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TITLE: DEUTERON AND ANTI-DEUTERON PRODUCTION IN CERN EXPERIMENT NA44

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Deuteron and anti-deuteron production in CERN experiment NA44

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The abundances of light nuclei probe the later stages of the evolution of a system formed in a relativistic heavy-ion collision. After the system has cooled and expanded, nucleons in close proximity and moving with small relative momenta coalesce to form nuclei. Light nuclei production enables the study of several topics, including the mechanism of composite particle production, freeze-out temperature, size of the interaction region, and entropy of the system. NA44 is the only relativistic heavy-ion experiment to have both deuteron and anti-deuteron results in both pA and AA collisions and the first CERN experiment to study the physics topics addressed by d and $\bar{d}$ production.

1. NA44 Experiment

CERN experiment NA44 is a focusing spectrometer, optimized for the study of identified single and multiple particle distributions near mid-rapidity. The spectrometer has high quality particle identification at the trigger level and achieves a high data rate. We measure p+Be (approximation to p-p) and pA collisions at 450GeV, and AA collisions at 200GeV/A in the same experiment. Two angular settings of the spectrometer with respect to the beam axis are used, 44 mrad and 131 mrad, referred to as the low-p_T and the high-p_T settings, respectively. The experiment has been described in detail elsewhere [1,2].

Particle identification of light nuclei is achieved via time-of-flight from three hodoscopes, two threshold Cherenkov counters and a uranium/scintillator calorimeter (UCAL). Cuts on energy deposition aid in eliminating background and in confirming the measurement of a particle vs. an antiparticle; for the antiparticle, one sees the rest mass in the UCAL. Figure 1 shows typical mass-squared distributions after particle identification cuts. The top plot shows a clearly resolved deuteron peak measured with our low-p_T spectrometer setting; the deuteron distribution is used to define limits in which to search for $\bar{d}$'s. The lower plots show $\bar{d}$'s measured from the low and high-p_T settings; there is essentially no background. Deuterons are measured in the rapidity interval $1.8<y<2.5$ and are compared to protons in the same y range.

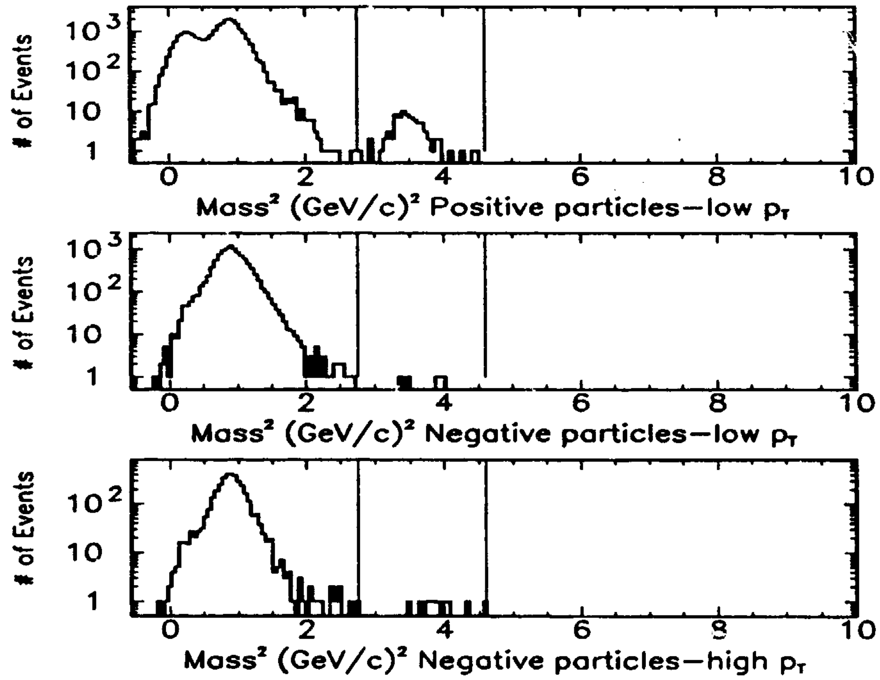

Figure 1. Mass^2 distributions measured at low and high-p_T spectrometer settings.

2. Results

The coalescence model has successfully described light particle production in medium energy AA [3,4,5,6,7], and high energy pA and pp collisions [8,9]. The model states that deuterons are produced by the coalescence of protons and neutrons with similar momenta [7, 10]. It will be shown that this simple assumption is not adequate for high-energy heavy-ion collisions where it is also necessary to consider the spatial distributions of the nucleons. If the system is in equilibrium and can be described thermodynamically, the rms radius of the interaction region, R, can be expressed as [11]:

$$R = (N_{tot} 9\pi^2\hbar^3 / mZ_{tot}B_A)^{1/3} \quad (1)$$

where Z_{tot} and N_{tot} are the fragment proton and neutron numbers and B_A is the

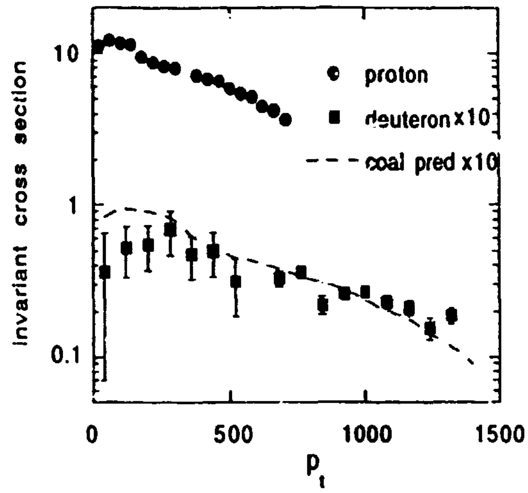

Figure 2. Deuteron and proton invariant cross sections. PRELIMINARY.

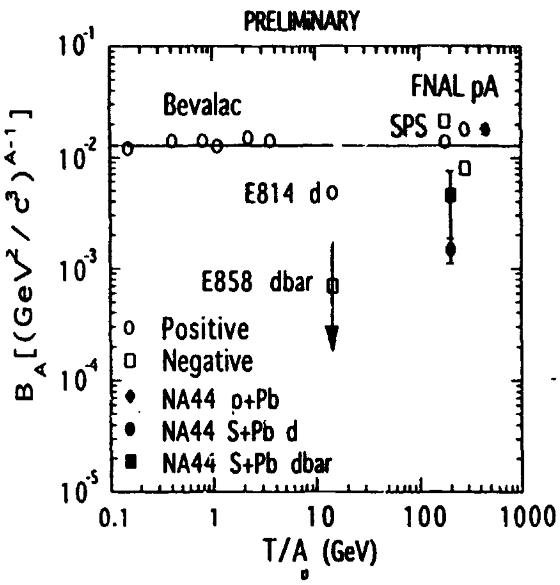

Figure 3. Compilation of B_A values. PRELIMINARY

coalescence scaling factor, $(dN_d/dy)/(dN_p/dy)^2$.

Figure 2 shows the invariant cross section of protons and deuterons, as well as a prediction to the deuteron distribution. The proton data are used to predict the shape of the deuteron distribution and extract an average B_A parameter. Although the shape of the deuteron distribution appears not to differ significantly from the prediction, B_A actually increases by a factor of 4 in going from low to high p_T. This indicates a departure from the coalescence model.

The inverse slope from the deuteron distribution is 349±47 MeV/c (with systematic errors of 15% on the absolute values of the slopes). The slope parameters extracted from π, K, p, and d show a systematic increase with particle mass which is consistent with the scenario of transverse expansion [12].

Figure 3 shows a compilation of B_A values as a function of kinetic energy per nucleon. The value of B_A is constant in the medium energy AA, high energy pA and pp results [5,8,9,13-15]. Indeed, the NA44 pPb result agrees very well with other pA measurements. Included in Figure 3 is the E814 d B_A [16], the E858 $\bar{d}$ value based on two $\bar{d}$ candidates [17], and the NA44 d and $\bar{d}$ B_A values. The NA44 $\bar{d}$ value is based on 12 candidates, the largest sample yet collected in heavy-ion collisions. It is difficult to directly compare the AGS and NA44 results as B_A depends on p_T, centrality and other variables [16]. However, a general decrease in B_A implies a freeze-out volume and radius that are larger in comparison to those of the d or $\bar{d}$. Figure 3 is clear evidence of expansion of the system beyond the size of the colliding nuclei in AA collisions at CERN and indicative of minimal expansion at the Bevalac, pA and pp collisions. The sensitivity of B_A to collision dynamics makes it necessary to consider both momenta and spatial distributions of the nucleons in high-energy heavy-ion collisions. In addition, determining the rms radius of the interaction region is complicated as Eq. 1 only considers the momentum distribution of the nucleons.

The NA44 d and $\bar{d}$ yields have been compared to RQMD/C [18]. The coalescence treatment is based on a Wigner function formalism and considers both the spatial and momentum distributions of the nucleons before they coalesce. The yields from RQMD/C agree fairly well with the NA44 measured yields.

The relative abundances of light nuclei can be used to measure the entropy per baryon of a system. E814 has taken a variation of the historic S/A equation [19] to include the contribution from pions [16]:

$$S/A = 3.945 - \ln\left(d/p\right) + \frac{N_\pi}{N_n} \tag{2}$$

ing Eq. 2, NA44 obtains S/A ≈ 20 for SPb, higher than the value obtained at the AGS by E814 (S/A=12.8) [16] and measurements at the Bevalac [10].

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