Mapping the Large Area Straw Detectors of the COMPASS Experiment with X-Rays

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The COMPASS experiment at CERN employs straw detectors for the tracking of hadrons and muons. An assembly of 15 double layers, each consisting of about 800 straws, is in operation. These are grouped in submodules of three double layers, one with straws horizontal to ground, one with vertical straws and one with straws tilted with respect to vertical by 10^o. In this way a space point is defined without ambiguity by each submodule. COMPASS can be seen as a double magnetic spectrometer. In the present setup, each dipole magnet is followed by two straw submodules. A fifth submodule provides additional tracking downstream of a large ring-imaging Cherenkov detector.

An X-ray CCD apparatus was developed for the off-line scanning of straw double layers [1,2]. It consists of an X-ray source and a 20x30 mm^2 CCD, both movable in an area of 3.6x3.6 m^2 on either side of the straw detector (Fig. 1a). The air cooled X-ray source is operated at a voltage of 50 kV, with typical exposure times of 4 seconds per picture. The CCD device has a pixel size of 44x44 μm^2. It is read out by a VME module. For both, the X-ray source and the CCD, x and y coordinates can be adjusted independently by means of stepping motors controlled by a Linux PC via serial interface.

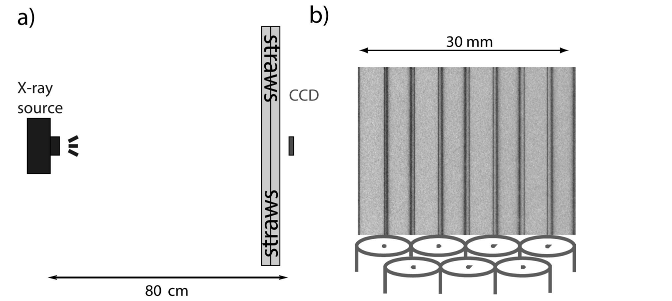

Fig. 1: a) X-ray CCD setup to image the straw double layers. b) Single CCD image of a double layer in the section of 6mm straws. The sharp black lines are due to anode wires, whereas the broad lines are the shadows of the straw walls (plus glue). The two layers are displaced with respect to each other by roughly one tube radius.

The CCD images (Fig. 1b) show sharp shadows of the anode wire and more diffuse shadows arising from the projection of the straw wall and the glue attaching neighbouring straws to each other. A pattern recognition program distinguishes these structures, even when they overlap, and determines the center of gravity for the anode wires with an accuracy better than 2 μm. A method of triple stereo imaging was developed that uses wire shadows at the edge of a CCD picture to reconstruct the CCD movement. By taking overlapping pictures for fixed source position the CCD movement is determined with high precision from the distance marked by the same wire shadow found at either edge of the CCD in 2 consecutive images. The procedure incorporates external reference wires to control and recalibrate the CCD position every 300 mm. The reference wires also provide a common coordinate system for different scans over the whole detector area.

The absolute wire coordinates are found to be reproducable within 30 μm over the total area of 8 m^2. It is noted that the accuracy of this procedure is essentially due to the excellent position resolution of the CCD. It does not require costly mechanics with active control of the CCD and source movements. Temperature effects are clearly seen. These limit the accuracy under realistic experimental conditions to about 50 μm, which is sufficient in view of the intrinsic straw resolution of 200 μm for minimum ionizing particles.

Since the calibration was carried out off-line it was checked with particle tracks. Other tracking detectors of the experiment allow an independent reconstruction of track positions in a central area of a straw plane. The coordinates x_0, corresponding to minimum drift times in the straws, yield the wire positions from small-angle tracking independent of the X-ray calibration.

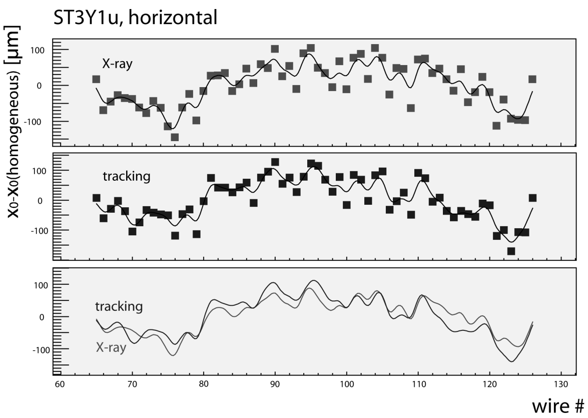

Fig. 2: Comparison between the wire positions from the X-ray calibration (upper panel) and from particle tracking (middle panel) in a central detector area covering 60 straws of 6 mm diameter. Plotted are the deviations from the nominal positions as defined by equal spacing. Gaussian smoothing ($\sigma = 2$ wires, full lines) suppresses the individual fluctuations, including the errors of the measurements, and underlines the high correlation between the two independent measurements (lower panel).

Satisfactory agreement between the wire coordinates from the X-ray calibration and those from small-angle tracking is found for all 9 layers of straws that were tested in this way. An example of a plane with straws parallel to ground is provided by Fig. 2. Since the tracking data were recorded one year after X-raying, in the course of which the detectors experienced seasonal temperature changes and a few reinstallations, one can expect that the X-ray calibration has long term validity.

References

[1] K. Platzer, Ph.D. thesis, LMU München, 2004
[2] K. Platzer, W. Dünnweber and H. Wellenstein, IEEE Trans. Nucl. Sci. **51** (2004) 1555