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

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 2.4-10^{29} cm^{-2}s^{-1} and 3.7-10^{29} cm^{-2}s^{-1}. Total recorded luminosity of L = 0.3 1/fb was achieved, what results in 77M events in UPC dataset.

Event selection
90 events pass the $\gamma\gamma \rightarrow e^+e^-$ selection in the data, while the MC simulation predicts 91 events.

Event characteristics
- 90 events pass the $\gamma\gamma \rightarrow e^+e^-$ selection in the data.
- 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_TES_VTE200 and L12TAU1_VTE200.
- It is presented as a function of the sum of transverse energy of two EM clusters corresponding to the $\gamma\gamma \rightarrow e^+e^-$ process.
- Error bars denote statistical uncertainties.
- Efficiencies are mostly consistent with 2018 results within uncertainties.

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.

Efficiency is calculated for three triggers from the pilot run: L1TAU1_VTE200, L1TAU1_TES_VTE200 and L12TAU1_VTE200.

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 equivalent to a flux of quasi-real photons, which can undergo collision with remaining quasi-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 (LbL) 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 LbL events may be sensitive to new physics involving axion-like particles. Therefore, during Run 3, it is essential to collect a large sample of LbL events with high efficiency.

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

References

This work was partly supported by the National Science Centre of Poland under grant number UMO-2020/37/B/ST2/01043 and by program „Excellence initiative – research university” for the AGH University of Science and Technology.