Freeze-out state from analysis of transverse momentum spectra in Pb+Pb collisions at 2.76 ATeV

Support:
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1. Motivation

- Hadrons are emitted at freeze-out and their spectra carry information about the state of the fireball at that time
- The freeze-out production can be paramertised by blast-wave model
- Many final state hadrons (including protons) are produced by decays of resonances – resonance production must be included in the analysis
- We include transverse flow and resonance decays in Monte Carlo simulation of the hadron production according to blast wave model

2. DRAGON: MC blast wave model

Production of hadrons at freeze-out is described by the emission function

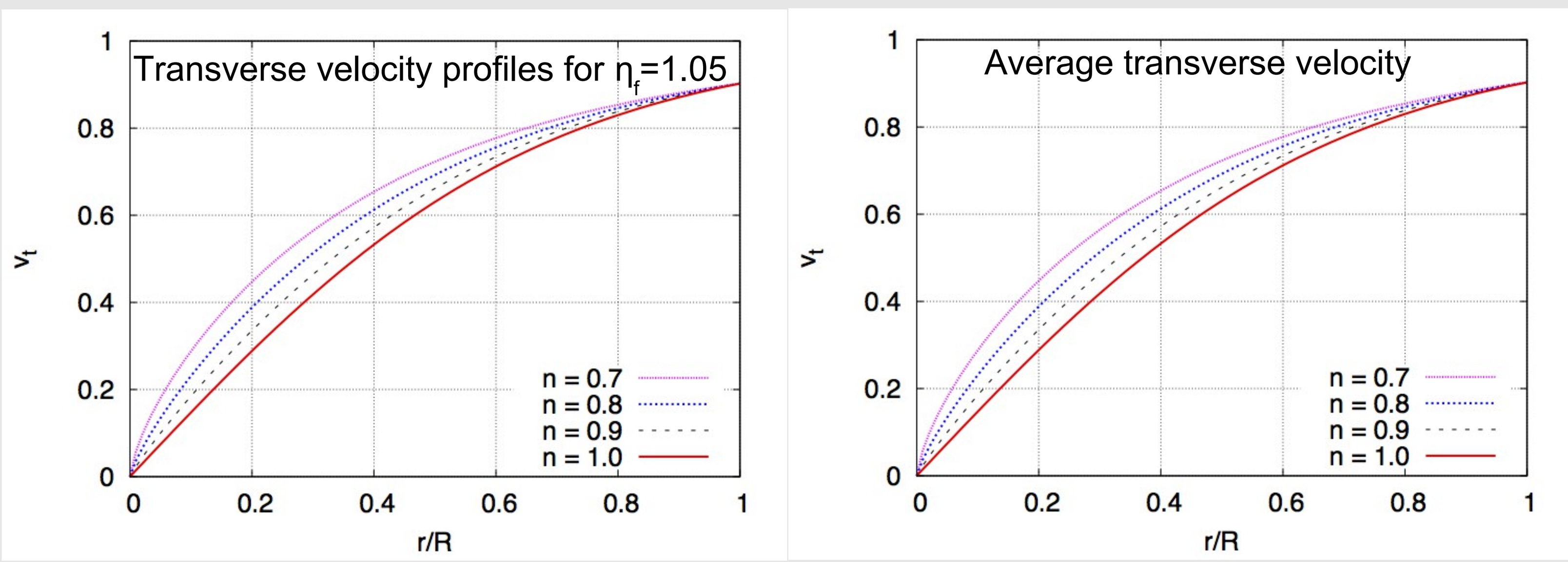
$$S(x,p)\,d^4x = \frac{2s+1}{(2\pi)^3} m_t \cosh(y-\eta)\, \exp\left(-\frac{p^\mu u_\mu}{T}\right) \Theta(R-r)\,\delta(\tau-\tau_0)\,d\tau\,\tau\,d\eta\,r\,dr\,d\phi$$

Expansion of the fireball is encoded in the velocity field uμ

$$u^\mu = (\cosh\eta\,\cosh\eta_t, \sinh\eta_t\,\cos\phi_b, \sinh\eta_t\,\sin\phi_b, \sinh\eta\cosh\eta_t)$$

Transverse expansion velocity is parametrised via transverse rapidity

$$v_t(r) = \tanh\eta_t(r) = \tanh\left(\sqrt{2}\,\eta_f\left(\frac{r}{R}\right)^n\right)$$



Included baryonic resonances up to 2 GeV and mesonic resonances up to 1.5 GeV. Strong decays, also cascading decays.

3. The procedure

- With DRAGON [1] we fit transverse momentum spectra of pions, kaons, protons [2], K0s, lambdas [3], cascades and omegas [4] from Pb+Pb collisions at 2.76 ATeV
- Absolute normalisaiton is a separate fit parameter for each spectrum, no information is obtained on the size of the fireball
- We scan the space of parameters: for each transverse flow gradient ηf and temperature T we Monte Carlo generate a set of events and compare the spectra to data
- With coefficients values better describing data we generate higher statistics

Conclusions

- Resonance contribution to hadron production is important and should not be omitted when analysing transverse momentum spectra
- With increasing centrality the freeze-out tempearture grows and transverse velocity decreases.
- Our numerical results agree with those obtained by ALICE [2], in spite of resonance contributions missing in those fits. (Note that we have slightly different dependence of transverse velocity on radial coordinate.)
- Multiply strange baryons have at intermediate pt steeper spectra than resulting from the fitted temperature. This may indicate earlier freeze-out. In fact, separate fit to only these species yields higher freeze-out temperature and weaker transverse expansion

References

[1] B. Tomášik, Comp. Phys. Commun. **180** (2009) 1652

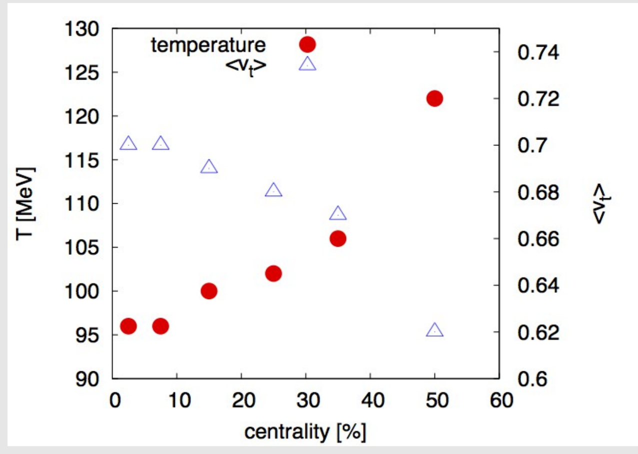
[2] B. Abelev et al. (ALICE collab.), Phys. Rev. C **88** (2013) 044910

[3] B. Abelev et al. (ALICE collab.), Phys. Rev. Lett **111** (2013) 222301

[4] B. Abelev et al. (ALICE collab.), 1307.5543

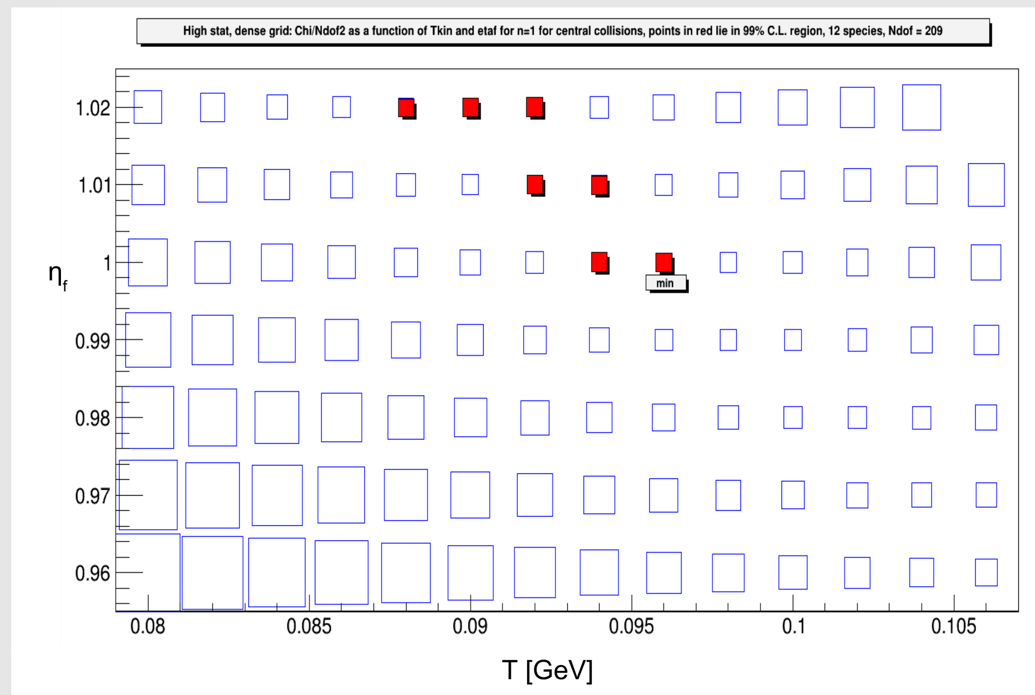
4. Results on thermal parameters

Parameters obtained from fits at different centralities

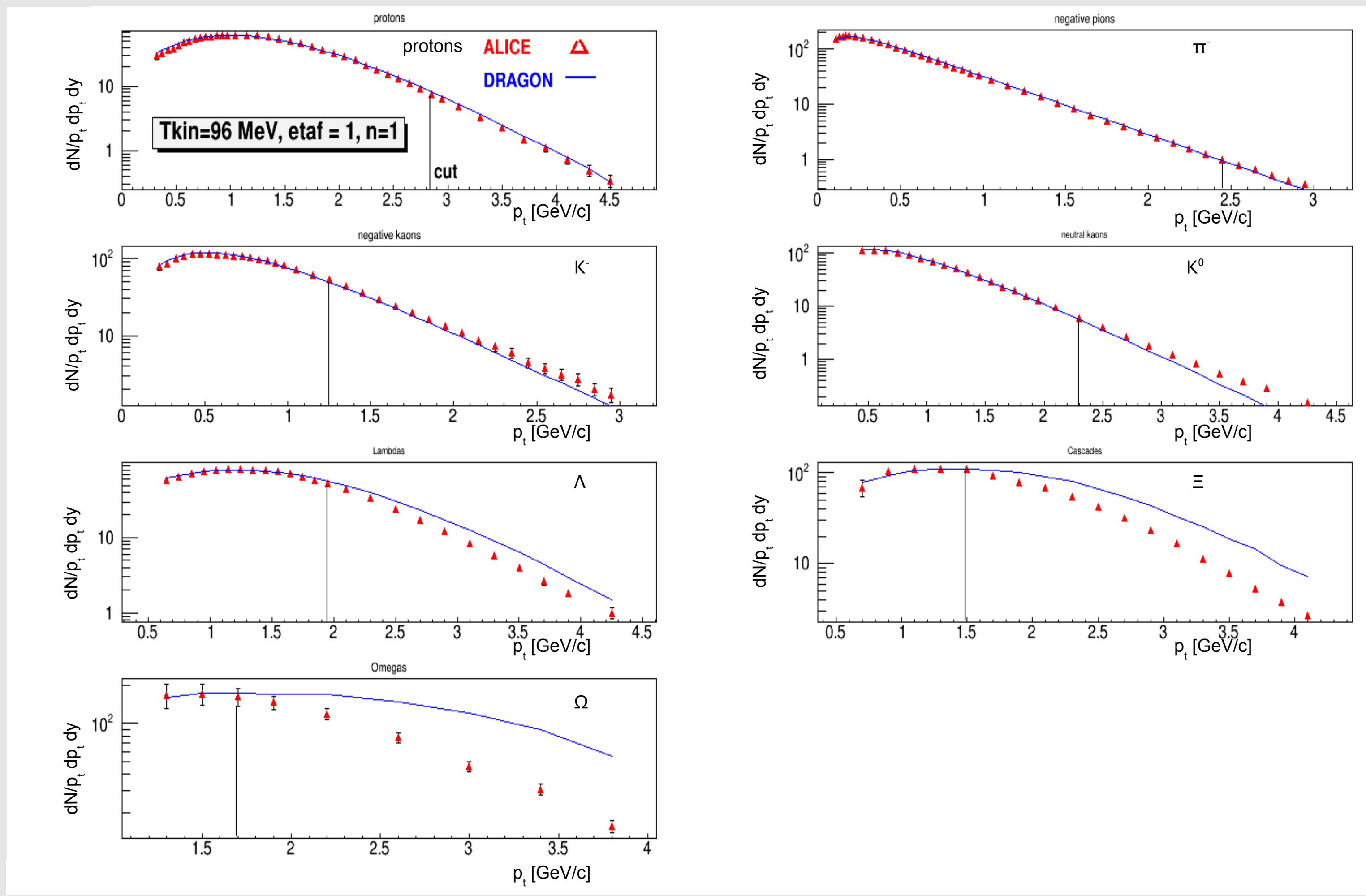


centr.	n.of. spec.	T_{kin} [MeV]	η_f	n	χ^2/N_{dof}	N_{dof}
0-5%	12	96	1.0	1.0	0.366	197
5-10%	8	96	1.0	1.0	0.386	194
10-20%	12	100	0.98	1.0	0.400	201
20-30%	12	102	0.96	1.0	0.379	183
30-40%	6	106	0.92	1.0	0.393	151
40-50% (60%)	12	122	0.86	1.1	0.941	167
0-5% Ξ and Ω	4	130	0.82	0.8	0.468	39

Example: fit to centrality class 0-5%. The size of the squares corresponds to the value of χ^2. Red points are 99% CL. Best fit is indicated.



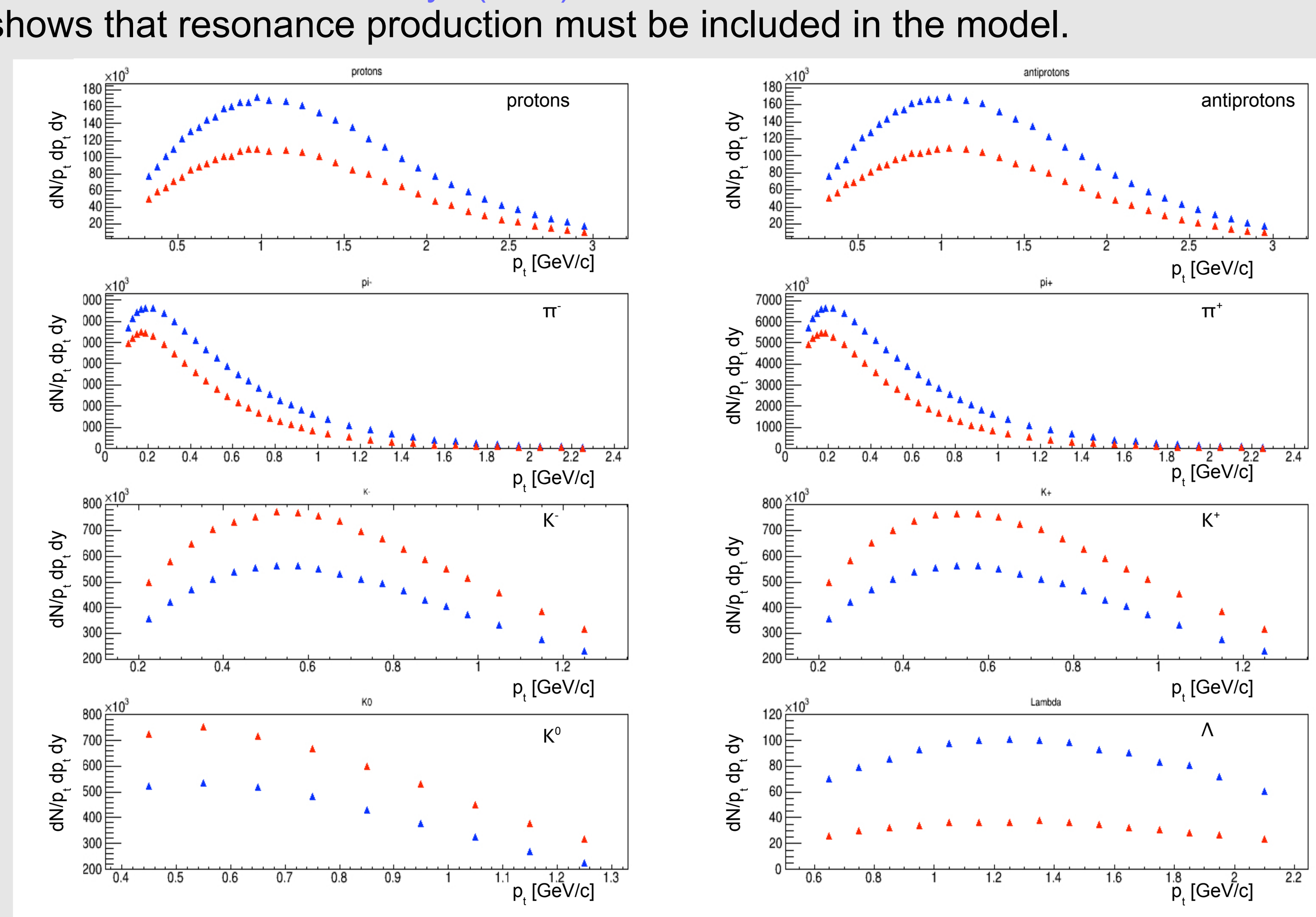
Comparison of best fit MC simulation to data from ALICE



NB: spectra of multiply strange baryons do not agree with data, particularly at higher p_t
This might be due to earlier freeze-out. Separate fit to these spectra yields higher temperature and weaker transverse expansion.

5. The influence of resonances

Resonances contribute considerably to production of all hadron species. In the figure we show the contributions to hadron transverse momentum spectra from direct production (red) and from resonance decays (blue).
This shows that resonance production must be included in the model.



Fits to data with only direct production included in the model yields higher freeze-out temperature bu about 12 MeV.
E.g. for central collisions we obtain 105 MeV.