

Tracking with Straw Tubes in the PANDA Experiment

M. Bragadireanu¹, D. Pietreanu¹, M.E. Vasile¹, M. Idzik², D. Przyborowski², P. Kulesa³, K. Pysz^{3,a}, J. Biernat⁴, S. Jowzaee⁴, G. Korcyl⁴, M. Pałka⁴, P. Salabura⁴, J. Smyrski⁴, D. Bettoni⁵, E. Fioravanti⁵, I. Garzia⁵, M. Savriè⁵, P. Gianotti⁶, V. Lucherini⁶, E. Pace⁶, M. Mertens⁷, H. Ohm⁷, S. Orfanitski⁷, J. Ritman⁷, V. Serdyuk⁷, P. Wintz⁷, S. Dobbs⁸, A. Tomaradze⁸, G.L. Boca⁹, S. Costanza⁹, P. Genova⁹, L. Lavezzi⁹, P. Montagna⁹, A. Rotondi⁹, and S. Spataro¹⁰

¹ *Institutul National de C&D pentru Fizica si Inginerie Nucleara "Horia Hulubei", Bucharest, Romania*

² *AGH-UST, University of Science and Technology, Cracow, Poland*

³ *IFJ, Instytut Fizyki Jądrowej, PAN, Cracow, Poland*

⁴ *Instytut Fizyki, Uniwersytet Jagielloński, Cracow, Poland*

⁵ *Dipartimento di fisica, Università e sez. INFN di Ferrara, Italy*

⁶ *INFN, Laboratori Nazionali di Frascati, I-00044, Frascati, Italy*

⁷ *IKP, Forschungszentrum Jülich, Germany*

⁸ *Northwestern University, Evanston, U.S.A.*

⁹ *Dipartimento di Fisica, Università e sez. INFN di Pavia, Italy*

¹⁰ *Dipartimento di Fisica, Università e sez. INFN di Torino, Italy*

Abstract. The PANDA spectrometer will be built at the FAIR facility at Darmstadt (Germany) to perform accurate tests of the strong interaction through $\bar{p}p$ and $\bar{p}A$ annihilation studies. The charged particle tracking at PANDA will be done using both solid state and gaseous detectors. Among the latter, two straw tube detector systems will be built [1]. The cylindrical, central straw tube tracker features a high spatial and momentum resolution for a wide range of particle momenta from about 8 GeV/c down to a few 100 MeV/c, together with particle identification in the momentum region below about 1 GeV/c by measuring the specific energy-loss. A new technique, based on self-supporting straw double layers with intrinsic wire tension developed for the COSY-TOF straw tracker [2], has been adopted for the PANDA trackers. The development of the readout electronics for the straw tubes is ongoing. Prototypes have been produced and used to instrument straw tube modules that have been tested with cosmic rays and proton beams. Design issues of the PANDA straw tubes, together with the results of the prototype tests are presented.

The PANDA experiment [3] is one of four experiments planned for the future Facility for Antiproton and Ion Research (FAIR) [4] in Darmstadt, Germany. The scientific program of the PANDA Collaboration is oriented towards precise studies of strong interaction in the QCD transition region between asymptotically free quarks and hadronic matter. The maximum available center of mass total energy in the PANDA experiment ($\sqrt{s} = 5.46 \text{ GeV}/c^2$) will allow hadronic structures involving the charm quark degrees of freedom to be investigated. The PANDA detector will be installed around the internal target of the High Energy Storage Ring (HESR), which will accumulate, accelerate and cool up to 10^{11} antiprotons. In the experiment, the annihilation of antiprotons with

^ae-mail: krzysztof.pysz@ifj.edu.pl

momentum up to 15 GeV/c on a hydrogen target will populate all the conventional hadronic states, as well as the exotic ones. By working in the so called *high luminosity* mode of the HESR (where the luminosity reaches $2 \cdot 10^{32}/\text{cm}^2 \cdot \text{s}$) particle rare decays, as well as the spectroscopy of excited states will be studied. On the other hand, the *high resolution* mode of the HESR (where the beam momentum p spread is only $\sigma_p/p = 4 \cdot 10^{-5}$) will permit to scan the masses and determine the widths of the states with an accuracy never achieved before. The physics of hypernuclei and the influence of the nuclear medium on the properties of the hadrons will be studied with the use of nuclear targets. The complete description of the research program of the PANDA Collaboration can be found in the PANDA physics report [5].

The momentum determination of the charged products of the annihilation will be done by means of tracking them along their propagation path in a magnetic field. Two magnets are foreseen for PANDA: a 2 T magnetic field solenoid surrounding the interaction point, and a 2 Tm dipole placed in the forward region. Inside the solenoid, a set of detectors forming the so called **Target Spectrometer (TS)** will be installed. The system of forward detectors comprising the dipole magnet is called the **Forward Spectrometer (FS)**.

The tracks of the particles in PANDA will be reconstructed by an ensemble of solid state and gaseous detectors. In the TS are foreseen: a silicon **Micro Vertex Detector (MVD)** [6] which encloses the interaction point, a **Straw Tube Tracker (STT)** surrounding the MVD and the 3 layers of planar chambers based on GEM foils at forward angles. The 6 planar detectors made of straw tubes will be used for tracking of the particles of high longitudinal momenta in the FS.

The design of the PANDA straw trackers is a challenging issue due to the demanding performance requested to the detectors, motivated by both the physics program and also by the high rates foreseen. The STT performance should fulfill the following requirements:

- track position resolution in the radial direction $\sigma_{r\phi} < 150 \mu\text{m}$;
- track position resolution in the longitudinal (beam) direction $\sigma_z < 2.8 \text{ mm}$;
- energy loss resolution $\sigma_E/E < 10\%$ to assure the π/K separation;
- momentum resolution σ_p/p of about 3%;
- high rates capability with loads of few hundred kHz/cm of highly ionizing elastically scattered protons;
- long-lasting failure-free operation with electrical and mechanical stability.

High spatial and momentum resolution of the STT is demanded for particles momenta in the range from few 100 MeV/c to 8 GeV/c. Particle's identification, based on the specific energy loss measurements, is foreseen for low momentum particles below 1 GeV/c.

The **Forward Straw Tube Tracker (FSTT)** is composed of 10752 straw tubes organized in 6 planar tracking stations placed at distances from the target from 2.9 m to 7.5 m. The FSTT covers a range of polar angles of $\pm 5^\circ$ in the vertical, and of $\pm 10^\circ$ in the horizontal direction, respectively. The detector has an acceptance down to 2% of the beam momentum and measures the particle momenta with a resolution of 0.5%.

The design of the STT has been driven by the results of simulations of physics processes and of the detector response as well as by experimental tests performed with small and large scale prototypes exposed to cosmic radiation, radioactive sources and proton beams from the COSY accelerator in Jülich (Germany). The layout of the STT is a structure of densely packed straw tubes filling a cylindrical volume divided in two halves, each consisting of 3 sectors (Fig. 1). The detector's radial dimensions are $R_{in}/R_{out} = 150/420 \text{ mm}$ and the total length is $L = 1650 \text{ mm}$ including front-end electronics, gas distributors, HV connectors and slow control. Each sector will have 23-27 planar layers; 15-19

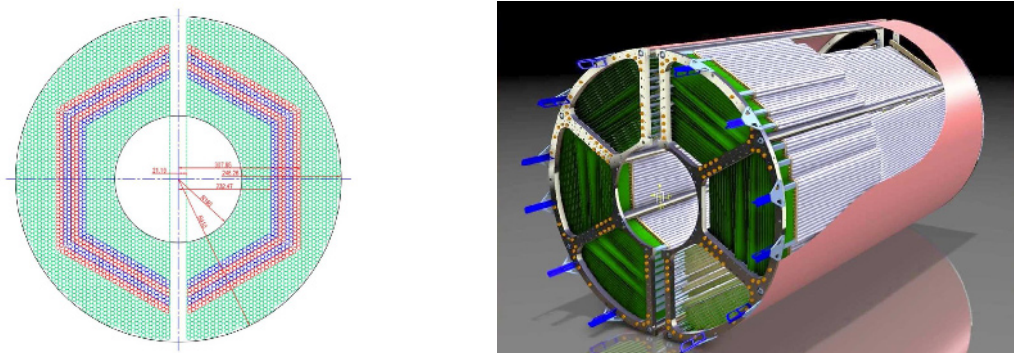


Figure 1. Left panel: cross section of the PANDA STT showing the dimension and the packing scheme of the straw tubes. The axially oriented straw tubes are drawn in green. The straw tubes oriented at $\pm 3^\circ$ are drawn in blue/red. Right panel: A CAD drawing presenting the STT from the backward side where the installation of front-end electronics is foreseen.

of them have straws parallel to the beam axis, the remaining 8 layers, which serve to determine the longitudinal position of the tracks, are tilted with respect to the beam direction by $\pm 3^\circ$. In Fig. 1 the axial layers are drawn in green, whereas the stereo layers in blue/red. The total number of straw tubes is 4636. The selected gas mixture is Argon with 10% of CO_2 as quencher. The operating gas pressure is 2 bars and the high voltage is set to have a gas gain of 5×10^4 . The detector thickness in terms of radiation lengths is 1.2%, where $2/3$ of the material budget comes from tube walls and $1/3$ from the gas.

The straw tubes have a diameter of 10 mm, a length of 1.5 m and are made of an Aluminized Mylar film. The wall thickness is only $27 \mu\text{m}$. A gold-plated Tungsten/Rhenium wire of $20 \mu\text{m}$ diameter is used as sense wire. Construction elements like end plugs, crimp pins, gas tubes, have been carefully selected to be light and made of chemically stable materials. The total weight of a single tube is only 2.5 g, corresponding to 4.4×10^{-4} of radiation length.

The straw layers assembly technique has been originally developed for the COSY-TOF straw tube tracker [2]. It consists in the production of straw double layers, which become self-supporting under the gas overpressure. Such panels assure precise geometrical positioning of wires and tubes and are mechanically rigid and stable. The anode wire tension is kept by the elongation of the straw tube induced by the gas overpressure. Thus, heavy support structures for the detector can be avoided. With this concept, high geometrical precisions of wire positioning has been achieved, together with a significant reduction of the material budget.

Extensive tests of all adopted solutions are undergoing with small and large scale prototypes. The test have the following goals:

- assessment of spatial and energy resolution;
- validation of the assembly technique and of all structural materials;
- development of the readout electronics;
- implementation of measures to prevent aging.

Tests performed with a large scale system of 2700 straws (but without magnetic field) yield a position resolution equal to $138 \mu\text{m}$. The long lasting operation of this system in vacuum has not

shown deterioration of the gas tightness. This is a strong evidence of the reliability of the technology and of the chosen materials.

The demand for STT to simultaneously perform the particle identification process by means of specific energy loss measurements has required a systematic study of the energy resolution of a multilayer straw-tracker. Tests using a prototype of 128 straws were done for minimum- as well as for highly ionizing protons. The results show that for tracks with about 20 hits in the PANDA STT, an uncertainty lower than 8% of the deposited energy can be achieved.

Continuous irradiation of straw tubes with the intense proton beam from the COSY accelerator during 199 hours has been performed. The detector has been operated at normal conditions. The total dose accumulated by the straw tubes reached 1.2 C/cm. Inspection of the detector performance after the test allowed to conclude that at moderate gas gain of 5×10^4 no ageing is expected for 99,7% of the PANDA- STT volume during 5 years of operation at full luminosity.

The electronics that has to process the signals of the PANDA straw tube trackers, has to assure an unambiguous signal identification in the harsh conditions of high luminosity. It has also to deliver simultaneous and precise information about the particle's traversing time and deposited energy in the detector volume, and to fulfill mechanical, electrical and financial constraints. Developments and tests are ongoing. The considered options are:

- a specialized ASIC chip allowing for baseline stabilization and ion-tail cancellation, delivering the hit time and the Time-over-Threshold (related to energy-loss) by means of LVDS signals. Signals from ASIC boards would be processed by Trigger and Readout Boards [7] working as digitizers and acquisition devices;
- signal analysis performed by a FPGA combined with a flashADC. This option will permit the continuous baseline determination, signal identification and an almost optimal timing combined with signal integration for energy loss evaluation. The flashADC would be associated with current amplifiers directly connected to the straw tubes.

Both options have been tested with the use of proton beams and show promising features.

Conceptual designs of mechanical frame and integration with PANDA setup, 3D-track reconstruction software and pattern recognition are under development.

References

- [1] W. Erni et al., Technical Design Report for the: PANDA Straw Tube Tracker, arXiv:1205.5441, Eur. Phys. J. A (2013) 49: 25, DOI: 10.1140/epja/i2013-13025-8.
- [2] P. Wintz, in Intersections of Particle and Nuclear Physics: 8th Conference CIPANP2003, AIP Conf. Proc. 698-1, 792 (2004);
- [3] PANDA collaboration, Letter of intent for PANDA - Strong Interaction Studies with Antiprotons, Technical report FAIR-ESAC, (2004), <http://www-panda.gsi.de/html/reports.php>
- [4] GSI Helmholtzzentrum für Schwerionenforschung, FAIR - An International Accelerator Facility for Beams of Ions and Antiprotons, Baseline technical report, (2006), <http://www.gsi.de/fair/reports/btr.html>.
- [5] PANDA Collaboration, Physics Performance Report, (2009), arXiv:0903.3905v1.
- [6] Micro Vertex Detector Technical Design Report, <http://arxiv.org/abs/1207.6581v2>.
- [7] M. Traxler et al., A compact system for high precision time measurements (< 14 ps RMS) and integrated data acquisition for a large number of channels, 2011 JINST vol. 6 C12004, DOI: 10.1088/1748-0221/6/12/C12004