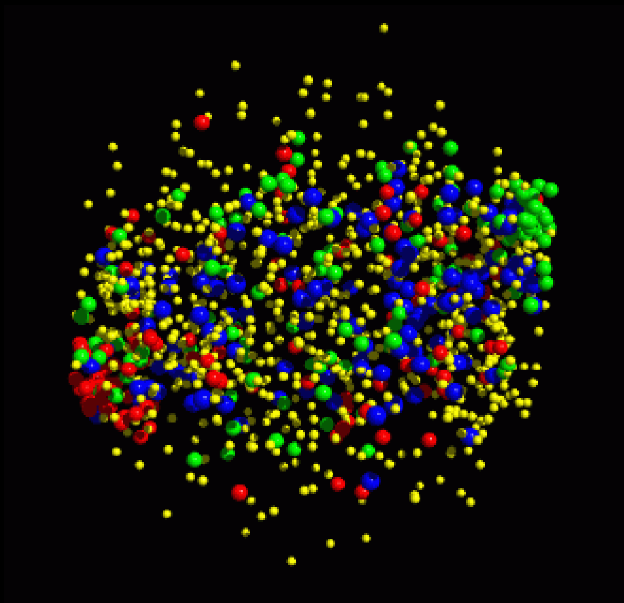
The CBM experiment at FAIR

Peter Senger (GSI)



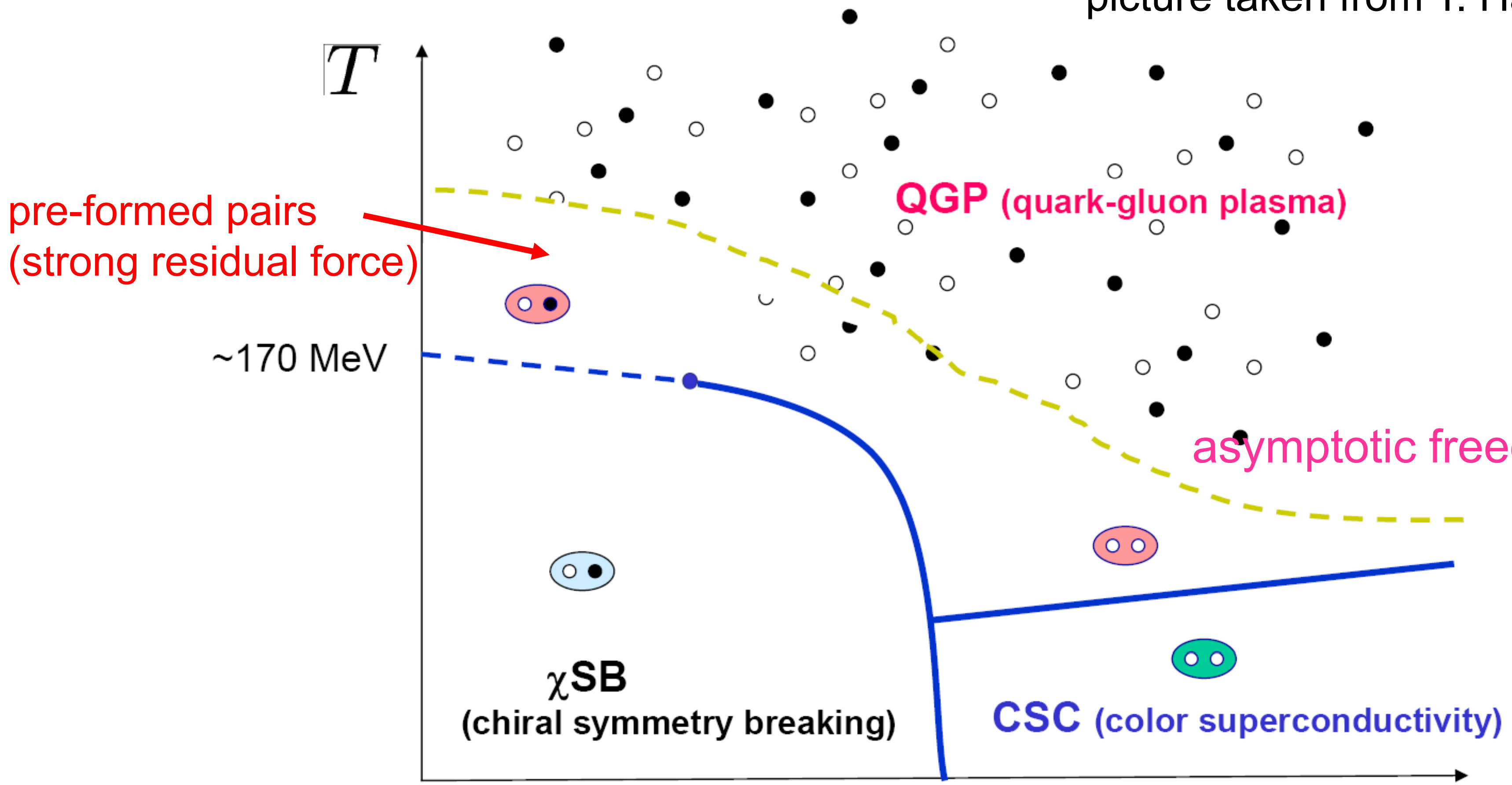
Outline:

- The CBM physics program
- The CBM setup
- Feasibility studies and Detector R&D

VISIM workshop, Bad Liebenzell, September 12 – 15, 2007

Phases of QCD

picture taken from T. Hatsuda



RHIC, LHC: cross over transition, QGP at high T and low ρ

Low-energy RHIC: search for QCD-CP with bulk observables

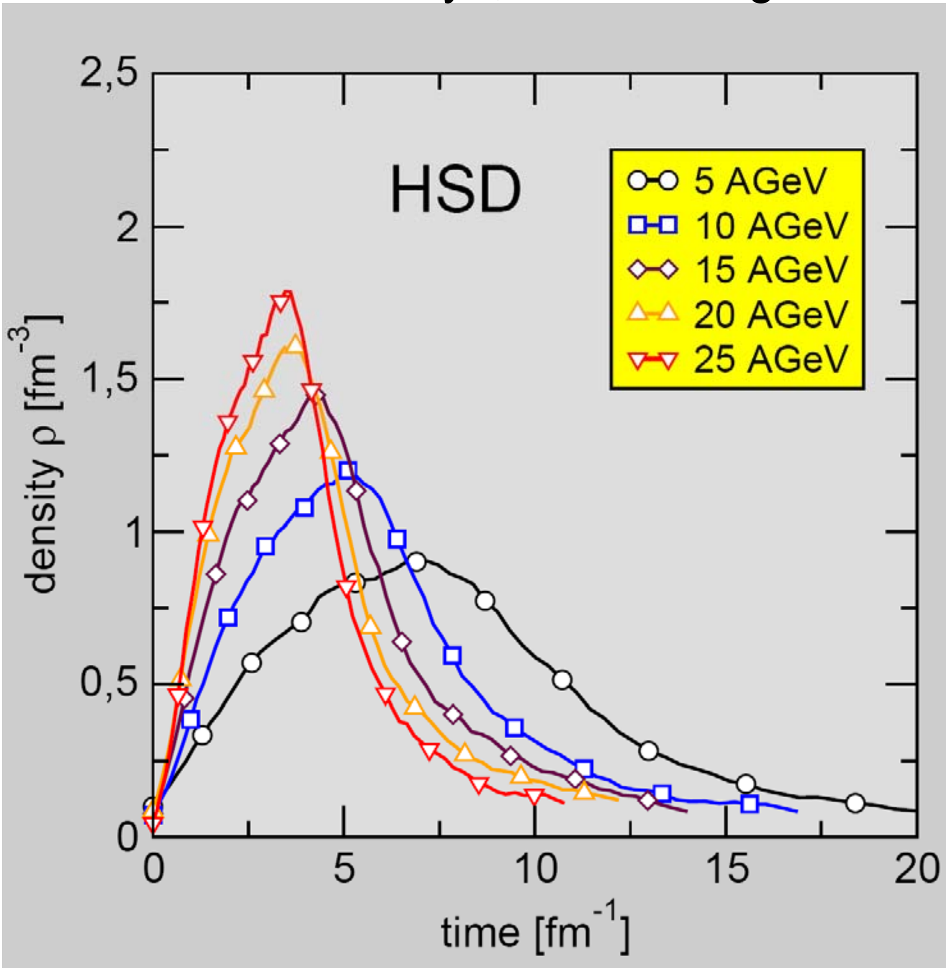
NA61@SPS: scan of phase diagram with bulk observables

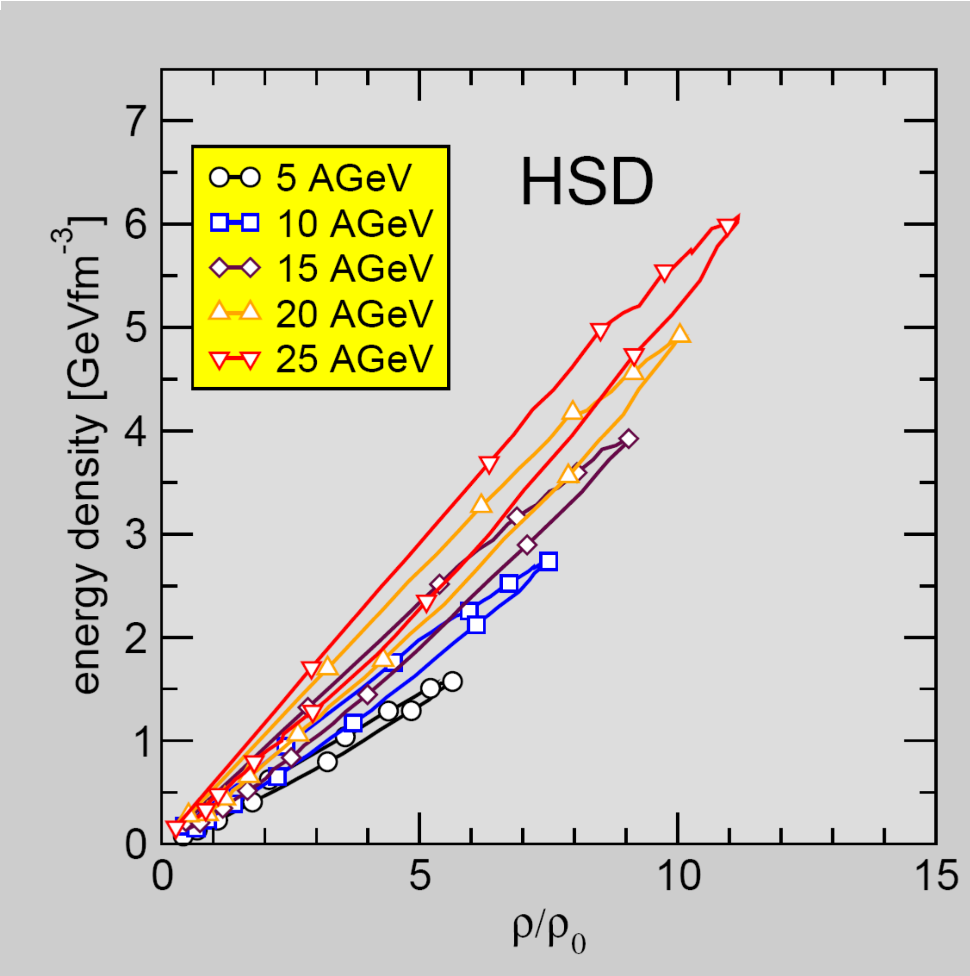
CBM@FAIR: comprehensive research program incl. rare probes

Baryon and energy densities at FAIR energies

Baryon/energy density in central cell (Au+Au, b=0 fm):
Transport code HSD: mean field, hadrons + resonances + strings

E. Bratkovskaya, W. Cassing

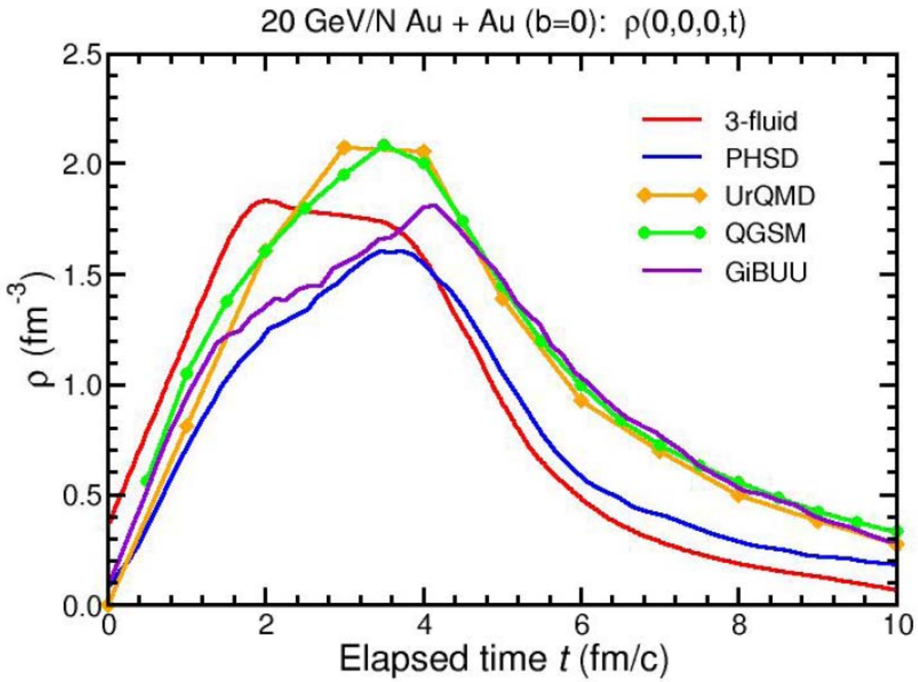




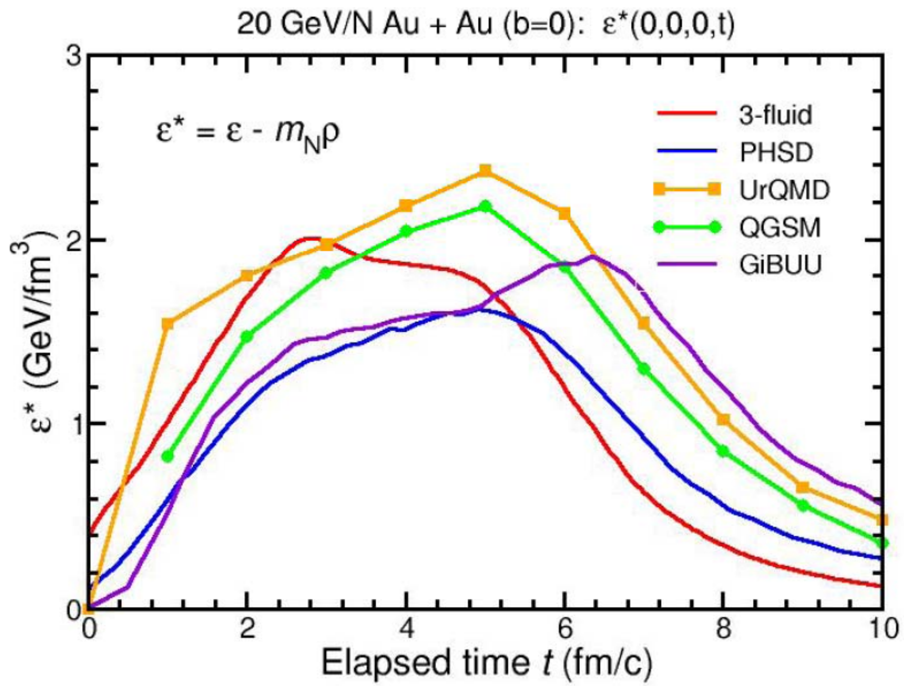
Densities from transport models: consistent picture

Compilation by J. Randrup, CBM Physics Book, in preparation
see also I.C. Arsene et al., Phys. Rev. C 75 (2007) 034902

net baryon density

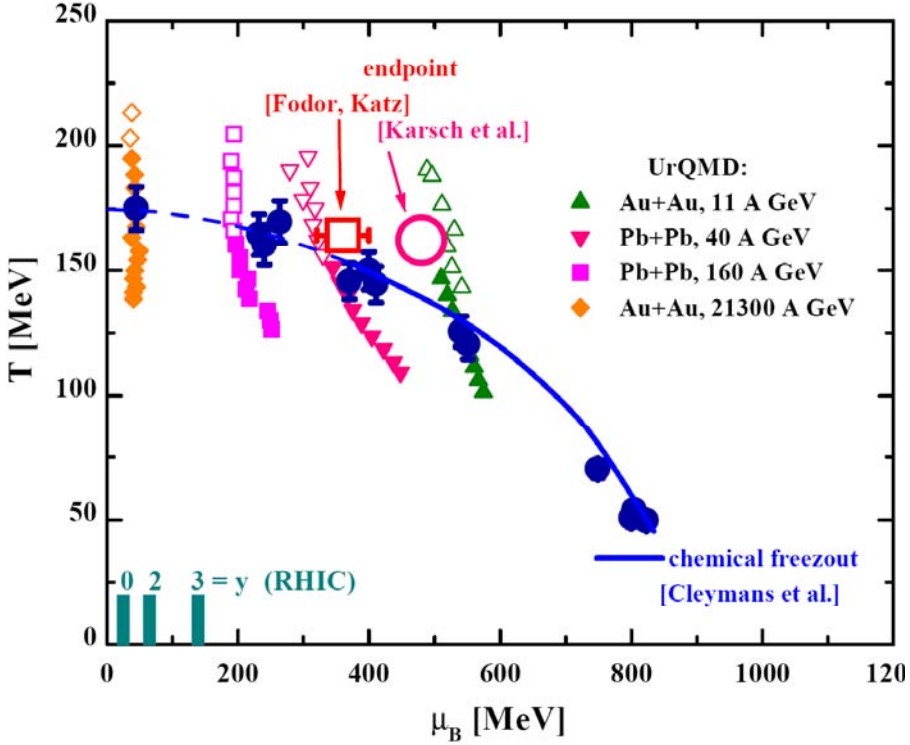


net energy density

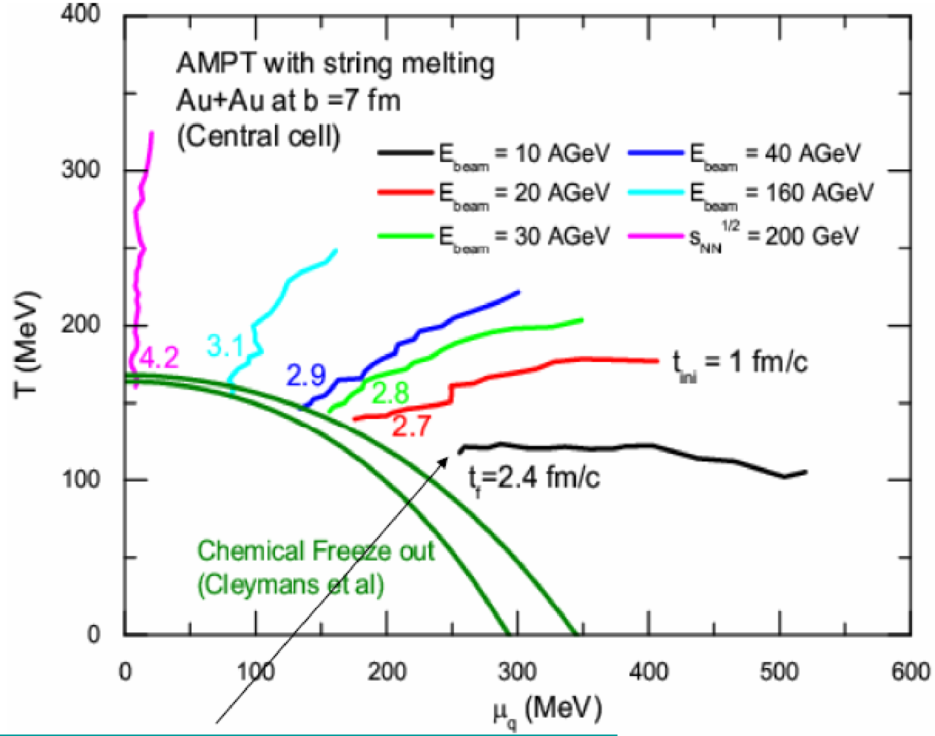


Trajectories from Transport models

UrQMD: H. Stöcker nucl-th/0506013

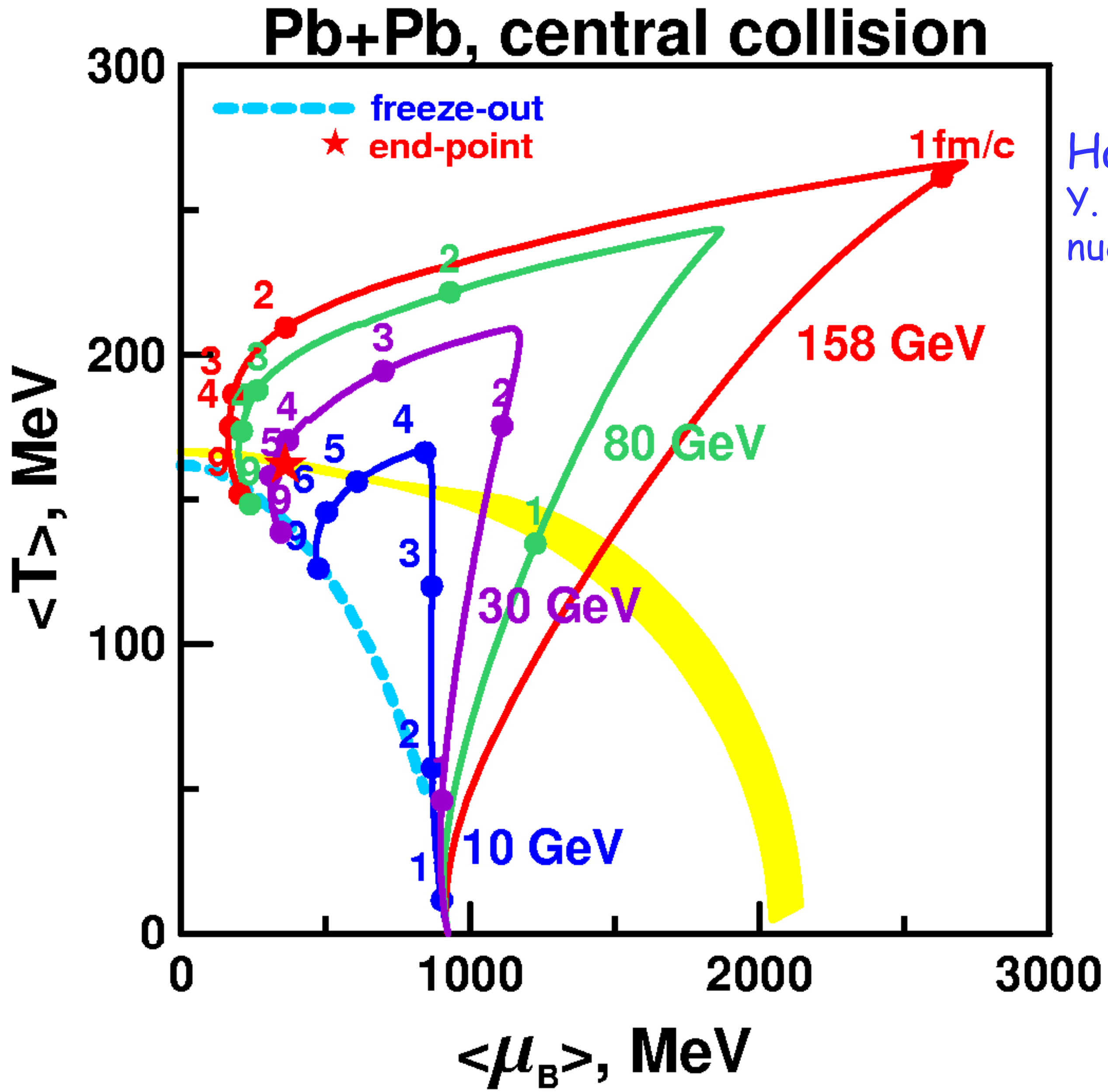


AMPT: C.M. Ko at CPOD 2007



Require first-order phase transition ?

"Trajectories" from 3 fluid hydrodynamics



Hadron gas EOS:
Y. Ivanov, V. Russkikh, V.Toneev
nucl-th/0503088

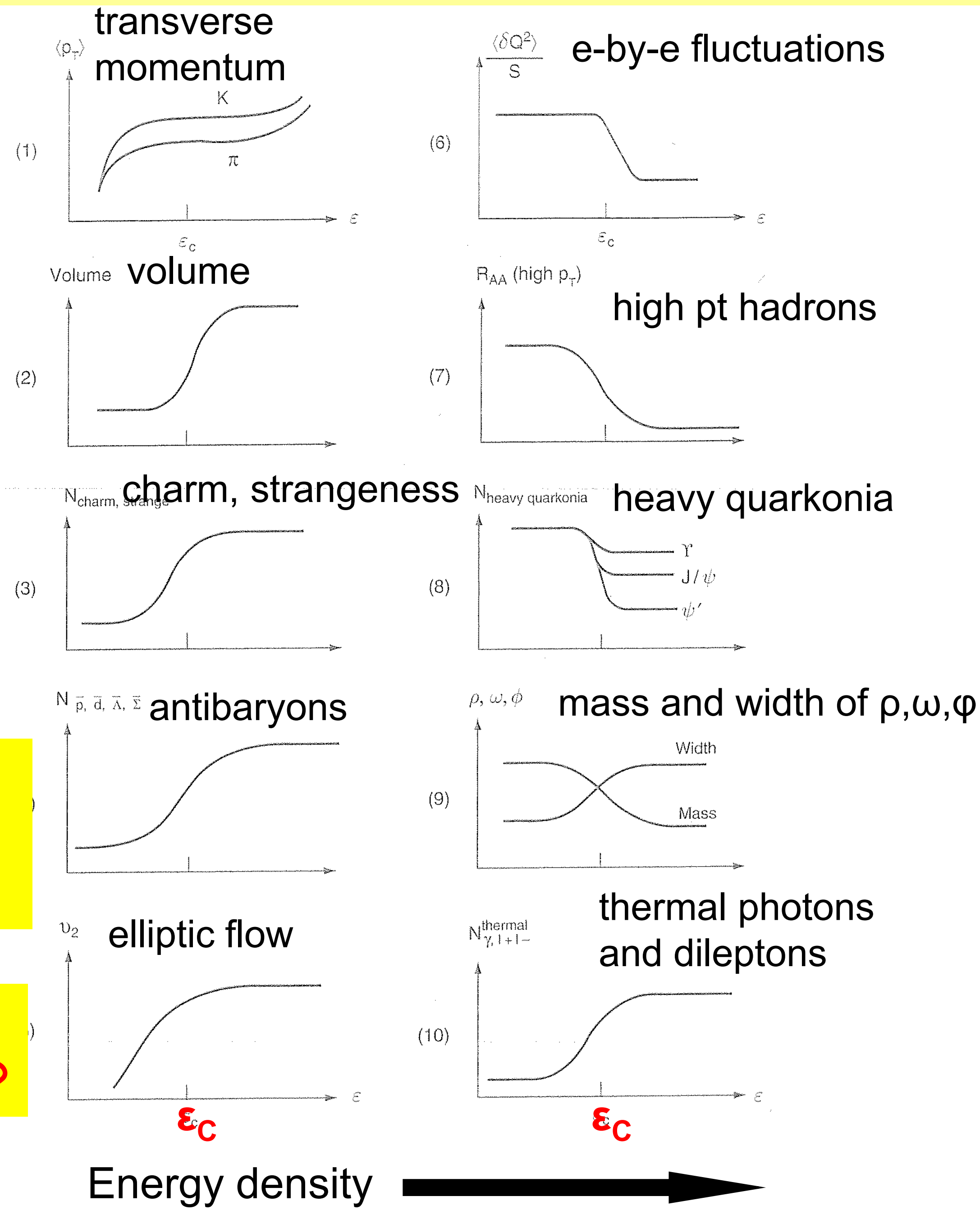
Possible signatures of QGP in heavy-ion collisions

taken from the book:
Quark-Gluon-Plasma:
from big bang to little bang
by
Kohsuke Yagi,
Tetsuo Hatsuda,
Yasuo Miake (2006)

adapted from an original
by Shoji Nagamiya

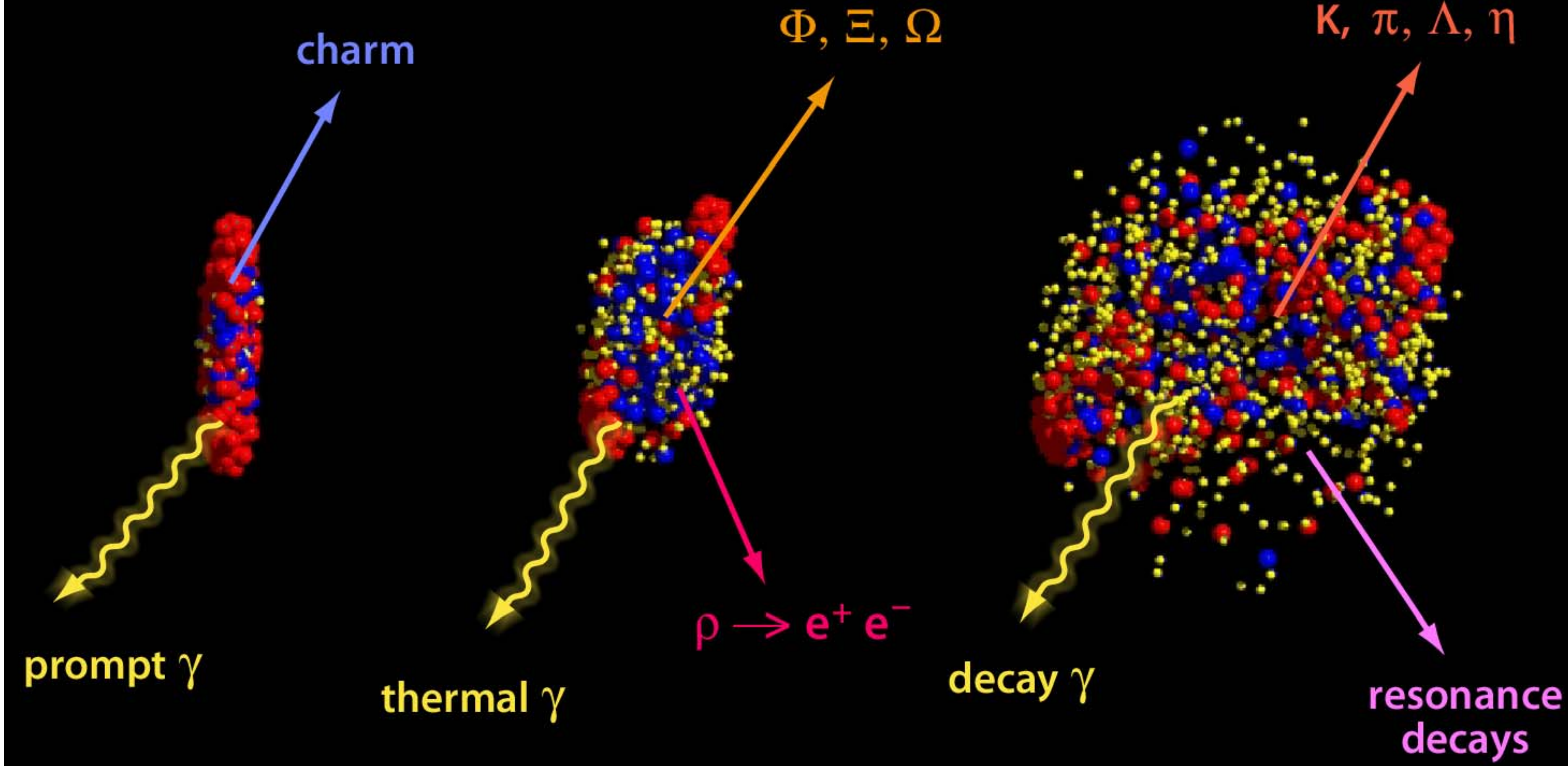
Seach for discontinuities
in excitation functions
of various observables !

How much are the signals
diluted by hadronization ?



Messengers from the dense phase ?

U+U 23 AGeV



Compressed Baryonic Matter: physics topics and observables

The equation-of-state at high ρ_B

- collective flow of hadrons
- particle production at threshold energies (open charm?)

Deconfinement phase transition at high ρ_B

- excitation function and flow of strangeness (K, Λ, Σ, Ξ, Ω)
- excitation function and flow of charm (J/ψ, ψ', D^0, $D^{\pm}$, Λ_c)
- melting of J/ψ and ψ'

QCD critical endpoint

- excitation function of event-by-event fluctuations (K/π,...)

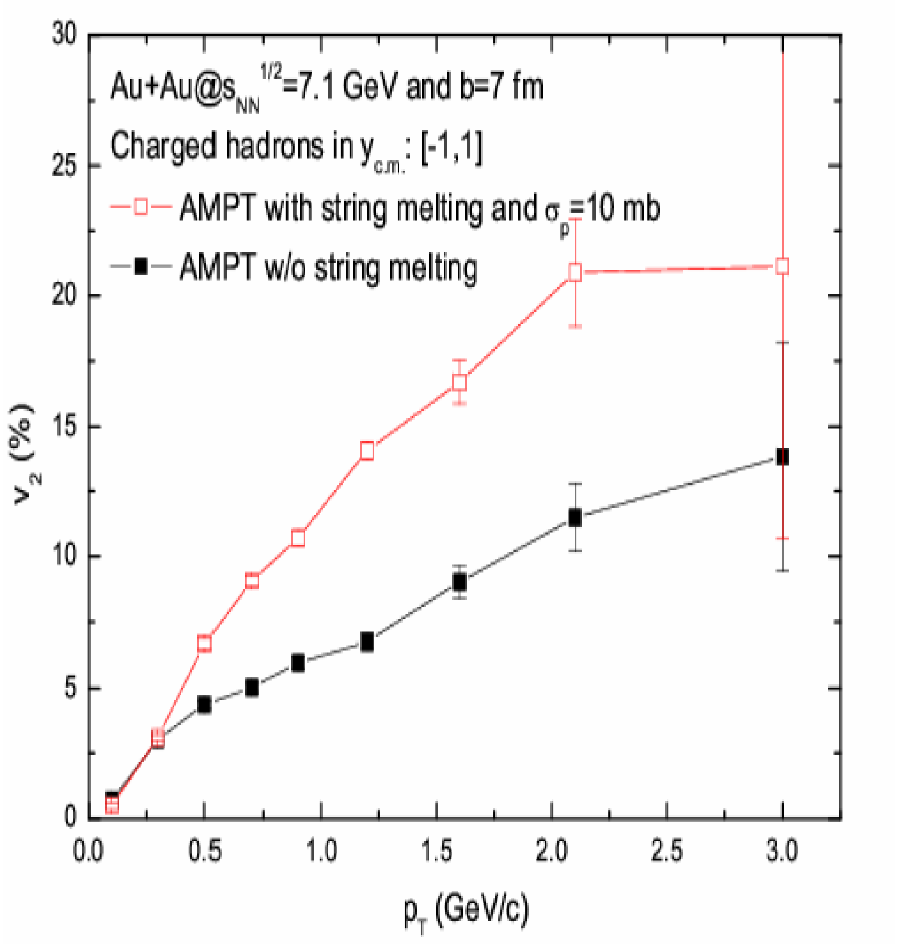
Onset of chiral symmetry restoration at high ρ_B

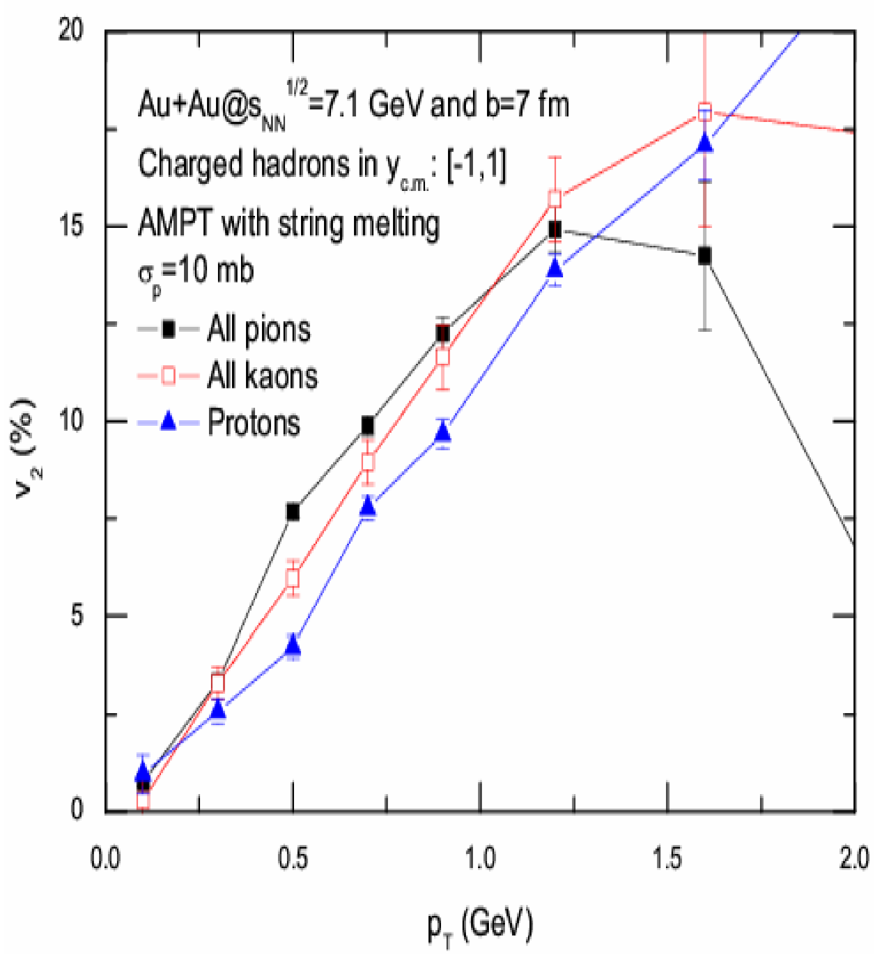
- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$, D)

CBM Physics Book in preparation

Elliptic flow at FAIR

AMPT calculations: C.M. Ko at CPOD 2007



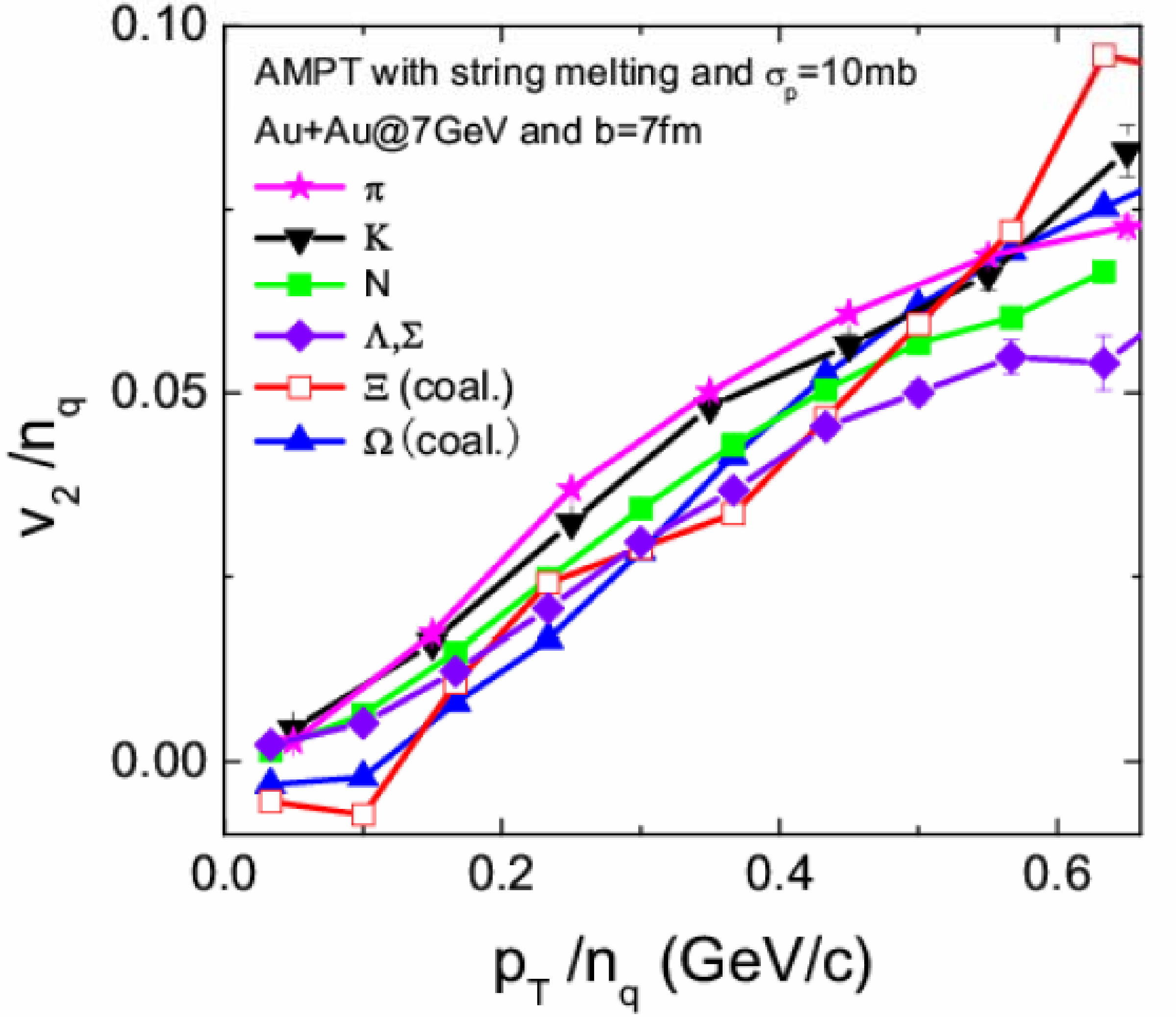


Partonic scattering enhances elliptic flow

Mass ordering of hadron elliptic flows

Scaled hadron elliptic flows at FAIR

AMPT calculations: C.M. Ko at CPOD 2007

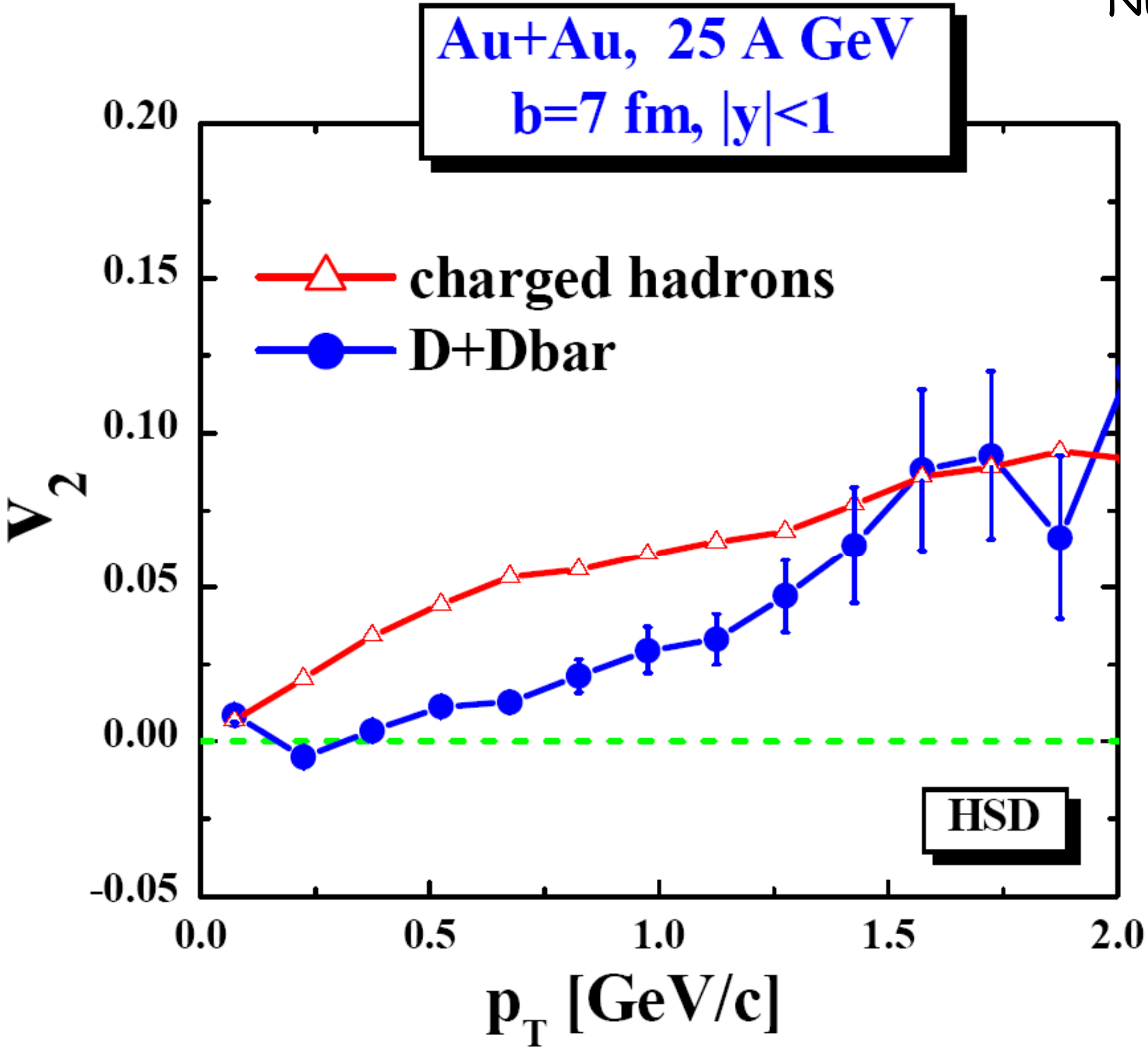


Approximate constituent quark number scaling !

Charmed elliptic flow at FAIR

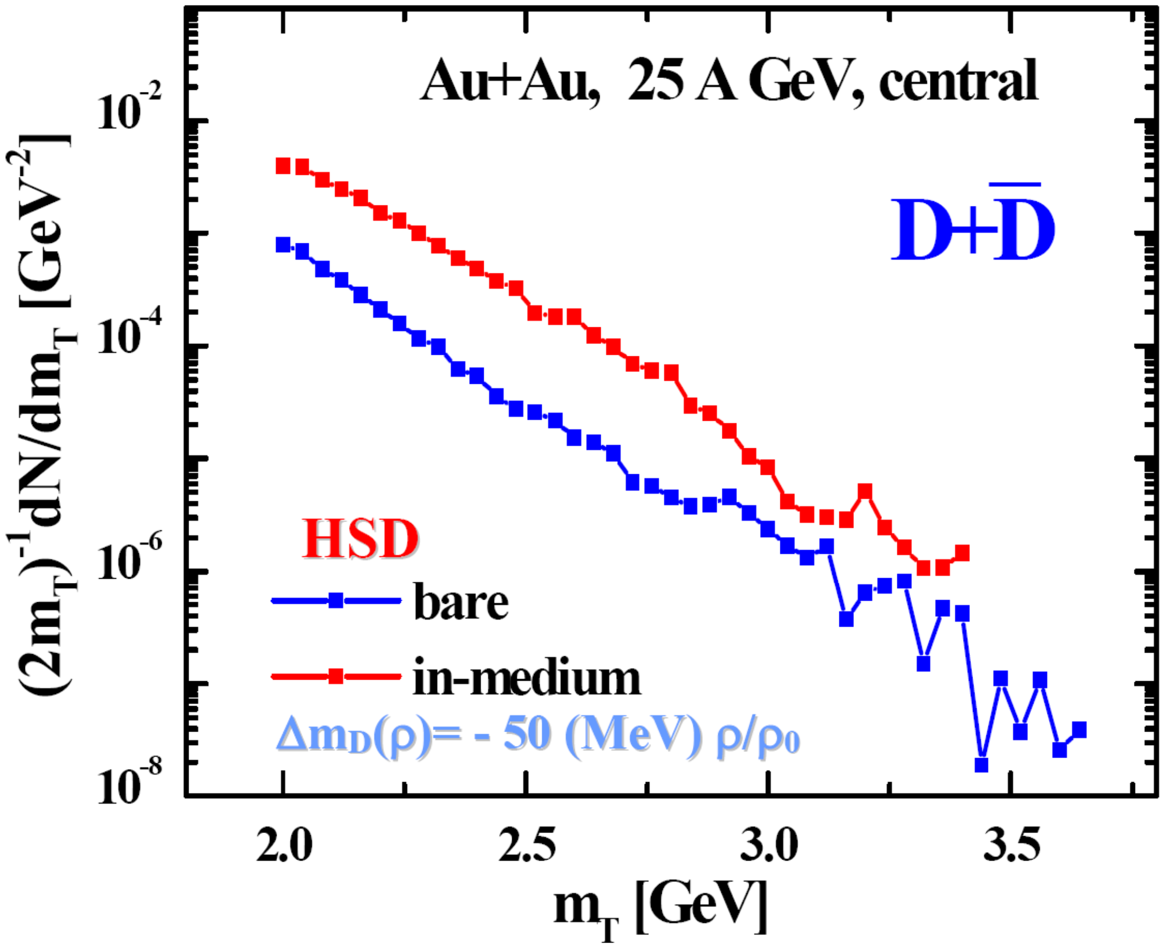
HSD calculations: E. Bratkovskaya at CPOD 2007

see also O. Linnyk, E. Bratkovskaya, W. Cassing, H. Stöcker, Nucl. Phys. A786 (2007) 183



strong initial flow of D and J/ψ due to partonic interactions ?

In-medium modification of D-mesons

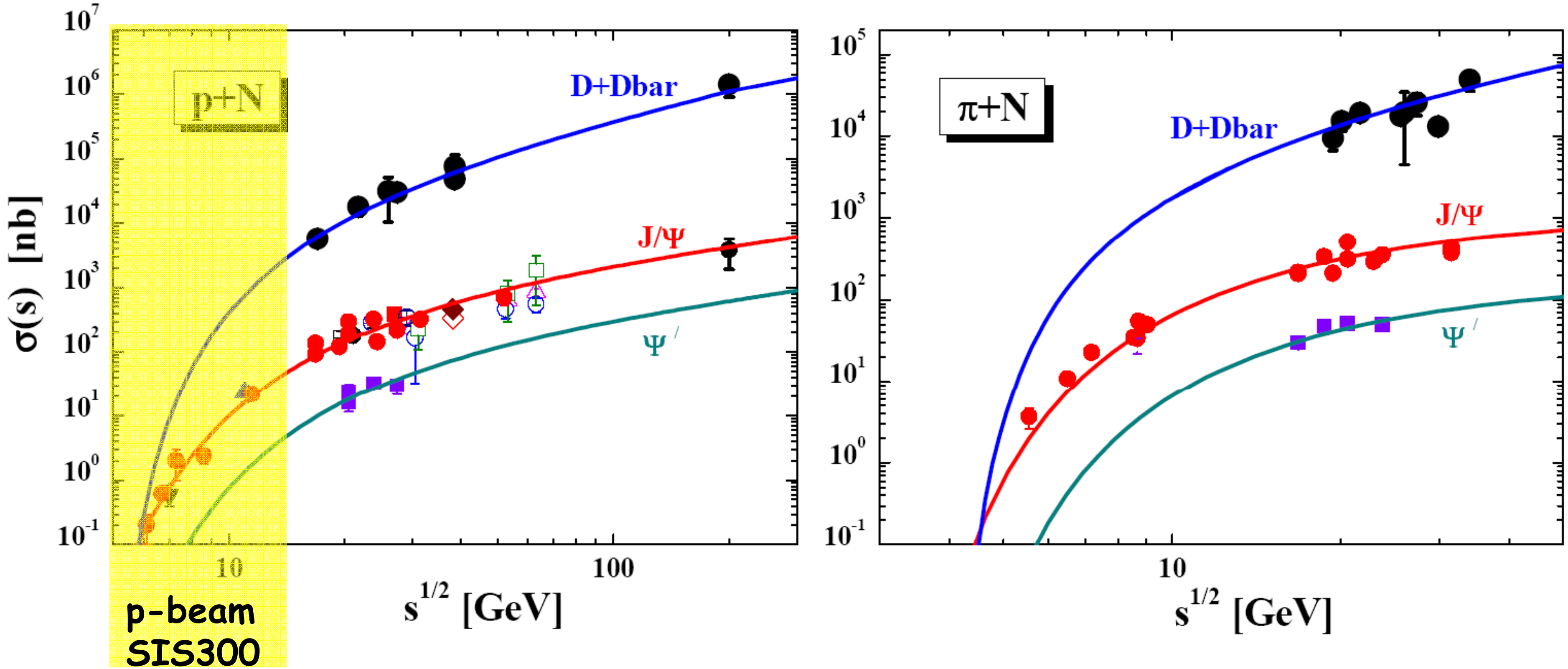


E. Bratkovskaya,
W. Cassing

How are particles with hidden and open charm produced in nuclear collisions at threshold energies?

Charm production in hadronic transport models: parameterization of measured cross sections

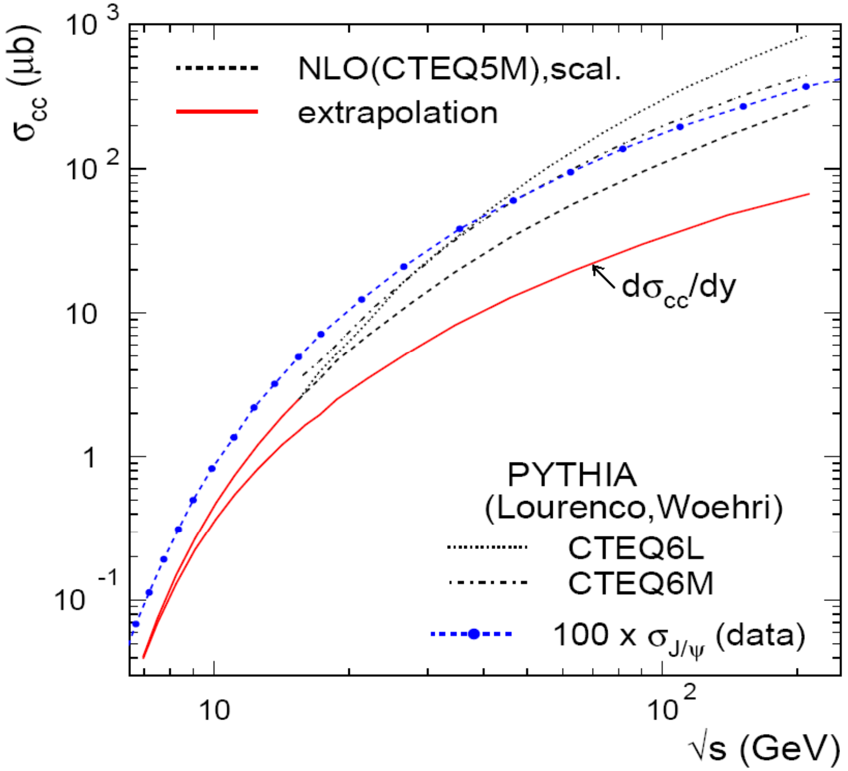
O. Linnyk, E. Bratkovskaya, W. Cassing, H. Stöcker, Nucl. Phys. A786 (2007) 183

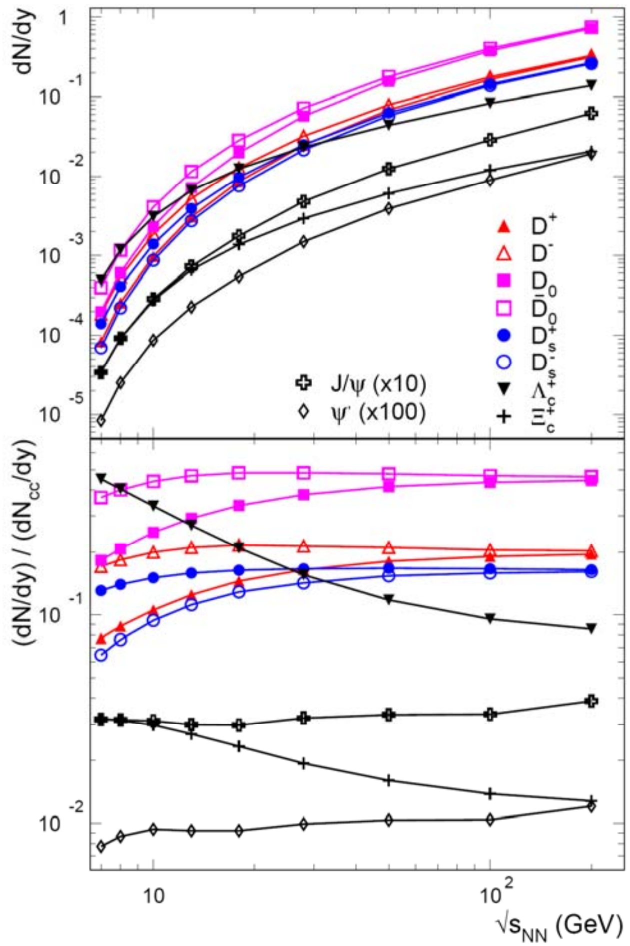


Charmonium and open charm production by statistical hadronisation in nuclear collisions at SPS/FAIR energies

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

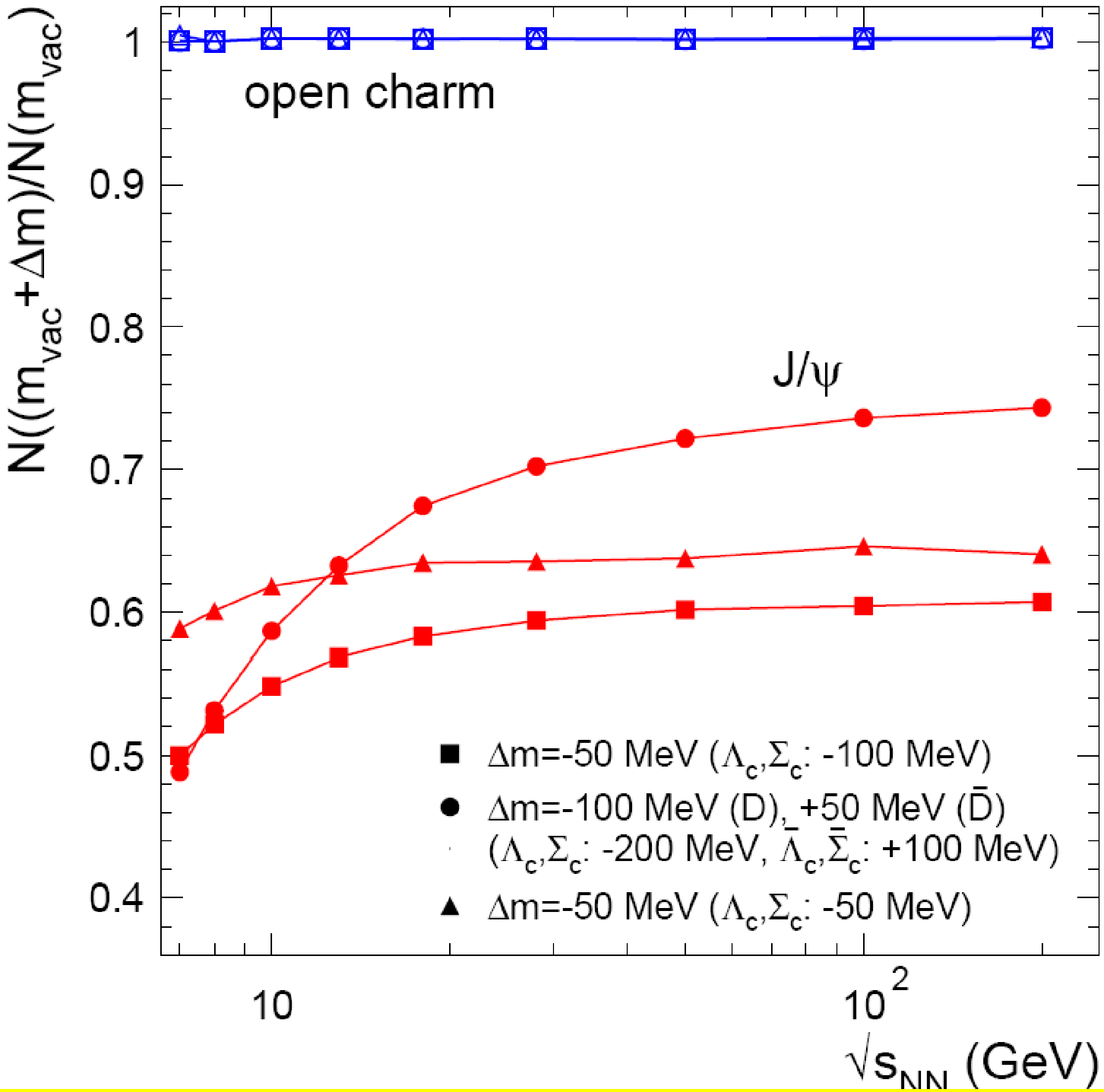
c-cbar production in hard collisions





In-medium modifications of open charm

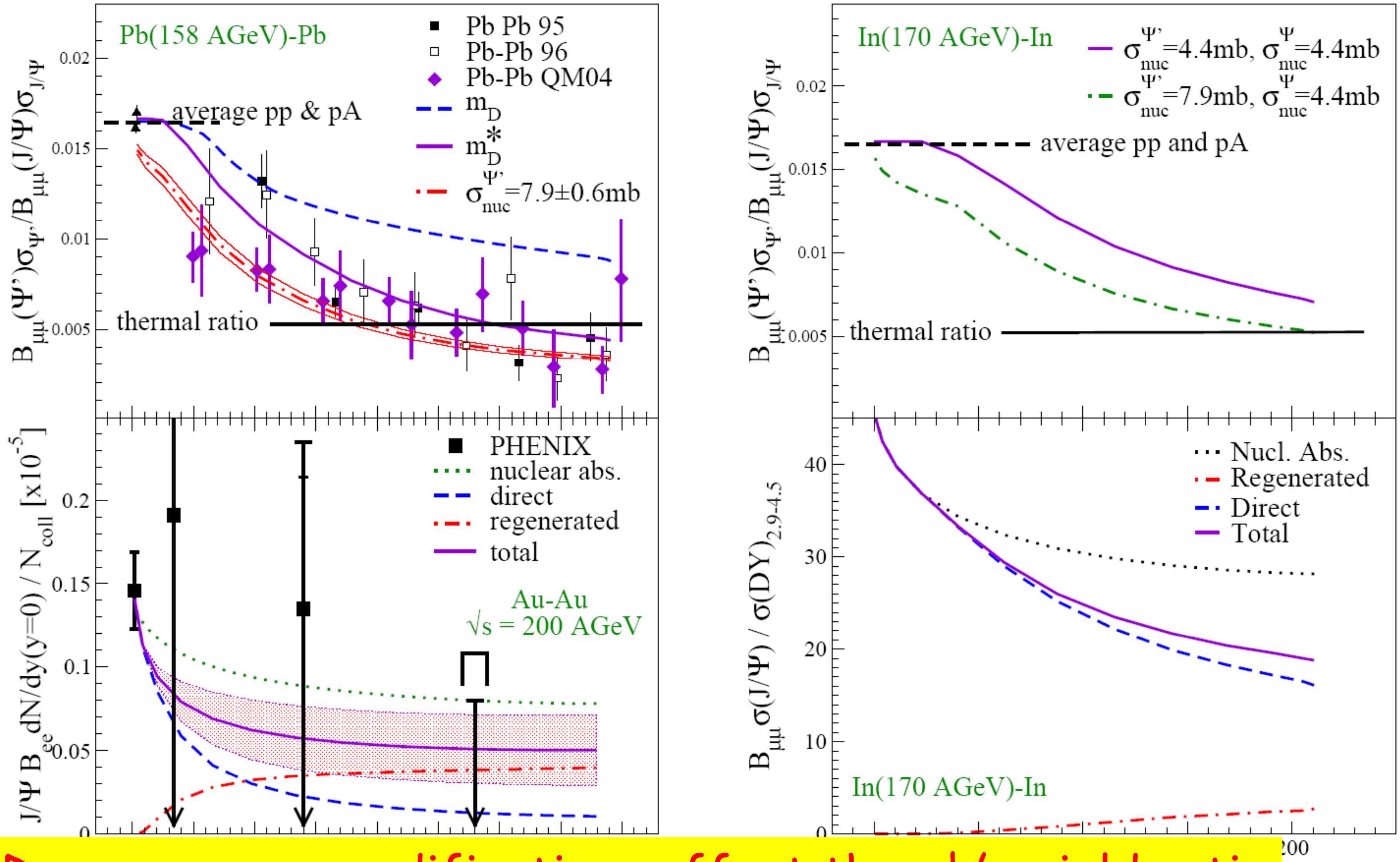
A. Andronic, P. Braun-Munzinger, K. Redlich, J. Stachel, arXiv:0708.1488



D meson mass modifications affect the charmonium yield

In-medium modifications of D mesons

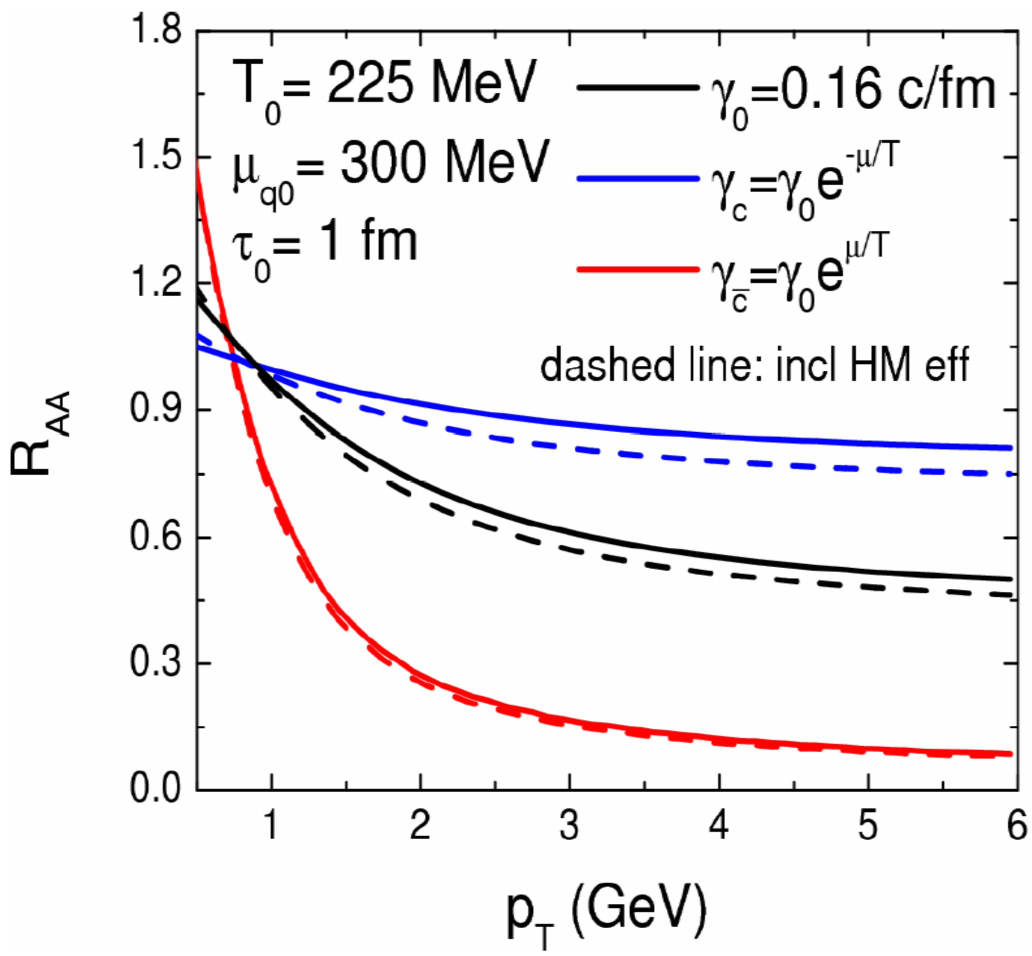
L. Grandchamp, R. Rapp and G. E. Brown, J.Phys. G30 (2004) S1355



D meson mass modifications affect the ψ'/ψ yield ratio

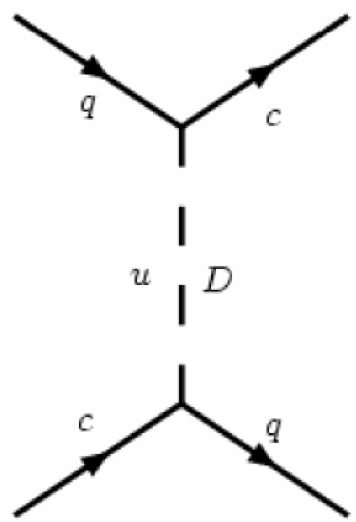
Charm quark propagation in the Quark-Gluon Plasma

H. van Hees & R. Rapp, PRC 71, 034907 (2005)



pQCD gives similar c and cbar cross sections in QGP, irrespective to the baryon chemical potential (black line).

Resonance scattering leads to different c and cbar cross sections in QGP with finite baryon chemical potential (red and blue lines)



Probing the quark-pluon plasma with charmonium

Quarkonium dissociation temperatures – Digal, Karsch, Satz

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

Upper bounds on dissociation temperatures:
Agnes Mocsy, P. Petreczky , SQM 2007

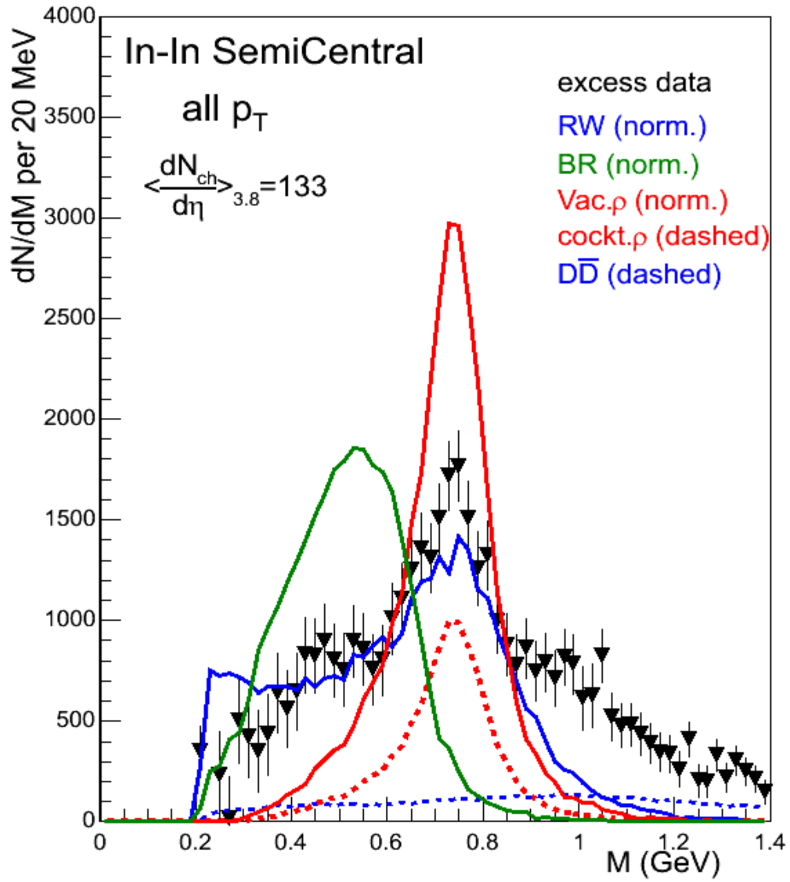
state	χ_c	ψ'	J/ψ	Υ'	χ_b	Υ
T_{dis}	$\leq T_c$	$\leq T_c$	$1.2T_c$	$1.2T_c$	$1.3T_c$	$2T_c$

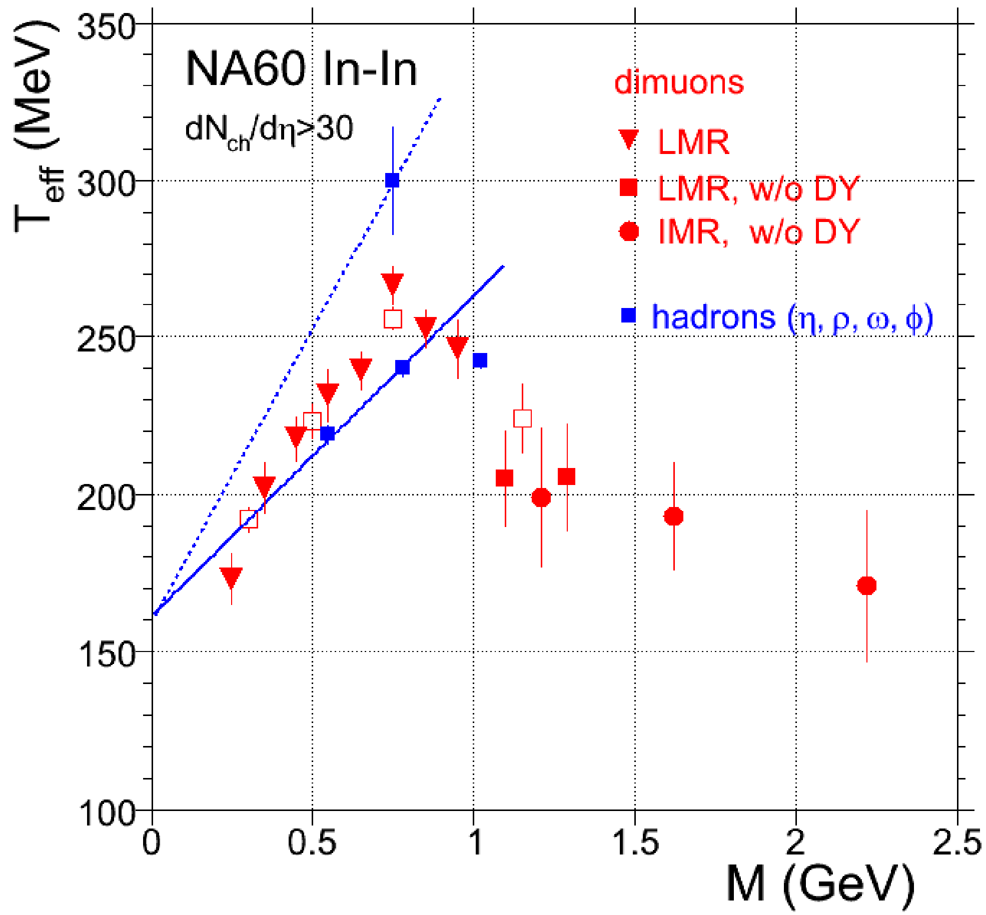
Charm summary:

- hidden/open charm is a very promising probe of QGP
- needed: excitation functions of J/ψ, ψ', D, Λ_C production in p+A and A+A collisions (incl. p_T-spectra, flow)

Dilepton signal from the deconfined phase?

excess dilepton distribution



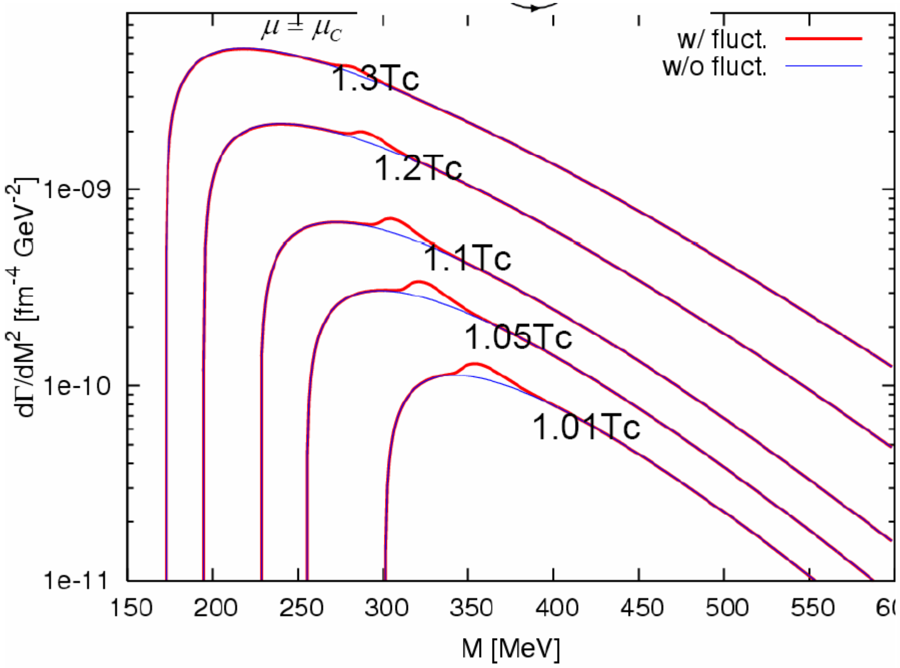


Dilepton signal of the QCD critical point?

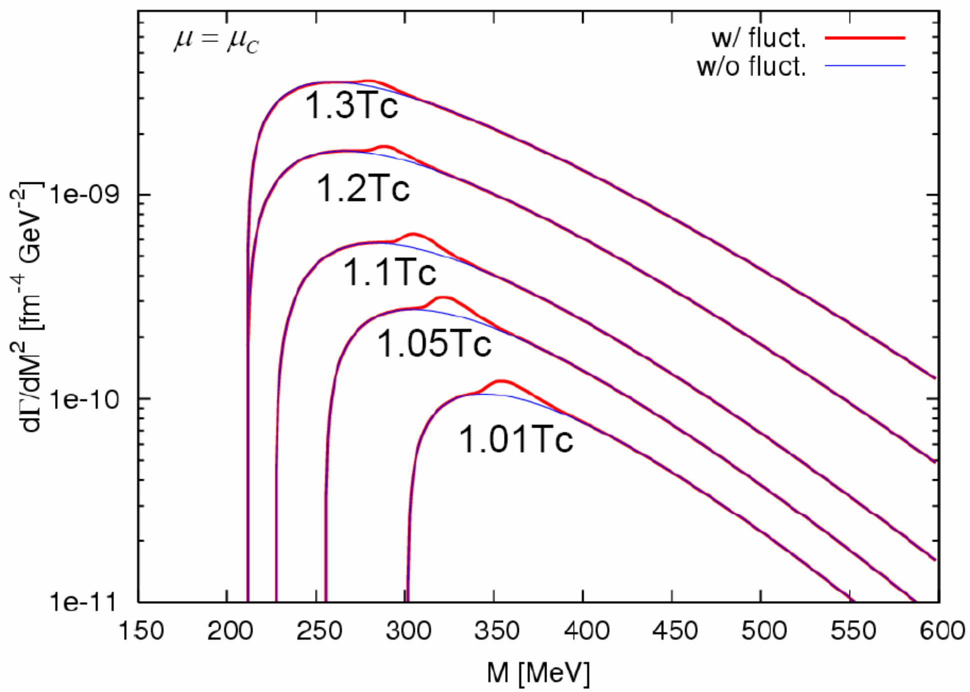
Teiji Kunihiro (YITP, Kyoto) CPOD2007

Softening of the sigma mode at T>Tc close to the CP, and vector-scalar (ω-σ) mixing

Di-electron Production Rate

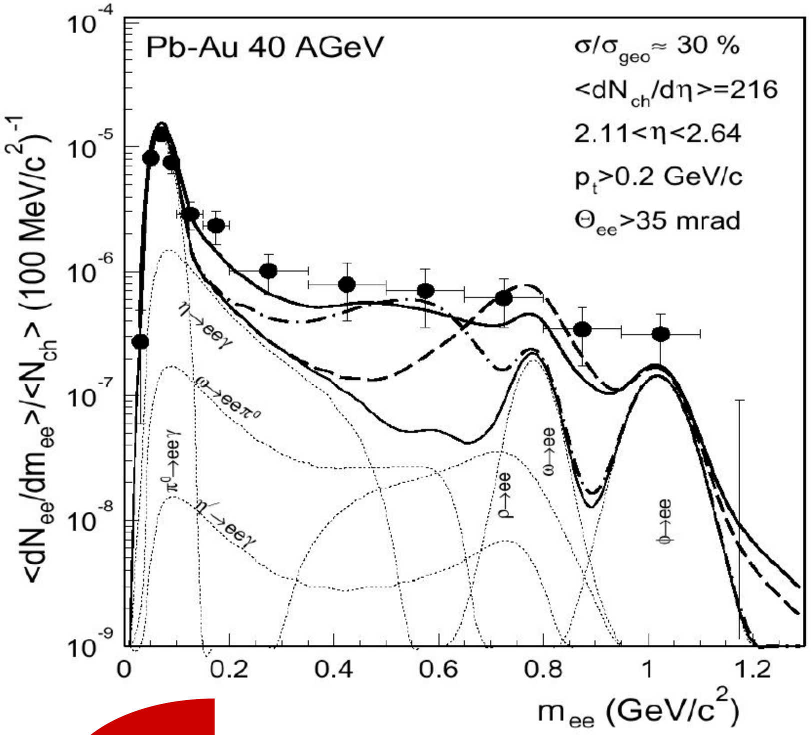


Di-muon Production Rate

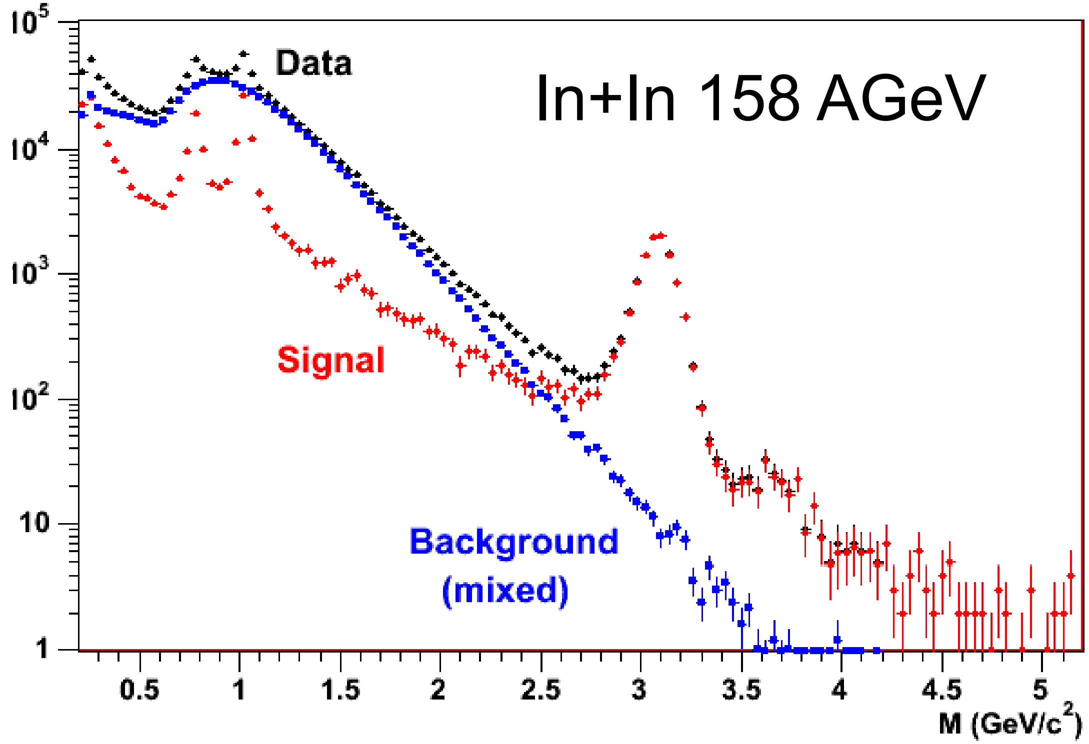


Probing chiral and deconfinement phase transitions with dilepton pairs

Data: CERES
Calculations: R. Rapp



Data: NA60

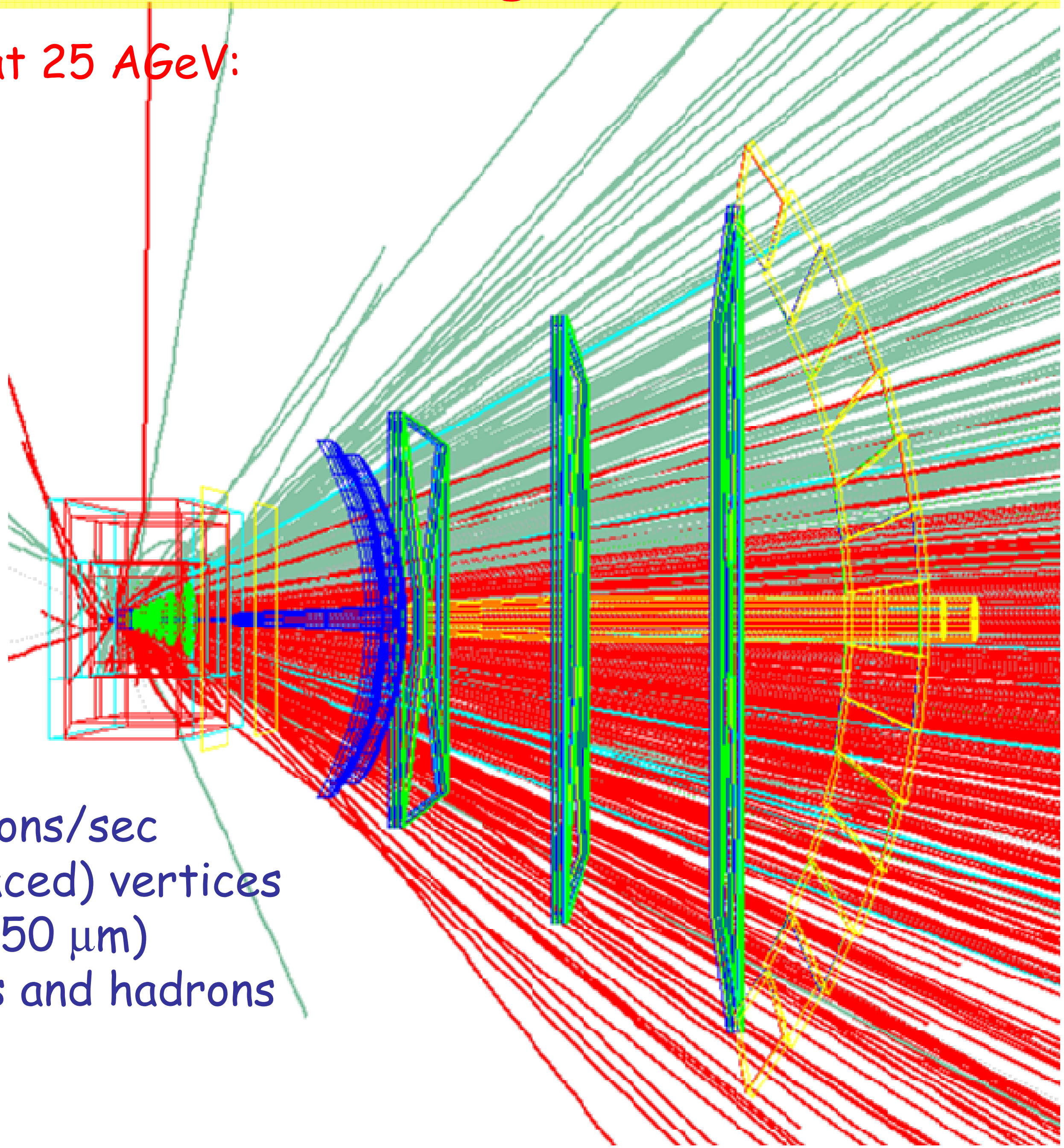


no ρ,ω,φ → e^+e^- ($\mu^+\mu^-$) data between 2 and 40 AGeV
no J/ψ, ψ' → e^+e^- ($\mu^+\mu^-$) data below 160 AGeV
needed: high statistics, excellent momentum resolution

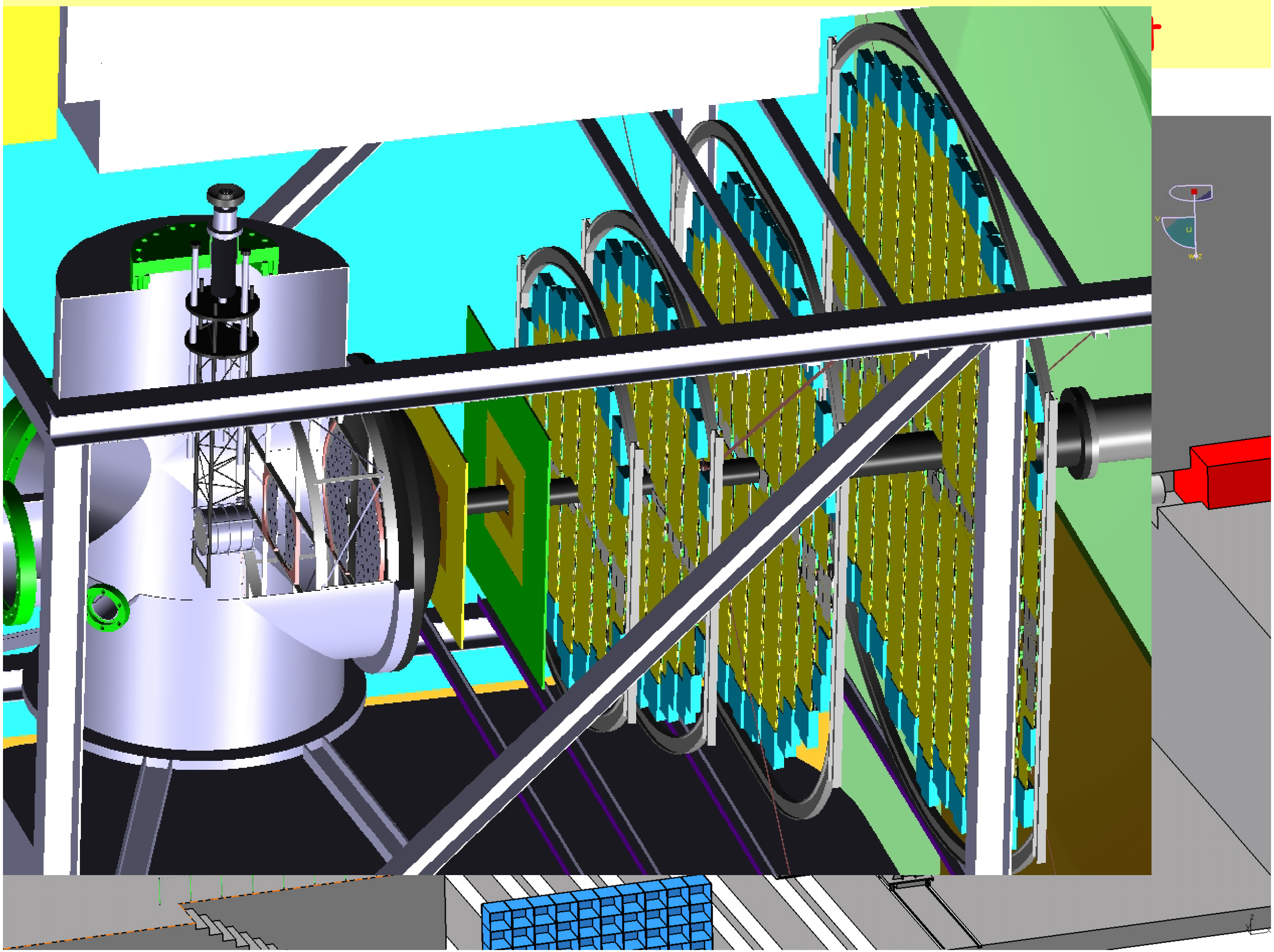
Experimental challenges

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

160 p
400 π^-
400 π^+
44 K^+
13 K^-



- up to 10^7 Au+Au reactions/sec
- determination of (displaced) vertices with high resolution (≈ 50 μm)
- identification of leptons and hadrons

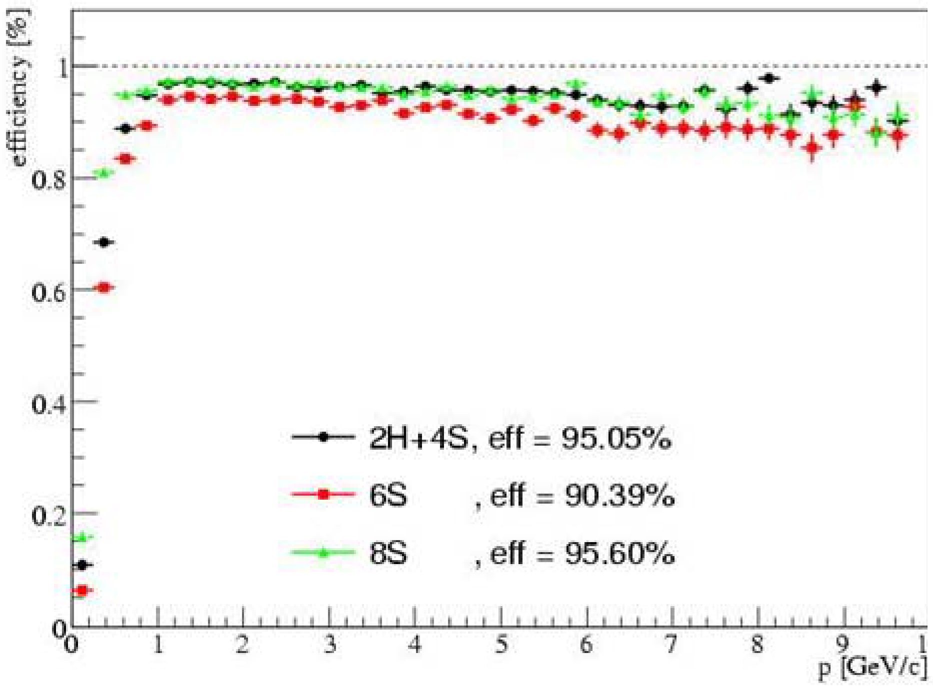


Track reconstruction in the silicon detector system

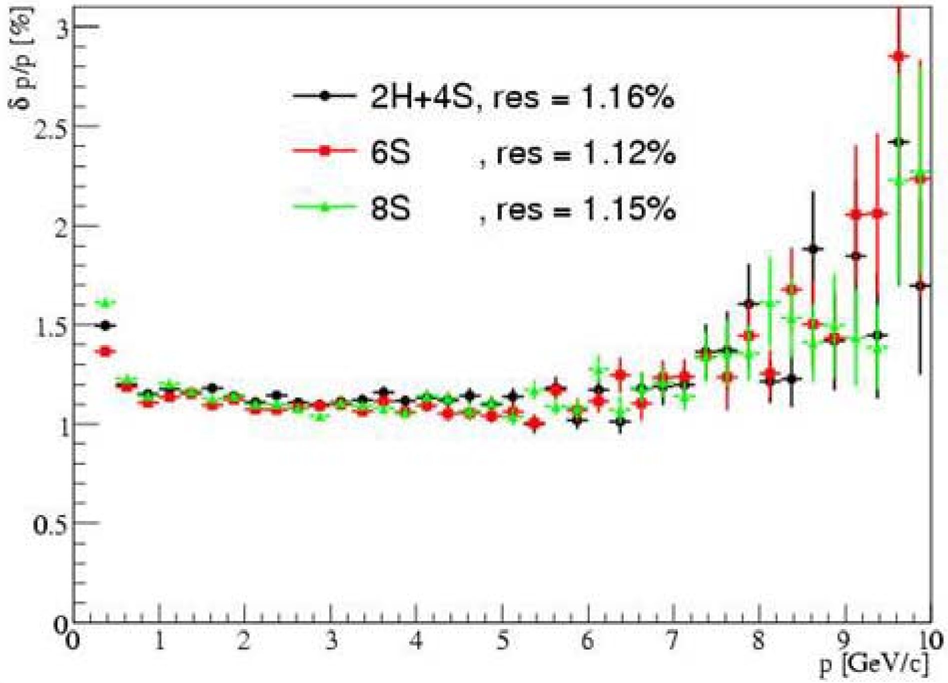
Different versions for main tracker (STS) under investigation:
- 2 hybrid pixels und 4 micro-strips
- 6 micro-strips
- 8 micro-strips

central Au+Au collision 25 AGeV, primary tracks:

reconstruction efficiency

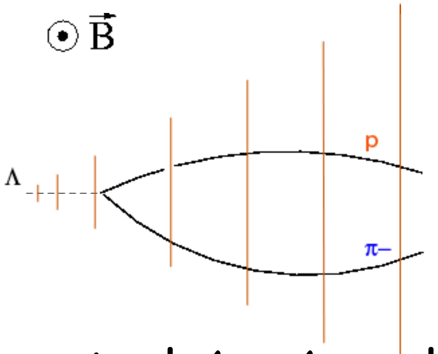


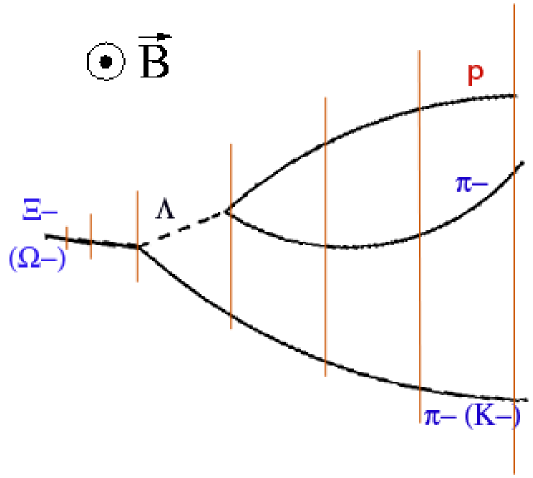
momentum resolution



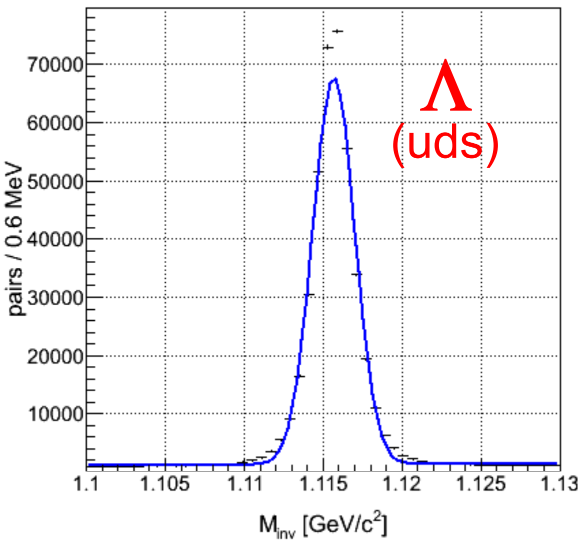
Hyperon detection with STS (no p, K, π identification)

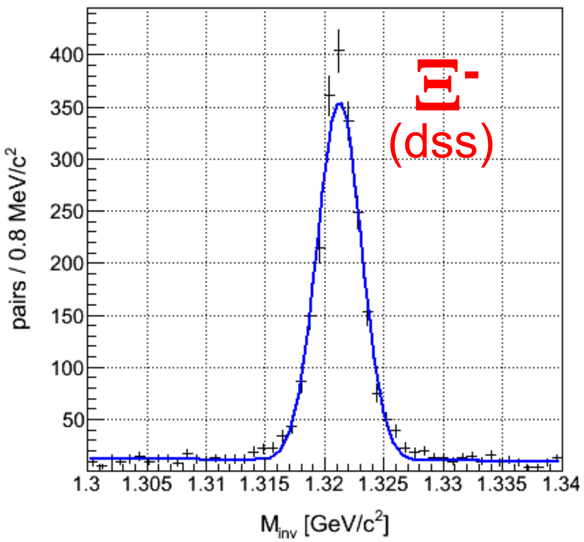
- Silicon tracker: 2 hybrid pixel (750 μm each), 4 microstrips (400 μm each)
- Strips with 50 μm pitch and 5^o stereo angle
- full event reconstruction

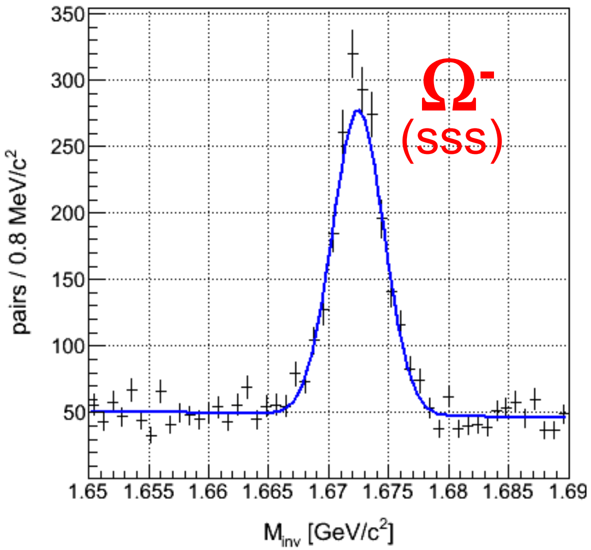




central Au+Au collisions at 25 AGeV:







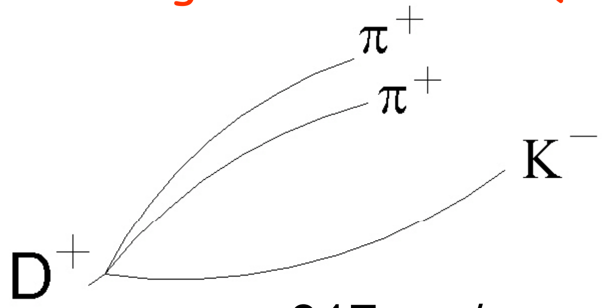
total efficiency 10.6% 2.1% 1.0%

Benchmark for MVD and STS performance: D mesons from Au+Au central collisions at 25 AGeV

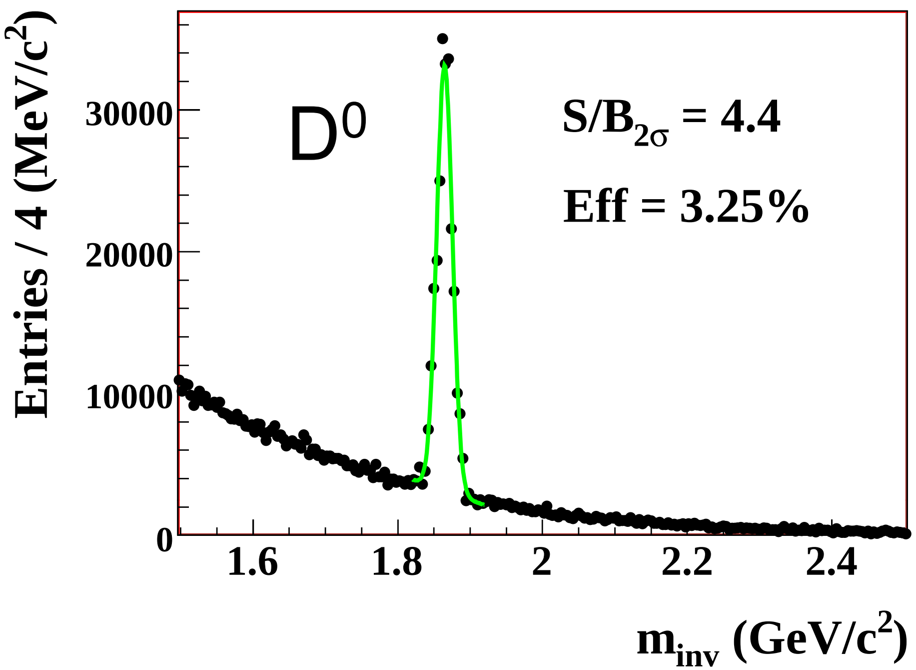
Full track reconstruction:
- realistic magnetic field,
- 2 MAPS, 6 micro-strip detectors
- proton identification via TOF

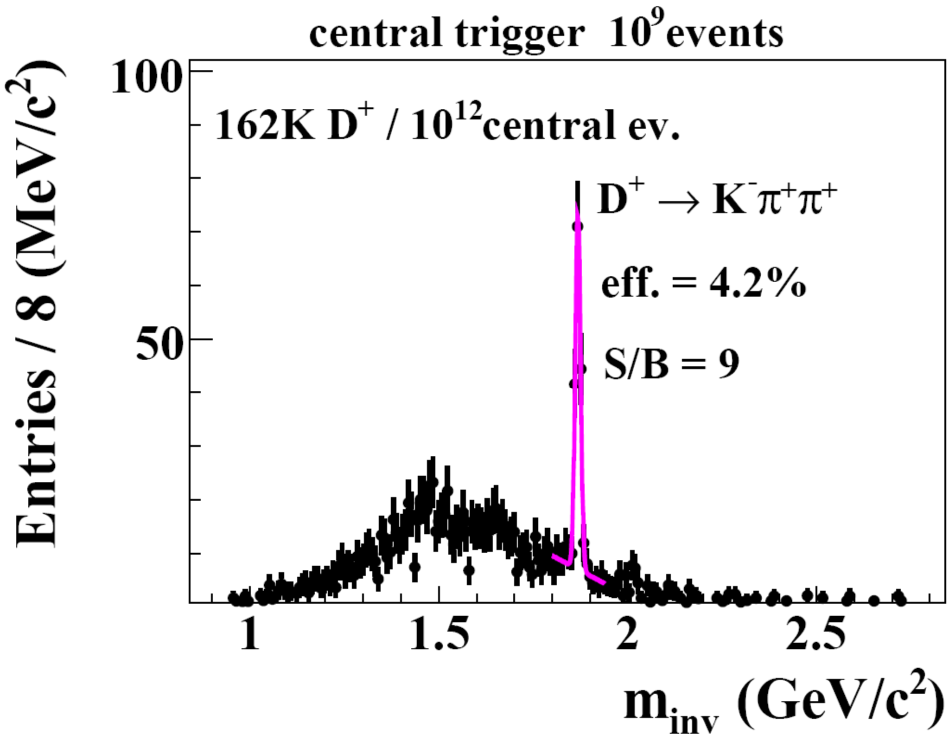
D production cross sections from HSD
Hadronic background from UrQMD

τ = 123 μm/c



τ = 317 μm/c



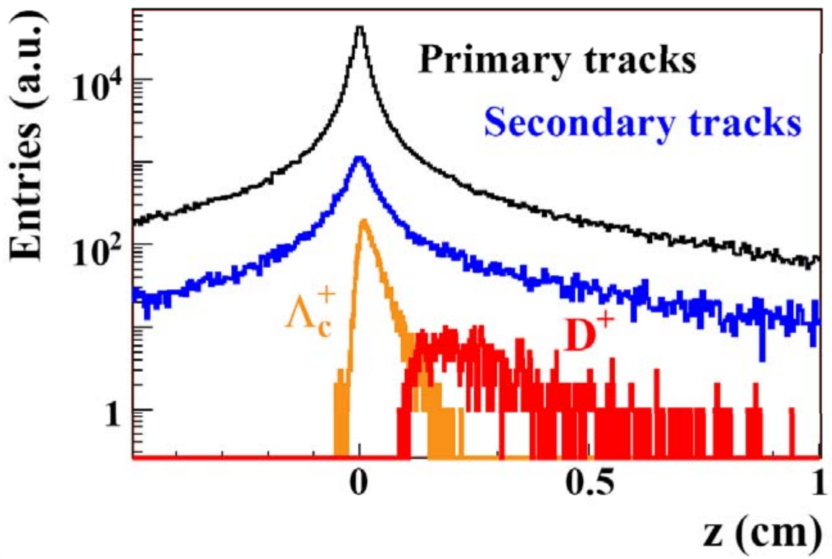


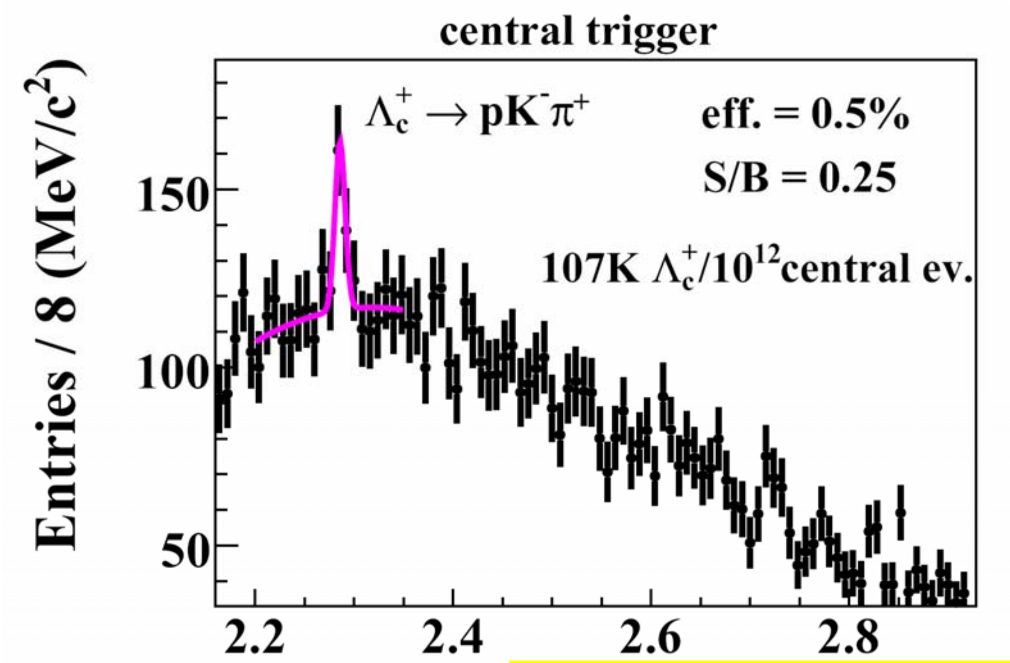
Preliminary results for Λ_C identification

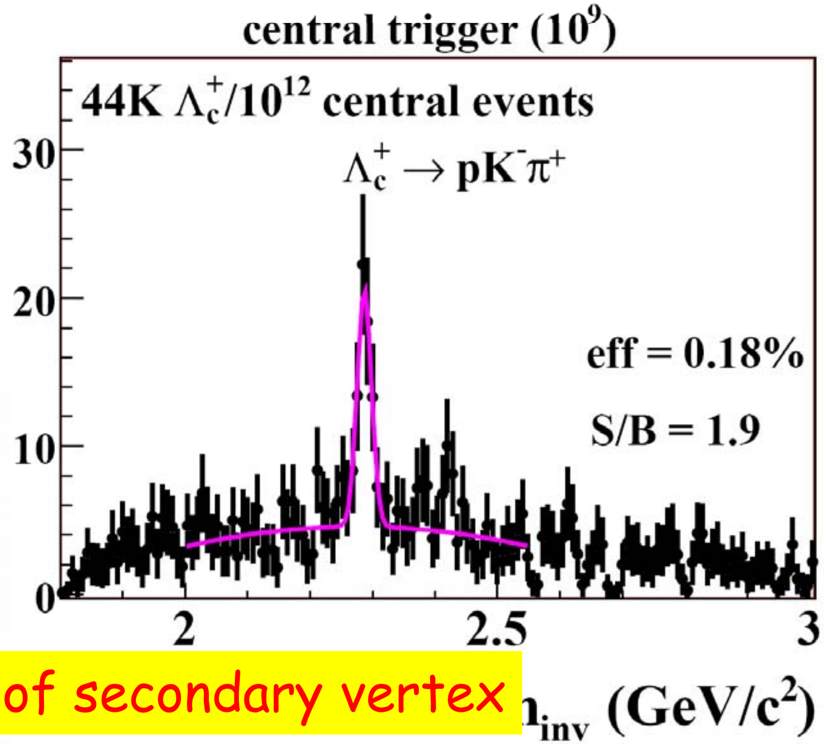
central Au+Au collisions at 25 AGeV
Λ_C cross section from statistical model

$\Lambda_C \rightarrow \pi^+ K^- p$
τ = 60 μm/c

Full track reconstruction:
- realistic magnetic field,
- 2 MAPS, 6 micro-strip detectors
- proton identification via TOF

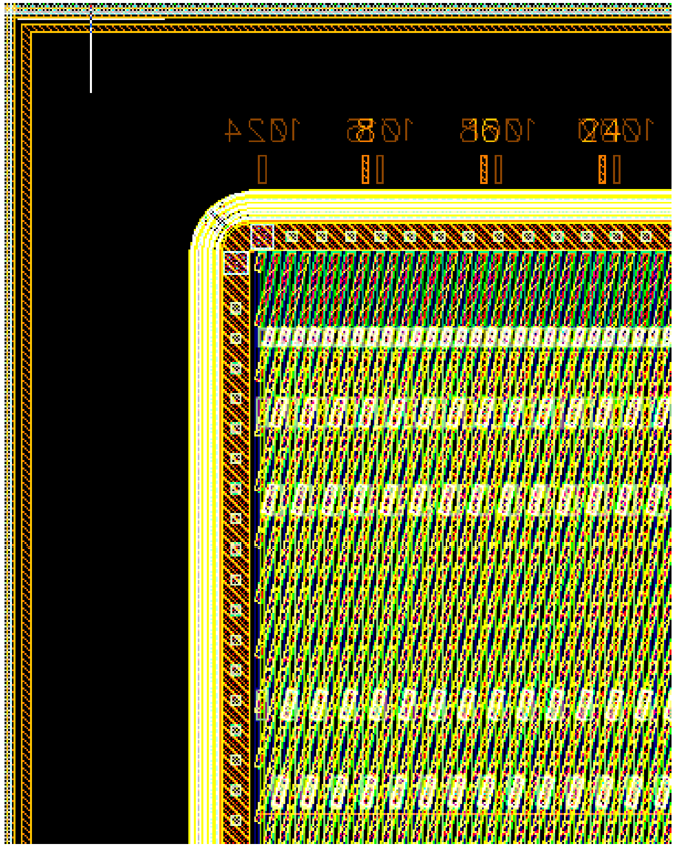


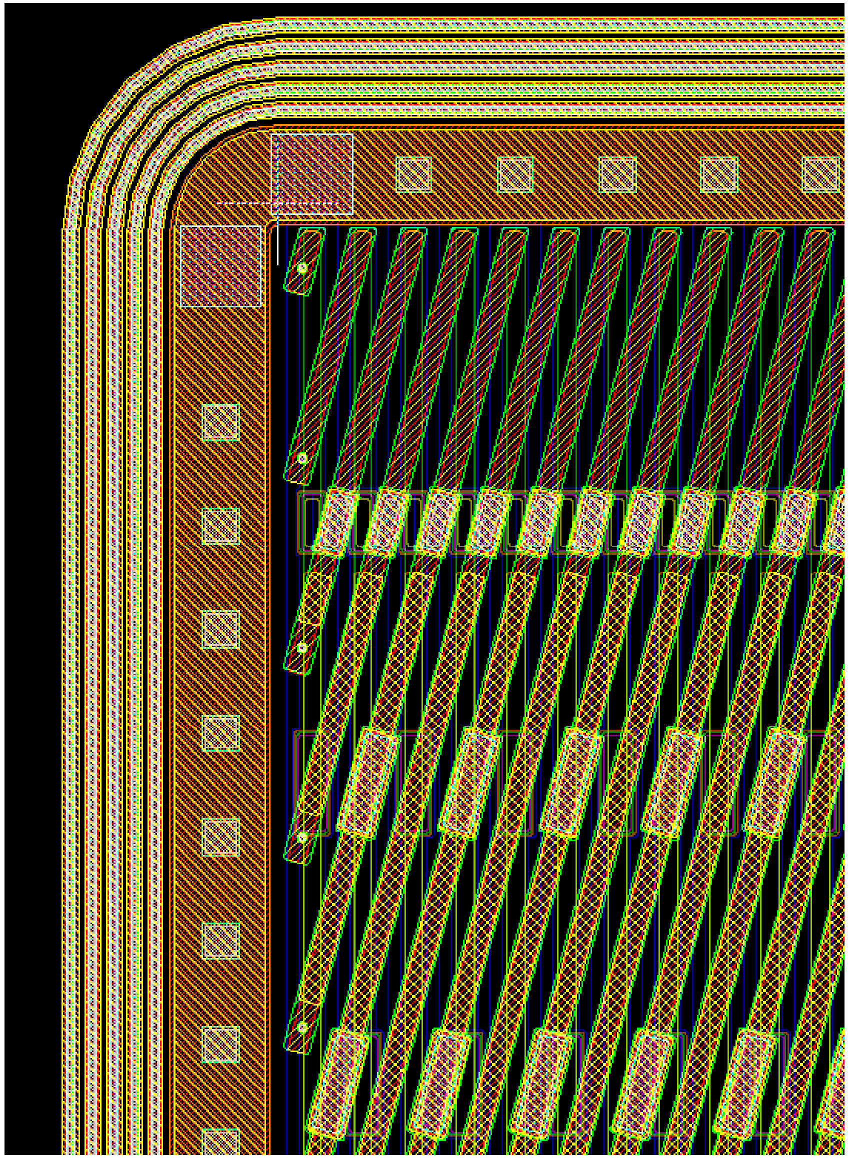




different cuts on χ^2 of secondary vertex

Micro-strip sensor layout



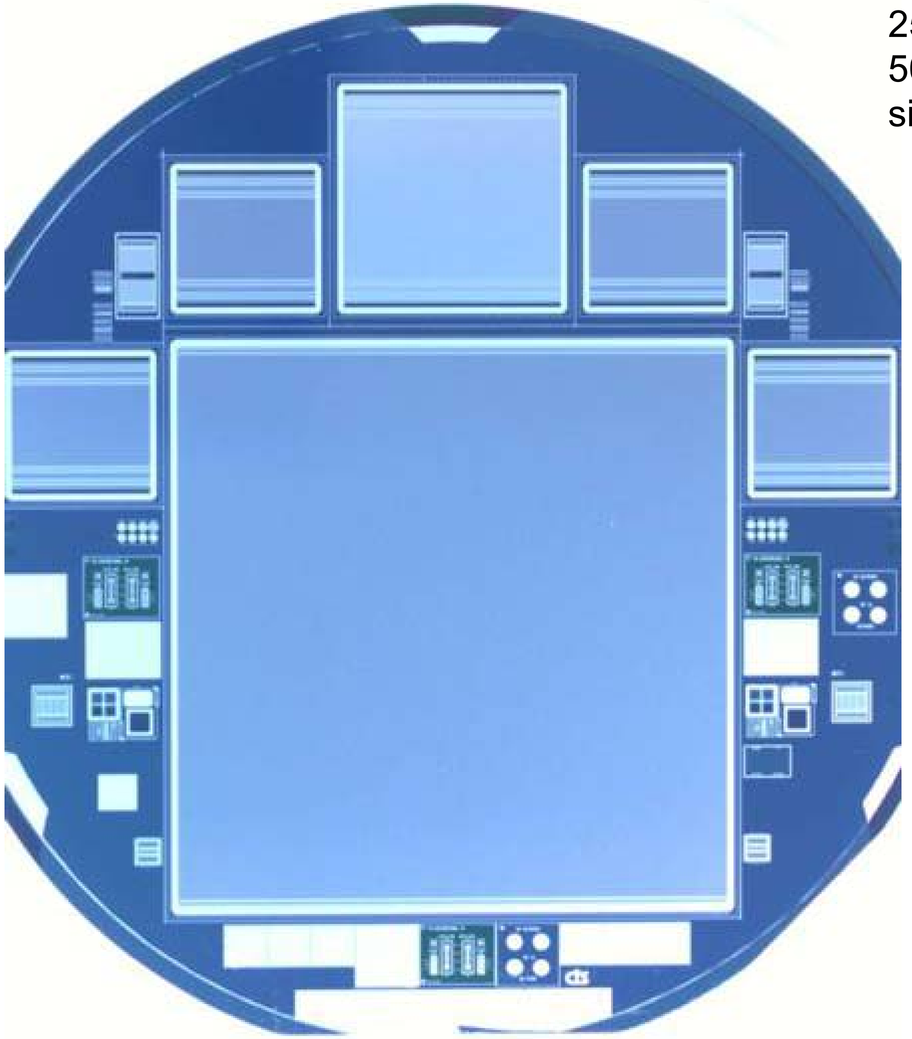


Design of 15 deg stereo sensor,
50 µm strip pitch, with double metal layer,

together with CIS company, Erfurt

Silicon microstrip detector prototype CBM01, 8/2007

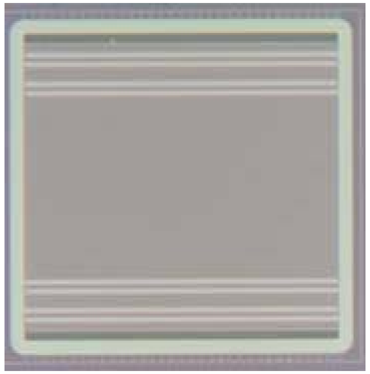
4" wafer, 285 µm Si



GSI – CIS Erfurt

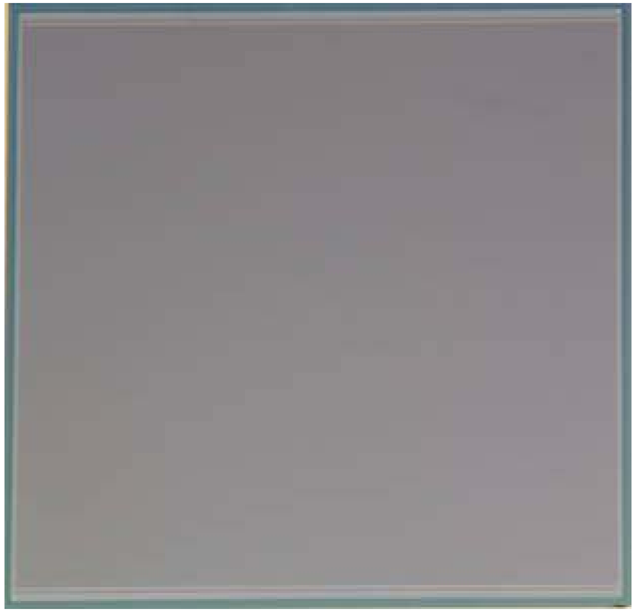
Test sensors

Double-sided, single-metal,
256×256 strips, orthogonal,
50(80) µm pitch,
size: 14×14 (22 ×22) mm²



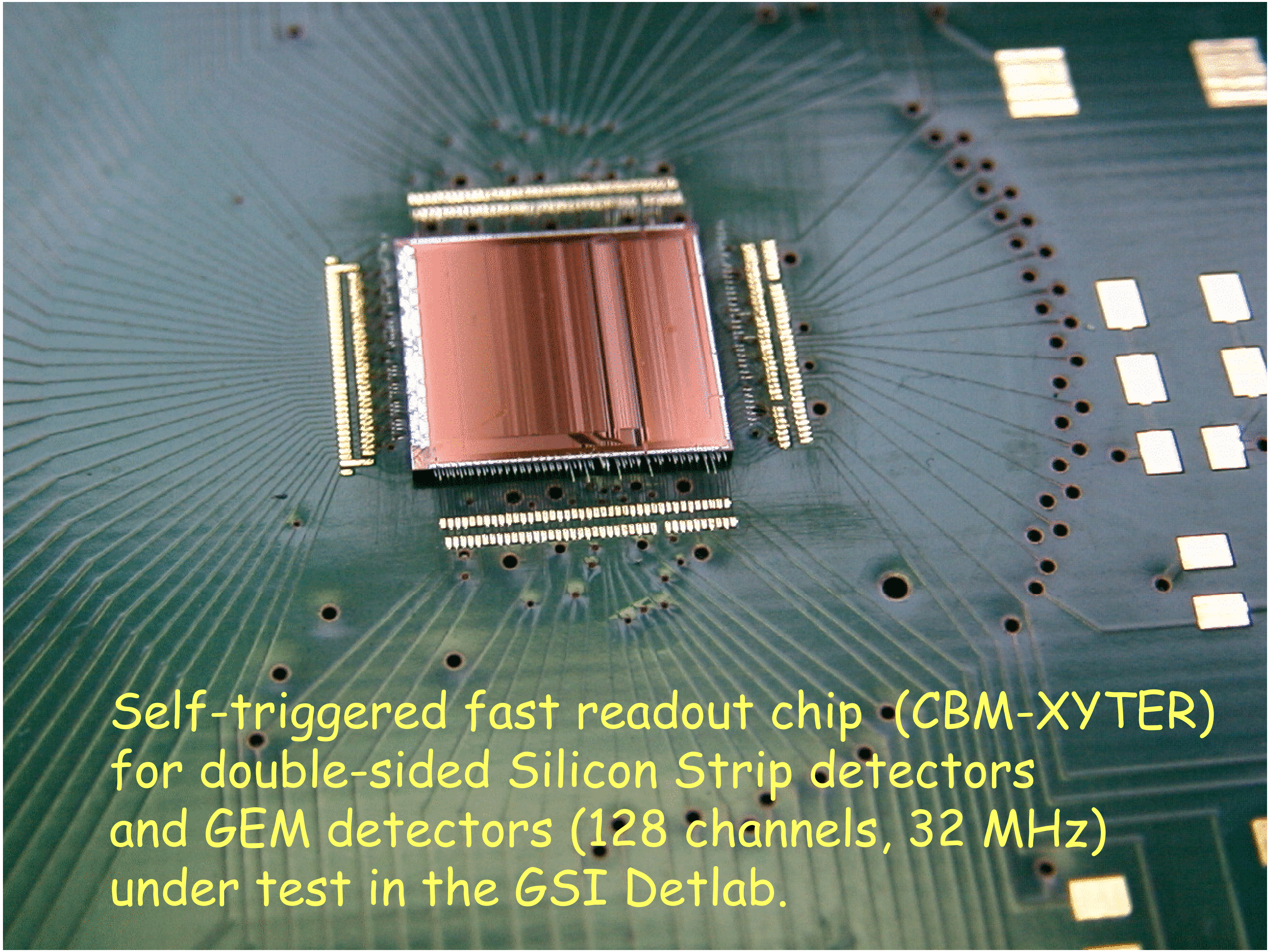
Main sensor

Double-sided, double-metal, 1024 strips per side,
50 µm pitch, 15° stereo angle, full-area sensitive,
contacts at top + bottom edge, size: 56×56 mm²



Silicon microstrip detector prototype CBM01, 8/2007

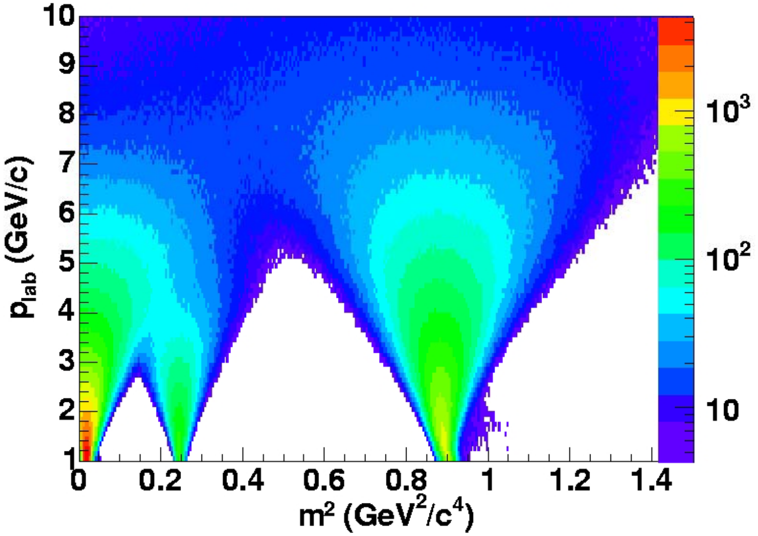
GSI – CIS Erfurt

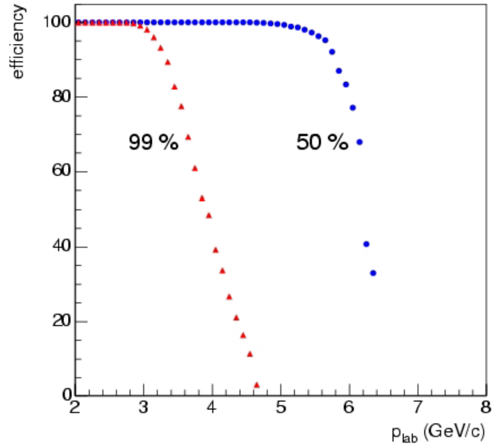


Self-triggered fast readout chip (CBM-XYTER)
for double-sided Silicon Strip detectors
and GEM detectors (128 channels, 32 MHz)
under test in the GSI Detlab.

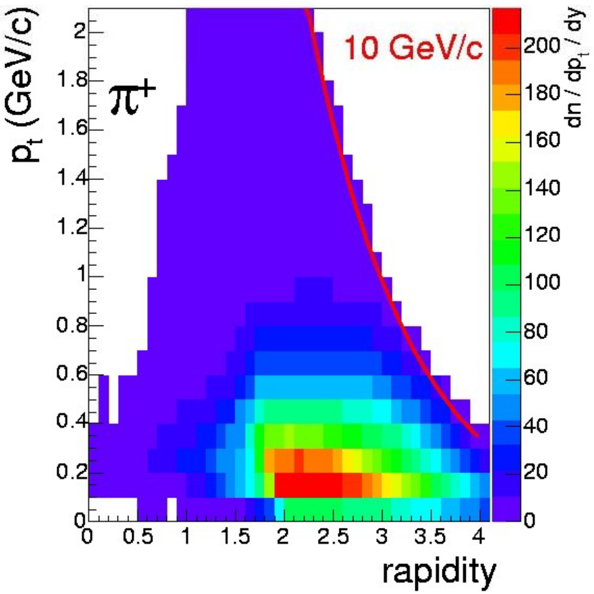
Particle identification by TOF

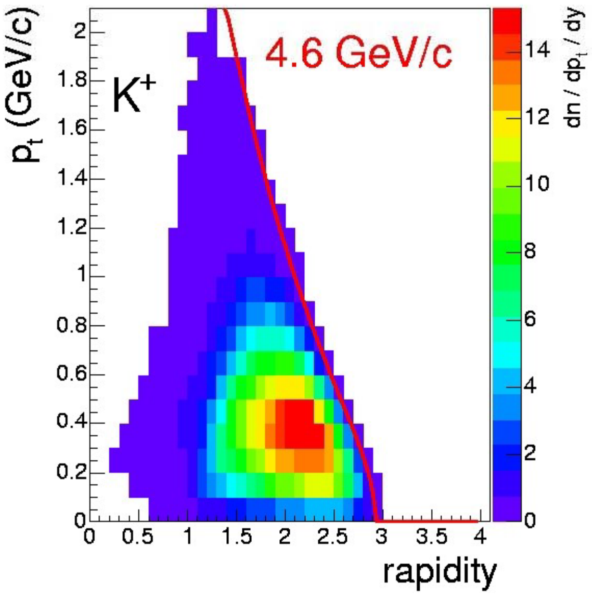
Simulations: UrQMD central Au + Au at 25 AGeV, GEANT
time resolution 80 ps, 10 m distance

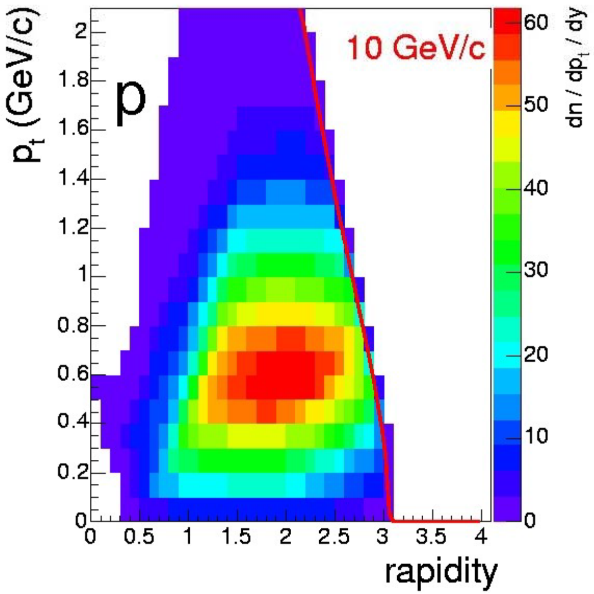




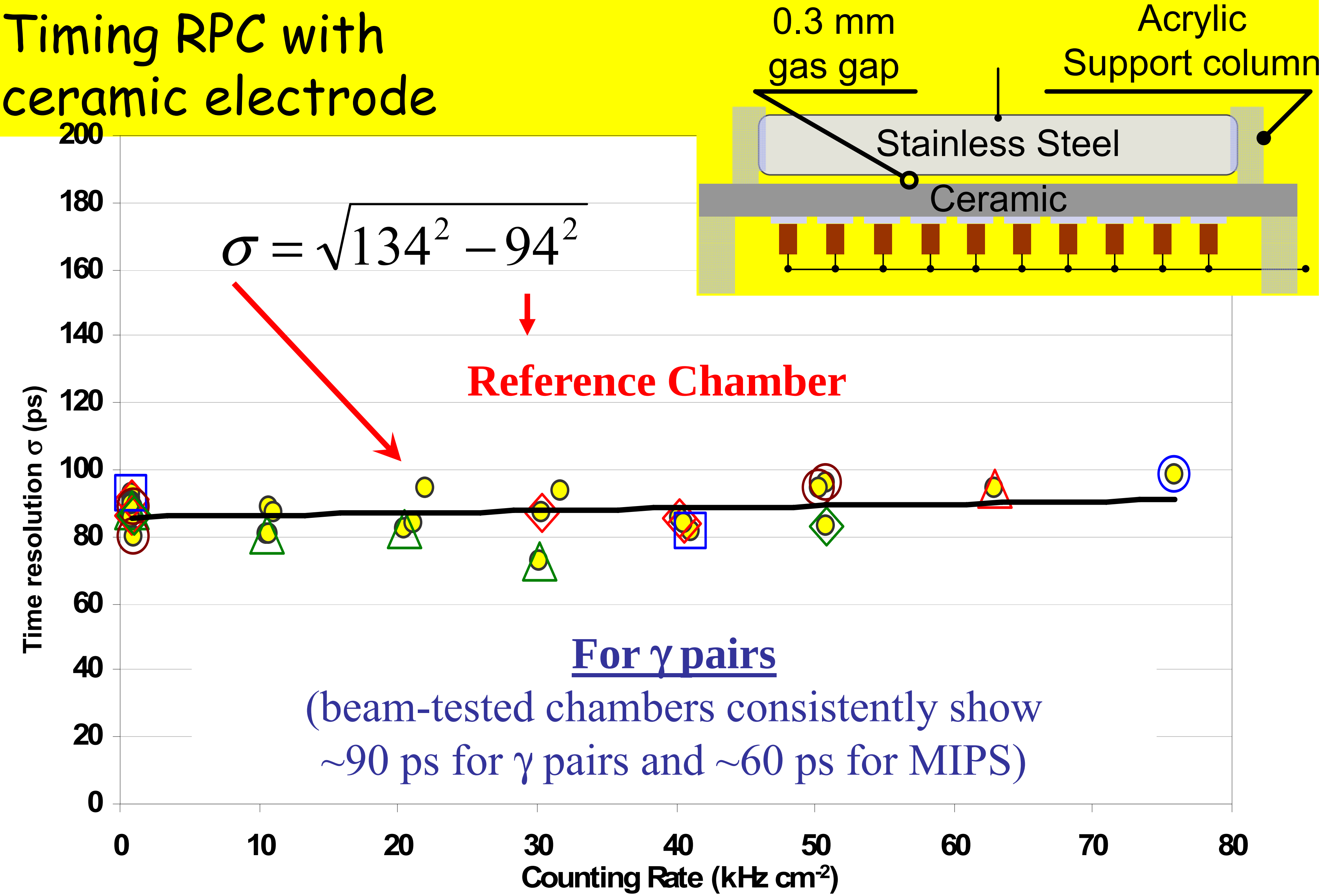
99 % purity:



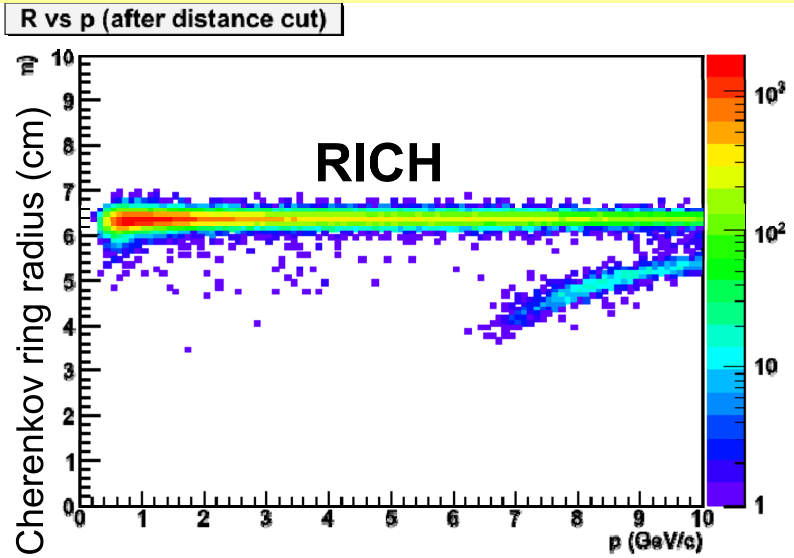


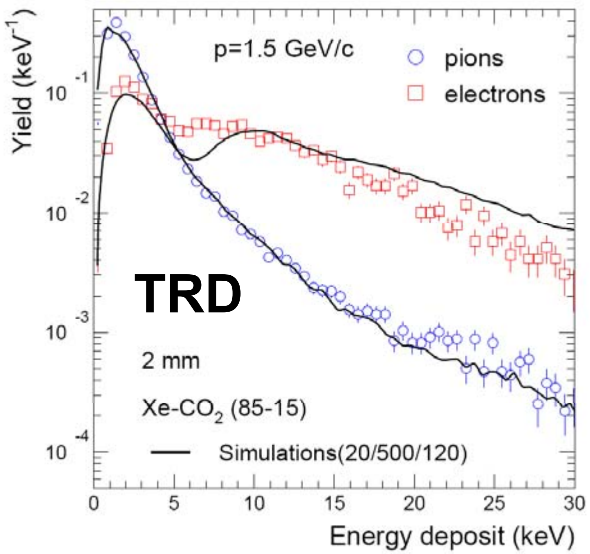


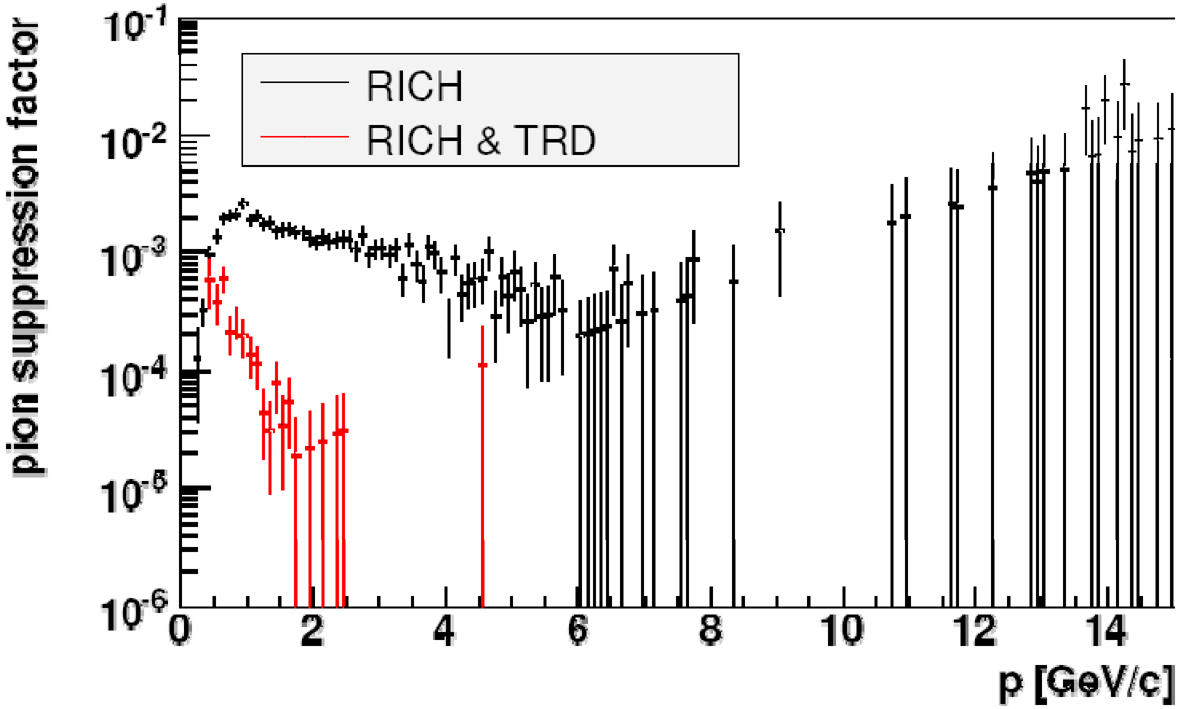
Timing RPC with ceramic electrode



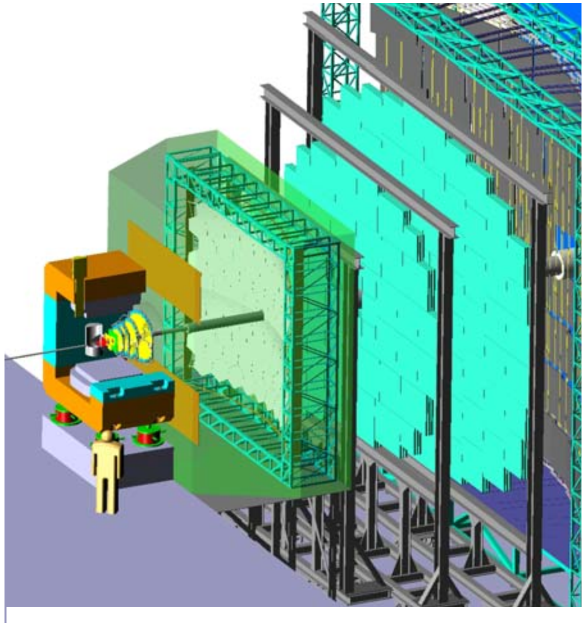
Electron identification with RICH and TRD





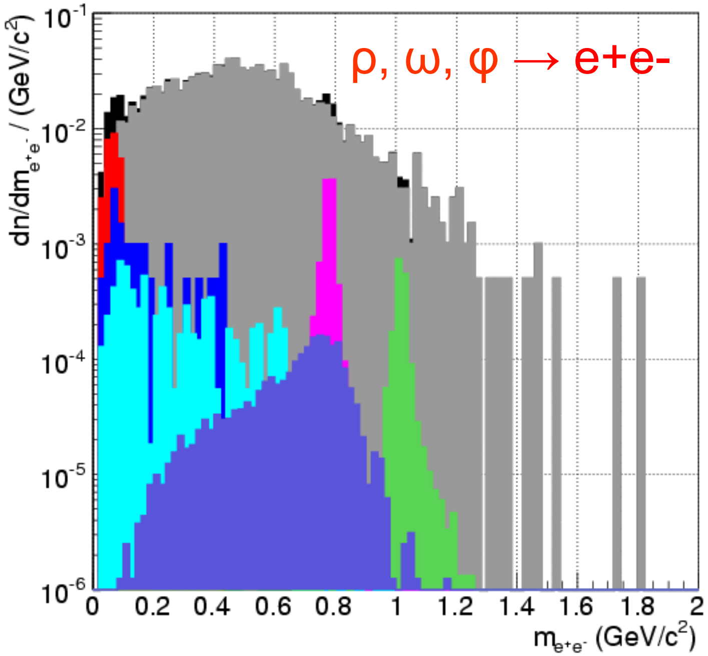


Vector meson identification via electron pairs in CBM

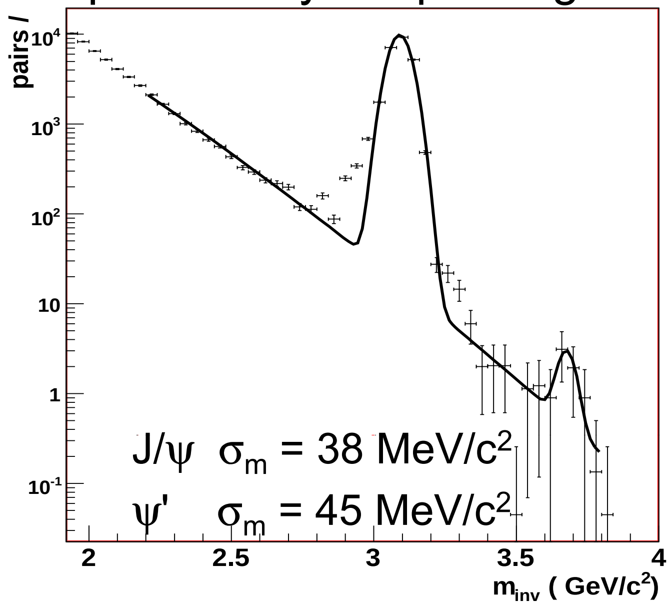


central Au+Au collisions at 25 AGeV

particle	S/B	ε (%)	σ (MeV)
ω	0.15	7.5	14
φ	0.13	9.1	14
ρ	0.002	4	
J/ψ	1.7	12	38
ψ'			



preliminary: 25 μm target



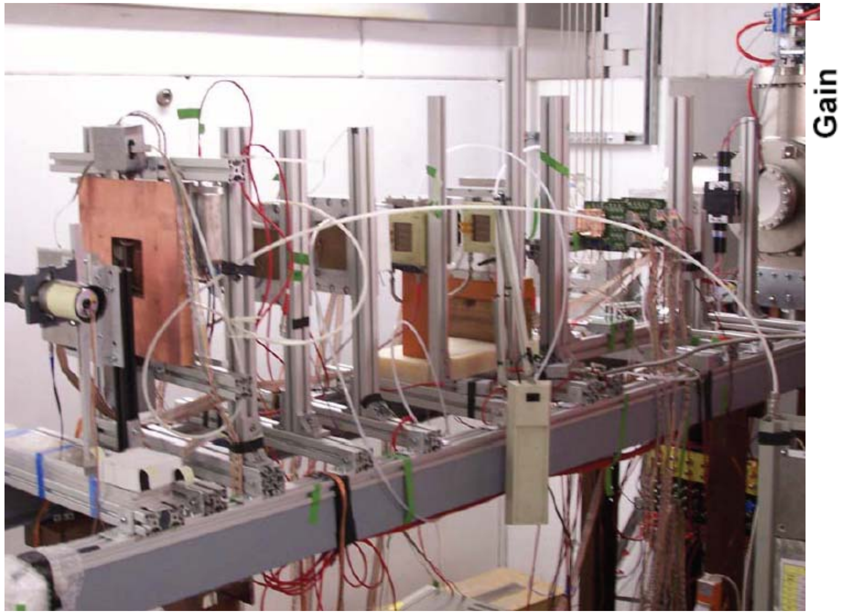
MWPC based TRD for CBM

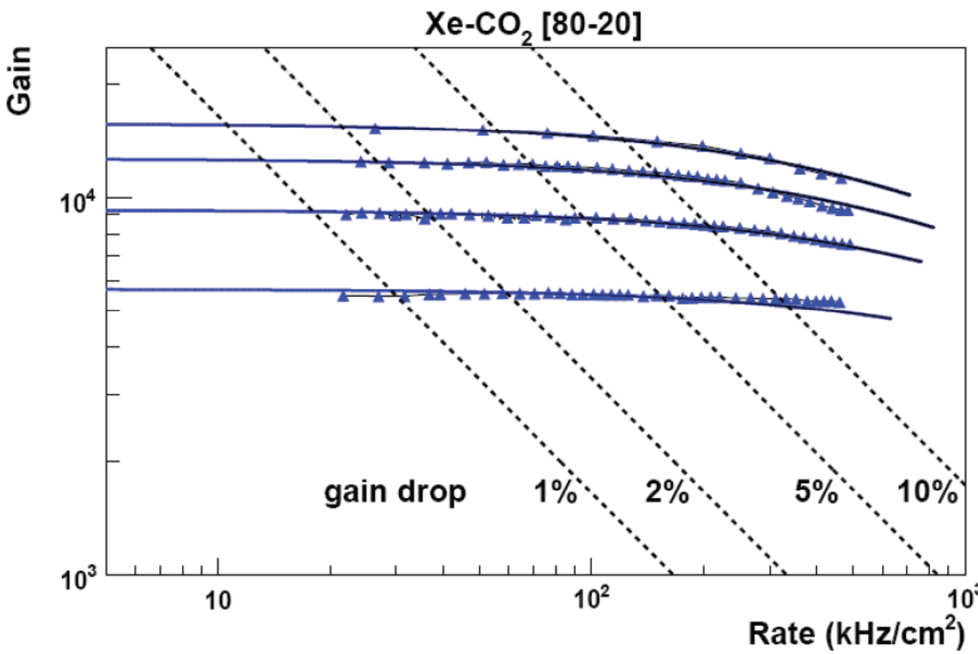
Design goals:

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

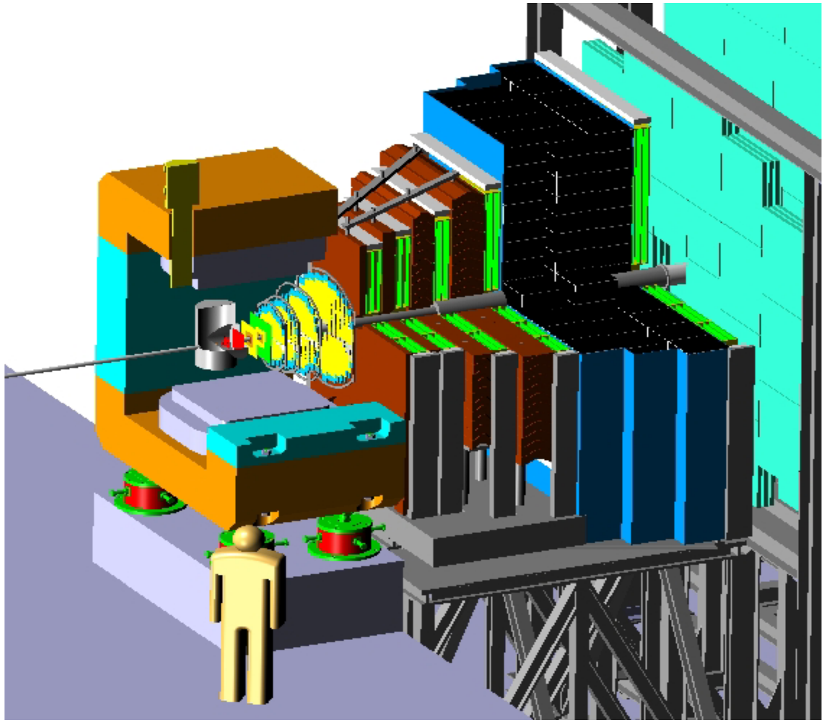
- High rate capability up to 100 kHz/cm^2
- Position resolution of about 200 μm
- Large area (≈ 450 - 650 m^2, 9 – 12 layers)

beam tests of new detector prototypes with realistic pad size and radiators (Bucharest-GSI-Dubna-Münster Collaboration) .
Rates > 100 kHz/cm^2 achieved without deterioration of the signal amplitude.





The CBM Muon Detection system



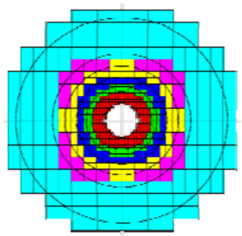
6 segmented absorber layers: 225 cm Fe: 13.5 λ_I

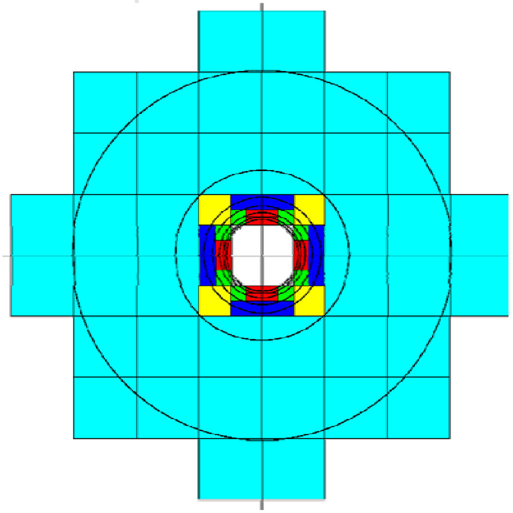
18 tracking detector layers

Assumed detector segmentation: 5% occupancy

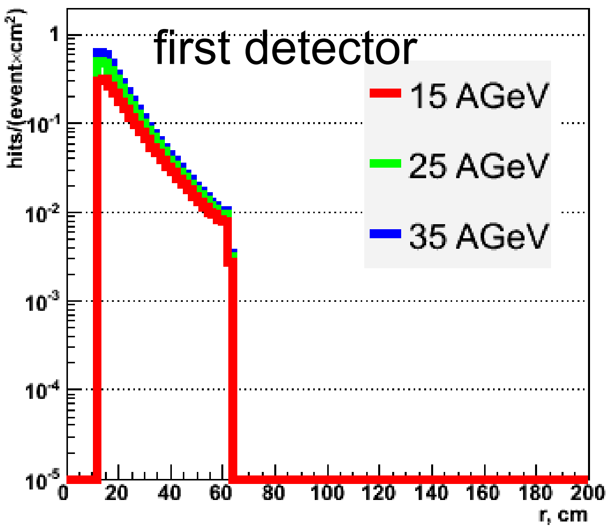
Simulations Au+Au central collisions at 25 AGeV

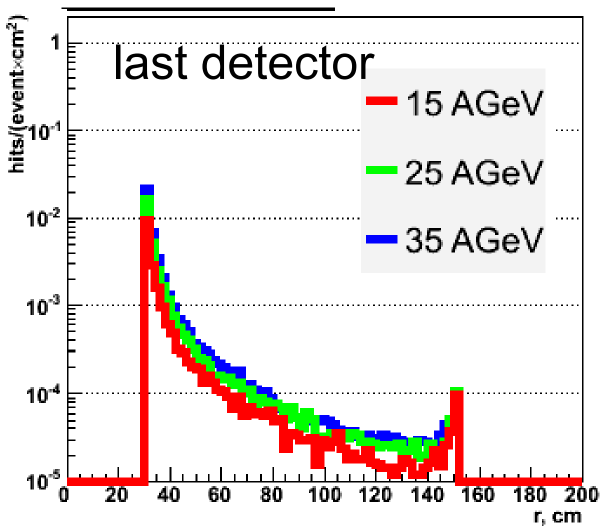
min pad 1.4 × 2.8 mm^2
space resolution:
x – 400 μm, y – 800 μm



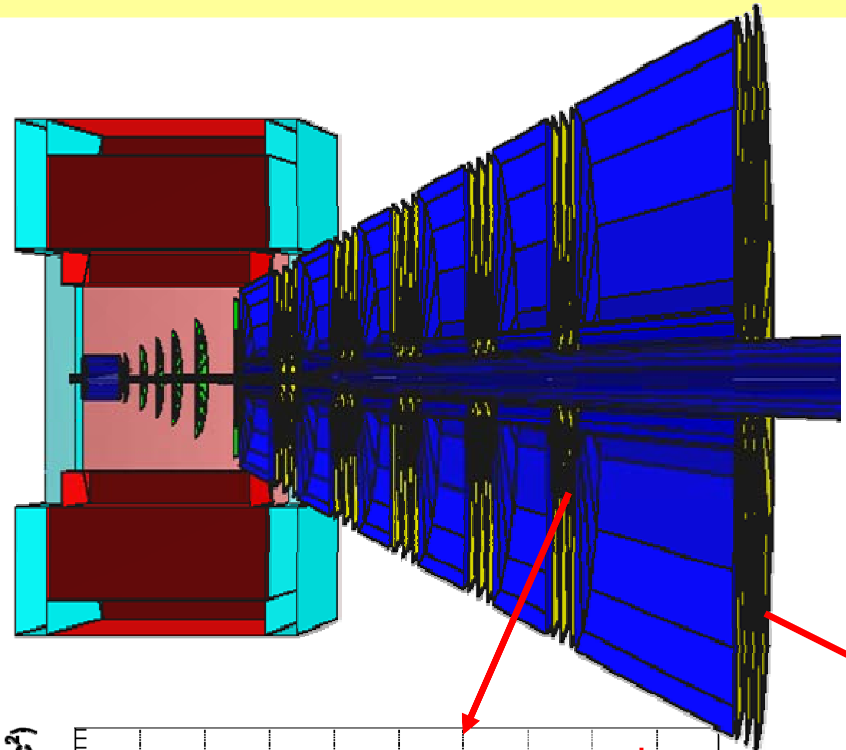


max pad 44.8 × 44.8 mm^2
space resolution:
x – 12.8 mm, y – 12.8 mm



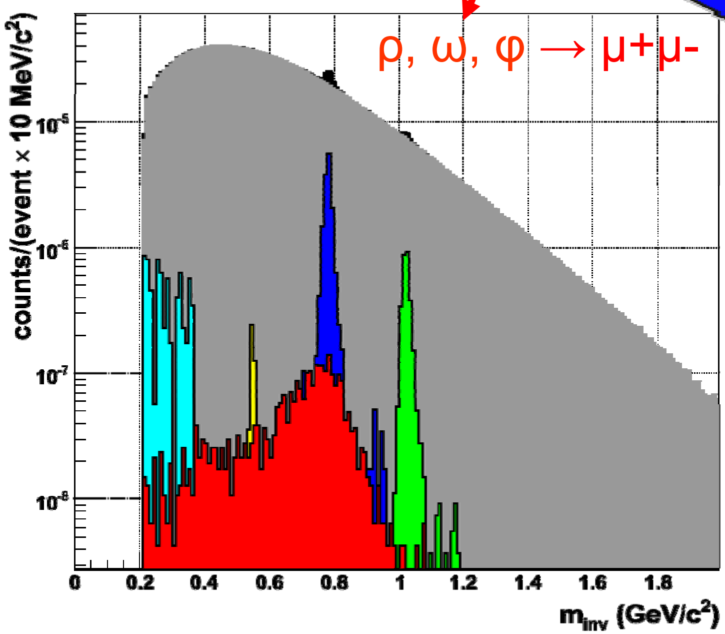


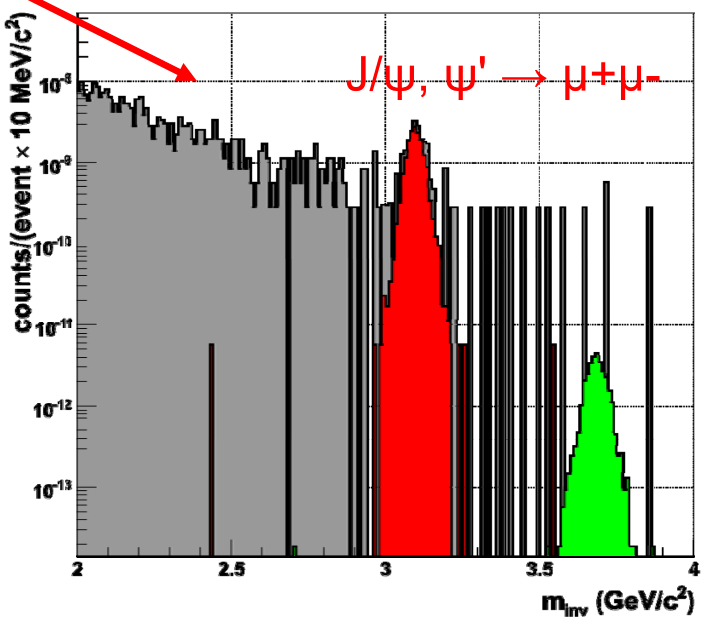
Vector meson identification via muon pairs in CBM



Central Au+Au collisions at 25 AGeV

particle	S/B	ε (%)	σ (MeV)
ω	0.11	4	10
φ	0.06	7	12
ρ	0.002	3	
J/ψ	18	13	21
Ψ'	1	16	27

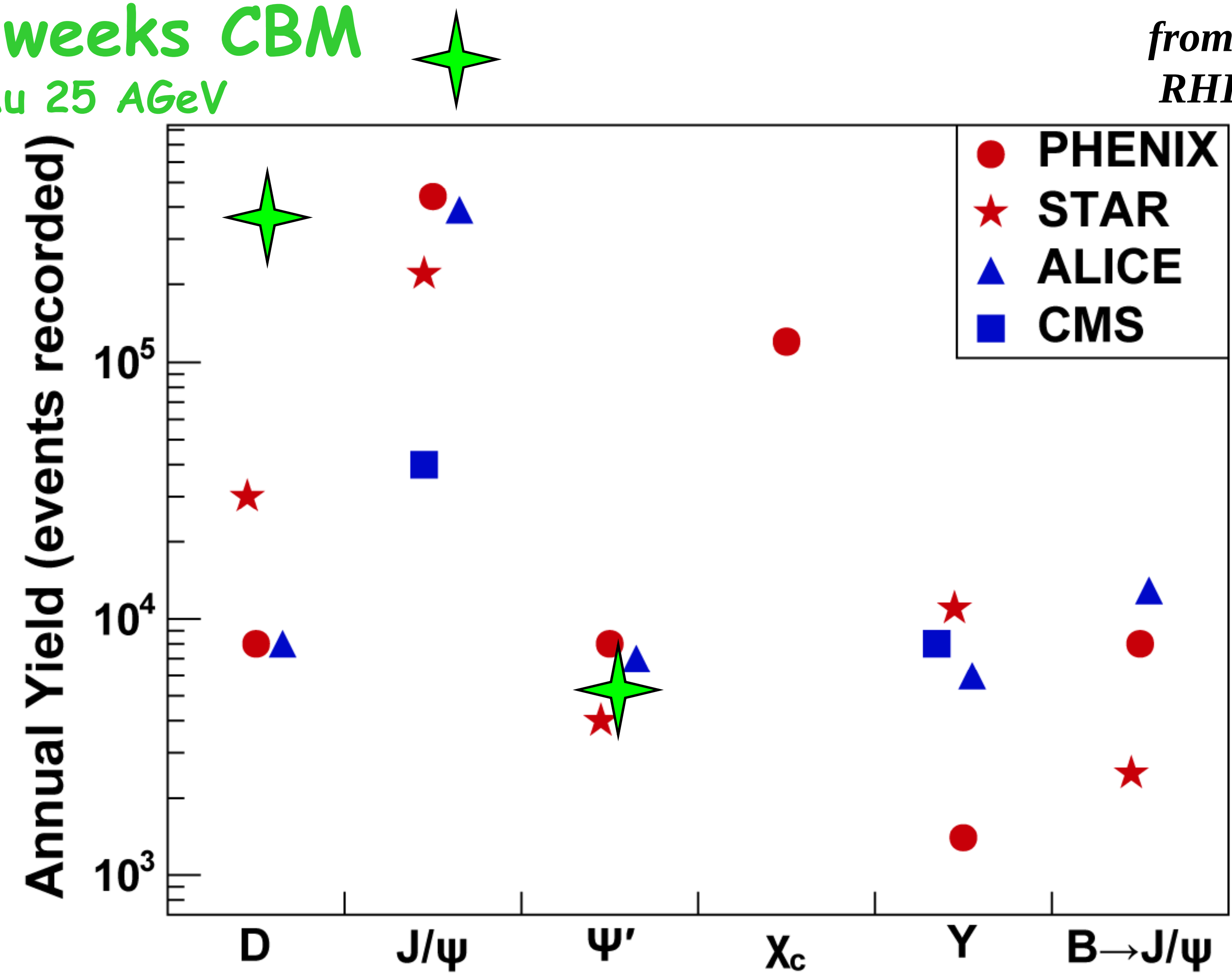




Annual yields at RHIC II & LHC

10 weeks CBM
Au+Au 25 AGeV

from Tony Frawley
RHIC Users mtg.



at LHC: (10-50) x σ ~10% of ℒ 25% running time

The CBM experimental program

Observables:

Open charm: D^o, $D^\pm$, D_s, Λ_c,
Charmonium: J/ψ, ψ' $\rightarrow$ e+e- (μ+μ-)
Dileptons from QGP, low-mass vector mesons: $\rho,\omega,\varphi \rightarrow$ e+e- (μ+μ-)
Strangeness: K, Λ, Σ, Ξ, Ω,
global features: collective flow, fluctuations, correlations ...

Systematic investigations:

A+A collisions from 8 to 45 (35) AGeV, Z/A=0.5 (0.4)
p+A collisions from 8 to 90 GeV
p+p collisions from 8 to 90 GeV
Beam energies up to 8 AGeV: HADES

Detector requirements

Large geometrical acceptance (azimuthal symmetry !)
good hadron and electron identification
excellent vertex resolution
high rate capability of detectors, FEE and DAQ

Large integrated luminosity:

High beam intensity and duty cycle,
Available for several month per year

CBM Collaboration : 52 institutions, ~ 400 Members

Croatia:
RBI, Zagreb
Split Univ.
China:
Wuhan Univ.
Hefei Univ.
Cyprus:
Nikosia Univ.
Czech Republic:
CAS, Rez
Techn. Univ. Prague
France:
IReS Strasbourg
Hungaria:
KFKI Budapest
Budapest Univ.

India:
Univ. Aligarh
IOP Bhubaneswar
Univ. Chandighar
Univ. Jaipur
Univ. Jammu
Univ. Srinagar
IIT Kharagpur
VECC Kolkata
SAHA Kolkata
Univ. Kolkata
Univ. Varanasi
Korea:
Korea Univ. Seoul
Pusan National Univ.
Norway:
Univ. Bergen

Germany:
Univ. Heidelberg, P.I.
Univ. Heidelberg, KIP
Univ. Frankfurt
Univ. Kaiserslautern
Univ. Mannheim
Univ. Münster
FZ Dresden
GSI Darmstadt
Poland:
Jag. 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 MSU, Moscow
St. Petersburg P. Univ.
Ukraine:
Shevshenko Univ. , Kiev


CBM Collaboration Meeting in Strasbourg Sept. 2006