



TECHNISCHE
UNIVERSITÄT
DARMSTADT

Status of SRC@JINR analysis

Valerii Panin and Efrain Segarra on behalf of SRC collaboration

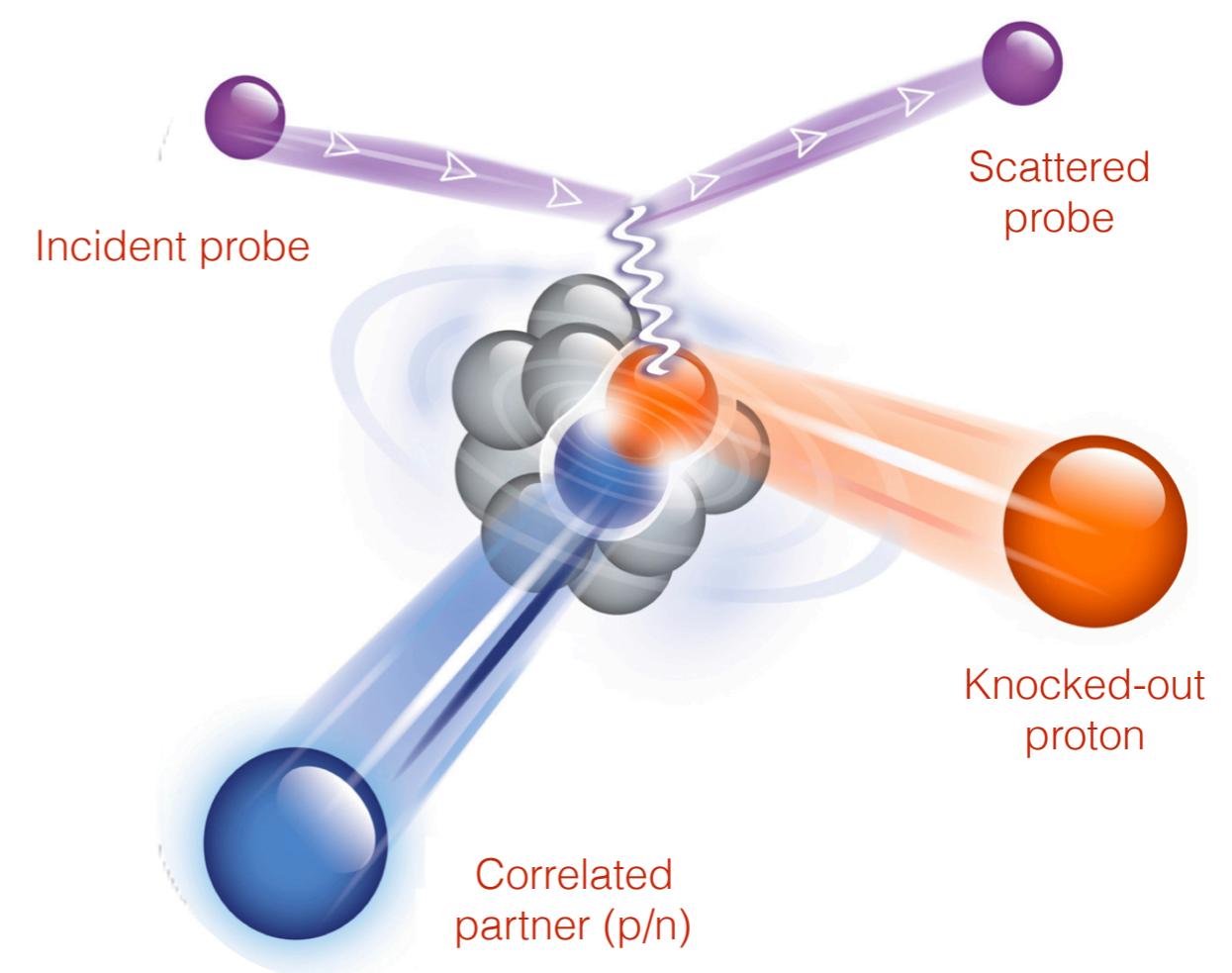
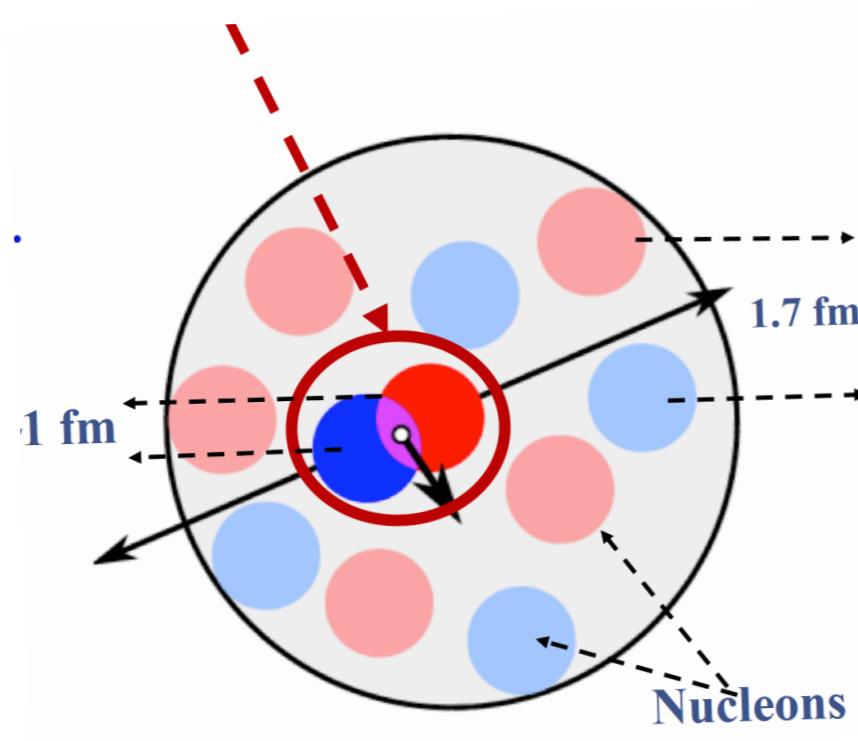
BMN Detector Advisory Committee Meeting
18 June 2019



Short-Range Correlations (SRC)

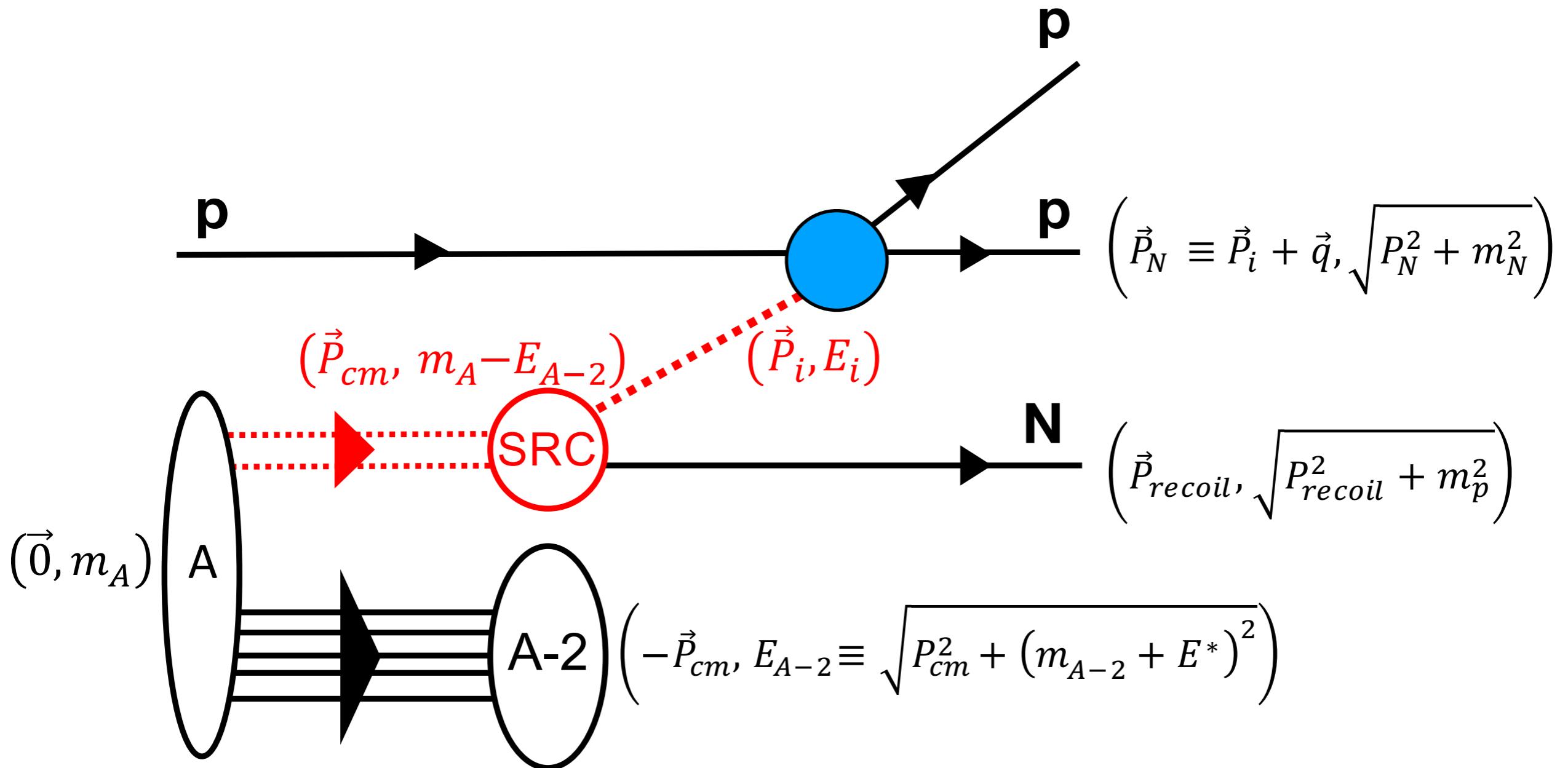
Nucleon pairs that are close together in the nucleus

Momentum space: *high relative and low c.m. momentum*, compared to the Fermi momentum (k_F)

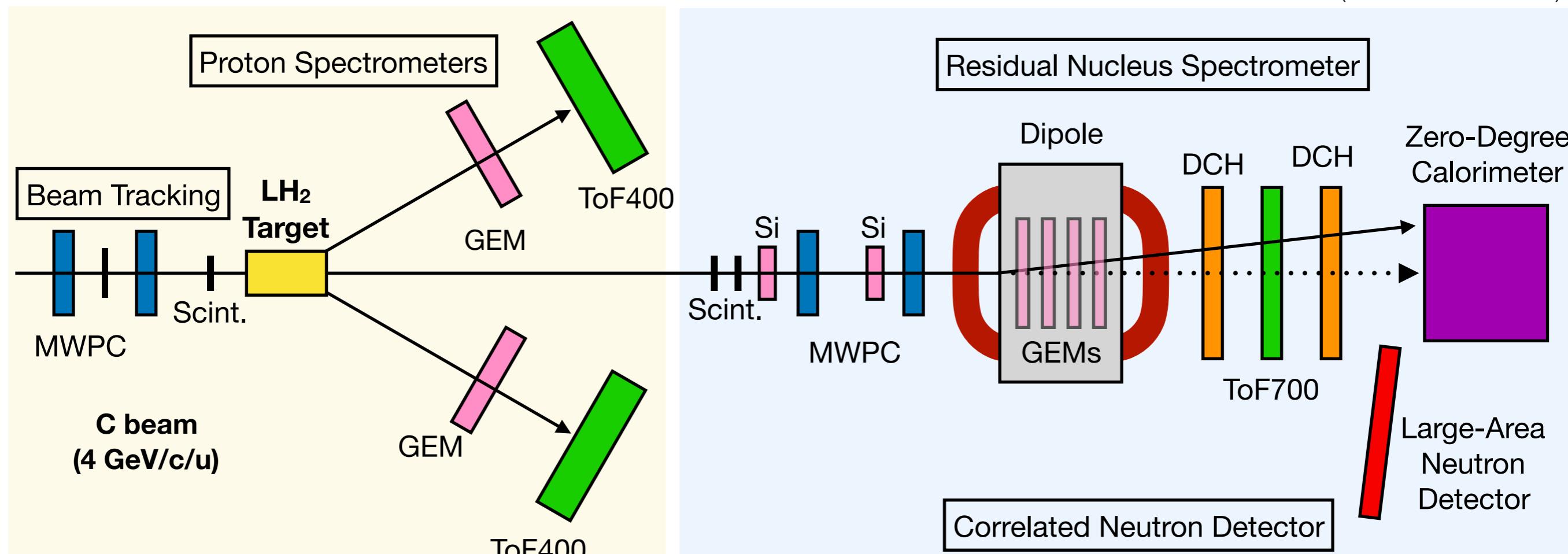
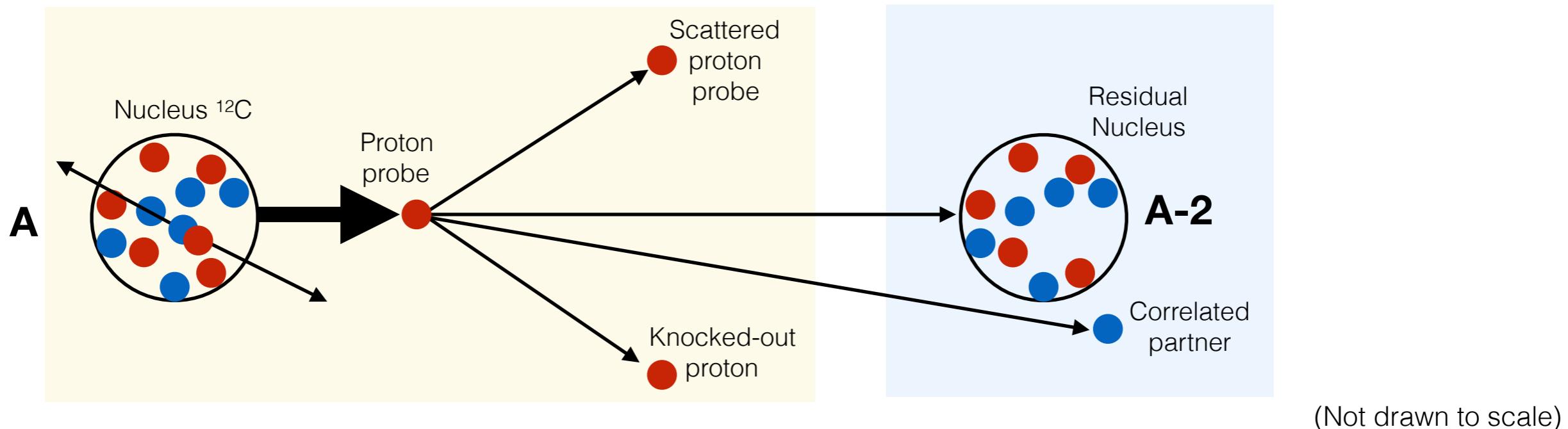


- * *Science 320 (5882) 1476-1478 (2008)*
- Science 346, 614 (2014)*
- Nature 560, 617–621 (2018)*

The state of the A-2 residual nucleus impacts SRC kinematics



First Fully Exclusive Measurement of Short-Range Correlated Nucleons in Inverse Kinematics at JINR



RFBR grant for SRC data analysis by Dr. Maria Patsyuk

Manpower

Name	Area of expertise
Vasilisa + V. Palchik	MWPC + Si
Nikolay Voytishin	DCH
Yuri Petukhov	TOF700
V. Babkin + M. Rumyantsev	TOF400
Yuri Uzikov	Theory
Maria Patsyuk	Coordinator

3 years, evaluation after each year

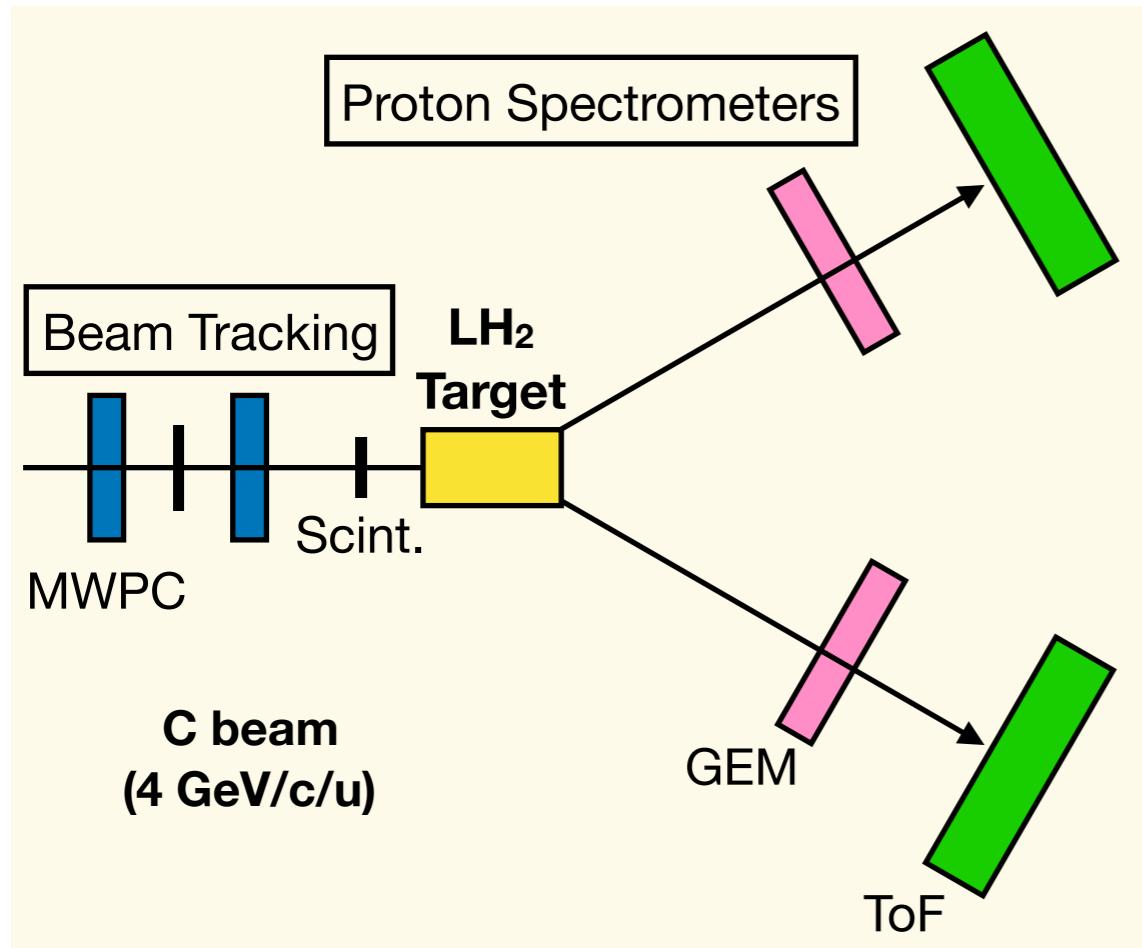
Plan for 2019:

- Calibration of detector systems
- Correlations between different detectors
- Identification of protons and A-2

Goals of the analysis

- Identification of quasi-elastic ($p, 2p$) events with ^{12}C beam
 - **QFS tagging and cleaner event sample**
 - optics calibration
 - GEM + TOF calibration
 - reconstruction of Pmiss and beam vector
- Study of A-2 residual system after SRC knockout
 - **N of tracks - DCH / Si / GEM / TOF700**
 - clean SRC event sample using TOF 400 + GEM + beam tracking
 - momentum reconstruction for fragments
 - **PID using TOF700**
 - efficiency corrections
 - yields for different fragmentation channels

QFS tagging

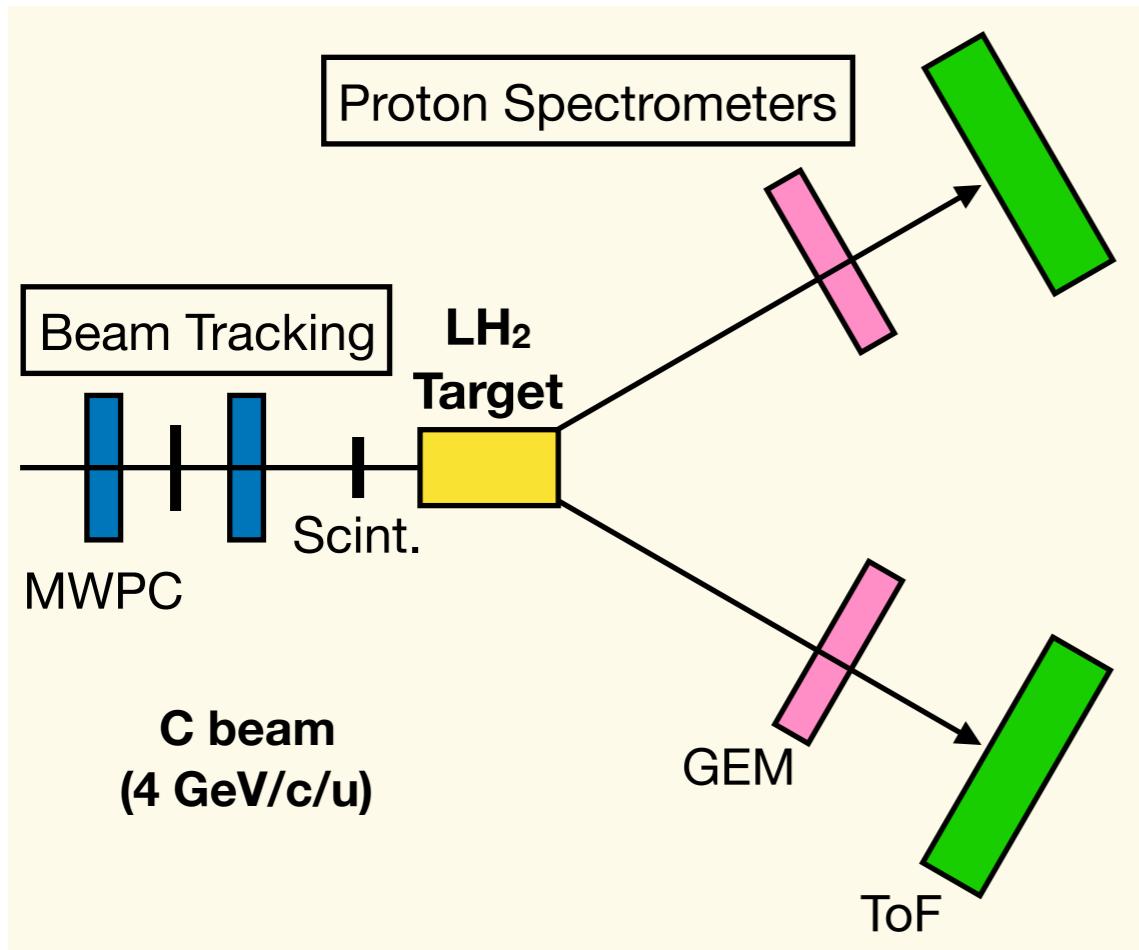


$$\beta = \frac{x}{c_{\text{air}} \cdot \text{ToF}}$$

$$|\vec{p}_1| = \frac{m_p}{\sqrt{1/\beta^2 - 1}}$$

$$\vec{p}_{\text{miss}} = \vec{p}_1 + \vec{p}_2 - \vec{p}_{\text{beam}}$$

QFS tagging



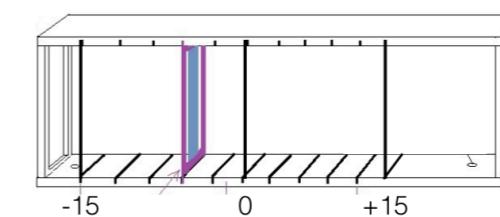
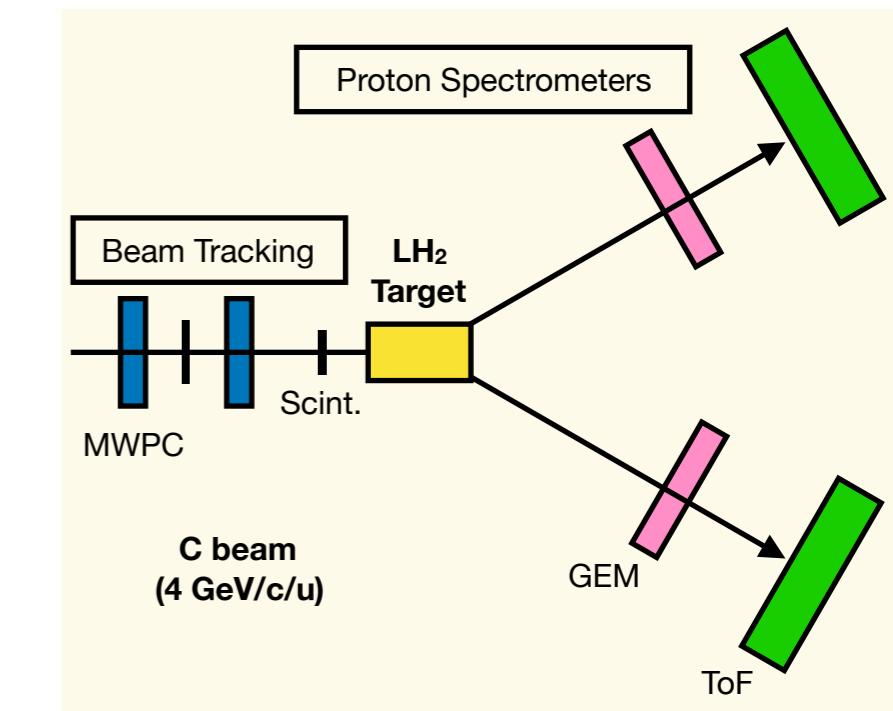
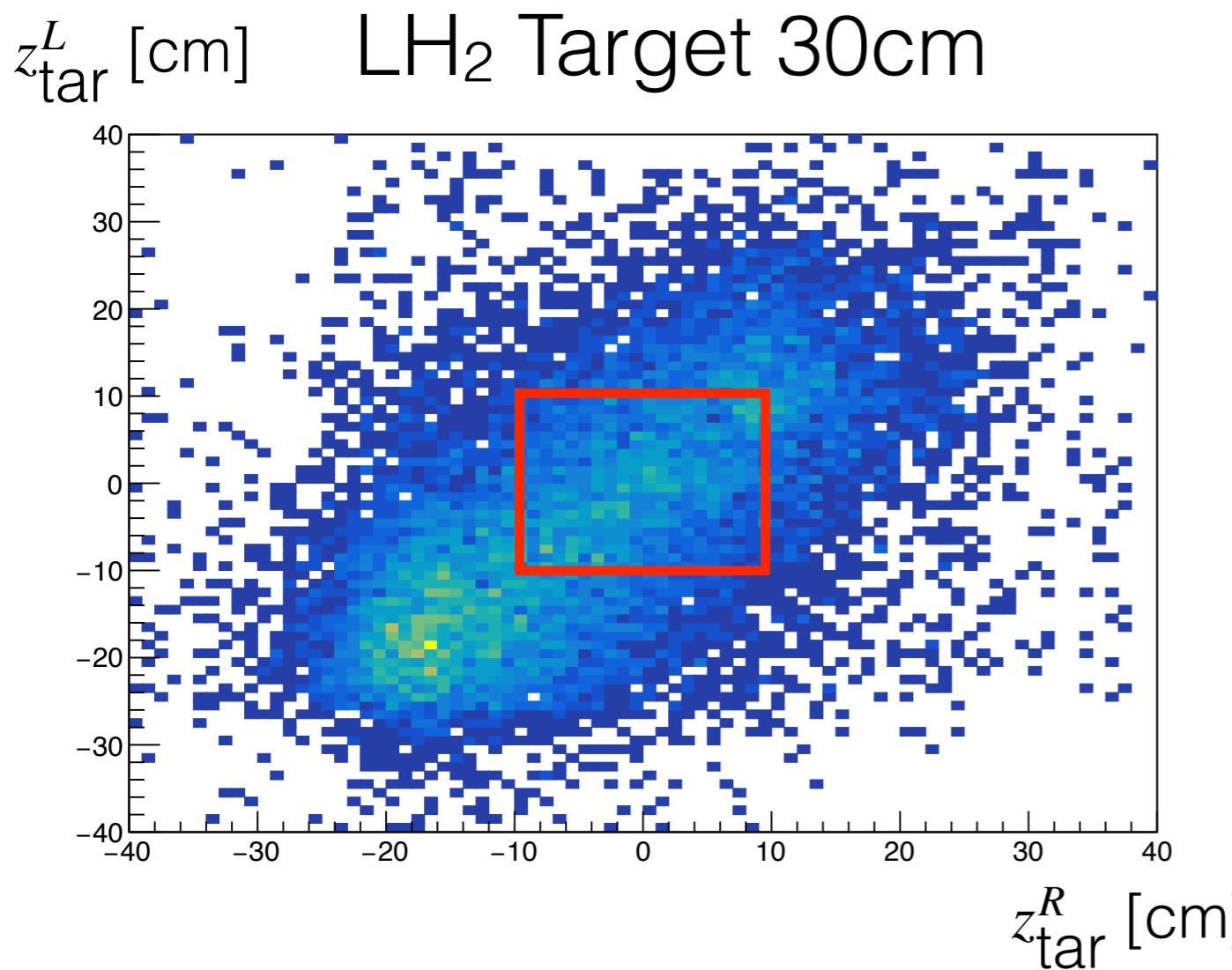
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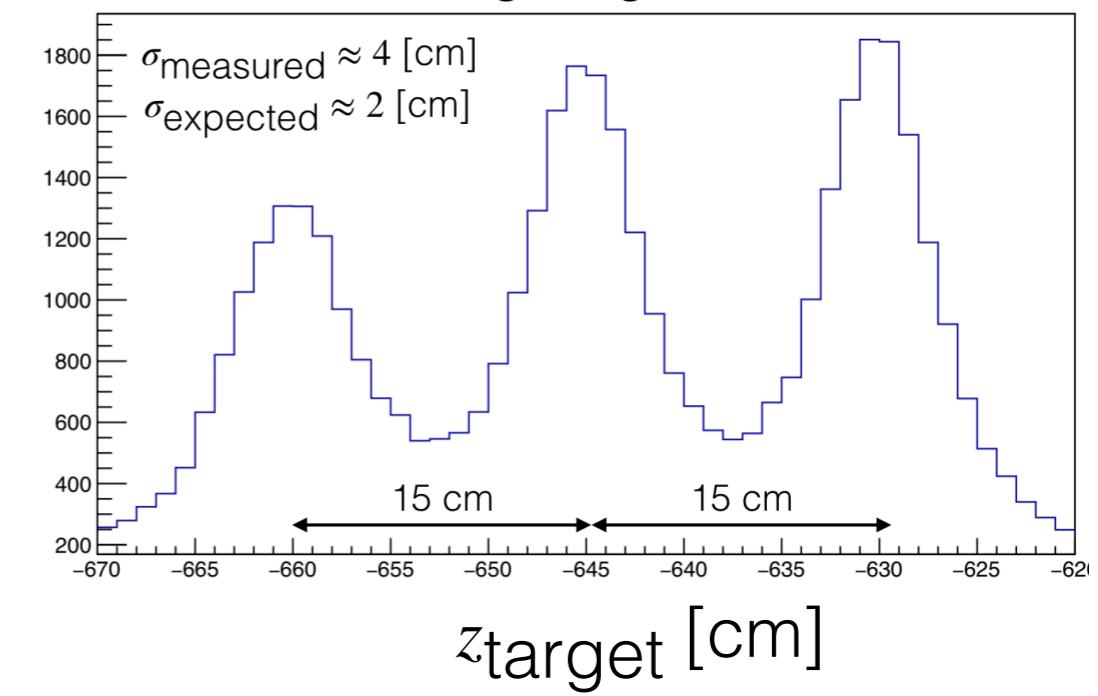
$$\vec{p}_{\text{miss}} = \vec{p}_1 + \vec{p}_2 - \vec{p}_{\text{beam}}$$

- Cannot discriminate pion from proton event-by-event in arms
- Need to have precise optics (for position measurement) & timing
- Need beam vector

Target Reconstruction on Production Data (GEMs)

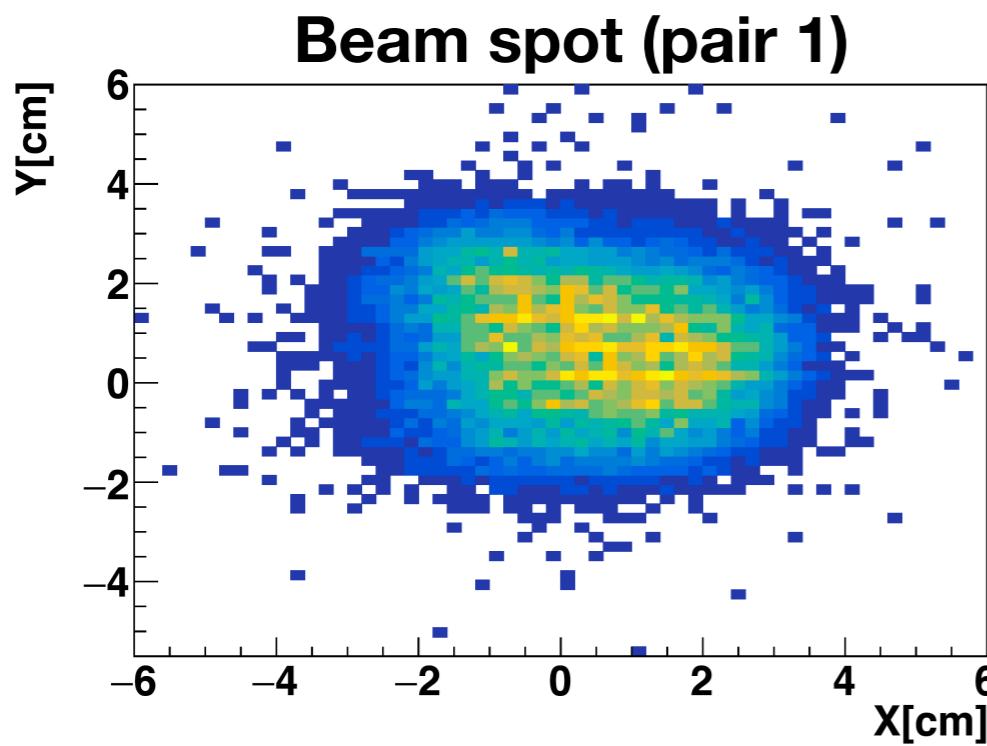
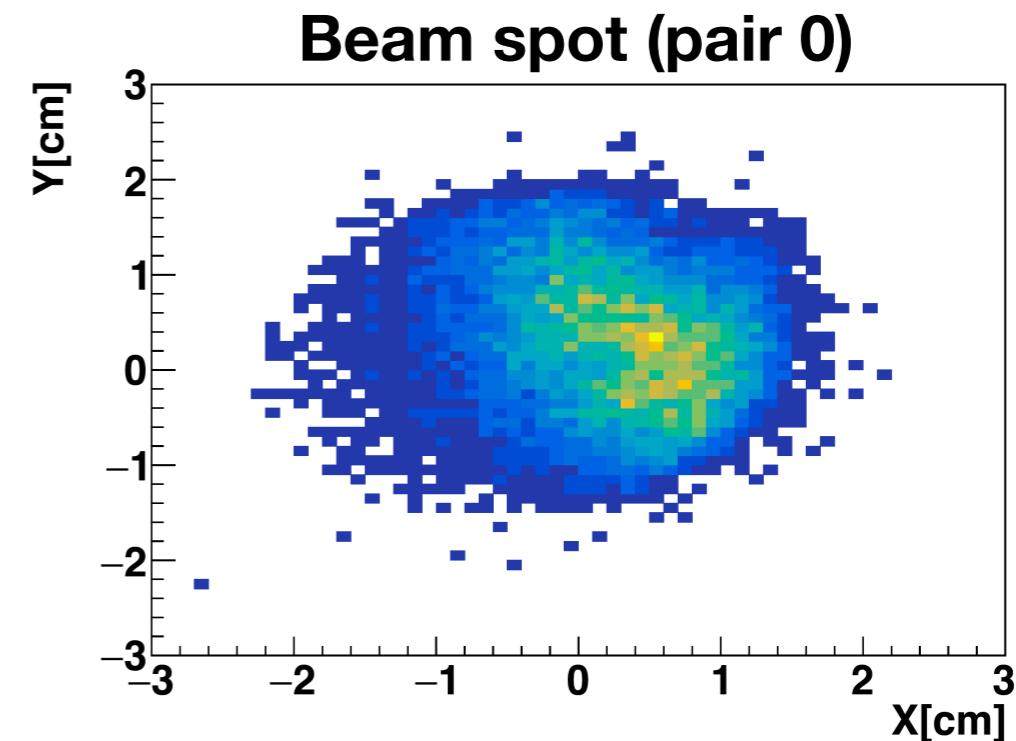
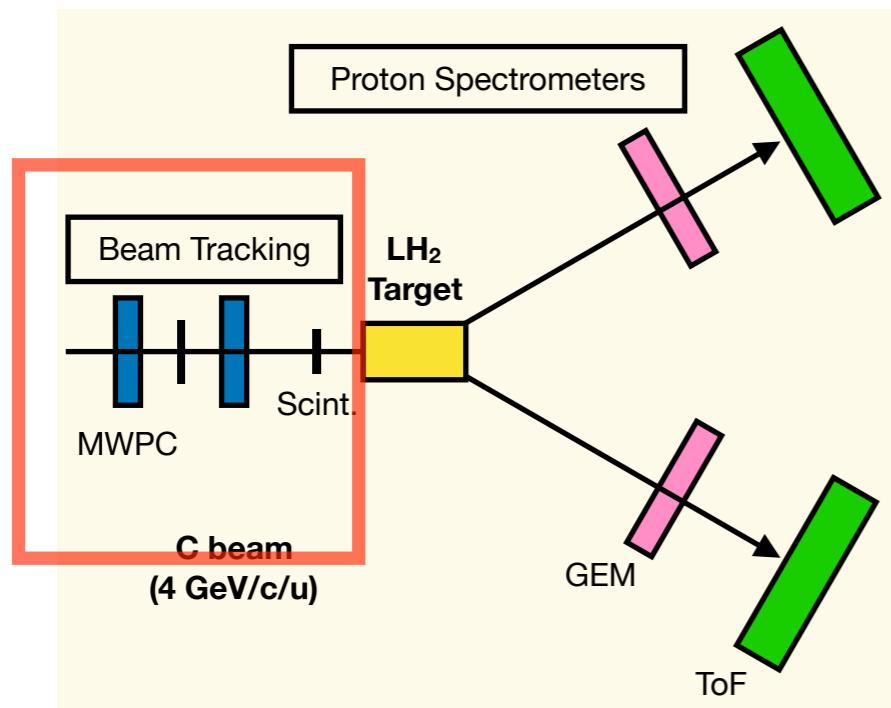


Reconstructing Target Position

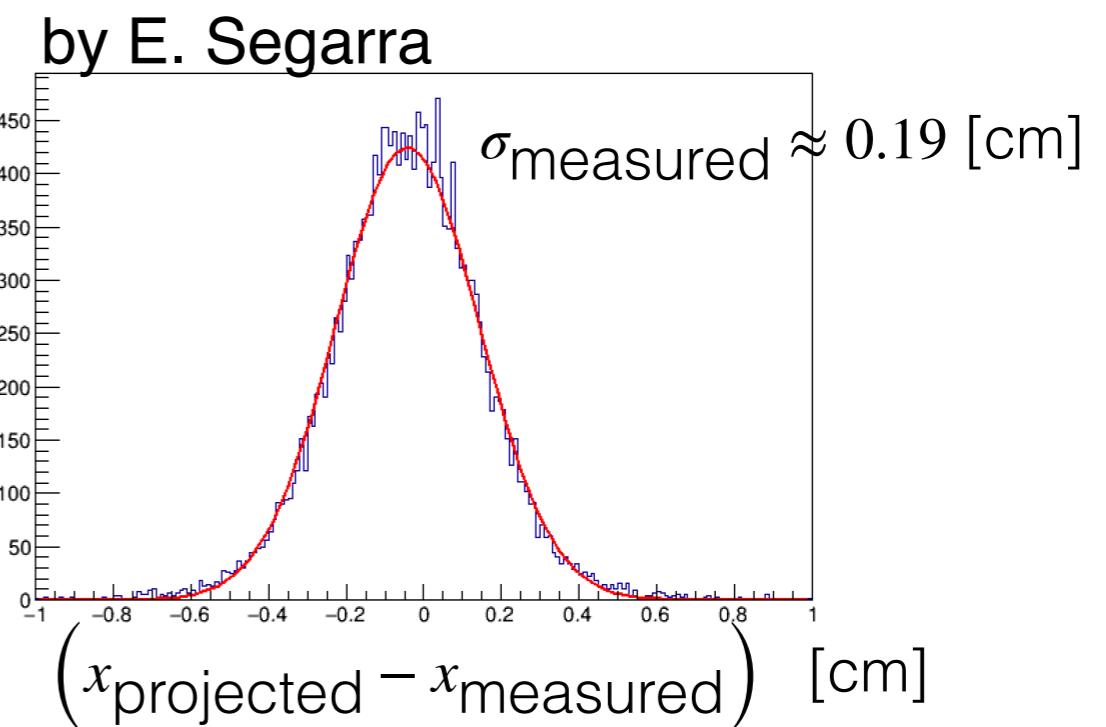


by E. Segarra

Extracting Beam Vector (all 4 MWPCs)

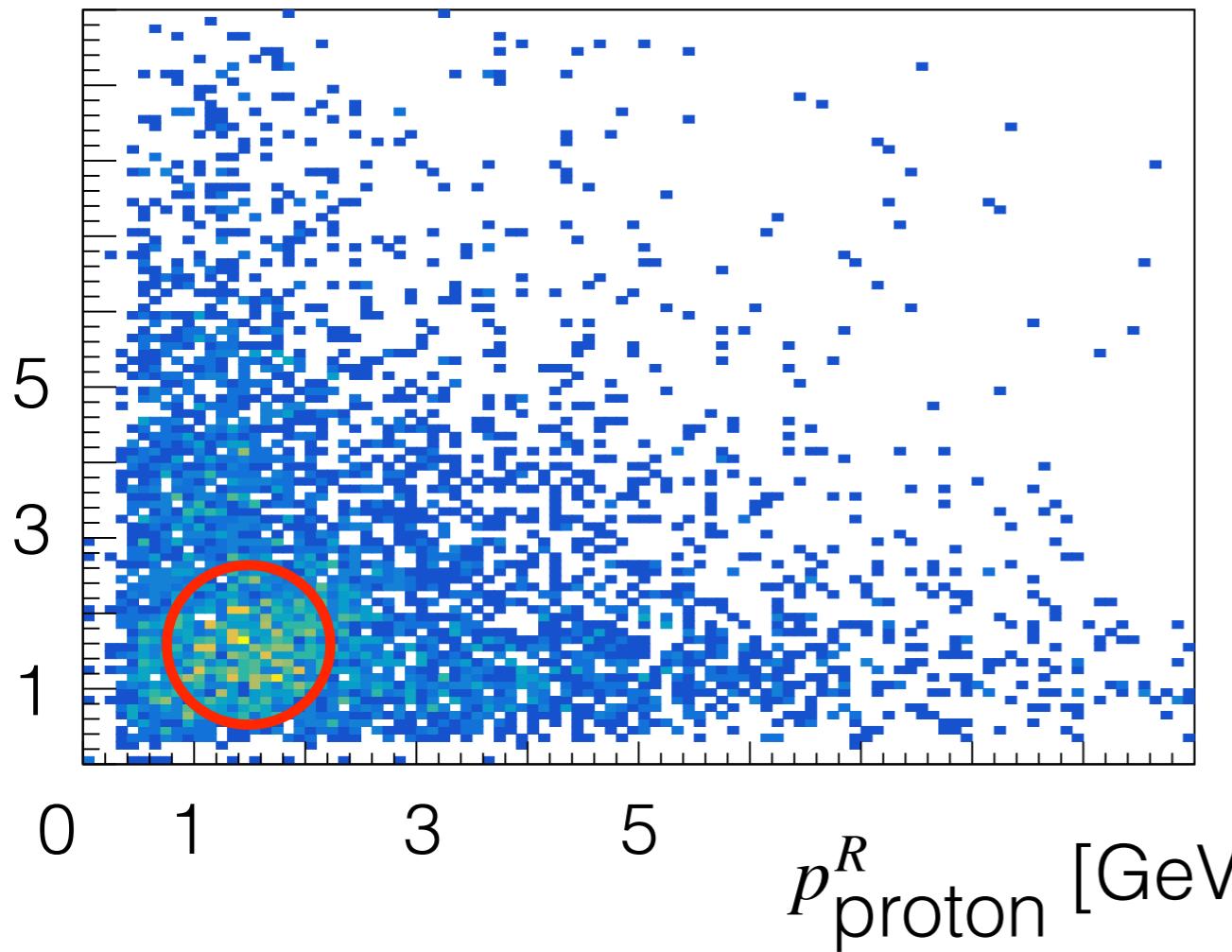


(Track Projection - Measured Hit)

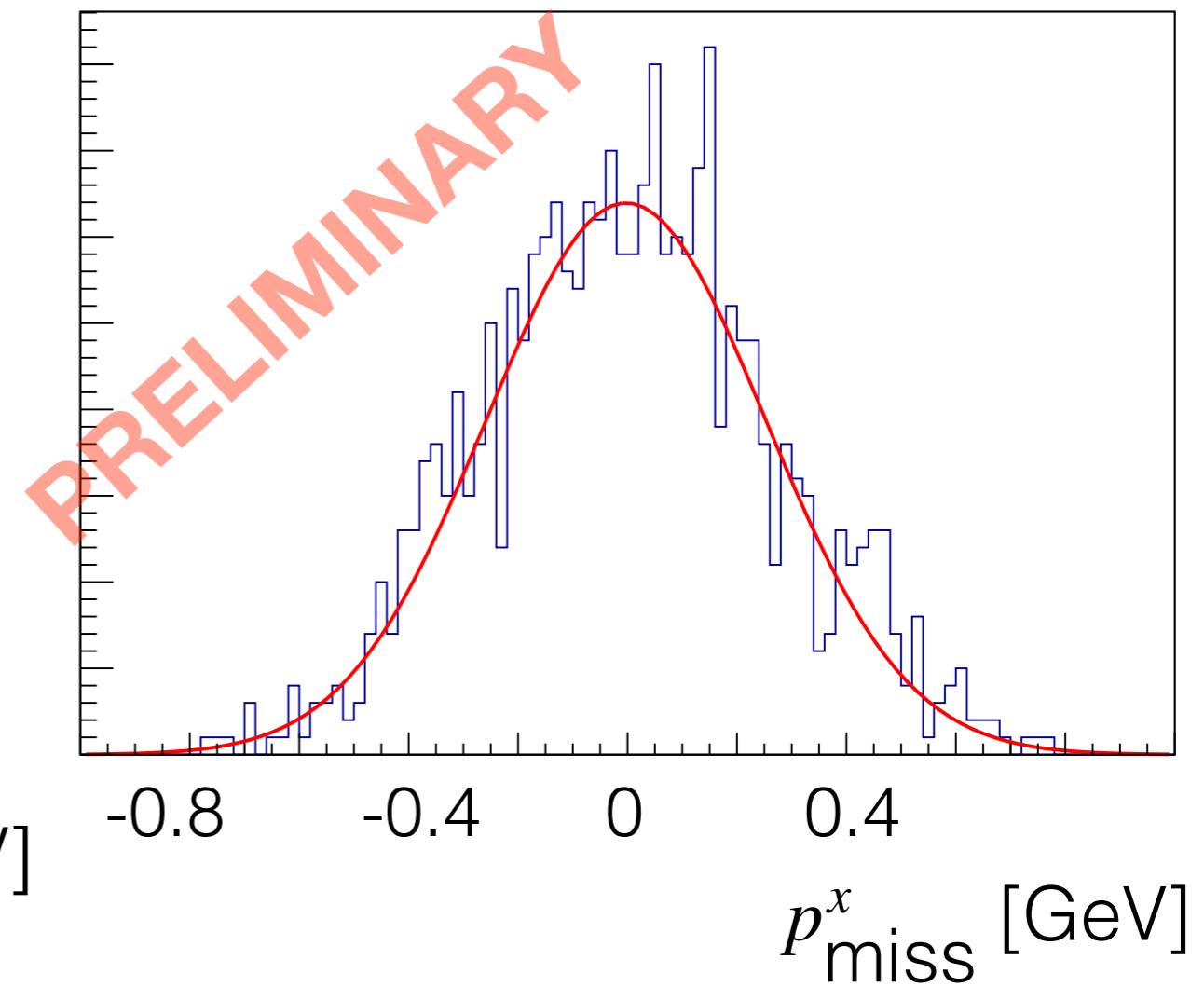


Looking at the (p,2p) reaction

p_{proton}^L [GeV]



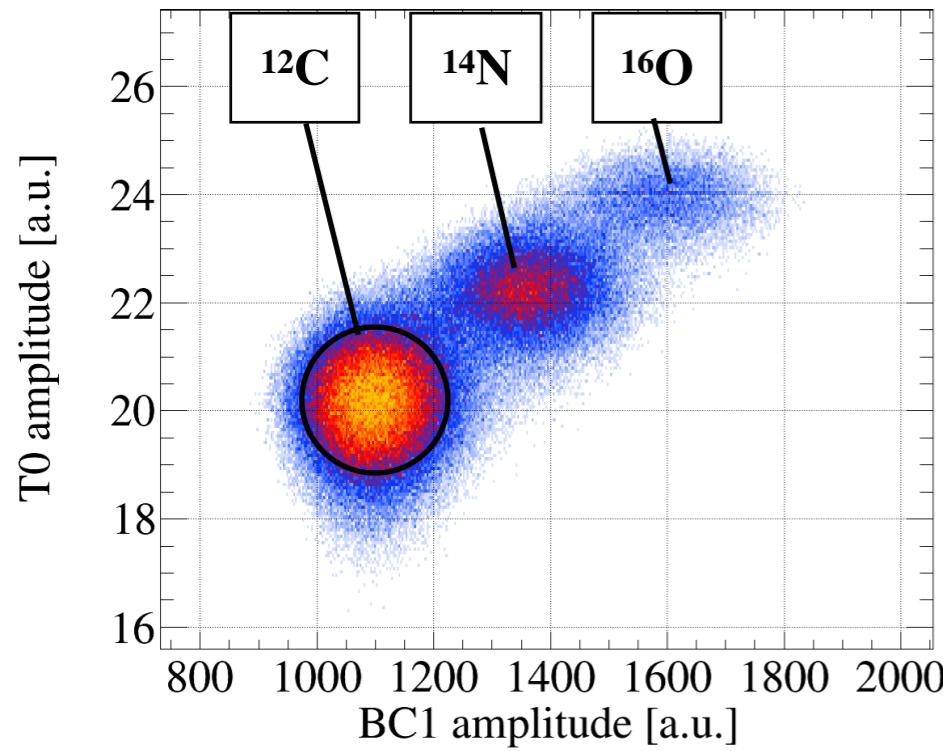
$$\vec{p}_{\text{miss}} = \vec{p}_1 + \vec{p}_2 - \vec{p}_{\text{beam}}$$



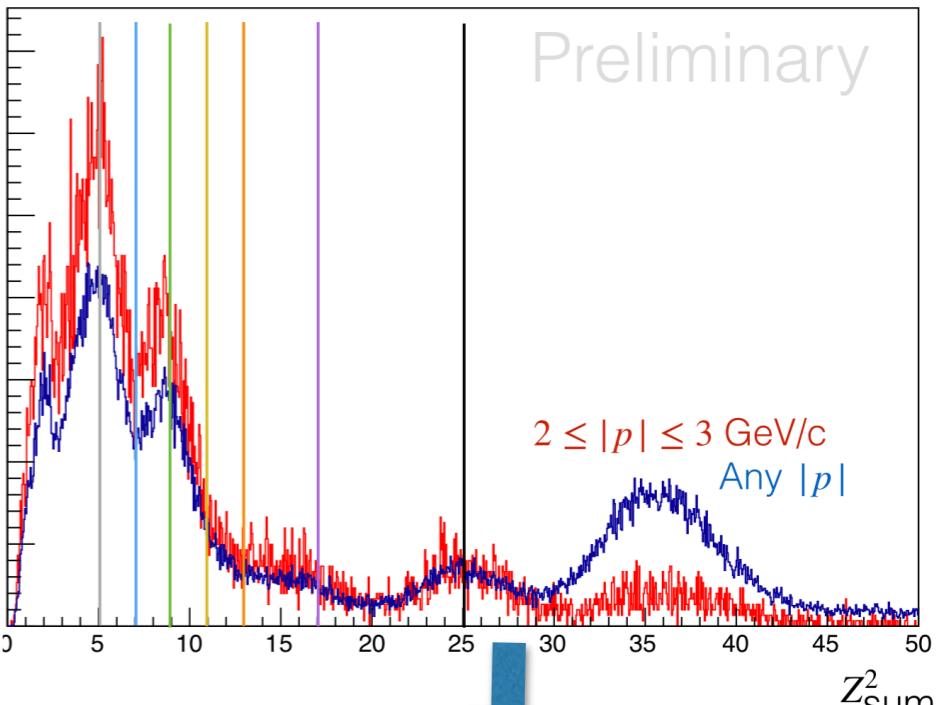
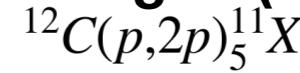
by E. Segarra

Identification of the residual system

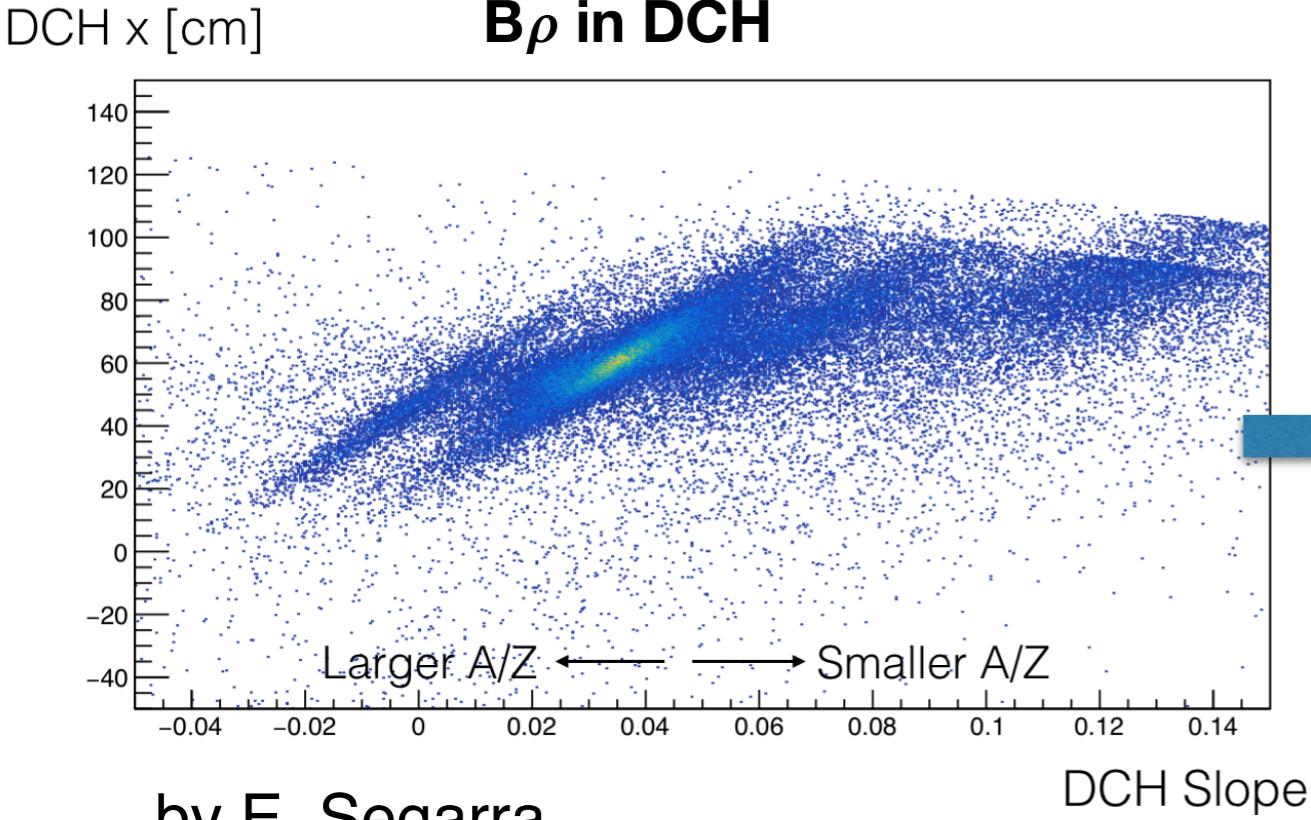
Incident beam



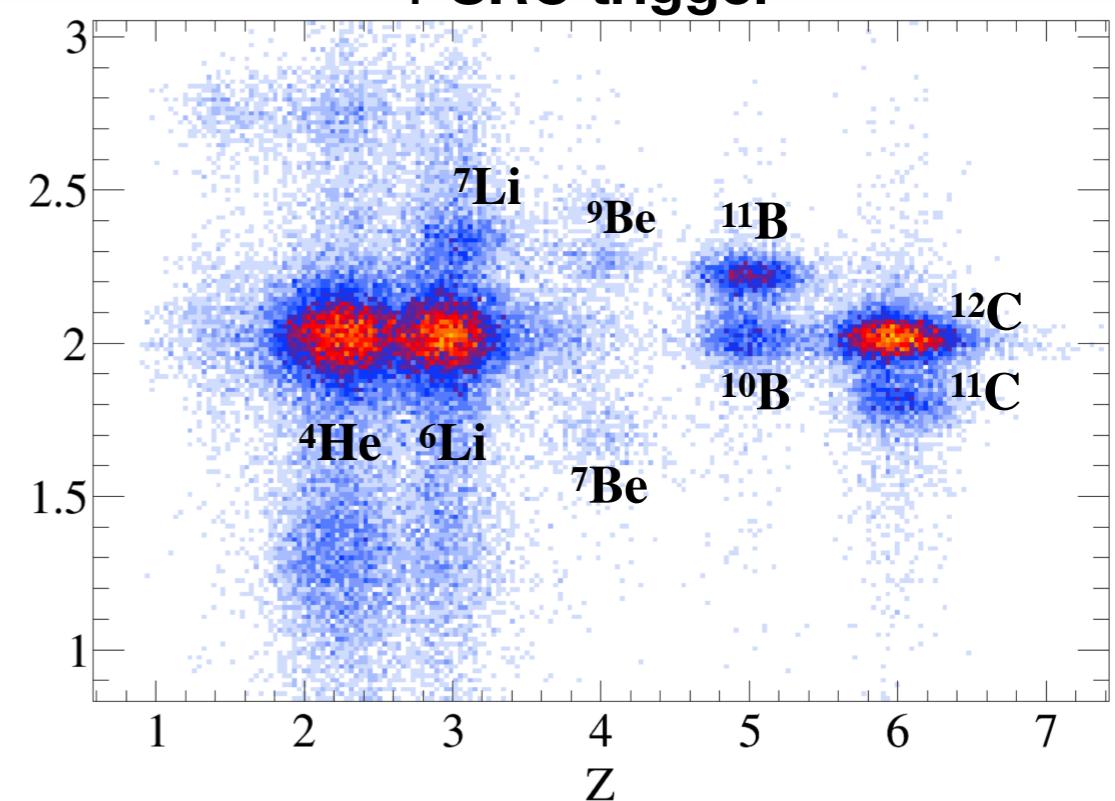
Z after the target (BC3 & BC4)



$B\rho$ in DCH



Combined PID of outgoing fragments + SRC trigger

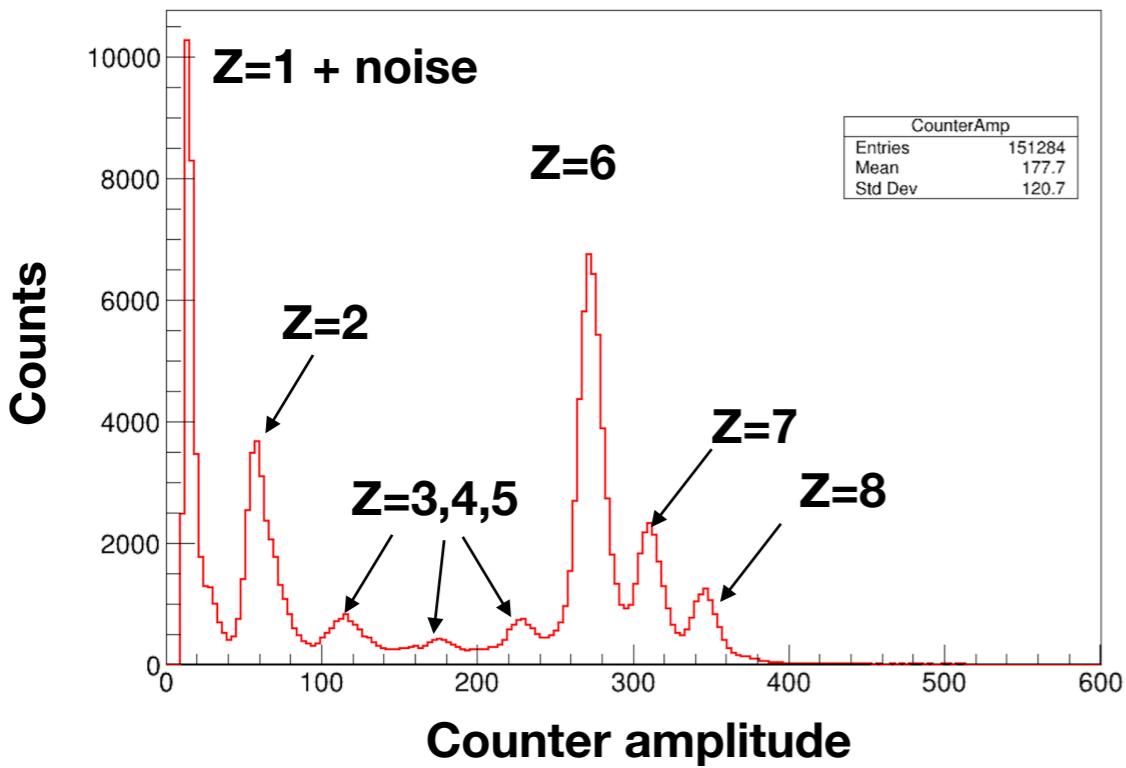


by E. Segarra

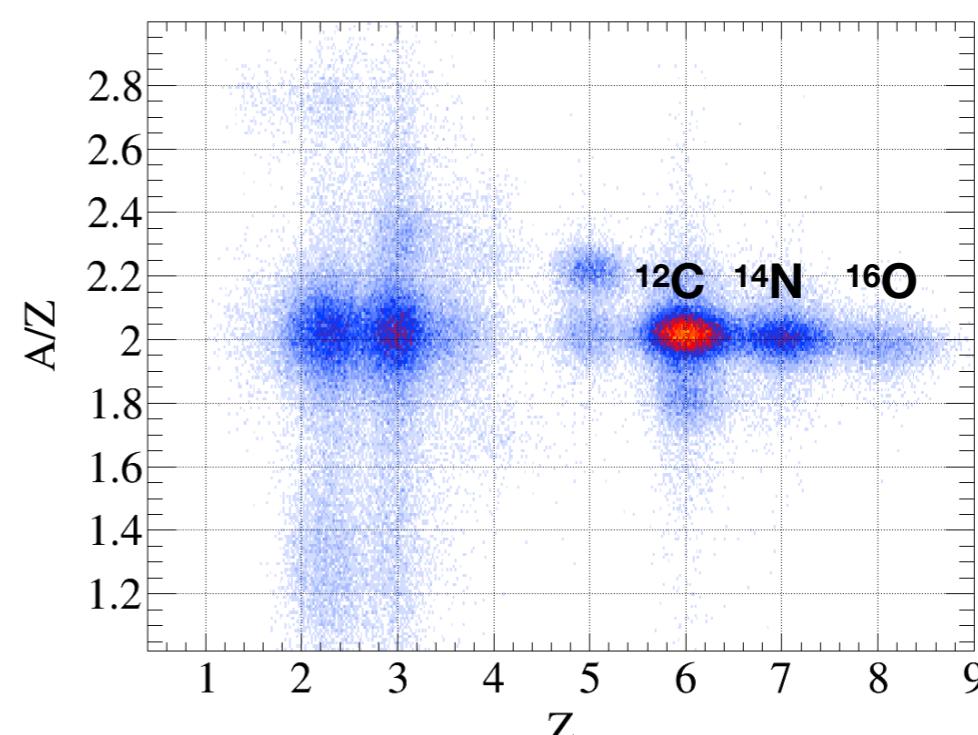
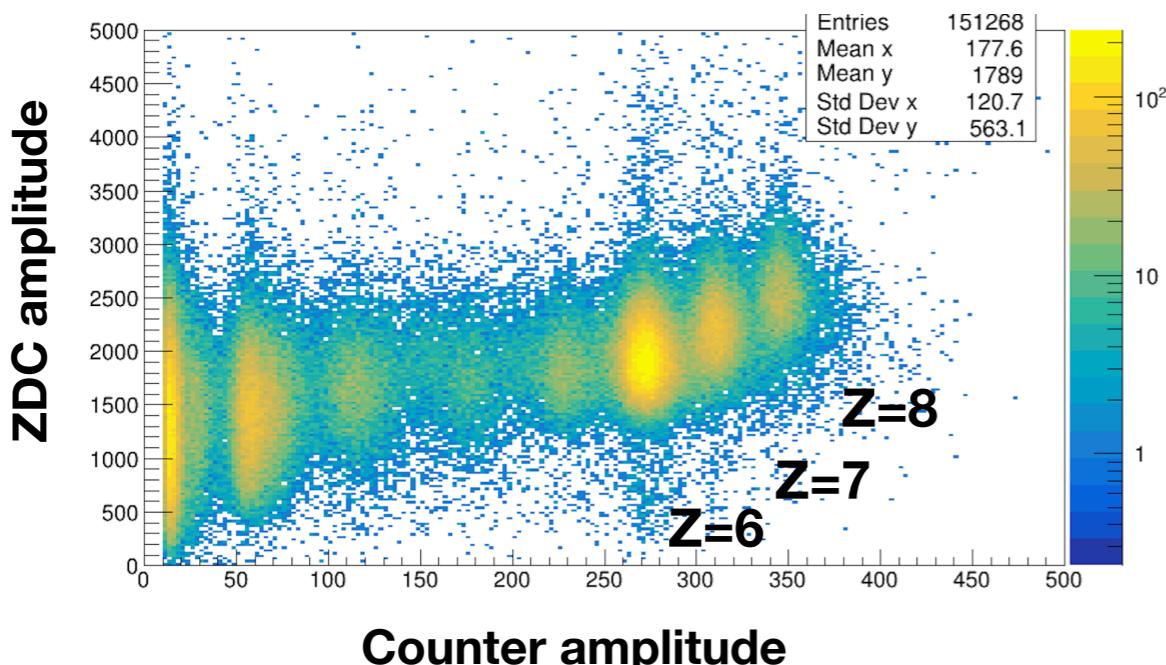
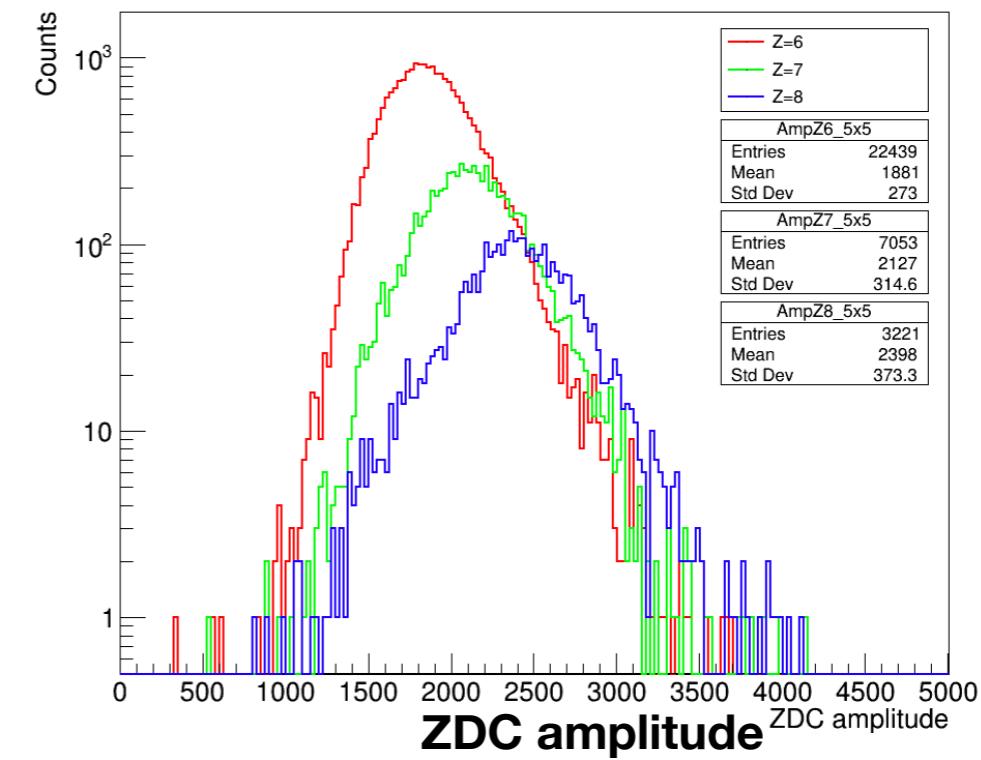
Comment from the last DAC meeting:

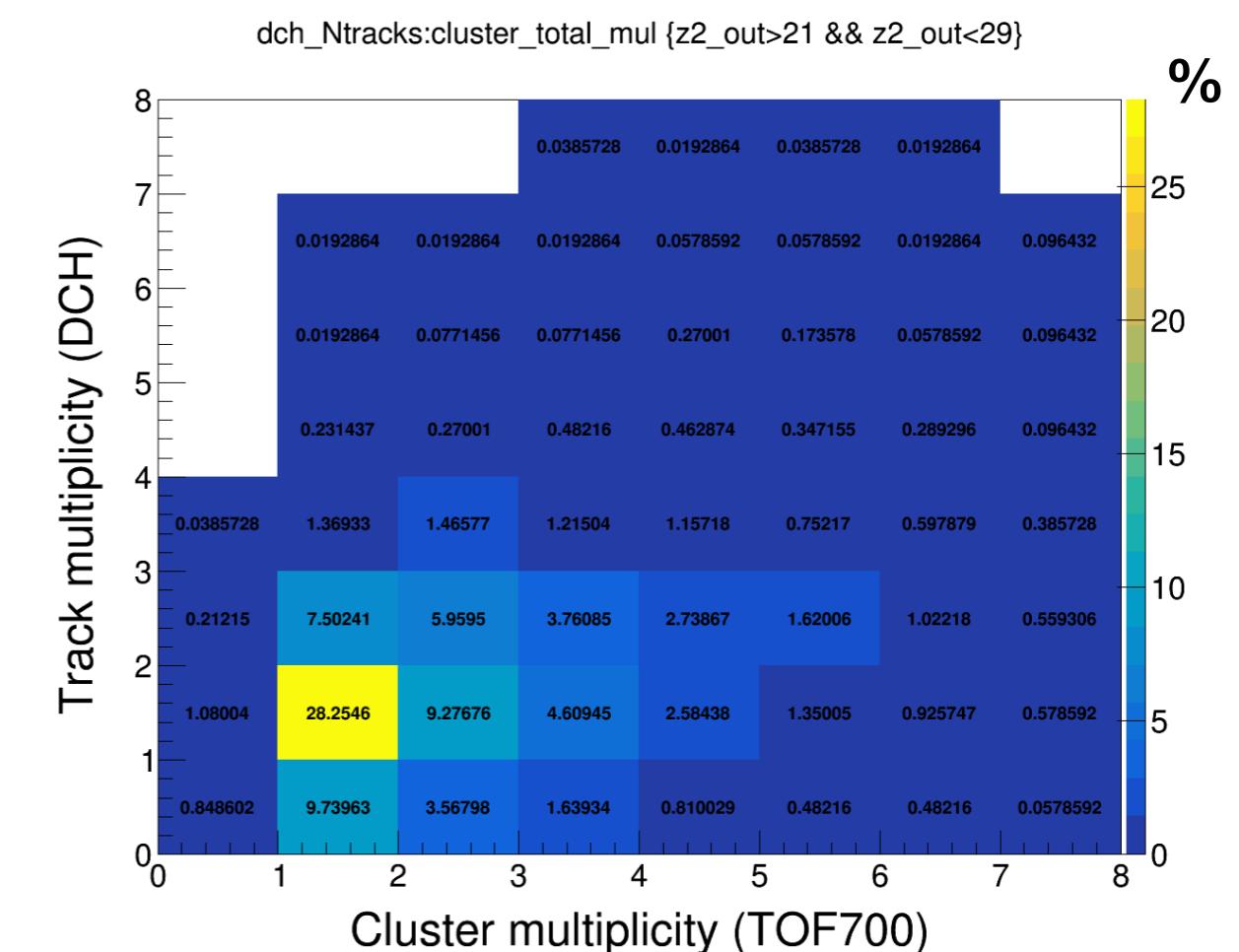
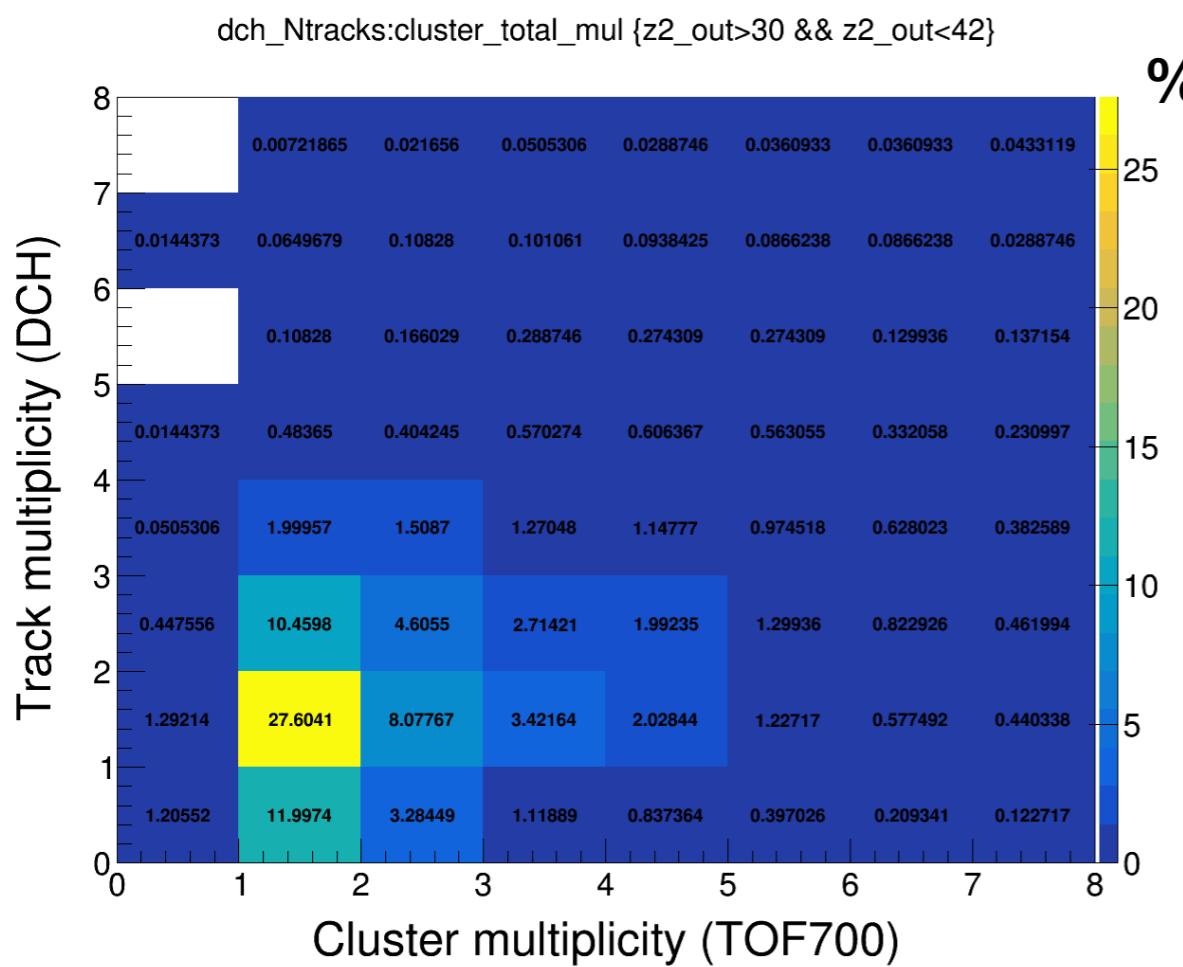
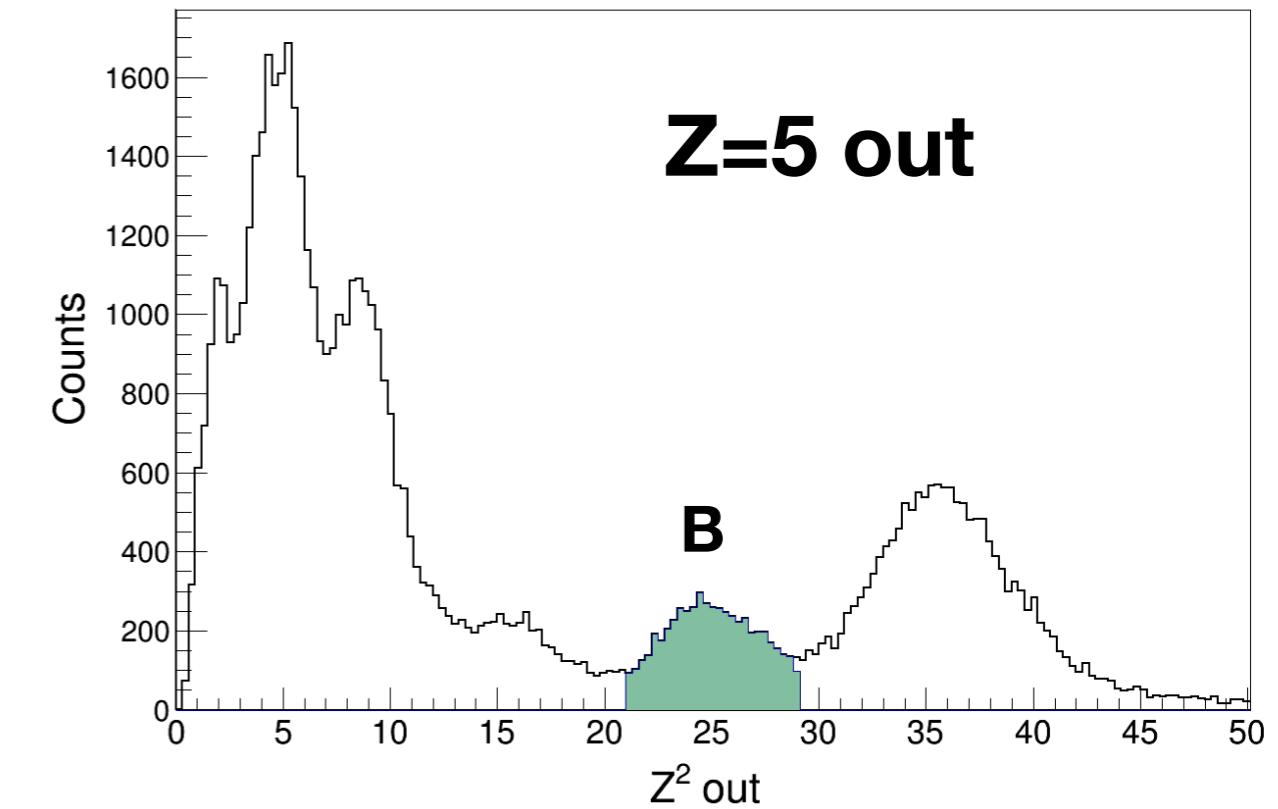
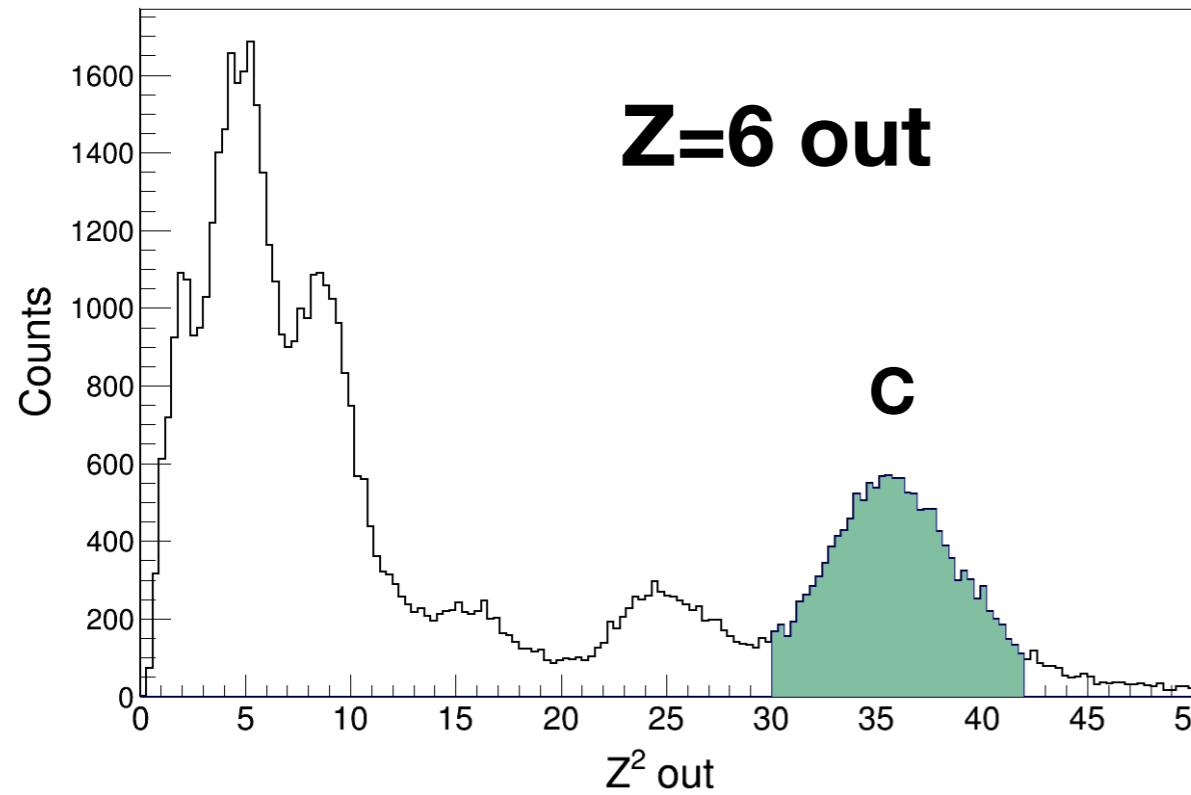
The group presents an “Incoming Z calibration (using N and O impurities in the beam)”, which is hard to understand how a carbon beam could have Oxygen impurities, clearly not from fragmentation. This puzzling effect needs immediate confirmation by the data in the ZDC (measuring the energy of the particles with good enough resolution to identify even ^{12}C from ^{11}C) in order to find if the Nuclotron accelerated ions with the same momentum/charge. Possible pile-up should also be looked at.

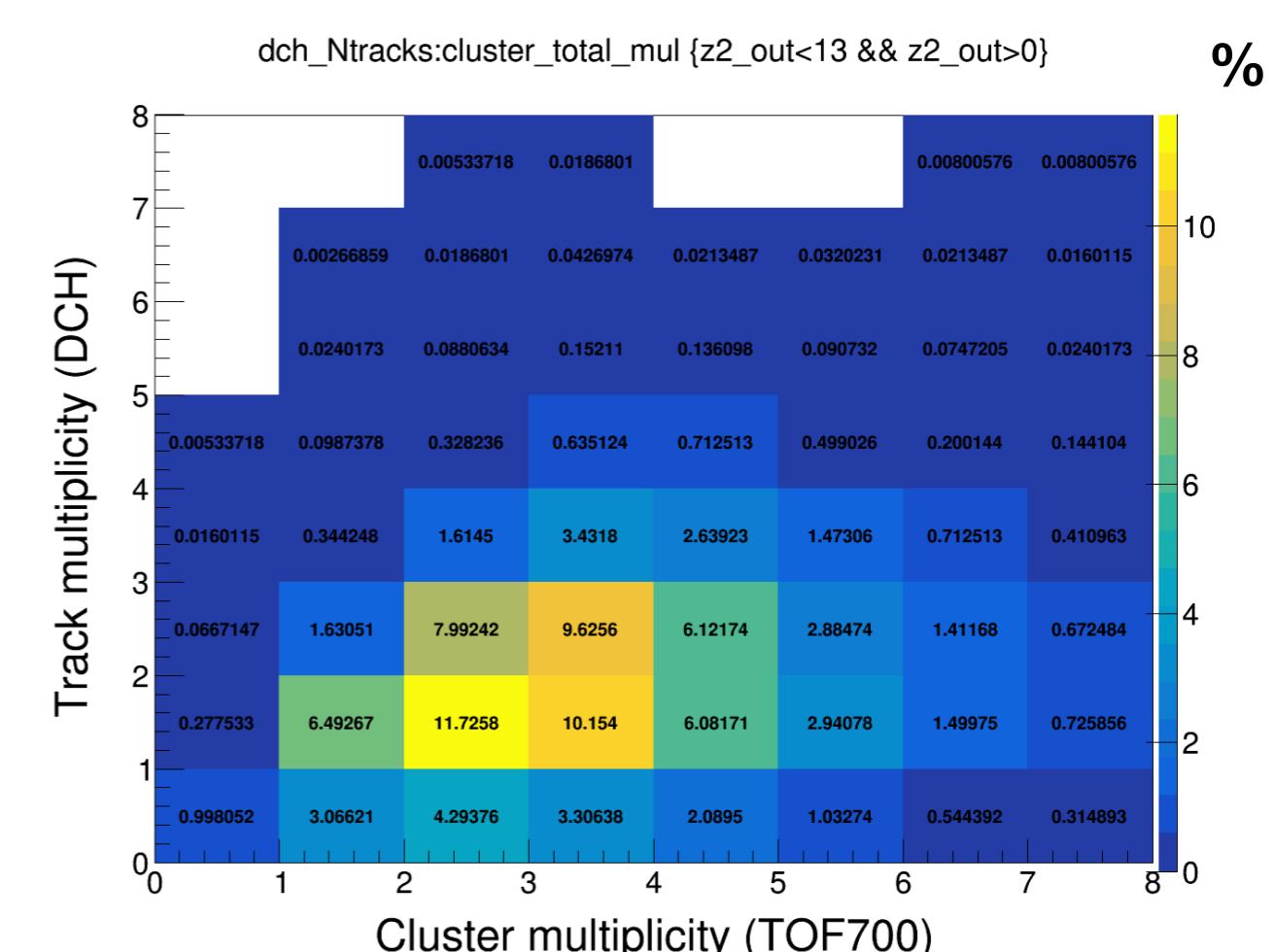
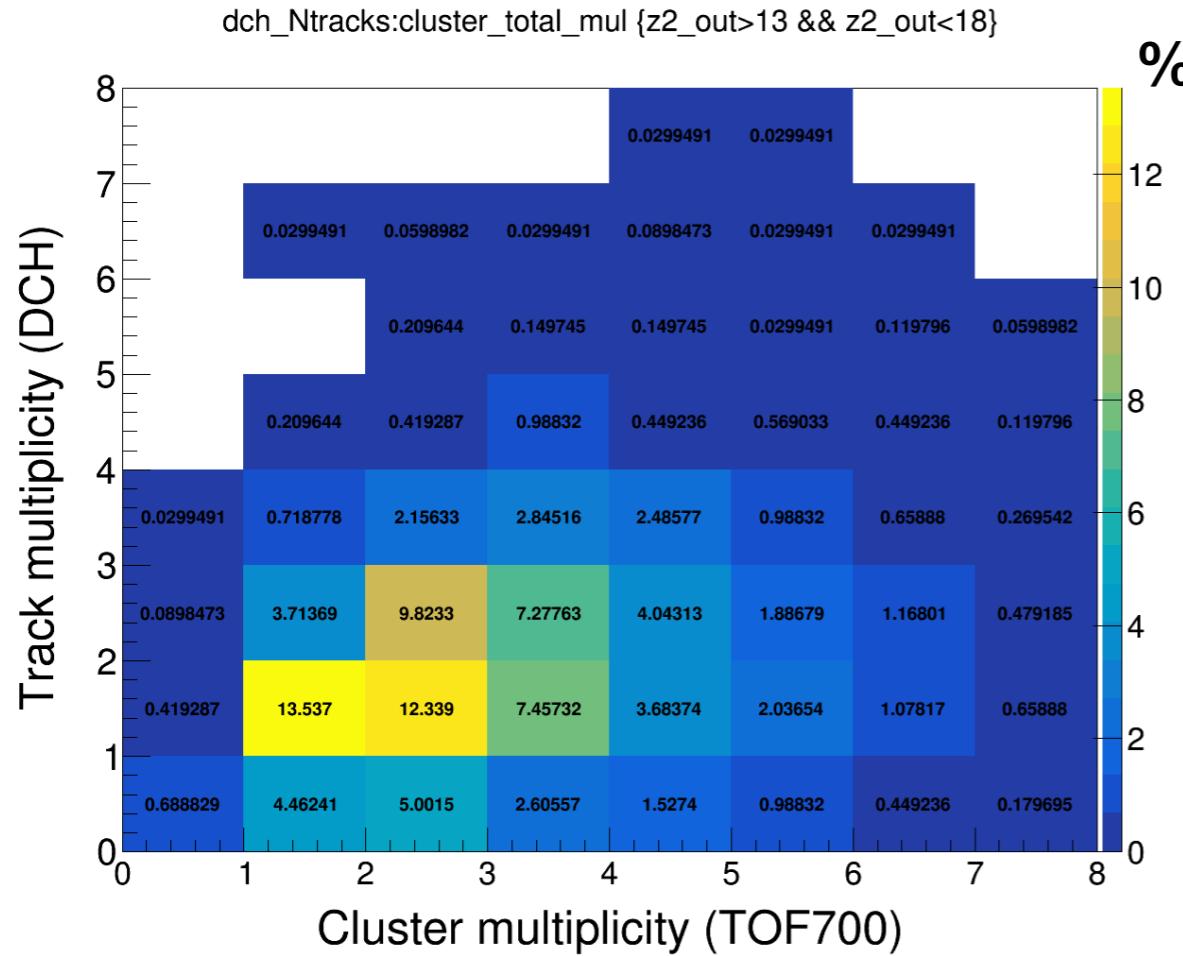
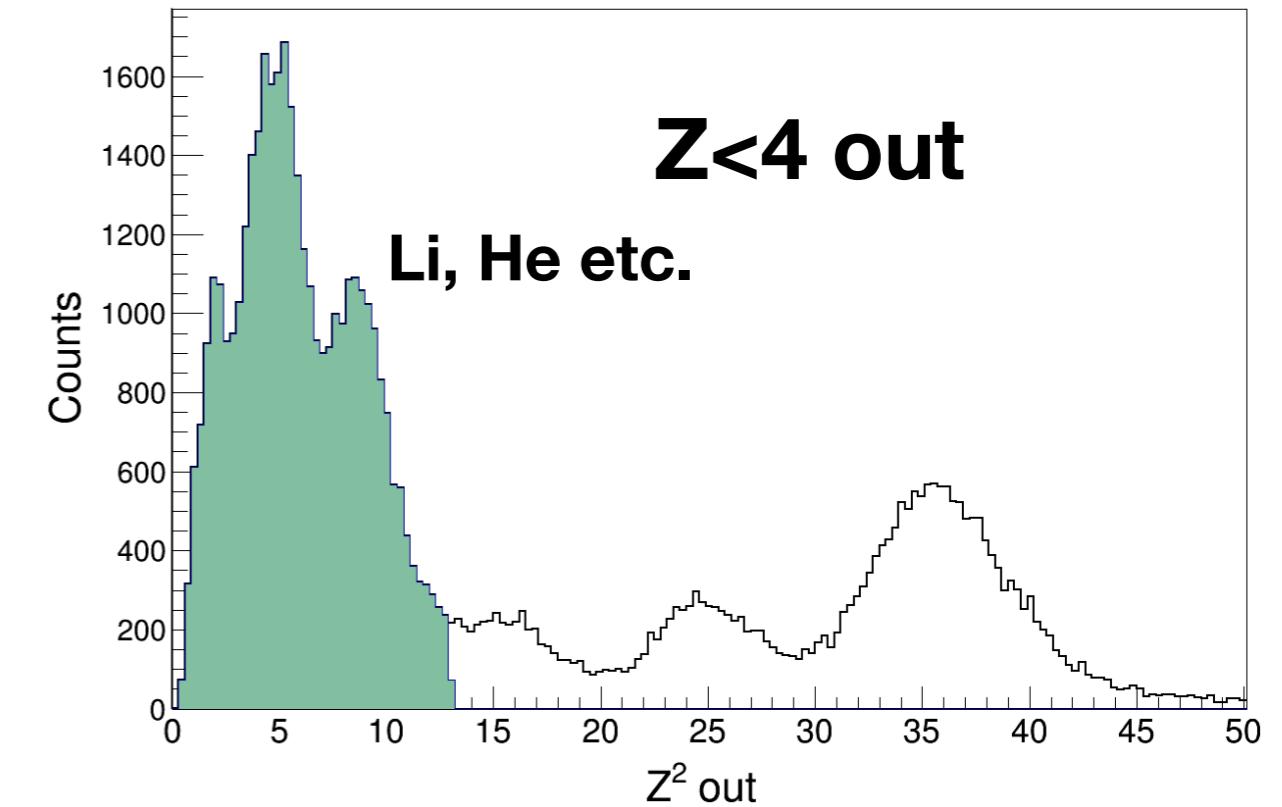
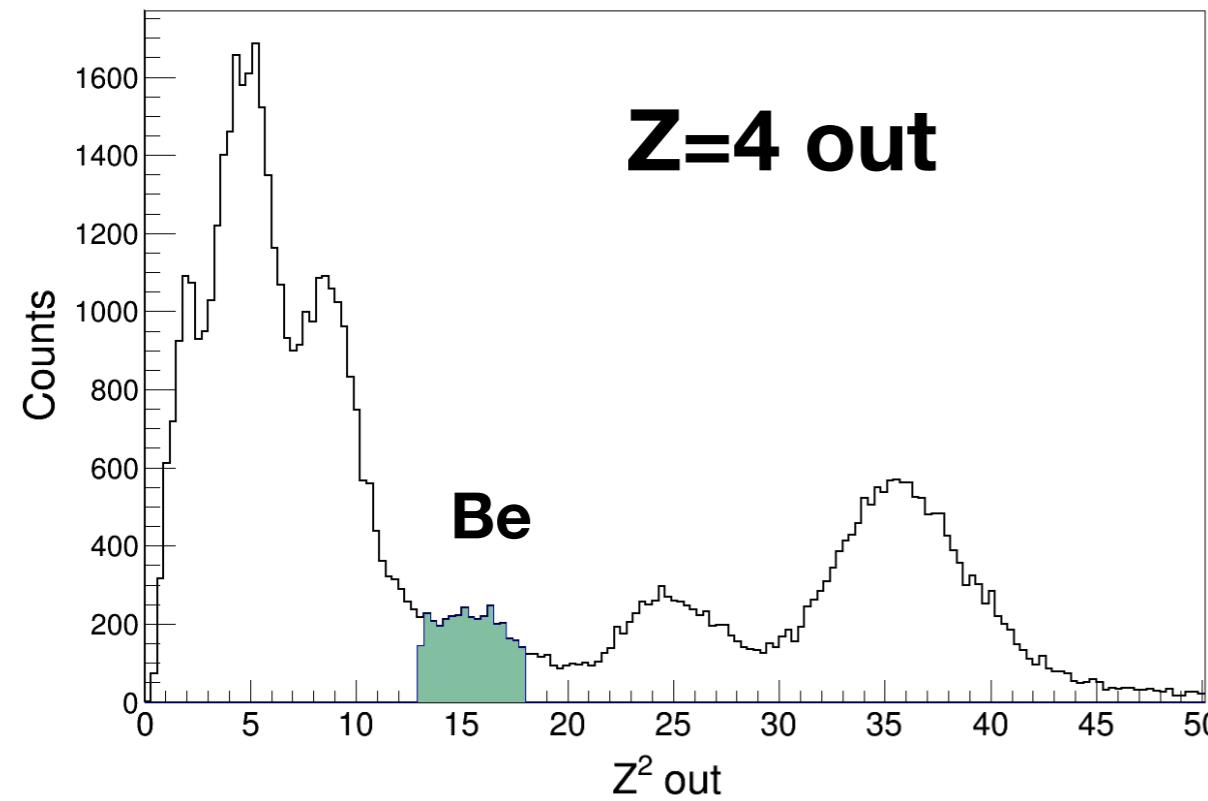
Scintillating counter before ZDC



Summed amplitudes of 25 (5x5) big ZDC modules
Position A, cluster 5x5, GemCut

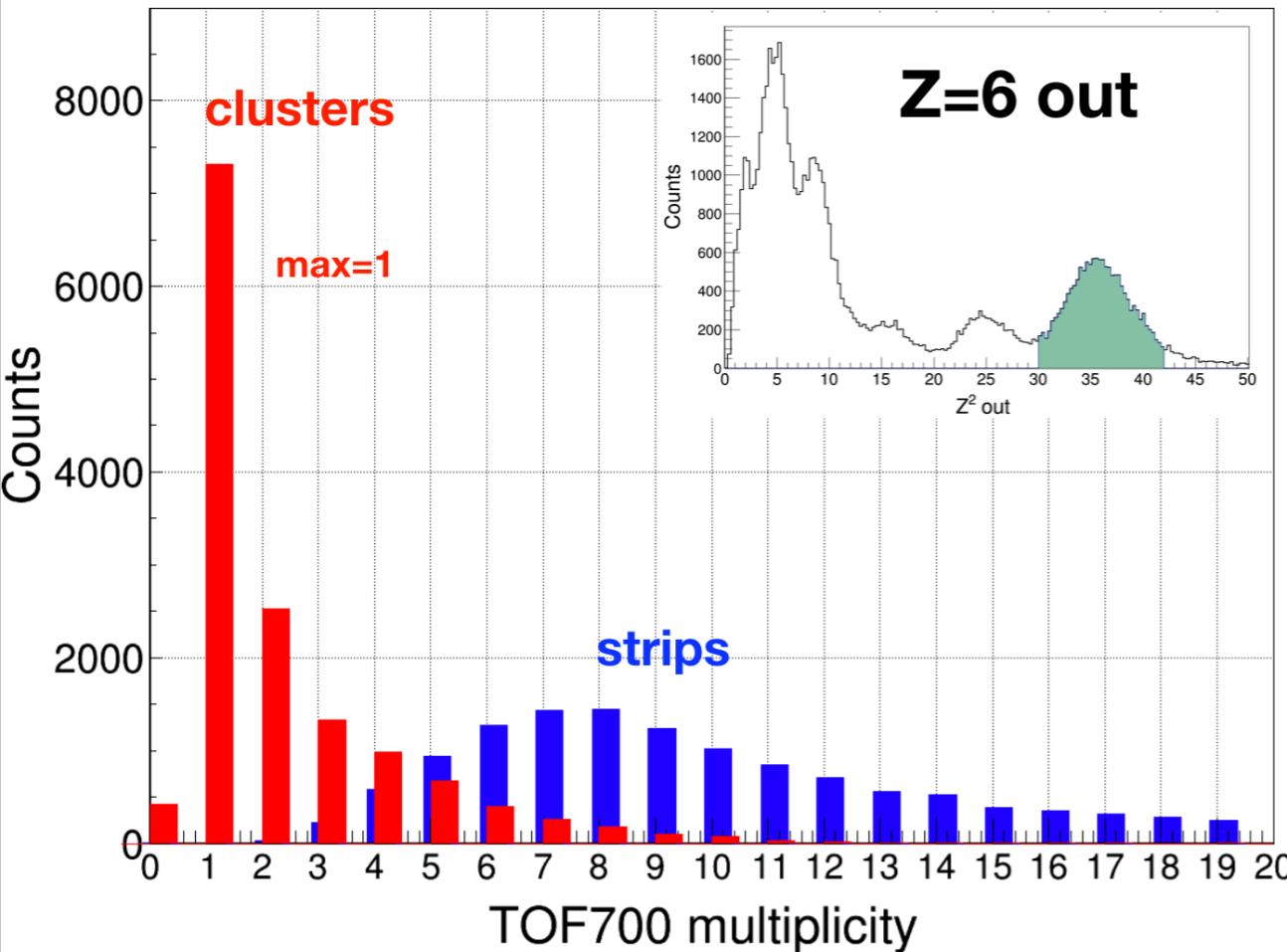




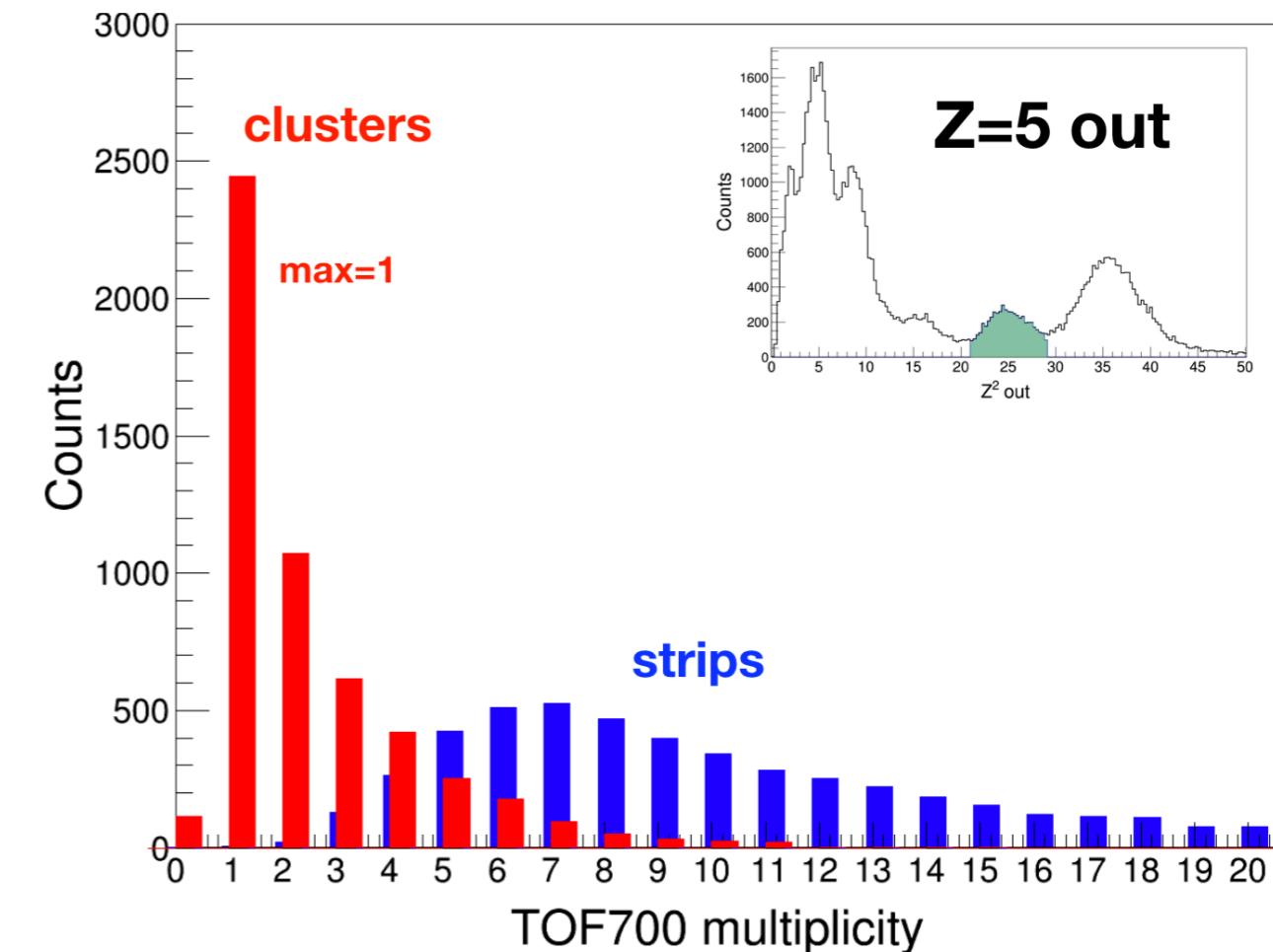


Counting particle hits in TOF700 (QFS trigger)

1 fragment



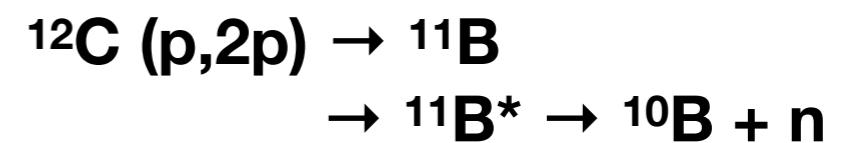
1 fragment



Example channel:

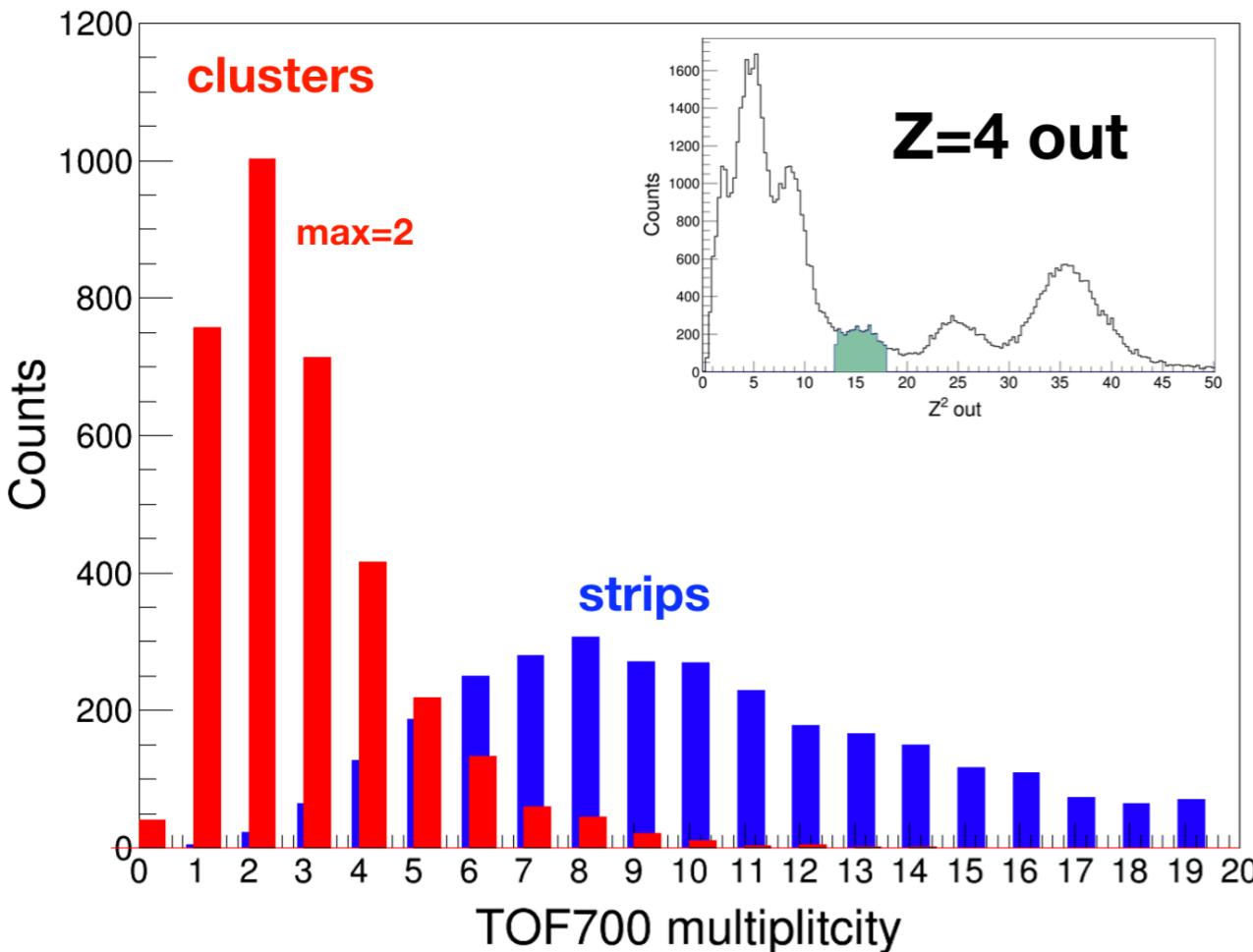


Example channel:

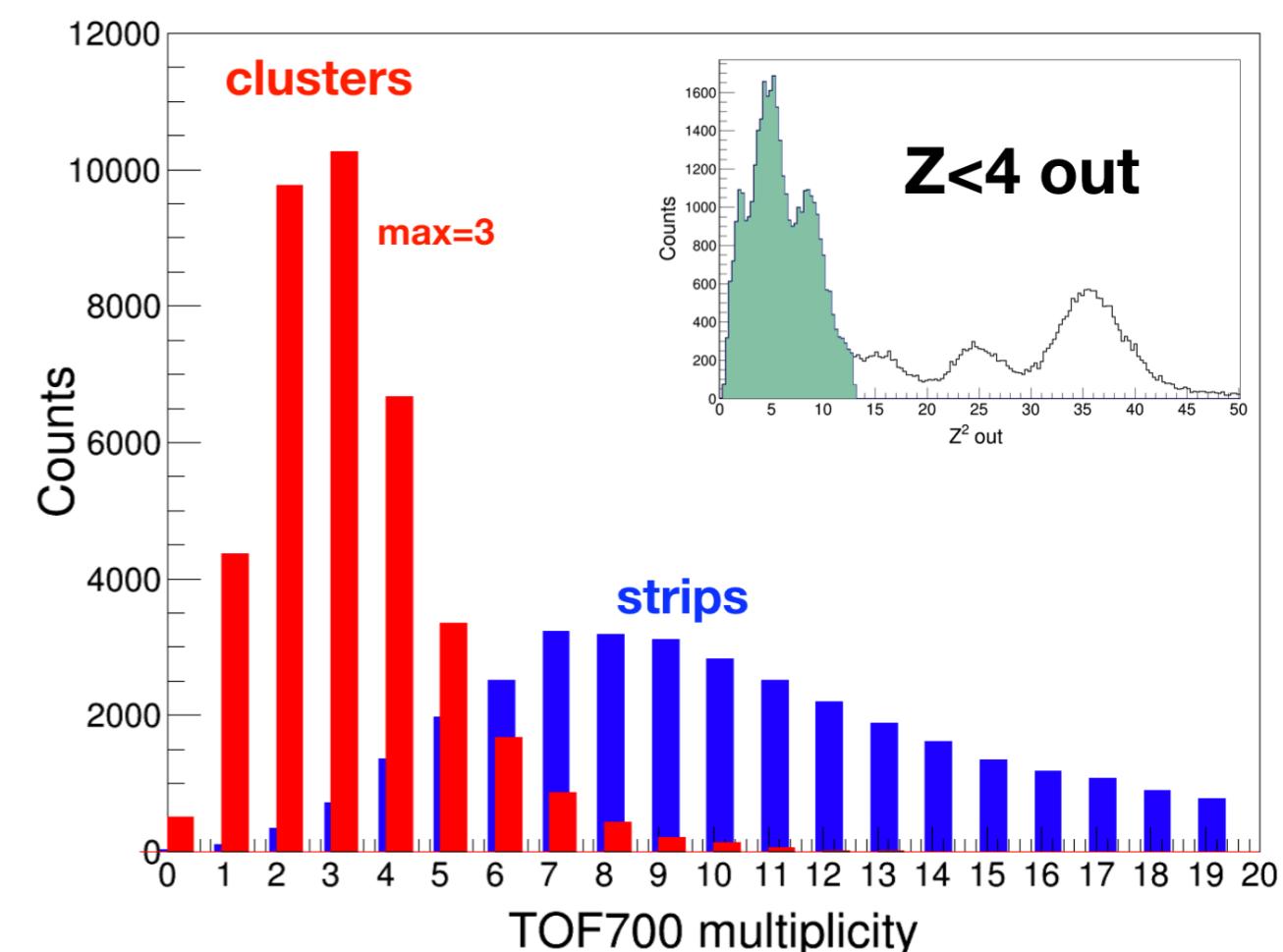


Counting particle hits in TOF700

2 fragments



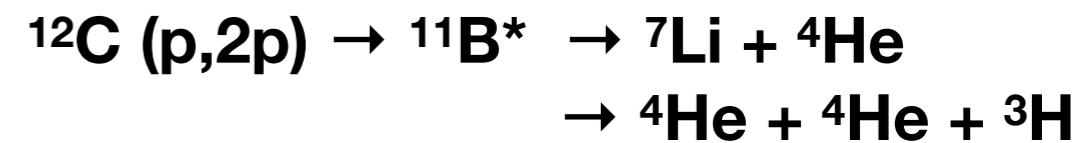
2+3 fragments



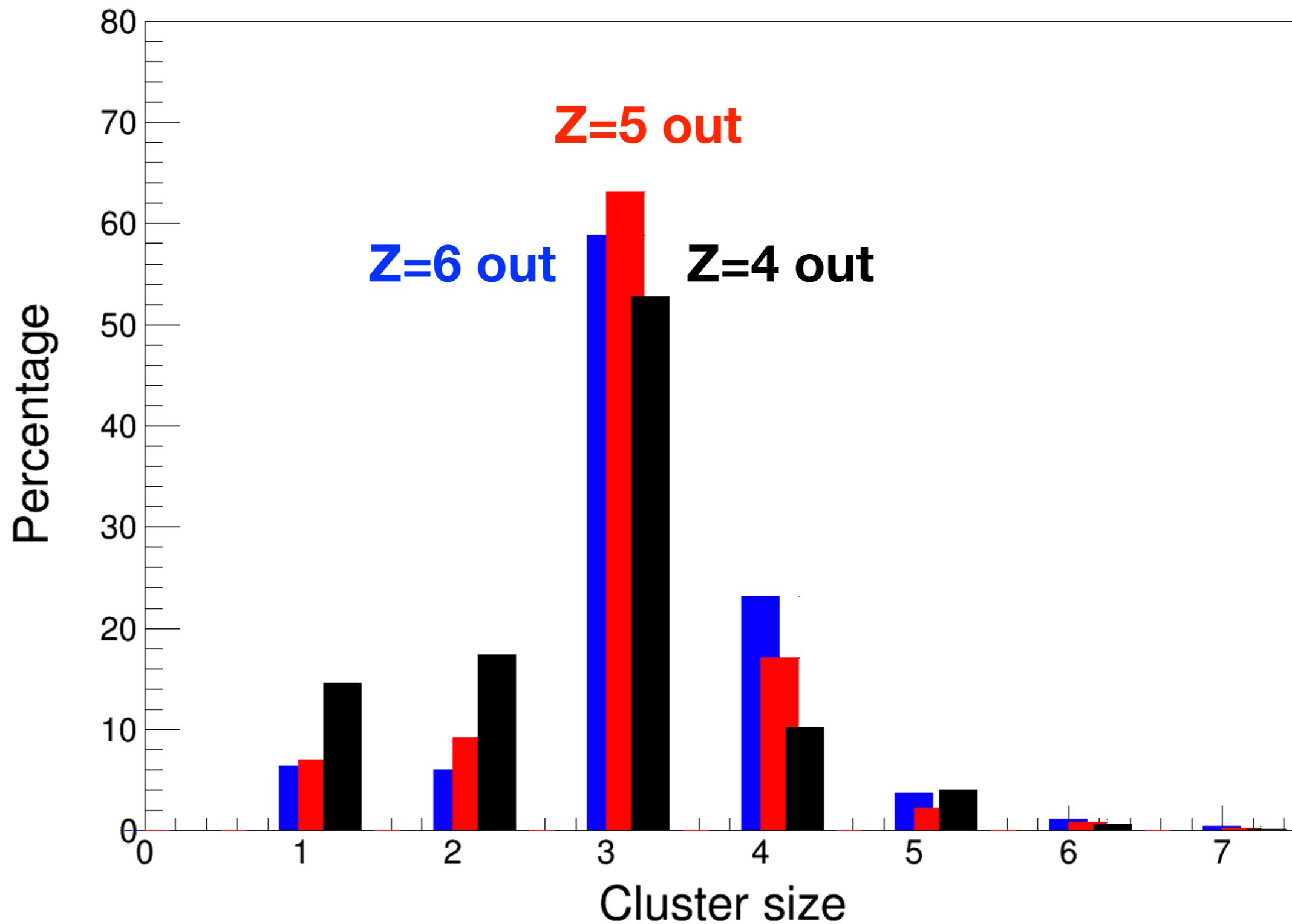
Example channel:



Example channel:



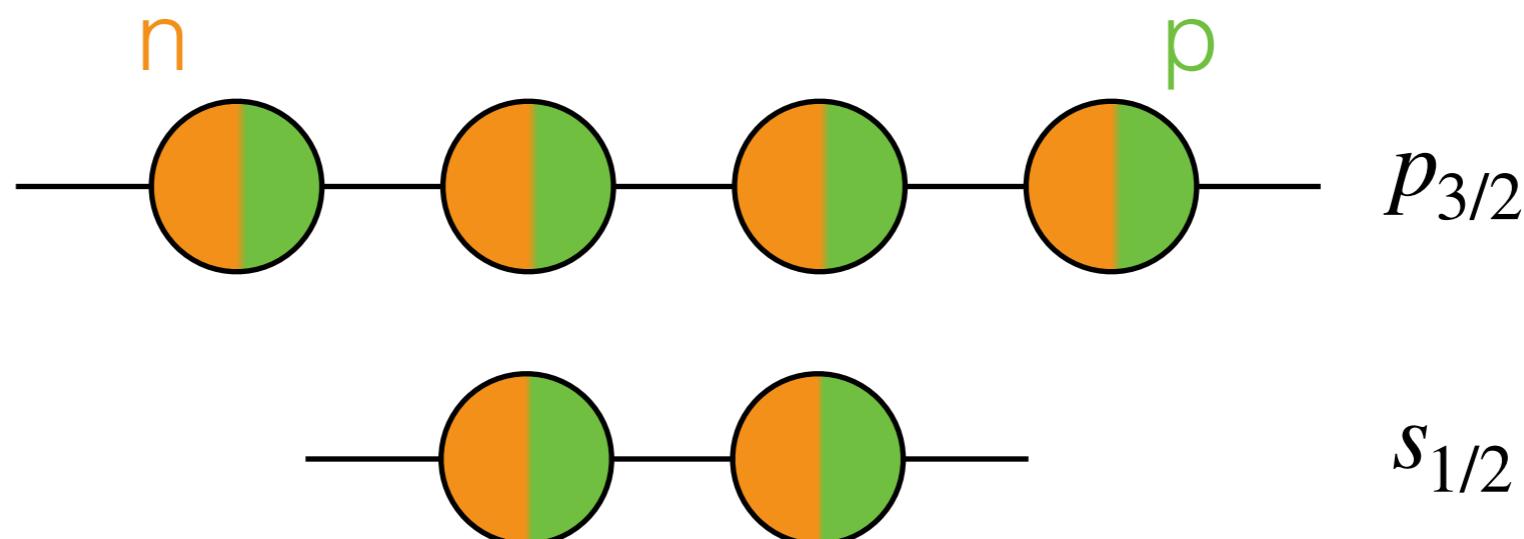
TOF700 cluster size



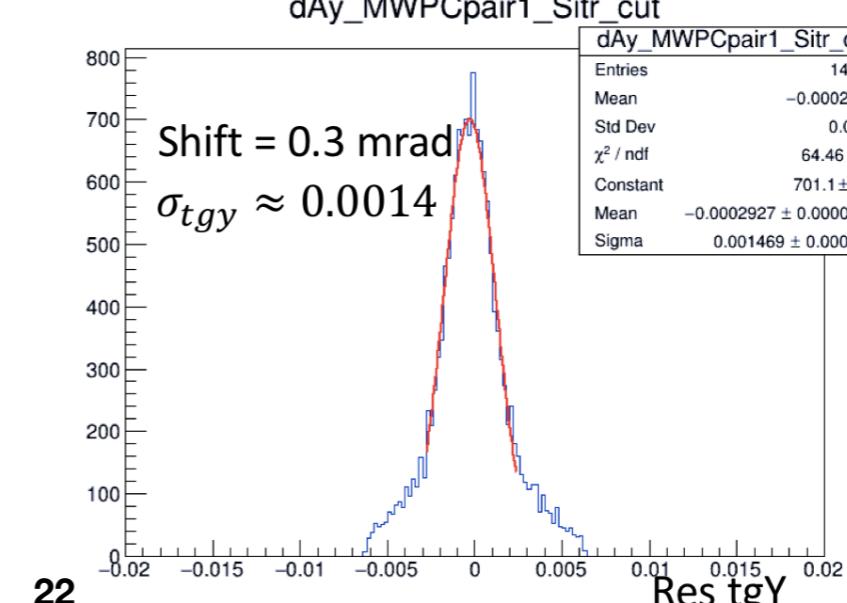
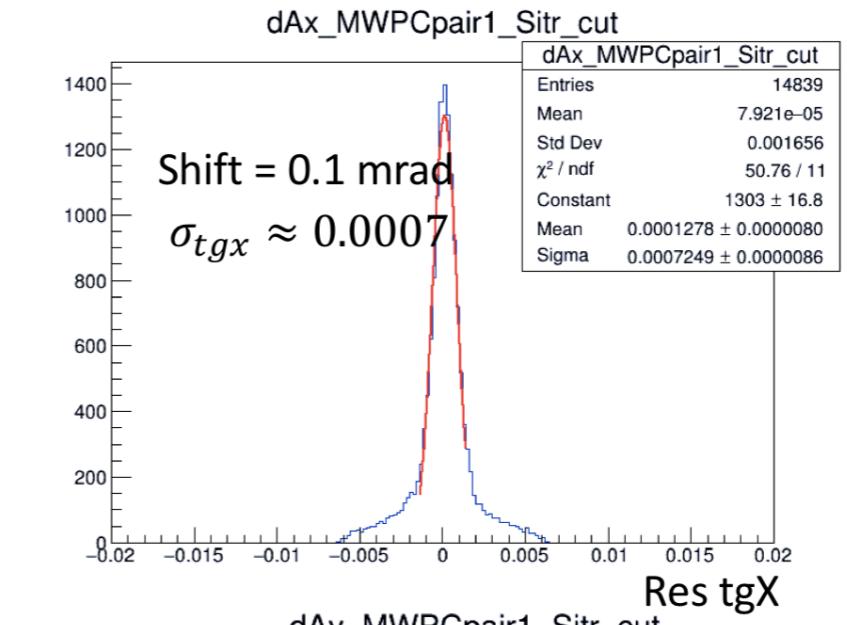
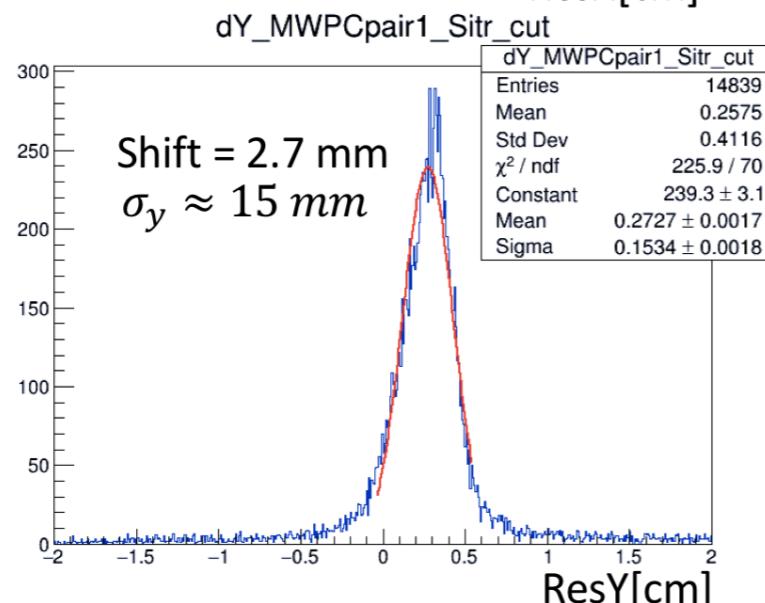
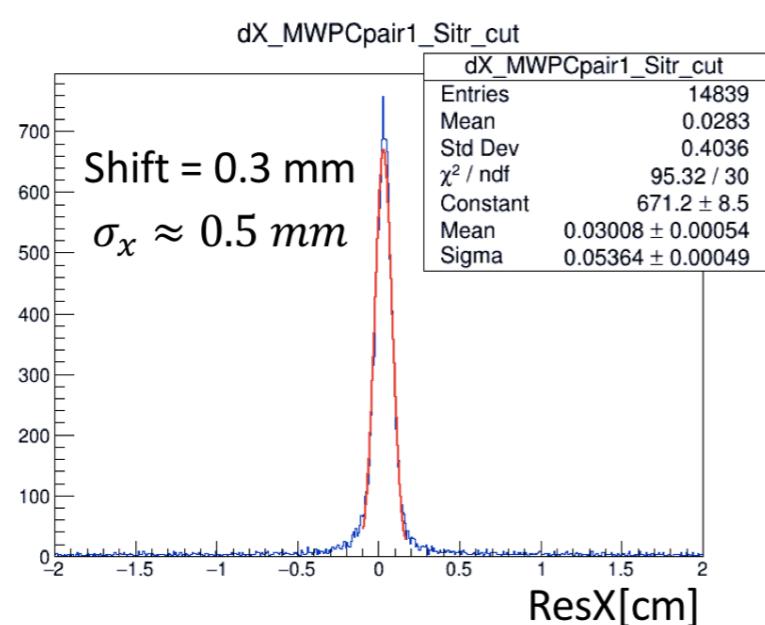
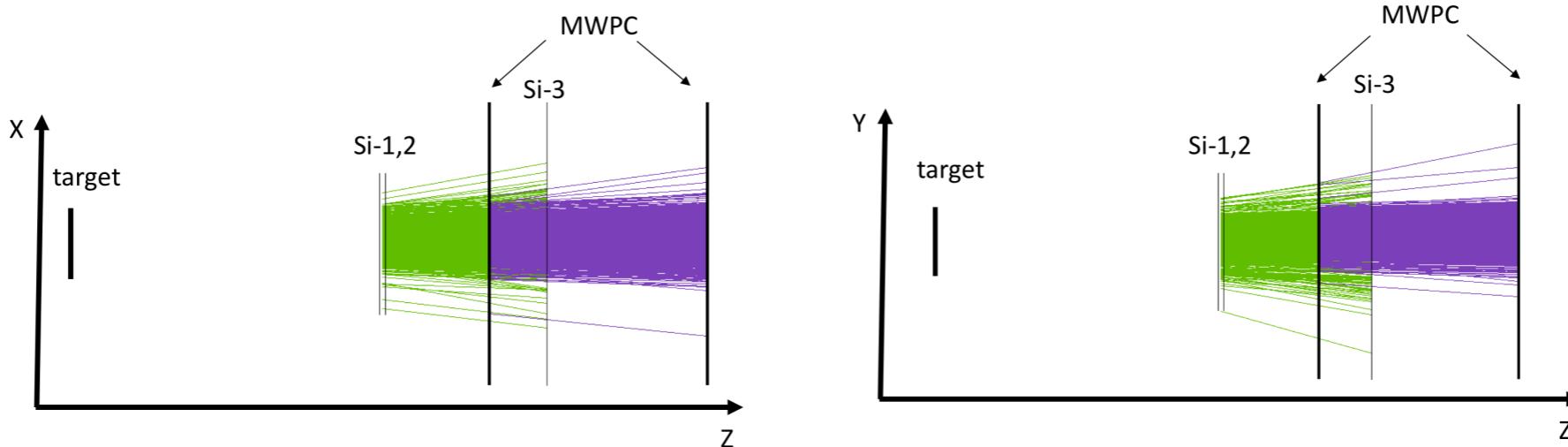
What we are moving towards next

- Integrating all of these components to identify QE and SRC knock-out events
- Applying X,Y, time calibration in TOF700 and track merging with DCH
- Merging global track information from MWPC, GEMs and Silicons
- Obtain PID and Lorentz vector of the (A-2) fragment

Residual system and SRC pair formation

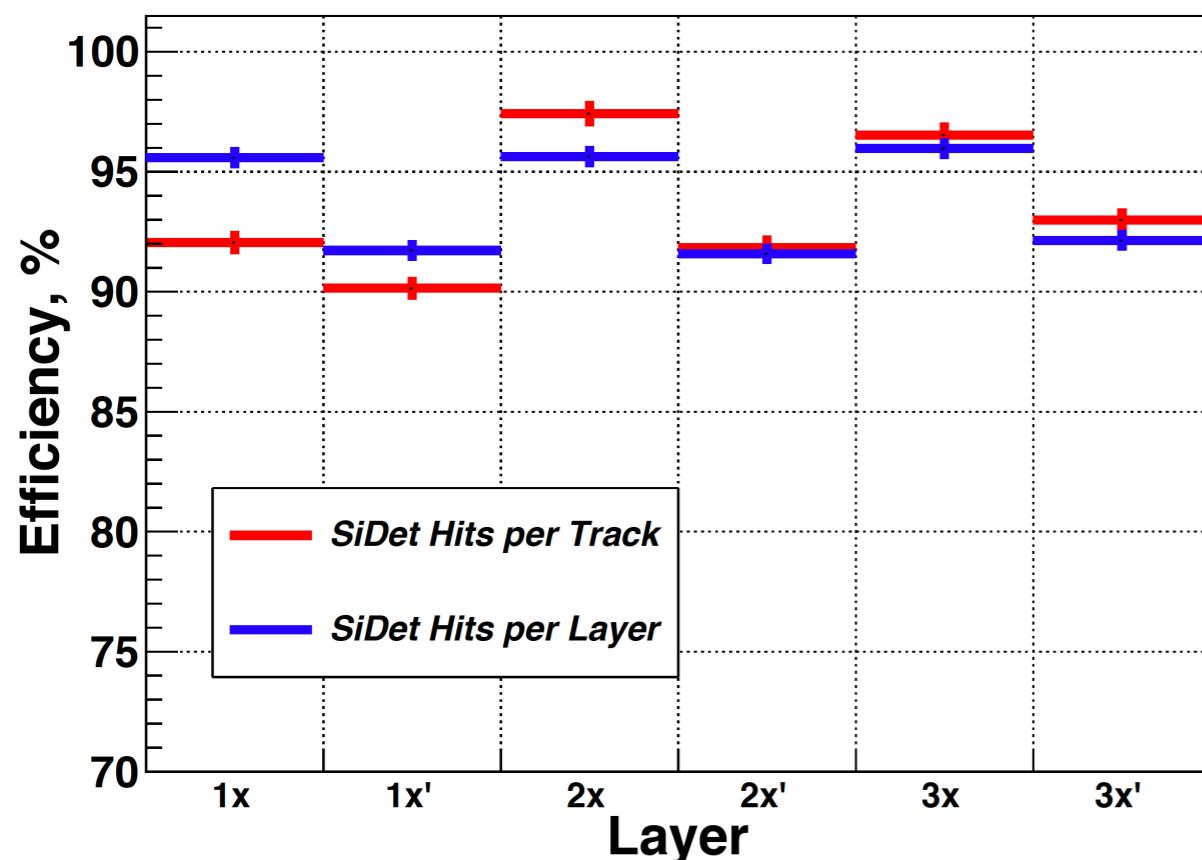


Tracking in Silicons + MWPCs (V. Lenivenko)

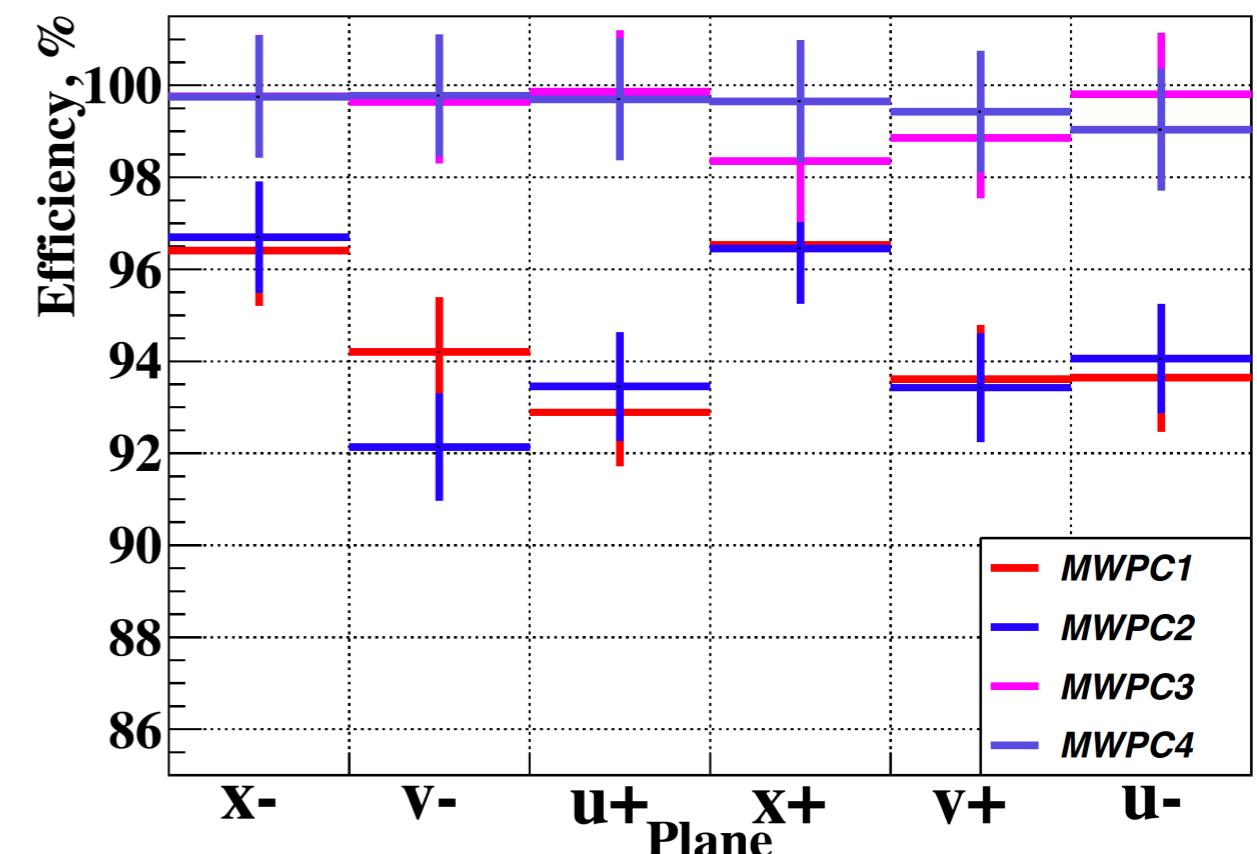


Efficiency in Silicons (beam)

Hit Efficiency per Layer on Track

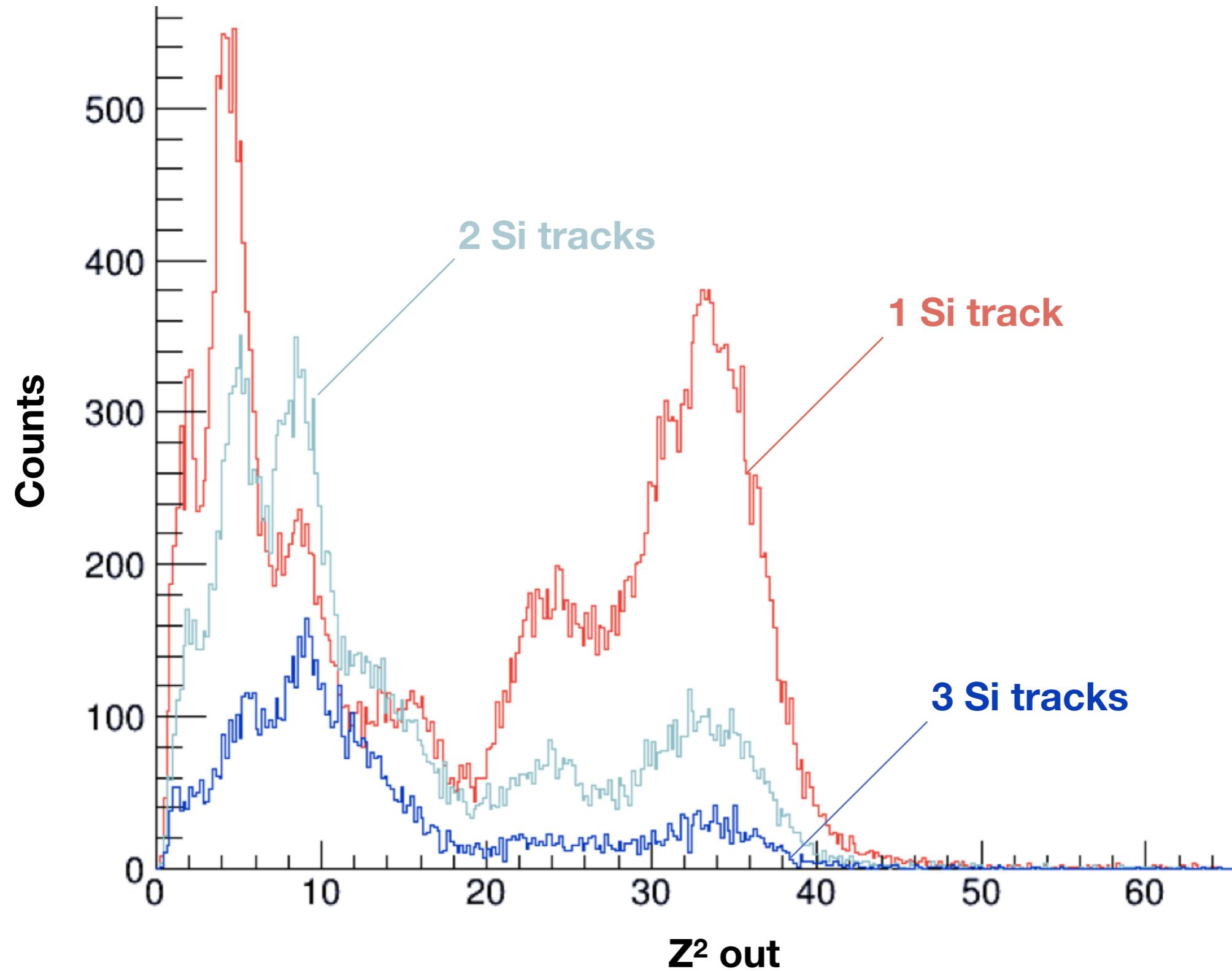


Efficiency in MWPCs (beam)

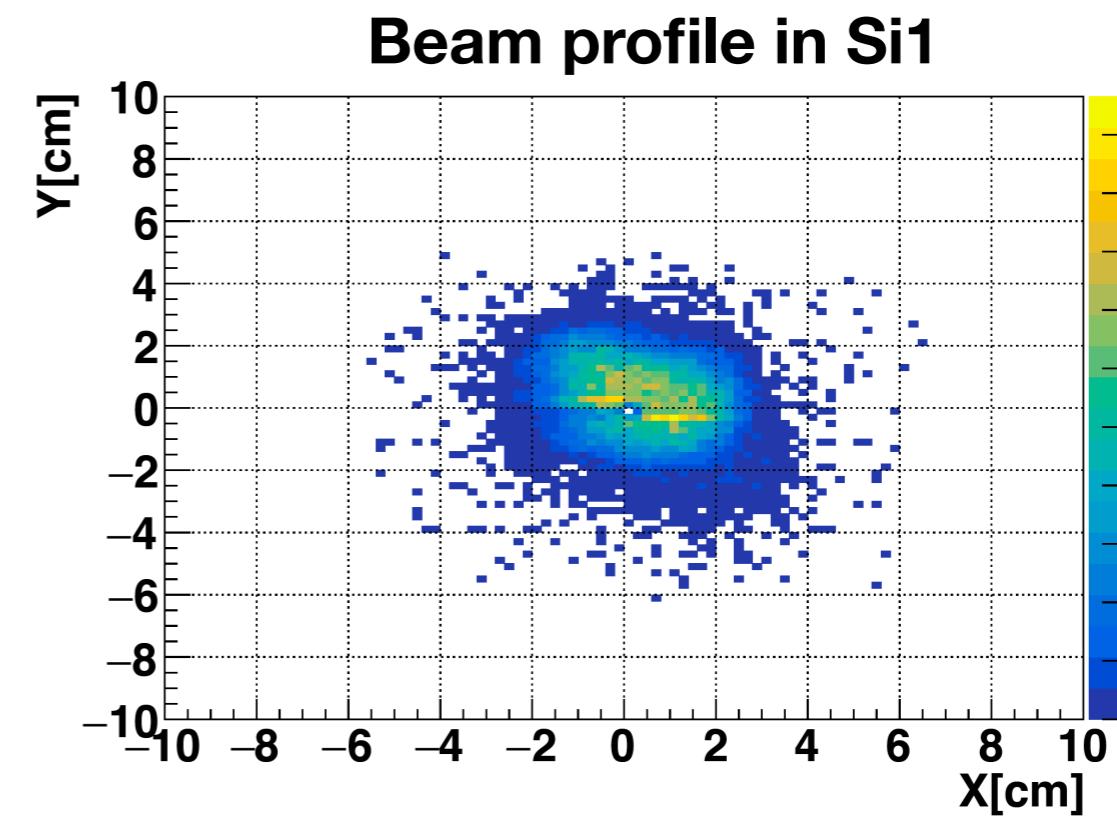
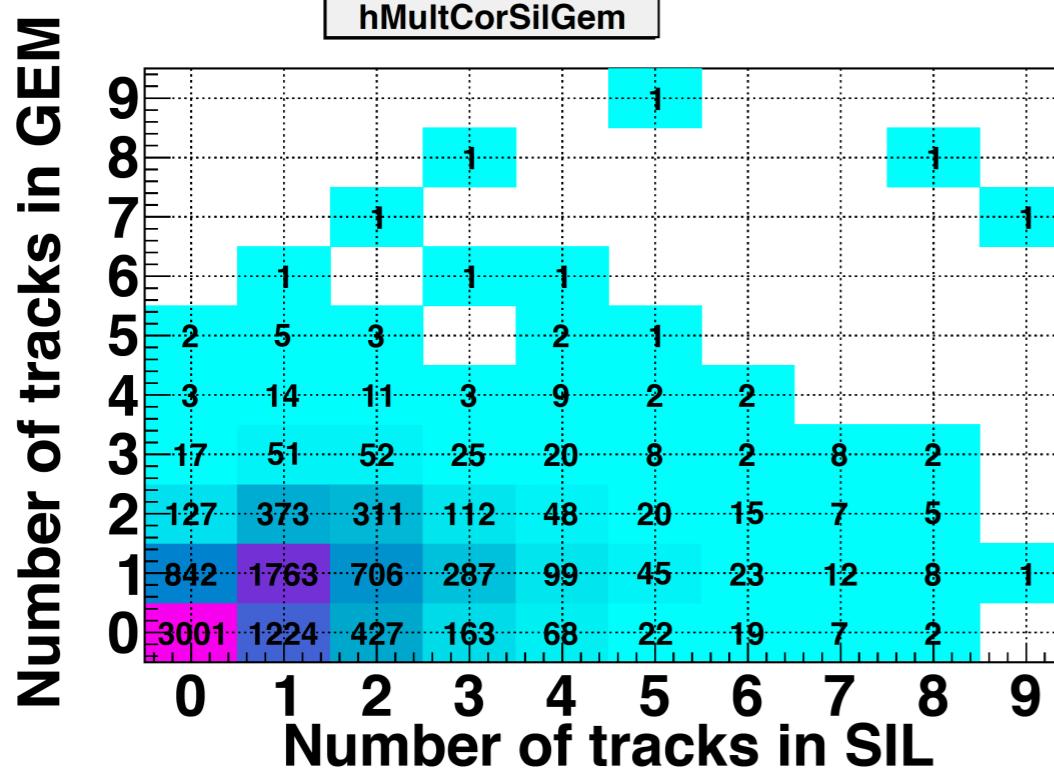
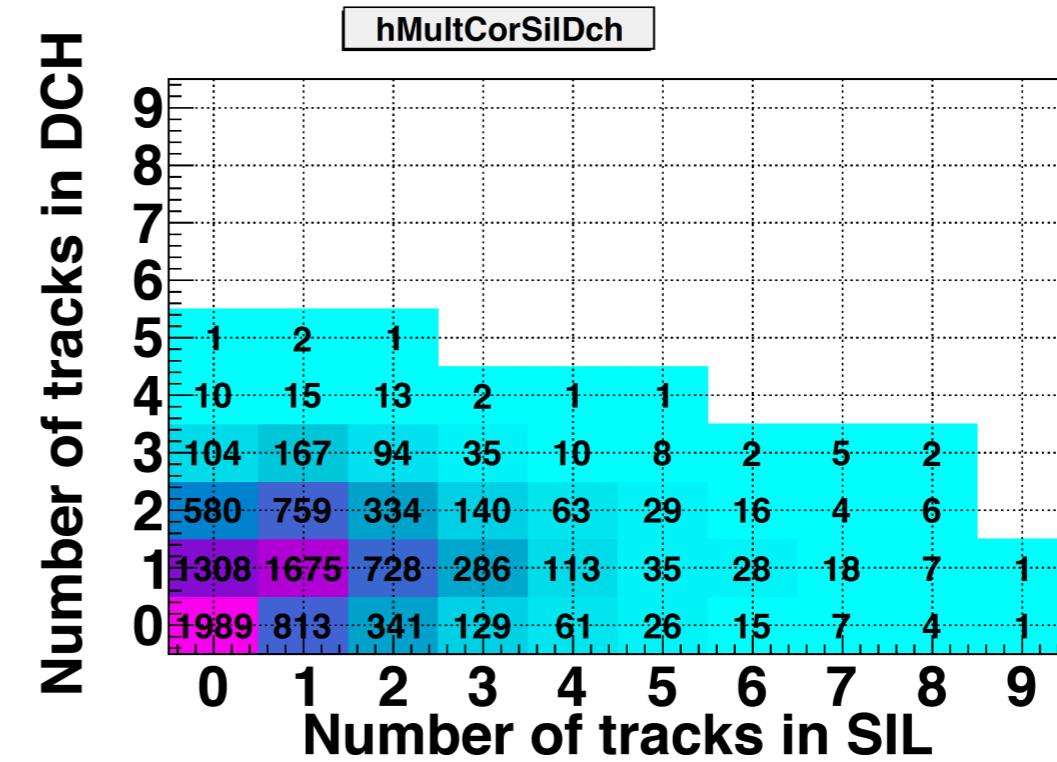
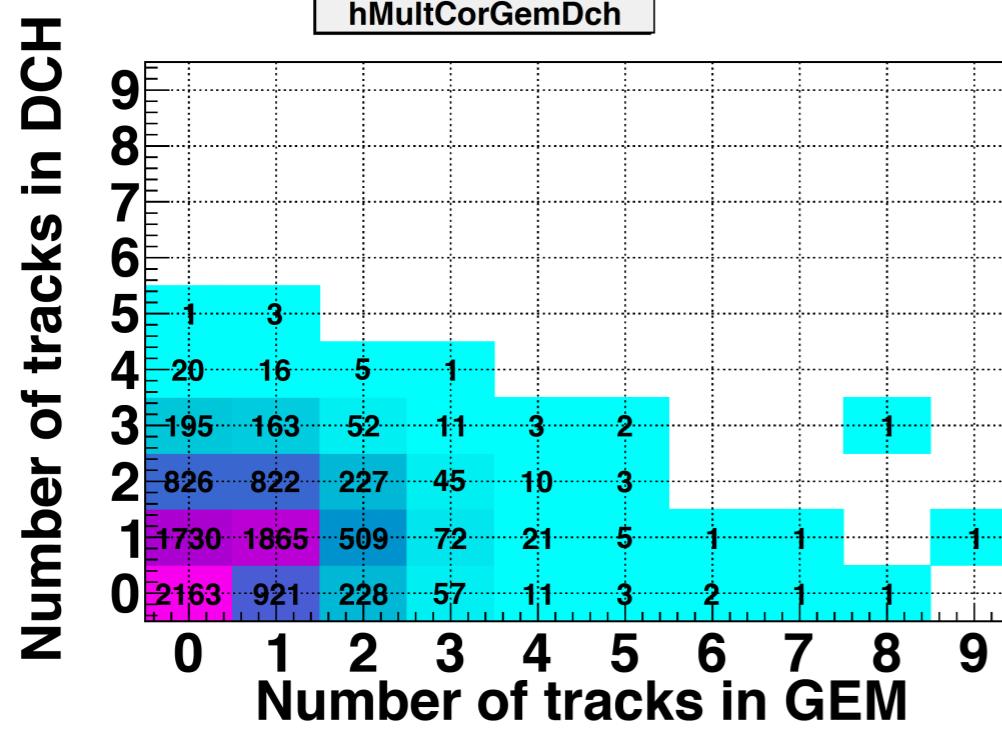


V. Lenivenko

Tracking in Silicons (V. Lenivenko)



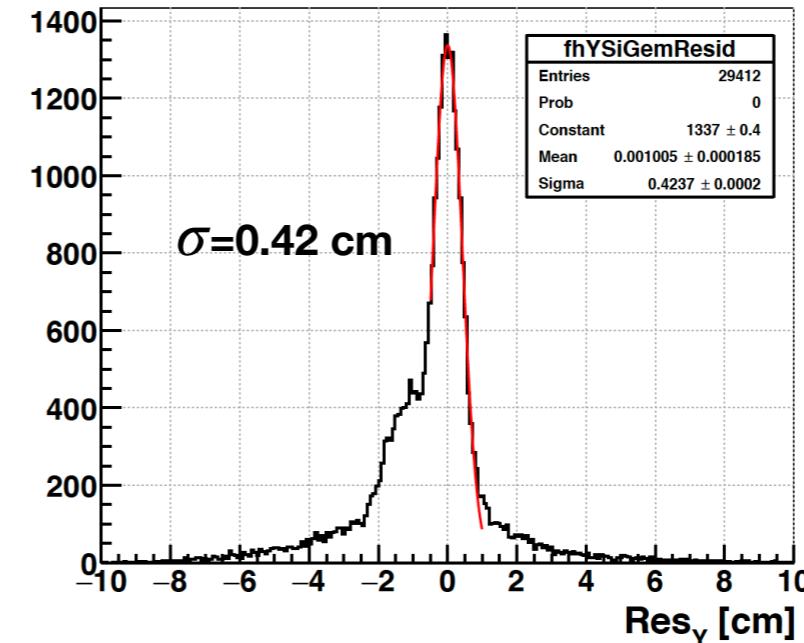
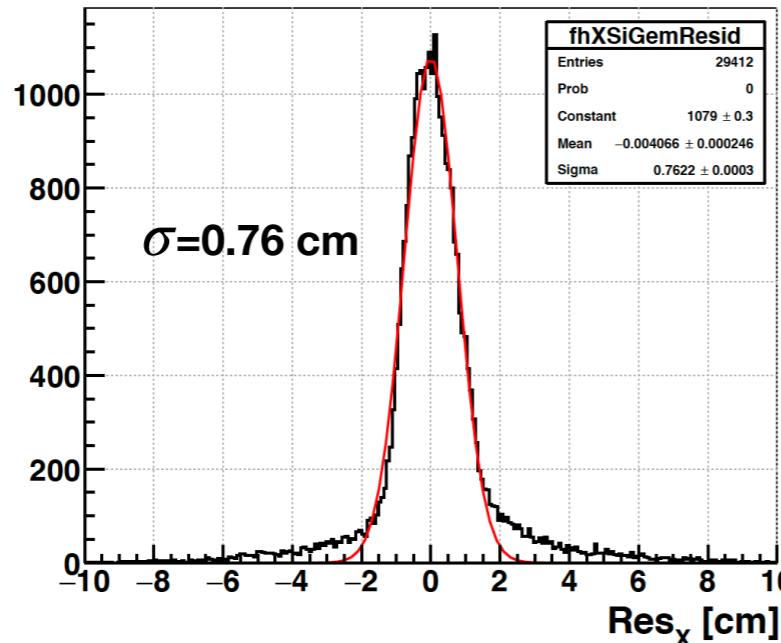
Merging tracks in different subsystems (V. Lenivenko, S. Merts)



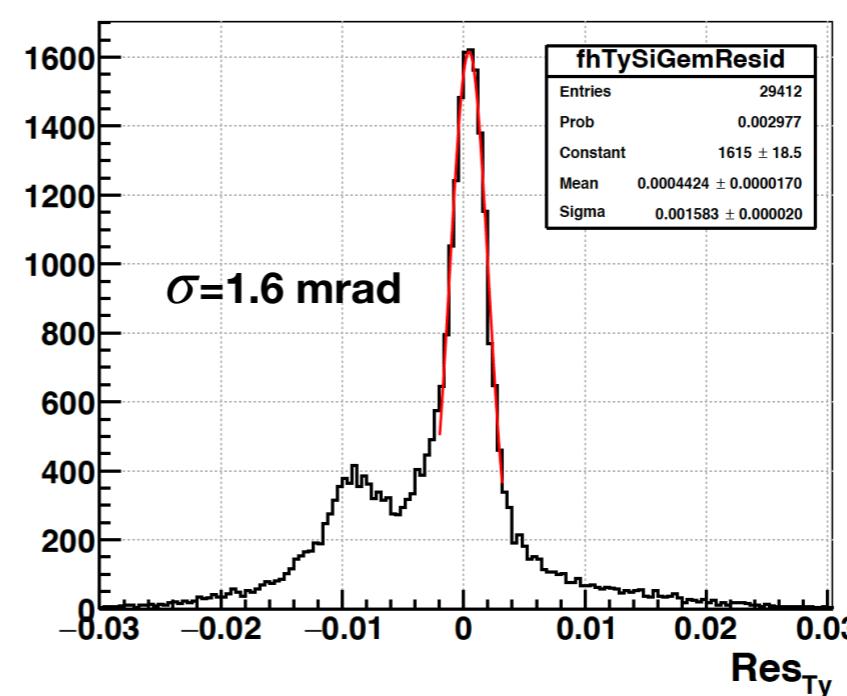
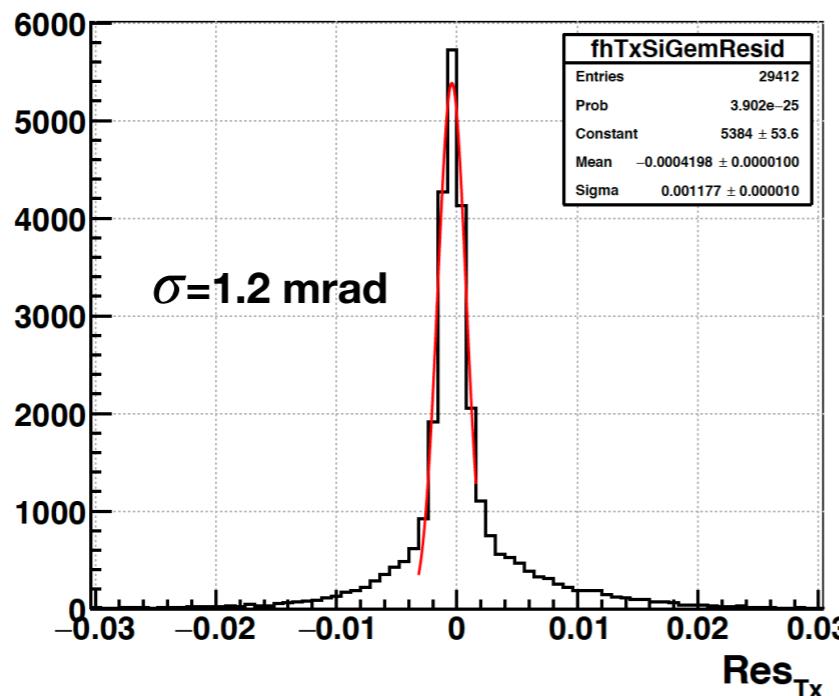
Merging tracks in different subsystems (V. Lenivenko, S. Merts)

(no target, no field)

SIL+GEM coordinate residuals after alignment



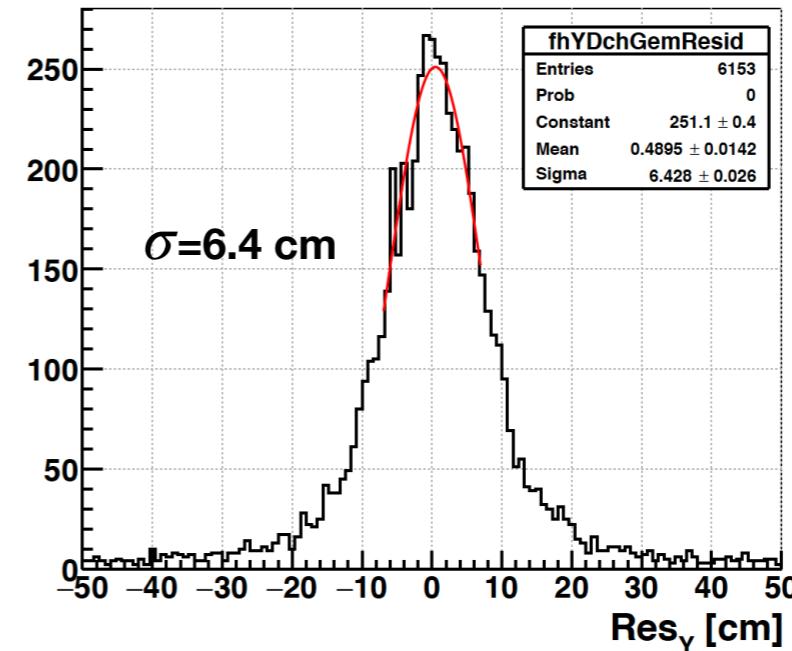
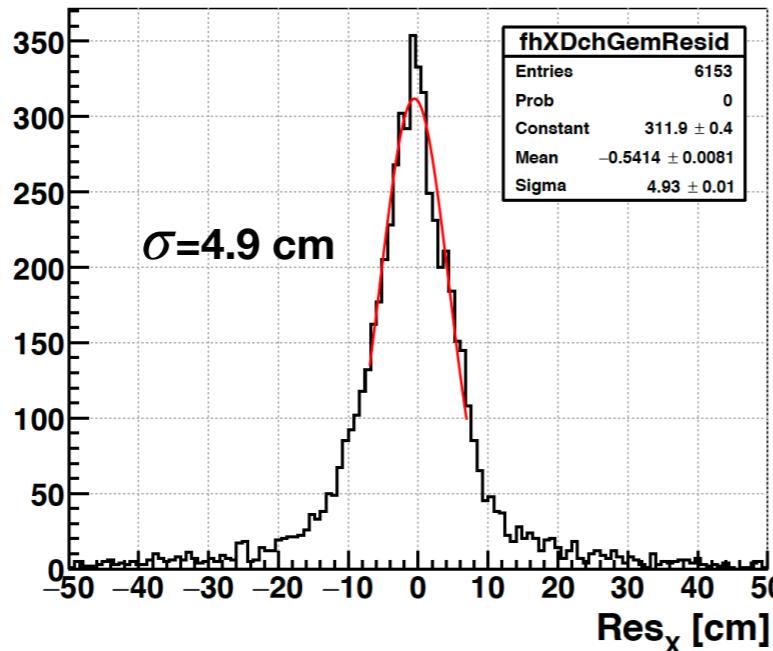
SIL+GEM angle residuals after alignment



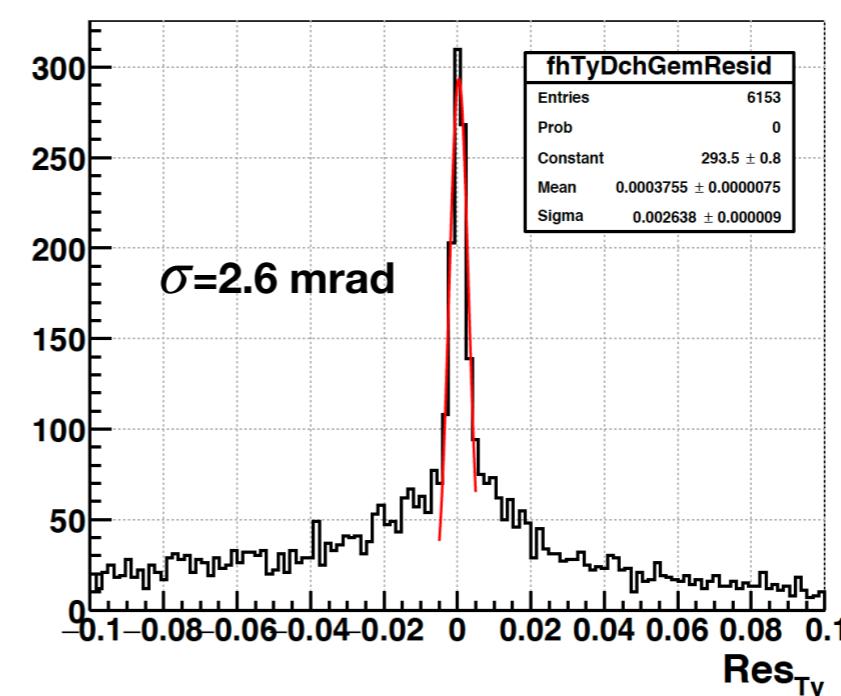
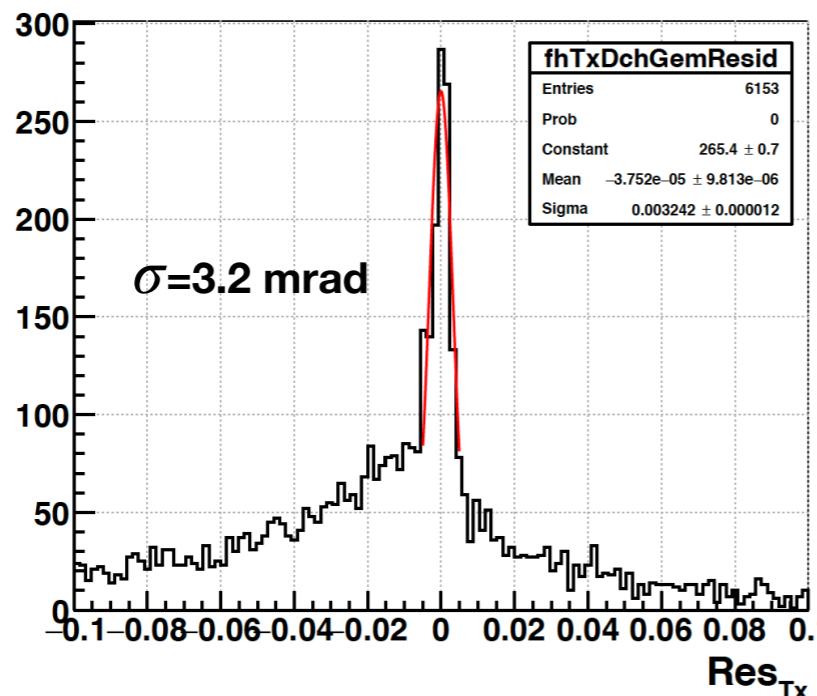
Merging tracks in different subsystems (S. Merts, N. Voitishin, V. Lenivenko)

(no target, no field)

GEM+DCH coordinate residuals after alignment

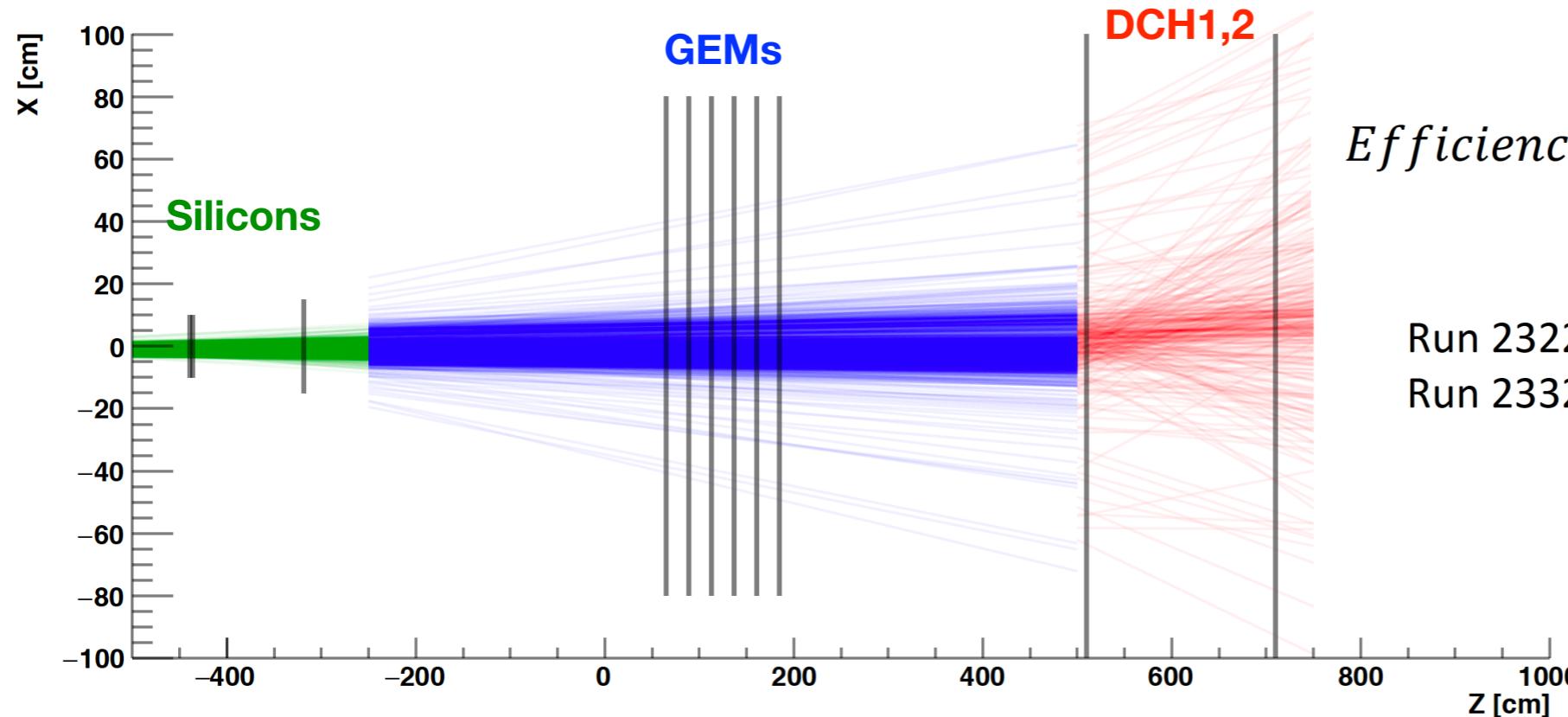


GEM+DCH angle residuals after alignment



Merging tracks in different subsystems (S. Merts, N. Voitishin, V. Lenivenko)

Relative alignment/matching of tracks - no target, no field

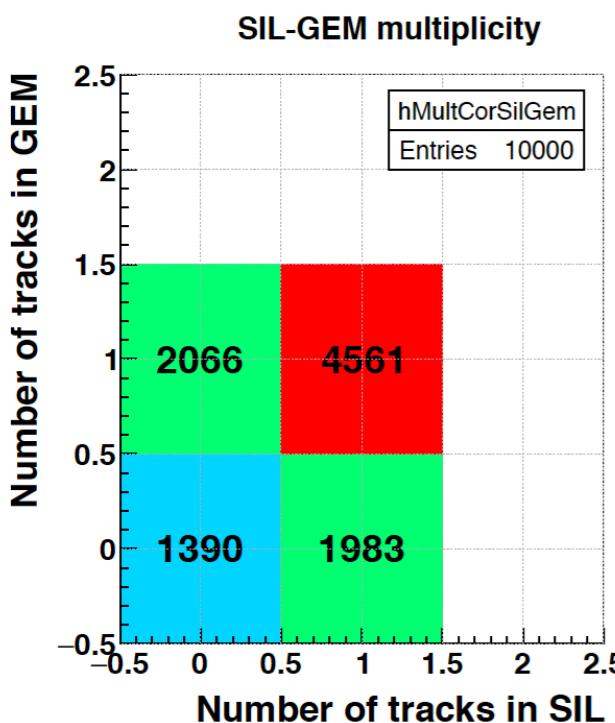


$$Efficiency = \frac{(DC1+DC2)_{matched\ track}}{GEM_{track}+DC1_{segment}} * 100\%$$

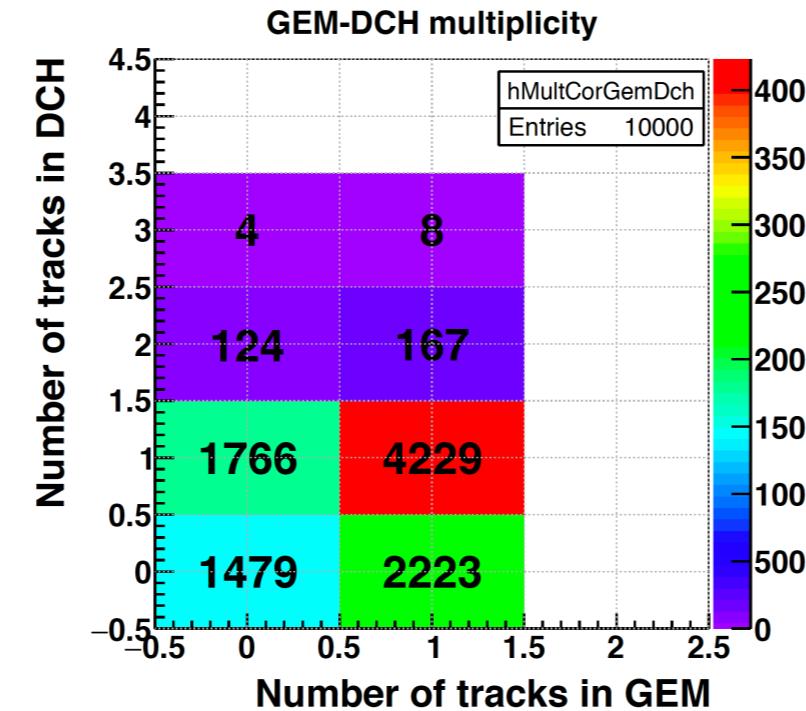
Run 2322 (900A, empty target) Eff = 66.1%

Run 2332 (1800A, empty target) Eff = 75.3%

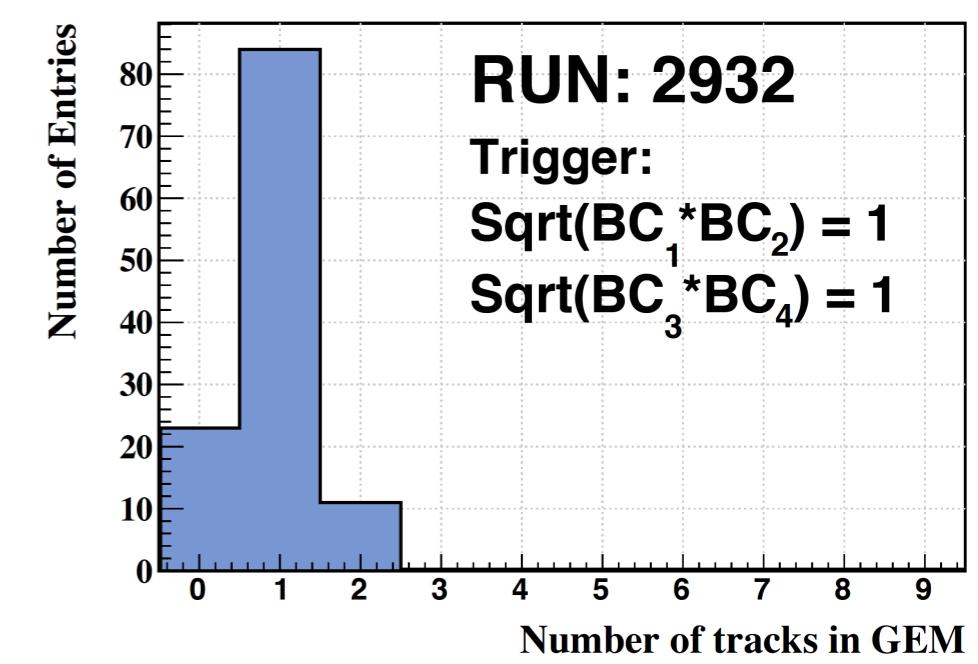
Empty target



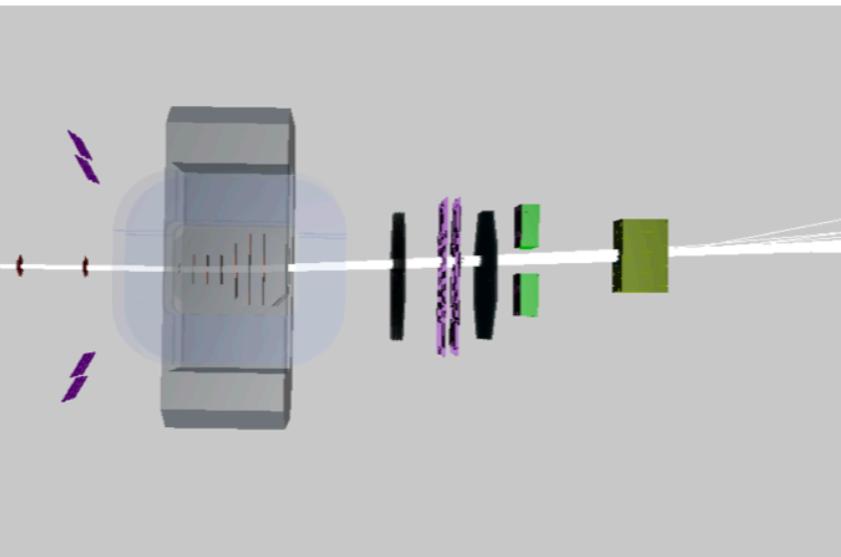
Empty target



Production run

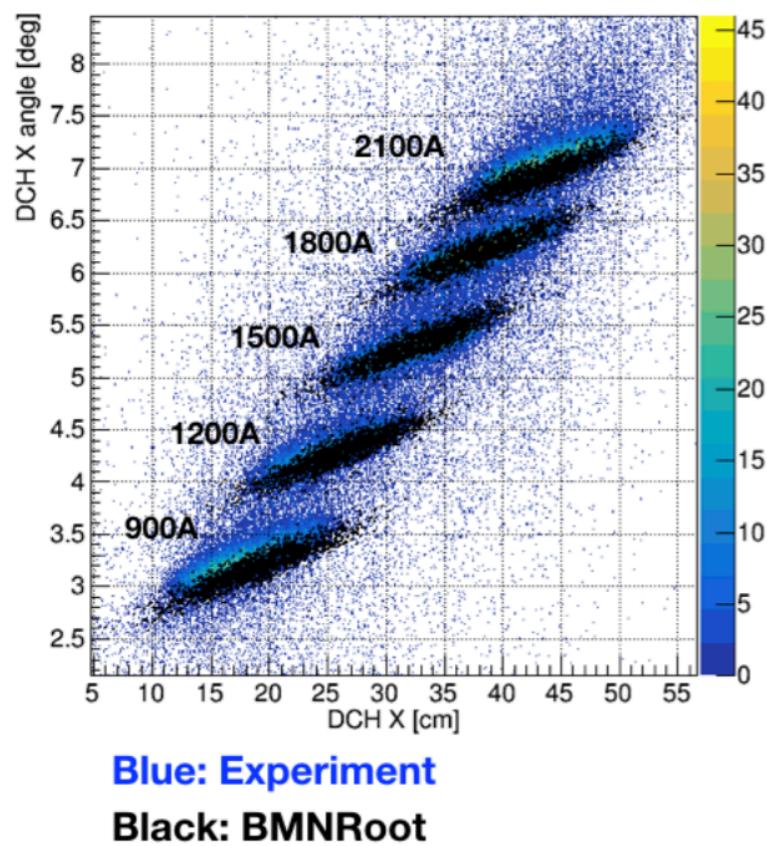


BMNRoot simulations

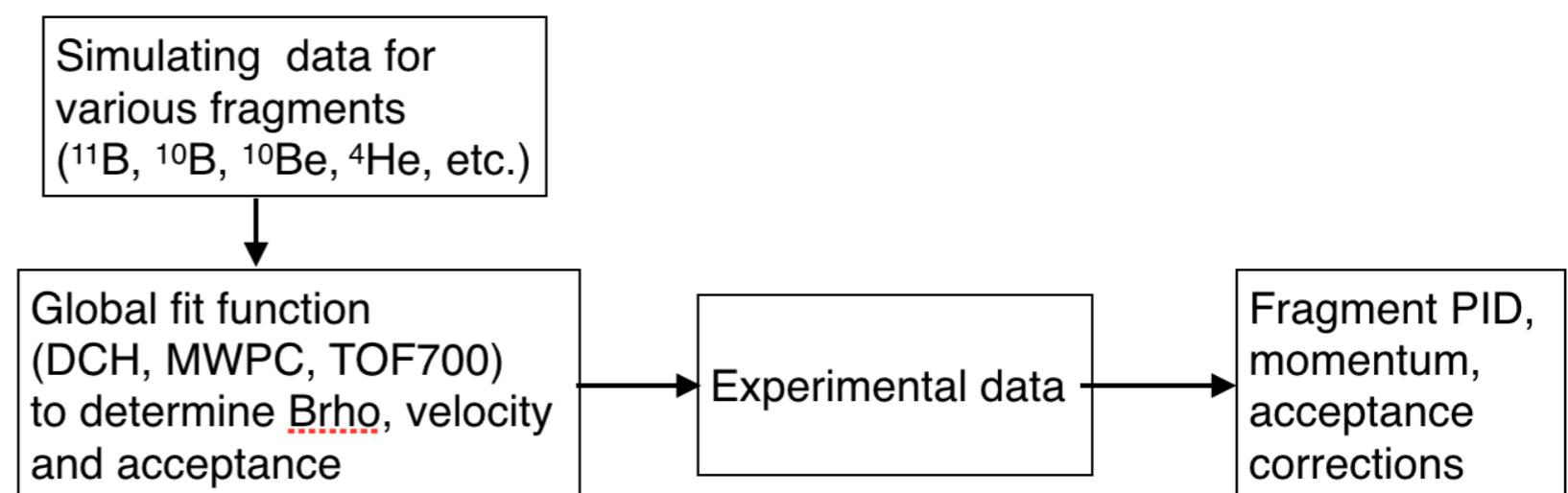


- New event generator introduced in BMNRoot
 - Realistic beam profile (angle, position and momentum spread)
- Fine adjustment of DCH hit positions and angles to match simulations for run 2332 (Empty target, B-field @ 1800A)

Unreacted ^{12}C beam profile



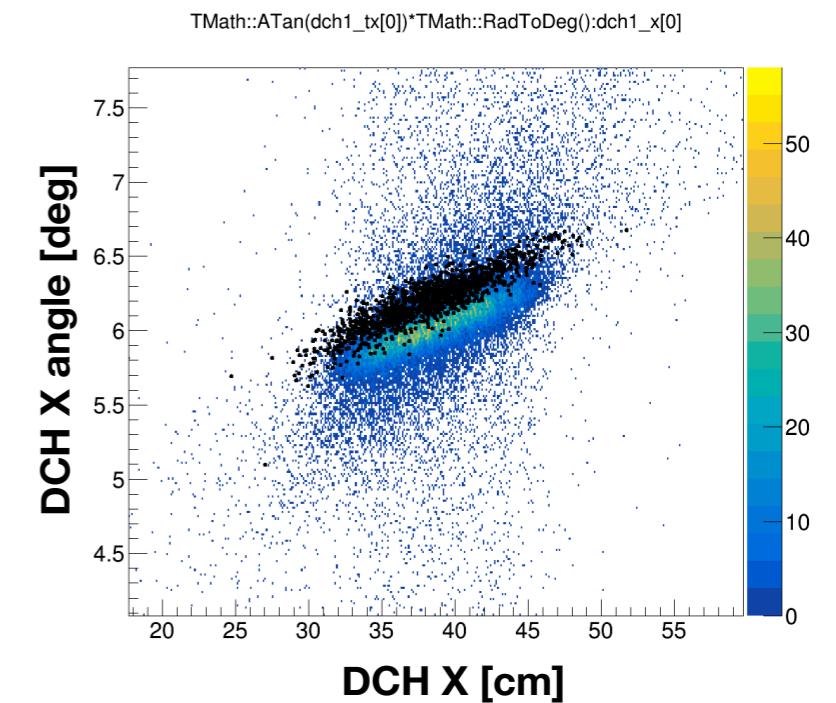
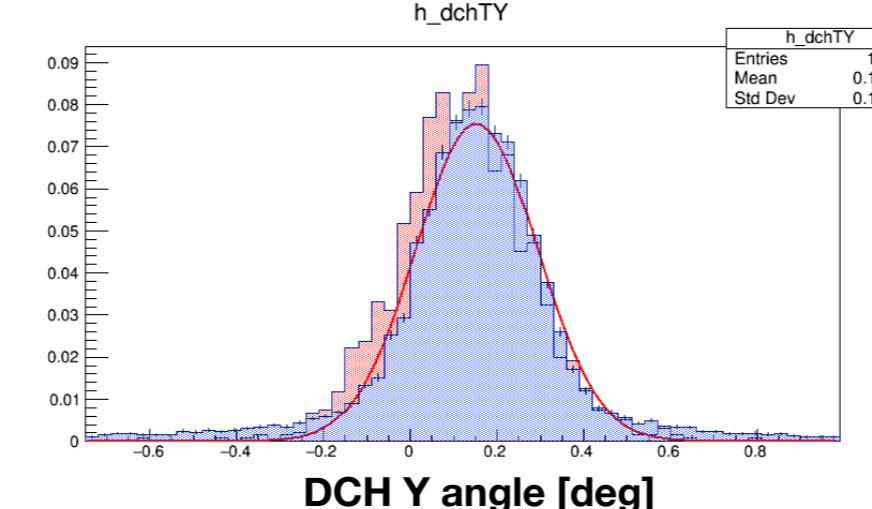
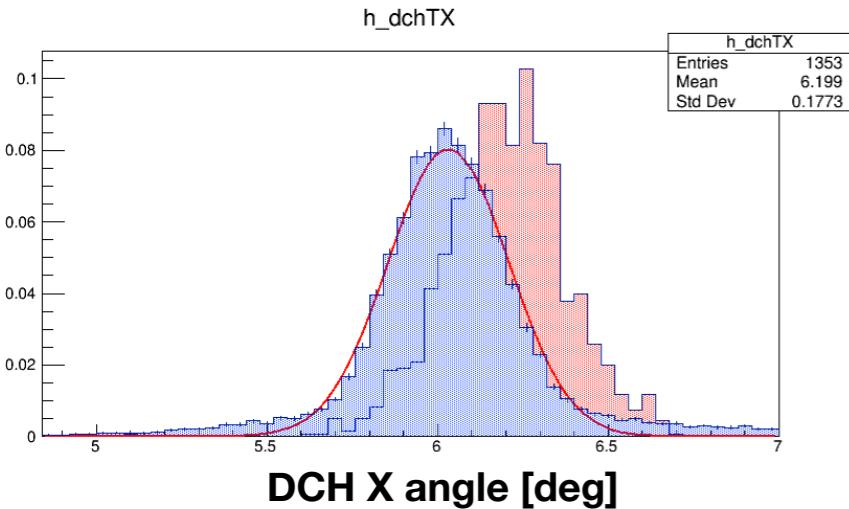
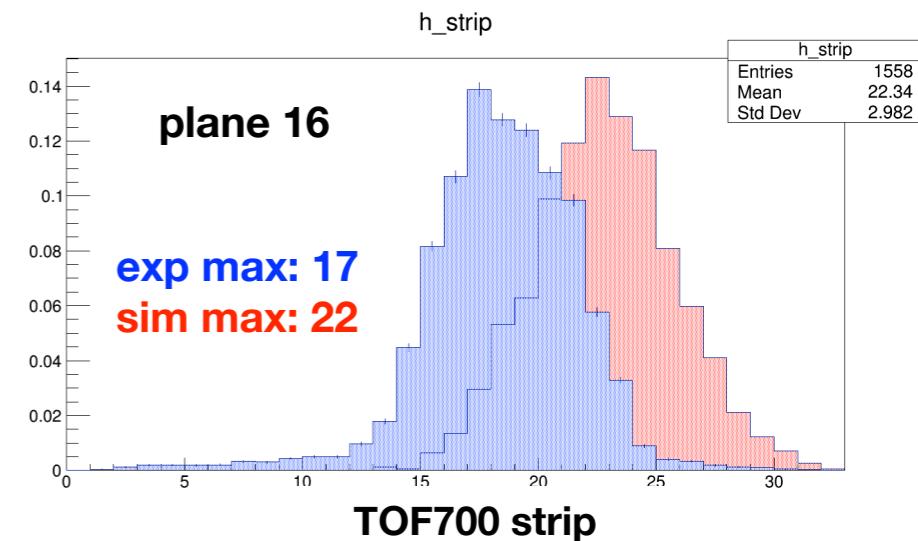
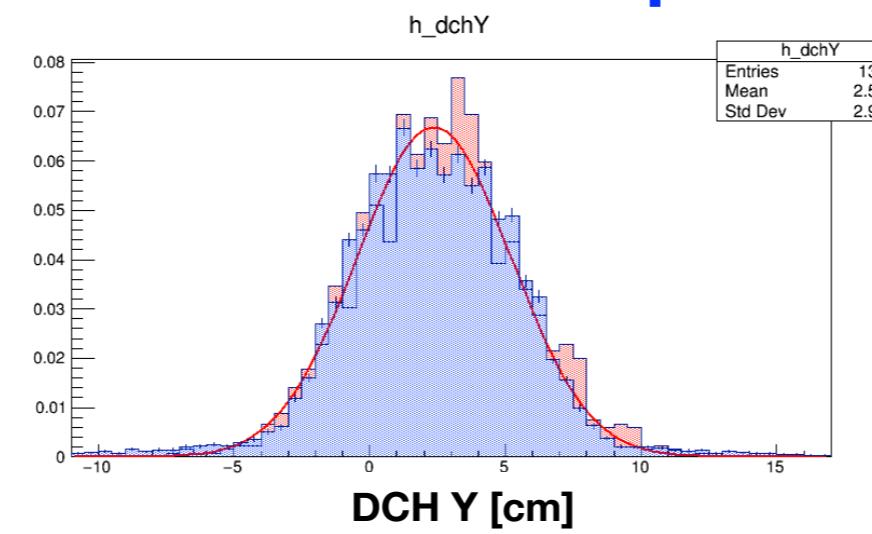
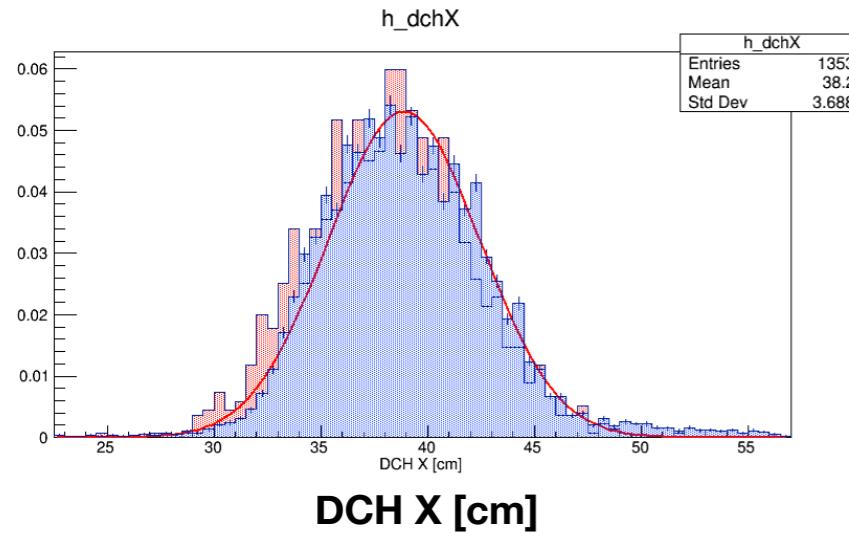
- Mismatch between simulations and experiment for different B-field settings
- Trying to extract tracking function for fragments using global fit of the simulated data



BMNRoot simulations

- DCH and TOF700 with nominal geometry.
- Realistic beam profile from MWPCs.
- B-field scaling 1.932 (1800A run 2332) from Hall probe.

simulation / experiment



Summary

- **Identification of p2p events**

- Preliminary reconstruction of the reaction vertex and proton momenta
 - Still lacking accurate optics calibration for GEM+TOF400
- Preliminary reconstruction of the beam vector from MWPCs, and P_{miss}

- **Identification of the residual system**

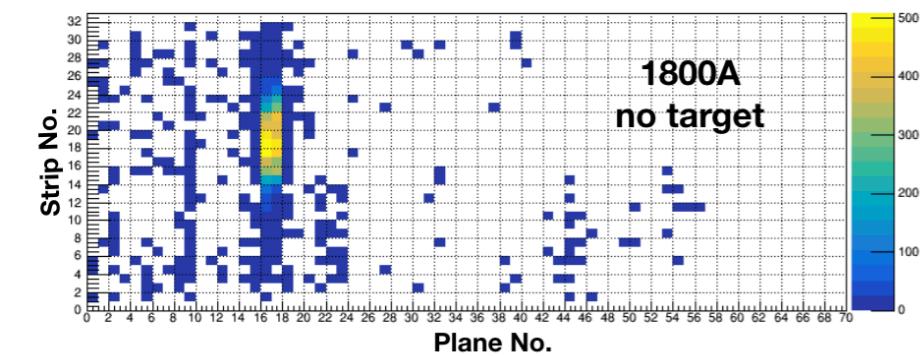
- Possible with DCH tracks and Z information from plastic
- Preliminary results on track multiplicities in DCH/TOF700/MWPC/
 - Information on the fragmentation of the residual system
 - Estimated detector efficiency in DCH, MWPC and Silicons
- First results of merging track information from different subsystems
 - DCH + GEM + Silicons + MWPC
- Ongoing work on global track reconstruction and tracking efficiency
- BmnRoot simulations are needed but not working properly at the moment

Outlook

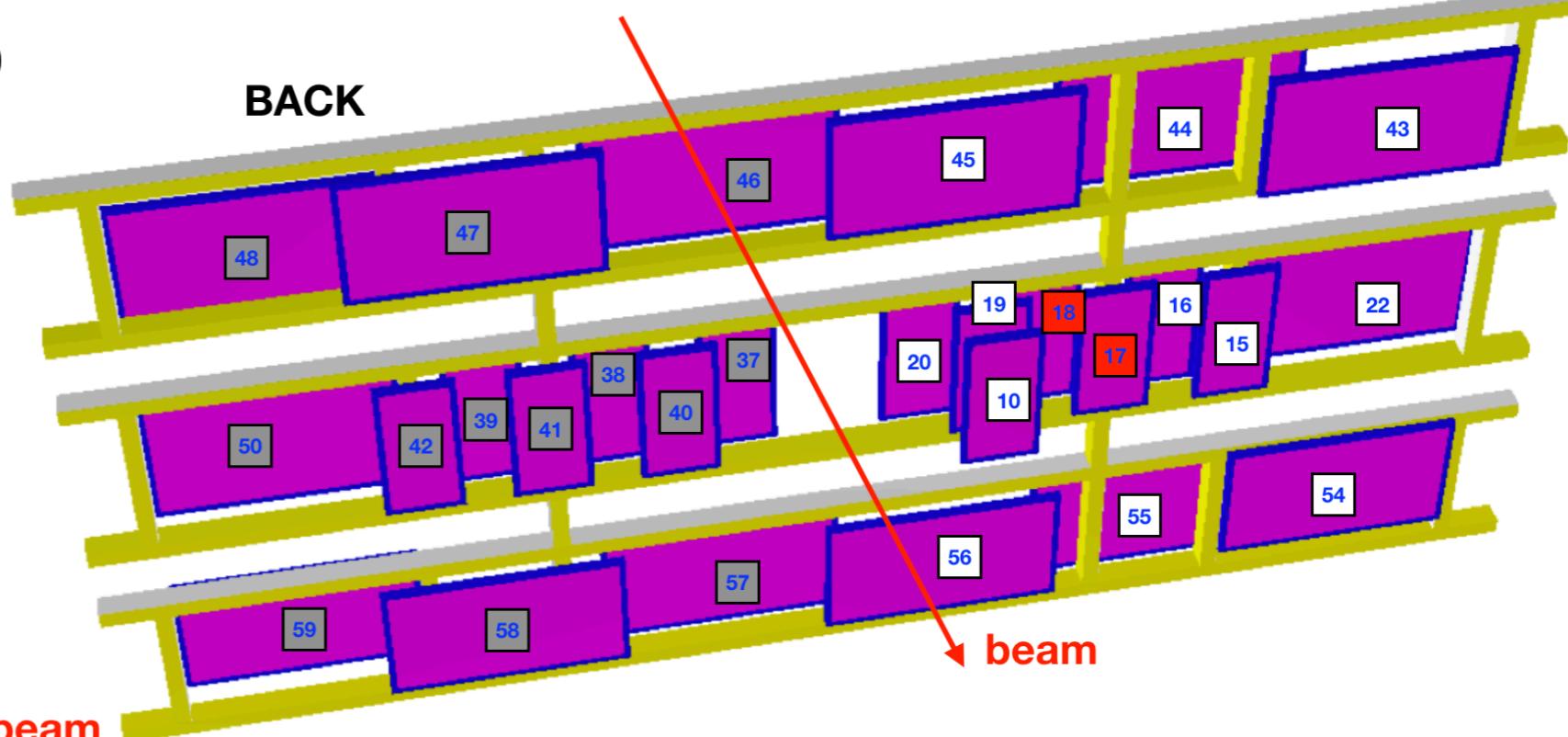
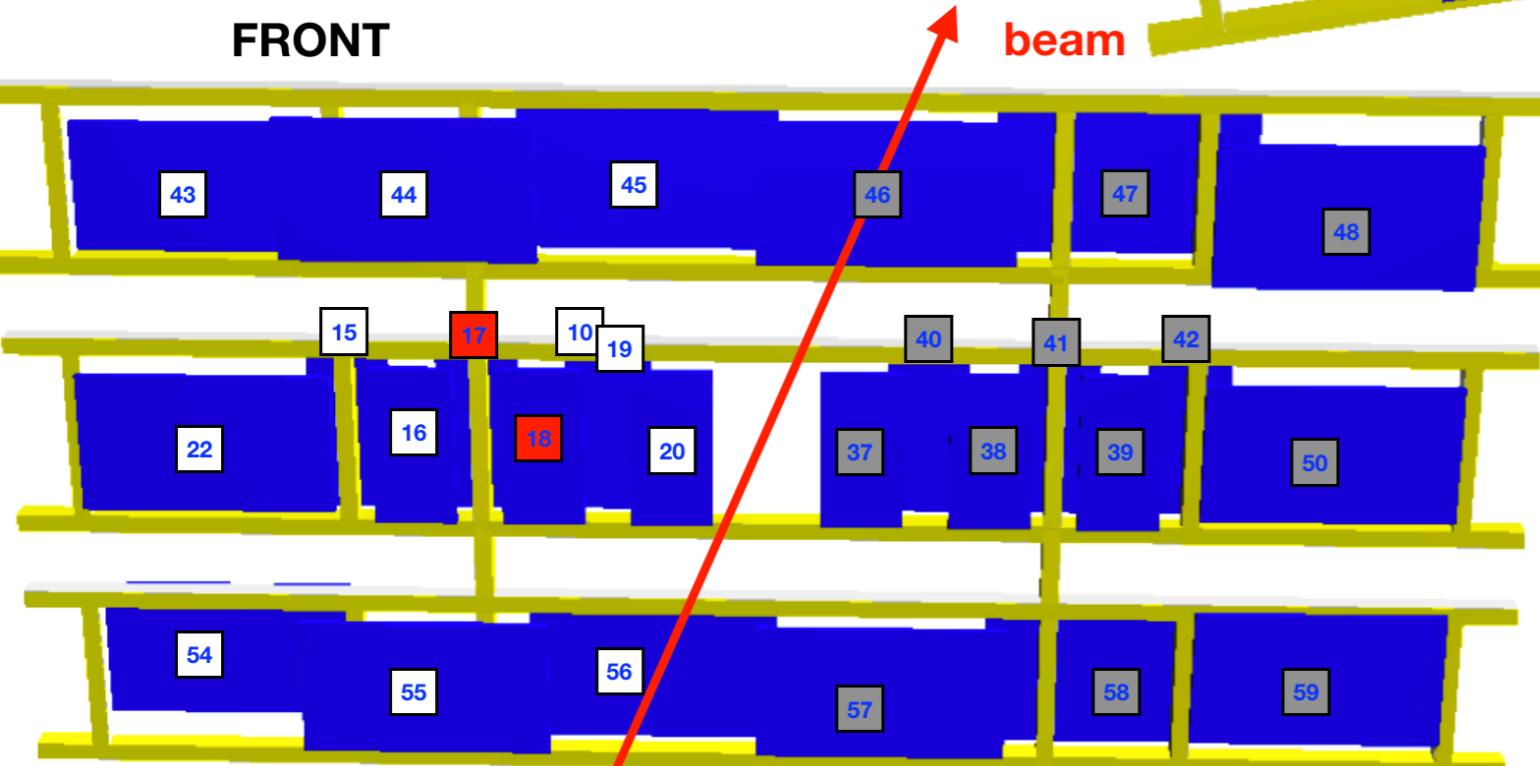
- Looking at SRC neutrons in LAND
- Merging information from all detectors to tag the final state
- Improving BmnRoot simulations
- 3 years RFBR grant from Maria Patsyuk for SRC data analysis

BCKP

Second (downstream) wall of ToF700



**¹²C is centered on plane 17 and 18
for B-field@1800A (physics run)**

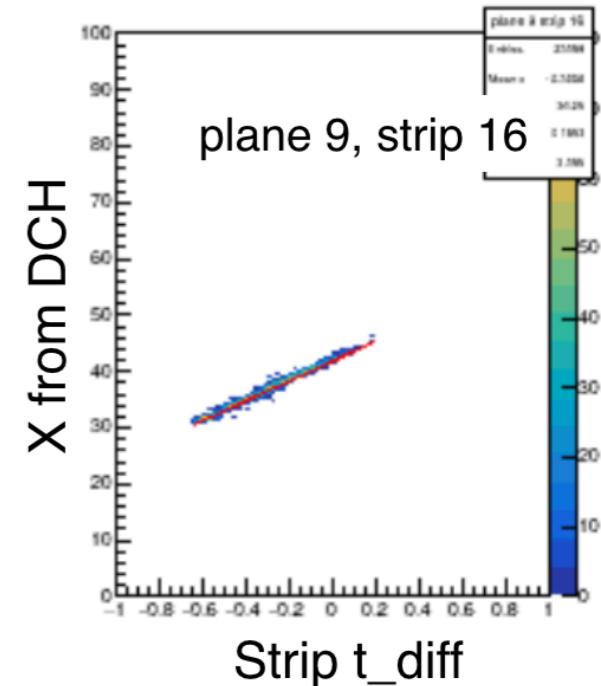
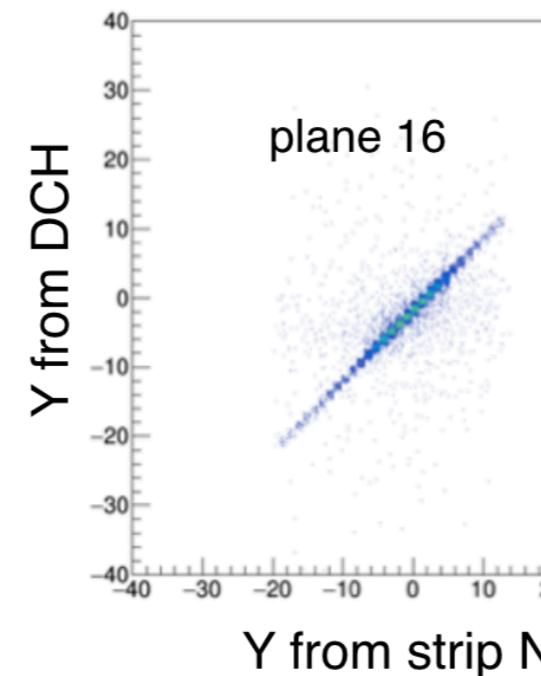
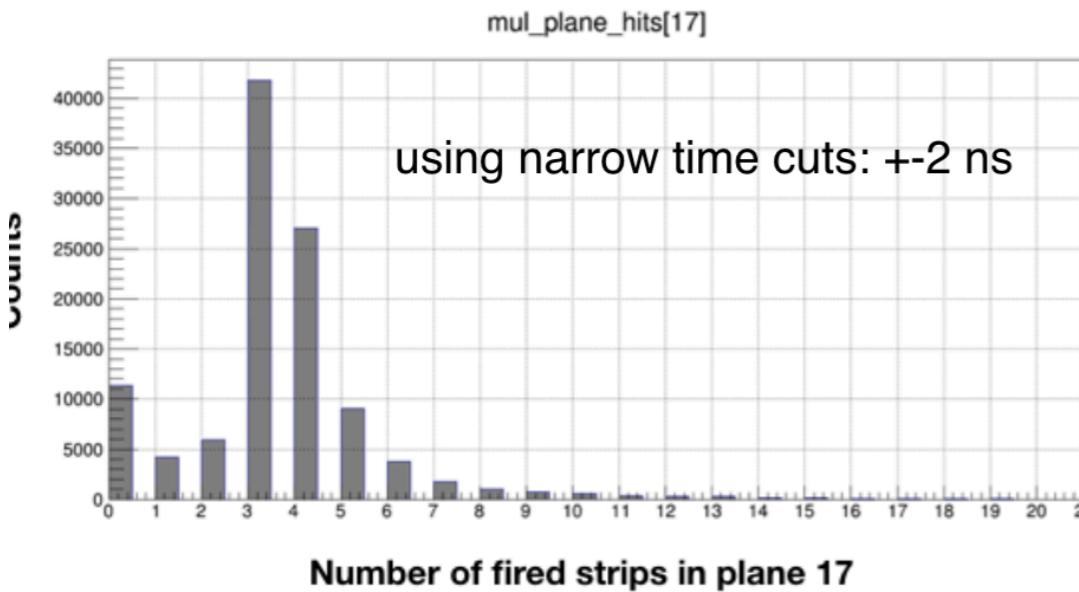


- Numbering as in digi file but 1 based ($N_{\text{digi}} = N - 1$)
 - Different from plane ID in the standard geometry file
 - Can differ from the numbering used in the simulation

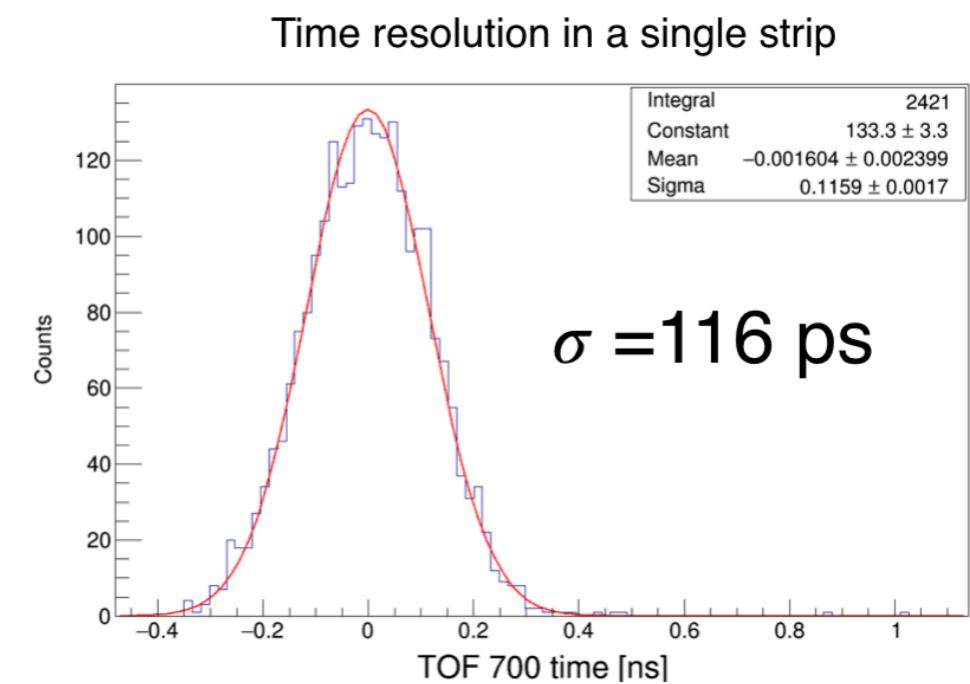
ToF700



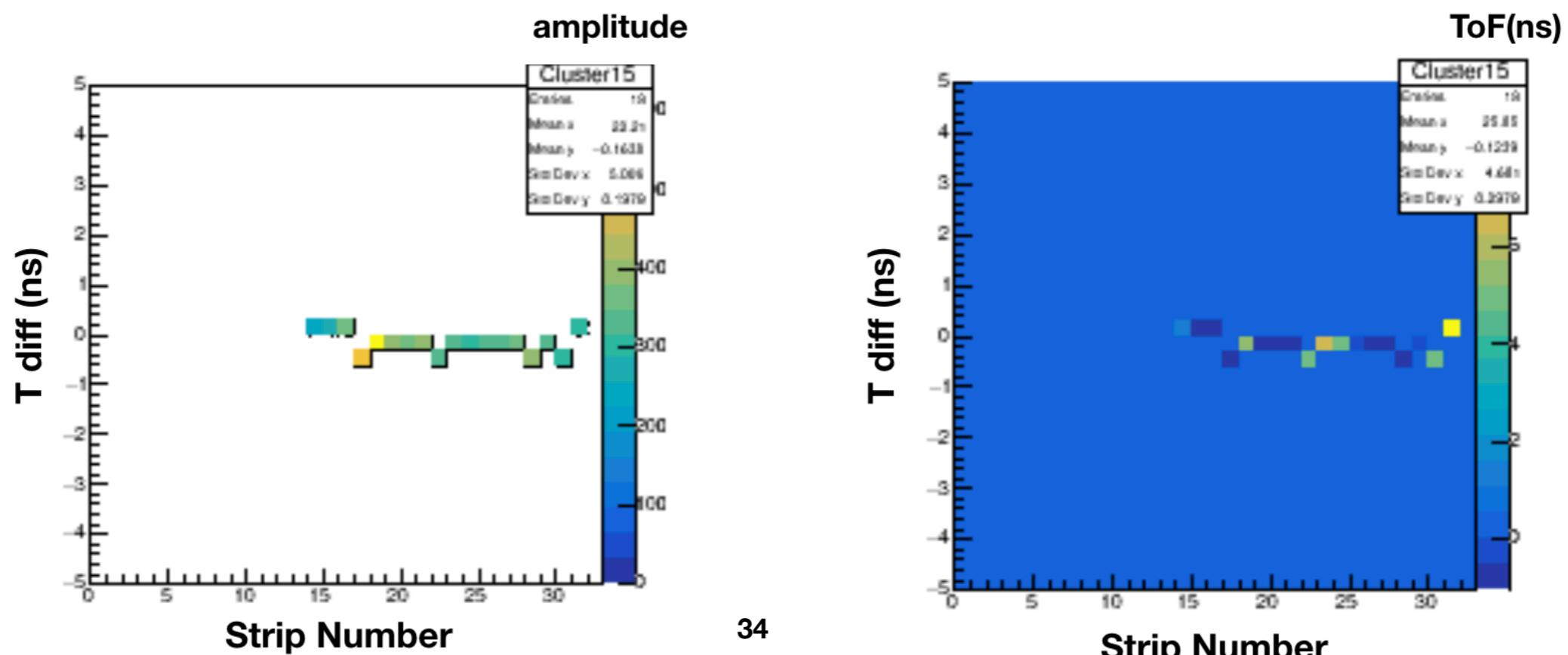
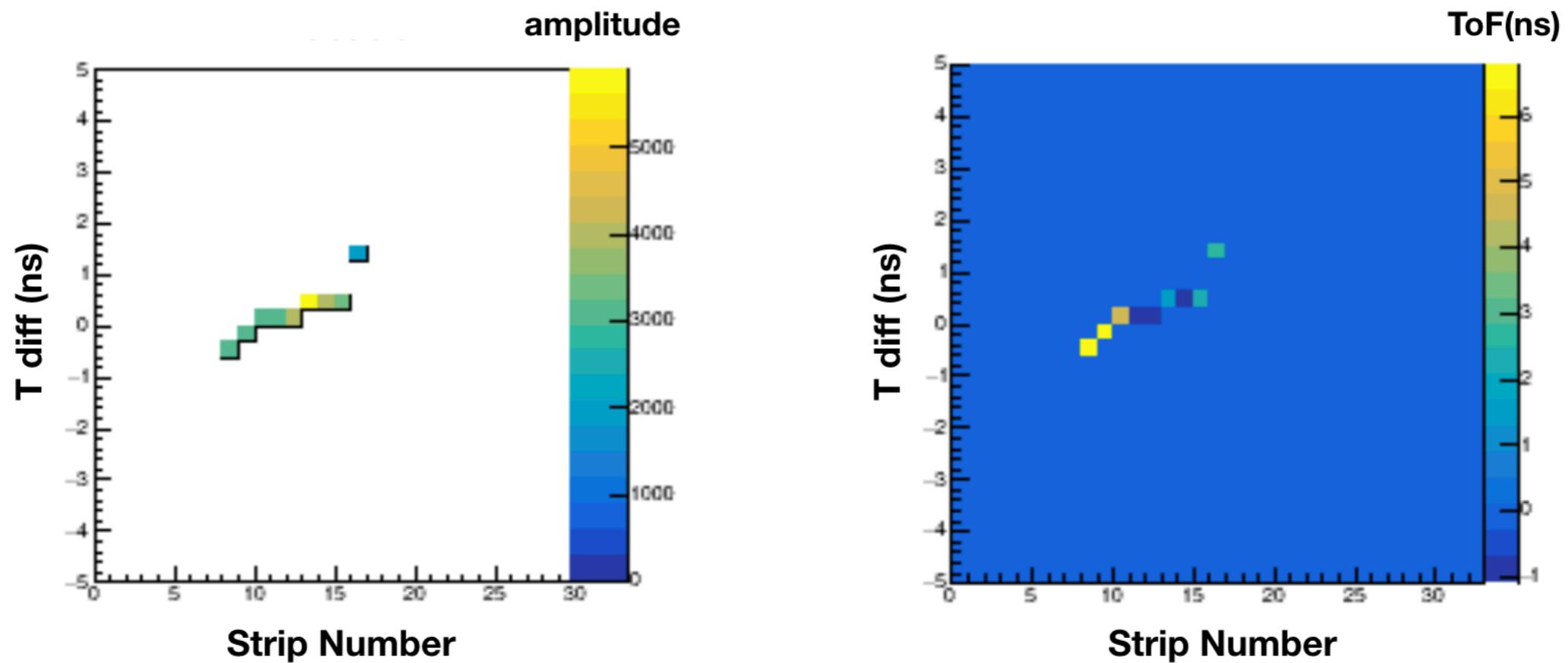
Example of position calibration



- Large hit multiplicity in TOF700
 - Improved by clustering algorithm
- Position calibration of TOF700 using DCH tracks
 - Unreacted ^{12}C
 - Depends on DCH alignment
 - Resolution: 5 mm sigma in X and Y
- Estimated time resolution: 116 ps (sigma)
- Absolute time-offset calibration for individual strips is based on BMNRoot simulation of unreacted ^{12}C
 - in progress



Single “cluster” events in plane 17 (no time cuts)



Single “cluster” events in plane 17 (no time cuts)

