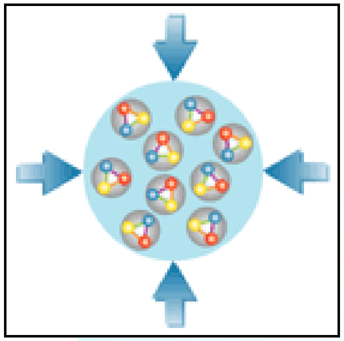


CBM

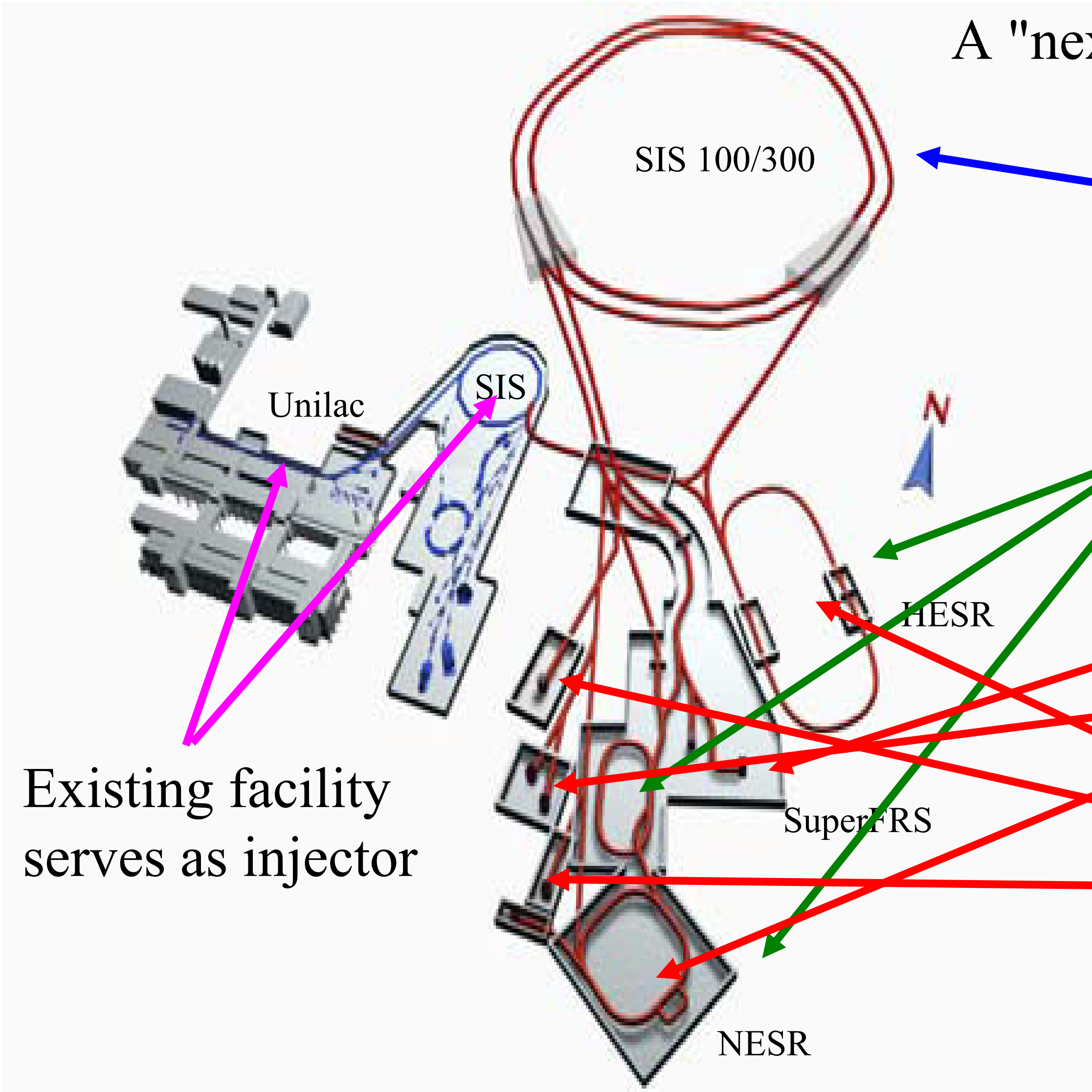
Relativistiv heavy-ion physics at FAIR

V. Friese

Gesellschaft für Schwerionenforschung
Darmstadt, Germany
v.friese@gsi.de

The QCD phase diagram : From theory to experiment
International Symposium, Skopelos, May 2004

The future at GSI : FAIR



Existing facility serves as injector

A "next generation" accelerator facility:

Double-ring synchrotron
1100 m circumference
100 / 300 Tm

Cooler/Storage rings
(CR, NESR, HESR)

Experimental areas for:

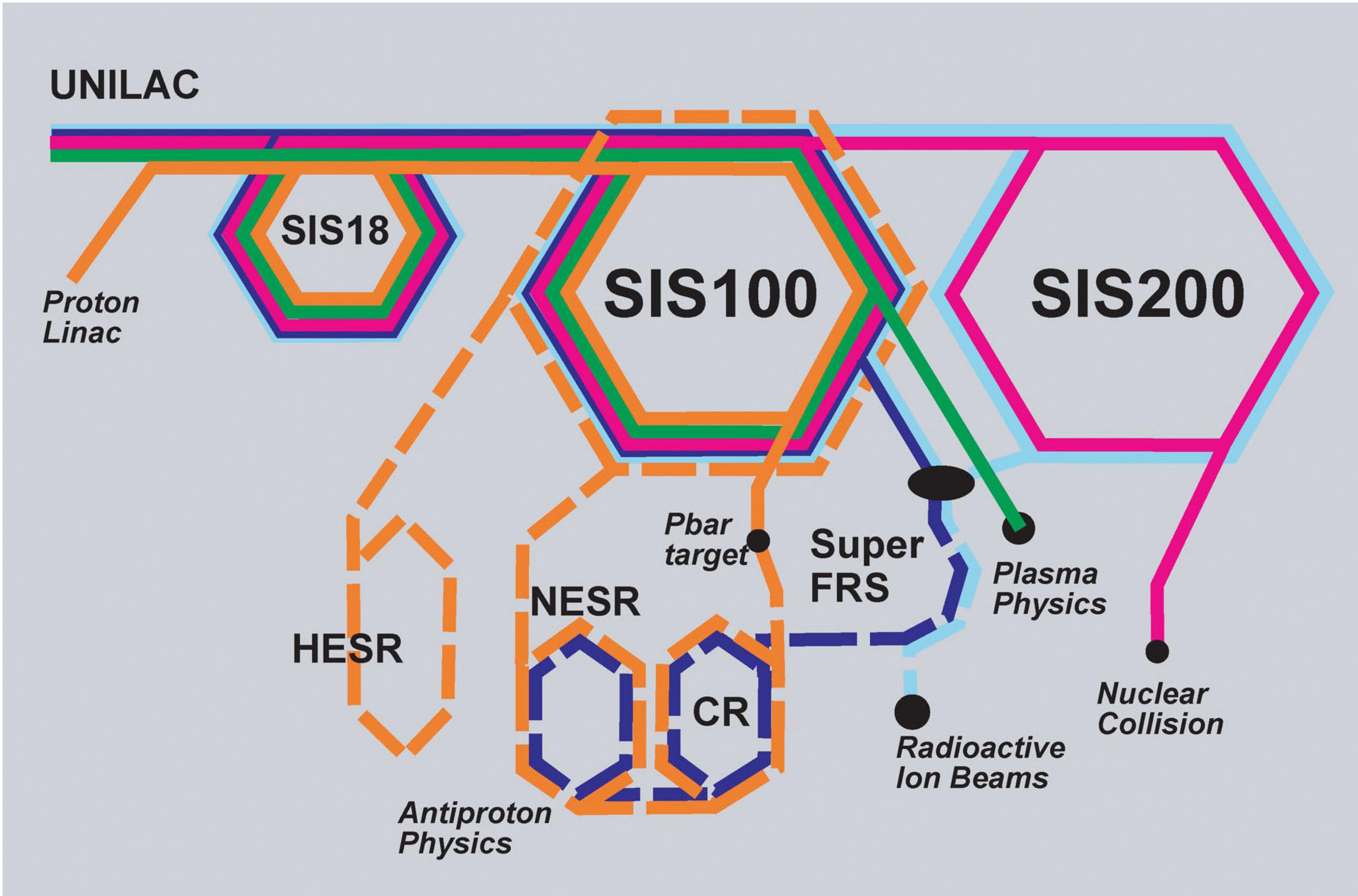
- nuclear structure
- plasma physics
- antiproton physics
- nuclear collisions
- atomic physics

Design Goals

- Higher beam energies: 35 AGeV for heavy ions, 45 AGeV for light ions
- Highest beam intensities : 10^9 U / s continuous, 10^{12} U pulsed
- Excellent beam quality
- Parallel operation for different physics programmes :

  - Particle physics
    charm spectroscopy, glueballs
  - Nucleus-nucleus collisions
    QCD phase diagram, compressed baryonic matter
  - Nuclear structure
    nuclei far from stability, nucleosynthesis
  - Plasma physics
    bulk high-density matter, inertial fusion
  - Atomic physics
    high precision studies of QED in extremely strong fields

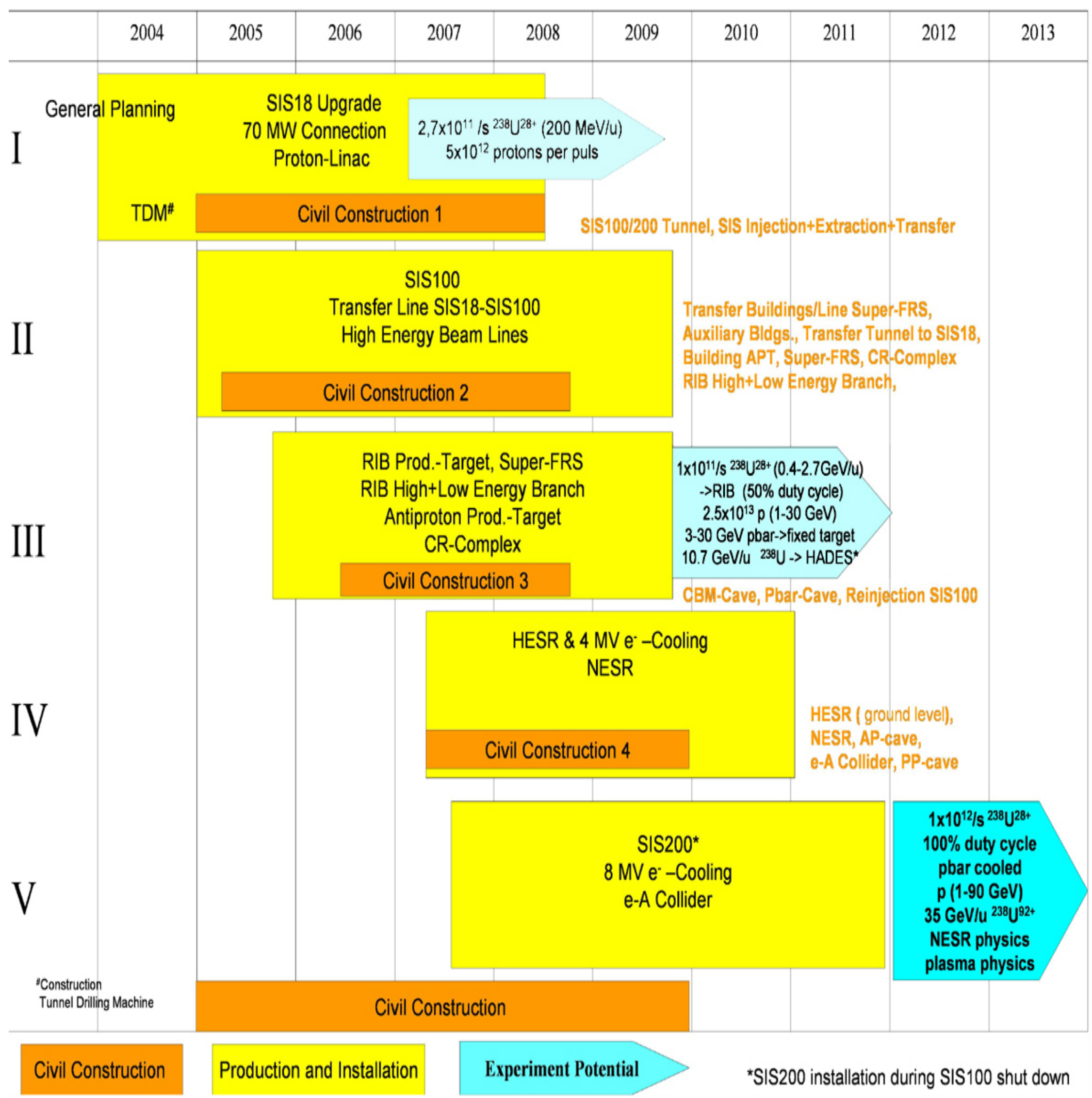
Parallel operation



Project Status

November 2001	Conceptual Design Report Cost estimate 675 M €
July 2002	German Wissenschaftsrat recommends realisation
February 2003	German Federal Gouvernment decides to build the facility. Will pay 75 %
January / April 2004	Letters of Intent submitted

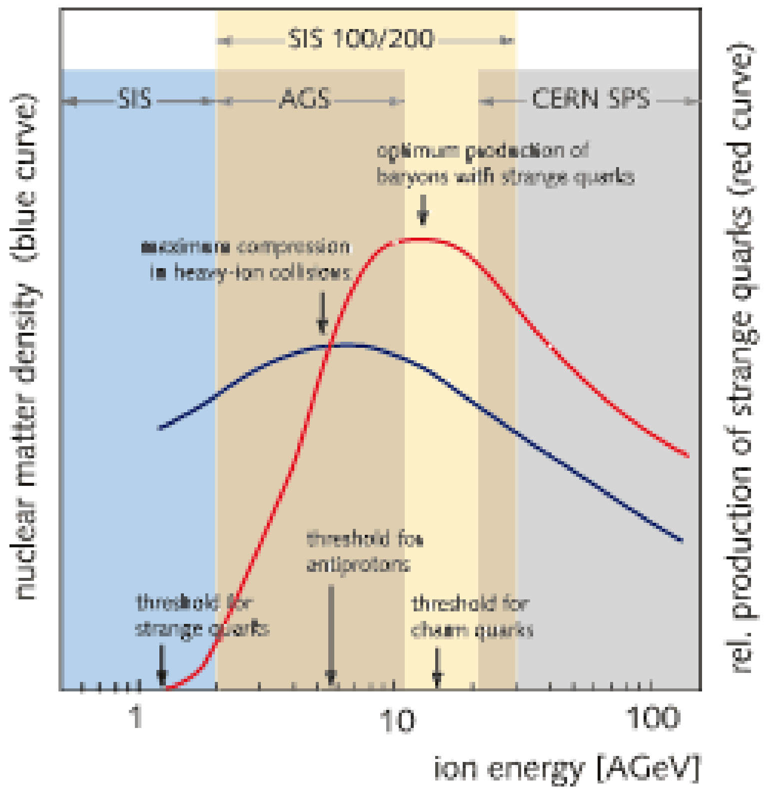
Timescale

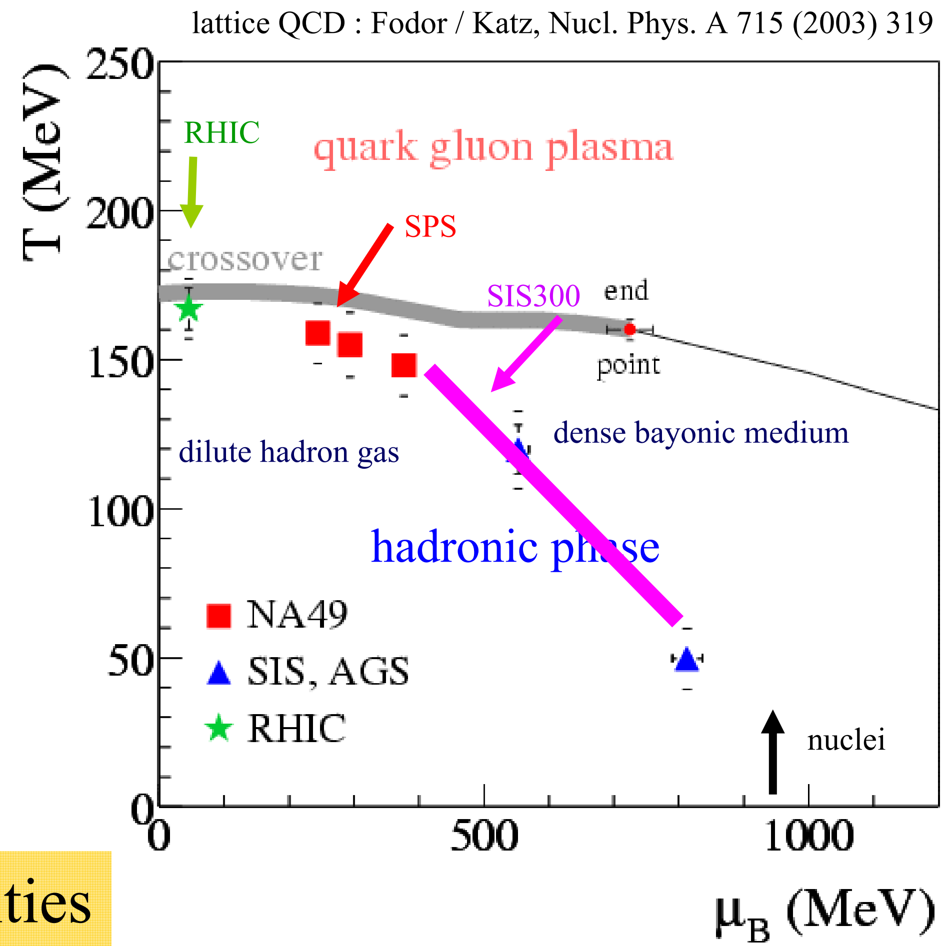


2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
I
General Planning
SIS18 Upgrade
70 MW Connection
Proton-Linac
2,7x10^11 /s 238U28+ (200 MeV/u)
5x10^12 protons per puls
TDM#
Civil Construction 1
SIS100/200 Tunnel, SIS Injection+Extraction+Transfer
II
SIS100
Transfer Line SIS18-SIS100
High Energy Beam Lines
Civil Construction 2
Transfer Buildings/Line Super-FRS,
Auxiliary Bldgs., Transfer Tunnel to SIS18,
Building APT, Super-FRS, CR-Complex
RIB High+Low Energy Branch,
III
RIB Prod.-Target, Super-FRS
RIB High+Low Energy Branch
Antiproton Prod.-Target
CR-Complex
Civil Construction 3
1x10^11/s 238U28+ (0.4-2.7GeV/u)
->RIB (50% duty cycle)
2.5x10^13 p (1-30 GeV)
3-30 GeV pbar->fixed target
10.7 GeV/u 238U -> HADES*
CBM-Cave, Pbar-Cave, Reinjection SIS100
IV
HESR & 4 MV e- –Cooling
NESR
Civil Construction 4
HESR (ground level),
NESR, AP-cave,
e-A Collider, PP-cave
V
SIS200*
8 MV e- –Cooling
e-A Collider
1x10^12/s 238U28+
100% duty cycle
pbar cooled
p (1-90 GeV)
35 GeV/u 238U92+
NESR physics
plasma physics
#Construction
Tunnel Drilling Machine
Civil Construction
Civil Construction
Production and Installation
Experiment Potential
*SIS200 installation during SIS100 shut down

Bad prospects for the trees...

The Future GSI and the QCD Phase Diagram

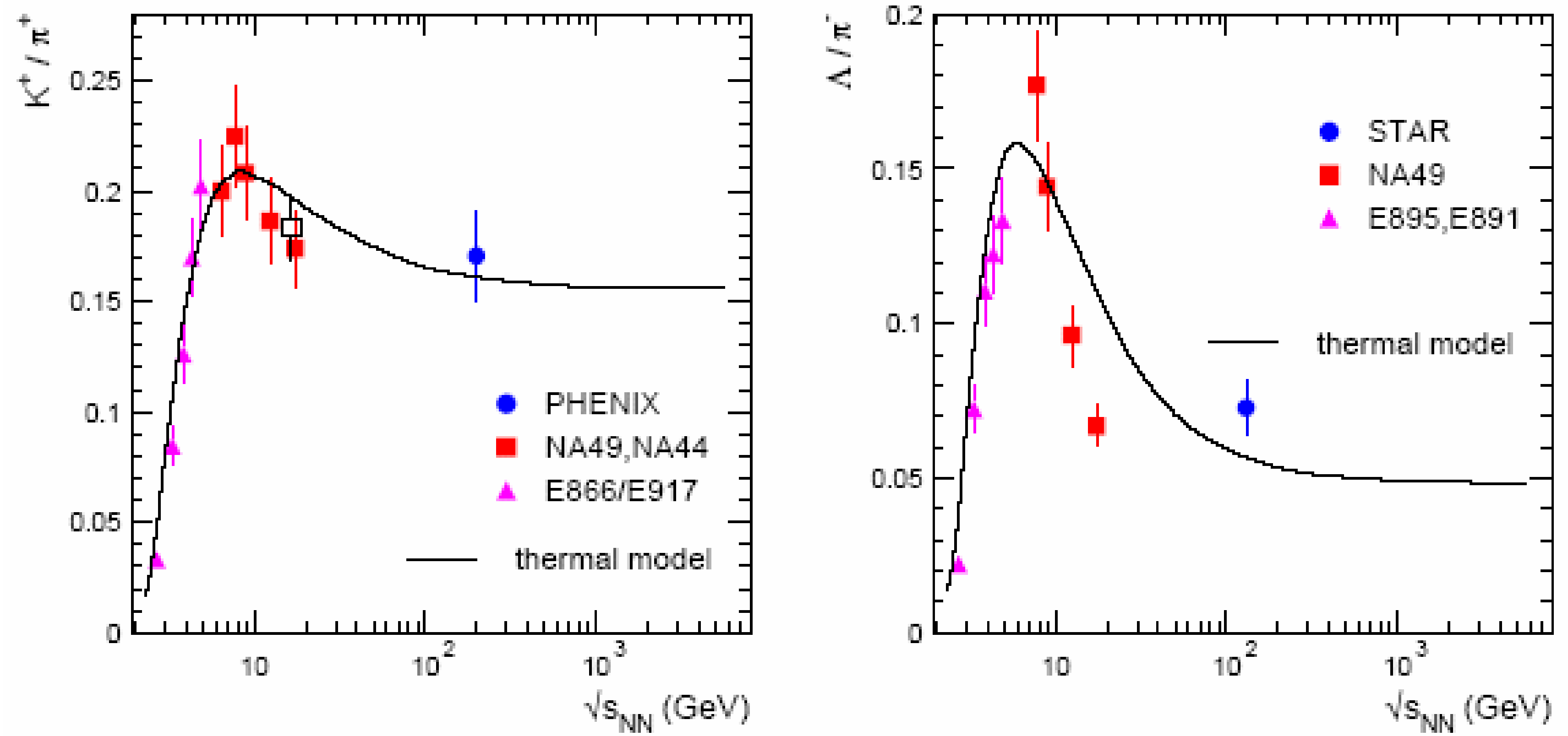




... operating at highest baryon densities
... reaching deconfinement ?
... close to the critical point ?

What do we know : Strangeness production

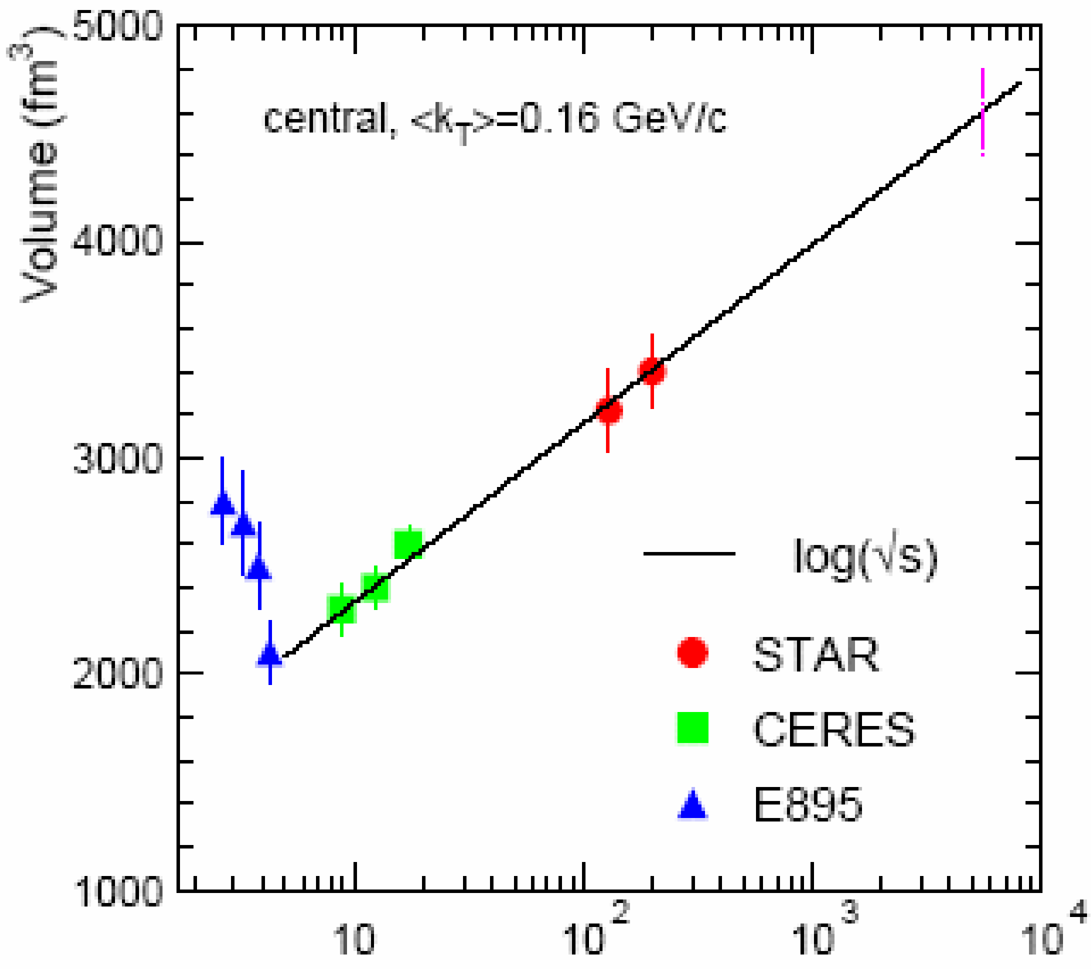
A. Andronic, p. Braun-Munzinger, hep-ph/0402291



Sharp structure in strangeness to pion ratio at low SPS energies

Failure of thermal models ?

What do we know : Reaction volume

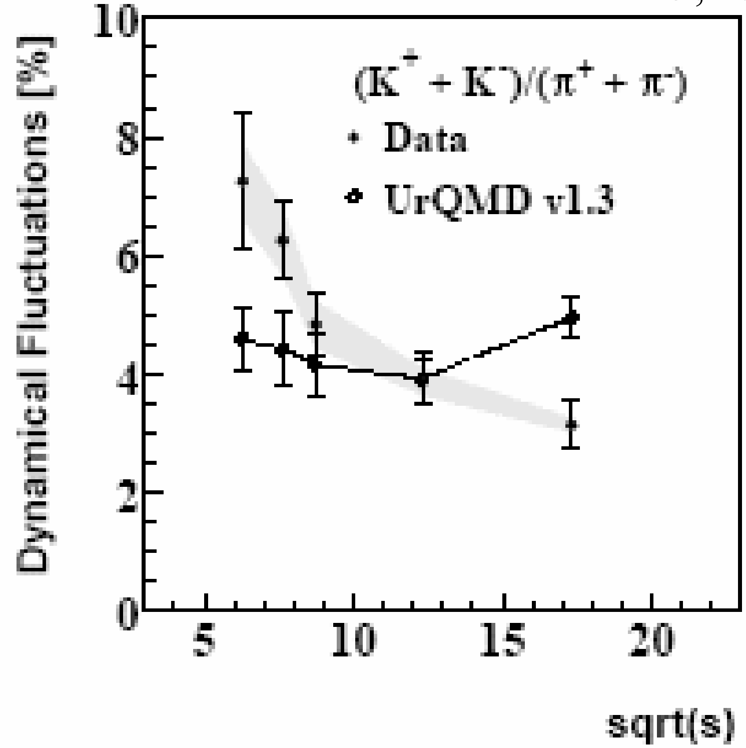


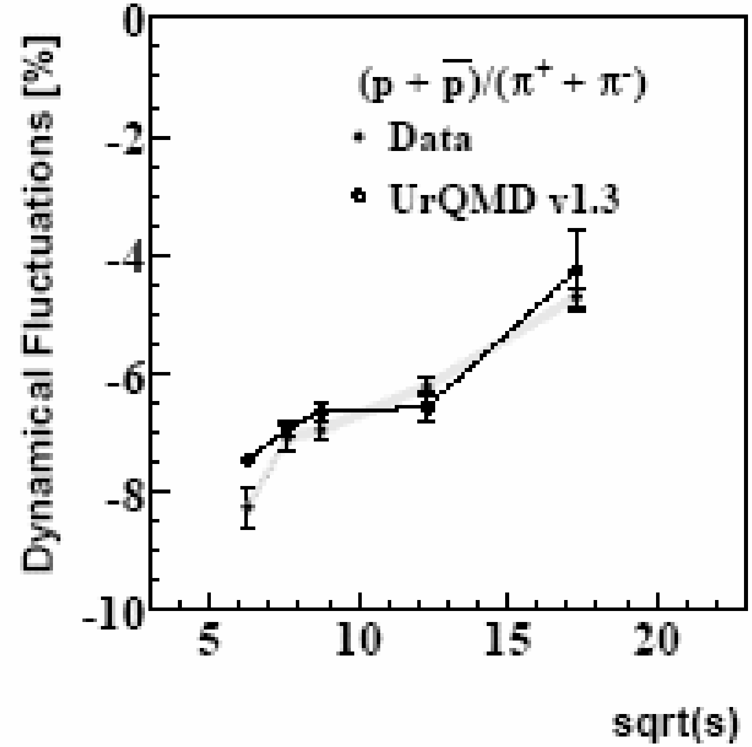
CERES, PRL 90(2003) 022301

volume extracted from pion HBT
exhibits non-monotonic behaviour

What do we know: Fluctuations

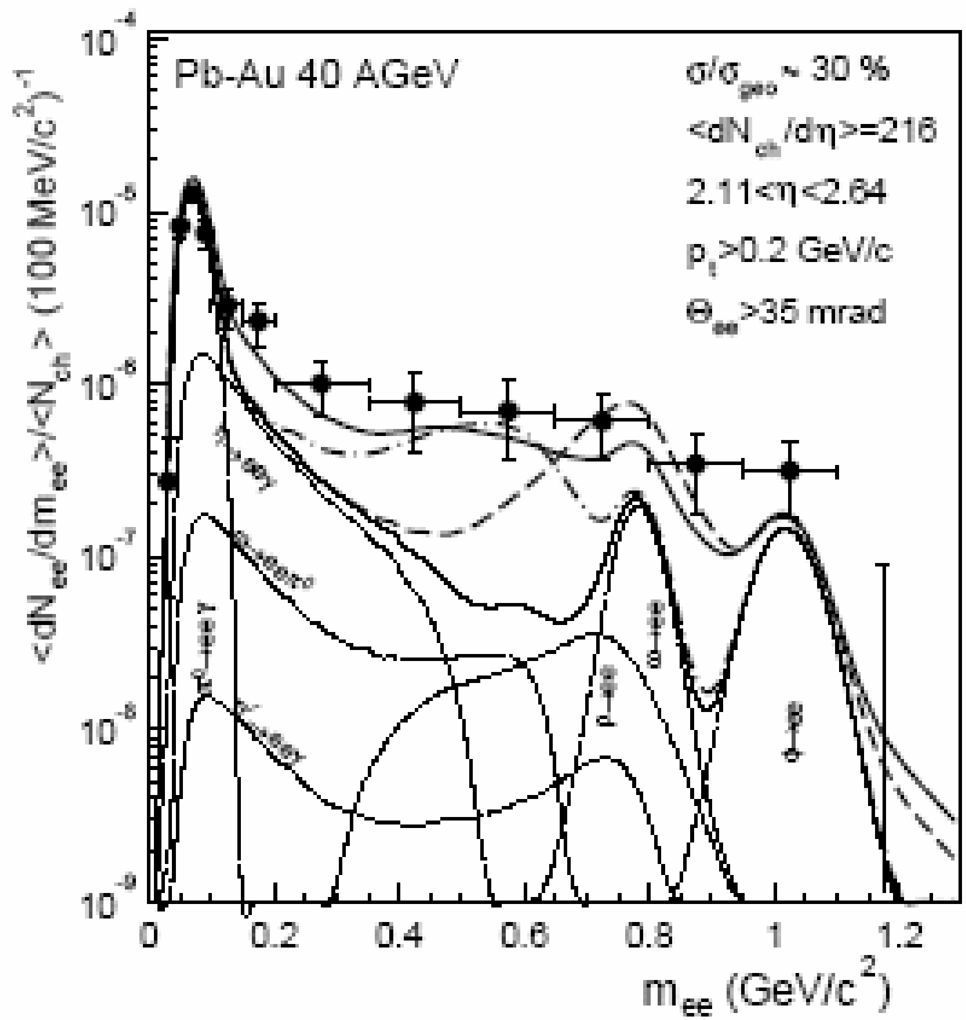
NA49, nucl-ex/0403035





- dynamical fuctuations reported by NA49
- increase towards low energies
- K/π : not reproduced by UrQMD
- p/π : correlation due to resonance decays

What we do know : Low-mass dileptons



CERES, PRL91 (2003) 042301

are enhanced more at 40 AGeVthan at 158 AGeV

in-medium ρ could explain the enhancement

measurements need to be refined and carried out at lower energies

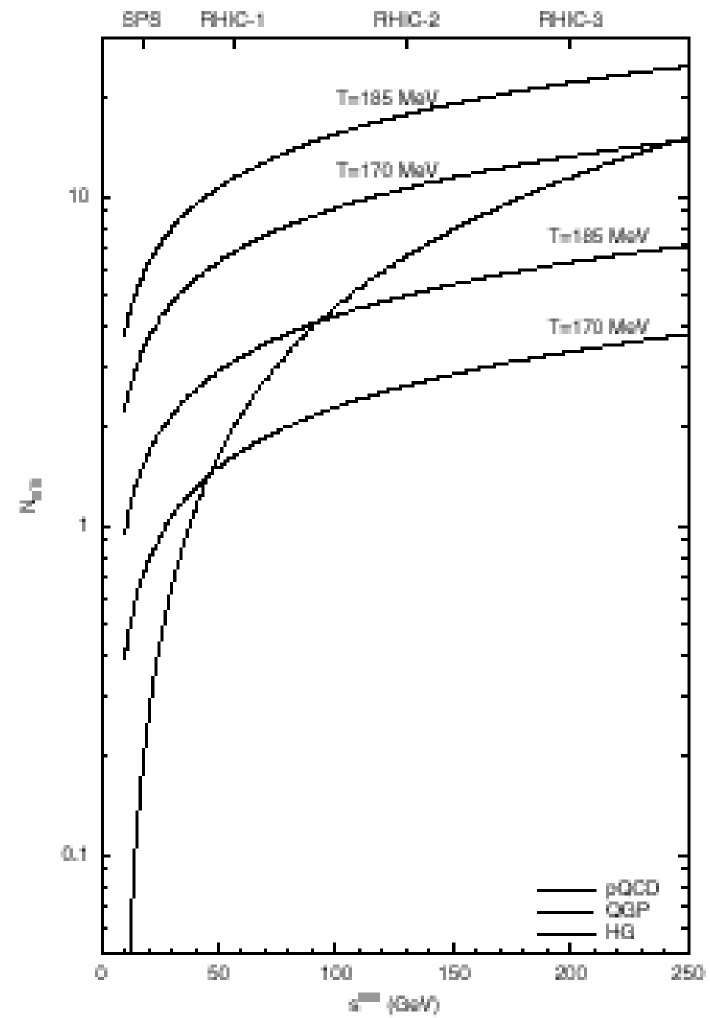
What we do not know: Charm production near threshold

Soft A dependence : $\langle D \rangle \sim \langle h^- \rangle \sim N_p$

pQCD : $\langle D \rangle \sim A^2 \sim N_p^{4/3}$

Hadron gas in chemical equilibrium
Canonical suppression analoguous to strangeness

Equilibrated QGP
+ statistical coalescence

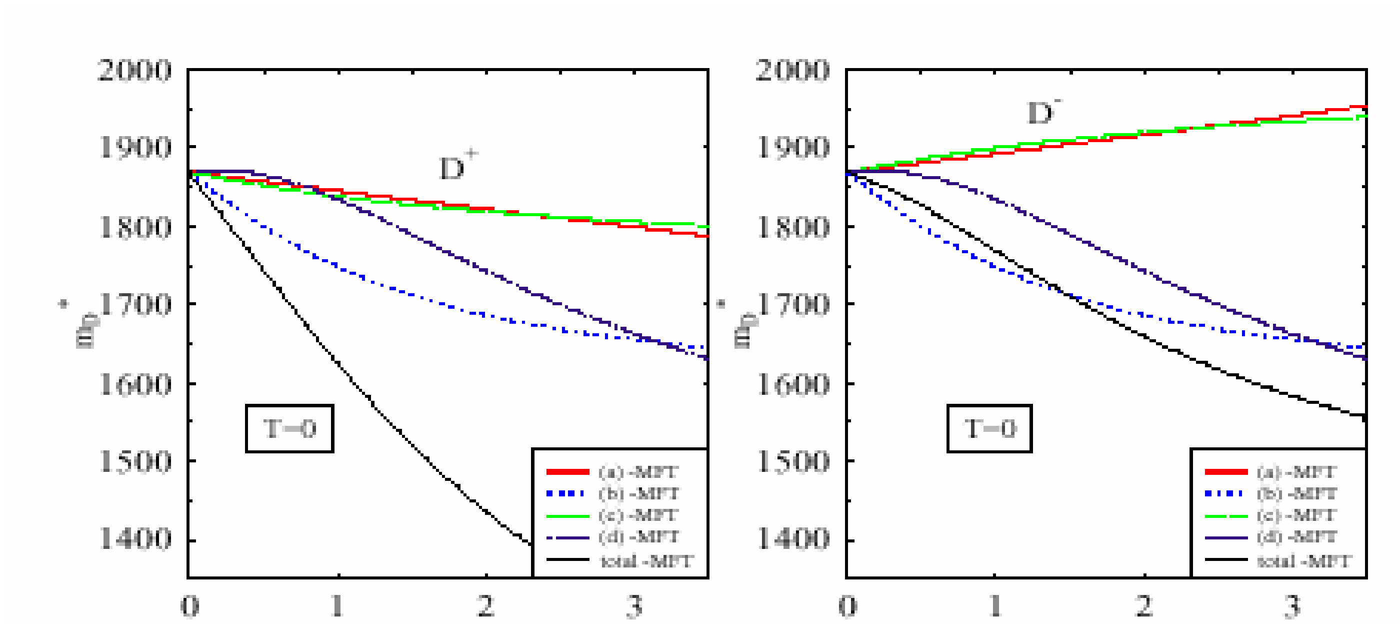


Gorenstein et al
J. Phys. G 28 (2002) 2151

Predictions of open charm yield differ by orders of magnitude for different production scenarios, especially at low energies

What we do not know: Open charm in dense matter

Various QCD inspired models predict a change of D mass in hadronic medium



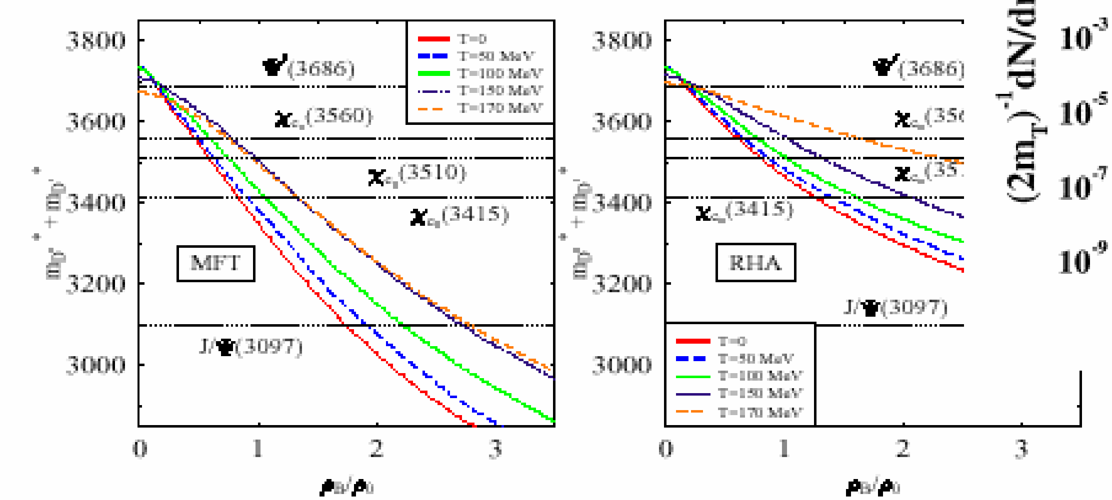
Mishra et al, nucl-th/0308082

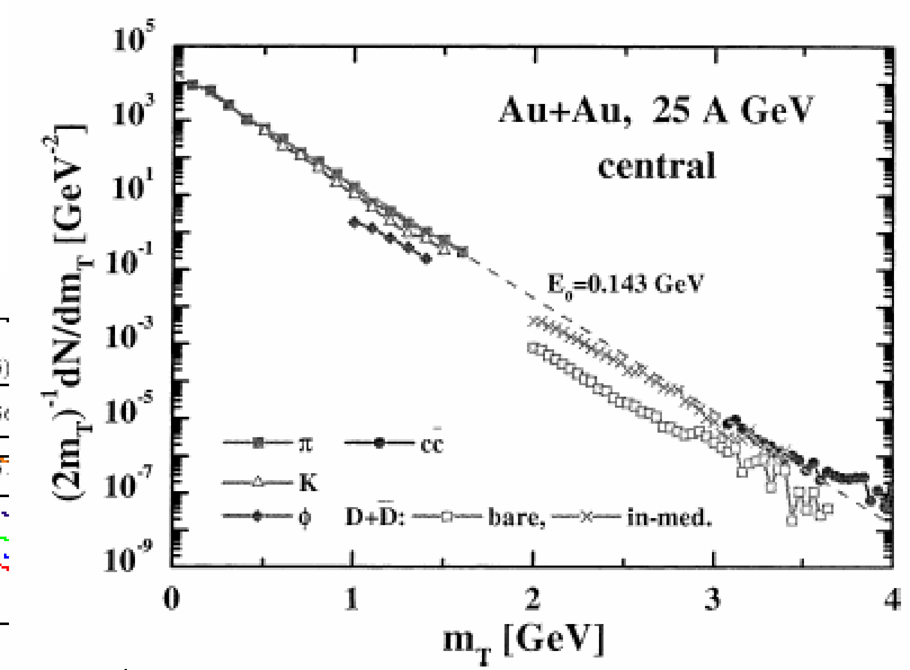
Substantial change (several 100 MeV) already at $\rho=\rho_0$
In analogy to kaon mass modification, but drop for both D^+ and D^-
Effect for charmonium is substantially smaller

Reduced D meson mass : consequences

If the D mass is reduced in the medium: DD threshold drops below charmonium states

Mishra et al, nucl-th/0308082





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

Decay channels into DD open for ψ', χ_c, J/Ψ
→ broadening of charmonium states
→ suppression of J/Ψ
→ enhancement of D mesons

HSD : D yield enhanced by a factor of 7 at 25 AGeV!

Physcis Topics and Observables

1. Indications for deconfinement at high ρ_B
   - enhanced strangeness production ?
     $K, \Lambda, \Sigma, \Xi, \Omega$
   - charm production ?
     J/ψ, D
   - softening of EOS
     measure flow excitation function
2. In-medium modifications of hadrons
   - onset of chiral symmetry restoration at high ρ_B
     $\rho, \omega, \phi \rightarrow e^+e^-$
     open charm
3. Critical point
   - event-by-event fluctuations

The good...

High beam intensity, quality and duty cycle
High availability due to parallel operation of accelerator

⇒ Possibility of systematic measurements:
beam energy (10 – 35/45 AGeV)
system size
even of very rare probes!

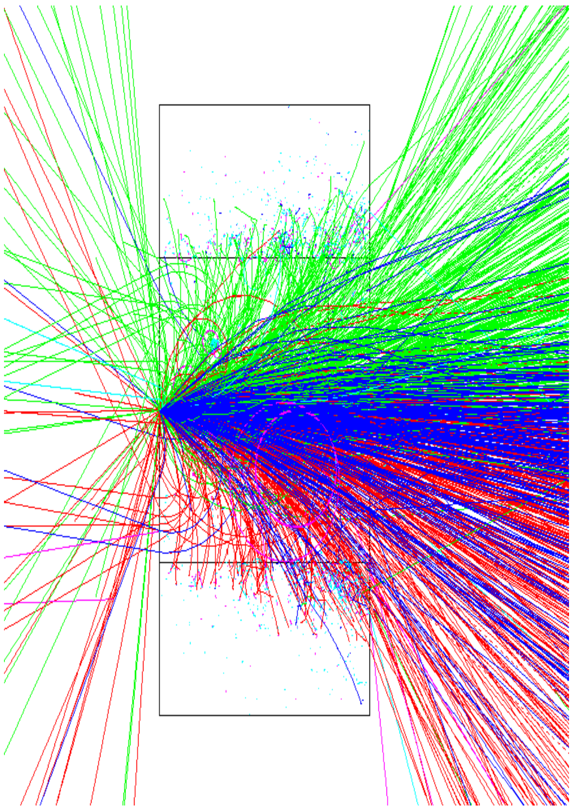
...the bad...

Only one slot for relativistiv nuclear collisions at future GSI

⇒ Build an "universal experiment" for both hadronic and leptonic probes, covering as many obervables as possible

...and the ugly

Au+Au @ 25 AGeV

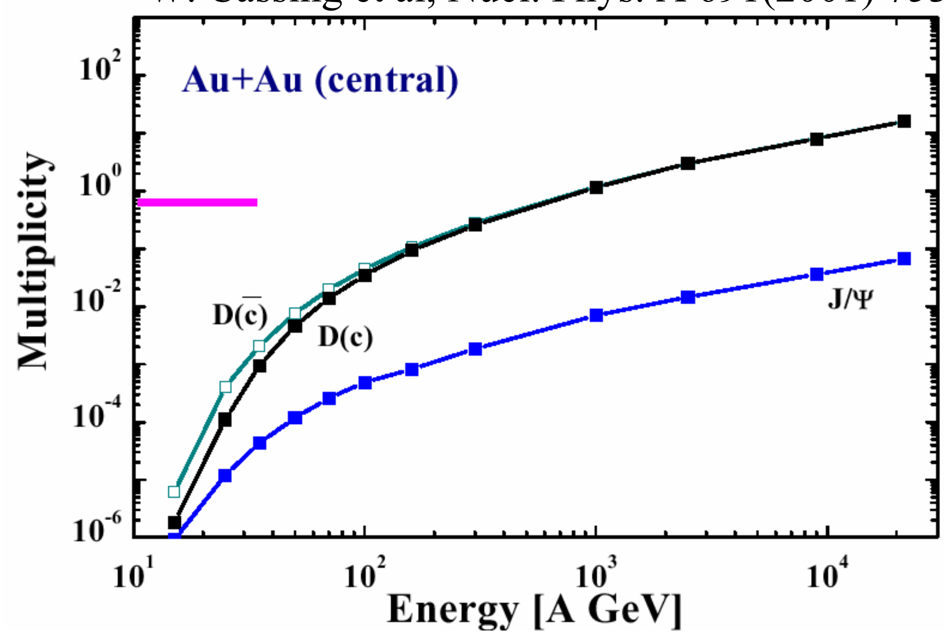


Rare probes in a heavy-ion environement:

charged muliplicity ≈ 1000

D multiplicity $10^{-4} – 10^{-3}$

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



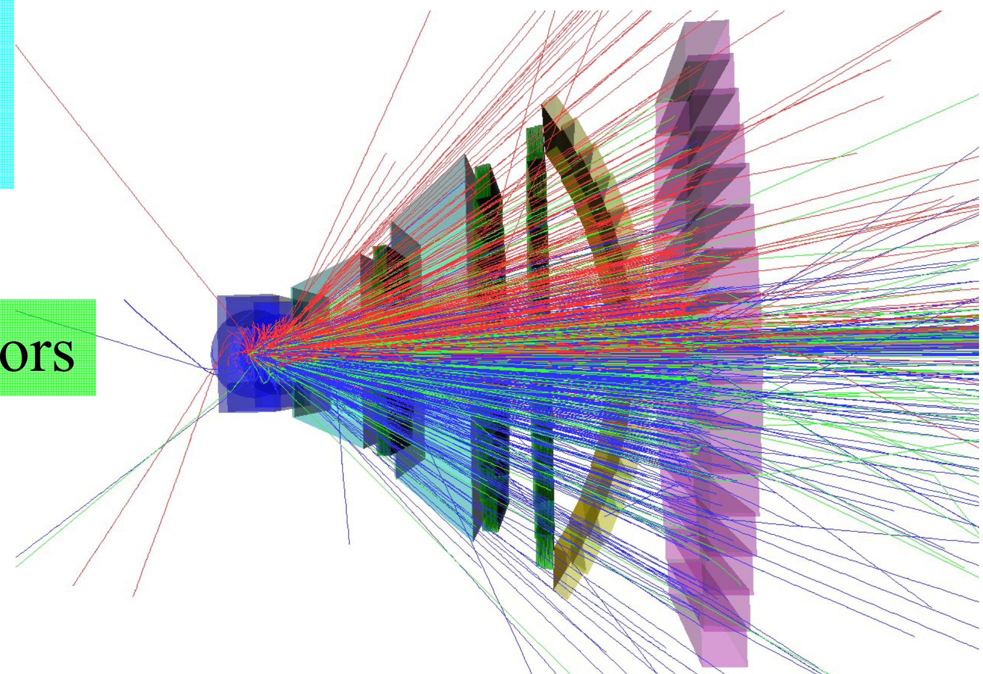
need : high event rates

highly selective trigger

Conditions and requirements

High track multiplicity (700-1000)
Beam intensity 10^9 ions/sec.
High interaction rate (10 MHz)

central Au+Au @ 25 AGeV, UrQMD + GEANT

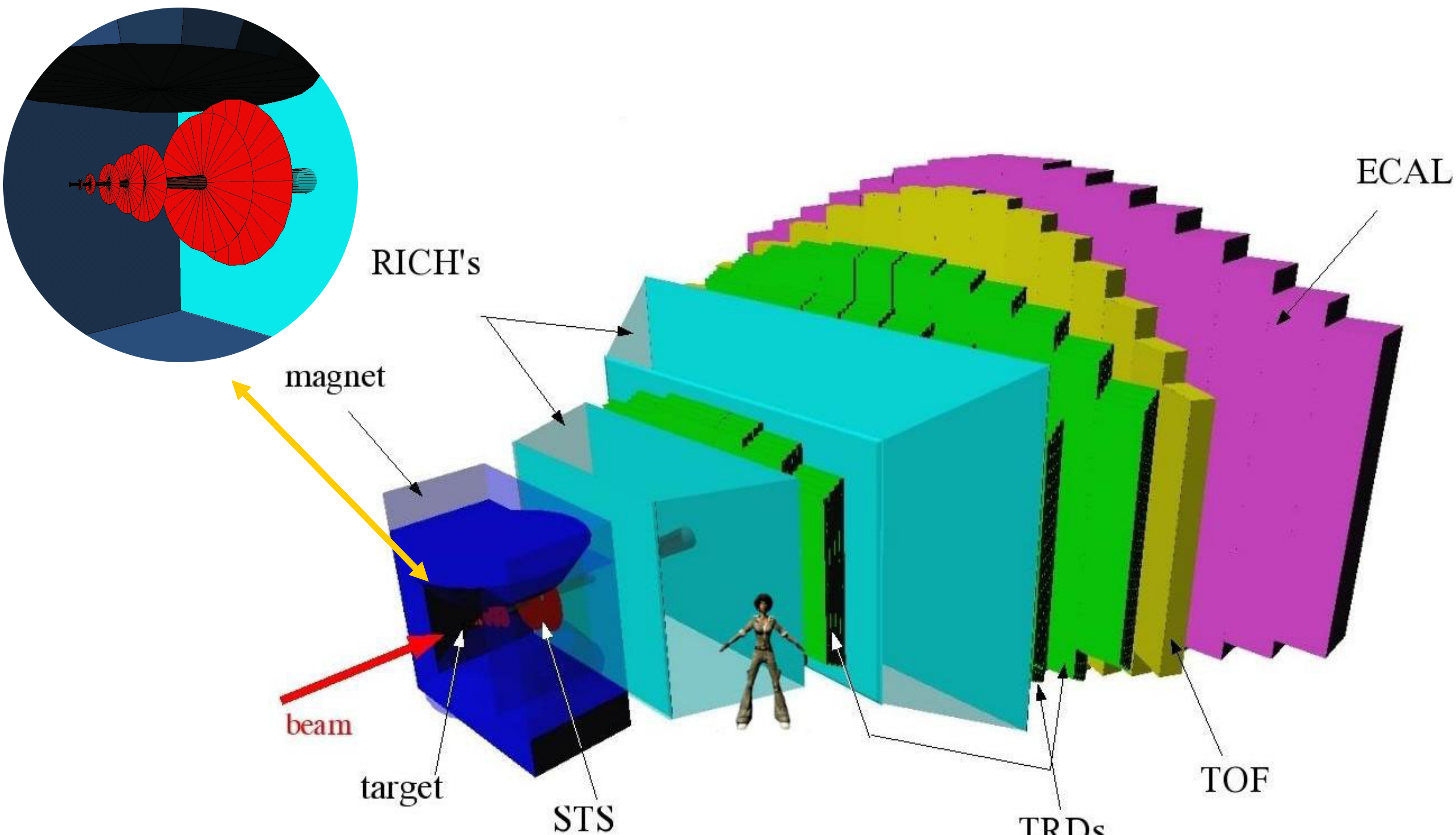


Need fast and radiation hard detectors

Detector tasks:

Tracking in high-density environment	STS + TRD
Reconstruction of secondary vertices (resolution ≈ 50 μm)	STS
Hadron identification : π / K / p separation ($\sigma_t \approx 80$ ps)	TOF
Lepton identification : π / e separation (pion suppression 10^{-4})	TRD + RICH
Myon / photon measurements	ECAL

The CBM detector : a strawman concept



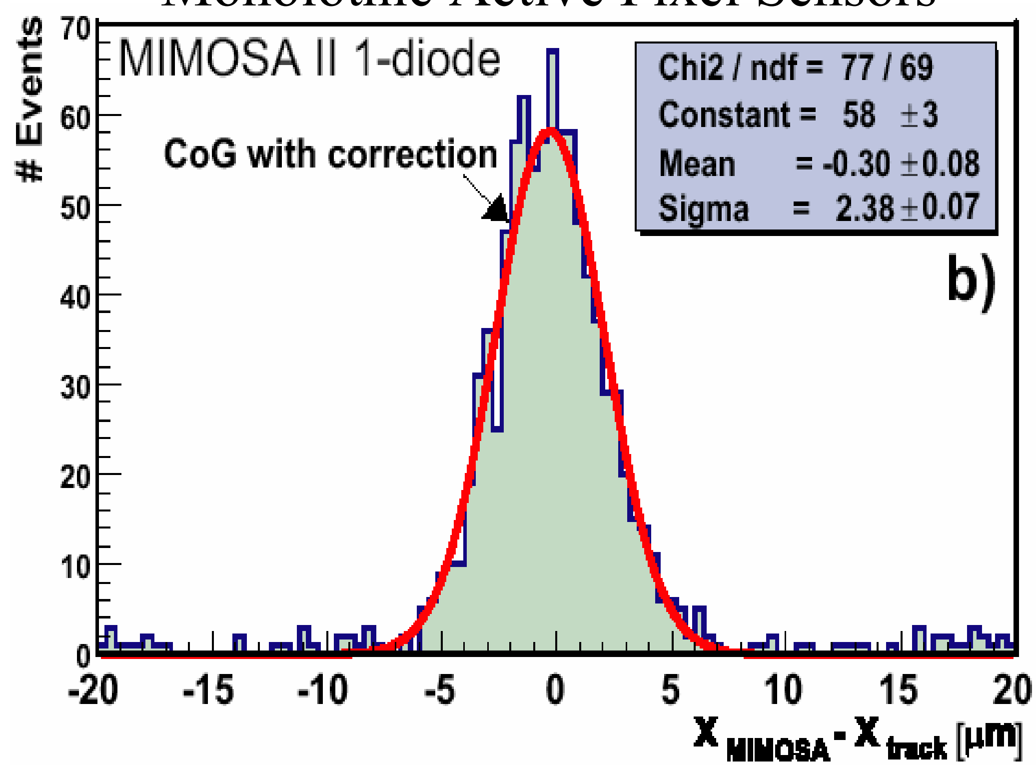
Setup in GEANT4

Tracking System

Requirements:

- Radiation hardness
- Low material budget
- Fast detector response
- Good positon resolution

Monolothic Active Pixel Sensors



Solution for outer stations:
fast strip detectors

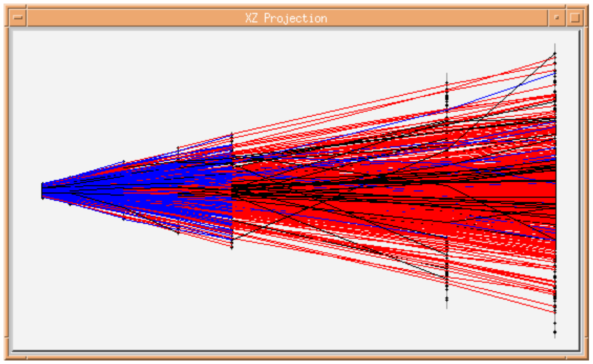
Pitch 20 μm

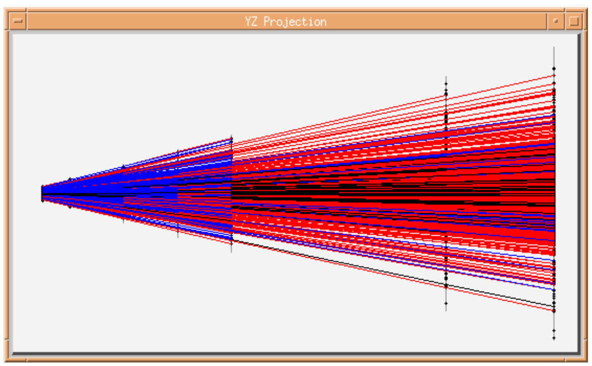
Low material budget : Potentially d = 20 μm

Excellent single hit resolution : ≈ 3 μm

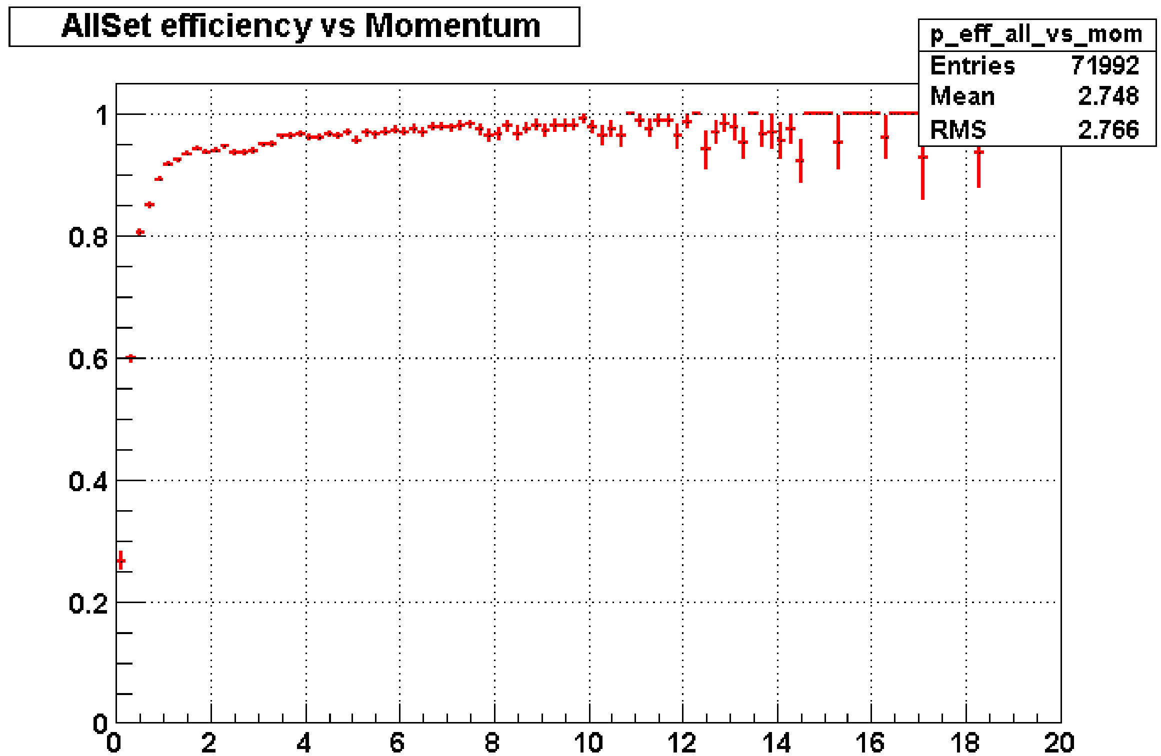
S/N = 20 - 40

Tracking





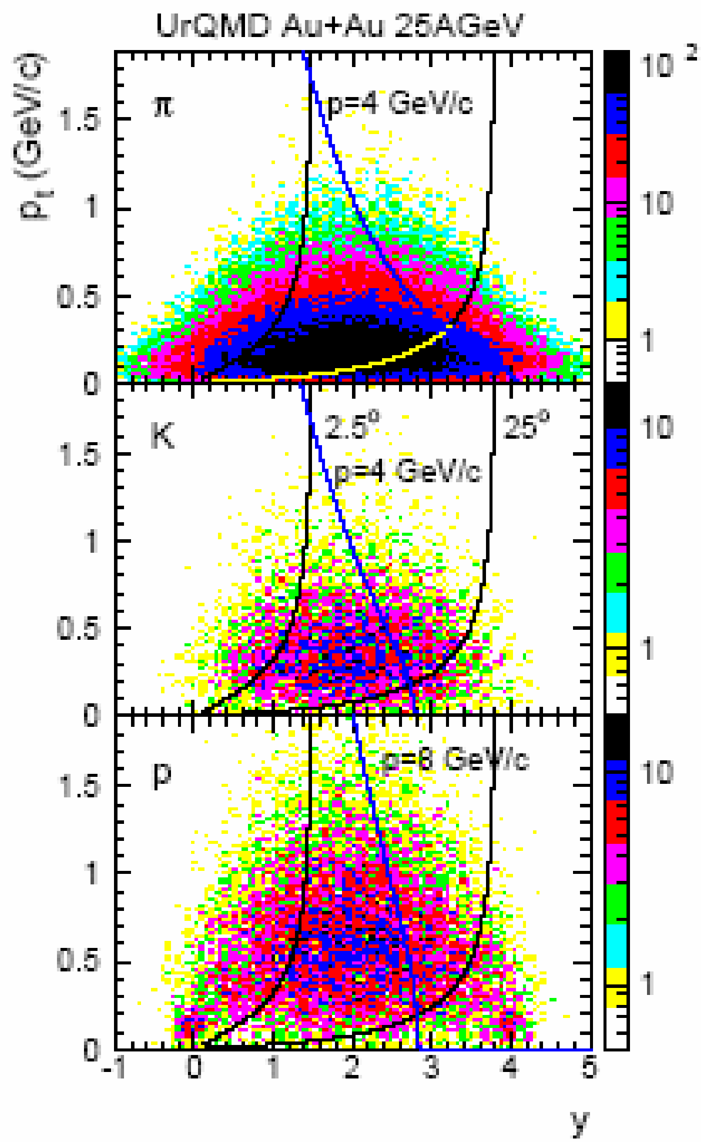
reconstructed tracks



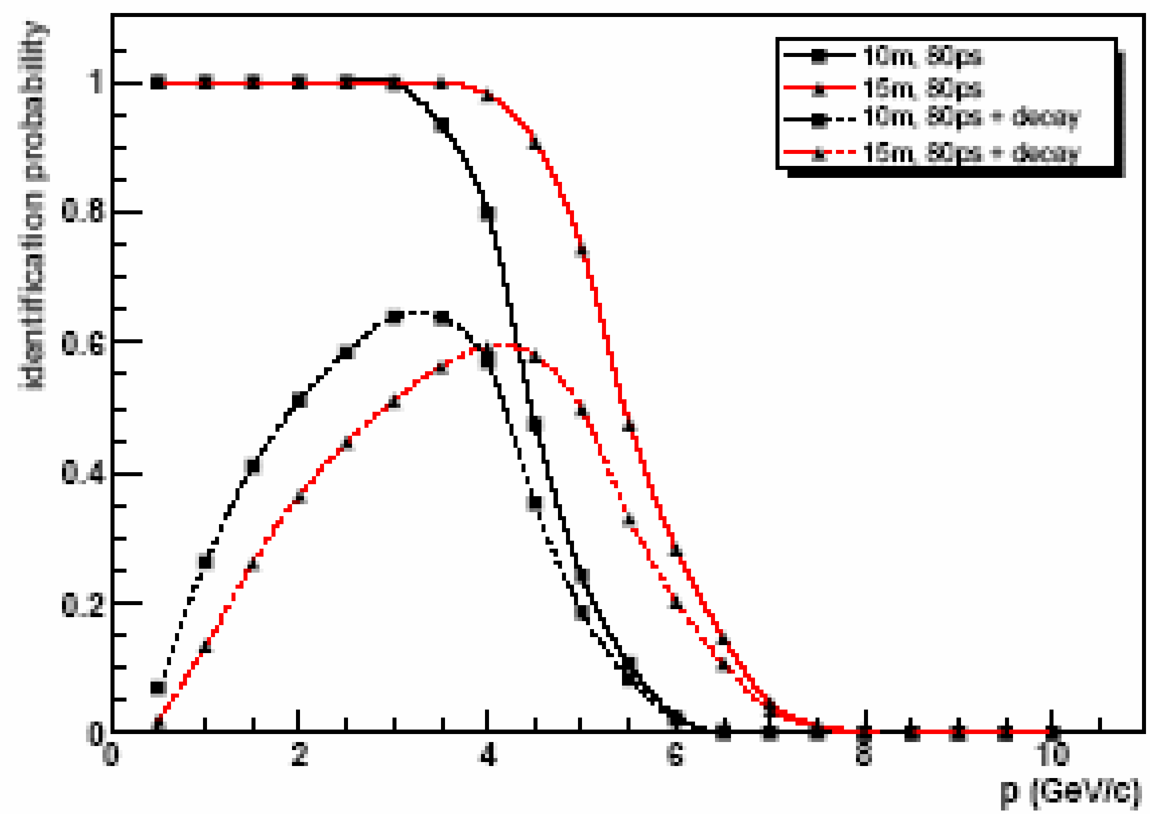
Reconstruction efficiency > 95 %
Momentum resolution ≈ 0.6 %

Event pile-up in first tracking stations (MAPS) not yet solved

Hadron identification



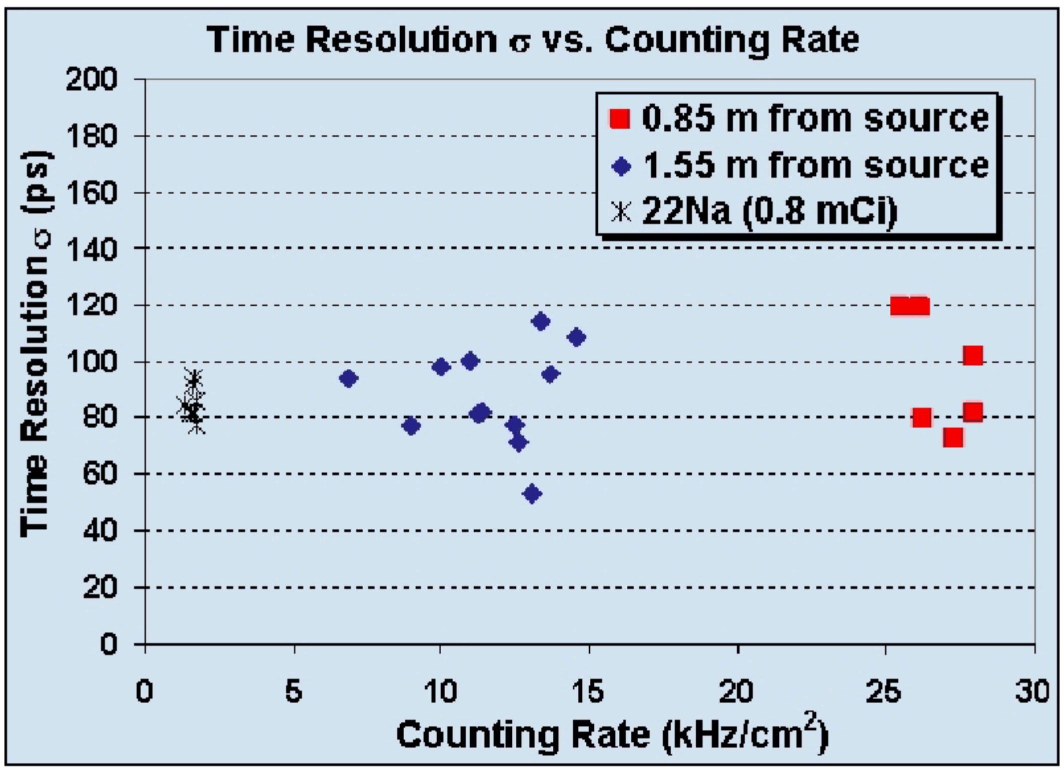
σ_{TOF} = 80 ps



Bulk of kaons (protons) can well be identified with σ_{TOF} = 80 – 100 ps

RPC developments for TOF

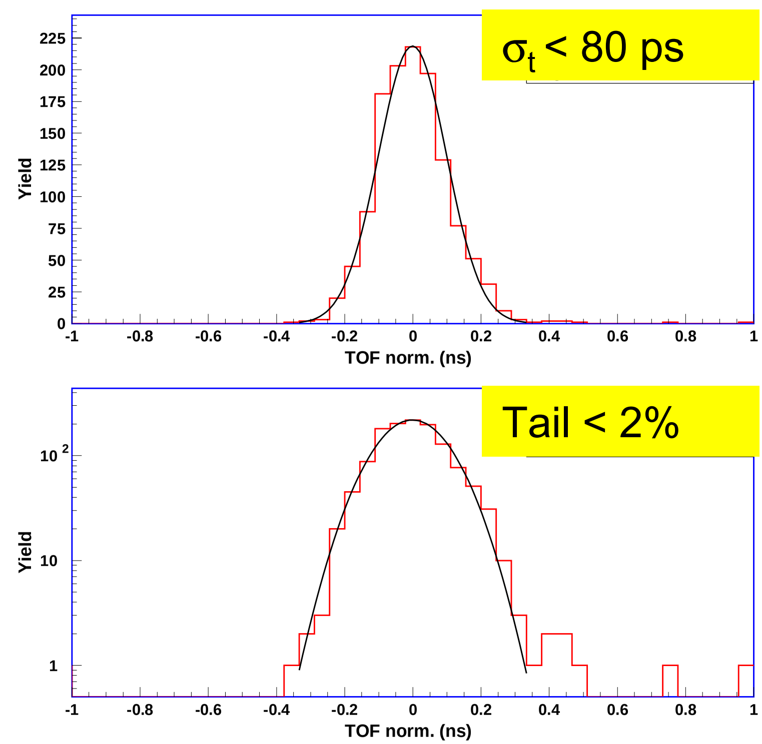
Challenge for TOF : Huge counting rate (25 kHz/cm^2)
Large area (130 m^2 @ 10 m)



R&D FOPI Upgrade

Detector resolution

90 cm-14 strips-4 gaps



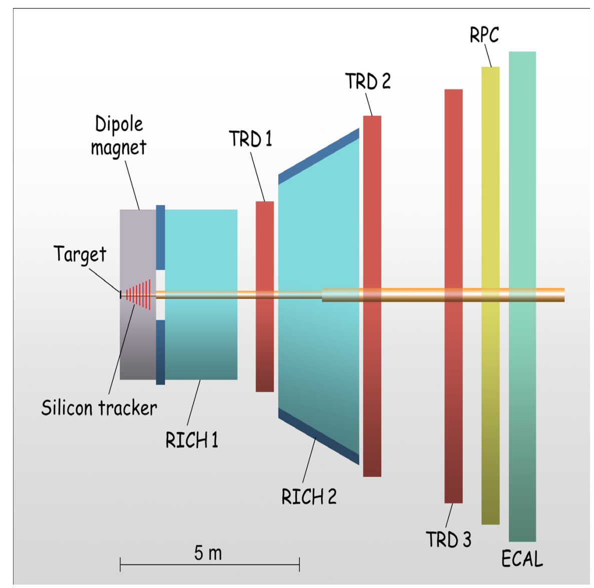
TRD

Duties
- e/π separation
- tracking

Requirements
- hit rate up to 500 kHz per cell
- fast readout (10 MHz)

Anticipated setup
- 9 layers in three stations (z = 4m / 6m / 8m)
- area per layer 25 / 50 / 100 m^2
- channels per layer 35 k / 55 k / 100 k

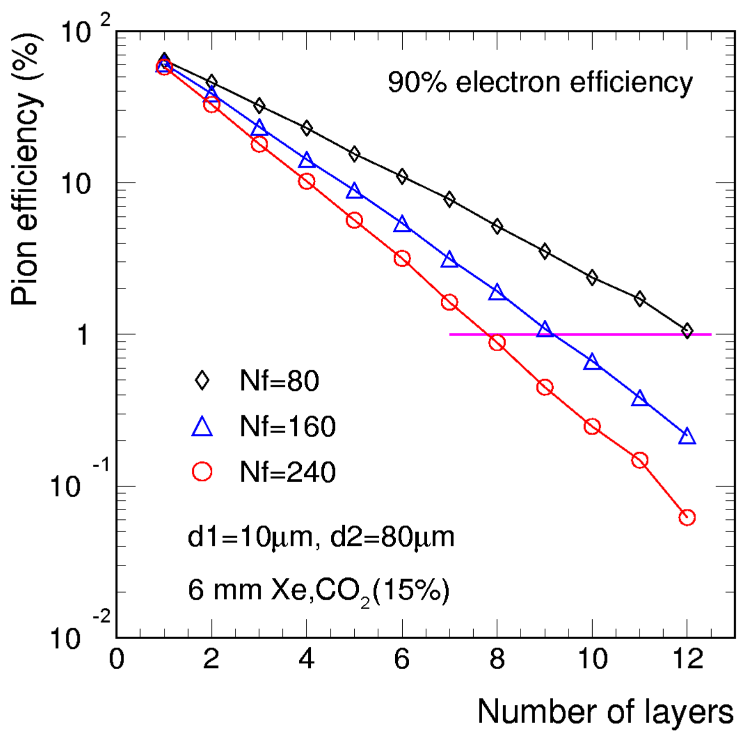
For most of the system state-of-the art (ALICE) is appropriate.
For the inner part, R&D on fast gas detectors in progress

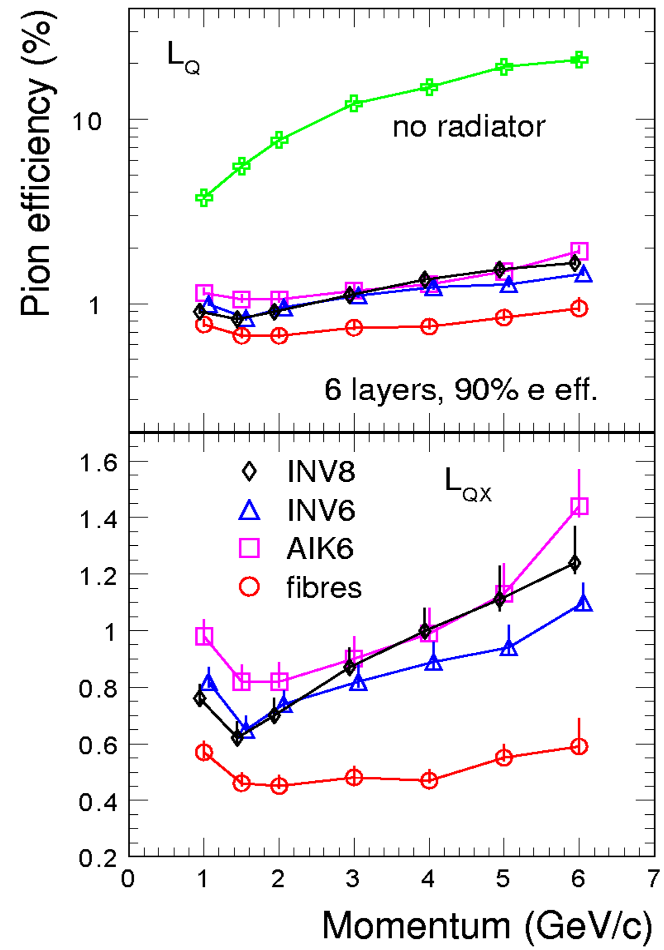


Readout options : drift chamber / GEM / straw tubes

TRD

Wire chamber readout studied at GSI requires small drift times → thin layers → more layers





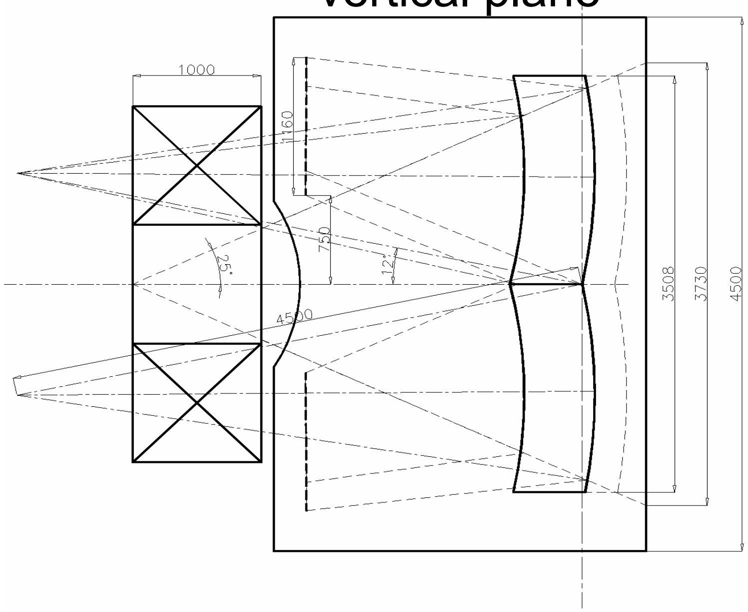
Pion efficiency of < 1% reachable with 9 layers

RICH

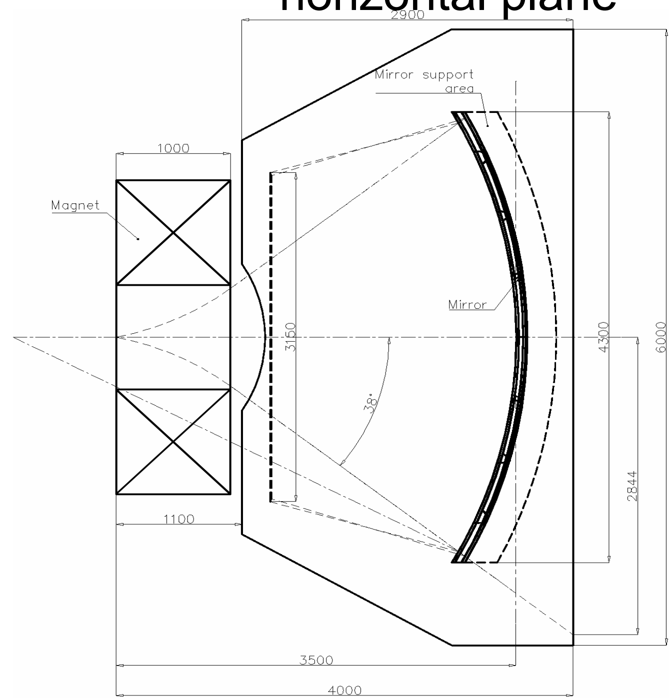
Duties
- e/π separation
- K/π separation ?

Optical layout for RICH1

vertical plane



horizontal plane



Mirror: Beryllium / glass

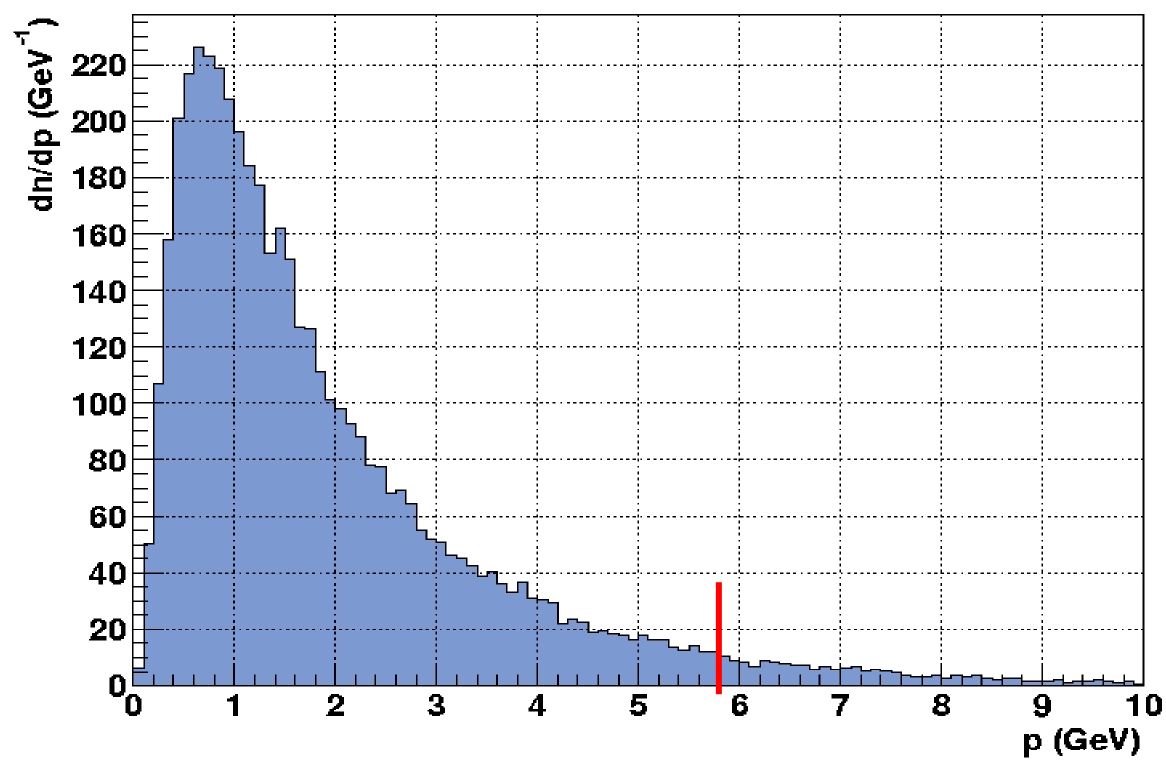
Two focal planes (3.6 m^2) separated vertically

RICH

Radiator gas: $C_4H_{10} + N_2$ (γ_{thr} = 16 – 41)

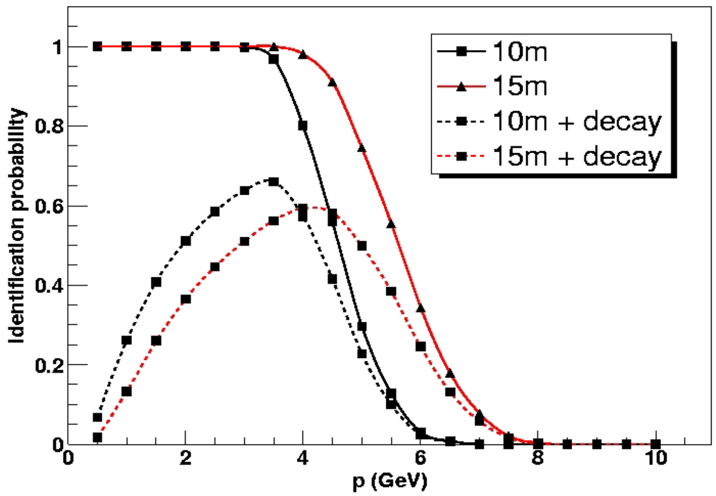
Photodetectors: photomultipliers or gas detectors

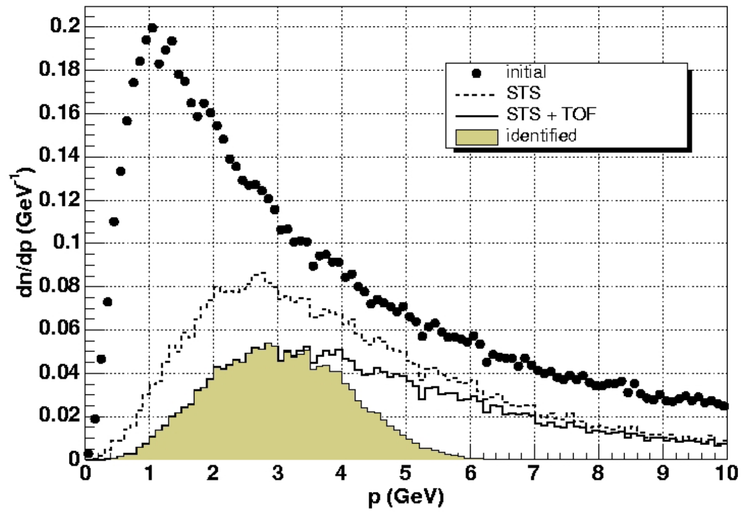
RICH1: γ_{thr} = 41
→ $p_{\pi,thr}$ = 5.7 GeV
→ (almost) hadron blind



RICH

Kaon ID by TOF deteriotes quickly above 4 GeV





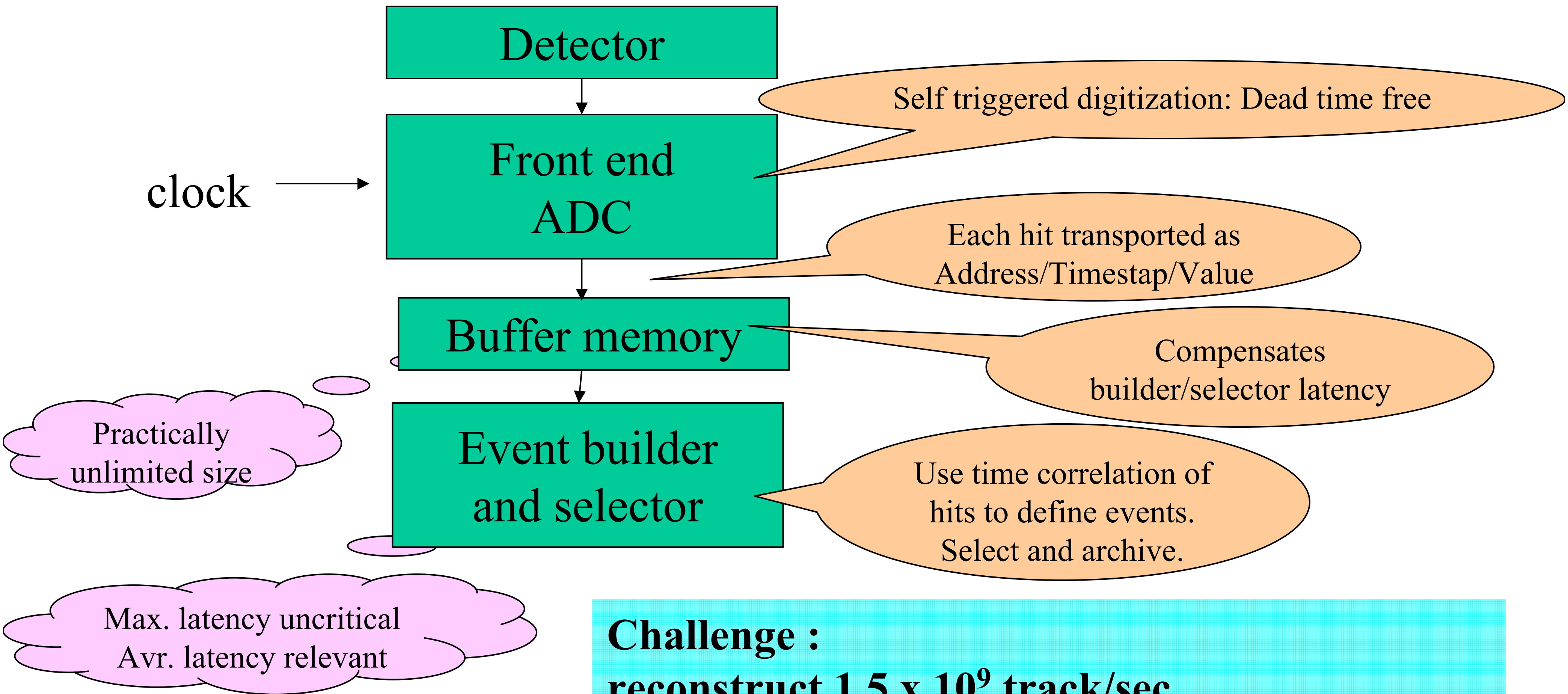
Kaon ID by RICH for p > 4 GeV would be desirable

Option for RICH2 ?

$\gamma_{thr} = 30 \rightarrow p_{\pi,thr} = 4.2$ GeV, $p_{K,thr}$=15 GeV

Problem: Ring finding in high hit density environment

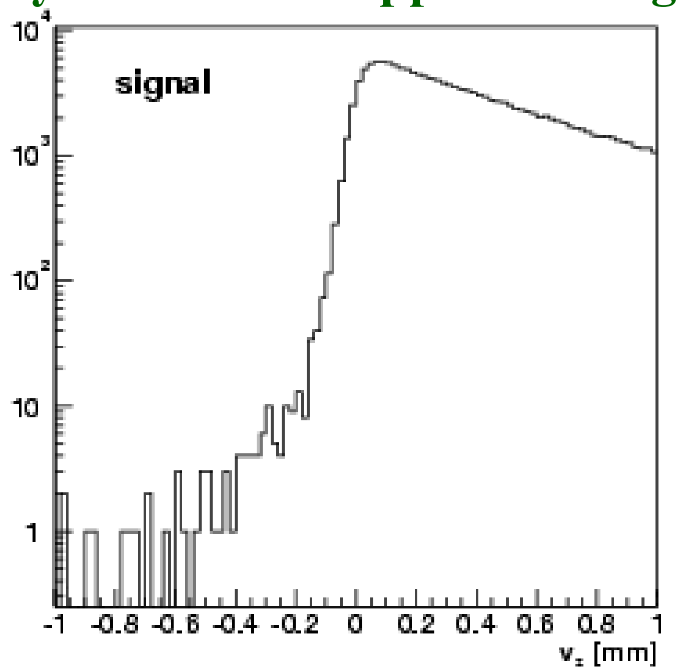
DAQ / Trigger Architecture

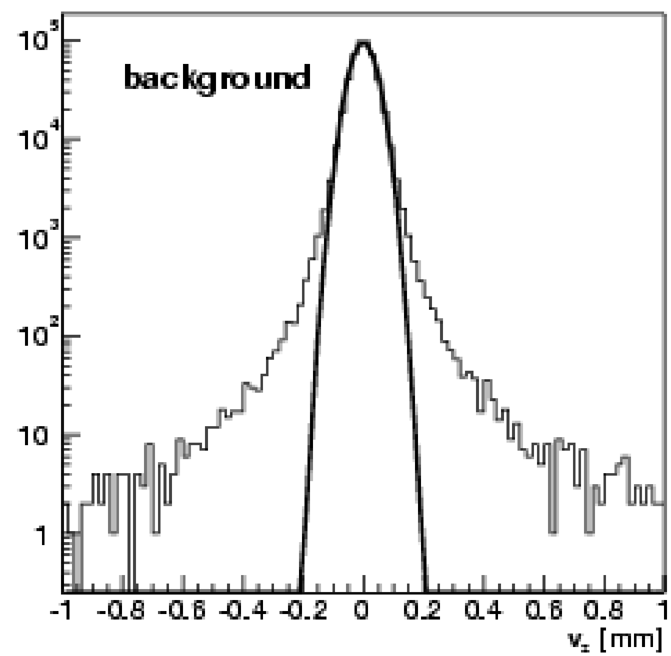


Challenge :
reconstruct 1.5 x 10^9 track/sec.
data volume in 1^{st} level trigger ≈ 50 Gbytes/sec.

Feasibility study : open charm

Key variable to suppress background: secondary vertex position





$D^0 \rightarrow K^- \pi^+$
(central Au+Au @ 25 AGeV)
Assuming $\langle D^0 \rangle = 10^{-3}$:
$S/B \approx 1$
detection rate 13,000 / h

Crucial detector parameters:
- Material in tracking stations
- Single hit resolution

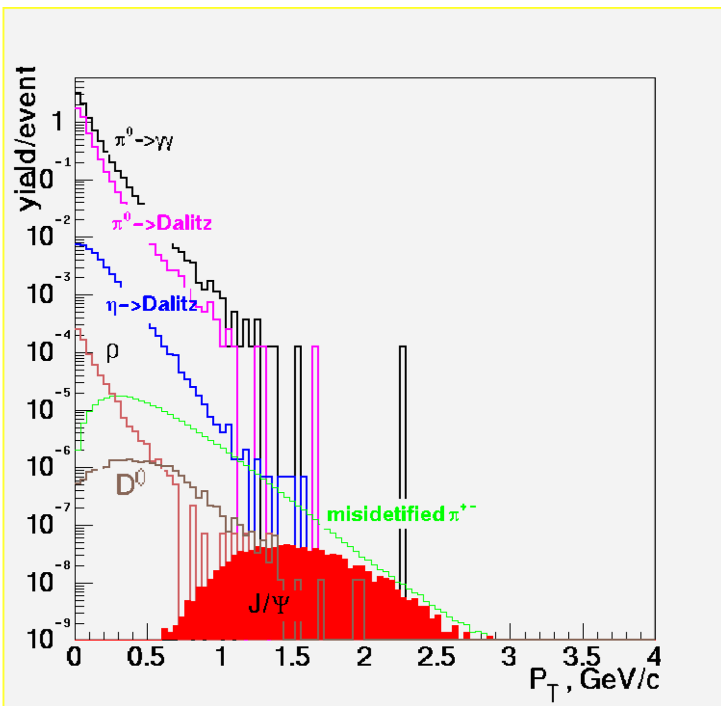
Similar studies for $D^+ \rightarrow K^- \pi^+ \pi^+$, $D^{*\pm} \rightarrow D^0 \pi^\pm$ under way

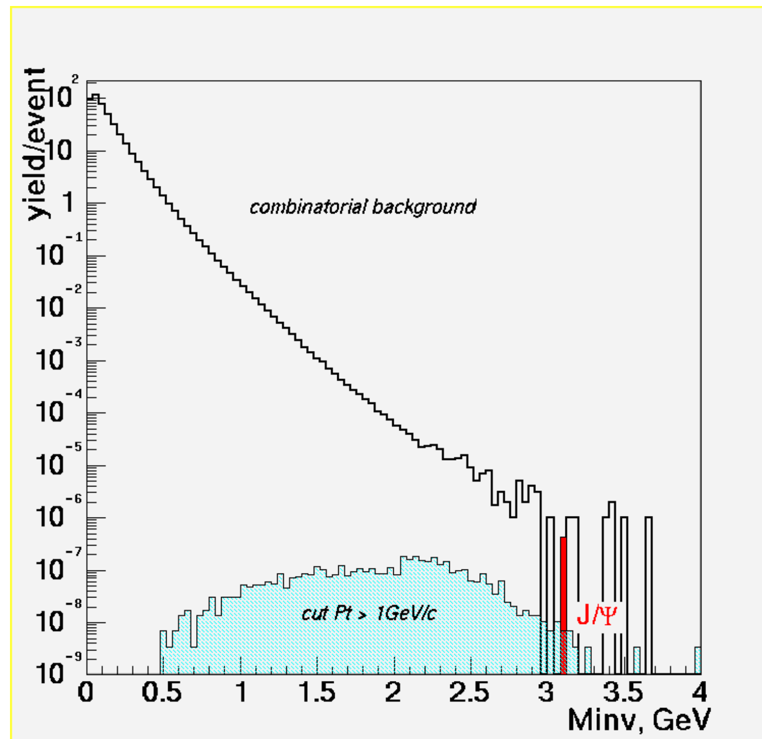
Feasibility study: $J/\Psi \rightarrow e^+e^-$

Extremely rare signal!

Background from various sources: Dalitz, conversion, open charm...

Very efficient cut on single electron p_T

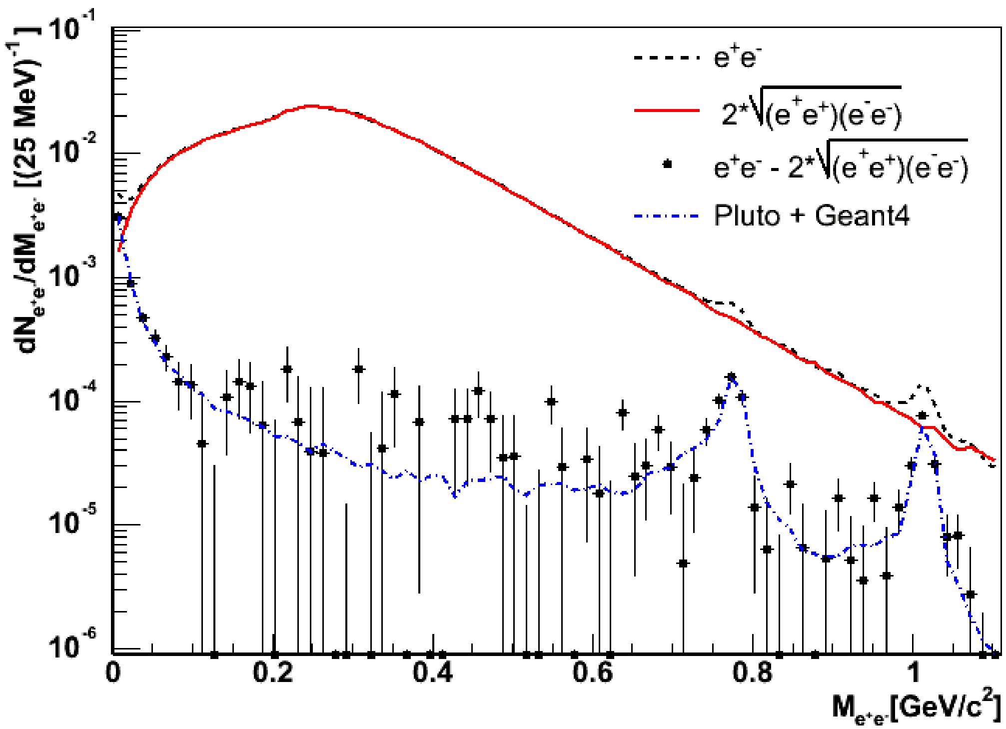




S/B > 1 should be feasible

Feasibility study : Light vector mesons

Background sources: Dalitz, conversion
no easy p_T cut; sophisticated cutting strategy necessary
depends crucially on elimination of conversion pairs by tracking and charged pion discrimination by RICH and TRD (10^4)



S/B = 0.3 (ρ+ω)
S/B = 1.2 (φ)

idealised: no momentum resolution

The CBM Collaboration

Croatia:
RBI, Zagreb

Cyprus:
Nikosia Univ.

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

France:
IReS Strasbourg

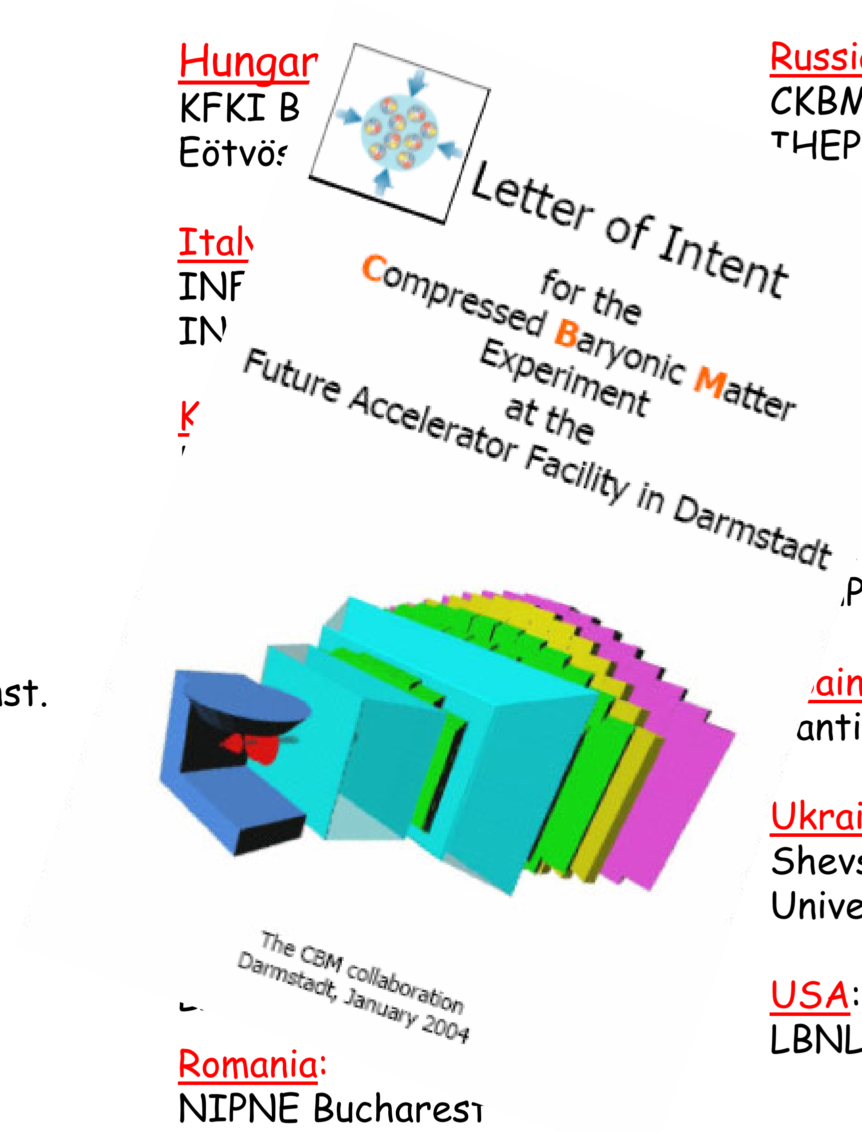
Germany:
Univ. Heidelberg, Phys. Inst.
Univ. HD, Kirchhoff Inst.
Univ. Frankfurt
Univ. Mannheim
Univ. Marburg
Univ. Münster
FZ Rossendorf
FZ Jülich
GSI Darmstadt

Hungar
KFKI B
Eötvös

Ital
INF
IN

K

Romania:
NIPNE Bucharest



Russia:
CKBM, St. Petersburg
THEP Protvino
…itzk
…ow
…etersburg
… Inst., Moscow
…NR Dubna
…NR Dubna
…INR Dubna
…sk State University
… St. Petersburg
…P, Moscow State Univ.

…ain:
…antiago de Compostela Univ.

Ukraine:
Shevshenko Univ. , Kiev
University of Kharkov

USA:
LBNL Berkeley

CBM : Status / Outlook

- CBM collaboration is formed: 250 scientists from 39 institutions
- CDR : November 2001, LoI : January 2004
- Work in progress: Detector design and optimisation
R&D on detetcor components
Feasibility studies of key observables
- Next step: Technical Proposal January 2005
- Could run in 2012!