Internship report: stability test of 2008 COMPASS data

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Abstract

The main goal of this project is to look for the abnormal runs from COMPASS experiment (2008). The COMPASS data being analyzed for each run were already preselected before the stability test. For seeking the abnormal runs, different parameters in each event are extracted and investigated, such as the position of primary vertices, angular distribution of recoiled protons, invariant mass of three pions, etc. By plotting values of the parameters from each different run, run number 70195, 69612, 70223, etc can be directly selected out because of disparities to the normal runs. The most significant abnormalities result from the inconsistency of half width value from pions and photons' invariant mass. The explanation of these disparities are made by further inspecting the corresponding photon number from ECAL2 and recoiled proton angular distribution.

1 Introduction

The COMPASS stands for "Common Muon and Proton Apparatus for Structure and Spectroscopy", a fixed target experiment for investigation of nucleon spin structure and hadron spectroscopy. The final experimental results are concluded by analyzing the data recorded by multiple kinds of detectors during process of scattering. Due to the complexity and sensitivity of COMPASS detectors, recorded data can be easily sabotaged by unexpected external conditions, such as electronic malfunction or unusual shutdown of components. The data with those unwanted effects should be selected out for improving the quality of data analysis in the final step. In this project, the abnormality resulting from these effects are only investigated for the data with different run numbers. By calculating and comparing values of multiple characteristic parameters of each run, the abnormal runs can be identified and further examined to postulate their probable causes. In the end, by checking the already existed information in log book, it then can be determined the data of which runs should be discarded.

2 Target and Detectors

COMPASS experiment comprises large number of detectors, for identifying and measuring the particles coming out of interaction vertices. There are also detectors which monitor the particle beams and trigger other components to decide when the signals should be read out or not. In this section, the basic functionalities of different kinds of detectors are introduced in a simple manner.

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2.1 Particle beam and target

To create the projectile particle beam, the proton beam, which is accelerated by the Super Proton Synchrotron (SPS), is firstly directed into Beryllium. From the nuclear reaction between proton and Beryllium nucleus, a secondary hadron particle beam is created, which is the incoming particle beam for the scattering experiment. In this project, the hadron beam is selected to be negative charged pion beam. But a small fraction of Kaon (2.4 %) can also exist in the incoming particle beam [ref]. The proton target, onto which pion beam is diverted, is in form of liquid hydrogen stored in a 40 cm height cylindrical container (see section).

2.2 Detector layout

The layout of COMPASS detectors is shown in figure 1. Proton target is located inside the RPD (recoil-proton detector). On the left of target locate SciFi (scintillating fiber), BC (Beam counter) and silicon detectors. The coincidence of signals from SciFi and BC is used for the beam trigger, setting the time reference of whole system. The silicon detectors are applied for determining the location of projectile beam, which is further used to calculate the position of primary vertex. On the downstream very close to the target, there are sandwich veto and PixelGEM/Micromegas/DC (Pixel GEM detector, micromegas detectors and drift chamber). The function of sandwich veto is to reject the signal readout when the scattering polar angle of out-going particle is too large to measure. The structure of sandwich veto can be seen in figure 2, where the veto can be triggered if polar angle is out of acceptance. Behind the sandwich veto, PixelGEM/Micromegas/DC detectors are implemented to

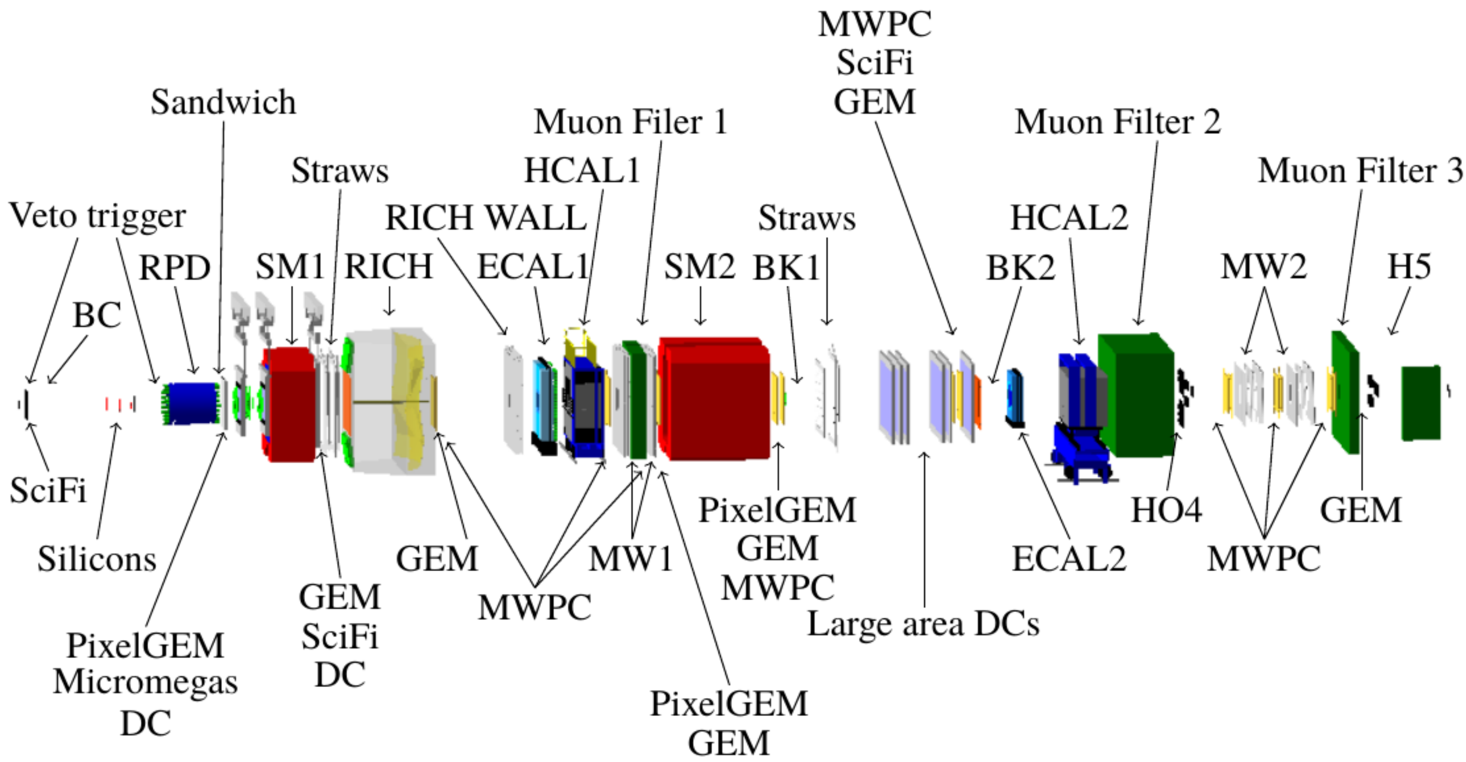


Figure 1: The layout of COMPASS detectors. The length of whole setup is around 50 meters. Pion beam comes from the left side of detectors and hits the target, which is surrounded by recoil-proton detector (RPD). On the right side of target, two different sets of detectors are used to measure out-going particles with small and large scattering angles.

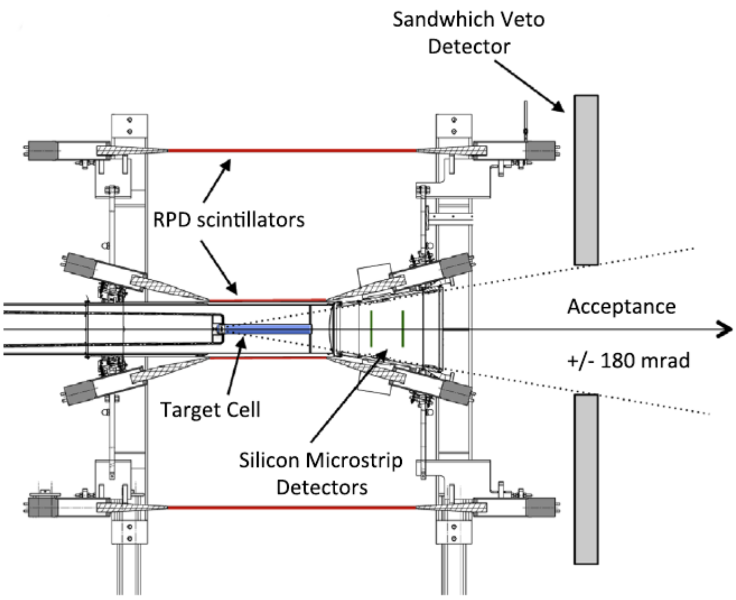


Figure 2: Scheme of detectors around the target region. The sandwich veto on the right prevent unmeasurable events with large scattering angles. Source: [1]

measure the angles of out-going particles with high accuracy and resolution. On the downstream further away from the target, two different sets of detectors are set up for measuring out-going particles with small and large scattering angles.

The first set, located in the front, is used as large angle spectrometer (LAS). The major components of LAS are SM1 (solenoid magnet 1), tracking detectors, RICH (ring-image Cherenkov detector), ECAL1, HCAL1 and Muon filter. SM1 provides the magnetic field to deviate charged particles. The degree of deviation is measured by the tracking detectors on the both sides, which can calculate the momentum of out-going charged particles. The RICH detector on the right side on SM1 is used to improve the permanence of experiment by separating π and K in high intensity environment[2]. ECAL1 is an electromagnetic calorimeter used to measure the energy of particles like electrons or photons while HCAL1, a hadron calorimeter, is used to measure the energy of hadron particles. Muon can be identified by tracking detectors behind a muon filter, which intercept every particles except muon.

The second set, located at the end of downstream, is deployed as small angle spectrometer (SAS). Most of its components have the same functionalities as their counterparts in LAS. The main additional detectors in SAS contains two BKs (beam killer), which are basically two scintillating counters. They are used to veto the non-interacting particle beams[1].

3 Data and interaction

The data recorded by multiple detectors are stored in different partitions. Before carrying out the stability test in this project, the data being analyzed are already pre-selected. In this section, an overview about data storage and pre-selection is discussed, followed by a short in-

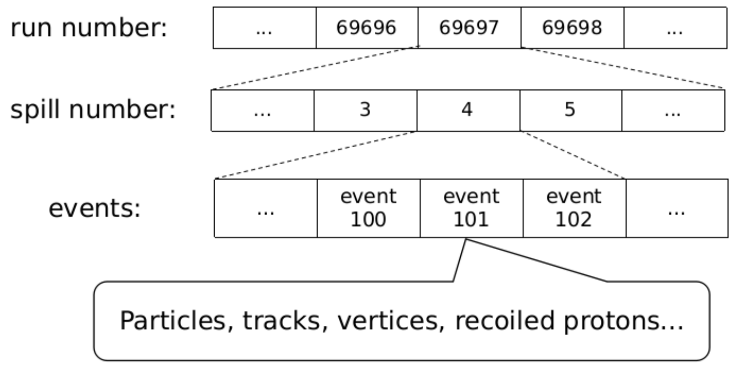


Figure 3: Scheme of data storage structure. Data from the detectors are categorized into three different levels.

troduction of probable interaction giving rise to selected data.

3.1 Data storage

There are three different partition levels regarding the data storage, as is shown in picture 3. First, the whole data are stored with different run number. The event data with same run number are further divided into different spill number. One spill corresponds to one period of process, in which the particle beam is bunched and de-bunched. Time expansion of each spill is around 48 seconds [3], which is time period of SPS (super proton synchrotron). Similarly, each spill contains large amount of events. One event represents a single scattering between π and proton and it contains the measurements of the corresponding event from detectors, such as tracking detectors or calorimeters.

3.2 Data preselection

The data used in this stability test are not raw data coming directly from detectors, but rather being preselected previously. Event is only selected if it meets following 4 conditions:

- A best primary vertex was found
- Primary vertex Z-position Z_{pv}: $-200\,\text{cm} < Z_{pv} < 160\,\text{cm}$
- Exactly one or three charged tracks, leaving the primary vertex
- Charge sum of all three tracks $= -1$

The first condition requires the existence of primary vertex. This is because the vertex position is not the value that can be directly measured by detectors. It is rather reconstructed by determining the intersecting point between two charged particle tracks. Thus, there could be no primary vertex constructed in some events, which should be selected out. Second condition excludes the events where outgoing particles are not coming from the interaction on proton target but rather on some detectors. Therefore, the position of primary vertex should be around the target region. The third and fourth condition guarantees the data after selection correspond to the elastic scattering or the interaction where one π is scattered into three charged π.

3.3 Scattering process

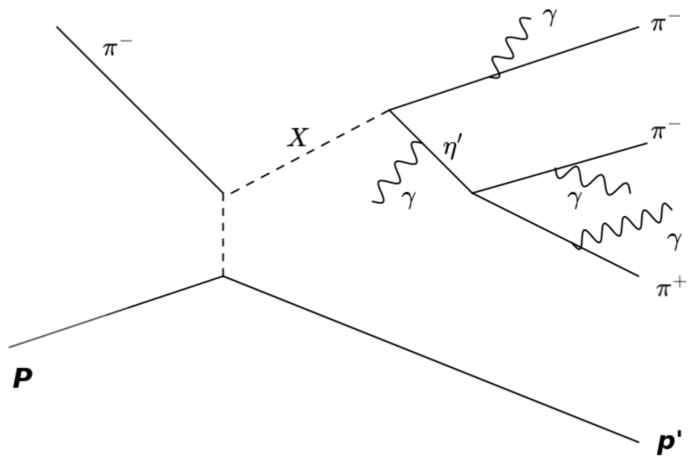


Figure 4: Scheme of one possible inelastic scattering between π and proton. In such case, pi^- is excited and consecutively decays into 3 charged π, during which multiple photons can also be emitted.

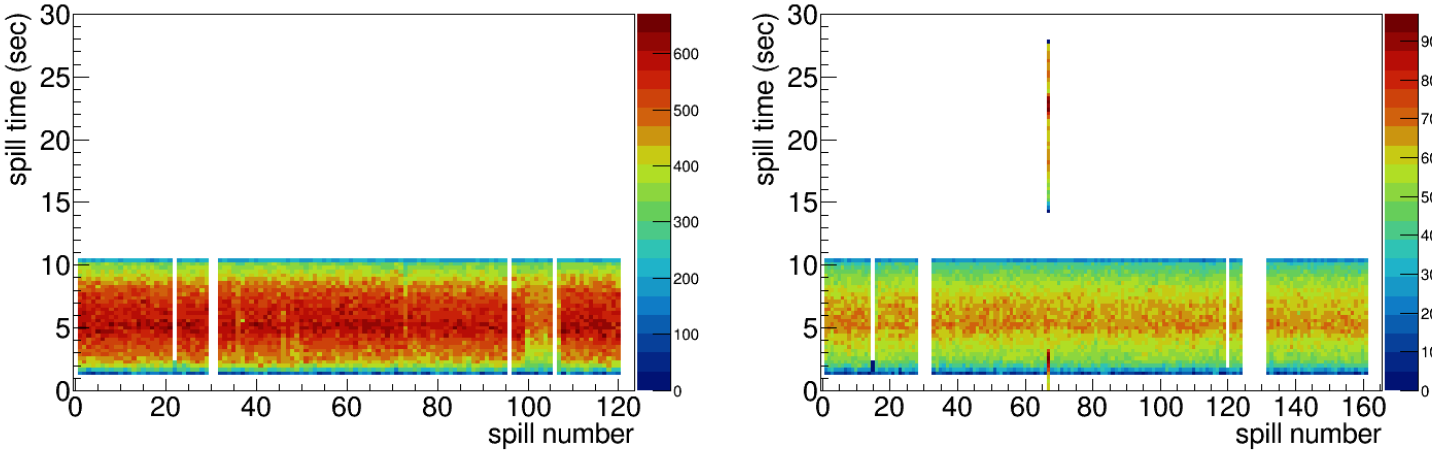
The interaction that is looked into for this stability test is inelastic scattering of one π^- scattered into three charged π. Due to the preselection, charged ejectile particles are very likely to be π^-, π^+, π^-. One possibility of the interaction is shown in figure 4. By scattering off the proton target, π^- is excited into a high energy state (X), which in a very short time, decays into π^- and η'. Due to instability of η', it finally decays into π^- and π^+ as well. Meanwhile, certain number of photons are also emitted by electromagnetic radiation.

4 method of testing

The main method of stability testing is to check the values of multiple parameters in different runs and determine the abnormal runs by comparison. The most important characteristic parameters of testing is the invariant mass distribution of all out-going particles. The other parameters, such as photon number recorded by different ECALs, can also be used for the diagnosis of abnormalities. In the following subsections, different parameters are investigated for each run:

4.1 Number of events

The number of events for each run can be vastly different after the preselection. By using PHAST data analysis framework, the event number for each spill of every run is counted and plotted. Since incoming particle beam only exist in certain time interval of spill, event numbers are not spread throughout whole time period of the spill. From the figure 5a, one can easily see that normally



(a) Run number 70171

(b) Run number 70195

Figure 5: Temporal distribution of event numbers for each spill number. The color band represents the number of events per 0.3 seconds (time resolution) for each spill. The y axes represent the time from starting moment of each spill. (a) A normal temporal distribution (run number = 70171). The effective time expansion of particle beam is around 9s and distribution of each spill is centrally concentrated. (b) An abnormal temporal distribution (run number = 70195). Particle beam occurred in inactive time period.

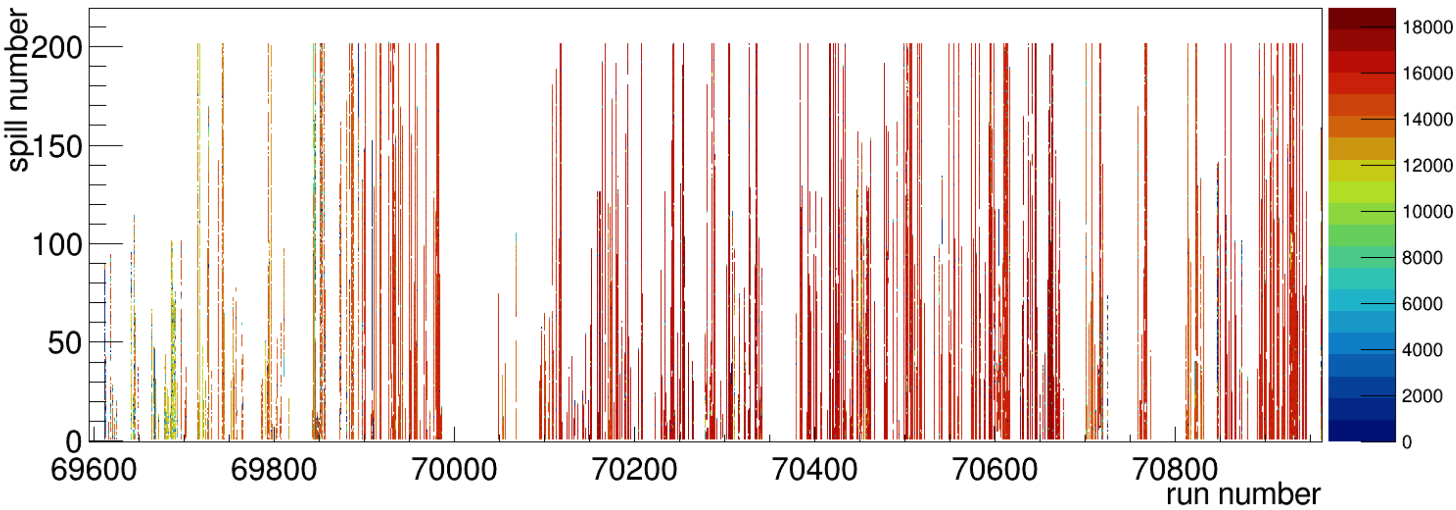


Figure 6: Event distribution with respect to spill number of each run number. The color band shows the value of event counting in certain spill of certain run. The run number ranging from 69595 $\sim$ 70963 while the maximal of spill number cannot exceed above 200. The number of events can goes up to 18000 per spill whereas it could also amount to only few thousands or less, especially in the beginning of experiment.

events are only distributed on the time interval 1.2 s $\sim$ 10.5 s of the spill period. There is a short dead period of 1.2 s before the start of particle beam and a long inactive period after the stop of beam at 10.5 s until the end of spill (at around 48 s). However, as is shown in figure 5b, there exists one abnormal run, where the effective time interval of one spill is more than 2 times larger than the normal one. This shows that the particle beam occurs during the inactive time interval not only right at the beginning of spill (0 s $\sim$ 1.2 s), but also after the first stop of beam (14.1 s $\sim$ 27.9 s). Such abnormality could probably result from the trigger problem, due to which events are recorded with wrong time scale.

After selecting out the run with abnormal temporal distribution discussed above, the number of events can be compared for each spill in every run, as is shown in figure 6. The event number distribution is quite uneven throughout the experiment after the preselection. Runs in the beginning usually have low values of event counting and most of them don't have any event in some spills. Moreover, there exist large number of vacant runs with no events in all spills. Therefore, one can consider the number of events of each run as one of the characteristic parameters to test the stability of experiment. However, analyses such as invariant mass of three pion mass are independent from the number of events one have for each run. Thus, the variation of event distribution throughout the experiment could have little or no effect towards results of the analyses.

4.2 Vertex positions

The next parameter that could be investigated is the position of vertices.

4.3 Photon and energy cut

4.4 Three pions invaraint mass

4.5 Total invariant mass

4.6 Recoil proton

4.7 Correlation of abnormalities

5 Results and discussion

6 Conclusion

References

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