Study of noisy pixel appearance and thermal neutron fluxes with Timepix3 in ATLAS

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Outline

Introduction

Introduction - ATLAS Timepix3 devices

ATLAS MPX and TPX networks were used to:

- Measure radiation field at different positions in ATLAS and use the results for ATLAS simulation validation.
- Measure the activation of material during and after collisions.
- Measure ATLAS luminosity.

In this presentation we use the newly installed (before end of Run-2) Timepix3 devices in ATLAS to study their capability for improved luminosity determination.

Introduction - ATLAS Timepix3 devices

ATLAS Timepix3 features:

- Stack of two independent silicon detectors (I4 and J4).
- Time binning of 1.56 ns.
- 256 x 256 independent pixels.
- Simultaneous measurement of time and energy.
- Continuous readout.
- Synchronization with LHC clock.

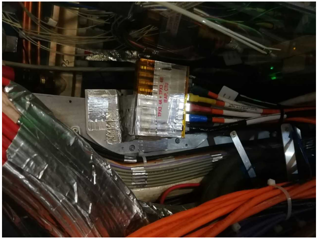


Figure: Timepix3 devices

Introduction - ATLAS Timepix3 devices

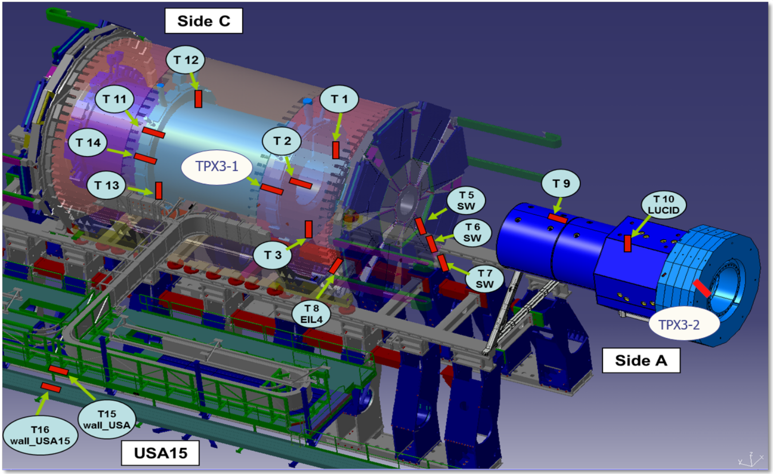


Figure: Location of TPX and Timepix3 devices in ATLAS

- TPX3-1 used for analysis located 4.6 m away from interaction point.

Introduction - ATLAS Motivation

Problem 1: Appearance of random noisy pixels creating count rates not following a standard luminosity curve.

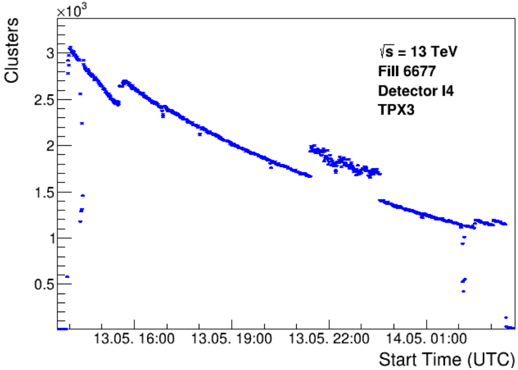


Figure: Time history of Timepix3 cluster count for LHC fill 6677

- Conduct a noisy pixel analysis to find them and remove them.

Introduction - ATLAS Motivation

Problem 2: Activation of surrounding material can create a background signal which adds a systematic uncertainty to the luminosity measurement.

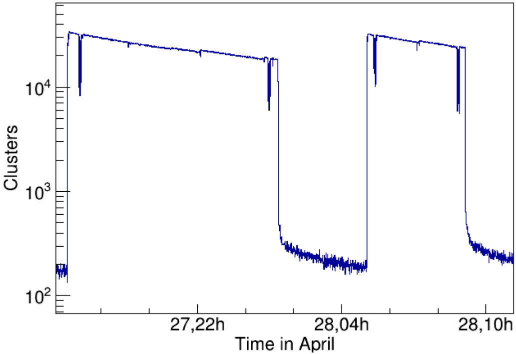


Figure: Cluster count contribution to the signal

- Mitigate the problem by using only the thermal neutron count rate.

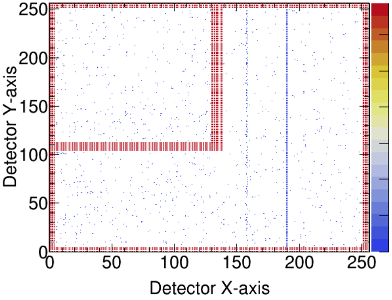
Noisy pixel removal

Noisy pixel removal - Method

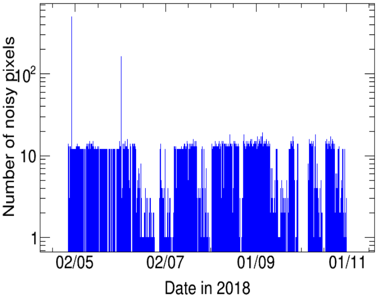
For the implementation of the noisy pixel removal we must understand the following:

- A pixel is considered noisy if its count rate is 5 standard deviations away from the mean count rate of all pixels.
- The borders of the detector are more prone to noise so they are removed from the analysis.
- Detector I4 had a LiF cover for thermal neutron identification. To account for the different statistics below the converter, the removal was done separately for this region.
- The configuration matrix of the detector resets every 3 hours so the noisy pixel removal must be done every time it resets.

Noisy pixel removal - Results



(a) Noisy pixels removed as seen in the detector

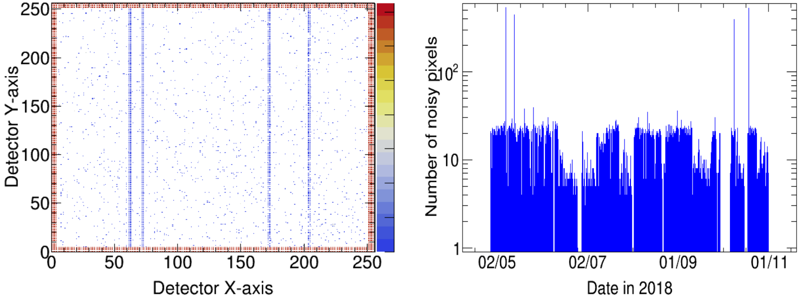


(b) Number of noisy pixels removed

Figure: Noisy pixels removed from April to October for detector I4

- Less than 15 noisy pixels are removed every 3 hours.
- Two columns have common registry.

Noisy pixel removal - Results



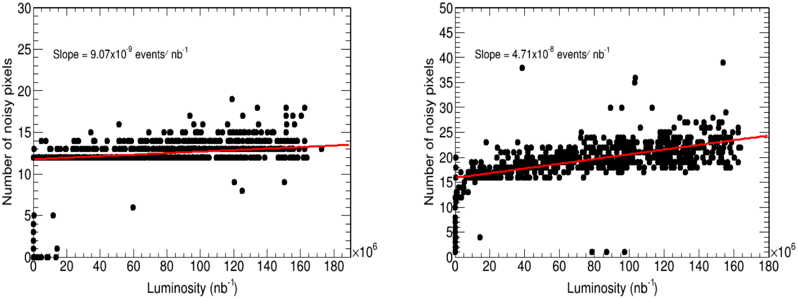
(a) Noisy pixels removed as seen in the detector

(b) Number of noisy pixels removed

Figure: Noisy pixels removed from April to October for detector J4

- Less than 20 noisy pixels are removed every 3 hours.
- Two columns have common registry.

Noisy pixel removal - Results



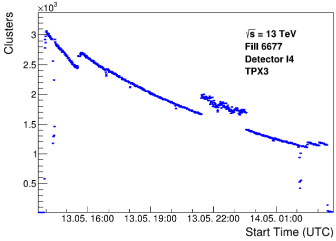
(a) Noisy pixels detector I4

(b) Noisy pixels detector J4

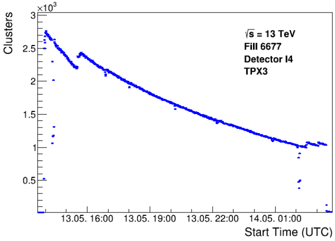
Figure: Relation between noisy pixels and integrated luminosity per 3 hours

- No strong correlation with luminosity.

Noisy pixel removal - Improvement



(a) Luminosity curve with noisy pixels



(b) Luminosity curve without noisy pixels

Figure: Time history of Timepix3 cluster count for LHC fill 6677

Thermal neutrons

Thermal neutrons

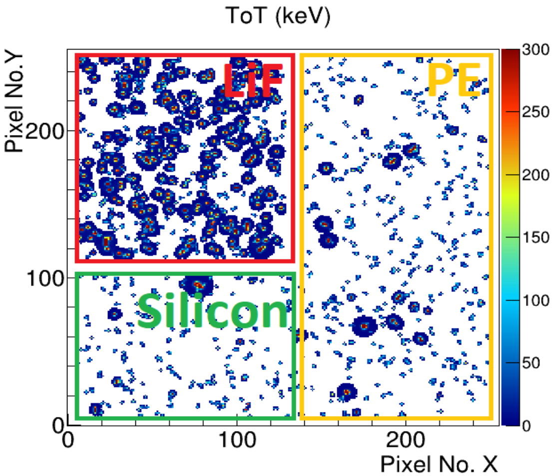


Figure: LiF converter effect and detector I4 region separation

- Thermal neutron fluxes were determined through the $^{6}Li(n,\alpha)^{3}H$-reaction.

Thermal Neutrons

The thermal neutrons fluxes in the detector can be determined using the following equation:

$$\phi_i = \frac{\frac{N_{LiF}}{A_{LiF}} - \frac{N_{Si}}{A_{Si}}}{\varepsilon} \tag{1}$$

- $\phi_i \rightarrow$ Thermal neutrons fluxes per LHC fill
- $N_{LiF} \rightarrow$ Number of heavy blobs found in the LiF region
- $N_{Si} \rightarrow$ Number of heavy blobs found in the silicon region
- $A_{LiF} \rightarrow$ LiF region (upper left side of the detector)
- $A_{Si} \rightarrow$ Silicon region (lower left side of the detector)
- $\varepsilon \rightarrow$ detector efficiency (1%)

Thermal neutrons

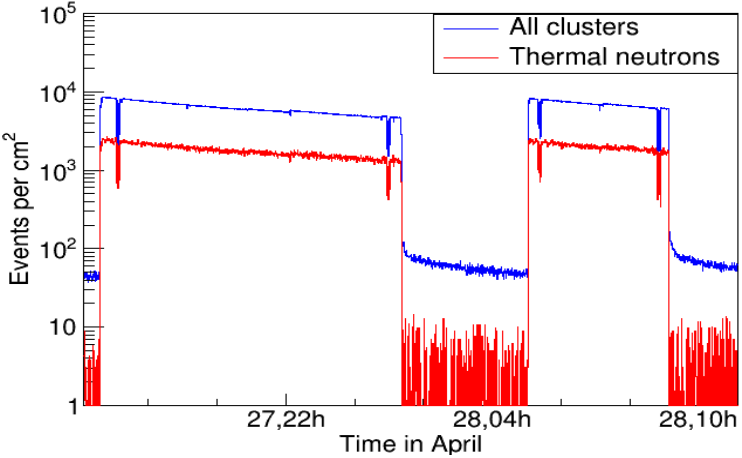
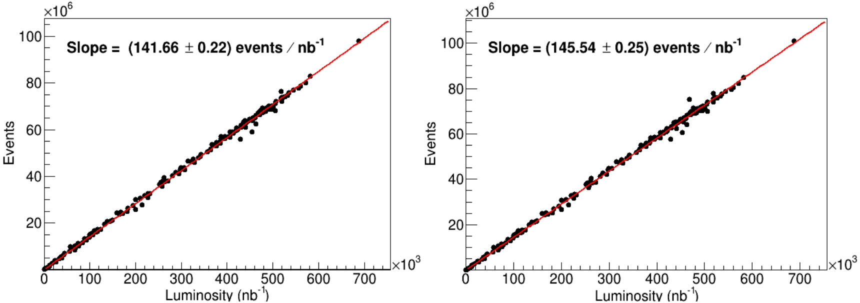


Figure: Influence of thermal neutrons to the signal

- Activation is not seen in the thermal neutron signal.

From clusters to luminosity

From clusters to luminosity



(a) Clusters detector I4 (b) Cluster detector J4

Figure: Relation between clusters and luminosity per fill

Remarks:

- Due to failures of the control PC data of some fills were not complete (these were removed from the analysis).
- Special physics fills are not considered.

From clusters to luminosity

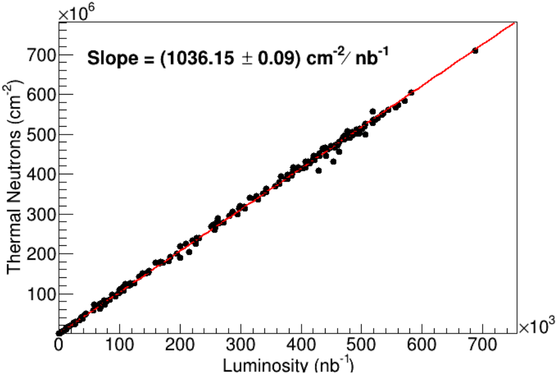


Figure: Relation between thermal neutrons and integrated luminosity per fill

Remarks:

- Due to failures of the control PC data of some fills were not complete (these were removed from the analysis).
- Special physics fills are not considered.

Luminosity curve

Luminosity curve - Model

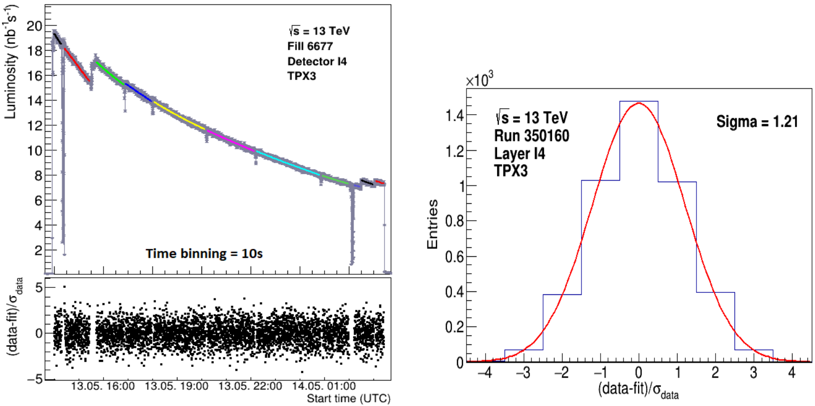
The bunch population N evolution is described by

$$-\frac{\mathrm{d}N}{\mathrm{d}t} = \lambda_{bb}\frac{N^2}{N_0} + \lambda_g N$$

$$\text{with} \quad N_0 = \text{Initial Population}$$
$$\lambda_{bb} = \text{Loss rate due to beam} - \text{beam interactions}$$
$$\lambda_g = \text{Loss rate due to beam} - \text{gas interactions}$$

$$\Rightarrow \quad N(t) = \frac{N_0 e^{-\lambda_g t}}{1 + \frac{\lambda_{bb}}{\lambda_g}(1 - e^{-\lambda_g t})}$$

Luminosity curve - Fitted luminosity curve



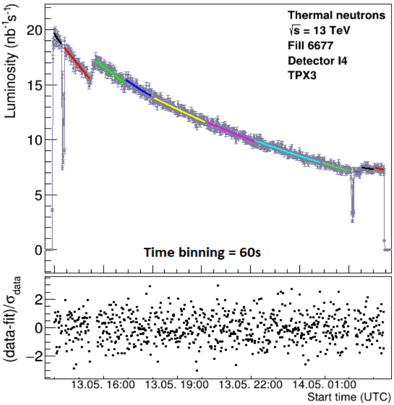
(a) Luminosity curve

(b) $(data - fit)/\sigma_{data}$

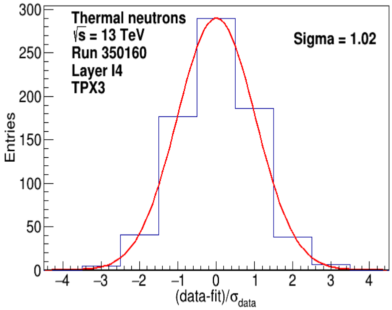
Figure: Fitted luminosity curve - All clusters

- The sigma value higher than 1 is due to systematic effects (activation).

Luminosity curve - Fitted luminosity curve



(a) Luminosity curve



(b) $(data - fit)/\sigma_{data}$

Figure: Fitted luminosity curve - Thermal neutrons

Conclusions

Conclusions

- The noisy pixel removal has been implemented and on average less than 0.1% of the pixels are removed.
- Thermal neutrons show less background signal than the other types of clusters.
- Clusters are strongly correlated to luminosity which allows us to find a normalization factor between them.
- Using thermal neutrons for the luminosity curve lowers the systematic uncertainties from the clusters count rate.

Thank you for your attention!

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