Luminosity Direct Photon Calorimeters

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Far-forward/ far-backward Review
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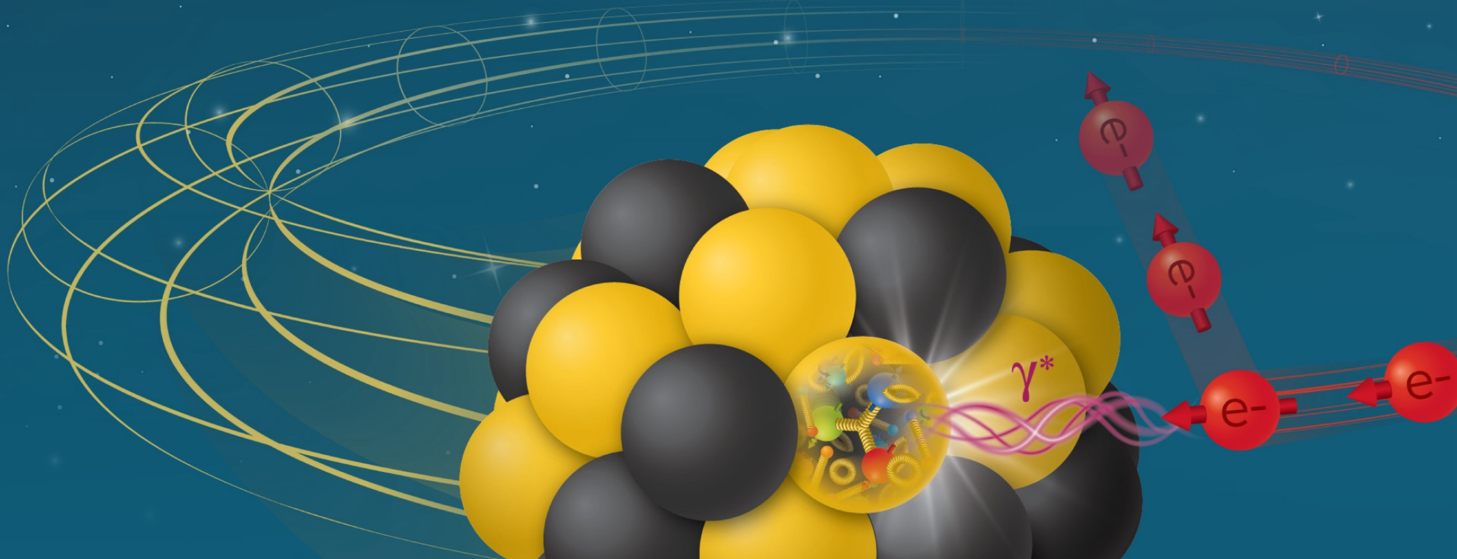
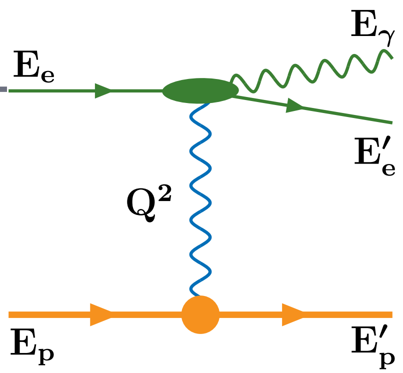
Electron-Ion Collider



Direct photon calorimeters: physics requirements



Direct photon (movable) calorimeters are **a must at the EIC,** to ensure **at least 1% precision** of EIC luminosity determination + high robustness:

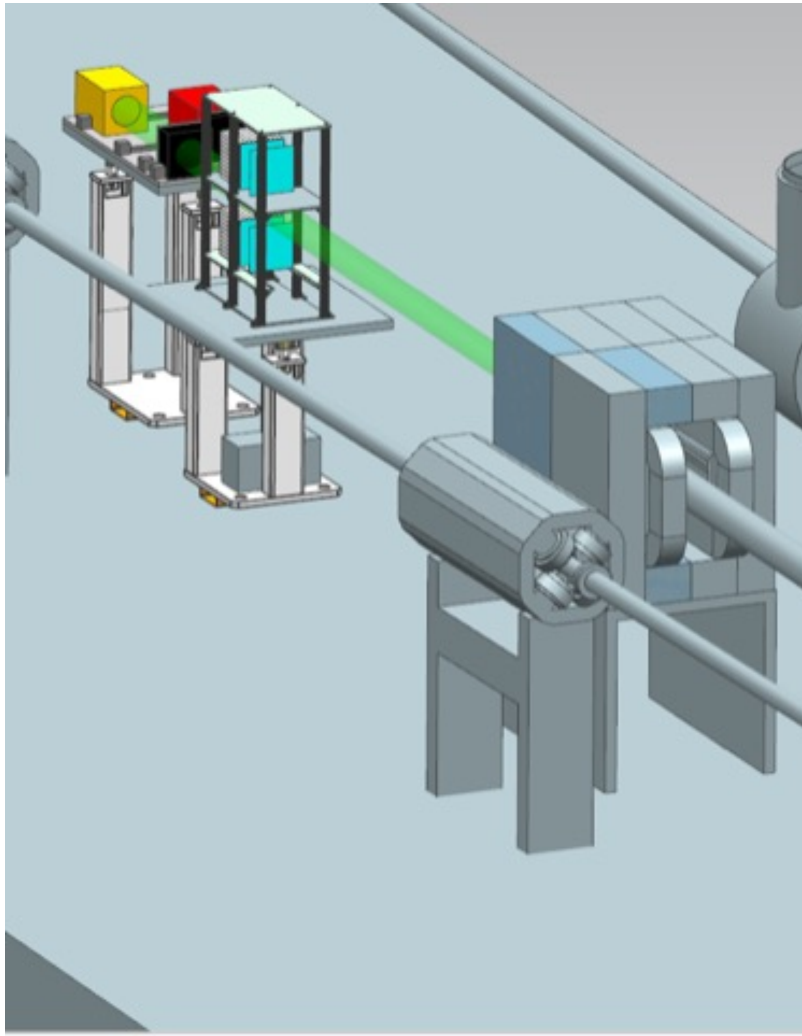
1. Needed for very precise measurements of **full bremsstrahlung spectrum** at all beam energies to verify bremsstrahlung suppression due to beam-size effects
2. Needed for very precise **<1% reference** luminosity measurements
3. Direct photon calorimeter will be used **for ≲1% routine luminosity measurements** during initial ePIC years, for *L* up to about 10^{33} $cm^{-2}s^{-1}$ (with *complementary* systematics wrt PS luminosity)
4. During this initial EIC phase direct photon calorimeter will be also used for unique measurements of **Initial State Radiation** (ISR) in DIS.
5. At nominal luminosity, it will play crucial role in achieving required **10^{-4} precision** on “bunch-to-bunch” **relative luminosity measurements**, and may still provide 1% precision on absolute *L*
6. Associated SR monitors will provide **fast, bunch-to-bunch, synchrotron radiation level feedback** to machine

Direct photon measurements: detector requirements

1. For reference luminosity measurements and for running at low and medium luminosity ⇒ calorimeter with very good energy resolution of **<15%/√*E*** is needed, to fully profit from powerful data-driven calibration techniques, and to ensure precise ISR measurements

2. At nominal luminosity, as good photon energy resolution is demanded as is possible in extreme running conditions

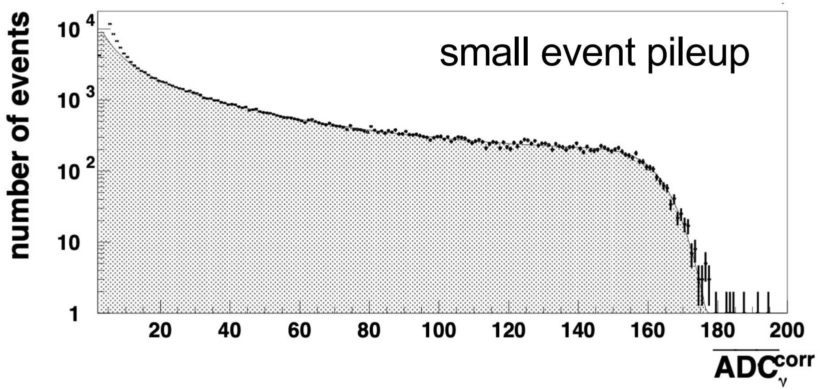
3. Detectors (and their FEE) have to withstand huge event rates, and channel occupancies reaching 100% already at medium luminosities



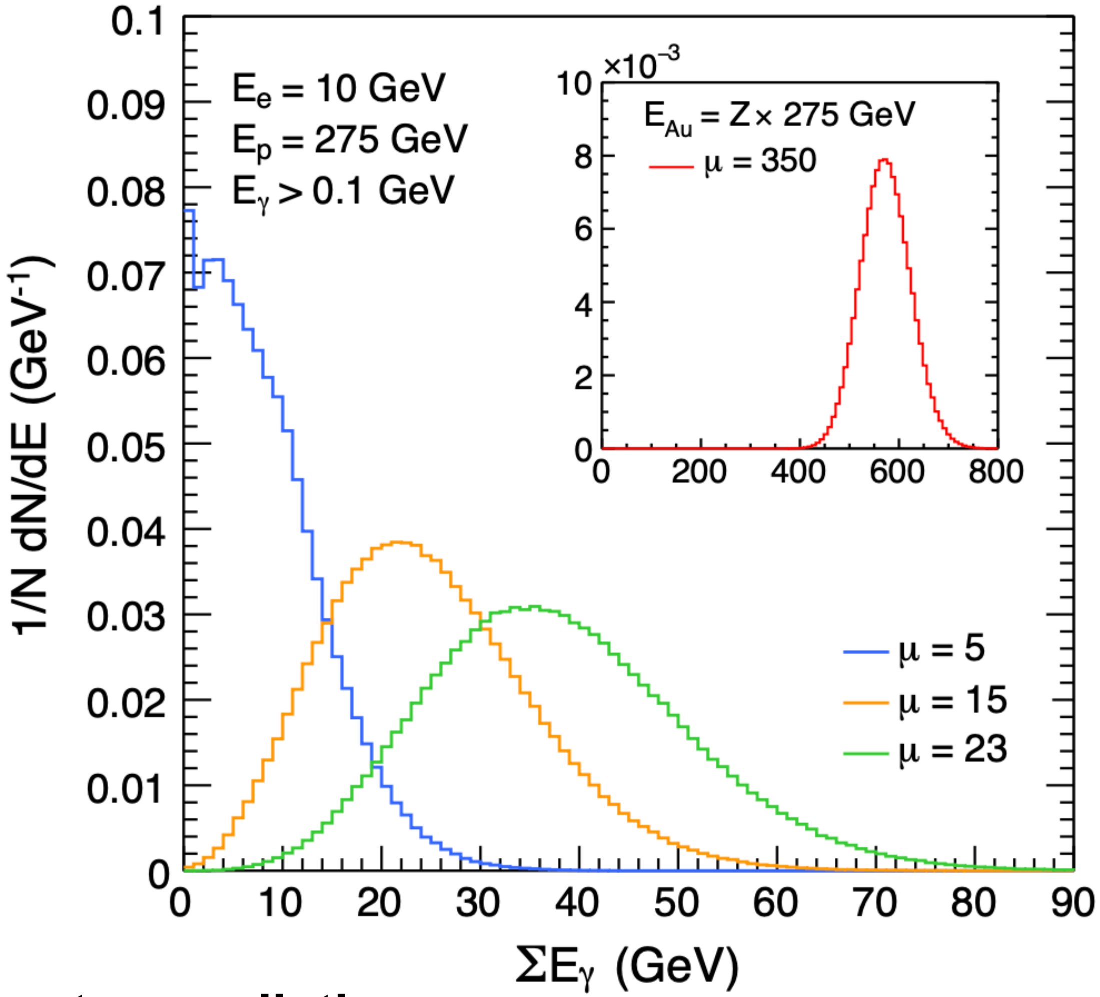
Working conditions

Two major challenges must be coped with:

1. **Huge and unavoidable irradiation** of active material (Sci/Q) due to bremsstrahlung itself, **at EIC every 10 ns ⇒**

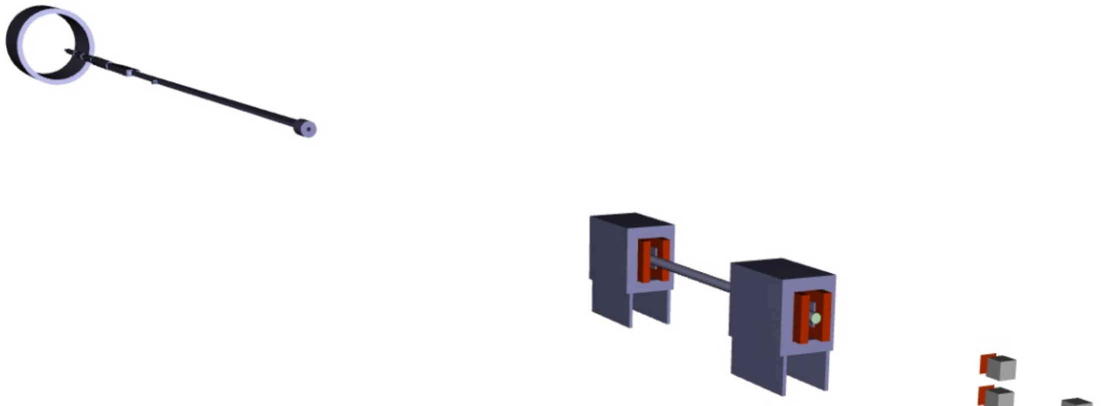


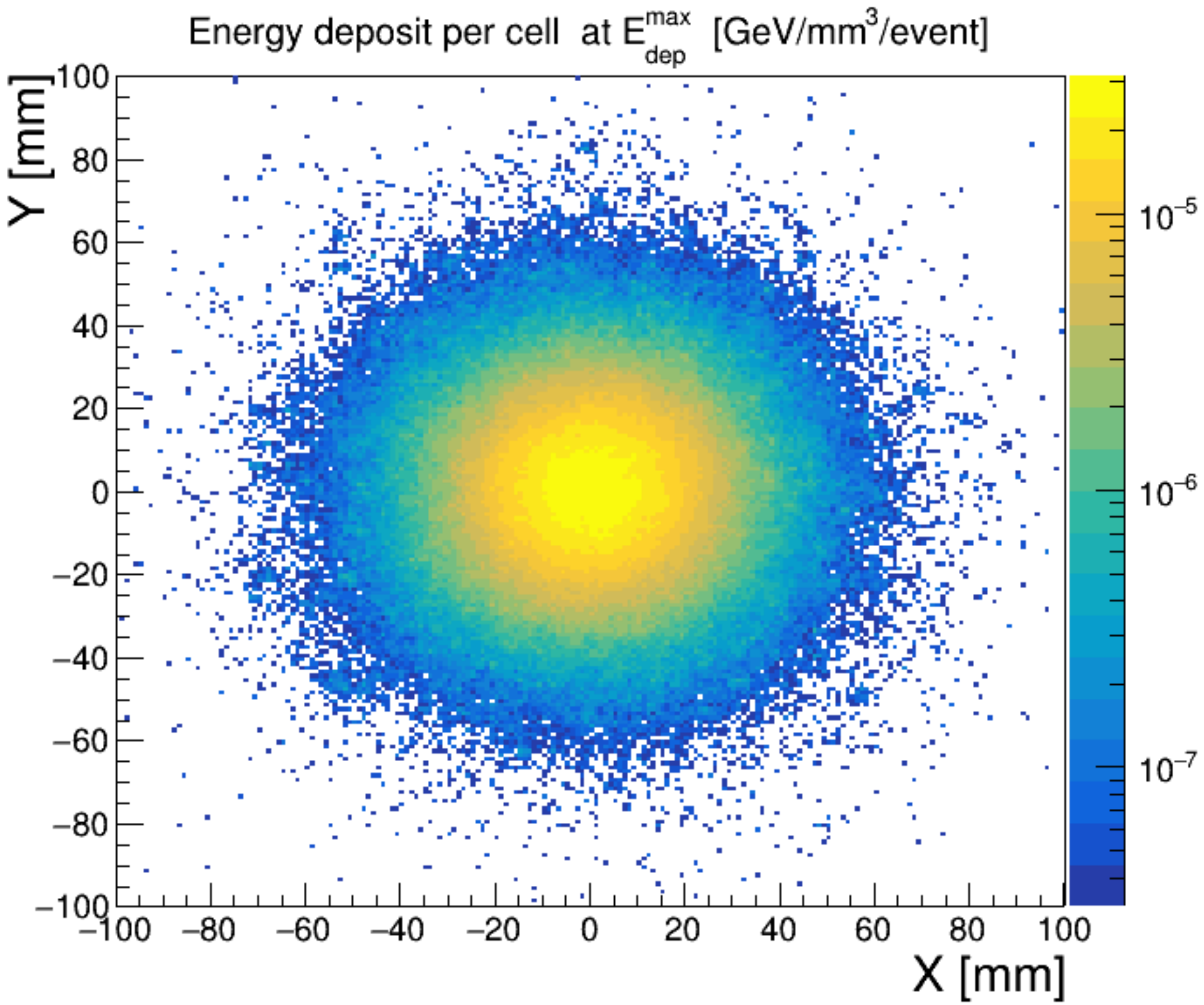
HERA I – measured bremsstrahlung spectrum – *Acta Phys. Polon. B* **32** (2001)



2. Huge and unavoidable flux of (direct) **synchrotron radiation**

Simulations of direct photon calorimeter irradiations

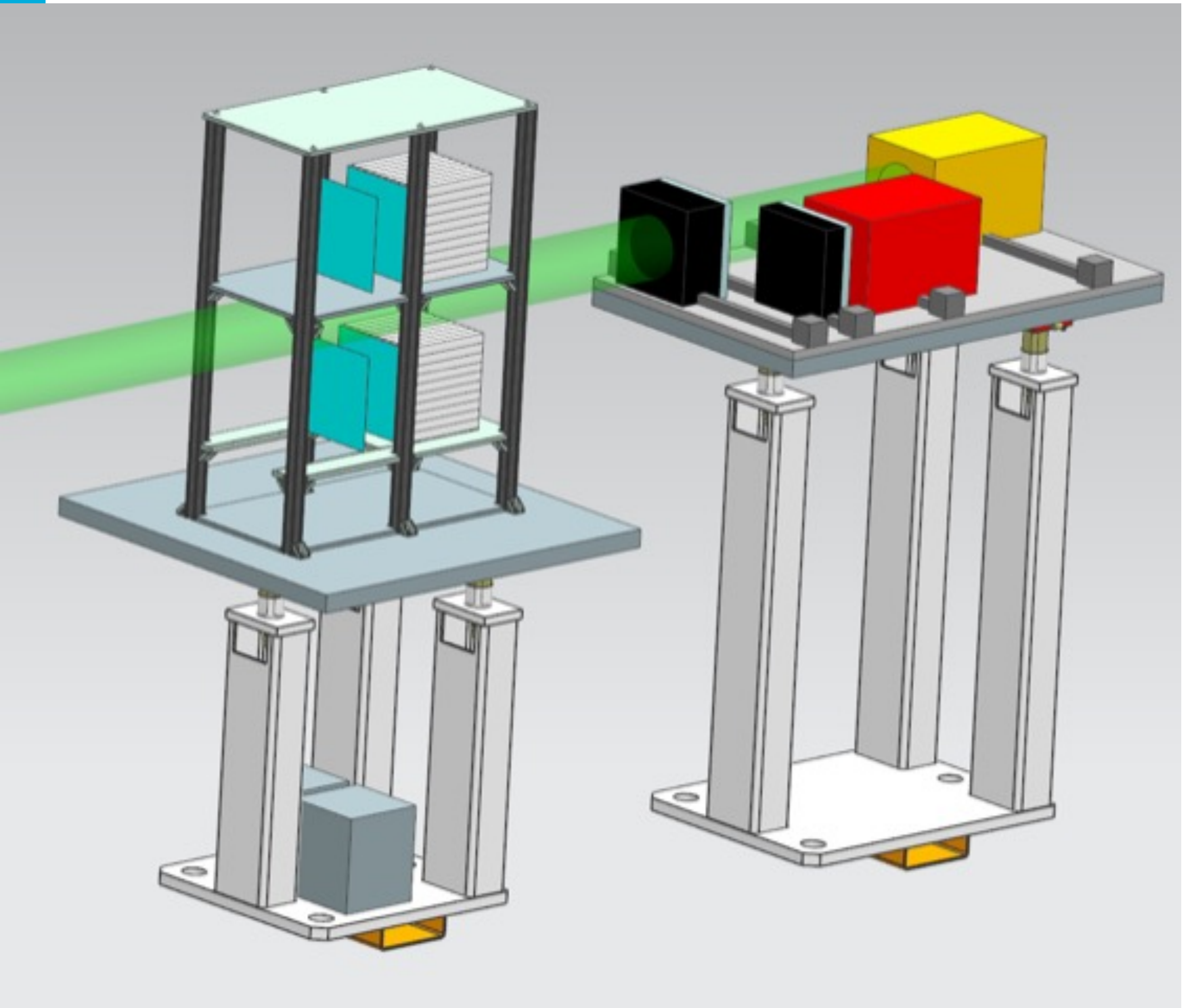




G4 simulations predict maximal irradiation density of about **2 MeV/g** per photon ⇒ maximal annual (local) dose, assuming 100 fb^{-1}, of about **7 MGy**!

- Only quartz fibers can be used then
- Irradiation levels can be partially mitigated by changing calorimeter position from time to time ⇒ at 10 fb^{-1} one can use SciFi as dose < 0.1 MGy

SR filtering



1. No extra SR attenuation needed at 5 GeV

2. Only 5 cm graphite block (< 0.3 X_0) is needed to stop all SR at 10 GeV

3. 35 cm graphite (< 2 X_0) is needed to stop SR at 18 GeV – it is good news as such filter was used for direct photons at HERA I, when 1% luminosity precision was achieved

Calorimeter baselines

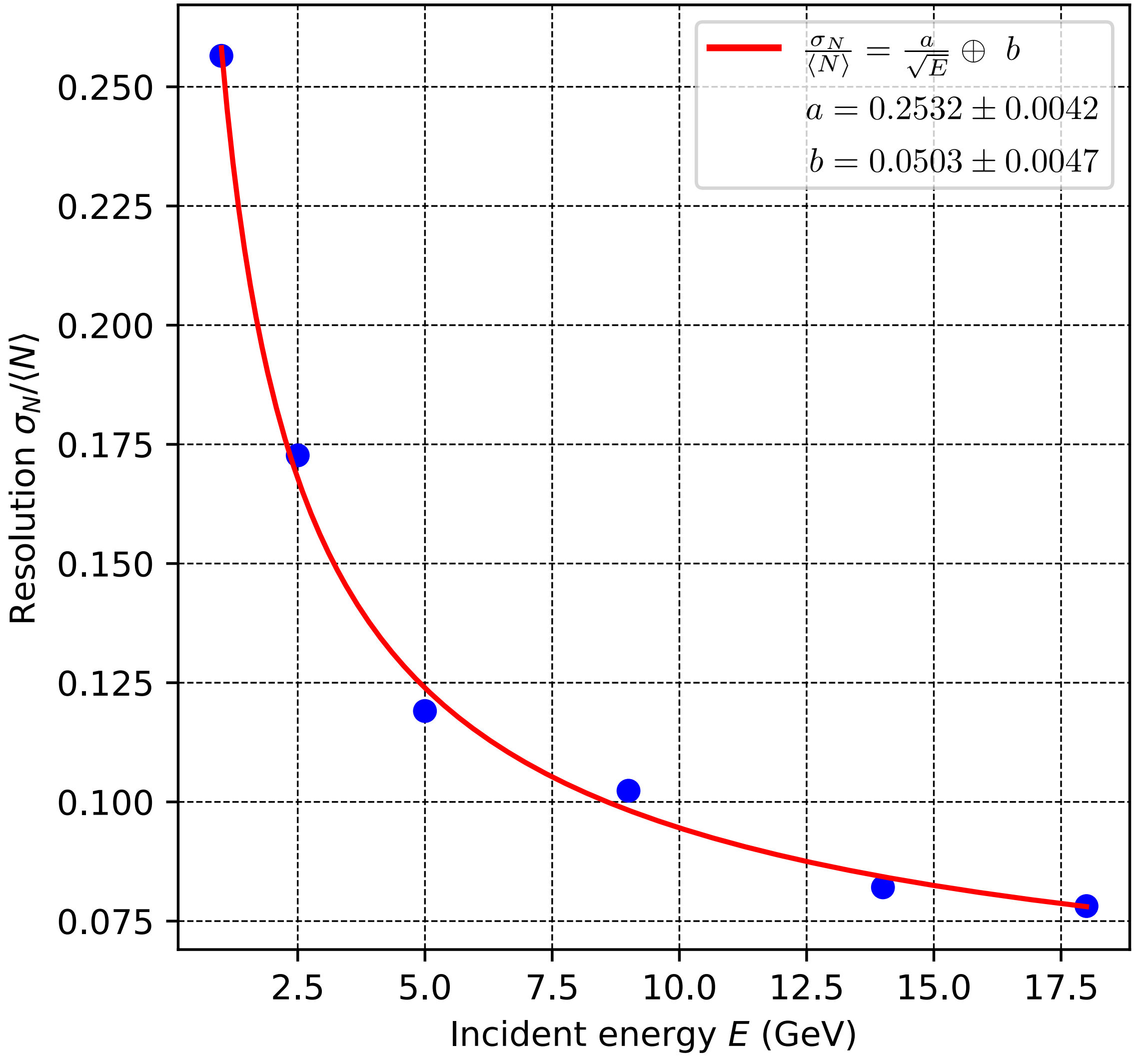
1. **Tungsten SciFi** direct photon calorimeter will capitalize on fECAL developments ⇒ 4×4 configuration of fECAL towers with 10×10 readout cell configuration using SiPM (100 channels to digitize) with expected resolution of 12%/√E ⇒ to be used at low/medium luminosity and for reference/calibration runs

2. **Copper QFi** direct photon calorimeter will be developed/built in collaboration with CTU/Prague colleagues – its tentative configuration: 1.5 mm diam. quartz fibers spaced by 2.5 mm ⇒ same 10×10 readout configuration with SiPM (100 channels to digitize) ⇒ to be used at nominal luminosity

\+ **SR monitor**: 16 hor. + 12 ver. quartz "fingers" with SiPM readout (28 channels to digitize)

QFi simulations

Performance of copper quartz fiber calorimeter (as used in ALICE) for 1.5 mm fiber diameter and 2.5 mm fiber spacing ⇒ 25%/$\sqrt{E}$[GeV] energy resolution obtained assuming PDE = 40%



FEE

228 readout channel signals (128 at a time) will be digitized with **200 MHz sampling rate with 10-bit resolution,** using custom-made boards with flash ADC. These cards will be streaming out **ALL** data @256 Gb/s

Note: same cards can be used for FEE of low-Q^2 calorimeters for medium to high luminosity running, when their channel occupancy becomes close to 100%

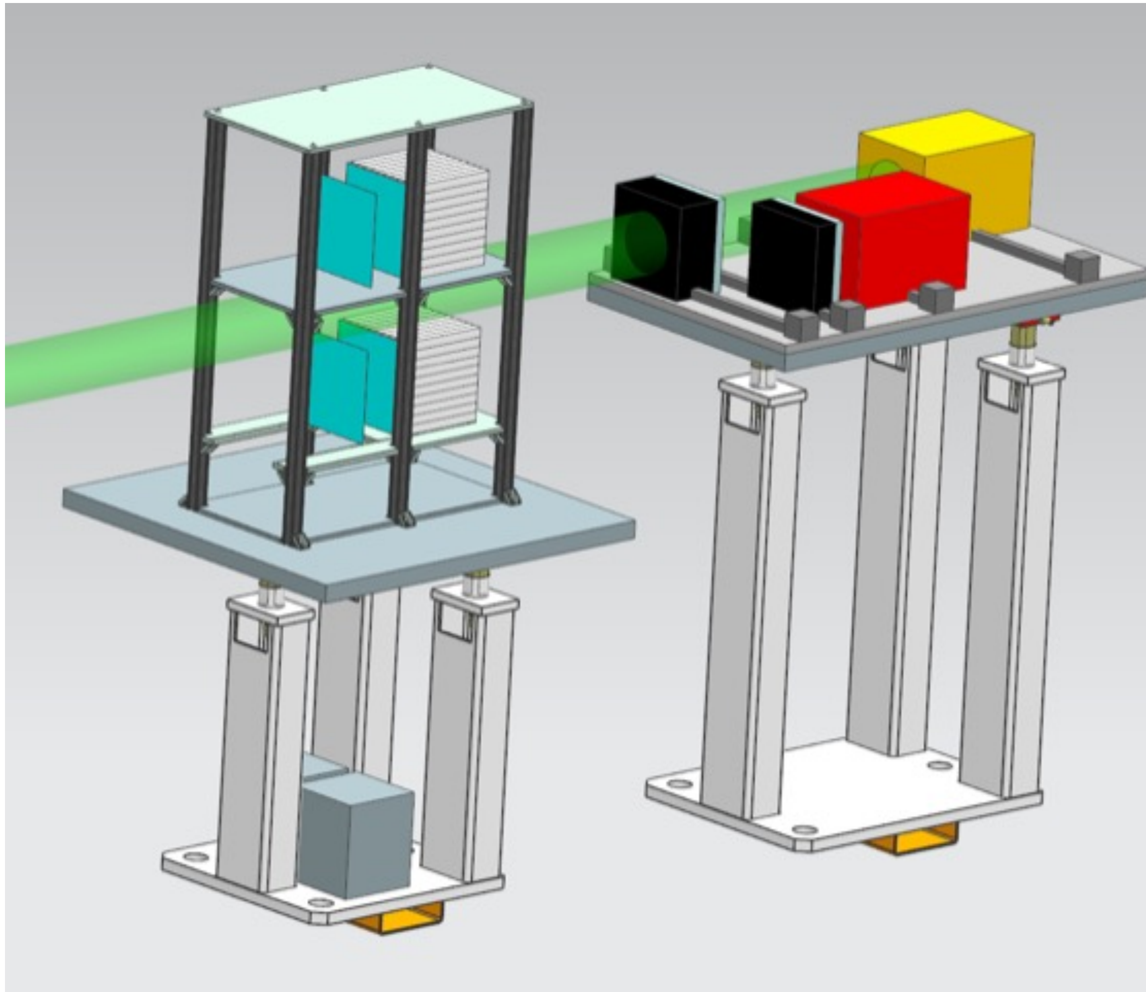
Working example: JLab FADC250 16-channel VME boards with 250 MHz sampling rate and up to 12-bit resolution ⇒

Infrastructure items

Direct photon system does **not** interfere with beamline elements and is composed of:

1. Support table is of 1 m^2 size with about 100 kg load, unless overall shielding is also supported
2. 4 (5) movable "tablettes" for 2 (3) SR filters with quartz monitors + 2 calorimeters
3. Low power (Peltier) calorimeter cooling
4. On-detector electronics

No other media needed but LV/HV



Developments and test beams

1. First QFi prototypes should be ready for test beams in 2025 – to verify G4 modelling + precisely measure impact of dead material/filters in front

2. By end of 2025 we should have very good understanding of front-end electronics requirements and perform first tests of proposed solutions

Summary

1. Working conditions for direct photon calorimeters are well understood now – huge SR flux can be well attenuated

2. Direct photon calorimeters' baseline has been established

3. First calorimeter prototypes including initial FEE cards should be ready in 2025 for studies at test beams