Hadronization: Does the Statistical Model Freeze-Out Curve meet the Lattice Parton-Hadron Phase Boundary?

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Motivation

Lattice QCD extrapolation to finite µB predicts the parton-hadron coexistence line in the (T, µB) plane.

Assumptions:
- Hadronization creates chemical equilibrium freeze-out.
- Hadron abundances freeze out directly at QCD hadronization, and survive the hadronic expansion stage (7).

Under these assumptions:
- Statistical Model (SM) freeze-out curve locates the QCD phase boundary curve.

Our aim: Consider the “Empirical freeze-out curve” (1,2).

Questions:
- Why does the freeze-out curve appear to fall below the lattice curve at higher µB?
- Does the hadronic expansion phase REALLY preserve the hadronic multiplicity distribution?

Hadronic Expansion Effects

UrQMD Study of Hadronic Expansion Effects on Hadron Yields

- Employ the recent hybrid version (3) of UrQMD: Hydrodynamic (3→1) phase until energy density < 1 GeV/fm³, plus hadronic emission à la Cooper-Frye.
- Attach UrQMD hadronic expansion as an “afterburner” stage.
- Compare hadronic yields directly after Cooper-Frye with those after the “afterburner” stage.

Serious Annihilation Effects in baryon and antibaryon sector:
- At SPS: selective annihilation of Ξ, Ω, and Ξ. The rest essentially unaffected.
- At RHIC and LHC: annihilation tends to be symmetric for baryons and antibaryons; Ξ, Ω unaffected, while Ω and Ξ are enhanced.

Statistical Model Analysis

UrQMD at SPS Energies

Approach:
- Fit SM to UrQMD “hydro only”
- Fit SM to UrQMD “hydro plus afterburner”

NA49 Data

SM fit to NA49 data (5) in full acceptance central Pb+Pb 17.3 GeV OMITTING p, Ξ, and Ω from the fit (see (2) for details).

Striking Similarity to UrQMD survival plot in Fig. 2. Thus, data shows similar selective antibaryon deficits as predicted by UrQMD.

UrQMD at LHC Energy

Similar UrQMD plus statistical model analysis applied to central Pb+Pb collisions at √s = 2.7 TeV.

The obtained (∈f, µB) with a fit to a suitably restricted hadron sample is close to the hadronization point.

Conclusions

- The hadronic expansion phase does IN FACT distort the hadrochemical equilibrium created at hadronization.
- Indeed, in statistical model fits to UrQMD, the final state (afterburning) effects cause a general downward shift in the (∈f, µB) positions of the chemical freeze-out points, by about 10-15 MeV (2) in the SPS energy range. At the LHC, the predicted shift in temperature is of the order of 6-8 MeV with sizeable discrepancies of p, Ξ, and Ω.
- The resulting chemical freeze-out curve thus needs revision.

A refined data analysis with the SM will result in a modified freeze-out curve that will more closely follow recent lattice calculations (6).

References


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