



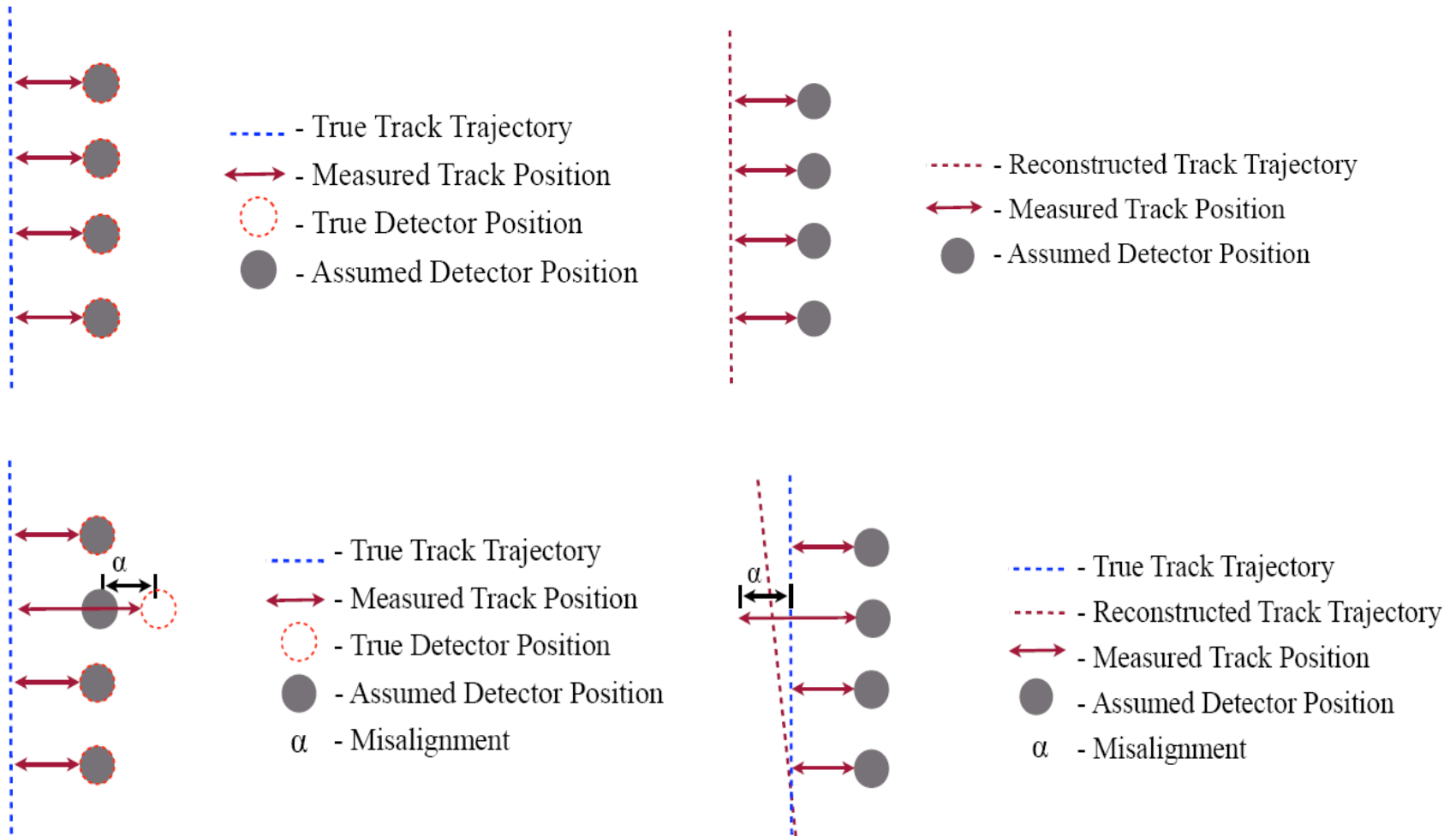
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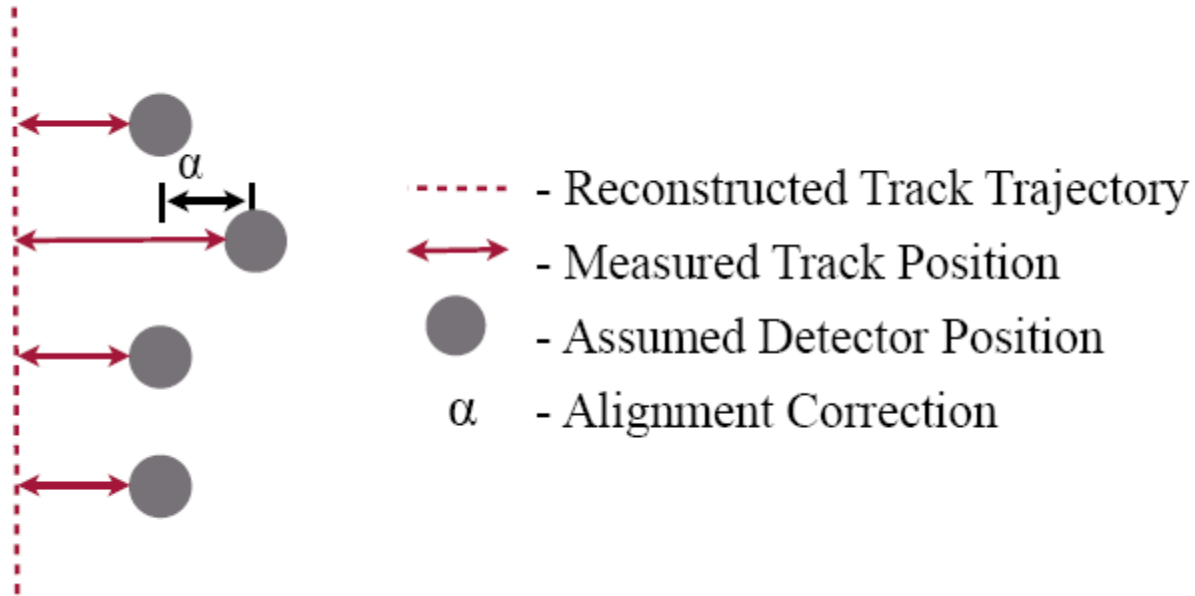
Status of geometry alignment of BM@N tracking detectors

Zarif Sharipov

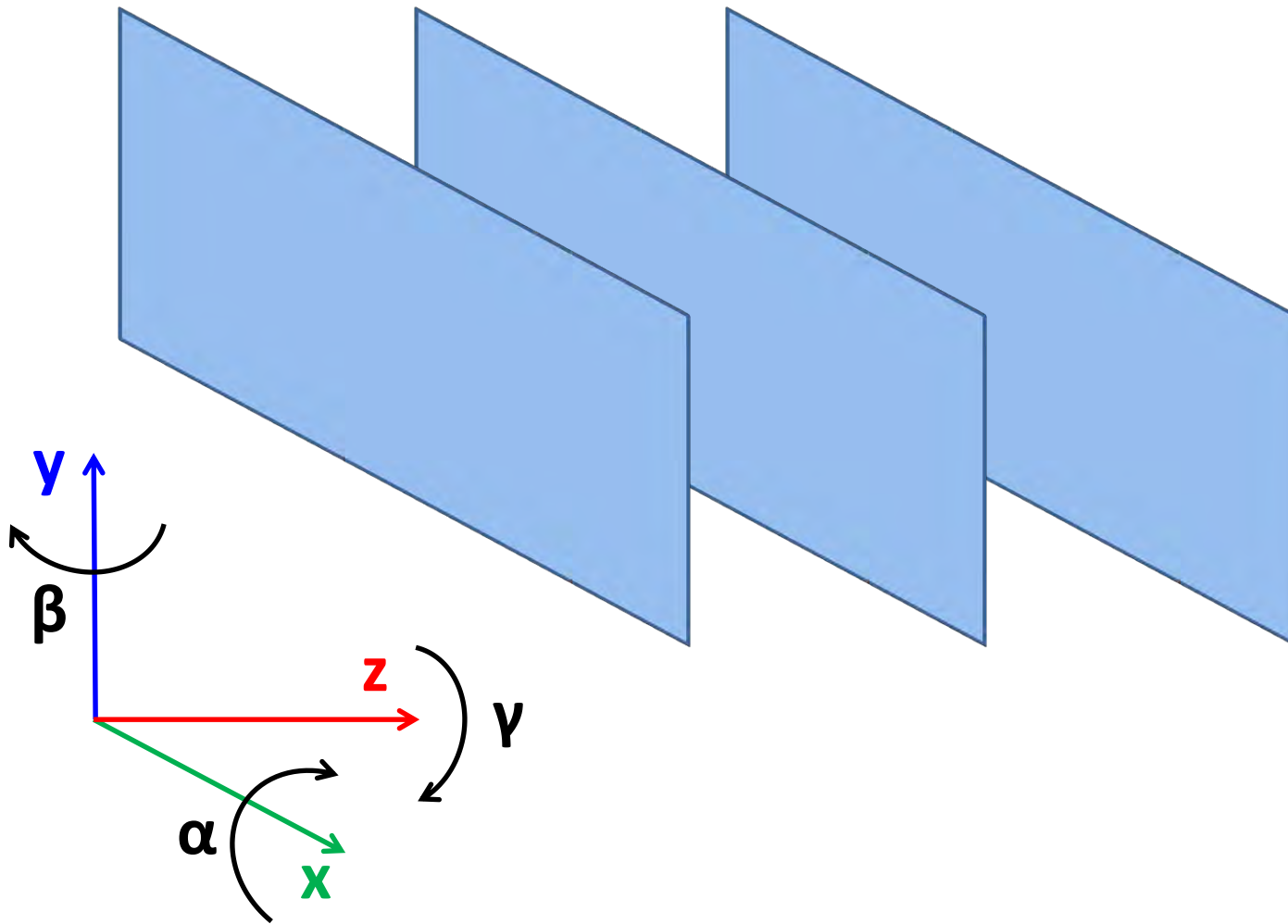
Introduction to Alignment



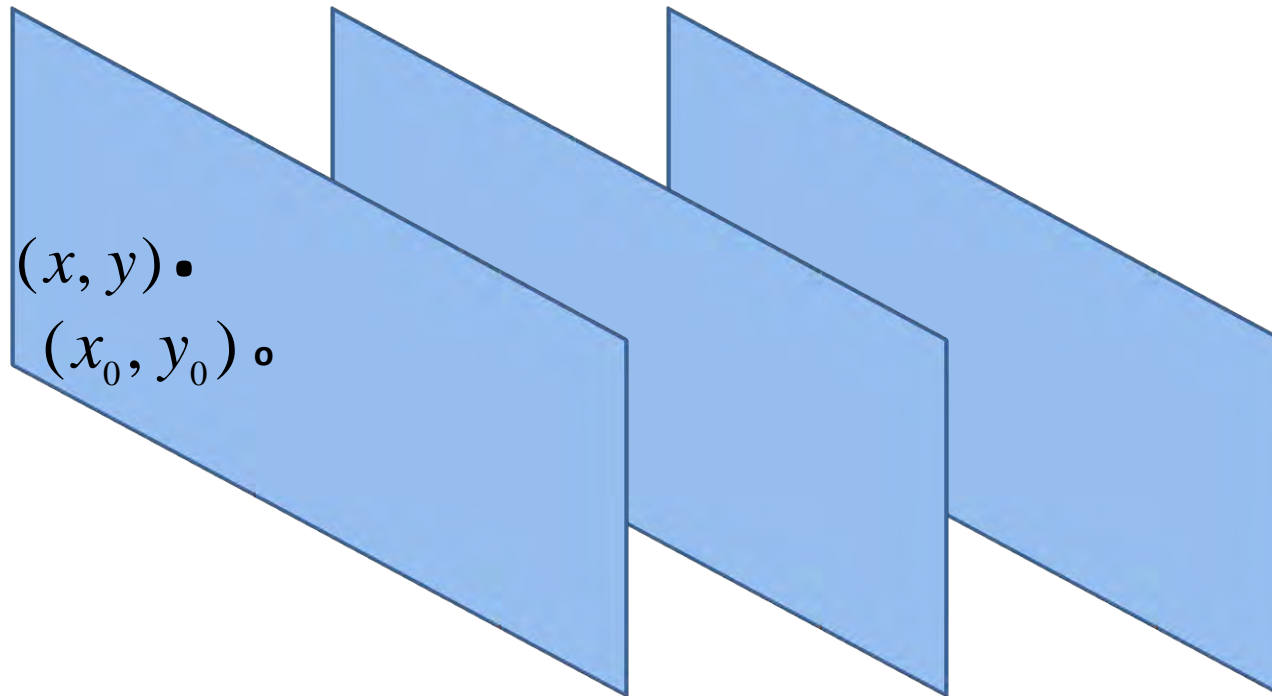
Introduction to Alignment



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Introduction to Alignment



$$\Delta S^2 = (x - x_0)^2 + (y - y_0)^2$$

$$\chi^2 = \sum_{i=1}^{n_{track}} \sum_{j=1}^{n_{det}} \frac{[\Delta S_{ij}(u_{ij}, \alpha_i^t, \alpha_j^a)]^2}{\sigma_j^2}$$

Alignment for x and y

$$\mathbf{Ax} = \mathbf{B}$$

$$\Delta S_{ij} = u_{ij} - A_i z - B_i + du_j$$

$$\alpha_i = A_i, \quad i = 1, \dots, n_{tr}$$

$$\alpha_i = B_i, \quad i = n_{tr} + 1, \dots, 2n_{tr}$$

$$\alpha_i = du_j, \quad i = 2n_{tr} + 1, \dots, 2n_{tr} + n_{det} - 2$$

$N_d = 6$ - number of detectors
 $N_t = 5$ - number of tracks
 $\alpha_1, \dots, \alpha_{10}$ - parameters of tracks
 $\alpha_{11}, \dots, \alpha_{14}$ - alignment parameters of the detectors

S_2 0 0 0 0 0 S_2 0 0 0 0 0 S_2 0 0 0 0 0 S_2 0 0 0 0 0 S_2	S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1	Z_2 Z_3 Z_4 Z_5 Z_2 Z_3 Z_4 Z_5 Z_2 Z_3 Z_4 Z_5 Z_2 Z_3 Z_4 Z_5 Z_2 Z_3 Z_4 Z_5
S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1 0 0 0 0 0 S_1	N_d 0 0 0 0 0 N_d 0 0 0 0 0 N_d 0 0 0 0 0 N_d 0 0 0 0 0 N_d	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Z_2 Z_2 Z_2 Z_2 Z_2 Z_3 Z_3 Z_3 Z_3 Z_3 Z_4 Z_4 Z_4 Z_4 Z_4 Z_5 Z_5 Z_5 Z_5 Z_5	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	N_t 0 0 0 0 N_t 0 0 0 0 N_t 0 0 0 0 N_t

1. Volker Blobel, Claus Kleinwort. A New method for the high precision alignment of track detectors (<https://arxiv.org/abs/hep-ex/0208021>)
2. https://www.desy.de/~kleinwrt/MP2/doc/html/draftman_page.html

Alignment for x, y and z

$$\Delta S_{ij}^2 = (x - x_0)^2 + (y - y_0)^2$$

$$x = A_x z + B_x, \quad y = A_y z + B_y$$

$$x = (A_x^0 + dA_x)(z + dz) + B_x,$$

$$y = (A_y^0 + dA_y)(z + dz) + B_y$$

$$x = A_x^0 z + dA_x z + A_x^0 dz + \underbrace{dA_x dz}_{\text{circled}} + B_x$$

Alignment for x, y and z

S_2	0	0	0	0
0	S_2	0	0	0
0	0	S_2	0	0
0	0	0	S_2	0
0	0	0	0	S_2

S_1	0	0	0	0
0	S_1	0	0	0
0	0	S_1	0	0
0	0	0	S_1	0
0	0	0	0	S_1

Z_2	Z_3	Z_4	Z_5
Z_2	Z_3	Z_4	Z_5
Z_2	Z_3	Z_4	Z_5
Z_2	Z_3	Z_4	Z_5
Z_2	Z_3	Z_4	Z_5

$Ax_1^0 z_2$	$Ax_1^0 z_3$	$Ax_1^0 z_4$...
$Ax_2^0 z_2$	$Ax_2^0 z_3$	$Ax_2^0 z_4$...
...

S_1	0	0	0	0
0	S_1	0	0	0
0	0	S_1	0	0
0	0	0	S_1	0
0	0	0	0	S_1

N_d	0	0	0	0
0	N_d	0	0	0
0	0	N_d	0	0
0	0	0	N_d	0
0	0	0	0	N_d

1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1

Ax_1^0	Ax_1^0	Ax_1^0	...
Ax_2^0	Ax_2^0	Ax_2^0	...
...

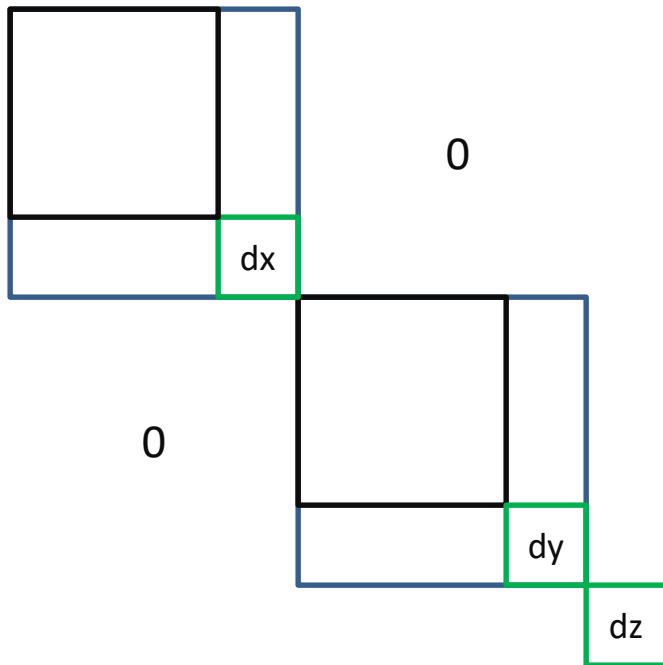
Z_2	Z_2	Z_2	Z_2	Z_2
Z_3	Z_3	Z_3	Z_3	Z_3
Z_4	Z_4	Z_4	Z_4	Z_4
Z_5	Z_5	Z_5	Z_5	Z_5

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

N_t	0	0	0
0	N_t	0	0
0	0	N_t	0
0	0	0	N_t

$\sum_i Ax_i^0$	0	...
0	$\sum_i Ax_i^0$...
...	...	$\sum_i Ax_i^0$

Alignment for x, y and z



Principle of alignment

1. IMSL Fortran Library

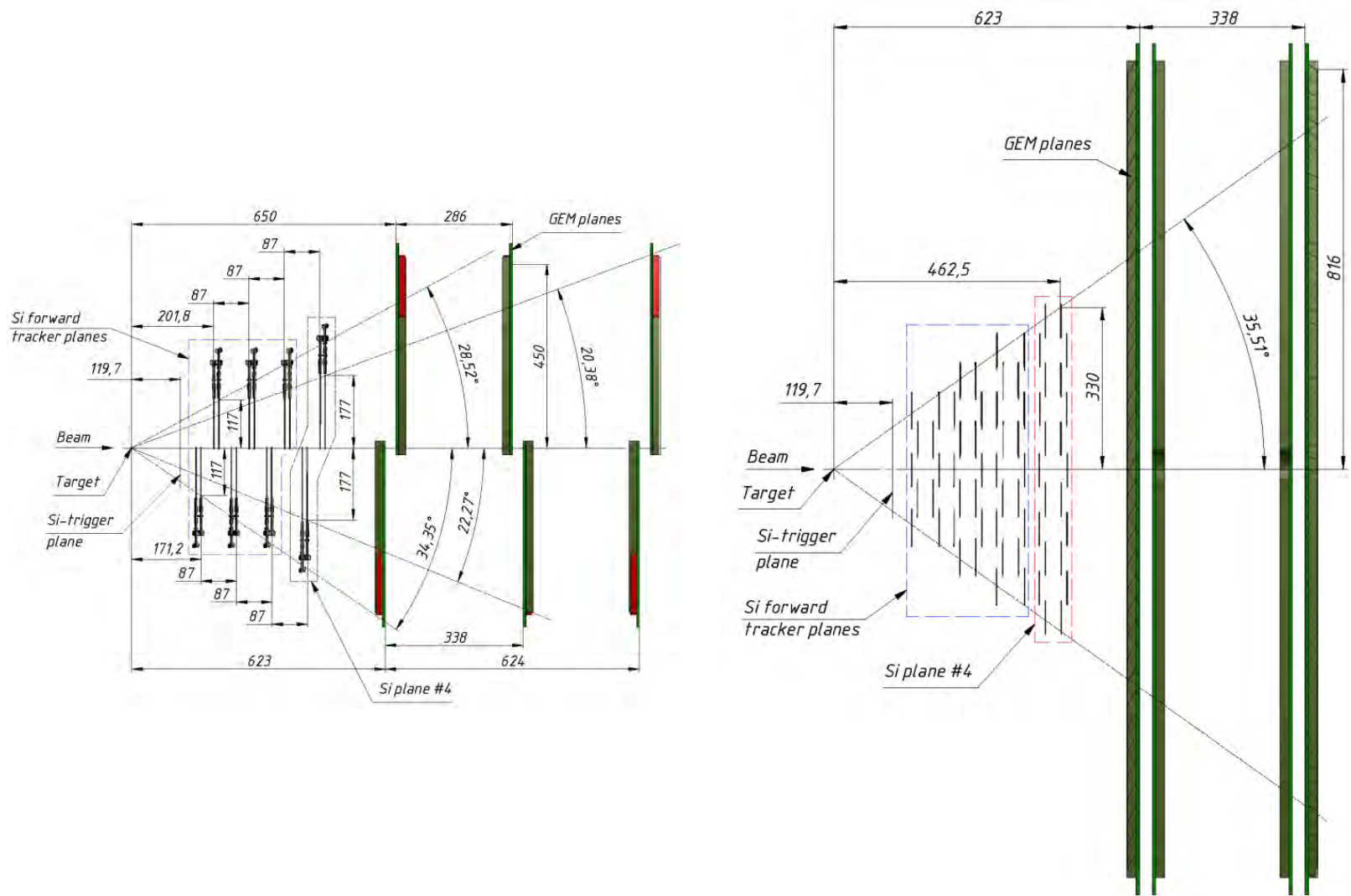
(<https://www.imsl.com/products/imsl-fortran-libraries>)

2. Eigen

(https://eigen.tuxfamily.org/index.php?title=Main_Page)

3. Millepede-II

(https://www.desy.de/~kleinwrt/MP2/doc/html/draftman_page.html)



Schematic view of Forward Silicon detectors including 4th Si plane and first large aperture GEM stations in YZ (left) and XZ (right) projections.