Particle spectra and yields in central Pb+Pb at 40, 80 and 158 *A*GeV

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for the NA49 collaboration

Outline

- Energy dependence in central Pb+Pb
  - longitudinal flow (rapidity spectra)
  - transverse, radial flow (m_T spectra)
  - particle yields
- Upper limit for open charm @ 158 *A*GeV

Central Pb+Pb data

- 40 *A*GeV 7%, 900k events
- 80 *A*GeV 7%, 300k events
- 158 *A*GeV 10%, 800k events
- 158 *A*GeV 20%, 3M events

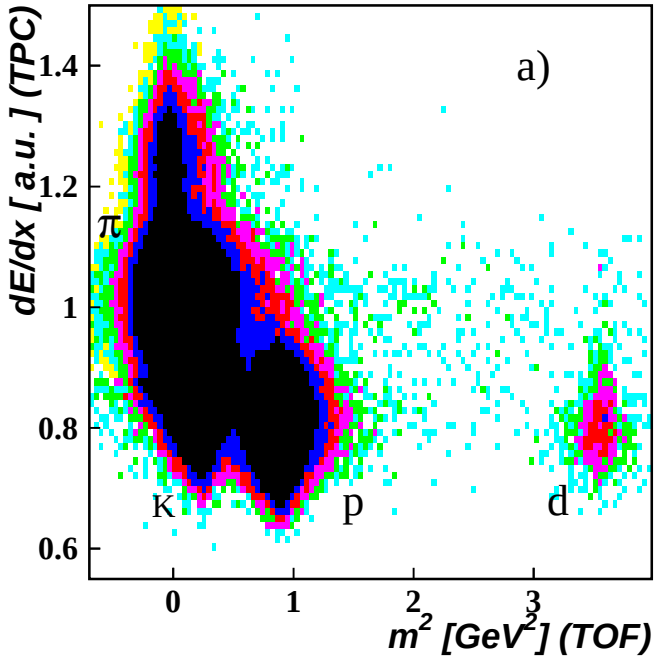
Other available data include:

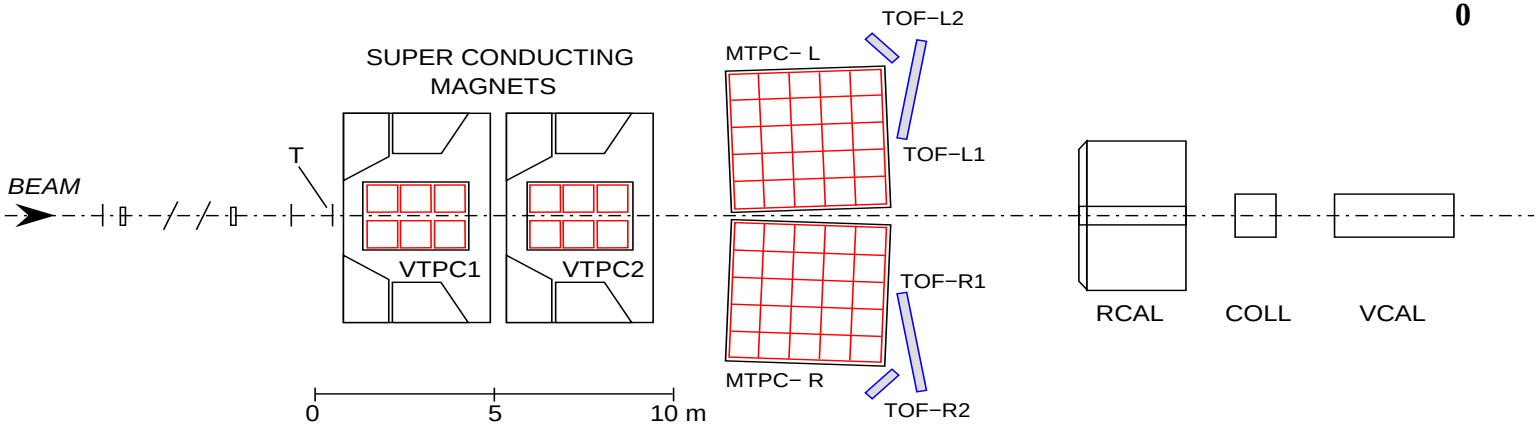
- 158 *A*GeV
  - π+p, p+p, d+p, p+Pb — cf. M. Kreps parallel session
  - C+C, Si+Si, Pb+Pb minimum bias — cf. C. Hoehne, parallel session
- 40 *A*GeV mimimum bias

The NA49 experiment

Large acceptance spectrometer

- Particle identification by *dE/dx* (in TPC) and *TOF*
- Magnetic field scaled with beam energy to keep *TOF*−detector at mid−rapidity



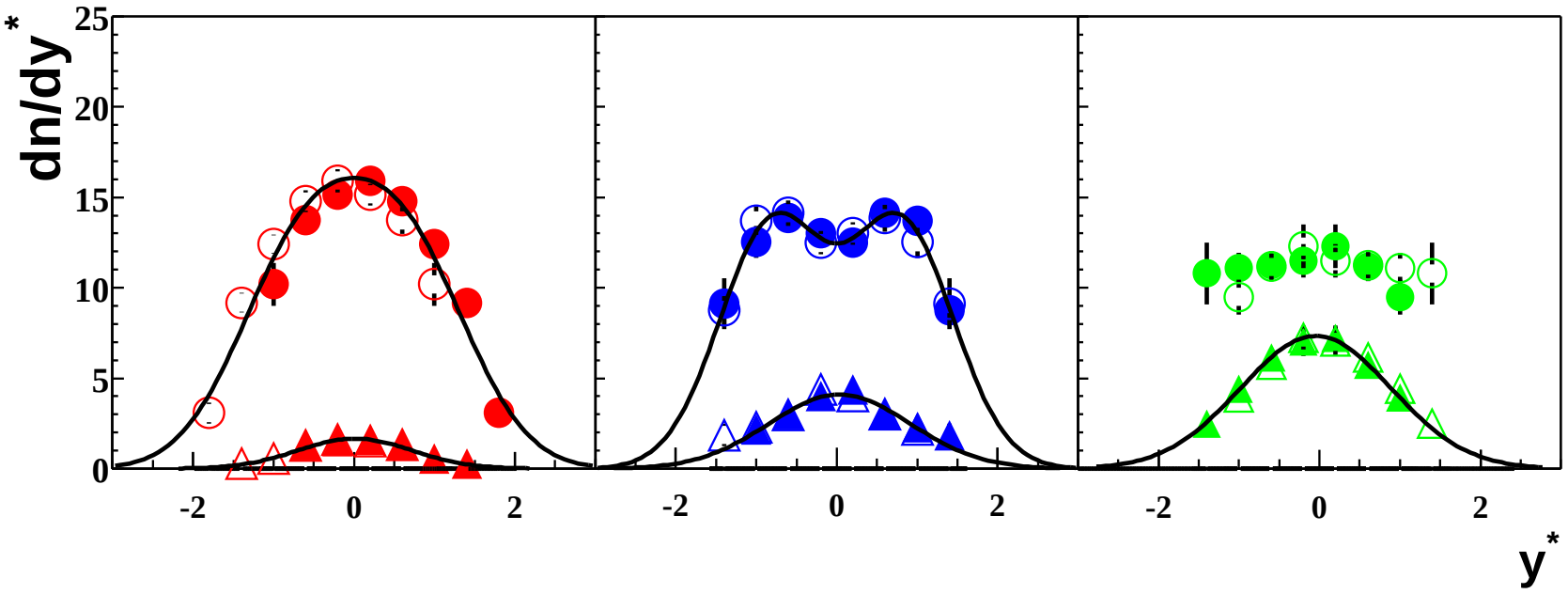


Λ rapidity spectra at 40, 80 and 158 *A*GeV

final results, to be published

Parallel session presentation by A. Mischke

40 *A*GeV 80 *A*GeV 158 *A*GeV



● Λ

▲ $\bar{\Lambda}$ $(\times 4)$

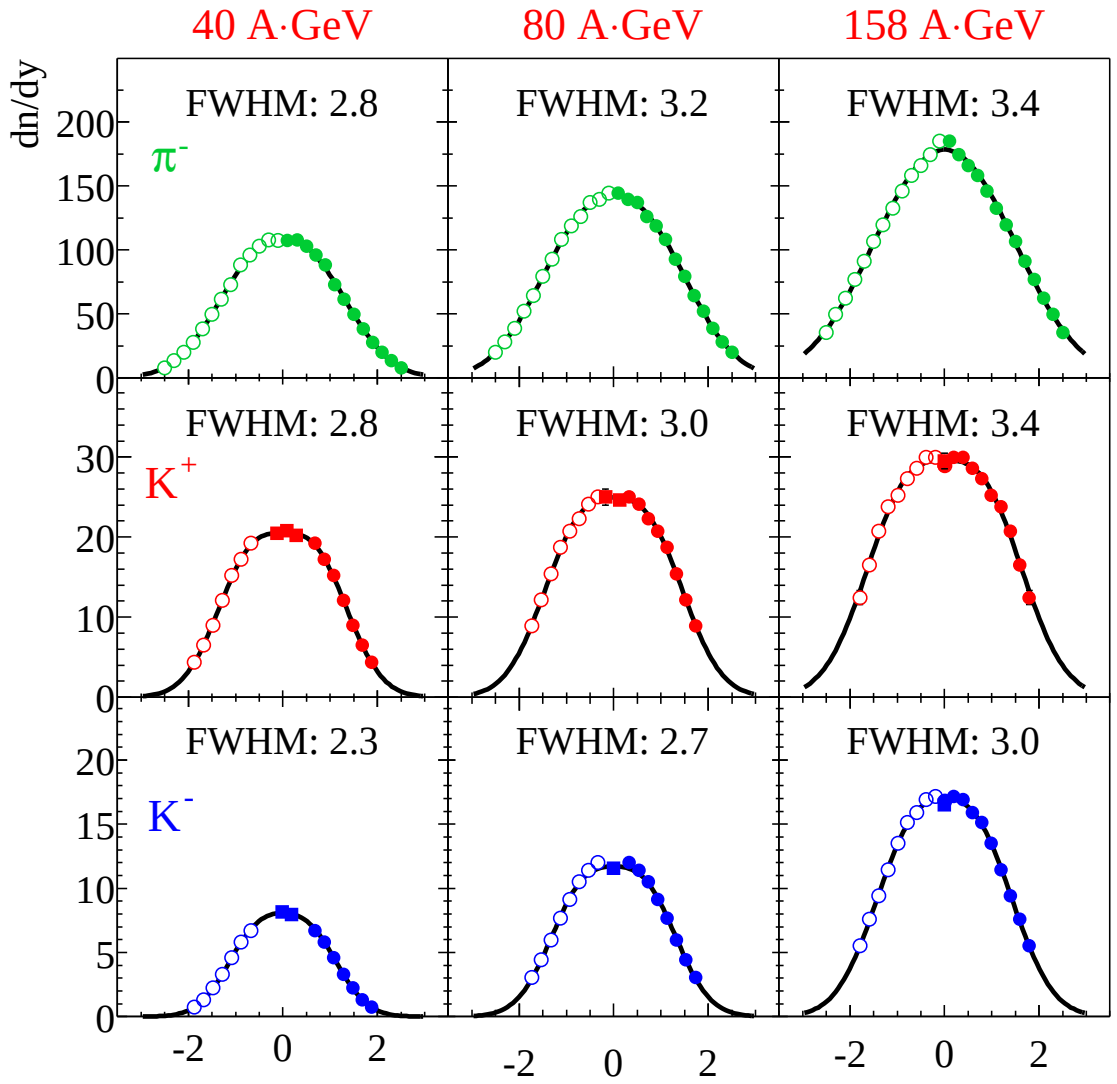
40, 80 *A*GeV 7% central
158 *A*GeV 10% central

Rapidity spectra broaden with increasing beam energy, but Λ much broader than $\overline{\Lambda}$

Rapidity spectra for K, π

Spectra broaden with energy, K^+ spectra broader than K^-

Could be connected to Λ width, due to ΛK pair production.



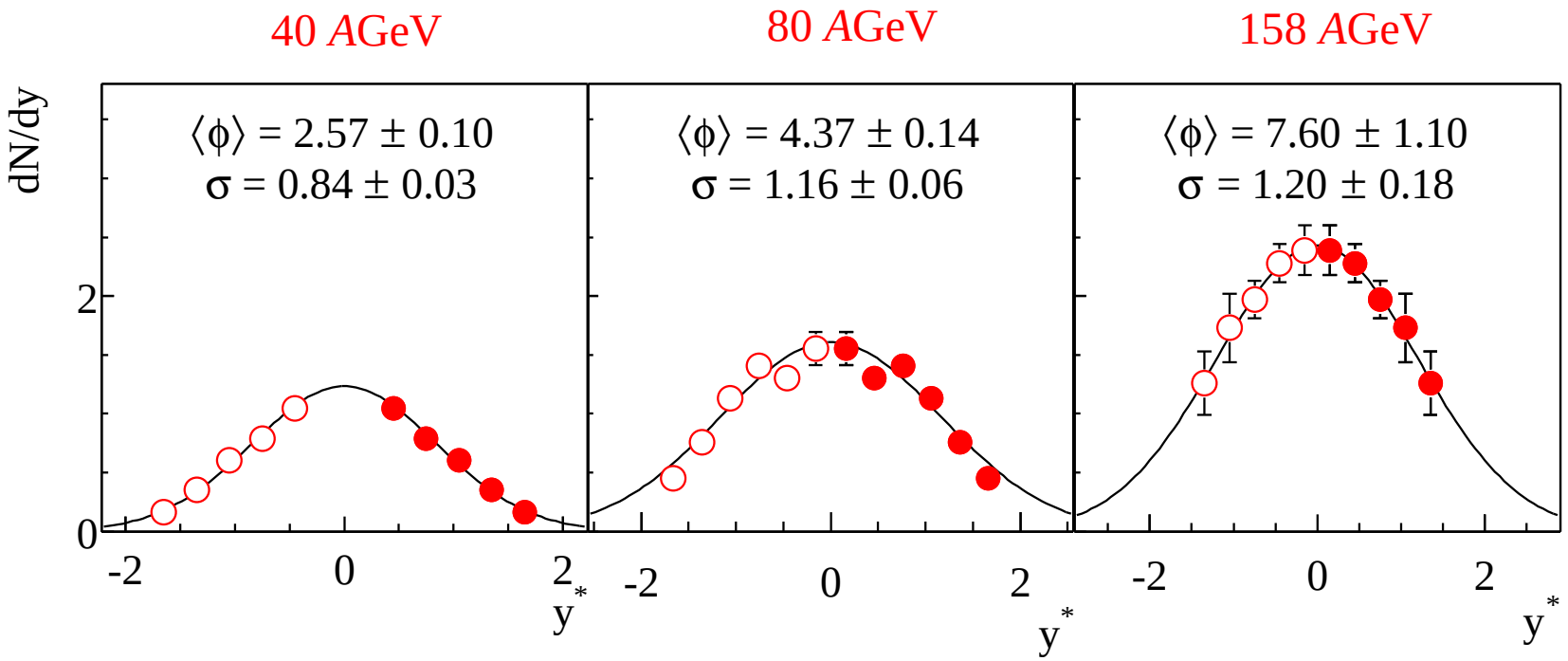
40, 80 *A*GeV 7% central
158 *A*GeV 5% central

fit: sum of two gaussians

final results: nucl−ex /0205002, submitted to Phys. Rev.C

φ rapidity spectra

$\varphi \rightarrow K^+ K^-$

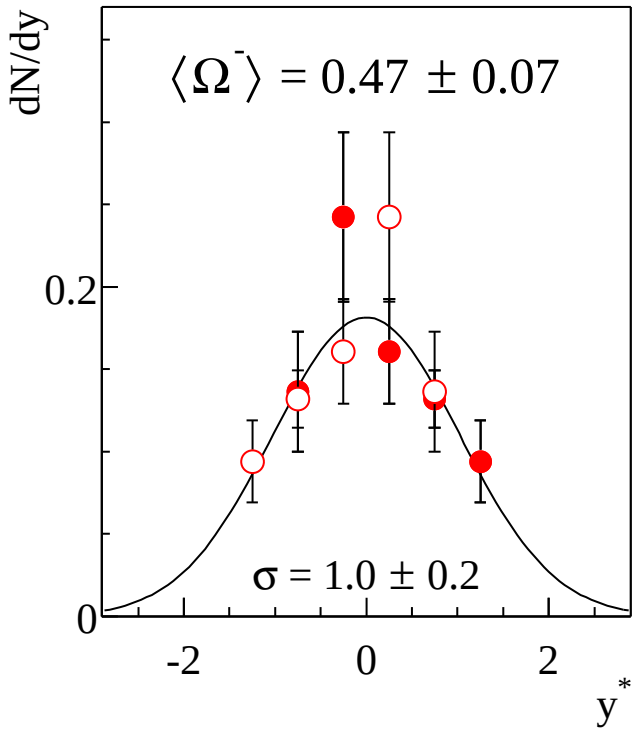


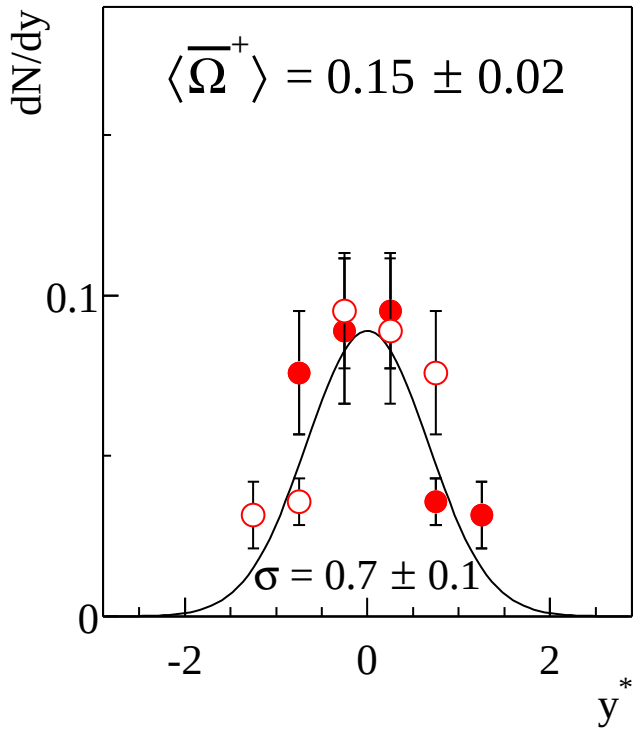
40, 80 *A*GeV 7% central
158 *A*GeV 5% central

New preliminary φ spectra (*y* and m_T) available at 40, 80 *A*GeV

Again: increasing width with energy

Ω rapidity spectra @ 158 *A*GeV





High statistics data sample taken in 2000 (3M events, 20% central)

$$\frac{\bar{\Omega}^{+}}{\Omega^{-}} = 0.32 \pm 0.06$$

ratio < 1 not expected in string models

Bass et al., nucl−th/0204049

Mid−rapidity m_T spectra at 40 *A*GeV

π^-, $K^{+,-}$, Λ, $\bar{\Lambda}$ final results

p, $\bar{p}$, φ, d preliminary results

Radial flow fit:

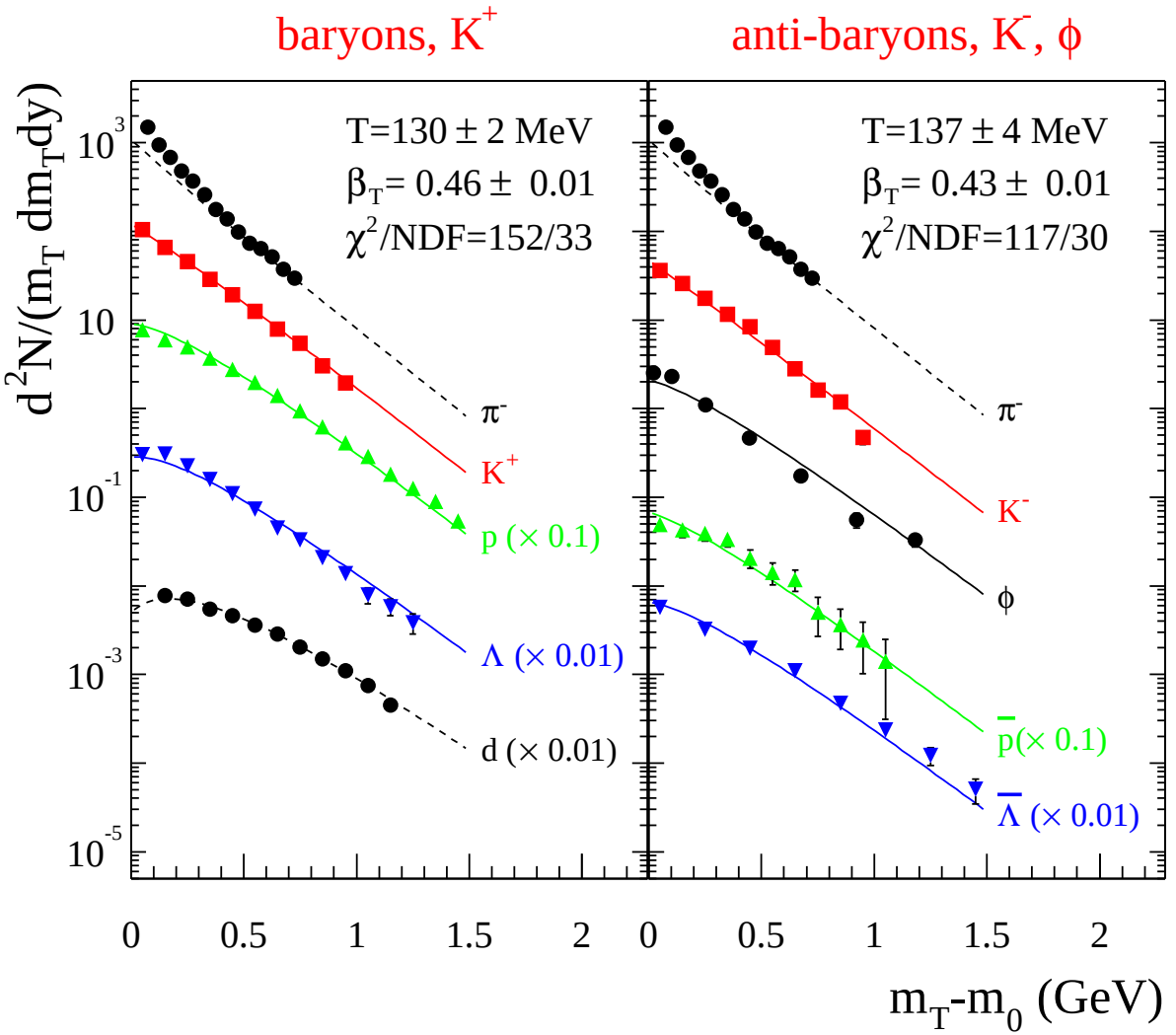
$$\frac{dN}{m_T\,dy\,dm_T} \propto m_T K_1\left(\frac{m_T \cosh\rho}{T}\right) I_0\left(\frac{p_T \sinh\rho}{T}\right)$$

$\rho = \operatorname{atanh}\beta_T$

Schnedermann, Sollfrank, Heinz, Phys. Rev. C 48 (1993), 2462

Baryons and anti−baryons show similar behaviour, deuterons not far off

not included in fit:
π due to resonance contribution,
d due to coalescence formation



7% of inelastic cross section

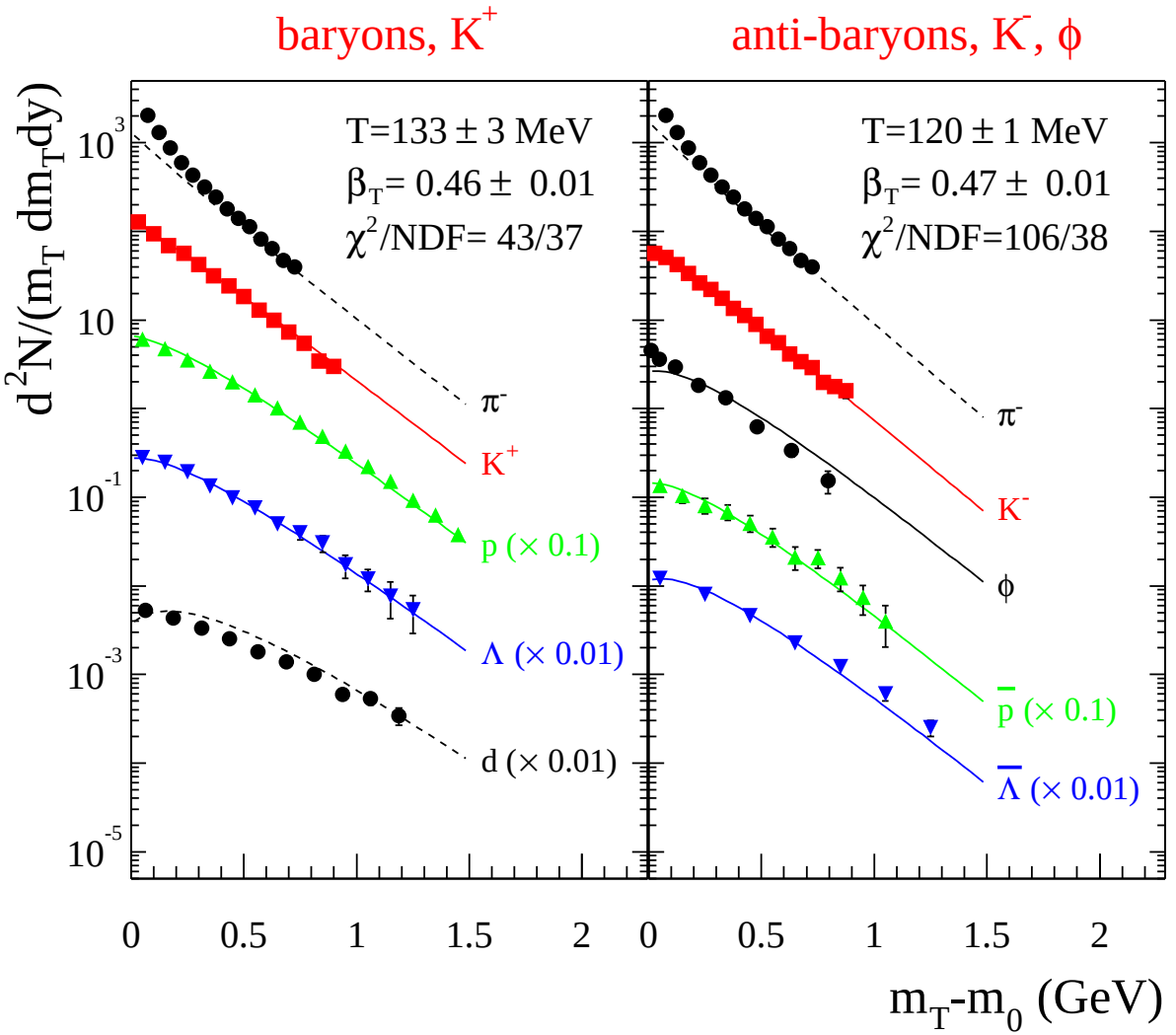
φ: rapidity integrated spectra

Mid−rapidity m_T spectra at 80 *A*GeV

π^-, $K^{+,-}$, Λ, $\bar{\Lambda}$ final results

p, $\bar{p}$, φ, d preliminary results

Fit results similar to 40 *A*GeV



7% of inelastic cross section

φ: rapidity integrated spectra

Mid−rapidity m_T spectra in 158 *A*GeV

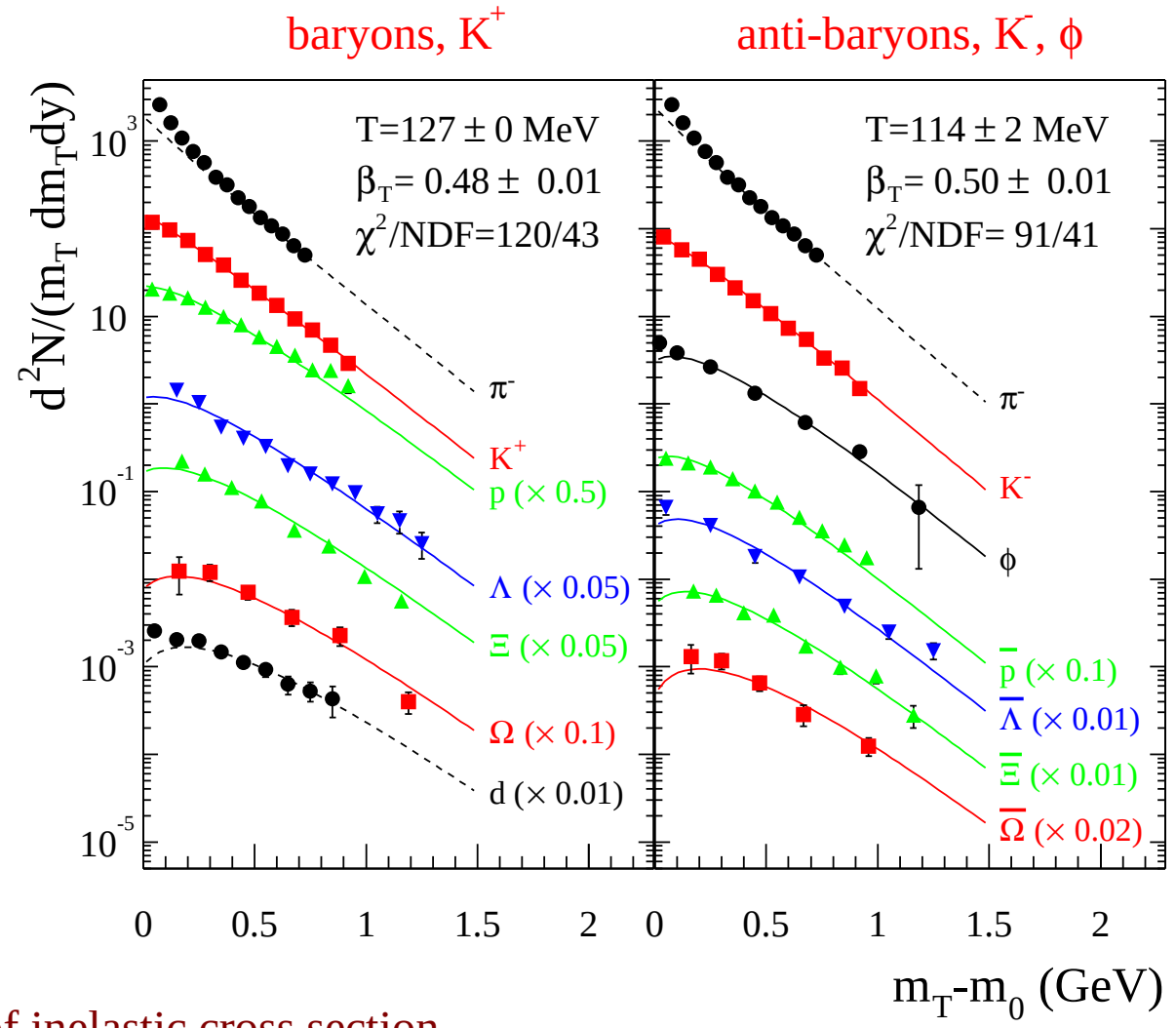
π^-, $K^{+,-}$, Λ, $\bar{\Lambda}$ final results

p, $\bar{p}$, d, Ω preliminary results

Ξ, φ already published

Blast wave fit also describes Ω and Ξ spectra

At all three energies:
T≈120−130 MeV
β_T≈0.4−0.5

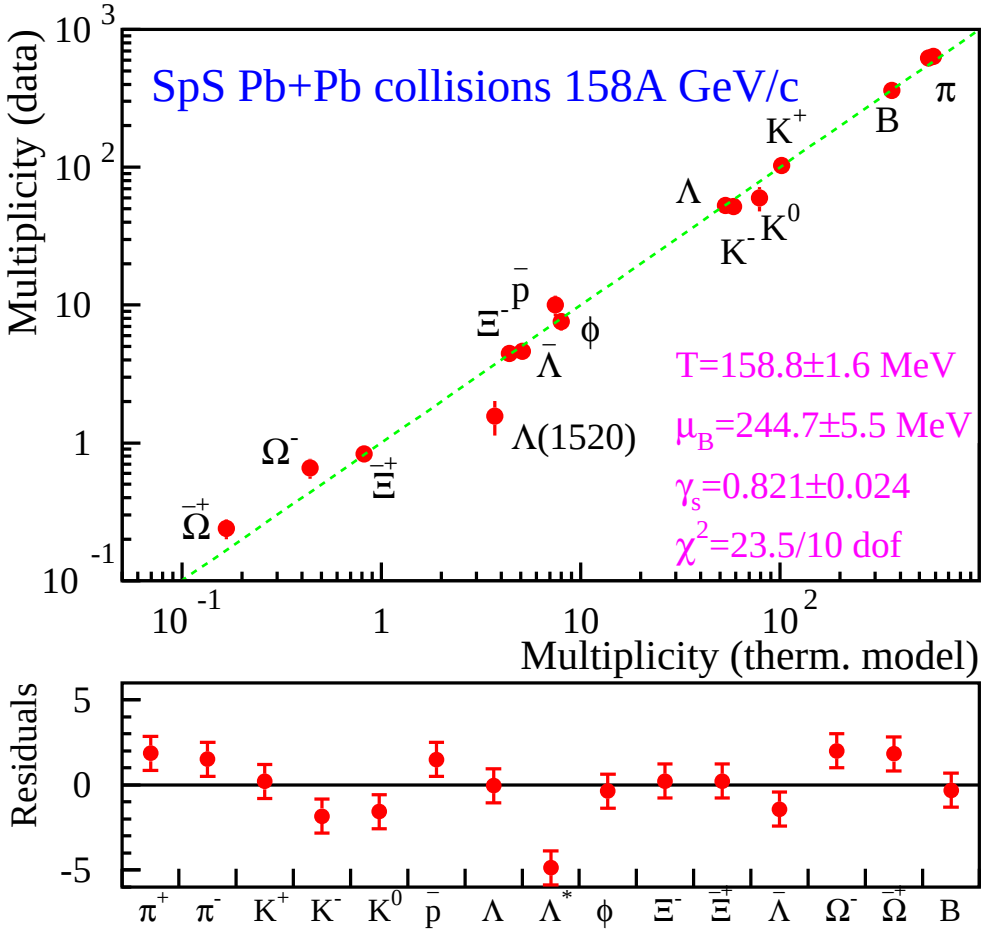


10% of inelastic cross section, except π, *K* (5%) and Ω (20 %)

φ, Ω, Ξ rapidity integrated spectra

Particle yields at 158 *A*GeV

All total yields measured by NA49, including final results for K, π and new preliminary Ω, fitted by F. Becattini



Hadron gas fit with partial strangeness saturation describes multiplicities over several orders of magnitude

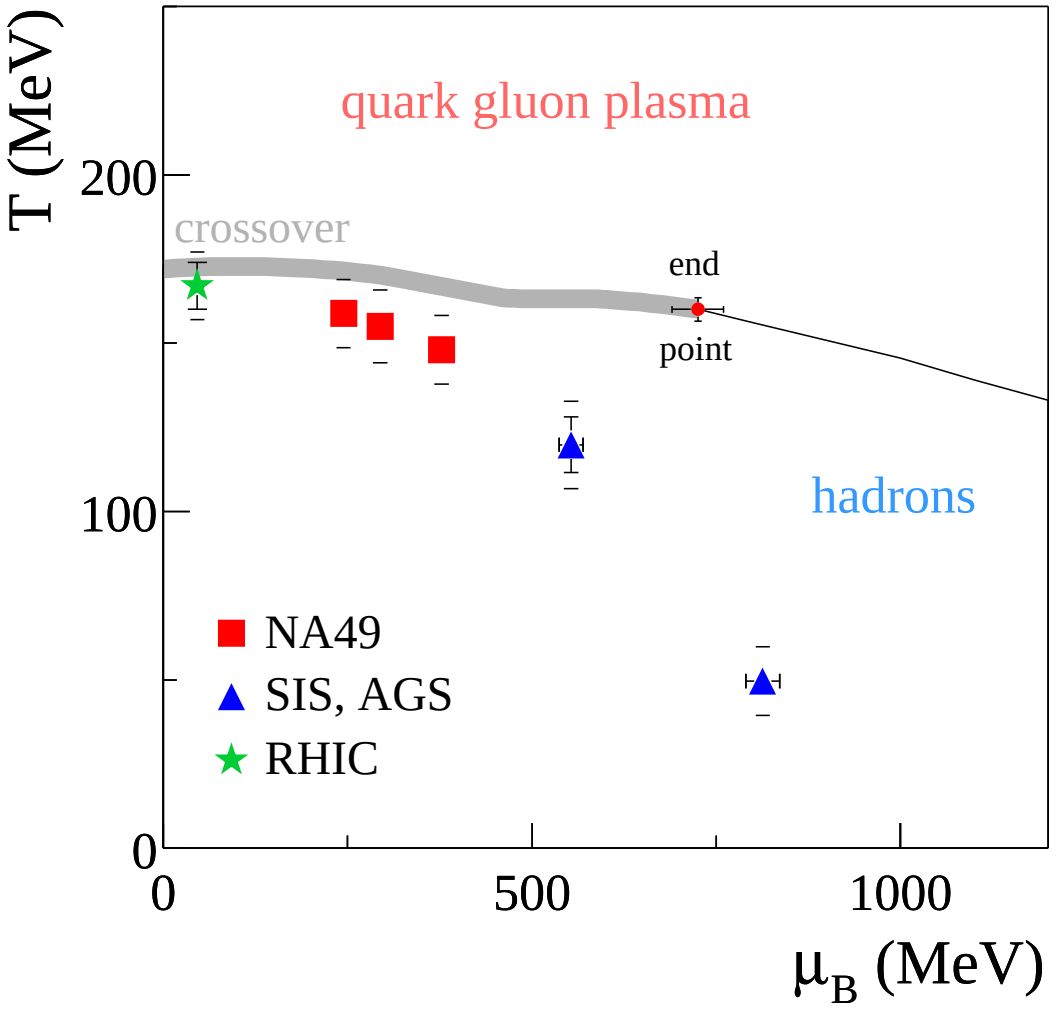
All multiplicities scaled to 5% centrality, using the ratio of pion multiplicities (factor 1.08 for 10%, 1.38 for 20%)

Chemical freeze−out in the T−μ_B plane

40 and 80 *A*GeV yields also fitted

	40 *A*GeV	80 *A*GeV	158 *A*GeV
T (MeV)	148 ± 2	155 ± 4	159 ± 2
μ_B (MeV)	377 ± 7	294 ± 15	244.5 ± 4.7
γ_S	0.75 ± 0.02	0.72 ± 0.03	0.82 ± 0.02
χ^2/NDF	$14.8/4$	$10.4/4$	$23.5\ /\ 11$

fits by F. Becattini



- Freeze−out parameters on a (relatively) smooth curve
- Curve approaches phase boundary in the SPS energy range
- Even at RHIC, the parameters do not enter QGP−phase

Cross−over line from Z. Fodor, S.D. Katz hep−lat/0204029

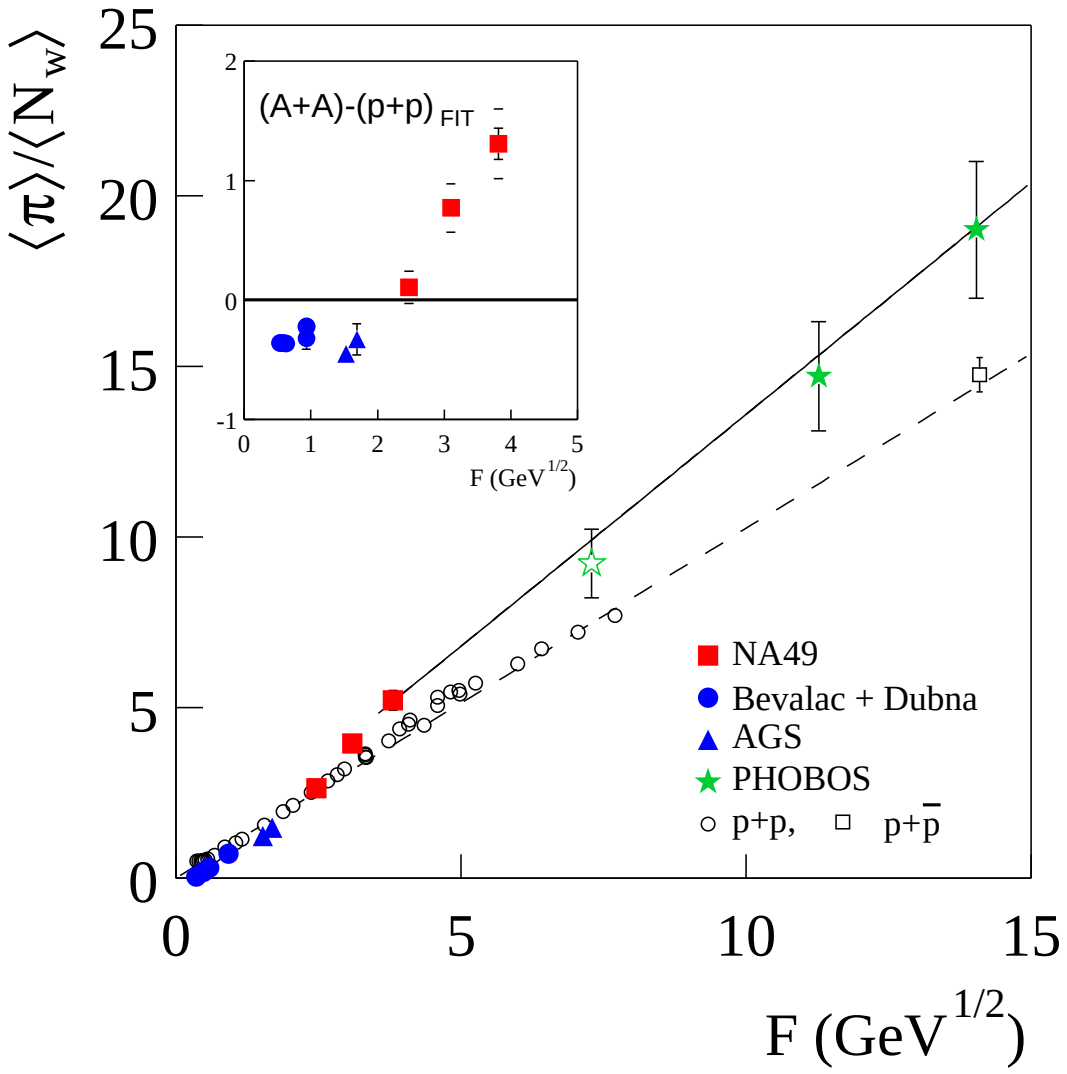
Energy dependence of pion production

Change from pion suppression in AA compared to pp at low energy to enhancement at high energy

Can be interpreted as an increase of the number of degrees of freedom

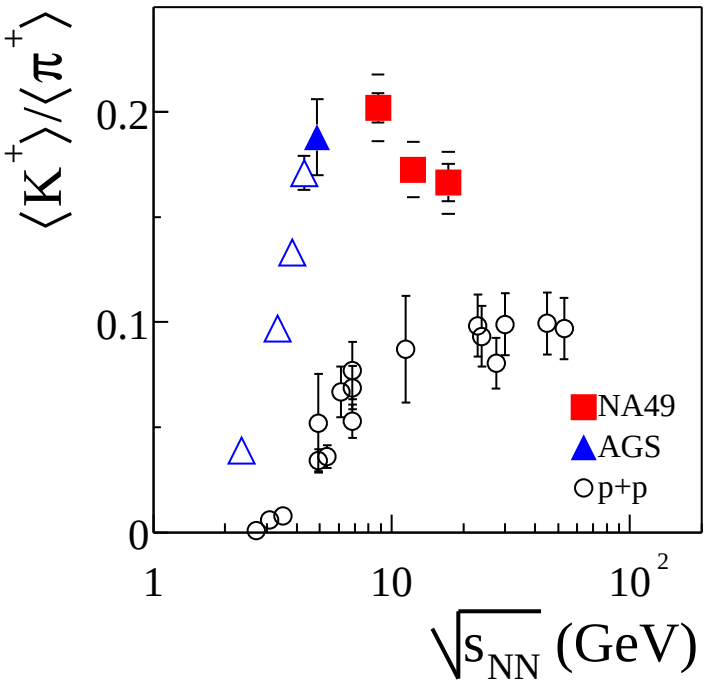
$$\frac{\langle \pi \rangle}{\langle N_w \rangle} \propto g^{1/4} F$$

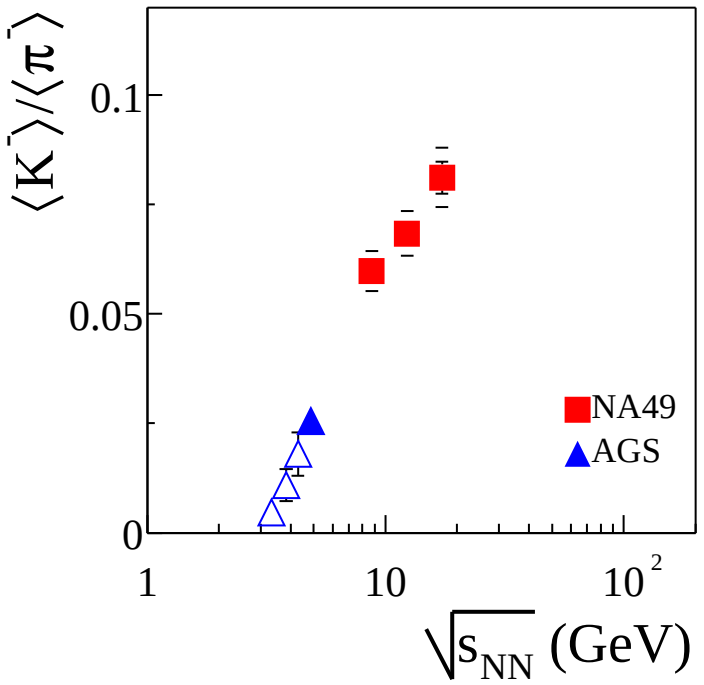
M.Gazdzicki, M.I. Gorenstein,
Acta Phys. Pol. B 9, 2705



$$F \stackrel{\text{def}}{=} \left(\sqrt{s_{NN}} - 2m_N\right)^{3/4} / \sqrt{s_{NN}}^{1/4}$$

Energy dependence of kaon production





K^+ shows maximum at 40 *A*GeV

Monotonic increase for K^-

Energy dependence of strangeness production

$\bar{s}$ carried by

$K^+, K^0, \bar{\Lambda}$ (incl. $\bar{\Sigma}^0$),

$\bar{\Sigma}^{\pm}, \bar{\Xi}^{0,+}, \bar{\Omega}^+$

$\langle K^0 \rangle \approx \langle K^+ \rangle, \langle \bar{K}^0 \rangle \approx \langle K^- \rangle$

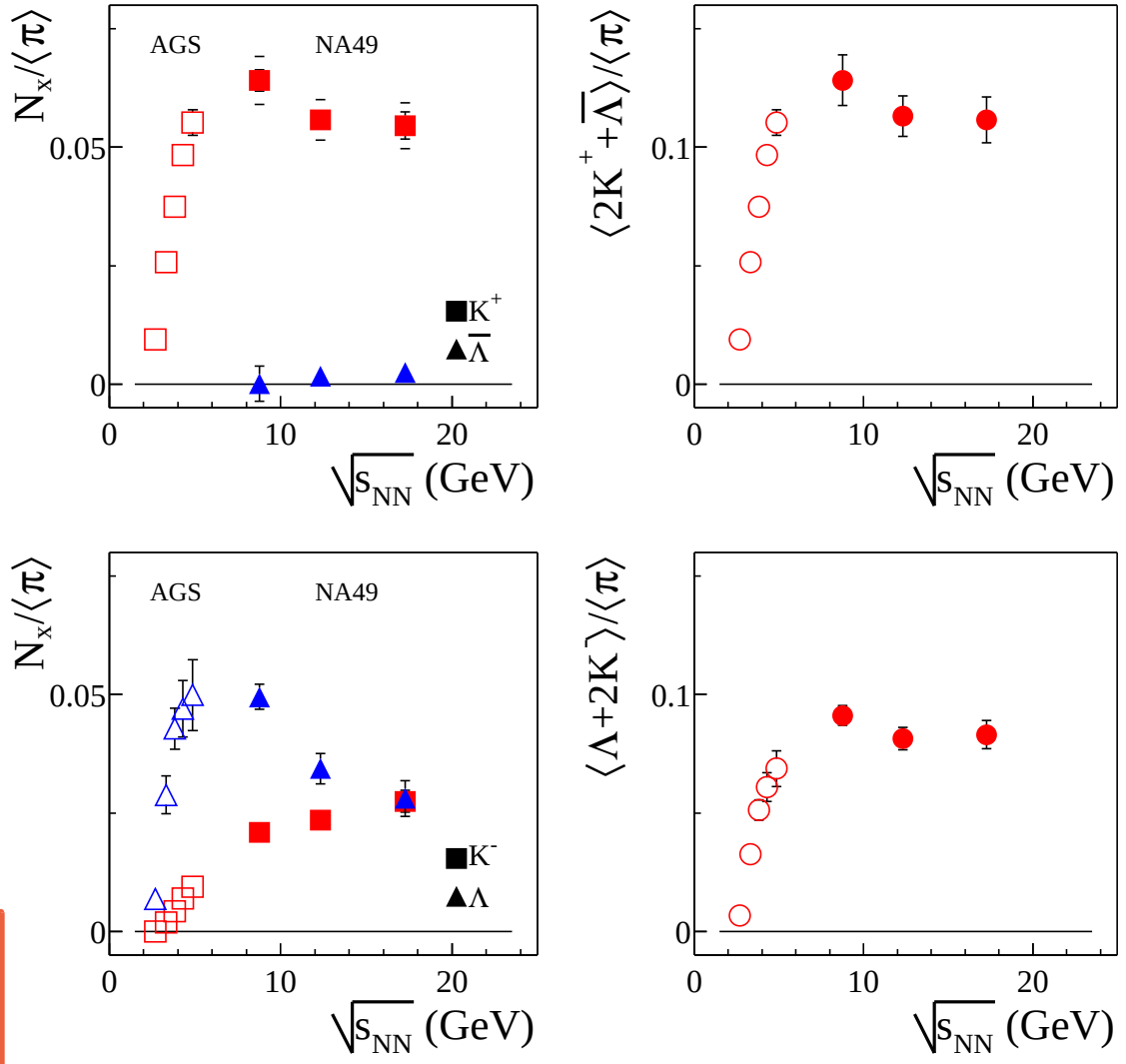
by isospin symmetry

s carried by

$K^-, \bar{K}^0, \Lambda$ (incl. Σ^0),

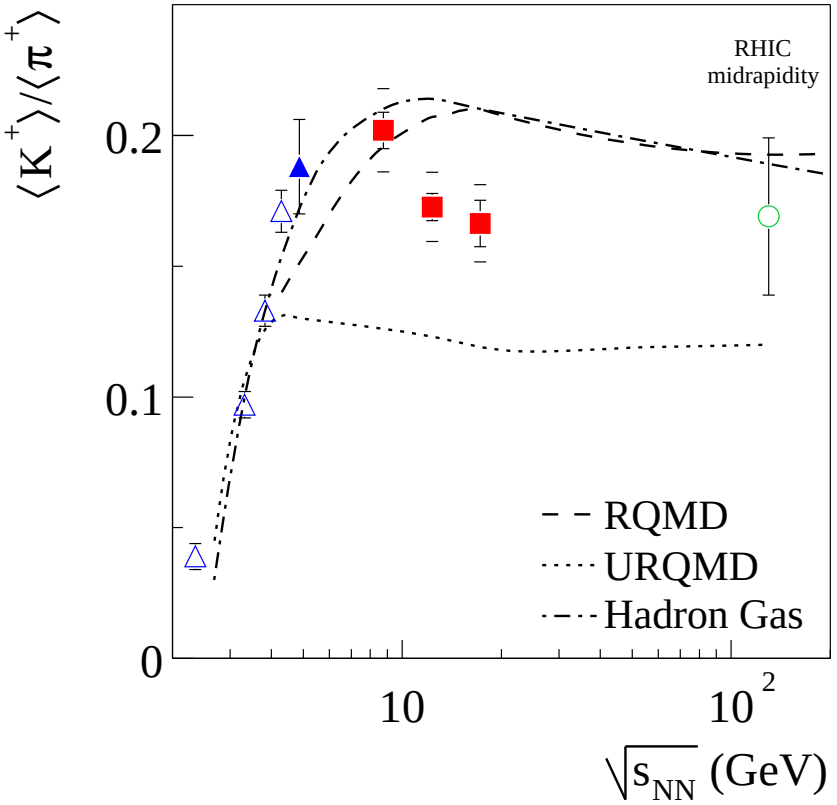
$\Sigma^{\pm}, \Xi^{0,-}, \Omega^-$

Both s and $\bar{s}$ show maximum around 40 *A*GeV

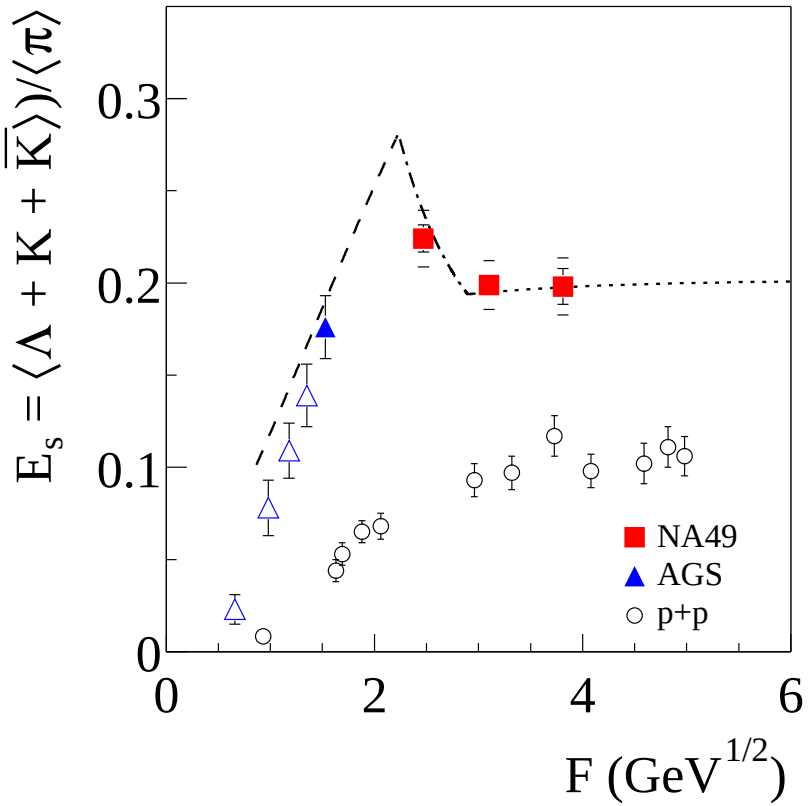


Model comparisons

Hadronic models



Model with phase transition



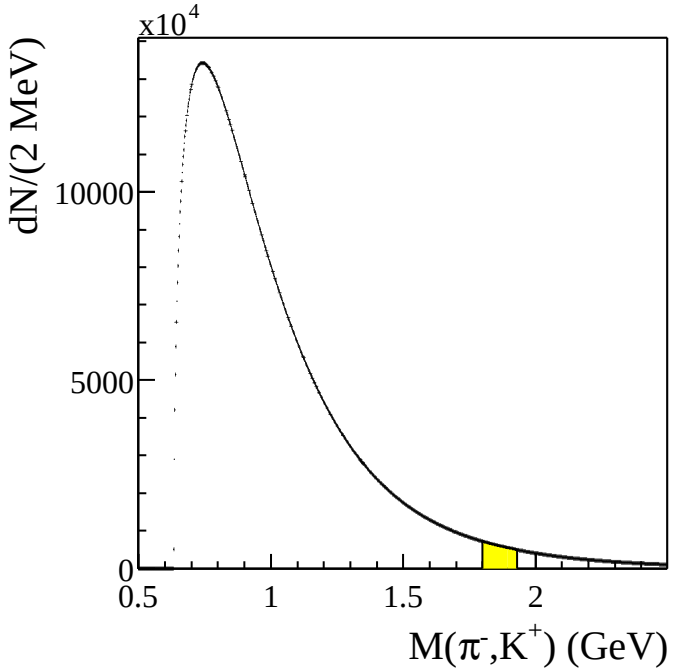
RQMD: Wang, Liu, Sorge, Xu, Yang, Phys. Rev. C61, 064904
UrQMD: Sorge, Stöcker, Greiner, Nucl. Phys. A498, 567c
Hadron Gas: Braun−Munzinger, Oeschler, Cleymans, Redlich, Nucl. Phys. A697, 902

M.Gazdzicki, M.I. Gorenstein,Acta Phys. Pol. B 9, 2705

A (possible) sharp maximum can only be accommodated in a model with a phase transition

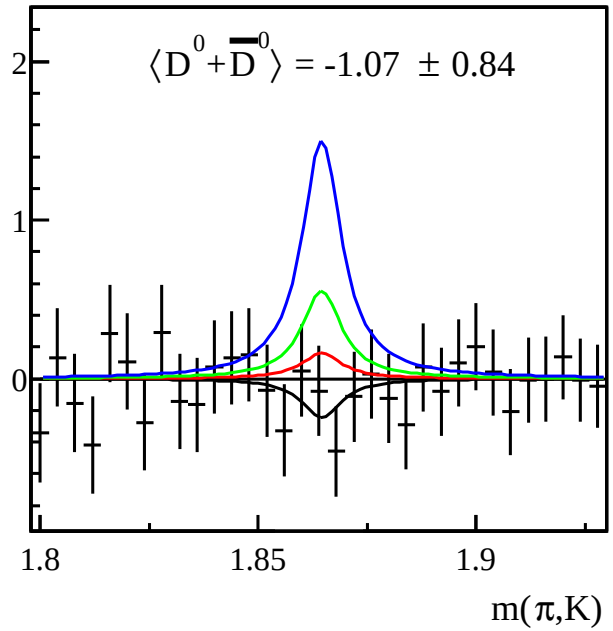
Open charm limit

total invariant mass distribution



background: polynomial fit

after background subtraction



NA50: 3x pQCD Eur. Phys J C 14, 443

ALCOR P Levai et al., nucl−th/0011023

equilibrium QGP (T=265 MeV)

Gazdzicki and Markert, hep−ph/9904441

All 158 *A*GeV data used:
800k 10% central +
3M 20% central

No early equilibration of charm in QGP

Conclusions

Energy dependence:

- Longitudinal flow different for Λ, K^+ (Ω) than for $\overline{\Lambda}$, K^- ($\overline{\Omega}$)
- Radial flow similar for particles and anti−particles
- Radial flow does not change significantly in SPS energy range

  (T=120−130 MeV, β_T=0.4−0.5)
- Chemical freeze−out parameters approach phase boundary at SPS
- Change from pion suppression to enhancement around 40 *A*GeV

Is there a (sharp) maximum in the strangeness yield around 40 *A*GeV?

Run at 20, 30 *A*GeV foreseen this year

High statistics at 158 *A*GeV:

- $\overline{\Omega}/\Omega \approx 0.3$
- Open charm upper limit does not exclude factor 3 enhancement

  (observed in dimuons by NA50)

The NA49 collaboration

S.V. Afanasiev,T. Anticic, B. Baatar, D. Barna, J. Bartke, R.A. Barton,
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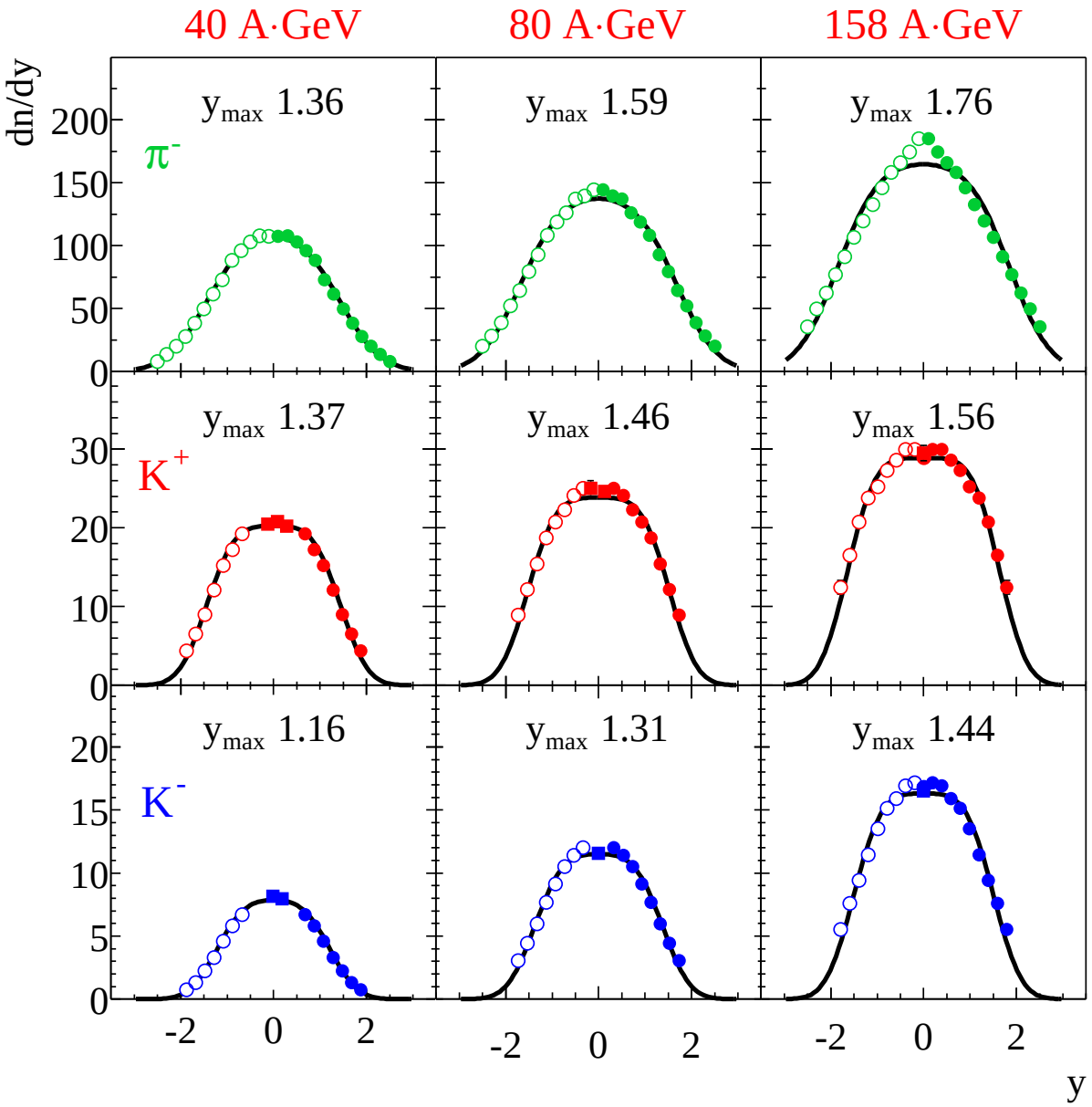
Longitudinal flow fit

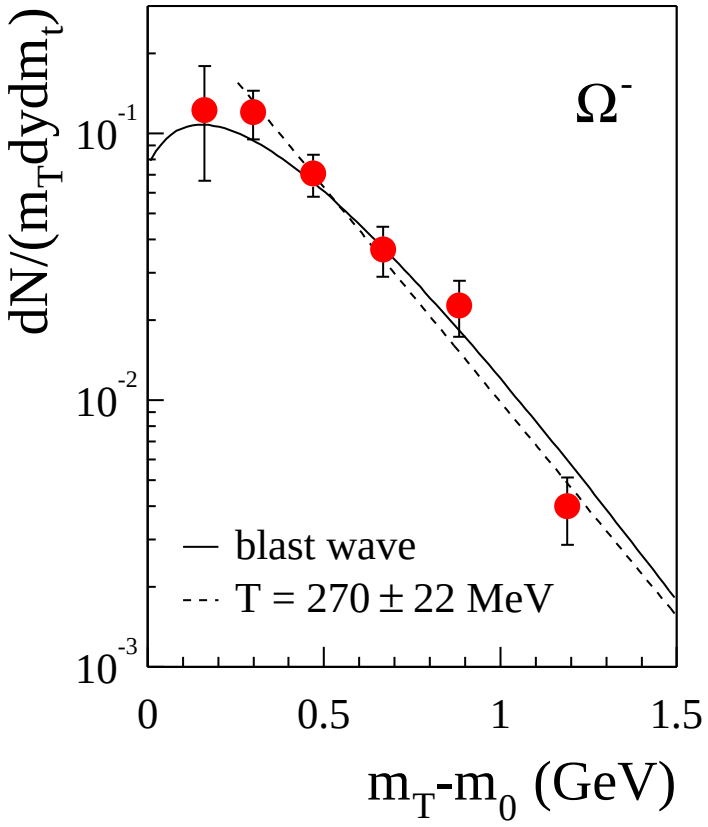


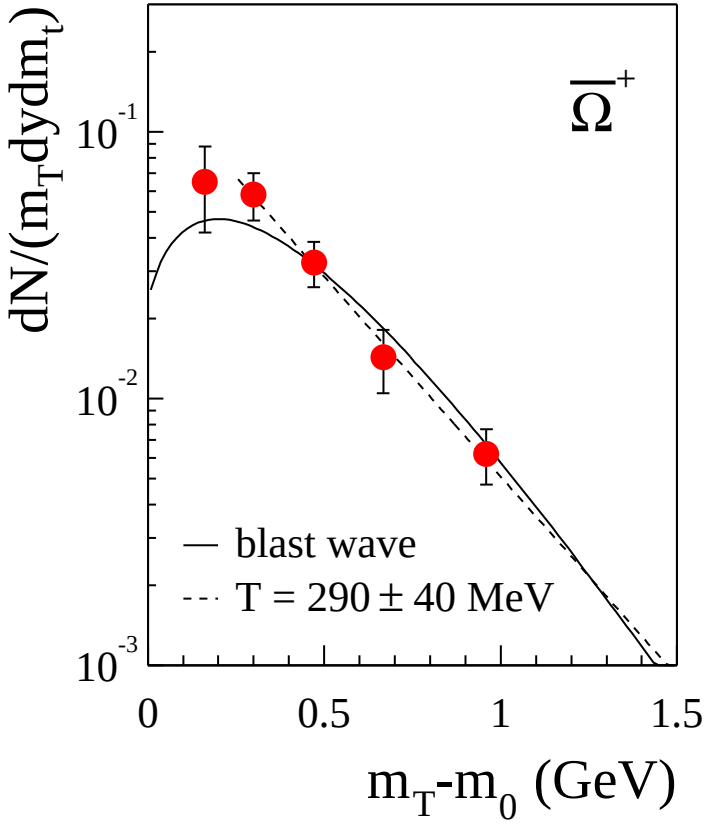
$$\int_{-y_{max}}^{y_{max}} dy_b \frac{dN_{th}}{dy}\left(y - y_b\right)$$

T=120 MeV used
(result only weakly dependent on this value)

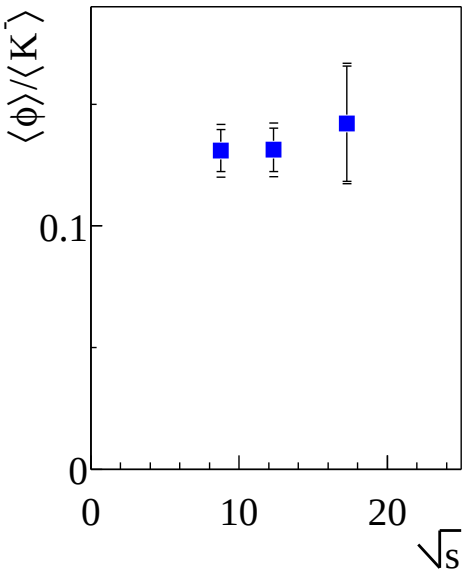
Reasonable description of data, but no common y_{max} for kaons and pions

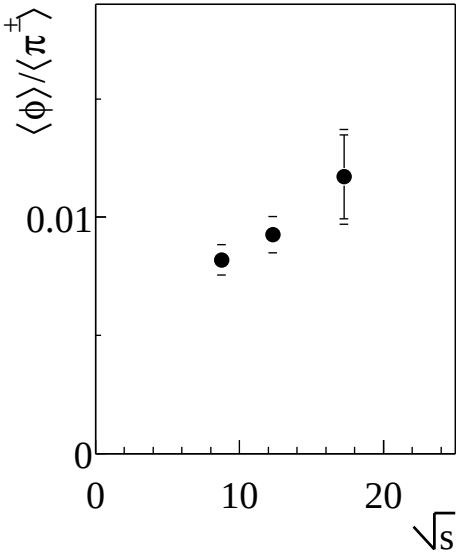
Ω m_T spectra





φ multiplicity





φ/π increases,
φ/K⁻ constant