

The ATLAS Run-2 Trigger: Design, Menu, Performance and Operational Aspects

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ATLAS utilises a two-level trigger system. The hardware L1 trigger selects events based on energetic e/y, τ , jets, missing transverse energy and μ signatures, reducing from the interaction rate of 40 MHz to 100 kHz while maintaining high efficiency for physics object selection. The software High Level Trigger further reduces the rate to 1 kHz on average. The trigger menu allocates the available bandwidth to physics groups depending on the instantaneous luminosity.

ATLAS Run-2 Trigger & Data Acquisition Trigger Rates & Bandwidth → L1 menu of **512** trigger L1 Trigger Rate [kHz Multi MUON **ATLAS** Trigger Operation items & combinations. Single EM 120 L1 Group Rates (with overlaps) Tile/TGC → E.g. **MU15**, **2EM12** Single JET pp Data July 2016, √s= 13 TeV Detector 100 → Rates are controlled via Level-1 Calo Level-1 Muon Read-Out prescale sets. Barrel Pre-processor sector logic 80 → Instantaneous luminosity [L] from LHC falls with time. 60 JEP (jet, E) CP (e,γ,τ) MUCTPI O → Prescale sets computed for 40 a set of fixed values of L. **DataFlow** → Lower-threshold items are Read-Out System (ROS) 20 enabled once the L has CTPCORE fallen sufficiently, causing 1000 1200 1400 1600 800 an **increase** in the rate. Luminosity Block [~ 60s] **Central Trigger** ATLAS Trigger Operation Rol Fast TracKer Single Electrons ള 2000 HLT Physics Group Rates (FTK) 🔘 $\mathbf{O} = \text{New or}$ Single Jet 2 1800 (with overlaps) → ATLAS Trigger Menu of Multi Jets upgraded for pp Data July 2016, √s= 13 TeV b-Jets Missing Trans. Energy ਲੋਂ 1600 ਦੇ 1400 High Level Trigger O(1000) active chains. Run-2 (HLT) Photons → Each chain is a sequence of Processors O(28k) L1 Topo Event feature extraction & Tier-0 hypothesis testing algorithms. 800 2000 → Chains, primary and support, Saved Data 2016, √s= 13 TeV 1800 600 are grouped within signatures. .1 Rate 400 Run taken on Aug 25, 2016 → For 2016, prescale sets are 1200 200 1000 defined up to L=1.5x10³⁴ cm⁻²s⁻¹ 400 600 800 1000 1200 1400 1600 overlap removal L1Topo: $2 \times p_{T}^{\mu} > 6 \text{ GeV}, m_{uu} \in [2,9] \text{ GeV}, \Delta R_{uu} \in [0.2,1.5]$ Luminosity Block [~ 60s] **ATLAS** Trigger Operation pp Data July 2016, √s= 13 TeV → Event Building [EB] denotes if all (full) or partial sub-detector data are recorded for an event. Main Physics (full EB) 71.9% → Peak rates around 2.75 Gb s⁻¹. Delayed Physics (full EB) L1Topo Commissioning Express stream (full EB) → Majority of chains record to Trigger Level Analysis (partial EB) Main stream with full EB. Detector Calibration (partial EB) → Express reconstructed first, Other Streams (full EB) → Topological trigger greatly provides calibration data. L1Topo: $2 \times p_T^{\mu} > 6$ GeV, $m_{\mu\mu} \in [2,9]$ GeV, $\Delta R_{\mu\mu} \in [0.2,1.5]$ HLT: $2 \times p_T^{\mu} > 6$ GeV, $m_{\mu\mu} \in [4.0,8.5]$ GeV reduces L1 rates with → **Delayed** physics reconstructed later, e.g. during end of 12.7% minimal impact on physics. year stops when less demand on computational resource. Trigger Level Analysis: high rate (3 kHz) of just the **Trigger Rate Predictions & Monitoring** trigger data. Used in dijet resonance searches. **High Level Trigger Physics Performance** L1_EM22VHI L1_TAU60 **ATLAS Trigger Operations** (July 22, 2016) Trigger Efficiency Efficiency **Electrons** Photons **ATLAS** Preliminary ATLAS Preliminary 3.6 Online 1.2 Predicted Data 2016, $\sqrt{s} = 13 \text{ TeV}$, 2.7 fb Data 2016, √s = 13 TeV 3.2 Trigger E rates (kHz) L1_MU20 L1_XE50 L1_4J15 0.8 0.8 2.5 0.6 ■ HLT_g25_loose HLT_e17_lhvloose_nod0 HLT g35 loose 2 0.4 ▲ HLT_g120_loose Z→ ee MC ▼ HLT_g140_loose 15h 15h 14h 10² 10 → Per-chain parametrised form factors provide real time Offline isolated photon E_ [GeV] monitoring predictions based on the current luminosity. Offline electron E_T [GeV] **ATLAS** Preliminary $_{J/\psi}$ B Y(nS) Efficiency Ldt = 3.2 fb^{-1} $p_{T}(\mu_{1}) > 4 \text{ GeV}, p_{T}(\mu_{2}) > 4 \text{ GeV}$ $p_{_{+}}(\mu_{_{+}}) > 6 \text{ GeV}, p_{_{+}}(\mu_{_{2}}) > 4 \text{ GeV}$ Jets Entries / 10⁶ 8.0 $p_{\tau}(\mu_{1}) > 6 \text{ GeV}, p_{\tau}(\mu_{2}) > 6 \text{ GeV}$ Single muon trigger: $p_T(\mu_1) > 20 \text{ GeV}$ **ATLAS** Preliminary Supporting dimuon trigger: $p_{T}(\mu_{z}) > 4 \text{ GeV}$, $p_{T}(\mu_{z}) > 4 \text{ GeV}$ 0.6 10⁵ Data 2015 Di-muons O HLT_j25 (L1 random)

10

11

 $m(\mu^+\mu^-)$ [GeV]

8

7

10⁴

 10^{3}

HLT_j60 (L1_J20)

HLT_j110 (L1_J30)

○ • HLT_j175 (L1_J50)

HLT j380 (L1 J100)

10³

0.2

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Online

Data Quality