Optimization of light-by-light triggers from 2022 pilot lead-lead run in ATLAS

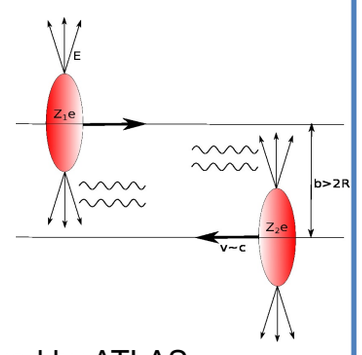
Karolina Domijan on behalf of the ATLAS Collaboration

Trigger definitions

- L1 (Level 1) - the first stage of hardware-based trigger for ATLAS
- TAU1 – at least one EM cluster has been registered with a minimum p_T = 1 GeV, 2TAU1 means two EM clusters, etc.
- TE4 – total transverse energy at least 4 GeV
- VTE200 – veto on events with total transverse energy above 200 GeV
- MBTS – at least one hit in the Minimum Bias Trigger Scintillators has been registered
- TRT – at least one signal generated from tracks that cross the TRT detector

Ultraperipheral collisions and light-by-light scattering

Ultraperipheral heavy-ion collisions (UPCs) are a very unique class of events. In this case, the impact parameter between two incoming lead nuclei is greater than the sum of their radii, so that they do not interact primarily through the strong nuclear force, but interact through their electromagnetic (EM) field. These EM fields are are equivalent to a flux of quasi-real photons, which can undergo collision with oncoming quassi-real photons or nuclei. In particular, they can be used to study very rare processes, such as light-by-light scattering.



Light-by-light scattering (LbyL) is a very rare process that was first observed by ATLAS experiment in 2019, based on Run-2 lead-lead data [1]. Only about 100 events of such a process have been observed in the full Run-2 data set [2]. Recently, it has been proposed that LbyL events may be sensitive to new physics involving axion-like particles. Therefore, during Run 3, it is essential to collect a large sample of LbyL events with high efficiency.

Data from Pb+Pb pilot run

In preparation for data collection in 2023, a pilot lead run took place in November 2022. A record collision energy of 5.36 TeV was established. There were two fills with peak luminosity $2.4 \cdot 10^{25}$ cm^{-2}s^{-1} and $3.7 \cdot 10^{25}$ cm^{-2}s^{-1}. Total recorded luminosity of L = 0.3 1/μb was achieved, what results in 77M events in UPC dataset.

Trigger strategy

Obtaining as much LbyL data as possible is only achievable by designing appropriate triggers. In order to assess trigger performance, exclusive pairs of electrons from UPCs ($\gamma\gamma \rightarrow e^+e^-$) are used. These events feature similar detector signatures with larger cross-sections.

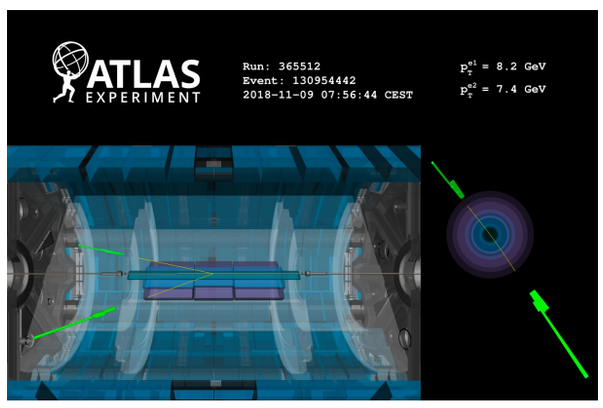
Monte Carlo

Data are compared with dedicated Monte Carlo simulation. STARlight + Pythia8 sample for $\gamma\gamma \rightarrow e^+e^-$ process is used ($m_{\gamma\gamma}$ > 1.8 GeV, 100k events, σ = 3.714 mb) reconstructed in the latest software version.

Event selection

$\gamma\gamma \rightarrow e^+e^-$ events are required to pass following selection:

- Number of tracks = 2
- Tracks have opposite electric charges
- Number of electromagnetic clusters ≥ 2
- A track and an EM cluster have to be matched with ΔR < 0.8
- Track p_T > 0.5 GeV
- Track acoplanarity (aco = 1 - |ΔΦ|/π) < 0.04
- Supporting triggers based on L1 MBTS or TRT trigger decision are imposed on data only



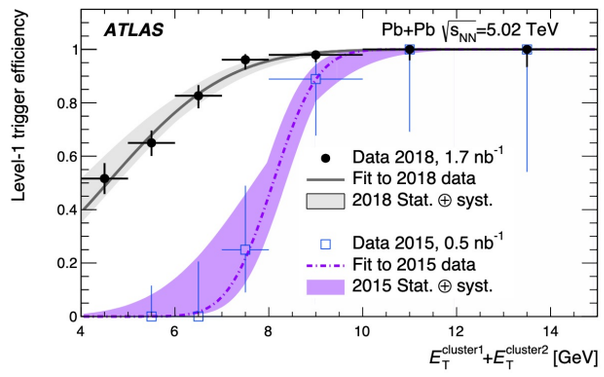
Trigger efficiency

We have analyzed L1 trigger efficiencies in the pilot run.

Trigger efficiency ($\epsilon(E_T^{cluster1} + E_T^{cluster2})$) is calculated for $\gamma\gamma \rightarrow e^+e^-$ process using formula:

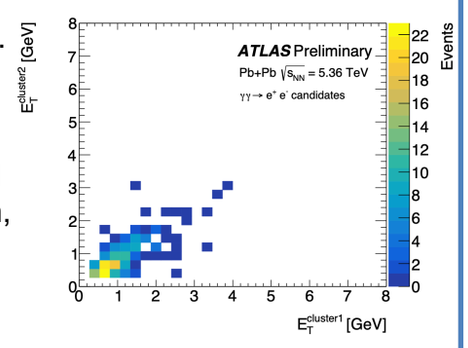
$$\epsilon = \frac{\text{events passing considered trigger}}{\text{all events passing supporting triggers}}$$

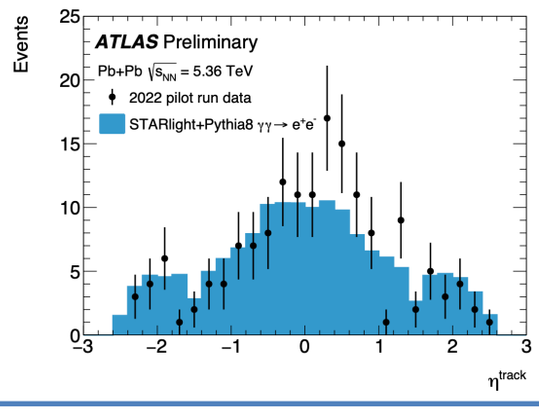
Results are compared with the fit to 2018 data [2] trigger efficiency (L1_TAU1_TE4_VTE200 OR L1_2TAU1_VTE50)

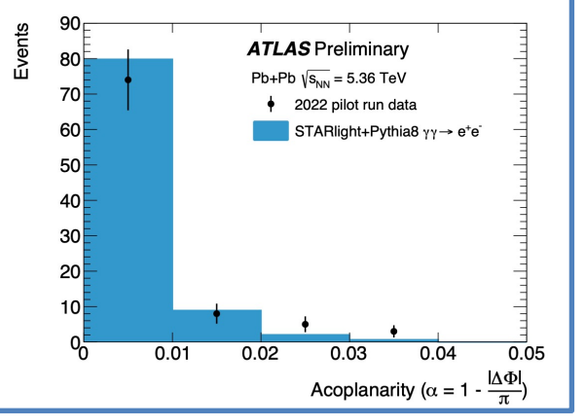


Event characteristics

- 90 events pass the $\gamma\gamma \rightarrow e^+e^-$ selection in the data, while the MC simulation predicts 91 events.
- Data events pass the L1TAU1_VTE200 trigger.
- MC distributions are normalized to the integrated luminosity recorded in the pilot run, cross section, number of generated events in each sample and moreover, are weighted with 2018 reference.
- Good agreement is found.

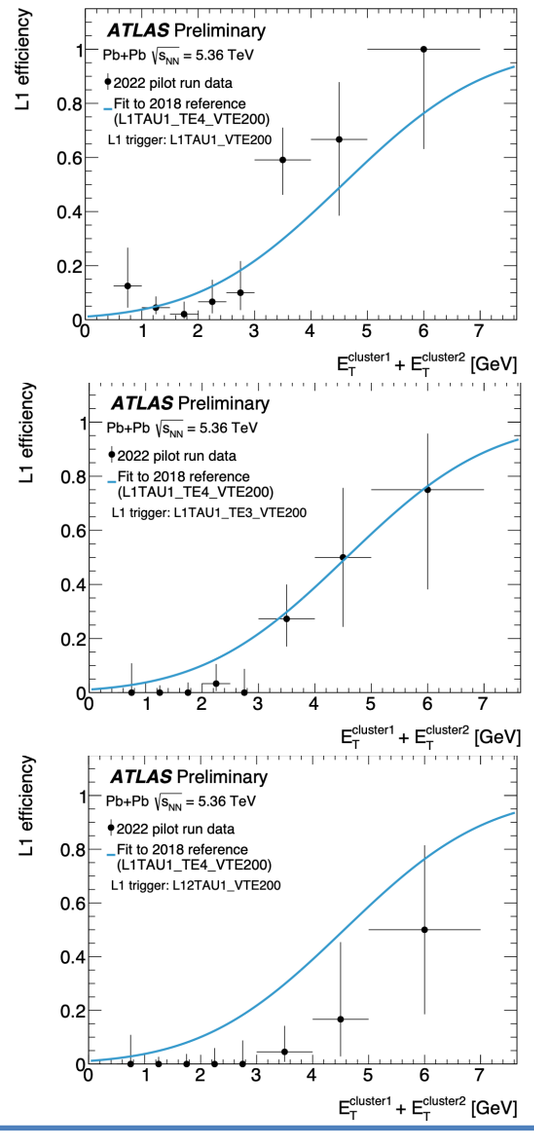






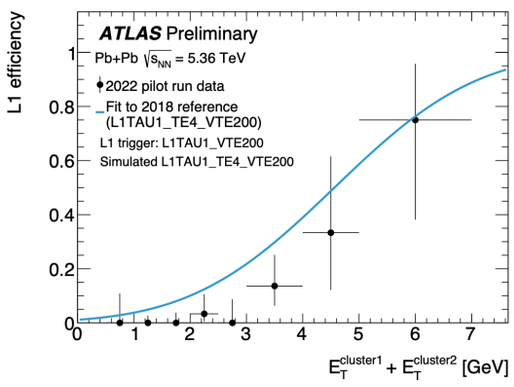
Efficiency results

- Efficiency is calculated for three triggers from the pilot run: L1TAU1_VTE200, L1TAU1_TE3_VTE200 and L12TAU1_VTE200.
- It is presented as a function of the sum of transverse energy of two EM clusters corresponding to the γγ → e+e- process
- Error bars denote statistical uncertainties.
- Efficiencies are mostly consistent with 2018 results within uncertainties.
- HLT_noalg_L1TAU1_VTE200 trigger seems to be the most efficient, which is expected due to no lower cut on L1 TE
- HLT_noalg_L1TAU1_TE3_VTE200 trigger is best described by the reference fit.
- HLT_noalg_L12TAU1_VTE200 is the least efficient due to the restrictive requirement of two EM signals.



L1_TE4 trigger simulation

- In order to make an exact comparison of efficiency from the pilot run with the 2018 reference, decision of L1_TE4 needed to be simulated.
- This is done by applying a cut on a total energy distribution on events selected by L1TAU1_VTE200 trigger.
- The little reduction in efficiency values wrt 2018 reference in the pilot run is due to increased noise compared to Run 2.



References

[1] The ATLAS Collaboration. Observation of Light-by-Light Scattering in Ultraperipheral Pb+Pb Collisions with the ATLAS Detector. Phys. Rev. Lett. 123 (2019) 052001.

[2] The ATLAS Collaboration. Measurement of light-by-light scattering and search for axion-like particles with 2.2 nb^{-1} of Pb+Pb data with the ATLAS detector. JHEP 03 (2021) 243.

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