2 Track Analysis for the Glueball Search at 13 TeV for Proton-Proton Collision

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Abstract

An analysis of proton-proton collisions at 13 TeV was conducted using the C++ programming language and the ROOT data analysis framework. Ntuples were utilized to store particle properties, which were subsequently visualized and analyzed through 2D and 1D histograms. Gaussian fits were applied to characterize distributions and identify potential statistical significance. Additionally, plots of `dE/dx` against P were created to investigate changes in energy loss, and plots of `P` against tracks were generated to test the conservation of momentum. While most histograms exhibited expected behavior, an intriguing irregularity was observed in the `dxy` distribution against the azimuthal angle: a wavy, unphysical variation. This unexpected pattern suggests a potential systematic effect that requires further investigation.

1 Introduction

The TOTEM experiment at LHC utilizes Roman Pot detectors strategically positioned within the Compact Muon Solenoid (CMS) detector in a diagonal and parallel configuration relative to the beam direction to conduct a comprehensive search for the elusive glueball particle. By meticulously analyzing the outcomes of high-energy elastic proton-proton collisions at 13 TeV, we aim to unravel the properties of this enigmatic particle.

The collisions produce a plethora of short-lived particles, including the glueball, which can decay into two tracks of mesons. These mesons subsequently decay into four tracks composed of pions and kaons, necessitating precise tracking of scattered beams to identify potential glueball candidates. The LHC's intricate detector system necessitates the careful definition of key kinematic variables for both CMS and TOTEM experiments due to their distinct kinematic coverage. While CMS primarily focuses on transverse momentum, TOTEM specializes in forward physics. The center-of-mass energy for these experiments was set at $\sqrt{s} = 13$ TeV, implying that each beam carried an energy of 6.5 TeV.

Key parameters analyzed during my research included transverse momentum P_t, pseudo-rapidity η, azimuthal angle ϕ, energy loss (`dE/dx`), and z-distance (`dz`), where the pseudo-rapidity is given as:

$$\eta \equiv -\ln\left(\tan\frac{\theta}{2}\right)$$

These parameters provide crucial information about the momentum, angular distribution, energy loss, and origin of the particles, enabling us to effectively distinguish between glueball candidates and background processes.

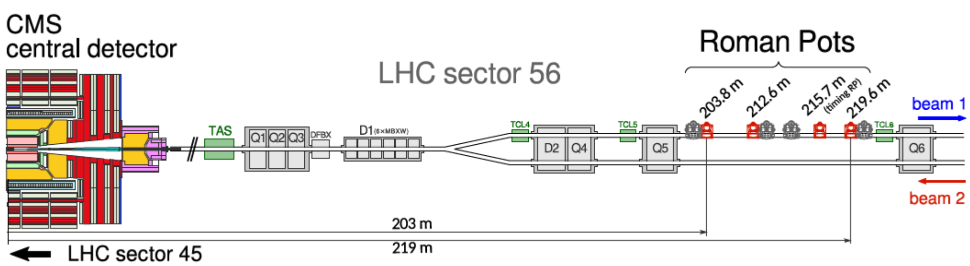


Figure 1: System view of the CMS roman pot detector.

2 Results and Discussions

2.1 Energy Loss vs Momentum

Figure 2 shows a scatter plot investigating the relationship between energy loss (`dE/dx`) and momentum (P). A clear inverse proportionality between `dE/dx` and `P` is observed, suggesting that particles with lower momentum tend to lose more energy as they traverse the detector.

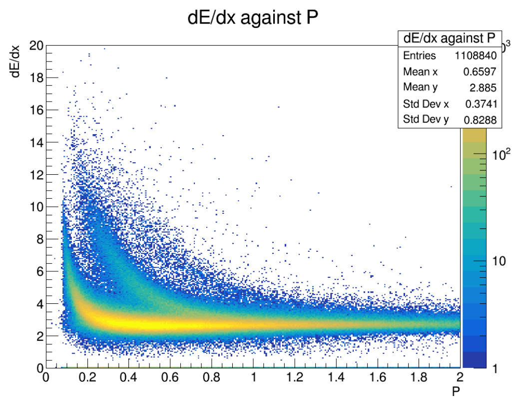


Figure 2: Scatter plot of energy loss (`dE/dx`) against transverse momentum P.

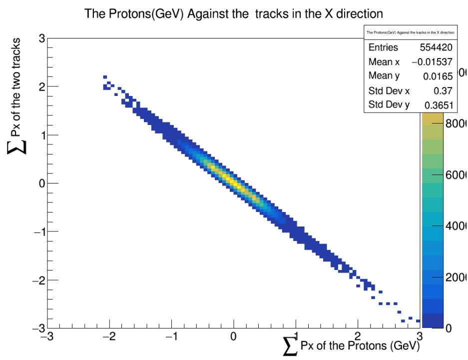
The scatter plot exhibits a smooth pattern, indicating no significant deviations from the expected trend. This observation supports the reliability of the data.(Some furthur analysis needs to be done to be sure)

2.2 Conservation of Momentum

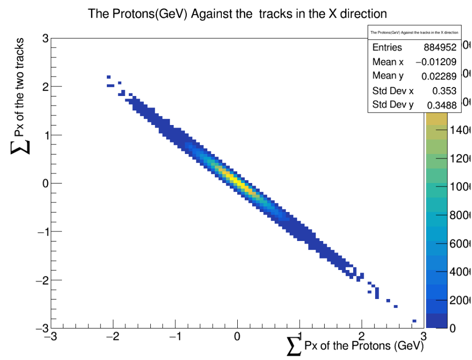
The Noether's theorem follows that if a system is invariant under translations in the transverse direction, then the transverse momentum of the system is conserved,and to test for that the conservation of momentum in the particles and the tracks were checked:

$$P_{(xR)} + P_{(xL)} + P_{(x1)} + P_{(x2)} = 0$$
$$P_{(yR)} + P_{(yL)} + P_{(y1)} + P_{(y2)} = 0$$
$$P = P_t \cdot \cosh\eta, \quad P_x = P_t\cos\phi, \quad P_y = P_t\sin\phi$$

where; $P_{(x1)}$,$P_{(x2)}$ are the components of the P_t in the X-direction
$P_{(y1)}$,$P_{(y2)}$ are the component of the P_t in the Y-direction
ϕ is a measure of the angular position of a particle in the plane perpendicular to the beam axis
R = sector 56 and L = sector 45 of the detectors

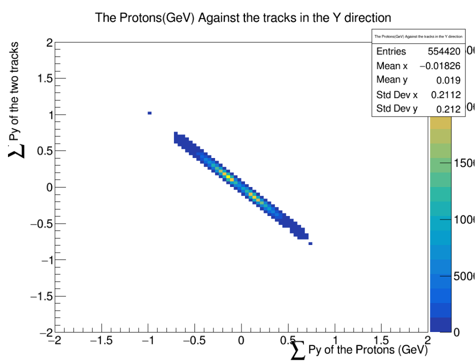


(a) for the diagonal detector

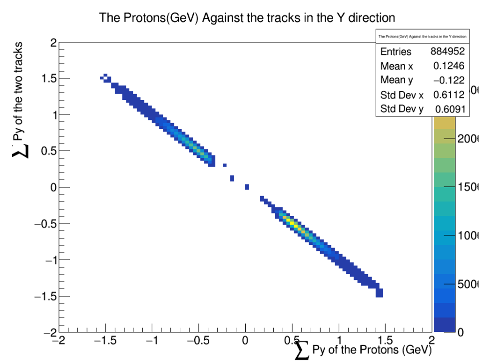


(b) for the parallel detector

Figure 3: Both graphs illustrate the x-component of track momentum versus proton momentum



(a) for the diagonal detector



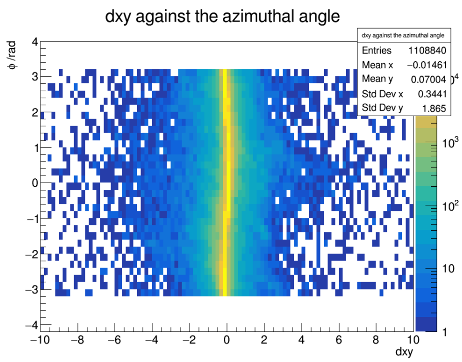
(b) for the parallel detector

Figure 4: Both graphs illustrate the y-component of track momentum versus proton momentum

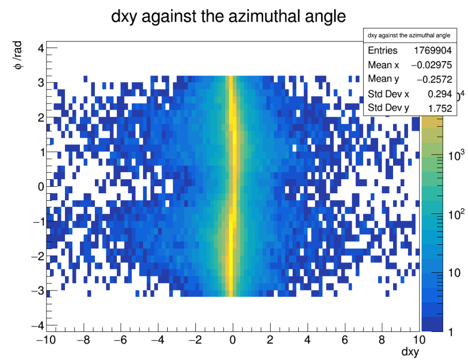
From the graph, the coordinates look symmetrical, so we can say the momentum is conserved in the track system.

2.3 Unphysical variation of the azimuthal angle

A deeper analysis of the four identified tracks revealed intriguing patterns in their properties. Notably, certain scatter plots displayed distinct peaks, suggesting potential anomalies or fluctuations within the data. To validate the consistency of these observations, additional plots were generated comparing the d_{xy} (distance of closest approach to the beamline) against the ϕ (azimuthal angle) for two of the tracks. This analysis sought to determine whether the observed peaks were persistent or merely statistical artifacts.



(a) for the diagonal detector



(b) for the parallel detector

Figure 5: Both Graphs are distribution of the dxy against the Azimuthal Angle

From the graph it can be observed that the the direction of the beam chanegs slightly at -1 and later got back to track at 1

3 Conclusion

This study conducted a thorough analysis of proton-proton collisions at 13 TeV using advanced data analysis techniques. The results showed that most histograms behaved as expected, validating the experimental setup and analysis method. However, the irregularities observed in the `dxy` versus `phi` distribution suggest that further investigations are needed to identify the root cause of these anomalies. The ongoing analysis will focus on identifying systematic effects that could explain the unexpected patterns and further refining the search for the elusive glueball particle.

References

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