Measurement of Inclusive Spectra of Neutrons Produced by Fast Antiproton Annihilation at Nuclei

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Inclusive neutron (n) spectra were measured by time of flight (TOF) using 1.22 GeV $\overline{\mathrm{p}}$ from LEAR, CERN, as projectiles and natural C, Al, Cu, Ag, Ho, Ta, Au, Pb, Bi, U targets. From the n spectra $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ was obtained, where E denotes the n kinetic energy. The sum of two Maxwellian distributions was fitted to $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ yielding $(\mathrm{d}\sigma/\mathrm{d}\Omega)_i$ and the temperature parameters T_i for the low (evaporative, i = 1) and high (preequilibrium, i = 2) energy parts, respectively. $(\mathrm{d}\sigma/\mathrm{d}\Omega)_2$ rises with A, i.e., proportional to the nuclear volume, whereas $(\mathrm{d}\sigma/\mathrm{d}\Omega)_1$ increases with a larger power of A. $T_1(A)$ is constant being about 4 MeV, $T_2(A)$ decreases slightly from 50 MeV to 40 MeV. $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ is compared with INC model calculations [1].

The scintillator S1 positioned 16.14 m upstream from the target, was used as a start detector for the TOF measurement. The stop signal was provided by eight NE213 liquid scintillation counters (D1 - D8) with diameters and thicknesses in the ranges 10.2 – 12.7 cm and 5.1 – 10.2 cm. In front of each liquid scintillator a 3 mm thick plastic scintillator was mounted which was used as a charged particle veto counter. The angles of the detectors towards the $\overline{\mathrm{p}}$ beam are −145°, −125°, −75°, −50°, −25°, +25°, +50°, +110°, respectively.

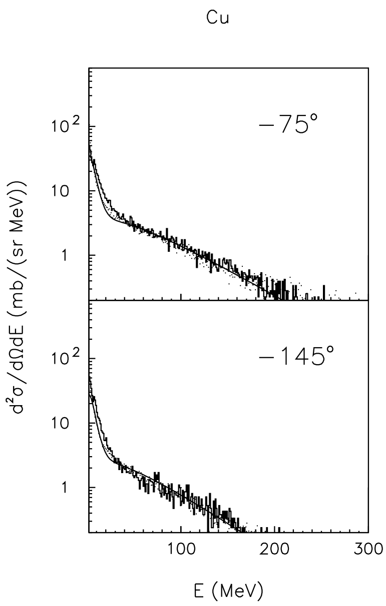

Fig. 1: Double differential inclusive n production cross section $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ vs E for a 1.8 g/cm^2 thick Cu target. The dots denote the measured points, the drawn lines the function of eq. 1 fitted to the measured points with K_i and T_i $(i = 1, 2)$ as fit parameters and the histograms INC calculation results, respectively.
a. Above. Measured with D3. Below. Measured with D1.

In fig. 1 $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ vs E for Cu is shown. $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)$ was approximated by the sum of two Maxwellian distributions

$$\frac{d^2\sigma}{d\Omega dE} = K_1 \frac{\sqrt{E}}{T_1^{3/2}} e^{-\frac{E}{T_1}} + K_2 \frac{\sqrt{E}}{T_2^{3/2}} e^{-\frac{E}{T_2}} \tag{1}$$

describing the evaporative and preequilibrium part of the n spectrum by two constants K_1 and K_2 being proportional to $(\mathrm{d}\sigma/\mathrm{d}\Omega)_1$ and $(\mathrm{d}\sigma/\mathrm{d}\Omega)_2$ and two temperature parameters T_1 and T_2, respectively. INC model calculation results are included in fig.1.

Fig. 2 shows K_i and $T_i (i = 1, 2)$ vs A for detector 3. K_2 rises linearly with A, K_1 at a larger power of A. T_2 decreases slightly, whereas T_1 is constant.

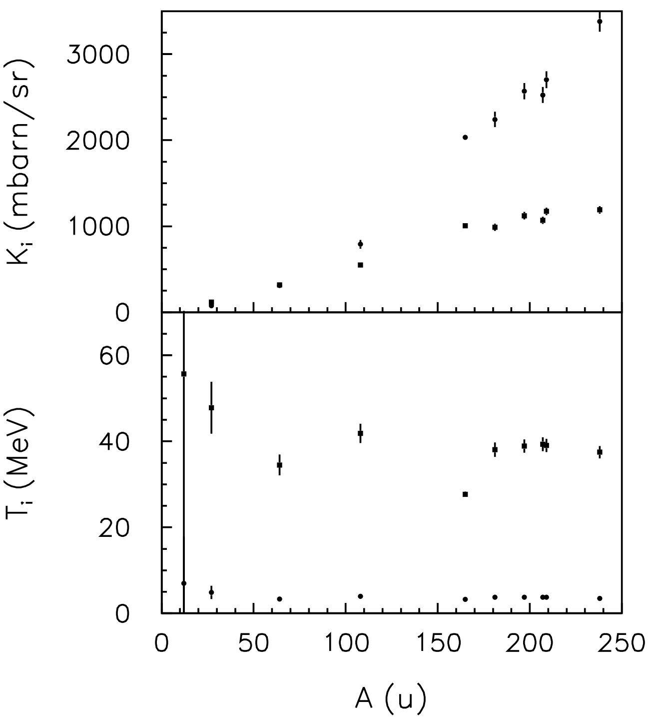

Fig. 2: K_i and T_i (i = 1, 2) vs target mass number A for -75° reaction angle (D3). Above. The dots indicate K_1, the squares K_2, respectively. Below. The dots indicate T_1, the squares T_2, respectively. The error bars denote statistical errors.

References

[1] E.S. Golubeva *et al.*, Physics of Atomic Nuclei **57** (1994) 2007