PROCEEDINGS OF SCIENCE

Straw Tracker of the future Spin Physics Detector at NICA collider

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The Spin Physics Detector (SPD) at the NICA collider at JINR is being developed to measure the nucleon spin structure. Polarized proton and deuteron beams will collide at the centre-of-mass energy up to 27 GeV in the proton-proton collision mode, with instantaneous luminosity up to 1e^{32} Hz/cm^2. Tracks of charged particles will be measured in the magnetic field of a superconducting magnet with Straw-based Tracking system. Besides of the track coordinate measurements, the tracker will be used. as a part of the particle identification system (PID). The barrel part of the tracker will be made of thin-wall straw tubes produced with ultrasonic welding of a metallized PET foil. The straws have 1 cm diameter and will be assembled in self-supporting octants made of 31 double-layers, resulting in total in ~25 000 readout channels. The tracker should have a good spatial resolution and provide measurements of the particle ionization losses serving the PID. This implies a challenging requirement to the tracker readout electronics. In this talk we present several possible concepts of the readout electronics together with simulation of the straw response compared to the test beam measurements

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1. Introduction

The Spin Physics Detector (SPD) [1] is designed to explore the nucleon spin structure with colliding polarized proton and deuteron beams. The centre-of-mass energy will reach up to 27 GeV in the proton-proton collision mode. The detector will be installed in the experimental hall of the NICA collider. The Silicon Vertex Detector (VD) will provide the vertex position measurements with the resolution of better than 100 µm, which is sufficient for reconstruction of secondary vertices originating from D-meson decays. The Straw tube-based Tracking system (ST) placed within a solenoidal magnetic field of up to 1 T at the detector axis should provide the transverse momentum resolution $\sigma(p_T)/p_T \approx 2\%$ for a particle momentum of 1 GeV/c. To reduce the multiple scattering and photon conversion effects, the material budget of the inner detector part should be minimized as much as possible. The Time-of-Flight system (TOF) with a time resolution of about 60 ps will provide 3σ π/K and K/p separation of up to about 1.2 GeV/c and 2.2 GeV/c, respectively. Possible use of the Focusing Aerogel Ring-Imaging Cherenkov detector (FARICH) in the detector endcaps will extend this range significantly. Detection of photons will be provided by the sampling Electromagnetic Calorimeter (ECal) with the energy resolution $\sim 5\%/\sqrt{E} \oplus 1\%$. The Range (muon) System (RS) will be used for muon identification. It can also act as a rough hadron calorimeter. The pair of Beam-Beam Counters (BBC) and Zero Degree Calorimeters (ZDC) will be responsible for the local polarimetry and

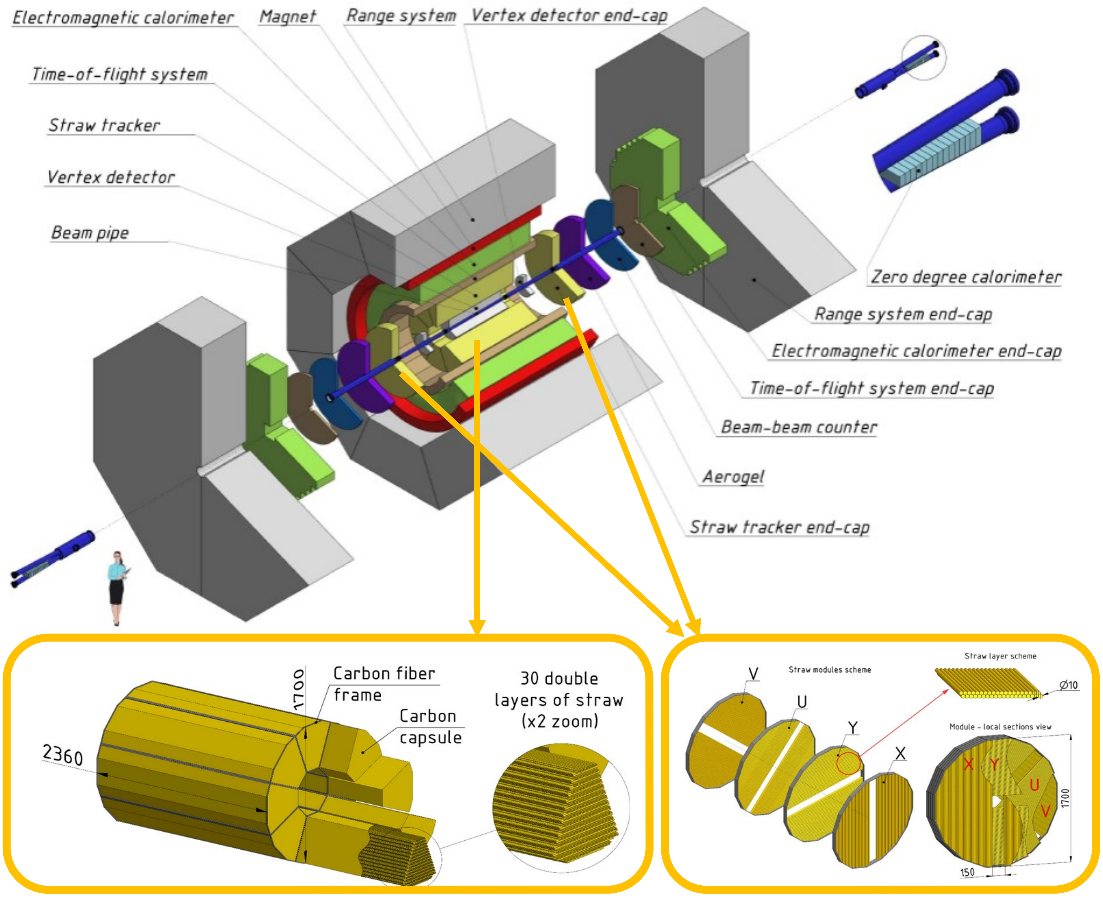

Figure 1: A 3D view of the Spin Physics Detector with detailed sketches of the barrel and endcap Straw Trackers.

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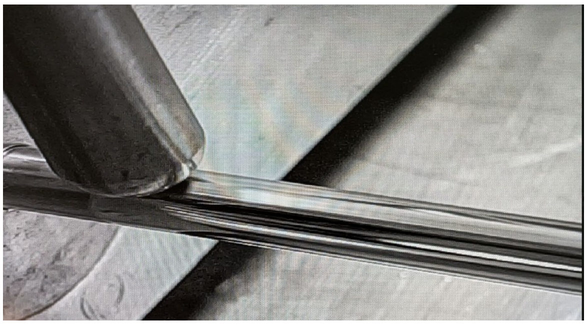
luminosity control. Figure 1 shows a 3D view of the Spin Physics Detector with detailed sketches of the barrel and endcap Straw Trackers

To minimize possible systematic effects, the SPD will be operated with a triggerless Data Acquisition (DAQ) system. The design instantaneous luminosity up to $1e^{32}$ Hz/cm^2 will result in the collision rate of about 4 MHz, and several hundred thousand detector channels pose a significant challenge to the DAQ, online monitoring, offline computing system, and to the data processing software.

2. Design principles of the Straw Tracker

The purpose of the Straw Tracker (ST) is to reconstruct tracks of primary and secondary charged particles with high efficiency and precision, and, using the measured track curvature in the magnetic field, to perform precise measurement of their momenta. The Straw Tracker should also contribute to particle identification using the ionization energy loss (dE/dx) measurements. The spatial resolution of the ST is required to be about 150 µm. The tracker will be built of low-mass straw tubes, similar to those of many modern operating or developing detectors, such as straw trackers of NA62 [2],[3], ATLAS[4], Dune [5], COMET [6], SHiP [7], Mu2e [8], COMPASS [9], NA64 [10], and other experiments.

Those trackers are made of straws produced with two significantly different technologies. The ATLAS Transition Radiation Tracker, the COMPASS, Mu2e and NA64 tracking systems consist of straws produced from two thin films wound together to form at tube. Modern technology of ultrasonic welding has been developed for the NA62 Straw Tracker and is considered for future tracking systems of the Dune, COMET and SHiP experiments. Figure 2 demonstrates the production process of such tubes.



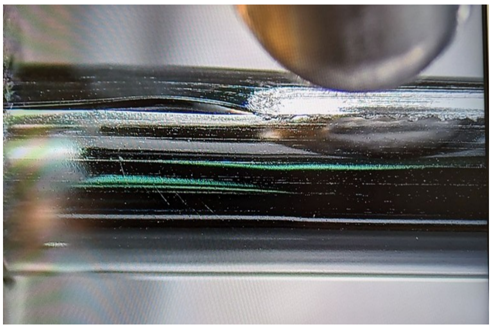


Figure 2: An ultrasonic head and a straw during the welding process (left) and a zoomed view of the seam during the welding(right).

The SPD Straw Tracker will exploit both technologies, the straw winding for the endcap, and the ultrasonic welding for barrel parts. We describe here the barrel part of the SPD Straw Tracker.

2.1 Design and material of the barrel straws

The barrel part of the ST consists of about 26 000 straw tubes. The straws will be manufactured from a thin polyethylene terephthalate (PET) foil, which is welded longitudinally by ultrasonic welding to form a tube. The straws have the active length from 10 cm to 2.7 m and

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the nominal inner diameter of 9.8 mm. Their inner surface has a double layer metal coating (Cu/Au) to provide electrical conductance of the cathode. Anode is done of 30 um golden plated tungsten wire placed inside the straw. The operation high voltage is chosen to provide about 45000 of the charge amplification for 70%Ar+30%CO_2 working gas mixture. The tracker will operated at the pressure close to the atmospheric value.

The choice of the straw material is a compromise between many different requirements, like the tracker material budget, permeation of gases, mechanical properties, adhesion of the metal coating, bonding with epoxy glue, and the ability to be ultrasonically welded into a tube. A summary of the PET specifications is given in Table 1.

Description	Specifications
PET film	polyethylene terephthalate type Hostaphan RNK 2600 of (36 ± 2) μm thickness
Density	1.4 g/cm^3
Copper layer thickness	50 nm
Gold layer thickness	20 nm
Resistivity of straw tube (2.1 m)	$\sim$70 Ω
Permeation of naked film, (10^{-12} Torr$\times$1$\times$cm/s$\times$cm^2$\times$Torr)	6 for He, 0.06 for Ar, 1 for CO_2

Table 1: Properties of the straw cathode material

The straw tubes of the barrel SPD Straw Tracker will be manufactured from a biaxially oriented coextruded film made of PET. One side of the film is chemically pre-treated to improve adhesion. This side is chosen for epoxy bonding between the straw tube and the straw fixation plug made of polyetherimide (PEI). The non-treated side is coated by a conductive layer of 50 nm of copper followed by a 20 nm protective layer of gold. The conductive layer is inside the tube, while the outer side of the cathode is uncoated and pre-treated chemically for bonding. The thickness of the film is 36 µm.

2.2 Ultrasonic welding – the SPD straw production and quality control

The straw manufacturing process in general follows the procedure developed for the Straw Tracker of the NA62 experiment [2]. The tubes are manufactured of a 36 µm thick PET foil, coated at one side with two thin metal layers (0.05 µm of copper and 0.02 µm of gold) in order to provide electrical conductivity of the cathode, and to improve impermeability of the working gas mixture (Ar/CO_2). The operating NA62 Straw Tracker demonstrates the high quality of straws produced with ultrasonic welding using such type of foil. The tracker consists of 7168 straws and operates inside a vacuum volume. The total leak rate of the whole NA62 Straw Tracker does not exceed 7 mbar/min.

Prior the new straw production run, several straws of 10 mm diameter have been produced with the ultrasonic welding technique and used for dedicated mechanical tests. Part of them were cut in 20 segments of about 25 cm long and tested under overpressure until the breaking point. The breaking pressure was found to be 9 bar in average, and no any sample was broken at the pressure below 8.5 bar.

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The control of the straw production quality is kept at the same level as has been implemented for the NA62 straws. During the ultrasonic welding process the seam quality is checked by an operator in real time. It is verified with a digital microscope during the welding process and the full set of images is recorded for every straw. All straw tubes made so far in the ongoing production run have good seams.

Several measurements and tests are performed after the production. The seam width and the straw inner diameter are examined with optical methods. The electrical DC resistance of the cathode is measured. The edges of the produced straws are always cut off and are used in dedicated quality tests. The straw elongation and the breaking force are measured for every cut peace.

The produced straws undergo several overpressure tests with temporary end-plugs glued into both ends of each straw. An overpressure test with up to $\Delta P \approx 3$ bar is done for a period of about 1 hour. Then a long term overpressure test with $\Delta P \approx 1$ bar is performed for least 30 days. The pressure reduction of 100 mbar at the end of the test is set as the quality threshold, however, no any of the produced straw was found to be below this threshold.

3. Summary

Active phase of the SPD Straw Tracker R&D is ongoing in many directions such as the detector construction optimization, engineering, prototyping, development of the readout electronics concepts and work on simulation and reconstruction software. The activity is based on the experience of the operating and developing Straw Trackers (NA62, DUNE, etc). R&D on the design of the supporting frame is ongoing aiming to reduce the material budget preserving the construction redundancy and maintenance flexibility. The SPD Stage 1 has more moderate requirements to the Straw Tracker hit rate capabilities, but is very challenging due to the requirements to combine good tracking and particle identification functions. SPD Straw Tracker development profits from the ongoing general Straw Tracker R&D for the front-end electronics solutions.

To ensure the required amount of straw in the SPD experiment, JINR is expanding its production capacity. Despite the high level of quality of the straw produced (out of 8k straw working for more than 10 years in the NA62 experiment, only 1 channel does not work), active R&D work continues for further technology development.

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