Low energy photons in B0

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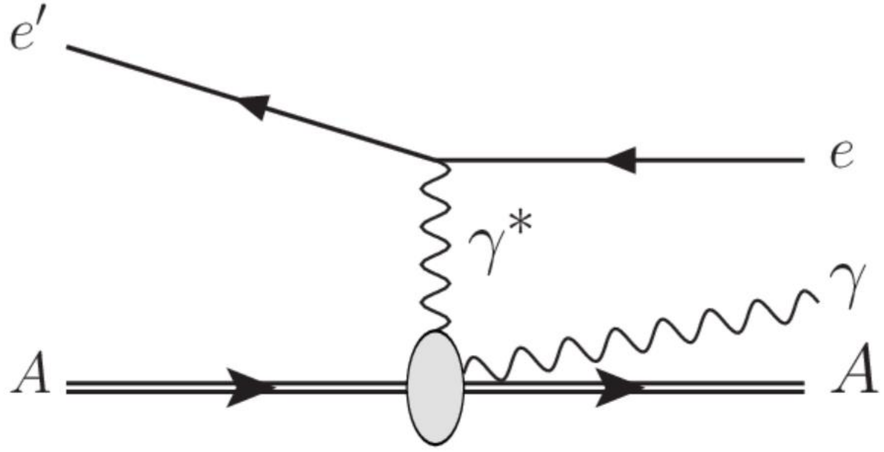
Motivation and strategy

- In many eA interactions, ion emits a photon via the deexcitation mechanism.
- Due to the boost of the ions ($\gamma_A = E_h \cdot Z/m_A$, where E_h is hadron beam energy), forward photons are produced.
- Photon were generated isotopically ($cos\theta \sim Uni[-1,1]$, $\phi \sim Uni[0,2\pi]$), at discrete energies in ion rest frame, and were boosted in the electron-ion lab frame.
- Events of the form of $e + A \to e' + A + \gamma$ are written in hepMC format, storing the beam energy configuration, and were propagated through the ePIC detector simulation and reconstruction.
- Ions and electrons were disabled in simulation



Photon spectra

- Photons with two energies were generated: 5 MeV and 7 MeV, with $P(5MeV) = P(7MeV) = 0.5$. Motivated by the energy range of excited ions in PbPb collisions at the LHC, [Eur. Phys. J. A (2021)]
- Two hadron beam energies were considered[1]: 108 and 39.4 GeV/n

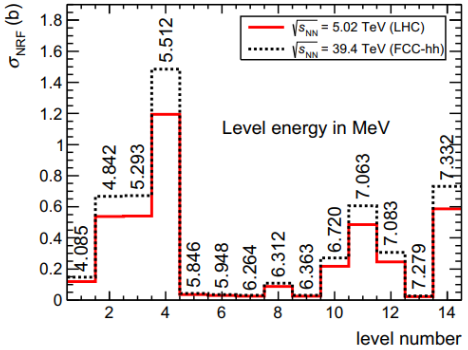
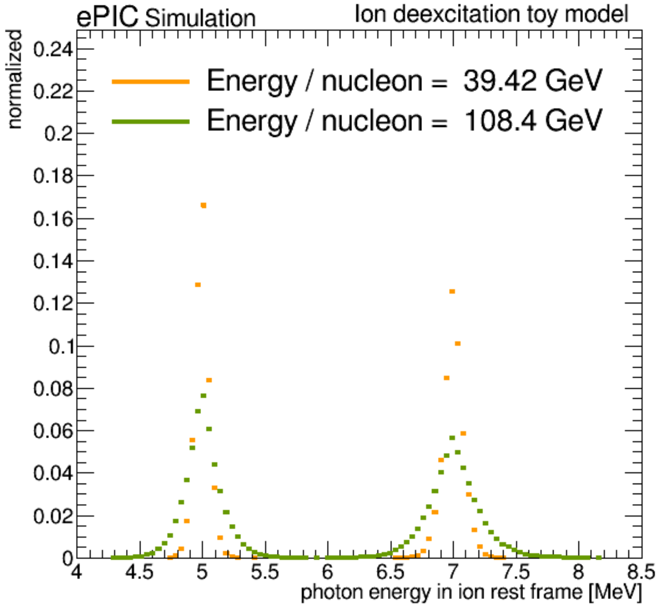
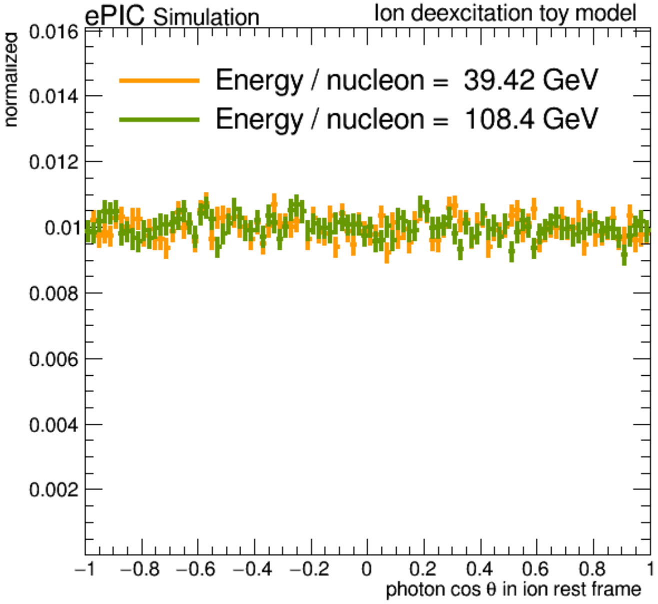
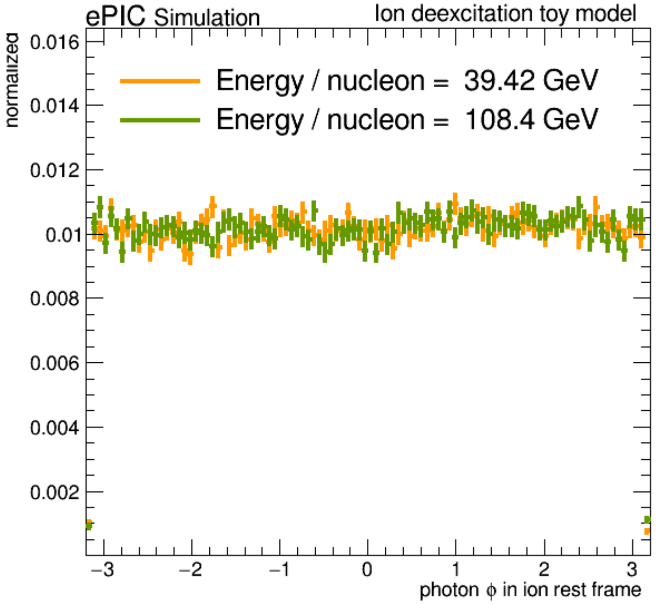


Fig. 2 NRF cross sections for ultraperipheral ^{208}Pb–^{208}Pb collisions at the LHC and FCC-hh, respectively, at $\sqrt{s_{NN}}$ = 5.02 TeV (solid histogram) and at $\sqrt{s_{NN}}$ = 39.4 TeV (dashed histogram)



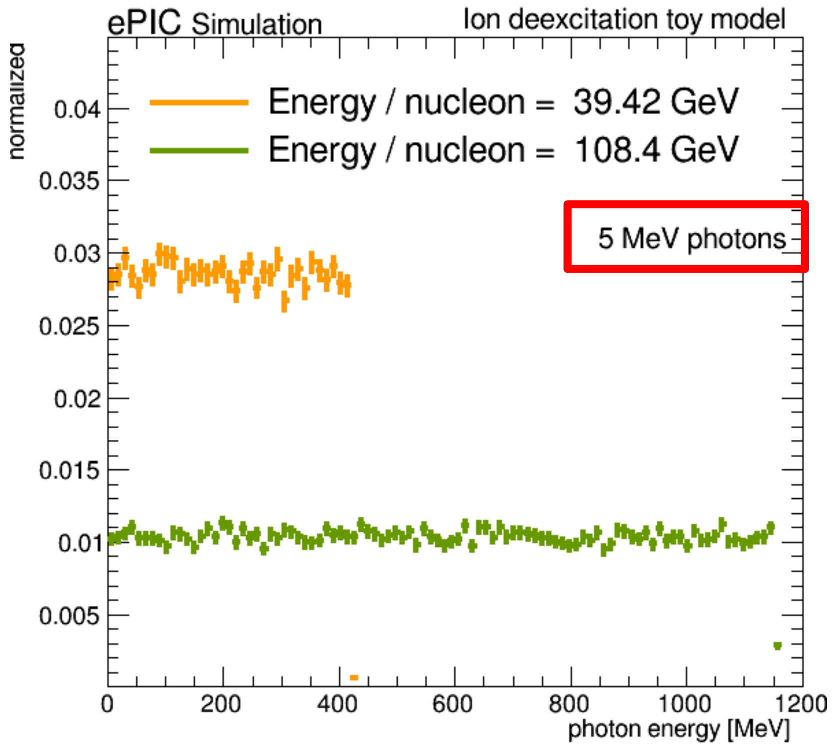


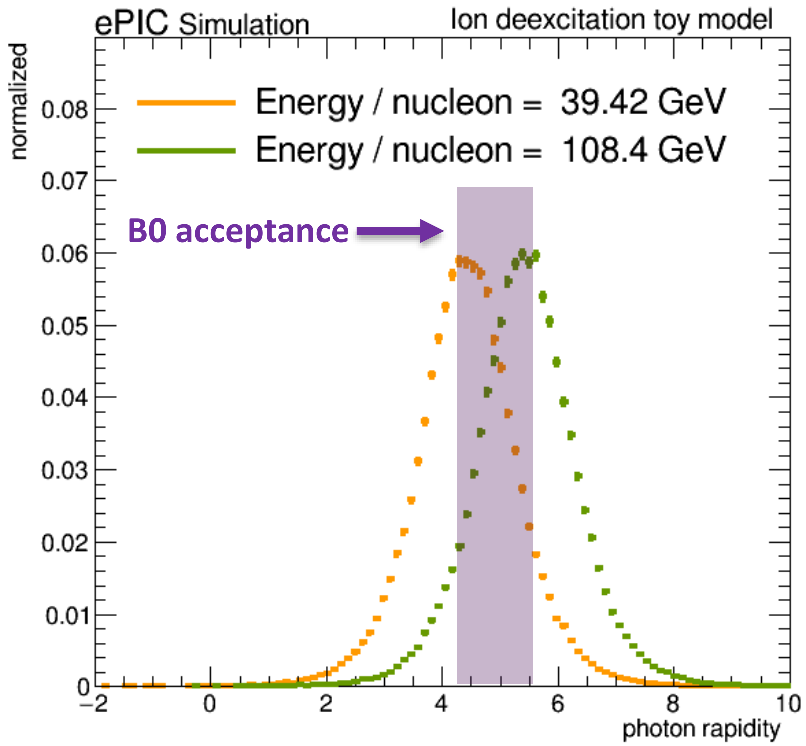


[1] Limited range constrained by the [Afterburner], discussed here: https://github.com/eic/afterburner/issues/5

Photon boost

- In lab frame and hadron beam coordinate system[1], photons are boosted, acquiring higher energies resulting in large rapidity distribution

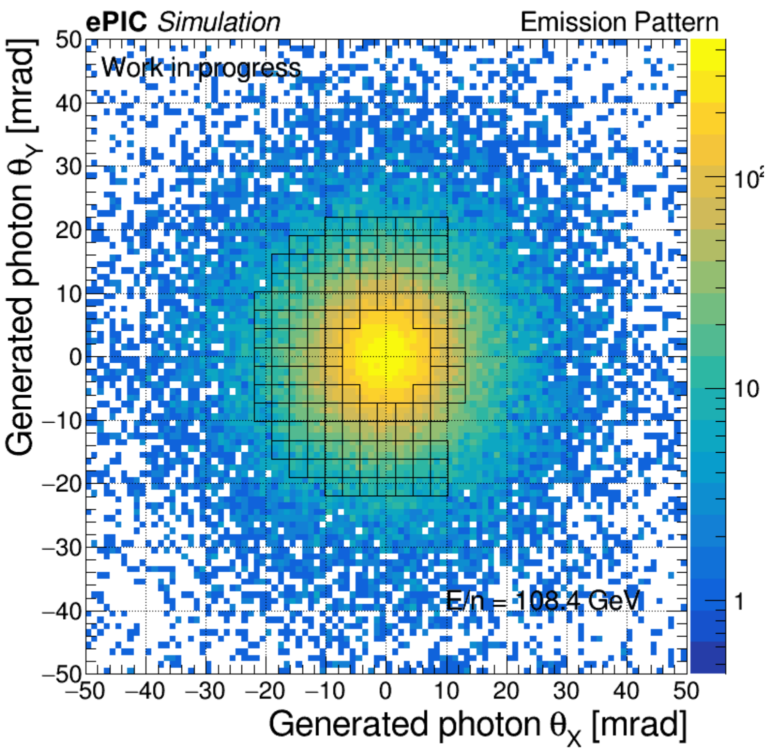


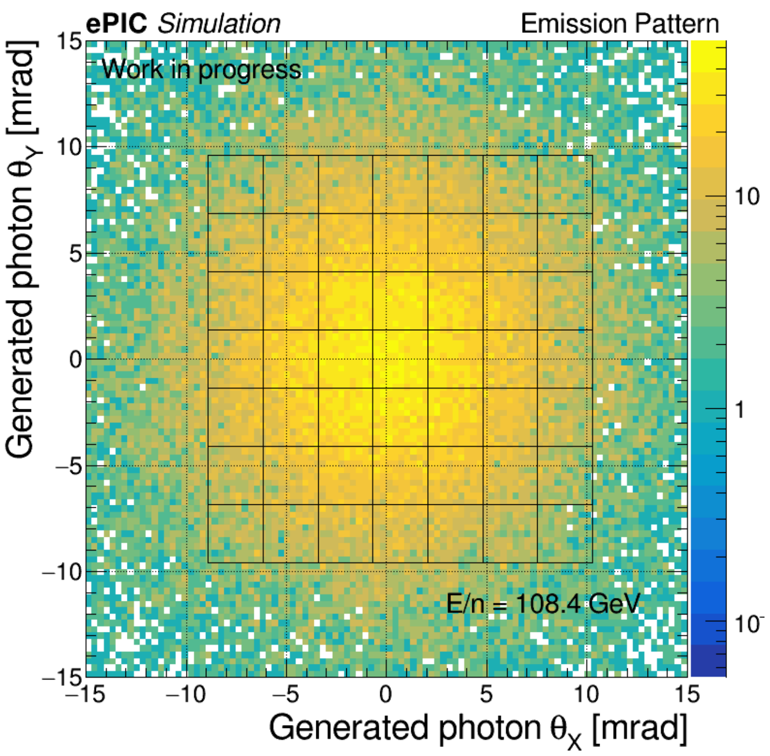


[1] use tlv.RotateY(Xangle) ROOT function to move to hadron coordinate system, Xangle=25e-3 rad

Simulation results

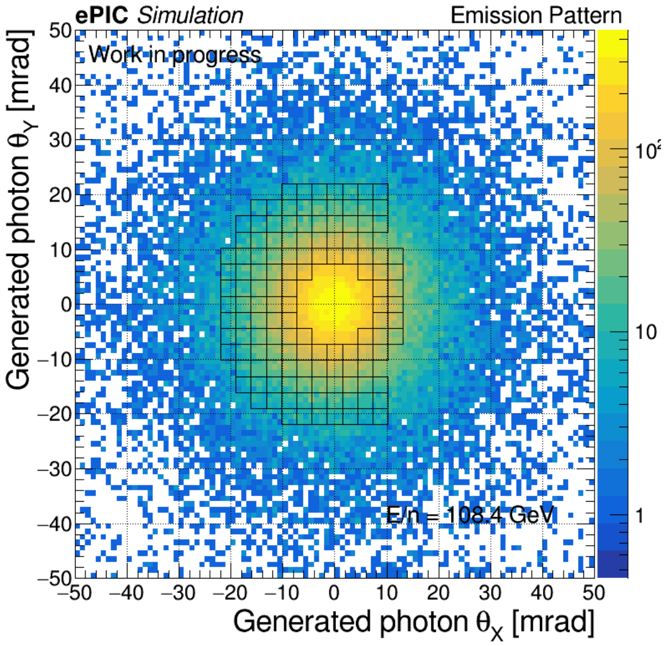
- In the forward region, the ZDC and the B0 detectors can measure forward photons.
- Photon spatial distribution at the interaction point for 108 GeV/n Pb beam.
- B0 and ZDC detector contours are shown in top of the distributions.

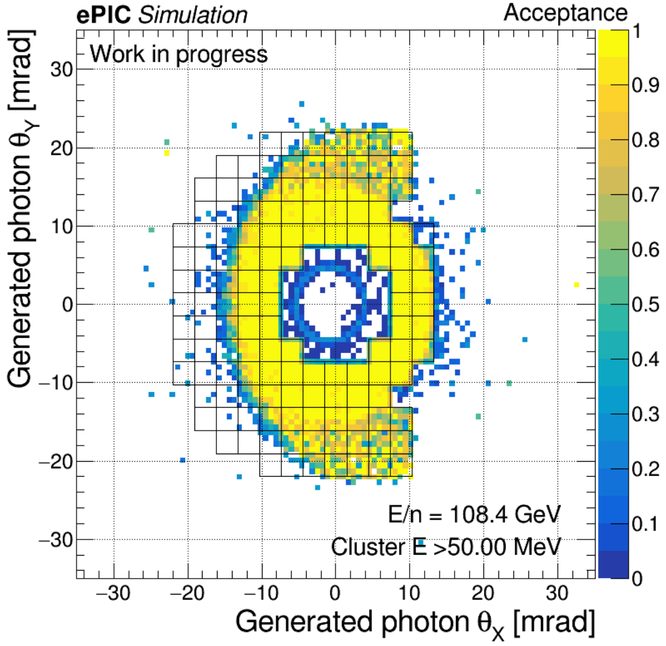




Simulation results

- Geometrical acceptance of B0 detector for 108 GeV/n Pb beam
- Clusters in B0 detector above a certain thresholds are considered

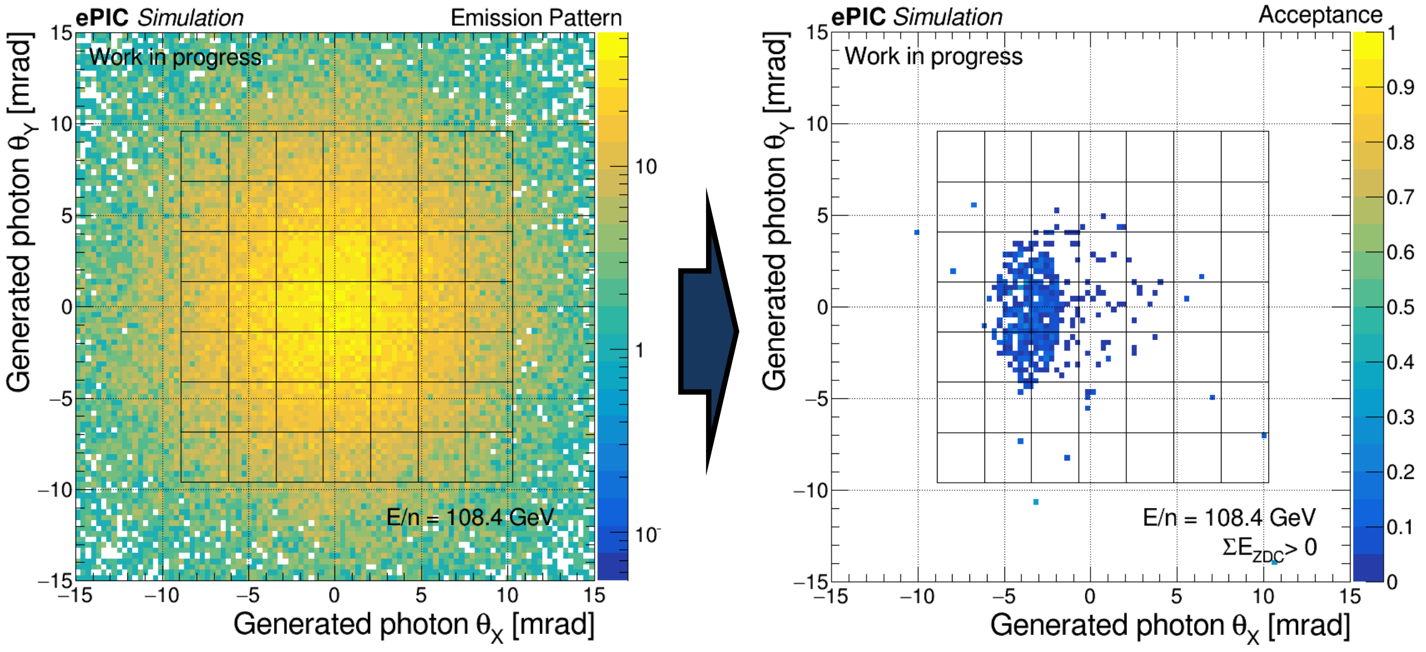




γ energy in A rest frame	Within B0 acceptance	B0 acceptance + At least one cluster in B0 with E > 50 MeV
5 MeV	40%	33%
7 MeV	40%	33%

Simulation results

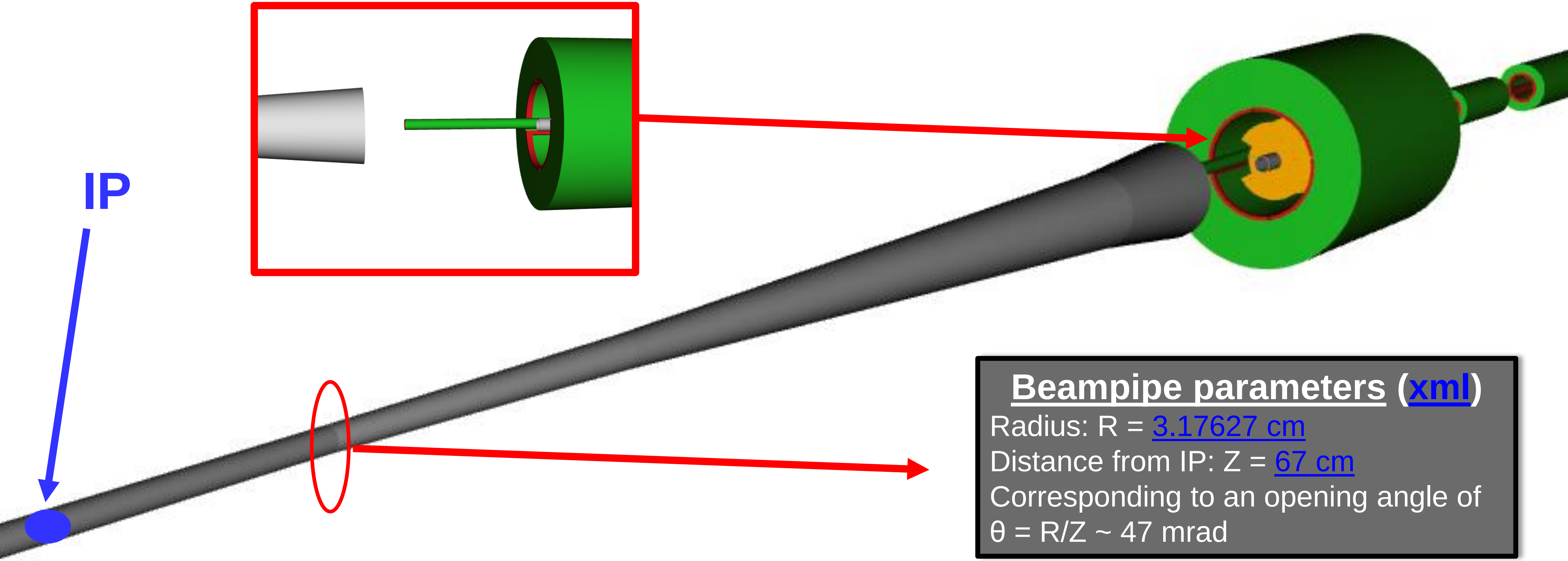
- Geometrical acceptance of ZDC detector for 108 GeV/n Pb beam
- Consider detected photons if any hit in ZDC detector was reconstructed.



γ energy in A rest frame	Within ZDC acceptance	ZDC acceptance + Signal in ZDC above 0
5 MeV	60%	<1%
7 MeV	60%	<1%

ePIC detector geometry

- Photons up to ~ 15 mrad don't cross the beampipe resulting in high acceptance in B0 detector.



Beampipe parameters ([xml])

Radius: R = 3.17627 cm

Distance from IP: Z = 67 cm

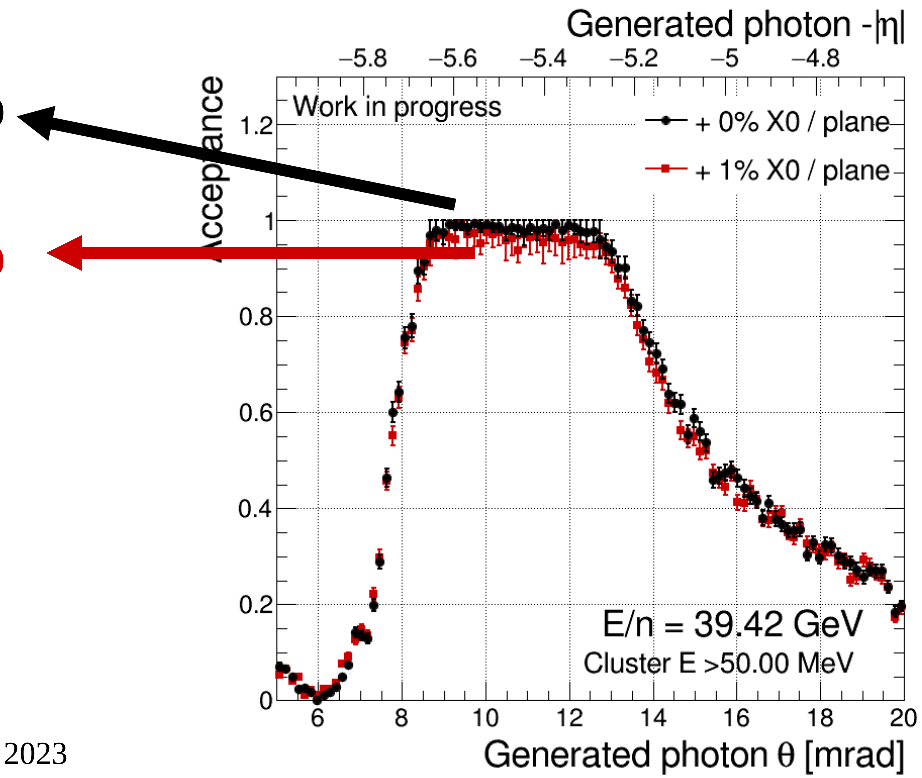
Corresponding to an opening angle of $\theta = R/Z \sim 47$ mrad

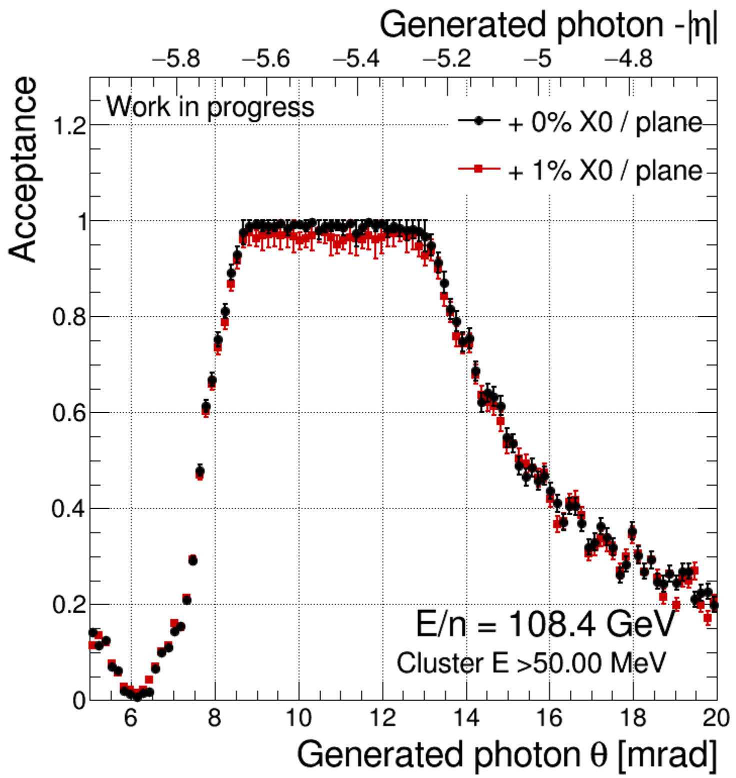
ePIC detector geometry

- The only material photons with θ<15mrad see is the B0 Tracking detectors.
- B0 tracker = 0.3 mm of SiOxide and 0.12 mm of CarbonFiber (link)
- To check the effect of additional material, a 0.1436 mm of Cu was added to each layer resulting in 1%X0 / tracking station = 4%X0 additional material budget before the B0ECAL

98.9%

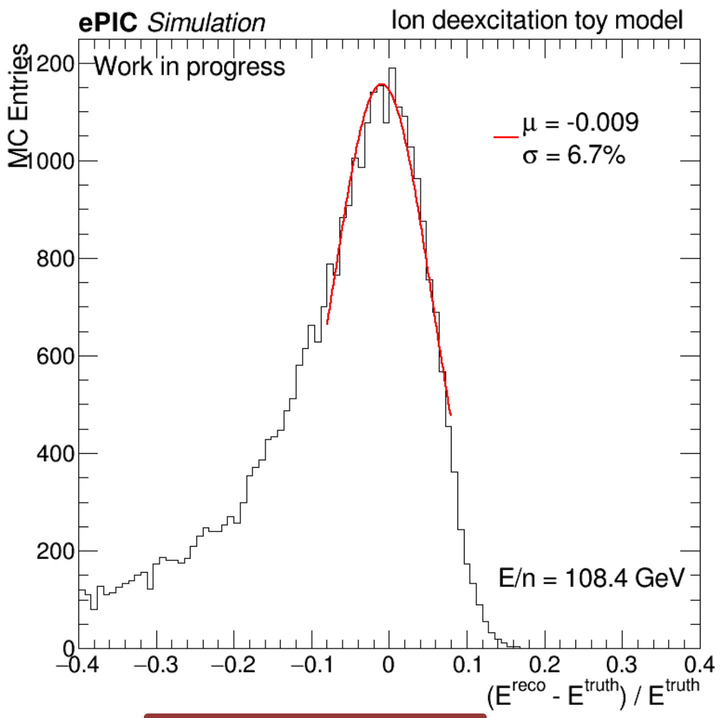
96.3%

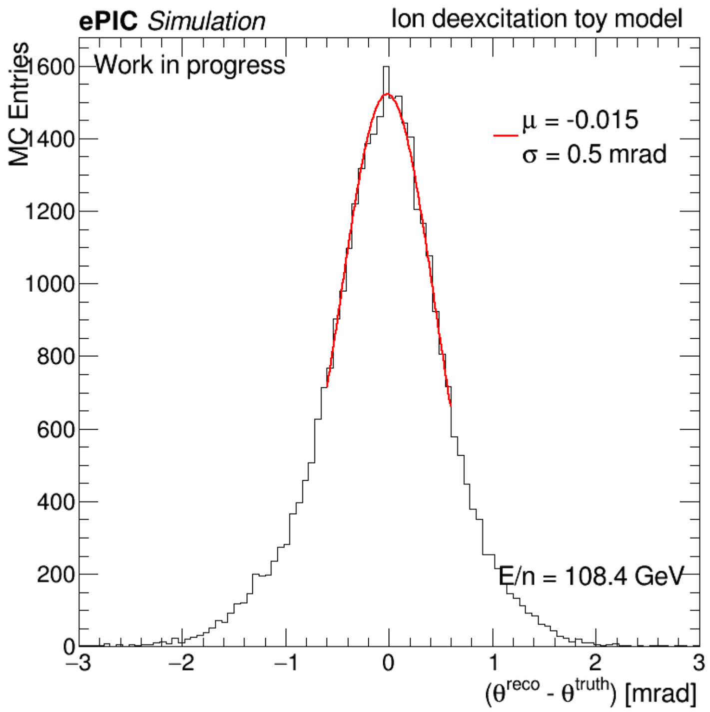




Simulation results

- Reconstruction of photon energy in the ion rest frame requires good position and energy resolution
- Using reconstructed clusters (EICRecon) to determine photon 4-momentum



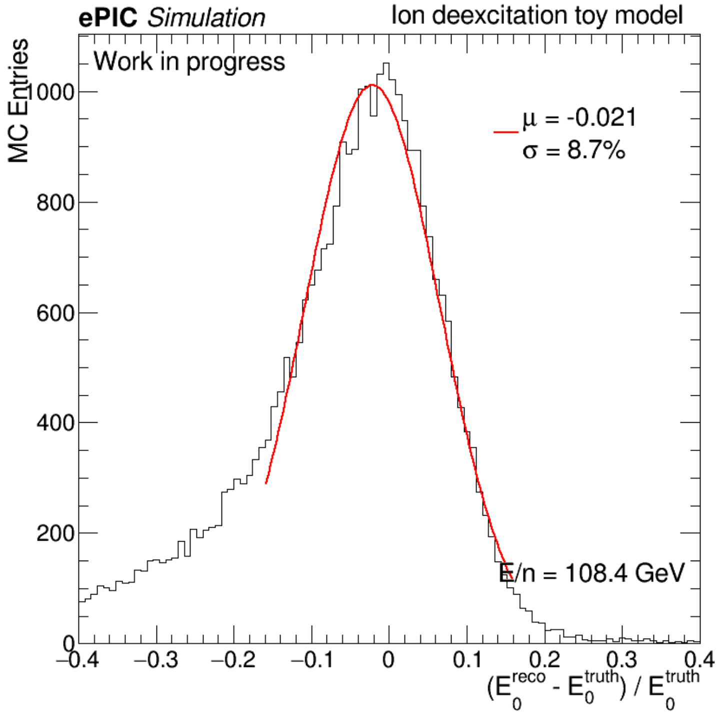


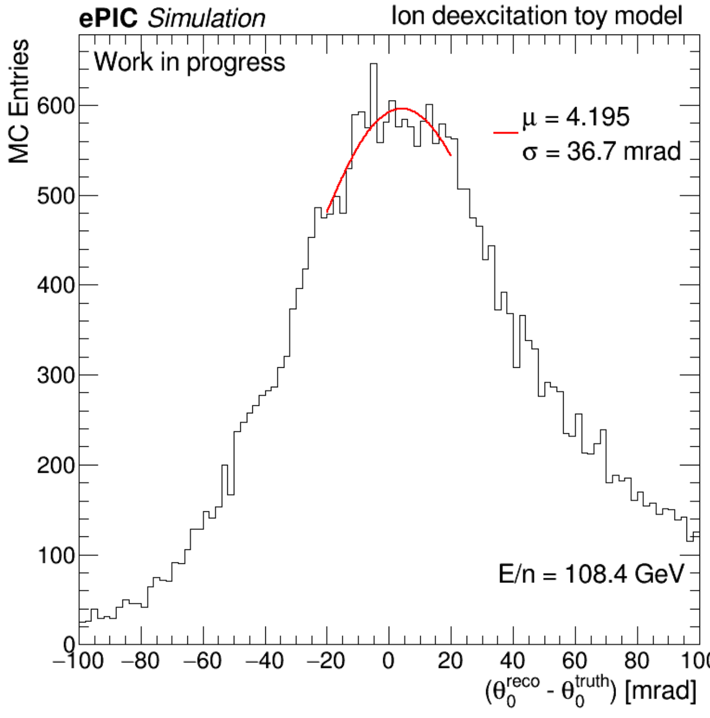
$\sigma/E \sim 6.7\%$ with long tail

$\sigma \sim 0.5$ mrad = 3.2 mm

Simulation results

- Reconstruction of photon energy in the ion rest frame requires good position and energy resolution
- Using reconstructed clusters (EICRecon) to determine photon 4-momentum
- Reconstructed photons are boosted to ion rest frame



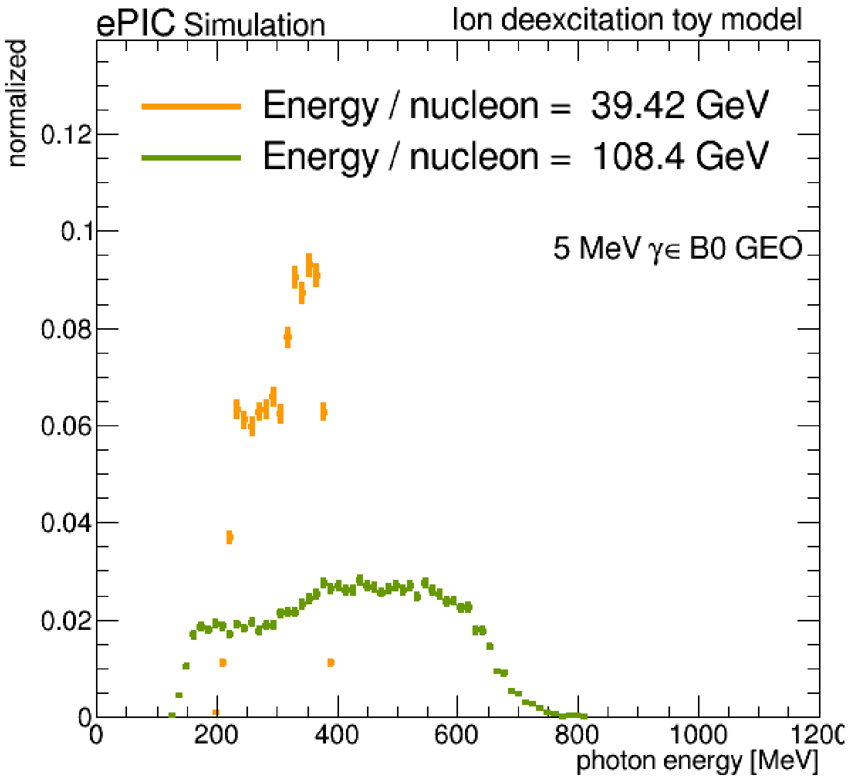


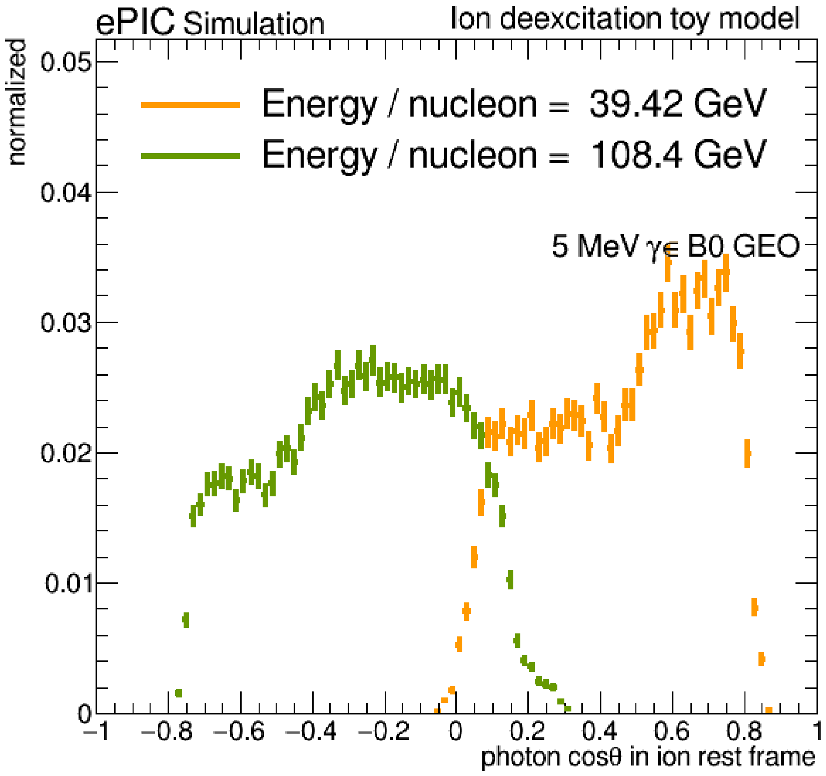
σ/E ~ 9%

Can resolve directionality

Simulation results

- The B0 geometrical acceptance forces detectable photons to be at higher energies and biases the angular distribution in ion rest frame.
- Energy and angular distribution for photons emitted within the B0 geometrical acceptance:



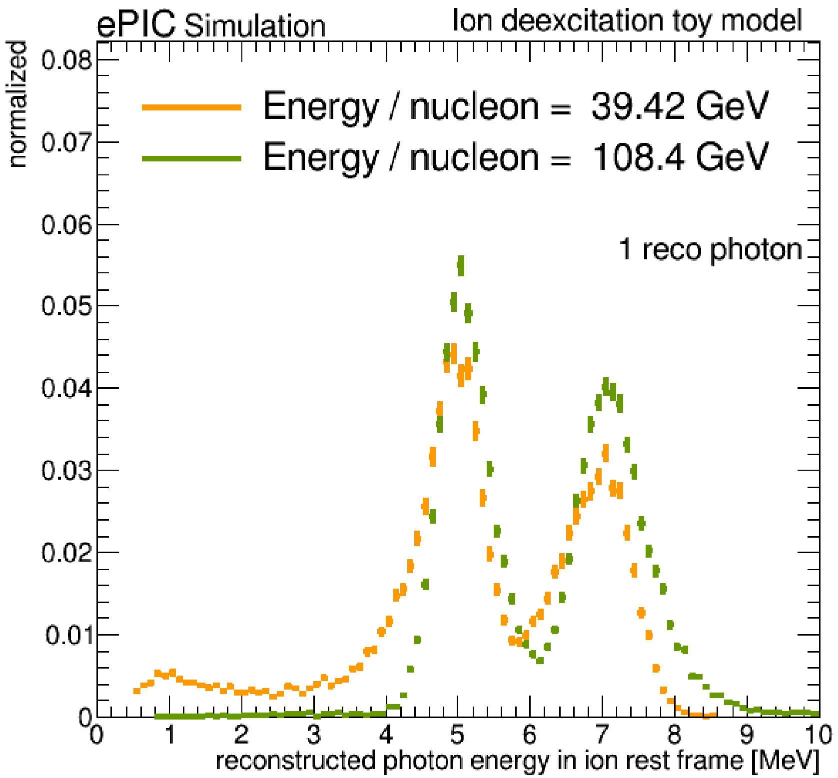


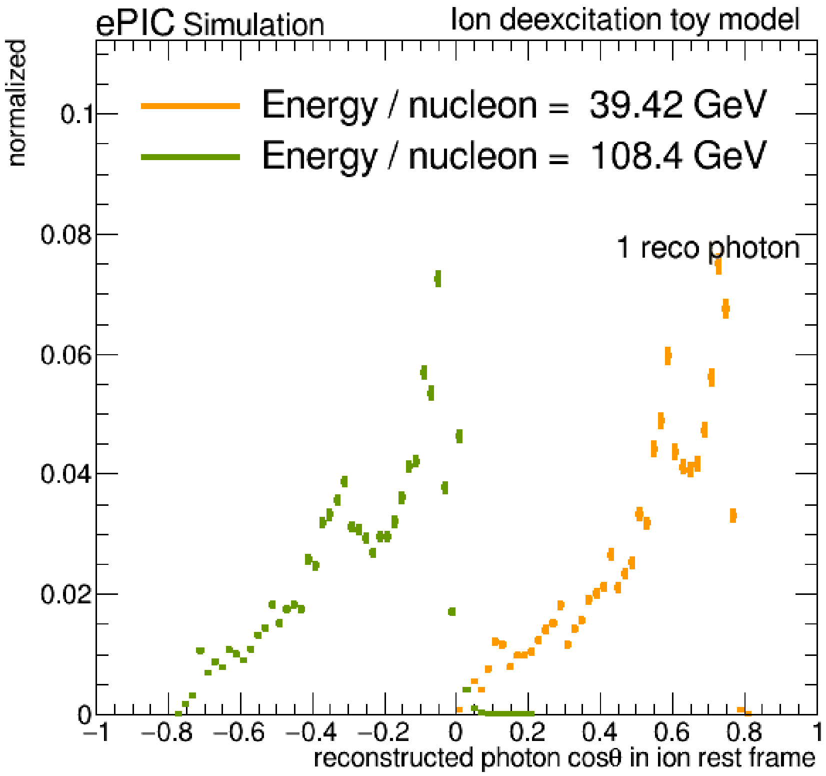
θ>2.5mrad → E > 150 MeV

Distorted cosθ* distribution

Simulation results

- Photons are reconstructed from the calibrated B0ECAL clusters.
  - Energy reconstruction – good separation for the toy model (ΔE = 2 MeV)
  - Angular reconstruction – large bias due to geometrical acceptance and resolution





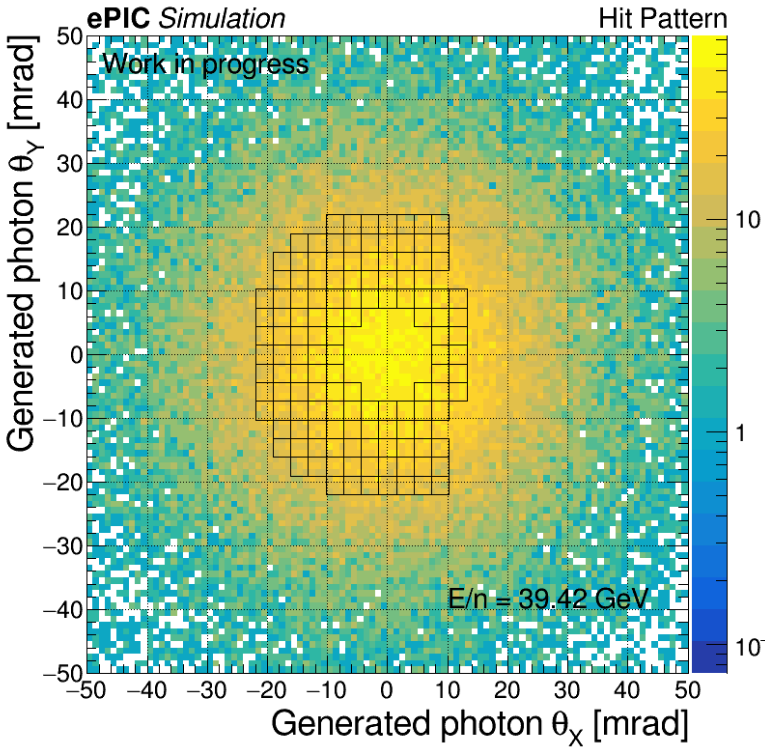
Summary

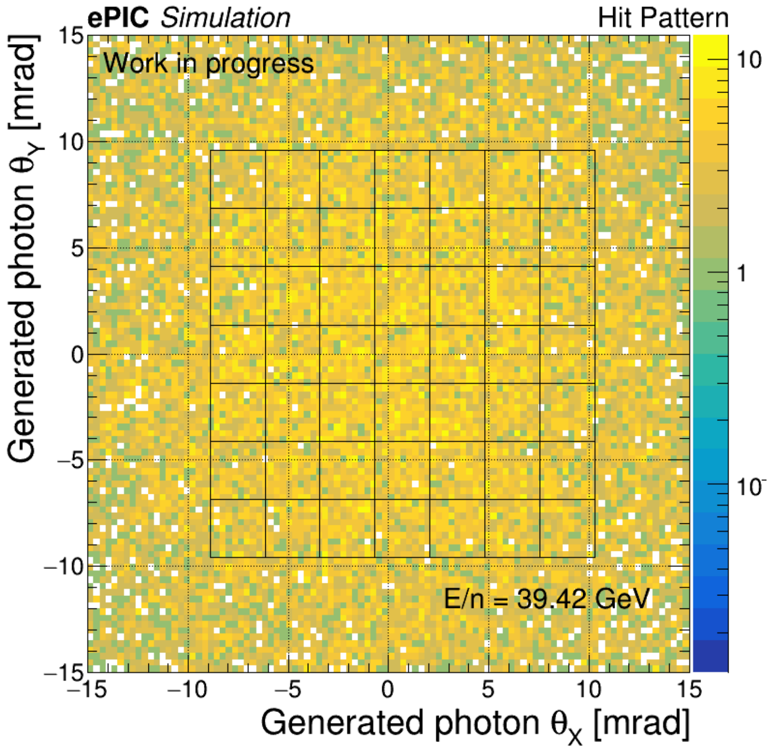
- Feasibility study for ~MeV photons from ion deexcitation has been performed for ePb beam energies
- Geometrical acceptance of ~40% in B0 detector for forward photons was computed.
- B0 ECAL cells with energy thresholds above 50 MeV result in ~70% photon detection efficiency (the main loss is due to intersect with the beampipe).
- B0 is the only detector with high efficiency for O(100MeV) photons in $|\eta|>4.5$
- Photon energy resolution in ion rest frame <10%(!)
- Photon spatial resolution in lab frame – 3.3 mm (B0 crystal size is 20 x 20 mm^2)
- Further studies including realistic physics model is needed to access the full potential of this event topology

Backup

Simulation results

- In the forward region, the ZDC and the B0 detectors can measure forward photons.
- Hit pattern for 39.4 GeV/n Pb beam in B0 and ZDC detectors :

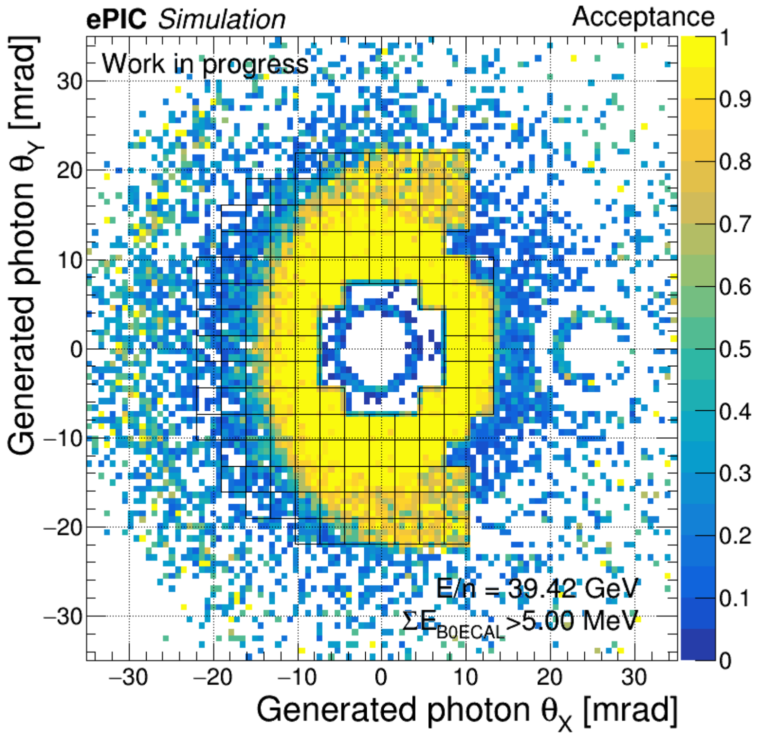


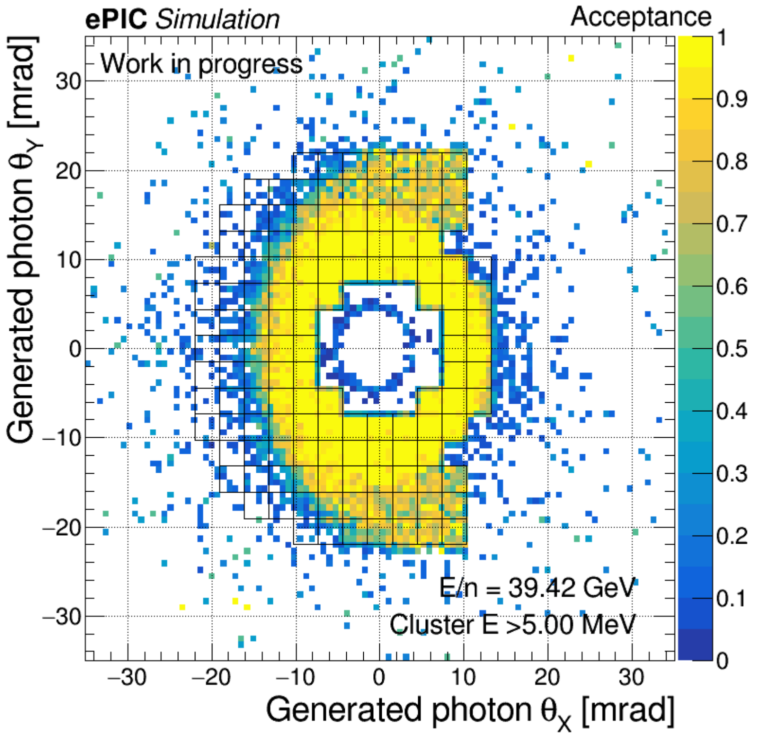


Simulation results

- Geometrical acceptance of B0 detector for 39.4 GeV/n Pb beam:

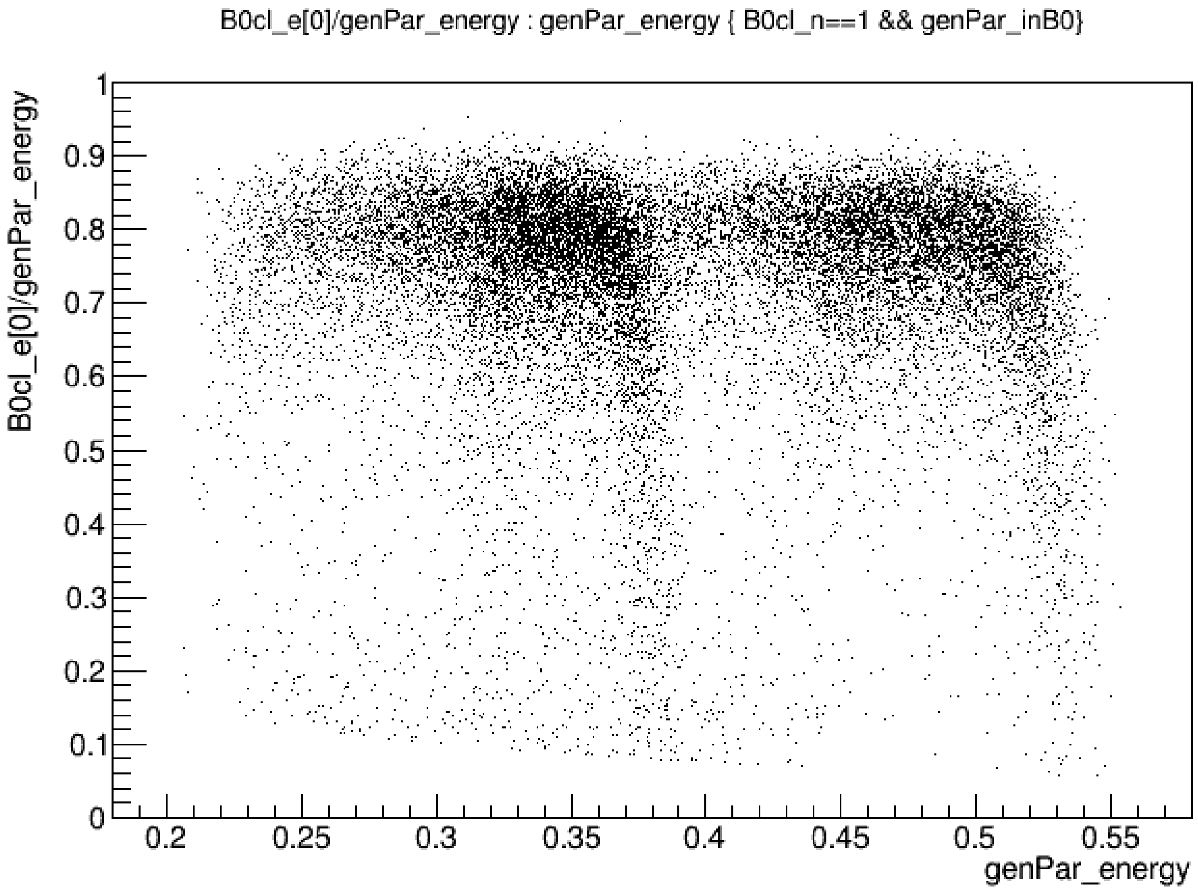
γ energy in A rest frame	Within B0 acceptance	B0 acceptance + At least one hit in B0 with E > 5 MeV	B0 acceptance + At least one cluster in B0 with E > 5 MeV	B0 acceptance + At least one hit in B0 with E > 10 MeV	B0 acceptance At least one cluster in B0 with E > 10 MeV
5 MeV	31.5%	23.4%	22.6%	23.4%	22.6%
7 MeV	31.8%	24.3%	23.3%	24.2%	23.3%

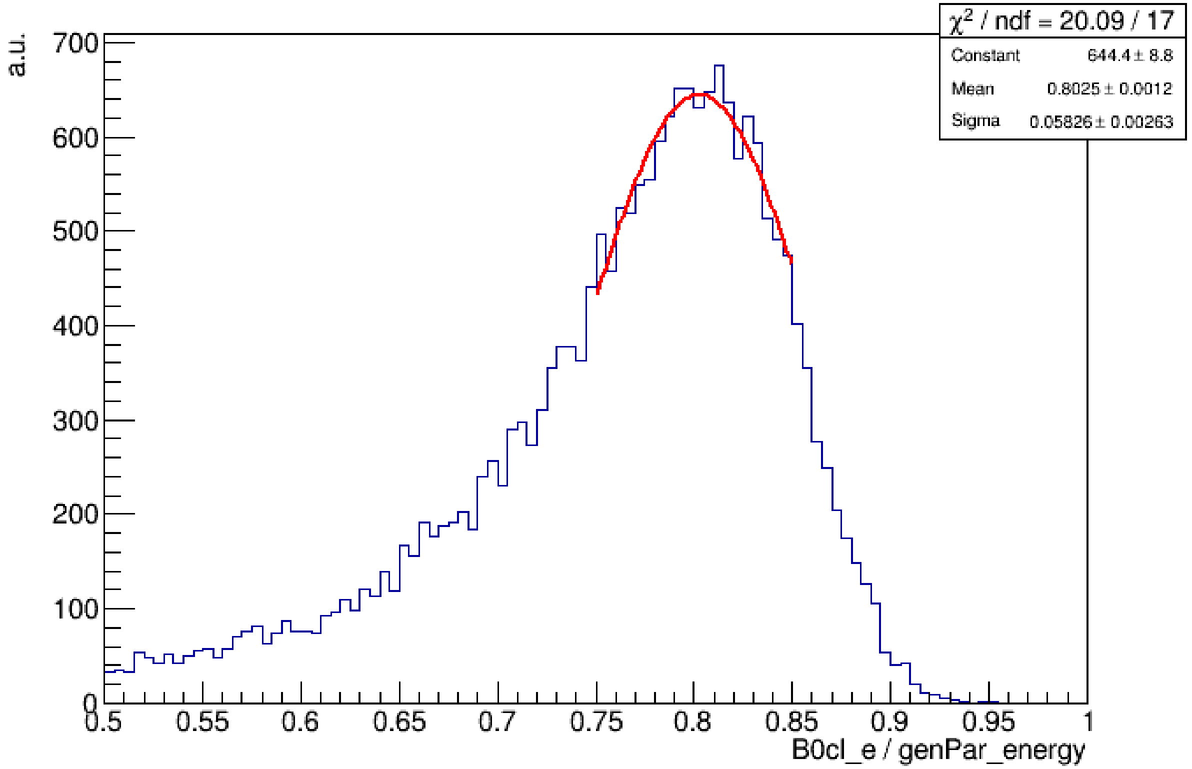




Photon calibration

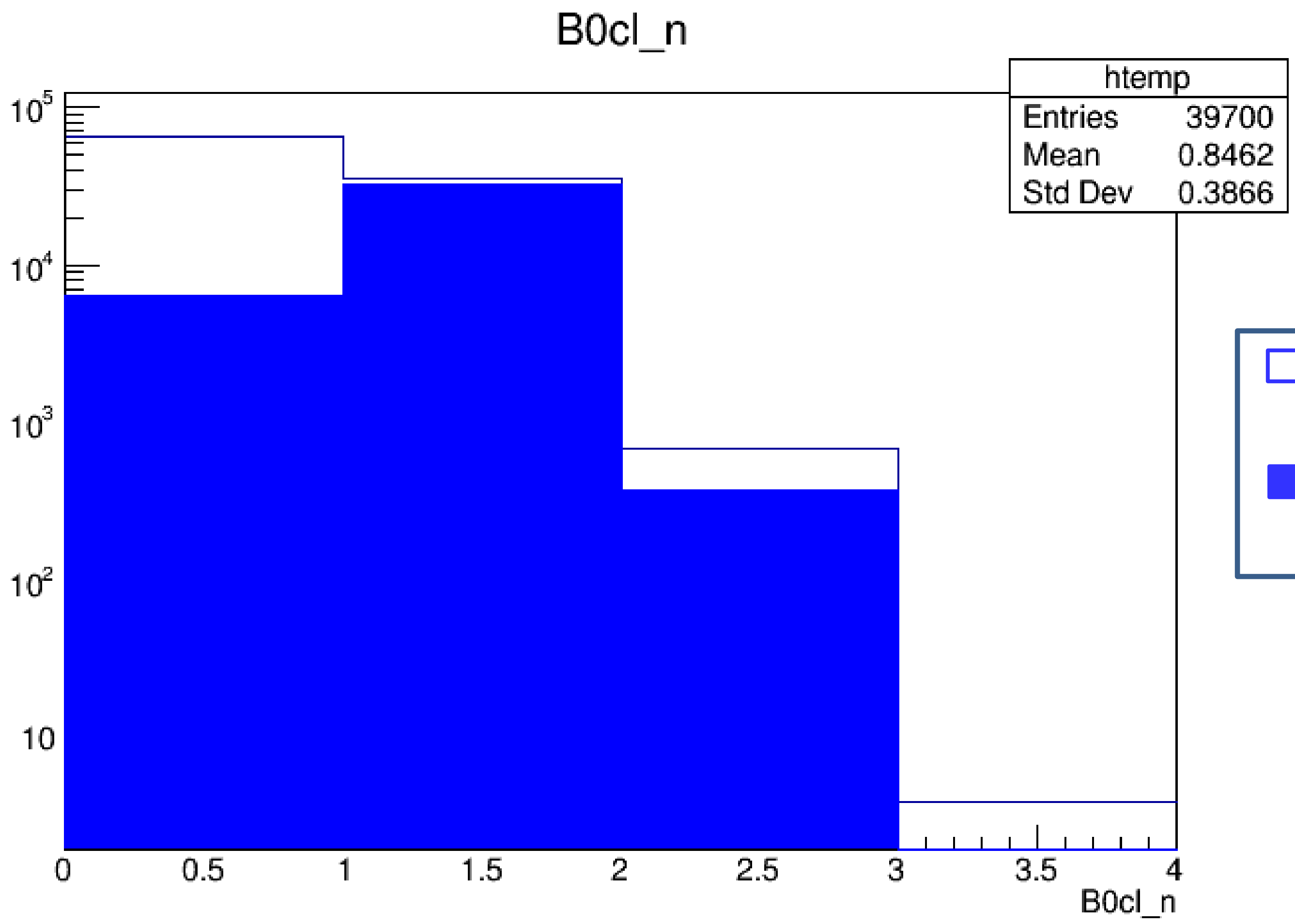
- Due to a constant response vs photon energy the calibration factor computed for the inclusive sample. Calibration factor C = 1.2461090





Photon reconstruction

- In most of the events we have only 1 energy cluster



Number of photons in event

With gen photon within the B0 Acceptance