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Event reconstruction for the CBM-RICH prototype beamtest data in 2014

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A B S T R A C T

The Compressed Baryonic Matter (CBM) experiment at the future FAIR facility will investigate the QCD phase diagram at high net baryon densities and moderate temperatures in A+A collisions from 2 to 11 *A*GeV (SIS100). Electron identification in CBM will be performed by a Ring Imaging Cherenkov (RICH) detector and Transition Radiation Detectors (TRD).

A real size prototype of the RICH detector was tested together with other CBM groups at the CERN PS/T9 beam line in 2014. For the first time the data format used the FLESnet protocol from CBM delivering free streaming data. The analysis was fully performed within the CBMROOT framework. In this contribution the data analysis and the event reconstruction methods which were used for obtained data are discussed. Rings were reconstructed using an algorithm based on the Hough Transform method and their parameters were derived with high accuracy by circle and ellipse fitting procedures. We present results of the application of the presented algorithms. In particular we compare results with and without Wavelength shifting (WLS) coating.

1. The CBM experiment

The Compressed Baryonic Matter (CBM) experiment will be a dedicated setup for the measurement of fixed target heavy ion collisions at the future FAIR accelerator at Darmstadt [1]. It will explore the phase diagram of nuclear matter at high net baryon densities and moderate temperatures. The research program of the CBM experiment will start with primary beams from the SIS100 synchrotron (protons up to 29 GeV, Au up to 11 *A*GeV). The beam extracted to the CBM cave reaches intensities up to 10^9 Au ions per second. A key item of the CBM physics program is the precise measurement of low-mass vector mesons and J/ψ in their leptonic decay channel. For these studies excellent electron identification in terms of efficiency and purity is required.

Electrons will be identified by the Ring Imaging Cherenkov detector (RICH) combined with several Transition Radiation detectors (TRD) positioned behind the Silicon Tracking System (STS). The CBM detector setup in its electron configuration is shown in Fig. 1.

2. The CBM-RICH detector

The RICH detector is the main detection system for identification of

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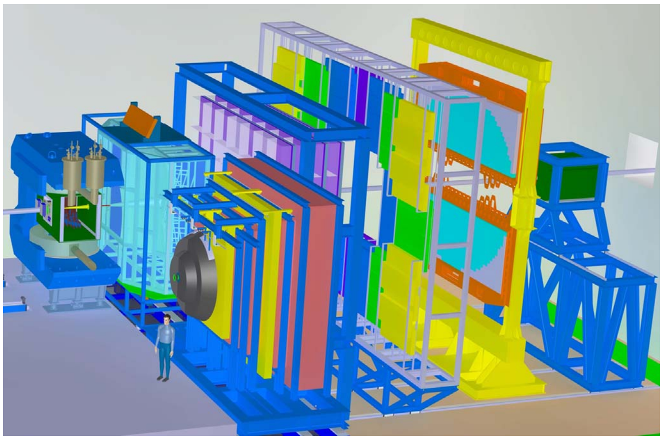

Fig. 1. Sketch of the CBM experimental setup. From left to right: STS tracking system inside a dipole magnet, RICH detector (Muon detector alongside), TRD detector, Time-of-flight wall (TOF), Electromagnetic CALorimeter (ECAL) and Projectile Spectator Detector (PSD).

electrons and suppression of pions in the momentum range below 8 GeV/c. A gaseous RICH detector with focusing mirrors and photon detector planes will be built. CO_2 gas (γ_{thr}=33, $p_{thr,\pi}$=4.65 GeV/c) at 2 mbar overpressure will be used as radiator gas. The mirror plane is split horizontally into two halves above and below the beam pipe. Each half consists of ≈40 spherical mirror tiles with 3 m radius of curvature. High UV reflectivity mirrors consisting of an $Al+MgF_2$ coating on a 6 mm SIMAX glass substrate will be used. The Cherenkov photons are projected onto two photon detector planes approx. 2×0.6 m^2 each located behind the CBM dipole magnet inside iron shielding boxes in order to reduce the magnetic stray field (< 1 mT at the photo cathode). The CBM-RICH photon detector will consist of about 850 Hamamatsu H12700 Multianode Photomultiplier tubes. See [2–5] for details on the CBM-RICH.

3. The CBM-RICH prototype

A full-scale prototype of the RICH detector was built in 2011 (see Fig. 2) in order to validate the detector design and check the simulation performance.

This prototype was tested for the third time together with other CBM groups at the CERN PS/T9 beam line in November 2014. For the first time the analysis of the RICH data was fully performed within the CBMROOT framework [6].

Readout chain. The RICH prototype readout chain consists of two main parts (see the scheme in Fig. 3). The first part is the PADIWA [7,8] front end module serving as discriminator of the analog PMT signals. Each PADIWA front-end module provides 16 channels; groups of 4 modules were combined for the readout of a single PMT. The discriminated output pulse is transmitted to the TRB3 FPGA-TDC [7,8] readout board. The TRB3 is a multi-purpose FPGA board, consisting of 4+1 Lattice ECP3 FPGAs. Each of them can be configured as a FPGA TDC, providing up to 4×64 TDC channels of high precision. All individual TRB3 boards were operated synchronously by using a common 200 MHz clock generator.

4. Data analysis

The RICH data was written in HLD file format [8]. The data analysis starts from data unpacking which includes several steps: 1) Retrieving raw messages from the data stream. One MAPMT pixel was read out by one PADIWA channel which is split to two TDC channels- one for the leading edge and one for the trailing edge of a signal. 2) Matching leading and trailing edges. 3) Fine time calibration. The fine time counter in the TDC uses the Tapped Delay Line. The standard calibration procedure based on Look Up Tables is implemented [9]. 4) Synchronization of TDCs. The time offset for each TDC is calculated based on a synchronization signal on channel 0. 5) Building of raw hits. The raw hits contain the information about leading and trailing time, TDC identifier and TDC channel number.

The raw hits are not grouped into events but stored as free streaming data. Fig. 4 shows the distribution of the number of RICH hits with time. The implemented event building procedure uses a reference time signal from the hodoscope (or UV-LED pulser, laser pulser, finger scintillator). All raw RICH hits which belong to a time window (300 ns) around the reference time are collected into one event. Then the TDC identifier and the channel number information from the raw hits are converted to X and Y positions on the PMT plane using a corresponding mapping mechanism. After this step the hits are sorted by events and stored in the standard CBMROOT containers. From this step on the standard CBMROOT routines can be used for the further analysis. Rings are reconstructed using an algorithm based on the Hough Transform method and their parameters are derived with high accuracy by circle and ellipse fitting procedures [10–15]. The algorithms are the same as those used in the event reconstruction for simulated data.

Fig. 5 shows two examples of single events with detected Cherenkov photons and reconstructed rings.

Fig. 6 shows an example of the analysis results for the position H (see Fig. 2, right) before removing the WLS coating for 2 GeV/c electrons.

5. WLS coating

In the 2014 beam time we continued to study the performance of WLS films on the new H12700 MAPMTs with UV-extended window

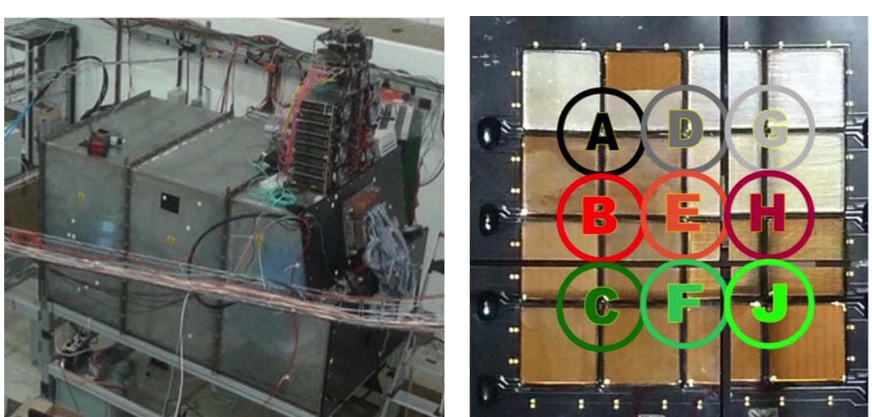

Fig. 2. Left: Photograph of the CBM-RICH prototype. Right: photograph of the PMT plane used during beam time at CERN-PS in 2014. Letters indicate tested ring positions.