POLARIZED TARGET FOR DRELL–YAN EXPERIMENT AT COMPASS

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Abstract

In the polarized Drell–Yan experiment at the COMPASS facility in CERN a pion beam with momentum of 190 GeV/c and intensity up to 10^8 pions/s will interact with transversely polarized proton target. The muon pair produced in Drell–Yan process will be detected. The solid-state NH_3 as polarized proton target will be polarized by dynamic nuclear polarization at very low temperatures. The maximum polarization reached during data taking is expected to be up to 90%. The non-interacting beam and other particles produced inside the target except the muons will be stopped in the hadron absorber after the target. Two target cells, each 55 cm long and 4 cm in diameter separated by a 20 cm gap, will be used. In total the target material volume will be about 691 cm^3.

Drell–Yan data taking is expected to start in 2014–2015 for period of approximately 180 days. The current status of the target, the required modifications and the future plans are presented.

1 Introduction

COMPASS [1] is a fixed-target experiment situated at CERN Super Proton Synchrotron (SPS) North Area. For physics data taking it uses either hadron or muon beams[1]. The beam interacts with a target, which can be polarized. COMPASS detector is a universal spectrometer with good particle tracking and identification capability.

COMPASS experiment focuses on spin structure studies and hadron spectroscopy [2]. A set of measurements to study the structure of hadrons was proposed [3], including the first ever measurement of a single-polarized Drell–Yan (DY) process using a pion beam and a transversely-polarized proton target. It aims to confirm some crucial predictions of QCD, namely pseudo-universality i.e. change of sign of the Sivers and Boer–Mulders TMDs when measured in Semi-Inclusive Deep Inelastic Scattering (SIDIS) and in DY processes.

As the DY cross section is small, the luminosity should be as high as possible. In COMPASS case this corresponds to the beam intensity of about 10^8 pions/s. That is the highest hadron beam intensity COMPASS has ever used, which leads to several challenges for the detection, data acquisition and polarized target.

[1]Produced by proton beam from the SPS accelerator hitting a Be target. The beam can be either positive or negative with momentum up to 280 GeV/c. Muons are naturally longitudinally polarized.

2 Polarized target

The Polarized Target (PT) system [1,4] has an essential role in COMPASS spin structure studies. It can provide large amount[2] of target material polarized to a high degree[3].

The cooling is provided by a Dilution Refrigerator (DR), which has a cooling power of about 5 mW at 75 mK [7]. A large-aperture superconducting magnet provides a field up to 2.5 T parallel and 0.64 T perpendicular to the beam axis. Homogeneity of the longitudinal field is about 10^{-5} T.

The target material is polarized by Dynamic Nuclear Polarization (DNP) method [6] at about 0.5 K. When the optimal polarization is reached, the target is switched to a "frozen spin" mode at about 50 mK. A long spin-lattice relaxation time at such temperature (in order of 10^3 hours) allows to perform reasonably efficient experiment. Two Microwave (MW) systems for DNP allow to have target cells with opposite polarization to reduce systematic errors in measured asymmetries. The polarization is measured by a continuous-wave NMR.

3 Drell–Yan program at COMPASS

Drell–Yan (DY) process can be represented by the Feynman graph on Fig. 1. The main advantage of DY process for hadron structure studies is that there are leptons in the final state, which means that the cross section does not involve any fragmentation function but only convolution of structure functions of both hadrons. The process is very well calculable, dedicated calculations of the pion-induced DY process for the COMPASS kinematics were recently published [8].

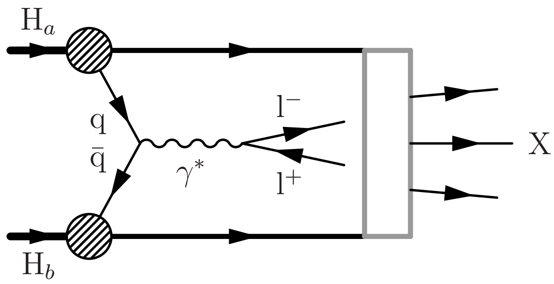

Figure 1: The Drell–Yan process. A quark-antiquark pair from the two hadrons annihilate, producing a lepton-antilepon pair in final state. The gray box denotes hadronization.

The disadvantage of the DY process is a small cross section. To overcome this a high-intensity pion beam will be used resulting in a large secondary-hadron flux. A special hadron absorber was designed to stop the non-interacting beam and all secondary particles except muons right after the target to avoid a spectrometer flooding-up [3]. It will be made of stainless steel and alumina, with a tungsten beam plug in the center to stop the beam. For the measurement at COMPASS this means worse vertex resolution in comparison with SIDIS program, as the absorber introduces significant multiple scattering.

The high intensity pion beam together with the hadron absorber will cause higher radiation dose[4] in the experimental building. Because of that the control room will be moved to another building.

[2] A cylinder of about 4 cm in diameter and about 120 cm long

[3] Over 80% in case of H in NH_3 and over 50% in case of D in ^{6}LiD [5]

[4] About 3.6 μSv/h, which exceeds CERN limit for permanently occupied area

4 Modifications of the PT for the DY program

The intense pion beam and the presence of the hadron absorber require modifications of PT, including the target cells. The new cell design consists of two cells (4 cm in diameter, 55 cm long) with 20 cm long MW stopper[5]. The wider gap between the target cells is needed to ensure correct assignment of events to the cells.

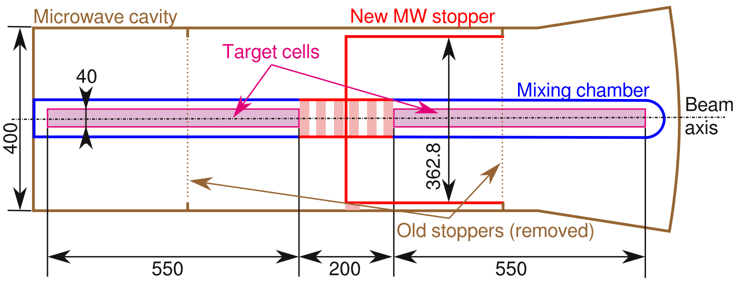

Figure 2: The modified MW cavity. The upstream MW stopper was removed, the downstream one was replaced by a special adapter and a wider stopper fitting in the 20 cm gap between the 55 cm long target cells.

The NMR system for polarization measurement will have 10 coils. 4 coils will probably be placed outside of each cell (for measurement in longitudinal field) and one inside each cell (coil axis parallel to the beam axis—for measurement in transverse field). Design of the coils is in development. A special adapter was designed for the MW cavity to accommodate one MW stopper of 20 cm length instead of two (see the Fig. 2).

Because of the absorber the whole target has to be moved by 2.3 m upstream from the standard (SIDIS) position. The target platform will be lifted by a crane and moved to its new position. A special support craning construction was designed by CERN for this purpose. The helium lines, cabling, MW waveguides and other equipment will be moved to the new position as well.

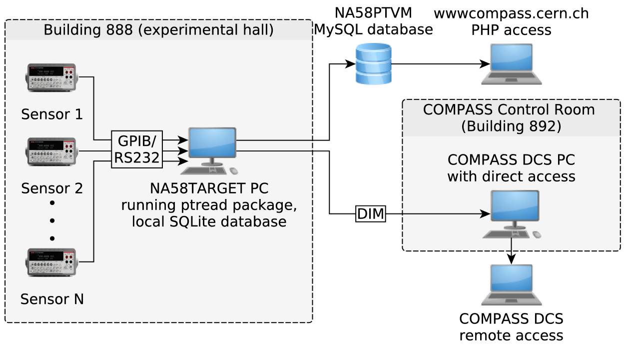

Figure 3: Diagram of ptread communication. The Linux computer with ptread package reads sensors. Data can be stored locally in SQLite database, sent to MySQL database and published by DIM server for COMPASS DCS.

It was decided to abandon the LabVIEW™ system [9] for dilution refrigerator monitoring. A new, more robust, Linux-based software package called ptread is being developed instead. It is written C++ and Perl. It can communicate with the standard COMPASS DCS[6] using DIM library [10] and write data into MySQL or SQLite database. These features are important for the remote monitoring. The main advantage is that the package is modular and easily adjustable. It can load the target configuration from a file. Fig. 3 shows functionality of the monitoring system.

There is a Programmable Logic Controller (PLC) unit designed to monitor the most important parameters of DR [9]. It runs simultaneously with the standard DR control system and is powered from a source not sensitive to power-failures. The needle valves of DR will be controlled probably by another PLC.

[5]The SIDIS design was three cells (30-60-30 cm long, 4 cm in diameter) with 5 cm long stoppers.
[6]Centralized, PVSS-based detector control system

The superconducting target magnet is being refurbished by CERN magnet group. The work is almost finished. The group will provide control and safety systems too.

5 Status of the polarized target preparations

The modified MW cavity was successfully tested earlier this year. The new target cells are being prepared. The movement of the target platform is planned to be done by the end of 2013. The superconducting magnet refurbishment is finishing, the magnet should be ready for installation in March 2014. The magnet vacuum was successfully tested recently and cooling tests will follow soon. The dilution refrigerator was leak-tested at room temperature, no leaks were found.

6 Conclusion

COMPASS has now the possibility to make the first-ever measurement of single-polarized Drell–Yan process. Preparation for this involves polarized target modifications which are progressing well. The target should be ready and fully operational by the end of the summer 2014 to allow measurement during the fall 2014 and over the whole 2015.

Acknowledgements

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