NET CHARGE FLUCTUATIONS IN *p-p* COLLISIONS AT 13 TeV

Sameeksha Hiwale (200260045) Yashasvi Bhatt (200260059)
Niare Doyom (200260032) Baddam Hemanth Reddy (200260013)
Snehal Naik (200260053) Shreya Shrivastava (200260051)
Rhishabh Suneeth (200260040) Shadab Anjum (200260048)

Indian Institute of Technology Bombay, Mumbai, India

ABSTRACT

An understanding of trends observed in net charge fluctuations for simple systems like *p-p* systems is useful as it can be extended to systems involving heavier ions. In this report we analyse the net charge fluctuations observed in hadronic collisions with respect to multiplicity. In order to analyse the given data we plot 1-D histograms and scatter plots for six multiplicity classes. We quantify the net charge fluctuations by examining deviation observed from a Gaussian fit in charge distributions and overall net charge trends per event in terms of mean and variance.

1 INTRODUCTION

Investigation of fluctuations in experimental observables such as pseudorapidity (η), transverse momenta (p_T), charged-particle multiplicity etc. helps in better understanding the mechanism of charged particle production in a collision system and in judging if other collision types also show similar trends. The collision system being examined in this report is a *p-p* collision at centre-of-mass energy 13 TeV. Charged-particle multiplicity if defined as the number of charged particles being produced from an interaction, which in this case is a *p-p* collision. For analysis, the acceptance region has been defined based on pseudorapidity (η) and transverse momenta values (p_T). Particles with $|\eta| < 1.0$ and $p_T > 0.05$ GeV/c are chosen to belong to the acceptance region and $|\eta| > 1$ to be in the non-acceptance region. For this analysis, the net charge for each event (unless otherwise mentioned) is defined as the sum of charges of the charged particles in the acceptance region ($|\eta| < 1$ and $p_T > 0.05$ GeV/c) produced during the *p-p* collision.For particles in the acceptance region ($|\eta| < 1$ and $p_T > 0.05$ GeV/c) having variance of net charge per event σ^2 and mean net charge per event μ, we define the scaled variance as follows:

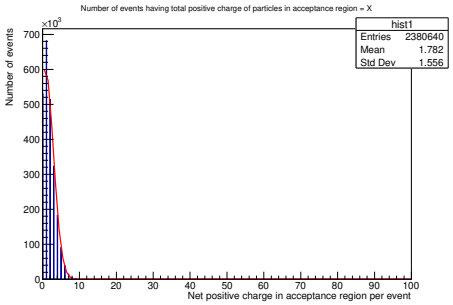
$$\textit{Scaled Variance} = \sigma^2_{scaled} = \sigma^2/\mu^2$$

The data for this system consists of 4 million events and has been generated using the PYTHIA 8 Monte Carlo generator. The data was sorted into six different multiplicity classes namely, *pytree020, pytree2040, pytree4060, pytree6080, pytree80100* and *pytree100*, classified based on their multiplicity ranges.

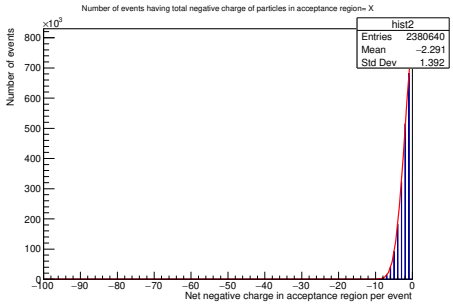
2 EXPERIMENTAL OBSERVATIONS

In sections 2.1-2.6 we look at positive (N_+), negative (N_-) and net charge ($N_{ch} = N_+ - N_-$) distributions with respect to multiplicity in the form of 1-D histograms. For the multiplicity histograms , the binning has been done in the region of particles having $|\eta| > 1.5$. We also try to determine if there exists any correlation between charged-particle multiplicities in the region with $|\eta| < 1.0$ and $p_T > 0.05$GeV/c, and region with $|\eta| > 1$ using scatter plots. If particles are produced independently then there will be no correlation observed in the scatter plots, and hence, by the central limit theorem, the charge distributions are expected to be Gaussian. In each of the plots, the red marker indicates a Gaussian fit.

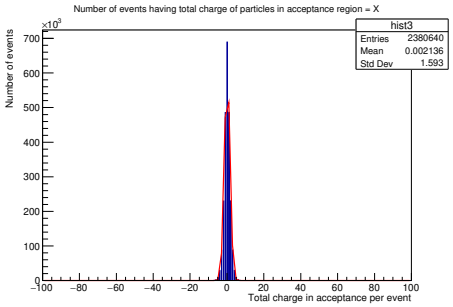
2.1 Multiplicity Class *pytree020*



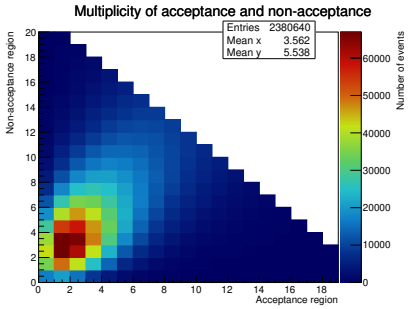
(a) Frequency vs. N_+



(b) Frequency vs. N_-



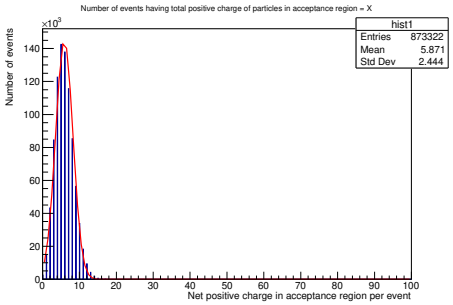
(c) Frequency vs. N_{ch}



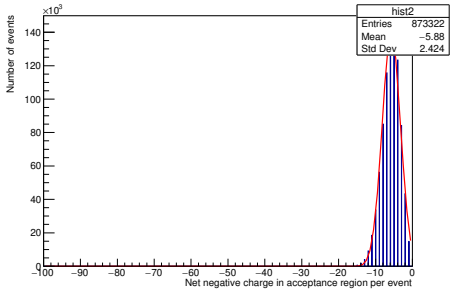
(d) Multiplicity scatter plot

Figure 1: Plots for events in the multiplicity range 0-20

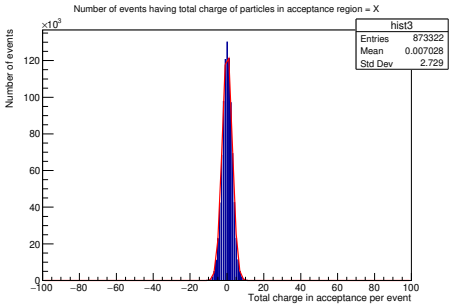
2.2 Multiplicity Class *pytree2040*



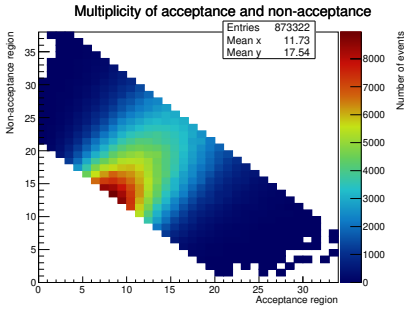
(a) Event Frequency vs. N_+



(b) Event Frequency vs. N_-



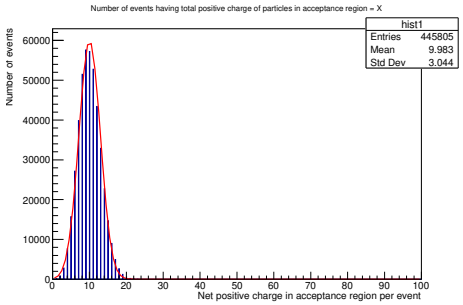
(c) Event Frequency vs. N_{ch}



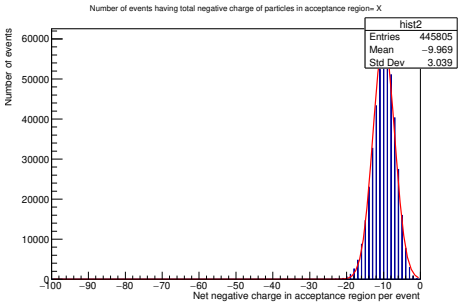
(d) Multiplicity scatter plot

Figure 2: Plots for events in the multiplicity range 20-40

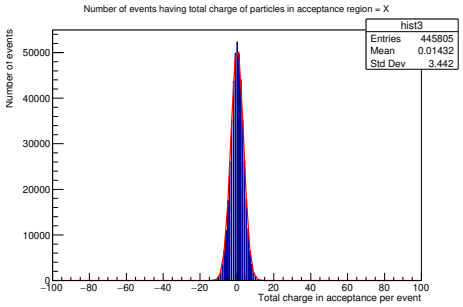
2.3 Multiplicity Class *pytree4060*



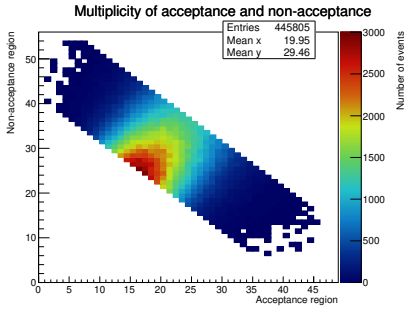
(a) Event Frequency vs. N_+



(b) Event Frequency vs. N_-



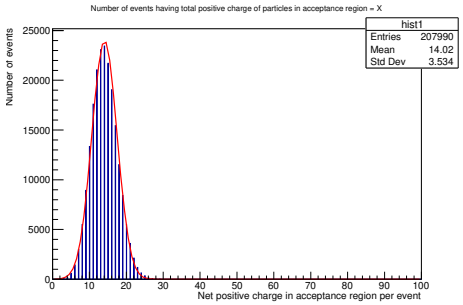
(c) Event Frequency vs. N_{ch}



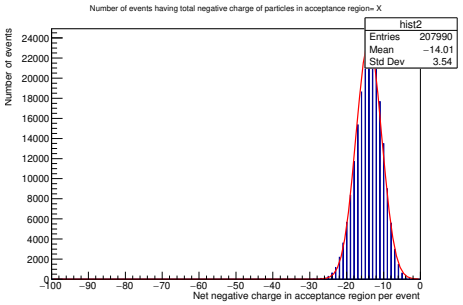
(d) Multiplicity scatter plot

Figure 3: Plots for events in the multiplicity range 40-60

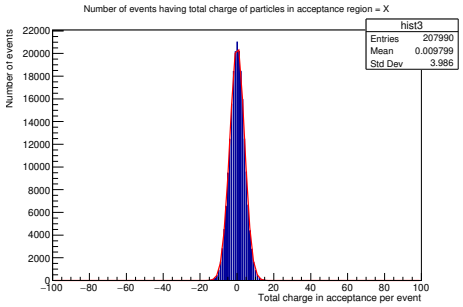
2.4 Multiplicity Class *pytree6080*



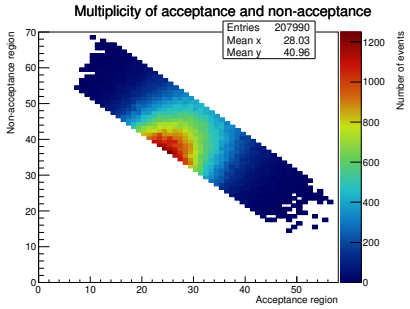
(a) Event Frequency vs. N_+



(b) Event Frequency vs. N_-



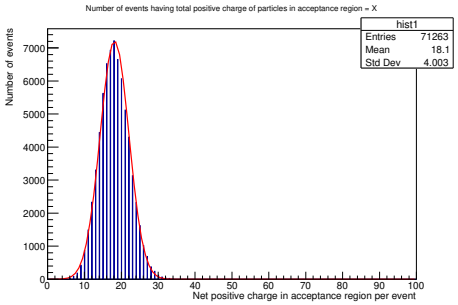
(c) Event Frequency vs. N_{ch}



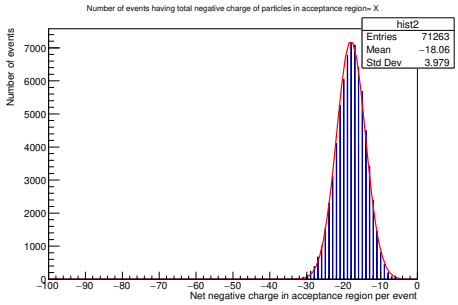
(d) Multiplicity scatter plot

Figure 4: Plots for events in the multiplicity range 60-80

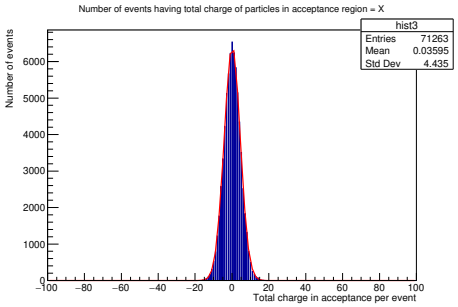
2.5 Multiplicity Class *pytree80100*



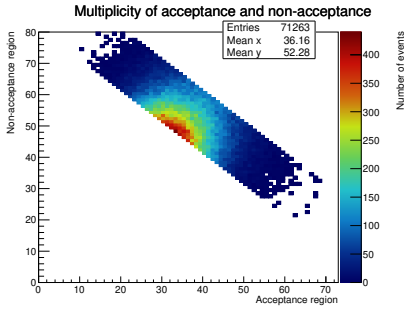
(a) Event Frequency vs. N_+



(b) Event Frequency vs. N_-



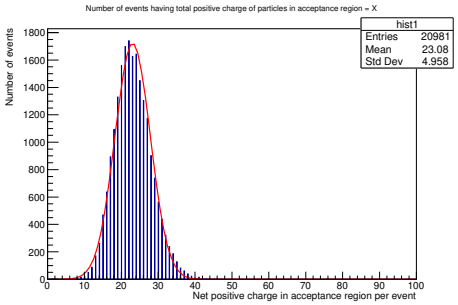
(c) Event Frequency vs. N_{ch}



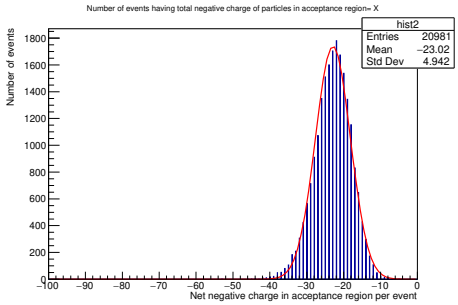
(d) Multiplicity scatter plot

Figure 5: Plots for events in the multiplicity range 80-100

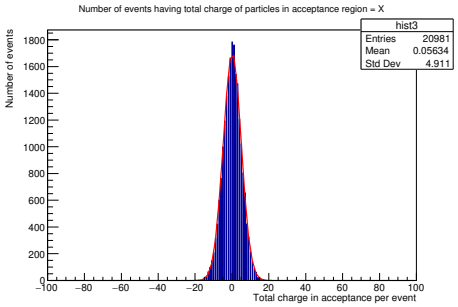
2.6 Multiplicity Class *pytree100*



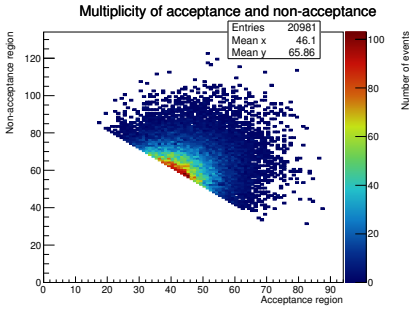
(a) Event Frequency vs. N_+



(b) Event Frequency vs. N_-



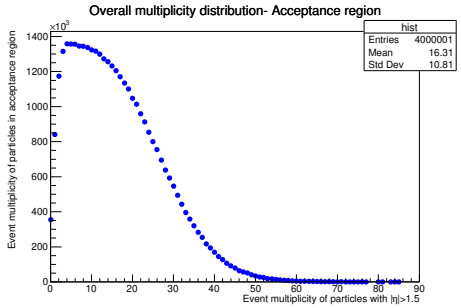
(c) Event Frequency vs. N_{ch}



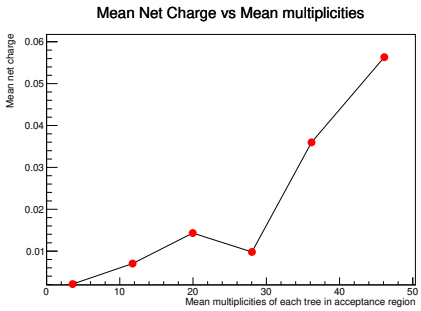
(d) Multiplicity scatter plot

Figure 6: Plots for events with multiplicity beyond 100

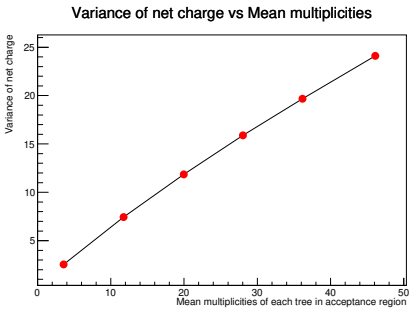
2.7 Overall trends



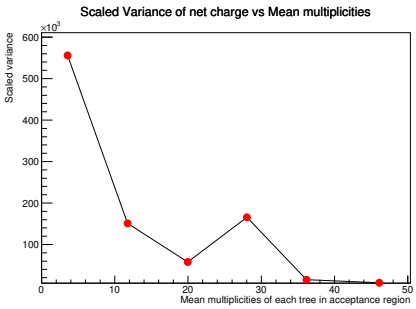
(a) Multiplicity distribution for $|\eta| < 1.0$, $p_T > 0.05$ GeV/c



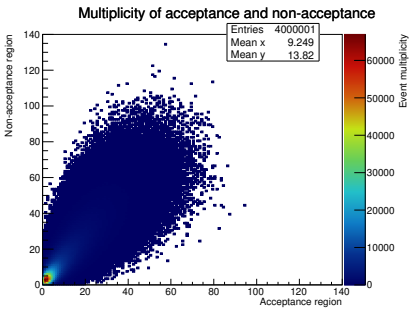
(b) Mean Net Charge vs. Multiplicity



(c) Variance of Net Charge vs. Multiplicity



(d) Scaled variance $\left(\frac{\sigma^2}{\mu^2}\right)$ of Net Charge vs. Multiplicity



(e) Overall multiplicity scatter plot

Figure 7: Overall trends

3 SUMMARY

Multiplicity class	Number of Events	Mean Net charge (μ)	Variance (σ^2)	Scaled Variance (σ^2/μ^2)	Mean multiplicity
pytree020	2380640	0.00213598	2.5362	1187.37	3.56205
pytree2040	873322	0.00702834	7.44593	1059.42	11.7344
pytree4060	445805	0.0143224	11.8498	827.363	19.9509
pytree6080	207990	0.00979855	15.8854	1621.2	28.032
pytree80100	71263	0.0359513	19.6655	547.004	36.1607
pytree100	20981	0.0563367	24.1145	428.042	46.0979

Table 1: *Table summarising data observed across all multiplicity classes. Here the variance is the variance of net charge of all particles having $|\eta| < 1$ and $p_T > 0.05$ GeV/c of each event in a multiplicity class and multiplicity denotes the number of particles with $|\eta| < 1$ and p_T>0.05 GeV/c in each event.*

- The N_+, N_- and N_{ch} distributions for charged particles in the acceptance region ($|\eta| < 1$ and $p_T > 0.05$) for each of the six multiplicity classes show are all approximately Gaussian. The mean net charge is seen to be very close to zero in each case.
- The slight deviation observed from the Gaussian fit in the charge distribution plots, indicates a very small non-zero correlation coefficient.
- From Figure 7b we observe that mean net charge of particles is roughly directly proportional to multiplicity and almost tending to zero although there is a slight decrease observed in pytree6080 (60-80 multiplicity class) which has a mean multiplicity in the acceptance region ($|\eta| < 1$ and $p_T > 0.05$) close to 28.
- In Figure 7c we see that the variance of net charge linearly increases with multiplicity, as the plot is approximately a straight line.
- Mean Net Charge and Variance of Net charge are higher for higher multiplicity values as compared to lower multiplicities. From Figure 7a we also see that higher multiplicity classes have lesser number of events than those of lower multiplicity classes. Hence a possible reason for an approximately increasing behaviour in Figure 7b and Figure 7c is the lesser number of events for higher multiplicity classes.
- Scaled variance decreases monotonically till mean multiplicity 20, and decreases again after mean multiplicity of 28, hence it shows an irregular (increasing) behaviour in the 20-28 mean multiplicity interval mainly due to the corresponding decrease in the mean net charge as stated in the third point above.
- From the above table, it can be seen that mean multiplicity of particles in the region $|\eta| < 1$ and $p_T > 0.05$ increases linearly (approximately) with the increase in overall multiplicity. This is also seen in the overall 2D scatter plot which shows a correlation factor of 0.85 between multiplicities in the $|\eta| < 1$ and $p_T > 0.05$ region and $|\eta| > 1$ region for unit bin length.
- From the above observations and a few others which are out of the scope of this report, it can be concluded that a *p-p* collision system bears close resemblance to *Pb-Pb* collision system at high energies, as shown in the paper [1].

References

[1] Evidence for collectivity in pp collisions at the lhc. *Phys. Lett. B 765 (2017) 193*, 2016. *(https://arxiv.org/pdf/1606.06198.pdf).*