GEM TN-92-228

Test of GEM Alignment Scheme with Cathode Strip Chambers and X-Ray Source

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November 10, 1992

Abstract:

Study of projective alignment scheme with the test bench, containing three modules of cathode strip chambers and X-ray source, is proposed.

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1 Introduction

1.1 Main goals of the projective alignment scheme (PAS)

The projective alignment scheme, proposed for GEM in Ref.1, uses projective straightness monitors readings with appropriate interpolation procedures for correction of high momentum muon sagitta and has the following goals:

- To correct measured value of muon sagitta corrupted due to relative displacements of different superlayers and thereby to soften the requirements for chamber positioning;
- To minimize sagitta error due to chamber deformations;
- To make the system of alignment monitors redudant and self-testable.

The proposed alignment scheme was studied with the Monte Carlo program and promising results were obtained (see Ref.1). But the muon system alignment is the problem of great importance, and real chamber alignment test is inevitable.

1.2 Possible methods of PAS test

A model of GEM muon detector towers could be constructed with relevant optical system as proposed in Ref.1. Another way to test PAS principles is to use muon chamber prototype as detecting element of alignment system.

Charge particles could be used for such test. But simple evaluation shows that the cosmic rays flux is too small for this purpose.

Fix-target accelerator beams don't simulate divergence of particles from the collider interaction point (typical transverse momentum $p_t \simeq 0.5\text{GeV/c}$), and we need to move chamber set relative to the beam direction for simulation of this effect. Required tolerances are not very severe (see below Eq.6), but tedious.

We propose to resolve these difficulties by using X-rays for simulation of high-momentum muon trajectories (see Ref.2).

2 X-ray test bench

2.1 Geometrical layout and requirements for X-ray source

The possible geometrical layout of the X-ray test bench is shown in Fig.1. Three cathode strip chambers of dimensions 50cm x 50cm are posed in parallel planes with separation of 30cm. Angle ϕ is equal to 22.5^0 to correspond to GEM sector angle ($360^0/16 = 22.5^0$). X-ray source is situated on the distance

$$h = 120cm$$

from the farest chamber.

What are the requirements for X-ray source?

Firstly we have to calculate σ_{FS}^{div}, the mean false sagitta due to non-zero value of α_{div}, divergence angle of X-rays . The value of false sagitta FS is equal to:

$$FS = \frac{x_1 + x_3}{2} - x_2, \tag{1}$$

where x_i is the coordinate of X-ray quantum in the i-th chamber.

The value of σ_i, dispersion of x_i, is equal to

$$\sigma_i = \alpha_{div} r_i,$$

where r_i is the distance to the source. So,

$$\sigma_{FS}^{div} = \sqrt{\frac{\sigma_1^2 + \sigma_3^2}{4} + \sigma_2^2} \simeq h\alpha_{div}. \tag{2}$$

The dispersion of false sagitta due to limited internal spatial resolution of cathod strip chambers σ_{int} is equal to:

$$\sigma_{FS}^{int} = \sqrt{\frac{\sigma_{int}^2 + \sigma_{int}^2}{4} + \sigma_{int}^2} \simeq 1.2\sigma_{int}. \tag{3}$$

We assume that

$$\sigma_{int} \simeq 100\mu$$

If we require error due to the divergence to be neglected in comparison with the internal error:

$$\sigma_{FS}^{div} \simeq \sigma_{FS}^{int}/2 \simeq 60\mu$$

we obtaine the requirement for α_{div}:

$$\alpha_{div} \leq \frac{60\mu}{1.2m} = 50mkrad. \tag{4}$$

Then, it is necessary to estimate the requirements for X-ray direction accuracy.

Monte Carlo calculations show that for this layout the value of false sagitta will be corrected if shifts of the chambers in any direction Δ:

$$\Delta \leq 3mm \tag{5}$$

and rotations of the chambers relative to any axis Ψ:

$$\Psi \leq 6mrad \tag{6}$$

These calculations show that the necessary z-coordinate (alonge the strips) measurement accuracy σ_z should be:

$$\sigma_z \leq 6mm, \tag{7}$$

So, the requirement for X-ray direction accuracy σ_θ:

$$\sigma_\theta \leq \frac{\sigma_z}{h} = \frac{6mm}{1.2m} = 5mrad. \tag{8}$$

The requirement for the accuracy σ_ϕ:

$$\sigma_\phi \simeq \Psi \leq 6mrad. \tag{9}$$

2.2 Preliminary plan of test

Procedure of test should be following. X-rays are directed to the appointed places near the perimeter of the outer chamber and false sagittas, measured by cathode strip chambers, are calculated. This is the simulation of straightness monitors readings. Then X-rays are directed inside the tower solid angle, and measured for these directions false sagittas are compared with the values of the interpolation function, calculated from "monitors readings" (see Ref.1).

We propose to study the following effects:

- chamber shifts and rotations relative to different axes(chambers are moved);
- chamber temperature expansion/contraction (chambers are heated);
- chamber torsion (chambers are bent);
- chamber gravitational sag (chambers are loaded);
- non-projectivity of monitor directions and particle trajectories;
- necessary number of straightness monitors.

3 Conclusions

Proposed procedure to test basic principles of PAS looks reasonable: requirements to X-ray CSC test facility do not exceed expected performance parameters (beam divergence of 50mkrad, direction angle accuracy of 5 mrad). Evidently a full scale prototype is required to investigate technical aspects of PAS implementation. However we expect that crucial features of the projective alignment scheme can be demonstrated in the nearest future even with use of existing CSC prototypes.

Acknowledgments

We gratefully acknowledge Mike Marx and Gena Mitselmakher for their helpful comments on the content of this note.

References

[1] Mitselmakher G. and Ostapchuk A.,"New Approach to Muon System Alignment", GEM internal note TN-92-202

[2] Lapina L. et al.,"X-Ray Test Station for Cathode Strip Muon Chambers", GEM internal note TN-92-136

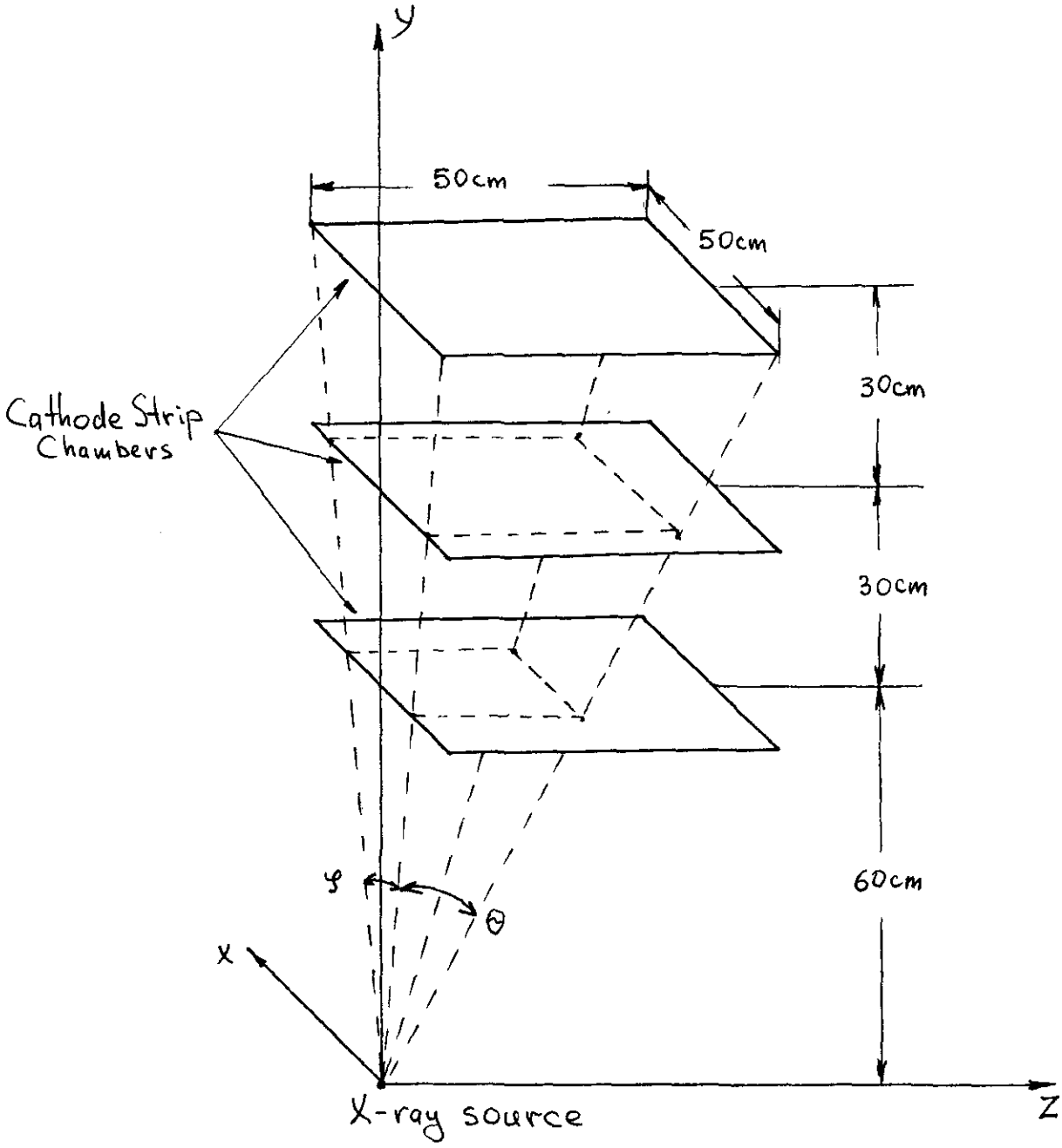

Fig.1 Geometrical Layout of X-ray CSC Test Bench