Polarized Negative Hydrogen Beam from the New Polarized Ion Source ◇

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Nuclear reaction spectroscopy with highest energy resolution and polarized hydrogen ions as projectiles is an effective tool to approach current questions in nuclear physics. We refer to our recent studies, the resolution of the fragmentation of the double octupole strength in ^{208}Pb, the determination of the level-scheme of the odd-odd nucleus ^{196}Au and the observed evidence of supersymmetry, or the resolution of the coupling of single particle orbitals to a deformed core as for ^{153}Sm [1–3].

At present, this kind of studies is limited by the intensity of the polarized beam from our Lamb-Shift ion source (about 100 nA on target). Fig. 1 shows a vertical section of our newly developed Stern-Gerlach source with electron-cyclotron-resonance (ECR) ionizer and supersonic cesium gas jet as charge exchange unit. An intensity of 5 μA of $\vec{D}^-$ ion beam with an emittance equivalent to the acceptance of the tandem accelerator was observed in first laboratory tests. This increase in intensity by an order of magnitude with respect to the Lamb-Shift ion source will improve the brilliance of the ion beam. Scattering or transfer experiments with an energy resolution of 3 keV FWHM at beam energies up to 30 MeV will become feasible. Multi-particle transfer reactions will profit decisively from the increase in intensity .

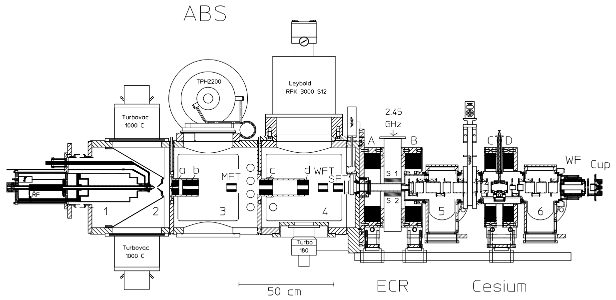

Fig. 1: Vertical section of the Stern-Gerlach atomic beam source (ABS), the ECR ionizer, the electrostatic lens system and the cesium gas target. A moveable wire scanner for beam profile measurements or a Faradaycup was installed at the position of the cesium gas target for diagnostics of the positive ion beam. A compact Wien-filter allows to determine the composition of the ion beam and to estimate the degree of depolarization. (For more detail see [4].)

The neutral polarized atomic hydrogen beam from the Stern-Gerlach atomic beam source has an intensity of 6×10^{16} atoms/sec and a nuclear polarisation of P > 95 % [5]. It is ionized in an electron-cyclotron-resonance plasma, electrostatically transported over a distance of 60 cm and focussed into the center of the cesium gas target. For an energy of the positive ion beam of 500 eV/u the efficiency for double electron pickup is up to 30 % at a Cs vapour density of 10^{15} Cs-atoms/cm^2. A compact Wien-Filter at the end of the ion source enables the diagnostics of the ion beam composition.

The ECR plasma burns most efficiently when in addition to the polarized beam about 40 % of N_2 buffer gas is added. Results for positive and negative ion beams are presented in fig. 2 in four subsections. Bottom section d shows our first observation of a negatively charged polarized $\vec{D}^-$ ion beam with an intensity of 5 μA. In sections a-c Wien filter mass spectra and beam profile scans are presented for positive ion beams, a and b show two different optimizations for the ion optical setting with reference to the cesium cell. The polarized positive $\vec{D}^+$ beam in b has a maximum intensity of 45 μA in an emittance of $\epsilon <$1.6 cm·rad·$\sqrt{eV}$. In a, an intensity of 35 μA corresponds to $\epsilon <$0.7 cm·rad·$\sqrt{eV}$. The emittances are estimated from the drift region in the Cs gas target, but additionally limited by the Wien-Filter.

The comparison of polarized and unpolarized beam composition in b and c allows to estimate the depolarization of the ion beam due to recombination. In the polarized case b, the positive $\vec{D}^+$ ion beam (M2) dominates and the fraction of recombined ${D_2}^+$ ions (M4) is comparatively weak. The unpolarized case c was realized by ionization of D_2 gas, which was injected by a side inlet into the ECR volume. Here the ${D_2}^+$ peak dominates. The amount of the injected D_2 gas was adjusted to the standard plasma current of 0.6 mA, as in a,b and d. From the comparison of the ratio of mass 4 to mass 2 peaks in b and c we conclude, that the contribution from recombination to beam depolarization is only 3 %.

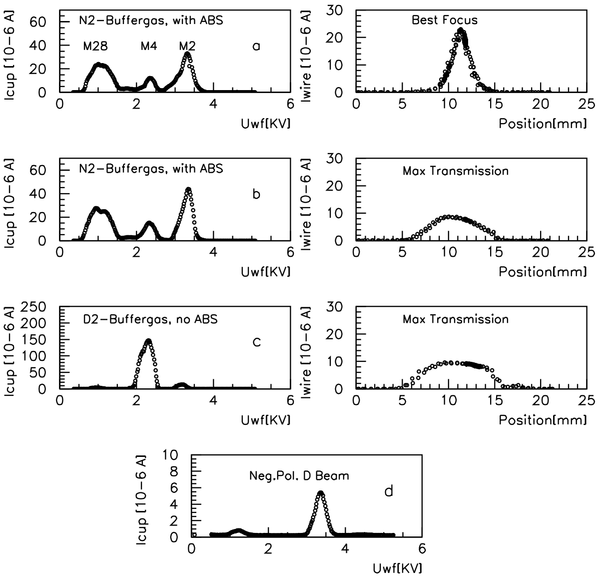

Fig. 2: Wien-filter mass spectra and beam profile scans for positive polarized $\vec{D}^+$ ion beams (sections a and b) and unpolarized D_2 gas inlet (c). Best focus and max. transmission refer to different ion optical settings with respect to the cs gas target. The intensity of the negative $\vec{D}^-$ ion beam of 5 μA (d) is not yet optimized.

The depolarization due to hyperfine coupling in the magnetic holding fields of 1 kGauss during charge exchange is negligible for deuterium. For hydrogen it causes a reduction in polarization of about 15 %.

References

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◇ Supported by BMBF, DFG and BL-Munich.