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Analysis of Pt spectra from PbPb at LHC

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Based on ALICE Collaboration ArXiv:1303.0737[hep-ex]
Centrality dependence of pi,K,p production in Pb-Pb at 2.76 TeV

Phases of hadron fireball evolution

- T_c = 175 MeV .... phase transition from QGP to hadron gas
- $T_c < T < T_{ch}$=165 MeV: Hadron gas in local thermal and chemical equilibrium
- T_{ch}=165 MeV: chemical freeze-out
- $T_{ch} < T < T_{kin}$=90 MeV: Hadron gas in thermal but not chemical equilibrium
- T_{kin} = 90 MeV (?): kinetic freeze-out

Blast wave parametrization of the fireball does not include resonance decays

DRAGON fit to data

DRAGON is Monte Carlo code based on Blast Wave model with addition of decays of unstable resonances, 277 hadrons included

A possible fragmentation of fireball is included

Momenta of hadrons generated from Boltzmann distribution

B. Tomášik, Comp. Phys. Commun. 180 (2009) 1642- 1653.

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

$T_{ch} = 0.1656\ GeV$

$\mu_B = 0.002\ GeV$

$\mu_S = 0.0069\ GeV$

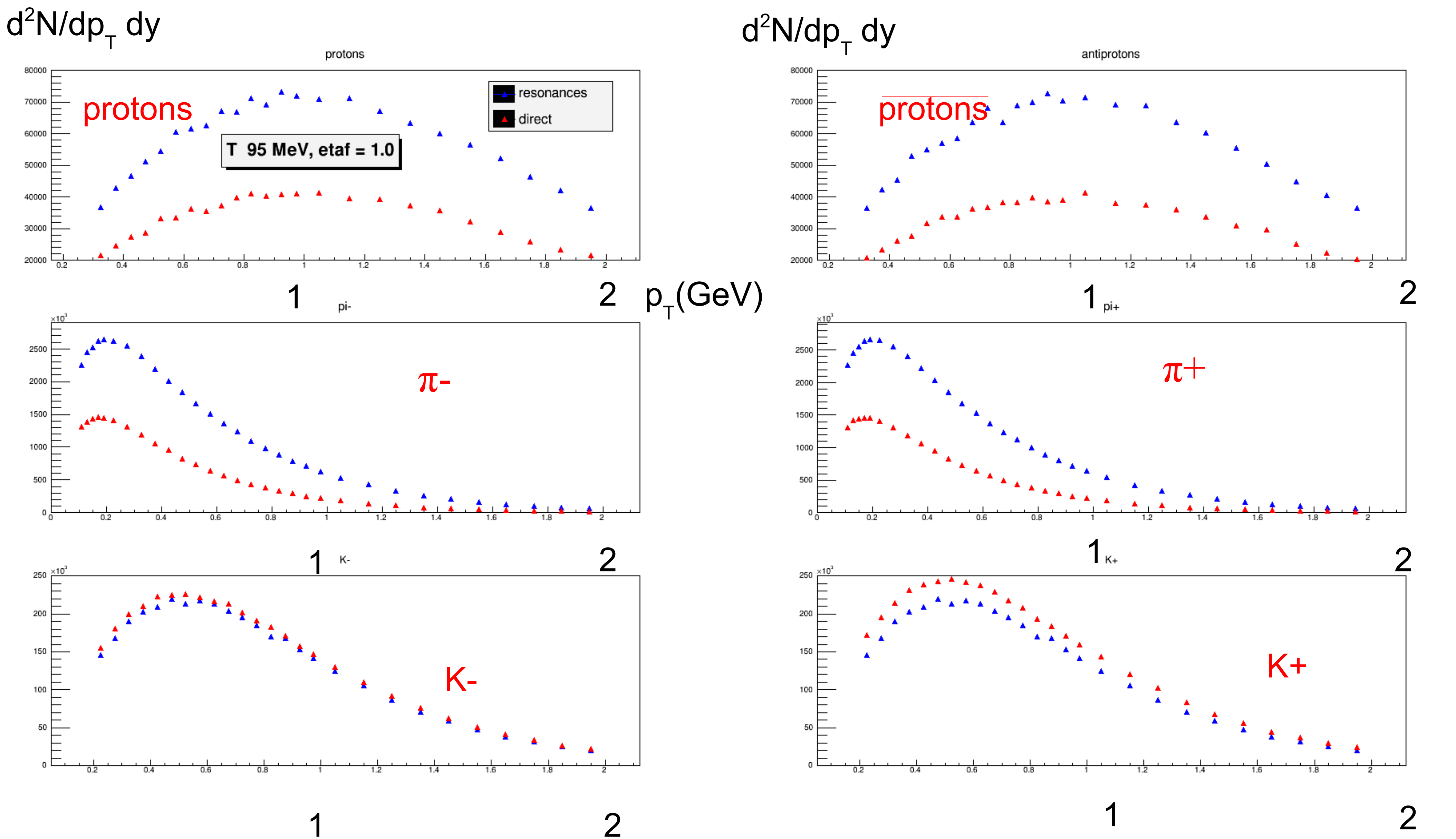
y uniform (-1,1)

T_{kin} *and* η_f *are varied to find the best fit*

$$v_t = \tanh\Big(\underbrace{\sqrt{2}\,\eta_f \frac{r}{R}}_{\text{Transverse rapidity}}\Big)$$

R is radius of cylindrical fireball at freeze-out

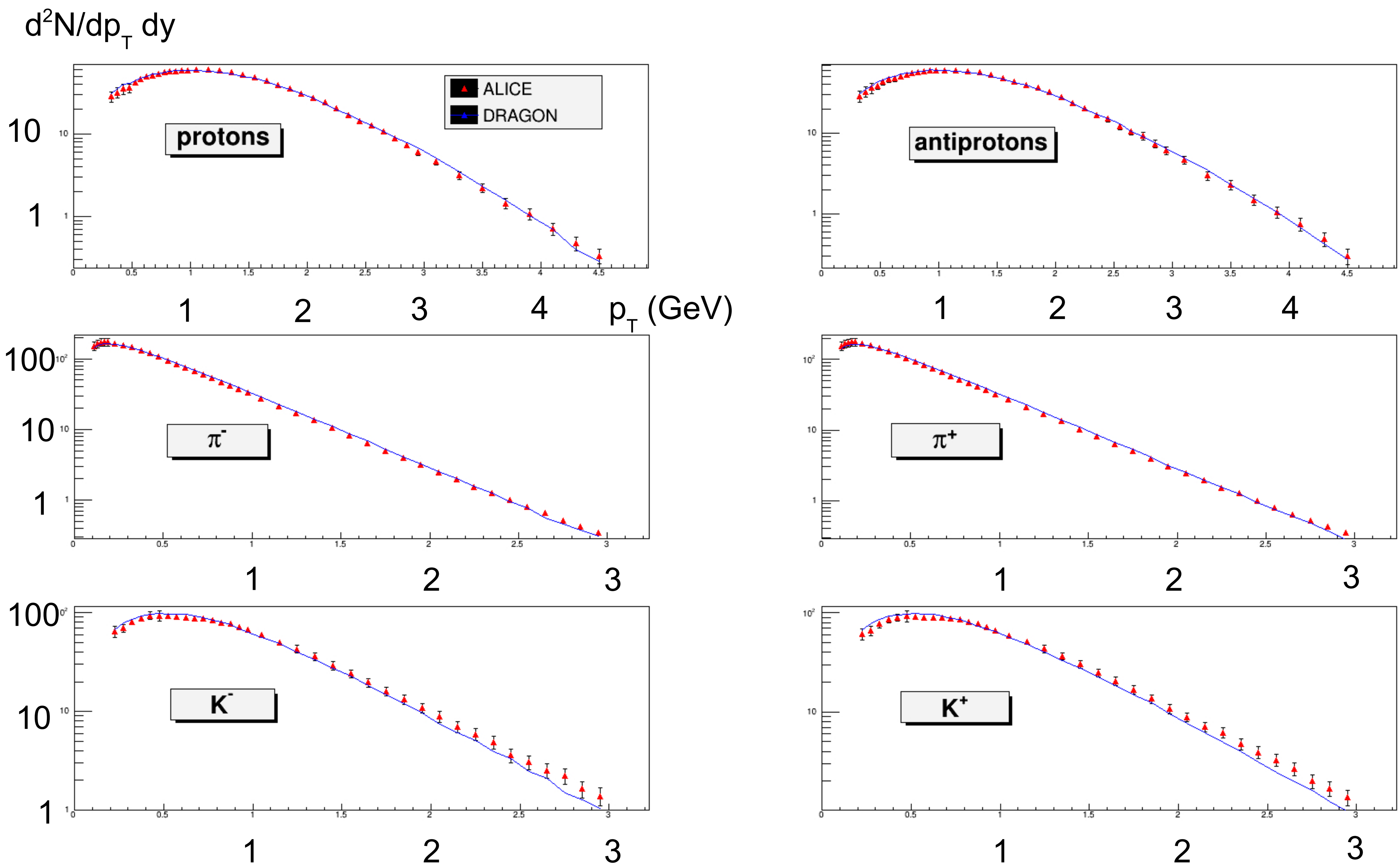
DRAGON P_T spectra: particles produced directly vs resonance produced



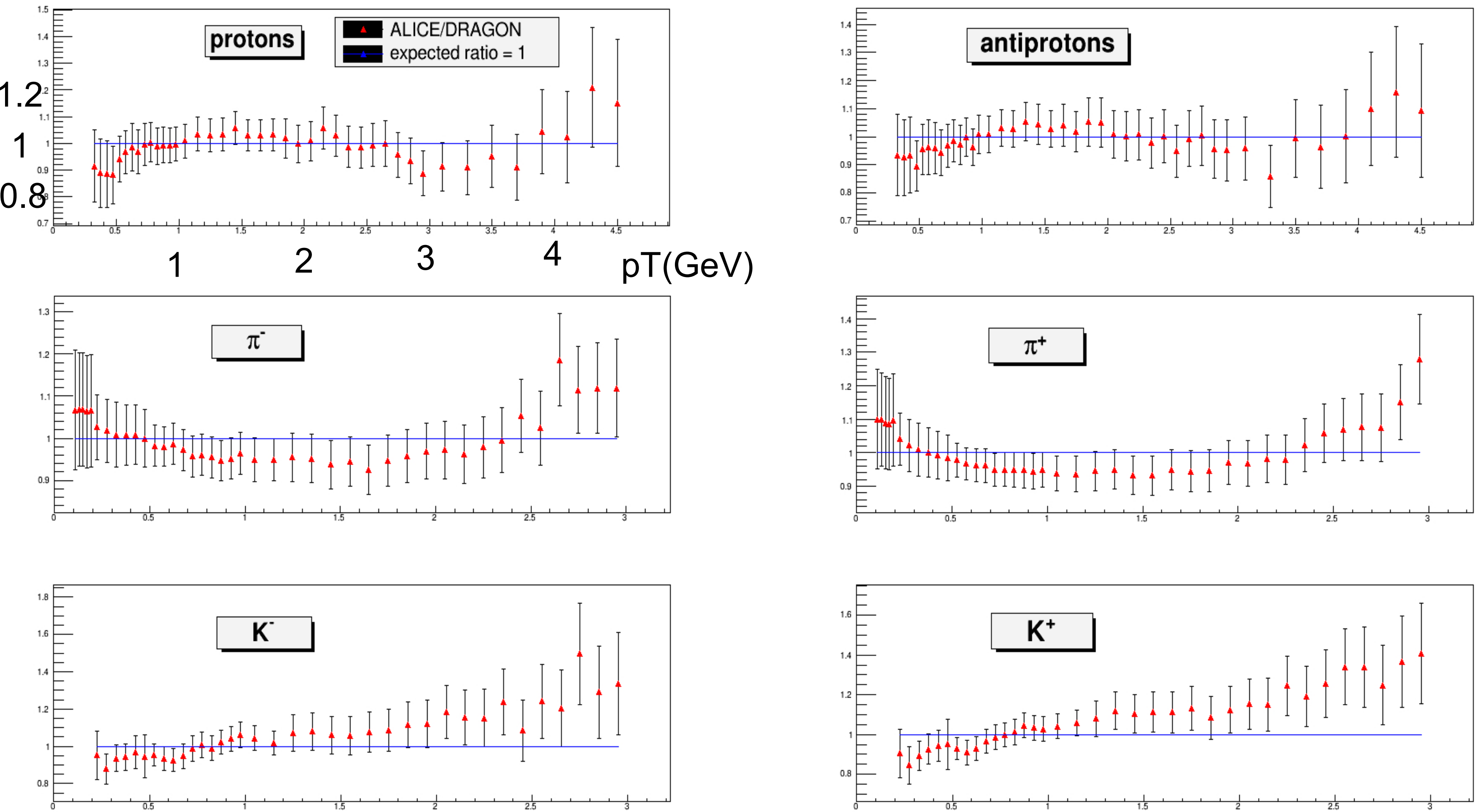
Transverse momentum spectra (ALICE vs DRAGON)

0-5% most central Pb+Pb experimental data

T = 95 MeV, η_f = 1.0



ALICE/DRAGON



Minimum $\chi 2$

$$\chi^2(T_{kin},\eta_f)=\sum_{i=1}^{6}\sum_{j=1}^{j_{max}}\frac{[N_{DRAGON}^{norm}(i,j,T_{kin},\eta_f)-N_{ALICE}^{norm}(i,j)]^2}{\sigma_{ALICE}^{norm}(i,j)^2}$$

i runs over six species p,anti-p, π-, π+,K-,K+
j runs over all p_T bins (j_{max} = 42, 41, 36 for p/anti-p, pions and kaons respectively)
$0.3 < p_T < 4.6$ GeV for p/anti-p,
$0.1 < p_T < 3.0$ GeV for pions,
$0.2 < p_T < 3.0$ GeV for kaons

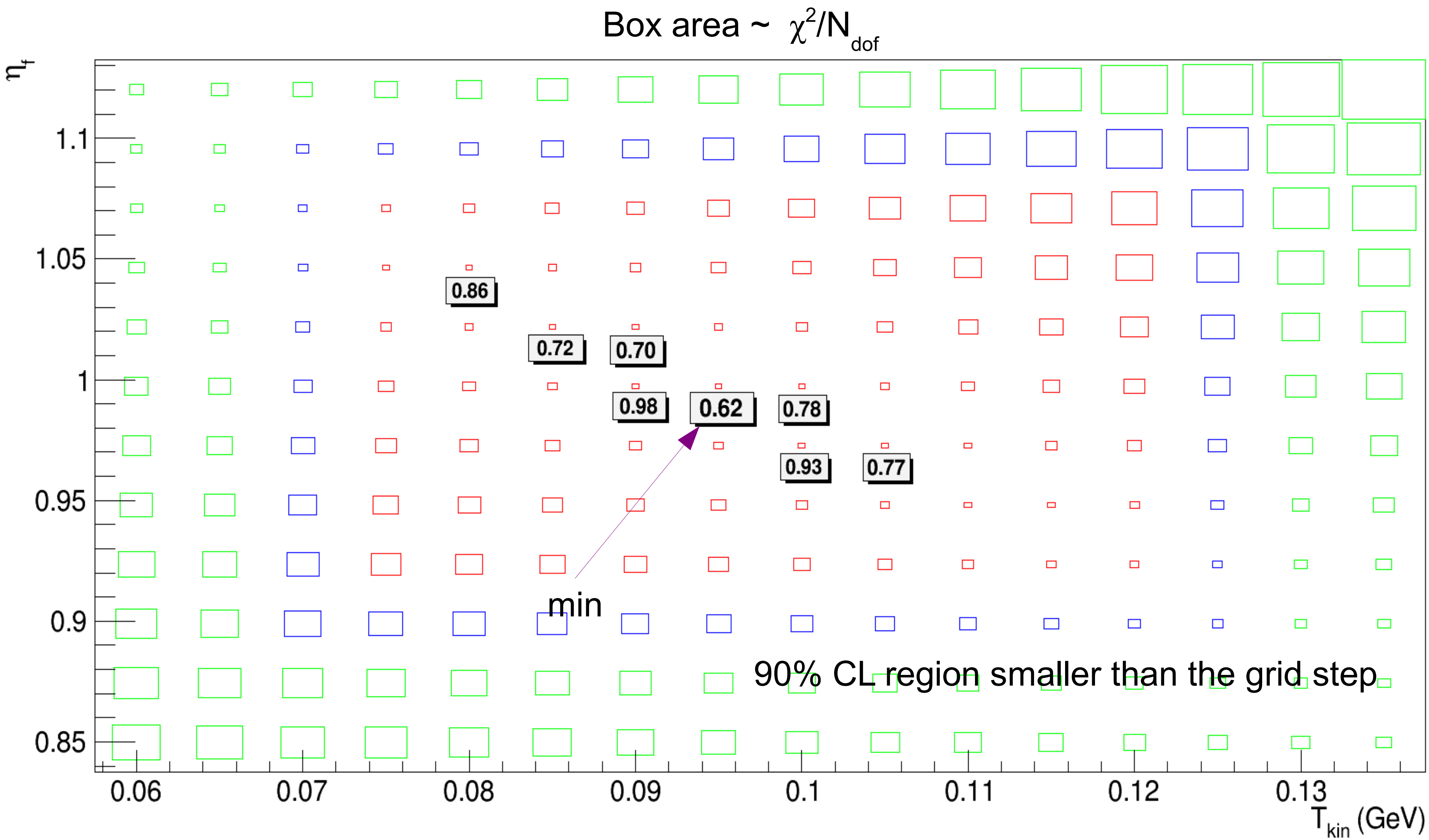
N_{DRAGON} (N_{ALICE}) gives normalized numbers of hadrons of i-th species in the j-th bin

σ is combination of statistical and systematic errors.

Each of the six hadron spectra is normalized independently.

χ^2 results as function of T and η_f

Centrality 0-5% Full spectra



Minimum for different centralities

Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	95	1	0.673
5-10%	95	1	0.764
10-20%	105	0.975	0.733
20-30%	120	0.925	0.881
30-40%	125	0.9	1.044
40-50%	145	0.825	1.411
50-60%	155	0.775	1.900

Full spectra

Table 1: Freeze-out temperatures and transverse expansion parameters from the fits to transverse momentum spectra at different centralities based on 1400 simulated events.

Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	95	1	0.673
5-10%	95	1	0.764
10-20%	105	0.975	0.733
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Full spectra

Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	75	1.05	0.293
5-10%	75	1.05	0.350
10-20%	85	1.025	0.398
20-30%	90	1.00	0.493
30-40%	100	0.950	0.730
40-50%	120	0.875	0.988
50-60%	135	0.800	1.428

Pt(max) = 2 GeV

Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	65	1.075	0.097
5-10%	65	1.075	0.144
10-20%	65	1.050	0.137
20-30%	70	1.025	0.145
30-40%	70	1.000	0.212
40-50%	75	0.950	0.276
50-60%	90	0.850	0.509

Pt(max) = 1 GeV

Pions, protons and kaons

Pt(max) = 2 GeV

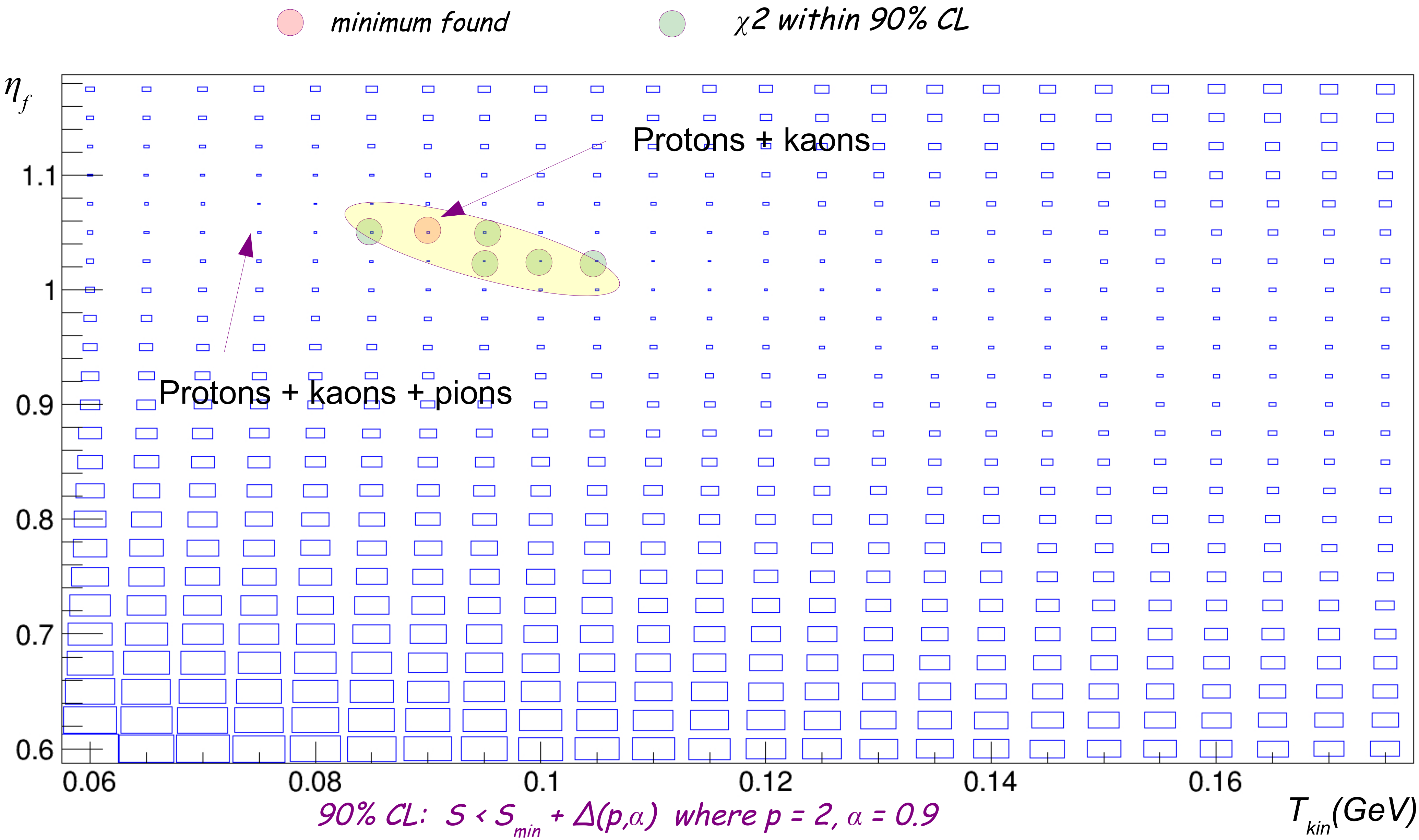
Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	75	1.05	0.293
5-10%	75	1.05	0.350
10-20%	85	1.025	0.398
20-30%	90	1.00	0.493
30-40%	100	0.950	0.730
40-50%	120	0.875	0.988
50-60%	135	0.800	1.428

Protons and kaons

Pt(max) = 2 GeV

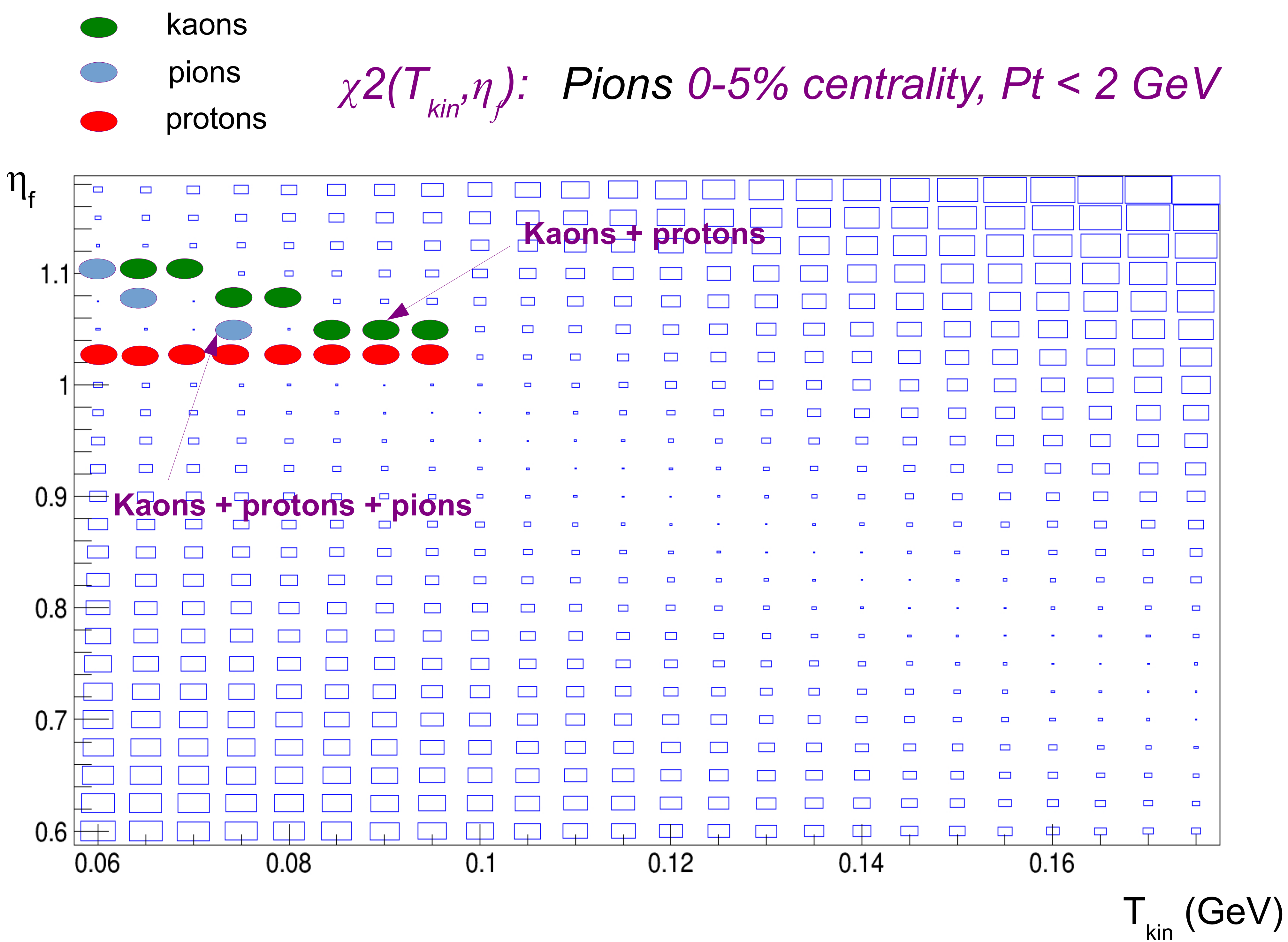
Centrality	T_{kin} [MeV]	η_f	χ^2/N_{dof}
0-5%	90	1.050	0.192
5-10%	95	1.025	0.219
10-20%	110	1.000	0.240
20-30%	115	0.975	0.205
30-40%	125	0.925	0.211
40-50%	145	0.850	0.188
50-60%	175	0.750	0.246

$\chi 2(T_{kin},\eta_f)$: protons + kaons, 0-5% centrality, $P_T < 2$ GeV

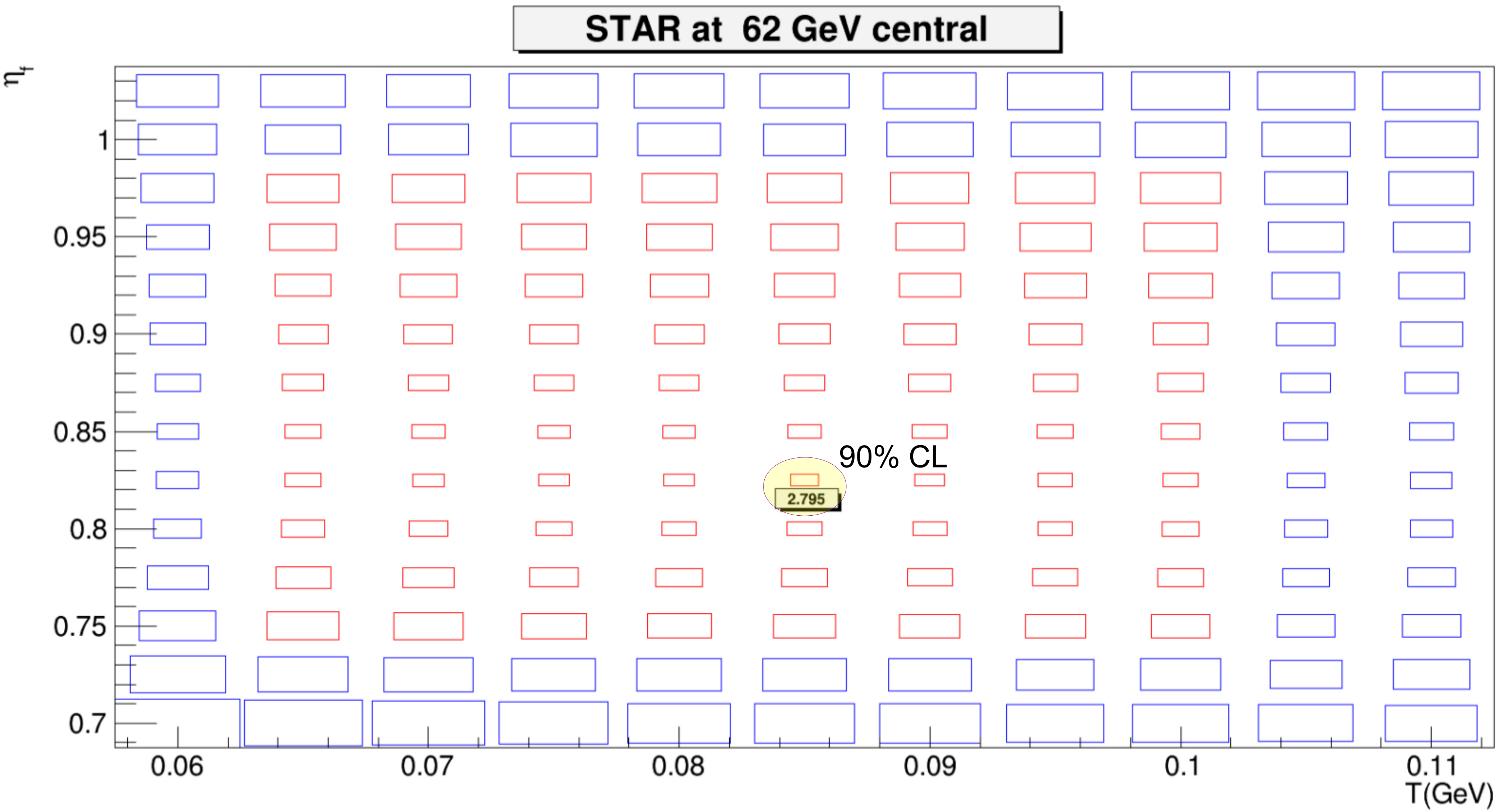


90% CL: $S < S_{min} + \Delta(p,\alpha)$ where $p = 2$, $\alpha = 0.9$

probability($\chi 2$(p degrees of freedom) $< \Delta$) $= \alpha$



kaons
pions
protons
$\chi2(T_{kin},\eta_f)$: Pions 0-5% centrality, Pt < 2 GeV
η_f
1.1
1
0.9
0.8
0.7
0.6
Kaons + protons
Kaons + protons + pions
0.06
0.08
0.1
0.12
0.14
0.16
T_{kin} (GeV)



STAR (62 GeV): T_{kin} = 85 MeV, η_f = 0.825, all particles, spectrum up to Pt $\approx$ 1 GeV

ALICE: T_{kin} = 90 MeV, η_f = 1.05, protons+kaons, Pt < 2 GeV

Conclusions

- *Protons, pions and kaons receive important contribution from resonance decays (Resonant p/direct p ~ 1.9 for T_{ch} = 165 MeV)*
- *DRAGON fits to ALICE 0-5% data yield T_{kin} = 75 – 95 MeV and η_f = 1.0 – 1.05 for T_{ch} = 165 MeV*
- *Careful treatment of high p_T cut needed*
- *Add K0, Lambda, Xi, Omega*
- *Do some particles freeze out before others?*
- *Pion chemical potential?*

Transverse momentum spectra (ALICE)

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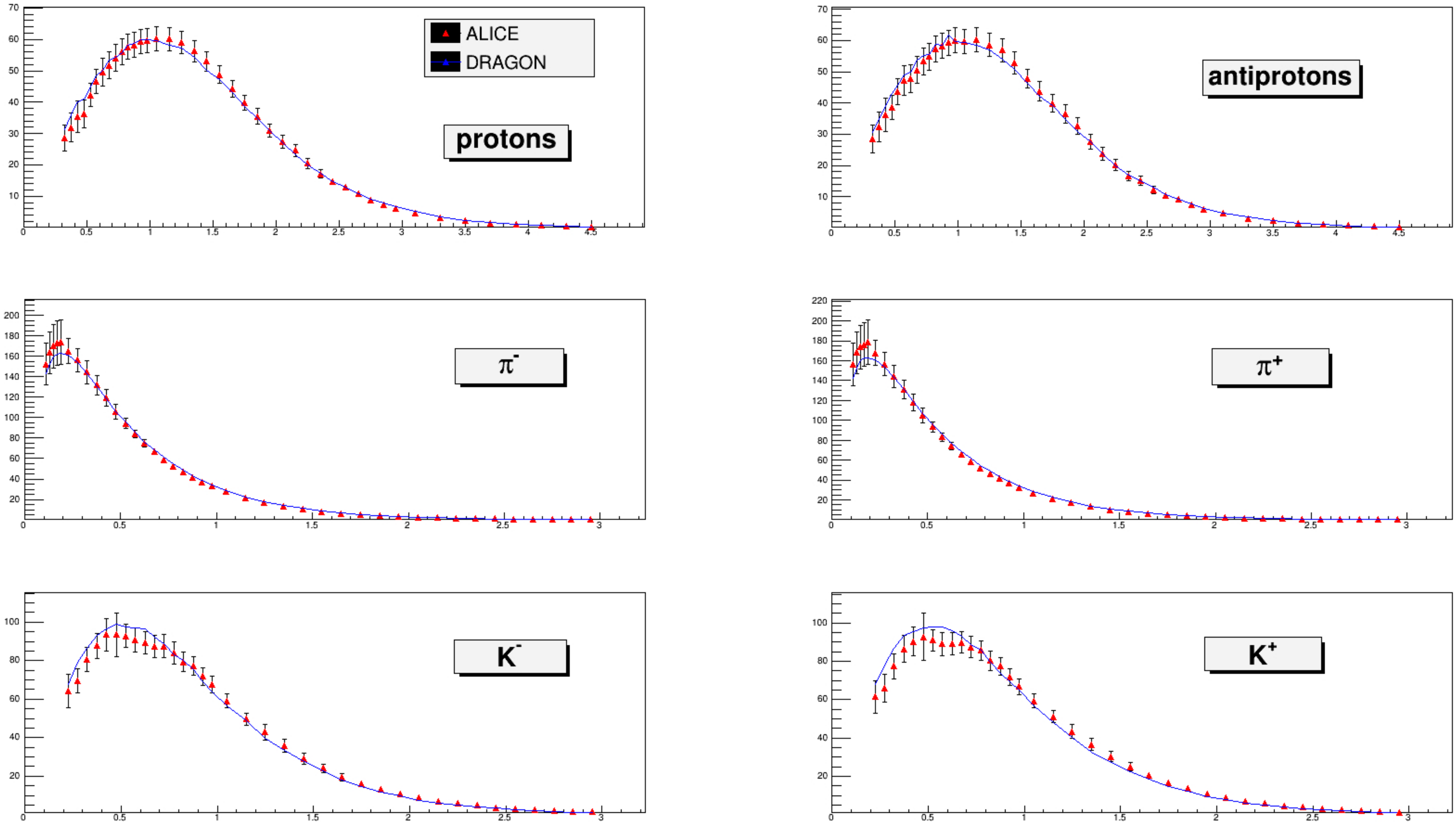

More comments

- Log scale for Pt
- Is Dragon publicly available and easy to use? We use very old blast wave, maybe I could tell my people to try it out. How do you include resonances?
- Upper Pt cuts should be different for each particle – make ratio of Pt spectra for data and fit and where the difference is more than 20%, make the cut
- Do not rely too much on pions they are least sensitive to flow effects and most sensitive to all other things (QCD something)
- Systematic errors are big and correlated, we are conservative, have 3 detectors and have to combine errors, STAR just one
- Try to include Lambdas, Omegas and Cascades (I will send you a link if we published it). Lambdas should fix you up (still large enough elastic cross section so they freeze out at the same T. Omegas and Cascades have small X-section, may freeze out before
- Comparison with STAR – it would be nice to see that flow behaviour goes to higher pT for ATLAS than STAR
- It would be interesting to see if some particles freeze out before others
- Try chemical potential of pions by hand to see how it affects the pT spectra
- It is OK to sum particle spectra with antipart spectra and average them

cont'd

- Switch off weak decays of resonances (this is done in the data)