GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Nuclear Matter Physics at SIS100, GSI, April 2009

Dense Nuclear Matter: an experimentalists view

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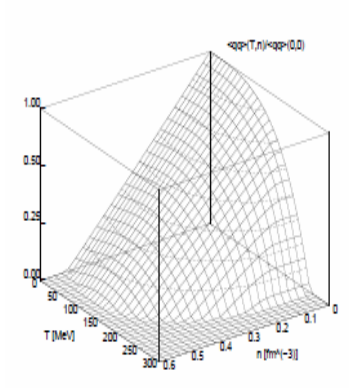
What are the relevant degrees of freedom of nuclear matter at 2 - 5 ρ_0?

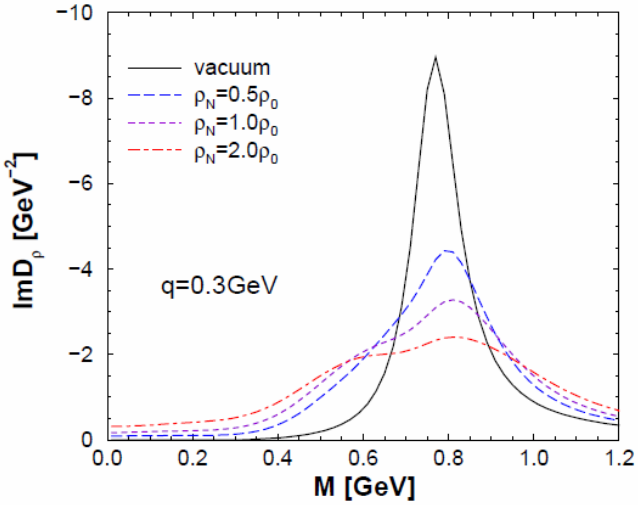
20 years of dileptons from HI collisions

The search for signatures of a partial restoration of the spontaneously broken chiral symmtery (SBχS): ☞ look for the ρ meson (Vector Meson Dominance).

Mass shifts (χ condesate):

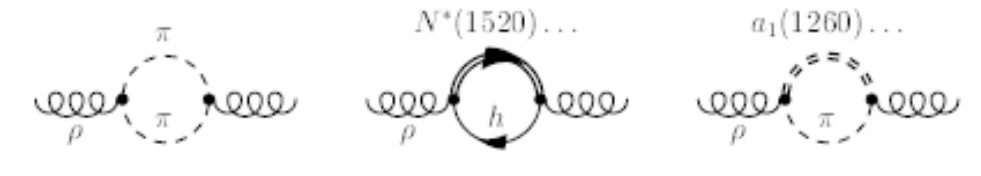
- G. E. Brown and M. Rho
- T. Hatsuda and S. H. Lee

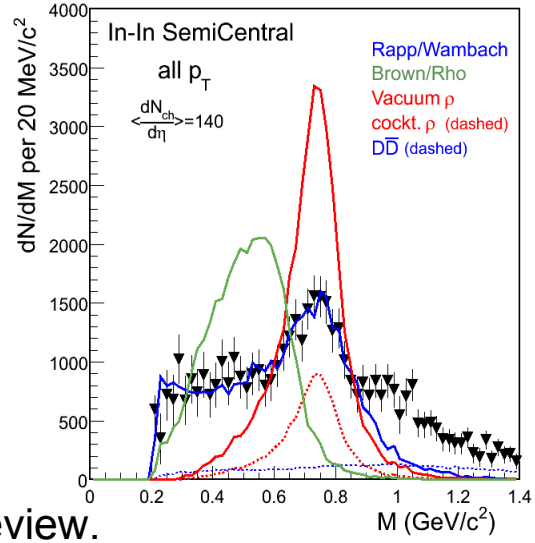




Broadening (hadronic):

- B. Friman, H.J. Pirner ….
- F. Klingl, W. Weise ….
- R. Rapp and J. Wambach





As of today no rigorous evidence for restoration!

No evidence for in-medium ρ from HADES!

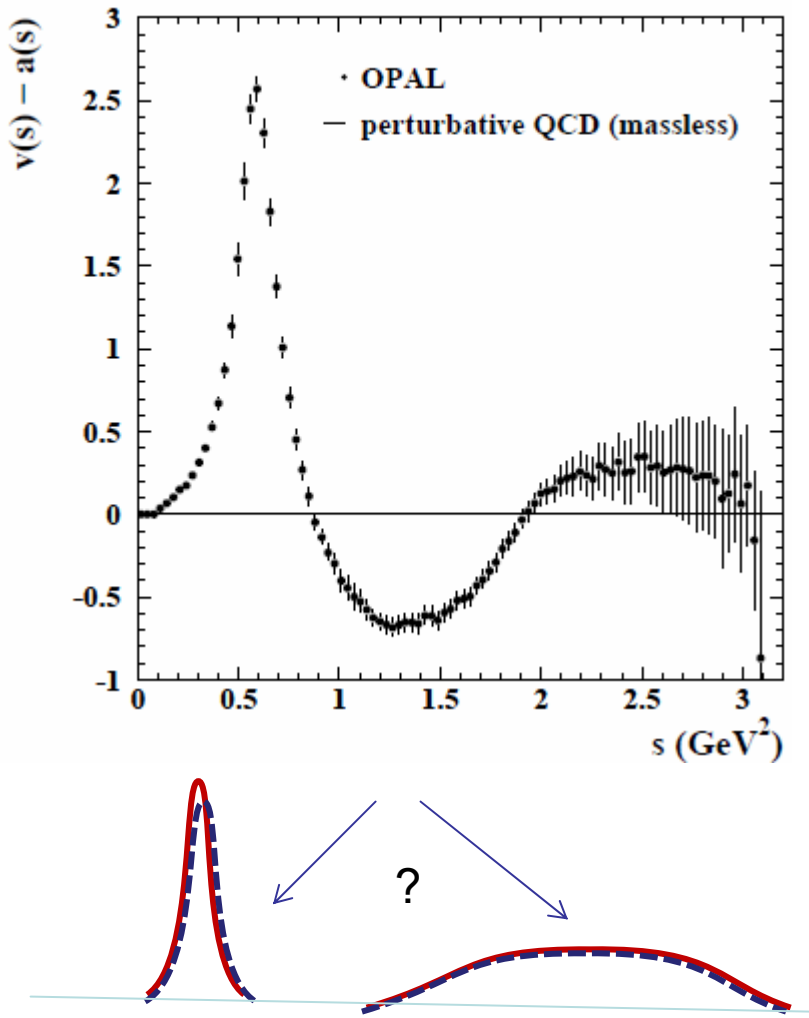
See arXiv:0901.3289v1 (Hees, Rapp, Wambach) for recent review.

Restoration of SBχS

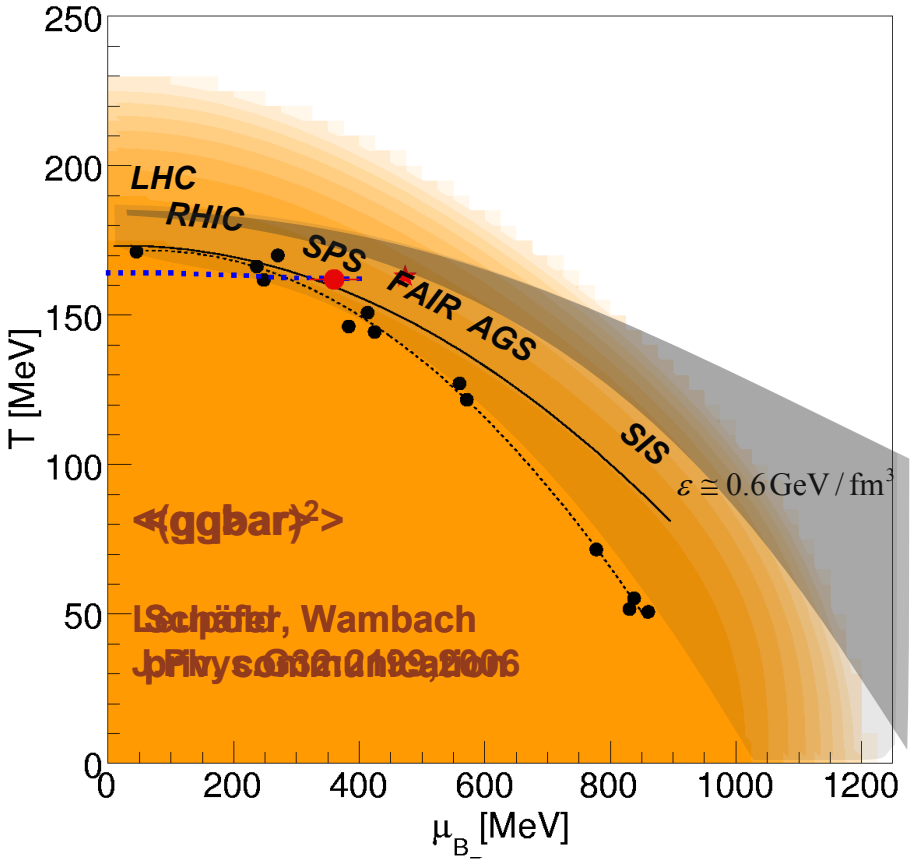
- The only direct evidence for a restoration of chiral symmtery is an aligment of the vector and axial vector spectral strength.
- a_1 is in any case hard to detect
  - mostly $\pi\rho$, also $\pi\gamma$
- The order parameter of chiral symmtery breaking is the four quark condensate (Weinberg sum rules)

$$\frac{1}{\pi}\int ds\, s^2\, \mathrm{Im}\left(R^V(s) - R^A(s)\right) \propto \left\langle \bar{q}\Gamma\lambda_\alpha q\, \bar{q}\Gamma\lambda_\alpha q\right\rangle$$

But both states can acquire a huge width at the same time!



The phase diagram of nuclear matter



Chemical freeze-out points derived from Statistical Hadronization Model

- Universal conditions for freeze-out (?)
- Limiting temperature T_{max}?
- Why is it woking at low beam energies?

LQCD explores unknown regions from solid grounds at μ_B=0.

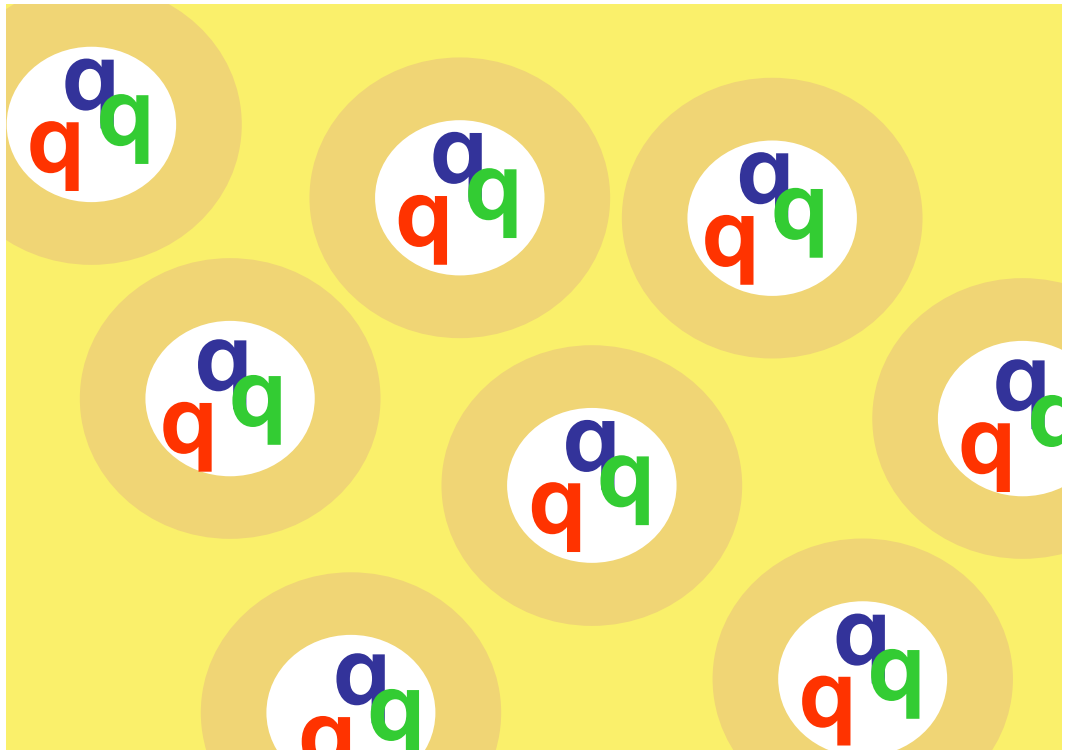
- $T_c = T_{max}$?
- 1st order phase transition
- Critical point ?

QCD inspired models demonstrate the melting of the condesates.

A. Andronic, P. Braun-Munzinger, K. Redlich, J. Stachel
J. Cleymans, K. Redlich

Ignorant interpretation (Cloudy Bag Model)

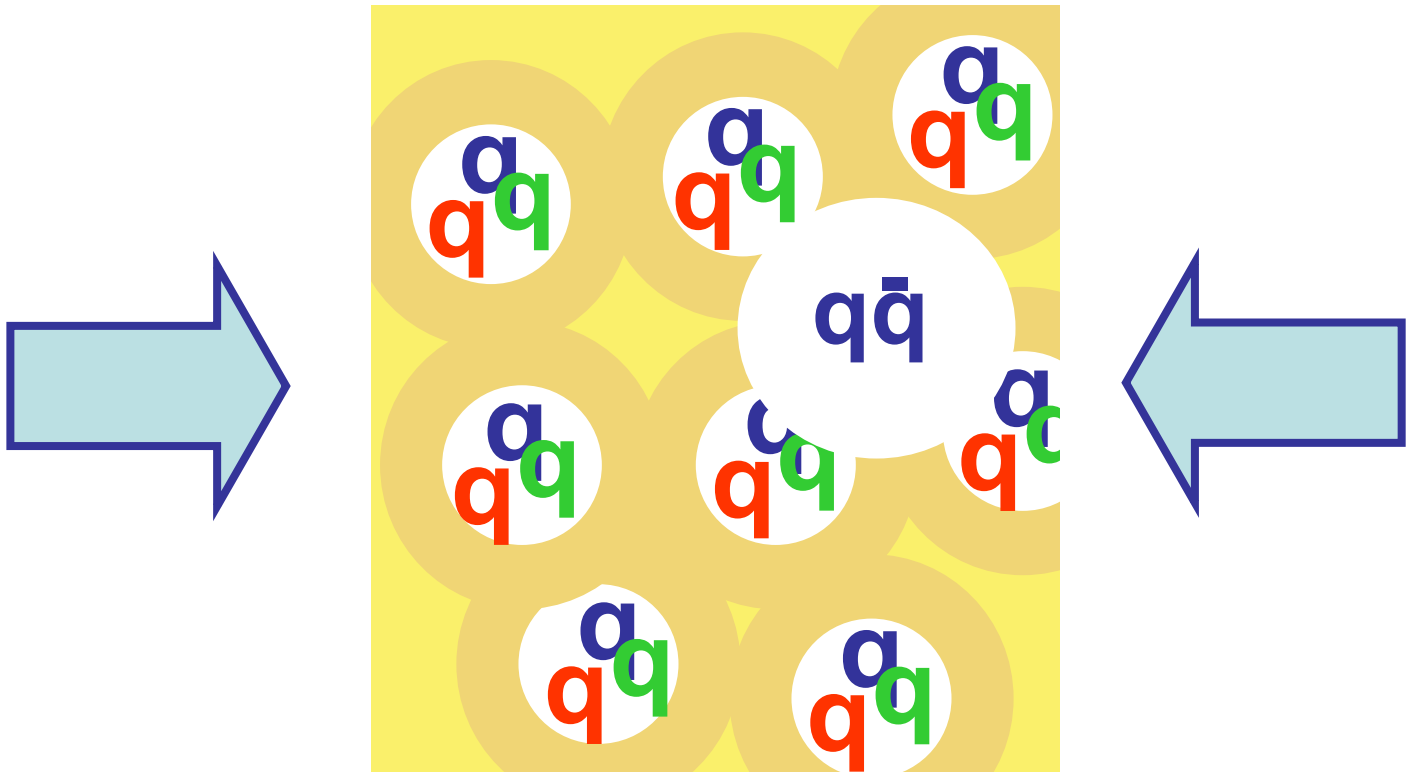
1 fm : equiv. to 100 MeV (uncertainty relation)



$T \cong T_c$, $m_B \sim 0$

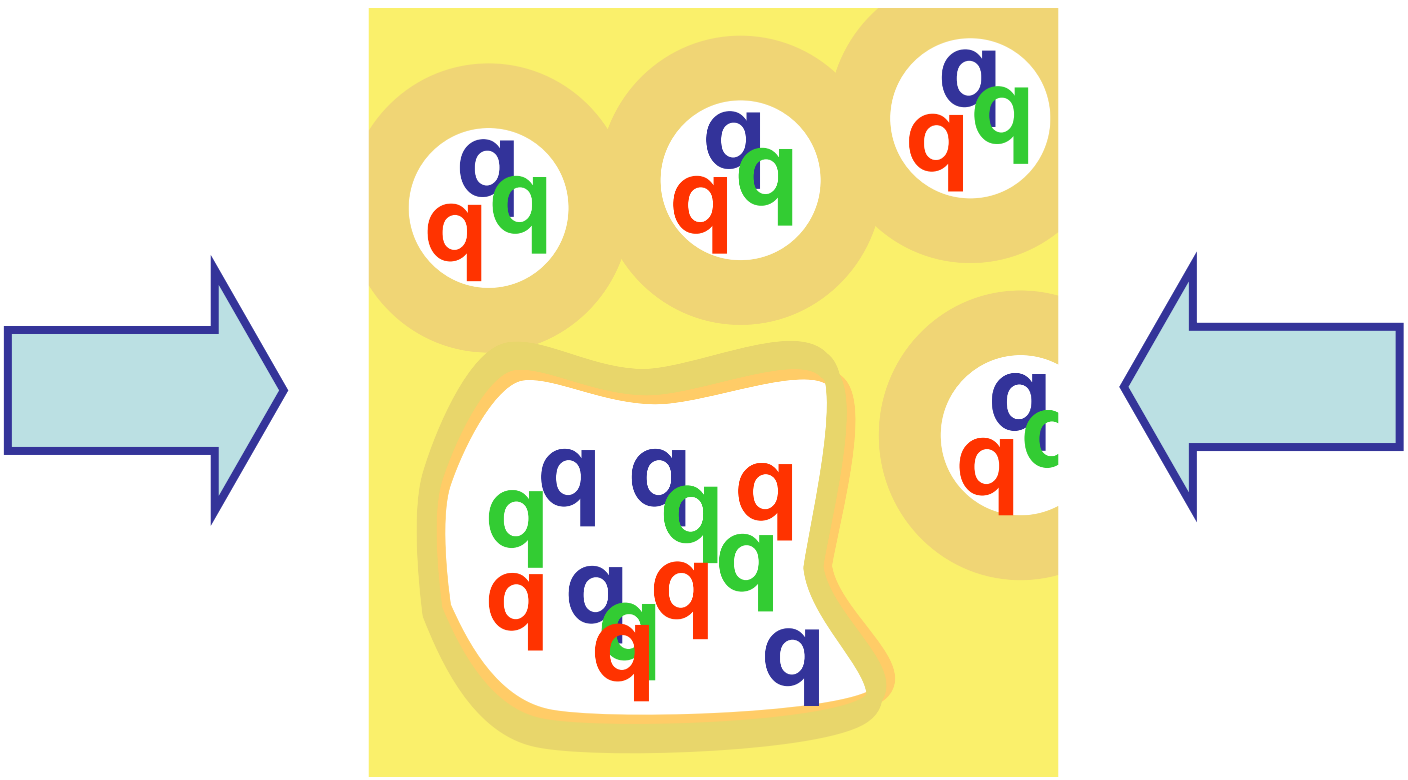
Excitation/melting of the vacuum/cloud. ☞ smooth cross over

$T << T_c$, finite μ_B



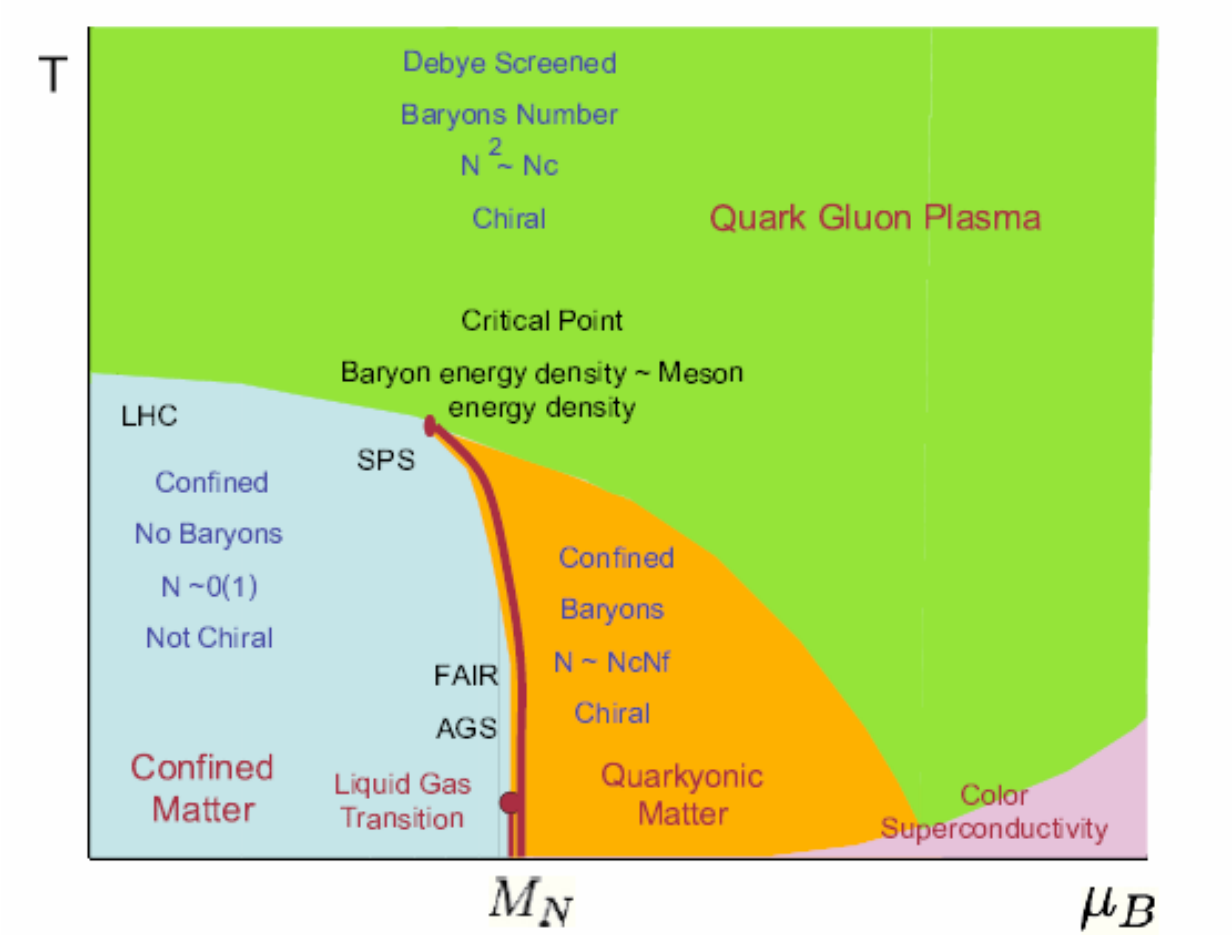
$T \ll T_c$, finite μ_B

Bag fusion ☞ 1st order



Phase diagram from large N_c

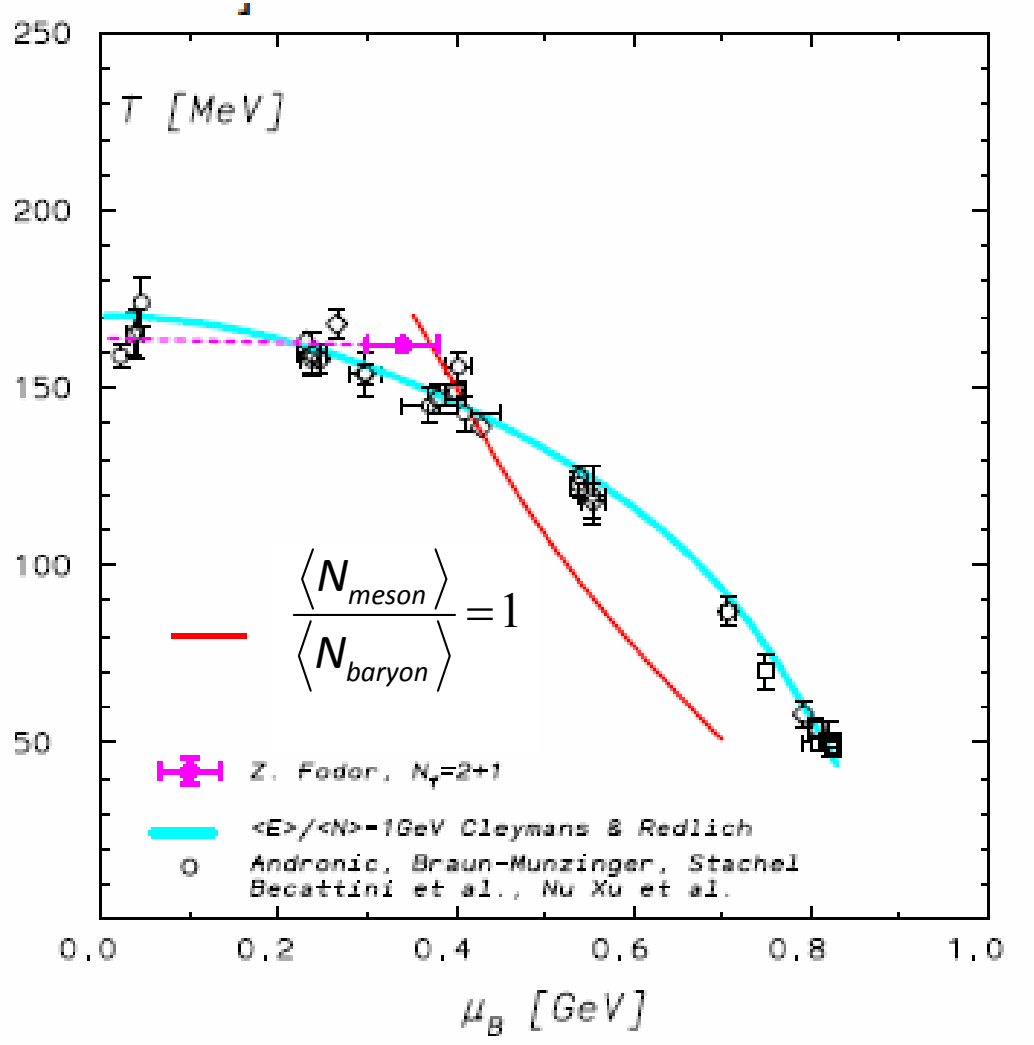
Larry McLerran, QM09 ☞ conjecture for $N_c = 3$



Quarkyonic Matter: Confined gas of perturbative quarks!

Role of freeze-out line.

Meson to baryon ratio may seperate quarkionic from non-quarkionic world.

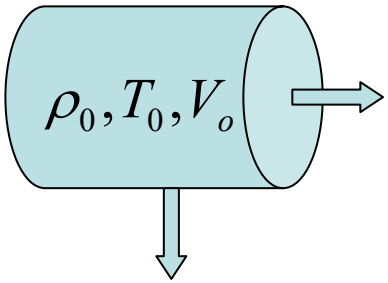


Red line from Hadron Gas Model, Sasaki QM09

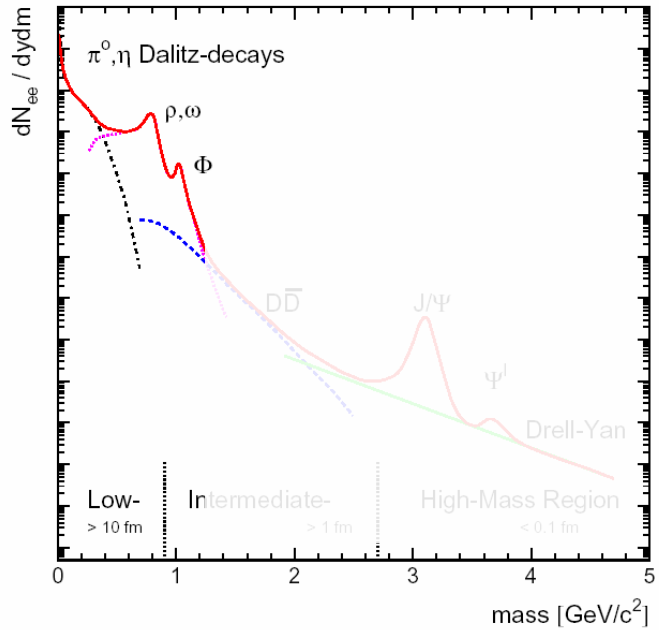
Observable I

Thermal dilepton rate ...

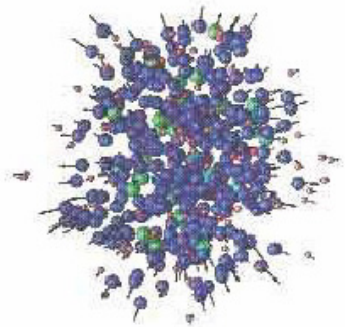
$$\frac{d^3N}{dMdydp_t} \equiv \int_{t=0}^{\infty} \frac{d^4\varepsilon}{dp}\left[T(x), \mu_B(x), \vec{v}_{coll}(x), ..\right] dx$$



isentropic expansion



...or from transport



In future:

- use transport to generate statistical ensembles
- Couple hydro to transport and calculate dileptons from hydro also.

Observable II

Strangeness production and equilibration.

- Try to seperate yields from „core“ and „corona“.