Improvement of Si+MWPC Tracking with SRC Data. Algorithm for Run8 Upstream Track Reconstruction

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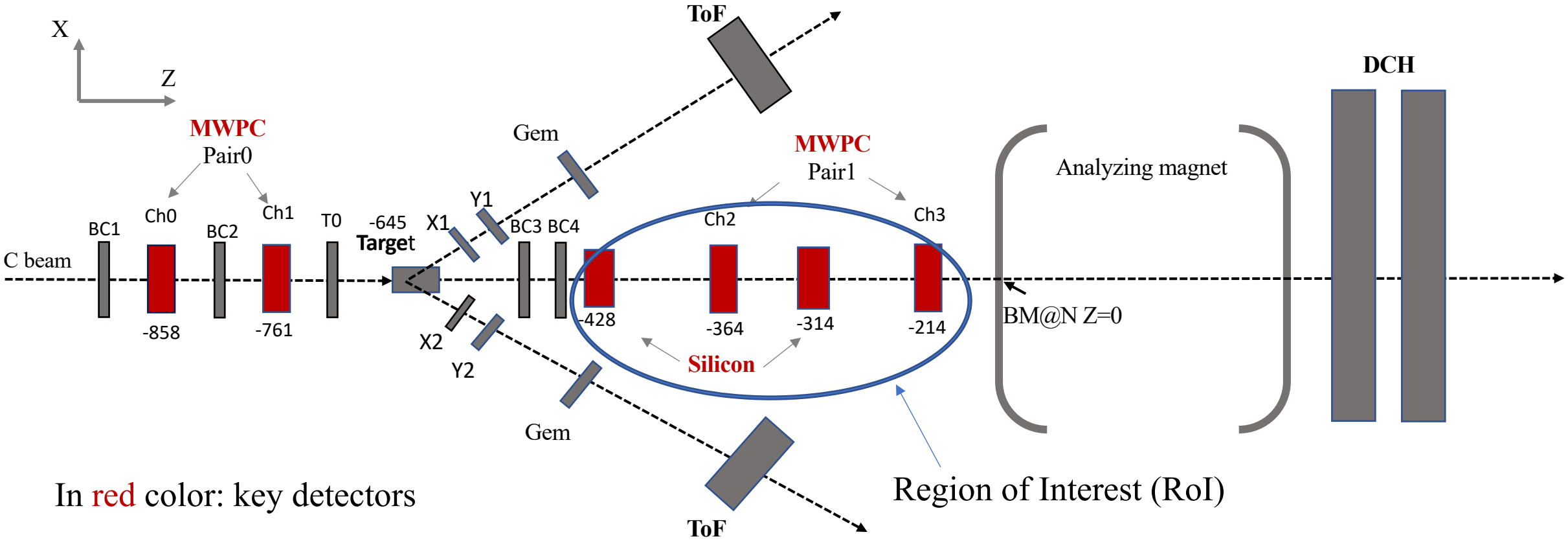
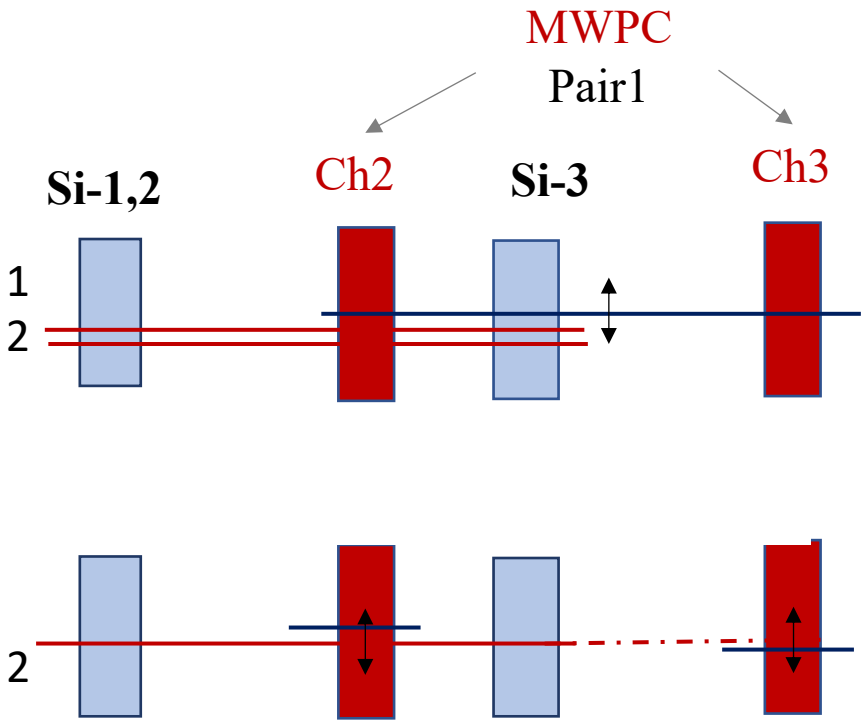
3-8 October 2021

SRC RUN7 CONFIGURATION (2018):

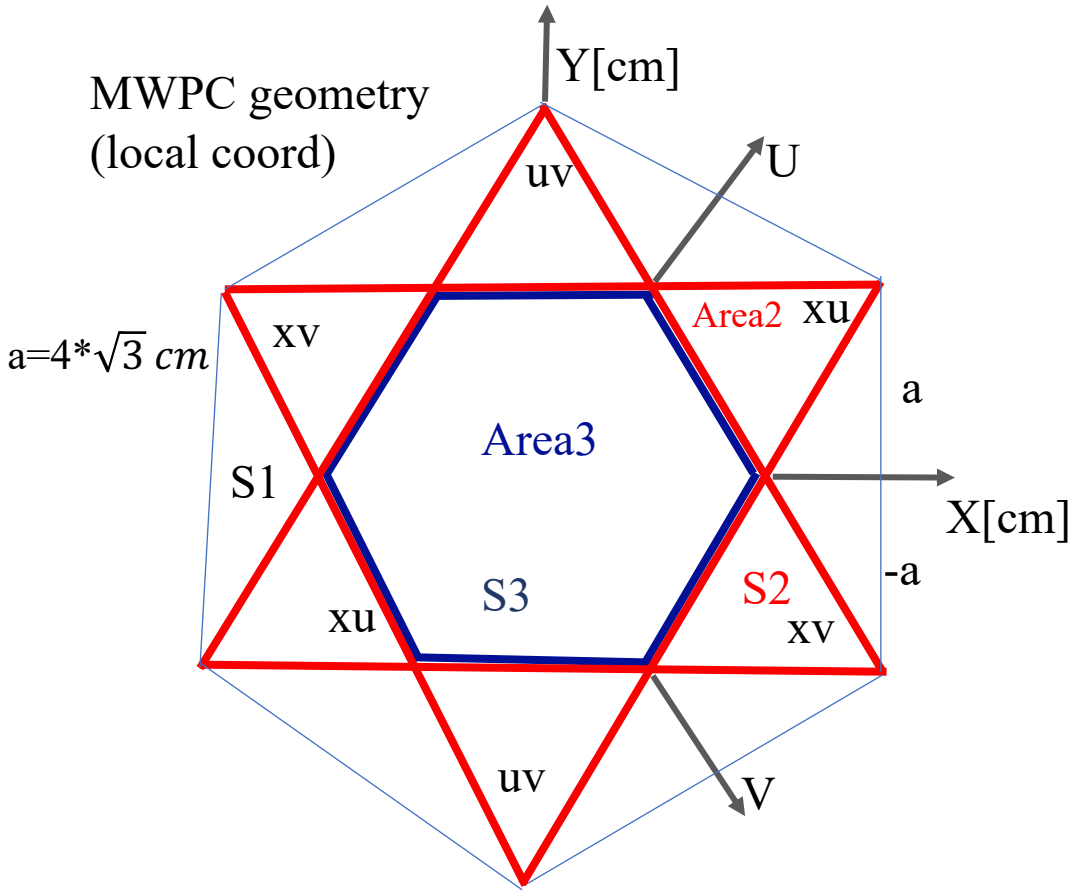


Upstream (MWPC-Si) Track Algorithm



1. Si Tracks building in SiDets
2. MWPC Tracks (Pair1) building in Ch2 & Ch3
3. Si Tracks – MWPC Tracks (Pair1) matching
4. Matching of the rest Si Tracks with MWPC Segments separately (Ch2 or Ch3)
5. Track fitting by 2 systems => **Upstream track**

MWPC Working Area is Increased (downstream the target)



One-coor. S1-area is not used

MWPC has 6 planes:
U,V are rotated by ± 60 degrees to the X-axis

Area3
- is the area of intersection of 3 coordinates: XVU (6-planes segment possible)
- Area 3 ≈ beam area (it's basically 1 track)

Area3 was used in old algorithm of MWPC track reconstruction

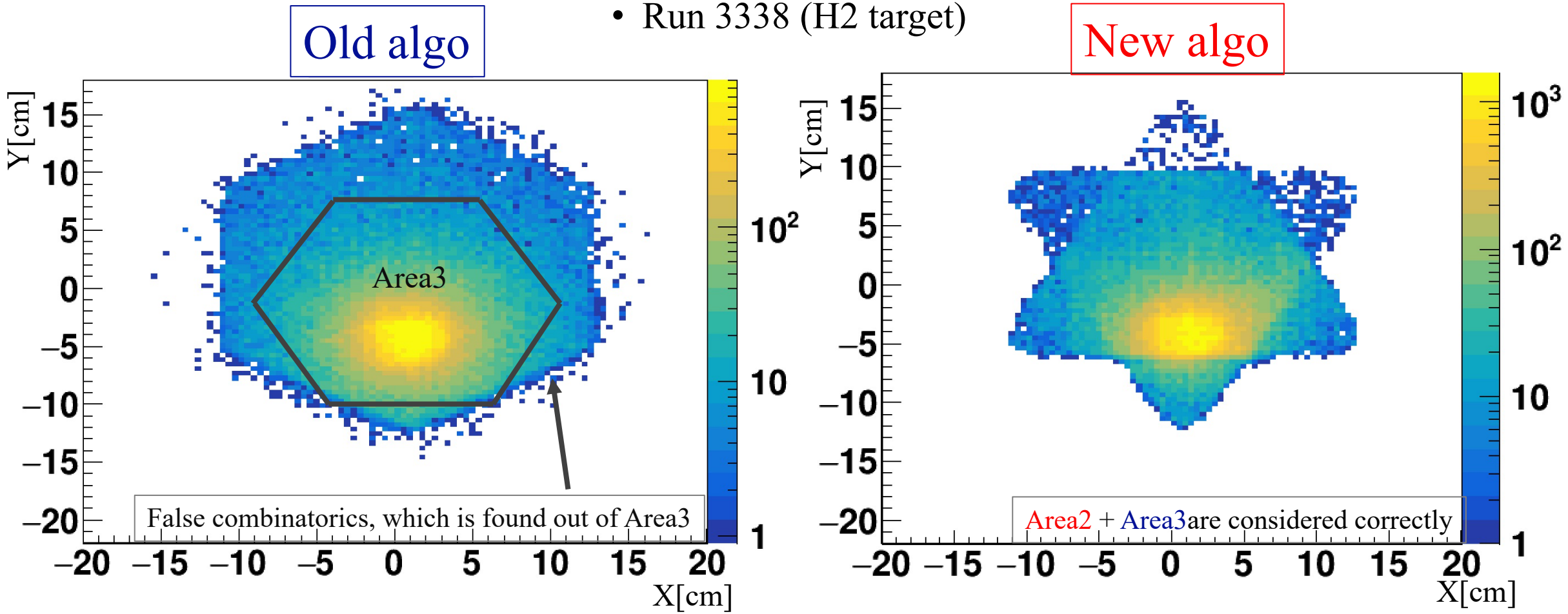
Area2 is the area where 2 coordinates intersect:
$U_1\,U_2\,V_1\,V_2$ or $X_1\,X_2\,V_1\,V_2$ or $X_1\,X_2\,U_1\,U_2$
(4- planes segment possible)

S1 = S2 = S3 = 166 cm^2

The adding of Area2(S2) doubles the working area!

Improvement in New Algo: False Combinatorics were Rejected

- Run 3338 (H2 target)

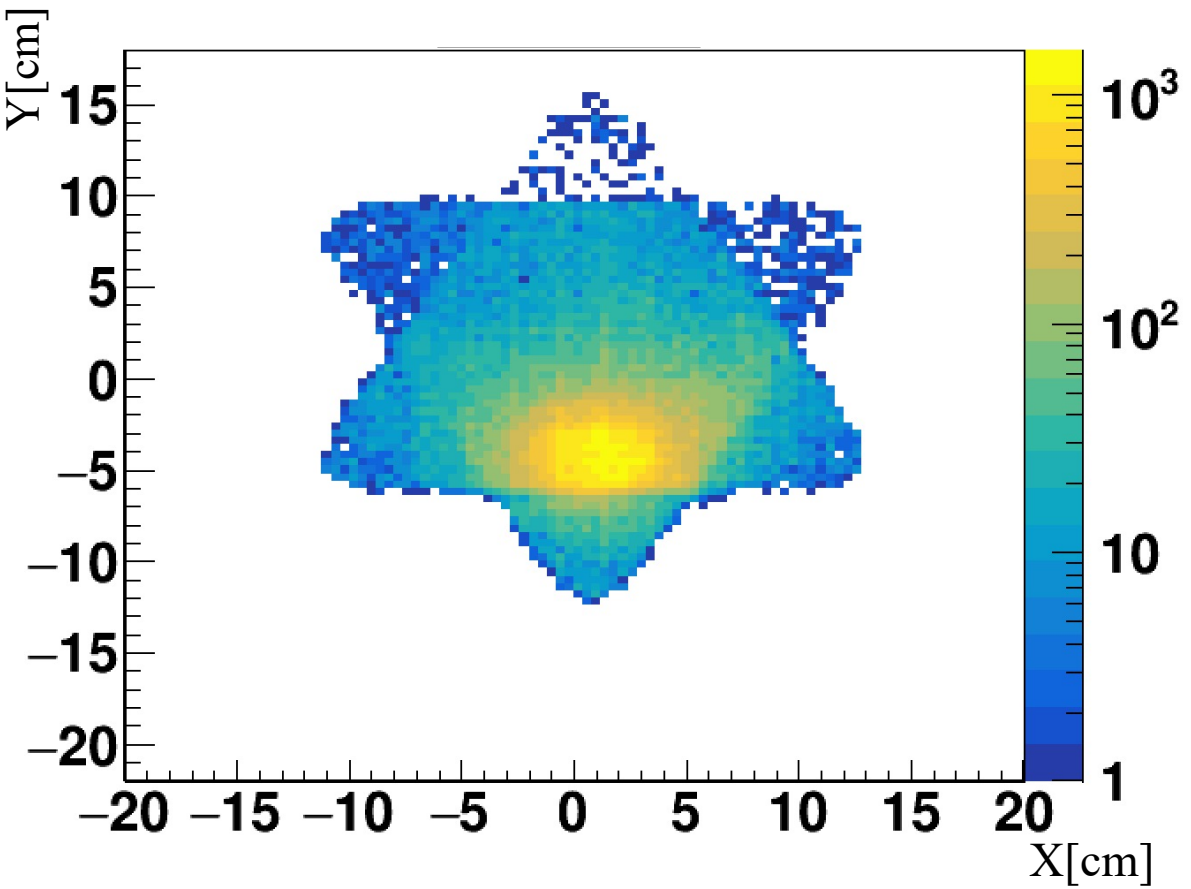


Ch2 segments coordinate plots. The same for Ch3 and Pair1

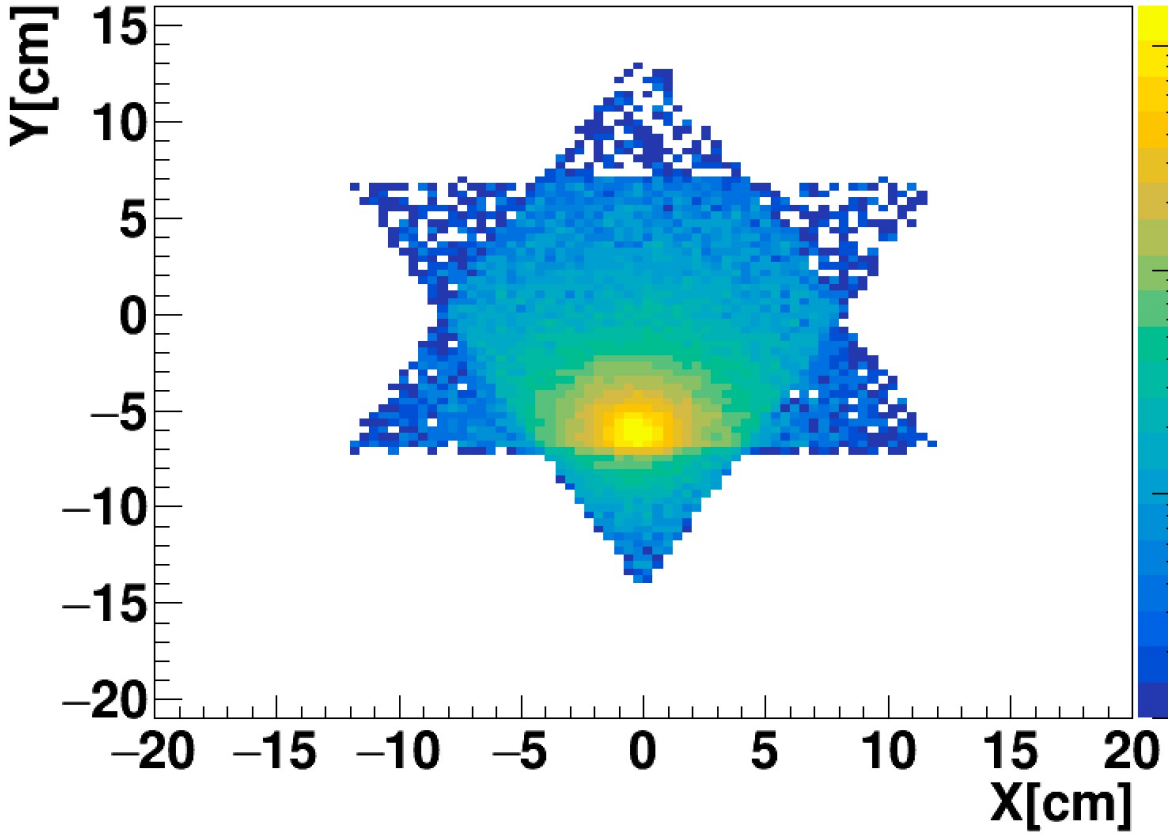
Data vs MC: Coordinate Plots for Ch2 Segments

New algo

Data Run 3338 (H2 target)



MC true (QGSM)

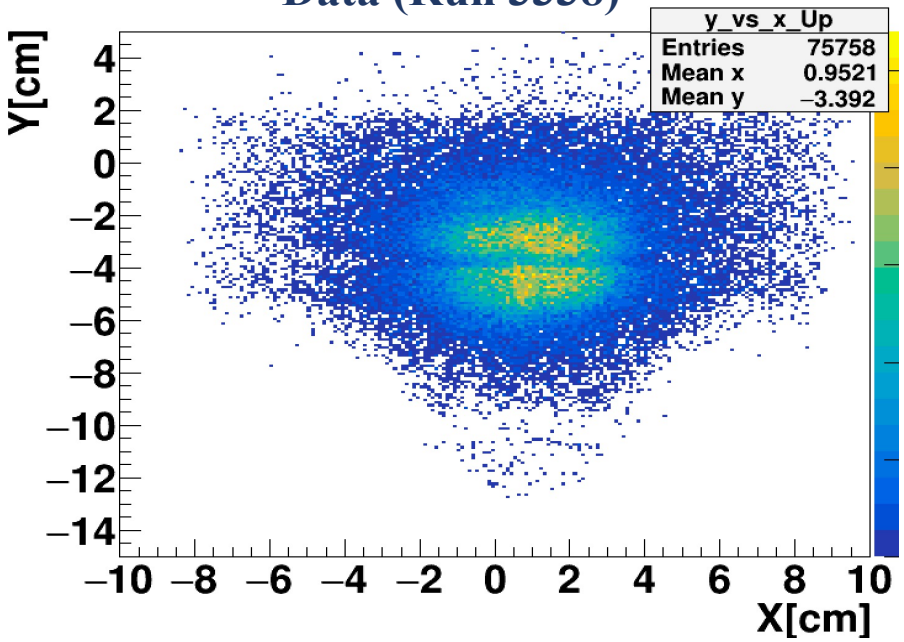


Good agreement between experimental and MC data is obtained

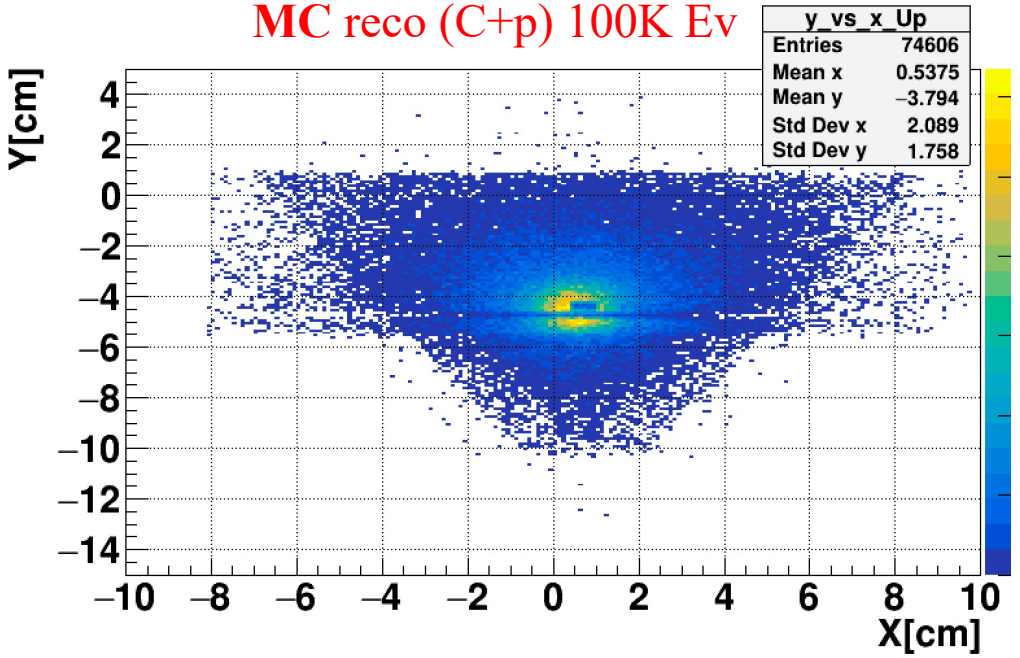
Data vs MC : Upstream Tracks (Y vs X)

A good correspondence between MC & Data for Upstream tracks

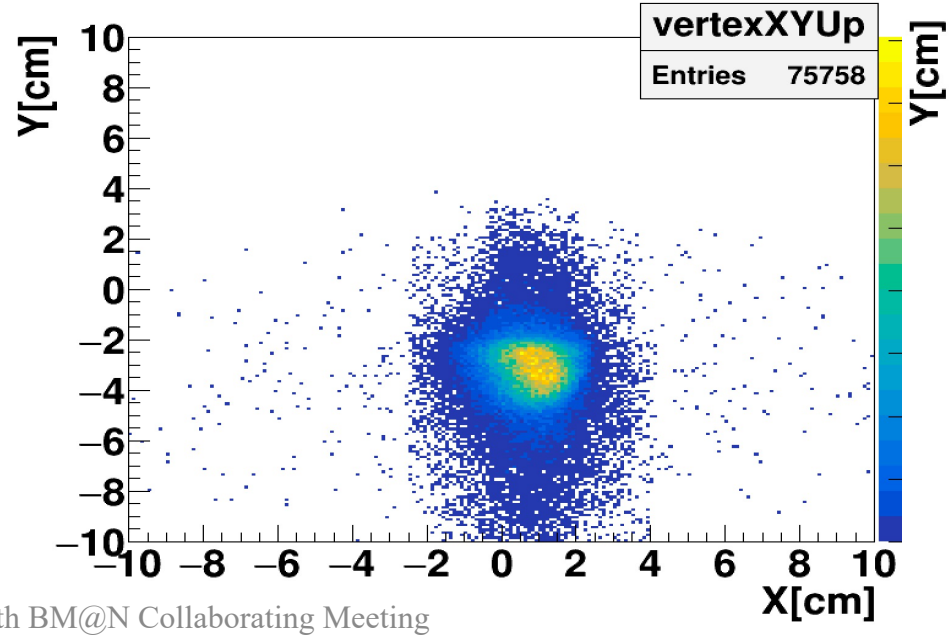
Data (Run 3338)

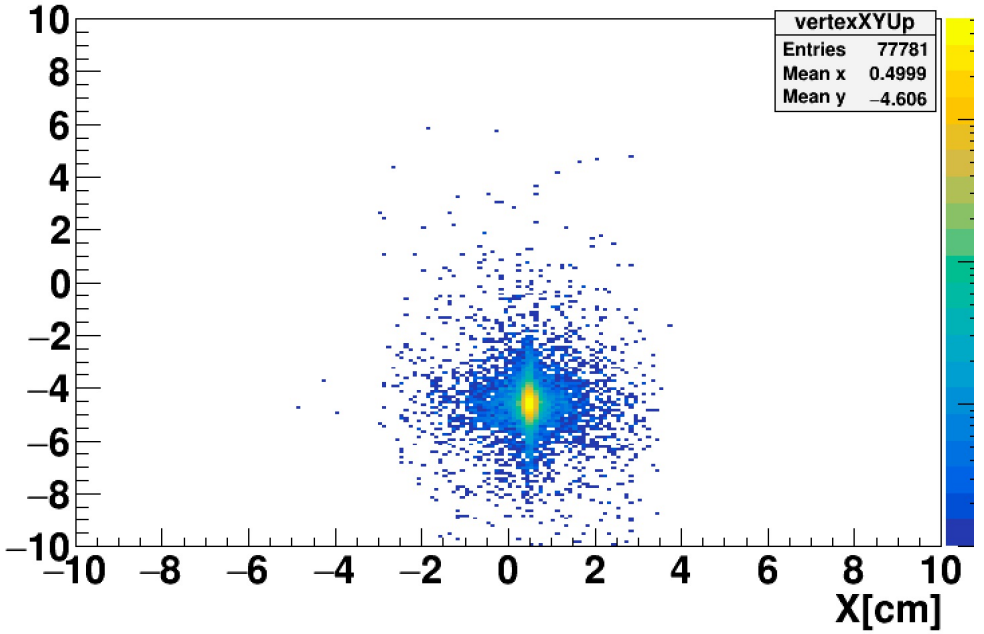


MC reco (C+p) 100K Ev



Z = -350 cm

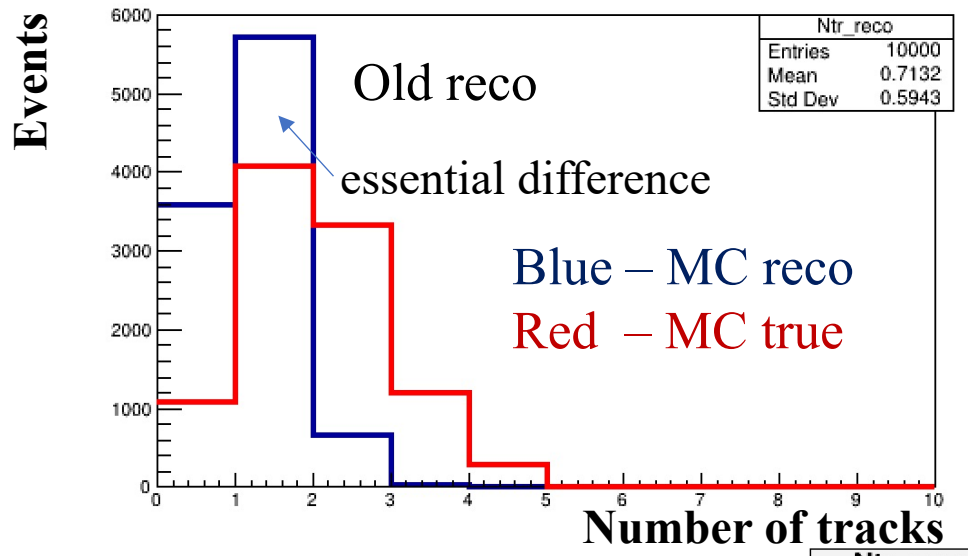


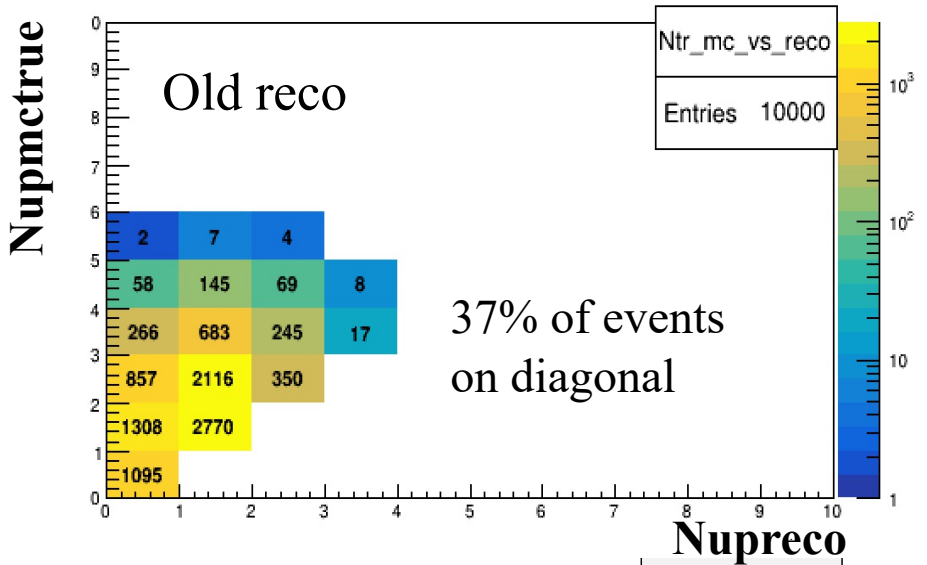


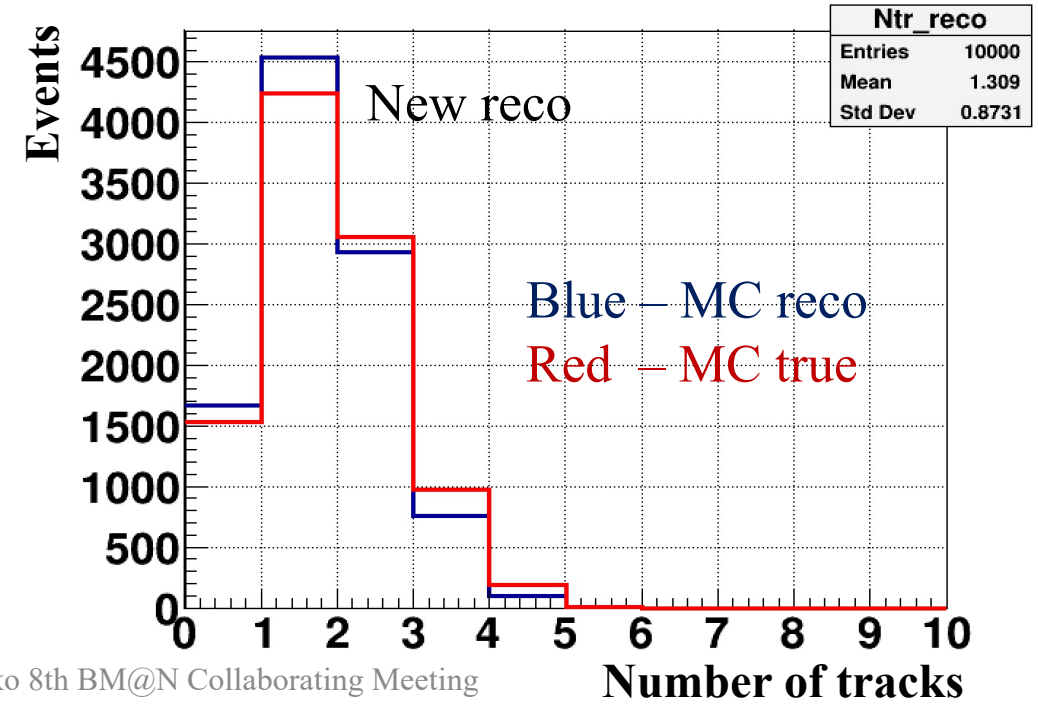
Z = Z vertex

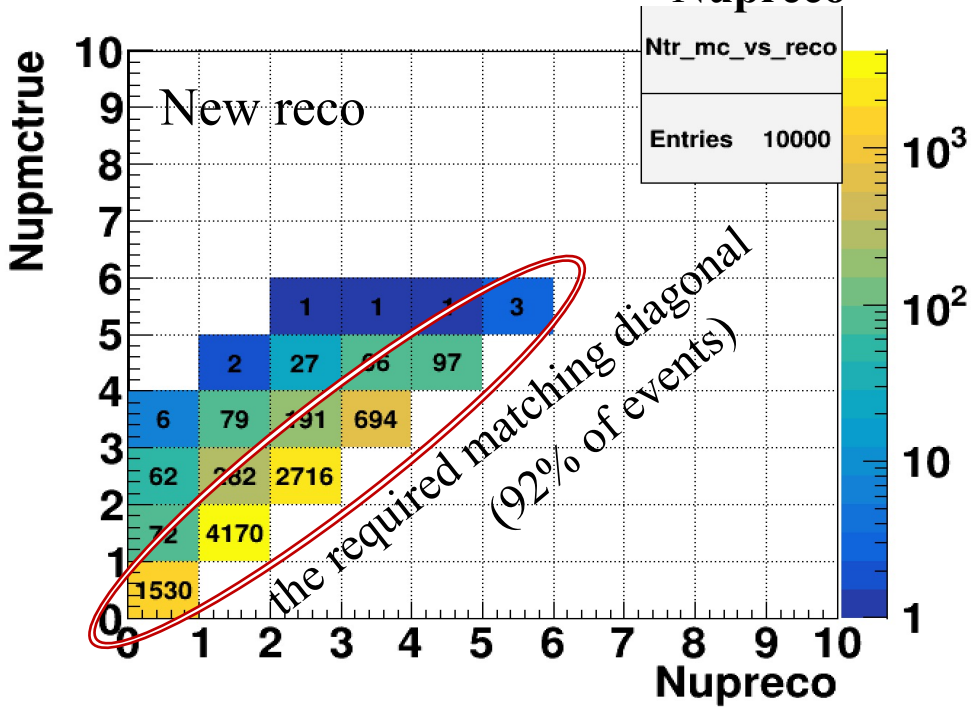
MC reco vs MC true: Upstream Reco Algo Improvement

DCM-SMM





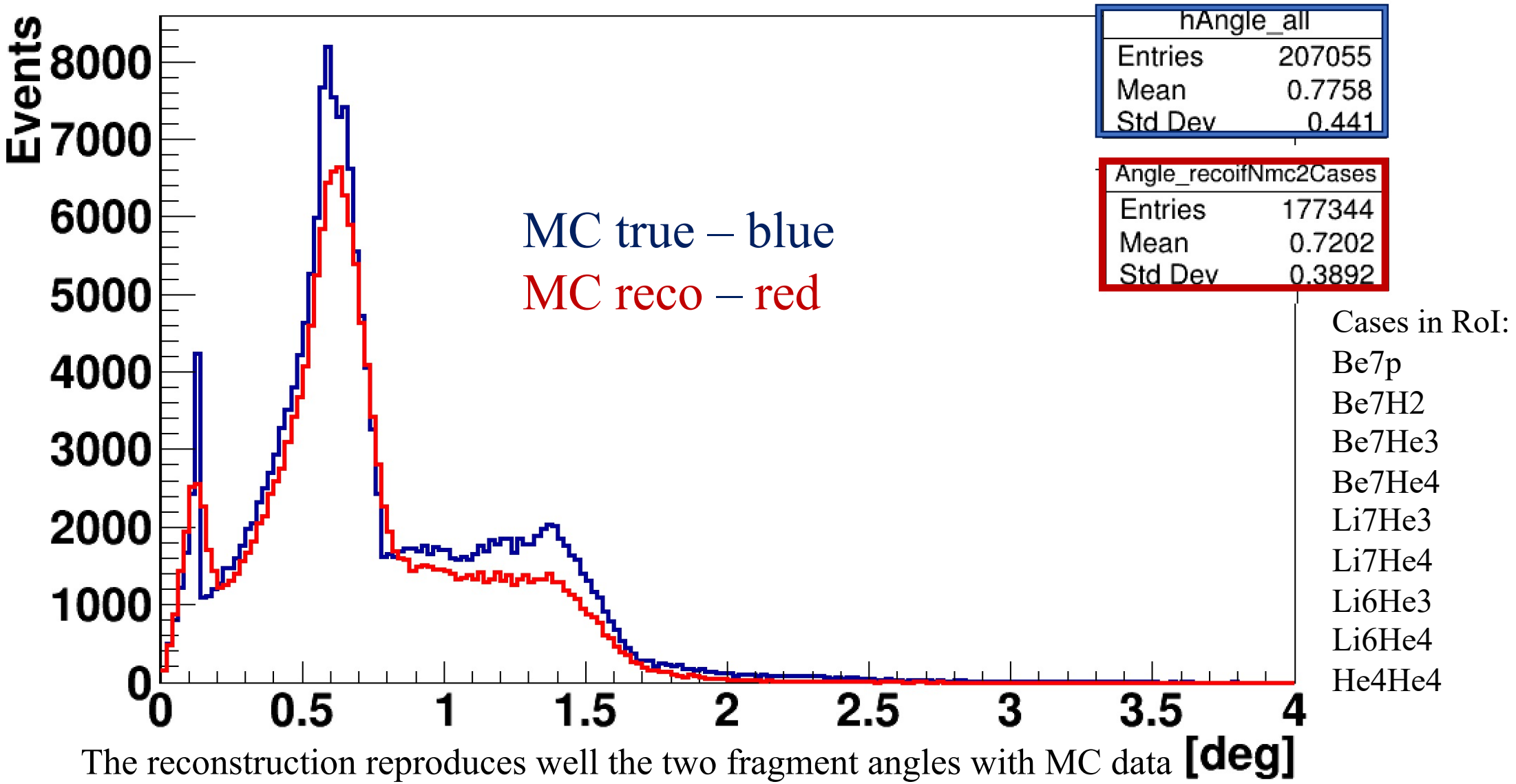




MC True vs Reco: Angle between Two Upstream Tracks

DCM-SMM

1M events



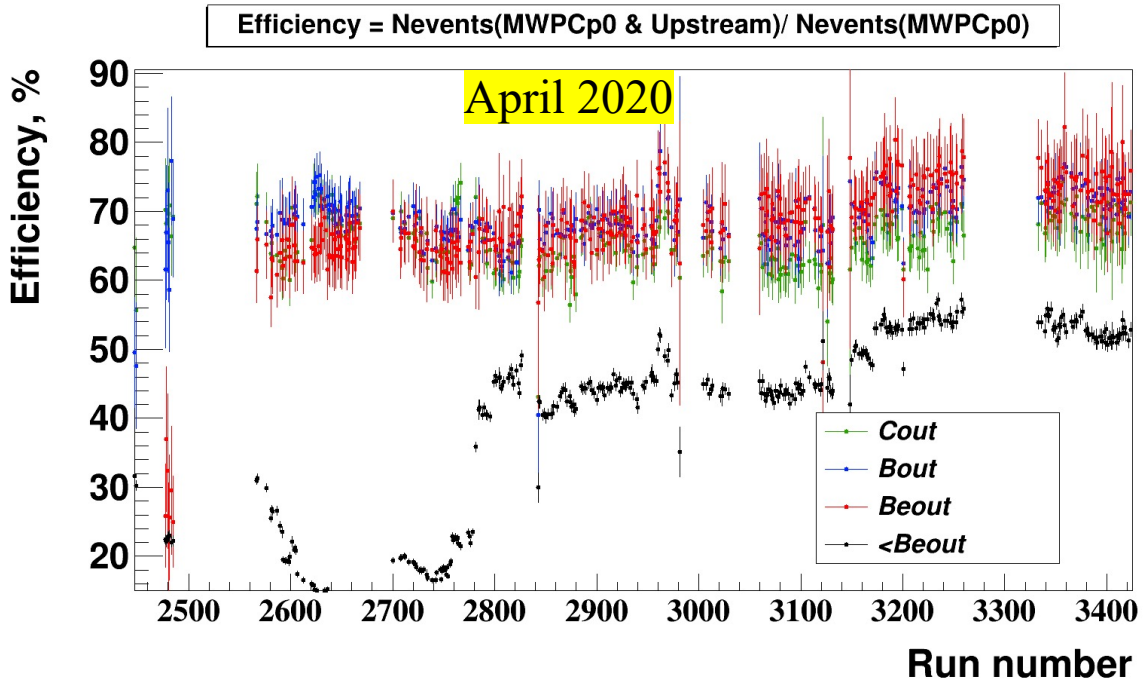
Cases in RoI:
Be7p
Be7H2
Be7He3
Be7He4
Li7He3
Li7He4
Li6He3
Li6He4
He4He4

The reconstruction reproduces well the two fragment angles with MC data

Detector and Algorithm Efficiency(SRC Data)

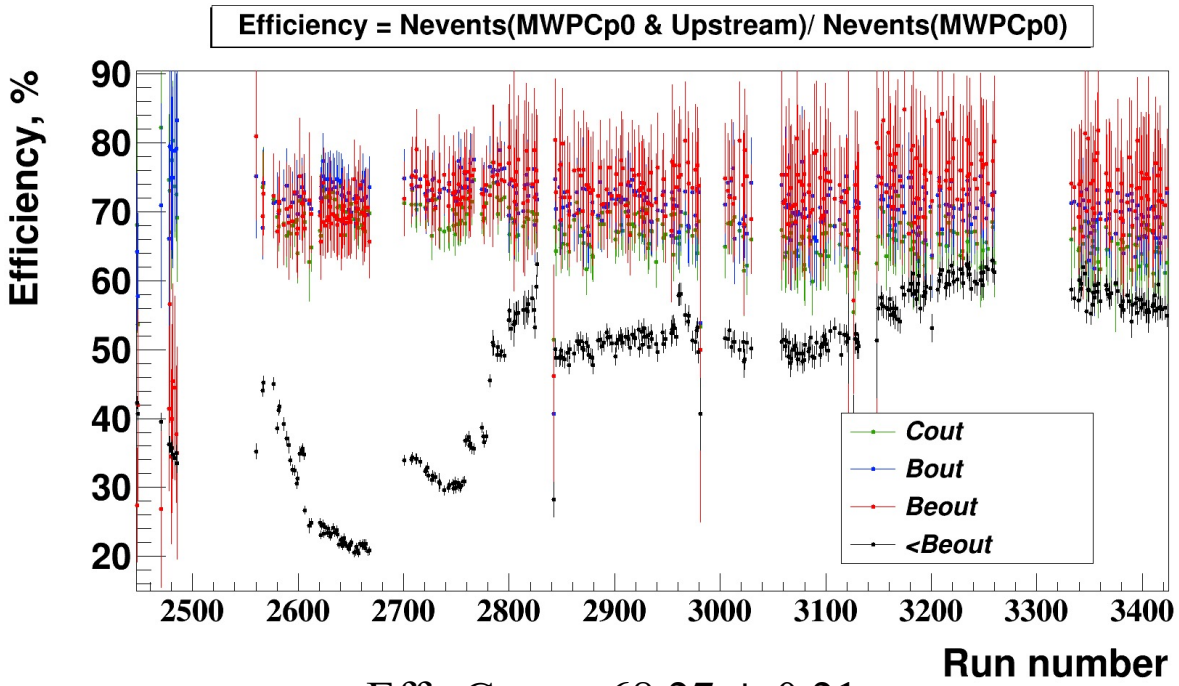
$$\text{Efficiency} = \frac{\text{N of events with tracks in the Upstream system}}{\text{N of events with tracks before the target(Pair0)}}$$

Old algo



Eff Cout = 65.71 ± 0.16
Eff Bout = 69.04 ± 0.19
Eff Beout: 68.23 ± 0.26
Eff <Be out: 38.16 ± 0.04

New algo



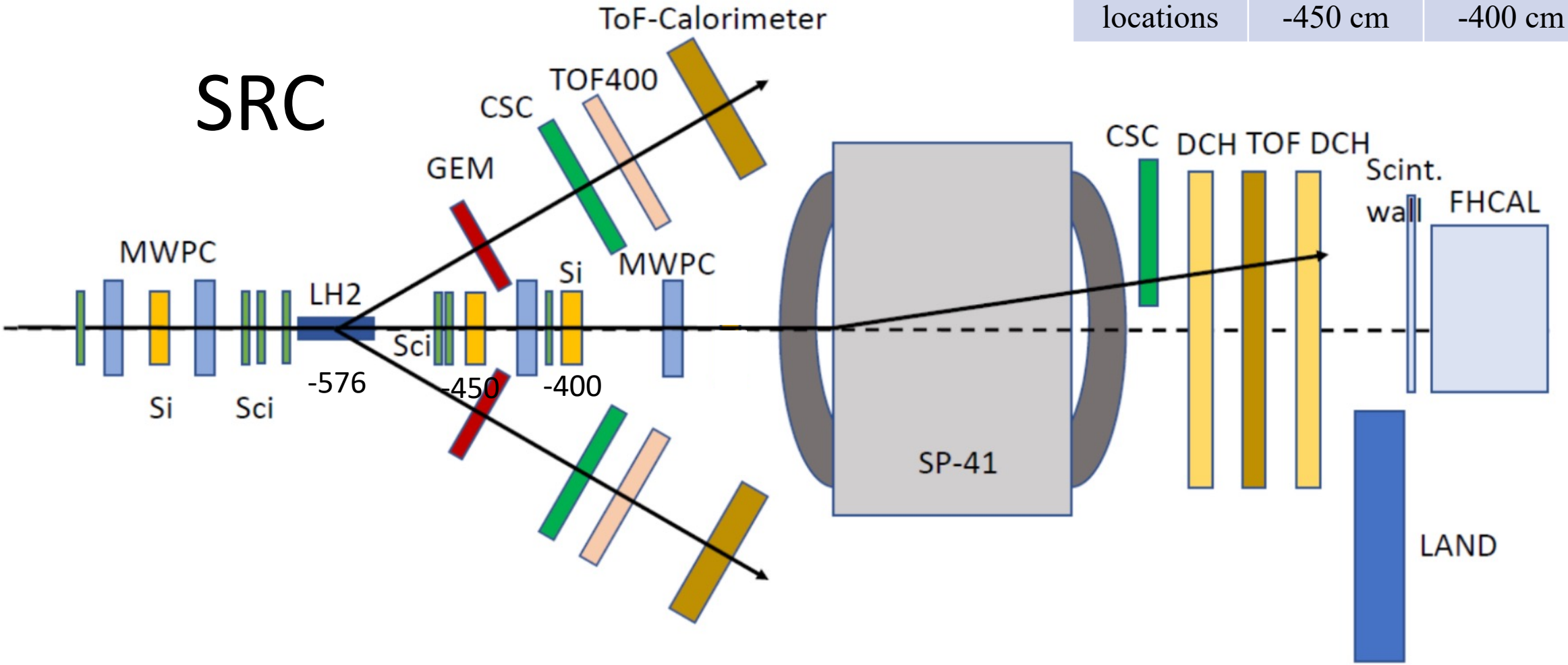
Eff Cout = 68.27 ± 0.21
Eff Bout = 71.56 ± 0.26
Eff Beout: 72.33 ± 0.36
Eff <Be out: 42.13 ± 0.06

Conclusions (RUN7)

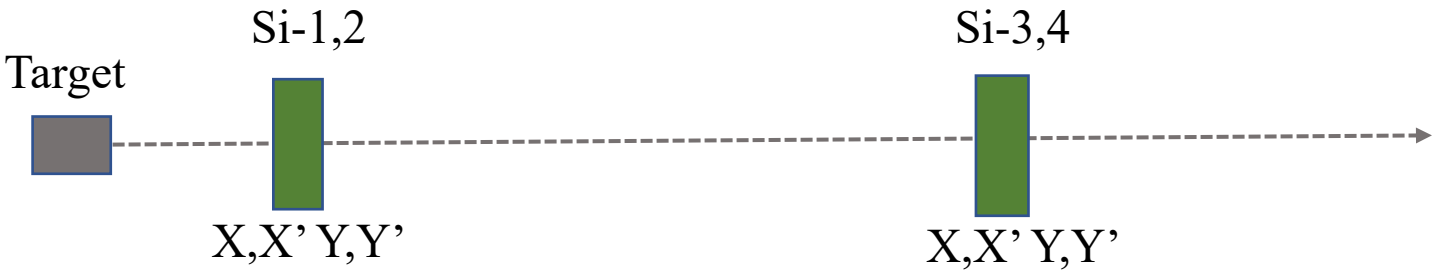
- An algorithm for Upstream tracks reco based on MWPC and SiDet has been improved
- Number of MC true & MC reco tracks coincide in 92% of events (old reco 37%)
- Due to this the reconstruction reproduces the two track angles behavior with MC data
- Y vs X profiles between MC and SRC data are in good agreement
- Upstream reco efficiency is increased by 3-4% with SRC data
- New reco algo & realistic MC for Upstream region will be implemented into bmnroot

2021 Experiment: Setup

	SiDet-1,2	SiDet-3,4
locations	-450 cm	-400 cm

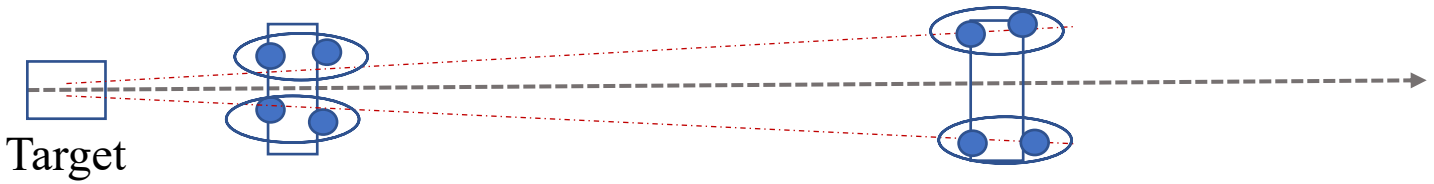


Algo for RUN8



Mainly we will use SiDet info (high precision & good efficiency)

1. Search pairs $|X - X'| < \delta$ in Si1 or Si3. $|Y- Y'| < \delta$ in Si2 or Si4
2. $(X, X') \Rightarrow \tilde{Y}$
   $(Y, Y') \Rightarrow \tilde{X}$
   Search correspondence and compose spatial fragments of track
3. Build tracks from track fragments which are looking at Vertex



4. MWPC use for confirmation

Algo for RUN8(cont.)

But

- Si gap 1mm between modules

(B^{11} MC data: 17% of events in gap)

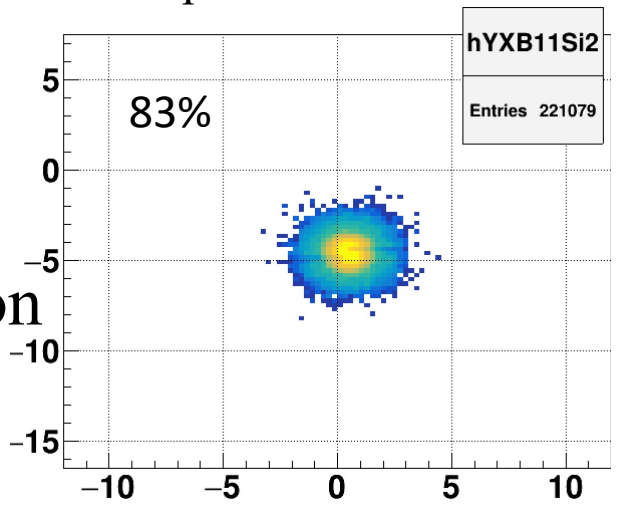
- Si strip has charge overflow in beam region

  => Loss in coordinate precision

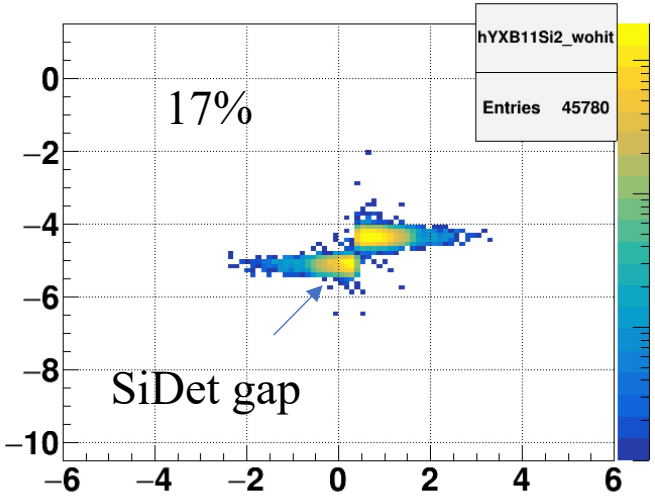
- Possible SiDet failure

MC data

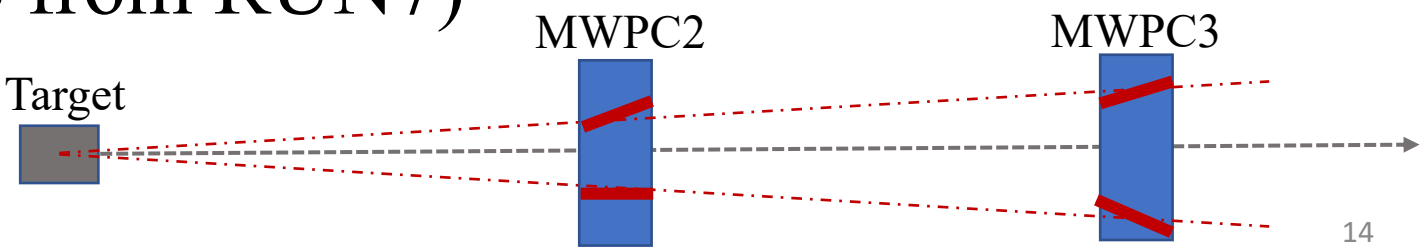
Y vs X position of B^{11} in SiDet



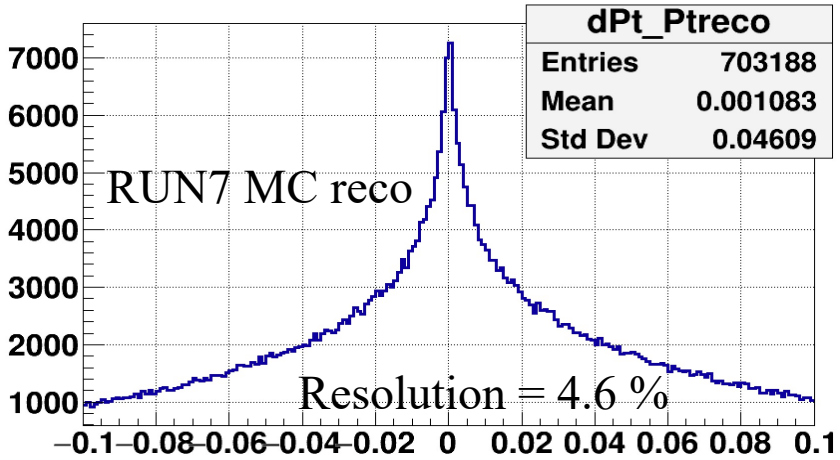
B^{11} w/o hits in SiDet



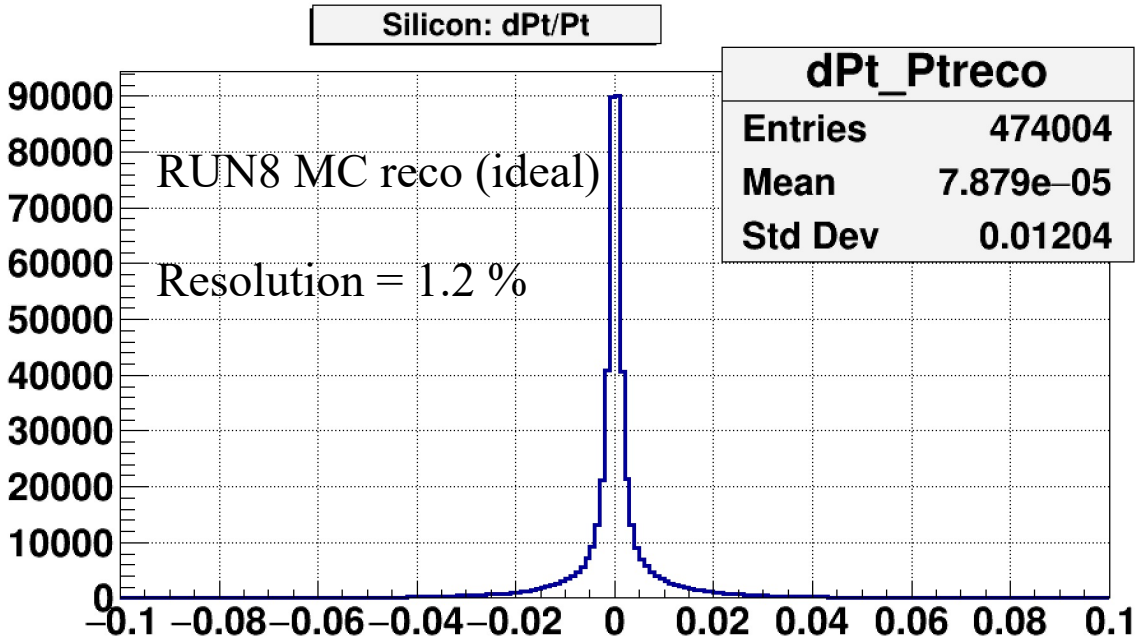
MWPC 2/3 segments (algo from RUN7)

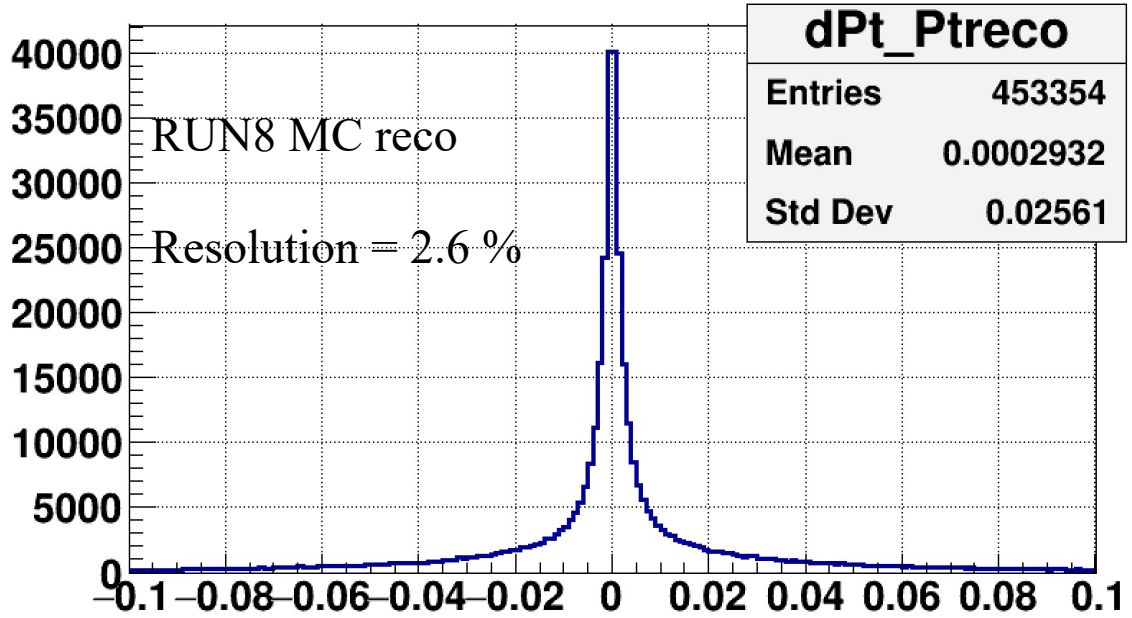


SiDet dPt/Pt Distributions: $\frac{dP_t}{P_t} = \frac{P_t^{reco} - P_t^{MC}}{P_t^{MC}}$



- $\sigma_{x,y}$ 30 μm => 50 μm *(more realistic)*
- Hit efficiency 100% => 85% (worse than expected)
- The orthogonal coordinate for inefficiency $\sigma_{x,y}$ = 1.6 mm



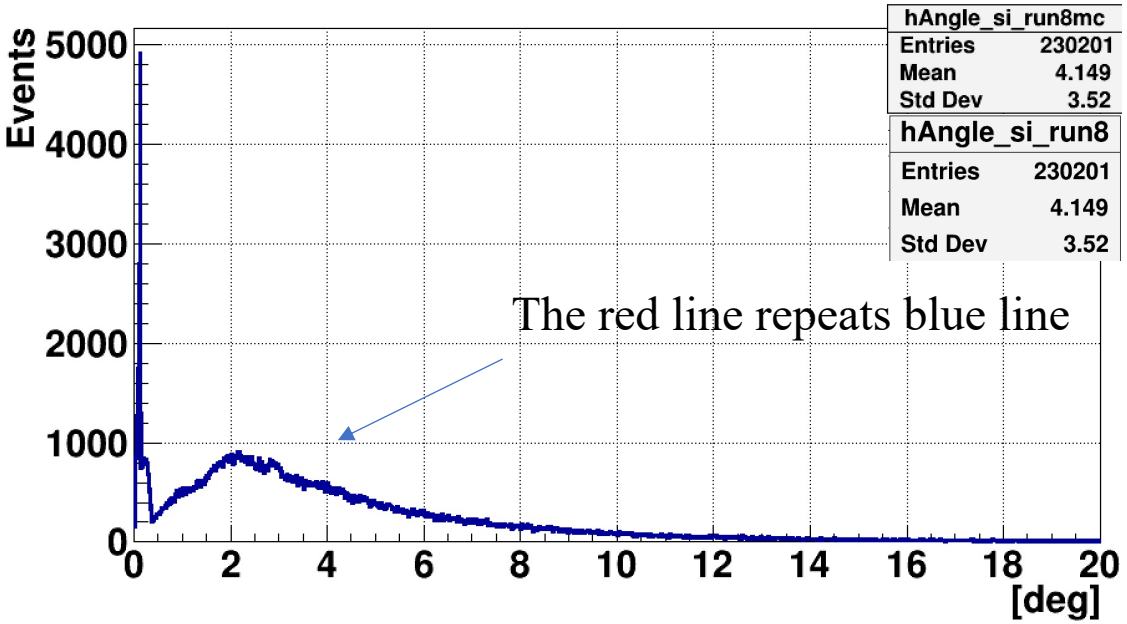


Expected RUN8 Pt-resolution: 2 times better than in RUN7

MC-true vs MC “reco”: Angle between Two Fragments in SiDet (wide angle region)

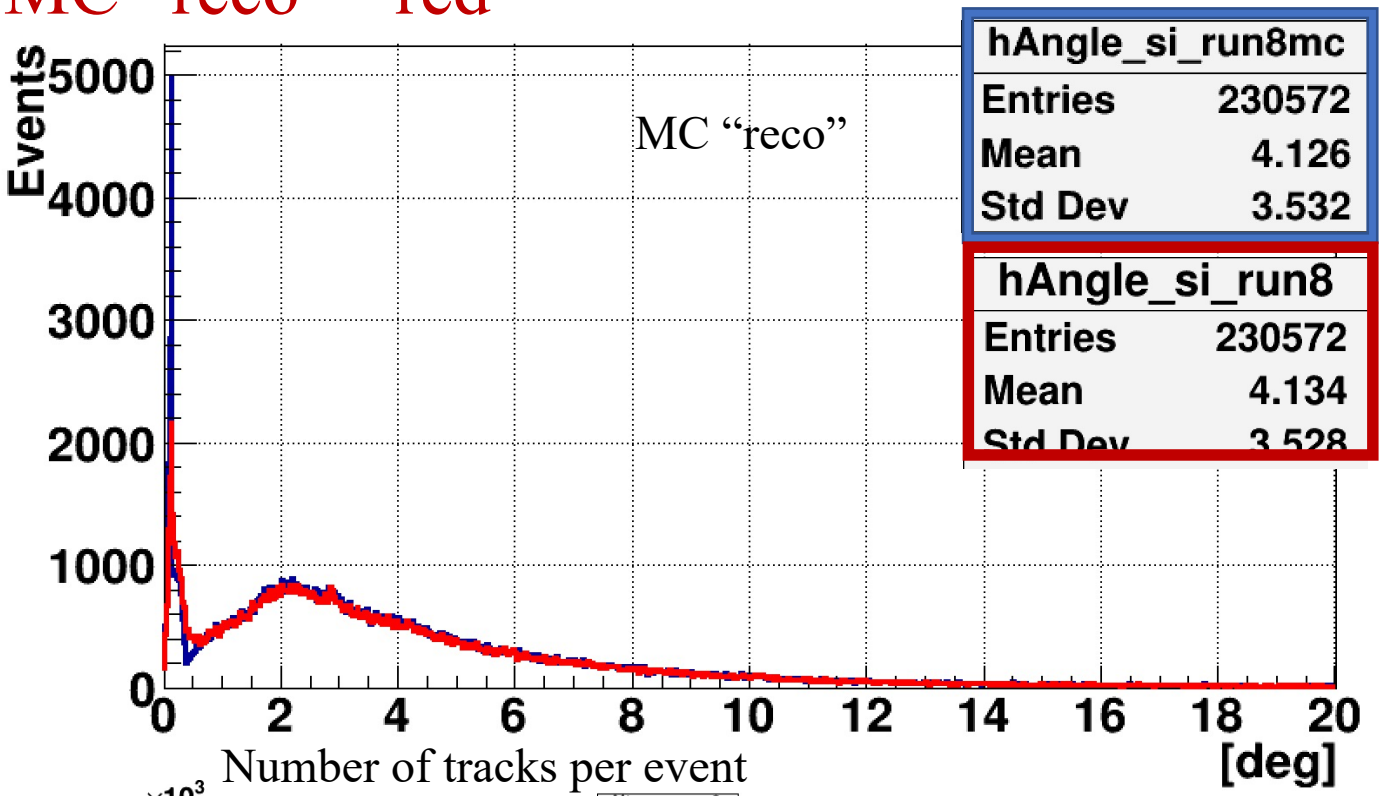
MC – blue MC “reco” - red

MC reco ideal



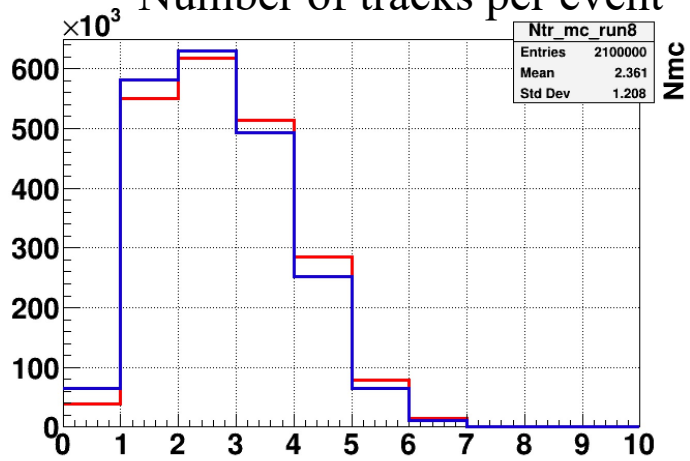
The red line repeats blue line

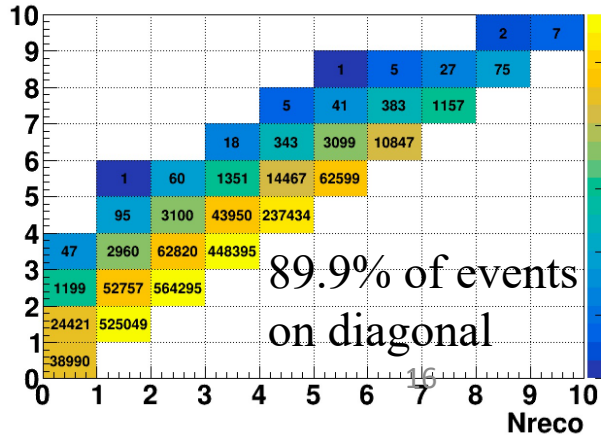
MC “reco”



For wide angle region we can’t see the difference for angle between two tracks

Number of tracks per event



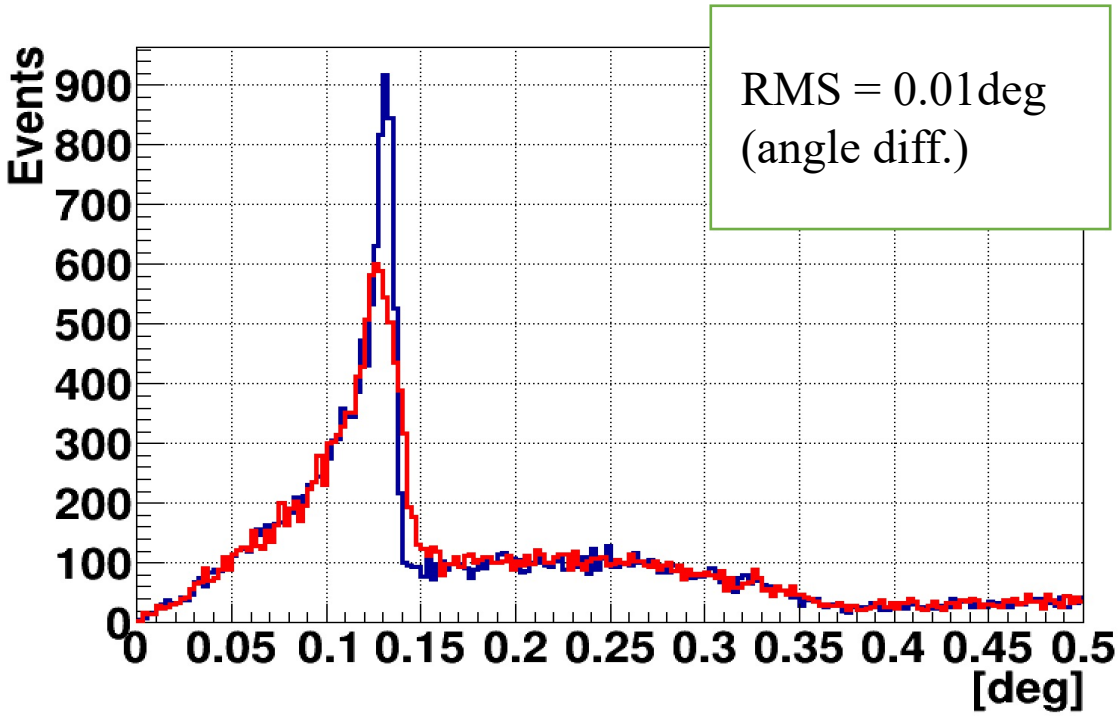


MC vs MC "Reco": Angle between Two Fragments in SiDet (small angle region)

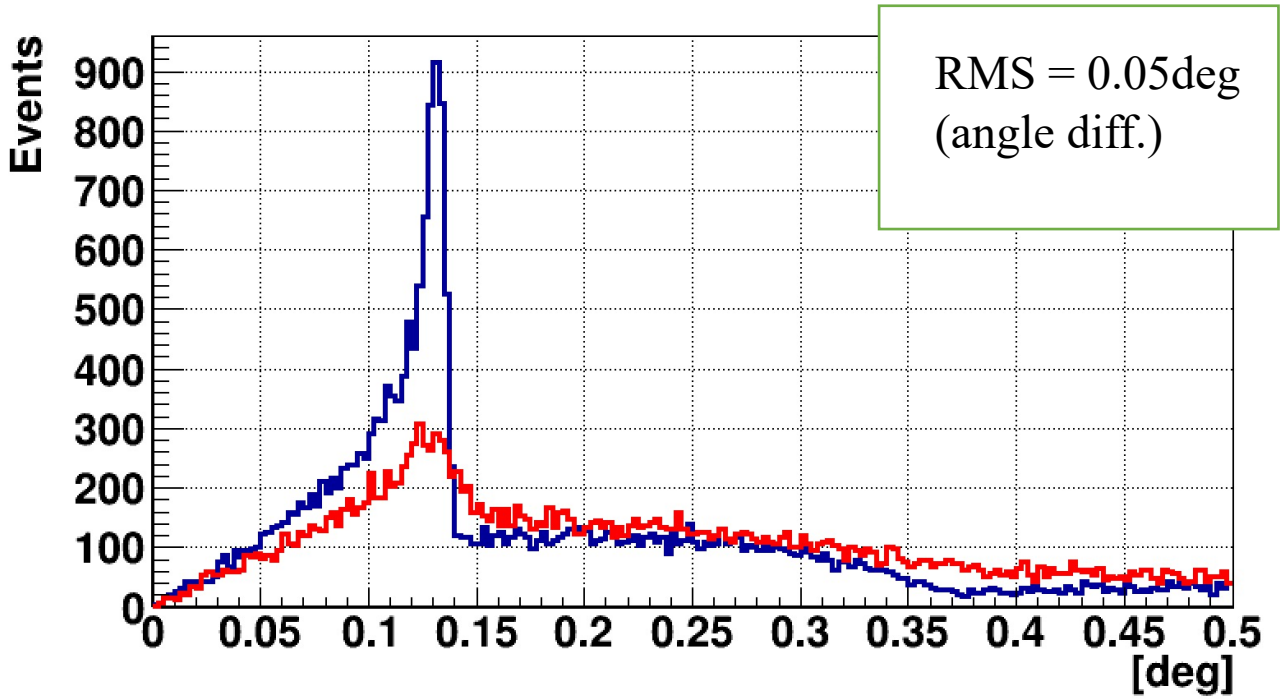
MC – blue

MC "reco" - red

MC reco ideal



MC "reco"



For small angle region we see some difference for angle between two tracks but it's not so essential

Conclusions (RUN8)

- The track reconstruction method for RUN8 which is based on two pairs of X&Y oriented SiDets has been studied in detail
- dPt/Pt resolution in SiDet is expected to be two times better than in previous RUN
- Number of MC true & MC reco tracks coincide in 90% of events
- The scalar angle between two fragments in SiDet is well recognized

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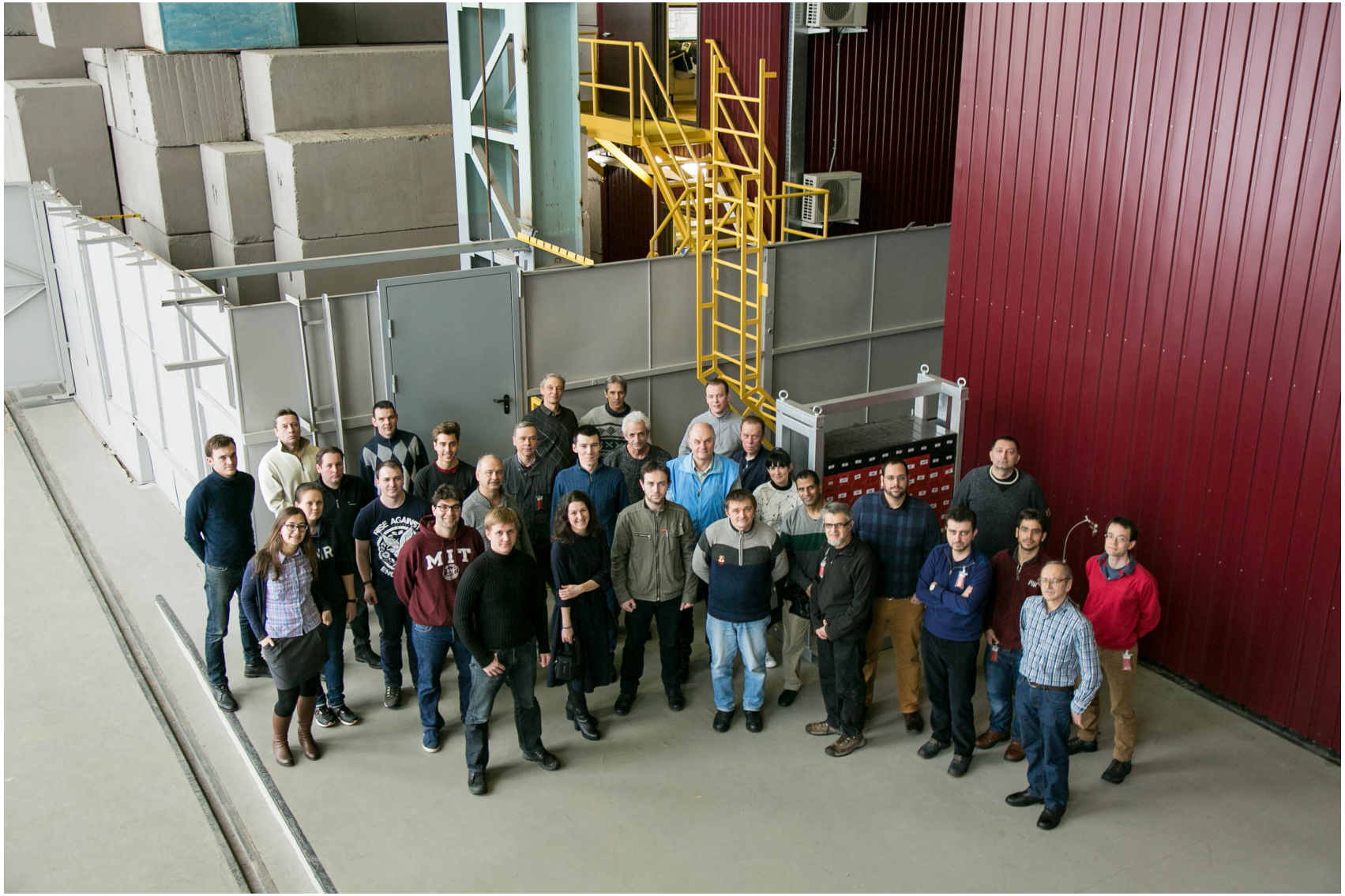
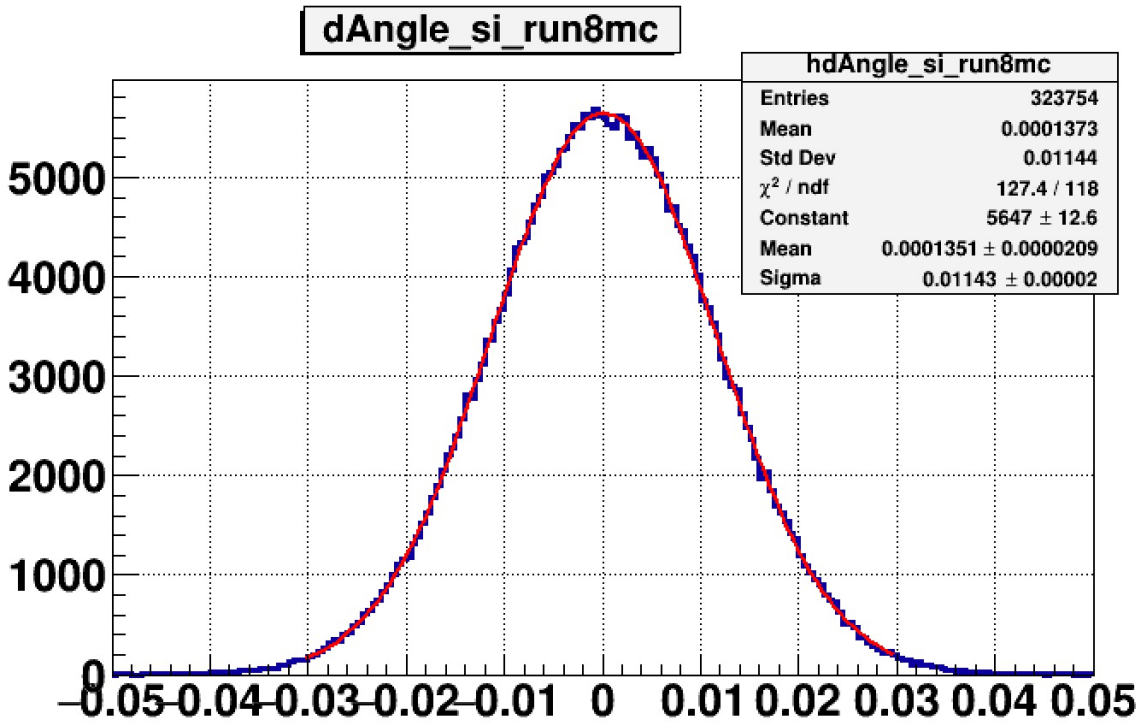
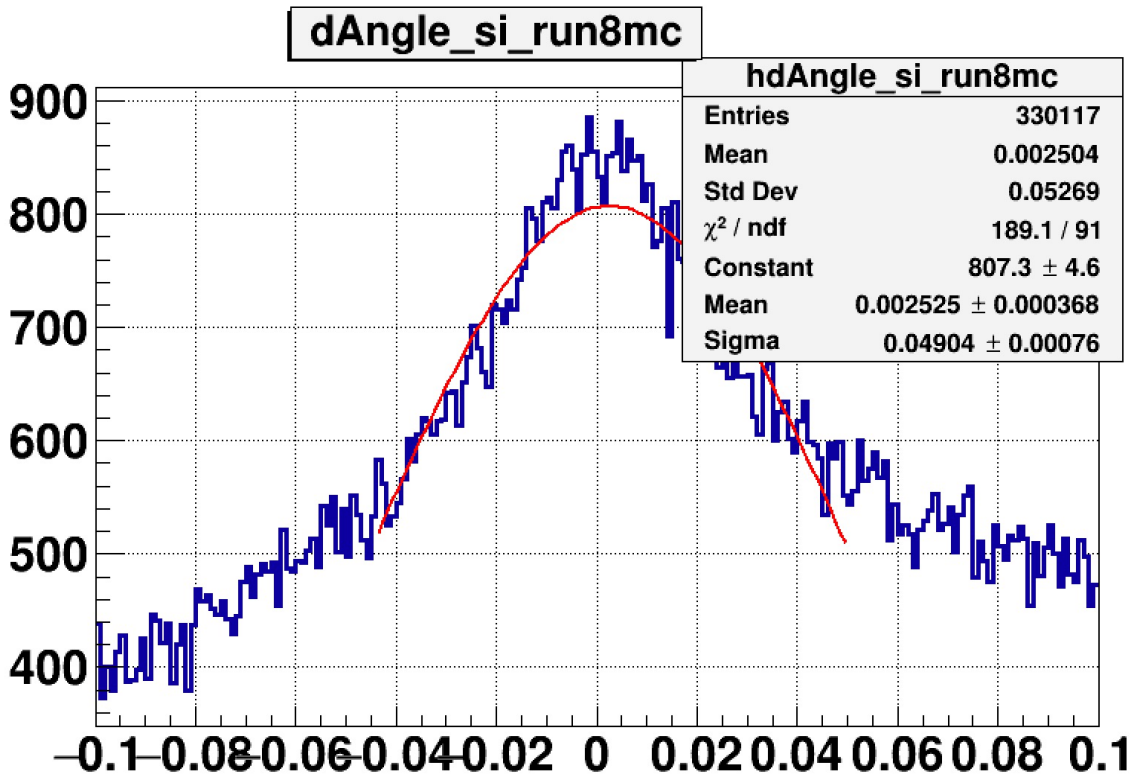
Thank you for your attention!



Back up

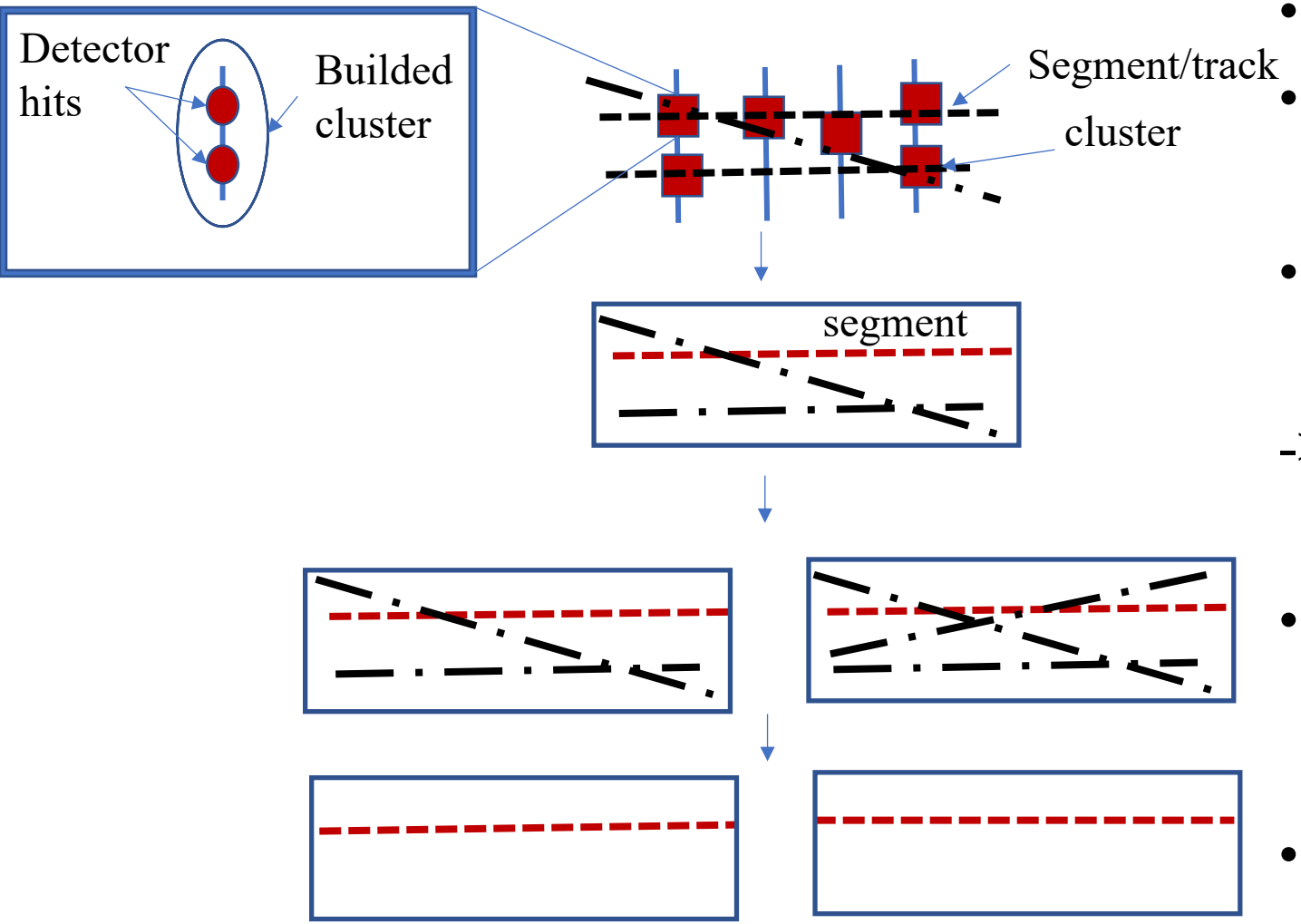

dAngle_si_run8mc
hdAngle_si_run8mc
Entries 323754
Mean 0.0001373
Std Dev 0.01144
χ² / ndf 127.4 / 118
Constant 5647 ± 12.6
Mean 0.0001351 ± 0.0000209
Sigma 0.01143 ± 0.00002
5000
4000
3000
2000
1000
0
-0.05 -0.04 -0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05


dAngle_si_run8mc
hdAngle_si_run8mc
Entries 330117
Mean 0.002504
Std Dev 0.05269
χ² / ndf 189.1 / 91
Constant 807.3 ± 4.6
Mean 0.002525 ± 0.000368
Sigma 0.04904 ± 0.00076
900
800
700
600
500
400
-0.1 -0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1

Acceptance in detector systems for RUN7

	vertex	Si1	Si2	Si3	PC2	PC3	DC1	DC2
B11 (acceptance)	266976	229023 (.86)	221079 (.83)	230985 (.87)	266859	266858	266858	266858
Li7He4 (acceptance)	1263	1159 (.91)	1038 (.82)	1104 (.87)	1263	1256	1263	1263

The reconstruction algorithm upstream the magnet
in each system (SiDet & MWPC)

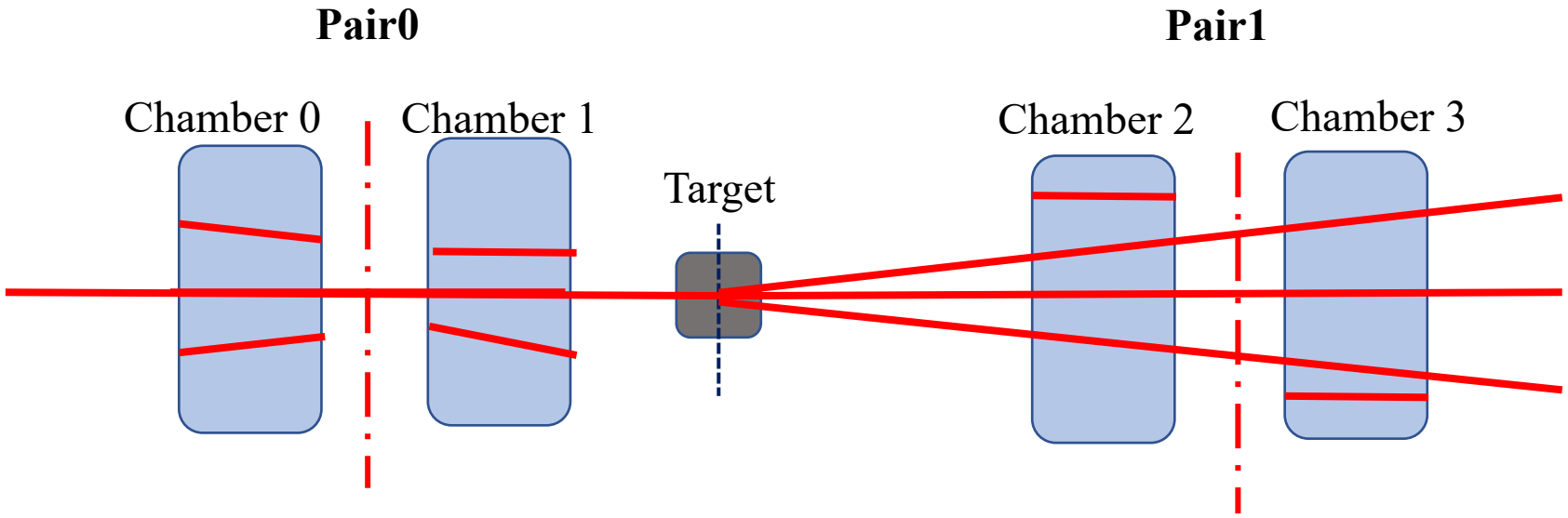


- Hit reading & cluster building
- Track-segment candidates building
- Fitting with a straight line by using measurements

-> Select the best segment by χ^2 – criteria

- Track-segments are matching between different detectors
- Resulting tracks are fitted

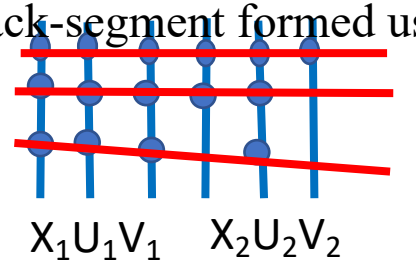
Improved Track Reconstruction in MWPCs



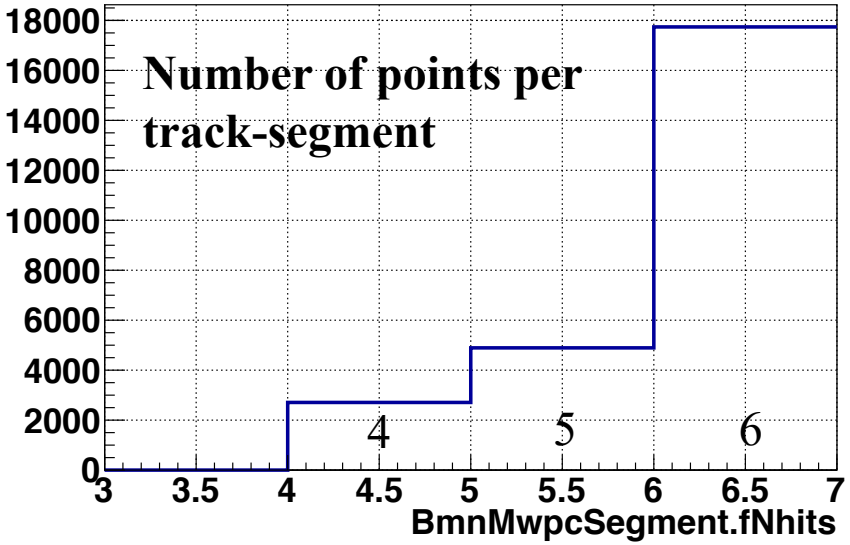
MWPC working regime was not optimal- the clusters were huge

Track-segment = reconstructed straight track in one chamber

1. Track-segment formed using



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



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

Track Reconstruction in Silicon Detector

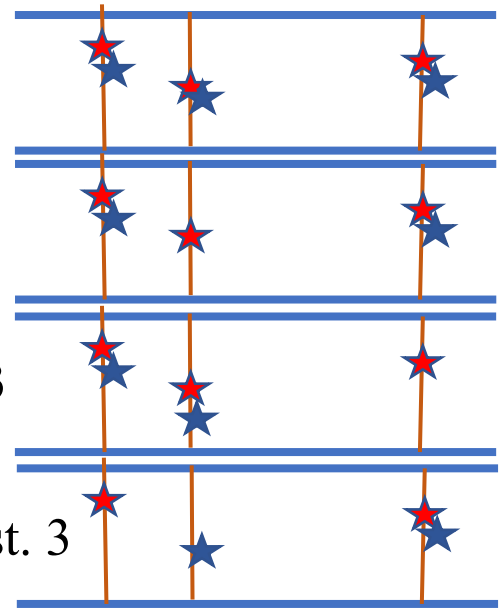
1. **X and X' (2.5°)** neighboring fired strips – cluster center

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

2. **Track Reconstruction** using various cases

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

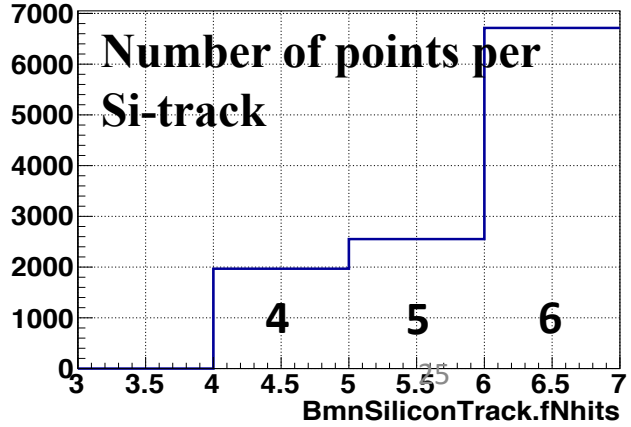
- Case 1: 6 hits (3 spatial points) per track
- Case 2: 1 spatial point in st. 1 and 3 + X / X' in st.2
- Case 3: 1 spatial point in st. 1 and 2 + X / X' in st. 3
- Case 4: (X + X') in (st. 1 + st. 2) + spatial point in st. 3



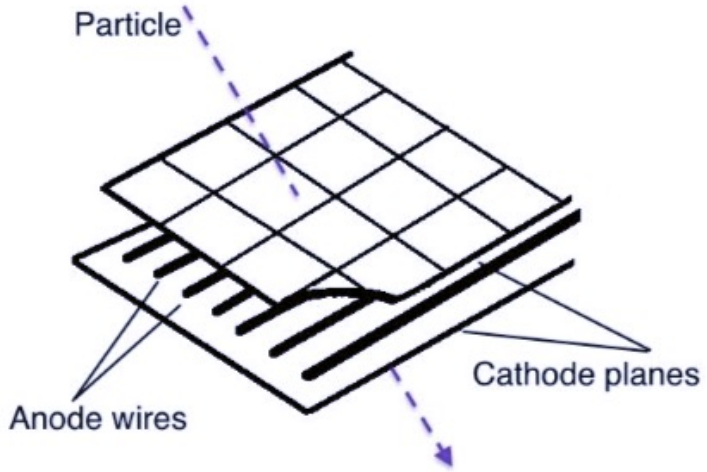
★ - X hit
★ - X' hit

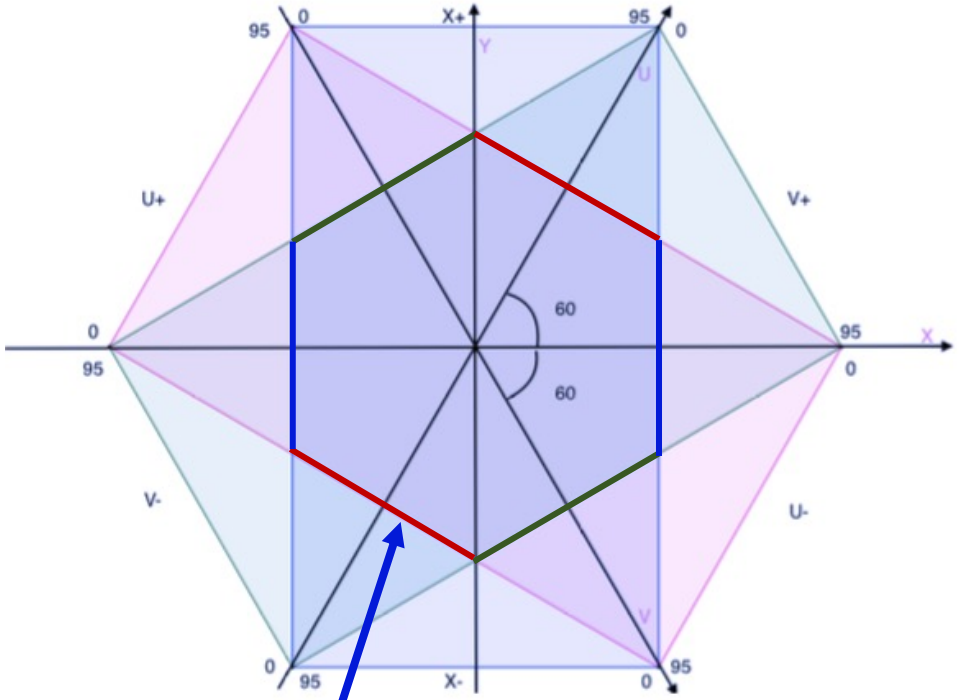
3. **Straight line fit on X & X'** – coordinates, rough Y – coordinate: $Y = \frac{X' - X}{tg2.5°}$

Accepted track goes out from the target area



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.

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

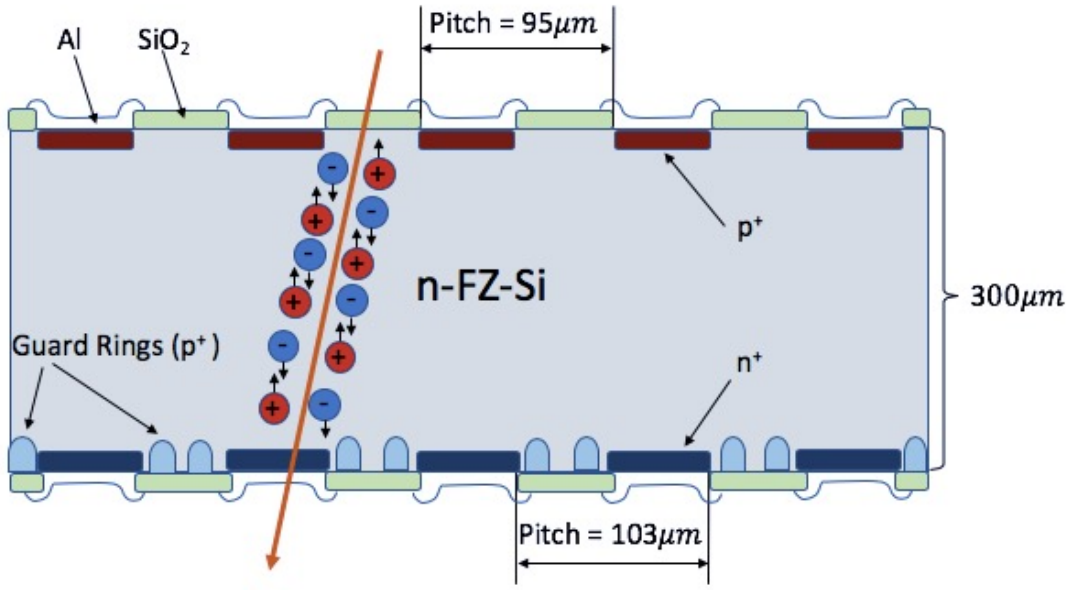
$$V = \frac{x - \sqrt{3}y}{2},$$

This point should satisfy the following condition:

$V + U - X = 0$

The intersection of these planes is a working area.

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

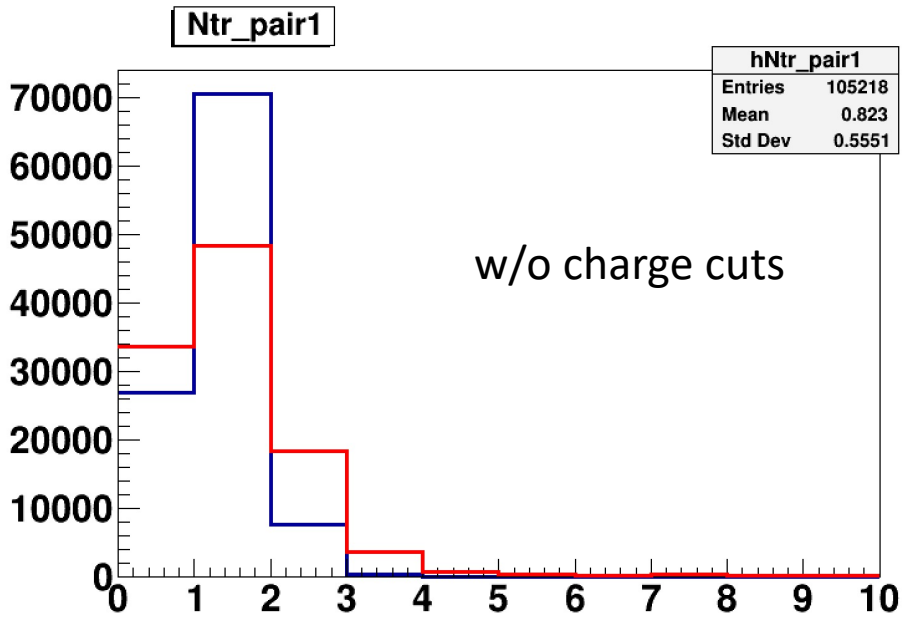
Full sensitive size of 25 x 25 cm^2

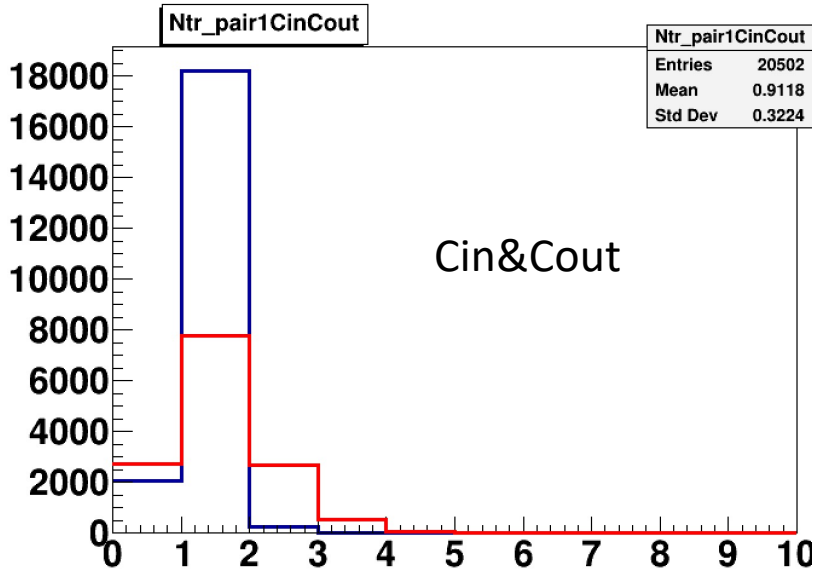
The contribution to the collected charge value is given by both electron and hole flow.

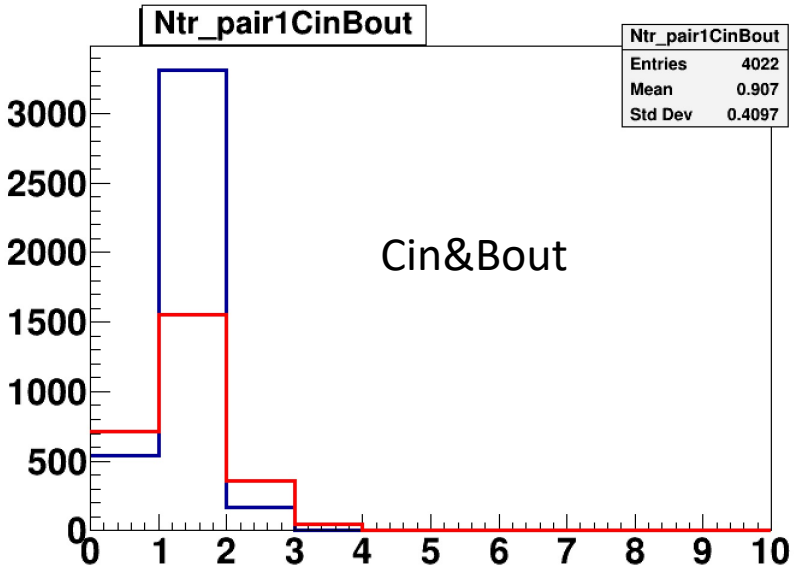
- Run 3338 (H2 target)

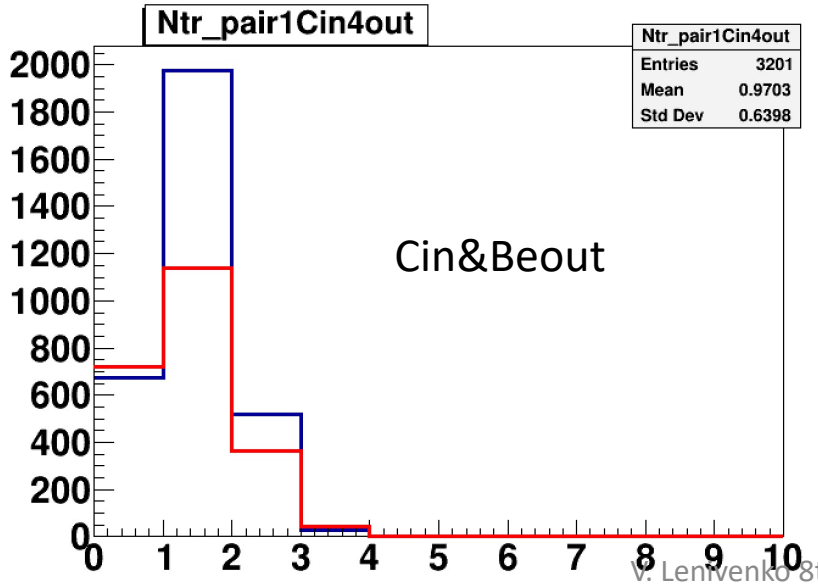
Number of Mwpc(pair1) tracks

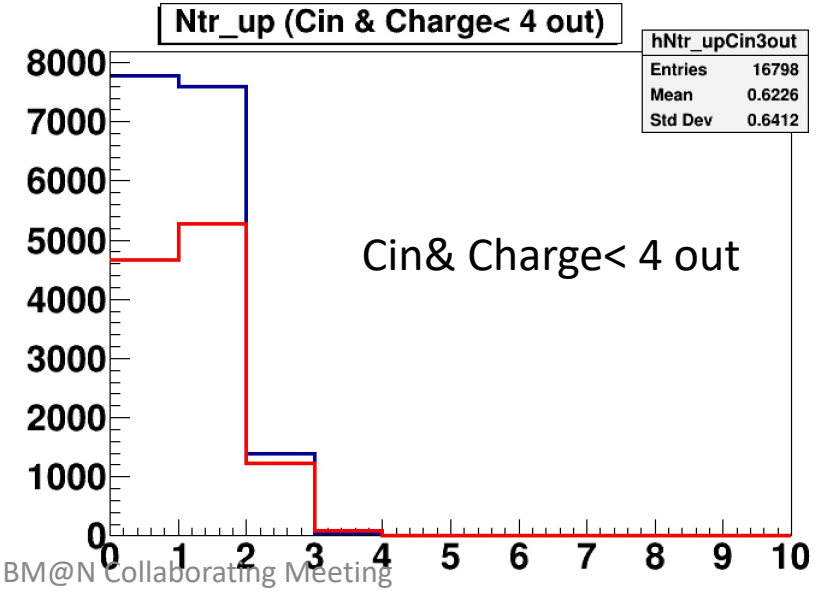
Red – new algo
Blue – old algo









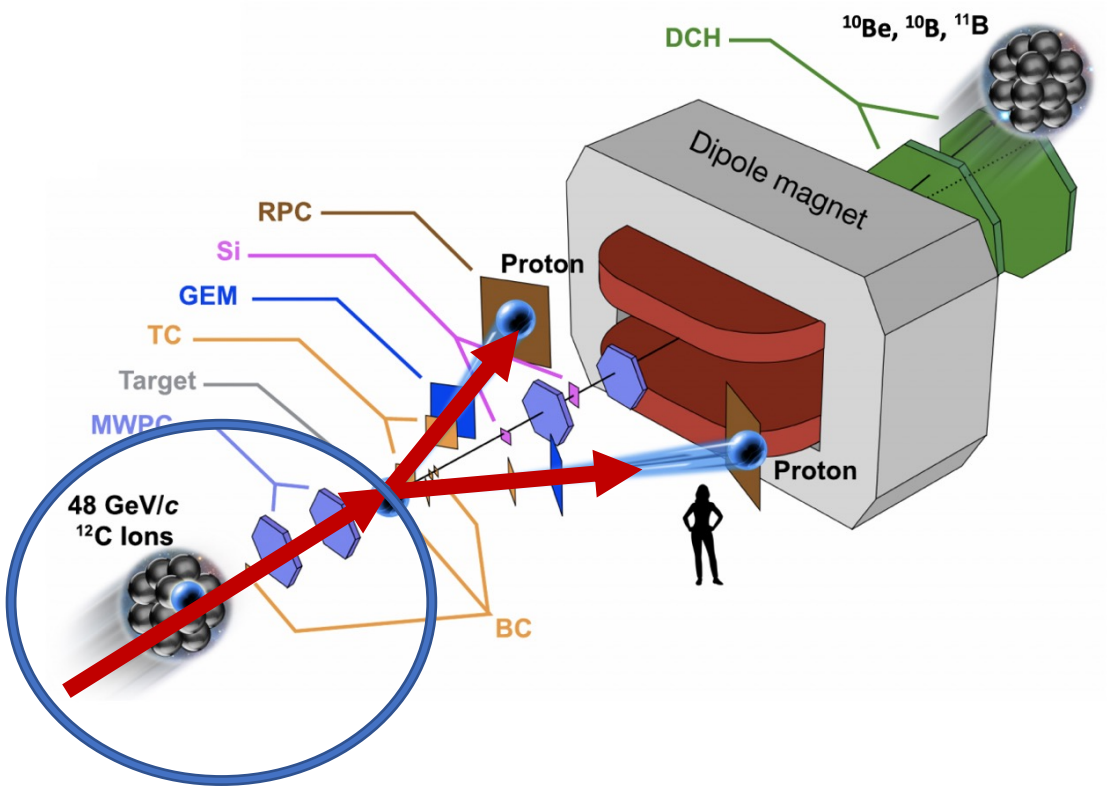


New algorithm makes tracks cleaner.

Combinatorics effect is suppressed

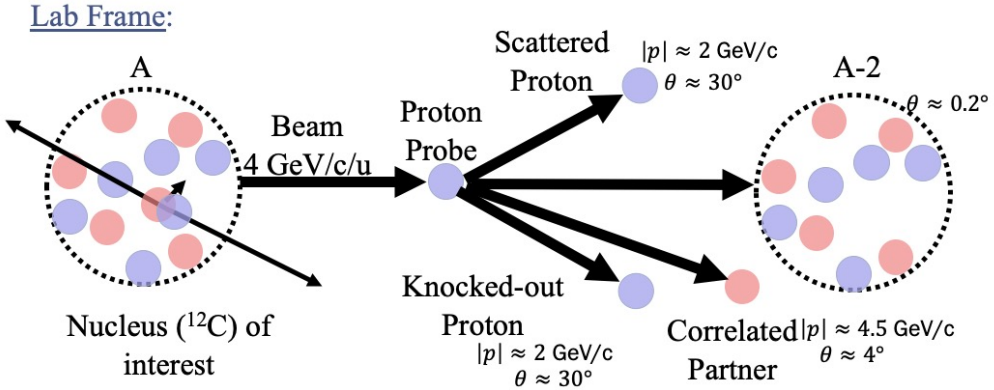
Analysis: Proton momentum before the interaction

First analysis paper accepted for publication (Phys.Nature)!



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

the reaction of knocking out nucleons from the target

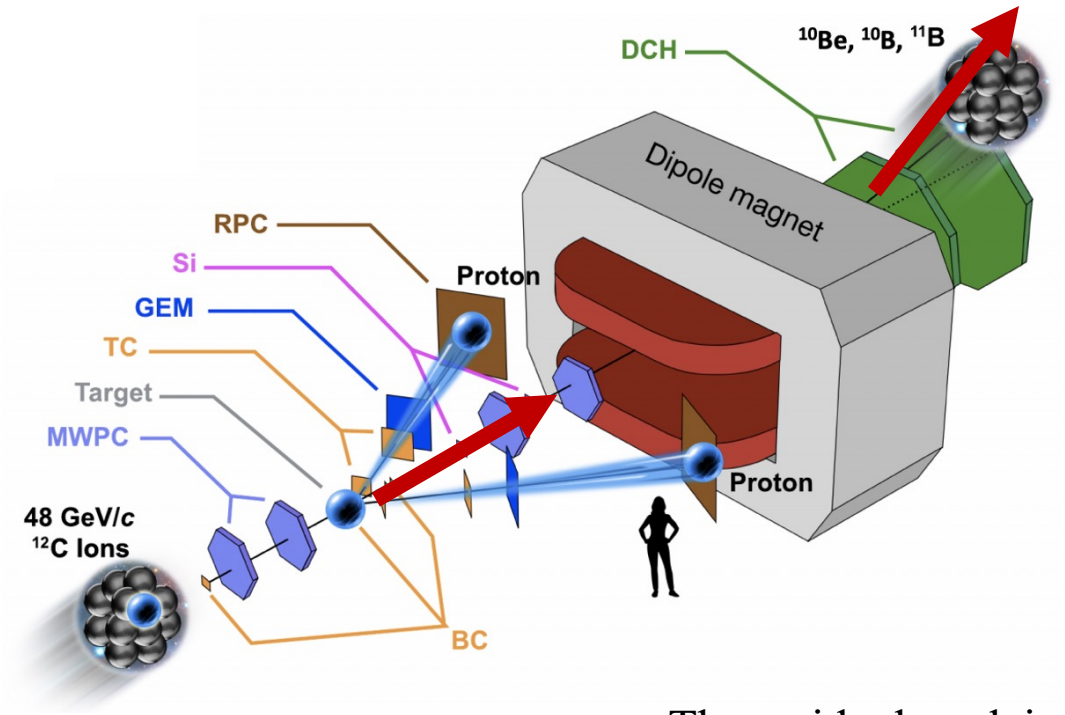


- The proton momentum before the interaction was reconstructed using 3 vectors :

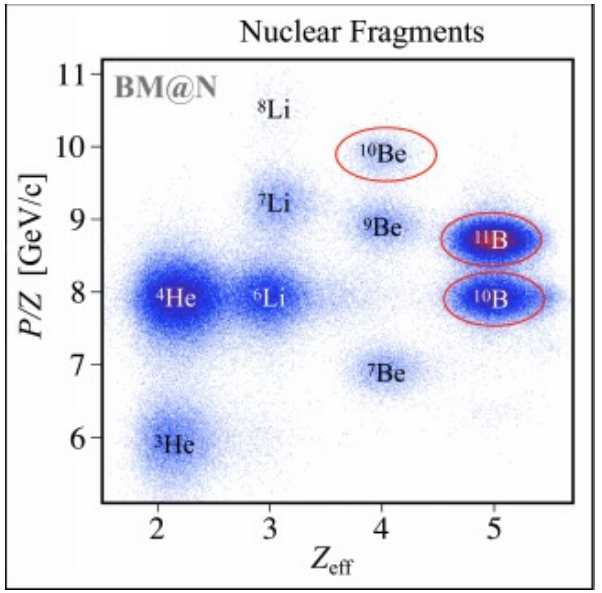
Incoming vector to the target and 2 protons in the arms

Analysis: momentum of the residual ion

First analysis paper accepted for publication (Phys.Nature)!



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



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

Now we are working to analyze the rest of the final states