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PRECISE ALIGNMENT OF SILICON SENSORS USED IN AMS EXPERIMENT

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ABSTRACT

In this paper, we describe a precise and fast method for the alignment of silicon sensors in AMS experiment. Some studies on the precision of assembly jigs used in Perugia Assembly Line and measurement results done on the several AMS ladders are also reported.

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1. INTRODUCTION

The Alpha Magnetic Spectrometer (AMS) is a space borne particle physics experiment designed to search for and measure, with a much greater sensitivity than heretofore possible, antinuclei in space [1, 2].

To measure the trajectory of charged particles in the AMS magnetic field, to deduce their momentum and charge sign, AMS Spectrometer has a Silicon Tracker composed by six layers of double-sided silicon microstrip detectors. Each layer is composed by several silicon ladders with lengths from 29 to 62 cm. The ladders are composed by double sided silicon sensors (7 to 15 depending on the ladder position) with dimensions 72.045μm x 41.360μm x 300μm and the associated front-end electronics.

The two sides of the sensors measure the track position in the bending (y) and non-bending (x) directions.

On the S side of silicon sensors (with p^+ implantation), the strips are oriented parallel to the short side of silicon sensor. They are connected by ultrasonic wire bonding to the strips of neighboring silicon, so that on this surface of the ladder a channel represents a line, which contains strips from all silicon sensors. The ladder is oriented so that the magnetic field is parallel to the strips on S side. This face will measure coordinates on the direction perpendicular to the magnetic field (bending direction). For S side, all strips are read-out with a pitch of 110μm by the readout system. The required resolution for bending coordinate is 10μm. In order to exploit this accuracy, the silicon sensors have to be lined up on the longitudinal direction of the ladder with an accepted root-mean-square less then 5μm.

On the K side of silicon sensors (with n^+ implantation), the strips are oriented parallel to the long side of silicon sensor. A thin Kapton cable glued on the sensors connects the strips by diagonal traces, which run across the ladder from one sensor to another. The read-out pitch on the K side is 208μm which satisfy the required resolution of 30μm. This

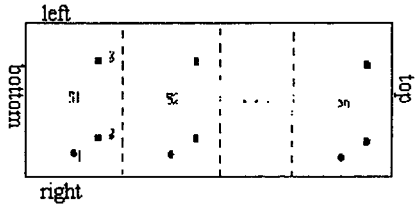

Fig. 1 An oversimplified sketch of the jig

face will measure coordinates on the perpendicular direction to magnetic field (non-bending coordinate).

2. ALIGNMENT METHOD

The big number of silicon sensors in one ladder and comparatively, the big number of ladders reclaim a sturdy and fast method for assembly silicon sensors in the ladder. This method is based on the alignment of the silicon sensors to three pins located on a precise assembly jig. Figure 1 presents an oversimplified sketch of this jig.

Precise position of each silicon (S1, S2...) is determined by the position of these three pins, 1, 2 and 3 on the figure. After positioning one silicon sensor against the three pins, it is maintained in this position by vacuum until the kapton film is gluing on top of them. In Figure 1 the characteristic denomination used to specify the position of reference crosses measured on each silicon sensor (bottom-right, top right, bottom left and top left) can be seen also.

In Perugia Assembly Line, two assembly jigs (jig nr. 3 and 5 of those made in Geneva [3]) were used for AMS experiment. They were dedicated for assembly ladders with 11 and 12 silicon sensors.

The jigs manufacturing precision was studied measuring the position of holes, which fix de pins. Figure 2 shows some measurement results for jig nr 3, using positions for the first 11 silicon sensors. We can see the distributions of residuals to the line which fits positions of all points 1 (on the right part of image) and the distributions of residuals versus positions of holes on the ladder. Also, the tilts of the lines determined by positions 2 and 3 to OY axis (OX axis is directed along ladder) were studied and the results will be presented somewhere else.

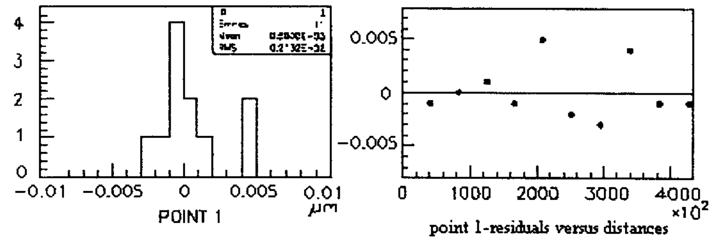

Fig. 2 The results of measurements for positions of the holes

To evaluate the effect of the jig manufacturing precision, we converted the above manufacturing errors in silicon sensor positioning errors, assuming perfect positioning of the silicon sensors against the pins and ideal sensors with the following dimensions: the angle between sides of 90 degrees, distances between reference crosses of 40760μm x 71445μm and distances from crosses to the edge of 300μm.

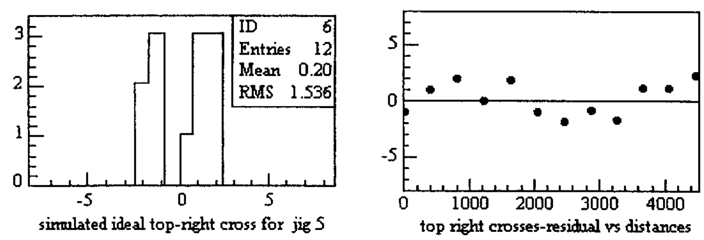

Fig. 3 The results obtained for the right reference crosess

The positions of reference crosses were measured and we obtained a r.m.s. for distribution of distances between right crosses (bottom and top altogether) on two neighboring silicon sensors of 1.5μm and r.m.s. for distribution of residuals to the fit line for right part crosses of 2μm. Maximal value of residuals is 4μm for top-right crosses and 5μm for bottom-right crosses and that happens for the sensors nr. 6 and 9, which have also a big deviation of residuals for positions of point 1.

The same analysis was done for jig nr.5, but for the first 12 silicon sensors (jig 5 was used especially for 12 silicon sensors ladders). The holes for the pins labeled with number 1 have a smaller dispersion comparatively to jig nr 3, and that explains a better alignment of right crosses for this jig with respect to jig nr. 3. The r.m.s is 1.5μm for jig nr. 5 (see Figure 3) and 2μm for jig. 3. Maximum residual is 3μm for the sensors labeled with number 12 (bottom-right crosses).

Other main sources of errors in alignment are uniformity of the cut of the silicon sensors and wrong positioning of the sensors to pins. Silicon sensors are cut in SELMIC, Finland. Extensive measurement of cutting line of silicon sensors made in Perugia, have point out that distances from crosses to cutting line are distributed close to 300μm, with r.m.s 5μm.

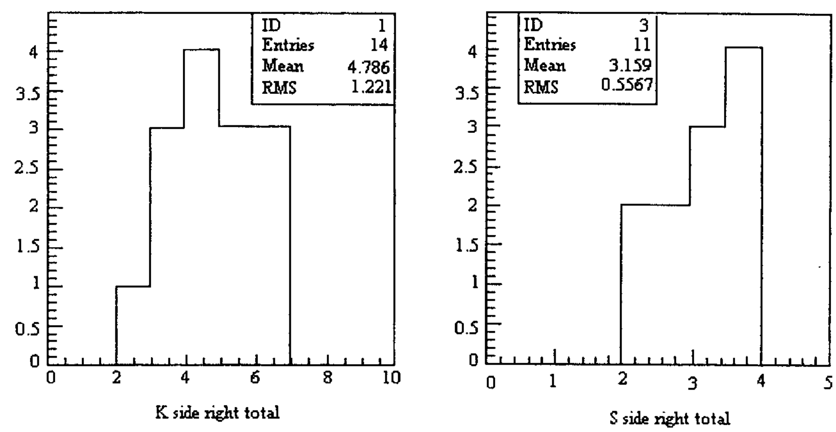

Fig. 4 The r.m.s. for the longitudinal distribution

To avoid wrong positioning of the sensors to the pins we have developed a checking program to automatically measure three points on the silicon edge, which was previously aligned to the pins. The hits are made with the stylus of 3D Coordinate Measuring Machine Mitutoyo. Before we have measured a statistical significant sample of silicon sensors positioned to pins and we have found referencing values for these points. We have accepted a tolerance of 5μm with respect to referencing values. The procedure of alignment is repeated if this condition is not fulfilled.

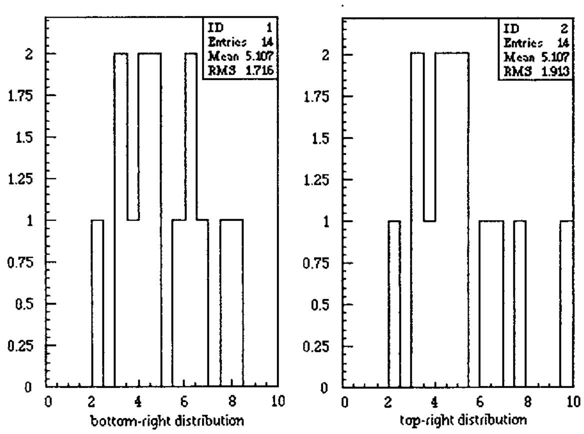

Figure 5 Intercross distances distribution for K side

3. RESULTS AND CONCLUSIONS

Figure 4 shows preliminary results obtained assembling ladders of 12 silicon sensors in Perugia, using jig 3 and 5. Longitudinal distributions of crosses on K side and on S side are not likewise. For S side, all ladders fulfill σ<5μm criterion. Mean value of r.m.s is 3μm, with a dispersion 0.5μm.

On the K side the r.m.s. is 5μm. There is a clear difference between S side and K side. That can come from a not so good relative positioning of the silicon K and S side masks. Silicon sensor cut is done with respect to the S side mask, so the K side mask is sometimes shifted and/or rotated with respect to the edge of the sensor, resulting in a possible abnormal sensor misalignment when metrology is done on the K side. Important for K side is distribution of distances between two neighboring sensors. Figure 5 shows a mean value of the r.m.s of these distances of 5.1μm.

These results show that the pin alignment method is fast and precise enough for AMS purpose.

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