

A Radially and Rotationally Adjustable Magnetic Mangle for Electron Beams

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William Lu, William Soh, Achyuta Rajaram, Daniel Jeon

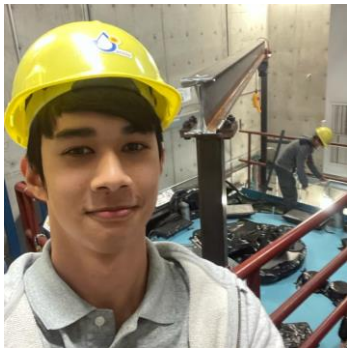
Myriad Magnets

Phillips Exeter Academy, Exeter, NH, USA

September 16, 2023



The Team



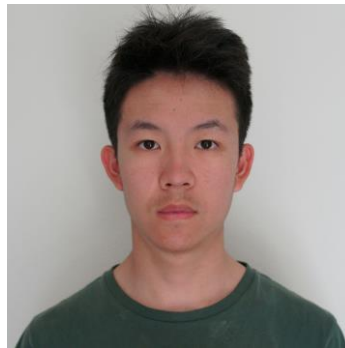
Ishaan Vohra (Team Lead)
Anime connoisseur



Achyuta Rajaram
I have 2363 pictures
of cats on my phone



Aubrey Zhang
Father of 7 parrots and 1 cat



William Lu
I swear I have a smiling picture



Isabella Vesely (Chief
Engineer)
Professional igloo builder



Will Soh
Professional snow fort builder

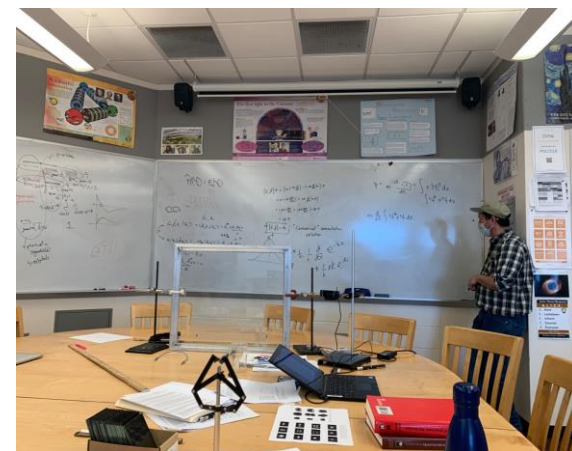
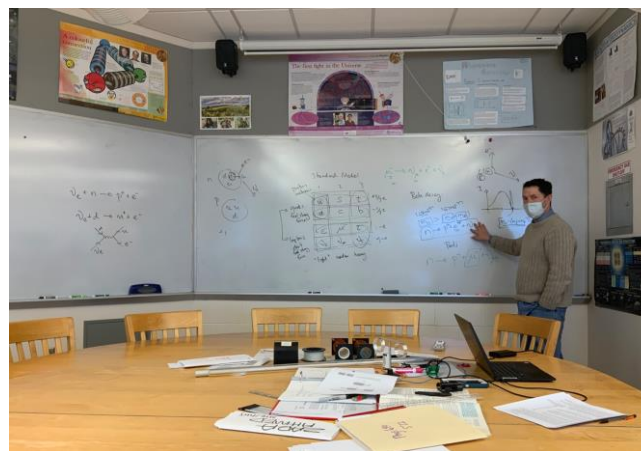
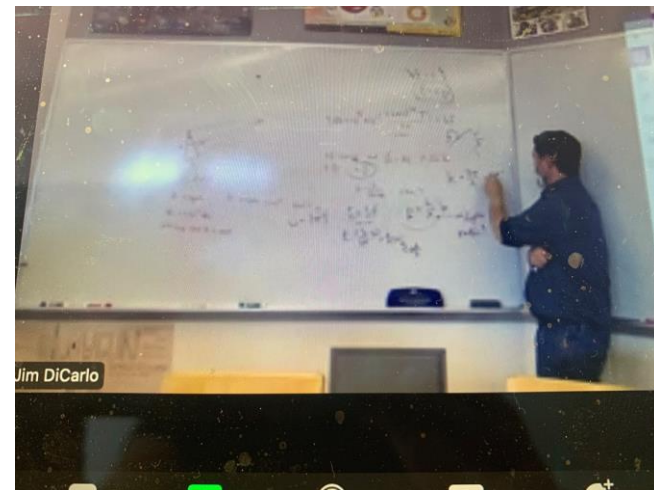
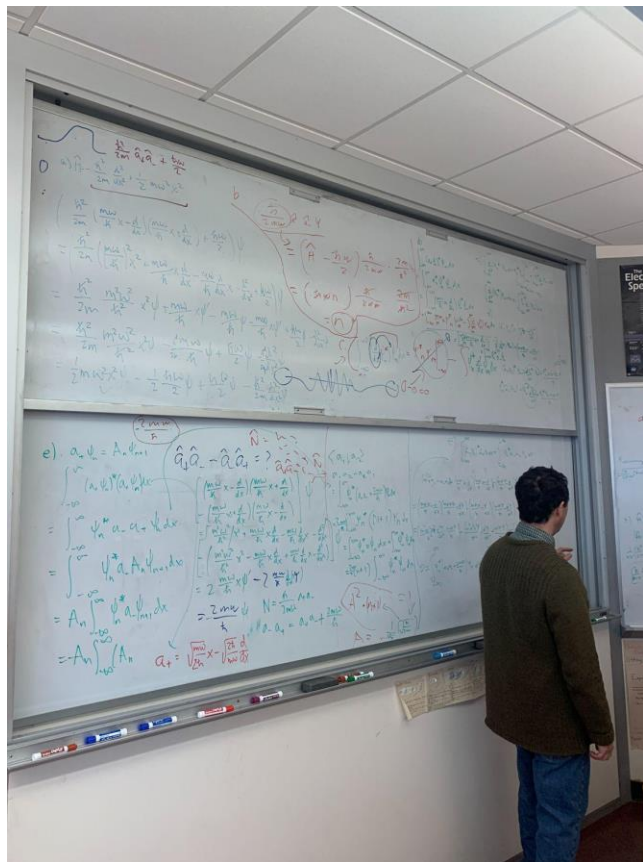


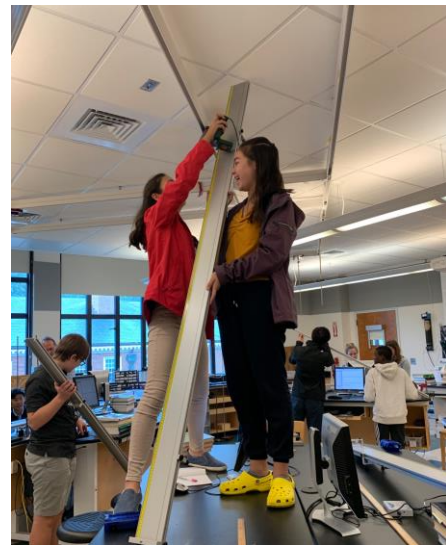
Daniel Jeon
Fifa Mobile Lover



Peter Morand
Salmon trousers enjoyer

Team Coach: Mr. DiCarlo





Our School



Experiment motivation

Testing the viability of an adjustable magnetic mangle Halbach array as a proof of concept for electromagnet alternatives in accelerators

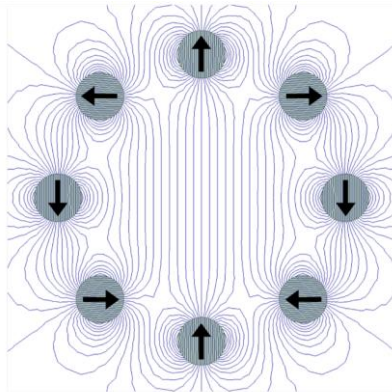
- Replace electromagnet energy usage as a contributor to climate change
- Safer to use near other electronics and pacemakers due to small external field
- Modular design: cost effective (compared to electromagnets), and reduces waste

Magnet design: introduction

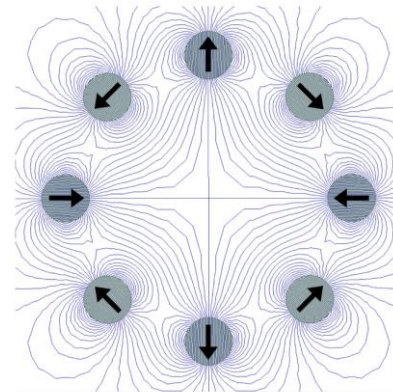
A mangle of 8 permanently diametrically-magnetized cylinders arranged in a circle to produce either a dipole or quadrupole field

Modularity:

- By rotating the magnets, the mangle can be switched between dipole and quadrupole configurations
- By moving the magnets radially inward or outward, the field strength can be adjusted

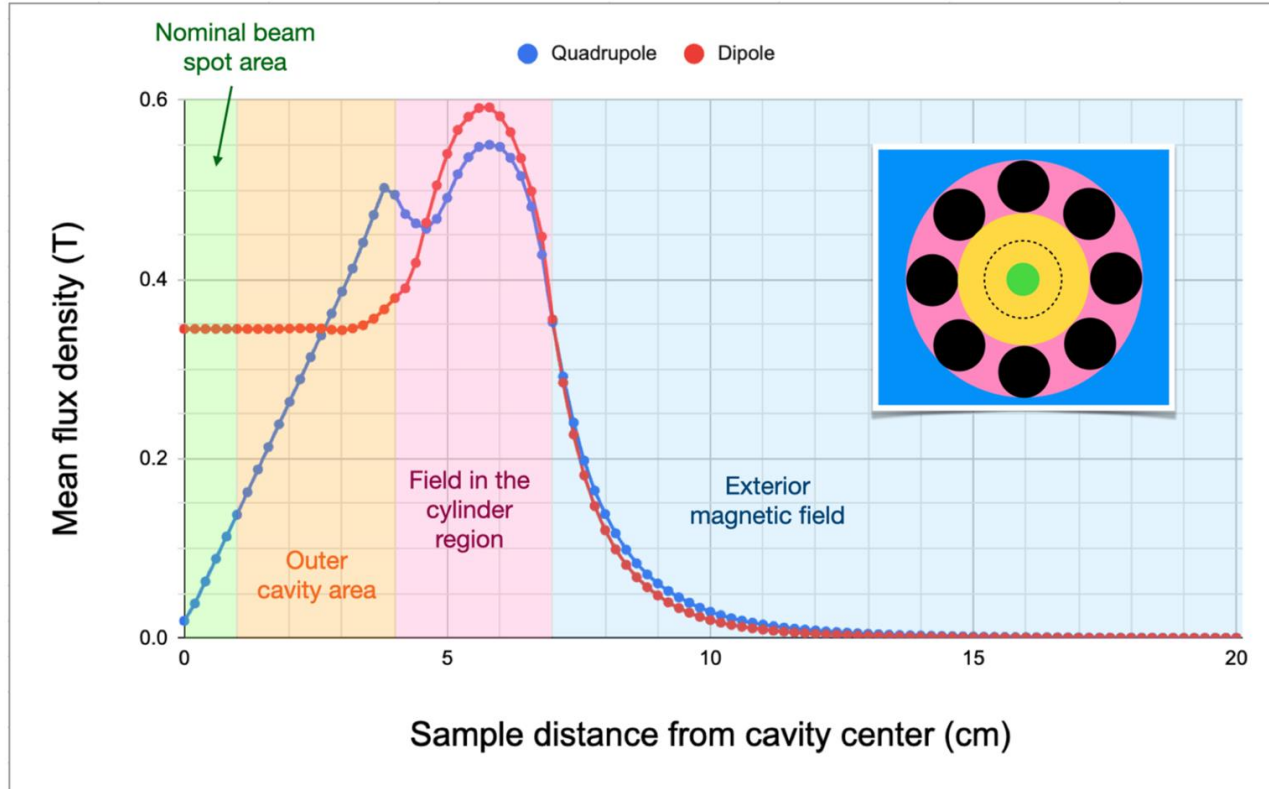


(a) Dipole arrangement



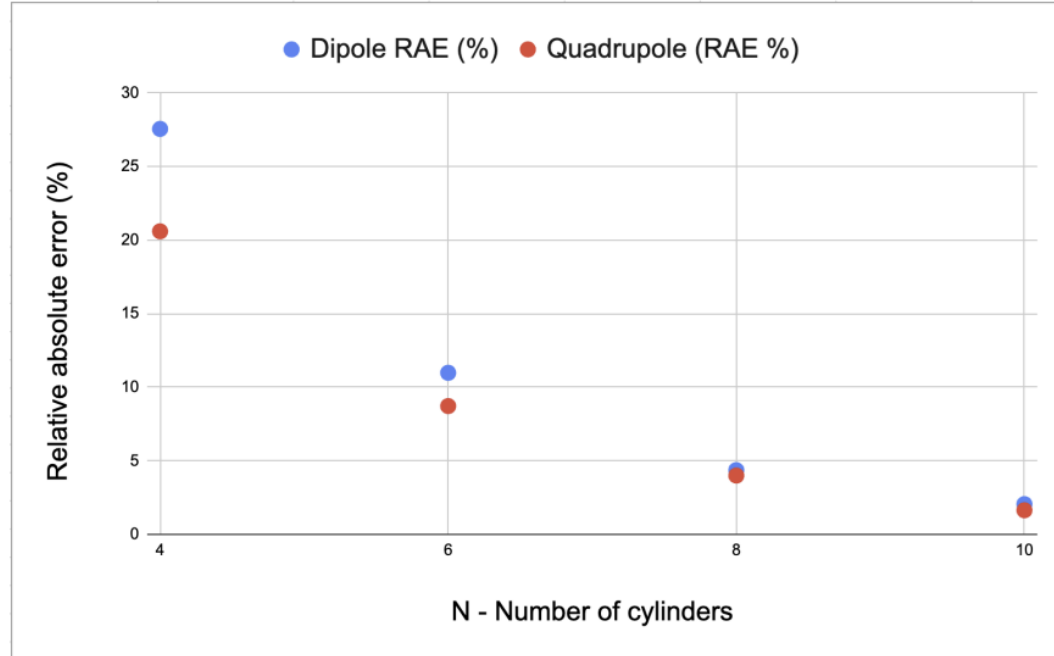
(b) Quadrupole arrangement

Magnet design: introduction (cont'd)

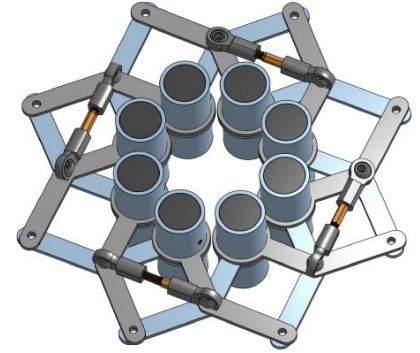
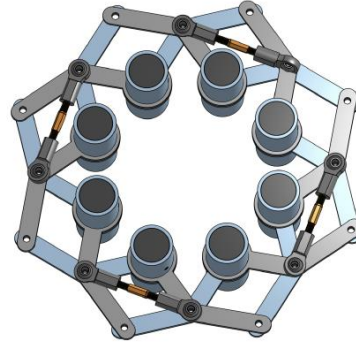
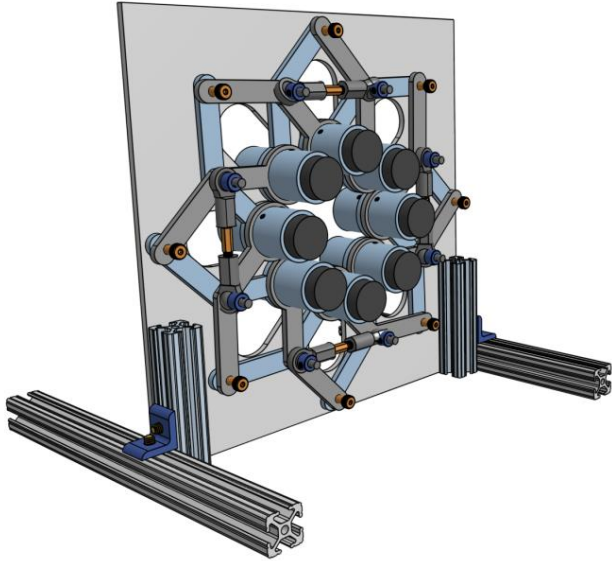


Magnet design: determining optimal cylinder number

- Performed simulations in ANSYS Maxwell and quantified the deviation of the mangle's field from the corresponding ideal field using Relative Absolute Error (RAE).

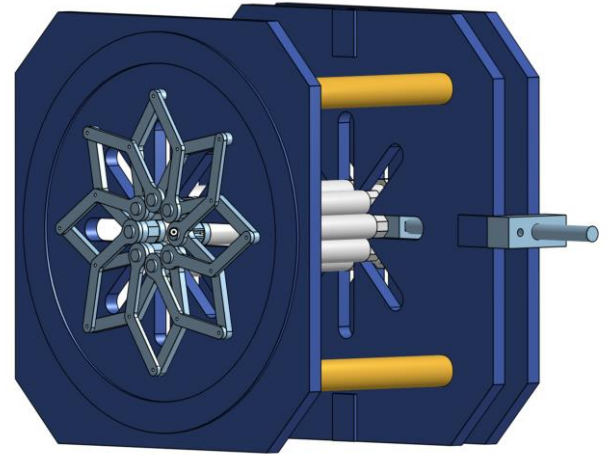
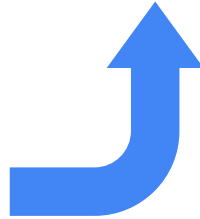
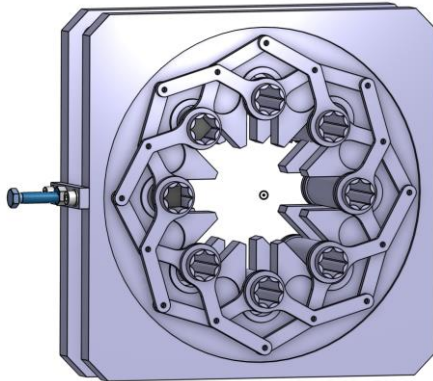
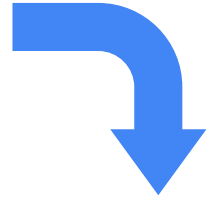
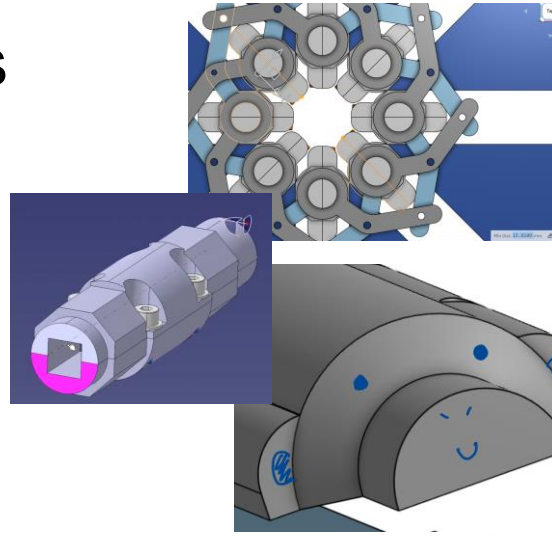
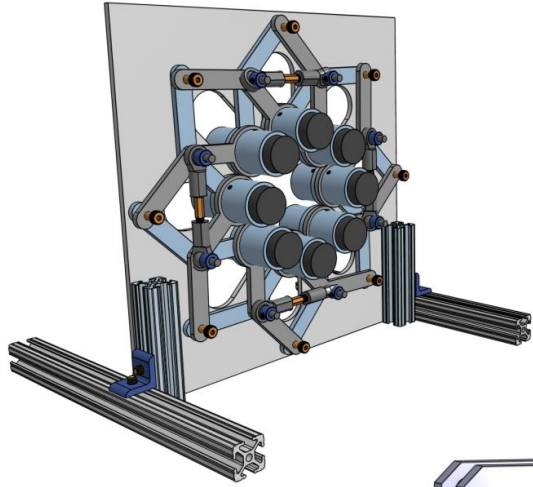


Original Mangle Design



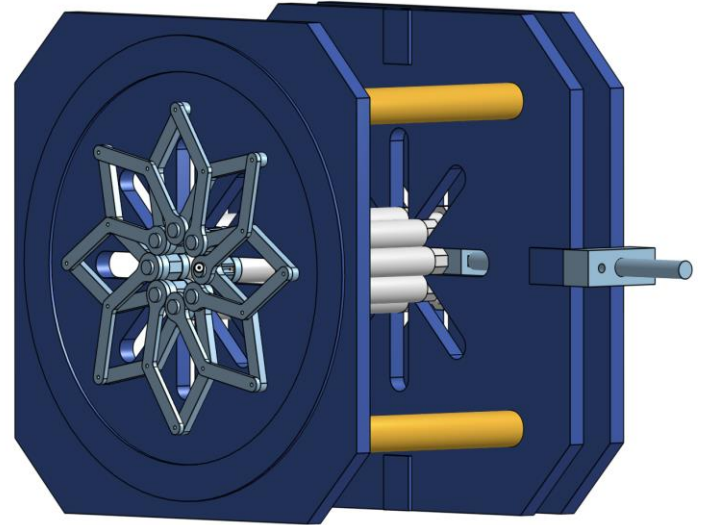
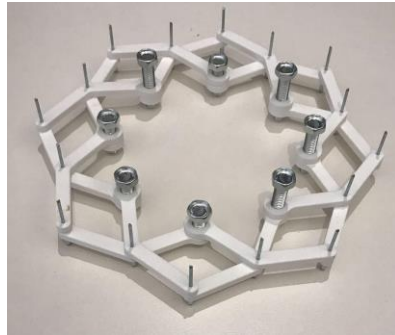
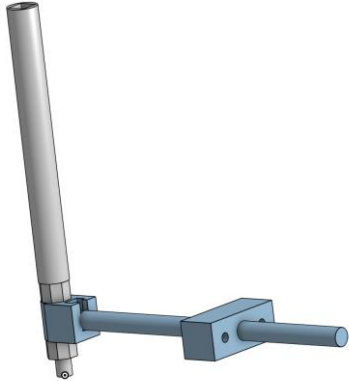
- This is our original design for the brace structure, this was created with the goal to create on the fly radial and rotational adjustment of our magnet
- For our experiment here, we are using two stationary halbach arrays, one set to a dipole configuration and another set to a quadrupole configuration

Some Design Iterations



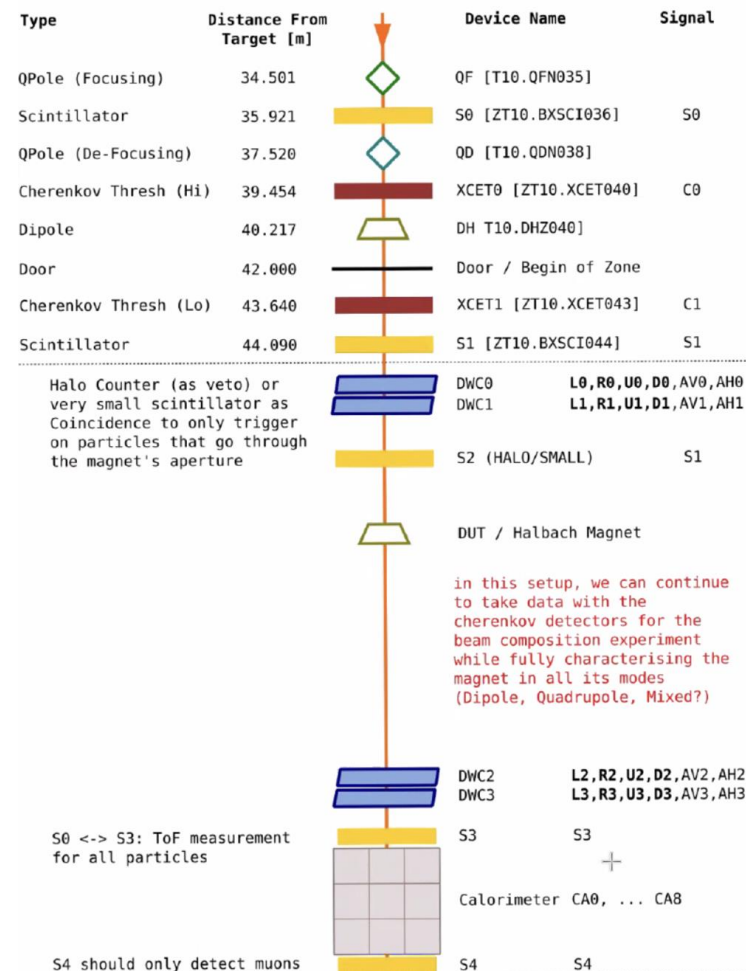
Final Mangle Design

- This design encapsulates the magnets within casings to prevent them from moving and rotating
- To rotate the magnet, casings slide radially on along octagonal pins
- One casing has a mechanism to push, pull, and hold the linkage in place

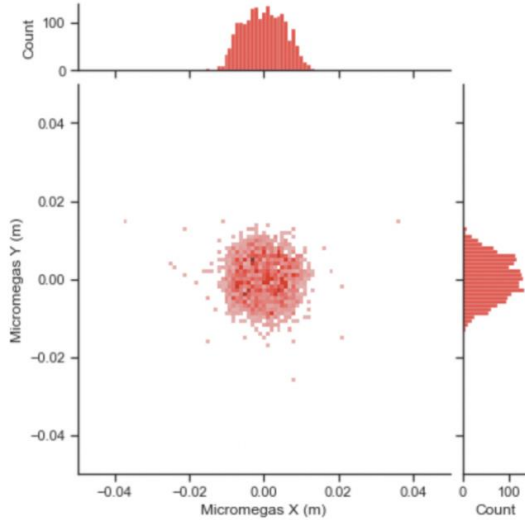


Experiment design: detector setup

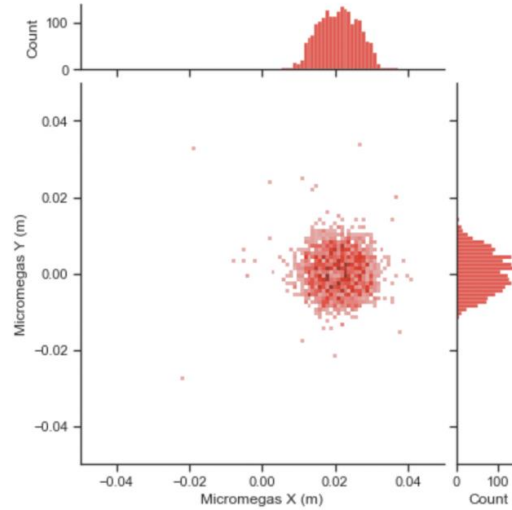
Setup 2: Characterise Halbach Magnet



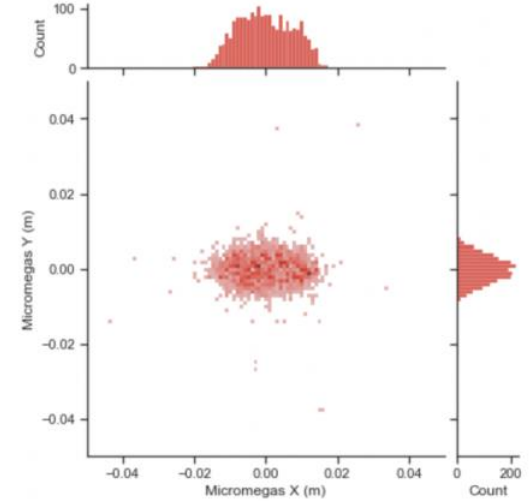
Experiment design: data analysis



(a) No magnetic mangle present in beam-line



(b) Dipole configuration with radial arrangement of $d = 6.0$ cm ($B = 0.29$ T)



(c) Quadrupole configuration with radial arrangement of $d = 7.0$ cm ($g = 6.1$ T/m)

Thank you!

Thank you to

DiCarlo

Martin

Berare

Markus

Sarah

Margherita

BL4S team

We look forward to the next
two weeks!!

Backup Slides

Magnet design: determining optimal cylinder number

- As N , the number of magnets, increases, deviation from ideal magnetic field decreases, but for very large N rotating each magnet becomes impractical
- Performed simulations in ANSYS Maxwell and quantified the deviation of the mangle's field from the corresponding ideal field using RAE

$$\text{RAE} = \frac{\sqrt{\sum_{i=1}^n |\vec{B}_{mangle_i} - \vec{B}_{ideal_i}|^2}}{\sqrt{\sum_{i=1}^n |\vec{B}_{ideal_i}|^2}}$$

\vec{B}_{mangle_i} and \vec{B}_{ideal_i} are the mangle field and corresponding ideal field vectors at a given sample point i out of n total sample points.

Defining the corresponding ideal field

For each set of cross-sectional mangle field with a given N , we define the corresponding ideal fields (centered at the origin) to be

$$\vec{B}_{dip}(x, y) = [0, B]$$

In the dipole case and

$$\vec{B}_{quad}(x, y) = g[-x, y]$$

In the quadrupole case.

The magnitude of the ideal dipole's flux density, B , is obtained from the flux density at the array center. The ideal quadrupole's magnetic flux gradient, g , is obtained through a linear regression.

Experiment design: data analysis (cont'd)

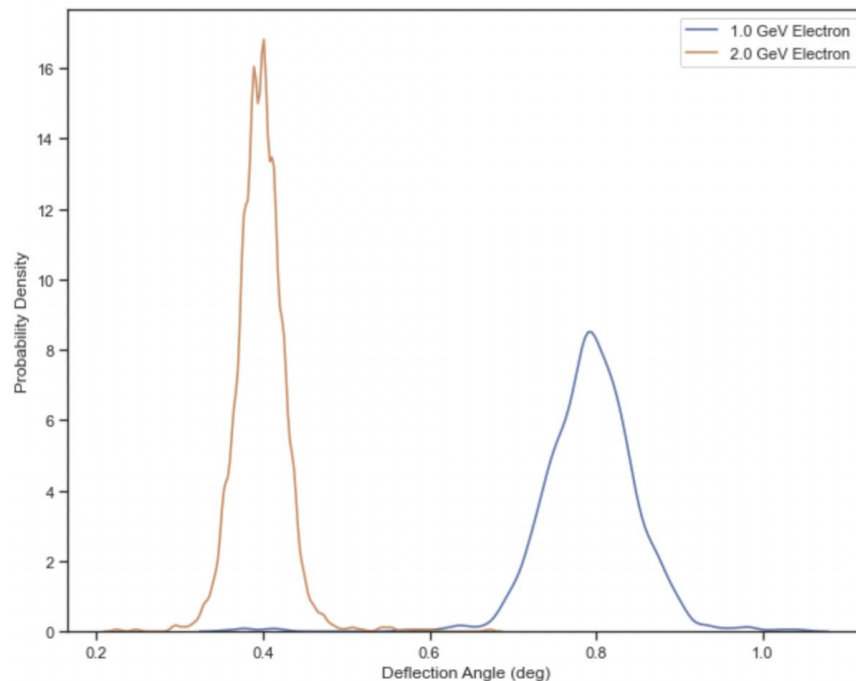


Figure 10: GEANT4 simulation: Normalized deflection angle distributions at 1.0 GeV and 2.0 GeV passing through the mangle dipole configuration.