Data analysis at the CMS Level-1 Trigger: Migrating complex selection algorithms from offline analysis and High-Level Trigger to the trigger electronics

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Experimental context

CMS at CERN's Large Hadron Collider is a multi-purpose detector to explore new phenomena. It must be able to record all collisions interesting for physics, whilst discarding the rest. The trigger and data acquisition systems provide this task.

The trigger system has the following characteristics:
- Two-tier system: Level-1 (L1) and High-Level Trigger (HLT)
- L1 is made of fast electronics, HLT is a processor farm

Challenging, rapidly evolving conditions

- LHC design luminosity: 10^{34} cm^{-2}s^{-1}
- Current peak luminosity: 1.5×10^{34} cm^{-2}s^{-1}
- Planned luminosity for HL-LHC: up to 7.5×10^{34} cm^{-2}s^{-1}
- Average pileup in 2016: 27 superimposed events
- Average pileup for HL-LHC (unleveled): 140-200 events
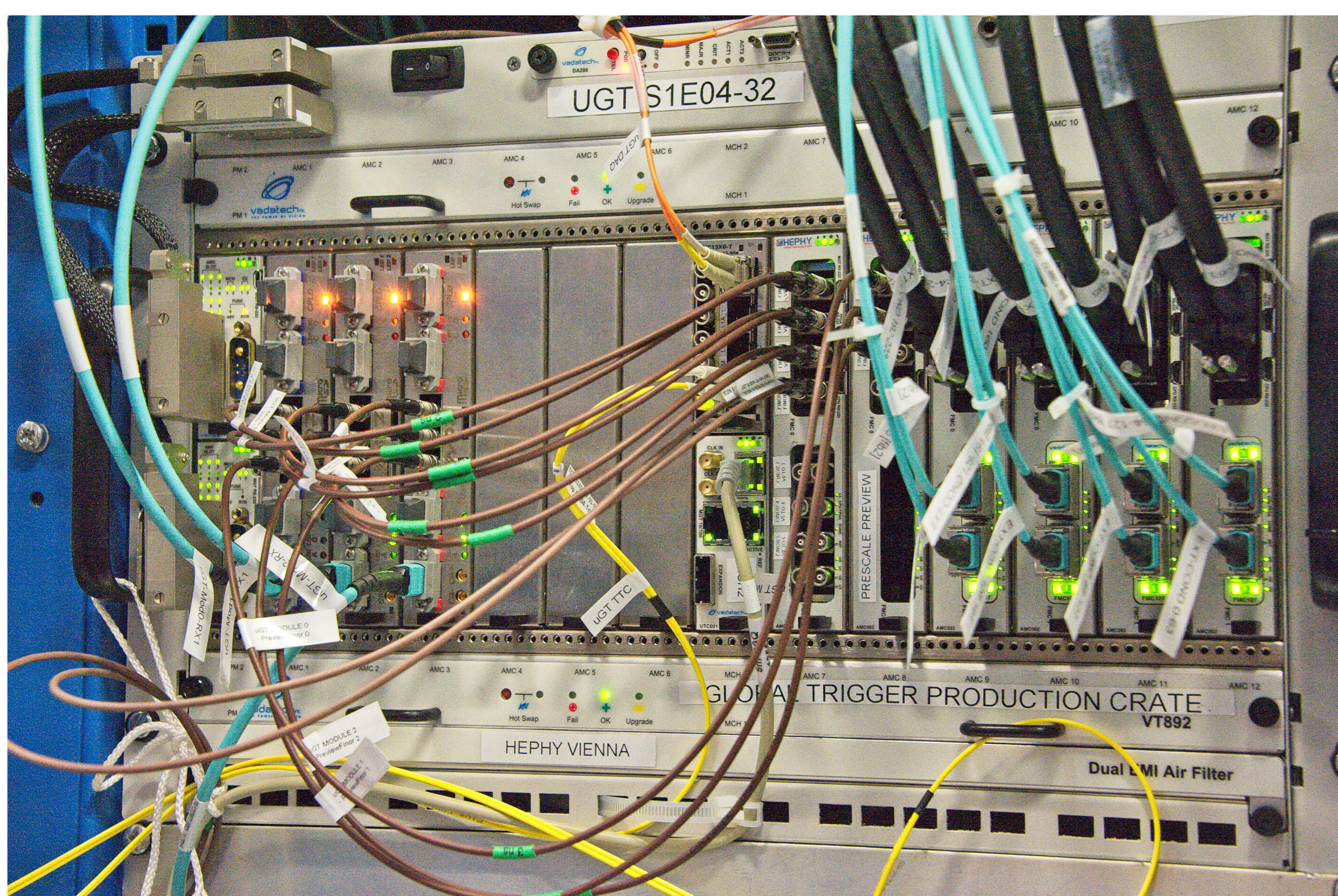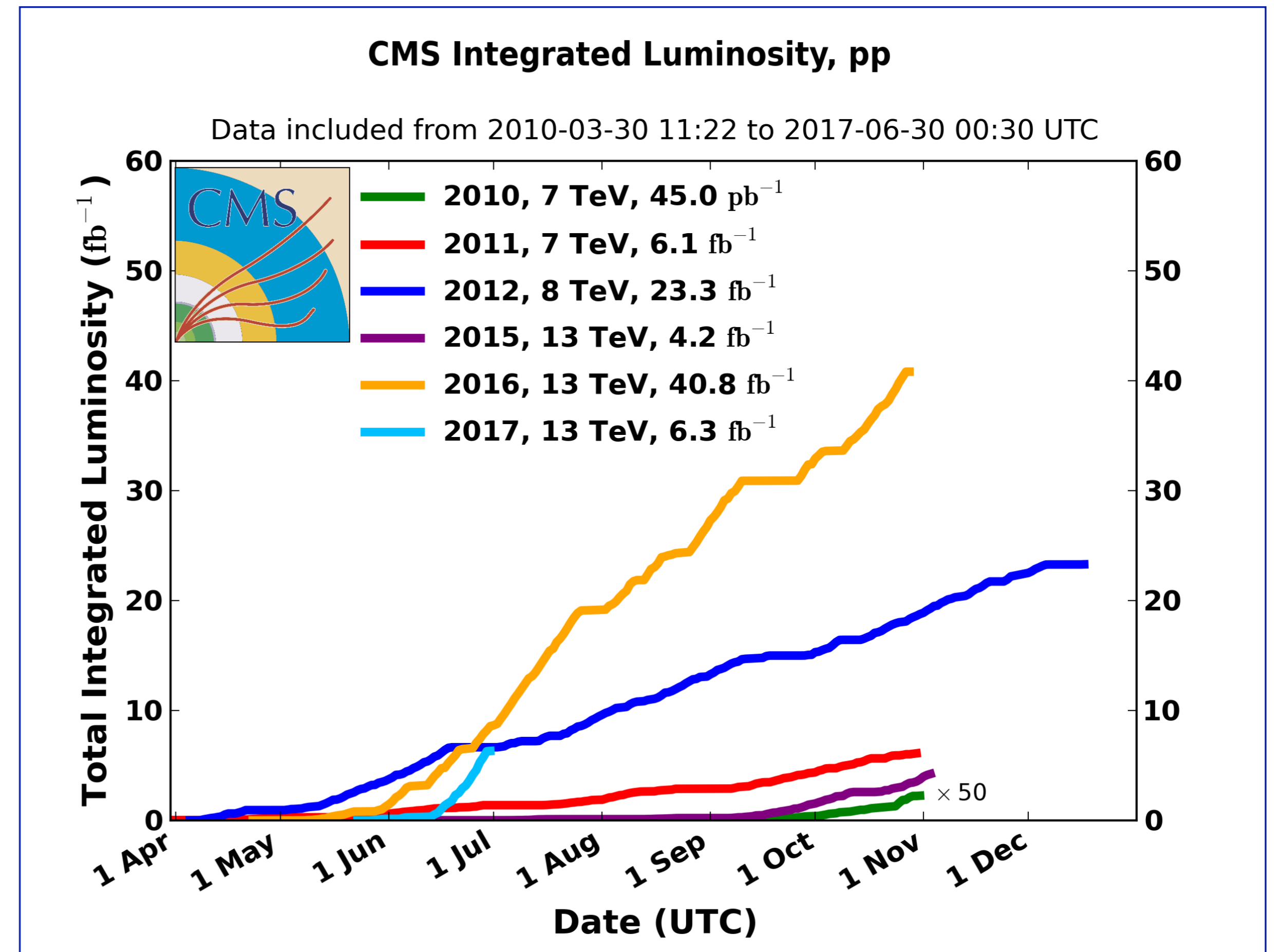
## Level-1 Global Trigger

- It represents the highest stage of the Level-1 hierarchy
- It is implemented in µTCA technology, with large FPGA's
- It receives and synchronizes inputs from the calorimeters, the muon detectors as well as beam radiation and luminosity detectors
- It issues the L1 trigger decision based on several hundreds of logic algorithms running in parallel
- It is possible to prescale algorithms, depending on luminosity
- Very high flexibility in trigger menu design
- Current maximum output rate: 100 kHz, HL-LHC: up to 1 MHz

Global Trigger Algorithms

- Algorithms are based on candidate trigger objects such as electrons/photons, taus, jets, muons, energy sums, missing transverse momentum
- Objects have information on energy/momentum, location, quality
- Energy or momentum thresholds are usually applied
- Topological conditions may be applied
- Combinations of different object types are possible (cross-triggers)
- Complex, analysis-like conditions such as invariant mass are possible

$$M_{inv} \approx \sqrt{2p_{T1}p_{T2}[\cosh(\eta_1 - \eta_2) - \cos(\varphi_1 - \varphi_2)]}$$
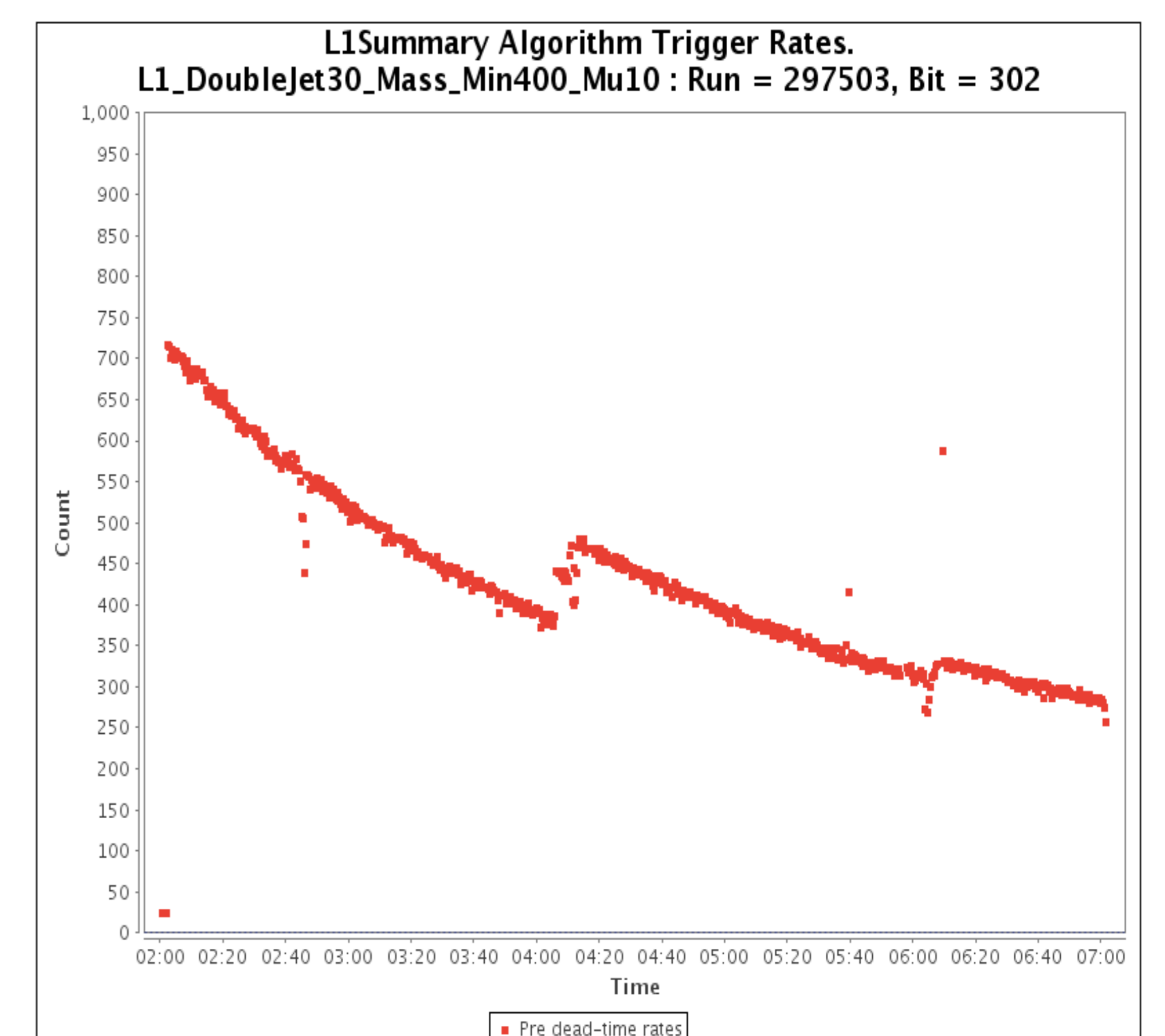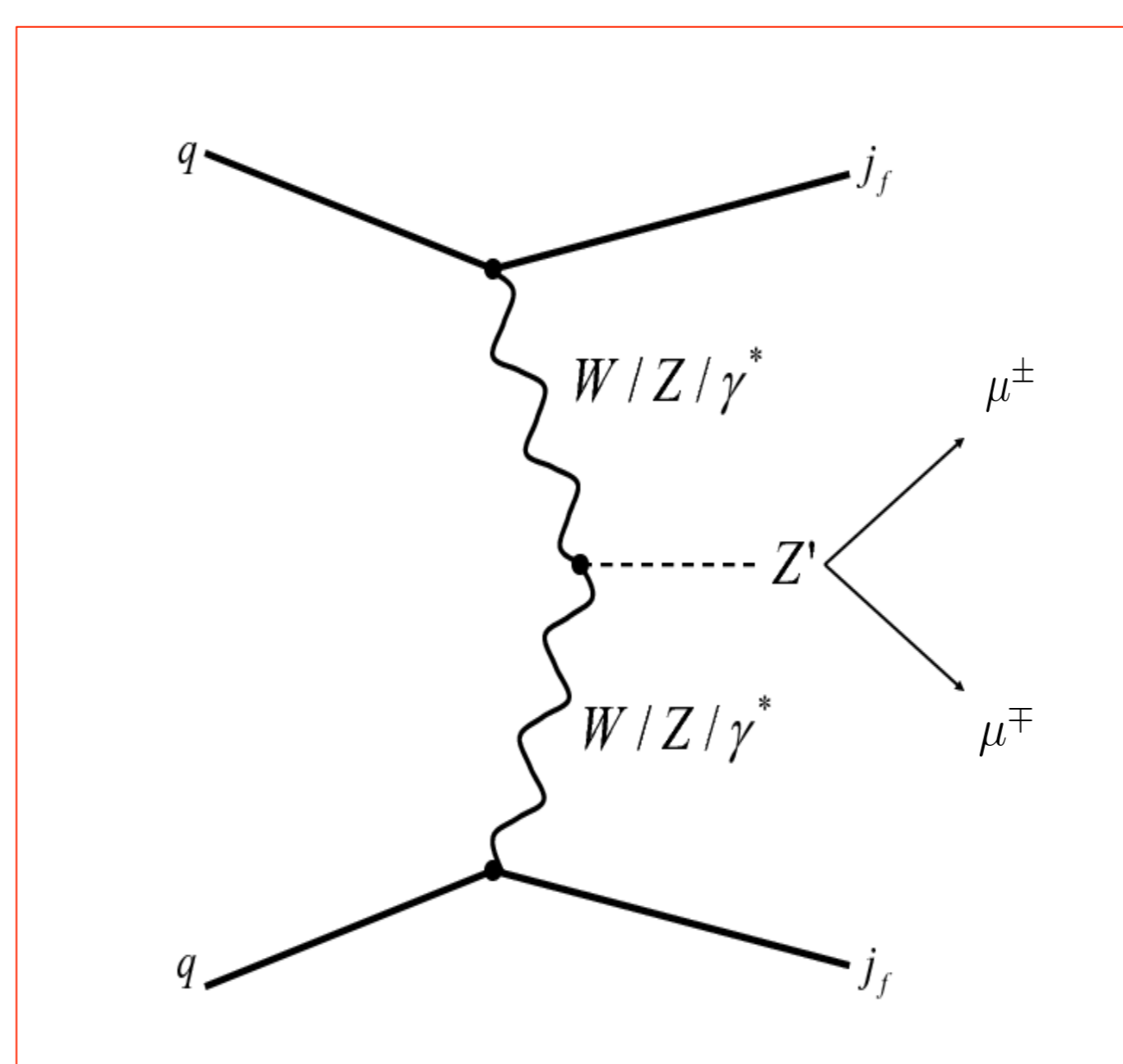
Trigger Menu Editor

- Tool for physicists to develop algorithms, in particular complex ones
- The trigger menu – the set of algorithms running in parallel – is stored as an XML file
- A VHDL producer translates the XML menu into code that can be synthesized

Further information

http://globaltrigger.hephy.at