THE POLARISED SOLID TARGET FOR THE CRYSTAL BALL EXPERIMENT AT MAMI *

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The A2-collaboration at the Mainz Microtron MAMI is measuring photon absorption cross section using circularly and linearly polarized photons up to the energy of 1.5 GeV. The photons are produced in the 'Bremsstrahlungs' process. In the years 2005/2006 the Crystal Ball detector with its unique capability to cope with multi photon final states was set up in Mainz. Since 2010 the experimental apparatus has been completed by a polarized target. The horizontal dilution refrigerator of the Frozen-Spin Target has been constructed and is operated in close cooperation with the Joint Institute for Nuclear Research in Dubna, Russia. The system offers the opportunity to provide longitudinally and transversely polarized protons and deuteron. In this paper the operation experience of this new Frozen-Spin Target and first results from the runs in 2010 and 2011 are presented.

1. The 'Crystal Ball at MAMI'

1.1. *The MAMI accelerator*

The MAMI accelerator (see Figure 1) with its source of polarized electrons, based on the photoeffect on a strained GaAs crystal, routinely delivers polarized beams with a maximum energy of 1608 MeV. We typically have a degree of polarization of about 85 %. Details about the new machine type can be found in reference [1].

The electrons are used to produce a secondary beam of real photons in the 'Bremsstrahlungs' - process. The energy of this photons is detected in the Glasgow-Mainz tagging-system [2].

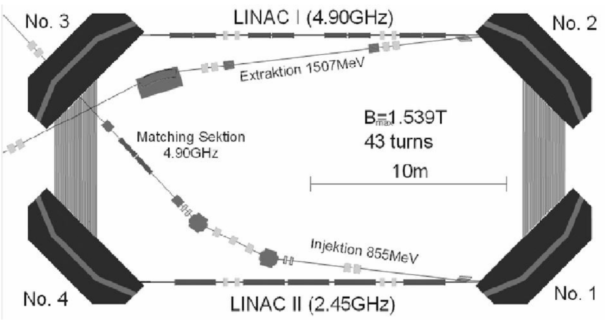

Figure 1. The accelerator stage MAMI C is realized as a Harmonic Double Sided Microtron HDSM. Main features of this new machine concept are the four 90° bending magnets and the two LINACs working on 2.45 GHz and the first harmonic.

1.2. *The Crystal Ball detector setup*

The central detector system consists of the Crystal Ball calorimeter combined with a barrel of scintillation counters for particle identification and two coaxial multiwire proportional counters for charged particle tracking. This central system provides position, energy and timing information for both charged and neutral particles in the region between 21^o and 159^o in the polar angle and over almost the full azimuthal range.

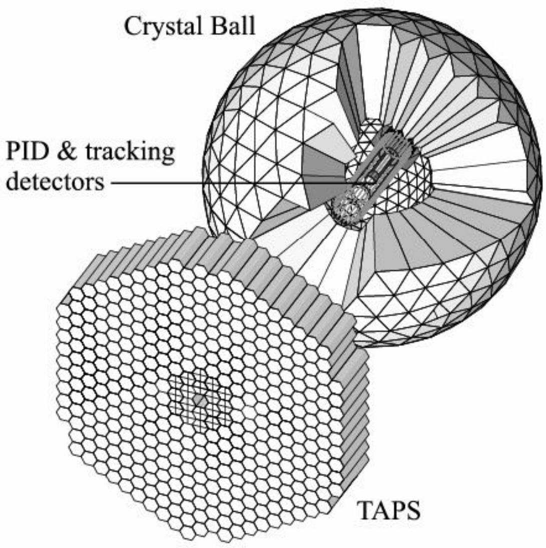

Figure 2. The Crystal Ball calorimeter, with cut-away section showing the inner detectors, and the TAPS forward wall.

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At forward angles, less than 21°, reaction products are detected in the TAPS forward wall. The full, almost hermetic, detector system is shown schematically in Figure 2.

The full angular coverage of this detector system sets very rigorous condition for the construction of the polarized target.

2. The Polarized Target

The new frozen spin target was designed to retain the high angular acceptance of the detector system. The main boundary condition for the outer diameter of the frozen spin target cryostat was the most inner particle identification detector with a diameter of 104 mm. The internal holding coils had to be as thin as possible to allow particles to punch through.

The core of the frozen spin target for the Crystal Ball detector is a specially designed, large horizontal $^3He/^4He$ dilution refrigerator (see Figure 3) that was built in cooperation with the Joint Institute for Nuclear Research (JINR) Dubna.

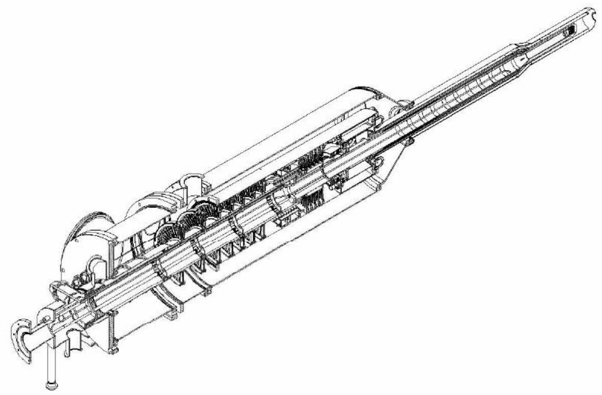

Figure 3. 3D- construction of the dilution refrigerator.

Figure 4. The dilution refrigerator with longitudinal holding coil.

The cryostat has a separator working at 3 K and an evaporator working at 1.2 K in the pre-cooling stages. These are pumped by rotary pumps with pumping speed of 60 m^3/h, 100 m^3/h and 250 m^3/h (company Busch). The beam axis is equal to the cryostat axis and the target material has to be loaded along the beam axis using a specially adapted, twofold target insert. This target insert needs to seal the cavity against the beam pipe vacuum. It has minimum limitations for the particle detection and fits into the central core of the inner Particle Identification Detector (PID2). This was achieved by using the frozen-spin technique with the new concept of placing a thin superconducting holding coil on the thermal radiation protection shields of the refrigerator. Longitudinal and transverse polarizations are possible. For longitudinal polarization a solenoid has to be installed, for transverse polarization a 4 layer saddle coil is needed, see Figure 5.

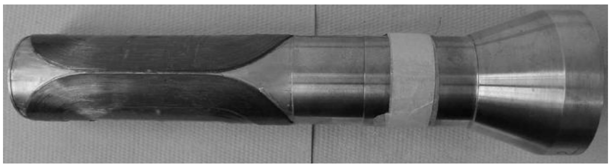

Figure 5. The internal superconducting holding coils for transverse field operating at 1.2 K can be seen.

The transverse coil has been in operation for more than 4000 hours in the years 2010 and 2011 at a current of 35 A, corresponding to a field of 0.45 T. The current leads are optimized for low thermal input: In the first step we enter into the cryostat with thick, normal conducting copper wire to a temperature of 70 K, in the next step high temperature superconducting band is used. The helium consumption for stable operation of the complete cryostat (target material at 25 mK and holding coil at 0.45 T) was below 2.5 liters per hour, showing a very economic design of all heat exchangers.

Figure 6 shows, that we could reach a very stable operation regime. A typical temperature curve is plotted, showing a stability of better than ± 0.2mK over a time scale of 1 day.

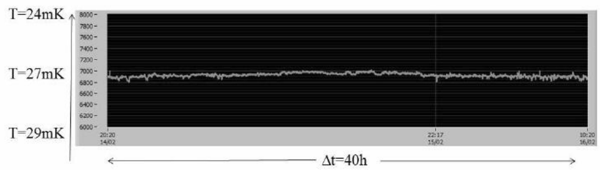

Figure 6. Typical temperature curve in the ’frozen spin mode’.

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The NMR system to measure the degree of target polarization is a serial resonance circuit with a coil within or around the target material. We have used Tempo doped Butanol and Trityl doped deuterated Butanol target substrates, provided by the Bochum polarized target group [3].

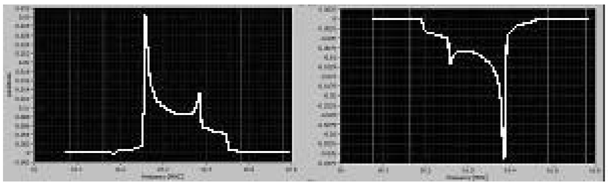

Figure 7. NMR signals of highly polarized deuterium.

In conclusion, we have achieved the following target parameters:

- Maximum total tagged photon flux in the energy range of 4.7 to 93 % of E_0: $5 \cdot 10^7\ s^{-1}$, with relaxation time of around 1500 hours for protons and deuterons at a magnetic field of 0.45 T and a temperature of 25 mK.
- Proton density in 2 cm cell: $N_T = 9.1 \cdot 10^{22} cm^{-2}$.
- Average proton polarization P_p = 70 %.
- Deuteron density in 2 cm cell: $N_T = 9.4 \cdot 10^{22} cm^{-2}$.
- Average neutron polarization P_n = 60 %.

Acknowledgments

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