Status of the CBM experiment at FAIR

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Observables

The Compressed Baryonic Matter (CBM) experiment is designed to explore the QCD phase diagram in the region of high net-baryon densities using rare diagnostic probes. The layout of the CBM detectors is driven by the corresponding experimental requirements concerning reaction rates, radiation tolerance, particle densities, and selectivity. The experimental challenges are illustrated in Fig. 1, which depicts the yield of various particle species produced in central Au+Au collisions at 25A GeV. The yield is defined as the product of particle multiplicity times branching ratio for the decay products under consideration, e.g. the di-leptonic decay of vector mesons (ρ, ω, ϕ, J/ϕ) and the hadronic decay of open charm (D mesons). Note that the particle yield per collision spans 13 orders of magnitude with leptons and hadrons in the exit channel, embedded in about 800 charged particles. Multi-strange hyperons, vector mesons and charmed particles will be measured for the first time at FAIR energies with CBM, which therefore has a substantial discovery potential.

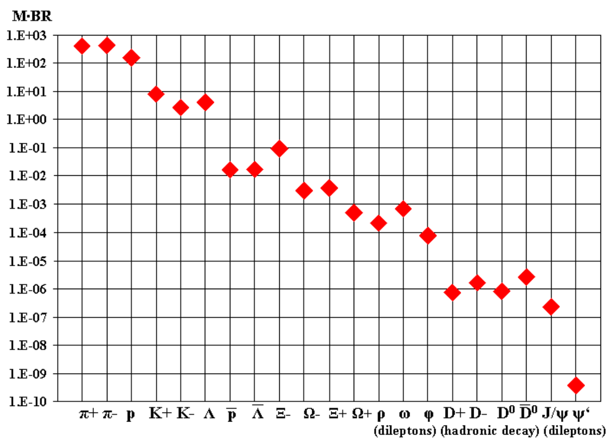

Figure 1: Particle multiplicities times branching ratio for central Au+Au collisions at 25A GeV as calculated with the HSD transport code and the statistical model. For the vector mesons (ρ, ω, ϕ, J/ϕ), the decay into lepton pairs was assumed, for D mesons the hadronic decay into kaons and pions.

Selected R&D activities for CBM

The **CBM SC dipole magnet** has a large aperture (gap height 130 cm, gap width 160 cm) in order to host the Silicon Tracking System (STS). The last STS station exhibits a height of about 120 cm including its front-end boards and the thermal enclosure. In beam direction, the magnet yoke is very compact (length 100 cm) in order to achieve a polar angle acceptance of $\pm 25°$. The engineering design of the magnet is in progress.

The precise determination of the secondary decay vertices of charmed particles requires a highly-granulated, fast, radiation-hard, and low-mass detector system. The **CBM Micro-Vertex Detector (MVD)** consists of silicon pixel stations, which are based on ultra-thin Monolithic Active Pixel Sensors (MAPS). In 2010, sensors could be produced with a high-resistivity CMOS process, resulting in a high signal-to-noise value even after irradiation with an integrated neutron dose of $10^{13}\mathrm{n_{eq}/cm^2}$. Further improvements are expected with smaller feature size. A prototype read-out-system and a mechanical detector design were developed.

The **CBM Silicon Tracking System (STS)** is based on double-sided micro-strip sensors. Large-area prototype detectors with outer dimensions of 6.2 cm by 6.2 cm and 1024 AC-coupled strips per side were produced. The front and back side strips are inclined by a stereo angle of 15°. Short strips in the sensor corners are interconnected to a strip in the opposite corner via a second metallization layer. The sensors will be used to build a demonstrator ladder. Further double-sided micro-strip test sensors with new radiation tolerant structures were designed.

The sensors are read out via low-mass cables of up to 50 cm length in order to keep the active area of the detector free of electronics. The cables consist of micro-line-structured aluminium layers on polyimide carrier foils.

Two prototype Silicon tracking stations consisting of double-sided silicon micro-strip sensors, ultra-thin readout cables, and self-triggering readout electronics were successfully tested at COSY with a 3 GeV proton beam. Detailed simulations were performed in order to understand the expected radiation damage in the sensors. The layout of the detector stations, i.e. the number and size of the sensors mounted on the vertical ladder structures, was optimized to reduce the number of spare parts while preserving the tracking performance.

The **RICH photo-detector** exhibits an active area of 2.4 $\mathrm{m^2}$, which is covered by multi-anode photomultipliers (MAPMTs). Beam tests at GSI and CERN and measurements with LEDs in the laboratory demonstrated that the Hamamatsu H8500 with 64 pixels is very well suited for the detection of single Cherenkov photons. Properties like the quantum efficiency (with and without wavelength shifting films), crosstalk and the performance of MAPMTs in the presence of magnetic fields were successfully studied. The MAPMT signals were read out by the self-triggered electronics of the nXYTER chip. The results were very promising, also in view of the possible use of a future CBM ASIC for the RICH photo detector. The RICH gas system was designed and is presently being built. The reflectivity of different mirrors was investigated.

The **CBM Transition Radiation Detector (TRD)** has to provide electron identification and pion suppression by a factor of the order of 100 for momenta above 1 GeV/c at hit rates of 100 $\mathrm{kHz/cm^2}$. Such a high pion suppression factor (corresponding to a pion efficiency of 1%) together with an electron efficiency of better that 90% can only be achieved with 9 - 12 layers of TRD chambers, resulting in an overall detector area of almost 1000 $\mathrm{m^2}$. Several prototype detectors were developed to fulfill the requirements. One approach is to use fast multi-wire chambers with a thin amplification region with and without drift section. These detectors were read out by a newly developed self-triggered SPADIC chip, which both amplifies and digitizes the pulses from the CBM-TRD. Another option is a two-dimension position sensitive prototype TRD with diagonally split rectangular (i.e. triangular) read-out pads, which allow a position determination both across and along the pads. This detector is read out by a new Fast Analogue Signal Processor (FASP). The various prototype TRDs were successfully tested at CERN using a mixed beam of electrons and pions with momenta of 1 - 5 GeV/c.

In order to identify the soft muons from vector meson decays in a large combinatorial background, the **CBM muon detector** is designed as an instrumented hadron absorber. The detection system comprises six iron slabs of different thickness (20 cm - 100 cm) with detector triplets behind each iron absorber (18 detector layers in total). The development of the muon tracking detectors concentrates on the construction and test of prototype gaseous detectors based on different technologies. The detector layers behind the first and second hadron absorber (particle density up to 500 $\mathrm{kHz/cm^2}$) will be based on GEM technology or on hybrid detectors combining different technologies. Various prototype detectors were built and tested with radioactive sources and particle beams: double and triple thin GEMs, double thick GEMs, and thin and thick GEMs with Micromegas. We investigated the use of single-mask GEM foils, which can be produced in large size at moderate costs. In the third and forth absorber gap (particle density up to 5 $\mathrm{kHz/cm^2}$), we may either use hybrid detectors or Micromegas with a resistive strip layer suppressing the sparks. The latter technology allows to build large-area detectors. For the last detector layers where the occupancy is low, we foresee multiple-layer straw tubes. Prototype triple GEM detectors read out by a free-streaming FEE and DAQ system were successfully tested at COSY with a 3 GeV proton beam. The hybrid detectors were successfully tested with 5 GeV proton and pion beams at CERN.

A start version of the muon detection system was developed with three absorber layers and three detector triplets only. This system would allow to identify J/ψ mesons in Au+Au collisions at SIS-100, i.e. at beam energies below the J/ψ production threshold in nucleon-nucleon collisions, which is 11.3 GeV.

Time-of-flight measurements in CBM require a large-area, highly granulated and fast detector, which will be based on Multigap Resistive Plate Chambers (MRPC). Hit rates of up to 20 $\mathrm{kHz/cm^2}$ are expected to occur in the inner part of the **CBM-TOF wall**. Prototype MRPCs were built with electrodes made of special glass with a resistivity of the order of $10^{10}\,\Omega/\mathrm{cm}$. With a 10-gap MRPC, a time resolution of about 70 ps was achieved at a rate of 20 $\mathrm{kHz/cm^2}$. In order to cope with the high particle density per event at small emission angles, a high-granularity MRPC was developed. This prototype exhibits a symmetric structure with 2×8 glass electrodes and a read-out electrode with short strips (46 mm long). The resulting time resolution is 57 ps. A MRPC with electrodes made of low-resistivity ceramics was built and tested at rates up to 200 $\mathrm{kHz/cm^2}$. At large polar emission angles, i.e. in most of the active area of the CBM-TOF detector, the hit rate is of the order of 1 $\mathrm{kHz/cm^2}$. At such low rates, a conventional MRPC in multi-strip configuration with thin standard float glass can be used. For this application, a fully differential prototype MRPC was built and tested successfully at COSY with a proton beam, together with a high-granularity prototype MRPC with low-resistivity glass electrodes. In the test experiment, both detectors were read out with self-triggered front-end electronics.

The free-streaming **CBM data read-out system** sends the hit information of each detector together with time stamps into the data acquisition chain. The hits have to be associated to physical events by the reconstruction algorithms. A software package was developed which allows the generation of Monte-Carlo data consisting of hits with individual time stamps, and removing the correlation of detector hits with events. The next step is to develop ”4-dimensional” event reconstruction algorithms, which take the time information into account for track reconstruction and pattern recognition.