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# Proton-Arm Spectrometer for the SRC Experiment

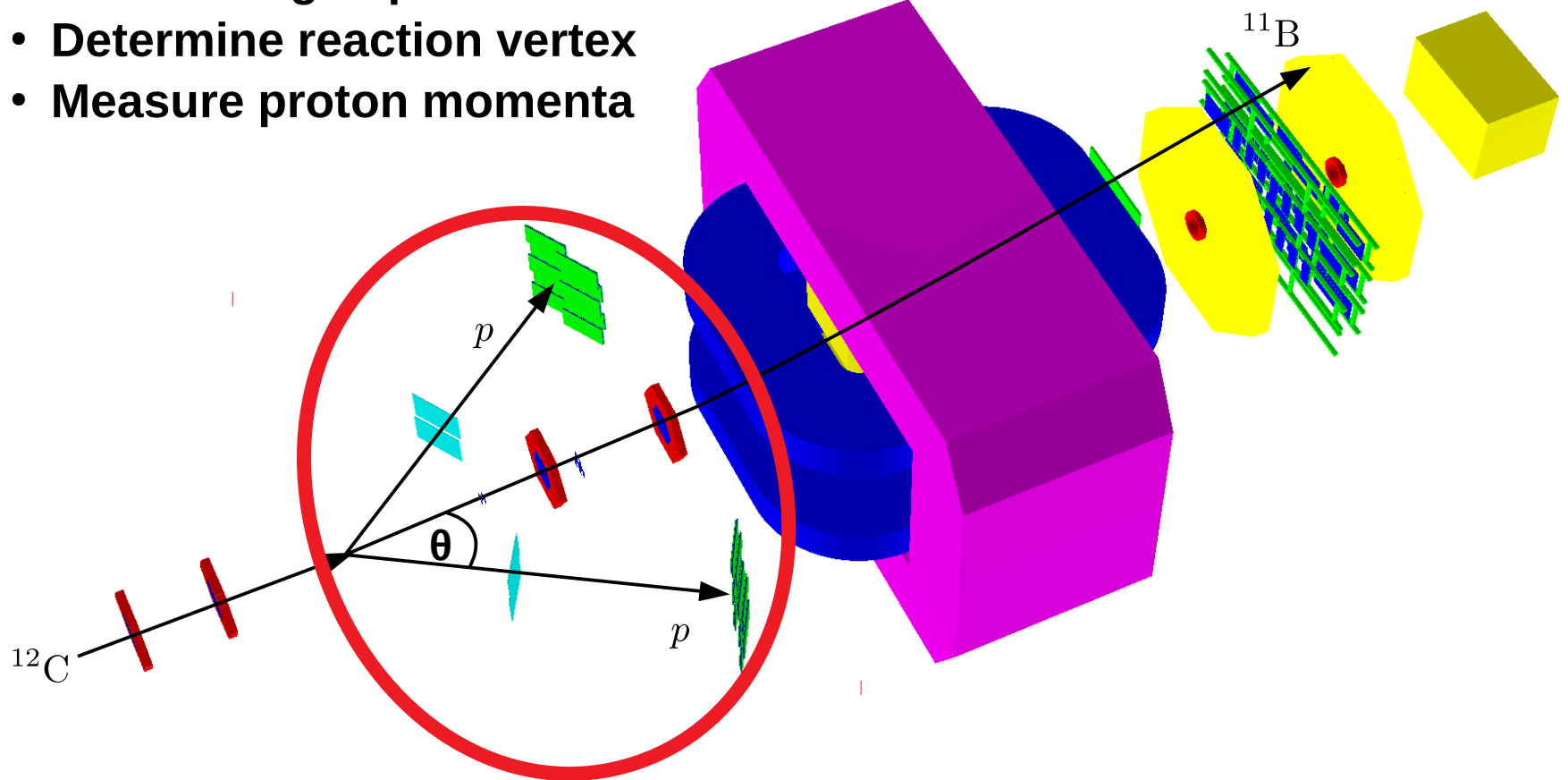
Julian Kahlbow and Efrain Segarra  
for the SRC Collaboration

5<sup>th</sup> BM@N Collaboration Meeting  
April 20<sup>th</sup>, 2020



# Proton-Arm Spectrometer at SRC Experiment

- Track charged particles
- Determine reaction vertex
- Measure proton momenta

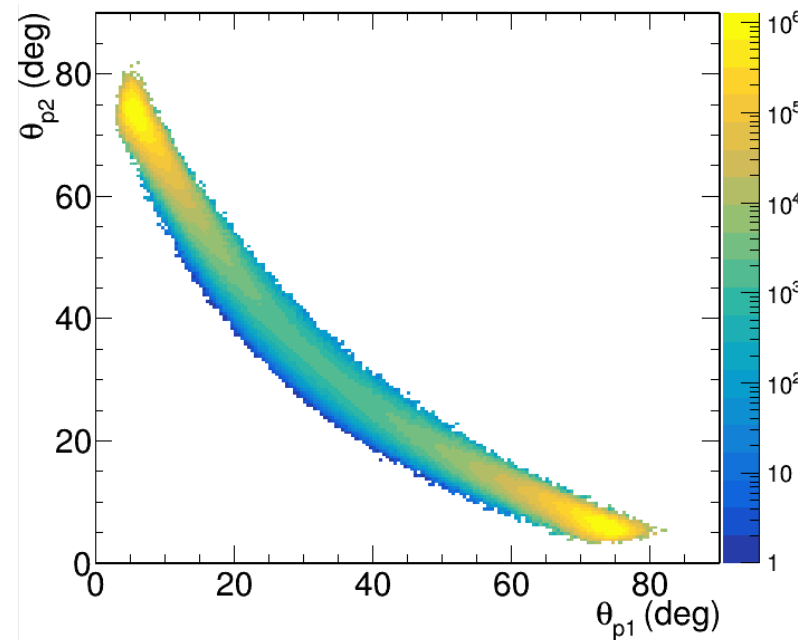


# Quasi-elastic Scattering in Inverse Kinematics

$^{12}\text{C}(p, 2p)^{11}\text{B}$  at 4 GeV/c/u

90° c.m.  $pp$  scattering: forward focused protons in lab. system

Proton-proton polar  
angle correlation  
(simulation)

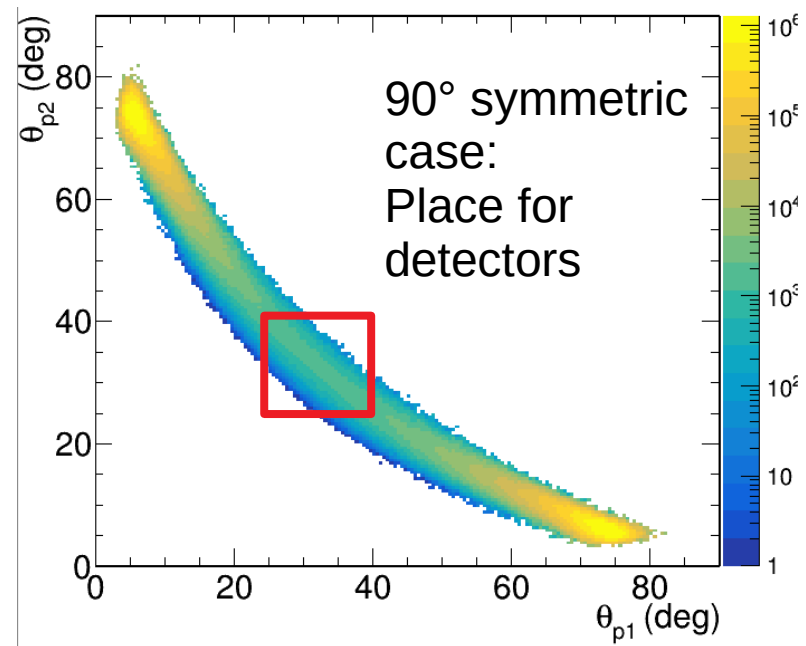


# Quasi-elastic Scattering in Inverse Kinematics

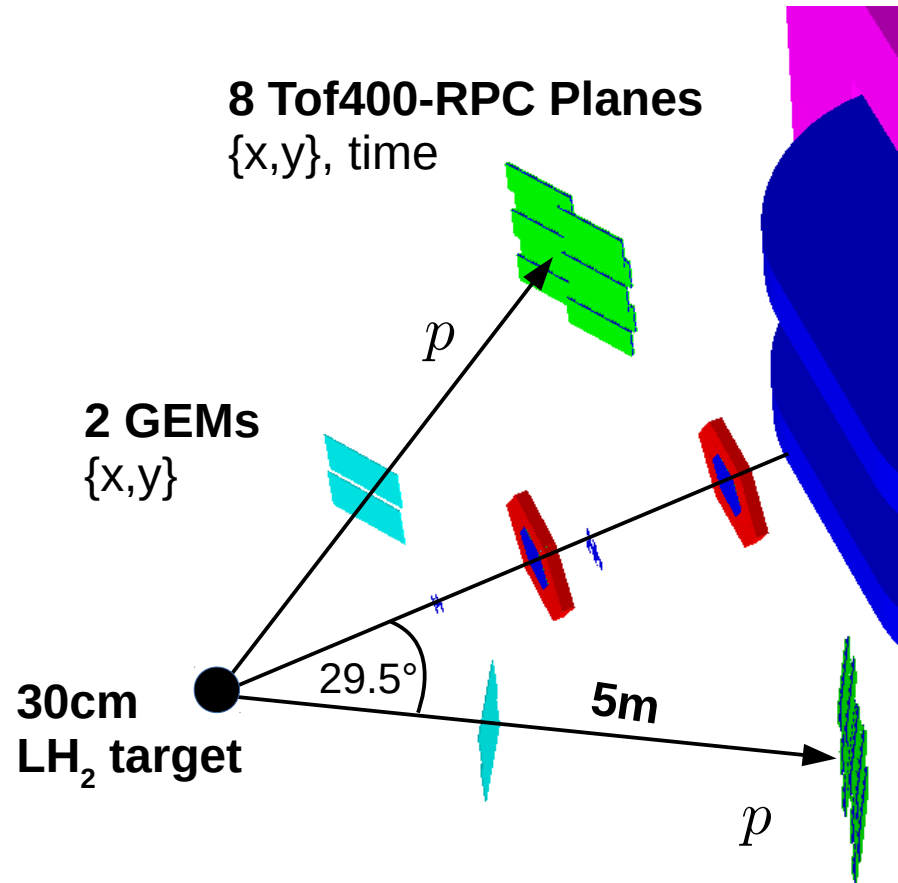
$^{12}\text{C}(p, 2p)^{11}\text{B}$  at 4 GeV/c/u

90° c.m.  $pp$  scattering: forward focused protons in lab. system

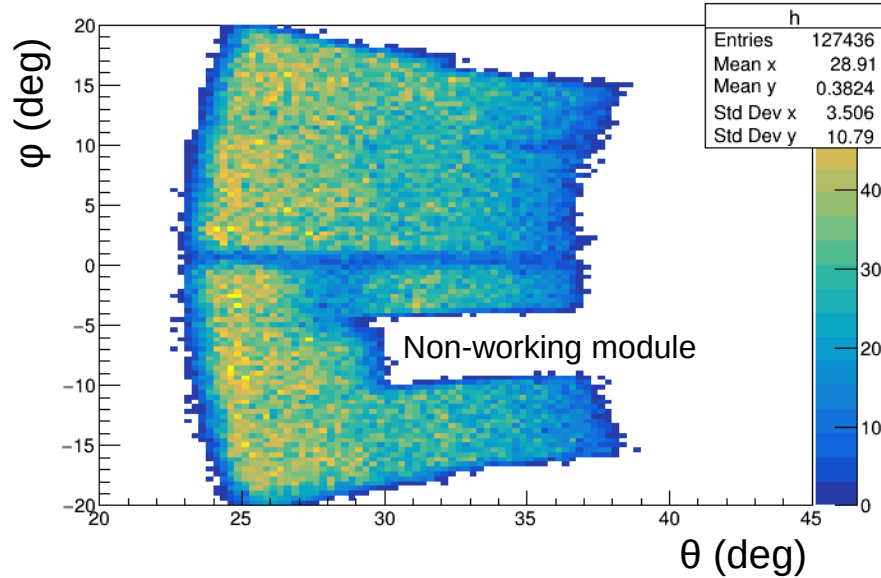
Proton-proton polar  
angle correlation  
(simulation)



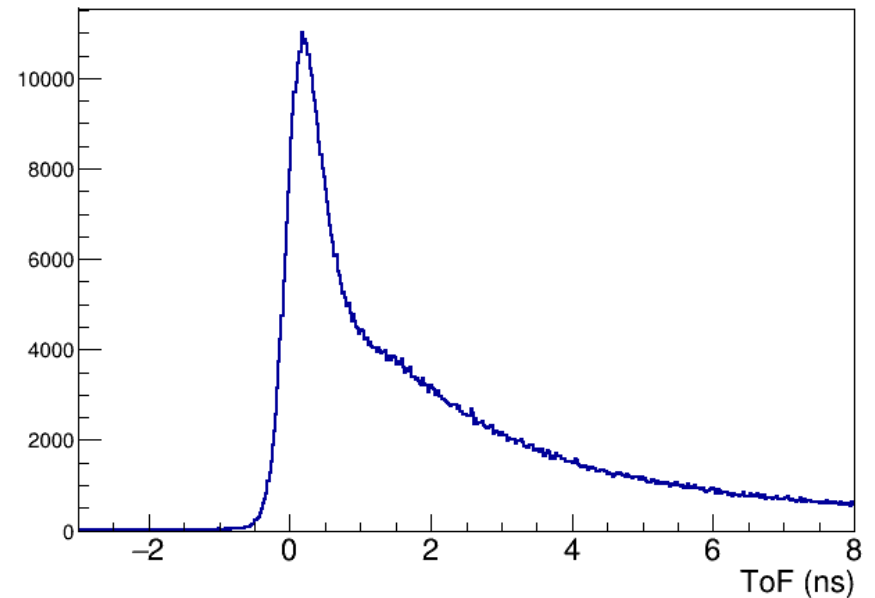
# Proton-Arm Spectrometer



# Tof400 Measurements

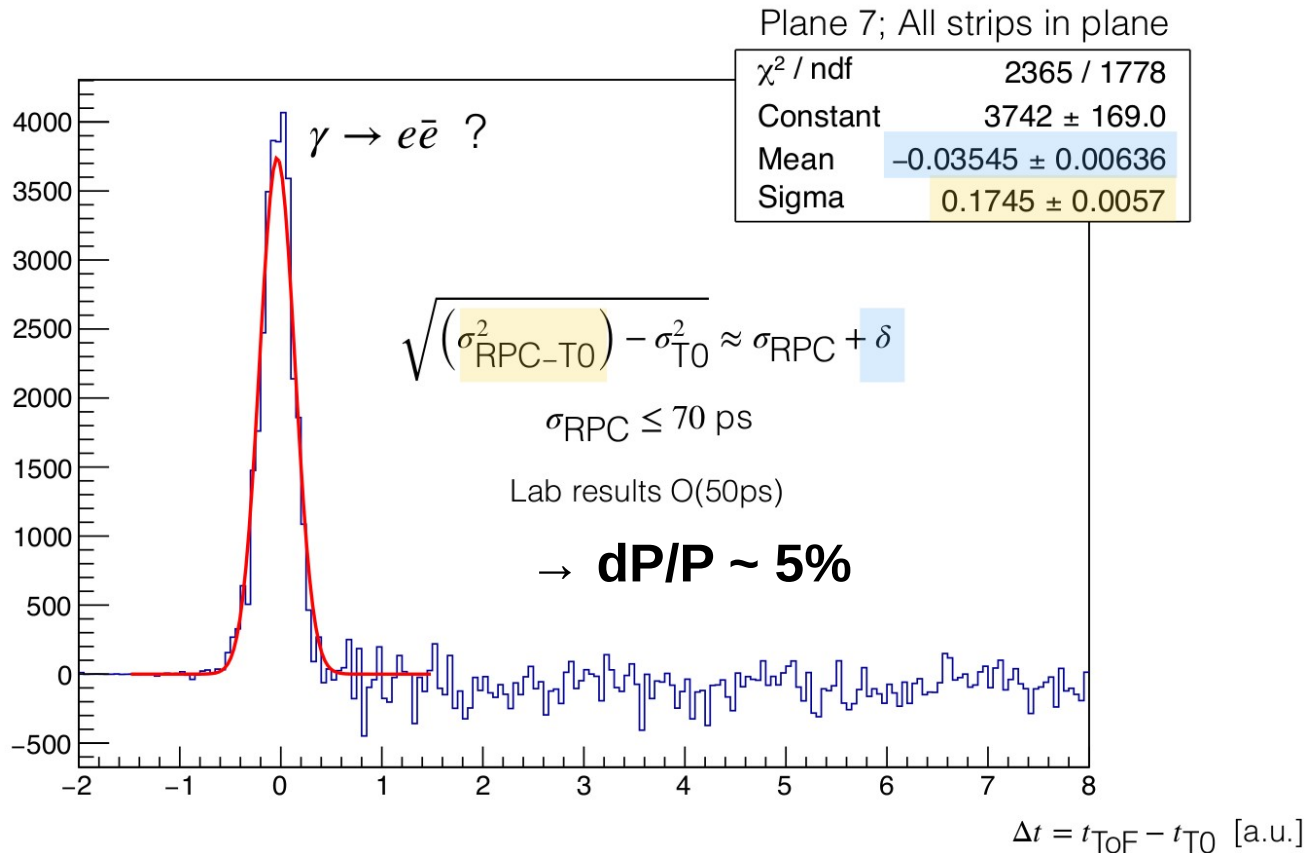


Time-of-flight normalized to flightlength  
internal Alignment done using Pb target runs



# Time-of-Flight Resolution

Tof spectrum with and without Pb wall directly in front of RPC



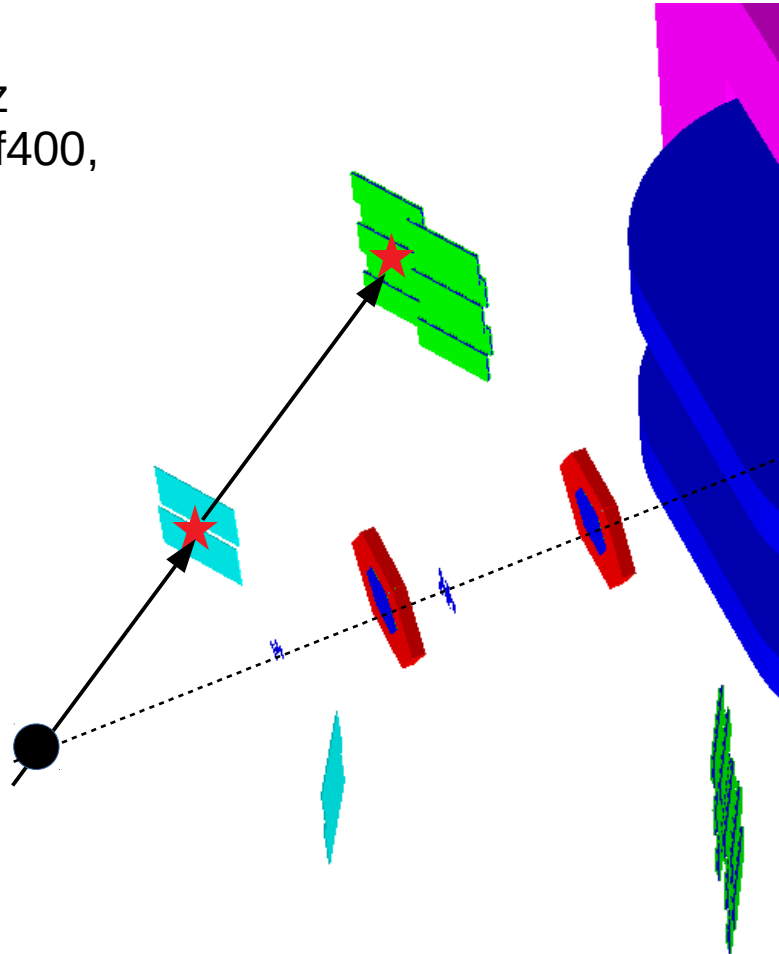
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# Vertex Tracking

Determine the starting point in target

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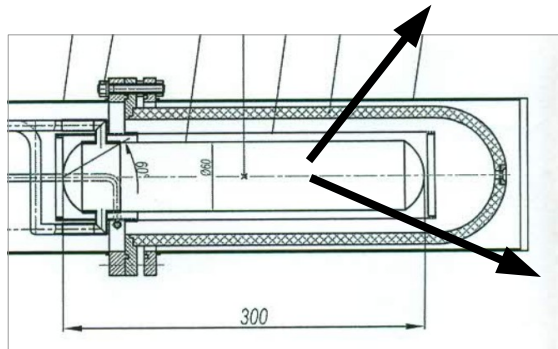
1. Straight line in xz and yz  
from point in GEM and Tof400,  
4 points needed



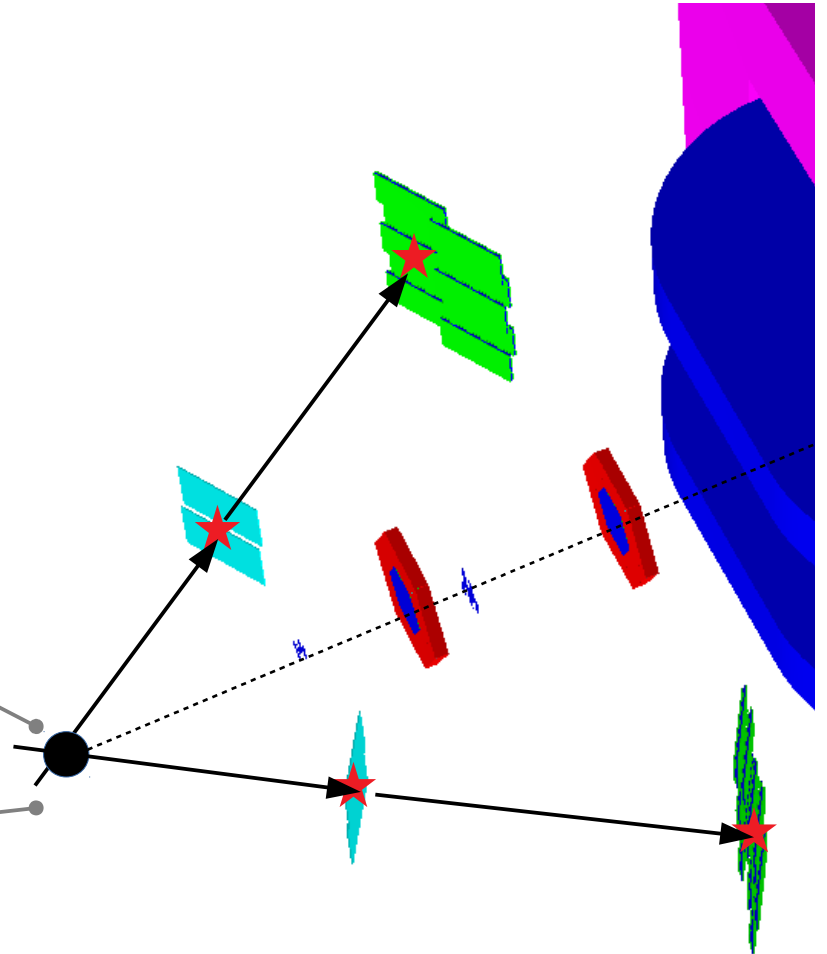


# Vertex Tracking

1. Straight line in  $xz$ ,  $x=f(z)$ , and  $yz$ ,  $y=f(z)$ , from point in GEM and Tof400, 4 points needed
2. Determine 2 tracks' closest point



LH<sub>2</sub> target



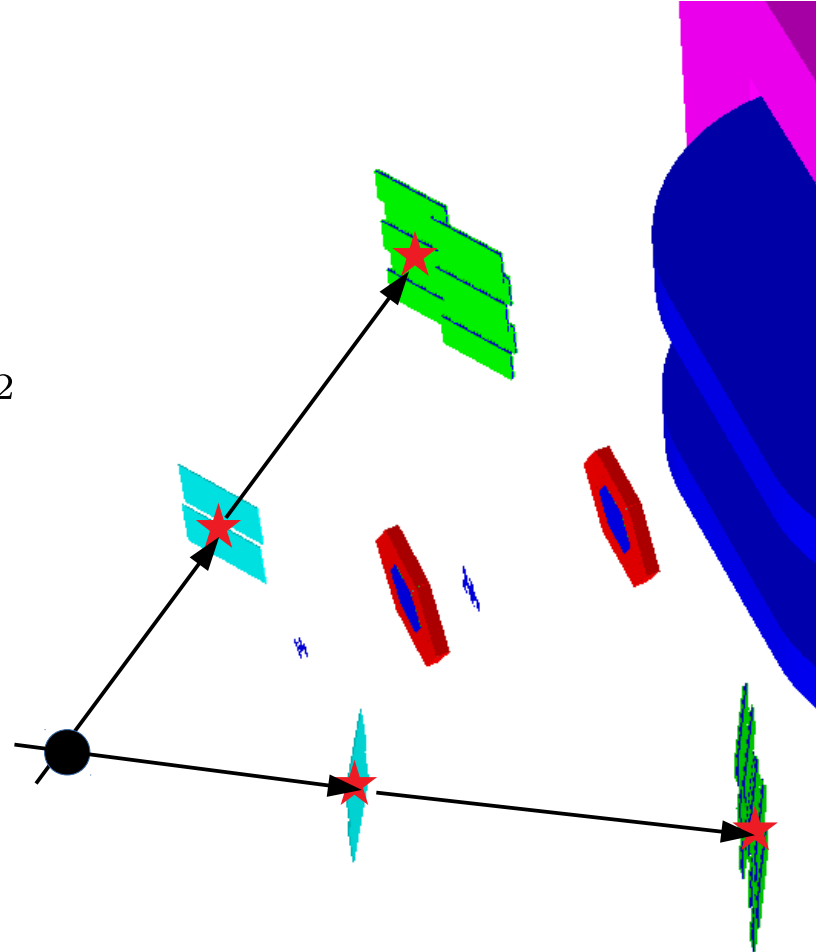
# Vertex Tracking

1. Straight line in xz,  $x=f(z)$ , and yz,  $y=f(z)$ , from point in GEM and Tof400, 4 points needed

2. Determine 2 tracks' closest point

$$D^2 = (x_l - x_r)^2 + (y_l - y_r)^2 + (z_l - z_r)^2$$

$$dD^2 = \frac{\delta D^2}{\delta z_l} dz_l + \frac{\delta D^2}{\delta z_r(z_l)} dz_r(z_l) = 0$$



# Vertex Tracking

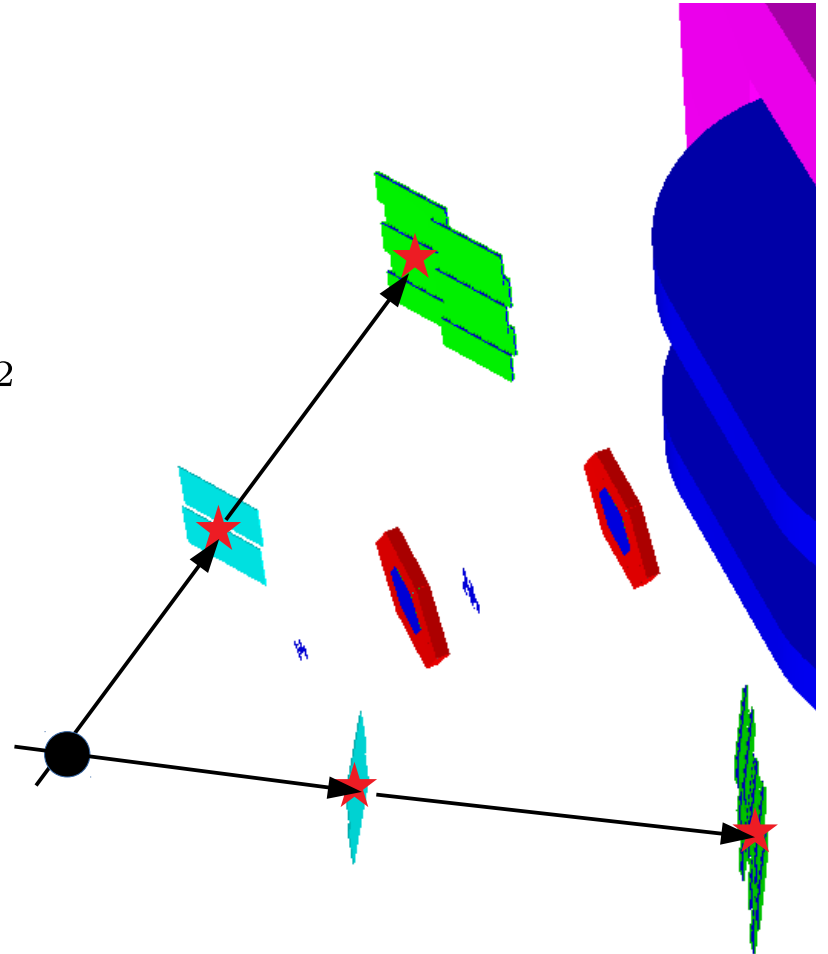
1. Straight line in xz,  $x=f(z)$ , and yz,  $y=f(z)$ , from point in GEM and Tof400, 4 points needed

2. Determine 2 tracks' closest point

$$D^2 = (x_l - x_r)^2 + (y_l - y_r)^2 + (z_l - z_r)^2$$

$$dD^2 = \frac{\delta D^2}{\delta z_l} dz_l + \frac{\delta D^2}{\delta z_r(z_l)} dz_r(z_l) = 0$$

3. The smallest distance of all hit combinations determines the reaction vertex  $\{x,y,z\}$

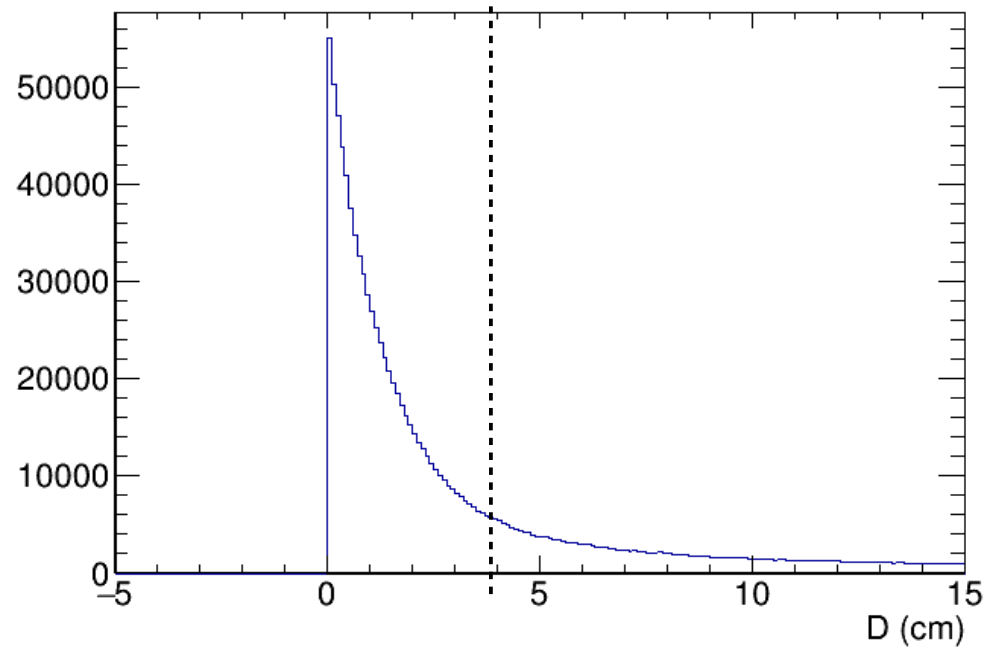


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# Vertex Quality

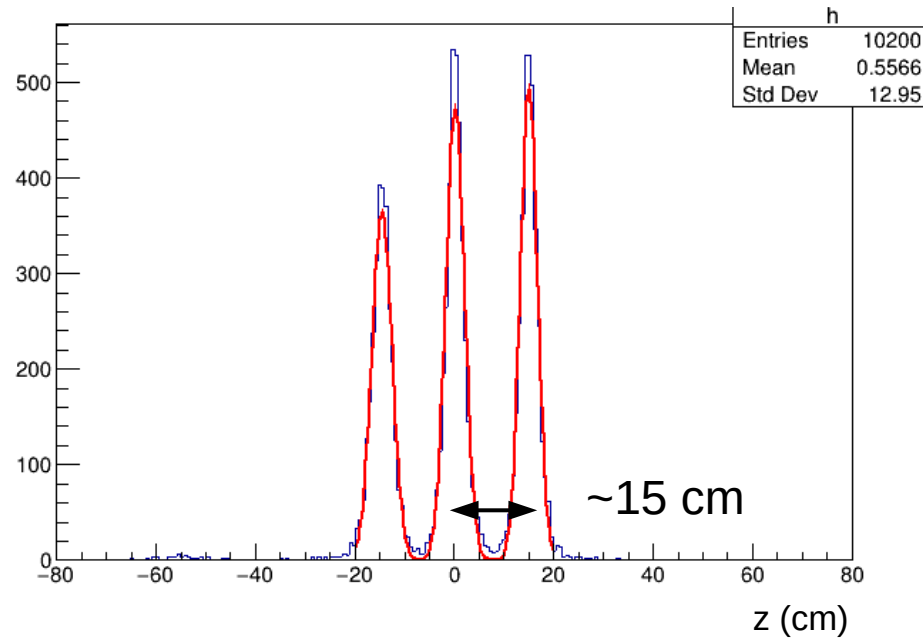
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Minimal Distance < 4cm



# Pb Target for Calibration

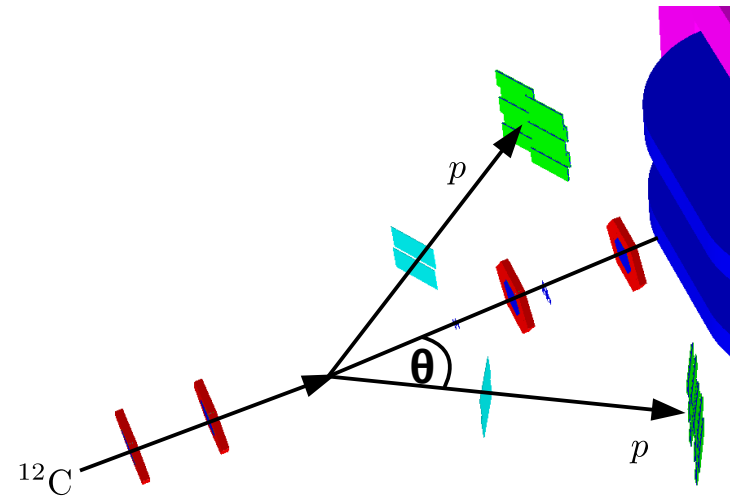
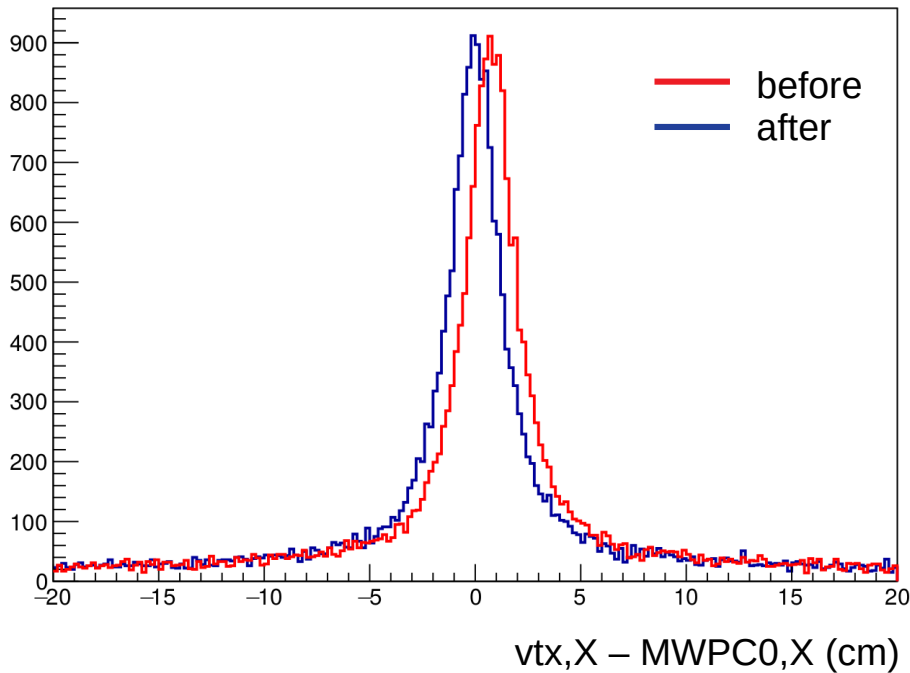
z-Vertex from 3Pb targets (0.9cm)



**Position Resolution  $\sigma(z) < 2\text{cm}$**

# Alignment Procedure

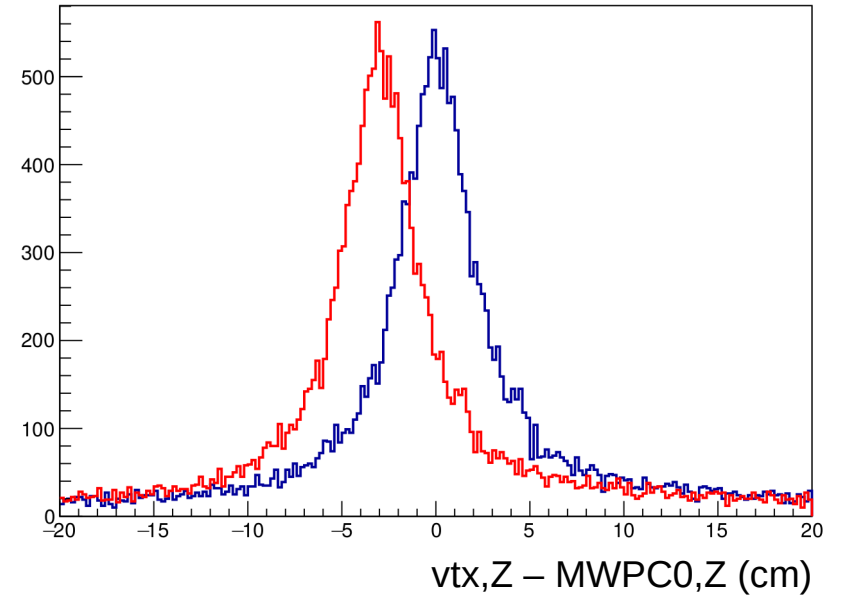
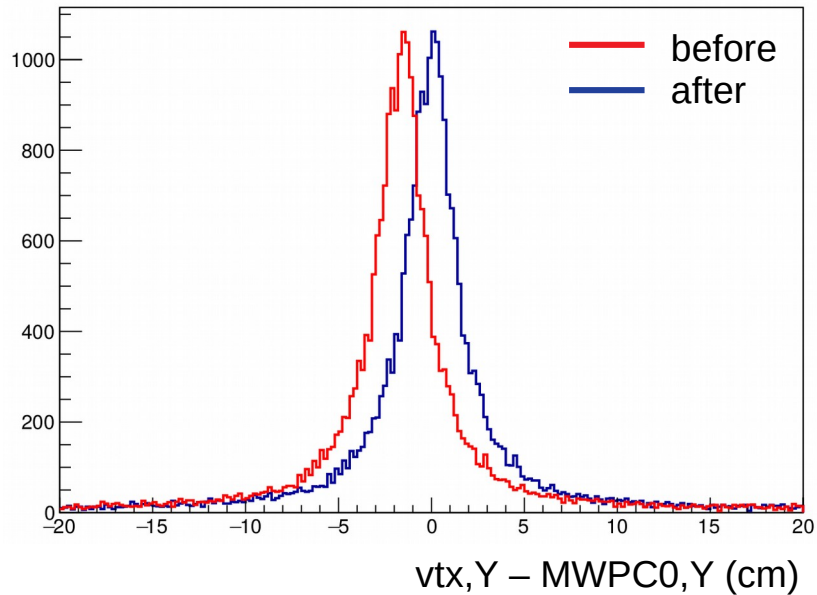
1. Align full (GEM-Tof400) system relative to MWPC0 vertex



MWPC0 ... beam extrapolated to target position

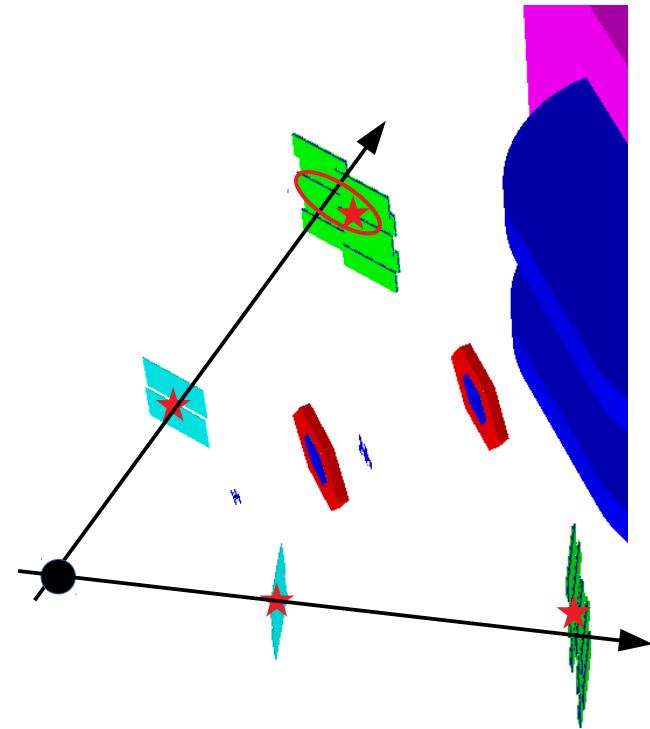
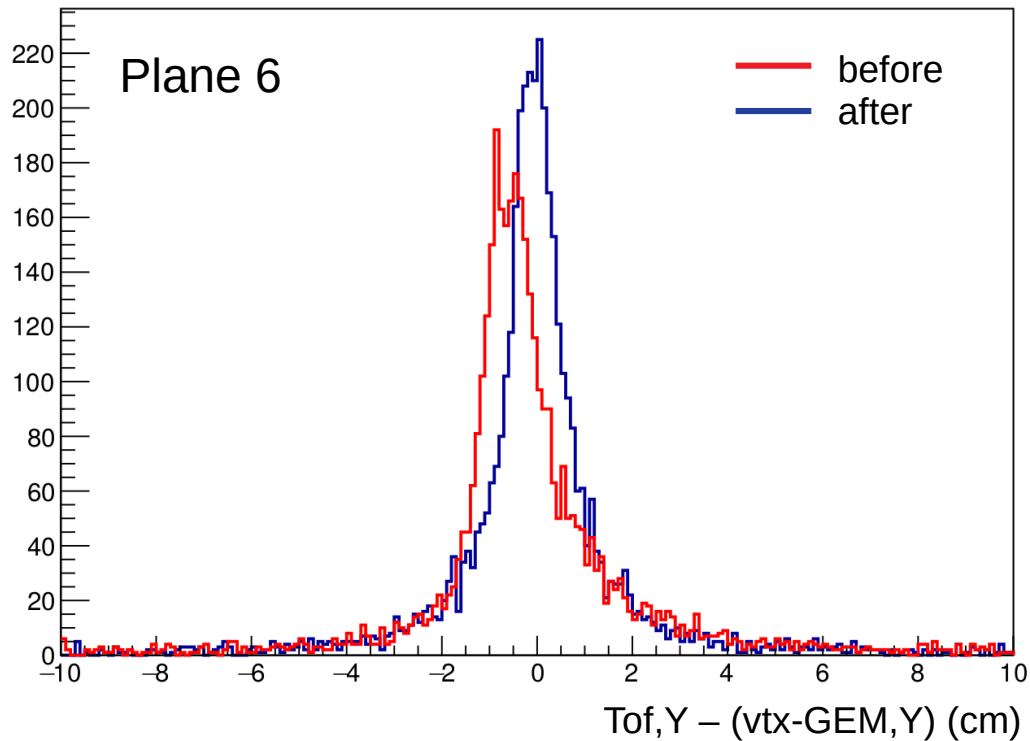
# Alignment Procedure

1. Align full (GEM-Tof400) system relative to MWPC vertex



# Alignment Procedure

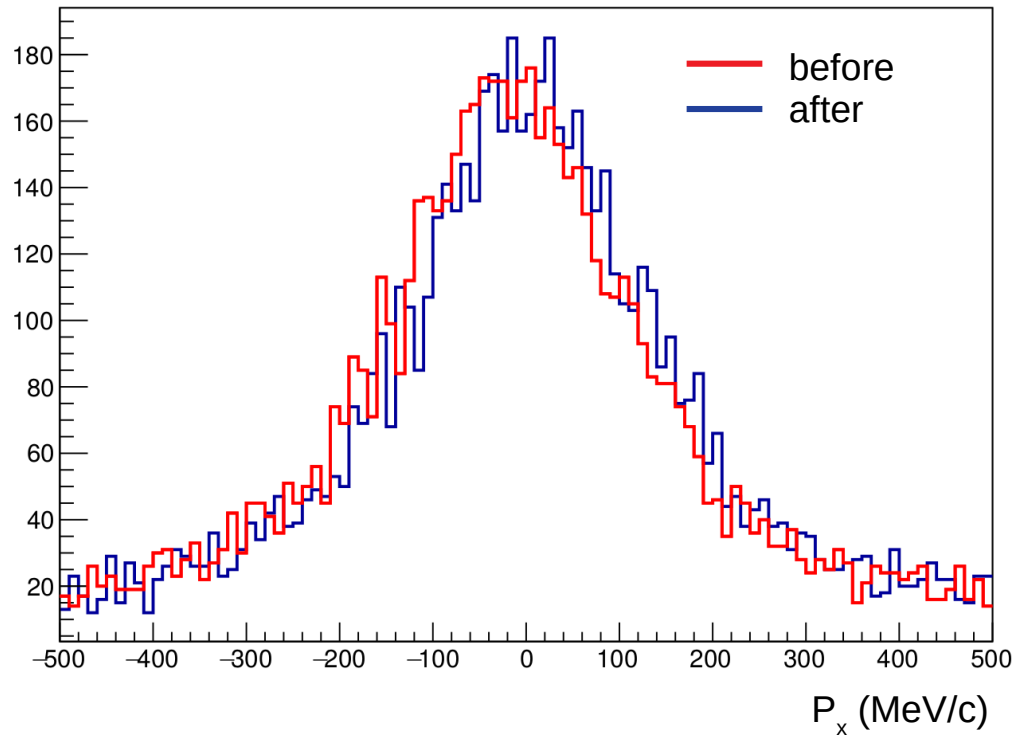
- Align separate Tof400 planes relative to vertex-GEM track in iterative way, GEM is fixed





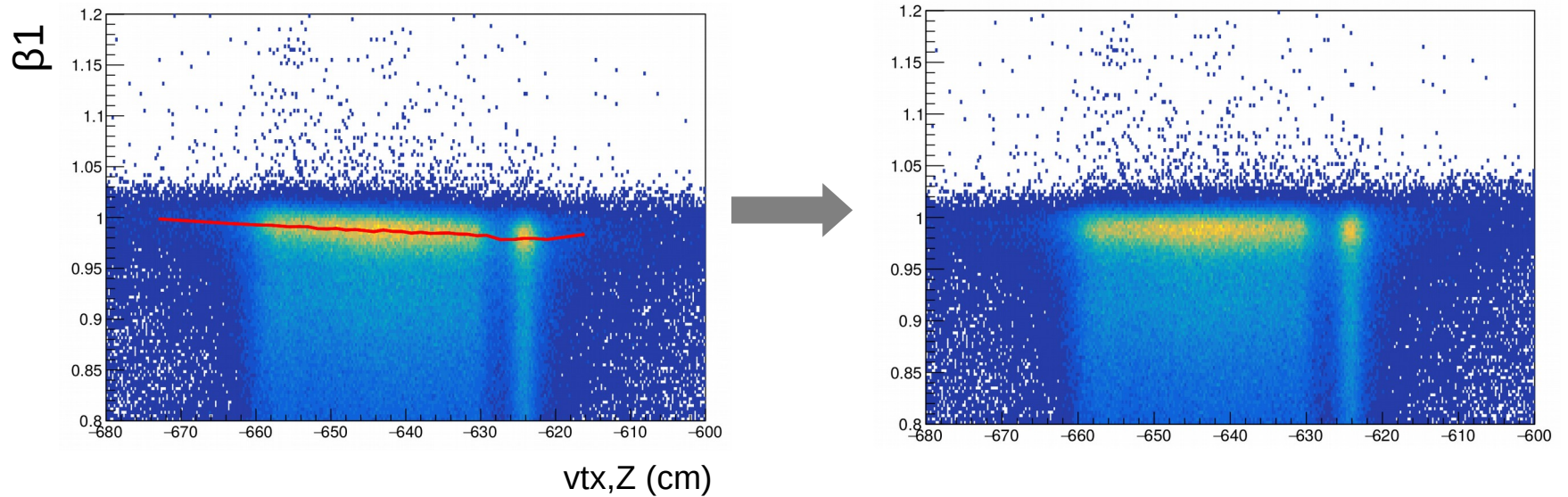
# Alignment Procedure

## 3. Rotate arms to center momentum distribution



# Alignment Procedure

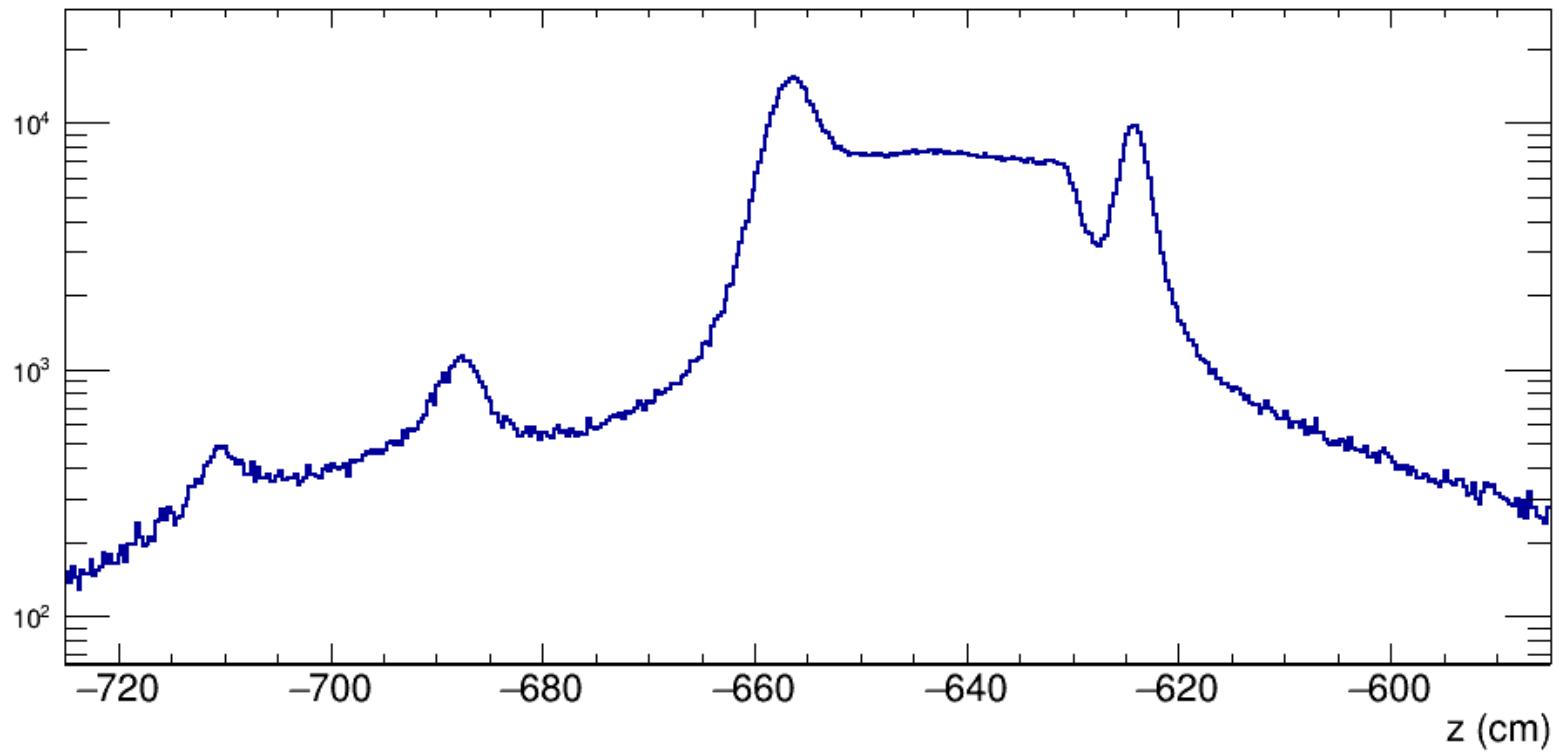
4. Correct for remaining vertex dependence of the particle velocity (while  $\beta_1$ - $\beta_2$  is flat)



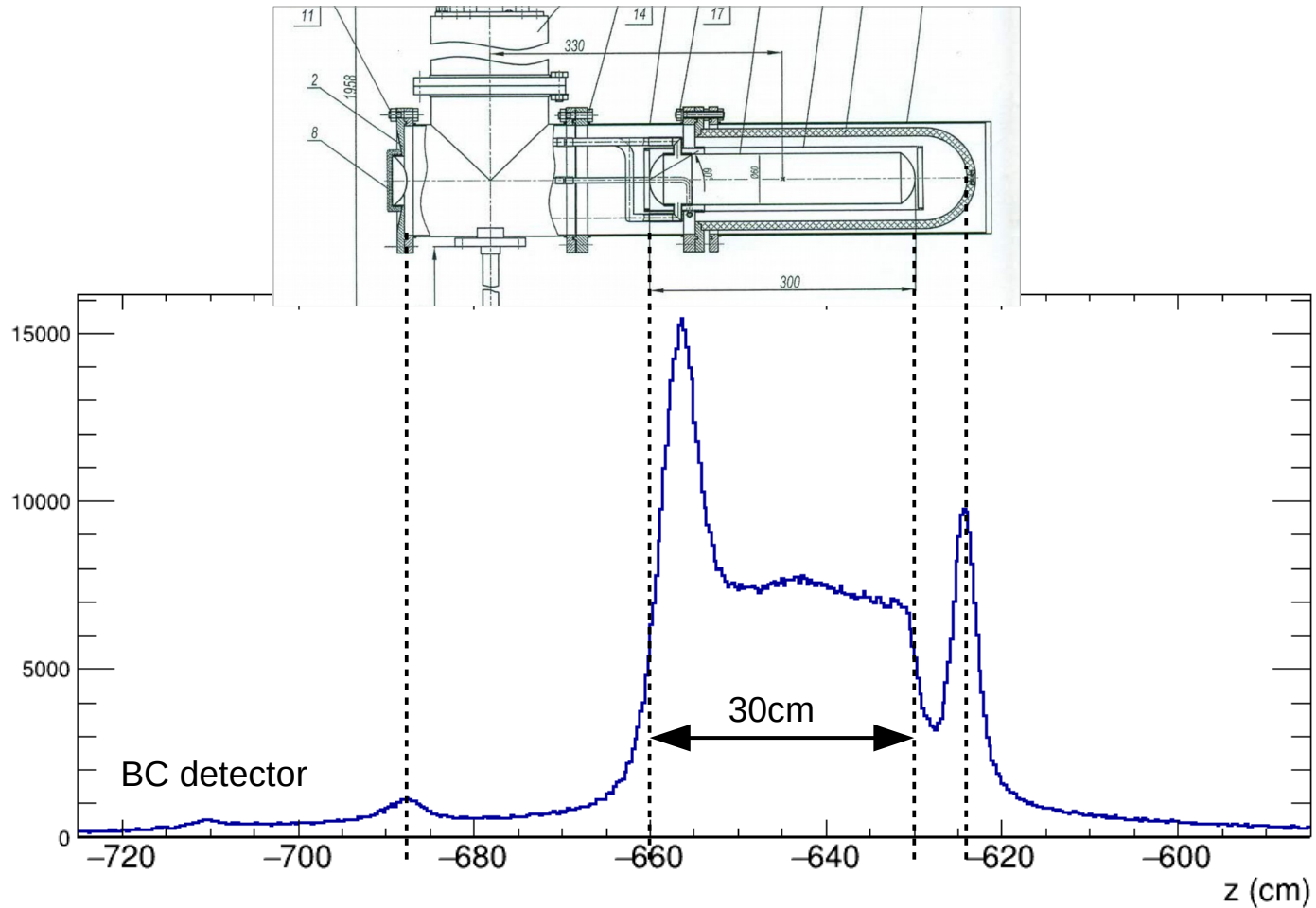
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# Liquid Hydrogen Target Vertex

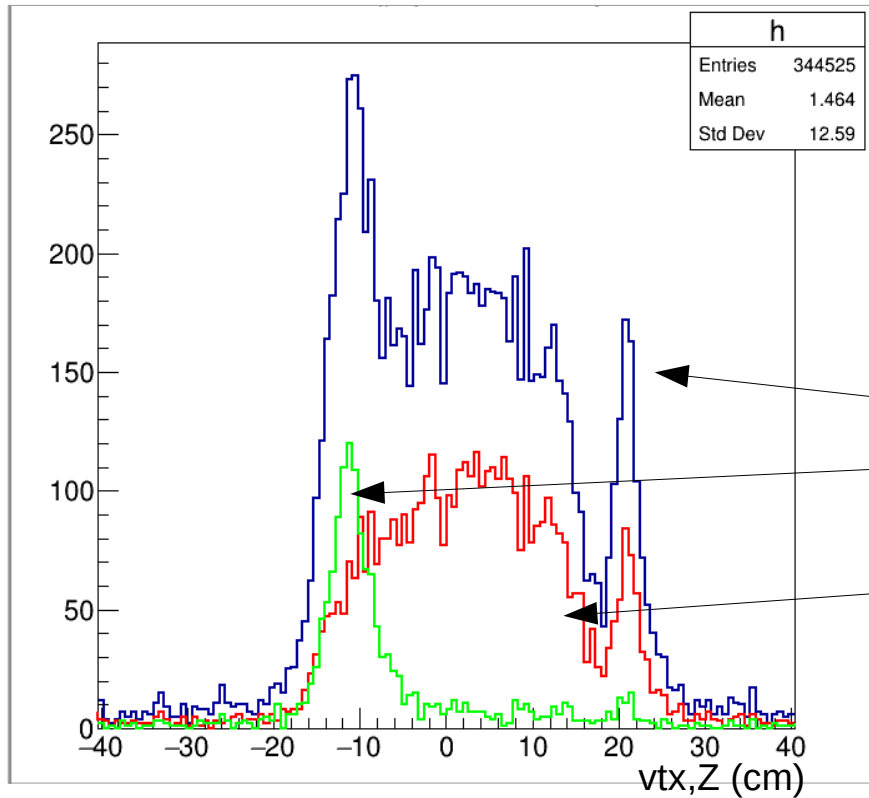
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# Liquid Hydrogen Target Vertex

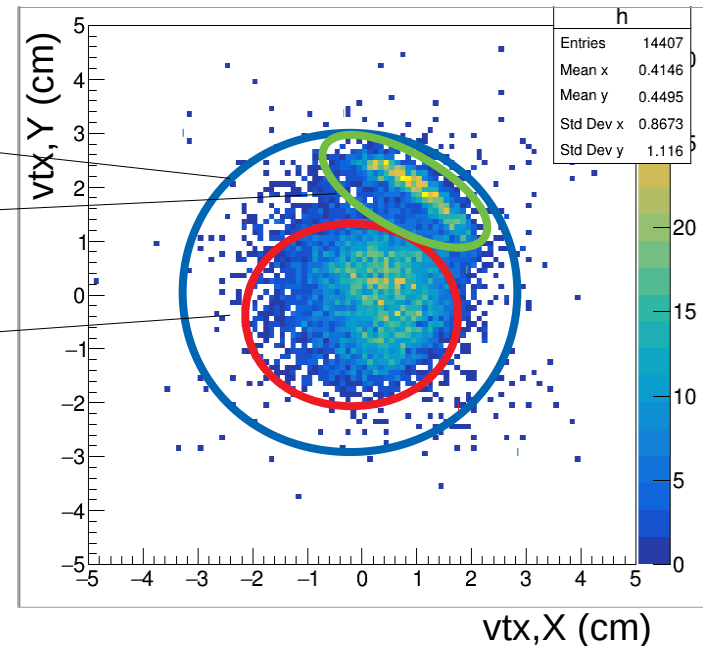


# Liquid Hydrogen Target Vertex



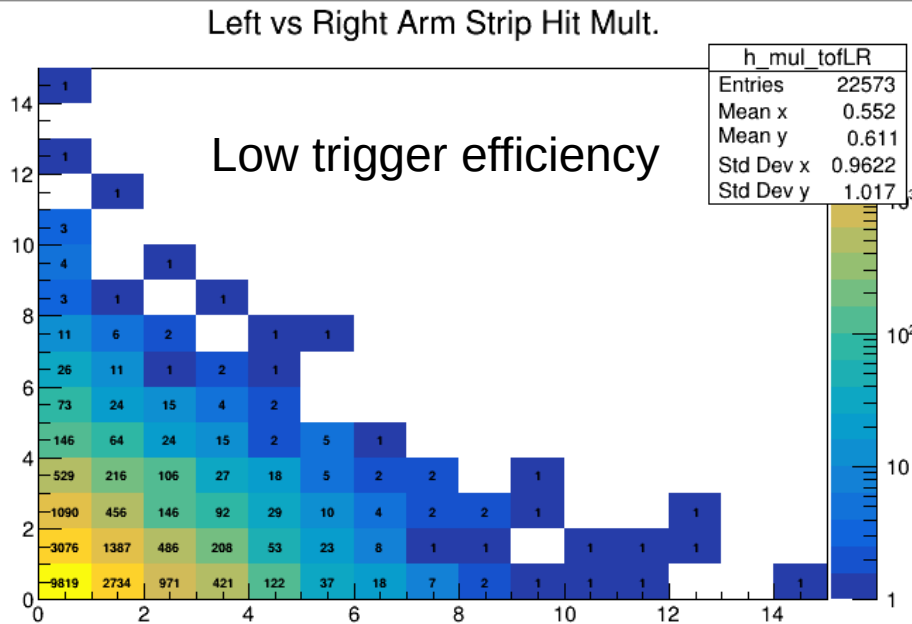
**XY Vertex**  
(using the MWPC0)

Beam partly hitting the target vessel



# Detector Efficiency and Acceptance

## Tof400



- Toff400 efficiency ~85% (M. Rumyantsev)

- Tof400 covers ~60% of GEM

11B+12C+TRIG+GEM 1.00

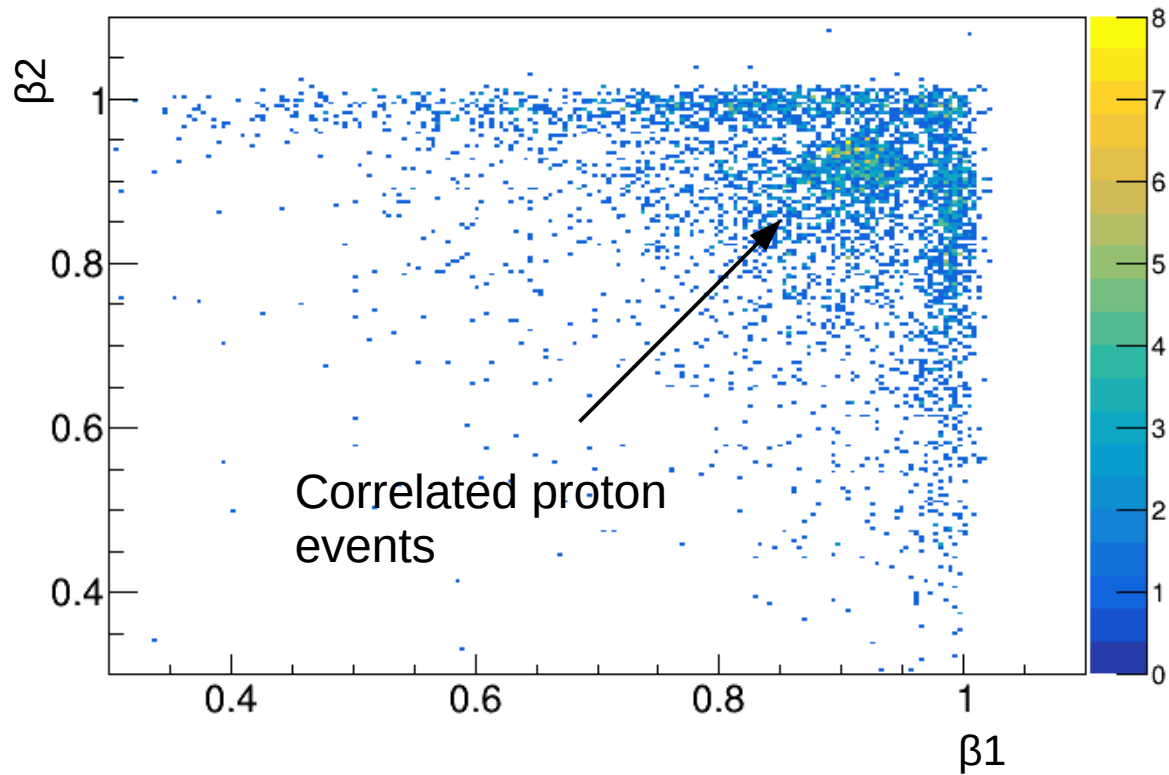
11B+12C+TRIG+TOF+NOGEM 0.03

11B+12C+TRIG+GEM+TOF 0.40

11B+12C+TRIG+GEM+TOF+ARMVTX 0.40

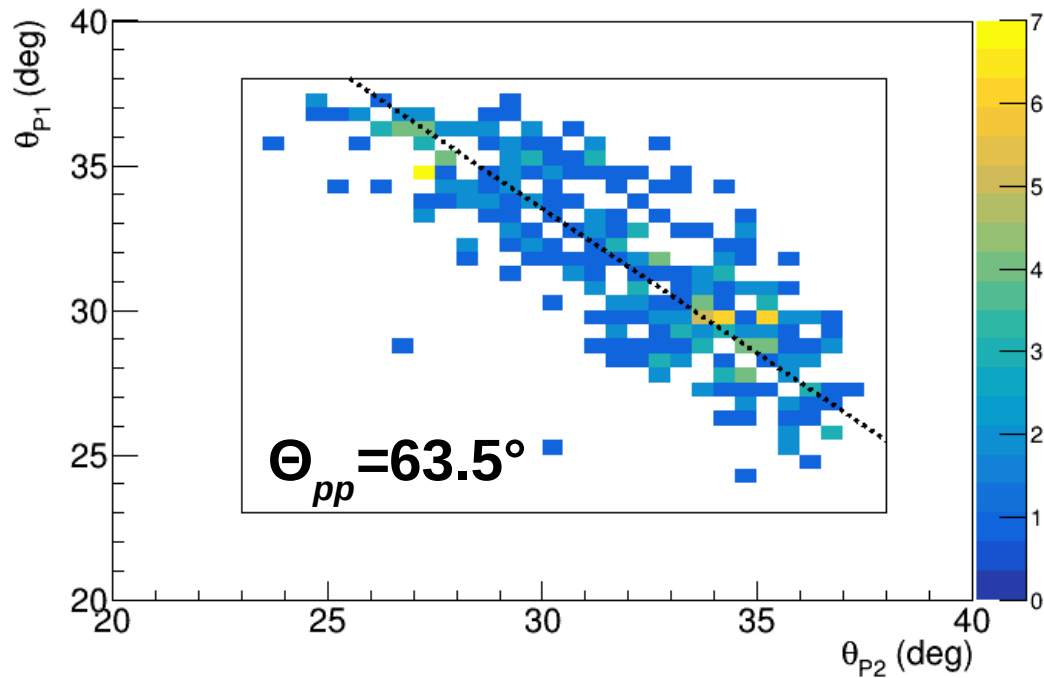
# Proton Identification in Arms

Velocity cut for single track in left and right arm

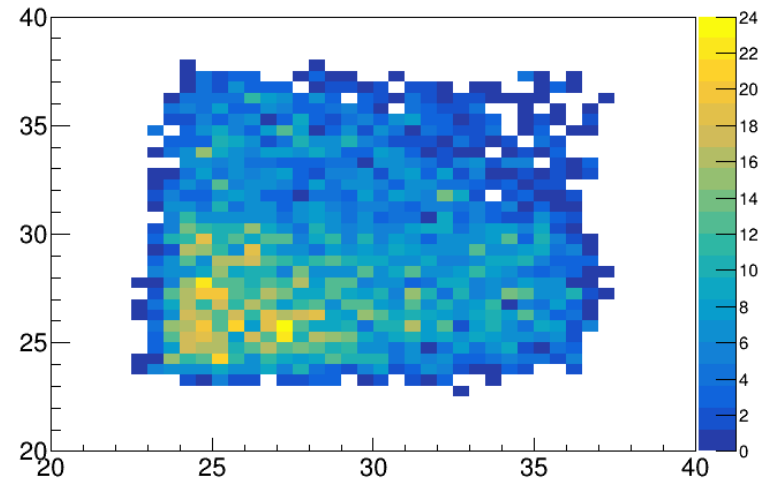


$\beta = \text{flightlength} / \text{Tof}$

# Outlook: Signature of Quasi-Free Scattering

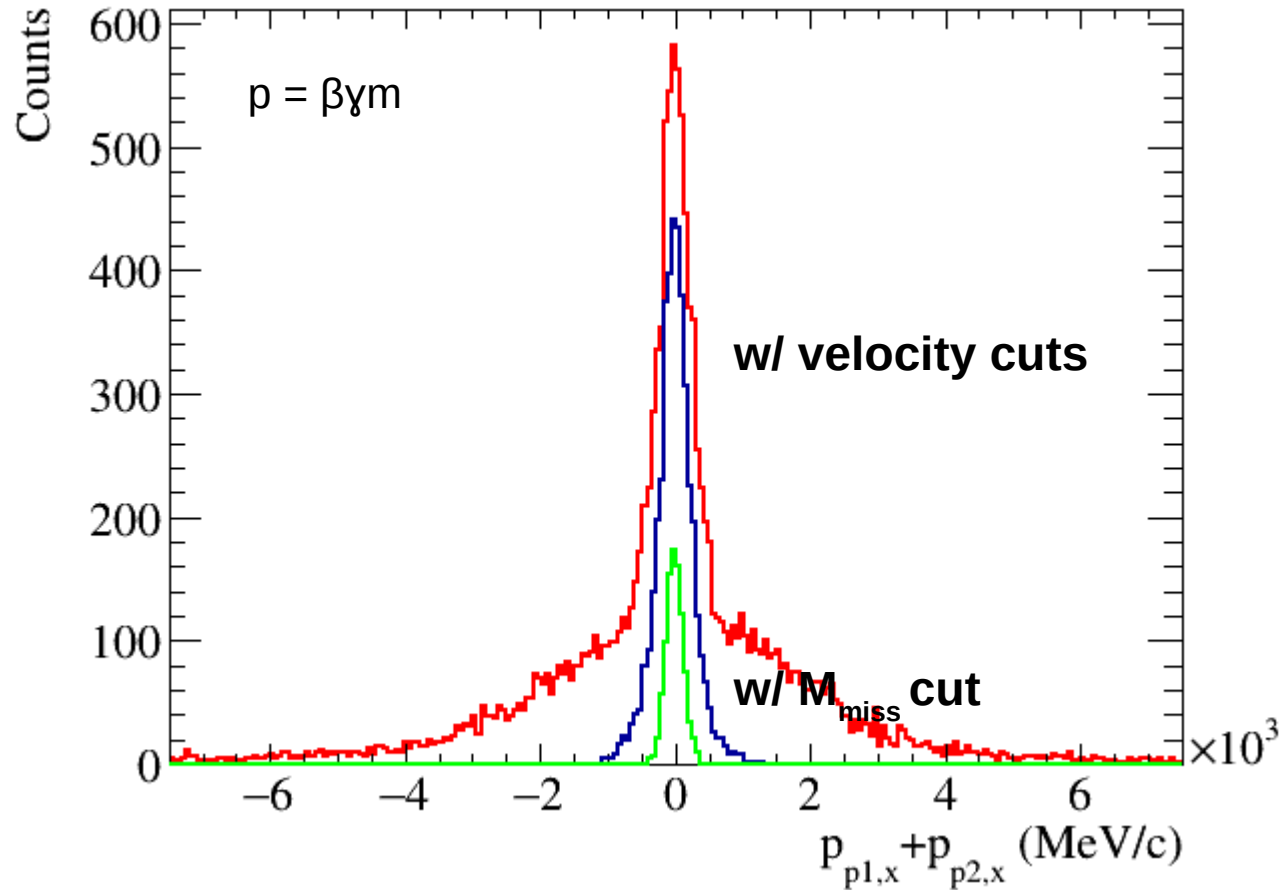


Applying velocity and missing Mass cuts





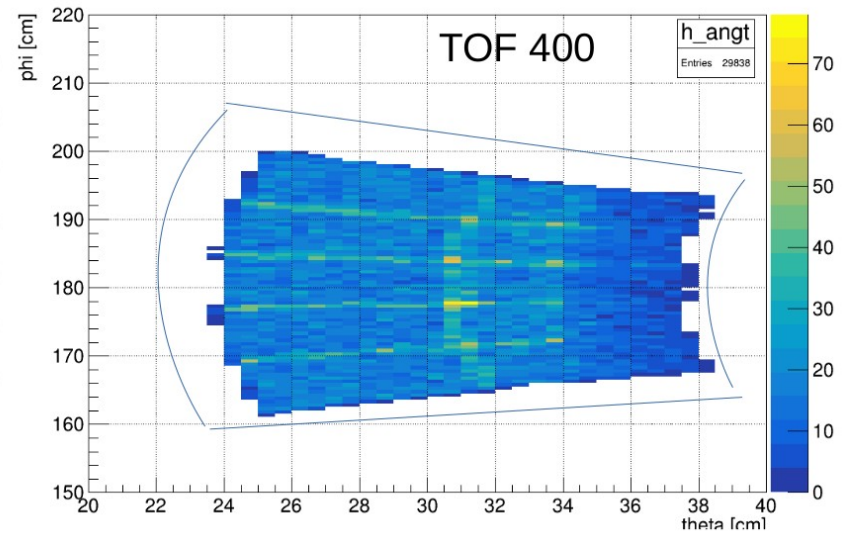
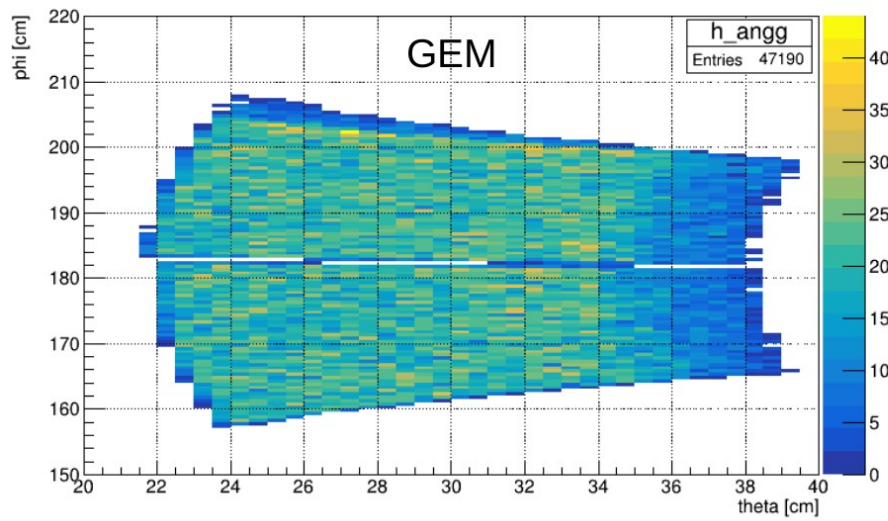
# Outlook: Momentum Distributions

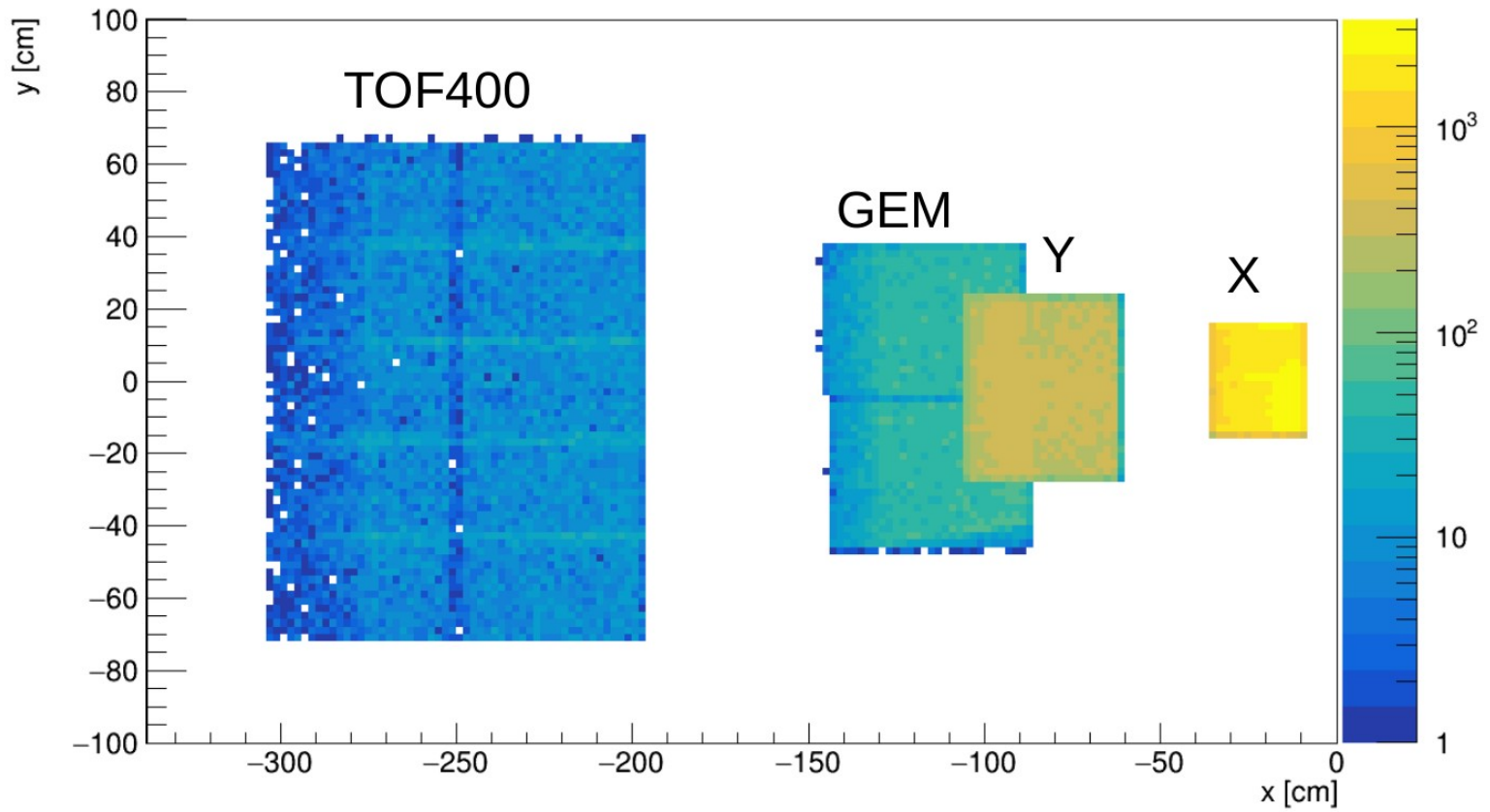


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**Thank You for Your Attention.**  
**Many Thanks to the Collaborators**







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T0	0.763766
T0+BC1	0.763727
T0+BC1+BC2	0.763689
T0+BC1+BC2+X1	0.763593
T0+BC1+BC2+X2	0.763593
T0+BC1+BC2+X1+X2	0.763573
T0+BC1+BC2+X1+Y1	0.763458
T0+BC1+BC2+X2+Y2	0.762708
T0+BC1+BC2+X1+Y1+X2+Y2	0.762669
TRIG+GEML	0.515607
TRIG+GEMR	0.453967
TRIG+GEM	0.331686
TRIG+TOFL	0.31053
TRIG+TOFR	0.324858
TRIG+TOF	0.151399
TRIG+GEML+TOFL	0.231176
TRIG+GEMR+TOFR	0.211943
TRIG+GEM+TOF	0.122993
TRIG+BC3	0.695586
TRIG+BC4	0.558554
TRIG+BC3+BC4	0.55765
TRIG+GEM+TOF+BC3	0.104895
TRIG+GEM+TOF+BC4	0.0750649
TRIG+GEM+TOF+BC3+BC4	0.0748534
11B+12C	185
11B+12C+TRIG	0.983784
11B+12C+TRIG+GEM	0.362162
11B+12C+TRIG+TOF+NOGEM	0.027027
11B+12C+TRIG+GEM+TOF	0.145946
11B+12C+TRIG+GEM+TOF+ARMVTX	0.145946

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