Studies of Short Range Correlations in inverse kinematics at BM@N at the NICA facility

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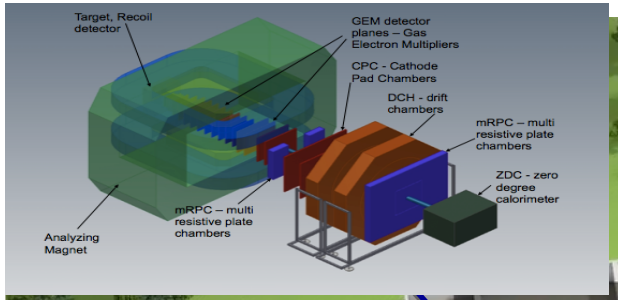
for the SRC at BM@N Collaboration

Plan

- The BM@N setup at the Nuclotron
- The Short Range Correlations
- Tracking and time of flight detectors of the setup
- First data from the tracking detectors
- Conclusion

The NICA basic facility

BM@N



BM@N (Detector)
Extracted beam

SPD
(Detector)

MPD
(Detector)

E-cooling

Collider ring (c=503 m)

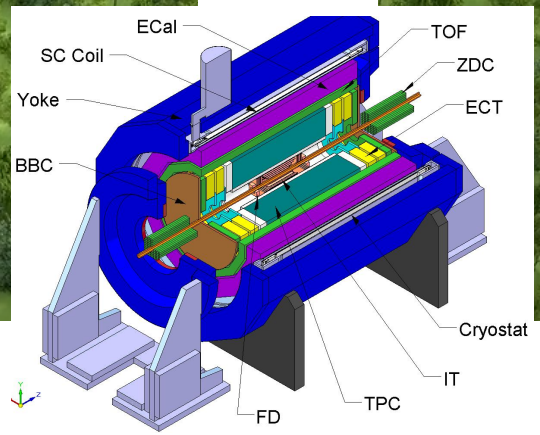
Injection Complex

Nuclotron

Booster

Nuclotron ring (c=251,5 m)

MPD

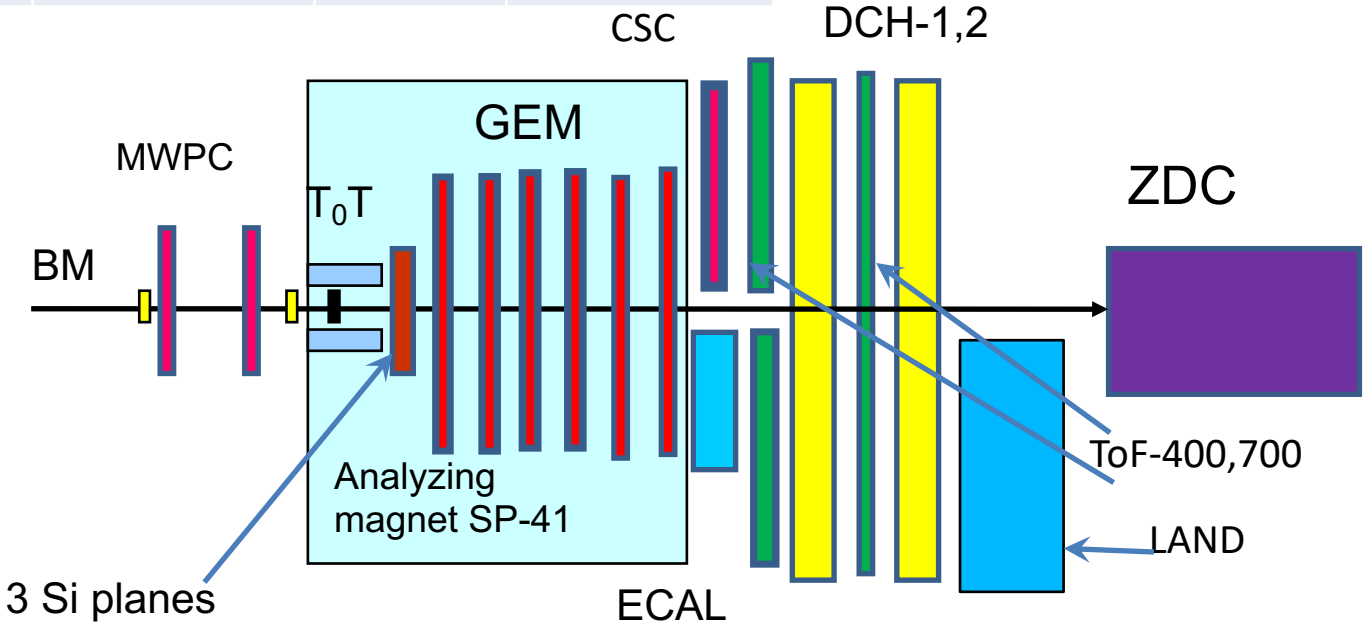


Baryonic Matter at Nuclotron (BM@N)

experiment at Nuclotron extracted beams

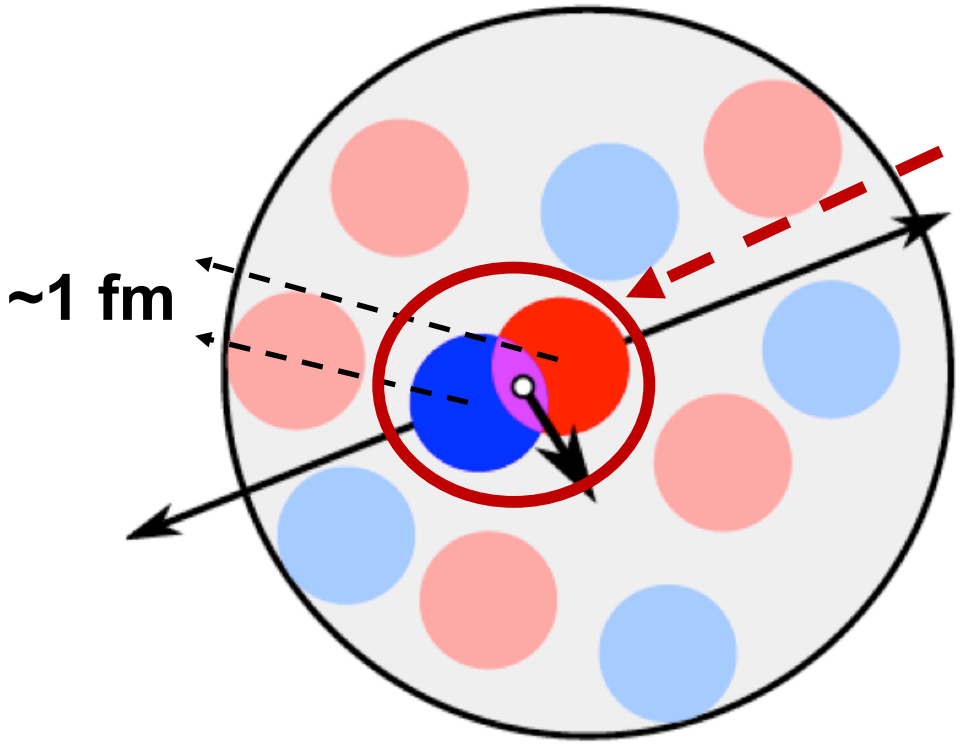
year	2016	2017 spring	2018 spring	2020	2021
beam	d	C	Ar, Kr, C(SRC)	Au	Au, p
max. intensity, Hz	0.5M	0.5M	0.5M	1M	5M
trigger rate, Hz	5k	5k	10k	10k	50k
experim. status	technical run	technical run	technical run + physics	stage 1 physics	stage 2 physics

BM@N Collaboration:
Russia: *INR, MEPhi, SINP, MSU, IHEP, S-Ptr Radium Inst.*
Bulgaria: *Plovdiv University;*
China: *Tsinghua University, Beijin;*
Poland: *Warsaw University of Technology;*
Israel: *Tel Aviv Uni., Weitzman Inst.*
Germany: *Frankfurt Uni.; GSI*
USA: *MIT, FIU, ODU, PSU*
France: *CEA*



Short Range Correlations

Approximately 20% of nucleons in a nucleus belong to strongly interacting, short-lived correlated pairs.



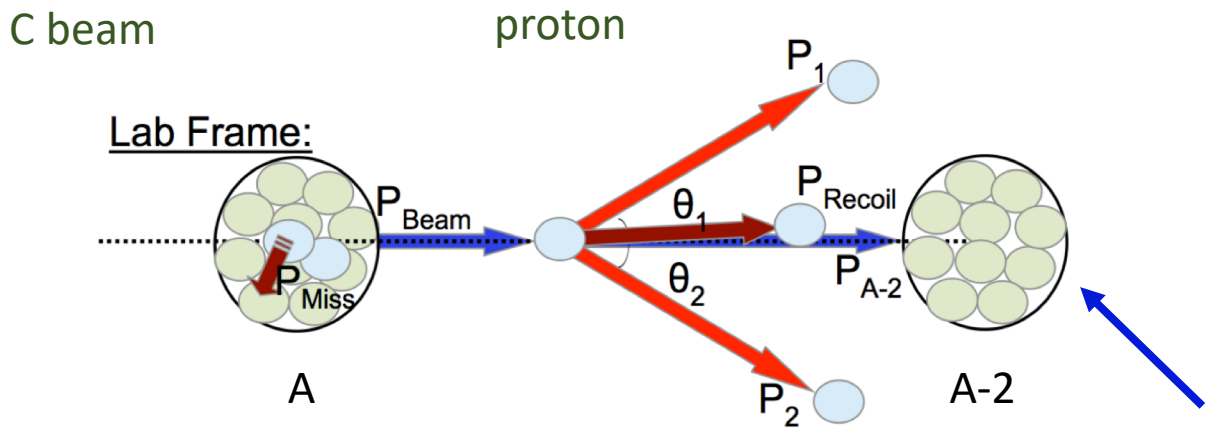
2N Short Range Correlated pair:

- Nucleons within these pairs have high absolute and low center of mass momentum.
- Almost all high-momentum nucleons in the nucleus belong to SRC pairs.
- SRC pairs are the important part of the nuclear wave function and also the densest objects available on Earth.
- They are relevant for understanding of dense baryonic matter and neutron stars.
- They are also important for nuclear parton distribution functions and neutrino oscillations.

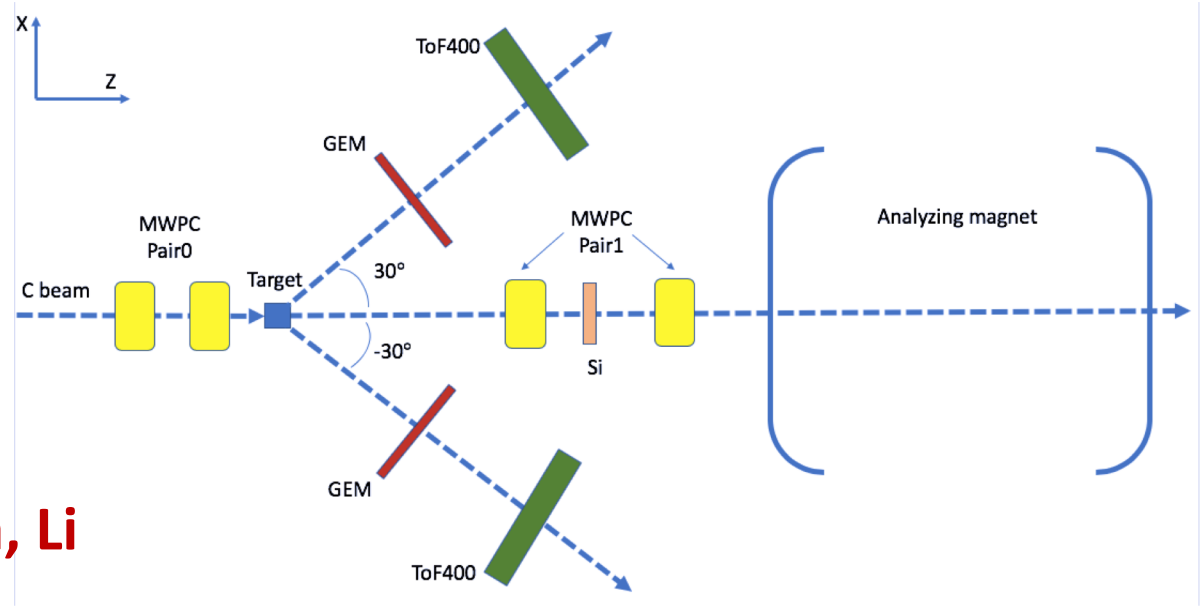
The new physics program of BM@N is about Short Range Correlations!

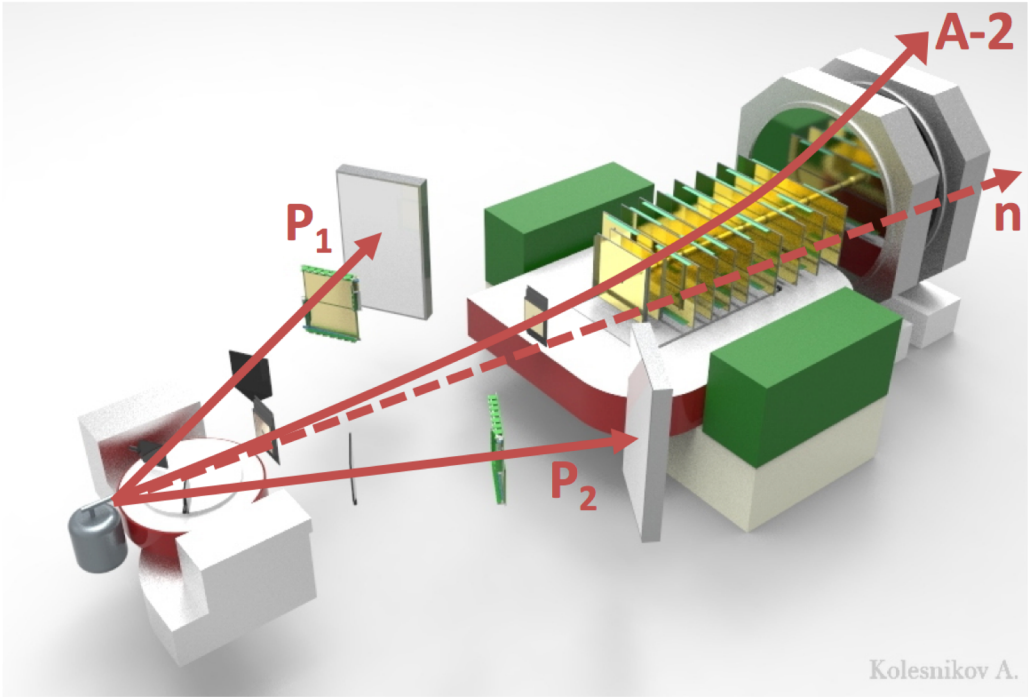
Inverse reaction kinematics for SRC at BM@N

Traditionally, properties of SRC pairs are studied using a particle beam hitting a nucleus.
We hit a nucleus with the beam and hope to break apart an SRC pair.



B, Be, Alpha, Li

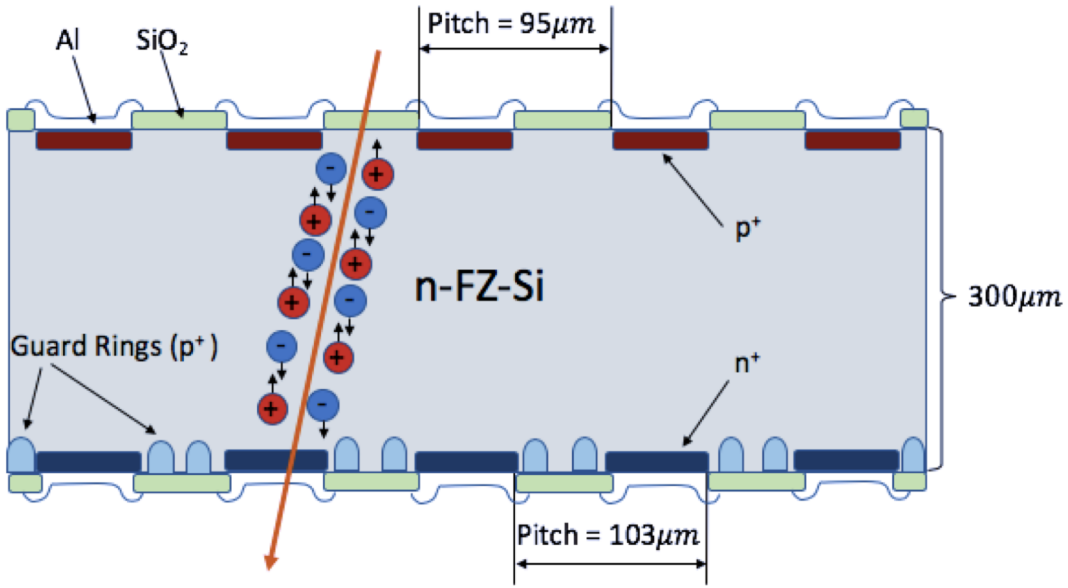




We use:

- GEM and ToF400 for the arms: measure the momentum of the two protons and restore the interaction point.
- Scintillator detector: which signal is proportional to Z^2
- TOF-700 information: measure A-2 - define A and Z
- MWPC, Si-detector and DCH: turning angle determination

Silicon Tracking detector



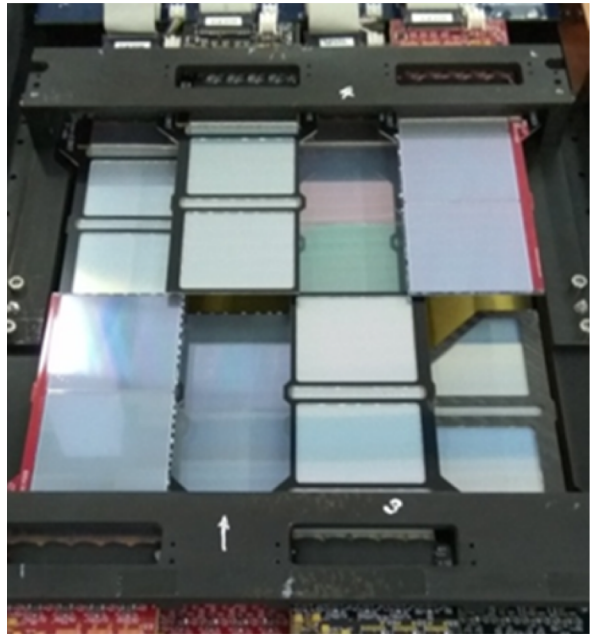
Double-Sided Silicon Detectors (DSSD)

- 2-coordinate Si strip detector

Capability of stable operation in conditions of high loadings up to 10^6 Hz/cm^2
Response time is 10-15 ns
Coordinate resolution ~ 50 μm

640 X strips with 0˚
640 X' strips with 2.5˚
The pitch of X strips : 95 μm
The pitch of X' strips :103 μm.
Thickness of detectors is 300 μm

Full sensitive size of 12 x 12 cm^2

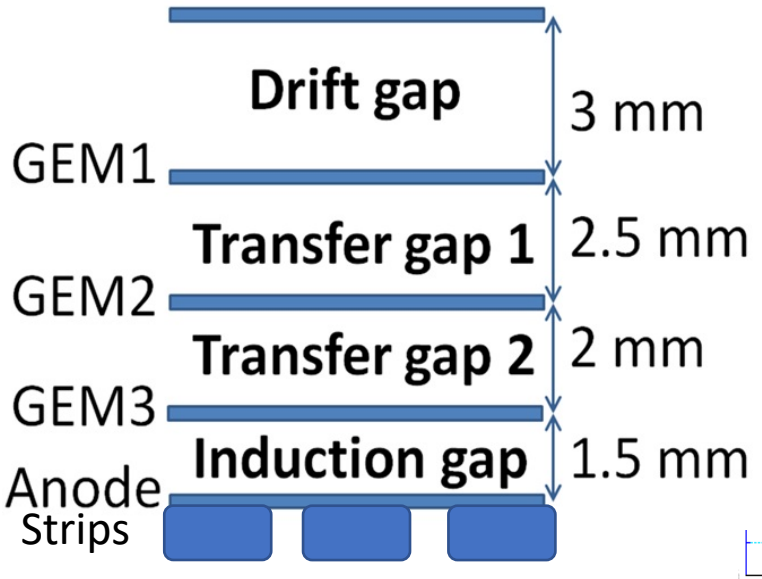


Full sensitive size of 25 x 25 cm^2

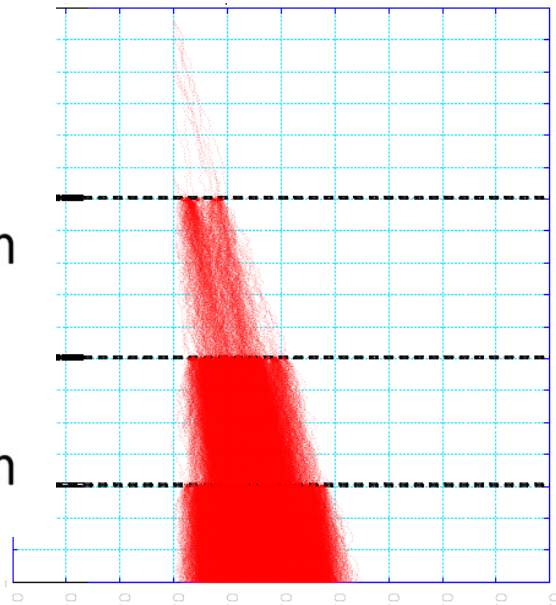
The contribution to the collected charge value is given by both electron and hole flow.

Gas Electron Multiplier

•2-coordinate triple GEM detector



Schematic cross section



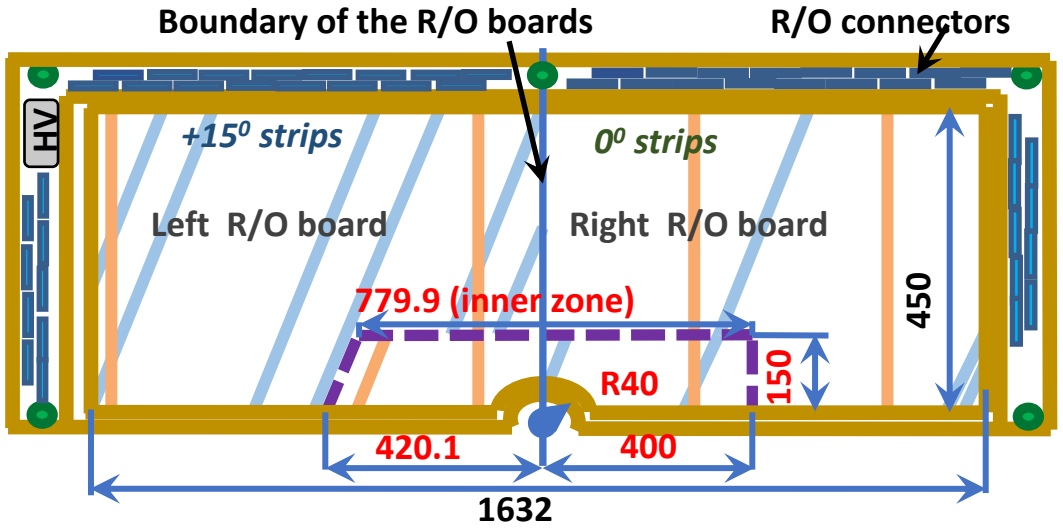
Avalanche for the triple GEM cascade in magnetic field of 0.5 T (Garfield simulation)

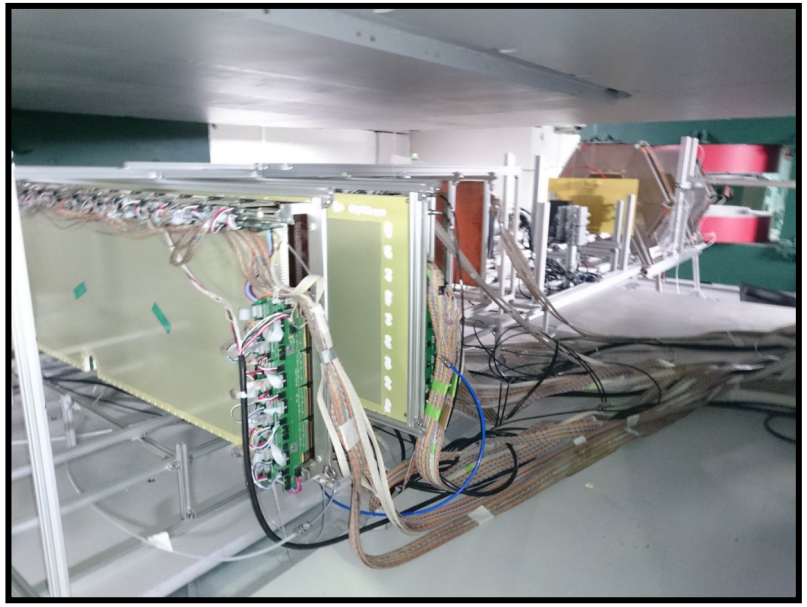
- Stable operation in conditions of high loadings up to 10^5 Hz/cm^2;
- High spatial and momentum resolution;
- High geometrical efficiency (better than 95%);
- Coordinate resolution w/o mag. field $\approx 120\mu m$

Strip pitch: 800 µm

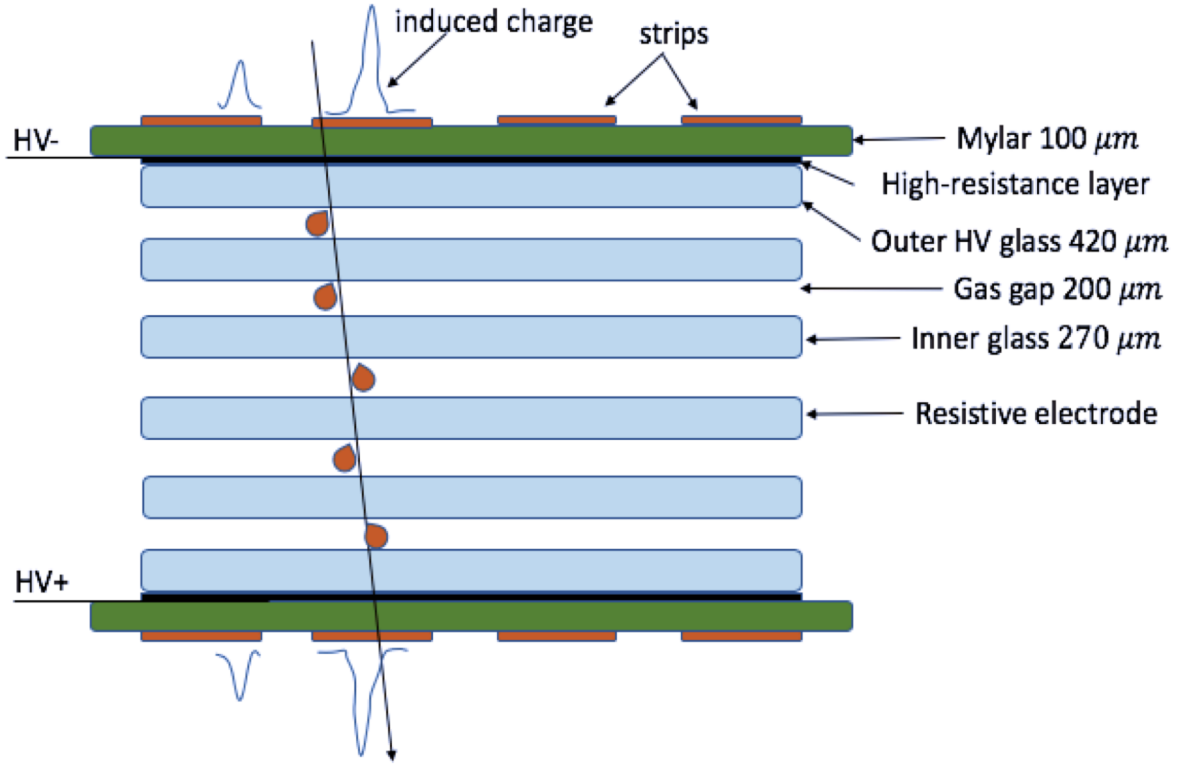
X-strips(0^0) width: 680 µm

X'-strips(15^0) width: 160 µm



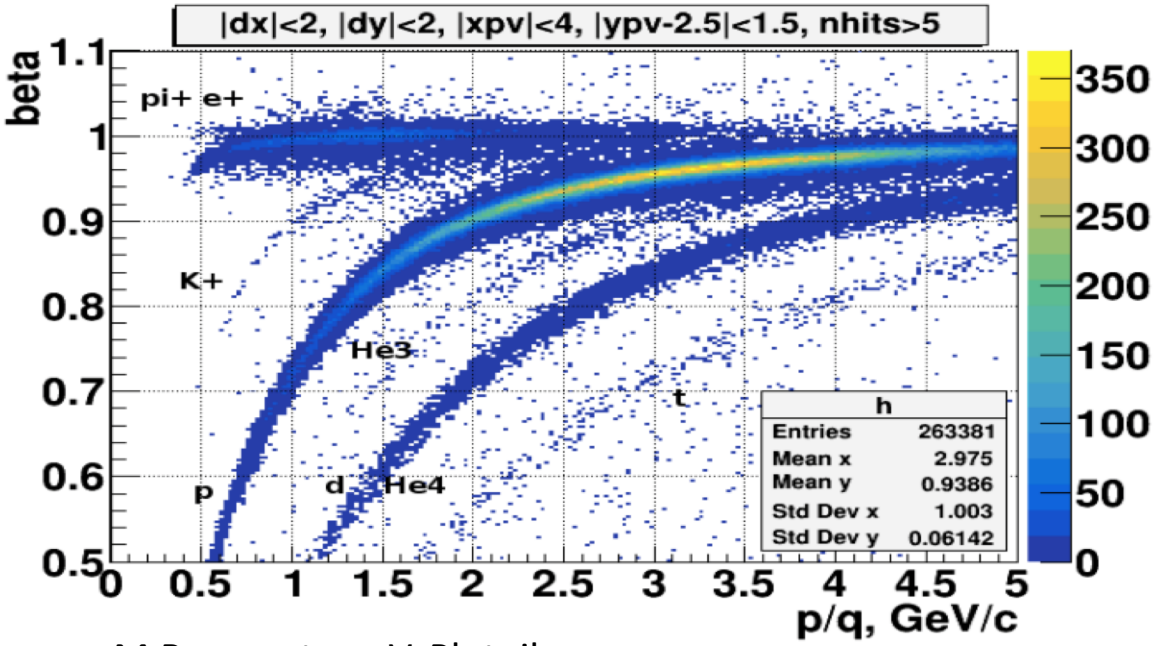


Time of Flight detector
on multi Resistive Plate Chamber



- MRPC are well known for **large area coverage**.
- They have **good timing characteristics**.
- MRPC is quite **easy to manufacture** and it is **relatively inexpensive**.
- ToF detector **time resolution ~50 ps** (T0 - not counted).

Ar beam, 3.2 AGeV

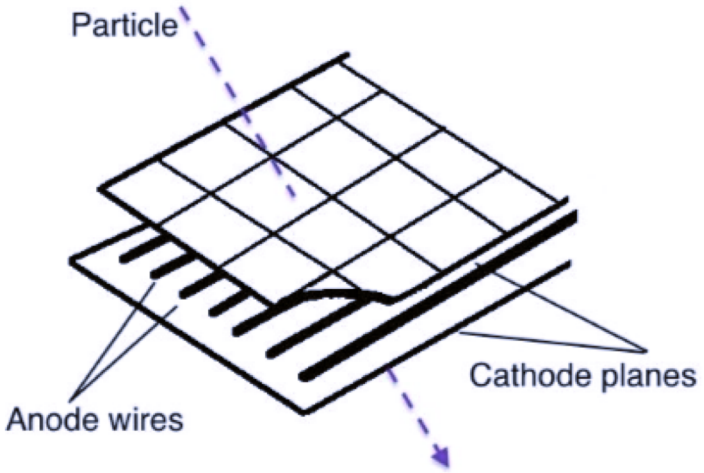


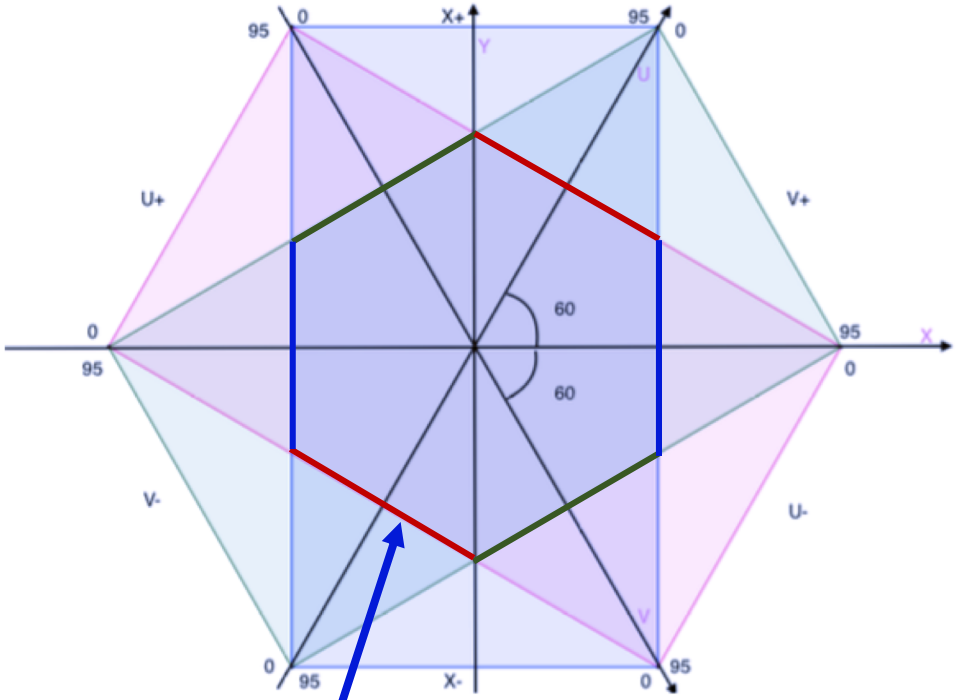
M.Rumyantsev, V. Plotnikov

The ToF-400 wall consists of two part (left and right) are placed symmetrical to the beam.

ToF-400 walls on the mounting frame
20 detectors (48 strips)
$24 \times 48 = 960$ strips (10*300 mm with pitch 12.5 mm)
$960 \times 2 = 1929$ electronics channels

Multi Wire Proportional Chambers





Each MWPC has 6:
two **X**, two **U** and two **V**-planes
with wire angles 0°,±60°.
Wire pitch is d = 2.5 mm.
Coordinate resolution is $^{d}/_{\sqrt{12}}$ = 0.72 mm.

$$U = \frac{x + \sqrt{3}y}{2},$$

$$V = \frac{x - \sqrt{3}y}{2},$$

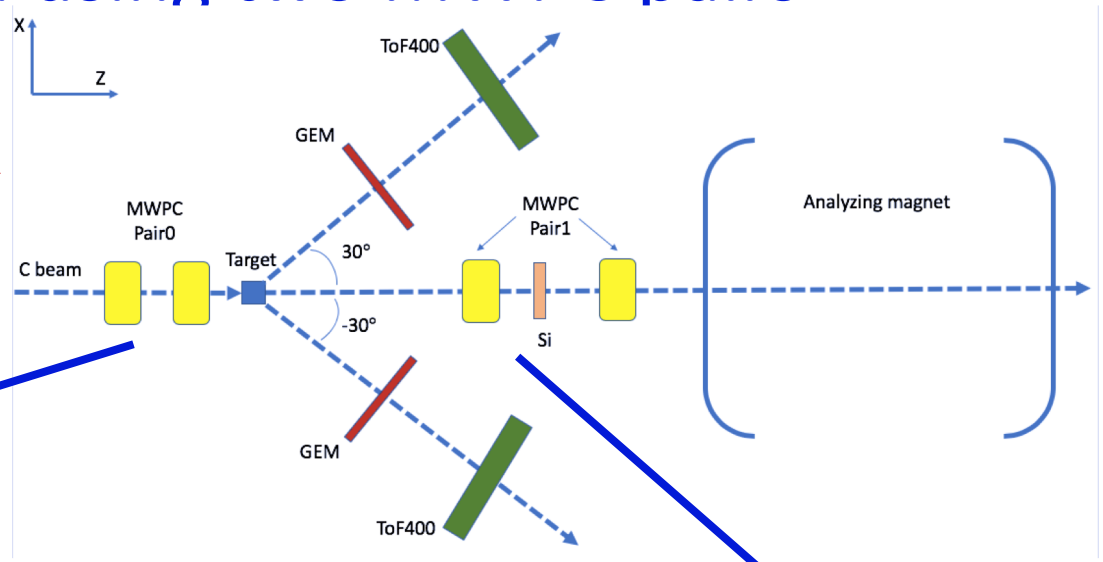
This point should satisfy the following condition:

$V + U - X = 0$

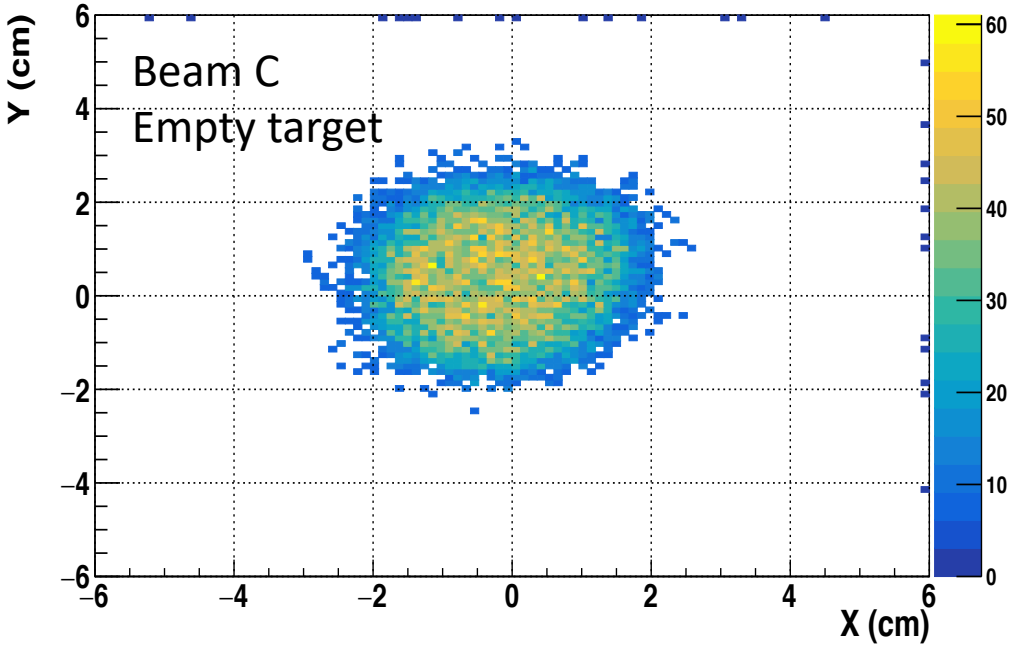
The intersection of these planes is a working area.

Beam spot in the target area using two MWPC pairs

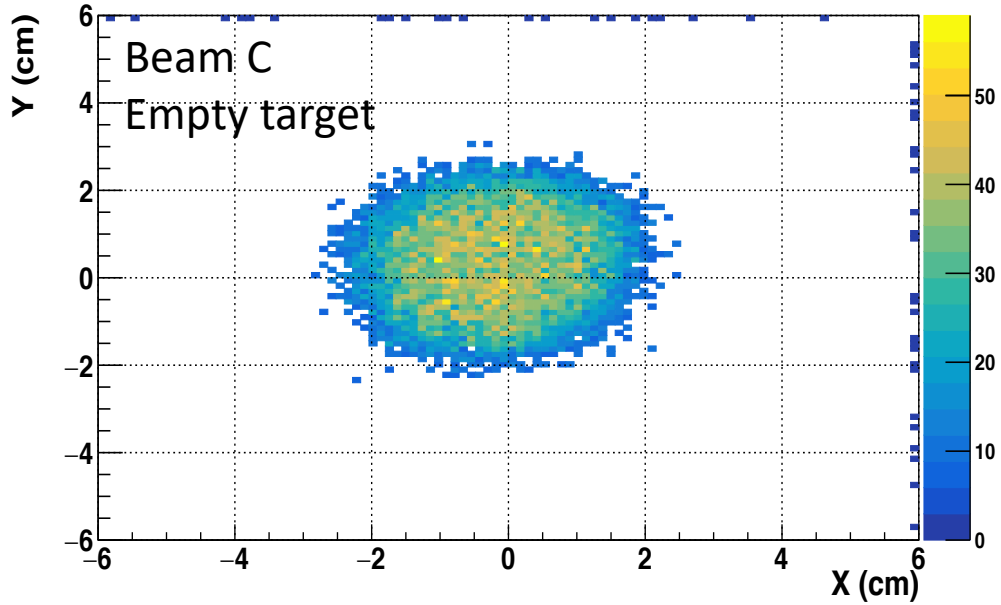
We started to look into the vertex reconstruction using the **four straight tracks**:
the incoming and outgoing beam, and the two tracks in the arms.



Reconstruction from MWPC pair before target

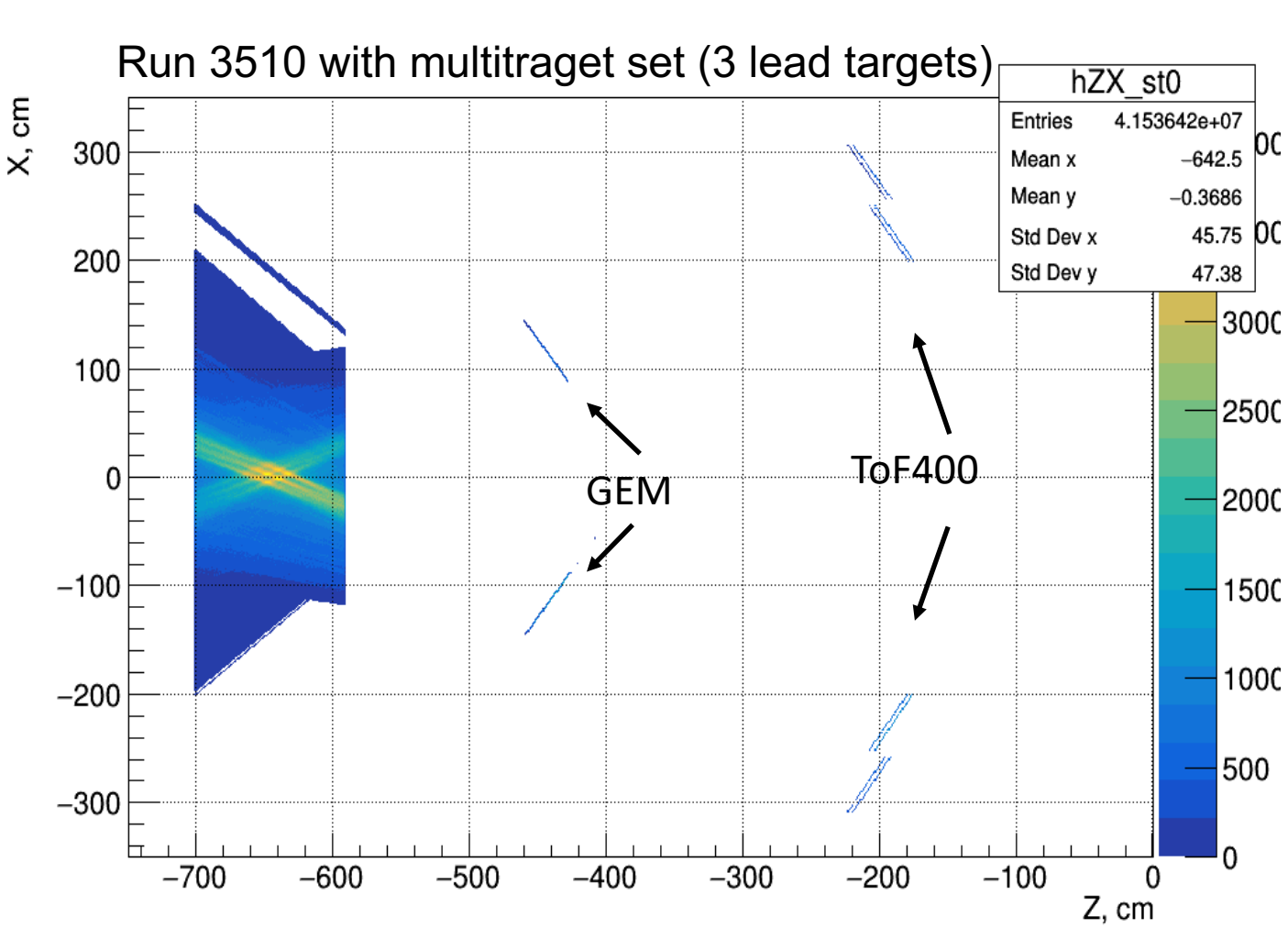


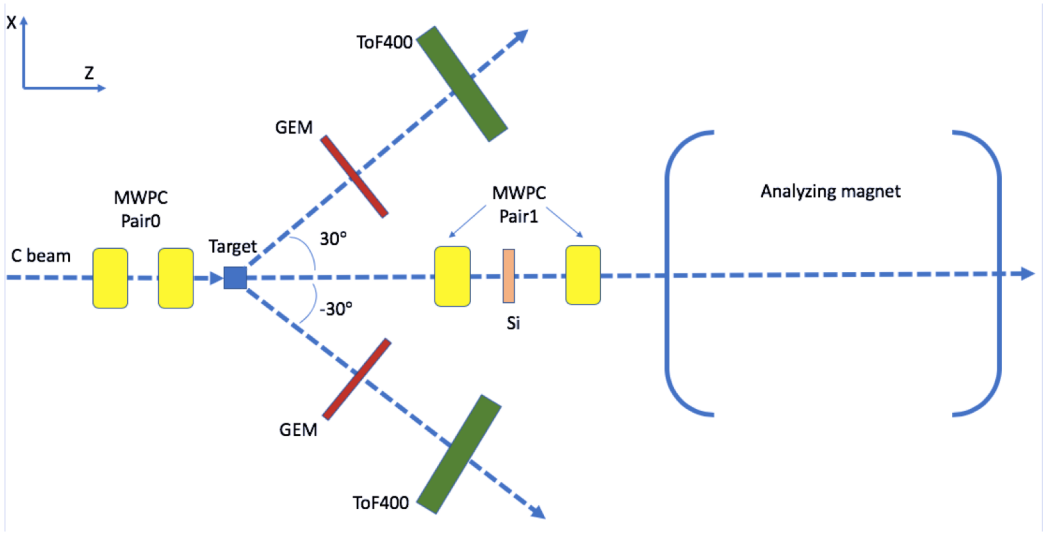
Reconstruction from MWPC pair after target



We see the beam spot in the target area using the first two chambers and the second two chambers

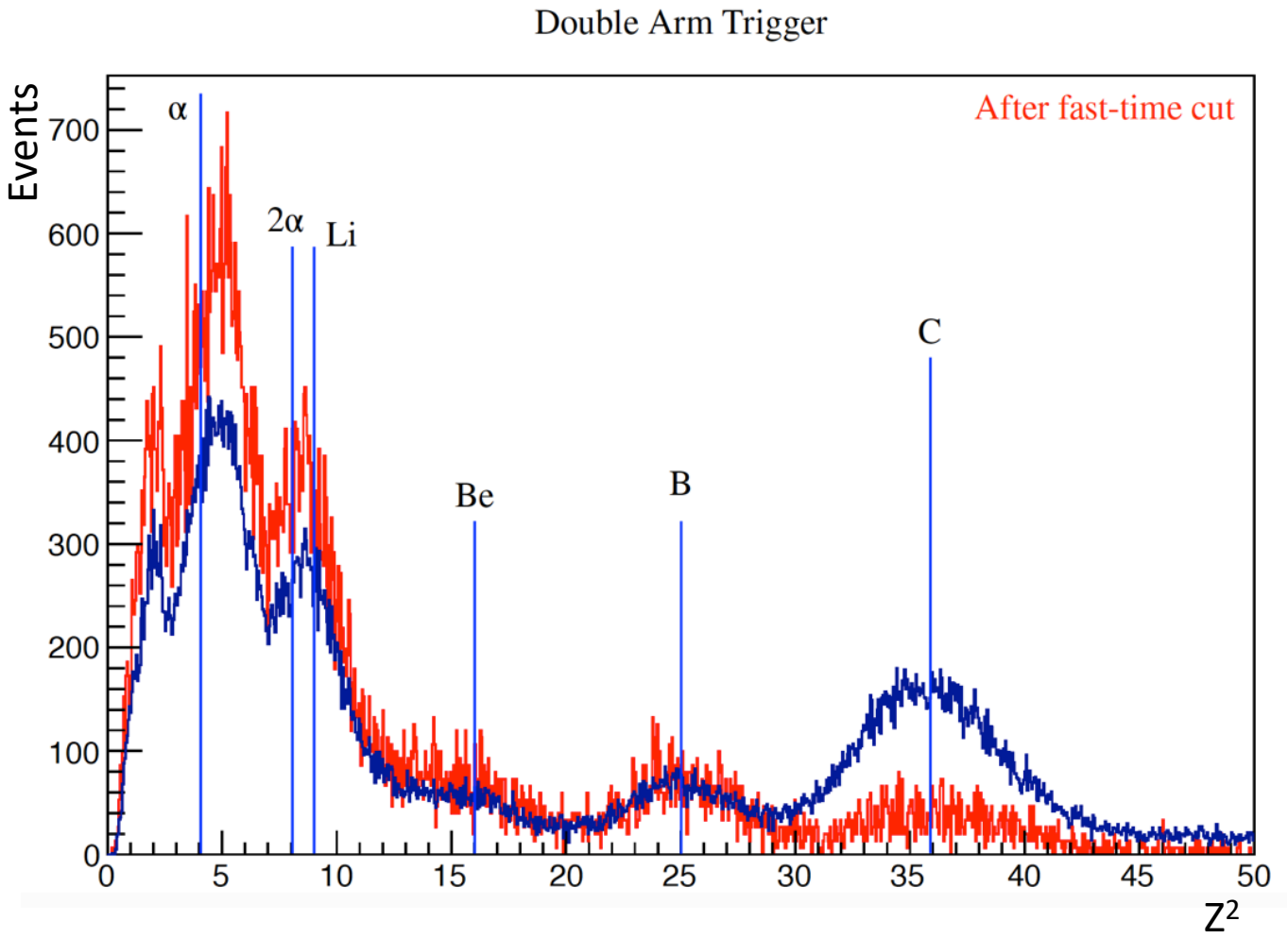
Left & right arms (GEM + ToF) in the target area





Here we reconstructed the vertex for the first time using the tracks from arms.

Scintillator counter after the target



The blue – the spectrum for all events

The red – case with two particles in **both arms**, and some of them are **protons by ToF** information.

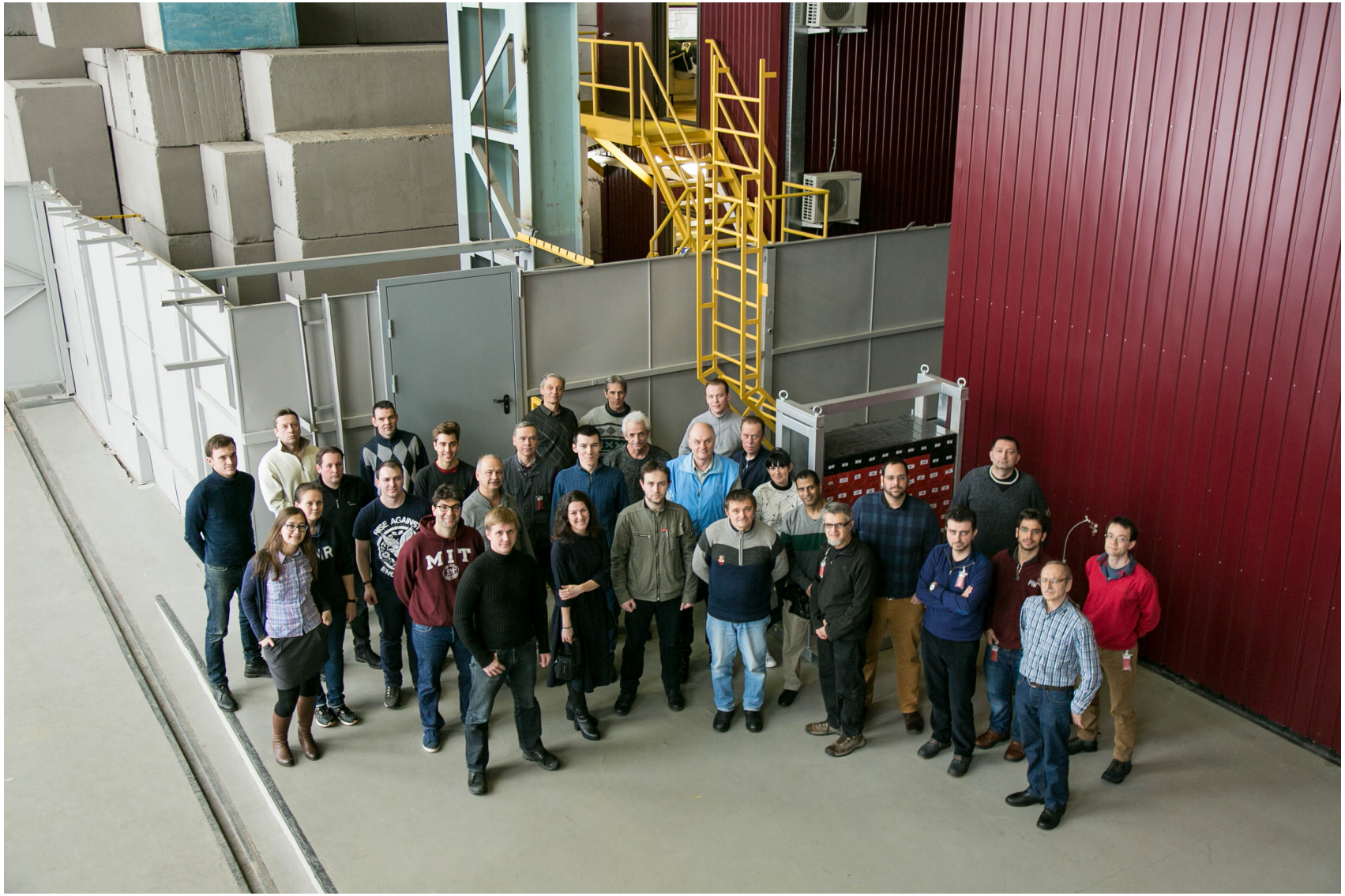
The change between **the blue** and **the red** shows the **carbon peak** (which was a beam) **decreasing**, and the contributions of **low-charge nuclei**, such as alpha, lithium, **increasing**.

This graph illustrates, that we see different nuclei, which were formed after the interaction, **and we can distinguish them by charge**.

Conclusion

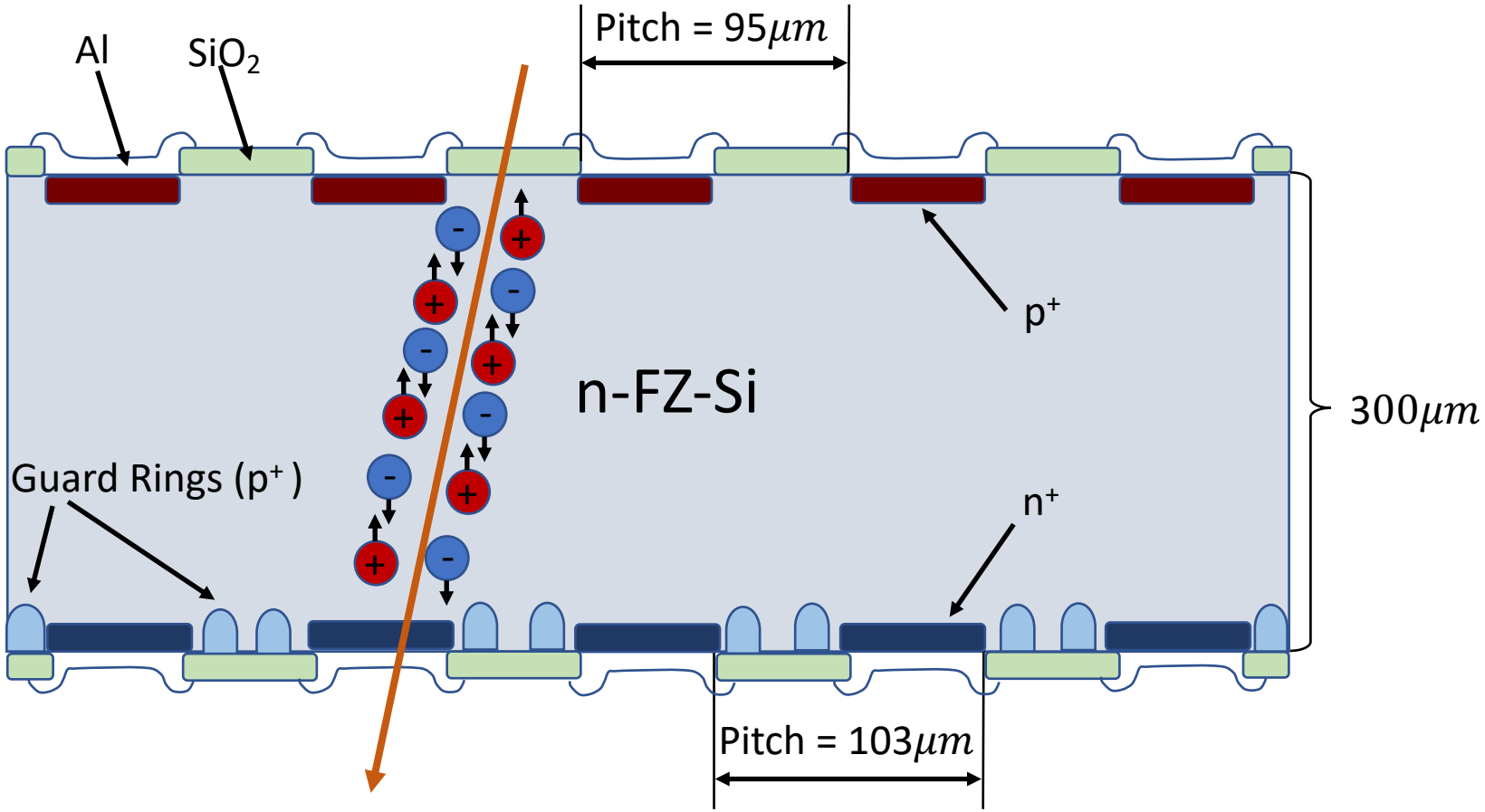
- The BM@N experiment is the first experiment at the NICA facility. It is already taking data since 2015.
- This year we started the new physical program at BM@N about the Short Range Correlations in nuclei.
- The BM@N setup has a number of detector systems, which allow identification of the residual nucleus after interaction for the first time!
- The data analysis is ongoing, and we can see the beam spot and the first signs of the interaction point reconstruction. Looking forward to the exciting physics results from that measurement!

Thank you for your attention!

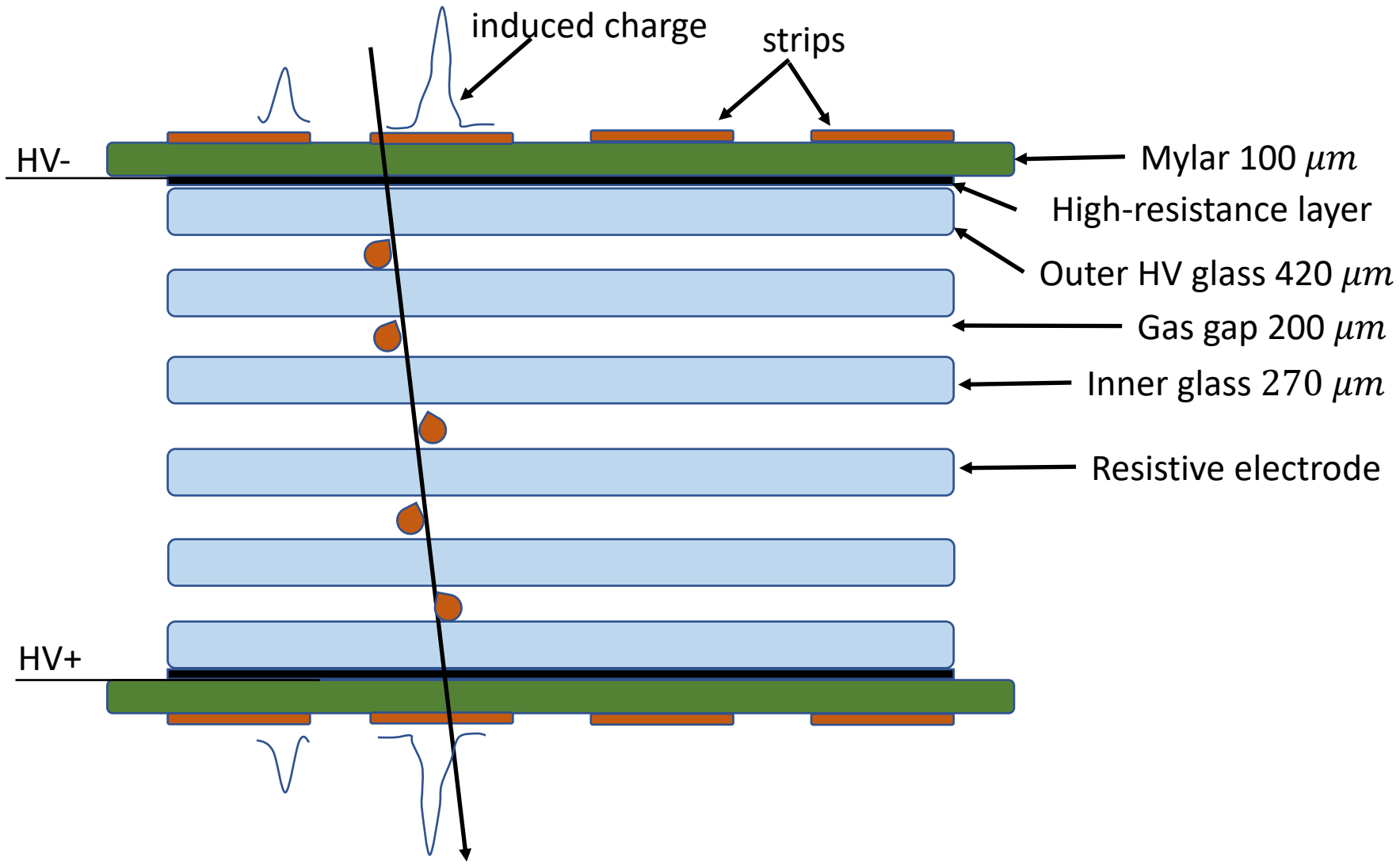


Back up

Double-Sided Silicon Detectors (DSSD)



ToF-400 based on mRPC



GEM

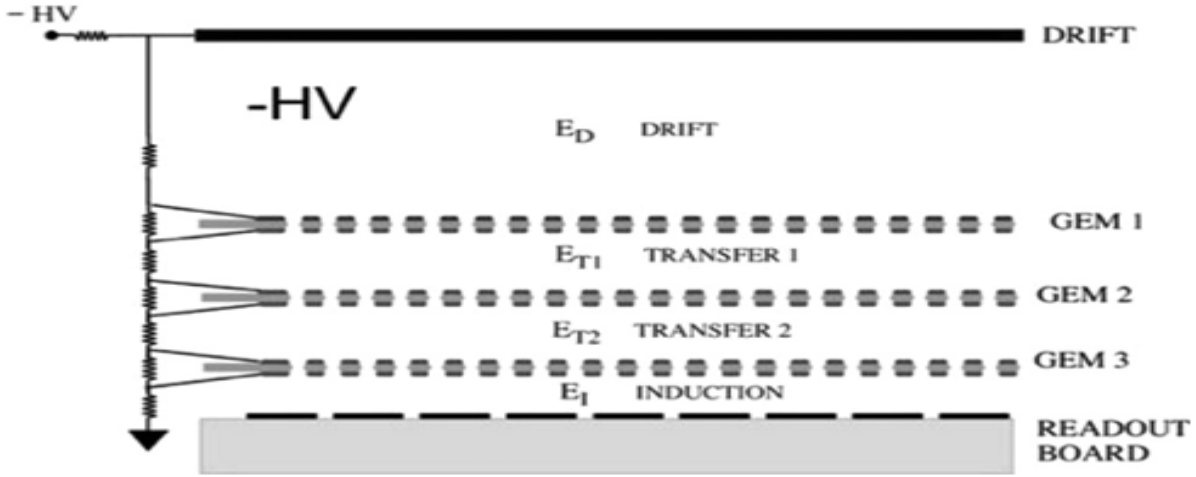


Fig. 10. Schematics of a Triple-GEM detector.

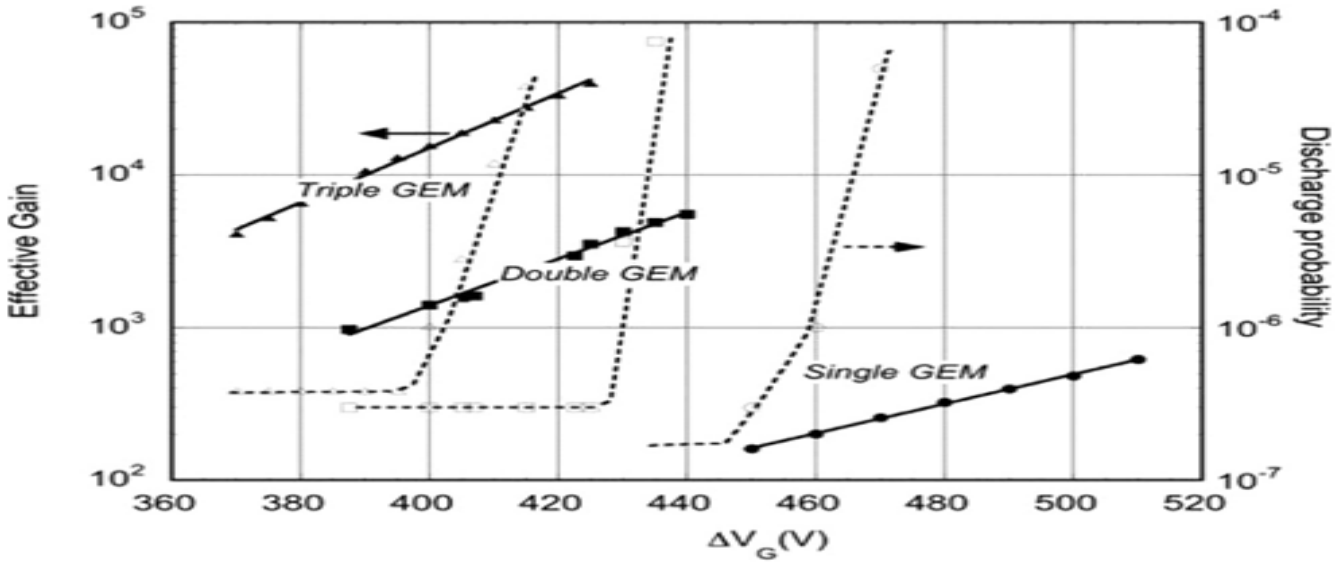
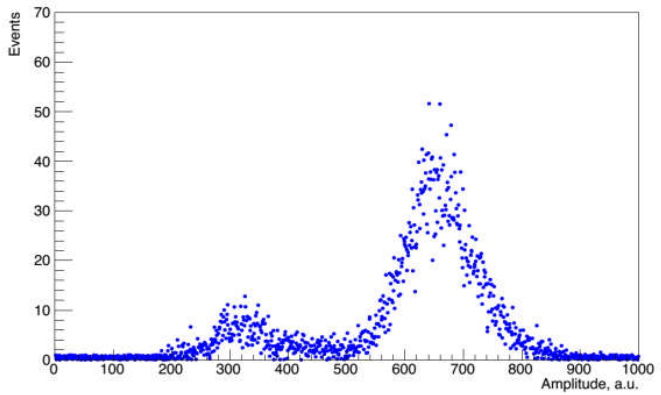
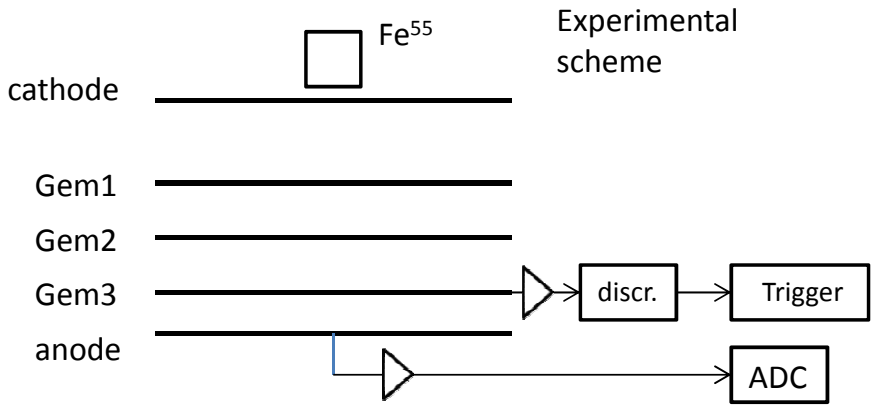


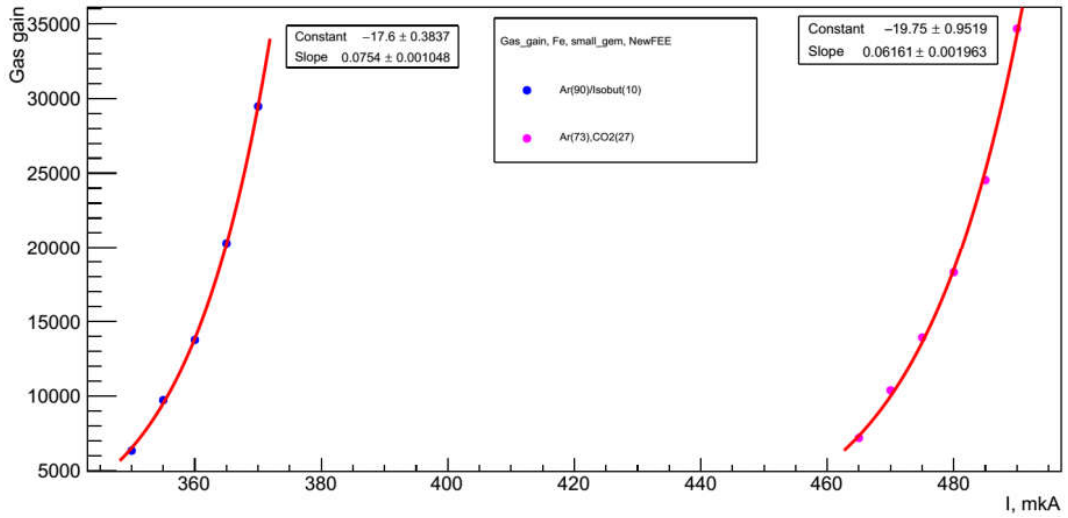
Fig. 11. Effective gain and discharge rates as a function of voltage in multi-GEM detectors.

GEM Gas Gain Measurements



Amplitude distribution, Ar(70)/CO2(30), Fe^{55}



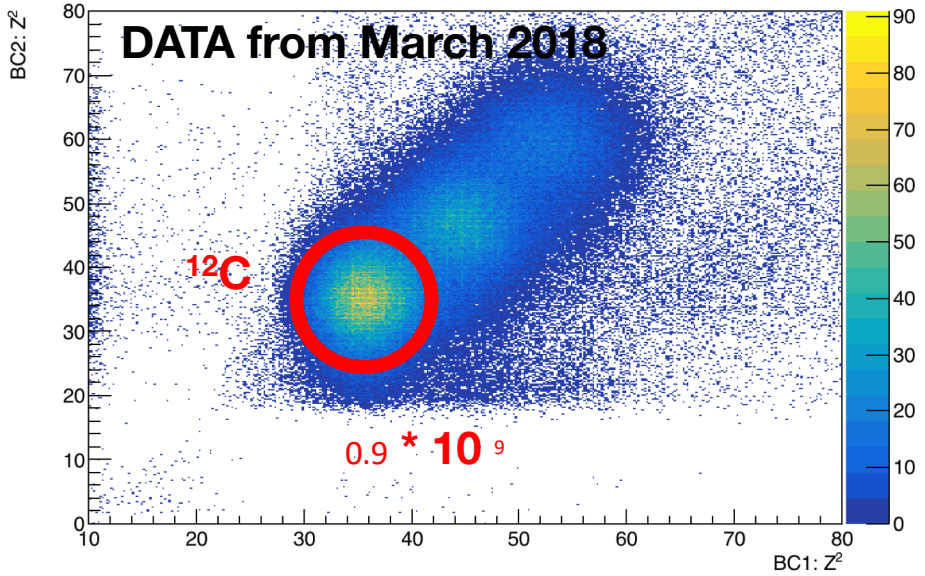


GEM gas gain for Ar(70)/CO2(30) and Ar(90)/Isobutane(10) gas mixtures

Preliminary glance on the collected data

Parameters	Values
Beam Time	10 days: March 4 - 17
Flux	~ 1 * 10^5 ions/s
SRC trigger BC1, BC2, BC3	5 * 10^6
C in, B out events	0.5 * 10^6
C in, Be out events	1.5 * 10^6
C, B + p in LAND	1000
C, B + n in LAND	0.2 * 10^6

Charge Separation Before Target



Charge Separation After Target