Measurement of Inclusive Spectra of Particles Produced by Fast $\bar{\mathrm{p}}$ Annihilation at Nuclei

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Inclusive spectra of neutral (n) and charged particles (p, $K^{\pm}$) were measured by TOF using 1.22 GeV $\bar{\mathrm{p}}$ from LEAR, CERN, as projectiles and natural C, Al, Cu, Ag, Ho, Ta, Au, Pb, Bi, U targets with thicknesses in the range $0.4-5.7\,g/cm^2$. A 2 mm thick plastic 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, respectively. In front of each liquid scintillator a 3 mm thick plastic scintillator was mounted which was used as a charged particle veto counter. The detectors were positioned around the target at angles θ between $-145°$ and $+110°$ and distances r between 0.9 m and 2.0 m. The resulting double differential cross section $\mathrm{d}^2\sigma/(\mathrm{d}\Omega\mathrm{d}E)(T)$, where T denotes the kinetic energy of the produced particle, the n/p ratio and $K^{\pm}$ yield will be compared with intranuclear cascade model values.

During a spill (ca. 1h) $\bar{\mathrm{p}}$ hit S1 at a rate of about $10^5\ \mathrm{s}^{-1}$. S1 is positioned in an air gap between the LEAR and the experimental vacuum system. After S1 the $\bar{\mathrm{p}}$ travelling inside a 15 cm diameter vacuum tube pass two plastic scintillator diaphragms, the second one with changeable width, which are operated as veto counters. Then, the $\bar{\mathrm{p}}$ fall onto the square shaped 5 cm wide target. After the target the $\bar{\mathrm{p}}$ leave the vacuum tube through a thin steel window and pass two more plastic scintillators which can be used as veto counters indicating a nuclear reaction in the target.

For particle identification ΔE vs E is plotted for events of produced particles and γ rays yielding separated groups of events in an upper and lower window. ΔE and E are given by $\Delta E = E1 - E2 +$ const. and $E = E1 + E2$, respectively. E1 denotes the integrated intensity of the rising part of the liquid scintillator signal before the maximum and E2 the integrated intensity of the falling part after the maximum. I.e, ΔE describes the shape of the signal separating γ-rays and light particles as $\pi^{\pm}$ from n, p, d, t, α and $K^{\pm}$. n produces recoil p at the H or α particles via the (n,α)reaction at the C of the scintillator. ΔE of $K^{\pm}$ is small because of the $\mu^{\pm}$ energy loss peak following the $K^{\pm}$ decay. E corresponds to the particle energy. n events were selected by means of the lower window in the ΔE vs E plane and requesting the charged particle veto. An additional selection of n events was made in the E vs T plane, where T denotes the n kinetic energy deduced from TOF. Non-physical events with E>T are rejected. The projection on the T axis corrected for the finite intrinsic n efficiency $\varepsilon(T)$ calculated by the MC program CECIL yields $d^2\sigma/(d\Omega dE)$ shown in fig. 1. $d^2\sigma/(d\Omega dE)$ was approximated by two Maxwellian distributions describing the evaporative and preequilibrium part of the n spectrum by two temperatures T_1 and T_2, respectively. An excitation energy of the compound nucleus E^* can be calculated from T_1 to be $E^* = a\,\tilde{T}^2 - 2.5\,\tilde{T}$, where $\tilde{T}$ is given by $\tilde{T} = T_1 \cdot 12/11$ and $a = A/10$ is the level density parameter of the Fermi gas model [1]. Intranuclear cascade model calculation results [2] are included in fig. 1.

Charged particles are measured by demanding a signal in the plastic scintillator in front of the liquid scintillator. They can be separated by plotting corresponding events in the E vs v plane, where the velocity v is deduced from TOF. At the smaller v side of the most intense p group d,t and α, at the larger v side $K^{\pm}$ events are separated. The intensity of the high energy $K^{\pm}$ events is larger than that of the low energy $K^{\pm}$ because of the longer lifetime of the high energy $K^{\pm}$ in the laboratory system.

References

[1] A. Bohr and B.R. Mottelson, Nuclear Structure, vol. 1 (W.A. Benjamin Inc., New York, 1969) p. 155

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

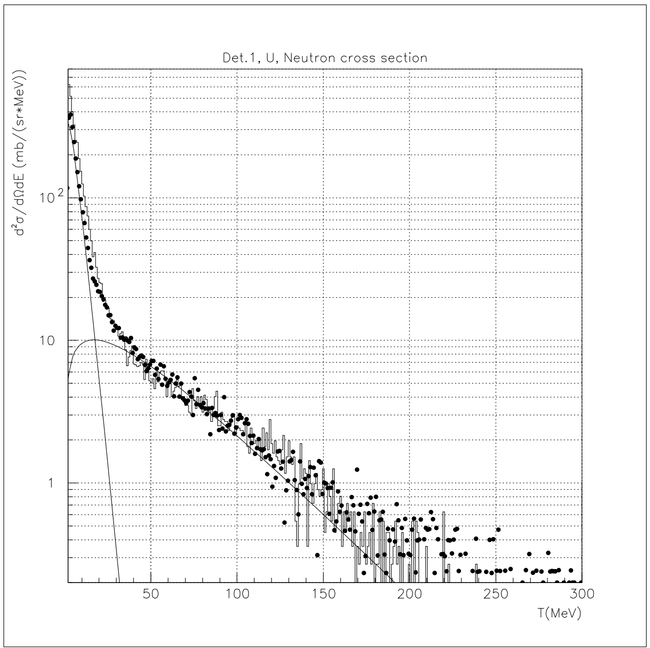

Fig. 1: Dots: Double differential n production cross section vs T measured with $1.2 \cdot 10^6$ $\bar{\mathrm{p}}$ projectiles on a $5.72\,\mathrm{g/cm^2}$ thick U target using a liquid scintillator detector D1 at an angle $\theta = -145°$ and a distance $r = 0.927\,\mathrm{m}$ from the target, T is the kinetic energy obtained from TOF. The diameter of D1 is 5 inches, the thickness 2 inches. Drawn line: Maxwellian distributions fitted to the data yielding $T_1 = 3.39\,\mathrm{MeV}$ and $T_2 = 34.01\,\mathrm{MeV}$ for the low and high energy part, respectively. From T_1 $E^* = 315.52\,\mathrm{MeV}$ results. Histogram: INC calculations (cf. ref. 2).