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PROTON RAPIDITY DISTRIBUTIONS FROM 60 GEV/N ^{16}O+Au COLLISIONS

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Abstract: An analysis of the proton rapidity distribution in central ^{16}O+Au collisions at 60 GeV/n measured in the NA35 streamer chamber detector at the CERN SPS is presented. The charge excess of positive particles over negative particles was measured. The rapidity distribution of the charge excess which can be associated with the primordial protons in the collision is studied in terms of the nuclear stopping power and is compared to the predictions of various models.

Central ^{16}O+Au collisions at 60 GeV/n were studied using the NA35 streamer chamber detector. The emphasis of this study was to determine the degree of nuclear stopping at an incident energy intermediate between 14.6 GeV/n and 200 GeV/n since these two energies have been studied extensively [1,2,3] and may be representative of different stopping regimes. Most fixed-target experiments at relativistic energies lack good acceptance forward of mid-rapidity due to high track densities. Therefore information derived from transverse energy distributions is used to measure the degree of stopping. The simplest method uses calorimetry to determine the total transverse energy of particles per event ($E_T^{tot} = \sum E \sin\theta_{lab}$). This method compares E_T^{tot} to what is expected from a fully stopped projectile, which results in isotropic particle emission with a transverse energy sum $E_T^{max} = \pi/4(\sqrt{s} - m_i)$, where m_i is the total mass of all initial state particles. The measure of stopping in an event is then given by E_T^{tot}/E_T^{max}. Using this approach a study of ^{28}Si+Au collisions at 14.6 GeV/n reveals complete stopping[1], whereas at 60 GeV/n the data exhibit 0.6 stopping in ^{16}O+Au[4] and 0.9 in ^{16}O+W[2]. At 200 GeV/n, experiments report 0.5 stopping in ^{16}O+Au[3], and 0.7 in ^{16}O+W reactions [2].

A more sophisticated model [5] allows a broader width for the rapidity distribution of produced particles, as observed experimentally, than that obtained for isotropic emission. This results in a smaller E_T^{max} than obtained from the previous method since more energy is allowed to propagate longitudinally and hence there is less transverse energy available. In this approach the amount of stopping in ^{16}O+Au collisions is estimated to be 1.0, 0.93 and 0.84 at incident energies of 14.5 GeV/n, 60 GeV/n and 200 GeV/n respectively.

The data used in this analysis consist of 89 central O-Au events (10,500 positive tracks and 7400 negative tracks) taken at a beam momentum of 60 GeV/n ($\sqrt{s}$ = 10.7 GeV/n). A high transverse energy calorimeter trigger was used to select the most central collisions corresponding to 1% of the total inelastic cross-section. In a geometrical model it is estimated that the ^{16}O nucleus interacts on the average with a cylinder of 55 target nucleons (25p + 30n). Particle trajectories were recorded on film and measured offline to yield the momentum and charge sign of each particle. In this analysis one camera view of a possible three was used. Therefore the measurement consists of the projected quantities: the longitudinal component of momentum along the beam and one transverse component p_y of the momentum. To compensate for the missing component of p_T in the rapidity calculation, $(\pi/2)p_y$ is substituted for p_T, since the average 2-dimensionsal projection of a 3-dimensional vector is diminished in magnitude by $2/\pi$. The resulting quantity is labelled quasi-rapidity. From simulation studies the distribution of the difference between true rapidity and quasi-rapidity was found to have a width of σ=0.09 units in the kinematic region of interest. Measuring in one view only, compared to conventional 3-view processing, increases statistics by greater than a factor of three since the 3-view practice of matching tracks from different views is eliminated. The overall efficiency for the data sample is $\geq$99%.

The proton quasi-rapidity distribution is obtained by subtracting the quasi-rapidity distribution of negative particles from positive ones, both calculated using the proton mass. This assumes a cancellation of produced π^+ with π^-, K^+ with K^- and protons with antiprotons, leaving the original non-produced protons. In isospin-symmetric systems equal numbers of produced π^+ and π^- are expected. Since ^{16}O is isospin-symmetric π^+ and π^- production are assumed to be equal for rapidities forward of the center-of-mass.

The data is displayed for the region forward of mid-rapidity (Y_{CM}=1.8 in the 16-on-55 system). The integrated contents furnish an estimate of 10.88$\pm$0.68 protons, larger than the 8 protons initially forward of mid-rapidity, but smaller than the 16.5 protons expected from calculations for a fully stopped projectile in a 16-on-55 collision.

A comparison of the proton quasi-rapidity distribution measured in $^{16}O+Au$ collisions with those predicted by various models is displayed in Fig.1. The dashed line represents the prediction of the Landau hydrodynamical model [6] with complete stopping for the system 16-on-55. It has a maximum at mid-rapidity which is far above the data points. This excess of protons forward of mid-rapidity compared to the data is a result of isotropic emission in the model. Comparisons were also made varying the number of target participants in the Landau model but a reasonable fit could not be made to the data.

The rapidity distribution of protons from 60 GeV/n $^{16}O+Au$ collisions in a multiple nucleon-nucleon collision model, MARCO[7], is displayed in Fig.1. Using a linearly increasing x distribution ($\alpha=2$), where x is the fraction of energy plus longitudinal momentum retained per nucleon-nucleon collision the MARCO calculations reproduce the data. However, MARCO requires a flat x distribution ($\alpha=1$) to fit transverse energy spectra from the same data set [7].

The rapidity spectrum from FRITIOF is also displayed in Fig.1. It has a broad peak centered at $Y_{pro}=3.3$ whereas the data continue to rise toward mid-rapidity. It thus appears that there is more stopping of protons in the data, despite the fact that FRITIOF was generated with zero impact parameter, i.e. maximum centrality.

Our substitution of the charge-excess distributon for the proton distribution neglects any inequality between the K^+ and K^- production rates. This can be caused when the contribution of K^+'s from associated production is not cancelled by negative particles in the same rapidity bin. The expected excess of K^+ production cannot be precisely estimated as sufficient kaon data have not been measured at 60 GeV/c. In the present analysis it is neglected, since the effect is estimated to be approximately 10% compared to the differences observed between the data and the models in Fig.1. This estimate is derived from the FRITIOF model which predicts only 0.5 K^+ forward of center of mass, spread over about 2 units of rapidity.

A comparison of the proton and π^- rapidity distributions for the same data set is displayed in Fig.2. The data plotted forward of mid-rapidity show similar shapes for the two. The protons are lower by a factor of 0.35. A similarity of shape can be interpreted as emission from a common source.

In summary, a comparison of our data with the Landau hydrodynamical model[6] indicates that the ^{16}O projectile does not stop completely in the Au target for central collisions at 60 GeV/n. The MARCO multiple collision model does not simultaneously describe the transverse energy distribution and the proton rapidity distribution. These discrepancies indicate that measurements of stopping derived from transverse energy spectra alone may not be reliable and that rapidity distributions of primordial baryons must be considered.

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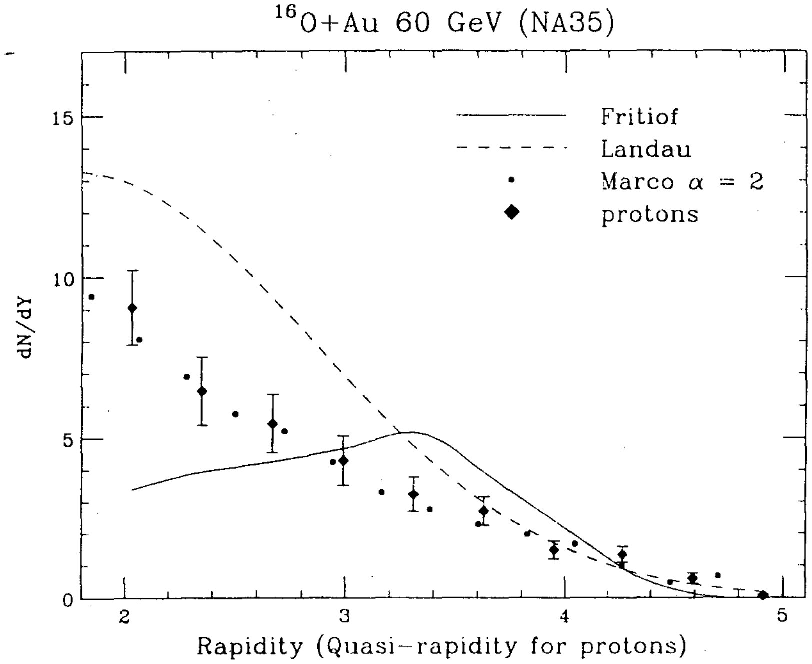
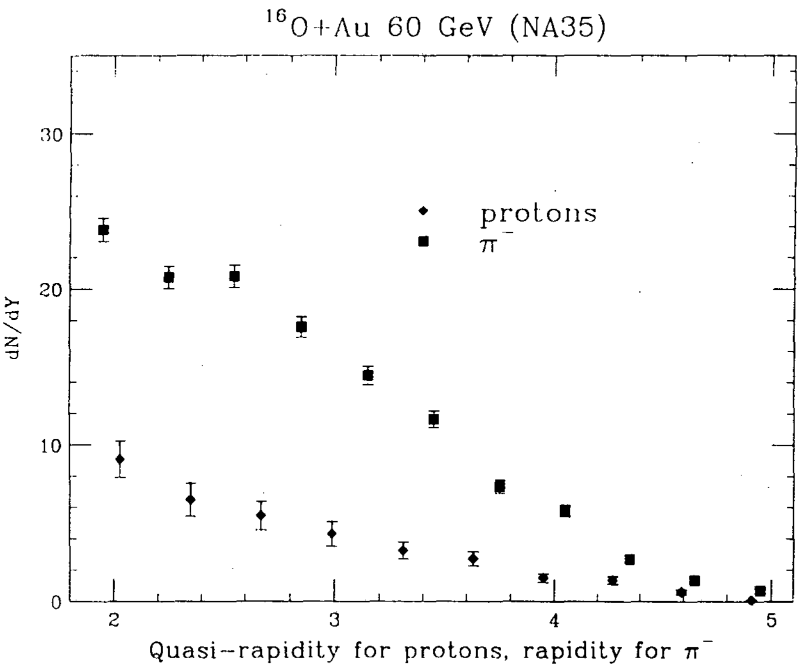
Figure Captions:

1) Proton rapidity distributions for the data and several models

2) Rapidity distributions of protons and π^- from ^{16}O+Au collisions at 60 GeV/n





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