The H_2-Cluster Target at the ESR Storage Ring

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The internal gasjet target of the ESR storage ring provides an important tool for a broad range of atomic and nuclear physics experiments. In the reaction chamber the stored ions cross a transverse oriented molecular or atomic supersonic gasjet. The jet is produced by expanding a gas through a Laval nozzle with a diameter of 0.1 mm. To meet the UHV requirements of the ESR, the actual setup consists of an injection and dump part, both separated by skimmers in four stages of a differential pumping system [1]. The diameter of the gas-jet in the reaction chamber is about 5 mm.

To operate the target with very different gas species at optimum performance, the distance of the nozzle to the 1st skimmer can now be adjusted via remote control. Typical distances between nozzle and first skimmer amount to 30 mm for light gases and 60 mm for heavy gases. As a further and new option, the nozzle can be cooled with liquid nitrogen to a temperature of 77 K. This leads to clusters formation for light gases especially for hydrogen and thus to an increase in the target density by more than two orders of magnitude. The stagnation pressure can be varied between 100 mbar and 20 bar, depending on the nozzle geometry and gas species in use. Target gases currently available are: H_2, N_2, CH_4, Ar, Kr and Xe. In Fig. 1 the achievable target densities are given for two different distances between the nozzle and the 1st skimmer. For the expensive noble gases such as krypton or xenon, a recycling system is used, which cleans and recompresses the gas.

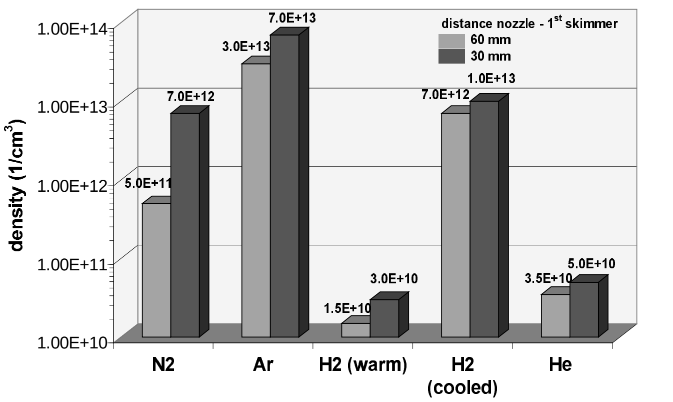

Figure 1: Achievable target densities for the different gases and for two different distances between the nozzle and the 1st skimmer.

The cooling of the nozzle is performed with a dewar which is filled with liquid nitrogen. During the adiabatic expansion of a gas through a nozzle the temperature of the gas can drop below the vapour pressure curve. This leads to a supersaturation of the gas and condensation can take place. The threshold of this process depends on the gas species, the stagnation pressure and the nozzle diameter. Due to clustering the total amount of gas only increases by about 35%, but the density increases by more than two orders of magnitude (compare Fig. 2). The reason is, that the clusters are mainly formed in the middle of the gasjet, which is cut out with the 1st skimmer. This leads to a target density for the H_2-cluster jet of up to $1*10^{13}$ H-atoms/cm^3.

In April 1999 we performed a first test of the H_2-cluster target under experimental conditions at the ESR storage ring. In this beam time the deceleration mode of the ESR was applied for a beam of bare lead ions allowing us to reach a beam energy of as low as 25 MeV/u. It was the first time, that an experiment with such a low beam energy could be performed at the ESR. We like to point out that the H_2-target is of particular relevance for high-Z ions at very low beam energies. Here, in contrast to heavier target such as N_2, the small atomic-reaction cross-sections for H_2 lead to moderate beam lifetimes of approx. 1 min. As a further advantage the width of the momentum distribution of the electrons in the target (Compton profile) is strongly reduced in comparison with heavier targets. As an important consequence, the use of the H_2 cluster target for decelerated heavy-ions results in a very narrow line profile for radiative-electron transition (REC). This is depicted in figure 3 where an x-ray spectrum is shown recorded at the observation angle of 150° for $Pb^{82+} \rightarrow H_2$ collisions at 25 MeV/u. In the spectrum, the width of the REC profiles is almost as narrow as those of the characteristic Lyα-transitions allowing to separate almost completely the j-subshell components of L-REC.

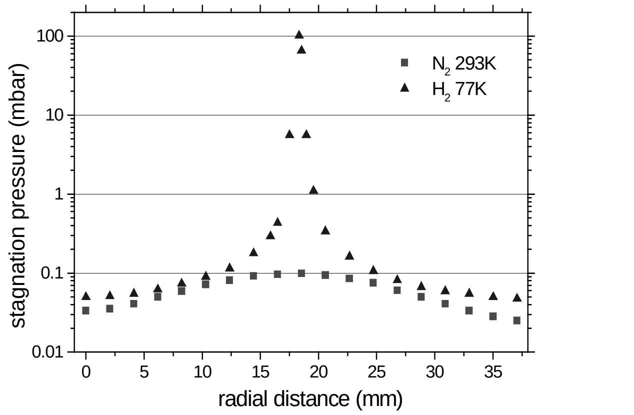

Figure 2: Due to the cooling of the nozzle and of the gas before the expansion, the hydrogen gas clusters and the density of the jet increases. The curves were measured via a stagnation tube for a warm (293 K) and cool (77 K) hydrogen jet at a distance of about 30 mm after the nozzle, without a skimmer.

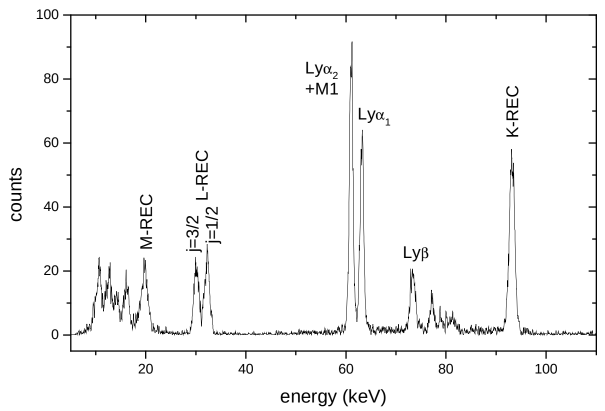

Figure 3: X-ray spectrum for the collision of 25 MeV/u $Pb^{82+} \rightarrow H_2$. The observation angle was 150° [3].

[1] A. Gruber et al, NIM A282 (1989) 78-93
[2] H. Reich et al., Nucl. Phys. A626 (1997) 417c-425c
[3] A. Krämer et al, to be published (2000)