TRIGGERS FOR EXCLUSIVE PROCESSES WITH PHOTONS AND ELECTRONS IN ULTRA-PERIPHERAL LEAD-LEAD COLLISIONS IN THE ATLAS EXPERIMENT IN RUN3

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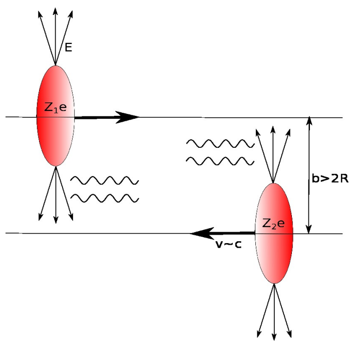
Exclusive processes

- Heavy ion lead-lead data were collected in 2015, 2018 (Run 2), 2023 and 2024 (Run 3)
- Collisions of nuclei at ultra-relativistic energies are typically studied for processes in which the nucleons interact hadronically, producing **quark–gluon plasma**
- Second important group of data from heavy-ion collisions are **ultra-peripheral collisions** (UPC), with impact parameters beyond twice the nuclear radius
- Lead ions do not interact primarily through the strong nuclear force, but interact through their electromagnetic (EM) field
- UPC can induce a wide variety of exclusive final states in lead–lead (Pb+Pb) collisions – dileptons, dijets, and diphotons, e.g. **light-by-light scattering**
- UPC processes are a new tool to **search for beyond Standard Model** physics



Trigger definitions

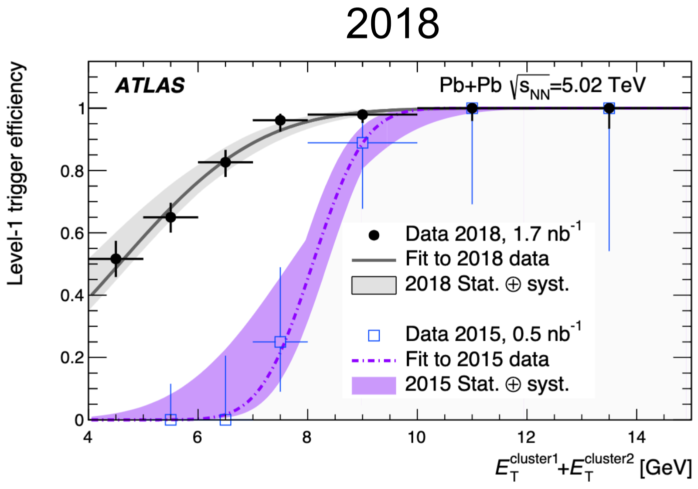
- L1 (Level 1) - the first stage of hardware-based trigger for ATLAS
- HLT - second stage of software-based trigger for ATLAS
- TAU1 – at least one EM cluster has been registered with a minimum p_T = 1 GeV, 2TAU1 means two EM clusters, etc.
- TE4 – total transverse energy at least 4 GeV
- VTE200 – veto on events with total transverse energy above 200 GeV
- vpix - veto on a number of pixel hits in the pixel detector, e.g. vpix30 rejects events with a number of pixel hits > 30
- TRT – at least one signal generated from tracks that cross the Transition Radiation Tracker
- ZDC - signal is generated in response to the presence of particles with energies above a certain threshold in the ZDC detector.

Trigger efficiency

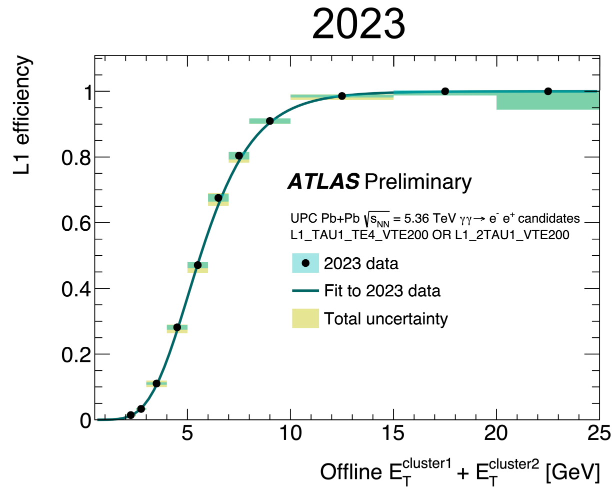
- Exclusive electron pairs, $\gamma\gamma \to e^+e^-$, are used for calculating trigger performance
- These events feature similar detector signatures to photons but have larger cross-sections
- Trigger efficiency ($\epsilon(E_T^{cluster1} + E_T^{cluster2})$) is calculated for dielectron events using formula: $\epsilon = \frac{\text{events passing considered trigger}}{\text{all events passing supporting triggers}}$

L1 trigger efficiency

2018



2023

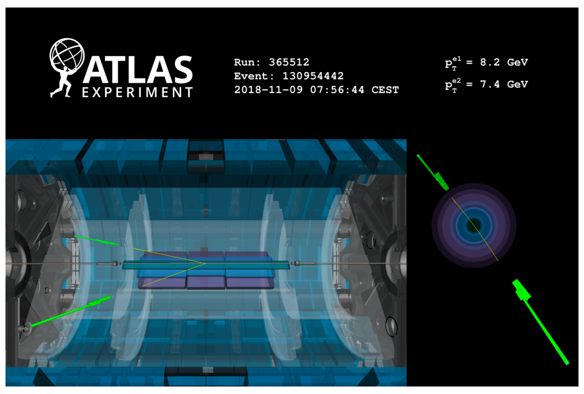


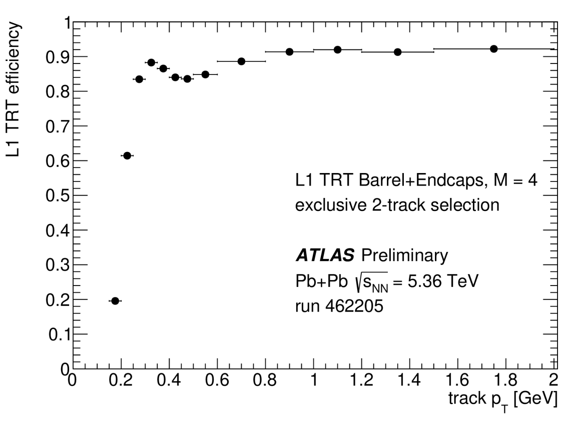
- L1 trigger efficiency is measured as a function of the transverse energy sum of the two leading offline electromagnetic (EM) clusters
- Performance is calculated for a logical OR of two triggers:
  - L1_TAU1_TE4_VTE200 and L1_2TAU1_VTE**50** (2018)
  - L1_TAU1_TE4_VTE200 and L1_2TAU1_VTE**200** (2023)
- In preparation to 2018, the L1 thresholds were optimized to significantly increase the number of collected data in comparison to 2015
- The 2023 and 2018 efficiency curves are comparable
- The **precision** o 2023 efficiency measurement has been **improved significantly**

Event selection

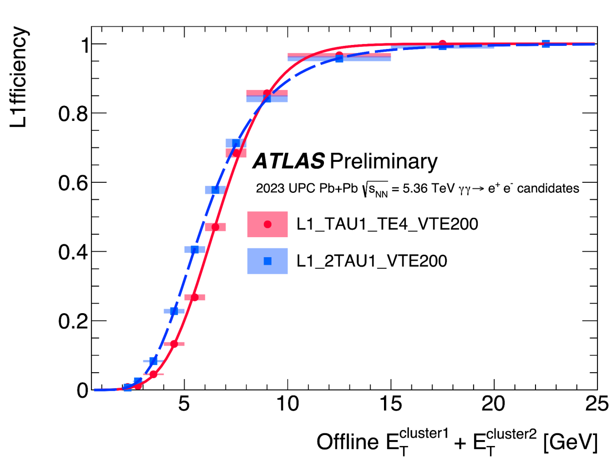
$\gamma\gamma \to e^+e^-$ events are required to pass the following selection:

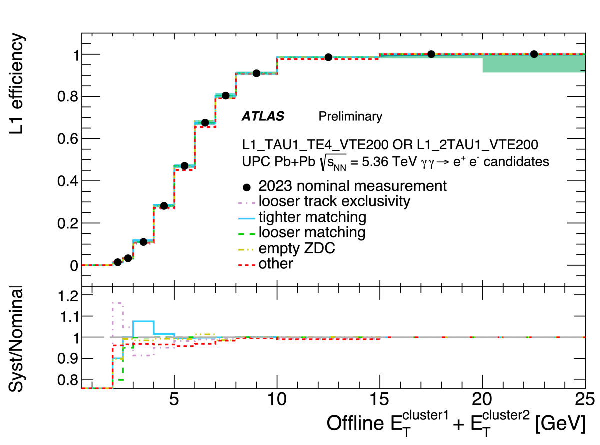
- Number of tracks = 2
- Tracks have opposite electric charges
- Track p_T > 1 GeV
- Track acoplanarity (aco = 1 - |ΔΦ|/π) < 0.01
- Number of electromagnetic clusters ≥ 2
- EM cluster E_T > 1 GeV
- EM cluster |η| < 2.47 without the calorimeter transition region
- A track and an EM cluster have to be matched with ΔR < 0.4
- **Supporting triggers** based on L1 **TRT** and **ZDC**





Trigger efficiency measurement





- The biggest contribution to the uncertainty comes from factors related to the number of tracks, and the matching criteria between a track and EM cluster

- Top figure shows a L1 trigger efficiency calculated separately for L1_TAU1_TE4_VTE200 and L1_2TAU1_VTE200 triggers
- L1_TAU1_TE4_VTE200 is more efficient for higher sum E_T, while L1_2TAU1_VTE200 works better for smaller sum E_T
- Several sources of systematics considered:
  - Looser track exclusivity
  - Tighter matching criteria between EM clusters and tracks
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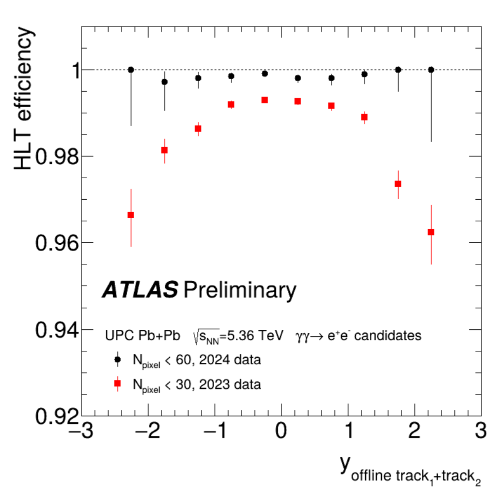
  - No signal in the ZDC calorimeter
  - Other:
    - Tighter track acoplanarity
    - Looser acoplanarity cut
    - Inclusion of the calorimeter transition region in the cluster η selection
    - Tighter track selection
- **Total systematic uncertainty is comparable with statistical uncertainty**

HLT trigger efficiency



- Plot shows a comparison of 2023 and 2024 measurements
- Veto for events with more than 30 pixel hits was introduced in Run 3 after vpix15 was deemed inefficient during the Run 2
- The cut was further changed to vpix60 for 2024 data taking
- **Efficiency almost 100%** with no dependence on rapidity
- This trigger is essential for measuring photons, i.e. light-by-light scattering

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