Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 568 (2006) 258–262
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Requirements for the Silicon Tracking System of CBM at FAIR

Johann M. Heuser[a,*], M. Deveaux[a,b], C. Müntz[c], J. Stroth[c]

[a] Gesellschaft für Schwerionenforschung mbH (GSI), Planck-Str. 1, 64291 Darmstadt, Germany
[b] Institut de Recherches Subatomiques, 23 rue du Loess, 67037 Strasbourg, France
[c] J. W. Goethe-Universität Frankfurt am Main, Max von Laue-Str. 1, 60438 Frankfurt/Main, Germany

for the CBM Collaboration
Available online 27 June 2006

Abstract

The Compressed Baryonic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt will systematically study dense baryonic matter created in collisions of intense heavy-ion beams with nuclear targets. The research addresses current questions of strong-interaction physics as confinement in normal nuclear matter, chiral symmetry restoration in deconfined matter at high temperatures and densities, and the search for the critical end-point of the phase boundary. With beams of ions as heavy as Au and U, energies up to 45 GeV/nucleon and intensities up to 10^{12} ions per pulse, FAIR will enable CBM to probe the phase diagram of quantum chromo dynamics (QCD) in a region poorly known, while being complementary to current and future research programmes at RHIC and LHC.

The CBM experiment is planned as a fixed-target spectrometer optimized for the detection of rare probes. Among these are open charm and low-mass vector mesons, important observables for the initial energetic and dense phase of the collisions. The experimental concept and challenge is to accomplish charged particle tracking in the high-multiplicity, high-radiation collision environment. This will be realized exclusively with a silicon tracking detector system installed in a strong magnetic dipole field directly behind the target. Key to the physics of CBM and benchmark for the tracking is the reconstruction of short-lived charmed mesons that puts high demands on the silicon detectors.

The article presents a conceptual design of the CBM experiment with emphasis on the silicon tracking system. Requirements for silicon microstrip and pixel detectors and their arrangement in the tracker are discussed in relation to important physics observables addressed by CBM.

PACS: 25.75.−q; 29.40.Gx; 61.82.Fk

Keywords: Heavy-ion collisions; FAIR; Compressed baryonic matter; CBM; Open charm; Low-mass vector mesons; Silicon vertex tracker; Pixel detector; Microstrip detector; Radiation tolerance; Small material budget; Data-push readout architecture

1. Introduction

The Compressed Baryonic Matter (CBM) experiment [1] at the future international Facility for Antiproton and Ion Research (FAIR) [2] in Darmstadt, Germany, has been proposed to address fundamental questions of strong interaction physics. Experimental results obtained at the CERN-SPS and at RHIC indicate that a new state of matter is created in high-energy heavy-ion collisions that consist of fundamental constituents: The ‘‘Quark Gluon Plasma’’. These and future experiments at the CERN-LHC produce this state of matter at high temperatures and low baryon-chemical potential. The QCD phase diagram, however, exhibits also a region of high baryon densities that is poorly known, both theoretically and experimentally from first measurements at AGS and SPS years ago. The properties of strongly interacting matter at high baryon densities—as it exists in the interior of neutron stars—are largely unknown. The detailed exploration of super dense baryonic matter is the aim of the CBM experiment. It requires the availability of intense and high-quality beams for systematic studies of rare and penetrating probes. They will be provided by the double ring

*Corresponding author. Tel.: +49 6159 71 2717; fax: +49 6159 71 2785.
E-mail address: J.Heuser@gsi.de (J.M. Heuser).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2006.05.238

synchrotron SIS-100/SIS-300, the heart of the future accelerator complex of FAIR.

2. The CBM experiment

The CBM experiment, schematically shown in Fig. 1, is planned as a fixed-target spectrometer at a primary beam extraction line of SIS-300. Its core detection system is a Silicon Tracking System of unprecedented performance. CBM builds on a novel concept for charged particle tracking and heavy-flavor decay vertex measurement in fixed-target heavy-ion physics. The tracks and momenta of all charged particles created in the nuclear collisions are exclusively reconstructed with the Silicon Tracking System. A similar vertex spectrometer was recently pioneered by the NA60 experiment [3] at the CERN SPS. Microstrip detector stations, perhaps supported by other silicon detectors, perform track and momentum measurement. Pixel detector stations in the vicinity of the target enable high-precision vertex detection. The reconstruction of charged-particle tracks and the identification of decay vertices, in particular of massive short-lived particles containing a charm quark ("open charm"), have to be achieved at high track densities and at interaction rates of up to 10^7 per second.

3. Requirements for the CBM Silicon Tracking System

3.1. Performance benchmark

The benchmark for the performance of the Silicon Tracking System (STS) is the reconstruction of D-mesons through their hadronic decays $D^0 \to K^-\pi^+$ and $D^\pm \to K^\mp\pi^\pm\pi^\pm$. They have to be identified among the about 1000 charged particles that are produced in a central heavy-ion collision. The task is to find secondary vertices formed by the two and three decay particles in less than a few hundred microns distance from the collision vertex, as the average decay lengths are short ($D^0 : c\tau \approx 124\,\mu m$, $D^\pm : c\tau \approx 317\,\mu m$. The event vertex must be resolved at much higher level, and the tracks of the decaying meson must be reconstructed with enough pointing resolution so that the secondary vertex can be distinguished from the event vertex and other particles decaying with longer lifetime. This requires the application of thin detectors since very low multiple scattering even at low momenta is critical for the pointing precision of the reconstructed tracks. The space points themselves must be measured with high resolution, especially close to the target to enhance the vertex measurement. This calls for small pixel cells.

3.2. Conceptional design

In a conceptional design study, a compact detector configuration as shown in Fig. 2 was assumed to perform the measurement. Seven detector planes are arranged in the 1 m long gap of a superconducting dipole magnet with 1 Tm bending power. This layout allows for a generic momentum resolution of better than 1% at 1 GeV/c. The geometrical acceptance of the tracker is 50–500 mrad. Charged particle tracking is realized with four thin microstrip detector planes in the downstream part of the telescope. They are assumed to be based on fine-pitch double-sided sensors with two-coordinate projective read-out. Three or two pixel detector planes close to the target measure true space points with very high position resolution as required for the vertex identification. Their material budget must be very low and they may be installed in a vacuum. The first pixel detector plane is located in 5 cm distance from the target and has an active area of about

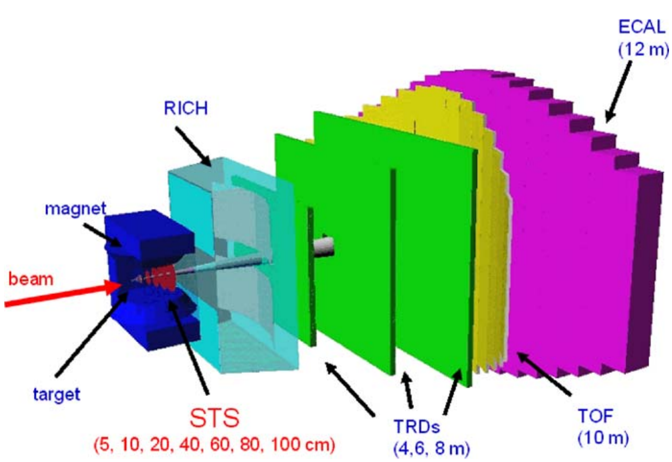

Fig. 1. The concept of the CBM experiment: charged particle tracking exclusively in a Silicon Tracking System (STS), in a compact magnetic field directly behind the target. Particle identification downstream of the magnet in ring imaging Cherenkov counters (RICH) and transition radiation detectors (TRDs), together with a time-of-flight (TOF) measurement, and electromagnetic calorimetry (ECAL). A dedicated muon identification system is under study.

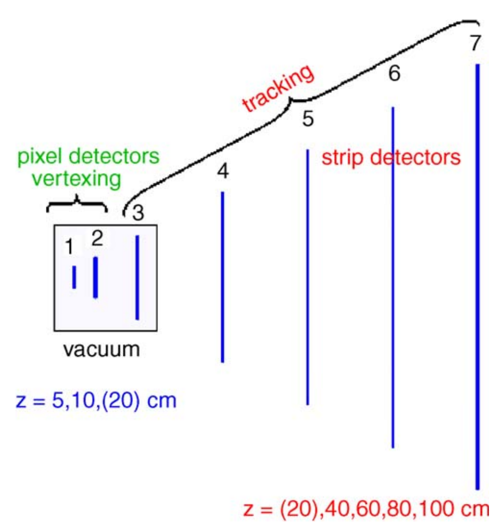

Fig. 2. Configuration of the Silicon Tracking System for a conceptional design study. Two detector regions focussing on tracking and vertexing are indicated.