



JOINT INSTITUTE FOR NUCLEAR RESEARCH
Dzhelepov Laboratory of Nuclear Problems
Scientific-experimental Department of Colliding Beams

FINAL REPORT ON THE SUMMER STUDENT PROGRAM

***“Development of a Code System for
Supporting the Tracks Identification in
Timepix Detectors”***

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Abstract

In response to the requirement of classify the different clusters from Timepix detectors, using the libraries from Root and ITK software, a new script was developed allowing to analyze, sort and visualize the cluster tracks according to their linearity level. This script also allows build linearity, length, volume and area distribution histograms of clusters for selected frame numbers. The code was verified with a set of experimental data from Timepix detectors located at ATLAS cavern experiment.

Introduction

In the 1990s, CERN researchers conceived the multinational Medipix project with the objective of developing high-quality segmented silicon detectors with integrated readout electronics that would be suitable for working both in the field of high energy physics, as in applications where high-quality images are required, as is the case in medicine. In its beginnings, the collaboration consisted of only four institutes, and they were able to redesign the electronic reading of detectors of the LHC (Large Hadron Collider), thus producing the chip Medipix. Actually, this project has partners in more than 30 countries, including the Russian Federation ([Medipix 2017](#)).

Currently these pixelated detectors are using some alternative materials like gallium arsenide compensated with chromium (GaAs:Cr) ([Butler et al. 2015](#)), because it has several advantages with regard to silicon, such high resistance to radiational damage. GaAs:Cr has higher atomic number (Z) and mass density than Si. These properties are very attractive because the cross section for the photoelectric effect depends on Z^5 and this phenomenon constitutes one of the main photon interaction with the matter ways at low energies ([Kurková and Judas 2016](#); [Sato et al. 2016](#)). This material presents greater density, for that reason is possible to be applied for detection of high energy X-rays. Other advantages are that GaAs:Cr detectors operate at room temperature which simplifies experimental designs and decreases their cost.

The characteristics of these pixelated hybrid detectors allow register the trajectories of particles interacting with them (tracks). The Dzhelepov Laboratory of Nuclear Problems is interested in analyze and separate the tracks in a straight line from the curves ones obtained by Timepix detectors located in different positions of the ATLAS experiment cavern. To optimize and obtain more information in this process of classification is necessary create a new script for calculate the linearity of all clusters, being this the main goal of the work.

Methods

The operation of the Timepix detector generally consists of a sequence of independent measurement intervals, named frames, during which the interaction's records are stored and processed at the end of each one. It is possible to select the duration and quantity of the frames before carrying out the measurement. In each frame, there are several pixels clusters, which correspond to individual interactions with the detector ([Llopert et al. 2008](#)).

In order to process each frame and cluster individually, a Root code system was used. Root is a software for the statistical management of data oriented to its analysis, visualization and storage ([Root 2017](#)). It allows working with large amounts of information (10 Terabytes per run).

In our working group, we have implemented a script that uses Root libraries to process the data coming from the Timepix detectors. This script is named `ProcessGaAsPixData.C` and allows separate and storage each cluster individually. It also makes two cuts off to work with the data that are of interest:

Cut 1: Pick out the clusters located in the previously selected detector working area.

Cut 2: The clusters that are more likely associated to e-m interactions were selected.

When each cluster of the Timepix detectors was obtained separately, it was necessary to use Insight Segmentation and Registration Toolkit (ITK) libraries to complete their processing ([ITK 2017](#)). To separate the clusters of curved lines from those corresponding to straight lines, a new script was created using the ITK libraries. This script analyzes each frame and cluster individually performing a new cut, consisting in select the clusters which satisfy a certain linearity criterium.

The new code also stores each cluster as a two-dimensional array ($A[x][y] = E$), where x and y are the pixel coordinates and E is the deposited energy in the analyzed pixel. Then, the information of each cluster is transformed into a grayscale image (figure 1 (top)) to apply the Skeletonization (process that transforms the track to one-pixel thickness line, preserving the topology and being equidistant to the borders) (figure 1 (bottom)).

The next step is calculated the real length of the track (RI) and the Euclidian distance (Ed). Then, it is possible to estimate the straight degree of the track using the linearity parameter ($L = Ed / RI$). The real length of the track is obtained directly from the number of pixels in the image after skeletonization. For determining the Euclidean distance, first it is necessary to locate the ends of the track and then calculate the distance in a straight line between them.

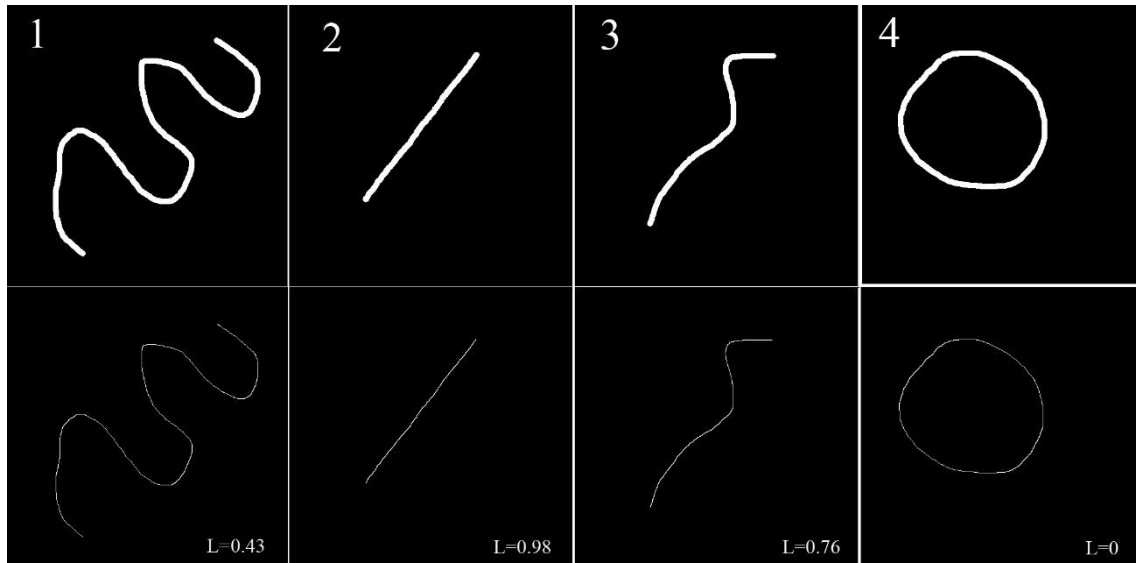


Figure 1. Images of clusters before and after the process of skeletonization.

In figure 1, four test images are shown before they have been skeletonized (top). After the use of the Skeleton script the above pictures were transformed, as presented in the bottom images, making possible to calculate their linearity values (in the right bottom corner of each image).

To execute the new developed script is necessary firstly open Root and introduce the next command line:

```
.x ProcessGaAsPixData.C++(a,b,c,d,e,f,g,h,i,j,k,l,m,n,o)
```

Where:

a - Detector Id

b - Run number

c - 1/0

d - Minimum frame (if c=0)

e - Maximum frame (if c=0)

f - Minimum cluster size to be considered = 20

g - Maximum cluster size to be considered = 300

h - Minimum cluster high to be considered = 0

i - Maximum cluster high to be considered = 11 810

j - Minimum D1 = 0

k - Maximum D1 = 0.3

l - Minimum D2 = 0

m – Maximum $D2 = 0.2$

n – Minimum linearity value to be considered

o – Maximum linearity value to be considered

Note that the Skeleton script previously should be copied in the same directory where is located the file ProcessGaAsPixData.C and the energy threshold was fixed at 70 keV.

Results

The data from the TPX31, TPX32 and TPX33 detectors were processed. Each file has 81 800 frames. Figure 2 shows the first 2000 frames of each detector (to allow visualization) before (left column) and after the first two cuts have been applied (right column).

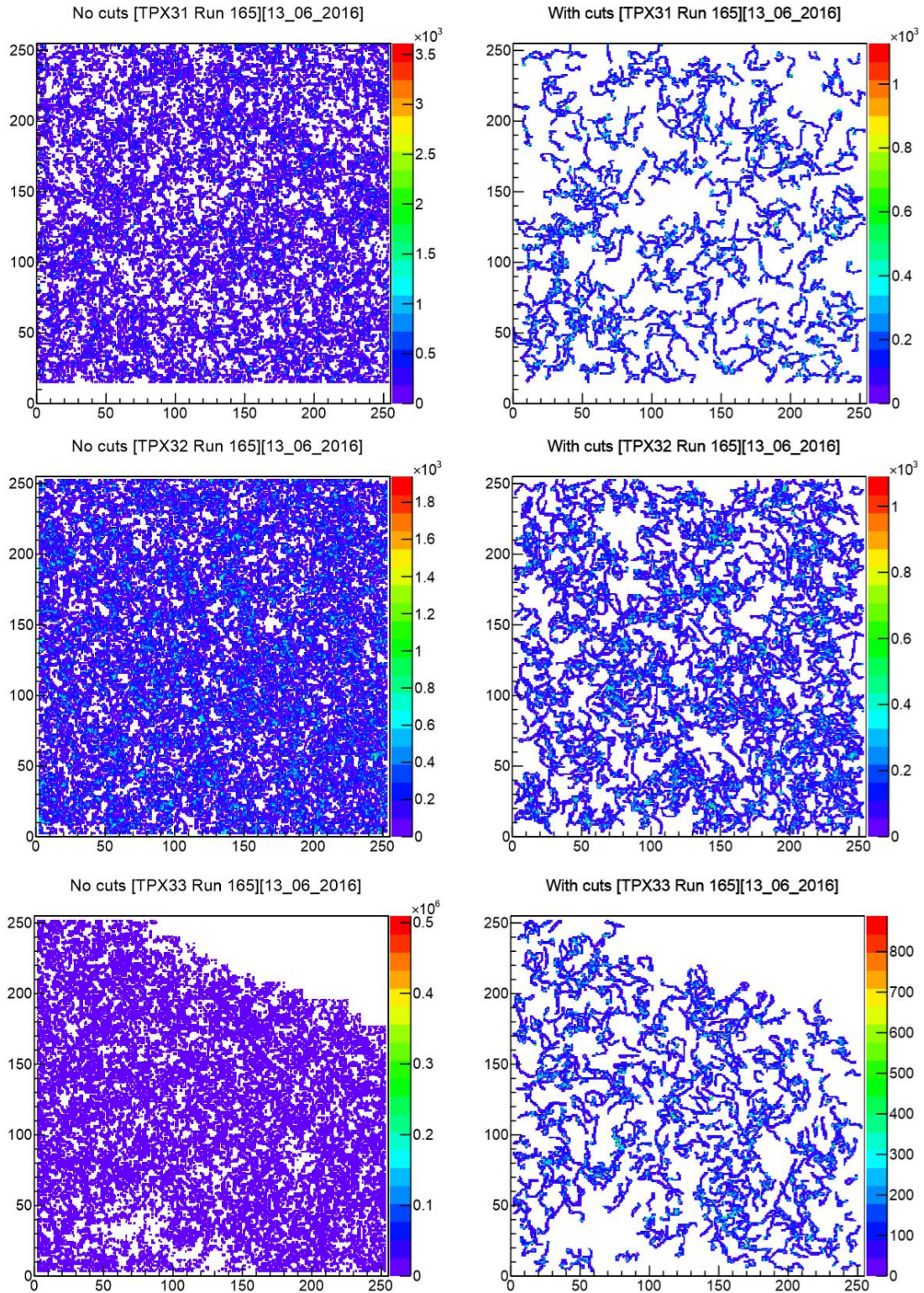


Figure 2. Representation of the first 2000 frames, of the 31, 32 and 33 TPX detectors (from top to bottom).

After these first two cuts, the new Skeleton script is used to select a linearity range of interest between 0 and 1. As example, when select the interval 0.9 - 1 the obtained results (clusters that satisfise these conditions) are displayed as can be seen in figure 3.

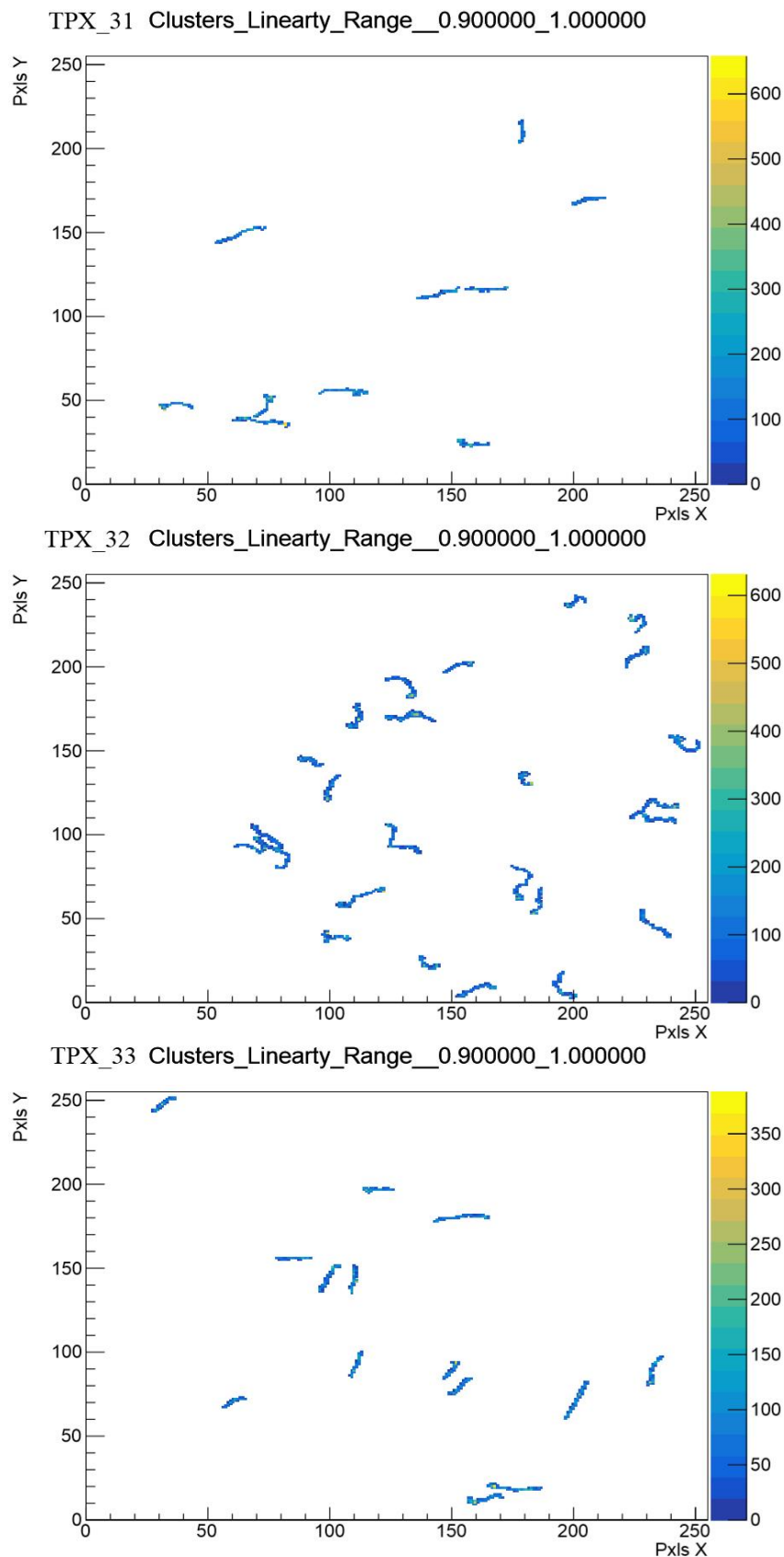


Figure 3. Representation of the first 2000 frames that have a linearity value greater than 0.9.

This script also allows construct histograms with the values of the length of each cluster after being skeletonized and linearity cut (figure 4).

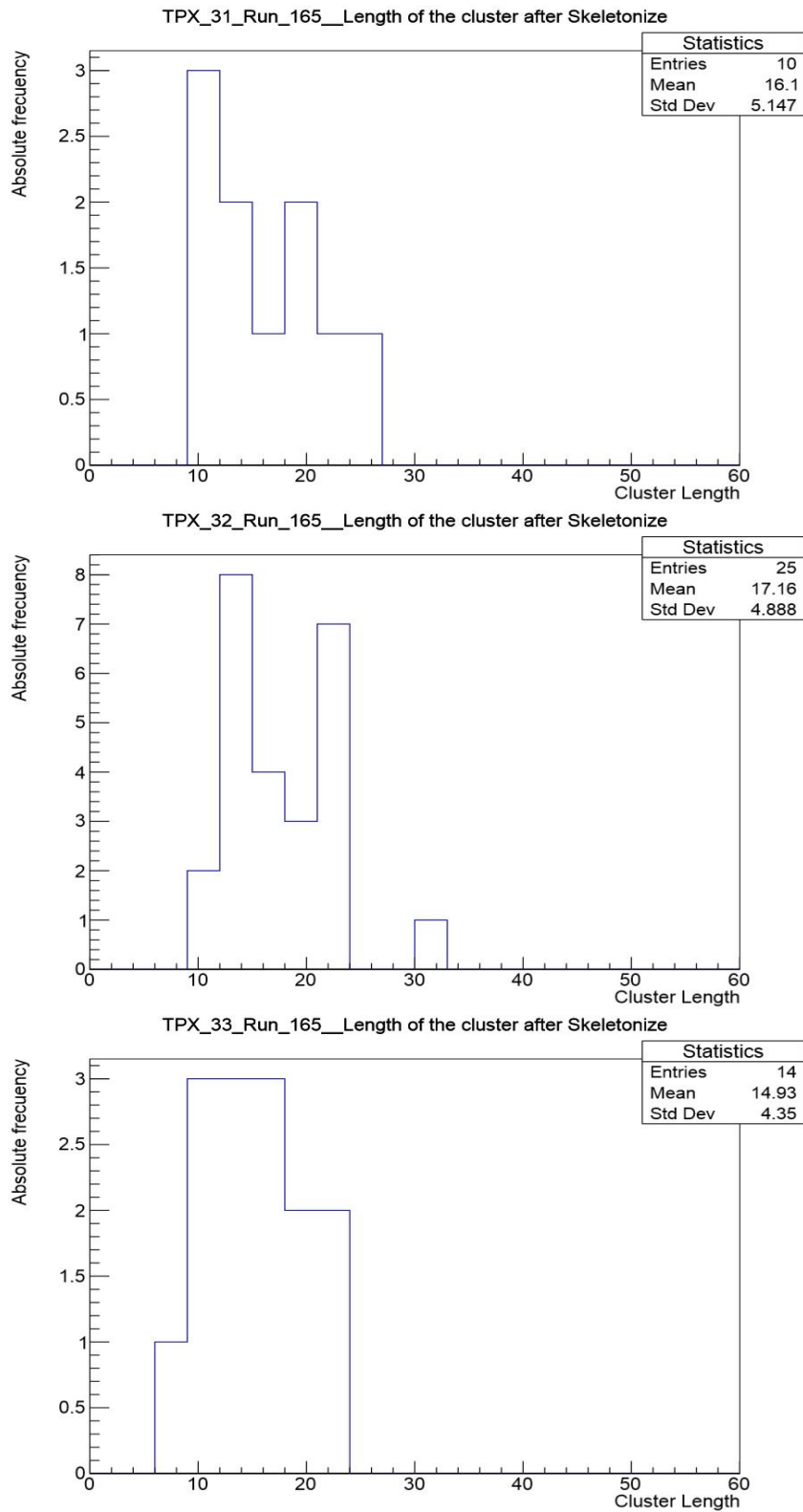


Figure 4. Length histograms of the clusters after being skeletonized for the first 2000 frames.

The script gives the possibility to process all the frames at the same time in order to analyze the behavior of the linearity of all their cluster (figure 5). In the current

example (approximately one million clusters), for each detector was obtained that the linearity oscillates around an average value of 0.7. The 75% of the clusters have values of linearity greater than 0.7. These results indicate that the radiations that affect the detectors are mainly from heavy charged particles and light charged particles with high energy values (Holy et al. 2008).

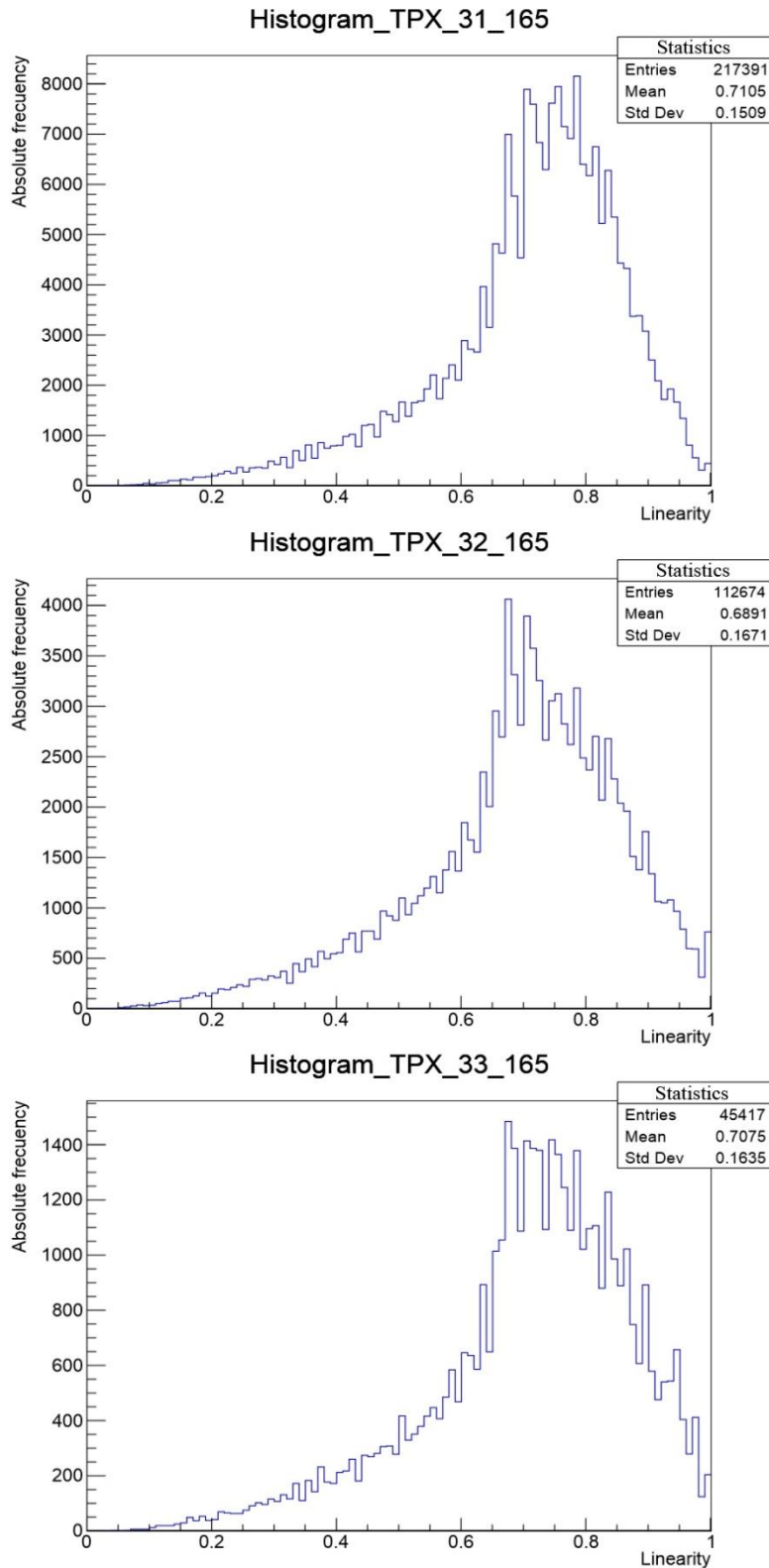


Figure 5. Histograms of linearity in TPX detectors 31, 32 and 33.

Other possibility of the script is to analyze the behavior of the length of all clusters. This information is useful for identifying the incident particles (figure 6). The average value of the length of the clusters is in the range 25-30 pixels, this indicates that most of the interactions are caused by heavy charged particles because they have small lengths.

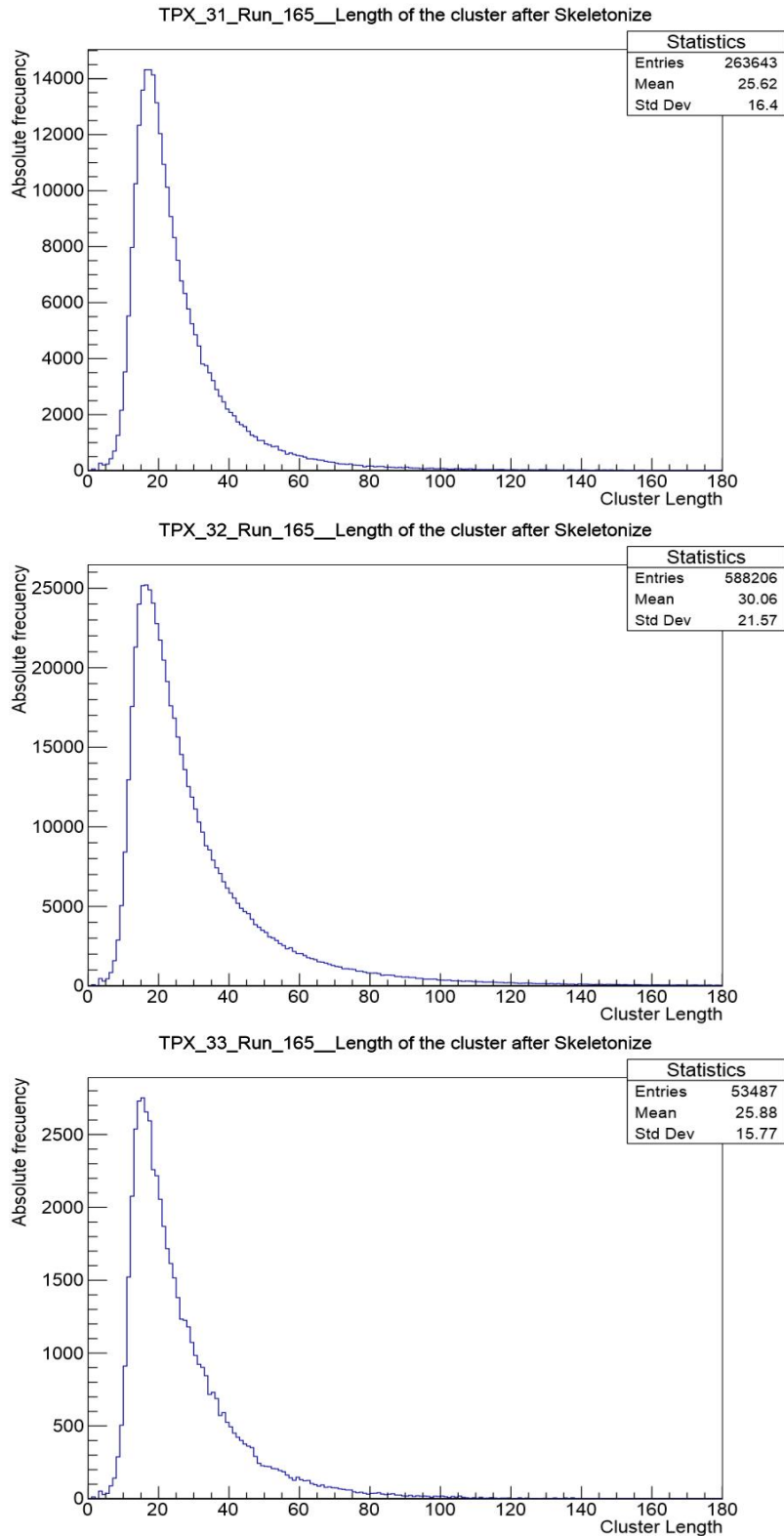


Figure 6. Length histograms of the clusters after being skeletonized.

In order to verify the effectiveness of the code all the frames were analyzed to select the cluster with greater linearity (0.99 - 1) (figure 7). These images and the length histograms (figure 8) show the interesting presence of clusters with a high linearity and very significant length.

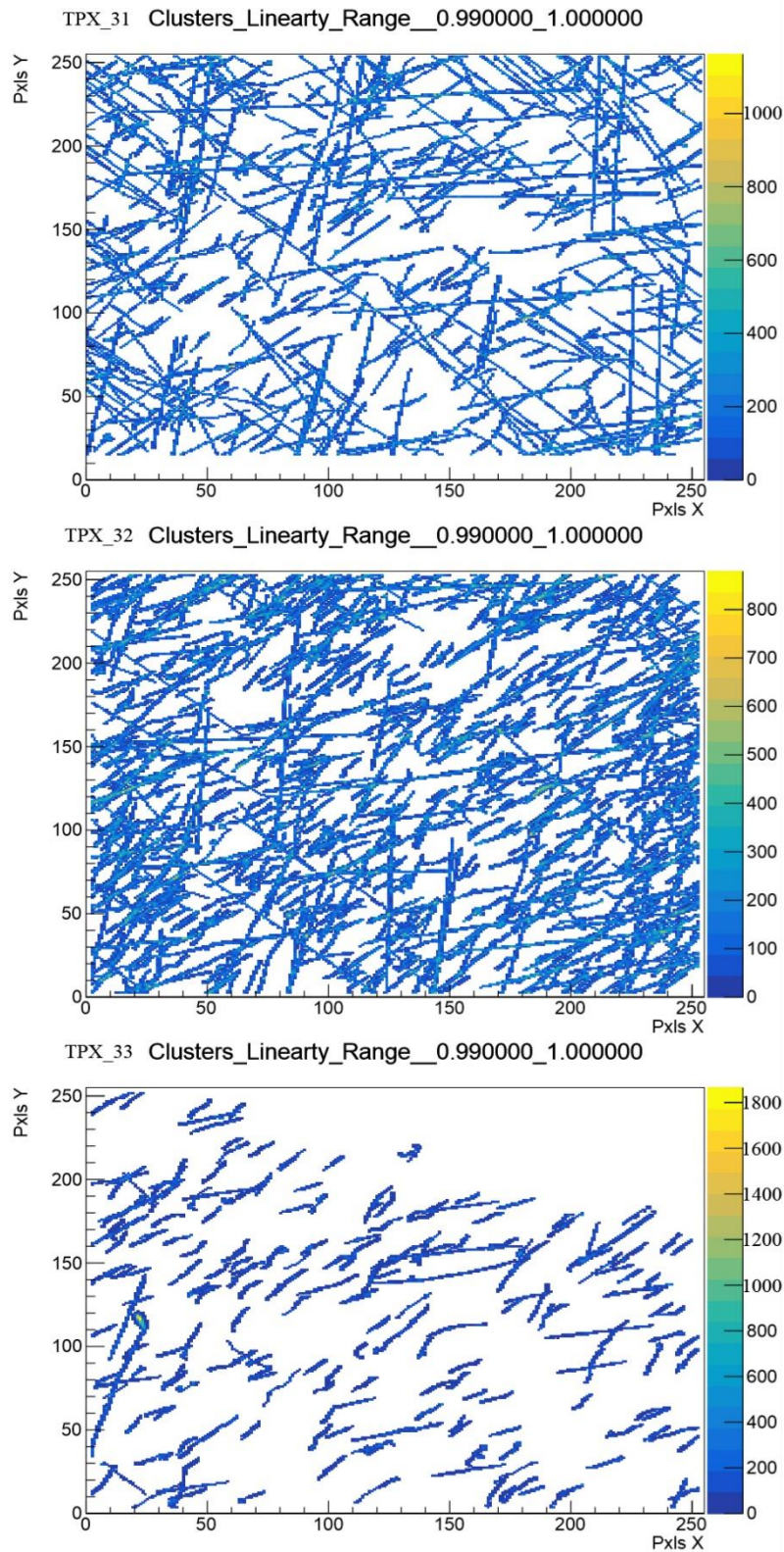


Figure 7. Clusters that have linearity values greater than 0.99.

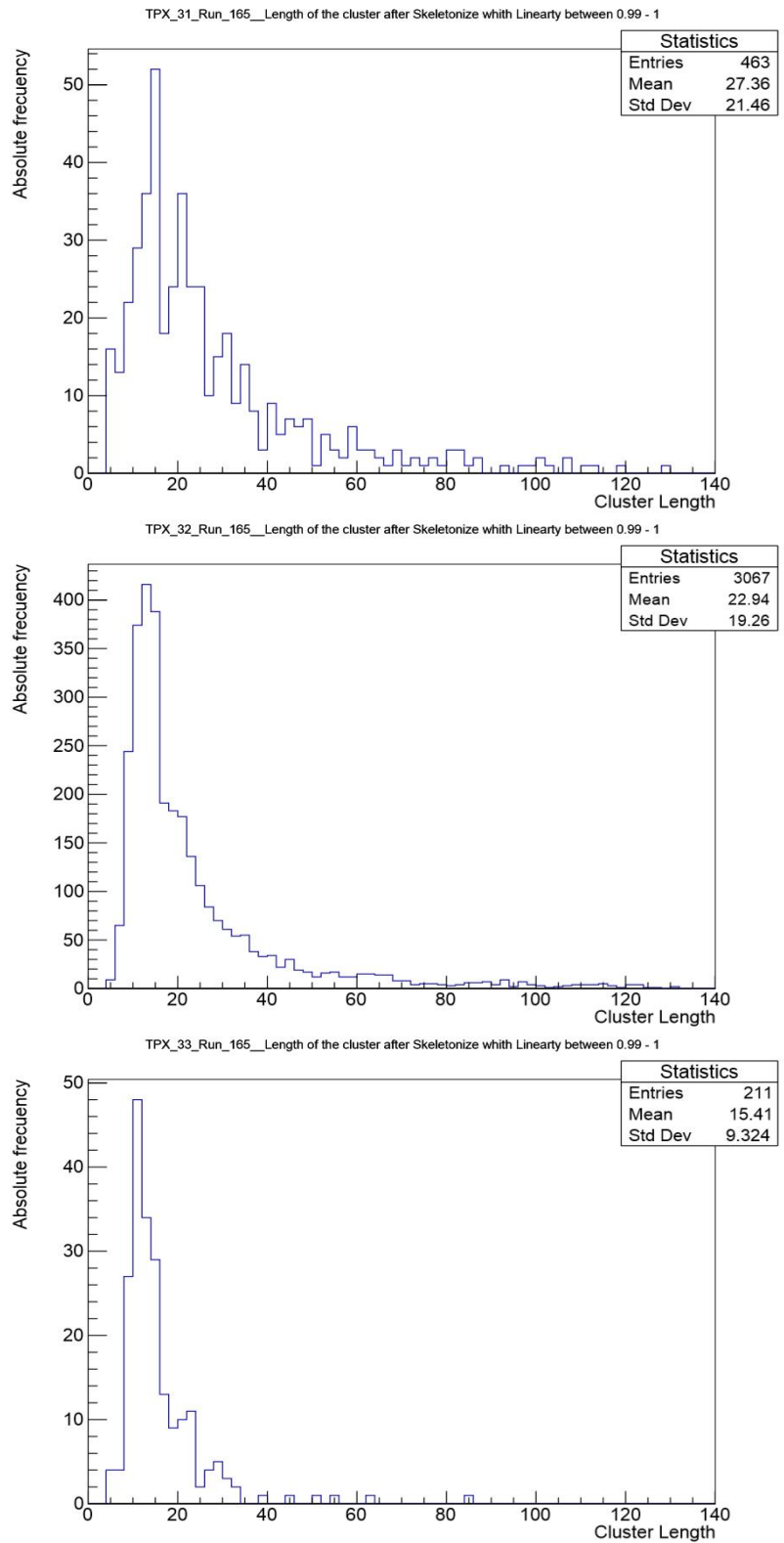


Figure 8. Length histograms of the clusters that have linearity values greater than 0.99 after being skeletonized.

Finally, this new Skeleton script also allows build histograms of the cluster's volume and analyze the area distribution of each cluster.

Conclusions

The objective planned at the beginning of this work was fulfilled. A new script was created that allows, using the Root and ITK libraries, to classify and visualize the different clusters according to their linearity level. This code sort the particles tracks according a linearity criterion of interesting. The script also allows build length, volume and area distribution histograms of the clusters a selected frame number. In order to test the script a set of experimental data from Timepix detectors located at ATLAS cavern experiment was used.

Recommendations

In order to continue developing this work, will be very useful improve some aspects of the Skeleton script. The efficiency of the code can be better if the two first cuts and the skeletonization process will put in the same script; the only problem is unified the libraries from Root and ITK. This aspect was not solved because the time for the investigation was not enough. The developed code does not process the clusters that have more than two ends, this phenomenon is due to the overlap of two or more interactions, and this limitation should be eliminated.

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