

ADDENDUM–4 to PROPOSAL SPSLC/P264

Request for 80 A·GeV Pb Beam in 1999 Heavy Ion Run

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The aim of the NA49 experiment [1] at the CERN SPS is a comprehensive and consistent study of hadronic interactions ranging from the elementary hadron–nucleon processes via hadron–nucleus interactions to collisions of heavy nuclei (A+A) at a variety of nuclear masses and energies. One of the main motivations for this programme [2, 3] is a critical test of the possibility that in the early stage of A+A collisions at the top SPS energy a new state of matter with deconfined quarks and gluons (Quark Gluon Plasma [4]) is created. This reaction scenario is consistent with anomalies observed in hadron production in A+A collisions at the SPS [5].

The hypothesis of QGP creation in A+A collisions at SPS implies that a transition from confined to deconfined matter created at the early stage should occur at collision energies lower than the top SPS energy. This transition is predicted to be accompanied by rapid changes or non-monotonic behaviour in the collision energy dependence of observables which are sensitive to the early stage (entropy and strangeness yields [6], flow [7] and event-by-event fluctuations [9]). In fact the data on A+A collisions at lower energies (AGS: ≈ 15 A·GeV, JINR Dubna: ≈ 4.5 A·GeV, Bevelac LBL and SIS GSI: below 3 A·GeV) together with the existing data at the highest SPS energy seem to indicate such behaviour in pion and strangeness [6] production and suggest that the transition may take place between top AGS energy (≈ 15 A·GeV) and top SPS energy for Pb nuclei (≈ 160 A·GeV) [10]. In the following we briefly summarize the basic results.

In a statistical/thermodynamic interpretation of hadron production the increase in the number of degrees of freedom at the early stage of the collision due to a transient QGP phase should be reflected in more abundant pion production. In fact, the energy dependence of the difference between the mean pion multiplicity per participant baryon for central A+A collisions and nucleon–nucleon (N+N) interactions indicate a change (Fig. 1 [6]). Up to the AGS energy the pion production in A+A collisions is reduced by about 0.3 pion per baryon relative to N+N interactions, approximately independent of collision energy and the size of colliding nuclei. This suppression pattern is not continuing at SPS energies. The data on central S+S and Pb+Pb collisions show an enhanced pion production by about 0.5 pion per baryon. The transition from suppression to enhancement occurs between AGS and SPS energies.

A reduction of the mass of strangeness carriers in partonic as compared to hadronic matter as well as a change in the effective number of strange degrees of freedom should reflect itself in the energy dependence of strangeness production. The ratio of the multiplicity of strange particles to pions is shown in Fig. 2 for central A+A collisions and N+N interactions [6]. Both ratios show a rapid increase from Dubna to AGS energies. The ratio for N+N interactions increases further by a factor of 2 when going from AGS to SPS energy. No such increase is observed for central A+A collisions, indicating a change of the energy dependence of the relative strangeness (to pion) production again occurring between AGS and SPS energies.

The data presented in Fig. 1 and Fig. 2 are in agreement with the prediction of a statistical model of the early stage in which deconfinement sets in between 30 and 65 A·GeV [9]. In particular the model predicts a non-monotonic behaviour of the strangeness to pion ratio, the maximum value of this ratio should be reached at the beginning of the transition region.

When crossing the transition region one may expect [7, 8] a modification of the equation of state which can influence the flow pattern of hadrons. Also observation of this signal of the transition needs data on nucleus–nucleus collisions at several energies (for more details see a note by E. Shuryak attached to our paper).

It is also argued [11] that the results at low SPS energies may allow to locate a possible second order critical point in the phase diagram of strongly interacting matter. Events which freeze-out in the vicinity of the critical point should exhibit large event-by-event fluctuations

which can be measured by the NA49 experiment (for more details see a note by K. Rajagopal, E. Shuryak, M. Stephanov and F. Wilczek attached to our paper).

In order to test the hypothesis of the transition to the deconfined matter occurring in the energy range between the top AGS and top SPS energies the NA49 Collaboration asked [2, 3] for a heavy ion run in 1999 with low energy Pb beam (5 weeks of 40 A·GeV beam and one week of 80 A·GeV beam). In January 1999 the SPSC scheduled the low energy Pb run at 40 A·GeV for the 1999 run period, however our request for 80 A·GeV beam was not granted.

In the meantime we have gathered new experimental data in support of our previous request of a short period of Pb beam at 80 A·GeV in 1999. At the end of the 1998 Pb-beam physics period extraction of 40 A·GeV Pb ions was set up in an SPS machine development run with beam in the H2 line. During 12 hours NA49 recorded about 30k central Pb+Pb collisions. In order to optimize the acceptance of the detector for the low energy run, the magnetic field in the Vertex Magnets was reduced to 1/4. The preliminary rapidity distribution of negatively charged hadrons for central Pb+Pb collisions at 40 A·GeV is presented in Fig. 3. It allows to make a first very preliminary estimate of the pion multiplicity in these collisions. Final efficiency and background corrections are still not ready which leads to an increased systematic error. The preliminary result at 40 A·GeV is plotted in Fig. 1. Evidently a supplementary measurement at the intermediate energy of 80 A·GeV is required to determine the energy dependence of pion production more precisely.

In order to illustrate that also other relevant physics observables can be extracted from the data collected during the short run we show several examples. In Fig. 4 three projections of the two pion correlation function are plotted for the 40 A·GeV Pb+Pb test data. The corresponding fitted radius parameters of the correlation function are compared in Fig. 5 with the results at AGS and top SPS energies. A rapid increase of the longitudinal parameter between AGS energy and 40 A·GeV is observed. The transverse momentum spectrum of K^- mesons identified by *TOF* and dE/dx measurements are presented in Fig. 6.

This preliminary analysis of the test data on central Pb+Pb collisions at 40 A·GeV demonstrates that even a short beam period enables NA49 to obtain significant physics results.

In order to establish the change of the energy dependence necessary to approach 160 A·GeV results additional data at an intermediate energy are needed. It is clear that data at 80 A·GeV should significantly help to establish the energy dependence of hadron production in the critical energy region in which rapid changes are observed. Four days of 80 A·GeV Pb beam should result in more than 100k central Pb+Pb collisions (50% efficiency is assumed). This allows for a study of inclusive production (integrated yields and spectra) of pions, neutral and charged kaons and hyperons. In addition precise analysis of two pion correlation and event-by-event fluctuations will be possible.

We repeat therefore our request for several days of 80 A·GeV Pb beam during the heavy ion run period in 1999.

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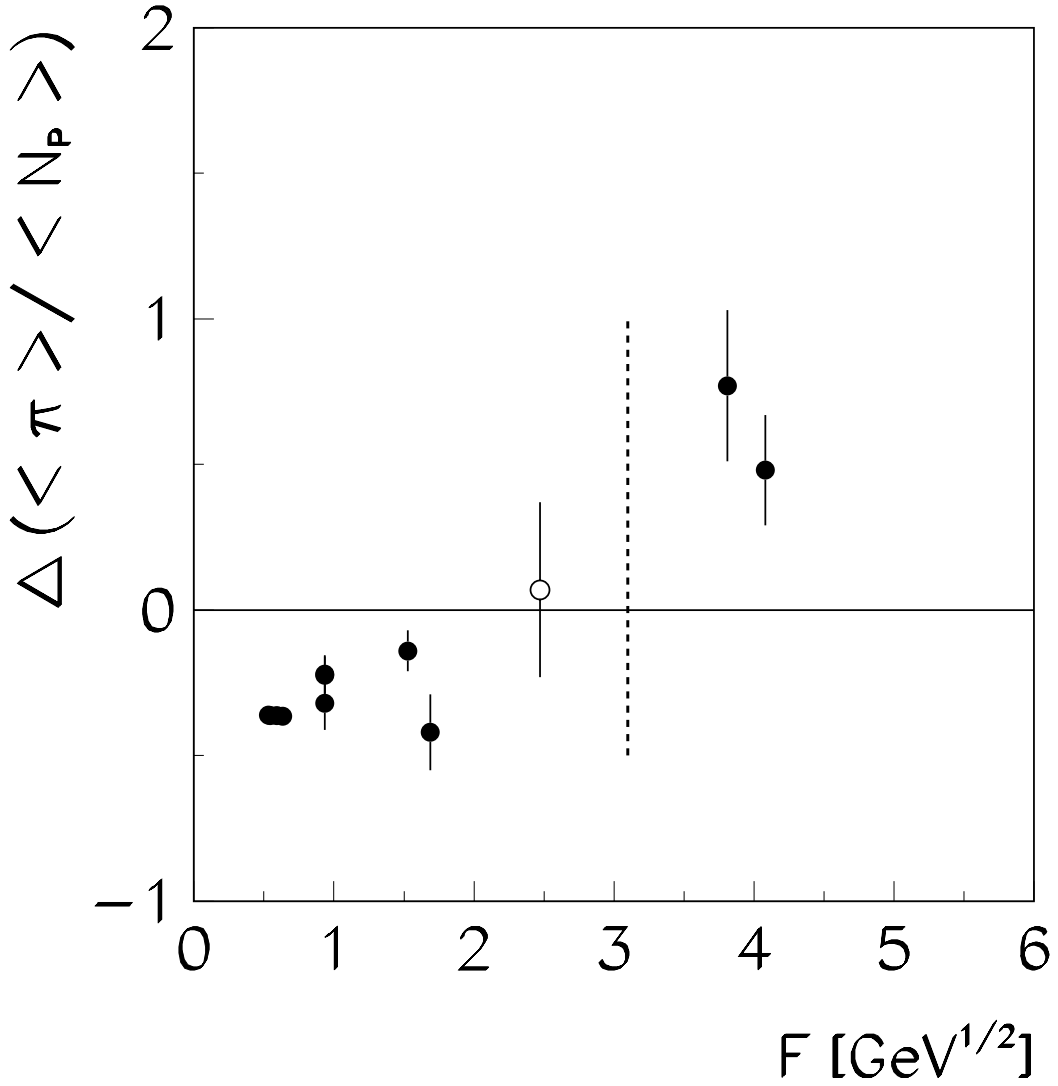


Figure 1: The dependence of the difference between pion/baryon ratios for central A+A collisions and nucleon–nucleon interaction at the same energy per nucleon on the collision energy [6] measured by the Fermi energy variable, $F = (\sqrt{s_{NN}} - 2m_N)^{3/4} / \sqrt{s_{NN}}^{1/4}$. The preliminary result for central Pb+Pb collisions at 40 A·GeV is shown by the open symbol. The dashed vertical line is plotted at 80 A·GeV.

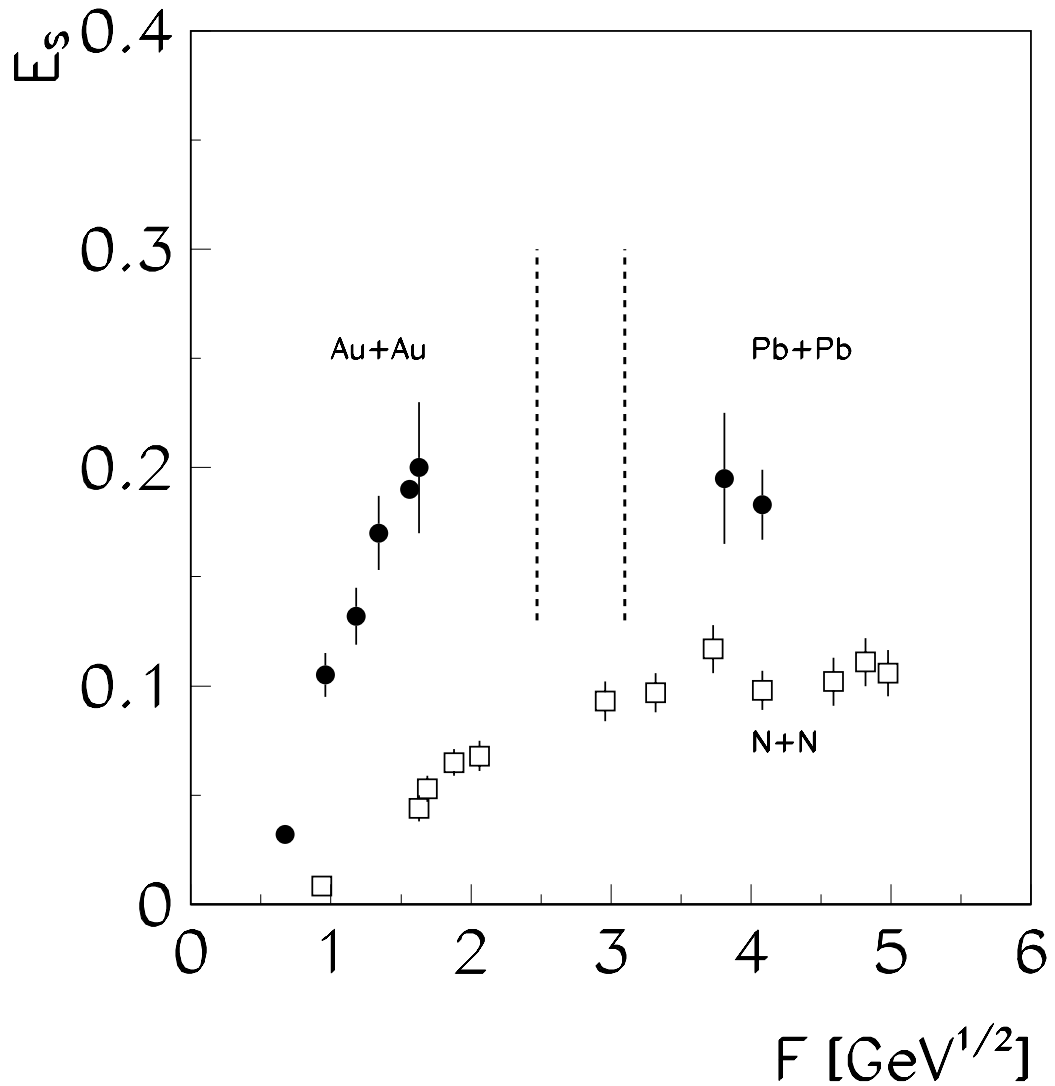


Figure 2: The dependence of the strangeness/pion ratio, $E_S = (\langle\Lambda\rangle + \langle K + \bar{K}\rangle) / \langle\pi\rangle$, for central A+A collisions (closed circles) and nucleon–nucleon interactions (open squares) as a function of collision energy [6] measured by the Fermi energy variable, F . The dashed vertical lines are plotted at 40 and 80 A·GeV.

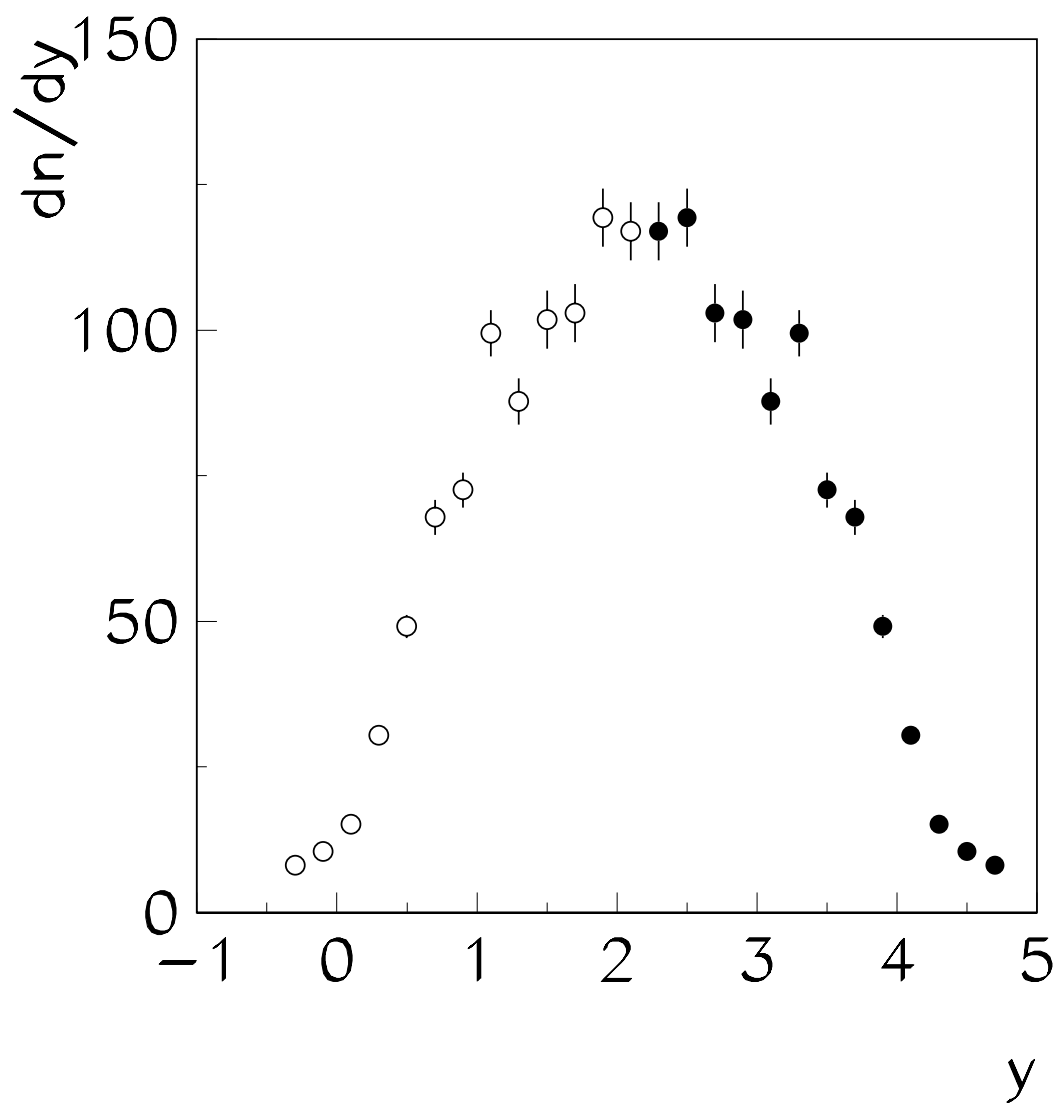


Figure 3: Rapidity distribution of negatively charged hadrons produced in central Pb+Pb collisions at 40 A·GeV. Full circles indicate measured data whereas open circles show points reflected with respect $y = y_{CMS}$.

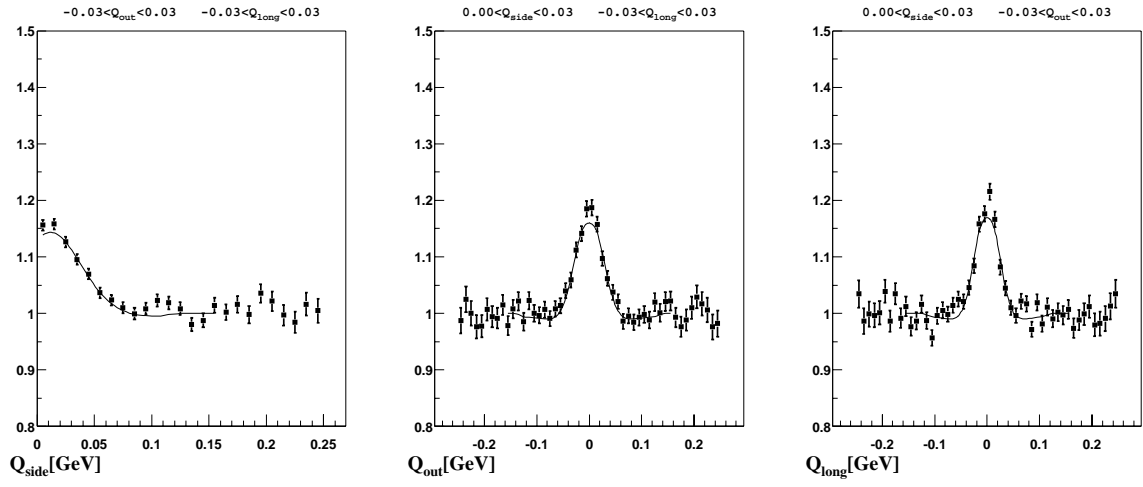


Figure 4: Projections of the two pion correlation function obtained in central Pb+Pb collisions at 40 A·GeV using the test data ($\langle y_{\pi\pi} \rangle = 4.2$ and $\langle k_T \rangle = 0.12$ GeV/c).

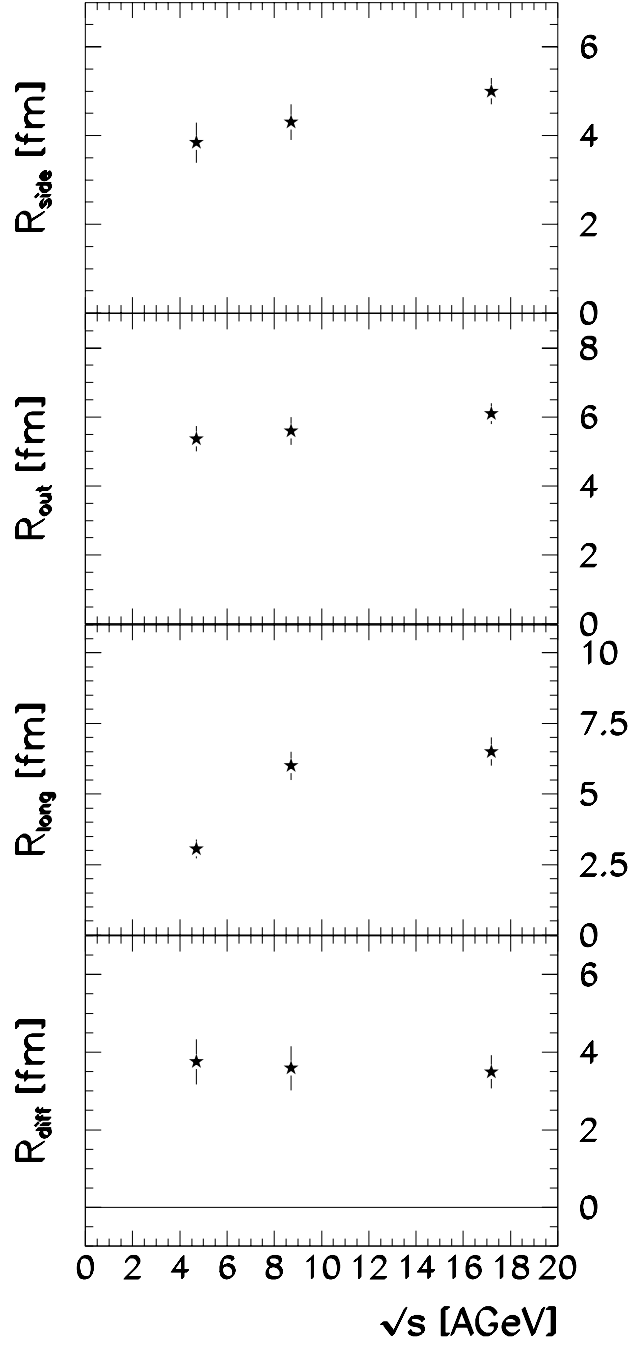


Figure 5: The collision energy dependence of the fitted radius parameters of the two pion correlation function for central Pb+Pb(Au+Au) collisions. The preliminary data point at $\sqrt{s} = 8.7$ GeV is from the 40 A·GeV test Pb+Pb data ($\langle y_{\pi\pi} \rangle = 4.2$ and $\langle k_T \rangle = 0.12$ GeV/c).

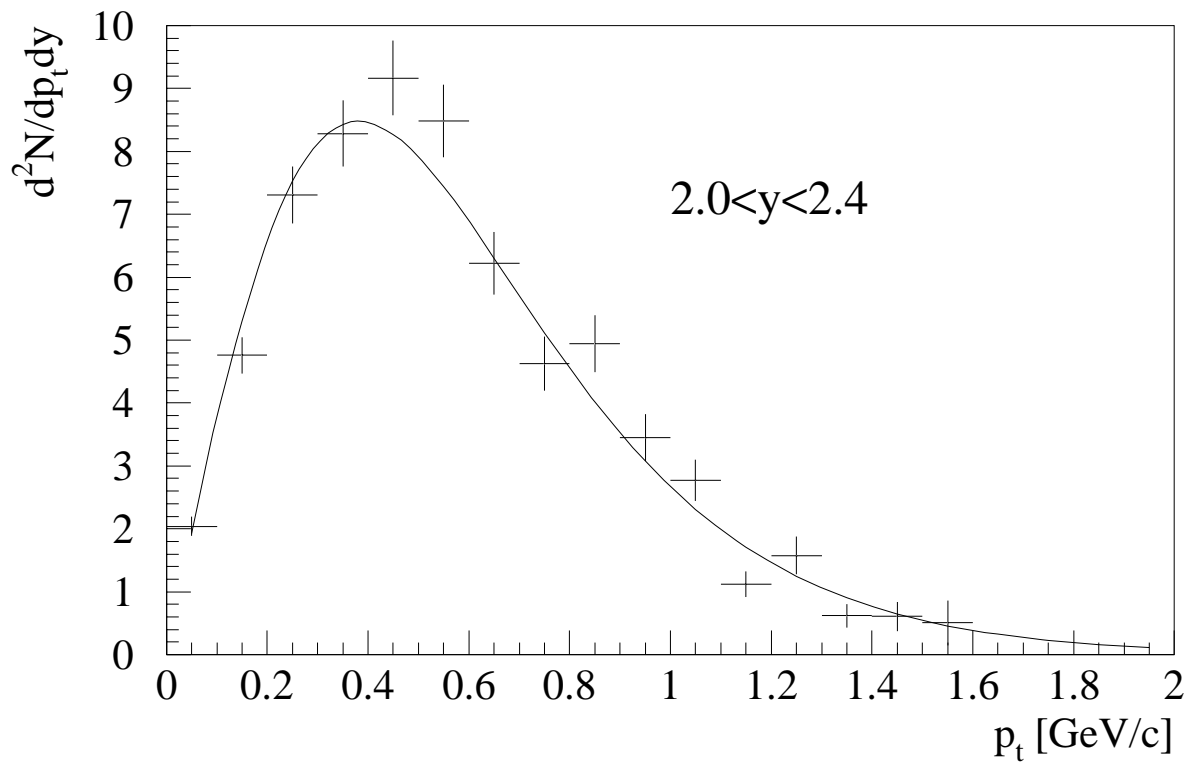


Figure 6: Transverse momentum spectrum of midrapidity K^- mesons produced in central Pb+Pb collisions at 40 A·GeV obtained using the test data.