angular distribution and spectrum measurements:
  - Detailed study in simulation to check the possibility and optimize the setup in the soonest time.

Beam position after the magnet

```
R[Ee_] = Sqrt[Ee^2 - me^2] / (clight * B)
```

$$\frac{\sqrt{Ee^2 - me^2}}{B\, clight}$$

```
S[Ee_] = R[Ee] - Sqrt[R[Ee]^2 - zm^2]
```

$$\frac{\sqrt{Ee^2 - me^2}}{B\, clight} - \sqrt{\frac{Ee^2 - me^2}{B^2\, clight^2} - zm^2}$$

```
sint[Ee_] = zm / R[Ee]
```

$$\frac{B\, clight\, zm}{\sqrt{Ee^2 - me^2}}$$

```
tgt[Ee_] = sint[Ee] / Sqrt[1 - sint[Ee]^2]
```

$$\frac{B\, clight\, zm}{\sqrt{Ee^2 - me^2}\sqrt{1 - \frac{B^2\, clight^2\, zm^2}{Ee^2 - me^2}}}$$

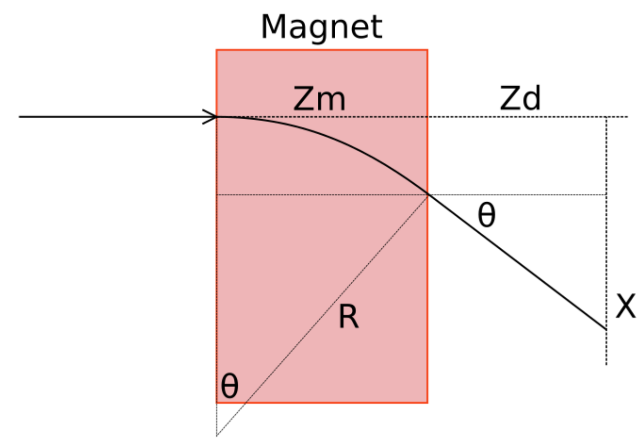
```
xd [Ee_] = S[Ee] + zd * tgt[Ee]
```

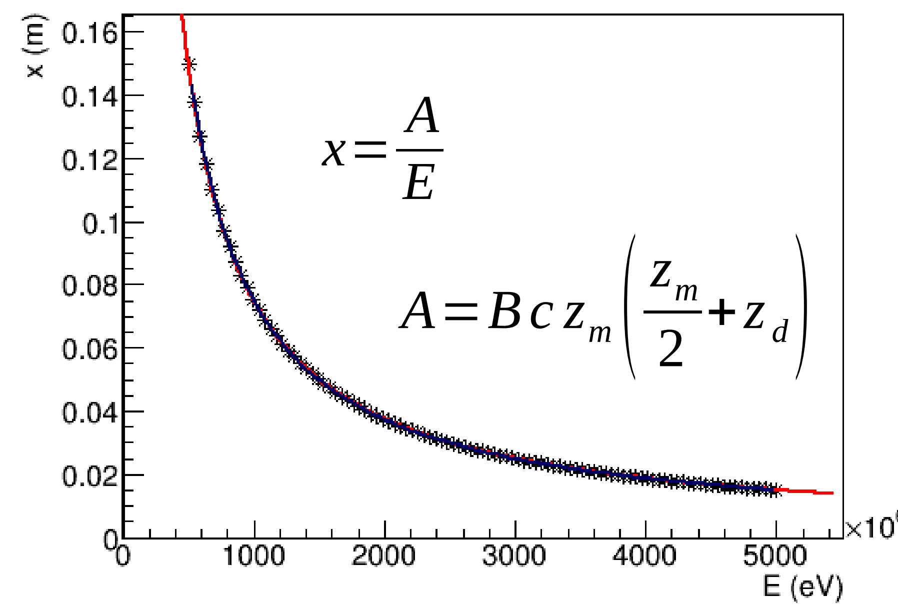
$$\frac{\sqrt{Ee^2 - me^2}}{B\, clight} - \sqrt{\frac{Ee^2 - me^2}{B^2\, clight^2} - zm^2} + \frac{B\, clight\, zd\, zm}{\sqrt{Ee^2 - me^2}\sqrt{1 - \frac{B^2\, clight^2\, zm^2}{Ee^2 - me^2}}}$$

$$E_1 - E_2 = E_1 \frac{\Delta x}{x_1 + \Delta x}$$

5 * 3/(4.5+3) = 2 (GeV)

X_1 is defined by the telescope plane geometry, for ALPIDE it is 4.5 cm.






```
Minimizer is Minuit / Migrad
Chi2                      =   6.30474e-08
NDf                       =           100
Edm                       =   3.34551e-21
NCalls                    =            15
p0                        =   7.4997e+07   +/-   3870.76
B*c*Zm*(Zm/2+Zd): 7.49481e+07
```