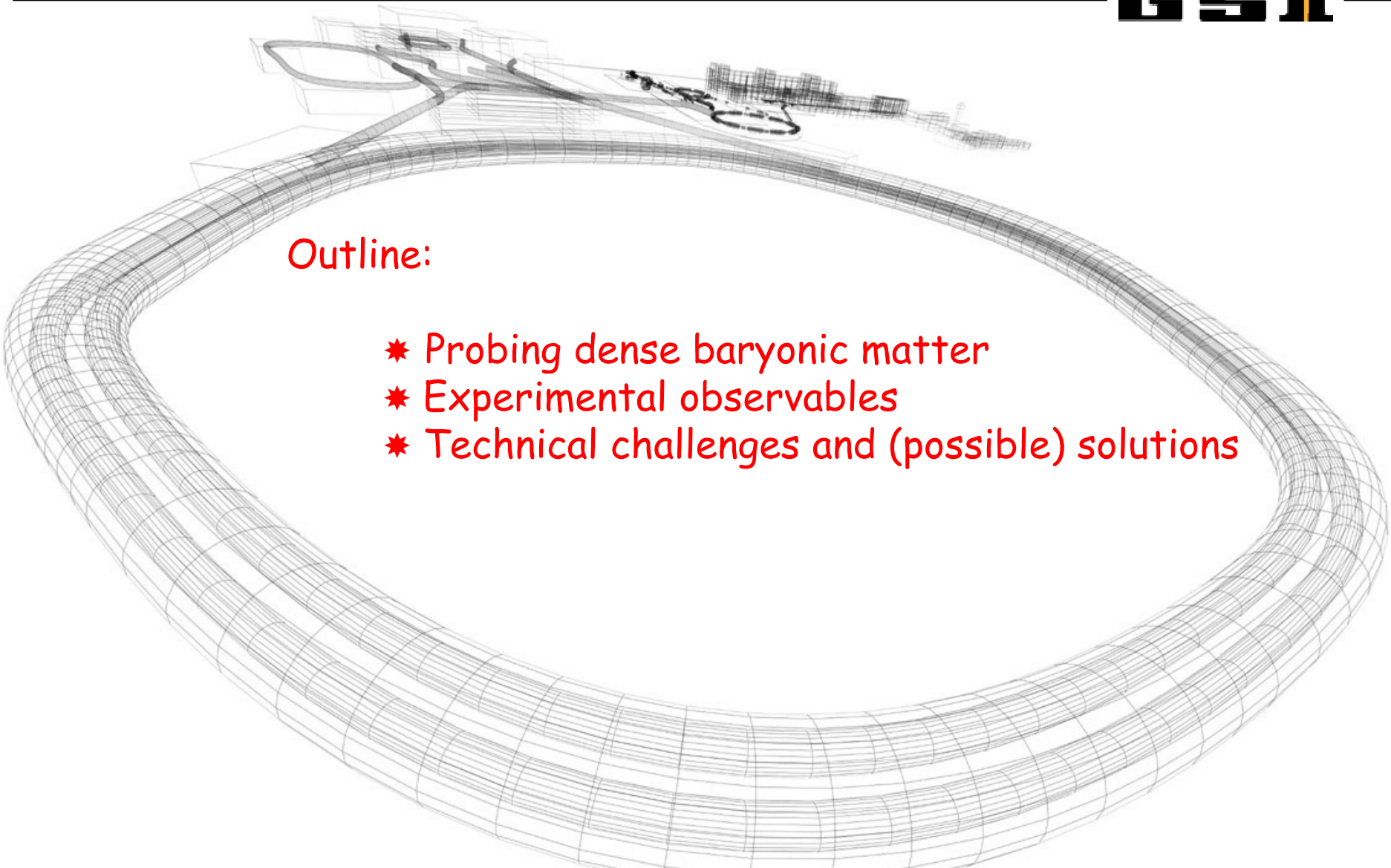
The Compressed Baryonic Matter Experiment at the Future Accelerator Facility in Darmstadt

Peter Senger

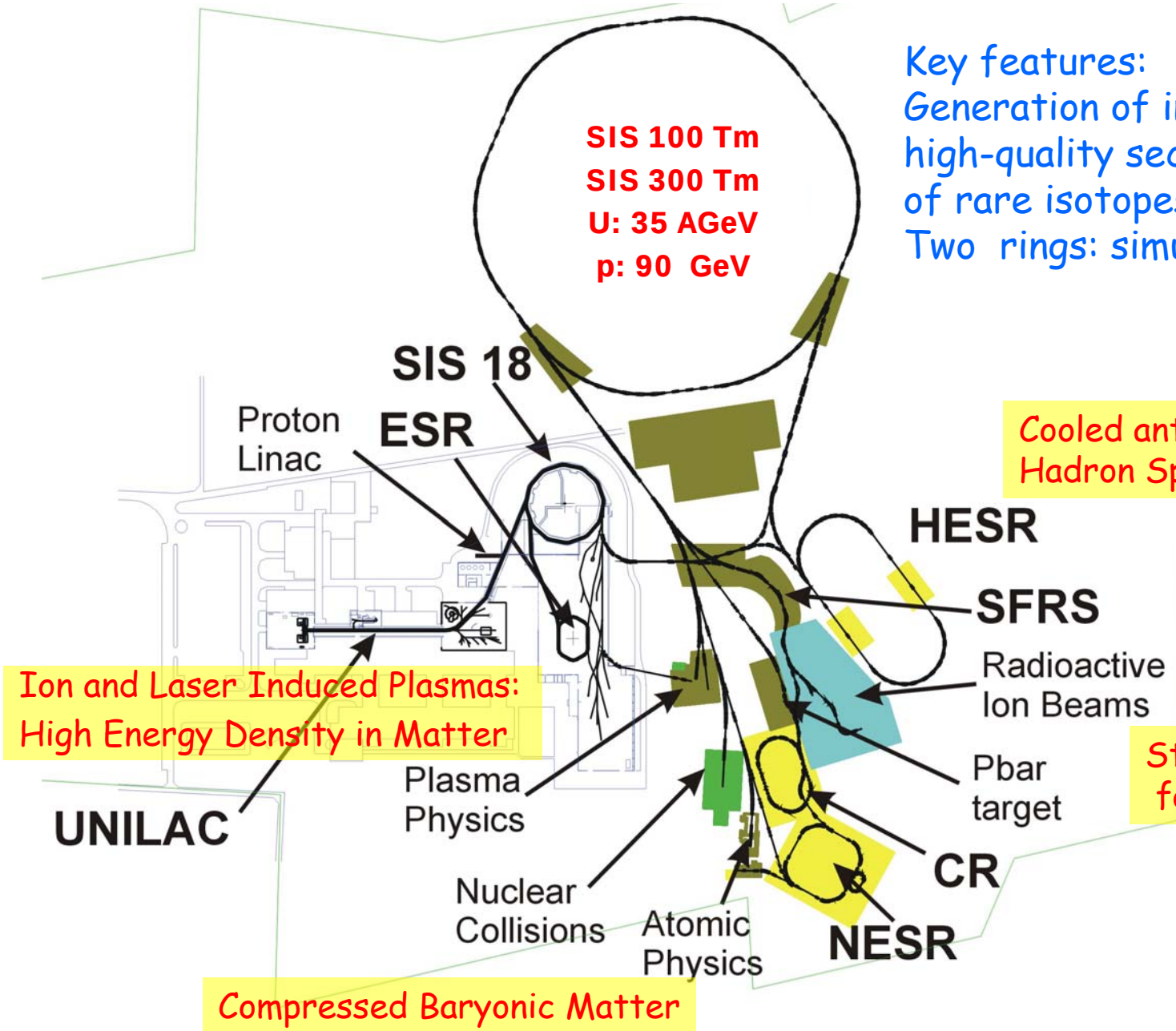


Outline:

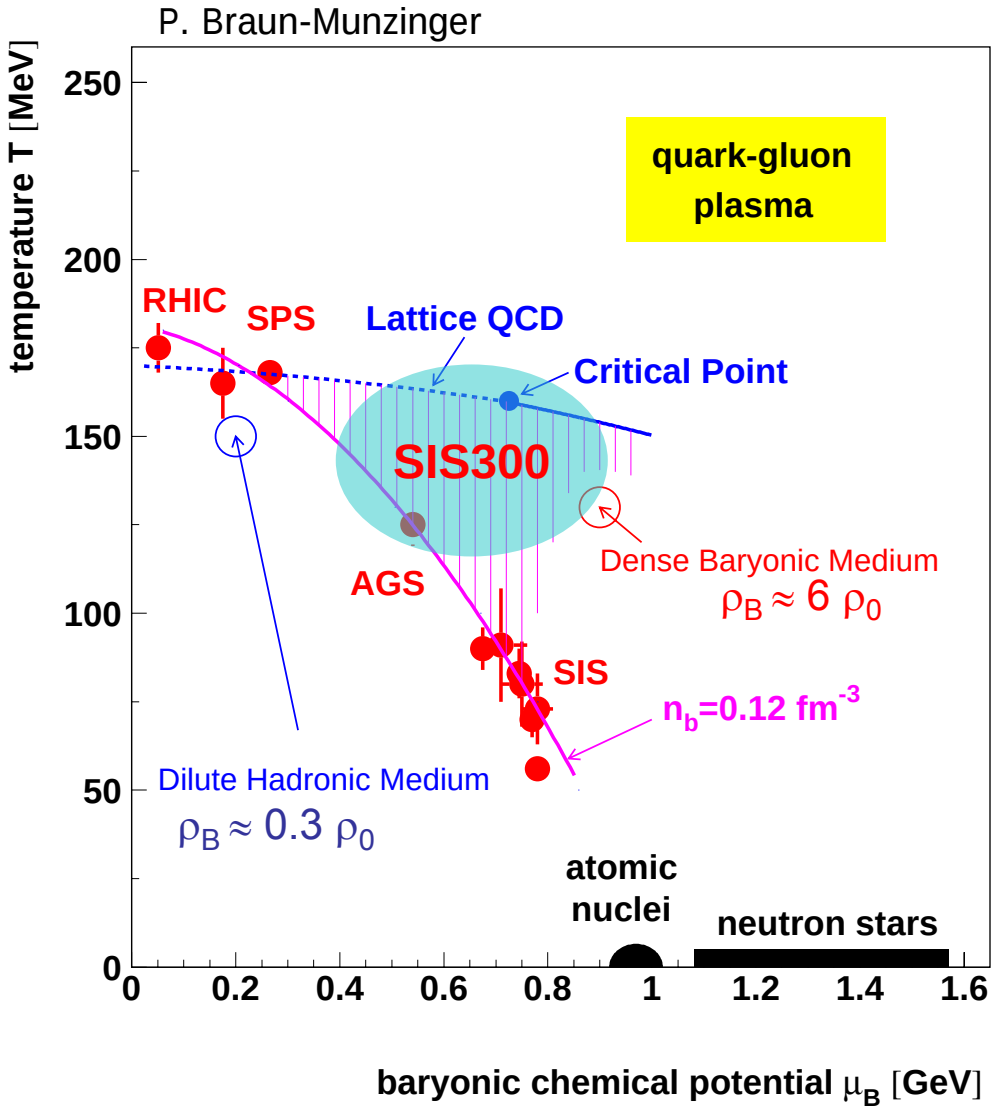
- Probing dense baryonic matter
- Experimental observables
- Technical challenges and (possible) solutions

The future international accelerator facility

Key features:
Generation of intense,
high-quality secondary beams
of rare isotopes and antiprotons.
Two rings: simultaneous beams.



Mapping the QCD phase diagram with heavy-ion collisions



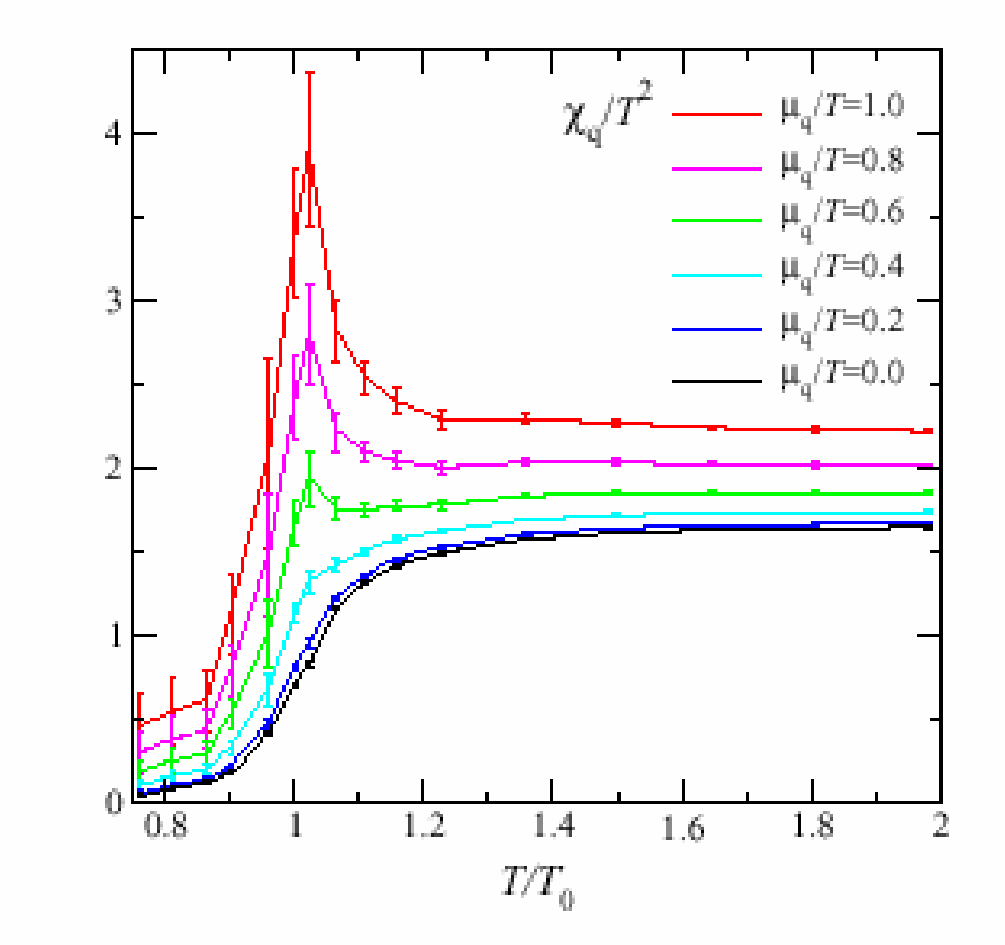
baryon density:

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

baryons - antibaryons

Mapping the QCD phase diagram with heavy-ion collisions

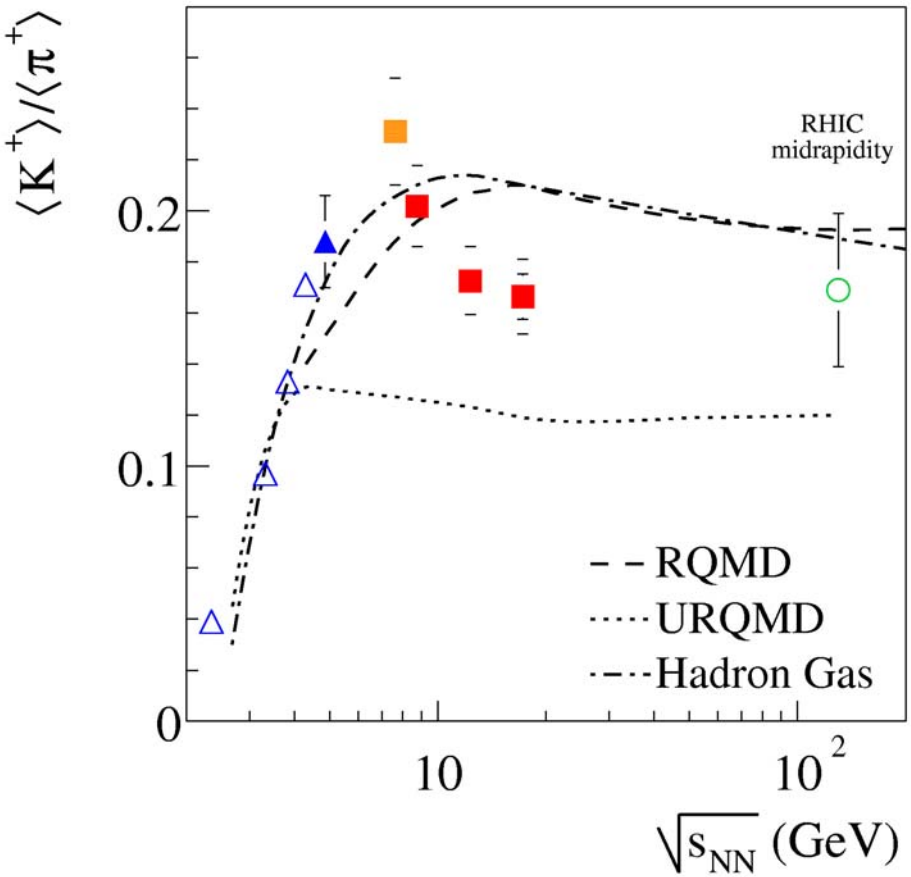
C. R. Allton et al, hep-lat 0305007

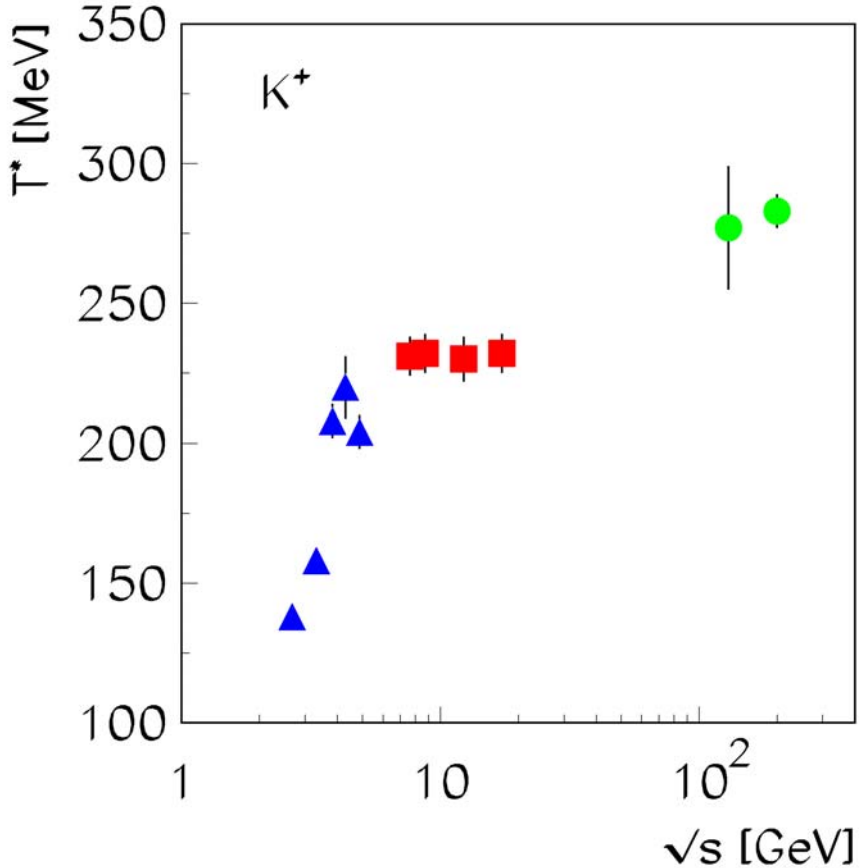


Lattice QCD :
maximal baryon number density fluctuations at T_C for $\mu_q = T_C$ ($\mu_B \approx 500$ MeV)

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

New results from NA49 (CERN Courier Oct. 2003)





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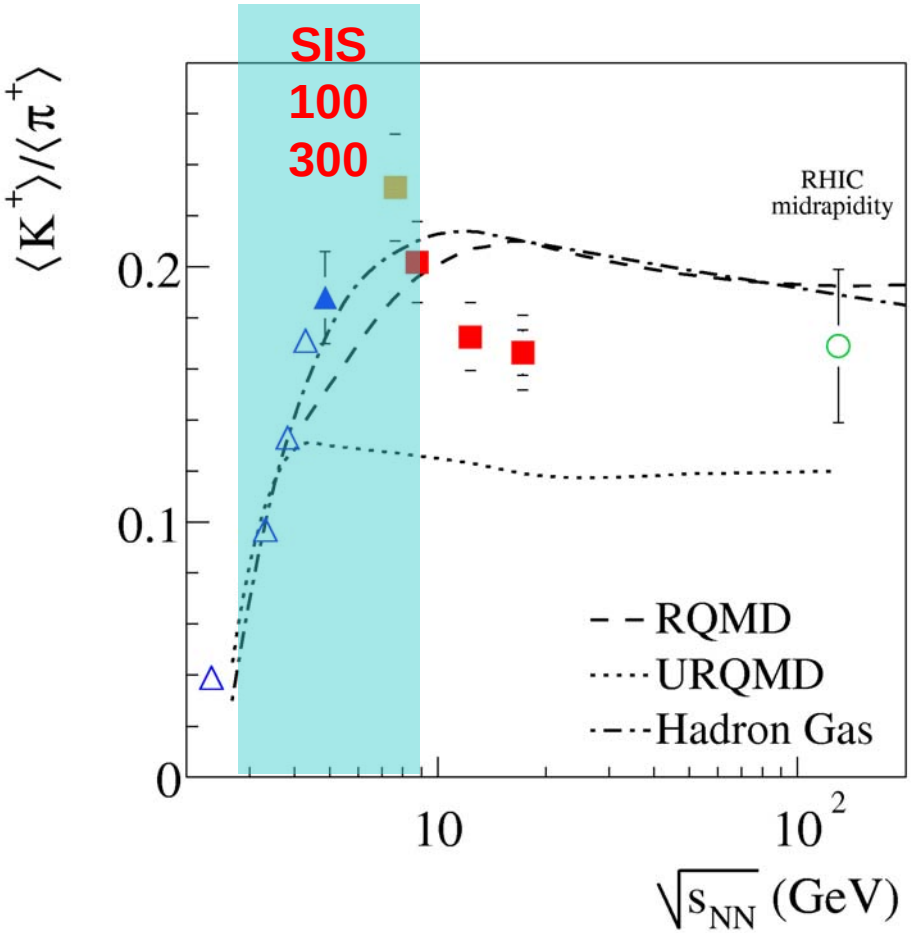
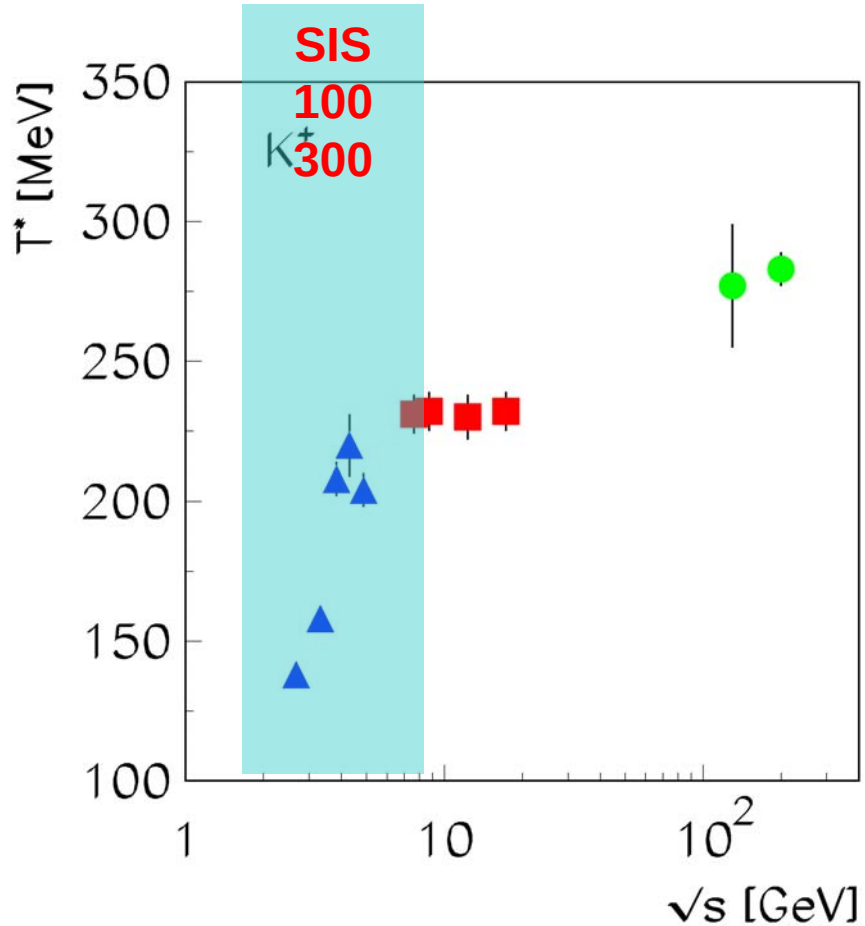




CBM physics topics and observables

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

     measure: ρ, ω, ϕ $\rightarrow$ 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 ?

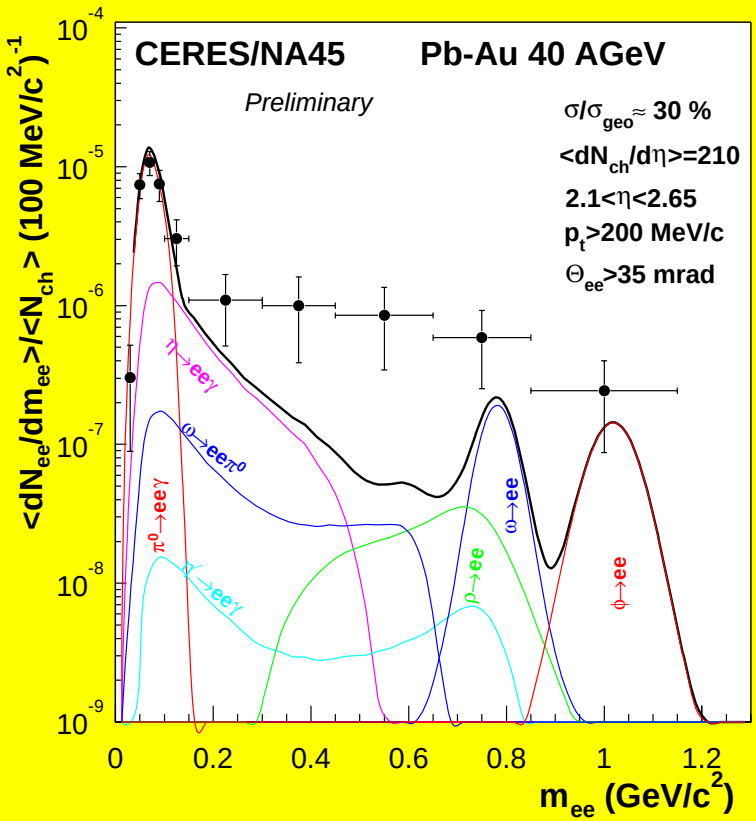
     measure: J/ψ, D
   - ↳ softening of EOS

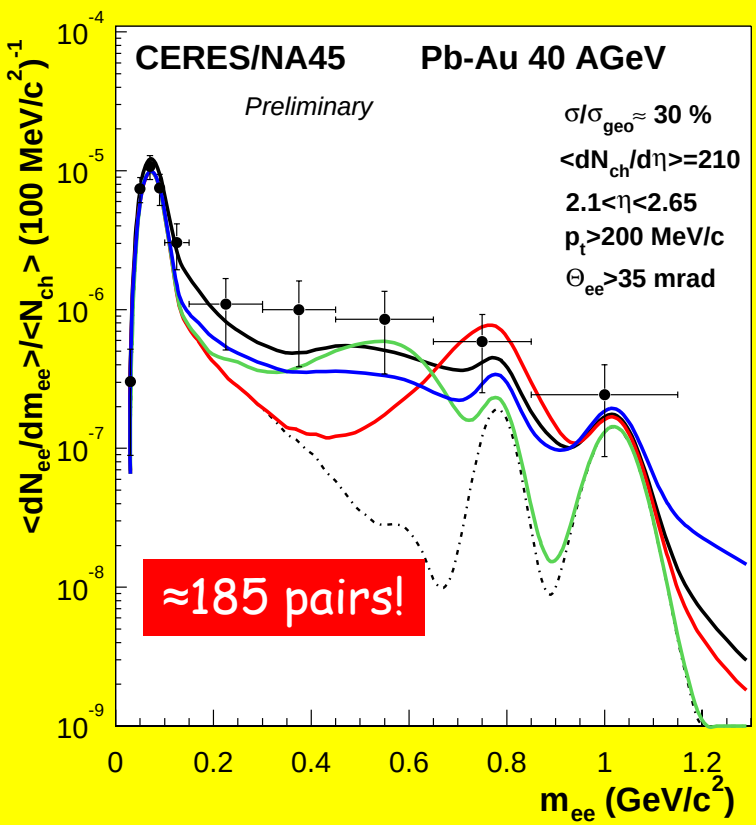
     measure flow excitation function
4. Critical point
   - ↳ event-by-event fluctuations
5. Color superconductivity
   - ↳ precursor effects ?

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

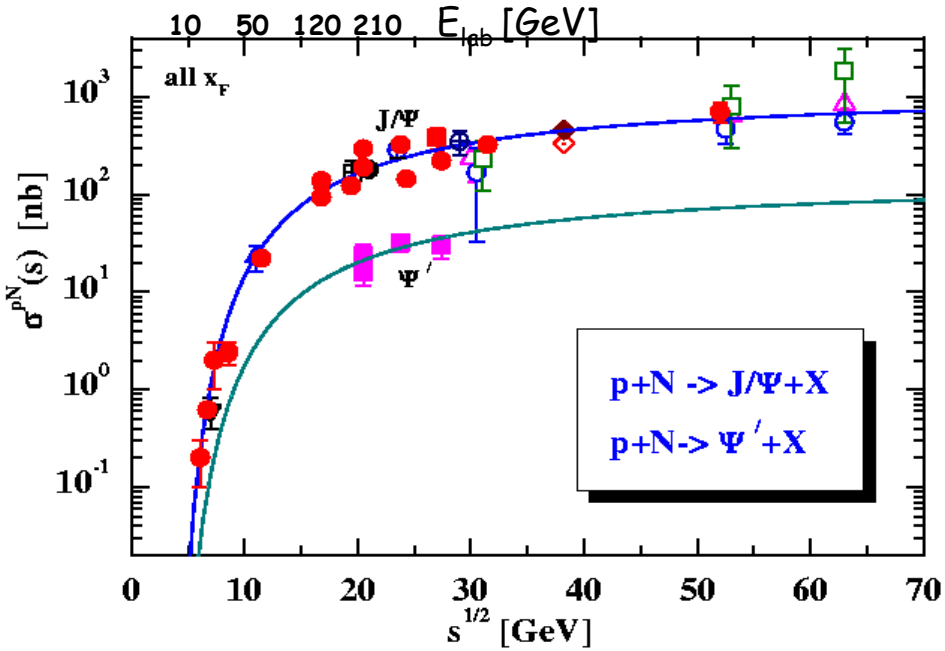
+ Vacuum rho spectral function

+ Rho spectral function with dropping mass

+ In-medium rho spectral function

+ Lowest order pQCD rate

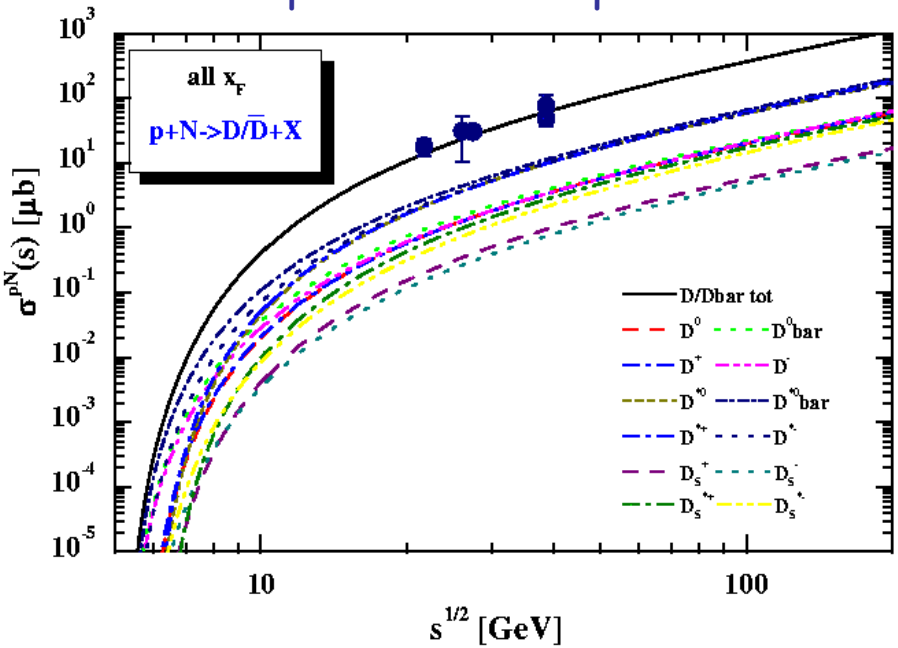
J/ψ experiments: a count rate estimate



central collisions	25 AGeV Au+Au	158 AGeV Pb+Pb
J/ψ multiplicity	$1.5\cdot10^{-5}$	$1\cdot10^{-3}$
beam intensity	$2\cdot10^{8}$/s	$2\cdot10^{7}$/s
interactions	$8\cdot10^{6}$/s (4%)	$2\cdot10^{6}$/s (10%)
central collisions	$8\cdot10^{5}$/s	$2\cdot10^{5}$/s
J/ψ rate	12/s	200/s
6% J/ψ $\rightarrow e^+e^-$ ($\mu^+\mu^-$)	0.7/s	12/s
spill fraction	0.8	0.25
acceptance	0.25	≈ 0.1
J/ψ measured	0.14/s	≈ 0.3/s
	≈ $8\cdot10^{4}$/week	≈ $1.8\cdot10^{5}$/week

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%)

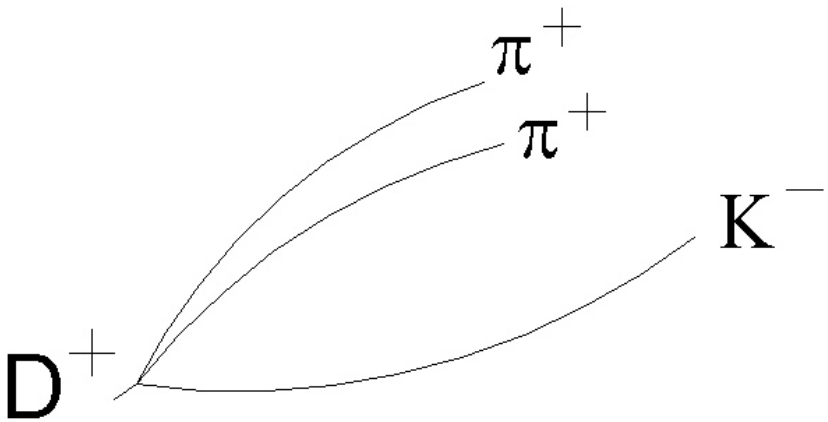
$D^+ \rightarrow K^-\pi^+\pi^+$ (9 ± 0.6%)

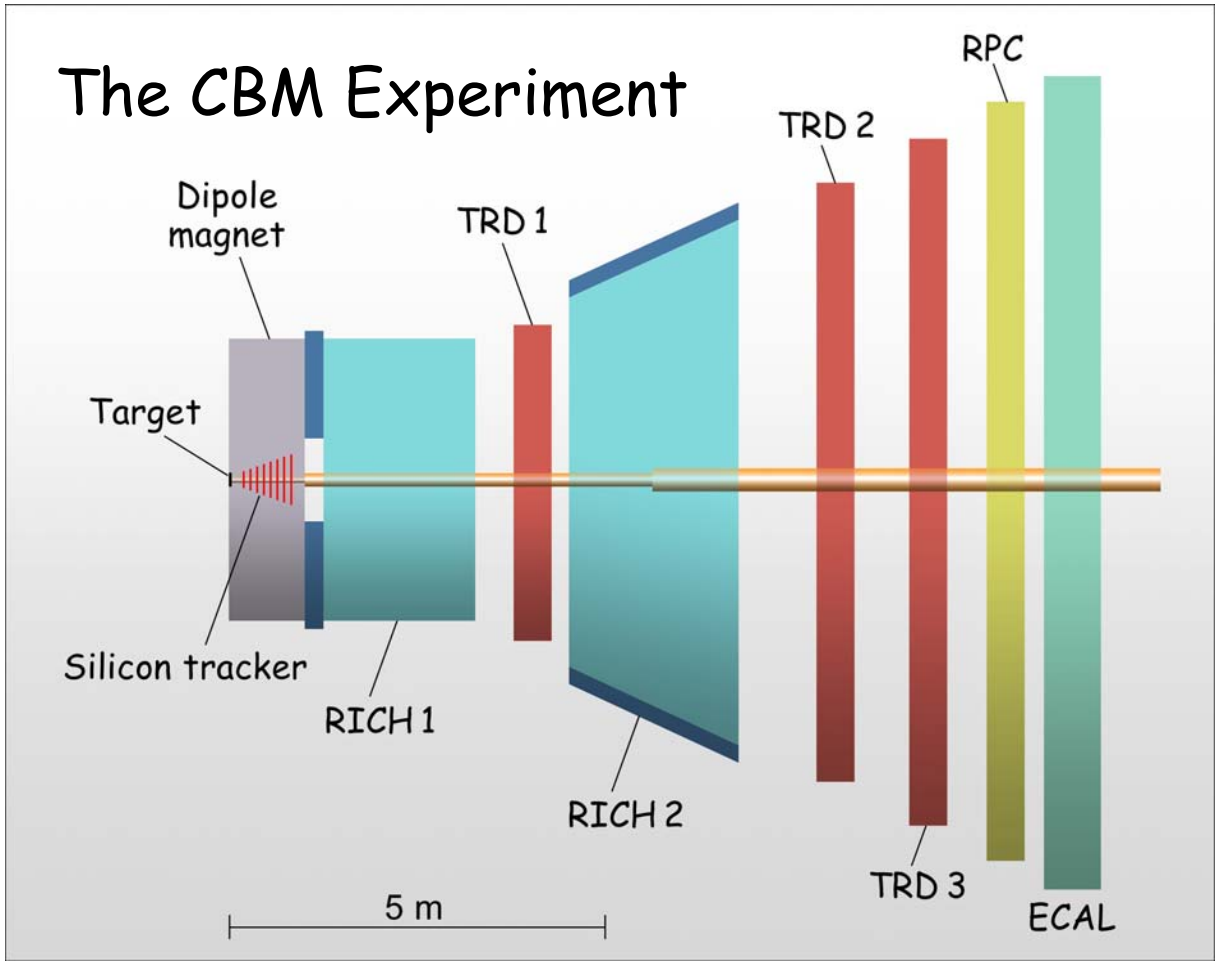
D^0 ($c\tau$ = 124.4 μm):

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

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

Measure displaced vertex
with resolution of ≈ 30 μm !



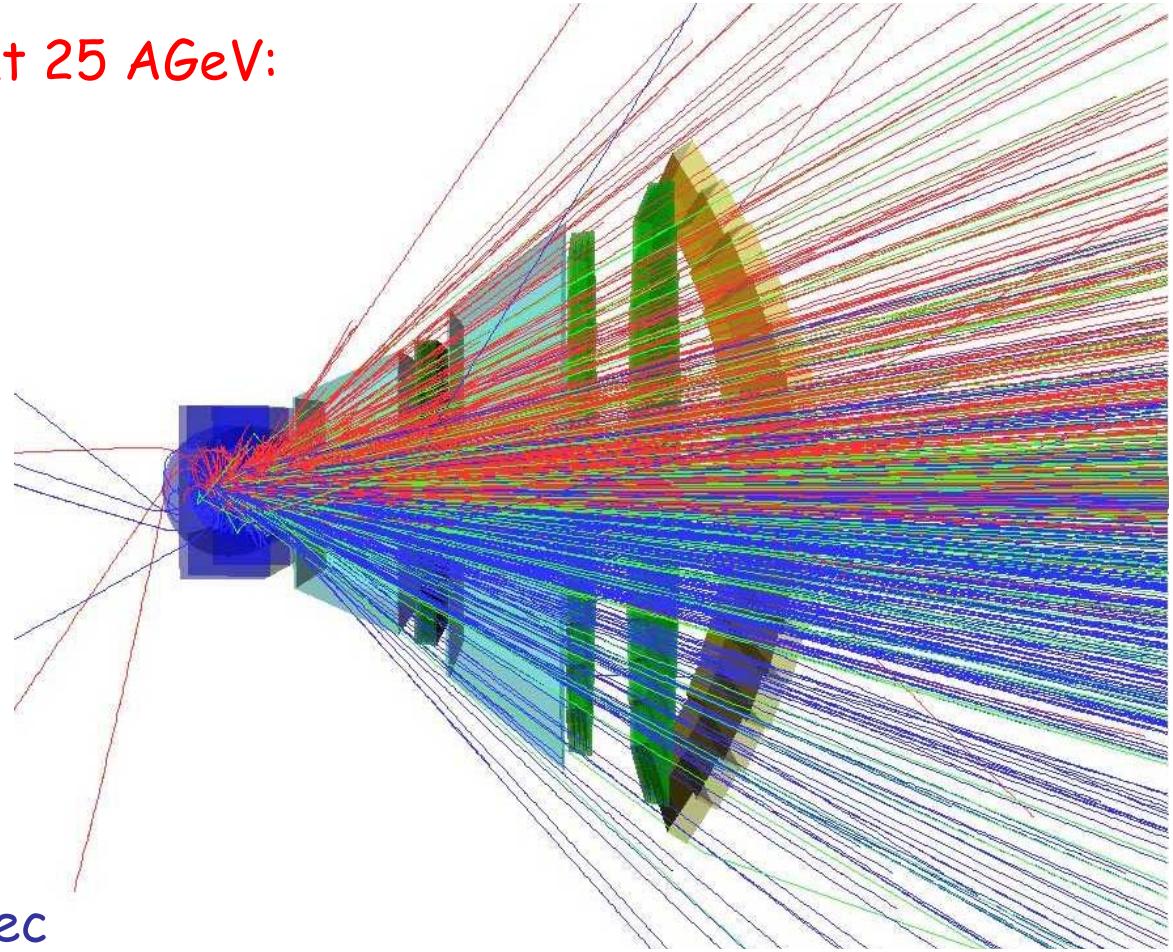


- Radiation hard Silicon pixel/strip detectors in a magnetic dipole field
- Electron detectors: RICH & TRD & ECAL: pion suppression up to 10^5
- Hadron identification: RPC, RICH
- Measurement of photons, π^0, η, and muons: electromagn. calorimeter (ECAL)
- High speed data acquisition and trigger system

Experimental challenges

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

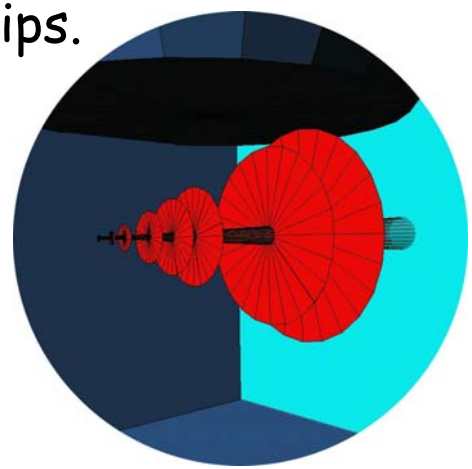
160 p
400 π^-
400 π^+
44 K^+
13 K^-



- 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

Design of a Silicon Pixel detector

Silicon Tracking System: 7 planar layers of pixels/strips.
Vertex tracking by two first pixel layers
at 5 cm and 10 cm downstream target



Design goals:

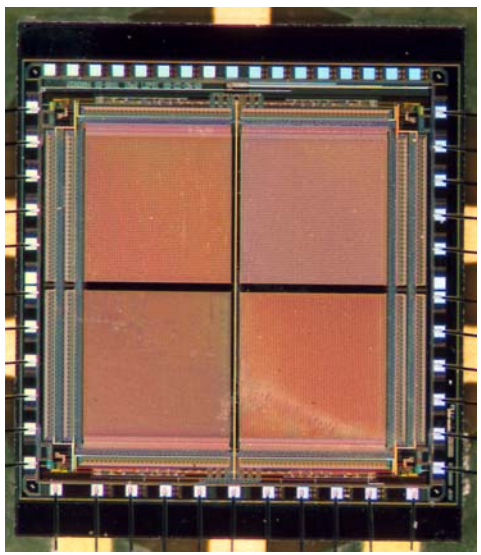
- low materal budget: d < 200 μm
- single hit resolution < 20 μm
- radiation hard (dose 10^{15} neq/cm^2)
- fast read out

Roadmap:

R&D on Monolithic Active Pixel Sensors (MAPS)

- pitch 20 μm
- thickness below 100 μm
- single hit resolution : ≈ 3 μm
- Problem: radiation hardness and readout speed

Fallback solution: Hybrid detectors



MIMOSA IV
IReS / LEPSI Strasbourg

Experimental conditions

Hit rates for 10^7 minimum bias Au+Au collisions at 25 AGeV:

	TRD 1 (D = 4 m)			TRD 2 (D = 6 m)			TRD 3 (D = 8 m)			RPC (D = 10 m)			ECAL (D = 12 m)		
Polar angle [mrad]	rates [kHz/ cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/ cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/ cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/ cm^2]	area [m^2]	N per cm^2 x 10^{-2}	rates [kHz/ cm^2]	area [m^2]	N per cm^2 x 10^{-2}
50	140	0.25	6.3	62	0.5	2.6	35	1	1.6	22	1.5	1	15.5	2	0.65
100	62	1	4.4	27	2.3	2.0	15	4	1.1	10	6	0.7	6.8	9	0.5
200	25	4	1.1	11	9	0.5	6	16	0.28	4	25	0.2	2.8	36	0.13
300	12.5	8.6	0.6	5.5	19	0.25	3	34	0.14	2	54	0.09	1.4	76	0.06
400	6	16	0.3	2.7	36	0.13	1.5	64	0.08	1	100	0.05	0.7	144	0.03
500	4	24	0.2	1.8	54	0.09	1	96	0.05	0.6	150	0.03	0.45	216	0.02

Rates of > 10 kHz/cm^2 in large part of detectors !

↳ main thrust of our detector design studies

Design of a fast TRD

Design goals:

e/π discrimination of > 100 (p > 1 GeV/c)

- High rate capability up to 150 kHz/cm^2
- Position resolution of about 200 μm
- Large area (≈ 500 m^2, 9 layers)

Roadmap:

Outer part: ALICE TRD

Inner part:

- GEM/MICROMEGAS readout chambers
- Straw tube TRT (ATLAS)
- Fast read-out electronics

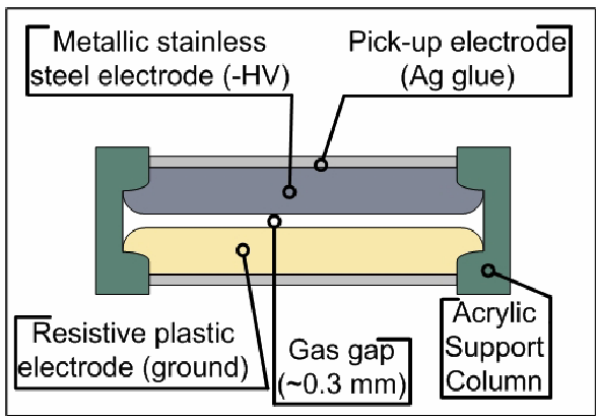
Design of a high rate RPC

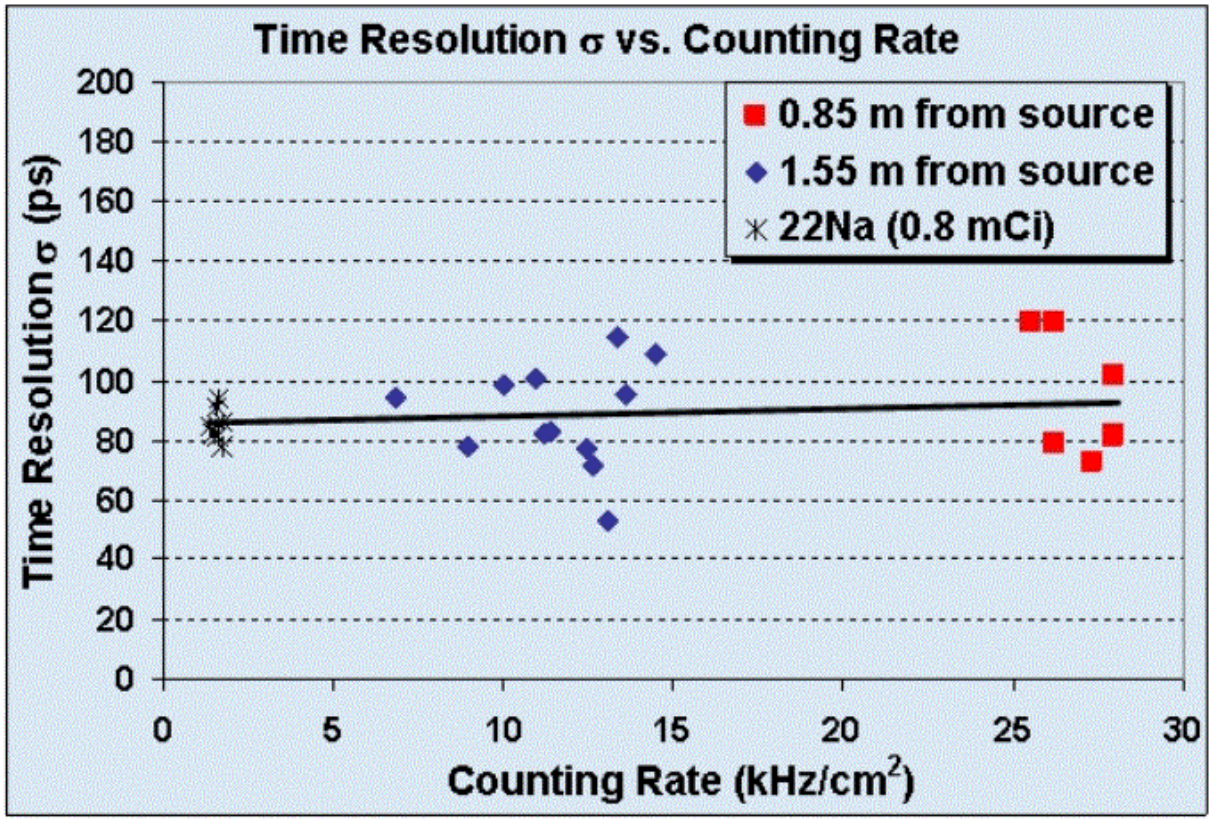
Design goals:

- Time resolution ≤ 80 ps
- High rate capability up to 25 kHz/cm2
- Efficiency > 95 %
- Large area ≈ 150 m2
- Long term stability

Prototype test:

detector with
plastic electrodes
(resistivity 10^9 Ohm cm.)
P. Fonte, Coimbra





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

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
Univ. Bergen
KFKI Budapest
Silesia Univ. Katowice
Univ. Warsaw

Analysis
GSI Darmstadt,
Heidelberg Univ,

CBM R&D Collaboration : 38 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 Frascati

Korea:
Korea Univ. Seoul
Pusan National Univ.

Norway:
Univ. Bergen

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