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TWO-AND THREE-DIMENSIONAL RECONSTRUCTION AND ANALYSIS OF THE STRAW TUBES TOMOGRAPHY IN THE BTEV EXPERIMENT

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Abstract

A check of the eccentricity of the aluminised kapton straw tubes used in the BTeV experiment is accomplished using X-ray tomography of the section of tubes modules. 2 and 3-dimensional images of the single tubes and of the modules are reconstructed and analysed. Preliminary results show that a precision better than 40 μm can be reached on the measurement of the straw radii.

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1 INTRODUCTION

The BTeV experiment [1] uses straw tubes glued in modules and embedded in a structure mechanically untensioned [2], where straw and microstrip detector are integrated, allowing a minimum amount of materials. A check of the eccentricity of the straw tubes and their position is accomplished using X-ray tomography of the module sections.

2 BTEV DETECTOR

Experiment straw section is scanned orthogonal to the vertical axis of the tomograph with 27 μm resolution. Data are initially reduced in a numerical 8-bit matrix of 1024x1024 points, then converted to an IMAQ Image of LabVIEW.
Figure 1 show the raw tomographic image of a straw tube section (section♯10, 1024x1024 pixels, 27 μm/pixel, 256 values of greys). Not all the tubes of the module are contained in the field of view. Figure 1 also shows evident traces of glue, deposited on the external surfaces of the straw tubes, especially in the points of contact of adjacent tubes. Only the internal surfaces are well defined in the images and, in order to detect and to measure possible mechanical deformations of the tubes, this forces to study the geometry of the these surfaces. Figure 2 shows the distribution of the greys values of the previous figure.
An improvement of the signal-to-noise con be obtained just setting an upper threshold of the intensity, as it is shown in Fig.3, reporting the effect of a threshold of 210 of the image of Fig.1. As an example, an arbitrary straight of the pixels along this line is shown if Fig.4, where the two peaks point out the positions of the crossing points (Edges) of the line with the internal surfaces of the two adjacent tubes. The transformation of the Edges coordinates from the line reference to the image reference is easily obtained from the coordinates of the line end points in the image reference. On this base, an automatic procedure is defined in order to obtain the Edges of 14 tubes of a section of the module.
The procedure is as follows. First an image containing a Region of Interest is built, then the patterns recognising such a region are extracted from the tomography. At the Edge pointed out on the base of contrast figures, three orthogonal coordinates X,Y,Z, defined in the tomograph system (Tomo reference), are attributed, where the Z is common to all the Edges of the same section. This allows the reconstruction of the 2 and 3-dimensional images of single tubes and of the entire module.
We do not expect a perfect positioning of the module on the tomograph reference plane, and even in the case of perfect positioning we would not expect a perfect parallelism be-

tween the tubes of the module. Therefore, the section Edges of each straw tube are fitted to an ellipse. The centres of the ellispes of all sections are in turn fitted to a straight line: the axis of the straw tube.
Projecting the Edges of a section on the plane orthogonal to the axis of its straw tube the contribution to an elliptical configuration due to a not perfect vertically of the tube is eliminated.

3 Results

We fit the data points to an ellipse, and define as Ellipse Parameter the quantity $\underline{\underline{(\underline{PF_1}+\underline{PF_2})/2}}$ where P is a point on the ellipse, $F_{1,2}$ are the ellipse foci, and $\underline{PF_i}$ their distances.
In order to evaluated the amount of the mechanical deformation of the straw tubes cross section from the expected circular shape, we then fit the data to a circle. Figure 5 shows the standard deviation of the histograms of the Edge radius, and the width of gaussian fit to the Ellipse Parameter of the projected edges for the 14 straw tubes analyzed. In the worst case the mechanical deformation respect to the circular cross section have a distribution with a standard deviation of about 1.5 pixel, corresponding to about 40μm, largely contained in the 100μm specification in order not to spoil the electric field inside the straw tube. The precision of our technique in determining the variation of the straw cross-section from circularity cam be estimated by the difference in quadrature of the two variances in Fig.7, which is about 1.2 pixels at most, corresponding to about 30μm. The three-dimensional rendering of slices reconstructed is shown in Figure 8.

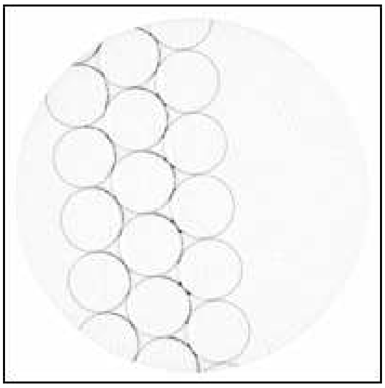

Figure 1: Example of raw tomography image of straw tubes module (1024x1024 pixel, 27μ/pixel)

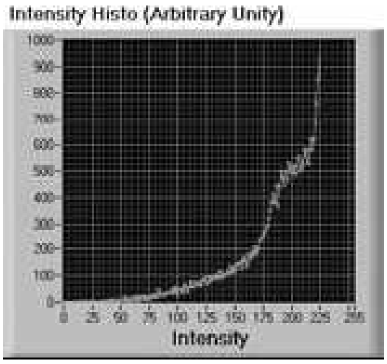

Figure 2: Grey intensity histogram of Fig.1

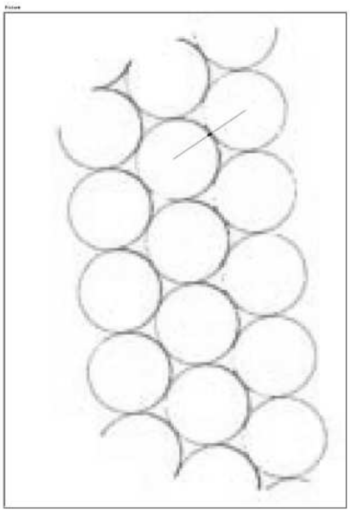

Figure 3: Same tomography of Fig.1 with a grey intensity threshold of 210. The intensity distribution along the segment is shown in Fig.4.

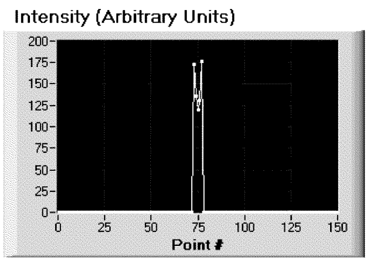

Figure 4: Intensity along the line of Fig.3.

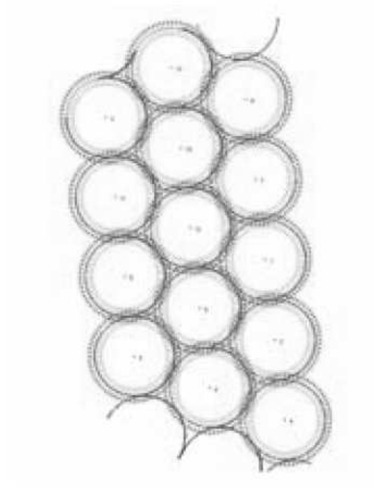

Figure 5: Edges of 14 straw tubes of the section$\sharp 10$ of the module. Each Edge is chosen as the first met in the arrow direction, from the inside to the outside of the Region of Interest, pointing out to the internal surface of the straw tube. Circles fitting the Edges, their centers and order number are also shown

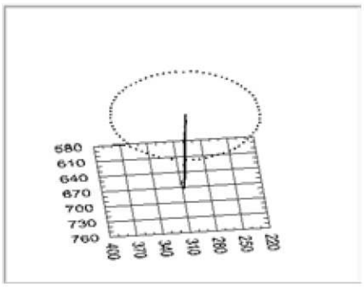

Figure 6: Axis and Edges of Section $\sharp 130$ of the straw tube$\sharp 4$ in Tomo reference. The Straw axis is at 9 degree respect to the tomograph vertical axis (the figure axis is not in scale respect the horizontal ones)

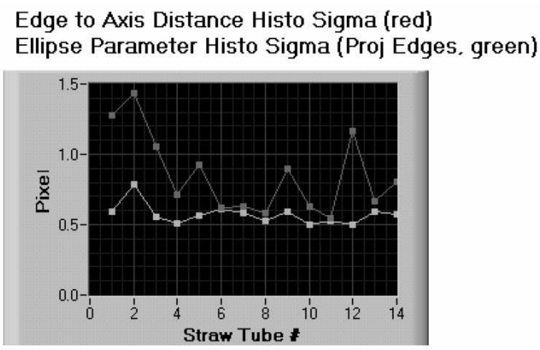

Figure 7: Standard deviation of the histogram of the Edge radius (red) and sigma of the gaussian fit to the ellipse parameters of the projected edges (green) for 14 straw tubes.

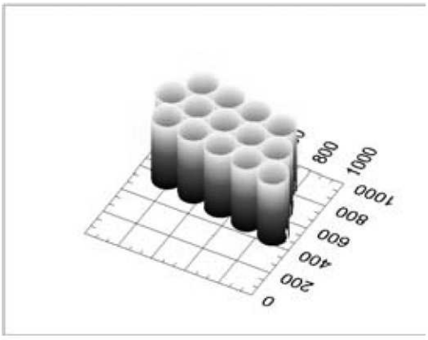

Figure 8: 3-D reconstruction in Tomo reference of the 14-straw module.

4 CONCLUSIONS

We have developed a new technique to visualize lw-mass surface of cylindrical shapes widely used in HEP detectors, such as straw tubes. The technique uses x-ray computed tomography, implemented with an original optical recognition, pattern recognition and analysis code, Labview-based. Preliminary results show how the precision of our technique in determining deviation from circular shapes are better than 30μm.

References

[1] Fermilab Experiment E-0897/E-0918, J.Butler, S.Stone co-spokespersons; see www-btev.fnal.

[2] E.Basile et al., ”A Novel Approach for an Integrated Straw tube-Microstrip Detector”, accepted by Transactions on Nuclear Science (2005).