Dilution refrigerator for COMPASS polarized target

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Abstract

A new experiment, COMPASS (COmmon Muon and Proton Apparatus for Structure and Spectroscopy), on the spin structure of a nucleon is being prepared at CERN. The main goal of the muon programme is to measure the gluon contribution $\Delta G/G$ to the nucleon spin. This experiment requires a large acceptance of 180 mrad for the polarized target and minimum amount of extra material in the target. We present the dilution refrigerator used to cool and polarize the target material of ^{6}LiD.

Keywords: refrigerator; polarization; techniques

The measurement of gluon polarization $\Delta G/G$ is done by determining the asymmetry of particles originated in an open charm lepto production [1]. Two oppositely polarized target cells are used in order to vanish the false asymmetry by the beam flux. The difference in the apparatus acceptance for upstream and downstream is taken care of by periodical reversal of polarization in both cells. A muon beam 100 - 200 GeV, focused to 30 mm diameter and polarized to $P_\mu \approx 0.8$ is used, with $2 \cdot 10^8 \mu$/spill within 2 s of 14.4 s. The target material is ^{6}LiD, $P_t \approx 0.5$, in two ∅ 30 mm and 60 cm long cells. A dilution refrigerator is needed to keep the material well below 100 mK for minimum spin-lattice relaxation at 0.5 T when the polarization is being reversed. During the Dynamic-Nuclear-Polarization (DNP), done by pumping microwaves with slightly different frequencies to the two halves of the target cell, large cooling power is needed at temperatures of 200 - 400 mK. DNP is based on the unpaired electron spins, which have been produced by irradiation to the target material.

The dilution refrigerator was originally built for the SMC experiment at CERN [2], Fig. 1. Loading of the target cell is possible when both the target material and the cryostat are below 100 K. This is done from left by inserting target holder tube into the mixing chamber. It is essential to stay below 100 K since the target materials have critical temperatures of 100 - 120 K. For the COMPASS experiment minimum amount of construction material in the geometrical acceptance of 180 mrad is de-

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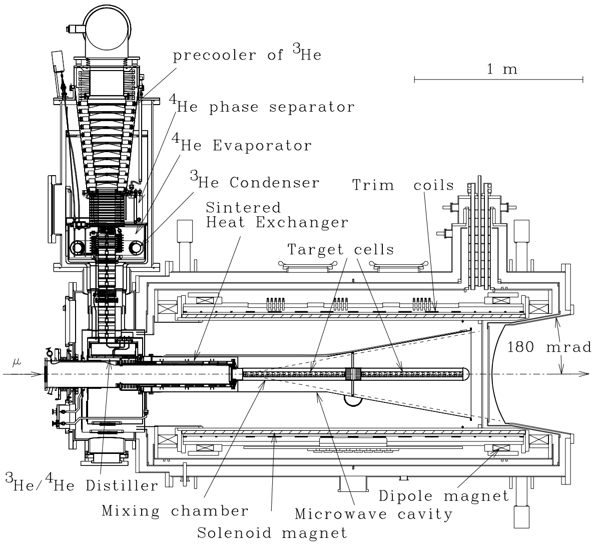

Fig. 1. The COMPASS target cryostat, target and polarization magnet. The muon beam transverses the cryostat from left to right and the resulting scattered particles have 180 mrad acceptance. Minimum amount of extra material on the path of the outcoming particles is desired.

sired. Thus the mixing chamber is made from thin 0.6 mm glass fiber epoxy, the cavity is closed by 0.1 mm Cu sheet and the radiation shields at 4 K and 77 K are made of thin 0.1 mm Al. The cryostat is flow-type and is fed continuously from a 2000 l LHe buffer dewar to the ^{4}He phase separator. The dewar is filled continuously from a liquefier. The radiation shields and the microwave cavity are kept cold with a flow of cold ^{4}He gas or liquid. A liquid ^{4}He consumption between 15 and 40 l/h is typical depending on the ^{3}He flow. The conical copper microwave cavity is divided into two by a thin microwave stopper. The isolation is needed in order to avoid depolarization of the target halves by the microwaves leaking from the other side. During the experiment the polarization is measured continuously with NMR coils embedded into target material.

The pumping of the ^{3}He circulation is done with 8 Root's blowers in series giving pumping speed of 13500 m^3/h. The total amount of ^{3}He is 800 l NTP and the ^{3}He flow rate 27 - 350 mmol/s with 25 % of ^{4}He. Charcoal traps at room temperature and

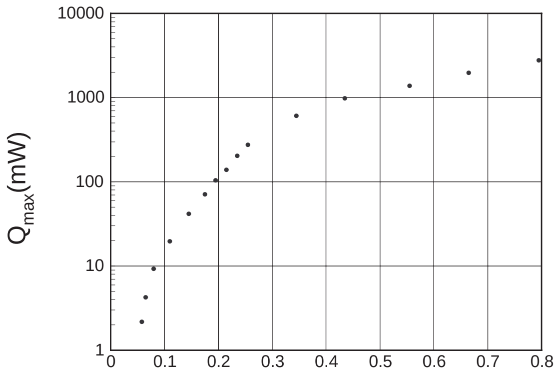

Fig. 2. The maximum cooling power vs. mixing chamber temperature measured in the SMC experiment [2].

at 77 K are used to trap impurities in the returning gas flow. Incoming ^{3}He is precooled with the heat exchangers in the still pumping line and condensed in the ^{4}He evaporator. It is further cooled down in the heat exchangers of the pumping line between the ^{4}He evaporator and the still. The ^{4}He liquid level in the evaporator is kept constant by monitoring it with a capacitive level gauge and using a motor driven needle valve. The tubular heat exchanger below the ^{3}He/^{4}He distiller is made of a flattened stainless steel tube with surface area of 0.1 m^2. It is followed by a series of sintered copper heat exchangers with 12 m^2 total surface and a typical thickness of 0.75 mm. The measured cooling power is depicted in Fig. 2.

References

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