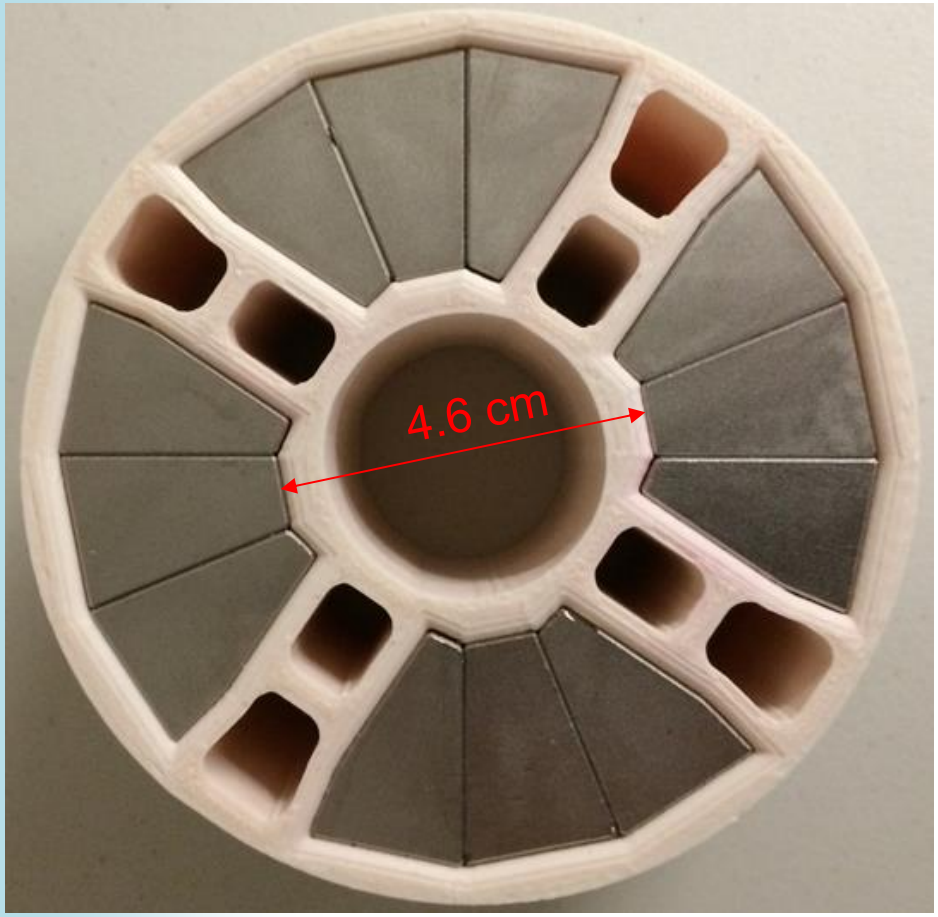
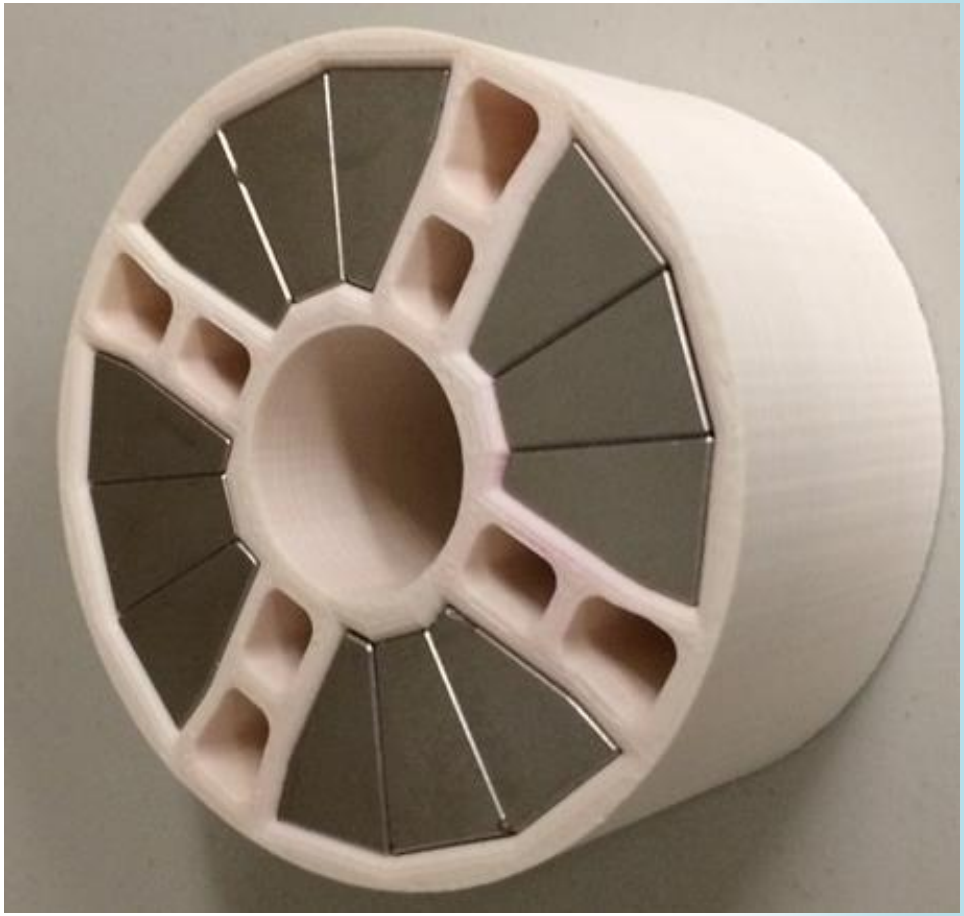
Correction Methods for Permanent Magnets

Based on Nick Tsoupas's modified Halbach quadrupole for eRHIC

First Magnet Prototype (x5 built)



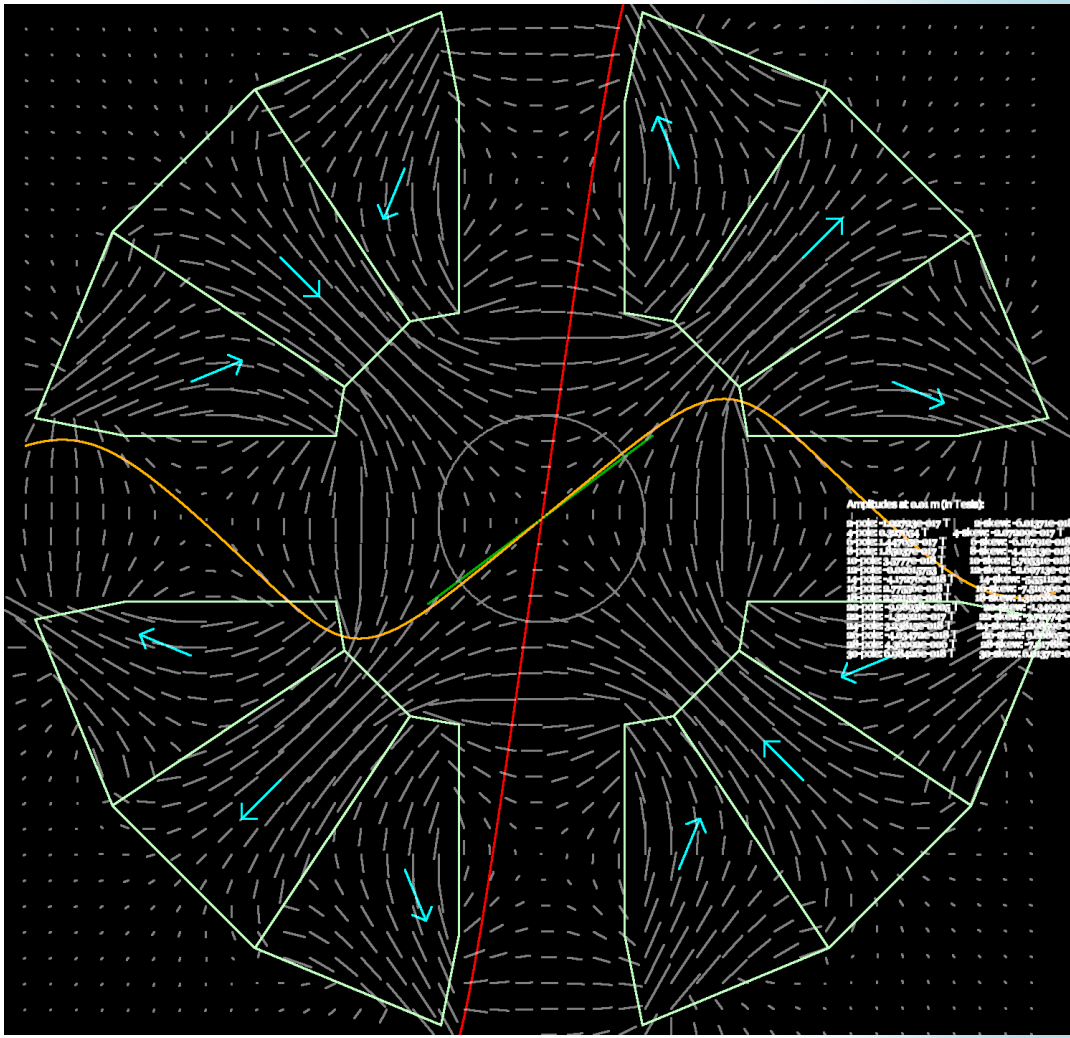


First Magnet Prototype (x5 built)

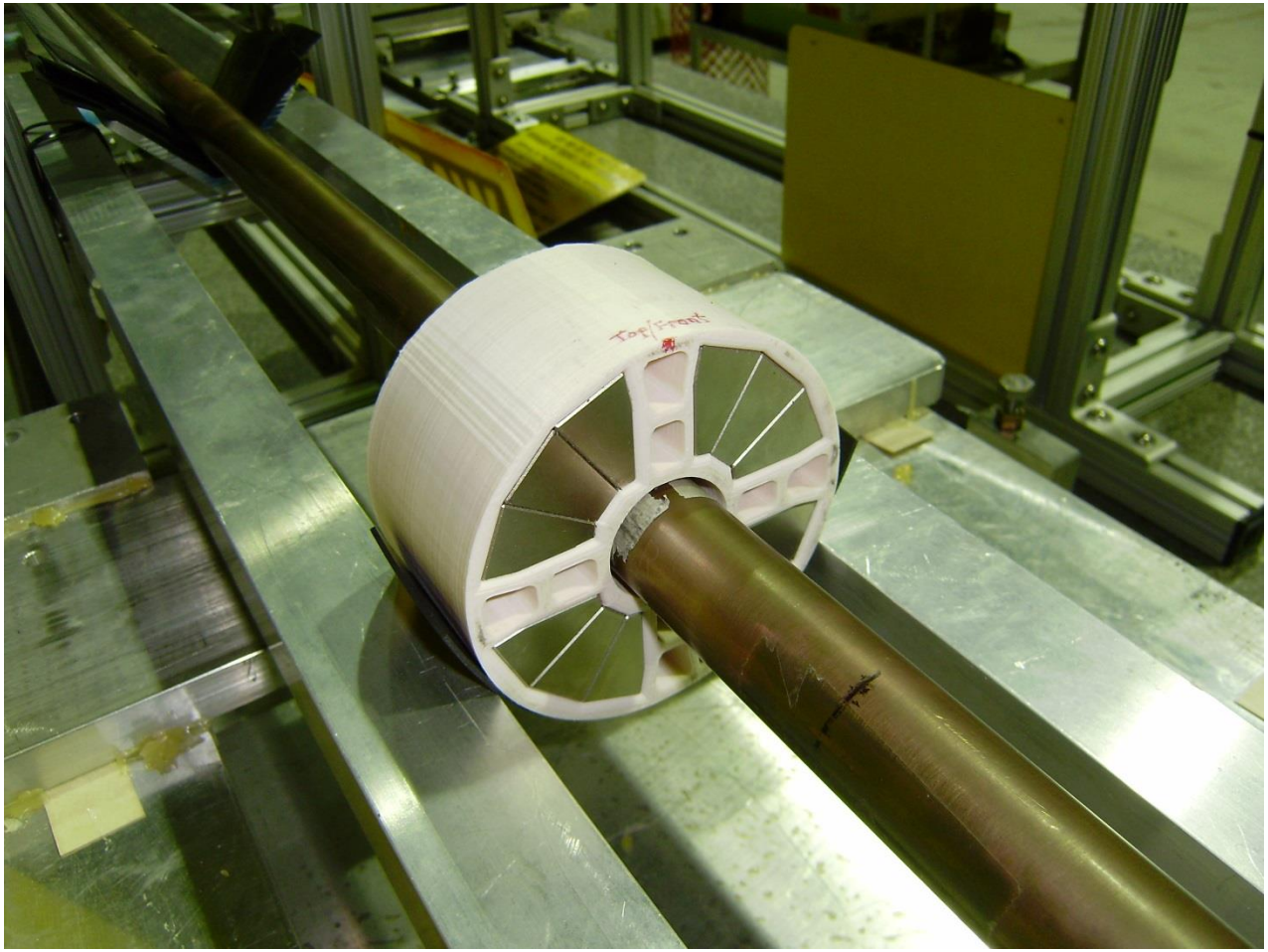
- One of 3 options in the eRHIC magnet LDRD
  - Others were Wuzheng/iron poles and rectilinear
- Design by Nick Tsoupas, open midplane ±8mm
- Assembled by George Mahler with 3D printer
- Material SmCo N26HS provided by Shin-Etsu
  - Unfortunately blocks adjacent to the open midplanes had wrong magnetisation direction
    - But this was a known error so can be simulated
    - Produces primarily 12-pole

Stephen's PM2D Code

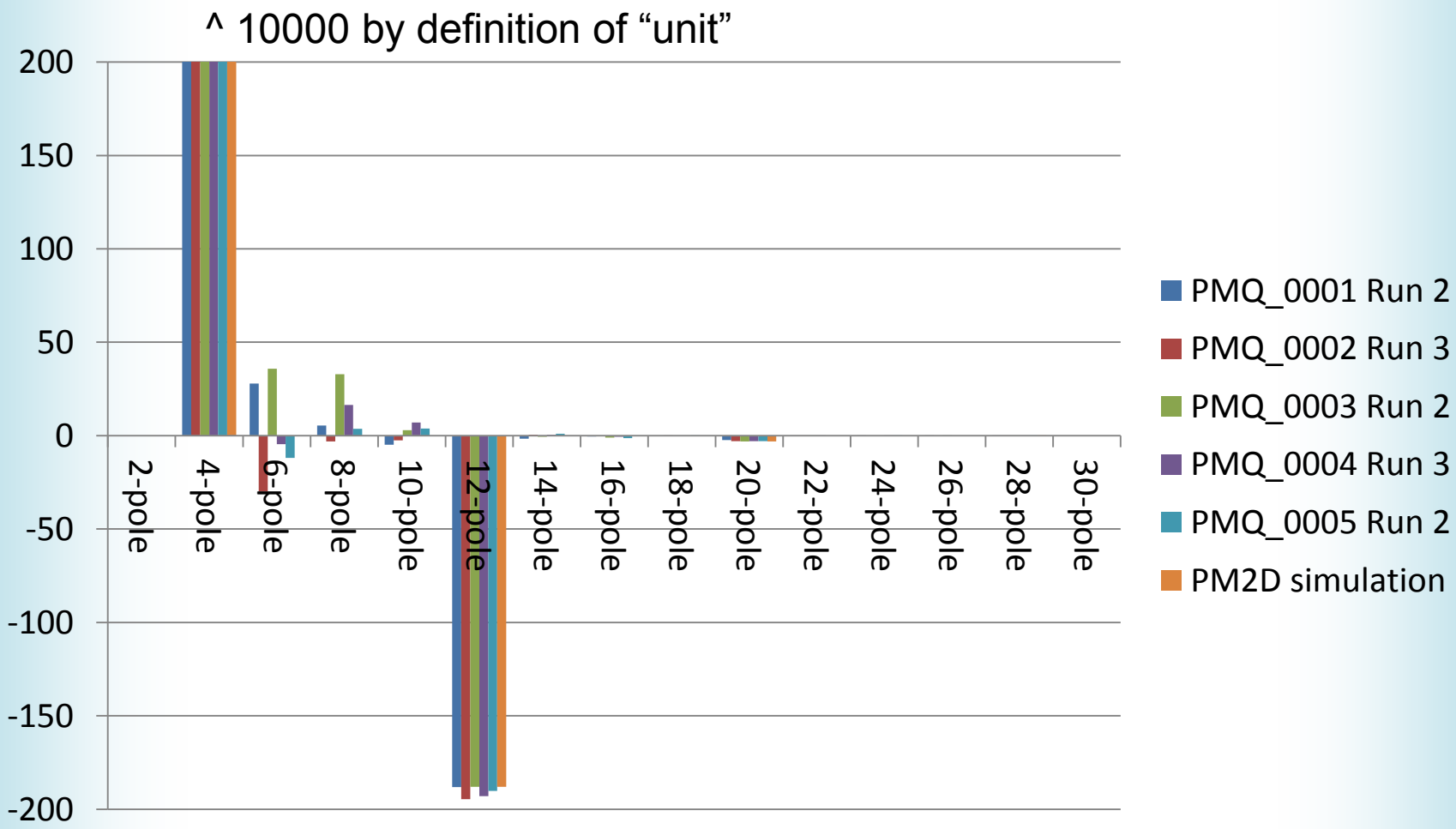
- Assumes fixed **M** vector in each block (1.07T here)
  - Equivalent surface currents
  - Biot-Savart law
- Assumes μ=1
  - Actually ~1.05



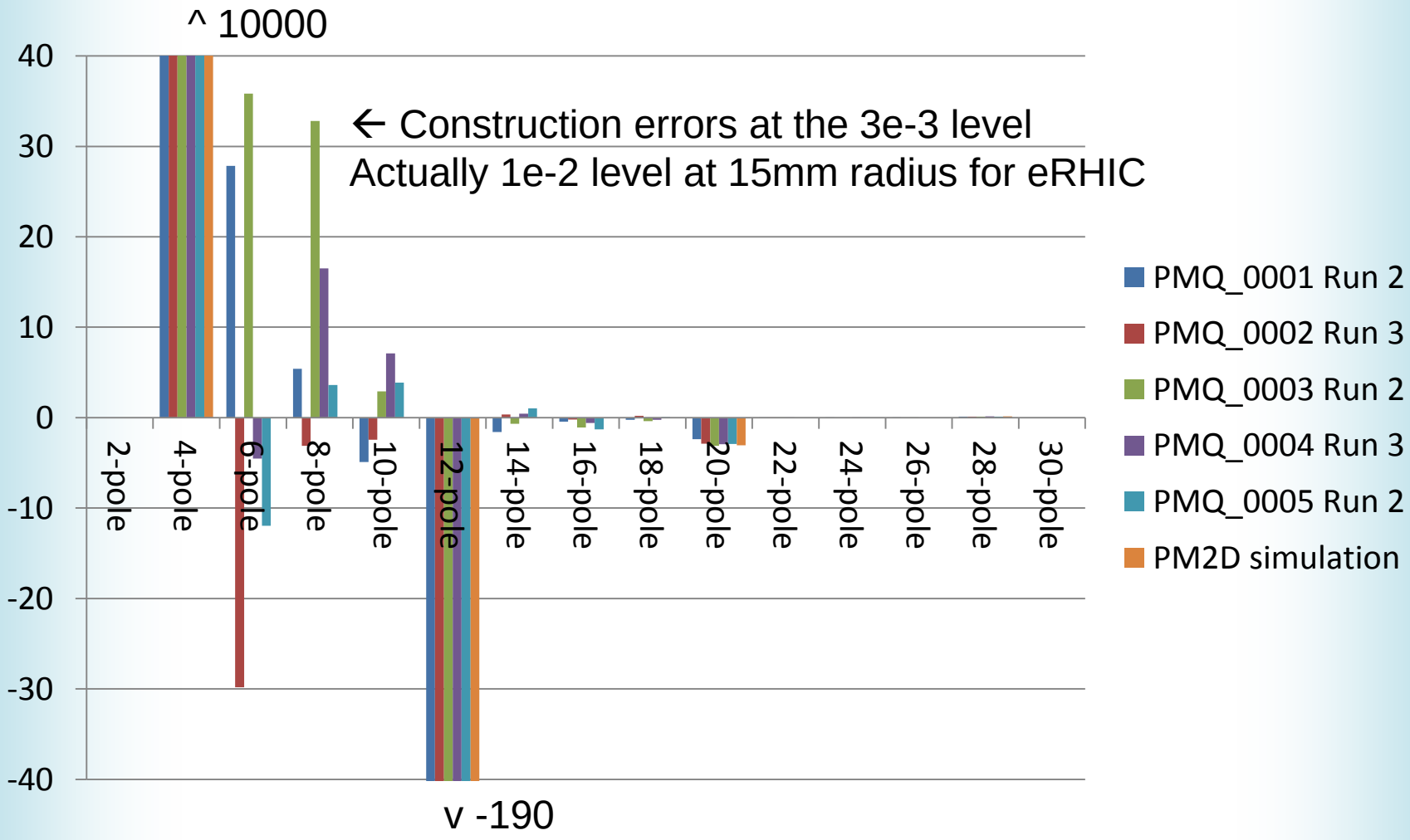
Rotating Coil Measurement in Building 902 Annex by Animesh Jain



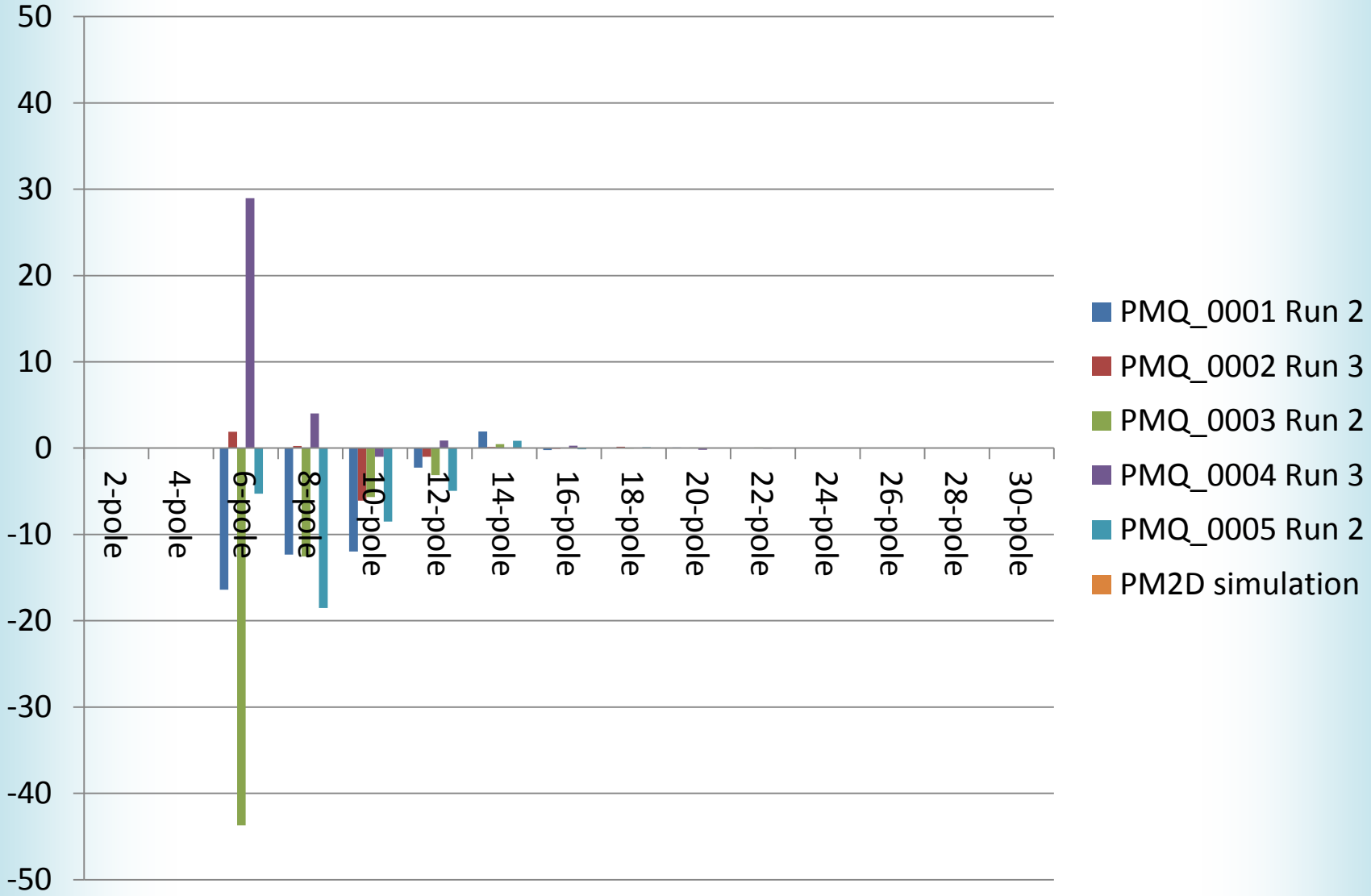
Normal Poles at r=1cm



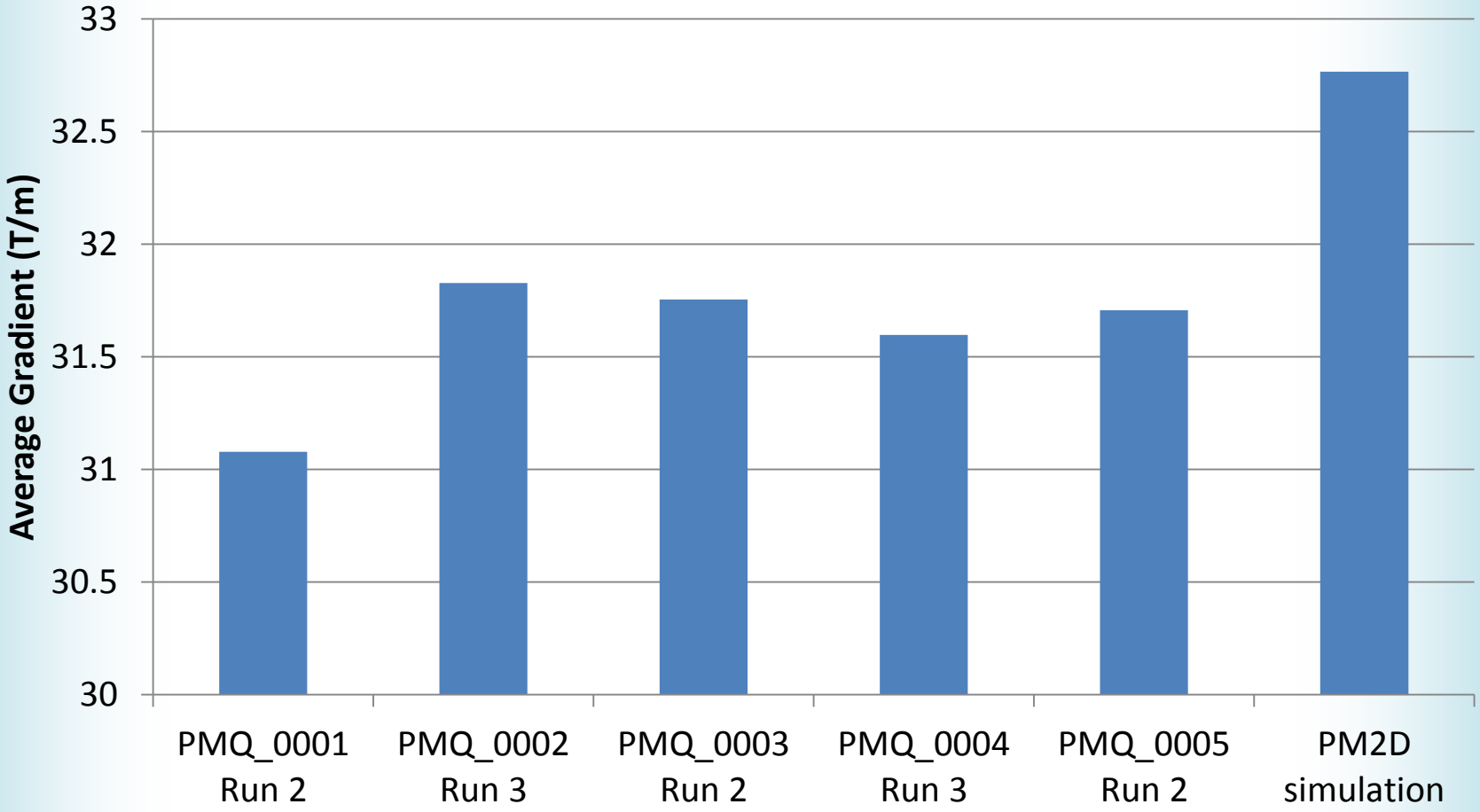
Normal Poles at r=1cm (Zoom)



Skew Poles at r=1cm

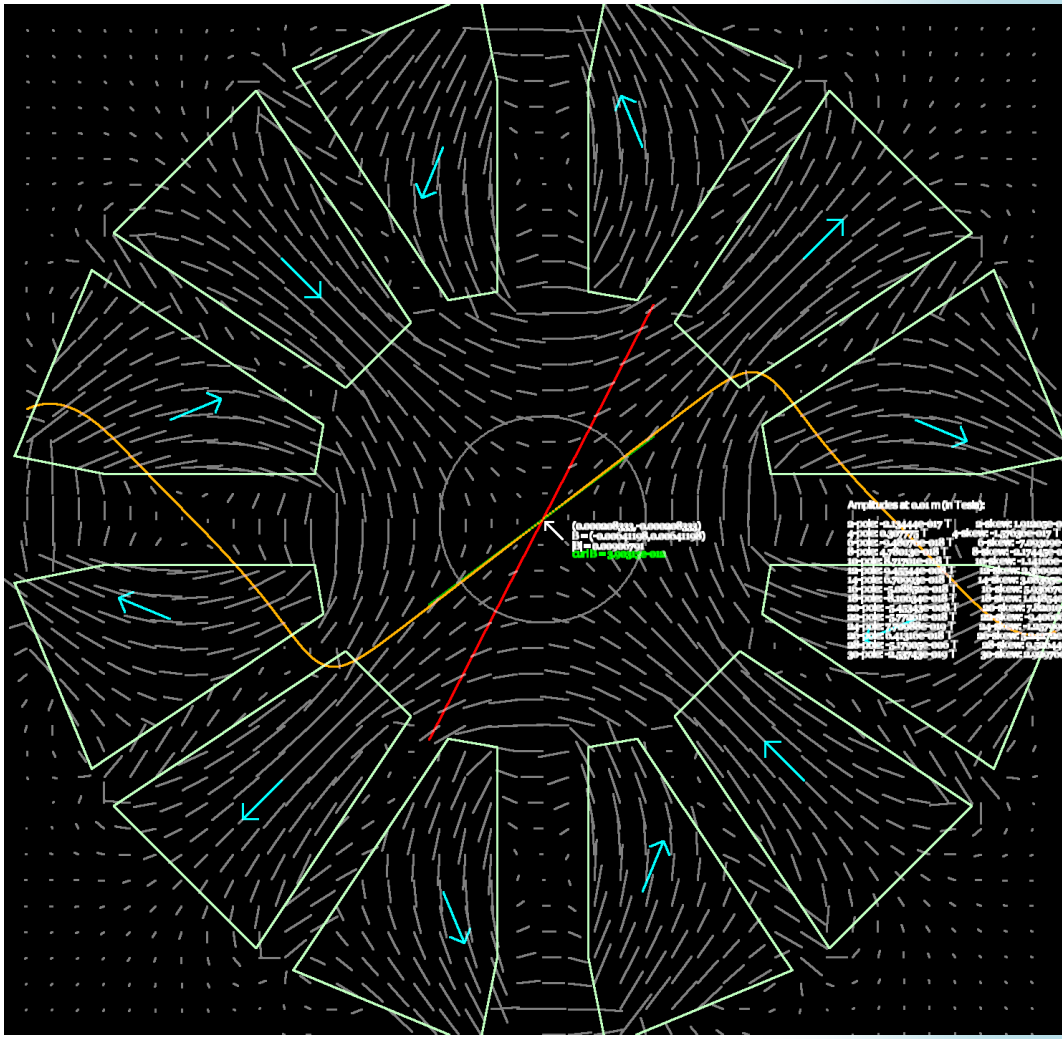


Quad Strengths (for 6cm length)

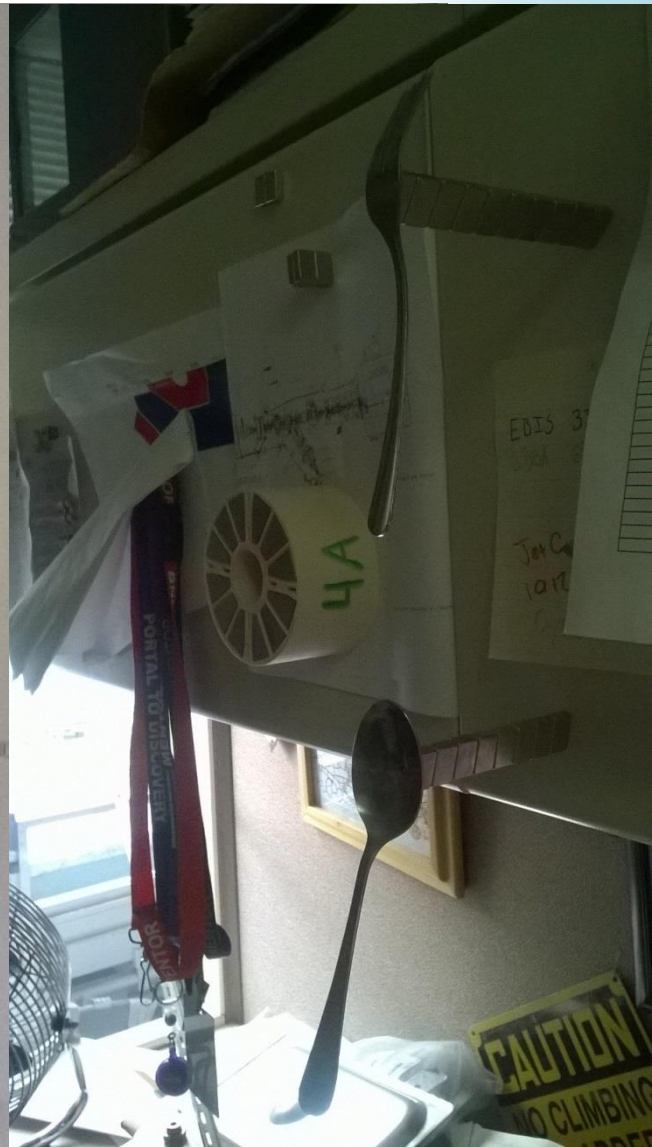


PM2D Suggests Displacements

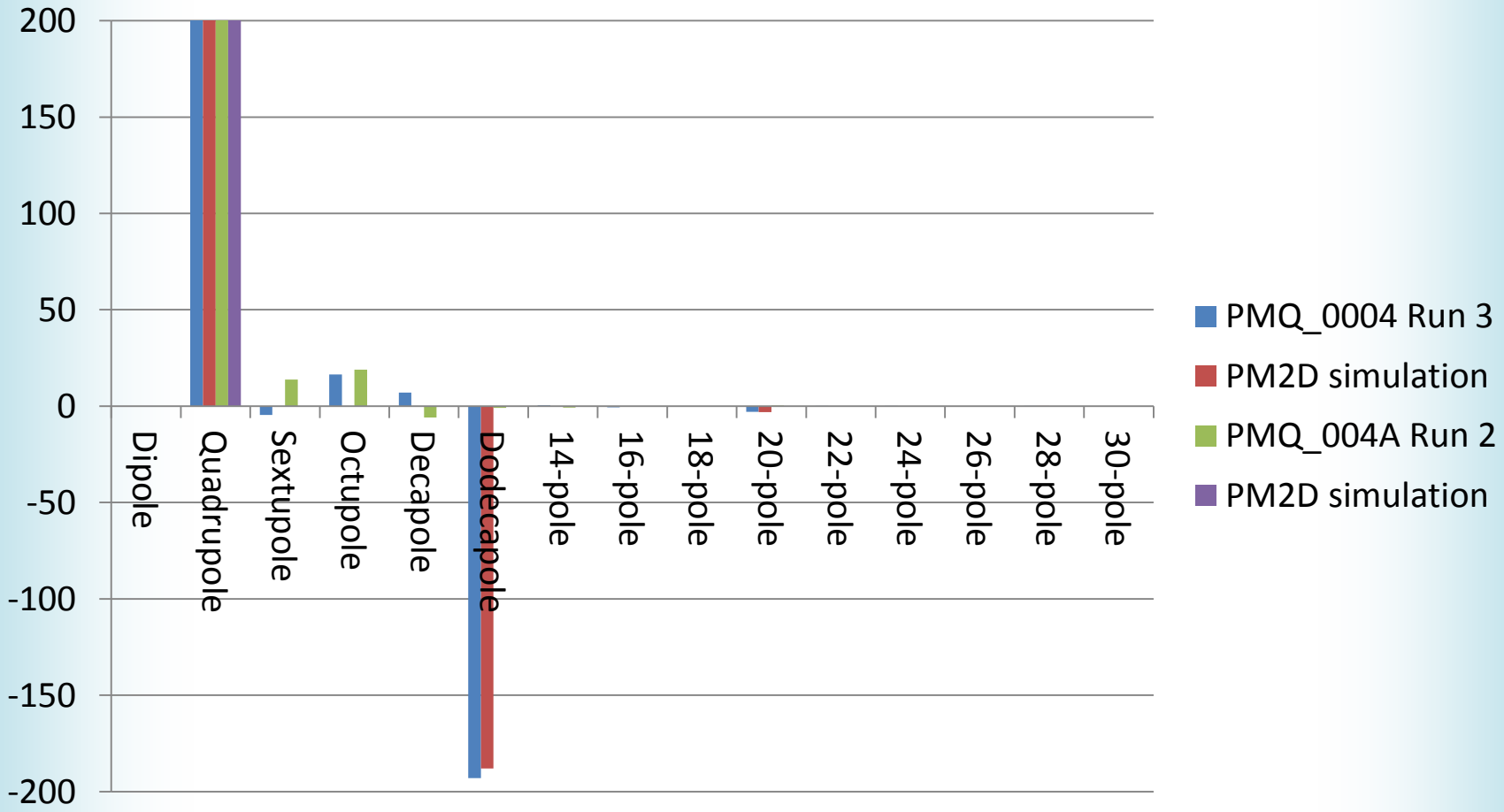
- Nulls 12-pole and 20-pole in theory
- Δx = -3.607mm
- Δy = 2.147mm
- New magnet holder 3D printed
- Magnet 4 blocks reused → “004A”



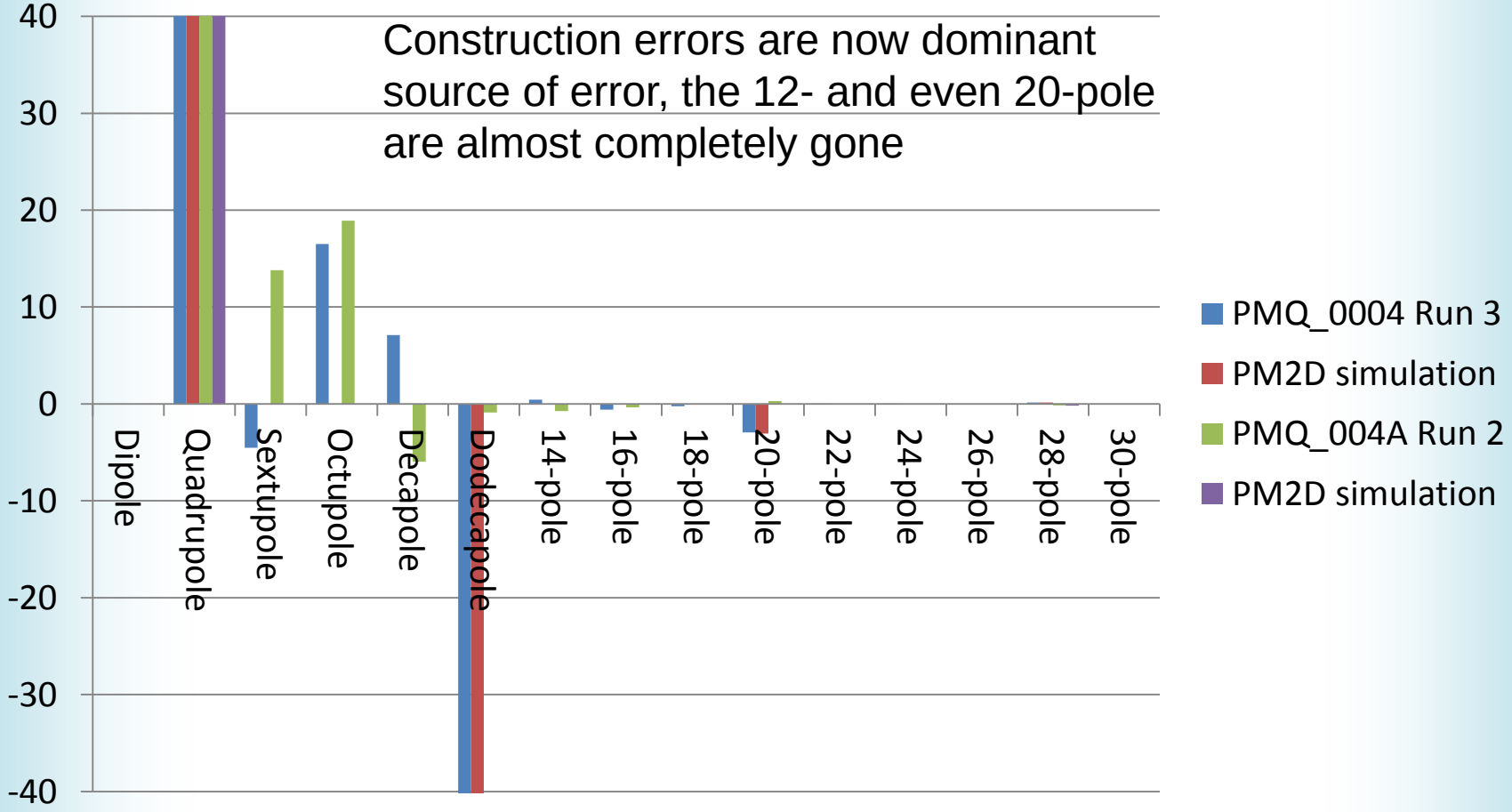
Magnet PMQ_004A



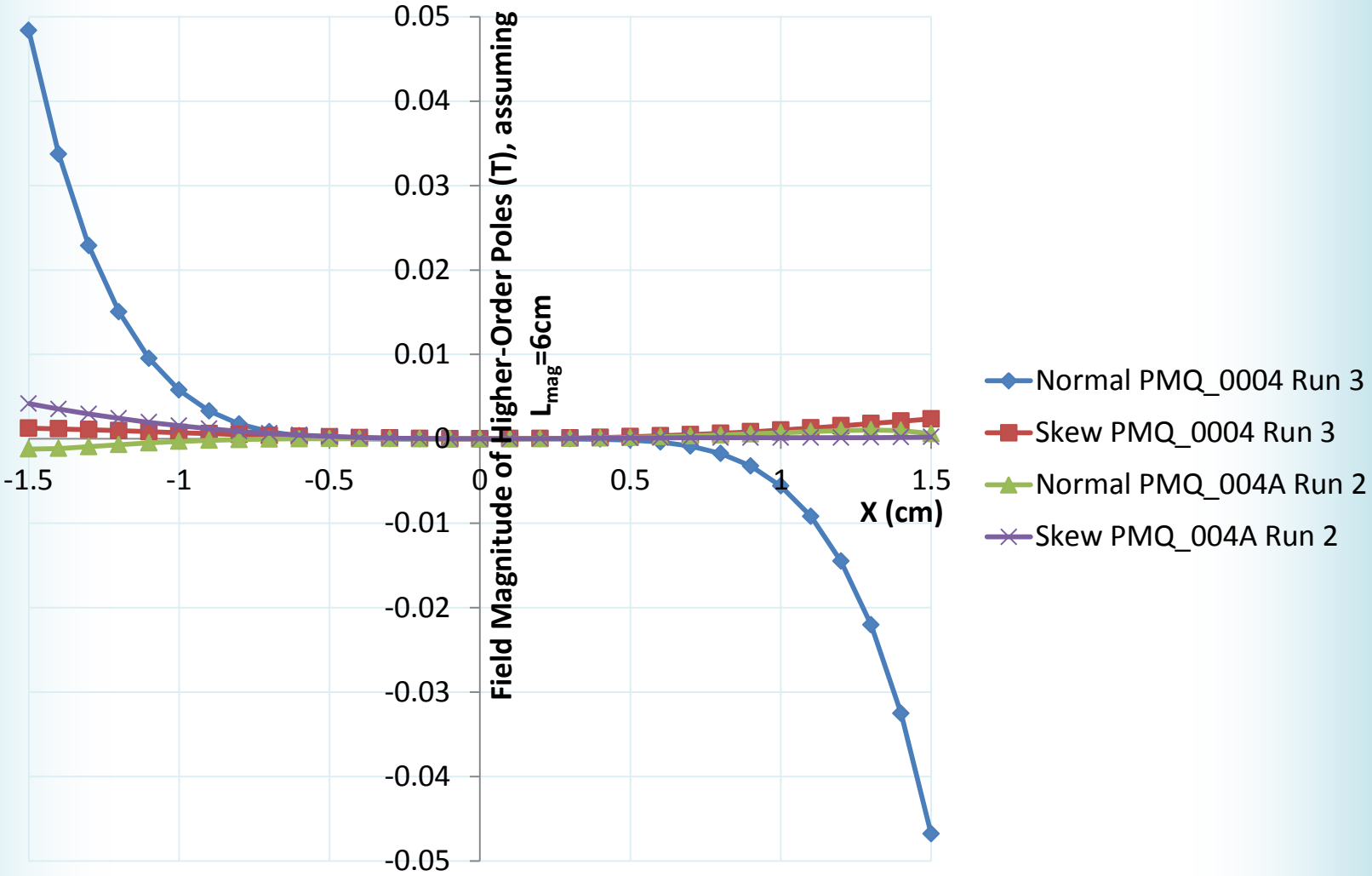
Normal Poles at r=1cm



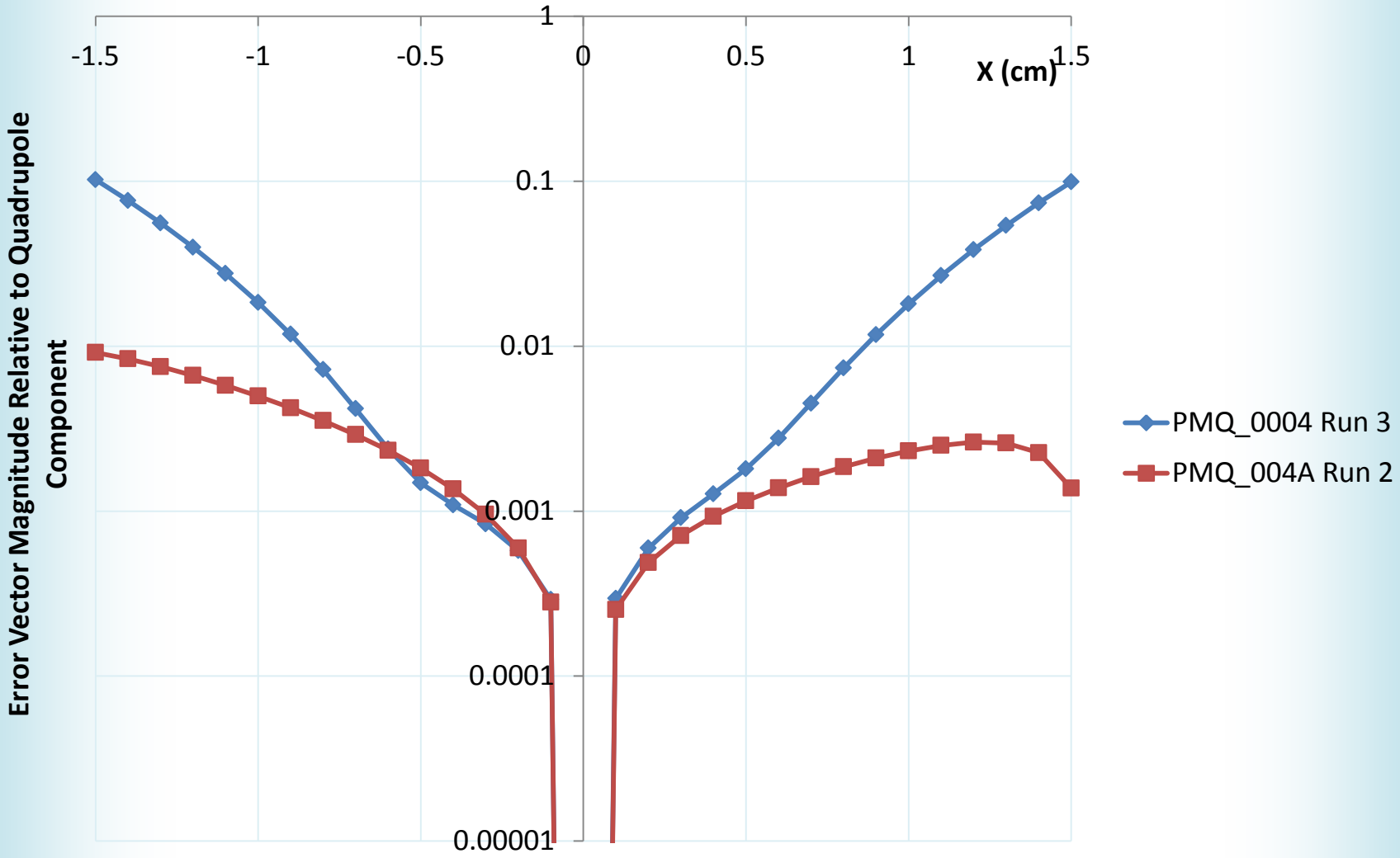
Normal Poles at r=1cm (Zoom)



Error Magnitude on X-axis



Relative Error on X-axis

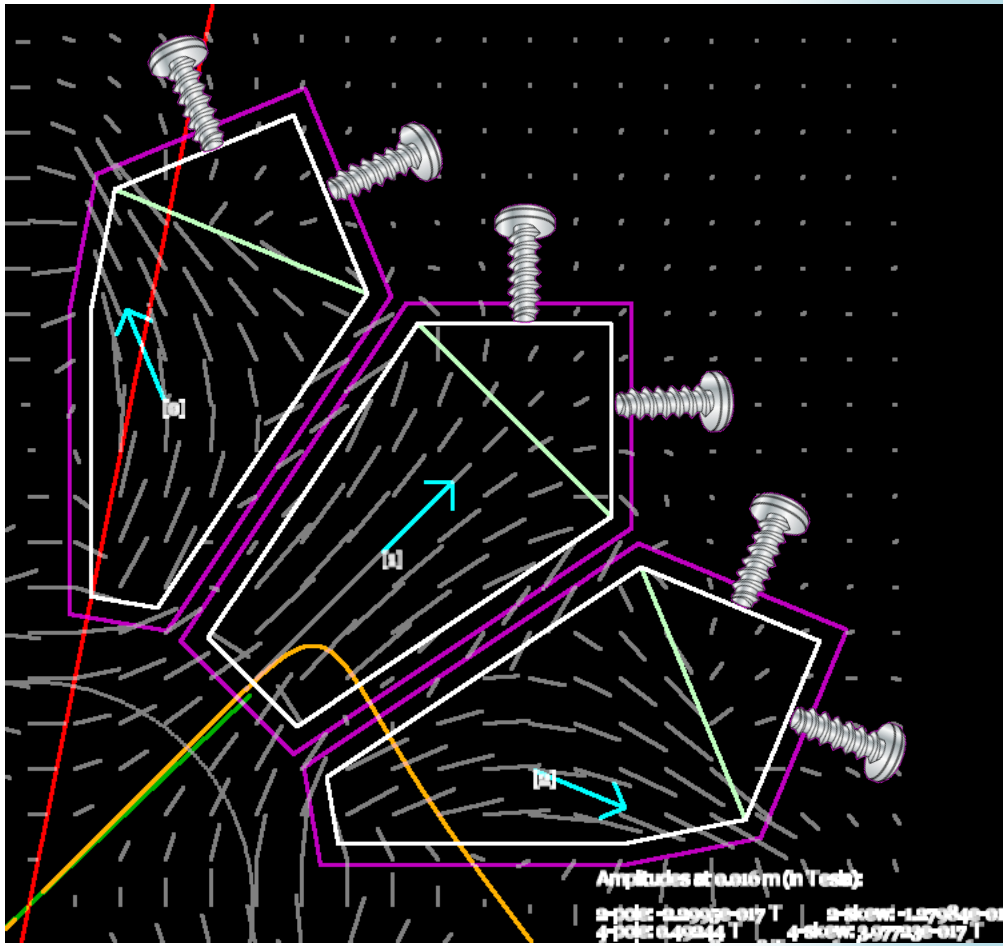


Construction/Magnetisation Errors

- As measured in the radiation test, magnetisation varies at 1e-2 level per block
- Also 3D printing construction errors
- Can feed the measured error poles back into PM2D and ask it to displace blocks to cancel
  - This requires both X and Y displacements
    - Radial-only doesn't kill both normal and skew
  - Typically requires up to 0.3mm displacements

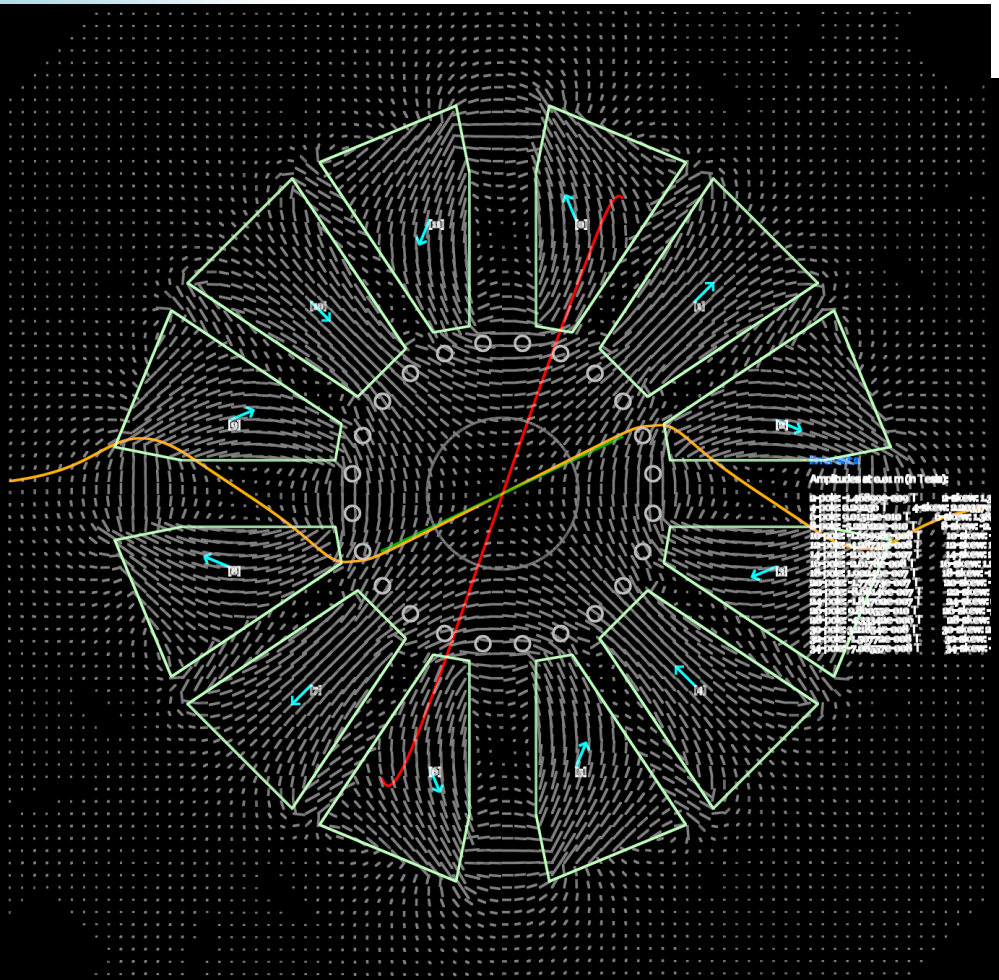
Towards Fine Correction Demo

- We were going to add screws and correct fine errors
  - Turns out forces on blocks are not simply repelling
- Now investigating the use of iron wires
  - Easier?



Iron Wires Design Work in Progress

Wires act like dipole sources with strength equal to local ambient field
Various thickness wires up to ~1mm diameter needed, about 6 per quadrant
Initial results in PM2D are promising



Amplitudes in units:

2-pole: -0.00	2-skew: 0.00
4-pole: 10000.00	4-skew: 0.00
6-pole: 0.00	6-skew: 0.00
8-pole: -0.00	8-skew: -0.00
10-pole: -0.00	10-skew: -0.00
12-pole: -0.00	12-skew: 0.00
14-pole: -0.01	14-skew: 0.01
16-pole: -0.00	16-skew: 0.04
18-pole: 0.01	18-skew: -0.07
20-pole: -0.01	20-skew: -0.03
22-pole: -0.03	22-skew: -0.01
24-pole: -0.01	24-skew: 0.02
26-pole: 0.00	26-skew: -0.00
28-pole: -0.15	28-skew: -0.01
30-pole: 0.00	30-skew: 0.01
32-pole: -0.00	32-skew: -0.01
34-pole: -0.00	34-skew: -0.00