Real-time flavor tagging selection in ATLAS

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Why b-tagging?

The possibility to identify and tag jets originating from b-quarks is an important aspect for many physics analyses, such as:

- Top quark production.
- Probing the flavour structure of new physics.
- Higgs bosons decaying to a b-quark pairs.
- Supersymmetric signatures, e.g. 3rd generation squarks.

Due to the large multi-jet production rate at the LHC it is challenging to study signatures without relying on leptons to trigger the event. The b-jet trigger offers an advantage compared to calorimeter-based jet triggers as it additionally exploits track information to identify b-jets.

The ATLAS detector consists of three main parts which are the inner detector, calorimeters and muon spectrometer. Each part of the detector provides specific information and helps the reconstruction of events.

Inner Detector (ID): Reconstructs charged particle trajectories and measures their momentum. It has excellent performance in the momentum resolution and reconstruction efficiency together with capability to identify secondary vertices formed by the hadronization of b-quarks. It is composed of three independent subsystems:

Pixel detector

- 3 layers and 3 disks of silicon-based pixels
- pixel size 50 x 400 μm2

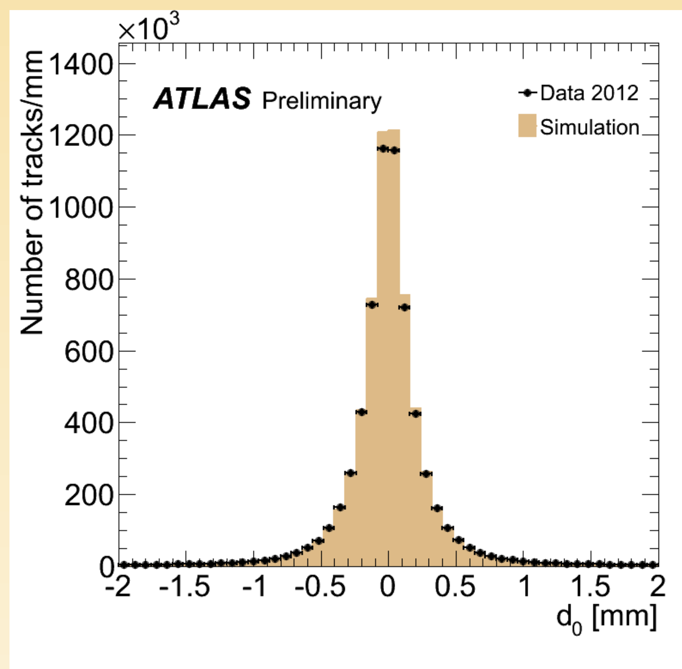
SemiConductor Tracker (SCT)

- 4 layers and 9 disks of stereo silicon strips
- strip size 80 μm

Transition Radiation Tracker (TRT)

- Straw drift tubes
- Tube diameter 30 μm

ATLAS Detector

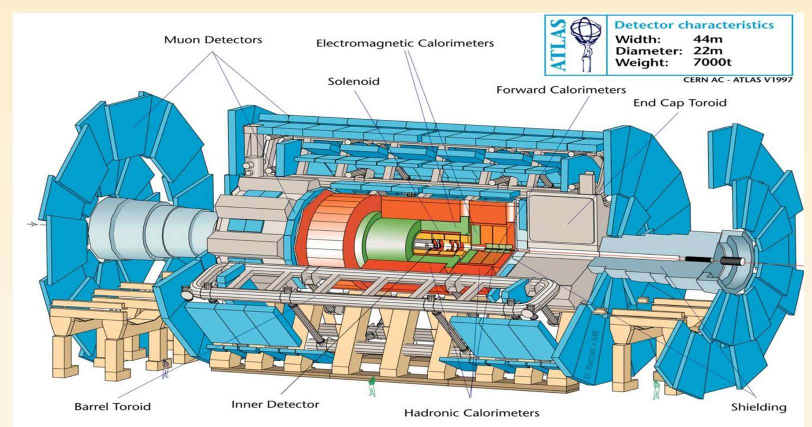


Data and simulation comparison of transverse impact parameter d_0. No-pileup 2012 8TeV Minimum Bias data/simulation. Vertex z position and transverse momentum weighting were applied. Selection cuts : barcode < 200000, Pt > 500 MeV, $|\eta| < 2.5$, $|d_0| < 1.5$mm, B-layer hits >=1 when expected, nSCTHits>=1

Calorimeters: The electromagnetic calorimeter identifies and measures the electrons and photons. The hadronic calorimeter identifies jets formed by the hadronization of quarks.

The Muon System: Consists of a combination of detectors providing precision hit measurements and fast trigger information. The MS identifies muons and provides a large lever arm to improve their momentum measurement.

The schematic view of the ATLAS detector.



ATLAS Trigger System

Level 1

- Based on hardware, coarse information from calorimeters and muon system, identifies regions of interests (ROIs)
- 70 KHz maximum output rate and latency is 2.5 μs

Level 2

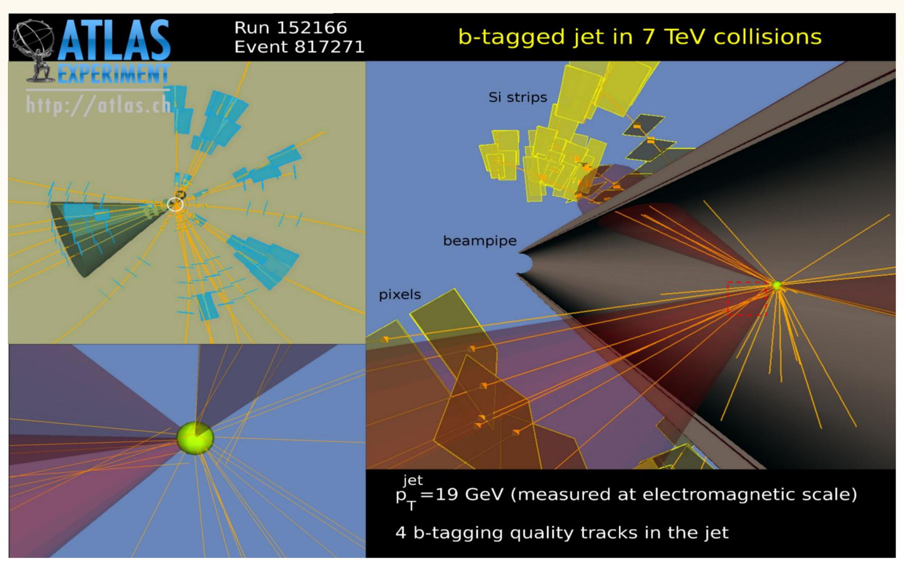
- Data from all sub-detectors at full granularity but only in limited detector RoIs seeded by LVL1. Access to ID allows track reconstruction
- 5 KHz output rate and latency ~75 ms

Event Filter

- Guided by LVL2 result with the ability to access all sub-detector data at full granularity
- 700 Hz average output rate and latency ~1 s

HIGH LEVEL TRIGGER (HLT)

b-jet identification

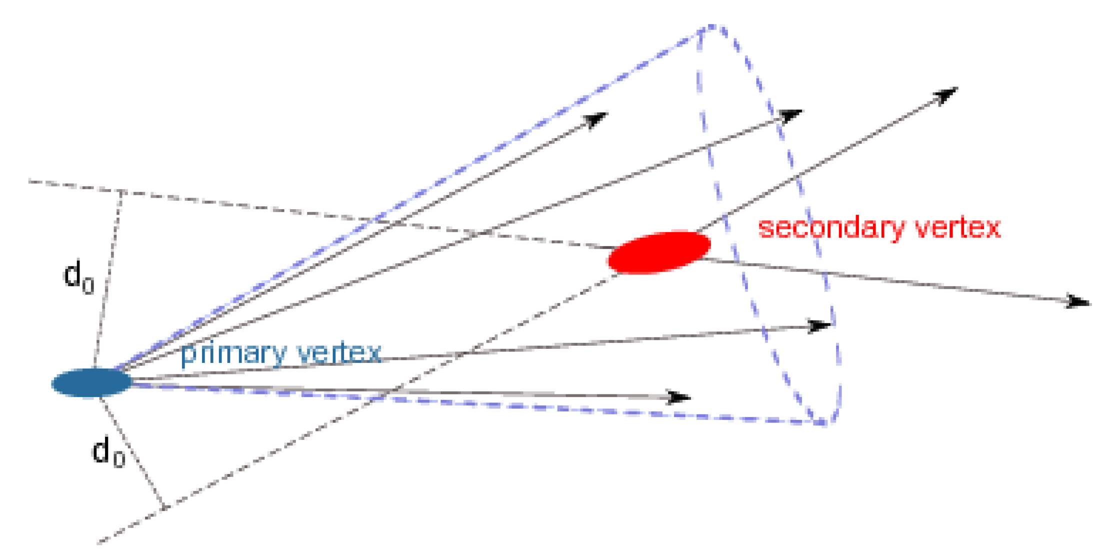


- Primary Vertex (PV) Reconstruction
- Secondary Vertex (SV) Reconstruction
- Track Impact Parameters (d_0,z_0)

The identification of jets originating from the hadronization of b-quarks is possible because of b-quark decay properties like:

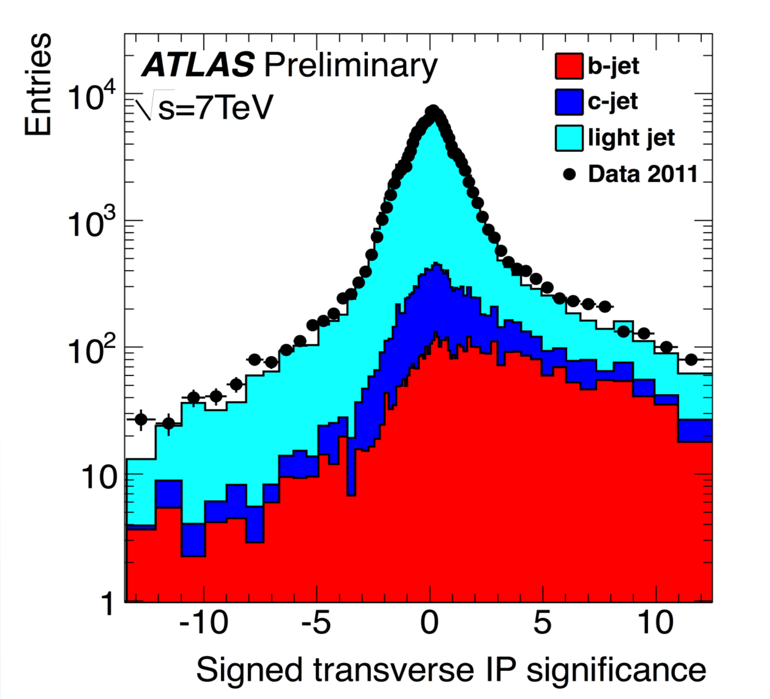
- ***Relatively long lifetime of B-hadrons*** – of the order of 1.5 ps – that allows them to travel several millimeters before decaying.
- ***Presence of a secondary vertex*** and its associated properties .

These properties can be used to distinguish b-jets from jets that are coming from the light quarks or gluons.



ATLAS Real Time Flavor Tagging Algorithms

Online b-jet tagging selection is based on transverse signed impact parameter of reconstructed tracks. The **JetProb** method computes the probability for a jet to originate from the primary vertex, based on the transverse impact parameter significance $S(d_0)$ of tracks pointing to the jet.



$$S(d_0) = \frac{d_0}{\sigma(d_0)}$$

Signed transverse impact parameter significance of reconstructed tracks at the Event Filter level. Plot shows that the asymmetric positive tail due to tracks originating from b-jets. The agreement between data and simulated samples can be seen clearly.

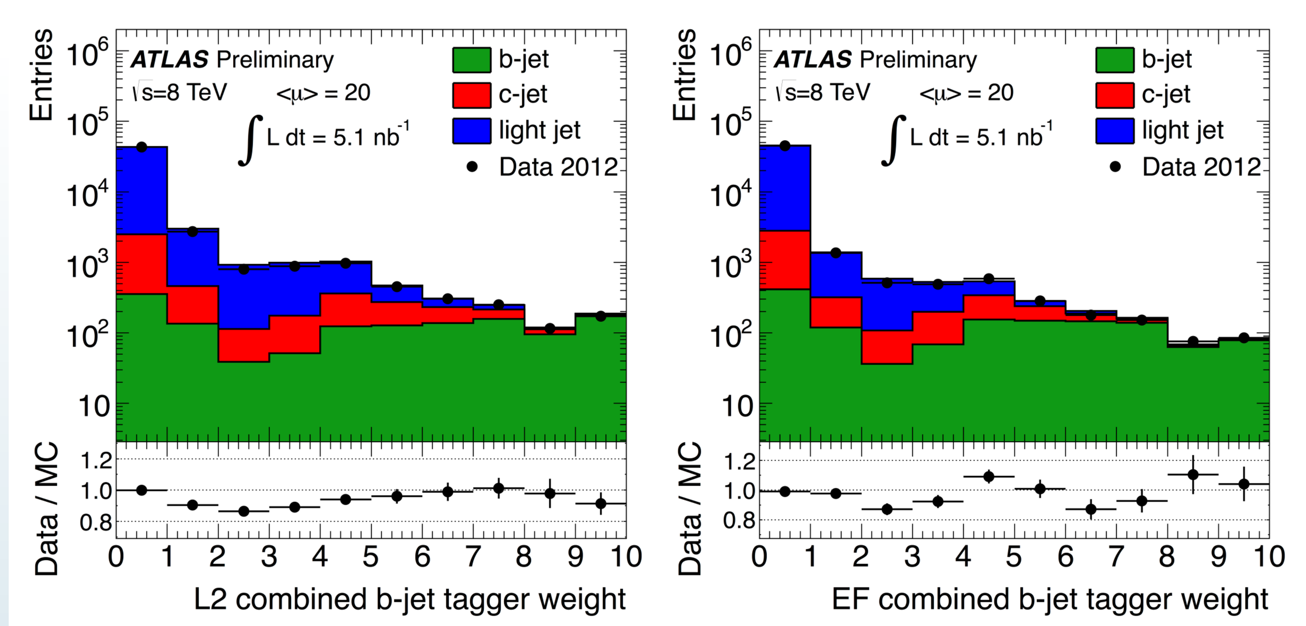
2011 √s = 7 TeV

JetProb Algorithm

A combination of two algorithms, *impact parameter significance and the secondary vertex likelihood-based taggers* were used in 2012 b-jet triggers. The **likelihood-ratio** tagger uses the expected transverse and longitudinal impact parameter distributions for b-jets and light jets separately. The online tagger is based on a likelihood-ratio evaluated using the expected distributions for b- and light-jets for two groups of variables. Spatial variables, corresponding to the transverse and longitudinal impact parameter significances for tracks from b- and light jets. Secondary vertex variables, as the invariant mass at the vertex, the number of two-track vertices and the fraction of energy in the SV are used.

2012 √s = 8 TeV

Likelihood Ratio



Jet weight distribution for the tagger based on the combination of the impact parameter significance and the secondary vertex likelihood-based taggers, calculated from prescaled Event Filter tracks and Level 2 tracks. In Event Filter jets with p_T> 55 GeV and η < 2.5. In Level 2 jets with p_T> 55 GeV and η < 2.5. Only statistical errors are shown.

2015 √s = 14 TeV Plans

- Better tracking via extra silicon pixel detector layer at 3.2 cm from beam line.
- Ability to use same programming objects and any complex b-tagging algorithm adopted for offline b-jet identification.
- B-jet trigger will be used in conjunction with signatures that contained charged leptons, to avoid increasing the leptonic energy thresholds.
- 3D reconstruction of a primary vertex is under investigation.
- Additional info such as the reconstruction of a third vertex from the decay of a c-quark produced in the decay of the b-quark may be an option.
- Improved timing performance and reconstruction strategy for HLT tracking to allow operation at very high pile-up regimes.