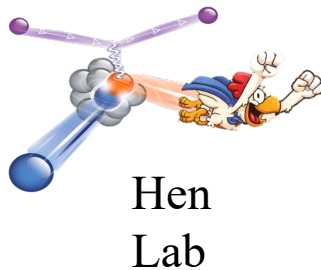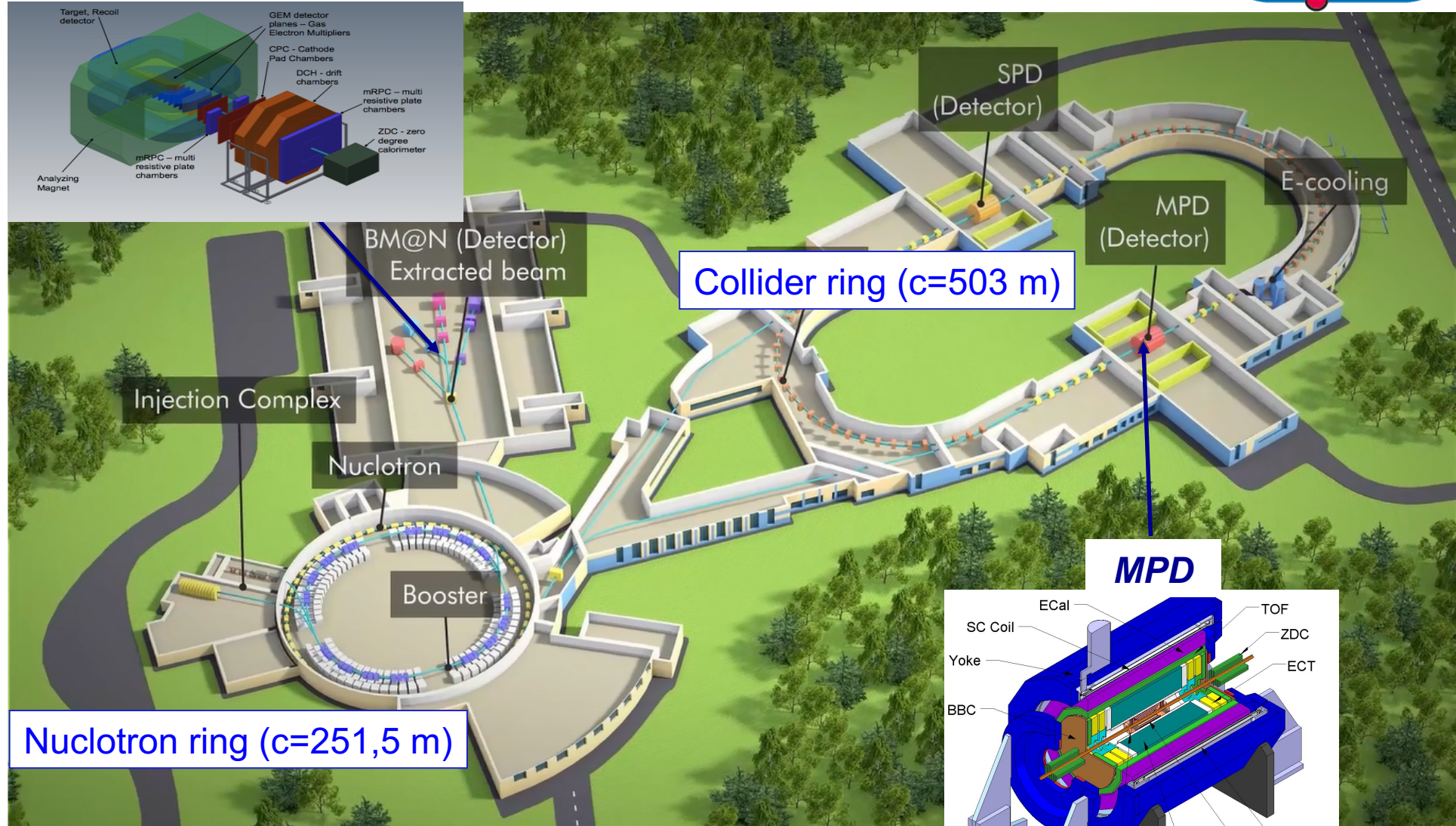# SRC at BM@N: reconstruction of tracks upstream and downstream the target using the MWPC and Silicon detector systems

Vasilisa Lenivenko for SRC at BM@N collaboration
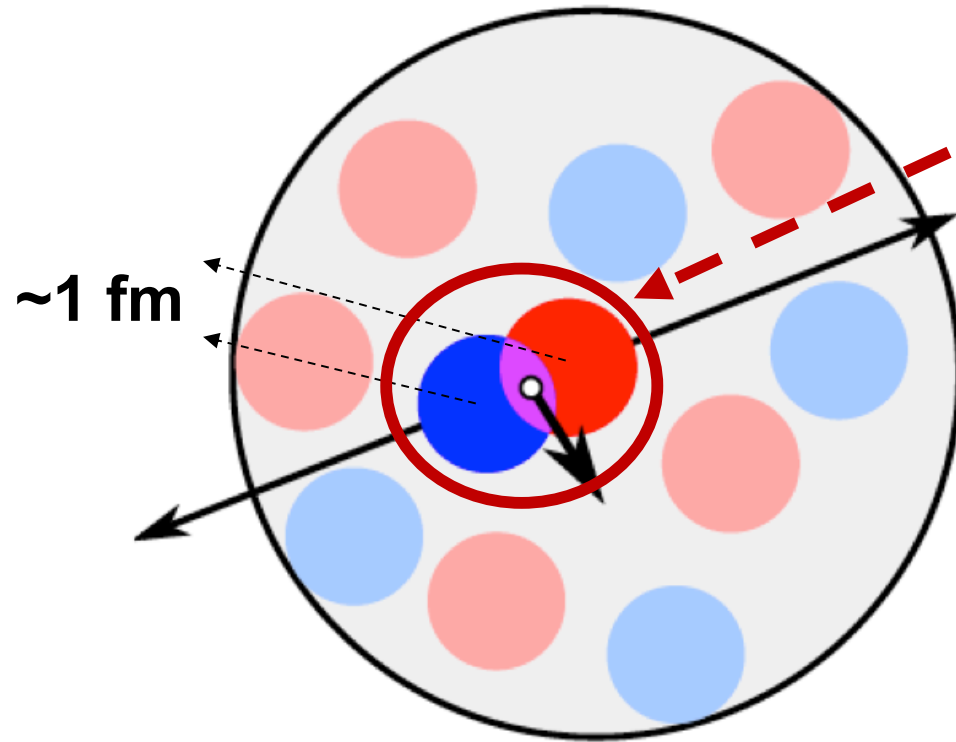
AYSS-2020
9-13 November

Hen
Lab

Collider ring (c=503 m)

Nuclotron ring (c=251,5 m)

MPD

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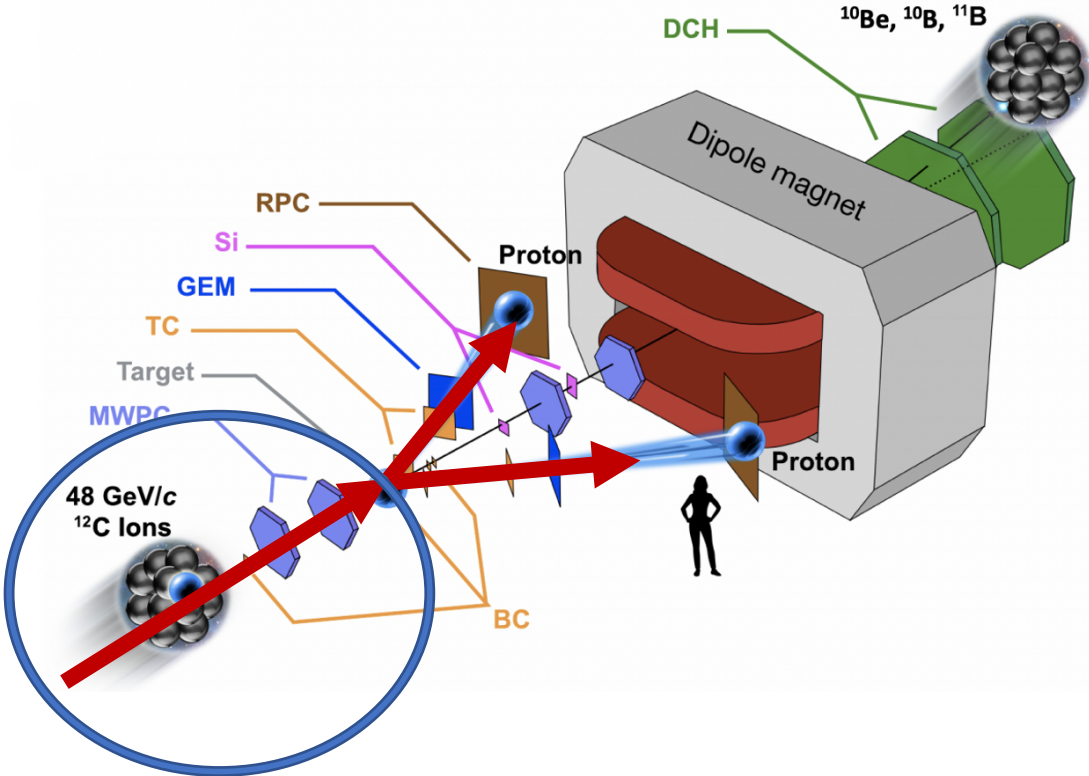
The new part of physics program of BM@N is about Short Range Correlations!

SRC RUN CONFIGURATION (IN 2018):
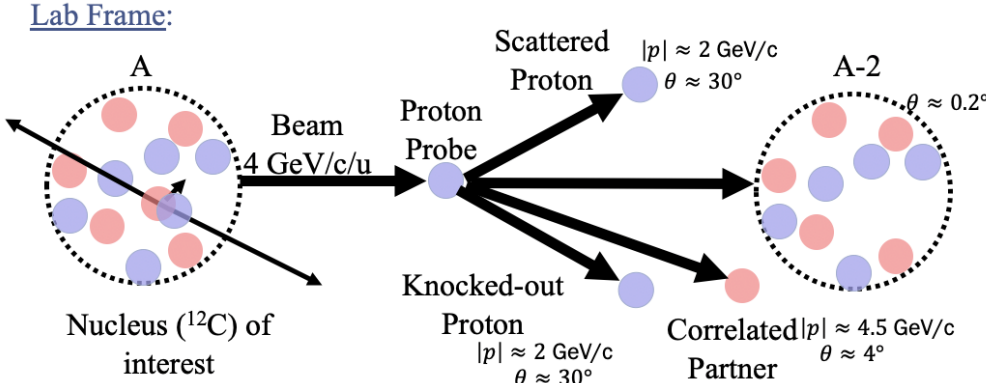

In red color: key detectors
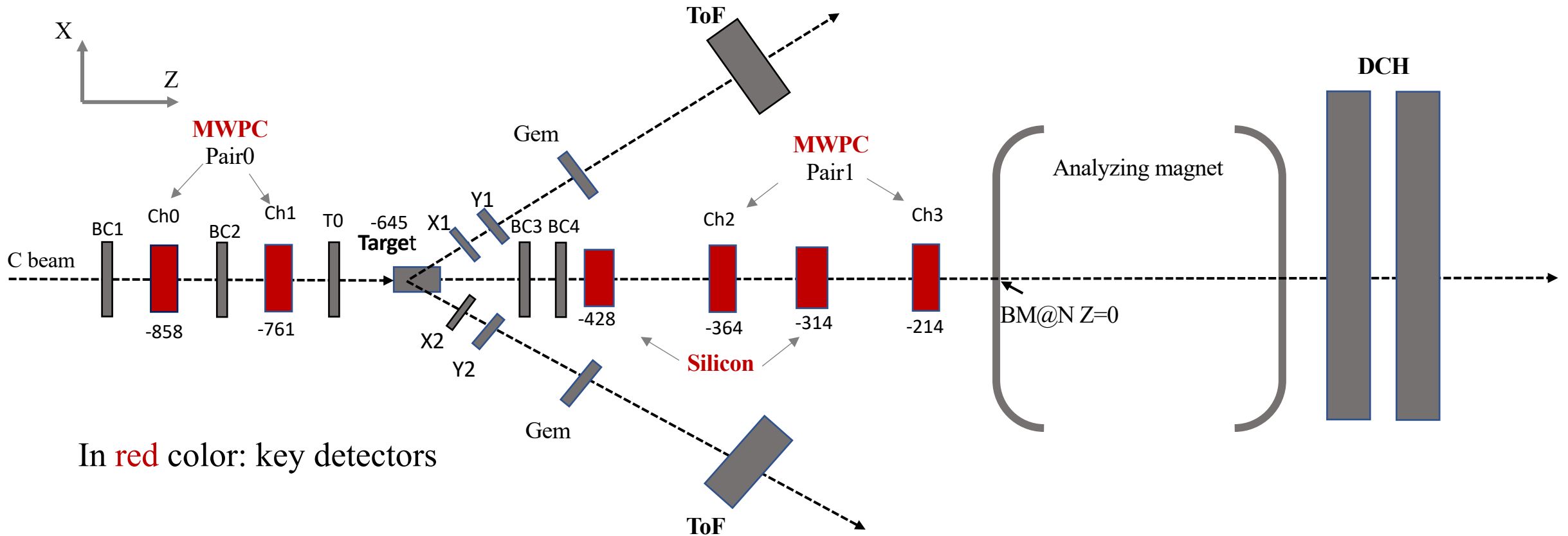
Analysis: Proton momentum before the interaction
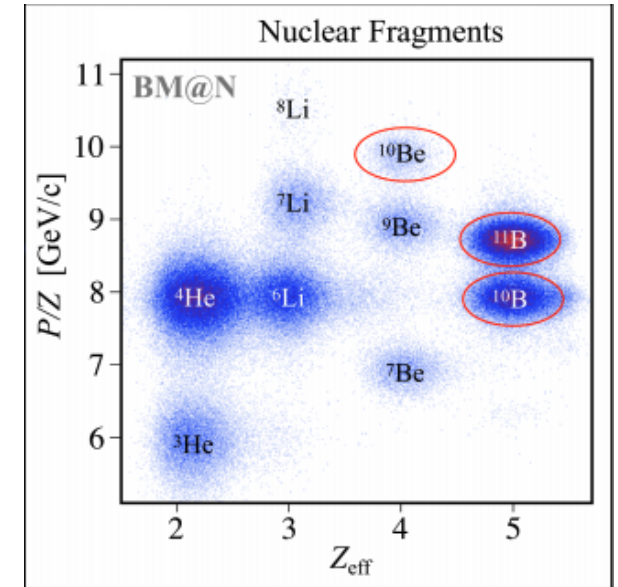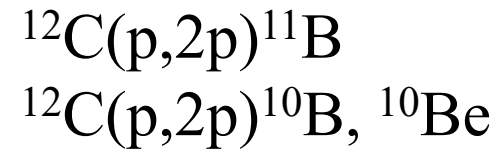
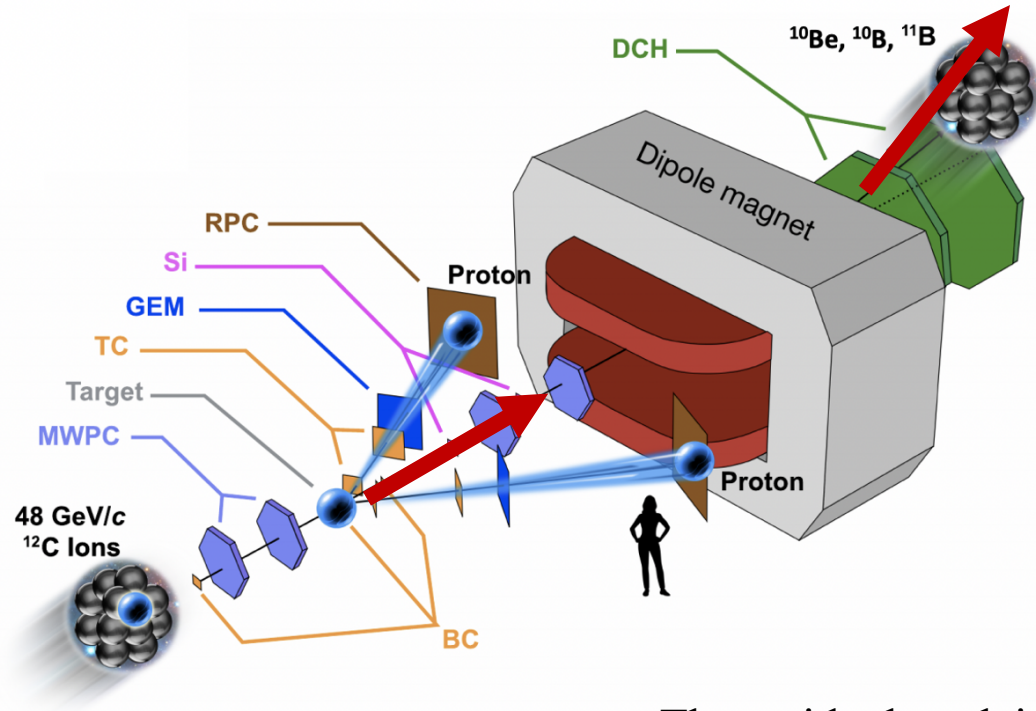First analysis paper submitted for publication!

- The momentum of the proton in the nucleus before interaction are key part physical analysis

- The proton momentum before the interaction was reconstructed using 3 vectors :
Incoming vector to the target and 2 protons in the arms

Analysis: momentum of the residual ion

First analysis paper submitted for publication!

^{12}C(p,2p)^{11}B
^{12}C(p,2p)^{10}B, ^{10}Be

$$^{12}\text{C}(p,2p)^{11}\text{B}$$
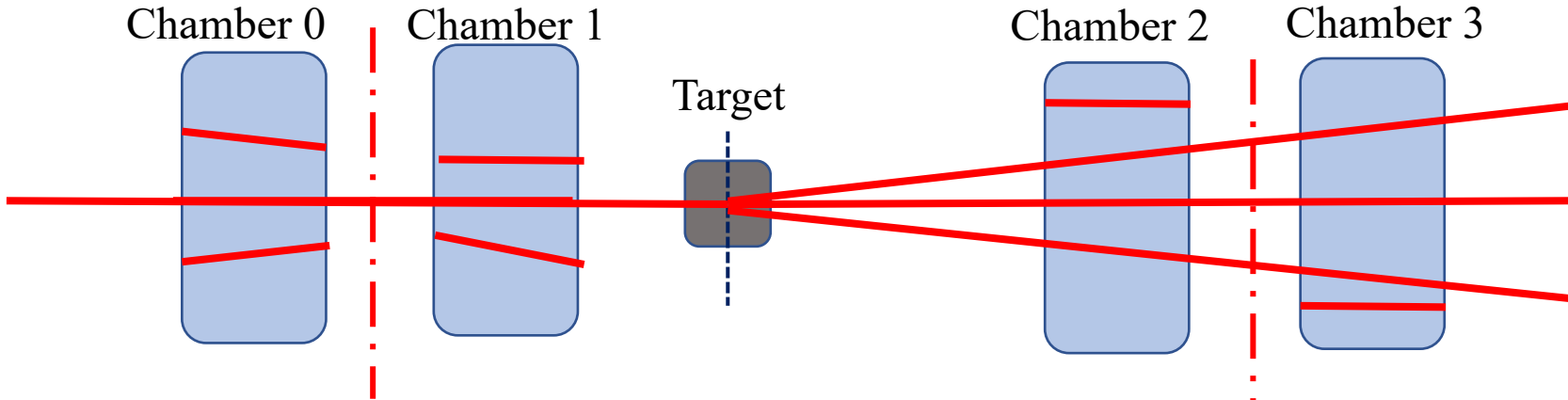$$^{12}\text{C}(p,2p)^{10}\text{B}, {}^{10}\text{Be}$$

The residual nuclei momentum was restored based on two straight segments:
upstream and downstream the analyzing magnet

The possibility of registering the residual nuclei is a unique opportunity to BM@N!

Improved Track Reconstruction in MWPCs

Pair0

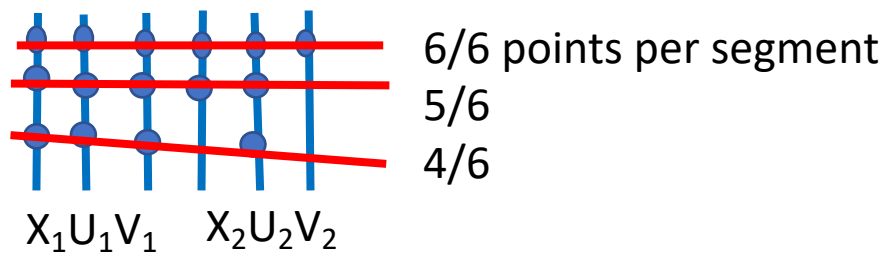Chamber 0   Chamber 1

Target
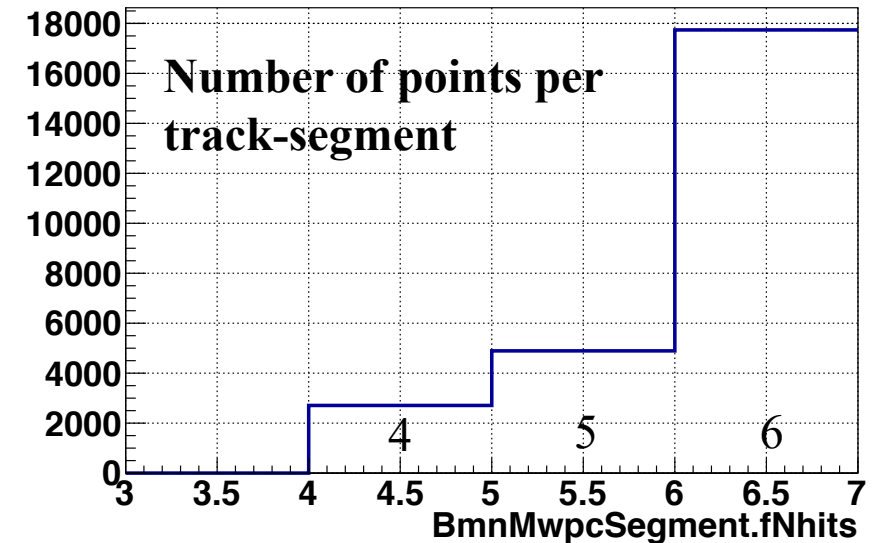
Pair1

Chamber 2   Chamber 3

MWPC working regime was not optimal- the clusters were huge

Track-segment = reconstructed straight track in one chamber

1. Track-segment formed using

6/6 points per segment
5/6
4/6

$X_1U_1V_1$ $X_2U_2V_2$

2. Reconstruct & fit track-segment in each chamber
3. Extrapolate segments to $Z_{0,1}= (Z1+Z2)/2$ & select best pairs by χ^2 criteria, **angles are not taken into account**
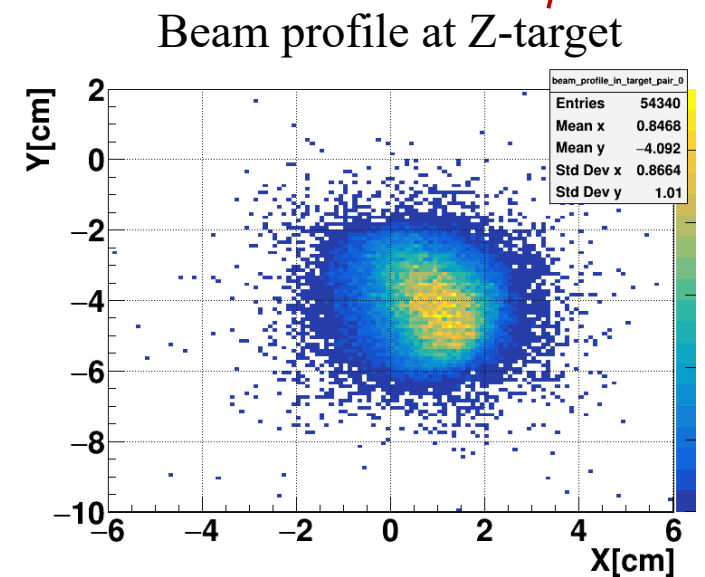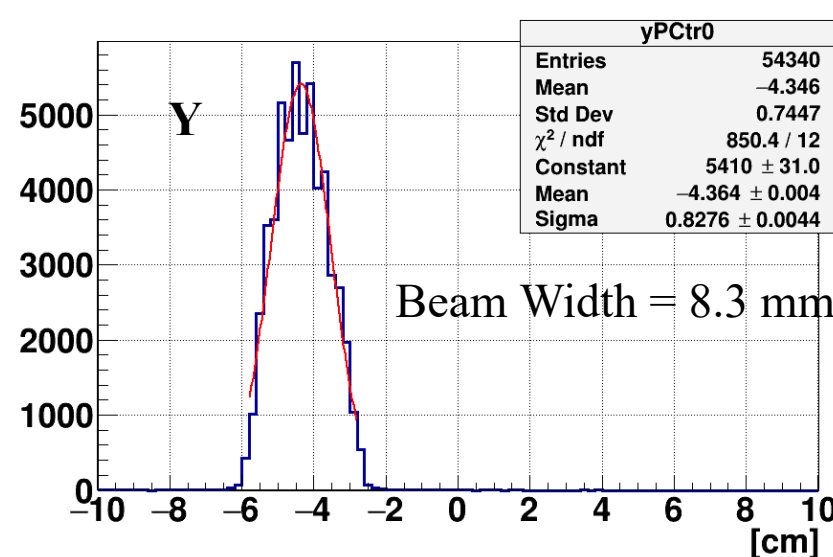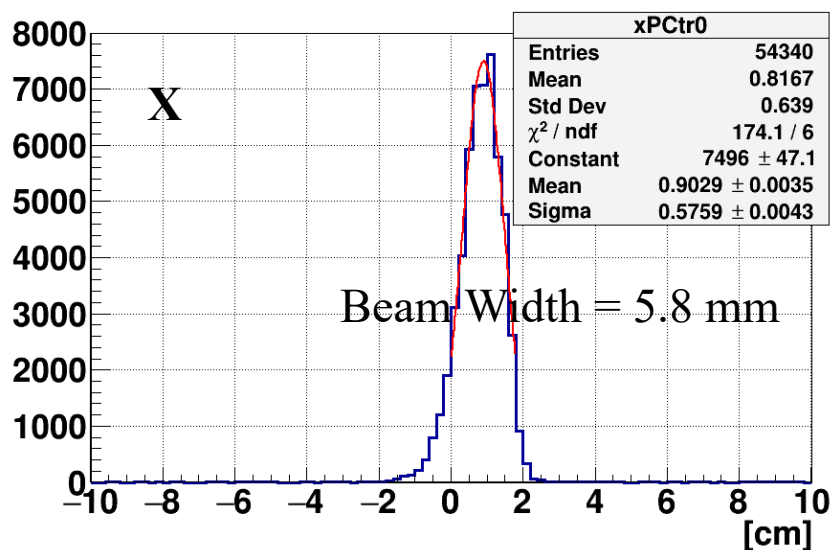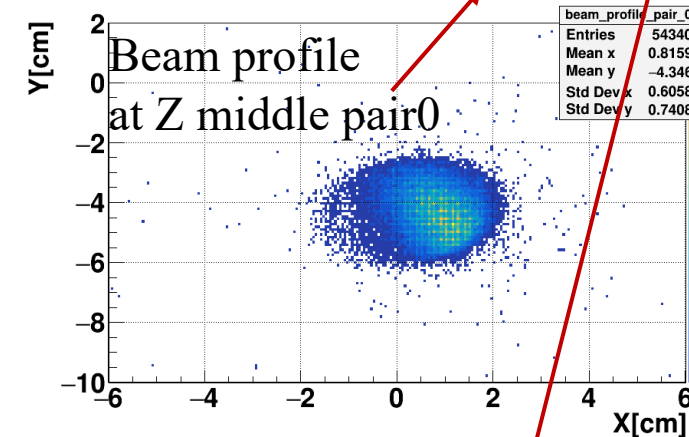4. MWPC track in Pair0 and Pair1

Number of points per track-segment

4   5   6

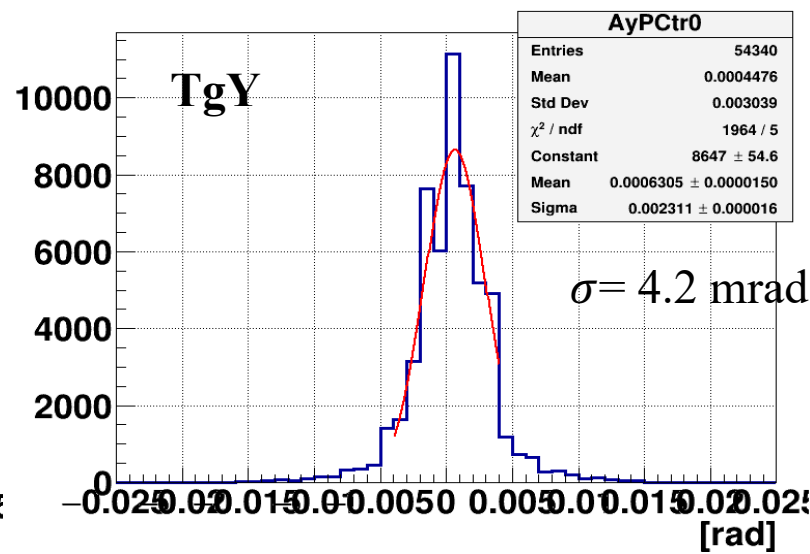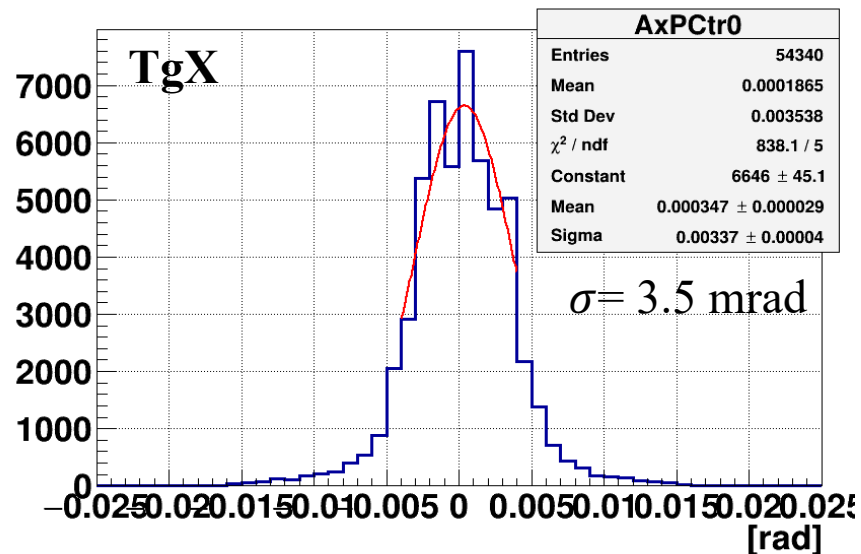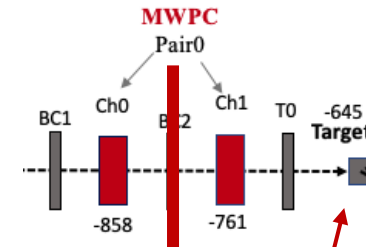3   3.5   4   4.5   5   5.5   6   6.5   7

BmnMwpcSegment.fNhits

MWPC-Track (Pair0) Parameters upstream the target

Run 3430, empty target | Cin cut | at Z middle pair0

TgX

AxPCtr0	
Entries	54340
Mean	0.0001865
Std Dev	0.003538
χ^2 / ndf	838.1 / 5
Constant	6646 ± 45.1
Mean	0.000347 ± 0.000029
Sigma	0.00337 ± 0.00004

σ= 3.5 mrad

TgY

AyPCtr0	
Entries	54340
Mean	0.0004476
Std Dev	0.003039
χ^2 / ndf	1964 / 5
Constant	8647 ± 54.6
Mean	0.0006305 ± 0.0000150
Sigma	0.002311 ± 0.000016

σ= 4.2 mrad

Beam profile
at Z middle pair0

beam_profile_pair_0	
Entries	54340
Mean x	0.8159
Mean y	−4.346
Std Dev x	0.6058
Std Dev y	0.7408

X

xPCtr0	
Entries	54340
Mean	0.8167
Std Dev	0.639
χ^2 / ndf	174.1 / 6
Constant	7496 ± 47.1
Mean	0.9029 ± 0.0035
Sigma	0.5759 ± 0.0043

Beam Width = 5.8 mm

Y

yPCtr0	
Entries	54340
Mean	−4.346
Std Dev	0.7447
χ^2 / ndf	850.4 / 12
Constant	5410 ± 31.0
Mean	−4.364 ± 0.004
Sigma	0.8276 ± 0.0044

Beam Width = 8.3 mm

Beam profile at Z-target

beam_profile_in_target_pair_0	
Entries	54340
Mean x	0.8468
Mean y	−4.092
Std Dev x	0.8664
Std Dev y	1.01

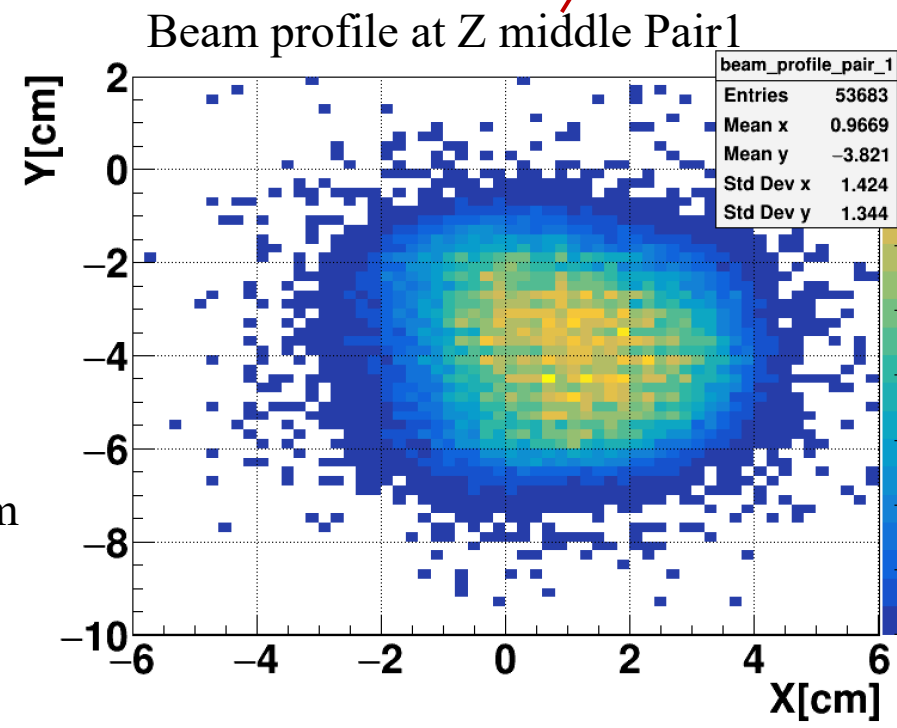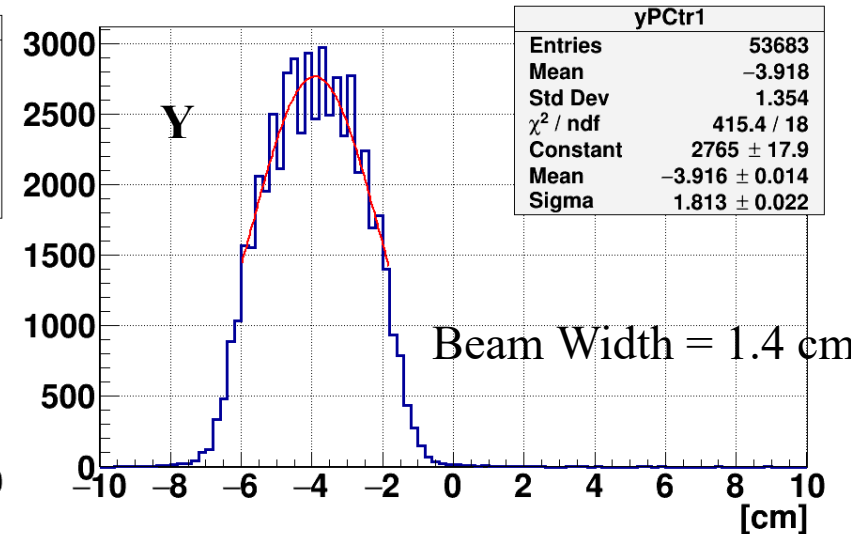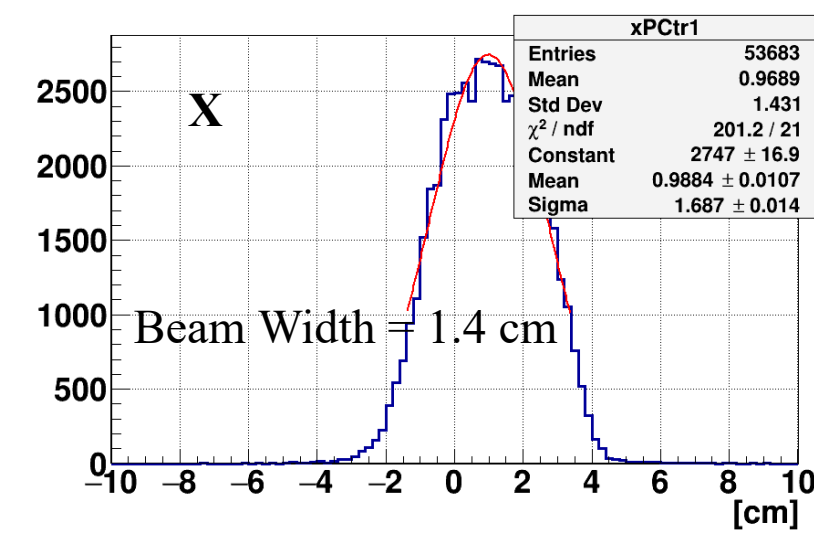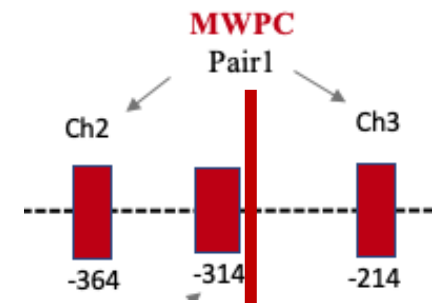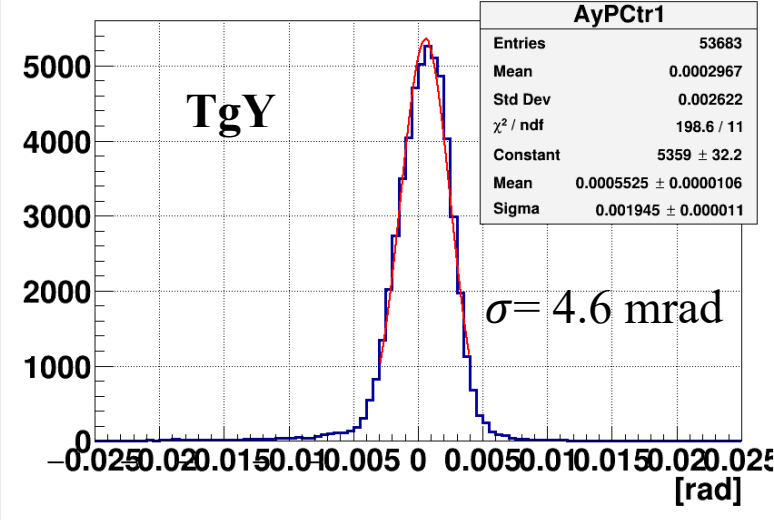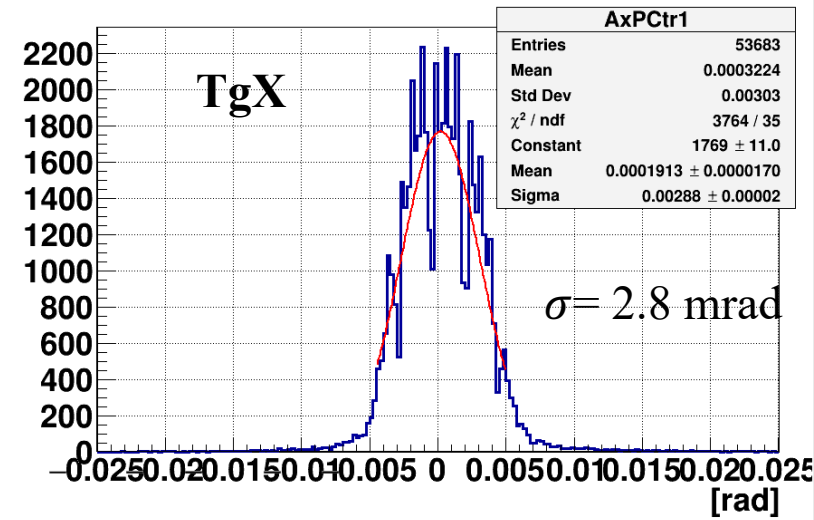# MWPC-Track (Pair1) Parameters downstream the target

Run 3430, empty target   CinCout cut

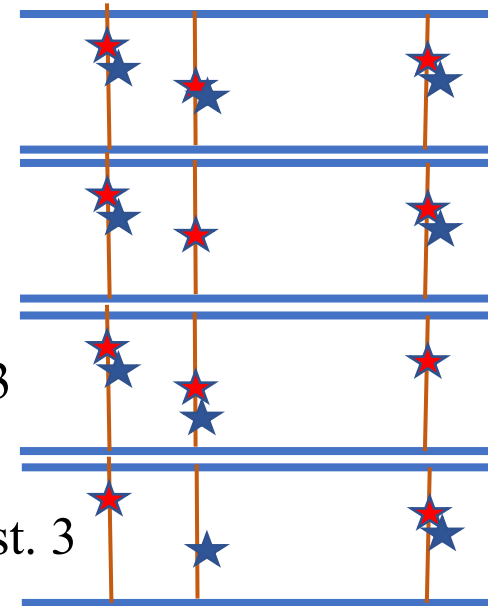# Track Reconstruction in Silicon Detector

1. **X and X' (2.5°)** neighboring fired strips – cluster center

$$CoG = \frac{\sum^N A_i * i}{\sum^N A_i}, A_i - \text{charge amplitude on } i-\text{th strip}$$

2. **Track Reconstruction** using various cases

- Case 1:   6 hits (3 spatial points) per track

- Case 2:   1 spatial point in st. 1 and 3 + X / X' in st.2

- Case 3:   1 spatial point in st. 1 and 2 + X / X' in st. 3

- Case 4:   (X + X') in (st. 1 + st. 2) + spatial point in st. 3

3. **Straight line fit on X & X'** – coordinates, rough Y – coordinate: $Y = \frac{X'-X}{tg\, 2.5°}$

Accepted track goes out from the target area

1. Silicon was not the most optimal configuration
2. X's reading ineffective

⭐ -   X hit

⭐ -   X' hit

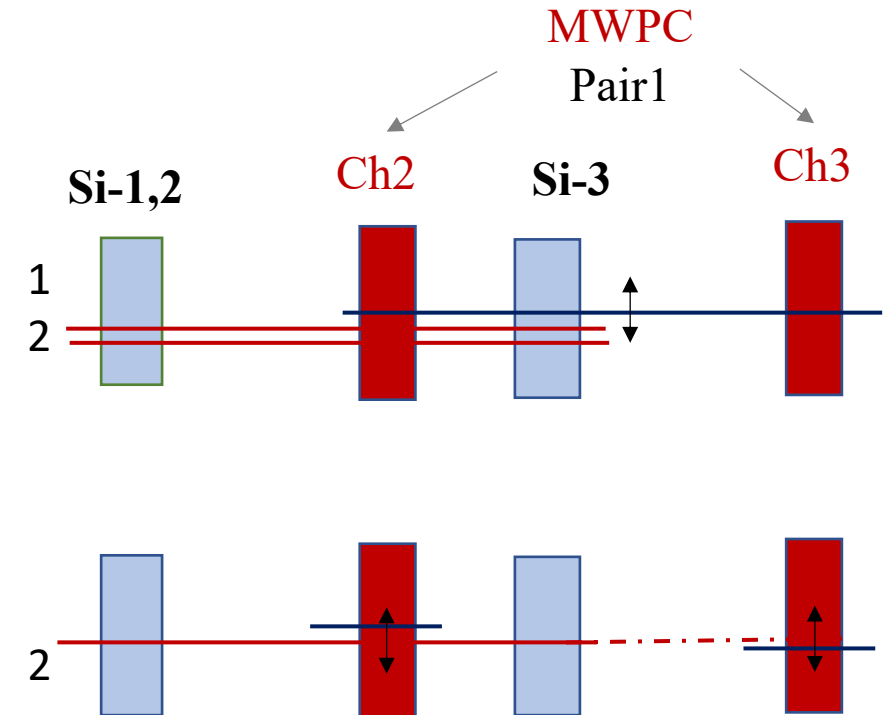Number of points per Si-track
BmnSiliconTrack.fNhits
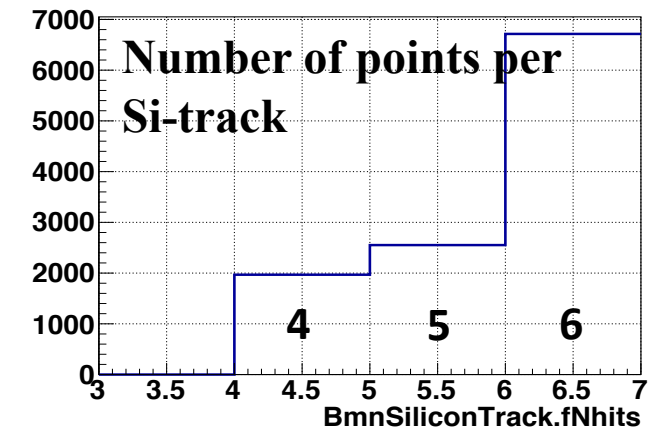
Two Stages of MWPC-Si Matching

We need a straight track upstream the analyzing magnet (for identification).
There were 2 systems (MWPC and Silicon Detector),
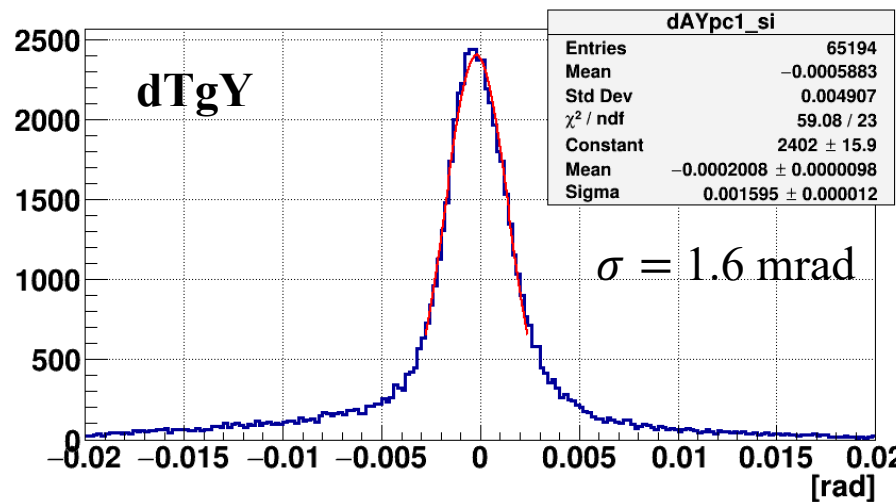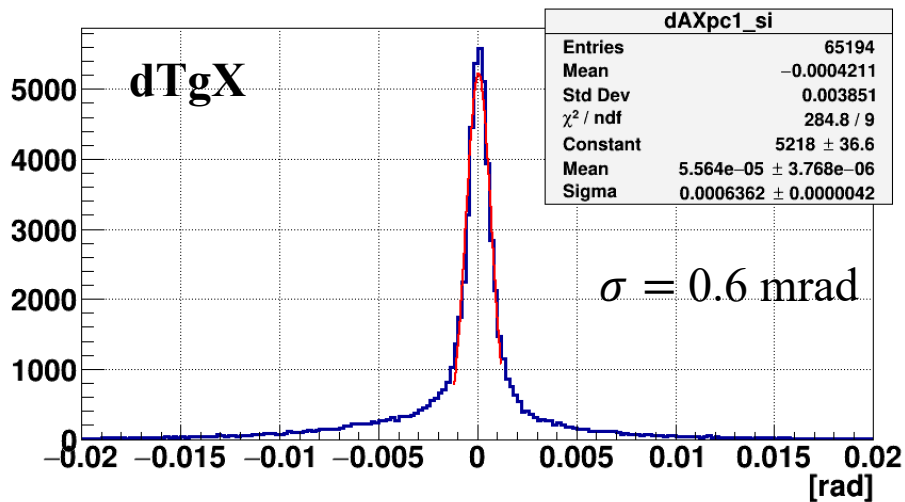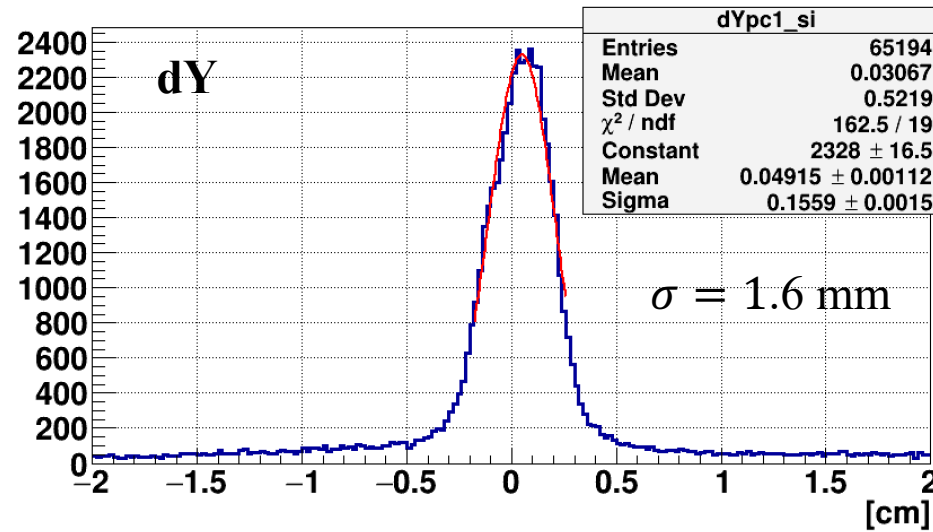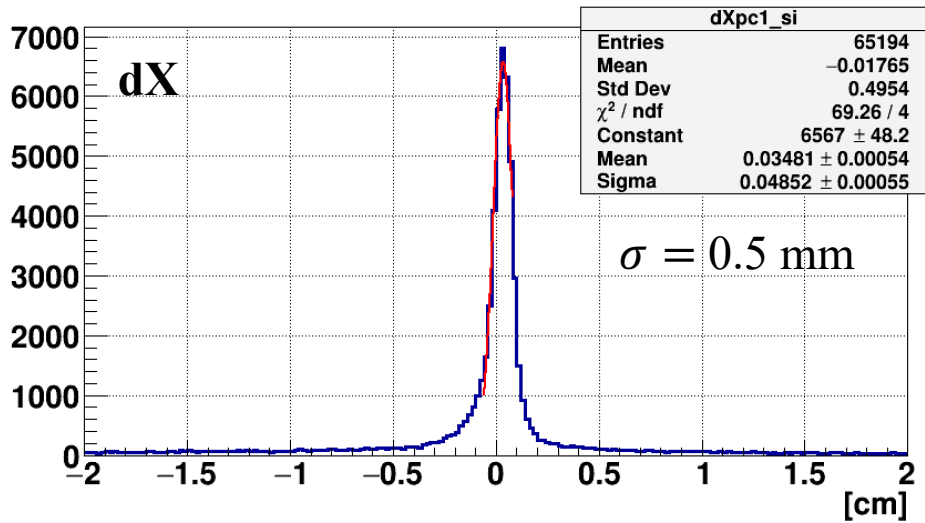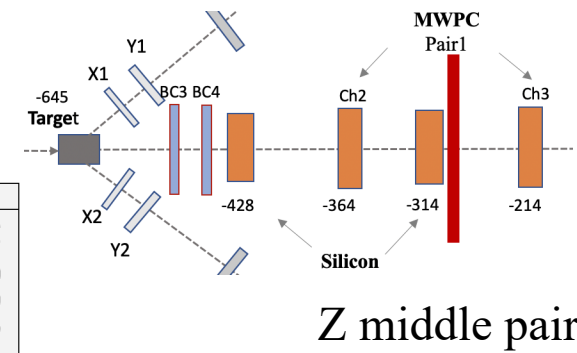We need to make a combined track from them

1. Si Tracks – MWPC Tracks (Pair1) matching with
minimal distance

2. Matching of rest Si Tracks with MWPC Segments
(Chamber 2 or Chamber 3)

Good Si – MWPC Matching at Z middle pair1

Run 3430, empty target

dX

dXpc1_si	
Entries	65194
Mean	−0.01765
Std Dev	0.4954
χ^2 / ndf	69.26 / 4
Constant	6567 ± 48.2
Mean	0.03481 ± 0.00054
Sigma	0.04852 ± 0.00055

$\sigma = 0.5$ mm

dY

dYpc1_si	
Entries	65194
Mean	0.03067
Std Dev	0.5219
χ^2 / ndf	162.5 / 19
Constant	2328 ± 16.5
Mean	0.04915 ± 0.00112
Sigma	0.1559 ± 0.0015

$\sigma = 1.6$ mm

dTgX

dAXpc1_si	
Entries	65194
Mean	−0.0004211
Std Dev	0.003851
χ^2 / ndf	284.8 / 9
Constant	5218 ± 36.6
Mean	5.564e−05 ± 3.768e−06
Sigma	0.0006362 ± 0.0000042

$\sigma = 0.6$ mrad

dTgY

dAYpc1_si	
Entries	65194
Mean	−0.0005883
Std Dev	0.004907
χ^2 / ndf	59.08 / 23
Constant	2402 ± 15.9
Mean	−0.0002008 ± 0.0000098
Sigma	0.001595 ± 0.000012

$\sigma = 1.6$ mrad

Z middle pair1

Precise coordinate in Si
→ extrapolation to MWPC

$\sigma\, X_{Si} \sim 50$ um ;
$\sigma\, Y_{Si} \sim 1$ mm

$\sigma\, X_{MWPC} = 2.5/\sqrt{12}$ [mm]
$\sigma\, Y_{MWPC} = \sigma\, X_{MWPC} * \sqrt{2}$

Good detector resolution achieved

Residuals X (Hit-Fit)

Silicon1   **Silicon2**   **MWPC2**   **Silicon3**   **MWPC3**

σ = 17 um σ = 21 um σ = 0.46 mm σ = 11 um σ = 0.49mm

Residuals Y (Hit-Fit)

σ = 0.75 mm σ = 0.84 mm σ = 0.55 mm σ =1.36 mm σ = 0.16mm

13
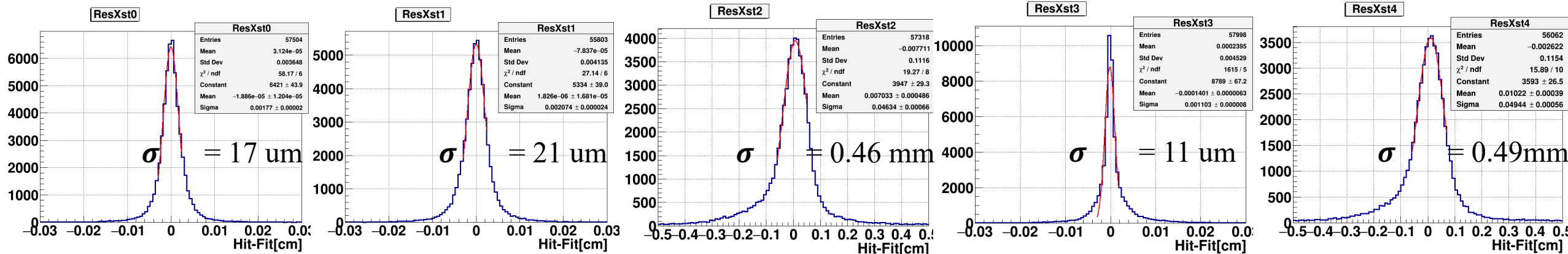
Detector and algorithm efficiency
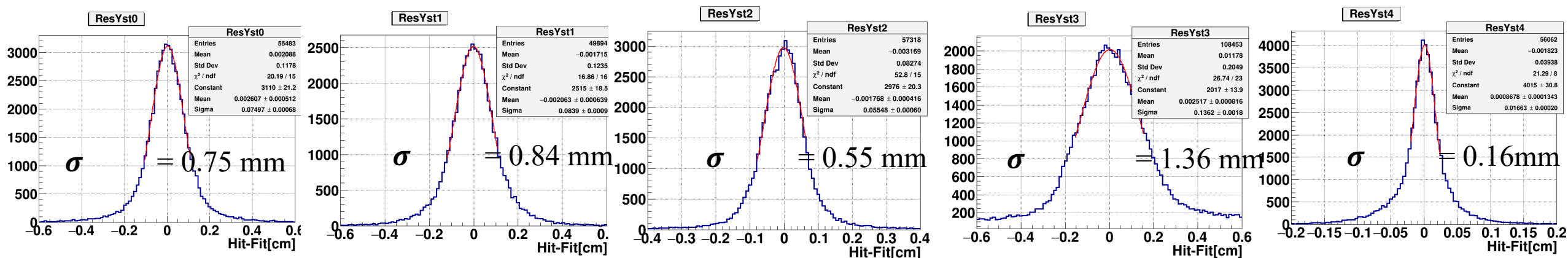
Detector and algorithm efficiency

Efficiency = N events MWPCp0 & Si /N events MWPCp0
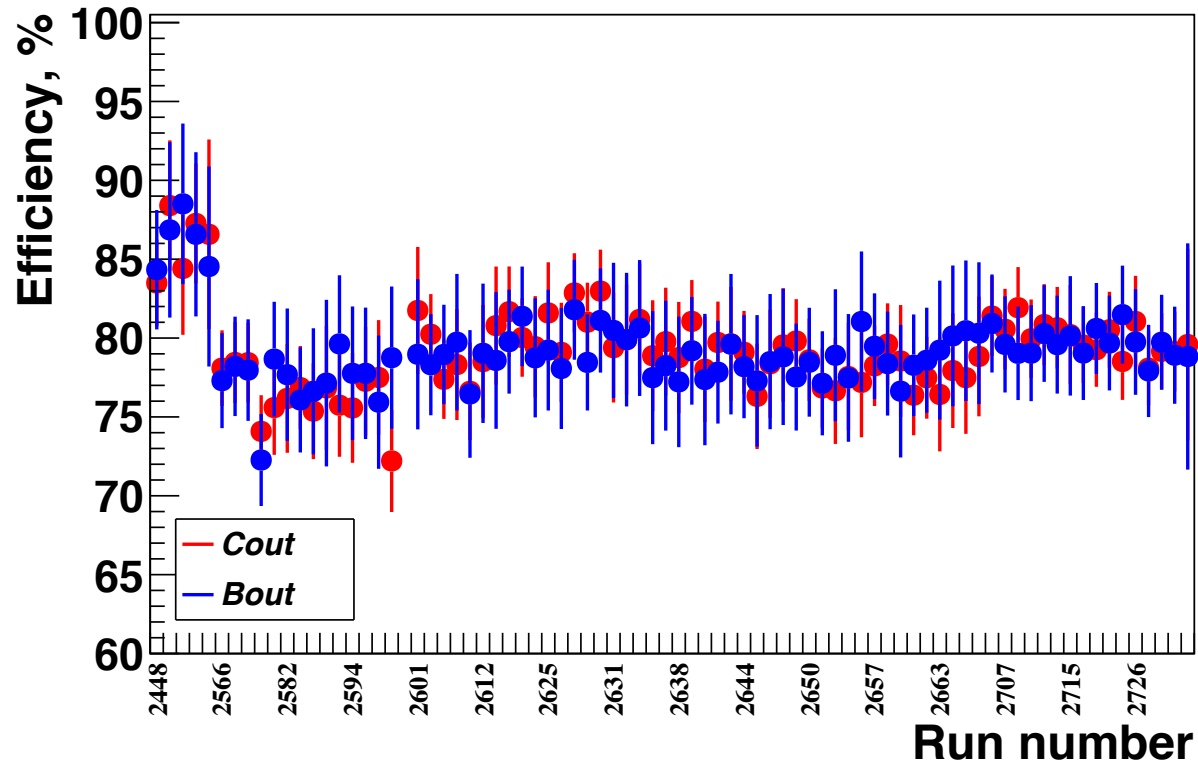
Efficiency = N events MWPCp0 & p1 /N events MWPCp0
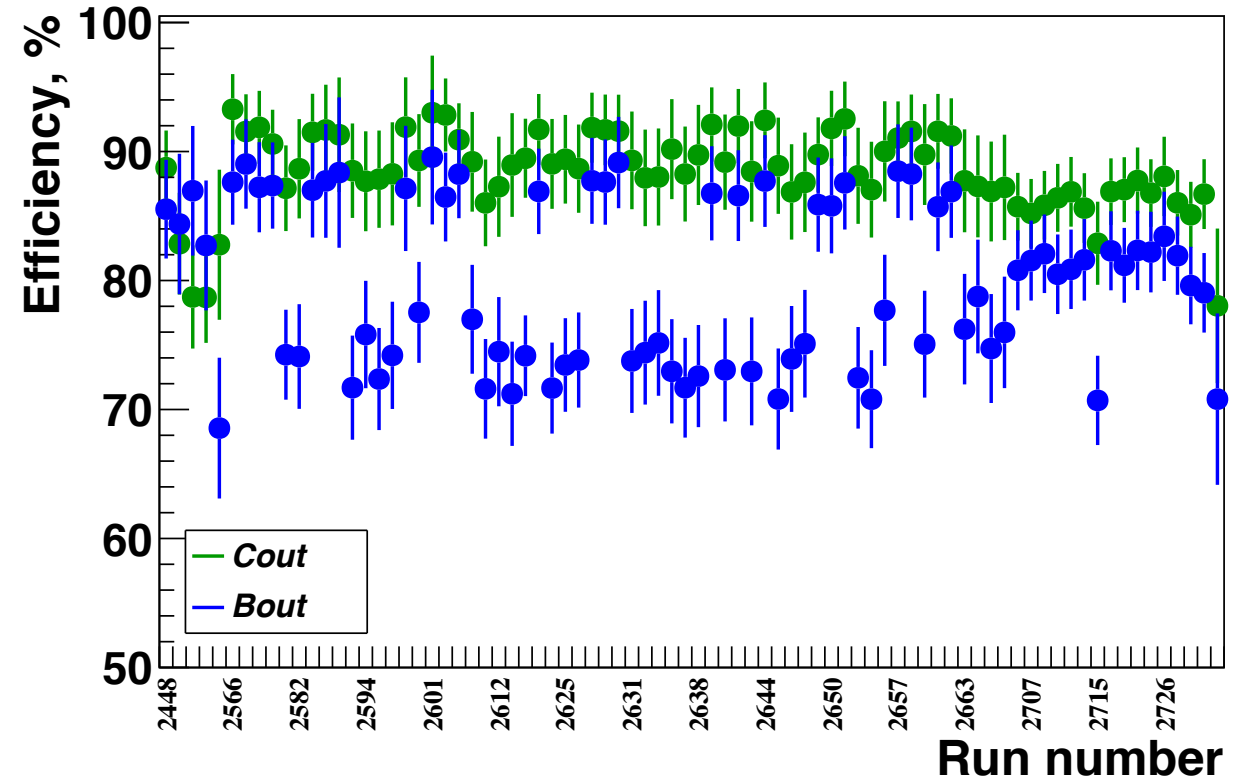
Conclusion

- Track reconstructed using MWPC and Si are a key element for the first physics analysis submitted for publication

- MWPC, Si and the combined MWPC-Si track reconstruction was developed and implemented in BmnRoot classes

- Simulation of MWPC and Si was developed and will be implemented in BmnRoot classes for the full BM@N simulation in the near future
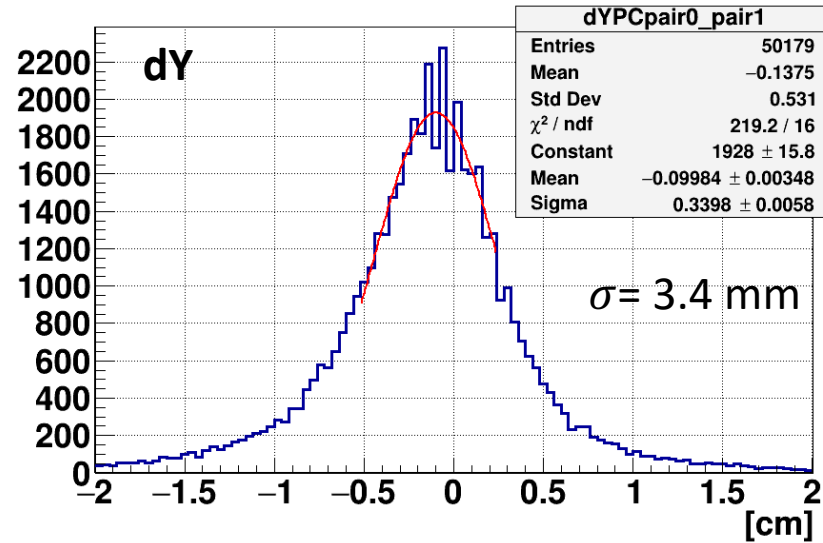
vasilisa@jinr.ru
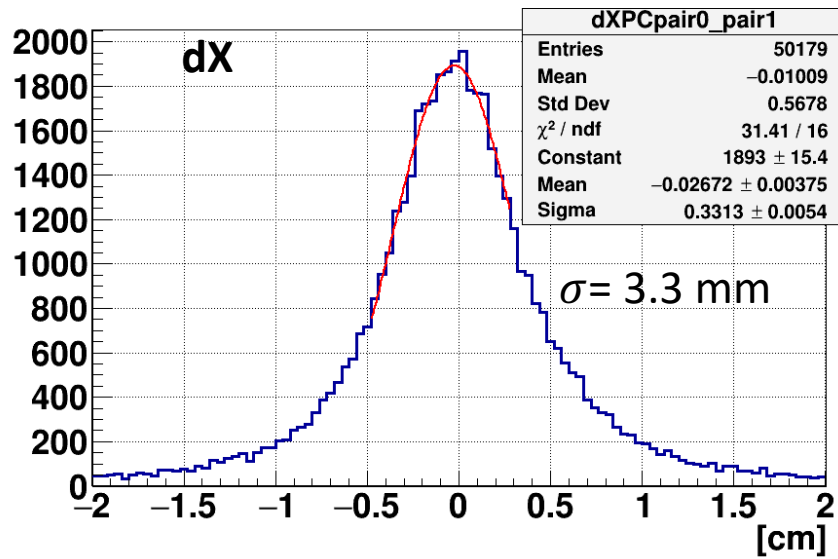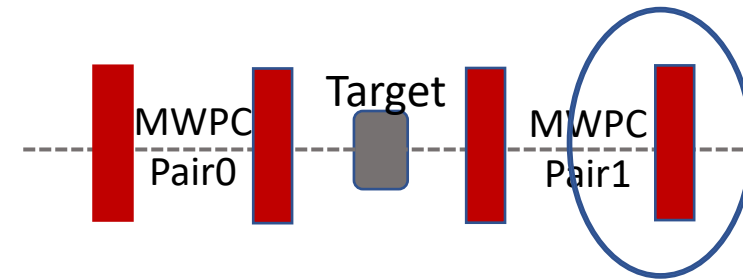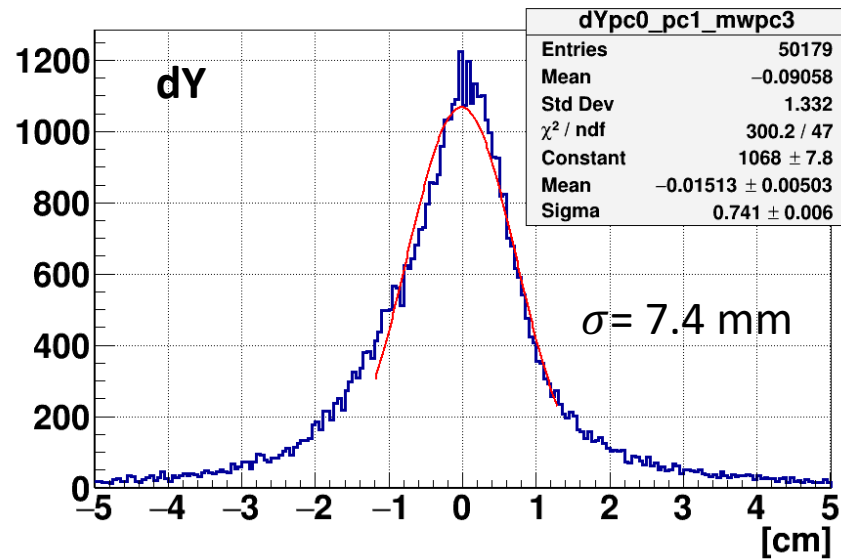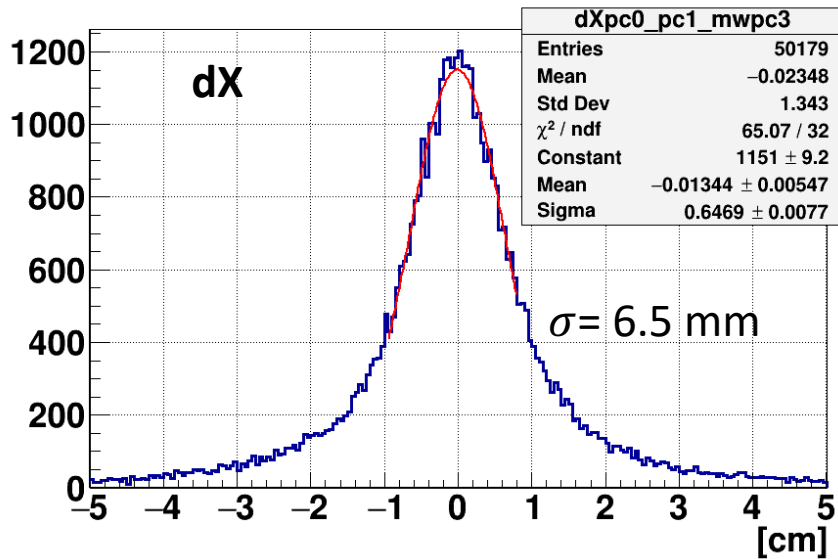
Thank you for your attention!
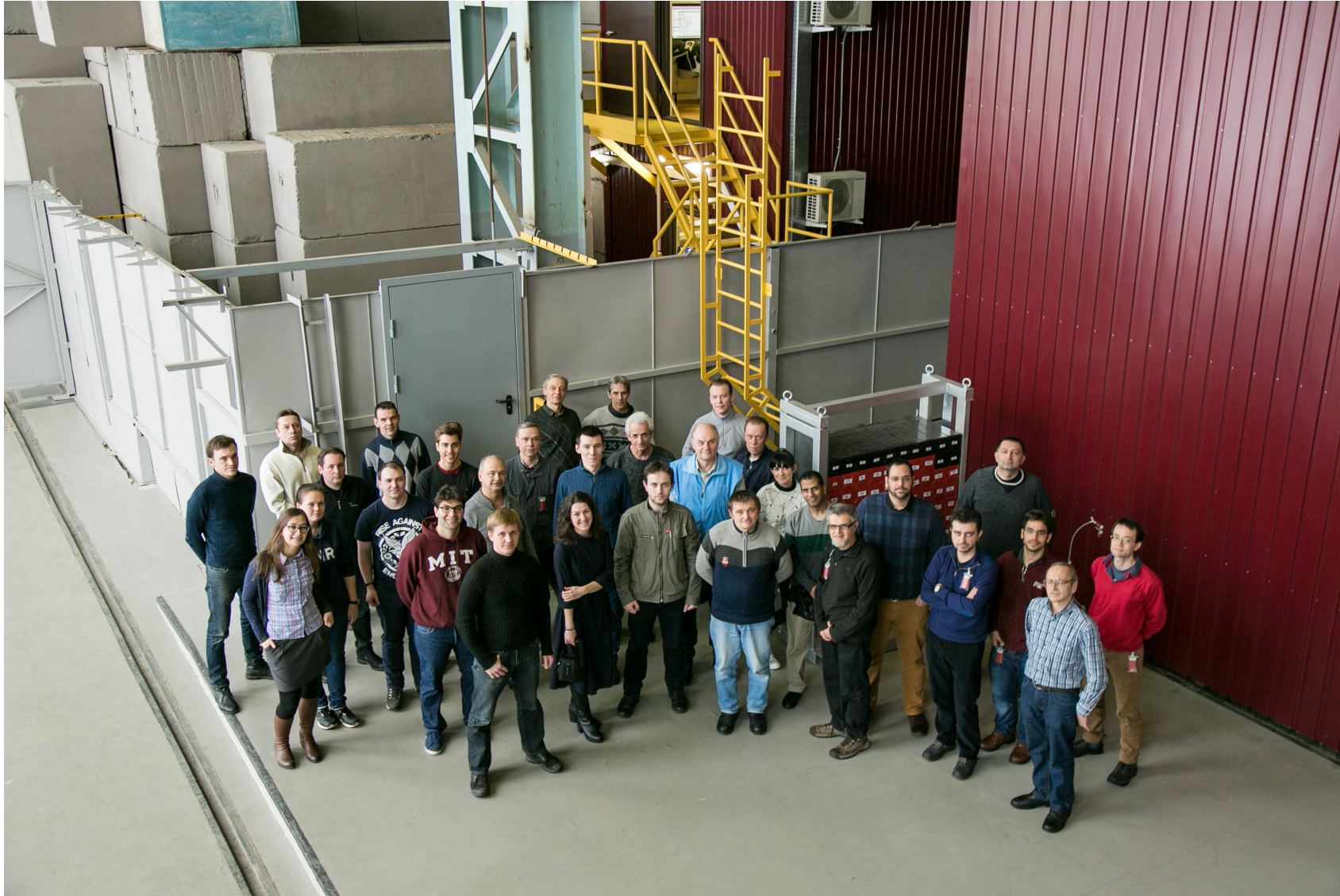
Back up

Charge vs Run number using BCs counters
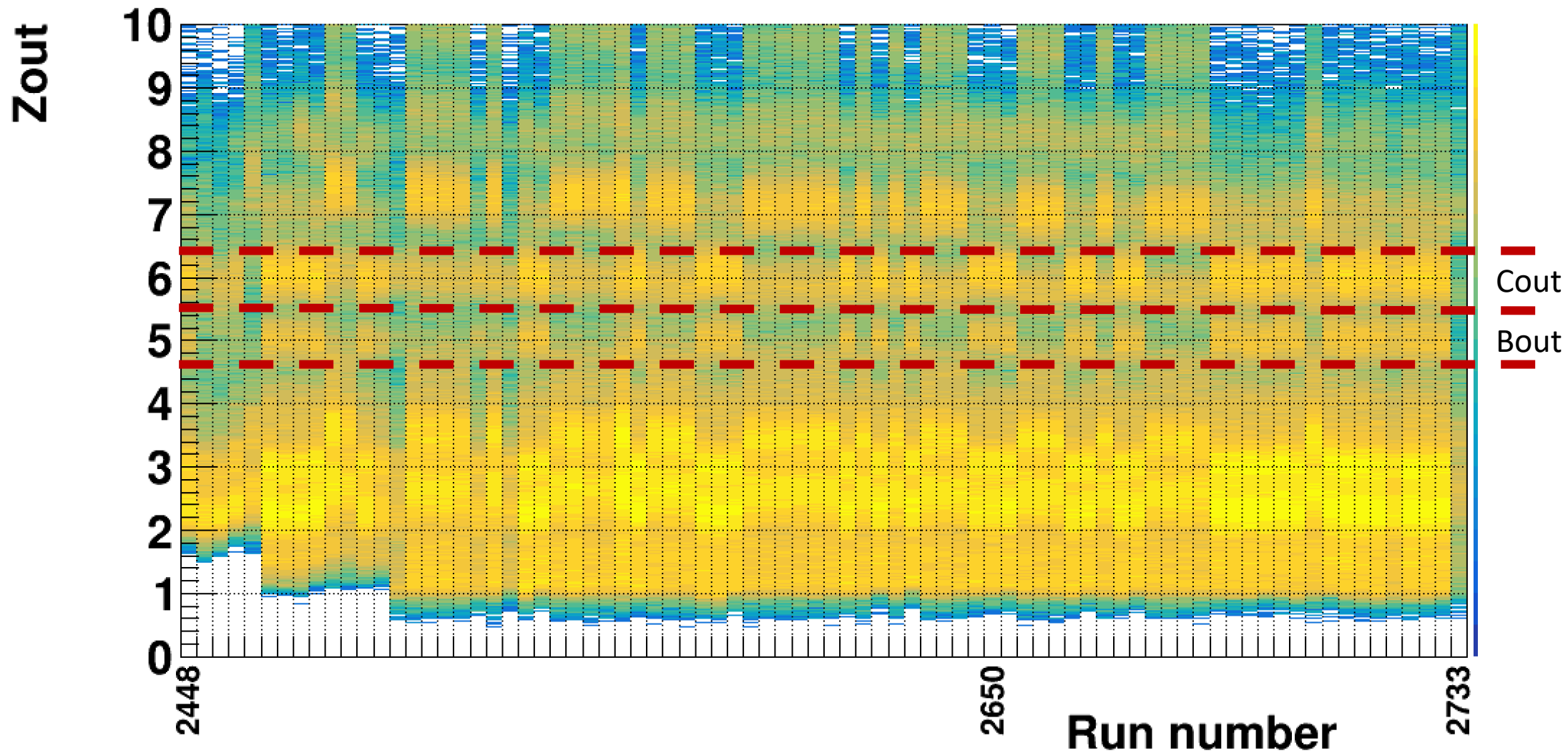
Pair0 – Pair1 matching; Run 3430 (empty target); CinCoutcut
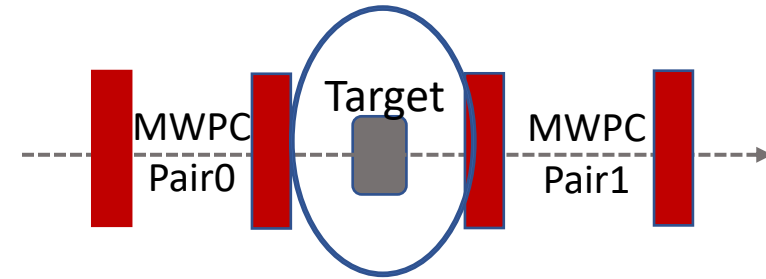
Pair0 − Si matching; Run 3430 (empty target); CinCoutcut
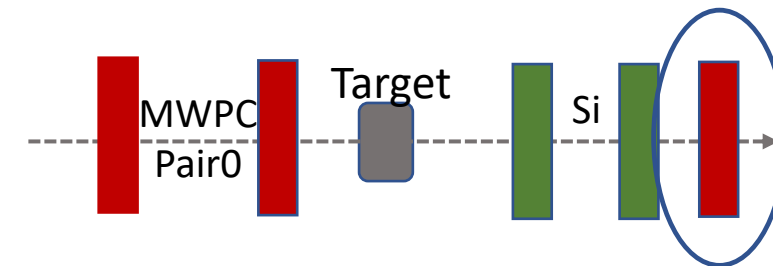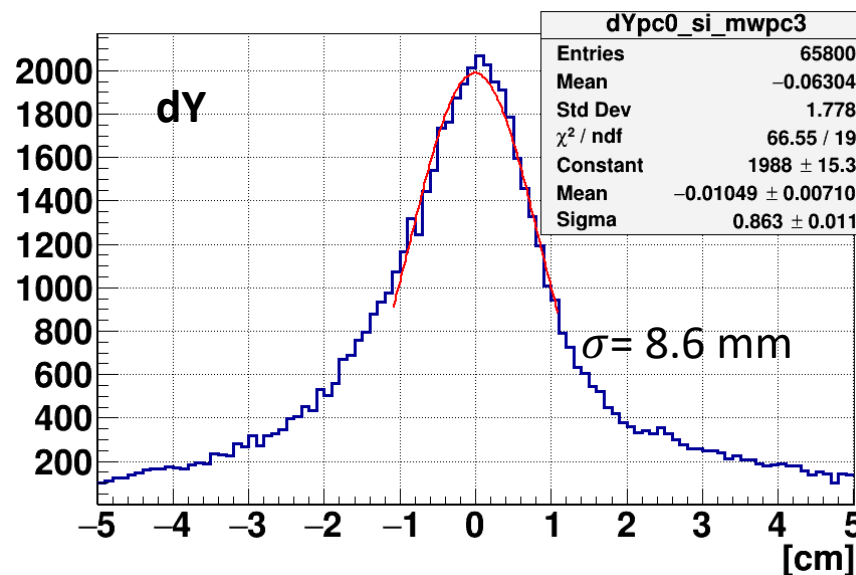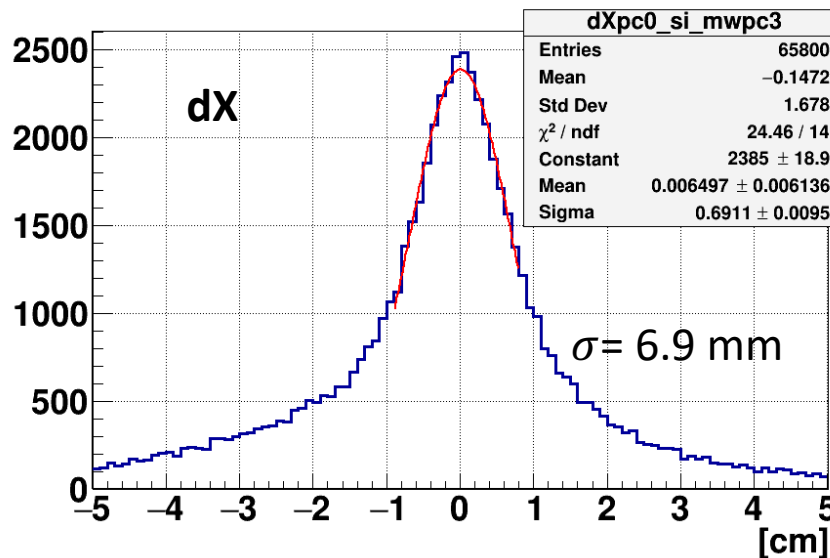
Highest statistics : 66 Kev
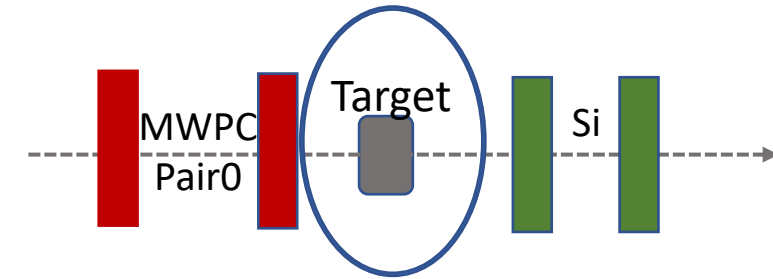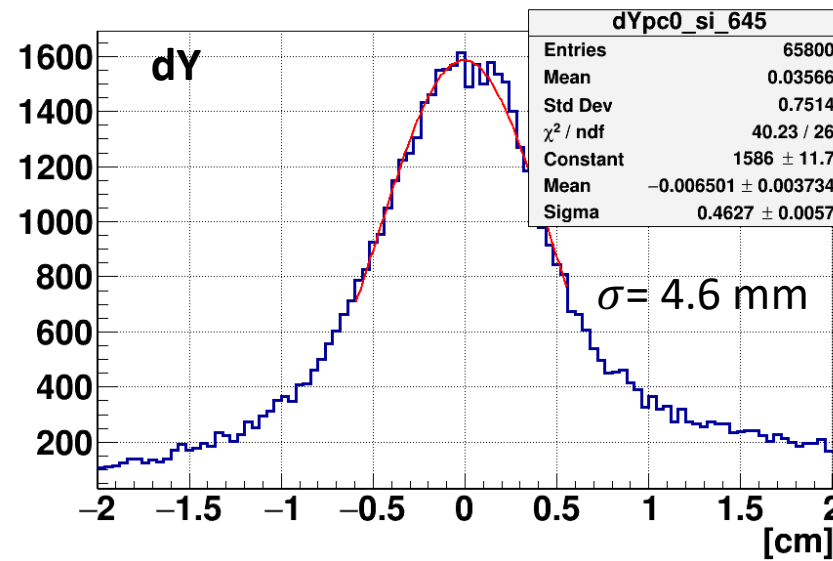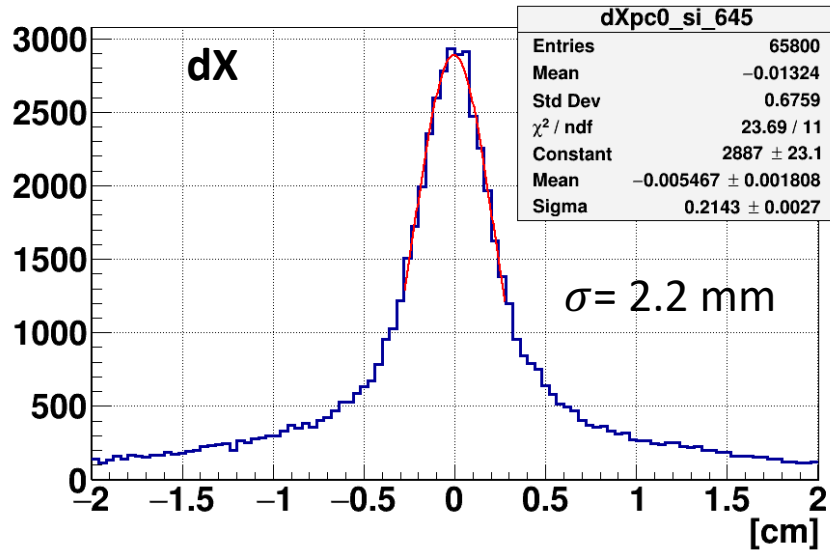
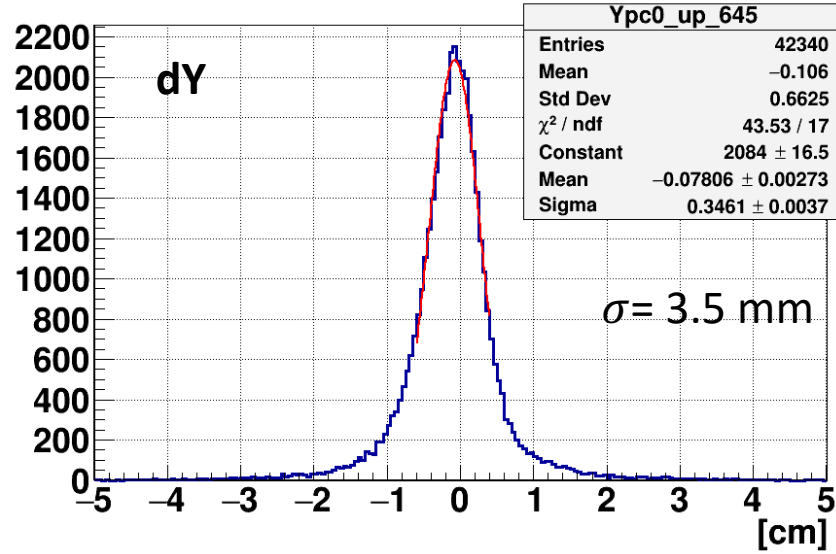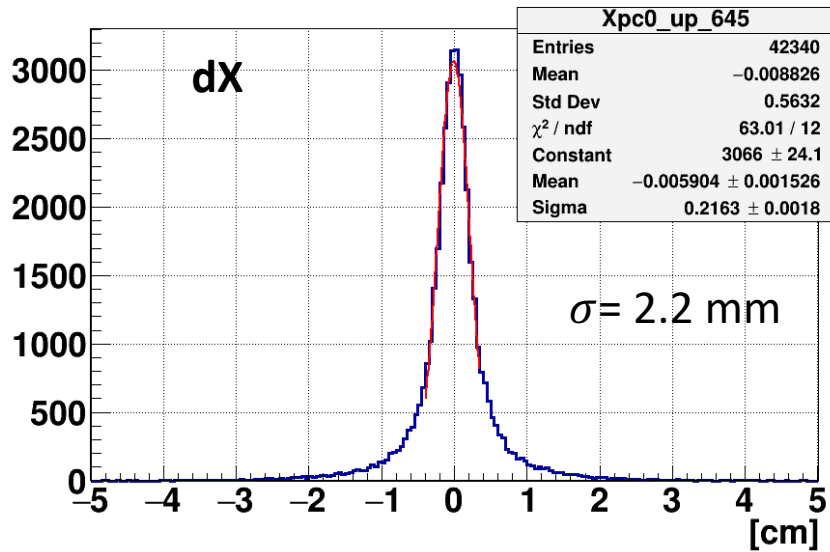
At Z-target:Widths are minimal

SigmaX is better & SigmaY is worse due to SiDet accuracy

Extrapolation to Z-mwpc3

All MWPC & SiDet are aligned correspondently the magnet: all means = 0

Pair0 – Upstream **matching;** Run 3430 (empty target); CinCoutcut

dX

Xpc0_up_645

Entries	42340
Mean	−0.008826
Std Dev	0.5632
χ² / ndf	63.01 / 12
Constant	3066 ± 24.1
Mean	−0.005904 ± 0.001526
Sigma	0.2163 ± 0.0018

σ= 2.2 mm

dY

Ypc0_up_645

Entries	42340
Mean	−0.106
Std Dev	0.6625
χ² / ndf	43.53 / 17
Constant	2084 ± 16.5
Mean	−0.07806 ± 0.00273
Sigma	0.3461 ± 0.0037

σ= 3.5 mm

Statistics is 1.5 times lower: 42 Kev

Upstream Track

Si   MWPC

MWPC
Pair0   Target

At Z-target: Widths are minimal
SigmaX is similar to Pair0-Si matching
But SigmaY is better
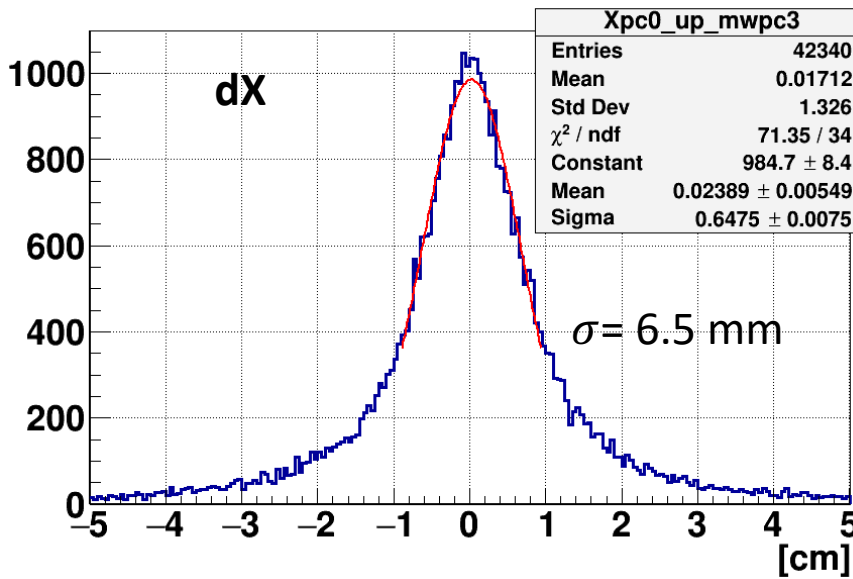
dX

Xpc0_up_mwpc3

Entries	42340
Mean	0.01712
Std Dev	1.326
χ² / ndf	71.35 / 34
Constant	984.7 ± 8.4
Mean	0.02389 ± 0.00549
Sigma	0.6475 ± 0.0075

σ= 6.5 mm

dY

Ypc0_up_mwpc3

Entries	42340
Mean	−0.08909
Std Dev	1.324
χ² / ndf	51.85 / 30
Constant	942.9 ± 8.5
Mean	0.04921 ± 0.00650
Sigma	0.6614 ± 0.0101

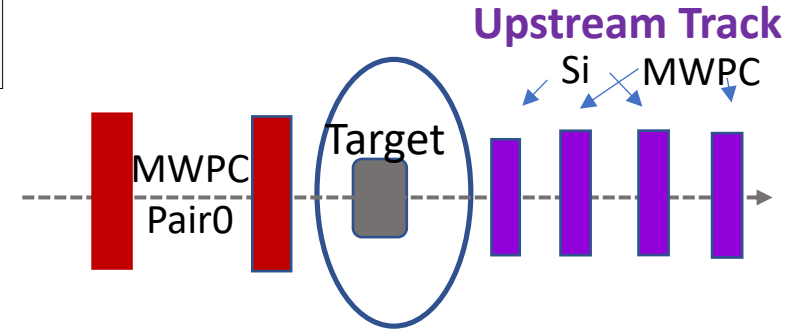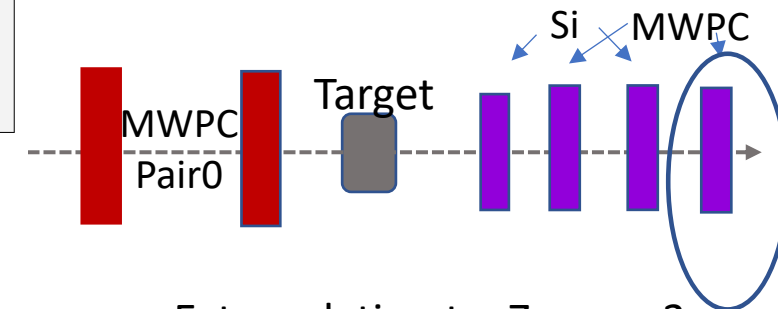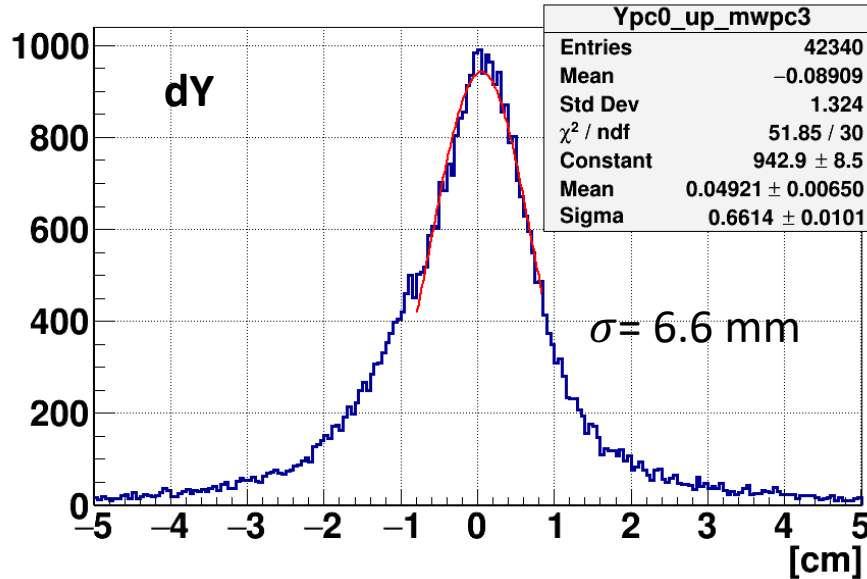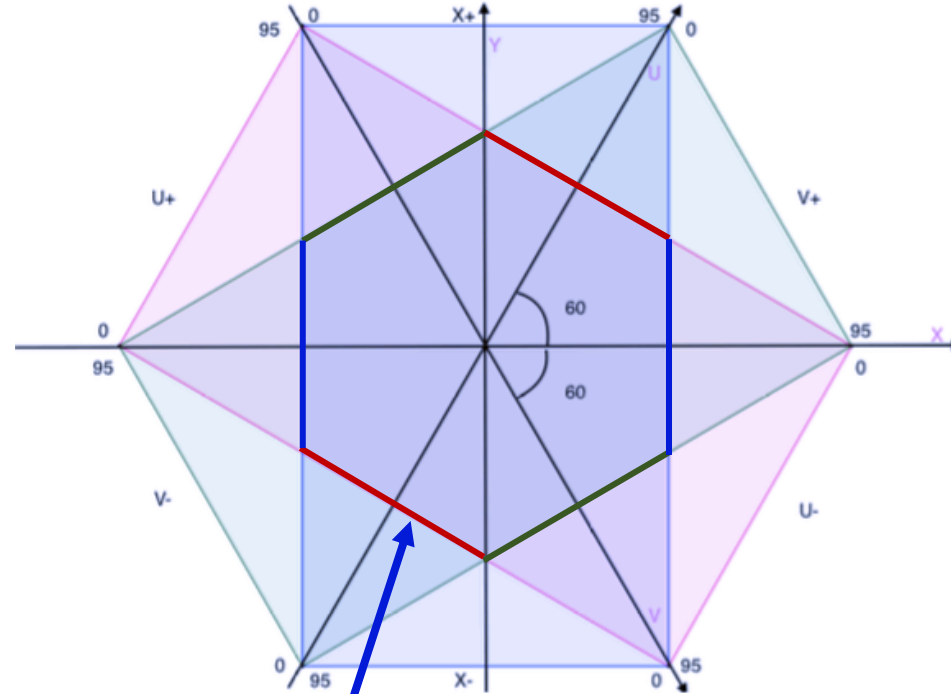σ= 6.6 mm

Si   MWPC

MWPC
Pair0   Target

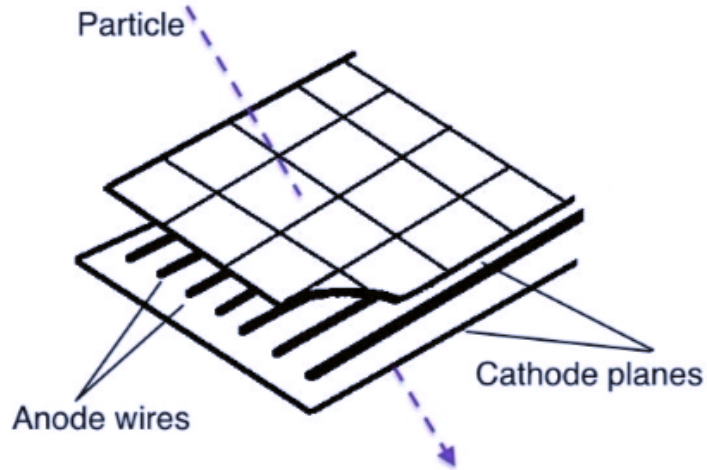Extrapolation to Z-mwpc3

All MWPC & SiDet are aligned correspondently the magnet: all means = 0

Multi Wire Proportional Chambers

Particle

Anode wires

Cathode planes

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 $\frac{d}{\sqrt{12}}$ = 0.72 mm.

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

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

This point should satisfy the
following condition:

The intersection of these planes is a working area. $V + U - X = 0$
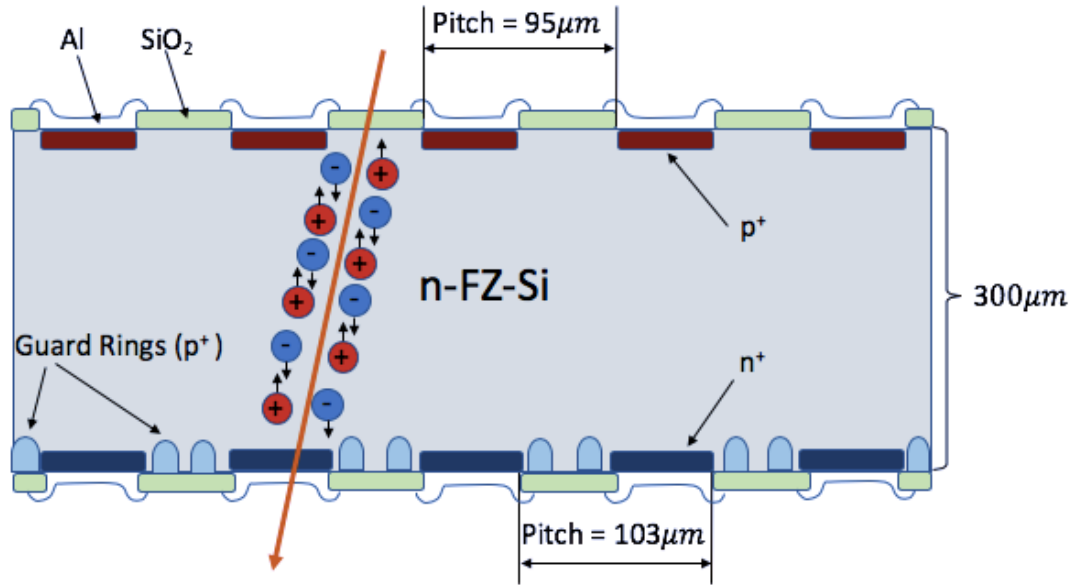
Silicon Tracking detector

Double-Sided Silicon Detectors (DSSD)

- 2-coordinate Si strip detector

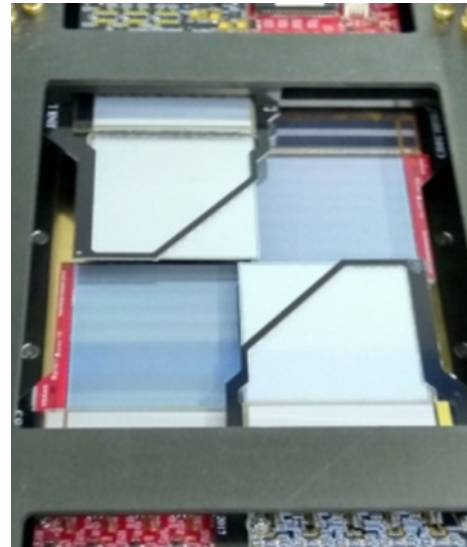Capability of stable operation in conditions of high loadings up to 10^6 Hz/cm^2
Response time is 10-15 ns
Coordinate resolution ~ 50 μm

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

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

Full sensitive size of 12 x 12 cm^2

Full sensitive size of 25 x 25 cm^2