Detecting Soft Photons with the B0 Detector @ ePIC

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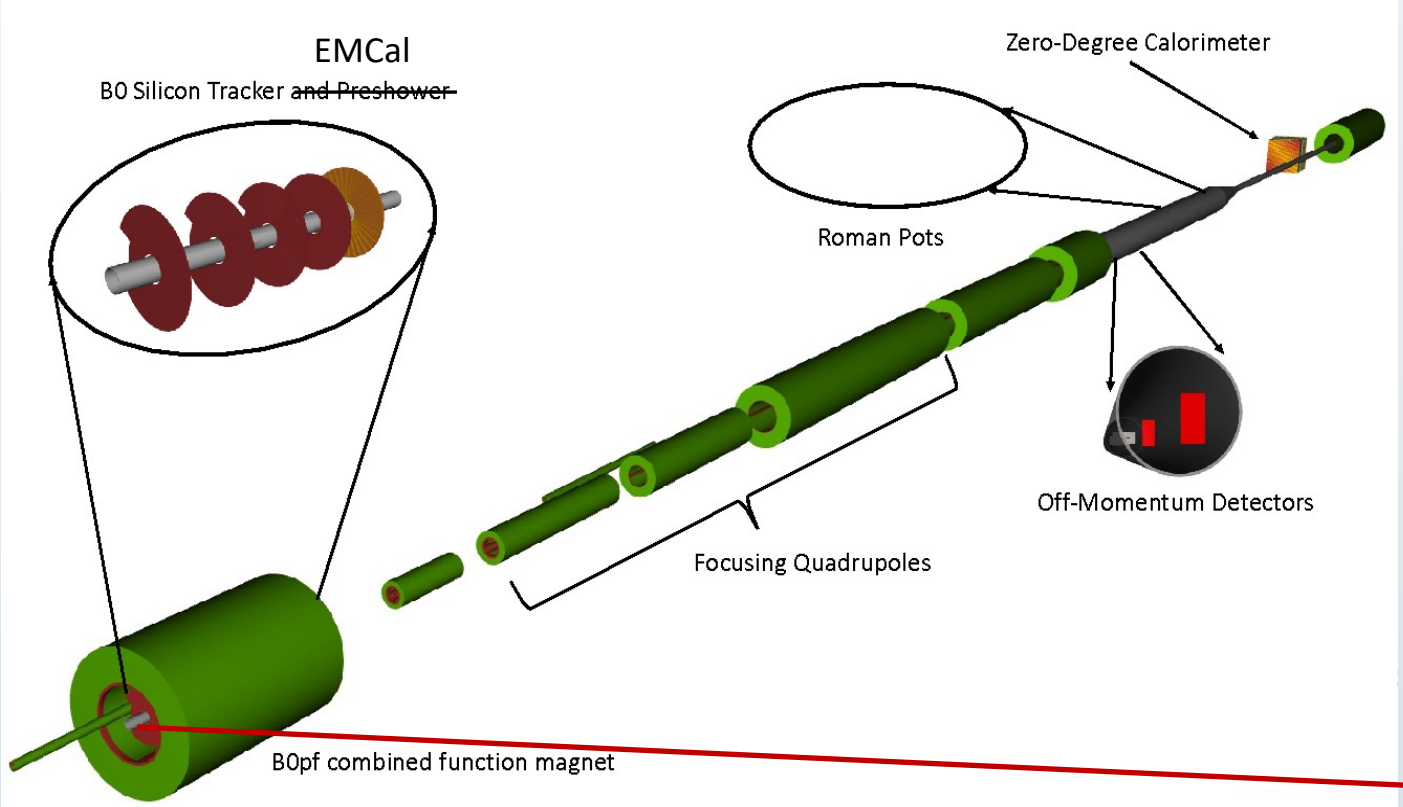
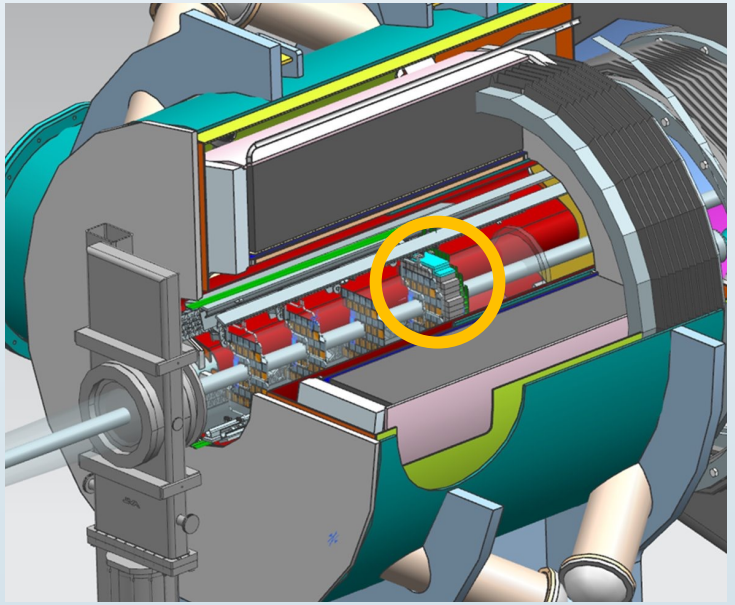
Introduction

- In many eA interactions, the ion emits soft photons (MeV) via nuclear de-excitation in the ion frame.
- The emitted photons are boosted in the forward direction ($\eta > 0$) with the beam energy.
- **At the EIC a forward (4.6< η < 5.9) calorimeter (B0 ECal) may be able to detect these photons**
- This study tries to give an estimation of the B0's detecting capabilities of soft photons.

B0 Calorimeter

- The B0 detector comprised of four tracking layers and an EM calorimeter (scintillating crystals).
- The detector is located at the forward region of the EIC , z = 6.8 meters from the interaction point.





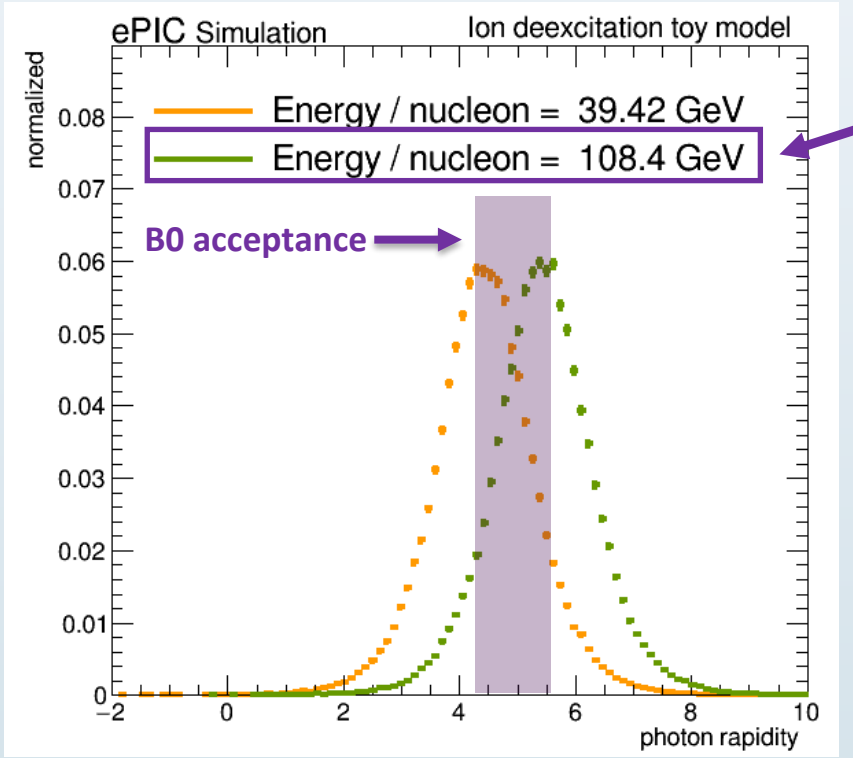
Toy Model For Soft Photons

- Start with two discrete energies - 5 MeV, and 7 MeV in the ion rest frame -

  (inspired by study at LHC , Eur.Phys.J,A(2021))

- Photons were generated isotropically ($\cos\theta \sim Uni[-1,1]$, $\phi \sim Uni[0,2\pi]$).

- Both beam energies give photons in acceptance
  - 'Forward' θ emission from low energy beam
  - 'Backward' θ emission from high energy beam
  - 32% and 40% of generated photons found to be within the B0 rapidity coverage for 39.4 and 108.4 GeV beam energy respectivly.



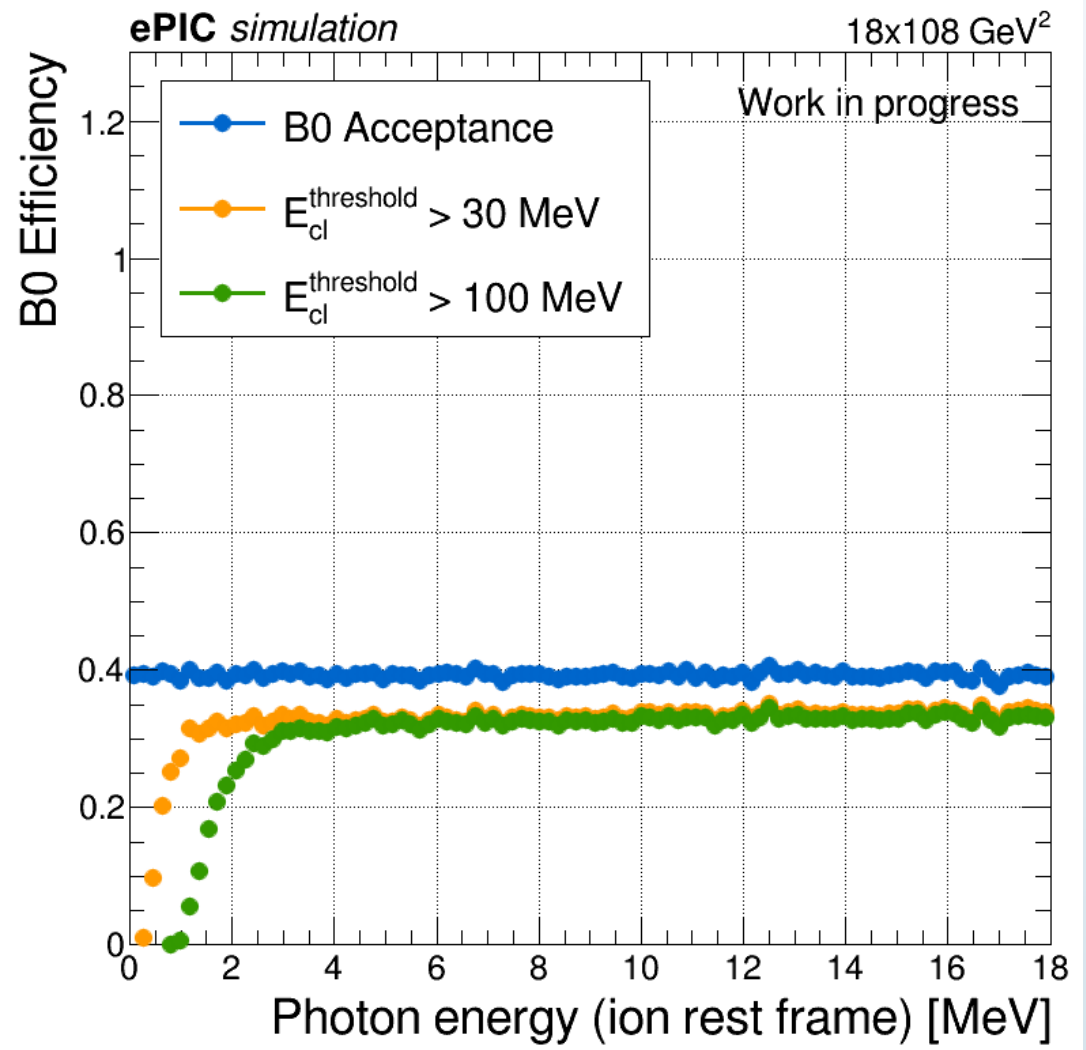
- Full study: (https://indico.bnl.gov/event/18761/contributions/78067/attachments/48260/81978/LowEphotons_BGU_2023_06_27.pdf)

Initial Results using Toy Model

- We generated photons in the Pb's rest frame with energies varying from 0 to 18 MeV.
- EICRecon to reconstruct the deposited energy of the photons in the B0 ECal.

$$\text{B0 Acceptance} = \frac{photons\ which\ hit\ the\ B0\ crystal}{Total\ photons}$$

Cluster = Reconstructed photon energy in the B0 Ecal.



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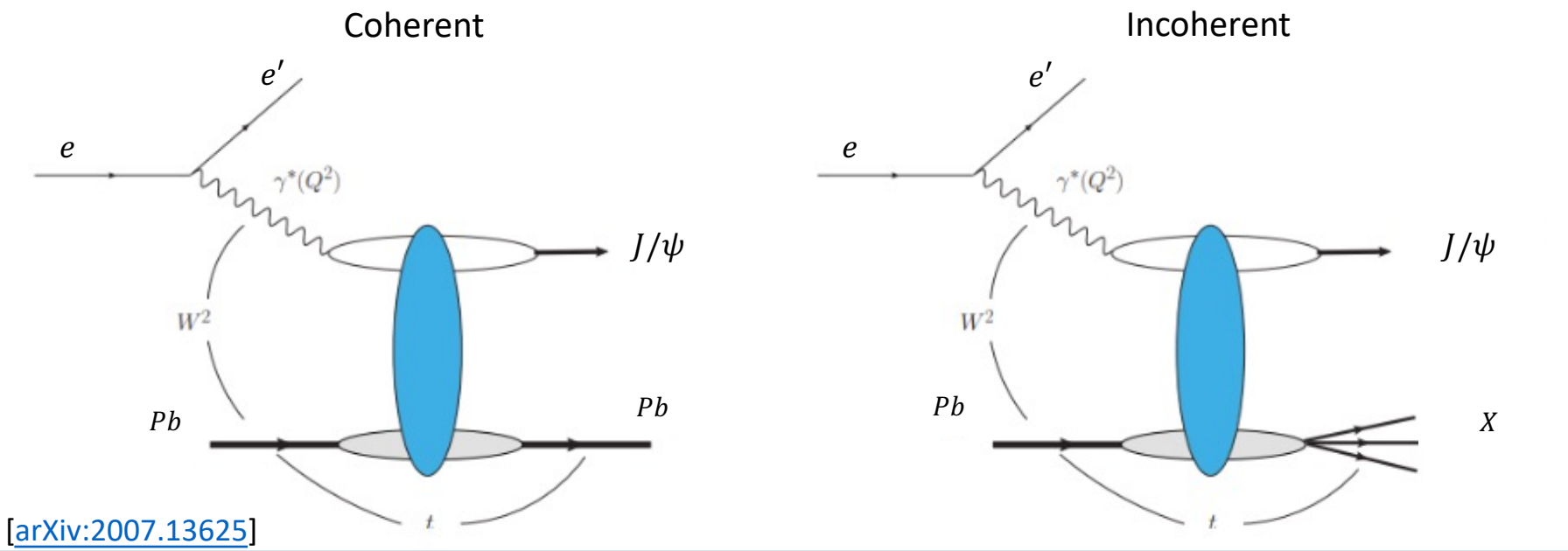
Vector Meson Production

- We are examining J/ψ vector-meson production from ePb collisions ($18\times108\ \mathrm{GeV}^2$).
- J/ψ vector-meson production can be categorized into two main processes:
  1. Coherent VM production: $\mathrm{e} + \mathrm{P}b \rightarrow e' + Pb + J/\psi$
  2. Incoherent VM production: $\mathrm{e} + \mathrm{P}b \rightarrow e' + J/\psi + X$



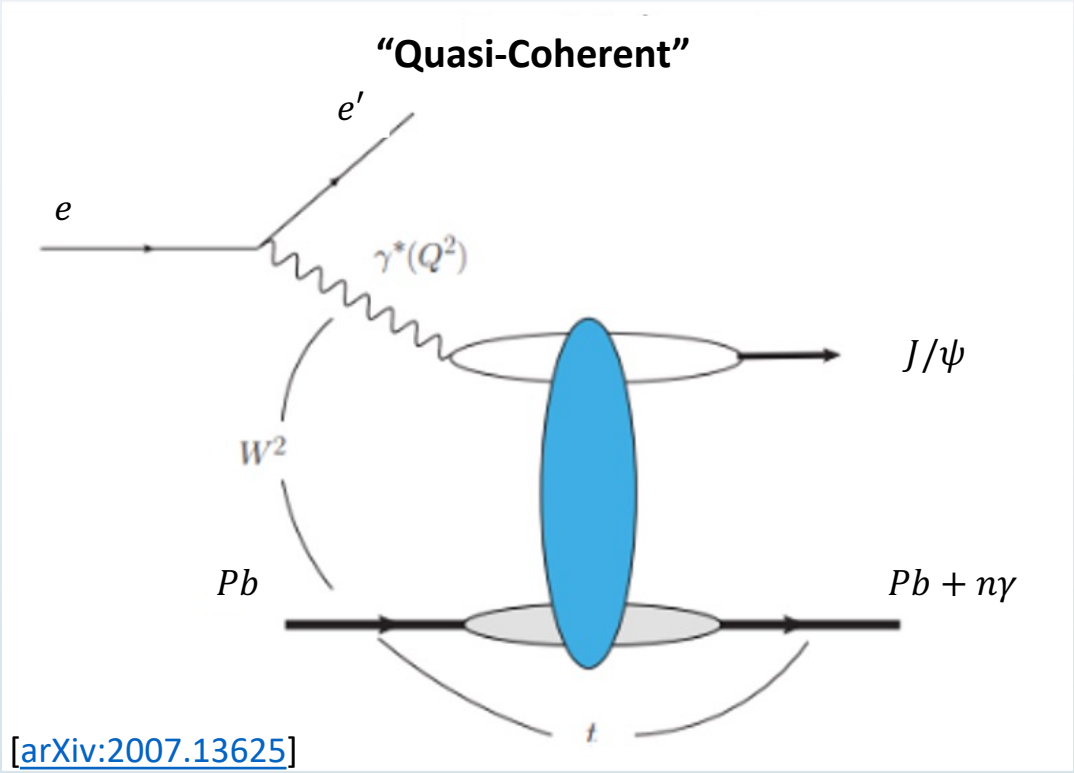
[arXiv:2007.13625]

Add a Photon …

- Another type of process:

$$\mathrm{e} + \mathrm{P}b \rightarrow e' + Pb + J/\psi + n\gamma \quad , n = 1, \ldots \approx 6$$

- It is unclear if this type of process has the charectaristics of a coherent or incoherent VM production. For convenience , we call these events "**Quasi-Coherent"** events.



[arXiv:2007.13625]

Note: In Quasi-Coherent events the Pb Ion is excitated → Emits photons when going through de-excitation.

Analysis

Analysis Steps:

1. We used BeAGLE (MC event generator) generated data of these processes. (Thanks to Mark Baker for producing the data).(https://wiki.bnl.gov/eic/index.php/BeAGLE)
2. Filter only Quasi-Coherent events with $^{208}_{82}Pb$ final state Ion from the BeAGLE HEPMC files.
   **Filter == Only events with final state $^{208}_{82}Pb, \gamma, \mu^+, \mu^-$ particles ($J/\psi \rightarrow \mu^+\mu^-$).
3. Use the HEPMC files to analyze the different kinematics in the events.
4. Use EICRecon to reconstruct the B0 Ecal Cluster energy.

Original data with ≈ 6.7 milion events. → **Filter** → Only "Quasi-Coherent" events, ≈ 230k events (3.5%). → **Analyze** → Understand the kinematics of these events.

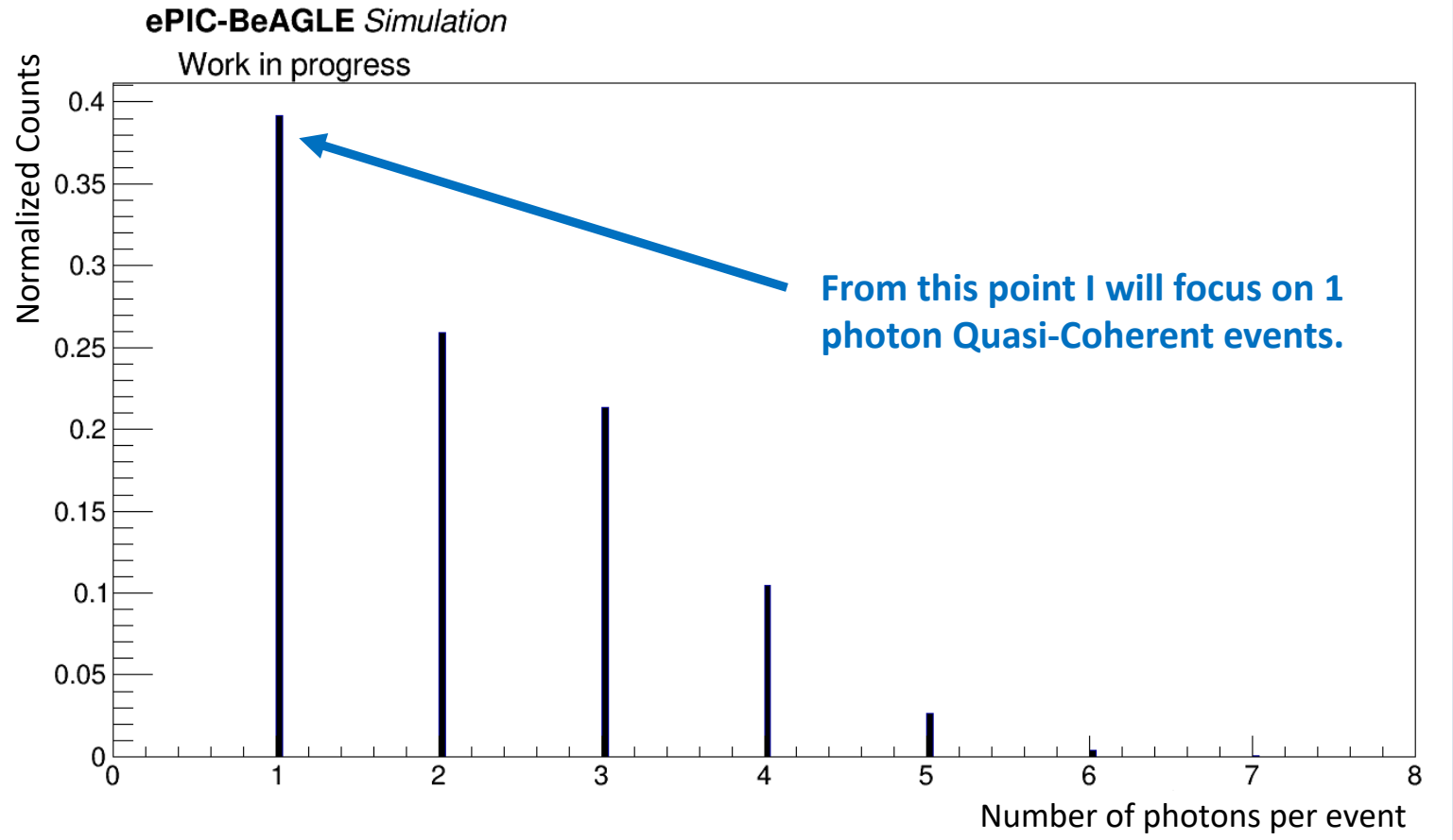
Analysis Configurations:

- $H_{beam\ energy}$ = 275 GeV
- Z_{Pb} = 82
- A_{Pb} = 208

→ Nucleon Energy (lab frame): $H_{beam} * \frac{Z_{Pb}}{A_{Pb}} = 108.4$ GeV

Number of Photons per Event

- In total we analyzed ≈ 230K Quasi-Coherent events. The distribution of the number of photons per Quasi-Coherent event ($e + Pb \rightarrow e' + Pb + J/\psi + n\gamma$) is shown below:

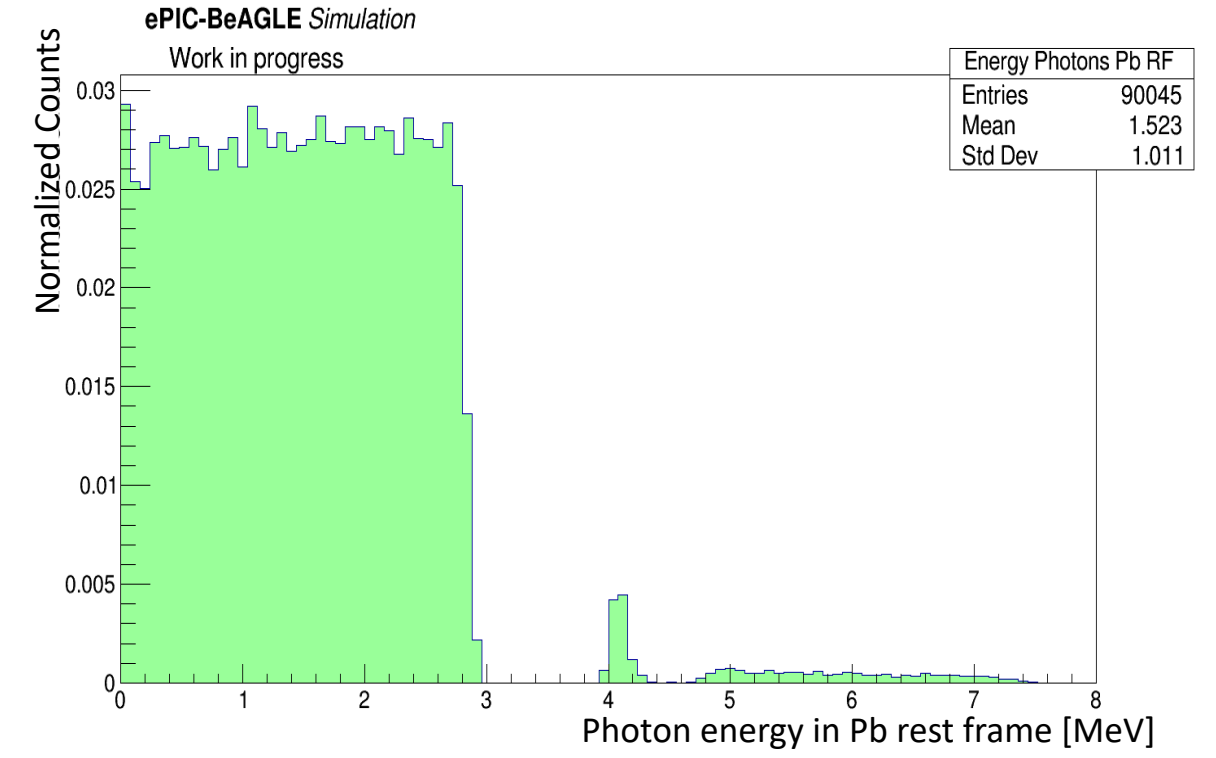


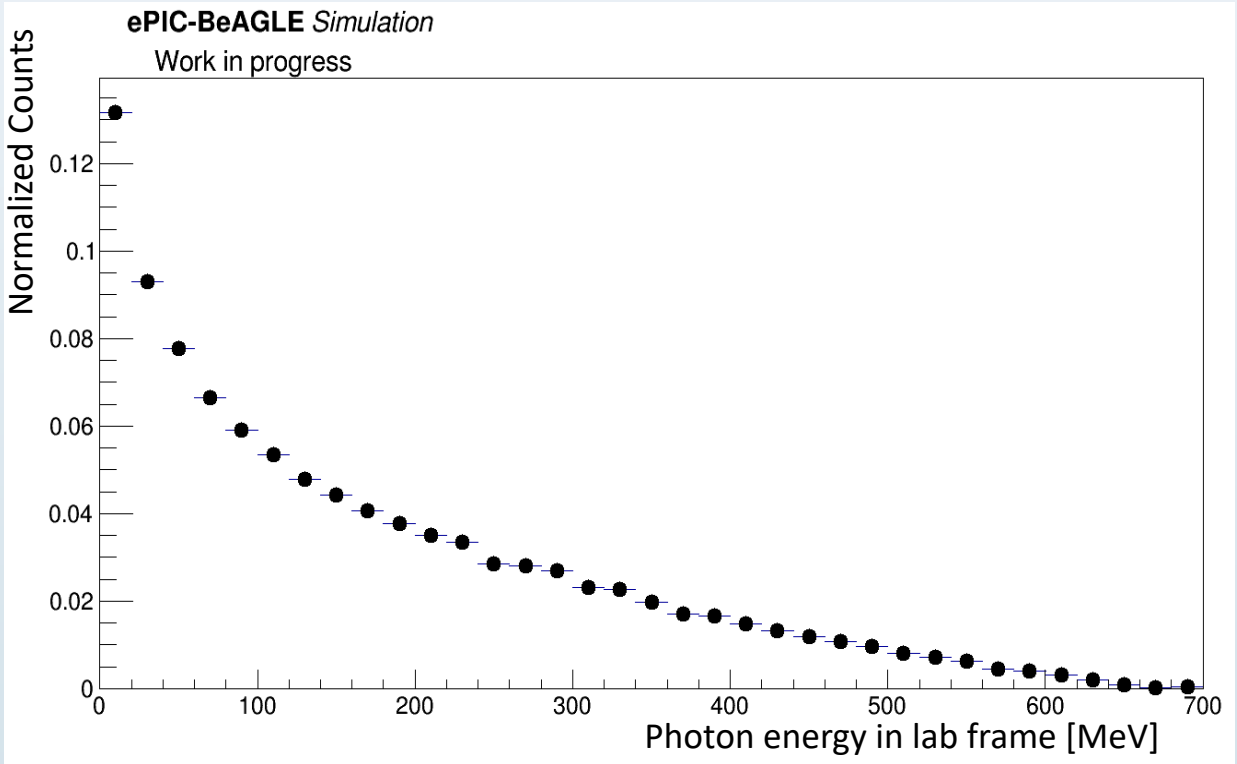
Note: These are all final state photons (status = 1).

1 Photon “Quasi-Coherent” Photon Energy

- Ion frame energy shows distinct features
- Features largely smoothed over in lab frame

Boost

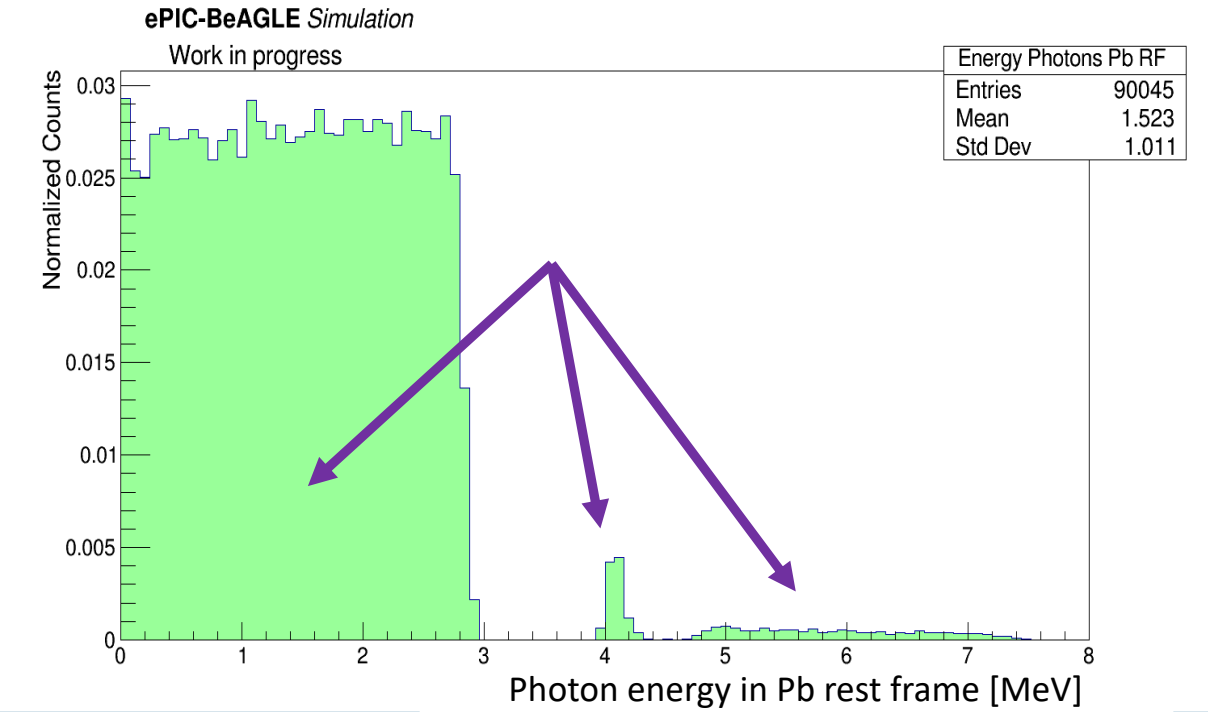


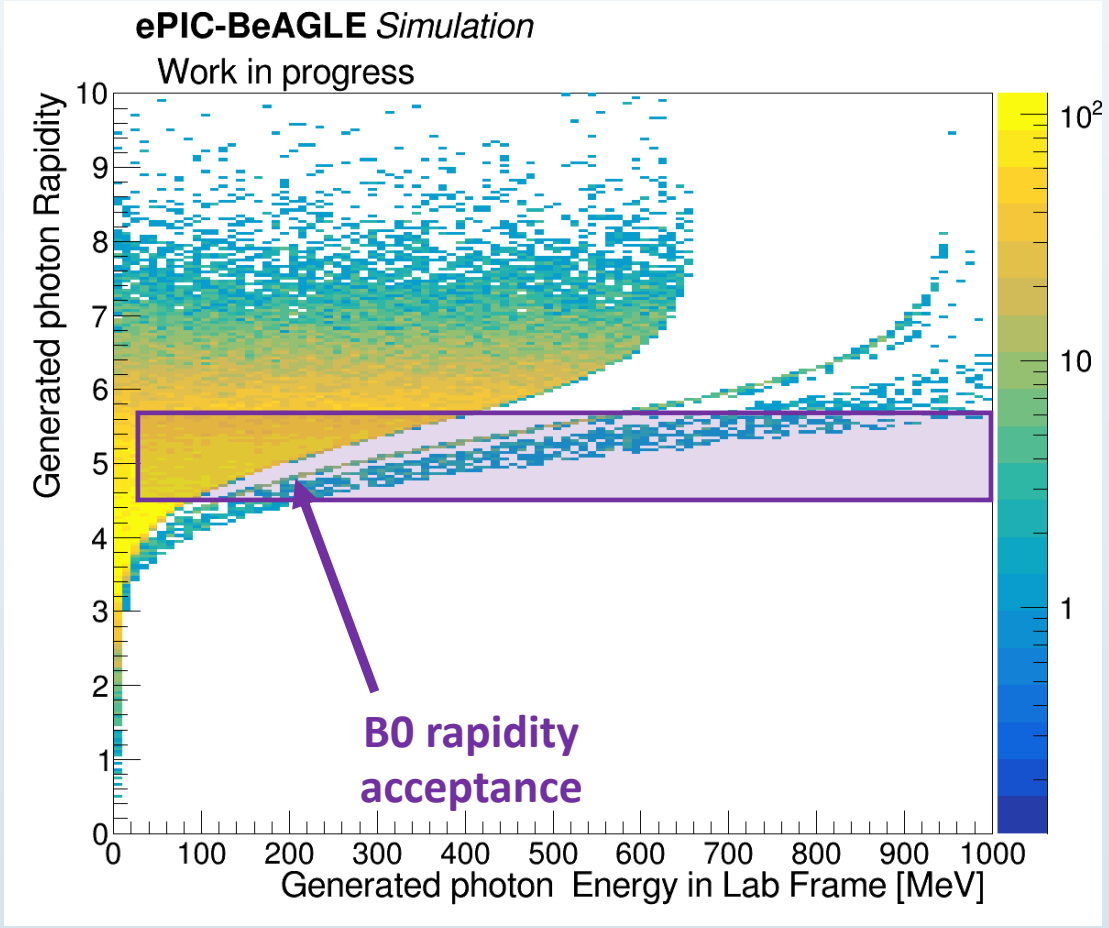


1 Photon "Quasi-Coherent" Events

- We only measure a particular slice in rapidity **$4.6 < \eta < 5.9$**

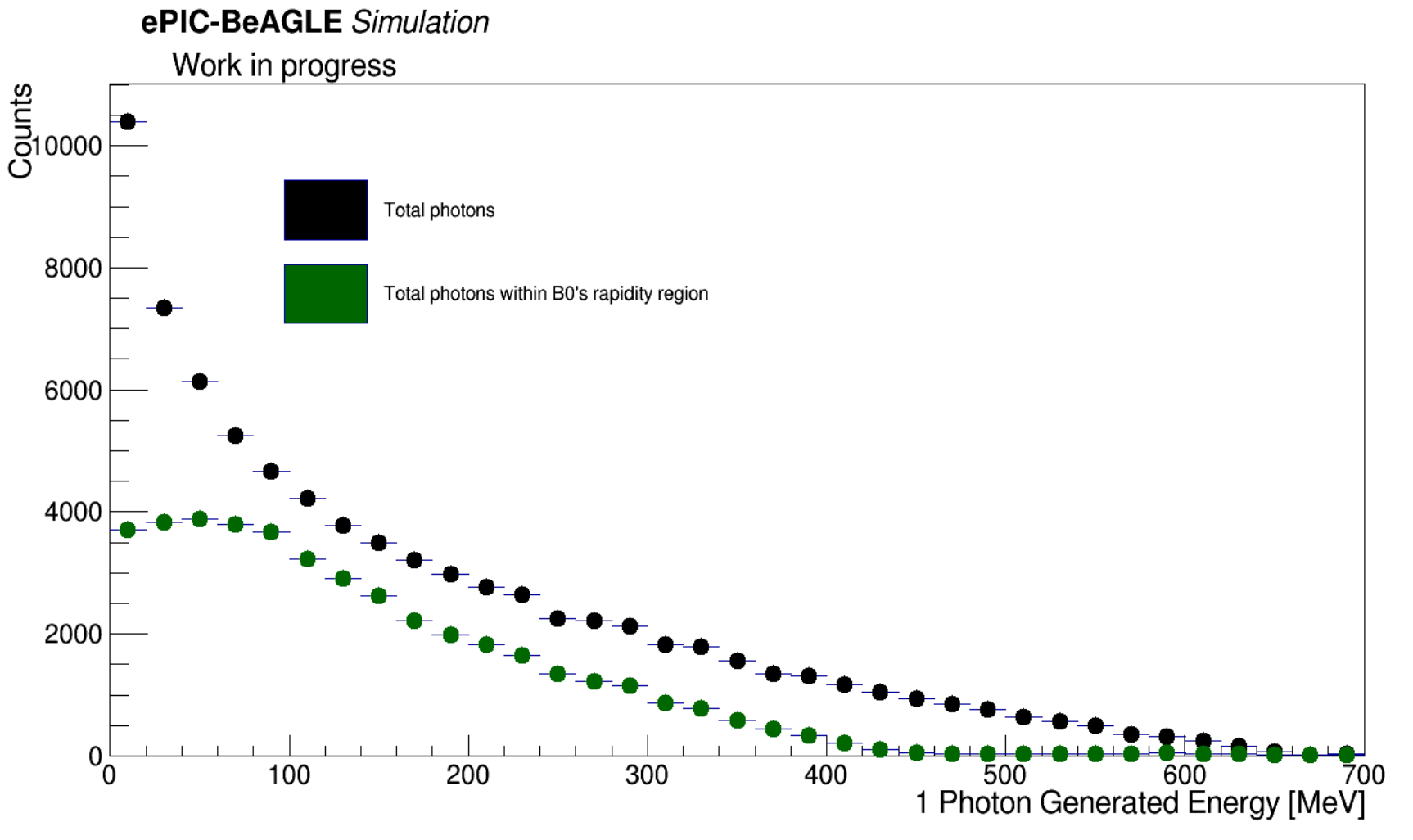
- **47%** of photons within B0's rapidity acceptance
- (In rapidity vs E we again see the three distributions)





1 Photon “Quasi-Coherent” Events

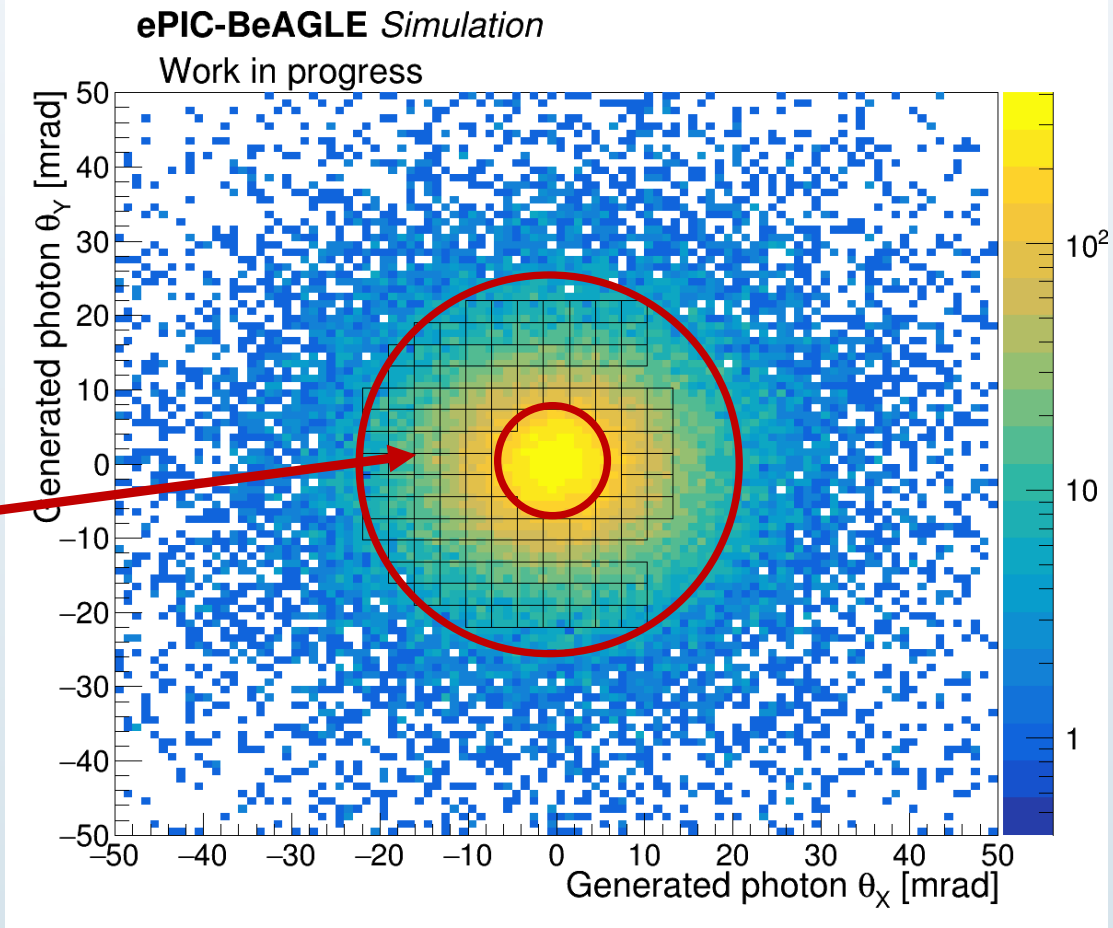
- Energy distribution in B0 rapidity acceptance



1 Photon “Quasi-Coherent” Events

- B0 calorimeter does not cover the entire rapidity window
- Photon emission pattern in the lab frame:

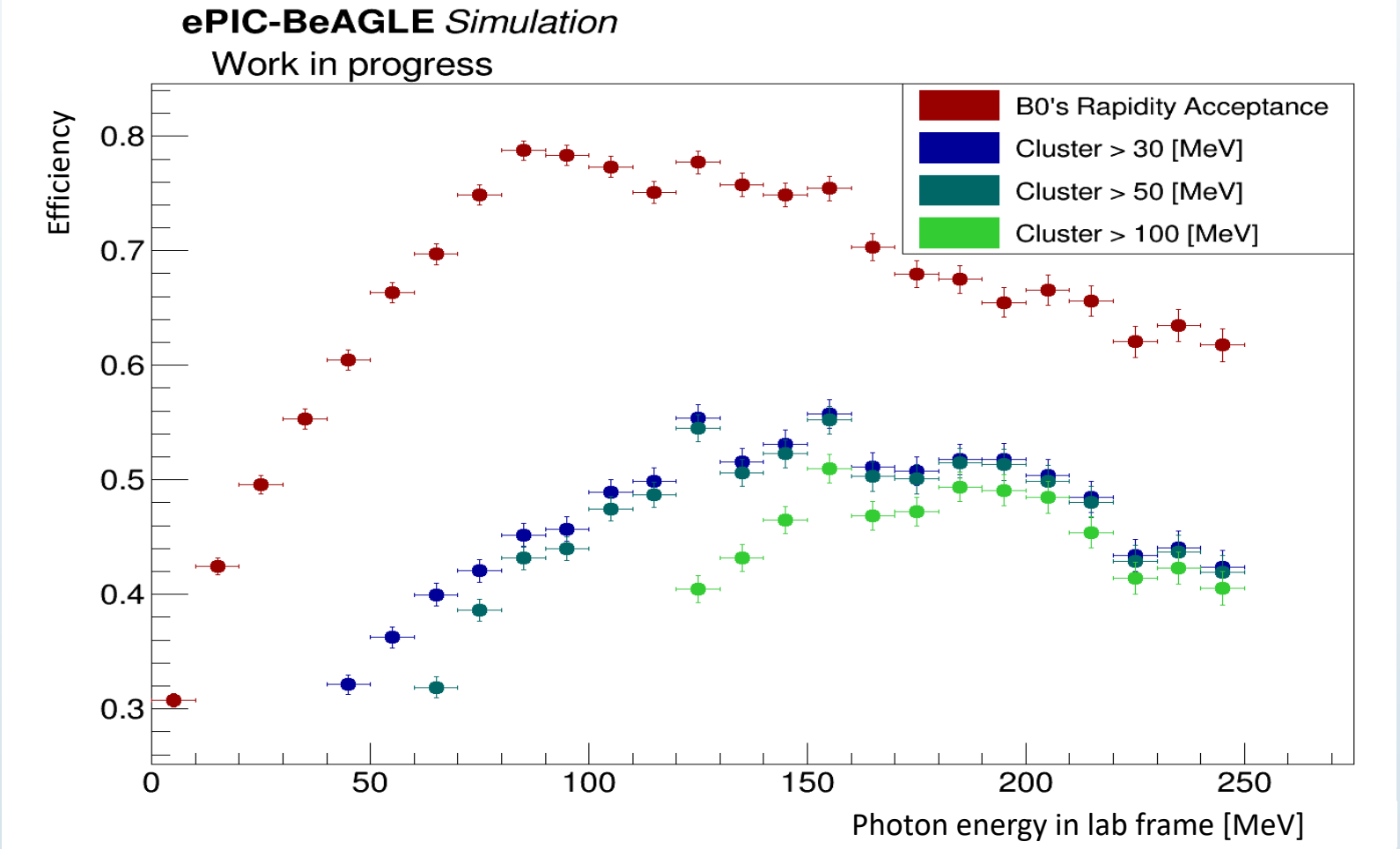
Within B0 rapidity acceptance



1 Photon “Quasi-Coherent” Events

- Overall 47% of photons within 4.6< η < 5.9
  - Acceptance strongly energy dependent
- Requiring B0 signal.
- Realistic Energy cluster requirement lead to efficiency greater than ~30% for greater than ~50 MeV.

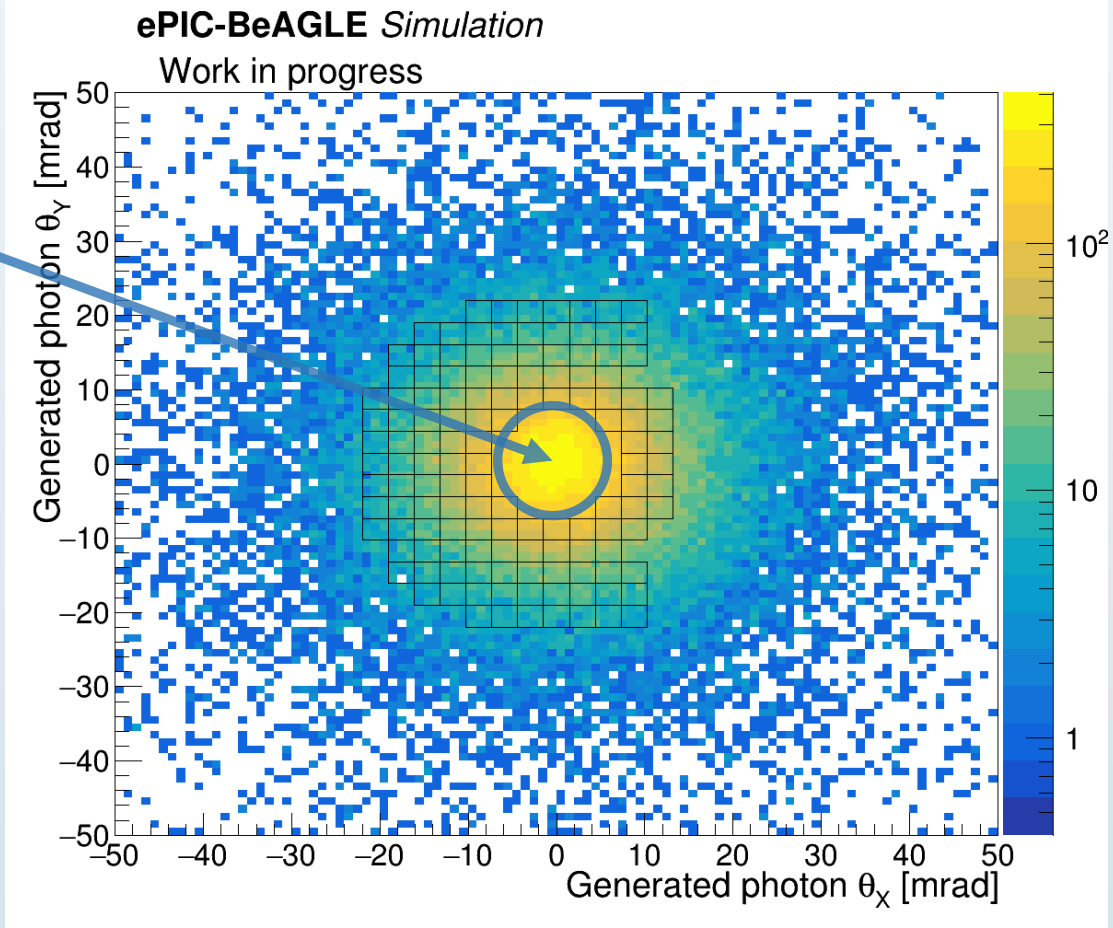
B0 rapidity Acceptance $= \frac{photons\ with\ 4.6 < \eta < 5.9}{Total\ photons}$



1 Photon “Quasi-Coherent” Events

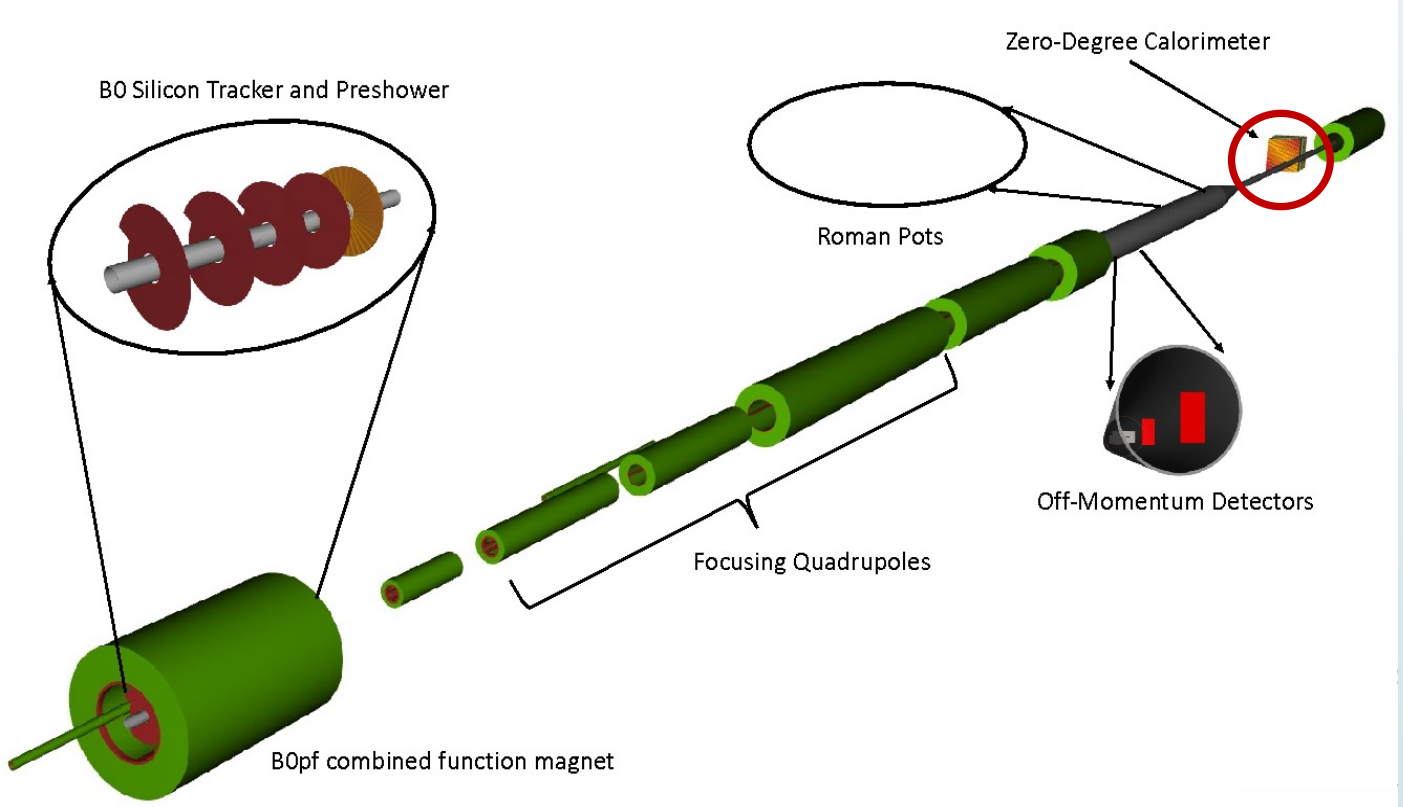
- Now, going back to the soft photon emission pattern in the lab frame, we can see that a lot of photons are emitted at rapidity higher than B0:

Within ZDC rapidity acceptance?



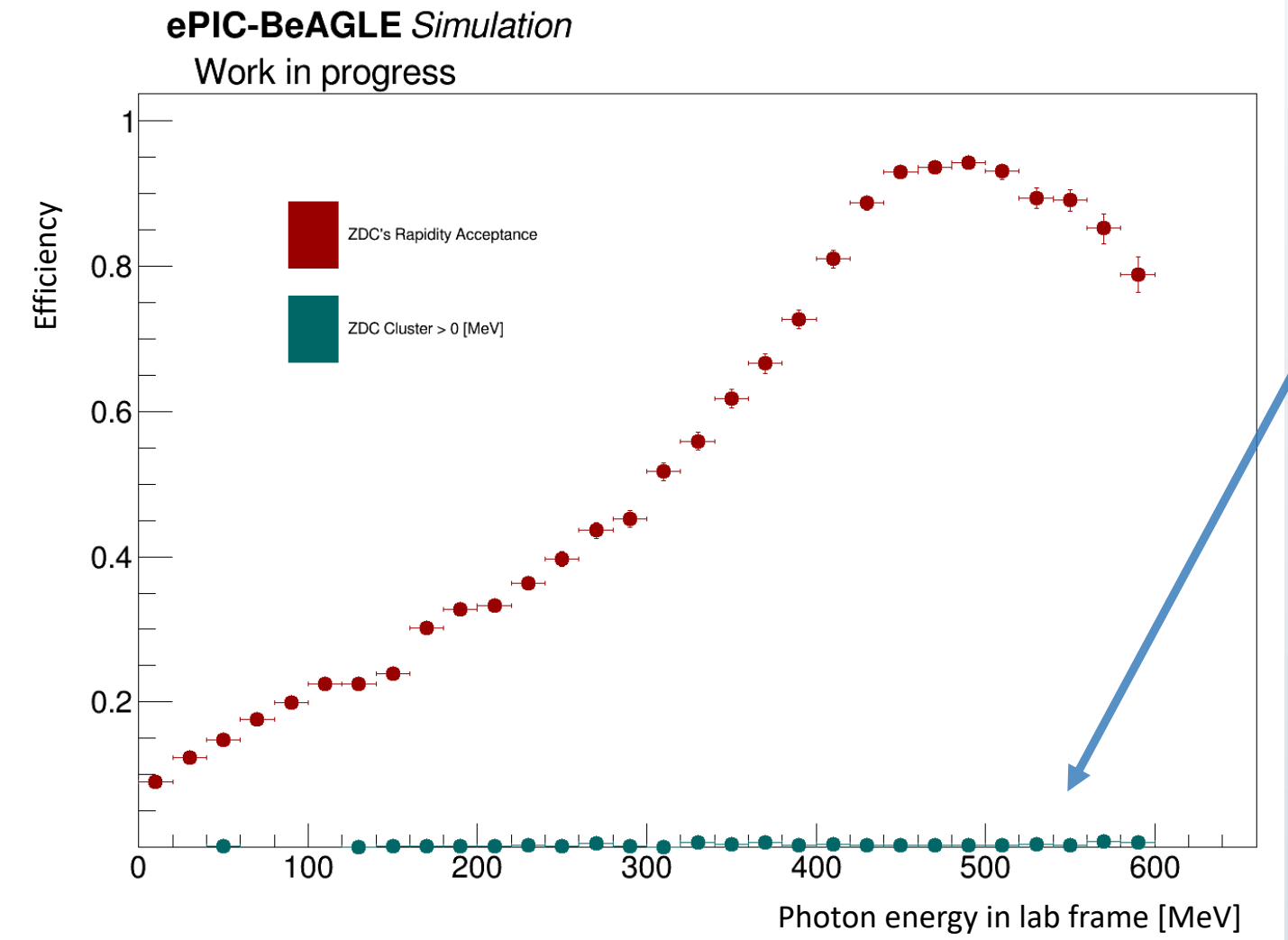
The ZDC

- The ZDC is located at around z= 40 meters from the interaction point, comprised of tracking layers and EM calorimeter.
- The ZDC has a rapidity acceptance region of $\eta > 6$.
- Can we measure soft photons there?



1 Photon “Quasi-Coherent” Events

- Generated an efficiency plot for the ZDC detector:



- **Many of the soft photons fall into ZDC rapidity coverage but …**
- **We see that the ZDC’s efficiency is < 1%.**
- **The photons interact with the beam pipe before getting to the detector (at least in present ePIC setup)**

$$\text{ZDc Acceptance} = \frac{photons\ with\ \eta{>}6}{Total\ photons}$$

Summary

- In “Quasi-Coherent” processes, the nucleus is excited → Soft photons are emitted via nuclear de-excitation.
- **Photons are detectable in B0, reasonable reconstruction requirements give efficiency $\sim$30% from 50 MeV**
- B0 is the only forward detector which can detect these soft photons.

Future Steps

- Further study of Quasi-Coherent processes with the ePIC simulation.
- Studies of background processes in ePb collisions.

Thanks!

Backup

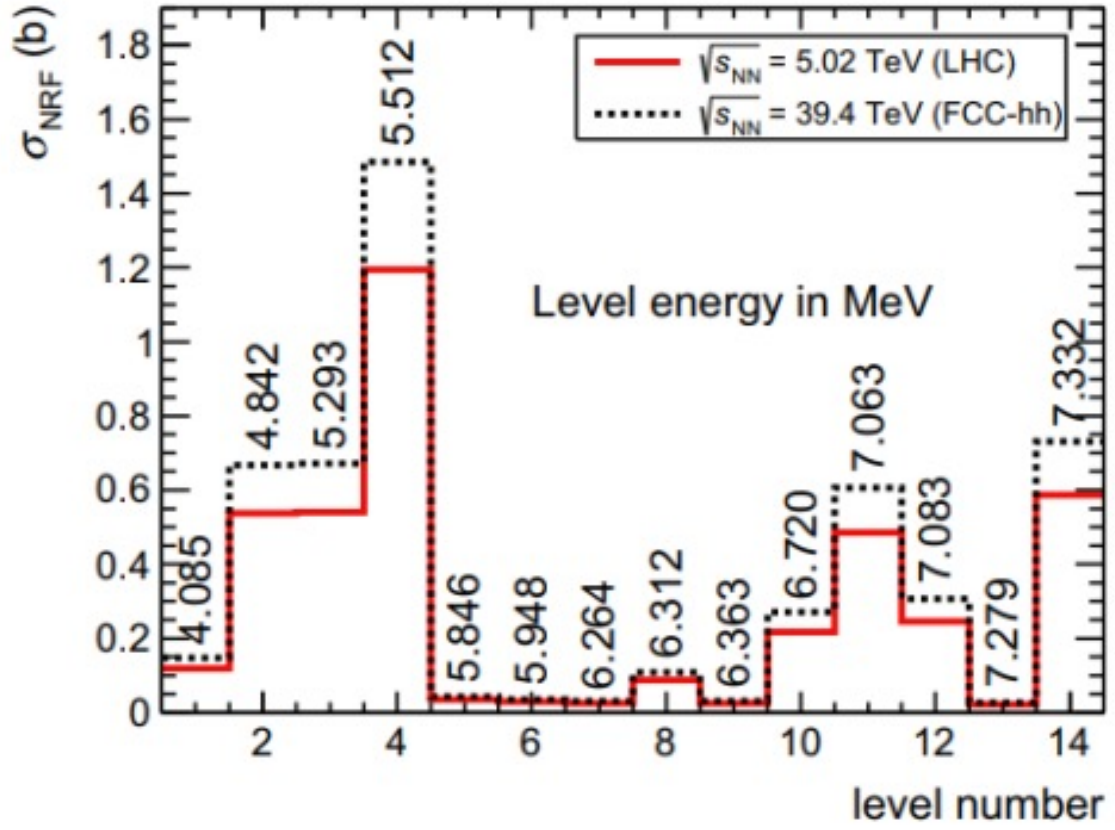


Fig. 2 NRF cross sections for ultraperipheral ^{208}Pb–^{208}Pb collisions at the LHC and FCC-hh, respectively, at $\sqrt{s_{NN}} = 5.02$ TeV (solid histogram) and at $\sqrt{s_{NN}} = 39.4$ TeV (dashed histogram)