

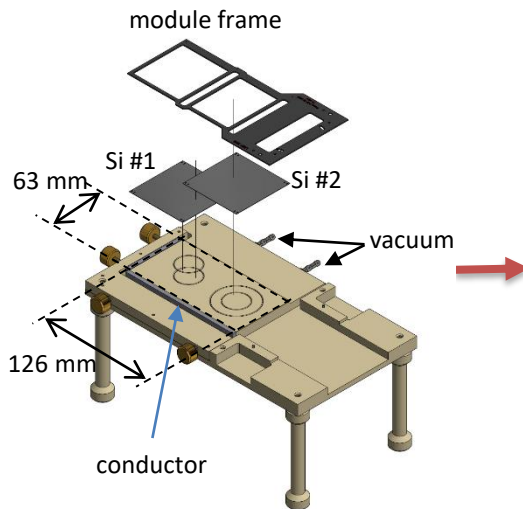


*E.V. Zubarev, [O.G. Tarasov](#) behalf on Forward Silicon Tracker team*

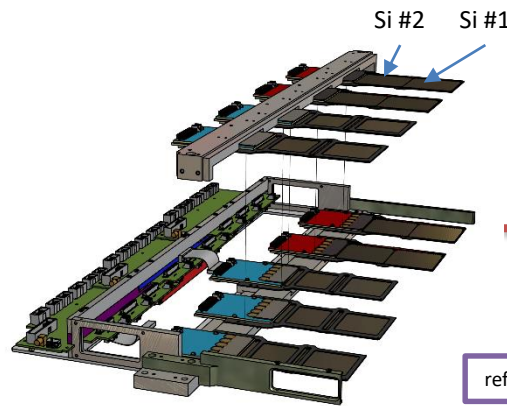
# 10th Collaboration Meeting of the BM@N Experiment at the NICA Facility

## The accuracy of the assembly is based on:

1. On the accuracy of cutting Si-detectors using a diamond disc (through) -  $\pm 20$  microns (measurement results slide # 4);
2. On the accuracy of assembly by the conductor of Si-detectors with a frame -  $\pm 30$   $\mu\text{m}$  (measurement results of the assembled modules, the inaccuracy of clause 1. is included in  $\pm 30$   $\mu\text{m}$ );
3. After assembling the plane, the true position of each Si-detector is measured on a video measuring microscope NVM II-5040D "NORGAU" with an accuracy of  $\pm 20$   $\mu\text{m}$ . Measurements are transmitted in the form of a file (table) to the physical group for analysis and reconstruction of "hits".

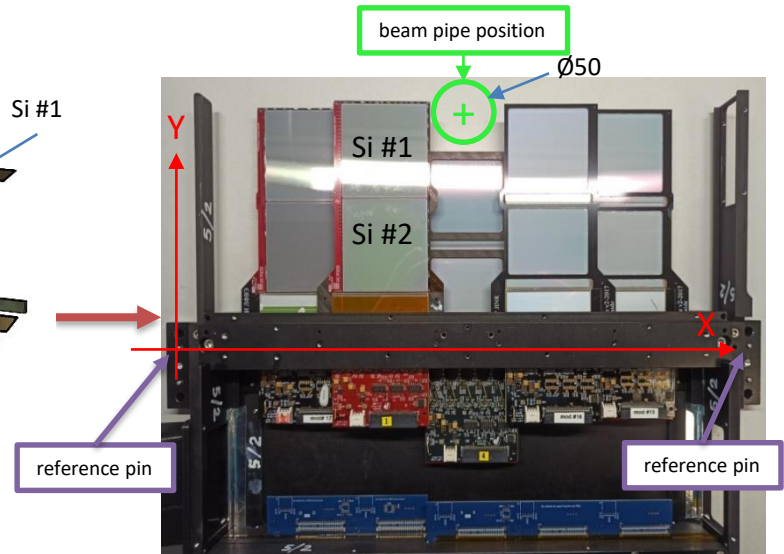


Assembling the module



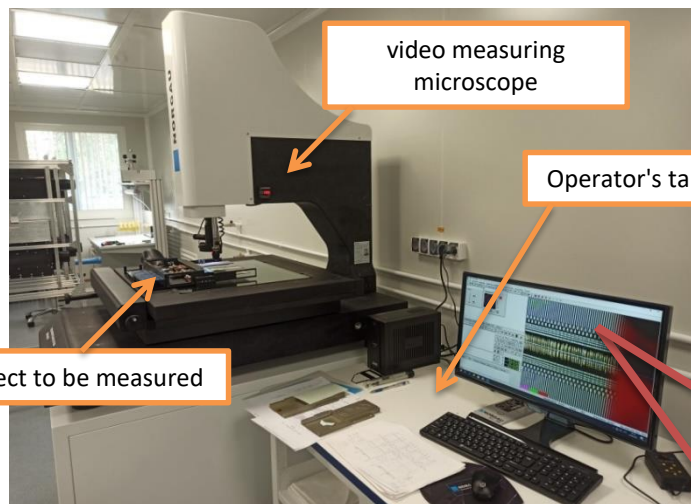
Assembly of half-planes

The modules are installed in two levels with overlap.

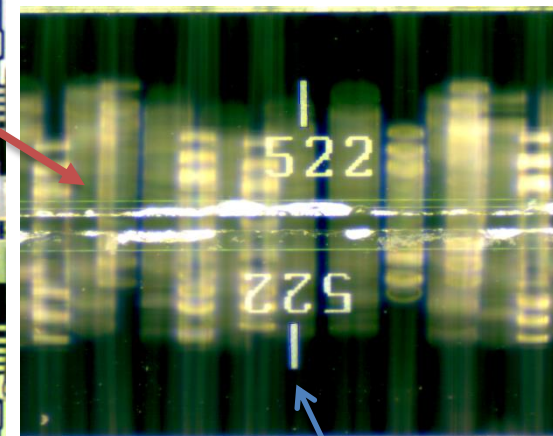
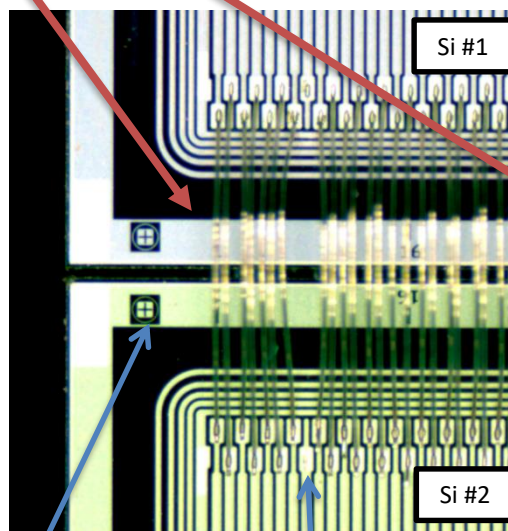
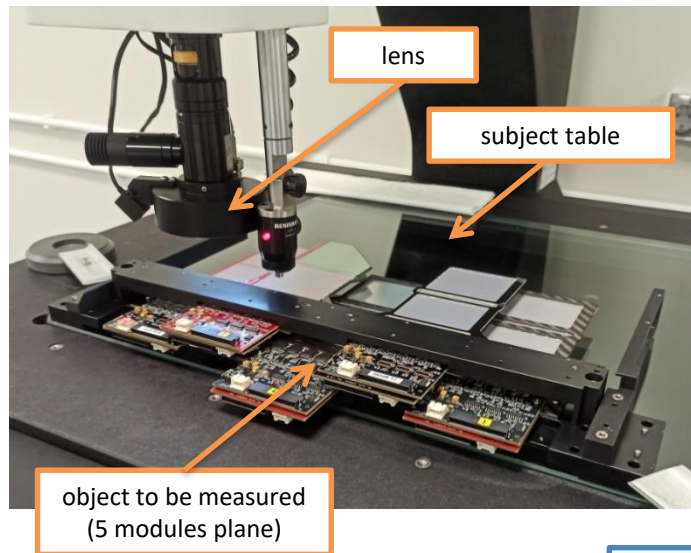


Measurement of the true position of each Si-detector relative to the coordinate system (X,Y,Z) of the outer reference pins of the plane

Measurements of the position of Si-detectors in modules and planes were carried out on a non-contact video measuring microscope "NORGAU" NVM II-5040D.

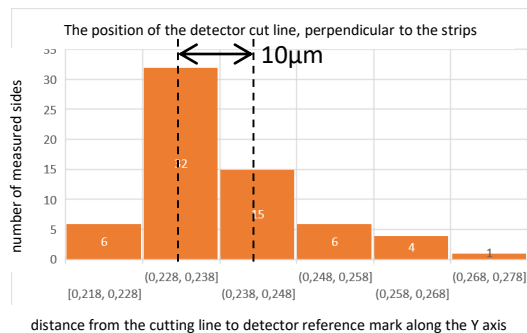
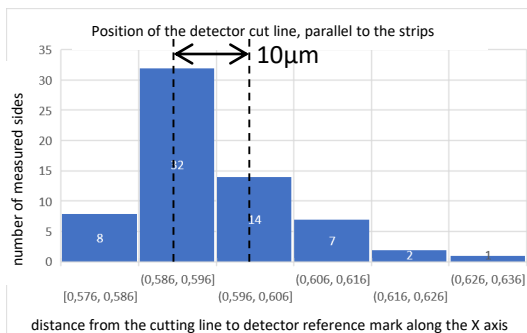
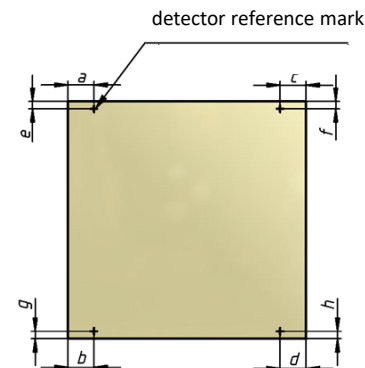


«NORGAU» NVM II-5040D	
X- and Y-axis move range (mm)	500 x 400
Z-axis move range (mm)	250
Permissible absolute error of linear measurements along the X and Y axes ( $\mu\text{m}$ )*	$\pm(2.5+L/200)$
Permissible absolute error of linear measurements along the Z-axis ( $\mu\text{m}$ )*	$\pm(2.5+L/100)$
* L - measured length in mm	

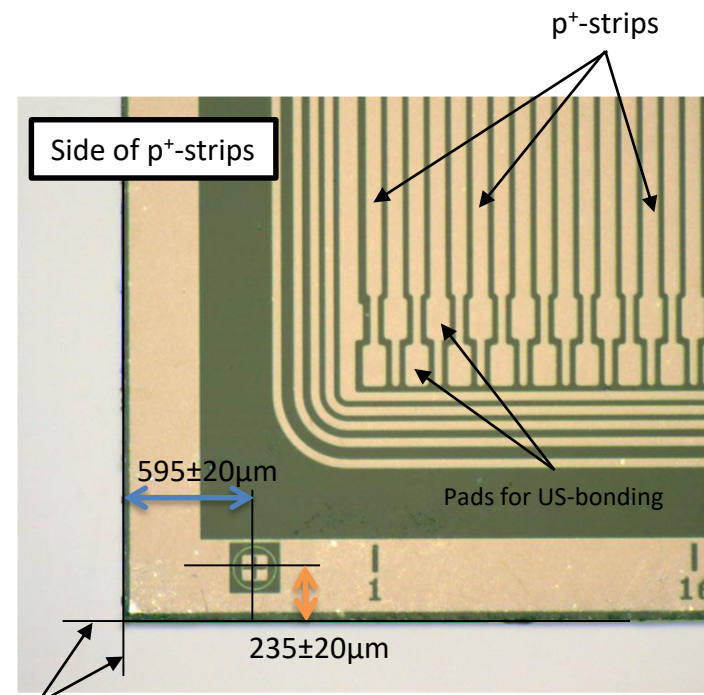


# Measurement of cutting accuracy of Si detectors (mm)

sensor	a	b	c	d	e	f	g	h
#13В	0,588	0,595	0,593	0,591	0,235	0,227	0,232	0,239
#13Н	0,598	0,603	0,587	0,581	0,244	0,247	0,238	0,236
#15/2016В	0,595	0,596	0,592	0,591	0,234	0,236	0,233	0,236
#15/2016Н	0,595	0,594	0,591	0,595	0,233	0,233	0,235	0,232
#15В	0,608	0,599	0,594	0,605	0,233	0,246	0,253	0,240
#15Н	0,603	0,606	0,588	0,587	0,234	0,233	0,251	0,258
#16/2017В	0,600	0,595	0,589	0,591	0,232	0,230	0,234	0,234
#16/2017Н	0,602	0,601	0,581	0,587	0,242	0,244	0,225	0,244
#17/2016В	0,595	0,593	0,595	0,597	0,231	0,232	0,236	0,240
#17/2016Н	0,595	0,597	0,593	0,593	0,234	0,236	0,230	0,230
#43В	0,596	0,595	0,598	0,601	0,246	0,243	0,233	0,239
#43Н	0,607	0,603	0,596	0,592	0,253	0,249	0,236	0,238
#44В	0,587	0,576	0,627	0,615	0,263	0,242	0,227	0,245
#44Н	0,584	0,579	0,612	0,609	0,259	0,256	0,220	0,222
#45В	0,592	0,582	0,614	0,626	0,259	0,269	0,236	0,229
#45Н	0,585	0,576	0,609	0,622	0,246	0,261	0,232	0,218



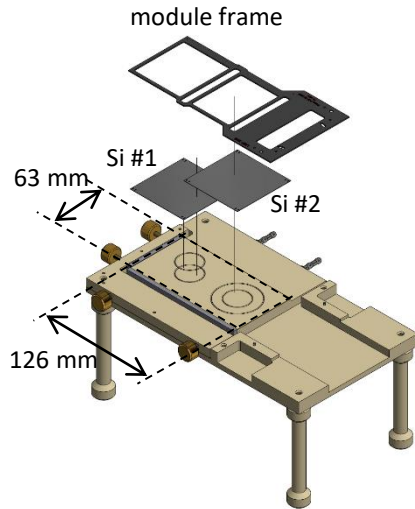
The spread of the position of the edge of the cutting line relative to the reference crosses is  $\pm 20 \mu\text{m}$



cutting line

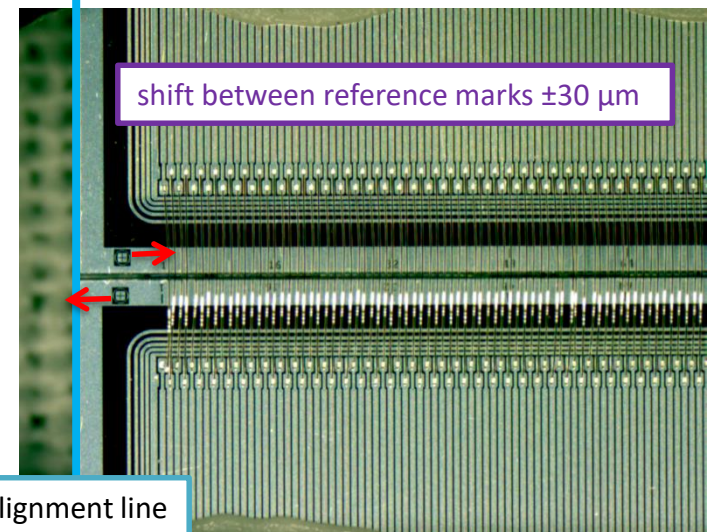
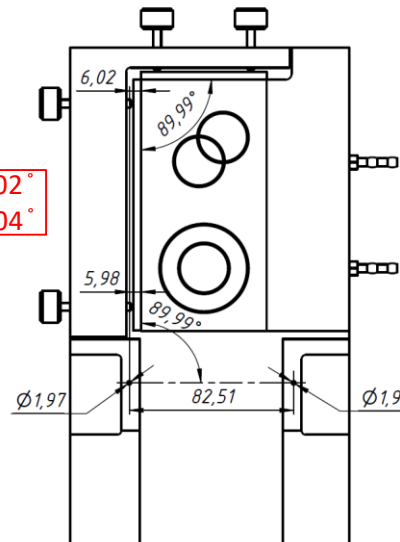
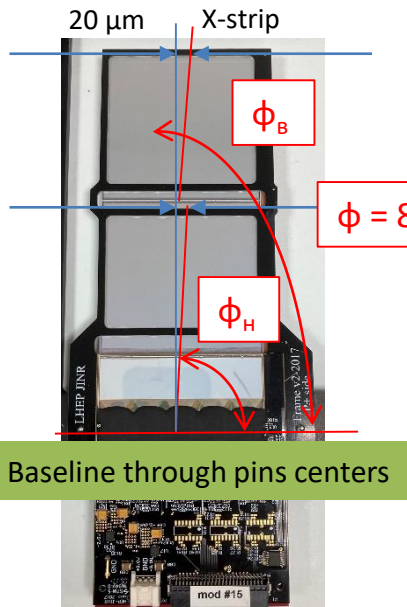
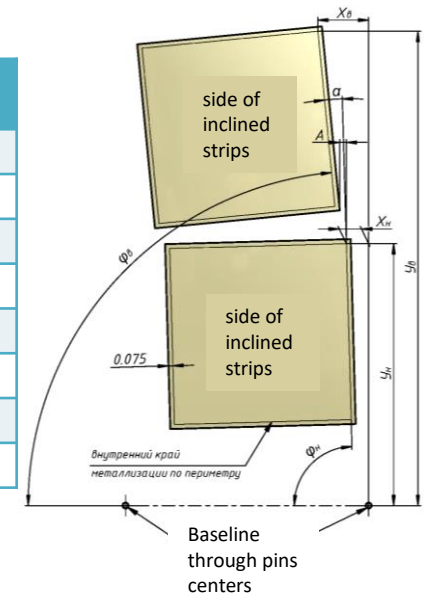


# Measurement of the accuracy of the position of Si-detectors in the modules

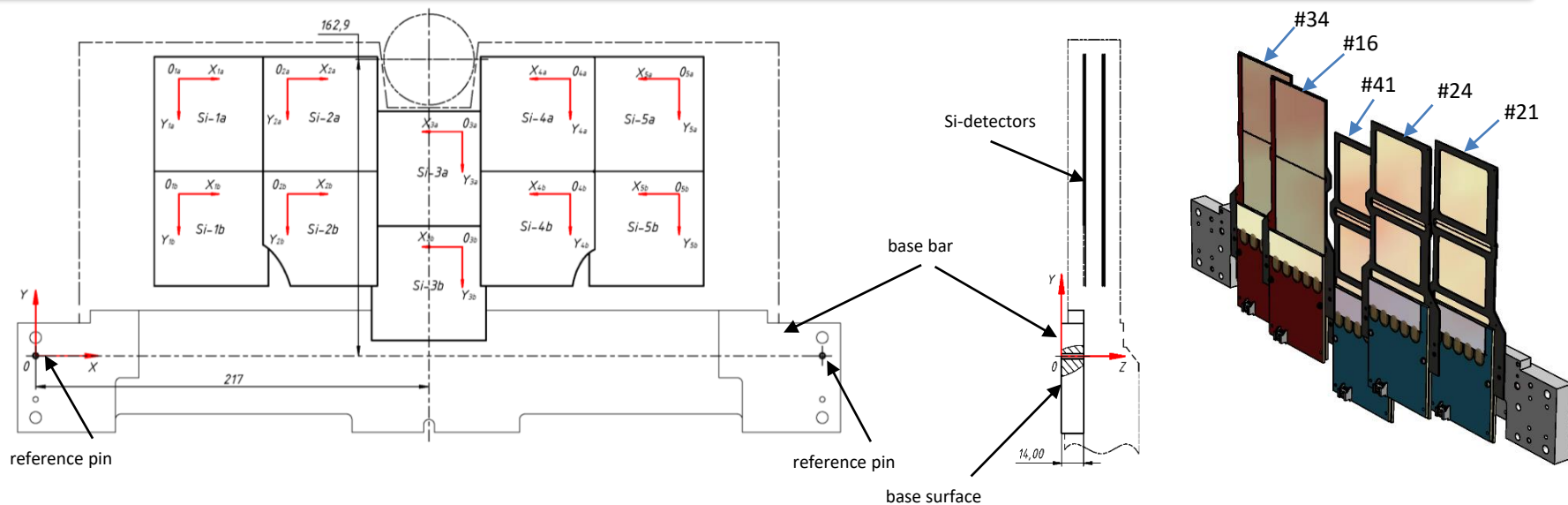


Modul #	X <sub>B</sub> (mm)	Y <sub>B</sub> (mm)	X <sub>H</sub> (mm)	Y <sub>H</sub> (mm)	φ <sub>B</sub> (deg.)	φ <sub>H</sub> (deg.)	A (mm)	α (deg.)
#13	6.084	151.994	6.044	88.974	89.993	89.998	0.031	0.005
#15/2016	6.082	152.029	6.053	89.001	89.969	89.993	-0.006	0.025
#15	6.094	152.003	6.046	88.978	89.974	89.988	0.019	0.014
#16/2017	6.079	152.031	6.047	88.987	89.973	89.994	0.002	0.021
#17/2016	6.112	152.032	6.038	88.980	89.960	89.997	0.031	0.037
#43	6.078	152.012	6.064	88.968	89.973	89.972	-0.015	-0.001
#44	6.122	152.026	6.101	88.972	89.936	89.954	-0.028	0.018
#45	6.128	152.002	6.074	88.936	89.967	90.000	0.017	0.033

The accuracy of the assembly is  $\pm 30$  microns according to the measurement results.



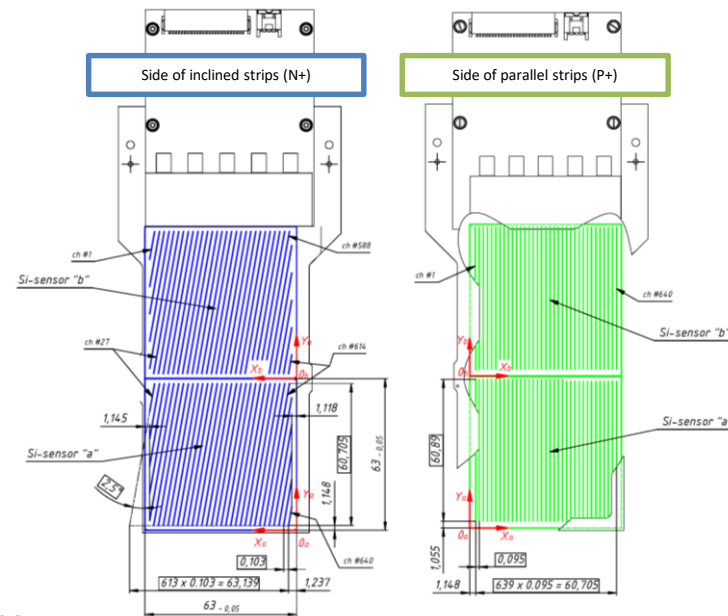
The true position of Si-detectors in the half-plane (5 modules).  
(The measurement data is transmitted to the physical group).



Position of Si-detectors in the half-plane  
# 5/2 (06.07.22)

detector location	$X \pm 0.02^*$ (mm)	$Y \pm 0.02^*$ (mm)	rotation in the plane OXY (deg.)	$Z \pm 0.2^{**}$ (mm)	Module Serial Number
Si-1a	65.63	164.25	0.03 cw	15.9	#34
Si-1b	65.64	101.26	0.01 ccw	15.7	
Si-2a	125.54	164.23	0.04 ccw	27.5	#16
Si-2b	125.61	101.26	0.01 cw	27.5	
Si-3a	248.69	134.23	0.02 cw	14.5	#41
Si-3b	248.60	71.23	0.03 cw	14.2	
Si-4a	308.50	164.25	0.01 cw	26.1	#24
Si-4b	308.51	101.26	0	26.0	
Si-5a	368.71	164.27	0.07 cw	14.4	#21
Si-5b	368.61	101.27	0.03 cw	14.2	

\*-position of the origin point of the Si-detectors in the coordinate plane OXY (tied to the outer reference pins).  
\*\*-the distance from the base surface of the base bar to the middle of the Si-detector surface farthest from it.

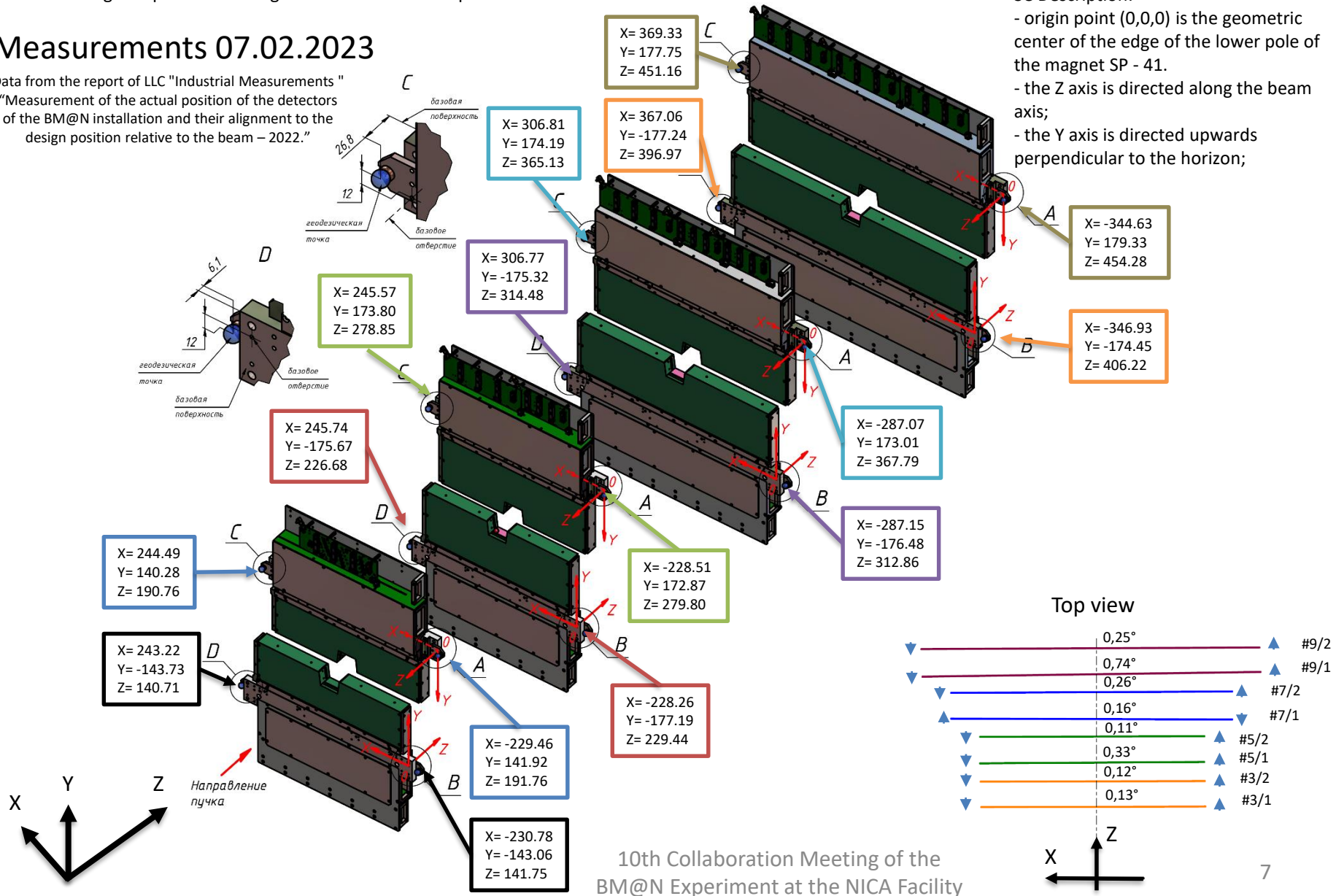


# Results of measurements of the location of half-planes in the BM@N-2022 (physical session - run Xe).

❖ Linking half-plane bases to geodetic measurement points

## Measurements 07.02.2023

Data from the report of LLC "Industrial Measurements"  
"Measurement of the actual position of the detectors  
of the BM@N installation and their alignment to the  
design position relative to the beam – 2022."

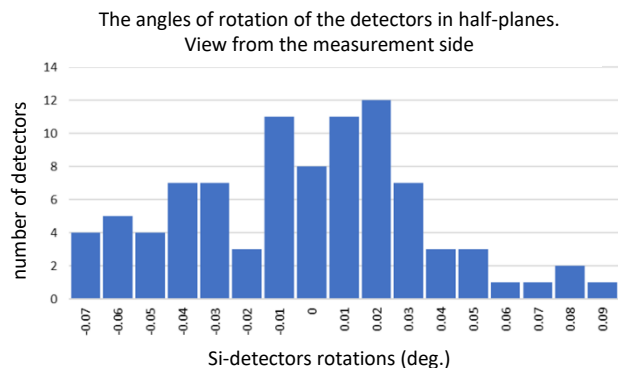


# True positions of Si-detectors on all planes by session BM@N-2022 (physical session -run Xe). The data is transferred to the physical group.

Положение Si-сенсоров в полуплоскости # 3/1 (12.07.22)						Положение Si-сенсоров в полуплоскости # 3/2 (12.07.22)					
Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля	Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля
Si-1	125.48	130.98	0.04 пр. час.	27.9	#3-0/22	Si-1	125.56	130.86	0.02 пр. час.	27.0	#5-0/22
Si-2	248.54	101.10	0.03 пр. час.	14.0	#2-0/22	Si-2	248.52	101.13	0.04 пр. час.	14.5	#6-0/22
Si-3	308.48	131.00	0	26.1	#1-0/22	Si-3	308.50	131.12	0.01 по час.	26.0	#4-0/22

Положение Si-сенсоров в полуплоскости # 5/1 (11.07.22)						Положение Si-сенсоров в полуплоскости # 5/2 (06.07.22)					
Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля	Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля
Si-1a	65.51	164.29	0.04 пр. час.	14.9	#35	Si-1a	65.63	164.25	0.03 по час.	15.9	#34
Si-1b	65.66	101.19	0.06 пр. час.	15.3		Si-1b	65.64	101.26	0.01 пр. час.	15.7	
Si-2a	125.53	164.25	0.01 по час.	27.2	#38	Si-2a	125.54	164.23	0.04 пр. час.	27.5	#16
Si-2b	125.57	101.18	0.01 пр. час.	27.4		Si-2b	125.61	101.26	0.01 по час.	27.5	
Si-3a	248.43	134.28	0.04 по час.	14.6	#42	Si-3a	248.69	134.23	0.02 по час.	14.5	#41
Si-3b	248.47	71.27	0.01 по час.	14.3		Si-3b	248.60	71.23	0.03 по час.	14.2	
Si-4a	308.52	164.23	0.03 по час.	25.9	#27	Si-4a	308.50	164.25	0.01 по час.	26.1	#24
Si-4b	308.49	101.24	0.01 по час.	26.0		Si-4b	308.51	101.26	0	26.0	
Si-5a	368.43	164.32	0.01 пр. час.	14.3	#32	Si-5a	368.71	164.27	0.07 по час.	14.4	#21
Si-5b	368.42	101.32	0.07 пр. час.	14.2		Si-5b	368.61	101.27	0.03 по час.	14.2	

\*-положение точки начала координат Si-сенсора в координатной плоскости ОХУ (привязана к наружным базовым отверстиям).  
 \*\*-взгляд на лист.  
 \*\*\*-расстояние от базовой поверхности базовой рейки до середины дальней от неё поверхности Si-сенсора.



Положение Si-сенсоров в полуплоскости # 7/1 (17.03.22)						Положение Si-сенсоров в полуплоскости # 7/2 (17.03.22)					
Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля	Позиция сенсора	X $\pm$ 0.02* (мм)	Y $\pm$ 0.02* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля
Si-1a	65.59	164.17	0.05 пр. час.	27.7	#14	Si-1a	65.53	164.30	0	26.9	#7
Si-1b	65.48	101.15	0.05 пр. час.	27.6		Si-1b	65.53	101.32	0.02 по час.	27.2	
Si-2a	125.53	164.26	0.06 пр. час.	15.8	#36	Si-2a	125.36	164.20	0.07 пр. час.	15.7	#22
Si-2b	125.57	101.28	0.05 пр. час.	15.6		Si-2b	125.43	101.20	0.03 пр. час.	15.5	
Si-3a	185.55	164.18	0.07 пр. час.	27.6	#9	Si-3a	185.55	164.31	0.01 пр. час.	27.3	#2-21
Si-3b	185.57	101.18	0.06 пр. час.	27.5		Si-3b	185.56	101.29	0.01 по час.	27.4	
Si-4a	308.56	134.28	0.03 по час.	13.9	#33	Si-4a	308.44	134.11	0.02 по час.	14.4	#6-21
Si-4b	308.47	71.31	0.03 пр. час.	13.9		Si-4b	308.41	71.12	0	14.1	
Si-5a	368.61	164.27	0.02 по час.	25.4	#30	Si-5a	368.50	164.27	0.03 по час.	27.1	#4-21
Si-5b	368.53	101.27	0	25.9		Si-5b	368.47	101.27	0.02 по час.	26.2	
Si-6a	428.63	164.26	0.02 по час.	14.2	#15	Si-6a	428.30	164.27	0.03 пр. час.	14.0	#31
Si-6b	428.55	101.27	0.01 по час.	14.0		Si-6b	428.33	101.29	0.04 пр. час.	13.9	
Si-7a	488.77	164.20	0.08 по час.	25.6	#29	Si-7a	488.47	164.24	0.01 по час.	26.0	#1-20
Si-7b	488.63	101.21	0.08 по час.	26.0		Si-7b	488.46	101.22	0.04 по час.	25.9	

Положение Si-сенсоров в полуплоскости # 9/1 (31.03.22)						Положение Si-сенсоров в полуплоскости # 9/1 (31.03.22)					
Позиция сенсора	X $\pm$ 0.03* (мм)	Y $\pm$ 0.05* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля	Позиция сенсора	X $\pm$ 0.03* (мм)	Y $\pm$ 0.05* (мм)	Разворот в плоскости ОХУ (град.)**	Z $\pm$ 0.2*** (мм)	Серийный номер модуля
Si-1a	65.56	164.26	0.03 пр. час.	15.4	#12	Si-1a	65.61	164.27	0.01 пр. час.	15.8	#39
Si-1b	65.50	101.26	0.05 пр. час.	15.5		Si-1b	65.61	101.24	0	15.7	
Si-2a	125.57	164.19	0.04 пр. час.	26.7	#5-21	Si-2a	125.49	164.25	0.02 пр. час.	27.6	#8
Si-2b	125.52	101.27	0.03 пр. час.	27.3		Si-2b	125.54	101.22	0.01 по час.	27.6	
Si-3a	185.64	164.34	0	15.8	#25	Si-3a	185.46	164.18	0.06 пр. час.	15.9	#28
Si-3b	185.54	101.35	0.01 по час.	15.7		Si-3b	185.52	101.17	0.04 пр. час.	15.7	
Si-4a	245.49	164.30	0.07 пр. час.	27.4	#18	Si-4a	245.55	164.26	0.03 пр. час.	27.5	#20
Si-4b	245.47	101.32	0.06 пр. час.	27.5		Si-4b	245.58	101.25	0.02 пр. час.	27.6	
Si-5a	368.53	134.35	0.02 по час.	14.7	#31	Si-5a	368.53	134.17	0.02 по час.	14.3	#10
Si-5b	368.45	71.37	0.01 пр. час.	14.4		Si-5b	368.49	71.15	0.01 пр. час.	14.1	
Si-6a	428.51	164.30	0	25.9	#40	Si-6a	428.51	164.20	0.02 по час.	26.1	#19
Si-6b	428.45	101.30	0.01 пр. час.	26.1		Si-6b	428.47	101.20	0.01 пр. час.	26.0	
Si-7a	488.70	164.33	0.03 по час.	14.5	#23	Si-7a	488.67	164.13	0.09 по час.	14.9	#3-21
Si-7b	488.56	101.33	0.05 по час.	14.4		Si-7b	488.57	101.13	0.06 по час.	14.3	
Si-8a	548.54	164.33	0.01 пр. час.	25.6	#26	Si-8a	548.57	164.14	0.02 по час.	26.1	#13
Si-8b	548.46	101.34	0.01 пр. час.	25.9		Si-8b	548.52	101.12	0.02 по час.	26.1	
Si-9a	608.68	164.30	0.05 по час.	14.6	#11	Si-9a	608.67	164.14	0.05 по час.	14.1	#17
Si-9b	608.55	101.28	0.02 по час.	14.4		Si-9b	608.57	101.14	0.04 по час.	14.0	



## Conclusions:

- The correct method of assembling Si-detectors into a module based on the positioning of Si-detectors by the cutting line on the conductor has been chosen;
- Measuring the position of each Si-detector after assembling the planes compensates for inaccuracies in intermediate assembly operations;
- In preparation for the next session of the BM@N experiment, the installation of planes should be carried out under the supervision of surveyors;
- By the next session of the BM@N experiment, make changes to the design of the planes to install additional geodetic marks

Спасибо за внимание!