Searches for Axions in Heavy-Ion collisions at ATLAS

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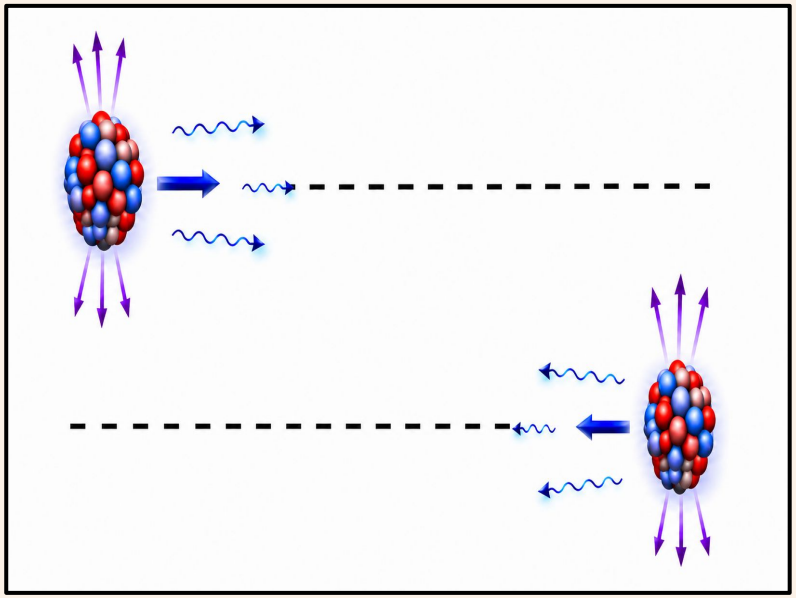
Analysis Overview

Analysis: Measurement of **light-by-light scattering (γγ→γγ)** in Ultra-Peripheral Pb+Pb collisions at $\sqrt{s_{NN}}$ = 5.36 TeV collected in 2023, corresponding to an integrated luminosity of 1.63 nb^{-1} recorded by the ATLAS experiment at the LHC.

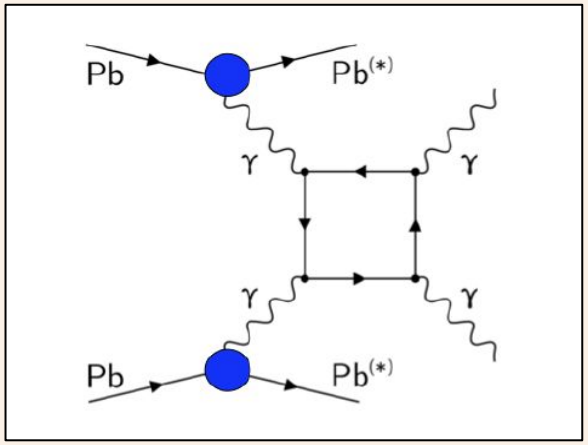
Ultra-Peripheral Collision (UPCs) & Light-by-light (LbyL) scattering:

- Special type of Heavy-ion Collision:
  - Interaction between two ions:
    Nuclear ❌ Electromagnetic (EM) ✅
- Mainly two collisions:
  - Photon-Photon **(γγ)**
  - Photon-Nucleas **(γA)**.
- Our study is focussed on **γγ** collision.
- Specifically LbyL scattering **(γγ→γγ).**



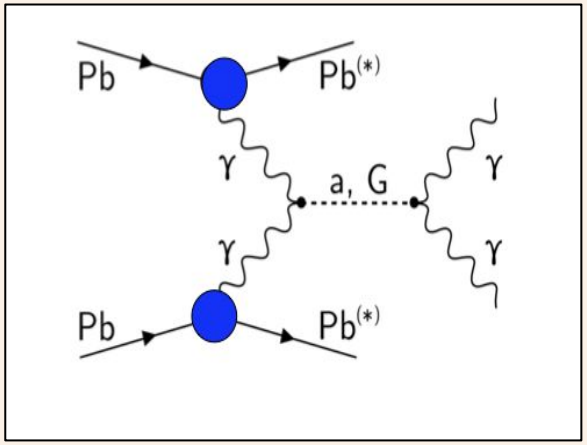
Motivation

- In Standard Model (SM):
  - LbyL is allowed in QED via virtual one-loop box diagrams.
  - And it being a rare process the measurement of its cross-section precisely is very important.



$\gamma\gamma \rightarrow \gamma\gamma$ in SM

- In various extension of SM:
  - LbyL can occur via resonance production such as Axion-like-Particles (ALPs) or spin-2 Gravitons.
  - Thus making it sensitive to new physics.



In BSM

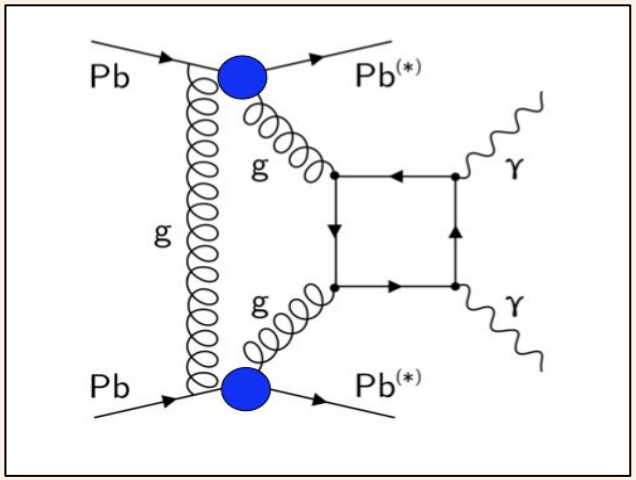
Main Backgrounds:

In our measurement, the final-state signature of interest is two low-energy photons and no reconstructed charged-particle tracks.

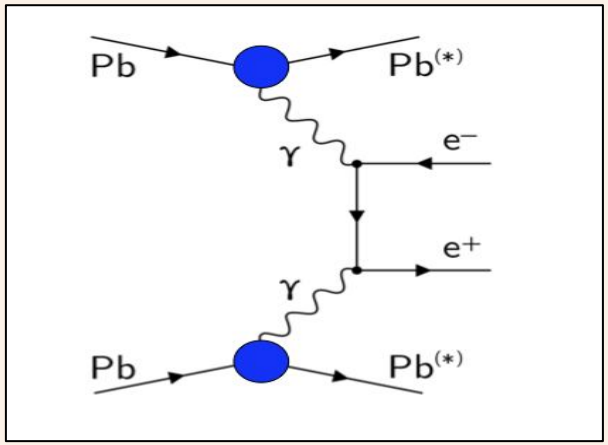
But this final state can also be mimicked by the following processes:

- Central Exclusive Production (CEP)
- Dielectron Production.

The misidentification of electrons as photons can occur when the electron track is not reconstructed or the electron emits a hard bremsstrahlung photon.



Central Exclusive Production (CEP)



Dielectron Production: $\gamma\gamma \rightarrow e^+e^-$

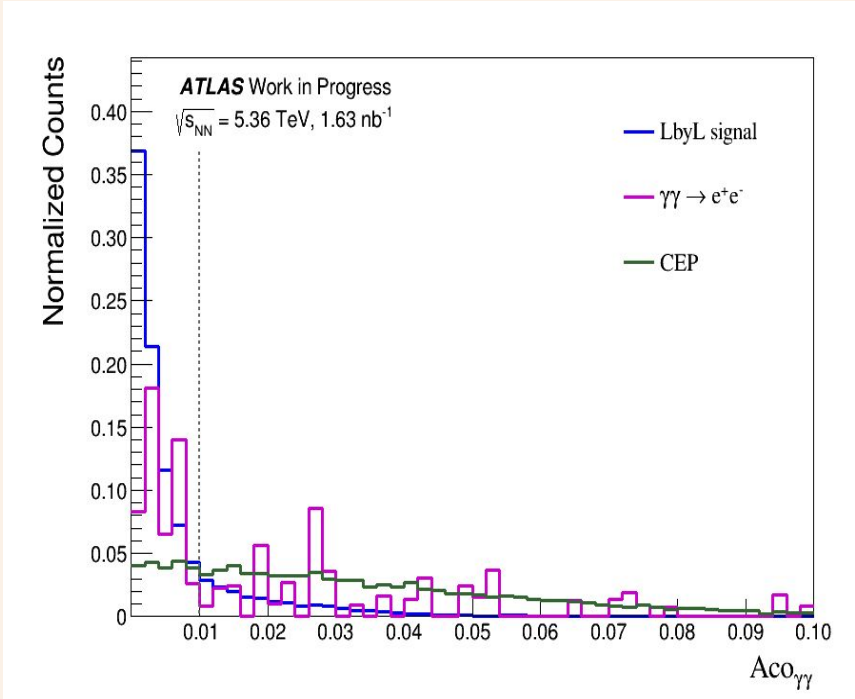
Event Selections:

Event selections that are currently being used in our analysis are as follows:

- Events with two photons passing Photon Identification Algorithm.
- Electron Veto (e-veto)
- Diphoton acoplanarity cut:

  $(1-\phi_{\gamma\gamma}) < 0.01$ Signal Region (SR)

  $(1-\phi_{\gamma\gamma}) > 0.01$ Control Region (CR)



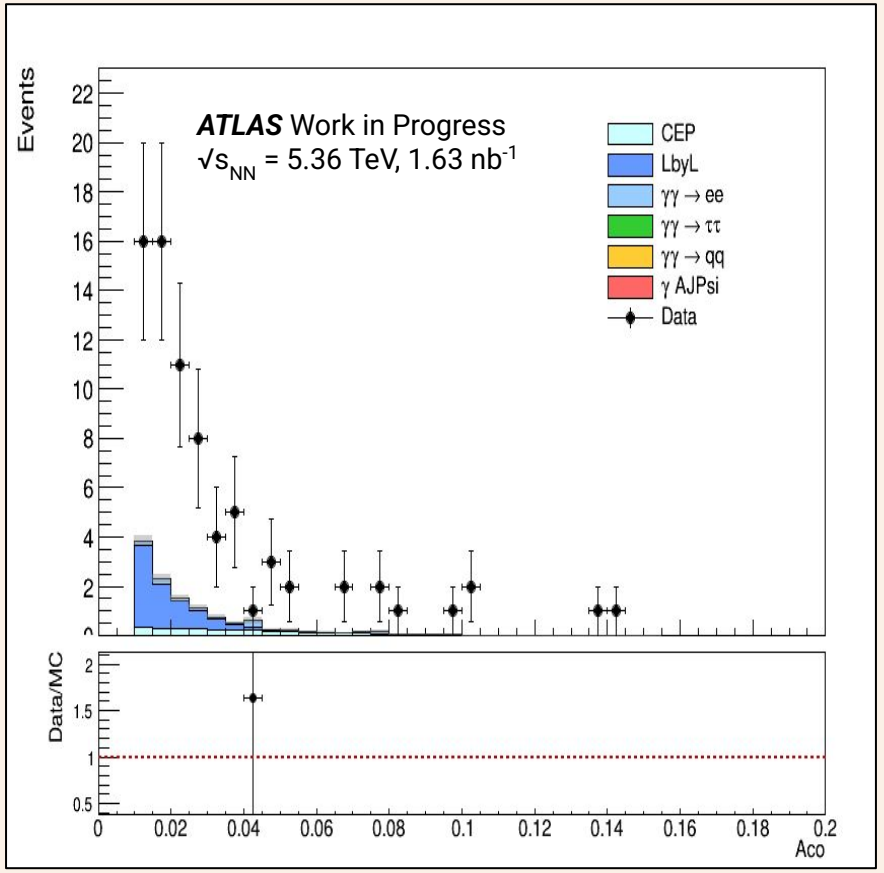
The CR (Aco > 0.01) can be used for various purposes:

- Test all the event selection criteria and electron veto.
- Calculate their efficiency in Data & MC.
- Background estimation.

Testing the event selections:

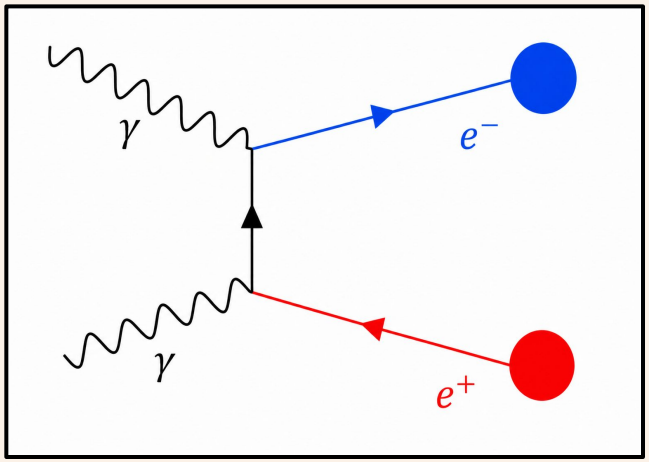
- More events in data than in MC.
- The current e-veto plays a role in this.
- **γγ→e+e-** (Large Background and to kill it we need e-veto)
- So we modify the e-veto:
  - EGamma Reconstructed Electron veto
  - Events with a track-cluster pair having:

    $\Delta\eta < 0.1$ & $\Delta\phi < 0.3$ → vetoed



- We calculate the efficiency of the e-veto using tag & probe method.

Tag & Probe:

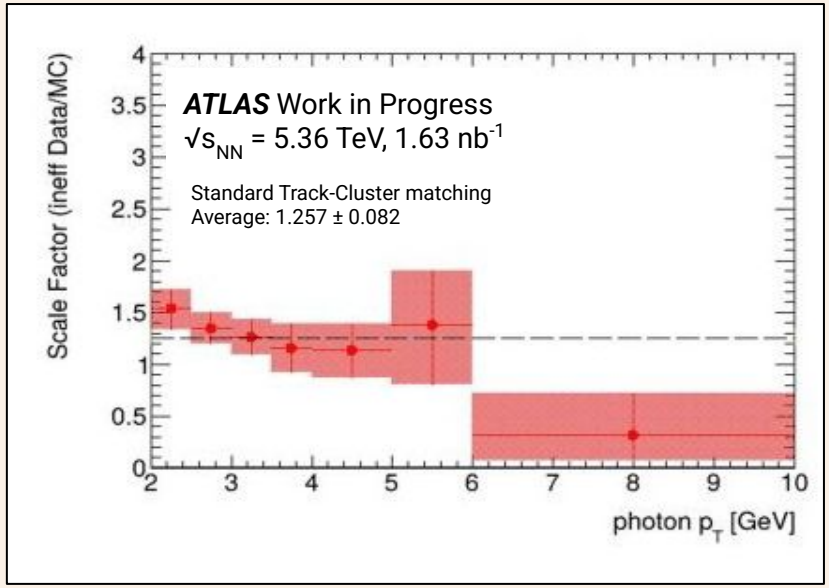


Why Tag & Probe?

- Shower shapes (calorimeter variables) for electrons → poorly modelled.
- Track variables → poorly modelled.
- Results in different electron identification efficiency for MC vs Data.
- Need SF = $\epsilon_{Data} / \epsilon_{MC}$ to correct MC efficiencies and get accurate predictions.

Steps of Tag & Probe:

- Determines efficiencies from double object final states.
- **Tag**: tighter selection to reduce background.
- **Probe:** used to measure the efficiency or inefficiency of interest.
- And from that the Scale Factor.



Results:

Applying the SF:

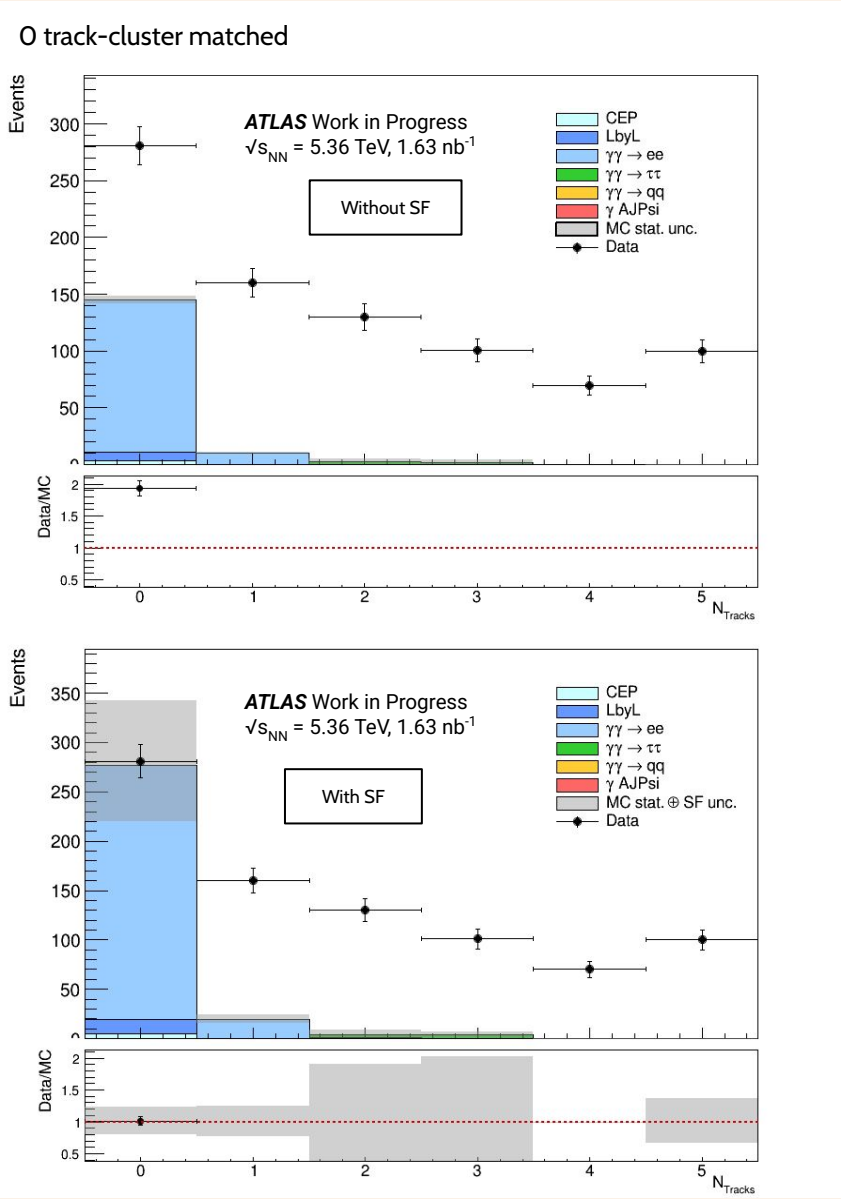
- Number of events in the region broken up in sub-regions:
  - 0 track-cluster matched.
  - 1 track-cluster matched.
  - 2 track-cluster matched.

Conclusion:

The scale factor works and corrects as it should be doing the 0 track region.

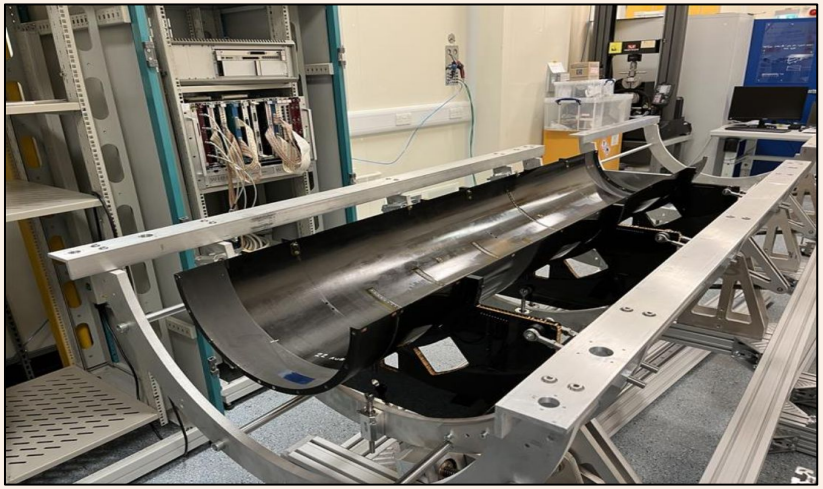
Next Step:

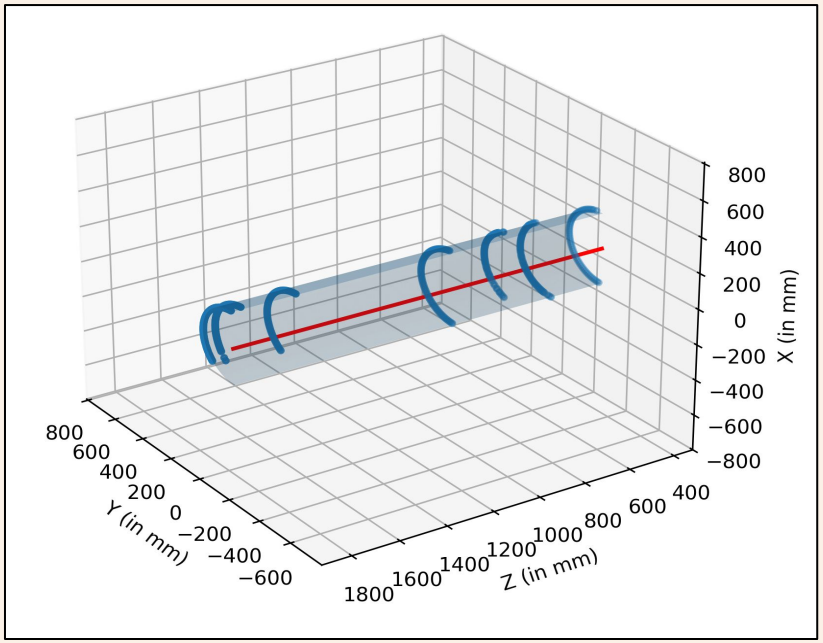
Checking what are the extra tracks in Ntrack > 0?



Qualification Task:

- Metrology of Carbon Fiber half-cylinders of Inner Tracker (ITk) of ATLAS.
- Analysed the point cloud data produced by photogrammetry system.
- Determined the best fit to the nominal cylindrical geometry.
- Modeled the deviation using fourier modes to account for different kind of distortions.





Next Step:

- Writting the Qualification Task report.

Thank You