A Detector System for 3-dimensional Hydrogen Analysis by Proton Proton Scattering at SNAKE

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The new nuclear nanoprobe SNAKE (**S**uperconducting **N**anoscope for **A**pplied nuclear (**K**ern-) physics **E**xperiments) will be a tool to focus 20 MeV protons to 100 nm beam spot size at a beam current of about 100 pA [1,2]. This facility establishes the possibility of a sensitive 3-dimensional scanning of hydrogen distributions with a sub-micron lateral resolution using the technique of elastic proton proton (p-p) scattering [3]. The high proton energy enables analysis at targets up to some 100 μm thickness (e. g. Carbon). At SNAKE the scattered projectile and recoiled target protons are detected coincidentally in forward direction with a 1 mm thick annular silicon strip detector as shown in figure 1. It covers scattering angles from 30° to 60° corresponding to a hole diameter of 20 mm and an outer diameter of 70 mm. The backside is divided into 16 sectors in order to achieve a high background suppression of accidental coincidence events, which is necessary using such a large solid angle of detection (2.3 sr).

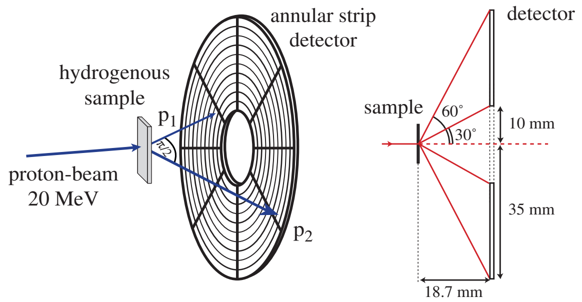

Fig. 1: Left: principle of p-p scattering with an annular strip detector (schematic), right: side view of the applied detector drawn to scale

The major advantage of p-p scattering is the lowest possible irradiation damage in ion beam analysis of hydrogen. Irradiation damage is dominantly produced via Rutherford scattering processes on electrons (ionisation) and on nuclei (atomic displacements). The detection cross section for elastic p-p scattering is enhanced 500 times above the Rutherford cross section for 20 MeV protons. In addition, nearly all of the usable solid angle of detection is covered by the detector. Therefore the ratio of detection cross section to damage cross section is larger than in any other ion beam analysis technique. As a result, it will be possible to detect hydrogen concentrations in solids (e. g. diamond) below 100 ppm or to analyse biological samples with sub-micron resolution each.

Depth profiles of hydrogen distributions can be obtained by analysing the sum energy of both protons. With a 1° angular resolution of the detector (48 concentric rings) geometrical effects are reduced to a minimum. Calculations show that therefore a depth resolution better than 10 μm is achieved at a target thickness up to 200 μm Carbon.

The new detector system was tested in August 1999 with a 300 μm thick prototype counter and two 1 mm thick silicon pads (60 mm × 40 mm) behind, in order to get full energy information of the both coincident protons (s. figure 2). The energy signals of the 48 rings (front) and the two residual energy signals were generated together with the coincidence signals of the 16 sectors (back) by a multichannel amplifier device with a built in multiplexing unit. The detector electronics was integrated in the data acquisition system MAR$_{a}$BOU [4] of the accelerator lab. Hence the coincidence analysis could be realized by data filtering online or offline and several conditions for coincidence events were tested at count rates up to 10 kHz.

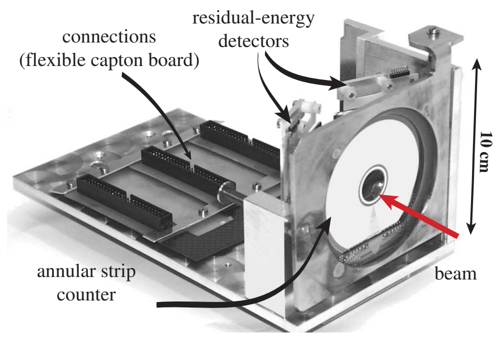

Fig. 2: 300 μm thick detector prototype with 1 mm Si-pads

Figure 3 shows a sum-of-angles spectrum of proton hits in opposing sectors. Therefore the responding ringnumbers of each opposite sector hit (pp-event) were converted into a scattering angle and added. As anticipated the p-p scattering event results in a 90° sum-of-angles peak. Some minor peaks arise left and right of the main peak because of some defect rings and double hits in the strip detector.

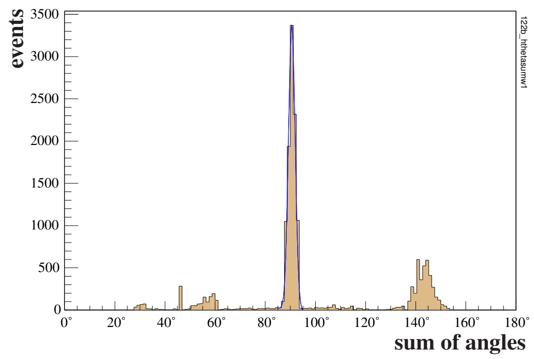

Fig. 3: Sum-of-angles spectrum of coincident proton events

Both the coincidence analysis and the depth profiling worked in principle. For future applications the planned 1 mm thick detector has to be mounted and modifications at the coincidence electronics have to be done in order to measure at high count rates up to 100 kHz/sr. These rates are necessary for planned investigations of hydrogen distributions in 50 μm thick CVD-grown diamonds with a sub-micron lateral resolution.

References

[1] G. Dollinger *et al.*, this report, p.89
[2] G. Datzmann *et al.*, this report, p.90
[3] B. L. Cohen et al. J. Appl. Phys. **43** (1972) 19
[4] C. Broude *et al.*, Jahresbericht 1998, p. 104