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**NEGATIVE PARTICLE PRODUCTION IN NUCLEAR
COLLISIONS AT 60 AND 200 GeV/NUCLEON**

NA35 COLLABORATION

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NEGATIVE PARTICLE PRODUCTION IN NUCLEAR COLLISIONS

AT 60 AND 200 GeV/nucleon

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Abstract

The results on spectra of negative particles produced in $^{16}\text{O} + \text{Au}$ and $p + \text{Au}$ collisions at 200 GeV/nucleon and $^{16}\text{O} + \text{Au}$ at 60 GeV/nucleon are presented. The correlations of average rapidity and average transverse momentum with event multiplicity are studied. Spectral shapes are similar for central $^{16}\text{O} + \text{Au}$ and $p + \text{Au}$ collisions. The transverse momentum and rapidity distributions for central $^{16}\text{O} + \text{Au}$ and $p + \text{Au}$ collisions differ strongly from corresponding distributions for $p + p$ interactions.

The Fritiof model fails to describe the shapes of the transverse momentum distributions. The simple thermodynamical model of a single fireball does not fit the midrapidity transverse momentum distributions, and the rapidity distributions.

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1. Introduction

Nuclear collisions at ultrarelativistic energies open a new field of study in strong interaction physics. The possibility to create high energy density over extended regions of space may lead to a new phase of matter consisting of deconfined quarks and gluons [1]. The study of particle production in nuclear collisions will contribute to the understanding of the conditions under which the quark-gluon plasma may be produced.

In this paper we present results of the CERN SPS experiment NA35 [2] on negative particle production. Rapidity and transverse momentum distributions are obtained for $^{16}\text{O} + \text{Au}$ and $p + \text{Au}$ collisions at 200 GeV/nucleon (GeV/n) and $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n. The correlations of average rapidity and average transverse momentum with negative particle multiplicity are studied. To find possible deviations from a simple linear extrapolation of nucleon-nucleon collisions our results are compared with the Fritiof model predictions [3]. The shapes of the transverse momentum distributions are compared to the results of $p + p$ interactions at the same energy per nucleon. It is attempted to interpret the transverse momentum distributions around midrapidity in the spirit of the thermodynamical model.

The experimental details are described in Section 2. In Section 3 we present and discuss the experimental results. Conclusions are presented in Section 4. The results on cross-sections and multiplicities for collisions of O^{16} with nuclear targets at 200 and 60 GeV/n are presented in [4].

2. Experimental Setup

The data were obtained from a $2 \times 1.2 \times 0.72 \text{ m}^3$ Streamer Chamber [5] placed in a magnetic field of 1.5T and exposed to beams of protons and ^{16}O nuclei accelerated in the CERN SPS to 60 and 200 GeV/n. A gold target of 0.94 g/cm^2 thickness was placed 8 cm upstream from the chamber entrance window. Three cameras equipped with image intensifiers of 2000 fold luminous gain registered the interactions on 70 mm film. The picture quality is good as is seen in Fig. 1 in which an event obtained from a central collision of ^{16}O with Au at 60 GeV/n is shown. The overall spatial resolution in the chamber was about 2 mm.

For the subsequent analysis three triggering systems were used:

- A minimum bias trigger ('MBT') selecting essentially all inelastic collisions (see also reference [4]).
- A forward energy veto trigger ('FET') selecting interactions with total energy deposited in the Veto calorimeter covering the projectile fragmentation region ($\theta_{\text{lab}} < 0.3^\circ$) smaller than some threshold energy. It essentially vetoes events having more than a certain number of projectile spectators.
- A transverse energy trigger ('TET'), selecting interactions for which the total transverse energy deposited in the Photon Position Detector (PPD) calorimeter ($2.44^\circ < \theta_{\text{LAB}} < 14.4^\circ$ 200 GeV/n and $3.1^\circ < \theta_{\text{LAB}} < 18.0^\circ$ for 60 GeV/n) exceeded some transverse energy threshold. The PPD contains about 98% of the electromagnetic and some fraction of the hadron shower energy.

The general setup of all detectors and the details of the trigger calorimeters are described in references [5 and 6].

For several trigger modes (see Table I) the tracks of all negatively charged particles from $p + \text{Au}$ and $^{16}\text{O} + \text{Au}$ interactions were measured. The corresponding event samples are labeled in the text by the abbreviation of the trigger mode and the corresponding trigger cross section in [mb]. In different laboratories different measurement and reconstruction procedures were used. The results of the data acquisition procedures are subject to various experimental biases connected with losses due to unmeasurable tracks, details of the reconstruction procedures, γ conversion in the target producing additional electron and positron tracks, secondary interactions, and decays of strange particles close to the target.

Appropriate corrections for the measurement and reconstruction biases were applied. Corrections for electron and positron admixture from γ conversion in the target were obtained from a Monte Carlo calculation using the experimental negative particle distributions and assuming equal π^0 and π^- meson multiplicities and spectra. The biases due to secondary interactions and particle decays close to the target are estimated to be small in comparison with statistical and other systematic errors.

The data from the phase-space region $0.5 < y_\pi < 4.5$, $p_{\text{LAB}} > 0.1 \text{ GeV/c}$, and $p_T < 2 \text{ GeV/c}$ are considered to be acceptance corrected and essentially bias free. A comparison was made with results of measuring film with streamer tracks generated from simulated events, for which multiplicity and momenta are known. Along with an

analysis of the applied corrections, this allows us to estimate that the systematic errors in $\langle p_T \rangle$, $\langle y \rangle$, and n_- are less than 15 MeV/c, 0.1, and 10% respectively (for the definition of n_- see Table I). The influence of the rapidity cut on the mean value of the rapidity distribution, $\langle y \rangle$, at the highest multiplicities was estimated using the Fritiof code: $\langle y \rangle_{\text{true}} = \langle y \rangle_{\text{observed}} + \Delta y$, where $\Delta y \approx -0.03$ for $^{16}\text{O} + \text{Au}$ and $\Delta y \approx 0.06$ for $p + \text{Au}$ at 200 GeV/n and $\Delta y \approx 0.16$ for $^{16}\text{O} + \text{Au}$ at 60 GeV/n.

Table I. Summary of the data samples analysed in the paper. Incident momentum per nucleon (P_{LAB}), projectile and target nuclei (A_P, A_T), trigger mode (see text), trigger cross section (σ), ratio of this cross section to the total inelastic cross section ($\sigma/\sigma_{\text{inel}}$), measured number of events (N_{ev}), and average particle multiplicity n_- as obtained from the scan [4] are given.

TABLE I

P_{LAB} [GeV/n]	A_P, A_T	Trigger Mode	σ [mb]	$\sigma/\sigma_{\text{inel}}$	N_{ev}	$\langle n_- \rangle$
200	p + Au	TET *	260	0.16	324	11.3
200	0 + Au	FET	700	0.20	108	97
200	0 + Au	FET	56	0.016	167	124
200	0 + Au	TET *	46	0.013	54	129
60	0 + Au	MBT	3440	1.00	80	27
60	0 + Au	FET	1360	0.40	58	67
60	0 + Au	TET *	130	0.038	70	80

*) The electromagnetic PPD calorimeter is sensitive also to hadronic energy for which, in the configuration with magnetic field on, the conversion algorithm applied to calculate the transverse energy is incorrect. It has been found, however, that the trigger dependence on this bias is small: in comparing the field on and off configurations the trigger cross sections differ only by 30% for identical PPD high transverse energy thresholds.

Samples of negative particles (after corrections for electrons) are expected to consist mainly of π^- mesons. Therefore we assume the pion mass in the calculation of the rapidity for negative particles. Nonidentified negatively charged kaons and antiprotons induce an apparent increase of $\langle y \rangle$ to larger values. Thus $\langle y \rangle_{\pi^-} = \langle y \rangle_{\text{observed}} - \Delta y$, where $\Delta y \approx 0.05$ is obtained for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and $\Delta y \approx 0.04$ at 60 GeV/n from the corresponding Fritiof event samples. In the following sections no corrections have been made for these effects and statistical errors are indicated only.

3. Experimental Results

In this section the rapidity and transverse momentum distributions of negative particles are presented and discussed. The distributions are normalized to the average multiplicity of the event samples considered:

$$p(x) = (1/N_{\text{ev}}) dn_-/dx$$

where x stands for y or p_T . The rapidity distributions of negative particles produced in central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n are shown in Fig.2. The position of the maximum of the rapidity distribution at 200 GeV/n is well below $y=3$, which is the position of the maximum and the mean value for $p + p$ interactions at this energy. Its width ($\Delta y_{\text{FWHM}} = 3.1$) is smaller than that of minimum bias $p + p$ data at 200 GeV [7] where it is about $\Delta y_{\text{FWHM}} = 3.5$, and also much smaller than the width of the rapidity distribution for minimum bias $p + \text{Xe}$ interactions [7]. The shape of the y distribution for central $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n is similar to the 200 GeV/n case. For the widths of the y -distributions as function of n_- (not shown) we find a slow increase if the trigger is relaxed towards peripheral collisions. Also, the multiplicity decreases and the position of the maximum moves toward the corresponding value for $p + p$ collisions, showing the dependence of particle production characteristics on collision centrality.

Although narrower than minimum bias $p + p$ distributions the central collision $^{16}\text{O} + \text{Au}$ rapidity distributions are still significantly wider than those obtained from particles which are emitted isotropically from a fireball at rest in the c.m. system ($\Delta y_{\text{FWHM}} \approx 1.8$). This width is roughly temperature independent for $T > 100$ MeV. Our data thus show a significant preponderance of longitudinal over transverse momen-

turn. In fact, we obtain a ratio of mean p_T to mean longitudinal momentum in the $(16 + 56)$ c.m. frame for negative particles of about 0.6 for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n (FET(56)) with a systematic error (derived from the Fritiof model) of at most 0.15 due to our limited acceptance in rapidity. The isotropic fireball model prediction is $\pi/2 = 1.57$.

When studying the difference between nucleus-nucleus collisions and hadron-hadron interactions the selection of the impact parameter range plays an important role. This macroscopic parameter determines the overlap between projectile and target nuclei and thus the number of nucleons participating in the reaction. For sufficiently large impact parameters nucleon-nucleon collision characteristics are expected to dominate whereas phenomena special to nucleus-nucleus collisions might occur at small impact parameters. Since the impact parameter is not directly measurable we have chosen the negative particle multiplicity n_- as the observable which replaces the impact parameter. We base this choice on the results obtained from the Fritiof code in which a strong correlation between n_- and b is found, as shown in Fig.3.

In Fig.4 the mean rapidity, $\langle y \rangle$, is plotted as function of n_- for $^{16}\text{O} + \text{Au}$ and $p + \text{Au}$ collisions at 200 GeV/n (Fig.4a) and $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n (Fig.4b). The main features of the experimental data in Figs.4a and 4b are:

- (i) no significant dependence of $\langle y \rangle$ on the trigger mode for fixed n_- in $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n. This justifies the choice of n_- to study the systematic behaviour of particle production;
- (ii) a smooth decrease of the mean rapidity with increasing multiplicity, which is the consequence of the increasing number of participating nucleons from the target per participating projectile nucleon;
- (iii) consistency of $\langle y \rangle$ with the corresponding $p + p$ data at small multiplicities, i.e. large impact parameters. These observations are similar to the results from lower energy nucleus-nucleus collisions [8].

The solid lines in Fig.4 show the Fritiof model predictions (after subjecting the generated events to our acceptance cuts). The comparison with the Fritiof model reveals no dramatic differences; however, the mean rapidity of the experimental data seems to be consistently lower than the prediction at high multiplicities in nucleus-nucleus collisions. It should be noted that the mean rapidities in Fig.4 are not uniquely correlated with the rapidity of the centre of mass, y_{cm} , of an interacting system formed by A projectile and B target nucleons. y_{cm} has to be calculated from balancing to

zero the longitudinal momenta of all particles in each event. Even more important, the c.m. rapidity of the *produced* negative particles need not be the same as the c.m. rapidity of *all* participating particles.

The transverse momentum distributions of negative particles for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n are shown in Fig. 5. Their mean values and shapes are analysed in more detail below. The mean transverse momentum, $\langle p_T \rangle$, is studied as a function of n_- in Fig.6a and 6b for the reactions $^{16}\text{O} + \text{Au}$ at 200 and 60 GeV/n as well as $p + \text{Au}$ at 200 GeV. As in Fig.4 no trigger dependence is observed except for the highest transverse energy trigger data (see below). Only for the $p + \text{Au}$ collisions at 200 GeV is a significant variation of $\langle p_T \rangle$ with n_- observed. The $p + \text{Au}$ interactions exhibit a decrease of $\langle p_T \rangle$ with multiplicity which is reproduced qualitatively by the Fritiof model (solid line).

An increase of $\langle p_T \rangle$ with multiplicity, not observed in our data, was proposed to accompany the transition from the hadronic to a quark - gluon plasma phase [9]. A small rise of $\langle p_T \rangle$ with increasing multiplicity was observed in $p-p$ data from ISR [10] and SPS -collider experiments [11] in restricted intervals close to mid-rapidity. Also, significantly higher values of $\langle p_T \rangle$ than observed elsewhere have been reported for the π^0 fraction of cosmic ray events studied in the range from 0.5 to 10 TeV/n by the JACEE collaboration [12]. In order to check whether any of our events have an anomalously high $\langle p_T \rangle_{\text{ev}}$ we show in Fig.7a the distribution of the mean transverse momentum $\langle p_T \rangle_{\text{ev}}$ of individual events for $^{16}\text{O} + \text{Au}$ at 200 GeV/n (for a subsample of events from FET(56)). No high $\langle p_T \rangle_{\text{ev}}$ tail is visible at the level of our statistics. This finding is quantified in Fig. 7b where the ratio between the experimental distribution and a randomized distribution is presented. The latter was obtained by generating from the event sample contained in Fig.7a a new set of synthetic events (with the same multiplicity distribution) by a Monte Carlo redistribution of the single pion momenta from the pool of all measured tracks. The resulting distribution of the ratio is flat indicating the absence of multiplicity p_T -correlations.

So far we studied the behaviour of the mean transverse momentum as a function of the event multiplicity. It is also interesting to analyse how $\langle p_T \rangle$ depends on the rapidity of the particles. Fig.8 shows this dependence for central $^{16}\text{O} + \text{Au}$ collisions (FET(56) and TET(46)) at 200 GeV/n. The data for $p + p$ collisions at 200 GeV are also presented for comparison [13]. The mean transverse momentum for high transverse energy trigger data are significantly higher than the corresponding values for forward energy trigger data below $y = 3.5$ (Fig.8). It seems that the extremely high total trans-

verse energy per event required in the PPD calorimeter for this trigger condition is achieved not only by increasing the number of produced particles, as is apparent for the highest multiplicity data points (TET(46)) in Fig.6a , but also by increasing the mean transverse momentum per particle (Fig.8).

Although $\langle p_T \rangle$ for central $^{16}\text{O} + \text{Au}$ collisions is close to $\langle p_T \rangle$ for $p + p$ collisions at the corresponding energy, the shapes of these p_T distributions differ significantly. In Fig.9 we compare the transverse momentum distribution of negative particles produced in (min. bias) $p + p$ interactions [13] with the corresponding distributions for $^{16}\text{O} + \text{Au}$ FET(56) (Fig.9a) and $p + \text{Au}$ TET(260) (Fig.9b) collisions at 200 GeV/n. Plotted are the ratios of p_T -distributions normalized to unity, $R(p_T)$. It should be mentioned here that the rapidity distributions for $^{16}\text{O} + \text{Au}$ FET(56) and $p + \text{Au}$ TET(260) collisions are similar. We find drastic differences in the spectral shape between $p + p$ interactions and p and ^{16}O collisions with Au. Both show a significant excess of particles at low transverse momenta ($p_T < 0.5$ GeV/c) and at high transverse momenta ($p_T > 1$ GeV/c). The latter enhancement was first observed by Cronin et al. in hadron-nucleus interactions [14] and later in $\alpha + \alpha$ interactions at $\sqrt{s_{NN}} = 31$ GeV [15] and was usually interpreted on the basis of models assuming multiple hard scattering and/or high momentum components in nuclear structure functions [16].

The published $h + A$ data in the low p_T region ($p_T < 0.5$ GeV/c) are much poorer, however, the increase of $R(p_T)$ with decreasing p_T is well established experimentally [17,18]. The interpretation of this effect is not clear. Such a behaviour has also been observed in hadron-hadron collisions at the ISR [19] in a small interval around midrapidity. In general forming the $R(p_T)$ ratio of high over low multiplicity events, or comparing high with low c.m. energy data [20] or comparing $\alpha + \alpha$ with $p + p$ or $d + d$ collisions one is always led to the same qualitative finding that the more 'intense' collisions favour the low and high p_T particles. Naively one might be tempted to associate the effect with an increasing demolition of leading spectator quark or diquark structures as more 'intense' interactions are considered, which go along with a higher energy density trapped near midrapidity. Extending the argument to central $p + \text{nucleus}$ and $^{16}\text{O} + \text{nucleus}$ collisions, where the effect is even more manifest, one might argue that the higher number of scattering centers along the path of the incident nucleons readily accomplishes an even more efficient dissolution of leading quark structures.

The observables treated in the present study, rapidity distributions and the shape of mid-rapidity p_T distributions, should therefore not be reproduced by a superposition

of minimum bias $p + p$ data. Also we find that the Fritiof model does not reproduce the data either, as is observed in Fig.9a where the model prediction is shown as a solid line. The p_T distribution as obtained from the Fritiof model was divided by the same $p + p$ distribution as used for the experimental $^{16}\text{O} + \text{Au}$ data. The observed variation of $R(p_T)$ in the experimental data is not present in the Fritiof model. In general, the comparison of our data with the Fritiof model yields rough agreement in the behaviour of the $\langle y \rangle$ and $\langle p_T \rangle$ variables, but the details of the corresponding distributions differ significantly.

Thermodynamic models have been used in the analysis of high energy hadron-hadron collisions [21]. This picture should be especially suited to describe high energy central nucleus-nucleus collisions because of the large number of particles involved. The simplest approach, the formation of a single fireball in the c.m. system, makes definite predictions for both rapidity and p_T distributions. As already pointed out above the experimental rapidity distribution differs significantly from the predictions of the simple fireball model. As to the transverse momentum observable our results on two pion interferometry from $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n [22] suggest the formation of a fireball at midrapidity distinct from a reaction zone extending over the whole rapidity range. In the following we therefore analyse the transverse momentum spectra in a small interval around midrapidity. In Figs.10 and 11 we show the p_T -distributions of negative particles produced in the rapidity interval $2 < y < 4$ for $p + p$ (minimum bias) interactions [13] and $2 < y < 3$ for central $^{16}\text{O} + \text{Au}$ collisions. Assuming that the resulting distributions are made up only of pions emitted directly from a single fireball formed at midrapidity ($y = 2.5$ for $^{16}\text{O} + \text{Au}$ and $y = 3$ for $p + p$) we have fitted the temperature, T , of the Bose-Einstein distribution using the following function:

$$d\sigma/dp_T = C \int_{-y_1}^{y_2} (p_T m_T \cosh y / (e^{(m_T \cosh y)/T} - 1)) dy$$

where y_1, y_2 are the limits of the rapidity intervals and $m_T = \sqrt{p_T^2 + m^2}$. The fit is in qualitative agreement with the $p + p$ data although a small overshoot at low and high p_T is apparent here (Fig.11, $\chi^2/\text{NDF} = 2.2$, $T = 135 \pm 1/2$ MeV), whereas the fit for $^{16}\text{O} + \text{Au}$ (not shown in Fig.10) reveals large discrepancies leading to χ^2/NDF of 5.2. This means that the differences between the $p + p$ and $^{16}\text{O} + \text{Au}$ spectra, as observed when comparing Figs.10 and 11, rather accentuate than reduce the deviations from the thermal spectrum in the case of $^{16}\text{O} + \text{Au}$ collisions, contrary to the naive expectation that such multiparticle interactions achieve thermalization more easily.

Assuming an additional thermal source at rest at midrapidity, but with a different temperature, one can fit two temperatures and the relative yield of the two samples of pions (N_1/N_2) to the $^{16}\text{O} + \text{Au}$ spectrum at 200 GeV/n (Fig.11). The data are reproduced well for $T_1 = 43 \pm 4$ MeV, $T_2 = 153 \pm 5$ MeV, and $N_1/N_2 = 0.23 \pm 0.07$ with $\chi^2/\text{NDF} = 1.8$. The same qualitative finding has already been reported for pion spectra in Ar + KCl collisions at 1.8 GeV/n [23].

A somewhat similar two component structure has recently been observed in p_T spectra from nucleus-nucleus collisions in a cosmic ray emulsion experiment [24]. There the two components were attributed to a fireball temperature and a blast wave velocity. Confirmation of such an interpretation [25] will require analysis of the p_T spectra of nucleons, which we do not present here. It seems that only rather complicated thermal models can reproduce the p_T spectra of negative particles in hadron-nucleus and nucleus-nucleus collisions, even if only midrapidity particles are considered.

4. Conclusions

The average features of negative particle production in $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n and 200 GeV/n follow the behaviour of hadron-nucleus data at high energies and nucleus-nucleus data at lower energy. Strong differences are found between average hadron-hadron and central nucleus-nucleus collisions: it seems that some features of violent hadron-hadron collisions are reproduced in average central nucleus-nucleus collisions as well as in central hadron-nucleus interactions. The Fritiof model fails to describe our transverse momentum distributions for central collisions, although multiplicity distributions [4] are reproduced relatively well by the model. The transverse momentum spectra at midrapidity differ significantly from the expectations of the simple fireball model.

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Figure Captions

Fig. 1

A central $^{16}\text{O} + \text{Au}$ collision at 60 GeV/n as seen by the Streamer Chamber.

Fig. 2

Negative particle rapidity distribution for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n. Data are shown only in the rapidity range $0.45 - 4.55$.

Fig. 3

Correlation between impact parameter b and negative particle multiplicity n_- for $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n as derived from the Fritiof model. The dashed envelopes indicate the FWHM of the corresponding multiplicity distributions.

Fig. 4

Dependence of the mean rapidity on multiplicity of negative particles for $p + \text{Au}$ and $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n (a) and for $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n (b). Solid lines show the Fritiof model predictions.

Fig. 5

Negative particle transverse momentum distribution for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n and 60 GeV/n in the rapidity interval $0.45 < y < 4.55$.

Fig. 6

Dependence of average transverse momentum on multiplicity of negative particles for $p + \text{Au}$ and $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n (a) and for $^{16}\text{O} + \text{Au}$ collisions at 60 GeV/n (b). Arrows indicate $\langle p_T \rangle$ for inelastic $p + p$ collisions corrected for our acceptance cuts. Solid lines show the Fritiof model predictions.

Fig. 7

Distribution of $\langle p_T \rangle_{ev}$ for a subsample of 105 FET(56) events (a). The mean number of negative particles per event used in the averaging was about 115. (b) The ratio of the distribution in (a) with a distribution of M.C. events which were obtained by rearranging the single particle momenta from the pool of all measured tracks into a new set of synthetic events with the same multiplicity distribution.

Fig. 8

The average transverse momentum dependence on rapidity for central $^{16}\text{O} + \text{Au}$ collisions is compared for two trigger modes FET(56) and TET(46) at 200 GeV/n. Also shown are data from $p + p$ interactions at 200 GeV/c.

Fig. 9

Ratios of the transverse momentum distributions, $R(p_T)$, of $^{16}\text{O} + \text{Au}$ (a) and $p + \text{Au}$ (b) to $p + p$ at 200 GeV/n. The dashed lines indicate $R(p_T) \equiv 1$.

Fig. 10

Transverse momentum spectrum for minimum bias $p + p$ interactions at 200 GeV/c in the rapidity interval $2.0 < y < 4.0$. Also shown is a thermal model fit (see text).

Fig. 11

Transverse momentum spectrum for central $^{16}\text{O} + \text{Au}$ collisions at 200 GeV/n in the rapidity interval $2.0 < y < 3.0$. Also shown is a two temperature thermal model fit (see text).

Fig. 2

Fig. 1. A central $^{16}\text{O} + \text{Au}$ collision at 60 GeV/n as seen by the Streamer Chamber.

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11