# Blast-wave fits with resonances to $p_t$ spectra from Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

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## 1. Motivation

Find temperature and transverse expansion of the freeze-out state of the fireball by fits to $p_t$ spectra of various hadron species with **resonance decays included**

Data from ALICE collaboration: π,K,p [1]; $K^0$, Λ [2]; Ξ, Ω [3]; K*, Φ [4]

Scenario with two freeze-outs: $\mathbf{T_{crit} \geq T_{chemical} \geq T_{kinetic} \equiv T}$

Resonance decays are included with abundances given by $T_{chemical}$

We implemented blast-wave model with resonances as Monte Carlo → DRAGON

## 2. DRAGON: MC blast-wave model

Monte Carlo implementation of the emission function ***with 277 resonances*** [5]

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

Spectra given by $\frac{dN}{dy\, d^2p_t} = \int d\Sigma_\mu p^\mu \frac{1}{\exp\frac{p_\mu u^\mu}{T} \pm 1} = \int d^4x S(x,p)$

$$S(x,p)d^4x = \delta(\tau - \tau_{fo})\, m_t \cosh(\eta_s - y)\, \Theta(R-r) \times \frac{1}{\exp\frac{p_\mu u^\mu}{T} \pm 1} \tau\, d\tau\, d\eta_s\, r\, dr\, d\varphi$$

Transverse expansion velocity $v_t = \tanh\eta_t = \eta_f \left(\frac{r}{R}\right)^n$

Chemical composition given by $T_{ch}$ = 152 MeV and $\mu_B$ = 1 MeV. In the fits we vary: $T, \eta_f, n$.

**Comparison of ALICE fits to π, K, p with no resonances [1] (2nd column) with DRAGON fits with no resonances (3rd column) and with resonances (4th column).**
Applied cuts: 0.3 < $p_t$ < 3 GeV, 0.5 < $p_t$ < 1 GeV, 0.2 < $p_t$ < 1.5 GeV for p,π,K respectively.

| centrality | ALICE $T$ [MeV] | ALICE $\langle v_t\rangle$ | ALICE $n$ | no resonances $T$ [MeV] | no resonances $\langle v_t\rangle$ | no resonances $n$ | with resonances $T$ [MeV] | with resonances $\langle v_t\rangle$ | with resonances $n$ |
|---|---|---|---|---|---|---|---|---|---|
| 0–5% | 95 | 0.651 | 0.71 | 98 | 0.645 | 0.73 | 82 | 0.662 | 0.69 |
| 5–10% | 97 | 0.646 | 0.72 | 98 | 0.645 | 0.73 | 94 | 0.654 | 0.69 |
| 10–20% | 99 | 0.639 | 0.74 | 102 | 0.637 | 0.73 | 90 | 0.649 | 0.71 |
| 20–30% | 101 | 0.625 | 0.78 | 102 | 0.624 | 0.79 | 98 | 0.633 | 0.75 |
| 30–40% | 106 | 0.604 | 0.84 | 110 | 0.605 | 0.81 | 102 | 0.616 | 0.79 |
| 40–50% | 112 | 0.574 | 0.94 | 110 | 0.572 | 0.97 | 118 | 0.581 | 0.89 |
| 50–60% | 118 | 0.535 | 1.10 | 122 | 0.527 | 1.15 | 126 | 0.541 | 1.03 |
| 60–70% | 129 | 0.489 | 1.29 | 126 | 0.484 | 1.39 | 146 | 0.489 | 1.23 |
| 70–80% | 139 | 0.438 | 1.58 | 142 | 0.439 | 1.51 | 170 | 0.423 | 1.55 |

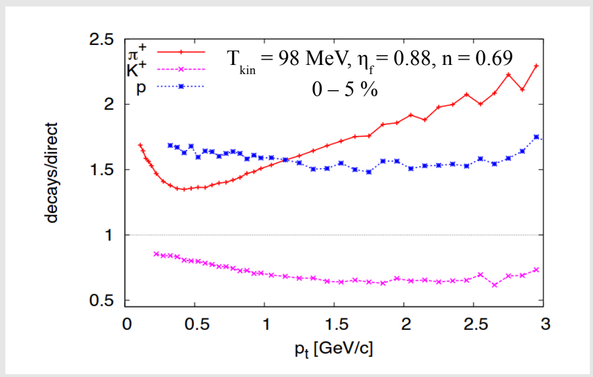
## 3. DRAGON: resonances/direct for π, K, p

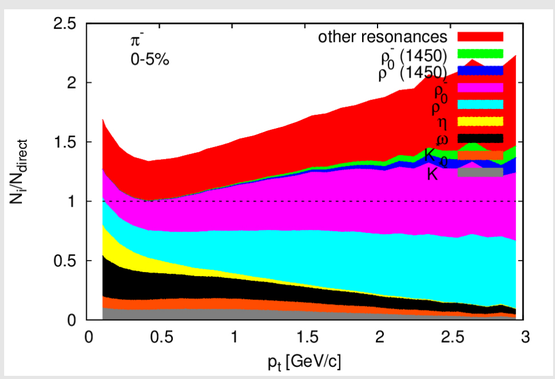
Pions from resonance decays peak over direct pions at both low $p_t$ and high $p_t$ for 0 – 5%

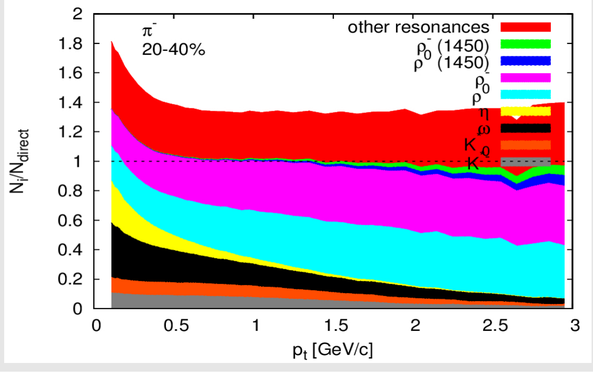
**Spectra anatomy of pions at various centralities:**

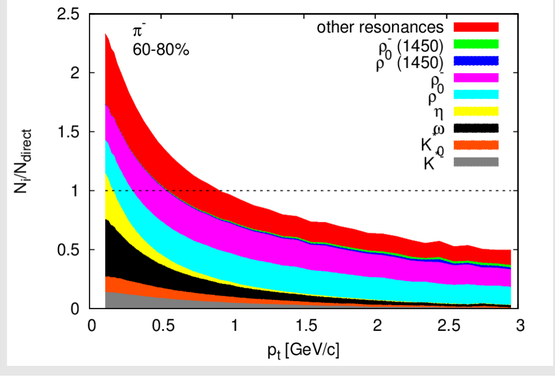
central: low temperature and strong flow: kicks to pions from ρ decays

peripheral: higher temperature and more thermal momentum to pions




## 4. Fit results on thermal parameters

π, p,K, Λ fits

| centrality | $T$ [MeV] | $\eta_f$ | $n$ | $\langle v_t\rangle$ | $\chi^2/N_{dof}$ | $N_{dof}$ |
|---|---|---|---|---|---|---|
| 0–5% | 98 | 0.88 | 0.69 | 0.654 | 0.214 | 194 |
| 5–10% | 98 | 0.88 | 0.71 | 0.649 | 0.266 | 197 |
| 10–20% | 106 | 0.87 | 0.71 | 0.642 | 0.272 | 210 |
| 20–40% | 114 | 0.86 | 0.81 | 0.612 | 0.294 | 202 |
| 40–60% | 138 | 0.82 | 0.99 | 0.548 | 0.347 | 195 |
| 60–80% | 166 | 0.77 | 1.43 | 0.449 | 0.449 | 168 |

Ξ, Ω fits

| centrality | $T$ (MeV) | $\eta_f$ | $n$ | $\langle v_t\rangle$ | $\chi^2/N_{dof}$ | $N_{dof}$ |
|---|---|---|---|---|---|---|
| 0–10% | 126 | 0.82 | 0.71 | 0.605 | 0.375 | 41 |
| 10–20% | 138 | 0.81 | 0.85 | 0.568 | 0.325 | 41 |
| 20–40% | 158 | 0.78 | 0.91 | 0.536 | 0.417 | 37 |
| 40–60% | 174 | 0.76 | 1.11 | 0.489 | 0.497 | 33 |
| 60–80% | 250 | 0.64 | 1.35 | 0.382 | 0.795 | 39 |

**Fit summary**

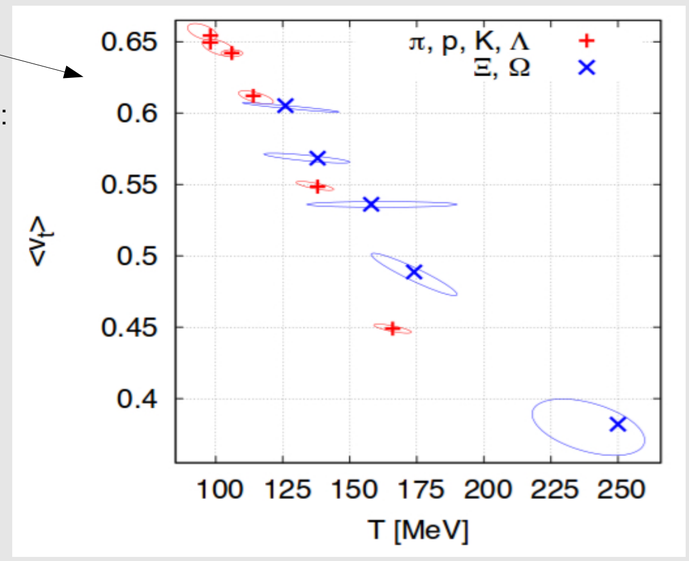
Fits for all particles limited to bins:

0.9 < $R_i = N_i^{exp}/N_i^{MC}$ < 1.1

Pions $p_t$ > 400 MeV/c

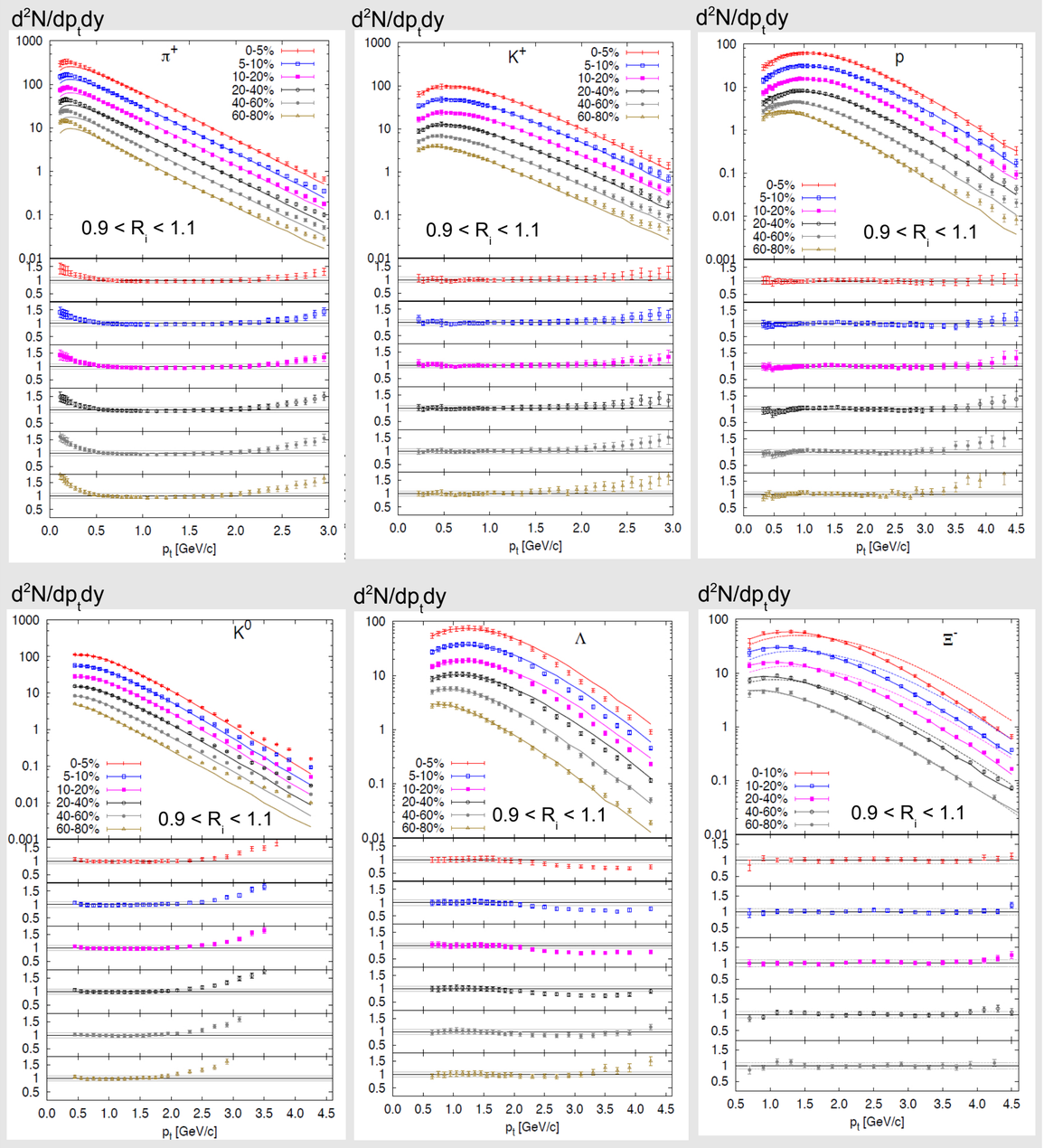
Red ellipses estimate 99% C.L.

Blue ellipses estimate 68% C.L.




## 5. Fits of pt spectra: $\pi^+$, $K^+$, p, $K^0$, Λ, Ξ

Spectra for various centralities are shown along with $R_i = N_i^{exp}/N_i^{MC}$ ratios.
All spectra including those for Ω, K* and Φ can be found in [6].




## References

[1] B. Abelev et al. (ALICE collab.), Phys. Rev. C **88** (2013) 044910
[2] B. Abelev et al. [ALICE collaboration], Phys. Rev. Lett. **111**, 222301 (2014)
[3] B. Abelev et al. [ALICE collaboration], Phys. Lett. B**728**, 216 (2014)
[4] B. Abelev et al. [ALICE Collaboration], arXiv:1404.0495 [nucl-ex]
[5] B. Tomášik, Comp. Phys. Commun. **180** (2009) 1652
[6] I. Melo, B. Tomasik, arXiv:1502.01247v1 [nucl-th]

## Conclusion:

- Resonances induce downward shifts ≤ 10 MeV in $T_{kin}$ for central collisions and upward shifts ≤ 25 MeV for peripheral collisions
- Multistrange baryons show freeze-out at higher temperature and weaker transverse flow.
- Chemical potentials inclusion currently under way (to lift assumption that resonances with abundances fixed at $T_{ch}$ decay only after kinetic freeze-out)