

Comparison of observables in the central region for different tunes in a Pythia 8 simulation for the study of MPI at 13 TeV

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Abstract

Multiple Parton Interactions (MPI) have been investigated in the ALICE collaboration in high multiplicity events at 13 TeV. This study was performed thanks to the Monte Carlo event generator Pythia 8. Here is presented the comparison between different tunes for different classes of events in the central region.

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1. Introduction

In this report will be presented the work I have accomplished during my 8 weeks at CERN as a Summer Student. I worked within the HMTF group (High Multiplicity Task Force) of the ALICE experiment. The goal of these 8 weeks was to compare the results from different tunes of the Monte Carlo generator Pythia 8 in the context of Multiple Parton Interactions (MPI) in high multiplicity events at 13 TeV.

Interest on MPI kept on growing these last years. They were observed at the LHC and are used to explain some results such as associated hadron production (Underlying Event) in high energy hadronic collisions with jets [1], [2]. With the energy in the center of mass increased, MPI will occur at higher rates.

In the first section will be detailed the theoretical and experimental context. Then is explained the study and how Pythia 8 was tuned. Finally, the obtained results are discussed.

2. Context

2.1. Multiple Parton Interactions (MPI)

Protons can be described as a collection of gluons and quarks -called partons [3]. It is then possible to have multiple parton hard-scatterings meaning events in which two or more distinct hard partonic interactions occur simultaneously in a single hadron-hadron collision (Figure 1, [4]). The events in which only two partons produce a hard scattering are called Single Parton Scattering (SPS). Two simultaneous scatterings refer to the class of events called Double Parton Scattering. The number of MPI in an event is assumed to be correlated to the multiplicity of this event.

2.2. ALICE experiment

ALICE (A Large Ion Collider Experiment) is the heavy-ion dedicated experiment at CERN. It was designed to cope with the high density of particles expected in Pb-Pb collisions [5]. There are three categories of detectors: central-barrel detectors, forward detectors and muon spectrometer (Figure 2).

This study is focused on the forward region. The plastic scintillator detector V0 is used as a trigger. It is composed of two detectors working at different pseudorapidity ranges: V0A works at $2.2 < \eta < 5.1$ and V0C at $-3.7 < \eta < -1.7$ (values after the upgrade for Run II).

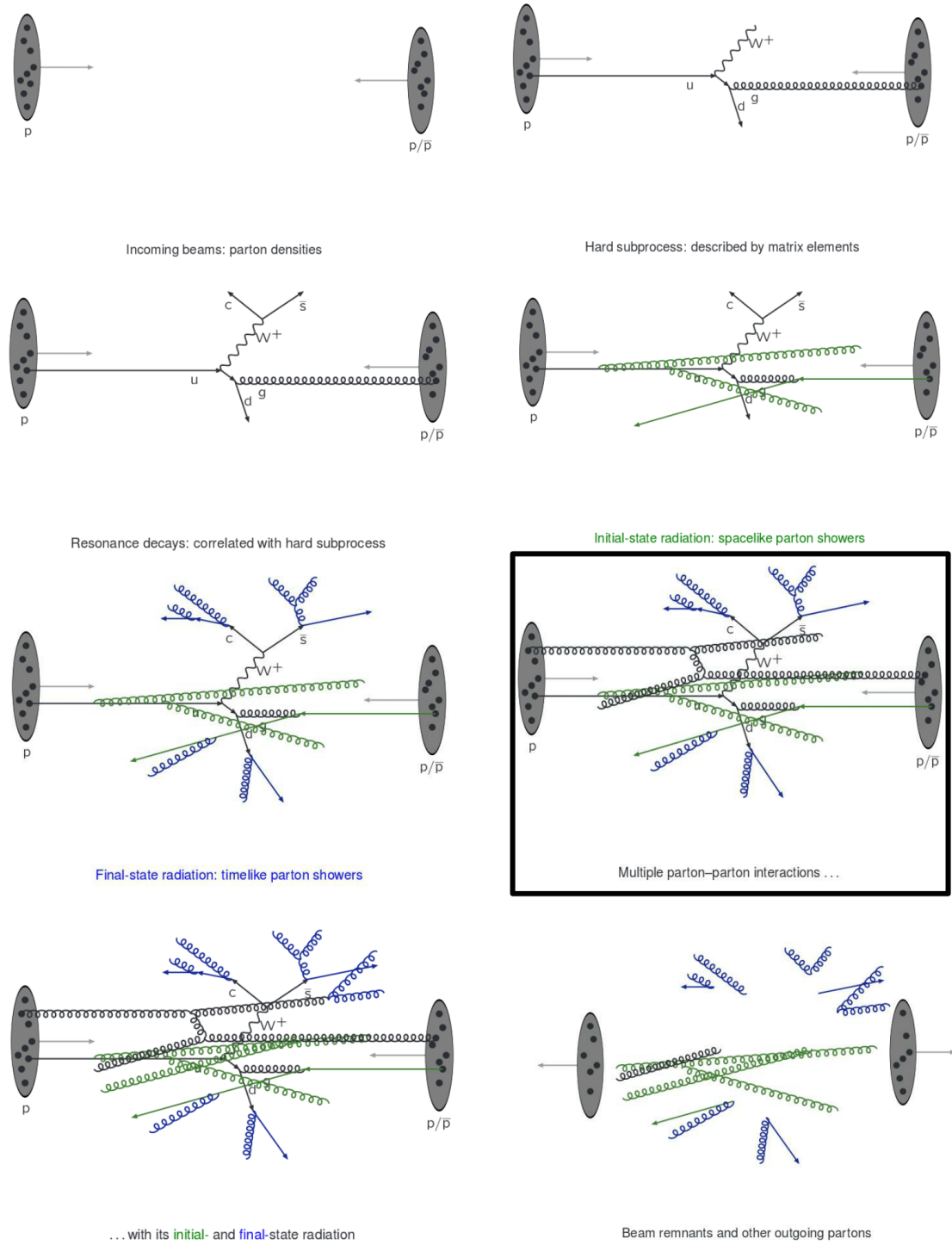


Figure 1: Scheme of the structure of an event

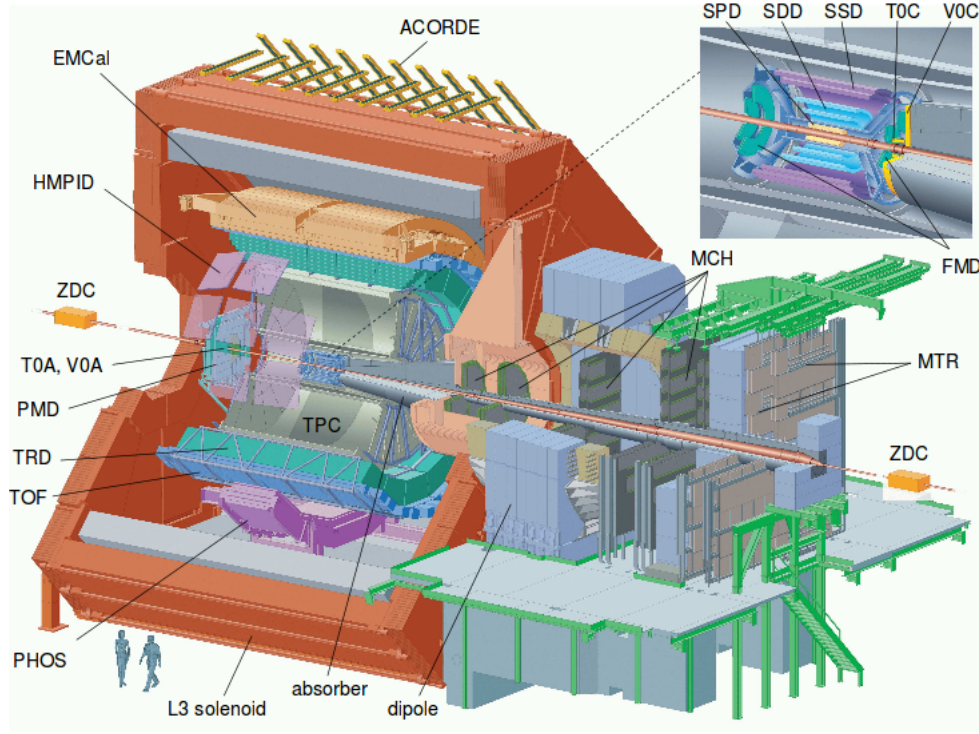


Figure 2: The ALICE experiment at CERN

3. The study

3.1. Experimental setup

The variable $V0M$ is used and defined as follow: $V0M = V0A + V0C$. Different classes of events can be defined as well: all events, events having $V0M > 1 \times \langle V0M \rangle$, $2.5 \times \langle V0M \rangle$, $5 \times \langle V0M \rangle$, $7.5 \times \langle V0M \rangle$ and $10 \times \langle V0M \rangle$. It is used to trigger high multiplicity events. Then, observables such as the pseudorapidity and the charged multiplicity N_{ch} are built in the central region $-1 < \eta < 1$ for those events. This allows to characterize events with a certain amount of activity in the forward region.

3.2. Monte Carlo event generator: Pythia 8210

Pythia 8 is based on the perturbative QCD model. The aim is to compare the results for different tunes [6]. Two sets of three were used: Monash, 4C and 4Cx as well as ATLAS A14 central tune with NNPDF2.3LO (later referred as ATLAS21), ATLAS A14 variation 1+ (ATLAS23) and ATLAS A14 variation 1- (ATLAS24).

The Monash tune is the default one [7]. 4C is based on tune 2C for Tevatron data and on a study of some early LHC data. The difference between 4C and 4Cx is that the latter deals with correlations between Bjorken- x of the first interaction and matter overlap [8]. More specifically, the Gaussian matter profile in 4Cx has an x -dependent width. ATLAS23 and ATLAS24 are variations of ATLAS21 with different color reconnection strengths and

α_s values [9]. They mainly focus on the evolution of transverse activity with leading track calorimeter jets. The ATLAS21 variations provide good coverage of the experimental and modelling uncertainties implicit in the tuning.

4. Results

A sample of 10 million events was generated. The first 1,000 events were used to compute $\langle V0M \rangle$, which values can be found in the table below:

	Tune Monash	Tune 4C	Tune 4Cx	ATLAS21	ATLAS23	ATLAS24
$\langle V0M \rangle$	16.804	15.330	14.914	16.433	16.250	16.651

Belowed is summarized the number of events triggered for each class for the different tunes:

	Tune Monash	Tune 4C	Tune 4Cx	ATLAS21	ATLAS23	ATLAS24
All events	9,998,999	9,998,999	9,998,999	9,998,999	9,998,999	9,998,999
$V0M > 1 \times \langle V0M \rangle$	3,402,539	3,408,196	4,029,984	3,336,908	3,365,139	3,311,296
$V0M > 2.5 \times \langle V0M \rangle$	374,622	366,330	367,010	379,713	418,482	361,594
$V0M > 5 \times \langle V0M \rangle$	60,059	66,053	65,962	64,567	82,005	47,562
$V0M > 7.5 \times \langle V0M \rangle$	6,625	9,658	10,500	8,745	16,571	4,444
$V0M > 10 \times \langle V0M \rangle$	301	720	936	518	1,640	152

One can note that the number of events selected drastically decreases as the activity in the forward region increases. About 10^4 events are rejected when going from all the events to those with $V0M > 10 \times \langle V0M \rangle$. For the lower classes of events, number of events triggered are of the same order. On the contrary, for the last class, number of events triggered can change up to one order of magnitude. The same can be observed for the class $V0M > 7.5 \times \langle V0M \rangle$.

The main class of interest is $V0M > 10 \times \langle V0M \rangle$ as the number of MPI is higher (Figure 3 and Appendix B). Due to higher statistics, it is more than likely that the class $V0M > 7.5 \times \langle V0M \rangle$ will be the one used for the data analysis. However, here will be presented the results for the former class and the all events class as a reference.

It has to be stressed that the number of MPI is not an observable - strictly speaking. It is rather an internal model parameter varying on an event-by-event basis. It is still strongly correlated to charged multiplicity. As seen in Appendix D, the average number of charged multiplicity increases as the activity in the forward region increases. Moreover, even in logarithmic scale, charged multiplicity (Figure 4) seem to have a similar behavior as to the number of multiple parton interaction.

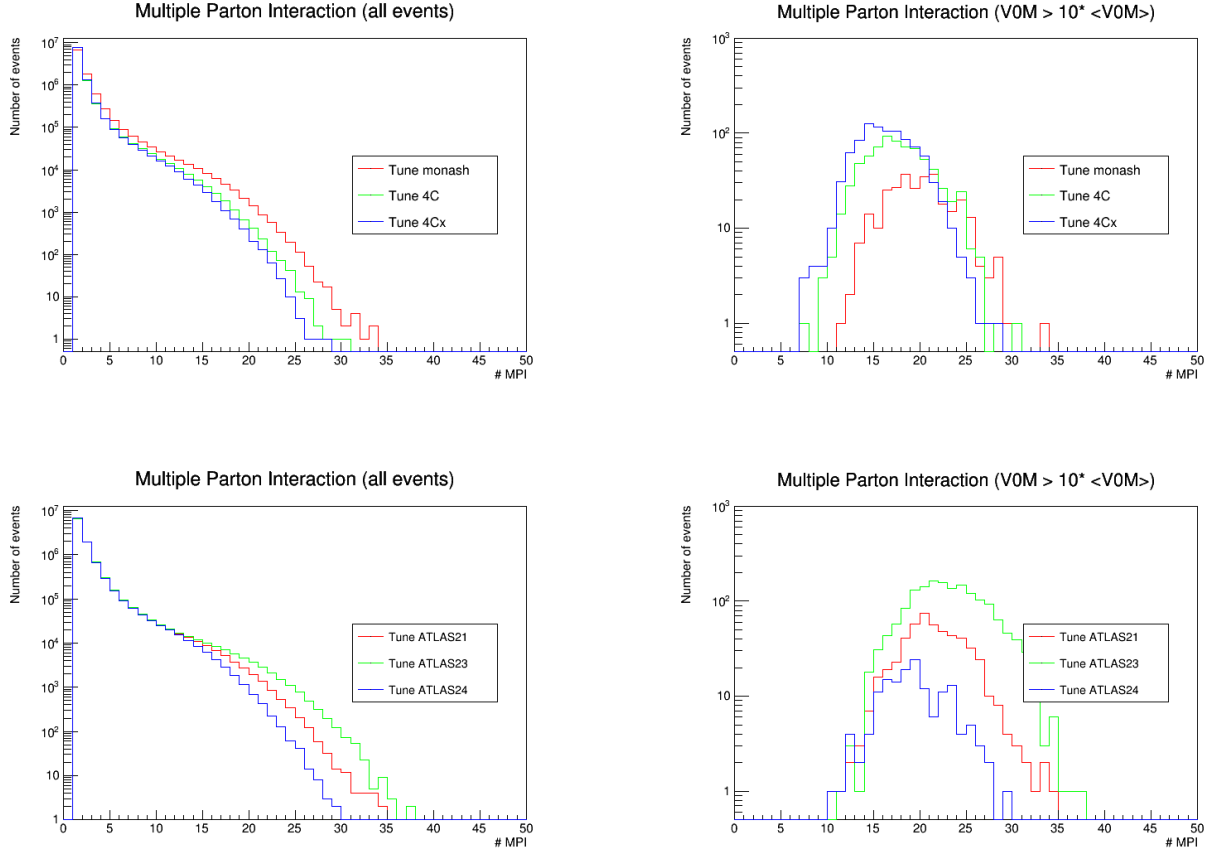


Figure 3: Multiple Parton Interaction for all the events and the class of events with the highest activity in the forward region

In order to really appreciate the difference between the tunes, one could plot the ratio between each curve. Due to a lack of time, this study was not performed. Still, it can be noted that the ATLAS21 leads to a different behavior for MPI and charged multiplicity.

The results for the pseudorapidity distribution seem coherent. When passing from the all event class to the $V0M > 10 \cdot \langle V0M \rangle$ one, the number of charged tracks per unit of pseudorapidity is roughly multiplied by 10 (Figure 6), and this for all the tunes.

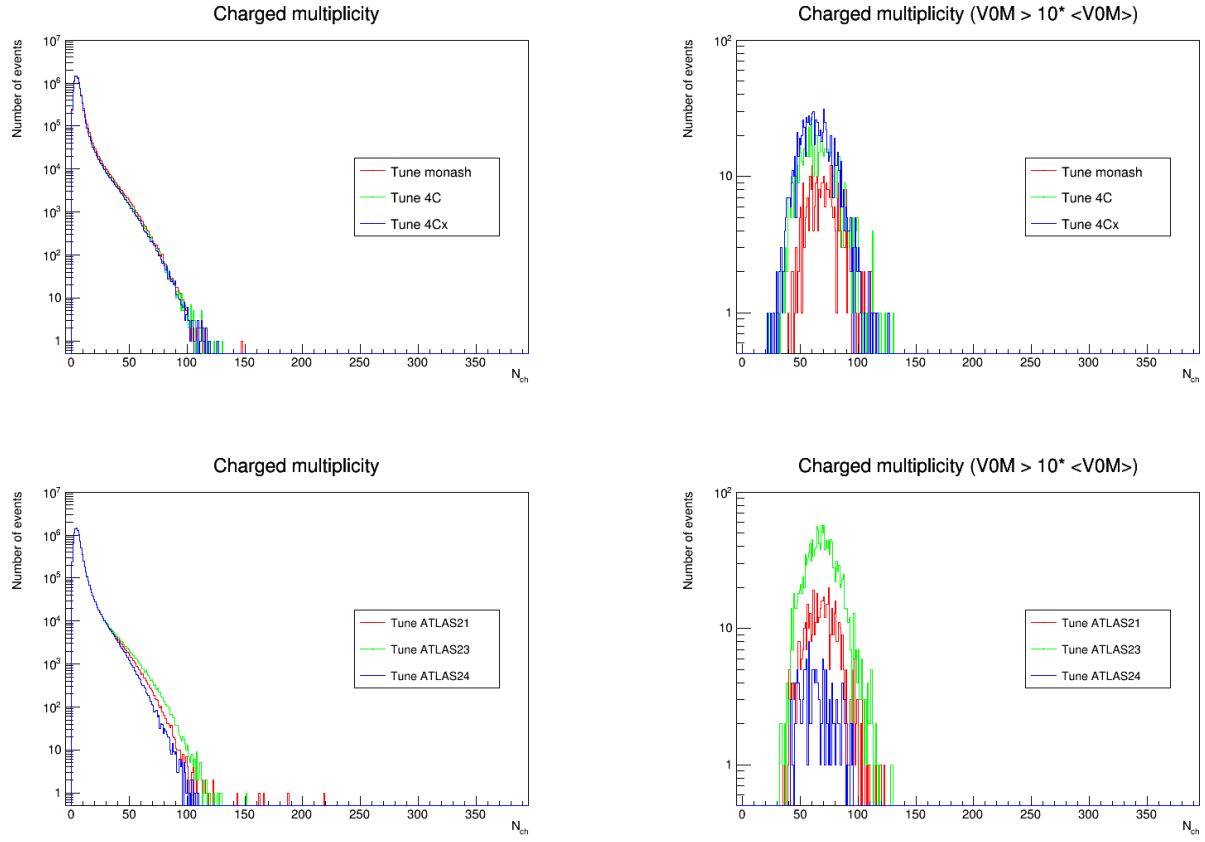


Figure 4: Charged multiplicity for all the events and the class of events with the highest activity in the forward region

In order to complete the study, a scatter plot was realised for the Monash tune (Figure 5). It can be observed that there is a strong correlation between the normalized average multiplicity in the forward region and in the central region.

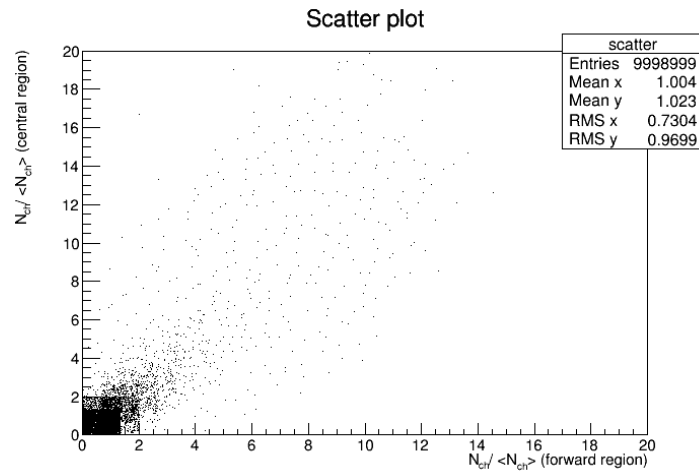


Figure 5: Scatter plot for the Monash tune

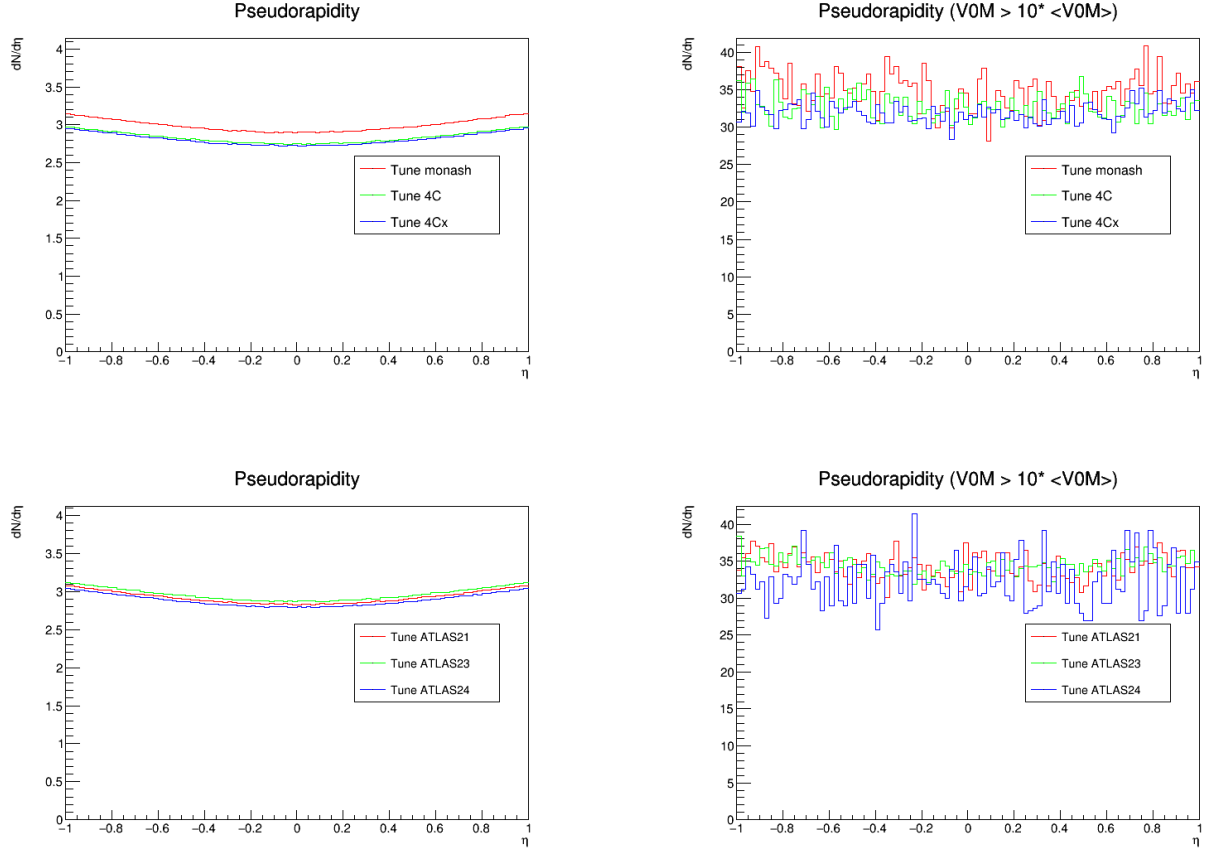


Figure 6: Pseudorapidity distribution for all the events and the class of events with the highest activity in the forward region

5. Conclusion

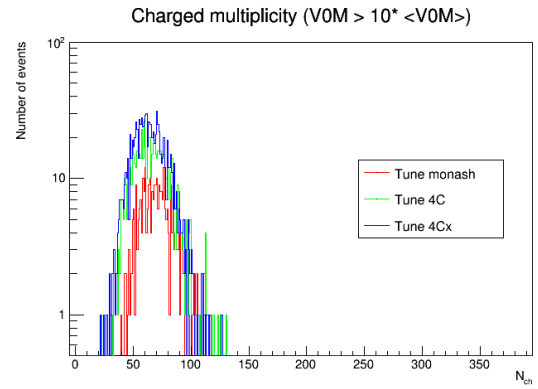
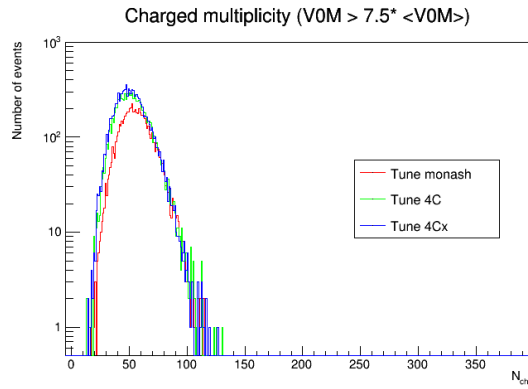
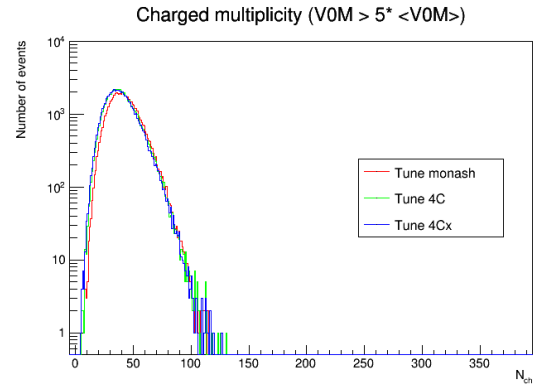
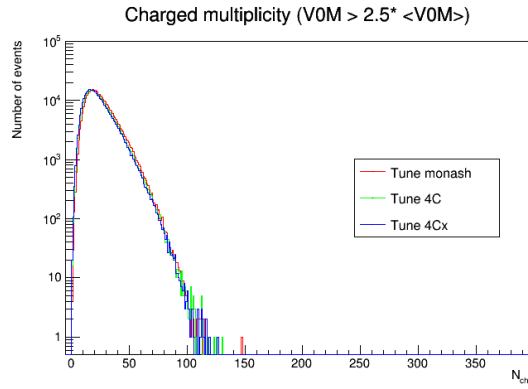
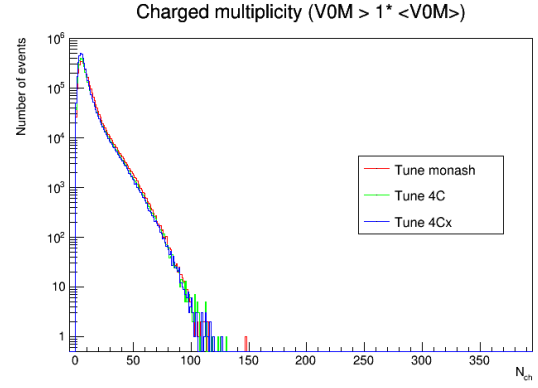
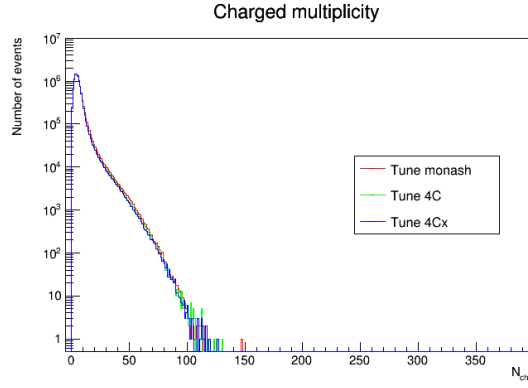
This preliminary study is consistent with the hypotheses made. Correlation between charged multiplicity and number of MPI can still be more investigated. The results given by the different tunes seem self consistent. The classes of events with the highest activity in the forward region are the more interesting ones -number of events triggered can change up to one order of magnitude. The data analysis should be able to say which one(s) fit more the LHC data.

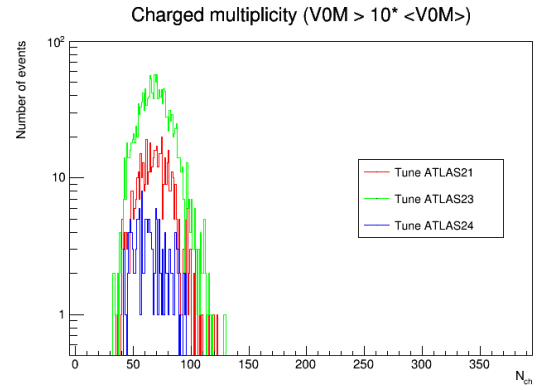
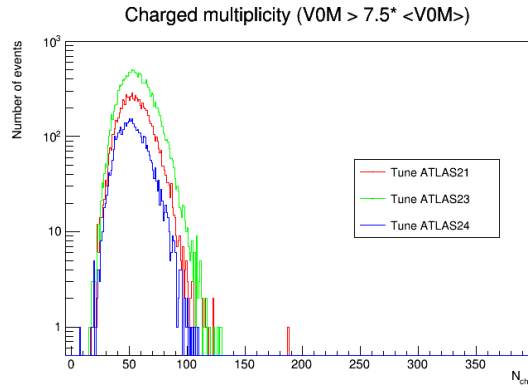
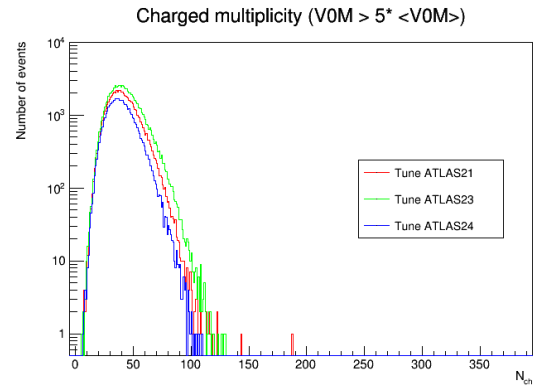
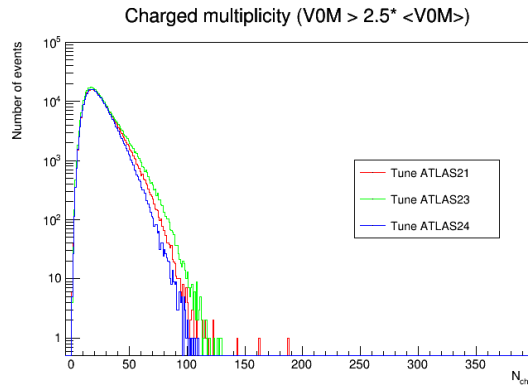
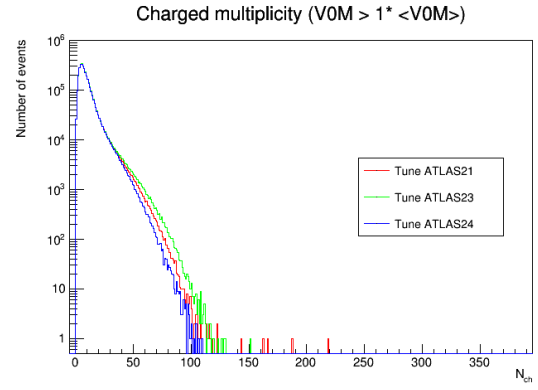
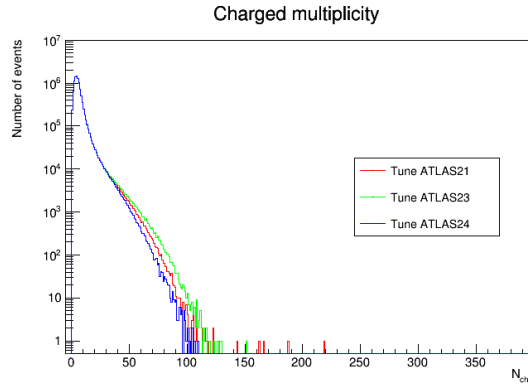
More tunes could be used for this study. Another possibility would be to compare those results to the one predicted by another Monte-Carlo generator such as DIPSY (relying on Muellers formulation of BFKL) or others.

References

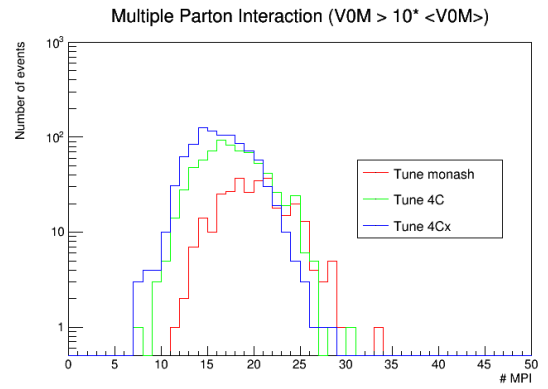
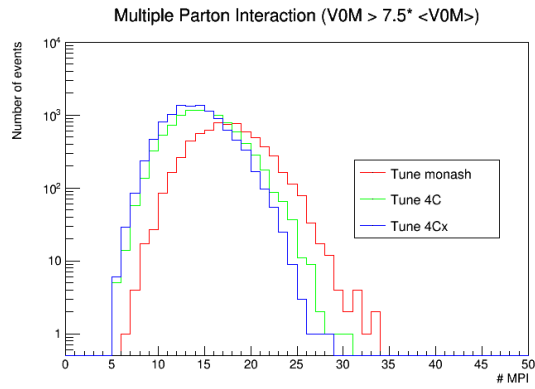
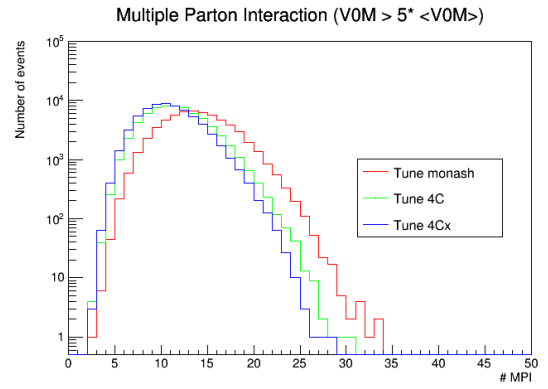
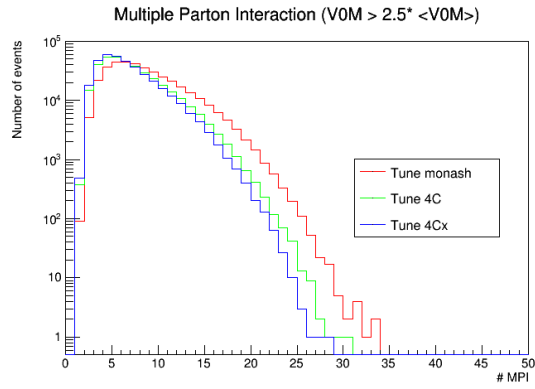
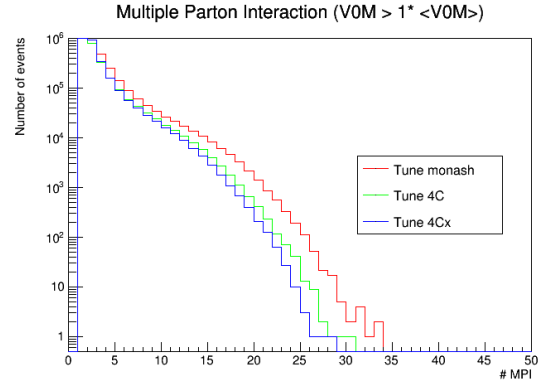
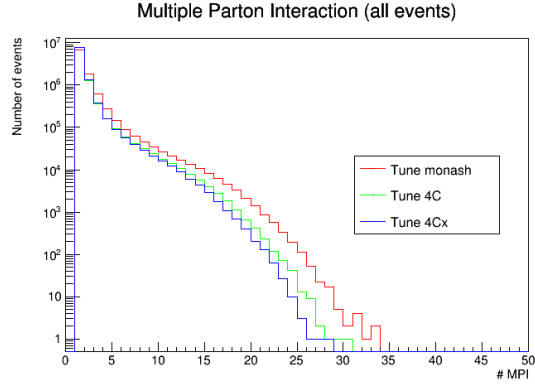
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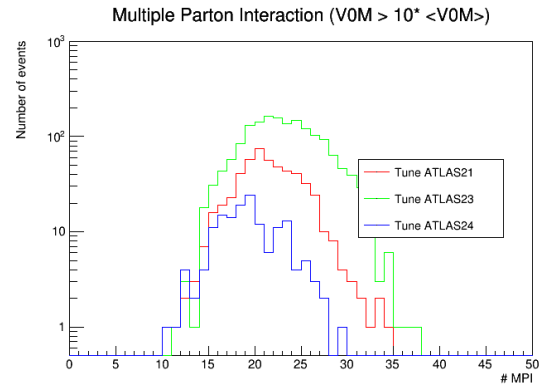
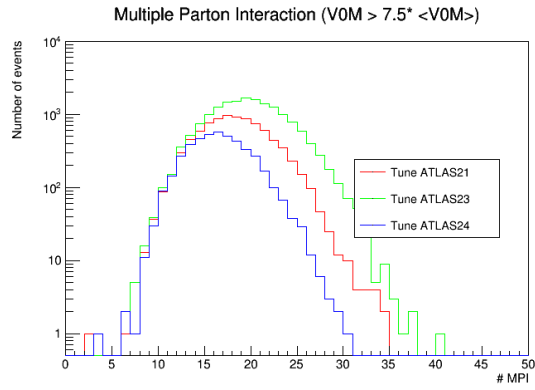
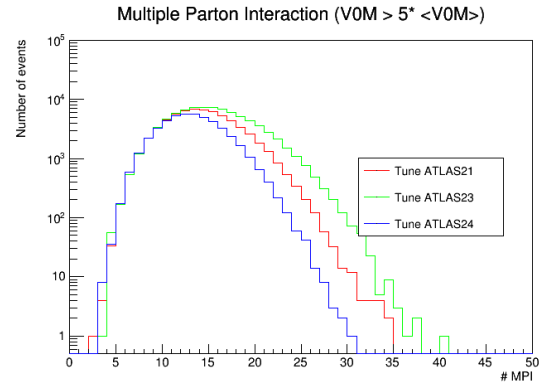
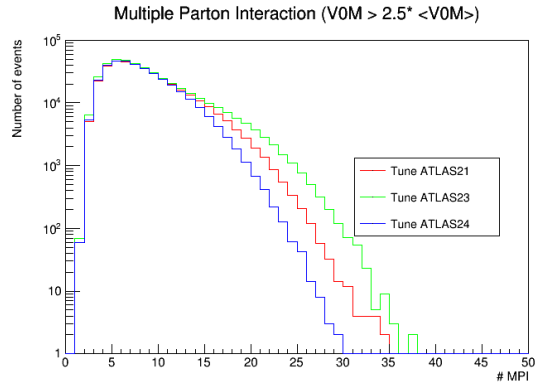
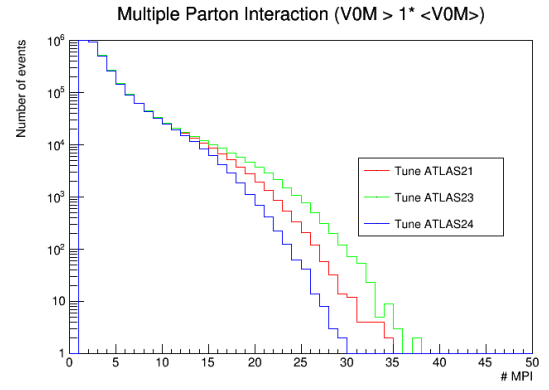
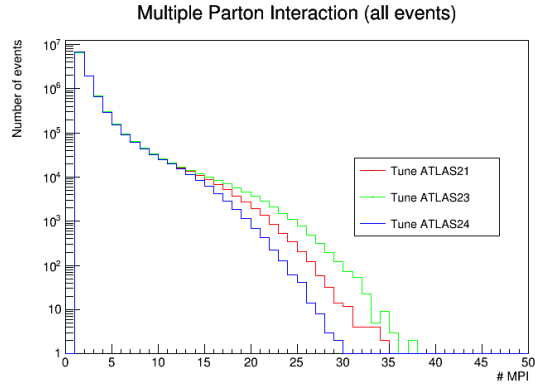
Appendix A. Charged multiplicity



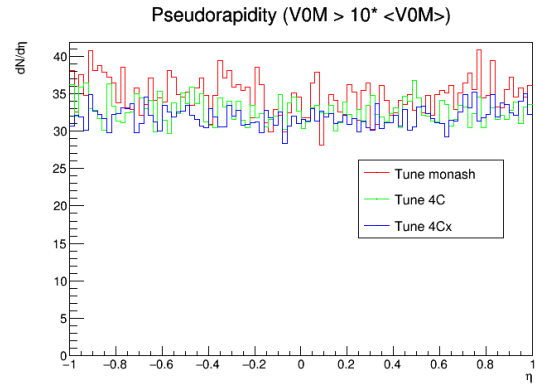
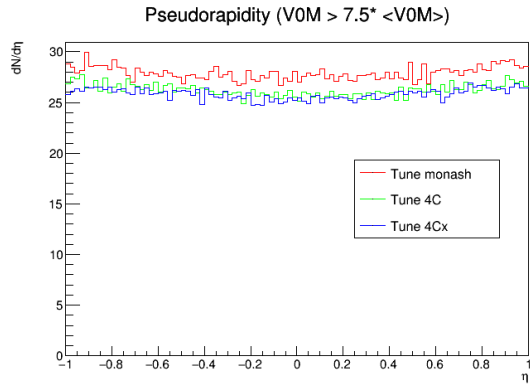
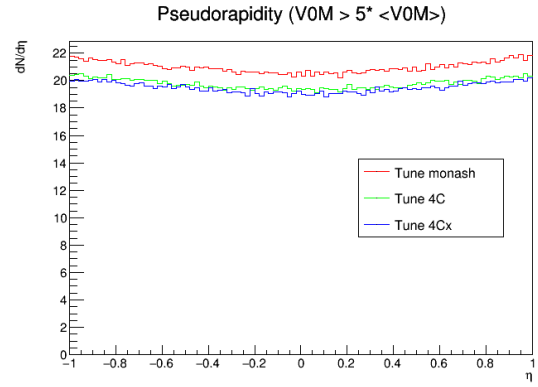
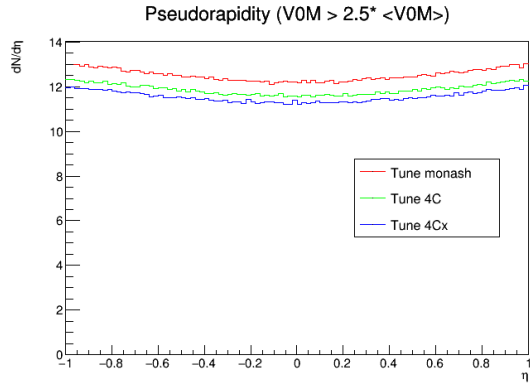
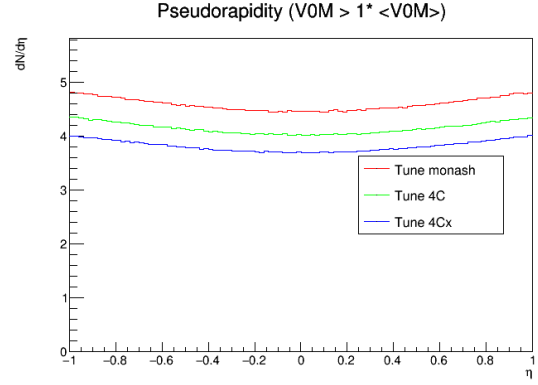
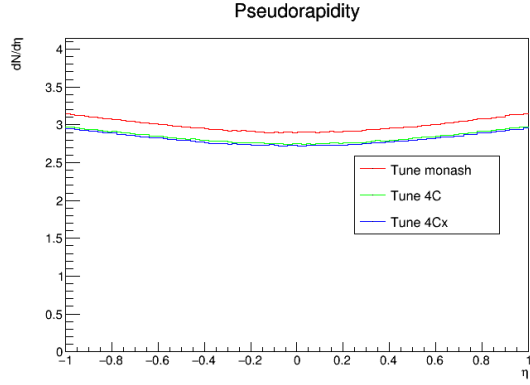


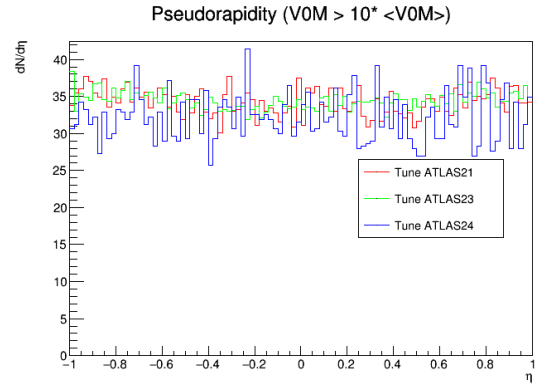
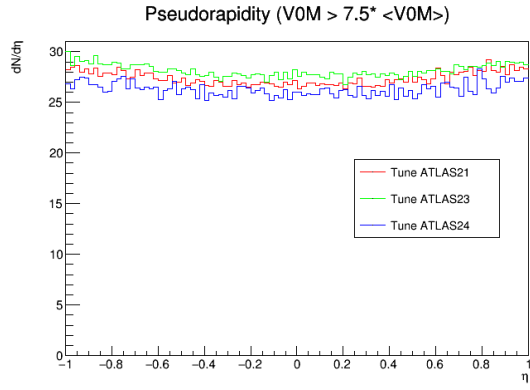
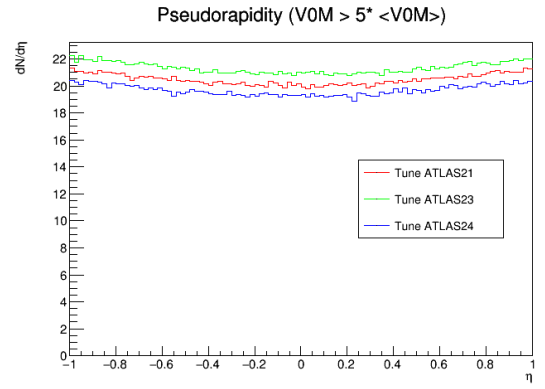
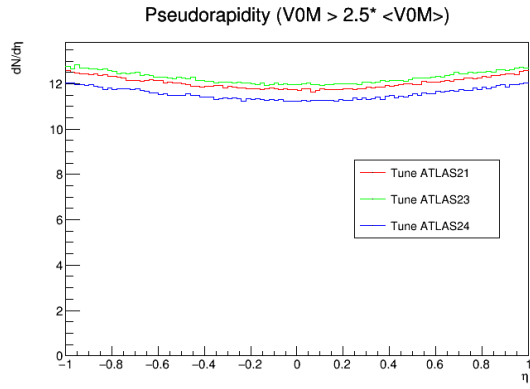
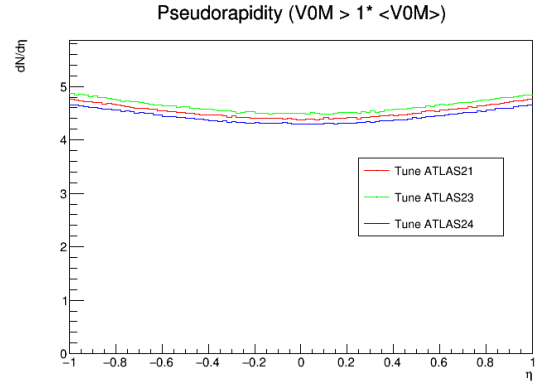
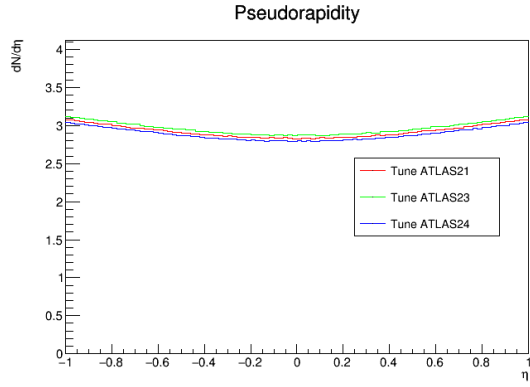
Appendix B. Multiple Parton Interaction





Appendix C. Pseudorapidity distribution





Appendix D. Statistics for charged multiplicity

Appendix D.1. Average charged multiplicity $\langle N_{ch} \rangle$

	Tune Monash	Tune 4C	Tune 4Cx	ATLAS21	ATLAS23	ATLAS24
All events	5.986	5.668	5.623	5.85	5.929	5.774
$V0M > 1 \times \langle V0M \rangle$	9.198	8.303	7.638	9.055	9.256	8.867
$V0M > 2.5 \times \langle V0M \rangle$	25.05	23.75	23.09	24.08	24.54	23.11
$V0M > 5 \times \langle V0M \rangle$	41.96	39.53	38.95	40.96	42.66	39.37
$V0M > 7.5 \times \langle V0M \rangle$	55.82	52.48	51.68	54.72	56.26	52.57
$V0M > 10 \times \langle V0M \rangle$	69.53	65.41	63.77	68.47	68.88	64.36

Appendix D.2. Root Mean Square (RMS)

	Tune Monash	Tune 4C	Tune 4Cx	ATLAS21	ATLAS23	ATLAS24
All events	5.677	5.366	5.262	5.51	5.819	5.229
$V0M > 1 \times \langle V0M \rangle$	8.184	7.856	7.258	7.975	8.494	7.496
$V0M > 2.5 \times \langle V0M \rangle$	12.41	12.38	12.31	12.25	13.35	11.19
$V0M > 5 \times \langle V0M \rangle$	13.05	13.16	13.18	12.94	13.92	12.05
$V0M > 7.5 \times \langle V0M \rangle$	13.89	14.11	13.92	13.58	14.07	12.93
$V0M > 10 \times \langle V0M \rangle$	14.48	15.89	15.01	14.37	14.56	13.79