

Trigger Primitive Analysis with Bi-207

21 January 2025

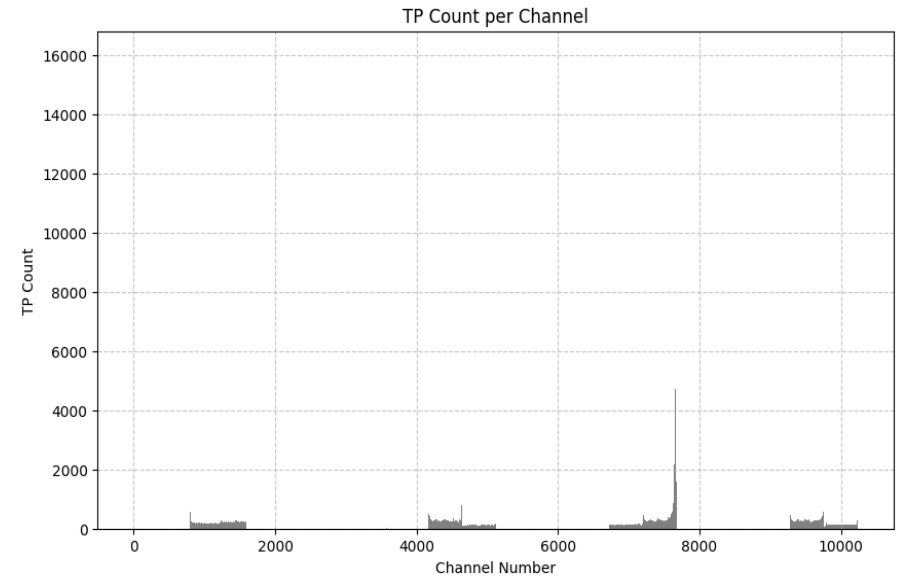
Samikshya Kar

Introduction

- A source of Bi-207 is present near APA 2 in the NP04 TPC, used for purity and calibration measurements in LArTPCs.
- It undergoes β^+ decay to Pb-207, which de-excites by emitting internal conversion (IC) electrons and γ rays.
- Internal conversion may lead to the release of Auger electrons and X-rays.
- Emitted γ rays interact with LAr through Compton scattering or the photoelectric effect, causing further ionization.

Requirements:

- Data: Five TP stream files of ProtoDUNE II Horizontal drift off-beam run (number: 026482)
- DAQ Packages: *justintime* to read the hdf5 files, *cluster_finder* for removal of cosmic events through DBSCAN clustering.



The figure is from a PD2HD off-beam run, with cosmic events removed via clustering. Distinct peaks in the APA 2 region, amid uniform noise elsewhere, are attributed to Bi-207 activity.

Objective: The aim is to isolate the Trigger Primitives (TPs) originating specifically from Bismuth-207 activity within the ProtoDUNE Time Projection Chamber . The properties of the TPs then has been analysed for evaluating the performance of the Trigger Primitive Generation (TPG). To achieve this, a signal region must first be identified, followed by an estimation and removal of the background contribution within that region (details on the next slide).

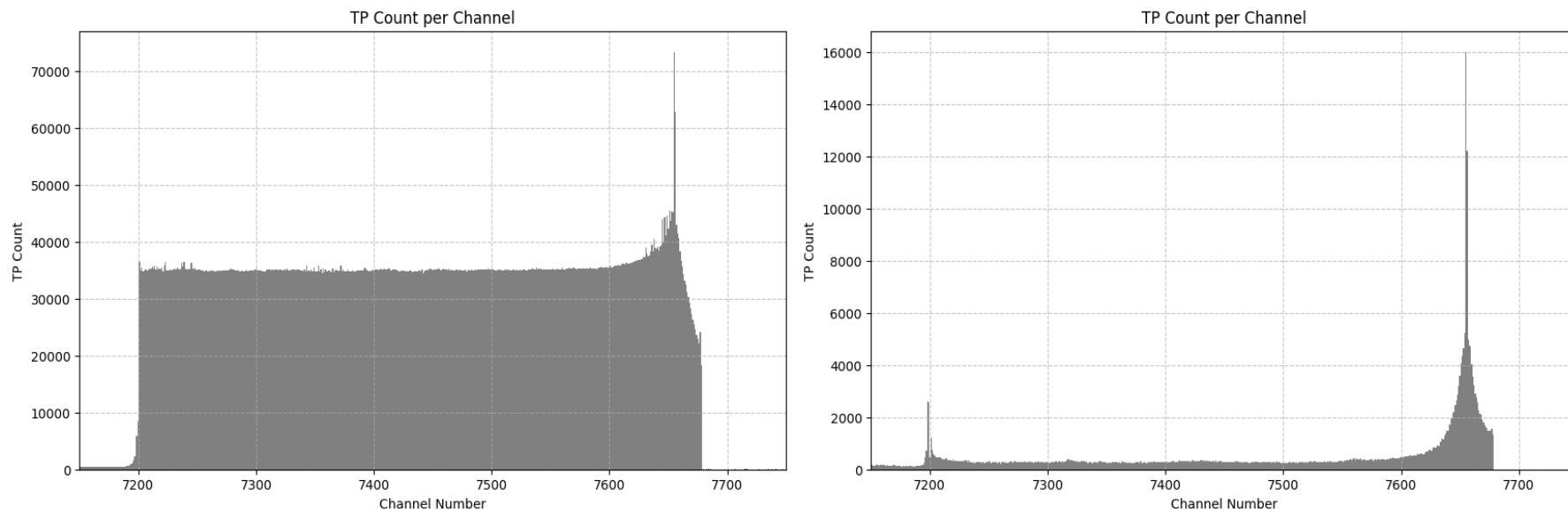
Steps

- Isolation of TPs only from APA 2 collection plane with cosmic event removal
- Visualisation of TP count per channel to identify Bi-207 activity
- Identification of signal and background region from the TP count per channel plot
- Plotting histograms of different TP properties for signal and background region
- Estimation and removal of Background from the Signal region

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Physics event removal



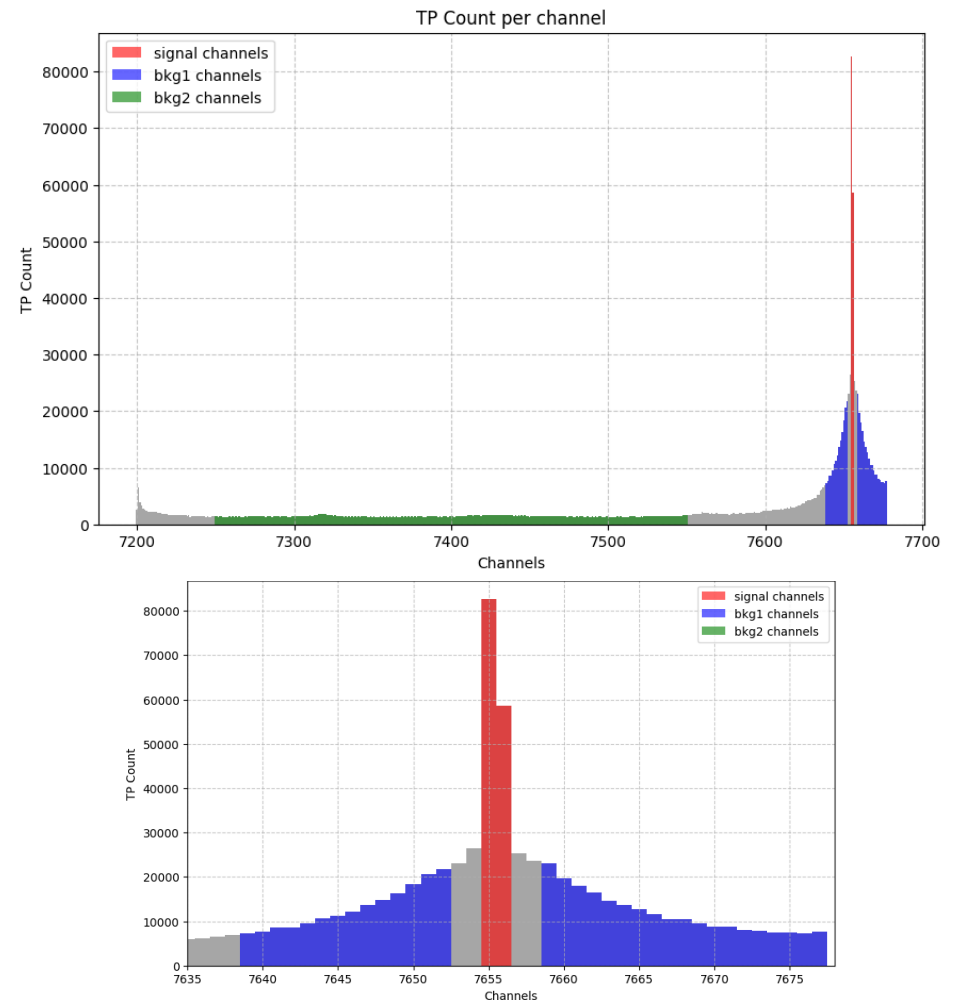
The left plot displays the TP count per channel around APA 2 from a single data file, while the right plot shows the result after removing clustered TPs. Testing with beam-on data could provide further insights on efficiency of this clustering method.

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TP Count per Channel

- The plot shows the TP count per channel for the non-clustered TPs from APA 2.
- Three regions are selected here based on visual inspection
- **Signal Region:**
Distinct peaks (in red), attributed to Bi-207 activity
- **Background Region 1:**
Uniform noise from other sources (depicted in green)
- **Background Region 2:**
Neighbouring channels around signal region influenced by Bi-207 gamma rays
- Immediate neighbouring channels around the signal region are excluded to avoid potential signal contamination

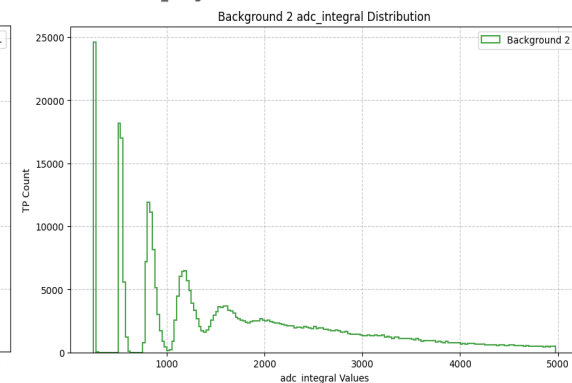
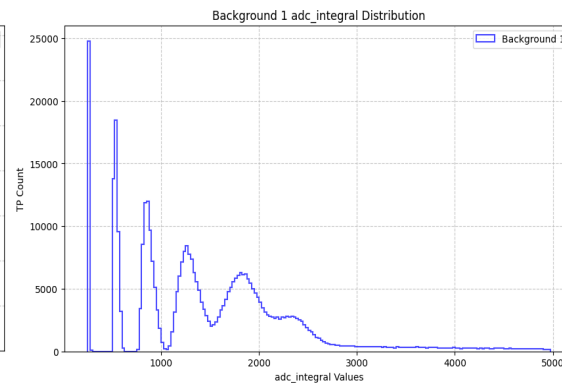
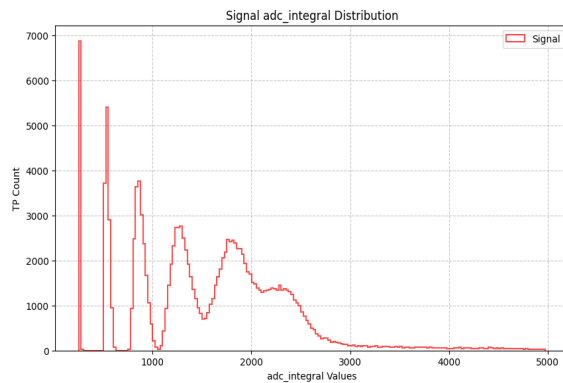
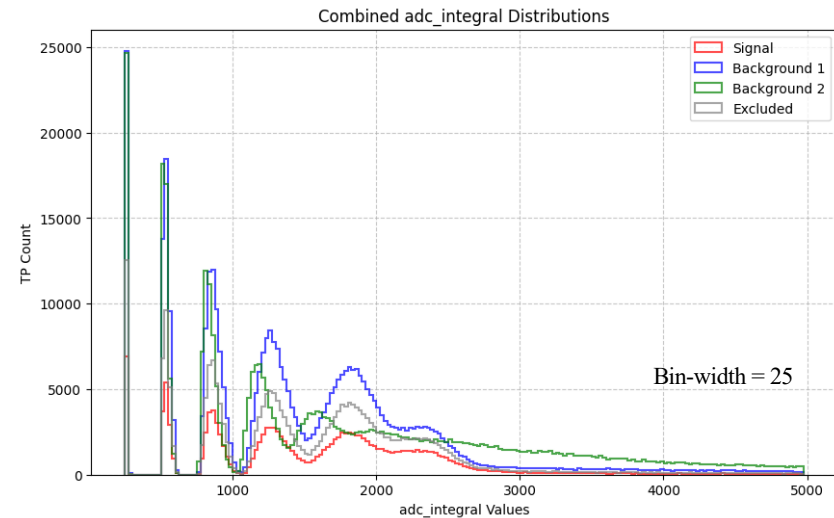


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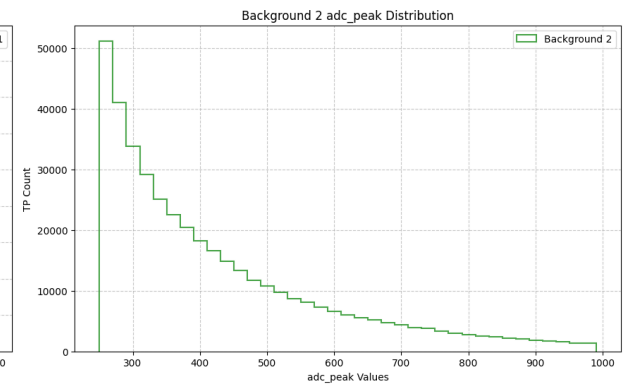
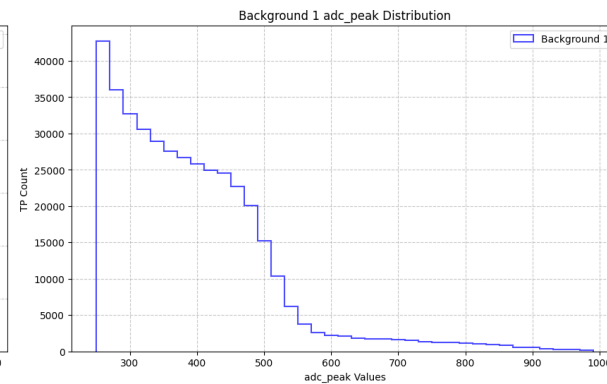
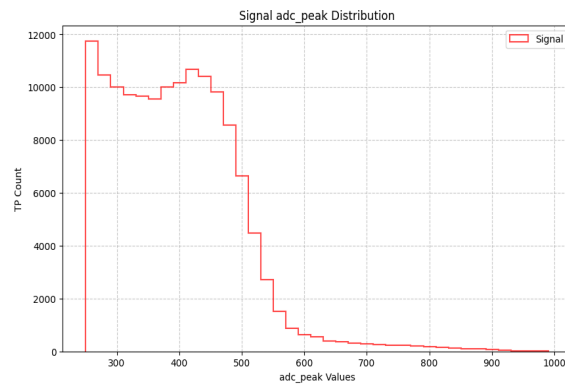
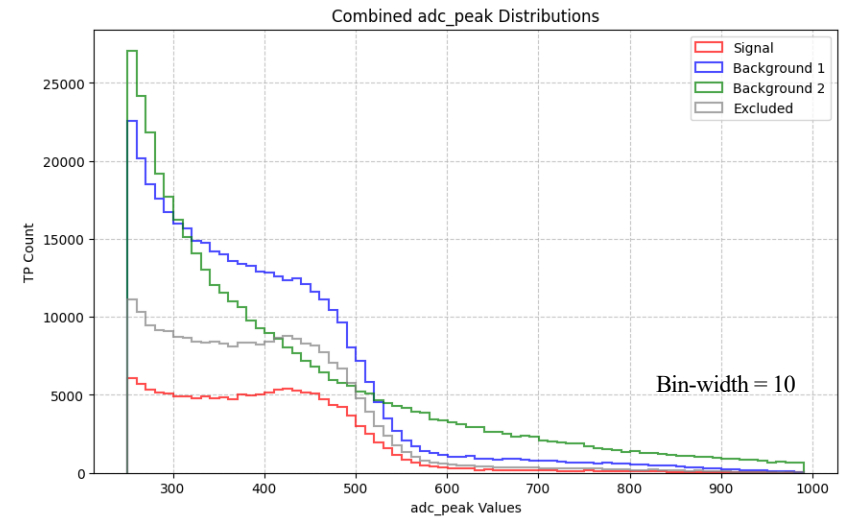
ADC Integral histogram

- The bottom plots show TP parameter distribution in the Signal and Background regions distinctly
- The right plot gives a comparison of shape and statistics of the distribution in different regions



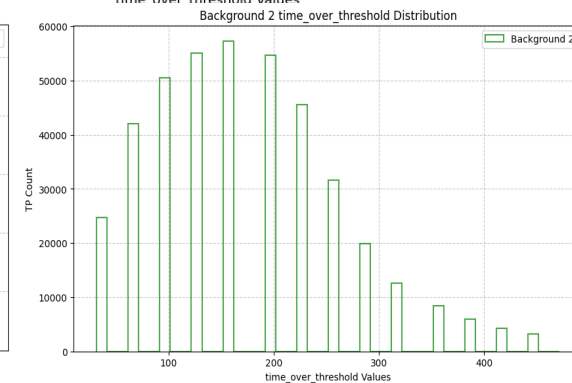
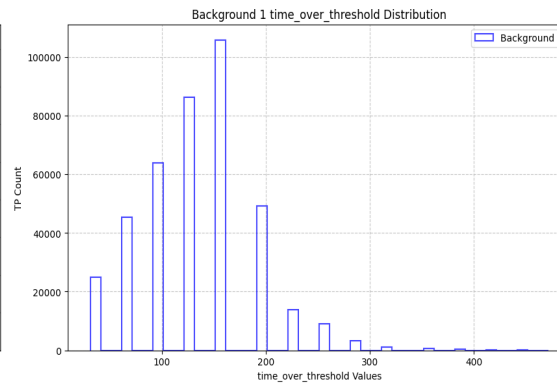
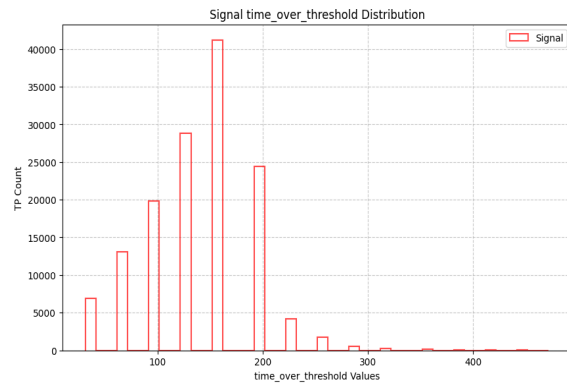
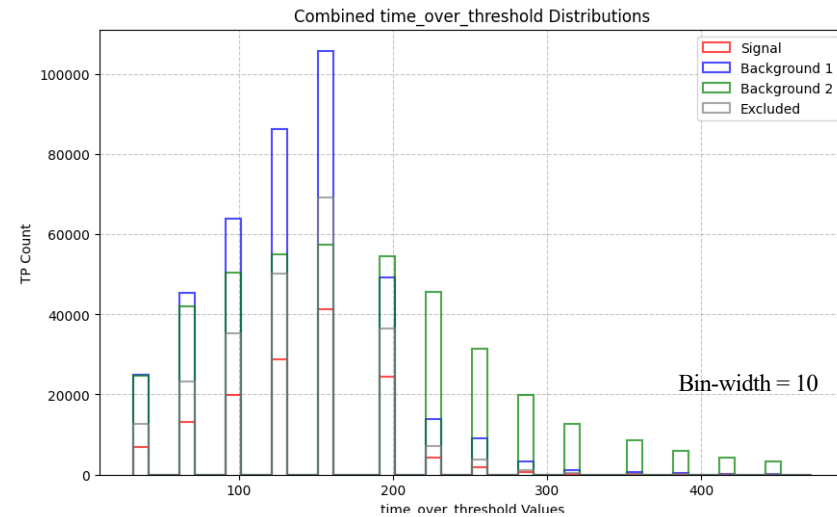
ADC Peak histogram

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Time Over Threshold histogram

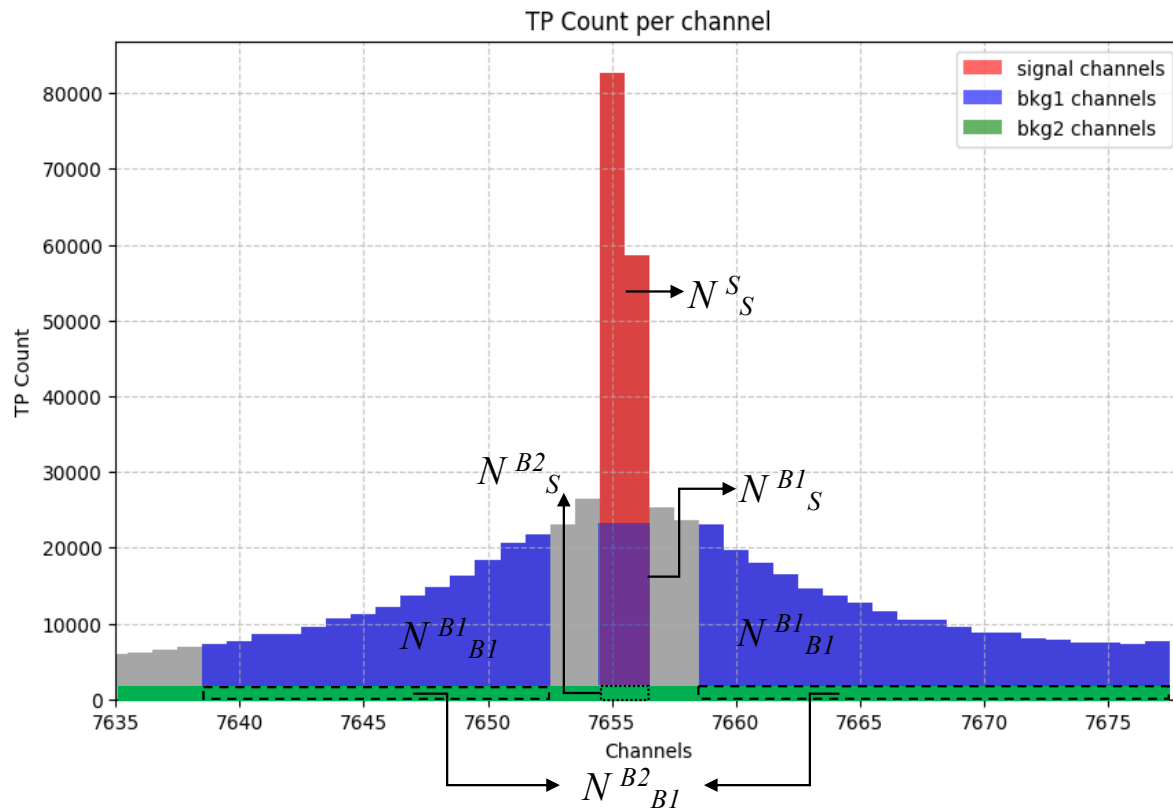
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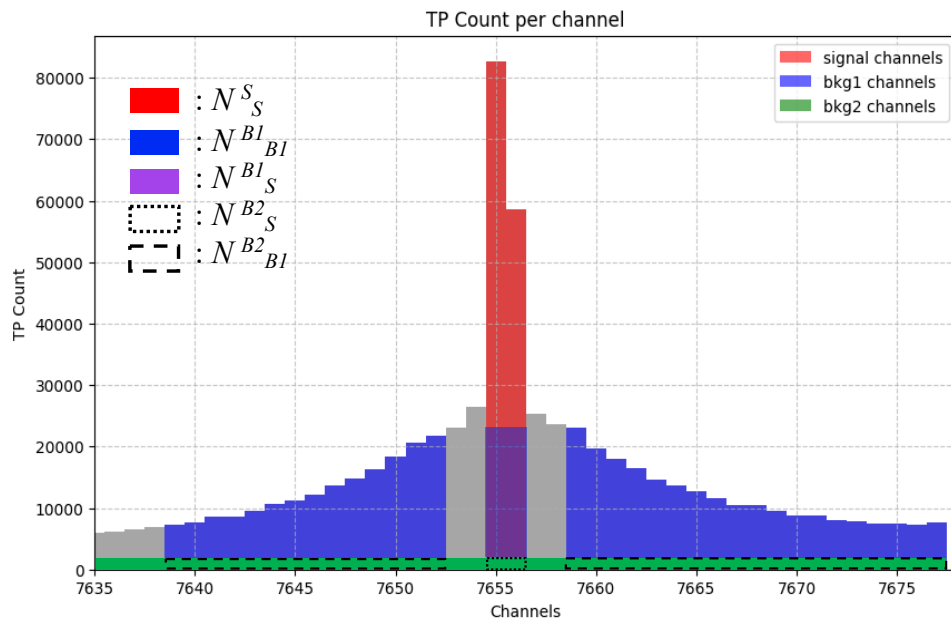
- Isolation of TPs only from APA 2 collection plane with cosmic event removal
- Visualisation of TP count per channel to identify Bi-207 activity
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- Plotting histograms of different TP properties for signal and background region
- **Estimation and removal of Background from the Signal region**

Background estimation



- N = Number of TPs
 - Q = TP parameter histogram (e.g. : ADC integral)
 - C = Number of channels
 - Notation: N^A_B
 - A = Estimated quantity
 - B = Region
- : N^{S_S} (Signal TPs in signal region)
■ : $N^{B^1_{B1}}$ (Background 1 TPs in Background 1 region)
■ : $N^{B^1_S}$ (background 1 TPs in Signal region)
 : $N^{B^2_S}$ (Background 2 TPs in Signal region)
 : $N^{B^2_{B1}}$ (Background 2 TPs in Background 1 region)

Background estimation



Assumption: Background 2 is relatively uniform in terms of TP count per channel as compared to the Background 1 and Signal region

First, estimating Background 2 in both Signal and Background 1 region:

$$N^{B2}_{B1} = N_{B2} \times \frac{C_{B1}}{C_{B2}} \quad (1)$$

$$Q^{B2}_{B1} = Q_{B2} \times \frac{C_{B1}}{C_{B2}} \quad (2)$$

$$N^{B2}_S = N_{B2} \times \frac{C_S}{C_{B2}} \quad (3)$$

$$Q^{B2}_S = Q_{B2} \times \frac{C_S}{C_{B2}} \quad (4)$$

Then, removal of estimated Background 2 from Background 1 (from 1 and 2) to finally estimate it in Signal region:

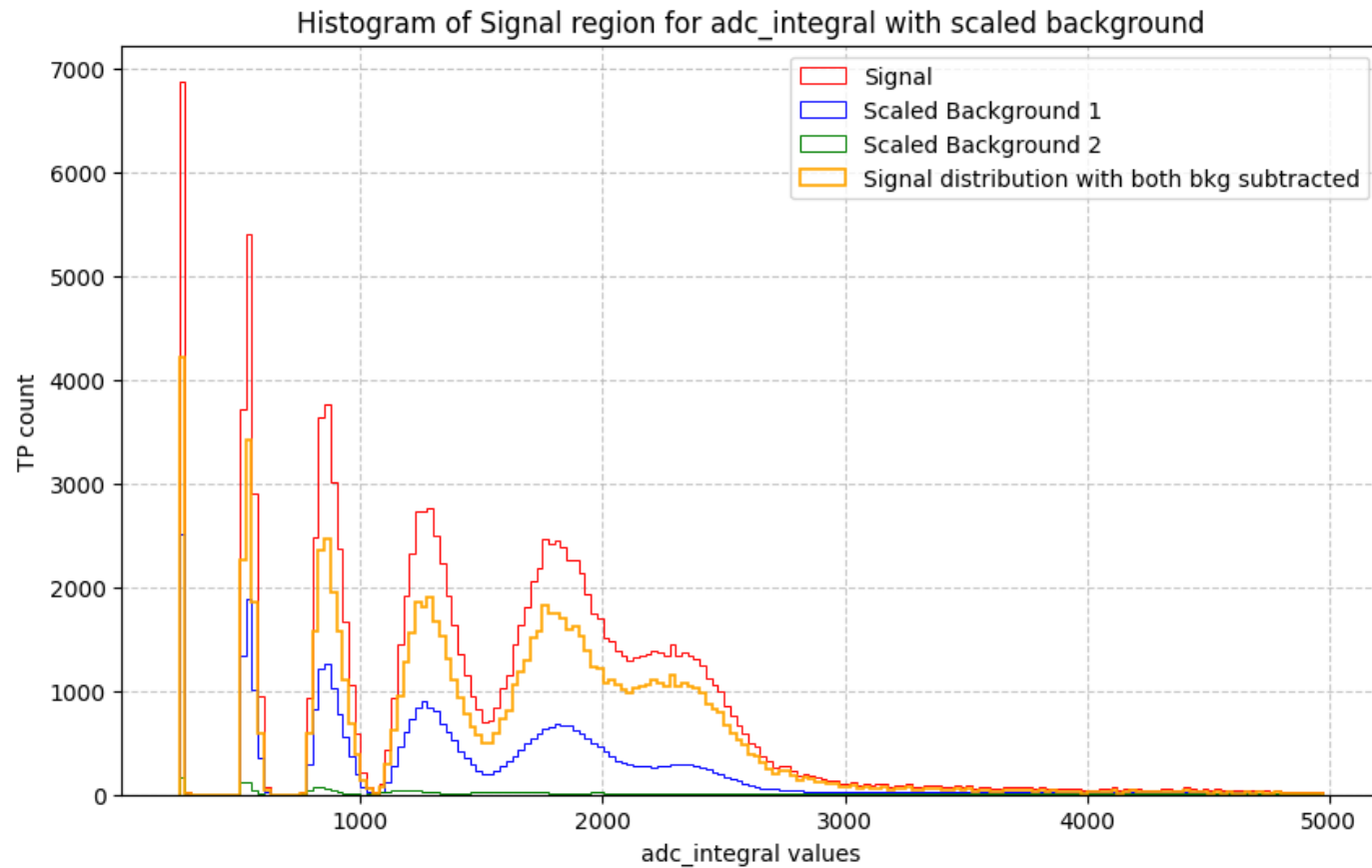
$$Q^{B1}_{B1} = Q_{B1} - Q^{B2}_{B1} \quad (5)$$

$$Q^{B1}_S = C_S \times (N^{B1}_S - N^{B2}_S) \times \frac{Q^{B1}_{B1}}{N_{B1} - N^{B2}_{B1}} \quad (6)$$

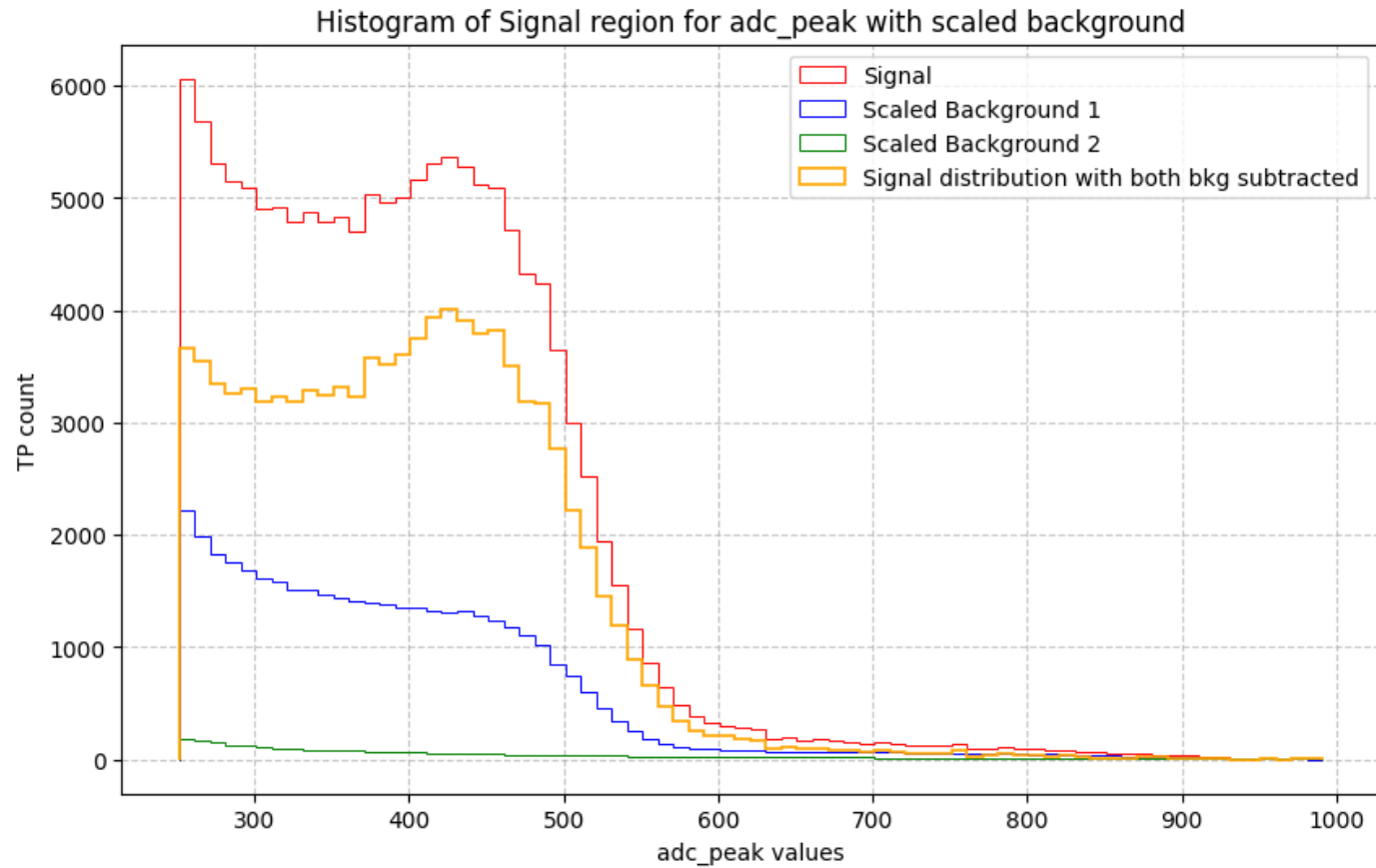
Finally, the end result to that gives the estimated parameter coming from signal TPs in signal region after the background removal (from 4 and 6) :

$$Q^S_S = Q_S - Q^{B1}_S - Q^{B2}_S \quad (7)$$

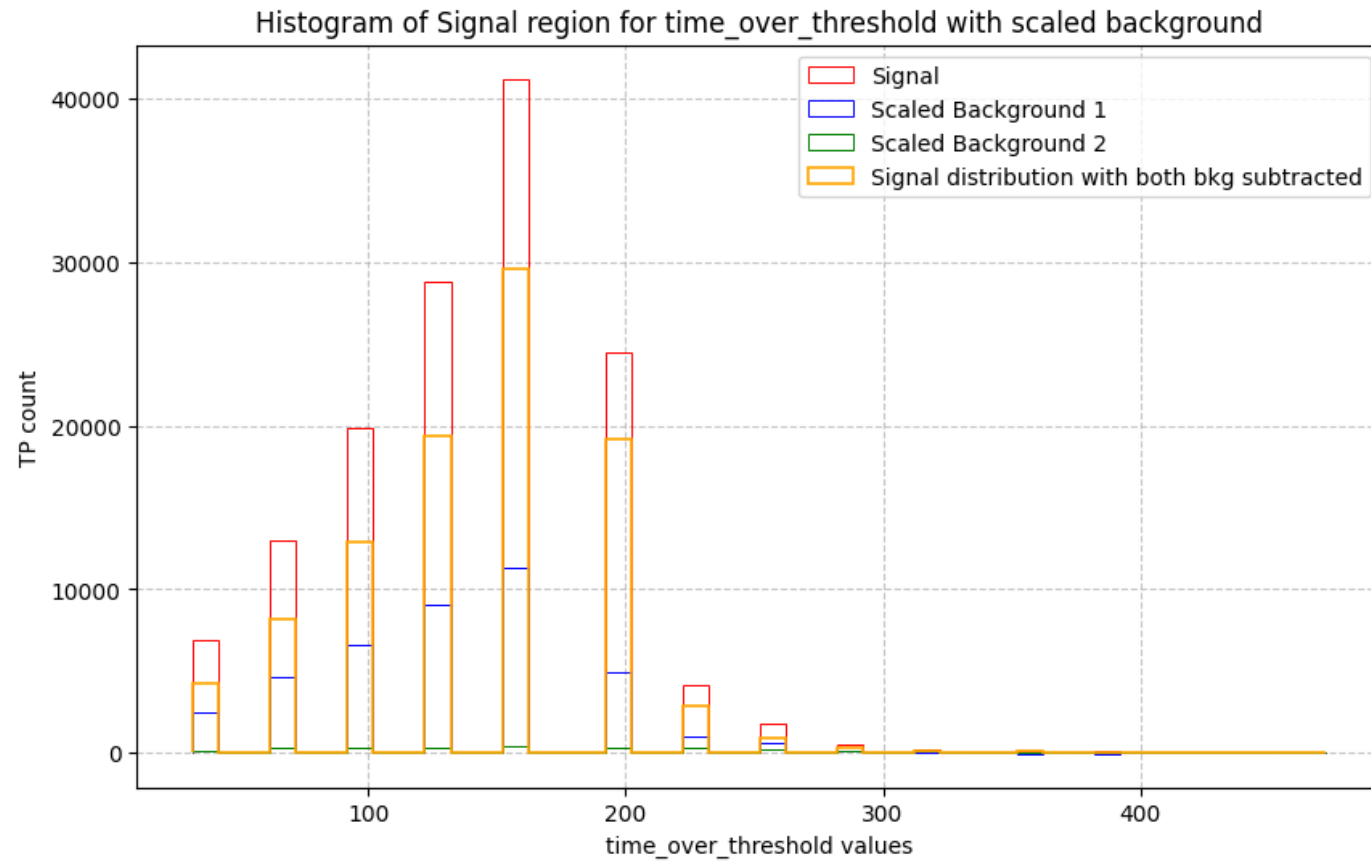
ADC Integral for Signal region



ADC Peak for Signal region



Time Over Threshold for Signal region

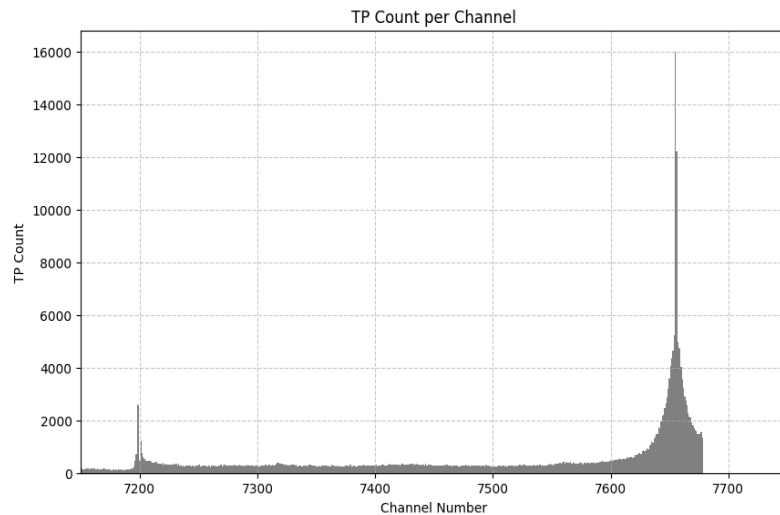


THANK YOU!

Procedure

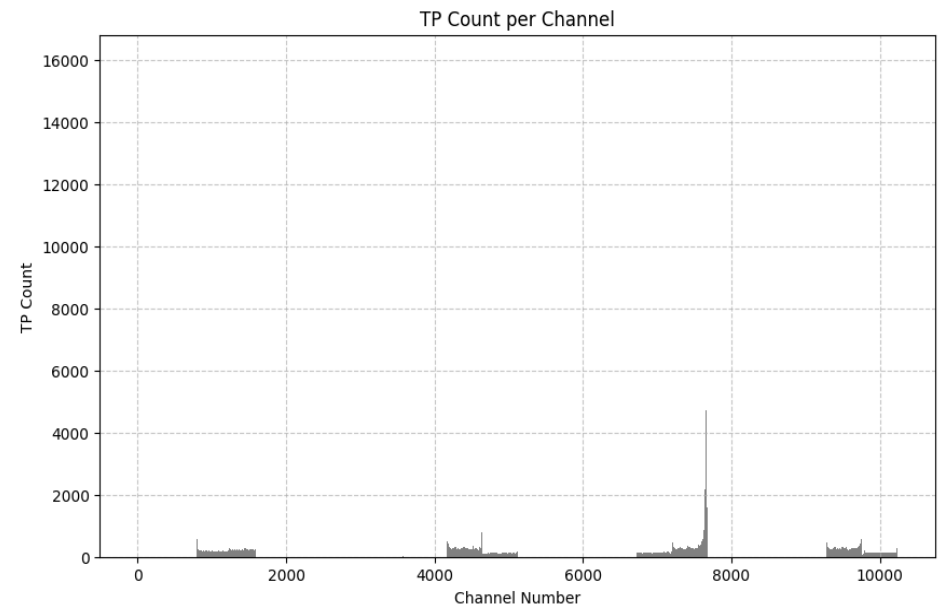
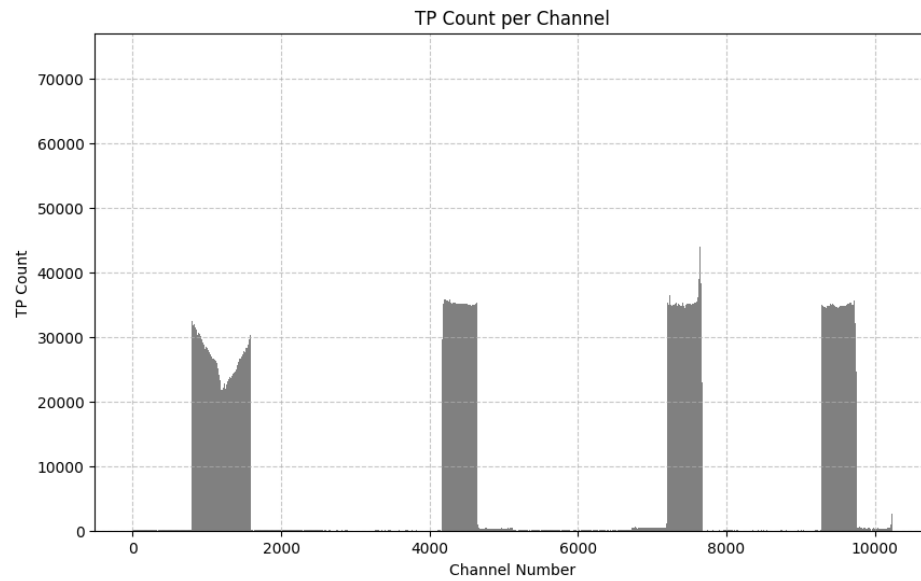
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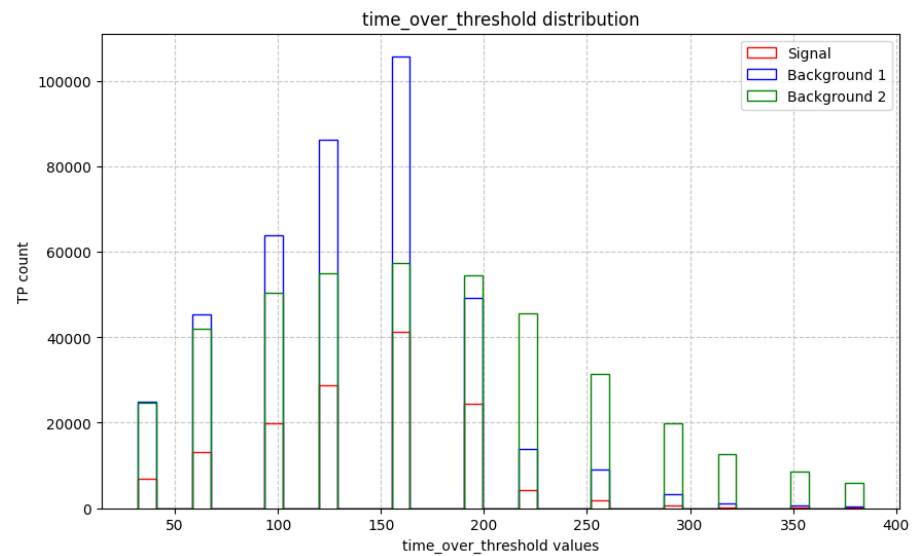
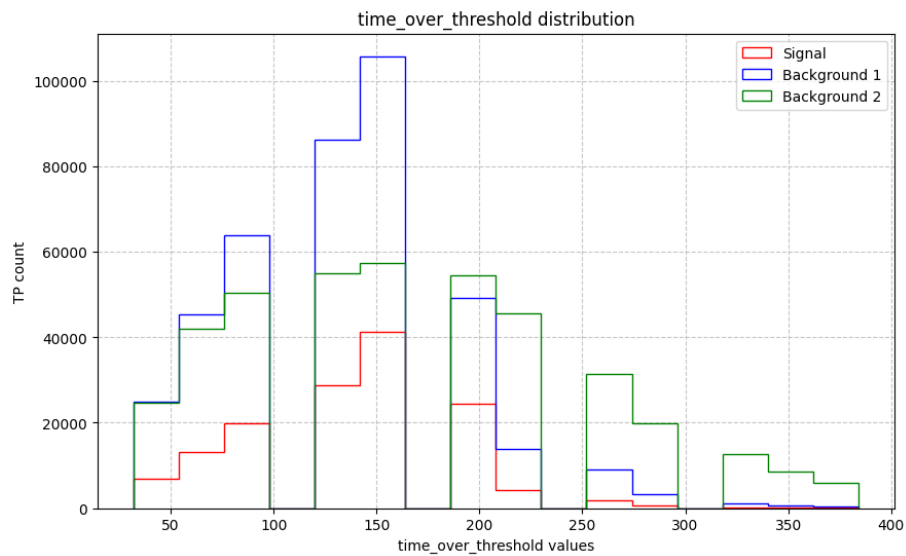


1. First Step: Removal of Cosmic events and isolation of TPs only from APA 2 collection plane
2. Visualisation of TP count per channel to identify Bi-207 activity (see plot below)
3. Identification of signal and background region from the above plot
4. Plotting histograms of different TP properties for signal and background region
5. Estimation of Background in the signal region by normalisation using TP number

Introduction and Objective



Time Over Threshold Histogram



- Bin-width = 25 (left) and 10 (right)