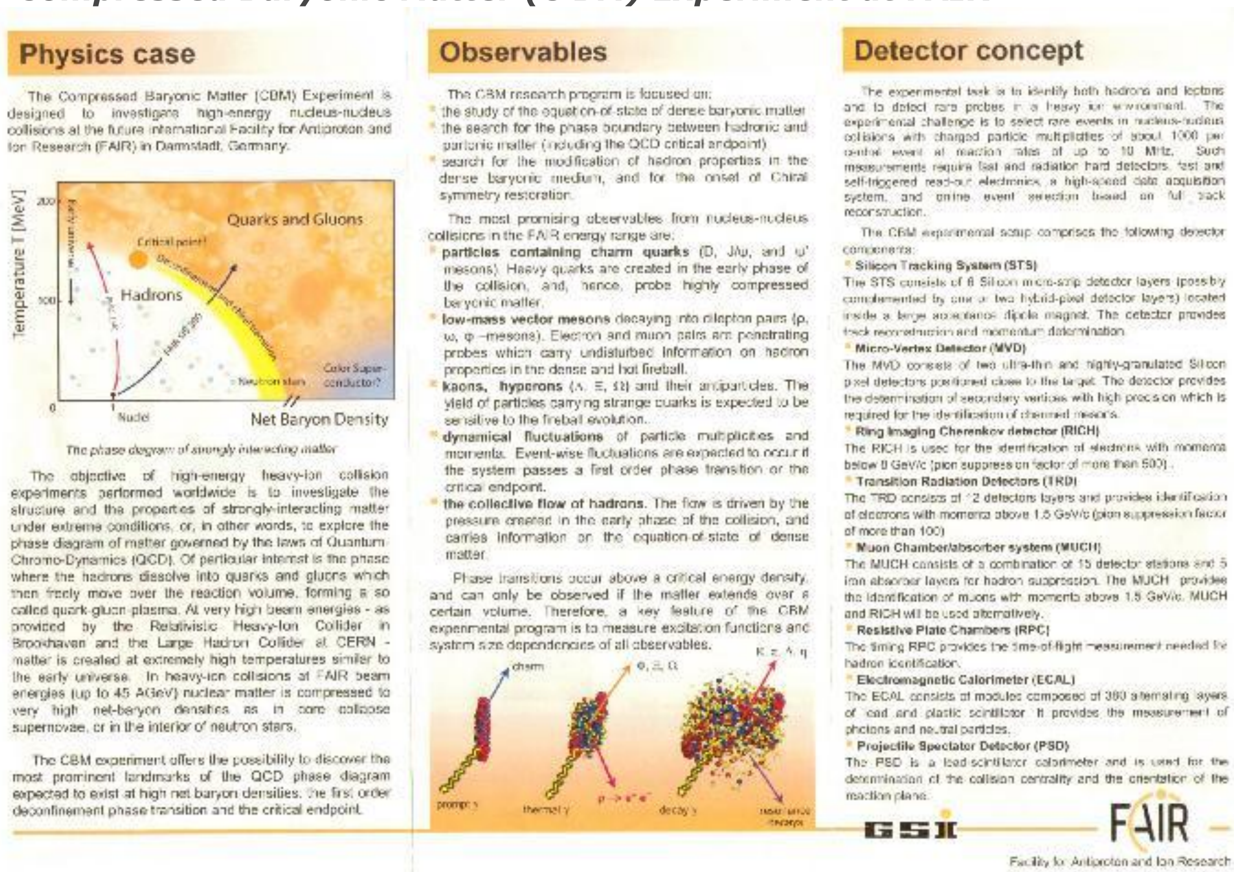
"Compressed Baryonic Matter (C BM) Experiment at FAIR"



Physics case

The Compressed Baryonic Matter (CBM) Experiment is designed to investigate high-energy nucleus-nucleus collisions at the future international Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany.

The phase diagram of strongly interacting matter

The objective of high-energy heavy-ion collision experiments performed worldwide is to investigate the structure and the properties of strongly-interacting matter under extreme conditions, or, in other words, to explore the phase diagram of matter governed by the laws of Quantum-Chromo-Dynamics (QCD). Of particular interest is the phase where the hadrons dissolve into quarks and gluons which then freely move over the reaction volume, forming a so called quark-gluon-plasma. At very high beam energies - as provided by the Relativistic Heavy-Ion Collider in Brookhaven and the Large Hadron Collider at CERN - matter is created at extremely high temperatures similar to the early universe. In heavy-ion collisions at FAIR beam energies (up to 45 AGeV) nuclear matter is compressed to very high net-baryon densities as in core collapse supernovae, or in the interior of neutron stars.

The CBM experiment offers the possibility to discover the most prominent landmarks of the QCD phase diagram expected to exist at high net baryon densities: the first order deconfinement phase transition and the critical endpoint.

Observables

The CBM research program is focused on:

- the study of the equation-of-state of dense baryonic matter
- the search for the phase boundary between hadronic and partonic matter (including the QCD critical endpoint)
- search for the modification of hadron properties in the dense baryonic medium, and for the onset of Chiral symmetry restoration.

The most promising observables from nucleus-nucleus collisions in the FAIR energy range are:

- **particles containing charm quarks** (D, J/ψ, and ψ' mesons). Heavy quarks are created in the early phase of the collision, and, hence, probe highly compressed baryonic matter.
- **low-mass vector mesons** decaying into dilepton pairs (ρ, ω, φ –mesons). Electron and muon pairs are penetrating probes which carry undisturbed information on hadron properties in the dense and hot fireball.
- **kaons, hyperons** (Λ, Ξ, Ω) and their antiparticles. The yield of particles carrying strange quarks is expected to be sensitive to the fireball evolution.
- **dynamical fluctuations** of particle multiplicities and momenta. Event-wise fluctuations are expected to occur if the system passes a first order phase transition or the critical endpoint.
- **the collective flow of hadrons.** The flow is driven by the pressure created in the early phase of the collision, and carries information on the equation-of-state of dense matter.

Phase transitions occur above a critical energy density, and can only be observed if the matter extends over a certain volume. Therefore, a key feature of the CBM experimental program is to measure excitation functions and system size dependencies of all observables.

Detector concept

The experimental task is to identify both hadrons and leptons and to detect rare probes in a heavy ion environment. The experimental challenge is to select rare events in nucleus-nucleus collisions with charged particle multiplicities of about 1000 per central event at reaction rates of up to 10 MHz. Such measurements require fast and radiation hard detectors, fast and self-triggered read-out electronics, a high-speed data acquisition system, and online event selection based on full track reconstruction.

The CBM experimental setup comprises the following detector components:

- **Silicon Tracking System (STS)**

The STS consists of 8 Silicon micro-strip detector layers (possibly complemented by one or two hybrid-pixel detector layers) located inside a large acceptance dipole magnet. The detector provides track reconstruction and momentum determination.

- **Micro-Vertex Detector (MVD)**

The MVD consists of two ultra-thin and highly-granulated Silicon pixel detectors positioned close to the target. The detector provides the determination of secondary vertices with high precision which is required for the identification of charmed mesons.

- **Ring Imaging Cherenkov detector (RICH)**

The RICH is used for the identification of electrons with momenta below 8 GeV/c (pion suppression factor of more than 500).

- **Transition Radiation Detectors (TRD)**

The TRD consists of 12 detectors layers and provides identification of electrons with momenta above 1.5 GeV/c (pion suppression factor of more than 100)

- **Muon Chamber/absorber system (MUCH)**

The MUCH consists of a combination of 15 detector stations and 5 iron absorber layers for hadron suppression. The MUCH provides the identification of muons with momenta above 1.5 GeV/c. MUCH and RICH will be used alternatively.

- **Resistive Plate Chambers (RPC)**

The timing RPC provides the time-of-flight measurement needed for hadron identification.

- **Electromagnetic Calorimeter (ECAL)**

The ECAL consists of modules composed of 380 alternating layers of lead and plastic scintillator. It provides the measurement of photons and neutral particles.

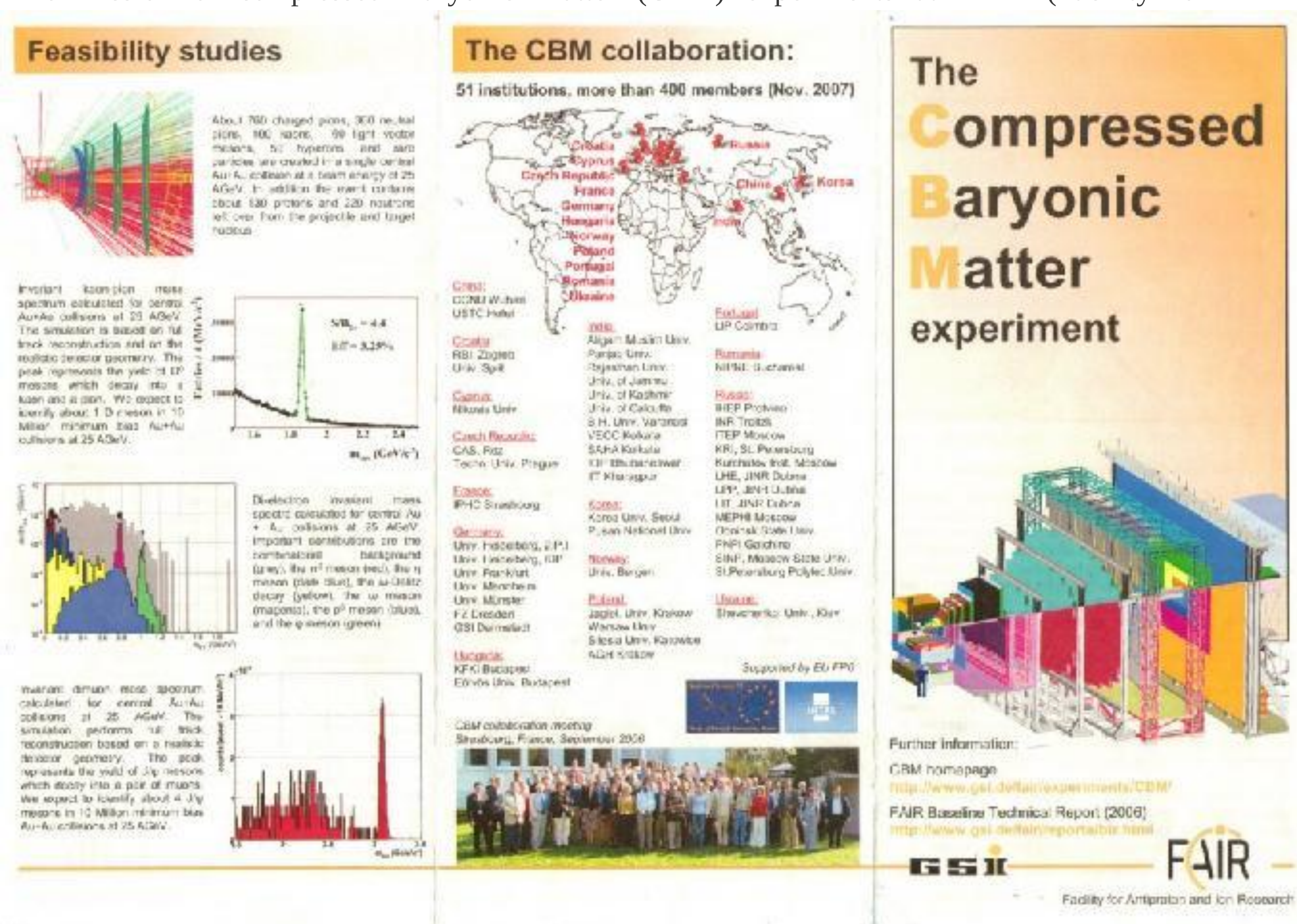
- **Projectile Spectator Detector (PSD)**

The PSD is a lead-scintillator calorimeter and is used for the determination of the collision centrality and the orientation of the reaction plane.

GSI FAIR

Facility for Antiproton and Ion Research

The mission of compressed Baryonic Matter (CBM) experiments at FAIR (Facility for



Feasibility studies

About 760 charged pions, 360 neutral pions, 100 kaons, 99 light vector mesons, 57 hyperons and rare particles are created in a single central Au+Au collision at a beam energy of 25 AGeV. In addition the event contains about 130 protons and 220 neutrons left over from the projectile and target nucleus.

Invariant kaon-pion mass spectrum calculated for central Au+Au collisions at 25 AGeV. The simulation is based on full track reconstruction and on the realistic detector geometry. The peak represents the yield of D⁰ mesons which decay into a kaon and a pion. We expect to identify about 1 D-meson in 10 Million minimum bias Au+Au collisions at 25 AGeV.

Dielectron invariant mass spectra calculated for central Au + Au collisions at 25 AGeV. Important contributions are the combinatorial background (grey), the π^0 meson (red), the η meson (dark blue), the ω-Dalitz decay (yellow), the ω meson (magenta), the ρ⁰ meson (blue), and the φ meson (green).

Invariant dimuon mass spectrum calculated for central Au+Au collisions at 25 AGeV. The simulation performs full track reconstruction based on a realistic detector geometry. The peak represents the yield of J/ψ mesons which decay into a pair of muons. We expect to identify about 4 J/ψ mesons in 10 Million minimum bias Au+Au collisions at 25 AGeV.

The CBM collaboration:

51 institutions, more than 400 members (Nov. 2007)

China:
CCNU Wuhan
USTC Hefei

Croatia:
RBI Zagreb
Univ. Split

Cyprus:
Nikosia Univ.

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Germany:
Univ. Heidelberg, P.I.
Univ. Heidelberg, KIP
Univ. Frankfurt
Univ. Mannheim
Univ. Münster
FZ Dresden
GSI Darmstadt

Hungaria:
KFKI Budapest
Eötvös Univ. Budapest

India:
Aligarh Muslim Univ.
Panjab Univ.
Rajasthan Univ.
Univ. of Jammu
Univ. of Kashmir
Univ. of Calcutta
B.H. Univ. Varanasi
VECC Kolkata
SAHA Kolkata
IOP Bhubaneswar
IIT Kharagpur

Korea:
Korea Univ. Seoul
Pusan National Univ.

Norway:
Univ. Bergen

Poland:
Jagiel. Univ. Krakow
Warsaw Univ.
Silesia Univ. Katowice
AGH Krakow

Portugal:
LIP Coimbra

Romania:
NIPNE Bucharest

Russia:
IHEP Protvino
INR Troitzk
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst. Moscow
LHE, JINR Dubna
LPP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP, Moscow State Univ.
St.Petersburg Polytec. Univ.

Ukraine:
Shevchenko Univ., Kiev

Supported by EU FP6

CBM collaboration meeting
Strasbourg, France, September 2006

The Compressed Baryonic Matter experiment

Further information:

CBM homepage
http://www.gsi.de/fair/experiments/CBM/

FAIR Baseline Technical Report (2006)
http://www.gsi.de/fair/reports/btr.html

GSI FAIR

Facility for Antiproton and Ion Research

Antiproton and ion Research) is to explore the QCD phase diagram in the region of high baryon densities. The detailed understanding of the evolution of the platonic /hedonic fireball requies no measurements which have not been yet performed at FAIR energies. The most promising observations are rare probes which carry information on the matter properties such as particles containing charm quarks (D mesons and charmonia), low mass vector meson decaying into dilepton pairs.

A large International Research Laboratory, the facilities for Antiproton and ion research is being built at GSI, Darmstadt, Germany to explore the nature of matter in the Universe and the fundamental force building them. This is a highly sophisticated accelerator complex which will provide the high energy precisely tailored beams of antiprotons and many kinds of ions at unprecedented quality and intensities. These charged particle beams will then be accelerated and employed to create new, often highly exotic particles in a series of parallel experimental programmes. In fact in 2006, a large international community around 2500 scientists from different countries compiled the FAIR Baseline. Technical Report detailing the layout and components of the accelerator system needed, the types of the experiments to be carried out. The heart of FAIR comprises of two large accelerator rings (a double synchrotron) to accelerate ions – from hydrogen ion (proton) to those of heaviest naturally occurring element, Uranium.

The innovative programme at FAIR will provide the very best young scientists worldwide with unparallel opportunities to participate in experiments which exploit cutting edge technology and which will make major discoveries. Working on FAIR experiments will give a wide variety of transferable, multidisciplinary skills. In this way, FAIR will contribute in creating a truly global scientific work force.
FAIR's scientific programme will thus contribute in the basic understanding of matter in all its forms, under a wide range of conditions. It will also illuminate how matter evolved on a cosmic scale from the beginning of time, through the nuclear cores of stars, to the levels of atomic complexity seen in our solar system.

The experiment was approved by German Scientific Advisory Committee. The German Federal Govt. together with the state of Hessen will provide the major part of the 1.2 billion Euros required for construction with the reminder being funded internationally by fourteen Countries France, China, Italy, Poland, India, Germany, Russia, Spain, Swedan, Grece, Finland and the UK. have signed a memorandum of understanding. The countries will contribute by supplying components, facilities and cash.

As a part of Indias contribution towards FAIR Programme Department of Science and Technology, DST Govt. of India has allocated 36 million Euros. The expression of interests were submitted by VECC, Kolkata, BARC Mumbai and other Institutions including University of Kashmir as a collaborator in Indian group for various projects/programmes.