GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Symposium on The Physics of Dense Baryonic Matter, GSI, 2009

The CBM physics programme

Joachim Stroth, Univ. Frankfurt / GSI

HIC for FAIR

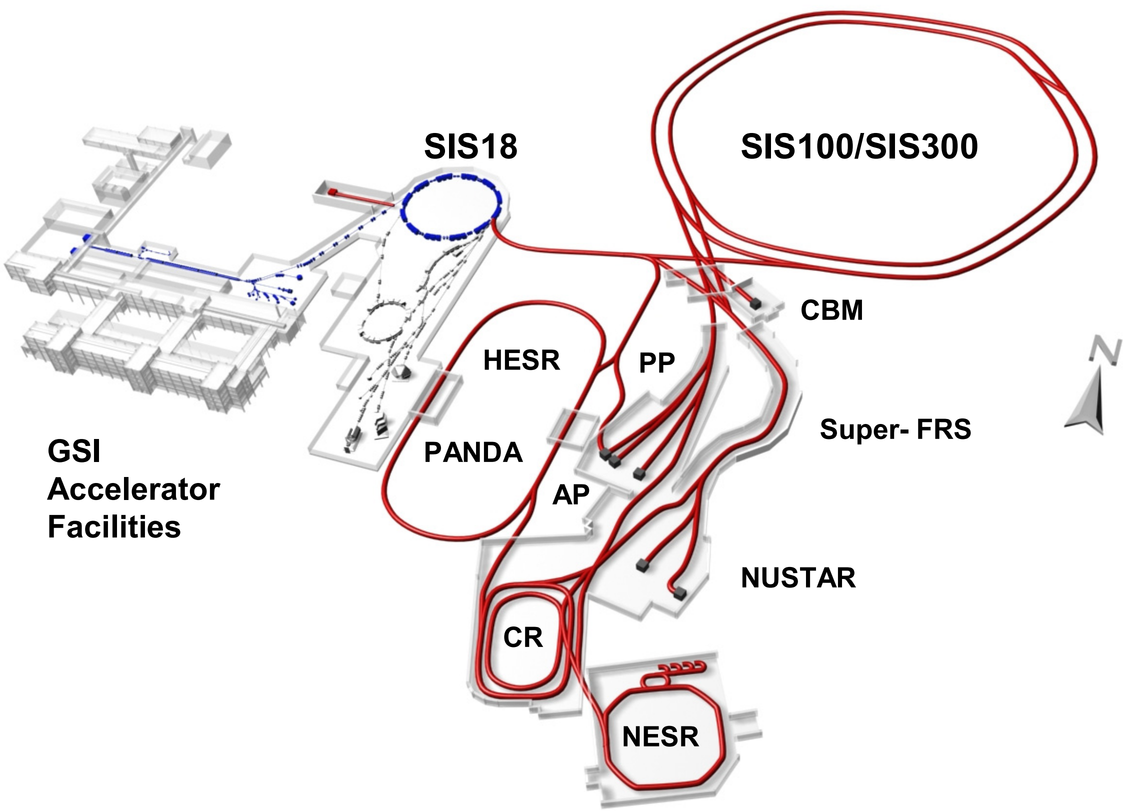
Agenda

- The phase diagramme at large μ_B
- Dileptons
- Charm production and propagation
- Experimental challenge

The scientific mission of CBM

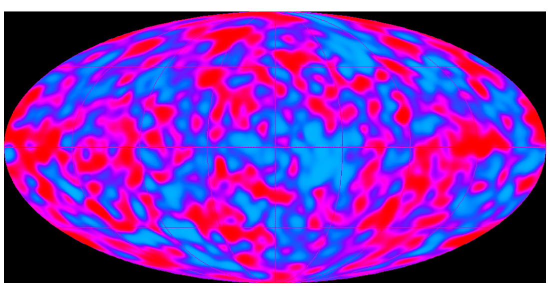
Explore Compressed Baryonic Matter, i.e. the nuclear phase diagramme in the region of large baryochemical potential by exploiting in particular rare and penetrating probes!

- High-rate and high-precision detector system with state-of-the-art technology!
- Brilliant heavy-ion beams from SIS-300 at FAIR with extended running periods!
- Systematic and multi-differential analysis!

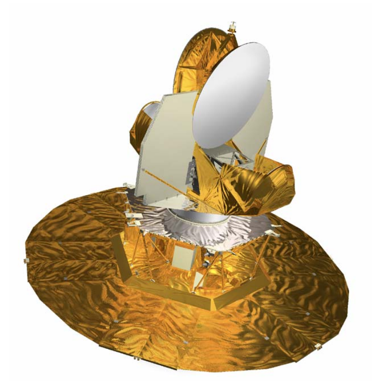


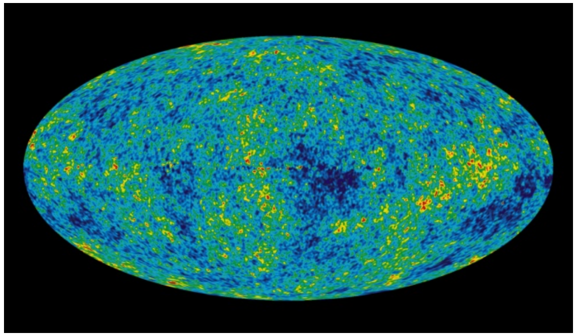
Inspired by CMB

COBE, 1989

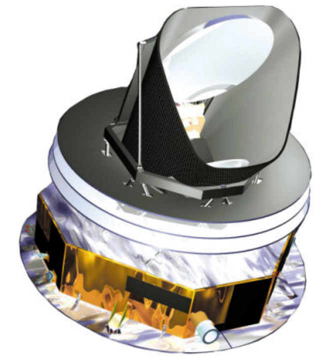


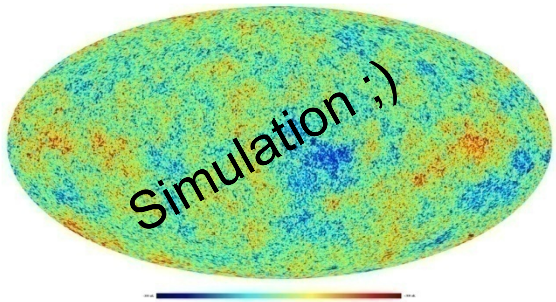
WMAP, 2001





PLANCK, 2009





More CBM

Phase transition at …

… very high $\sqrt{s}$ ($\mu_B \approx 0$)

- „melting“ of the non-perturbative vacuum.
- abundant pion production for $kT>m_\pi$

… moderate $\sqrt{s}$ ($\mu_B > 0$)

- Squeezing-out of the non-perturbative vacuum.
- Percolation of quarks?

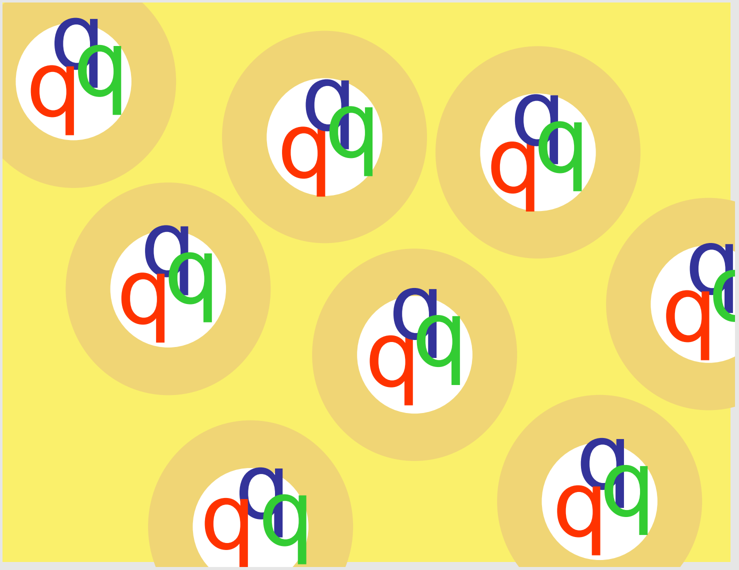
➢How do quarks propagate?

➢What are the properties of hadronic states?

➢Difference between the transition to deconfined/chirally restored phases at zero and finite μ_B?

Cloudy *Bag* *Model*:

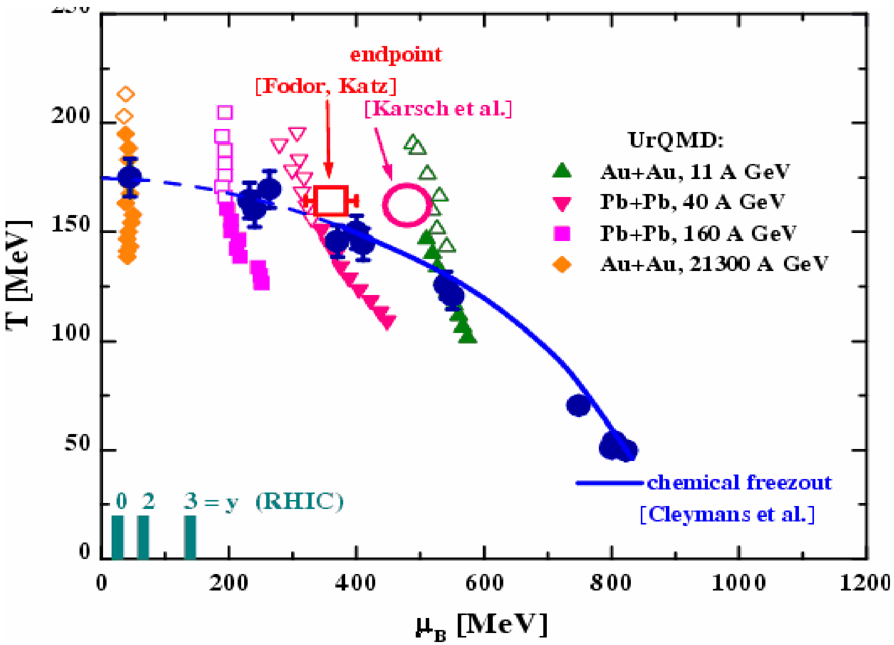
- *valence quarks* in a perturbative state
- embedded in a *non-perturbative vacuum*
- with a *meson cloud* interfacing between the two regions



Trajectories from transport models

Microsopic transport calculation.

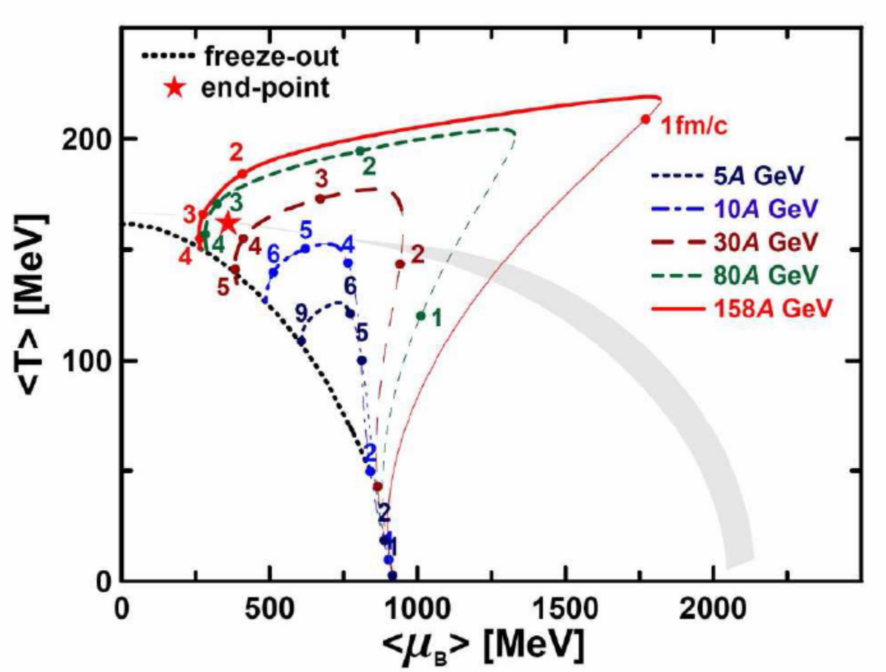
- Predict net-baryon densities of up to 5-10ρ_0.
- Validity in the high density phase?



H.Stöcker, E. Bratkovskaya, M. Bleicher et al., J.Phys.G31,S929(2005)

3-fluid hydro calculation.

- EOS without phase transition.
- Alternative approach for calculating dilepton production?

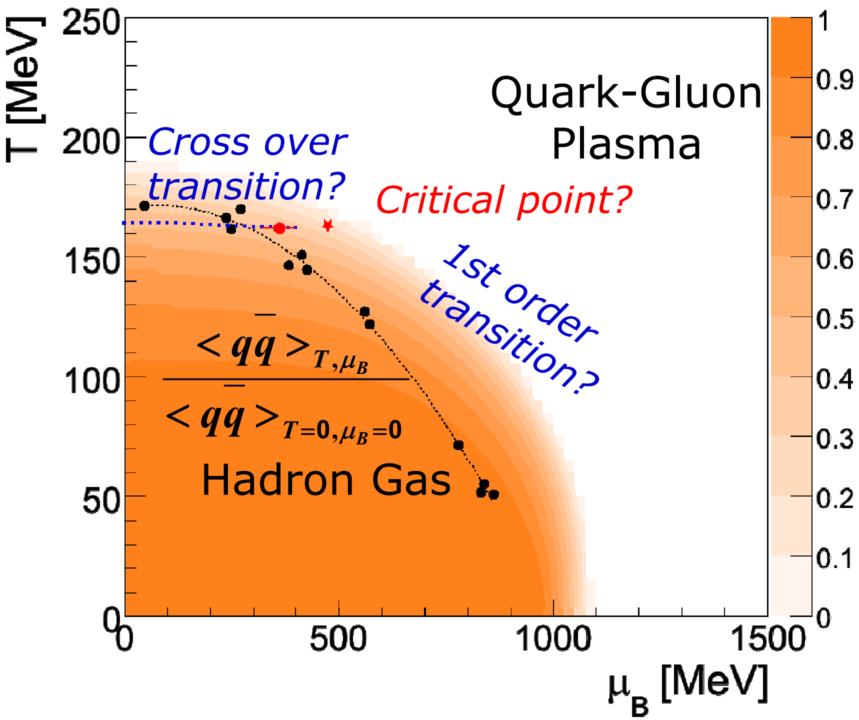


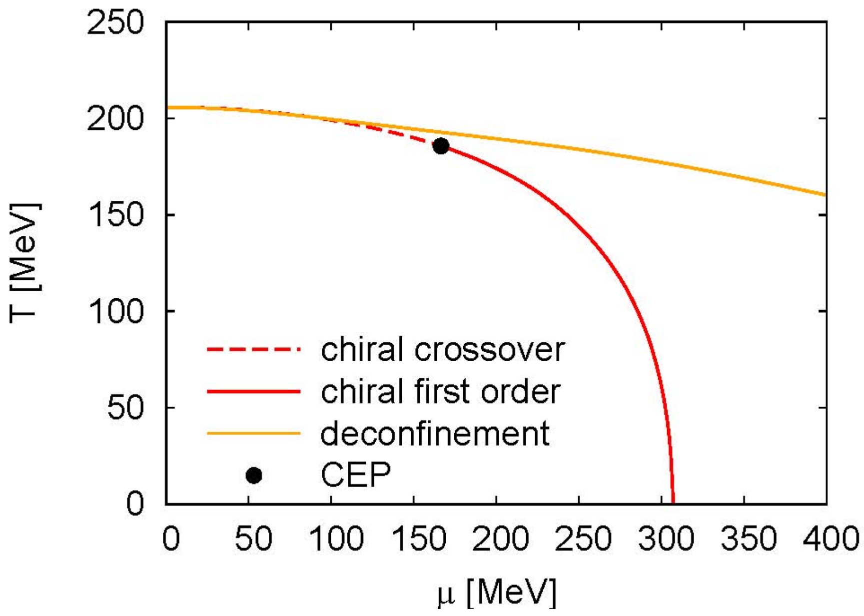
Y.B.Ivanov,V.N.Russkikh,V.D.Toneev, Phys.Rev.C73,044904(2006

Features of the phase diagramme

QCD inspired effective models predict rich structure of the phase diagramme at finite μ_B.

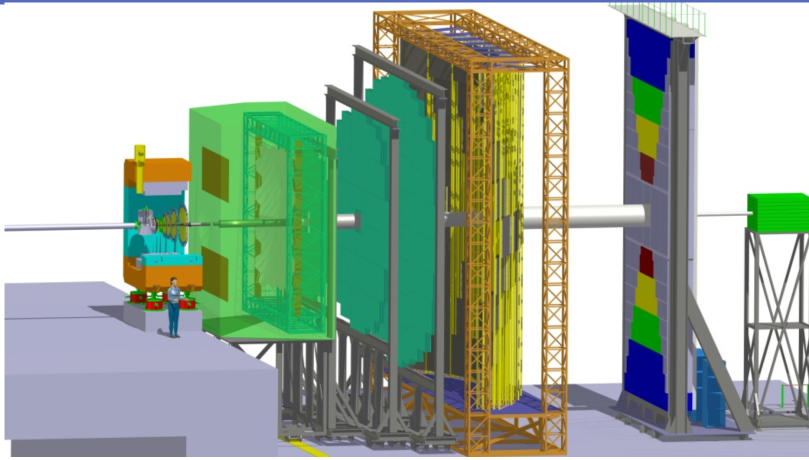
- Substantial depletion of the ciral condensate over almost the full lifetime of the fireball.
- Separation of the chiral from the deconfinement phase transition.
- 1st-order transition with a critical end point.

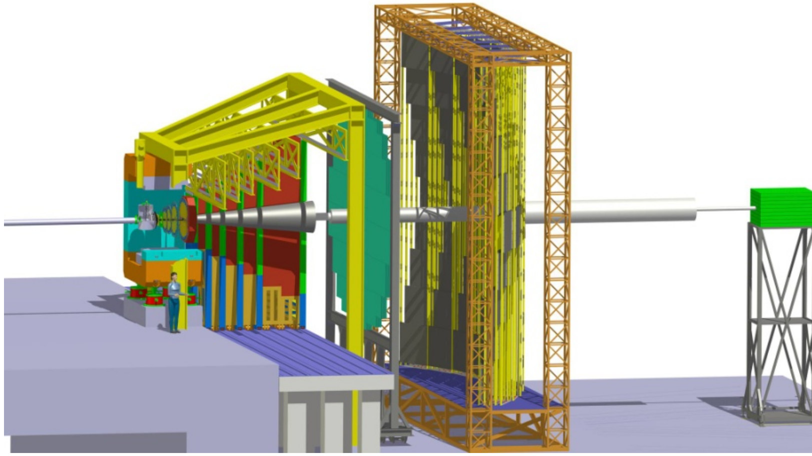




Bernd-Jochen Schaefer, Jan M. Pawlowski, Jochen Wambach, priv. comm. and Phys. Rev. D. 76 074023

The Physics Program of CBM in total





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,...)

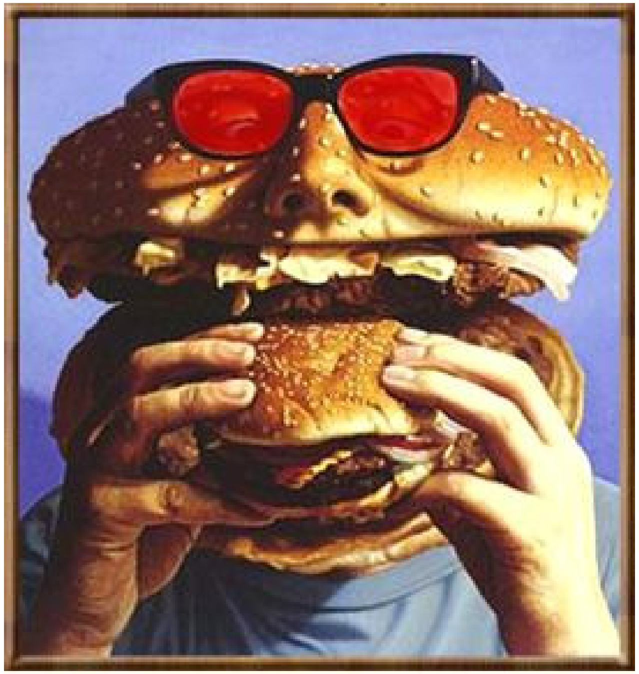
The equation-of-state at high ρ_B

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

Onset of chiral symmetry restoration at high ρ_B

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

Low-mass vector mesons. What do they tell about chiral symmtery restoration?

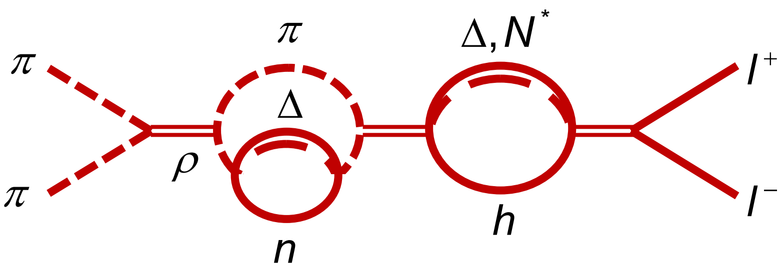


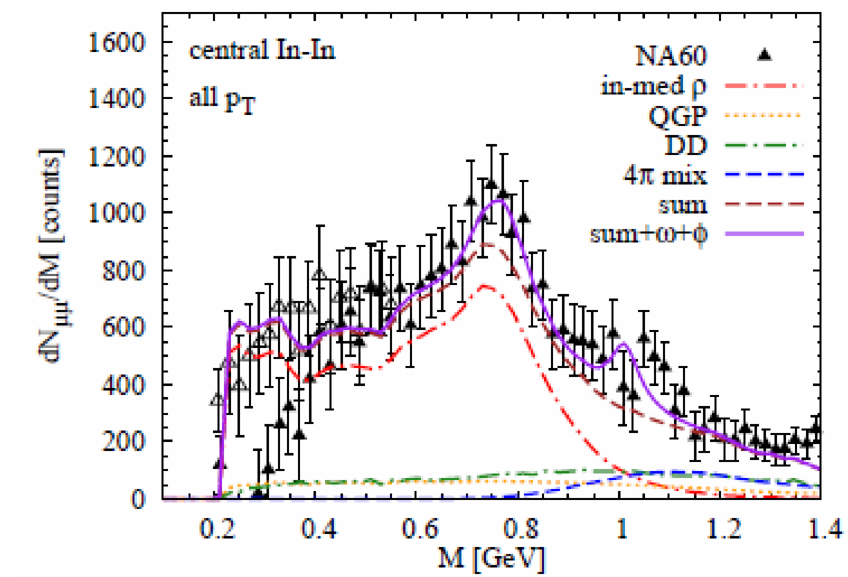
Low-mass lepton pairs, …

… the link to the microscopic properties of dense baryonic matter.

Special role of the ρ meson:

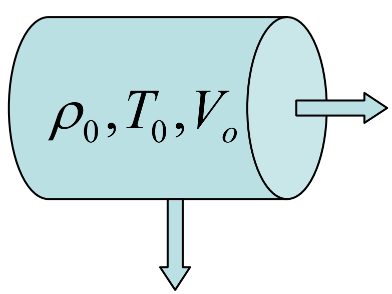
- short life time
- „photon-like“
- coupling to baryons!





R.Arnaldi,etal.[NA60collaboration], Phys.Rev.Lett.96,162302(2006))

Thermal dilepton rates



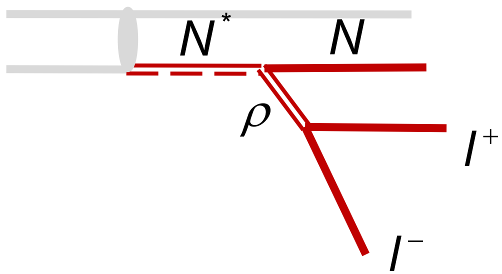
isentropic expansion

$$\frac{d^3N}{dMdydp_t} \equiv \int_{t=0}^{\infty} \frac{d^4\varepsilon}{d\mathbf{p}}\left[T(\mathbf{x}), \mu_B(\mathbf{x}), \vec{v}_{coll}(\mathbf{x}), ..\right] d\mathbf{x}$$

see e.g. R. Rapp, J. Wambach and H. Hees : arXiv:0901.3289

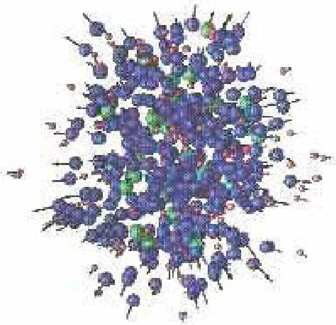
The importance of Resonance Dalitz-Decays …

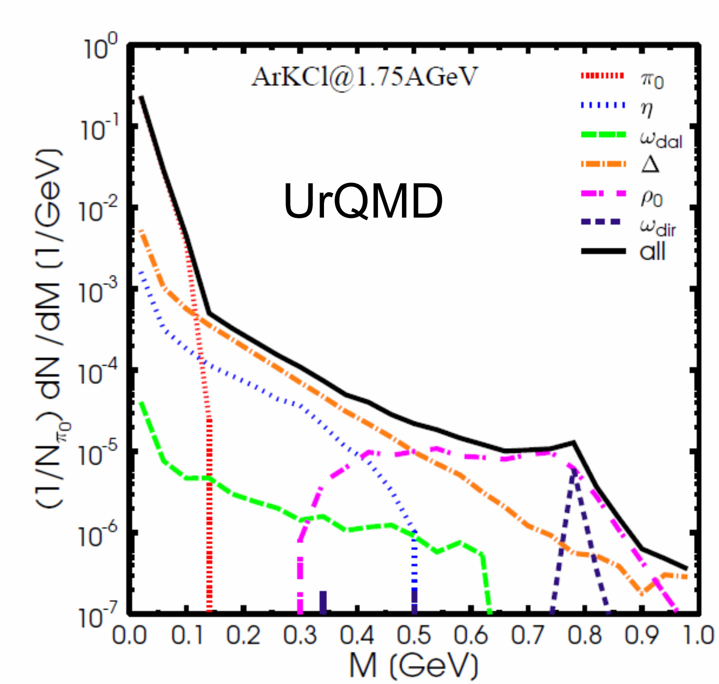
… as dominant source at low beam energies.



- Medium effects at moderate energies are closely linked to the effects at high beam energies through VMD.
- Understanding these contributions is mandatory for low-mass lepton pair programme at FAIR.
- Will be investigated with HADES.
- Theoretical treatment:
  - Off-shell transport (HSD)
  - 3-fluid hydro

e^+e^- from transport



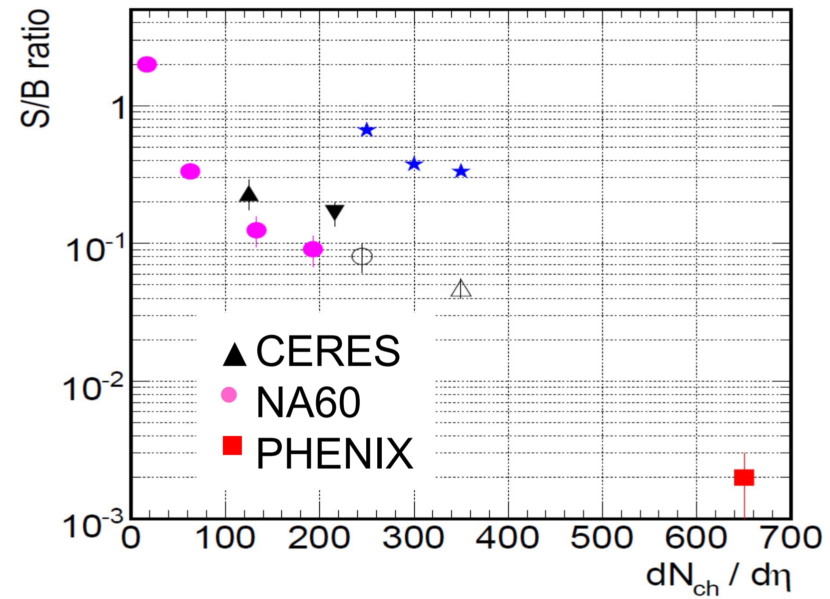


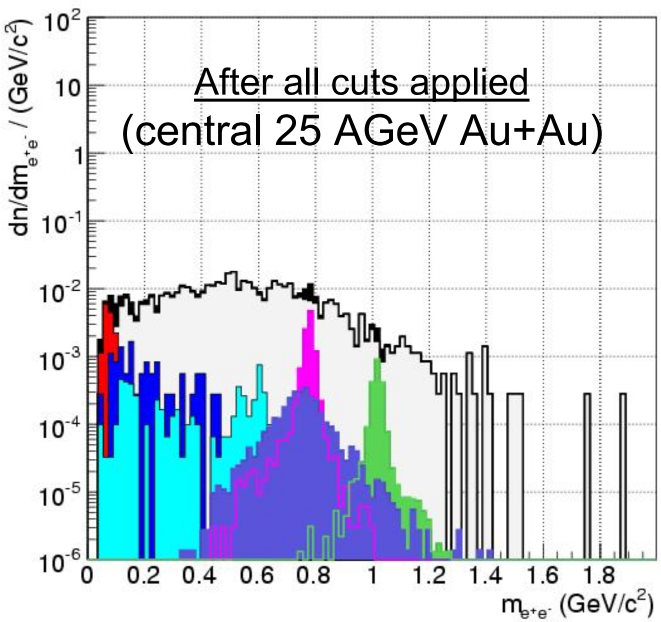
K.Schmidt, E.Santini, S.Vogel et al.: arXiv:0811.4073v2

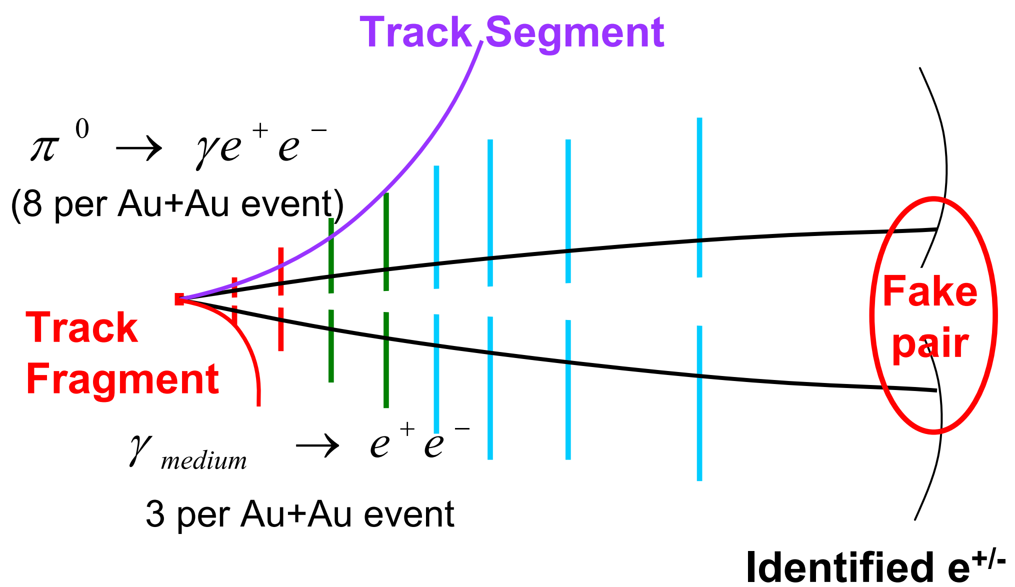
Reconstruction of low-mass electron pairs …

… without hadron-blind detector before the magnetic field.

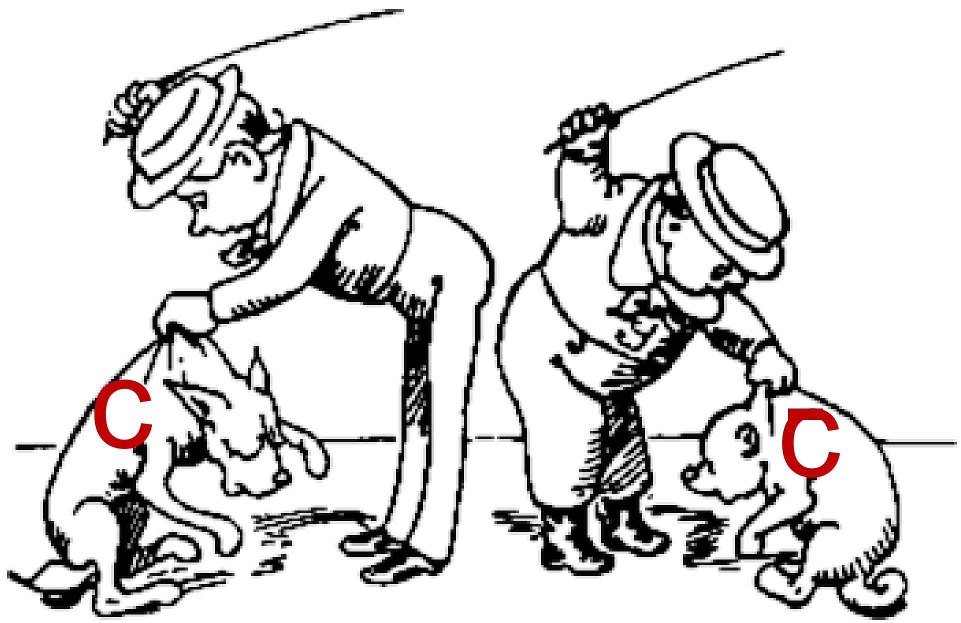
- Sufficient π discrimination from RICH and TRD (<10^{-4})
- Reduction of background by reconstructing pairs from γ-conversion and π-Dalitz decay by means of their track topology.







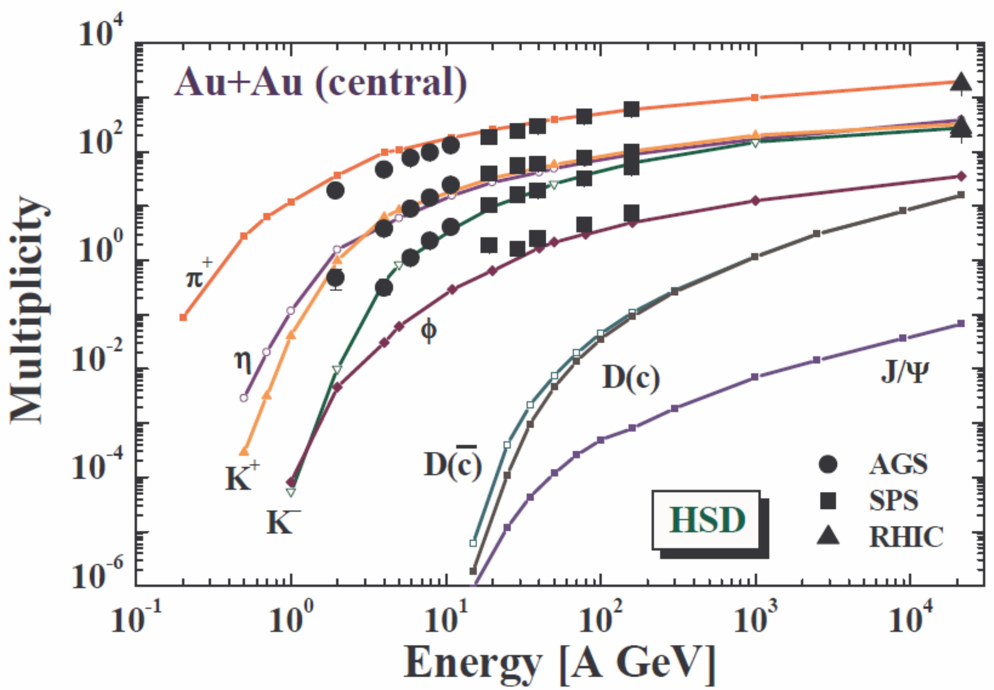
Charmonium suppression.



The Charm of CBM

Rare but feasible!

- Very sparse experimental information
- At threshold, production mechanism in pA and AA unclear.



W. Cassing, E.L. Bratkovskaya, and A. Sibirtsev, Nucl.Phys.A691,753(2001)

Open charm in CBM	
Mult.	M / 10^{12} events[1)]
$D^0 \rightarrow K^- + \pi^+$	
4 10^{-5}	56000
$\overline{D}^0 \rightarrow K^+ + \pi^-$	
1 10^{-4}	174000
$D^- \rightarrow K^+ + \pi^- + \pi^-$	
9 10^{-5}	195000
$D^+ \rightarrow K^- + \pi^+ + \pi^+$	
4 10^{-5}	103000

1) 10^{12} events ≅ 40 weeks running at 10^5 interaction rate.

☞Event selection: Real-time vertex finding in 20 Gbyte data/s.

Near threshold charm production

	$2m_q$	m_{VM}	$m_{VM} - 2m_q$	$\frac{m_{VM} - 2m_q}{m_{VM}}$
$u\bar{u}, d\bar{d}$	< 20 MeV	~ 780 MeV	760 MeV	97 %
$s\bar{s}$	~ 190 MeV	1020 MeV	830 MeV	81 %
$c\bar{c}$	~ 2500 MeV	3097 MeV	597 MeV	19 %

Does charm at FAIR play the same role like Strangeness at GSI?

Substantial differences due to the large charm quark masses:

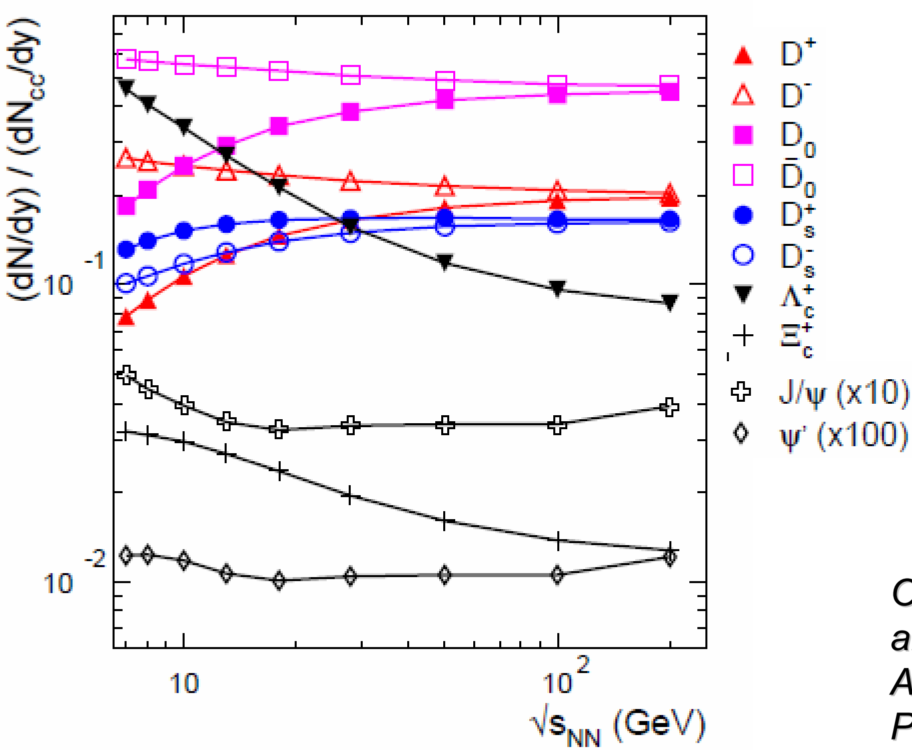
- Different interaction/production mechanism (Meson vs. Pomeron exchange)
- Charm pair produced in very short instant of time (~ $1/m_c$, i.e. of order 0,1 fm)
- Hadron formation time possibly similar (time needed to establish the proper sea-quark and gluon distribution)

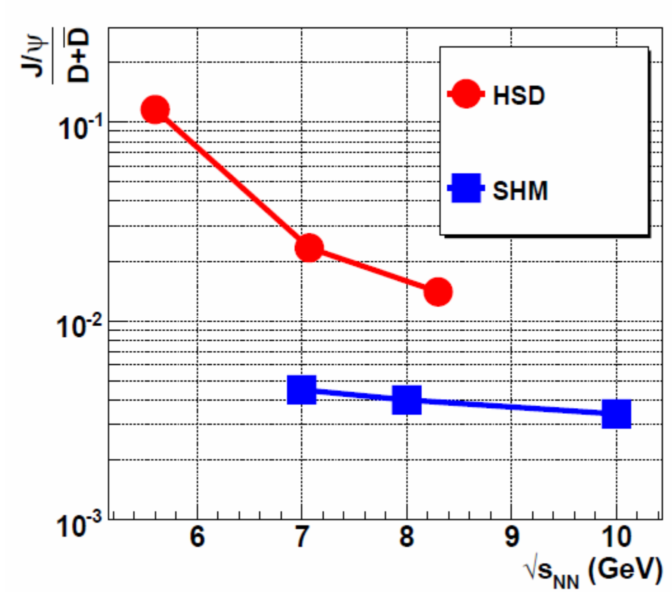
➢ *Medium-effects may determine the charm distribution over hadronic degrees of freedeom but likely not the multiplicity!*

Charm propagation

How are the produced charm quarks propagating in the dense phase, quark like or (pre-)hadron like ?

- Charmonium over open charm as indicator!
- Charmed baryons important for a complete picture.
- Are there indications of collectivity.





O. Linnyk, E. Bratkovskaya and W. Cassing, arXiv:0808.1504v1
A. Andronic, P. Braun-Munzinger, et al., Phys. Lett. B 659 (2007) 149, arXiv:0708.1488

The technological challenges:

1. Interaction rates & rate capability!
2. Radiation hardness!
3. High-performance computing!

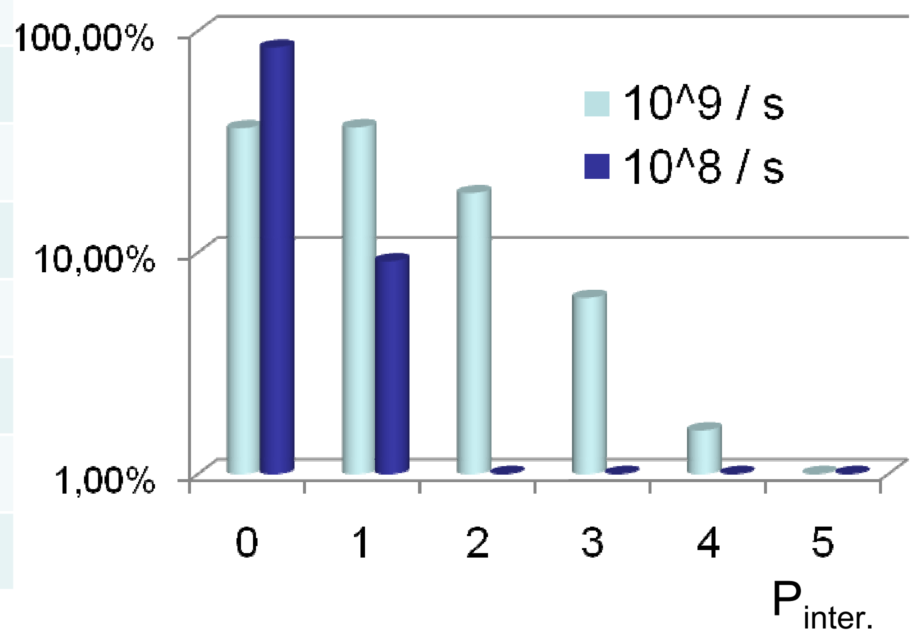
High interaction rates …

…require also good beam profile and micro time structure.

- SIS-300 optical lattice is optimized for slow extraction (SIS-100 is not).
- Most of the physics can be done with interactions rates up to 10^6/s .

10 weeks of beam on target			
Rate	Set-up		
25 kHz	No on-line event reduction		
$5\ 10^{10}$ K	$5\ 10^6\ \omega$	$10^6\ \phi$	$5\ 10^6\ \Omega^-$
100 kHz	On-line event reduction		
$5\ 10^3\ D^0$	$2\ 10^4\ D^+$	$4\ 10^4\ D^-$	$7\ 10^4\ \Lambda_c$
250 kHz	No MVD, muon trigger[1)]		
	$4\ 10^7\ \omega$	$6\ 10^6$	
>1 MHz	No MVD, highly selective ES		
	$10^5\ J/\psi$	$10^2\ \psi'$	

Reaction probability $P_{inter.}$ in a 100 ns time interval assuming perfect extraction and a 1 % target.



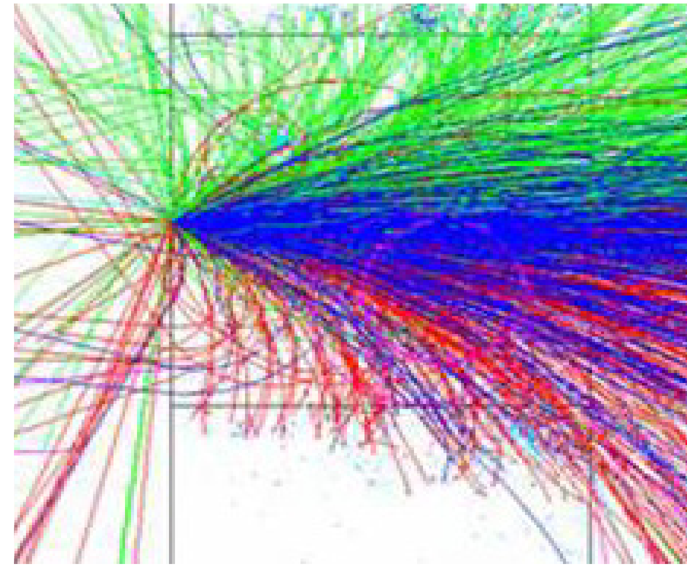
Open Charm measurements

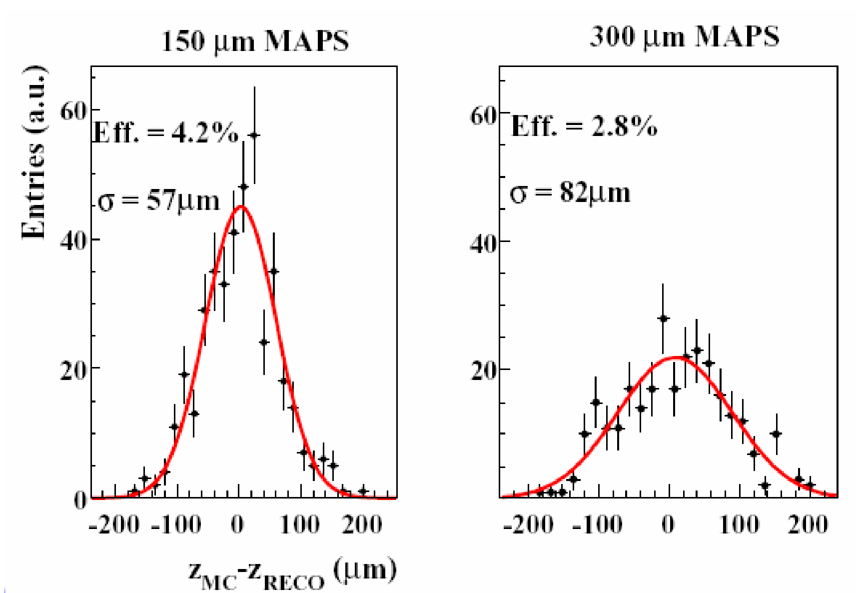
Challenge

- Online displaced vertex reconstruction with high precision.

Needs tracking system with

- high resolution.
- minimal material budget.
- fast on-line event selection.



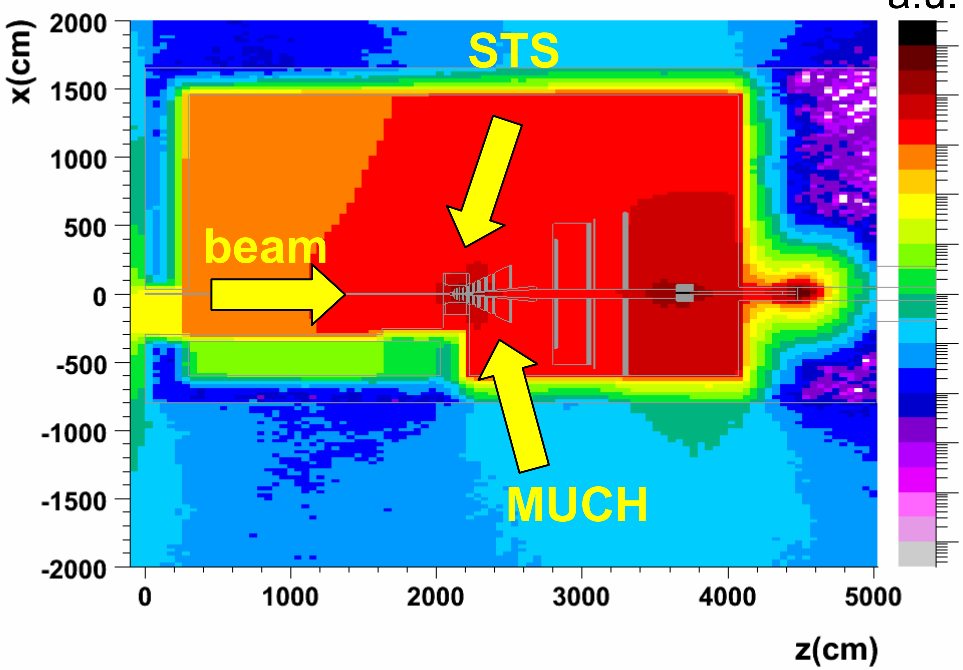


At 10^6 interaction/s real time reconstruction in ~20 Gbyte tracker data per second.

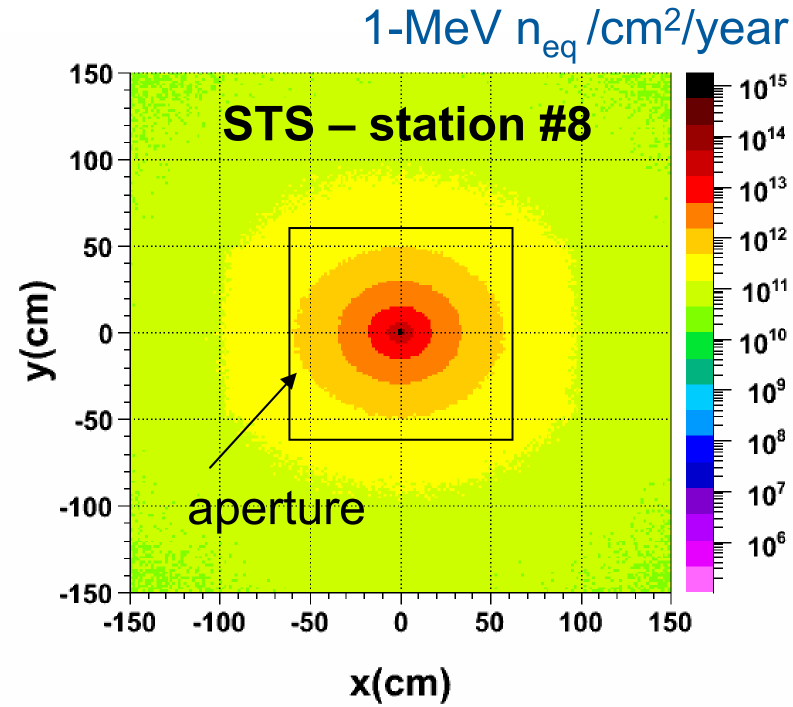
Radiation environment

Neutron fluence in CBM cave

UrQMD + FLUKA simulation,
25 GeV Au beam on Au target



Neutron fluence through Silicon Tracking System



Typical operation scenario: 6 years ⇒ up to 10^{15} n_{eq}/cm^2

⇒ radiation hardness regime of LHC/SuperLHC experiments

Summary

1. The physics of dense baryonic matter is extremely rich and provides complementary inside into matter governed by non-perturbative QCD (confinement and spontaneous breaking of chiral symmtery).
2. CBM gains its uniqness from the combination of a high-precision/rate detector with a dedicated facility providing brilliant beams for long running periods.
3. The program at FAIR is not a bargain but a reasonably moderate investment for a valuable and complementary insight into a very important aspect of QCD matter.
4. For details of the spectrometer and its anticipated performance see talk tomorrow by Claudia Höhne.

Please tell everybody who is not yet convinced ;)