Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: A.P. Nagaytsev 2017 *J. Phys.: Conf. Ser.* **938** 012026

IOP Conf. Series: Journal of Physics: Conf. Series **938** (2017) 012026 doi:10.1088/1742-6596/938/1/012026

A possible layout of the Spin Physics Detector with toroid magnet.

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Abstract. The Spin Physics Detector project for carrying out experiments at the 2-nd interaction point of the NICA collider is under preparation. The design of the collider allows reaching collision energy in the c.m.s. as high as $\sqrt{s}$= 26 GeV for polarized proton-proton collisions and $\sqrt{s}$ = 12 GeV for polarized deuteron-deuteron collisons with a luminosity of up to 10^{32} cm^2s^{-1} (for protons) and 10^{31} cm^2s^{-1} for deuterons. Such a high luminosity of polarized beams interactions opens unique possibilities to investigate a variety of polarization phenomena including those related to the nucleon spin structure. A proposal for the experimental set-up based on a toroid type magnet is presented.

The main physical tasks proposed for spin program at NICA (see Ref.1) can be divided into four blocks shown in Fig.1.

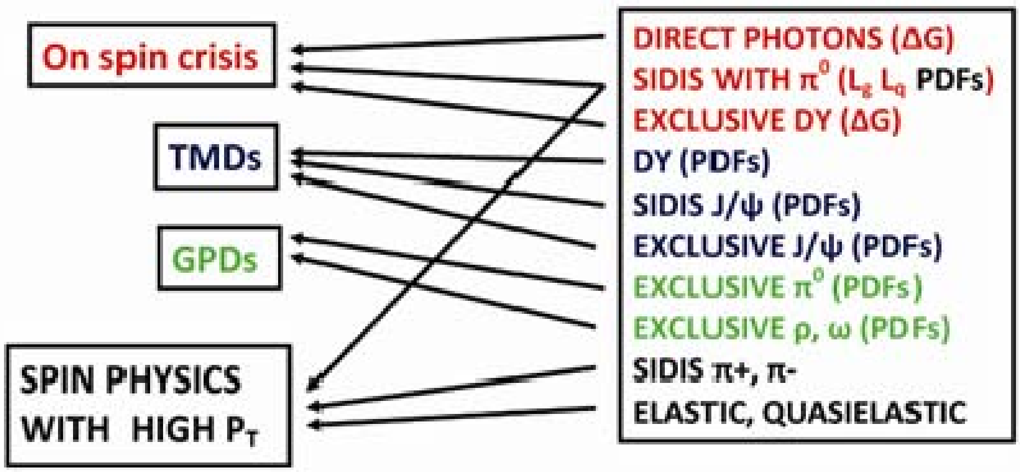

Figure 1. The main physical tasks proposed for spin program at NICA.

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IOP Conf. Series: Journal of Physics: Conf. Series **938** (2017) 012026 doi:10.1088/1742-6596/938/1/012026

Preliminary considerations of the event topologies (see Ref.1) for measurements shown in Fig.1 required the following characteristics of the experimental setup: 4π angular region around the beam, high-precision (better than 50 μm) and fast vertex detector, a tracking system that provides high accuracy (~200 μm) along the track, fast DAQ, minimum of material, measurement of neutral (π^0 etc) secondary particles, identification of charged particles with efficiency close to 100%, fast and modern trigger system, modularity and access to the elements of the setup, which will allow to upgrade and modify detectors for new research. SPD has to be equipped with the following sub-detectors: vertex detectors, tracking detectors, electromagnetic calorimeters, hadron and muon detectors and trigger system. Some of them must be in the magnetic field for which there are two options: either toroid or solenoid type.

A toroid magnet provides a field free region around the beam pipe and, due to that, does not influence on the beam trajectories and polarizations. It can consist of 8 superconducting coils symmetrically placed around the beam axis (see Fig. 2). A support ring upstream (downstream) of the coils hosts the supply lines for electric power and for liquid helium. At the downstream end, a hexagonal plate compensates the magnetic forces to hold the coils in place. The field lines of ideal toroid magnet are always perpendicular to the particles originating from the beam intersection point. Since the field intensity increases inversely proportional to the radial distance, greater bending power is available for particles scattering at smaller angles and having higher momenta. These properties help to design a compact spectrometer that keeps the investment costs for the detector tolerable. The toroid magnet requires insertion of the coils into the tracking volume occupying a part of the azimuthal acceptance. Preliminary studies show that the use of superconducting coils, made by the Nb_3Sn-Copper core surrounded by a winding of aluminum for support and cooling, allows one to reach an azimuthal detector acceptance of about 85%. For SPD measurements there is a disadvantage of the toroid solution related to a high non-uniformity of acceptance as a function of azimuthal angle in the laboratory frame and the some loss of detector acceptance.

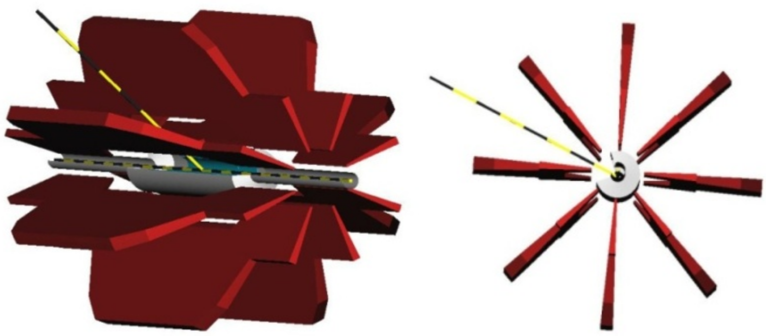

Figure 2. Possible view of SPD toroid magnet.

One example of the use of a toroid magnet for an experimental setup is the TORUS magnet for CLAS12 (see Ref.2). The torus magnet for the CLAS12 spectrometer is a 3.6-T superconducting magnet being designed and built as part of the Jefferson Lab 12-GeV upgrade (Fig.3). The magnet consists of six coil case (enclosed in a vacuum-impregnated coil pack) assemblies mounted to a cold central hub. The coil pack consists of a 117-turn double-pancake winding wrapped with two layers of 0.635-mm-thick copper cooling sheets. The coil case assembly is cooled by supercritical helium at 4.6 K. The details are given in Ref.2.

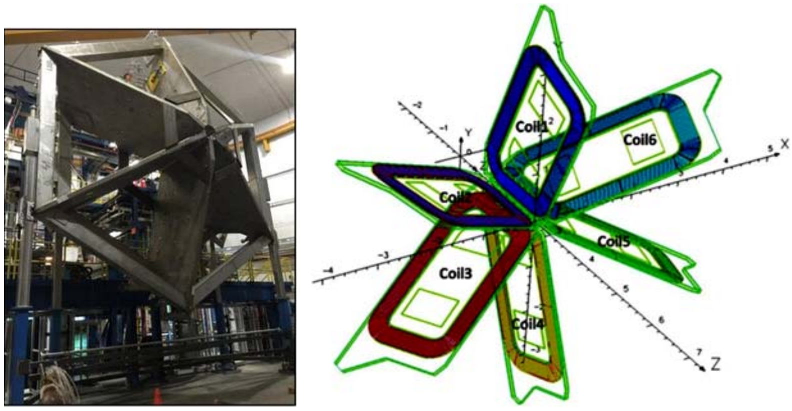

Figure 3. The views of TORUS magnet for CLAS12 (left) and superconducting magnet system (right).

The preliminary design of SPD with toroid magnet system is shown in Fig.4. The main parts of this scheme described below. They are shown in Fig.4 in red- toroid magnet, in yellow – electromagnetic calorimeter and in blue – muon system (RS).

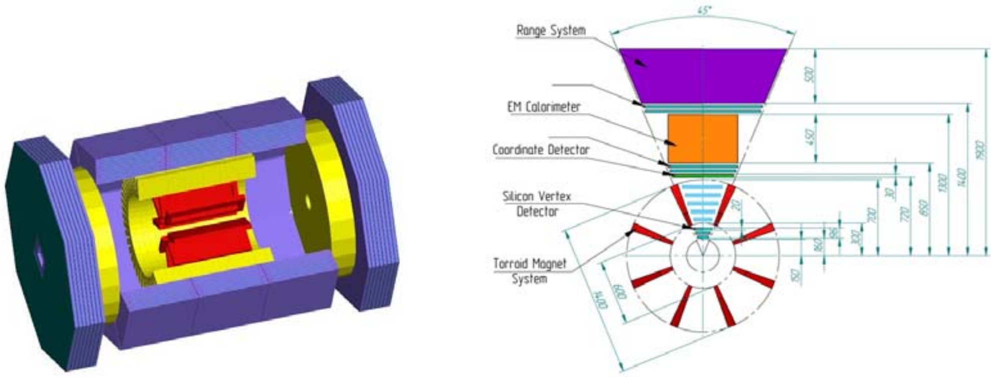

Figure 4. The view of SPD (left) and view of the barrel sector (right). Details are given in text.

The first coordinate system shown in Fig.4 (right panel) is vertex silicon detector. The most obvious technology for the vertex detector is a silicon one. Preliminary one can consider the vertex system approved for the MPD (see Ref.3). This detector can be located outside the beam pipe and can consist of several layers of double-sided silicon strips which provide a precise vertex reconstruction and tracking of the particles before they reach the general SPD tracking system and reject the secondary decay vertexes.

The coordinate system before calorimeter can be produced with straw tubes (Fig.5). This choice is based to the following properties of the straw tubes: the minimum of material for the tracks of the secondary particles ($X_0 \sim 0.1$), the time (~ 200-300 ns) and spatial (~100 μm) resolutions, provided the expected particle rates (DAQ rates ~ 100 Khz); developed production sites in JINR, Dubna. The details can be found in Refs.4.

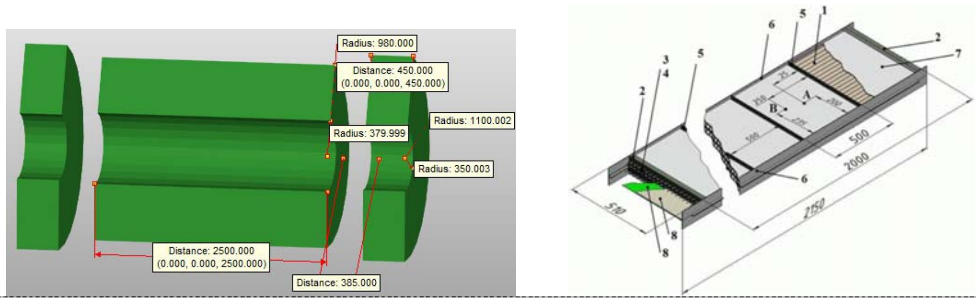

Figure 5. The view of coordinate system (left) and straw module (right).

The electromagnetic calorimeter (EM) will consists of "shashlyk" modules with the application of new readout techniques based on AMPD technology. The latest version of the electromagnetic calorimeter (ECAL) module, developed at JINR for the COMPASS-II experiment at CERN (see Fig.6), [5], can be a good candidate for ECAL in the barrel and end-cap parts of SPD. The modules can have an area of $4x4cm^2$ and a length of 30-40 cm (see Ref.5). The expected energy resolution can be $\sigma(E)/E = (5-8)\%/ E$. The calorimeter also can be used for the triggering of DY electrons.

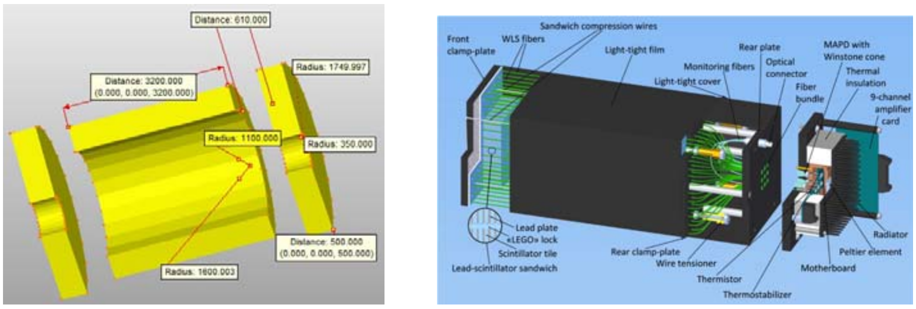

Figure 6. The view of ECAL(left) and module (right) Details are given in text.

The main task of the trigger system is to provide separation of a particular reaction from all reactions occurred in collisions. Each of them will be pre-scaled with: two muons (or electrons/positrons) in final states, various types of hadrons in final states (π+/-, K, p,...), photons (π^0, ω, η...), other reactions. RPC are proposed to be used as main trigger detector [see Ref. 6]. Also hodoscopes of scintillating counters can be used for triggering. They can be located before and after RS (or mounted in the last layers of RS) and before RPC. The view of detectors for trigger system is given in Fig.7.

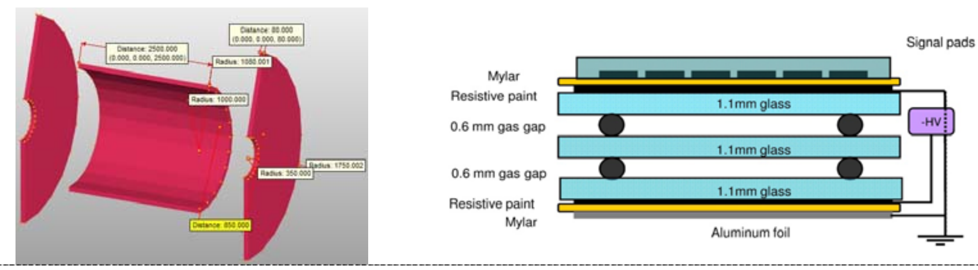

Figure 7. The view of trigger system (left) and possible RPC module (right).

The system of mini-drift layers with Fe layers called by Range System (RS) is the main muon system of the detector (see Fig.8). One can provide the clean (> 99%) muon identification for muons with momenta more than 1 GeV. The combination of responses from EM calorimeter and RS can be used for the identification of pions and protons in wide energy range. This system was taken as main muon detector for PANDA experiment (see Ref.7)

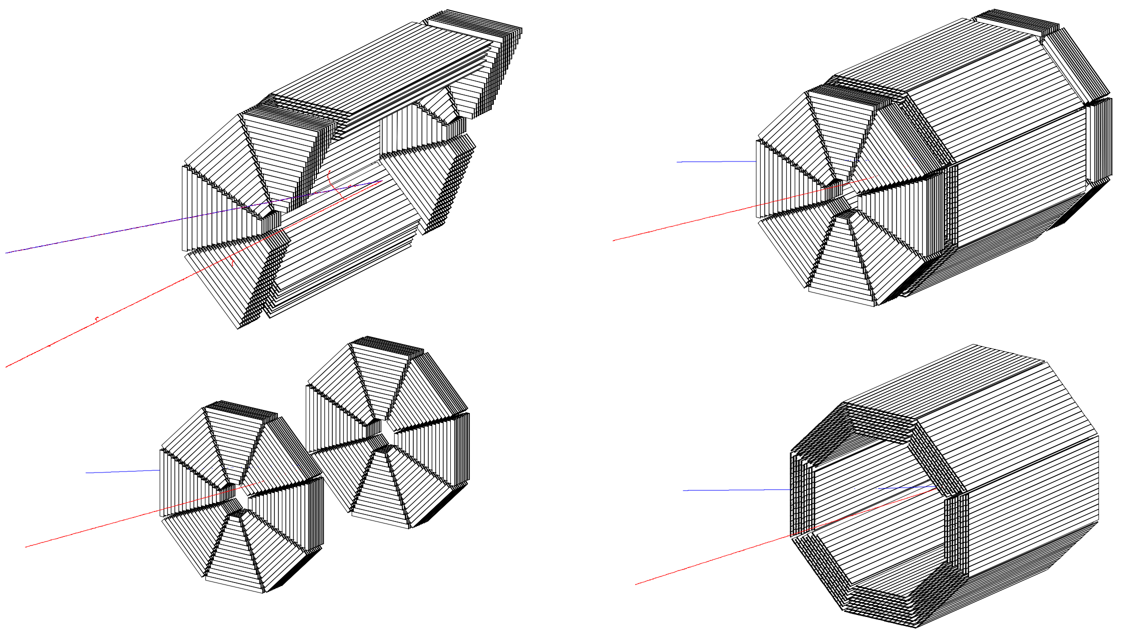

Figure 8. The views of Range System in SPD with muon tracks from DY process, obtained with PYTHIA generator.

The final version of the SPD will be defined after detailed Monte-Carlo simulations and consideration of requirements for other spin effects studies. Some preliminary pictures of experimental set-up with Drell-Yan and SIDIS events are shown in Figure 9.

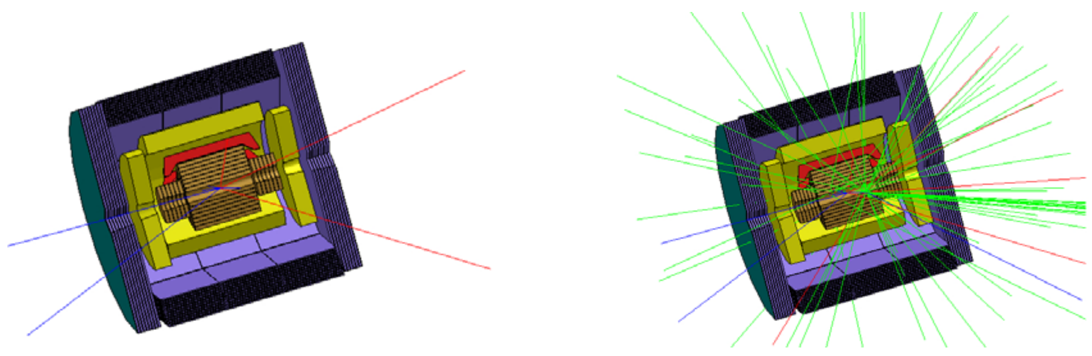

Figure 9. The Drell-Yan (left) and SIDIS events in SPD.

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