Heating Nuclei with Energetic Antiprotons

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Using a well known property of excited heavy nuclei to de-excite themselves by evaporating neutrons n and light charged particles (LCP: p,d,t,α,^{6}He or: H+He) we determined event-wise the dissipated energy for antiproton induced reactions on ^{nat}Cu, ^{165}Ho, ^{197}Au and ^{238}U targets (areal density of 1-2 mg/cm^2). With this method we deduce for the first time excitation energy distributions or rather absolute cross sections $d\sigma/dE^*$ following fast $\overline{p}$ annihilation.

The experiment PS208 [1] was carried out at LEAR at CERN, Geneva. The reaction products induced by energetic $\overline{p}$ (1.22 GeV) were detected by two 4π detectors — the Berlin Neutron Ball [2] and the Berlin Silicon Ball [3].

We describe a method to deduce thermal excitation energies based on the evaporation of light particles (LP: LCP+n). Prerequisite for the application of the many model codes is that the source is equilibrated when the evaporation starts. Therefore we cut off the small (typically 15%) contribution from pre-equilibrium emission at higher energy from the LCP spectra.

To determine for each reaction event the thermal excitation E^* we use the sum of all registered LP, $M_{\rm LP}$, and associate to it after correction for efficiency the excitation energy E^* with the same calculated mean $M_{\rm LP}$. For the calculation of $M_{\rm LP}(E^*)$ we employ the statistical model code GEMINI [4].

Fig. 1 displays the absolute cross sections $d\sigma/dE^*$ following $\overline{p}$ annihilation on U, Au, Ho and Cu. For heavy targets energies up to 1 GeV are reached in the tail of the distribution. Tab. 1 shows the A dependence of the experimentally determined mean excitation energy $\langle E^*\rangle$ and excitation energy per nucleon $\langle E^*/A\rangle$, where for A the mass loss in the intra-nuclear cascade (INC) stage is taken into account (A=$A_{\rm target}$-$\Delta A_{\rm INC}$). Also shown is the reaction cross section $\sigma_{\rm reac}$ (summing over E^* of Fig. 1) which scales well with the geometrical cross section assuming r_0=1.38 fm. Numbers in parentheses in Table 1 represent at least for the targets lighter than Cu an excitation energy of ($\approx$ 11 MeV/A) which is close to the nuclear binding energy. The INC-calculation in Fig. 1 agrees well with the data in the shape and in the absolute values of the distribution.

^A_ZX	$\langle E^*\rangle$ ($E^*_{\rm max}$) [MeV]	$\langle E^*/A\rangle$ (E^*_{max}/A) [MeV/A]	$\sigma_{\rm reac}$ [mb]	$\sigma_{\rm geo}$ [mb]
^{nat}Cu	146±20 (520)	2.61 (11.0)	990±90	892
^{165}Ho	280±30 (750)	1.80 (5.2)	1790±100	1695
^{197}Au	320±30 (850)	1.76 (4.8)	1980±120	1908
^{238}U	370±40 (950)	1.67 (4.4)	2250±130	2164

Table 1: Target dependence of $\langle E^*\rangle$, $\langle E^*/A\rangle$ (assuming A=$A_{\rm Target}$-$A_{\rm INC}$) and measured reaction cross section $\sigma_{\rm reac}$ as well as geometrical cross section $\sigma_{\rm geo}$. Numbers in parentheses show the maximum measured $E^*_{\rm max}$ or $E^*_{\rm max}/A$ corresponding to 1% of the reaction cross section.

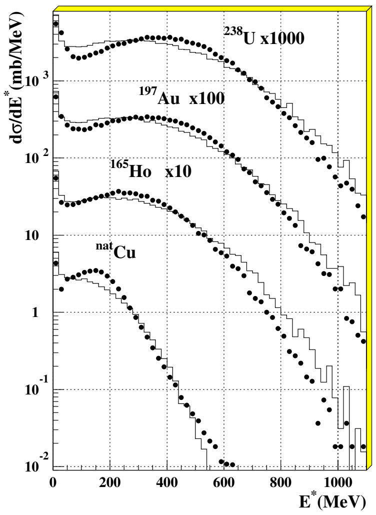

Fig. 1: Distribution of excitation energy $d\sigma/dE^*$ deduced from multiplicity of evaporated light particles (•) compared with INC-model (histogram).

References

[1] D. Hilscher et al., Ann. Rep. 1994 **HMI-B** (1994)
[2] J. Galin and U. Jahnke, J. Phys. G:Nucl Part. Phys. **20** (1994) 1105
[3] P. Figuera et al., Z. f. Physik **A352** (1995) 315
[4] R.J. Charity, Nucl. Phys. **A483** (1988) 371