COMPASS Polarized Target for Pion-Induced Drell–Yan Experiment

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The first ever polarized Drell–Yan (DY) measurement is under preparation at COMPASS experiment at CERN. One of the key parts is the low-temperature polarized target. Modifications are required to cope with the intense pion beam that will be used. Solid NH_3 will serve as a transversely-polarized target. Polarization is expected to be up to 90%. Two 55 cm long target cells give the target volume of about 690 cm^3. The data taking is expected to start on fall 2014 and to continue in 2015 (approximately 180 days). Current status of the target, the modifications and 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]. The first ever measurement of a single-polarized Drell–Yan (DY) process using a pion beam and a transversely-polarized proton target was proposed [3]. Its goal is to test some crucial predictions of QCD, namely a 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 the case of COMPASS this corresponds to the beam intensity of about 10^8 pions/s. That is the highest hadron beam intensity COMPASS has used so far, which leads to several challenges for the detection, data acquisition and the polarized target.

2 Polarized target

The low-temperature polarized target [1, 4] is a key instrument for COMPASS spin structure studies. It is one of the biggest systems of its kind in the world[2] and can provide degree of polarization higher than 80% in the case of H in NH_3 and 50% in the case of D in ^{6}LiD [5].

[1]Produced by proton beam from the SPS 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]The target volume has cylindrical shape with about 4 cm in diameter and is about 120 cm long.

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 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. The cooling is provided by a dilution refrigerator, which has a 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. Combination of the two fields allows measurement with transverse polarization and polarization rotation.

3 Drell–Yan program at COMPASS

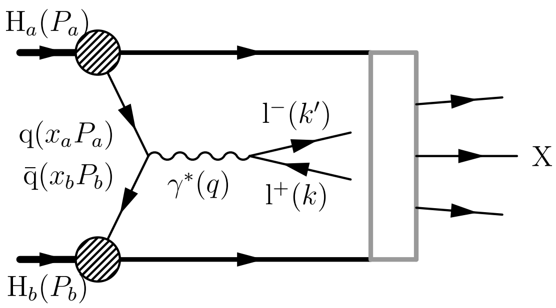

Figure 1: The Drell–Yan process. A quark-antiquark pair from the two hadrons annihilate, producing a lepton-antilepon pair in final state. The grey box denotes hadronization.

The Feynman graph on Fig. 1 shows the Drell–Yan (DY) process, which has lately attracted much attention as a tool for polarized hadron structure studies. Its main advantage is that only leptons are measured 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 well calculable, dedicated calculations of the pion-induced DY process for the COMPASS kinematics were recently published [8].

The disadvantage of the DY process is a small cross section. To collect a good statistics a beam with intensity up to 10^8 pions/s 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 is made of stainless steel and alumina, with a tungsten beam plug in the centre to stop the beam.

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

4 Modifications of the target for the DY program

The DY program, namely the intense hadron beam and the presence of the absorber brought need for modification of the target. New target cells were made. There are two cells (4 cm in diameter, 55 cm long) with 20 cm long microwave stopper in between[3]. The gap between the cells prevents event migration between oppositely-polarized cells. It is wider than in the SIDIS runs since the hadron absorber introduces significant multiple scattering, which worsens the vertex resolution. A special adapter was designed for the microwave cavity to accommodate two cells with one stopper instead of two.

The NMR system for polarization measurement has 10 coils. Three coils are placed outside of each cell and are oriented for measurement in the longitudinal field. Two coils are placed inside each cell near the ends for polarization homogeneity monitoring.

The target superconducting magnet was refurbished by CERN magnet group. In addition to the fixed trim coils it got various upgrades, e. g. better thermal insulation and new control and safety system.

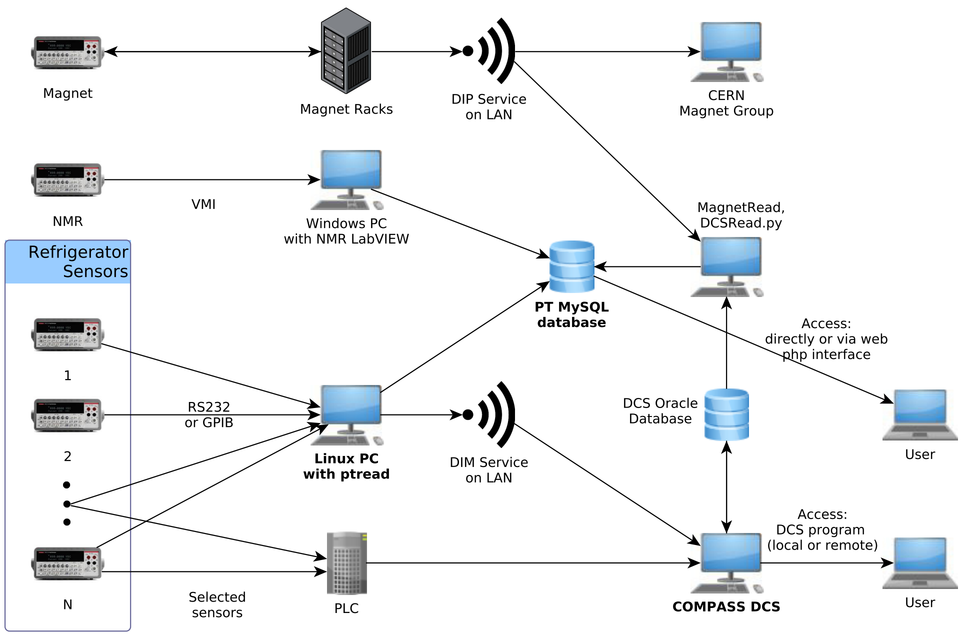

Figure 2: Diagram of target monitoring. The Linux computer with ptread package reads refrigerator sensors. Data can be stored locally in SQLite database, sent to MySQL database and published by DIM server for COMPASS DCS. The magnet is monitored by CERN experts and NMR by a LabVIEW^{TM} program.

Since the control room was moved from the experimental building, a remote control is necessary. For most systems the current COMPASS centralised Detector Control System (DCS) was working well, but the dilution refrigerator was only partly monitored by it. It was decided

[3] The SIDIS design was three cells (30-60-30 cm long, 4 cm in diameter) with 5 cm long stoppers.

to abandon the old LabVIEW^{TM} system [9] for refrigerator monitoring and to develop a new, more robust, Linux-based software called *ptread* instead. It can communicate with the DCS using DIM library [10] and insert data into MySQL and SQLite databases. These features are important for the remote monitoring. The main advantage is that the software package is modular and easily adjustable. Figure 2 shows how various subsystems of the target (including the refrigerator) are monitored.

In addition to the *ptread* PC there is a Programmable Logic Controller (PLC) unit that monitors the most important parameters of the refrigerator [9]. It is powered from a source insensitive to power failures.

5 Conclusion

The magnet was refurbished and is being cooled down and commissioned. Dilution refrigerator was tested and mounted in place. Its sensors are connected to the new Linux-based monitoring system. The new target cells are ready. The target will be prepared for the physics data taking, that is scheduled from the beginning of November 2014. Second run is planned for 2015. In total there should be about 180 days of data taking.

Acknowledgements

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