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Recent Results from NA49 on Pb+Pb Collisions at the CERN SPS

NA49 Collaboration
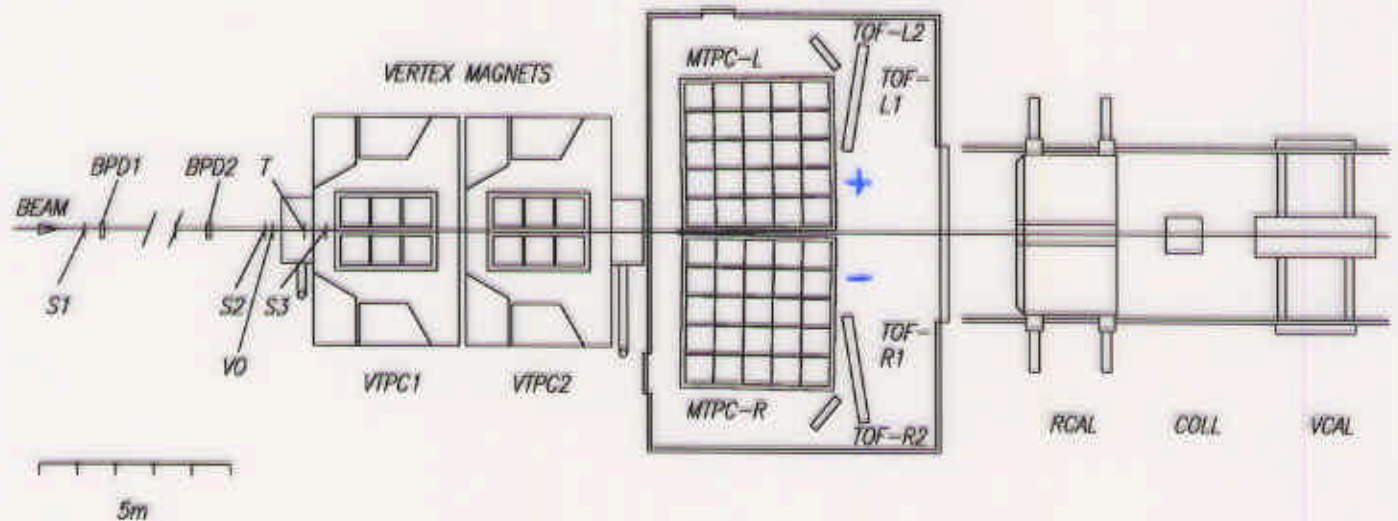
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- Hyperon Production
- $\Phi \to K^+ K^-$
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- Event-by-Event Fluctuations
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# The NA49 Experiment

NA49 performs hadronic meaurements

- large acceptance (80%) precision tracking in TPC's
- particle identification by dE/dx(50%) and TOF(6%)
- strange particle identification via decay topology
- centrality tagged by forward calorimeter (VCAL)

observables studied by NA49:

- spectra,correlations (kinetic freezeout stage – time,size,temperature,expansion flow)
- hadron yields (hadronisation process)
- strangeness enhancement (equilibration in early reaction stage)
- event-by-event fluctuations (kinetic and chemical equilibration)

charged particle identification in NA49

specific energy loss in TPC's: $\sigma_{dE/dx} = 4\%$
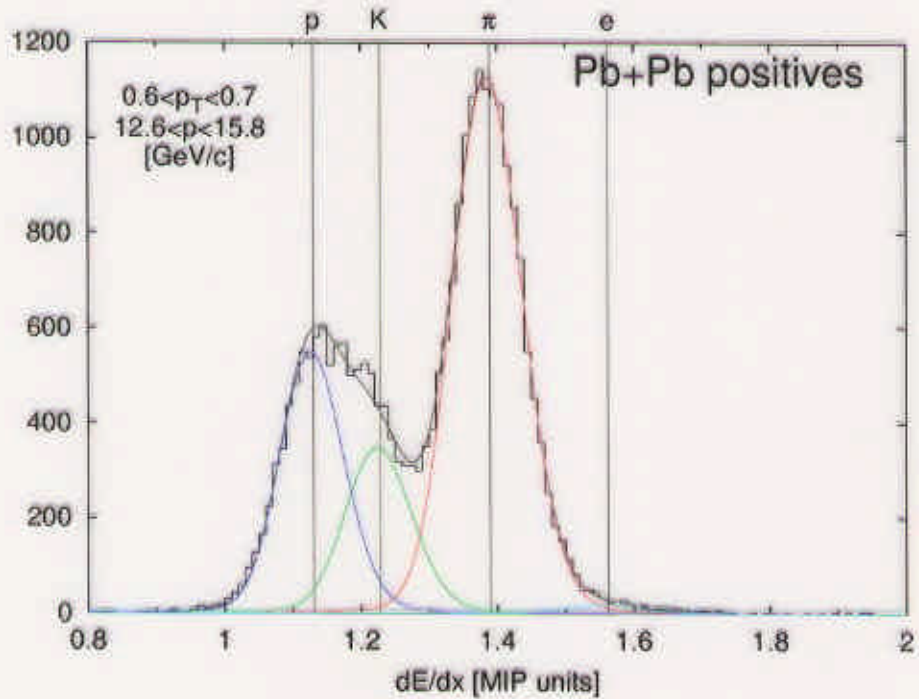
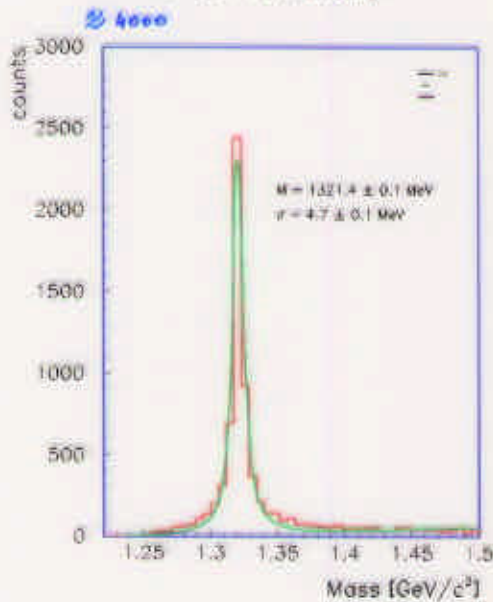## combined TOF and dE/dx: $\sigma_{TOF} = 60ps$
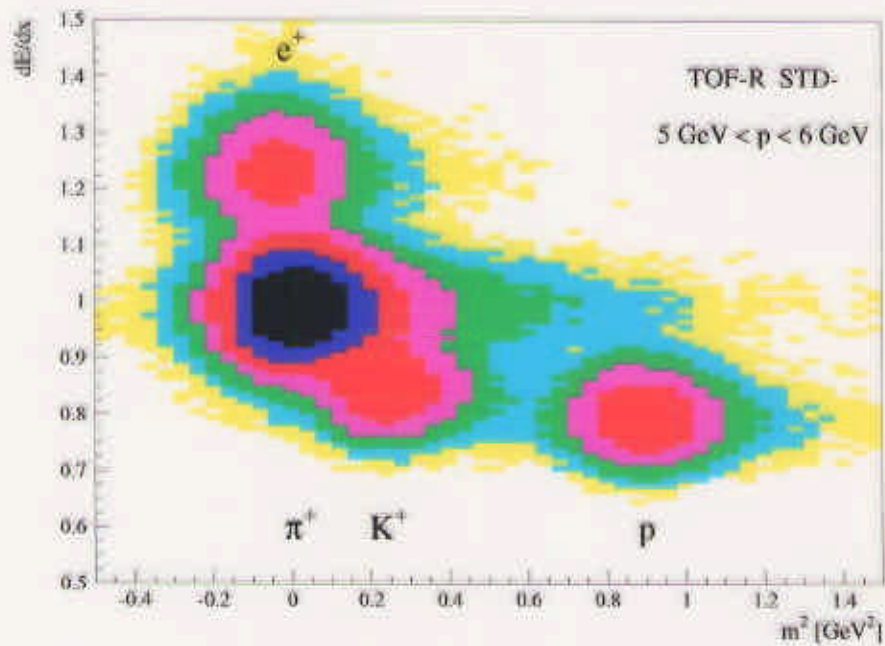
Ξ and Ω production
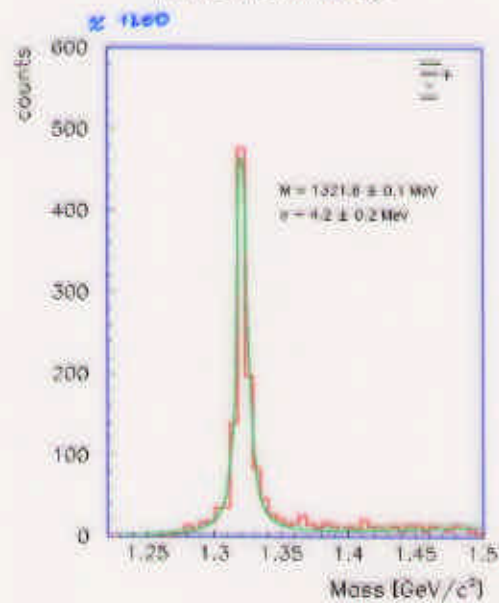
$$\Xi \to \Lambda + \pi \qquad (\text{B.R. } 100 \%)$$
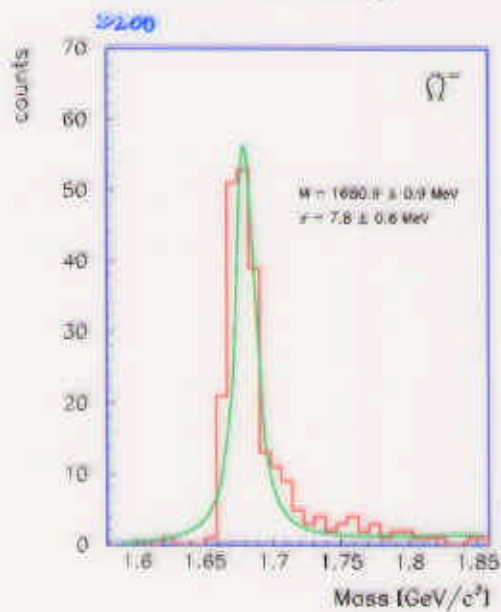$$\to p + \pi \quad (\text{B.R. } 64.1 \%)$$

NA49 Preliminary

NA49 Preliminary

Ξ^-
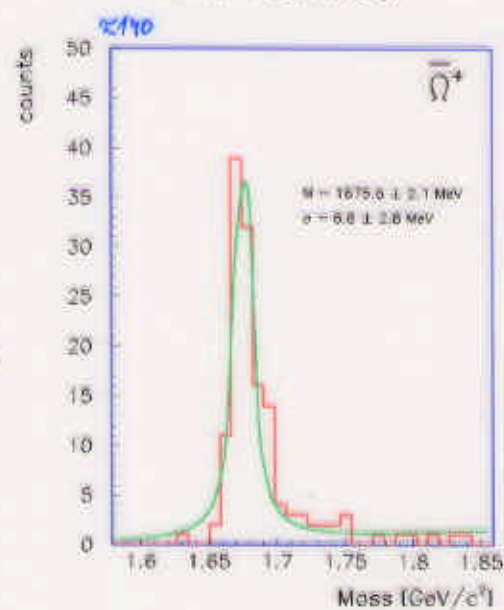
M = 1321.4 ± 0.1 MeV

σ = 4.7 ± 0.1 MeV

$\overline{\Xi}^+$

M = 1321.6 ± 0.1 MeV

σ = 4.2 ± 0.2 MeV

$$\Omega \to \Lambda + K \qquad (\text{B.R. } 67.8 \%)$$
$$\to p + \pi \quad (\text{B.R. } 64.1 \%)$$

NA49 Preliminary

NA49 Preliminary

Ω^-

M = 1680.9 ± 0.9 MeV

σ = 7.8 ± 0.6 MeV

$\overline{\Omega}^+$

M = 1675.6 ± 2.1 MeV

σ = 6.6 ± 2.6 MeV

counts

Mass [GeV/c²]
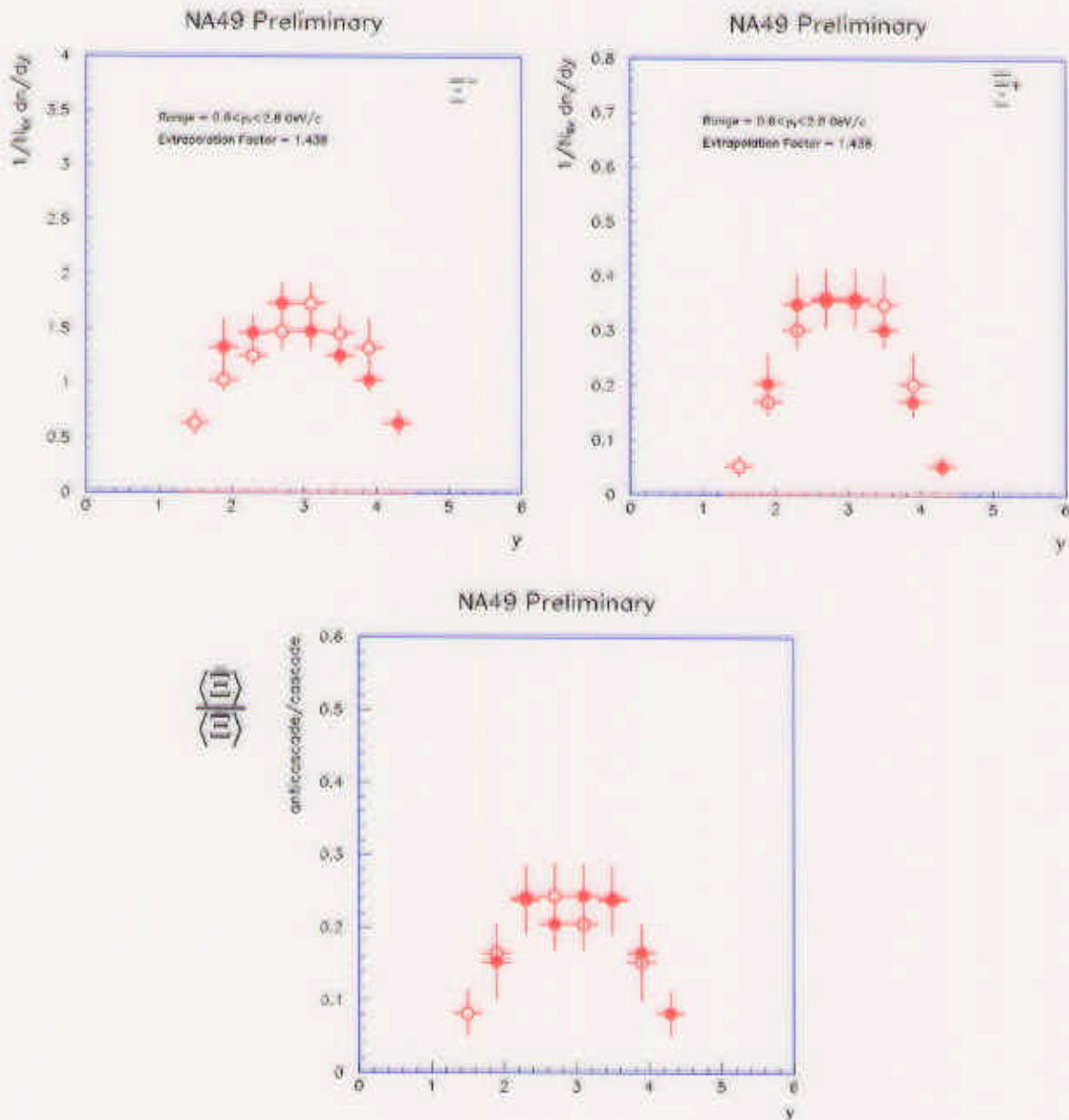
cascade yields:

improved efficiency of reconstruction programs
acceptance: $1.7 < y < 4.5$, $p_T > 0.6$ GeV/c

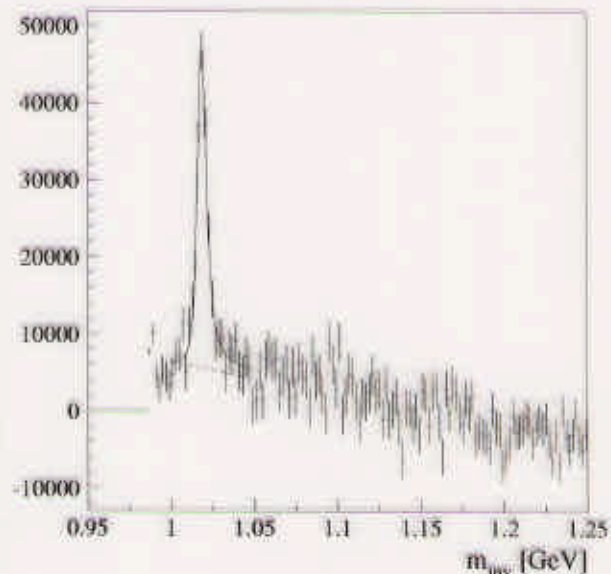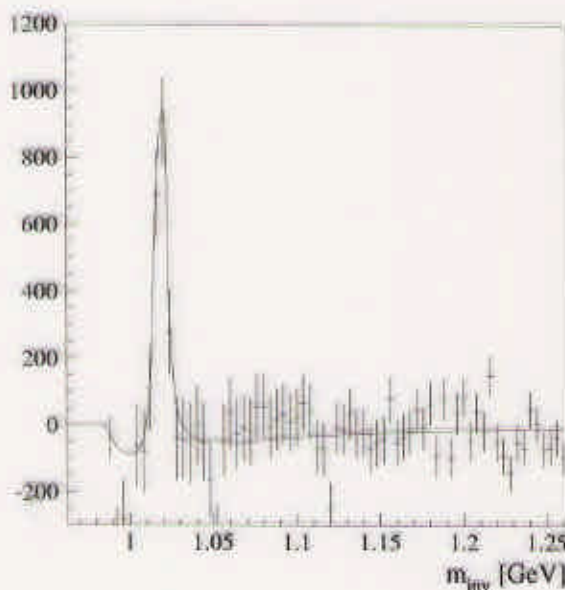yields of Ω production soon in $1.5 < y < 3.0$, $p_T > 0.6$ GeV/c

$\Phi \to K^+ K^-$ production

- hidden strangeness $s\bar{s}$ state, yield small in pp–interactions (OZI rule)

- sensitive to strangeness enhancement at partonic level (A.Shor)

- modification of M, Γ, decay B.R. in the dense fireball ? (Lissauer,Shuryak)

central PbPb collisions

dE/dx and TOF   dE/dx only
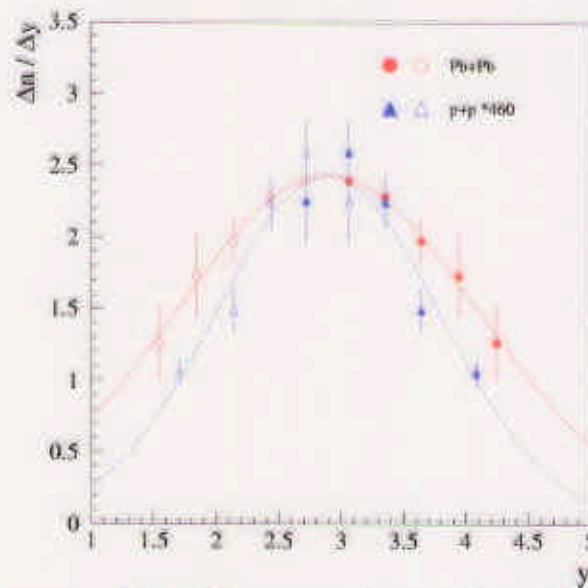

combinatorial background subtracted
Φ-peak fitted with relativistic Breit-Wigner
$(\Gamma = 4.43$ MeV$)$ folded with resolution σ_m

result: M $= (1018.7 \pm 0.5)$ MeV, $\sigma_m = (1.6 \pm 0.3)$ MeV
$\Longrightarrow$ no evidence for modification
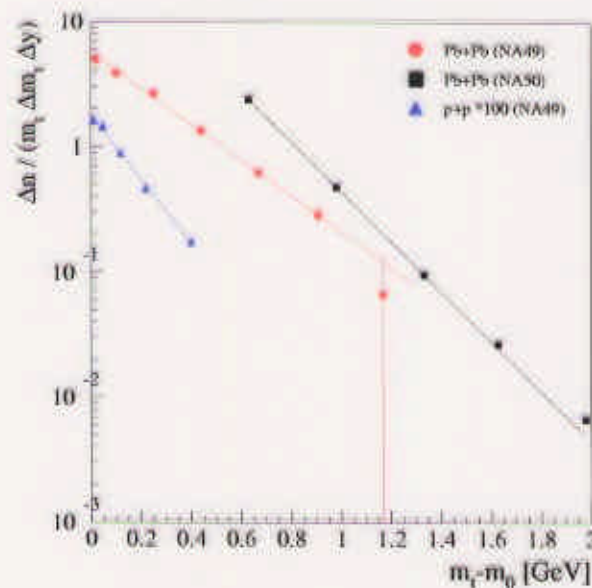
rapidity distributions:

$$\sigma_y$$
$$1.22 \pm 0.16$$
$$0.89 \pm 0.06$$

width increase pp $\rightarrow$ PbPb reactions for Φ, not seen for π, K

$M_t - M$ distributions:

$$T(MeV)$$
$$305 \pm 15$$
$$169 \pm 17$$

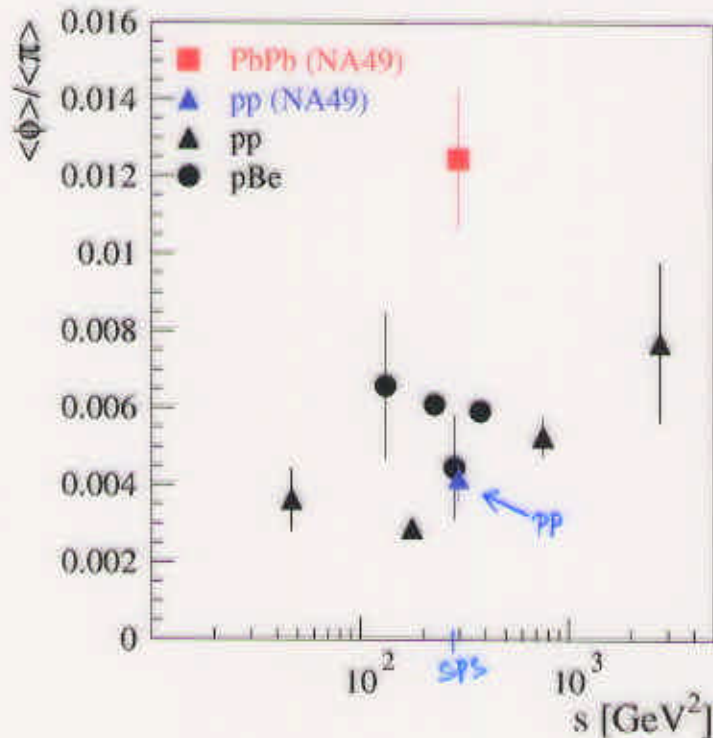inverse slope parameter T inceases pp $\rightarrow$ PbPb (transverse flow)

disagreement with prel. NA50 results from $\Phi \rightarrow \mu^+ \mu^-$ channel
speculative explanation (Shuryak) : rescattering of decay Kaons

nucl-th/9809045

Φ/π enhancement

<u>4π yields:</u> pp inelastic $\langle\Phi\rangle = 0.012 \pm 0.0015$
PbPb central 7.6 ± 1.1

with $\langle\pi\rangle = \frac{1}{2} \cdot (\langle\pi^+\rangle + \langle\pi^-\rangle)$

enhancement factors pp $\rightarrow$ PbPb :
$\langle\Phi\rangle/\langle\pi\rangle$ 3.0 ± 0.7
$\langle\Phi\rangle/N_{part}$ 3.6 ± 0.8

- Koch,Heinz,Pisut estimate factor < 6 for a model with QGP
  (isentropic hadronisation by coalescence at $T = 180$ MeV)

- Φ yield consistent with statistical hadronisation model fits

# $\Lambda^*(1520) \to pK^-$ production (preliminary)

- small width $\Gamma = 16$ MeV, B.R. 22.5 %, possibly detectable in PbPb collisions $\quad c \cdot \tau \approx 10$ fm

- particle identification essential to reduce huge combinatorial background

- in medium modification, yield versus statistical model ?
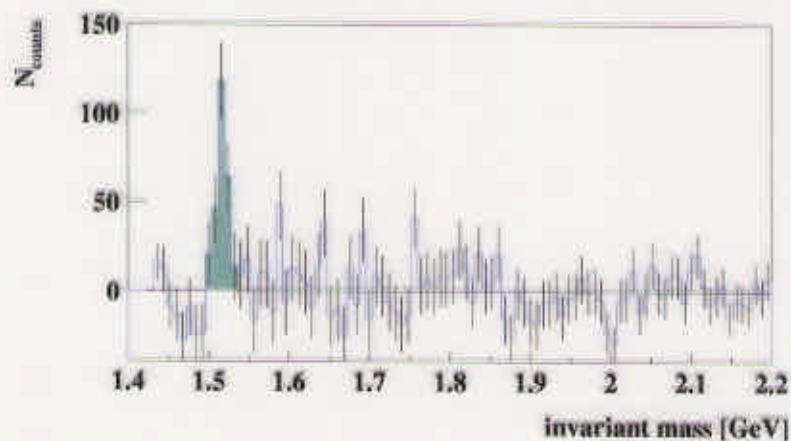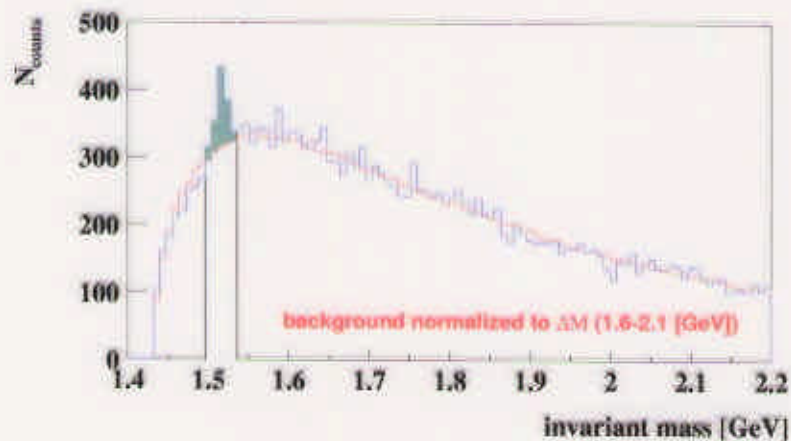
clear signal in inelastic pp collisions
$\langle\Lambda^*(1520)\rangle = 0.012 \pm 0.003$ per event

central PbPb collisions:

signal + bg = 15806833

simulation

signal = 11867
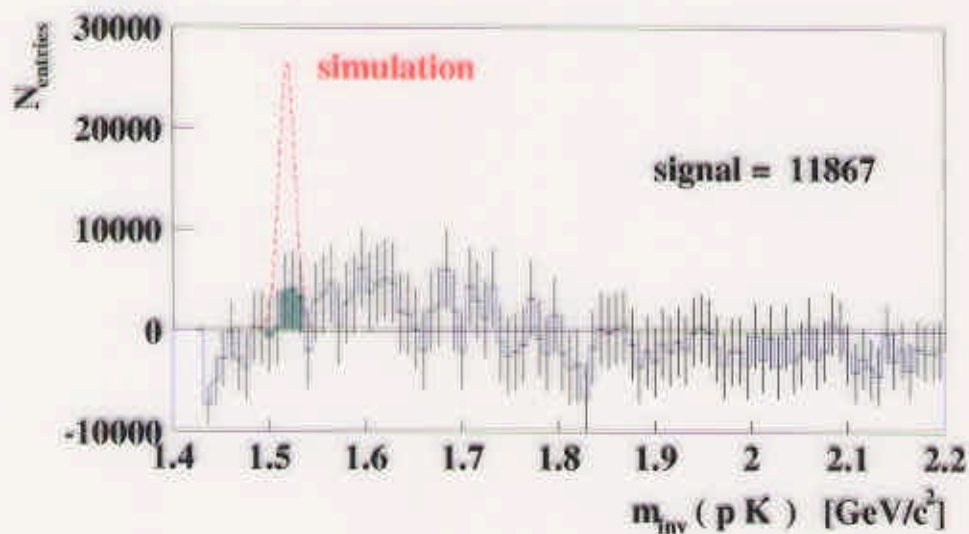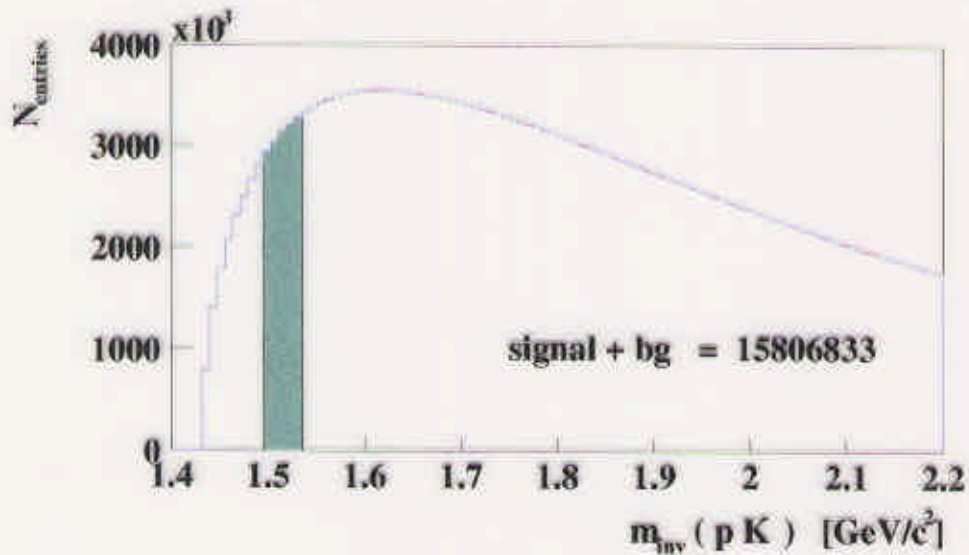
excess of 0.5 ± 0.3 not significant
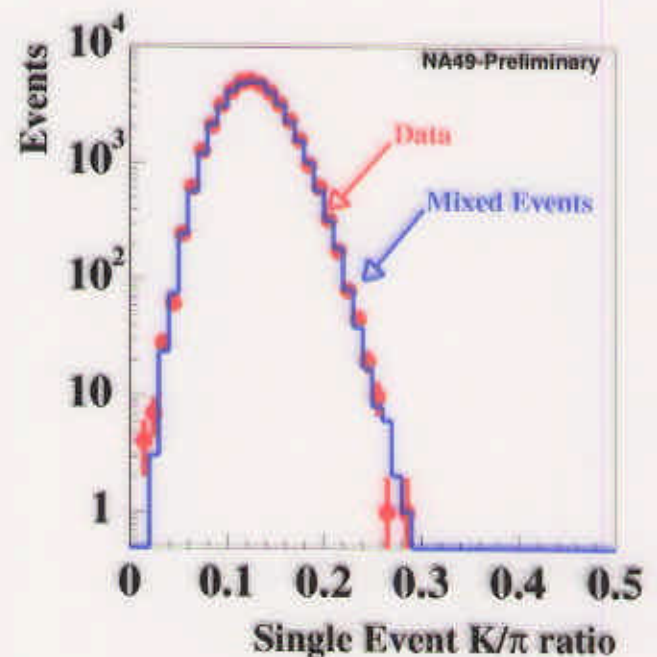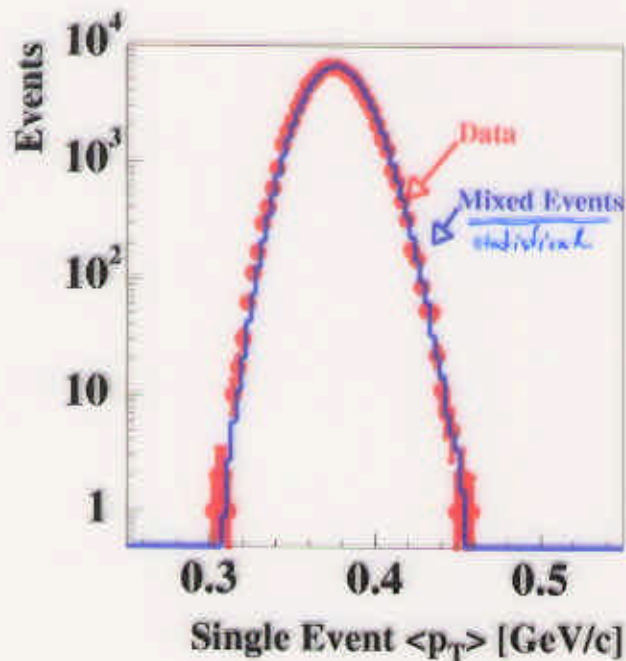upper limit $\langle \Lambda^*(1520) \rangle < 1.36$ per event at 95 % c.l.

- with N_{part} scaling expect yield of 2
- from statistical model fit predict yield of 3.6

Event-by-Event Fluctuations in Pb+Pb Collisions

probe equilibration and thermodynamical properties
of produced matter

$\langle p_T \rangle$: temperature,kinetic equilibration
K/π : strangeness content,flavor equilibration

measured fluctuations reproduced by mixed events
(number statistics)
90% c.l. upper limits for dynamical fluctuations:
1.2% in $\langle p_T \rangle$, 2.8% in K/π

no distinct event classes
events very uniform, expected with transient QGP phase

quantitative measure of $\langle p_T \rangle$ fluctuations:

$$\Phi_{p_T} = \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\overline{z^2}} \qquad Z = \sum_{i=1}^{N} z_i \qquad z_i = p_{Ti} - \overline{p_T}$$

designed to remove the effect of Poisson fluctuations

Result: $\Phi_{p_T} = 0.6 \pm 1.0 MeV/c$
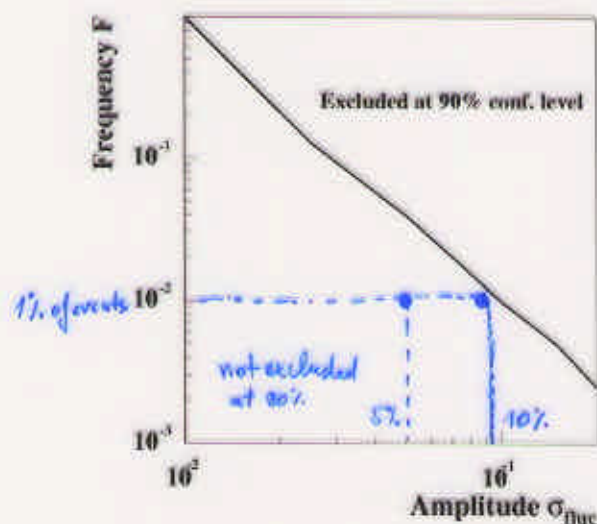
cancelling contributions from BE correlations $(5 \pm 1.5 MeV/c)$

2-track resolution $(-4 \pm 0.5 MeV/c)$

quantitative limits from fluctuation model : Phys. Lett. B453 (1999) 673

$$P(x) = 1/\sqrt{2\pi\sigma_{fluc}^2} \cdot exp(-(x-1)^2/(2\sigma_{fluc}^2))$$

scaling of momenta by factor x drawn from P(x) event-by-event

limit on production of DCC:

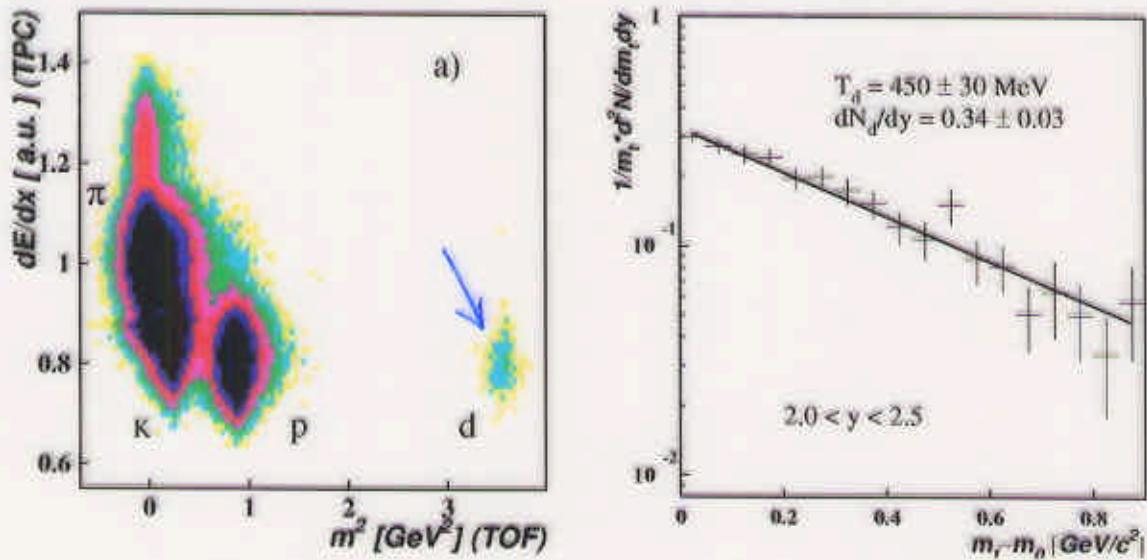deviation from isospin symmetry in pion charges at small p_T

$$P(f) = \frac{1}{2\sqrt{f}} \qquad f = N_{\pi^0}/(N_{\pi^+} + N_{\pi^-} + N_{\pi^0})$$

Fluctuating charged π multiplicity with $p_T < m_\pi$ according to $P(f)$
in domain ξ leads to increase of $\langle p_T \rangle$ fluctuations
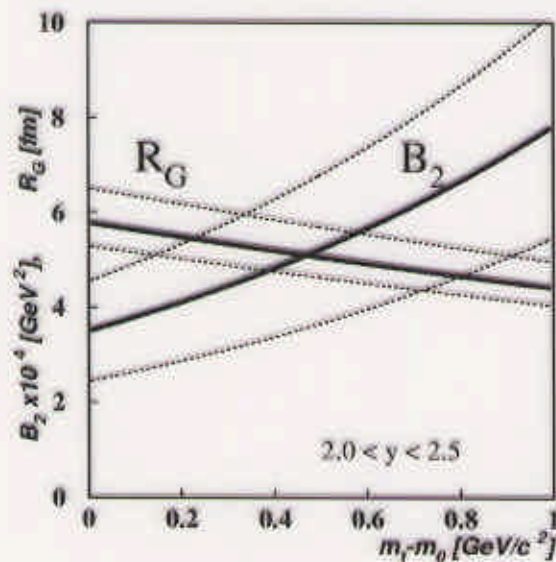
$\Longrightarrow$ upper limit $\xi < 3.5\%$

Deuteron production

information on freezeout stage via coalescence model

derive coalescence factor B_2 using d and p spectra:

$$B_2 = (E_d \cdot d^3 N_d / dP_d^3)/(E_p \cdot d^3 N_p / dP_p^3)^2 \text{ at } P_d = 2P_p$$
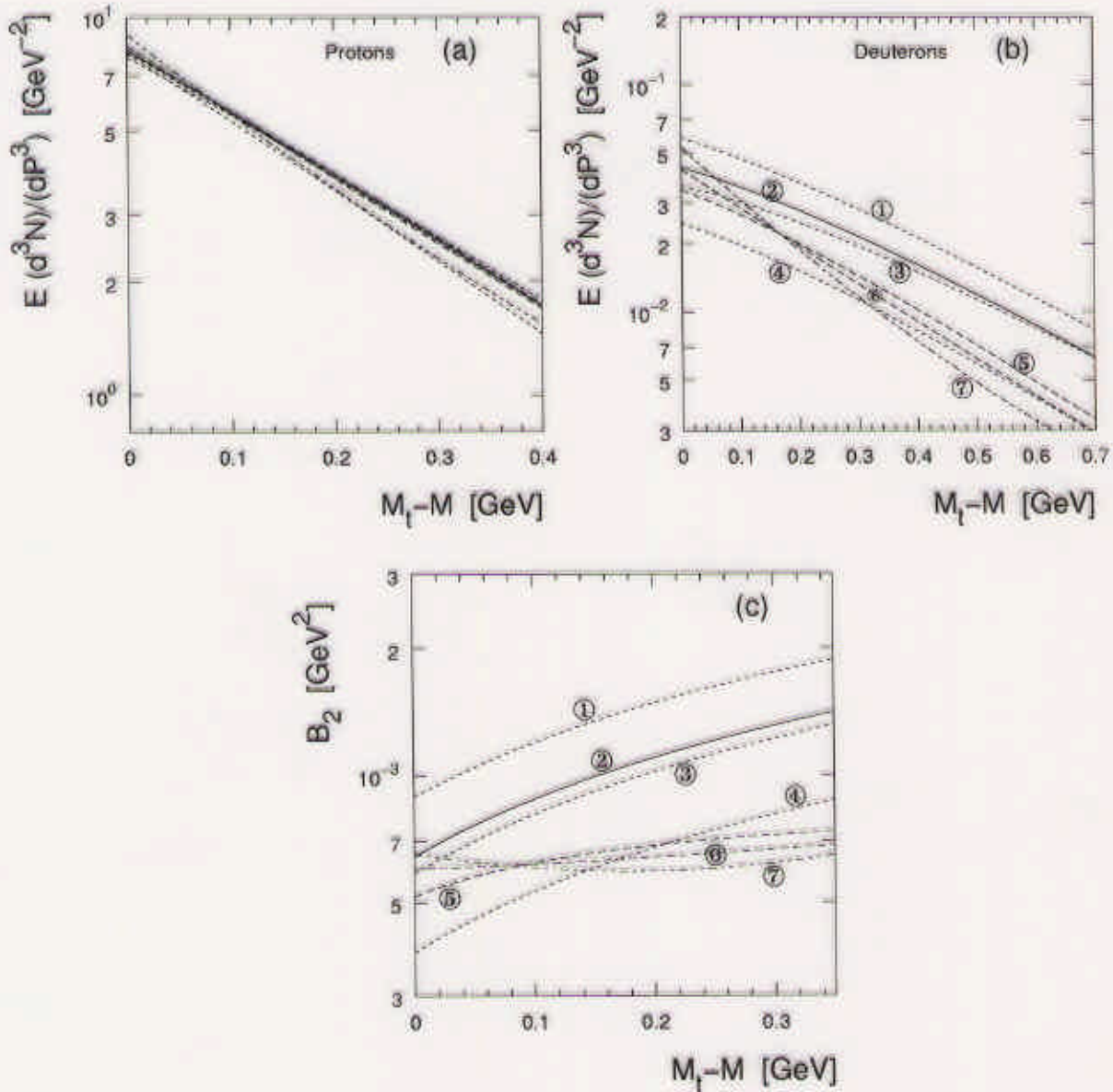

$R_G = 5.8 \pm 0.7 \, \text{fm}$

$\frac{dN_d}{dy} = 0.34 \pm 0.03$

estimate of freezeout radius: $R_G^3 = \frac{3}{4}(\sqrt{\pi}\hbar)^3 \cdot \frac{m_d}{m_p^2} \cdot \frac{1}{B_2}$

result consistent with $\pi\pi$ BE–correlation measurement

expanding source model: R.Scheibl,U.Heinz:PRC59(1999)

cluster spectra sensitive to shape of fireball
HBT meaurements constrain only rms radii

M_t dependence of B_2 favors box-shape radial density profile (1)-(4)

resulting parameters (4): $\tau_0 = 9 fm/c$ $\rho_{box} = 14 fm$
$T = 126 MeV$ $\eta_f = 0.28$ $\mu/T = 1.75$
(consistent with $\pi\pi$ HBT analysis)

Gaussian radial density profile excluded!

SUMMARY

Recent NA49 Results on PbPb Collisions

- **Results on Hyperon Production**
  - Increased Y coverage
  - Strangeness enhancement confirmed

- **Φ meson production via K^+K^- decay**
  - observed in pp AND PbPb central
  - Y distribution wider in PbPb
  - no modifications of M and Γ found

- **$\Lambda^*(1520)$ production via pK^- decay**
  - observed in pp ONLY, upper limit in PbPb
  - disappearance in PbPb due to FSI

- **Event-by-Event Fluctuations**
  - PbPb events ("centrality" trigger) very uniform
  - No Dynamical Fluctuations of $\langle p_T \rangle$ and K/π

- **Deuteron Production**
  - agreement with coalescence model
  - extracted size parameter consistent with BE analysis