Texas Active Target (TexAT)

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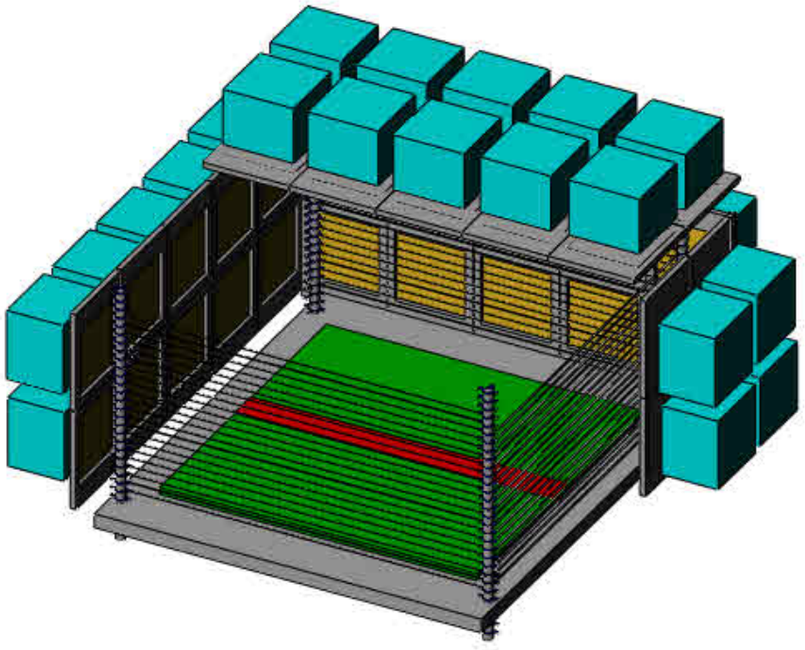
TEXAS A&M UNIVERSITY

Physics with TexAT

TexAT is designed to address questions in:



Structure of exotic nuclei

Clustering phenomena

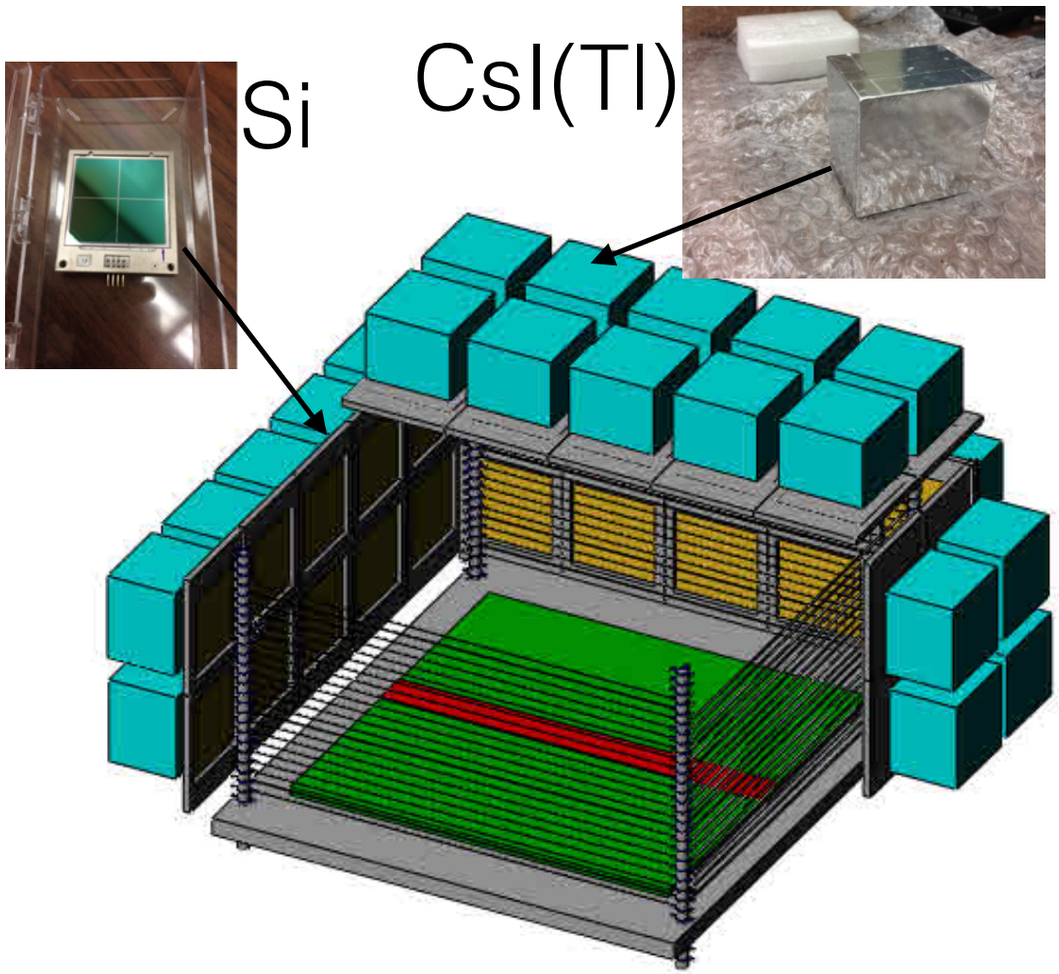
Nuclear astrophysics

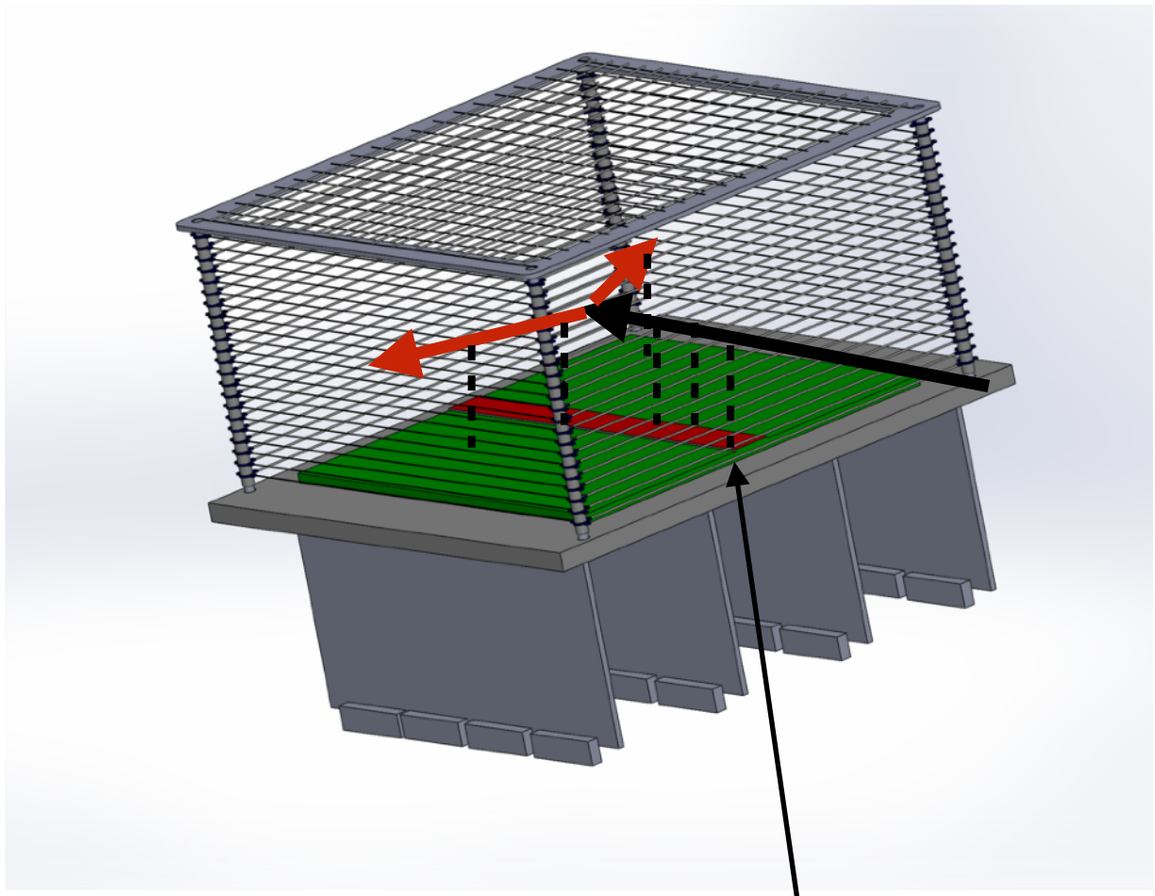
by measuring:

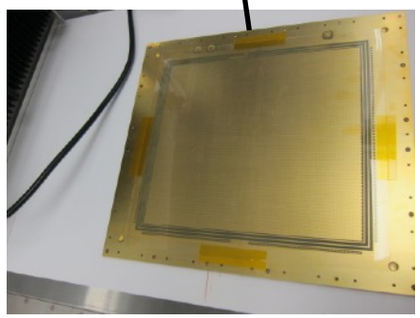
- ☑ Proton and α elastic and inelastic scattering excitation function
- ☑ direct (α,p) and (p,α)
- ☑ β-delayed charged particle decays
- ☑ Transfer reactions: (d,p), (p,d), (p,t), (d,^{3}He), etc.

with RIBs.

Texas Active Target (TexAT)







Si array - 10 quadrant detectors
for the front array,
16 + 8 + 8 top, left
side and right side
8 for the back - 50x4=**200 Si** channels total

CsI(Tl) - 50 scintillators - **50 PIN diode** channels

microMegas -
1,024 channels

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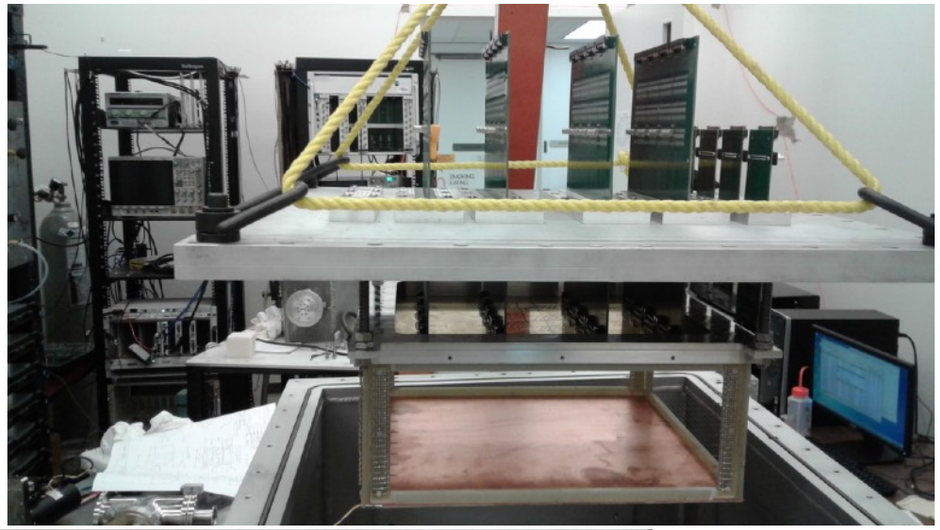
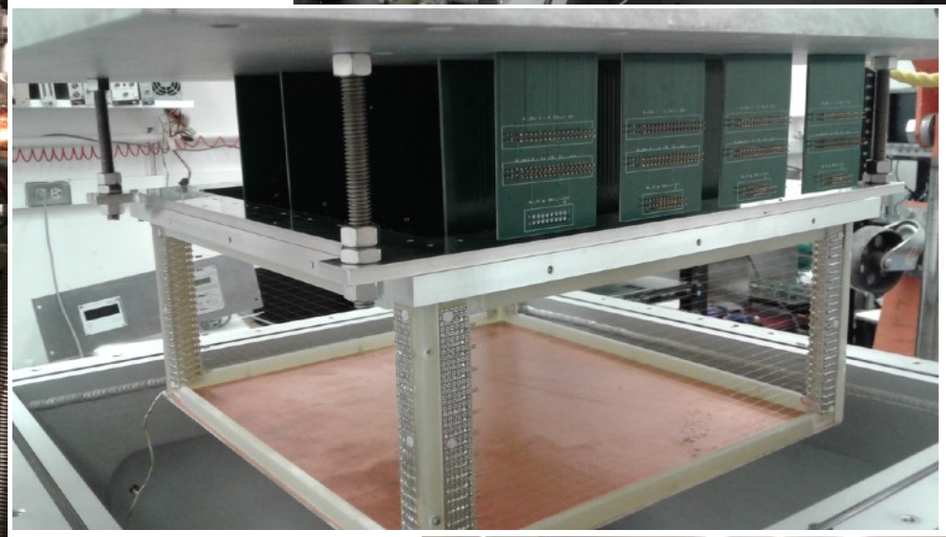
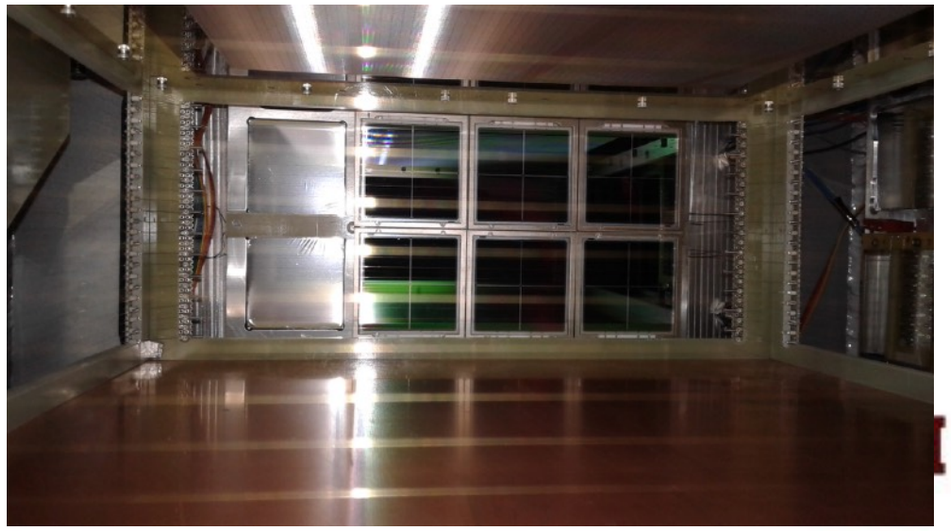


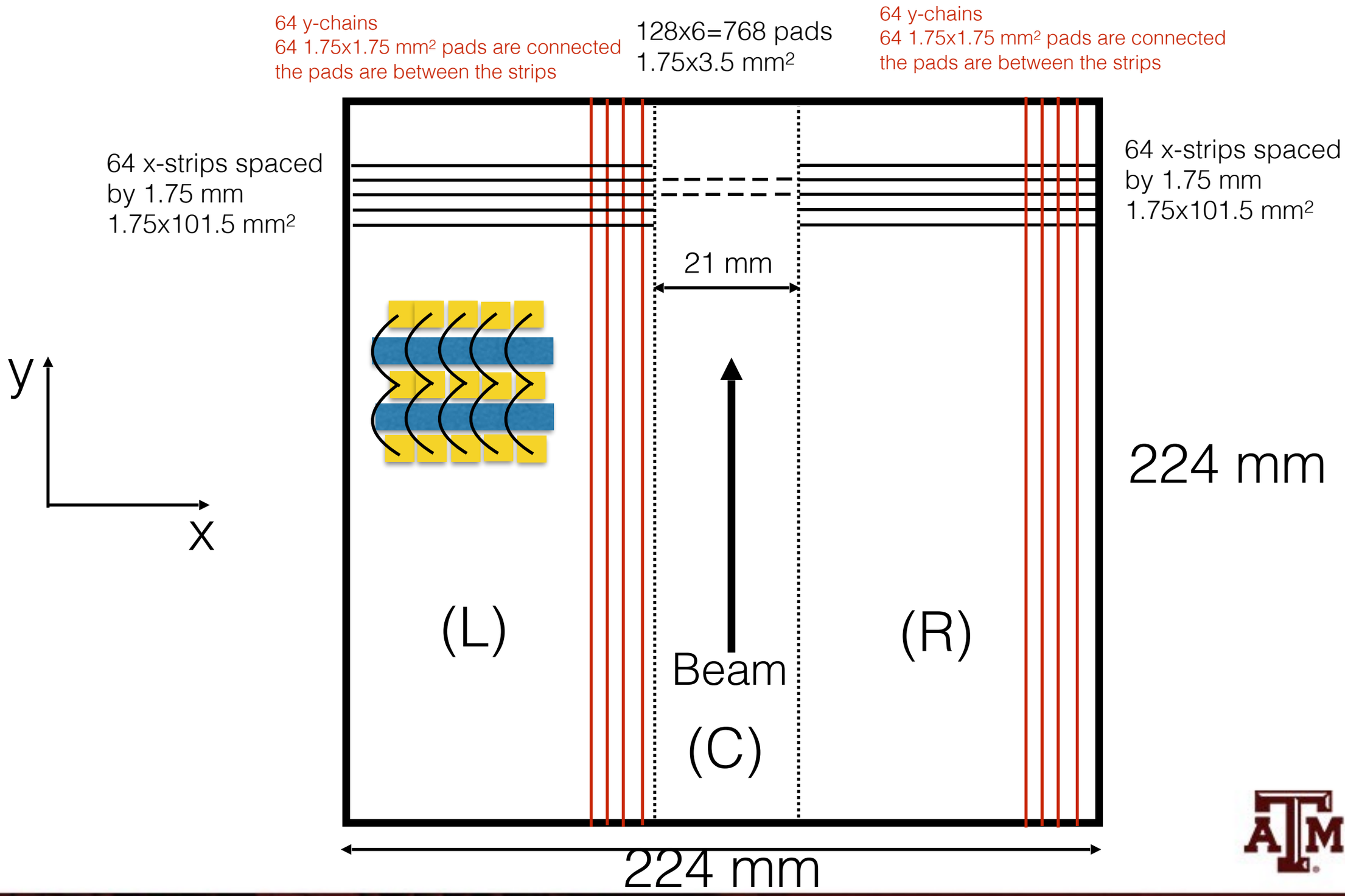


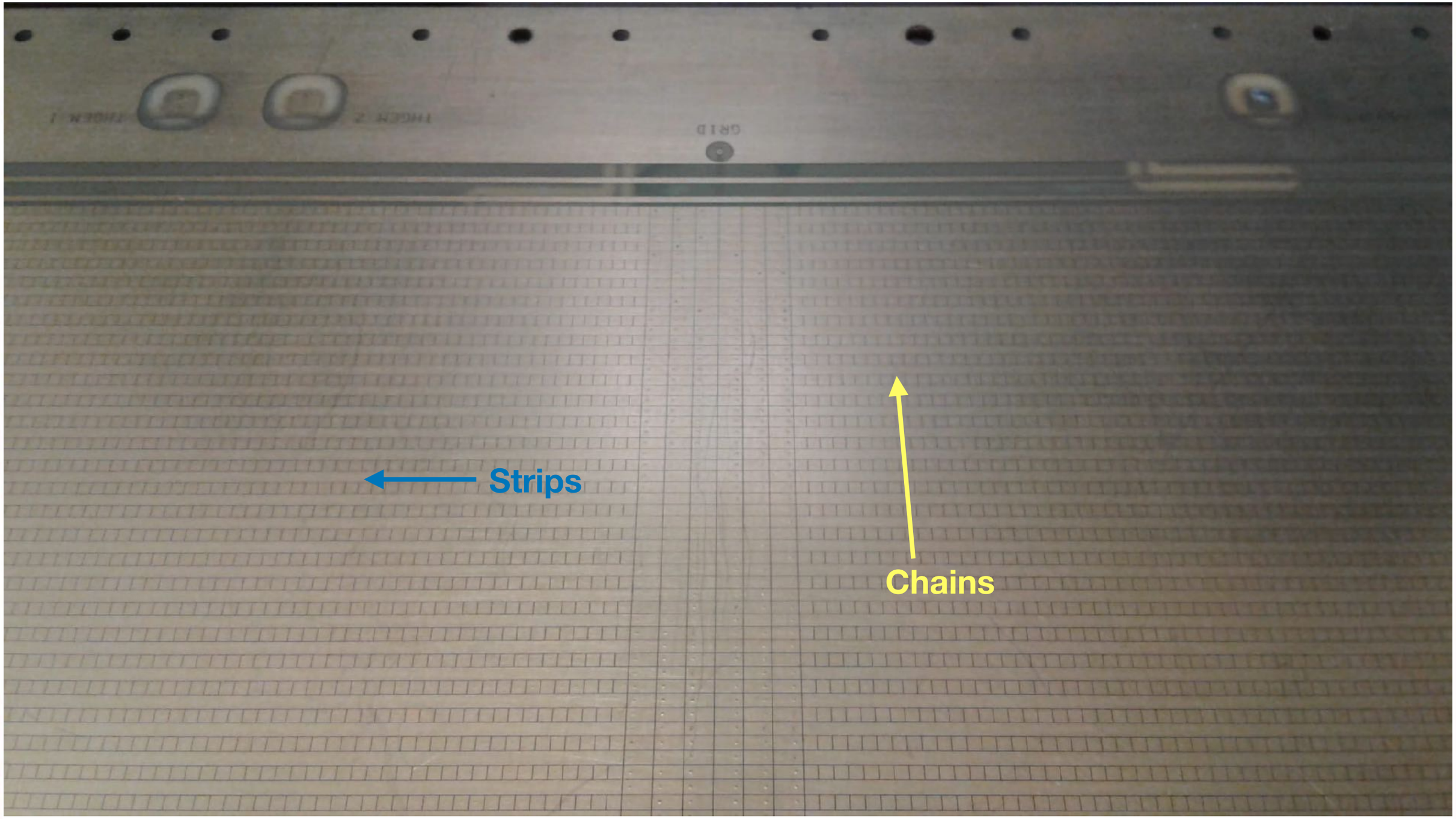


MicroMegas pads design

Active area: 224x224 mm

Number of independent channels: 1024




Strips
Chains
Central Pads
18 mm

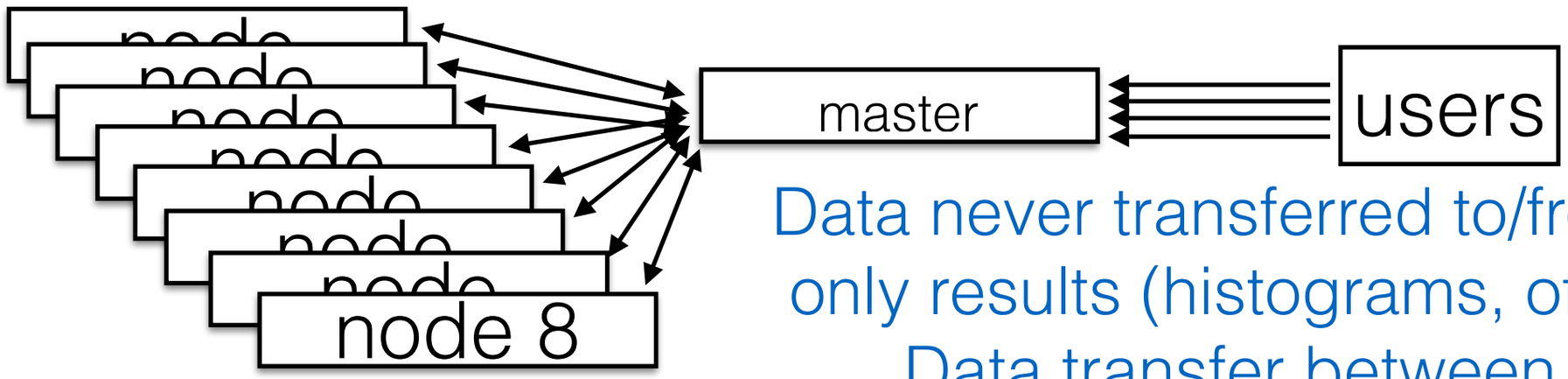
TexAT Utilizes GET Electronics

8 AsAd boards - 2048 channels
2 CoBos, 1 MUTANT
GET is used to read out ALL channels -
microMegas (1024); Si - (200); CsI(Tl) - (50)

Analysis Computing Infrastructure

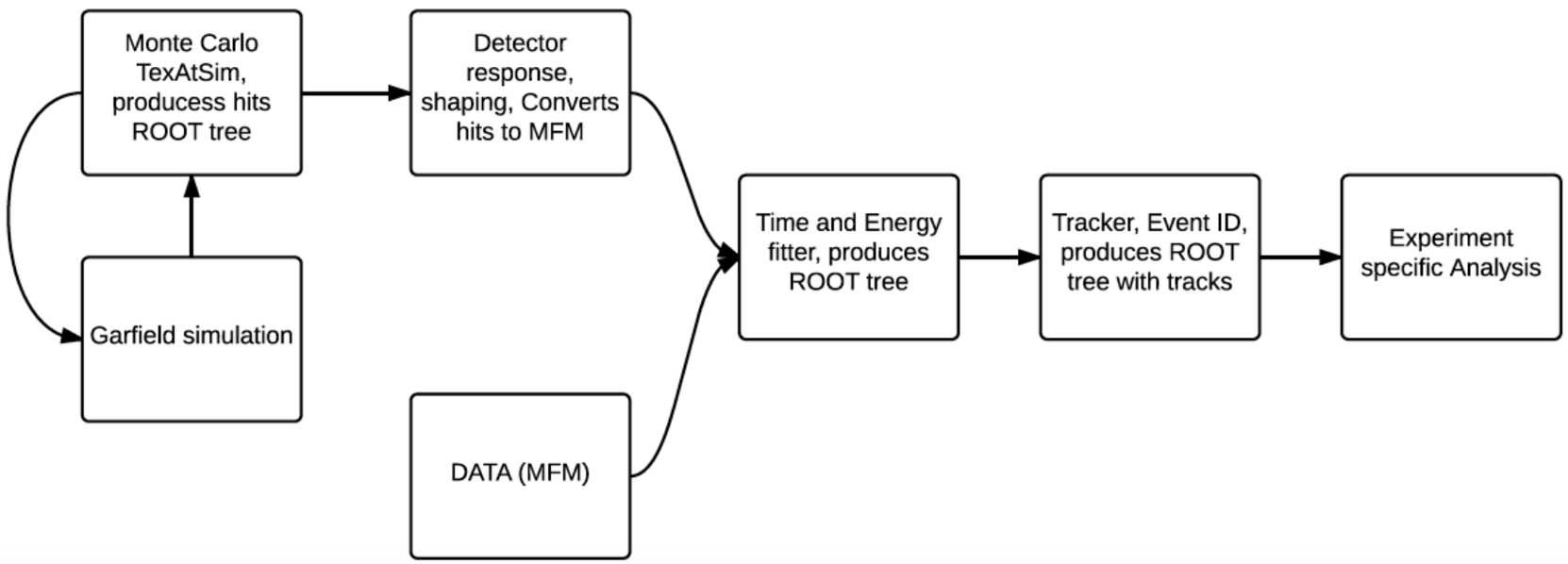
- Using "Big Data" tools actively supported and developed by a very large community (but still open source!)
- HDFS (Hadoop Distributed File System) for all data storage
  - Redundant, fault-tolerant, high-availability *distributed* file system
- Spark cluster engine handles parallel tasks
  - Spark + PyROOT gives parallel, **data local**, parallel processing of ROOT trees with TSelectors, similar to PROOF but more general with larger development base
  - Simple Python wrapper (less lines than a Condor script) allows easy batch processing (i.e. Geant4 applications)
- Entire compute/data node environment is contained in a Docker image and runs in a container
  - Setup of entire node after operating system install takes < 5 minutes

TexAT designated Cluster architecture



Data never transferred to/from master,
only results (histograms, of example)
Data transfer between nodes
minimized automatically by Spark software

TexAT software suite flowchart



Analysis Computing Infrastructure

Parallel Analysis Example:

~30 GByte data
230,000,000 events
1 Gbit network

Case 1	Case 2
✦ 1 node, 1 core	✦ 4 nodes, 24 cores
✦ All files looped with TChain	✦ Each file processed as separate task
✦ No data locality	✦ Data locality preferred
870 seconds 0.27 Gbit/s	40 seconds 6.0 Gbit/s

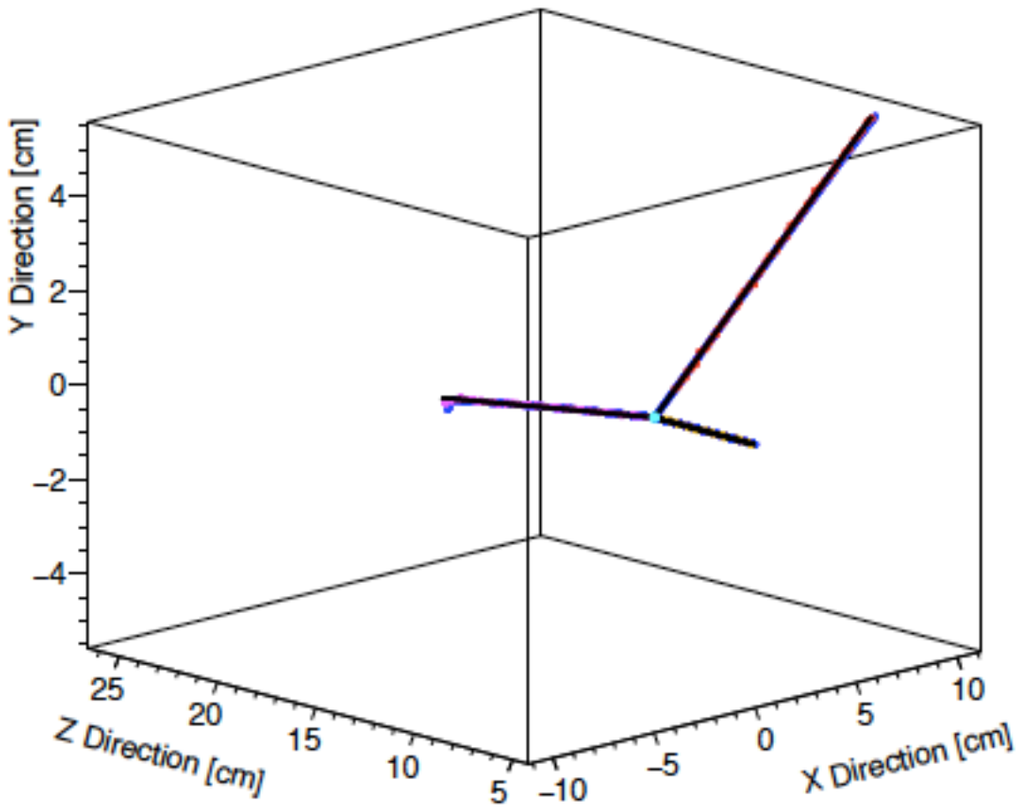
← *90%* →

With existing 8 node / 120 cores cluster **260 TB** of data can be **ALL** analyzed in ~**5 days** (except we do not have 260 TB data storage)

Vertex Reconstruction

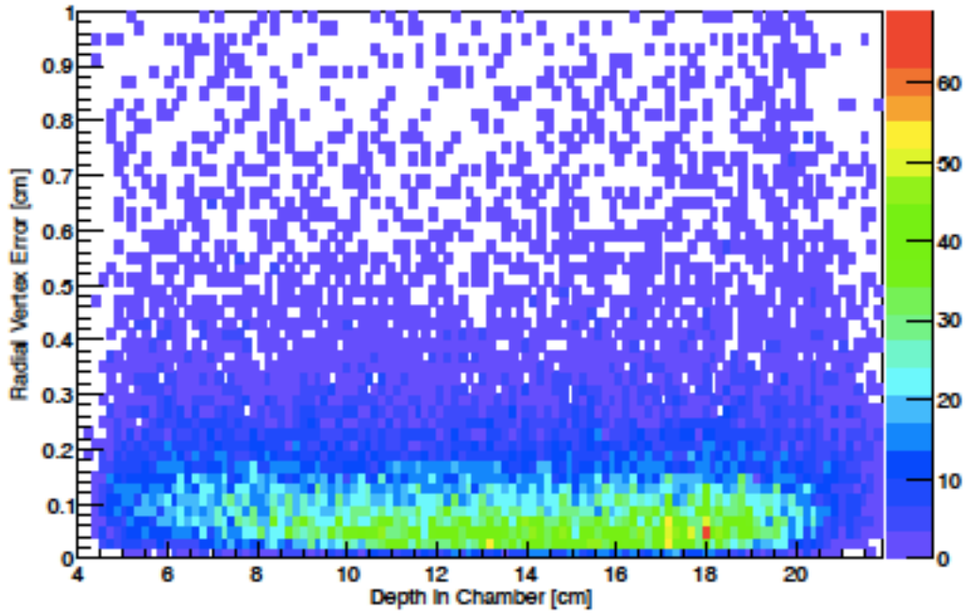
Procedure:

1. Assign incoming points in central region based on hits in ALL rows
2. Look for light particle hits in side regions and map strips(chains) to chain(strips) based on timing
3. If no side region hits, try to break central track using an energy discontinuity



4. Fit light product and incoming vectors and use point of closest approach to break incoming track into incoming and recoil points
5. Refit all light product, incoming and recoil points with three vectors intersecting at a vertex

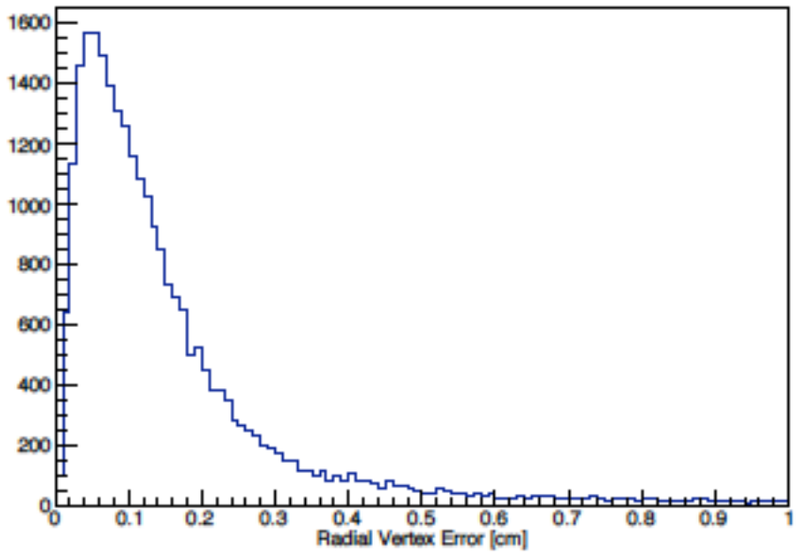
Vertex Reconstruction



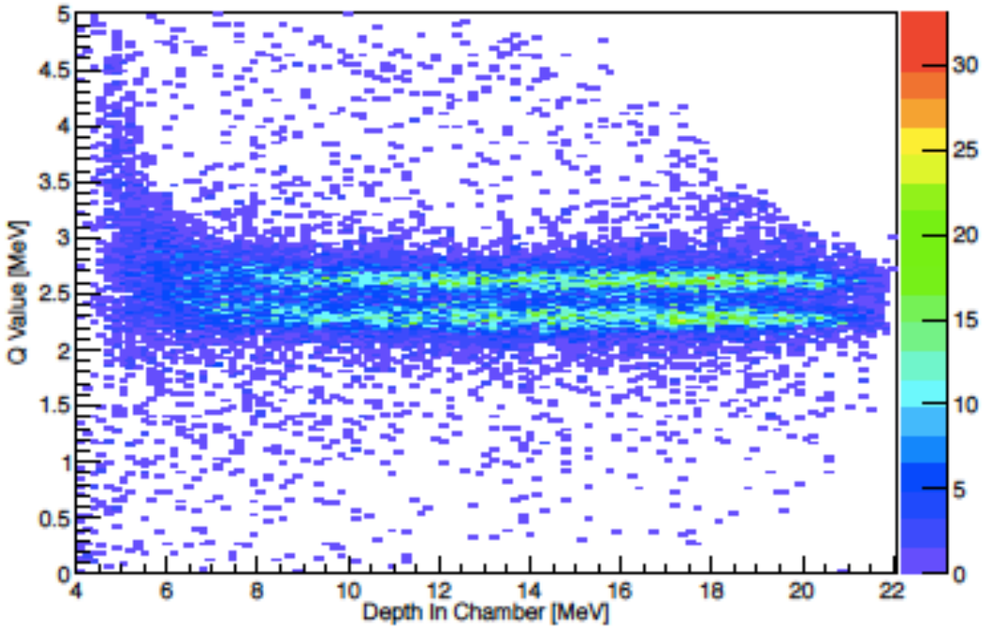
- Mean radial vertex error of 1.2 mm, peaking at 0.6 mm
- Reconstruction nearly independent of position

Future Improvements:

1. Use center of gravity for each row to determine incoming transverse position
2. Constrain events to be in a single reaction plane
3. Tailored for binary reactions — must generalize!



Q-Value Reconstruction

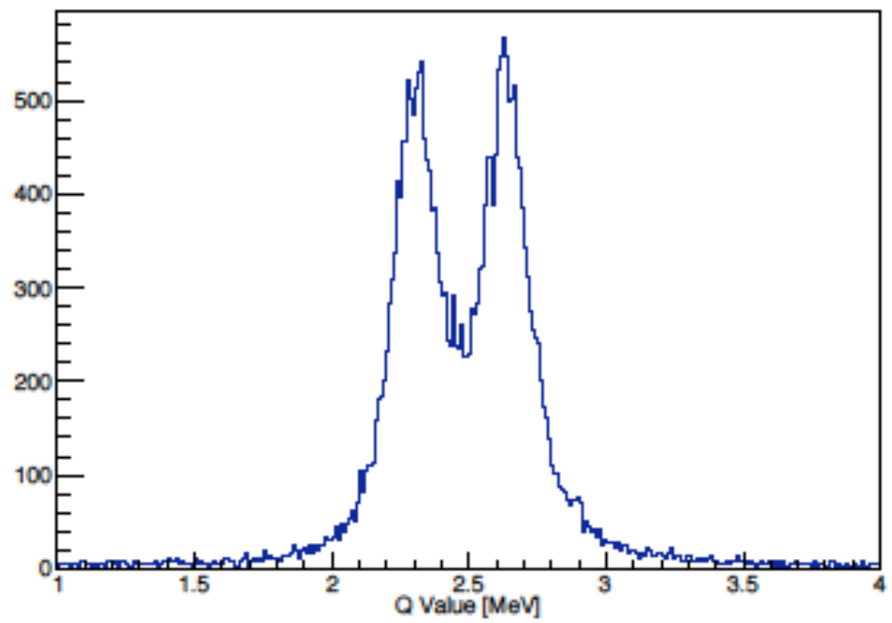


Q-value reconstruction uses energy of light particle from Si detector, incoming energy from vertex, and light particle angle

$^{18}Ne(\alpha,p)^{21}Na$ Q-Value: 2638.21 keV

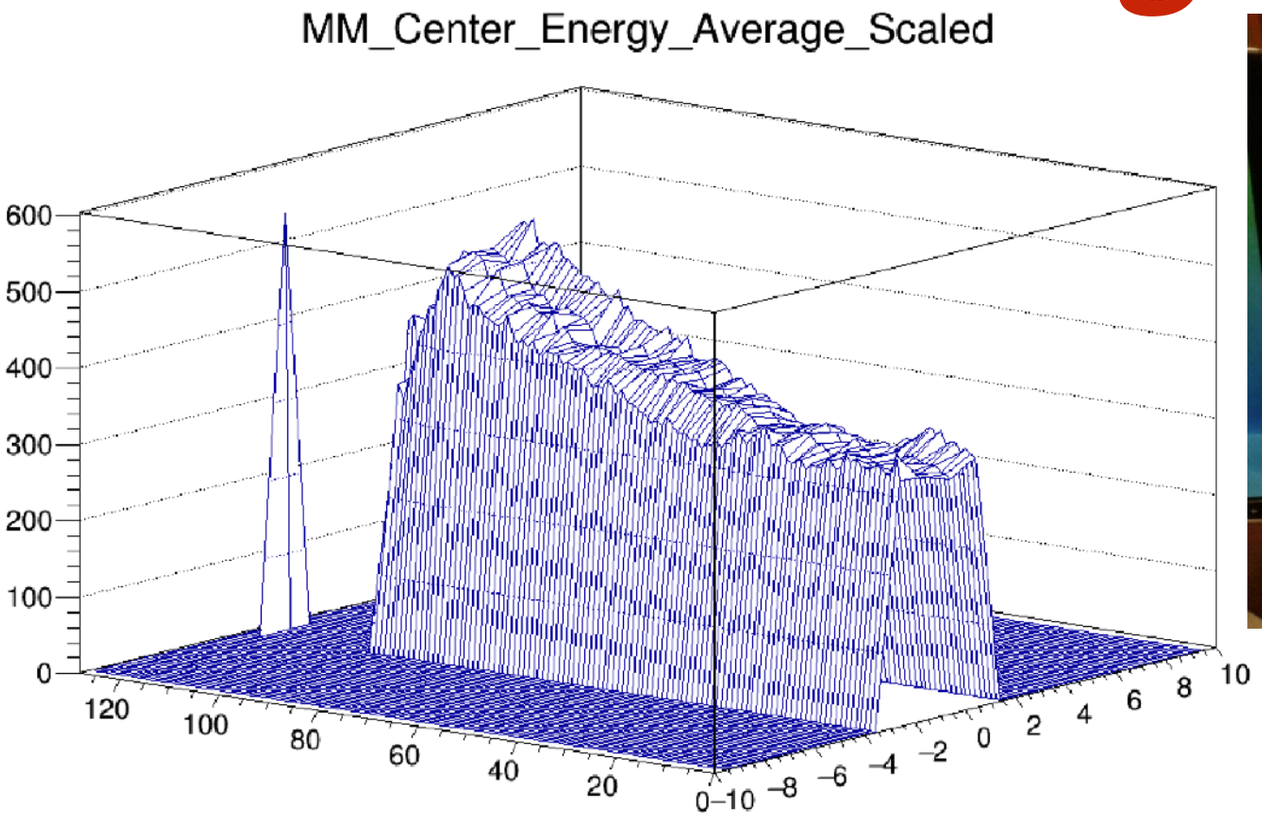
^{21}Na First Excited State: 331.90 keV

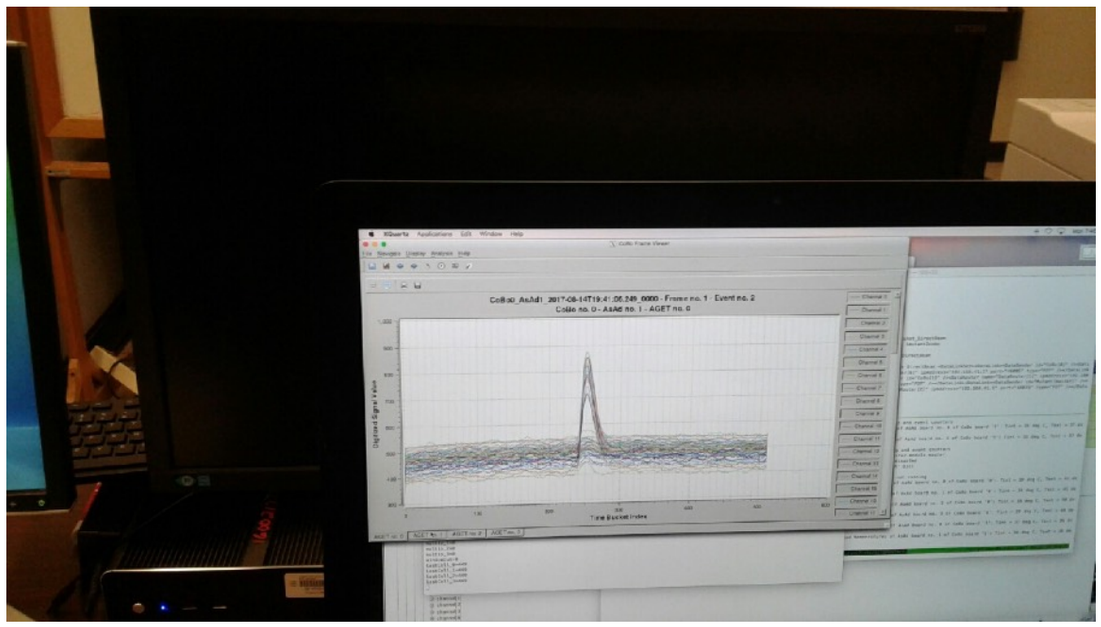
Q-value resolution: FWHM ~ 220 keV



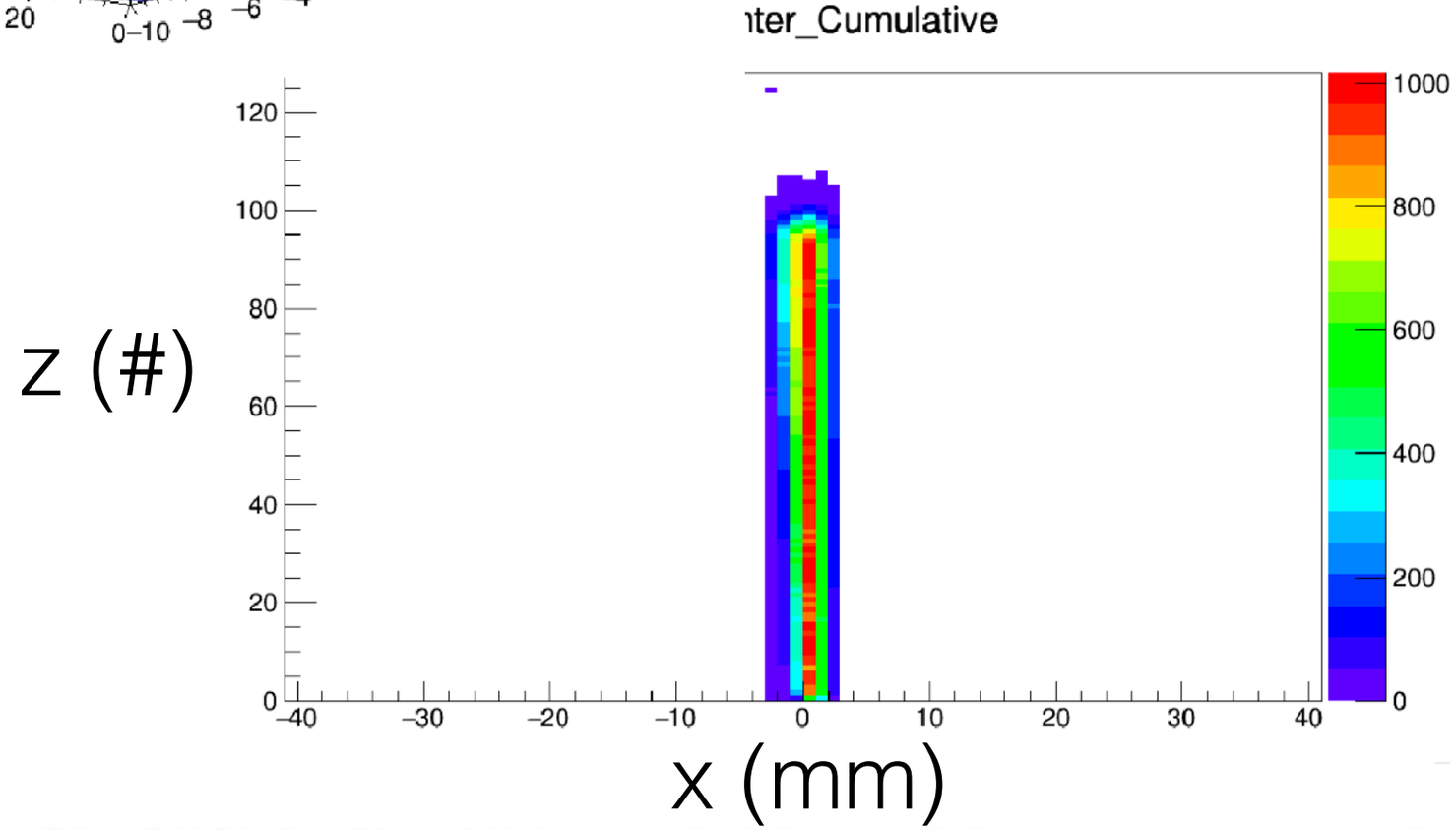
First light!

^{12}C beam - 50 MeV

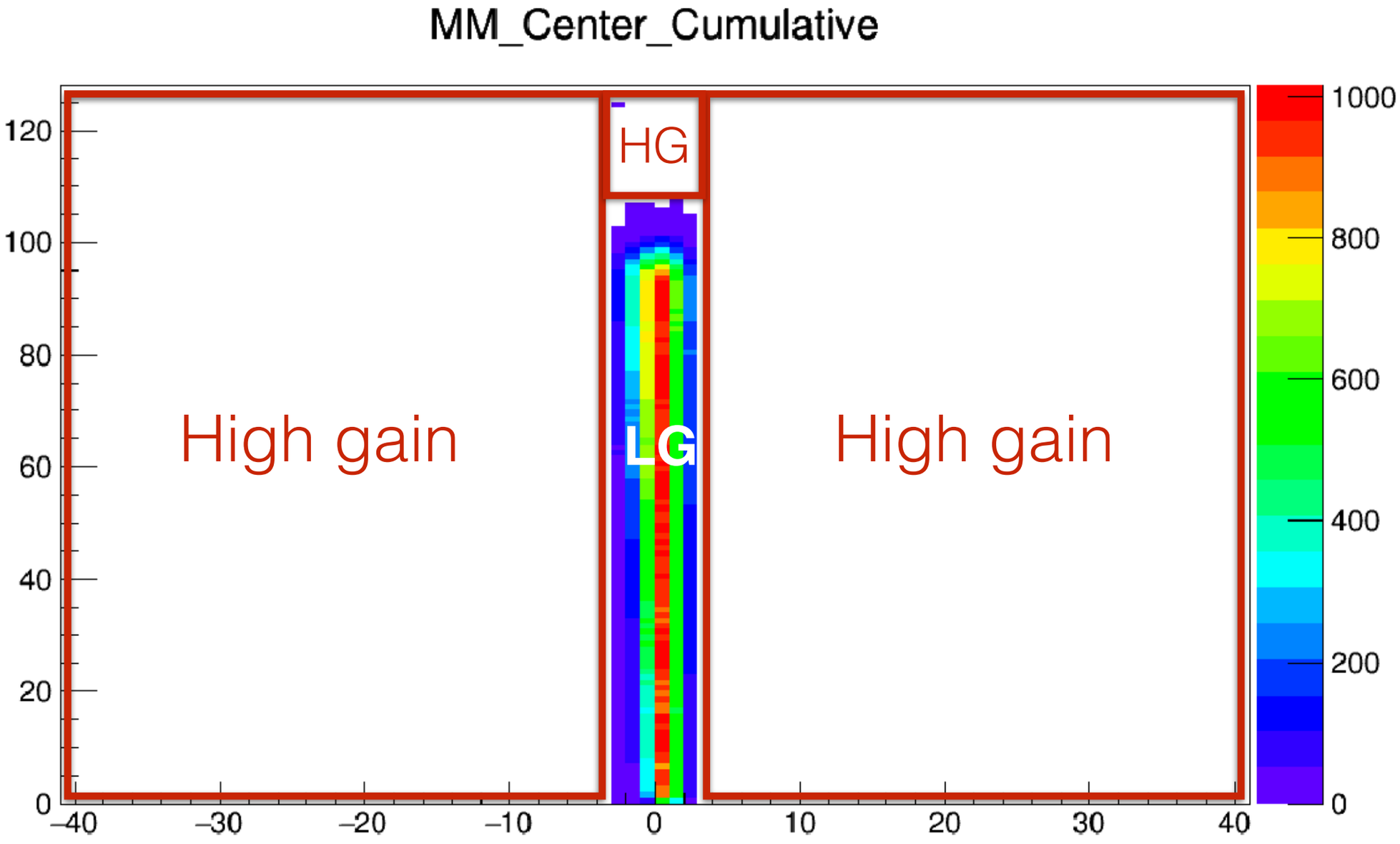


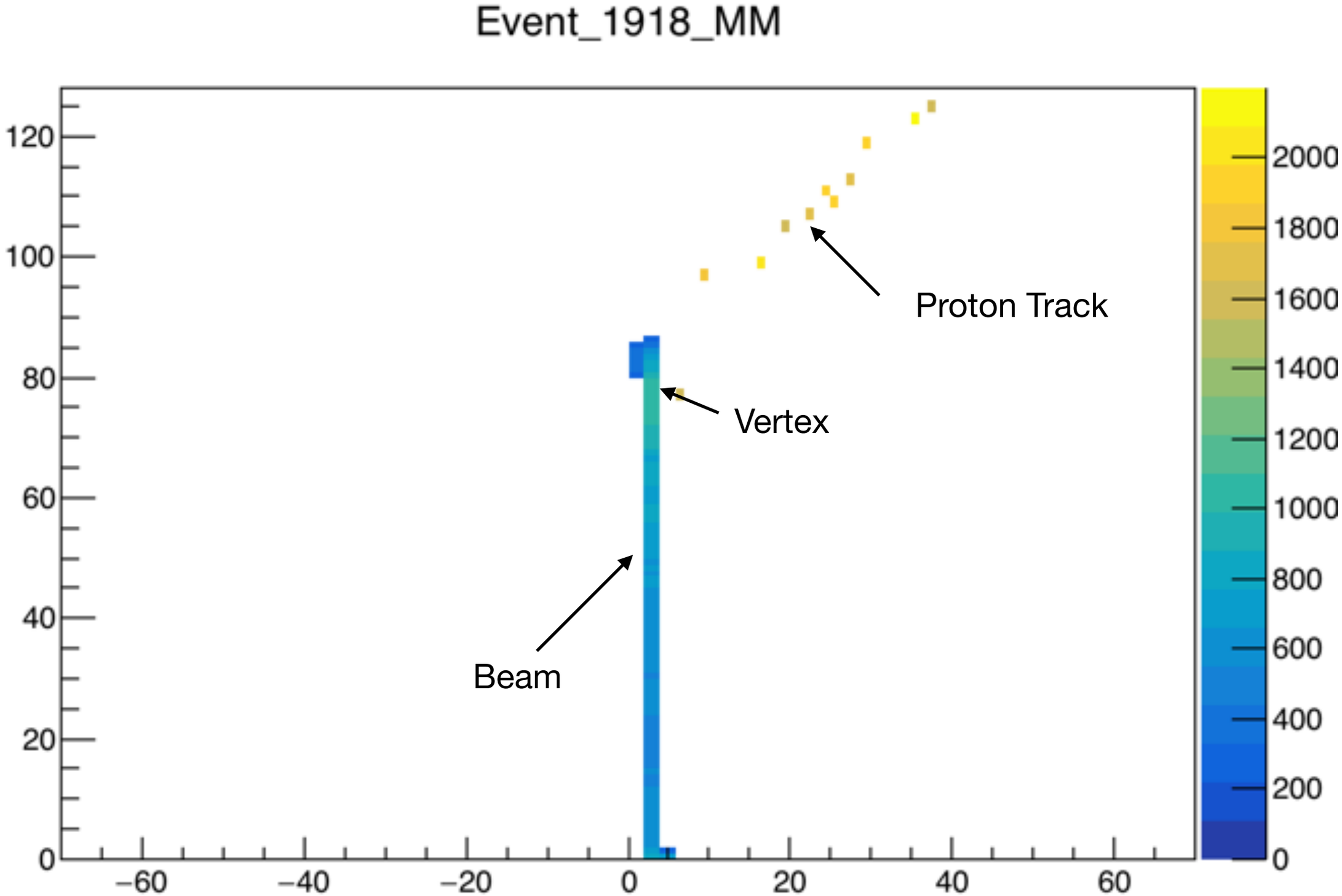


FIRST EVER BEAM EVENT IN TexAT
August 14, 2017 19:54:03

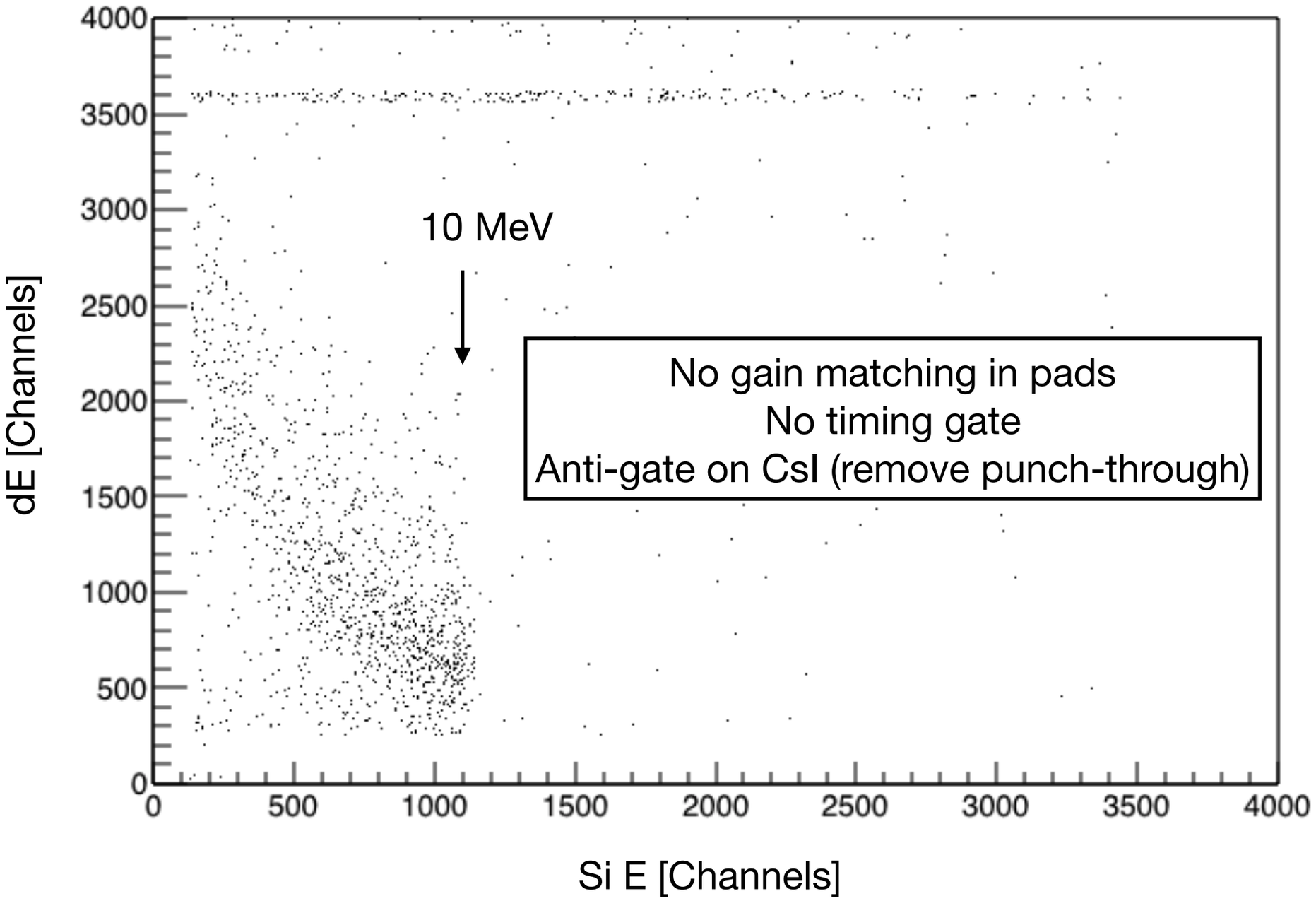


High/Low gain regions

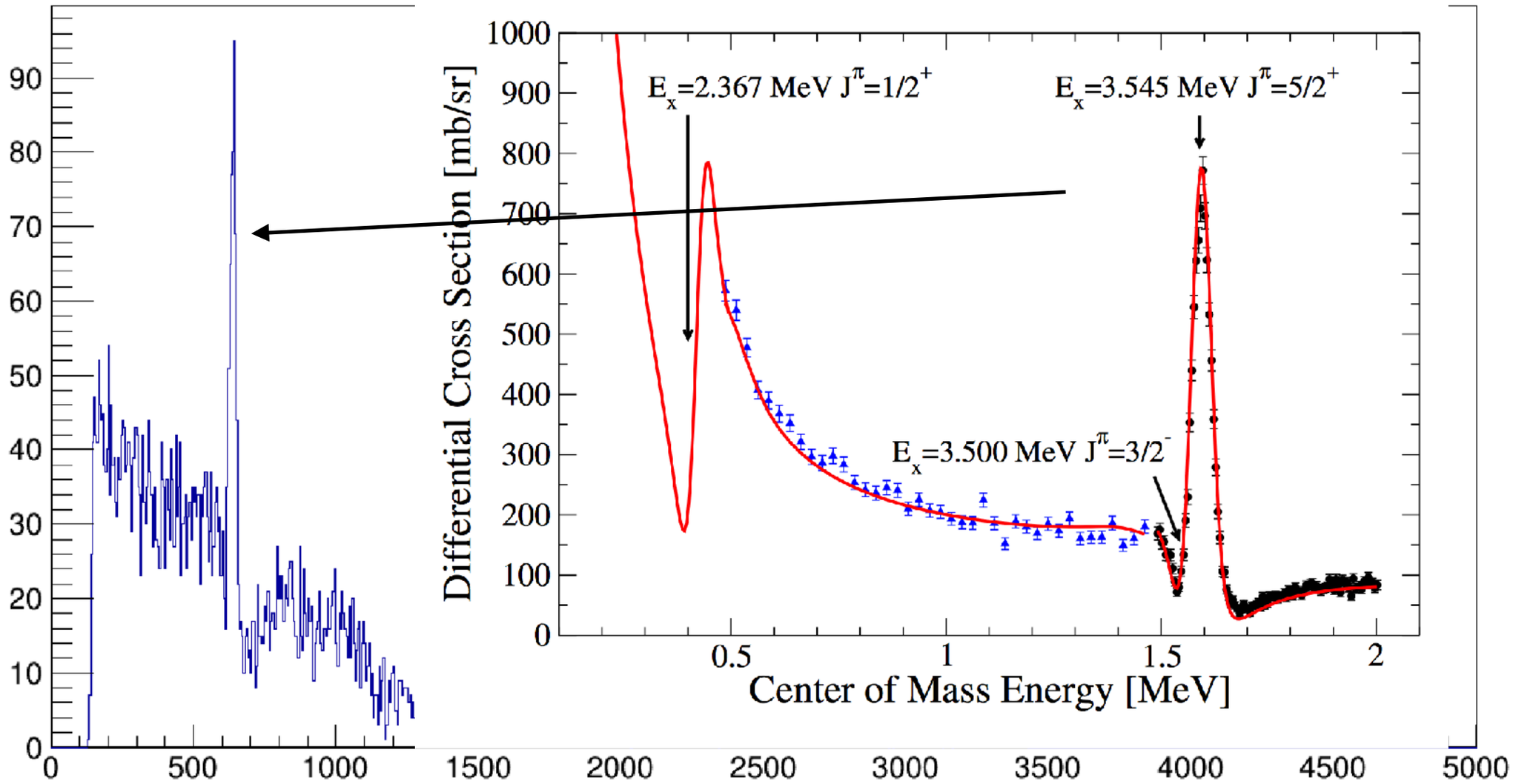



Event_1918_MM
Proton Track
Vertex
Beam
120
100
80
60
40
20
0
−60
−40
−20
0
20
40
60
2000
1800
1600
1400
1200
1000
800
600
400
200
0

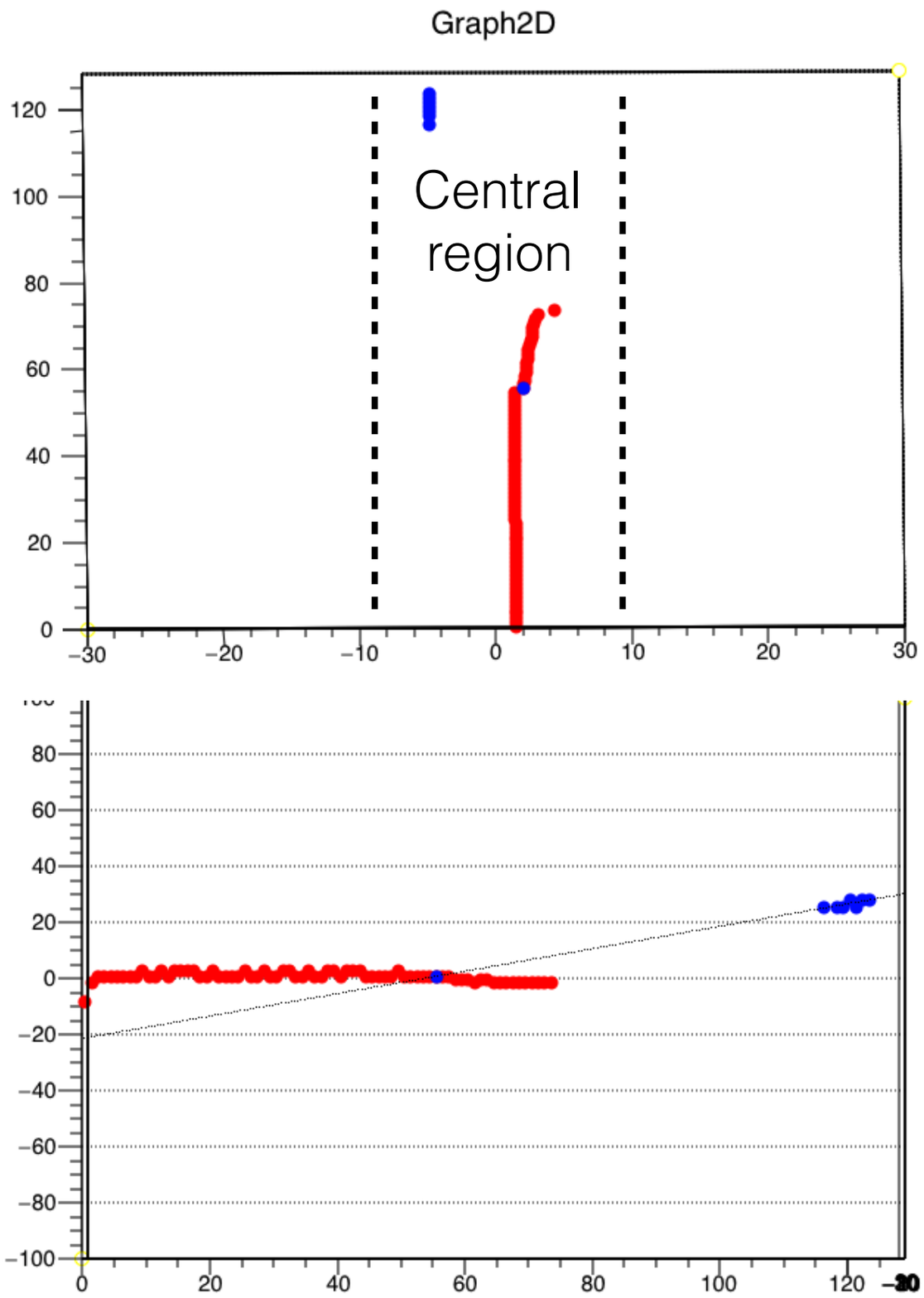
Looking at one of the central row of pads vs energy in forward detector

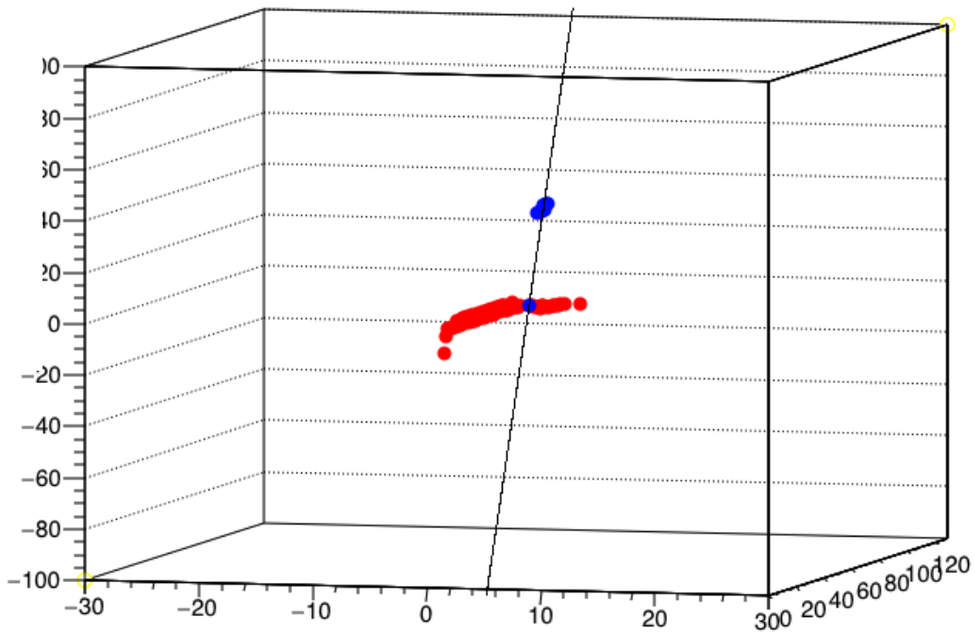


^{12}C(p,p) Forward Silicon Detector

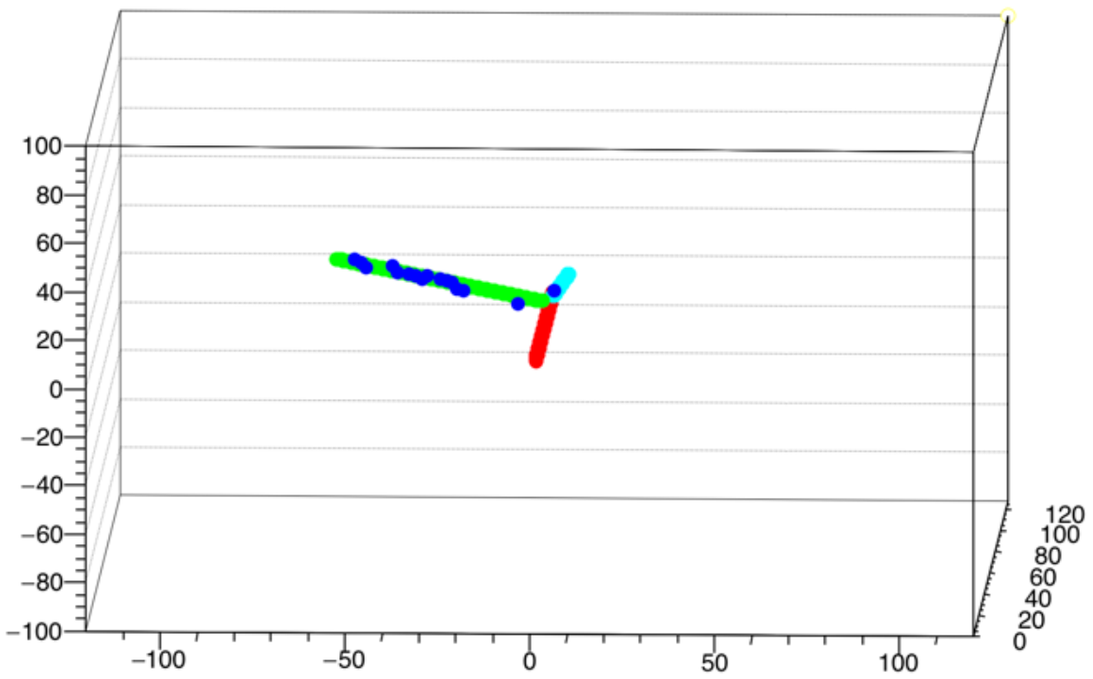


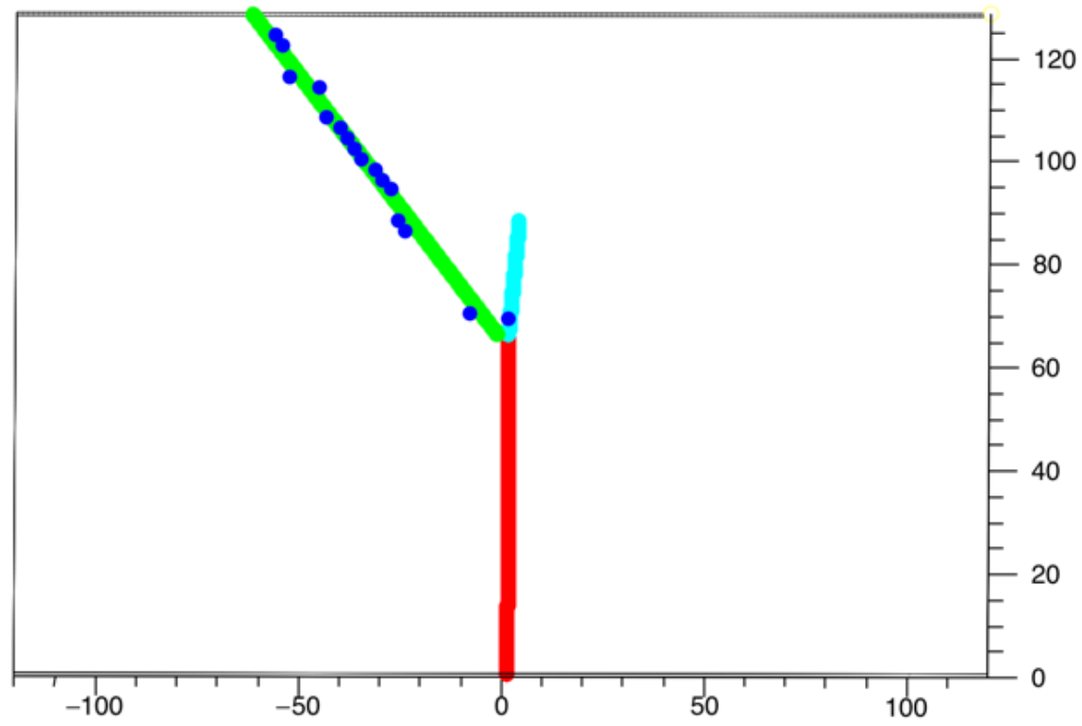
Typical event: Only central pads

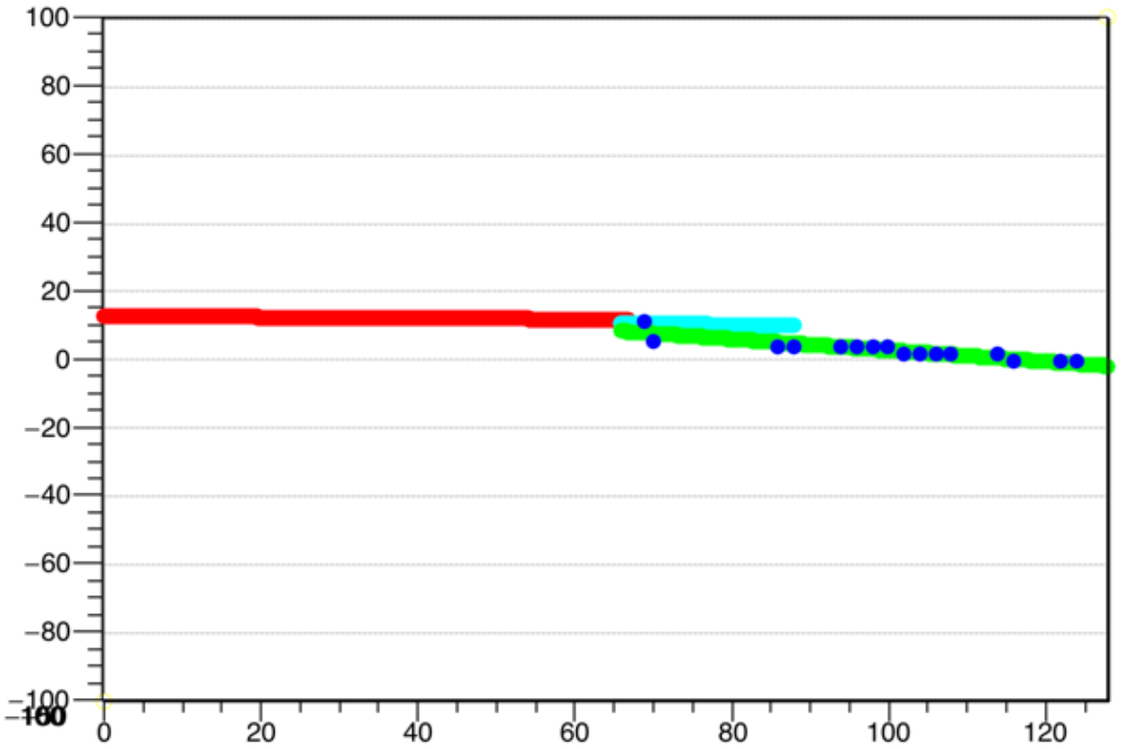




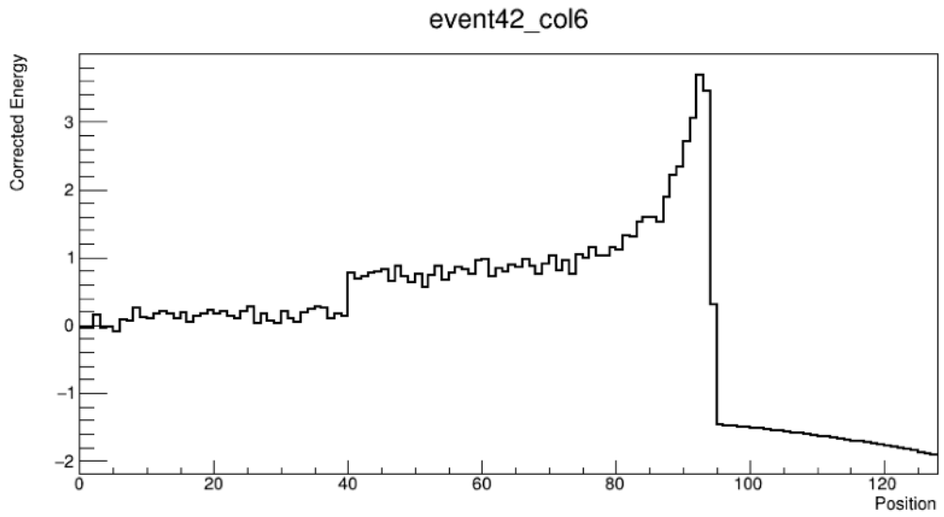
Typical event: Proton in Strips and Chains region

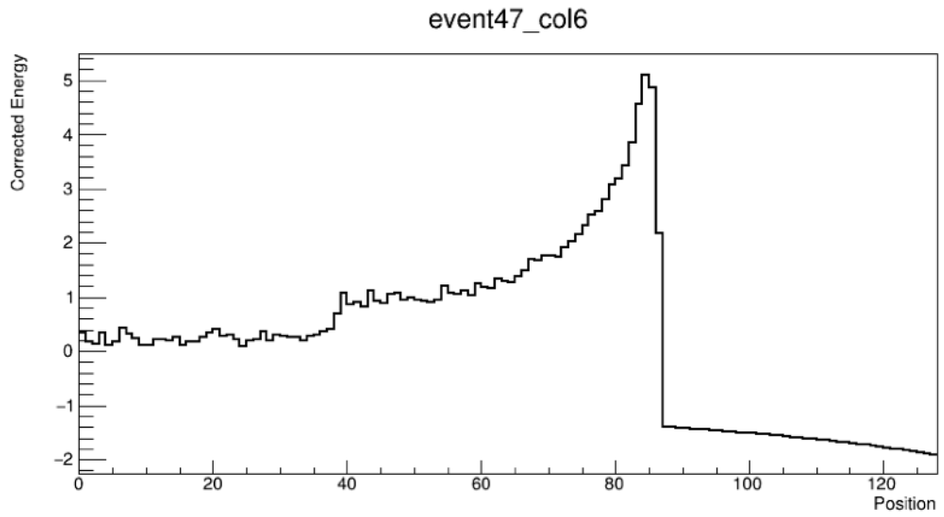


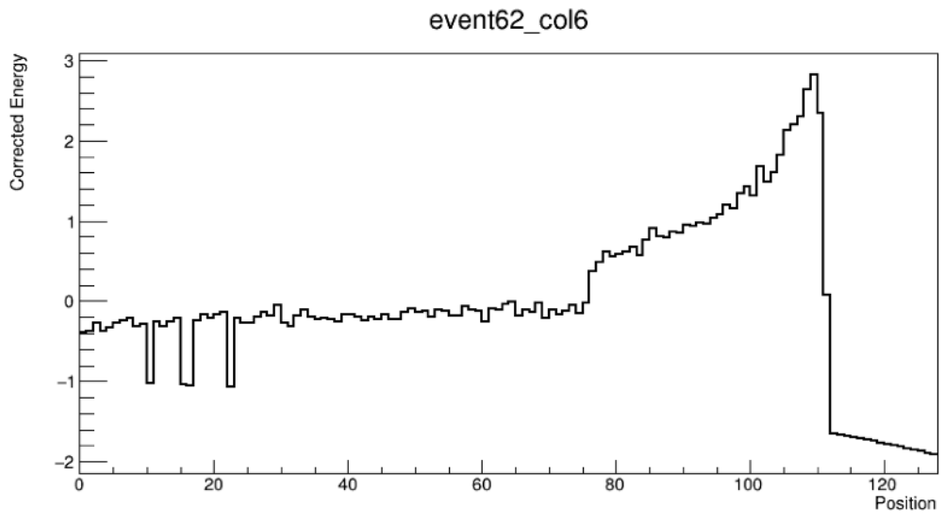


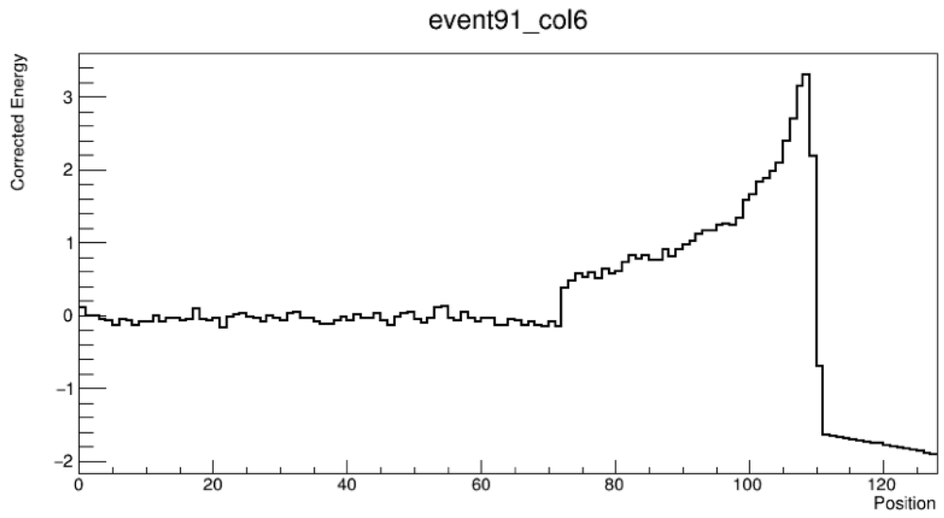


Identifying vertex by energy loss

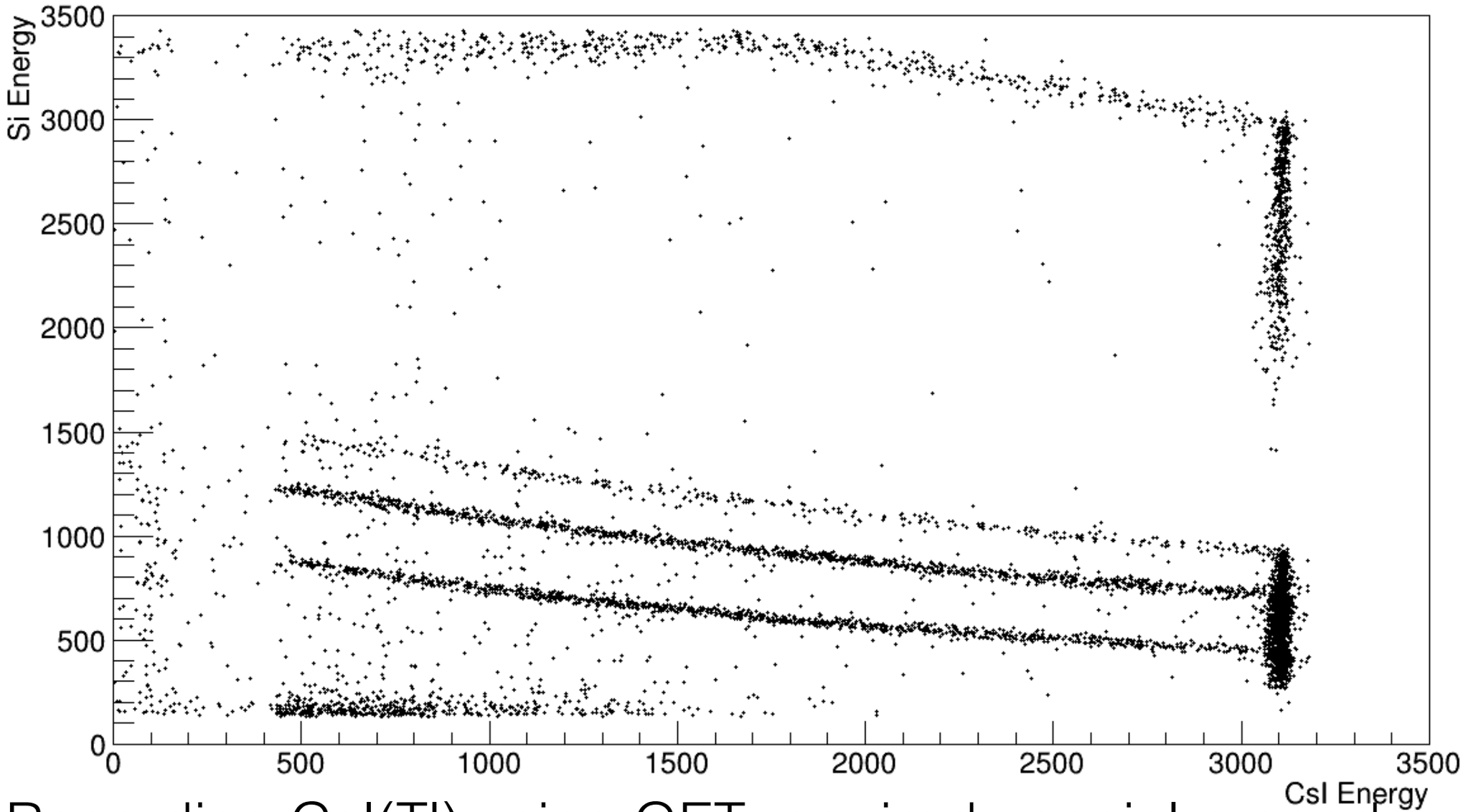








Si - CsI(Tl) dE-E plot, ^{8}Li beam

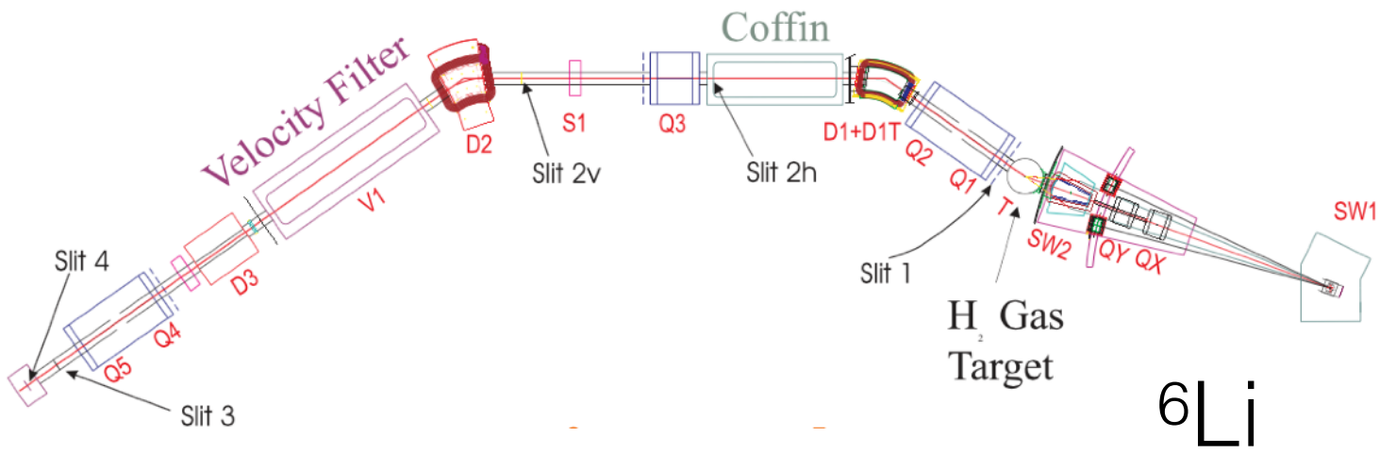


- Recording CsI(Tl) using GET required special procedure
- MESYTEC shaper output, shifted by 0.7 V, fed directly to gain2/inverter (last stage in AGET chip)
- ASTRE chip is a natural next step

Structure of ^{9}C: ^{8}B+p

Motivation:

Energy of sd-shell in A=9 T=3/2 iso-multiplet



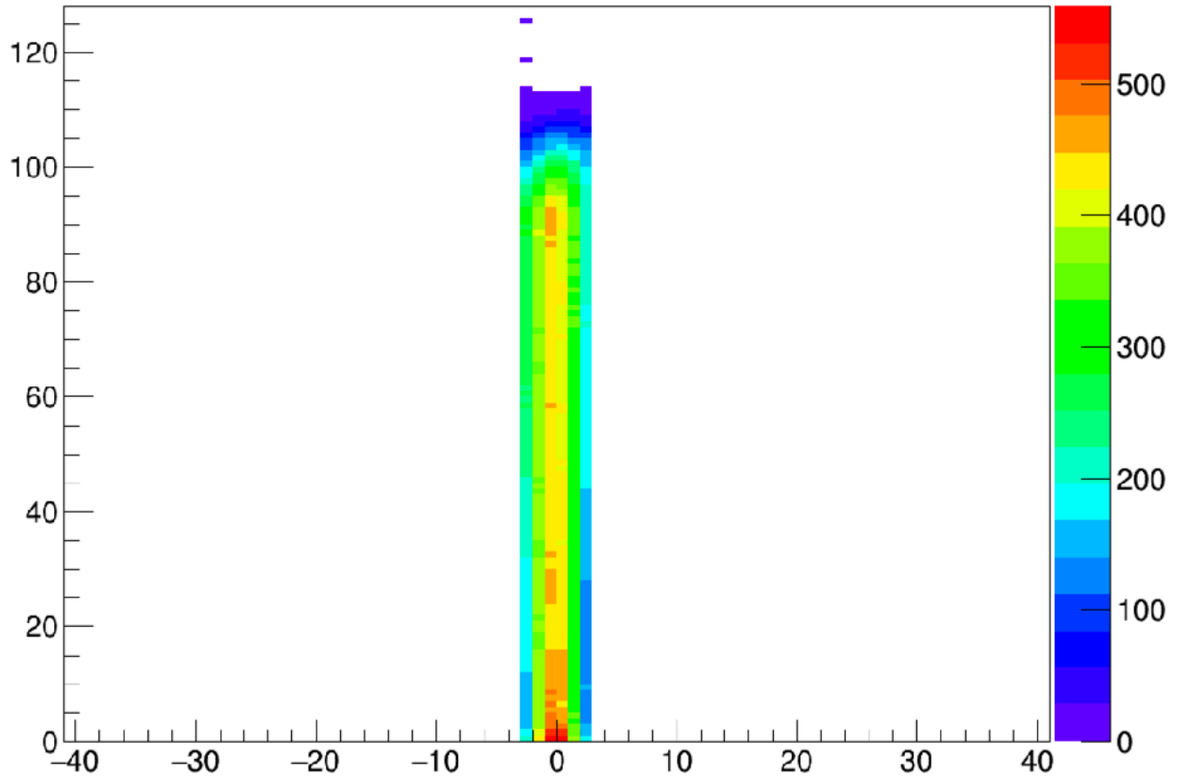
^{6}Li

First radioactive beam in TexAT

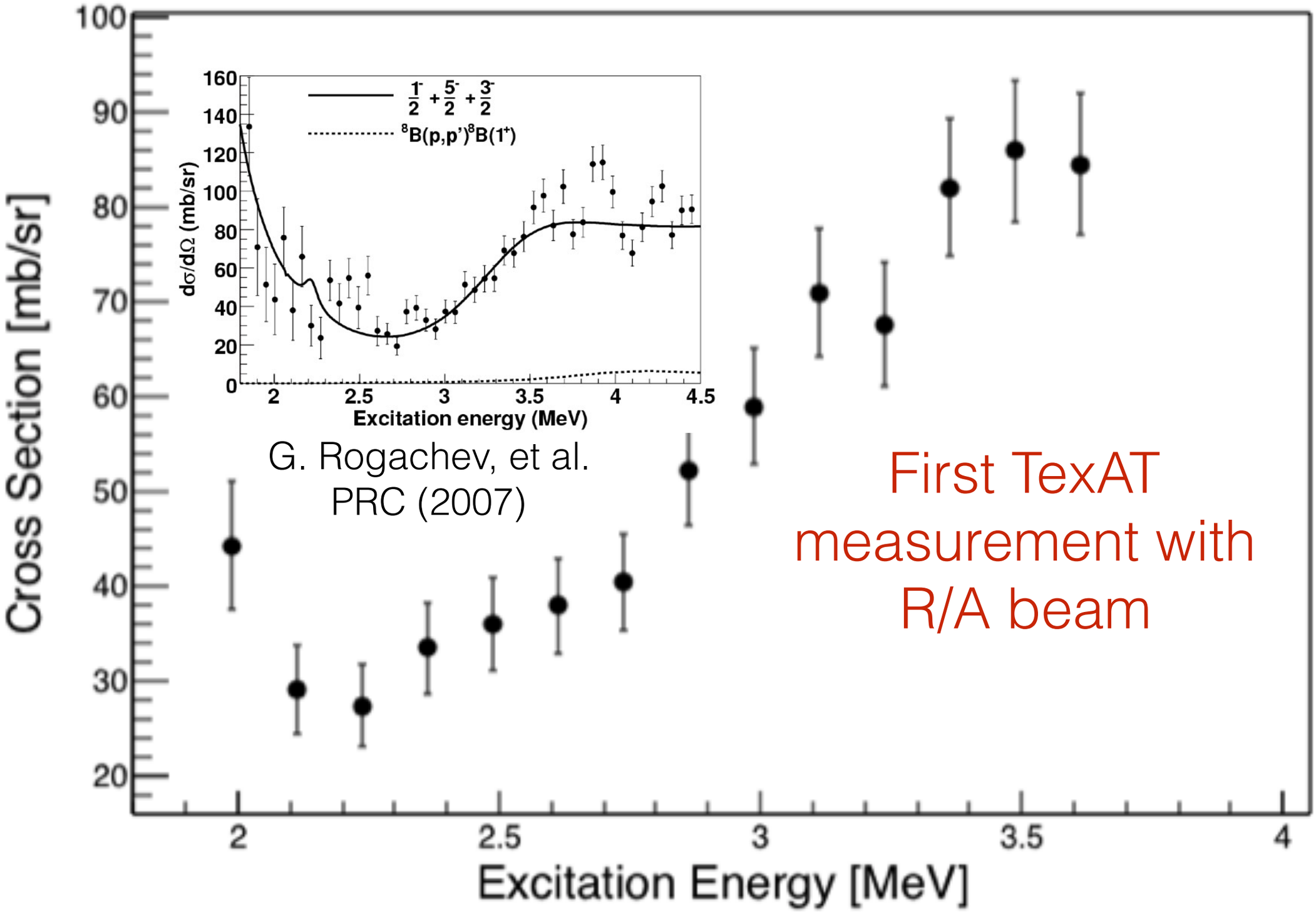
^{8}B at 7.5 MeV/u

10^{3} pps (~97% purity)

Methane at 500 torr



Excitation function for ^{8}B+p



G. Rogachev, et al.
PRC (2007)

First TexAT measurement with R/A beam

Future Improvements

- Gas amplifiers technology: use GEM-microMegas, double GEM and ThGEM
- ASTRE chip for CsI(Tl)
- Complete Si detectors array

Near future experimental campaigns

- Clustering: α elastic and inelastic scattering with r/a beams
- Isobaric Analog states: Proton scattering with neutron rich r/a beams
- Fusion CS of weakly bound isotopes

Summary

- ☑ TexAT - versatile active target detector system for measurements with rare isotope beams
- ☑ Combines microMega TPC, Si array and CsI(Tl)
- ☑ All channels are read out by GET electronics
- ☑ Commissioned in August 2017 - ^{8}B+p resonance scattering
- ☑ Improvements are planned
- ☑ The next campaign (with helium gas as an active volume) is planned for April

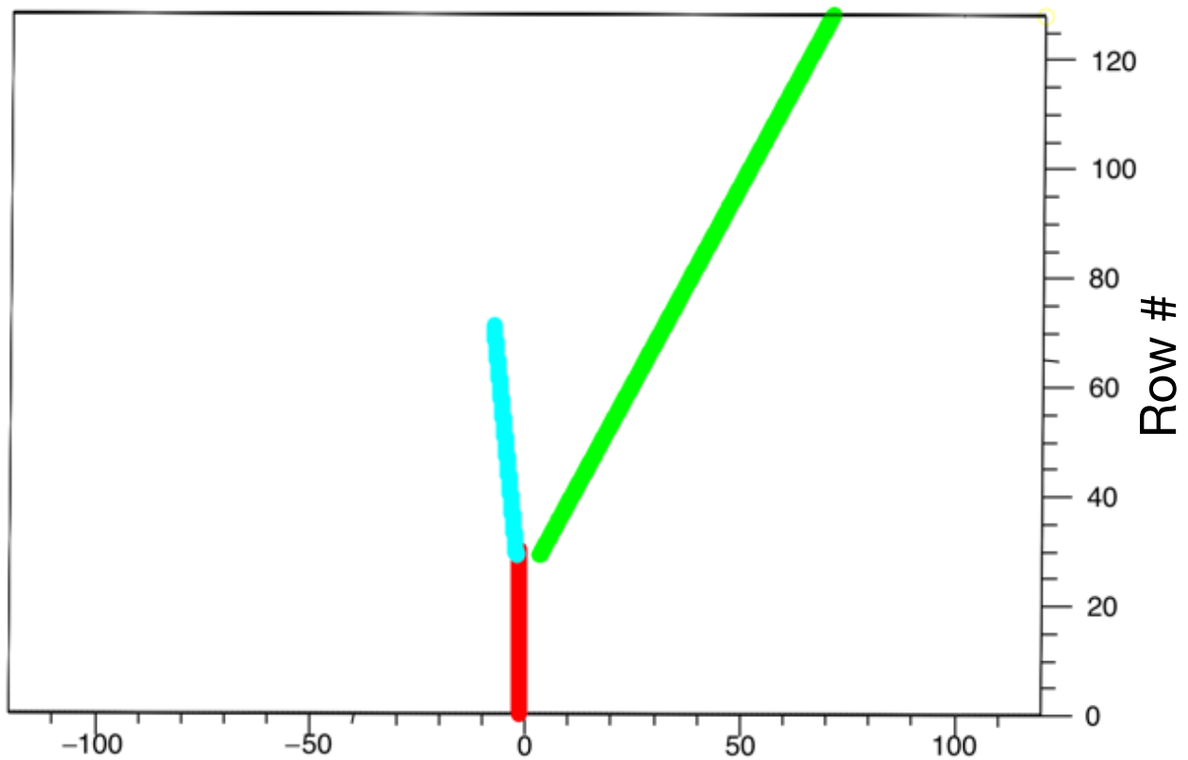
Acknowledgments

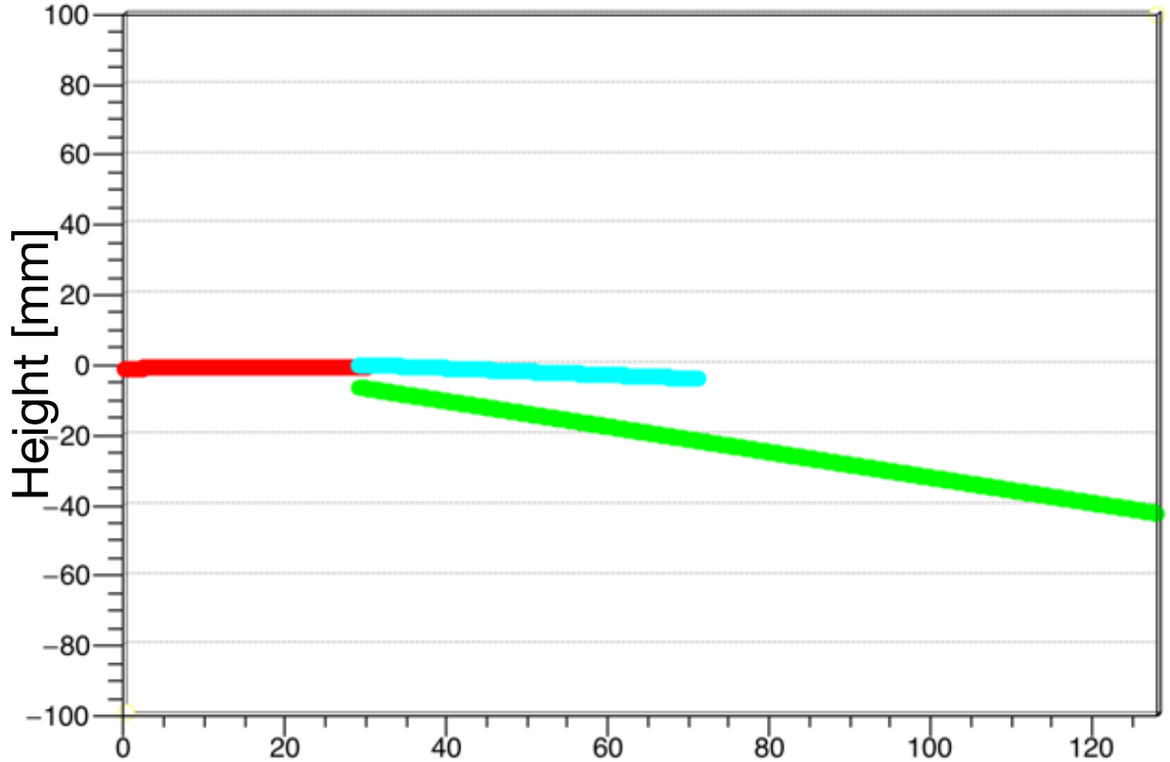
Texas A&M U: E. Aboud, C. Hunt,
S. Ahn, J. Hooker, S. Upadhyayula,
E. Koshchiy, GR, H. Jayatissa, M. Barbui

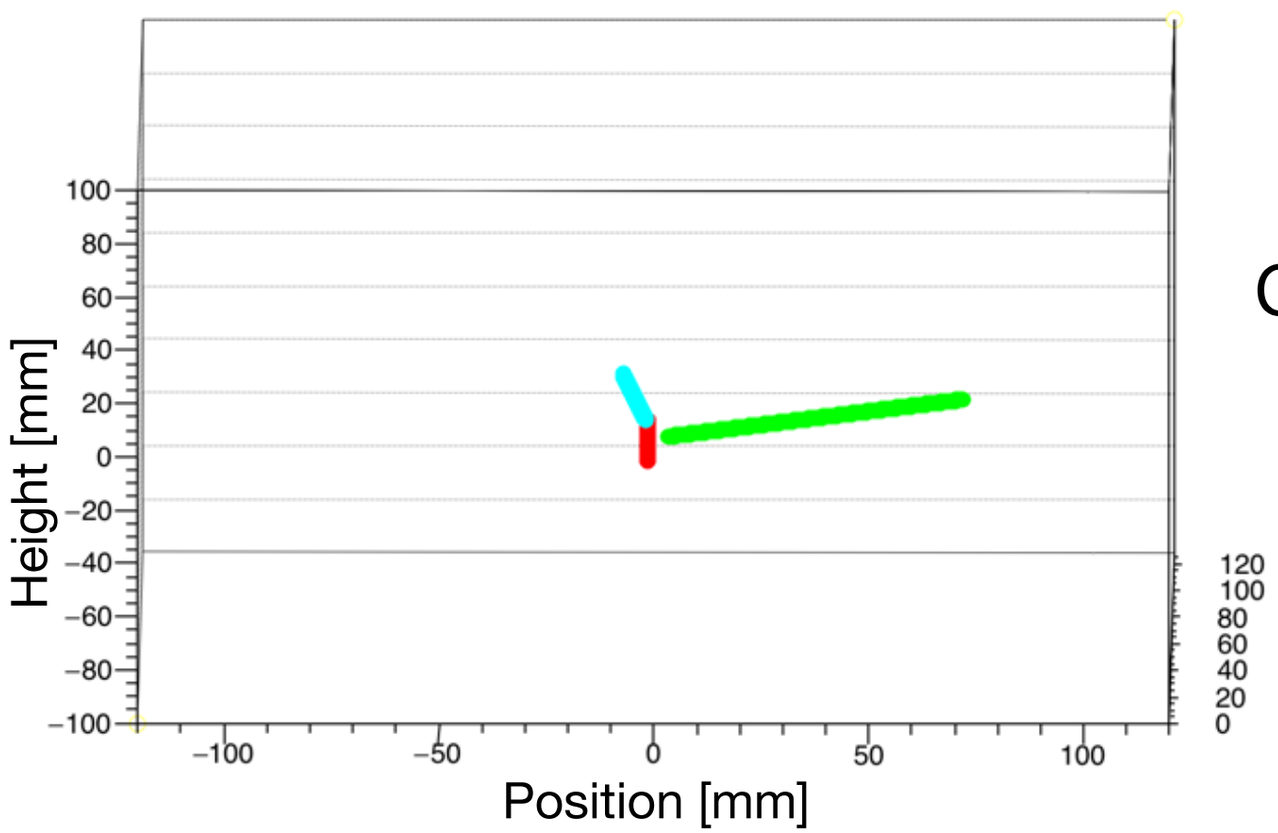
Texas A&M U / U of Michigan: Ethan Uberseder

CEA: Lolly Pollacco

Drawing events. For the forward proton events (central pads), I put the vertex in the proton track path. Here is an event without putting the vertex point in the proton track for the strips and chains

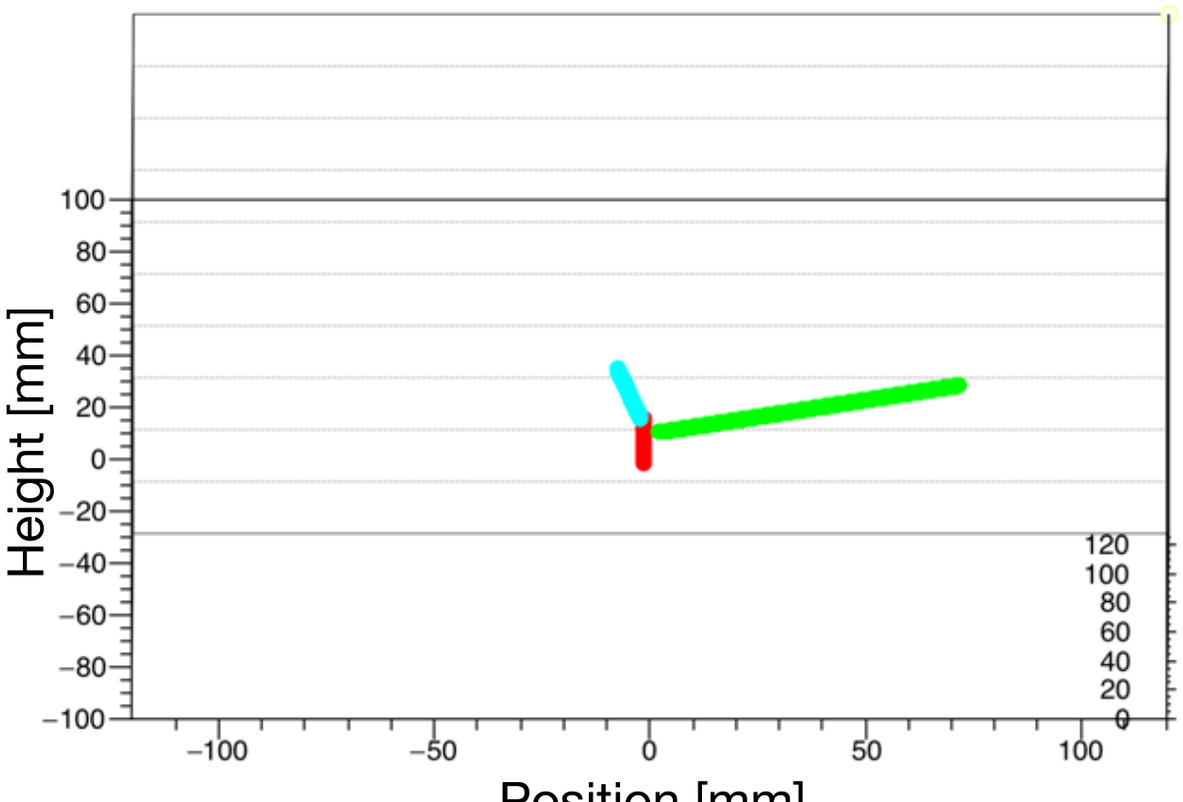


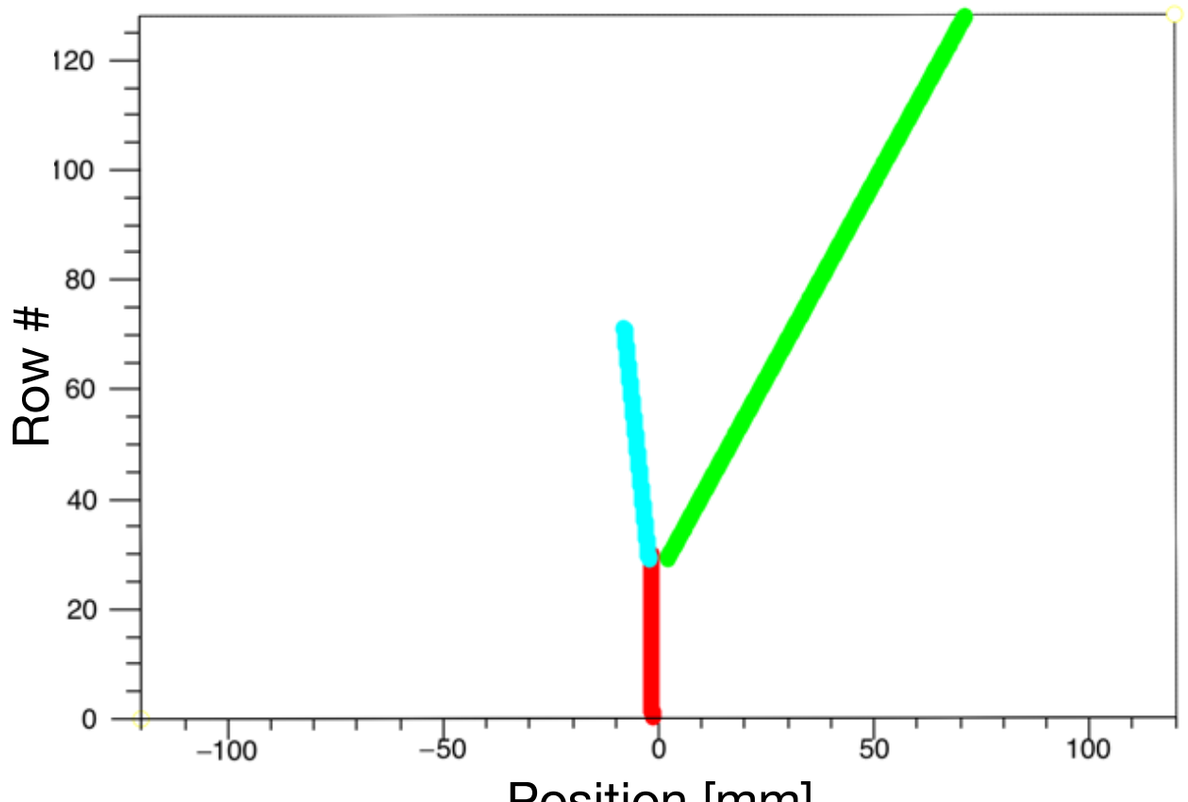


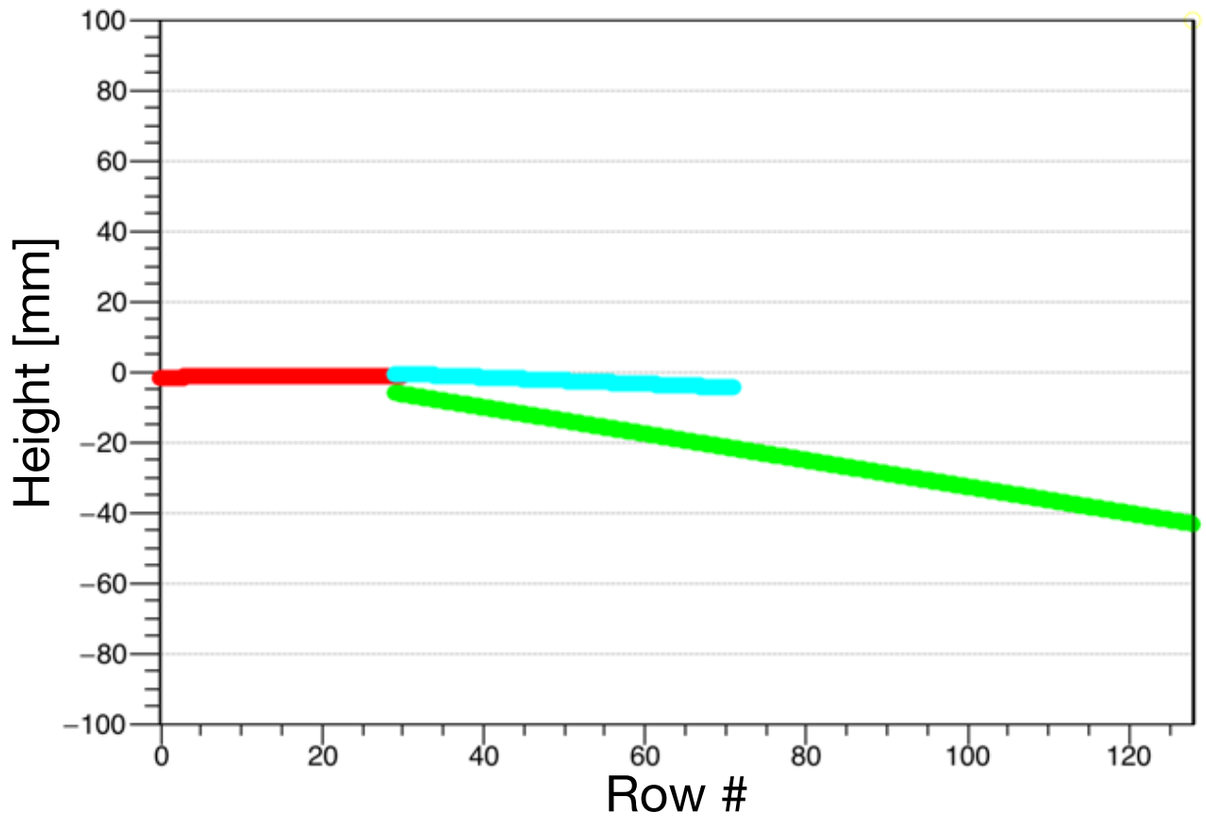


Clearly this agrees with the vertex location :)

The same event adding the vertex point into the path

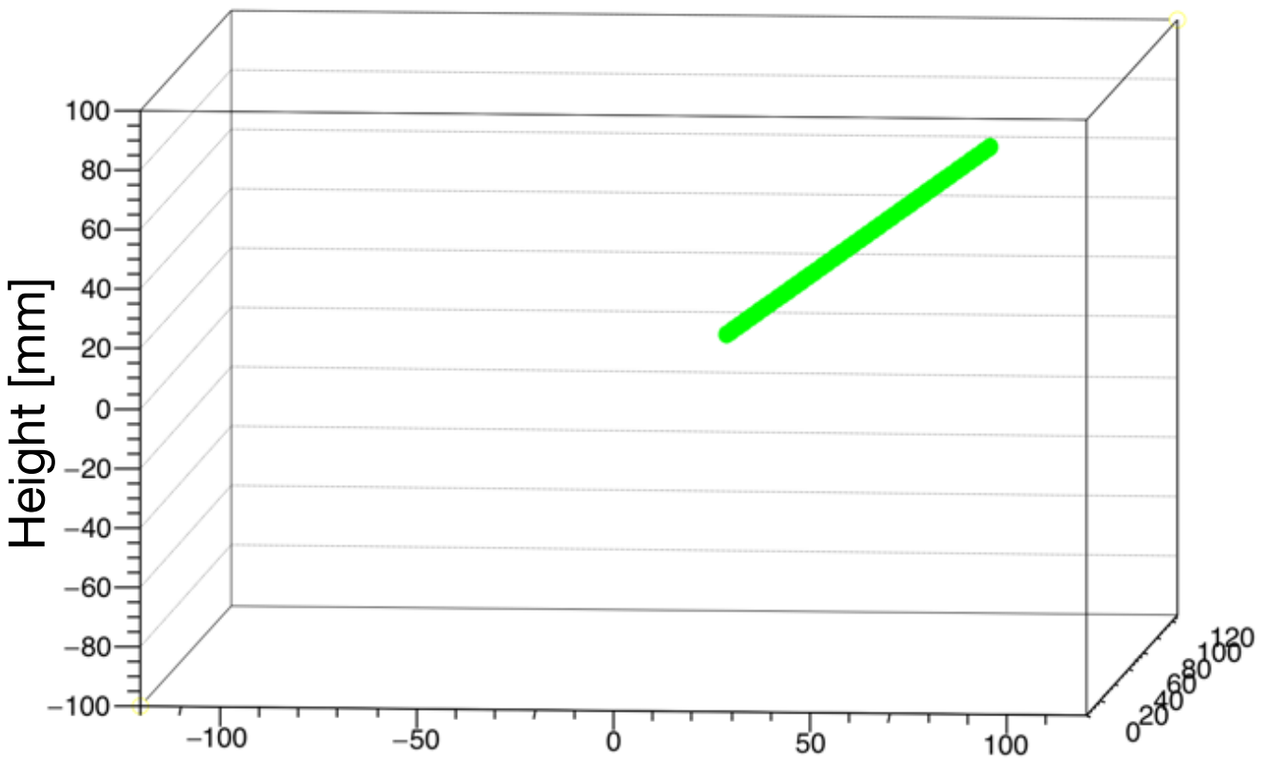


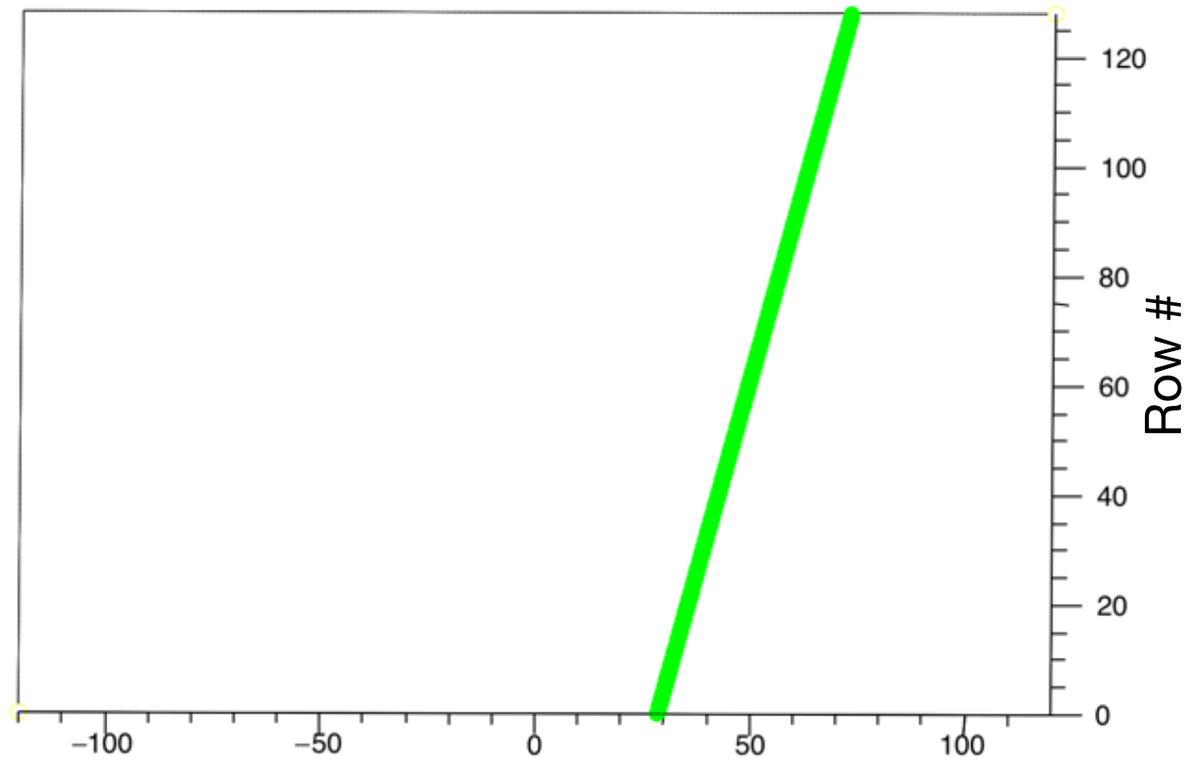


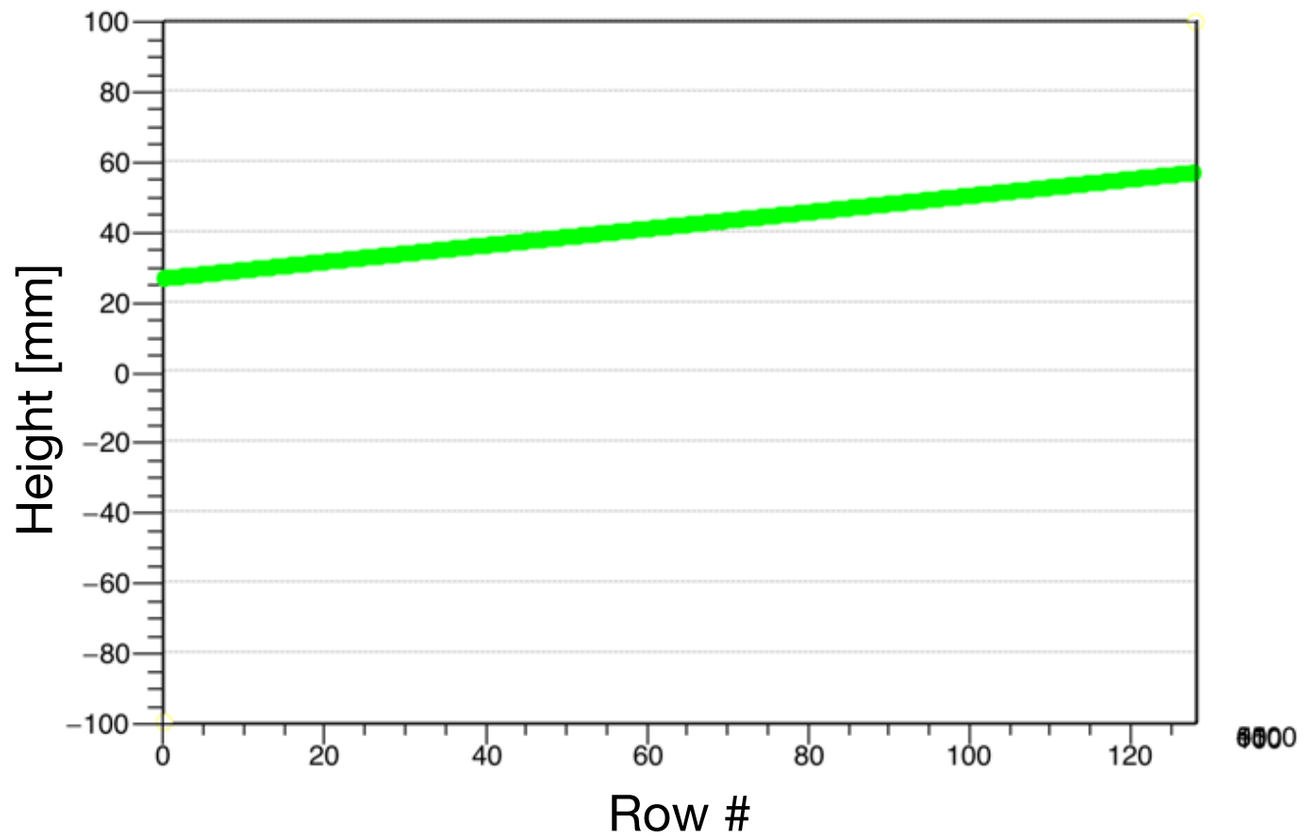


Not much change

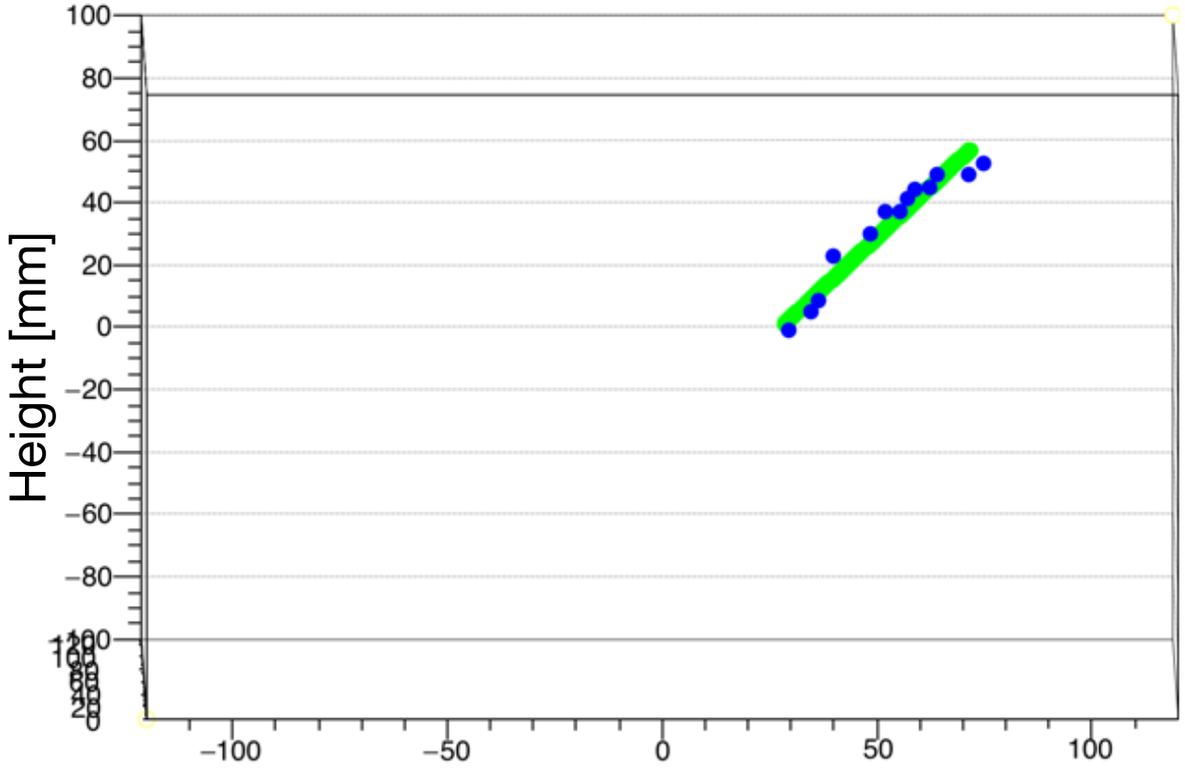
Proton going through side region of micromegas with no beam in central pads

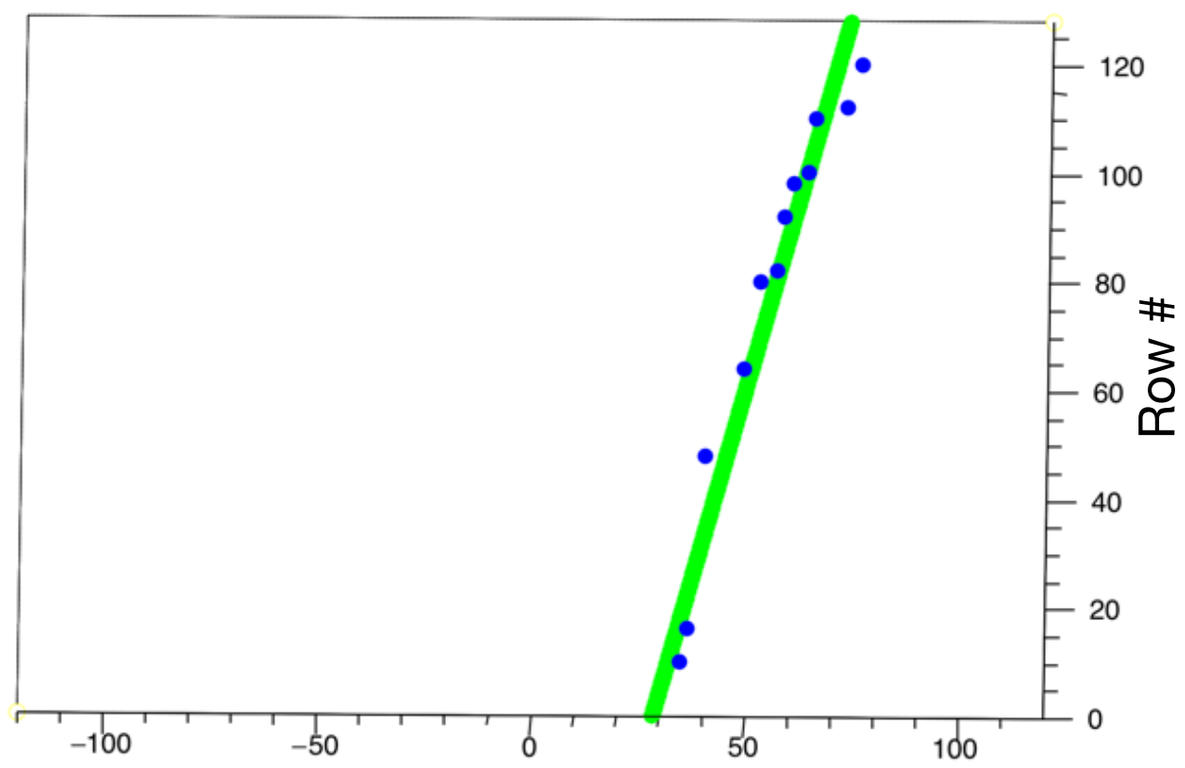






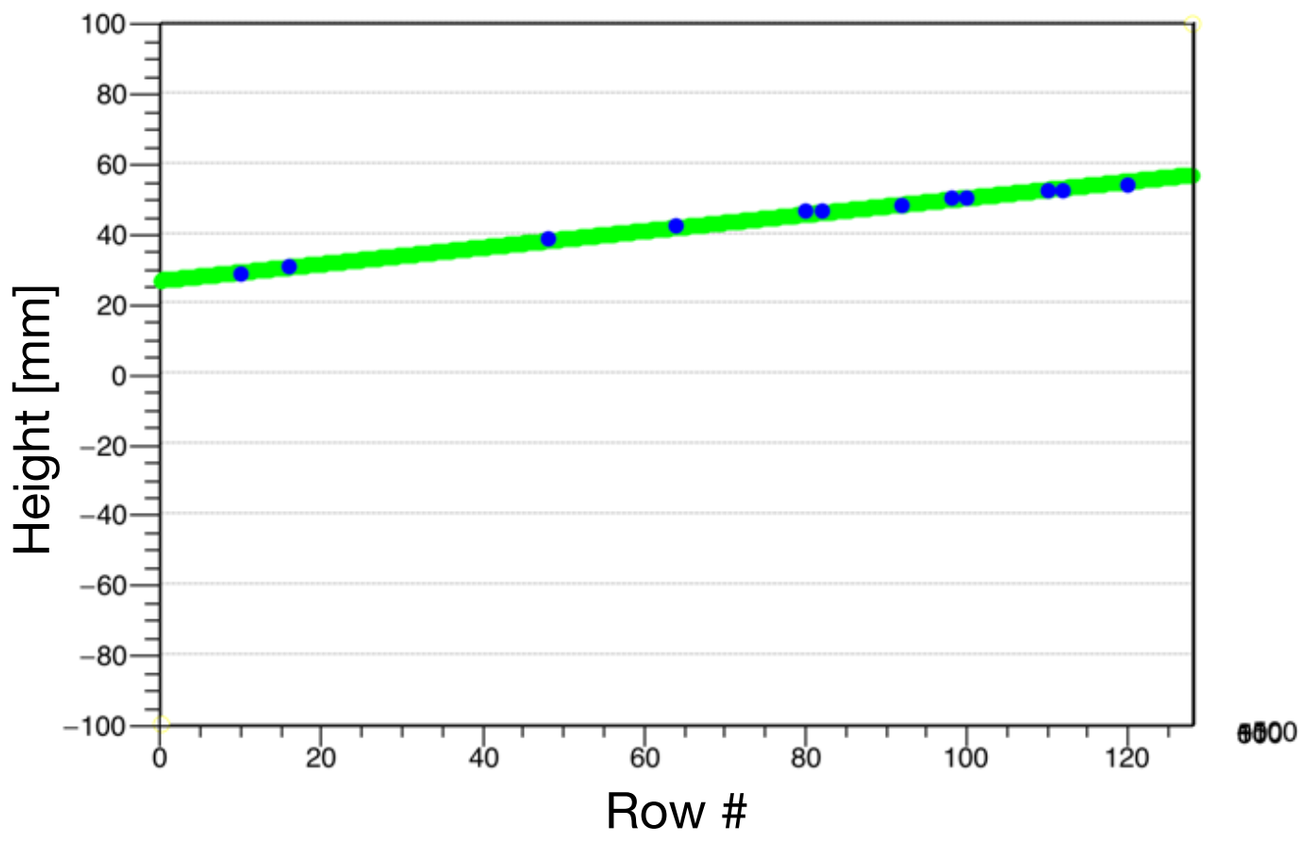
Same event but adding the strip/chain matching points



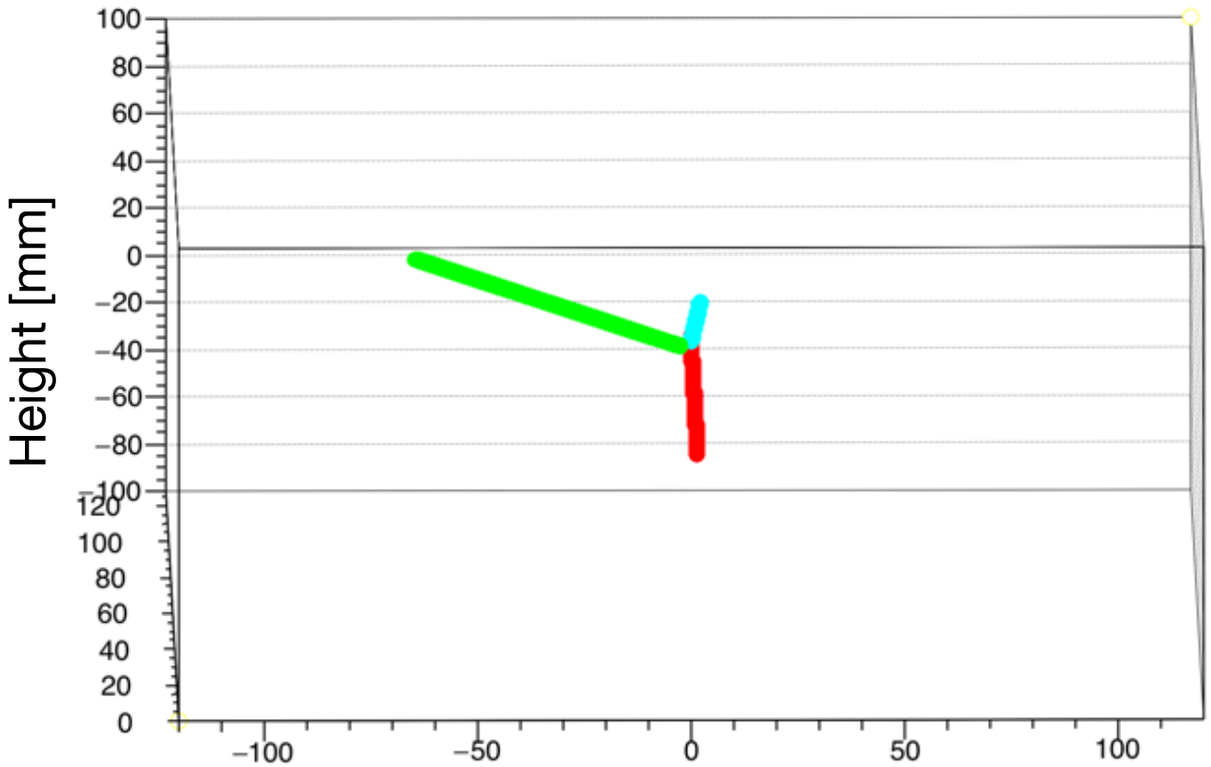


Position [mm]

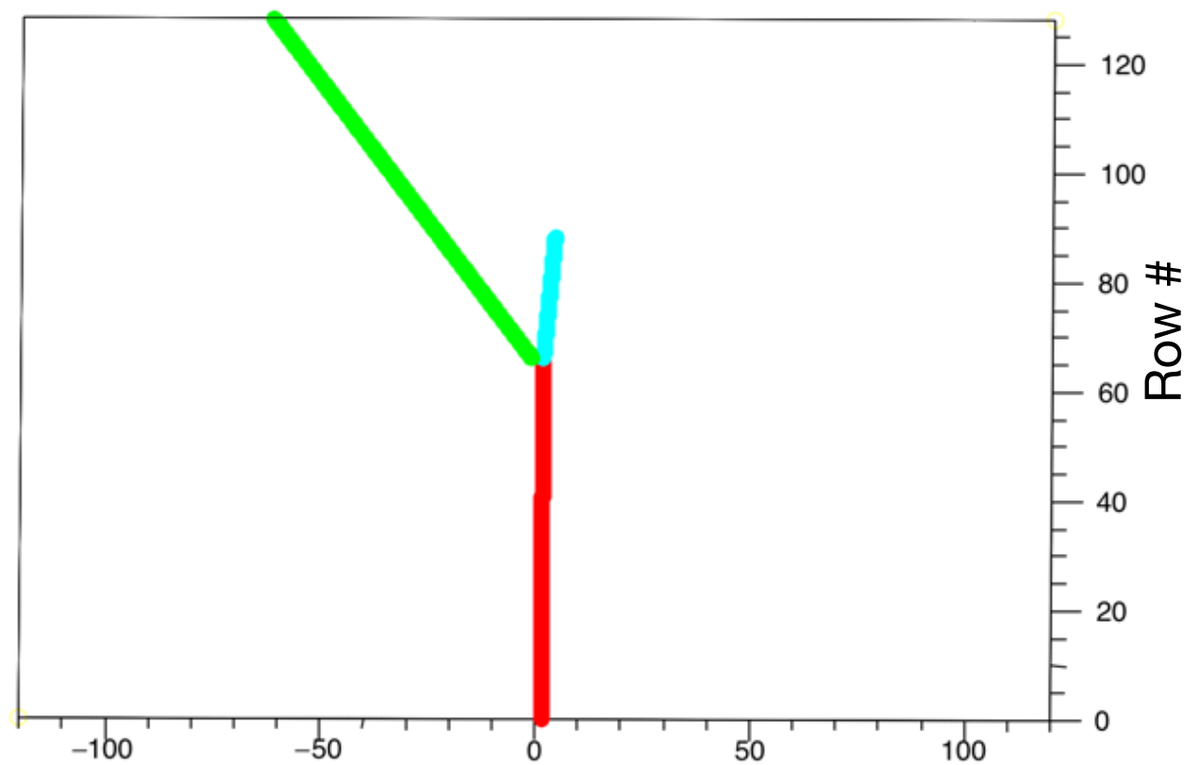
Position [mm]



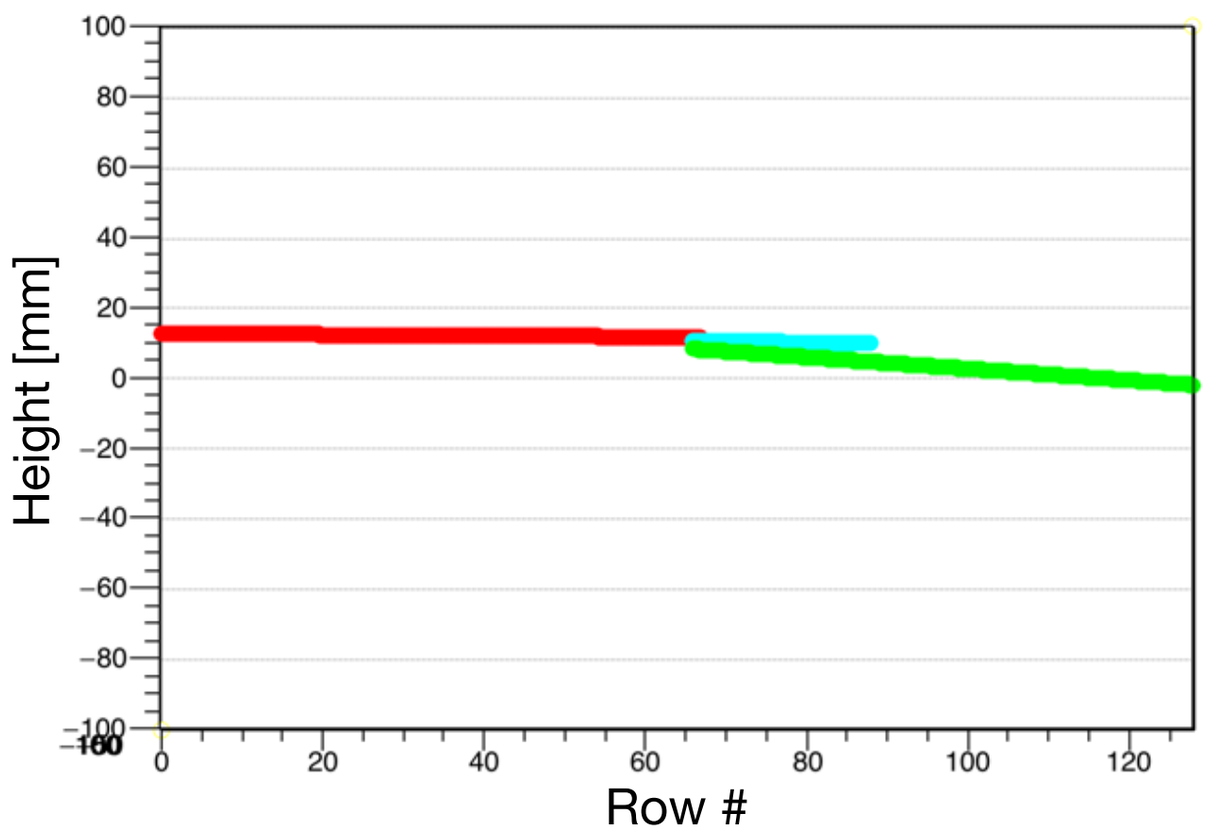
Event on left side



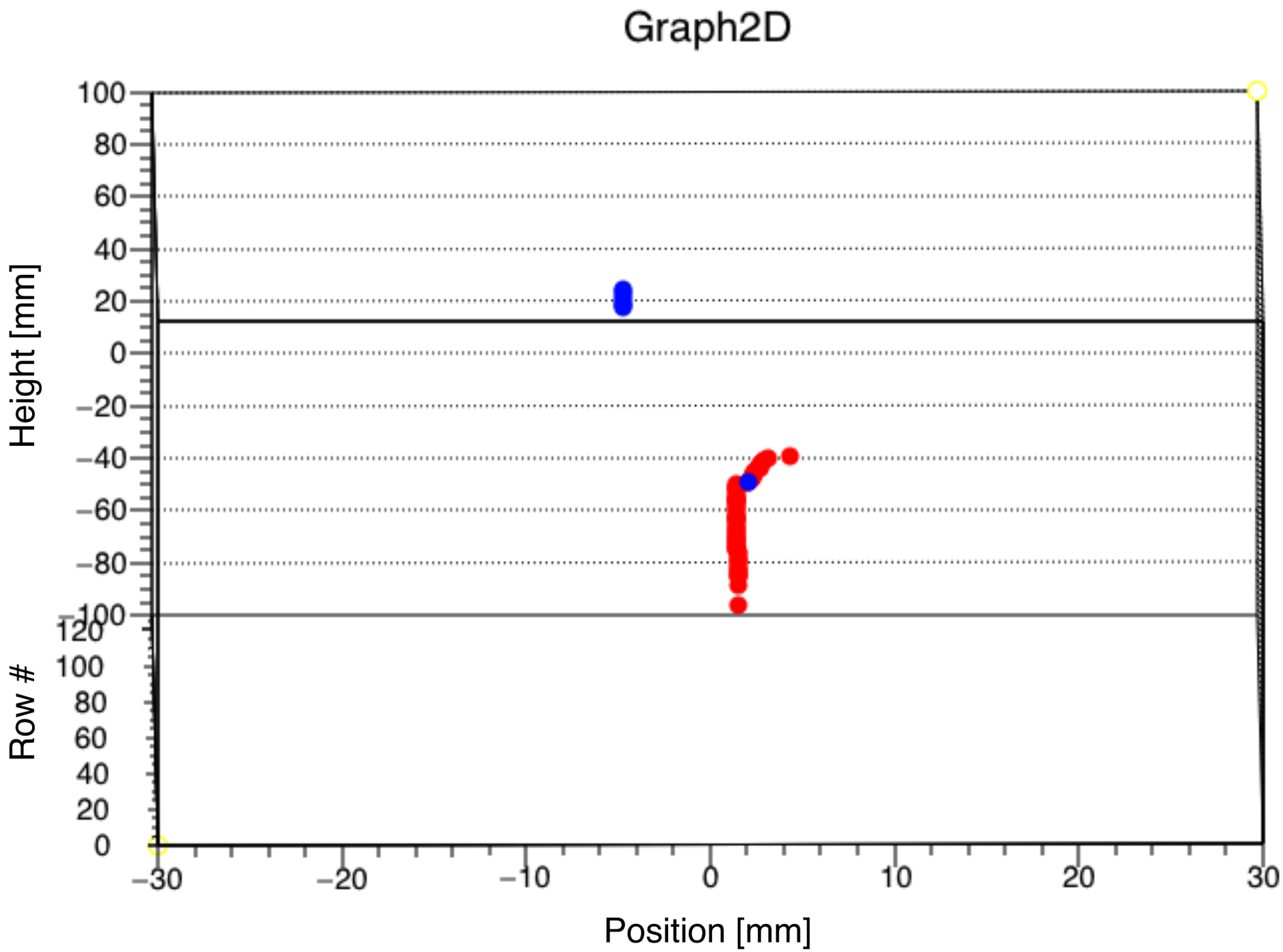
Position [mm]



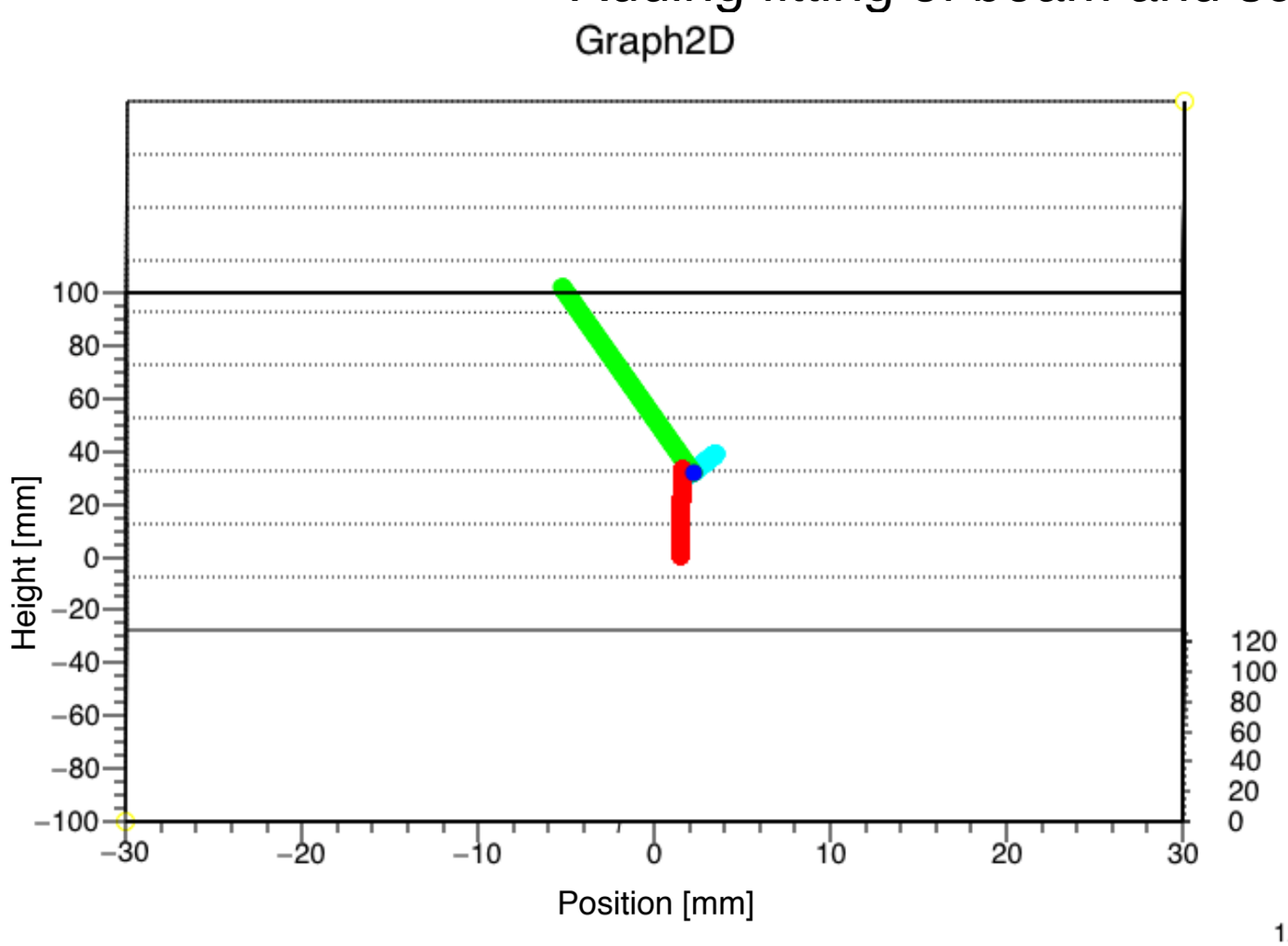
Position [mm]



Height in mm
Vertex point (Forced to be on the beam line)



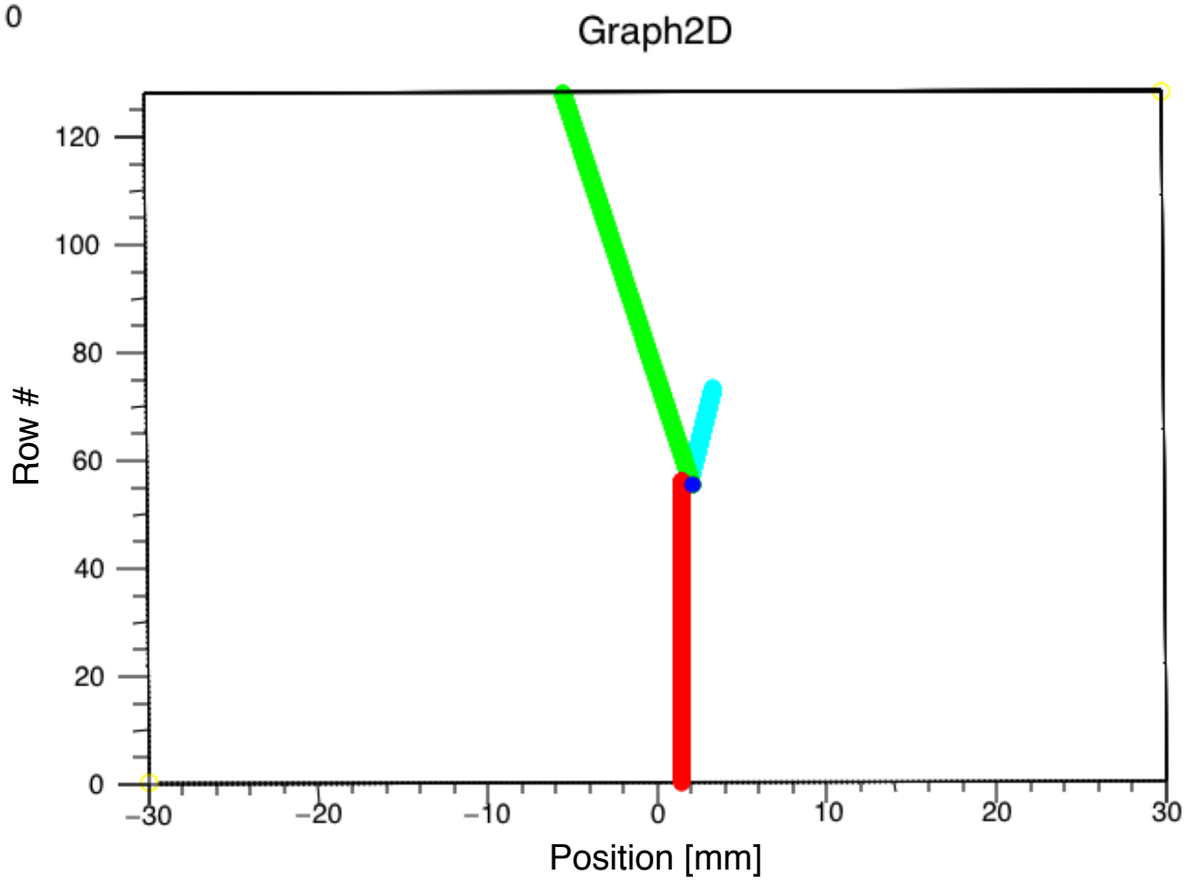
Adding fitting of beam and scattered beam particle



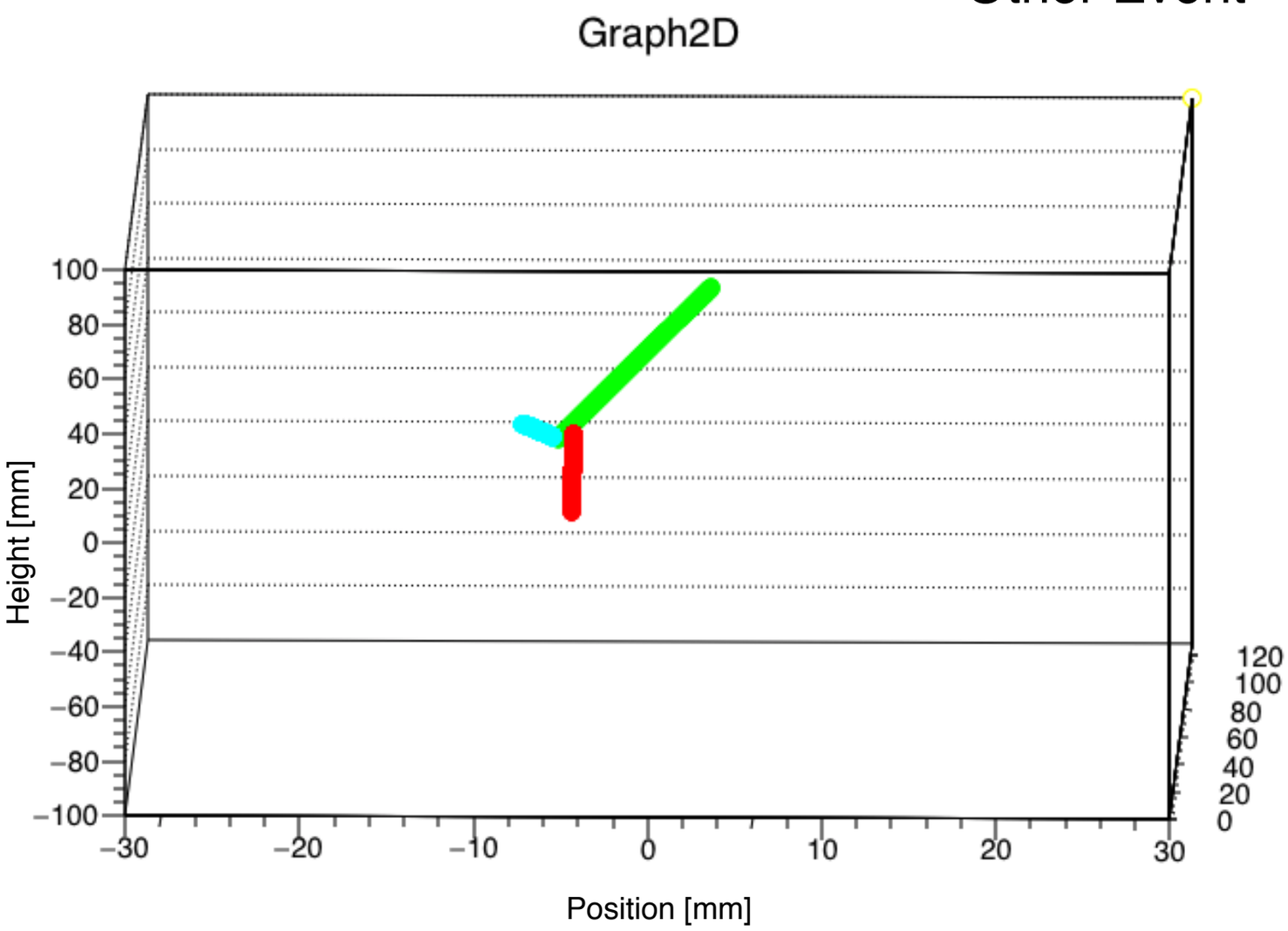
Beam

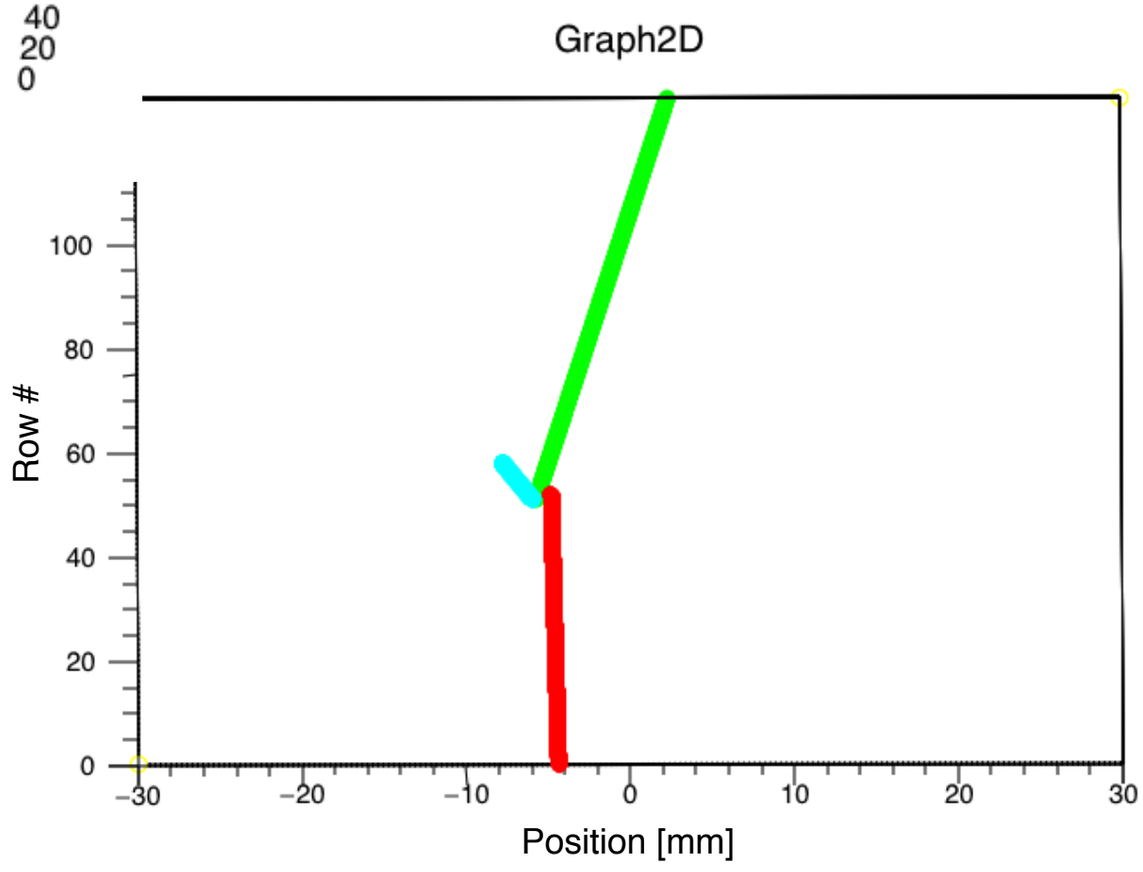
Scattered ^{8}B

Proton

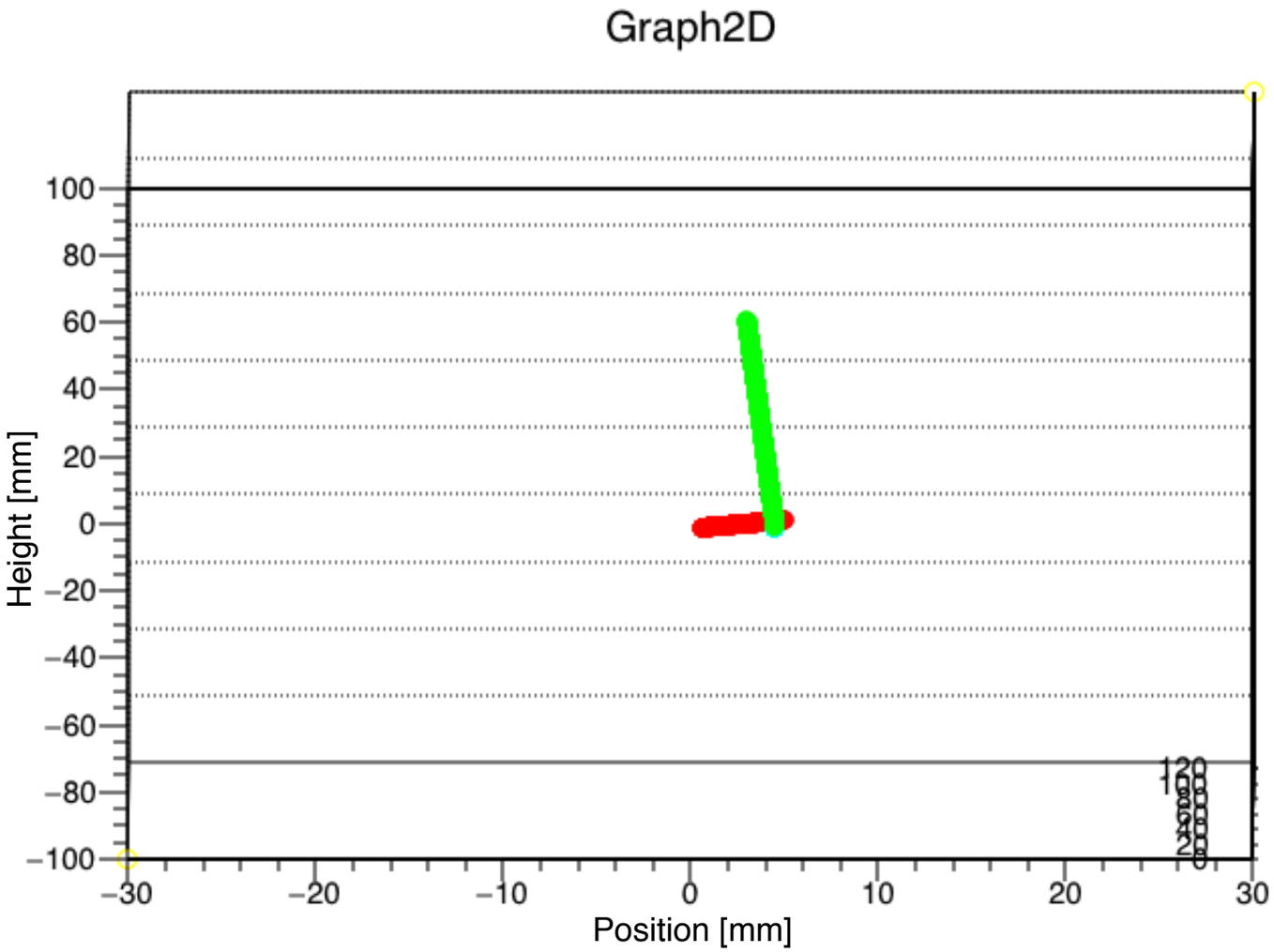


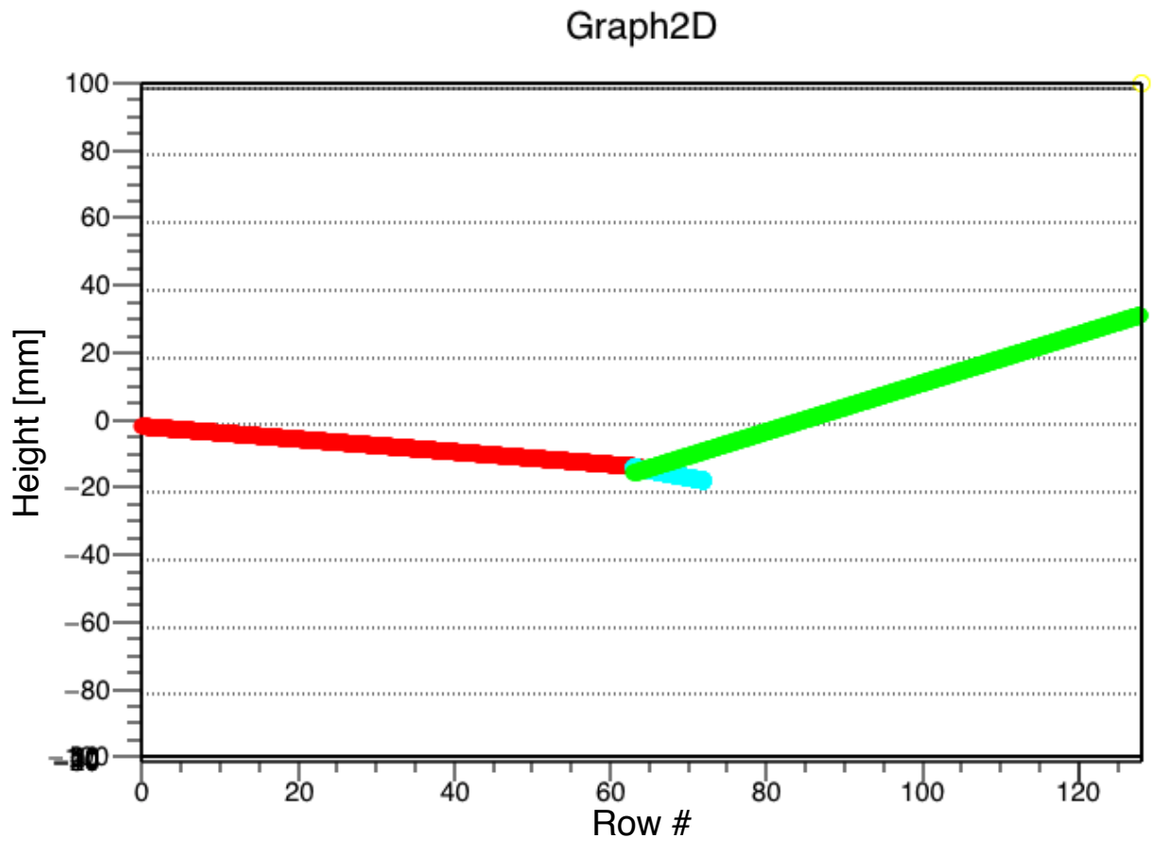
Other Event


Graph2D
Height [mm]
100
80
60
40
20
0
−20
−40
−60
−80
−100
−30
−20
−10
0
10
20
30
120
100
80
60
40
20
0
Position [mm]


Graph2D
Row #
100
80
60
40
20
0
−30
−20
−10
0
10
20
30
Position [mm]

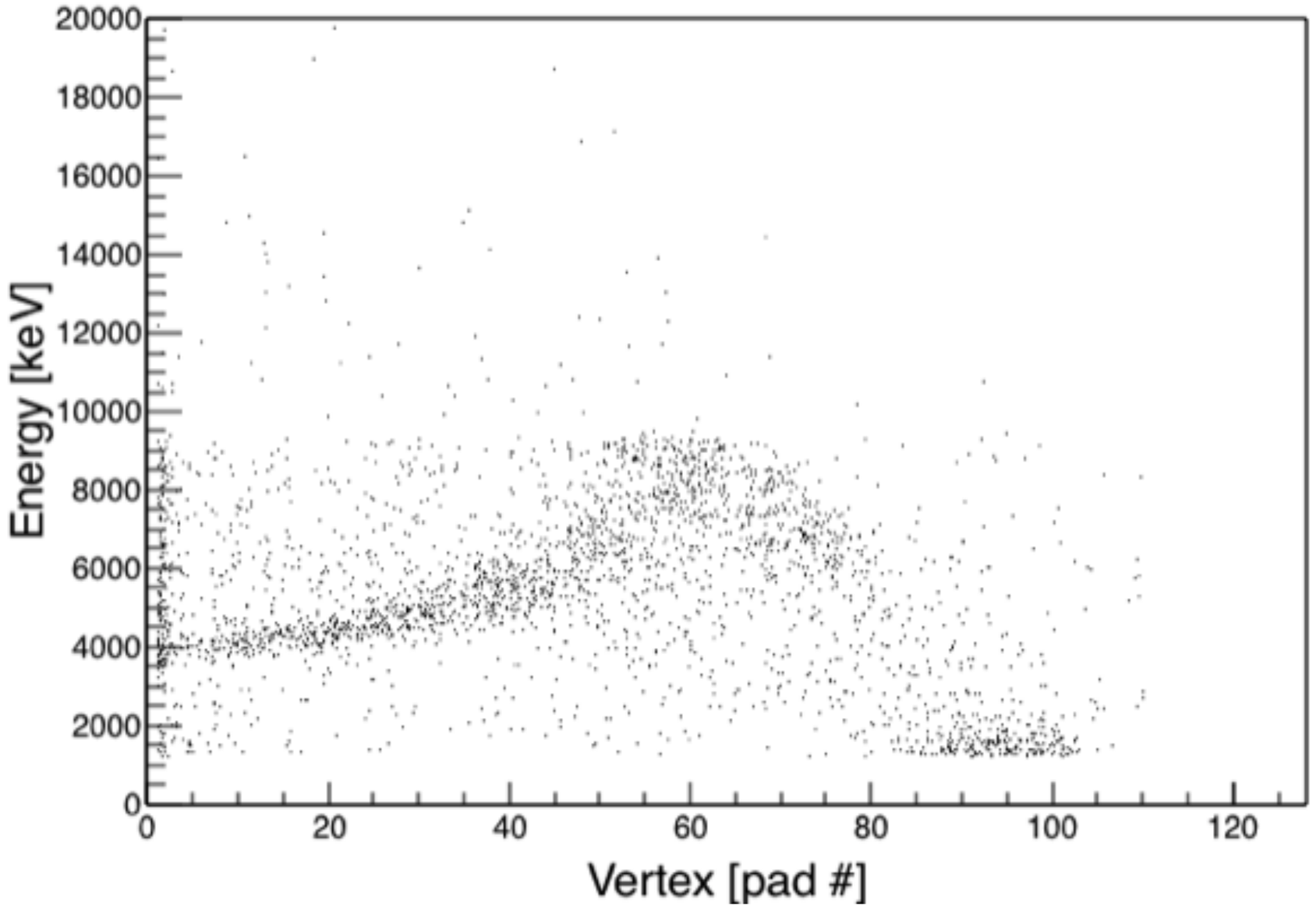
Other Event

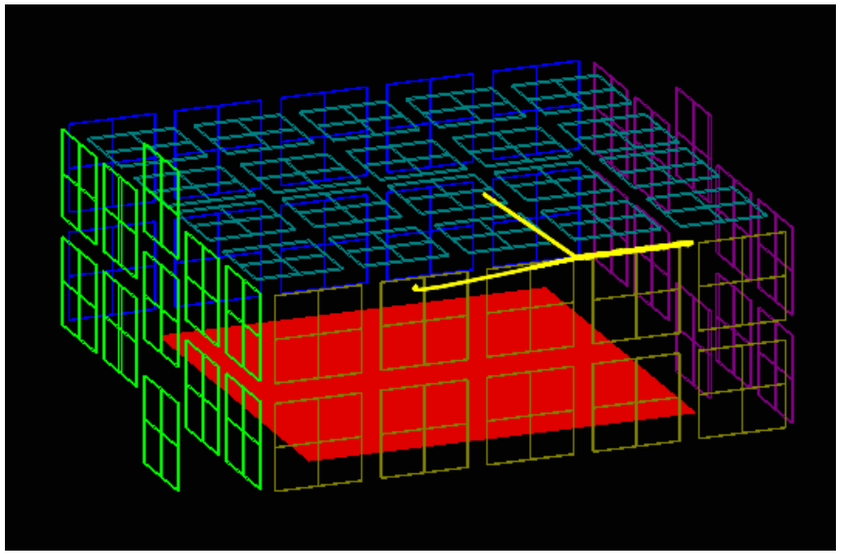

Graph2D
Height [mm]
100
80
60
40
20
0
−20
−40
−60
−80
−100
−30
−20
−10
0
10
20
30
Position [mm]


Graph2D
Height [mm]
100
80
60
40
20
0
−20
−40
−60
−80
0
20
40
60
80
100
120
Row #

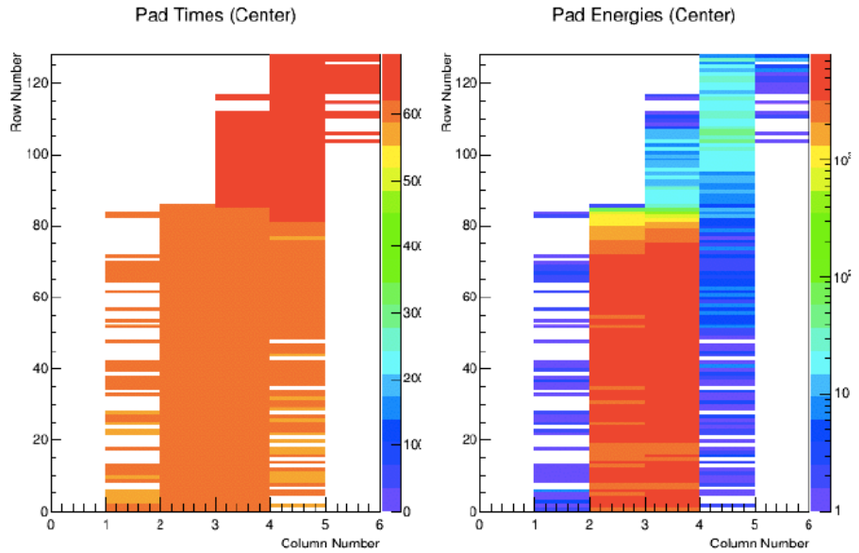
Status

- ☑ Conceptual design of TexAT - 100% complete.
- ☑ MC Simulation - 100% complete.
- ☑ GET Electronics - 100% complete.
- ☑ Scattering chamber hardware - 100% complete.
- ☑ microMegas - 100% complete (1 received, 4 more expected soon)
- ☑ Analysis Software - 75%
- ☑ Si detectors - 25%
- ☑ CsI(Tl) - 100% complete.
- ☑ Gas handling, vacuum components - 100% complete.
- ☑ ZAP boards - 100% complete.

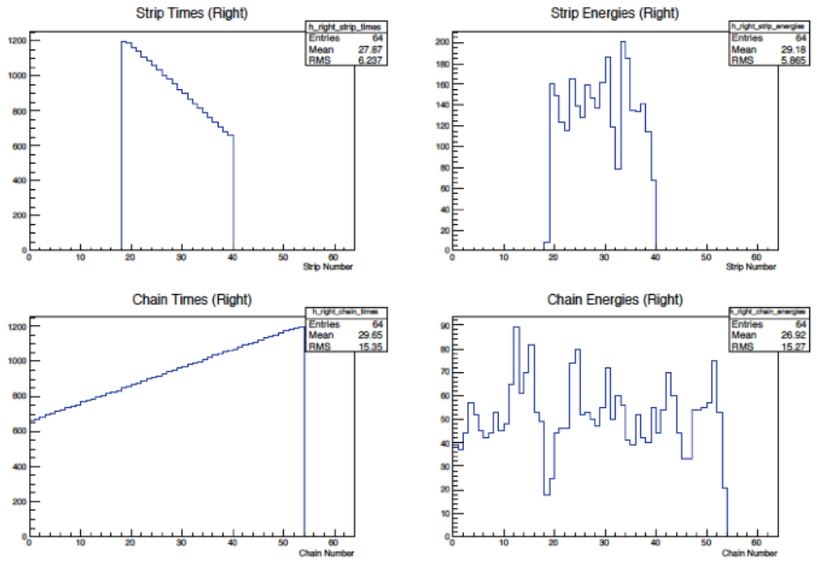

Energy [keV]
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
120
Vertex [pad #]



Reaction Simulations



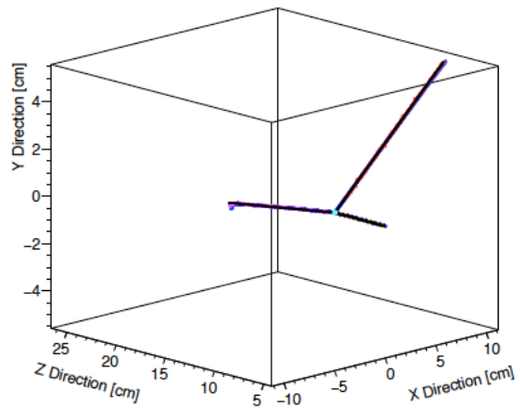
Reaction Simulations



Vertex Reconstruction

Procedure:

1. Assign incoming points in central region based on hits in ALL rows
2. Look for light particle hits in side regions and map strips(chains) to chain(strips) based on timing
3. If no side region hits, try to break central track using an energy discontinuity



4. Fit light product and incoming vectors and use point of closest approach to break incoming track into incoming and recoil points
5. Refit all light product, incoming and recoil points with three vectors intersecting at a vertex