Fast Tracking for the Second Level Trigger of the ATLAS Experiment Using Silicon Detectors Data

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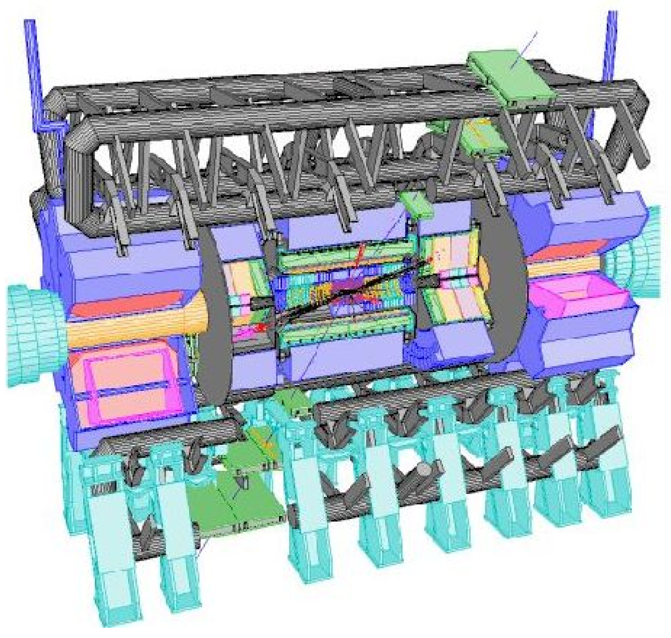
1 Introduction

The ATLAS detector will operate at the LHC collider studying pp collisions at 14 TeV center of mass energy. The region around the pp interaction point will be characterized by a very high density of charged tracks which can be reconstructed only by using detectors with high granularity which also grant low occupancy. The algorithm presented here aims at charged track reconstruction exploiting the precise 3D measurements of pixel detector (the innermost part of the tracking detector) within the time constraint of the second level trigger (10 ms).

2 ATLAS

(**A** **T**oroidal **L**HC **A**pparatu**S**)



ATLAS is a multi-purpose detector for the LHC collider (E_{CM}=14 TeV)

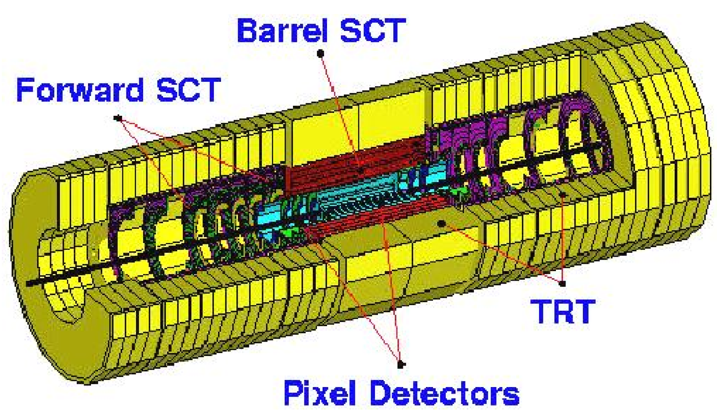
LHC running conditions:
High lum. $1\times10^{34}cm^{-2}s^{-1}$ ~ 25 pile-up evts/BC
Low lum. $2\times10^{33}cm^{-2}s^{-1}$ ~ 5 pile-up evts/BC

At the LHC design (high) luminosity the events are spread out along the beam direction by $\sigma(z)=5.6\ cm$. One of the most important tasks for the tracking is the determination of the z coordinate of the primary vertex $\longrightarrow$ allowing some rejection of background hits from other interaction points.

3 Tracking Detectors (Inner Detector)

The Inner Detector (ID) components:

- Pixel: 3 layers pixel Si detector [$R = 5.05, 8.85, 12.25\ cm$; Pitch $R\phi = 50\mu m$; Pitch $Z = 400\mu m$]
- SCT: 4 layers (barrel) and 9 disks (endcap) of stereo strips Si detectors
- TRT: Straw tubes tracker (Transition Radiation Tracker) (~ 30 hits per track)



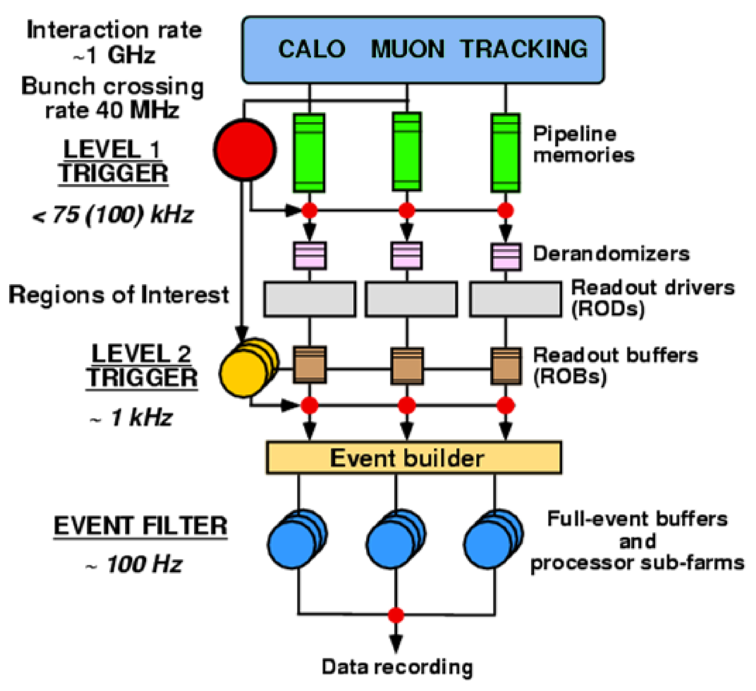
In the initial layout of the ID (approved, for budget reasons, for the initial data-taking period) the intermediate pixel layer and TRT C wheels at $|\eta| > 1.7$ are missing. Although a 300 μm B-layer Z-pitch was used for the results presented here, in practice the Z-pitch will be 400 μm.

4 Tracking in the High Level Trigger

The ATLAS event selection is structured in three levels, the first is a hardware trigger while the other two levels run on a commercial PC farm.

- Inner Detector data are available only at LVL2 and above
- LVL2 (~10ms) custom algorithms using information inside the Region Of Interest (ROI) defined by LVL1
- EF (~1s) refined selections (possibly seeded by LVL2 result) using simplified Offline algorithms

Dedicated tracking algorithms at LVL2 should be fast and access the smallest amount of data needed.
Complementary approaches have developed in order to maximize the physics reach.



5 Fast Tracking for the Second Level Trigger

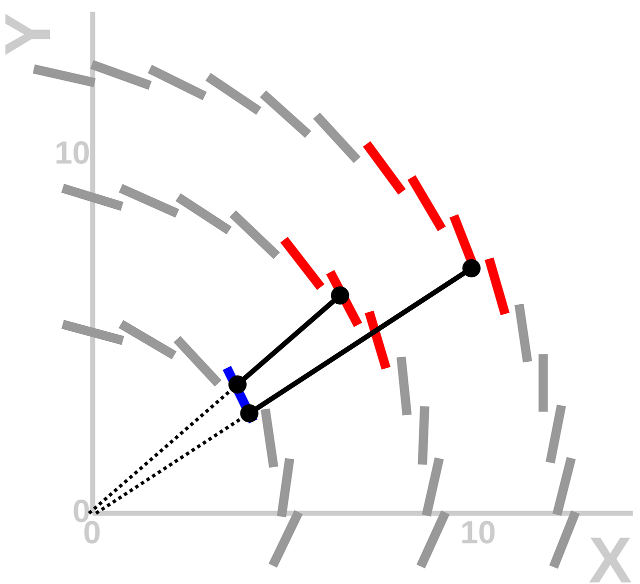
The tracking algorithm described in this poster aims to reconstruct the innermost part of track segment by selecting triplets of silicon hits (spacepoints). Initially based only on Pixel detector has been recently upgraded to use also the SCT data.

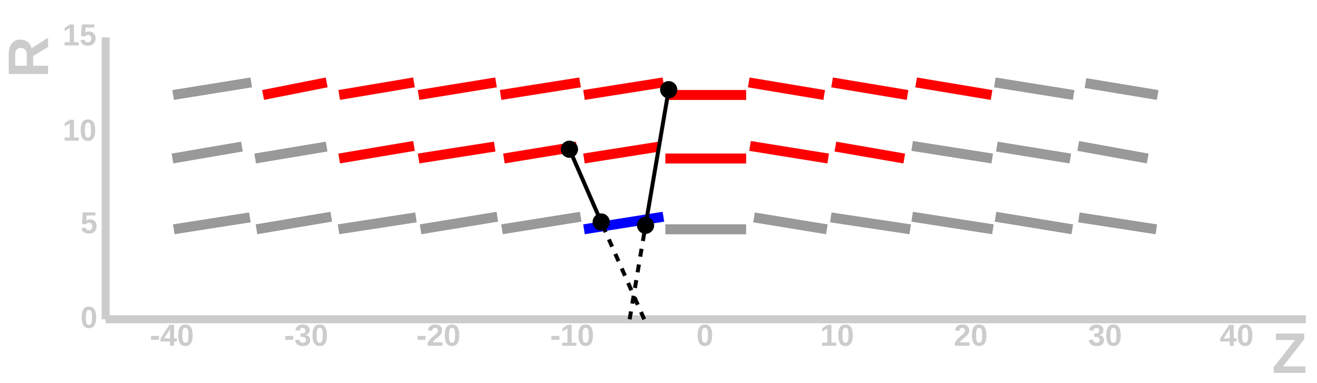
5.1 Sorting

All the spacepoints from a given RoI are ordered by detector module address (to speed-up data access).

5.2 Seeding

Using the sorted map and a Look-Up Table (LUT) linking each module within the B-layer to the ones belonging to second logical layer (collection of layers which are likely to contain the second point of the track), track seeds are formed by two space points and fitted with a straight line.
The line defined by each seed is extrapolated back to the beam line and the transverse and longitudinal impact parameter are computed.
The minimal p_T acceptance can be tuned by cutting on the transverse impact parameter.





5.3 Primary vertex reconstruction

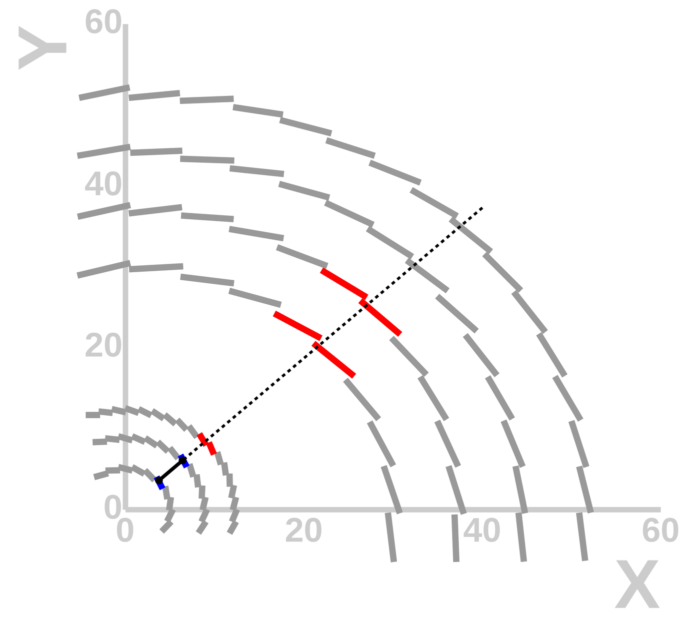
The z coordinate of primary vertex is estimated as the coordinate of the maximum of the histogram filled with the z impact parameters of the seeds.
More than one candidate is retained to improve efficiency ($\epsilon \sim 85-95\%$ depending on the luminosity and event topology). Efficient primary vertex reconstruction is needed to guarantee uniform performance in the different luminosity regimes.

5.4 Extension

Track seeds are extended with a third spacepoint using a second LUT.

Ambiguities (i.e. tracks sharing at least one point) are removed on the basis of the extrapolation distance.

The spacepoints triplets are then fitted (circle in the $r-\phi$ plane, line in the $r-z$ plane) and identified as candidate tracks.

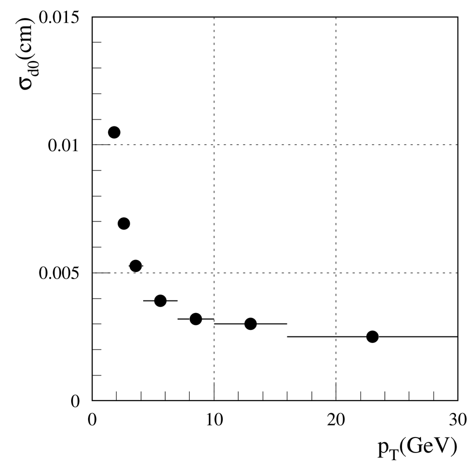


5.5 Performance

The algorithm reconstructs tracks in jets with an efficiency ranging from 80% to 90% (depending on the luminosity and event topology). Single electrons are reconstructed with an efficiency of about 95% for all the luminosities.

The track resolutions are summarized in the following table. The impact parameter resolution is shown in the plot as a function of p_T.

$\sigma(1/p_T)(GeV^{-1})$	0.006
$\sigma(\phi)(rad)$	0.7×10^{-3}
$\sigma(\eta)$	2.2×10^{-2}
$\sigma(z_0)(\mu m)$	340



The results of timing measurements on 2.4 GHz PC using b-jets (signal only) are given in the following table:

Sorting(ms)	Seeding(ms)	Extension(ms)	Tot. algorithm (ms)
~ 0.2	~ 0.5	~ 0.3	~ 1

The total algorithmic time scales to $\sim 1.4\ ms$ at low luminosity and $\sim 2.5\ ms$ at high luminosity. The timing performance is well within the LVL2 constraints.

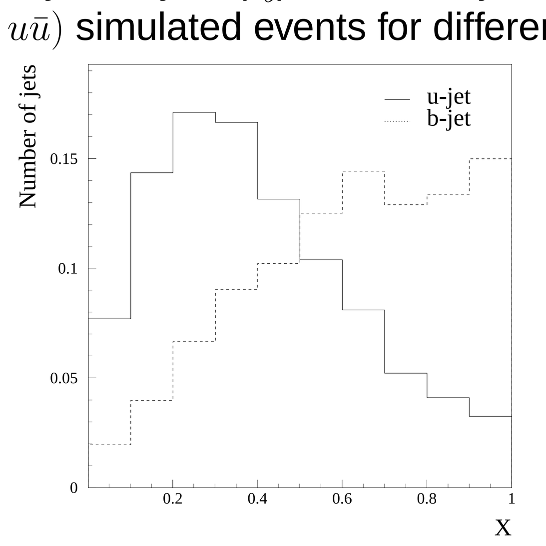
6 Application: online b-tagging

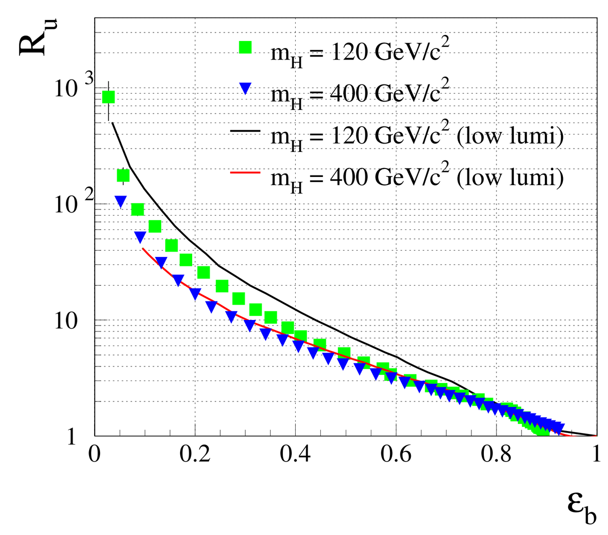
The possibility to preferentially select b-jets at LVL2 is an important ingredient to increase the flexibility of the ATLAS trigger strategy.

The algorithm presented here is based on the transverse impact parameter of reconstructed tracks. A discriminant variable is defined using the significance of the the transverse impact parameter $S = d_0/\sigma(d_0)$ of the tracks (where $\sigma_{d_0}(p_T)$ is determined from simulation)

$$W = \prod_{i=1}^{Ntracks} \frac{P_b(S_i)}{P_u(S_i)} \qquad X = \frac{W}{W+1}$$

The efficiency for b-jets (ϵ_b) and the rejection for light jets (R) have been studied on $WH(H\to b\bar{b})$ and $WH(H\to u\bar{u})$ simulated events for different Higgs mass.





The performance is robust with respect to luminosity and event topology. The rejection, although modest, is still useful to increase the acceptance of multi b-jets events (SUSY channels) and, more generally, to increase the flexibility of the trigger scheme.

7 Fast tracking: an alternative approach

An alternative approach for track reconstruction based on histogramming technique has been developed in ATLAS, it is composed of several sub-algorithm:

ZFinder Hits are selected in narrow ϕ slices, pairs of hits in each slice are extrapolated back to the beam line entering the z of the intersection in a histogram. The z-value corresponding to the peak of the histogram is taken as that of the primary vertex.

HitFilter Puts all hits into a histogram binned in ϕ and η. It finds clusters of hits within the histogram and creates group of hits if the cluster contains contributions from more than a given number of layers.

GroupCleaner Splits hits groups into tracks and removes noise hits from group. Each triplet of hits forms a potential track, groups of triplets with similar parameters are formed. Track candidates are accepted if a groups contains enough hits.

TrackFitter Verifies track candidates and finds track parameters by using a fast Object Oriented implementation of the Kalman filter algorithm.

This algorithm has been designed to use all the hits from the silicon detectors and hence to give precise track parameters (especially the track direction and p_T) and additional flexibility to work with different detector configurations. It is in many respect complementary to the algorithm presented here.

8 Integration in the ATLAS High Level Trigger Strategy

The pattern recognition algorithm presented here is based on the reconstruction of triplets of silicon hits identifying the innermost segment of the tracks. It can used as a standalone algorithm or as a first stage of more complex pattern recognition. The algorithm has been used extensively used both for b-tagging studies and reconstruction of isolated electrons.
The complimentary approaches to track reconstruction provide greater flexibility by allowing the optimum reconstruction tools to be used for specific trigger selections. This, together with the ability to cross-check performance, is crucial in order to maximize performance in the challenging environment of the second level trigger