Tracking charged particles is one of the essential tasks of the PANDA ex-
Experiment, providing information about primary and secondary decay vertices, momenta and types of charged particles emitted after antiproton-proton annihilation. Different tracking devices are under construction for the PANDA spectrometer and among them the two straw tube trackers. A new technique, based on the use of straw tubes operated at over-pressure has been adopted allowing the construction of self-supporting modules avoiding heavy mechanical frames.

Keywords: Gaseous detector; straw tubes; hadronic physics.

1. PANDA straw tubes

PANDA is a new experiment that will be installed at HESR, the new antiproton storage ring under construction as part of the new FAIR facility at Darmstadt, Germany. This experiment will investigate QCD in the charmonium mass range, and other aspects of particle and nuclear physics. It will be a fixed target detector with a Target Spectrometer (TS), surrounding the interaction point, and a Forward Spectrometer (FS) for detecting particles emitted at forward angles.

Tracking charged particles is one of the essential tasks of PANDA and for this reason different detectors will be used. Among them PANDA will have 2 straw tube trackers: the first, located in the TS, is a cylindrical device; the second, in the FS, consists of a set of planar detectors. Independently from their layout, the 2 systems will use self-supporting straw tube modules made of similar straws of 1 cm diameter. The cathode material is a thin aluminized mylar film (thickness 27 μm) with a gold-plated tungsten-rhenium wire, of 20 μm diameter, as anode. The anode wire is stretched by a weight of 50 g and crimped in copper, gold-plated pins. Cylindrical precision end-plugs, made from ABS with a wall thickness of 0.5 mm, close the tubes at both ends and provide the pin and the gas pipe housing. They are glued to the mylar film leaving a small 1.5 mm film overlap on both ends. There, a gold-plated copper-beryllium spring wire is inserted to provide either the cathode grounding and to allow a 2 mm tube elongation induced by the over-pressure of the gas mixture. The total weight of a fully assembled straw is only 2.5 g. The straw tubes are operated with an over-pressure of about 1 bar to allow the construction of self-supporting modules, a technique that has been developed and successfully implemented for the first time for the COSY-TOF straw tube tracker. In the following sections the details of the designs of the PANDA Central and Forward straw tube trackers are presented together with experimental results of the R&D phase.
2. Self-supporting straw tube modules

Straw tubes are single channel drift detectors consisting of an anode wire surrounded by a thin cylindrical cathode. With a wire tension\textsuperscript{a} of about 50 g inside a 1.5 m long straw tube, for the 4636 straws of the PANDA central tracker this adds up to a wire tension equivalent to about 230 kg which must be maintained. Usually, this is done by fixing the straw tubes inside a strong and massive support frame or by adding reinforcement structures. These methods inevitably increase the detector thickness given in radiation length and are not acceptable for the PANDA experiment. Therefore, it has been decided to adopt a technique based on self-supporting straw layers, with intrinsic wire tension, developed for the COSY-TOF straw tracker.\textsuperscript{2} The straw tubes are assembled and the wire is stretched by 50 g with an over-pressure of 1 bar. Then the tubes are close-packed and glued together to planar multi-layers on a reference table which defines a precise tube to tube distance of 10.1 mm. At the gas over-pressure of 1 bar the double-layer not only maintains the nominal wire tension but it also become self-supporting.

Figure 1 shows a pressurized straw multi-layer. The system is supporting the weight of a lead brick of 3 kg.

![Pressurized, close-packed straw layers show strong rigidity as demonstrated here by a 3 kg Pb-brick.](image)

The gas mixture used is Argon based with 10% CO\textsubscript{2} as quencher. This gas mixture is known as being one of the best for high-rate hadronic envi-

\textsuperscript{a}Usually given as the mass weight used to stretch the wire.
rornments due to the absence of polymeric reactions of the components once there is a clean gas environment including all materials and parts of the detector and gas supply system. The HV is set to have a gas gain not greater than $10^5$ in order to warrant long term operation. With these parameters, a spatial resolution, in the $r - \phi$ plane, of less than 100 $\mu$m is expected. This value has been extrapolated from the measured value obtained with straw tube prototypes of 1 m length operated at an over-pressure of 250 mbar (see Fig. 2).

![Spatial resolution measured with self-supporting straw tubes of length 1 m, operated at 1.250 bar.](image)

3. Energy loss measurements

A special requirement for the PANDA straw tubes is that of helping in the process of particle identification in the TS for particle momenta below 1 GeV/c. This is something not routinely done in other straw tube detectors, therefore this possibility has been deeply studied with Montecarlo simulations and experimental tests. Figure 3 (left) shows the distribution of the simulated specific energy losses for different particles, plotted versus the momentum. The radial path has been reconstructed by the measured drift radius and by the dip angle resulting from the fit. The dE/dx has been calculated with the truncated mean at 30% in order to cut out the higher dE/dx tails. Figure 3 (right) reports the separation power of the central straw tube tracker for the different particle species; particle’s identification is feasible below 0.8 GeV/c momenta.

To test experimentally these results a dense array of 128 straw tubes, arranged in four double-layers of 32 straws each, has been exposed to the proton beam of the COSY synchrotron of the Jülich Research Center. Straw signals have been fed into a 16-ch 240 MHz flashADC. For each event
Fig. 3. (left) Simulated distribution of dE/dx vs momentum for different particles. The superimposed lines are the mean value of the bands. (right) Separation power in the straw tube detector for different particle species. The vertical line at 0.8 GeV/c indicate the threshold below which identification is feasible.

the signals from the fired straws have been summed up to build the energy loss distribution and, as for the simulations, the truncated mean technique has been applied to cut out high energy tails. The energies of the truncated distributions have then to be divided by the appropriate reconstructed track lengths. Truncated energy loss distributions for different proton momenta are shown in Fig. 4 for 2.95, 1.0 and 0.64 GeV/c momenta. The results for

Fig. 4. (left) dE/dx distribution for protons of 0.640 MeV/c with Gaussian fit. Only events with 16 straw tubes per reconstructed track are included. (right) dE/dx distributions for protons of 2.95 GeV/c and 1.0 GeV/c with Gaussian fits. Only events with 18 straw tubes per reconstructed track are included. Truncated mean of 30 % is applied to all histograms.

the 0.64 GeV/c protons cannot be presented on the same energy scale of the results of 1.0 and 2.95 GeV/c due to the lower number of hit straws (16 instead of 18), and because a higher threshold was used during the
analysis of this data set. The results of these measurements give an energy resolution of 8% for 1.0 GeV/c protons. This improves at lower momenta with the increase of the particle energy deposit. At 0.64 GeV/c, with only 16 straws per track, the resolution is equal to 7%. For tracks inclined by 45° a systematical deterioration of the resolution of about 1% is observed. Nevertheless, it must be pointed out that in the PANDA central tracker the mean value of hit tubes will be around 23 improving energy resolution measurements.

4. The central tracker

The PANDA TS straw tube tracker (CT) occupy a cylindrical volume with an internal diameter of 150 mm and an external one of 418 mm. Due to the presence of the target pipe, in the x, y plane this volume is divided in two halves, with a gap of 42 mm in between. Along z, the allowed space is 1500 mm, plus 150 mm in the upstream region for electronics, gas supplies, and other services. To fill up this volume, it has been decided to use planar layers mounted in a hexagonal shape as shown in Fig. 5. The proposed arrangement consists of 4 double-layers parallel to the detector axis, 4 skewed double-layers, with an angle, with respect to the beam axis, of about ±3°, and further 2 straight double-layers. Finally, to approach the cylindrical shape, 7 layers with a decreasing number of straws are placed in the outer region. In total the detector consists of 4636 straws divided in two identical semi-chambers held by two light mechanical frames (8.2 kg in case of Aluminum). The overall detector will result in a material budget of 1.2% of a radiation length.

Fig. 5. (left) Arrangement of the straw tubes within the PANDA central tracker. (right) CAD drawing of the whole detector.
5. The forward tracker

The particle trajectories in the FS will be measured by the Forward Tracker (FT) consisting by three pairs of chambers made of straw tubes similar to those proposed for the CT. The first pair will be placed in front, the second within and the third behind a dipole magnet. The detection planes are built of separate modules, each containing 32 straws arranged in two layers as shown in Fig. 6. Each of the six stations of the FT contains four double-

![Fig. 6. CAD drawing of the first chamber of the PANDA FT. Nine modules, made of 32-straw-tubes, are mounted on a rectangular support frame. The opening in the middle of the detector is foreseen for the passage of the beam pipe.](image)

layers: the first and fourth layer contain vertical straws (0°) and the two intermediate layers - the second and the third one - contain straws inclined respectively at +5° and −5°. This arrangement allows a three dimensional reconstruction of events.

The straw plane of the FS will have a small gap in the center to allow the passage of the beam pipe.

References

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