A Stern-Gerlach Source for Intense and Bright Beams of Negative Polarised Hydrogen Ions ◇

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The new source for negative polarised $\vec{D}^-$ and $\vec{H}^-$ hydrogen ion beams, a Stern-Gerlach source with electron cyclotron resonance ionizer and cesium vapour target for charge exchange, produced in the laboratory stable negative polarised deuterium beams with intensities above 10 μA [1]. For mass-analysis a compact Wien-Filter with an acceptance similar to that of the tandem accelerator was used.

In October 1999 we started to disassemble our Lamb-Shift ion source [2] and to install the new source on the high voltage injector platform of the tandem accelerator. Meanwhile, three complete polarised angular distributions have been measured with deuterium beams: ^{186}W($\vec{\rm d}$,t) at 22 MeV, ^{160}Gd($\vec{\rm d}$,t) at 22 MeV and ^{130}Te($\vec{\rm d}$,p) at 18 MeV beam energy. Additional polarised information was accumulated to distinguish in earlier measured unpolarised 18 MeV ^{128}Te(d,p) data between p1/2 and p3/2 l=1 transfers.

Deuterium ion beam intensities above 500 nA on target have been observed. The beam intensity was limited by the use of moderate evaporation temperatures at the cesium vapour target to guarantee long-term stability during production runs. For the ($\vec{\rm d}$,t) experiments this beam intensity was sufficient, for the ($\vec{\rm d}$,p) reactions it had to be decreased by closing apertures at the entrance of the tandem accelerator.

For tuning of the polarisation the elastic scattering reaction 22 MeV ^{96}Zr($\vec{\rm d}$,d$_0$) is used at the scattering angle of 56 degrees. It has a vector analysing power of about A$_y$=−0.4 at low tensor analysing power A$_{yy}$. A coincident countrate in the Q3D-detector of 5 kHz is achievable at target densities of 5 $\frac{mg}{cm^2}$. The dependence of the cross section on the projectile spin is given by:

$$\sigma\binom{up}{down} = \sigma_{unpol}[1 \pm \frac{3}{2}A_y P_3 + \frac{1}{2}A_{yy}P_{33}] \qquad (1)$$

To tune polarisation the detector-countrate has to be minimised for projectile spins parallel to the normal of the scattering plane (spin up, P$_3$=+1) and maximised for antiparallel spins (spin down, P$_3$=−1).

Figure 1 shows part of the excitation spectra of the 18 MeV ^{128}Te($\vec{\rm d}$,p) reaction for the two beam polarisations with comparable integrated beam currents on target. The spectra are measured with the new focal plane detector described in ref. [3]. The energy resolution of 3.8 keV FWHM is excellent. The expected spin-orbit dependence is visible in the increased excitation probability of the j=l−$\frac{1}{2}$ lines (f$\frac{5}{2}$- and p$\frac{1}{2}$-) for polarisation up (pol=+1). For spin down projectiles (pol=−1) the j=l+$\frac{1}{2}$ states (p$\frac{3}{2}$-) are enhanced. The difference in line-content is particularly large at the p$\frac{1}{2}$- line. It has at 22.5 degrees a vector analysing power of about A$_y$=+0.6. A beam polarisation of P$_3$=70% results from equation (1) under the assumption of constant tensor polarisation for spin up and down beams.

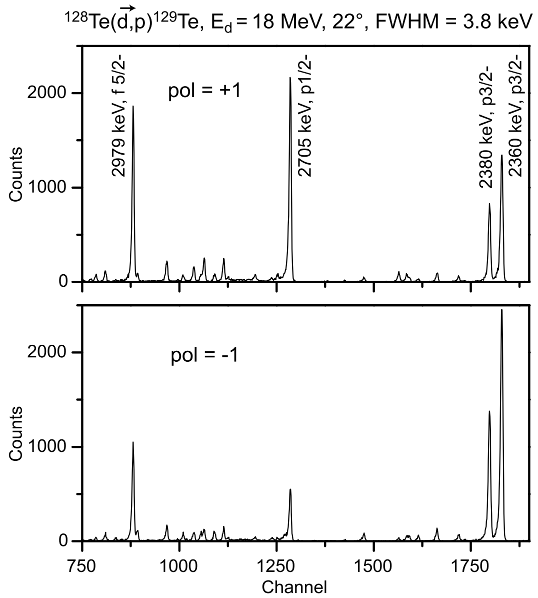

Fig. 1: Spectra of 18 MeV ^{128}Te($\vec{\rm d}$,p) for spin up and down beams.

The vector- (P$_3$) and tensorpolarisation (P$_{33}$) of a deuterium beam is given by the population probability of the magnetic substates n$_x$ of deuterium:

$$P_3 = (n_1 + n_6) - (n_3 + n_4) \qquad (2)$$

$$P_{33} = 1 - 3(n_2 + n_5) \qquad (3)$$

The four Stern-Gerlach sixtupole magnets of the atomic beam source are separated into two groups. Each of them focuses the magnetic substates 1 to 3 and defocuses the magnetic substates 4 to 6, which then do no longer contribute to the ion beam. An adiabatic mean field transition between the two groups of Stern-Gerlach sixtupole magnets is supposed to transform substate 3 into 4. The remainig atomic beam after the sixtupole magnets consists of substates 1 and 2 only and after the passage through a 2→6 strong field transition the atomic beam consists of substates 1 and 6 and is positively polarised. Alternatively a 1→4,2→3 weakfield transition produces spin down beams populating the magnetic substates 3 and 4. In both cases the beam has a tensor polarisation of P$_{33}$=+1. The tuning of the strong and weak field transitions depends strongly on the correct performance of the mean field transition not to alter the population of substate 1 or 2 and to deplete fully substate 3. The search for the best tuning parameters is a challenging task for the near future.

References

[1] Y. Eisermann *et al.*, Jahresbericht 1999, p. 102
[2] P. Schiemenz *et al.*, HPACAK **59 (4)** (1986) p.620
[3] H.-F. Wirth *et al.*, this report, p.71

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