mSTS data analysis for run number 159

Facility for Antiproton and Ion Research in Europe and
GSI Helmholtzzentrum für Schwerionenforschung

ZUZANNA GNUTEK

Internship and Training Project Report
Darmstadt, Germany
26-09-2019

GET INvolved 2018: THXXX (GI18-TH-XXX)

Author(s)
Zuzanna Gnutek
Warsaw Univeristy of Technology, Faculty of Physics
00-662 Warsaw, ul. Koszykowa 75, Warsaw - Poland
Email: zuziagnutek@gmail.com

Project Mentor/Supervisor
Dr. Volker Friese
CBM
GSI Helmholtzzentrum für Schwerionenforschung GmbH,
Planckstr. 1, 64291 Darmstadt, Germany
Tel: +49 6159 71 1619
Email: V.Friese@gsi.de

Program Coordinator
Dr. Pradeep Ghosh
GSI Helmholtzzentrum für Schwerionenforschung GmbH &
Facility for Antiproton and Ion Research in Europe GmbH
Tel: +49 6159 71 3257, Fax: +49 6159 71 3916
Email: Pradeep.Ghosh@fair-center.eu

GET Involved 2019: yyzz

Publisher: GSI Helmholtzzentrum für Schwerionenforschung GmbH,
Planckstr. 1, 64291 Darmstadt, Germany
Published: October 2019

Quote

" A person who never made a mistake never tried anything new."

Albert Einstein

Declaration

I hereby declare that the project entitled "mSTS data analysis for run number 159" is my own work.

Abstract

The Compressed Baryonic Matter experiment (CBM) is a next-generation heavy- ion experiment to be operated at the FAIR facility, currently under construction in Darmstadt, Germany. The data analysis is one of the major part of research. This report presents my three months experience at FAIR/GSI. The purpose of my Internship was to understand the raw data from mSTS for run number 159 and to make the bridge between theoretical and practical knowledge. This study attempted to understand how an analysis team works in the CBM.

Acknowledgements

The internship opportunity I had with GSI was a great chance for learning and professional development. Therefore, I consider myself a very lucky individual as I was provided with an opportunity to be a part of it. I am also grateful for having a chance to meet so many wonderful people and professionals who led me through this internship period.

I express my deepest thanks to Dr. Volker Friese, for taking part in decision process, giving necessary advices, guidance and arranged all facilities to make life easier.

I perceive as this opportunity as a big milestone in my career development. I will strive to use gained skills and knowledge in the best possible way, and I will continue to work on their improvement, in order to attain desired career objectives. I hope to continue cooperation with CBM team in the future.

Contents

List of Figures

Chapter 1

Introduction

1.1 Fair Project

FAIR will be one of the largest and most complex accelerator facilities in the world. FAIR is being built in Darmstadt, Germany. At FAIR, matter that usually only exists in the depth of space will be produced in a lab for research. Scientists from all over the world will be able to gain new insights into the structure of matter and the evolution of the universe from the Big Bang to the present. FAIR is under construction at GSI Helmholtzzentrum für Schwerionenforschung. Its existing accelerator facilities will become part of FAIR and will serve as first acceleration stage. For the realization of FAIR, accelerator experts, scientists and engineers of FAIR and GSI are working closely together in teams all over the world [1].

1.2 CBM experiment

The Compressed Baryonic Matter (CBM) experiment at FAIR is one of the major experimental projects at the upcoming FAIR facility. This experiment is focused on the exploration of the QCD (quantum chromodynamics) phase diagram in the region of of high baryon densities. The experimental challenge is to measure and to identify most of the particles which are produced in a high-energetic collision between two atomic nuclei. The CBM program can only be realized with a combination of fast detector systems and readout electronics. The detector is designed as a multi-purpose device which will be able to measure hadrons, electrons and muons in heavy-ion collisions. The optimization of the detector design is carried out through extensive feasibility studies which are performed within a newly developed software framework [2]. The experimental setup is optimized to reinvestigate with new probes a very promising territory of the QCD phase diagram, as shown in the following figure.

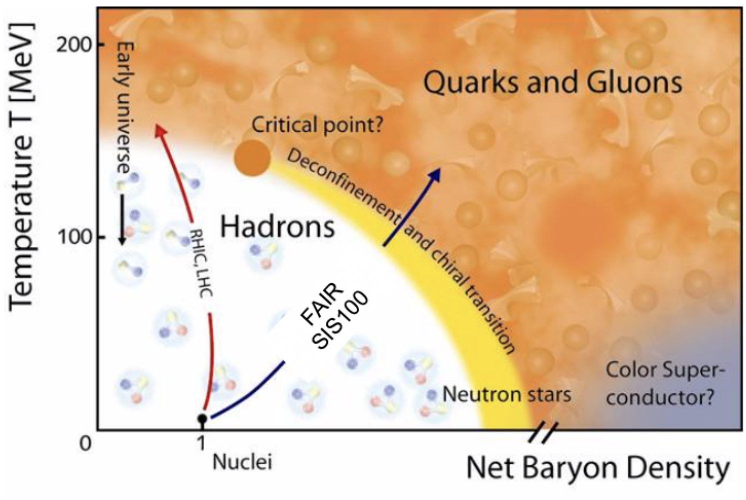


Figure 1.1: Sketch of the QCD Phase Diagram

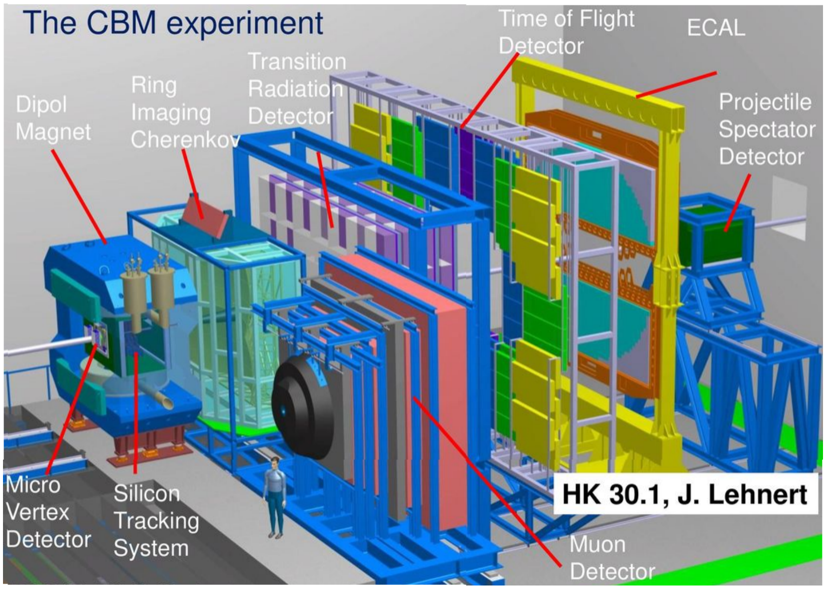


Figure 1.2: The Compressed Baryonic Matter experiment

The heart of the experiment will be a silicon tracking and vertex detection system installed in a large acceptance dipole magnet. The Silicon Tracking System (STS) is the key detector for measuring the momentum and tracks of up to 1000 charged particles produced in Au+Au collisions which happen at interaction rates up to 10 MHz on a fixed target. The Micro-Vertex Detector (MVD) is needed to determine secondary vertices with high precision for D meson identification. The measurement of electrons will be performed with a Ring Imaging Cherenkov (RICH) detector together with Transition Radiation Detectors (TRD) for electrons with momenta above 1.5 GeV/c. Muons will be measured with an active hadron absorber system consisting of iron layers and muon tracking chmbers (MuCh). For muon measurements the MuCh will be moved to the position of the RICH. Charged hadron identification will be performed by a time-of-flight (TOF) measurement with a wall of RPCs located at a distance of 10 m behind the target. The setup is complemented by an Electromagnetic Calorimeter (ECAL) in selected regions of phase space providing information on photons and neutral particles, and by a Projectile Spectator Detector (PSD) needed for the determination of the collision centrality and the orientation of the reaction plane [2].

1.3 mCBM

A CBM full system test-setup called mCBM@SIS18 ("mini-CBM", shortened to mCBM) is presently installed at the SIS18 facility of GSI/FAIR. The mCBM experiment allows to test and optimize the performance of the detector subsystems including the software chain under realistic experiment conditions which will significantly reduce the commissioning time for CBM at SIS100.

mCBM has been recognized as a FAIR Phase-0 experiment.

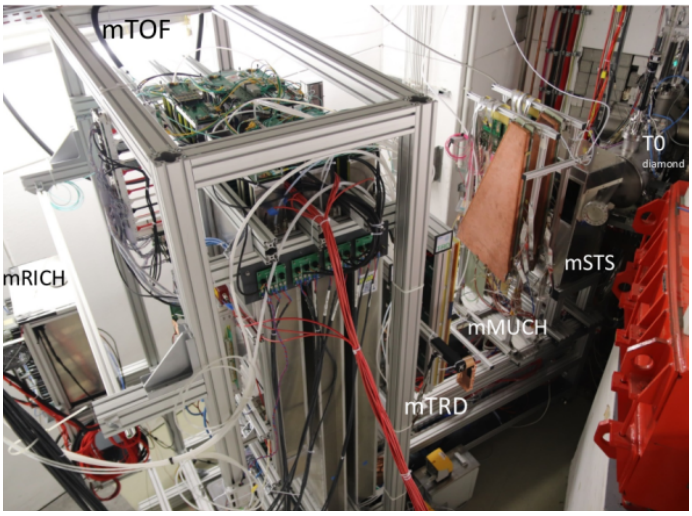


Figure 1.3: mCBM setup in March 2019

1.3.1 mSTS

The task of the mSTS is to provide track reconstruction and momentum determination of charged particles. In its currently studied versions the mSTS consists of two tracking layers of silicon detectors. The concept of the mSTS tracking is based on silicon micro-strip detectors on lightweight ladder-like mechanical supports. The sensors read out through multi-line micro-cabels with fast electronics at the periphery of the stations where cooling lines and other infrastructure can be placed [3].

.

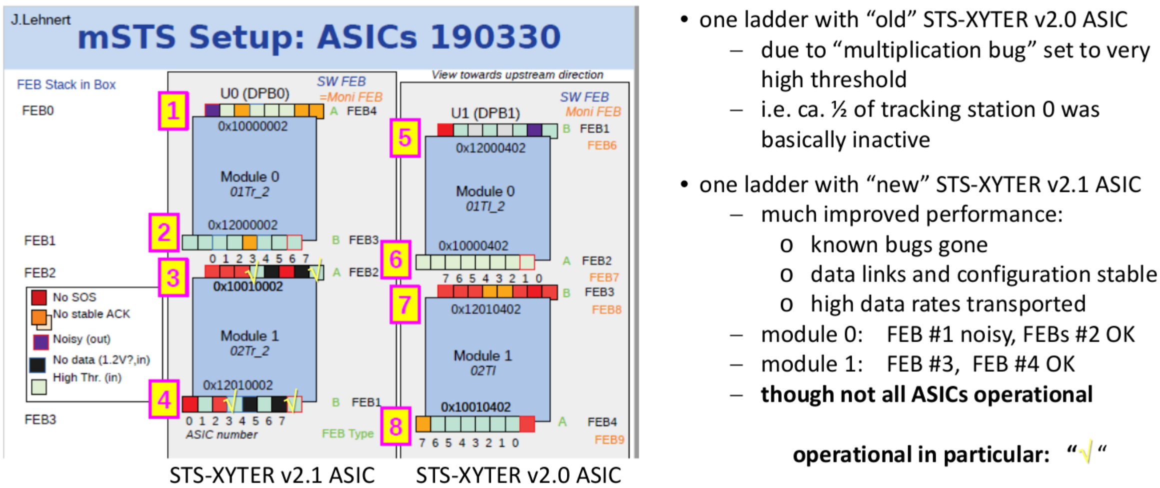


Figure 1.4: mSTS operational status 3/2019

In Figure 1.4 the Setup of mSTS is presented. The components are "half-ladders", detector ladders populated with two modules. Every module comprises a double-sided silicon microstrip sensor, segmented into 1024 strips per side.

Chapter 2

Data analysis

2.1 Analysis of mSTS raw data, without regarding data from other detectors

2.1.1 Charge distribution

During my first week of work, I went through some basic training regarding the mCBM experiment and more importantly the data analysis structure that had been crucial in my project. During this week I also studied meaning of the digi, cluster and hit. A digi is a representation of the smallest information unit delivered by the CBM-STS by a single readout channel, whereas cluster is a collection of digis in neighbouring module channels. A hit in the STS is a position measurement constructed from two clusters on the front and back side of the sensors, respectively, which have a geometric intersection.

The first part of my project was to analyse mSTS raw data for run number 159. For this purpose I used unpacked data provided by Dr. Alberica Toia and the reconstruction macro for mCBM data to find clusters and hits. Analysing data started with the question if it is possible to easily seperate good signal from noise. To answer this question I looked into the charge distribution of all digis (Figure 2.1).

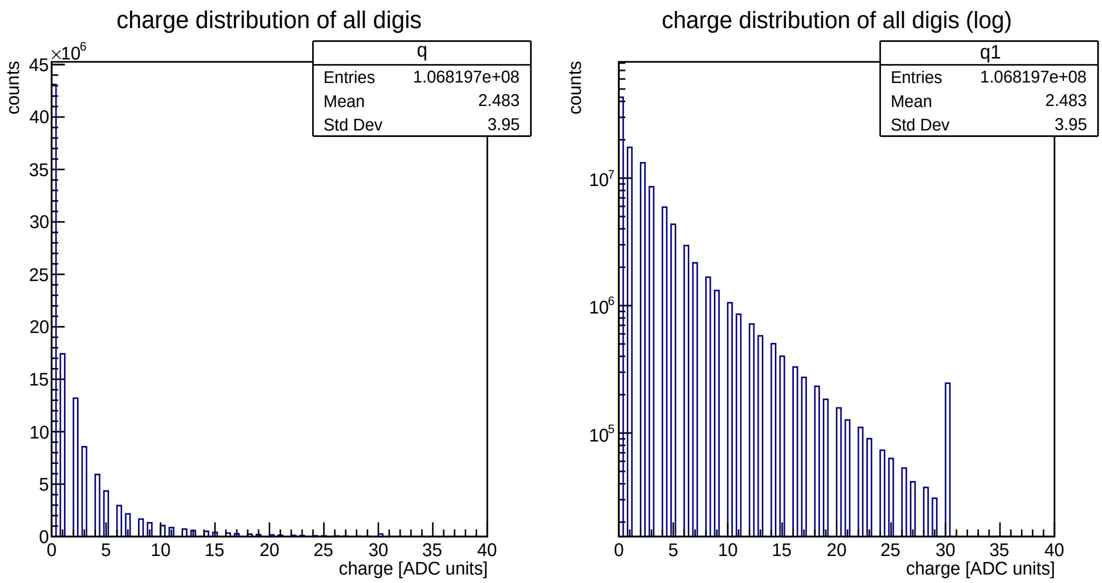


Figure 2.1: Charge distribution of all digis (lin/log)

As visible from Fig.2.1, an obvious seperation of signal and noise is not possible from the charge distribution.

The STS ASICs were operated with rather high threshold since the noise was higher than expected. This holds in particular for the ASICS of type STS-XYTER 2.0 (ladder 1), which in addition seem to have other buggy features. So I looked only in a first stage, at the STS-XYTER 2.1 modules (ladder 0), and made the charge distribution of digis in ladder 0. As we can see I got the same result like for all digis (Figure 2.2).

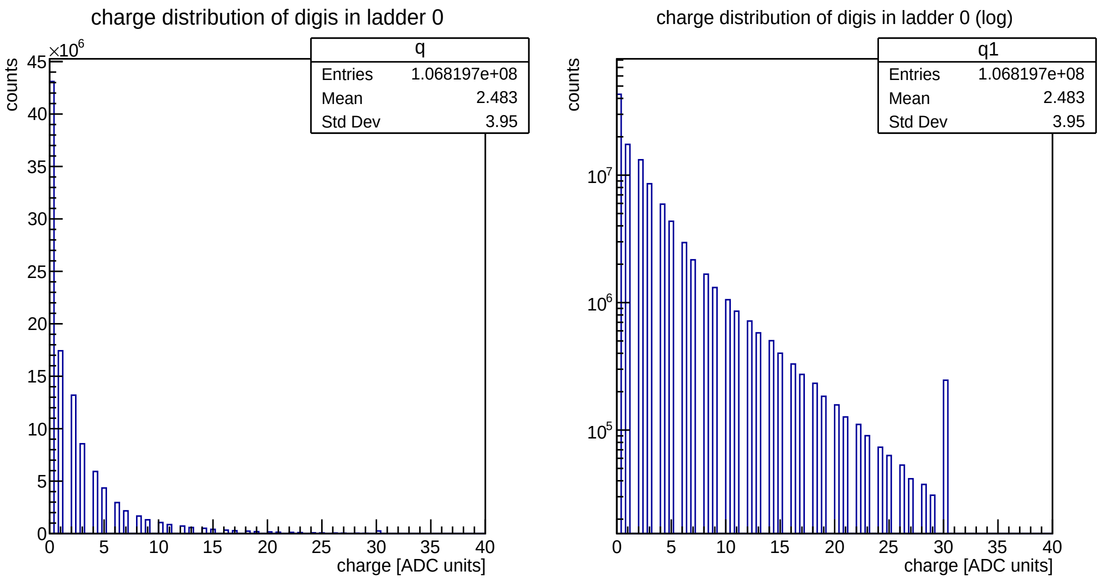


Figure 2.2: Charge distribution of digis in ladder 0 (lin/log)

2.1.2 Cluster analysis

The goal of the cluster reconstruction is to group digis originating from the same incident particle into one object called cluster. This procedure is implemented in two steps: the digis grouping and the determination of the cluster centre [3]. To check the result of cluster finding process I have made a cluster size distribution in ladder 0. As can be seen in Figure 2.3, clusters are found properly also some with large number of digis in a cluster, even up to 100 digis.

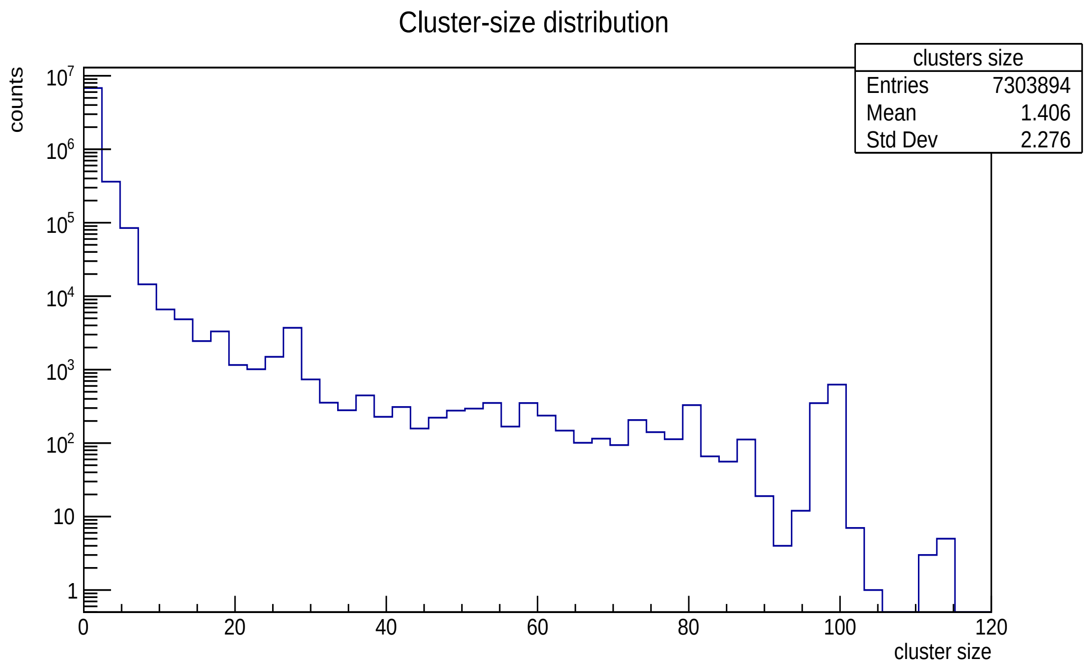


Figure 2.3: Cluster size distribution in ladder 0

Next part of the cluster analysis was the distribution of time differences of digis belonging to one cluster. I made this distribution twice for two different values of the time cut for digis in a cluster (Figure 2.4). First figure presents the distribution of time differences with default value which is calculated from the time errors of the digis. We see here the clear peak with expected resolution. The second figure shows the clear primary peak with expected resolution, but at 65 ns there are secondary peaks. The origin of these secondary peaks is not yet known. They seem to be caused by periodic noise in the readout ASICs with frequency of about 16 MHz.

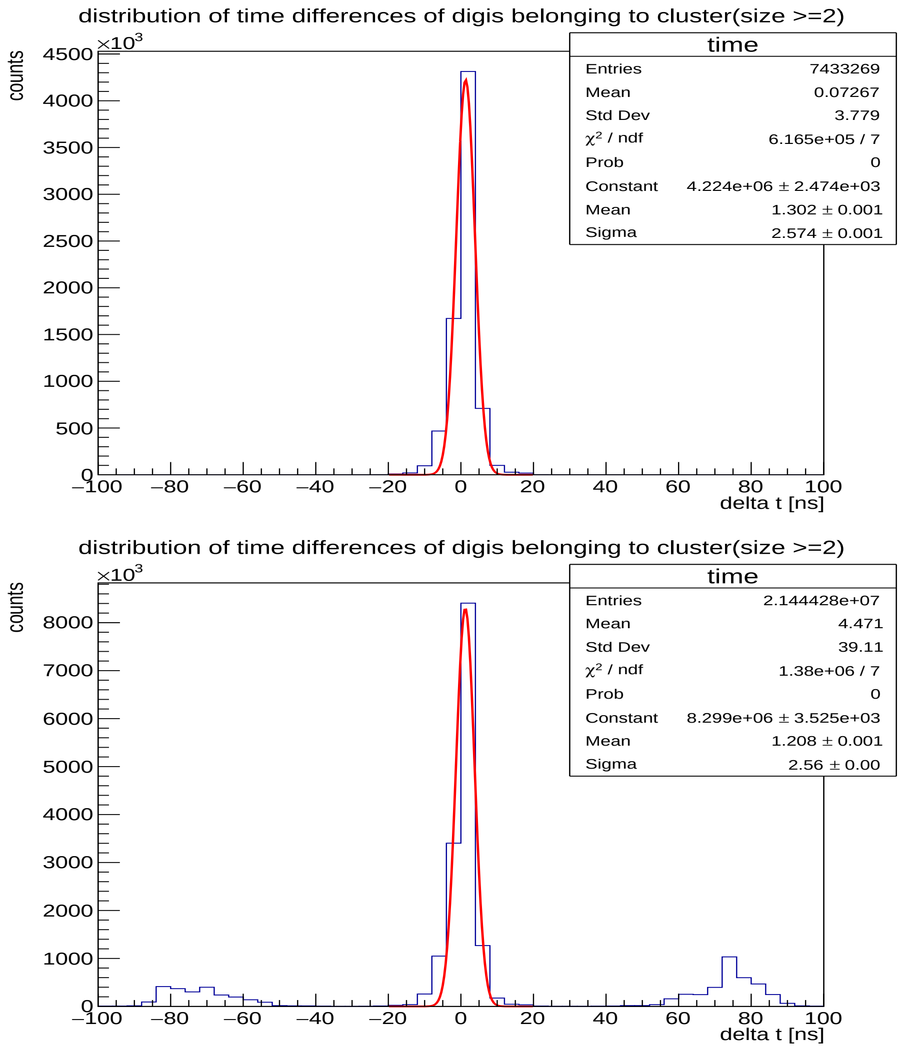


Figure 2.4: Time differences of digis in a cluster

2.1.3 Hits analysis

The last part of the mSTS data analysis was the hits analysis. A hit is a combination of two clusters, centres of which correspond to the strips on different sides of the sensor that geometrically cross each other. Hits are characterised by geometrical coordinates. The hit position is defined as the crossing point of the clusters on the p- and the n-sides of the sensor [4]. The Figure 2.5 shows the distribution of hits in mSTS. the triangular-shaped regions show the active area, represented by strips conected to working ASICs. Active area has been projected onto T0 and mMuCh. Unfortunately as we can see the mTOF is off the beam path (Figure 2.6).

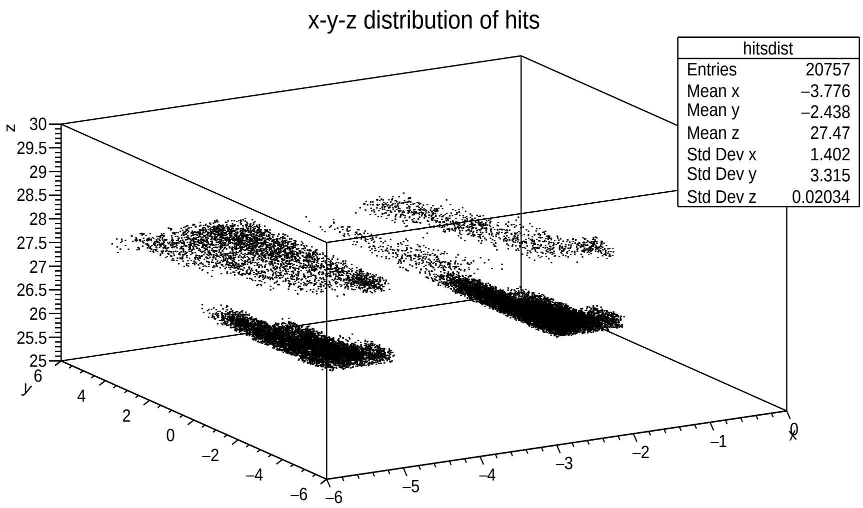


Figure 2.5: x-y-z coordinates of the found hits

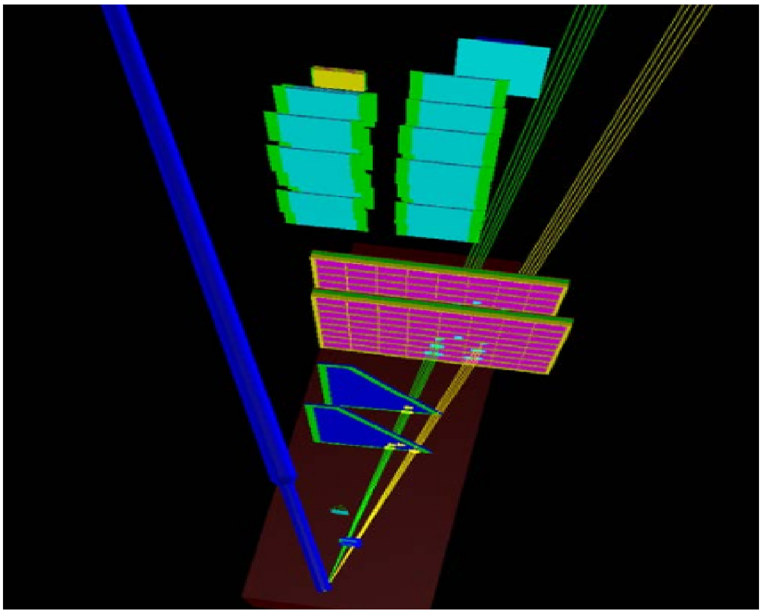


Figure 2.6: Extrapolated tracks for mCBM

2.2 Event-by-event analysis

In CBM we define an event as a collection of links to data objects, whereas the process of event-association is called event building. The simplest event building technique works at the level of individual activations of readout electronics channels (digis). This technique is fast, allows usage of standard event-based reconstruction algorithms for free-streaming data. Event building can be divided in two steps. The first one is an event finding to determine a moment of time when heavy-ion collision had happened. The second one is an event composition, when data, corresponding to the found event, is collected from several subdetectors of CBM setup. The idea was that the data after reconstruction in event-by-event mode should have less random noise. To test this hypothesis I used CbmMcbm2018EventBuilder() on the reconstruction level. I also set time cut digis for 1000 ns. The result of this analysis is presented in Figures 2.7,2.8 and 2.9.

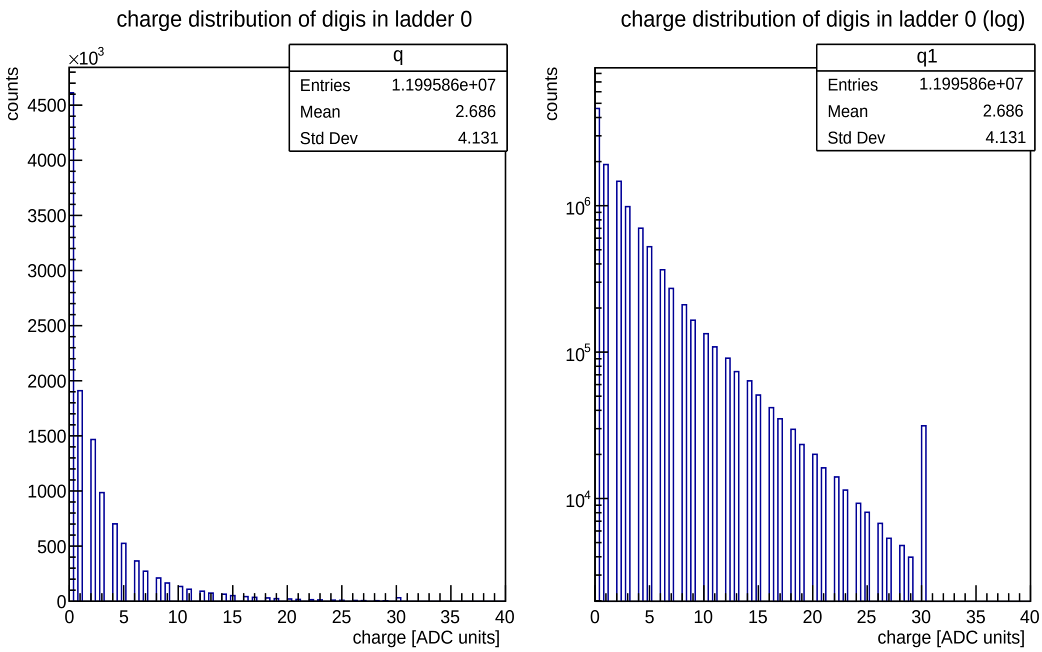


Figure 2.7: Charge distribution of digis in ladder 0

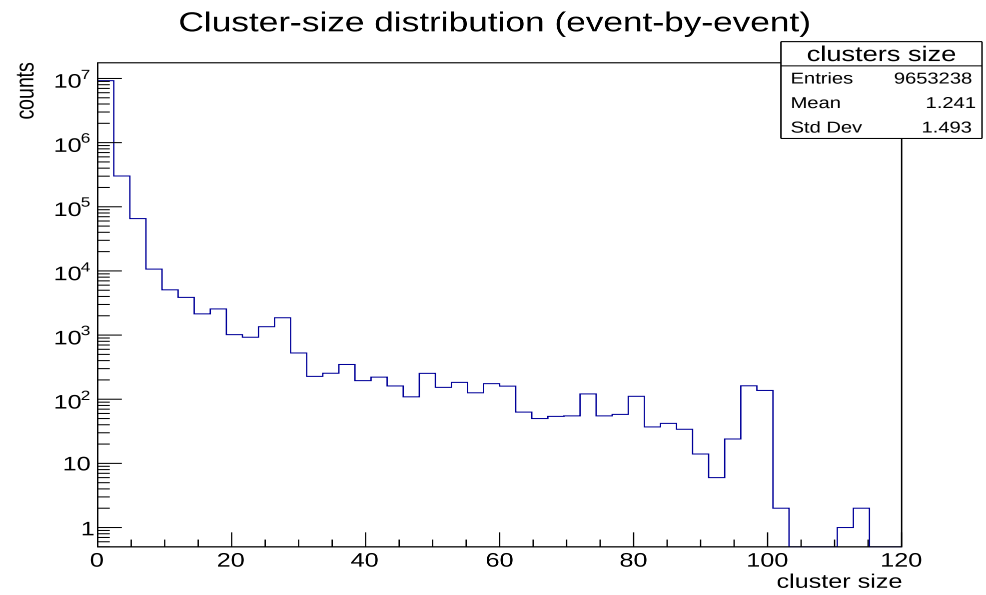


Figure 2.8: Cluster size distribution

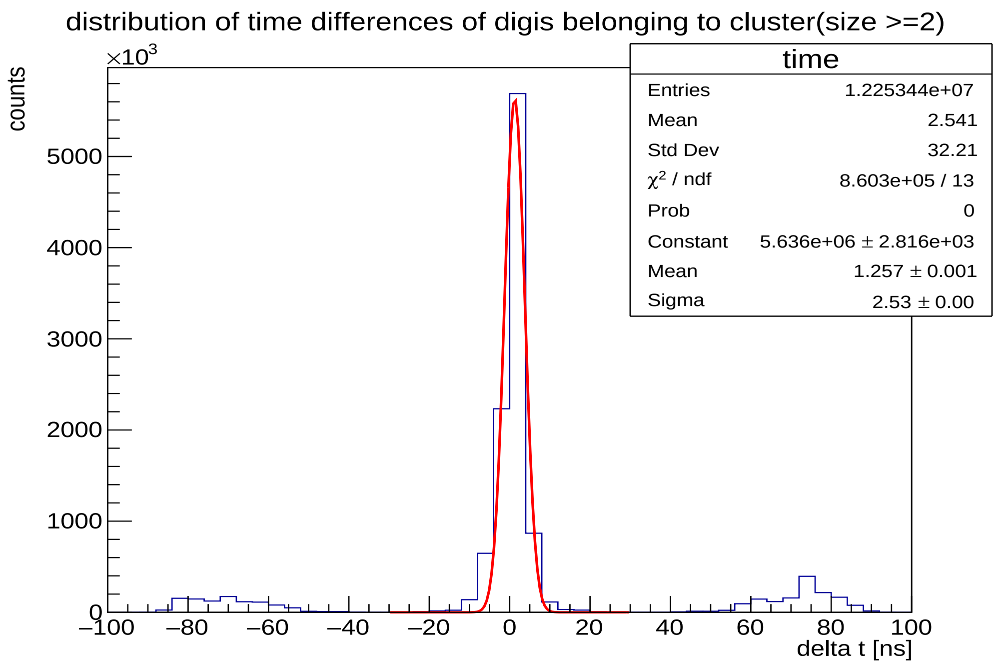


Figure 2.9: Distribution of time differences of digis belonging to a cluster

Inspecting the received plots, there is no obvious difference between data in event-by-event mode and raw data from mSTS detector shown in section "Analysis of mSTS raw data, without regarding data from other detectors". In conclusion, the majority of all data are noise or the majority of all data are signal. The noise between events is negligible.

2.3 mCBM simulation

Simulation is now recognised as the third main methodology of research. High-performance computers are enabling mathematical models of reality, based on our hypotheses, to be translated back into numerical results. These results can in turn be compared with raw data. The importance of simulation is that it allows parameters to be changed in the detectors to understand cause and effect at a level which is not possible in other ways. It also permits phenomena to be studied which might be too expensive or dangerous for conventional experimental methods. Another reason for comparison is to validate the theoretical and mathematical model and to indicate how it might be enhanced if results do not match [5].

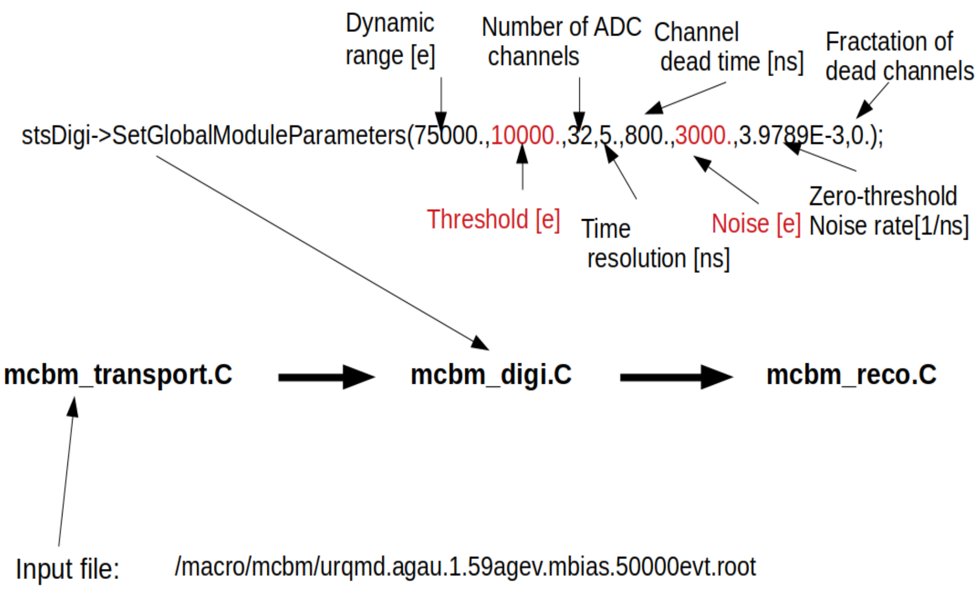
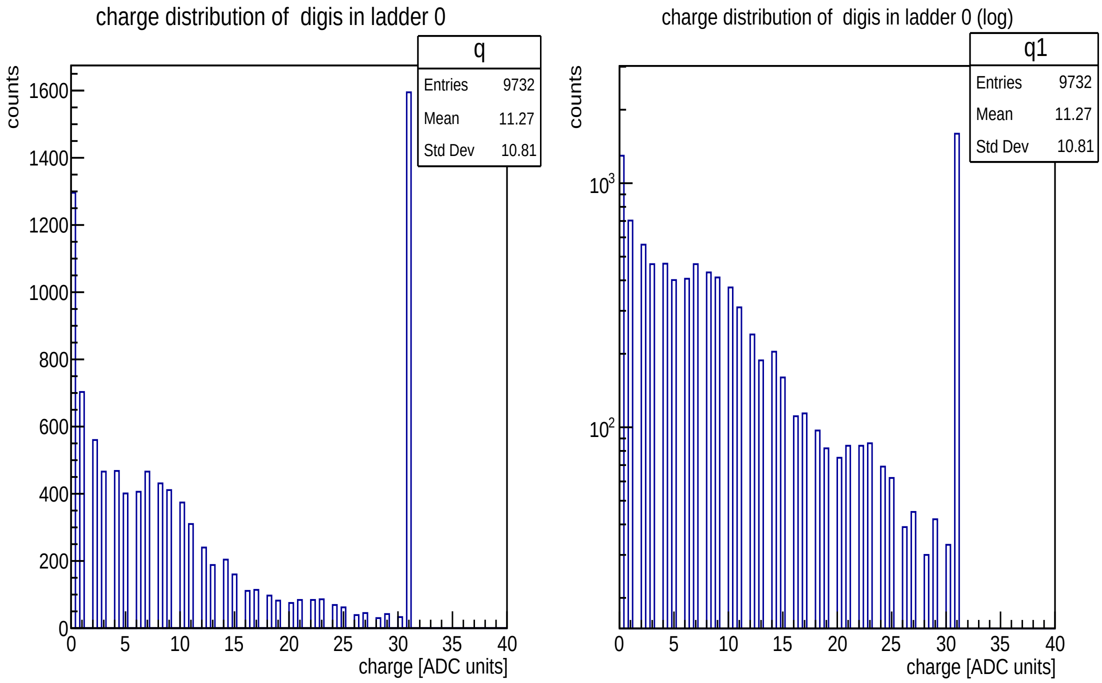


Figure 2.10: mCBM simulation steps

In Figure 2.10 steps of mCBM simulation are presented. In first step we run the mcbm_transport.C macro, the macro for standard transport simulation in mCBM using UrQMD input and GEANT3. The second step of simulation is the launch of run_digi.C. The detector response produces a raw data file from the transport data, which serves as input for reconstruction. Raw data will be delivered in time-slice format. On this level we can change global module parameters. In last step we reconstruct simulated data.

SIMULATION



RAW DATA

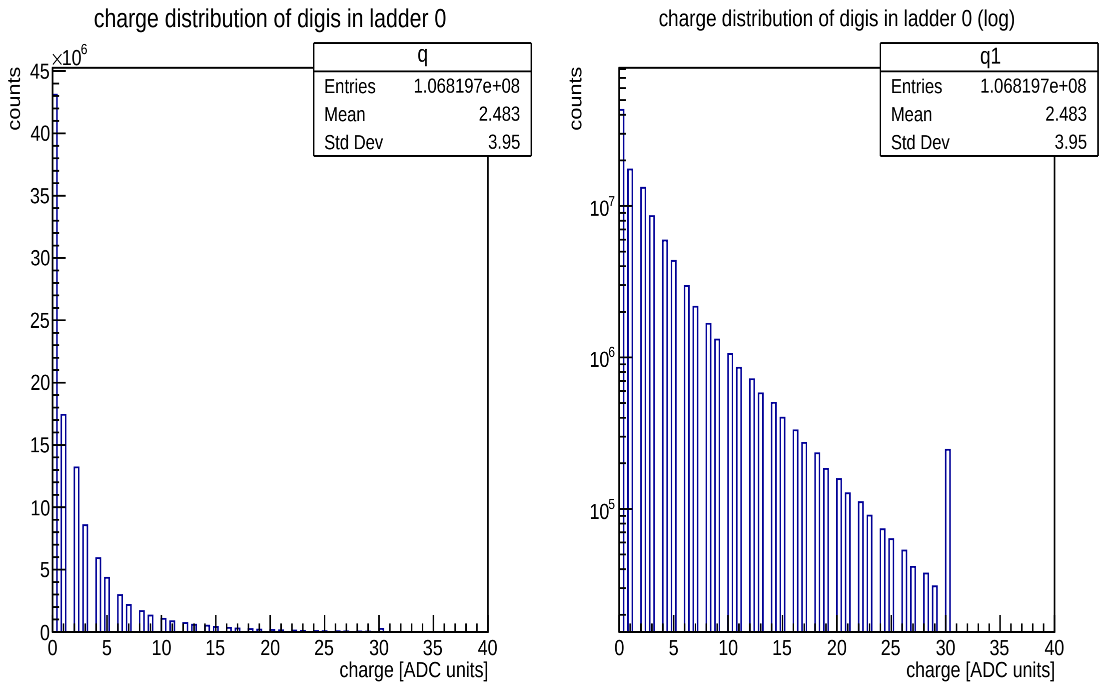


Figure 2.11: Charge distribution of digis in ladder 0 (comparison of simulated data and raw data)

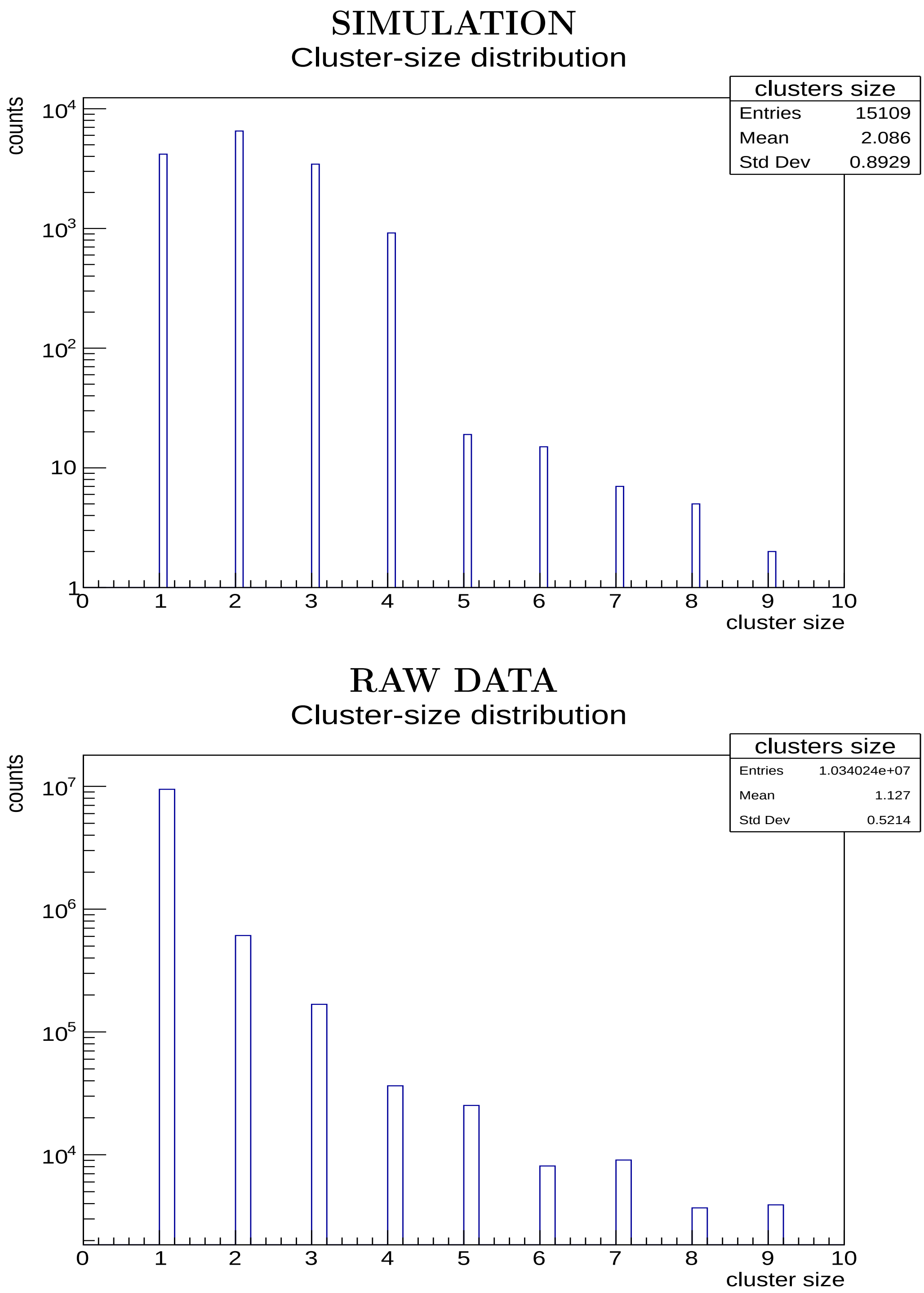


Figure 2.12: Cluster size distribution (comparison of simulated data and raw data)

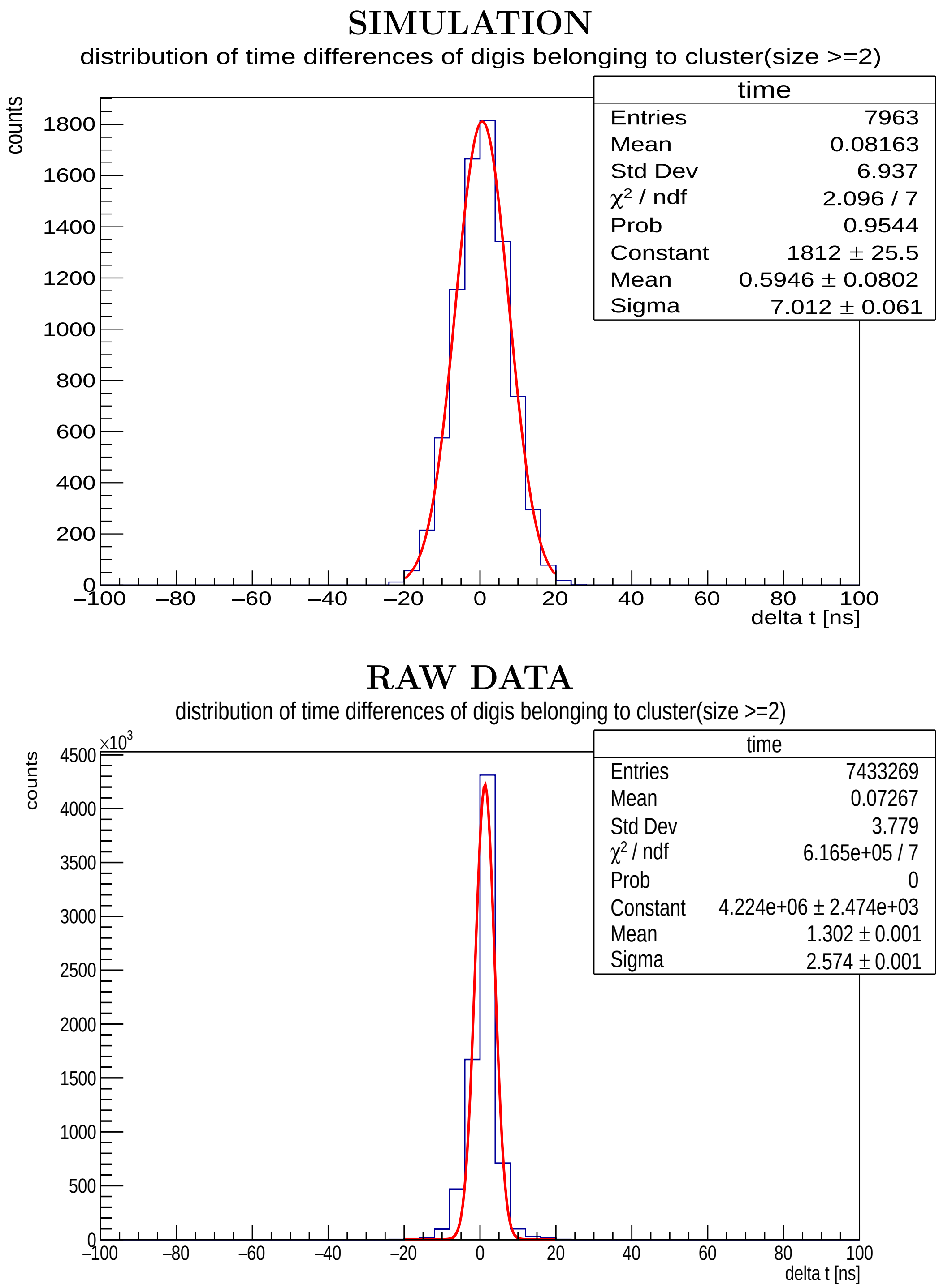


Figure 2.13: Distribution of time differences of digis belonging to one cluster (comparison of simulated data and raw data)

In order to compare raw data from mSTS for run number 159 with simulated data I set together results of these analysis. I compared charge distribution, cluster-size and time resolution. As can be seen in Figure 2.11, 2.12 and 2.13 there is a big difference between raw and simulated data. This fact is not surprising and we expected this kind of results because the simulation may not always produce accurate results. The mCBM team is currently working on improving simulation. The reason to have a detector description in software is to be able to understand the detector behaviour and to correct detector data for imperfect behaviour of the detector (efficiency). Thus, the detector model implemented in the simulation must correspond as well as possible to the reality. Therefore, it is necessary to adjust it on the basis of real experiment data.

Chapter 3

Summary

I investigated mSTS data from run 159, taken in March and April 2019. My findings are:
- there is no obvious separation of signal and noise from the charge distribution of digis,
- cluster and hit reconstruction work satisfactorily,
- the time resolution derived from the time difference of digis in a cluster is better than expected,
- in the time spectrum there is a periodic noise with a frequency of about 16 MHz, the origin of this noise is not yet understood,
- results form event-by-event analysis show similar results as the analysis of the full data stream, indicating that the majority of data is attributed to beam interactions, and that the inter-event noise is negligible,
- charge, cluster-size and time distributions are different in simulation when compared to real data. There is a need to adjust the detector module implemented in the simulations.

Bibliography

[1] B. Friman, J. Knoll, S. Leupold, J. Randrup, R. Rapp and P. Senger,editors *The CBM Physics Book* 814 (2011) 1.

[2] https://fair-center.eu [accessed:25.09.2019]

[3] T. Ablyazimov et al. (CBM Collaboration), *Eur. Phys. J. A* 53 (2017) 60.

[4] H. Malygina *Hit reconstruction for the Silicon Tracking System of the CBM experiment* (2018).

[5] https://www.sciencedirect.com/topics/computer-science/data-simulation [accessed: 25.09.2019]