High-Energy Photons from Bremsstrahlung

Experimental Data and Simulation

Marius Hoffmann, 18th of June 2020

LUXE and Bremsstrahlung

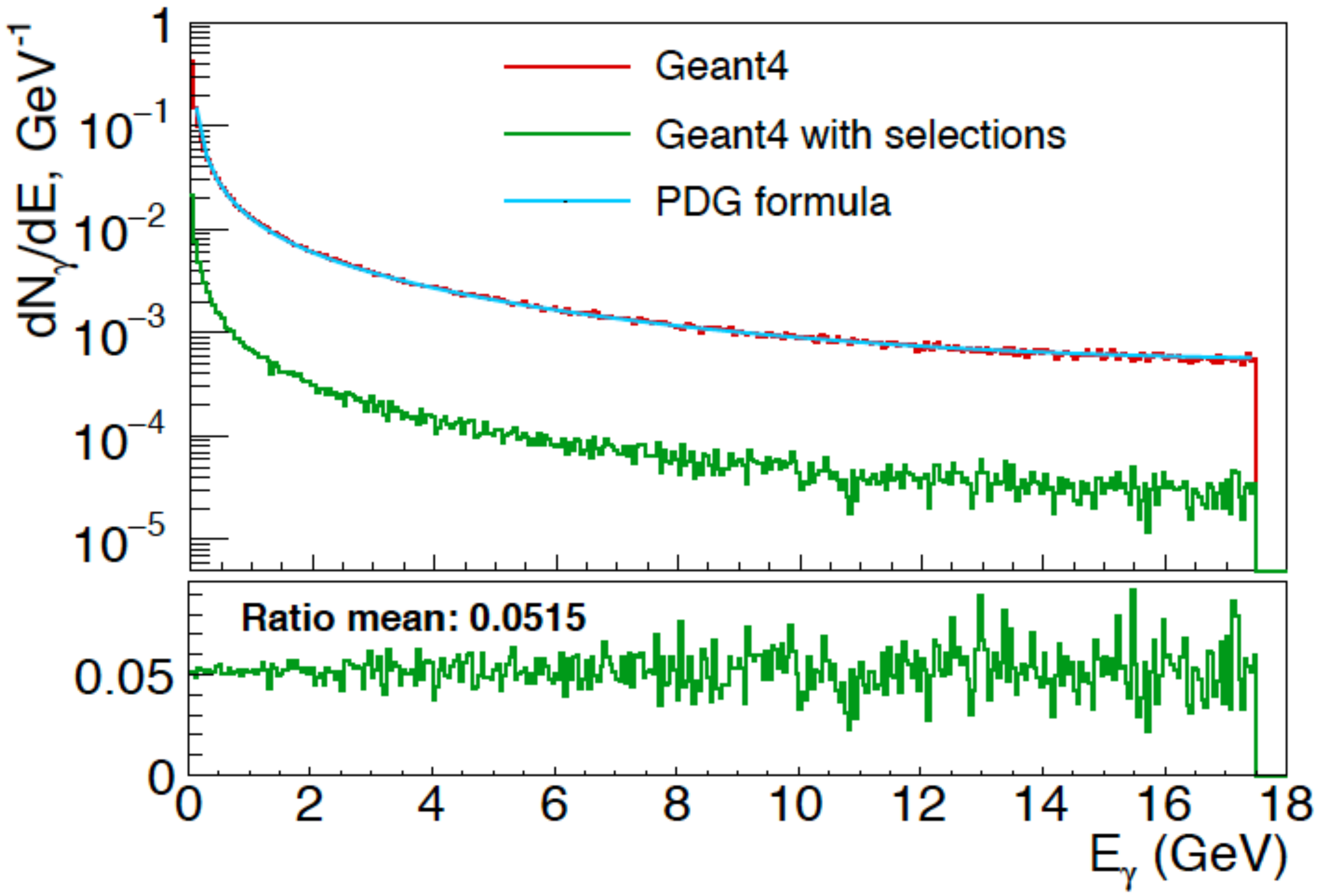
Plan and Simulation

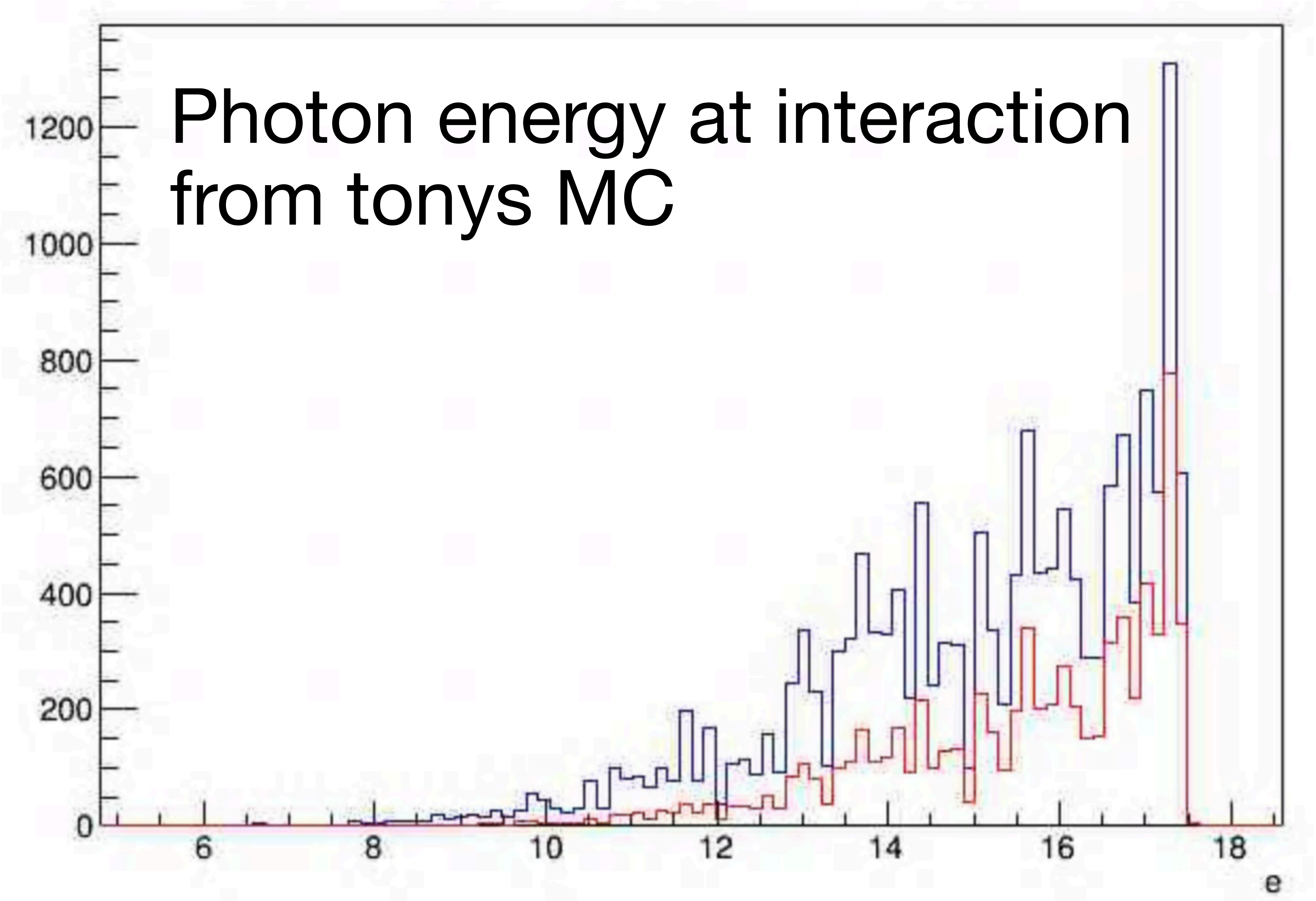
- The Production of the photon beam is planned by using a thin wolfram foil that is is put into the EU.XFEL electron beam, which then produces a photon beam
- The simulation of this beam-foil interaction has been performed by Sasha using GEANT4 which is used as input to the Laser-Beam-Monte-Carlo
- A note put together by Sasha on the Bremsstrahlung can be found in the LUXE internal webpage: [1]
- In this talk I take a look at the experimental validation of GEANT4 for the LUXE case

High-Energy Photons from Bremsstrahlung

- For LUXE, especially the highest energy photons are relevant, as the interaction probability increases with Beam Energy drastically

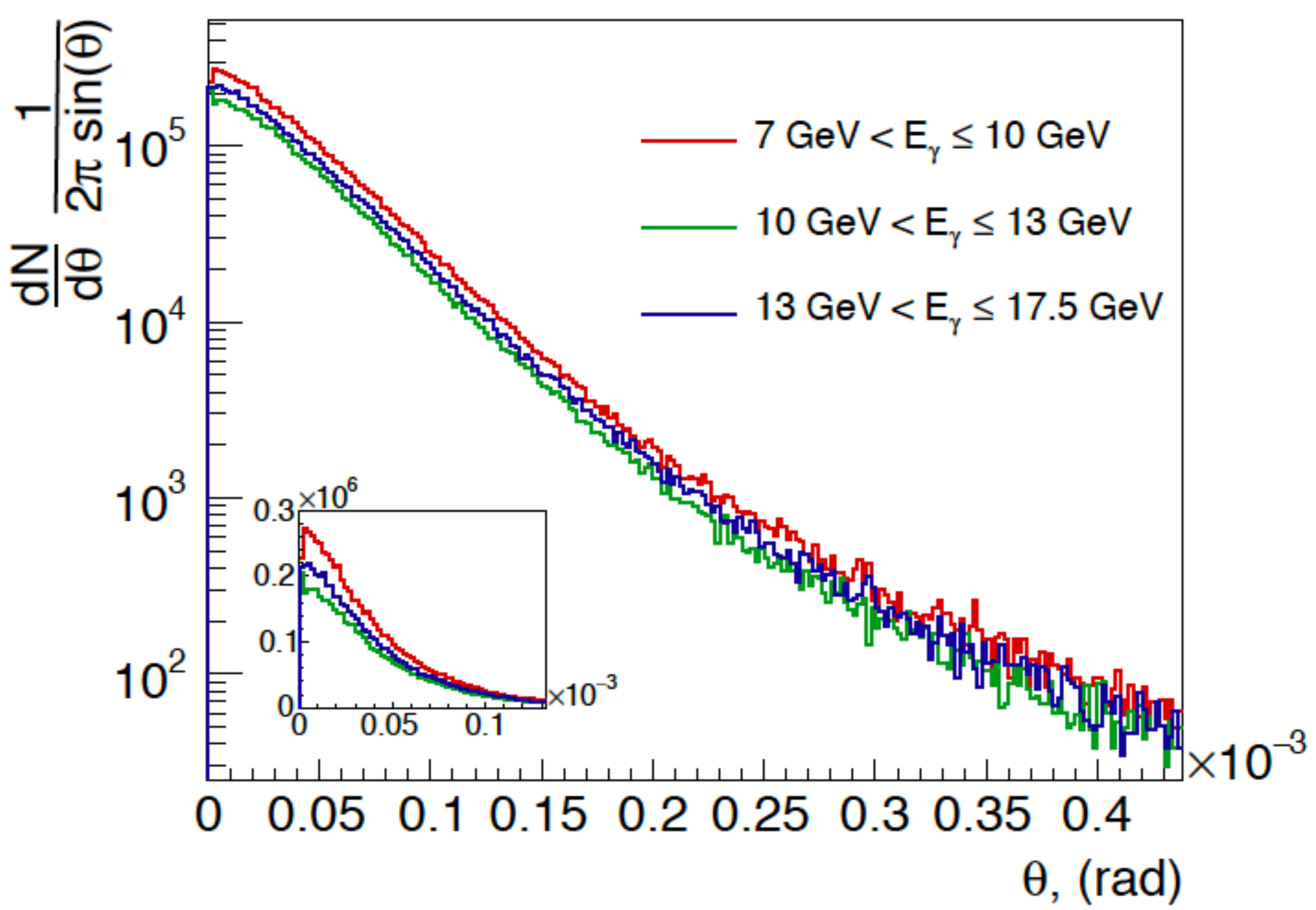
Bremsstrahlung energy spectrum[1]

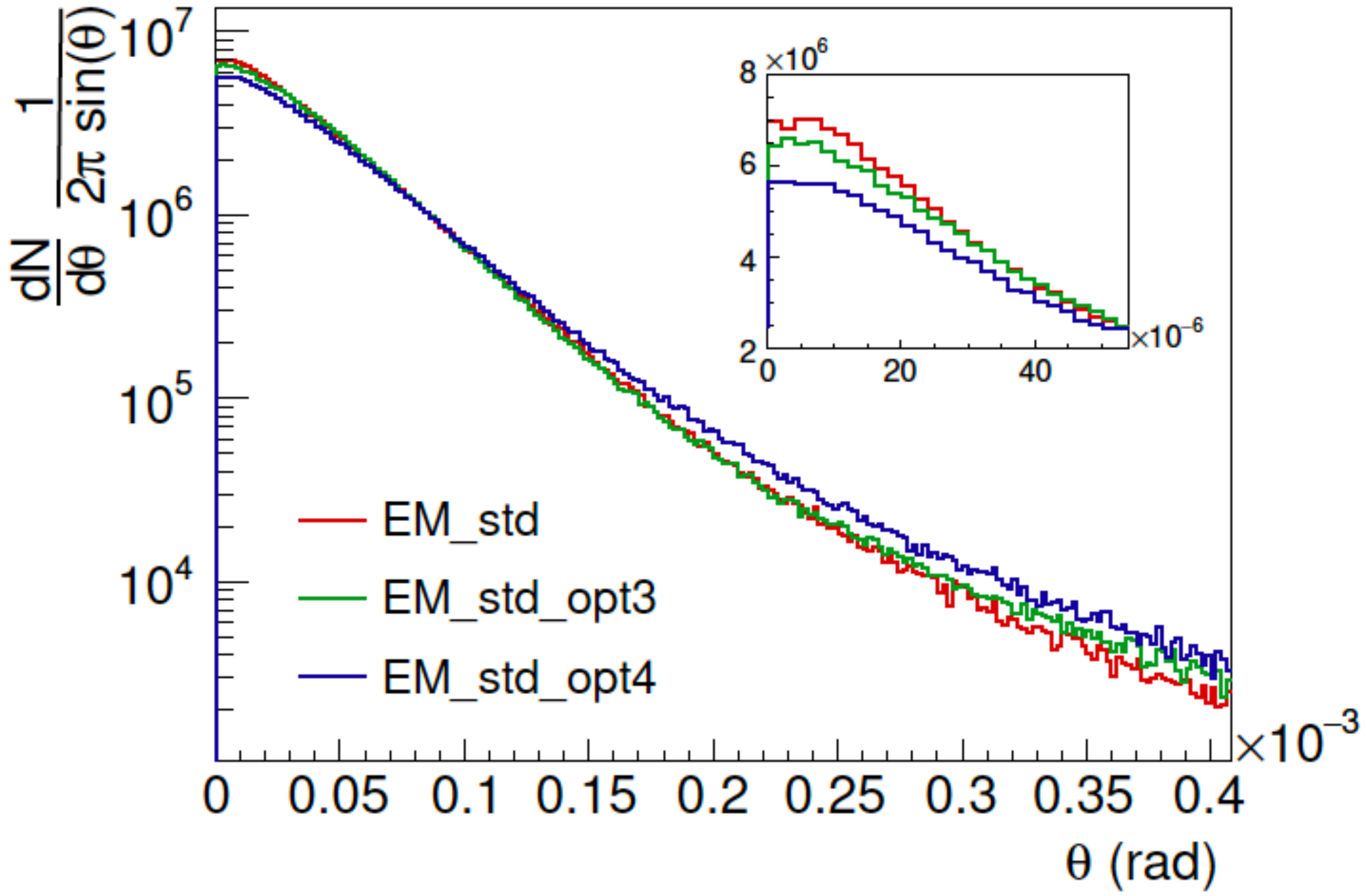




Angular Distribution of the brems-photons

- The angular distribution of the bremsstrahlung is highly relevant as it determines the number of photons in the very small laser interaction region.
- From Sashas studies we already learned that there is differences depending on the physics lists, which yields a systematic error of ~20%





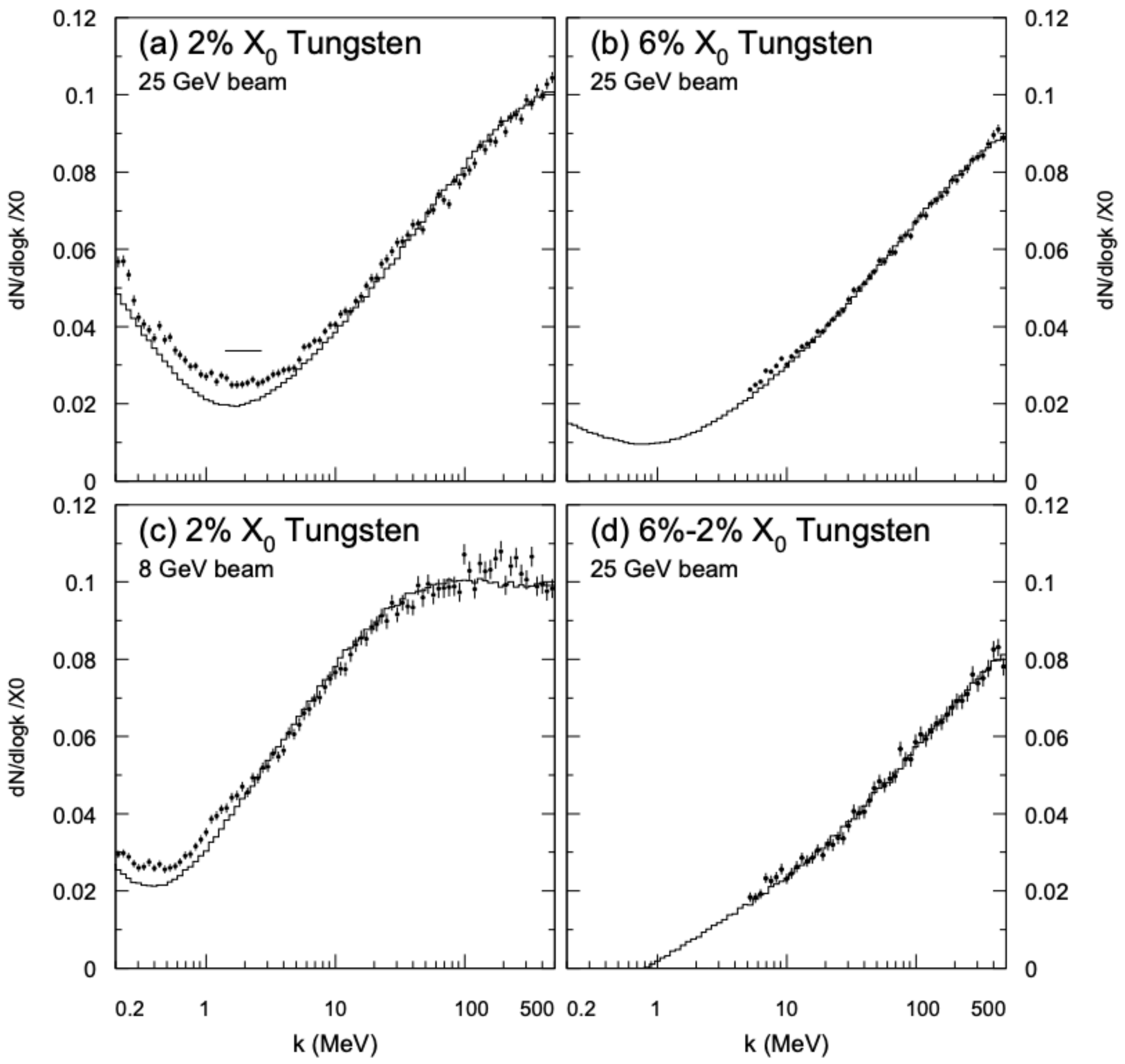
Experimental Situation

Validation of the GEANT4 simulation for high energies

- There is extensive data for photon-electron interaction at low energies 10eV-100MeV [3]
- A description of the validation experiments for high energies can be found at [2]
- Two experiments were conducted: E146 at SLAC and an experiment conducted for even higher energies at CERN SPS

E146
[4]

- Electron Energy: 8 and 25 GeV
- Photon Energies: 200 keV up to 500 MeV
  -> relatively low Energy Transfer
- Data not accessible in https://geant-val.cern.ch/



From [4]

FIG. 9. Measurements and Monte Carlo for our (a) 2% X_0 and (b) 6% X_0 tungsten targets at 25 GeV and (c) 2% X_0 at 8 GeV, while (d) is the result of subtracting (b) from (a). The flattening below 10 MeV is discussed in the text. The straight solid line in (a) between 1.5 and 2.7 MeV is the 'single radiator' calculation.

The experiment studied a very wide range of photon energies, from 200 keV to 500 MeV.

- The range doesn't result from the electron trigger

Electrons with energies below 17.4 (5.8) GeV for 25 (8) GeV beams missed the blocks and were not counted.

- Limitations result from the Calorimeter which consists of BGO crystals with attached photomultipliers that saturate

No Angular resolution!

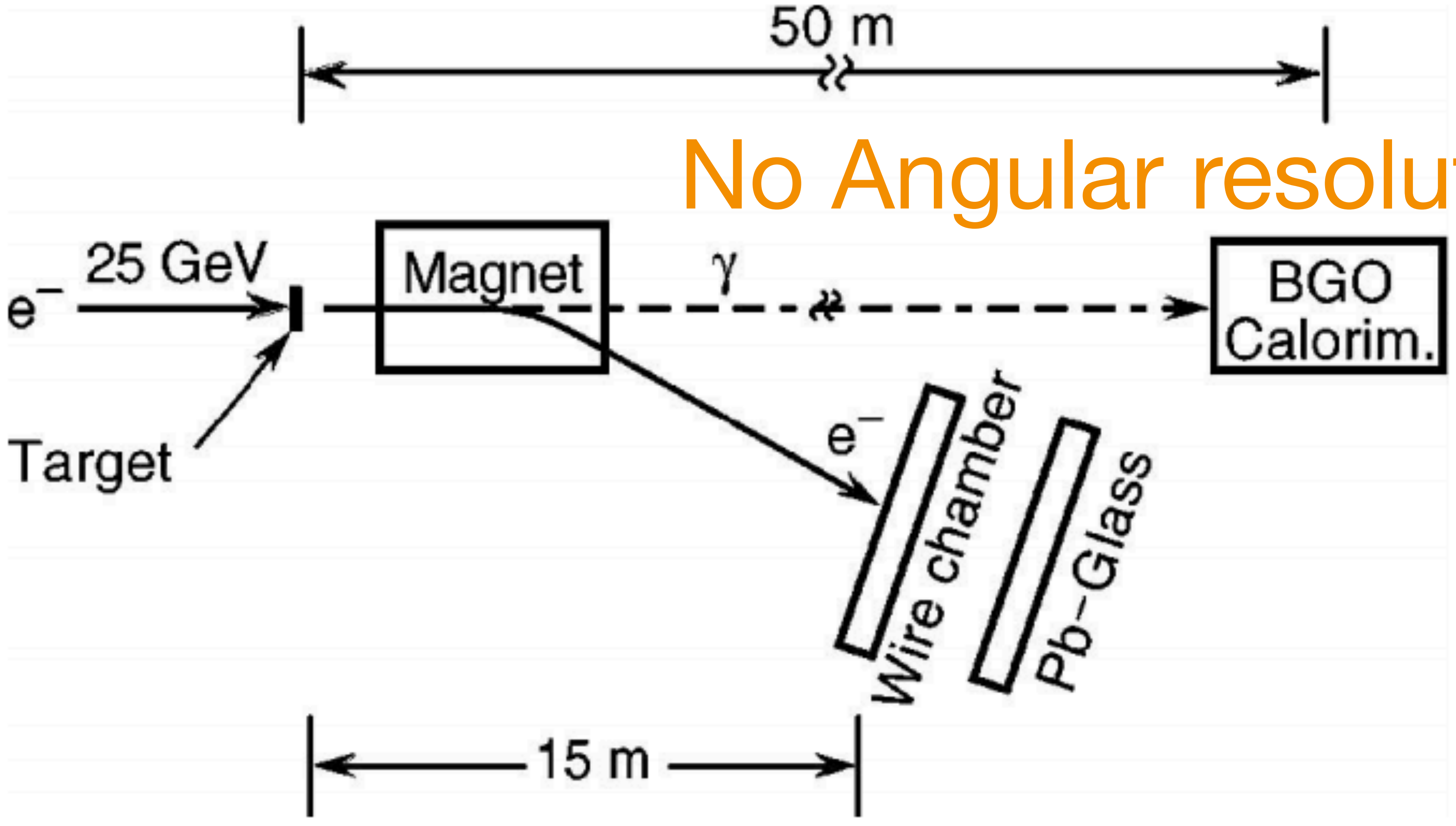


Fig. 1. The Layout of the E-146 experiment at SLAC, more details can be found in [9].

CERN SPS experiment [5]

- Electron Energy: 149 GeV(c), 207 GeV(b), 287 GeV(a)
- Photon Energy: >2 GeV also high energy transfer
- Tantalum has periodic Number 73, Wolfram 74
- Peak at high energy transfer

From [5]

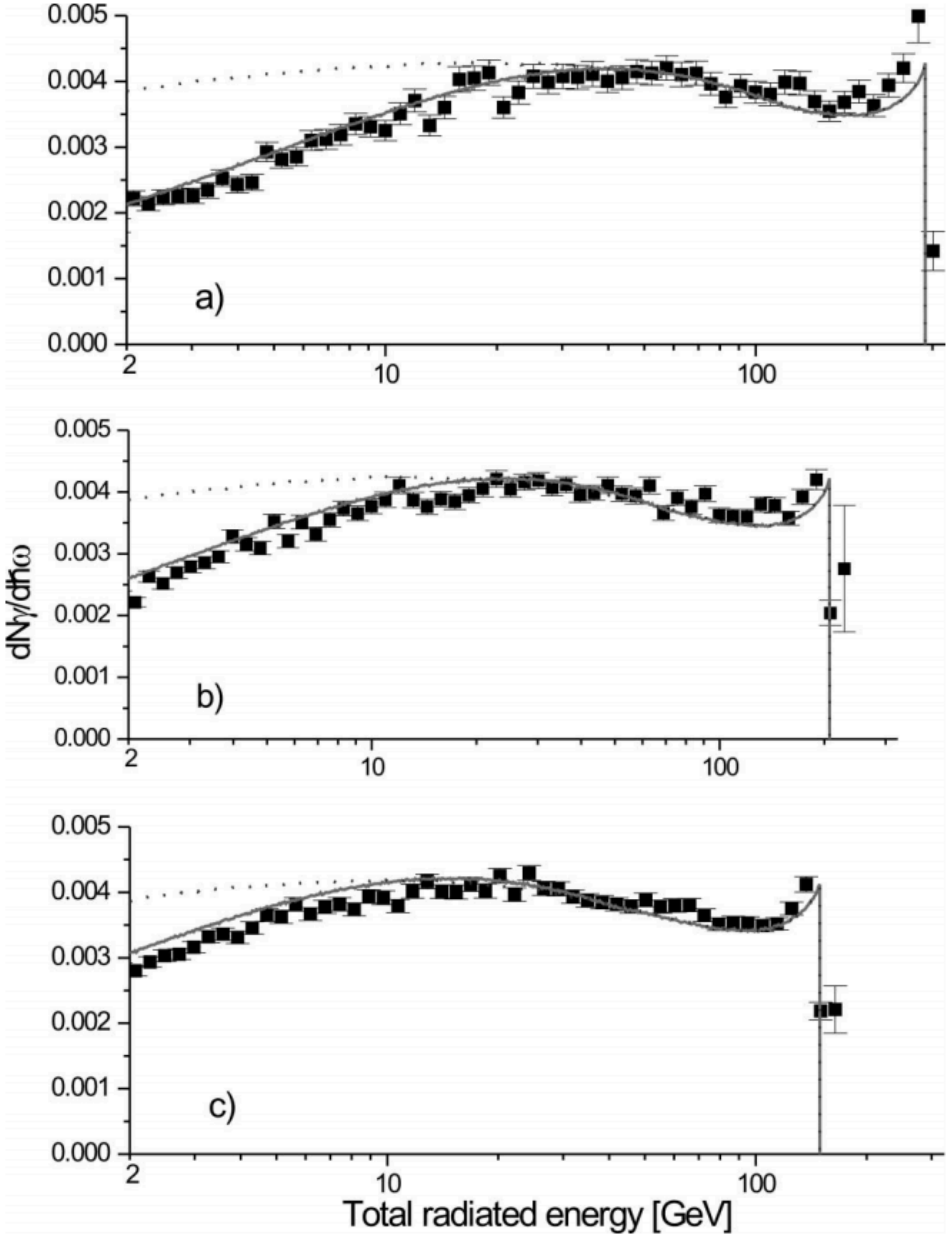


FIG. 10. As Fig. 9, but for tantalum.

SPS Setup

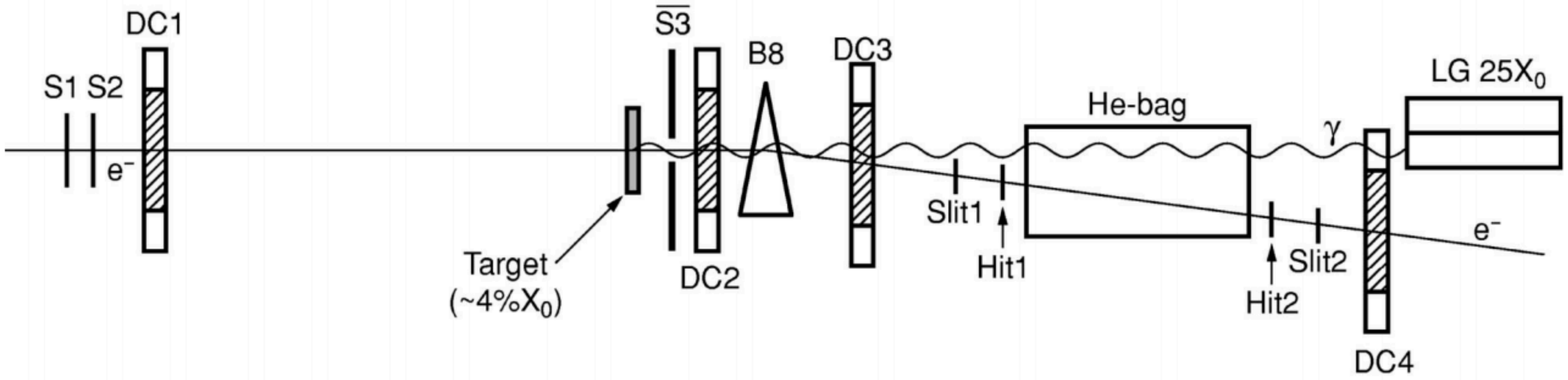


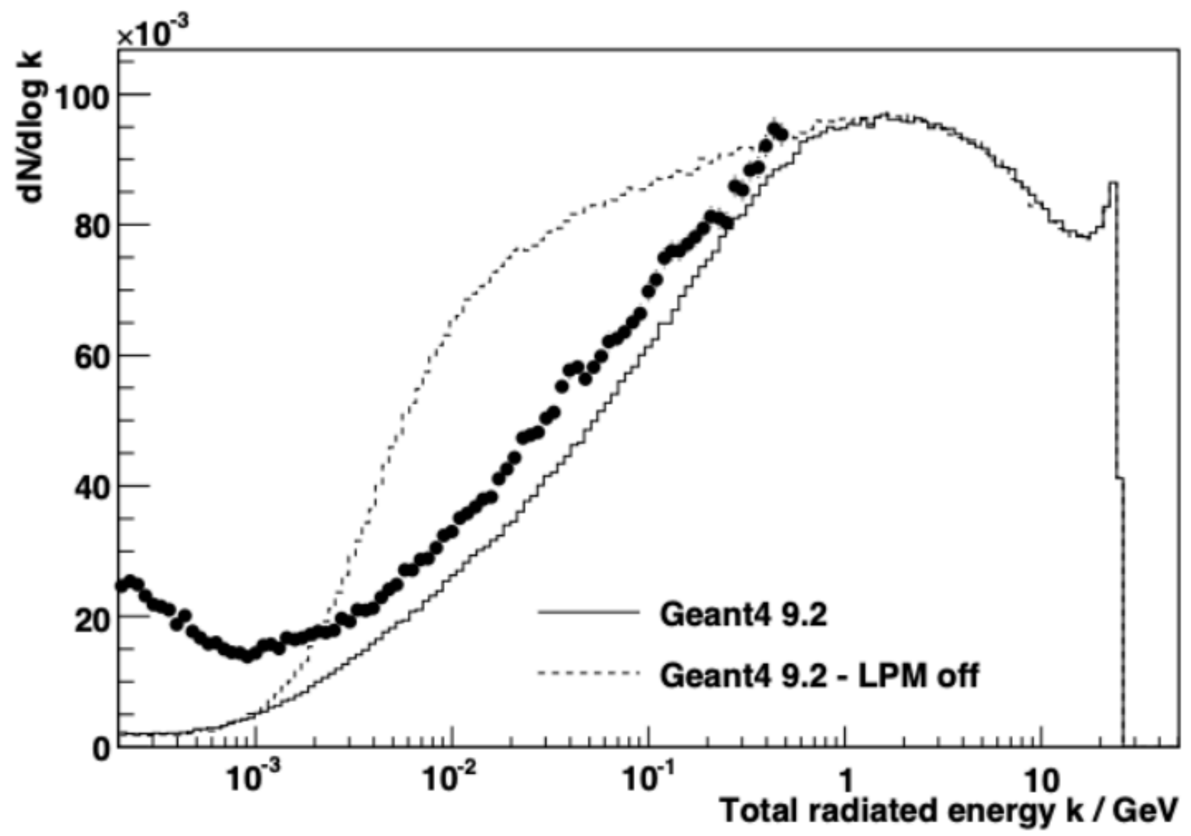
FIG. 2. A schematical drawing of the setup used in the CERN LPM experiment. Not to scale.

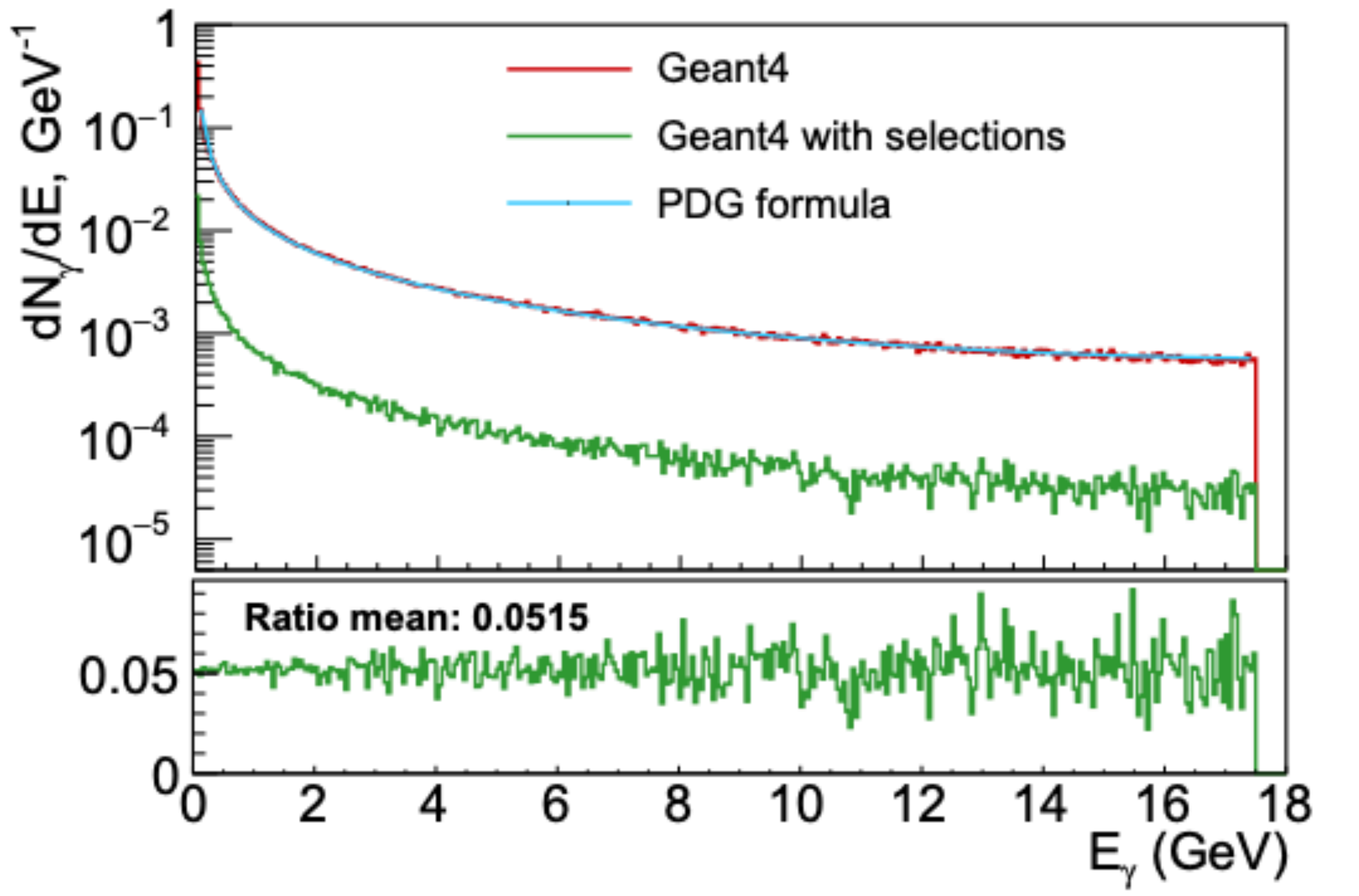
Good angular resolution for the electron (10 murad),
but non for the photon beam.

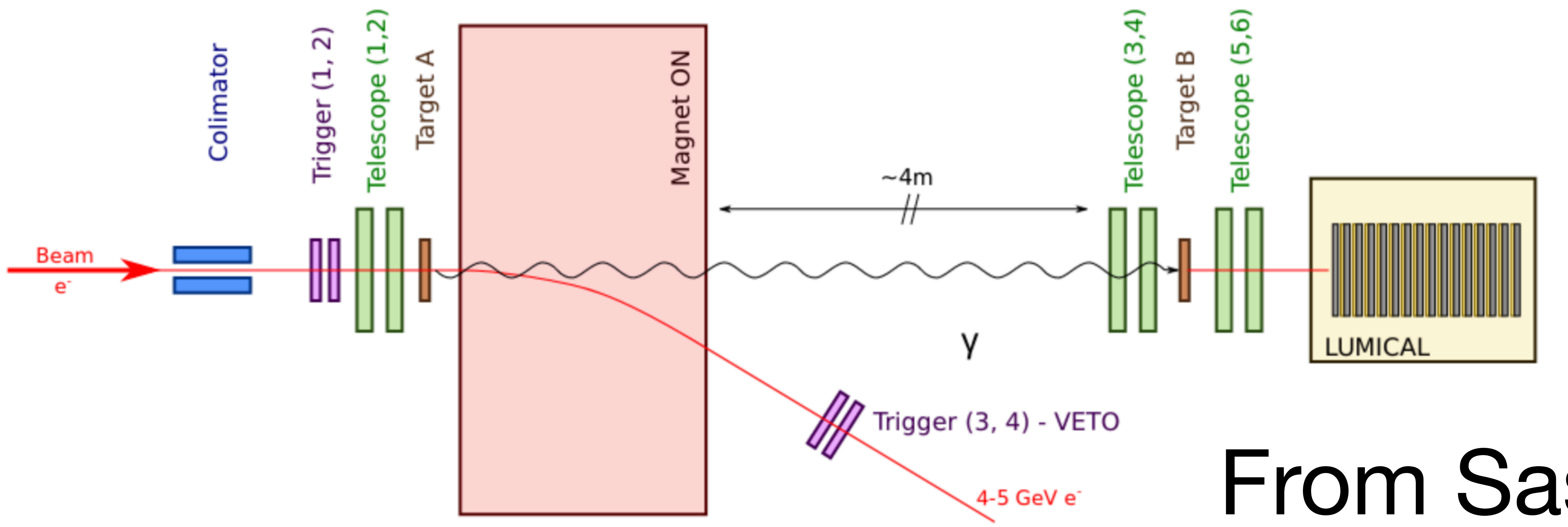
Spectrometer used is a lead-glass crystal calorimeter

March Testbeam

- Comparable setup
- Simulation look quite different







From Sashas talk

Figure 4: Comparison of bremsstrahlung spectra obtained from equation (3.1) and with GEANT4 simulation for a tungsten target of 35 μm (1%X_0) thickness. Green line shows the γ spectrum after imposing limits on position in the transverse plane to ± 25 μm which corresponds to the transverse size of the interaction area. The bottom plot shows the fraction limited by the interaction area.

Summary

- GEANT4 Validation Data for LUXE energy range only contains low energy transfer events
- For higher energies O(150 GeV) high energy data is also well described
- Missing
    - Validation of angular photon spectrum for high energy electrons
    - Therefore also information on dependence of angular distribution on energy.
- We already started our own effort to validate this data using the DESY testbeam
- Analysis of the recorded data still needs to be done

Bibliography

- [1] https://luxe.desy.de/sites/sites_desygroups/sites_extern/site_luxe/content/e98447/e98635/e98636/luxe_bremsstrahlung_eng.pdf
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- [4] P.L. Anthony et al., Bremsstrahlung suppression due to the LandauPomeranchuk-Migdal and dielectric effects in a variety of materials, Phys. Rev. D 56 (1997) 1373, SLAC-PUB-7413/LBNL-40054. https://arxiv.org/pdf/hep-ex/9703016.pdf
- [5] H.D. Hansen et al., Landau-Pomeranchuk-Migdal effect for multihundred GeV electrons, Phys. Rev. D 69 (2004) 032001. http://cds.cern.ch/record/974908