GEM TN-93-472

Reducing the Number of Projective Monitors in the GEM Alignment System

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Alignment of the GEM muon system with led-lense projective monitors considered. It was shown that 3 monitors is enough to correct for movements of chambers in assumption that they are thin.

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1 Introduction

The local alignment of the GEM muon system uses readings of optical straightness monitors for correction of sagitta systematic error, caused by deviations of muon chambers from their ideal positions [1],[2]. The baseline configuration includes 6 projective monitors per muon tower. In previous analysis [2, 3] it was considered that projective monitors measure only one coordinate. In fact, led-lense monitors gives us two displacements with equal accuracy. It was mentioned in [2] that making use of the measurements of the second coordinate could reduce number of monitors needed to align a muon tower. In this note, we will consider this point in detail.

2 Description of the method

It was shown in [4] that in case of small chamber displacements false sagitta as a function of θ and ϕ has form:

$$F(\xi,\eta) \approx a_{00} + \xi' \cdot a_{10} + \eta \cdot a_{01} + \xi' \cdot \eta \cdot a_{11} + \xi' \cdot \xi \cdot a_{20} \tag{1}$$

where

$$\begin{aligned}
\xi &= tg(\phi) - tg(\phi_0) && (2)\\
\xi' &= tg(\phi) && (3)\\
\eta &= tg(\theta) - tg(\theta_0) && (4)\\
\eta' &= tg(\theta) && (5)\\
a_{00} &= c \cdot D_y^{out} + (1-c) \cdot D_y^{inn} - D_y^{mid} && (6)\\
a_{10} &= -c \cdot D_x^{out} - (1-c) \cdot D_x^{inn} + D_x^{mid} && (7)\\
a_{01} &= c \cdot X^{out} \cdot R_x^{out} + (1-c) \cdot X^{inn} \cdot R_x^{inn} - X^{mid} \cdot R_x^{mid} && (8)\\
a_{11} &= -c \cdot X^{out} \cdot R_y^{out} - (1-c) \cdot X^{inn} \cdot R_y^{inn} + X^{mid} \cdot R_y^{mid} && (9)\\
a_{20} &= -c \cdot X^{out} \cdot R_z^{out} - (1-c) \cdot X^{inn} \cdot R_z^{inn} + X^{mid} \cdot R_z^{mid} && (10)\\
c &= \frac{X^{mid} - X^{inn}}{X^{out} - Xinn} && (11)
\end{aligned}$$

where ϕ_0 and θ_0 are polar angles of center of the tower. For the non-straitness function we have:

$$N(\xi,\eta) \approx b_{00} + \eta' \cdot b_{01} + \xi \cdot b_{10} + \eta' \cdot \xi \cdot b_{11} + \eta' \cdot \eta \cdot b_{02} \tag{12}$$

where

$$\begin{aligned}
b_{00} &= c \cdot D_z^{out} + (1-c) \cdot D_z^{inn} - D_z^{mid} && (13)\\
b_{01} &= -c \cdot D_x^{out} - (1-c) \cdot D_x^{inn} + D_x^{mid} && (14)\\
b_{10} &= -c \cdot X^{out} \cdot R_x^{out} - (1-c) \cdot X^{inn} \cdot R_x^{inn} + X^{mid} \cdot R_x^{mid} && (15)\\
b_{11} &= -c \cdot X^{out} \cdot R_z^{out} - (1-c) \cdot X^{inn} \cdot R_z^{inn} + X^{mid} \cdot R_z^{mid} && (16)\\
b_{02} &= -c \cdot X^{out} \cdot R_y^{out} - (1-c) \cdot X^{inn} \cdot R_y^{inn} + X^{mid} \cdot R_y^{mid} && (17)
\end{aligned}$$

Comparing equations (6-10) and (13-17) we see that

$$a_{10} = b_{01} \quad (18)$$
$$a_{01} = -b_{10} \quad (19)$$
$$a_{11} = b_{02} \quad (20)$$
$$a_{20} = b_{11} \quad (21)$$
$$(22)$$

So we have six coefficients unknown. For every led-lense monitor with coordinates ϕ_i and θ_i and readings δ_i^x and δ_i^y we have two equations:

$$\begin{cases} a_{00} + a_{10} \cdot \xi_i' + a_{01} \cdot \eta_i + a_{11} \cdot \xi_i' \cdot \eta_i + a_{20} \cdot \xi_i' \xi_i = \delta_i^x \\ b_{00} + a_{10} \cdot \eta_i' - a_{01} \cdot \xi_i + a_{11} \cdot \eta_i' \cdot \eta_i + a_{20} \cdot \eta_i' \xi_i = \delta_i^y \end{cases}$$

With three monitors we can solve the system and calculate sagitta correction using (1). However, this is insufficient to correct for torque chamber deformation, of course. To account for torque deformation we used four led-lense monitors, as it shown in figure 1. Sagitta corrections calculated with monitors $i-1$, i, $i+1$ are weighted with corresponding area W_i .

3 Tolerances

This method was simulated for the GEM baseline muon system configuration [1]. Chamber positioning requirements are listed in table 1.

Table 1.

distortion	SL 1	SL 2	SL 3
D_x, D_y, D_z	$\pm 3.0\ mm$	$\pm 1.5\ mm$	$\pm 3.0\ mm$
R_x, R_y	$\pm 2.0\ mrad$	$\pm 1.5\ mrad$	$\pm 1.5\ mrad$
R_z	$\pm 7.0\ mrad$	$\pm 3.0\ mrad$	$\pm 5.0\ mrad$

The requirements on rotation angles are determined by the chamber corners positioning accuracy and the size of the chambers. Torque deformation angle was allowed to be as large as it allowed by tolerances of the corners positioning. This means that the maximum torque angle is $2 \cdot R_z^{max}$.

The accuracy of led-lense monitors was taken to be 25 μm . We considered two sources of track non-projectivity:

- Bunch size was $0.02 \times 0.02 \times 5.0\ cm$ large; actual IP was randomly generated for each track.
- systematic shift of IP from the center of GEM. We assumed that IP lies within $3.0 \times 3.0 \times 3.0\ cm$ volume; actual shift was randomly generated for each set of chamber distortions.

In all simulation we assumed that chambers are thin. Considerations of chamber thickness is a subject of a future note.

4 Simulation results

We considered 50 random sets of chamber distortions. For every set, false and corrected sagitta was calculated for 50 tracks. Simulation results are summarized in table 2.

Table 2.

model considered	RMS of corrected sagitta distribution
shifts + rotations (sh+rot)	2.1 μm
sh + rot + torque (tq)	10.0 μm
sh + rot + tq + non-projectivity	20.2 μm
sh + rot + tq + monitor accuracy	14.6 μm
altogether	25.4 μm

The correction for a pure torque deformation is illustrated by figure 2. Figures 2a and 2c shows false sagitta and its dependance from θ and ϕ for a one set of chamber torques. The corrected sagitta behaviour is shown in figures 2b and 2d. Figures 3a and 3b illustrate the sagitta correction for the last row in table 2. Shown in figures 3c and 3d are dependence of corrected sagitta error vs led-lense monitor resolution and width of non-bend readout zones.

5 Conclusion

We showed that only three led-lense monitors are needed to correct for the chamber shifts and rotations. With four monitors we can correct for torque deformation as well.

References

[1] "GEM Technical Design Report", GEM TN-93-262, SSCL-SR-1219

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

[3] Paradiso J. "Analysis of an Alignment Scheme for the GEM Muon Barrel", GEM internal note TN-92-150

[4] Ostapchuk A. "Alignment, Based on the Measurements of Particle Non-Bend c Non-Bend Coordinate", GEM internal note TN-93-427

Figure Captions

Figure 1 Sagitta correction weighting

Figure 2 Correction for torque chamber deformation:
a) false sagitta distribution (cm)
b) corrected sagitta distribution (μm)
c) false sagitta distribution vs θ and ϕ (mrad)
d) corrected sagitta distribution vs θ and ϕ (mrad)

Figure 3 Corrected sagitta distributions:
a) false sagitta (cm) vs corrected sagitta (μm)
b) corrected sagitta (μm)
c) RMS of corrected sagitta distribution (μm)
vs led-lense monitor resolution (μm)
d) RMS of corrected sagitta distribution (μm)
vs width of non-bend readout zone (cm)

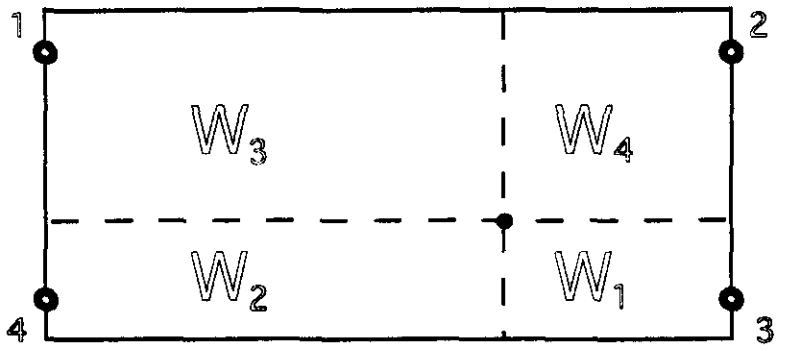

Fig. 1 Saggita correction calculated using monitors ***i-1,i,i+1*** has weigt W_i . Weighting all four corrections obtained makes possible to correct for torque defomration

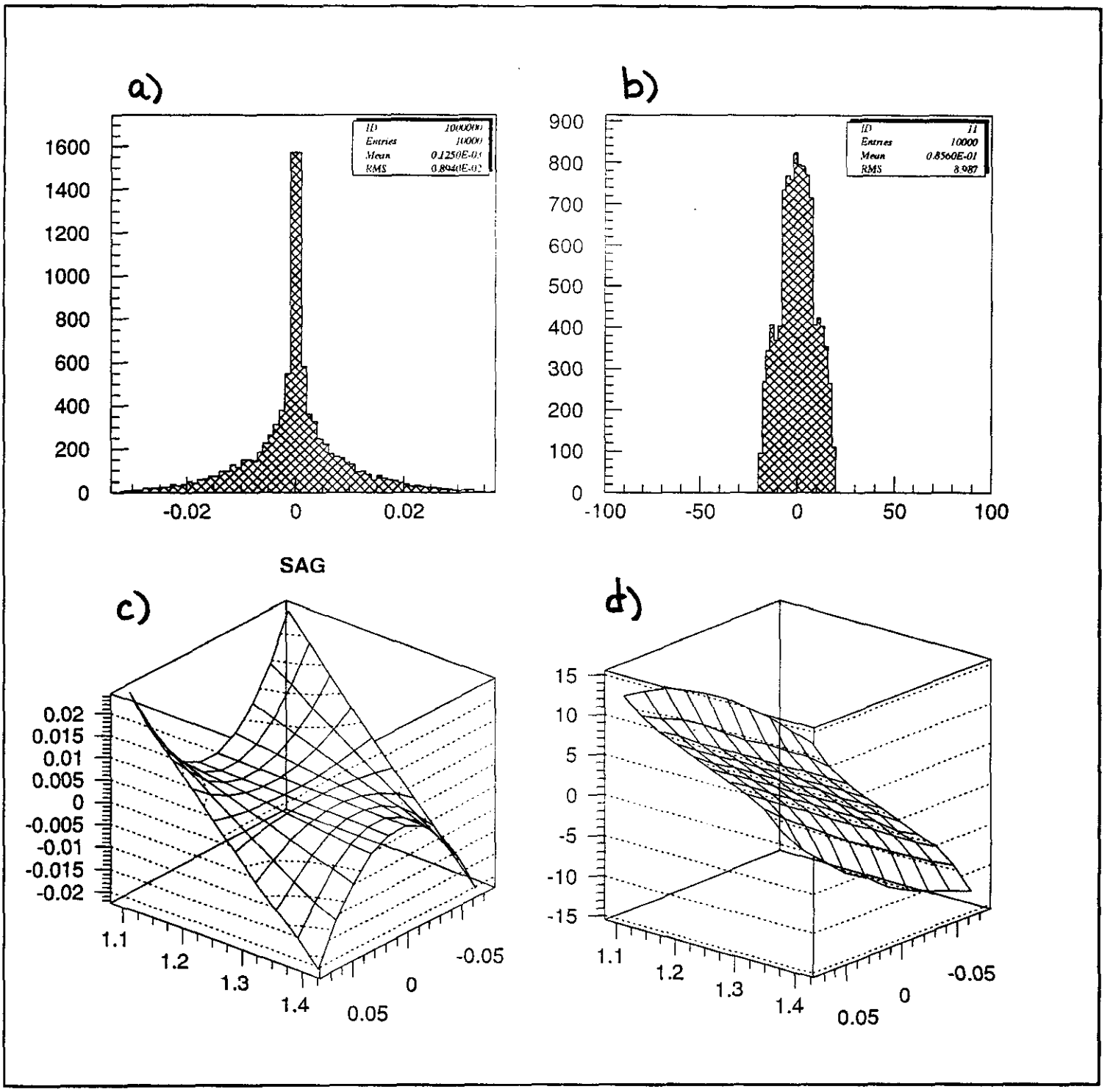
a)
ID 1000000
Entries 10000
Mean 0.1250E-03
RMS 0.8940E-02
1600
1400
1200
1000
800
600
400
200
0
-0.02
0
0.02
b)
ID 11
Entries 10000
Mean 0.8560E-01
RMS 8.987
900
800
700
600
500
400
300
200
100
0
-100
-50
0
50
100
SAG
c)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
1.1
1.2
1.3
1.4
0.05
0
-0.05
d)
15
10
5
0
-5
-10
-15
1.1
1.2
1.3
1.4
0.05
0
-0.05

Figure 2

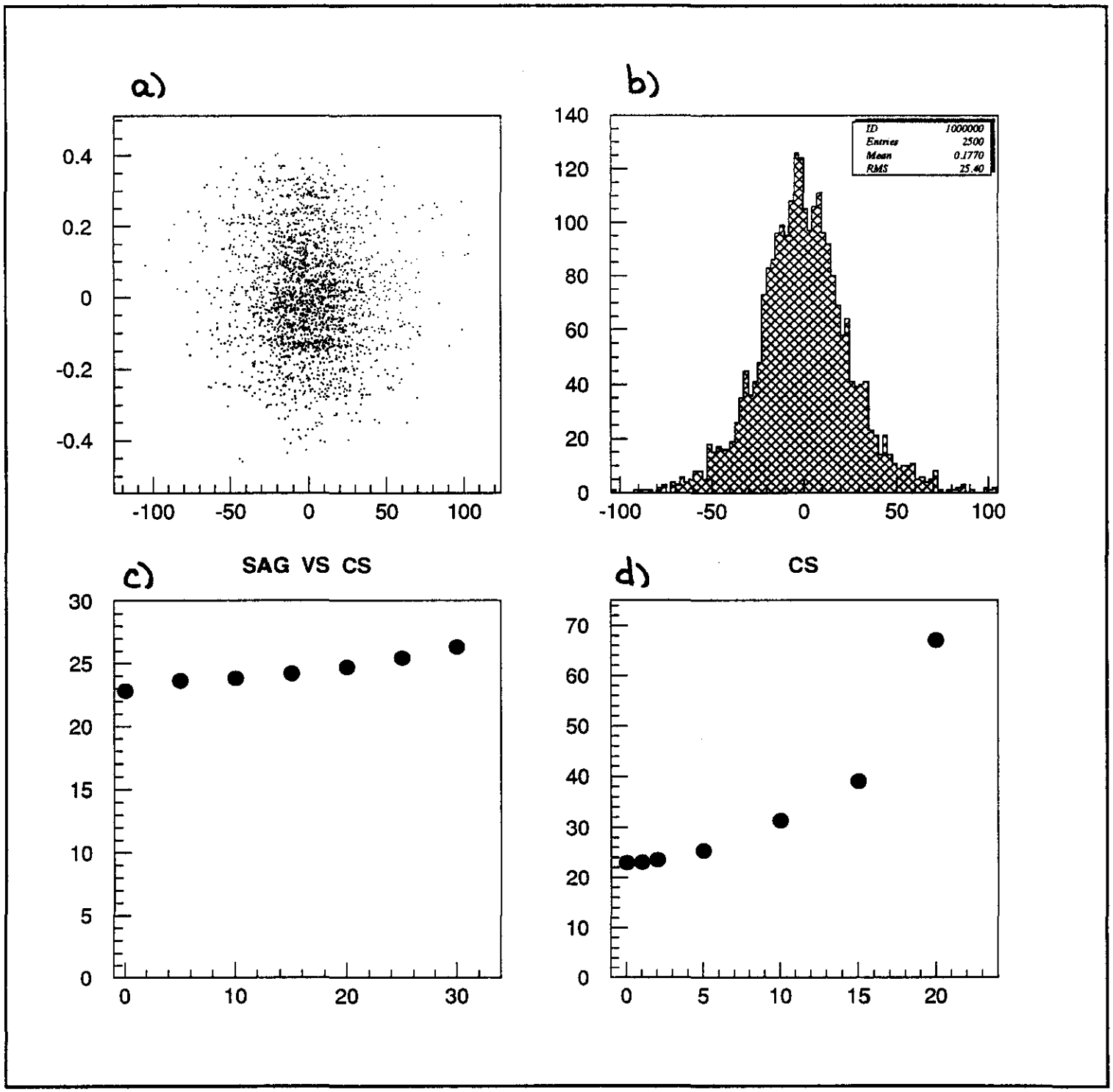
a)
0.4
0.2
0
-0.2
-0.4
-100
-50
0
50
100
b)
ID 1000000
Entries 2500
Mean 0.1770
RMS 25.40
140
120
100
80
60
40
20
0
-100
-50
0
50
100
c)
SAG VS CS
30
25
20
15
10
5
0
0
10
20
30
d)
CS
70
60
50
40
30
20
10
0
0
5
10
15
20

Figure 3