Development of a RICH detector for electron identification in CBM

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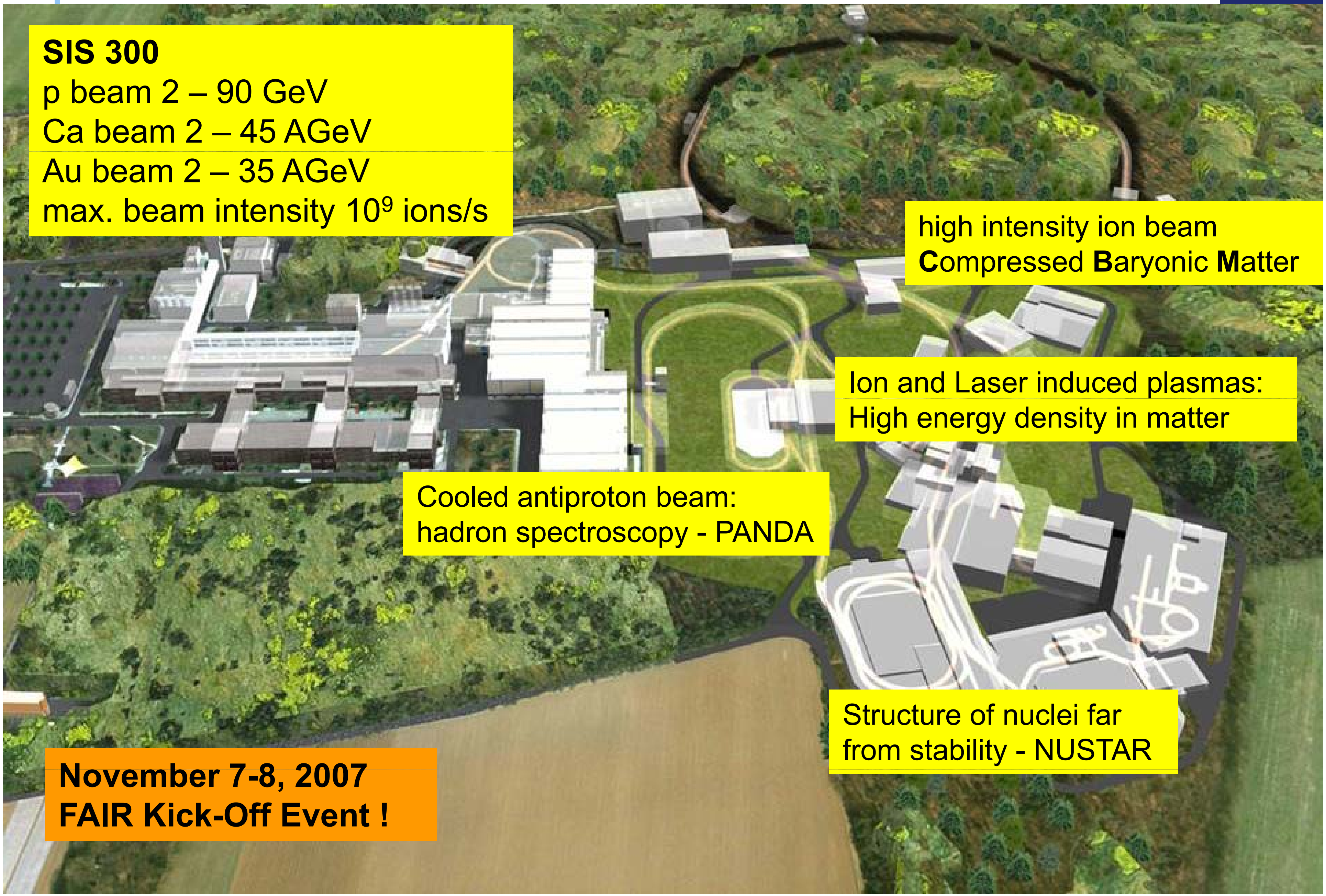
CBM collaboration

Sixth Workshop on Ring Imaging Cherenkov detectors (RICH2007)
Trieste, October 15-20, 2007

Outline

- **Introduction & motivation:**
  - CBM @ FAIR
  - dileptons
- **Detector concept of CBM**
  - RICH
- **Simulations**
  - detector performance
  - feasibility studies
- **RICH layout optimization and R&D**
- **Summary**

FAIR at GSI

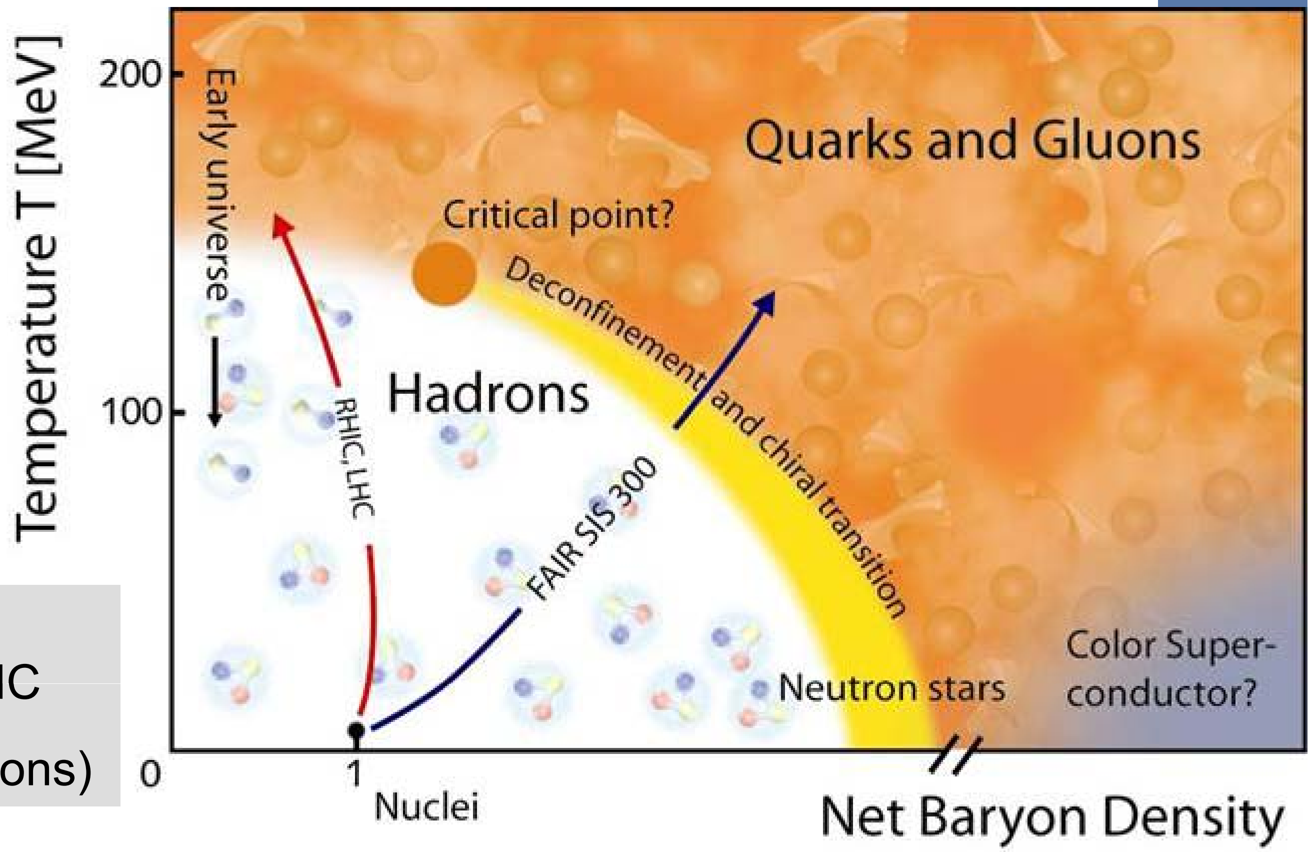

SIS 300
p beam 2 – 90 GeV
Ca beam 2 – 45 AGeV
Au beam 2 – 35 AGeV
max. beam intensity 10^9 ions/s
high intensity ion beam
Compressed Baryonic Matter
Ion and Laser induced plasmas:
High energy density in matter
Cooled antiproton beam:
hadron spectroscopy - PANDA
Structure of nuclei far
from stability - NUSTAR
November 7-8, 2007
FAIR Kick-Off Event !

Physics case of CBM

Compressed Baryonic Matter @ FAIR – high μ_B, moderate T:

searching for the landmarks of the QCD phase diagram
- first order deconfinement phase transition
- chiral phase transition (high baryon densities!)
- QCD critical endpoint

in A+A collisions from 2-45 AGeV starting in 2015 (CBM + HADES)



- physics program complementary to RHIC, LHC
- rare probes! (charm, dileptons)

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)
- charmonium suppression, sequential for J/ψ and ψ' ?

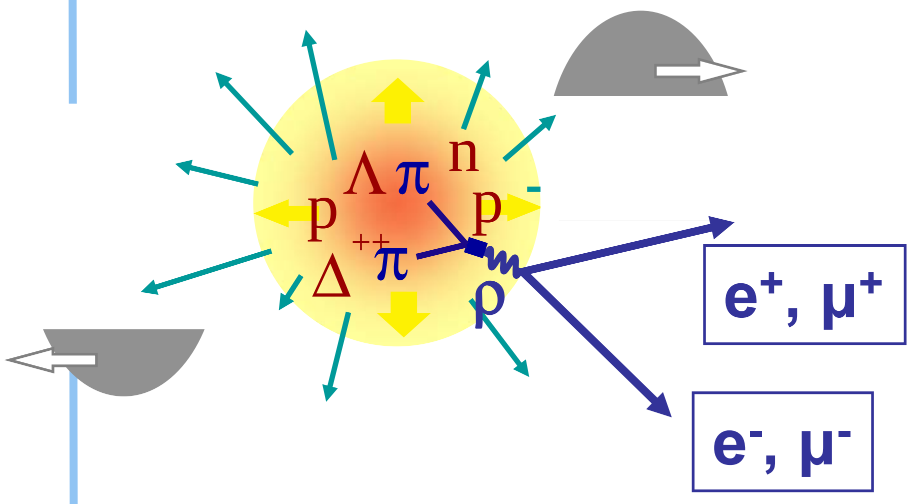
QCD critical endpint
- excitation function of event-by-event fluctuations (K/π,...)

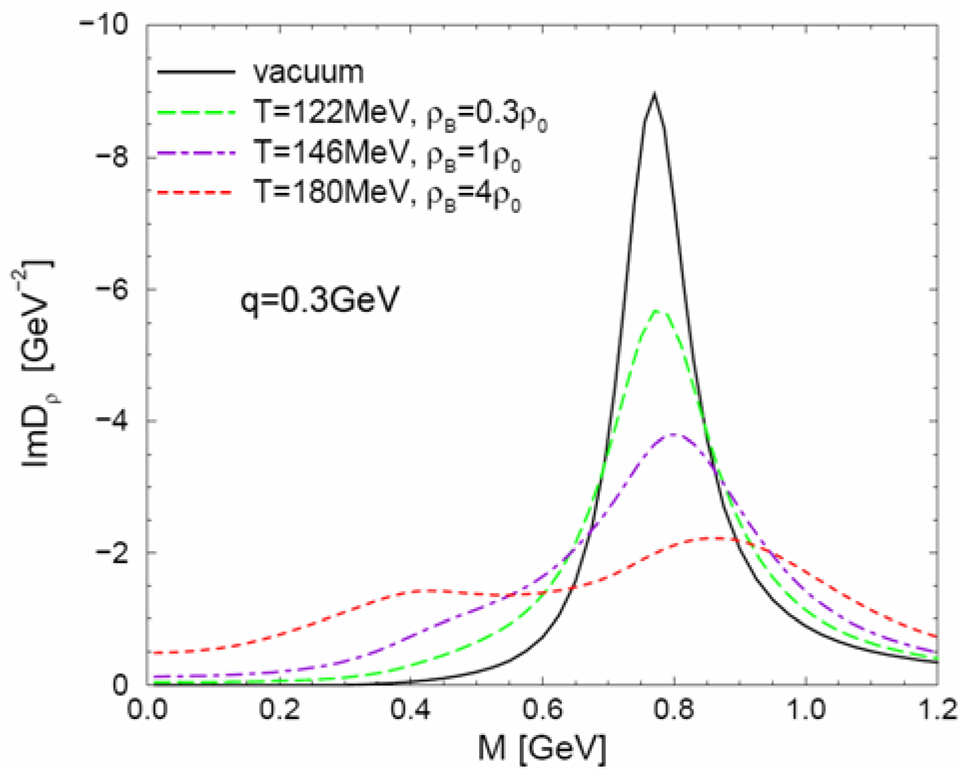
Onset of chiral symmetry restoration at high ρ_B
- in-medium modifications of hadrons ($\rho,\omega,\phi \rightarrow e^+e^-(\mu^+\mu^-)$, D)

- mostly **new** measurements
- **CBM Physics Book (theory) in preparation**

ρ-meson spectral function

- ρ-meson couples to the medium: "melts" close to T_c and at high μ_B
- vacuum lifetime τ_0 = 1.3 fm/c
- dileptons = penetrating probe
- ρ-meson spectral function particular sensitive to baryon density
- connection to chiral symmetry restoration?





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

Charm production at threshold

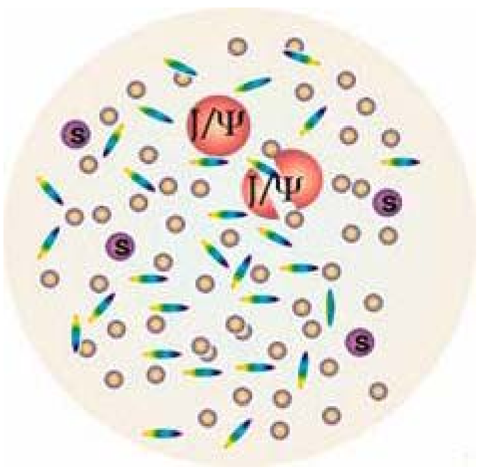
• CBM will measure charm production at threshold

→ after primordial production, the survival and momentum of the charm quarks depends on the interactions with the dense and hot medium!

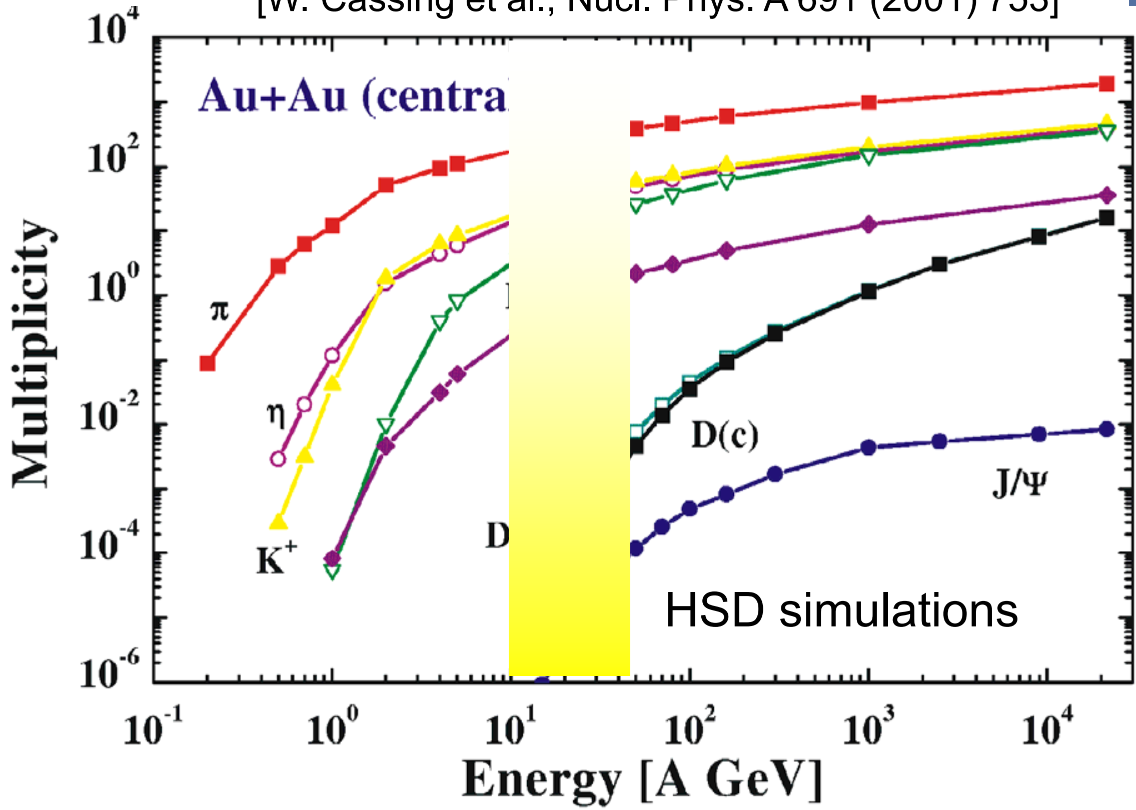
→ direct probe of the medium!

• charmonium in hot and dense matter?

• relation to deconfinement?



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



The CBM experiment

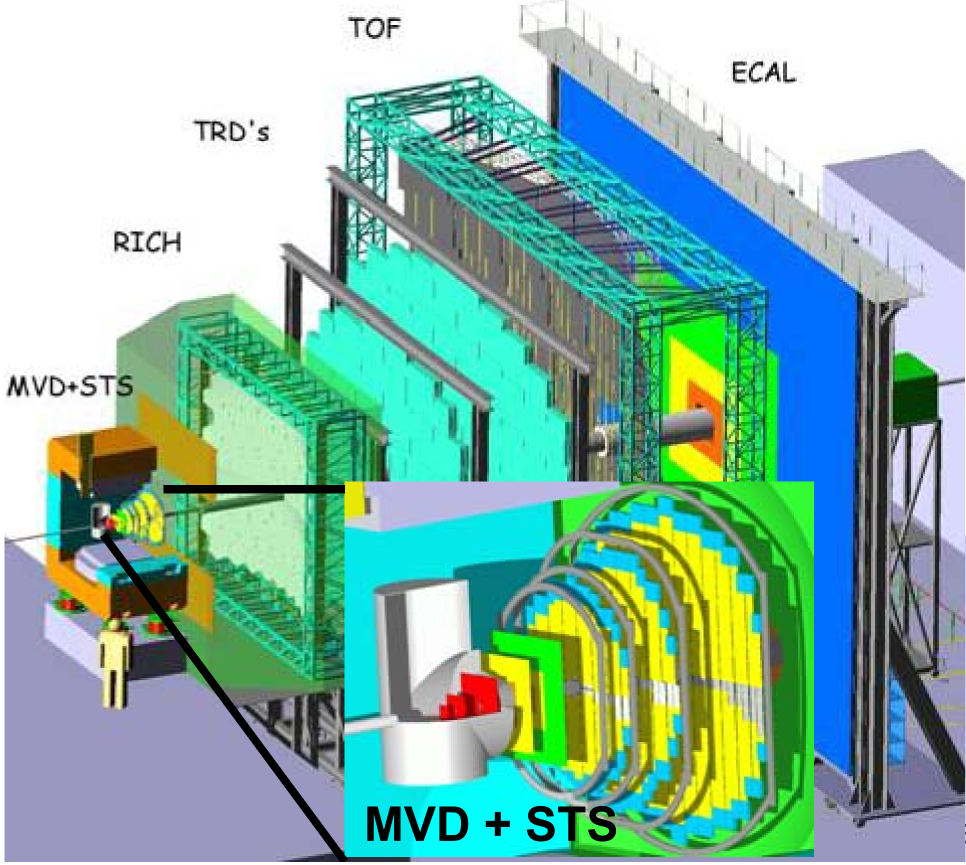
• tracking, momentum determination, vertex reconstruction: radiation hard silicon pixel/strip detectors (STS) in a magnetic dipole field

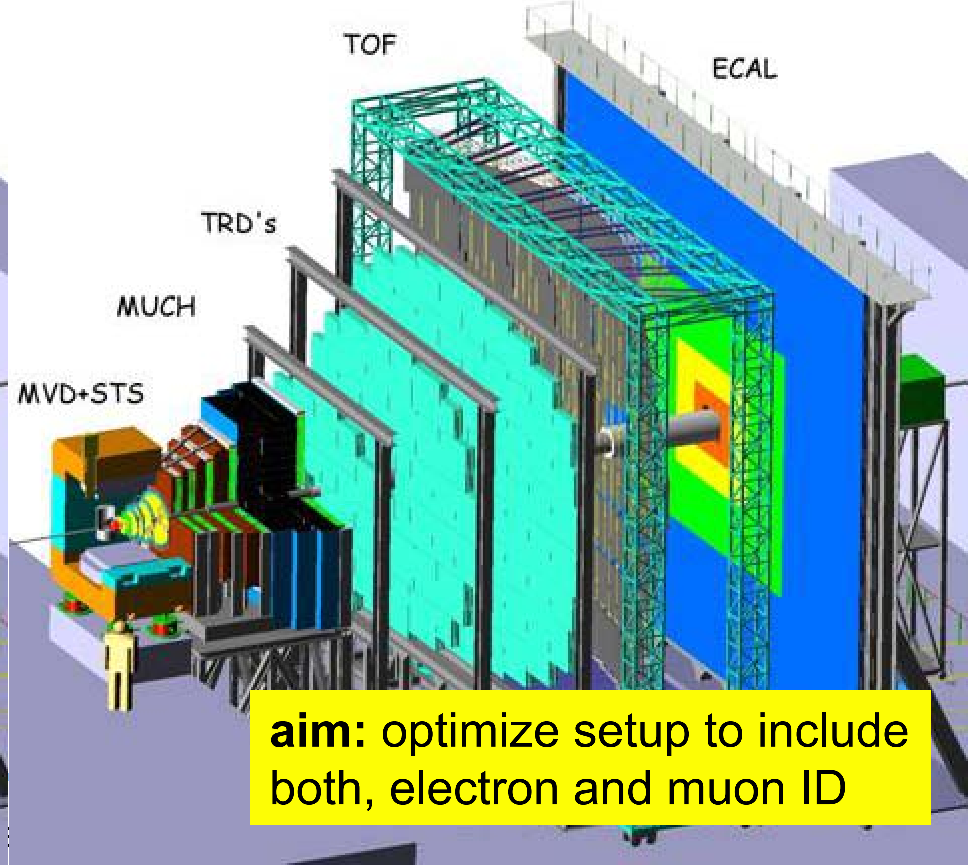
• hadron ID: TOF (& RICH)
• photons, π^0, η: ECAL

• PSD for event characterization
• high speed DAQ and trigger $\rightarrow$ **rare probes!**

• **electron ID**: RICH & TRD
$\rightarrow$ π suppression $\geq 10^4$

• **muon ID**: absorber + detector layer sandwich
$\rightarrow$ move out absorbers for hadron runs





aim: optimize setup to include both, electron and muon ID

RICH concept

task

• clean electron identification for $p \leq$ 8-10 GeV/c

• π-suppression factor ~ 500-1000, 10^4 if combined with TRD + TOF

• large acceptance (± 25°), good efficiency (~20 hits/ring)

challenges

• high track density:
central Au+Au collisions, 25 AGeV: ~600 charged tracks within ± 25°

• RICH detector positioned behind STS, Magnet (material budget!):
large number of secondary electrons

→ high ring & track density in RICH detector:
typical scale: ~100 rings: 30 π, 60 2nd $e^{\pm}$, 5-10 $e^{\pm}$ from target
→ fake rings, wrong ring-track matches

• interaction rates up to 10 MHz: self-triggered readout electronics

RICH concept (II)

concept

• gaseous RICH detector

• rather high Cherenkov threshold for pions (4.5-6 GeV/c)
→ N_2 radiator (γ_{th}=41, $p_{\pi,th}$=5.6 GeV/c)

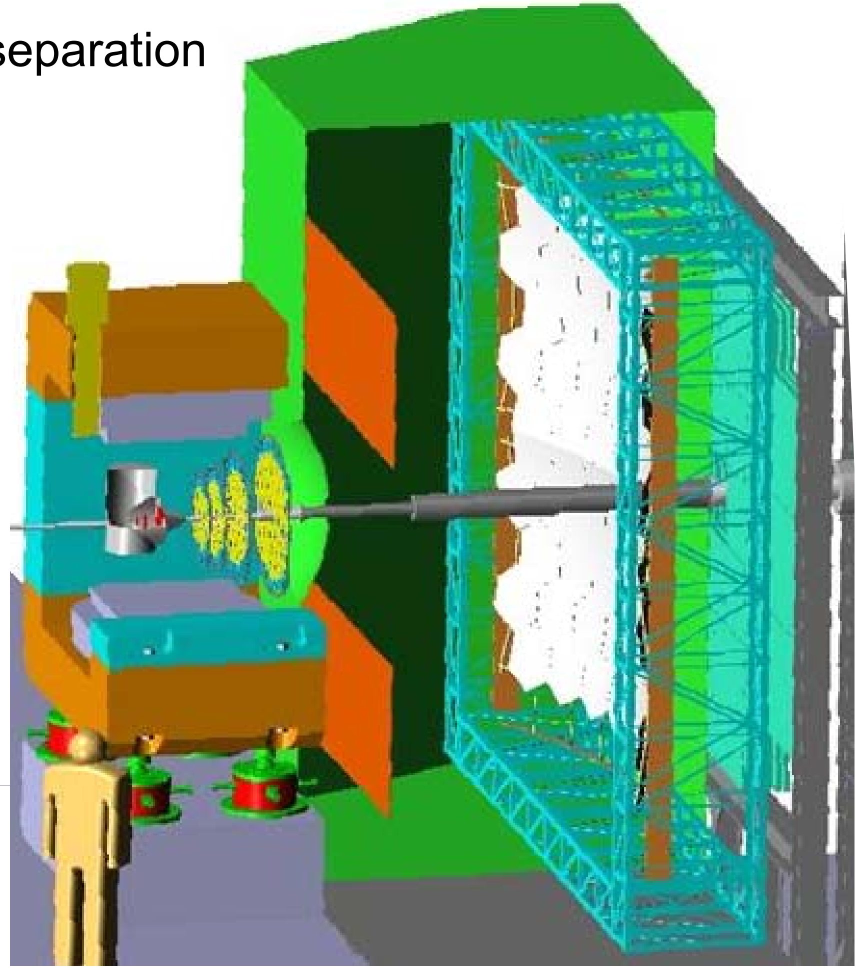
• glass mirrors (4-6 mm, R=4.5m) with vertikal separation
→ focus to upper & lower part of CBM
→ photodetector shielded by magnet yoke

• photodetector plane: PMTs
→ MAPMTs
(e.g. Hamamatsu H8500 with UV windows)

• no further windows

→ Cherenkov photons with $\lambda \geq$ 200 nm

→ 2.5 m radiator length (22 hits/ring)



Simulations

demand:

• prove feasibility of di-electron (low-mass vector mesons and charmonium) measurement with current CBM detector concept!

challenge of CBM detector setup for di-electron measurement:

• unusual layout because:

  • no electron identification in front of magnetic field

  → di-electron pairs from π^0-Dalitz decays and γ-conversion are opened

  • large material budget in front of detectors for electron-ID

  → many secondary electrons

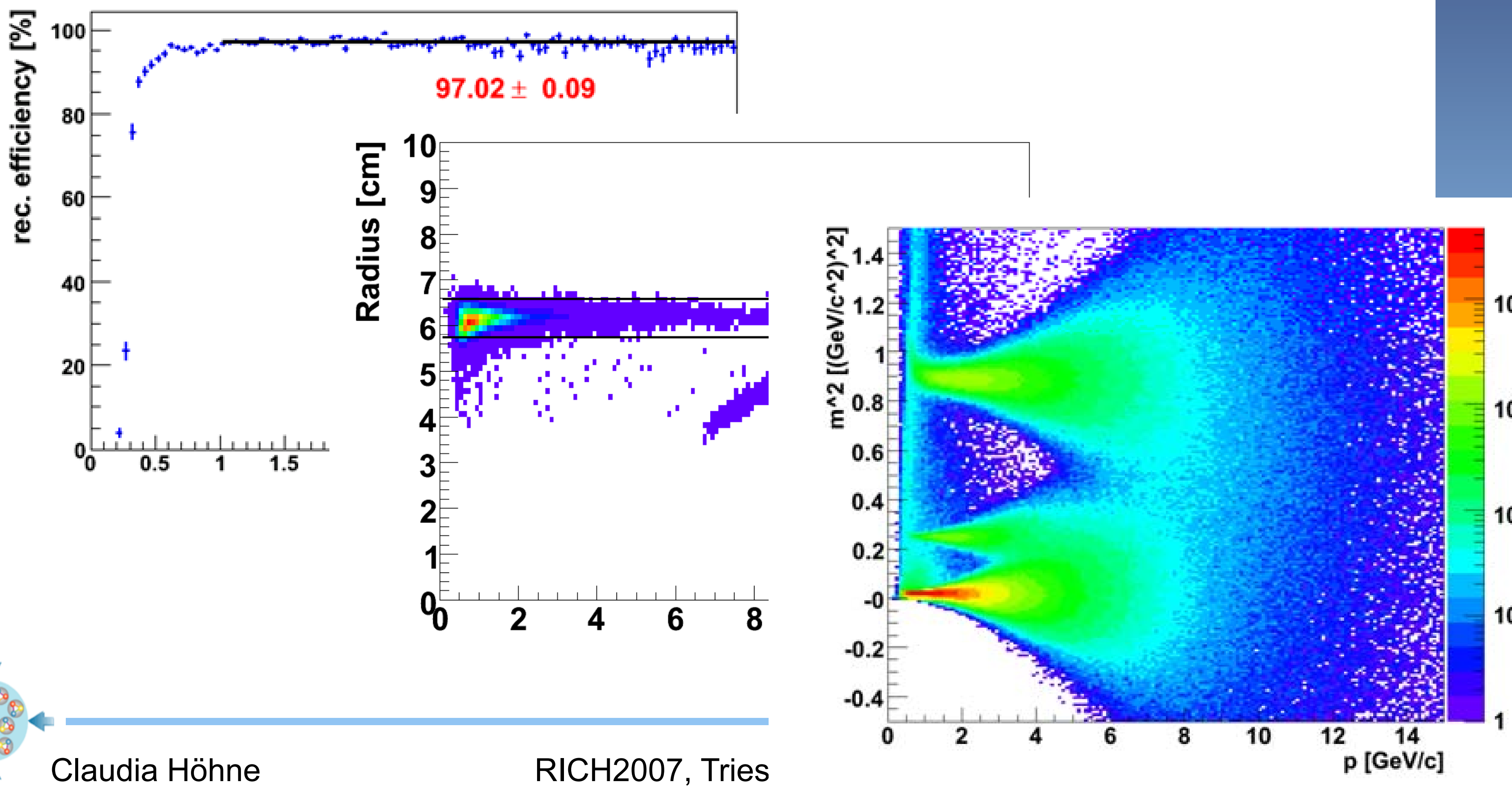
→ detailed detector and physics simulations performed!

• feasibility of physics measurements proven

• layout optimization and R&D on RICH started

CbmRoot simulation framework

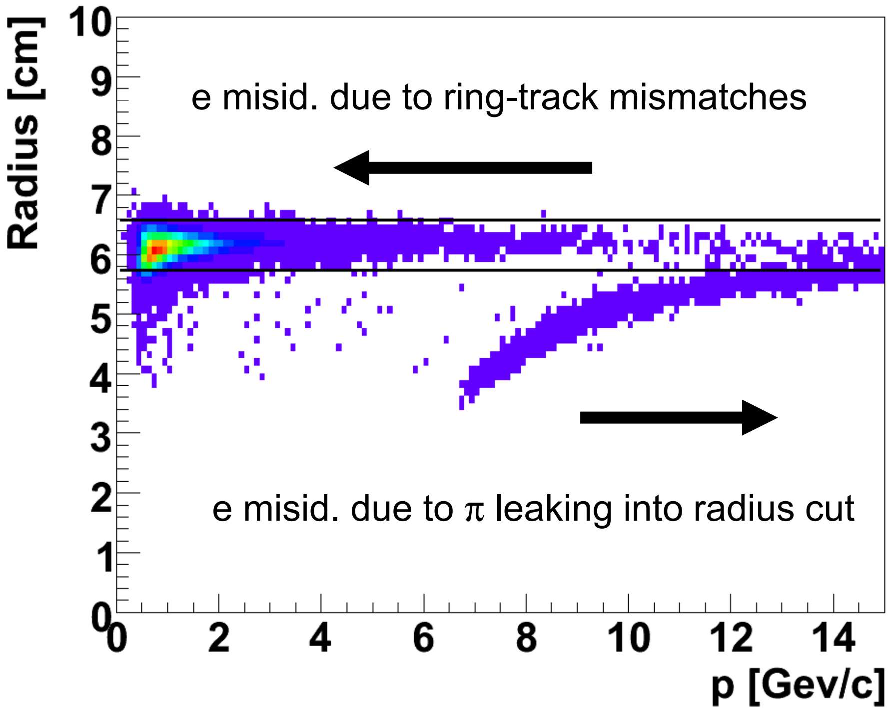
- detector simulation (GEANT3)
- full event reconstruction: track reconstruction, add RICH, TRD and TOF info
- result from feasibility studies in the following: central Au+Au collisions at 25 AGeV beam energy (UrQMD)

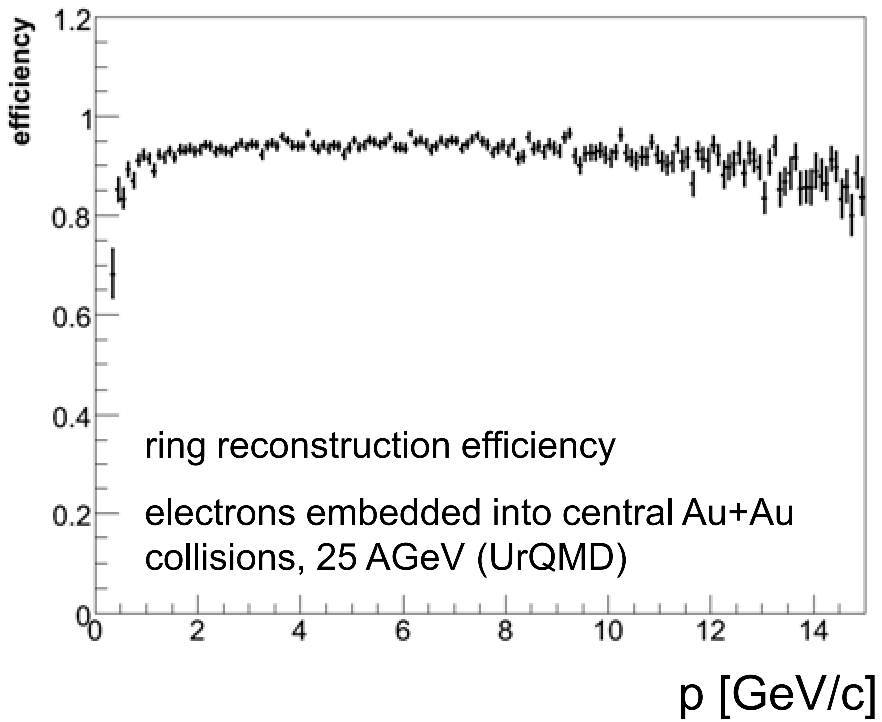


RICH in simulations

- RICH geometry: gas vessel (~ 6.5x5x3 m^3)
  N_2 radiator (photon absorption and dispersion from literature)
  glass mirror (3mm, reflection from HADES (Al+MgF_2 coating))
  photodetector (8x8 MAPMT H8500-03, ~6x6 mm^2 pixel size)

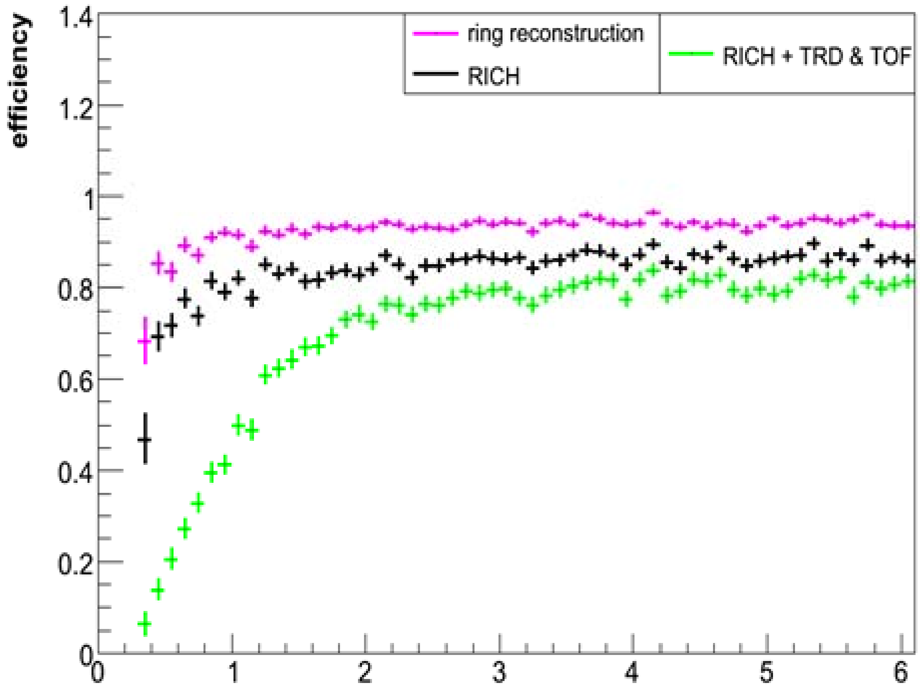
- Nhits/ring = 22, N_0 ~ 150 cm^{-1}, $\langle R \rangle_e$ = 6.2 cm, σ_R = 2.5%
  ~ 90 rings per central collision, 25 AGeV Au+Au (occupancy ~2-4%)



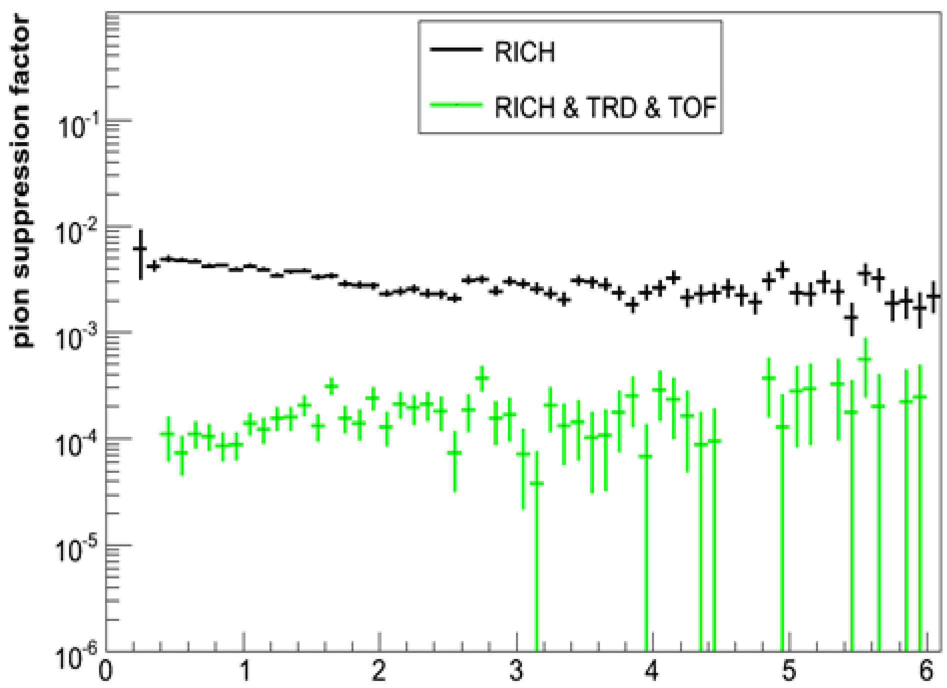


Performance of combined e-ID

- use TRD and TOF detectors for further electron identification
- combined purity of identified electrons ~96%



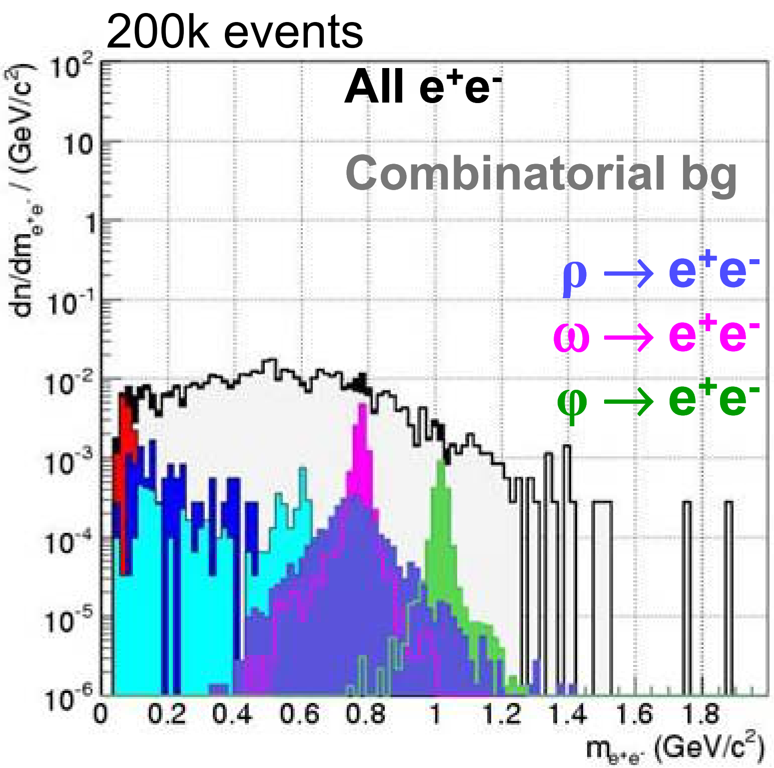
p [GeV/c]

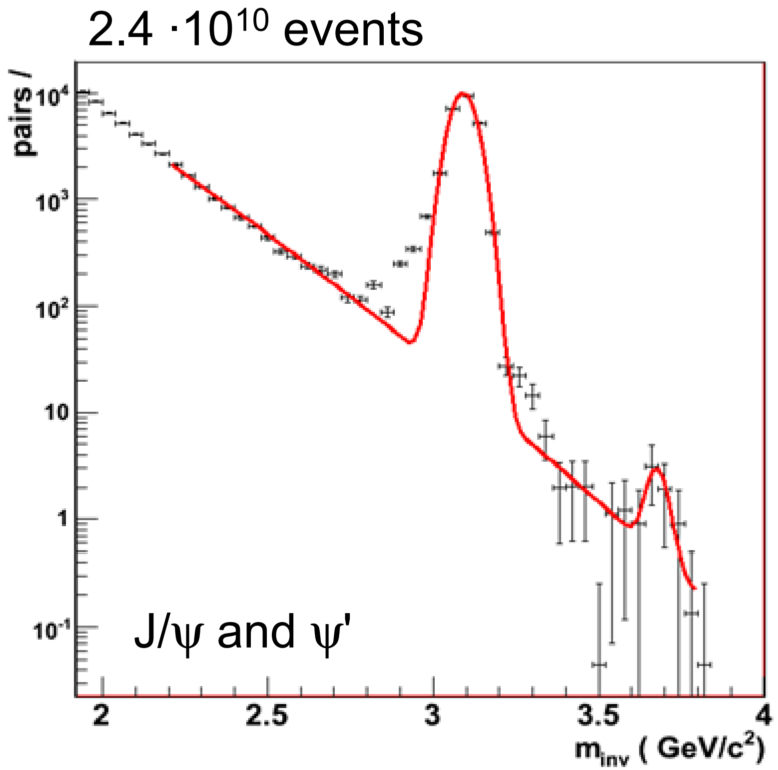


p [GeV/c]

Di-electron analysis

- feasibility studies for di-electrons with full event reconstruction and electron-ID
- di-electron pairs embedded into central Au+Au collisions, 25 AGeV (UrQMD)
- 25 μm Au target (1‰ interaction length) for suppression of (otherwise dominant) background of electrons from γ-conversion in the target (<π⁰> ~ 350)





→ background dominated by physical sources (75%) !

Optimization of RICH layout

- aim: develop more compact design while keeping physics performance
  → reduce size & costs!
- ansatz: keep ~ 22 hits/ring and overall layout concept
  → CO_2 radiator, reduced mirror radius of 3 m
- preliminary result of detector simulation: physics performance is kept

	large RICH	**compact RICH**
gas	N_2	CO_2
radiator length	2.5 m	1.76 m
full length of RICH	2.9 m	2.1 m
mirror radius	4.5 m	3 m
mirror size	2 x (5.7 x 2) m^2 ~ 22.8 m^2	2 x (4.2 x 1.4) m^2 ~ 11.8 m^2
photodetector size **	2 x (3.2 x 1.4) m^2 ~ 9 m^2	2 x (2.4 x 0.78) m^2 ~ 3.7 m^2
# channels	~ 200k	~ 85k

overall reduction by factor 2-3!

** further reduction possible on account of acceptance losses

RICH mirror

- cooperation with Hochschule Esslingen, University of Applied Sciences and Flabeg (Glass and Coatings Company)
  - → first mirror prototypes (6mm glass, Al+MgF_2 coating) to be delivered in November 2007
  - → test reflectivity, homogeneity, surface roughness
- simulations: maximum glass thickness (multiple scattering) ?
- test: minimum thickness while still having sufficient form stability?

Hochschule Esslingen
University of Applied Sciences

FLABEG

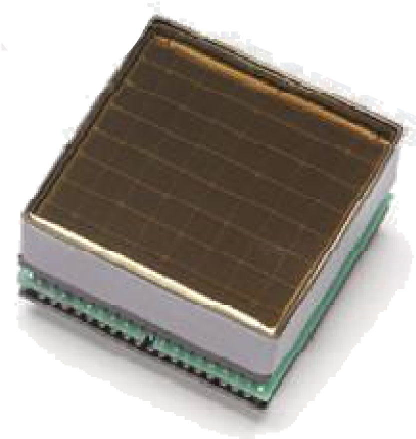
Photodetector

• interaction rates up to 10 MHz foreseen (charm production at threshold)

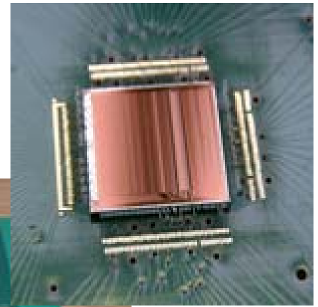
• fast readout and self-triggered electronics to cope with the high interaction rates and large data volume

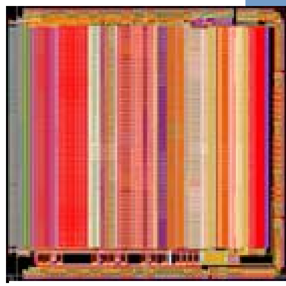
• couple to stable, fast photodetectors: flat panel MAPMTs

→ ongoing work for test set-up at GSI



readout chip test board





n-XYTER chip

e.g. H8500 from Hamamatsu
5.8x5.8 mm^2 pixel size
effective area/ extrenal size 89%

fast self-triggered readout electronics:
further development of n-XYTER (CBM-DETNI cooperation)
readout speed 250 kHz per Channel, 128 channels,
i.e. 32 MHz per chip

Summary & Future Plans

Simulations

• feasibility of di-electron measurement (low-mass vector mesons and J/ψ) proven with first, large RICH layout

RICH R&D

• optimization of RICH geometry with respect to costs & physics ongoing!

• (slow) start of mirror and photodetector R&D

• goal: RICH prototype within next 2-3 years, beam tests

CBM

• Technical Design Report ~2011

• be ready for data taking ~2015

CBM collaboration

China:
CCNU Wuhan
USTC Hefei

Croatia:
University of Split
RBI, Zagreb

Cyprus:
Nikosia Univ.

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

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

Hungaria:
KFKI Budapest
Eötvös Univ. Budapest

India:
Aligarh Muslim Univ., Aligarh
IOP Bhubaneswar
Panjab Univ., Chandigarh
Univ. Rajasthan, Jaipur
Univ. Jammu, Jammu
IIT Kharagpur
SAHA Kolkata
Univ Calcutta, Kolkata
VECC Kolkata
Univ. Kashmir, Srinagar
Banaras Hindu Univ., Varanasi

Korea:
Korea Univ. Seoul
Pusan National Univ.

Norway:
Univ. Bergen

Poland:
Krakow Univ.
Warsaw Univ.
Silesia Univ. Katowice
Nucl. Phys. Inst. 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, Moscow State Univ.
St. Petersburg Polytec. U.

Ukraine:
Shevchenko Univ. , Kiev

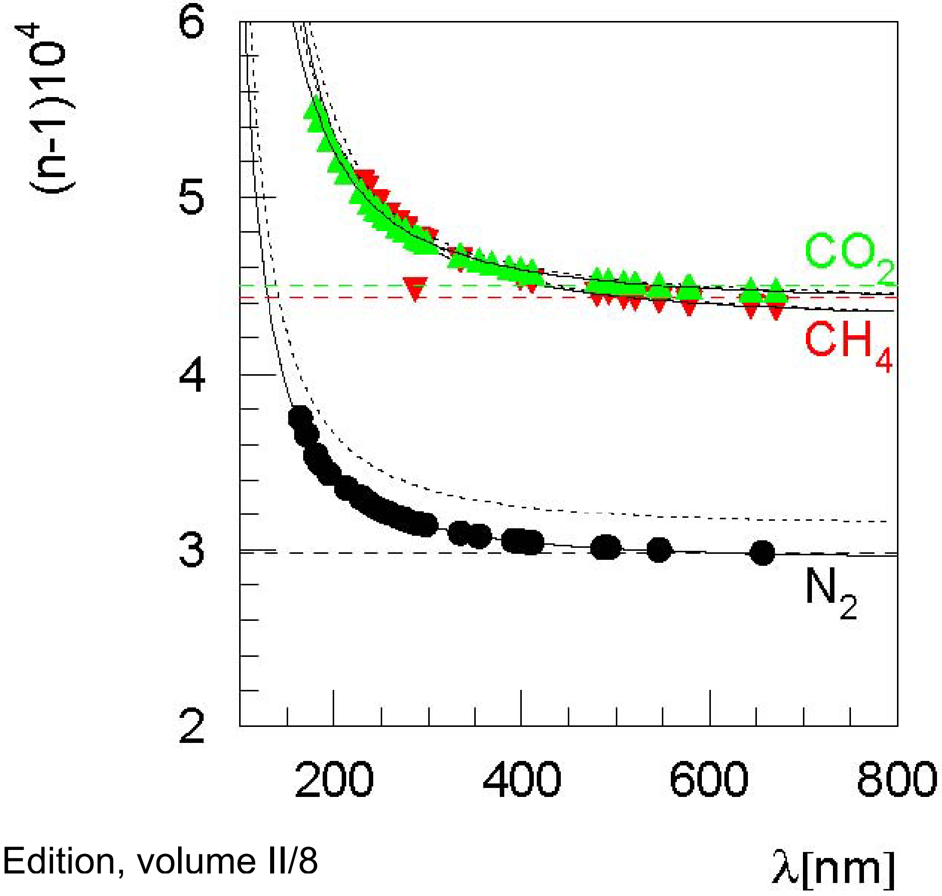
51 institutions, > 400 members

Dresden, September 2007

Additional slides

Parameters for simulation

chromatic dispersion

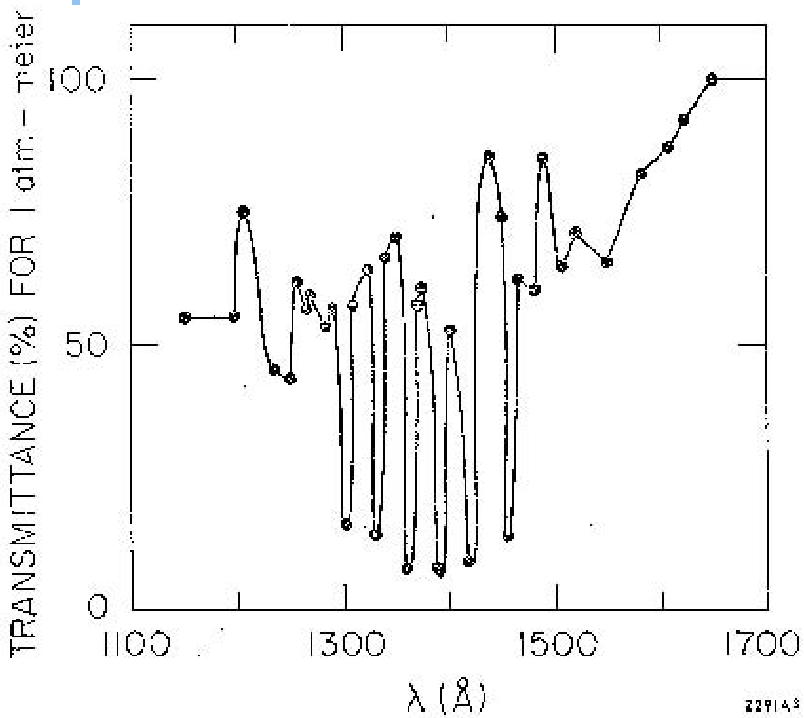


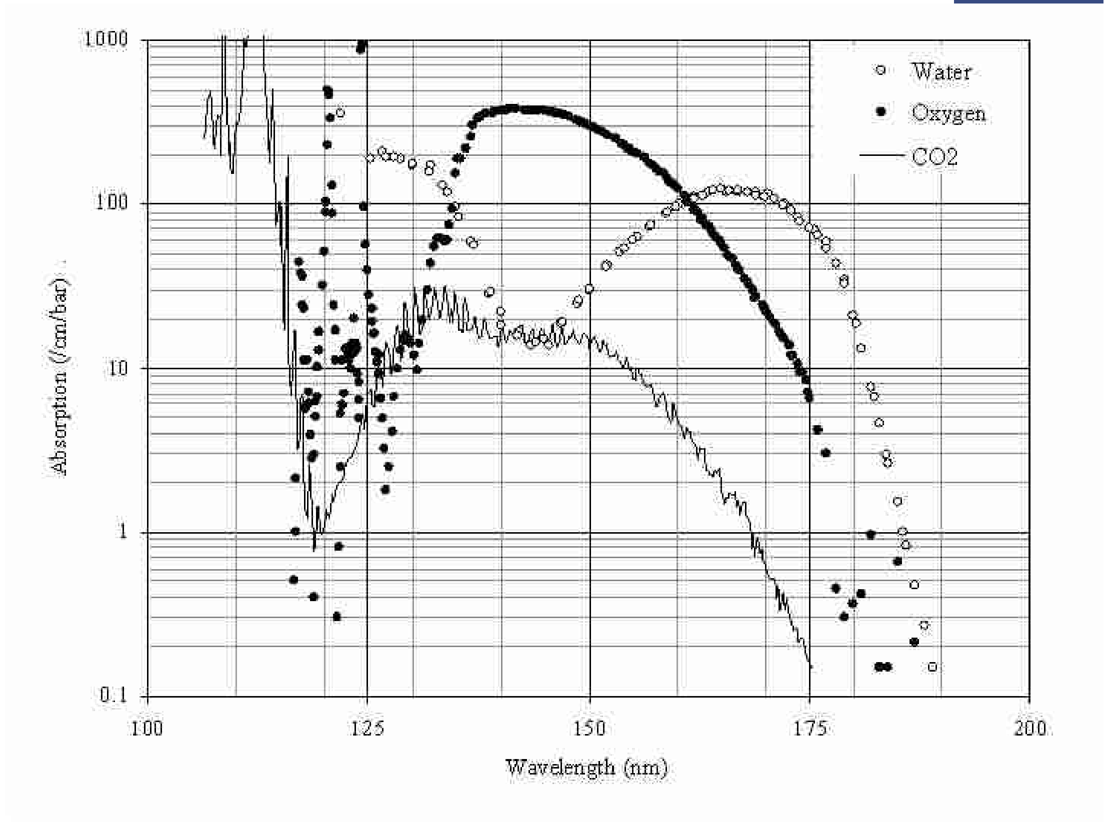
[Landolt Boernstein Series, 6th Edition, volume II/8

Ph.D. thesis of Annick Bideau-Mehu (1982)]

Parameters for simulation (II)

photon absorption



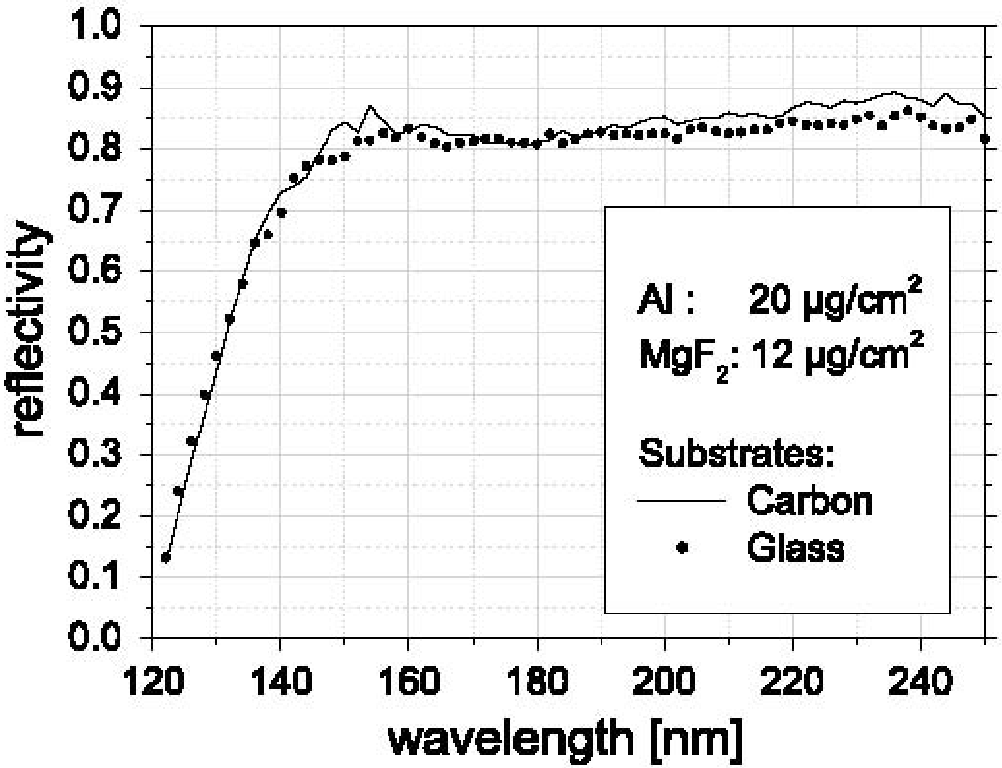


[Y.Tomkiewicz and E.L.Garwin, NIM V114 (1974) pp. 413-416]

[O. Ullaland, talk RICH2004]

Parameters for simulation (III)

mirror reflectivity (HADES)



[J.Friese for HADES, NIM A 502 (2003) 241]

Event display

UrQMD simulation of central Au+Au collisions, 25 AGeV

event display of inner fraction of RICH detector: