Open Charm

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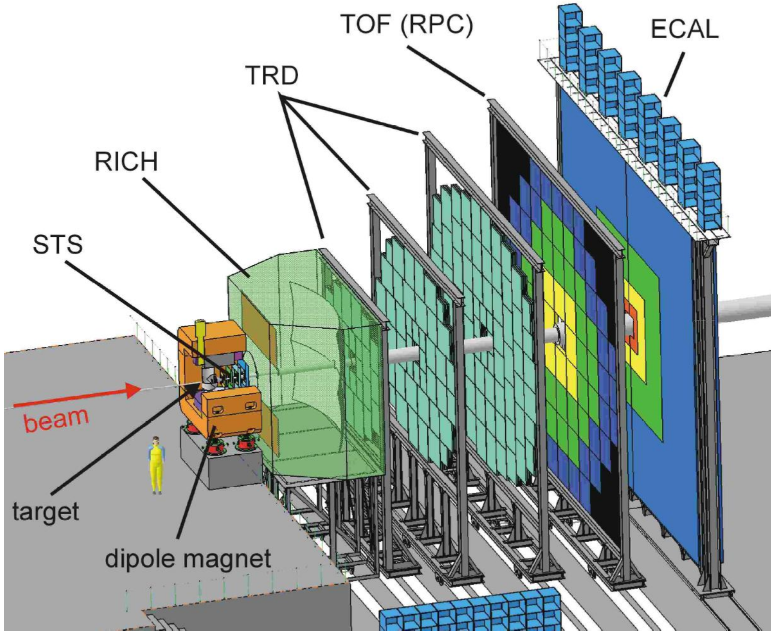
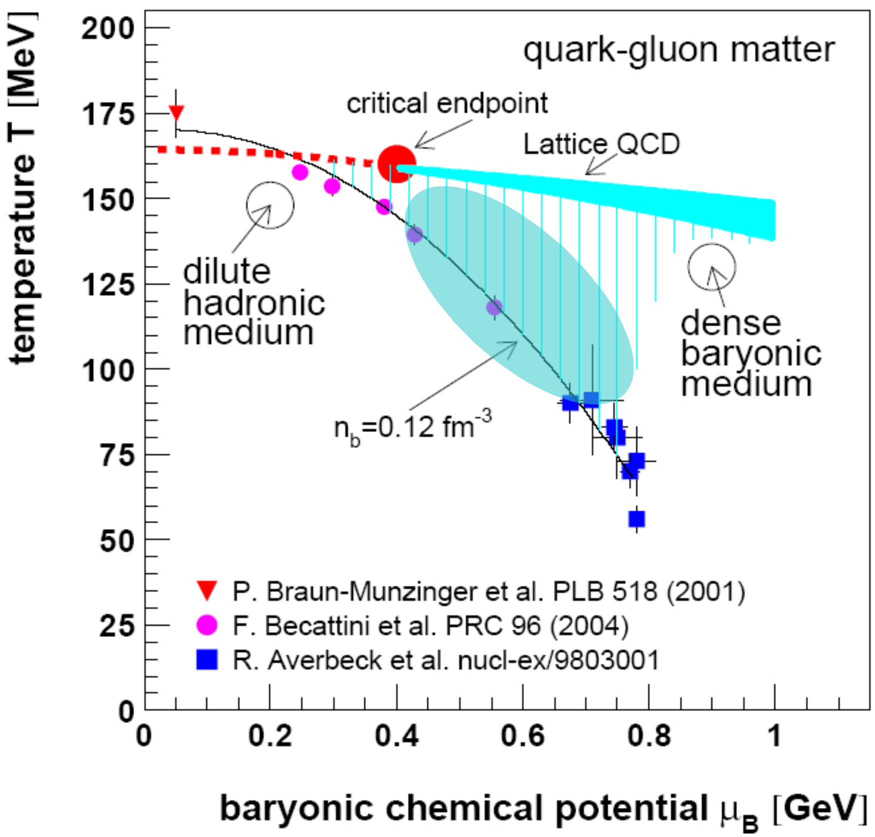


OUTLINE

- Motivations :
  - Dense hadronic matter and heavy-ion collisions
  - Charm
- Charm measurements (NA50)
- CBM at FAIR
- Summary

Heavy-Ion collisions at intermediate energies



Lattice QCD calculations predict a critical point :

- high μ_B : 1st order phase transition from baryonic medium to QGP
- low μ_B : continuous transition

Measurements (SIS, AGS, SPS and RHIC) of chemical freeze-out

-Reproduced by thermal models

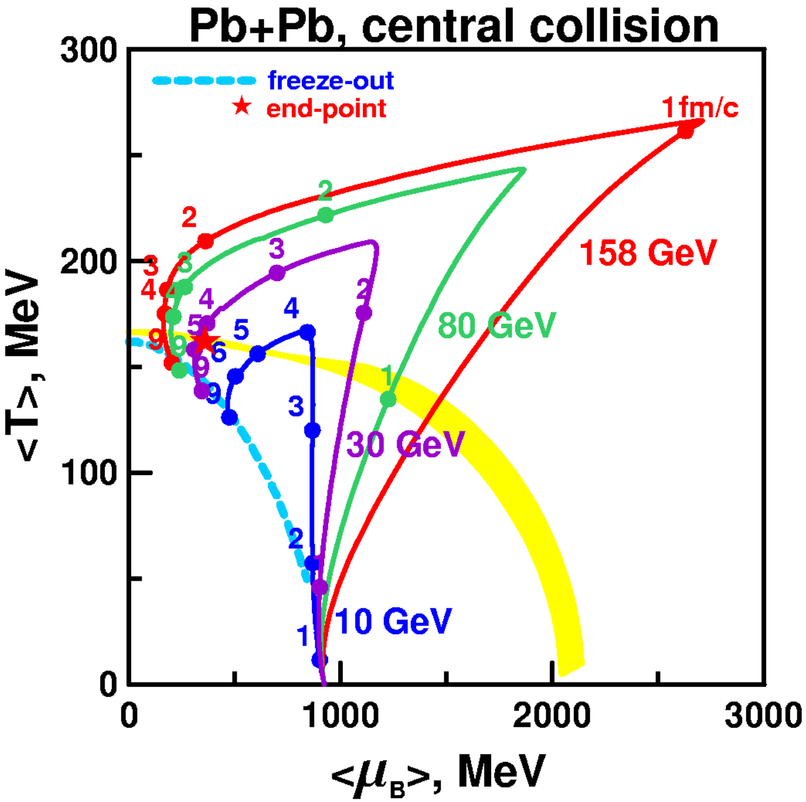
Beam energies 10 – 45 AGeV give access to:

- highest baryon densities

(Au+Au@20AGeV at SIS 200 : $\rho \approx 7\rho_0$)

- onset of phase transition (?)
- critical point (?)

Trajectories in the QCD phase diagram



V.Toneev et al., nucl-th/0309008

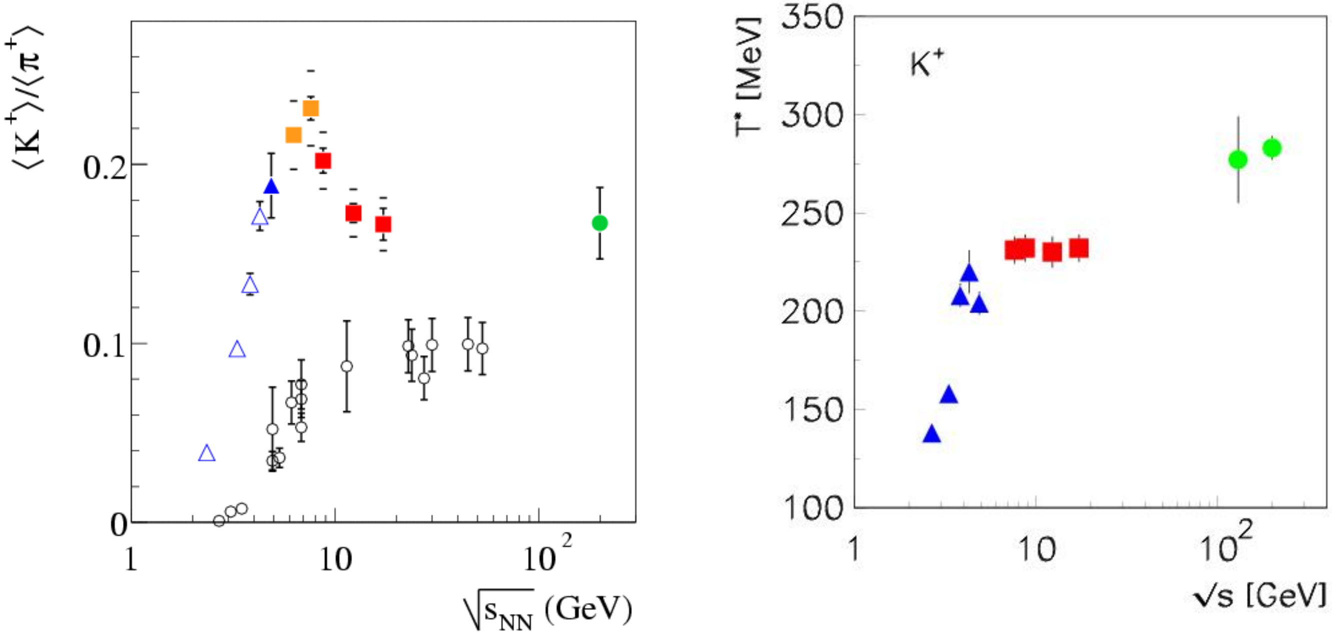
3 fluid hydro calculation with hadron gas EOS

phase boundary reached already at 10 AGeV

predicts 30 AGeV to hit critical point

Indications for onset of deconfinement at low SPS energies

NA49 (QM 2004)



•Peak in strange/nonstrange yield ratio
•Plateau of kaon slopes at SPS
→not satisfactorily explained in hadronic scenarios
Change of baryochemical potential ? Or Phase transition ?
→Can be modeled assuming 1st order phase transition

Charm

- Quark masses (MeV):
  - u ≈ 1-5
  - d ≈ 5-10
  - s ≈ 80-150
  - c ≈ 1000-1400
  - b ≈ 4100-4400
  - t ≈ 170000

Charm : “intermediate” mass
Not light (massless), not heavy
Can we apply pQCD (small α_S) for calculations ?

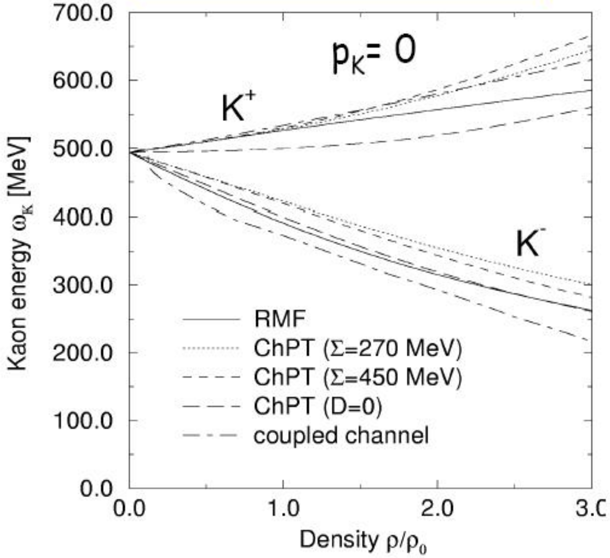
- D^0 ($c\underline{u}$)
  - mass 1864.5 MeV
  - Mean life :

$\tau = 412 \,.10^{-15}$ s

$c\tau = 123.4$ μm

In-Medium Effects

Strange mesons in nuclear matter

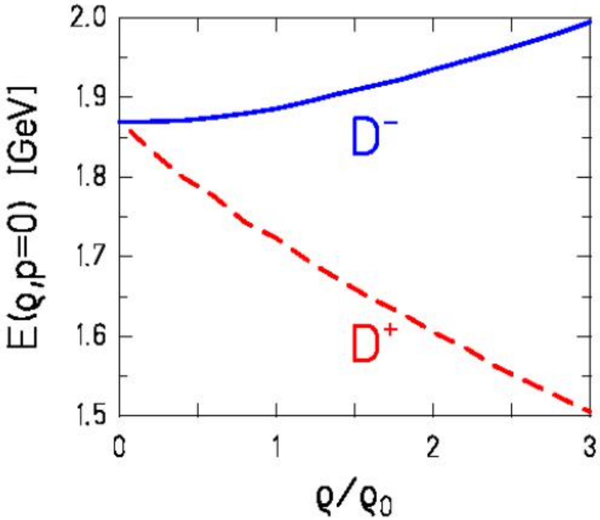


G.E Brown, C.H. Lee, M. Rho, V. Thorsson,
Nucl. Phys. A 567 (1994) 937

T. Waas, N. Kaiser, W. Weise,
Phys. Lett. B 379 (1996) 34

J. Schaffner-Bielich,
J. Bondorf, I. Mishustin ,
Nucl. Phys. A 625 (1997)

Charmed mesons in nuclear matter



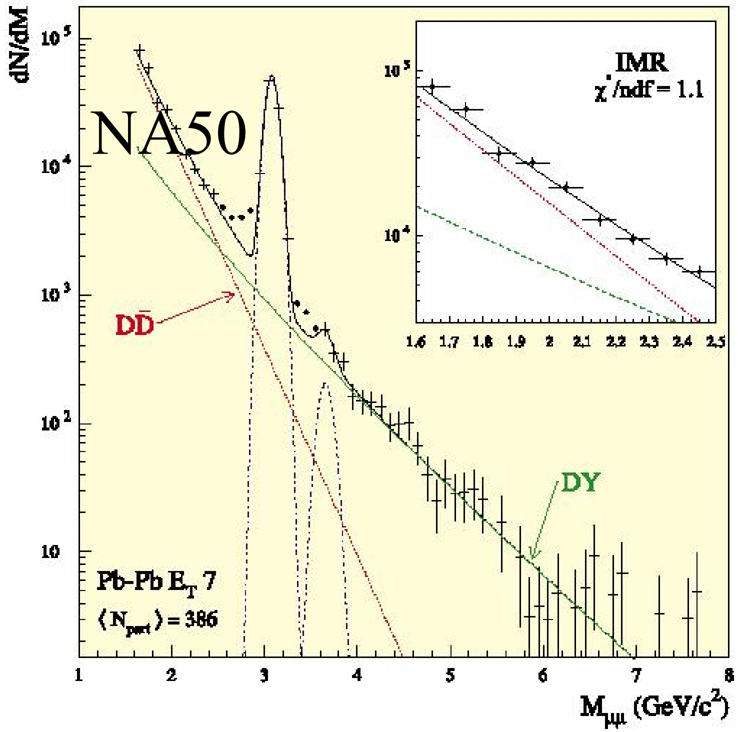
A. Sibirtsev, K. Tsushima,
A.W. Thomas,
Eur. Phys. J. A 6 (1999) 351

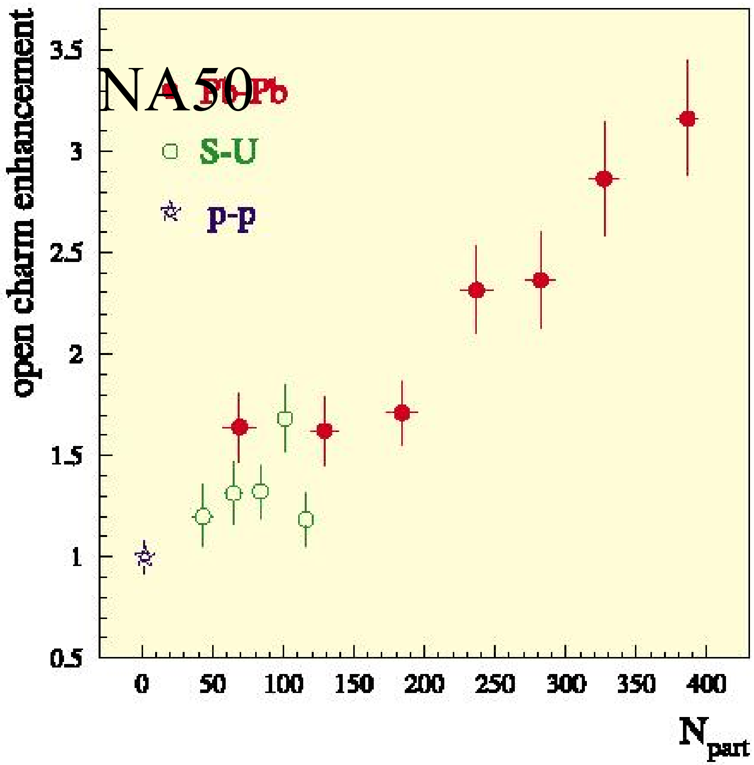
D meson masses are expected to drop in dense environment

should have strong effect on production yield

Medium effects best studied near threshold

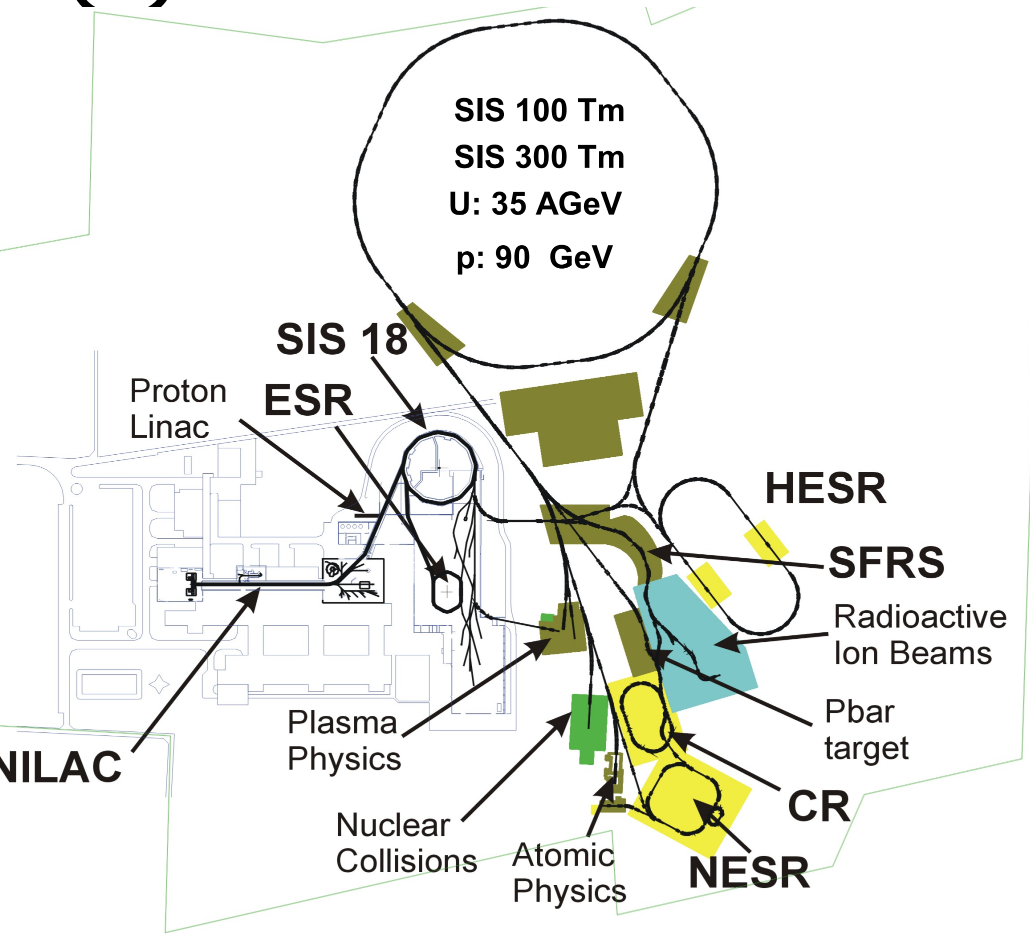
Open Charm enhancement (?) at SPS Pb+Pb





- NA50 measured di-muon distribution in 1.5<M<2.5 GeV.
- The mass distribution is well reproduced by DD pairs + Drell-Yan components in p+A (@450GeV) with charm cross section σ_{cc}/A = 36.2±9.1 μb, consistent with charm cross sections of other experiments
- In Pb+Pb, an excess of dimuon signal is observed. The excess can be explained by enhancement of charm production by factor of ~3 in central Pb+Pb.

FAIR @ GSI



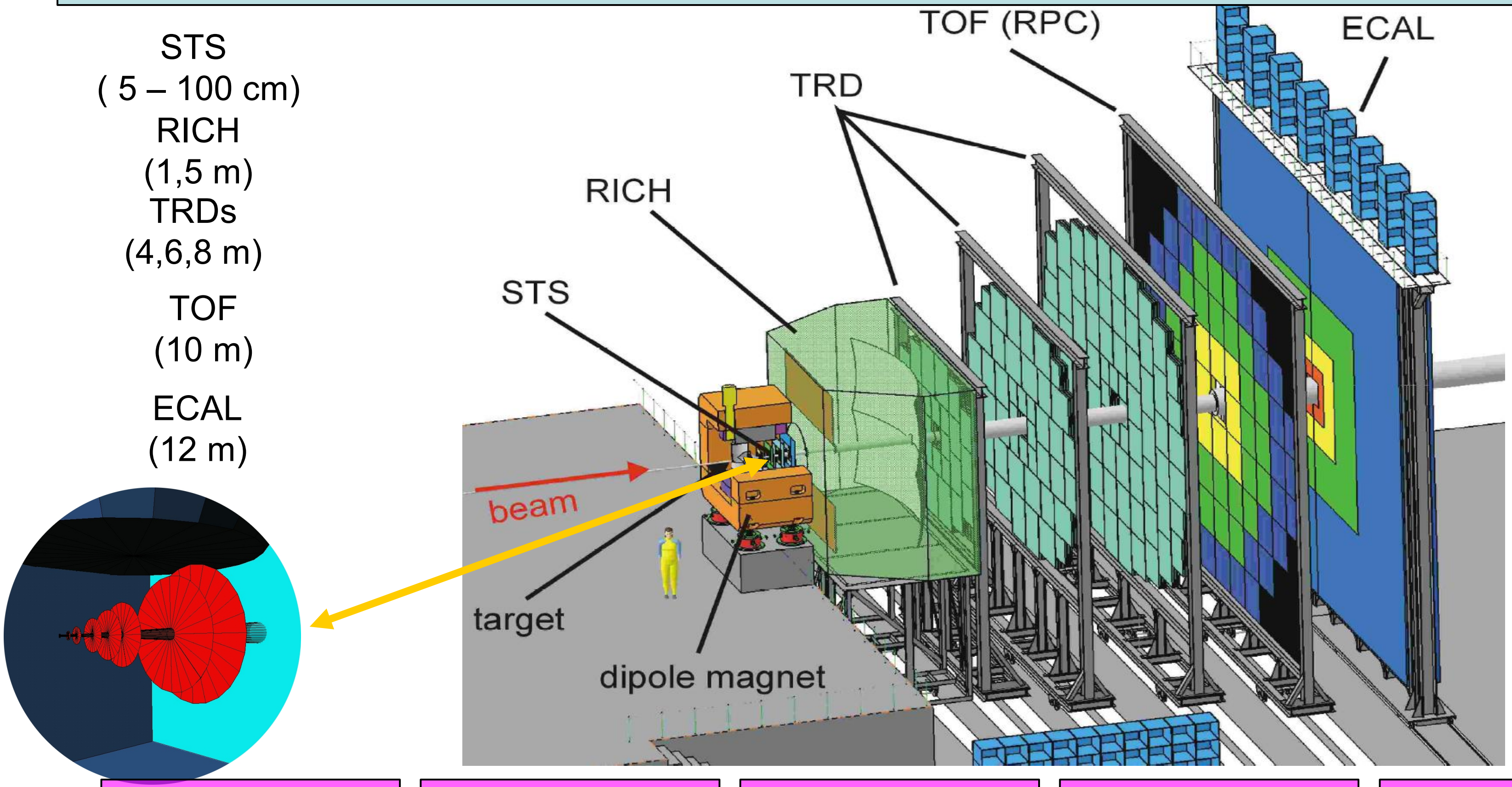
Facility for Antiproton and Ion Research

Experiments :

- CBM (Compressed Baryonic Matter)
- PANDA (Proton ANtiproton DArmstadt)
- The SuperFRS Project
- NUSTAR – International Nuclear Structure and Astrophysics Community
- SPARC – Stored Particles Atomic Physics Research Collaboration
- The FLAIR (Facility for Low-Energy Antiproton and heavy-Ion Research)
- ELISe – ELectron-Ion Scattering in a Storage Ring (eA collider)

CBM@FAIR
Baseline detector concept

STS
(5 – 100 cm)
RICH
(1,5 m)
TRDs
(4,6,8 m)
TOF
(10 m)
ECAL
(12 m)



STS tracking, displaced vertices	**RICH** electron ID	**TRD** electron ID	**TOF** hadron ID	**ECAL** lepton ID photons

The physics of CBM

?

!

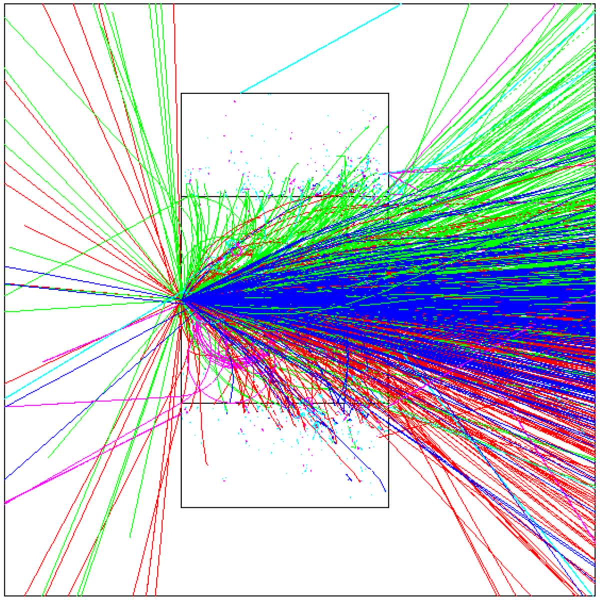
deconfinement at high ρ_B → strangeness (K, Λ, Σ, Ξ, Ω)
charm (J/ψ, D)
flow

in-medium properties of hadrons → ρ, ω, $\varphi \rightarrow e^+e^-$
open charm

critical point → fluctuations

Au+Au@25AGeV

- Total 800-1000 part/event
  - 328 π^+
  - 357 π^-
  - 161 P
  - 41 K^+
  - 13 K^-
  - 9 Σ^-
  - 8 Σ^+
  - D^0 yield predicted by HSD model :



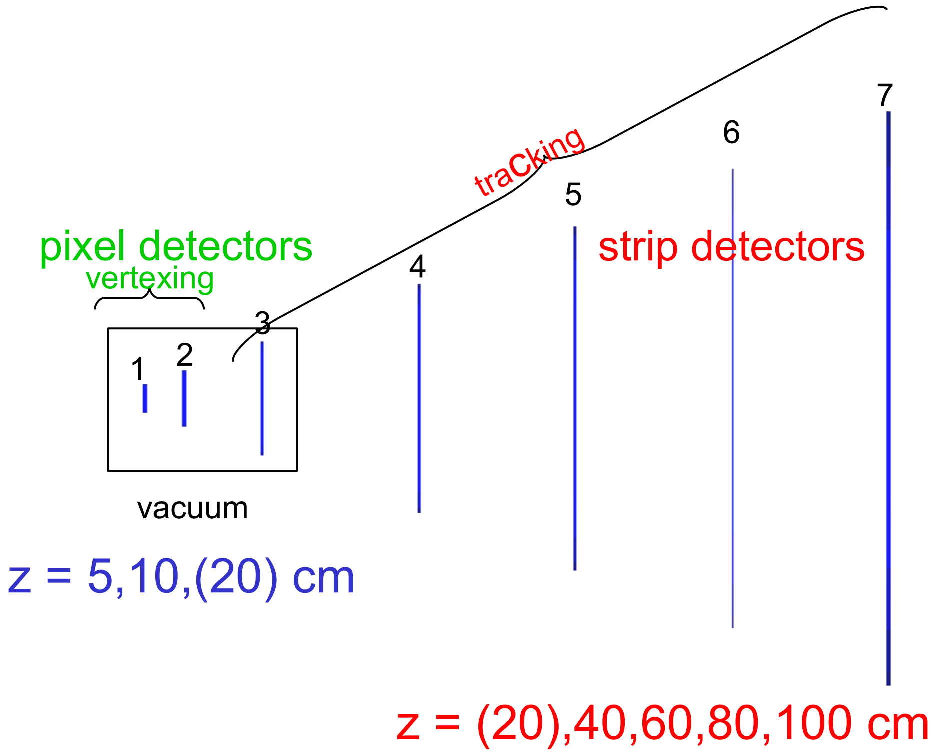
1.2-1.4 .**10^{-4}**/central event : rare probe

($D^0 \rightarrow K^- + \pi^+$ branching ratio 3.8%)

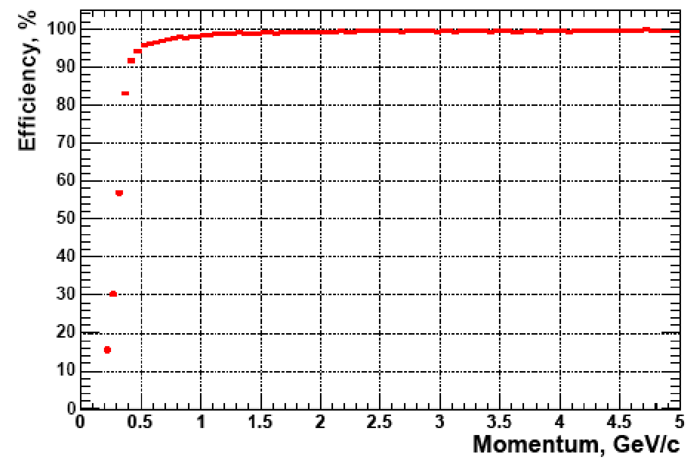
$\rightarrow$ Need high beam (interaction) rate :

10^9 ion/s (10^7 reaction/s with 1% target)

The Silicon Tracking System

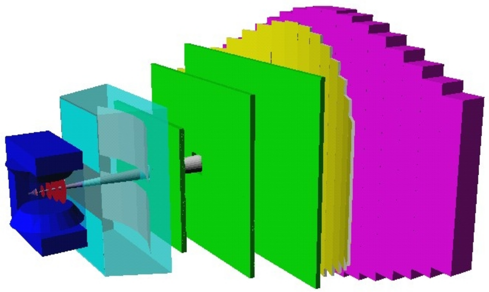


"minimal setup":
3 pixel stations
4 strip stations



momentum resolution < 1 %

Requirements
- Operation in mag field
- Close to target
- Radiation hardness
- High granularity
- Minimal thickness

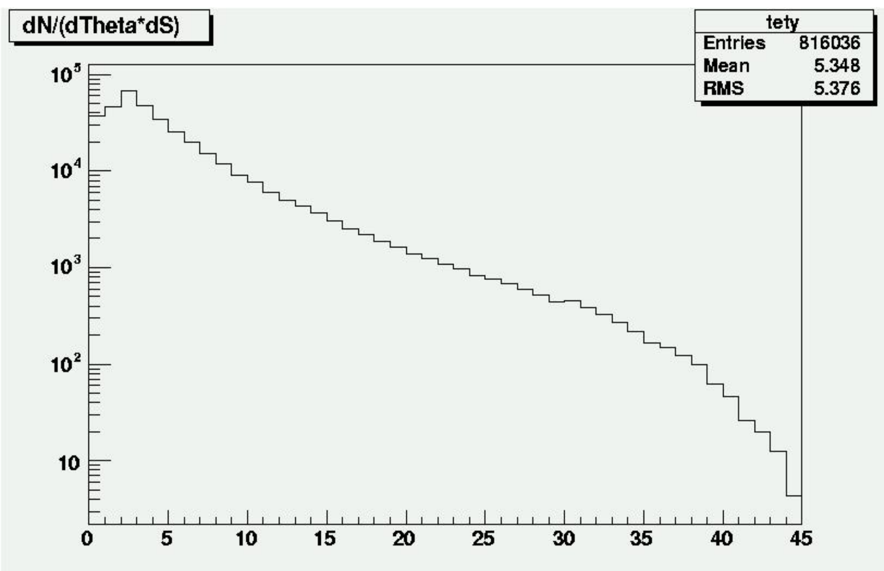


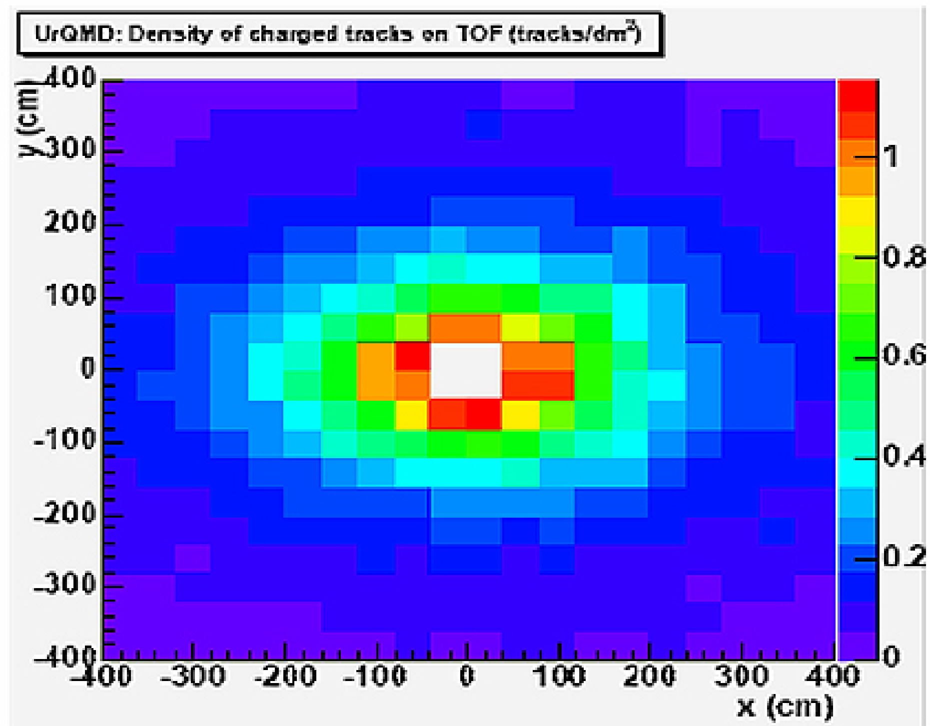
CBM-TOF

- Interaction rate **10^7Hz (~1000 tracks /event)**
- TOF wall at 10m from target from 3º to 27º
- Rate from 1kHz/cm^2 (27º) to 20kHz/cm^2 (3º)
  - Hit density from **6.10^{-2}/dm^2** to **1/dm^2** , more than **60000 cells** to have occupancy below 5%
  - **Total area >60m^2**

PID : mass resolution

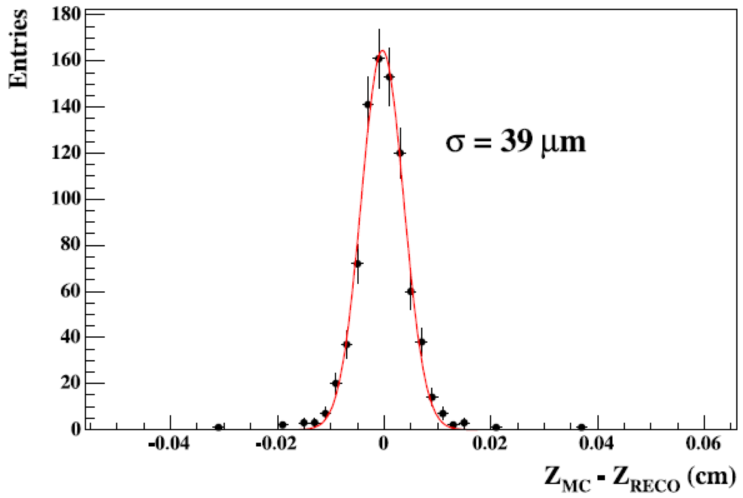
$\sigma_m^2 \approx p^2 \sigma_t / \beta^2 t$





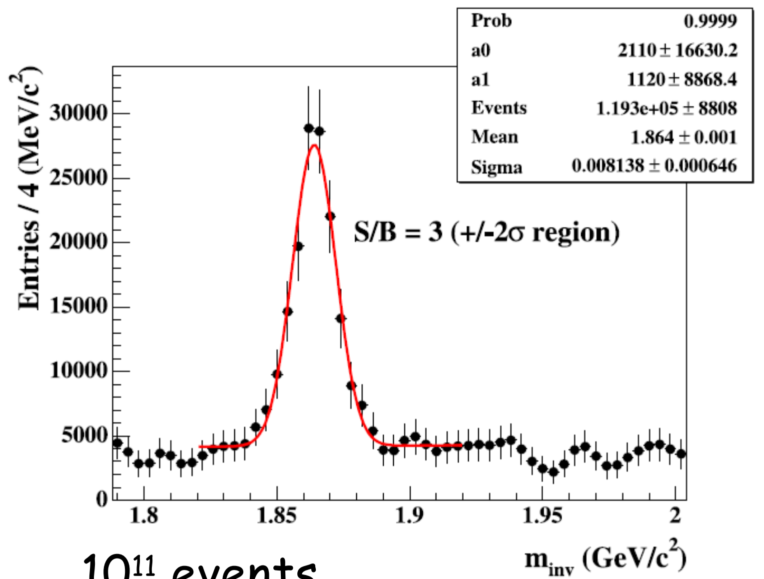
Detector performance: D mesons

Displaced vertex resolution



Simulation: STS only (no PID) with MAPS

Challenge: Implementation of secondary vertex cut in online event selection (reduction ≈ 1000 needed)



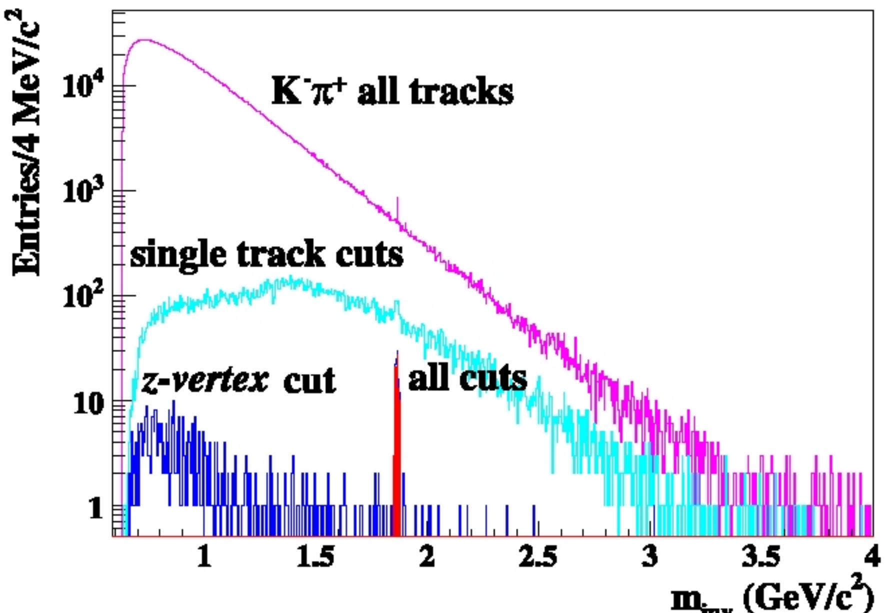
10^{11} events

Simulation Status

Results with tracking only :
This spectrum corresponds to 10^{12} minimum bias interactions (≈ 4 months of data taking at 0.1 MHz interaction rate)

- All tracks : Perfect PID
- Single track cuts : χ^2 distance to the primary vertex, p-cut, pt-cut
- z-vertex cut (250 μm)
- All cuts : D^0 pointing cut, geometrical vertex χ^2 cut

→ 104 events (8.5% efficiency)

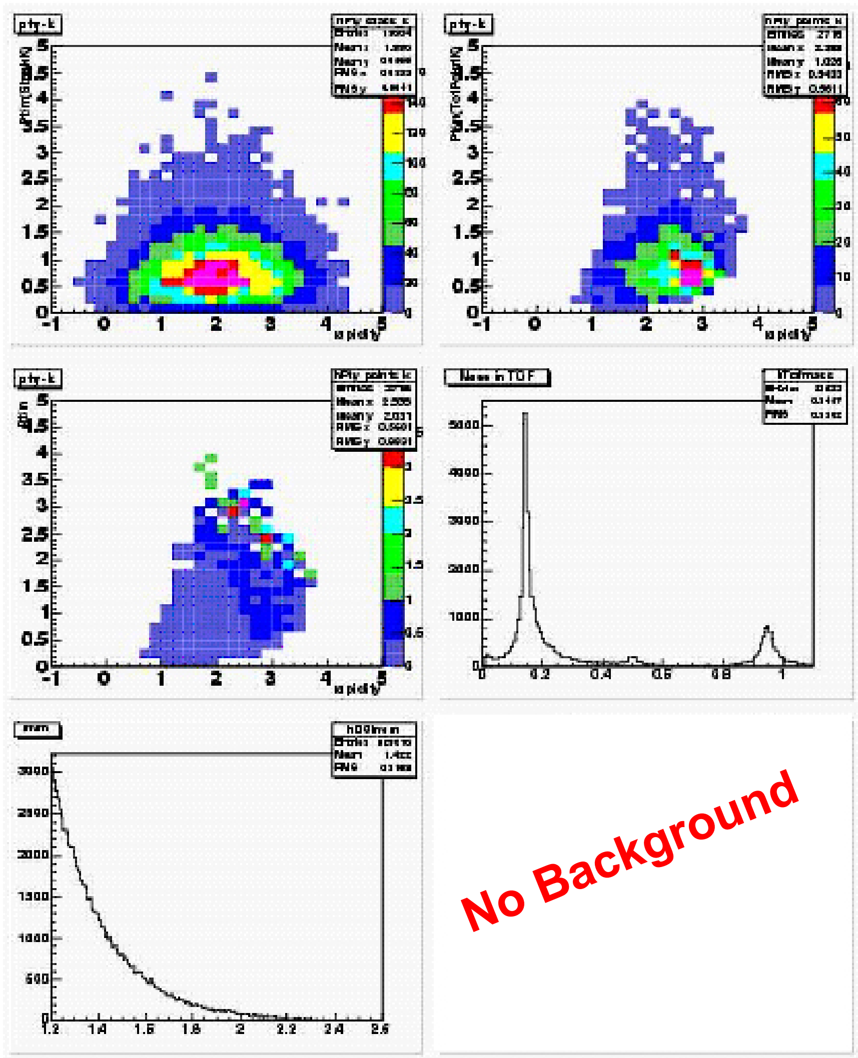


Gorbunov, Kisel and Vassiliev

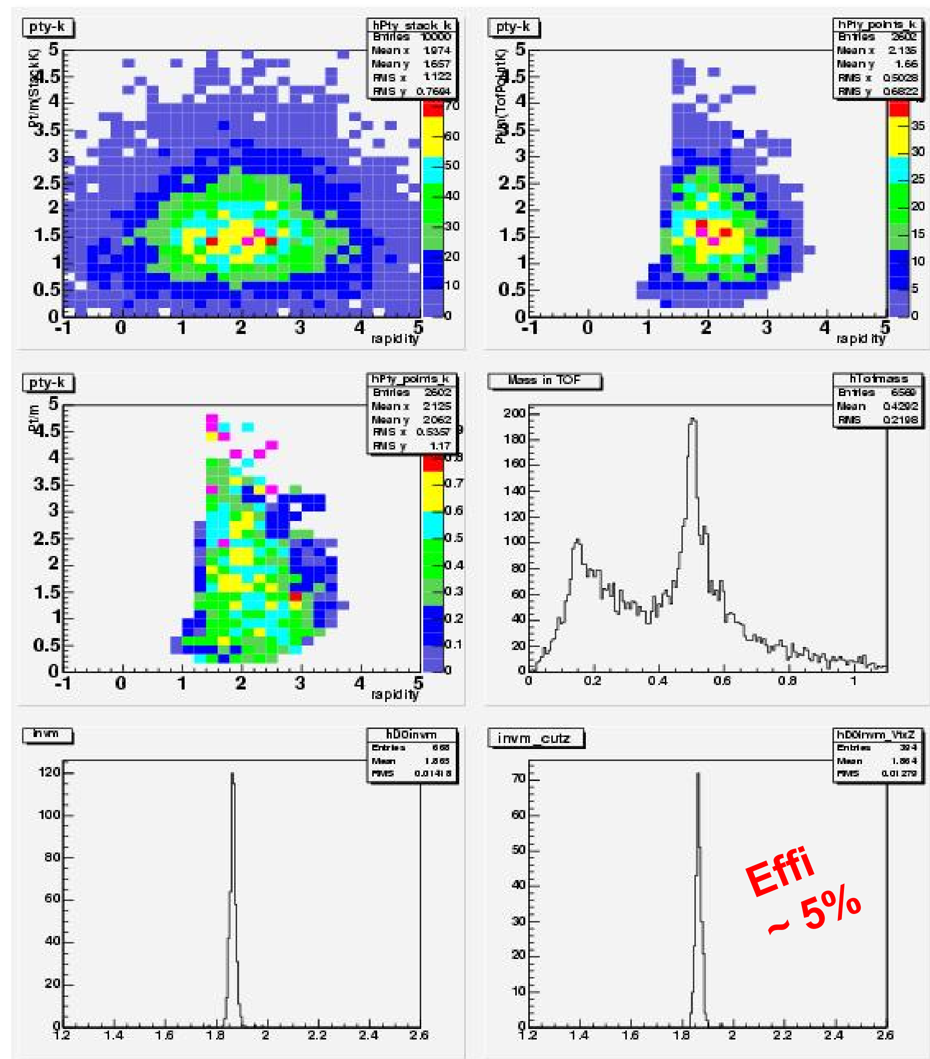
Everard Cordier

D0 Reconstruction

Urqmd (Au+Au@25AGeV)



Ds signal (0°< θ < 30°)

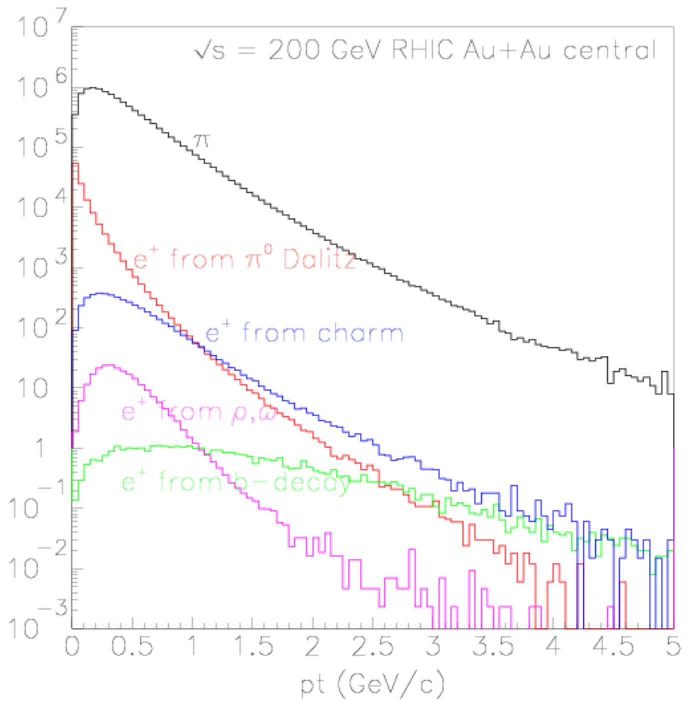


Summary

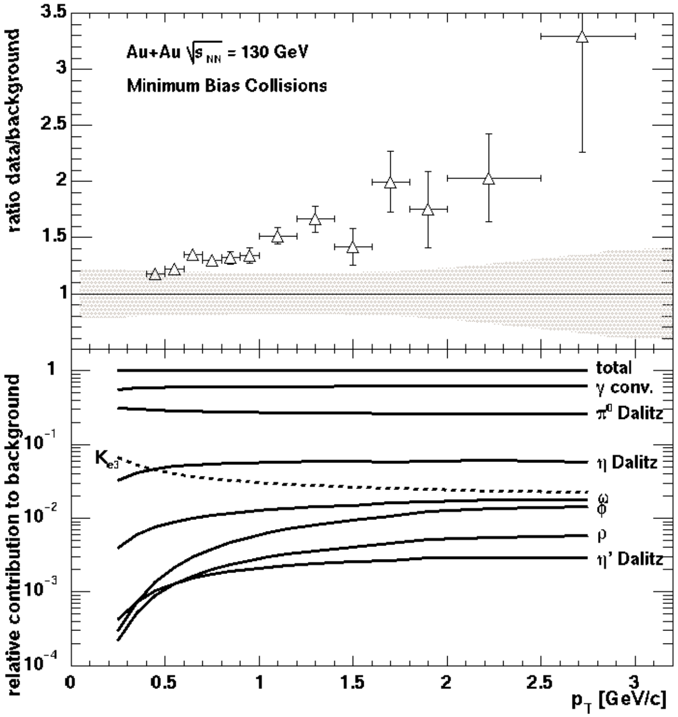
- Heavy-ion collisions can reach new states of matter (QGP?)
- Charm is an important probe to study the modifications in the medium, the phase transition and the critical point
- NA50 measured an open charm enhancement (?) by a factor 3
- Open charm production near threshold can be measured in CBM

Charm and single electron at RHIC

Simulation before RHIC



PHENIX data (PRL88)



- At RHIC, it is expected that charm decay can be the dominant component of single electron in pt > 1.5 GeV/c
  - Large production cross section of charm (300-600 ub)
  - Production of the high pt pions is strongly suppressed relative to binary scaling
  - Production of charm quark roughly scale with binary collisions.
- PHENIX observed "excess" in single electron yield over expectation from light meson decays and photon conversions → Observation of charm signal at RHIC