FROZEN SPIN SOLID TARGETS DEVELOPED AT THE LABORATORY OF NUCLEAR PROBLEMS (JINR, DUBNA)

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Experience with polarized targets and achievment of very low temperatures gave rise to the idea of using a new technique based on dissolving ^{3}He in ^{4}He to create a frozen spin polarized target. The short history of the development of such proton and deuteron targets at the Laboratory of Nuclear Problems (LNP) JINR is given. Lately, the Saclay-Argonne frozen spin proton polarized target used initially in E704 experiment at FERMILAB was upgraded with addition of the missing parts, and the first physics experiments was carried out.

A polarized solid-state target is one of the most important elements in the technique of polarization experiments. A new technique to produce low temperatures by dissolving ^{3}He in ^{4}He, which was worked out at the LNP JINR in 1966 [1] and by another group, [2] permitted to create a frozen spin polarized target. In the seventies, people in some laboratories began development of frozen spin polarized targets. First of these were: Niinikoski and Udo,[3] Borisov *et al.*,[4] and Isagava *et al.*[5]

A short history of the development of such proton and deuteron targets at the LNP will be given further. In 1975 the experiments on measurement of C_{nn} parameter in the elastic *pp* scattering were conducted at the LNP using our first frozen spin proton polarized target.[6] This target has been working at St. Petersburg Institute of Nuclear Physics (Gatchina) now. The second target was used for experiments with 40 GeV π^- at the accelerator of the Institute of High Energy Physics (Protvino).[7] Later the deuteron frozen target was developed, the Cr(V) complex with ligands on the bases of fully deuterated ethanediol and 1,2-propanediol was synthesized.Lots of articles (over 40) have been published since 1976 using these targets.

The next stage was a proton polarized frozen target for polarization parameter studies in *np* and *nd* scattering using 16 MeV polarized neutron beam produced by the Van-de-Graaf accelerator of the Charles University Nuclear Center in Prague.[8] This target is a complex including a stationary cryostat with a dilution refrigerator (the target temperature in working conditions is about 20 mK), a movable magnetic system providing a "warm" field and consisting of a superconducting solenoid and a superconducting split pair magnet with a large aperture, and electronic equipment for providing nuclear dynamic

Table 1: Polarized frozen targets developed at JINR.

Year of the 1st publication	Volume (cm^3)	Material	Magnetic field (T), dynamic/frozen mode	Accelerator (place)	Maximum polarization (%)
1976	15	$C_3H_6(OH)_2$ 1,2-propanediol with Cr(V)	2.69/2.69	Dubna, Gatchina (in use)	$P_{\pm} = 98 \pm 2$
1980	60	$C_3H_6(OH)_2$ with Cr(V)	2.06/0.45	Protvino (in use)	$P_{\pm} = 87 \pm 3$
1985	60	$(CD_2OD)_2$ deuterated propanediol with Cr(V)	2.06/0.45	Protvino (in use)	$P_{\pm} = 37 \pm 3$
1992	120		2.5	only refrigerator and magnet are available	
1994	20	$C_3H_6(OH)_2$ with Cr(V)	2.7/0.37	Prague (in use)	$P_{+} = 93 \pm 3$ $P_{-} = 98 \pm 2$
1995	140	$C_3H_6(OH)_2$ with Cr(V)	2.7/2.7	Dubna (in use)	$P_{+} = 80 \pm 3$ $P_{-} = 85 \pm 3$

polarization and detecting the NMR signal from the target. In 1997, the polarized target was modernized for using with deuterated material and the measured deuteron polarization consisted 40%.

The new development is the "Movable Polarized Target" (MPT) intended for the Dubna physics program at the Synchrophasotron-Nuclotron accelerator complex.[9] This target used initially in E704 experiment at FERMILAB[10] was reconstructed and upgraded in JINR by expert from DAPNIA (Saclay), JINR (Dubna), SPINP (Gatchina), INR RAS (Moscow) and KPTI (Kharkov). A collaboration was set up in order to reconstruct this facility making it the "MOVABLE" polarized target which could be easily transported from one beam line to another and get this unit operated in Russia or other country.

The first experiment using MPT and the polarized neutron beam of the JINR acelerator complex was performed in February 1995. A difference in transmission cross sections of polarized neutrons through polarized proton target, when the beam and target polarization directions are parallel and antiparallel, was measured.[11] The second run was done in July 1997. Both experiments were performed with longitudinal beam and target polarizations.

Now at the Laboratory of High Energies JINR a new superconducting solenoid has been constructed, which is a duplicate of the one used in the FERMILAB experiment. [12]

For further experiments, a transverse polarization of target protons (or deuterons) is required. So, a set of holding superconducting coils was constructed in Kharkov and has just been tested in Dubna. The magnetic system creating a transverse holding field consists of two superconducting coils disposed in separate liquid helium cryostat. [13] After the holding coils turning on, the polarizing solenoid is removed from a vicinity of the beam. A design of the current leads for the cryostat makes the holding system universal and permits to obtain not only vertical and horizontal transverse holding fields, but a longitudinal holding field with a large aperture too. In the latter case, only one coil is used.

The parameters of the frozen spin polarized targets created at the LNP JINR are given in Table 1. [13]

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