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Real-time flavour tagging selection in ATLAS

Lidija Živković,

Institute of Physics, Belgrade

On behalf of the ATLAS collaboration

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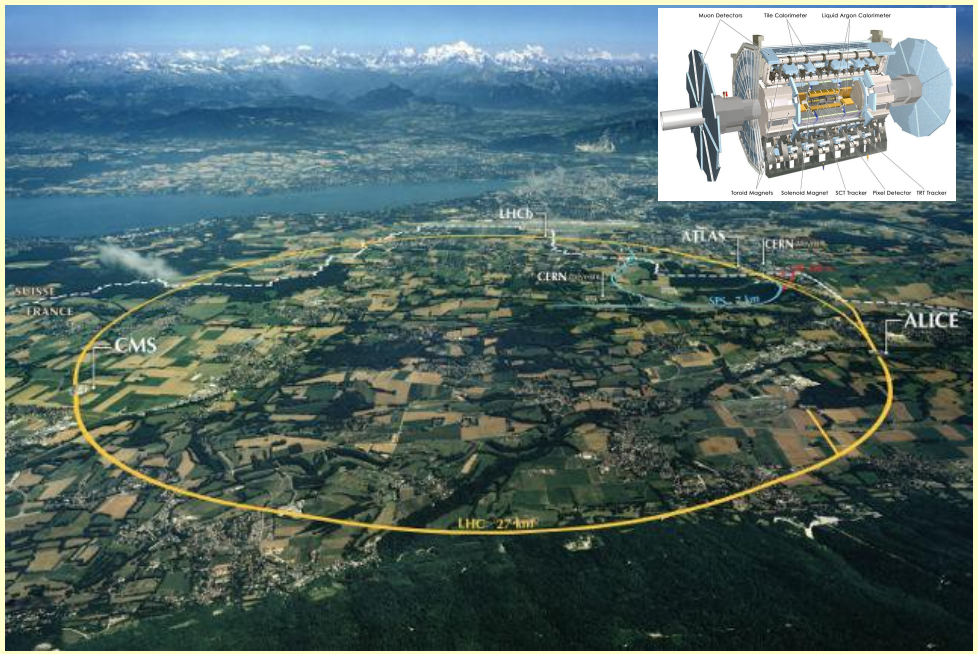
Outline

- Motivation
- Overview of the trigger
- b-jet trigger in Run 2
- Future – Fast TracKer

	Bunch spacing [ns]	√s [TeV]	Inst. Lumi [$cm^{-2}s^{-1}$]	<μ>
Run 1 2012	50	8	8×10^{33}	25 - 30
Run 2 2015 -	25	13	1.5×10^{34}	40 -45



μ – Collisions/bunch x-ing

- Increased energy, luminosity and pile up
  - => Rate increases by ~5 times
  - => Upgrade trigger

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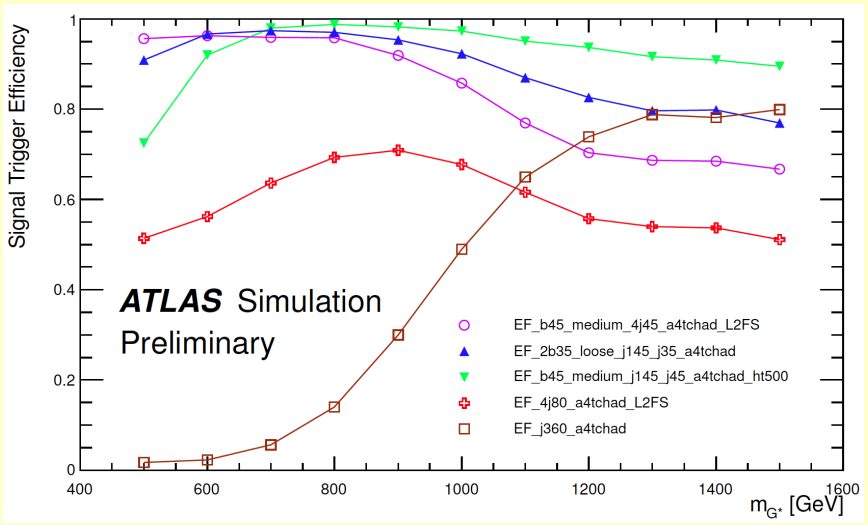
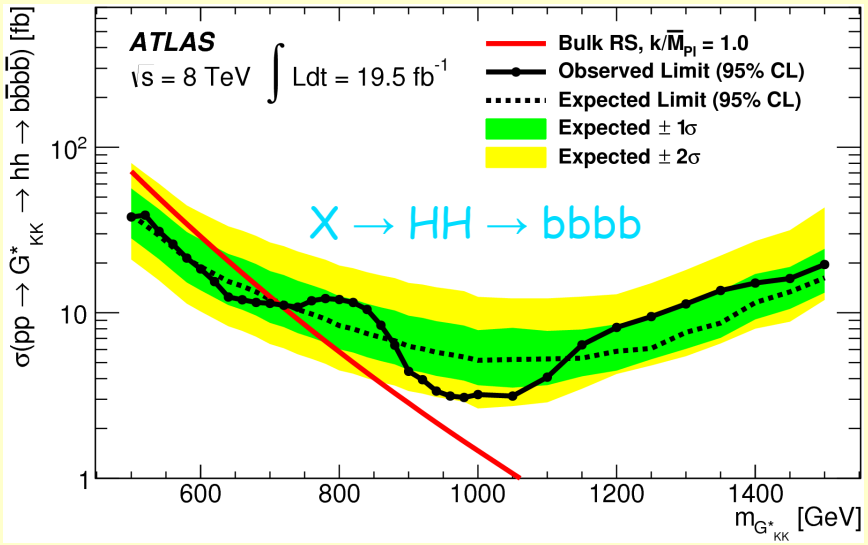
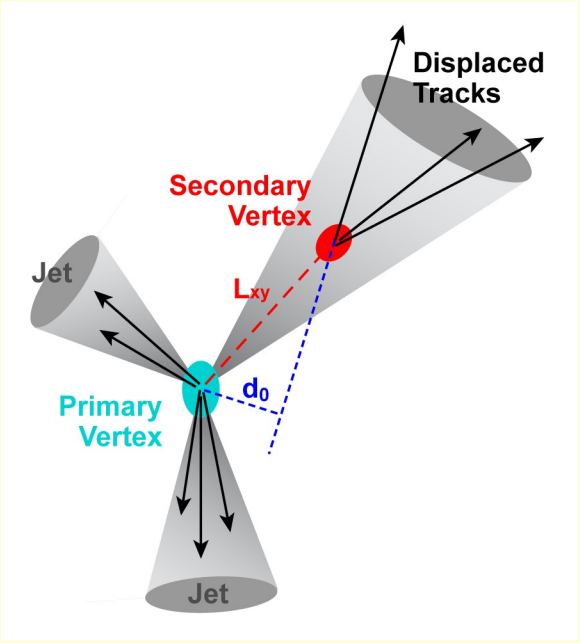
Motivation

- b-jet tagging is important in many physics analyses
- For final states with no leptons, b-jet triggers are crucial
  - All can benefit from their inclusion
- But triggering on b-jets is very challenging
  - Large output rate L1
    - multi-jet background not readily suppressed at L1
  - Tracking information critical
    - CPU/time expensive



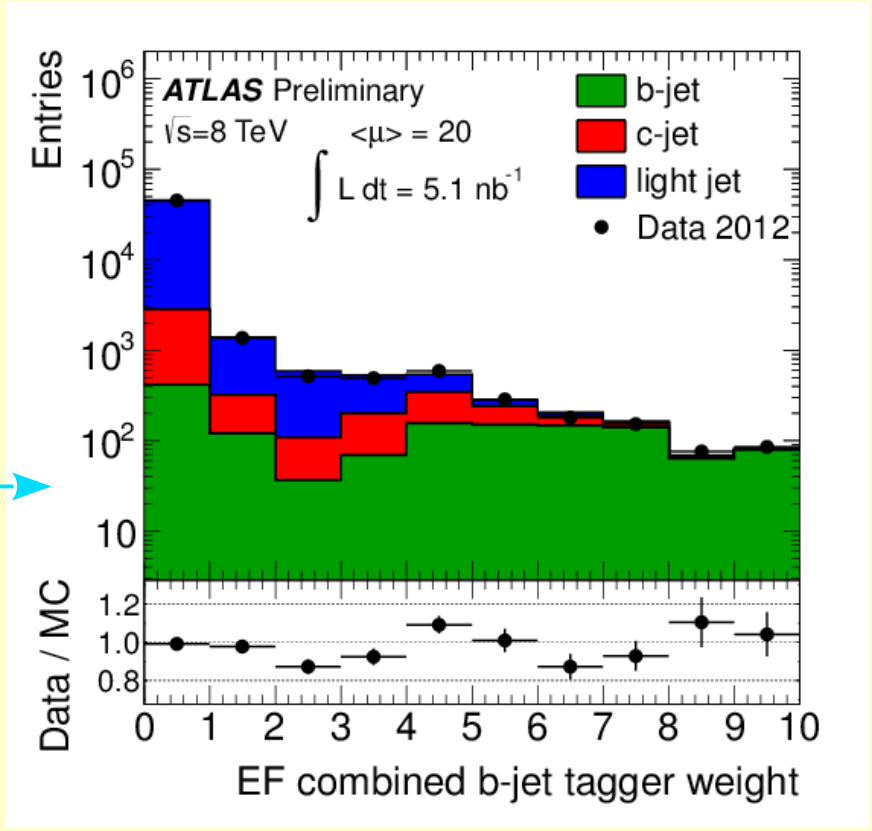


b-jet triggers



- Several B hadron properties can be exploited to tag the b-jets:
  - long B hadron lifetime (1.57±0.01 ps) corresponds to a measurable decay length (few mm for E≈ 50GeV)
  - high mass (~5.2 GeV)
- b-tagging exploits these using following
  - Secondary vertex (SV)
  - Impact parameter (IP)

  => Combine in multivariate technique (MVA)
- In Run 1 algorithms that ran online evolved:
  - 2012: IP3D+SV1 – combines transverse and longitudinal impact parameter distributions with the likelihood of the secondary vertex based on the mass, the number of two-track vertices and the fraction of the energy of the jet in the secondary vertex



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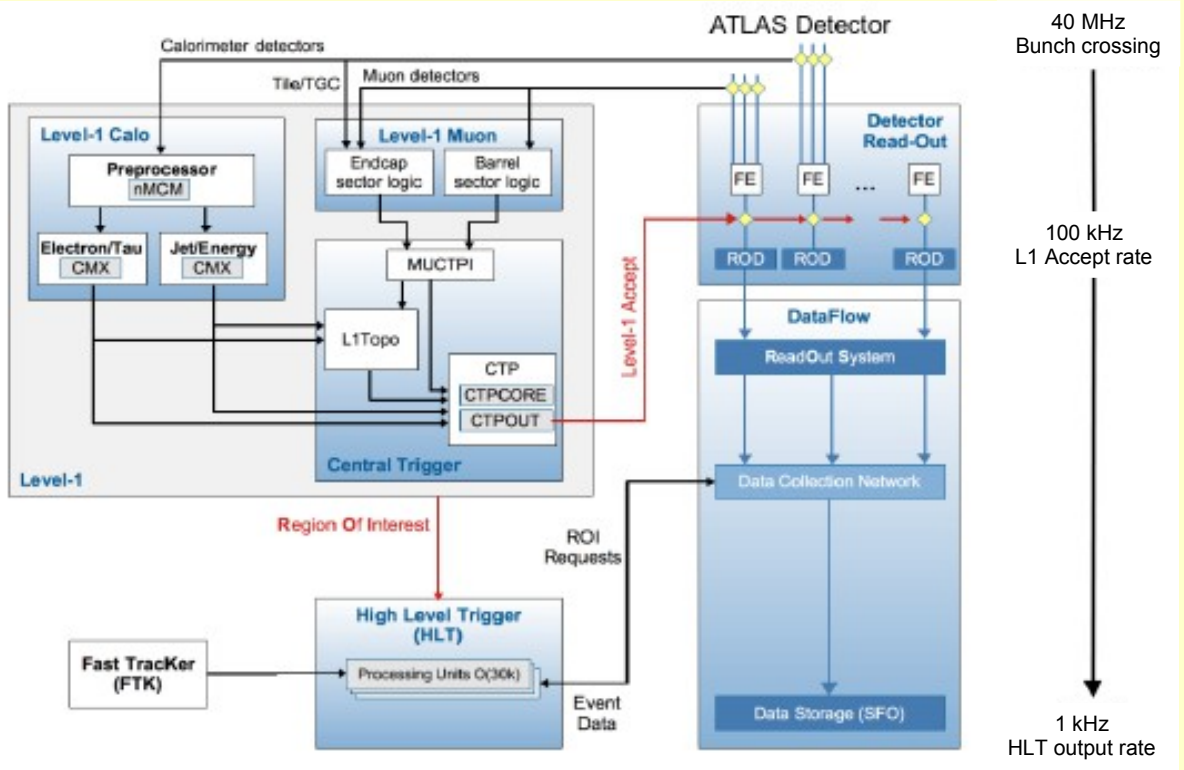
Overview of the trigger system

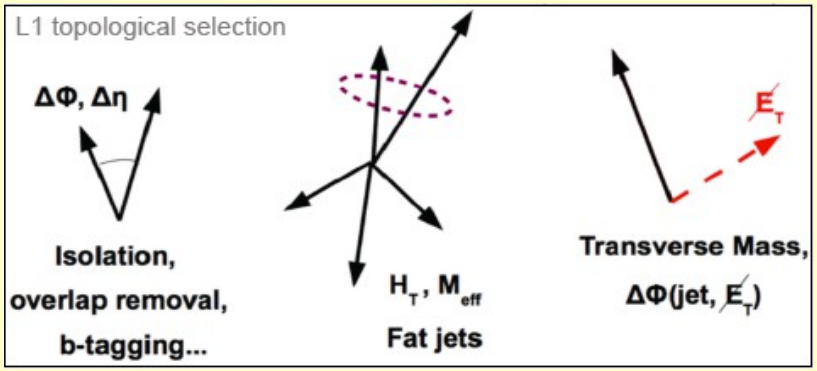
- Level-1 Trigger:
  - Custom electronics to determine Regions of Interest (RoIs) in the detector based on coarse calorimeter and muon detector information
  - Rate reduction: 40 MHz → 100 kHz (70 kHz in Run 1)
  - Latency 2.5 μs



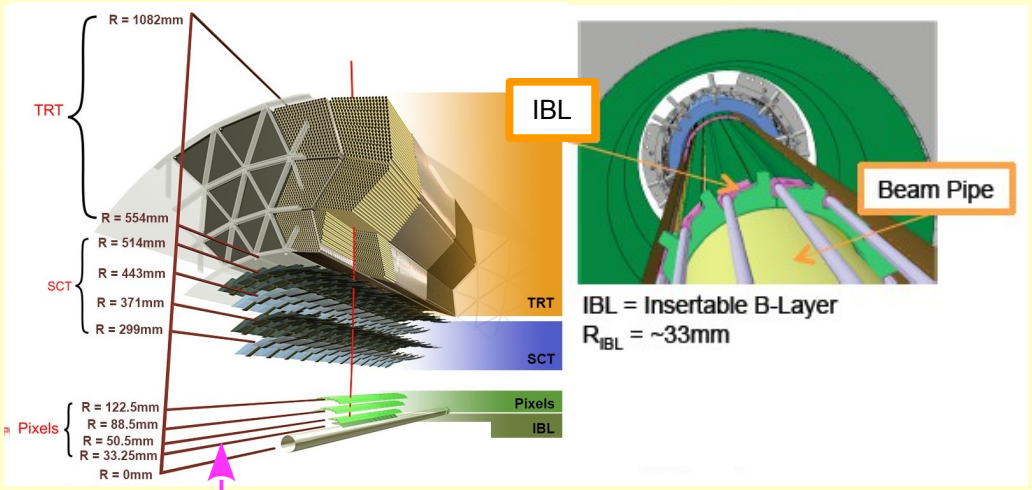
- High Level Trigger:
  - Software algorithms running on RoIs or full event information
  - Rate reduction: 100 kHz → 1 kHz (1.5 kHz peak)
  - Average latency 0.2 s

Hardware improvements relevant for b-jet triggers

- Insertable b-layer (IBL)
  - New pixel layer designed to assist in tracking (faster now) which is vital to accurately identify a b-jet
  - Introduction of IBL allows for better d_0/z_0 resolution



- L1 Topological trigger subsystem
  - Part of the new Central Trigger Processor (CTP)
  - Reconstructs derived physical quantities with a rate of 40 MHz
  - Trigger decision based on different topologies
    - ΔR between muon and jet allows for identification of possible semileptonic b-quark decays



More details later:
Yang Qin - ID

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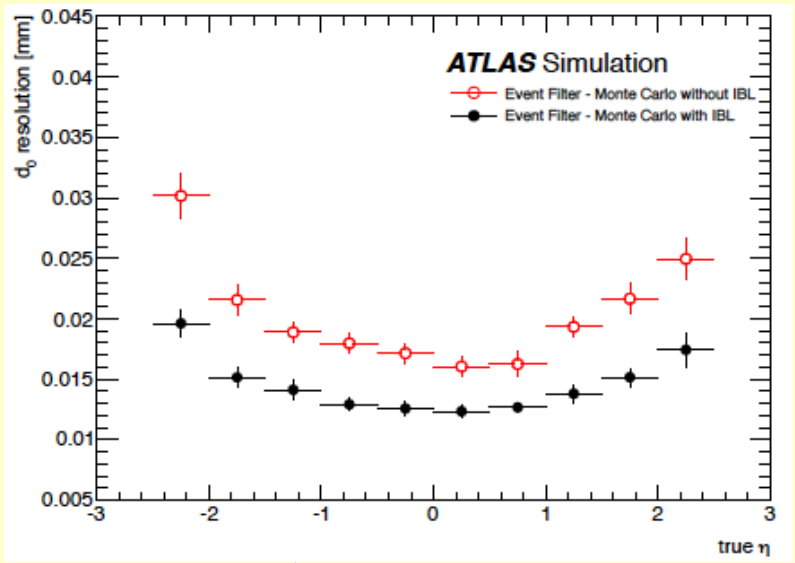

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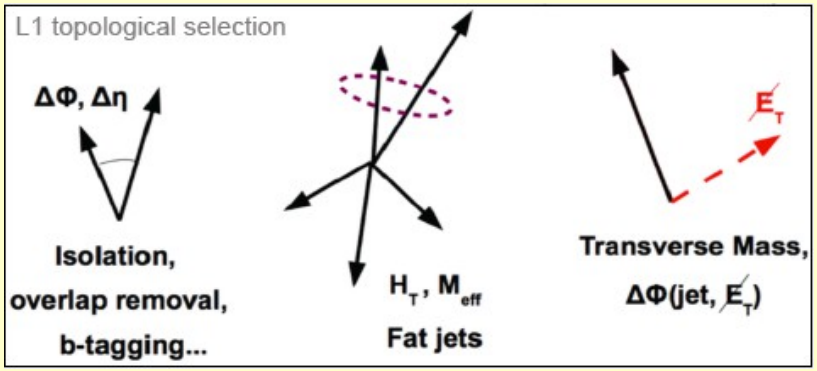

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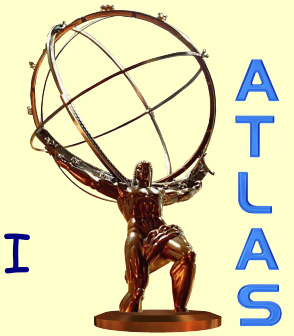
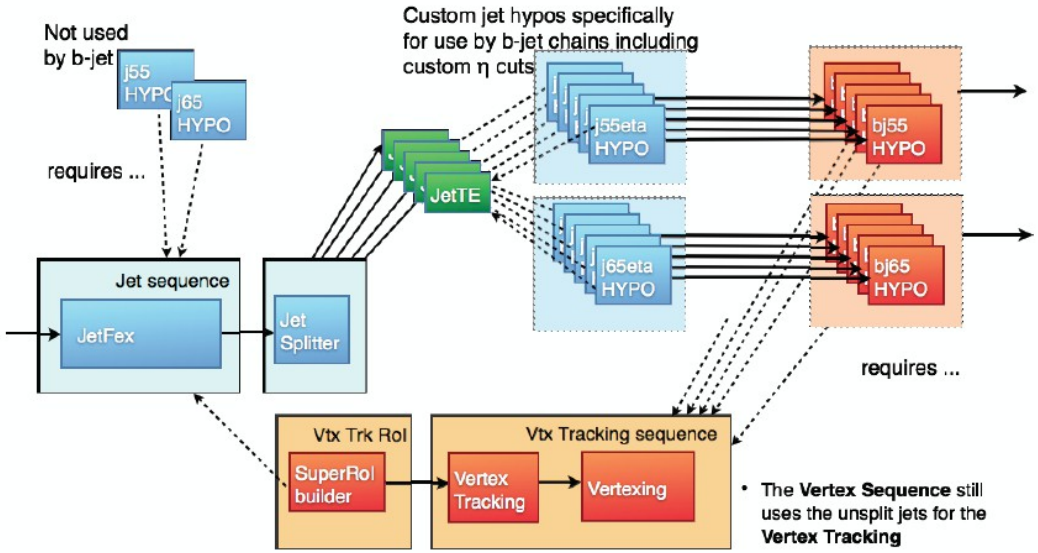
New High-Level Trigger features

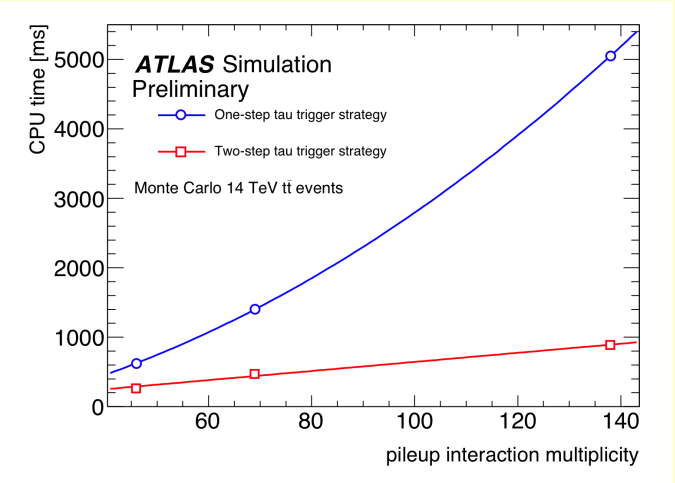


- The new merged HLT replaced Level 2 + Event Filter split in Run I
  - Reduced complexity of the system and dynamic resource sharing
  - Efficient coupling between HLT selection steps reducing duplication of CPU usage and network transfer of detector data
- Increased resources for larger CPU processing and network traffic, which scale with luminosity
- Software Improvements:
  - Adopted offline techniques and algorithms where possible.
    - Offline / Trigger harmonization simplify efficiency determinations.
    - Less code duplication between online & offline algorithms.
  - Increased use of global reconstruction
  - Advanced multiprocessing to fully utilize available hardware

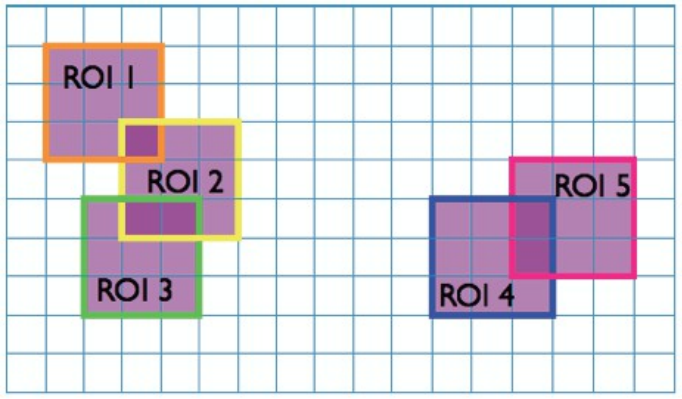
b-jet trigger improvements: new configuration

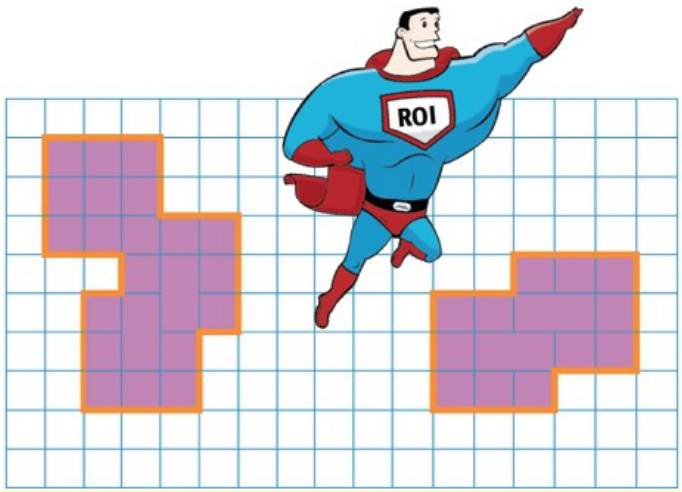
- Primary vertex finding is challenging and demanding in resources
- Multiple ROI: Multiple track reconstruction in overlapping areas
- Super-ROI: Unique reconstruction in single sROI → faster processing
- Two-step tracking – fast for primary vertex finding, precision for tagging





Tracking is expensive!

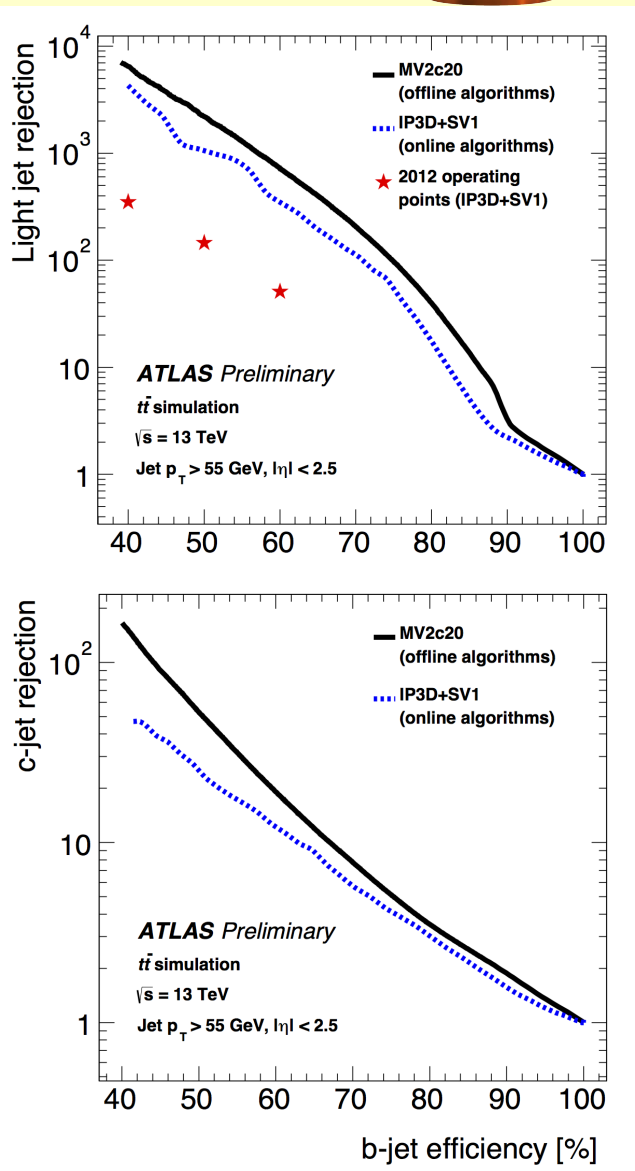




Offline tools

Loose	Medium	Tight
79%	72%	62%

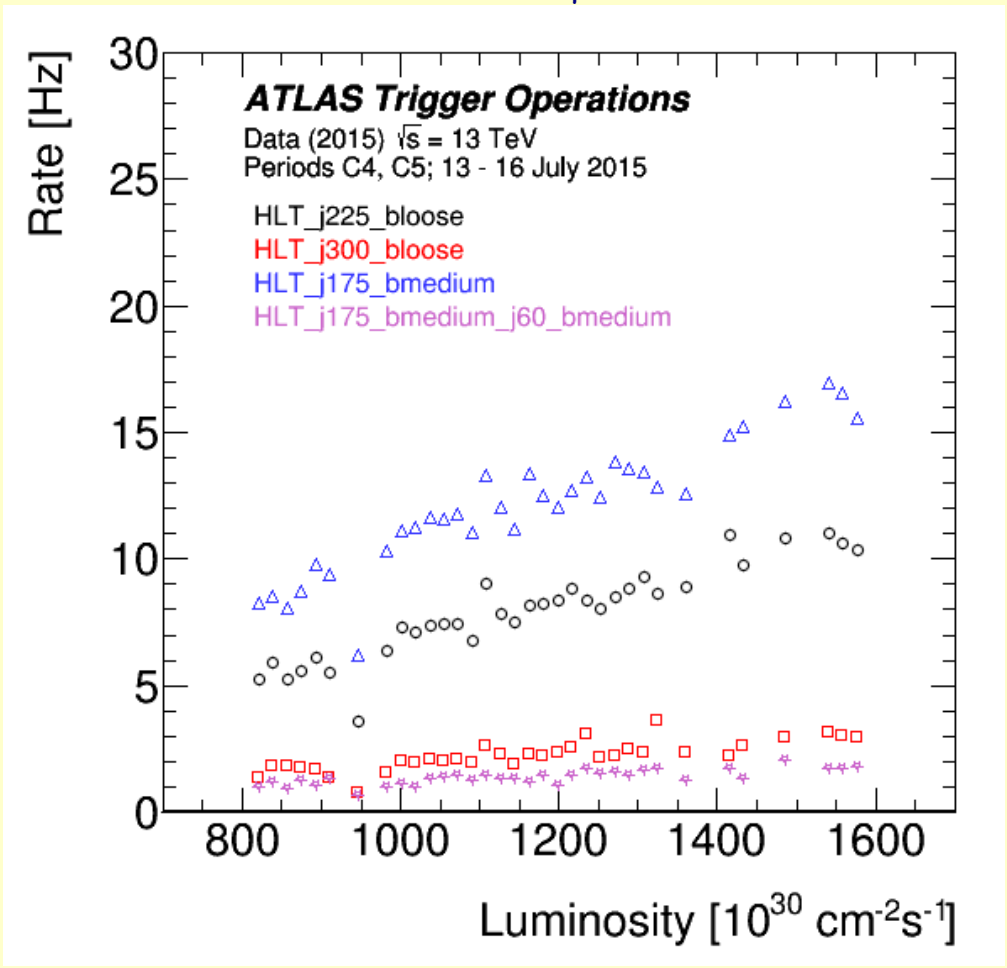
- In Run 1 b-jet trigger used a combination of IP3D and SV1
  - Both were specifically designed online algorithms that resembled offline algorithms
- Big effort to reuse offline code and move to the use of advanced tools and multivariate taggers online
  - Larger rejection power allows looser working point definitions
  - Efficiency for b-tagging is preserved
- MVA algorithm MV2c20 is used in Run 2
  - BDT using IP3D, SV1, and JetFitter
  - specialized for additional c-jet rejection
  - same algorithm is used in physics reconstruction



JetFitter: likelihood technique that exploits the topology of weak b- and c-decays

Run 2 b-jet trigger menu

- Multi b-jet items
  - From single high p_T to quadruple lower (down to 35 GeV) p_T items
  - Can be seeded from three 25 GeV L1 jets, or four 15 GeV L1 jets
  - Three operating points which correspond to the offline ones
- Muon-in-jet items
  - Single mu-jet, mu-jet+jets and mu-jet+b-jets
  - Usage of L1topo items
- Needed for Higgs boson and exotics physics
  - All hadronic ttH→ttbb, VBF H → bb, bA →bbb, X→HH→bbbb, 3rd generation squarks...



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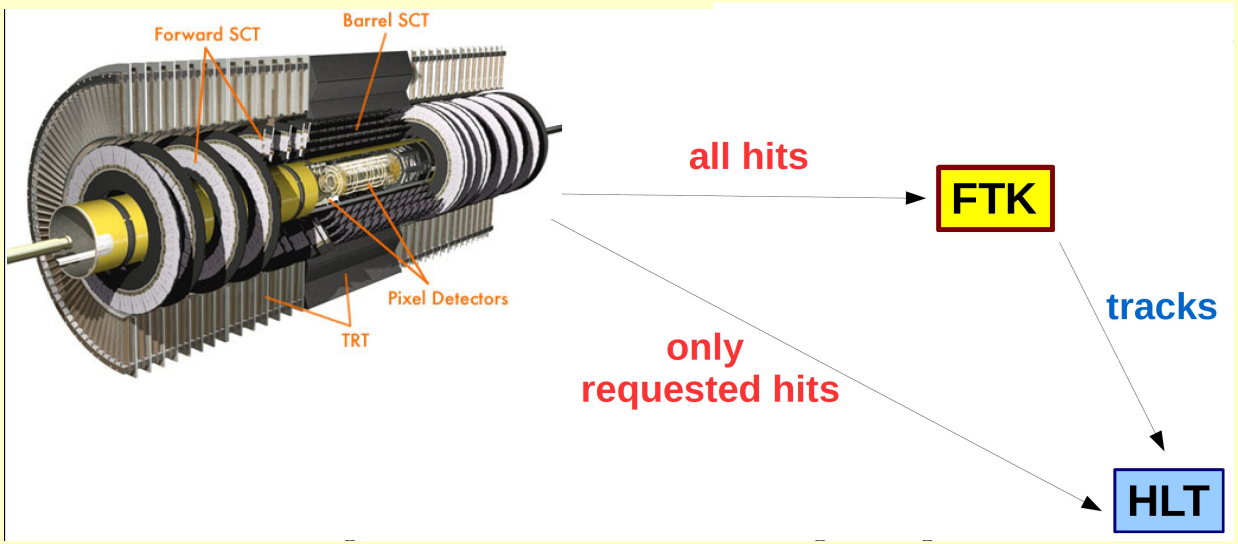
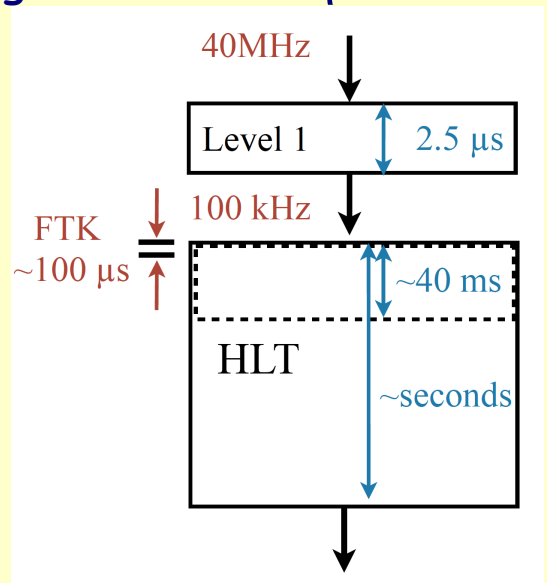
Future – Fast TracKer

- Hardware based track trigger which will start operate in Run 2
  - For every event passing the L1 trigger, FTK receives data from the 98 million channels of the silicon detectors and provides tracking information to HLT
  - Run at full L1 output rate; O(100 μs) latency
  - Track finding:
    - p_T > ~1 GeV / $|d_0|$ < 2 mm / $|z_0|$ < 110 mm
    - 5 track parameter / list of hits / χ^2 estimate
    - ~90% efficient with respect to the full offline tracking for central η

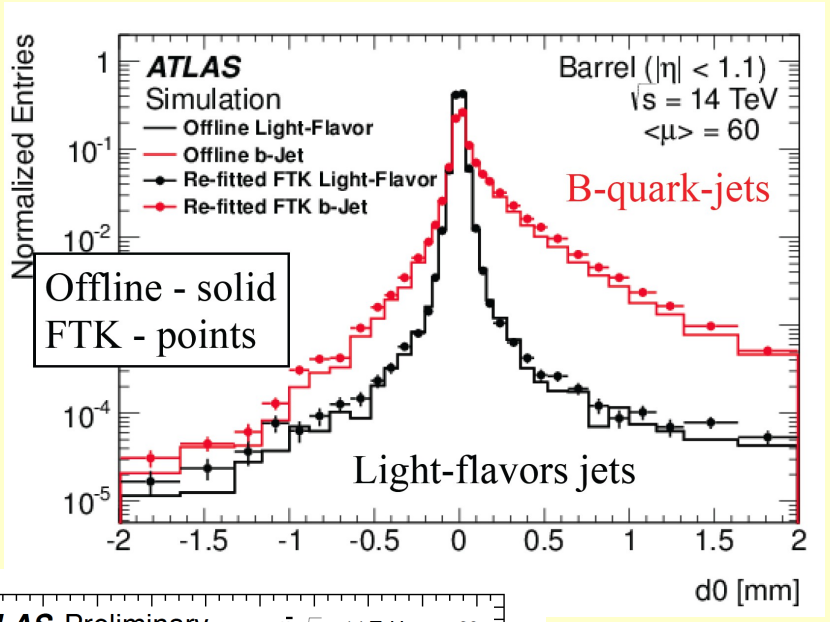
More details later:
Asbah Needa – FTK

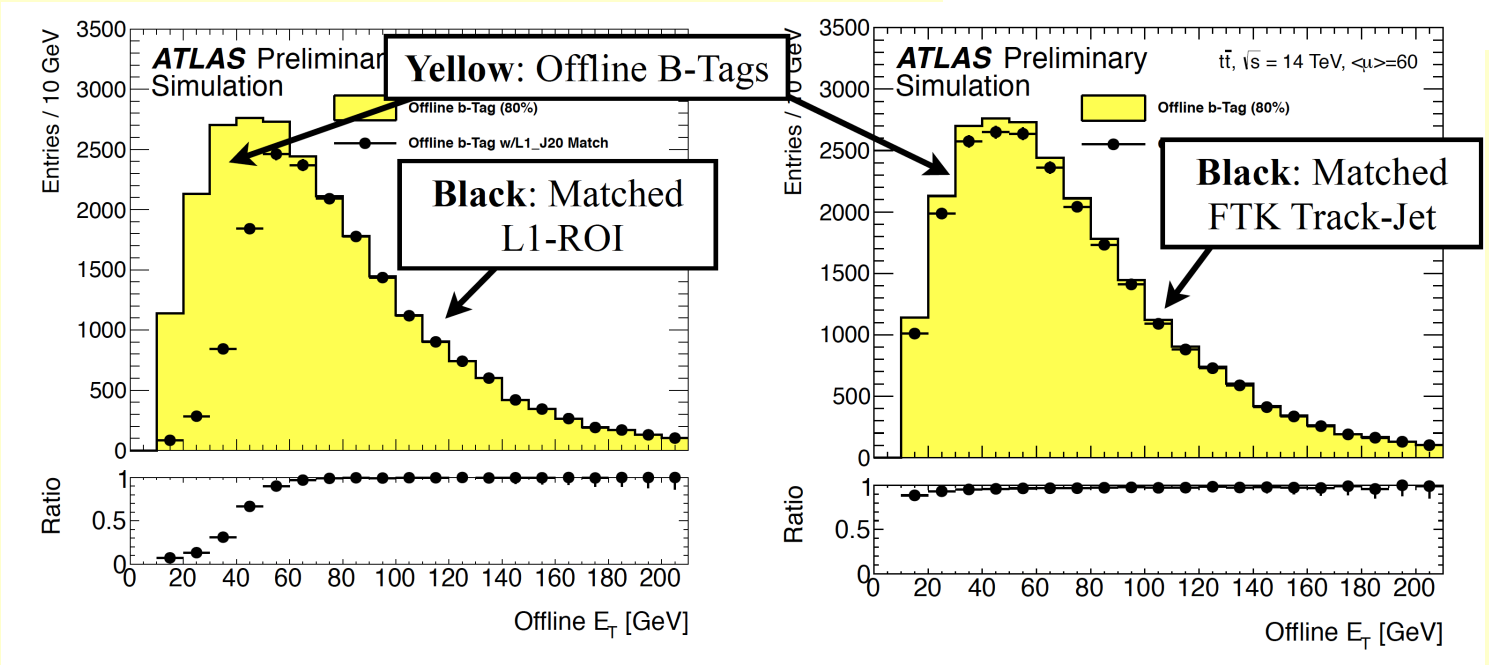




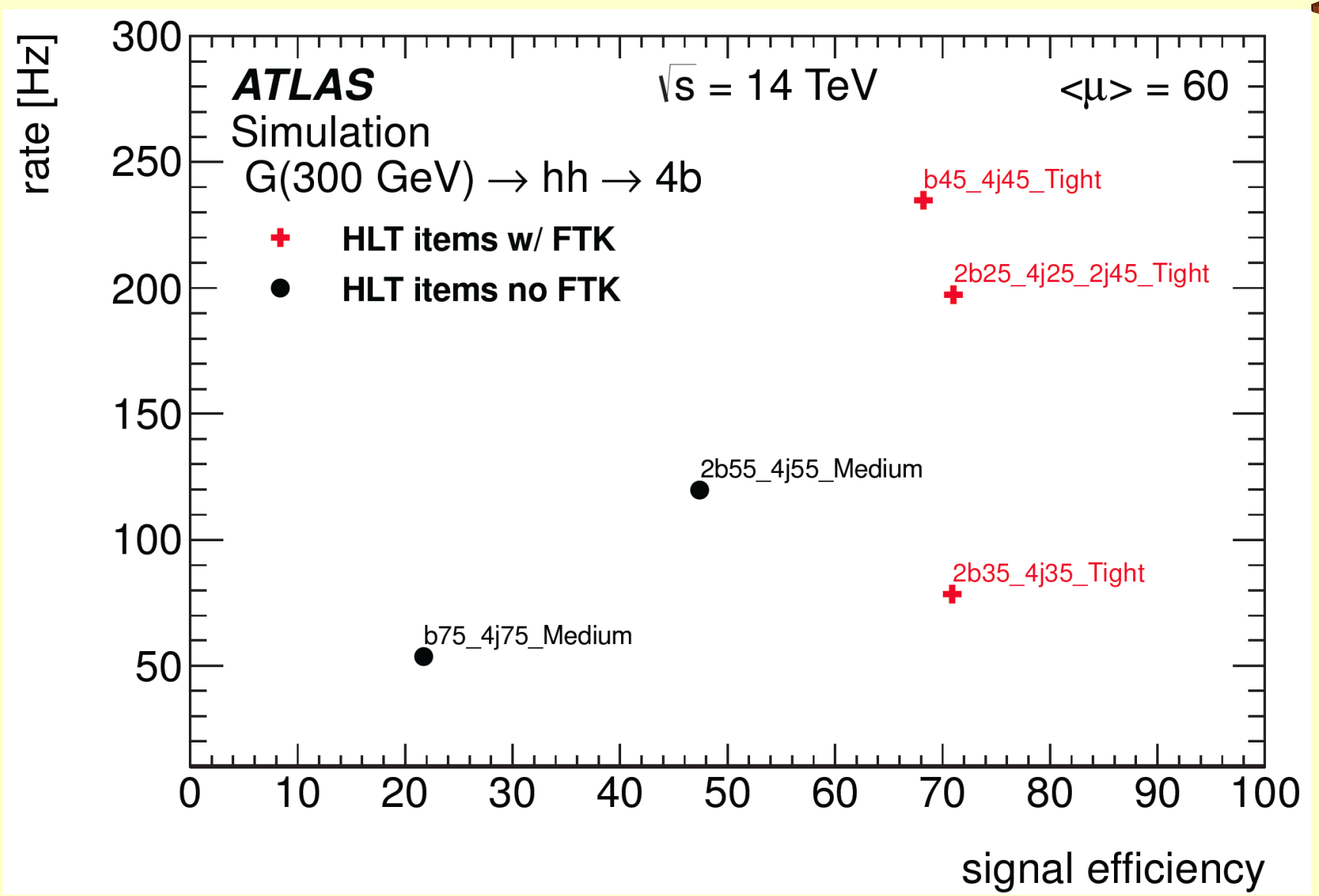
FTK: Application

- Possibility to refit tracks with offline like track fitter
  - Better estimation of track parameters
  - Reduction of fake tracks due to refined χ^2
- b-jet identification
  - Improve b-tag performance in RoI
  - Run track finding on more RoIs
  - Full scan b-tagging independent of RoI



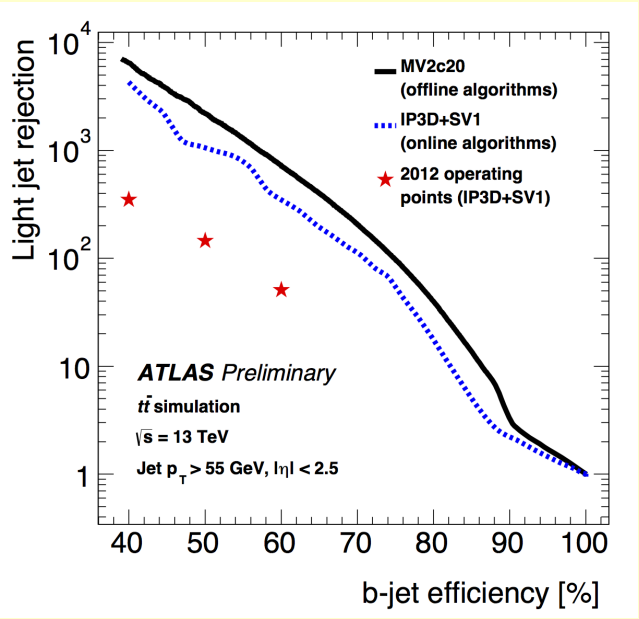


FTK: Possible improvement



Summary

- b-jet triggers are important for many physics analyses
  - One of the most complicated signatures
- Many changes in the ATLAS trigger system for Run 2
  - B-jet trigger software was revisited and many improvements are made
  - Diverse menu, comprising multi-jet and muon-in-jet items is already running in Run 2
- Future improvements are foreseen with an inclusion of the Fast TracKer



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Хвала на пажњи

Thank you

Спасибо