Simulation of the drift chambers for the BM@N experiment

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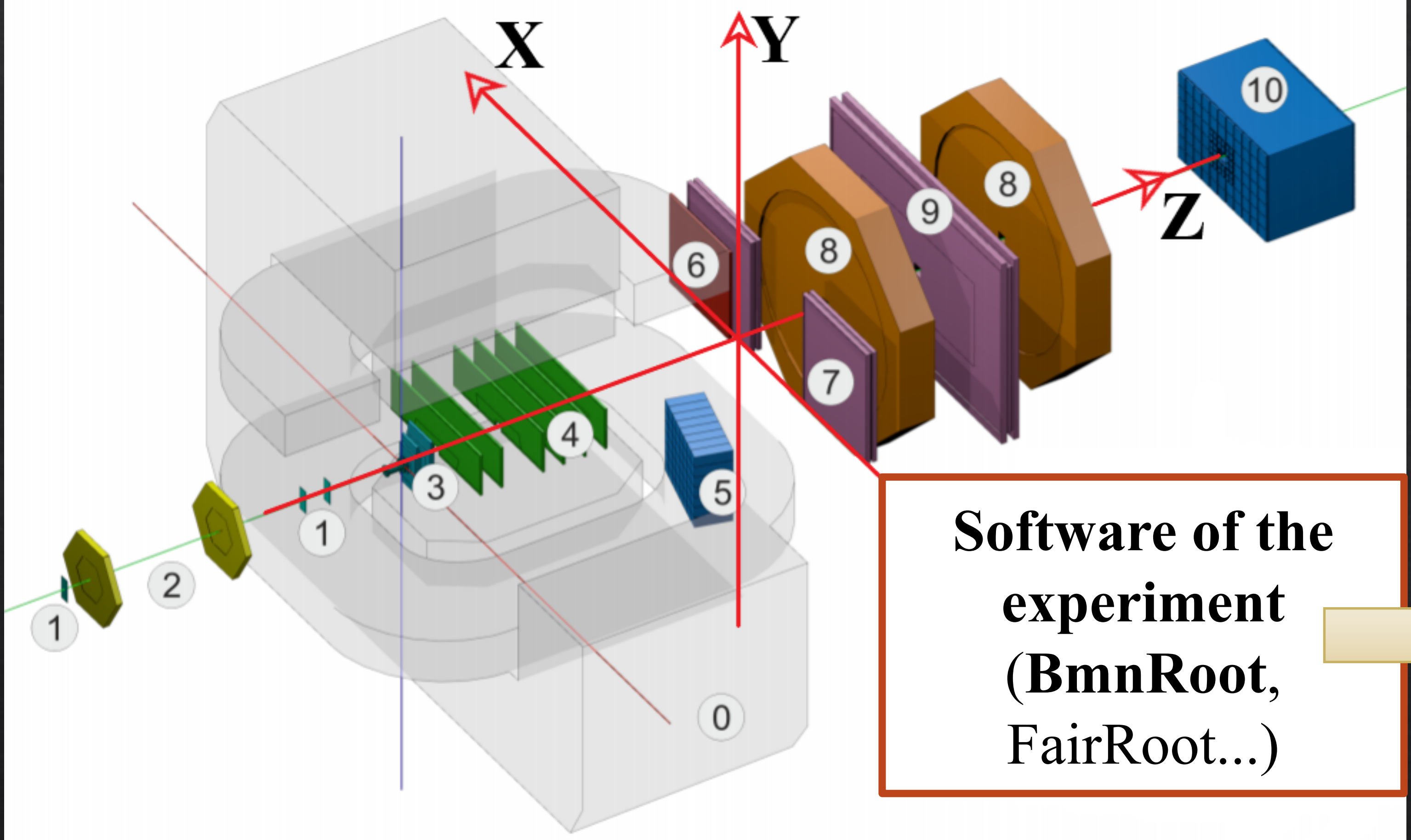
Purpose of the thesis

To improve the existing simulation of the drift chambers for the BM@N experimental setup

Tasks of the thesis research were following:

1. **Study of basic principles of drift chambers**
2. **Explore and learn to use the BmnRoot software framework**
3. **Master the object-oriented environment ROOT**
4. **Develop the simulation programming code**

The subject of the thesis



Software of the experiment (BmnRoot, FairRoot...)

Event generator (UrQMD, LAQGSM, Pythia...)

Detector simulation (Geant3, Geant4)

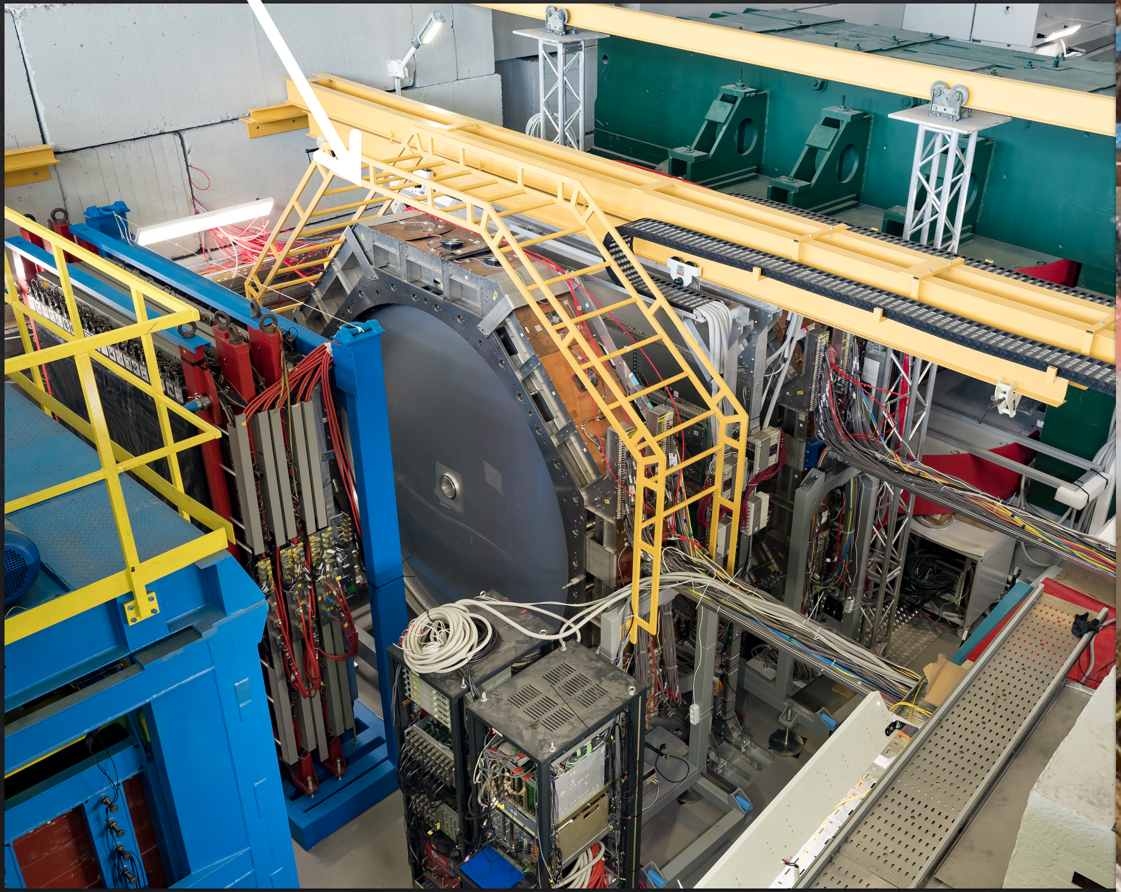
Digitization

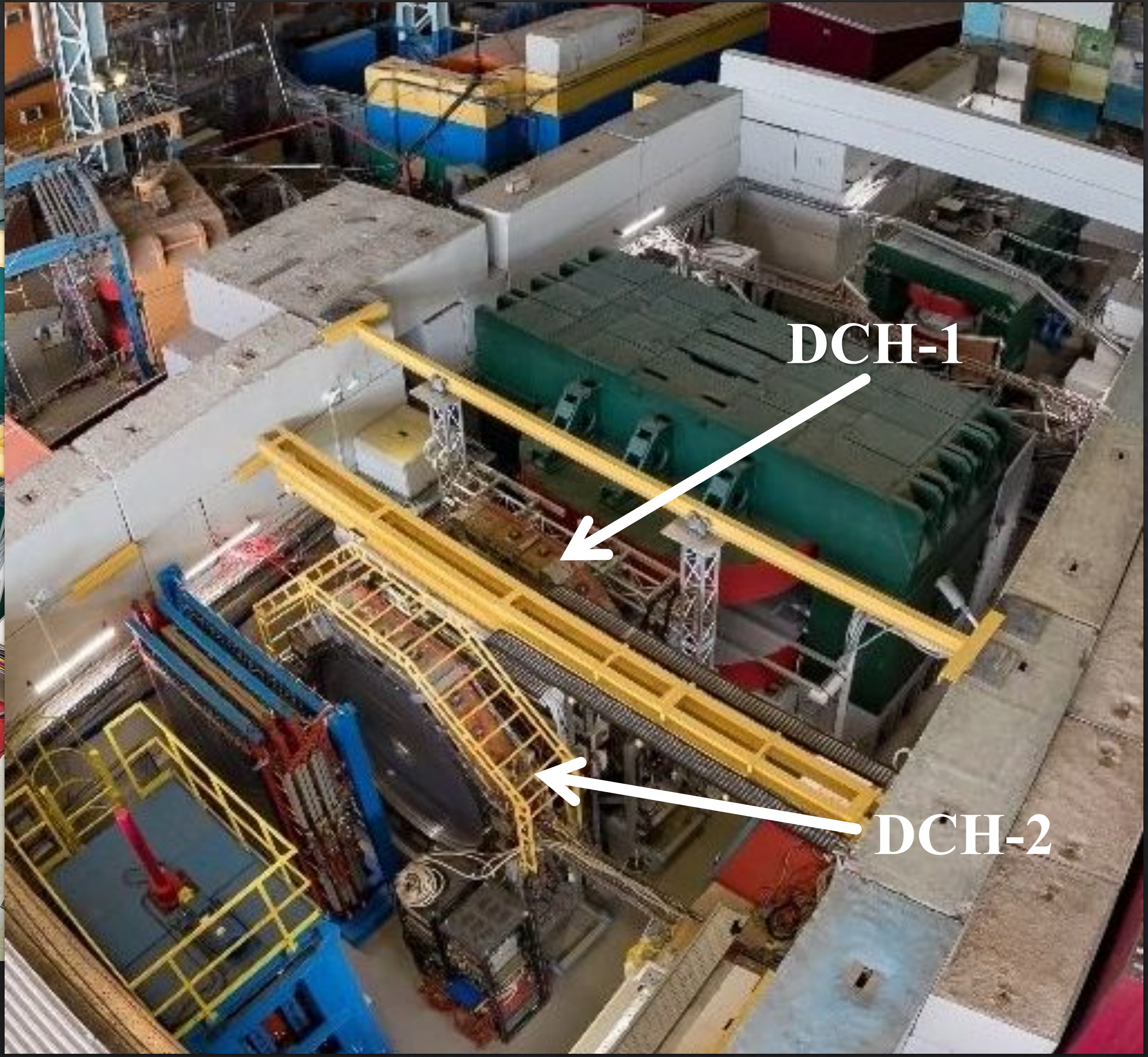
Reconstruction/Analysis

Fig. 1. The layout of the BM@N experiment [1]. Drift chambers are labeled by 8.

Drift chambers (DCH) at the BM@N setup

DCH-2





DCH-1

DCH-2

The following steps were done:

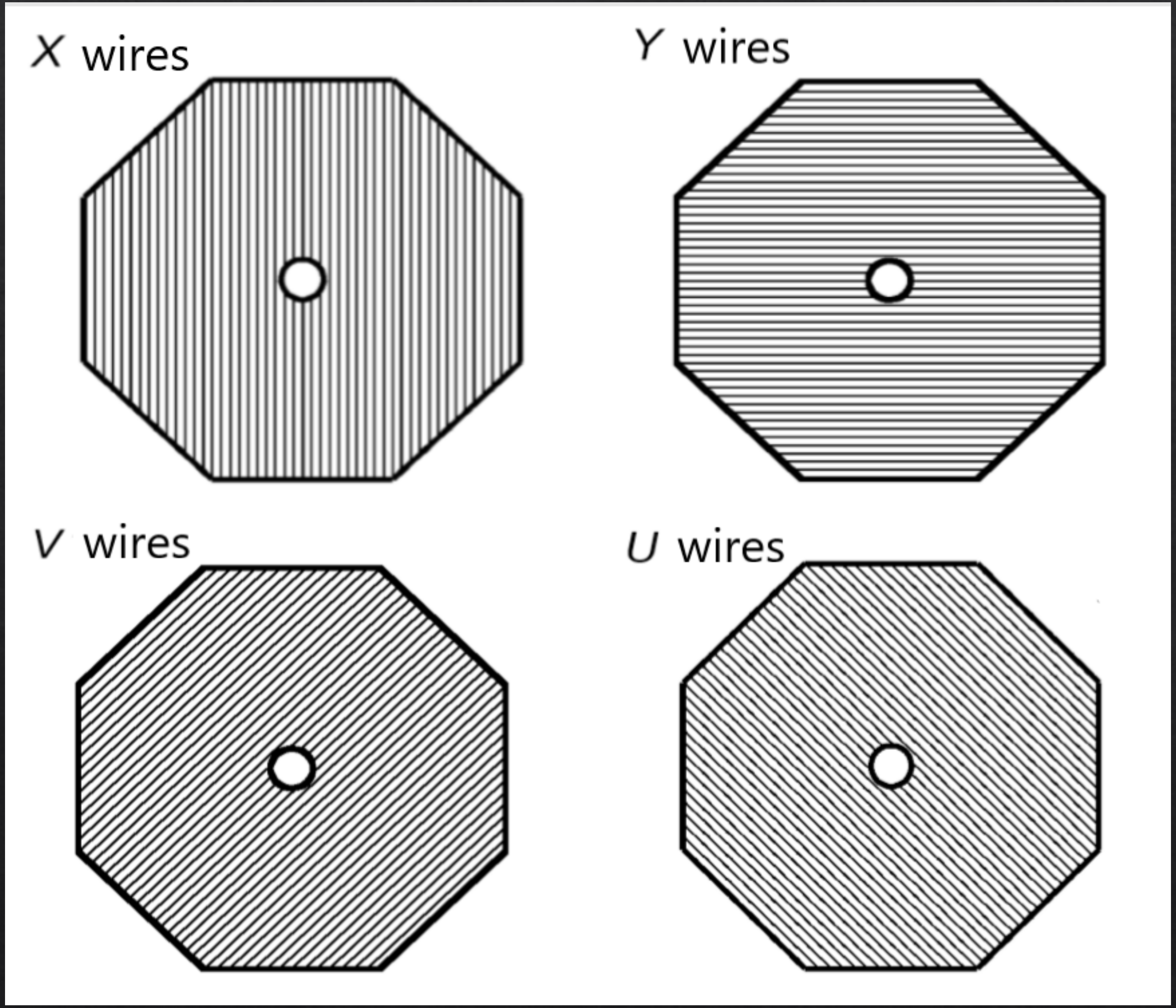
1. **The accurate shape of background noise** was accomplished by fitting XY distribution of DCH hits from ^{12}C ion beam with applied magnetic field of 2.7 Tm.

2. **The precise positioning of 8 wire planes of each drift chamber** was reconstructed with ROOT macro.

3. **Physical and background hits are separated** according to reference index.

4. **Individual hits were plotted for each wire plane** to illustrate the wires' orientation.

Geometry of the DCH



- **Octagonal** shape
- **8 wire planes in each DCH**

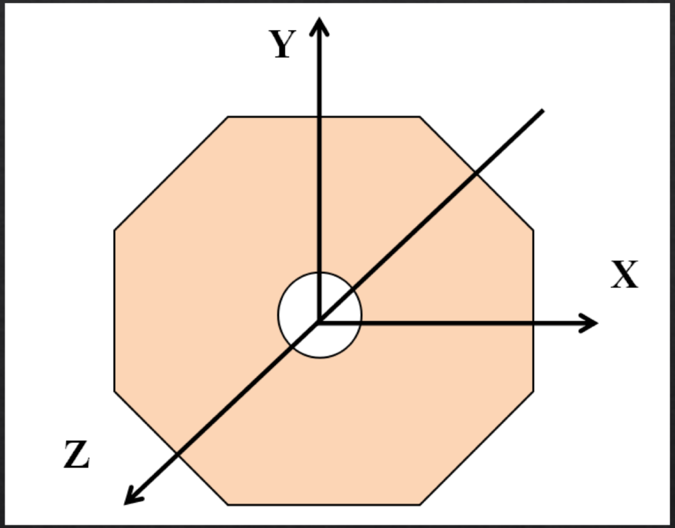
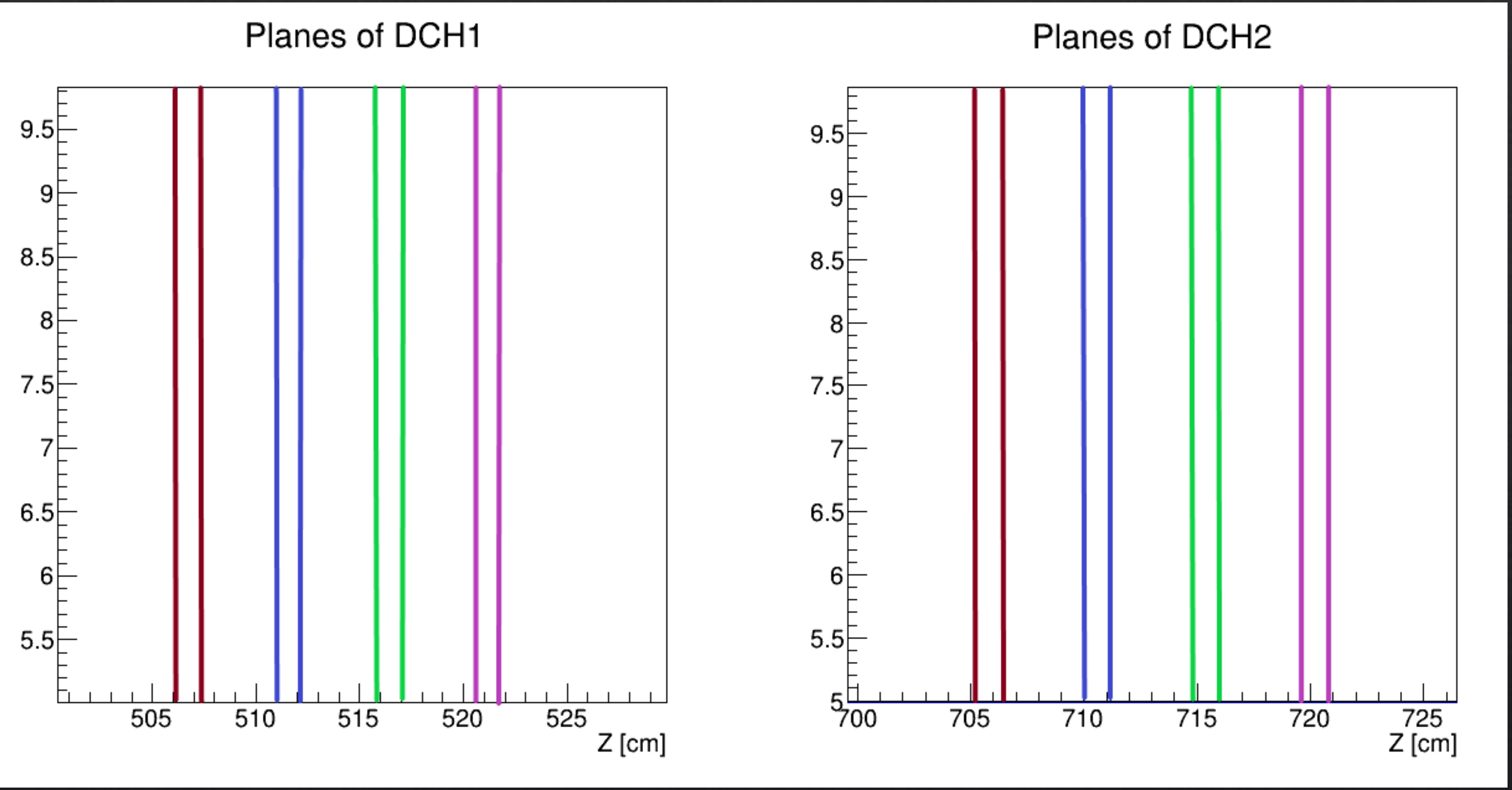


Fig. 2. Four different directions of wires in each DCH, orthogonal to the beam axis (Z axis) [3].

Positioning of wire planes in the DCH based on simulation



V-oriented wire plane
U-oriented wire plane
Y-oriented wire plane
X-oriented wire plane

Fig. 3. Z coordinates of wire planes in drift chambers.

X-profile distribution of experimental hits

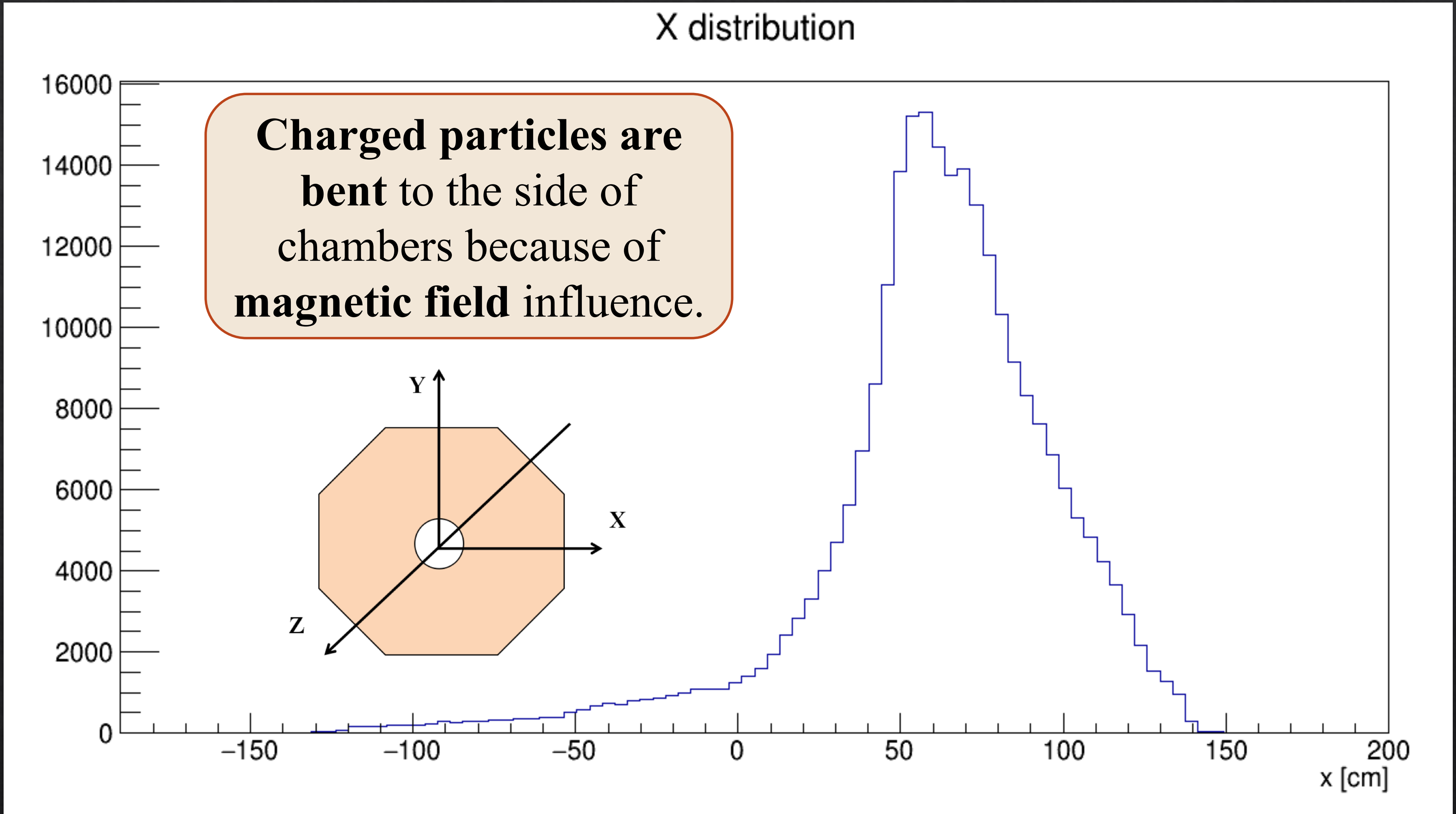
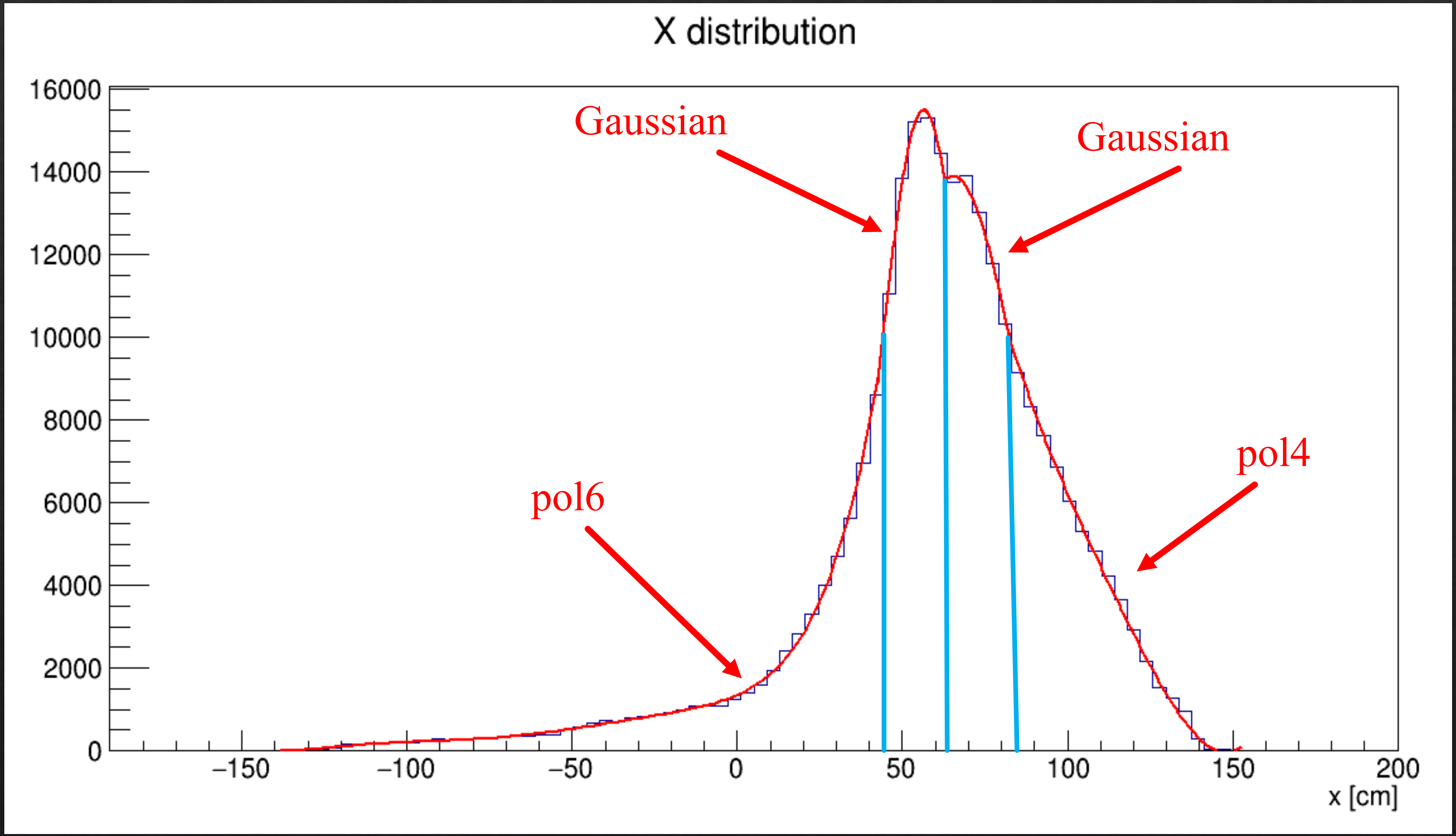


Fig. 4. Distribution of experimental hits in the DCHs according to X coordinate.

X-profile fitting



The fitting function was chosen as sum of several functions at different intervals of X axis to achieve adequate fitting parameters.

Fig. 5 . Fitting of hits distribution according to X coordinate.

Y-profile distribution of experimental hits

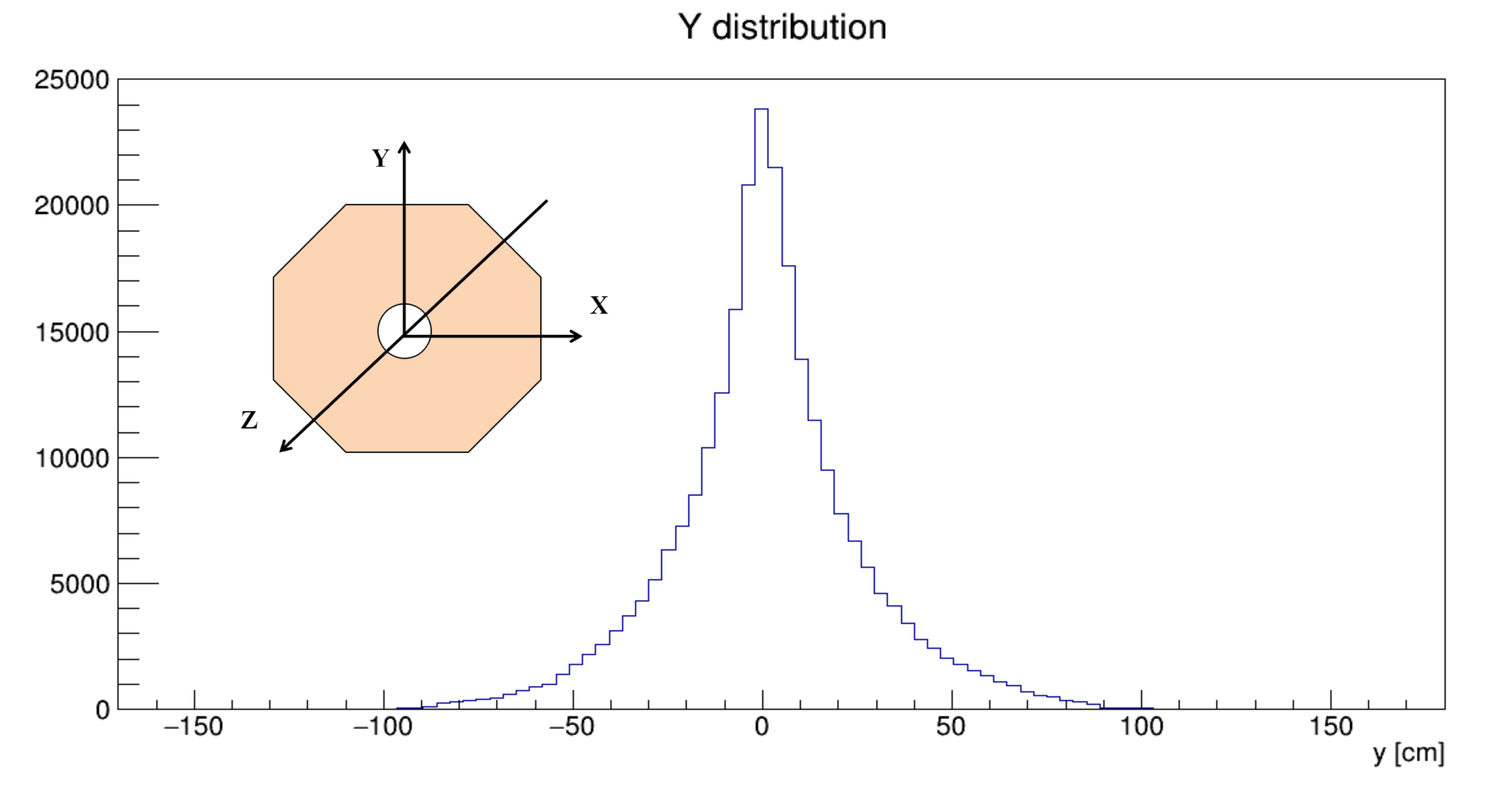
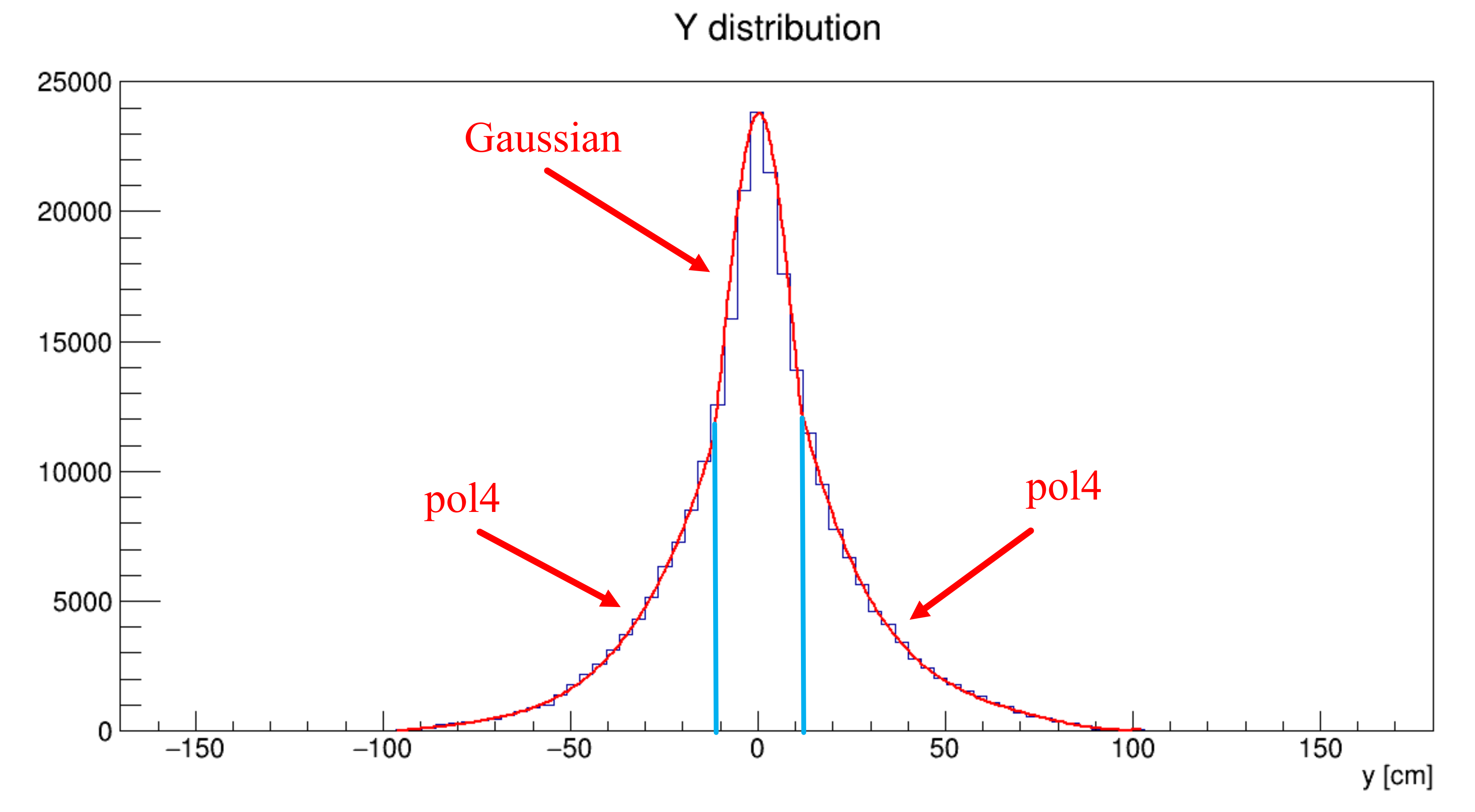


Fig. 6. Distribution of experimental hits in drift chambers according to Y coordinate.

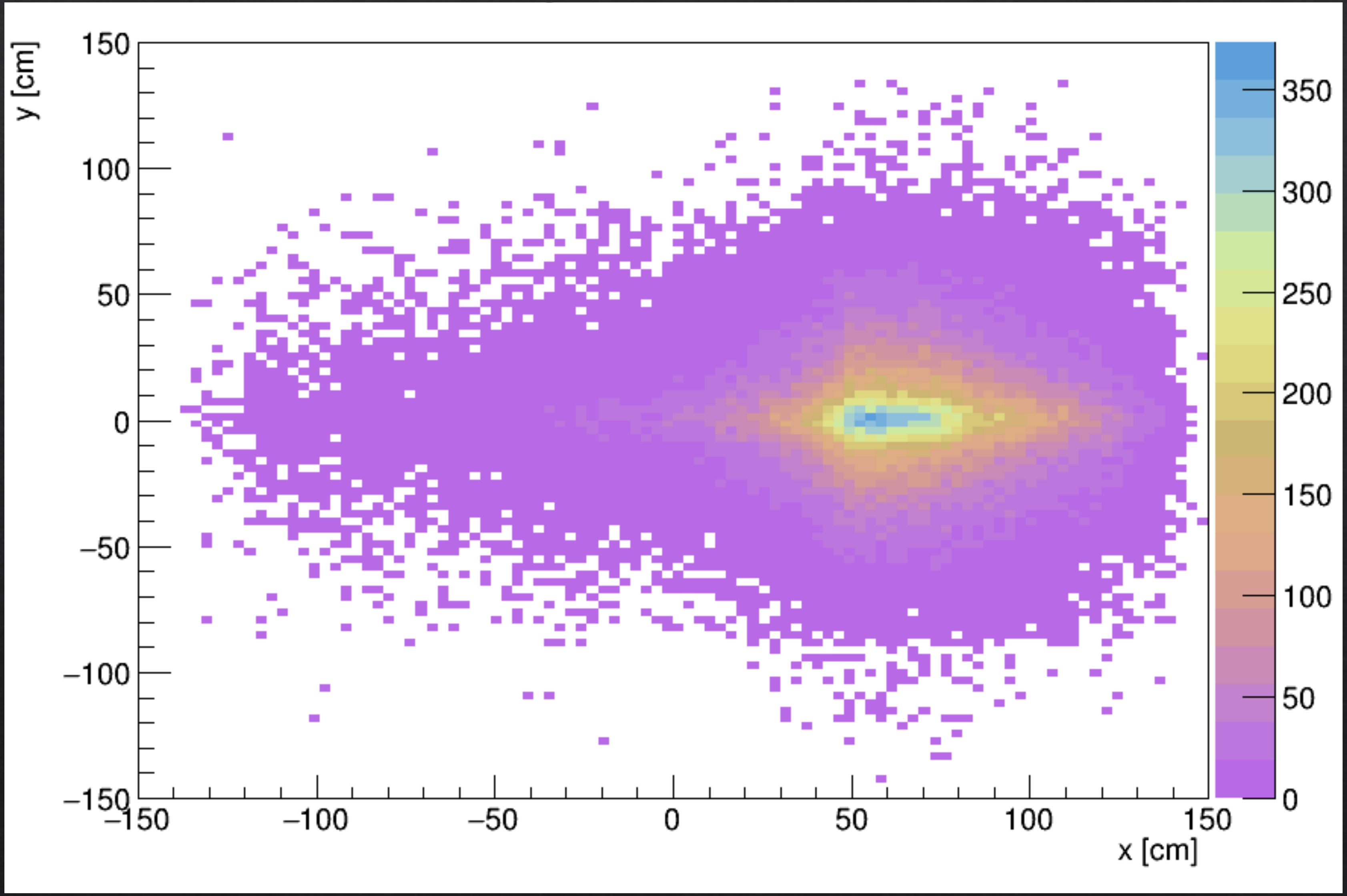
Y-profile fitting



The fitting function was chosen as sum of several functions at different intervals of Y axis to achieve adequate fitting parameters.

Fig. 7. Fitting of hits distribution according to Y coordinate.

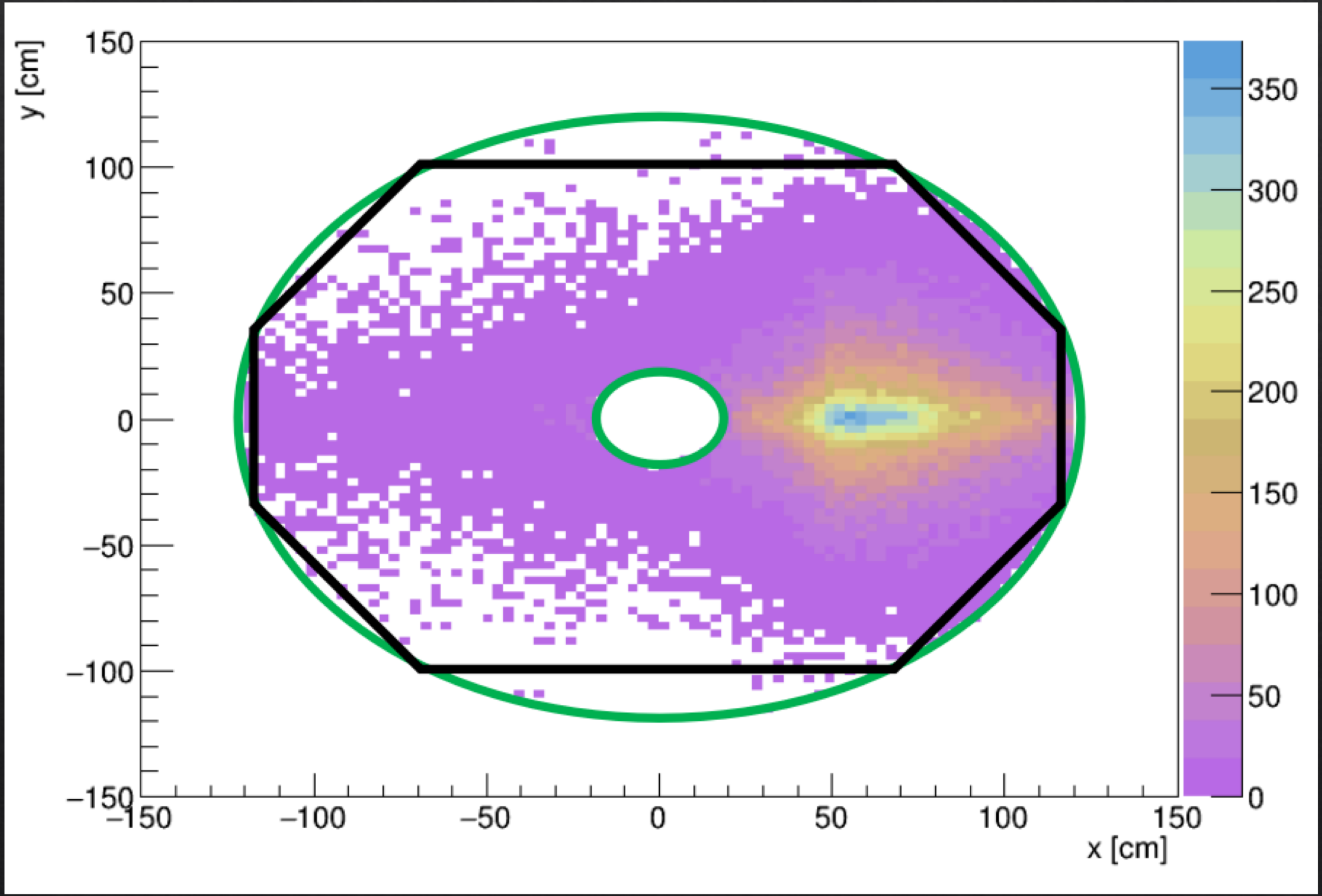
Simulated background hits



1000 events
10 background hits per wire plane in each event

Fig. 8. Distribution of simulated background hits in drift chambers.

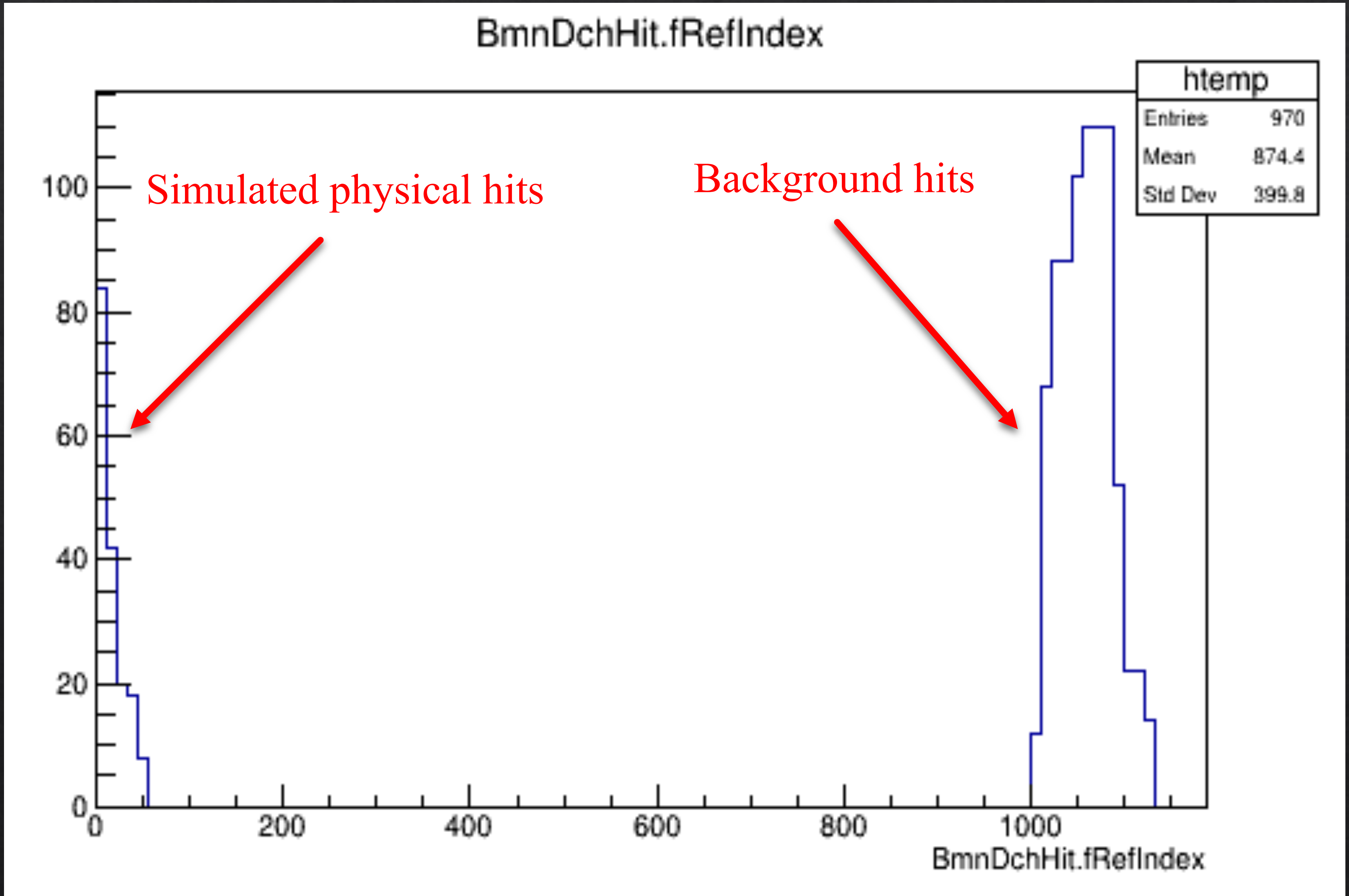
The geometry of the DCH for simulated background hits



1000 events
10 background hits per wire plane in each event

Fig. 9. Geometry for simulated background hits distribution. Green lines are circles of beam hole and outer sides of drift chambers. Black line - octagon fitted into circle.

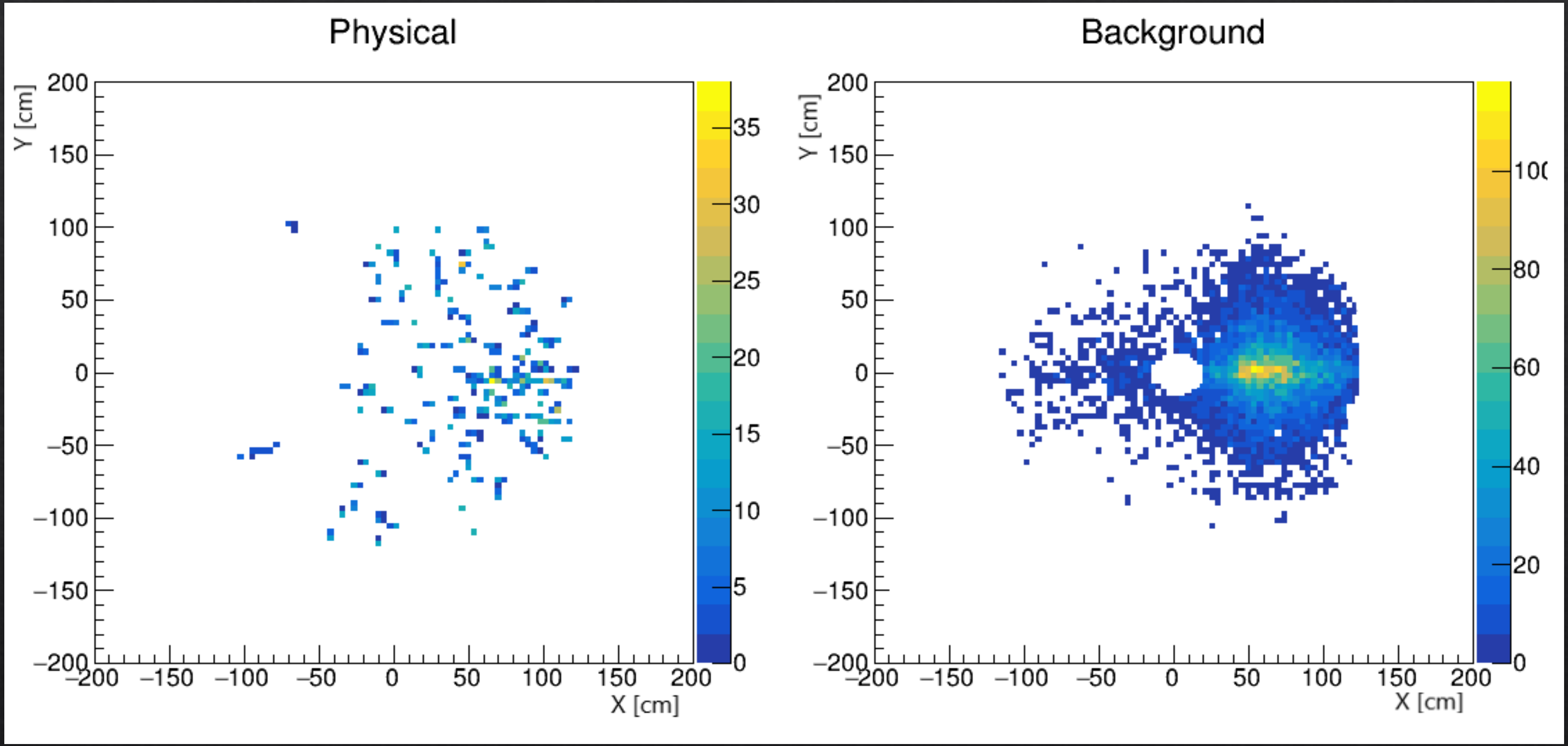
Separation of the simulated physical and background hits



For testing purposes reference index for background hits starts with 1000.

Fig. 10. Reference indices of simulated physical and background hits.

Simulated physical and background hits



100 events
5 protons per event
10 background hits per wire plane in each event

Fig. 11. Simulated physical and background hits in drift chambers.

Momentum of protons: 5 GeV/c
Azimuth angle range: (0; 360)
Polar angle in lab system range: (0; 5)

Simulated hits in the 1st DCH

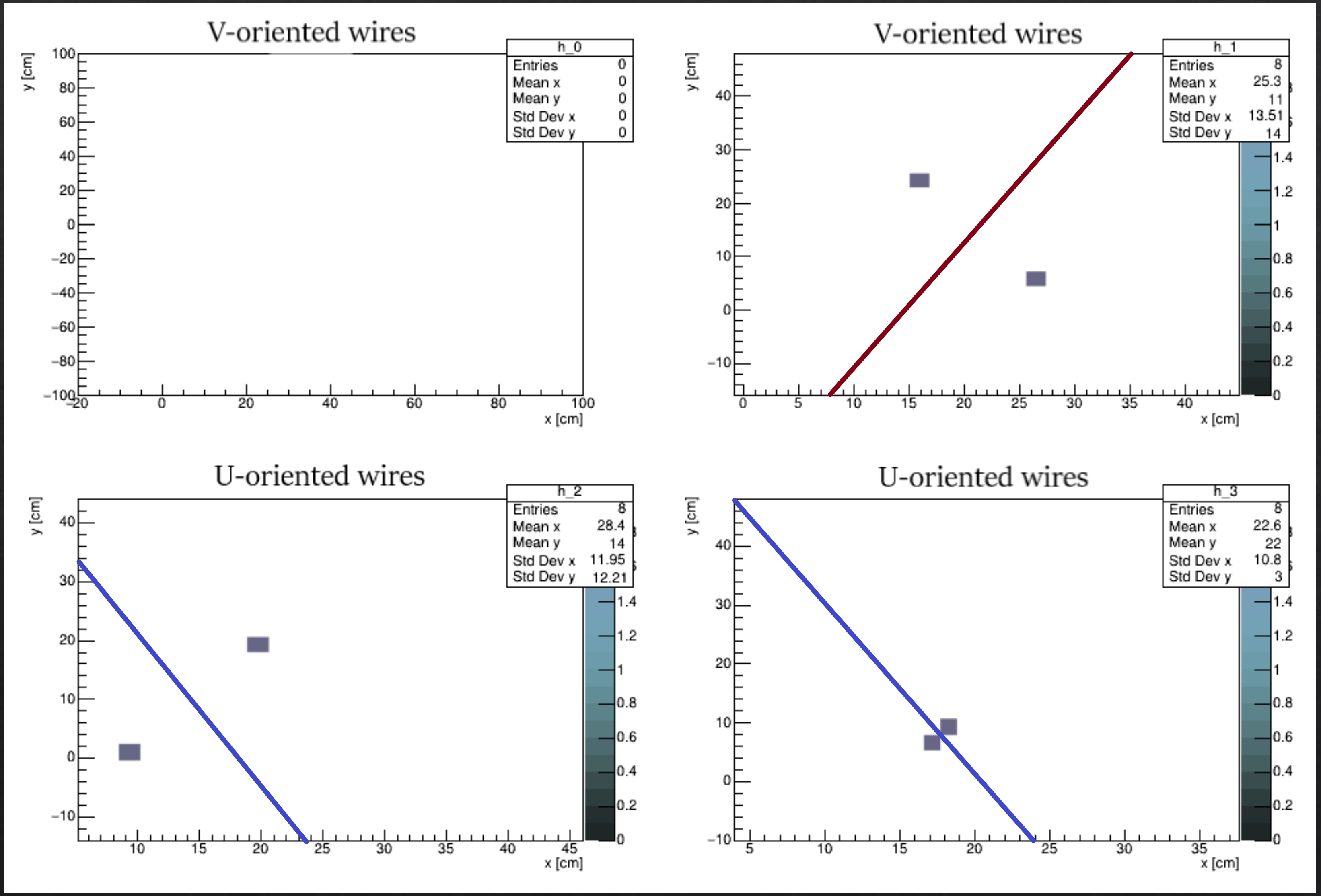
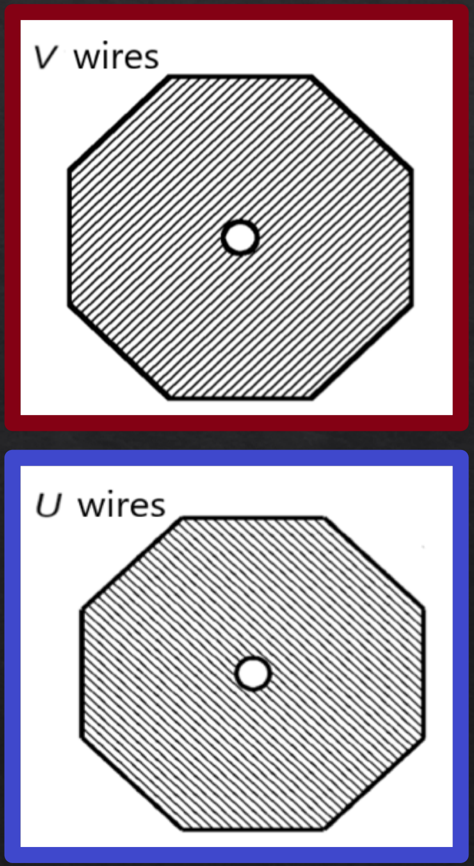


Fig. 12. Simulated hits on the 1st-4th wire planes in the 1st drift chamber.

Simulated physical and background hits are duplicated in the same way.



Simulated hits in the 1st DCH

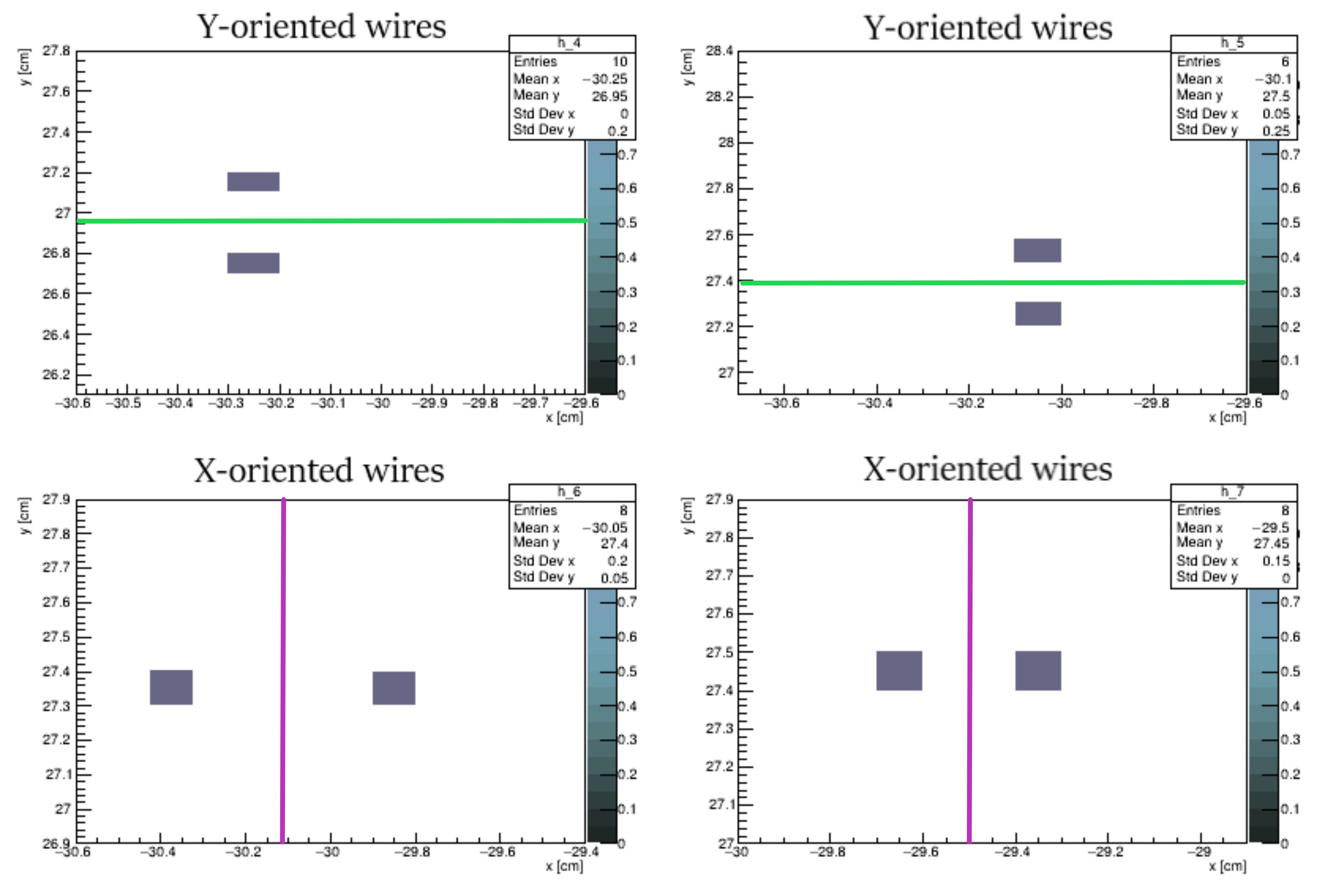
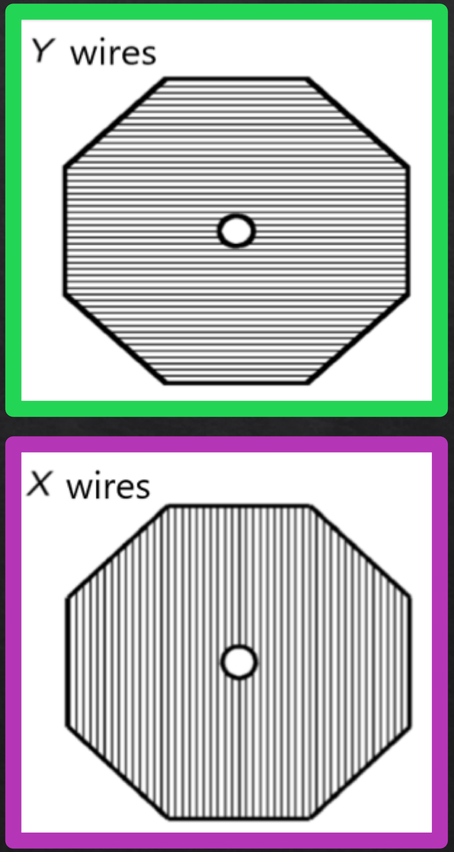


Fig. 13. Simulated hits on the 5th-8th wire planes in the first drift chamber.

Simulated physical and background hits are duplicated in the same way.



Results

1. The XY-profile of background noise was added into hit producing class for DCH of BM@N software.
2. The exact Z coordinates of planes are added into background generation algorithm of BM@N software.
3. The distribution of background hits is verified to be match the XY geometry of DCH.
4. A method of addition of background hits to simulation macro was developed.
5. A macro code for testing and visualization of the hits was developed.

The results of improved simulation will be used to determine the efficiency of drift chambers and improve the track reconstruction.

Thank you for your attention!

Backup slides

References

1. Official BM@N collaboration web-site: https://bmn.jinr.ru

2. The BM@N experiment at JINR: status and physics program / Baranov D., Kapishin M., Mamontova T., Pokatashkin G., Rufanov I., Vasendina V., Zinchenko A. - Dubna: JINR, 2018.

https://knepublishing.com/index.php/KnE-Energy/article/view/1757

3. Ján Fedorišin. Calibration, autocalibration and alignement of drift chambers in BMN experiment - Dubna: JINR, 2015.

http://bmnshift.jinr.ru/wiki/lib/exe/fetch.php?media=bmn_dch_oct2015_fedorishin.pdf

4. BM@N collaboration. BmnRoot: simulation and analysis framework for BM@N experiment - Dubna: JINR, 2016.

https://bmn.jinr.ru/wp-content/uploads/2019/07/BmnRoot_Start_Guide.pdf

NICA experiment

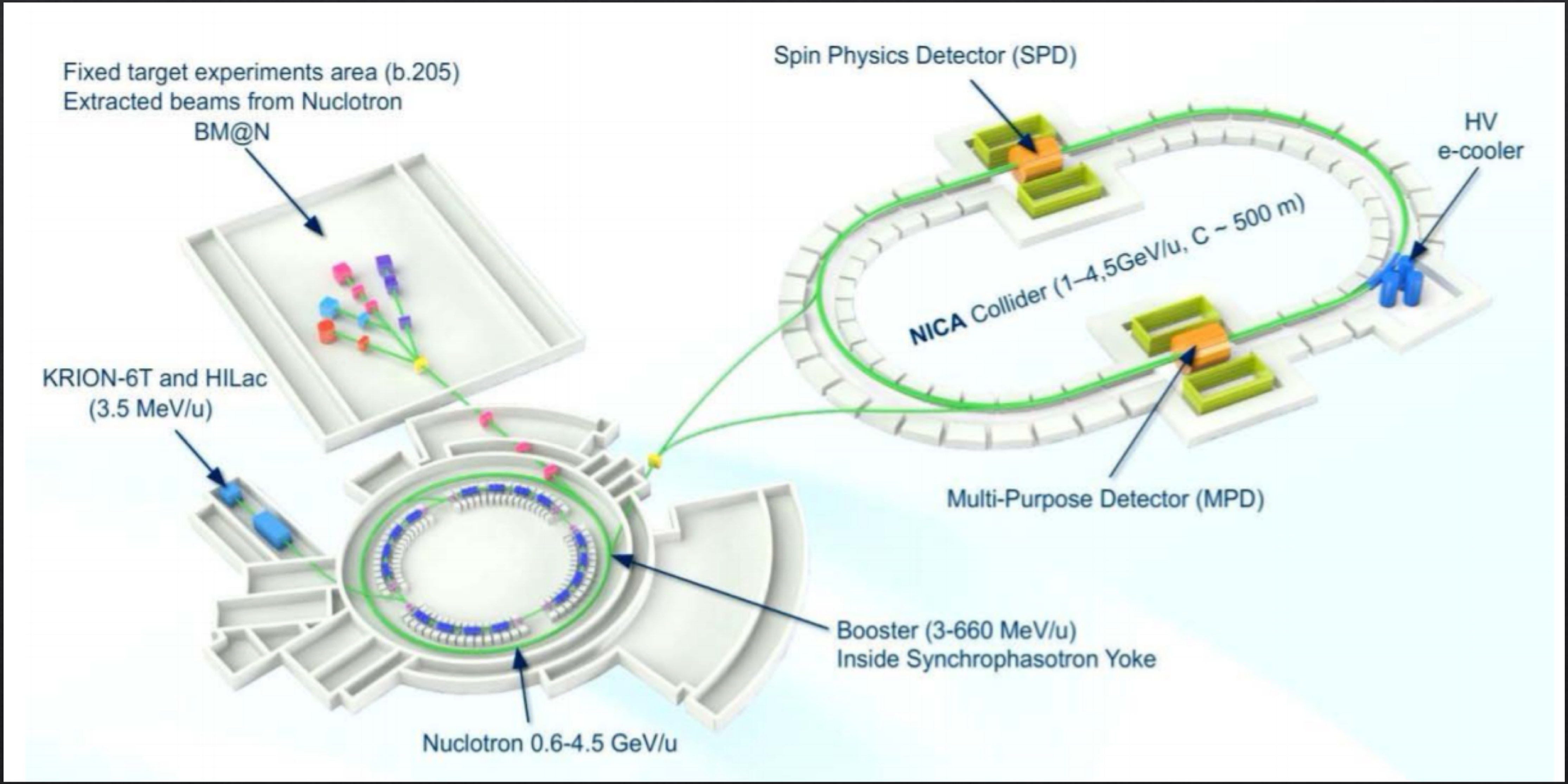


Fig. 14. NICA facility [4].

Operation of the drift chamber

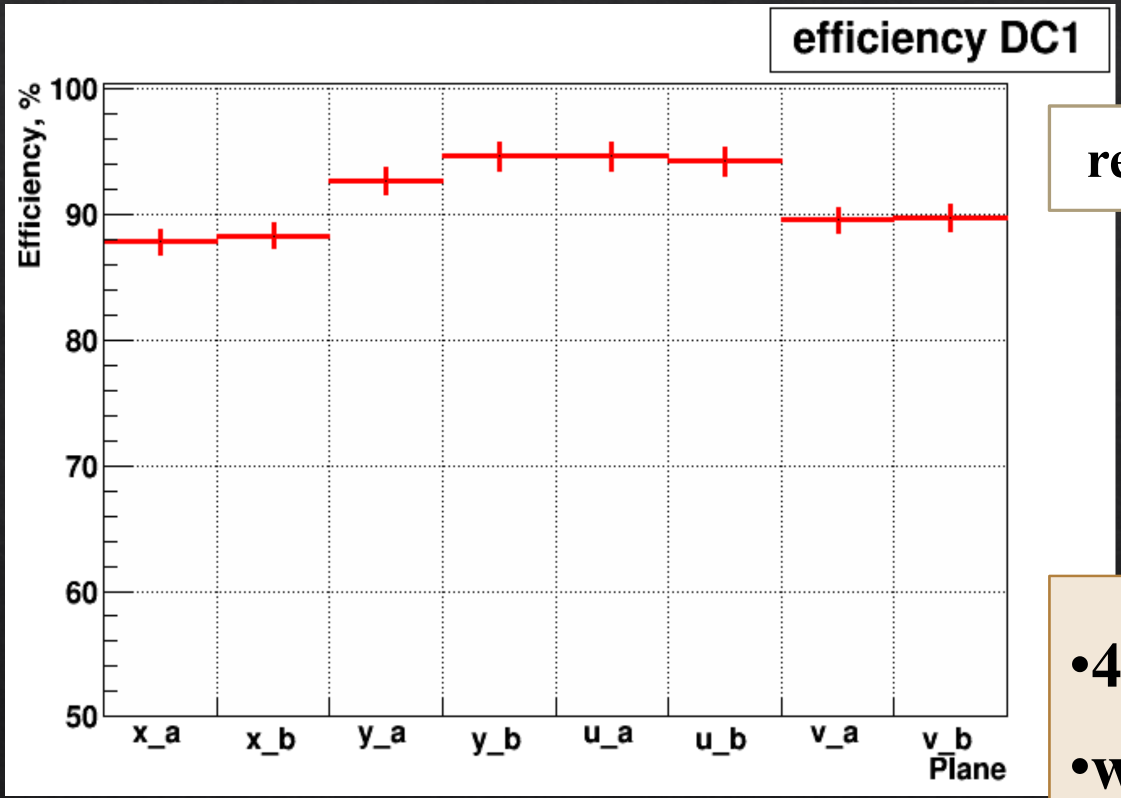
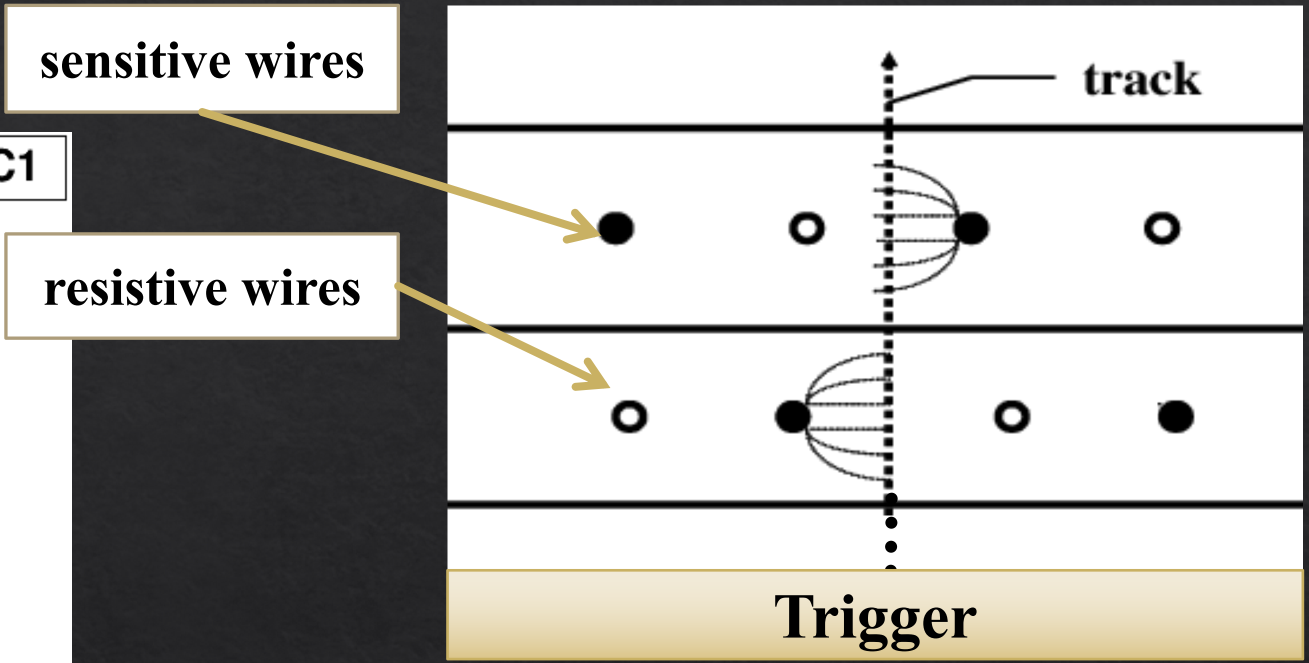


Fig. 15. Efficiency per layer in the 1st drift chamber.



- **4 double coordinate planes: 2x; 2y, 2u, 2v;**
- **wire angles 0°,90°,±45°;**
- **radius of central hole = 10 cm;**
- **2048 wires per chamber.**

Table 1. Fitting functions for X-profile distribution of experimental hits

Fitting function	Parameters		Corresponding interval	χ^2
$f_1(x)$	a_0	1349.04	$x \in [-139.3\,;\,43.5]$	160.371
	a_1	35.4982		
	a_2	1.17046		
	a_3	0.030353		
	a_4	0.000403174		
	a_5	$2.51526 \cdot 10^{-6}$		
	a_6	$5.89258 \cdot 10^{-9}$		
$f_2(x)$	A_1	15501.7	$x \in [42.5\,;\,63]$	8.85
	μ_1	56.4796		
	σ_1	13.2307		

Table 1. Fitting functions for X-profile distribution of experimental hits

Fitting function	Parameters		Corresponding interval	χ^2
$f_2(x)$	A_1	15501.7	$x \in [42.5\,;63]$	8.85
	μ_1	56.4796		
	σ_1	13.2307		
$f_3(x)$	A_2	13900	$x \in [62.5\,;83]$	12.72
	μ_2	65.423		
	σ_2	20.9521		
$f_4(x)$	b_0	129602	$x \in [81.7\,;153.2]$	417.9
	b_1	–3881.29		
	b_2	48.9642		
	b_3	–0.289986		
	b_4	0.00065102		

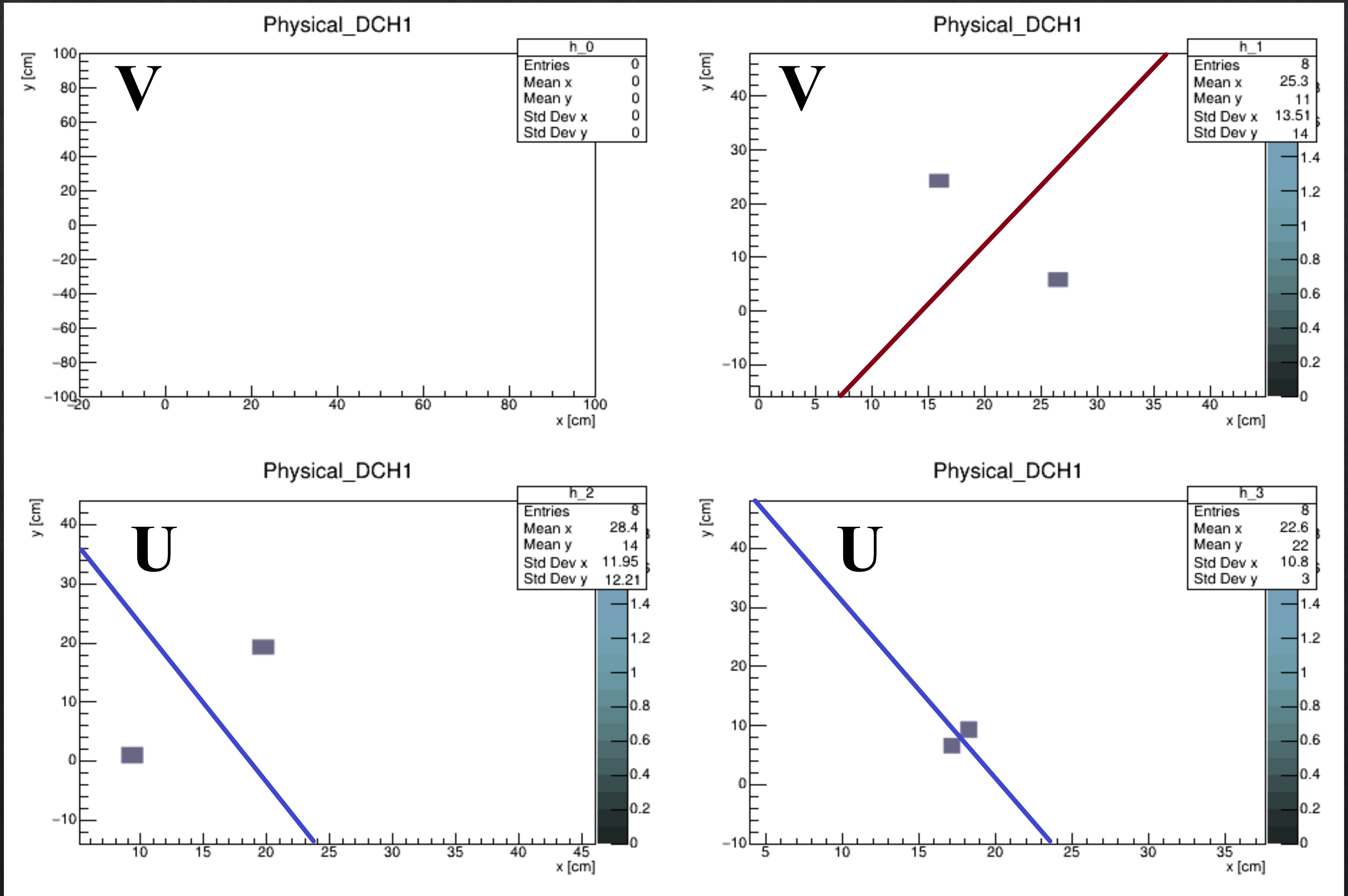
Table 2. Fitting functions for Y-profile distribution of experimental hits

Fitting function	Parameters		Corresponding interval	χ^2
$q_1(x)$	c_0	18358.5	$x \in [-96.5\,;-11]$	118.8
	c_1	718.389		
	c_2	11.0663		
	c_3	0.0783731		
	c_4	0.00021156		
$q_2(x)$	A_3	23800	$x \in [-12\,;12]$	80.66
	μ_3	0.297359		
	σ_3	9.8256		

Table 2. Fitting functions for Y-profile distribution of experimental hits

Fitting function	Parameters		Corresponding interval	χ^2
$q_3(x)$	p_0	20790.1	$x \in [11\,;103]$	176
	p_1	–895.049		
	p_2	16.085		
	p_3	–0.137006		
	p_4	0.000449122		

Simulated physical hits in the 1st DCH



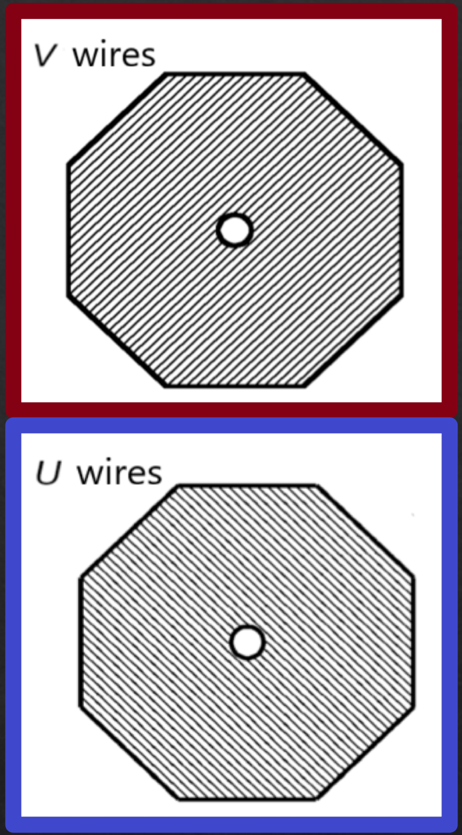
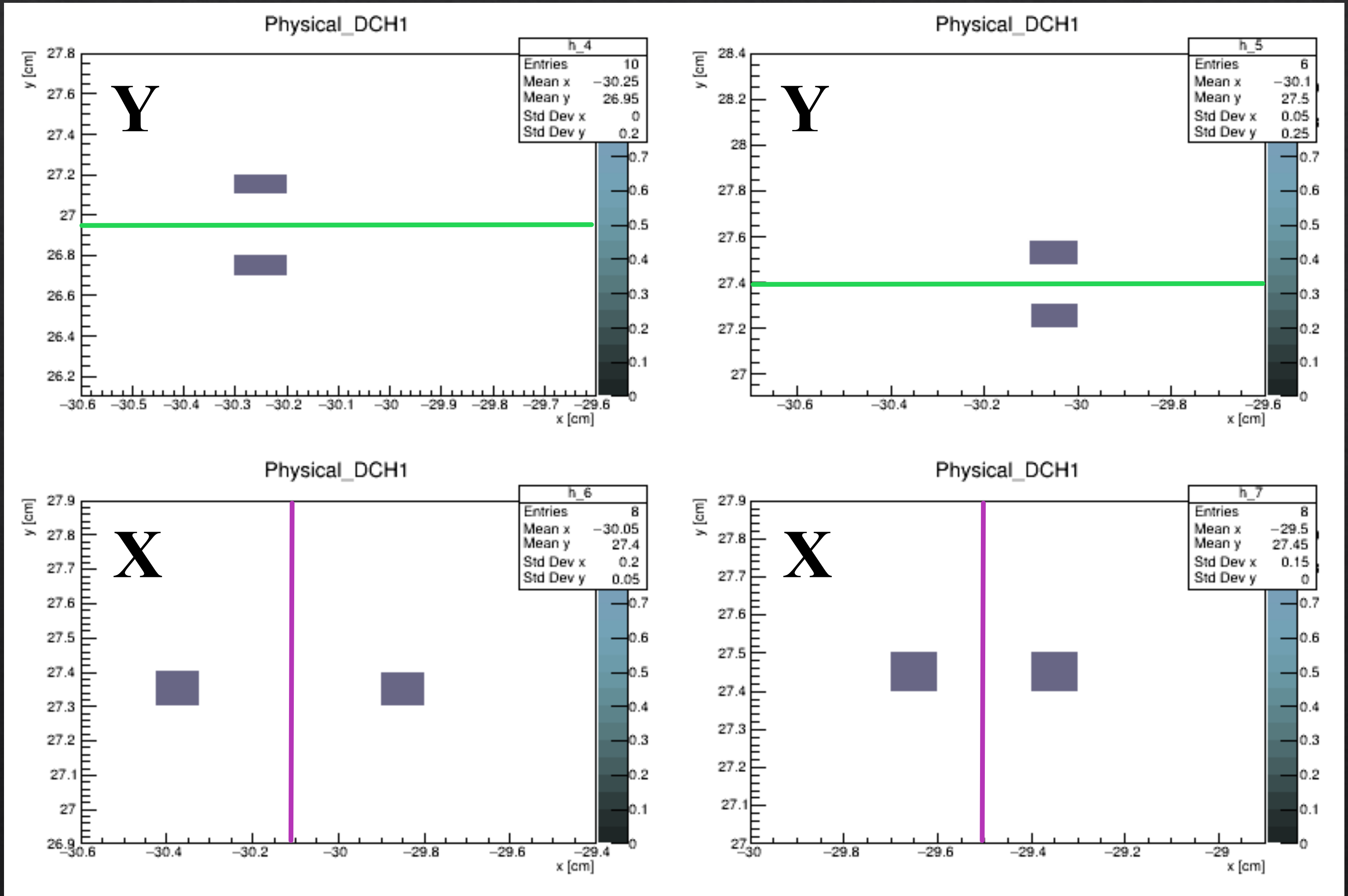
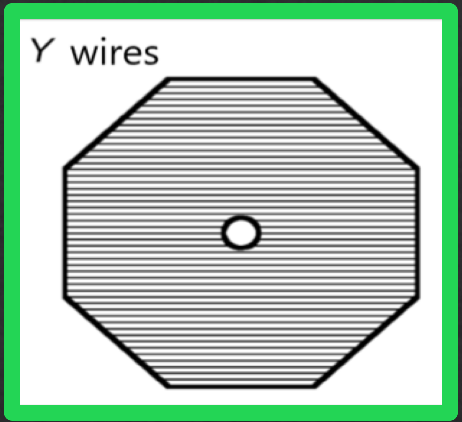


Fig. 16. Simulated physical hits on the 1st-4th wire planes in the first drift chamber.

Simulated physical hits in the 1st DCH





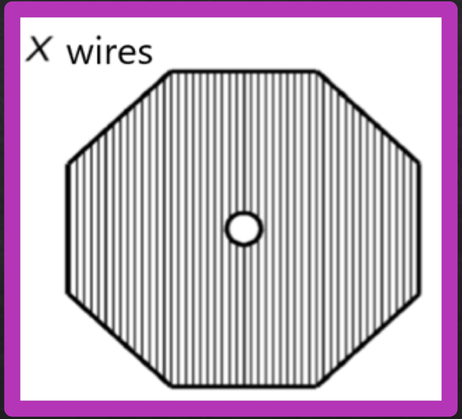


Fig. 17. Simulated physical hits on the 5th-8th wire planes in the first drift chamber.

Simulated physical hits in the 2nd DCH

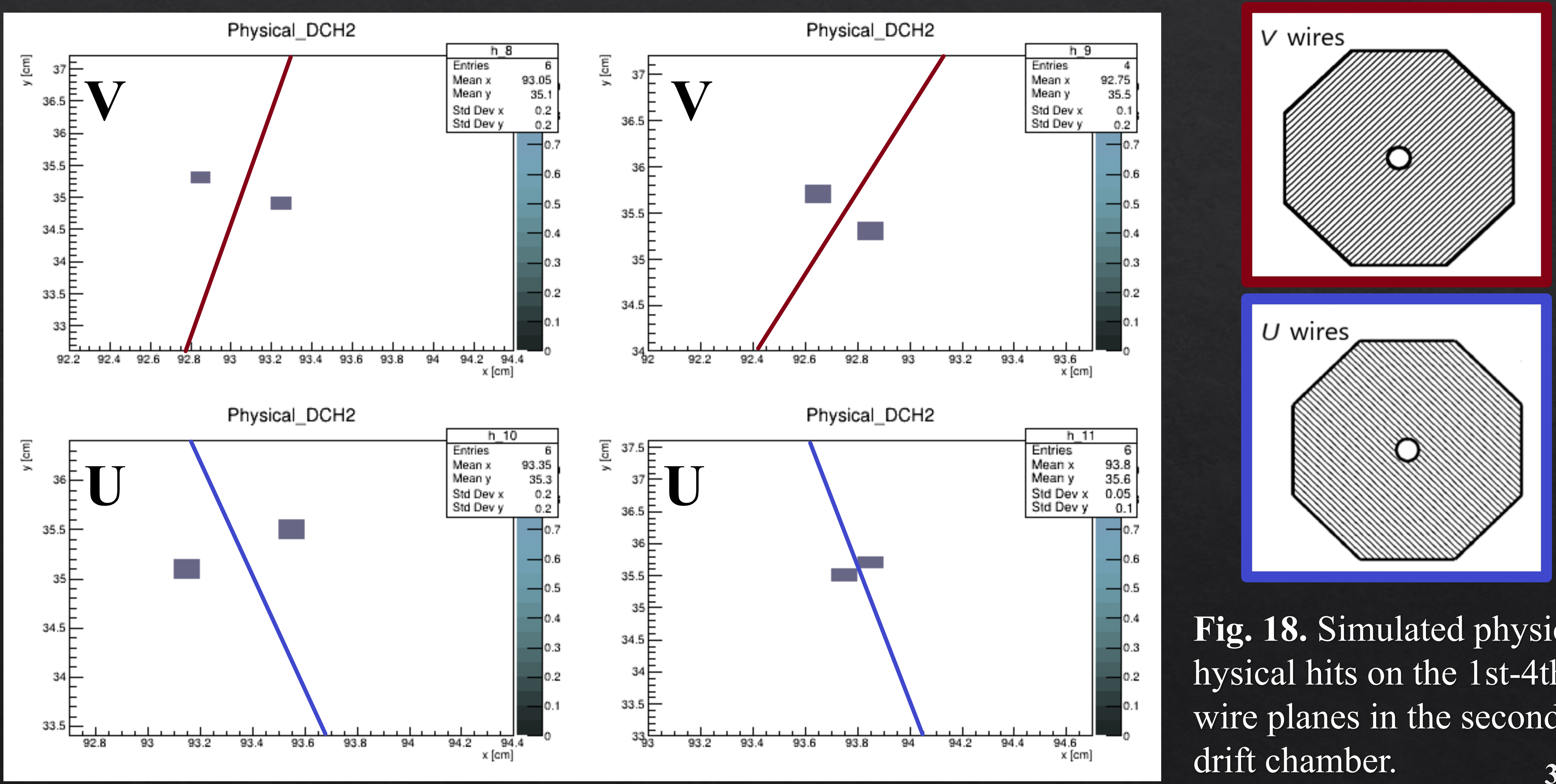
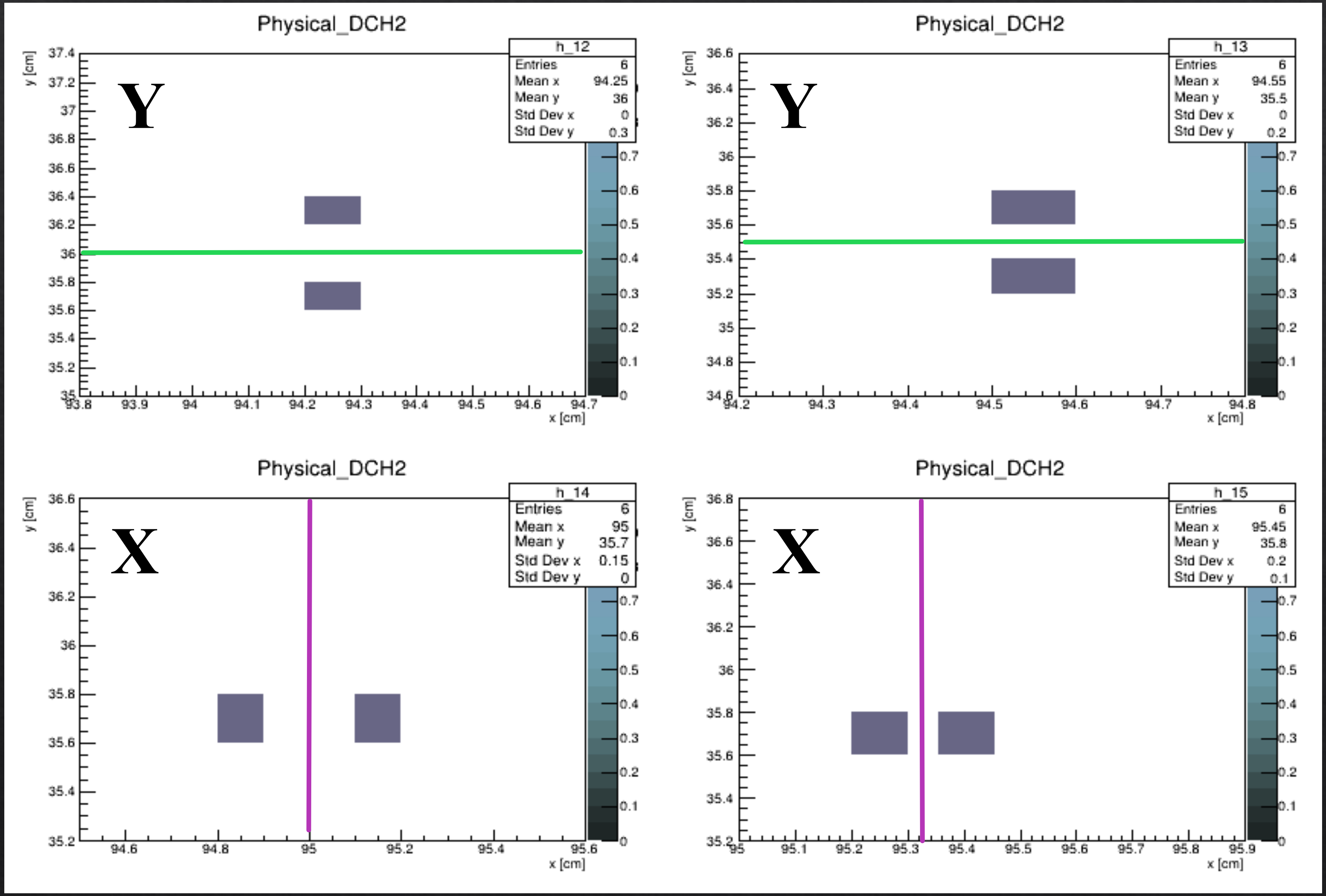
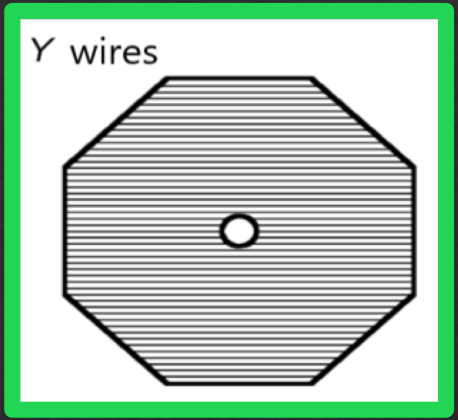


Fig. 18. Simulated physical hysical hits on the 1st-4th wire planes in the second drift chamber.

Simulated physical hits in the 2nd DCH





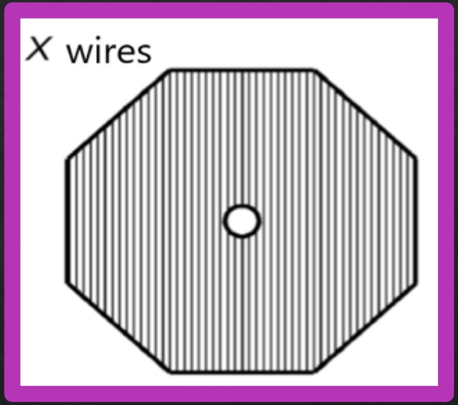
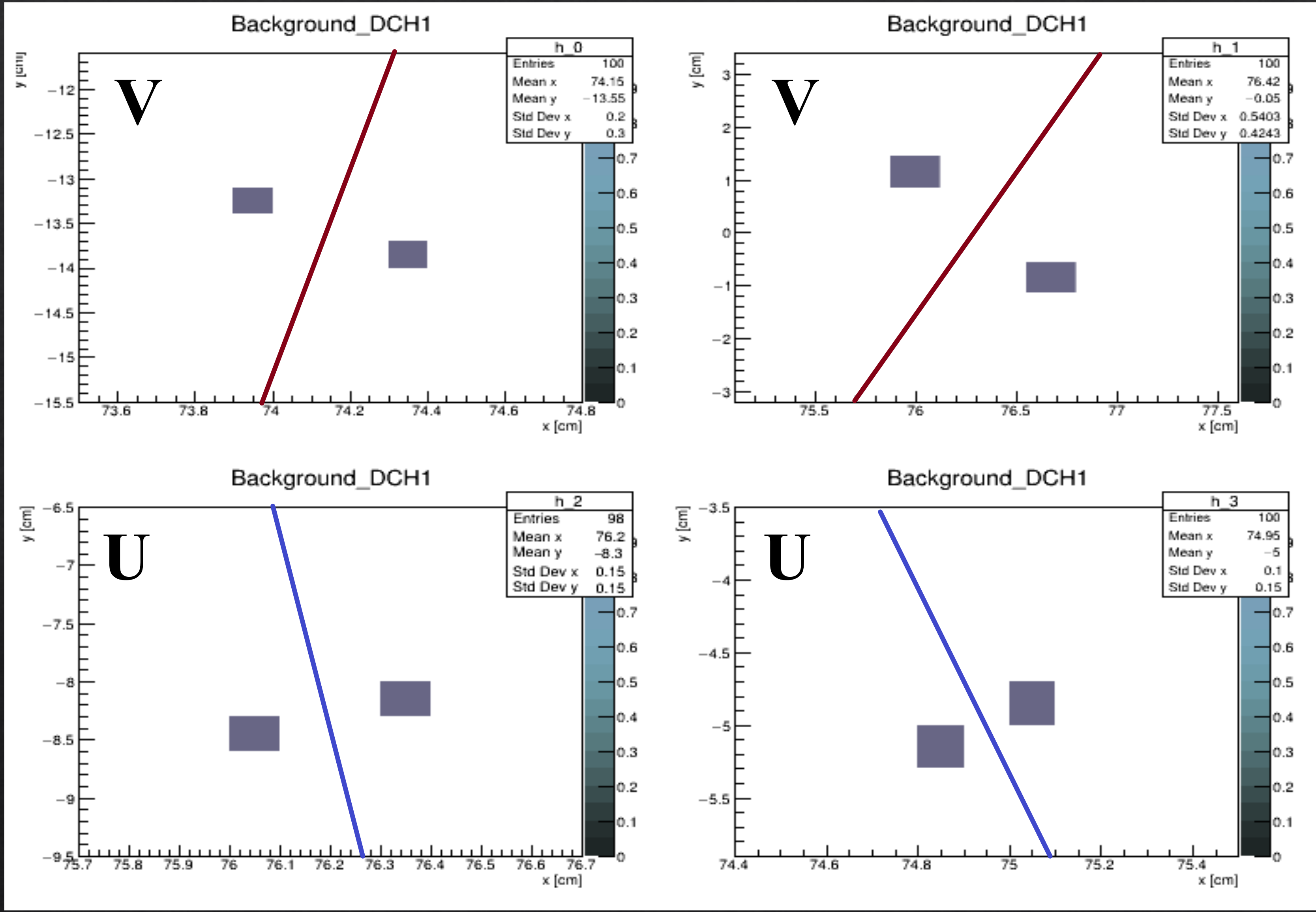


Fig. 19. Simulated physical hits on the 5th-8th wire planes in the second drift chamber.

Simulated background hits in the 1st DCH



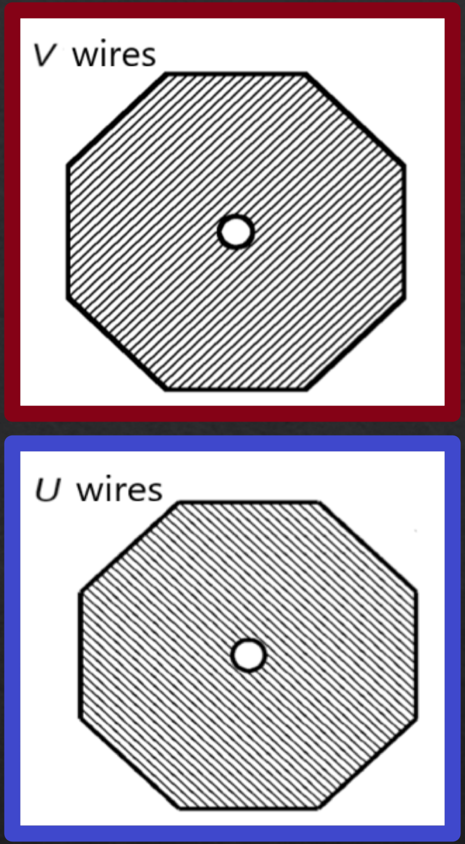
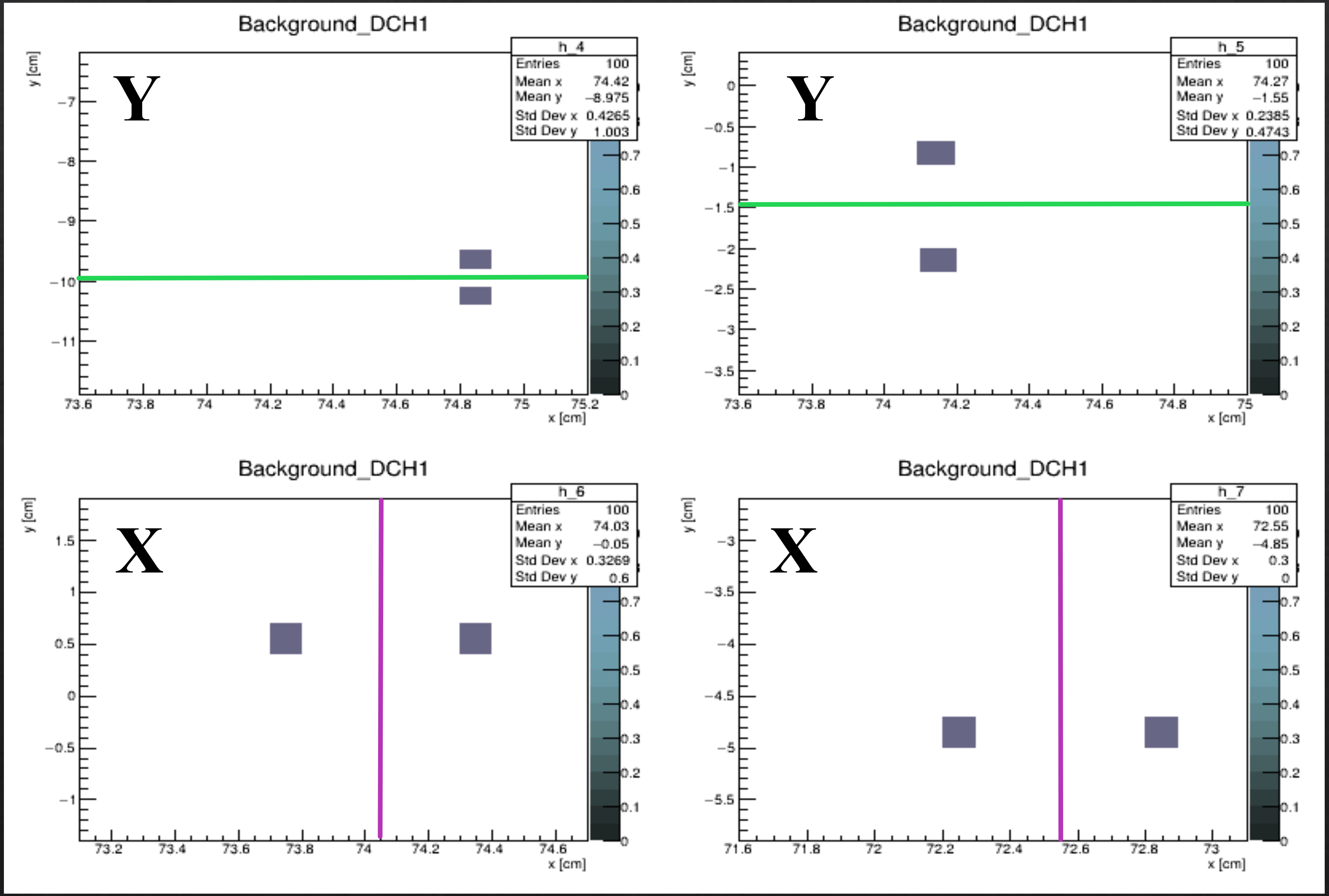


Fig. 20. Simulated background hits on the 1st-4th wire planes in the first drift chamber.

Simulated background hits in the 1st DCH



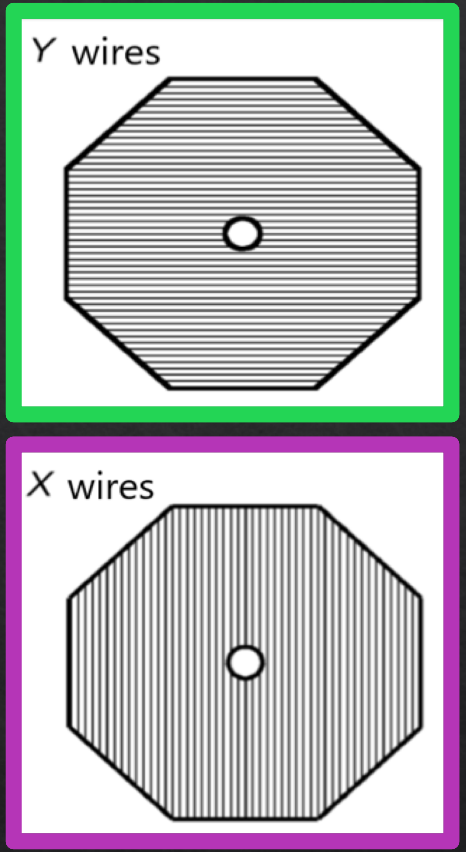


Fig. 21. Simulated background hits on the 5th-8th wire planes in the first drift chamber.

Simulated hits in drift chambers

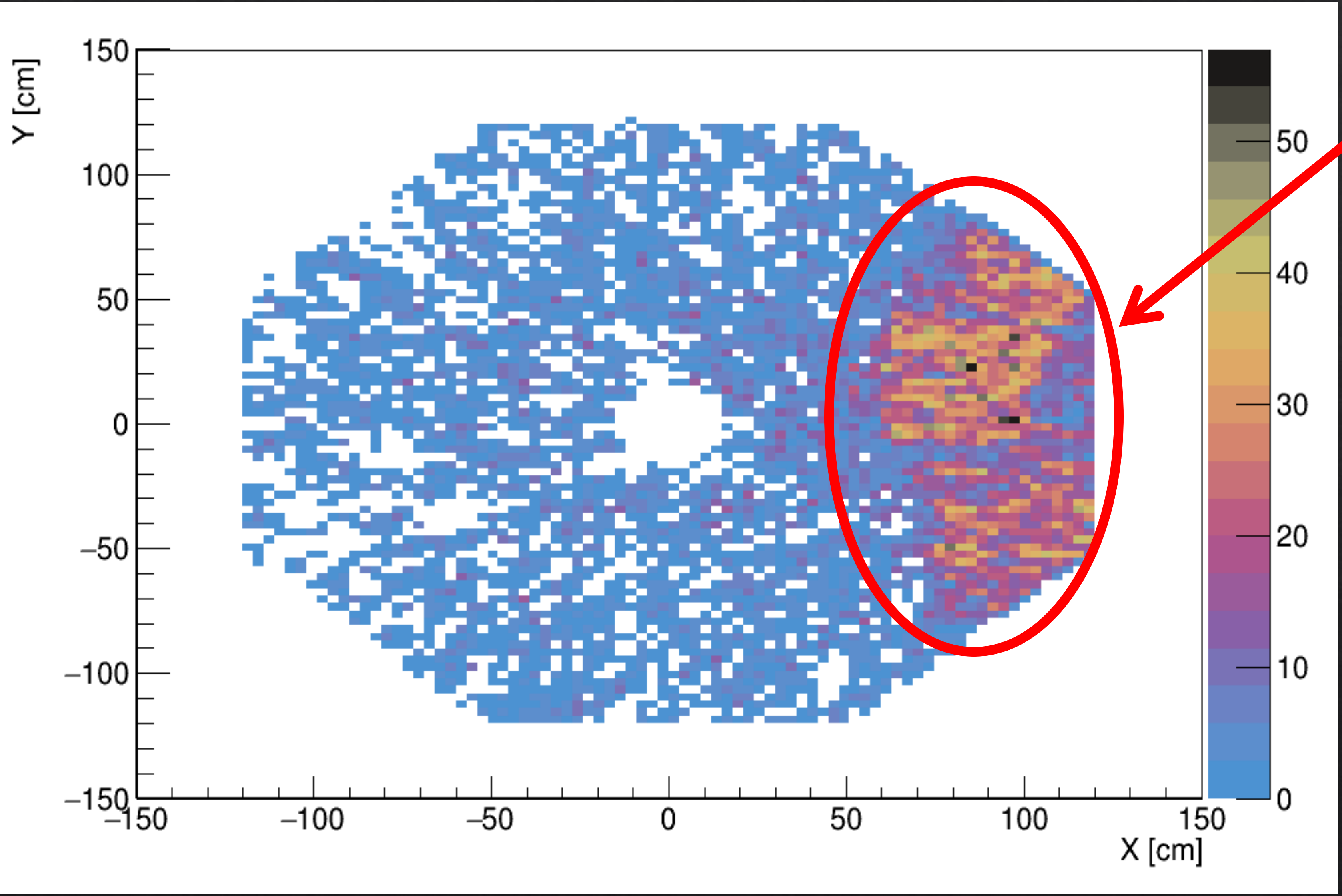


Fig. 22. Hits, generated with a single proton events in drift chambers.

Charged particles are bent to the side of chambers because of **magnetic field** influence.

1000 events
1 proton per event
Momentum of particles:
5 GeV/c
Azimuth angle range:
(0; 360)
Polar angle in lab system range:
(0; 5)