Hadrons at Freeze-out

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- Statistical model
- Blast wave model
- Summary

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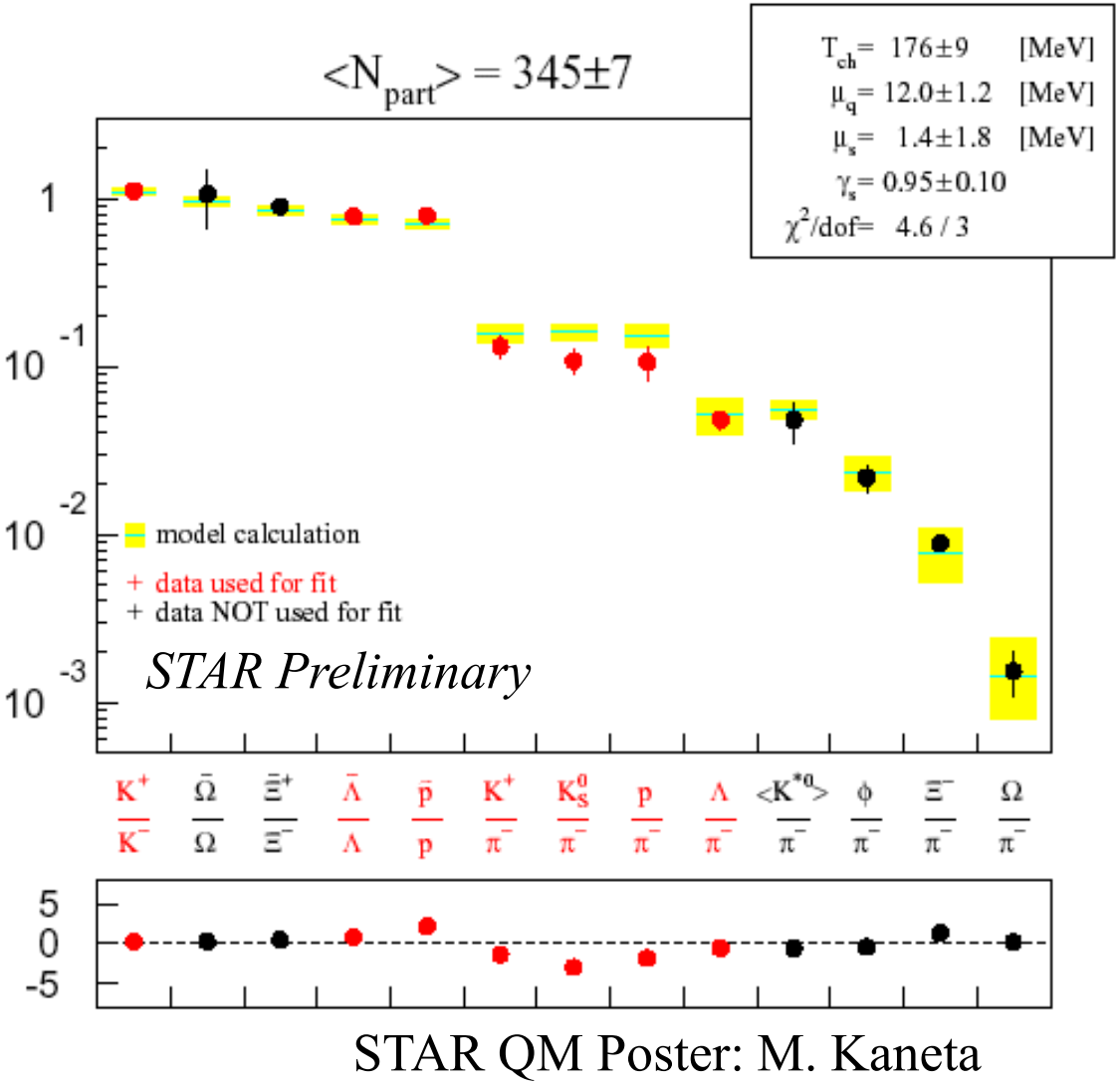
Ratios, experiment vs. a statistical model

Central
130 GeV Au+Au
Preliminary Data

Agreement between model and data is very good!

$$R = e^{-(\mu_i - \mu_j)/T}$$

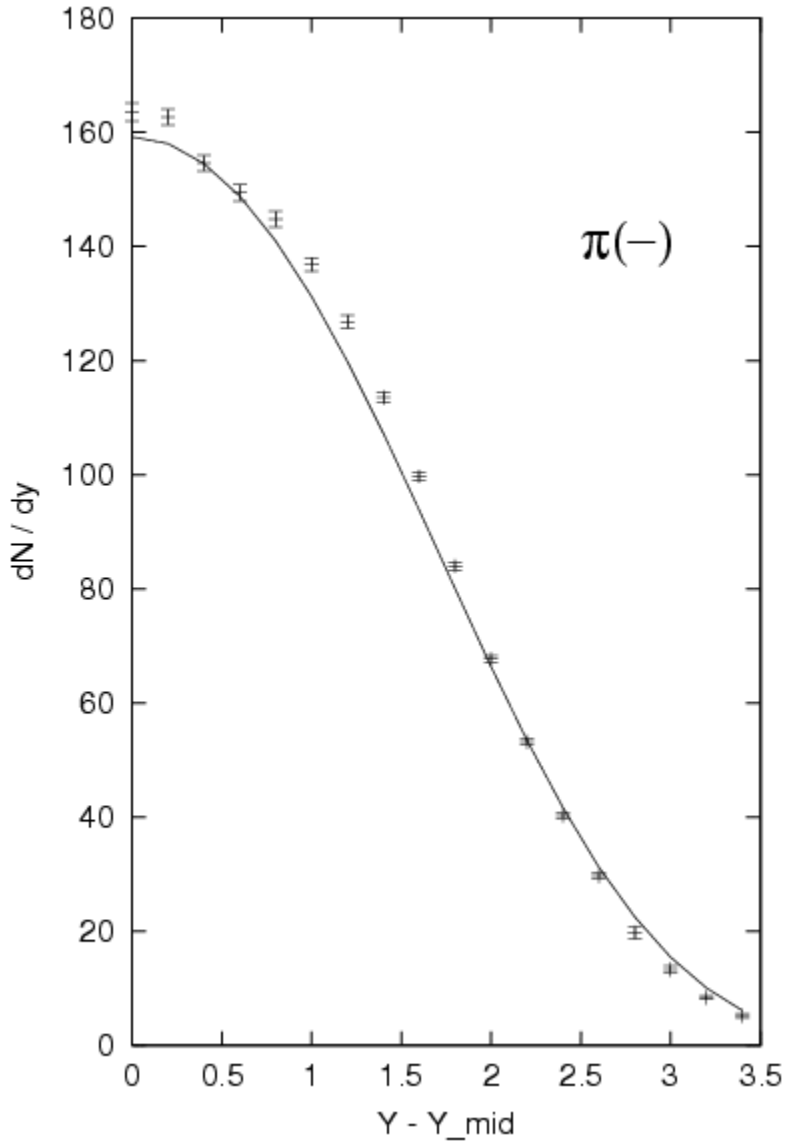
$$\mu_i = B_i \mu_B + S_i \mu_s$$



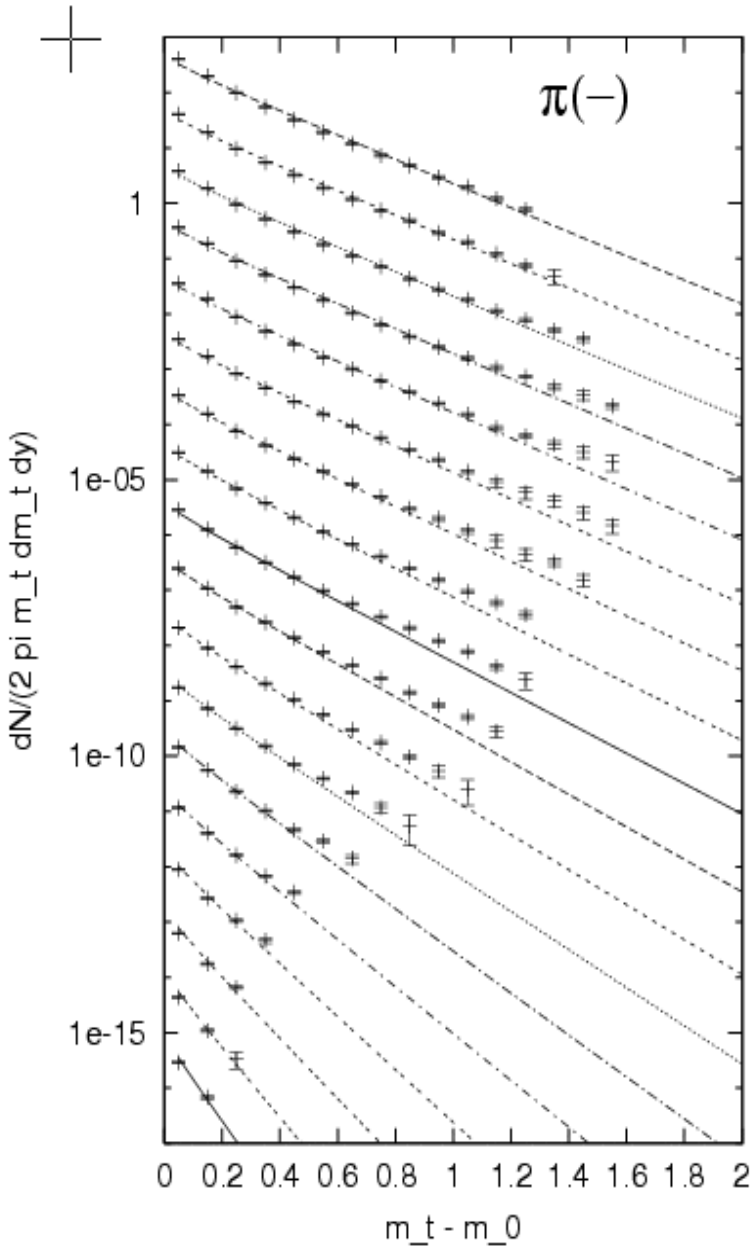
STAR QM Poster: M. Kaneta

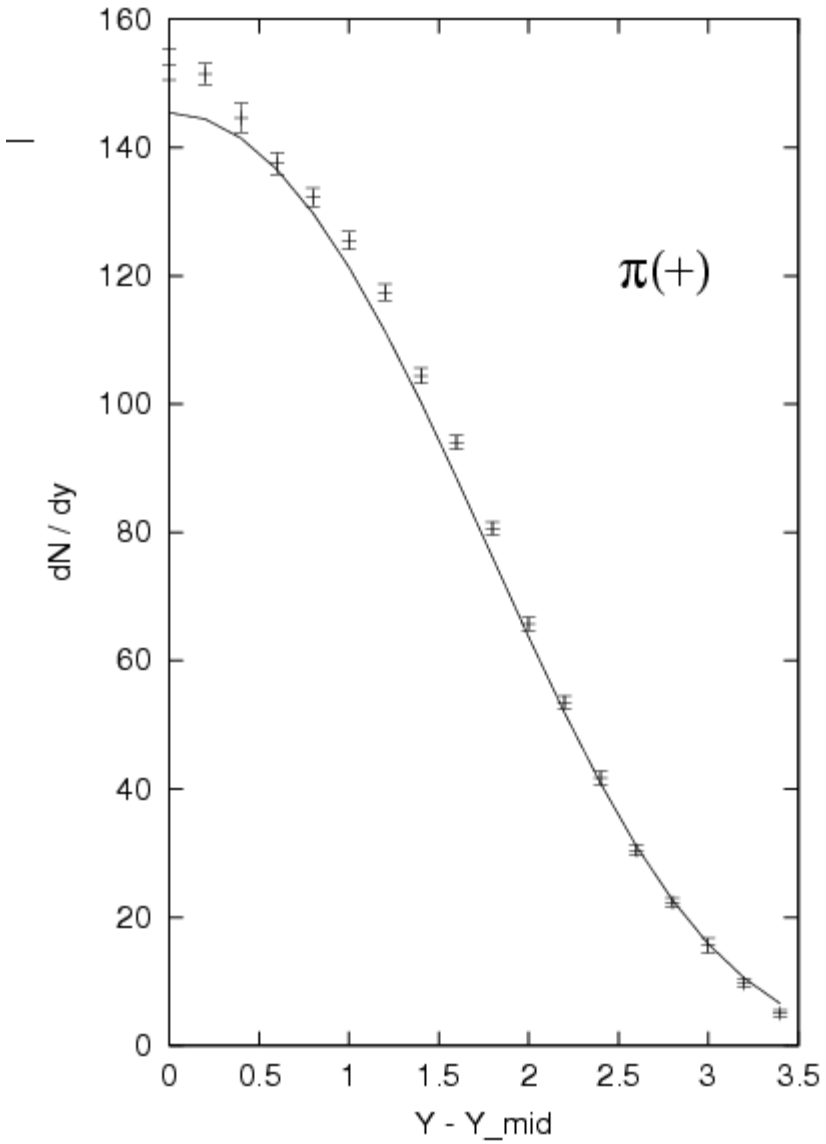
Does this mean the thermalization?

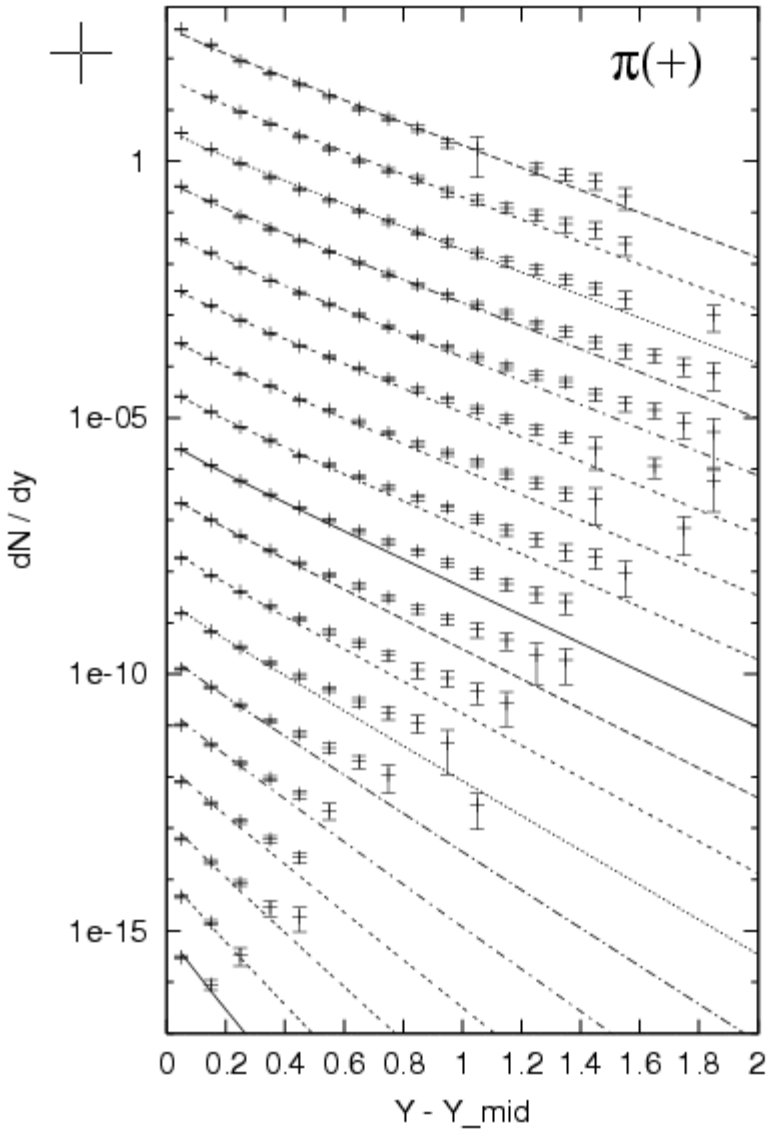
- this success can be achieved from the statistical model for the particle production without any assumption of the thermalization.

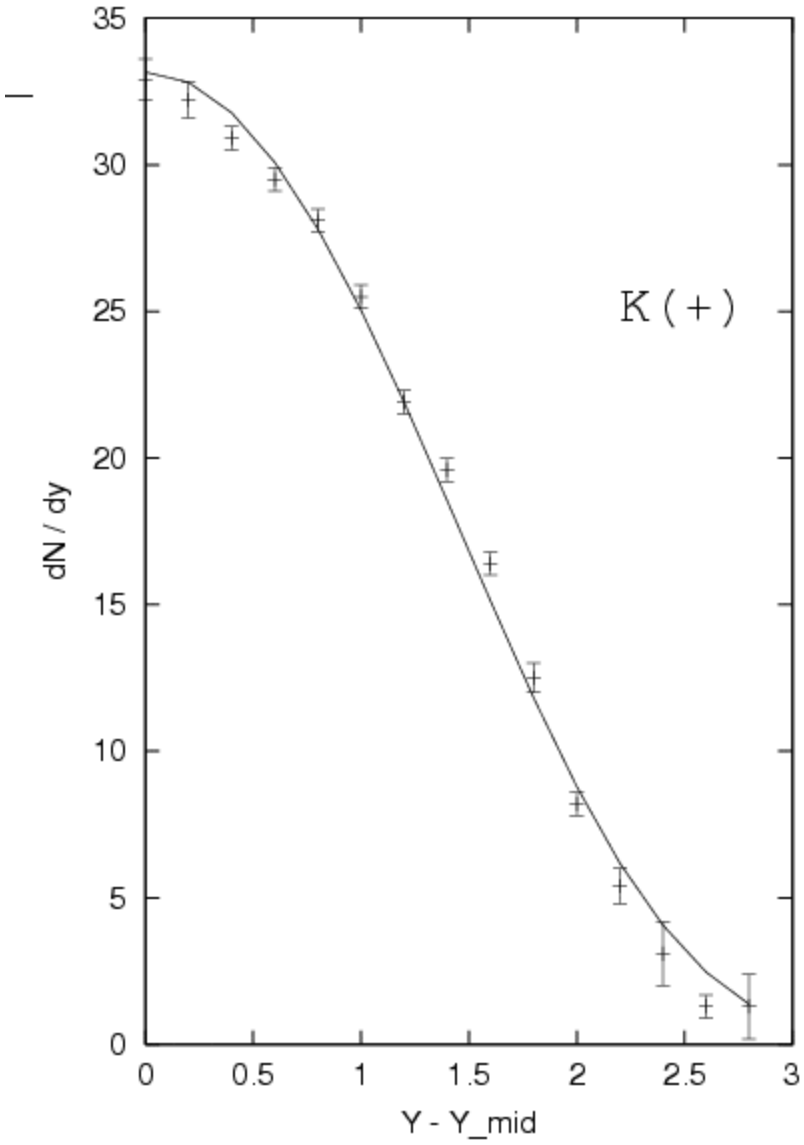


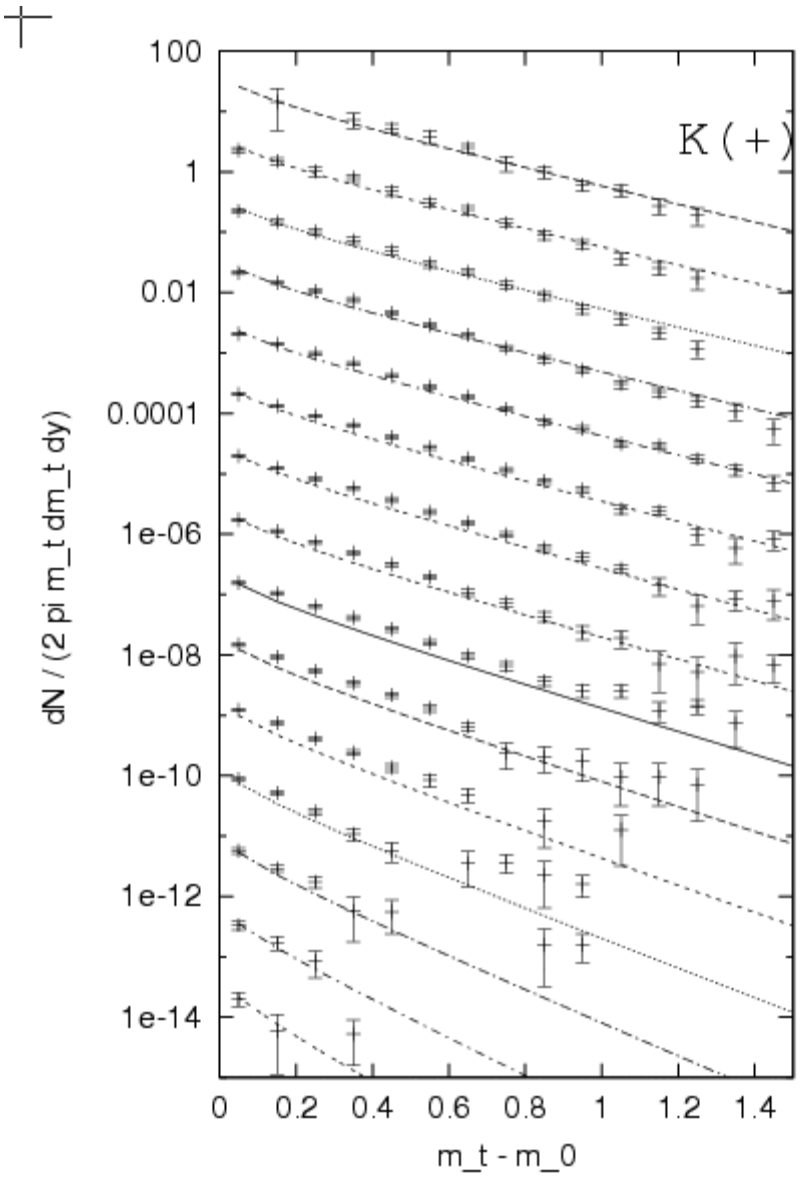
NA49
Pb+Pb

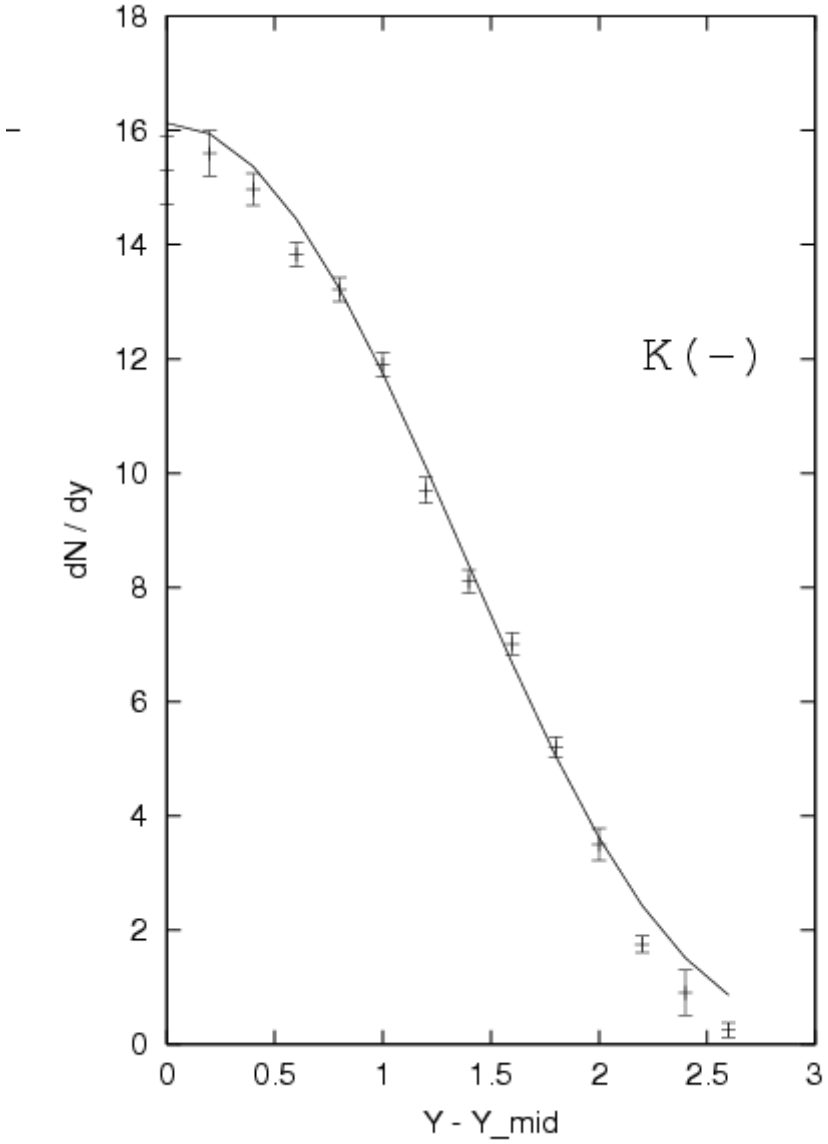

π(−)
1
1e-05
1e-10
1e-15
dN/(2 pi m_t dm_t dy)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
m_t - m_0

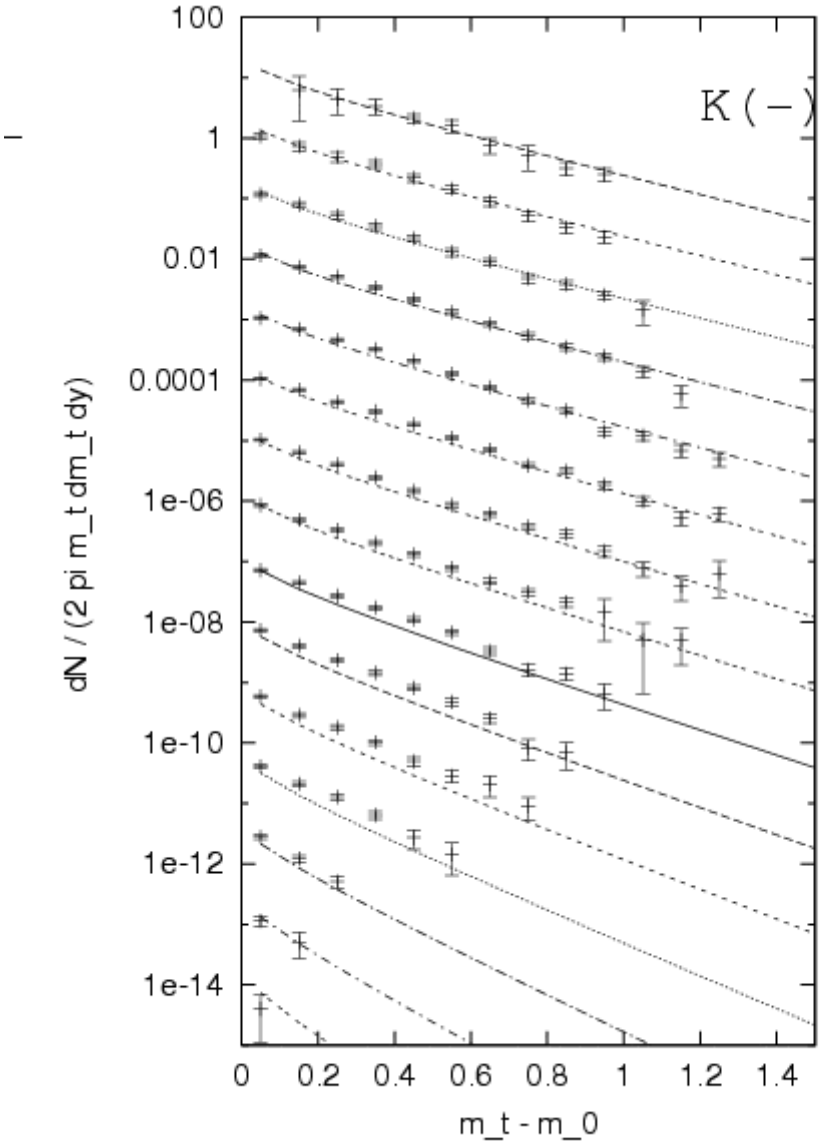

160
140
120
100
80
60
40
20
0
dN / dy
π(+)
0
0.5
1
1.5
2
2.5
3
3.5
Y - Y_mid


π(+)
1
1e-05
1e-10
1e-15
dN / dy
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Y - Y_mid


K(+)
dN / dy
Y - Y_mid
0
5
10
15
20
25
30
35
0
0.5
1
1.5
2
2.5
3

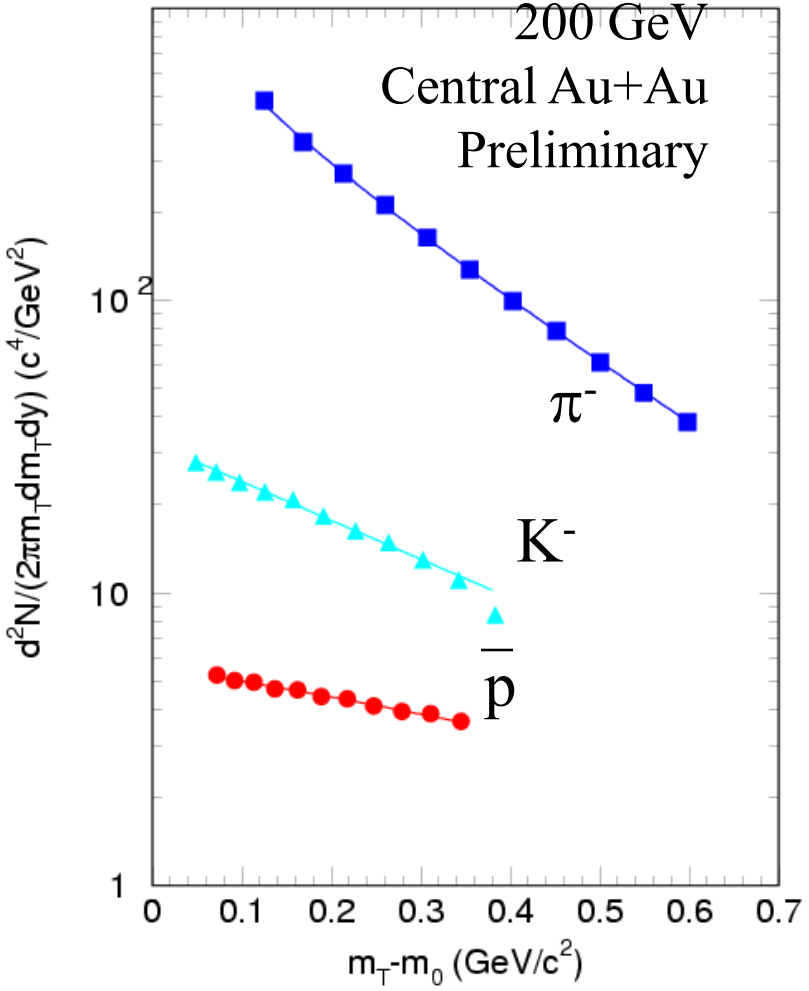

K (+)
100
1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
1e-14
dN / (2 pi m_t dm_t dy)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
m_t - m_0

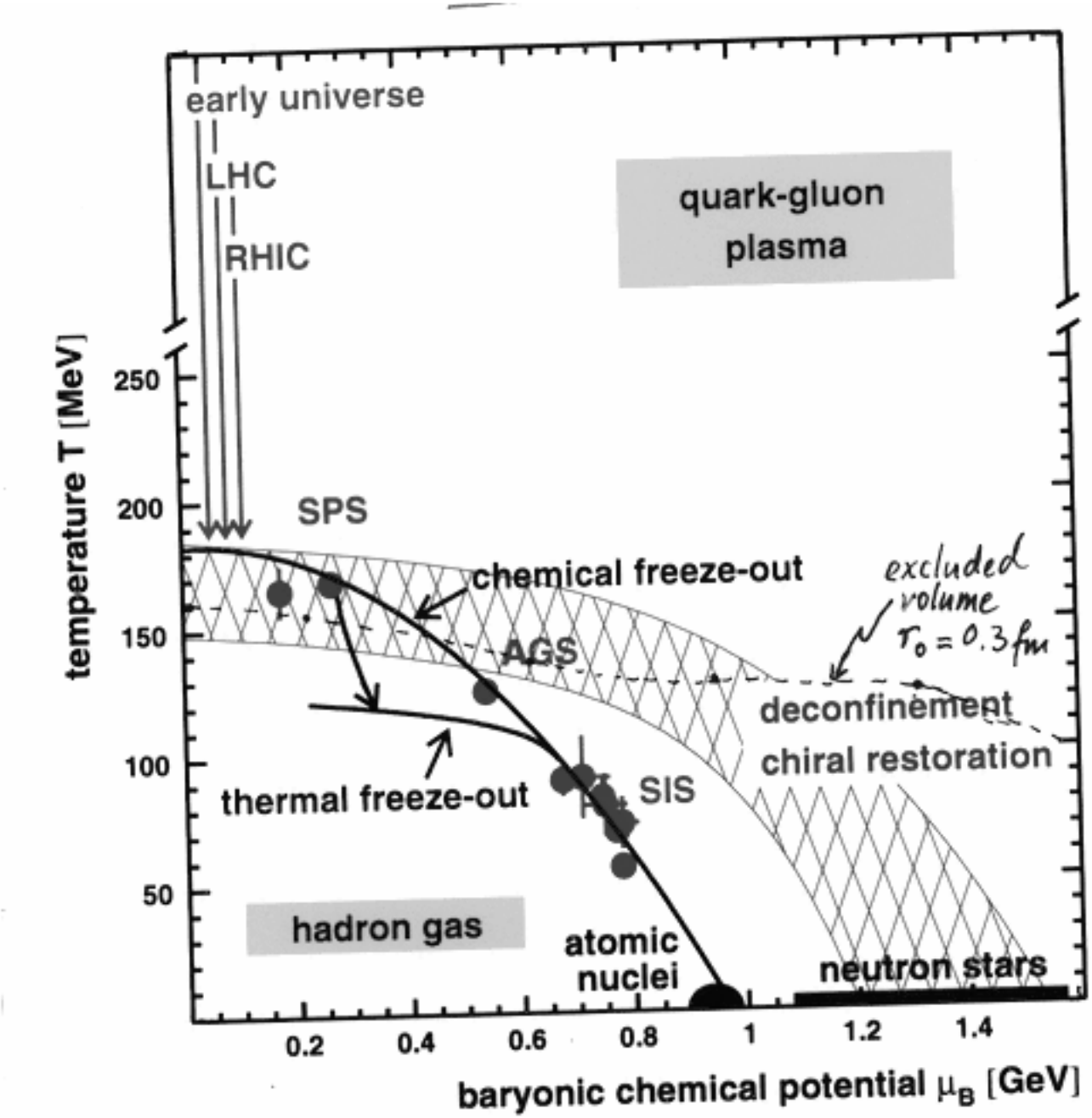

K (−)
dN / dy
Y - Y_mid
0
2
4
6
8
10
12
14
16
18
0
0.5
1
1.5
2
2.5
3

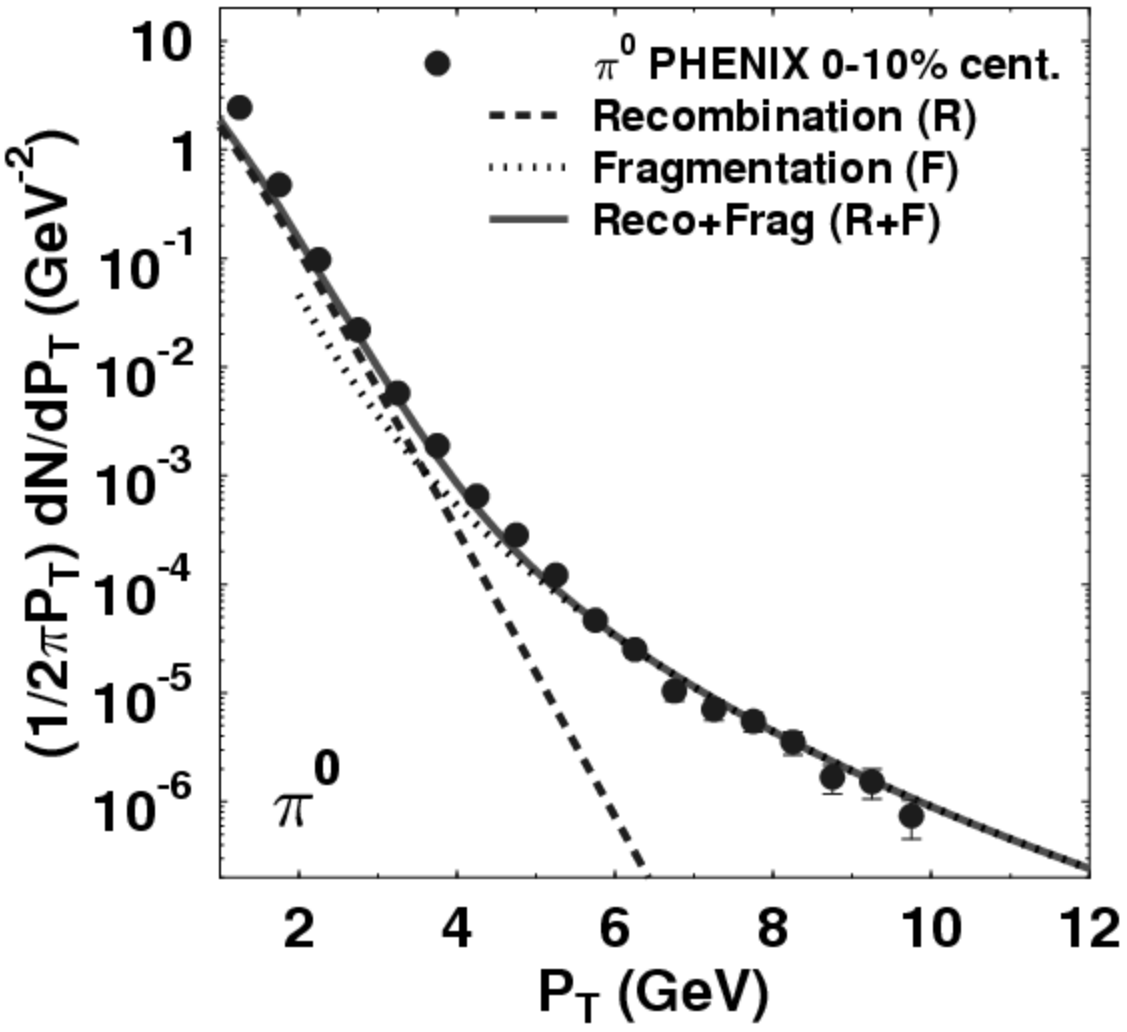

K (−)
100
1
0.01
0.0001
1e-06
1e-08
1e-10
1e-12
1e-14
dN / (2 pi m_t dm_t dy)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
m_t - m_0

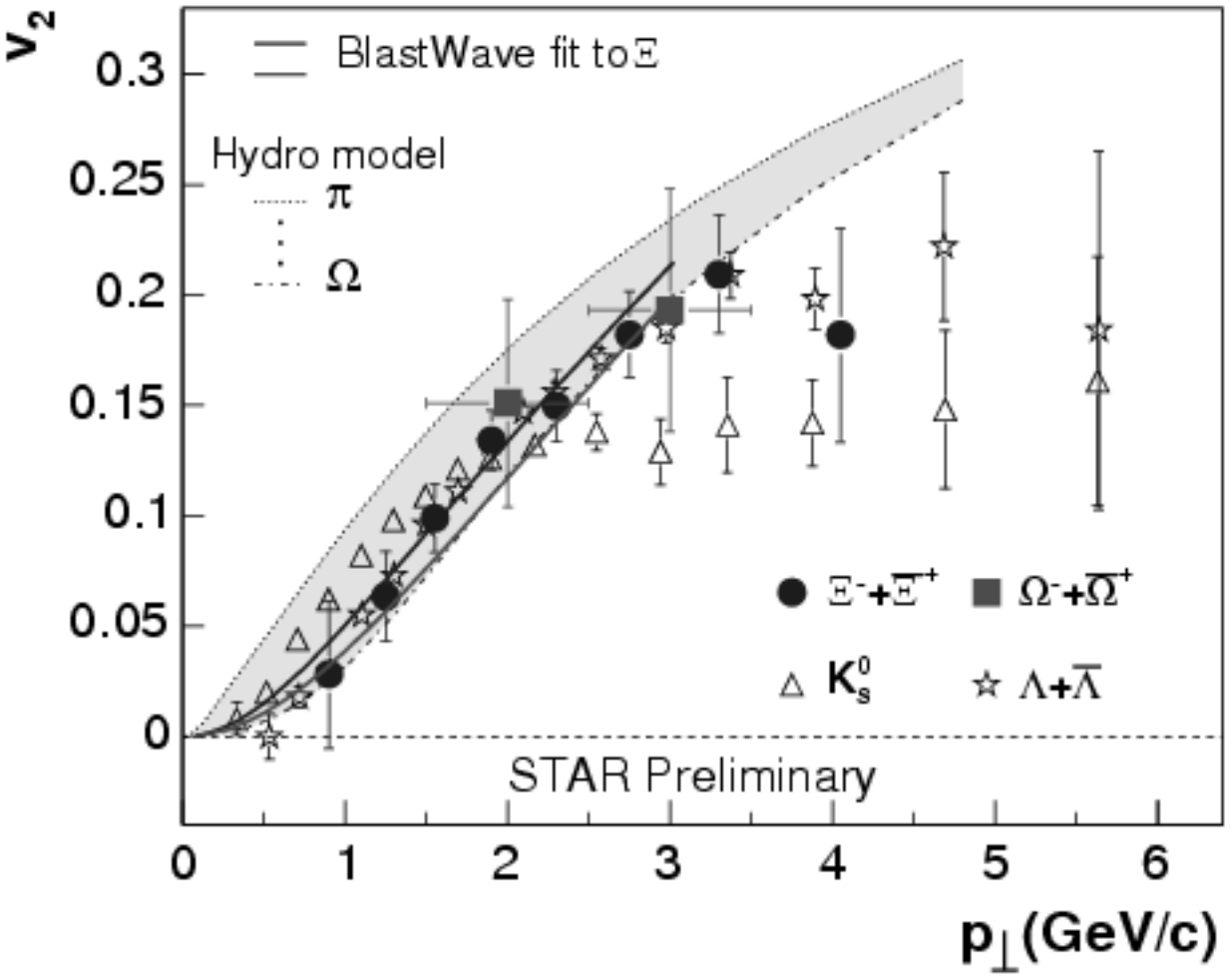
π^-, K^-, p: radial flow

- Exponential shape
- Higher the mass, flatter the slope




early universe
LHC
RHIC
quark-gluon plasma
temperature T [MeV]
250
200
150
100
50
SPS
chemical freeze-out
AGS
excluded volume
$r_0 = 0.3$ fm
deconfinement
chiral restoration
thermal freeze-out
SIS
hadron gas
atomic nuclei
neutron stars
0.2
0.4
0.6
0.8
1
1.2
1.4
baryonic chemical potential μ_B [GeV]


π^0 PHENIX 0-10% cent.
Recombination (R)
Fragmentation (F)
Reco+Frag (R+F)
π^0
$(1/2\pi P_T)\ dN/dP_T\ (GeV^{-2})$
P_T (GeV)
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
2
4
6
8
10
12


v_2
BlastWave fit to Ξ
Hydro model
π
Ω
0.3
0.25
0.2
0.15
0.1
0.05
0
$\Xi^-+\overline{\Xi}^+$
$\Omega^-+\overline{\Omega}^+$
K^0_s
$\Lambda+\overline{\Lambda}$
STAR Preliminary
0
1
2
3
4
5
6
$p_\perp$ (GeV/c)

summary

- The success of the chemical analysis does not necessarily mean the thermalization of the system produced during the heavy-ion collisions.

- Blast wave model seems to fit all the transverse mass spectra of various hadrons. However, there are still caveats. Simultaneous fitting is not a easy job.
  - This model is applicable only for mt < 2 GeV.

- chemical and thermal freeze-outs are different.
  - Need different normalizaton for each particles in fitting the mt spectra.