Equilibrium thermodynamics in heavy ion collision experiment

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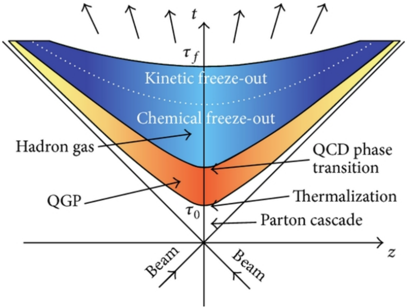
Motivation for a new state of matter



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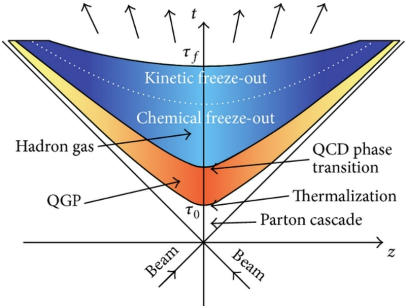

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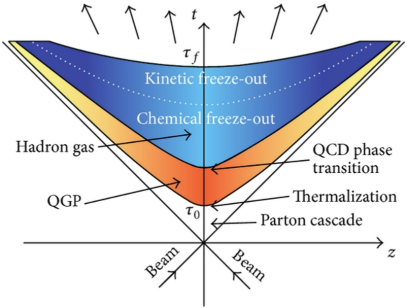

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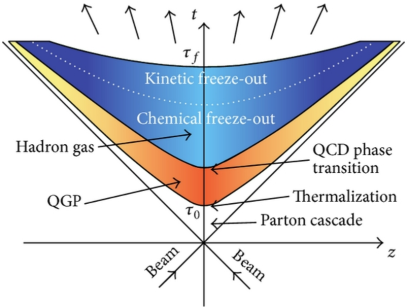

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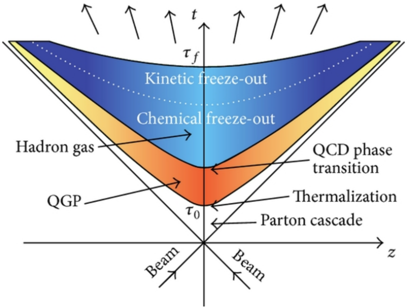

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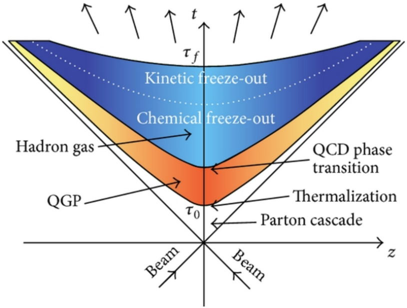

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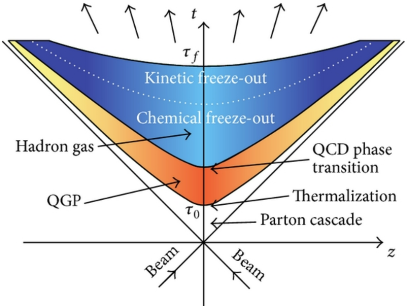

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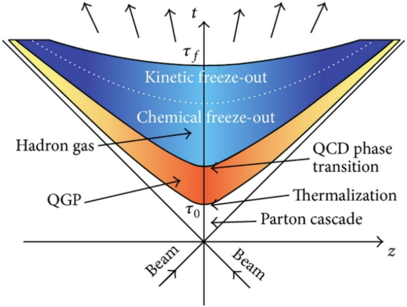

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- Chemical Freezeout (CFO)

- We can extract information about this last scattering surface (CFO) from experimentally detected hadron yield.
- A strongly interacting system in equilibrium can be described by thermodynamic parameters T, μ_Q, μ_B, μ_S.
- Extracted T vs μ_B for various experiments is expected to carry information about the phase diagram.

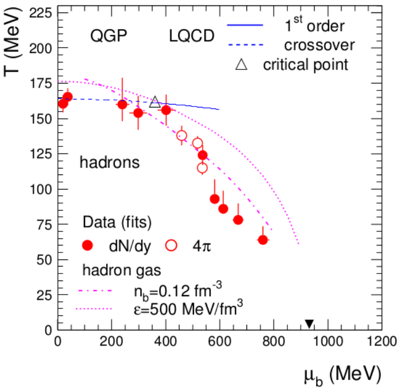

Figure : T vs μ_B[1]

[1] Andronic et. al Nucl.Phys.A772:167-199:2006;

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$$\boxed{\mathrm{n}_i = \frac{g_i}{(2\pi)^3} \int \frac{d^3p}{\gamma_S^{-j} \exp[(E_i - \mu_i)/T] \pm 1}.}$$

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• An additional factor γ_S has been used to incorporate kaon's deviation from equilibrium.

• $j = 1$ for $k^{\pm}$. For other strange and non-strange particles $j = 0$.

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- Information of the volume can be avoided by constructing ratios out of yields i.e

$$\boxed{\frac{dN_i/dy}{dN_j/dy} = \frac{n_i}{n_j}}$$

Extracting Parameter From Data

• Now we can try to fit the number density with experimental data for dN/dy.

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- Is there an alternate way to extract model parameters?

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$$\boxed{\frac{\sum_i \alpha_i n_i}{\sum_i \mid \alpha_i \mid n_i} = \frac{\sum_i \alpha_i \frac{dN_i}{dY}}{\sum_i \mid \alpha_i \mid \frac{dN_i}{dY}}}$$

- Here Q,B and S are the charge, baryonic and strange quantum number.

An Alternate Approach

- To extract T, we look at the antiparticles to particles ratio.

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- For γ_S we take ratio of $k^{\pm}$ to non-strange,

$$\boxed{\frac{n_{k^+} + n_{k^-}}{\sum_{non-strange} n_i} = \frac{\frac{dN_{k^+}}{dY} + \frac{dN_{k^-}}{dY}}{\sum_{non-strange} \frac{dN_i}{dY}}}$$

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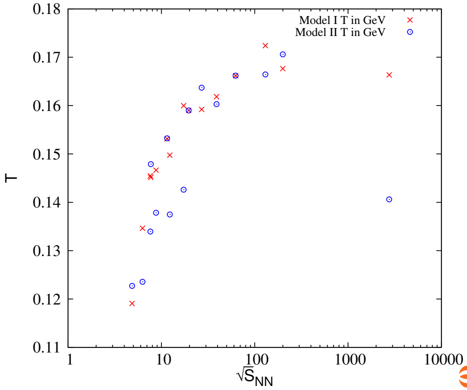
- We have not used $\Omega^{\pm}$ yield as it is not available for all $\sqrt{S}$.

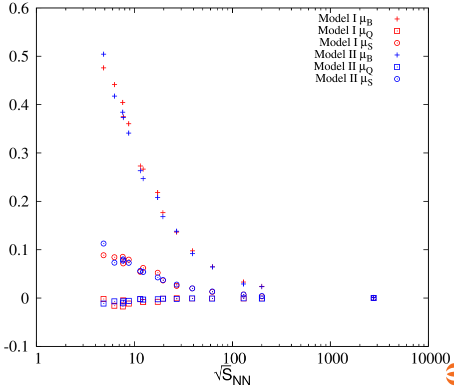
Variation of T w.r.t $\sqrt{S}$ in Model I and II

- There is a trend of saturation after $\sqrt{S} = 19.6 AGeV$.
- It approaches the flat region of the proposed phase diagram of hadron to QGP transition near $\mu_B = 0$.

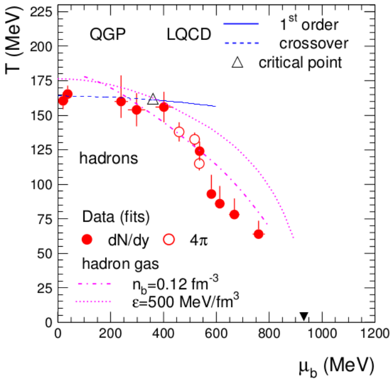


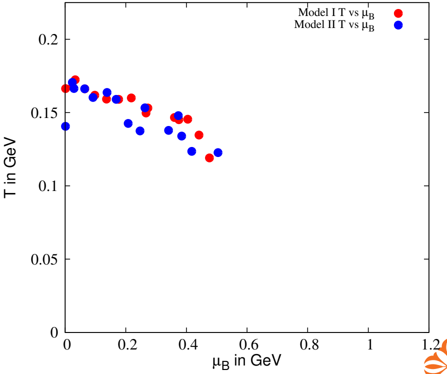
Variation of μ w.r.t $\sqrt{S}$ in Model I and II

- μ_B increases due to higher rate of baryon stopping in lower collision energy.
- The difference between μ_α's decrease with increaseing $\sqrt{S}$ and converges to zero at very high $\sqrt{S}$.
- At low $\sqrt{S}$, μ_Q becomes negative though both μ_B and μ_S remain positive for all the values of $\sqrt{S}$.



Variation of T vs μ_B in Model I and II





Variation of π^-/π^+ and k^-/k^+ with $\sqrt{S}$ in Model I and II

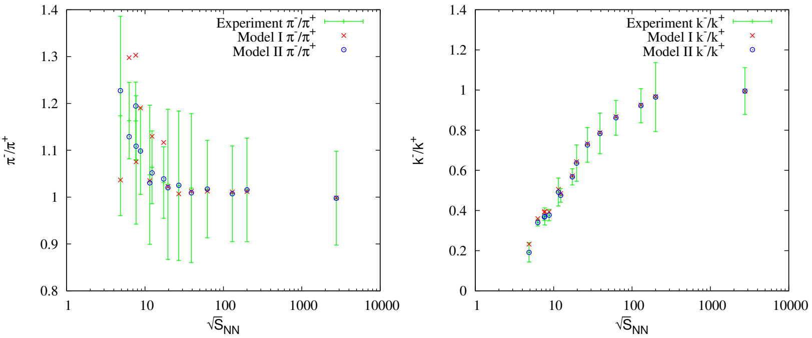
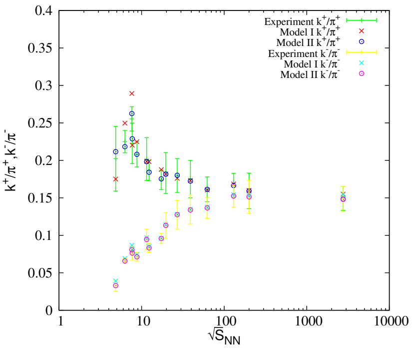


Figure : π^-/π^+ and k^-/k^+

Variation of kaon to pion ratio and γ_S w.r.t $\sqrt{S}$



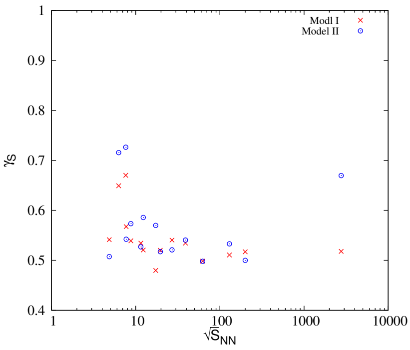


Figure : $k^+/\pi^+, k^-/\pi^-$ and γ_S

Variation of baryon to antibaryon ratio w.r.t $\sqrt{S}$

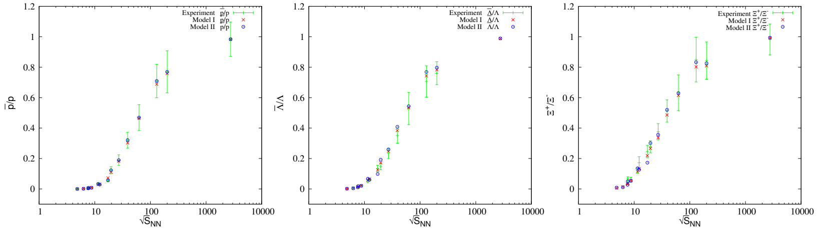


Figure : Variation of $\bar{p}/p$, $\bar{\Lambda}/\Lambda$ and Ξ^-/Ξ^+ with $\sqrt{S}$

Strange baryon to non-strange baryon ratio w.r.t $\sqrt{S}$

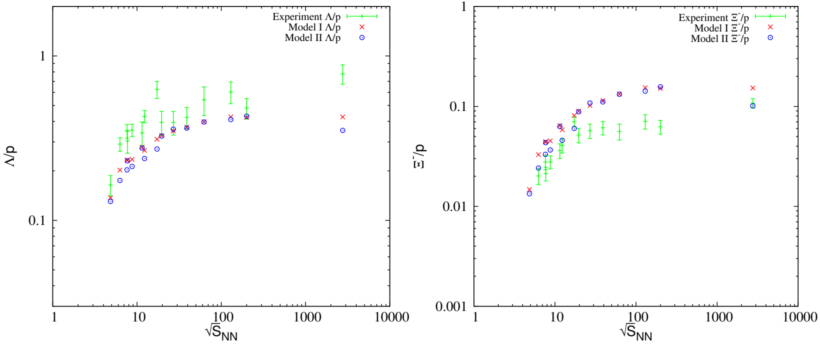
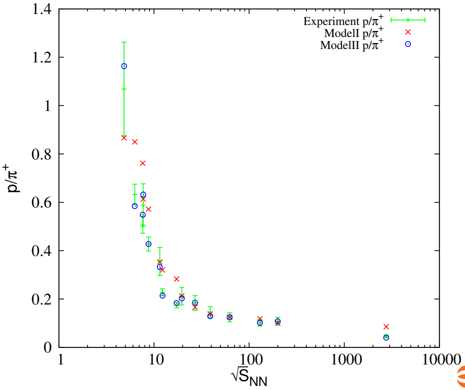


Figure : Variation of Λ/p and Ξ^-/p with $\sqrt{S}$

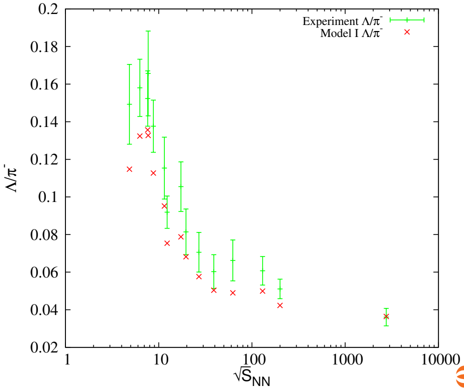
Variation of p/π^+ w.r.t $\sqrt{S}$ in Model I and II

- Model II has predicted it better as it has only pion,kaon and proton under consideration.
- In some $\sqrt{S}$ model I deviates from the experimental values.



Variation of Λ/π^- w.r.t $\sqrt{S}$ in Model I and II

- There is a "horn" in Λ/π^- also. Model I has reproduced the pattern of the horn quite beautifully.



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• For $\sqrt{S}$=4.30AGeV and below yield of $\bar{p}$ and $\bar{\Lambda}$ is not available. With better yield of multistrange sector, this work can be extended to the lower $\sqrt{S}$.


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