



# A track finding algorithm based on pixel detector for the ATLAS second level trigger

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## Outline

- ATLAS trigger strategy for the B-physics.
- PixTrig: a pixel based Level 2 track finding algorithm.
- Efficiency and performances.
- Application to the selection of rare B decays.
- Application to the b-tagging in multi-b jets events.
- Conclusions

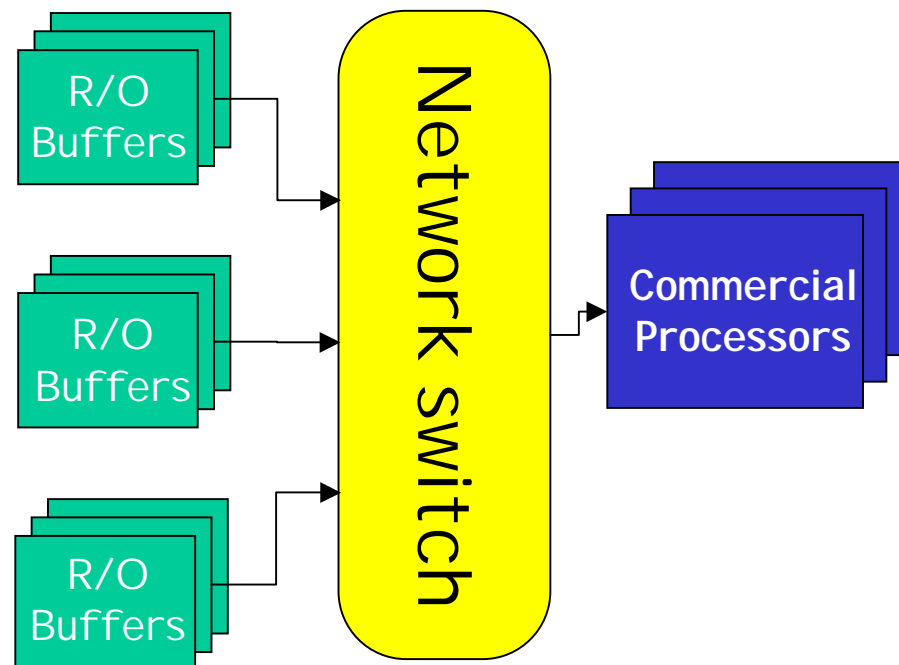


# The ATLAS Level 2 Trigger

The ATLAS second level trigger **refines** the decision taken at Level 1 using the data from the **different sub-detectors**, including the **trackers**.

It has to take its decision in **10-20 ms**, reducing the overall rate by a factor of 10 (from **100 KHz to 10 KHz**).

The implementation of this trigger will be based on a **farm of commercial processors** connected to the R/O buffers through a **switch**. **Hardware co-processors**, both at buffer and farm level, are also under study.





# LVL2 Processing Modes

The ATLAS trigger is mostly based on “Regions of Interest” (RoI). This means that every trigger component analyses only the portions of the detectors identified by the previous components; in the case of the LVL2, only the region where a muon or a jet where found at LVL1 are reconstructed.

In the case of the rare b decays reconstruction however, the interesting jet is usually not energetic enough to be seen at LVL1, so the event is triggered by a high  $p_T \mu$  in the second jet.

In this case a “Full Scan” is necessary at LVL2 to reconstruct the charged tracks in the whole inner tracker, and select the vertexes using invariant mass and impact parameter information.



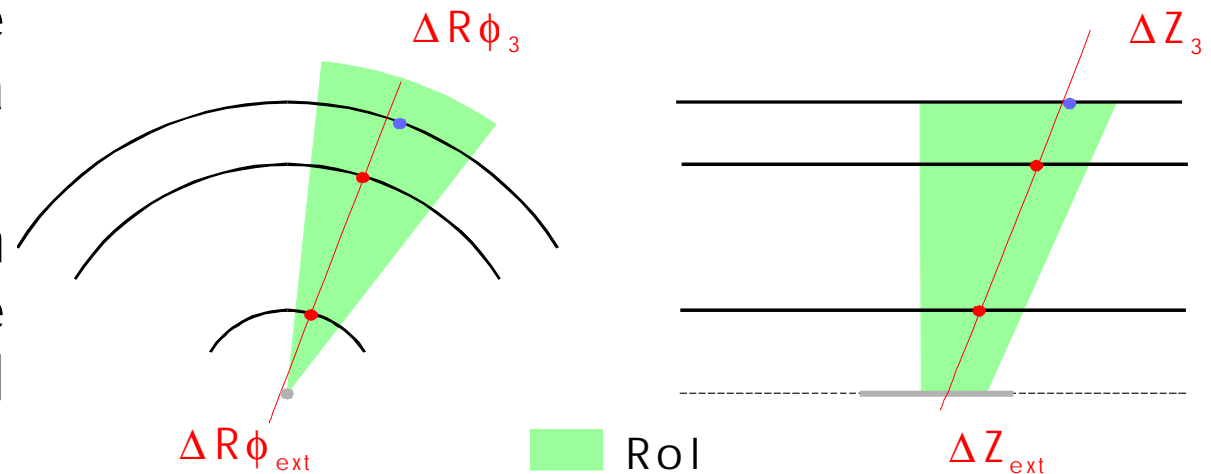
# PixTrig: The Basic Idea

**PixTrig** is a track finding algorithm designed to be used in **Full Scan** and **RoI guided mode**. Thanks to the **high resolution** and **low noise** of the pixel detector it can provide full **3d track reconstruction** and **impact parameter measurement** to be used in stand-alone mode or as seed for other algorithms.

PixTrig is a **pure combinatorial algorithm** using the ATLAS **pixel detector space points**: combinations in the two innermost layers are extrapolated to the third if pointing to the primary vertex. If a point close to the extrapolation is

found in layer 3, the points are kept as a candidate track.

**Overlaps** are solved on the basis of the **residuals** in the third layer.





# Logical Layers Definition

The original implementation of PixTrig was based on the **three physical layers** of the barrel pixel detector.

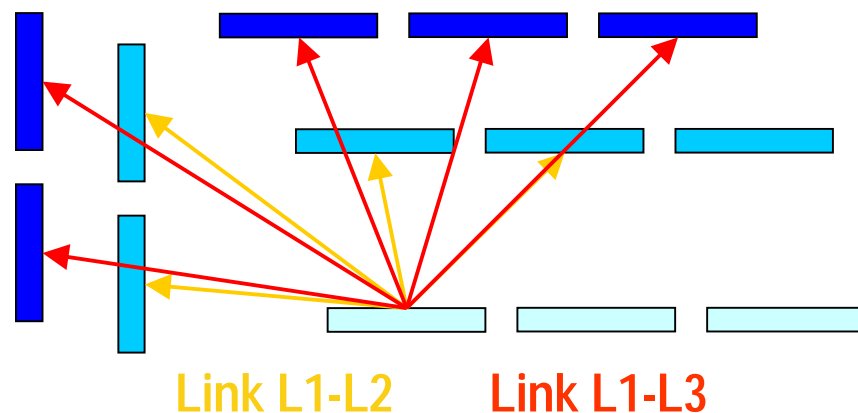
To adapt the algorithm to the **end-caps geometry** (where we have **five disks**) we moved, in the present C++ implementation within the ATLAS trigger simulation, to the definition of **"logical layers"**.

A logical layer is an **arbitrary collection of detector modules**. Logical **first** layers (every module in the **barrel B-layer** of the detector) have a **link** to the modules in the corresponding **second** and **third** logical layers.

This approach increase the flexibility of the algorithm and its robustness to the pixel inefficiencies.

However, we have to keep in mind that

More complexity in the Logical Layers → More combinations → Longer processing time and more fake tracks





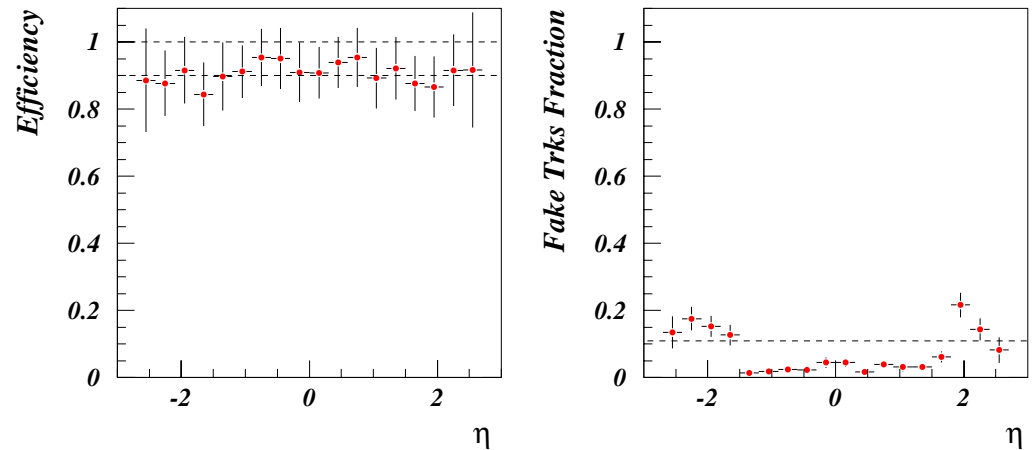
# Reconstruction Efficiency in jets

The reconstruction efficiency in jet RoI is close to 90% and flat over  $\eta$  and  $p_T$ .

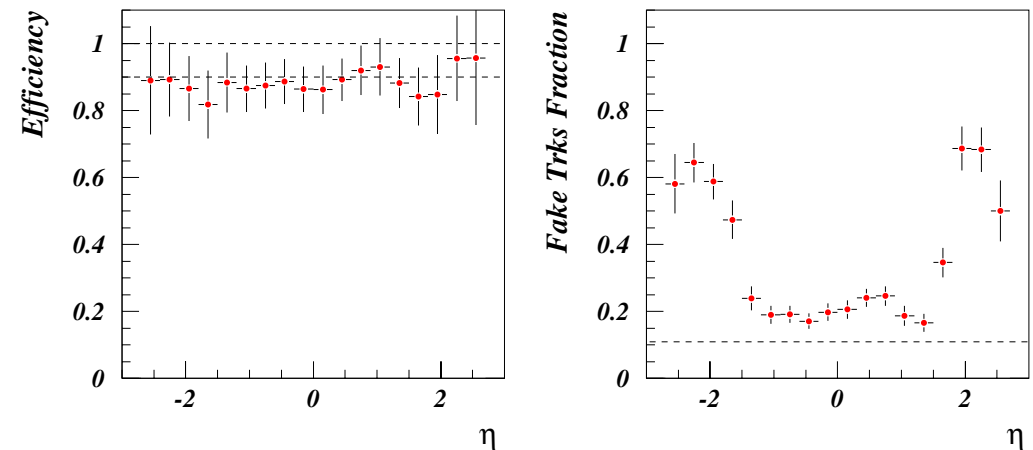
At low luminosity the fraction of fake tracks (combination of points coming from different particles) is always below 20% (it's higher in the end-caps because more combinations are possible there).

At design luminosity the fraction of fakes reaches 60% in the end-caps (spurious combinations lying on a straight line can be preferred to good tracks).

B-jets – No pile-up



B-jets – 24 ev. pile-up





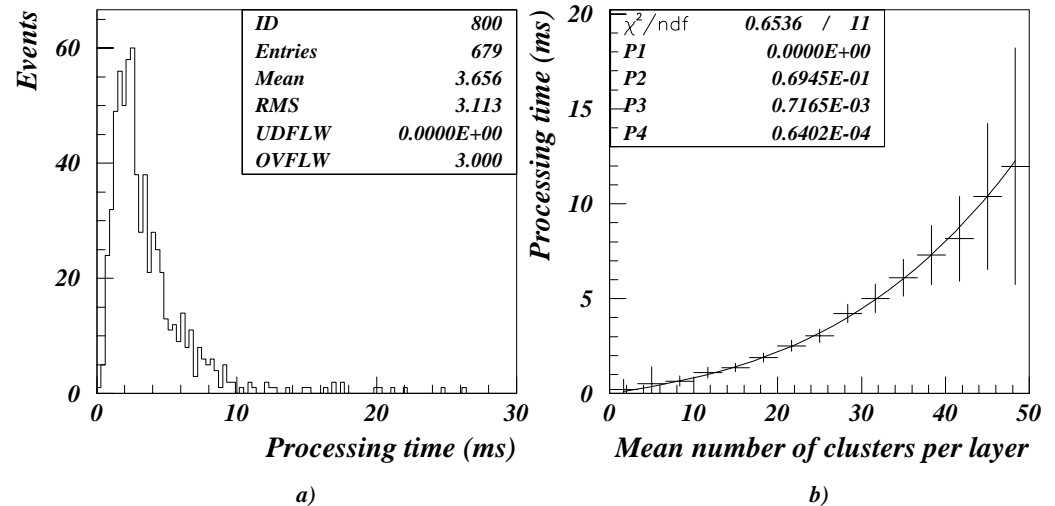
# Timing (jet Rol)

The processing time on a commercial Pentium III 500 MHz system is of 3.7 ms per jet.

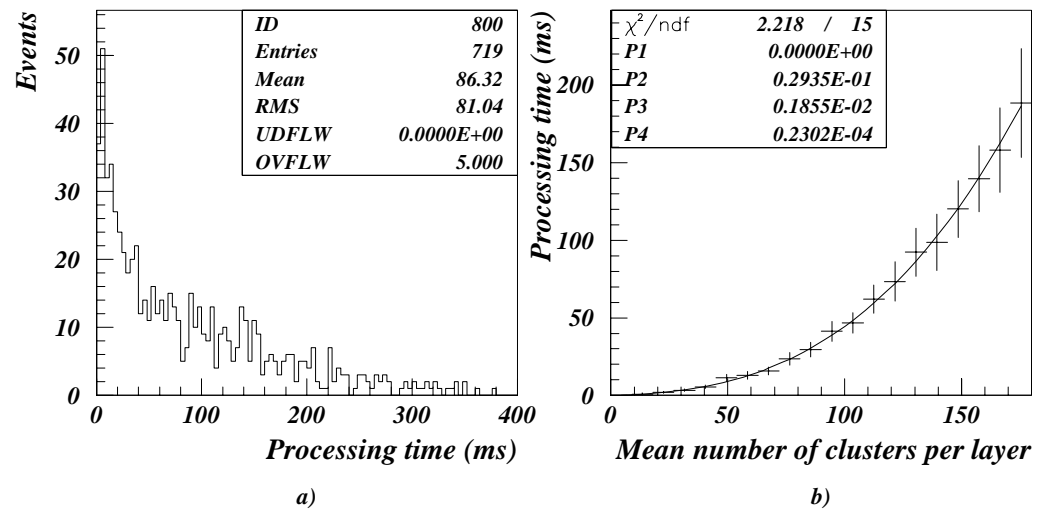
As expected, this time scales with the number of clusters in the Rol following a cubic law; however the coefficient of the third power is small, so the behavior is approximately quadratic.

At design luminosity, the average time needed to process a jet is close to 90 ms.

B-jets – No pile-up



B-jets – 24 ev. pile-up





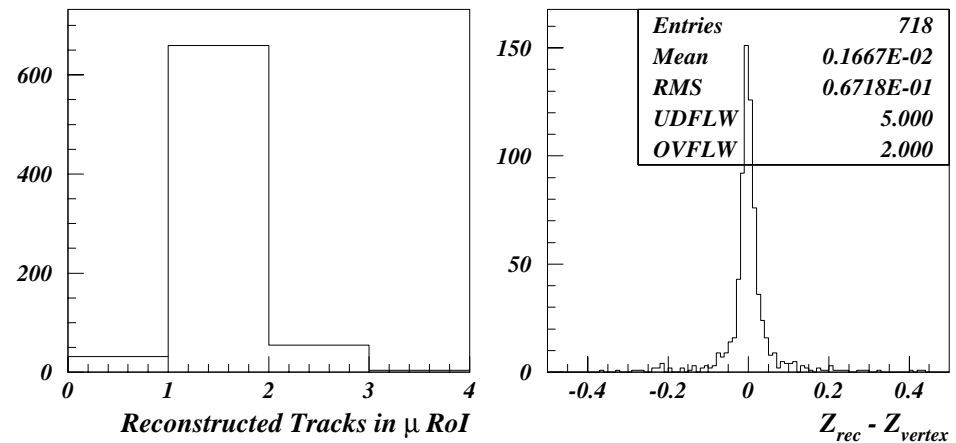
# $Z_{\text{vertex}}$ Reconstruction with a LVL1 $\mu$

To reduce the processing time we have to decrease the number of extrapolation to the third layer. This could be achieved using a hard cut on the  $Z$  impact parameter of the lay1-lay2 combinations, but the position of the primary vertex need to be known with some precision.

In events triggered at LVL1 by a muon, it is possible to use PixTrig itself with a high  $p_T$  threshold, to find the muon and reconstruct its  $Z_0$  (which is close to  $Z_{\text{vertex}}$ ).

In 95.7% of the events one candidate is found in the  $\mu$  RoI, and in 99% of the cases its  $Z_0$  is less than 5 mm apart from the  $Z$  of vertex.

The reconstruction of the vertex takes 0.5 ms.





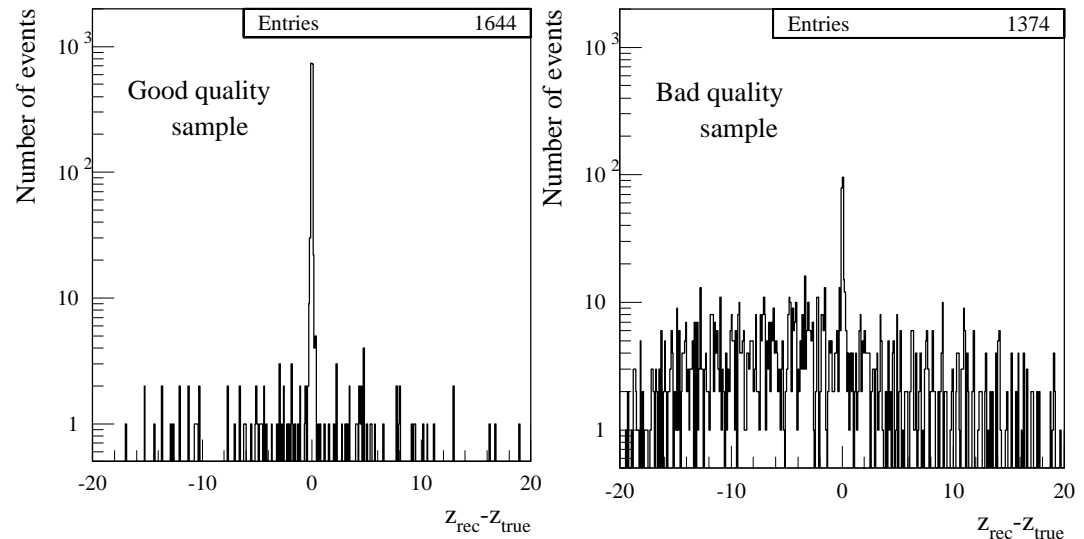


# $Z_{\text{vertex}}$ Reconstruction Inside a Jet

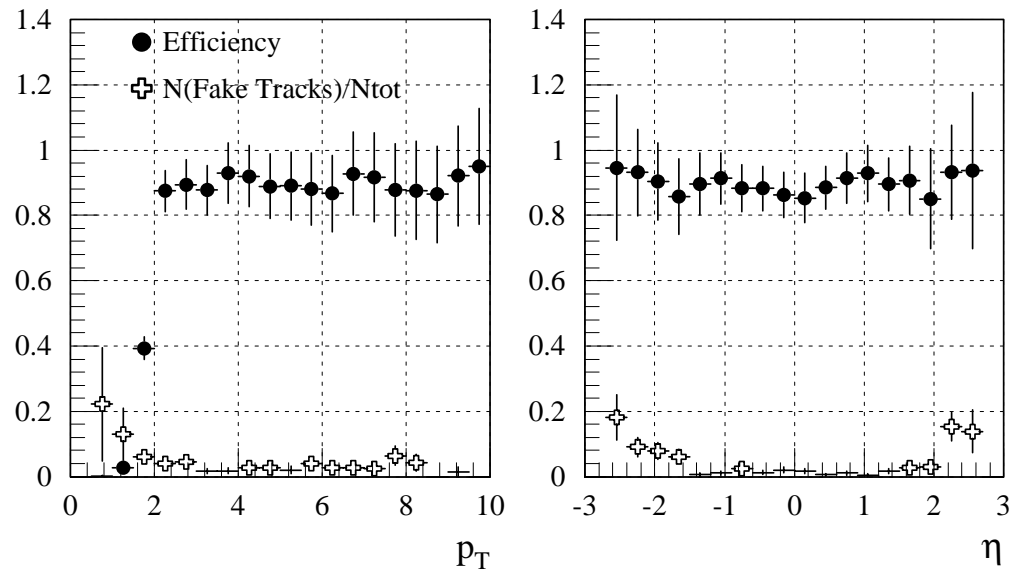
Inside a jet RoI, the position of the vertex can be reconstructed as the barycenter of the  $Z_0$  of the tracks in 55% of the events.

This does not save processing time, but allows a clean-up of the sample "a posteriori".

Using this method, the efficiency and purity achieved at design luminosity are similar to the low luminosity ones.



B-jets – 24 ev. pile-up





# Full Scan Efficiency and Timing

Full-scan on  $b$  events  
with at least one  $\mu$   
with  $p_T > 5$  GeV/c.

Low luminosity.

Track reconstruction  
 $p_T$  cut at 0.5 GeV/c.

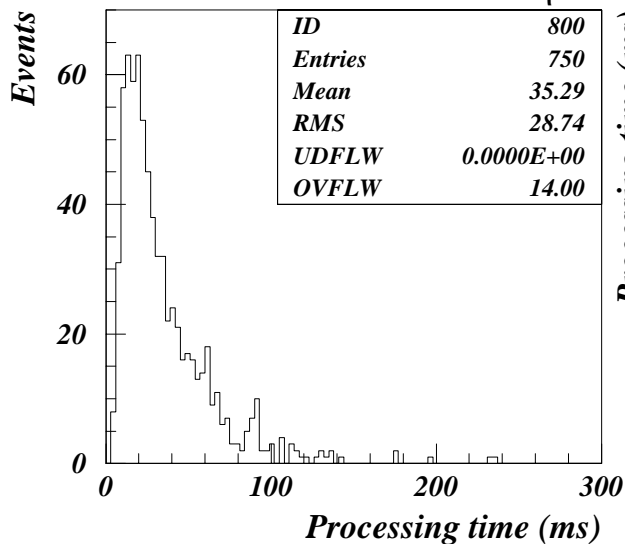
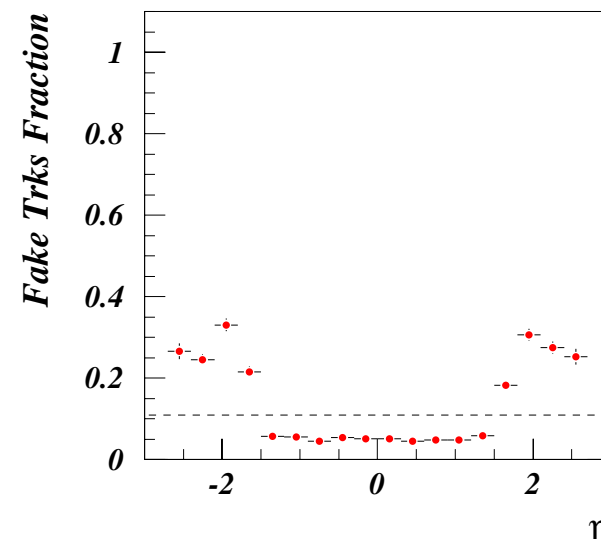
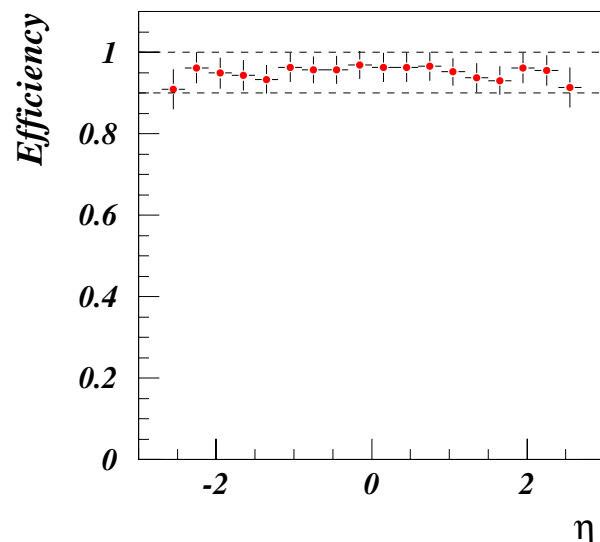
CPU: P111 500 MHz

$\epsilon$ : 95 %

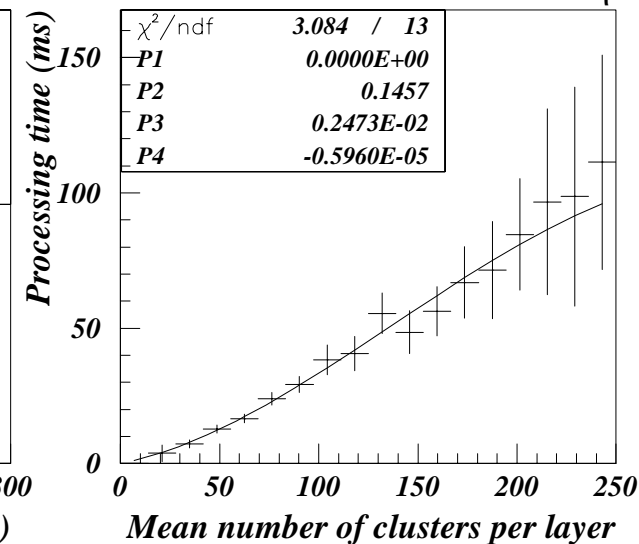
Fakes : 5% barrel

30% end-caps

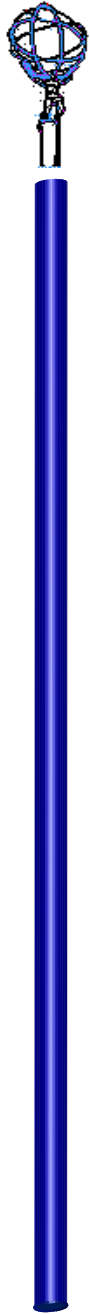
Total time: 35.3 ms,  
almost linear with the  
number of clusters.



a)



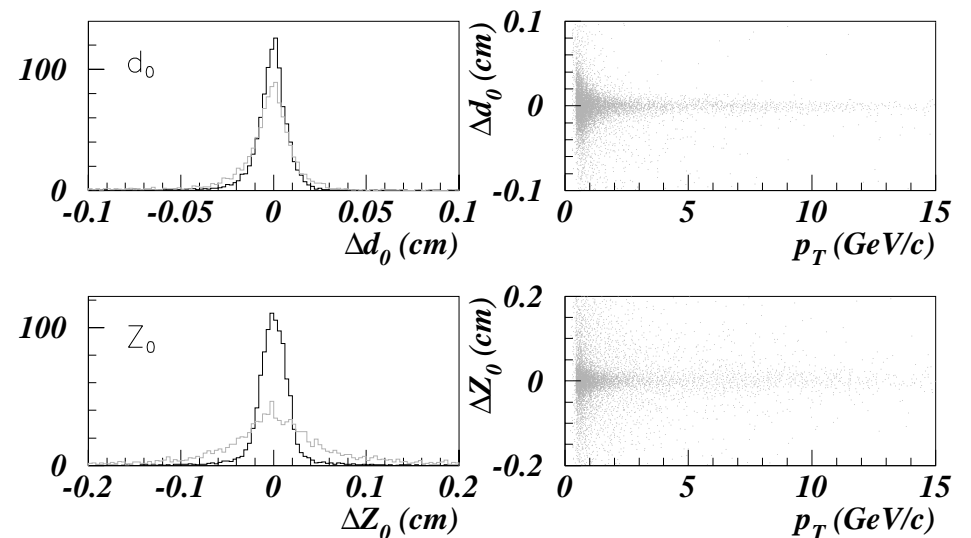
b)



# Track Parameters Resolution

The track parameters are calculated writing the equation of the helix connecting the three point in the space. The resolutions are all acceptable, if we consider that no fit is performed and all the points get the same weight. The error on  $d_0$  is dominated by the back extrapolation to the vertex

	Barrel	End-caps
$D_0$	68 $\mu\text{m}$	85 $\mu\text{m}$
$Z_0$	135 $\mu\text{m}$	324 $\mu\text{m}$
$\theta$	1.8 mrad	2.2 mrad
$\phi$	1.3 mrad	1.9 mrad
$1/p_T$	30 $10^{-3}$	34 $10^{-3}$

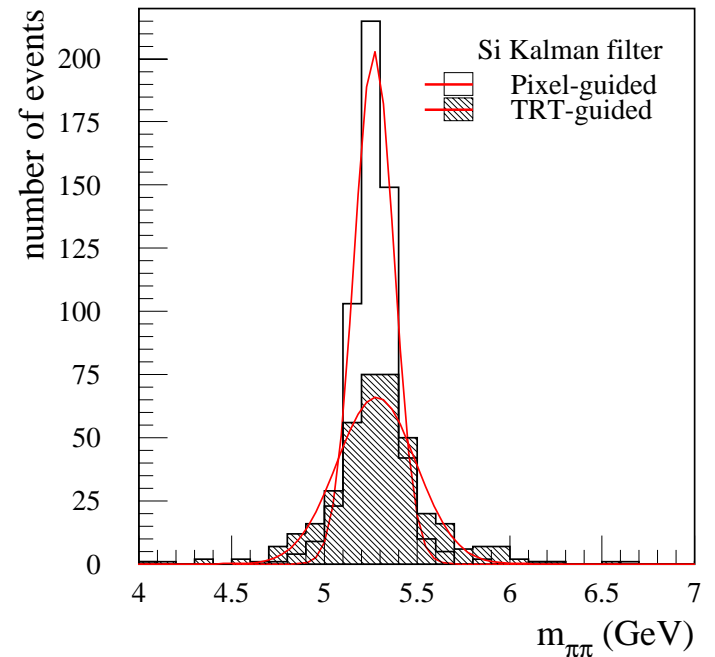




# Exclusive B decays at LVL2

For the selection of exclusive B decays, a complete track reconstruction in the inner tracker is performed following the direction of the seeds given by the full-scan. In this context, PixTrig provides good performances:

- it's fast
- it produces few track candidates
- it gives a full 3D definition of the tracks, limiting the volume scanned by the second stage algorithm
- it gives good overall resolution because it's less sensitive to the interactions in the material of the detector.



$p_T > 0.5$

	# of full seeds scan	total time
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PixTrig	39	36 ms	66 ms
TRT scan	171	150ms	317ms

# B-tagging at LVL2

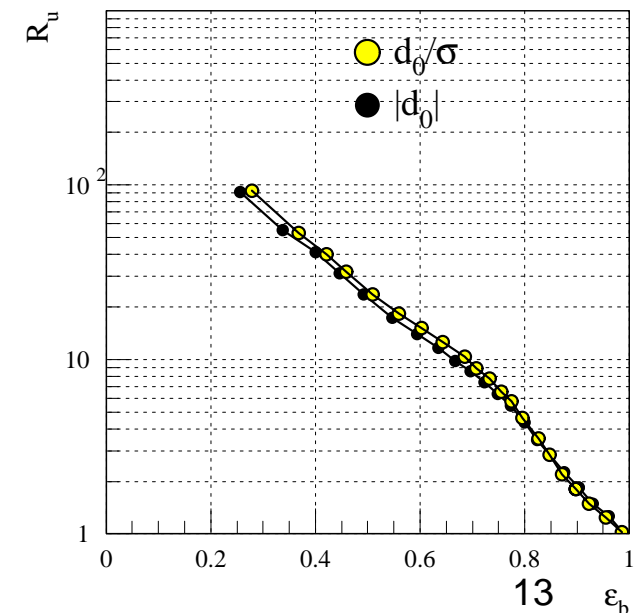
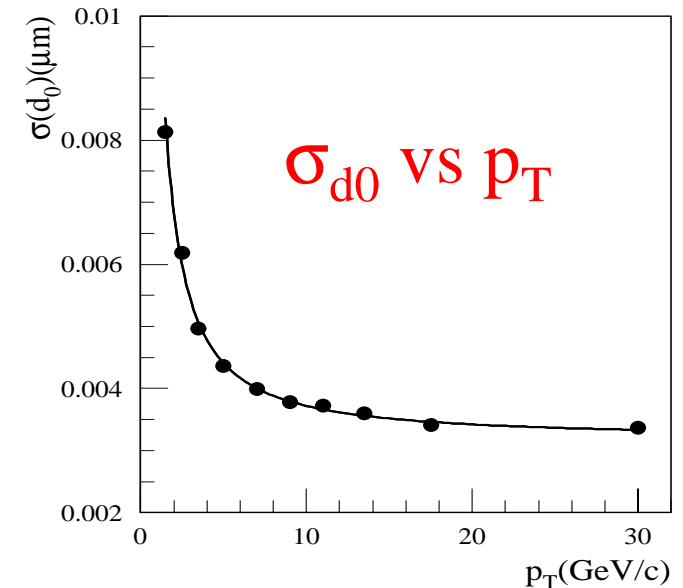
The B-tagging can be performed in one or more jet RoI using PixTrig alone. The method is the classical one, based on the likelihood ratio built on the  $d_0$  distributions for signal (b-jets) and background (u-jets).

Since no error on  $d_0$  is calculated, we can use the same weight for all the tracks or use a  $p_T$  parametrized error estimate.

The two methods give similar results:

$$\epsilon_b = 0.8 \quad R_u = 4$$

$$\epsilon_b = 0.5 \quad R_u = 25$$

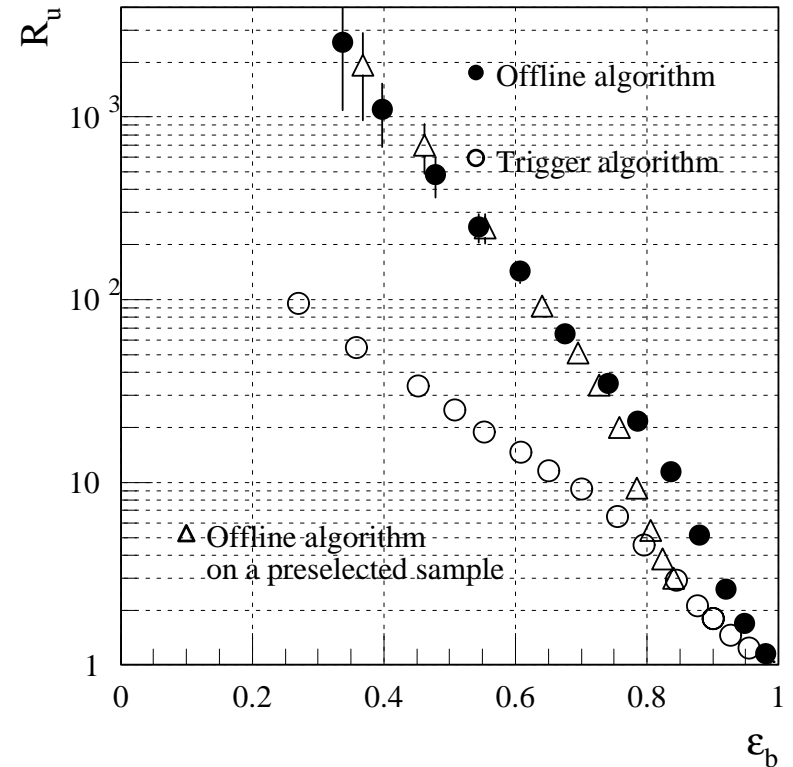




# Comparison with the off-line b-tag

It is important to check that the on-line preselection does not spoil the final off-line performances.

This plot compares the pure off-line results with those obtained running the off-line algorithm over a sample pre-selected with the on-line b-tagging tuned at  $\epsilon_b = 90\%$

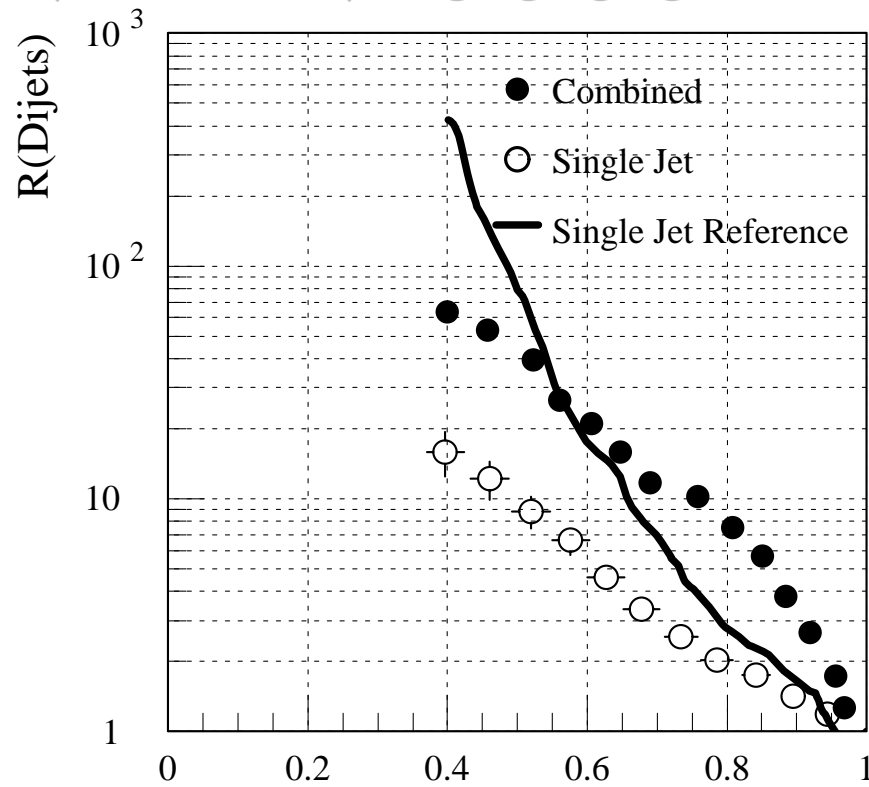




# Selection of $H \rightarrow hh \rightarrow bbbb$

The b-tagging can be used to increase the trigger acceptance of multi b-jets events, which are cut by high  $E_T$  thresholds at LVL1.

The price to pay is an increase of the jet-trigger rates which is significant at LVL1 and modest after the LVL2 btag.



Selection	Rate Increase	E on signal
Standard LVL1	1.0	19 %
LVL1 Loose	6.4	76 %
LVL1 Loose + Btag loose	2.0	58 %
LVL1 Loose + Btag tight	1.5	53 %

$\epsilon(4b)$



# Conclusions

The feasibility of a fast track finding algorithm based on the ATLAS pixel detector has been demonstrated.

The performances are within the LVL2 specifications both for the “full-scan” and the “RoI guided” mode. They benefit from the high precision and cleanness of the pixel space points.

The b-tagging could be useful at LVL2 to increase the acceptance of multi b-jet events.

Development is on-going in the following sectors:

- Fine tuning of the algorithm, especially in the end-caps
- Robustness to the detector inefficiency and misalignment
- Sensitivity to the clustering algorithm used