JOINT INSTITUTE
FOR NUCLEAR RESEARCH

MESHCHERYAKOV
LABORATORY of
INFORMATION
TECHNOLOGIES

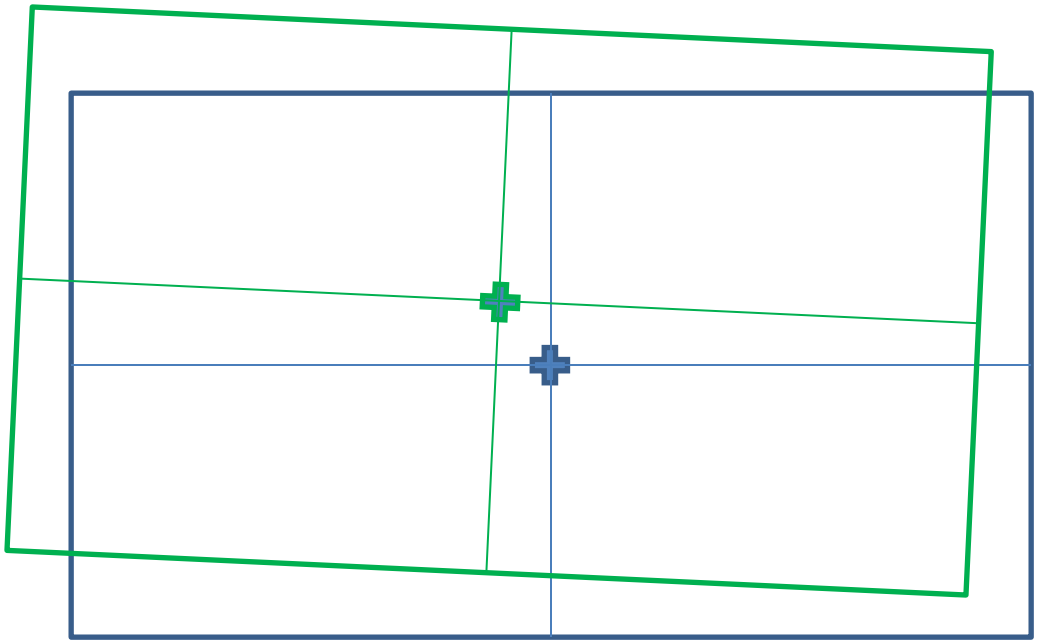
BM@N
Baryonic Matter at Nuclotron

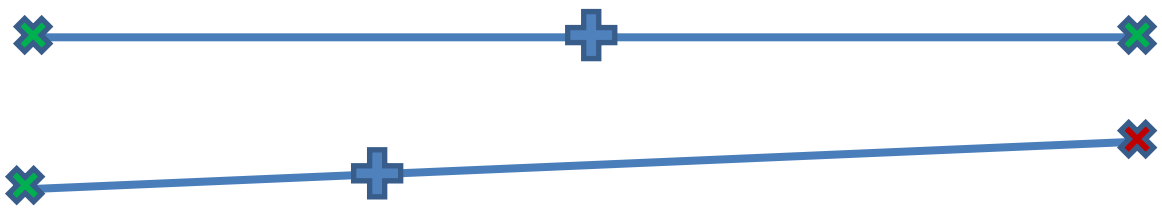
# Status of geometry alignment of BM@N tracking detectors

Zarif Sharipov

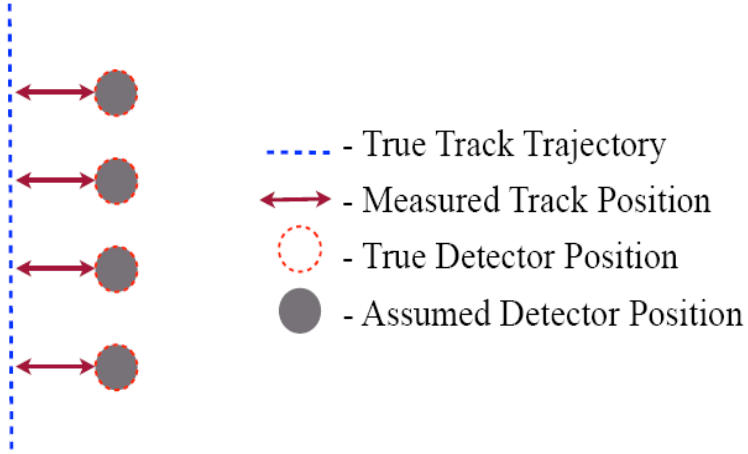
**Analysis & Software Meeting of the BM@N Experiment**

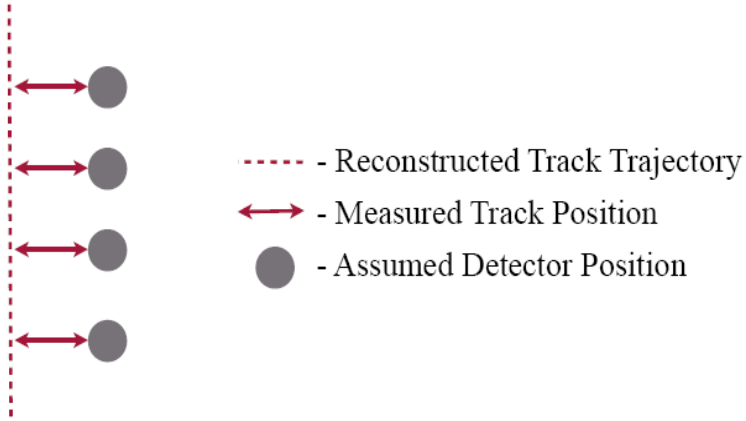
# Introduction to Alignment

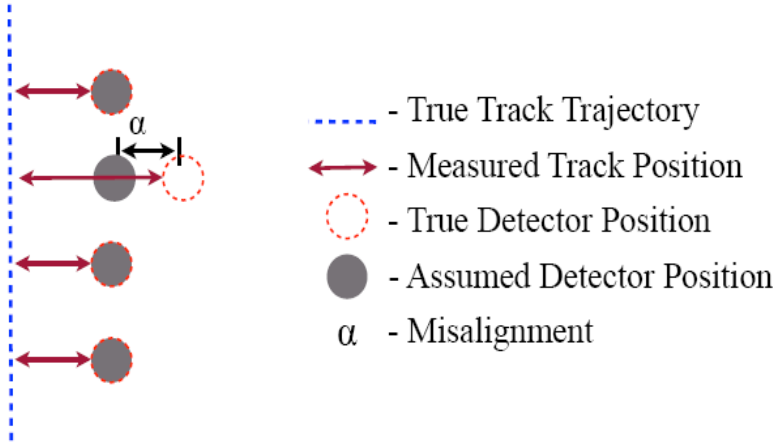


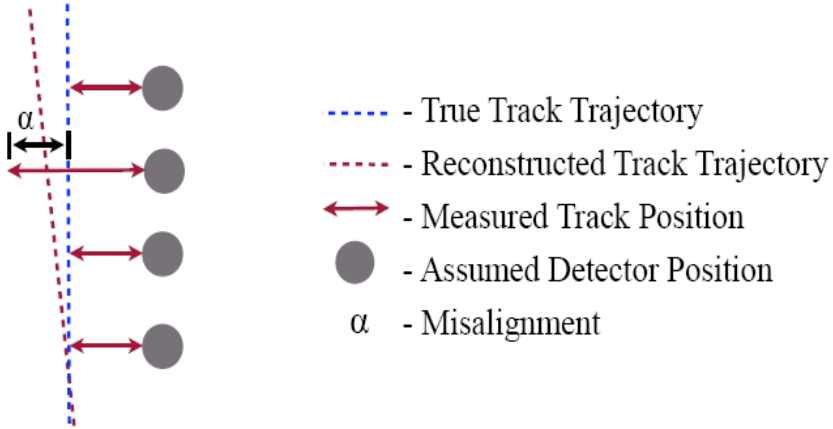


# Introduction to Alignment



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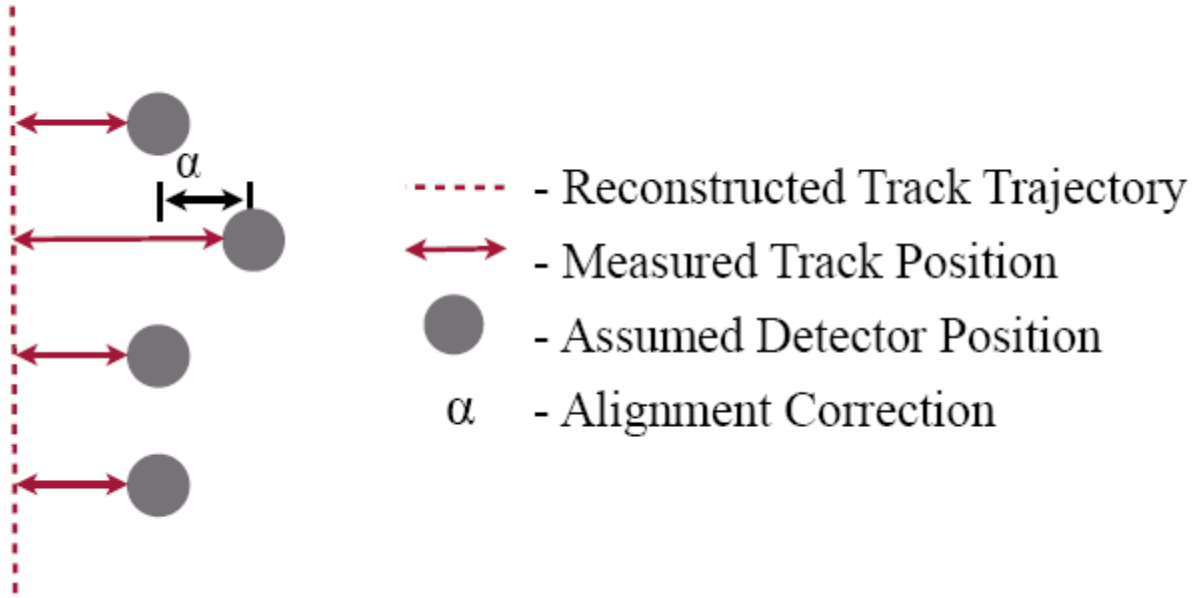

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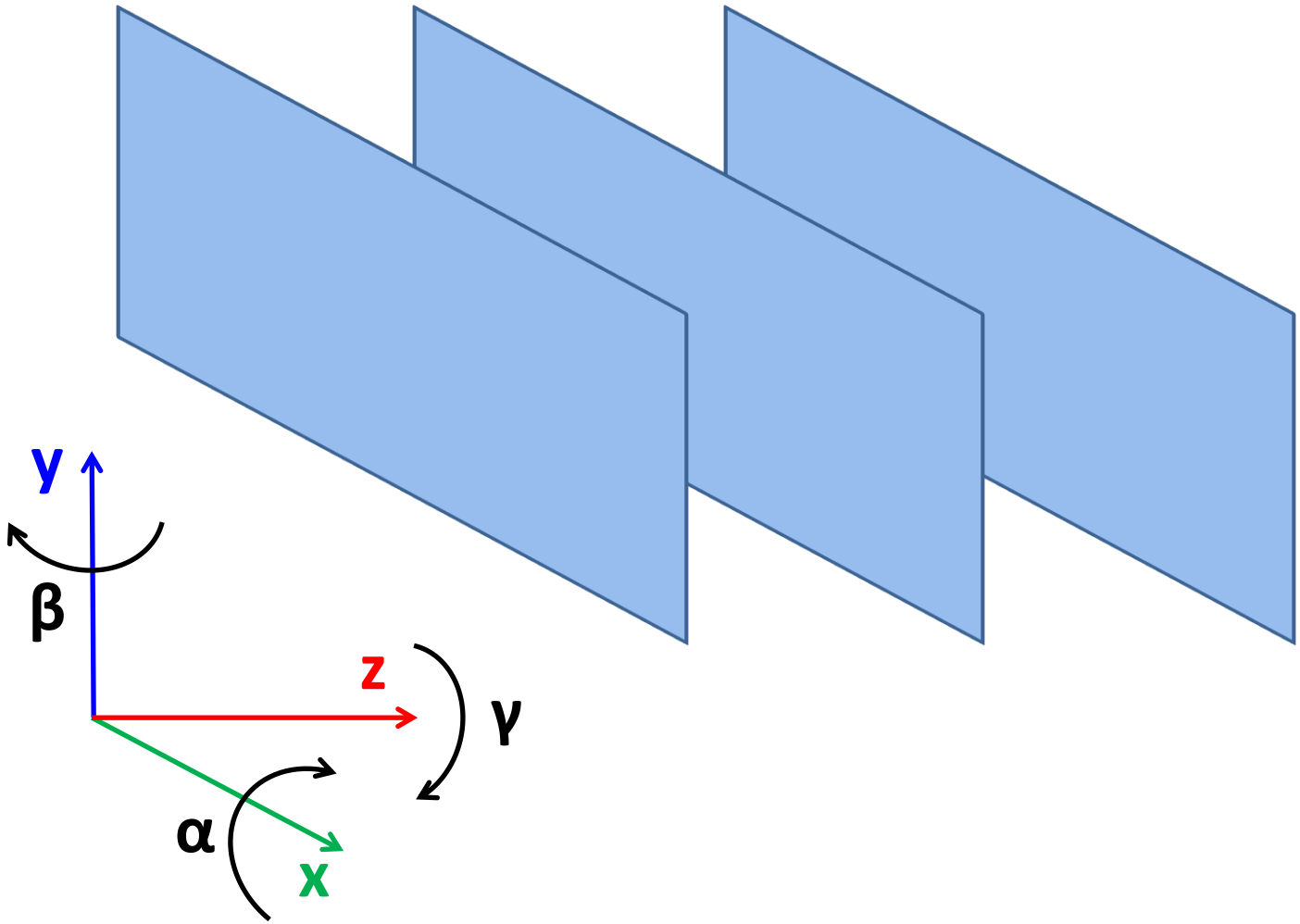

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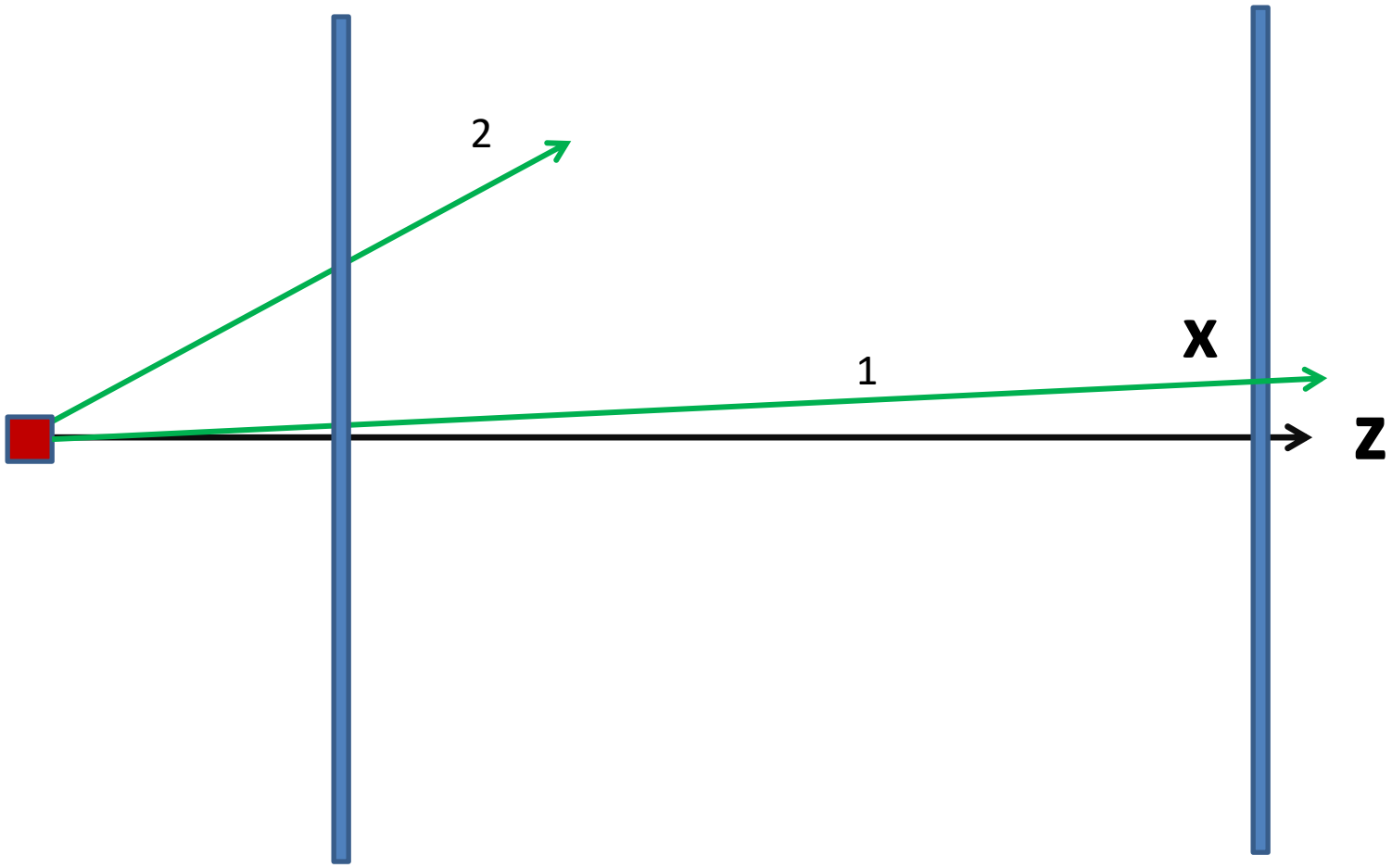
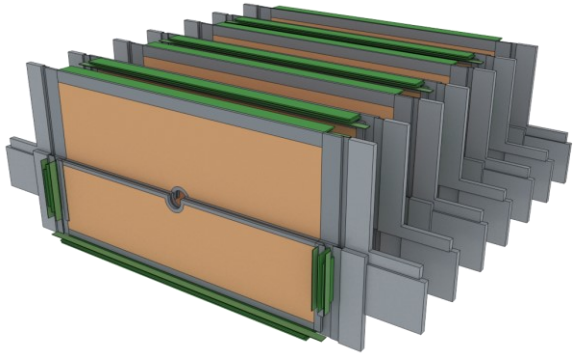
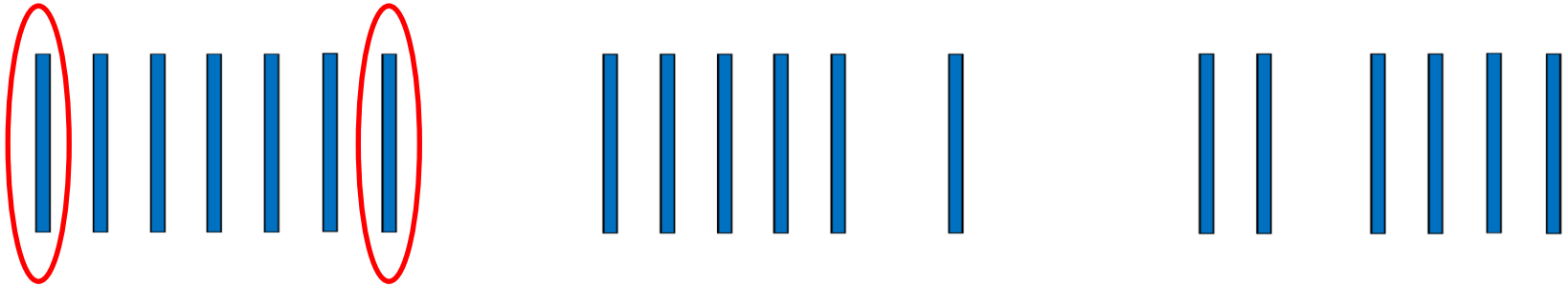
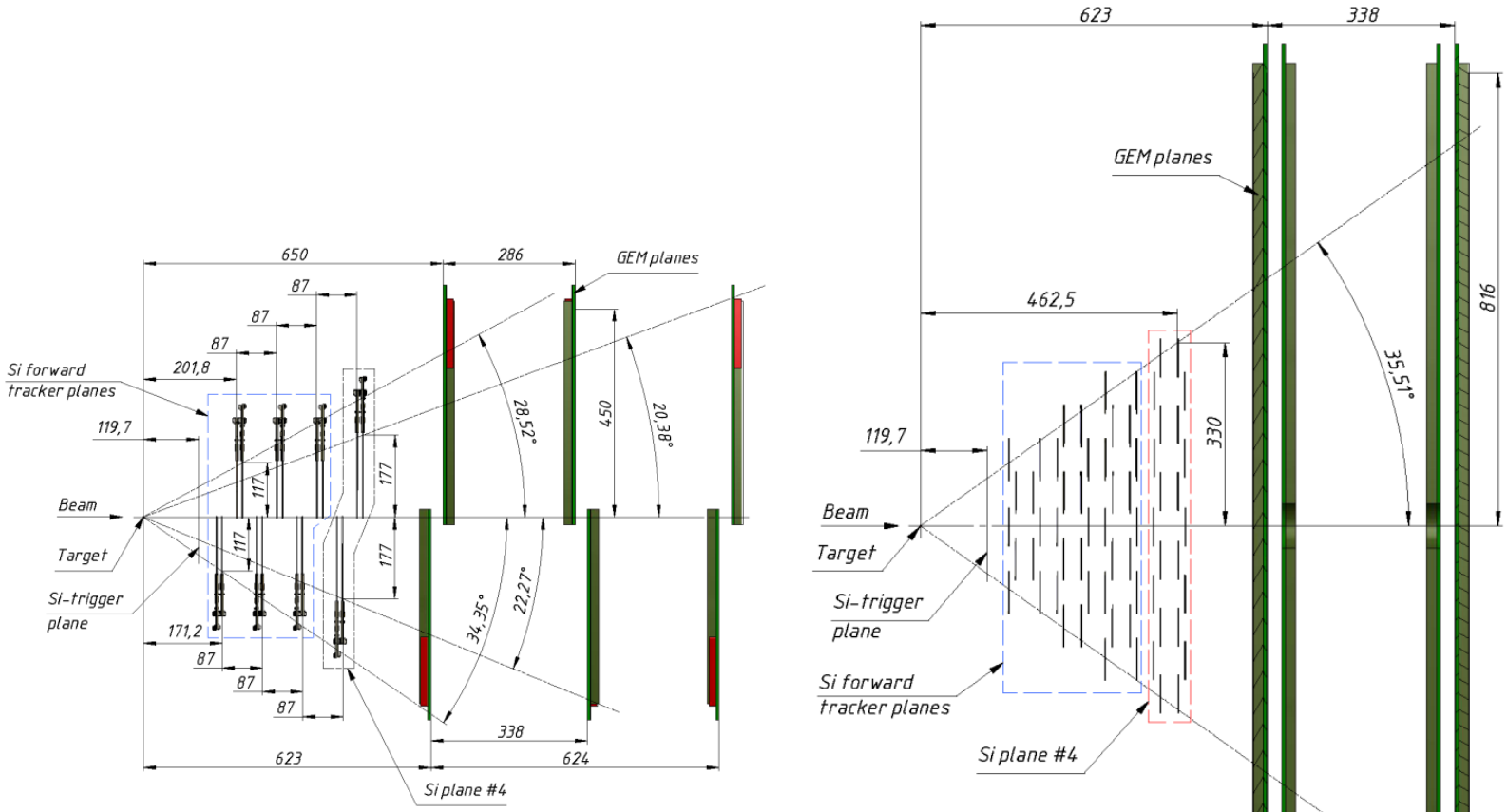


# RUN 7651

| | |
|---|---|
| Period: | 8 |
| Number: | 7651 |
| Beam: | A = -1, Z = -1 |
| Beam energy: | 3.8 GeV |
| Target: | A = -1, Z = -1 |
| Field voltage: | 0.2701 mV |
| N_events: | 100000 |

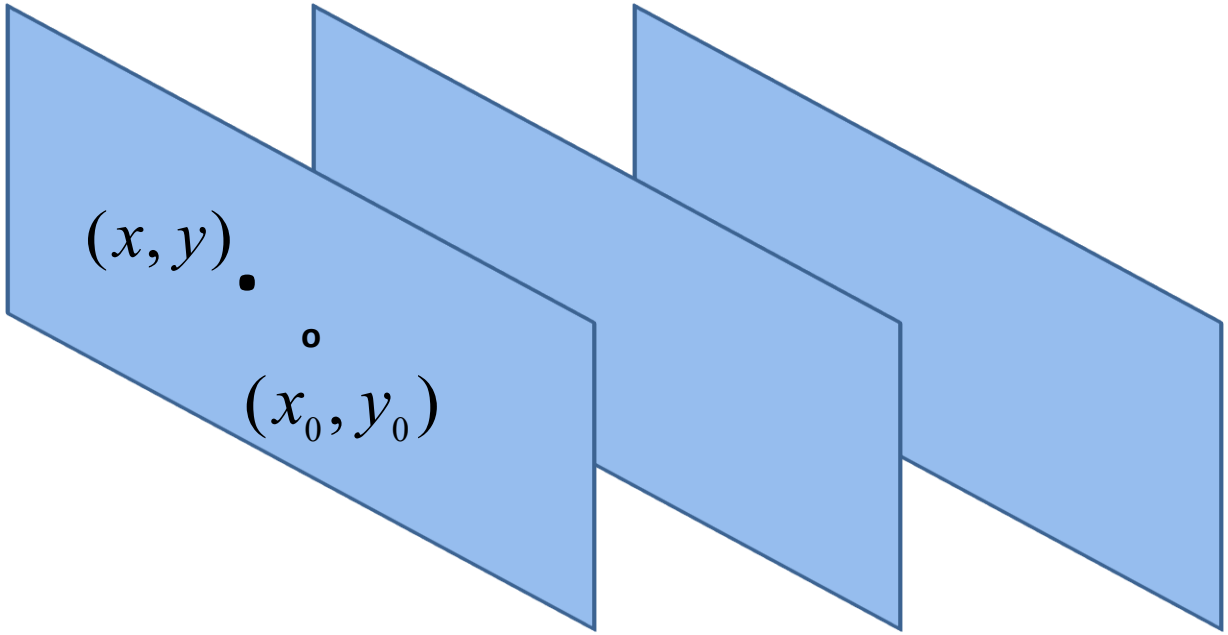







Schematic view of Forward Silicon detectors including 4th Si plane and first large apperture GEM stations in YZ (left) and XZ (right) projections.

# 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

$$\mathbf{Ax = B}$$

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

$$\alpha_i = A_i, \quad i = 1, \dots, n\_tr$$

$$\alpha_i = B_i, \quad i = n\_tr + 1, \dots, 2n\_tr$$

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

$$\begin{array}{|ccccc|ccccc|cccc|}
\hline
S_2 & 0 & 0 & 0 & 0 & S_1 & 0 & 0 & 0 & 0 & Z_2 & Z_3 & Z_4 & Z_5 \\
0 & S_2 & 0 & 0 & 0 & 0 & S_1 & 0 & 0 & 0 & Z_2 & Z_3 & Z_4 & Z_5 \\
0 & 0 & S_2 & 0 & 0 & 0 & 0 & S_1 & 0 & 0 & Z_2 & Z_3 & Z_4 & Z_5 \\
0 & 0 & 0 & S_2 & 0 & 0 & 0 & 0 & S_1 & 0 & Z_2 & Z_3 & Z_4 & Z_5 \\
0 & 0 & 0 & 0 & S_2 & 0 & 0 & 0 & 0 & S_1 & Z_2 & Z_3 & Z_4 & Z_5 \\
\hline
S_1 & 0 & 0 & 0 & 0 & N_d & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\
0 & S_1 & 0 & 0 & 0 & 0 & N_d & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\
0 & 0 & S_1 & 0 & 0 & 0 & 0 & N_d & 0 & 0 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & S_1 & 0 & 0 & 0 & 0 & N_d & 0 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & S_1 & 0 & 0 & 0 & 0 & N_d & 1 & 1 & 1 & 1 \\
\hline
Z_2 & Z_2 & Z_2 & Z_2 & Z_2 & 1 & 1 & 1 & 1 & 1 & N_t & 0 & 0 & 0 \\
Z_3 & Z_3 & Z_3 & Z_3 & Z_3 & 1 & 1 & 1 & 1 & 1 & 0 & N_t & 0 & 0 \\
Z_4 & Z_4 & Z_4 & Z_4 & Z_4 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & N_t & 0 \\
Z_5 & Z_5 & Z_5 & Z_5 & Z_5 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & N_t \\
\hline
\end{array}$$

$N_d$ = 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


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

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

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

$$x = A_x(z + dz) + B_x$$

$$x = A_x z + A_x dz + B_x$$

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

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

$$x = A_x^0 z + dA_x z + A_x^0 dz + dA_x dz + B_x$$

# Alignment for x, y and z

dAx_i

| | | | | |
|---|---|---|---|---|
| $S_2$ | 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 | $S_1$ |

| | | | | |
|---|---|---|---|---|
| $Z_2$ | $Z_2$ | $Z_2$ | $Z_2$ | $Z_2$ |
| $Z_3$ | $Z_3$ | $Z_3$ | $Z_3$ | $Z_3$ |
| $Z_4$ | $Z_4$ | $Z_4$ | $Z_4$ | $Z_4$ |
| $Z_5$ | $Z_5$ | $Z_5$ | $Z_5$ | $Z_5$ |

Bx_i

| | | | | |
|---|---|---|---|---|
| $S_1$ | 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 |

dx_i

| | | | | |
|---|---|---|---|---|
| $Z_2$ | $Z_3$ | $Z_4$ | $Z_5$ | |
| $Z_2$ | $Z_3$ | $Z_4$ | $Z_5$ | |
| $Z_2$ | $Z_3$ | $Z_4$ | $Z_5$ | |
| $Z_2$ | $Z_3$ | $Z_4$ | $Z_5$ | |
| $Z_2$ | $Z_3$ | $Z_4$ | $Z_5$ | |

| | | | | |
|---|---|---|---|---|
| 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 | $N_t$ | |

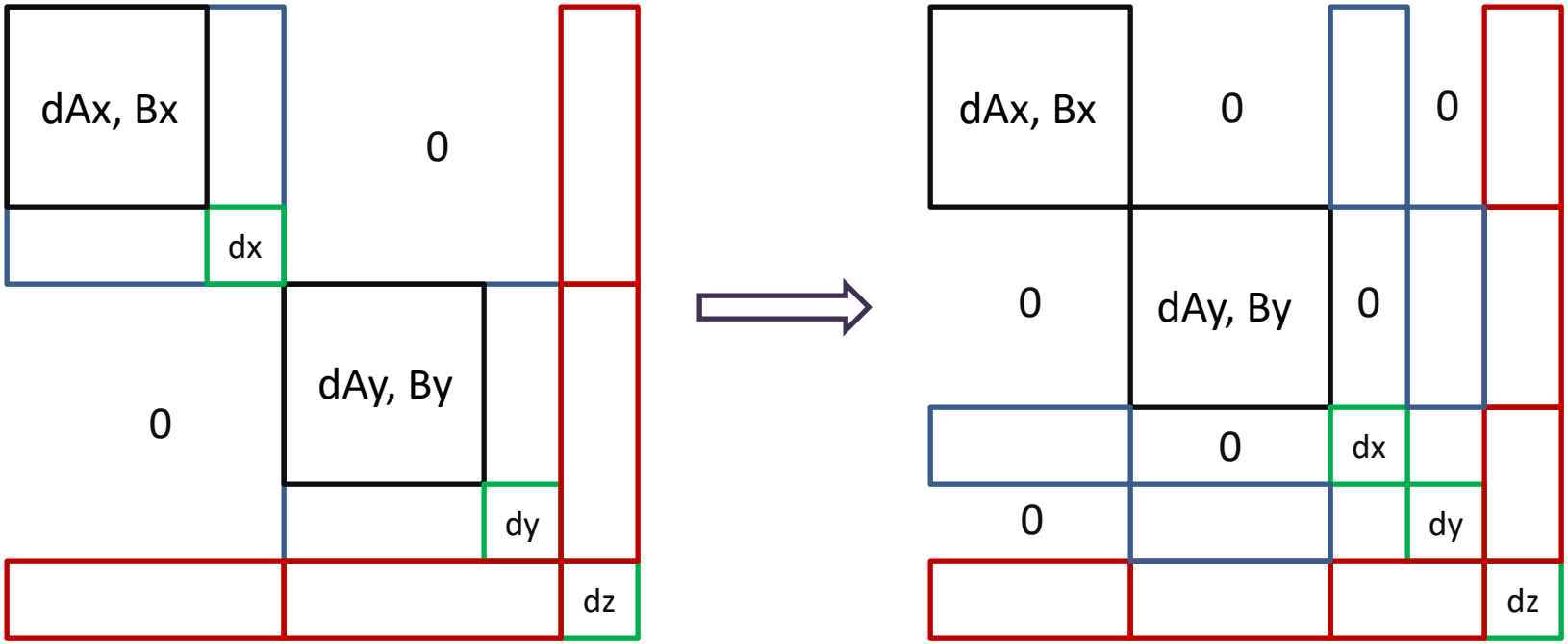
dz_i

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

| | | | |
|---|---|---|---|
| $Ax_1^0$ | $Ax_1^0$ | $Ax_1^0$ | ... |
| $Ax_2^0$ | $Ax_2^0$ | $Ax_2^0$ | ... |
| ... | ... | ... | ... |

| | | |
|---|---|---|
| $\sum_i Ax_i^0$ | 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)