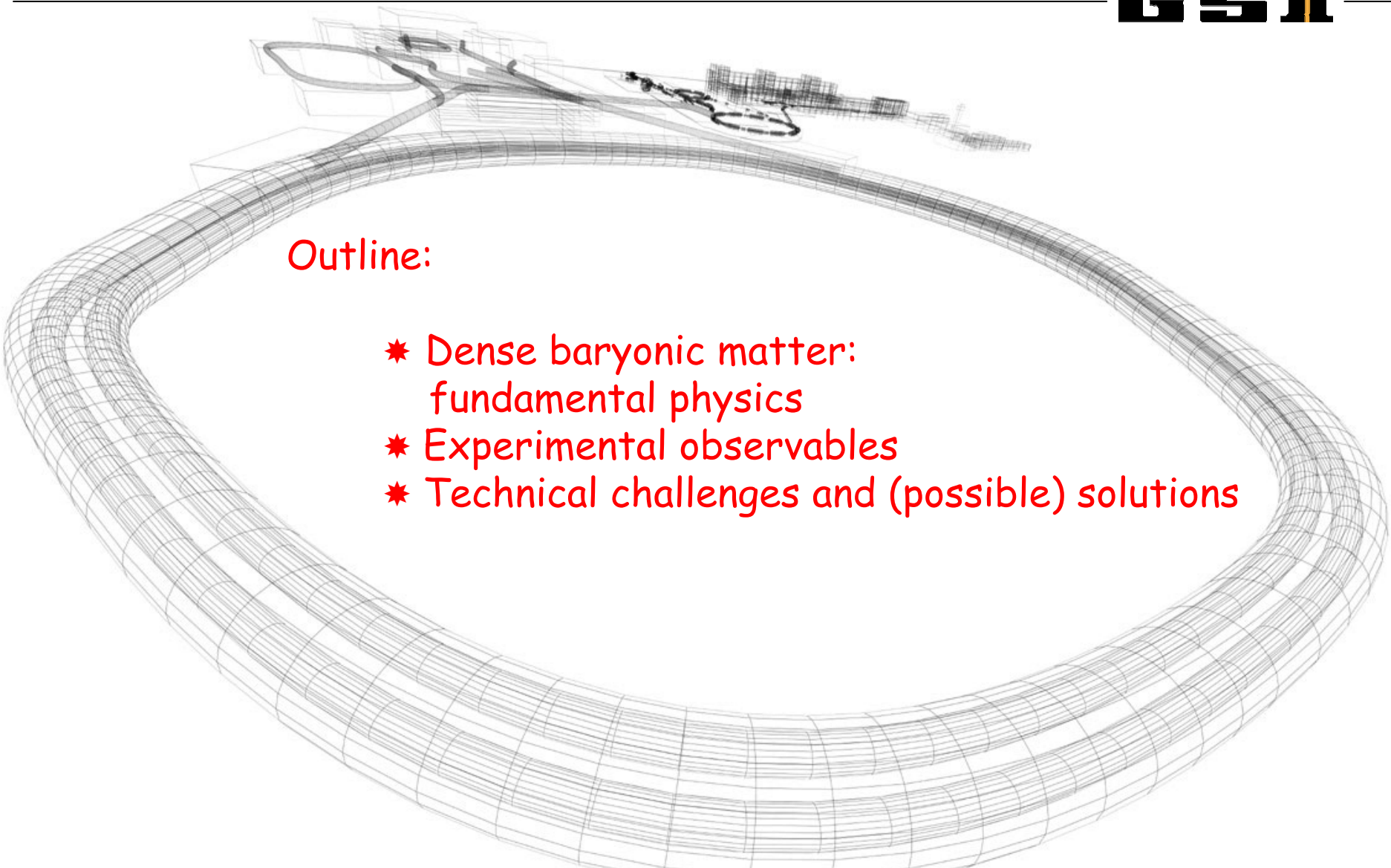
Nucleus-nucleus collisions at the future facility in Darmstadt - Compressed Baryonic Matter at GSI

Peter Senger

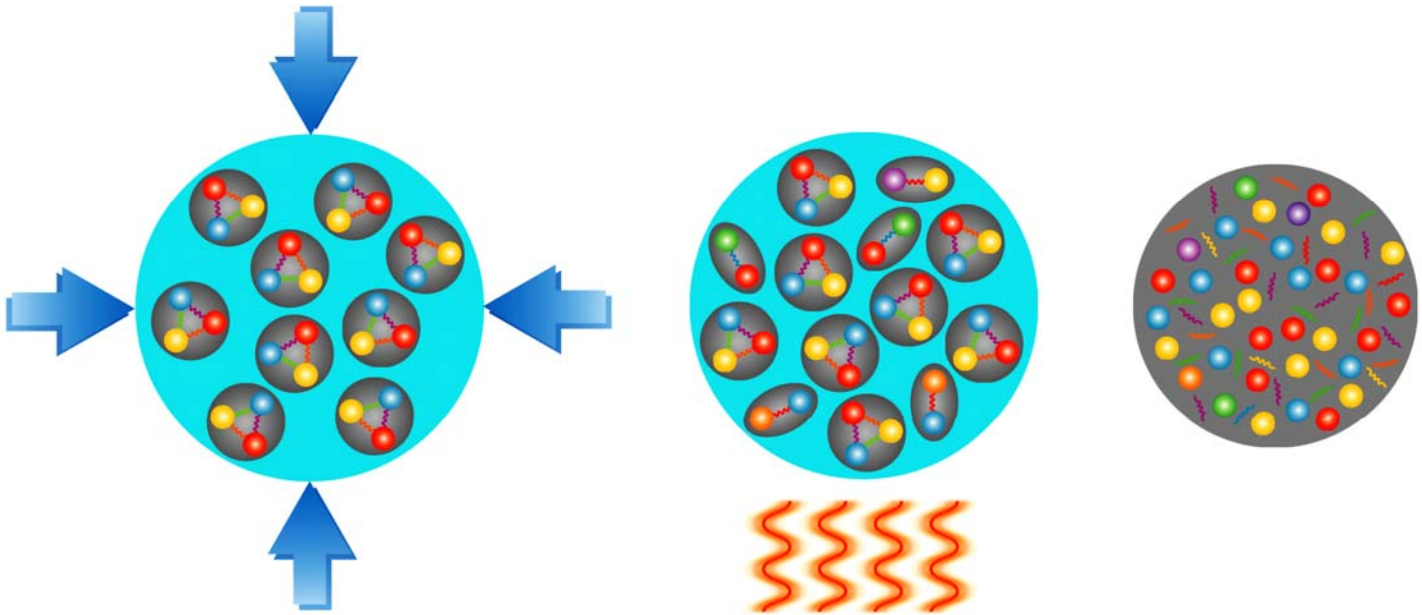


Outline:

- Dense baryonic matter: fundamental physics
- Experimental observables
- Technical challenges and (possible) solutions

States of strongly interacting matter

baryons hadrons partons

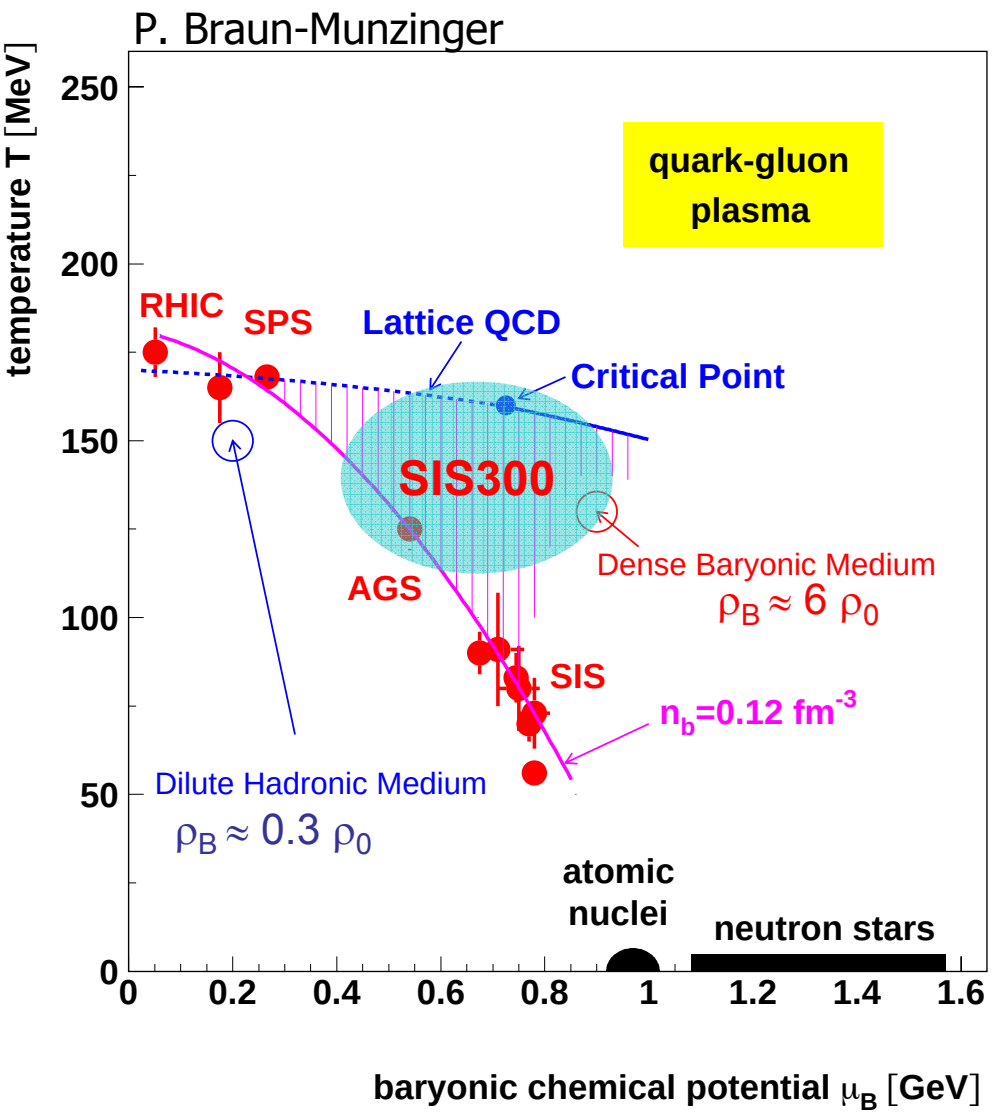


Compression + heating = quark-gluon plasma

(pion production)

Neutron stars Early universe

Mapping the QCD phase diagram with heavy-ion collisions



Analysis of particle ratios with statistical model: chemical freeze-out

baryon density:

$$\rho_B \approx 4\,(mT/2\pi)^{3/2} \times [\exp((\mu_B - m)/T) - \exp((-\mu_B - m)/T)]$$

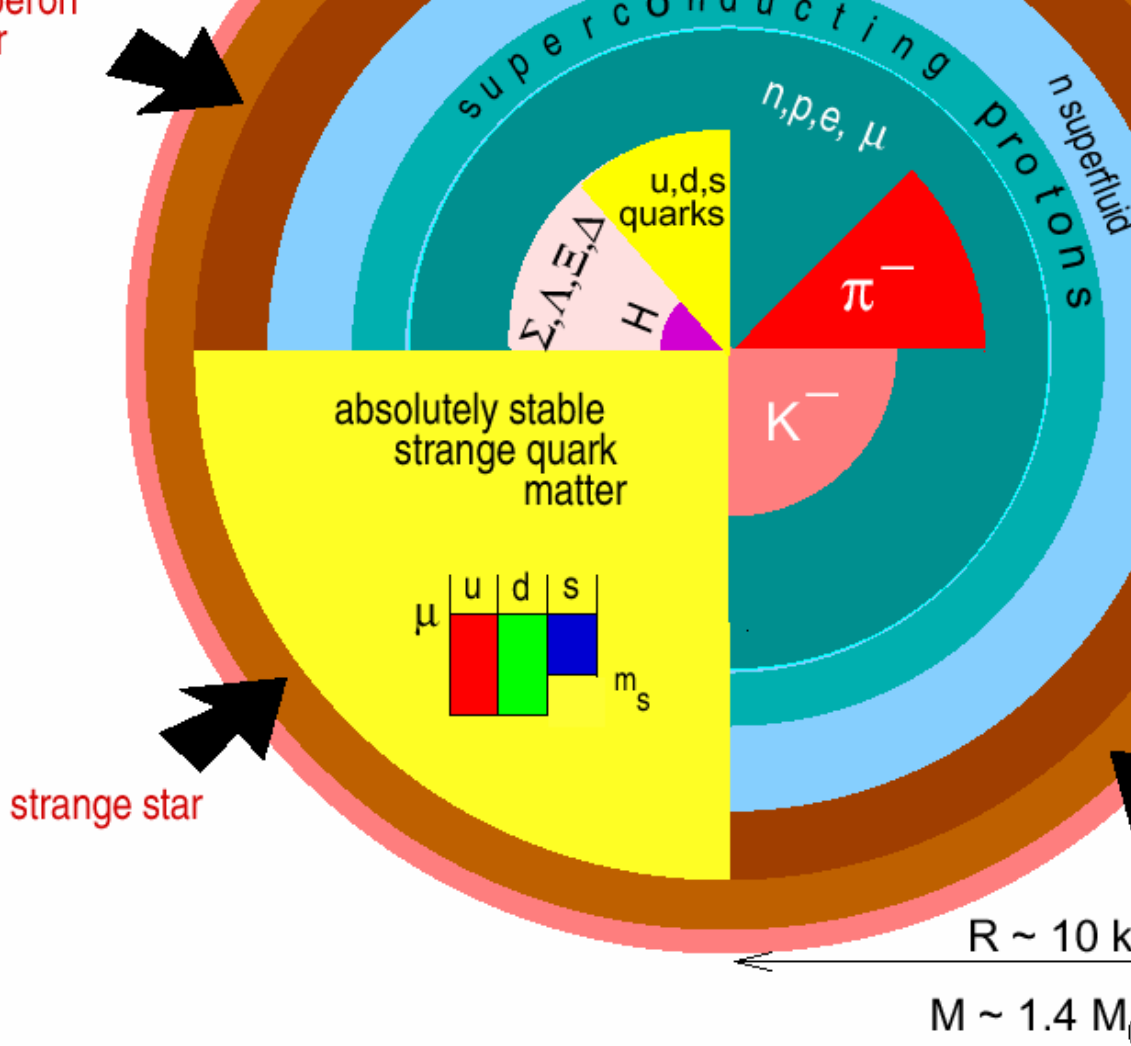
baryons - antibaryons

Fundamental quest

- Equation-of-state a
  stability of neutron
  supernova dynamics

- In-medium hadron p
  chiral symmetry re
  origin of hadron m

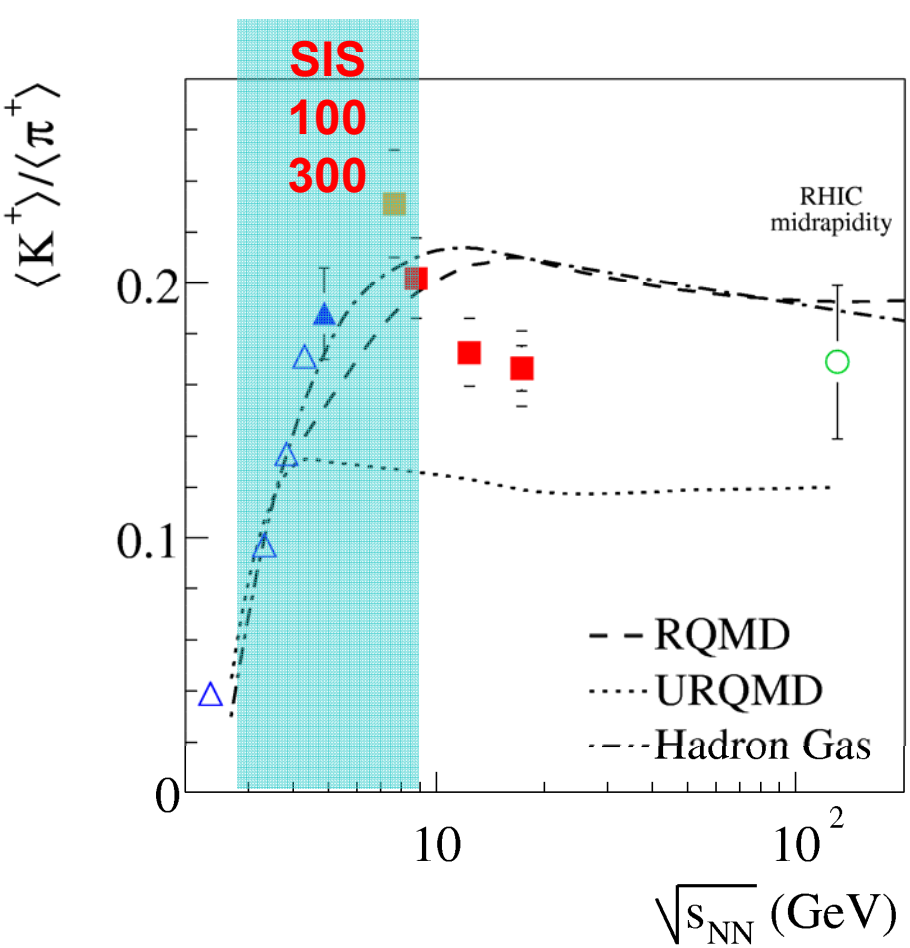
- deconfinement

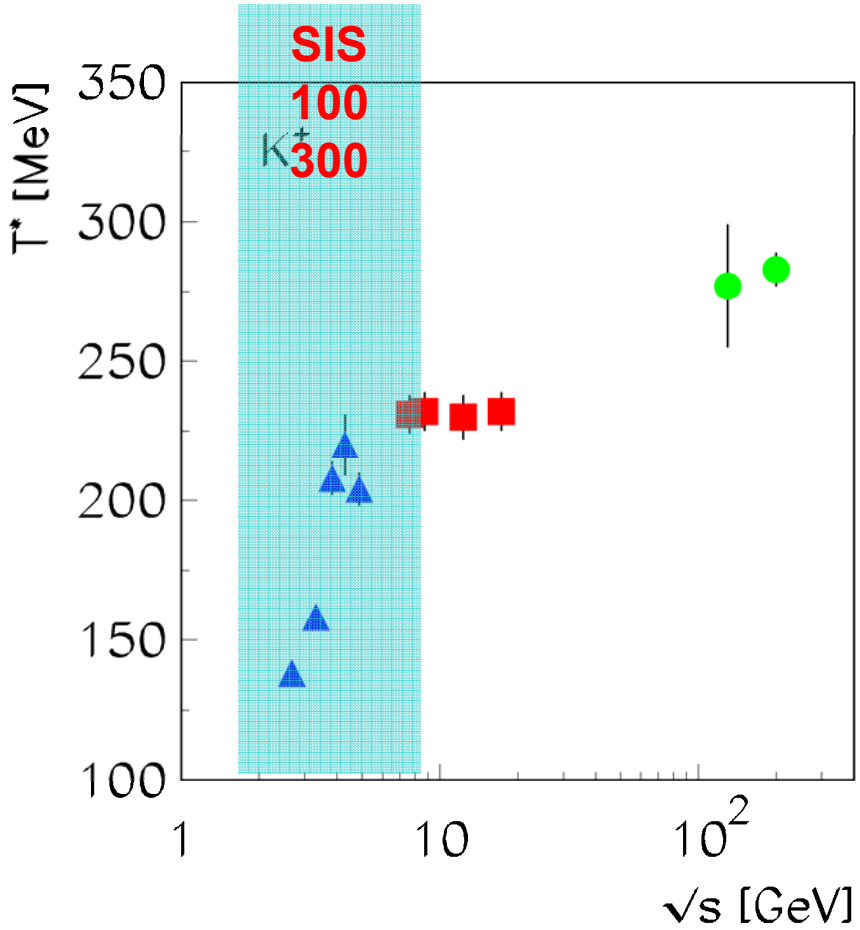



U+U 23 GeV/A
t=-17.14 fm/c
UrQMD Frankfurt/M

Experimental situation : Strangeness production in central Au+Au and Pb+Pb collisions

New results from NA49 (CERN Courier Oct. 2003)





CBM physics topics and observables

1. In-medium modifications of hadrons
   - ↳ onset of chiral symmetry restoration at high ρ_B

     measure: $\rho, \omega, \phi \rightarrow e^+e^-$

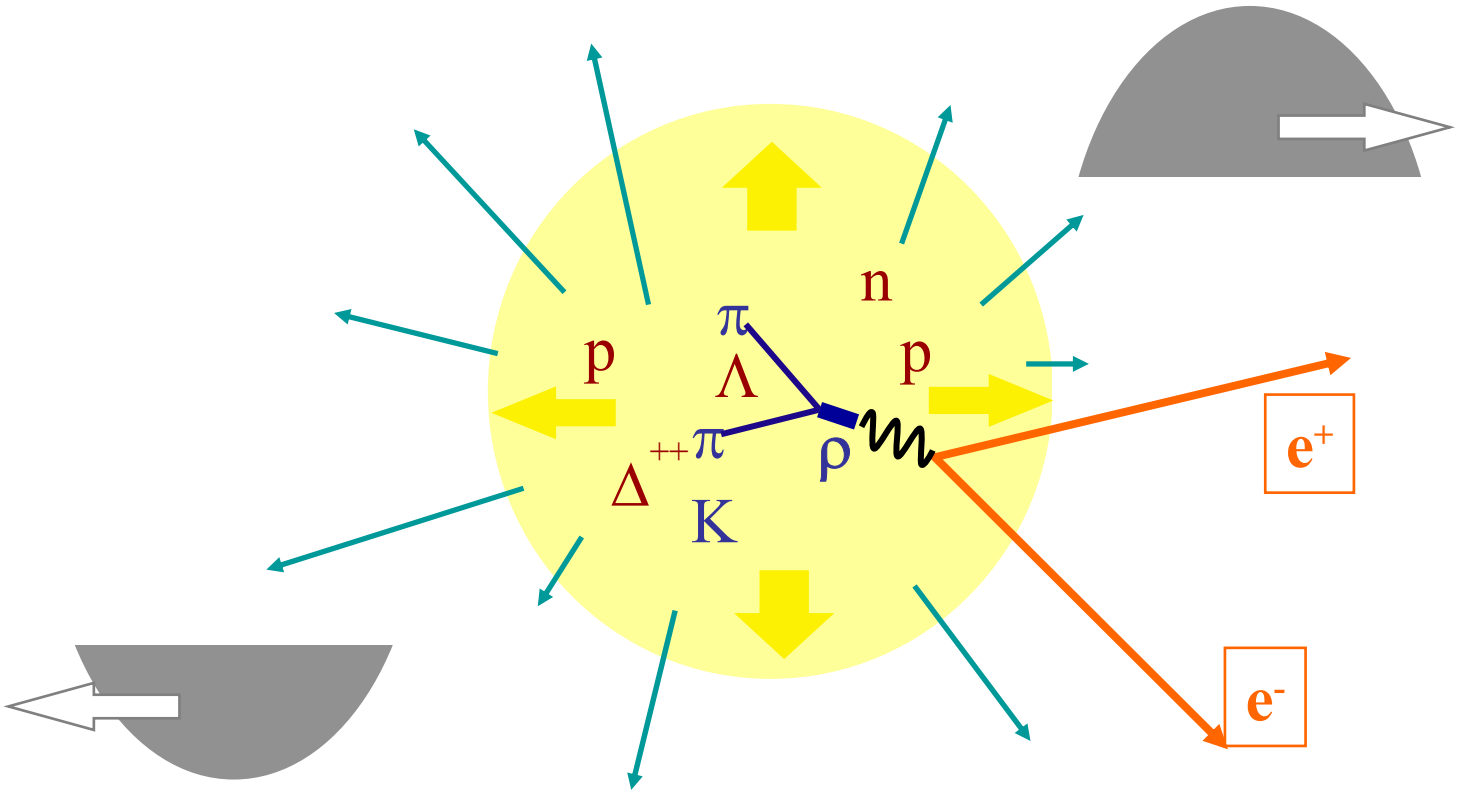
     open charm (D mesons)
2. Strangeness in matter (strange matter?)
   - ↳ enhanced strangeness production ?

     measure: K, Λ, Σ, Ξ, Ω
3. Indications for deconfinement at high ρ_B
   - ↳ anomalous charmonium suppression ?

     measure: J/ψ, D
   - ↳ softening of EOS

     measure flow excitation function
4. Critical point
   - ↳ event-by-event fluctuations

Looking into the fireball …



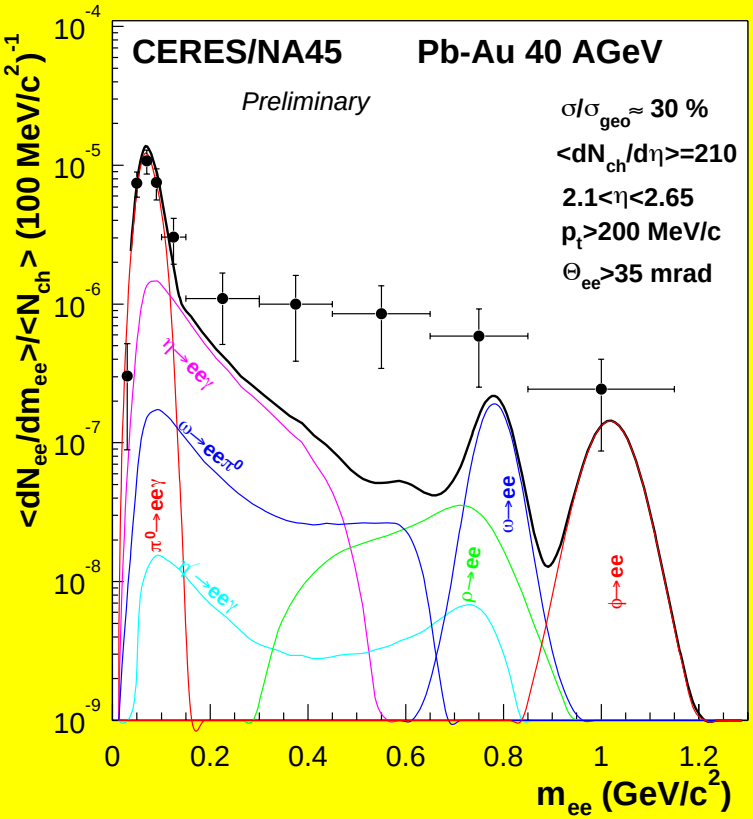
… using penetrating probes:

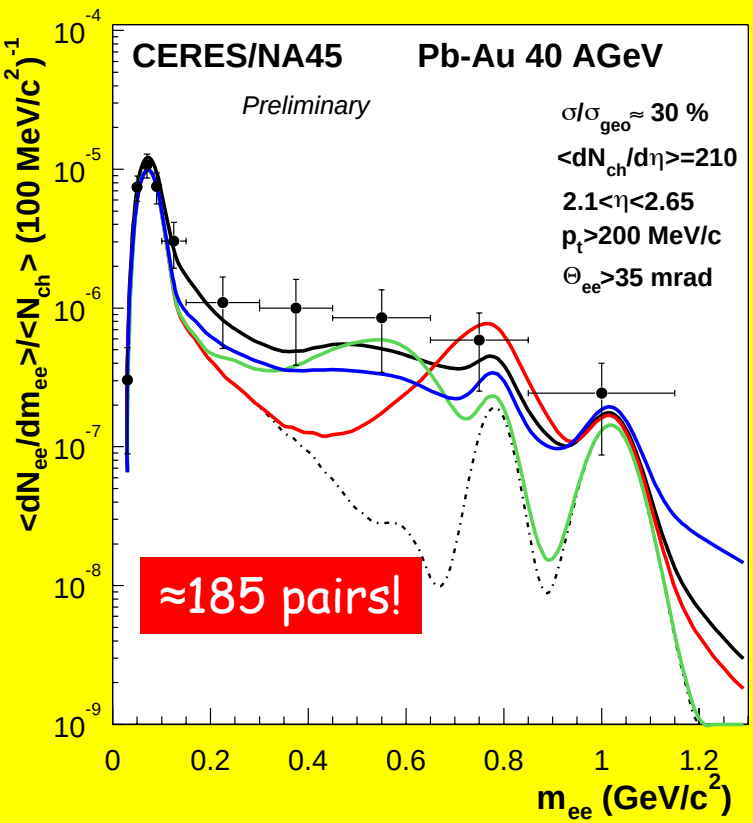
short-lived vector mesons decaying into electron-positron pairs

Invariant mass of electron-positron pairs from Pb+Au at 40 AGeV

CERES Collaboration

S. Damjanovic and K. Filimonov, nucl-ex/0109017





Number of pairs for m>0.2 GeV/c2: 180+-48

Ratio Signal/Background: 1/6

Hadronic decay cocktail:
- particle ratios taken from thermal model for Pb-Pb
-rapidity and pt distributions from systematics in Pb-Pb

Enhancement: measured pairs/decay cocktail: 5.0 +- 1.3

Hadronic decay cocktail

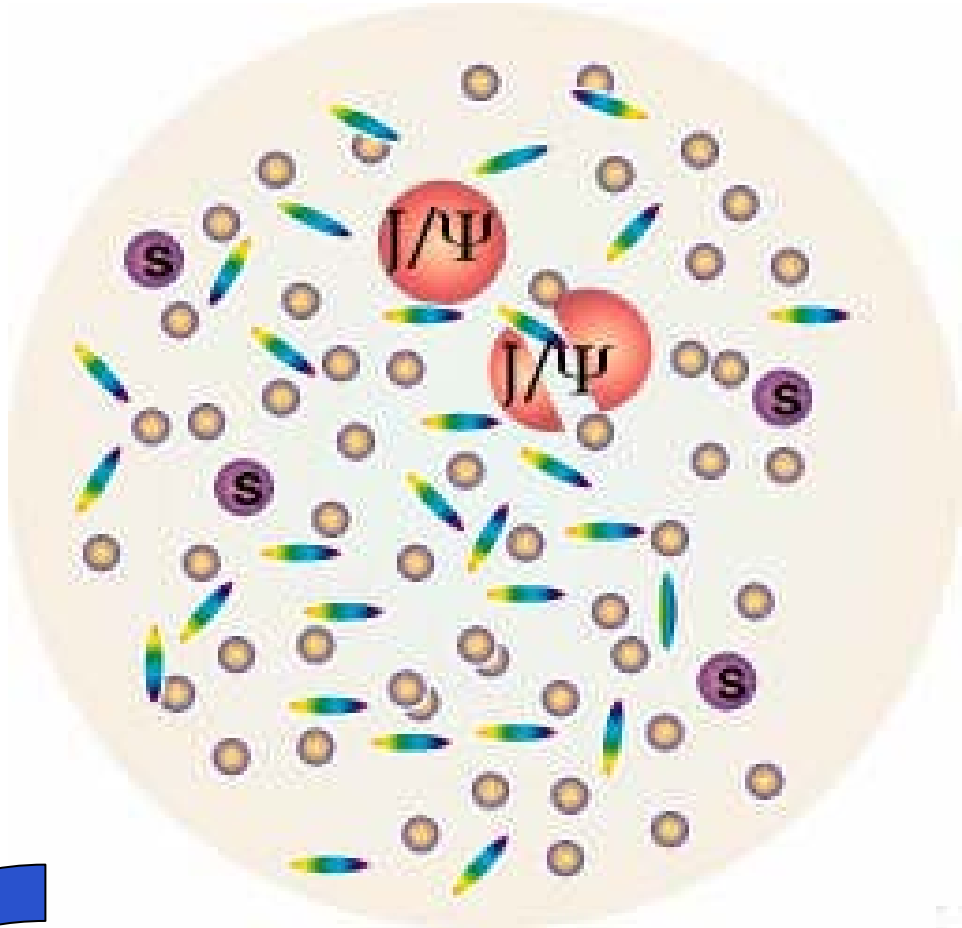
+ Vacuum rho spectral function

+ Rho spectral function with dropping mass

+ In-medium rho spectral function

+ Lowest order pQCD rate

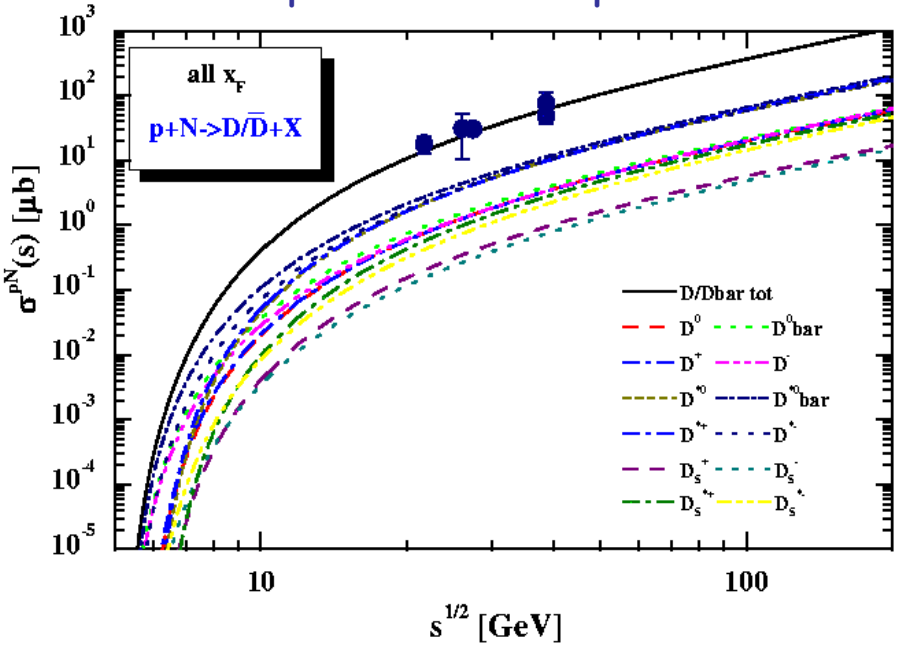
Signatures of the quark-pluon plasma ?



Anomalous suppression of charmonium (J/ψ) ???

Charmed mesons

D meson production in pN collisions



Some hadronic decay modes

$D^{\pm}$ ($c\tau$ = 317 μm):

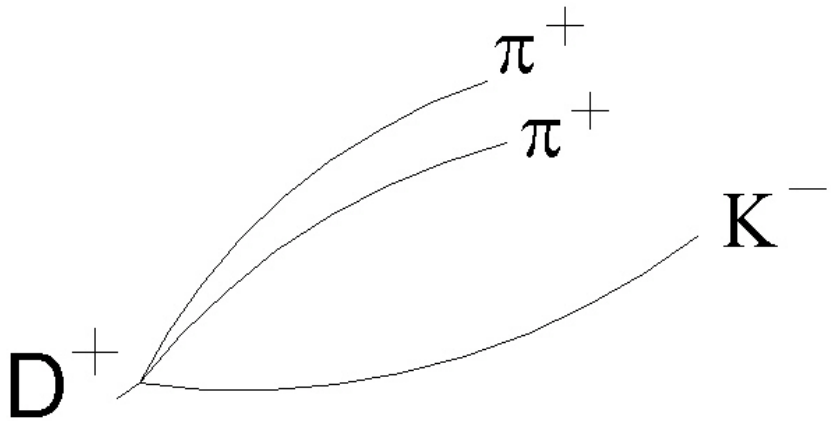
$D^+ \rightarrow K^0\pi^+$ (2.9±0.26%)

$D^+ \rightarrow K^-\pi^+\pi^+$ (9 ± 0.6%)

D^0 ($c\tau$ = 124.4 μm):

$D^0 \rightarrow K^-\pi^+$ (3.9 ± 0.09%)

$D^0 \rightarrow K^-\pi^+ \pi^+ \pi^-$ (7.6 ± 0.4%)

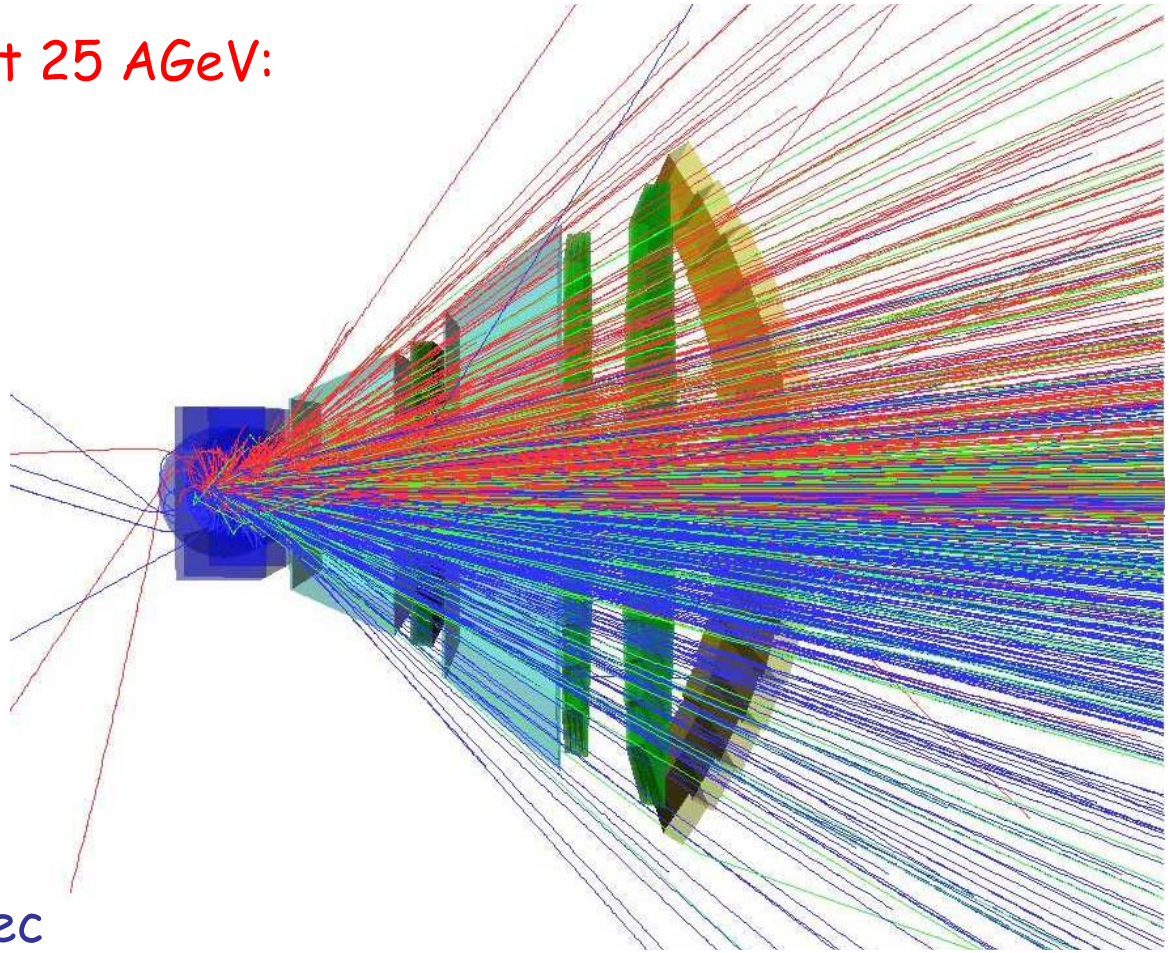


D mesons not yet measured in heavy-ion collisions !

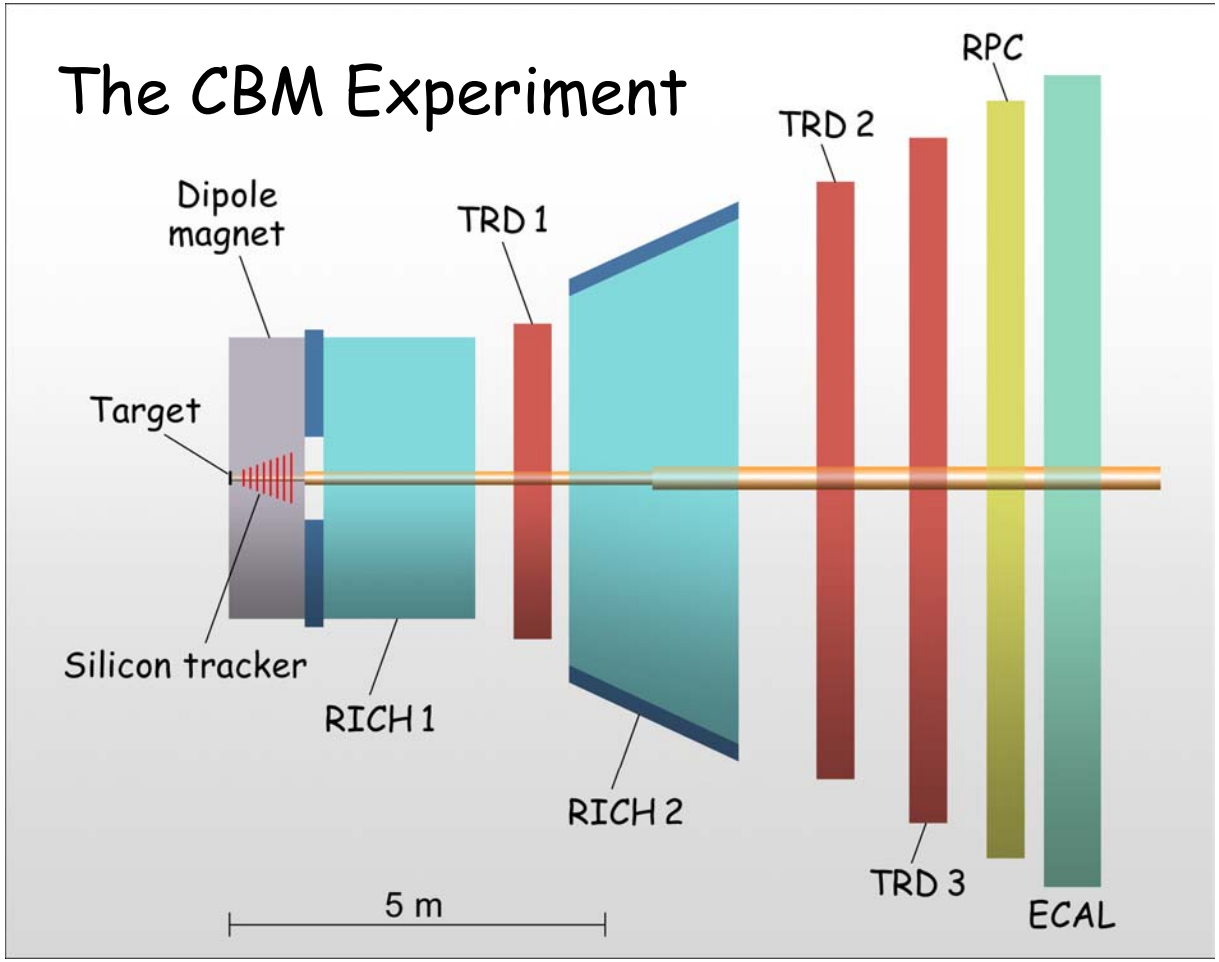
Experimental challenges

Central Au+Au collision at 25 AGeV:
URQMD + GEANT4

160 p
400 π^-
400 π^+
44 K^+
13 K^-



- 10^7 Au+Au reactions/sec
  (beam intensities up to 10^9 ions/sec, 1 % interaction target)
- determination of (displaced) vertices with high resolution ($\approx$ 30 μm)
- identification of electrons and hadrons



- Radiation hard Silicon pixel/strip detectors in a magnetic dipole field
- Electron detectors: RICH & TRD & ECAL: pion suppression up to 10^5
- Hadron identification: RPC, RICH
- Measurement of photons, π, η, and muons: electromagn. calorimeter (ECAL)
- High speed data acquisition and trigger system

CBM R&D working packages

Feasibility, Simulations

GEANT4: GSI

$\rho, \omega, \varphi \rightarrow e^+e^-$
Univ. Krakow
JINR-LHE Dubna

$D \rightarrow K\pi(\pi)$
GSI Darmstadt,
Czech Acad. Sci., Rez
Techn. Univ. Prague

$J/\psi \rightarrow e^+e^-$
INR Moscow

Hadron ID
Heidelberg Univ,
Warsaw Univ.
Kiev Univ.
NIPNE Bucharest
INR Moscow

Tracking
KIP Univ. Heidelberg
Univ. Mannheim
JINR-LHE Dubna

Design & construction of detectors

Silicon Pixel
IReS Strasbourg
Frankfurt Univ.,
GSI Darmstadt,
RBI Zagreb,
Univ. Krakow
LBNL Berkeley

Silicon Strip
SINP Moscow State U.
CKBM St. Petersburg
KRI St. Petersburg

RPC-TOF
LIP Coimbra,
Univ. Santiago de Com.,
Univ. Heidelberg,
GSI Darmstadt,
Warsaw Univ.
NIPNE Bucharest
INR Moscow
FZ Rossendorf
IHEP Protvino
ITEP Moscow

Fast TRD
JINR-LHE, Dubna
GSI Darmstadt,
Univ. Münster
INFN Frascati

Straw tubes
JINR-LPP, Dubna
FZ Rossendorf
FZ Jülich
Tech. Univ. Warsaw

ECAL
ITEP Moscow
GSI Darmstadt
Univ. Krakow

RICH
IHEP Protvino
GSI Darmstadt

Magnet
JINR-LHE, Dubna
GSI Darmstadt

Data Acquis., Analysis

Trigger, DAQ
KIP Univ. Heidelberg
Univ. Mannheim
GSI Darmstadt
JINR-LIT, Dubna
KFKI Budapest
Silesia Univ. Katowice
Univ. Warsaw

Analysis
GSI Darmstadt,
Heidelberg Univ,

CBM R&D Collaboration : 39 institutions , 15 countries

Croatia:
RBI, Zagreb

Cyprus:
Nikosia Univ.

Czech Republic:
Czech Acad. Science, Rez
Techn. Univ. Prague

France:
IReS Strasbourg

Germany:
Univ. Heidelberg, Phys. Inst.
Univ. HD, Kirchhoff Inst.
Univ. Frankfurt
Univ. Mannheim
Univ. Marburg
Univ. Münster
FZ Rossendorf
GSI Darmstadt

Hungaria:
KFKI Budapest
Eötvös Univ. Budapest

Italy:
INFN Catania
INFN Frascati

Korea:
Korea Univ. Seoul
Pusan Univ.

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

Portugal:
LIP Coimbra

Romania:
NIPNE Bucharest

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

Spain:
Santiago de Compostela Univ.

Ukraine:
Univ. Kiev

USA:
LBNL Berkeley

CBM Participation in EU Programmes:

EU FP6 Hadron Physics
(2004 – 2006)

Joint Research Projects (approved):

- Fast gaseous detectors
  Partner: INVENTOR, Krakow
- Advanced TOF Systems
- Future DAQ and trigger systems
  (Silesia Univ. Katowice, Univ. Warszawa)

Network activities (approved):

- CBMnet
  (Silesia Univ. Katowice, Univ. Krakow,
  Univ. Warszawa)

INTAS-GSI (2004-2005)

approved projects:

- Transition Radiation Detectors
- Straw tube tracker
  (Univ. Tech. Warszawa)
- Resistive Plate Chambers
- Electromagnetic calorimeter
  (Univ. Krakow)

New call EU FP6
(opened Nov.03, closed Mar04):

- Design of new facilities
- Construction of new facilities

The nuclear reaction experiment at the future facility at GSI