START Program Collider Mode: Reduce Magnetic Field

Friday, August 23, 2024

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Outline

- Reduced Magnetic Field
- Project "Collider Mode: Reduced Magnetic Field"
- Task 1: Track Reconstruction by Carlos Márquez
- Task 2: PID by Alejandro San Juan
- Future Work

Reduced Magnetic Field

Why we want to analyses the Reduced Magnetic Field?
We can reconstructed particles is based on the trajectory formed by the transverse momentum when interacting with the magnetic field

However, there are particles with low transverse momentum that, even with the full magnetic field, are not significantly affected. These particles are trapped rotating within the Time Projection Chamber, preventing them from reaching the detector limits and, therefore, they cannot reach other detectors.

This situation makes it difficult to accurately reconstruct this type of particle with low transverse momentum. But we want to reconstruct and record all particles.

Information that we will analyze.

The system we are studying is Request 28, that is, reduced magnetic field. We will compare it with full magnetic field, that is, Request 25.

	Request 25	Request 28
Collision system	Bi + Bi @9.2GeV	Bi + Bi @9.2GeV
Event Generator	UrQMD	UrQMD
Production	50 Million Events	10 Million Events
Magnetic Field	5 kG	2 kG

For the comparison, only 5 million events were analyzed from request 25. But in some cases less information was analyzed due to lack of time, not all events are analyzed.

Project "Collider Mode: Reduced Magnetic Field"

Task 1. Primary vertex determination and Particle Track reconstruction, optimization of cuts in η, p_T , number of hits on TPC.

Task 2. Particle identification determination of spectra using information about the energy losses (dE/dx) in the TPC and the Time-of-flight from the TOF detector.

Reduce Magnetic Field Track Reconstruction

First Steps: My Class

The first week I focus on writing my class, called "lowMgF", and getting the first transverse momentum histograms. A copy of my class can be found in the following path:

/scratch2/marquez/lowMgF

Or you can consult the following GitHub:

https://github.com/iamaldonado/START_Summer24/tree/main/CarlosMarquez/lowMgF

This class was worked on throughout the whole stay here in Dubna, so it was modified and optimized.

First Steps: Running in the Offline Cluster

We were analyzing 10 million events, so you had to write some macros to analyze it. Similarly, it can be found in the following route:

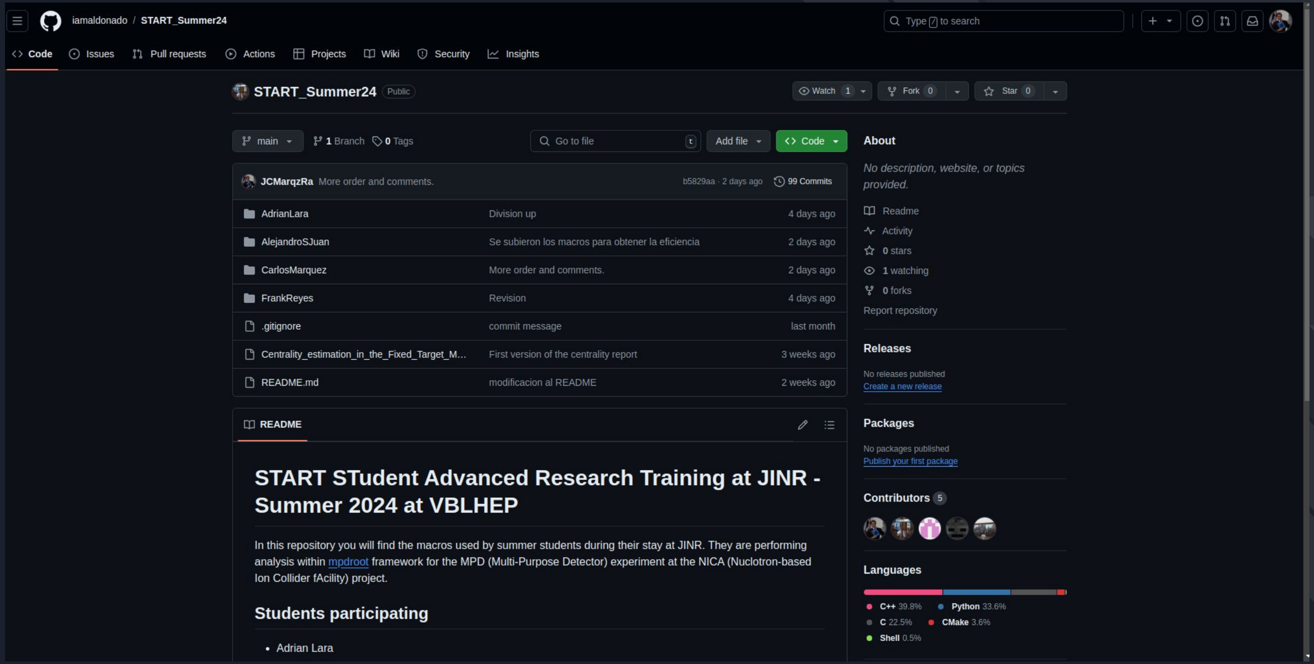
/scratch2/marquez/

Similarly, you can consult the following GitHub:
https://github.com/iamaldonado/START_Summer24/tree/main/CarlosMarquez/RunOffCluster

The function of these macros is to create several lists and folders, where in each folder a certain number of events are run. Initially analyzing the 10 million events took more than a day, with these macros, it takes about 4 hours.

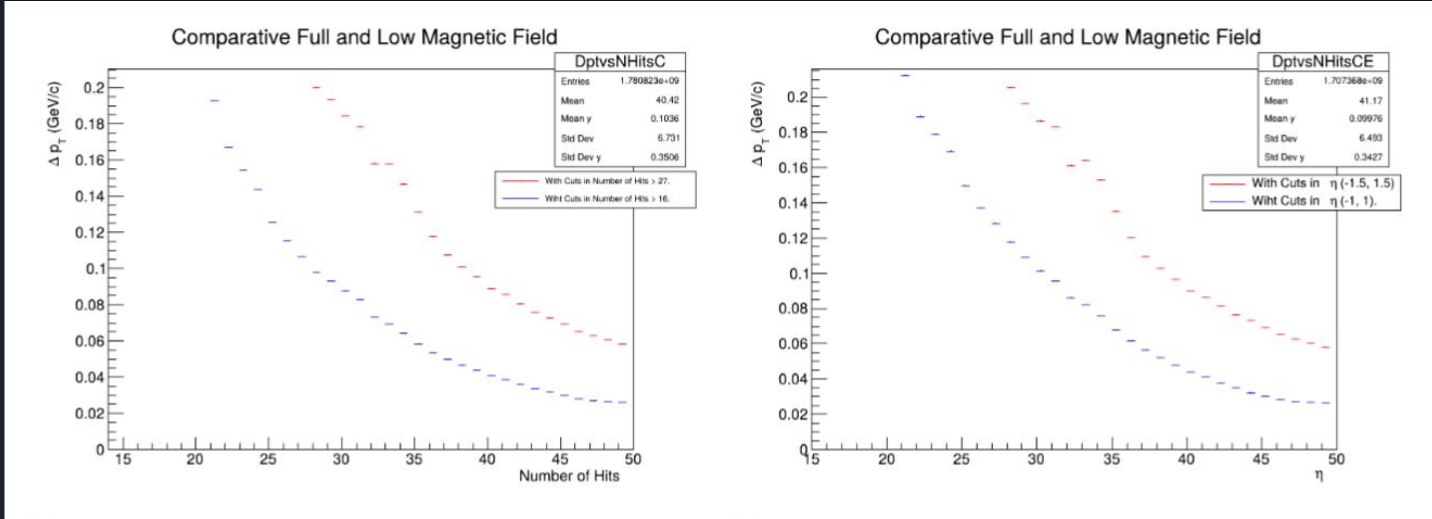
Rewrite, order and comment my code.

The code is cleaned and explaining each step. All the documentation can be found on GitHub where you find all my colleagues' work and mine.



Cut on the Number of Hits

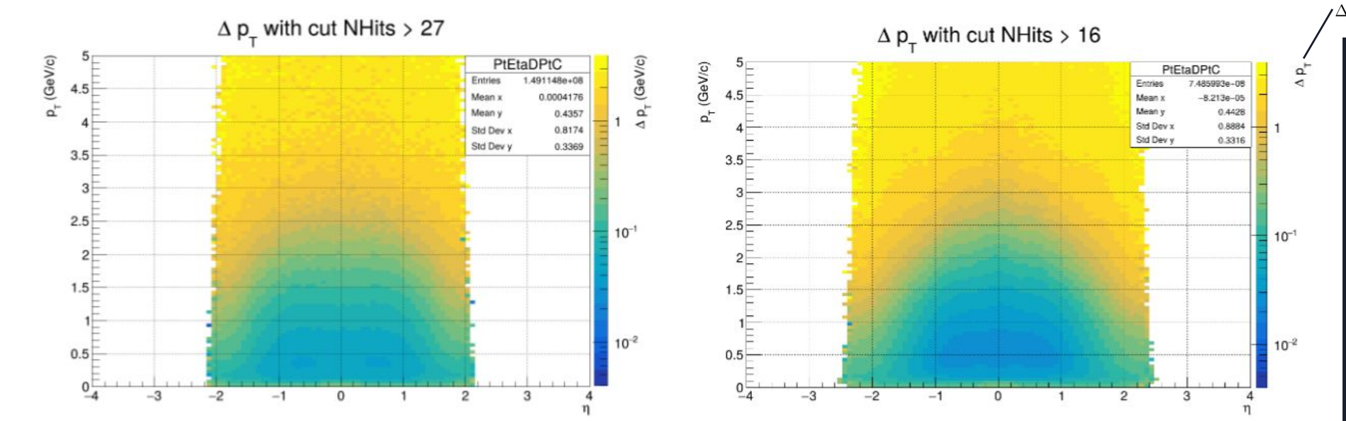
We obtain the distribution of the resolution of transverse momentum against Number of Hits, we make a cut in Number of Hits > 27 and comparative this distribution with th cut for Full Magnetic Field.



(a) Comparative Full and Reduce Magnetic Field with cut in Number of Hits.

(b) Comparative Full and Reduced Magnetic Field with cut in η.

Now we compare the phase space for the resolution of the transverse momentum. Comparing with the complete magnetic field and its respective cut.



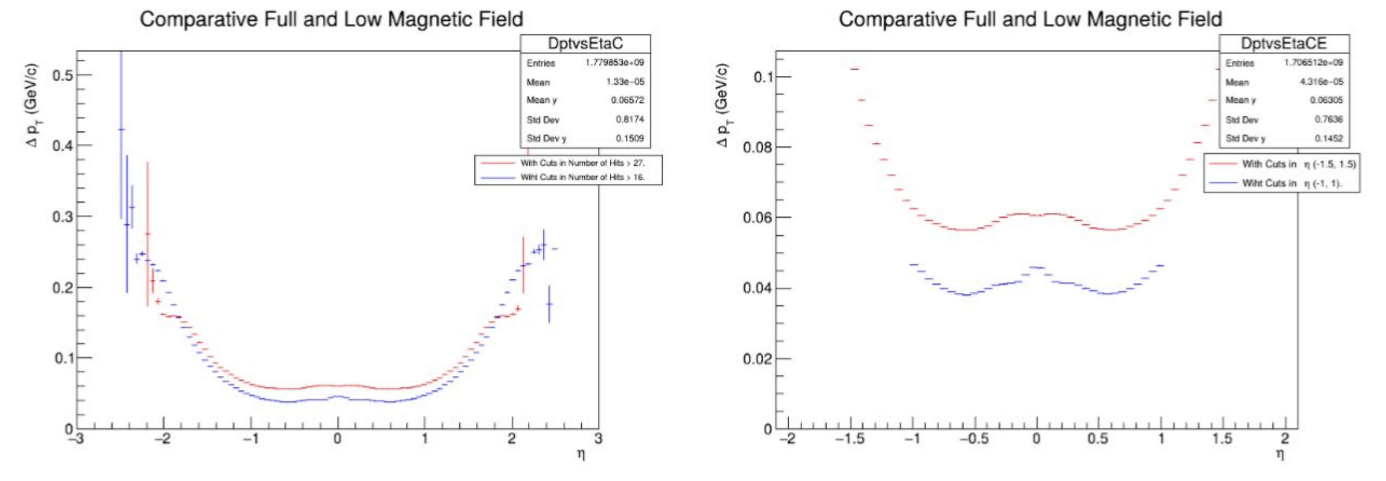
$$\Delta p_T = \frac{|p_T^{reco} - p_T^{MC}|}{p_T^{MC}}$$

(a) The Δp_T with cut in Number of Hits for Reduce Magnetic Field.

(b) The Δp_T with cut in Number of Hits for Full Magnetic Field.

Cut on the Pseudorapidity

We obtain the distribution of the resolution of transverse momentum against Pseudorapidity, we make a cut in Pseudorapidity ∈ (-1.5, 1.5) and comparative this distribution with th cut for Full Magnetic Field.

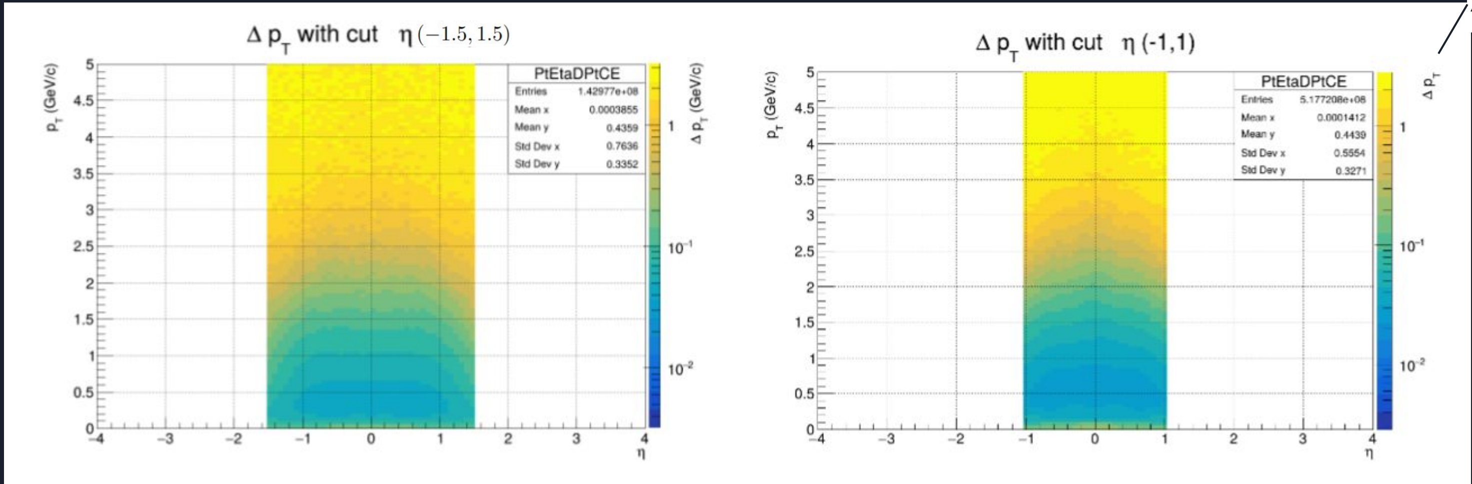


(a) Comparative Full and Reduced Magnetic Field with cut in Number of Hits.

(b) Comparative Full and Reduced Magnetic Field with cut in η.

Now we compare the phase space for the resolution of the transverse momentum. Comparing with the complete magnetic field and its respective cut.

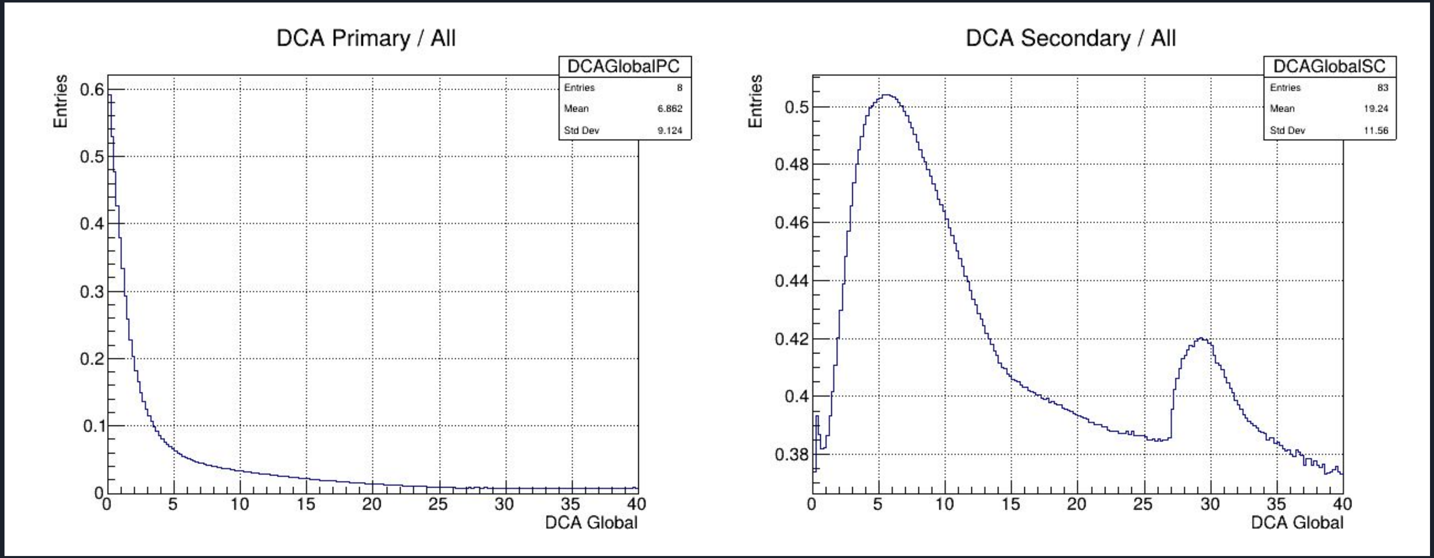
$$\Delta p_T = \frac{|p_T^{reco} - p_T^{MC}|}{p_T^{MC}}$$



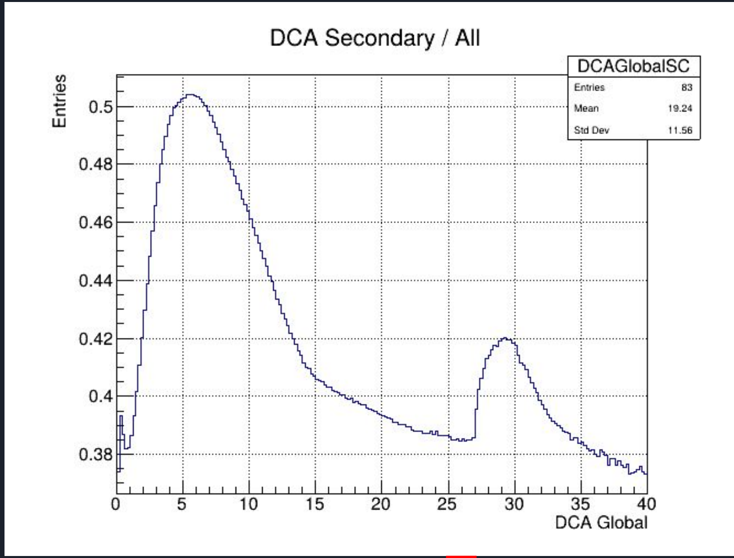
(a) The Δp_T with cut in η for Reduce Magnetic Field. (b) The Δp_T with cut in η for Full Magnetic Field.

Cut on the DCA Global

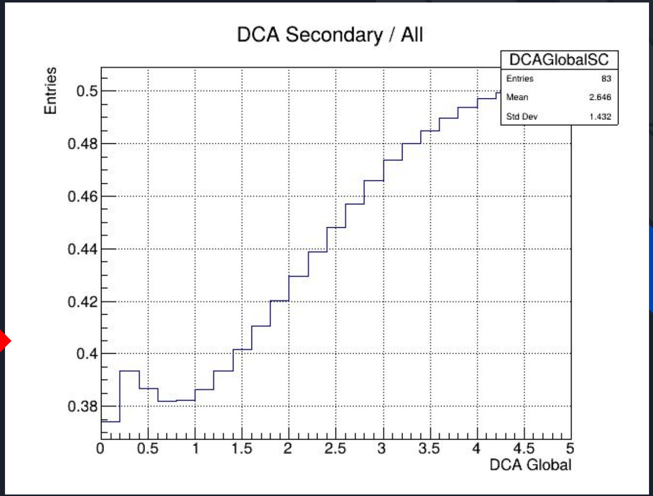
We obtained DCA Global's awards for all particles and primary and secondary particles. We divide primary into all particles and secondary into all particles



We review more calmly the division of secondary particles among all. So We made a zoom in on this section



We can identify a suitable cut point for the Global DCA parameter, which could be set at 1 cm. This would help us achieve a 30% error margin in the Global DCA variable.



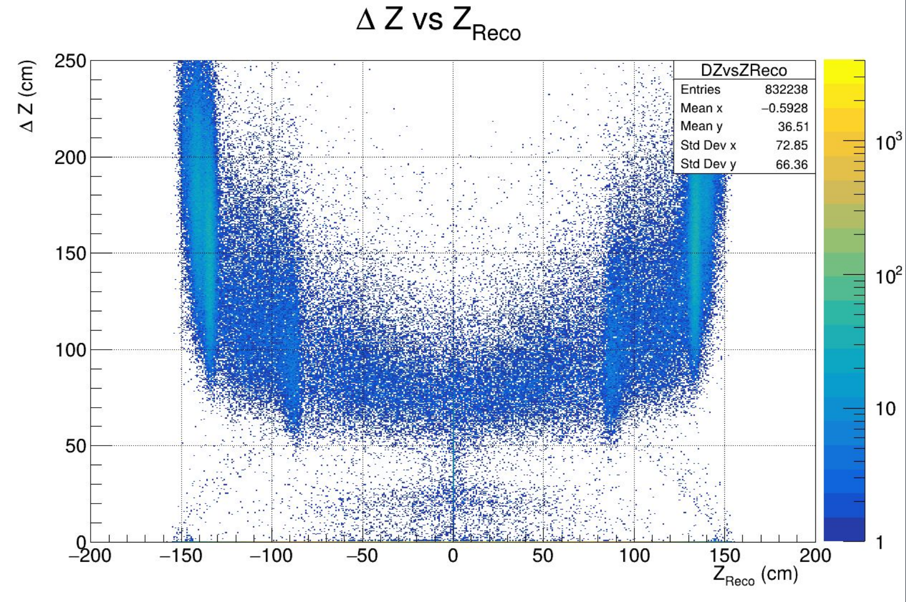
Cut on the Vertex Position

In this section it should be mentioned that corrections had to be made at the last moment. Because the resolution of the primary vertex was being defined incorrectly. The correct definition is:

$$\Delta Z = |Z_{reco} - Z_{MC}|$$

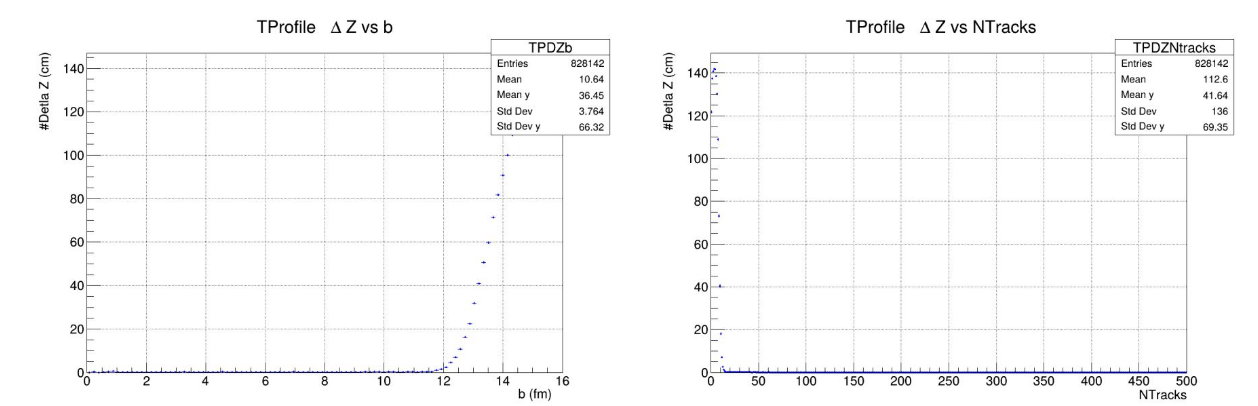
This correction was last minute. So we only had time to analyze 1 million events instead of 10 million events. But it helps us to see a little where we can make the cut.

With this correction, I made the plot of the resolution of the primary vertex against the primary vertex on the Z-axis, but now have sense.



We can see is a very thin yellow band with over 10^{3} events, which is considerably higher compared to what appears at -150 and 150. On the vertical axis, representing the primary vertex resolution, there are very few events above 50 cm.

Now, we obtain the resolution of the primary vertex against impact parameter and against Number of Track



(a) TProfile of the Resolution of the Primary Vertex versus the Impact Parameter.

(b) TProfile of the Resolution of the Primary Vertex versus the Number of Tracks.

In this histogramas, it is observed that for peripheral events, the parameter b should be greater than 12 fm (indicating low multiplicity), leading to an increased error in primary vertex reconstruction. Figure 15b indicates that if the number of tracks is small (in peripheral collisions), the resolution tends to increase its error.

The Cuts to Low versus Magnetic Field

Low Magnetic Field

Variable	Cut
Transverse Momentum	$p_T > 0.15\ (GeV/c)$
Pseudo rapidity	$\eta \in (-1.5, 1.5)$
Number of Hits	$Number\ of\ Hits > 27$
DCA Global	$DCA\ Global > 1\ cm$
Primary Vertex Position	$\mathrm{Vtx} \in (-50, 50)$

Full Magnetic Field

Variable	Cut
Transverse Momentum	$p_T > 0.1\ (GeV/c)$
Pseudo rapidity	$\eta \in (-1, 1)$
Number of Hits	$Number\ of\ Hits > 16$
DCA Global	$DCA\ Global > 0.5\ cm$

Efficiency of the Transverse Momentum

Now with this cuts, we see the Efficiency of the Transverse Moment. To obtain this, we divide the distributions of the transverse momentum reconstructed between the transverse momentum Monte Carlo.

$$Efficiency = \frac{p_T^{RECO}}{p_T^{MC}}$$

At the moment we only see the efficiency of the primary and secondary of the pions, protons and kaons. For this efficiency, we use pdg to identify this particles.

By the way, I only use all the cuts the the transverse momentum reconstruction, and for the transverse momentum, we only use:

Reconstruction

Variable	Cut
Transverse Momentum	$p_T > 0.15\ (GeV/c)$
Pseudo rapidity	$\eta \in (-1.5, 1.5)$
Number of Hits	$Number\ of\ Hits > 27$
DCA Global	$DCA\ Global > 1\ cm$
Primary Vertex Position	$\text{Vtx} \in (-50, 50)$

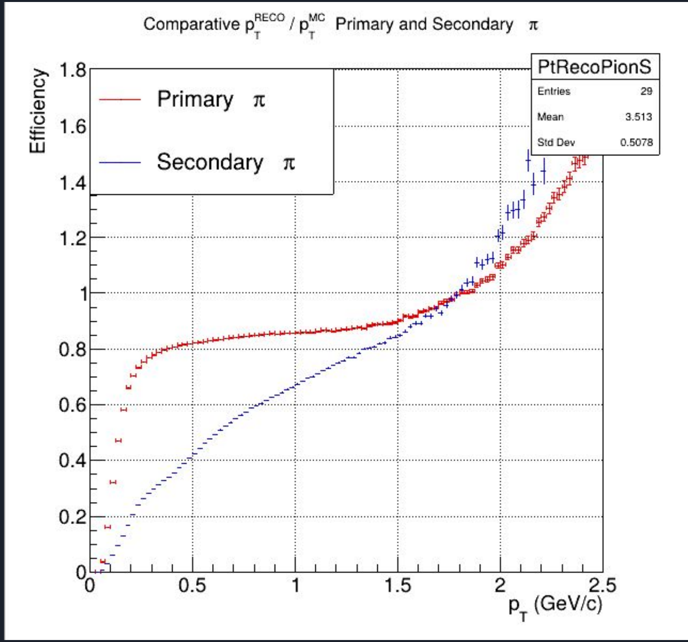
Monte Carlo

Variable	Cut
Transverse Momentum	$p_T > 0.15\ (GeV/c)$
Pseudo rapidity	$\eta \in (-1.5, 1.5)$
Primary Vertex Position	$\text{Vtx} \in (-50, 50)$

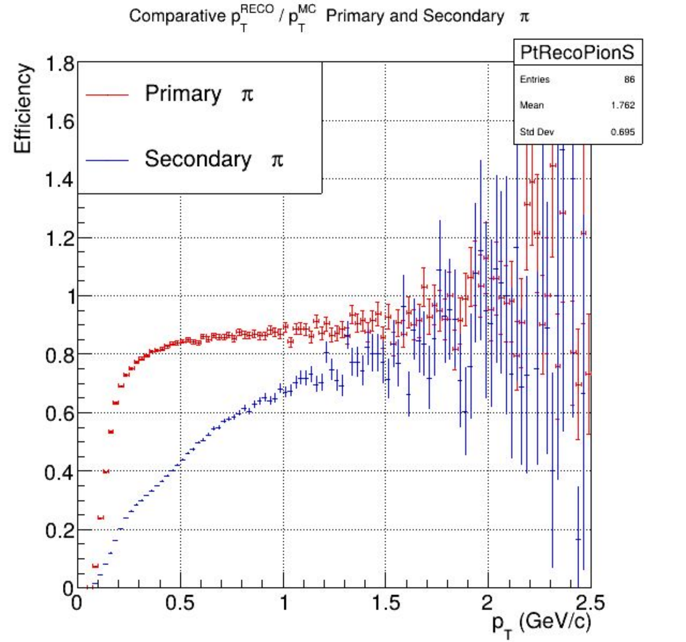
Efficiency of the Transverse Momentum of Pions

We compare low and full magnetic field:

Low Magnetic Field
10 Million events



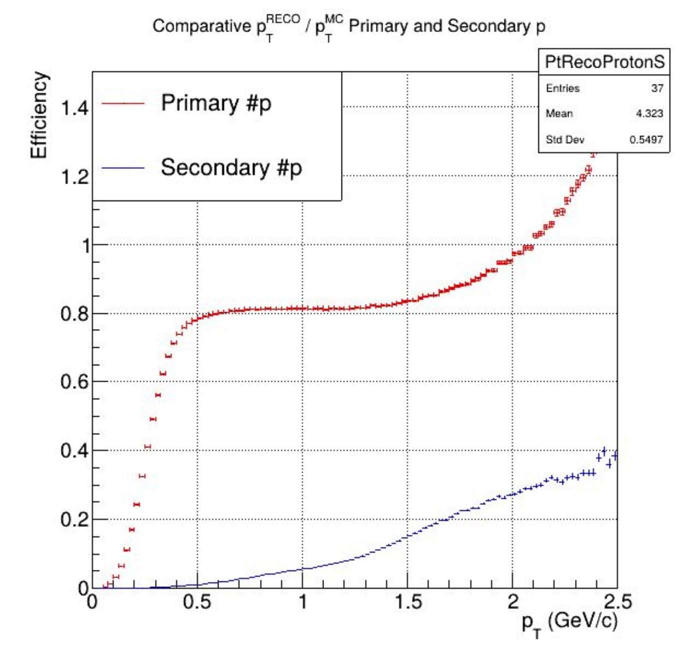
Full Magnetic Field
25, 000 events



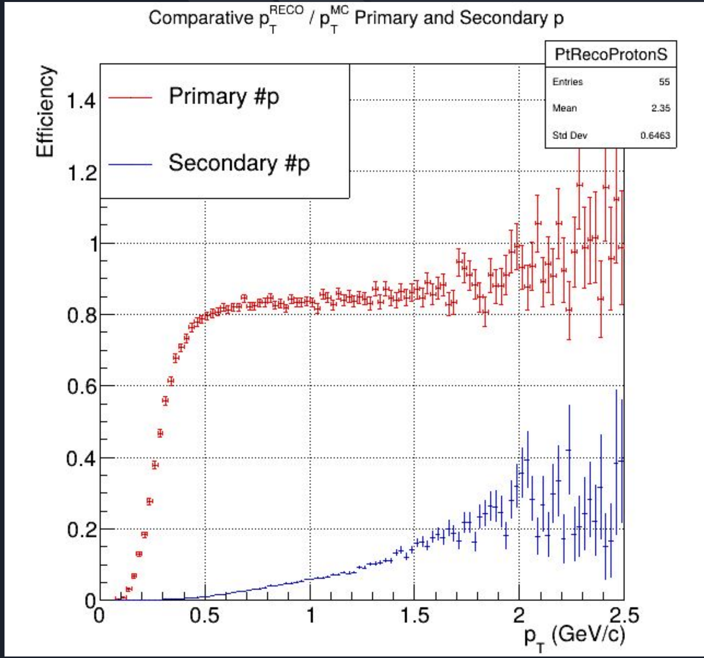
Efficiency of the Transverse Momentum of Protons

We compare low and full magnetic field:

Low Magnetic Field
10 Million events



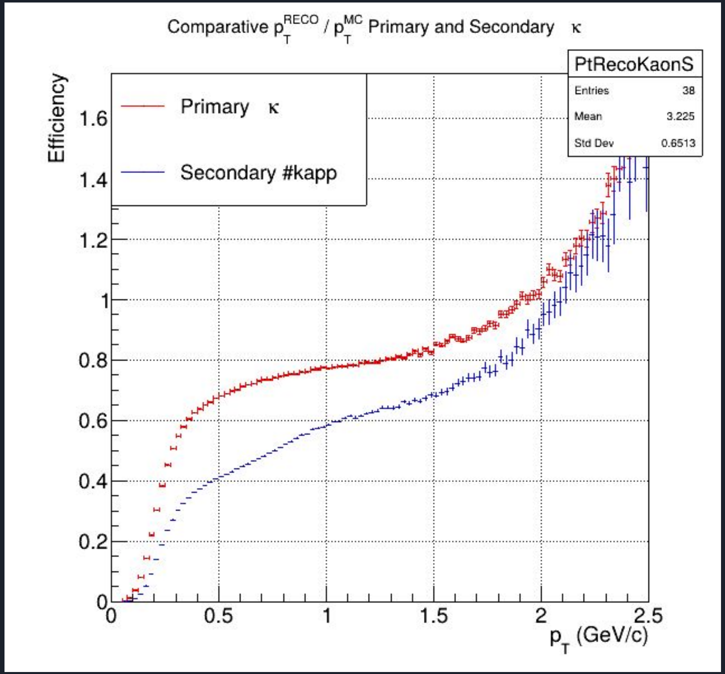
Full Magnetic Field
25, 000 events



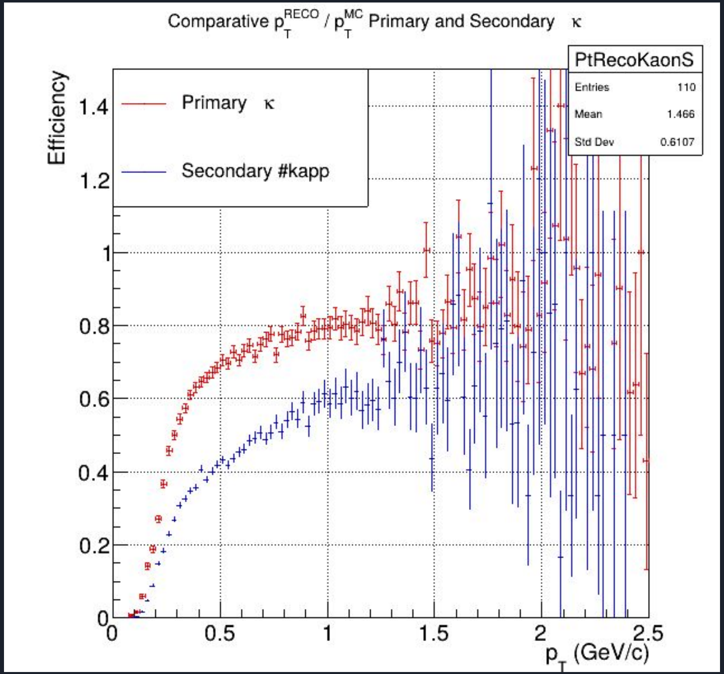
Efficiency of the Transverse Momentum of Kaons

We compare low and full magnetic field:

Low Magnetic Field
10 Million events



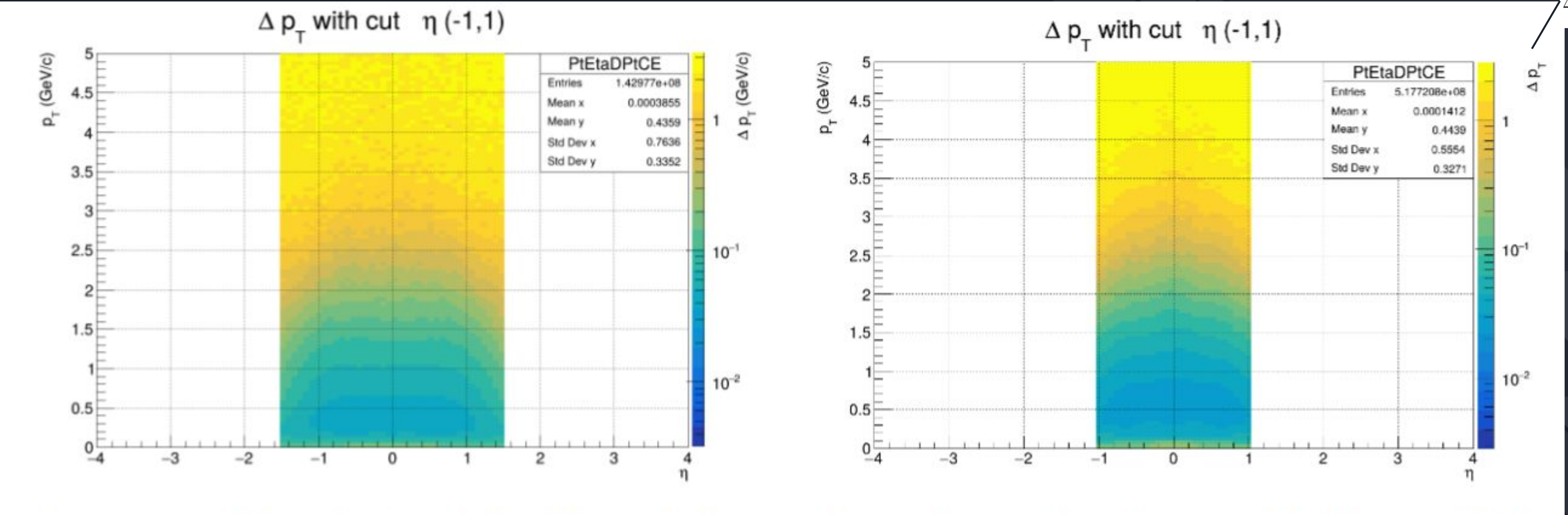
Full Magnetic Field
25, 000 events



Let's see the resolution in the phase space

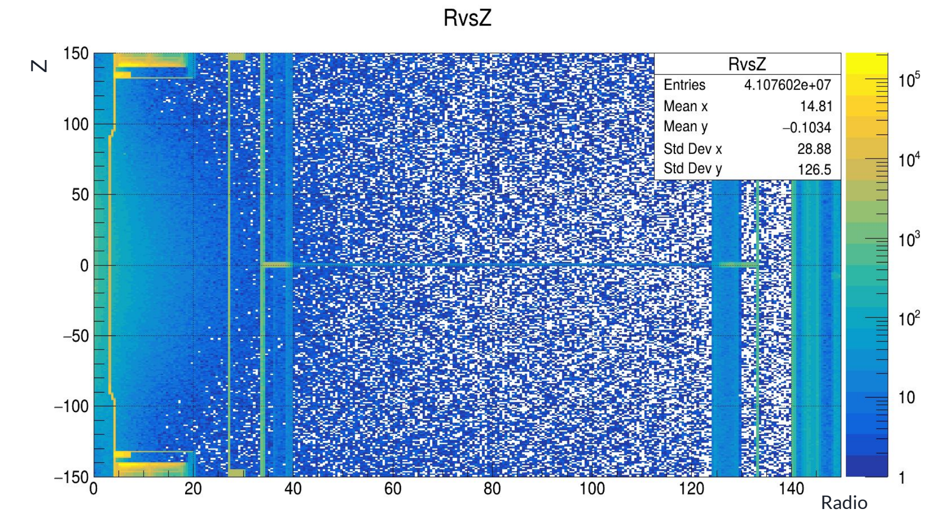
The histograms from the last pages have sense, because if we see this histogram. We can see that all up of 2 is noise.

$\Delta p_T = \frac{|p_T^{reco} - p_T^{MC}}{p_T^{MC}}$



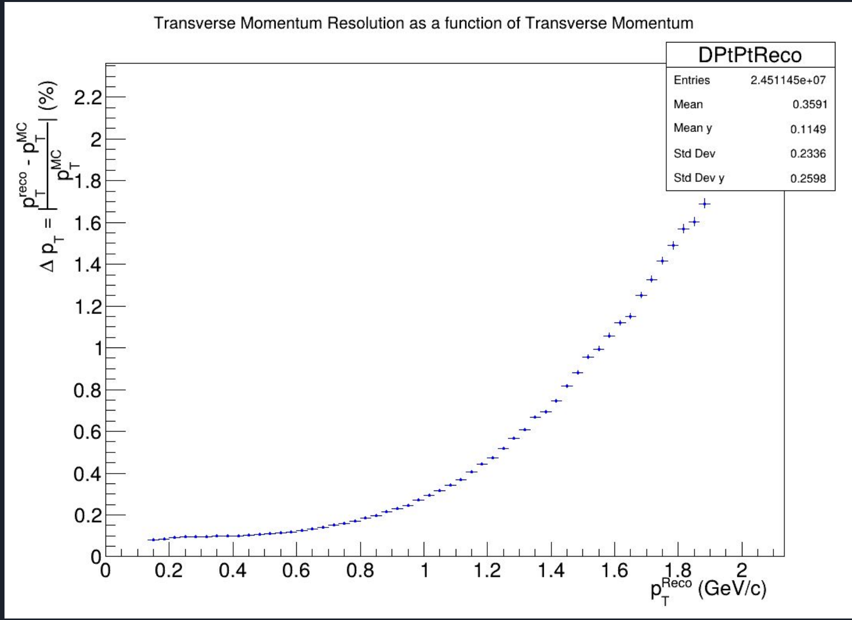
(a) The Δp_T with cut in η for Reduce Magnetic Field. (b) The Δp_T with cut in η for Full Magnetic Field.

Let’s see what happened with the secondary protons

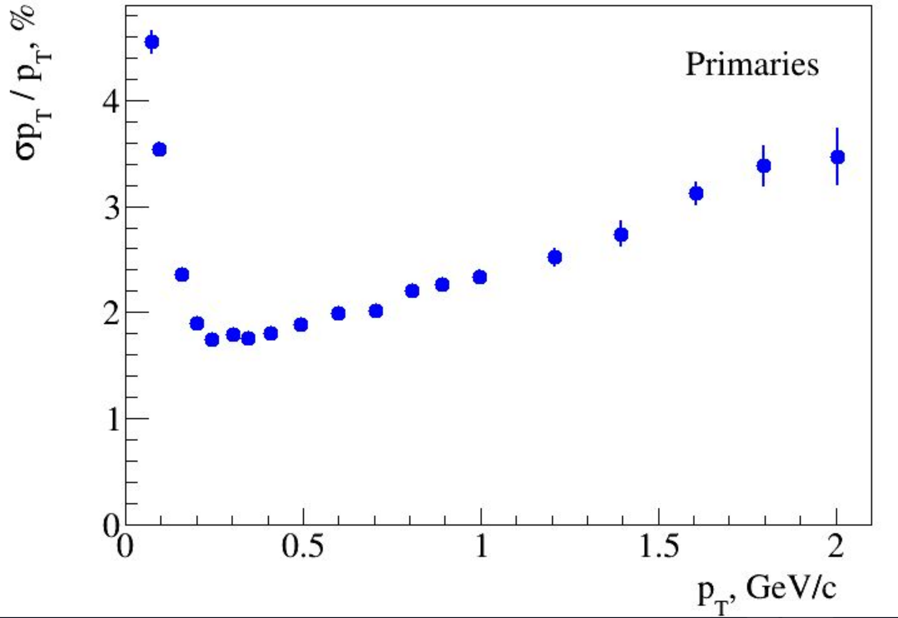


It shows that the vast majority of secondary protons are produced at the edge of the detector, resulting in very few successful reconstructions

Resolution of Resolution of Transverse Momentum versus Transverse Momentum Reconstructed

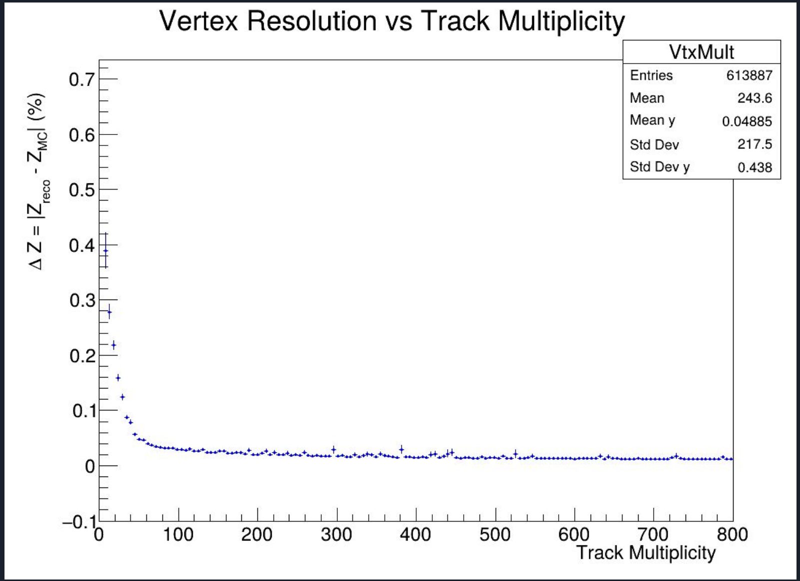


This histogram is what we obtain.

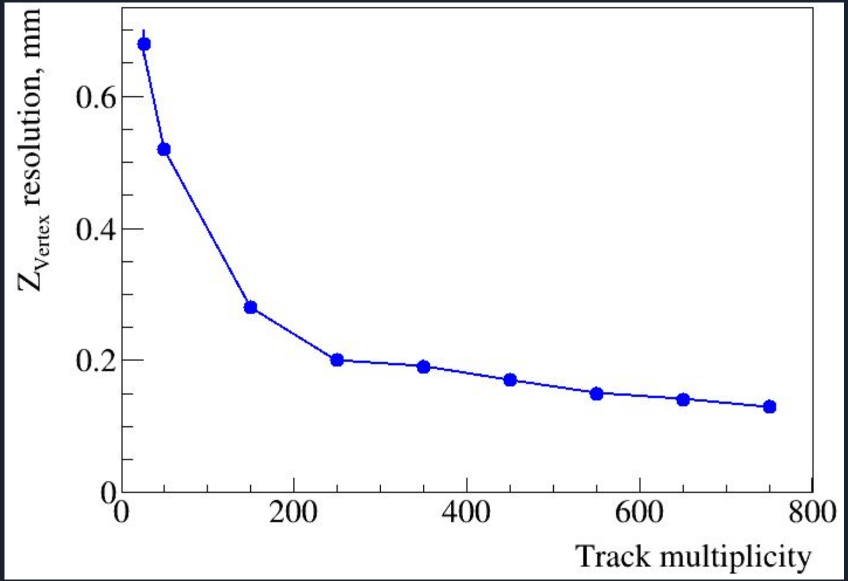


This histogram is from the paper of MPD

Resolution of Primary vertex vs Track Multiplicity



This histogram is what we obtain.



This histogram is from the paper of MPD

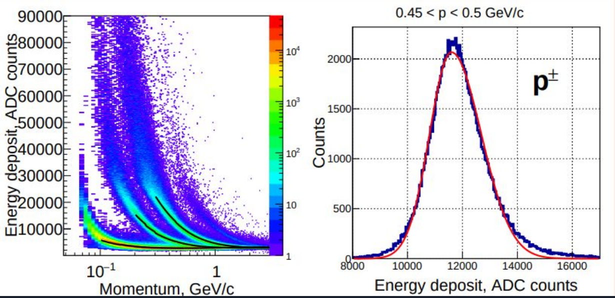
Summary

- I create my own class.
- Make different cuts on the variables.
- Compared Full and Reduced Magnetic Field.

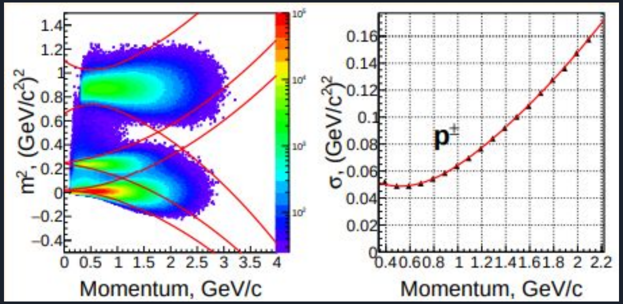
Reduce Magnetic Field Particle Identification

What do we know?

We know that PID is the combination of the probability that the detectors TPC, TOF and ECal have to detect a particle by reconstructing the tracks and thus be able to obtain parameterizations in dE/dx and m^2



TPC + TOF + ECal → Increase the number of particles identified



From the article: Particle Identification (PID) as a tool for the study of event-by-event fluctuations atMPD, Alexander Mudrokh on behalf of the MPD team.

What have we got so far?

Although the conditions we are studying are relatively new, there is already a class which performs particle identification under full magnetic field conditions

MpdPid and MpdPidQA

1. MpdPid class

1.1 Constructor with arguments

Constructor of MpdPid class:

```
MpdPid(Double_t sigM, Double_t sigE, Double_t E, Double_t C, TString generator, TString tracking, TString nSigPart);
```

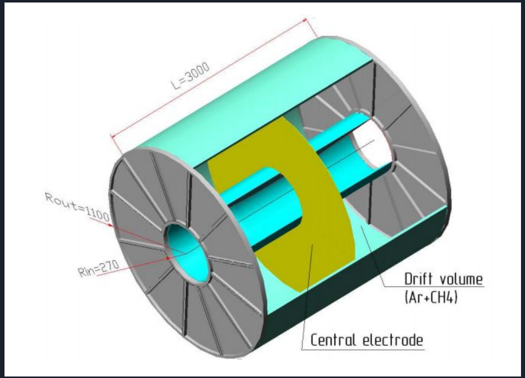
1. `sigM` – non-zero distance from the average mass-squared value (in terms of standard deviations);
2. `sigE` – non-zero distance from the average dE/dx value (in terms of standard deviations);
3. `E` – the collision energy;
4. `C` – scale coefficient of dE/dx, should be used if dE/dx has been multiplied by this value during the reconstruction process (if in doubt, put 1);
5. `generator` – the model which has been used in simulation, possible expressions are `"LAQGSM"` (`"QGSM"`), `"EPOS"`, `"URQMD"`, `"PHSD"`, `"PHSD_CENT"` (PHSD central events, 0 < b < 3 fm @ 11 GeV), `"PHSD_CSR"`, `"PHSD_NOCSR"` (PHSD + Chiral Symmetry Restoration (CSR) mechanism on/off), `"NSIG"` (model-independent n-sigma method) and `"DEFAULT"` (the "average" value, set by default);
6. `tracking` – can be `"HP"` (Hit Producer), `"CF"` (Cluster Finder MLEM) and `"CFHM"` (Cluster Finder MLEM + HEED, used by default);
7. `nSigPart` – string of particles which are used in n-sigma method, possible expressions are `"el"`, `"mu"`, `"pi"`, `"ka"`, `"pr"`, `"de"`, `"tr"`, `"he3"`, `"he4"` or their combinations.

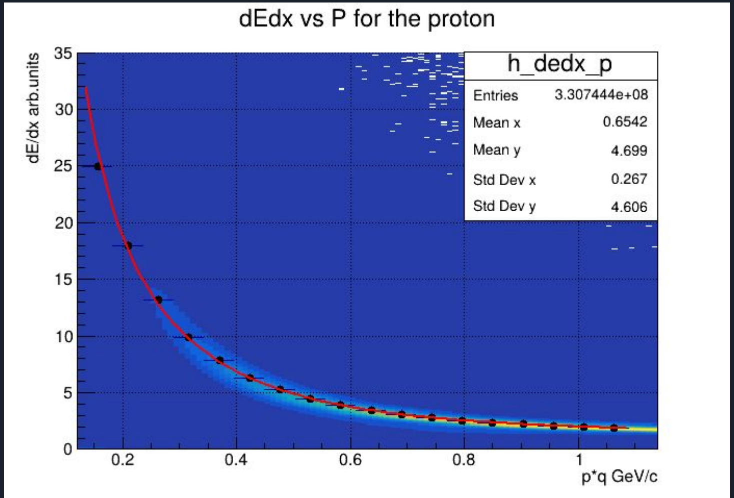
https://git.jinr.ru/nica/mpdroot/-/tree/dev/core/mpdPid

Parameterization of the energy loss dE/dx

Loss of energy by ionization is the process by which a charged particle loses energy as it passes through a medium, such as a detector

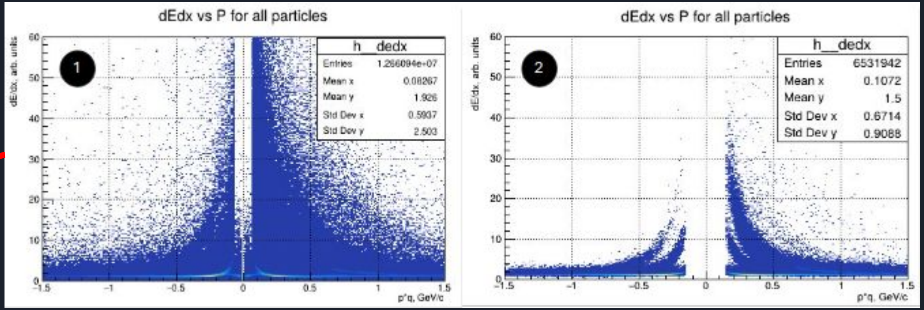
TPC → **will measure the ionization of charged particles**





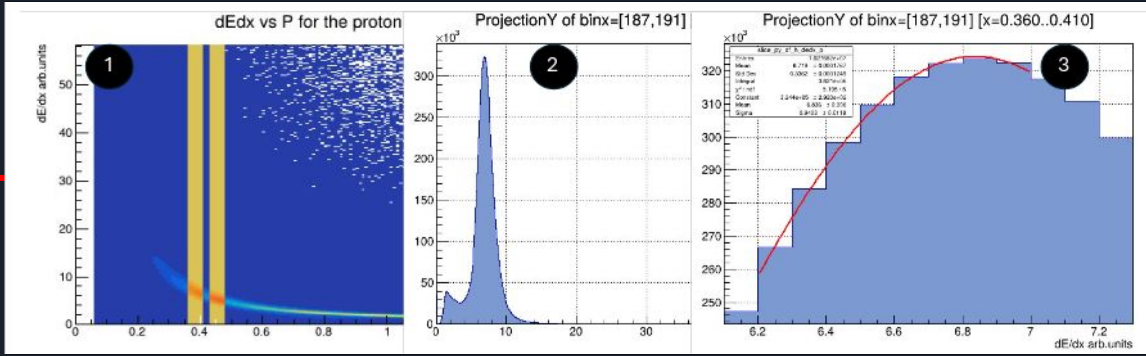
Obtaining the parameters of the Bethe-Bloch equation

Implemented the cuts for reduced magnetic field



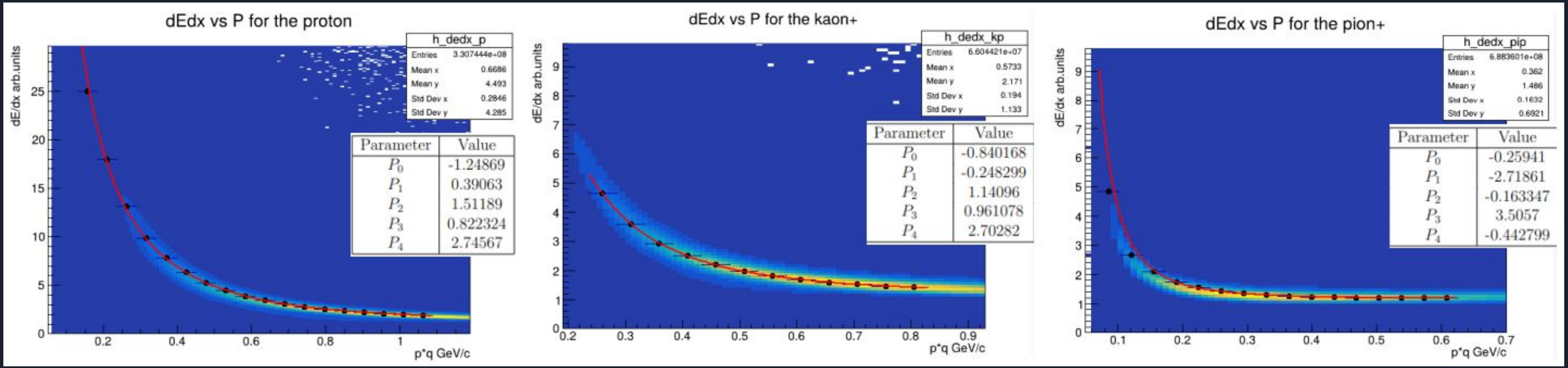
Bethe-Bloch equation obtained from class MpdPid

$$\left\langle \frac{dE}{dx} \right\rangle = \frac{P_0}{\beta^{P_3}}\left[P_1 - \beta^{P_3} - ln\left\{P_2 + \left(\frac{1}{\beta\gamma}\right)^{P_4}\right\}\right], \qquad \beta = \frac{p}{\sqrt{p^2+M^2}},$$

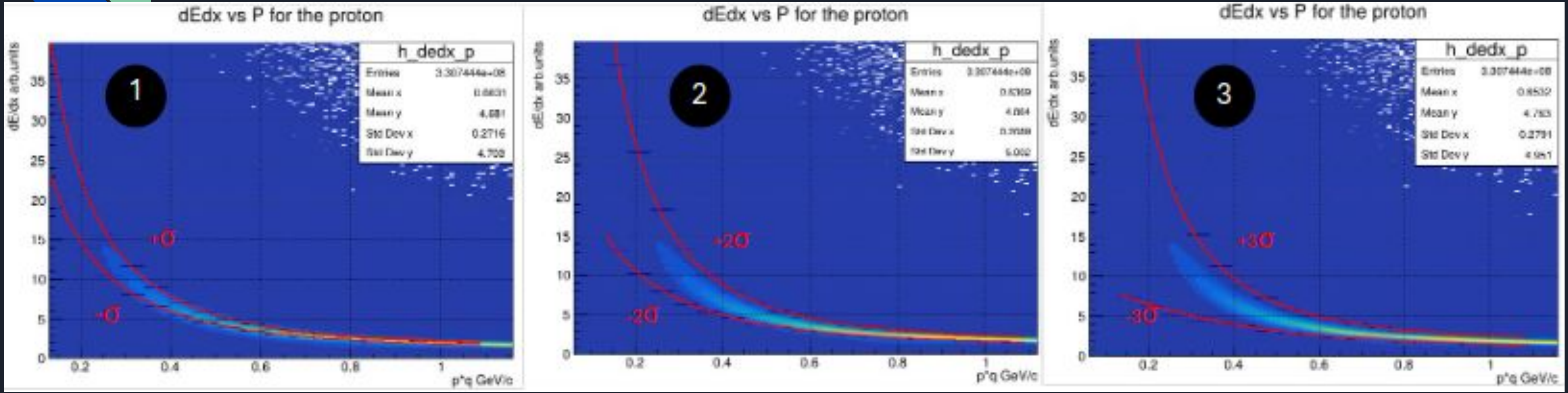


To obtain the parameters of each particle species, a specially created macro was used, which can be reviewed on the GitHub page: https://github.com/iamaldonado/START_Summer24/tree/main/AlejandroSJuan/EnerClass/Fit%20functions

Adjustment functions



Restricted distribution of energy loss



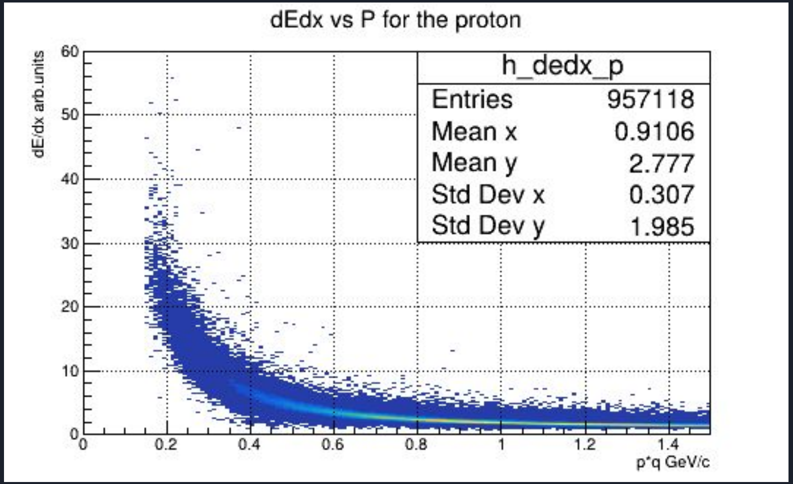
	proton		kaon		pion	
Parameter	$+1\sigma$	-1σ	$+1\sigma$	-1σ	$+1\sigma$	-1σ
P0	-2.58072	-3.70863	-0.817989	-0.564779	-0.327131	-0.182489
P1	1.16569	1.70197	-0.332111	-1.11641	-2.32774	-3.16187
P2	1.97189	2.64031	0.452453	0.799115	-0.340479	0.899613
P3	0.782313	0.434546	2.51922	0.808589	3.94556	3.10849
P4	2.20629	2.0007	0.356776	3.07986	-0.371293	-0.836771

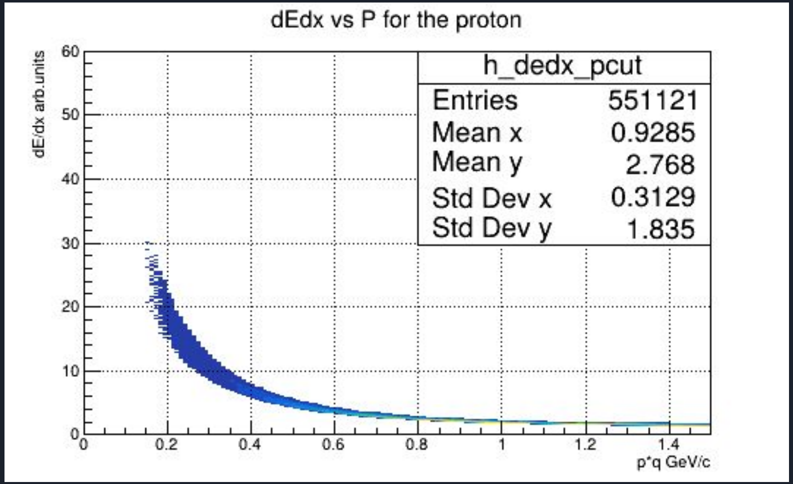
Table 3.3: *Parameters of the Bethe-Bloch equation for the limit functions "dEdx+1σ" and "dEdx-1σ".*

choosing a multiple of different sigma delimits a greater or lesser region, because it is known that about 68% of the value obtained from a normal distribution lies within a range of one σ (standard deviation)

Restricted distribution of energy loss

For protons

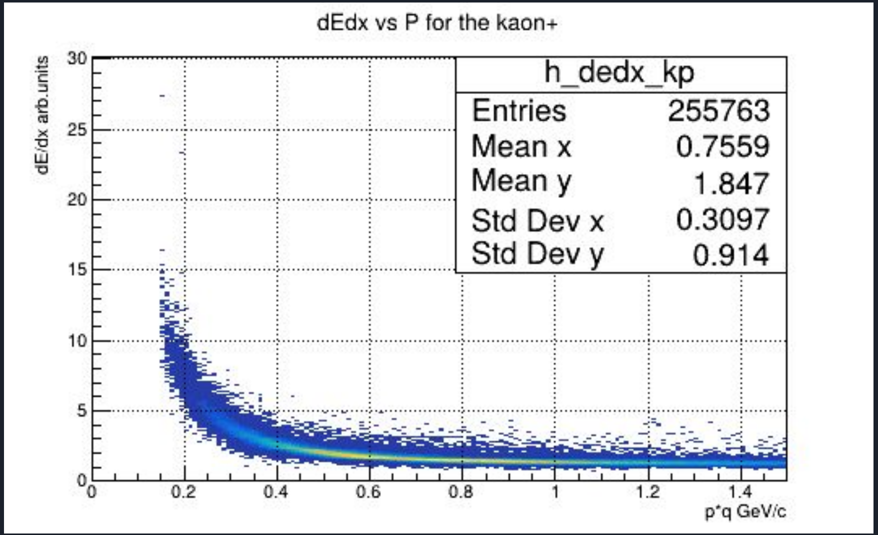


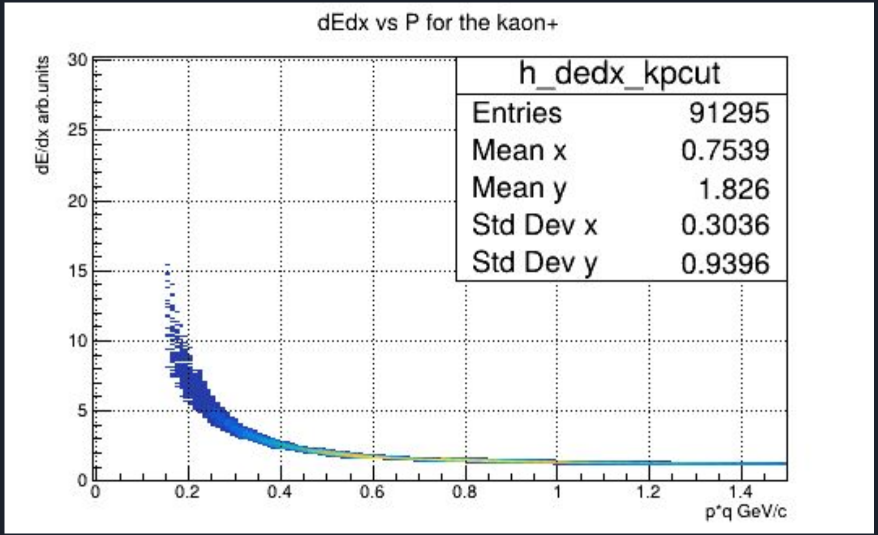


Percentage of particles eliminated: 57%

Restricted distribution of energy loss

For Kaons

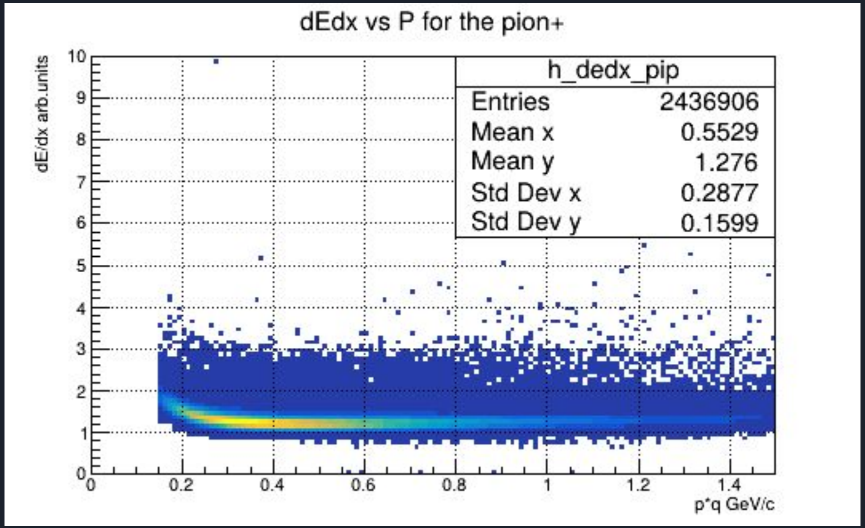


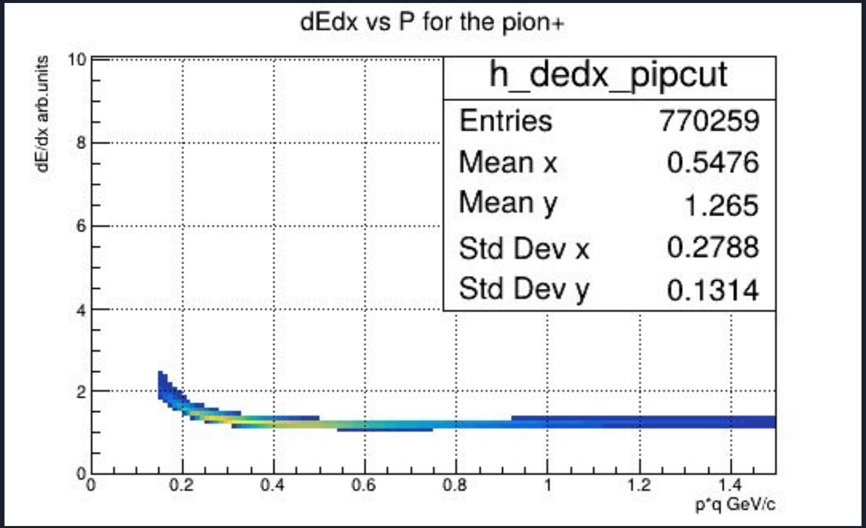


Percentage of particles eliminated: 35.7%

Restricted distribution of energy loss

For Pions



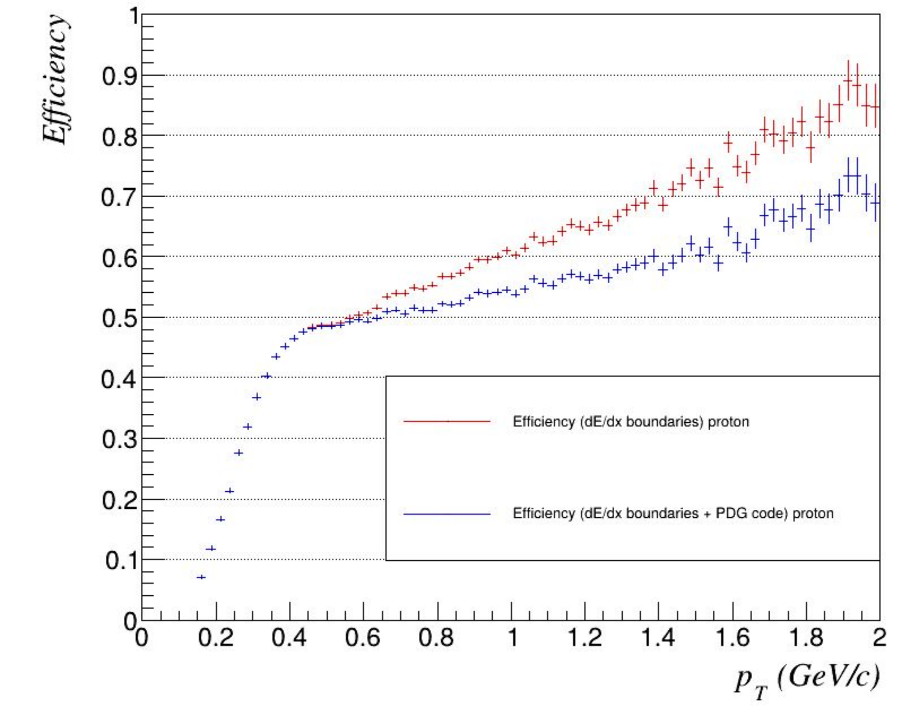


Percentage of particles eliminated: 31.6%

Efficiency

For Protons

$$Efficiency = \frac{right\ identified\ tracks}{alltrcks} = \frac{pT\ of\ reconstructed\ tracks}{pT\ of\ Monte\ Carlo\ tracks}$$



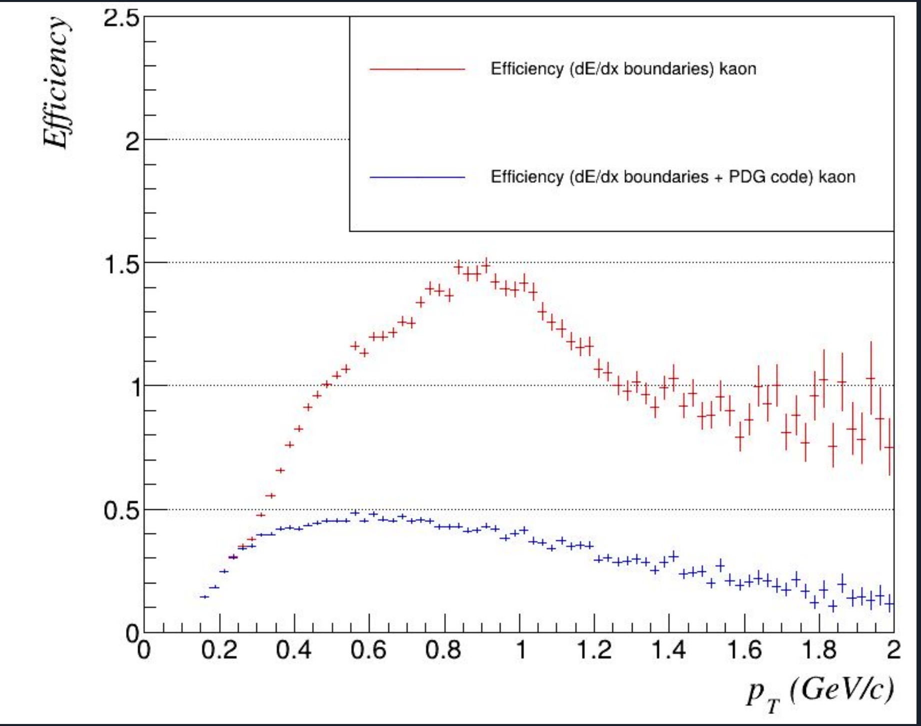
Two cases:
1.-pT with restriction on the value of dE/dx

2.- pT with restriction on the value of dE/dx + classification by PDG code

Efficiency

For Kaons

$$Efficiency = \frac{right\ identified\ tracks}{alltrcks} = \frac{pT\ of\ reconstructed\ tracks}{pT\ of\ Monte\ Carlo\ tracks}$$



Two cases:
1.-pT with restriction on the value of dE/dx

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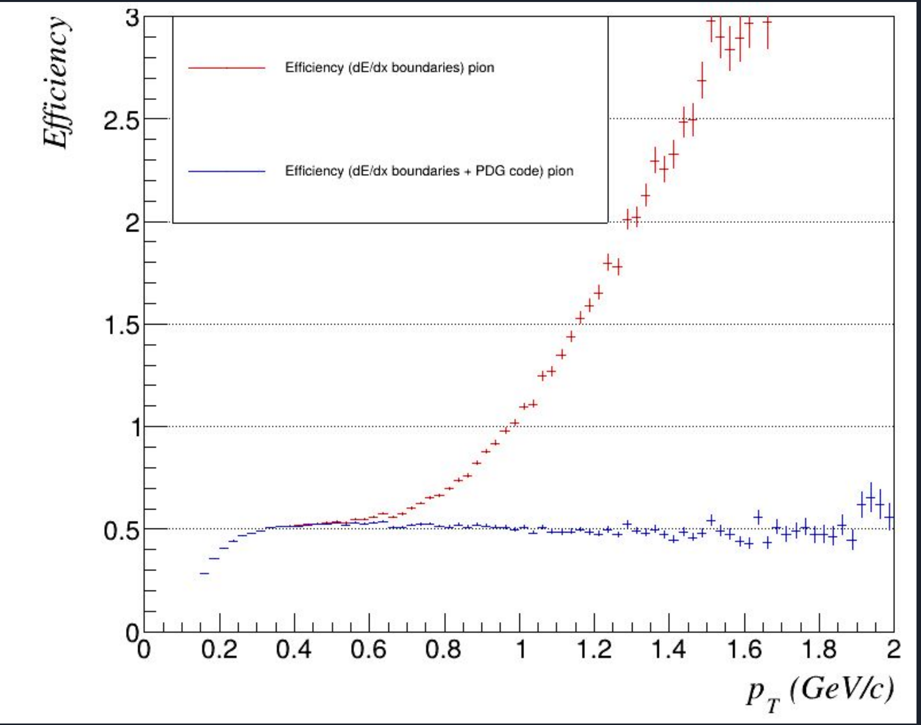
Efficiency

For Kaons

$$Efficiency = \frac{right\ identified\ tracks}{alltrcks} = \frac{pT\ of\ reconstructed\ tracks}{pT\ of\ Monte\ Carlo\ tracks}$$



Two cases:

1.-pT with restriction on the value of dE/dx

2.- pT with restriction on the value of dE/dx + classification by PDG code

Future Work

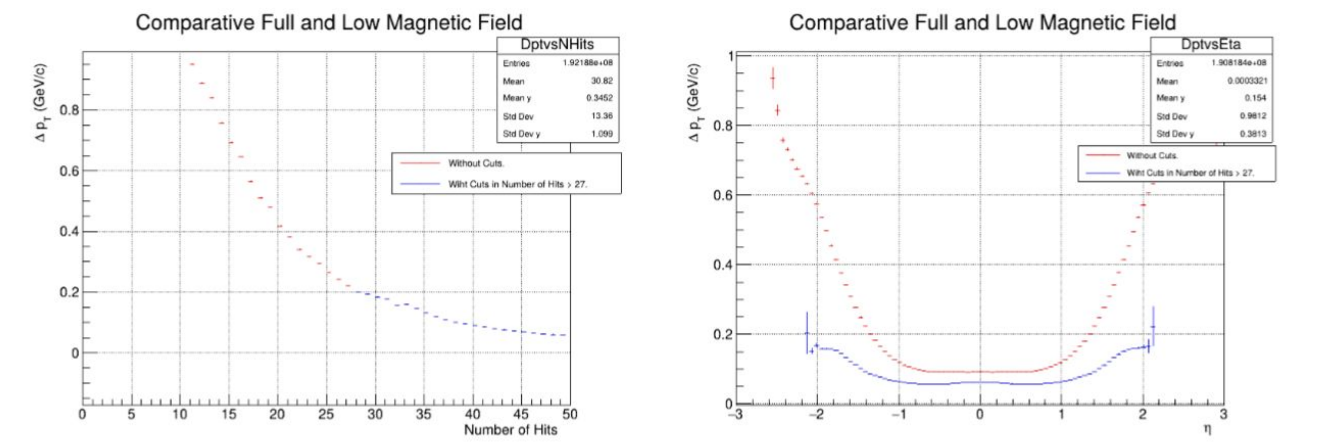
- We have a preliminar cuts for the case of reduce magnetic field. But we will try to continue this analysis and optimize the cuts.
- We will continue with this work from Mexico, and we are available for any analysis you may request.

Thanks..!!

BACKUP

Cut on the Number of Hits

We obtain the distribution of the resolution of transverse momentum against Number of Hits and against, we make a cut in Number of Hits > 27 and comparative this distribution without cuts.

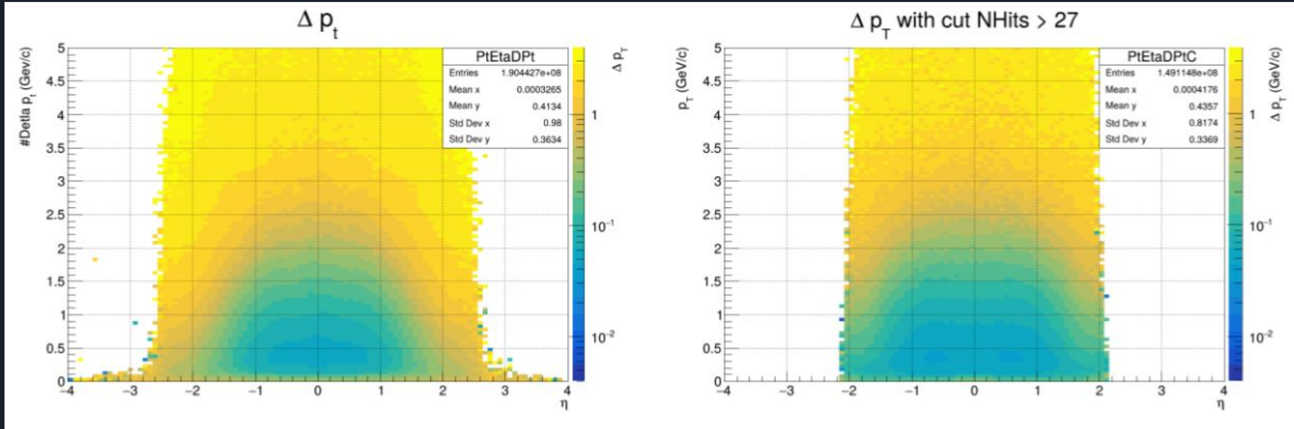


(a) Comparative of Δp_T vs Number of Hits with and without cuts Number of Hits.

(b) Comparative of Δp_T vs η cuts Number of Hits and cut in Number of Hits.

Cut on the Number of Hits

We obtained DCA Global's awards for all particles and primary and secondary particles. We divide primary into all particles and secondary into all particles

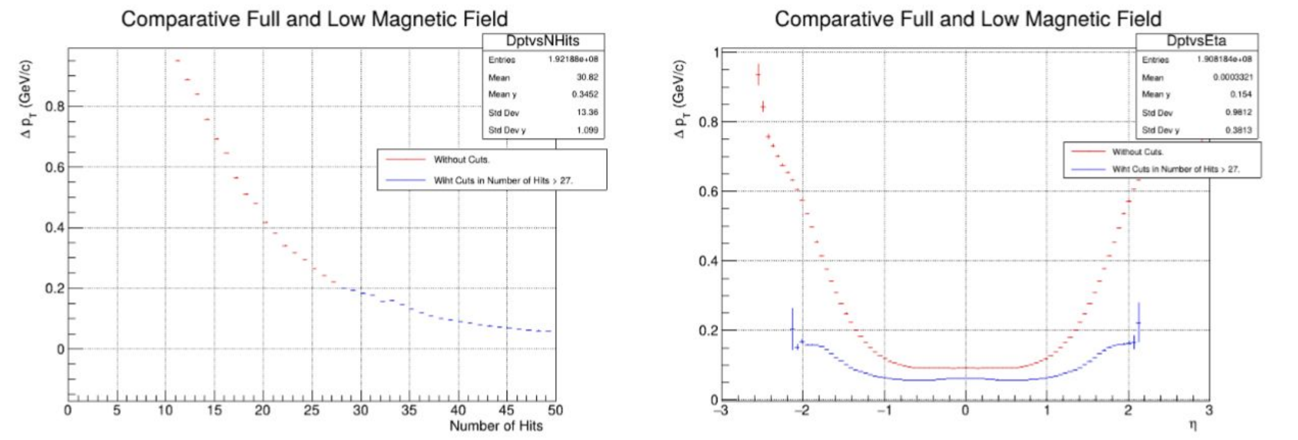


(a) The Δp_T without cut.

(b) The Δp_T with cut in Number of Hits.

Cut on the Pseudorapidity

We obtain the distribution of the resolution of transverse momentum against pseudorapidity, we make a cut ∈ (-1.5, 1.5) and comparative this distribution without cuts.

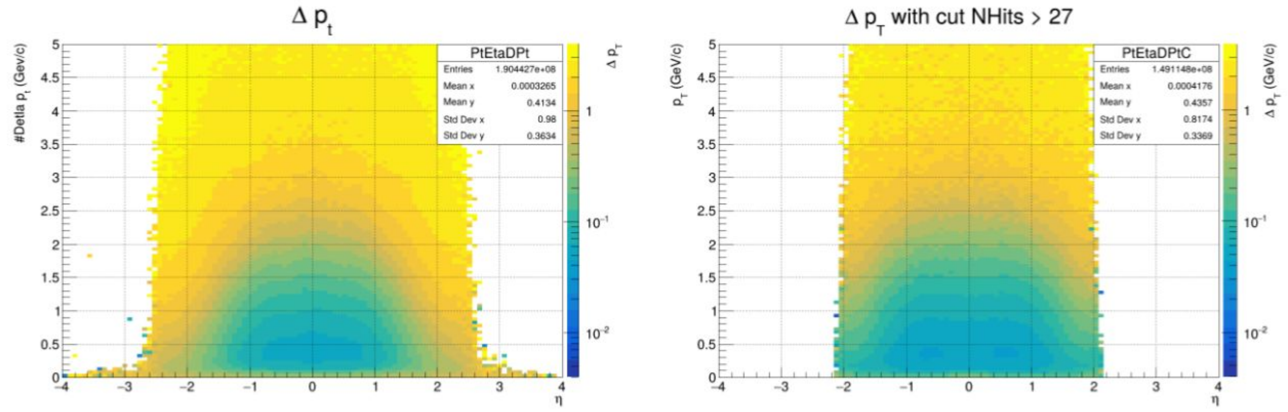


(a) Comparative of Δp_T vs Number of Hits with and without cuts Number of Hits.

(b) Comparative of Δp_T vs η cuts Number of Hits and cut in Number of Hits.

Cut on the Pseudorapidity

We obtained DCA Global's awards for all particles and primary and secondary particles. We divide primary into all particles and secondary into all particles



(a) The Δp_T without cut.

(b) The Δp_T with cut in Number of Hits.