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Simple control system of relative combs position on drift tube chamber assembling table

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Introduction

Heavy iron table with seven combs was used for BIL chamber prototype assembling in IHEP [1]. The combs are made of aluminum plate with glued balls on their top surface. Positions of the combs were measured by optical tools with precision 20 μm but such method consumes much time. For mass-production of the chambers more simple control system of comb position will be necessary.

Below we shall describe system of comb position control, which as we suppose is simple and has acceptable precision. The first results of measurements performed with mentioned above table will be also presented.

1. Description of the system.

The system is based on utilization of light beam diffraction after round screen. It is schematically shown in fig.1. There is a laser (λ=630 nm) at one end of the table. Light beam after laser goes through optical shaper and is directed over combs at one side of the table. Two pentaprizmes reflected the beam, which comes back over the combs of another side of the table and hit CCD, placed at the same end of the table as the laser. If round screen, in our case it is a ball (fig.2), is placed into the beam then CCD image gives us diffraction picture which main maximum position corresponds to projection of ball center on CCD plane. An example of typical diffraction CCD image is given in fig.3. Large black ring is ball shadow inside of which there is white narrow spot corresponding to the main diffraction maximum. Its radius is given by expression:

$$r = \frac{\lambda \cdot l}{2d},$$

where l is distance between ball and CCD, d is diameter of the ball and λ is wave length of laser light. Value of r is 30 μm for the closest to CCD position (1 in fig.1) and 300 μm for the largest distance. As center of the ball projection on CCD plane we used the center of gravity of the main diffraction spot. Measured statistical precision of this value is about of 1μm for the first point and 4-5 μm for the largest distance from CCD and it is caused by diffraction of light at parts of the laser and beam shaper and inhomogenity air refractive index along beam path. Moving the ball from one comb to another at both sides of the table and measuring coordinates of main spot (Y is perpendicular to table plane, Z is directed along comb) we can control the relative position of combs ends. Such method gives information about sag of the table but it is insensitive for twist of one.

For ideal combs and beam without divergence we would obtain liner dependence of the measured ball coordinate (Y or Z) versus distance of the ball from CCD (X). Due to uncertainties of the pentaprizmes there are two lines for direct and back beam. In fig.4 Y-coordinate of ball placed at 14 points is plotted versus distance of the ball from CCD along beam. Here and further we shall present results for 8-mm diameter balls at points 1-7 and 5.5 mm for points 8-14. Unfortunately there was some divergence of our light beam. It is equivalent to beam from point like source at distance about 27 m from CCD (fig. 5). For divergence beam if centers of balls are even at ideal line dependence of their coordinate versus distance from CCD is not linear:

$$P_i(x_i) = \frac{hx_i}{R - x_i} + const$$

To cancel the nonlinearity we shall use later follow function:

$$P_i^{'} = \left(P_i - \frac{hx_i}{R - x_i} \right) \times \left(\frac{R - x_i}{R} \right)$$

where P_i is measured coordinate (Y or Z) of projection ball center at CCD plane when ball is placed at distance X_i from CCD.

2. Results of combs position measurements

Measurements were performed during several days at significantly different conditions: temperature of the table was measured from 12.4 to 15.8^o C, sun light conditions were not stable also. Moreover between the first and the second measurements there was displacement of the pentaprizmes. Results of measurements are given in fig.6: a) and c) present Y- and Z-coordinate of ball projection versus distance from CCD; b) and d) - displacement of measured ball coordinate from straight line which goes through points for the first and the seventh combs. The lines were independent for direct and back beams. It is seen, that projection coordinates differ up to half of millimeter, but deviation of the points from the straight line is less than 50 μm and their spread from one measurement to another is less than 15-20 μm. The 4th comb has the largest Z-displacement (about of 45 μm) with different sign and about equal absolute value for direct and back beams. This displacement corresponds to 45 μm shift of the 4th combs as a whole.

Y-coordinates of ball projections deviate from the line less than 30-35 μm. The largest deviations were measured by direct beam for the 4th comb and back beam for the 3d one. As against to Z-coordinate, displacements of ball projections in Y-direction are not correlated for direct and back beams. An estimation of measurement precision is given in table 1, where RMS of displacements for each point obtained from 13 measurements are presented.

Table 1.

Direct beam, № of points	1	2	3	4	5	6	7
RMS, μm Z-coordinate	0.0	4.9	5.7	5.1	5.0	5.5	0.0
RMS, μm Y-coordinate	0.0	7.3	6.2	4.1	4.2	3.8	0.0
Back beam, № of points	14	13	12	11	10	9	8
RMS, μm Z-coordinate	0.0	1.9	7.0	1.9	5.5	5.9	0.0
RMS, μm Y-coordinate	0.0	2.1	4.1	2.9	4.0	3.9	0.0

Maximal value of RMS in the table is 7.3 μm, it corresponds to about of 5.1 μm if fit for all 7 combs would be used.

3. Table deformation due to light illumination

There are 22 day-light lamps (50 W each) placed over the table at height about 4 m. Their illumination causes heating of the table. To investigate its influence we performed measurements of the table shape by means of our system during several hours after switch on the lamps. Results are given in fig.7: a) and c) present Y- and Z-coordinate of ball versus distance from CCD; b) and d) - displacement of measured ball coordinates from straight line which goes through points for the first and the seventh combs independently for direct and back beams. It is clearly seen change of laser beam inclination for Y-coordinate (fig.7.a). Within of our measurement precision we do not see any influence of the lamps for Z-coordinate and for Y- and Z-displacements from line which goes through the 1^{st} and 7^{th} combs.

4. Table deformation after change of feet

Initially the table had 2 steel feet with area 600x400 mm^2 each. The BIL chamber assembling was performed with such feet and with quite unknown positions of table support points. During test of the table with help of the system described here its feet were replaced to realize tree-points support in the same area. Dependence of Y-coordinate combs displacement from line going through the 1^{st} and the 7^{th} combs is shown in fig.8.a for two measurements: before change of feet and two measurements after. There is about 50 µm difference of table sag for two sets of measurements.

Similar results for Z-coordinate are given in fig.8.b. Change of the table feet did not effect on comb position in this projection.

5. Table deformation under heating

We performed also the measurements of heating influence on the table shape when the bottom surface of the table was heated by 500 W lamp during 10 minutes at different places:

1. at the middle of the table;
2. at the end of the table with laser and CCD;
3. at the end of the table with pentaprizmes.

In fig.9 deviations from the straight line for Y-coordinates of combs are presented for two measurements without heating and for tree measurements with different local heating. It is seen that the local heating of 1 and 3 types can induce sag about 20-30 µm. Two results without the heating show precision of the measurements.

6. Influence of air flow on precision of the measurements

Any source of heat can cause an inhomogenity of refractive index of air along the beam path , which gives as result a distortion of image. To remove such influence the laser beam was enclosed into pipes, as it is shown in fig.1. During measurements results of which were presented before tubes were removed consequently and all measurements were done without one of the tubes. To investigate an influence of absence of the tube around the beam we did special test in hard conditions when 500 W lamp was placed over center of the table at 1m height. Results of the test are shown in fig.10, where difference of ball Y-coordinates in points 1,4,7,8,11,14 measured without one of the pipes around the beam and with all pipes is presented. Displacement of image can be about 100 µm due to air flow.

Conclusions

1. Simple system for control of combs relative position on the assembling table in Y- and Z-directions with precision better than 5 μm is described. The system can measure sag of the table but it can not measure its twist.
2. There are ways for increasing of measurements precision:
- careful enveloping of beam path from air flows;
- decreasing of light beam divergence and removing of diffraction at laser and beam shaper parts;
- decreasing of beam length by means of using two CCDs and splitting of the laser beam.
3. Precision of combs alignment done before BIL chamber assembling in 1996 was checked by independent method. Its value ±20 μm clamed in [1] was confirmed.

References

1. BIL chamber prototype assembly in Protvino. ATLAS Internal Note. MUON-No-178.

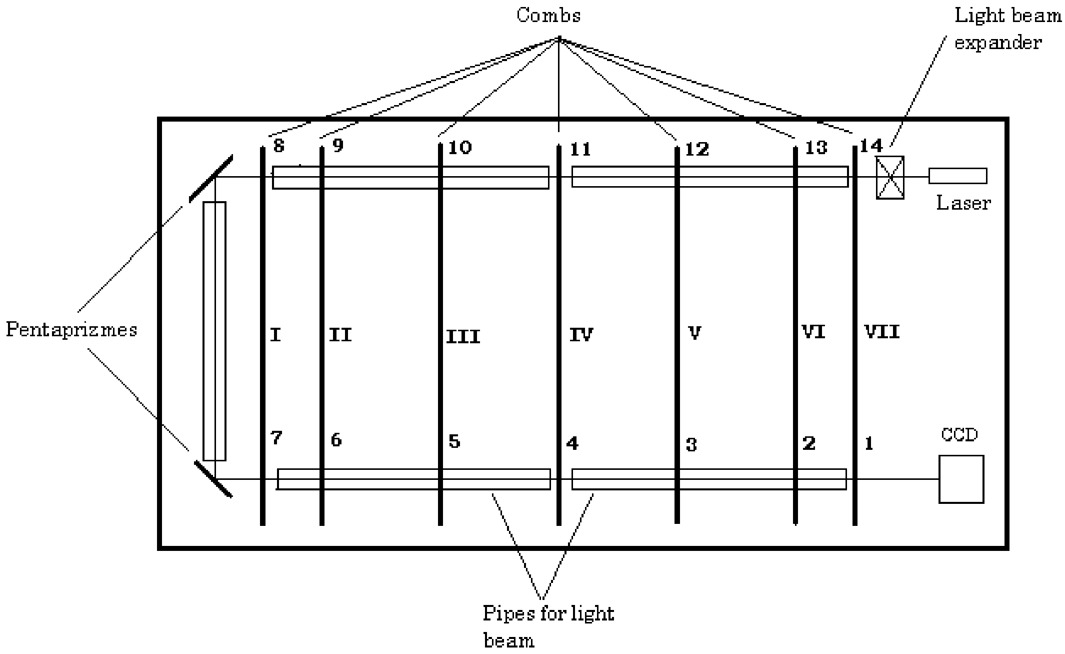

Fig.1. Setup of control system on the assembling table with combs.

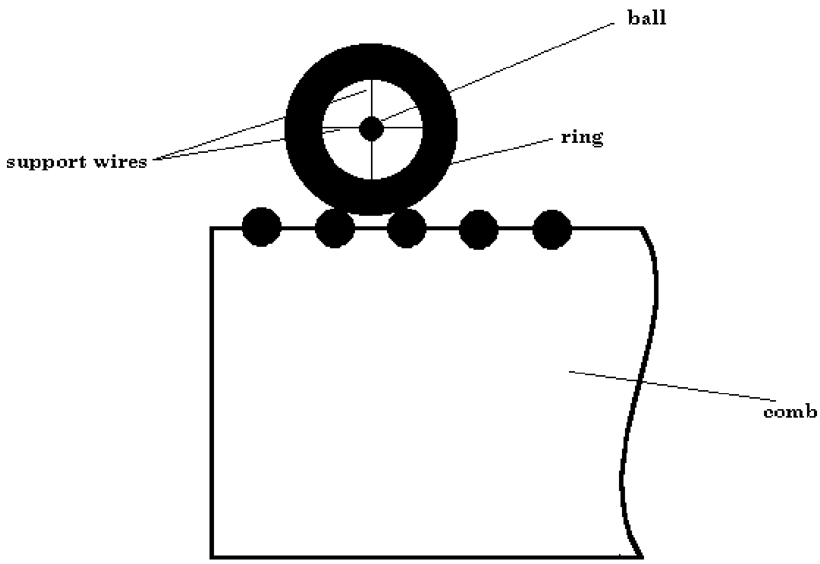

Fig.2. Scheme of ball setting on the comb.

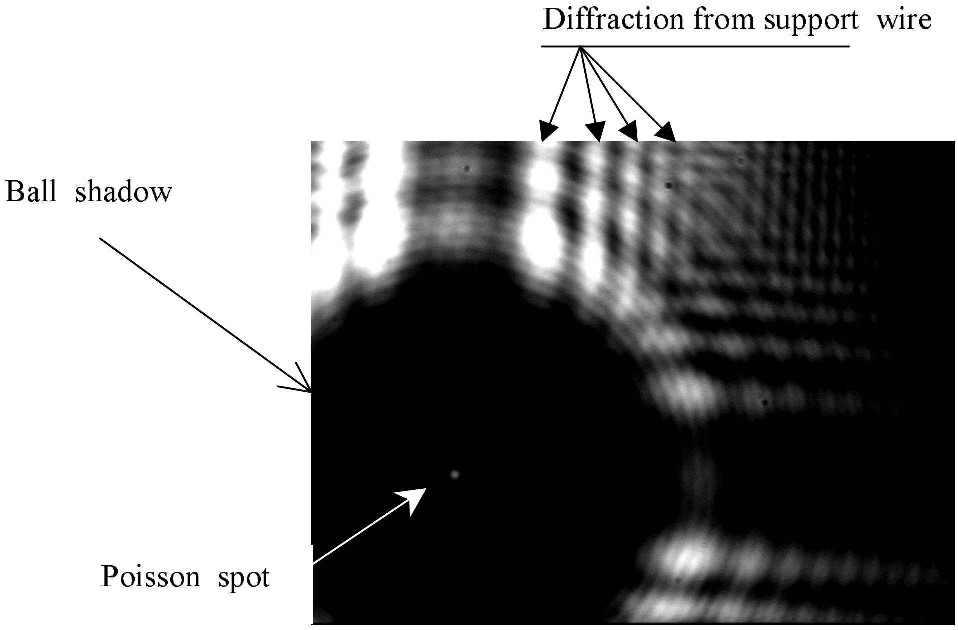

Fig.3. CCD image of diffraction from the ball.

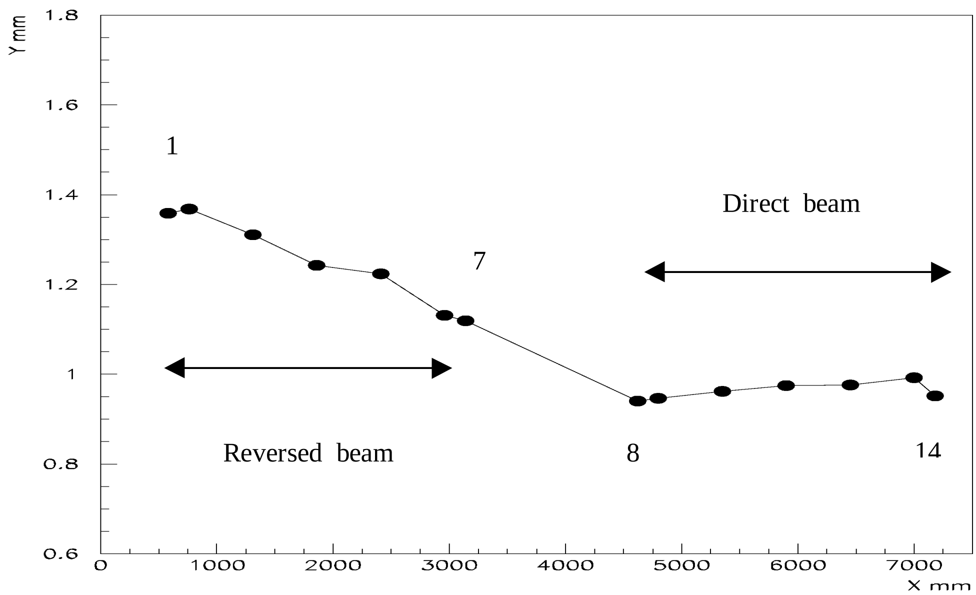

Fig.4. Y-coordinate of ball projection on CCD plane for 14 positions of the ball along laser beam.

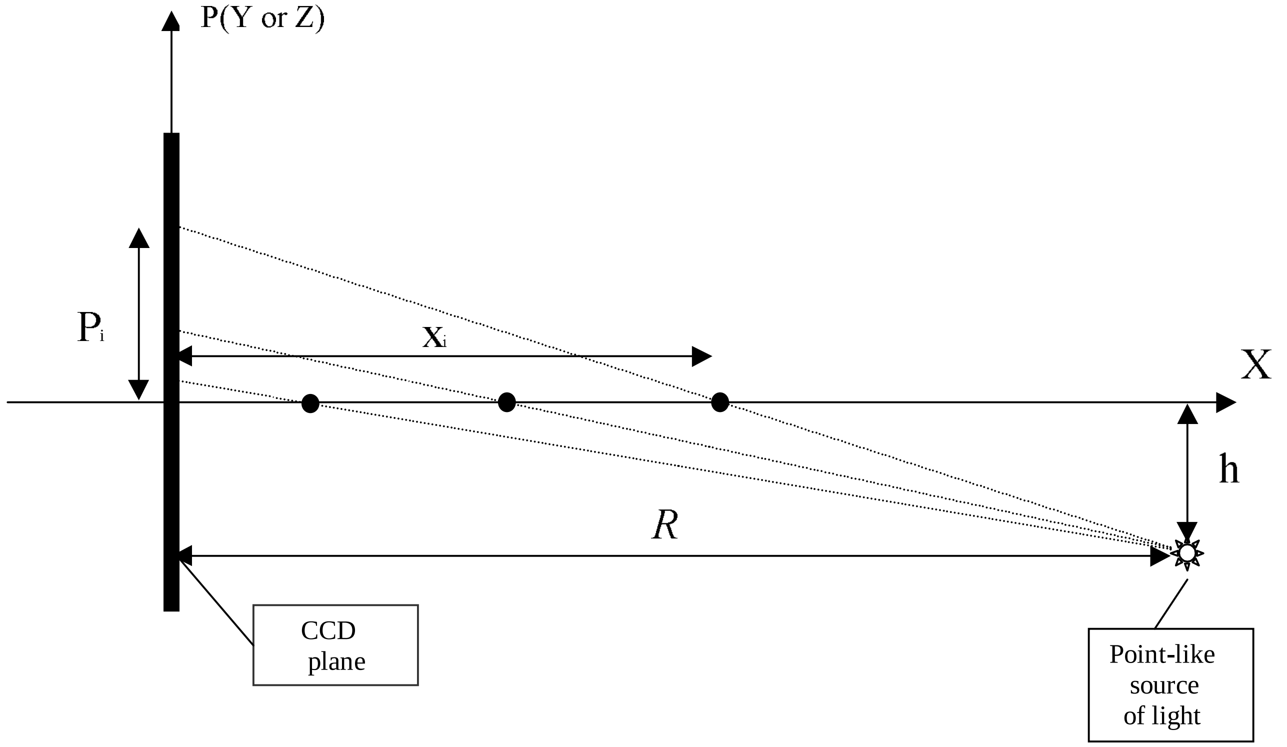

Fig.5. Scheme for definition of corrections for divergent beam.

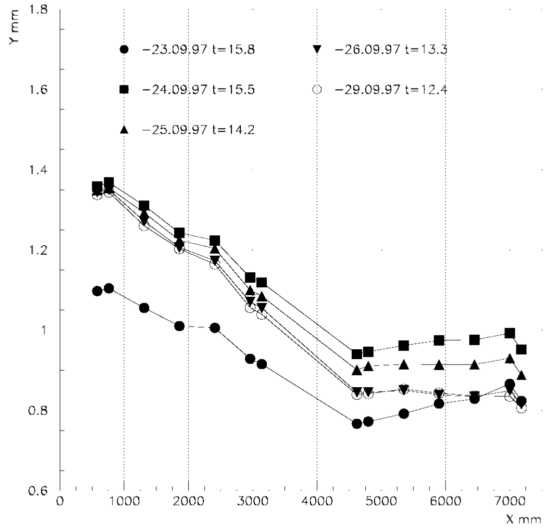

Fig.6(a). Y-coordinate of balls.

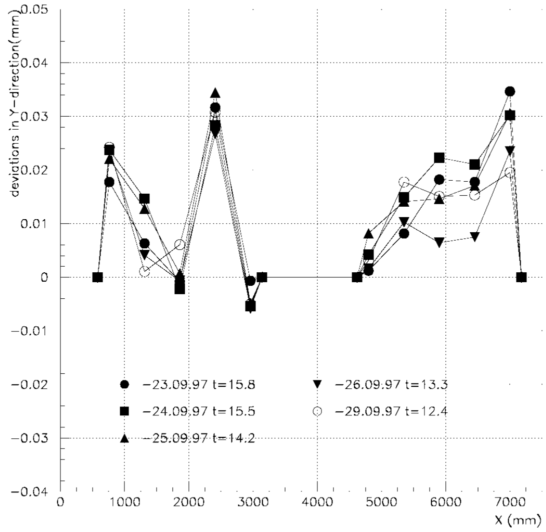

Fig.6(b). Y-coordinate deviations from straight line.

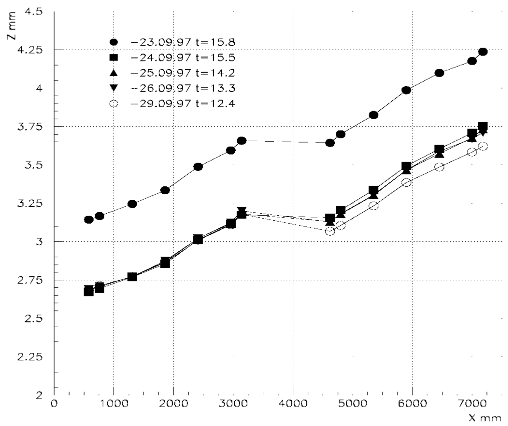

Fig.6(c). Z-coordinate of balls.

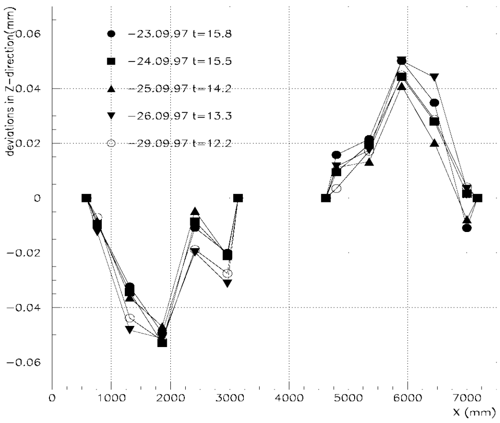

Fig.6(d). Z-coordinate deviations from straight line.

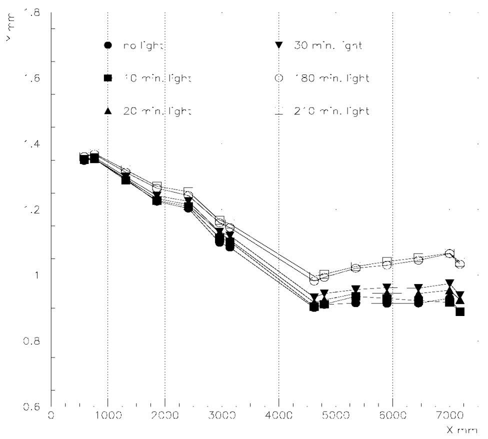

Fig.7(a). Y-coordinate of balls.

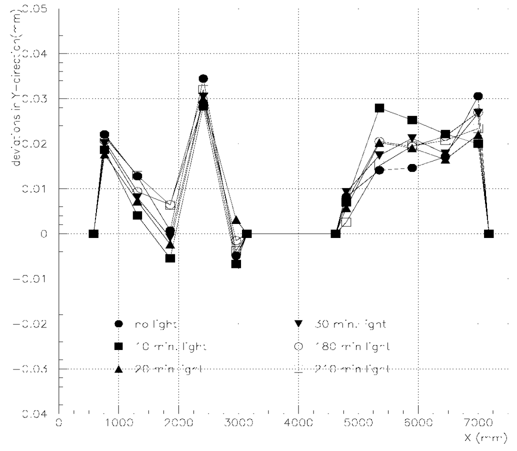

Fig.7(b). Y-coordinate deviations from straight line.

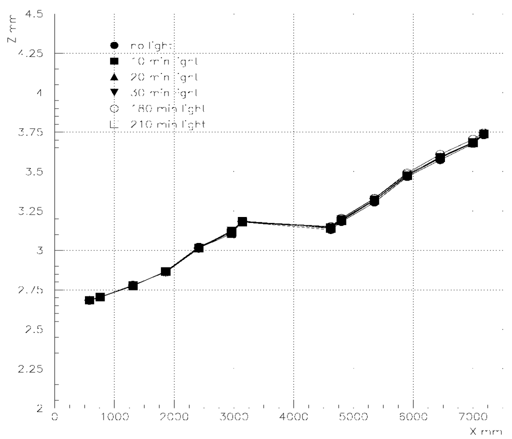

Fig.7(c). Z-coordinate of balls.

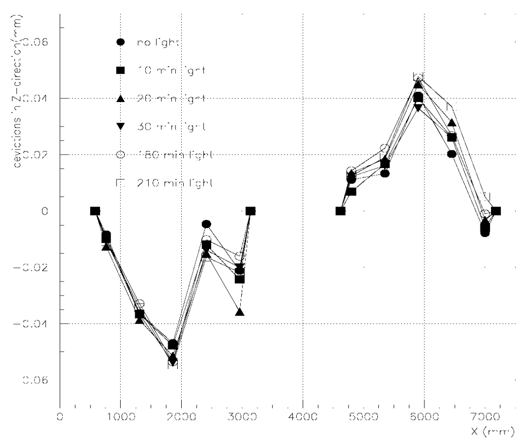

Fig.7(d). Z-coordinate deviations from straight line.

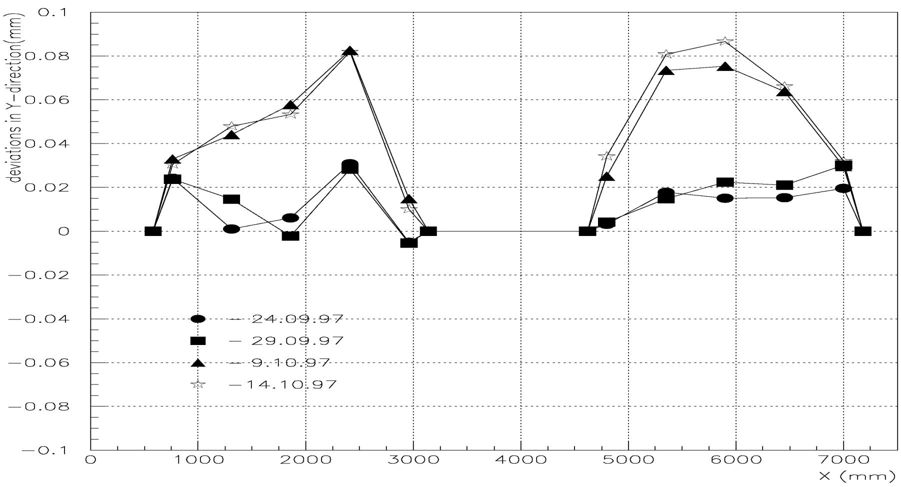

Fig.8(a). Y-coordinate deviations from straight line before and after installation of 3 points support for the table.

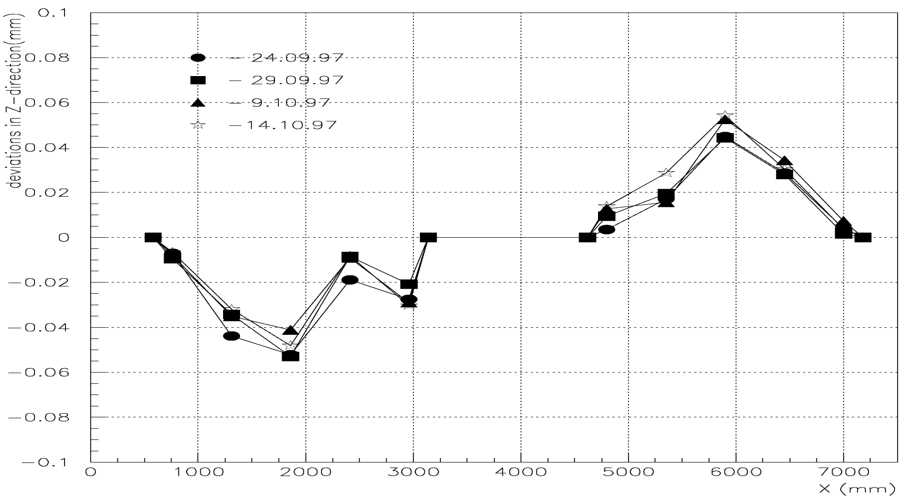

Fig.8(b). Z-coordinate deviations from straight line before and after installation of 3 points support for the table.

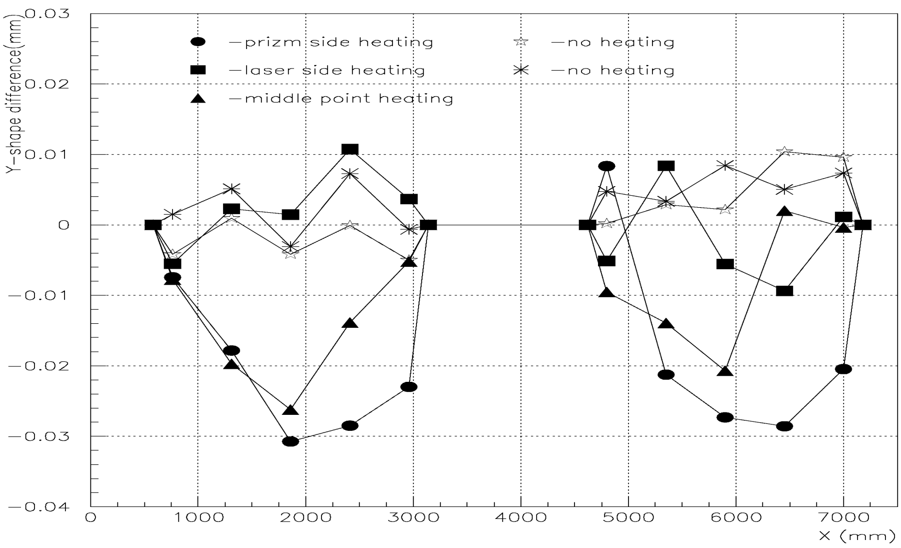

Fig.9. Y-coordinate deviation of balls from straight line with and without local heating of the table.

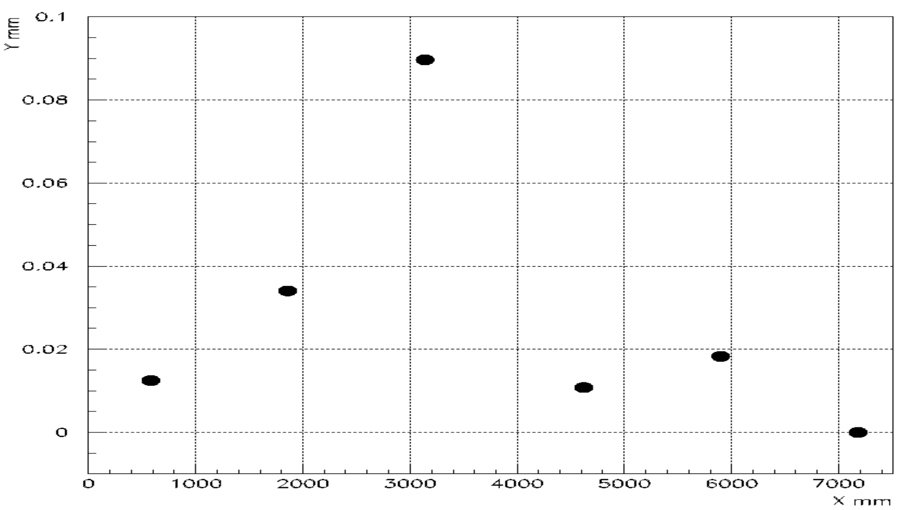

Fig.10. Difference of ball Y-coordinate without and with pipe around beam.