GEM TN-92-120

Alignment Requirements to Muon System

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Introduction.

The high muon momentum resolution requirements of GEM have determined the alignment performance of muon system. In terms of constant σ_p momentum resolution may be described:
$\Delta p_t/p_t = \sigma_p p_t$
where the momentum resolution requirements are /1/ $\sigma_p \leq 10^{-4}$ for barrel and $\sigma_p \leq 2.10^{-4}$ for endcups. The momenta of muon is reconstructed by measuring the sagitta:
$S[m] = .0375\frac{B[T]L^2[m]}{p_t[GeV]}$
Hence:
$\sigma_p = \frac{\delta S}{.0375BL^2}$
The sagitta is determined by measurements in three superlayers :
$\delta S = \sqrt{\frac{\sigma_1^2+\sigma_3^2}{2} + \sigma_2^2}$
The measurement error in bending (x) direction of superlayer is given by:
$\sigma_i = \sqrt{\frac{\sigma_{int}^2}{n_i * e_i} + \sigma_{algn}^2 + \sigma_{mcs}^2}$,
where σ_{int}- the intrinsic detector resolution(100μm for barrel, 75μm for endcups), n_i- the number of layer in superlayer (8/8/4 -barrel, 4/4/4 -endcup), e_i- the efficiency of layer (let's 0.8/0.9/1.), σ_{algn} - alignment error, σ_{mcs} - the error due to multiscattering (essential for middle superlayer). Thus we can to determine the requirements to local alignment of the muon chambers in bending direction. The dependence of σ_p versus σ_{algn} is shown on Fig.1 for barrel. The requirement $\sigma_{algn} \leq 25\mu$m was taken from σ_p limits($\delta S/S \leq 5\%$) . For endcups the same restriction have been obtained /2/($\delta S/S \leq 10\%$). The alignment of barrel modul in the beamline (z) direction is determined by longitudinal momentum resolution $\Delta p_l/p_l \simeq \Delta\Theta/\Theta \leq 1\%$ (then $\Delta z \leq 50$ mm) and the global alignment criteria. The alignment of endcups in beamline(z) and radial(y) directions is depended on $B_{r,z}$ uniformities near field shaper:
$\Delta p_t/p_t = \delta S/S - \delta B/B - 2\delta L/L$; where $\delta B/B \leq 1\%$, $2\delta L/L \leq 1\%$.
Using the components of $B_{r,z}$ we can to estimate $\Delta y \leq 2.5$ mm, $\Delta z \leq 2$ mm/3/. Otherwise

the restriction to Δy shift should be more strong if the endcups chambers have the radial direction of strip read out. In this case Δy shift aggravate the resolution in bending direction $\Delta y = \Delta x/\sin\phi \leq 160\mu$m (where $\phi_{max} = 10^o$).
The global alignment of muon system are determined essentially by multiscattering, trigger requirements, pattern recognition. The scattering in calorimeter defines the global alignment in bending direction. For barrel modul we have $\Delta x \leq 0.7$ mm and $\Delta x \leq 1$ mm for endcups(p_μ=500 GeV). The radial shift of modul is not essential for barrel as $\Delta y = \Delta x/tan\phi \leq 4$ mm ($\phi_{max} = 10^o$). For the endcups modul the alignment in the radial direction is determined by the uniformities of magnetic field. The physics requirements are summurized in Table 1.

Table 1.

Direction	Barrel	Endcups
Local alignment	mm	mm
bending, x	0.025	0.025
radial, y		0.16
beamline, z	50	2
Global		
bending,x	0.7	1
radial,y	4	2.5
beamline,z	50	2

Method.
The baseline 1 of GEM was used for the estimation of alignment tolerances of muon system. We will study the geometric contribution in the alignment. In the general coordinate system shown on Fig.2 the muon track is well described by the straight line : $\mu_i = M_i + m_i t$,(i=x,y,z). The muon modul consists of a 3 detector layers. We consider each layer as a rigid body. In the layer coordinates the readout (strip or wire) can be described as: $\rho_i = R_i + r_i t$. Let's imagine a track in detectors system as μ'. The muon chamber in i-layer measure the distance :
$d_i = \frac{|(R-M')(rxm')|}{|rxm'|}$
The sagitta will be: $S = (d_1 + d_3)/2 - d_2$. We will calculate the sagitta errors induced by misalignment of layers in muon modul. The misalignment of detectors means the rotation and shifts describing by translation matrix A_{jk}. The sagitta error will be $\delta S = |S - S'|$, there S' -the sagitta after shifts and rotations of any layer. As example the dependence of δS versus rotation of middle barrel layer is shown on Fig.3. The dependences of δS from different motions of barrel and endcups layers are shown on Fig.4 and 5 respectively. Thus the requirement to sagitta error $\delta S \leq 25\mu$m gives the requirements to matrix A and so to alignment accuracy of muon modul.

Alignment requirements.
The general conception of alignment is the stable monitoring of muon system with requiring accuracy. The positioning accuracy must to provide the work of monitoring system within the range of measurements. The measurements accuracy for barrel layers are shown on Fig.6. Fig.7 shows the tolerances of muon chambers in the layers. The precisely positioned(within $\Delta x, z \leq 25\mu$m) four beacons for each blocks are needed to fix the torques of block itself. The

measurements accuracy of endcups modul are shown in Fig. 8. The summary of measurements alignment accuracy are given in Table.2

Table 2.

Barrel layers	x-offset bending	y-offset radial	z-offset beamline	parallelism of centerline
inner	50μm	250μm	4mm	
middle	25μm	120μm	4 mm	$\pm$0.003mrad
outer	50μm	250μm	4 mm	
Endcups				
inner	50μm	320μm	250μm	
middle	25μm	160μm	120μm	$\pm$0.005mrad
outer	50μm	320μm	250μm	
near f.shaper	10μm	160μm	100μm	

Alignment monitors.
The different alignment techniques are studied to provide the measurement accuracy. For local alignment of layer the straightness monitor/4/, laser/5/, stretched wire have been supposed. The essential characteristics of monitors are given in Table 3.

Table 3.

monitor	accuracy	range	distance	notes
straightness monitor(ledlens)	10μm	100μm	~10 m	relative measurement
laser beacon	$\leq$ 25μm	2 mm	~12 m	absolute measurements
stretched wire(swat)	5μm	250μm	~10 m	sag of wire

The baseline conception of straightness monitoring provide the measurements along the muon track direction, as shown on Fig.9. These paths measure the dx,dy shifts of layers and rotation about x and y axis within: dx $\leq$ 10μm, dy $\leq$ 60μm, sx $\leq$ 0.01$mrad$, sy $\leq$ 0.005$mrad$, sz $\leq$ 0.1$mrad$. The measurements along z-direction of each superlayer within 25 μm in bending direction provide the alignment of blocks in superlayers. However this alignment don't measure some complex tolerances of modul shown on Fig.10. The additional alignment paths and the fixation of the alignment mounts on layer within 25μm both for x and z directions are needed. We note that the measurement along z-direction is rather complicate.
The other way is to align the "tower" moduls independently as shown on Fig.11. In this case is not necessary to measure the tolerances of blocks in the layer but the positioning of alignment mounts on blocks corners must be known within +25 μm. The measurement alignment accuracy depends on the "tower" size and place. For the length of blocks 3.5 m the projective alignment paths are fixing the tolerances within: $dx \leq 10\mu$m, $dy \leq 10\mu$m, $dz \leq 10\mu$m, $sx \leq 0.01mrad$, $sy \leq 0.005mrad$, $sz \leq 0.05mrad$ thus the sagitta error is determined by monitor accuracy $\delta S_{algn} \leq \delta s^{max}_{monitor} \leq 25\mu$m.
The baseline alignment technique is based on "led-lens" monitor to measure the relative shift of led, lens and photodiode. The double of alignment path is needed for identification of tolerances in this case. The multipoint laser alignment provide us the absolute measurement. We can

combine the mirrors, splitters and rotating head to fix the tolerances relatively to one point (see Fig.12). Moreover the range of measurement increases to few millimeters. The stretched wire technique is more attractive for the superlayer alignment of blocks in bending direction.
The alignment of the endcups module is more difficult. For angular structure of supports the alignment paths are similar to barrel. The radial structure of endcups with overlaping of layers require the analysis in detail.

Conclusion

This work has concentrated on setting local alignment criteria for muon modul. The missalignment errors was supposed less than the momentum resolution. The projective alignment paths seems more promizing. The full geometry will be created for global alignment study.

References.

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2. GEM TN-92-80.
3. GEM baseline 1. GEM TN-92-76.
4. F.Hartjes et al. NIM A269(1988), 544
5. F.Fabbretti, et al. NIM A280(1980) 13.

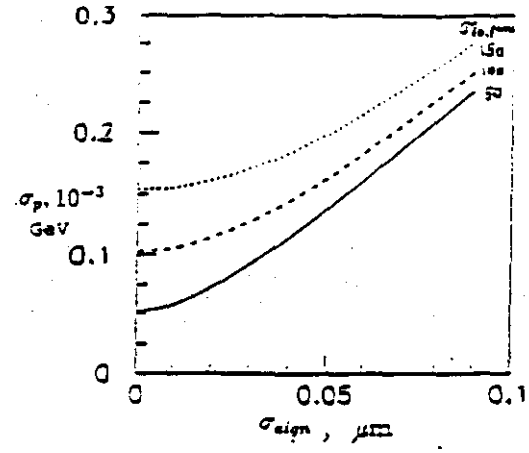


Fig.1 Momentum resolution in barrel modul versus misalignment errors for different intrinsic resolution σ_{int}.

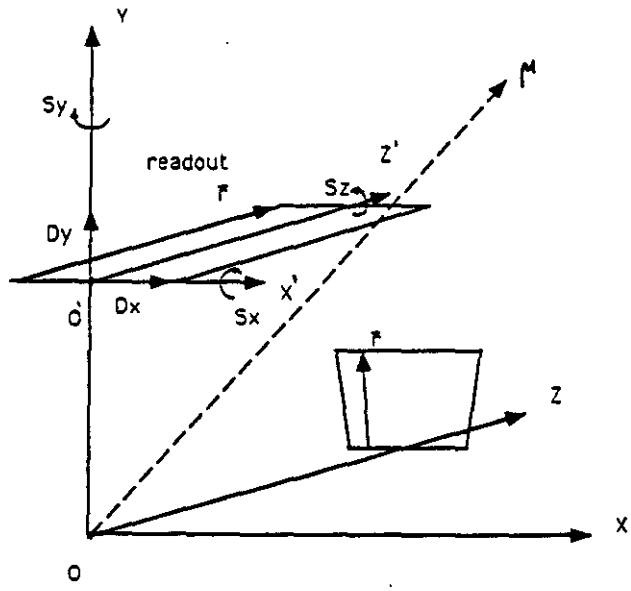


Fig.2 The coordinate system.

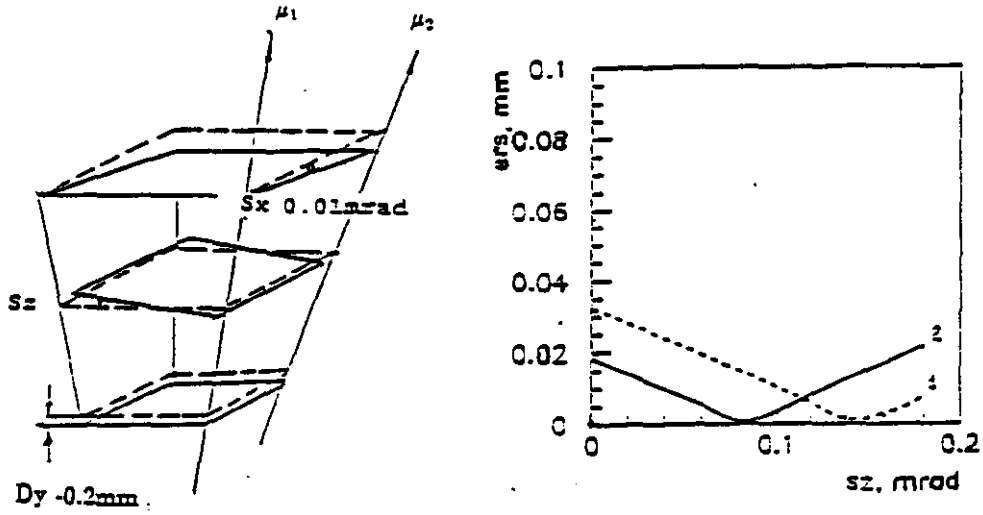
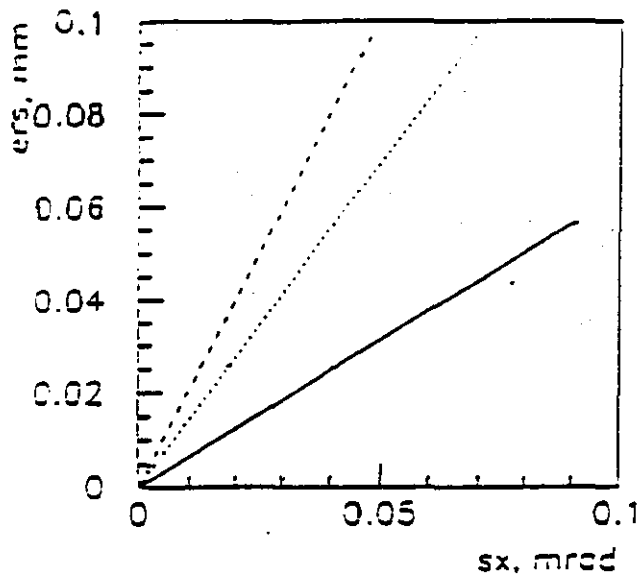
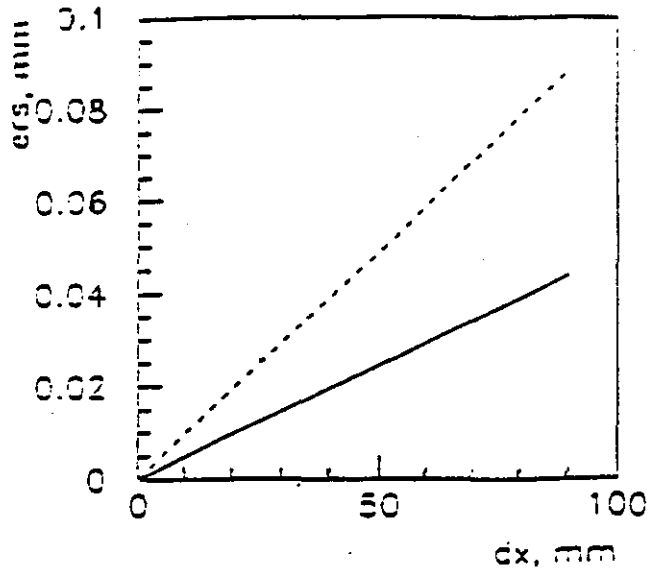
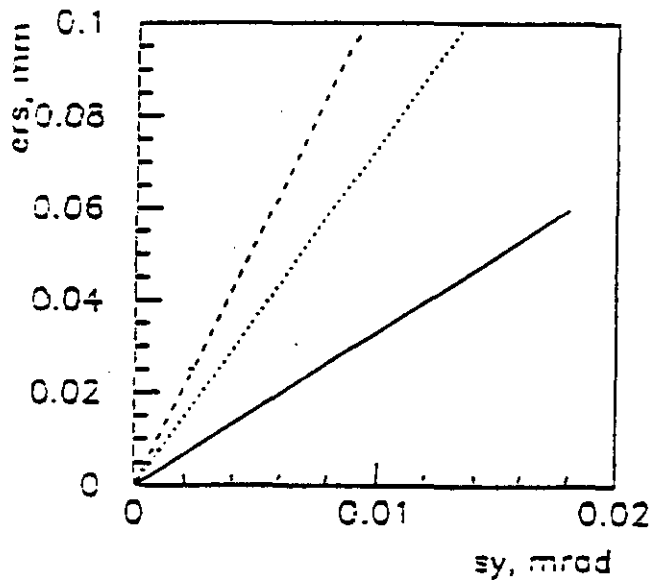
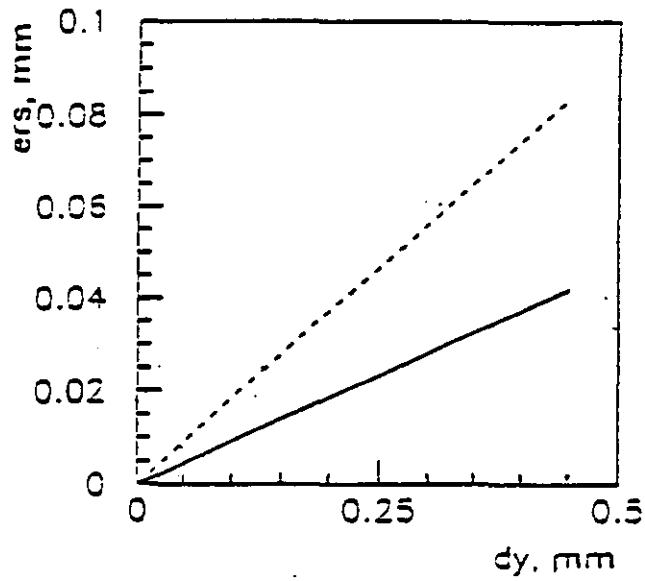


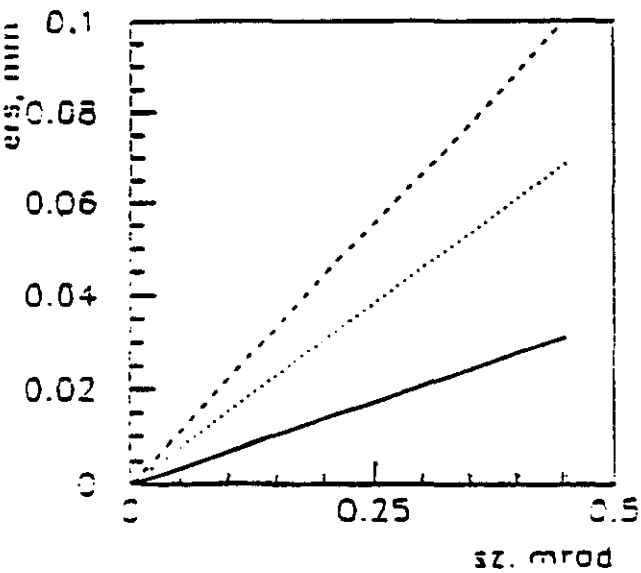
Fig.3 The sagitta error from rotation of middle barrel layer at shift of inner and rotation of outer layer.

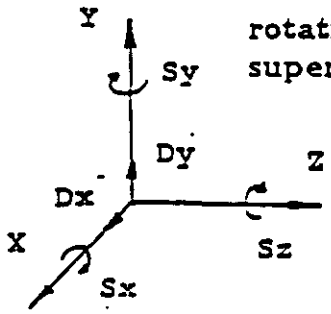












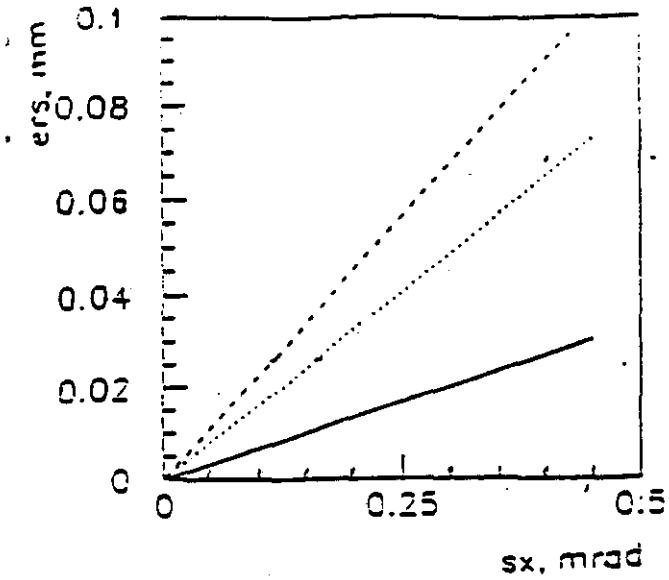
rotation and shift of block, superlayer relatively to muon track

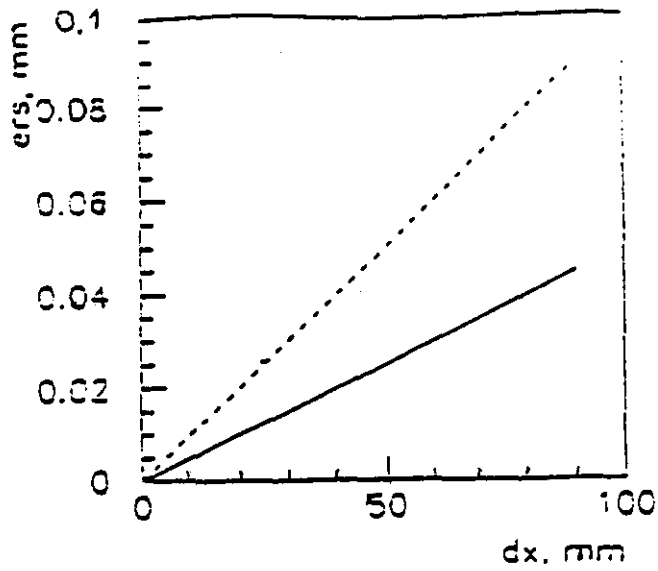
Fig.4 The sagitta error arising from rotation about x,y,z through an angle sx, sy, sz and shift along x and y for barrel modul.

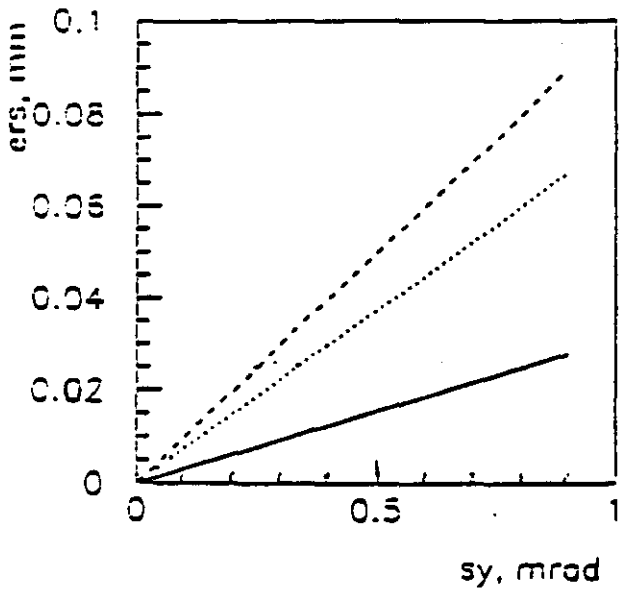
— inner superlayer

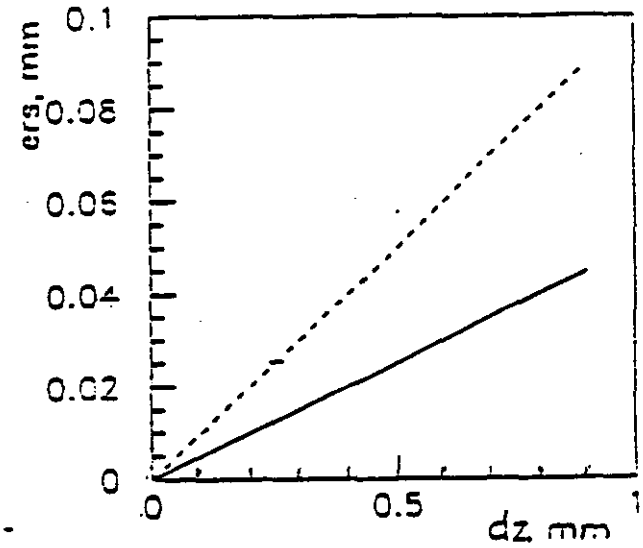
— middle

.. outer









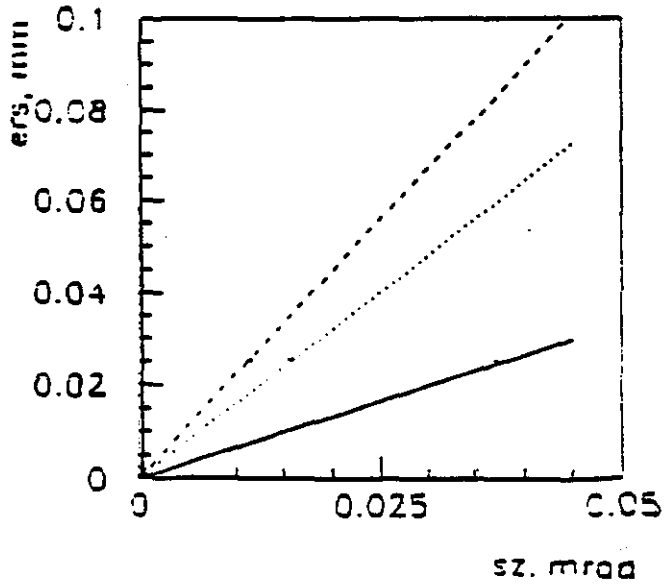


Fig.5 The sagitta error arising from rotation about x,y,z through an angle sx, sy, sz and shift for endcups modul.

— inner superlayer

- - middle

... outer

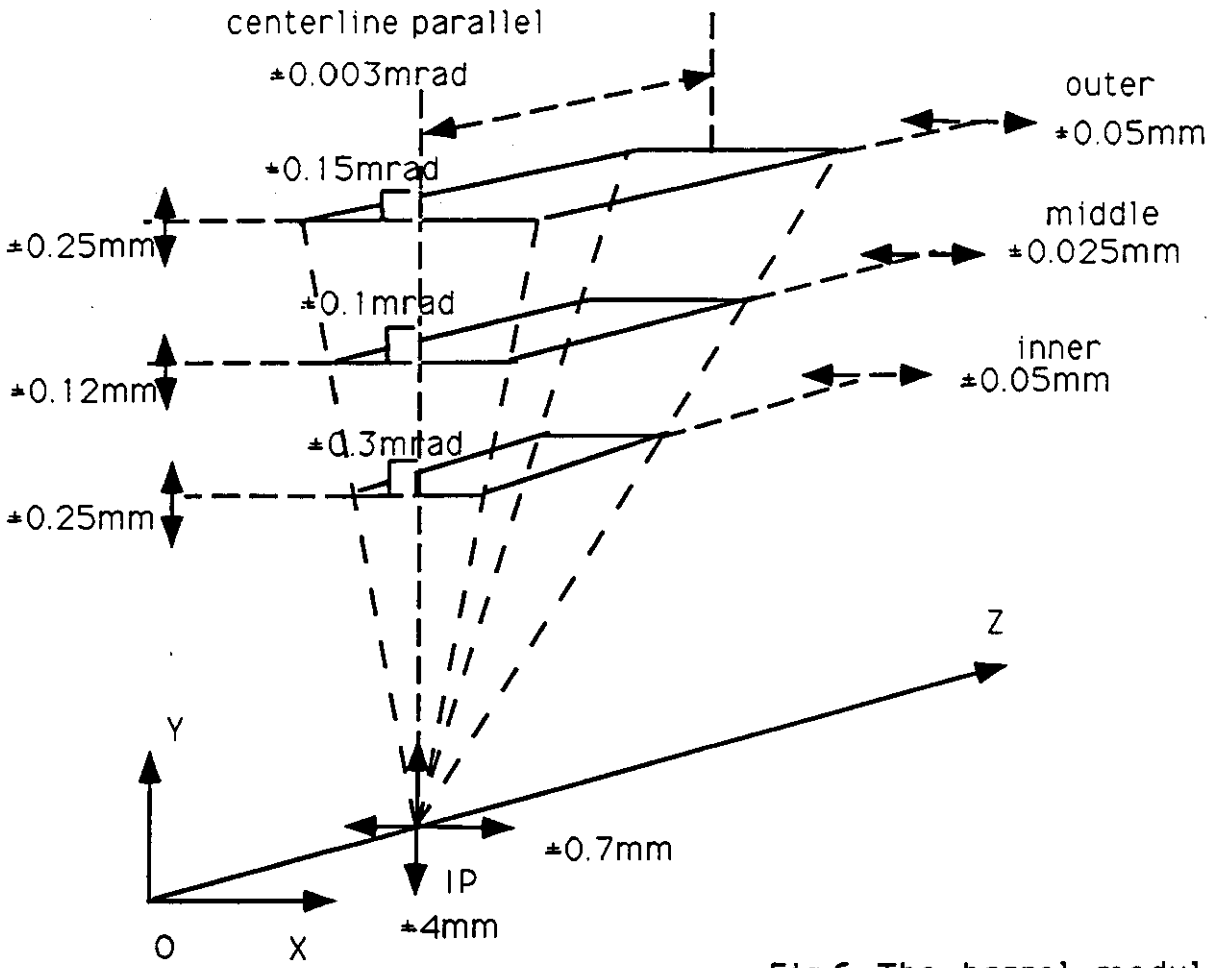


Fig.6 The barrel modul measurement accuracy.

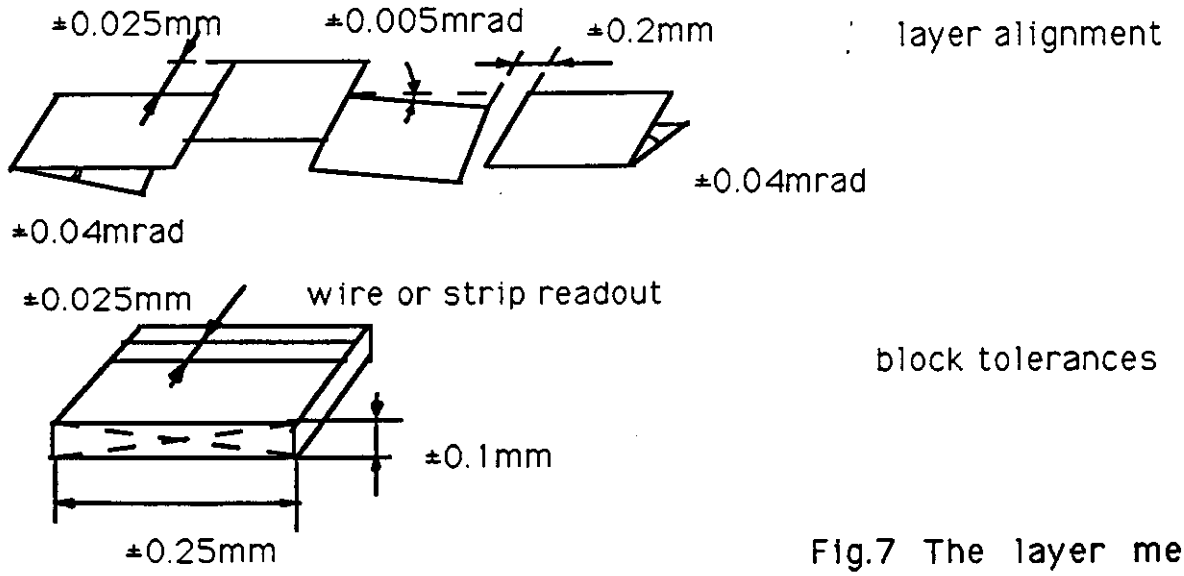


Fig.7 The layer measurement accuracy.

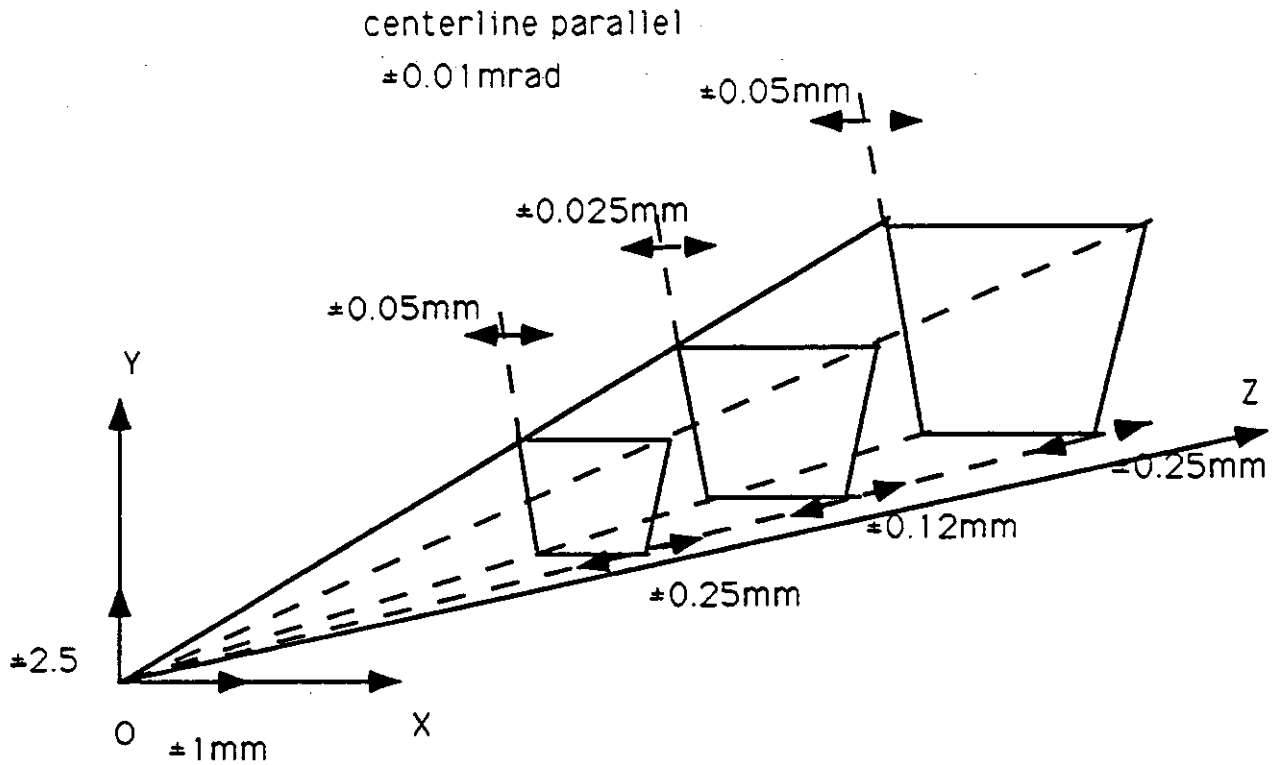


Fig.8 The endcups measurement accuracy.

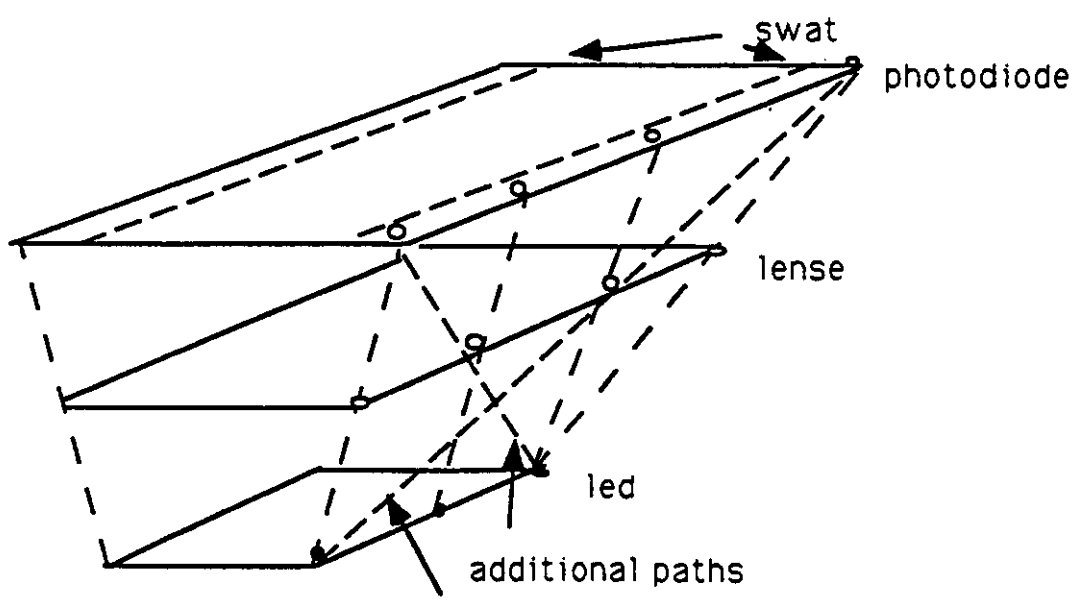


Fig.9 The straightness monitor for the barrel modul.

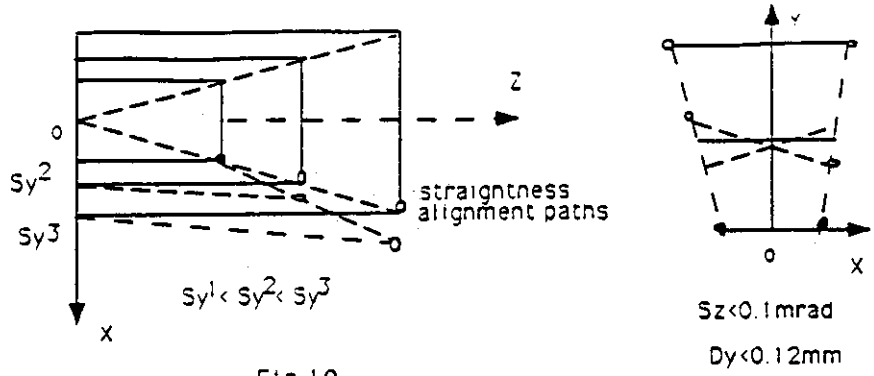


Fig.10.

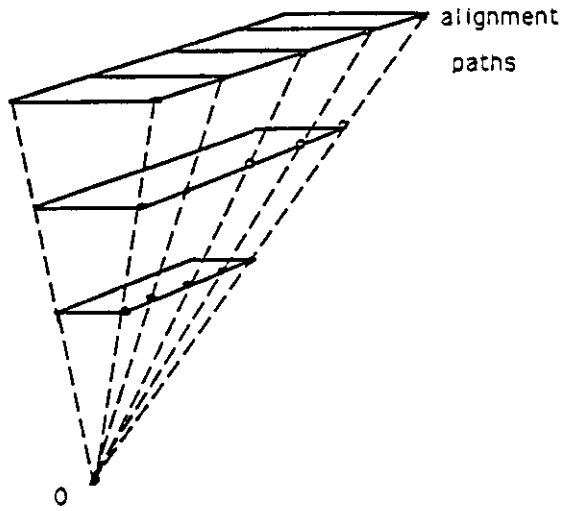


Fig.11 The "tower" concept of the alignment

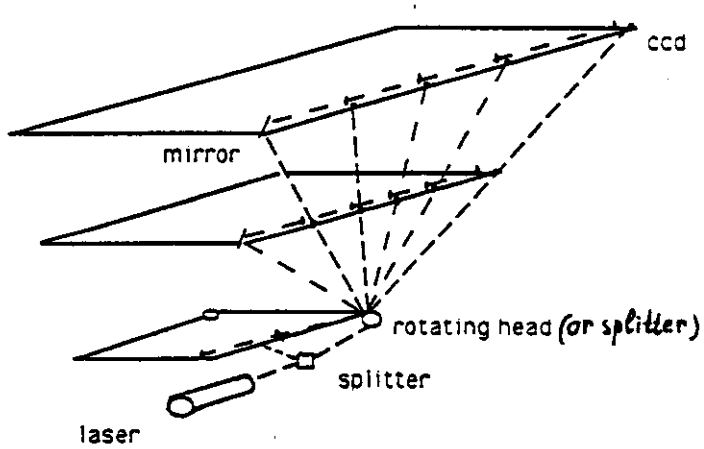


Fig. 12 The laser concept.