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A Quark-Gluon Plasma Search in $\bar{p}$–p at $\sqrt{s}$=1.8 TeV *

The E-735 Collaboration

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A QUARK-GLUON PLASMA SEARCH IN $\bar{p}$-p AT $\sqrt{s}$ = 1.8 TEV

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We present a survey of the recent results of E-735 in its search for QGP signals at the Fermilab Collider. The basic data are the inclusive P_t distributions of centrally produced π, K, $\bar{p}$ and Λ^0 as a function of total charged multiplicity in the collision; the variation of $<P_t>$ and particle ratios are derived. Preliminary results on π-π correlations and inclusive photon production are also presented.

1. INTRODUCTION

1.1. E-735 Detector Capability

The detector was designed to measure low-P_t particle production as a function of total changed particle multiplicity, N_c, in the central region. The main capabilities of the detector[1] can be summarized as follows:

a) Trigger on N_c in $|\eta| < 3.25$ and $\Delta\phi = 360^0$ using a scintillation counter hodoscope[2] with 270 elements.

b) Measure $\frac{d^2N}{dYdP_t}$ with P_t = 0.1 to 1.5 GeV/c for π, K, $\bar{p}$, Λ^0, and

η for η between -0.3 and 1.0 and $\Delta\phi = 20^0$, using time-of-flight and momentum measurements[3].

c) Tracking[4] (no field) in $|\eta| < 1.6$ and $\Delta\phi = 360^0$ with a resolution in η of 0.1.

1.2. Data Runs with E-735 Detector

There have been two data runs to date; the salient parameters along with the special detector conditions are listed in the following table.

<u>Data Run Parameters</u>

Parameters	1987 Run	1988-89 Run
Maximum luminosity	1×10^{27}	1×10^{28} cm $^{-2}$s^{-1}
$\int$ L d t (1.8 TeV)	0.3	20 nb^{-1}
Events recorded	3×10^6	15×10^6
Energies, $\sqrt{s}$	1.8	0.3, 0.54, 1.0, 1.8 TeV
Detector conditions	No CTC 3/4 of TOF Cu plates	NaI array
Range of $<\frac{dNc}{d\eta}>$	2 - 20	2 - 30
Range of ϵ_0(BJ)	0.5 - 5	0.5 -7 GeV/fm^3

1.3. Topics of Analysis

Specific topics presented in this report include:

a) $\frac{<d^2N>}{dYdP_t^2}$ distributions verses $\frac{dNc}{d\eta}$, (which is defined as $\frac{Nc}{6.5}$) and derived quantities for π, K, $\bar{p}$ and Λ^0.

b) Source size derived from π - π correlations.

c) The ratio of inclusive photons (P_t > 260 MeV/c) to pions vs. $\frac{dNc}{d\eta}$.

The new data on Λ^0 derive from the '88 - '89 data run; the photon data resulted from the Cu plates placed in the spectrometer magnet for part of the '87 data run.

2. TRANSVERSE MOMENTUM DISTRIBUTIONS AND THEIR $\frac{dN}{d\eta}$ DEPENDENCE

2.1. Non-single Diffraction Data for π, K, $\bar{p}$ and Λ^0

Figure 1 shows the recently published data[5] for $\pi^{\pm}$, $K^{\pm}$, and $\bar{p}$ along with the new $\Lambda^0 + \bar{\Lambda}^0$ data from the '88 - '89 run. The region of Y that is averaged over depends on P_t and particle type; in the Λ^0 analysis the cross section was assumed to be independent of Y. We note that the production of unstable particles whose flight paths are comparable to our vertex resolution (~ 5 cm) will contribute to the P_t spectra shown; K^0s to $\pi^{\pm}$, $\bar{\Lambda}^0$ and $\bar{\Sigma}^-$ to $\bar{p}$, and $\Xi^0 + \Xi^-$ to $\Lambda^0 + \bar{\Lambda}^0$. Estimates of these effects are in progress. One observation in Fig. 1 is a clear trend for heavier particles to fall more slowly with P_t; e.g. $\bar{p}$'s become more numerous than $K^{\pm}$ for $P_t > 1.1$GeV/c. After fitting the spectra to suitable functions in order to extrapolate to $P_t = 0$ (see ref. 5), we calculate $<P_t>$ in the P_t region 0 to 1.5 GeV/c to be:

$\pi^{\pm}$	$K^{\pm}$	$\bar{p}$	$\Lambda^0 + \bar{\Lambda}^0$
0.362 $\pm$ .005	0.51 $\pm$ .01	0.61 $\pm$ .02	0.64 $\pm$ .03 GeV/c

where errors are statistical. The new $\Lambda^0 + \bar{\Lambda}^0$ data contain 7100 events and have a $\Lambda^0/\bar{\Lambda}^0$ ratio of 1.07 $\pm$ 0.05, this compares to 400 events published[6] earlier.

2.2 Average P_t dependence on $\frac{dNc}{d\eta}$.

The higher statistics Λ^0 data from the '88 - '89 run permit a determination of $<P_t>$ vs. $\frac{dNc}{d\eta}$; this preliminary result is displayed in Fig. 2 along with the recently published data[5] on π, K, and $\bar{p}$; again $<P_t>$ is taken over the region 0.0 to 1.5 GeV/c. All four particle types share the common feature of a linear rise of $<P_t>$ with $\frac{dNc}{d\eta}$ in the interval 2 to 9 followed by a region of reduced slope. The data suggest that the $<P_t>$ of the $\bar{p}$'s increases again for $\frac{dNc}{d\eta} > 13$; the Λ^0 data look similar to $\bar{p}$, but are not adequate to confirm a second rise. Using Bjorken's formula[6] to estimate the initial energy density of the collision, yields 2.2 and 3.1 GeV/fm^3 for $\frac{dNc}{d\eta}$ values of 9 and 13.

2.3 Particle ratios vs. $\frac{dNc}{d\eta}$

Given $\frac{d^2N}{dYdP_t^2}$ spectra in bins of $\frac{dNc}{d\eta}$, we derive particle ratios per unit rapidity by integrating on P_t. As shown in ref. 5, the $\bar{p}/\pi^-$ ratio is constant at 7 $\pm$ 1% over the measured range of $\frac{dNc}{d\eta}$. Figure 3 gives the $\Lambda^0/\bar{p}$ ratio over a similar range of $\frac{dNc}{d\eta}$; it too appears to be independent of $\frac{dNc}{d\eta}$. It follows from these two results that the Λ^0/π ratio is also flat (to $\pm$ 15%) in this interval. In contrast the K/π ratio (ref. 5) increases by 30%.

3. SOURCE SIZE FROM π - π INTERFEROMETRY

From a set of 73 K events of the '87 data which have two or more tracks in the spectrometer arm, we have calculated[8] the two-body momentum space correlations for like-sign pions. The analysis was done using the variable q_t and

$q_{||}$ as suggested by Kopylov and Podgoretskii[9]; integrating over $q_{||}$ gives the correlation expression:

$$R\ (q_t) = N\ (1 + \lambda\ \exp\ (-\ r^2 q_t^{\,2})) \qquad (1)$$

with r the source size. Fig. 4 shows the correlation ($q_{||}$ < 0.3 GeV/c) and the fit to equation (1). The analysis gives a radius of 1.19 $\pm$ 0.12 fm; the data sample used had $<\frac{dN_c}{d\eta}>$ = 12. The UA1 collaboration has performed a similar analysis[10] in $\bar{p}p$ at $\sqrt{s}$ = 0.63 TeV; they find r to increase linearly with $\frac{dN_c}{d\eta}$. In Fig. 5 we show the UA1 plot along with our point and a recent result from CDF[11] also at $\sqrt{s}$ = 1.8 TeV; both points agree with the UA1 curve.

4. PHOTON-TO-PION RATIO vs. $\frac{dN_c}{d\eta}$

Utilizing the data taken with Cu converter plates in the spectrometer, the P_t distributions of γ's with P_t > 260 MeV/c have been obtained[12] as a function of $\frac{dN_c}{d\eta}$. Summing over P_t, one obtains the ratio $\gamma/(\pi^+ + \pi^-)$ vs. $\frac{dN_c}{d\eta}$, which is graphed in Fig. 6. Within errors of 20%, the ratio appears constant out to $\frac{dN_c}{d\eta}$ = 19.

5. SUMMARY AND OUTLOOK

The search by E-735 for QGP evidence in centrally produced particles in $\bar{p}p$ collisions has revealed several interesting results in the behavior with variation of $\frac{dN_c}{d\eta}$ in the measured interval from 2 - 18. In $<P_t>$ we see a decrease in slope for all particles near $\frac{dN_c}{d\eta} \simeq 9$ corresponding to a Bjorken initial energy density of 2.2 $\mathrm{GeV/_{fm}}^3$. Above $\frac{dN_c}{d\eta}$ = 10, the increase of $<P_t>$ is small except for $\bar{p}$'s where the data suggest a 25% increase in the region 13 - 18. In the particle ratios, normalizing to π's, they (K, $\bar{p}$, Λ^0, γ) are all independent of $\frac{dN_c}{d\eta}$ within errors of $\pm$ 15% except for $K^{\pm}/\pi^{\pm}$ which increases by 30% in the interval 7 to 18.

Based on the E-735 data analyzed to date, one can conclude that QGP is not manifest in $\bar{p}p$ collisions at 1.8 TeV. Nonetheless, there are the two effects mentioned above, which can be explored with much improved sensitivity using the high-statistics data of the '88 - '89 run.

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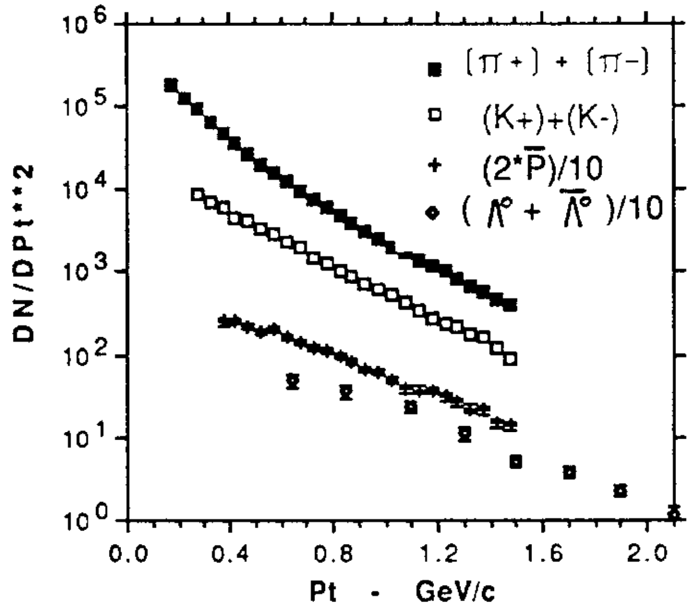

Fig. 1. Transverse momentum distributions for $\pi_\pm$, $K_\pm$, $\bar{p}$, and $(\Lambda^0 + \bar{\Lambda}^0)$ for non-single diffractive data.

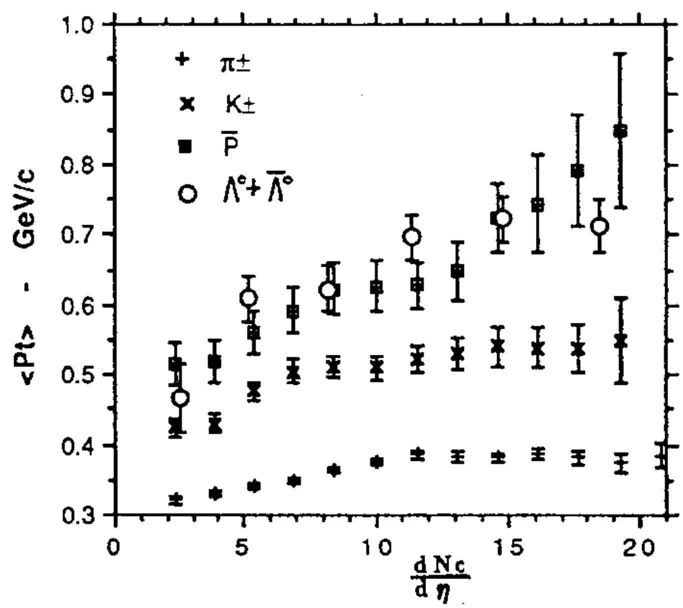

Fig. 2. $<P_t>$ vs. $\frac{dN_c}{d\eta}$ for $\pi_\pm$, $K_\pm$, $\bar{p}$, and $(\Lambda^0 + \bar{\Lambda}^0)$; averaged over P_t = 0-1.5 GeV/c.

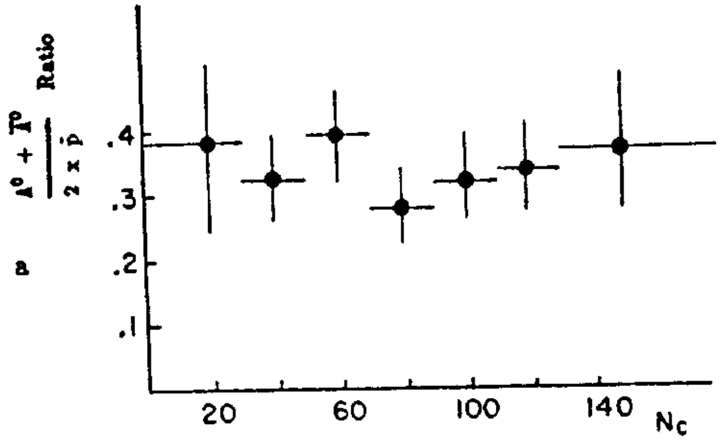

Fig. 3. Ratio $(\Lambda^0 + \bar{\Lambda}^0)/(2^*\bar{p})$ as a function of N_c. Errors shown include systematics.

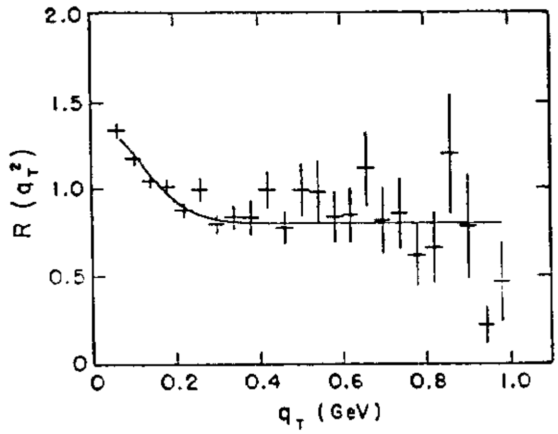

Fig. 4. Like-sign π-π correlation, $R(q_t)$, vs. q_t for $q_{||}$ less than 0.3 GeV/c.

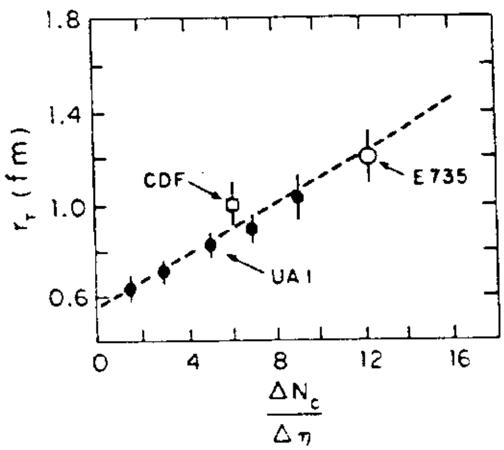

Fig. 5. Pion source radius, r_t, as a function of $\frac{dN_c}{d\eta}$.

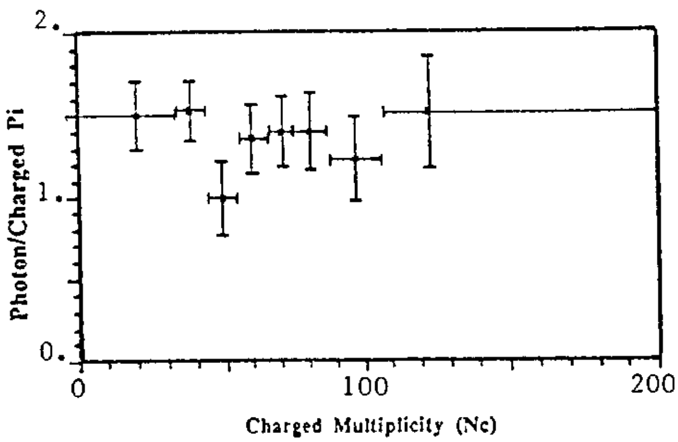

Fig. 6. Ratio of photons to charged pions vs. charged multiplicity.