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ANTIPROTON PRODUCTION IN 14.6 A·GeV/c SI+A COLLISIONS.

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Preliminary data are presented for the production of antiprotons and other charged particles produced in minimum bias and central Si+Al and Si+Au collisions measured using the E802 spectrometer at the Brookhaven Alternating Gradient Synchrotron. The antiproton data presented cover the range of transverse momentum from 0.3 to 1.2 GeV/c and lab rapidities from 0.9 to 1.7. The extracted rapidity densities, transverse mass slopes, and particle ratios from minimum bias and central Si+A collisions are compared to those measured in p+p and p+A collisions.

Experiment E802[1] at the Brookhaven National Laboratory Alternating Gradiant Synchrotron has systematically measured inclusive and semi-inclusive spectra for pions, kaons, protons, deuterons and antiprotons emitted from collisions of protons, ^{16}O and ^{28}Si at 14.6 A·GeV/c with targets ranging from beryllium to gold. Here we report preliminary measurements for antiproton production near mid-rapidity for minimum bias and central Si+Al and Si+Au collisions at 14.6 A·GeV/c. Antiproton production in nucleus-nucleus collisions has previously been measured for only subthreshold beam energies[2].

For all target and trigger combinations, approximately 1000 antiprotons have been measured using the E802 main spectrometer, with particle identification provided by the Time-Of-Flight (TOF) wall[1]. The resolution of the TOF wall (80 ps) and a flight-path of 650 cm allows clean separation of antiprotons and negative kaons up to momenta of 3.7 GeV/c (500 ps peak-to-peak separation). The antiproton data presented cover the range of transverse momentum from 0.3 to 1.2 GeV/c and lab rapidities from 0.9 to 1.7.

The invariant cross sections of charged particles at fixed rapidity are well described by

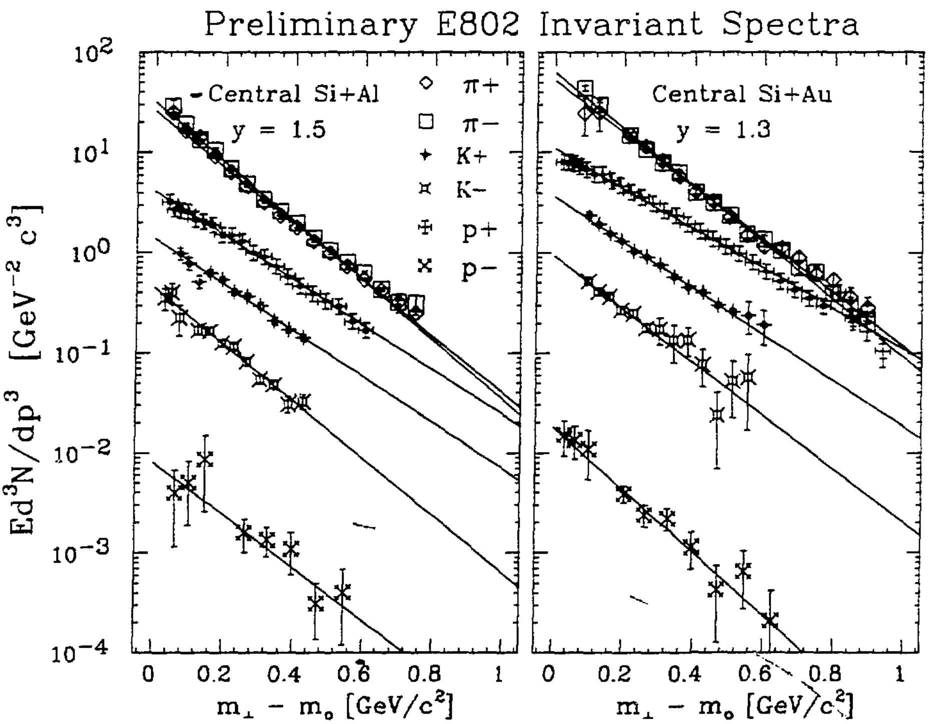

Figure 1: Invariant spectra of pions, kaons, protons and antiprotons produced in central Si+Al (left) and central Si+Au (right) collisions.

exponentials in transverse mass: $Ed^3N/dp^3 \propto \exp[-(m_\perp - m_o)/B]$. In Figure 1, we display the invariant cross sections of particles produced in central Si+Al and central Si+Au collisions at rapidities of 1.5 and 1.3, respectively. Exponential $m_\perp$ fits to the spectra are indicated by the solid lines. Central collisions are defined by a hardware cut on the observed multiplicity in the Target Multiplicity Array[1] corresponding to roughly the upper 7% of the distribution. Note that the invariant cross sections have been divided by their corresponding target-out corrected total trigger cross sections.

From Figure 1 it is evident that the inverse $m_\perp$ slopes (B) of particles depend on particle type as well as the production system. In Table 1, we summarize the inverse $m_\perp$ slopes of pions, kaons, protons, and antiprotons produced in minimum bias and central Si+Al and Si+Au collisions. The slopes have been averaged over the rapidity range $0.9 \le y \le 1.7$ in order to reduce the statistical uncertainties for the antiproton results. Within the statistical uncertainties of 30 MeV, the inverse $m_\perp$ slopes of the antiproton spectra are independent of the system from which the antiprotons are produced, having an average value of 140± 11 MeV. Whereas this value is similar to that of pions produced in the same collisions, the average antiproton slope is smaller than that of kaons and protons. In contrast, models with hydrodynamical expansion[3] have predicted that the proton and antiproton spectra should have similar slopes due to that the fact that they freeze out at the same time and have similar masses.

Although the antiproton slopes differ from those of protons produced in Si+A collisions, they are similar to slopes of antiproton spectra for p+p and p+A collisions at similar beam energies. From the antiproton distributions of references [4] and [5], we have extracted inverse $m_\perp$ slopes of 110–130 MeV for p+p collisions and 130–170 MeV for p+A collisions. For these data sets, the antiproton invariant cross sections plotted at fixed rapidities are well represented by exponential distributions in $m_\perp$ for transverse momenta down to 50 MeV/c.

System	Trigger	π^+	π^-	K^+	K^-	p	$\bar{p}$
Si+Al	Min Bias	153±1	152±1	165±6	162±12	177±1	122±27
	Central	153±1	146±1	173±5	147±6	190±1	141±18
Si+Au	Min Bias	156±1	151±1	172±14	158±8	202±1	151±38
	Central	156±1	151±1	193±3	180±6	219±1	143±16

Table 1: Measured inverse $m_\perp$ slopes averaged over the rapidity range $1.1 \leq y \leq 1.7$ of charged particles produced in Si+A collisions. The uncertainties quoted are statistical only. The systematic uncertainty is 5% for all particle slopes except for those of antiprotons for which the systematic uncertainty is 10%.

Another interesting result regarding antiproton production involves the yields of antiprotons relative to other particles. If one uses the $m_\perp$ fits shown in Figure 1 to extrapolate the measured cross sections to $p_\perp$=0, one can extract the rapidity density distribution through integration of the invariant spectra. In Table 2, we summarize K/π, K^+/K^-, $\bar{p}/\pi^-$ and $\bar{p}/K^-$ ratios of particle yields integrated over the rapidity range $0.9 \leq y \leq 1.7$ for Si+A collisions. In addition to the large K/π ratios reported previously[1], Table 2 indicates that the $\bar{p}/\pi^-$and $\bar{p}/K^-$ratios are decreasing with increasing system mass. The average antiproton and isospin averaged pion multiplicities for p+p collisions at 14.6 GeV/c are estimated to be $1.2 \cdot 10^{-3}$ and 1.2, respectively. Therefore, to within factors of two, the $\bar{p}/\pi^-$ ratios for Si+A collisions and p+p collisions are similar.

System		K^+/π^+ (%)	K^-/π^- (%)	K^+/K^-	$\bar{p}/\pi^-$ ($\cdot 10^{-3}$)	$\bar{p}/K^-$ (%)
Si+Al	Min Bias	12.6±0.4	3.0±0.2	4.1±0.3	2.1±0.4	6.8±1.3
Si+Al	Central	18±1	4.1±0.7	3.6±0.6	1.3±0.2	3.1±0.6
Si+Au	Min Bias	17.3±0.4	3.7±0.2	4.3±0.2	1.1±0.2	3.0±0.5
Si+Au	Central	19.3±0.5	4.1±0.2	4.4±0.2	0.73±0.07	1.8±0.2

Table 2: Summary of particle ratios for the rapidity range $0.9 \leq y \leq 1.7$. Uncertainties are statistical only. Systematic uncertainties are 10% for all ratios except those including antiprotons. Ratios with antiprotons have a systematic uncertainty of 15%. An additional systematic scale uncertainty may apply due to the chosen extrapolation form.

Because of the relatively large antiproton-proton annihilation cross section (30–60 mb) for low relative momenta (1–3 GeV/c)[6], the measured decrease of the $\bar{p}/\pi^-$ ratio may be the result of antiproton absorption either on spectator nucleons or on participant matter. RQMD model calculations[7] suggest that the large K/π ratios measured by E802 are the result of secondary rescattering. Such secondary rescattering should lead to the relative suppresion of antiprotons. Although results for antiproton production from RQMD are not yet available, Venus 3.07[8] suggests that roughly 90% of the antiprotons produced in Si+A collisions will suffer annihilation. Our results imply one of two scenarios for the initial production and absorption of antiprotons in Si+A collisions. If the effects of absorption are large, even for minimum bias Si+Al collisions as Venus suggests, then the initial production must be greatly enhanced in order to counter-balance the effects of absorption. Several mechanisms have been proposed to lead to such an enhanced production of antibaryons[9]. If the effects of absorption are small, then our data implies that the initial production of antiprotons is not greatly enhanced relative to that expected from individual nucleon-nucleon collisions for $y < y_{NN}$.

However, other effects could lead to similar trends for the $\bar{p}/\pi^-$ ratios, even in the absence of absorption. For example, the available nucleon-nucleon center of mass energy ($\sqrt{s}$) at the AGS is 5.5 GeV, compared to the production threshold for antiprotons in free nucleon-nucleon collisions which is $\sqrt{s} = 3.8$ GeV. Hence, the strong kinematical constraints imposed on antiproton production could also lead to a relative suppression, since the production of other particles such as pions is not as constrained.

In summary, we report the first measurements of antiproton production in nucleus-nucleus collisions for above-threshold beam energies. The measured inverse $m_\perp$ slopes of antiproton spectra, although similar to those measured in p+p and p+A collisions near the same beam energy, are noticeably different from those of proton spectra, in contrast to the predictions of models of nucleus-nucleus collisions with hydrodynamical expansion. The decrease in the measured $\bar{p}/\pi^-$ and $\bar{p}/K^-$ ratios with increasing system mass possibly indicates that effects due to antiproton absorption are being observed. This is encouraging since antibaryon production has been proposed as a measure of the baryon densities and freeze-out times achieved in relativistic heavy-ion collisions[10]. However, since the $\bar{p}/\pi^-$ ratios are within factors of two similar to those expected in p+p collisions at the same beam energy, the effects of absorption are not likely to be significantly greater than a factor of two, unless the initial production of antiprotons is greatly enhanced, even for minimum bias Si+Al collisions.

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