Soft Physics in ALICE

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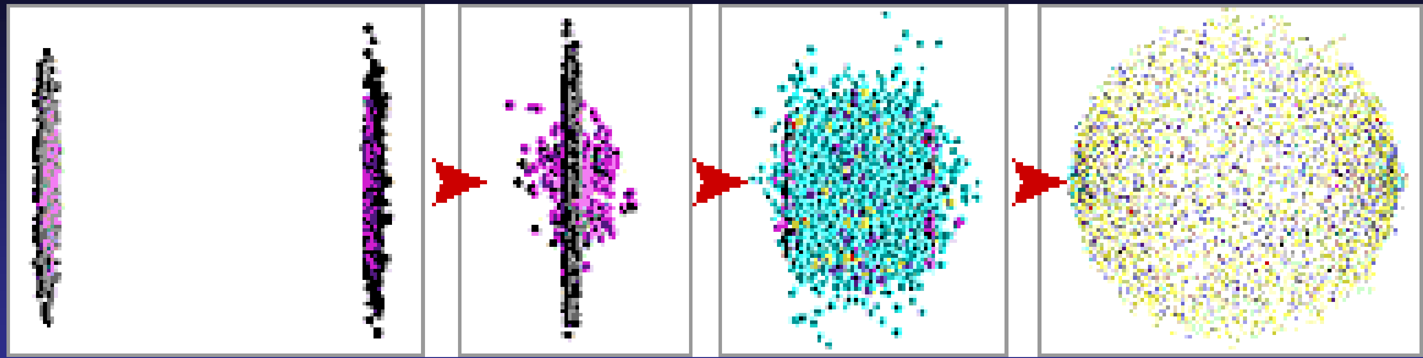
Outline

- Relativistic heavy ion collisions
- Some observables of the Soft Physics sector in ALICE:
  - Particle Abundances at LHC
  - Momentum spectra at LHC
  - Resonances at LHC
- Conclusions

Summary on rHIC @ RHIC

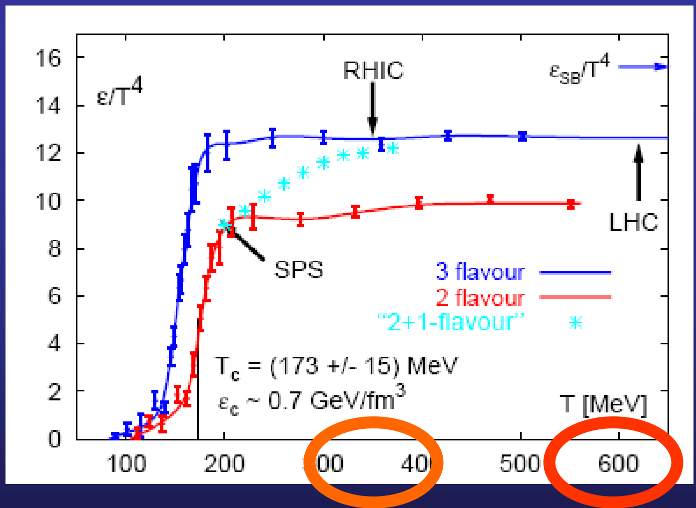
relativistic
Heavy Ion
Collision



Thermalization
τ < 1 fm/c

Expansion
1 fm/c < τ < 10 fm/c
(Hadrons →) partons → Hadrons
(QGP phase)

Freeze-out
10 ~ 15 fm/c < τ



- **q, g no more confined in hadrons.**
- **q, g interact in a bigger volume**

The particles are detected AFTER this phase !!

What's new @ LHC ?

Higher initial energy density	Au-Au @ $\sqrt{s_{NN}}$ = 200 GeV → Pb-Pb @$\sqrt{s_{NN}}$ = 5.5 TeV
Higher initial Temperature	360 MeV → 600 MeV (?)
Longer lifetime of the QGP phase	~ 6 fm/c → (?)

Hard processes contribute significantly to global observables, in contrast to RHIC (ALICE PPR vol I)

Will the theoretical assumptions for RHIC data be still valid at LHC ?

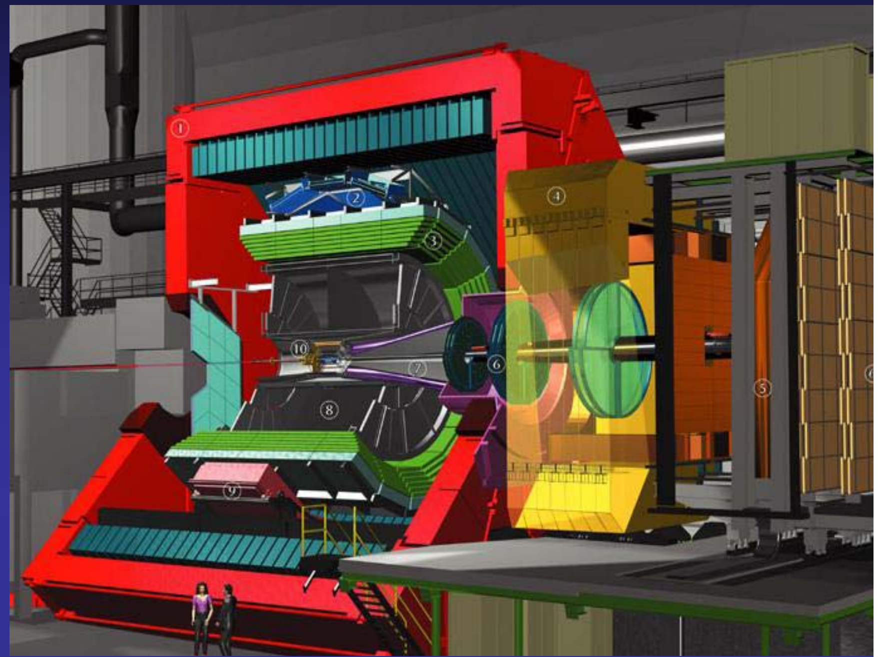
- Particle ratios via a statistical approach : Will the equilibrium be reached?
- The expansion phase via hydrodynamics : At which level could it describe momentum spectra and the bulk flow?

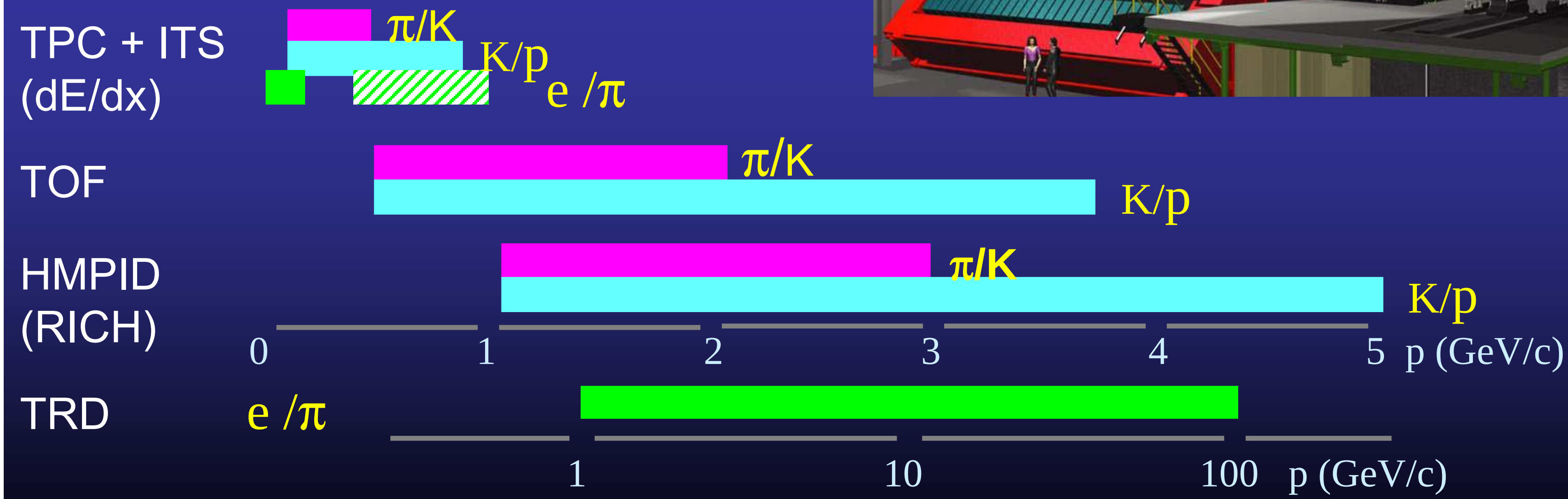
A good identification of particles is very important!!

ALICE experiment @ LHC

A unique capability to identify particles :

- Larger acceptance
- efficient PID in large pt domain (especially in the low pt region)





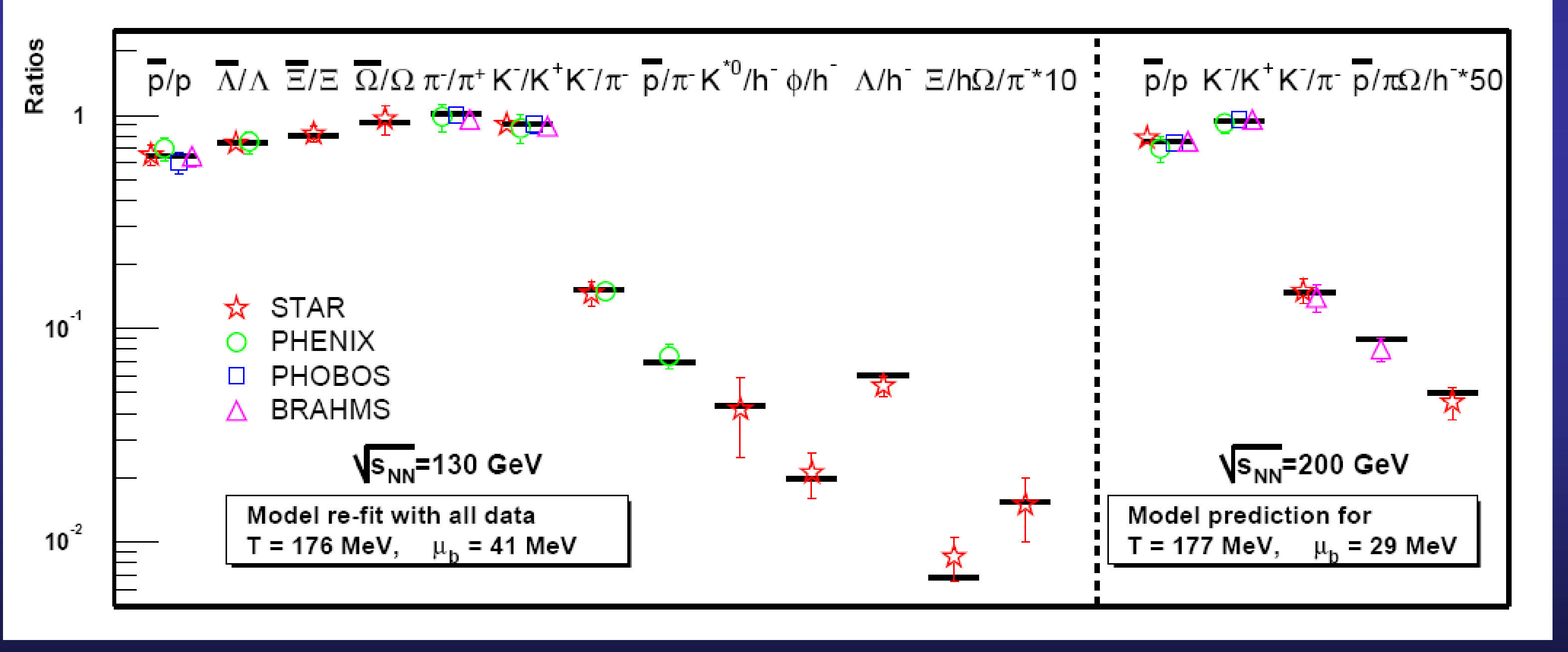
Particle abundances

Particle abundances @ RHIC

...many models but a common hypothesis : *Grand Canonical ensemble*

- Chemical equilibrium
- Strangeness and charge conservation

parameters : T and μ_B



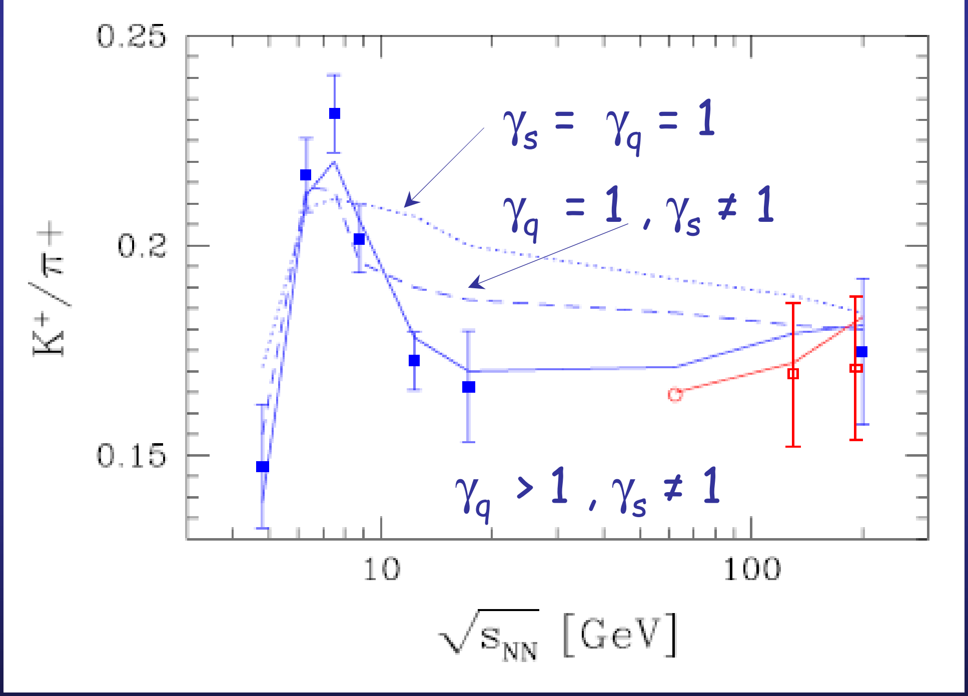
nucl-th/0304013 v1

Particle abundances

…what if deviations from chemical equilibrium exist?

-> new parameters : γ_s γ_q (q = u, d)

[Chemical equilibrium means γ_s = γ_q = 1]



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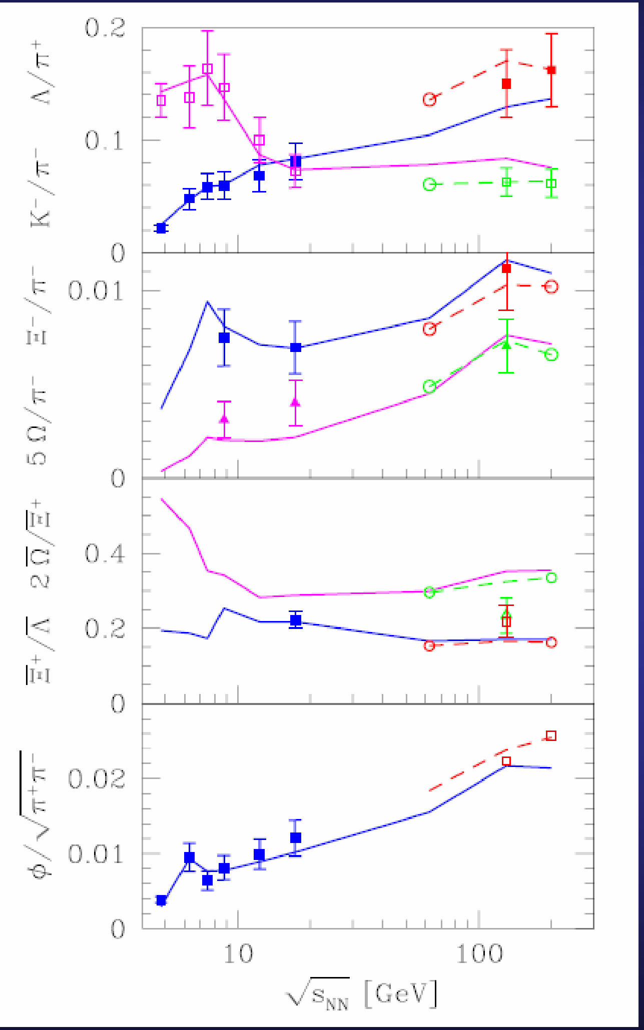
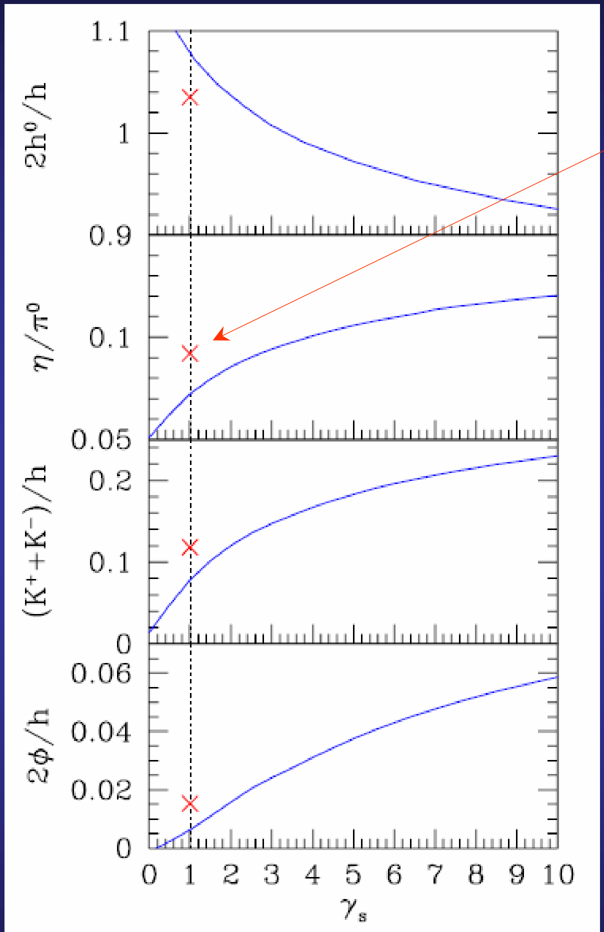
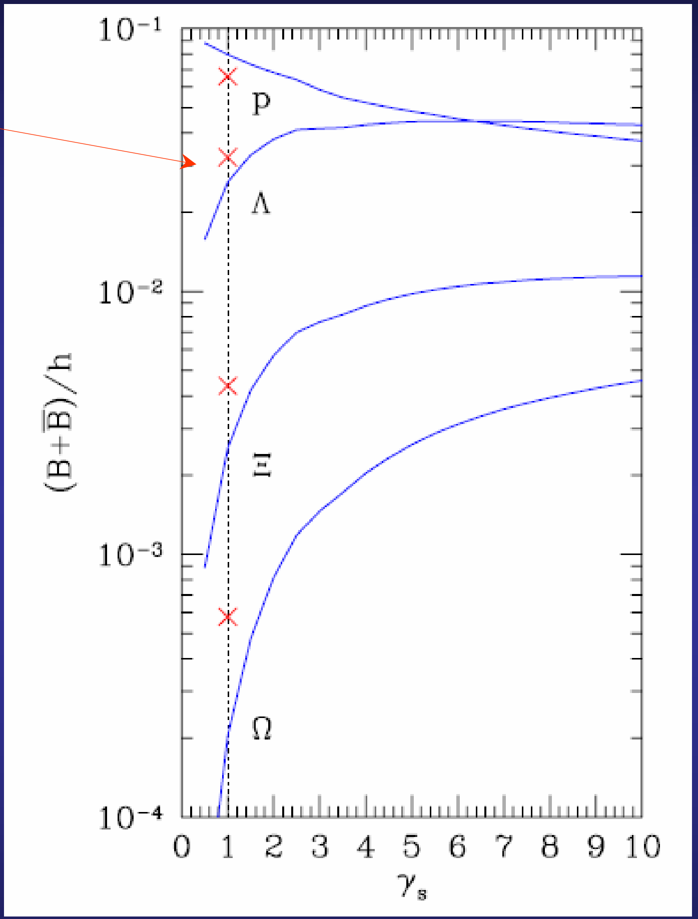


Particle abundances @ LHC



results for chemical equilibrium



Predictions for chemical equilibrium will provide new insights in the chemical properties of the plasma

"Soft hadron ratios at the LHC" Eur. Phys. J. C 45, 61-72 (2006)

Hadronic dynamics :
(hydrodynamical picture)

-Pt spectra
- elliptic flow

m_t spectrum

Hadrons show a collective behaviour

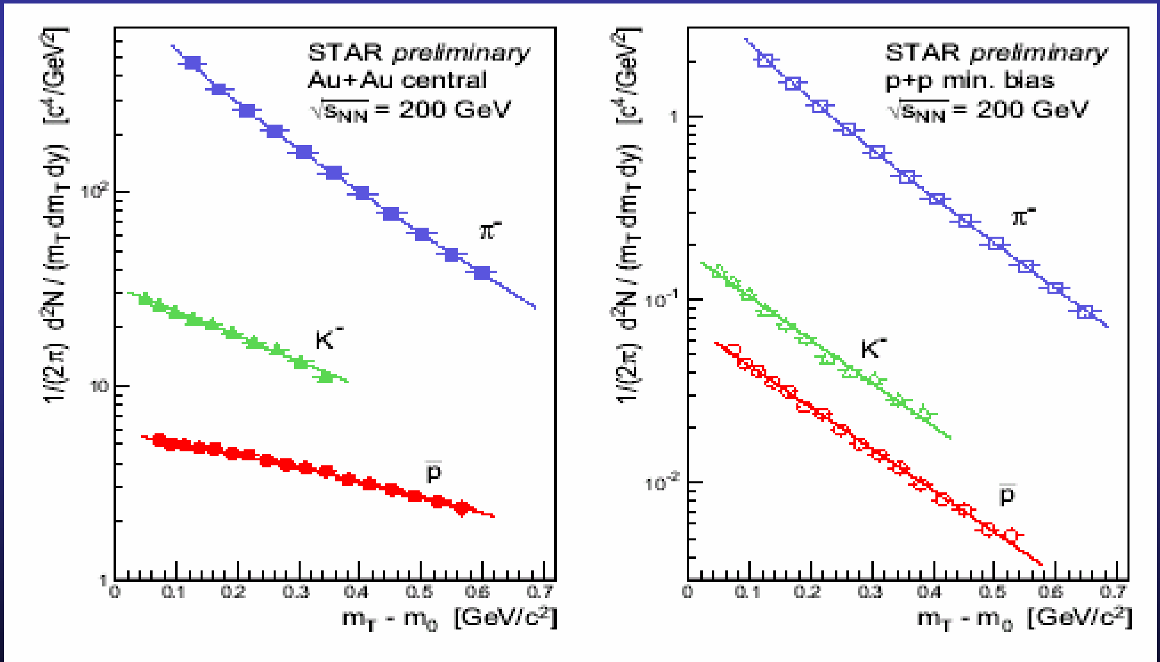
Hydrodynamical approach : non viscous cells of fluid in thermal equilibrium *nucl-th/0305084*

(microscopic time scales << macroscopic time scales)

$$m_T = \sqrt{p_T^2 + m^2}$$

$$\frac{dN}{m_T dm_T dy} \approx e^{-\frac{m_T}{T_{slope}}}$$

hep-ph/0407360 U. Heinz



Hydrodynamical calculations (sudden freeze out) show :

m_T-scaling (valid in p+p) is broken by the transverse flow of the fireball :

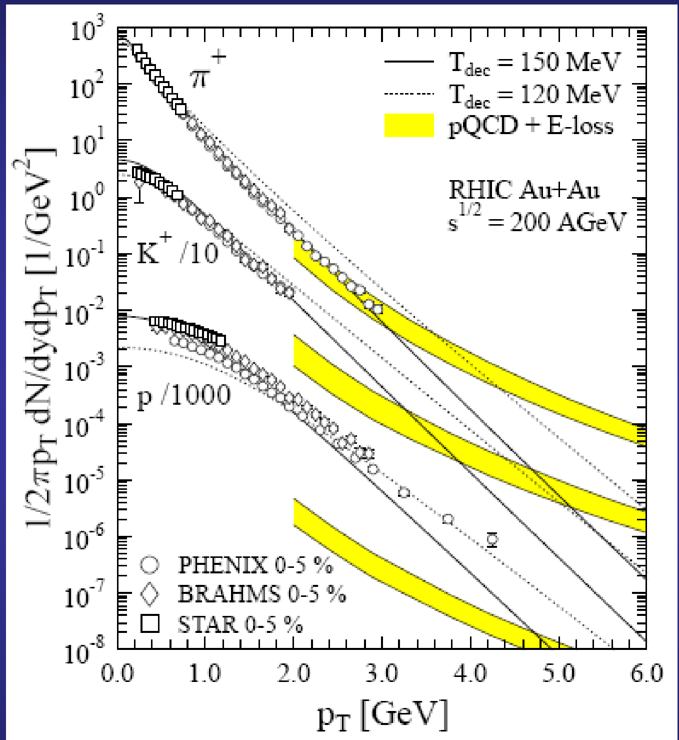
if $p_t \ll m_0$

$$T_{slope} = T_{dec} + m\langle\beta_T\rangle^2$$

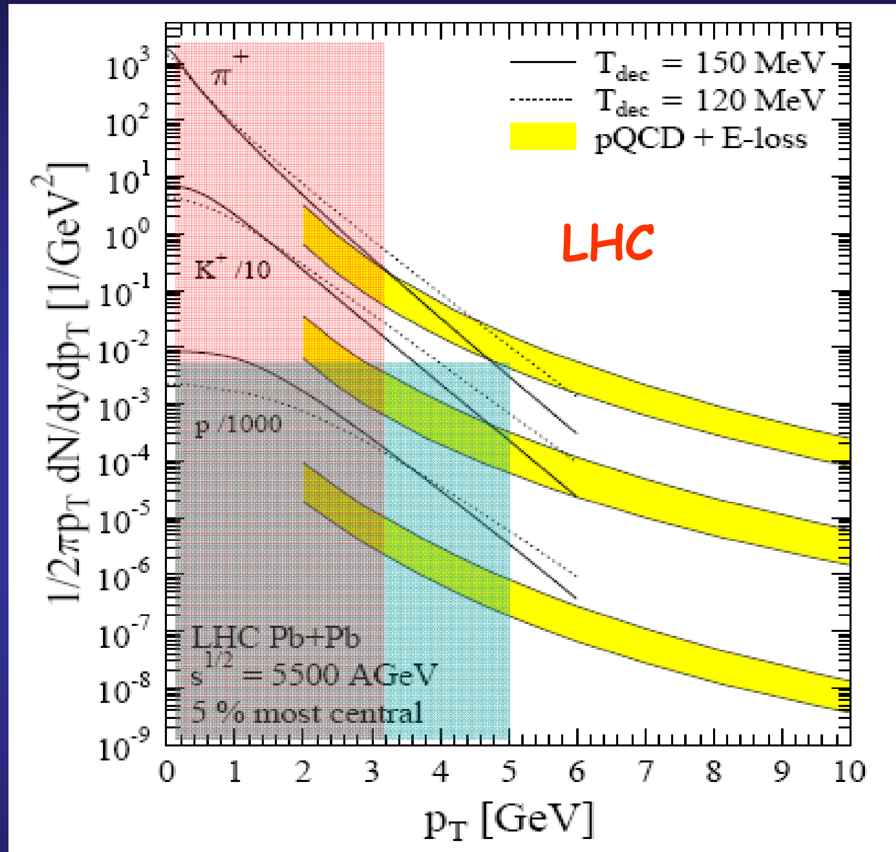
m_t spectrum

At LHC a stronger flow should develop so there should be a flattening of the pt spectrum

$T_{slope} = T_{dec} + m<\beta_T>^2$



(hep-ph/0506049 v1)



ALICE can clarify the interplay between soft processes and hard processes

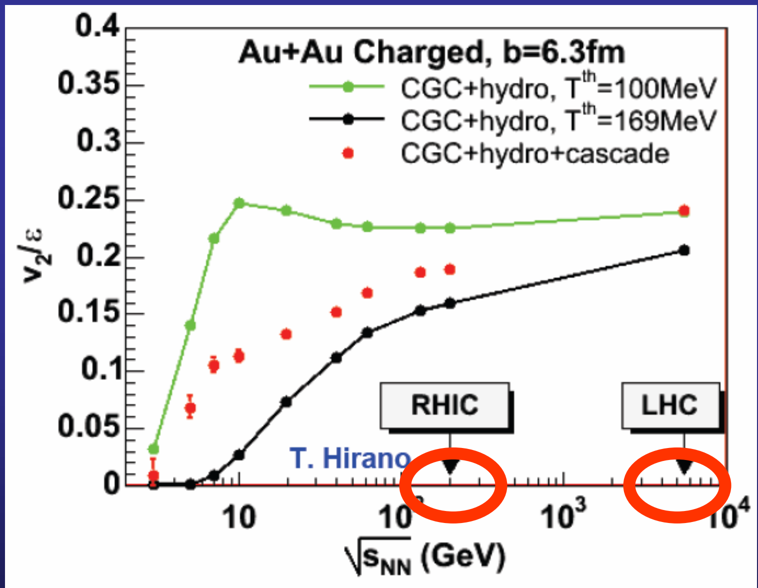
"The main ingredient of hydrodynamic models is the equation of state (EoS) for thermalized matter in heavy ion collisions" see : nucl-th/0410017 v1

Elliptic flow : v2

The spatial anisotropy and the pressure gradient lead to an anisotropic spatial distribution of the momenta in the transverse plane

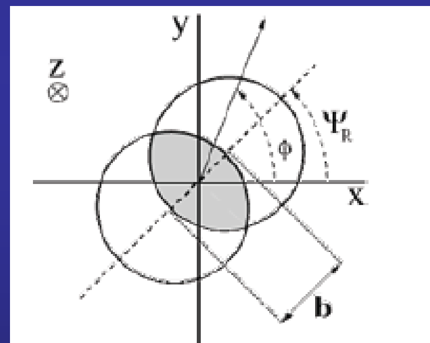
$$\frac{dN_i}{p_T dp_T\, dy\, d\varphi_p}(b) = \frac{1}{2\pi}\frac{dN_i}{p_T dp_T\, dy}(b)\left(1 + 2\, v_2^i(p_T, b)\cos(2\varphi_p) + \ldots\right)$$

$$v_n = \langle \cos(n(\phi - \Psi_r))\rangle$$



http://hq2006.bnl.gov/talks/Tuesday/RaimondSnellings.pdf

$$v_2 = \left\langle \left(\frac{p_x}{p_t}\right)^2 - \left(\frac{p_y}{p_t}\right)^2 \right\rangle$$



At LHC the contribution of hydrodynamical expansion of the QGP (with respect to hadronic cascades) should be much larger than at RHIC -> Better sensitivity to EoS

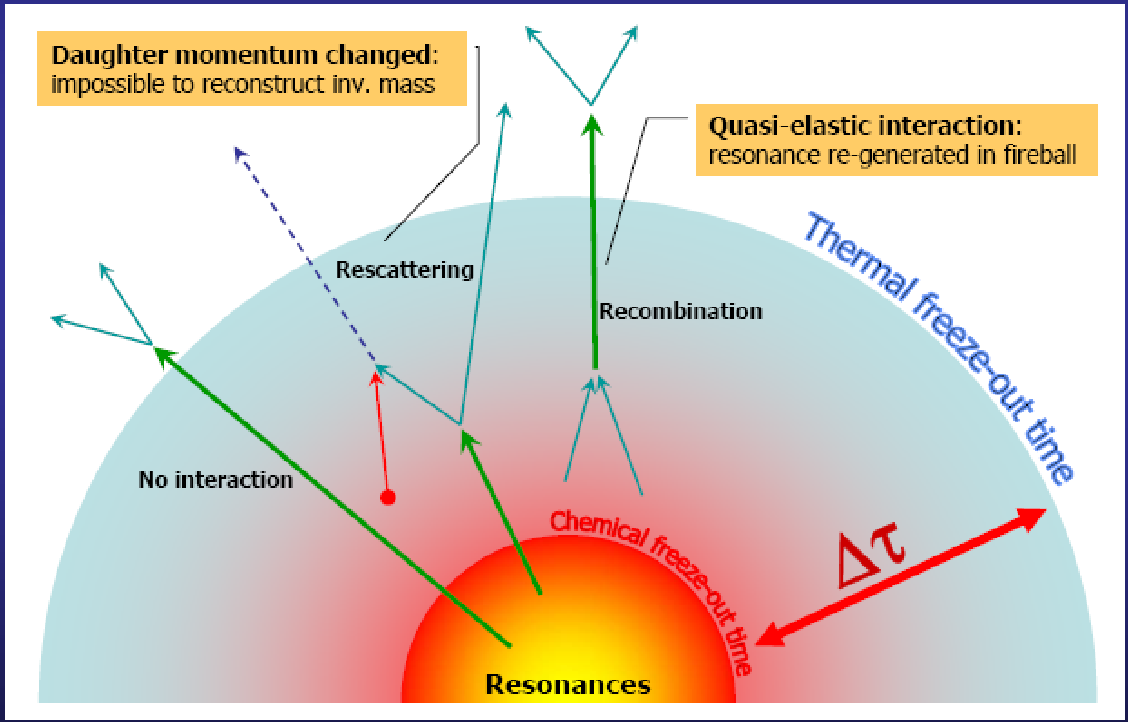
Resonances

Physical motivations

A good tool to understand QGP, rHIC dynamics and the hadronization process

-> Modification of the mass values and widths e.g. ρ(770)

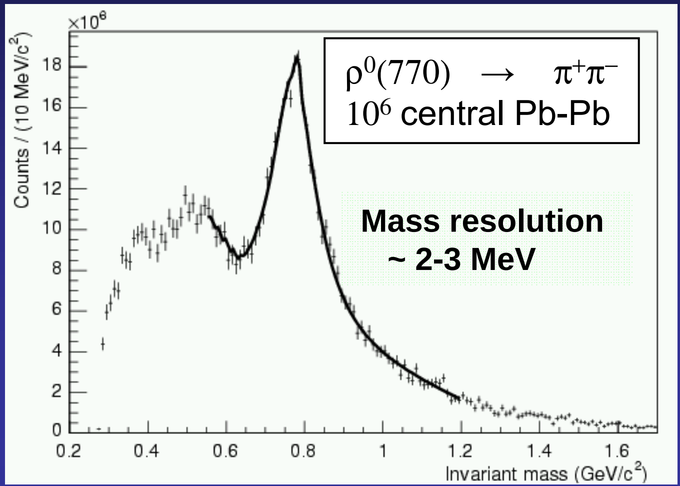
-> Interplay between recombination and rescattering e.g. K*/K

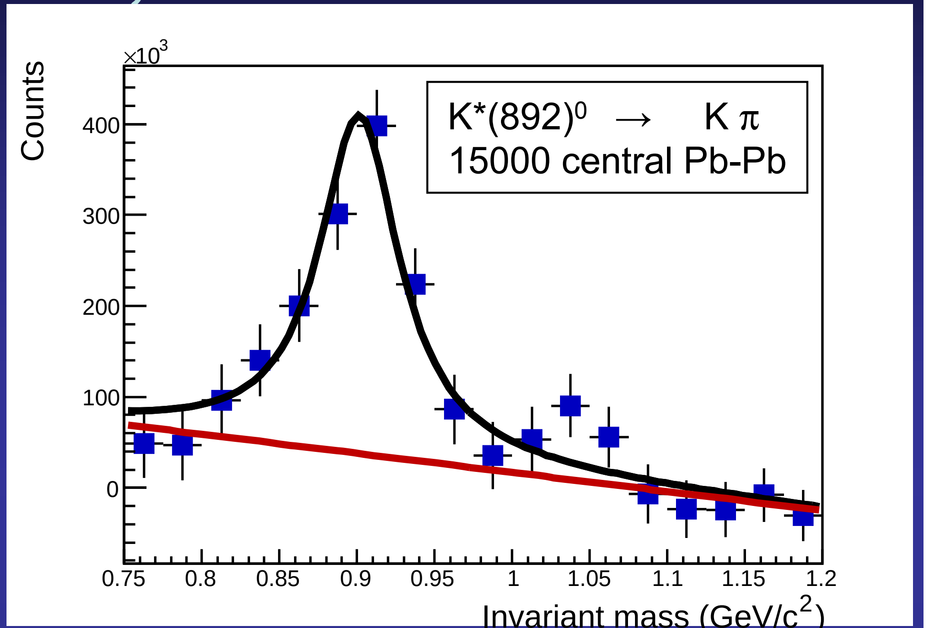


-> Hadronization : fragmentation, coalescence, … ? e.g. quark content/mass

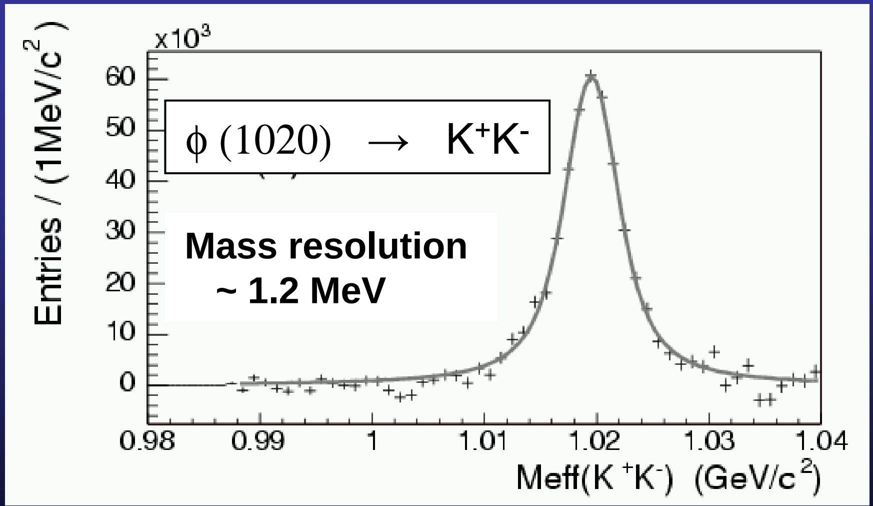
Resonances

Many preliminary studies in ALICE for the resonance identification (simulation results)





CERN-ALICE-INT-2005-039



Eur. Phys. J. C **45**, **Number 3** , 669 - 677 (2006)

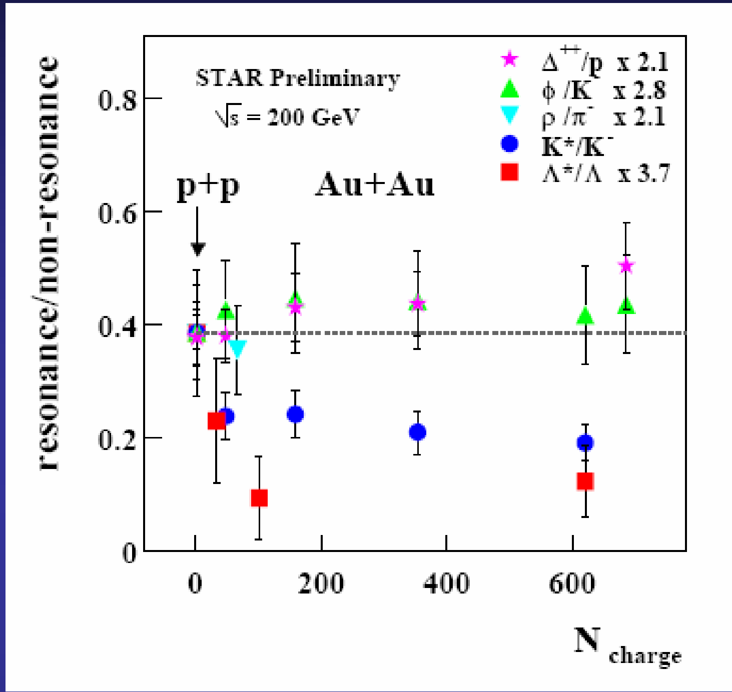
Leptonic decay channel do not suffer the multiple hadronic interactions in the final state - good probes of the plasma phase – see hep-ph/0010101 v1

…Further studies for

$\Phi \rightarrow e^+e^-$ identification

Chemical freeze out vs thermal freeze out

lifetime is compatible with the lifetime of the fireball (~15 fm/c)



nucl-ex/0404003 v1

Life times

Δ^{++} = 1.3 fm/c → too short?

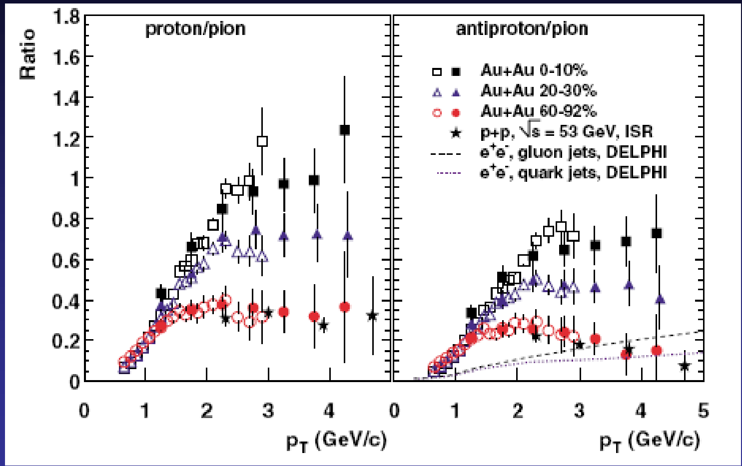
Φ = 44 fm/c (small cross section for scattering with non-strange hadrons)

K*(892) = 4 fm/c suppressed

Λ(1520) = 13 fm/c suppressed

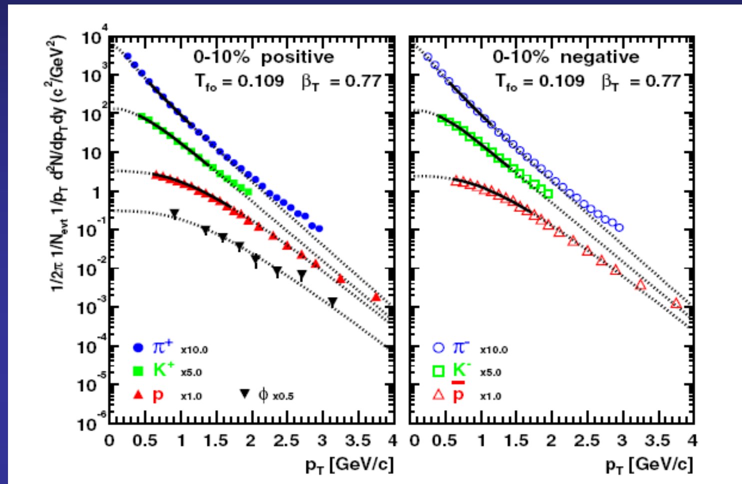
Suppression due to the rescattering → $\Delta\tau$ > 5 fm/c

Hadronization : mass or a quark content effect ?



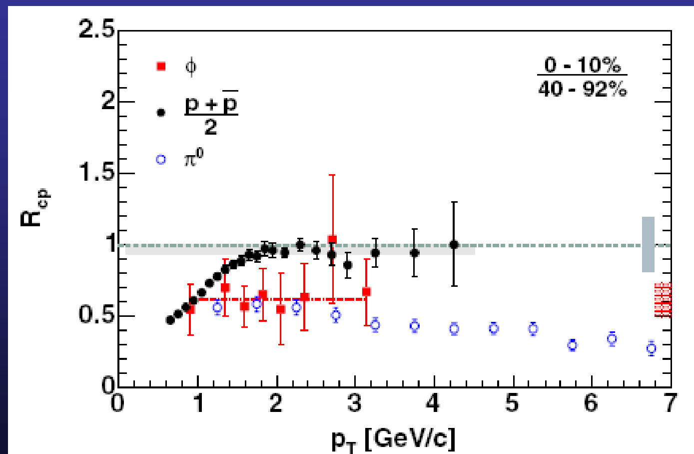
Phys.Rev.Lett. 91, 172301 (2003)

Eur.Phys.J.C43:317-322,2005



Φ(1020) spectrum can be described by the same parameters as the protons (->relevance of the mass!)

$$R_{CP}(p_T) = \frac{d^2N/dp_T d\eta/\langle N_{bin}\rangle(central)}{d^2N/dp_T d\eta/\langle N_{bin}\rangle(peripheral)}$$



Φ(1020) meson is suppressed with respect to protons as pions (-> relevance of quark content!)

Conclusions

At LHC a new regime should be found and this will affect particle production.

Among the questions :

- What about chemical equilibrum scenario at LHC?
- What about the hydro limit at LHC ?
- ALICE can reach succesfully the intermediate pt region (2-5 GeV/c)
  What is the interplay between soft and hard processes ?

ALICE is getting ready to give answers.

See you in September 2008 !

The End

arXiv:hep-ph/0002267

$$\langle n_i \rangle = (2J_i + 1)\frac{V}{(2\pi)^3}\int \mathrm{d}^3p \, \frac{1}{\gamma_s^{-s_i}\exp\left[(E_i - \boldsymbol{\mu}\cdot \mathrm{q}_i)/T\right] \pm 1}$$

where $\mathbf{q}_i$ is a three-dimensional vector with electric charge, baryon number and strangeness of hadron i as components; $\boldsymbol{\mu}$ the vector of relevant chemical potentials; J_i the spin of hadron i and s_i the number of valence strange quarks in it; the $+$ sign in the denominator is relevant for fermions, the $-$ for bosons. This formula holds in case of many different statistical-thermal systems (i.e. clusters or fireballs) having common temperature and γ_s but different arbitrary momenta, provided that the probability of realizing a given distribution of quantum numbers among them follows a statistical rule [7, 20]. In this case V must be understood as the sum of all cluster volumes measured in their own rest frame. Furthermore, since both volume and participant nucleons may fluctuate on an event by event basis, V and $\boldsymbol{\mu}$ (and maybe T) in Eq. (3) should be considered as average quantities [7].

Particle abundances

…many models but a common hypotesis : *Grand Canonical ensemble*

nucl-th/0304013 v1

$$\ln Z(T,V,\vec{\mu}) = \sum_i \ln Z_i(T,V,\vec{\mu}),$$

$$\vec{\mu} = (\mu_B, \mu_S, \mu_Q)$$

$$\ln Z_i(T,V,\vec{\mu}) = \frac{V g_i}{2\pi^2} \int_0^\infty \pm p^2 dp \ln[1 \pm \lambda_i \exp(-\beta\epsilon_i)],$$

$$\lambda_i(T,\vec{\mu}) = \exp(\frac{B_i\mu_B + S_i\mu_S + Q_i\mu_Q}{T})$$

$$\ln Z_i(T,V,\vec{\mu}) = \frac{VTg_i}{2\pi^2} \sum_{k=1}^{\infty} \frac{(\pm 1)^{k+1}}{k^2} \lambda_i^k m_i^2 K_2(\frac{k m_i}{T}),$$

$$n_i(T,\vec{\mu}) = \frac{\langle N_i \rangle}{V} = \frac{Tg_i}{2\pi^2} \sum_{k=1}^{\infty} \frac{(\pm 1)^{k+1}}{k} \lambda_i^k m_i^2 K_2(\frac{k m_i}{T}),$$