Direct measurement of photons from the electron-hadron bremsstrahlung at the EIC

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ePIC Luminosity group weekly meeting

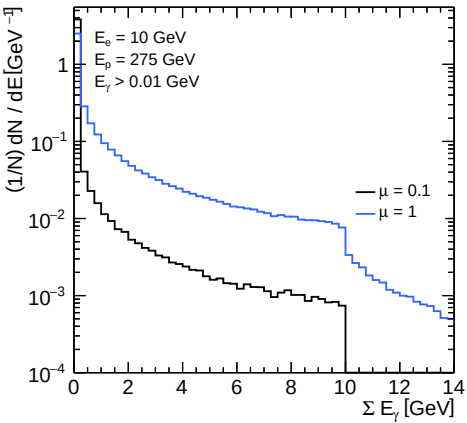
Motivation for this presentation

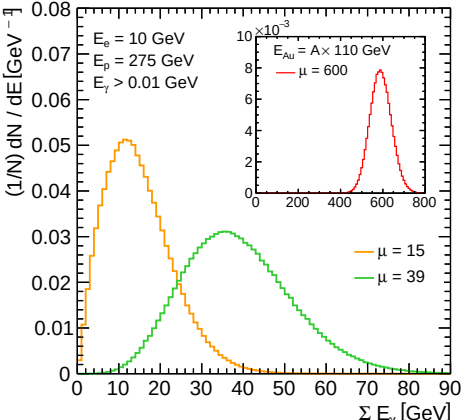
Study of the Cu-quartz “spaghetti" sampling calorimeter, as well as the homogeneous scintillator crystal calorimeter for luminosity measurements using direct photons from bremsstrahlung at the EIC.

- Obtained results of GEANT4 simulation with primary photons hitting directly the photon calorimeter will be very soon published by the Krakow group as the requested deliverable of our grant.
- (Part of) this study can be relatively quickly repeated using a proper description of the ePIC far backward region and the best EIC beam parameters to provide an input to the pre-TDR.

Working conditions at EIC

For this study, the bremsstrahlung photons were generated using the BREMGE event generator.





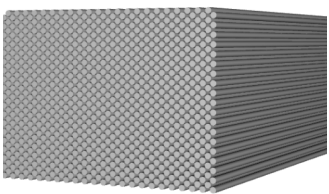
- For nominal *ep* luminosity: $\mu = 39$ for photons with $E_\gamma > 0.01$ GeV and $\sum E_\gamma \approx 35$ GeV per bunch crossing.
- For nominal *eAu* luminosity: $\mu = 600$ for photons with $E_\gamma > 0.01$ GeV and $\sum E_\gamma \approx 600$ GeV per bunch crossing.
- Transverse impact point was Gaussian-smeared, with $\sigma_x = \sigma_y = 1$ cm, to mimic the beam angular distribution at the distant interaction point.

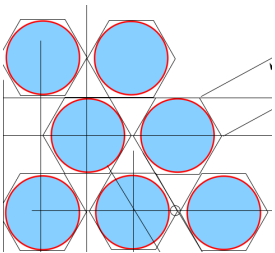
Detector design

For high-luminosity measurements, we consider a $30 \times 30 \times 50$ cm^3 Cu-quartz “spaghetti" sampling calorimeter with fibre centres forming a honeycomb pattern.

Tentatively, the distance between fibre centres is 1.15 mm and fibre radius is 0.25 mm with an effective fibre “volumetric fraction" of 16%.

The detector is tilted horizontally by 5 degrees mostly to avoid “particle channelling".

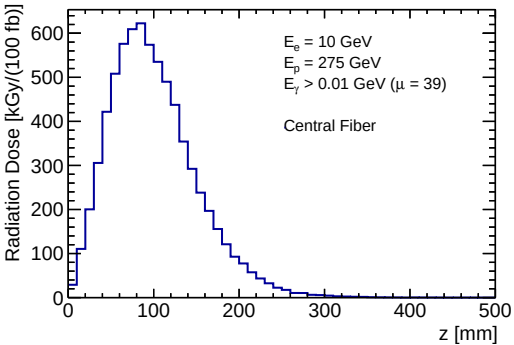


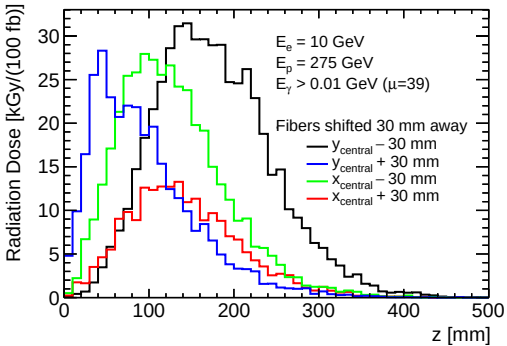


Remark: Twice the larger fibre radius was used for the above images with an effective fibre fraction of 64%; possibly, the final optimal fraction will be about 35%.

Radiation dose at EIC conditions

Radiation dose was evaluated for 100/fb of integrated luminosity with 1 mm steps along each quartz fibre.

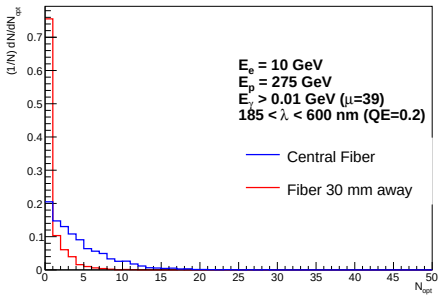


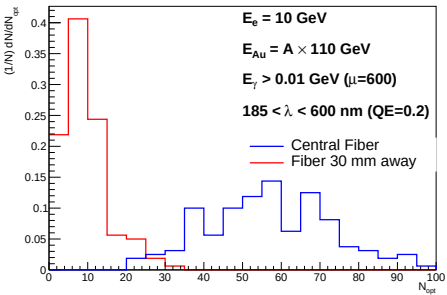


- maximum radiation dose of 600 kGy is at a depth of 90 mm
- 30 mm away from the central fibre dose is reduced by a factor of at least 20
- possible reduction of maximum dose by moving the detector from time to time.

Performance: multiplicity of optical photons

To mimic the performance of the photodectors, we use 20% of photon detection efficiency (PDE) when translating the number of optical photons reaching the end of the fibre to the effectively measured photoelectrons.

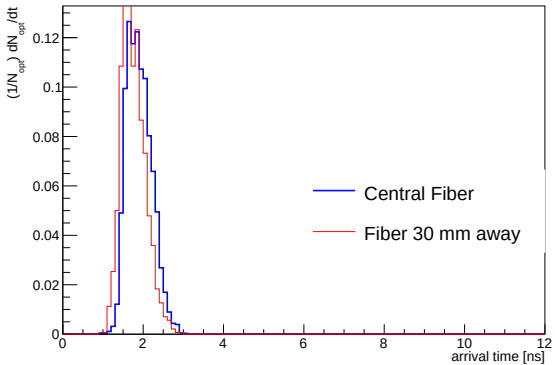




- At nominal EIC *ep* 10×275 collisions, we expect 160 effective optical photons per bunch crossing with on average 4 in the central fibre. Central fibre “signal occupancy" is about 80%.
- At nominal EIC *eAu*, we expect on average 60 effective optical photons in the central fibre with “signal occupancy" of 100%.

Performance: arrival time of optical photons

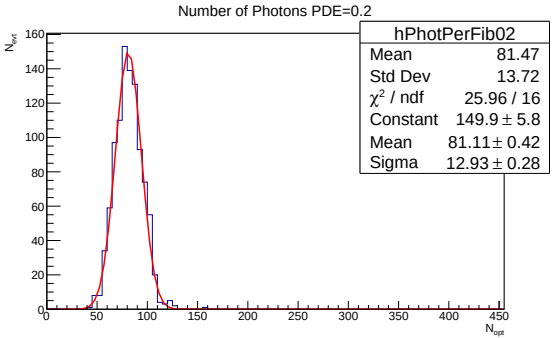
We do not simulate the spread of collision time. The distributions below include only the smearing/delay due to the effects of light propagation.

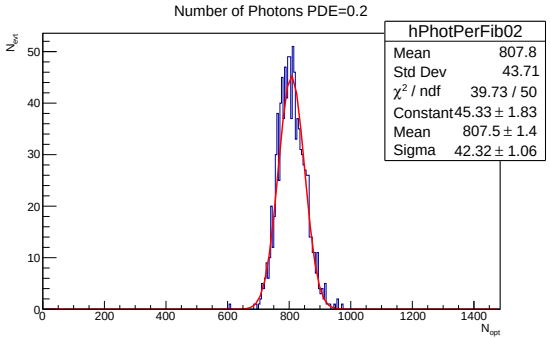


Light propagation smearing is fully included in ± 1 ns time window.

Performance: calibration of direct photon detector

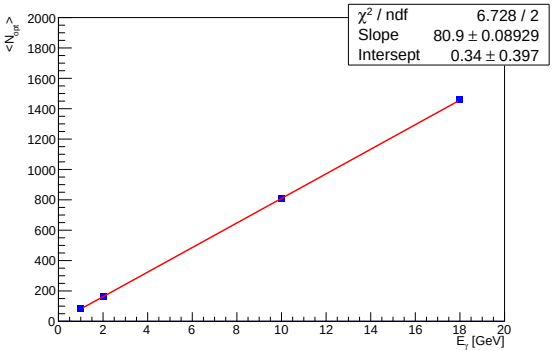
Calibration was performed with mono-energetic photon guns with energies: 1, 2, 10 and 18 GeV

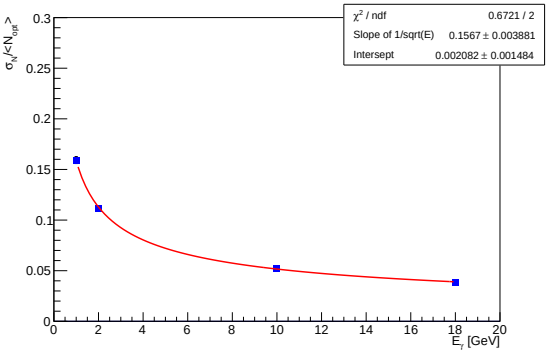




Detector shows Gaussian-like response with relative resolution μ_N/σ_N=16% for 1 GeV beam and 5% for 10 GeV beam.

Performance: linearity and resolution





Simulation shows perfect linearity and typical dependence of relative resolution as a function of photon energy:

$$\sigma_N/ < N >= \sigma_E/E \approx 0.16/\sqrt{E[\mathrm{GeV}]}$$

Summary

- We performed a simulation of the Cu-quartz “spaghetti" sampling calorimeter using GEANT4 including generation, propagation and collection of Cerenkov in quartz fibres.
- Simulation was performed for nominal/ultimate EIC condition for *ep* and *e*Au collisions.
- Results show promising performance both in expected radiation dose, and linearity and resolutions.
- Study can be quickly repeated, including ePIC far backward region instrumentation and expected EIC beam parameters.
- Following results can be added to the PDR