Laser Scan Analysis of NOνA Far Detector Layer Surfaces

Brian Mercurio
University of South Carolina, Columbia
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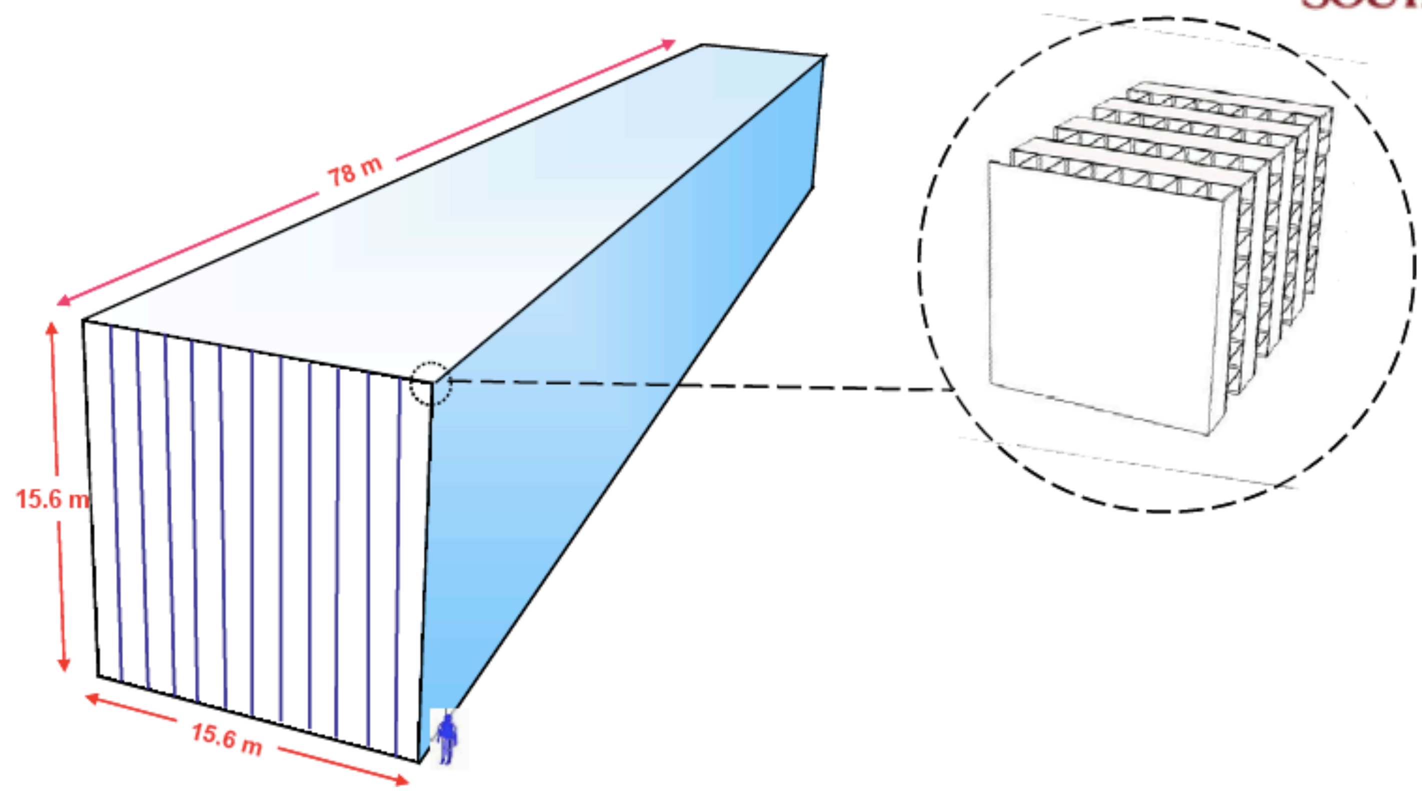
Outline

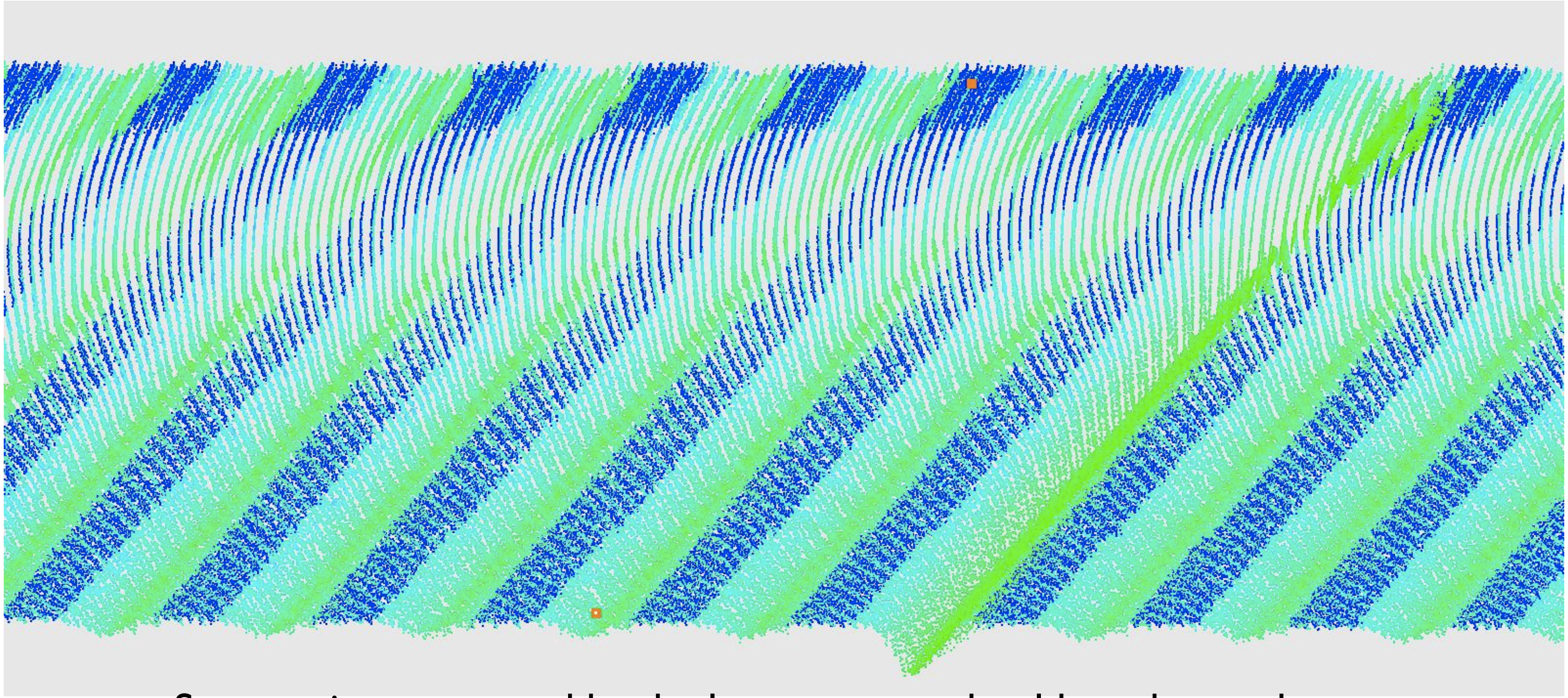
- Purpose of the laser scans of the layer surface.
- Coordinate systems.
- Algorithm of a computer program that analyzes the scanner output.
- Results from a recent scan.

Why We Scan the Surface



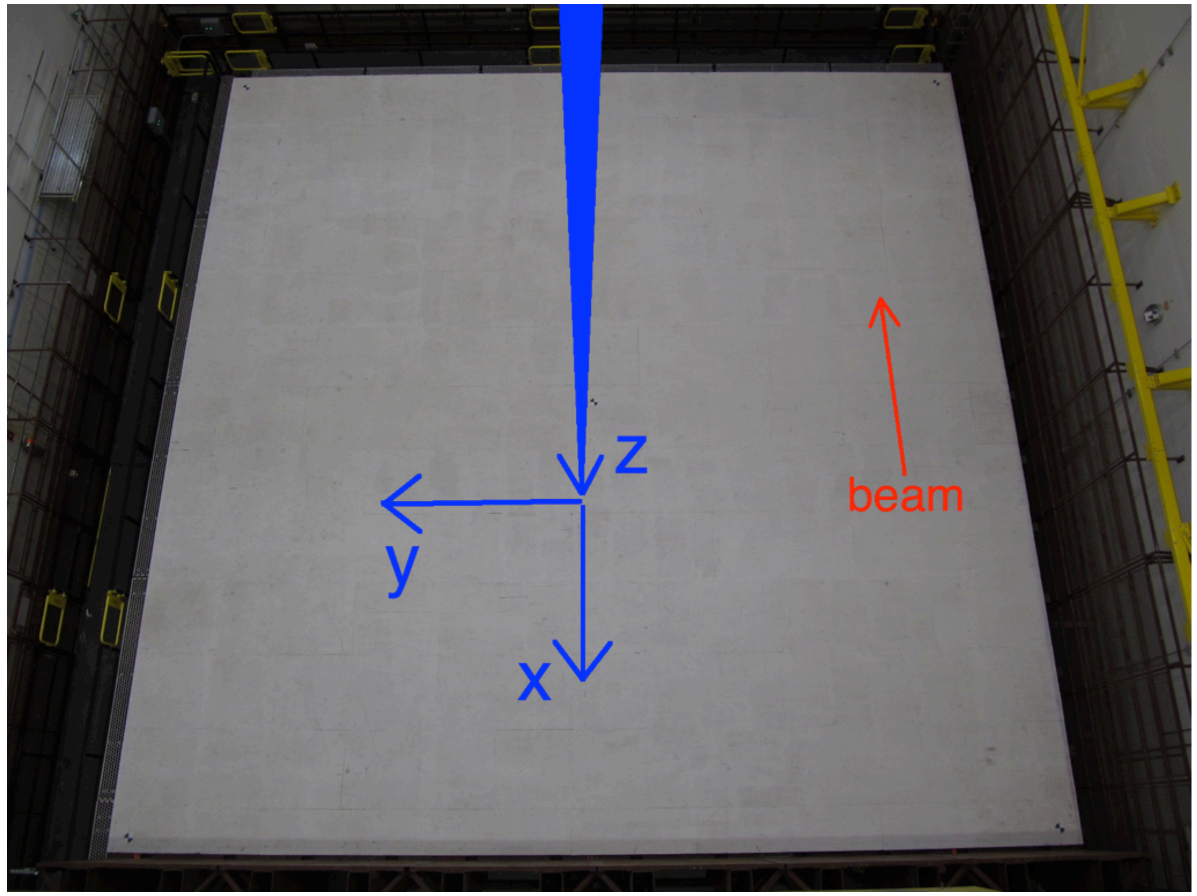
- NOνA far detector
  - 28 or 29 blocks.
  - 32 layers per block.
  - 12 modules per layer.
  - 32 detector cells per module.
- When a new layer is assembled, we need to check
  - How well the modules are lined up.
  - How flat the modules are.
- We want to know the positions of the cells for Monte Carlo programs.

Data Reduction and Quick Analysis



- Some points measured by the laser scanner should not be used to determine the smoothness or flatness of a layer.
  - Inside a groove (scallop).
  - Outside the plane.
- The points shown in dark blue are the ones we want to keep.
- A C++ program removes the unwanted points and preforms a quick analysis of the surface shape before the next layer is assembled.

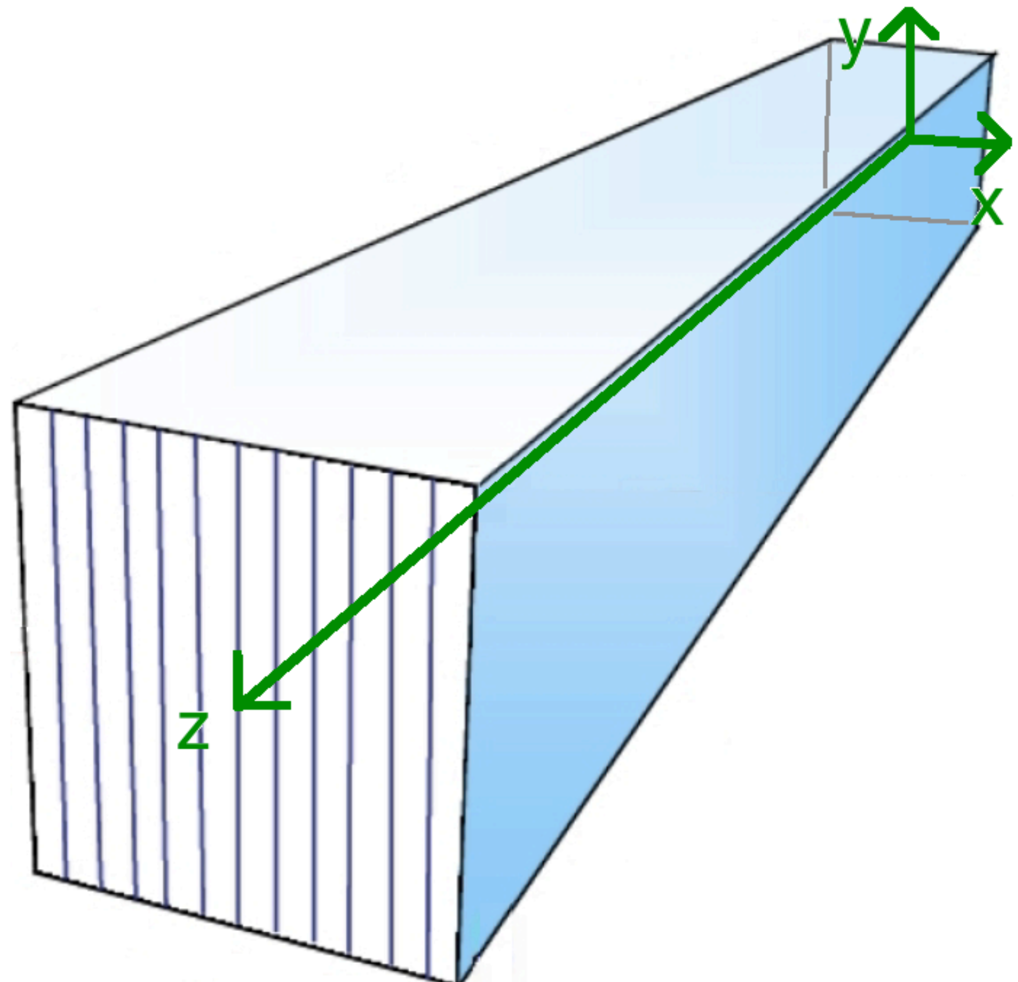
But First, Coordinate Systems



photographs by Ron Williams

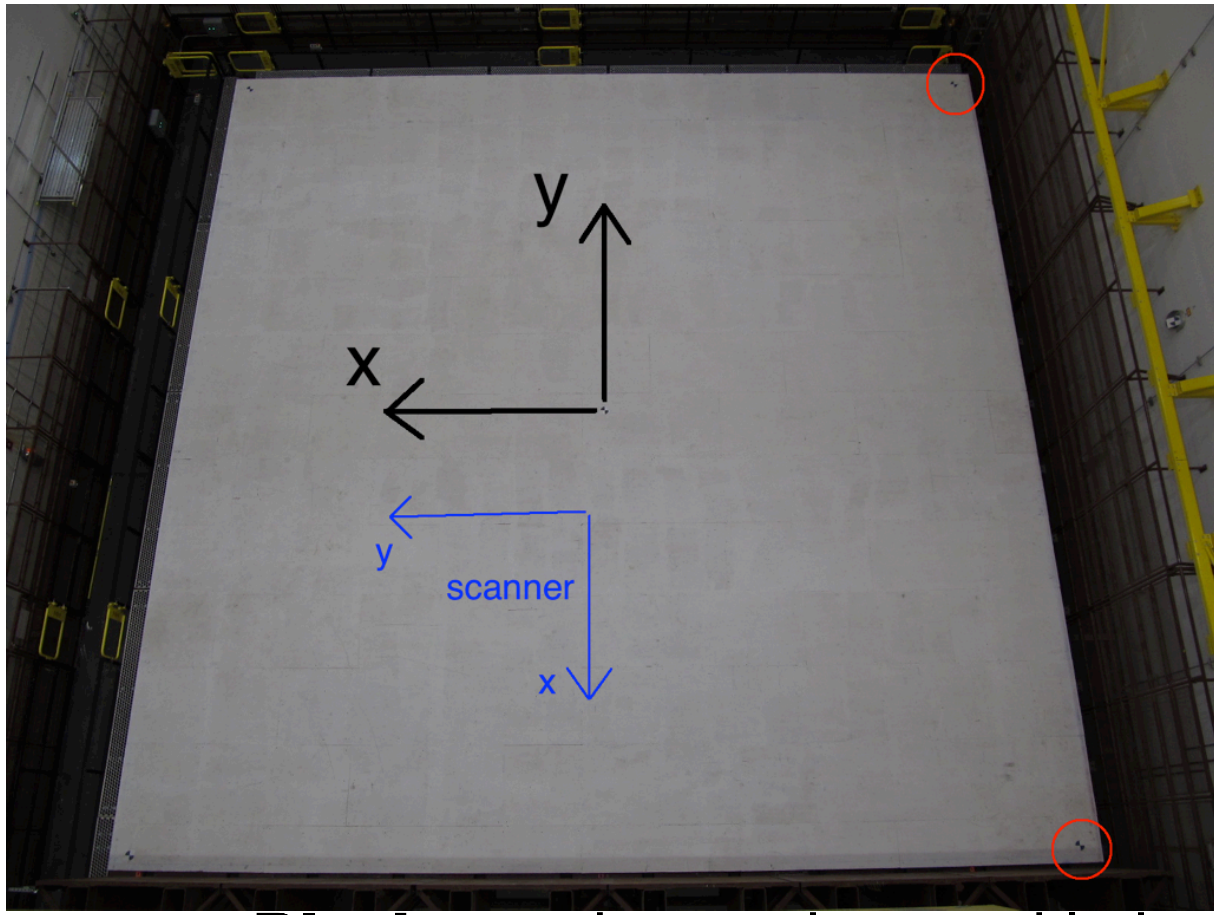
- In NOνA, "north" means a horizontal projection of the beam direction, and points close to northwest in geographic coordinates.
- The **scanner** coordinates are shown in blue.
  - Origin is at the scanner.
  - Z axis points down.
  - Y axis pointed west. X axis pointed upstream (south).
  - X axis and Y axis change whenever the scanner is reinstalled after maintenance.

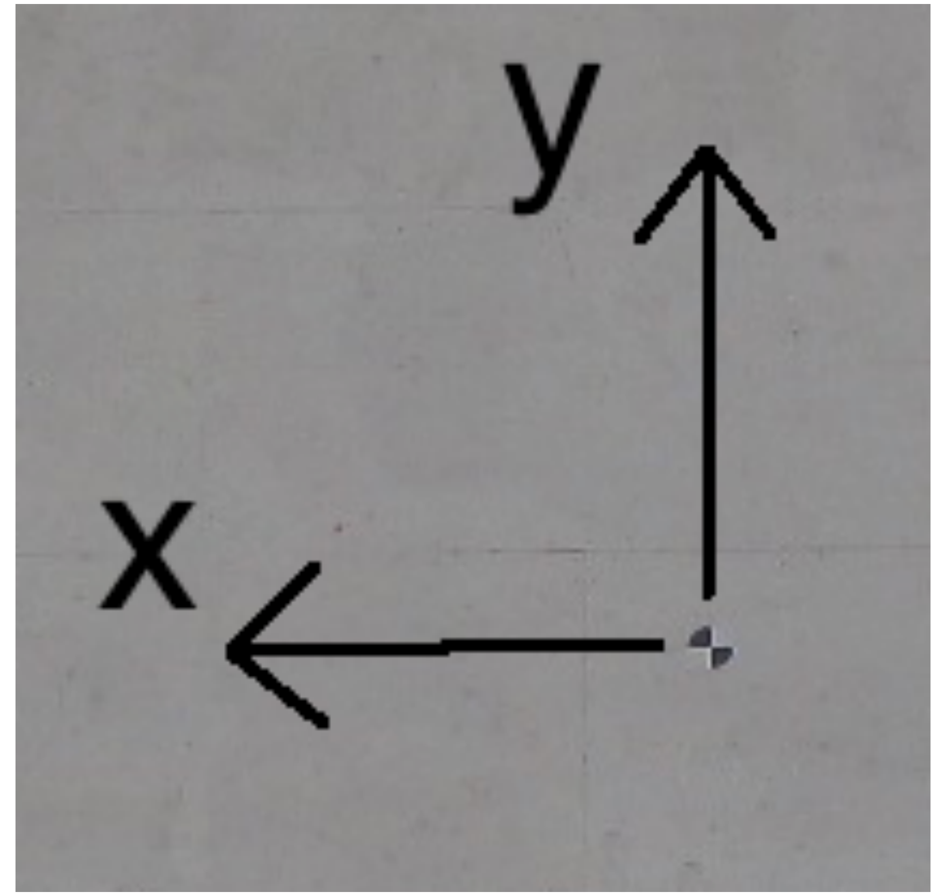
Coordinate Systems



- **Monte Carlo** coordinates
    - Origin is near the upstream side of the detector.
    - Z axis goes through the center of each unshifted vertical layer and points downstream (north).
    - Y axis points up.
    - X axis points west.

Coordinate Systems

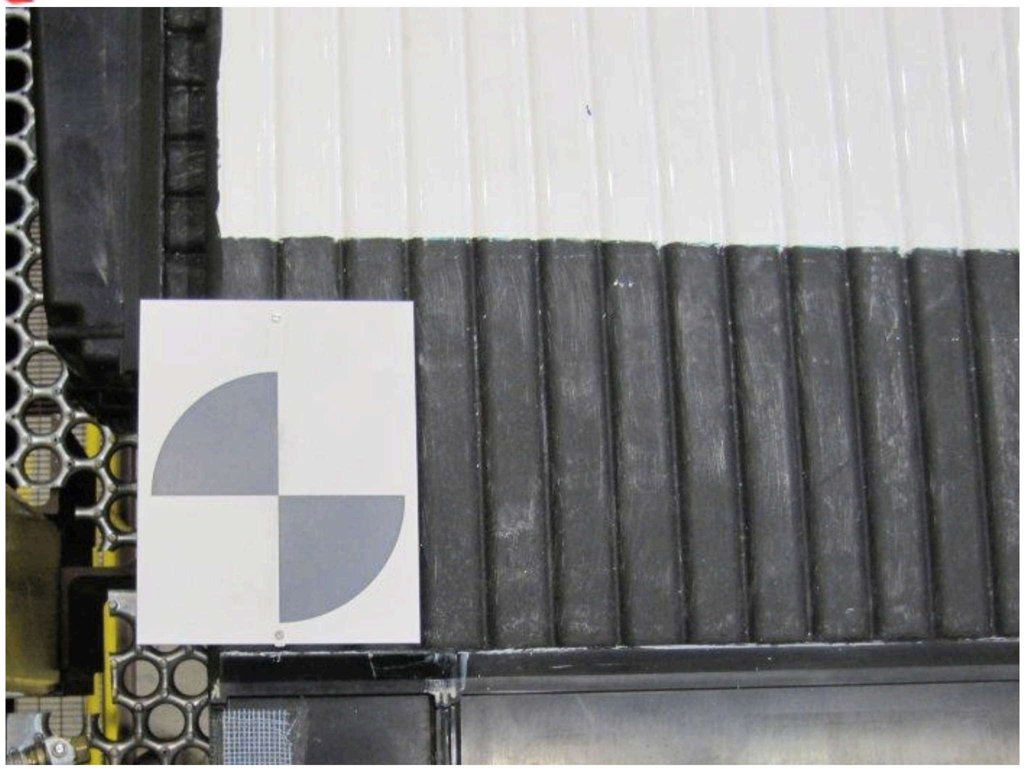




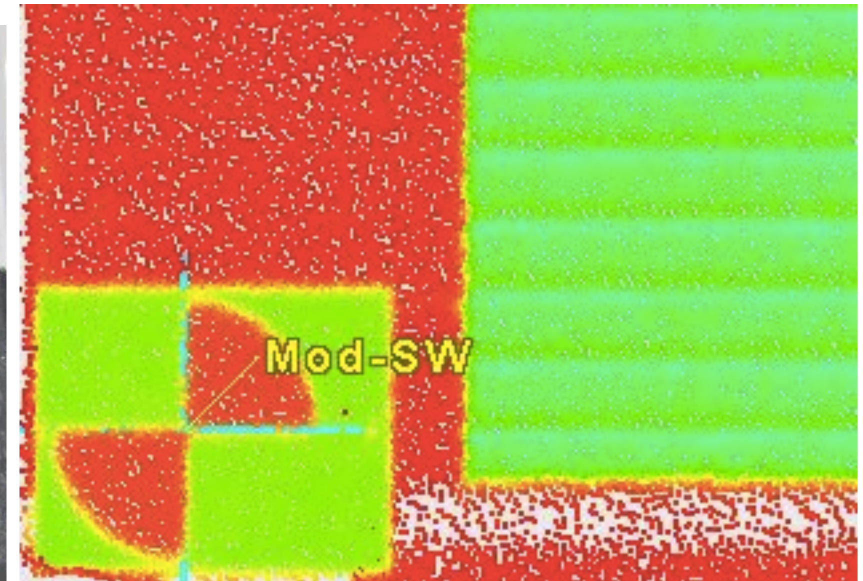
photograph by Ron Williams

- **Block** coordinates, shown in black
  - Origin is at the surface of the pivoter, under the expected center of Layer 31.
  - Z axis points down.
  - Y axis is parallel to the vertical cells and points north.
  - X axis points west.
- Three targets determine the conversion from scanner to block coordinates.
- After the block has been pivoted, the x and y values in block coordinates are the same as in Monte Carlo coordinates.

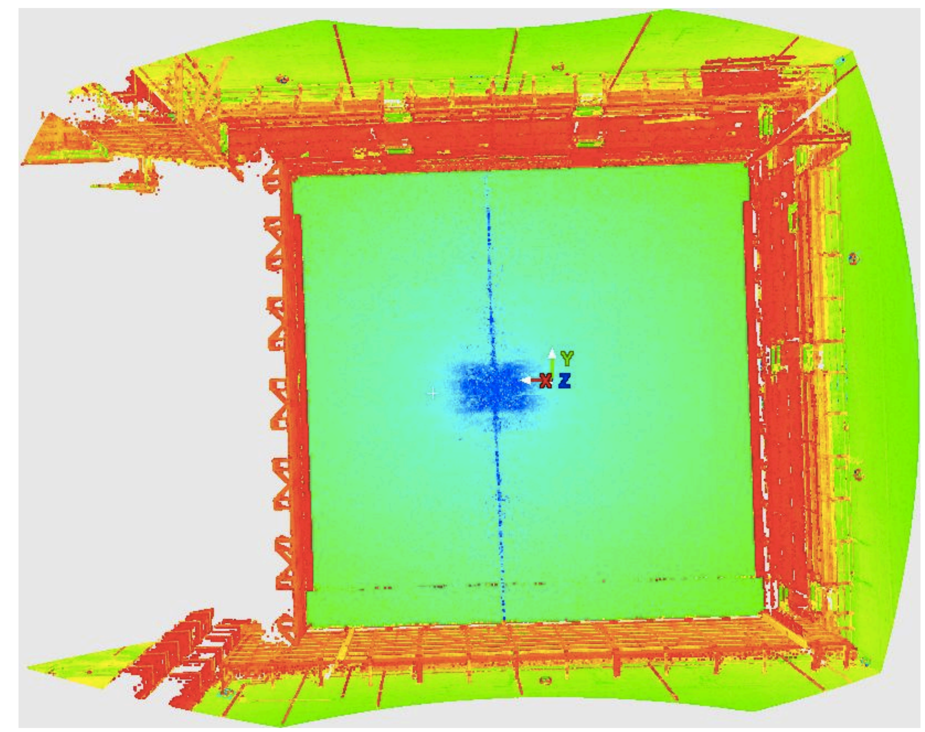
Points Outside the Plane

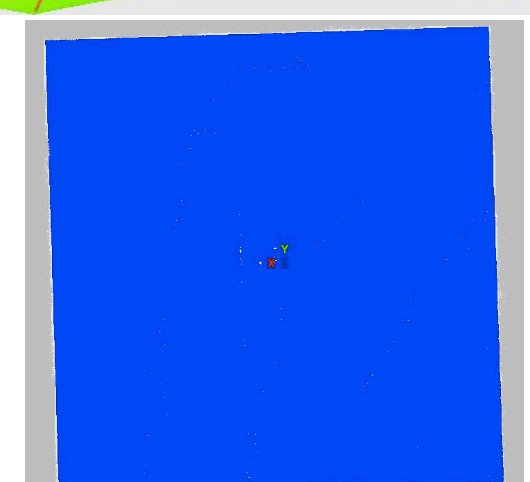


photograph by Bill Miller

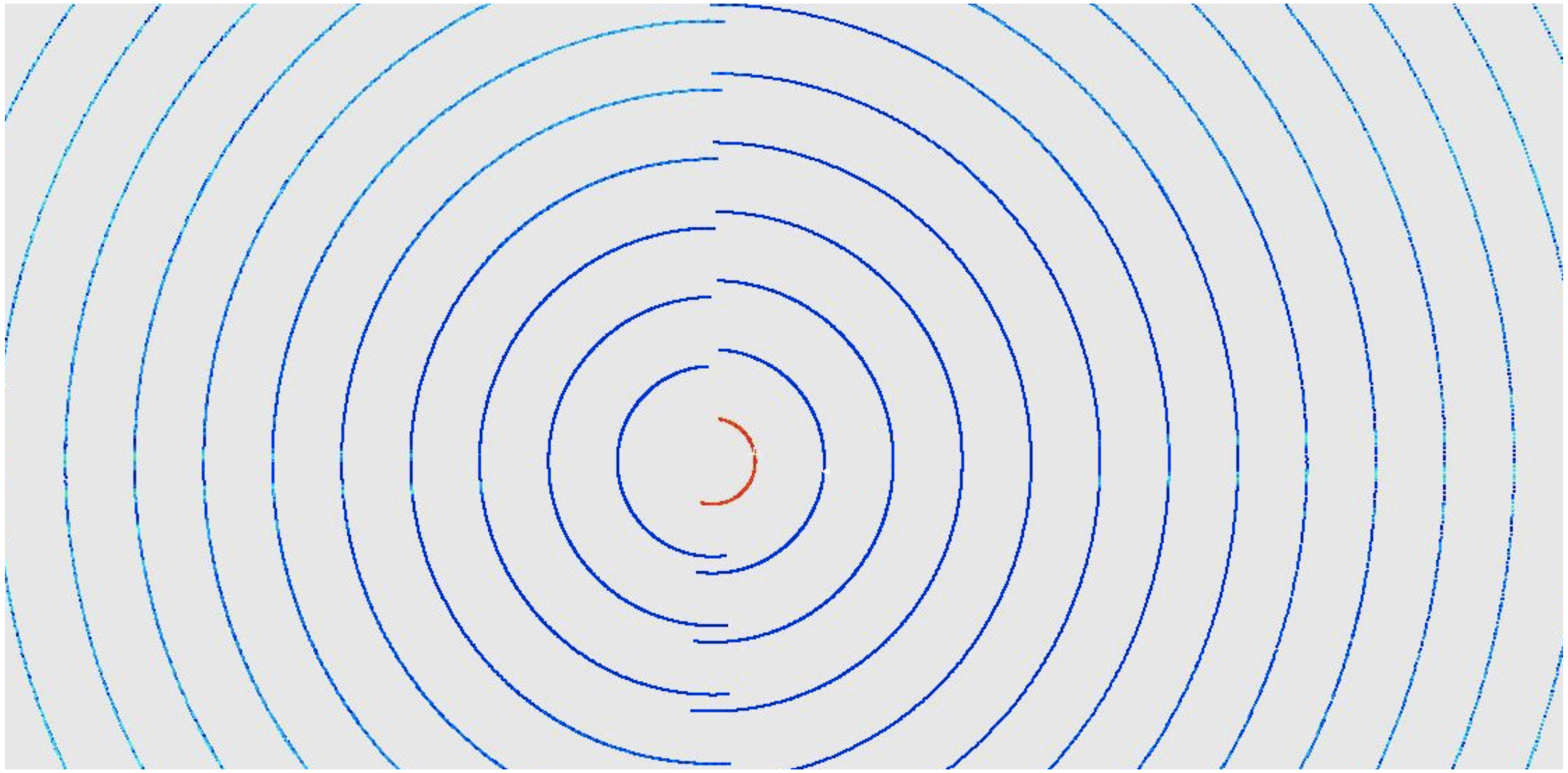


- Targets are placed at known positions relative to the edges of the plane.
  - In the groove between the first and second or last and second-to-last cells.
  - Pressed against the end cap.
- Use the maximum and minimum values of X, Y, and Z of the targets to define a volume that contains the white part of the surface.
- Remove all points outside that volume.



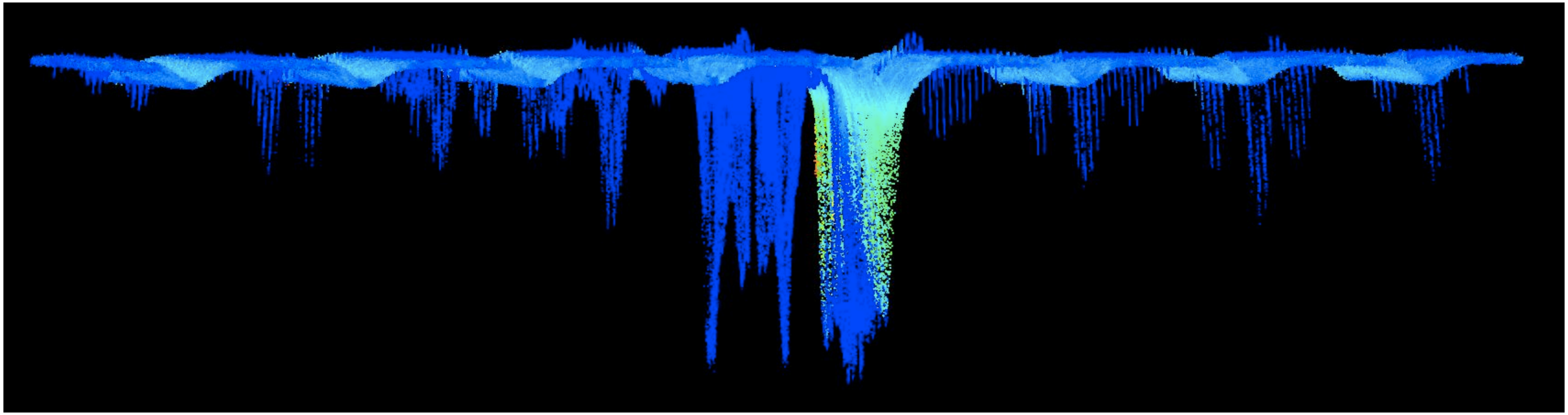


Thinning Near the Pole



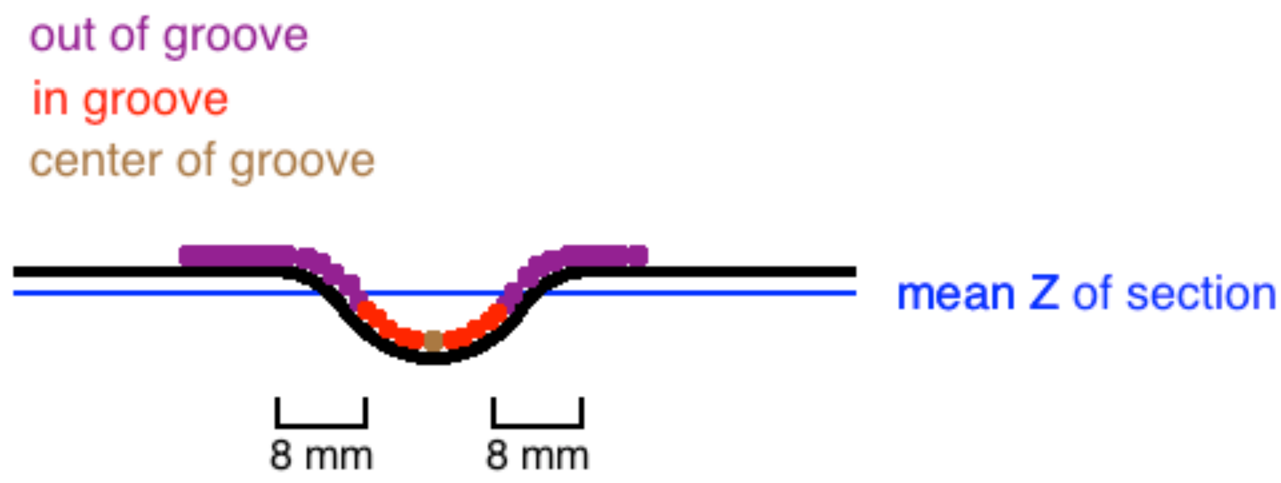
- Measurements are evenly spaced in polar coordinates, thus very dense directly below the scanner.
- Keep 0 points within 5 mm of the pole.
- Keep 1/100 of the remaining points within 3 cm of the pole.
- Keep 1/25 of the remaining points within 10 cm of the pole.

Spike Removal



- High intensity reflections make the surface appear to have spikes where it is close to the scanner and perpendicular to the scan direction.
- Divide the plane into 2400 sections of size ~25 cm × ~37 cm.
- For each section,
  1. Calculate the mean value of Z for the measured points in each section.
  2. Remove all points with Z value > 9 mm away from the mean.
  3. Recalculate the mean value of Z.
  4. Remove all points 6 mm away from the mean.
  5. Recalculate the mean value of Z.
- All remaining points are written to a text file in block coordinates.

Groove Removal



1. Divide each section into bins 1.5 mm along X (for vertical planes) or Y (for horizontal planes).

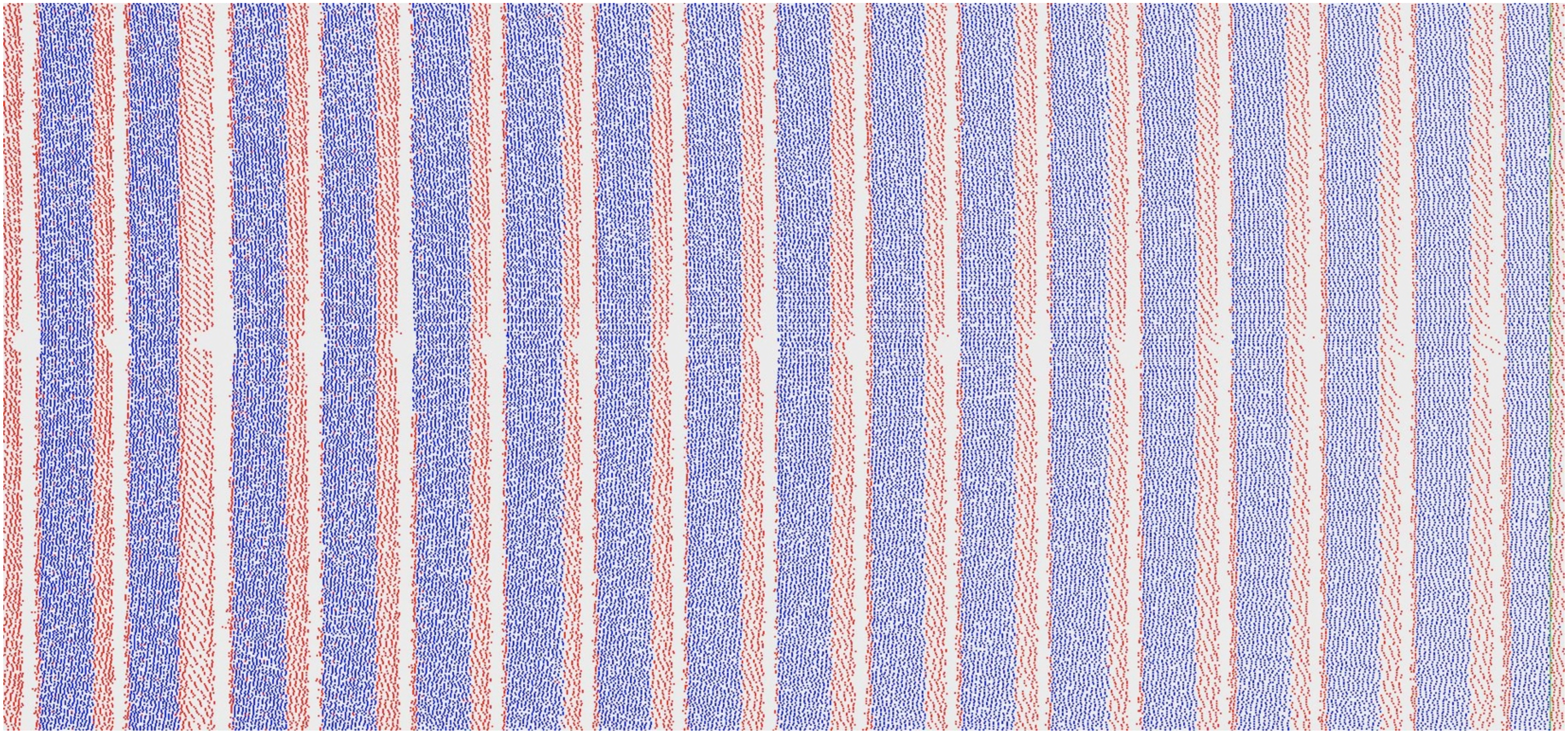
2. Calculate the mean value of Z inside each bin.

3. If (mean Z of bin) - (mean Z of section) > 1 mm, that bin is listed as inside a groove between cells.

4. Write the position of a bin if it's in a groove and lower than the four bins closest to it.

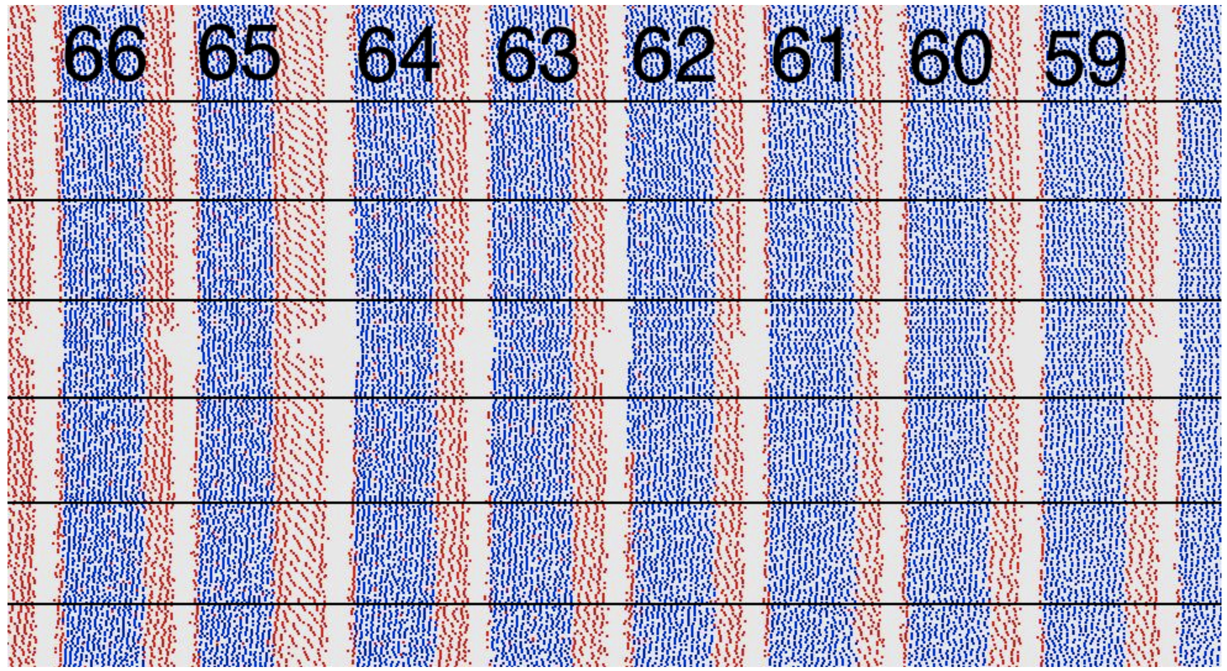
5. Remove all points in that section that are less than 8 mm from any bin that's inside a groove.

NDOS Block 5 Layer 28



- From the NOνA prototype detector.
- Red = removed points; blue = remaining points; white = no data.
- Now only a smooth surface remains.

Z Position of Different Cells

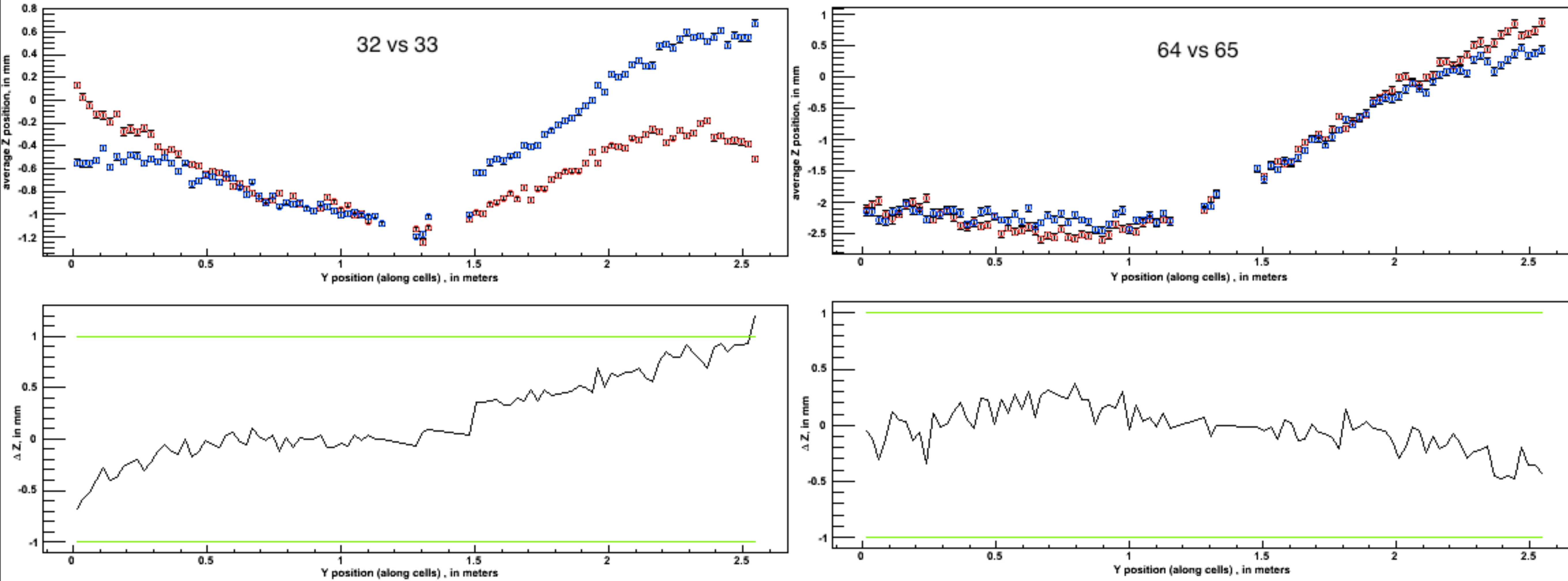


1. Divide the surface into a new set of sections 2.54 cm parallel to the cells and 15 m perpendicular to the cells.

2. Calculate the mean value of Z for each border cell within each section.

3. Plot Z as a function of Y (for vertical planes) or X (for horizontal planes) for cells at the module borders.

Z Position of Different Cells



- Unable to count cells where many points had been removed.
- We prefer |ΔZ| < 1 mm at the module boundaries.

Far Detector Construction

photograph by Ron Williams

- NOνA began to glue Far Detector modules to each other on August 1.
- Block 0 was assembled slowly so we could make sure every step worked.

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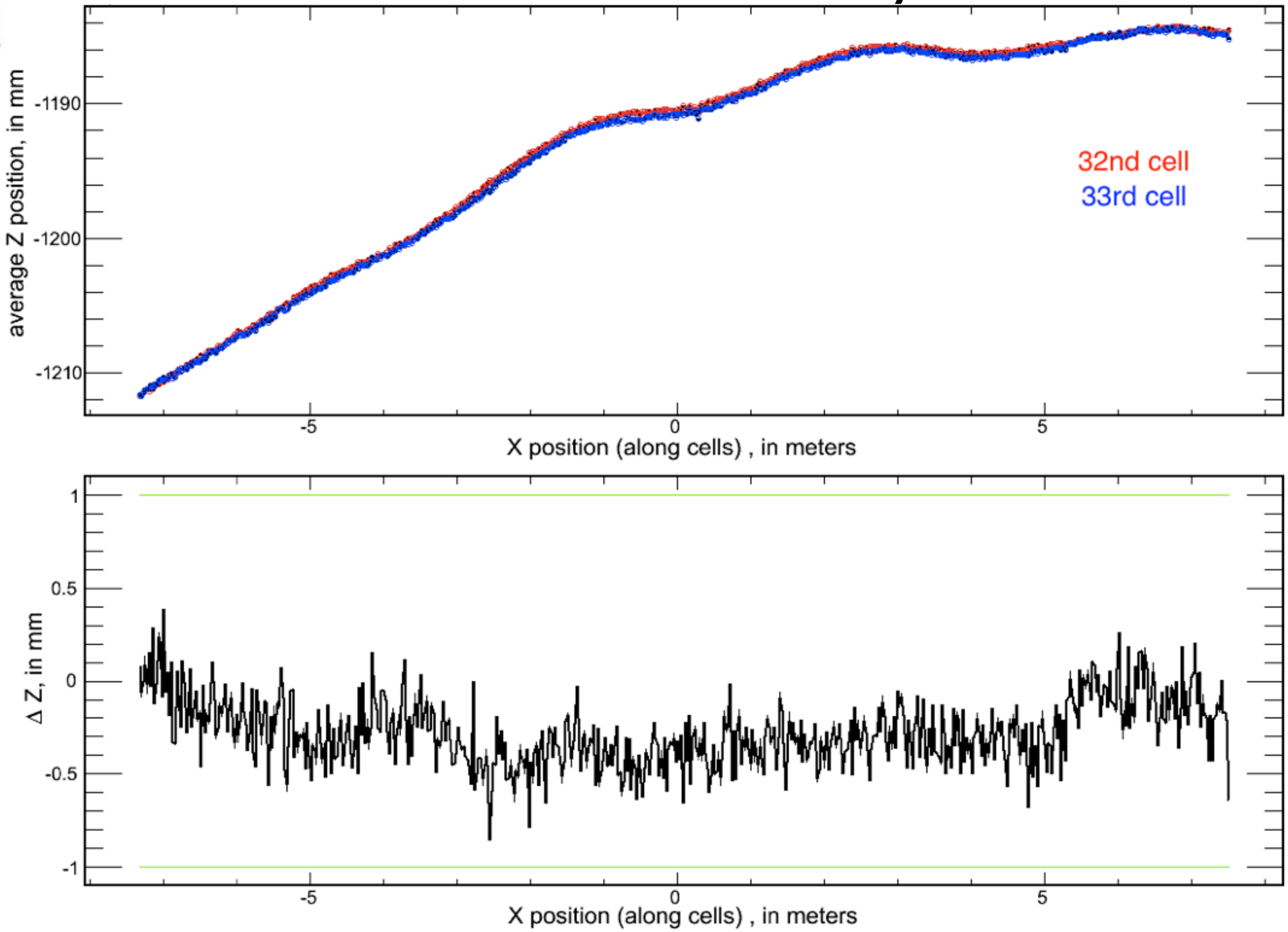
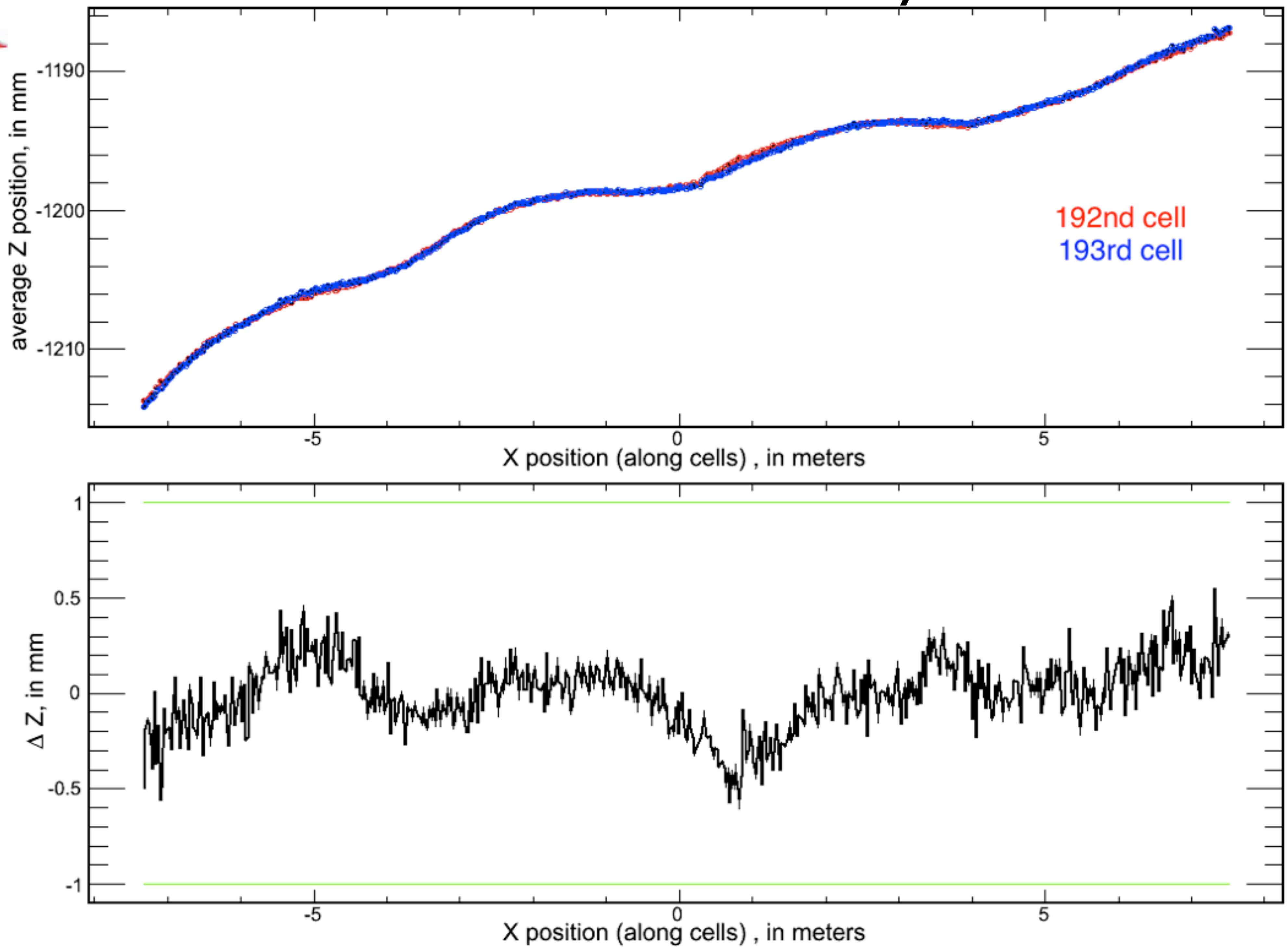
Far Detector Block 0 Layer 14



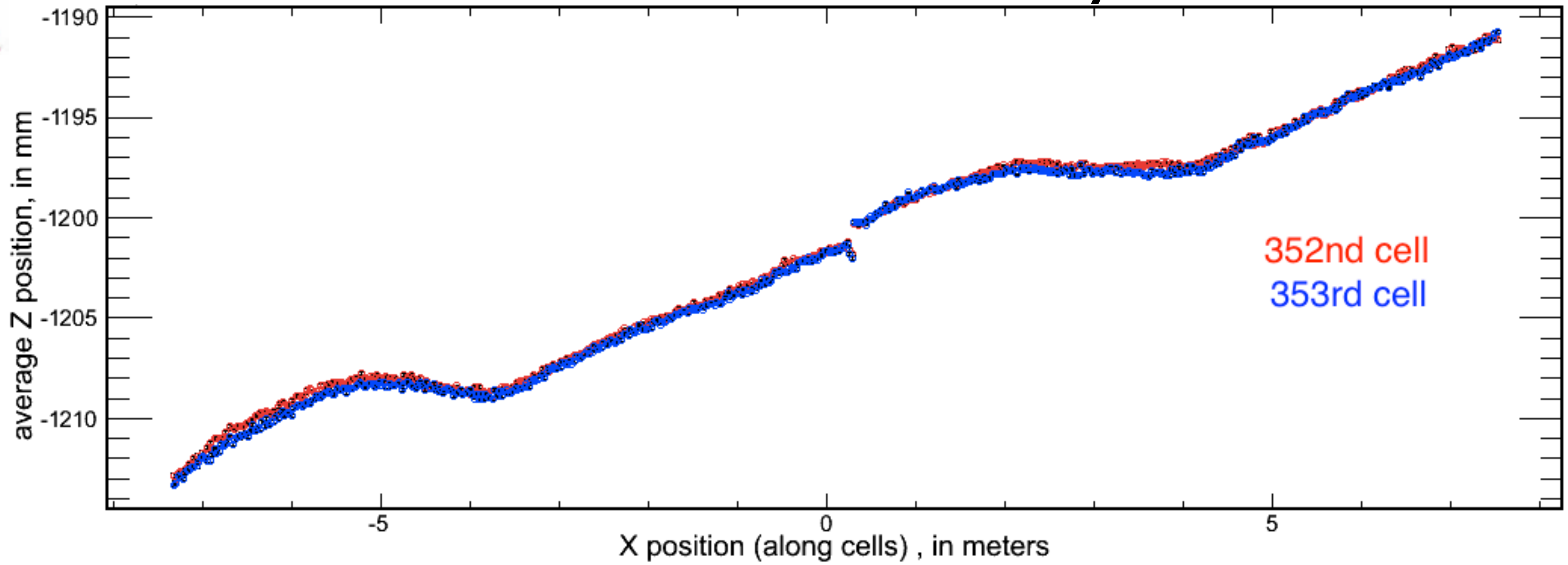
- ΔZ = 28 mm along the module border.
  - Table surface will be remeasured after Block 0 is finished.
- ΔZ < 1 mm across the module border.

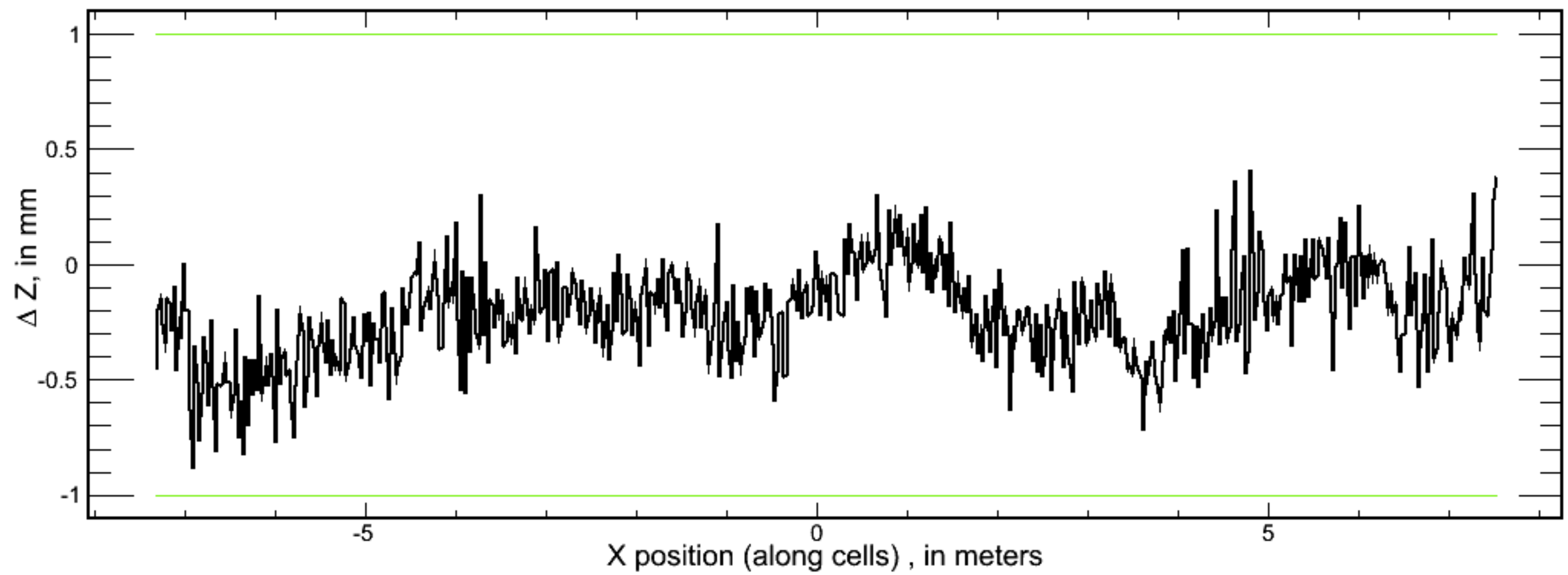
Far Detector Block 0 Layer 14



- Similar result to the 32nd cell vs 33rd cell border.

Far Detector Block 0 Layer 14





- Similar result to the 32nd cell vs 33rd cell border.
- We'll try to find the reason for that 2 mm jump in Z near the center.

Summary

- A laser scanner measures the upstream surface of every plane of the NOνA Far Detector.
- A computer program has been developed to reduce the data and make a quick estimate of the surface shape.
- It showed no evidence of major problems during the construction of Block 0.

Point Weighting

- Some parts of the scan have a much larger concentration of points inside the grooves than on the planar surface. This can put the mean value of Z too deep inside the grooves.

1. Divide the section into ~1 cm bins along X.
2. Count the number of points inside each bin.
3. A point's weight = 1 / (# points in bin).
4. Then calculate the mean value of Z in the section.

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