Strange Freezeout

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Outline

Introduction

- Hadron resonance gas (HRG) models have been the standard framework in describing the particle yields in Heavy Ion Collision experiments.
- Standard practice: A single chemical freezeout surface (T, μ_B, V and γ_s optional) where all the hadrons freezeout together.
- We ask: Is there a possibility to have further structure in the freezeout mechanism ? Does the present data on yields support such a picture ?

Why further structure ?

Hints from hadron chemistry

- 'Isospin changing' reactions (eg. $p + \pi^- \leftrightarrow n + \pi^0$) are the last to freezeout:
  - low activation energy
  - high pion density **Asakawa, Kitazawa (2011)**
- 'Strangeness changing' reactions (eg. $\Omega^- + K^+ \leftrightarrow \Xi^0 + \pi^0$) can freezeout much earlier:
  - high activation energy
  - Ω and K number densities are much less compared to π, hence $\Omega + K$ reaction is much suppressed;
- Propose 2CFO (strangeness+hidden strangeness, non strange) **SC, Godbole, Gupta (1306.2006); Bugaev et al (1308.3594)**

Framework

- Difference in activation energy for 'strangeness changing' and 'isospin changing' reactions $\Rightarrow$ strange hadrons freeze out first followed by non-strange
- All hadrons are immersed in the common isospin bath of π
- Thus comes the following 2CFO scheme
  - Let all strange hadrons and ϕ freezeout at (T_s, V_s and μ_{Bs})
  - Let all non-strange hadrons freezeout at (T_{ns}, V_{ns} and μ_{Bns})
  - Both surfaces share the same μ_Q obtained from the condition
    - $N_B/N_Q = 2.5$
- Use a canonical ensemble for strangeness

1CFO vs 2CFO: Yields

Discrimination $= 1 - \text{Yield}_{\text{Model}}/\text{Yield}_{\text{Exp}}$

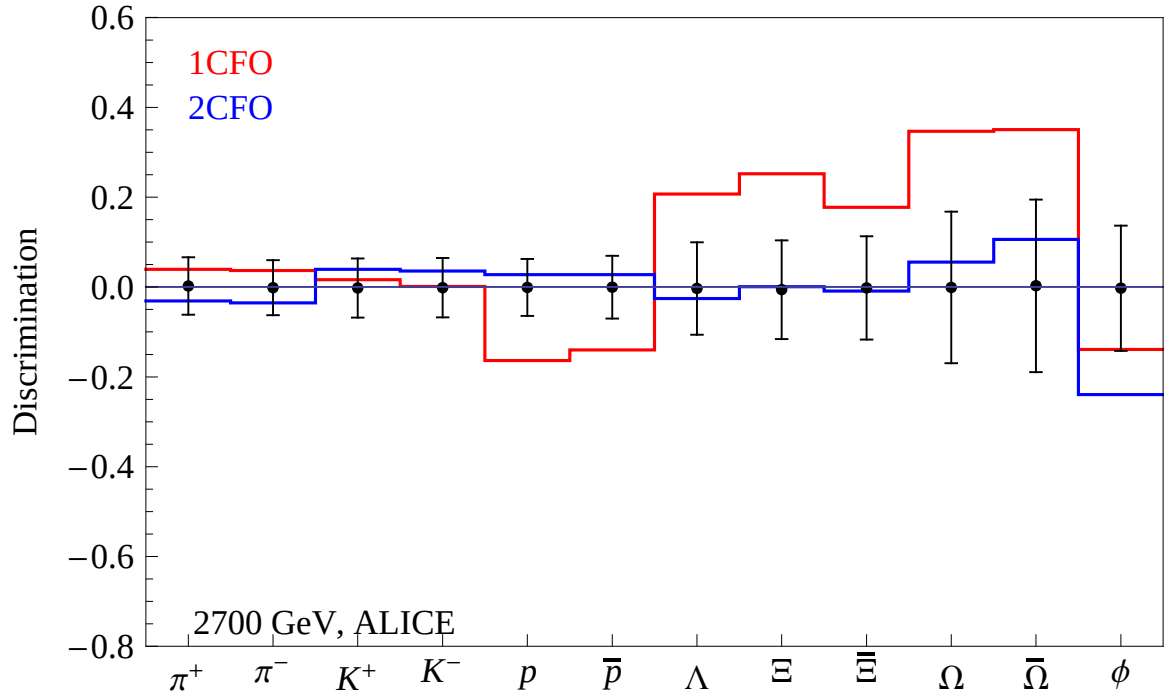

figure from SC, Godbole, Gupta 1306.2006

chemical freezeout curves

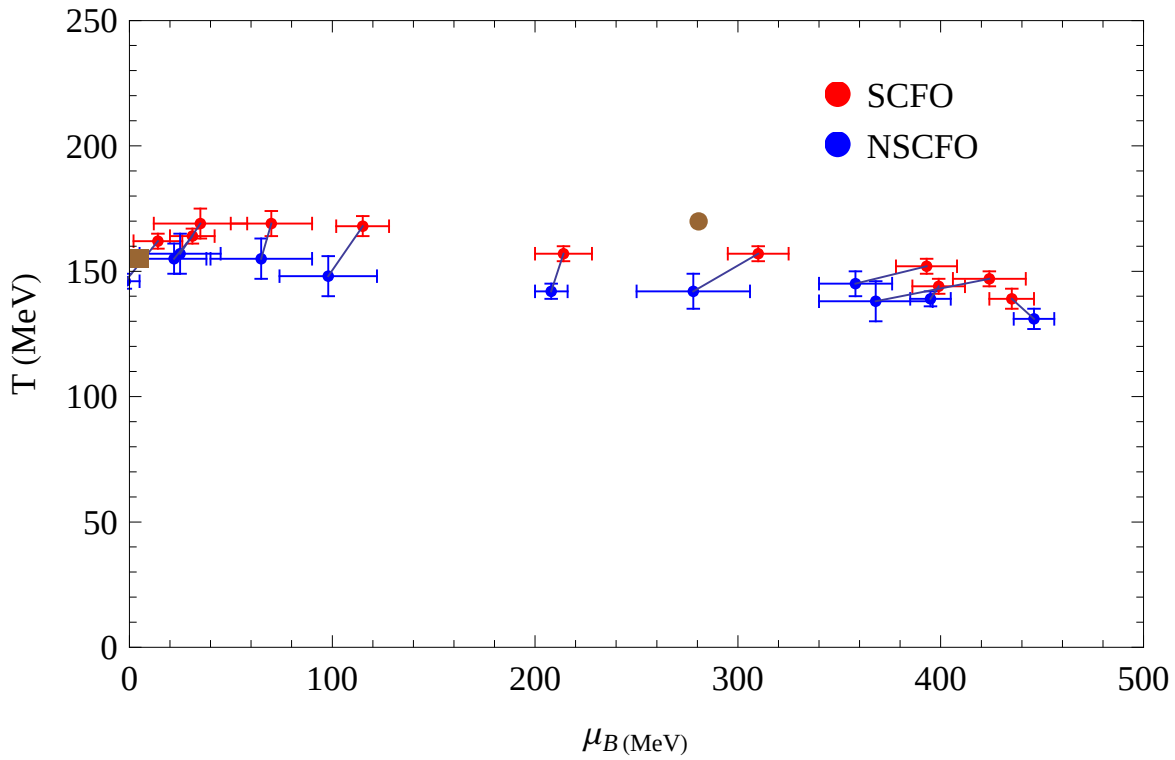

figure from SC, Godbole, Gupta 1306.2006

Realistic Volumes

$\zeta = V_{ns}/V_{HBT}$, pion correlation volume $V_{HBT} = \frac{4}{3}\pi R_o R_l R_s$

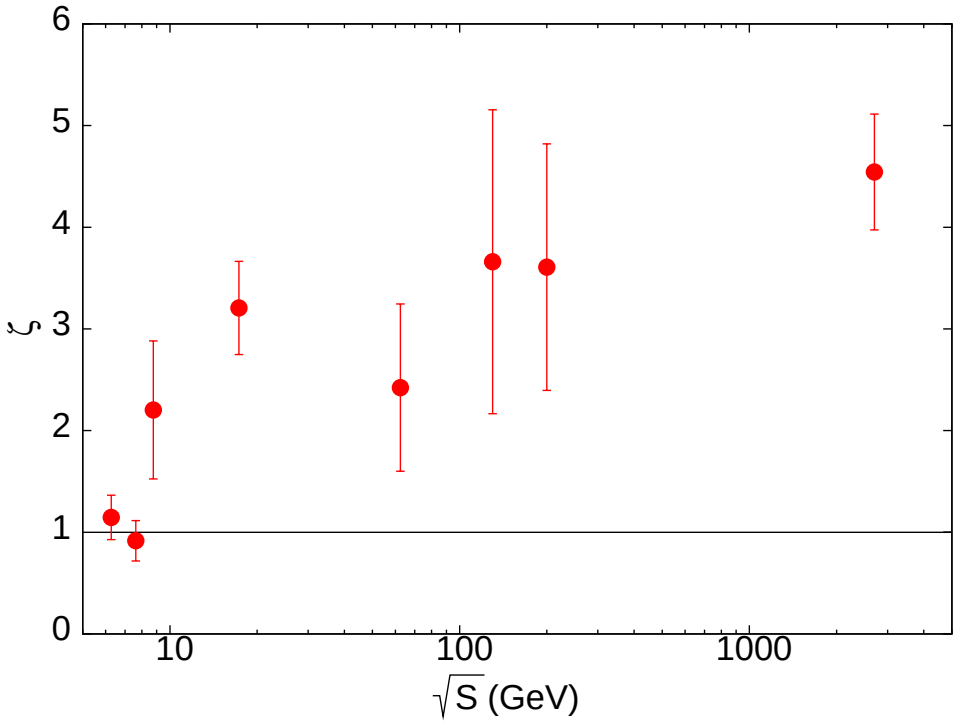

figure from SC, Godbole, Gupta 1306.2006

$T(\sqrt{S_{NN}})$, $V(\sqrt{S_{NN}})$: a peek into the fireball evolution

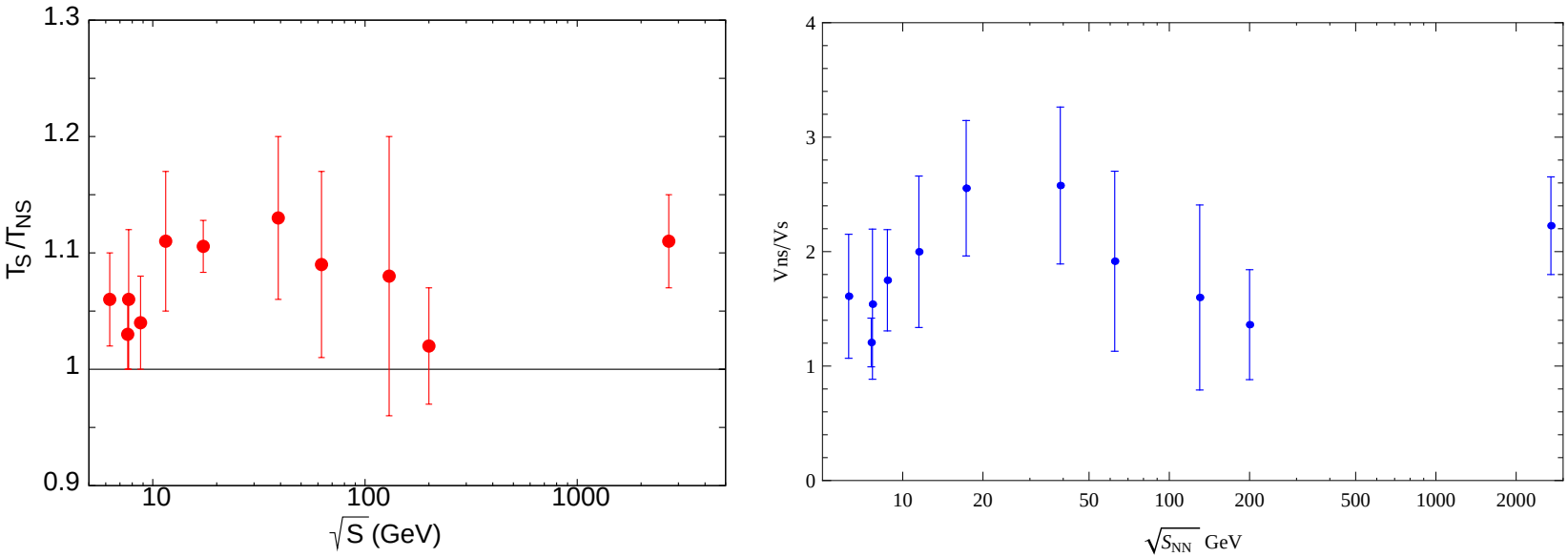

figure from SC, Godbole, Gupta 1306.2006

Outlook

- Hints from hadron chemistry for structures in CFO
- A simple 2CFO model with 6 parameters is analysed
- No proton anomaly in LHC
- Hints of effect of QCD chiral transition and critical point on freezeout; improved experimental errors crucial
- Instantaneous departure from equilibrium is problematic. Instead:
  - 1CFO + late stage $B\bar{B}$ annihilation **Bleicher et al** **Becattini et al**
  - 2CFO
  - some combination and new effects ?

Thank You

Backup: Weak decays

- Note: Direct transmutations between K and π through weak interactions are expected to happen much later and hence of no relevance in the context of HIC, however it is very crucial in order to observe the early freezeout of strangeness that the data on yields is clean from weak decays.