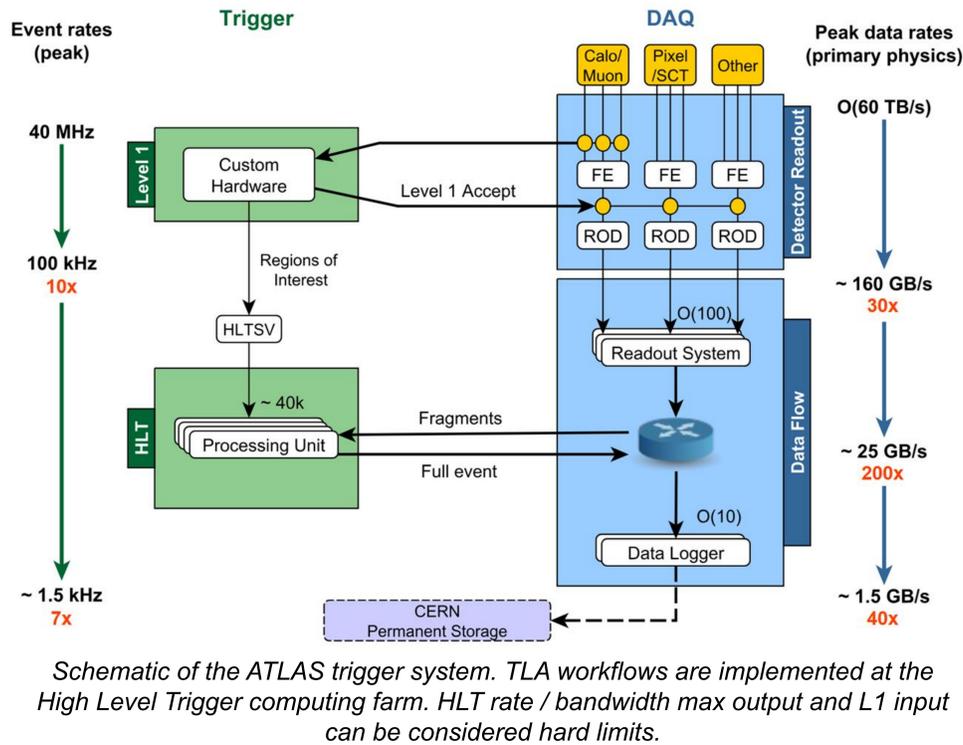# TRIGGER-OBJECT LEVEL ANALYSIS @ATLAS AND RUN 4 UPGRADES

Introduction & Motivation

- Storage rate constraints **O(1 kHz)** require strong selection cuts based on transverse momentum (p_T) of the final particle (interesting events are usually characterized by **high p_T**);
- Low-mass (< 1 TeV) events are discarded while events above threshold are fully stored on tape.

These loss of information brought to the introduction of **TLA** (*Trigger-object Level Analysis*) techniques @ATLAS to recover these low-mass signatures.

Schematic of the ATLAS trigger system. TLA workflows are implemented at the High Level Trigger computing farm. HLT rate / bandwidth max output and L1 input can be considered hard limits.

Rate & BW limits

Output to long-term storage is limited by two main factors:
- **bandwidth cap** (8 GB/s during Run 3), mostly saturated by *full events* (i.e. raw data containing all detector channels);
- **CPU processing power**: each full event needs to be reconstructed into *Analysis Object Data* (data format ready for statistical analysis).

In this context, *reconstruction* means the transformation of electronic signals into **trajectories** and **released energies** of identified particles. The main objective of TLA is to retain some **lightweight** physics objects from discarded events (**high** rate, **low** bandwidth).

TLA workflows

The **HLT** (*High Level Trigger*) is a **software-based** trigger level that operates event selection after the LVL1 hardware trigger. Without TLA, HLT trigger thresholds discard most of the < 1 TeV events, such as dijet events, even if some physics objects have been already reconstructed.
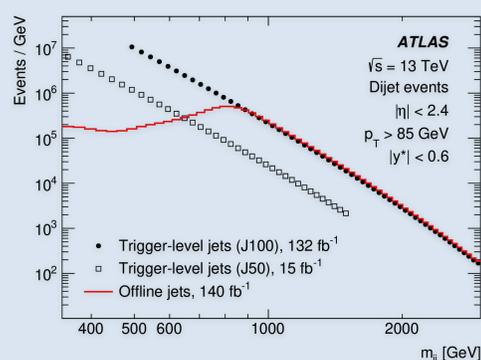
Discarded events can still carry valuable physics information: TLA workflows allow to retain **minimal event information** without a significant increase in bandwidth. Run 2 data show that TLA streams with lower energy thresholds (**black**) record **substantially more** events than the reconstructed physics stream (**red line**).

To implement TLA effectively, only **high-level physics containers** created by HLT reconstruction steps (HLT-Jets, HLT-Photons, etc.) are saved. More specifically, in the TLA triggering / filtering chain:
- instead of the high energy threshold set by HLT, a much lower one (possibly also 0, so no effective threshold) is used;
- **only** the containers created for the *specific chain signature* are pushed to the TLA stream;
- for each signature of interest a separate chain can be defined.

This workflow **shrinks the event size considerably** since, e.g. for jets, *only* HLT-Jets are requested to be reconstructed (less cpu) and *only* HLT-Jets will appear in the recorded event (less bandwidth).
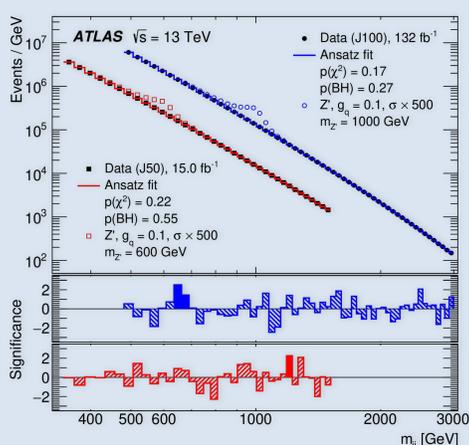

Figure: results for the search of Z' from more than 60 billion trigger-level events gathered during Run 2. Thanks to TLA, the mass sensitivity was lowered from the conventional 1 TeV to 375 GeV, the lowest inclusive dijet mass ever studied at the LHC (without additional constraints on the dijet system).

Phase II: Event Filter TLA

TLA workflows will be integrated in the High Level Trigger architecture for Run 4, named **Event Filter (EF)**, that will support much higher data rates (*see Riccardo's poster*).

A proposed data format hierarchy is depicted in the figure below:
- event passes EF selection ⇒ **full event recorded**;
- event rejected by EF:
  - *Full Scan Tracking* (**FS**) last performed ⇒ *only* FS products saved to TLA (tracks, high-level objects);
  - *Regional Tracking* (**ROI**) last performed ⇒ *only* ROI tracking products saved to TLA (ROI tracks, high-level objects).
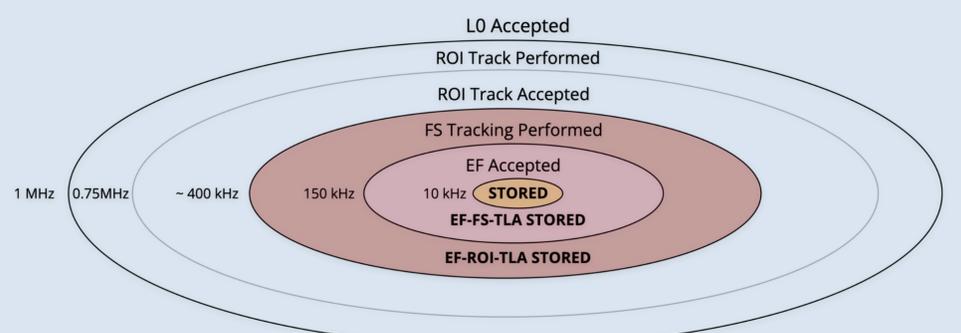
Our research is oriented towards exploring the different scenarios proposed by the *ATLAS TLA Task Force*:
- we obtained some **promising preliminary results** showing **stable** TLA rates **> 400 kHz** (with a full event rate of ~10 kHz);
- we are committed to further testing exploring **higher rates** at different event sizes;
- Also, simulations are being carried out to explore TLA capabilities with benchmark physics channels.

Conclusions

- High HLT thresholds **limit** low-mass sensitivity, discarding numerous possibly useful events.
- TLA reduces event size by **>100×**, enabling much **lower thresholds** at sustainable rates.
- This extends the discovery reach to **previously inaccessible** mass regions.
- Enhanced TLA implementations during Phase II will allow to **extract even more physics** from the same detector collisions.

Roberto Mastrofrancesco, *on behalf of* ATLAS Pavia

UNIVERSITÀ DI PAVIA   INFN   ATLAS EXPERIMENT