Instrumentation of a Level-1 Track Trigger in the ATLAS detector for the High Luminosity LHC

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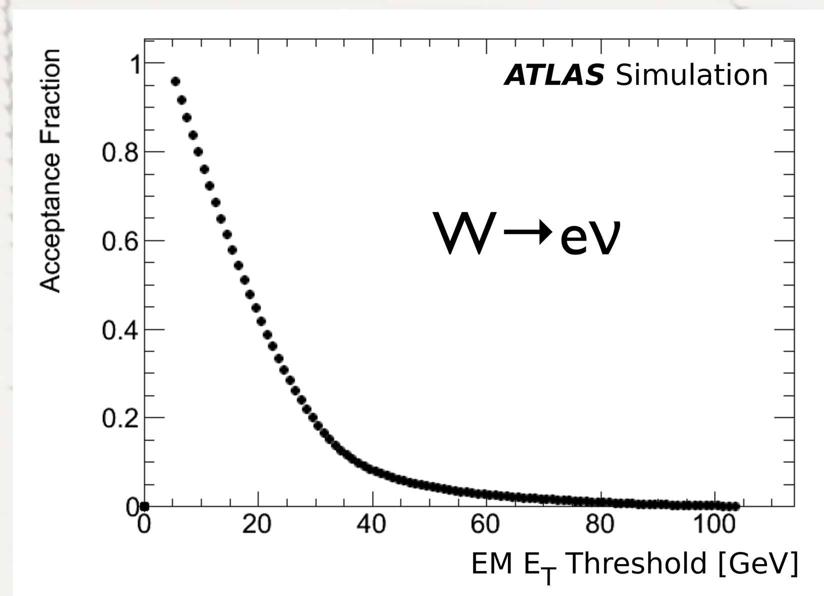
on behalf of the ATLAS Collaboration

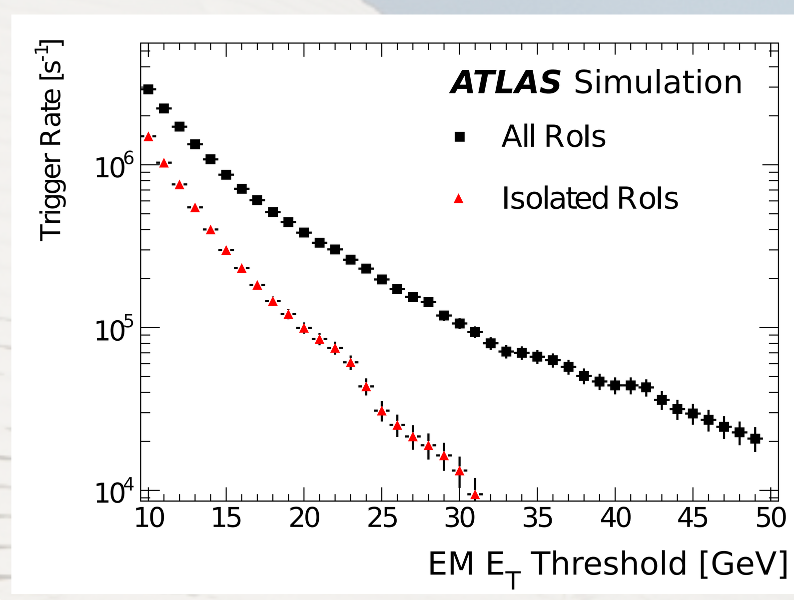
Introduction

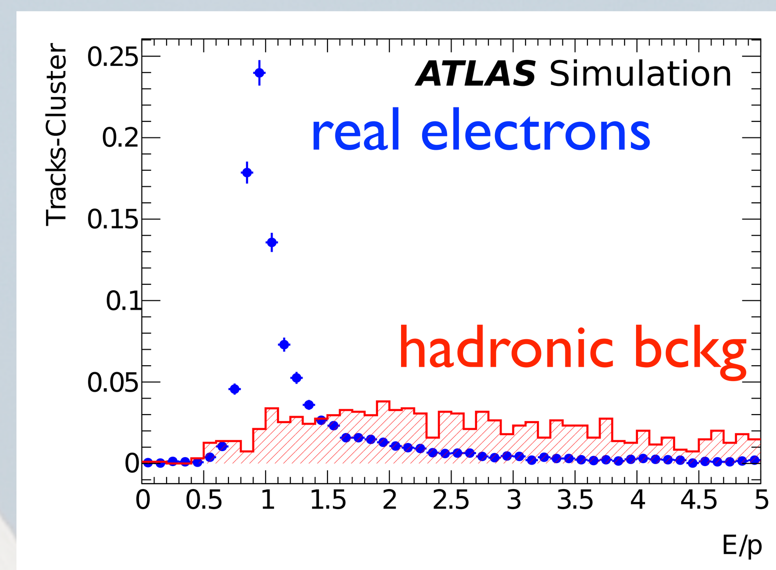
- HL-LHC in 2020: L=5x10^{34}cm^{-2}s^{-1} and 3ab^{-1} of data per experiment
- Need lepton triggers at thresholds of p_T~25 GeV
- But event rates: ~ x 5 and number of interactions per bunch crossing: $<\mu>$~120



Current ATLAS L1 Trigger and upgrades

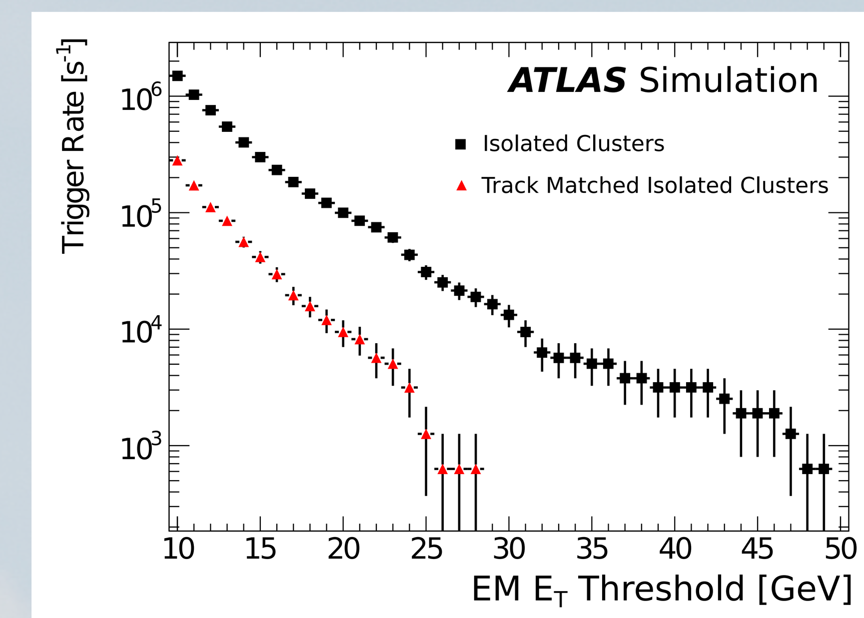
- Hardware L1: 40 MHz to 75 kHz, software L2 (RoI scheme): 3kHz, Event Filter: output rate: ~300 Hz
- L1: Coarse calorimeter and muon information, latency < 2.5μs
- Want to keep single lepton trigger rate below 20kHz
- During the long shut down of ~2018:
  - complete replacement of Inner Detector tracker
  - replace almost all of the on-detector FE electronics
  - FE not replaced: muon drift tubes → L1A ~ 200kHz and latency ~ 20μs





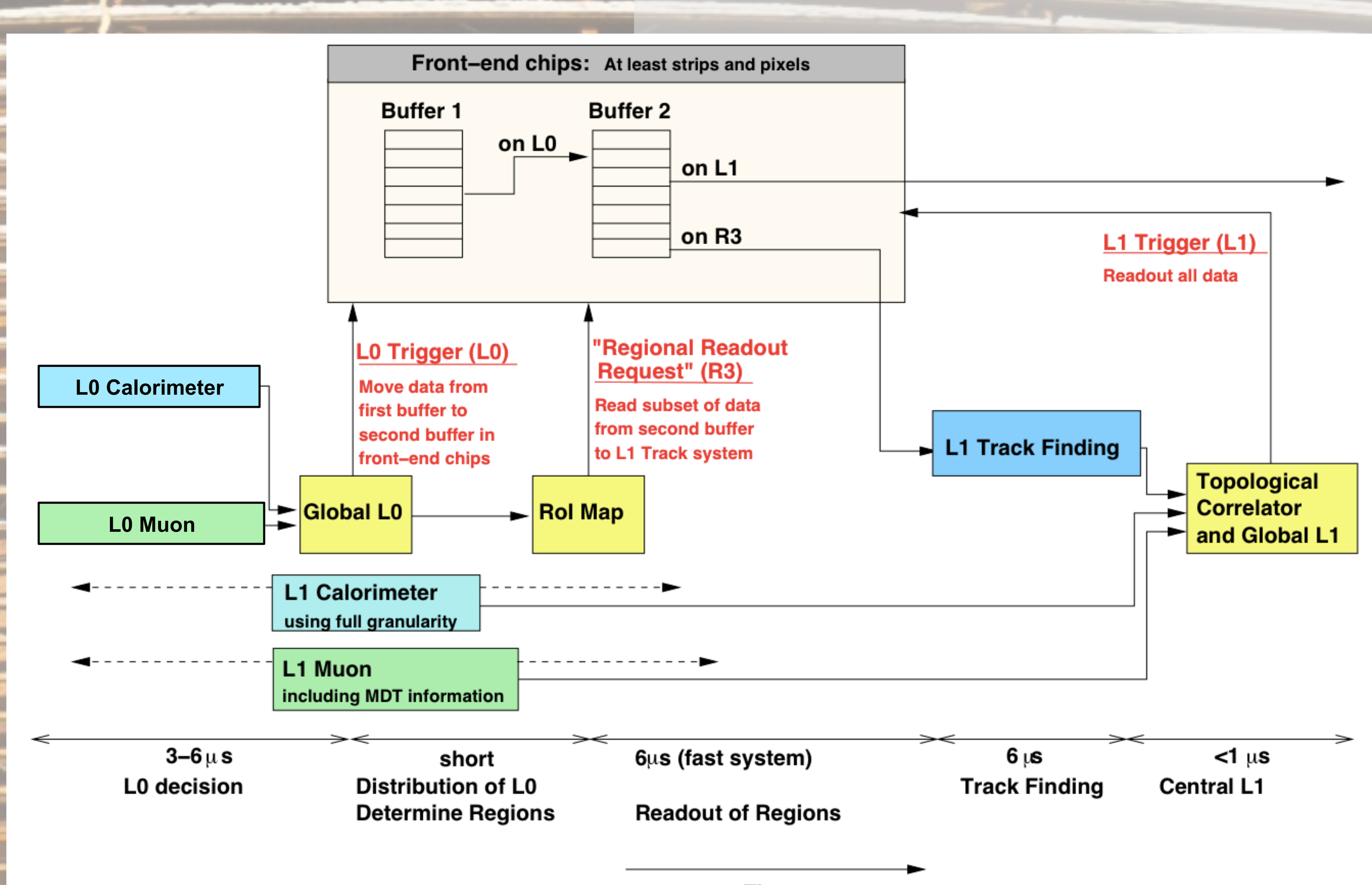
Benefits of Tracking at L1

- Reduce L1A rate (eg current HLT)
- Ensure objects are from Primary Vertex
- Reduce fake couple of leptons
- Possible track based isolation
- Added flexibility to trigger system



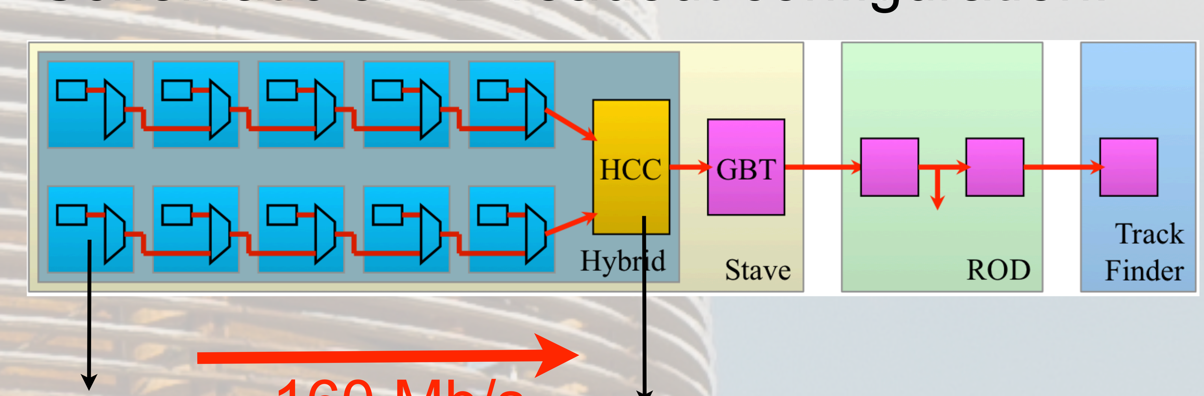
Option 1: L0/L1 trigger design using a Double Buffer Front-End Architecture

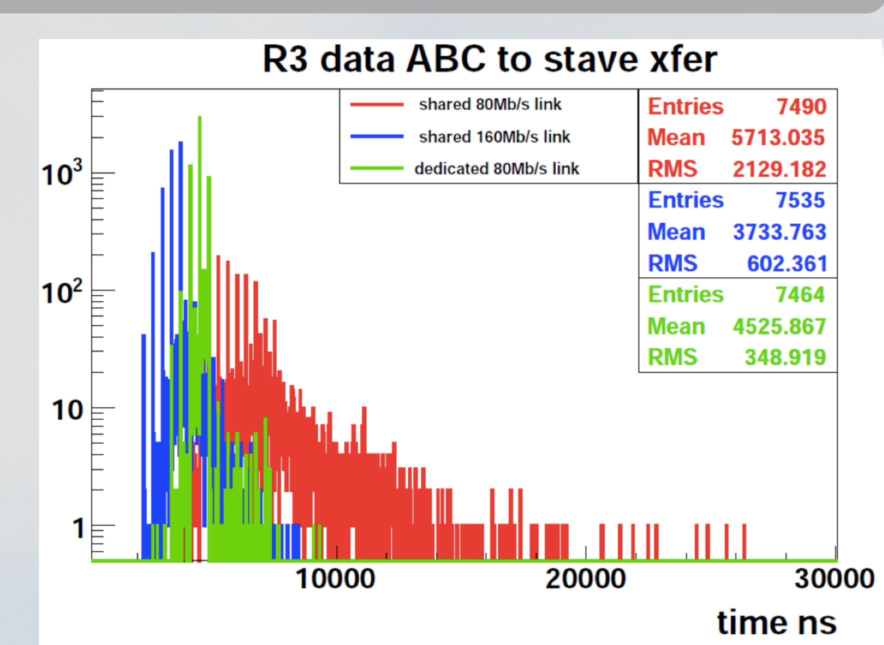
- L0: upgraded Calo+Muon triggers, 500kHz, latency < 6.4μs, builds RoI
- L1: Track Trigger, final L1 Accept within 20μs



Bandwidth reduction:
Bandwidth = (100kHz+ 500kHz x 10%) x event size = 150kHz x event size
→ 1.5 times bandwidth without track trigger

Schematic of FE readout configuration:





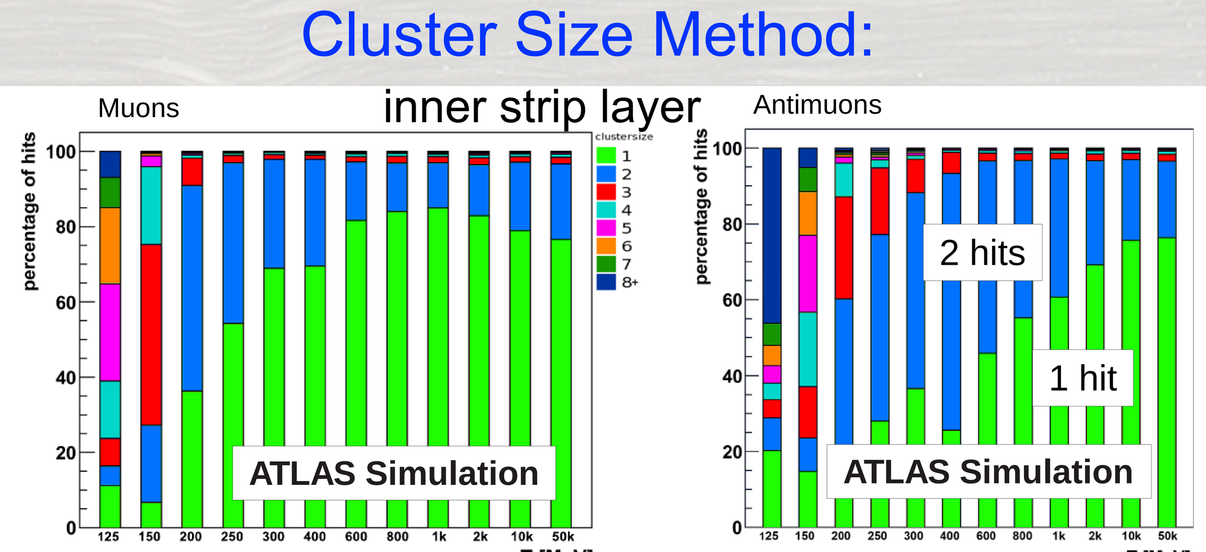
Benefits:
- minor changes to new tracker design
- low momentum tracks
- isolation criteria possible

Results:
- For $<\mu>$=200, L0A=300kHz, L1A=75kHz, R3=3kHz (fROI=1%)
- 160Mb/s link shared between R3 and L1 is optimum
- 98.5% of R3 data is received within 5.5μs
- separate buffers on the HCC for R3 and L1 (R3 prioritized)
- bandwidth required: 125 Mb/s (for $<\mu>$=140, L0A=500kHz, L1A=200kHz, R3=50kHz ,fROI=10%)

Option 2: Single hardware trigger level by using trigger layers in the new tracker

- filter high momentum tracks using doublet layer coincidences in closely spaced layers
- 2 local filtering methods studied, bandwidth reduction factor: 12-25

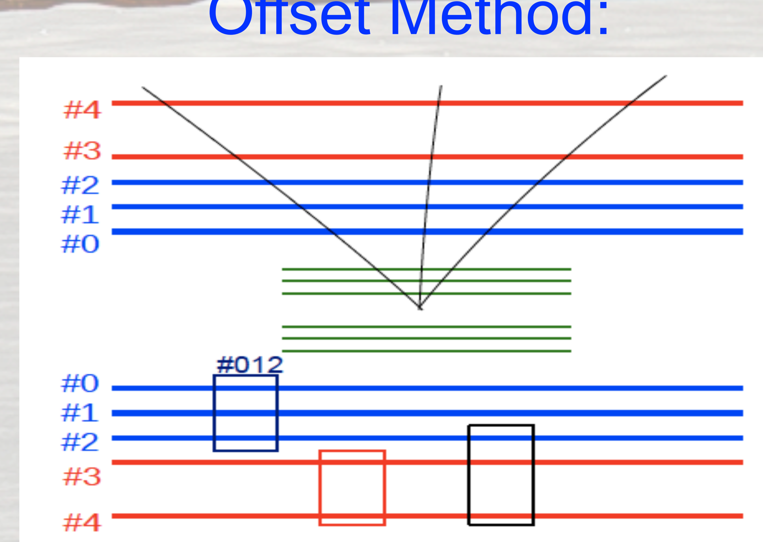
Cluster Size Method:

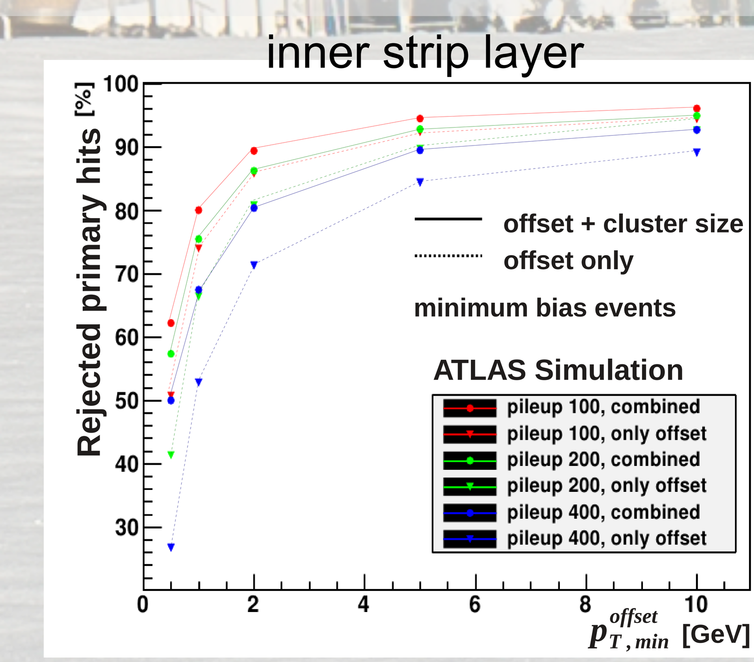


utopia design: strip sensors tilted by 10°

- cluster size is reconstructed on FE
- lower p_T tracks → charge sharing over several adjacent strips
- optimized cut: N ≤ 2

Offset Method:





- set stereo angle to 0
- match hits in inner and outer layers
- azimuthal distance related to p_T
- Best is to combine Cluster Size and offset

Global track reconstruction:
- hits from 2 or 3 layers combined, helix fitted and χ^2 cut applied
- will be done by associative memory

Track trigger rates of order 1 MHz achieved for p_T > 10-15 GeV, with ~ 75-80% eff

Benefits:
- no majors changes to FE of subdetectors
- finds all ID tracks
- redundant information