JOINT INSTITUTE
FOR NUCLEAR RESEARCH

MESHCHERYAKOV
LABORATORY of
INFORMATION
TECHNOLOGIES

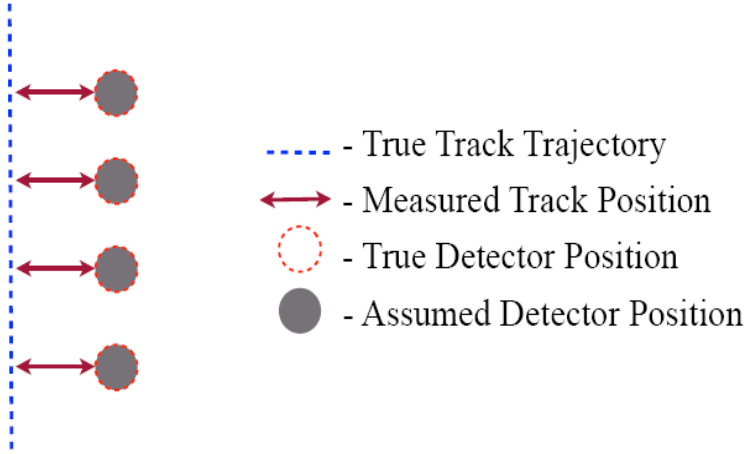
BM@N
Baryonic Matter at Nuclotron

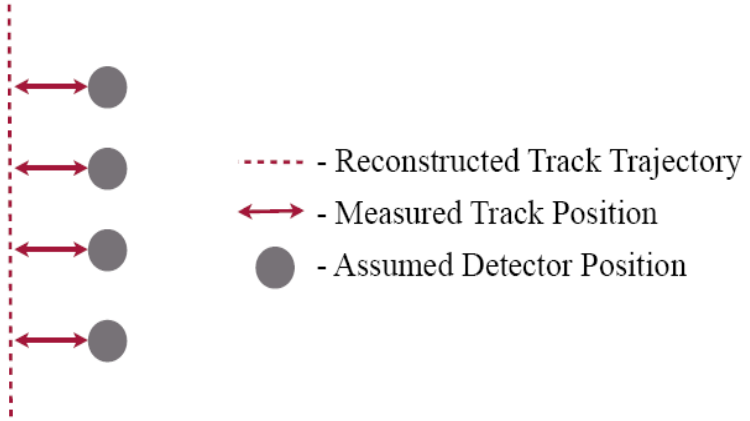
Geometry alignment of BM@N GEM detectors

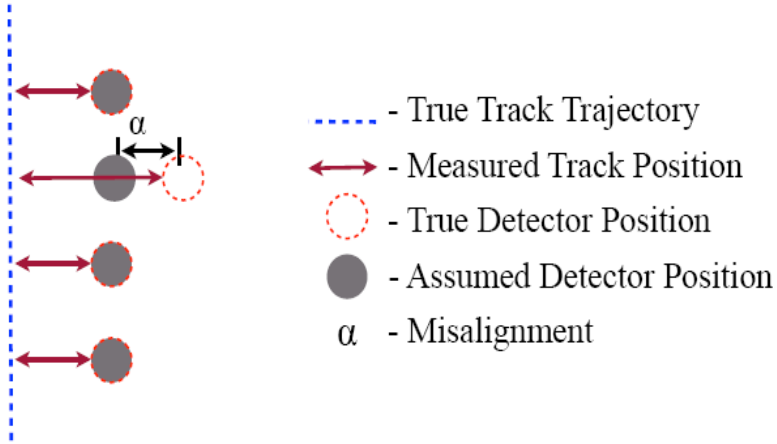
Zarif Sharipov

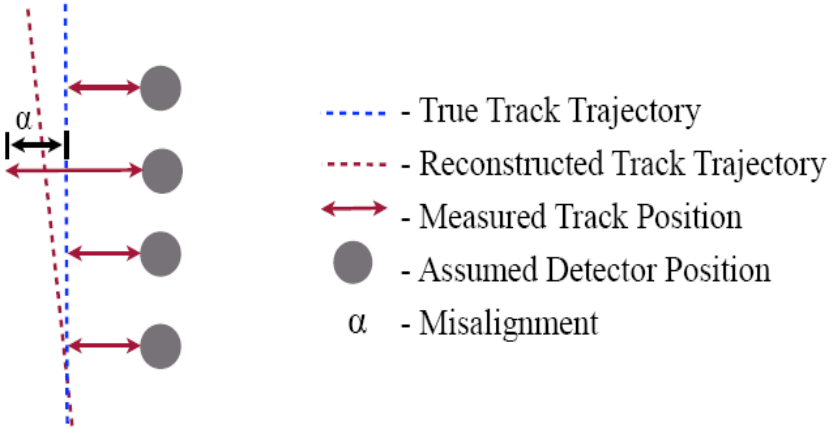
10th Collaboration Meeting of the BM@N Experiment at the NICA Facility

Introduction to Alignment

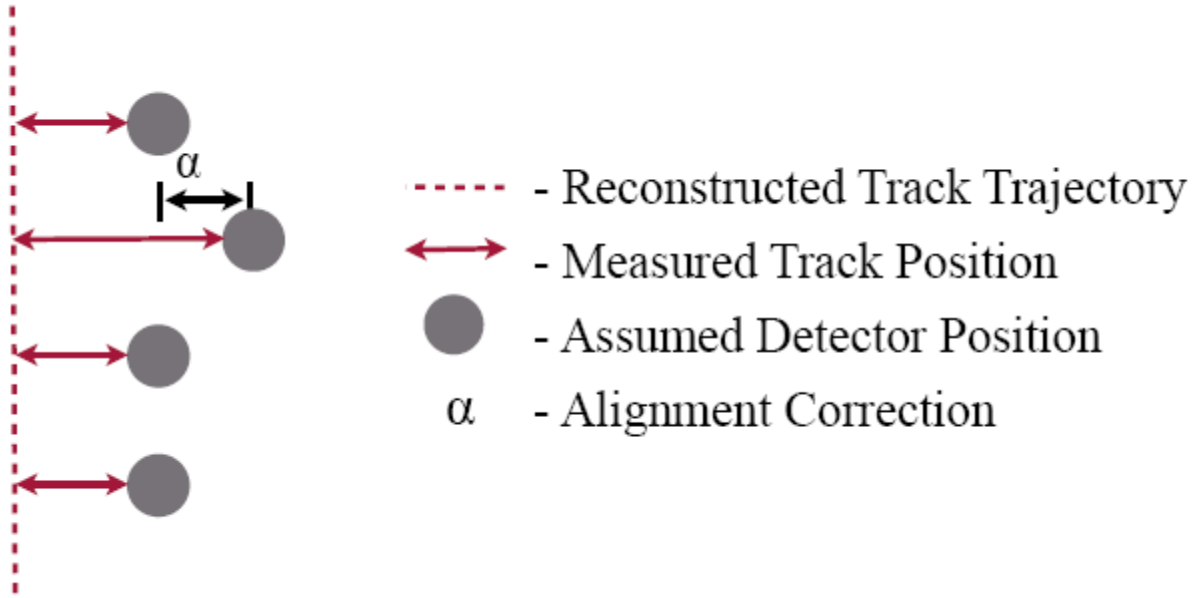




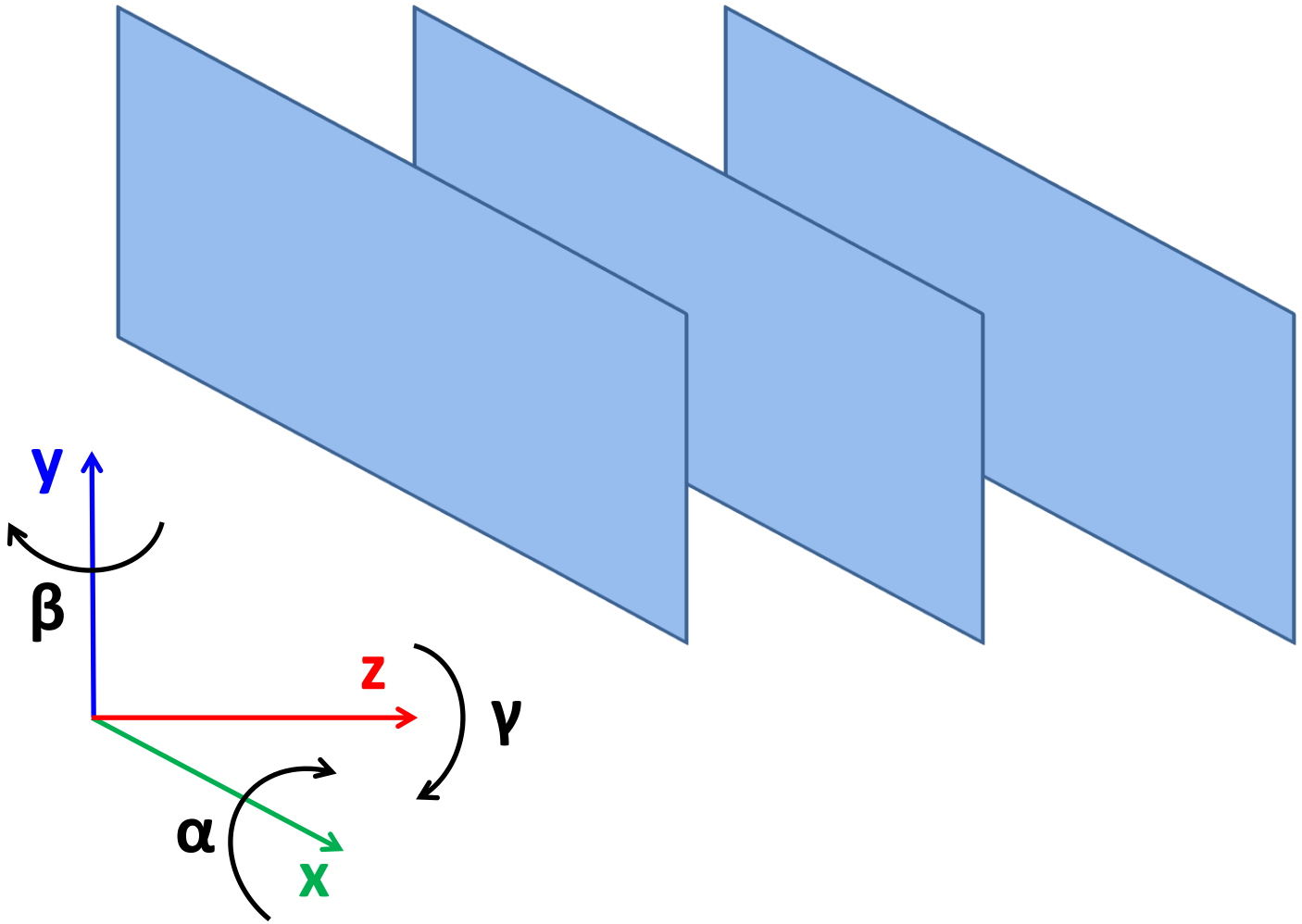




Introduction to Alignment



Introduction to Alignment



Principle of alignment [1, 2]

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

$$\Delta S_{ij} = \Delta S_{ij}^0 + \sum_k \frac{\partial \Delta S_{ij}}{\partial \alpha_k} \alpha_k$$

$$\frac{1}{2}\frac{\partial \chi^2}{\partial \alpha_m} = \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} \left(\Delta S_{ij}^0 + \sum_k \frac{\partial \Delta S_{ij}}{\partial \alpha_k} \alpha_k \right) = 0$$

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

Principle of alignment

$$\begin{pmatrix} \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_1} \frac{\partial \Delta S_{ij}}{\partial \alpha_1} & \cdots & \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_1} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} & \cdots \\ \vdots & \ddots & \vdots & \\ \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} \frac{\partial \Delta S_{ij}}{\partial \alpha_1} & \cdots & \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} & \\ \vdots & & & \ddots \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \vdots \\ \alpha_m \\ \vdots \end{pmatrix} = - \begin{pmatrix} \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_1} \Delta S_{ij}^0 \\ \vdots \\ \sum_i \sum_j \frac{1}{\sigma_j^2} \frac{\partial \Delta S_{ij}}{\partial \alpha_m} \Delta S_{ij}^0 \\ \vdots \end{pmatrix}$$

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

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

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

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

N_d = 6 - number of detectors

N_t = 5 - number of tracks

$\alpha_1, \ldots, \alpha_{10}$ - parameters of tracks

$\alpha_{11}, \ldots, \alpha_{14}$ - 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	

Principle of alignment

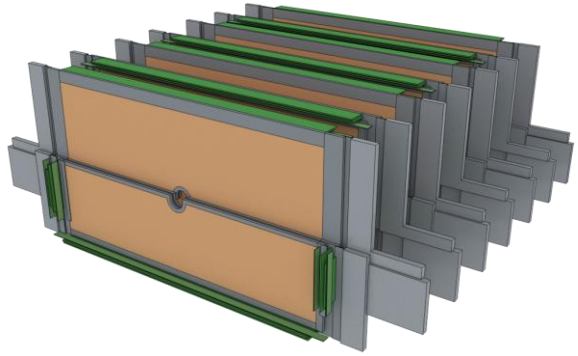
1. **IMSL Fortran Library**
(https://www.imsl.com/products/imsl-fortran-libraries)

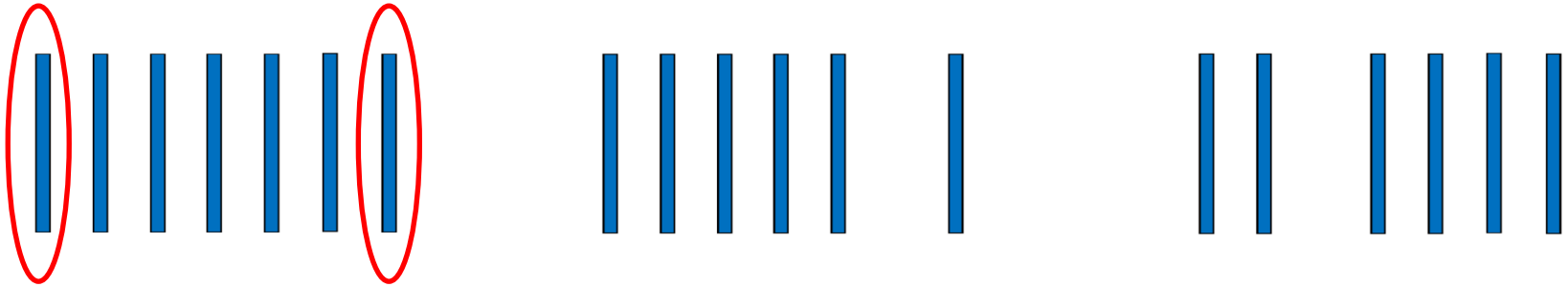
2. Eigen
(https://eigen.tuxfamily.org/index.php?title=Main_Page)

3. Millepede-II
(https://www.desy.de/~kleinwrt/MP2/doc/html/draftman_page.html)

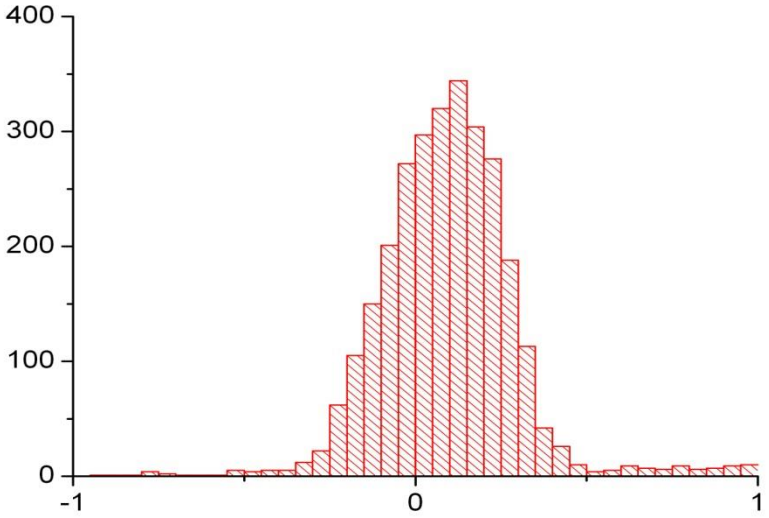
RUN 7651

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

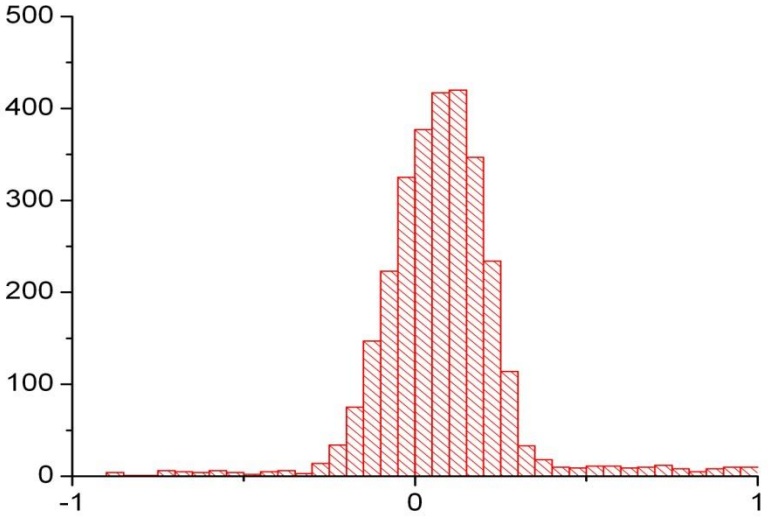




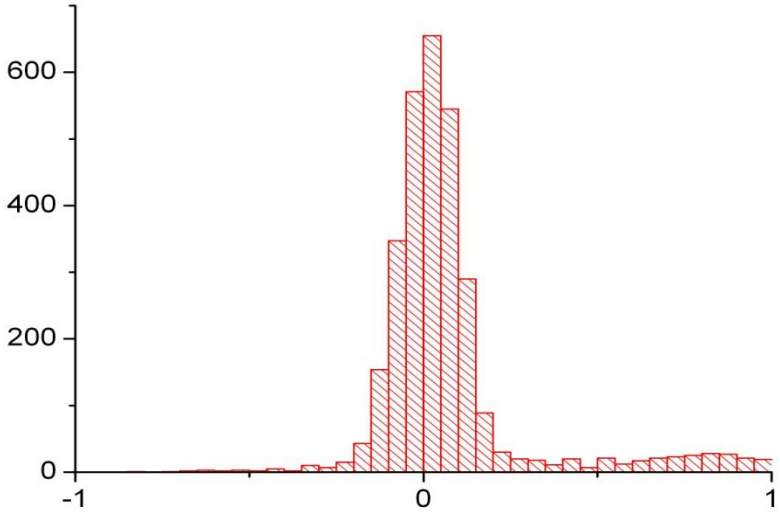
RUN 7651, mod0



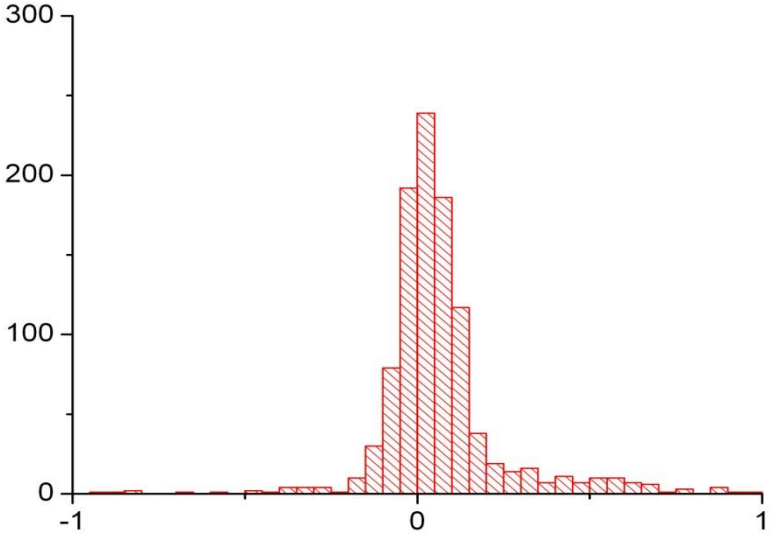
dx1 = 0.39498



dx2 = 0.31642

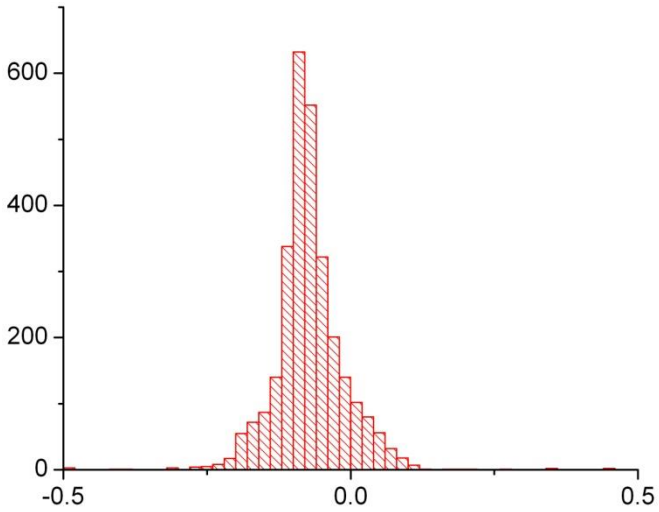


dx3 = 0.17054

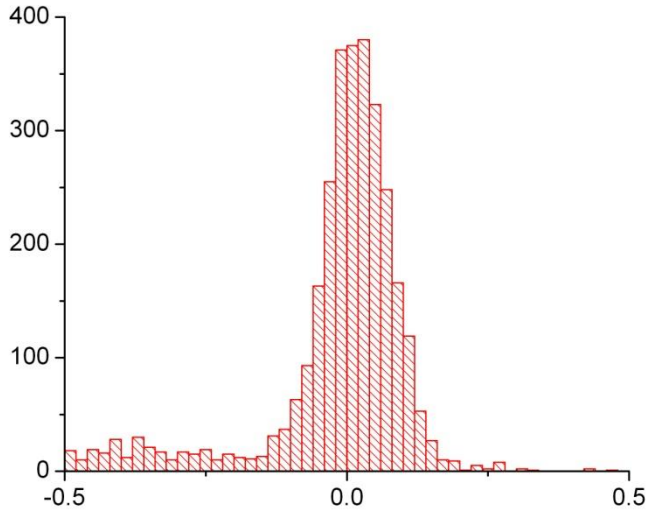


dx4 = 0.07993

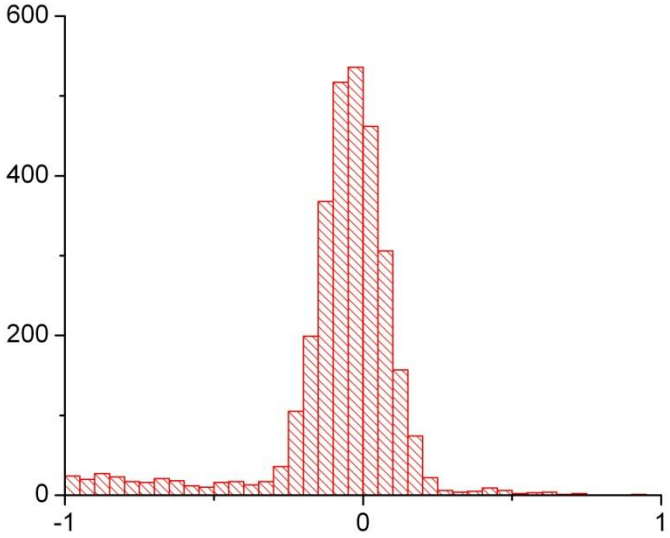
RUN 7651, mod0



dx5 = -0.07408

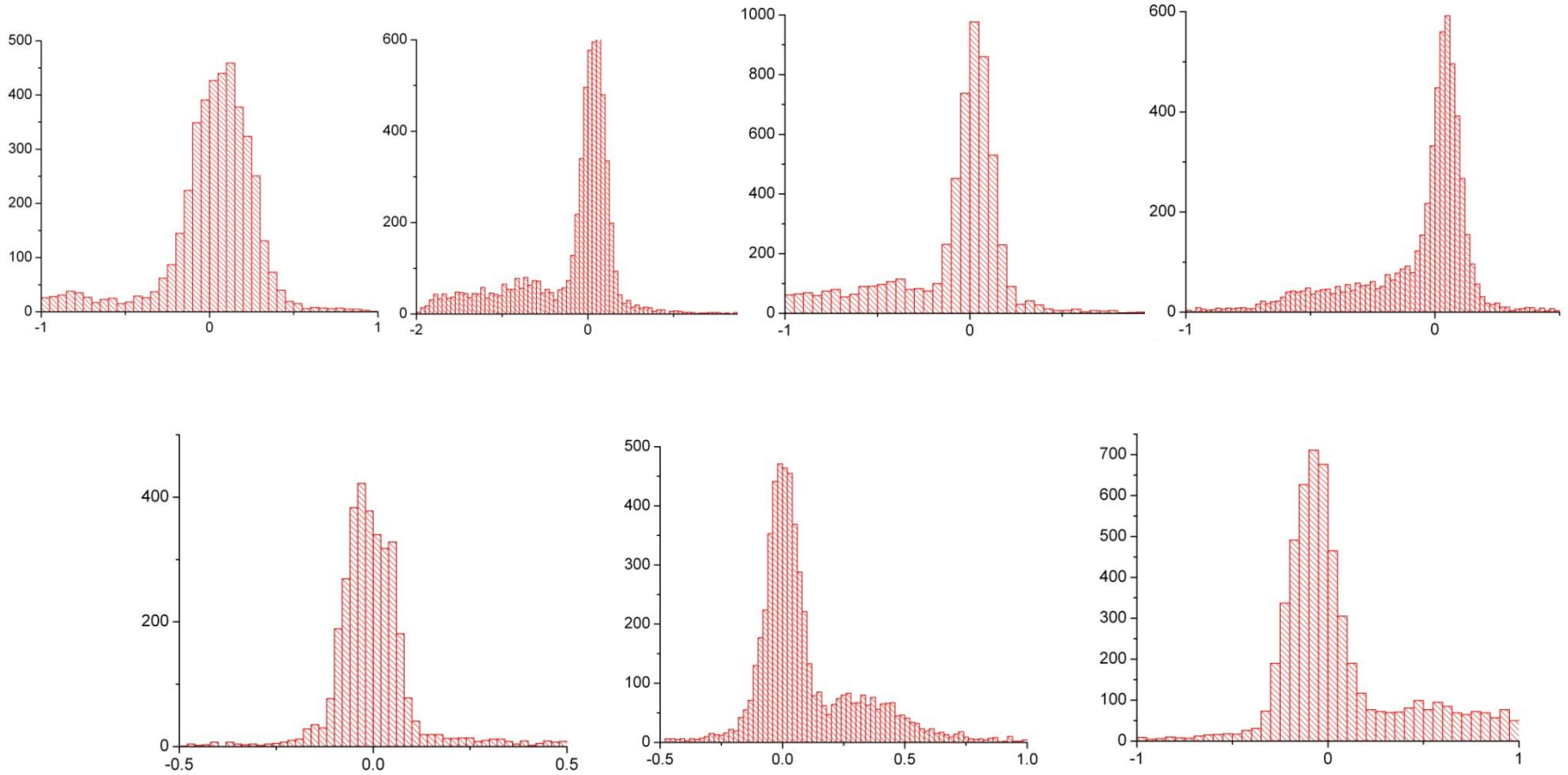


dx6 = -0.06904

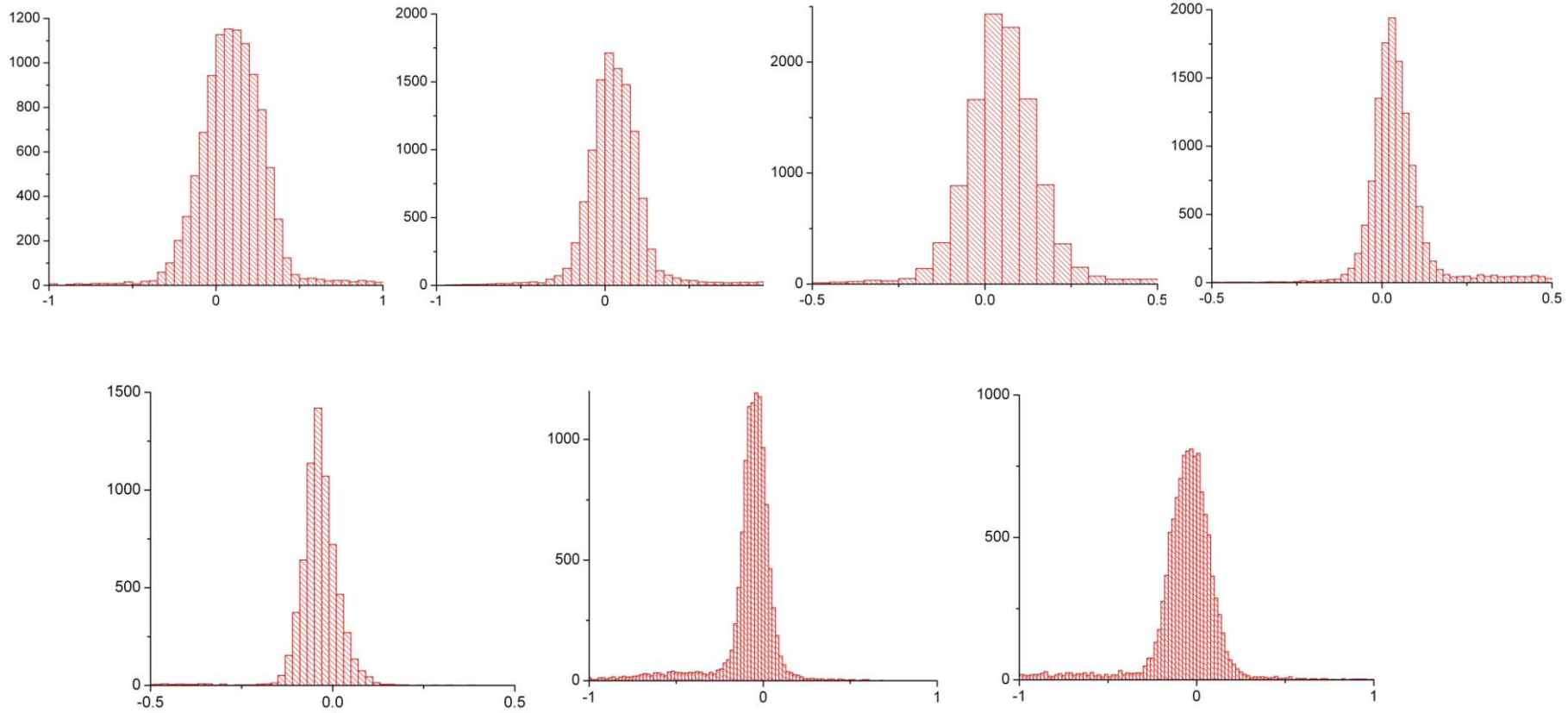


dx7 = -0.20953

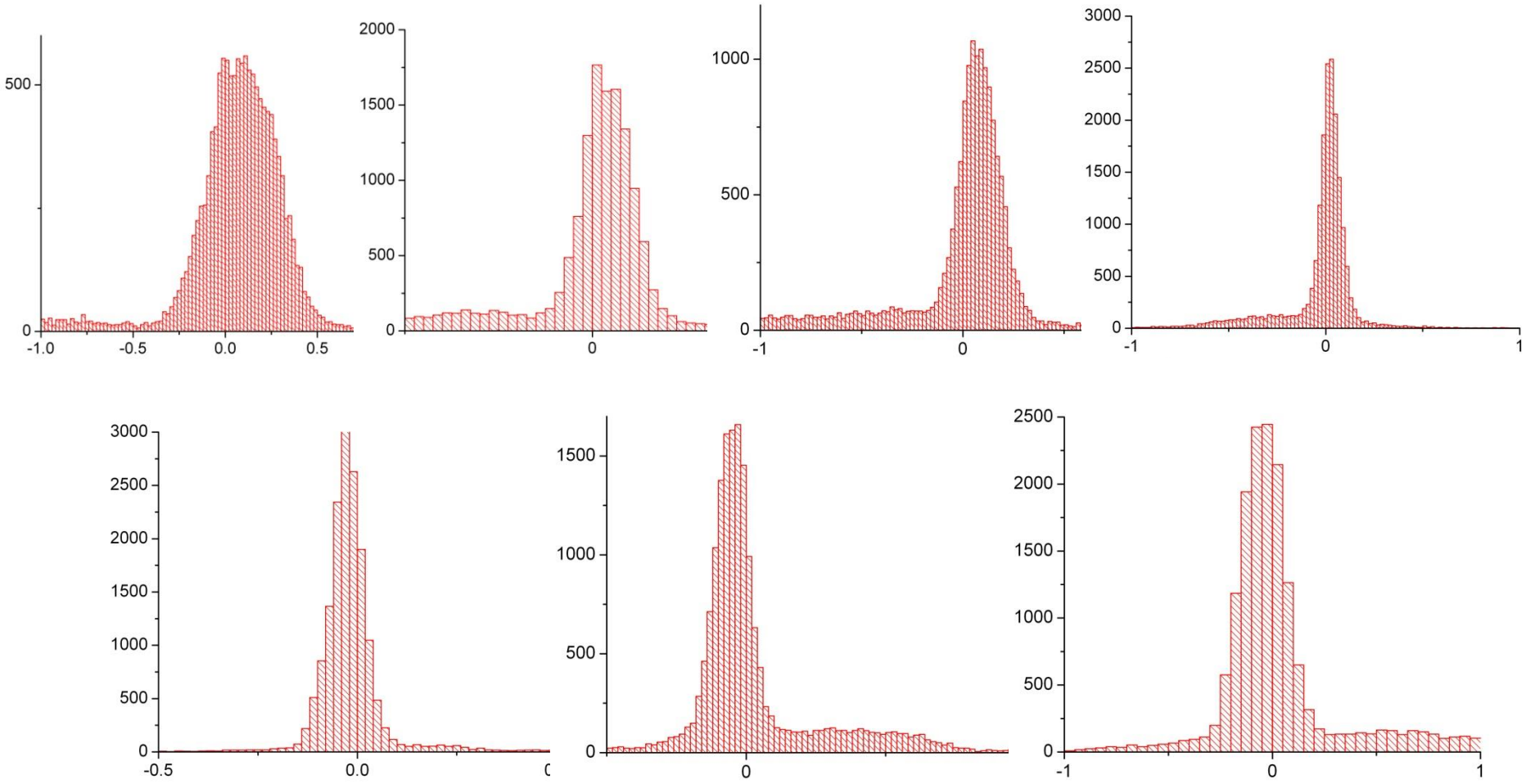
RUN 7651, mod1



RUN 7651, mod2



RUN 7651, mod3



RUN 7651 Summary dx

module 0

Mean	SD	Size
0.39498	0.86762	3309
0.31642	0.6966	3397
0.17054	0.4231	3321
0.07993	0.2303	1041
-0.07408	0.08578	2895
-0.06904	0.2452	3302
-0.20953	0.4855	3395

module 1

Mean	SD	Size
-0.2	0.74695	4811
-0.2395	0.67881	6151
-0.15294	0.44522	6064
-0.05939	0.29955	5823
0.00978	0.18982	3480
0.10455	0.24773	5721
0.15267	0.52695	6085

RUN 7651 Summary dx

module 2

Mean	SD	Size
0.29229	0.74386	11422
0.15765	0.50836	11929
0.12819	0.35597	12263
0.06682	0.15765	12741
-0.04119	0.11277	6782
-0.10345	0.25243	11346
-0.13366	0.40406	12144

module 3

Mean	SD	Size
-0.09989	0.74032	14772
-0.13648	0.62998	15128
-0.0678	0.47053	16791
-0.02658	0.24817	18996
-0.00448	0.21251	16369
0.03872	0.279	17214
0.08864	0.45539	17124