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REPORT ON THE WORKSHOP ON POLARIZED TARGET MATERIALS AND TECHNIQUES
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Introduction
This report is an overview on Polarized Target developments based on presentations at the 4th Workshop on Polarized Target Materials and Techniques. This workshop was held in Bonn-Bad Honnef in September 1984 and was organized by the Physikalisches Institut der Universität Bonn. A total of 32 participants (8 from the U.S. and Canada, 8 from Bonn and German universities, 14 from other West European countries and 2 from Japan) took part in the workshop which lasted 4 days.
The report is split in two parts. The situation in the field of polarized deuteron targets is reported in part I, that of polarized proton targets in part II, given by G. Court. There is no reference list at the end of these reports. The reader should consult the Table of Contents in the Workshop proceedings according to the author names in parentheses.

First of all, this kind of meeting turned out to be again very useful and a periodic workshop on this topic should be continued.
The proceedings of this workshop will be published by the Physikalisches Institut der Universität Bonn. Since most of the subjects are mainly of interest for specialists a short summary of the Workshop and some general remarks on the polarized target situation might be useful.

Some years ago there was a resurgence of interest in polarization phenomena in high energy physics. In recent years this is especially valid for the intermediate energy region, where a lot of activities in polarization experiments exist. In many cases serious experimental difficulties are arising because of the limitations of the available target materials.
For reasons known by everyone at this conference, there has been a strong need for more pure and radiation-resistant polarized target materials. Improvements in the target material cannot only save money, an important point since high and intermediate energy physics experiments are expensive, but even more important, they can enable new types of scattering experiments which are presently unfeasible. Also better targets certainly improve the quality of the data.
In order to look at these problems, the first Workshop was organized in conjunction with the meeting on High Energy Physics with Polarized Beam and Polarized Target held at the Argonne Laboratory in 1978. At that workshop it was suggested that radiation induced radicals alone could be used for the dynamic nuclear polarization (DNP) process, and that perhaps a practicable target with good polarization resistance to (further) irradiation could be produced. A short summary about the progress in this field - irradiated materials as improved polarized target materials - can be made as follows: The discovery of high polarizations in irradiated materials such as $^7$LiF, $^7$LiH and $^6$LiD (Saclay) and NH$_3$ (CERN) was decisive for the further developments. The discussions about the results, obtained in these samples, were one main topic on the 2nd Workshop, held in Abingdon in 1979. Since that time most of the developments in new improved target materials were concentrated on irradiated NH$_3$ as well as on irradiated ND$_3$. At the 3rd Workshop, held in Brookhaven in 1982, first detailed polarization studies on irradiated NH$_3$ and ND$_3$ were presented and it was clear that in the near future first scattering experiments with ammonia could be started.

For the first time irradiated NH$_3$ was used in high energy physics experiments, performed in Brookhaven and at CERN, and irradiated ND$_3$ in an intermediate energy physics experiment, performed in Bonn. Besides this, other activities during the last years are very important - such as finding hydrogen rich target materials suitable for chemical doping and the development of dilution refrigerators and frozen spin techniques. The present status of polarized deuteron targets allows to think about experiments with a tensor polarized deuteron target. Progress was also made for the most clean target material - atomic hydrogen.

So the presentations and discussions on the 4th Workshop were centered on the following topics:

I. Irradiated materials
   - Use in high and intermediate energy physics experiments
   - Radiation resistance studies
   - DNP in irradiated materials

II. Chemically doped hydrogen-rich materials

III. Technical developments
   - Irradiation techniques
   - Improvement in cryogenics
   - Frozen spin technology
   - NMR-technology

IV. Tensor polarization

V. Atomic hydrogen.
Part I - Deuterons
At present, most of the polarized target experiments with deuterons are performed at intermediate energies. The polarized deuteron is not only a good polarized neutron target, but also the study of its own properties - such as form factors - is of great interest.

However, with the use of deuterons in scattering experiments, one has to cope with additional problems - such as fermi motion between the nucleons, final state interactions and in the case of polarized target experiments its relatively low polarization. In addition, the exact determination of the deuteron polarization is extremely difficult. Hence, it is not surprising that the experimental information from polarized deuteron target measurements is rather scarce.

Deuteron polarization in the range of 25% to 45% is measured in deuterated alcohol materials. These polarization values were only achieved after a considerable improvement in cryogenics: the development of high power dilution refrigerators. It turned out that their use is even more important for polarized deuteron target than for proton targets. The dilution refrigerator is now standard equipment in most laboratories where polarized targets are in operation.

In this situation, a considerable progress could only be achieved by polarizing new materials with a higher content of polarizable deuterons compared to the commonly used deuterated alcohol materials.

Very high deuteron polarization (70%) was measured in irradiated $^6$LiD (Saclay 1980). However the sample size was very small and the result quoted was obtained at a field of 6.5 T. There are also a number of practical difficulties related to the manufacture of the material and the irradiation techniques. So, the work on improved deuterated target materials, useful for high or intermediate energy experiments, was concentrated on irradiated ND$_3$. ND$_3$ contains about 30% more polarizable deuterons than the best alcohol material. A deuteron polarization in ND$_3$ of 31% at 0.2 K and 2.5 T magnetic field were reported by a Bonn group (1980) and 25% at 1 K and 5 T by a Yale group, working at Slac (1982).

These values could now be exceeded in a photodisintegration experiment (Schilling). Starting with a deuteron polarization of 31% (using 'high temperature' pre-irradiated material) the polarization increased to 44% after additional irradiation at $\sim$200 mK with the photon beam. Detailed radiation resistance studies in ND$_3$ were performed at 1 K, using an external electron beam (Hartfiel). These measurements confirmed the extremely good radiation resistance behaviour (up to a factor of 30 better compared to the best previous material), which has been reported by the Yale group earlier. Furthermore, the results indicate that it is also advantageous to use 'high temperature' pre-irradiated material in the case of electron scattering experiments.
'High temperature' pre-irradiation means, that the paramagnetic radicals (necessary for DNP) are created by irradiating the material under liquid argon at about 90 K in a special refrigerator. In Bonn (Schilling, Brown), Brookhaven (Crabb) and Saclay (Durand) such irradiation facilities now exist, which all use the high intense electron beam from the injection linacs of the accelerators.

As with NH₃, here is also a potential problem with the background nuclei ¹⁴N (spin 1). The polarization of deuterons and unsubstituted protons in ND₃ were examined in detail in order to gain insight into the prevailing mechanism of DNP (Meyer). These measurements disagree with the equal spin temperature hypothesis. In this case the nitrogen polarization is not calculable, but it seems that the nitrogen nuclei are in spin temperature equilibrium with the deuterons. Corresponding data were presented, which show that the nitrogen nuclei are indeed polarized (Heyes).

Recent progress has been made also in chemically doped mixtures of borane-ammonia and perdeuterated ethylamine (Hill, Krumpolc). A deuteron polarization of 35% was obtained in a ³He-refrigerator. As with pure ammonia, there is an analogous problem with the background nuclei ¹⁰B, ¹¹B, ¹⁴N, which may be polarized. The polarization of the ¹¹B-nuclei was measured.

Future aspects for high and intermediate energy physics experiments with polarized targets were discussed. A review was given on the current situation concerning tensor polarization, and applications of a tensor polarized target in intermediate energy physics experiments were presented (Meyer). Experimental plans to use a polarized deuteron target (ND₃) at KEK, focussing on the experiment p+n→p+n, were reported (Horikawa). The latest results in p+p→pp elastic scattering were presented. They emphasized the importance of spin physics at high energies (Krisch).

In summary, important developments in the field of polarized targets were reported. The first experiments with irradiated NH₃ and ND₃ show that these materials are about to replace the alcohol materials. This is especially valid, where high intense beams are used. Therefore, a new generation of experiments also with electron beams, can be started.