

Fiducialization for the CBETA Magnets

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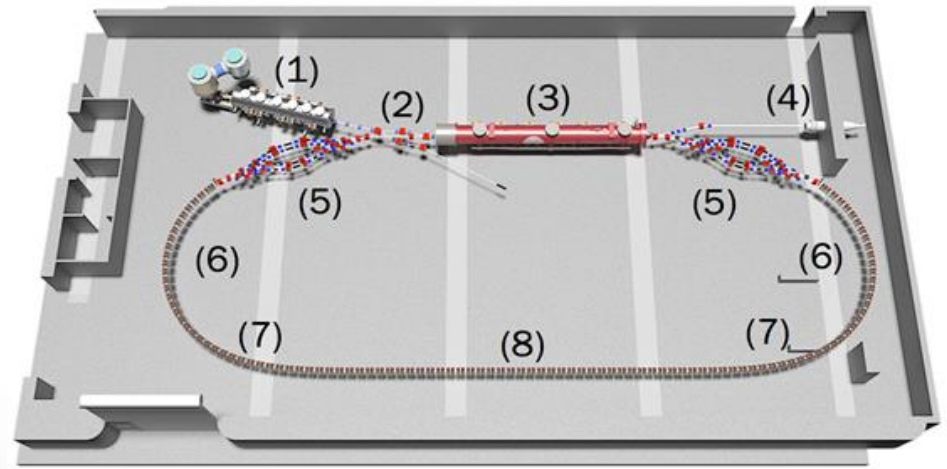
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The Cornell-BNL Energy Recovery Linac (ERL) Test Accelerator (CBETA)

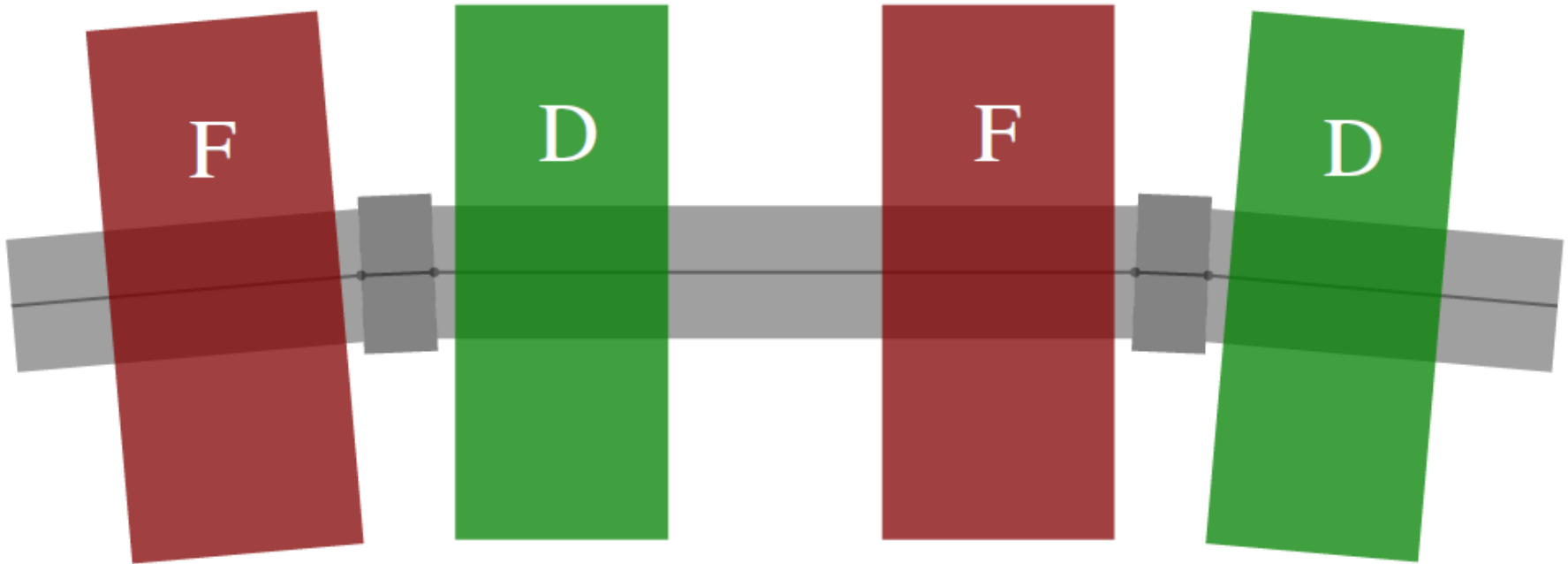
- the first ever multi-turn ERL with superconducting RF (SRF) acceleration
- the first ERL based on Non-Scaling Fixed Field Alternating Gradient (NS-FFAG) optics
- CBETA role as a prototype for the future Electron Ion Collider (EIC) in the present Relativistic Heavy Ion Collider eRHIC, as an ERL proof of principle for accelerating electrons with energy recovery

CBETA-Existing Injector (1), merger (2) with the Main Linac Cryo-module (MLC) (3). The rest of the accelerator is being built: spreaders (5), FFAG arcs (6), transitions to the straight (7), and the straight section (8).



FFAG Arc Cell Geometry

The basic cell is a doublet, consisting of a focusing quadrupole and a combined function magnet with a dipole and defocusing quadrupole component



Halbach Prototype Magnets

- QF (106) and BD (106)
- permanent magnets (not electromagnets)



Cubic Zirconia

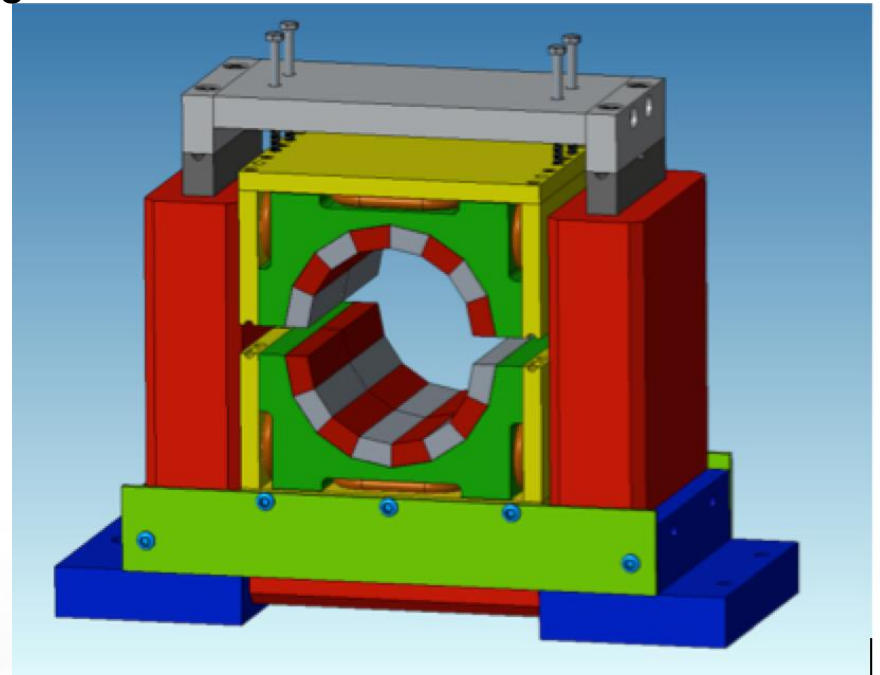
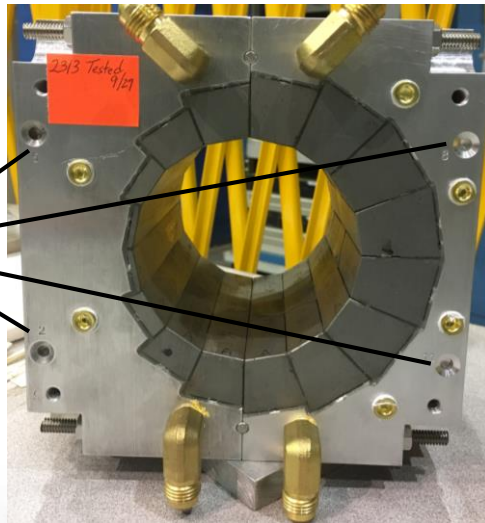


Halbach Prototype Magnet Frame

- Common aluminum outer frame
 1. provide high strength and low deflection when resisting the magnetic forces from the permanent magnet material blocks;
 2. were machined with tight tolerances to enable accurate block positioning
 3. provides excellent thermal conductivity enabling small temperature variations around the outer circumference
- The same window frame electro-magnetic corrector around them

24 survey
fiducials

- ❖ Upstream
- ❖ Downstream
- ❖ Top
- ❖ Bottom
- ❖ Sides



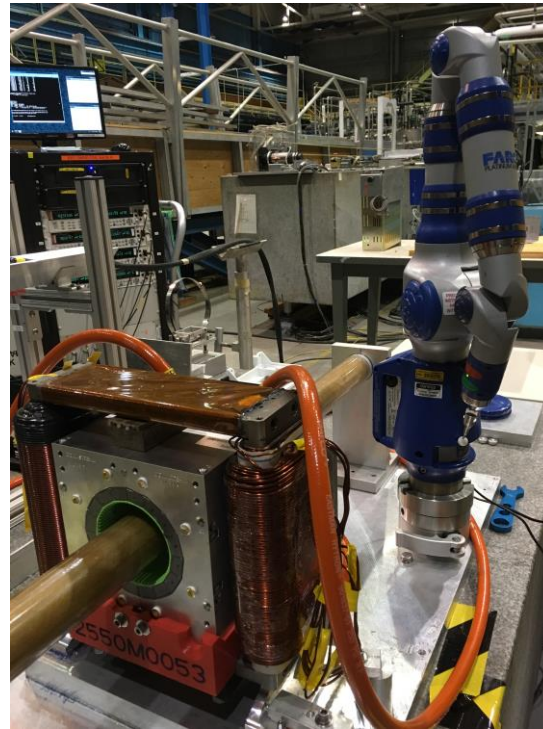
CBETA Magnet Tuning Wire Holders

A non-magnetic insert will be placed directly inside the permanent magnet blocks in every CBETA Halbach magnet in order to hold a set of iron “tuning wires”. These wires have various lengths around the perimeter of the aperture in order to cancel multipole field errors from the permanent magnet blocks. After the magnet is shimmed, survey is needed



Fiducialization

- Magnet fiducials and fiducials (7 or 8) on the base plate
- Rotating coil at multiple orientations
- Upstream and downstream surface
- Base plate
- 3 setups

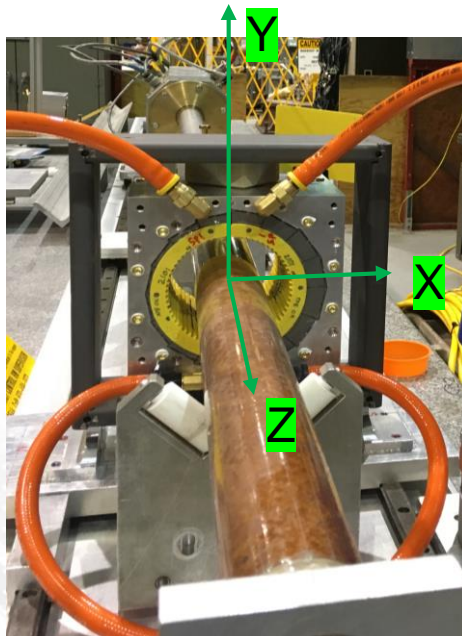


Measurement Plan (MP)

- Automation of the whole measurement process and analysis
 - ✓ Measurement window popup for guiding the process
 - ✓ Delete the unreachable fiducials (the cooling water is in the way) and name the fiducials as requested
 - ✓ For both of coil bench1 and coil bench2 survey to create different frame as requested
 - ✓ Export the txt files in the form as requested
- Benefit
 - ✓ Work efficiently
 - ✓ Easy for everyone in our survey group
 - ✓ Decrease error

Measurement Coordinates

- Frame Definition:
- ORIGIN: Magnetic center
 - +X: Radially outward
 - +Y: Vertically UP
 - + Z: Axial downstream
- The X and Y magnet positions are got from the rotating coil measurement
- The Z position is determined by the midpoint of the coil axis intersecting with the US and DS planes
- **Horizontal plane:** the rotation about the Z axis is derived from the rotating coil field data and the calibration of the coil's internal roll angle(next slide) from the E4E measurements
- The rotation about the X and Y axes is determined by the average of the normal to the US and DS planes



Rotating Coil Roll Angle Calibration

- A magnet must be measured and surveyed twice in the forward and reversed orientations
- This will be done at the start of the CBETA measurements and also whenever a significant roll angle change is observed in the daily readings

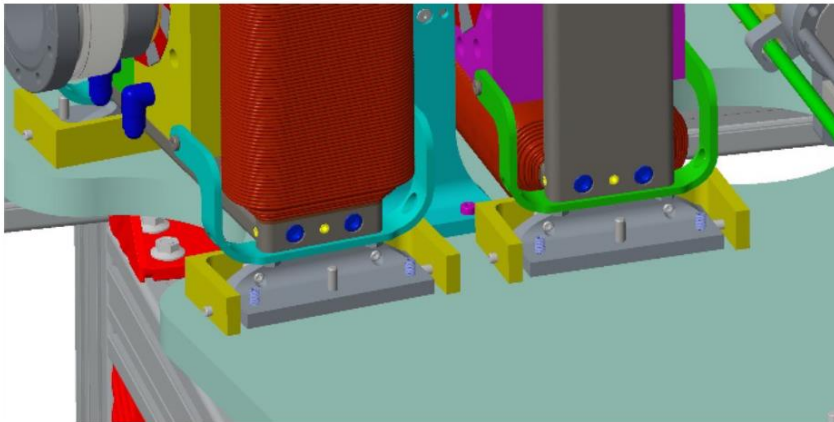
Measurement Accessory

- For Arm: fixed mounting base with rotatable hand
- For 2 coil bench stations: equipment with Arm box, cable and laptop



Adjustment for the Magnets on Girders

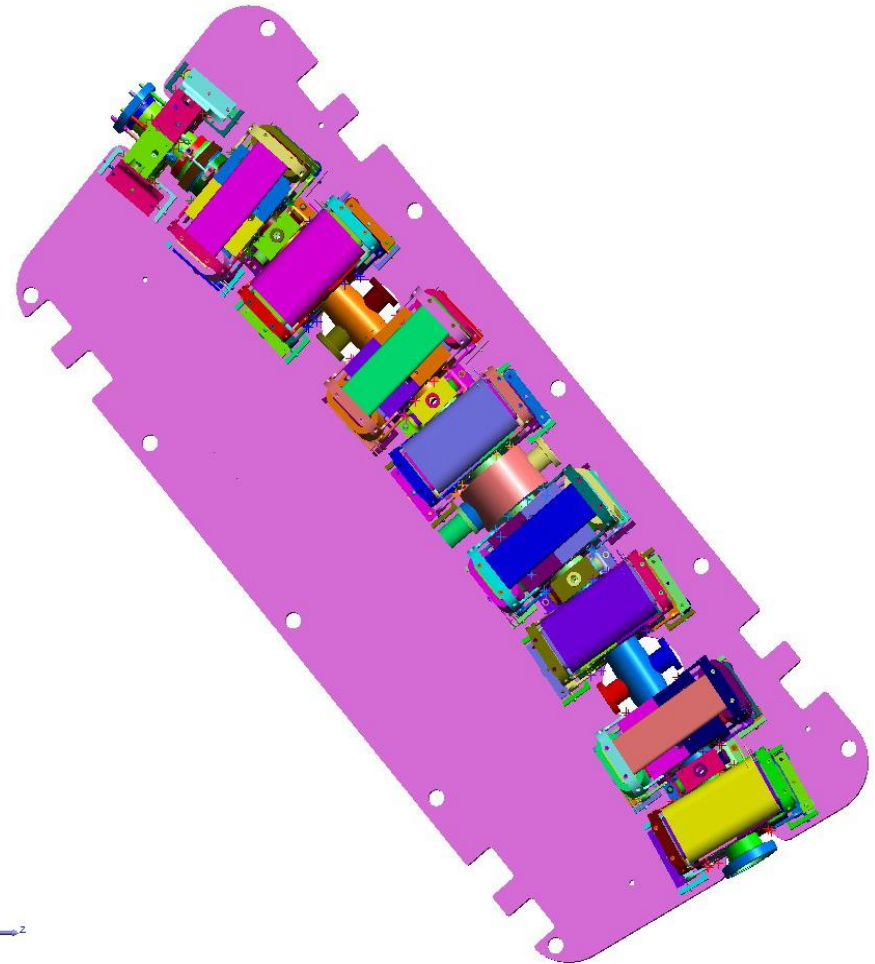
- Each magnet consists of a Halbach core surrounded by a relatively weak electromagnet corrector
- Accurate alignment of the integrated magnet assembly is achieved with multi-position jacking and alignment screws that can be locked into place after survey



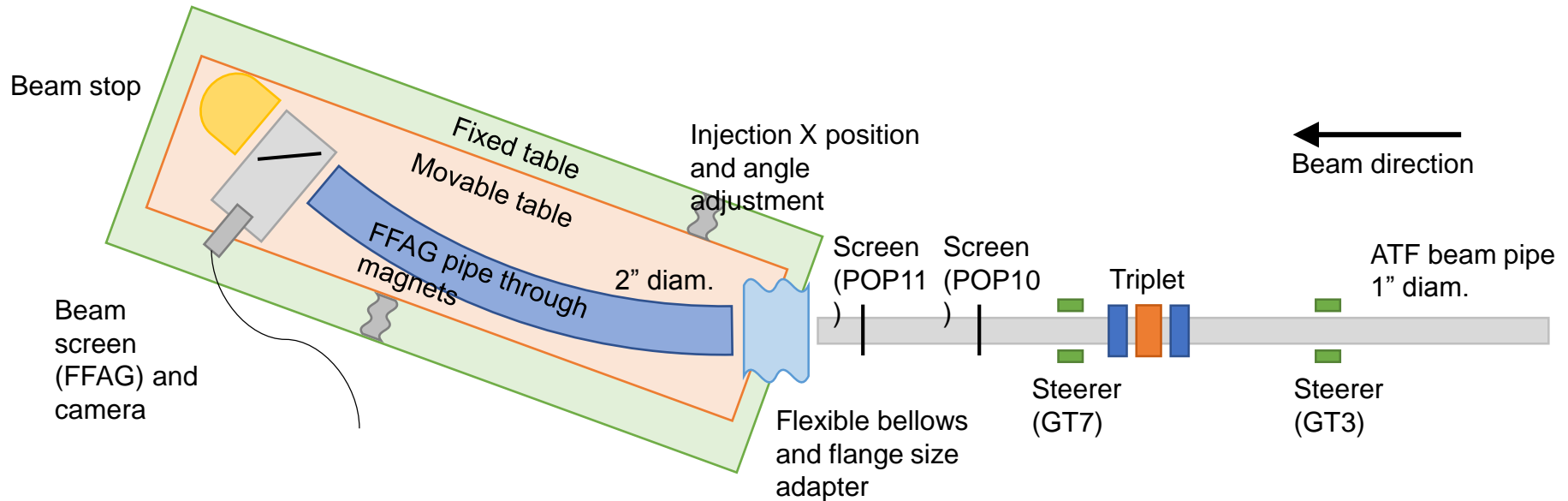
First Girder

- The first girder was build with Halbach magnets
fiducials deviation

Summary: Group to Group Relationship Groups: NONIMAL MAGNETS to USMN Composite			
Statistic	dX (mm)	dY (mm)	dZ (mm)
Min	-0.143	-0.209	-0.199
Max	0.266	0.067	0.217
Average	0.017	-0.062	-0.007
StdDev from Avg	0.087	0.056	0.103
StdDev from Zero	0.088	0.084	0.103
RMS	0.088	0.083	0.103
Count	90		



Test of Linear-Field Non-Scaling FFAG Arc with a Wide Energy Range

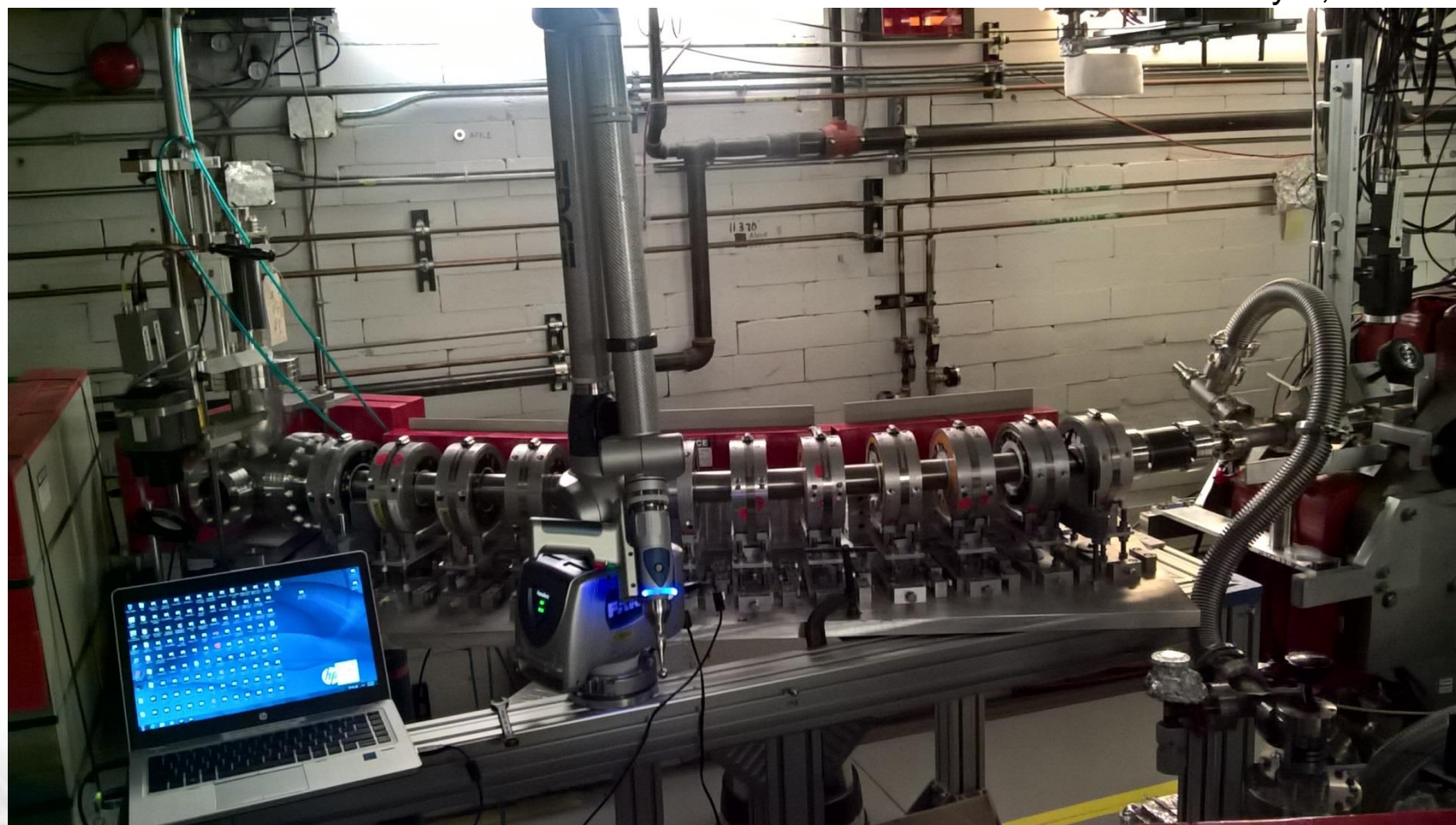


- Similar FFAG assembly
- Move to different positions for 5 different energies through survey

Survey in the Field

Most magnet offsets $<0.2\text{mm}$; RMS 0.1mm or better

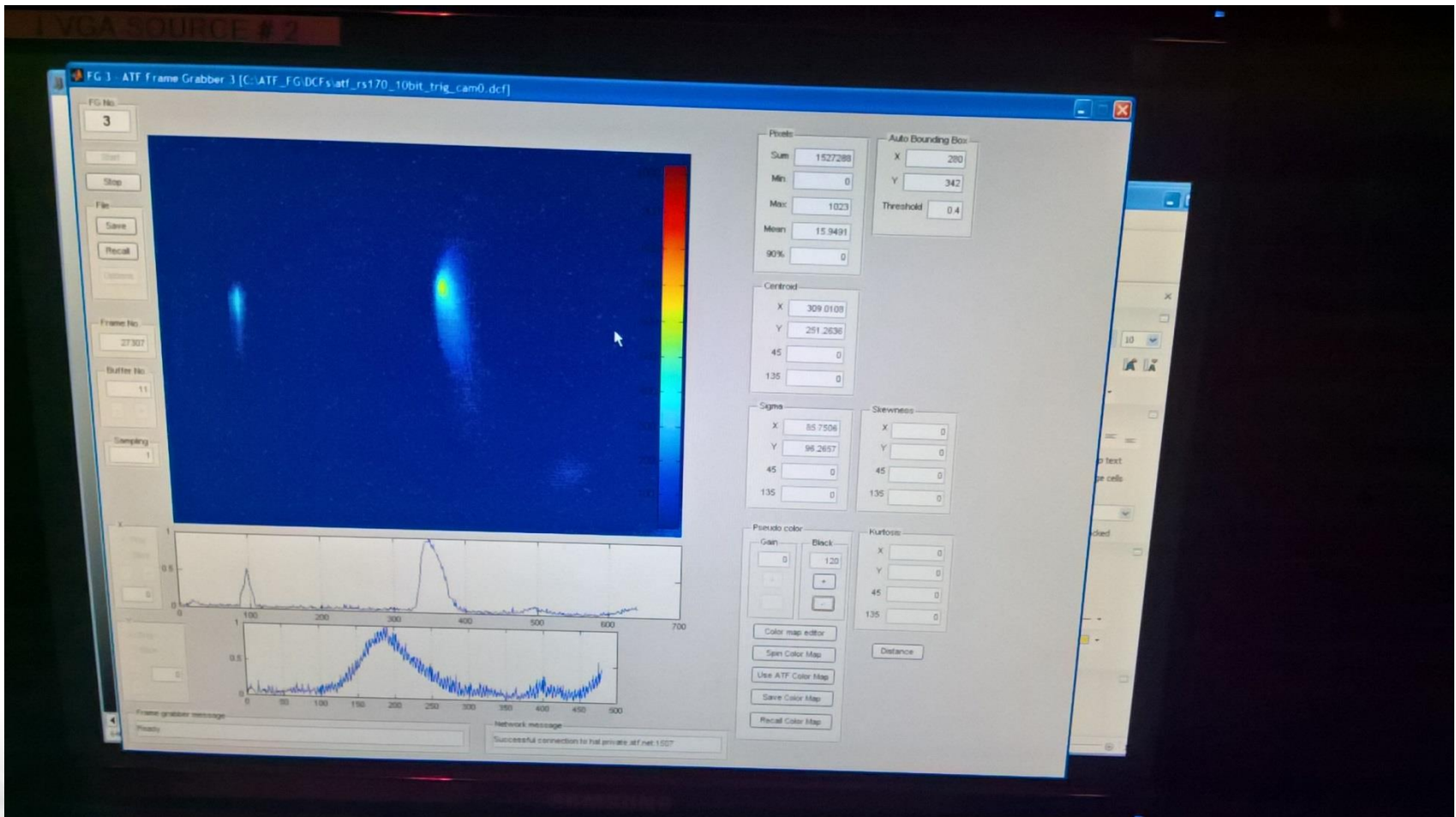
May 5, 2017



First Beam during Fault Studies

54MeV was the first energy to be tested

May 4, 2017



Conclusion & Future Plans

- More magnets will be fiducialized
- Currently everything goes smooth
- Will attend the accuracy survey for all of the assembly girders at Cornell

REFERENCES

1. Measurement Procedure for CBETA Halbach Magnets, Stephen Brooks, Nov 08,2017
2. Test of Linear-Field Non-Scaling FFAG Arc with a Wide Energy Range , Stephen Brooks, Sep 08,2017
3. CBETA - CORNELL UNIVERSITY BROOKHAVEN NATIONAL LABORATORY ELECTRON ENERGY RECOVERY TEST ACCELERATOR, Proceedings of IPAC2017

Thanks!