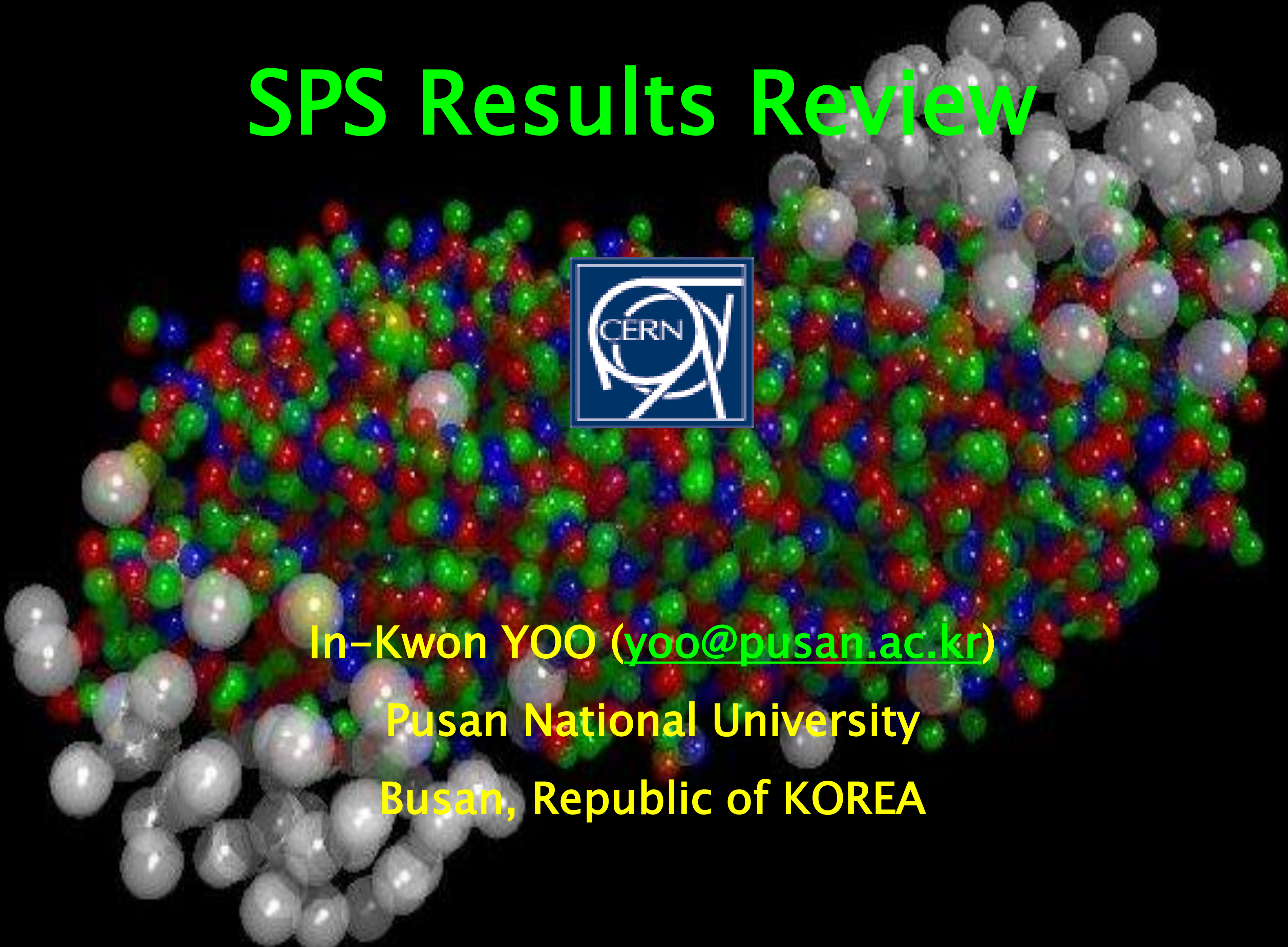
SPS Results Review



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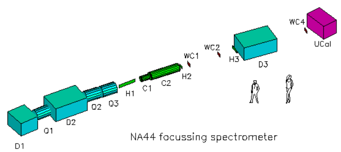
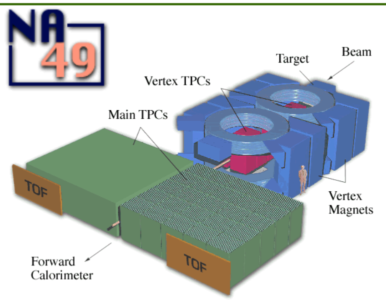
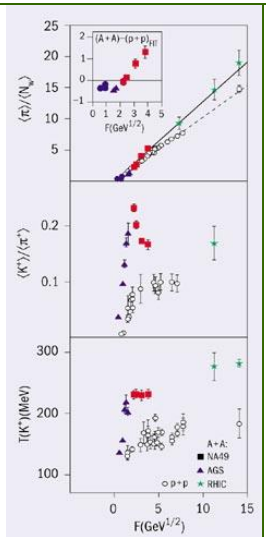
Experiments @ SPS.CERN

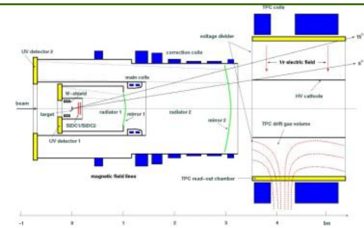


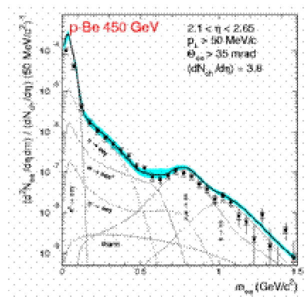
NA44 : The Focussing Spectrometer for one and two particles



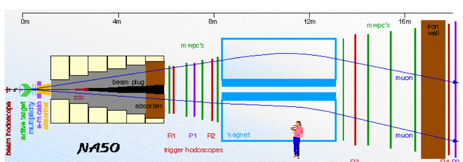


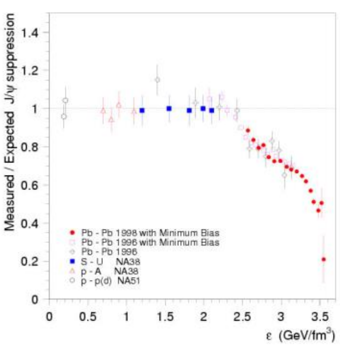
Large Acceptance Hadron Spectrometer



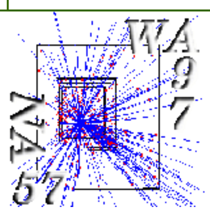


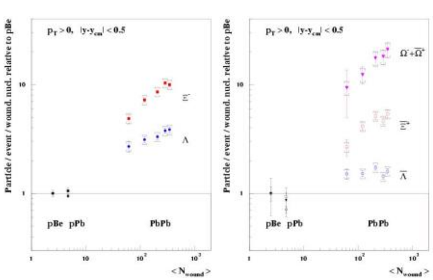
NA45 (CERES) : Study of Electron Pair Production in Hadron and Nuclear Collisions



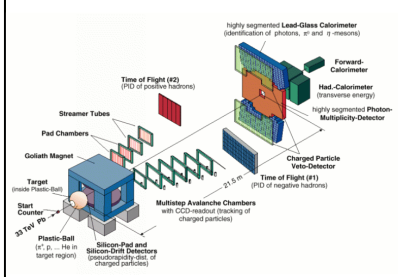


NA50 : Study of Muon Pairs and Vector Mesons



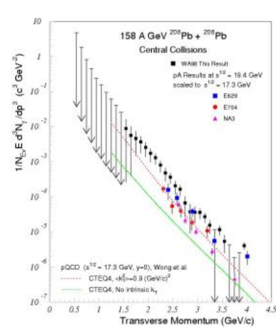


Study of Strange and Multistrange Particles



WA98 :

Direct photons

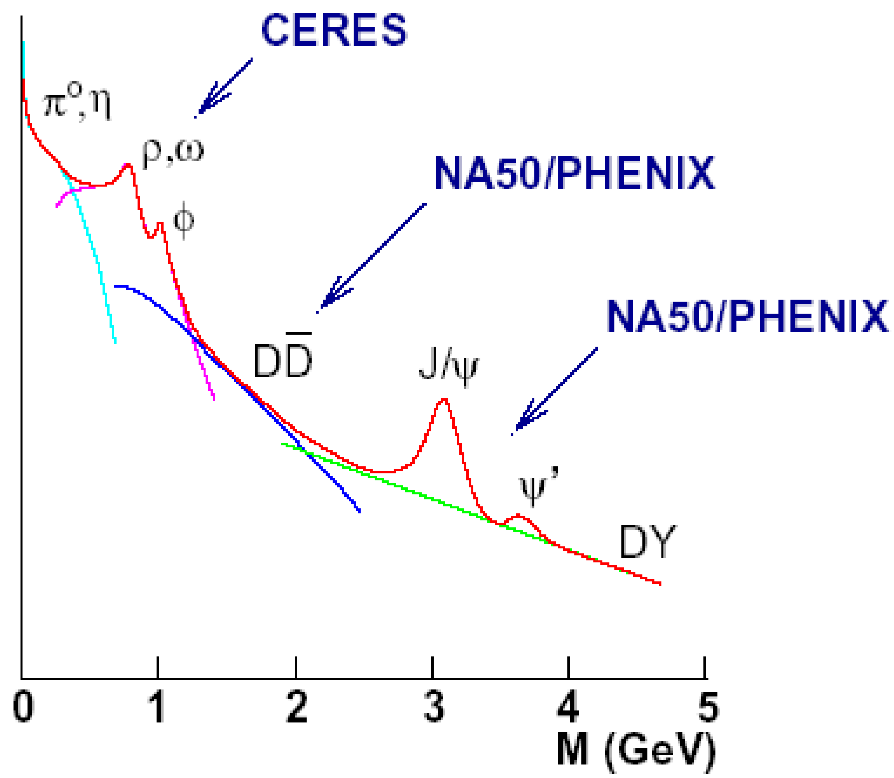


NA45 (CERES) @ SPS.CERN

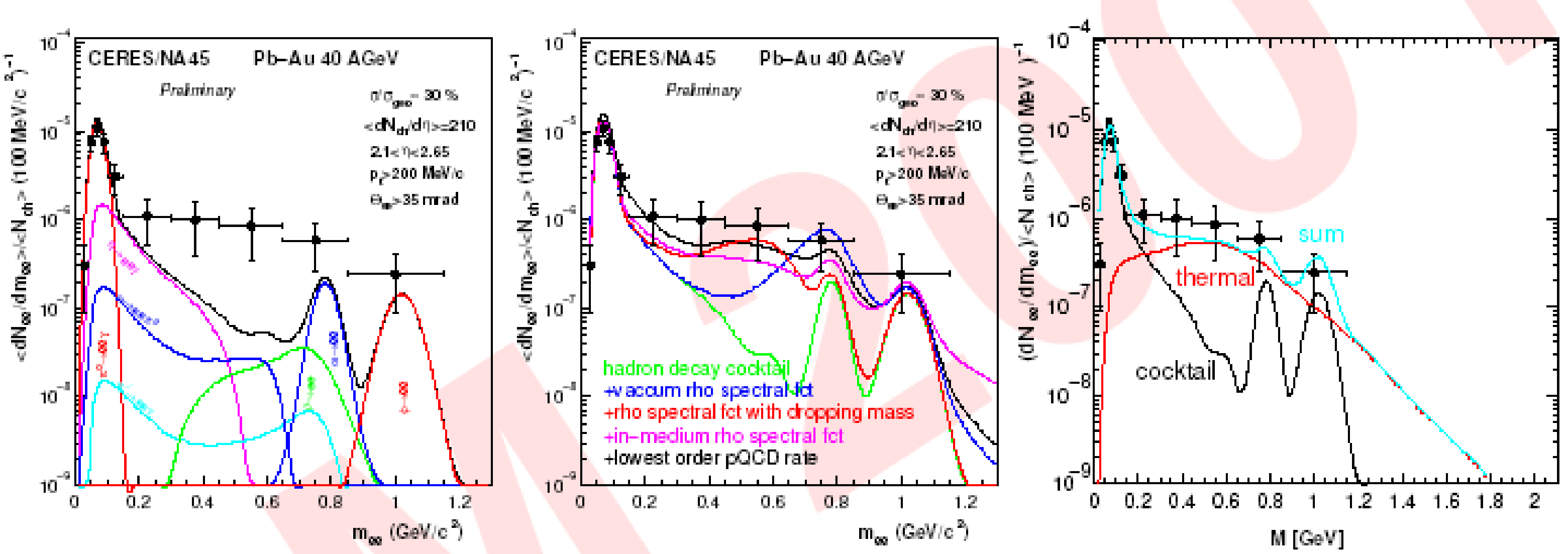
Dileptons @ SPS/RHIC

Goal

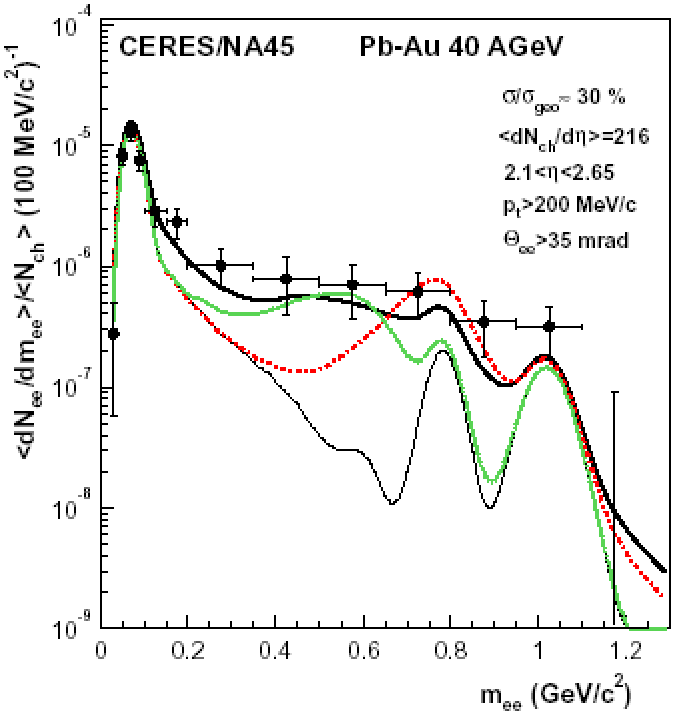
- Low mass enhancement
- due to strong in-medium modifications of ρ meson ↔ link to chiral symmetry restoration ?

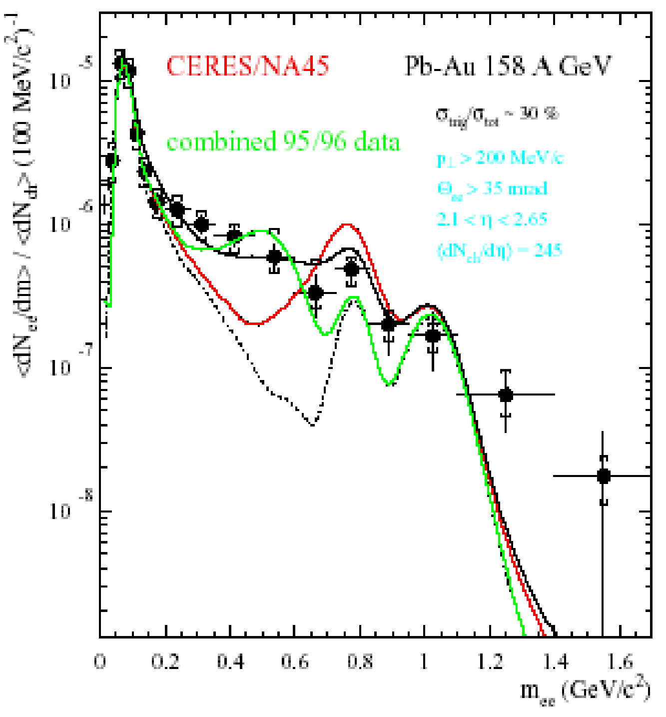


NA45 (CERES) @ SPS.CERN

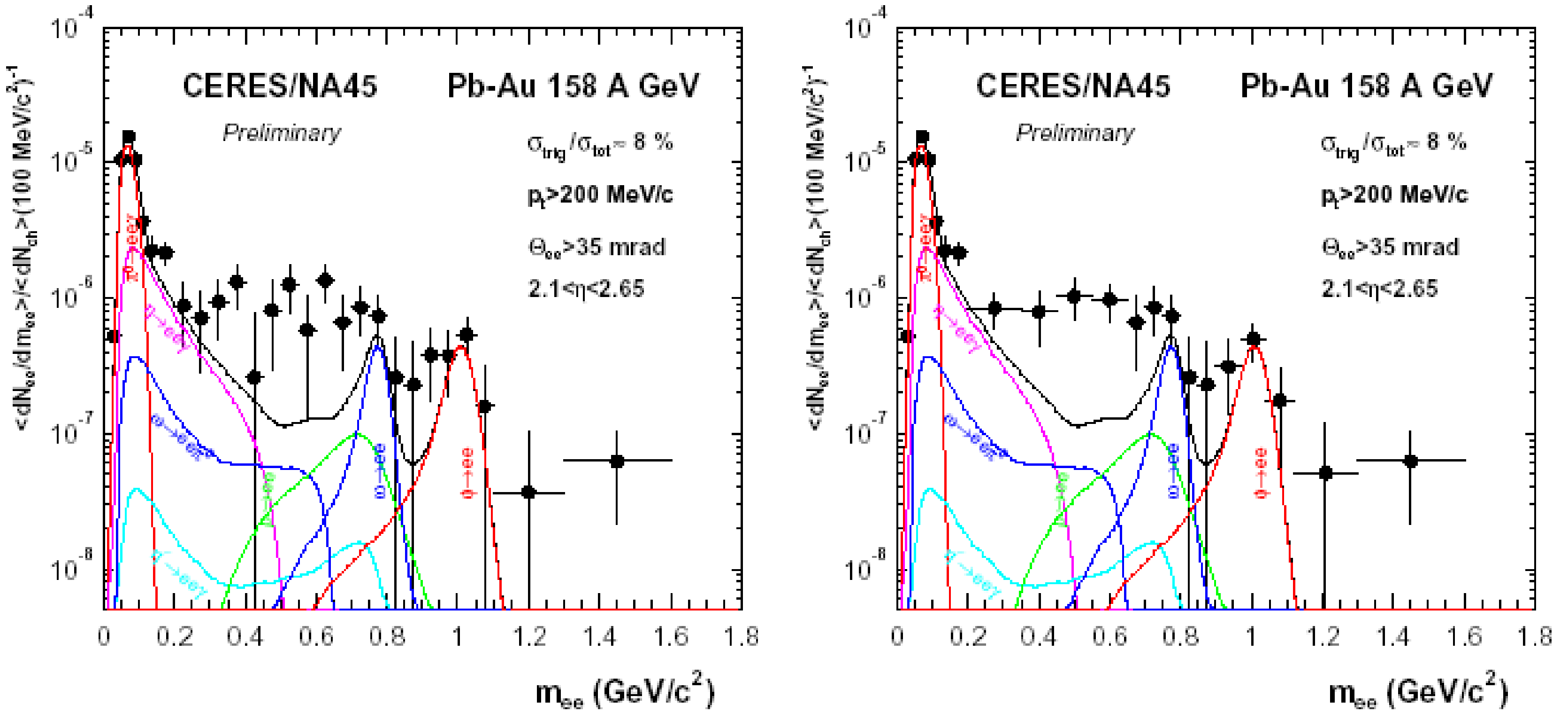


NA45 (CERES) @ SPS.CERN

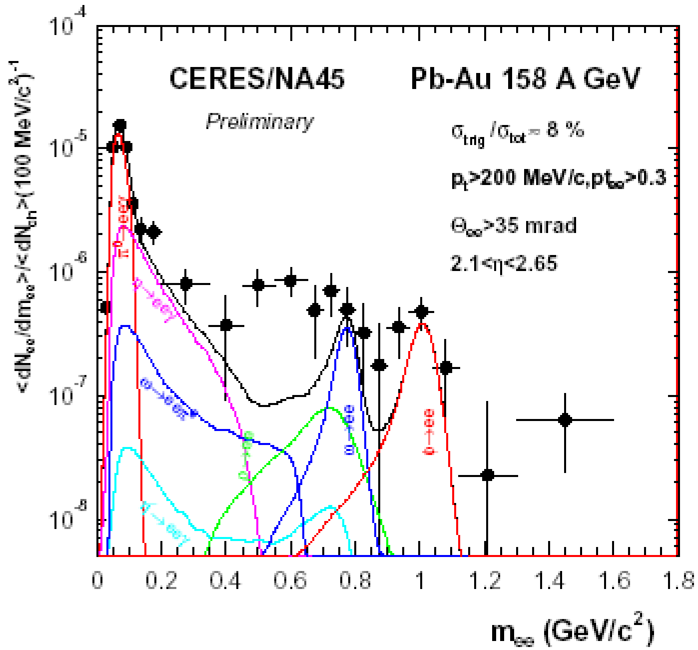




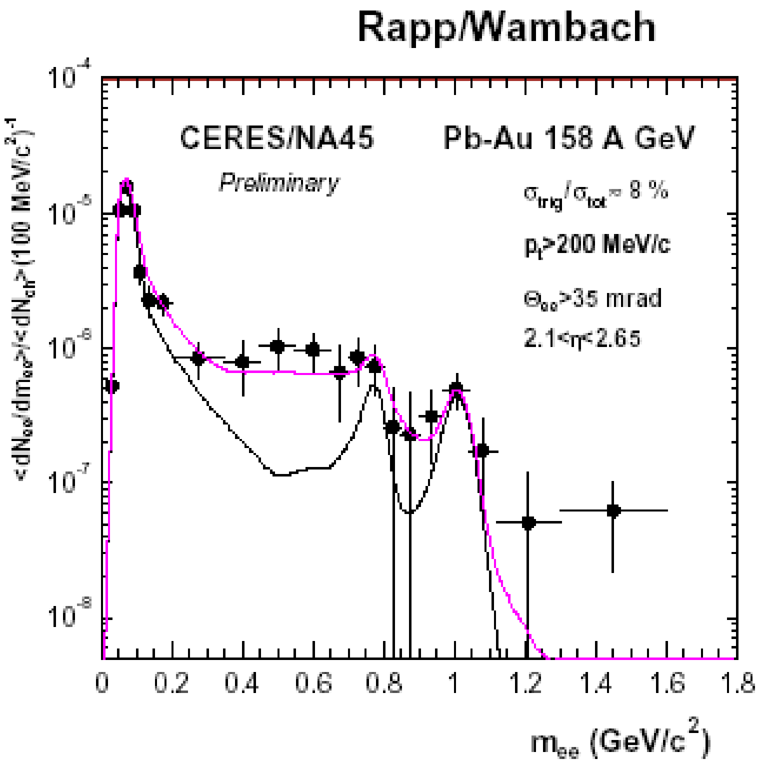
NA45 (CERES) @ SPS.CERN

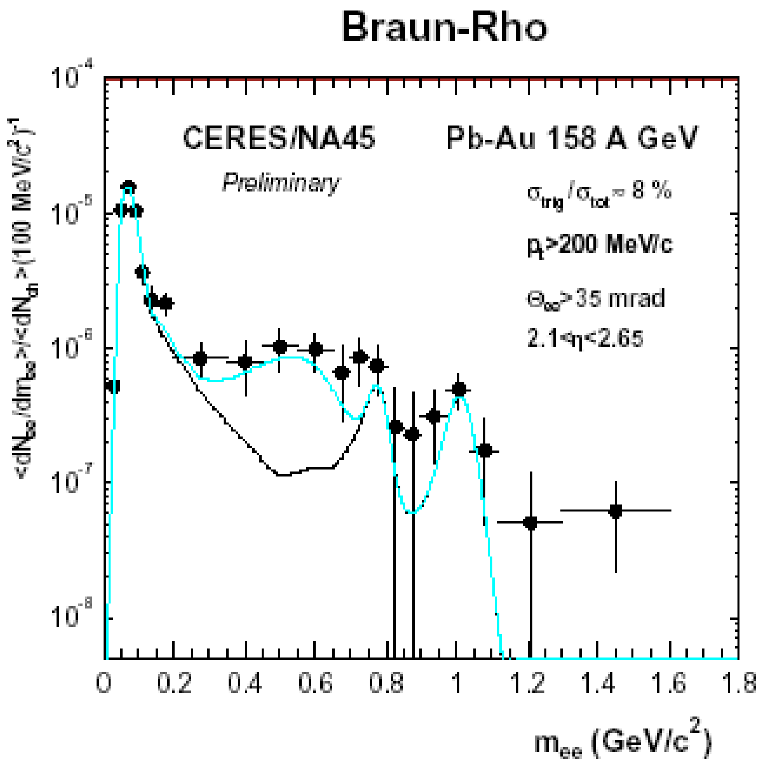


NA45 (CERES) @ SPS.CERN



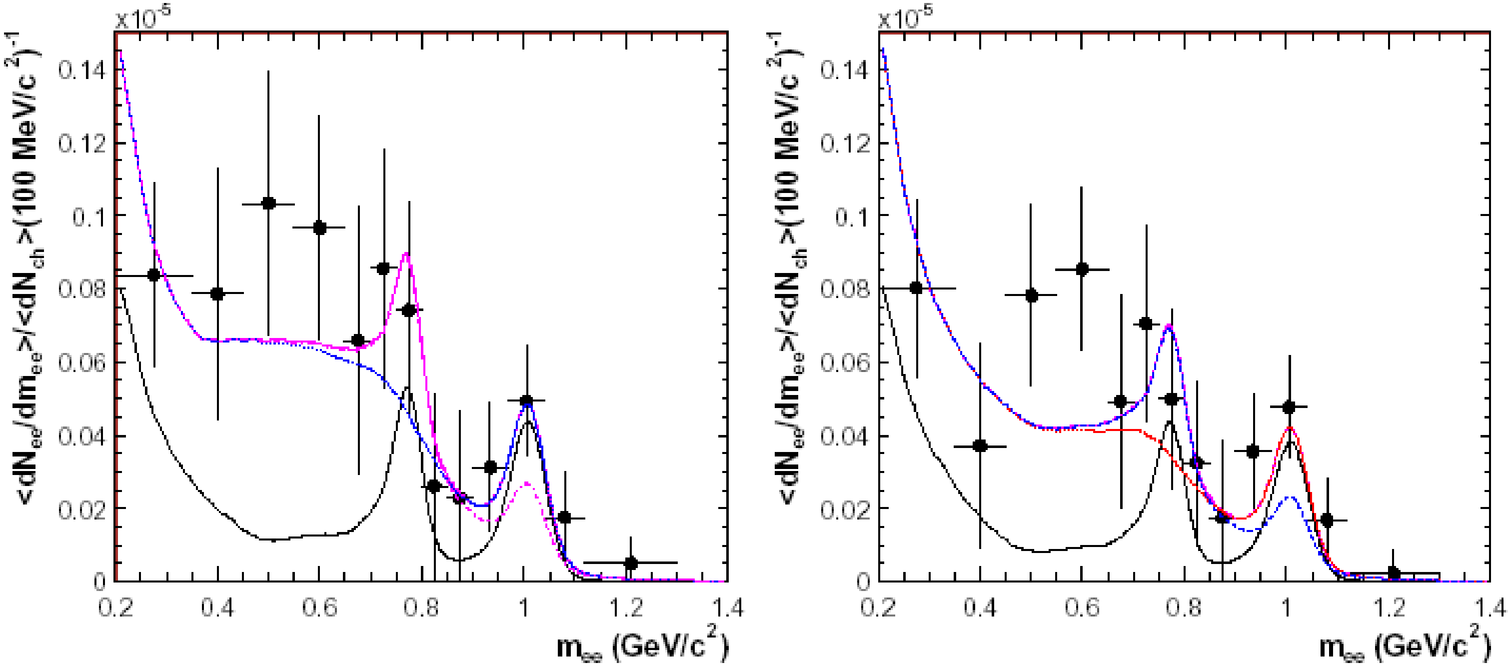
NA45 (CERES) @ SPS.CERN





NA45 (CERES) @ SPS.CERN

ϕ meson yields



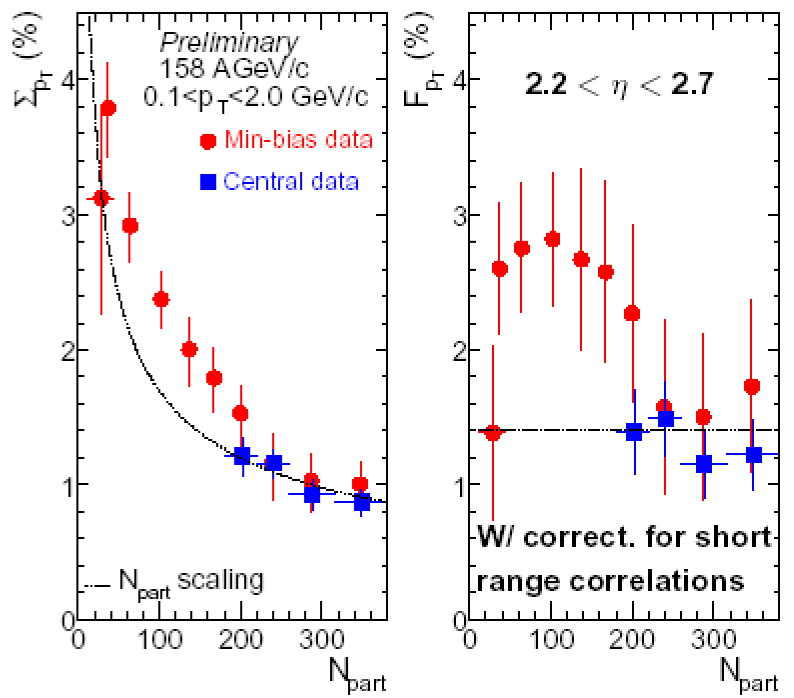
		p_t>0.2 GeV	+p_t^{ee}>0.3GeV
thermal ϕ yield	$N(\phi^{exp})/N(\phi^{model})$	**1.2±0.4**	**1.3±0.4**
ϕ reduced to 50%	$N(\phi^{exp})/N(\phi^{model})$	**2.6±0.8**	**2.9±0.8**

NA45 (CERES) @ SPS.CERN

Event-by-event mean p_T fluctuations at 158 AGeV/c

Talk of H. Sako in parallel session on Friday afternoon

- Centrality dependence of fluctuations in new analysis of minimum bias data
- non-monotonic dependence and enhancement over p+p extrapolation in semi-central events observed



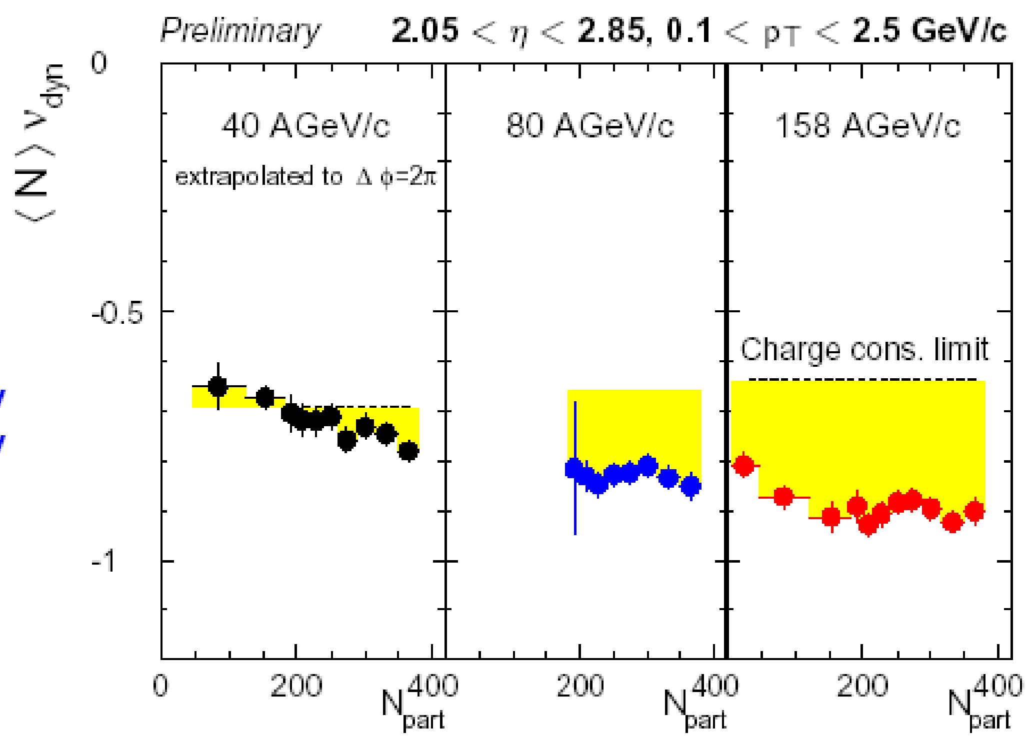
NA45 (CERES) @ SPS.CERN

Event-by-event net-charge fluctuations at 40, 80, and 158 AGeV/c

Talk of H. Sako in parallel session on Friday afternoon

Centrality and collision energy dependence

- smaller fluctuations than charge conservation limit
- decrease in centrality and collision energy observed



NA57 / WA97 @ SPS.CERN

NA57 studies the production of strange and multi-strange baryons in heavy ion interactions as a function of

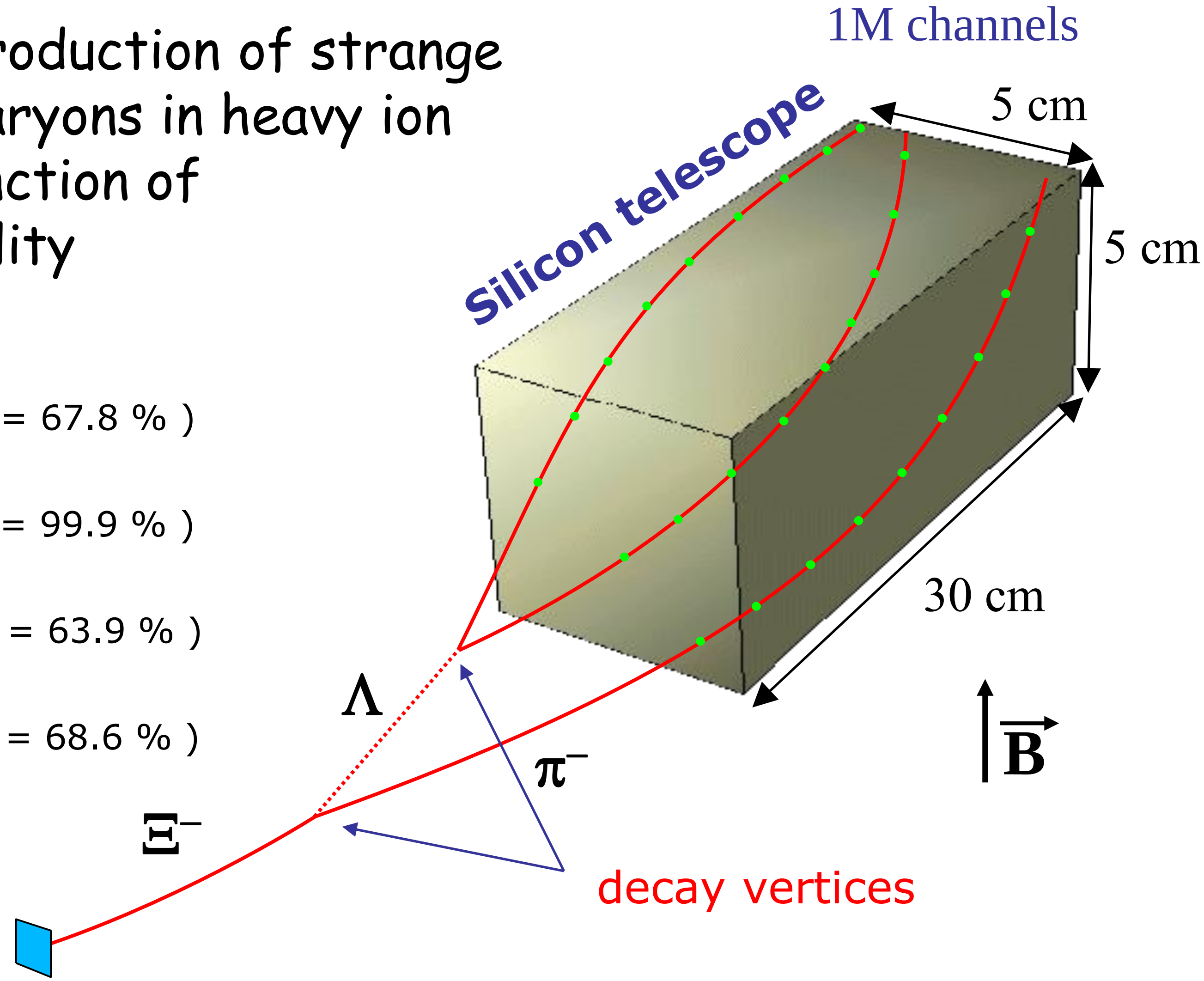
- collision centrality
- collision energy

$\Omega^- \rightarrow \Lambda + K^-$ (BR = 67.8 %)

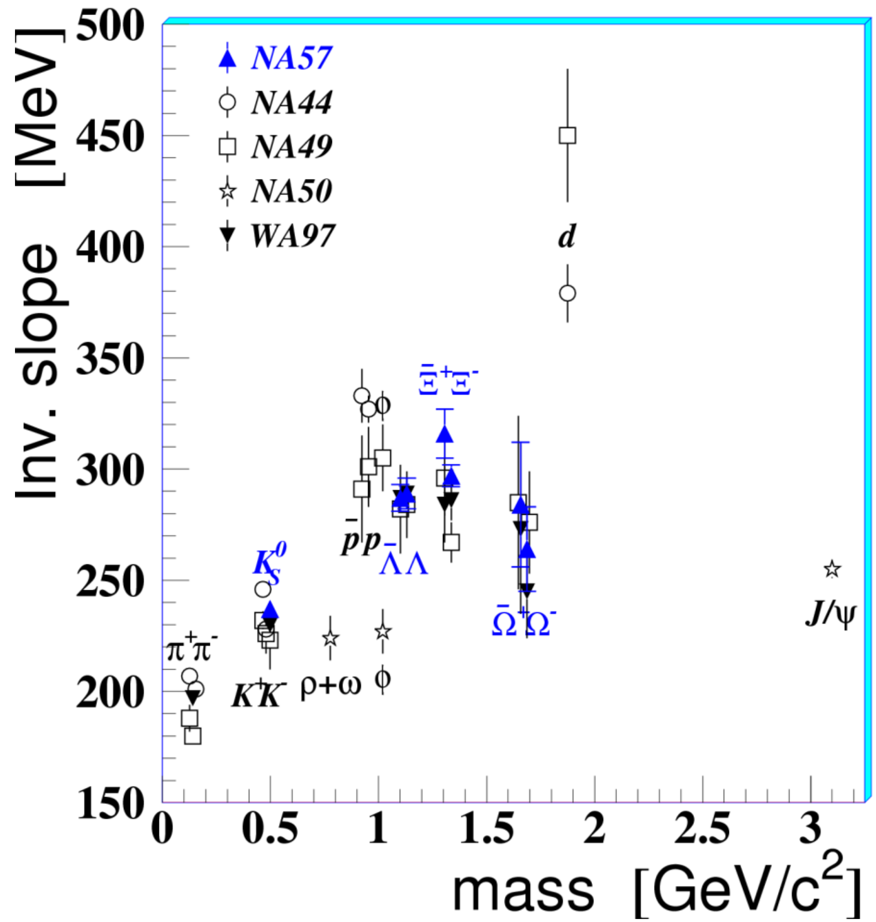
$\Xi^- \rightarrow \Lambda + \pi^-$ (BR = 99.9 %)

$\Lambda \rightarrow \pi^- + p$ (BR = 63.9 %)

$K^0_S \rightarrow \pi^+ + \pi^-$ (BR = 68.6 %)



Transverse mass spectra in Pb-Pb at 160 A GeV

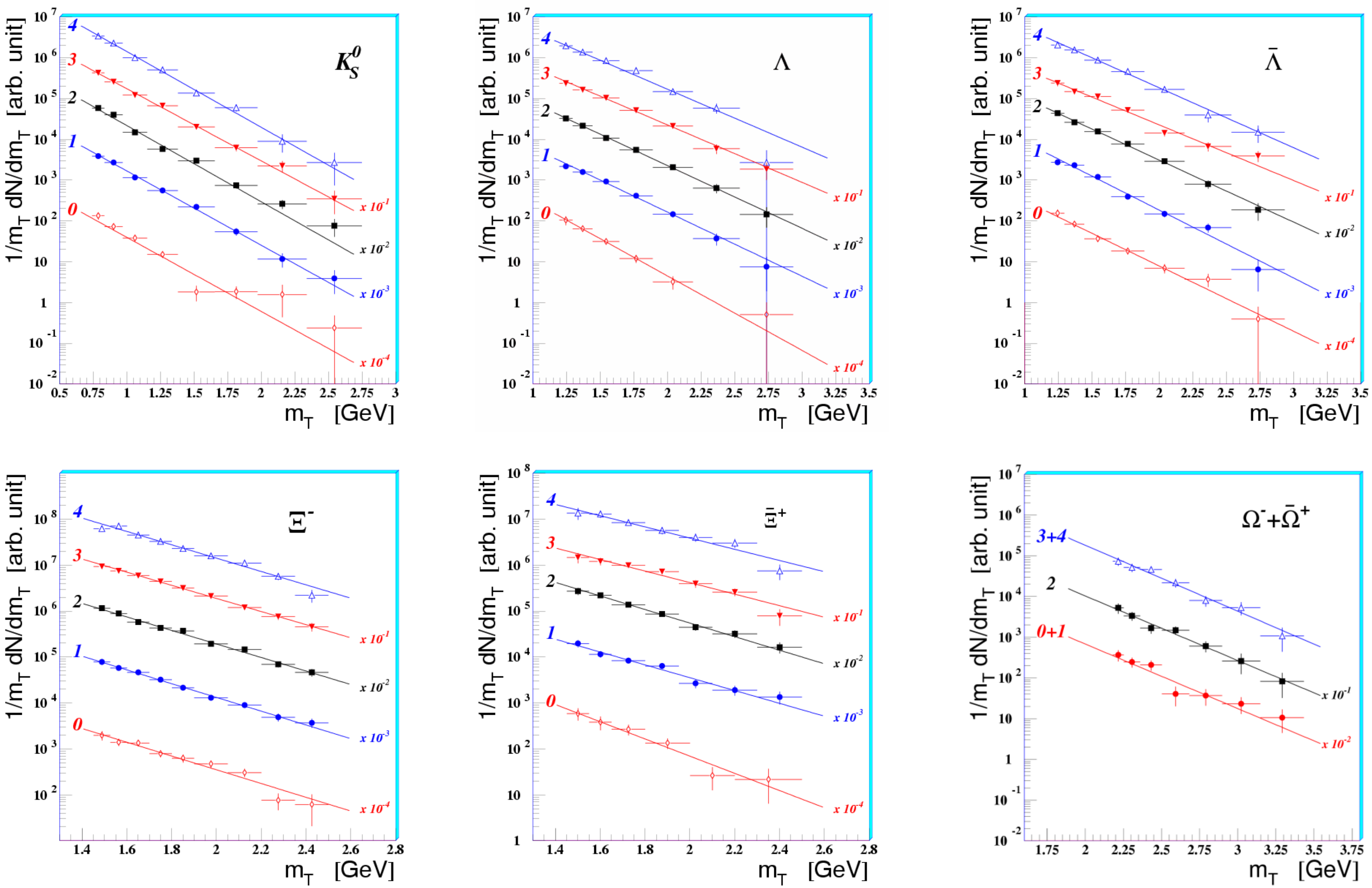


56% most central events

Inverse slopes (MeV)

K^0_S	237±4±24
Λ	289±7±29
$\bar{\Lambda}$	287±6±29
Ξ^-	297±5±30
Ξ^+	316±11±30
$\Omega^- + \Omega^+$	271±16±

Transverse mass spectra in Pb-Pb at 160 A GeV



m_T spectra in Pb-Pb at 160 A GeV/c

Hydro-dynamical picture:

the m_T spectra are sensitive to the transverse flow

Blast wave description of the spectra:

$$\frac{\mathrm{d}^2 N_j}{m_T \mathrm{d}y \mathrm{d}m_T} = \int_0^{R_G} A_j m_T \cdot K_1\left(\frac{m_t \cosh \rho}{T}\right) \cdot I_0\left(\frac{p_t \sinh \rho}{T}\right) r dr$$

$$\rho(r) = \tanh^{-1} \beta_\perp(r)$$

$$\beta_\perp(r) = \beta_S \left[\frac{r}{R_G}\right]^n \quad r \le R_G$$

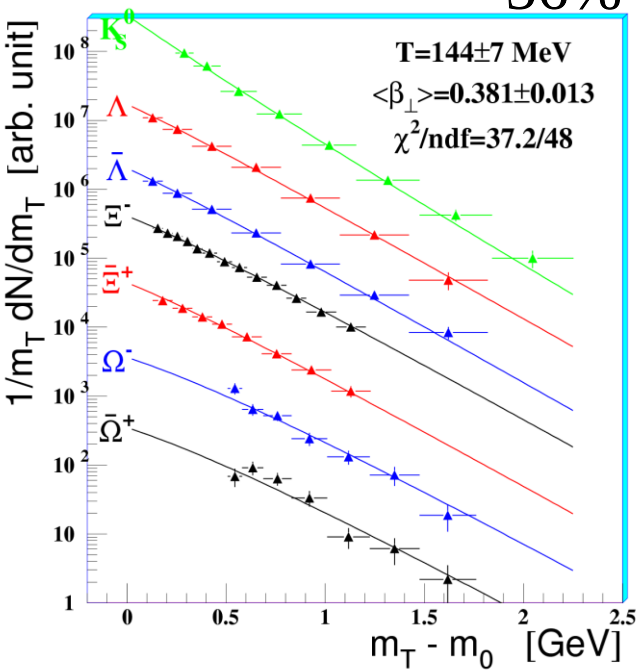
Uniform particle density

$$<\beta_\perp> = \frac{2}{2+n}\beta_S$$

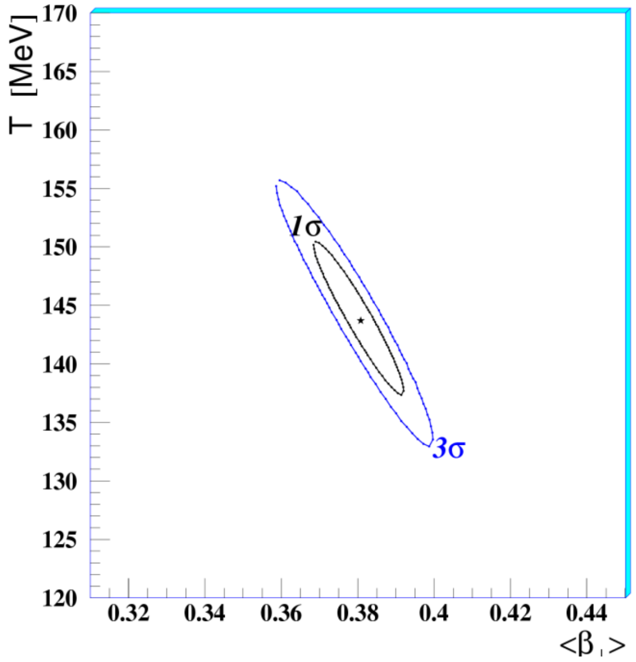
Ref: E Schnedermann, J Sollfrank and U Heinz, **Phys. Rev. C48 (**1993) 2462

Blast wave fit to strange particles

56% most central events



n=1

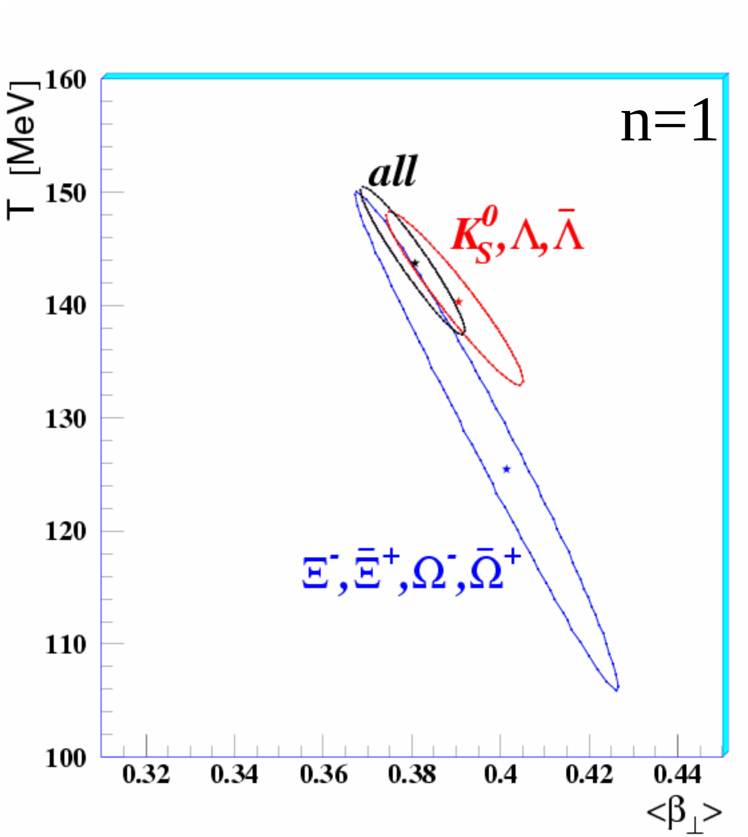


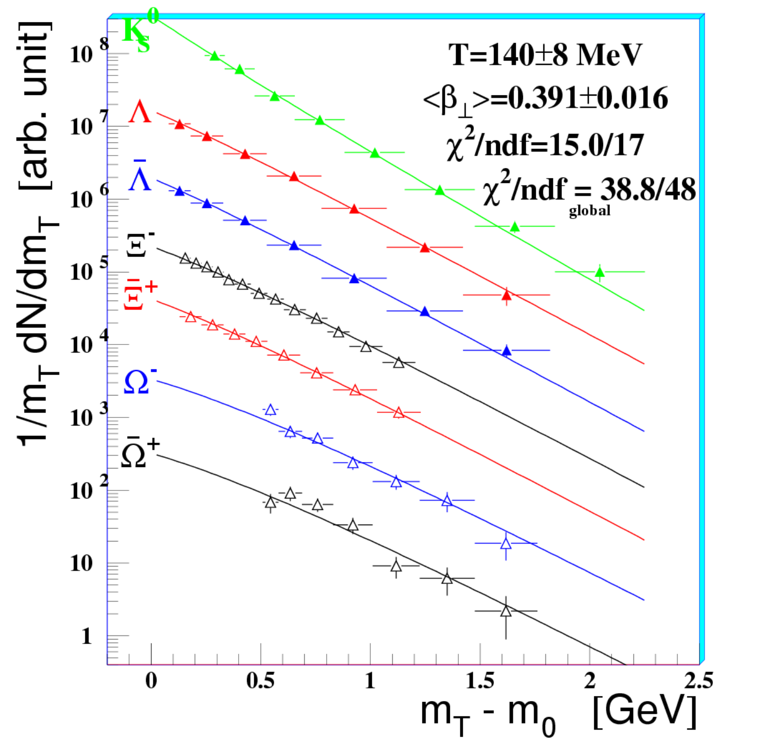
$$T = 144 \pm 7(\text{stat}) \pm 14(\text{syst})$$

$$\langle\beta_\perp\rangle = 0.381 \pm 0.013(\text{stat}) \pm 0.012(\text{syst})$$

- T and $\langle\beta_\perp\rangle$ depend weakly on **n**
- **n**=2 case disfavoured by data (bad χ^2)

Freeze-out parameters: multi- vs. singly strange particles



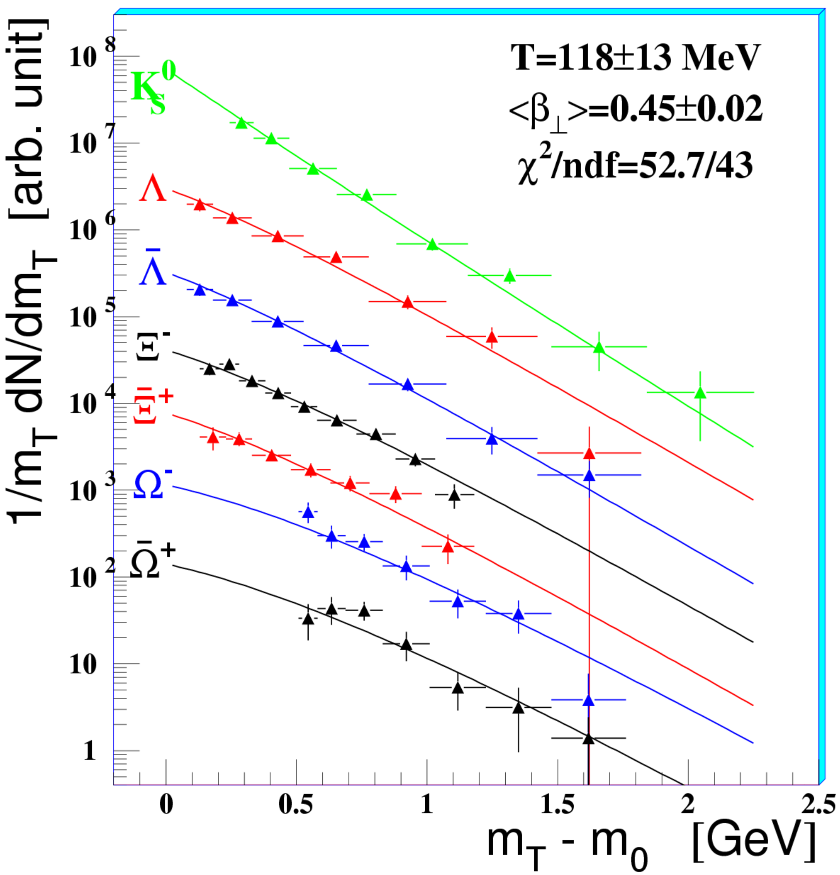


Fit to singly strange particles

- Fit driven by singly strange particles
- Ξ and Ω fit well with same parameters

Blast fit for most central collisions

5% most central events



	n	T (MeV)	$<\beta_\perp>$	χ^2/ndf
NA57	1	118±13	0.45± 0.02	53/43
NA49 (a)	0	127±1	0.48± 0.01	120/4 3
NA49 (b)	0	114±2	0.50± 0.01	91/41

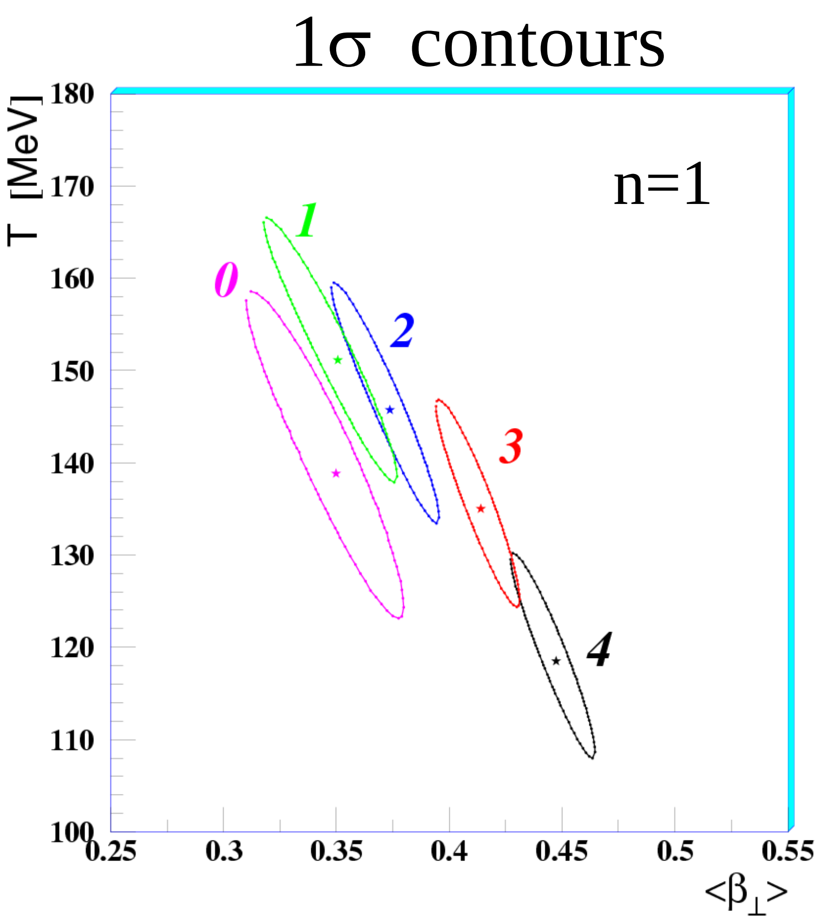
(a) K^+, p, Λ, Ξ^-, Ω^-

(b) K^-, $\bar{p}$, ϕ, $\bar{\Lambda}$, $\bar{\Xi}^+$, $\bar{\Omega}^+$

NA49 centrality: 5% for $K^\pm$, ϕ
10% for p, Λ, Ξ ; 20% for Ω

Ref: M van Leeuwen, **Nucl. Phys. A715 (**2003) 161c

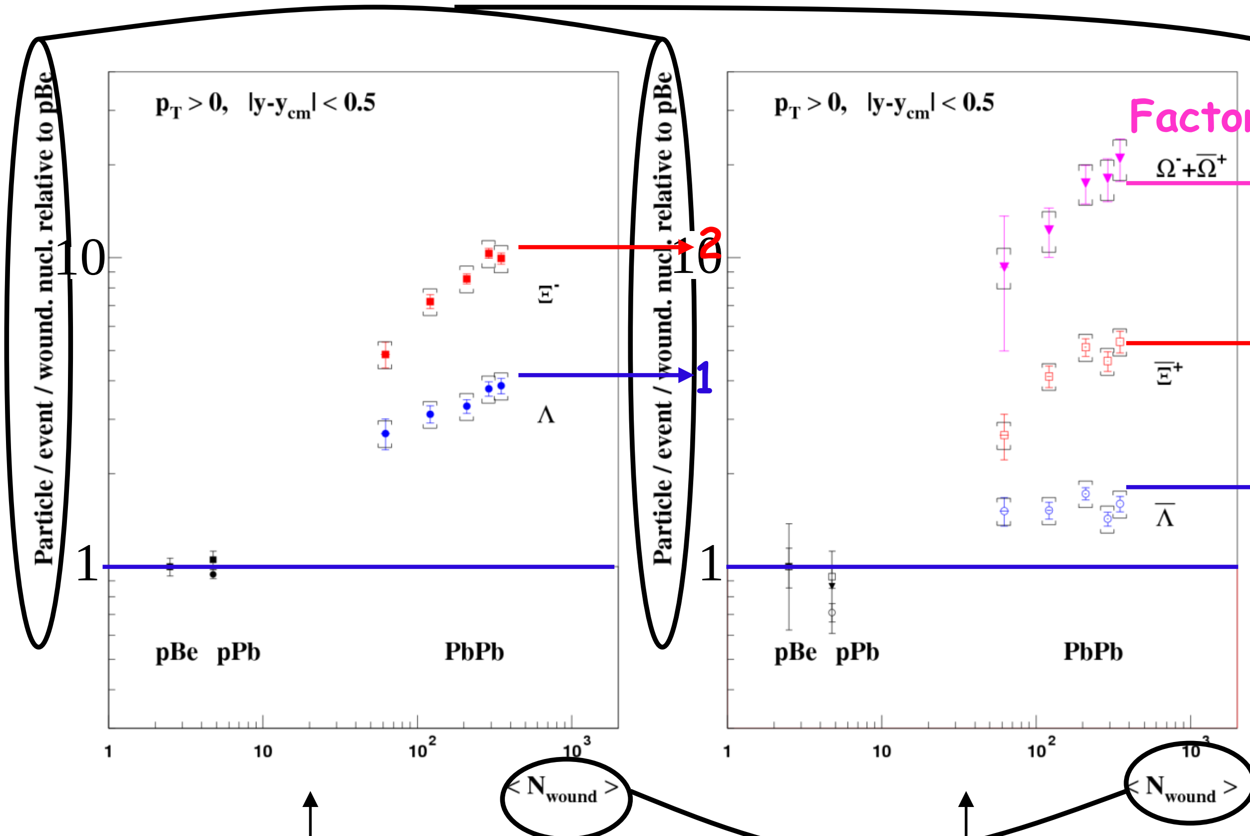
Centrality dependence of the thermal freeze-out in Pb-Pb at 160 A GeV



- With increasing centrality:
  - Transverse flow velocity increases
  - Freeze-out temperature decreases
- Earlier decoupling for
- peripheral collisions ?

Enhancements at 160 A GeV/c

Errors:
systematic
statistic



Factor ≅ 20 for Ω

3
2
1

Enhancement = $\dfrac{\langle Yield \rangle / \langle N_{part} \rangle}{(\langle Yield \rangle / \langle N_{part} \rangle)_{p\text{-}Be}}$

Hierarchy of the enhancements (QGP prediction)

No enhancement

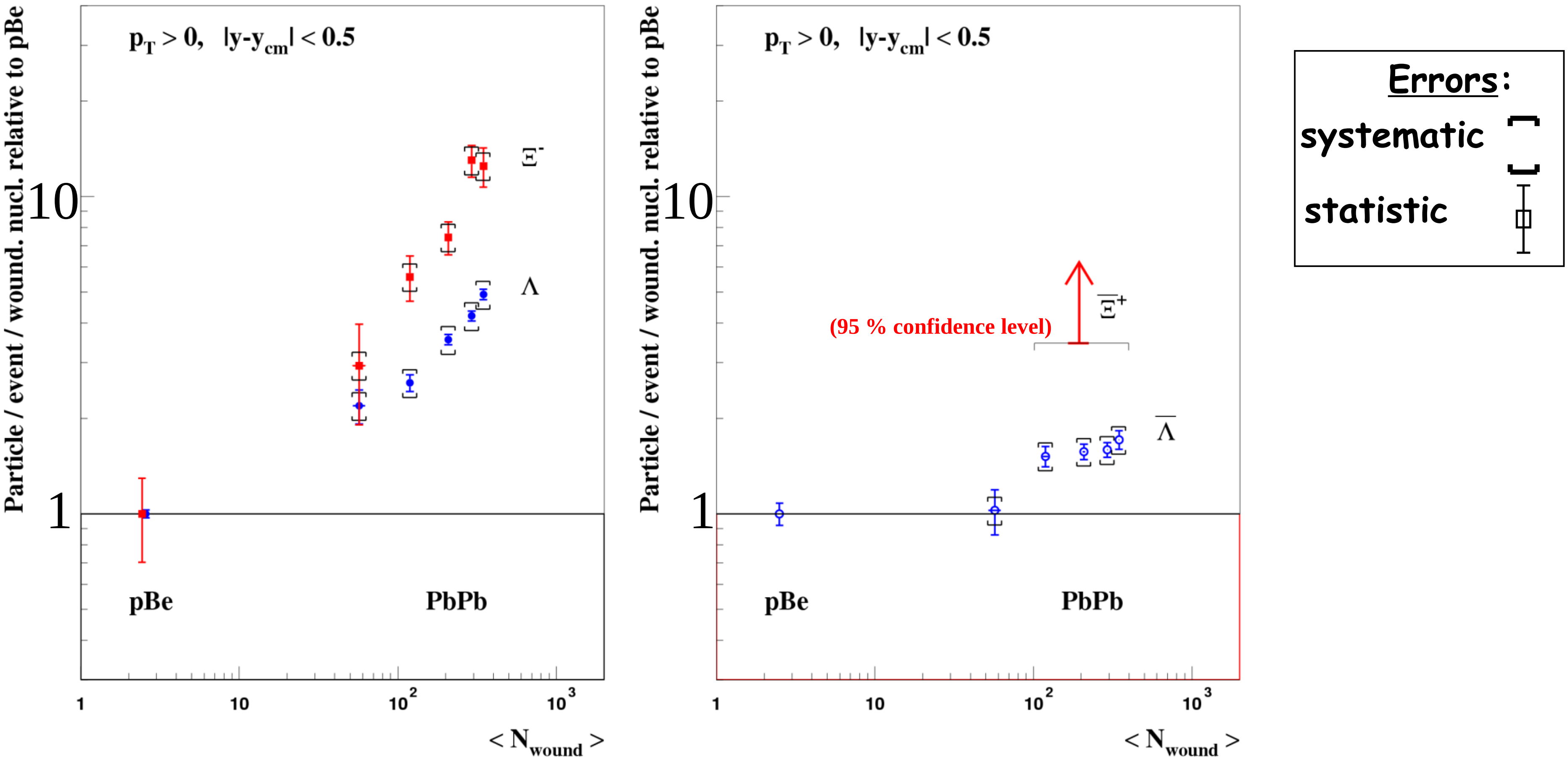
$\langle N_{part} \rangle$

Particles having quarks in common with the nucleon

Particles made up of newly created quarks only

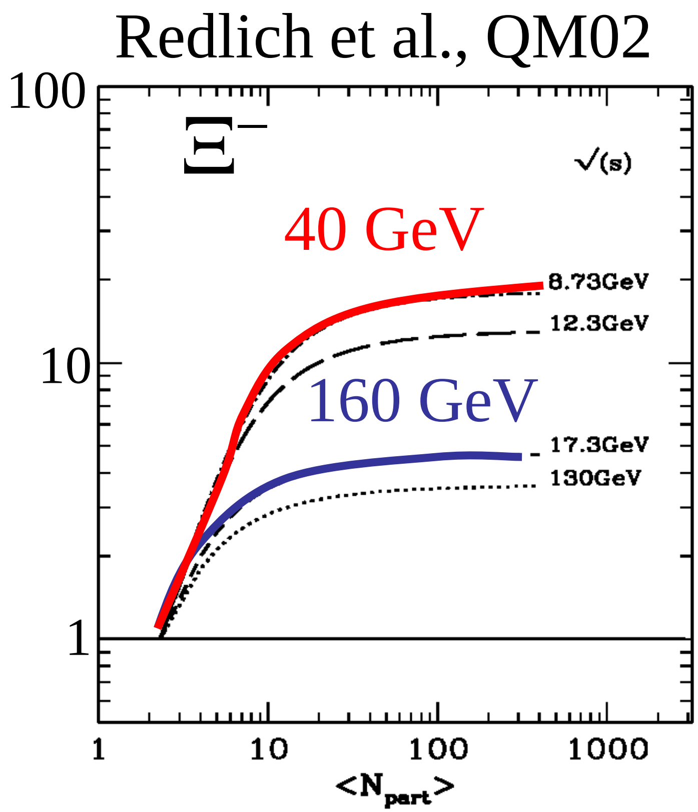
- Evidence of significant centrality dependence of enhancements in Pb-Pb (measurements in bin 0 essential)
- Saturation for the two-three most central bins ?

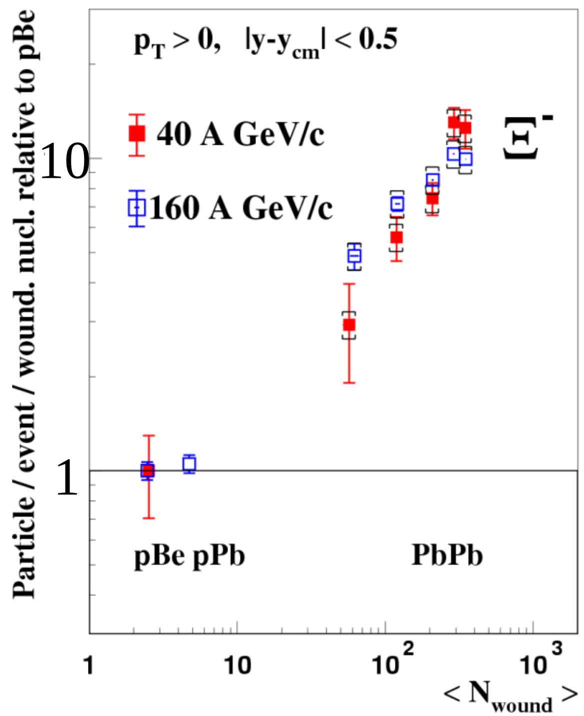
Enhancements at 40 A GeV/c



- Enhancements are still there at 40 GeV, with the same hierarchy as at 160 GeV: E(Λ) < E(Ξ)

Hyperon enhancements: 40 vs. 160 GeV

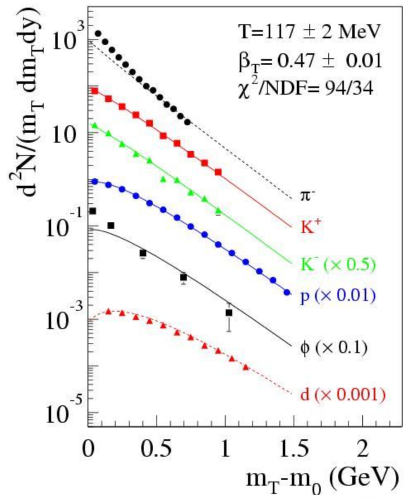




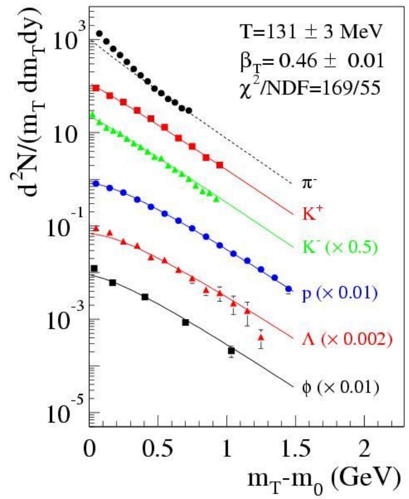
- In most central collisions (bins 3-4): enhancements at 40 are higher than at 160 GeV
- Enhancements increase more steeply at 40 than at 160 GeV

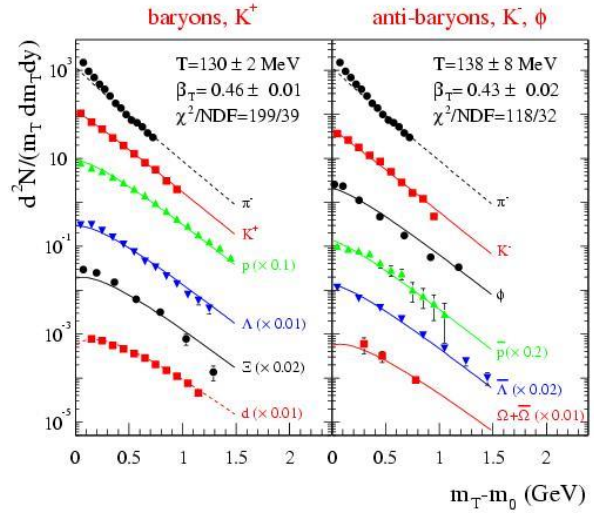
m_T Spectra $[d^2N/(m_T\, dydm_T) \sim exp(m_T/T)]$

20GeV



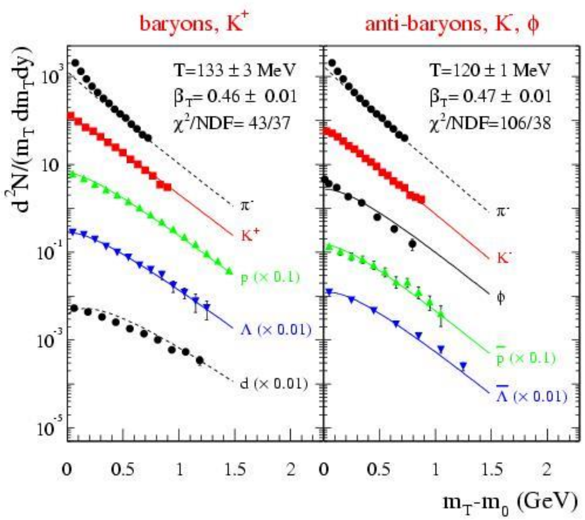
30GeV

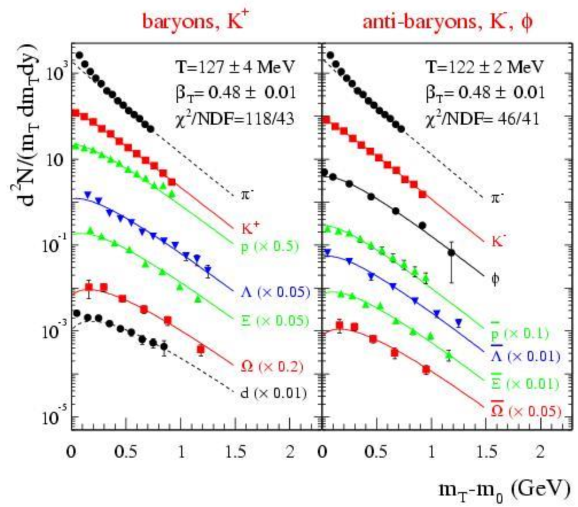




40GeV

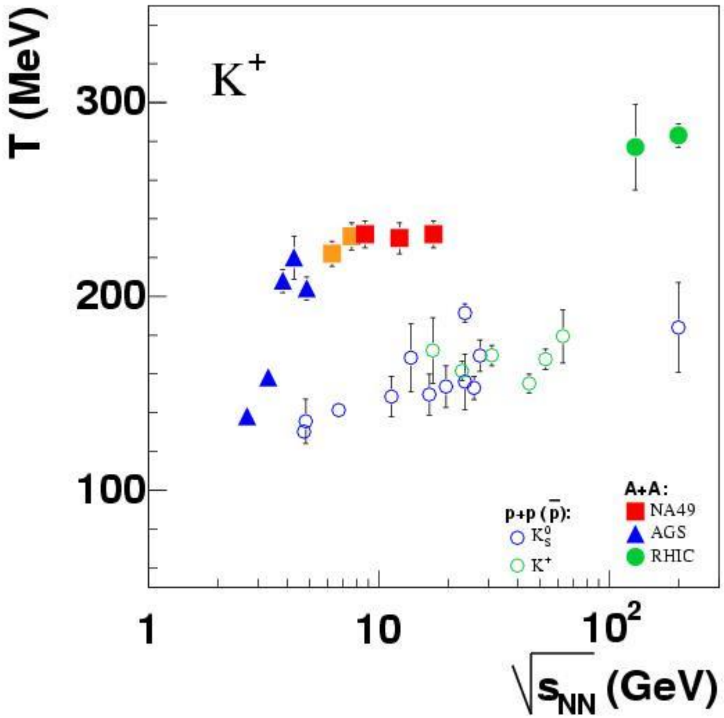
80GeV

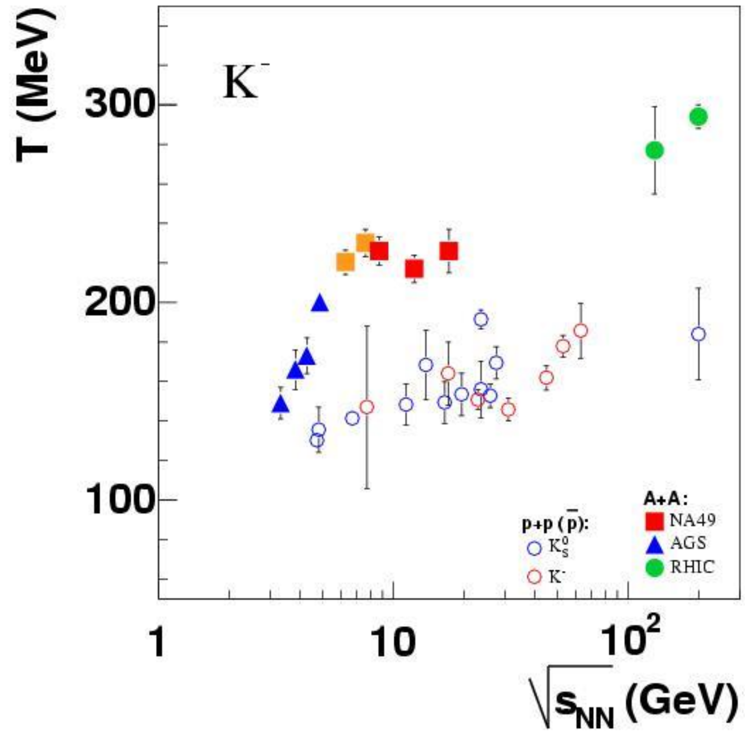




158GeV

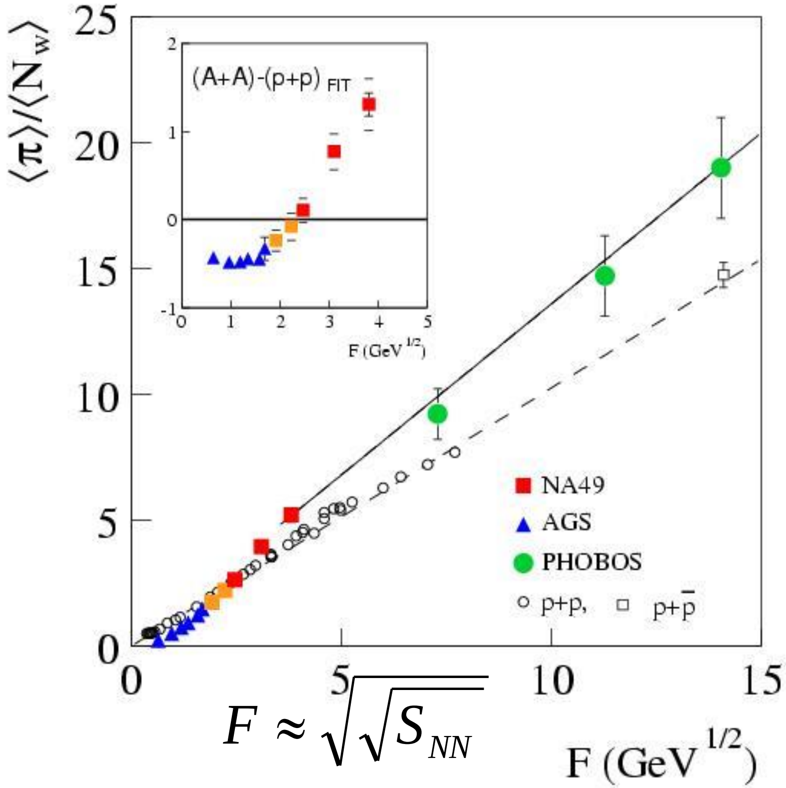
Slope vs. Energy



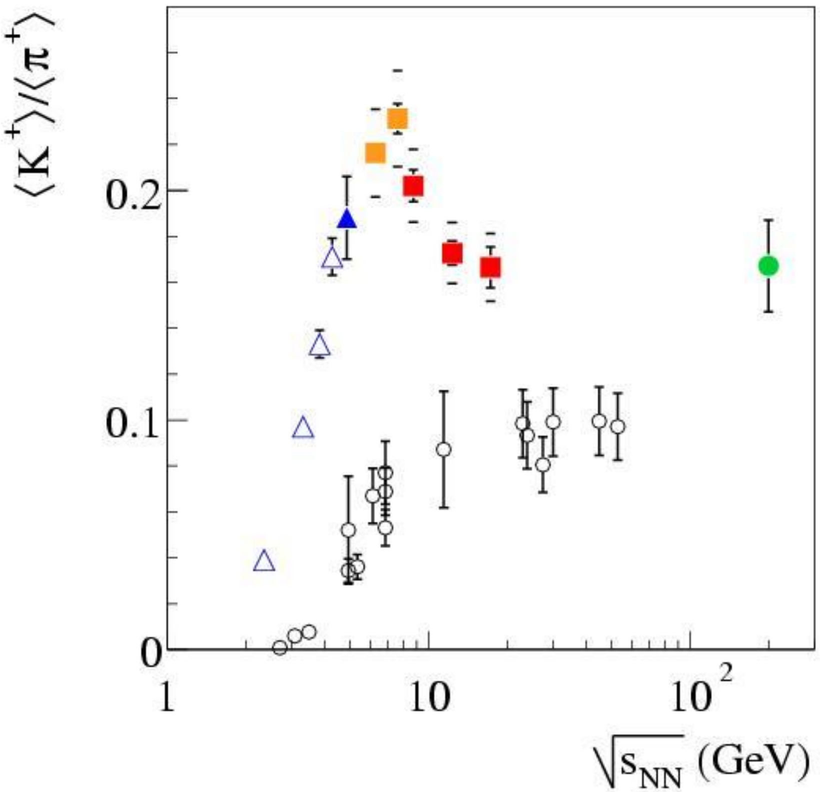


The Step at $E_{lab} = 20 - 30$ AGeV!

Multiplicity vs. Energy



$F \approx \sqrt{\sqrt{S_{NN}}}$



Onset, Horn at E_{lab} = 20–30 AGeV

The Pion Kink

M.Gazdzicki, Z.Phys. C66 (1995) 659

Deconfinement

↓

An Increase of Entropy, due to high number of effective degree of freedom in QGP

↓ $\langle\pi\rangle \sim$ Entropy

An Increase of Pion Yield at the Onset of Deconfinement

The early stage of the collisions : Fireball

↓

- $E \sim s^{1/2}$; $V \sim s^{-1/2}$
- $\varepsilon = E/V \sim s$; $\varepsilon \sim gT^4$
- $T \sim g^{-1/4}\, s^{1/4}$
- $\langle\pi\rangle \sim S \sim gVT^3 \sim g^{1/4}s^{1/4} = g^{1/4}F$

↓

$$\langle\pi\rangle \sim g^{1/4}\, F$$

Statistical Model of the Early Stage (SMES) :

M. Gorenstein, Acta Phys. Polon. B30 (1999) 2705

The Statistical Model of the Early Stage (SMS)

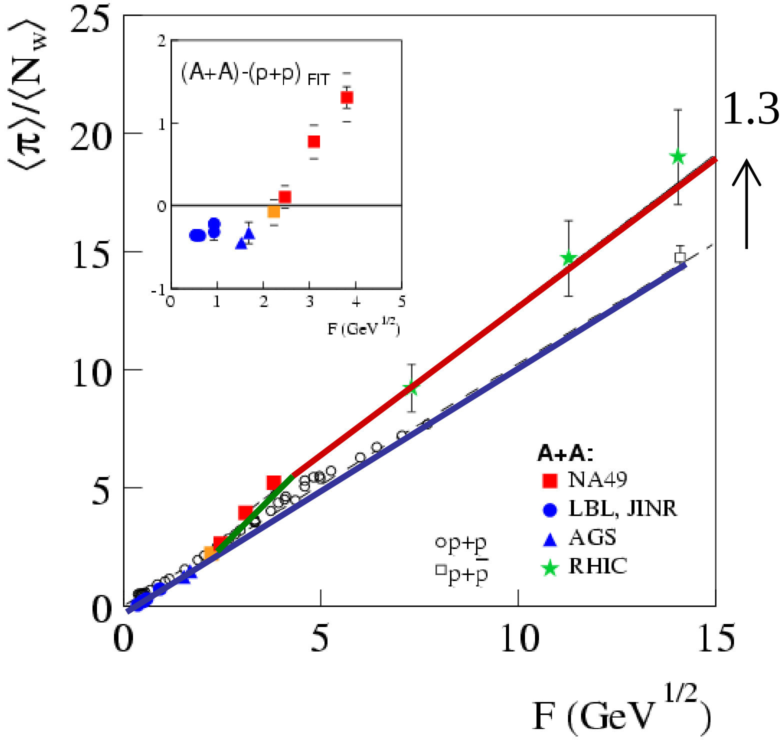
M.Gorenstein, Acta Phys. Polon. B30 (1999) 2705

g_H for hadron gas

$g_H < g_Q$

g_Q for QGP

$g_Q / g_H \sim (1.3)^4 \sim 3$



Strangeness Enhancement with the strange horn

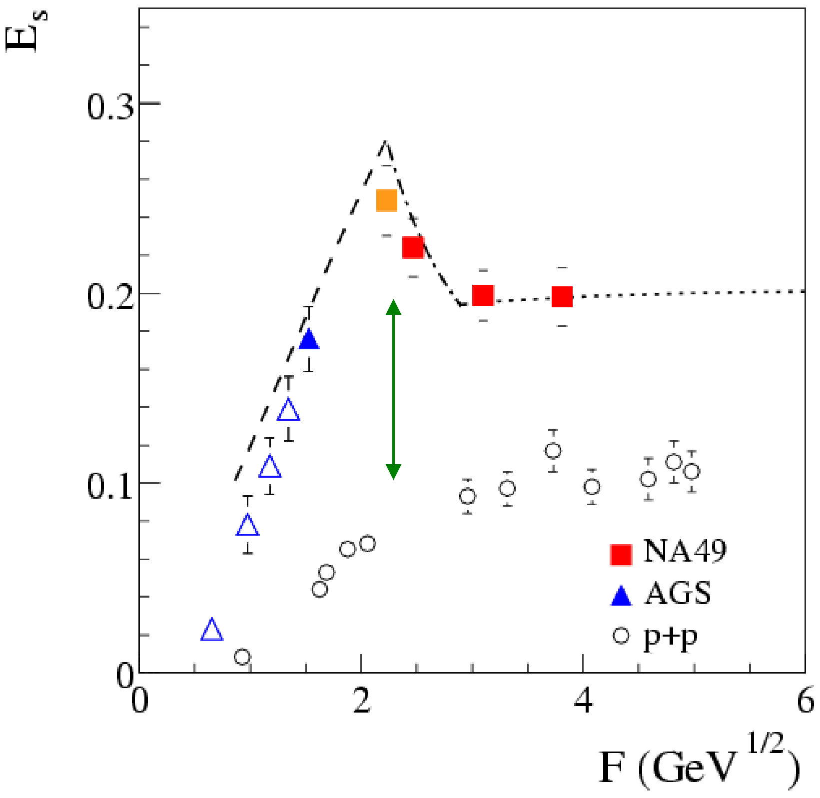
Strangeness Enhancement :

J. Rafelski, Phys. Rep. 88, 331 (1982)

Strange Horn :

M.Gazdzicki, D.Roehrich, Z.Phys. C71 (1996) 55

M.Gorenstein, Acta Phys. Polon. B30, 2705



Strange/Nonstrange Ratio

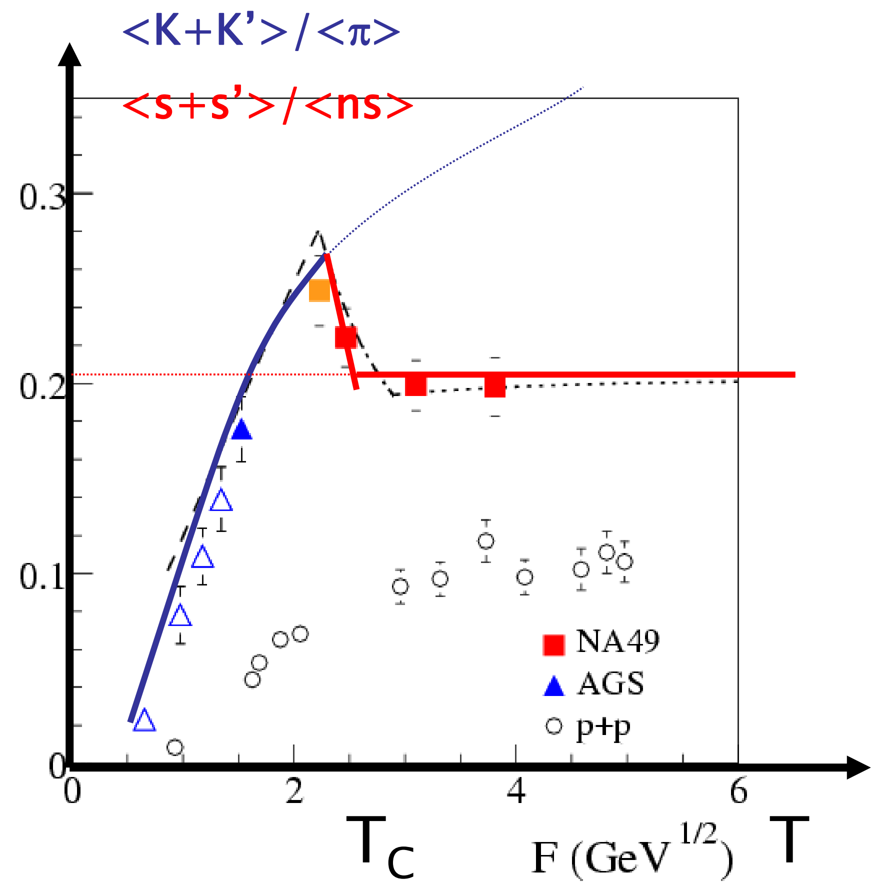
Hadron Gas (K+K')/π at T ~ T_C

<K+K'> ~ $T^{3/2}\exp(-m_K/T)$

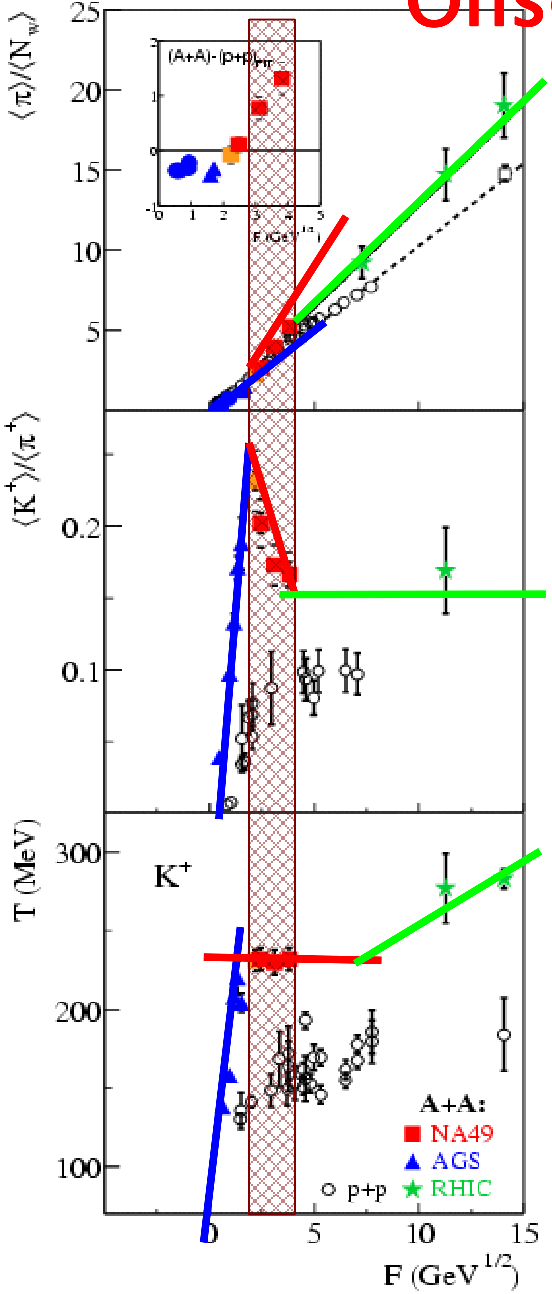
<π> ~ T^3

QGP at T > T_C (m_s < T)

<s+s'> ~ T^3



Onset of Deconfinement ? !



<π> ~ Entropy

Deconfinement :

An Increase of Pion Yield at the Onset

Strangeness Enhancement :

Hadron Gas – Mixed Phase – QGP

Anomaly in transverse Expansion

Highly Interested Region :

E_{Lab} ~ 20..30 GeV/u

HIM Outline (Suggestion)

- subjectwise theoretical & experimental Review (AGS-SPS-RHIC)
  - Hadron -
  - Lepton -
  - Correlations (HBT, BF etc.)-
  - E-by-E -
  - Jet -
  - Any other subject ?
- to be answered Where to go !
  - Which system / variables to be investigated ?
  - QGP is found ? Or not ? And then ?