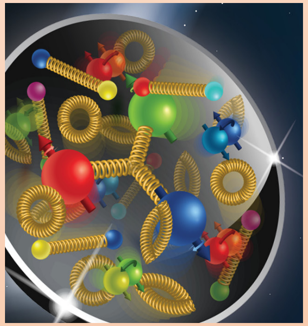
MiniSPD stand for testing Si-detectors

N. Barlykov, V. Burtsev, V. Dudin, T. Enik, A. Ivanov,
[*]E. Kokoulina, A. Kutov, E. Martovitski, V. Nikitin,
V. Popov et al.

On behalf of the SPD Collaboration

JINR, Russia, [*]P.O. Sukhoy GSTU, Belarus



XXXIX International Seminar NPCS
21-24.06.2022, Minsk, Belarus

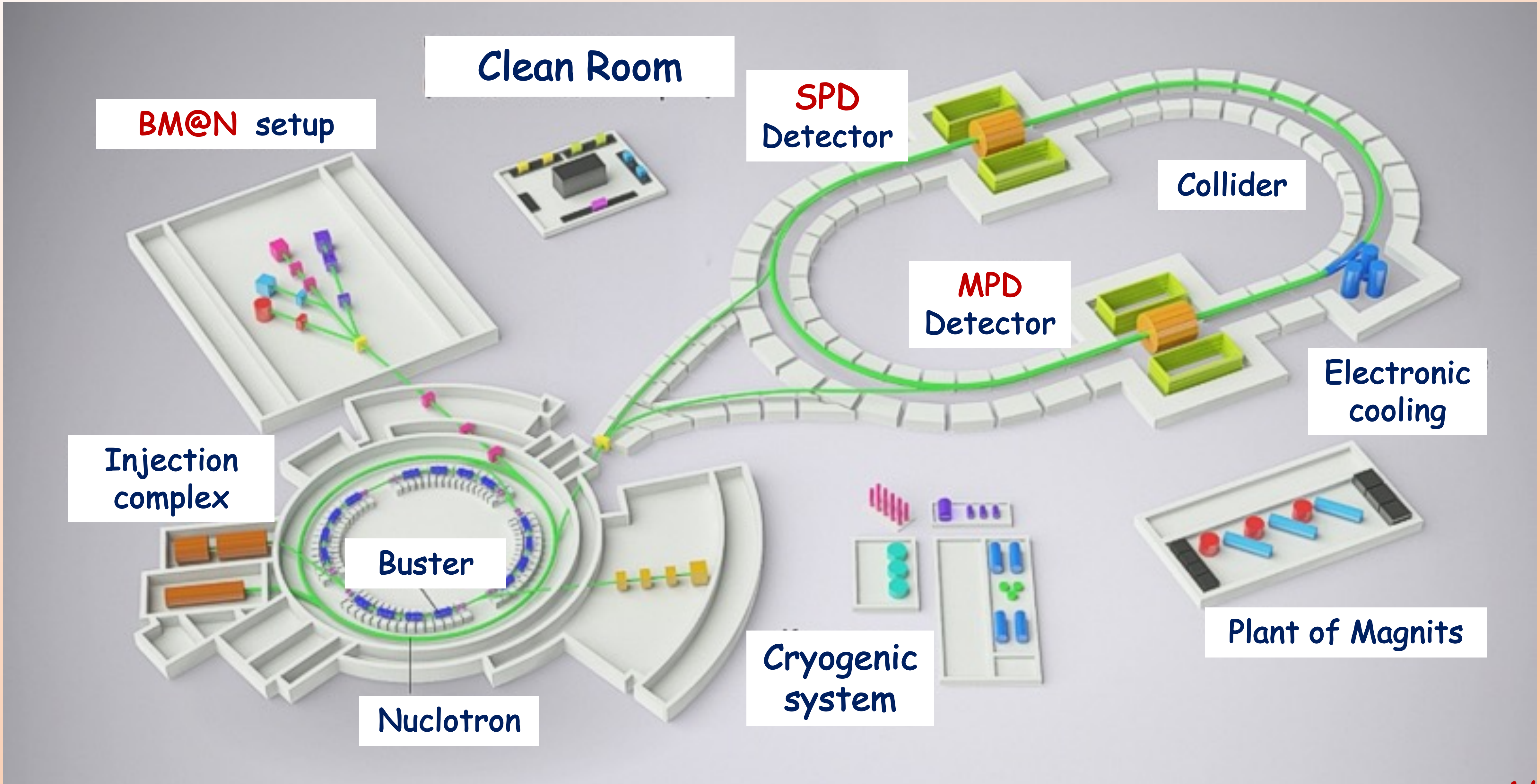
NICA (Nuclotron based Ion Collider fAcility)

Start of construction: 2013.

This accelerator complex is being created at the JINR, LHEP (Dubna, RF). Its main aims are studying:

1) the properties of dense baryonic matter, a special state of matter in the first moments after the Big Bang, formation of quark-gluon plasma (MPD);
2) gluon structure of proton (deuteron) (SPD).

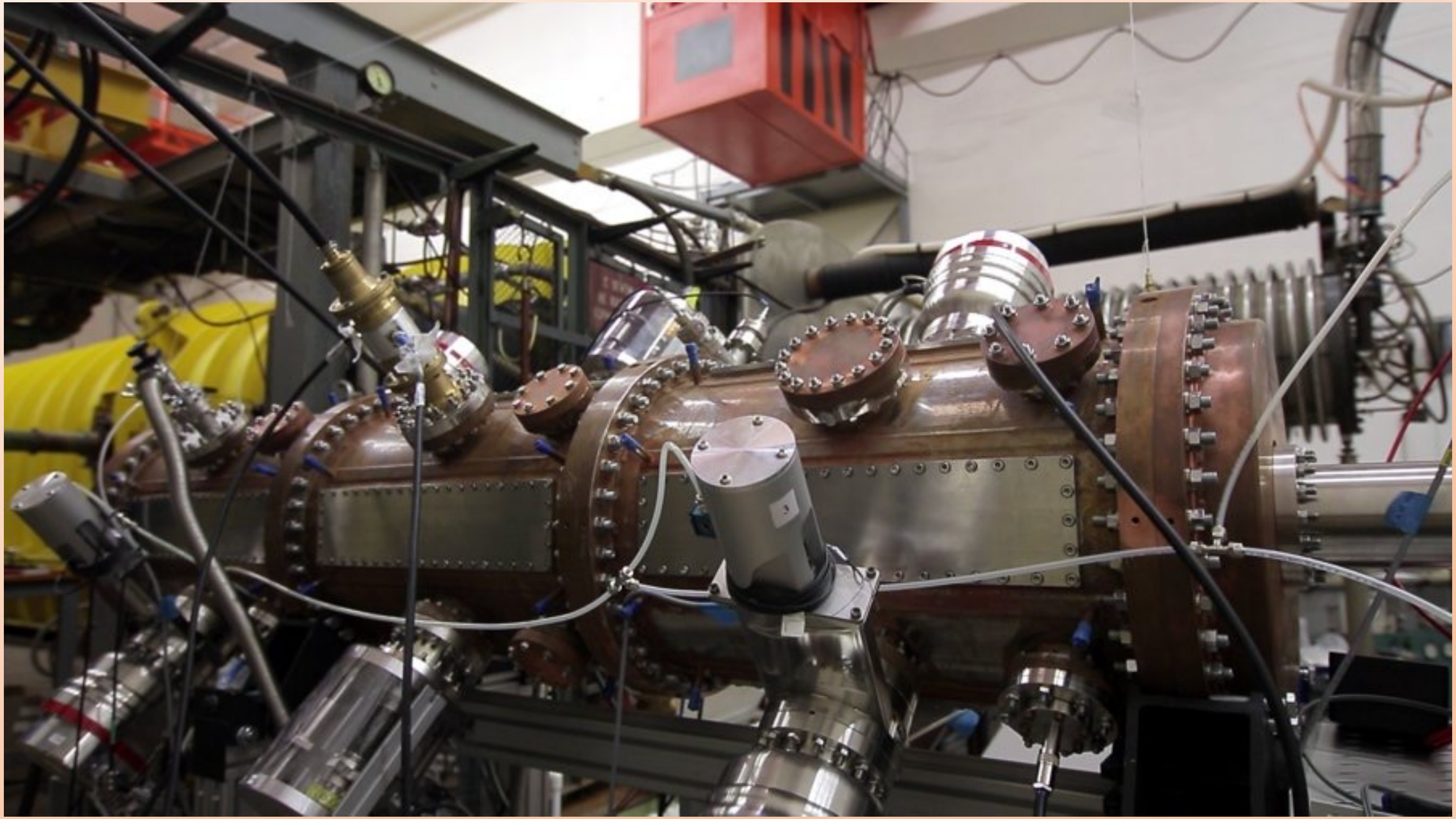
NICA areial view, April 2022



Clean Room
BM@N setup
SPD Detector
Collider
MPD Detector
Electronic cooling
Injection complex
Buster
Nuclotron
Cryogenic system
Plant of Magnits

NICA scheme

Light Ion Linear Accelerator (LU-20)



Nuclotron – superconducting heavy ion accelerator

First magnet in collider's tunnel

On 28 December last year, the first superconducting magnet was installed in the tunnel of the NICA accelerator complex. Moreover, a testing system of the MPD solenoid was launched. The magnet factory produces superconducting magnets not only for the NICA project but also for the German project FAIR. The next purchasers of Dubna magnets will be China and CERN.

The main tasks of SPD project

Spin is one of the fundamental properties of elementary particles. It cannot be explain by a static view of the proton:

total spin = s(q) + s(g) + angular momentum = 1/2.

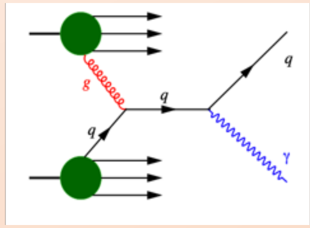
It's not just the number 1/2. It is the result of interaction between quarks and gluons, more probably gluons.

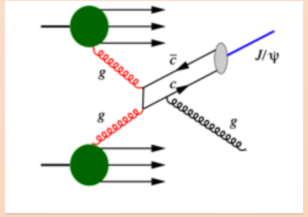
The origin of matter is a fundamental question of physics. Our SPD (Spin Physics Detector) project is aimed at study spin properties of nucleons and light nuclei.

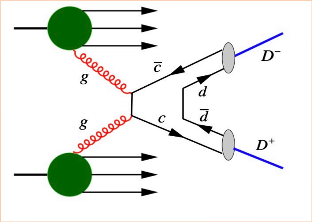
How are quarks and gluons, their spins distributed in space and on momentum inside the nucleon?

2102.00442[hep-ex]Conceptual design of the Spin Physics Detector (A. Guskov)

The main tasks of SPD project

- Direct photons  [SPD Collab. Phys.Part.Nucl. 52 (2021) 6]

- Nucleon PDFs by J/ψ production 

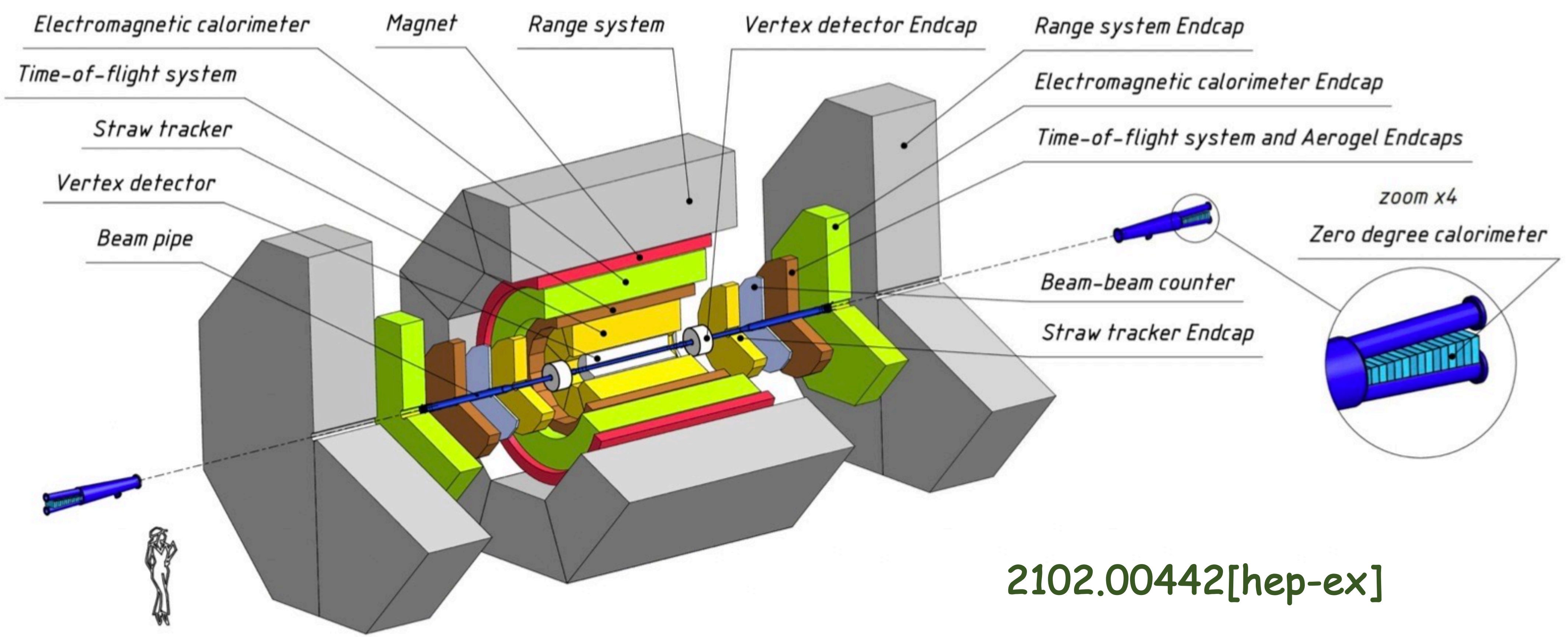
- Open charm production: D^0, $\bar{D}^0$, $D^{+/-}$, Λ_c, ... 

- Spin-dependent effects in elastic pp, pd and dd scattering
- Spin effects in exclusive hadron production
- Spin effects in production of hadrons with high p_T

pp, dd, pd polarized beams with energy $\sqrt{s_{NN}}$ = 3.4 – 10 GeV

luminosity pp (dd) is estimated up to 10^{32} (10^{31}) cm-2s-1

General layout of SPD setup

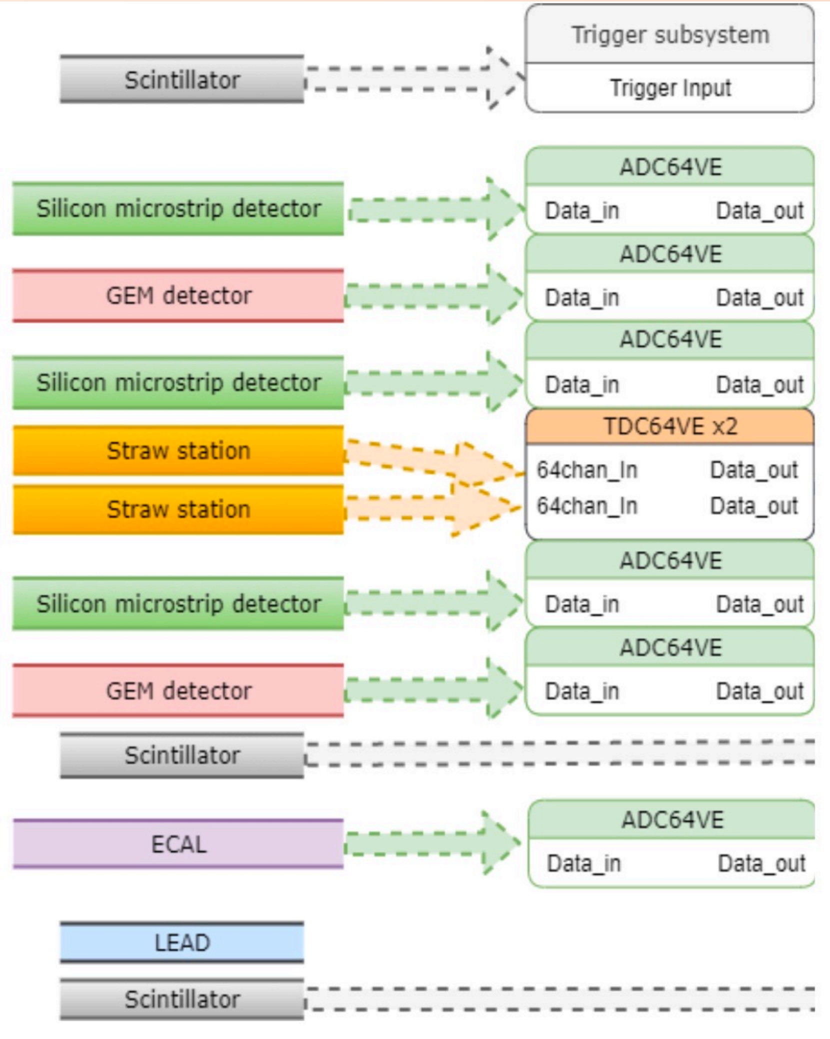


2102.00442[hep-ex]

Why do we need MiniSPD?

- ✓ MiniSPD is a setup for testing SPD detector prototypes with cosmic muons
- ✓ MiniSPD is used to test the Data Acquisition System (DAQ) of SPD
- ✓ MiniSPD is used to test the Detector Control System (DCS) of SPD
- ✓ MiniSPD is used to teach students how to work with real detectors

MiniSPD stand for testing SPD's elements



Top scintillator

Si

Si

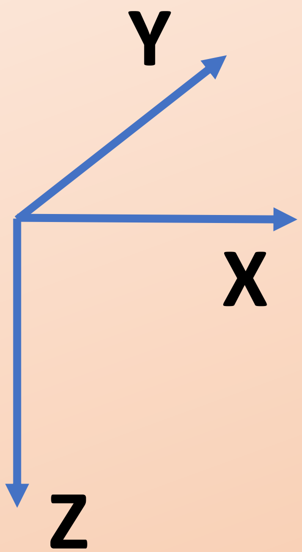
Si

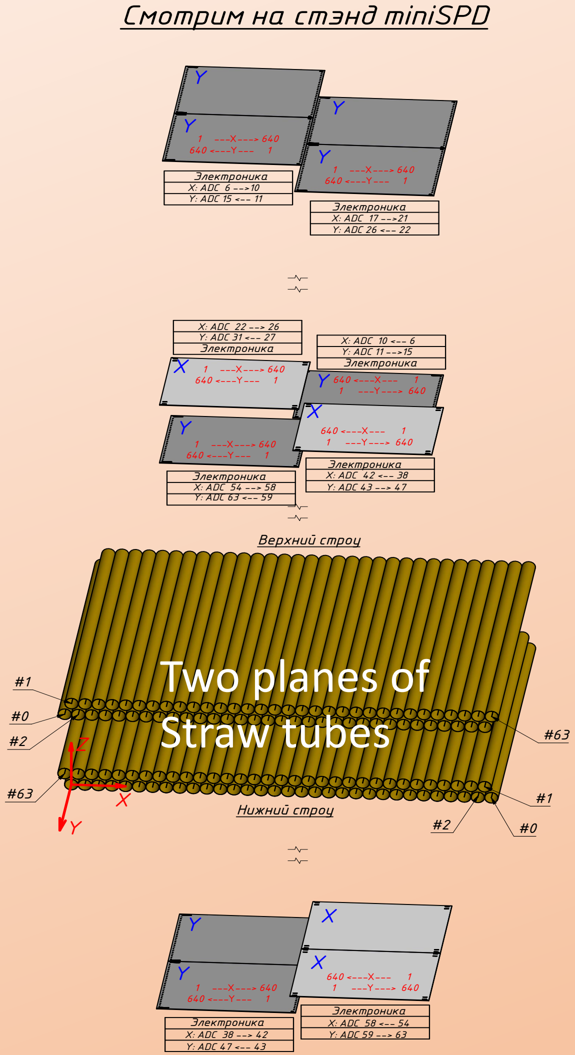
Trigger subsystem consists of 2 scintillators. Top: ScintPos[1] = 3 mm. Bottom: ScintPos[2] = 931,5 mm.

Bottom scintillator

Layout of silicon plates at MiniSPD stand

Our coordinate system



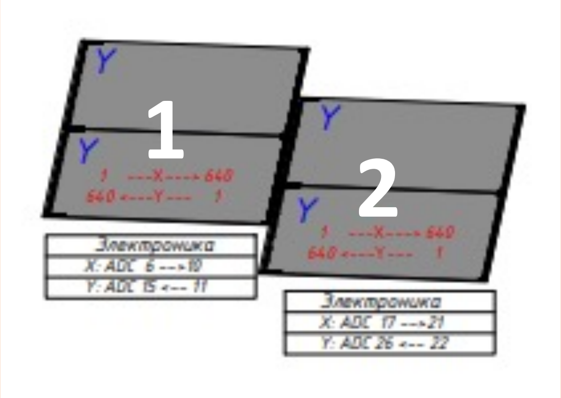


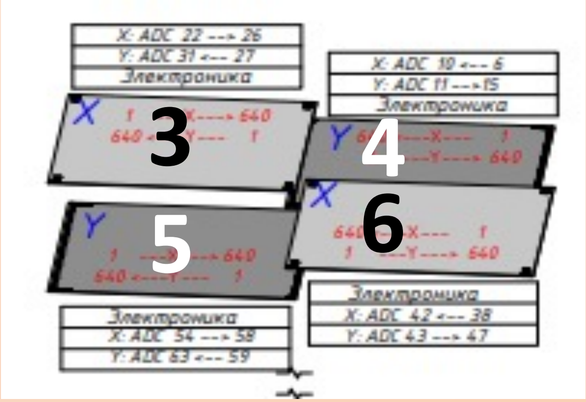
Modules of two-sided Si-plates: dark color indicates oblique (U, 2.5°) strips, light - vertical (X) strips

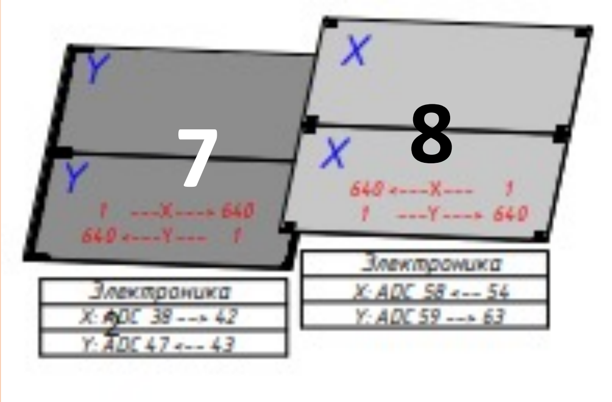
I. The top (I) module consists of two parts: left (1) and right (2) plates
II. The middle (II) module consists of 4 parts. We numerate them 3, 4, 5 and 6 parts from left to right.
III. The bottom (III) module is similar to I with numeration of left and right: 7 and 8.

Description of Si-modules

Coordinates (top/bottom):







1 - U/X, 2 – U/X

3 – X/U, 4 – Y/U
5 – U/X, 6 – X/U

7 - U/X, 8 – X/U

Numeration of strips
left -> right: X1, X2, X4, X5, X7, U1, U2, U3, U4, U5, U7;
right -> left: X3, X6, X8, U6, U8.

Thickness – 0.3 mm
Number of strips – 640
Pitch – 0,095 mm

Simulation of triggered strips

Adding of StripStepping.cc to SteppingAction.cc

We use GEANT4 for simulation. In StripStepping for every module and its parts:

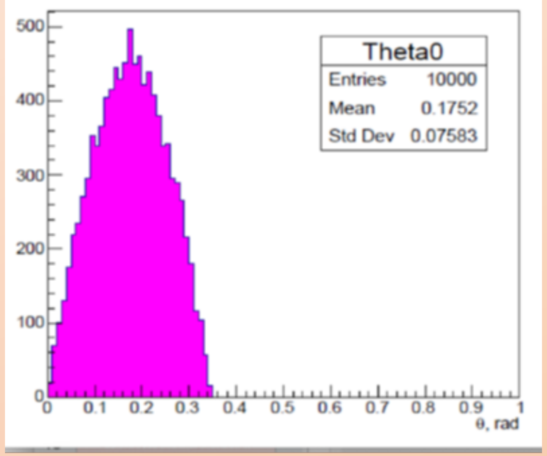
1. Connect the triggered strip number with X-coordinate, define U-coordinate for the same plane, the strip number on U-plate and its E_dep (energy deposition).
2. Sorting of the triggered strip number in increasing order for elimination of repeating numbers (for X & U).
3. Border accounting.

Positioning of Si-plates

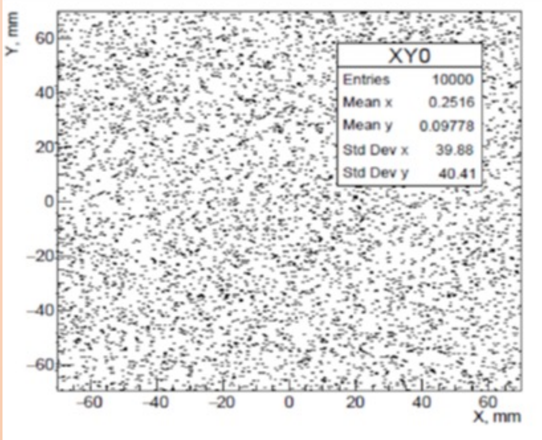
Plane	X, mm	Y, mm	Z, mm	Size, mm
X1, U1	-28,55	0	35,0	63 x 126
X2, U2	31,55	0	50,3	63 x 126
X3, U3	-32,55	-27,55	387,8	63 x 63
X4, U4	27,55	-32.55	395,1	63 x 63
X5, U5	-27,55	32,55	395,1	63 x 63
X6, U6	32,55	27,55	387,8	63 x 63
X7, U7	-28,55	0	893,5	63 x 126
X8, U8	31,55	0	886,2	63 x 126

Simulation of cosmic muons (170 MeV)

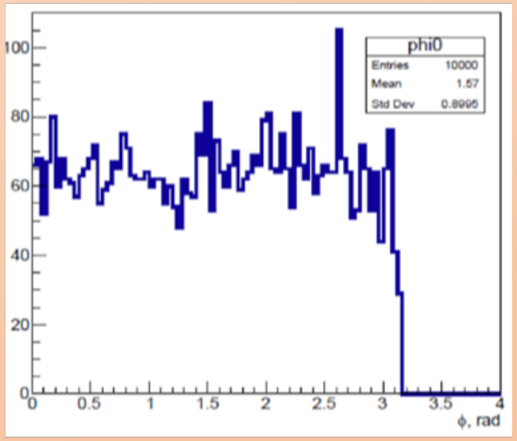
- Polar angle (θ) distribution by **cosine**
- Azimuthal angle (φ) - **uniform** distribution
- $\rho = \sqrt{x^2 + y^2} < R = 10$ cm - **uniform** distribution



$-10 < \theta < 10$

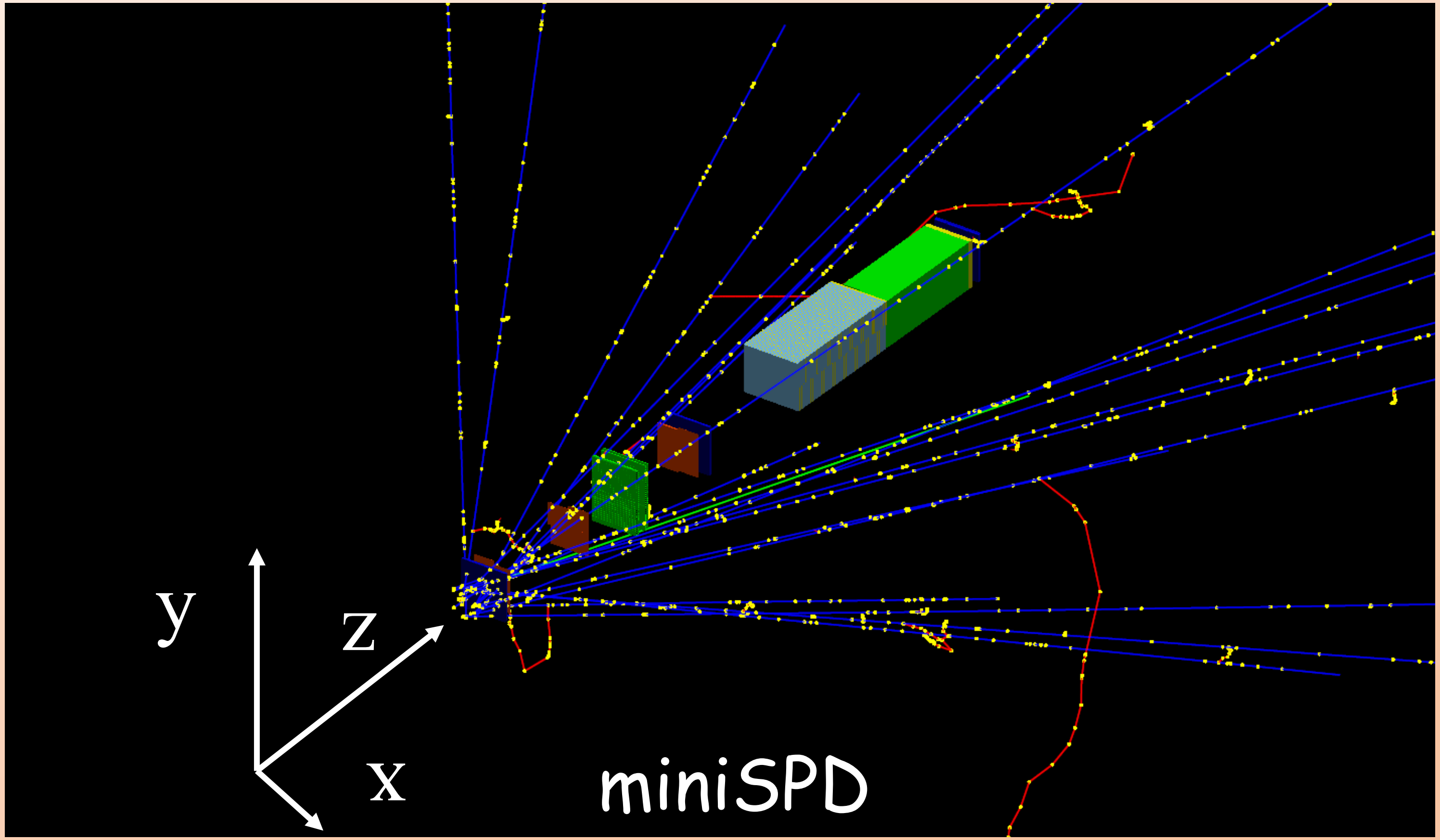


$\rho < 10$ cm



$0 < \varphi < 2\pi$

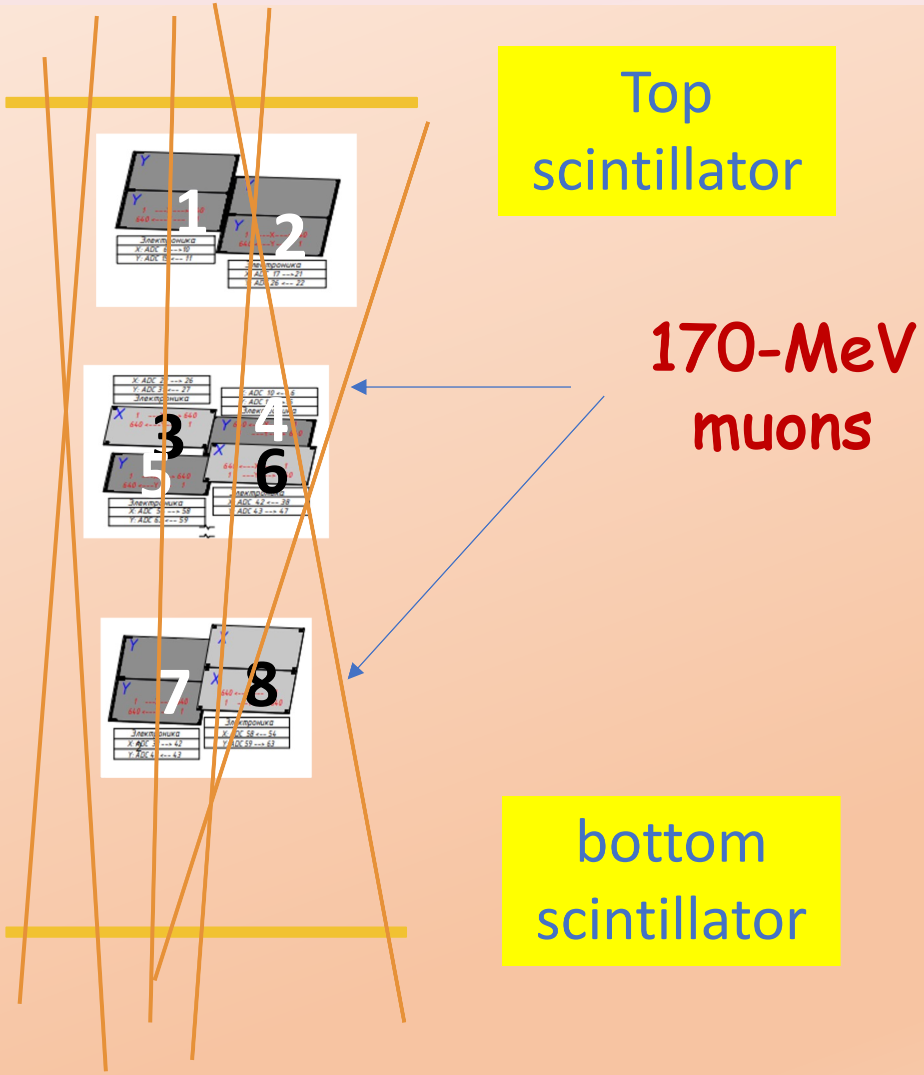
Simulation of cosmic rays by Geant4 at theta = 50 deg.



MiniSPD stand for testing of Si-detectors

We pick out events when top and bottom scintillators trigger.
At that one, two or three Si-plates can trigger.

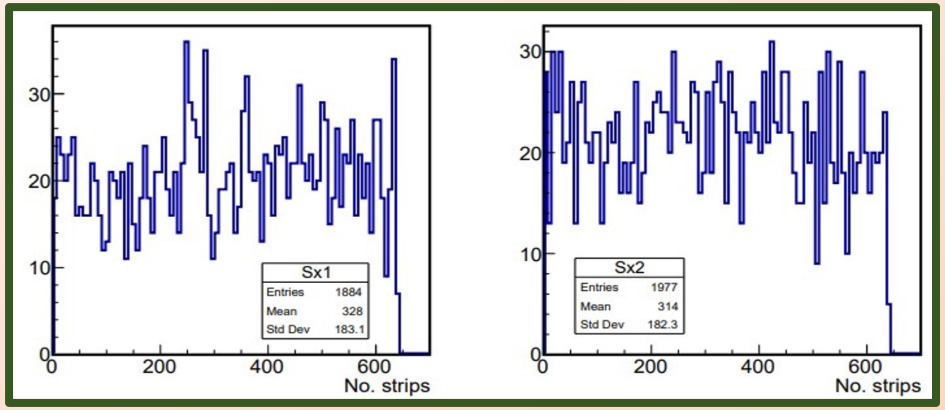
Simulation shows the scintillator response efficiency is close to 99.99 %.

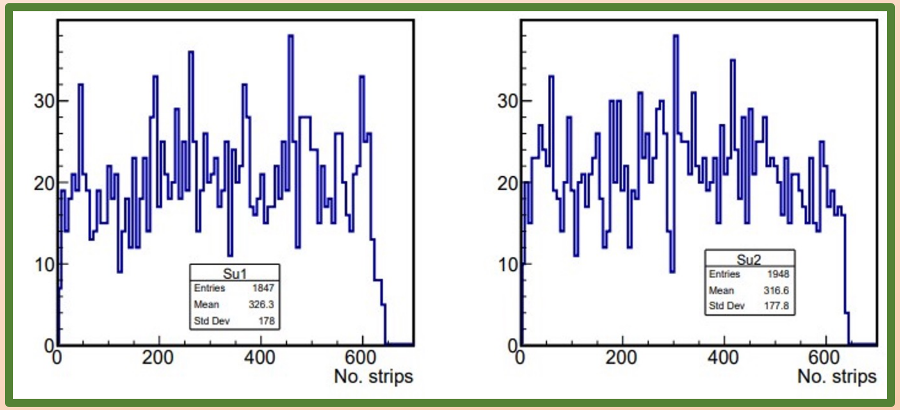


MiniSPD stand testing for Si-detectors

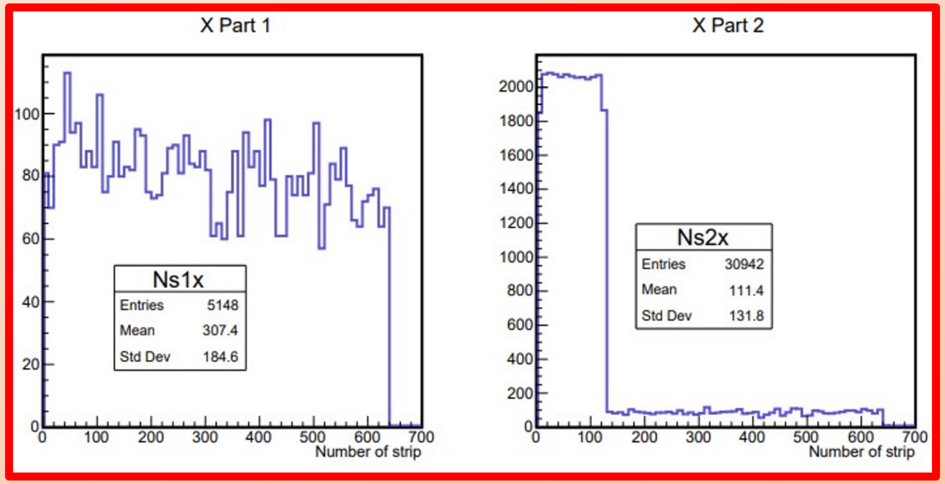
We compare our MC simulation of 50 000 muons with experimental data (~ the same number) obtained at operation of two scintillator triggers and Si-plates for miniSPD stand.

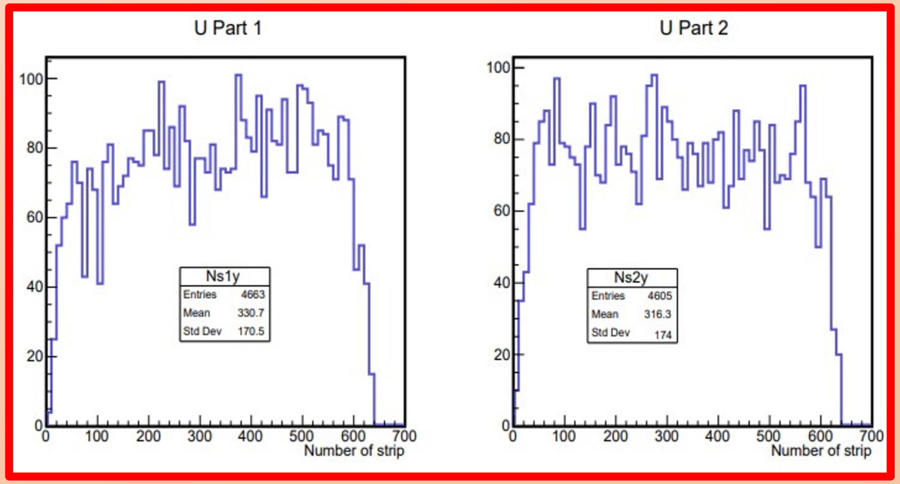
Strip number distributions for X1, X2, U1, U2 plates





MC





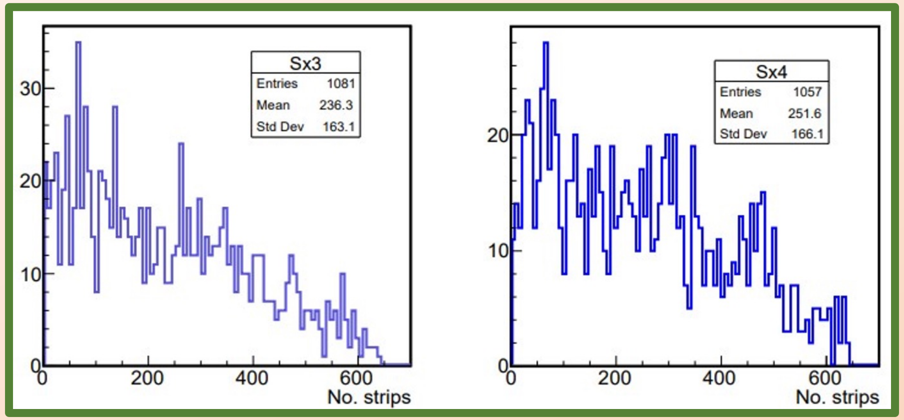
DATA

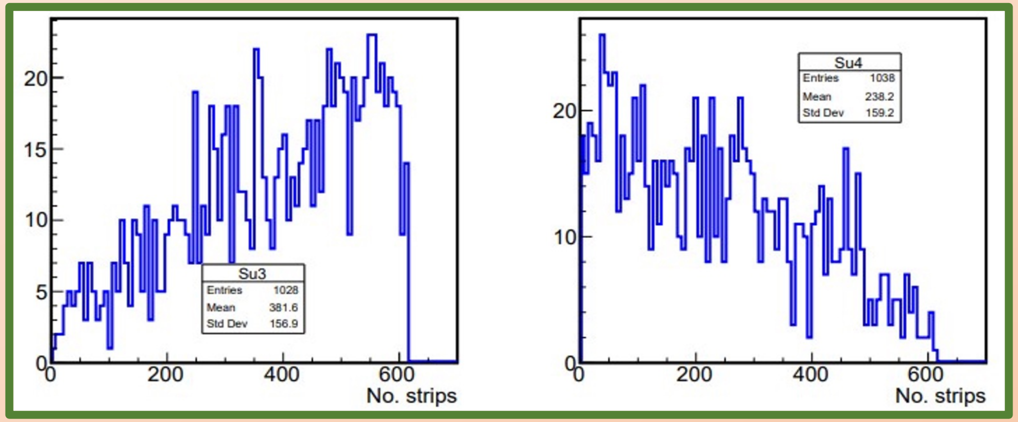
X1 - good work

X2 ~ 100 channels make enhanced noise

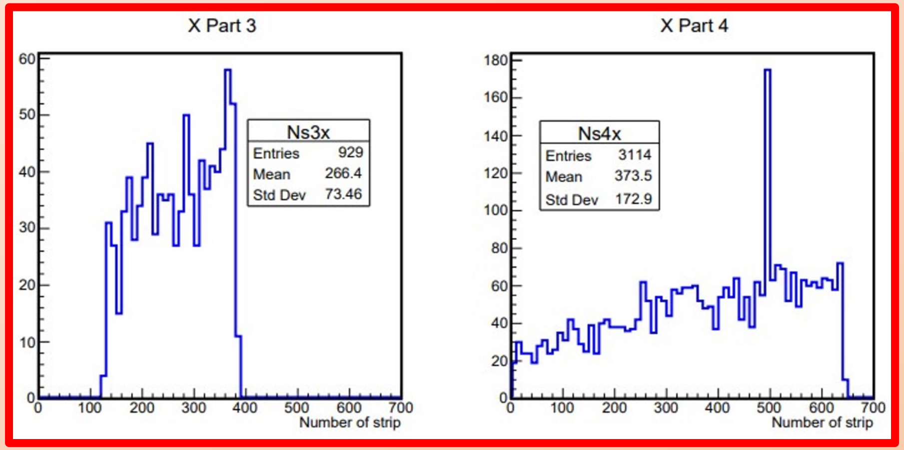
good work

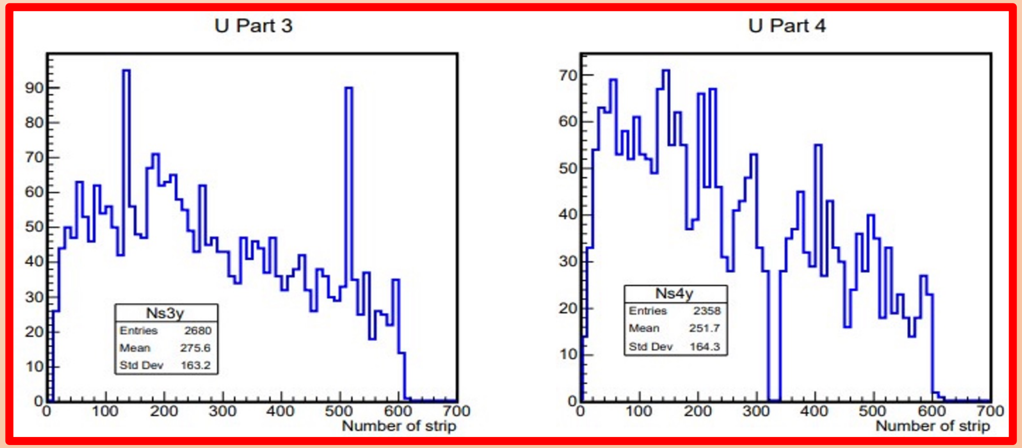
Strip number distributions for X3, X4, U3, U4 plates





MC





DATA

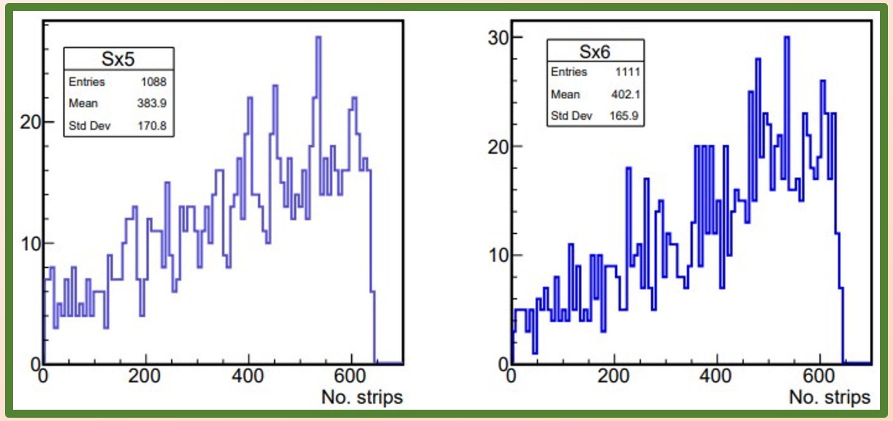
X3 ~ ½ of trips don't work

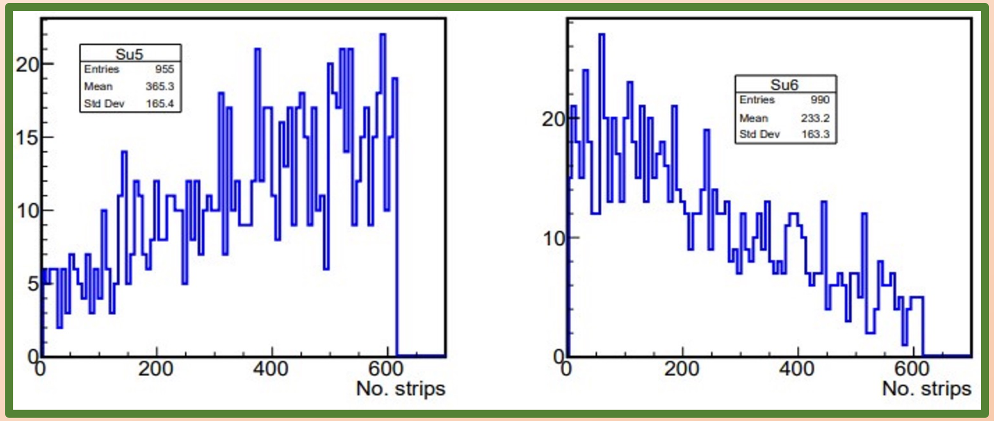
X4 – there are noise channels

U3 - noise channels

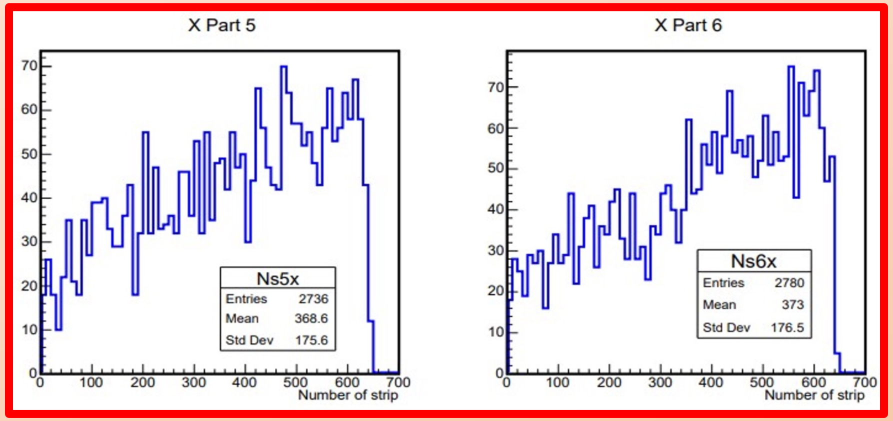
U4 - dead channels

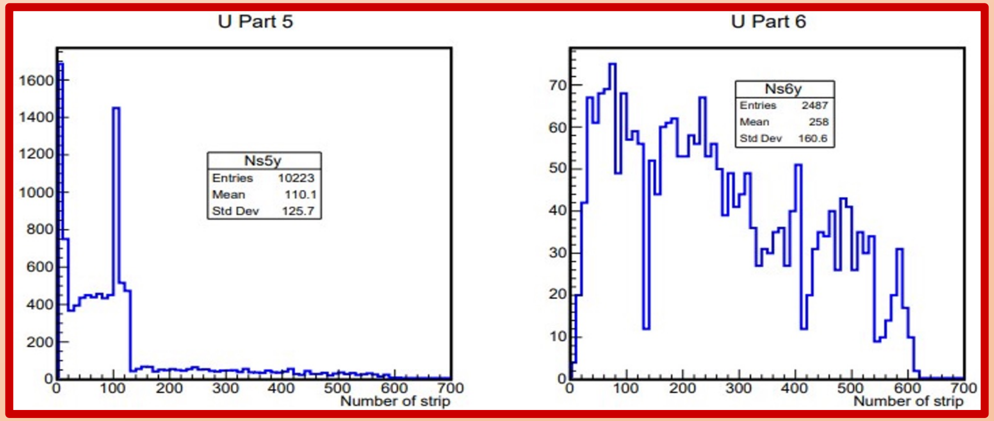
Strip number distributions for X5, X6, U5, U6 plates





MC





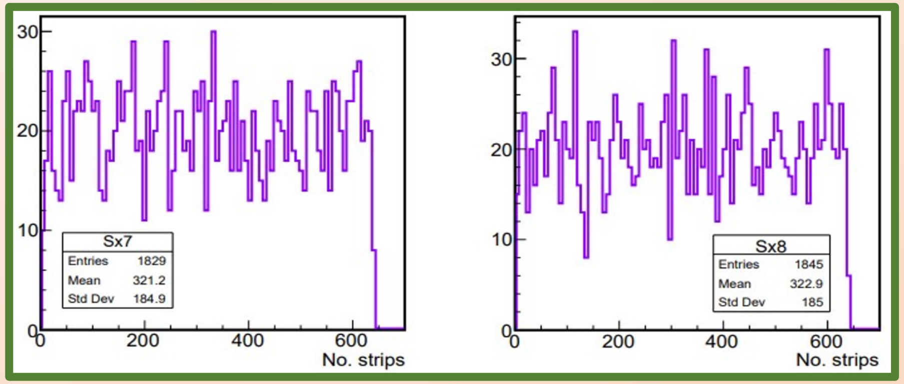
DATA

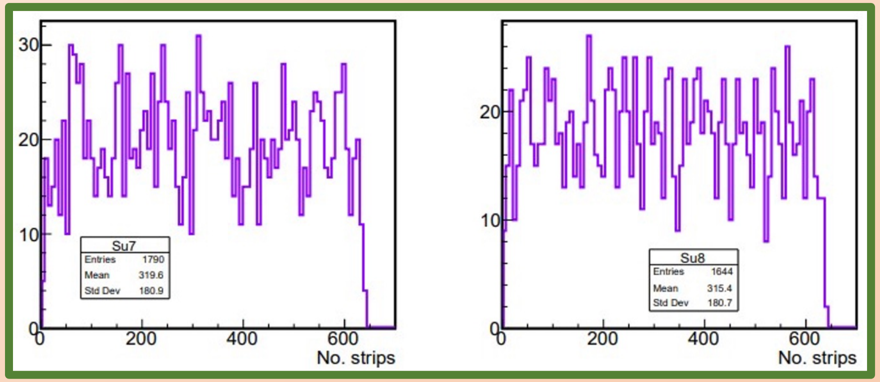
X5 and X6 - good work

U5 ~1/4 channels make noise

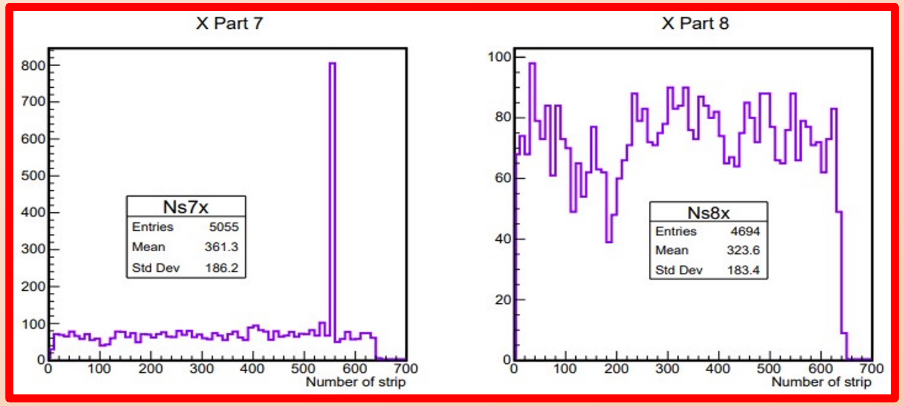
U6 - almost good work

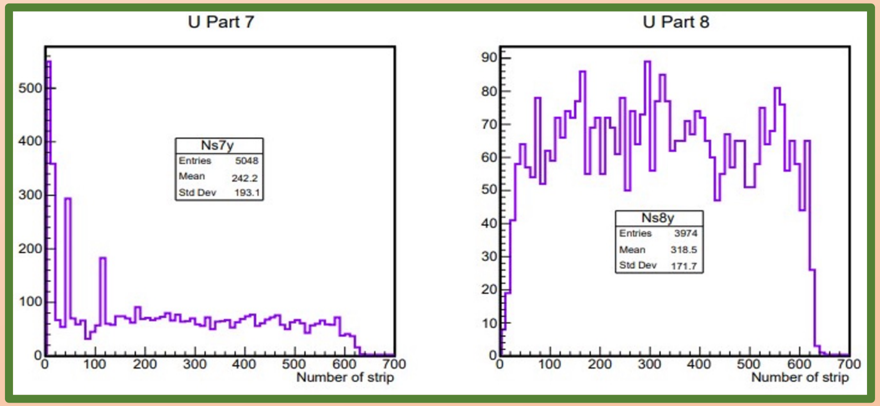
Strip number distributions for X7, X8, U7, U8 plates





MC





DATA

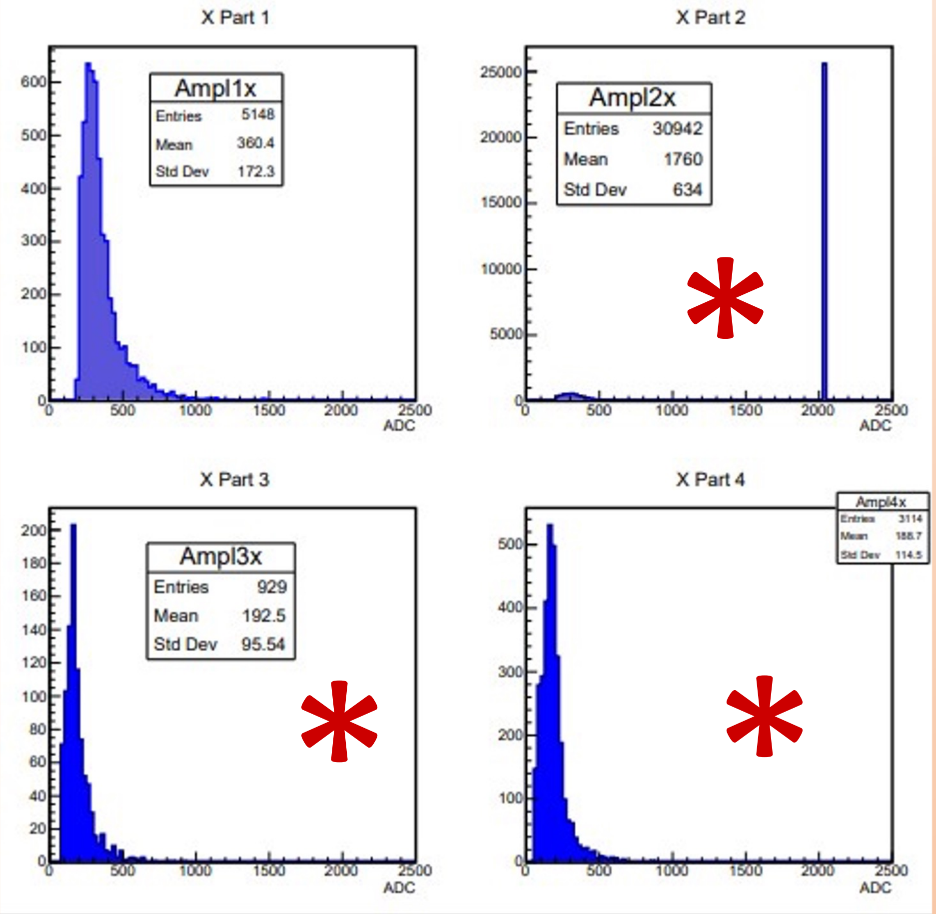
X7 – there are few noise channels

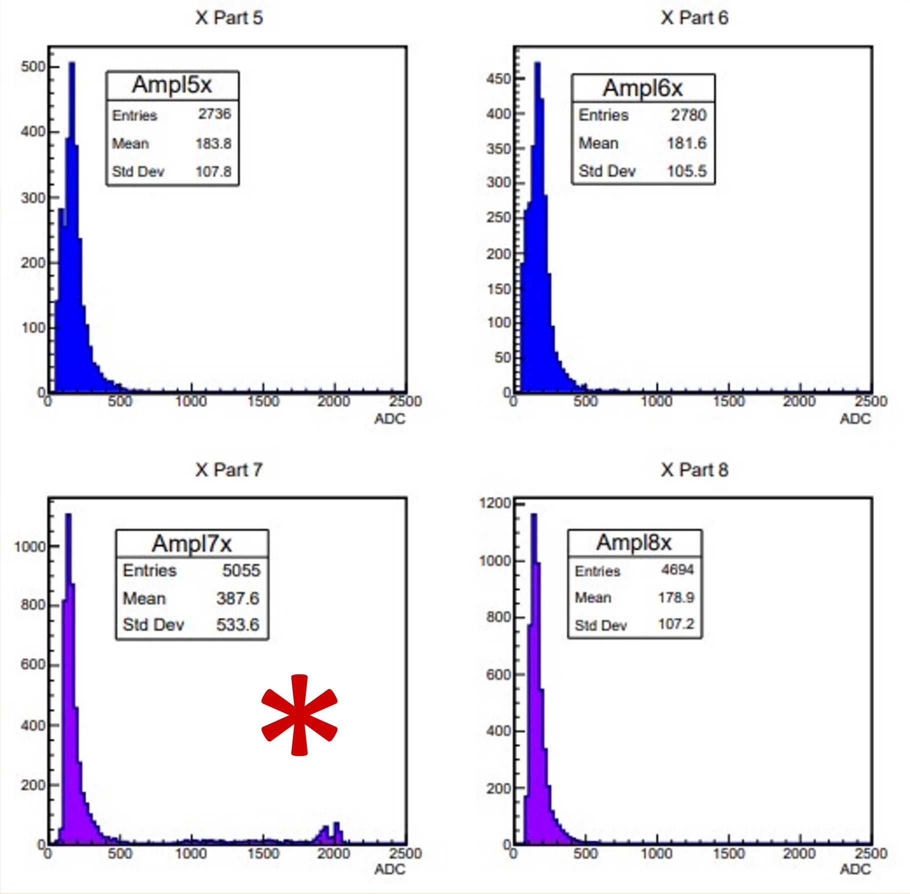
X8 – work almost well

U7 – there are some noise channels

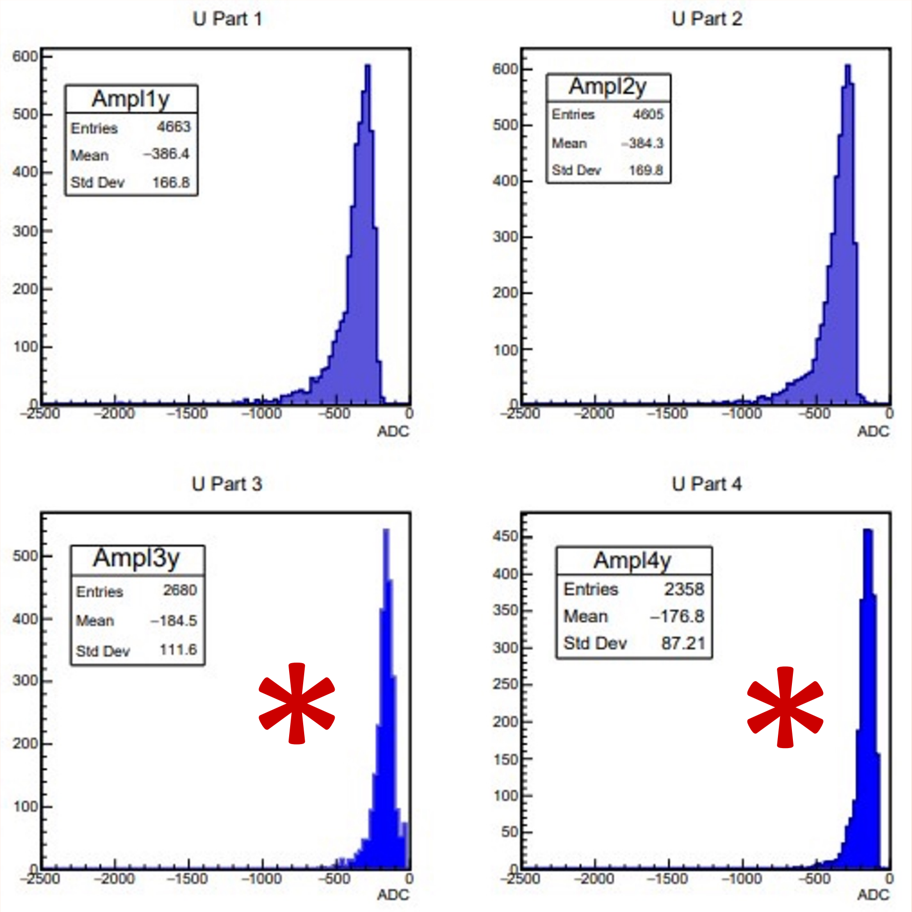
U8 works well

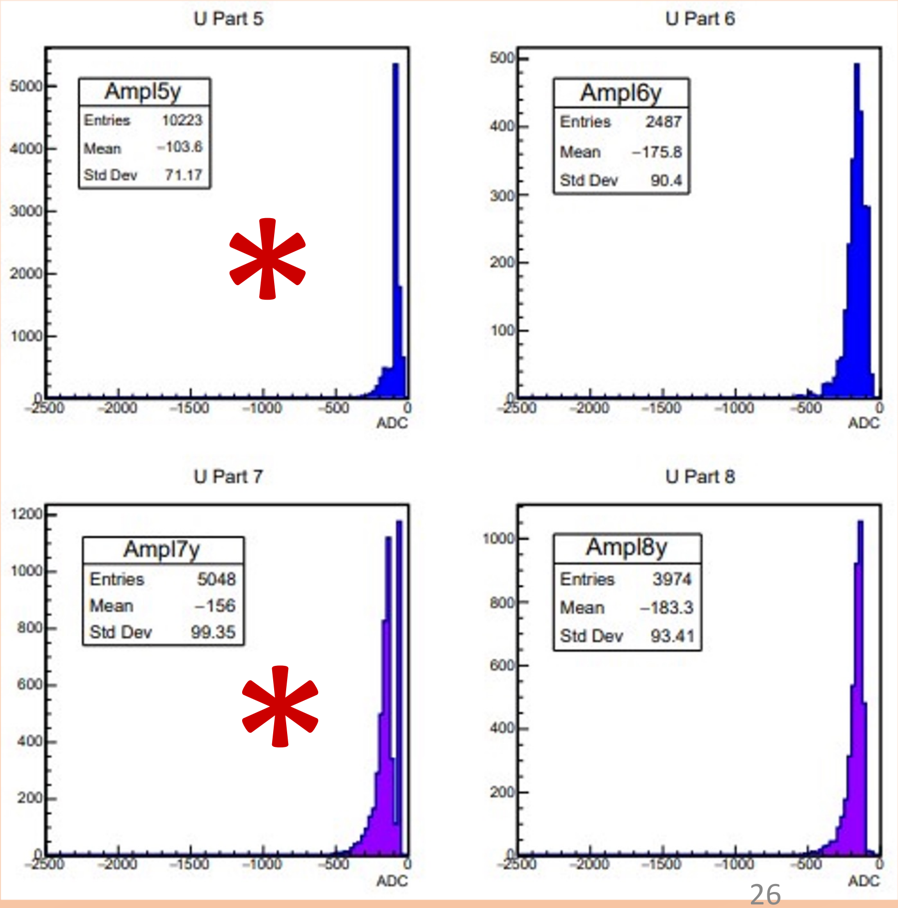
ADC for X & U plates (* - issues with electronics)



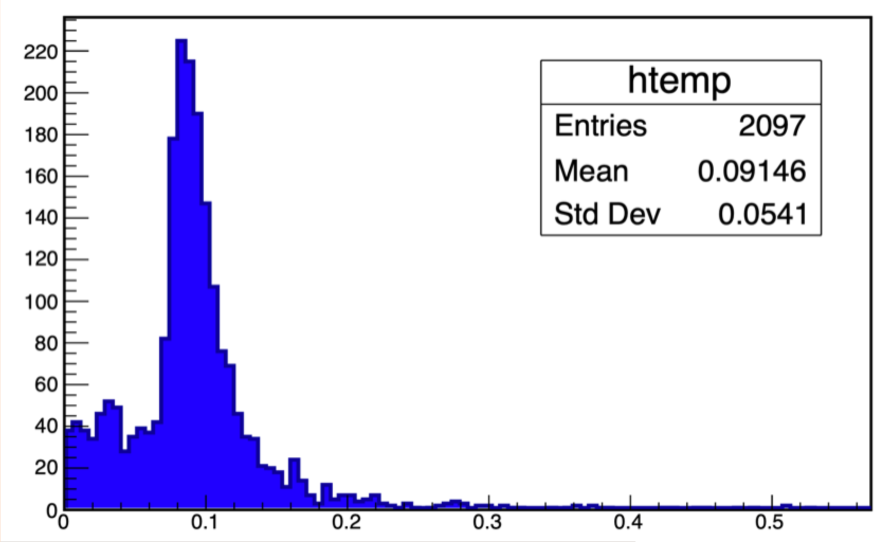


ADC for X & U plates (* - issues with electronics)

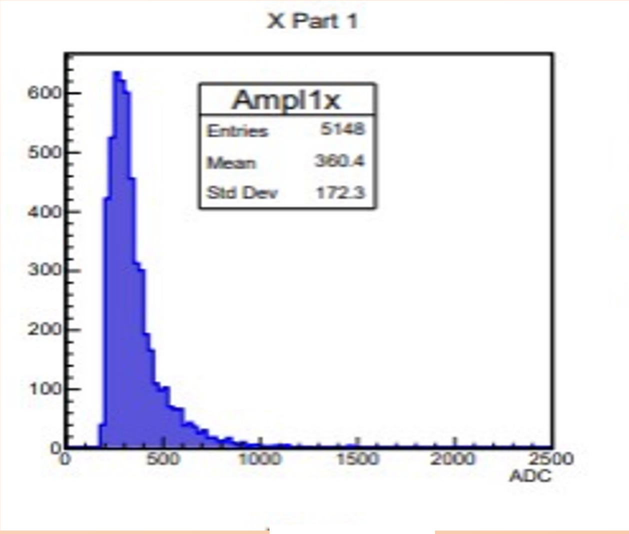




Lower registration threshold on energy



Ed, MeV

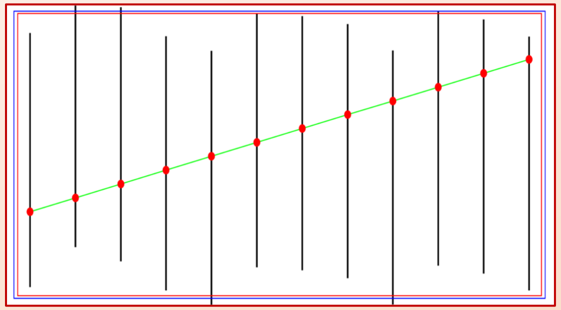


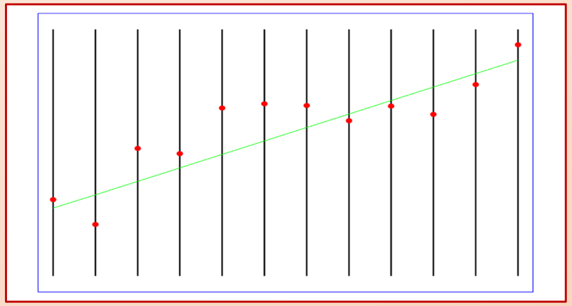
ADC

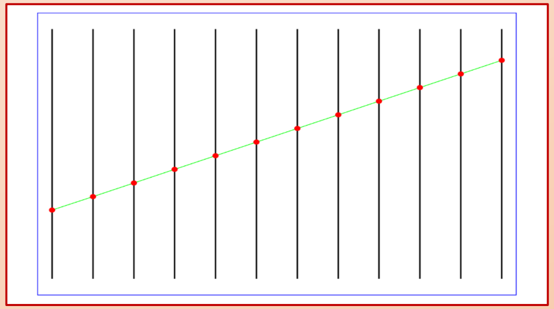
<ADC> ~ <Edep> (energy deposition in a single strip}, the lower threshold of ADC ~ the lower threshold registration of energy deposition (E_cut). Using good planes (X1, X6, U2, U8) we get

30 keV < E_cut < 60 keV and its average value is equal ~ 55 keV.

Alignment is minimization of residuals of F


Reality


Nominal geometry


Aligned detectors

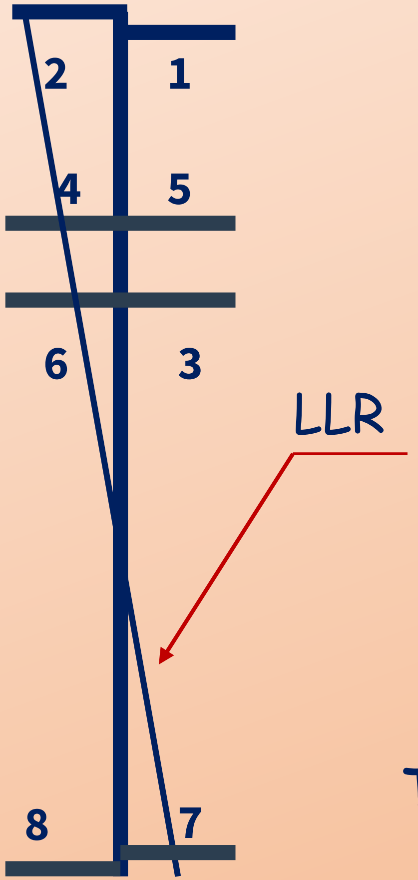
- $F = \sum_{events} \sum_{tracks} \sum_{hits} \left(\frac{d_i^2}{\sigma_{d_i}^2} \right)$, $d_i = u_{fit} - u_{mes}$

Large number of parameters: track parameters (4 * number of tracks) and shifts(numbers of detectors), number of hits >> parameters.

$$u_{fit} \rightarrow u_j(z_i) = (x_0 + t_x z_i)\cos(\alpha_i) + (y_0 + t_y z_i)\sin(\alpha_i) + \Delta u_i$$

Combinations of Si-modules for passing tracks

		N file	Comb.	Ntracks
Vertical tracks	I	268	LLL	5602
		157	RRR	4378
		248	LLL	3558
		137	RRR	2187
		158	RLL	3428
Oblique tracks	II	267	LLR	2396
		247	LLR	2105
		138	RRL	378
		257	LRR	2392
	III	148	RLL	1550
		168	RLL	1037
		237	LRR	3
Low level of noise	IV	258	LRL	88
		147	RLR	3
		167	RLR	0
		238	LRL	0



part, N	angle, deg
1	+2.5
2	+2.5
3	-2.5
4	+2.5
5	+2.5
6	-2.5
7	-2.5
8	+2.5

The same orientation for U-coord. is only for 148, 258, 248 combin.

Millipede procedure improves $\chi 2 - distr.$

Shifts for part 5 (mm)

Result of fit for global parameters

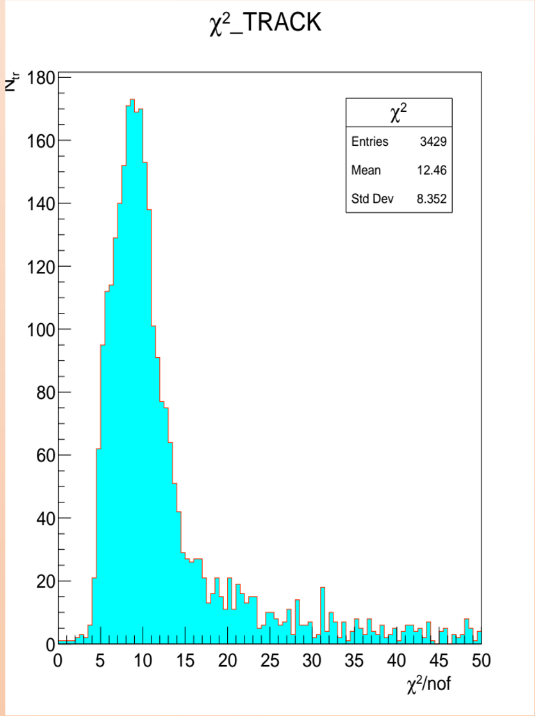
================

I	initial	final	
1	0.00000	0.00000	
2	0.00000	0.00000	
3	**0.02798**	**0.02841**	**- x-side**
4	**0.97531**	**0.97572**	**- u-side**
5	0.00000	0.00000	
6	0.00000	0.00000	

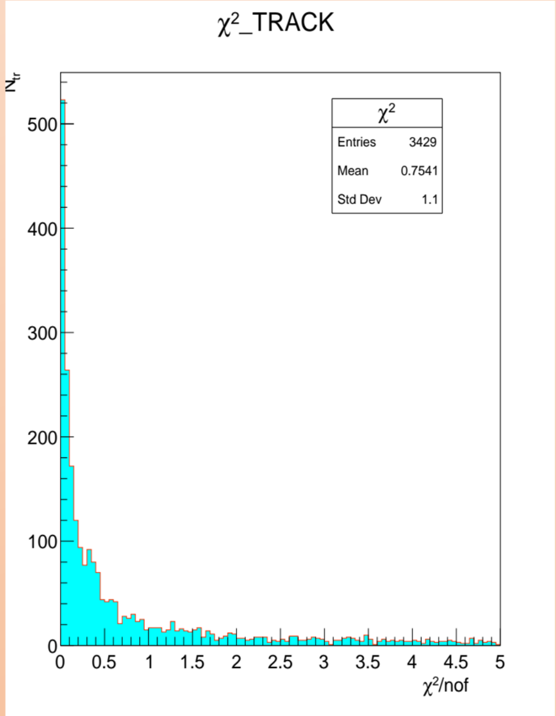
Total 3428 local fits,
1335 rejected.

148-file

χ^2 distributions



Before alignment



After alignment

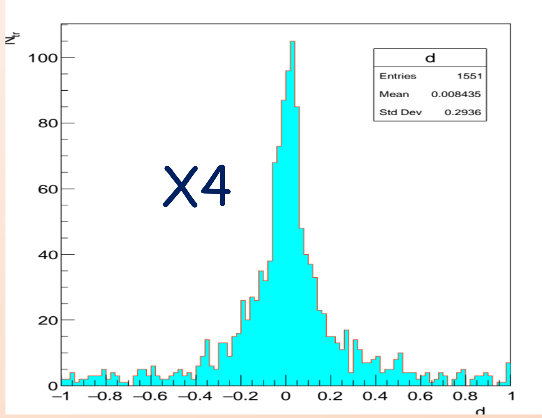
Residual distributions

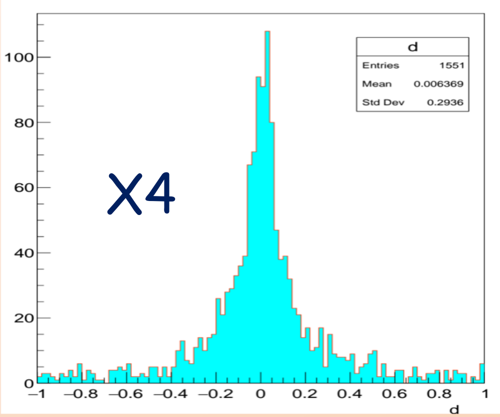
Before alignment

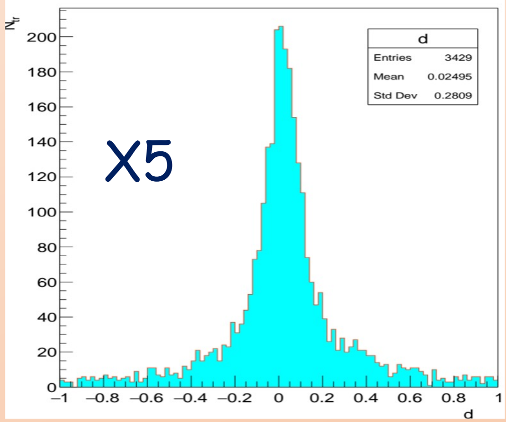
After alignment

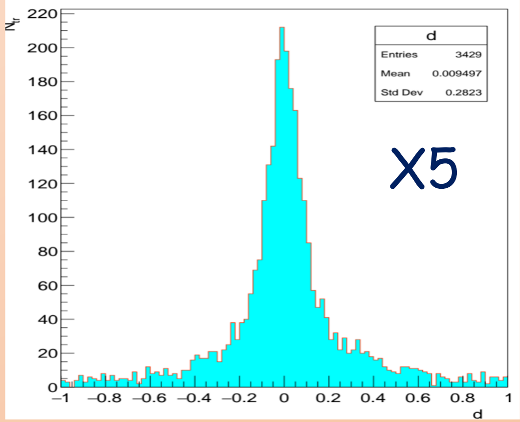
Before alignment

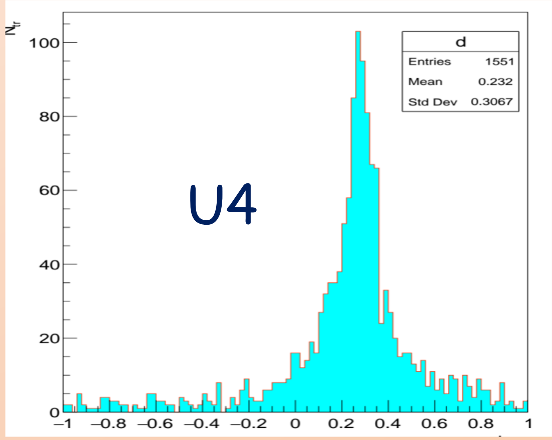
After alignment

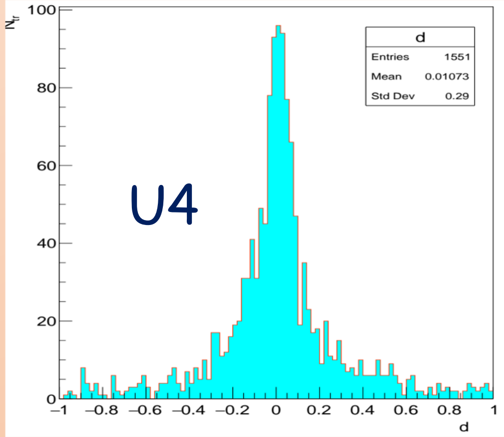


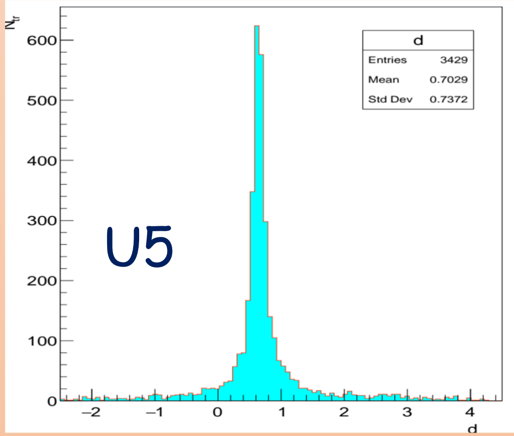


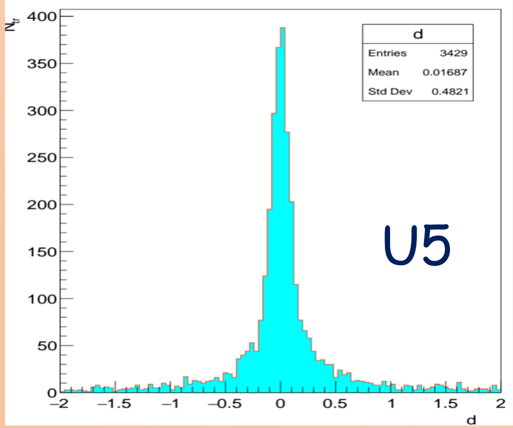












Parts 1,4,8

Parts 1,5,8

Millipede procedure improves $\chi 2 - distr.$

Shifts for part 4 (mm)

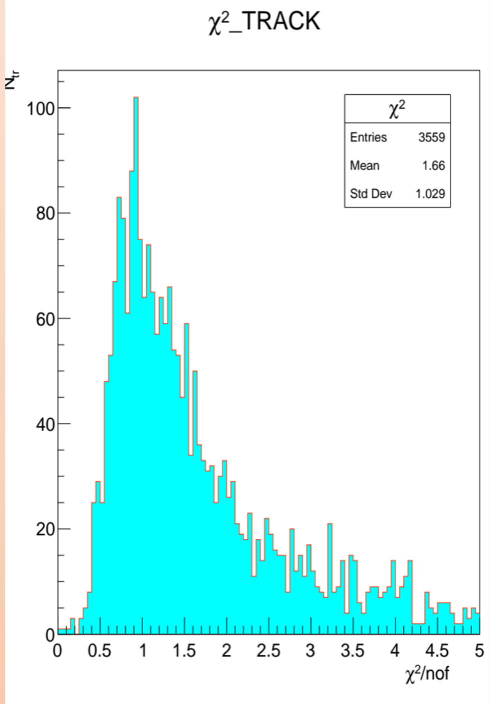
Result of fit for global parameters

- -

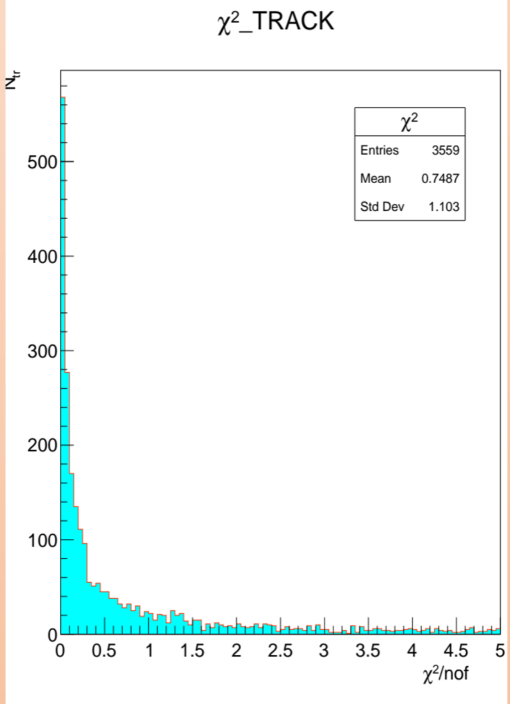
I	initial	final	
1	0.00000	0.00000	
2	0.00000	0.00000	
3	-0.00378	-0.00365	- x-side
4	0.34720	0.34735	- u-side
5	0.00000	0.00000	
6	0.00000	0.00000	

- - - - - - - - - - - - - - - - - - -

Total 3558 local fits,
1409 rejected.



Before alignment



After alignment

Results

1. Monte Carlo simulation of two-sided silicon plates of miniSPD stand is carried out for two cases: with and without taking into account operation of the scintillator triggers.
2. Comparison Monte Carlo simulation with experimental data allows to estimate the lower threshold on energy for a single strip operation.
3. Work of all parts (1-8) and their X and U sides of Si-detectors was analyzed and compared with MC simulation.
4. **Noisy and dead channels are seen directly from the distributions according to the numbers of the triggered strips.**
5. **Alignment task is solved for the middle (II) module. The distributions on residuals of its parts and $\chi 2$ on tracks are obtained.**

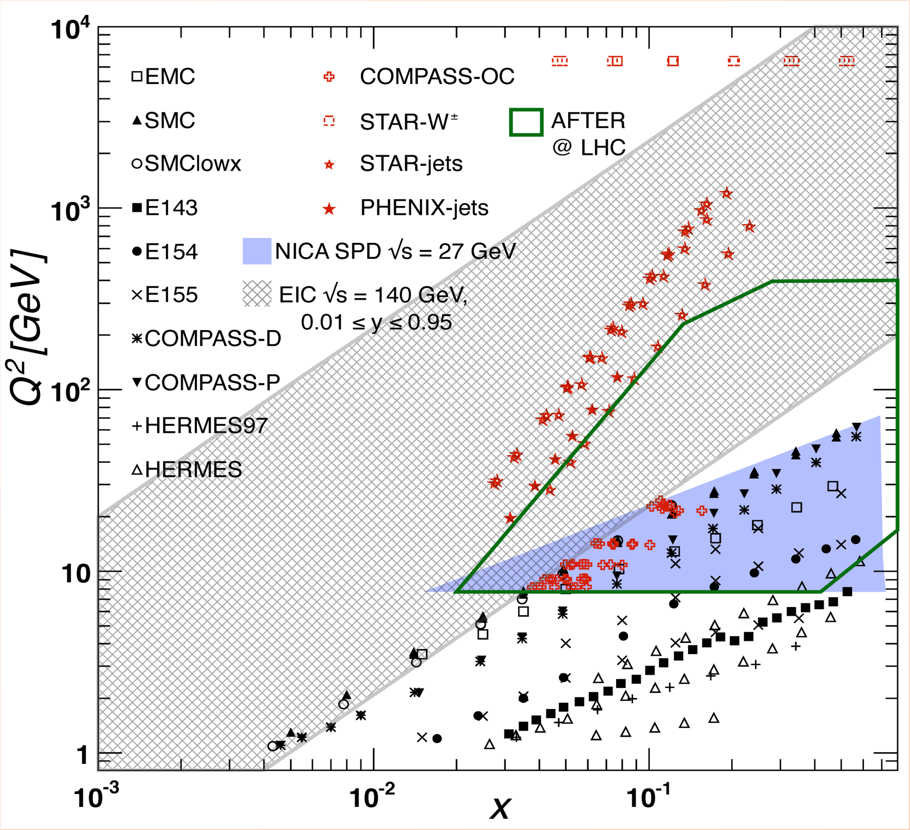
Outlook

1. We continue carrying out MC simulation of straw (drift) tubes to compare its with experimental data obtained at MiniSPD stand.
2. We also plan carrying out Monte Carlo simulation of the electromagnetic calorimeter work (16 modules).
3. It will allows us to start solving our basic task, studying (direct) soft photon yield and the pionic condensate formation (restoration of π^0) in pp (pd, dd) interactions at high multiplicity.

https://www.youtube.com/watch?v=wCqX_rNi-60&feature=emb_imp_woyt

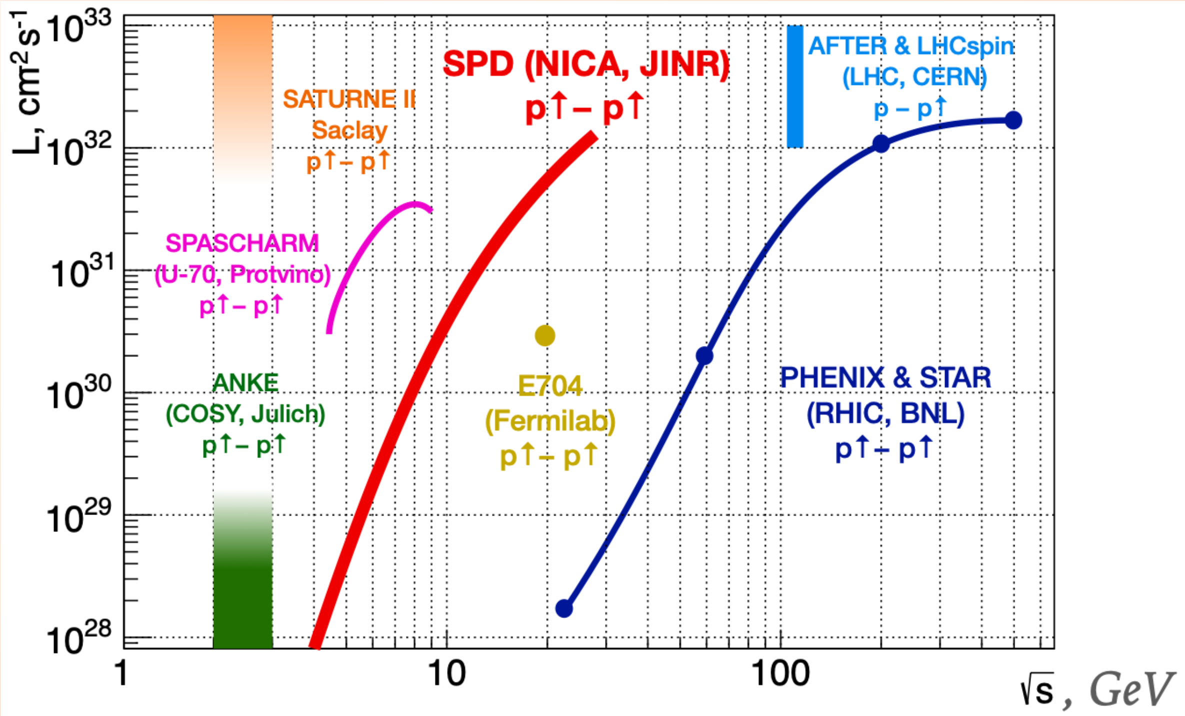
Backup

SPD compared to other spin experiments



Main present and future gluon-spin-physics experiments

Experimental facility	SPD @NICA [41]	RHIC [45]	EIC [36]	AFTER @LHC [34]	LHCspin [35]
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^\uparrow$-$p^\uparrow$ $d^\uparrow$-$d^\uparrow$ $p^\uparrow$-d, p-$d^\uparrow$	$p^\uparrow$-$p^\uparrow$	$e^\uparrow$-$p^\uparrow$, $d^\uparrow$,^{3}He$^\uparrow$	p-$p^\uparrow$,$d^\uparrow$	p-$p^\uparrow$
Center-of-mass energy $\sqrt{s_{NN}}$, GeV	≤27 (p-p) ≤13.5 (d-d) ≤19 (p-d)	63, 200, 500	20-140 (ep)	115	115
Max. luminosity, 10^{32} cm^{-2} s^{-1}	~1 (p-p) ~0.1 (d-d)	2	1000	up to ~10 (p-p)	4.7
Physics run	>2025	running	>2030	>2025	>2025



- Access to intermediate and high values of Bjorken x
- SPD is low energy but still collider experiment (compared to fixed target). Nearly 4π coverage
- Two injector complexes available ⇒ mixed combinations $p^{\uparrow}$-d and p-$d^{\uparrow}$ are possible