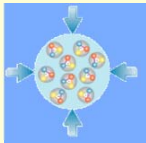
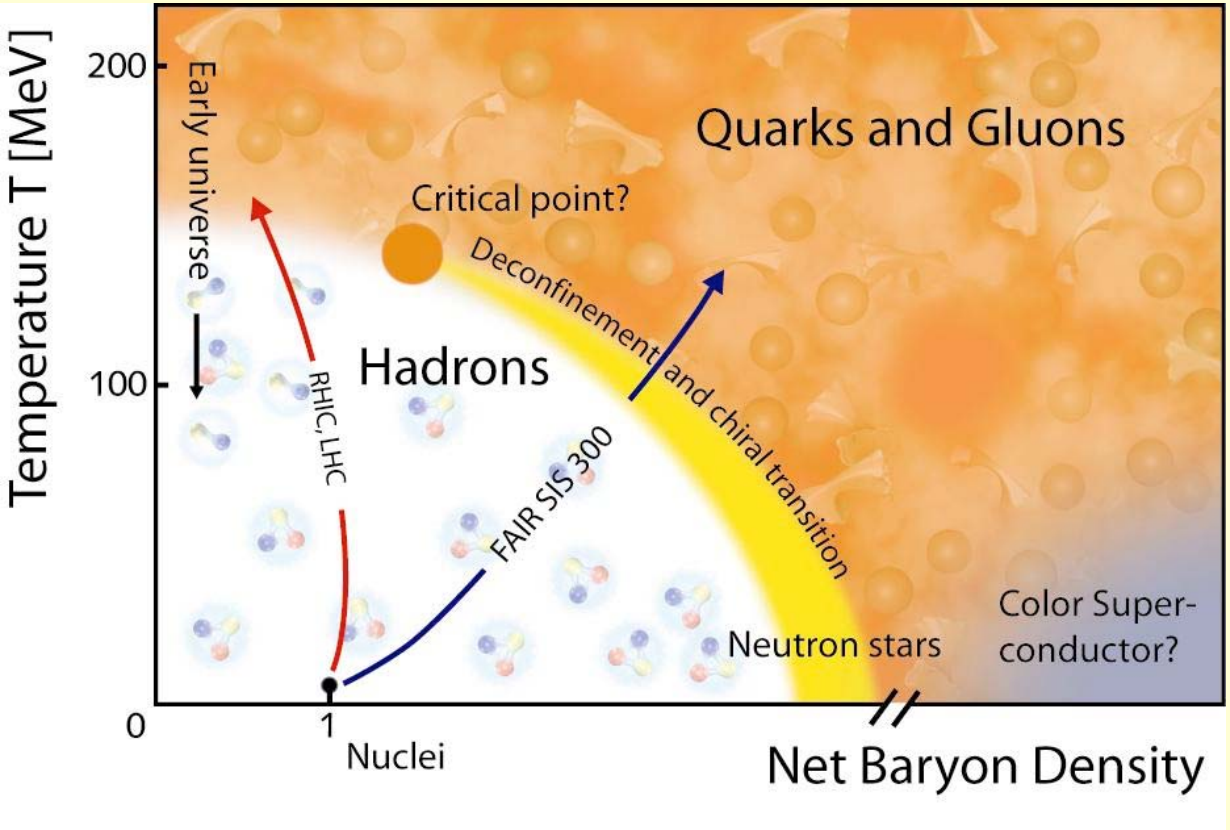


Exploring dense matter at FAIR: The CBM Experiment

Volker Friese

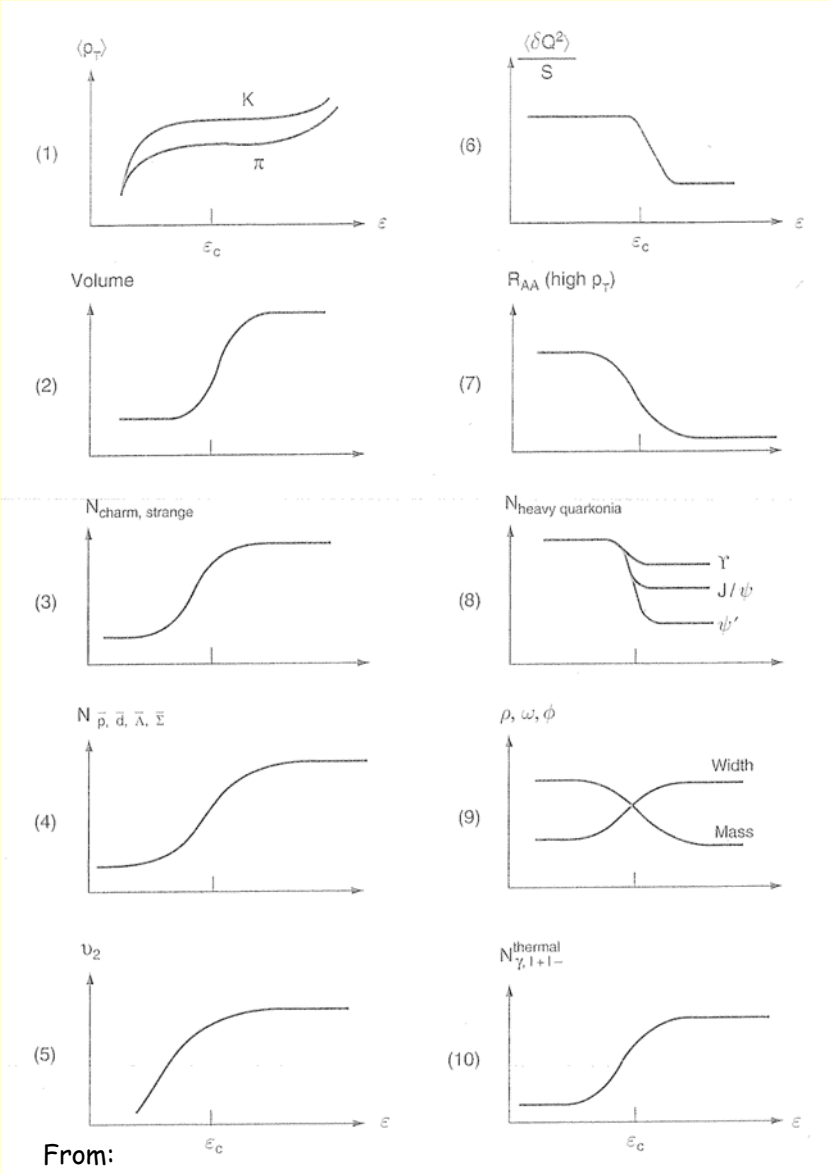
EMMI-Workshop, St. Goar, 1 September 2009

What's it all about



Landmarks of the QCD phase diagram:
- deconfinement phase transition
- chiral phase transition
- critical point

Signatures of phase transition in heavy-ion collisions



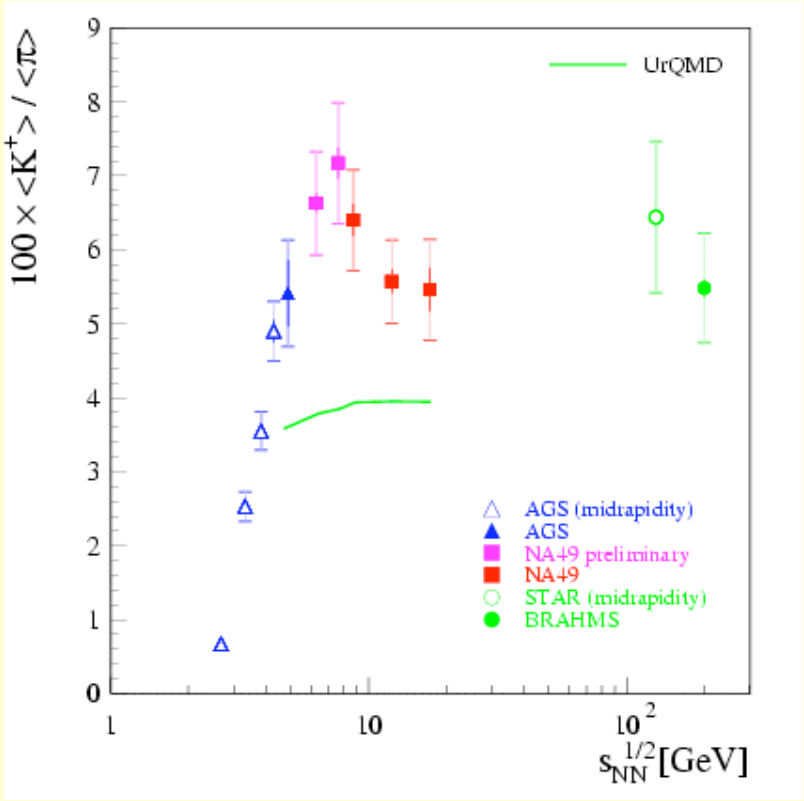
From:
Quark Gluon Plasma: From Big Bang to Little Bang, K. Yagi, T. Hatsuda, Y. Miake (2006)

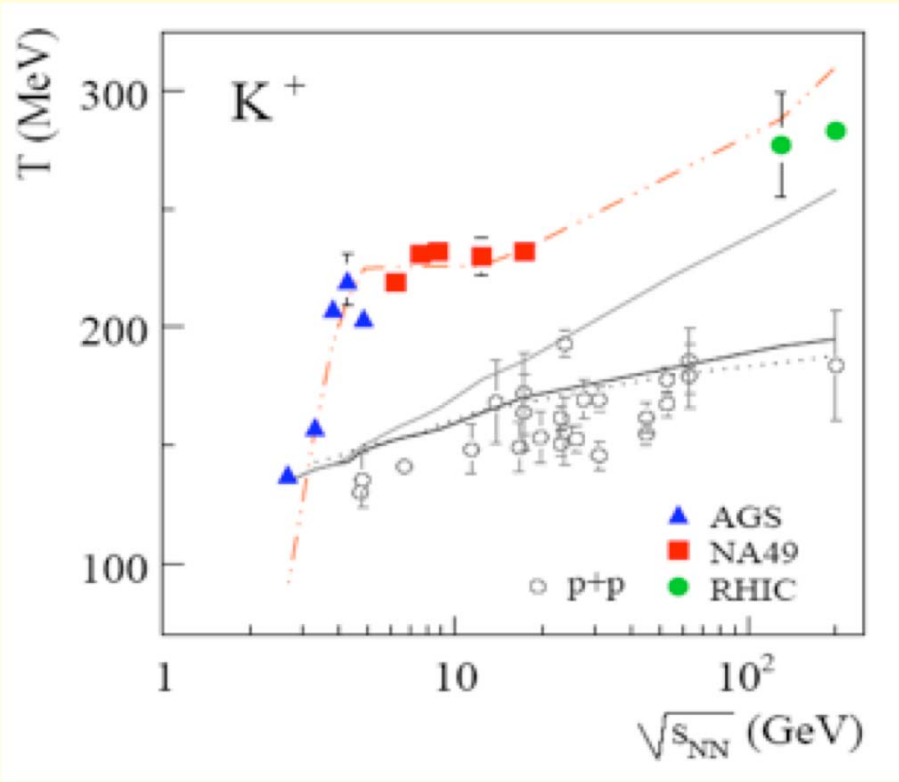
Search for discontinuities in energy or system size dependences

Requires:
- measurements at various beam energies
- different collision systems
- high precision
- high statistics

Signals may be diluted by finite size, finite lifetime, hadronisation

First indications?



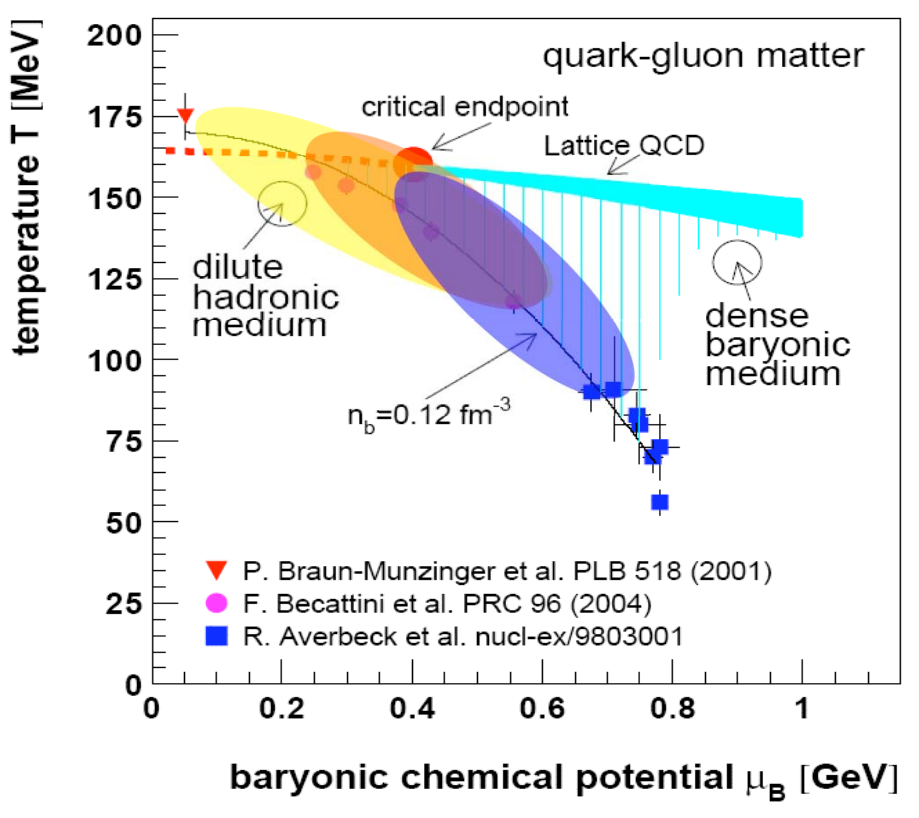


NA49 energy scan (SPS, 20 - 158 AGeV):
discontinuities in K/π, kaon slope parameters found

Indicates interesting energy region: 20 - 40 AGeV

High-density QCD: experimental programmes

Freeze-out points indicate: energy variation of heavy-ion collisions allows to scan the phase diagram



RHIC energy scan: Look for critical point with bulk observables

SPS (NA61): Look for the critical point with bulk observables (emphasis on light ions)

FAIR (CBM): Scan the phase diagram with bulk and rare observables:

- deconfinement phase transition
- properties of hadrons in dense matter
- maybe: critical point

NICA (MPD): Critical point, high-density matter, bulk observables

FAIR

Facility for Anti-Proton and Ion Research At GSI, Darmstadt

Hadron physics with anti-proton beams

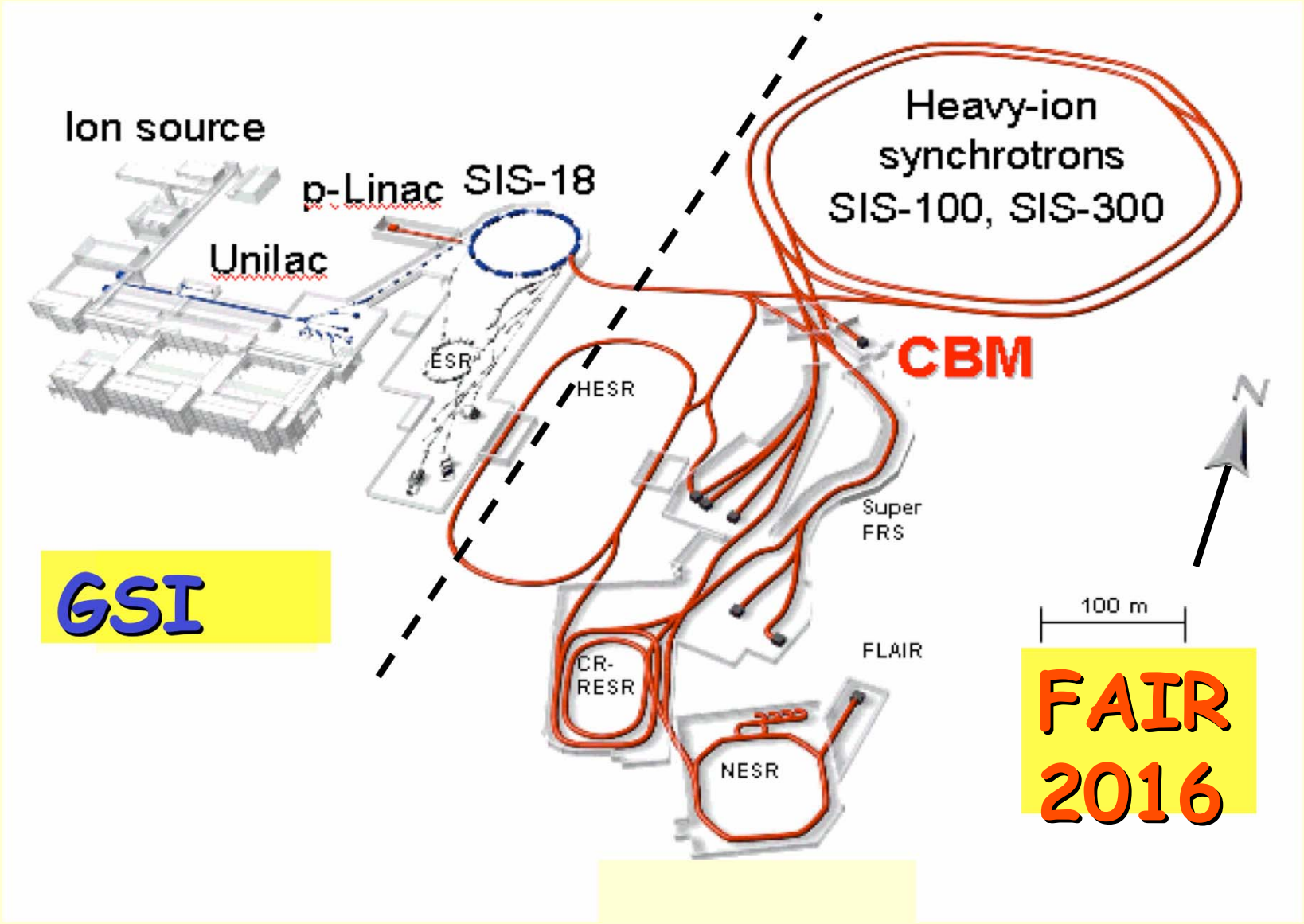
Nuclear structure physics with rare isotope beams

Plasma physics with short-pulsed heavy-ion beams

Atomic physics with highly charged ions and low-energy anti-protons

Nuclear collisions:
CBM
Ion beams 10^9/s
10 – 45 AGeV

Facility for Antiproton and Ion Research



SIS-100/300:

protons:

max: 90 GeV

ions:

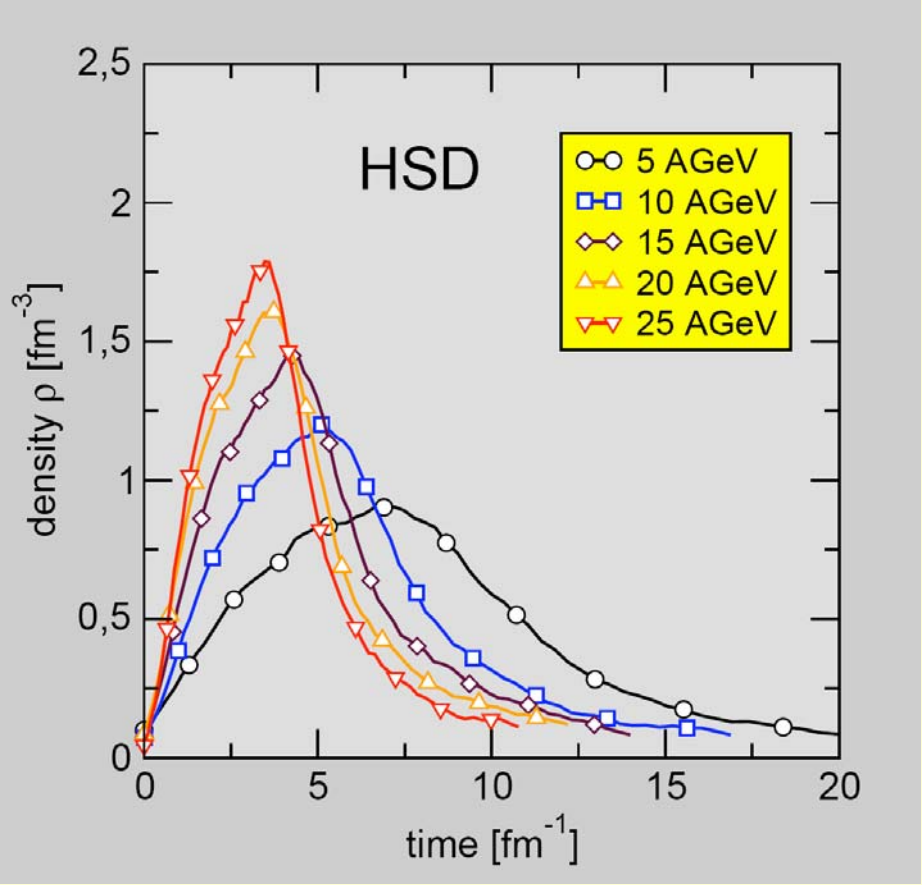
max. 45 GeV
up to Z/A=0.5
(35 AGeV Au)

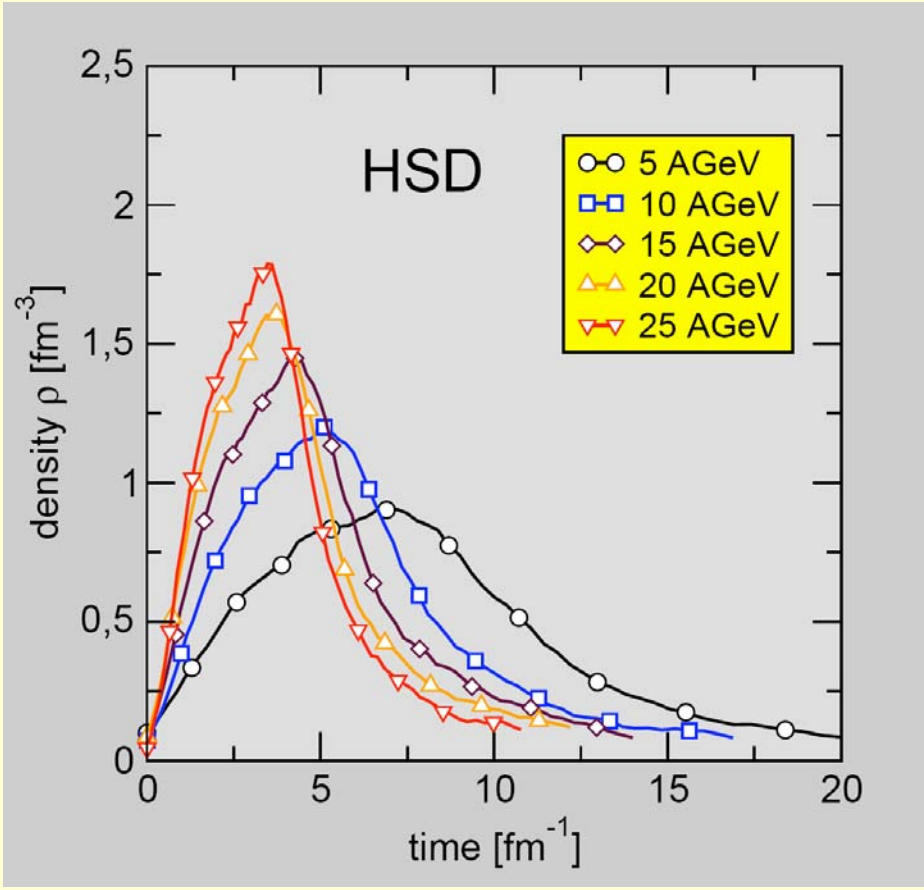
intensities:

up to 10^9 ions per second at CBM

Fireball conditions at CBM energies

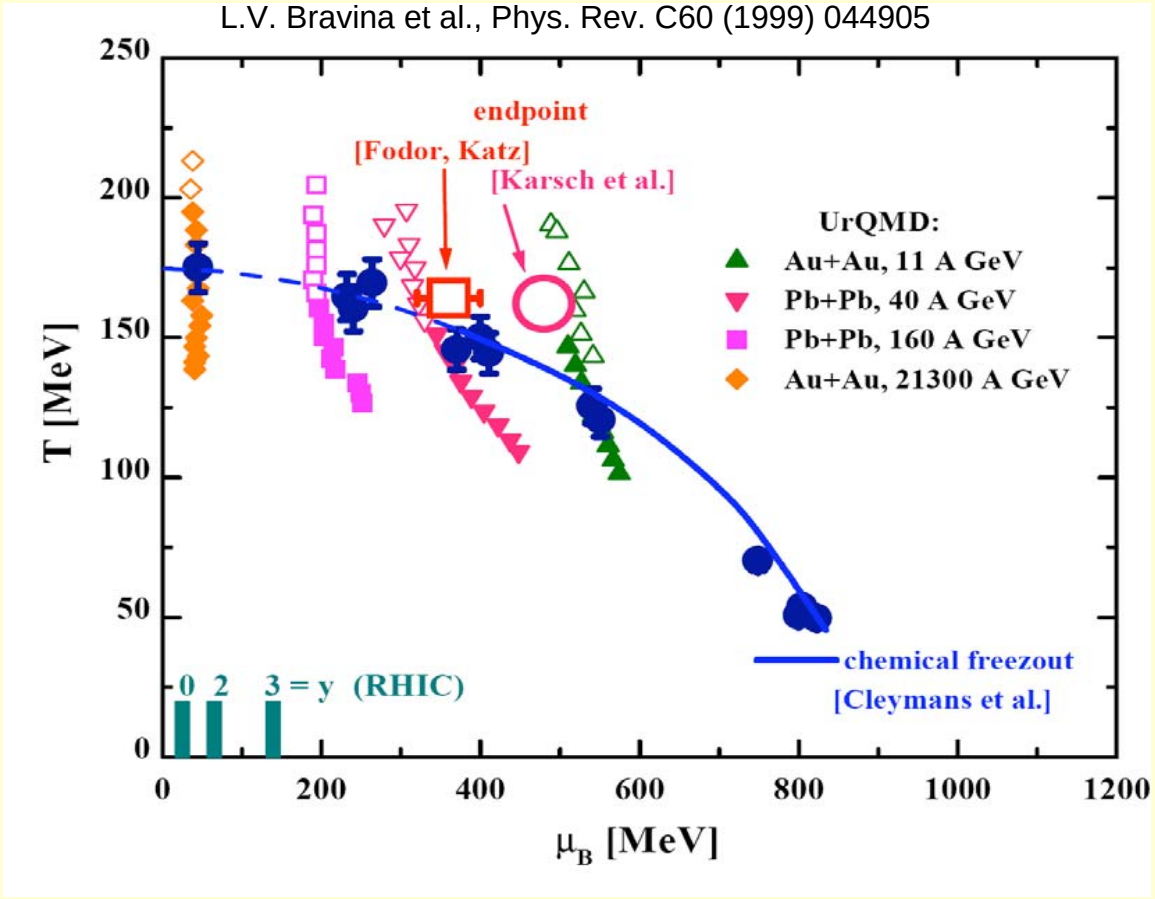
HSD, central Au+Au, central cell
Bratkovskaya & Cassing





Large baryon and energy density in central part of fireball predicted with hadro-string transport codes

Trajectories in the QCD phase diagram: UrQMD

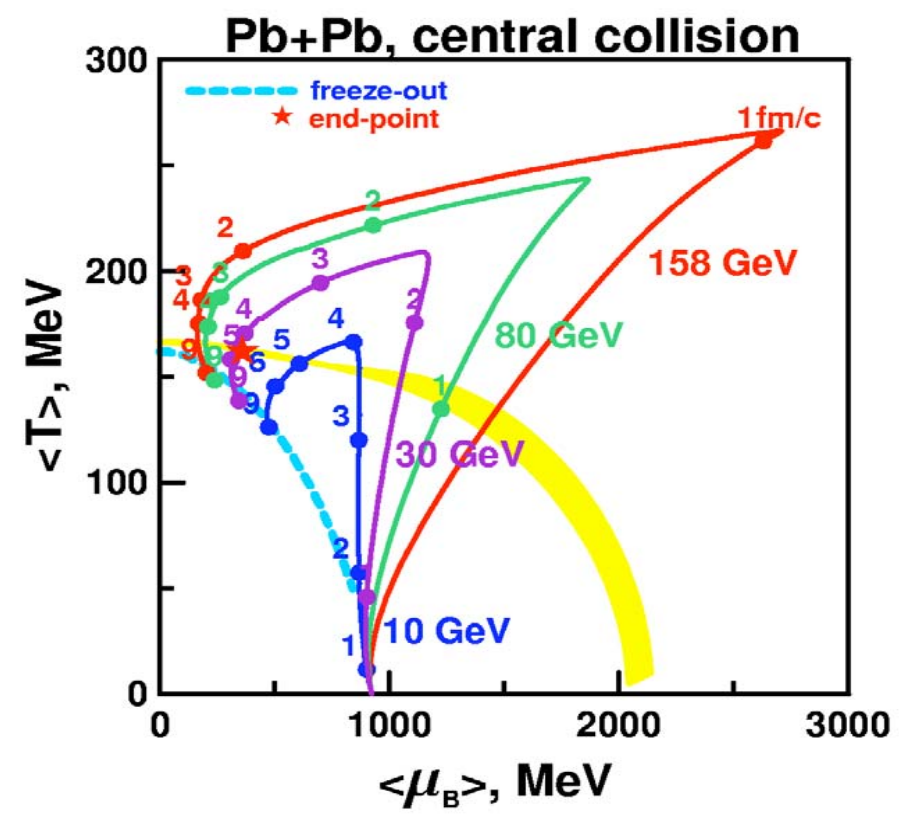


UrQMD (hadron-string transport):

Phase transition reached already at 11 GeV/nucleon

Trajectories in the QCD phase diagram: Hydro

Y. Ivanov, V. Russkikh, V.Toneev,
Phys. Rev. C73 (2006) 044904



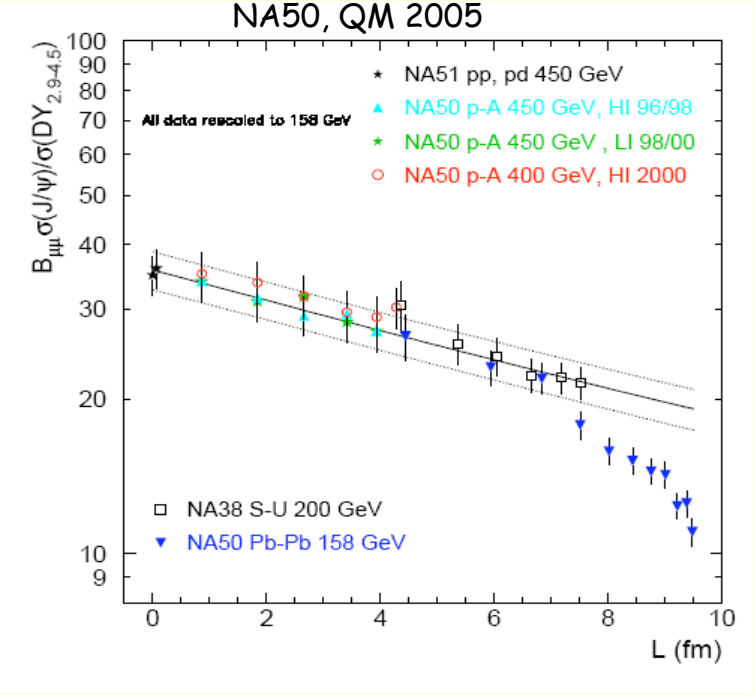
3 fluid hydro calculation with hadron gas EOS

predicts 30 AGeV to hit critical point

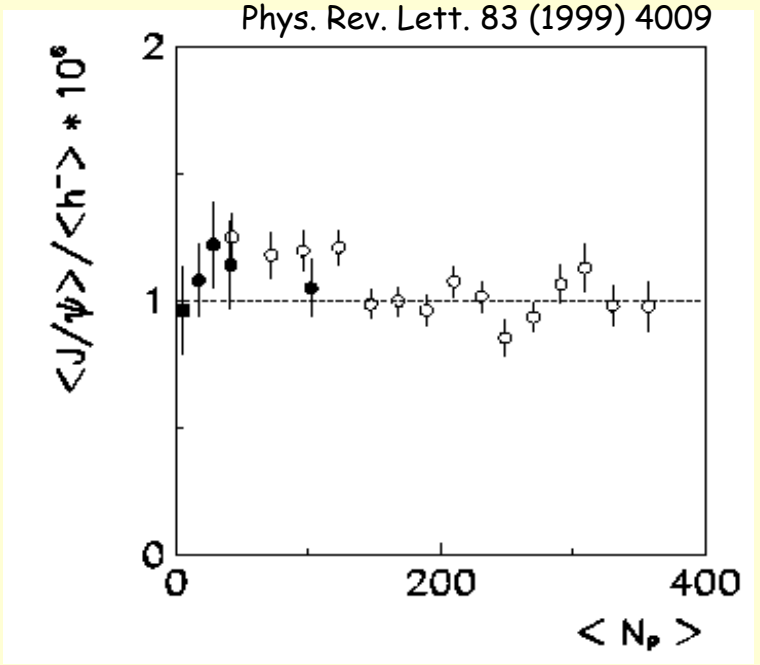
phase boundary reached already at 10 AGeV

Observables: J/ψ suppression

NA50, QM 2005

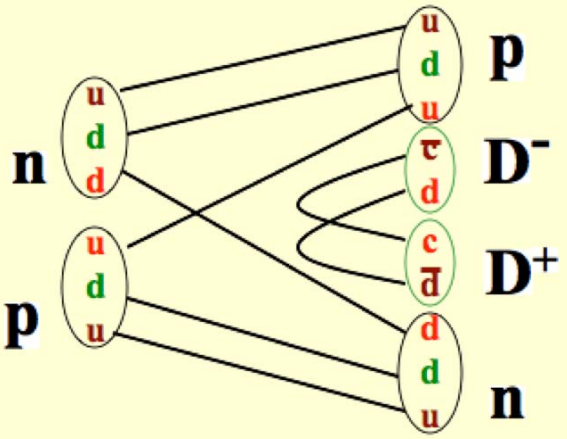


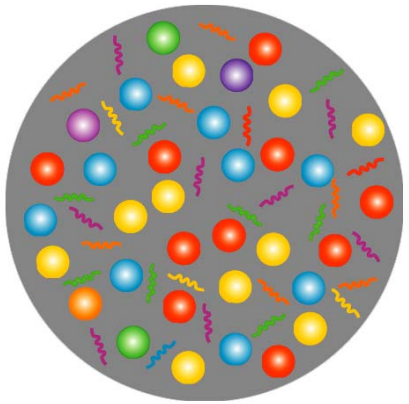
Gazdzicki & Gorenstein,
Phys. Rev. Lett. 83 (1999) 4009



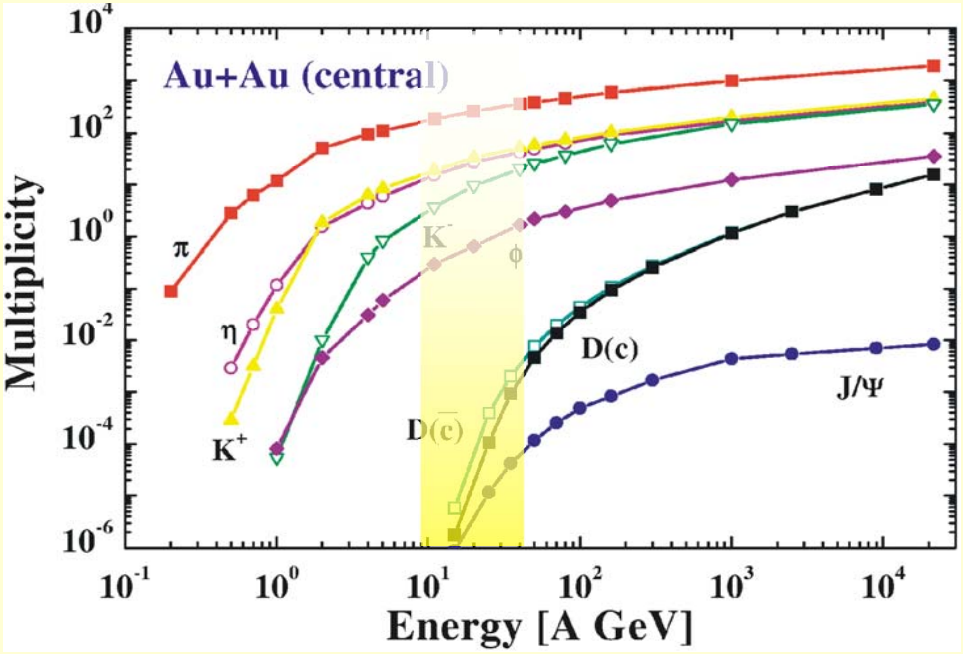
anomalous suppression observed at top SPS in J/ψ/ DY
suppression pattern similar at RHIC – why?
Is J/ψ production statistical?
onset of suppression at lower energies ?

Observables: Open charm - hadronic vs. partonic

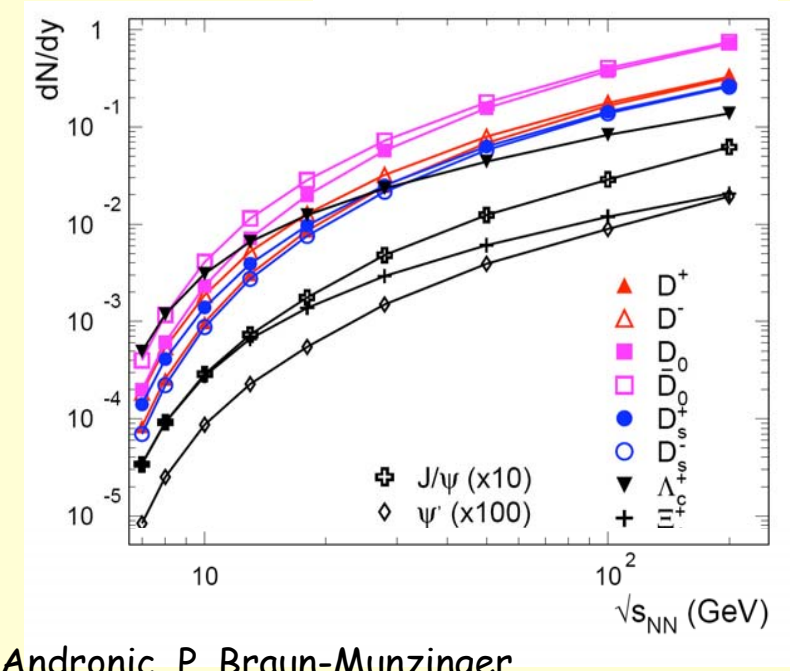




ccbar from pQCD +
Statistical hadronisation



W. Cassing et al., Nucl. Phys. A 691 (2001) 753

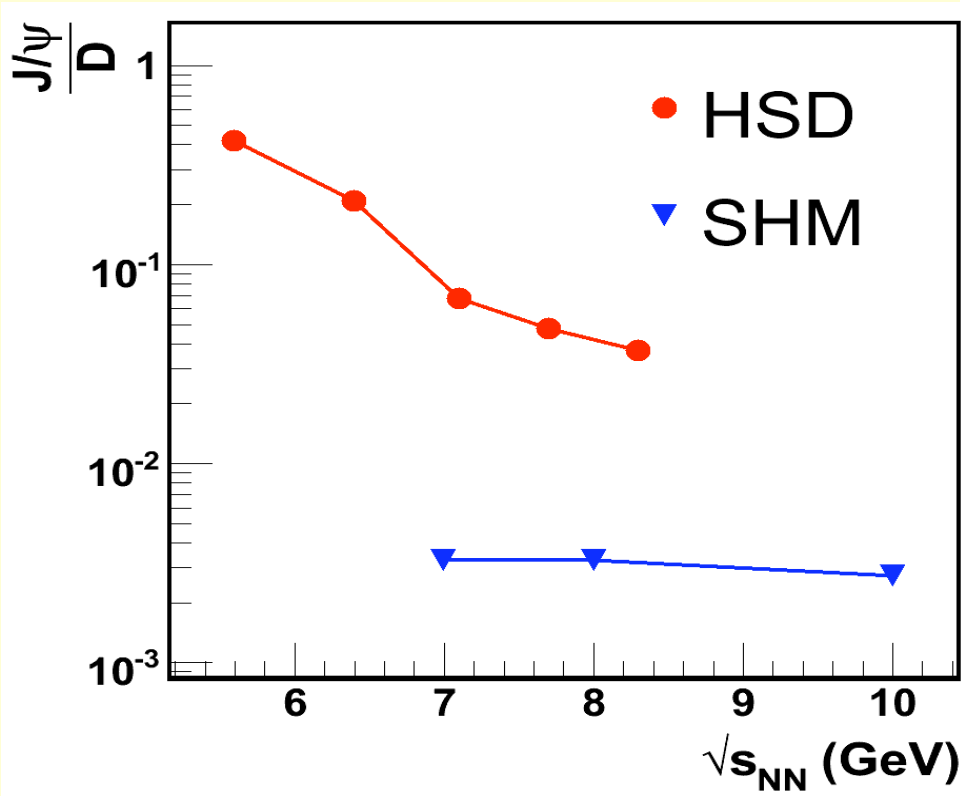


A. Andronic, P. Braun-Munzinger,
K. Redlich, J. Stachel, arXiv:0708.1488

Observables: hidden / open charm

Charmonium / open charm

hadronic matter



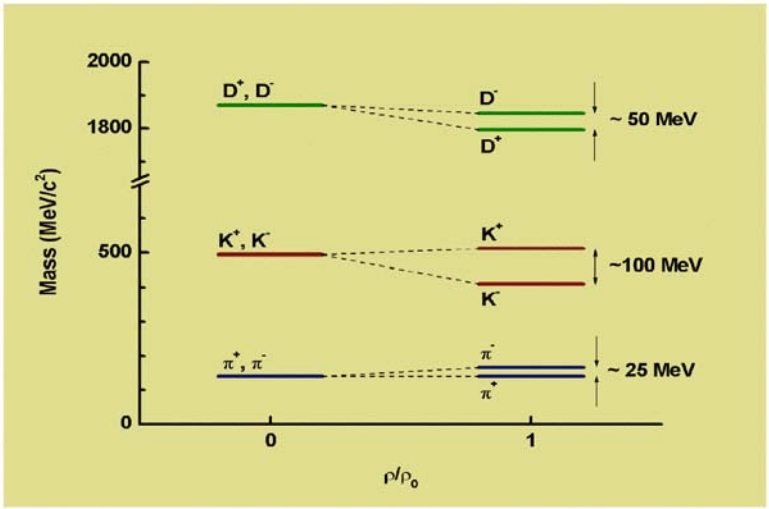
partonic matter

HSD: O. Linnyket al., Nucl. Phys. A786 (2007) 183

SHM: A. Andronic, et al., arXiv:0708.1488

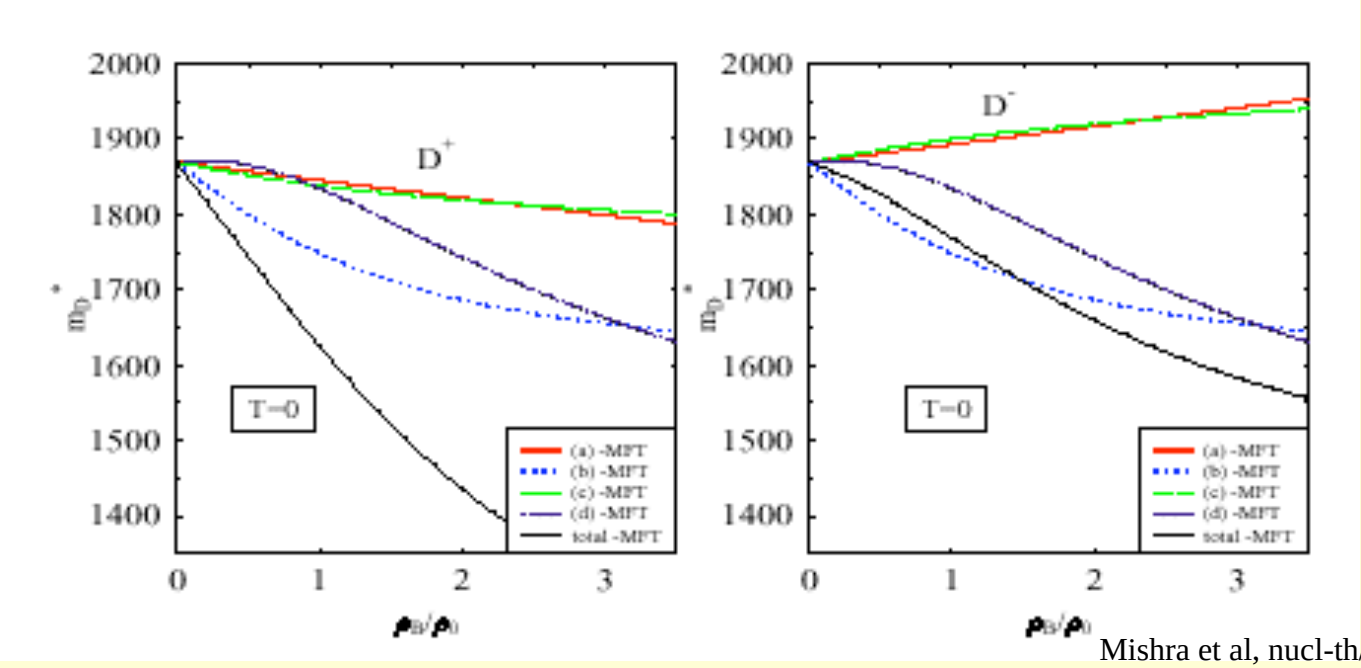
Ratio very sensitive to production scenario
c-cbar production cross section cancels out

Observables: open charm, mass modifications



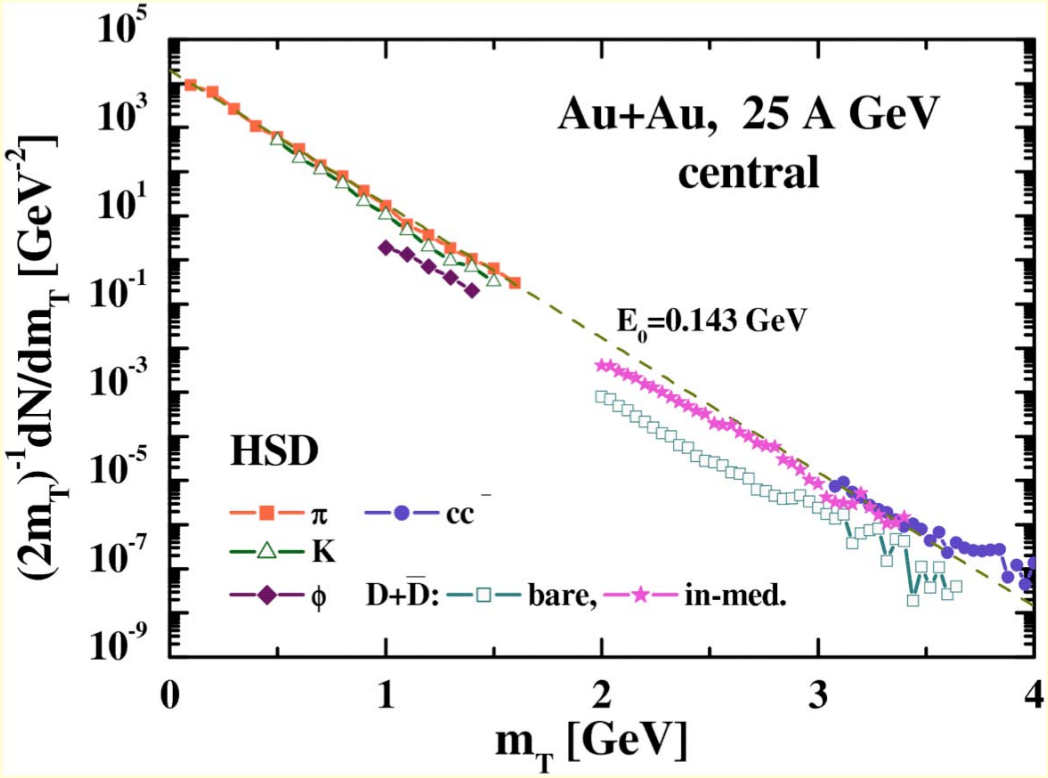
D mesons are expected to change masses in dense medium (analogue to kaons)

Should have effect on production yield

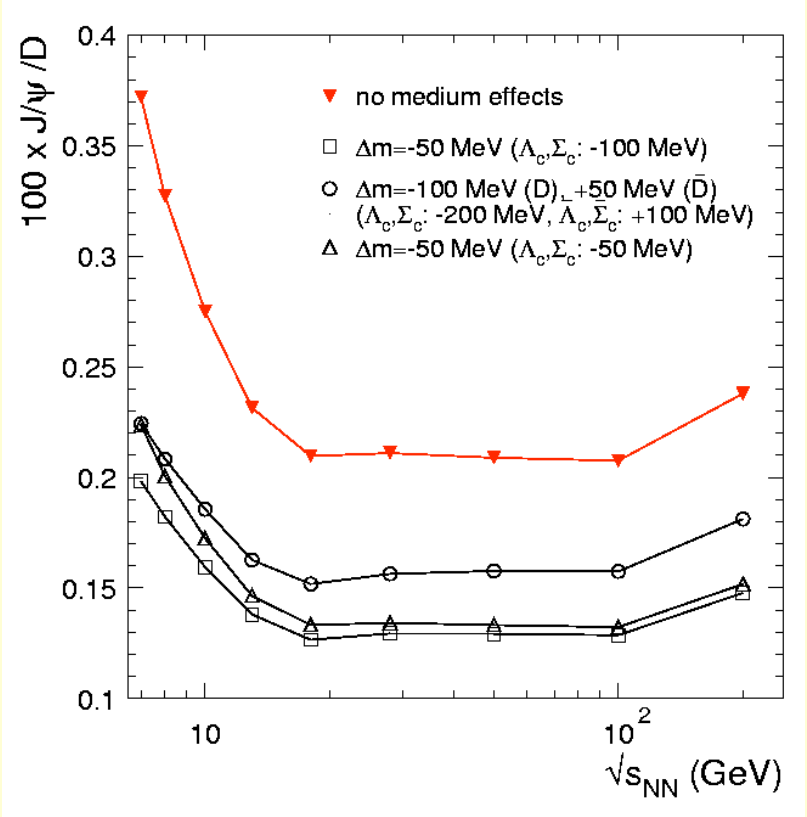


Mishra et al, nucl-th/0308082

Open charm: mass modifications



HSD: W. Cassing, E. Bratkovskaya, A. Sibirtsev, Nucl. Phys. A 691 (2001) 753

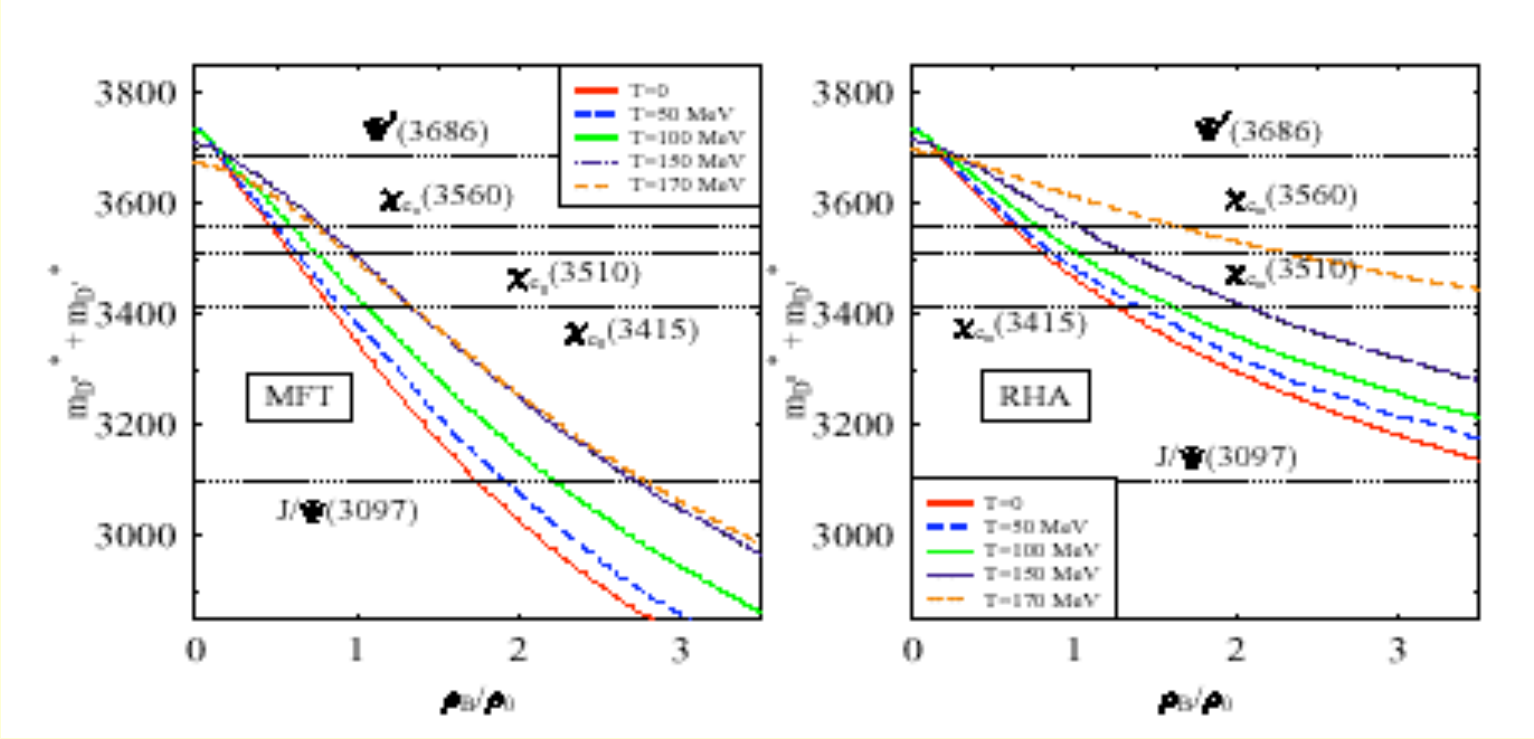


SHM: A. Andronic, P. Braun-Munzinger, K. Redlich, J. Stachel, arXiv:0708.1488

Model predictions: Modifications observable in D meson yield and/or J/D ratio

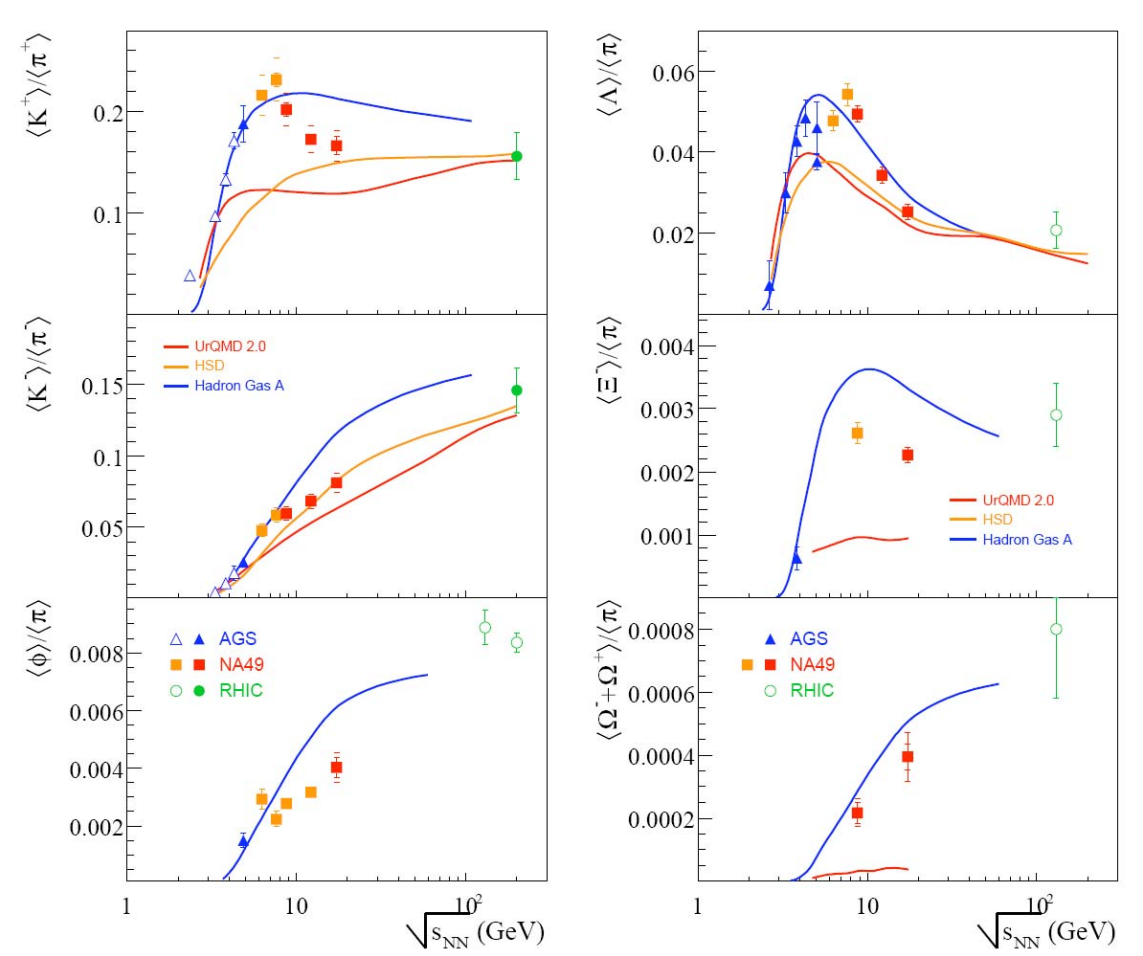
Open charm once again

Mishra et al, nucl-th/0308082



Once $2xm_D$ drops below charmonium thresholds: strong decay channel opens up
Effectr on J/ψ in dilepton channel?

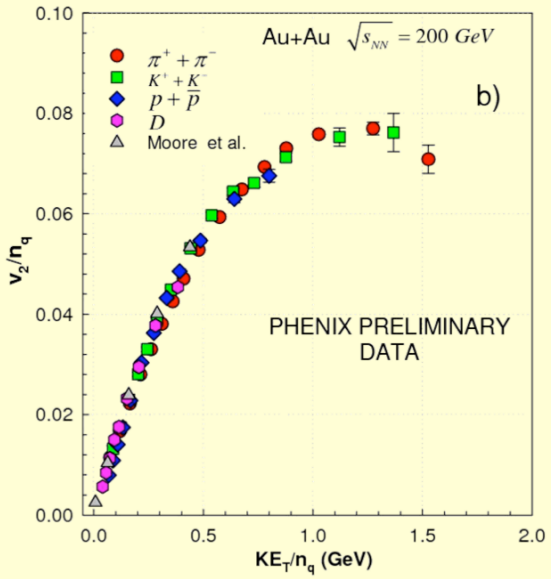
Observables: Strangeness



Does SHm acccount for all structures observed in the energy dependence of strange particle yield?

Required: Precision measurement of excitation function of strange particle production and propagation (flow), including Λ,Ξ, Ω

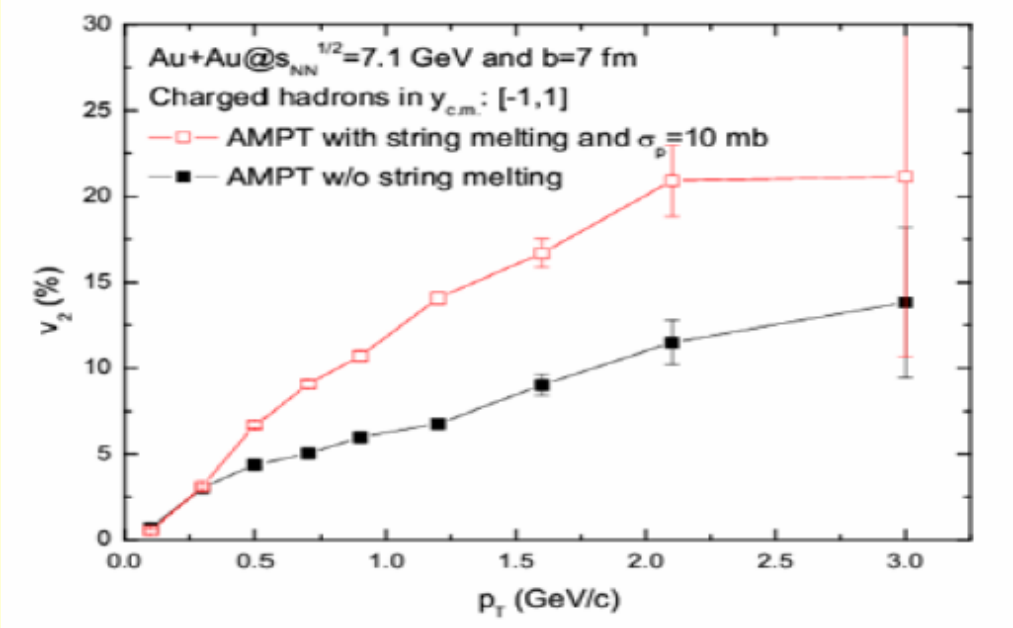
Observables: Elliptic flow

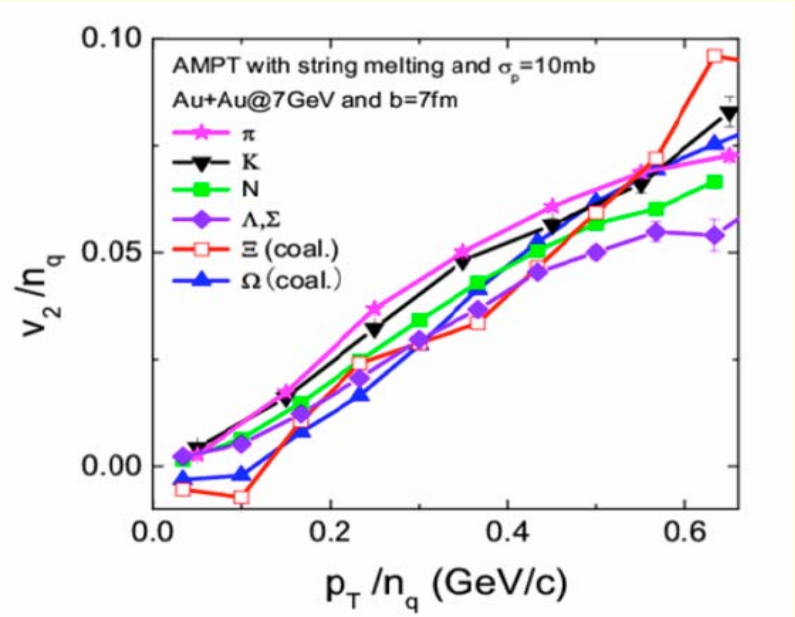


Lessons form RHIC: large flow, constituent quark number scaling indicates partonic origin

At CBM energies (AMPT): Partonic phase expected tp show up in increased flow and quark number scaling

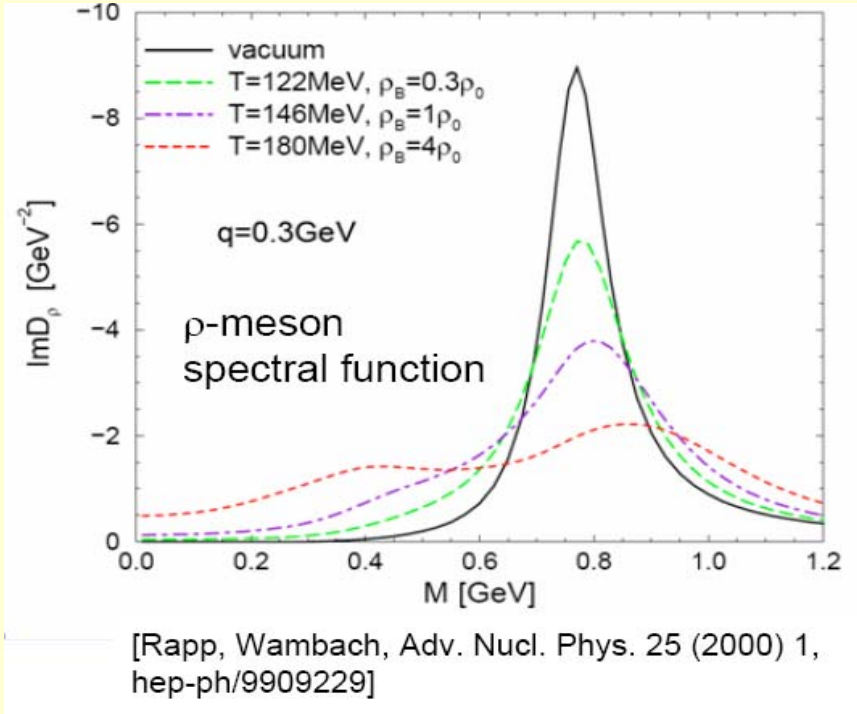
Look for onset of these phenomena in flow excitation functions



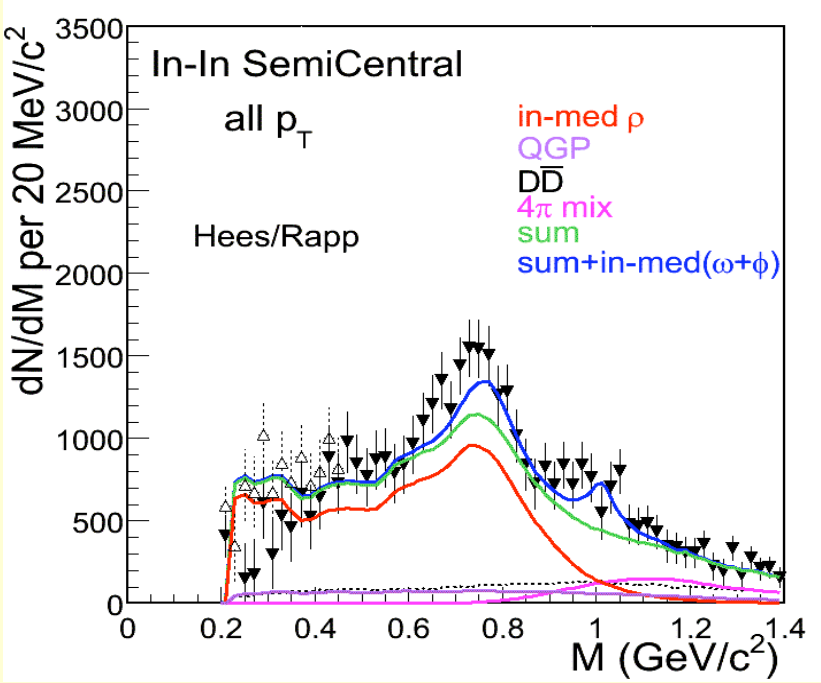


Approximate constituent quark number scaling !

Observables: In-medium properties of light vector mesons



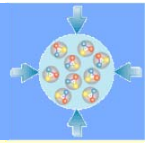
[Rapp, Wambach, Adv. Nucl. Phys. 25 (2000) 1, hep-ph/9909229]



The modification of hadron masses in a baryon-dense environment may signal the onset of restoration of chiral symmetry

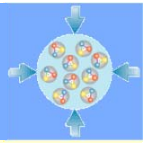
No data below 40 GeV/nucleon available

The CBM physics programme



- Excitation function and flow of strange hadrons (K, Λ, Ξ, Ω, ϕ)
- Excitation function and low of charmed hadrons (D^0, $D^{\pm}$, D_s, Λ_c)
- Charmonium (J/ψ, ψ')
- Spectral function of short-lived vector mesons (ρ, ω, ϕ) in the di-leptonic decay channels
- Event-by-event fluctuation (mean p_t, K/π, K/p, net charge, ...)

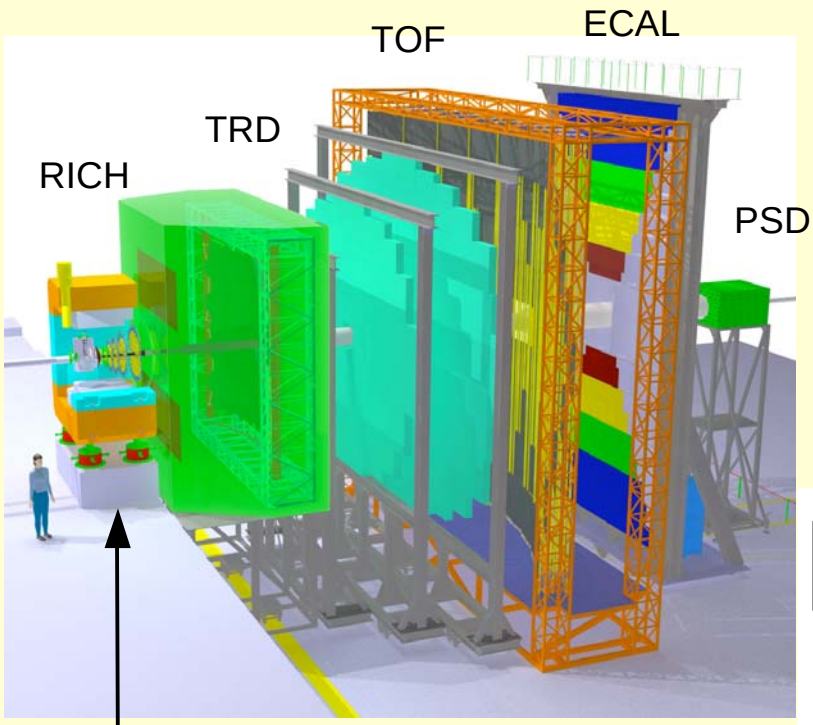
CBM: Requirements



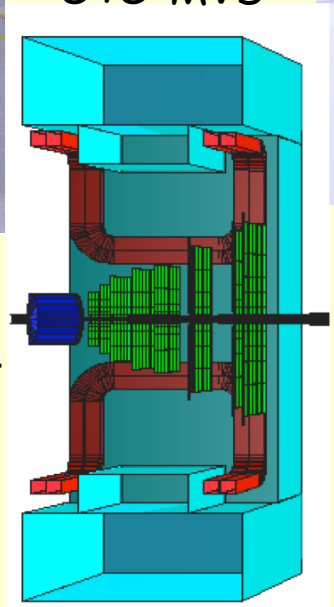
- Identification of hadrons: time of flight
- Identification of electrons: RICH, TRD
- Identification of muons: absorber system
- Micro-vertex capabilities for open charm
- High rates for rare observables (charm, multi-strange hyperons)
- Large acceptance (forward rapidity, low and high pt coverage)

The CBM experiment: Setup

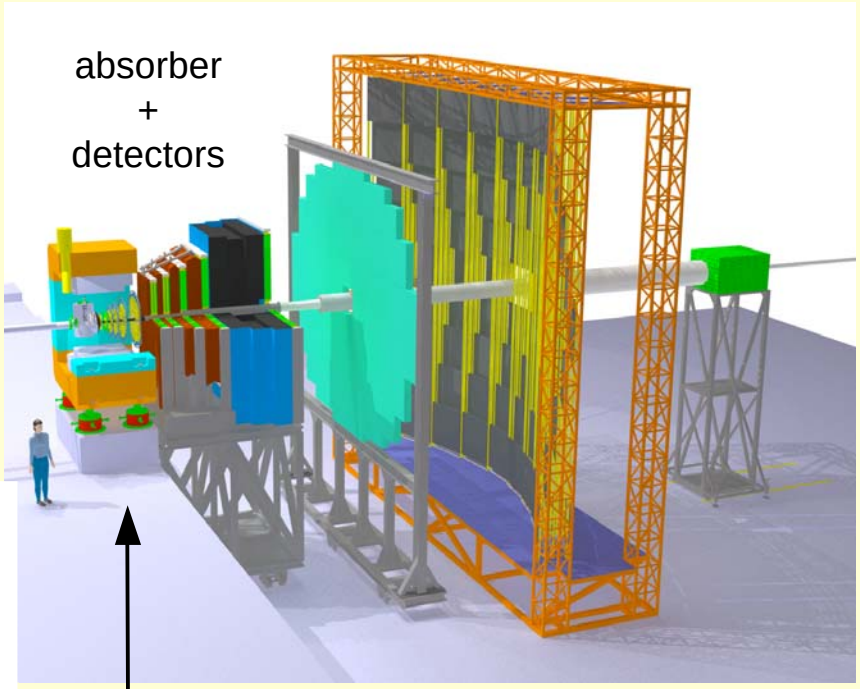
Electron + Hadron setup



STS+MVD



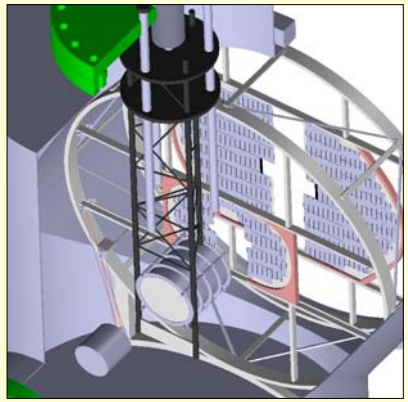
Muon setup



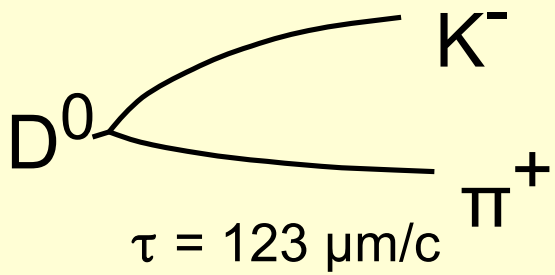
- Tracking in STS
- Vertexing in MVD
- Electron ID in RICH + TRD
- Hadron ID in TOF
- γ in ECAL
- Centrality in PSD
- μID in absorber system

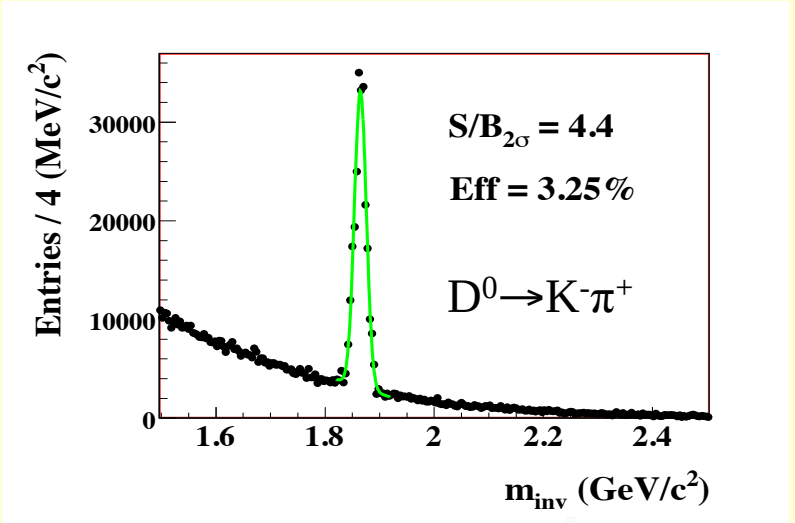
Feasibility: Open charm with the Micro-Vertex Detector

Ultra low-mass system, high single-hit resolution

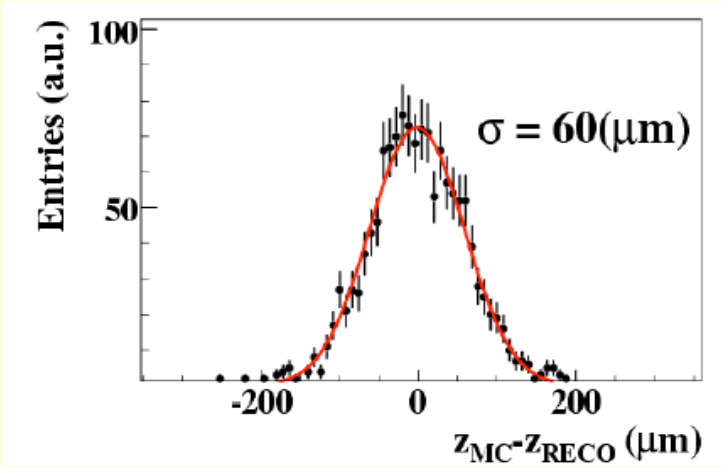


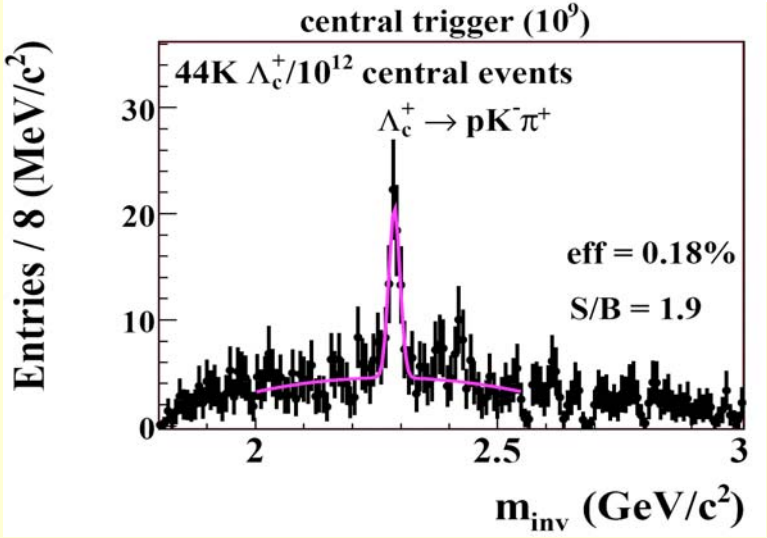
2 stations of MAPS detectors





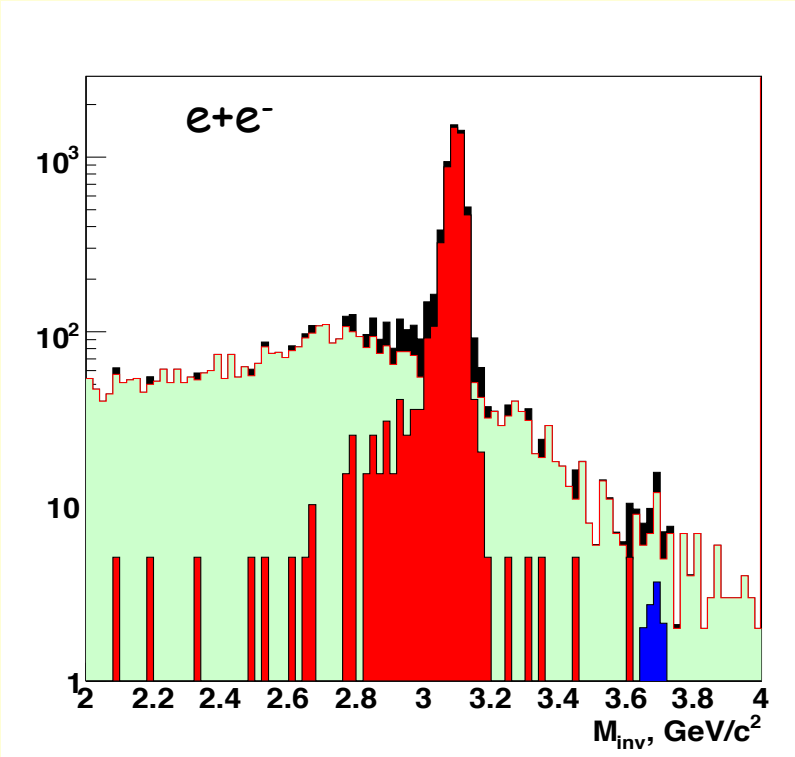
Vertex resolution for D^0



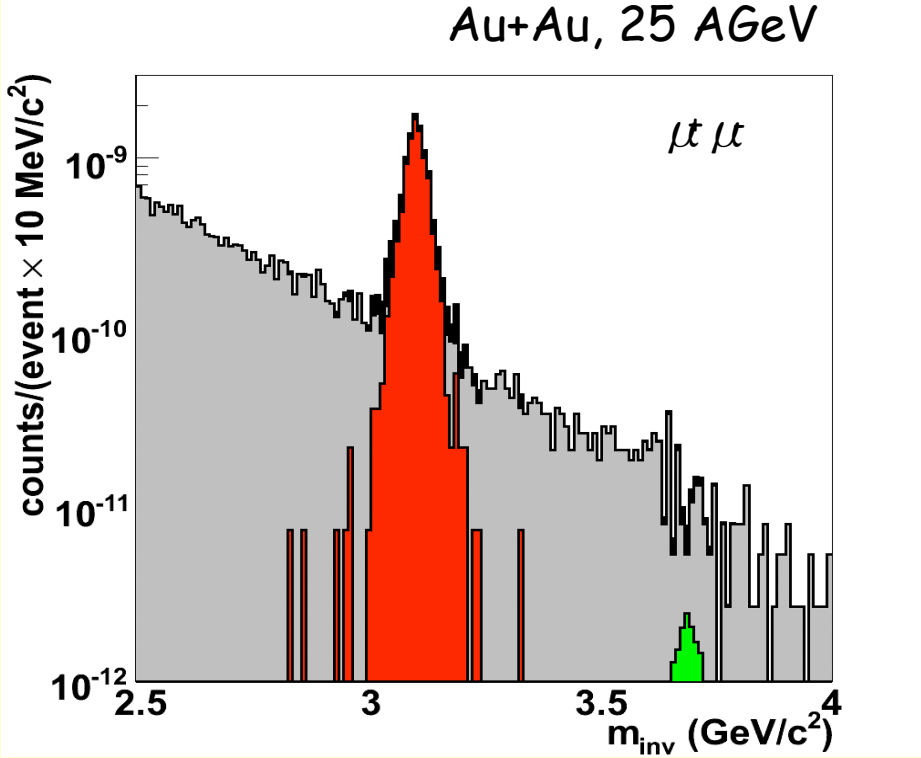


Feasibility: Charmonium

Pion suppression in RICH+TRD+ECAL

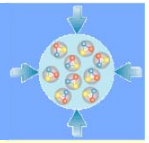


Hadron suppression by absorber



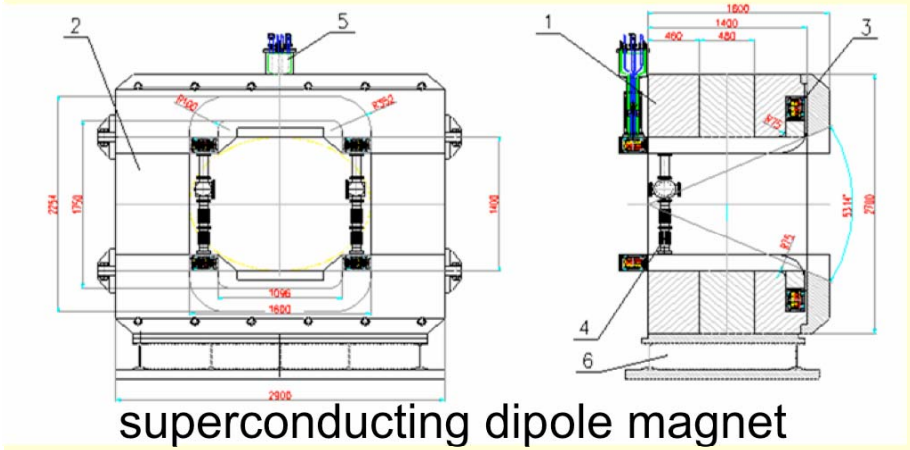
Similar performance for charmonium in electron and muon channels

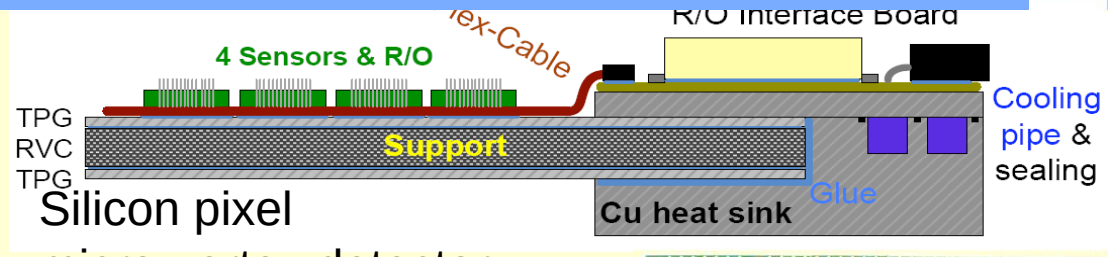
CBM Programme at SIS-100



- FAIR staging scenario: SIS-100 may come 2-3 years before SIS-300
- CBM core setup: MVD + STS + TOF
- A+A up to 10 AGeV: strangeness, flow excitation functions
- p+p, p+A up to 30 GeV: charm production
- Di-electron spectra with HADES upgrade

Preparations under way...





Silicon pixel micro-vertex detector