Application of BM@N Si-microstrip detectors at muon stand for testing straw detectors

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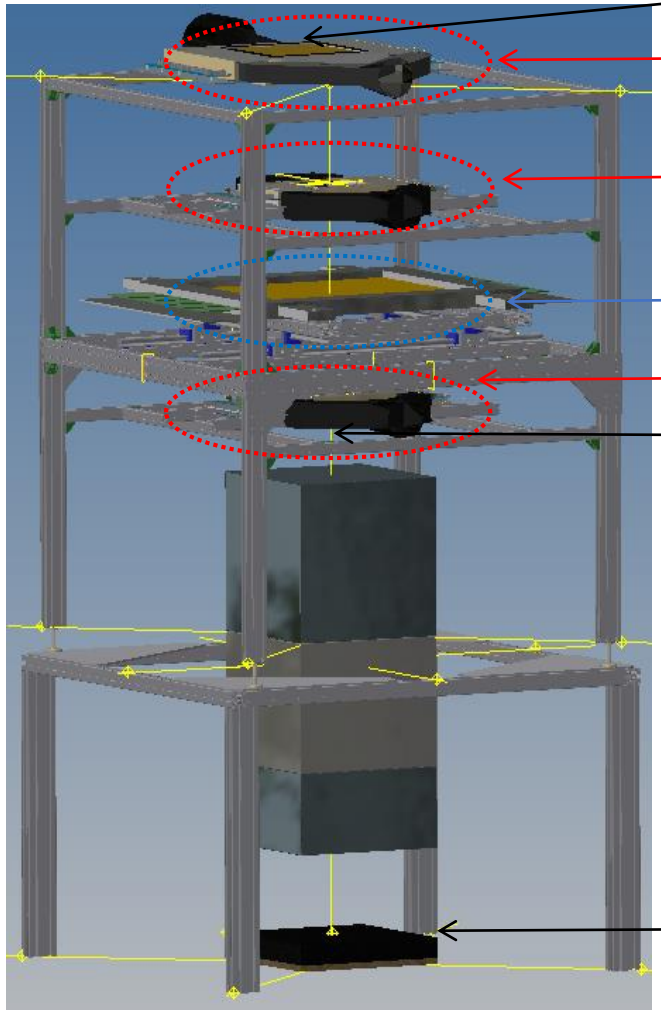
Motivation

After BM@N technical run in spring 2018, the first physical stage of the experiment will begin in 2021. For stop time Silicon tracking modules of BM@N Forward Silicon Detector are applied at muon stand to test and measure R-t characteristics of straw detectors (6 mm diameter, produced by JINR, Dubna) by reconstructing cosmic rays tracks (based on bmnroot software).

Muon stand setup



3D Model of muon stand

Cooling system

1st Scintillation trigger (150x150 mm^2)

1st Silicon Tracking Detector Station

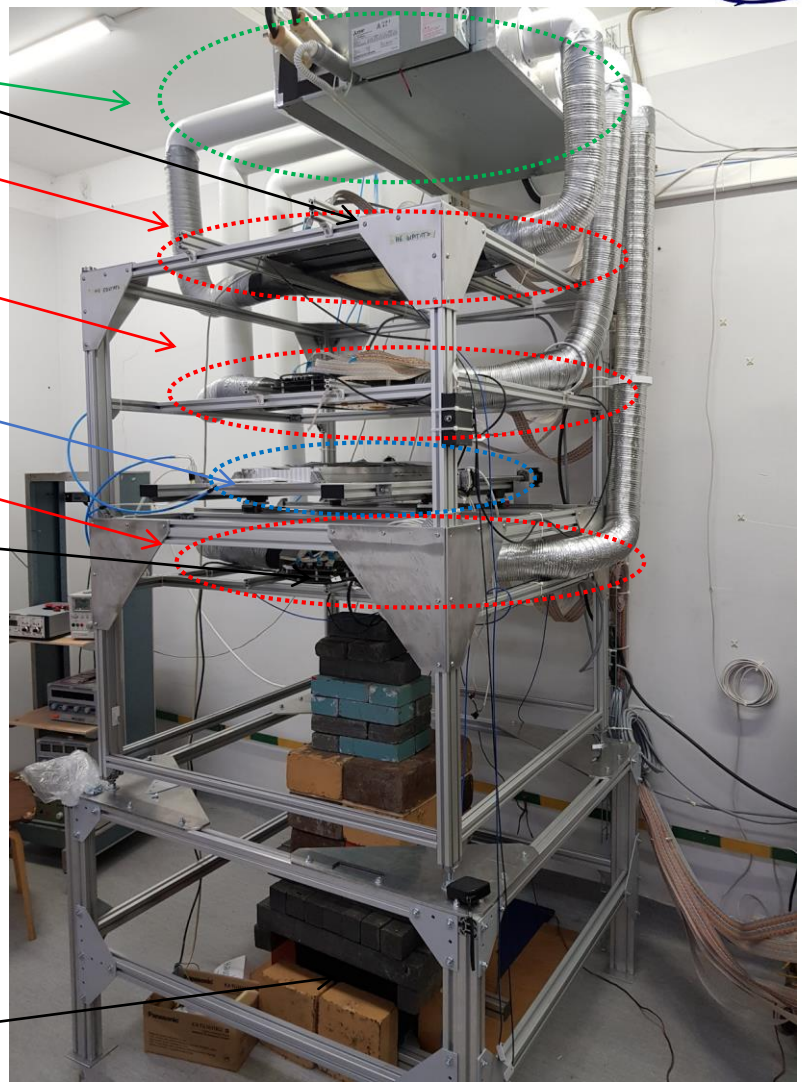
2nd Silicon Tracking Detector Station

2 straw detectors testing planes

3d Silicon Tracking Detector Station

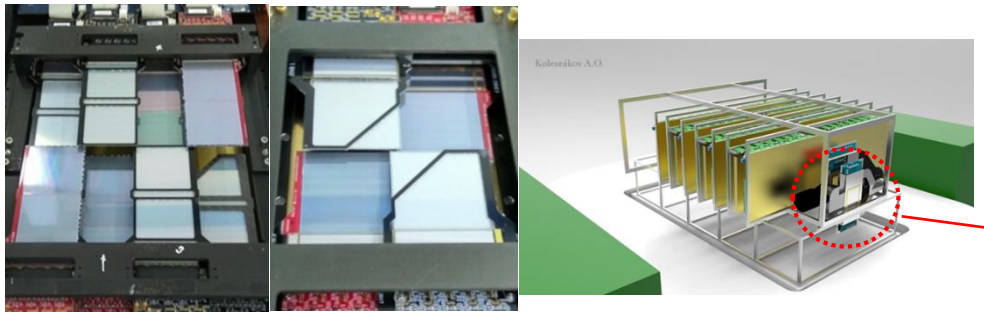
2nd Scintillation trigger (150x150 mm^2)

3d Scintillation trigger (400x400 mm^2)

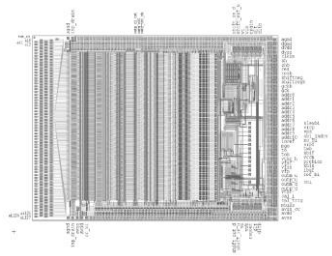


Assembled muon stand (October 2019)

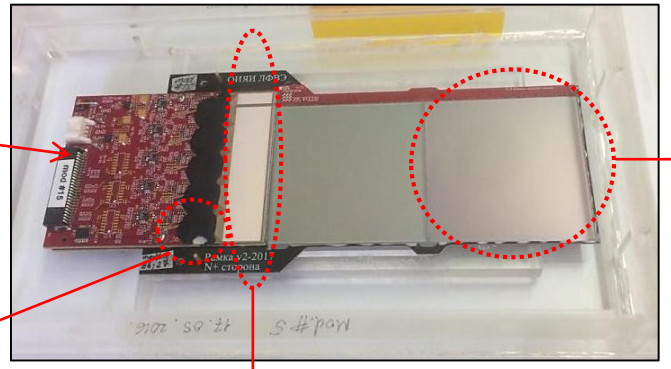
BM@N Silicon detector module design

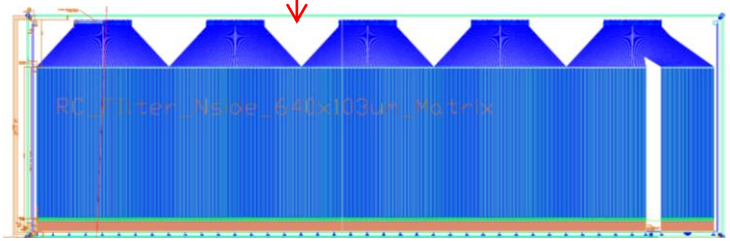


Positions of Forward and Vertex Silicon Detector at BM@N technical run March 2018
[M.Kapishin , Status of Baryonic Matter at Nuclotron, October 2018]

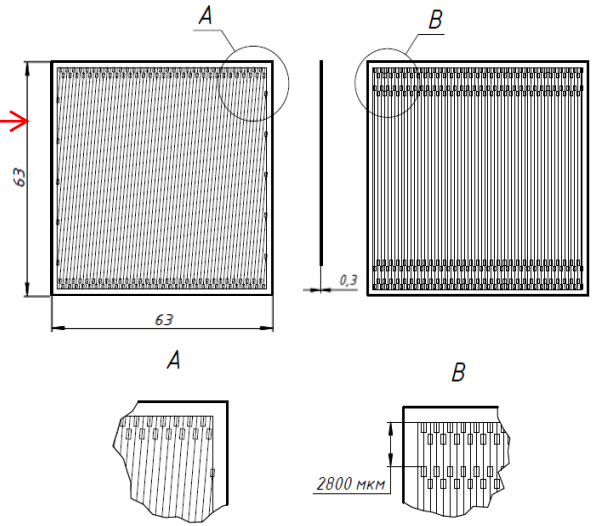


ASIC VATAGP7.1 (5 chips on each side of module)
Number of CSA: 128 channels
Dynamic range: ±30 fC
Peaking time (slow/fast shaper): 500 ns/ 50ns
ASIC noise (ENC): 70e +12e/pF (typ.)
Voltage supply: +1.5 V, -2.0 V
Gain from input to output buffer: 16.5 μA/fC
Output Serial analog multiplexer clock speed: 3.9 MHz
Power dissipation per channel: 2.2 mW



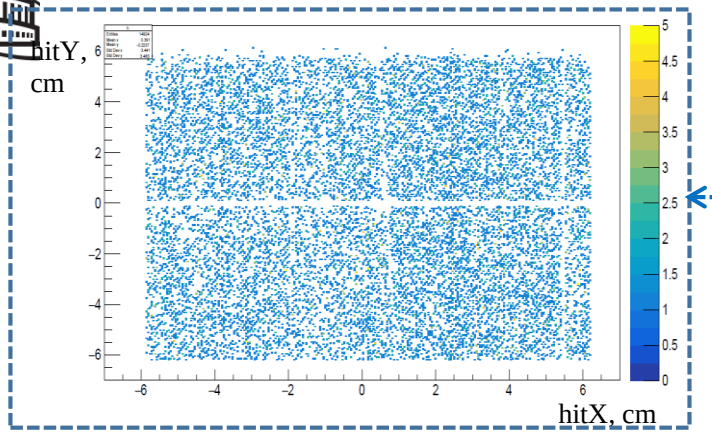


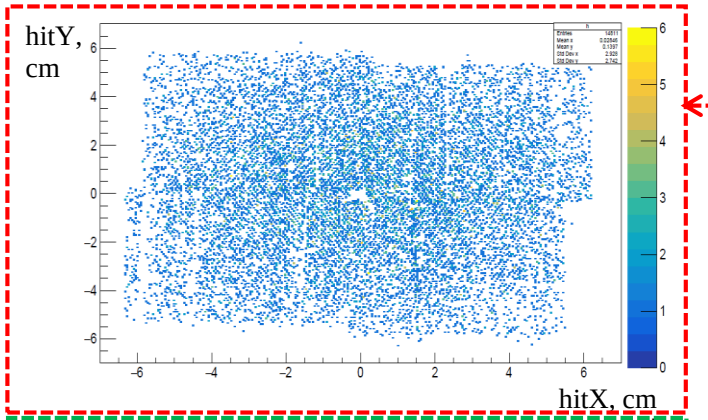
Pitch Adapter (n+) side
sapphire plates with Si-epitaxial layer Silicon On Insulator (SOI)
Number of channels: 640
Value of poly-Si resistors: ≈ 1 MΩ
Value of integrated capacitors: ≈ 120 pF
Capacitor working voltage: 100 V
Capacitor breakdown voltage: >150 V

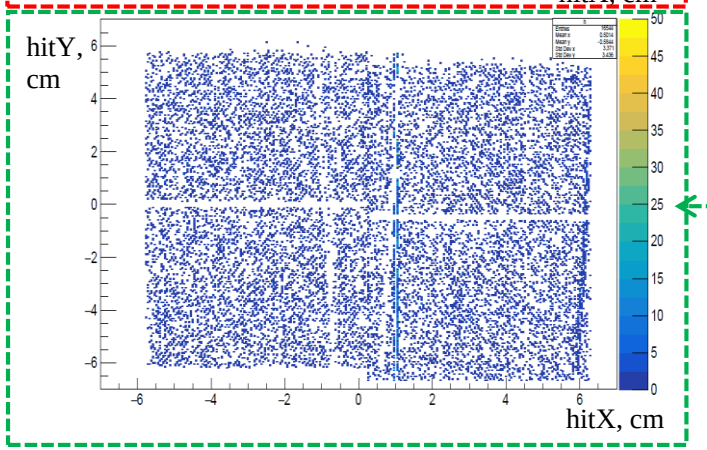


Size: 63x63x0,3 mm^3 (on 4” – FZ-Si wafers)
Topology: double sided microstrip (DSSD) (DC coupling)
Pitch p^+ strips: 95 μm;
Pitch n^+ strips 103 μm;
Stereo angle between p^+/n^+ strips: 2.5^0
Number of strips/DSSD: 640 (p^+)× 614(n^+)
Number of strips/module: 640 (p^+)× 640(n^+)

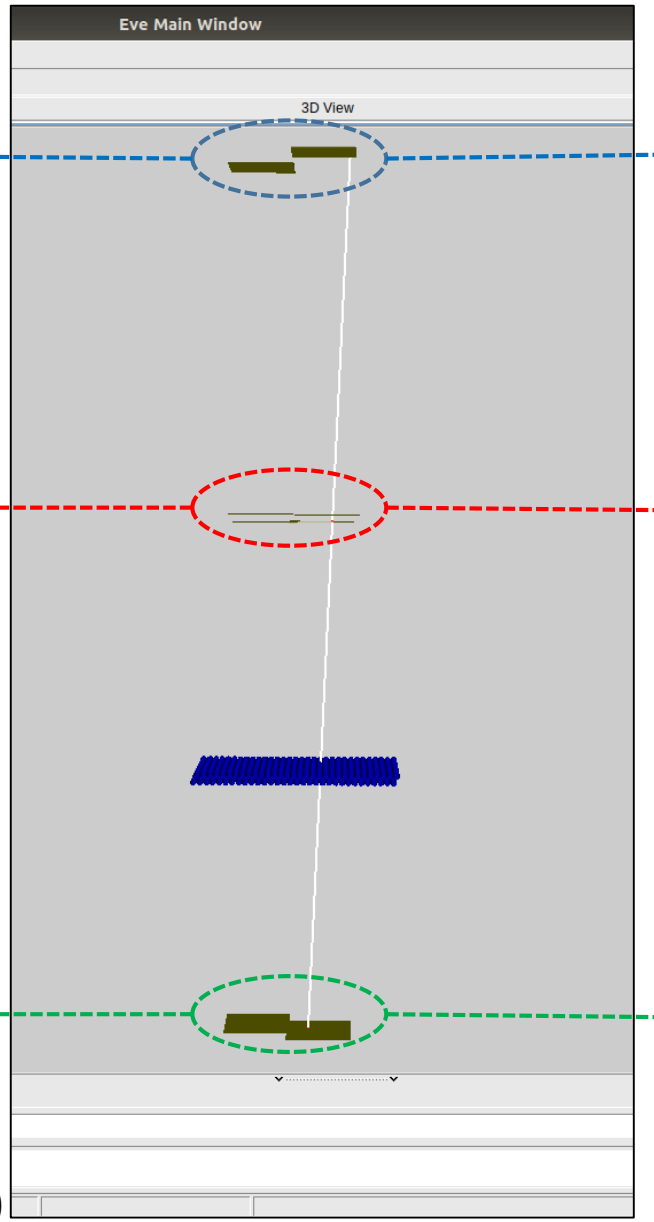
Events reconstruction



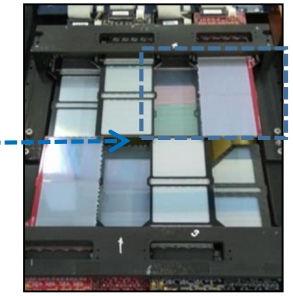


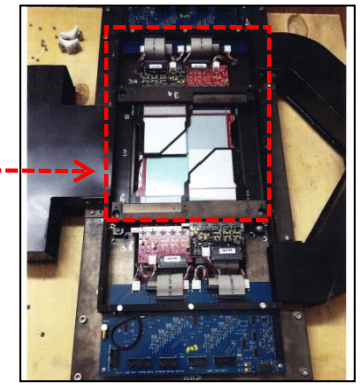


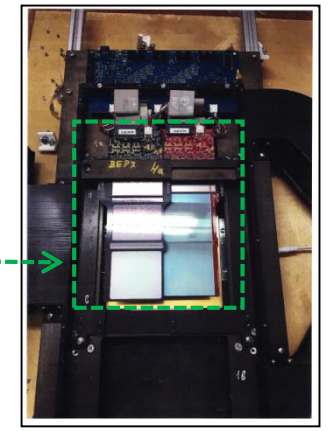
a)



b)



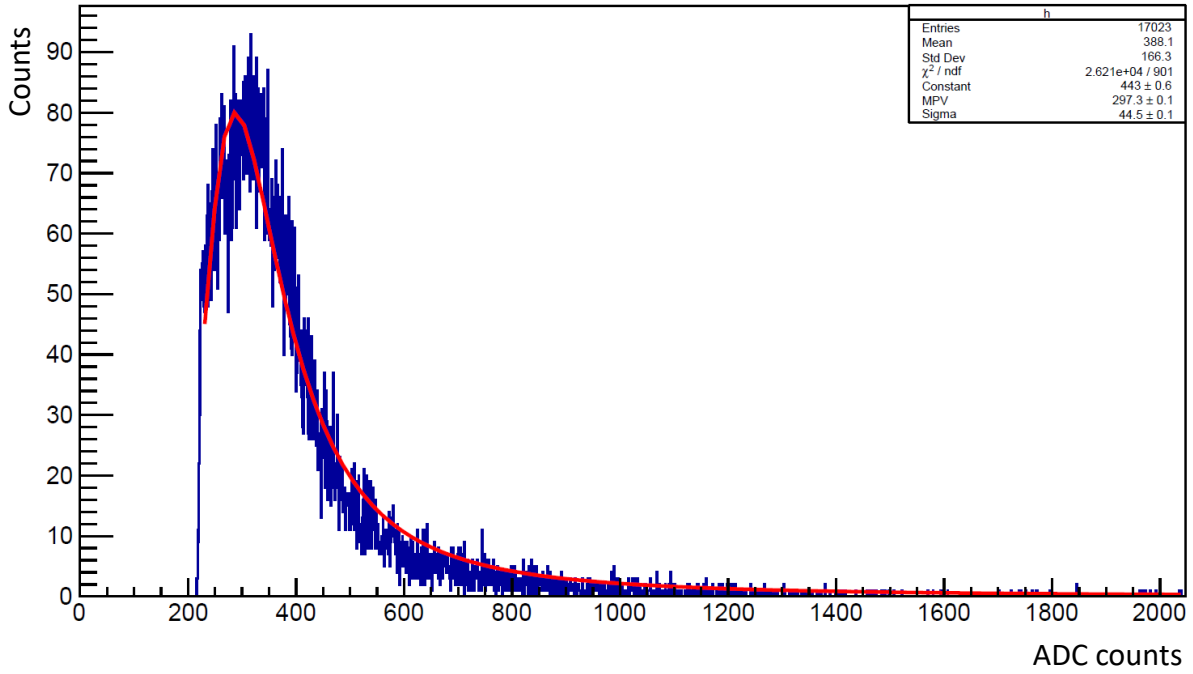


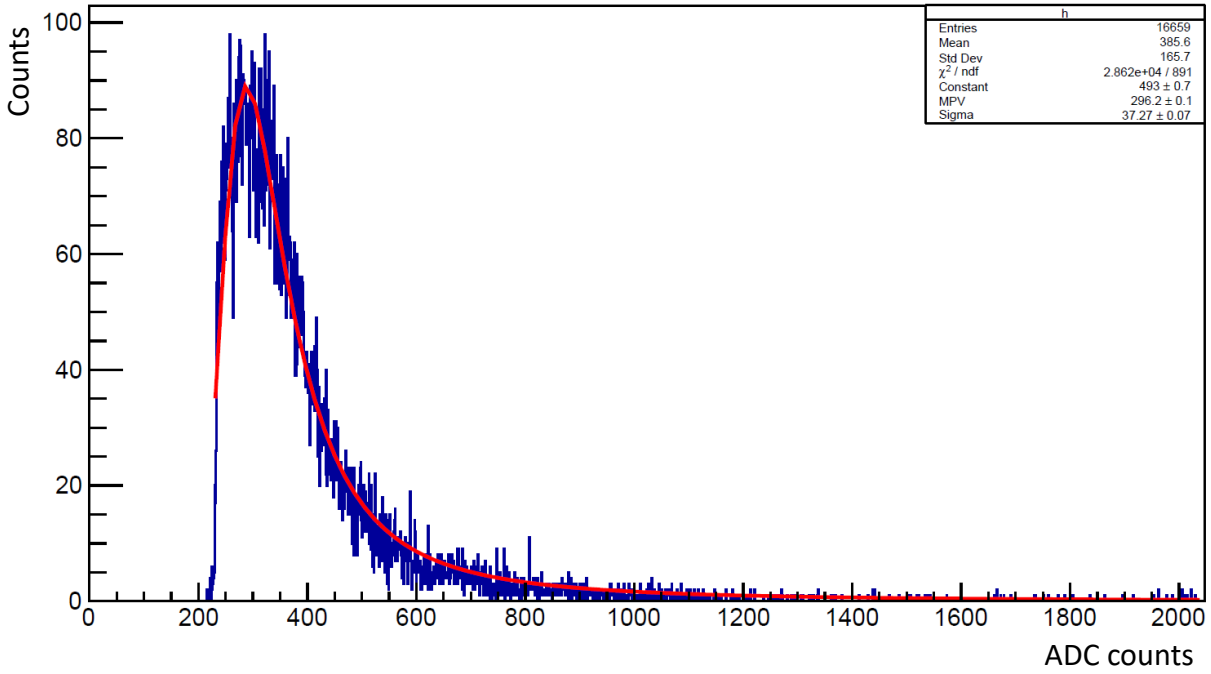


c)

a) Hits plots in BM@N Si-modules;
b) Reconstructed track in muon stand (based on bmnroot framework);
c) BM@N Silicon modules;

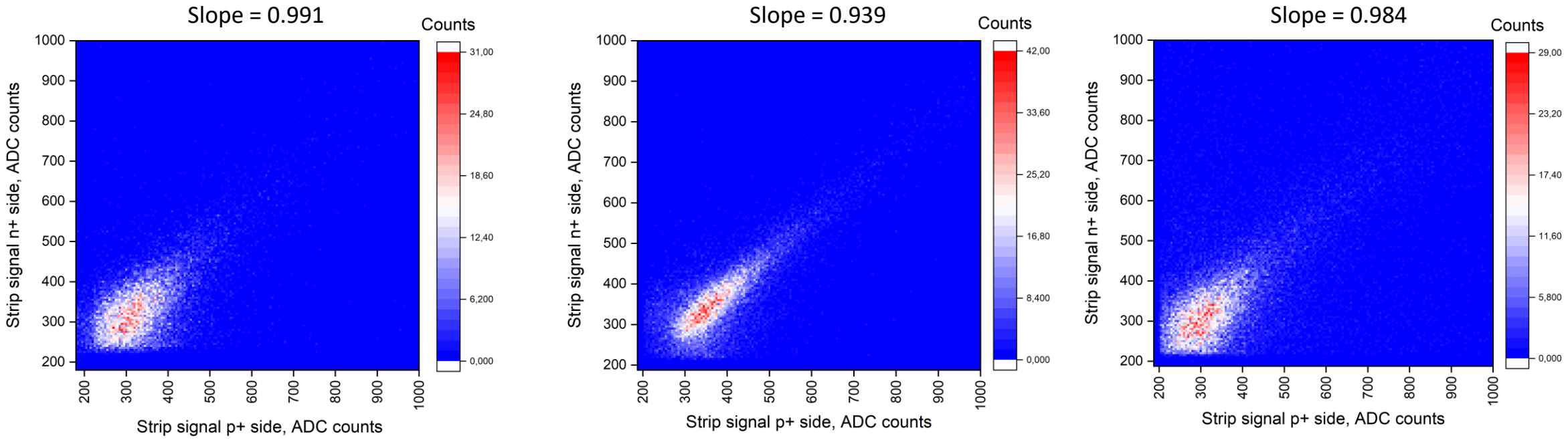
Tracking performance





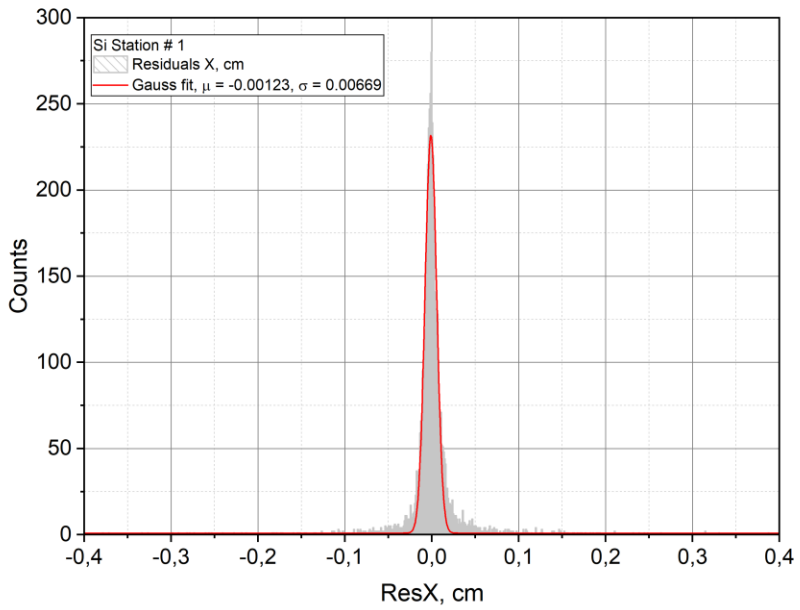
Amplitude distribution after noise cut (for 640 strips) of module #1 p+ (left) and n+ (right) sides 1st Silicon Tracking Detector Stations at Run #671 April 2019 (without Lead shield – no low-energy particle filtering);

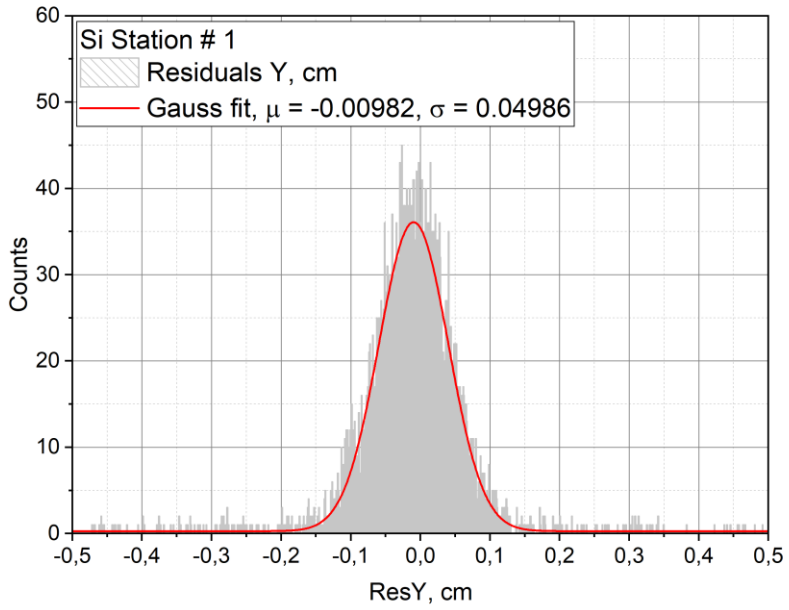
Tracking performance

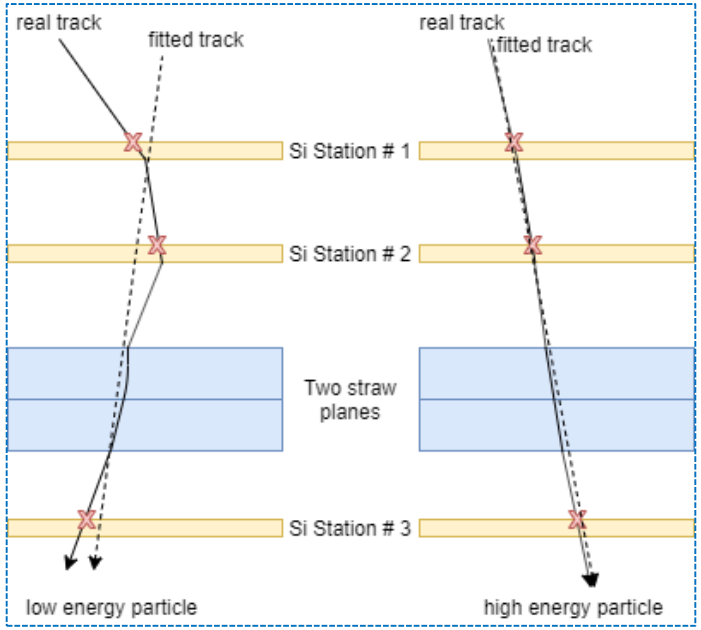


Amplitude p+/n+ strips correlation plots of 1st (left) 2nd (center) and 3d (right) Silicon Tracking Detector Stations at Run #671 April 2019 (without Lead shield – no low-energy particle filtering);

Tracking performance





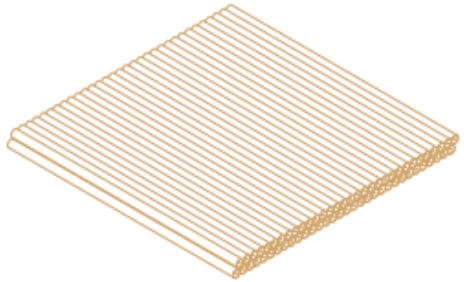


Schematic view of charged particle tracking performance with different energy

X (left) end Y (right) residual distributions of 1st Silicon Tracking Detector Station at Run #671 April 2019
(Track fitted with straight line => multiple Coulomb scattering wasn't take into account)

Si station #	σ_X, μm	σ_Y, μm
1	66.9	498.6
2	112.9	839.4
3	46.9	347.4

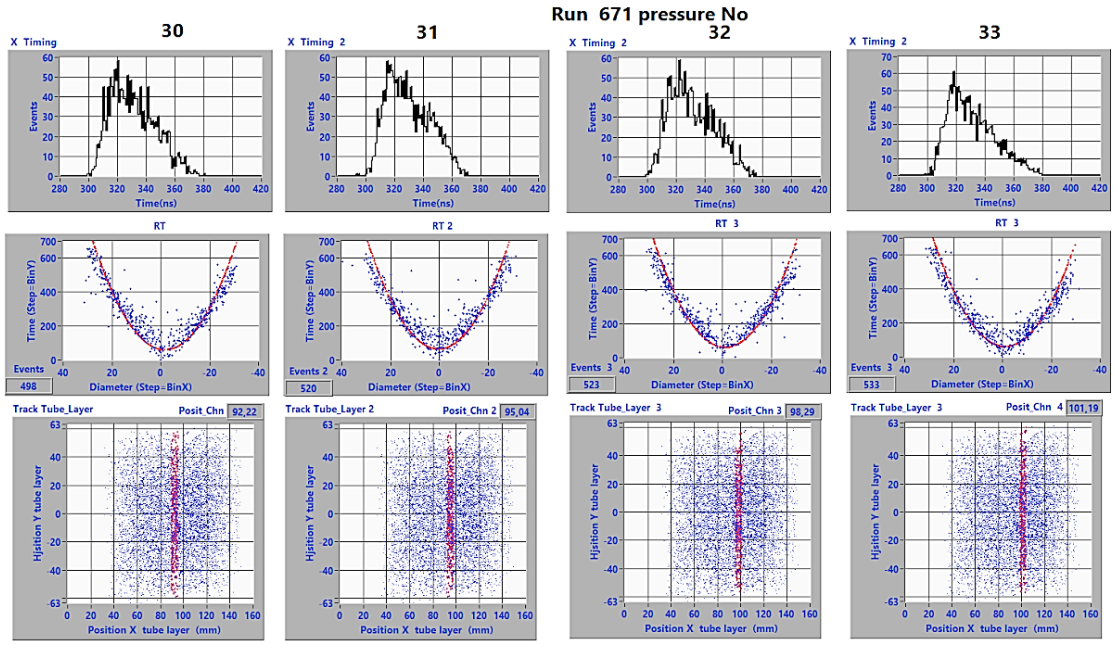
First straw detectors testing results

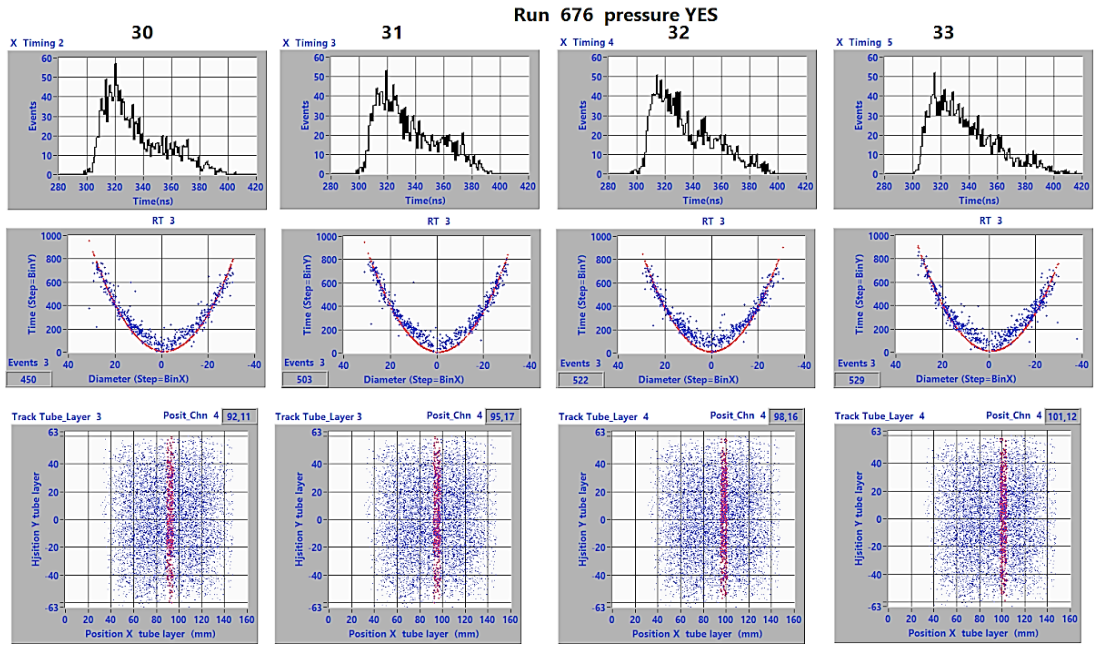


Straw detectors planes (64 tubes)

Straw detector diameter is 6 mm;
Anode diameter is 30 μm;
Gas – Ar (80%) and CO2 (20%) ;
$t_{drift} \sim \frac{p}{E}$, p – pressure inside detector, E – electric field;

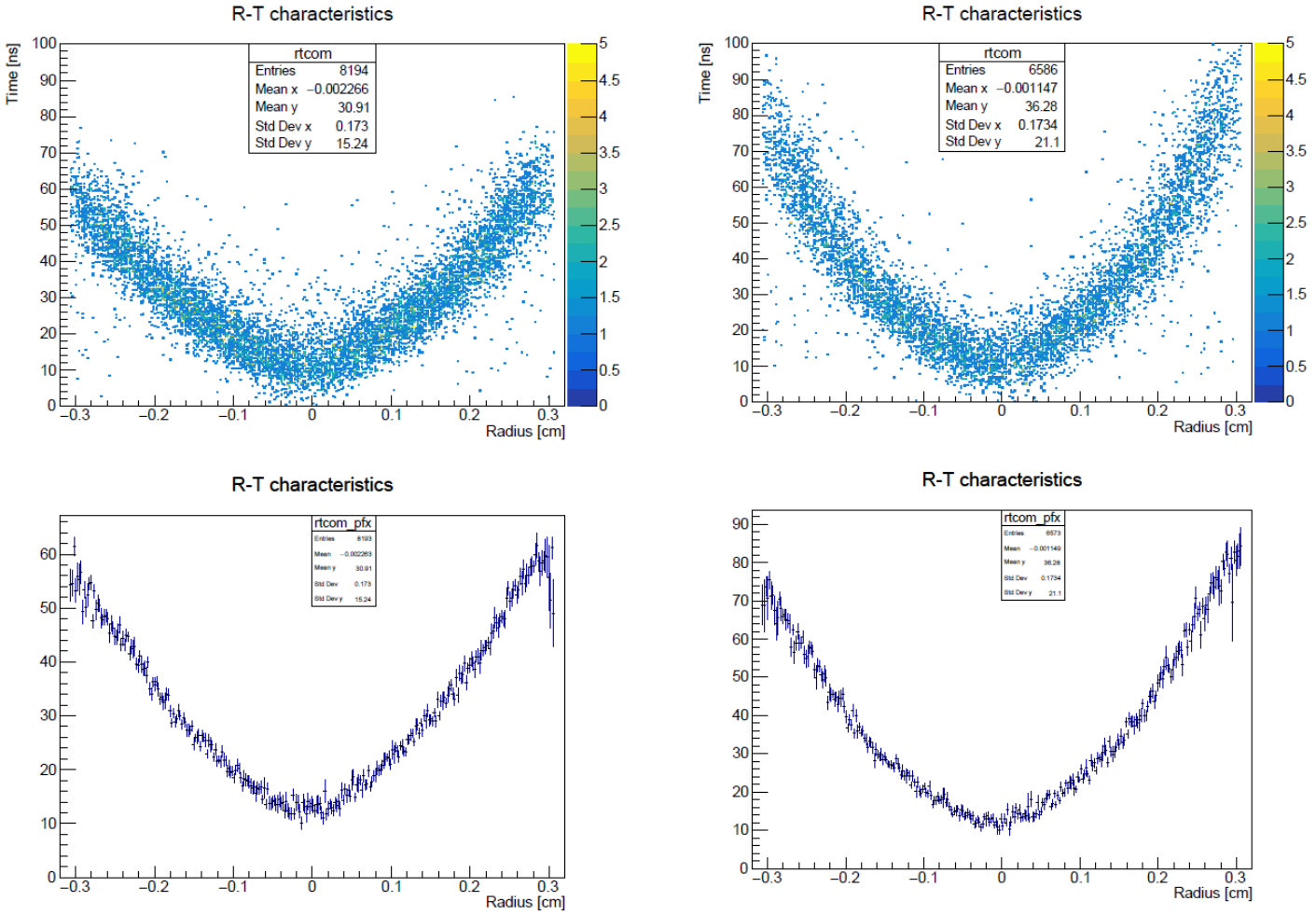
$$\frac{t_{max676}}{t_{max671}} = \frac{85\ ns}{55\ ns} \approx 1.55;\ \frac{p_{676}}{p_{671}} = \frac{1.6\ bar}{1\ bar} = 1.6$$





Time distribution (up), R-T distributions (center) and straw detector position projection on Silicon hit plot (down) for central tubes (30th, 31th, 32th and 33th) $V_{HVStraw}$ = 1960 V with different pressure: 1 bar (left, Run# 671 April 2019) and 1.6 bar (right, Run #676 May 2019)

First straw detectors testing results



R-T distributions (up) and its profiles (down) for all straw-detectors in triggering zone (from 10th to 50th tubes) with different pressure: 1 bar (left, Run# 671 April 2019) and 1.6 bar (right, Run #676 May 2019)

Conclusions and plans

Conclusions:

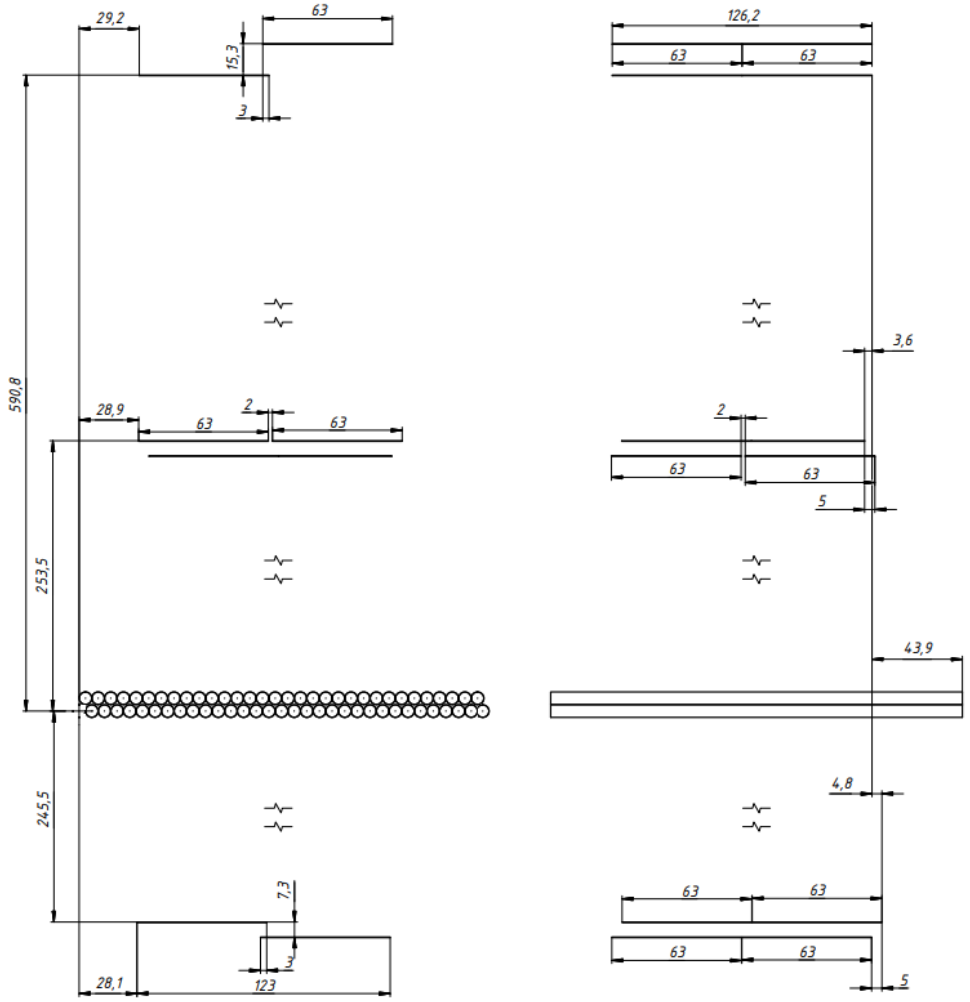
- First version of cosmic muon stand for testing straw detectors based on external BM@N Si detector tracking system – designed and produced;
- Software for track reconstruction is developed based on bmnroot framework;
- BM@N Silicon detector allow to detect coordinate and amplitude of m.i.ps signals;
- Average resolution of BM@N Si stations for X coordinate (parallel to straw detectors anode wire) is 75.6 μm it's bigger than $\frac{pitch_{p+}}{\sqrt{12}}$=27.4 μm, because measurements made without low-energy particle filtering;
- First straw detector testing results (Time and R-T distributions) are obtained at different pressure;

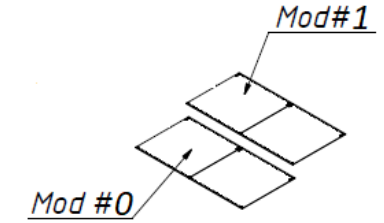
Plans:

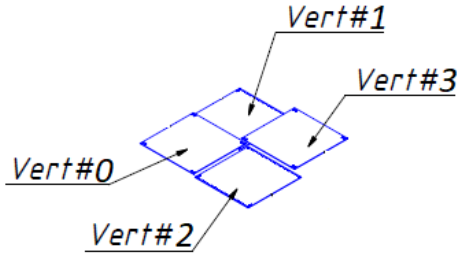
- Add new tracking detectors to increase measurement accuracy;
- Add calorimeter to scan trigger events by energy;
- Collect more data to build R-T for each straw detector (more 3000 trigger events per tube);
- Update reconstruction and online-monitoring programs.

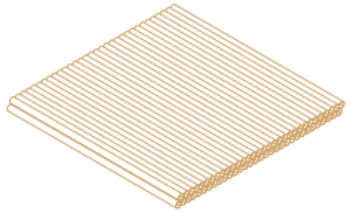
Backup slides

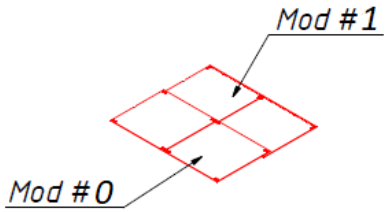
Muon Stand drawings

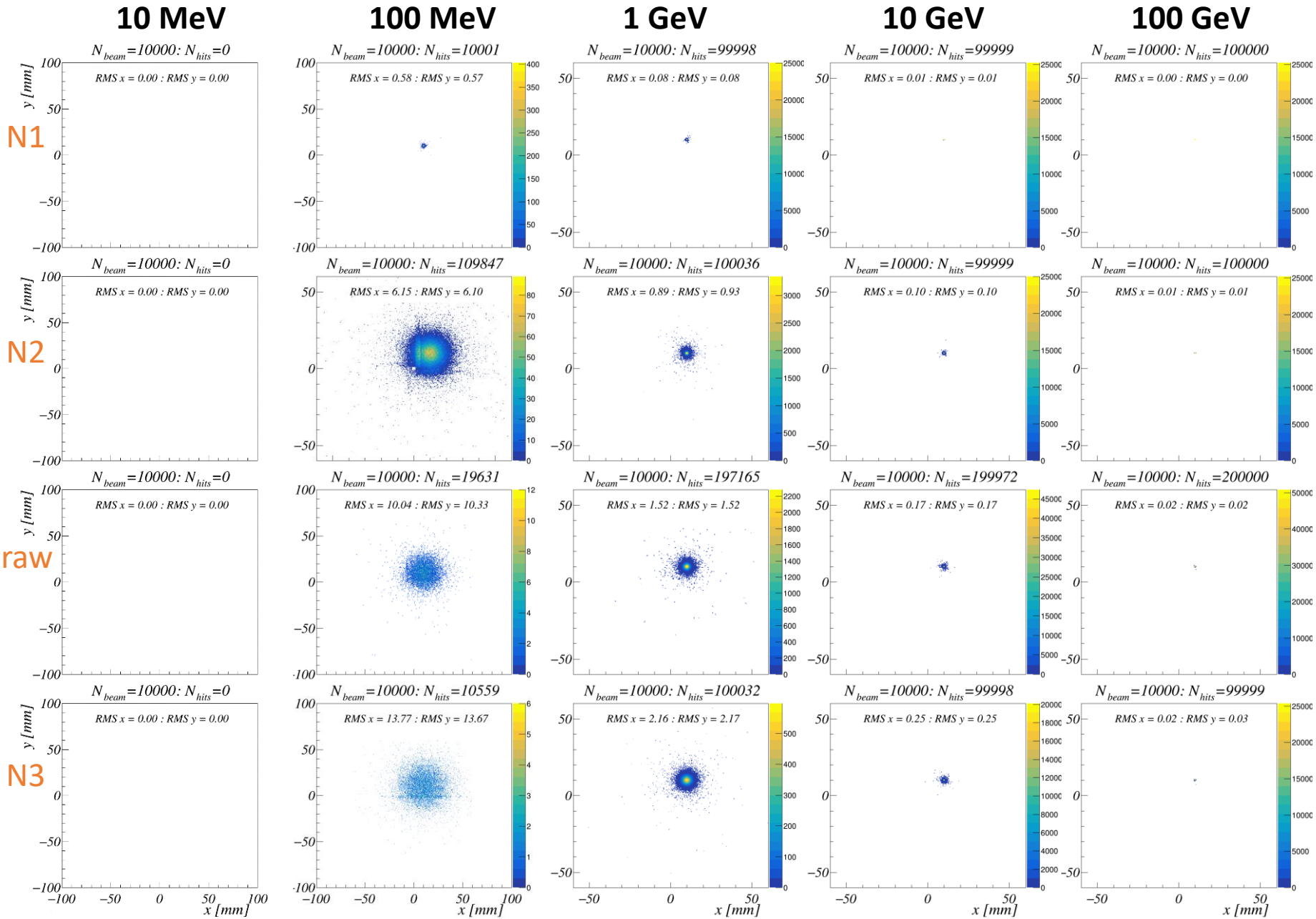












Geant4 modeling results for distributions of muon monoenergetic beam
in Silicon and Straw detectors, at 0.01, 0.1, 1, 10 and 100 GeV (without Lead shield)