A Radially and Rotationally Adjustable Magnetic Mangle for Electron Beams

Ishaan Vohra, Isabella Vesely, Peter Morand, Aubrey Zhang,
William Lu, William Soh, Achyuta Rajaram, Daniel Jeon

Myriad Magnets

Phillips Exeter Academy, Exeter, NH, USA

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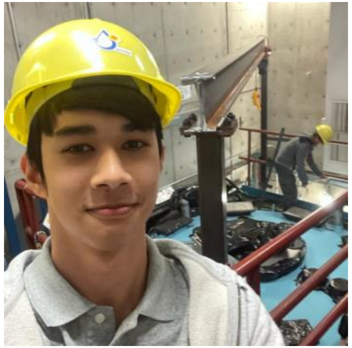
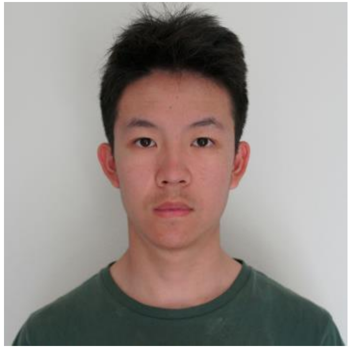
The Team



Ishaan Vohra (Team Lead)
Sevenoaks, England

Achyuta Rajaram
Hopedale, MA

Aubrey Zhang
Vancouver, Canada



William Lu
Austin, TX

Isabella Vesely (Chief Engineer)
Milwaukee, WI

Will Soh
Northbrook, IL

Daniel Jeon
New York, NY

Peter Morand
Simsbury, CT

Experiment motivation

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

Goals:

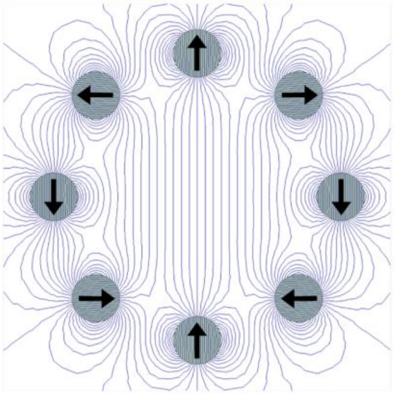
- Replace electromagnet **energy usage as a contributor to climate change**
- **Safer** to use near other electronics and pacemakers due to small external field
- Modular design: **cost effective** (compared to electromagnets), reduces waste

Magnet design: introduction

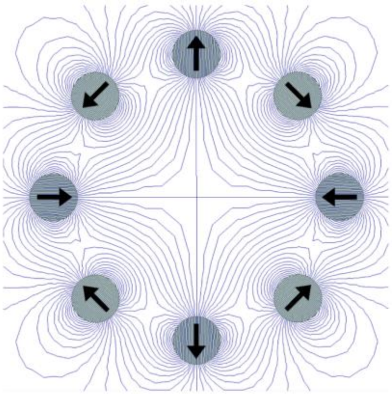
A mangle of 8 permanently diametrically-magnetized cylinders arranged in a circle to produce either a dipole or quadrupole field

Modularity:

- Rotating the magnets, the mangle can be switched: dipole ↔ quadrupole configurations
- By moving the magnets radially inward or outward, the field strength can be adjusted

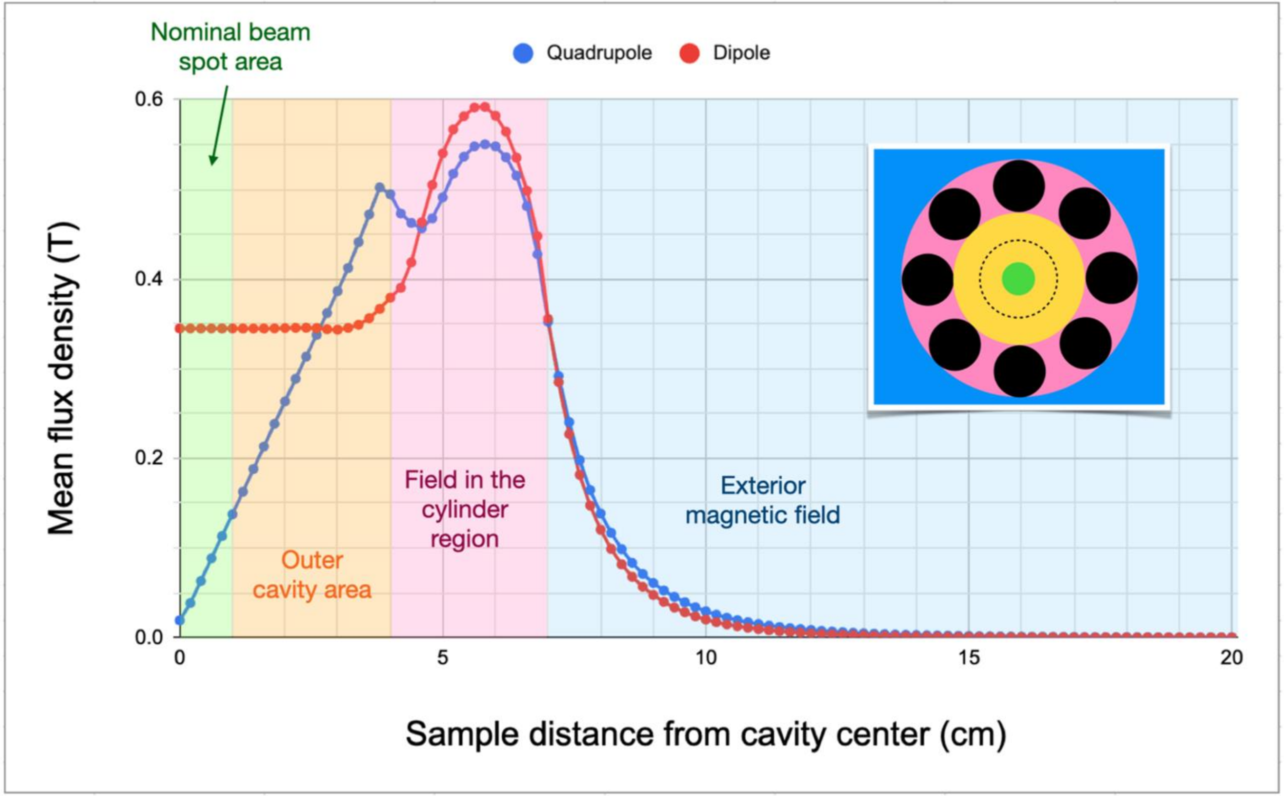


(a) Dipole arrangement



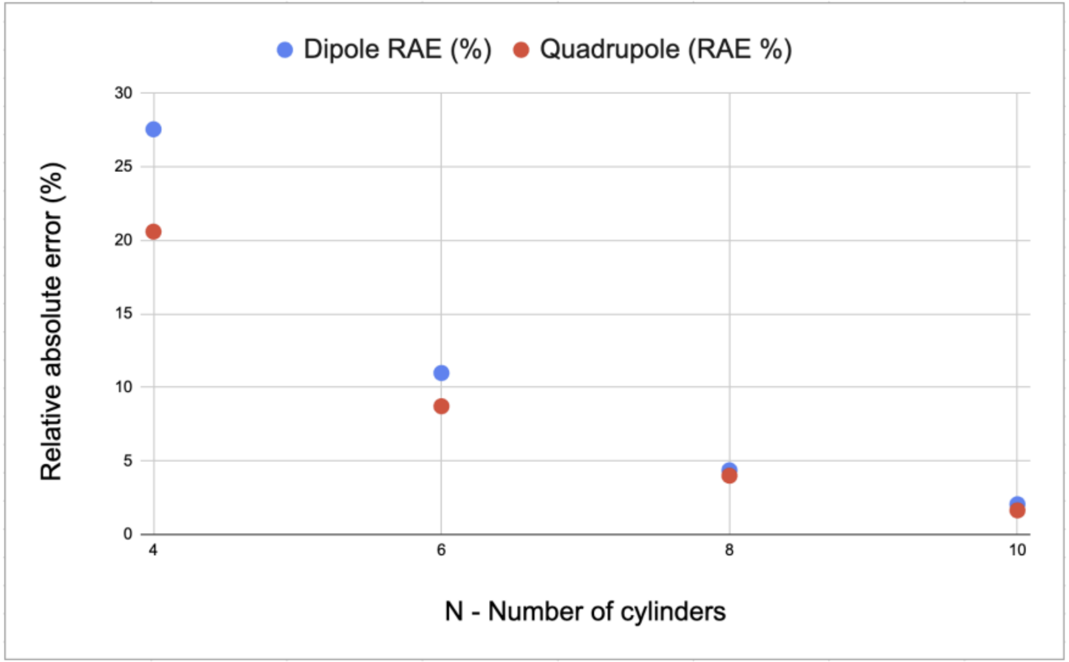
(b) Quadrupole arrangement

Magnet design: introduction (cont'd)

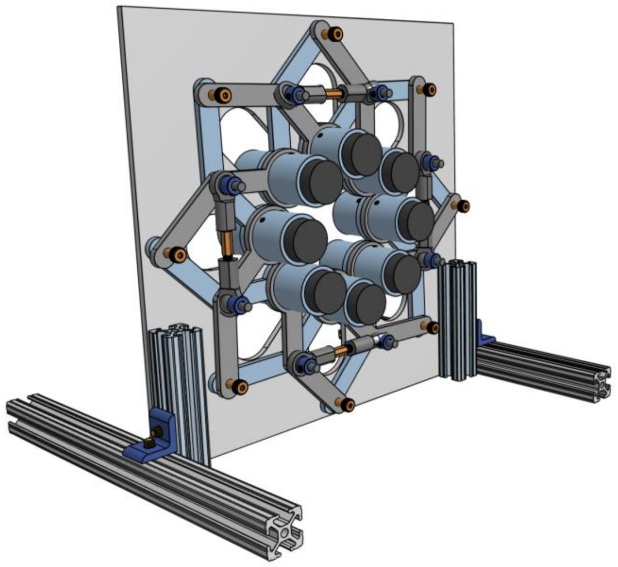


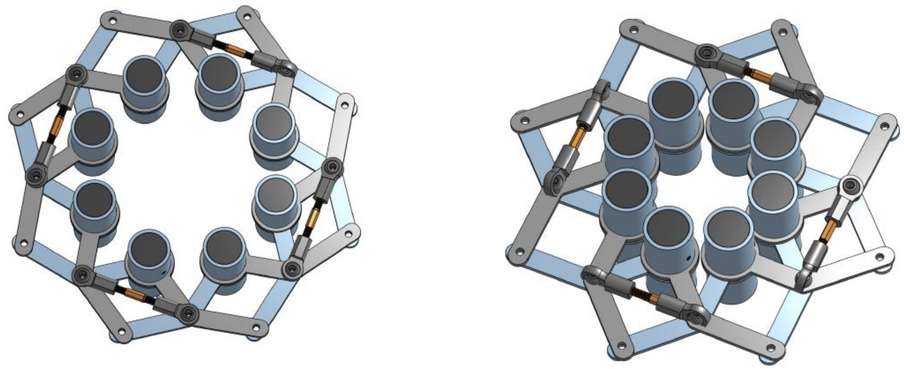
Magnet design: determining optimal cylinder number

- 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



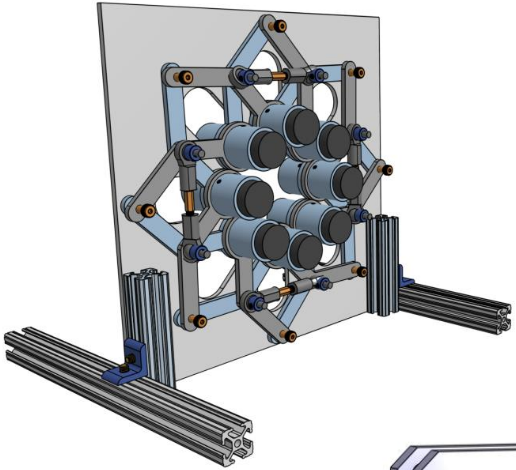


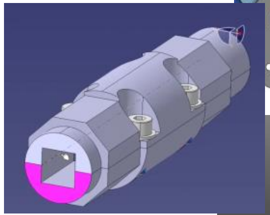
- **Goal**: create on-the-fly radial and rotational adjustment of our magnet
- **Updates**: experiment handling safety, structural safety

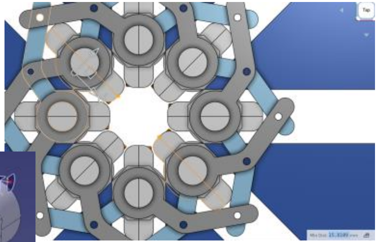
Final Experiments at CERN:

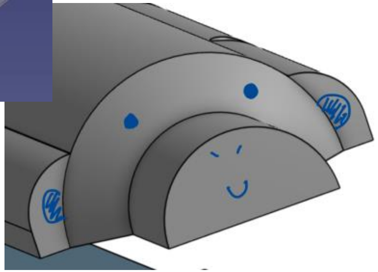
- Update mangle with improved lock mechanism
- Explore stationary Halbach arrays

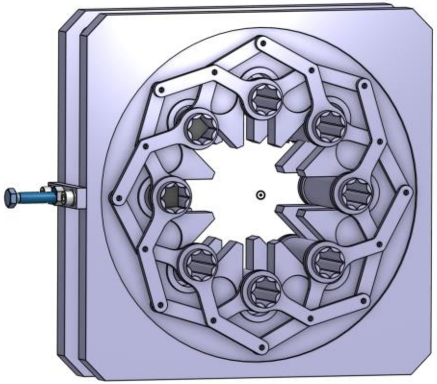
Many Design Iterations…





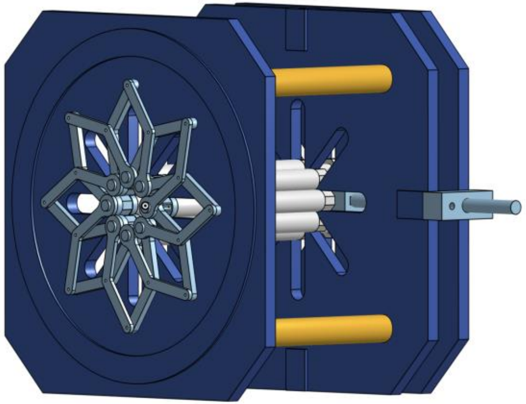






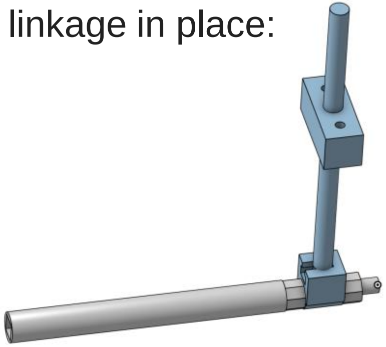
Final
(stationary)

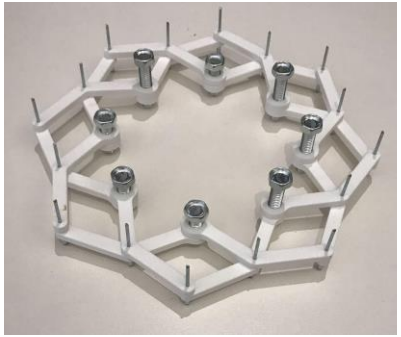
Final
(mangle)

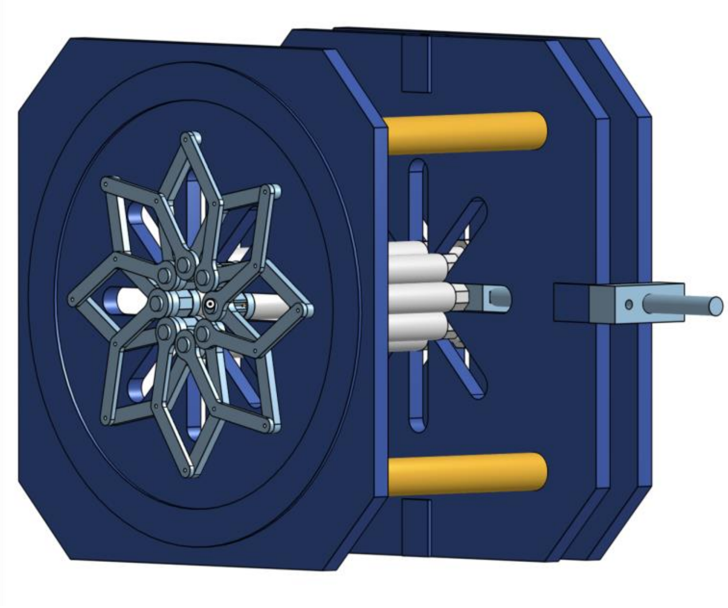


Final Mangle Design

- **Goal**: provide a **proof of concept** of a fully adjustable magnetic mangle
- **Magnets within casings**, prevent involuntary translational/rotational movement
- Rotation → **casings slide radially**, octagonal pins
- One casing has a mechanism to push, pull, and hold the full linkage in place:





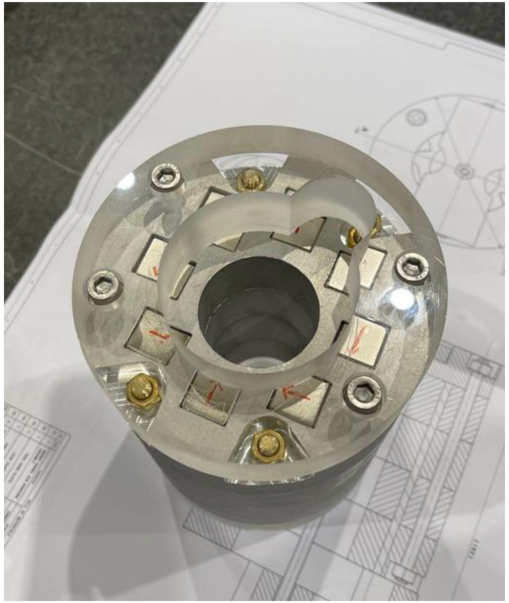


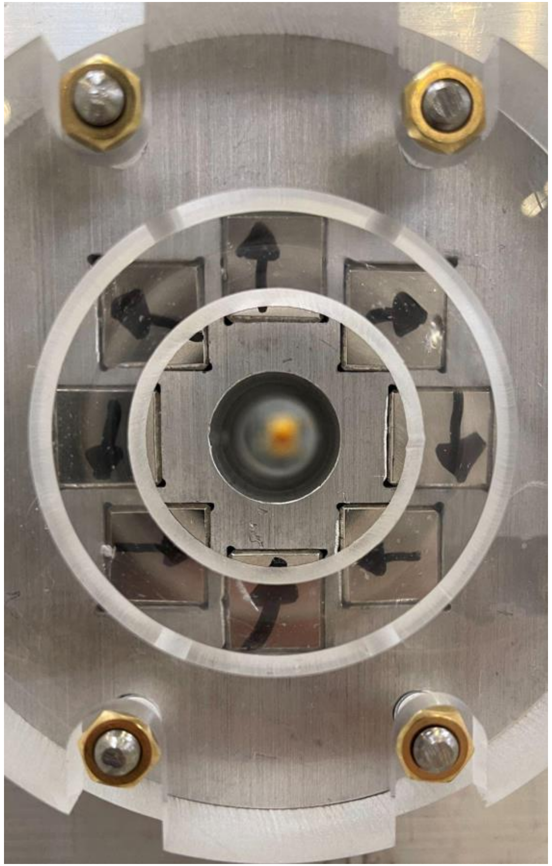
Final Stationary Design

- **Goal**: test the **utility of Halbach** arrays as alternatives to electromagnets, and study the effect of a **changing radius**

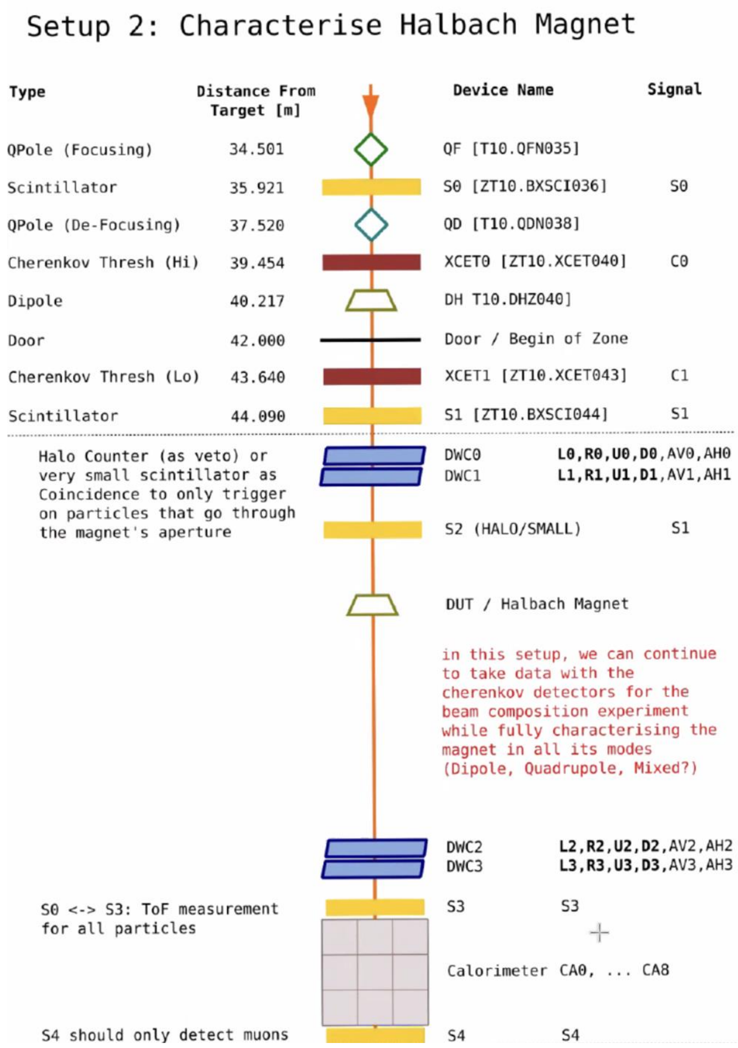
- Two Halbach **dipole arrangements,** stronger magnets → larger magnetic field

- Already in beam area!

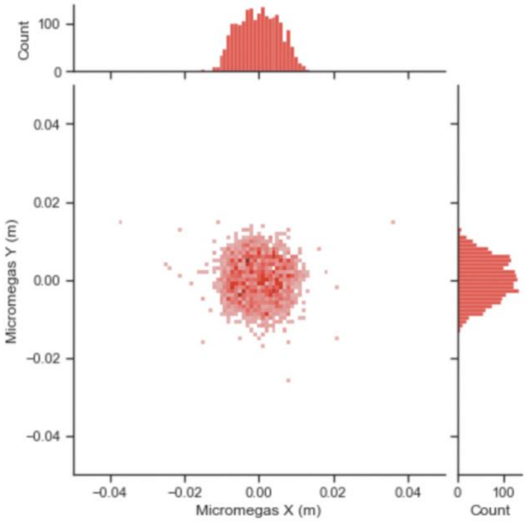




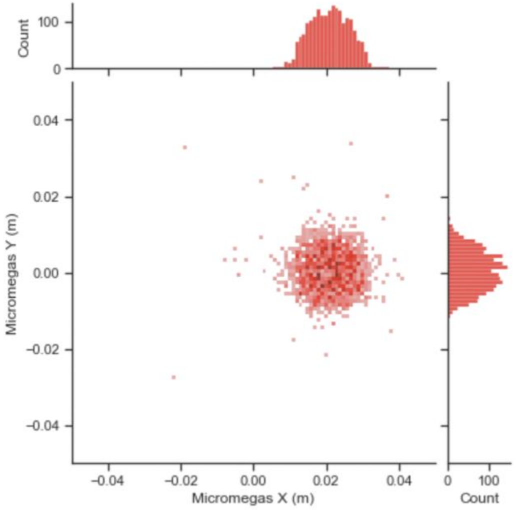
Experiment design: Detector Setup



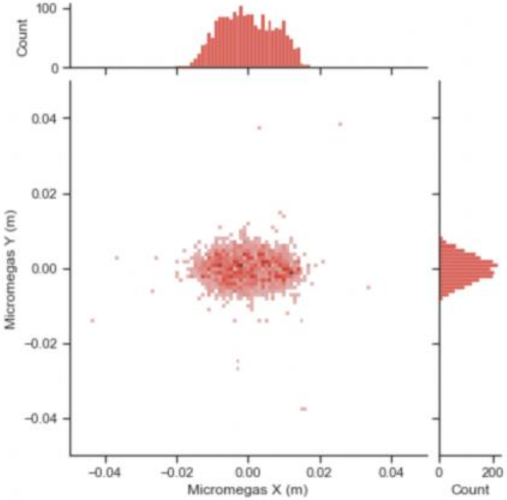
Experiment design: data analysis



(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!

Mr. DiCarlo

Sarah Zoechling

Markus Joos

Martin Schwinzerl

Berare Gokturk

Margherita Boselli

BL4S team and supporters!

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

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

$\vec{B}_{mangle_i}$ 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)

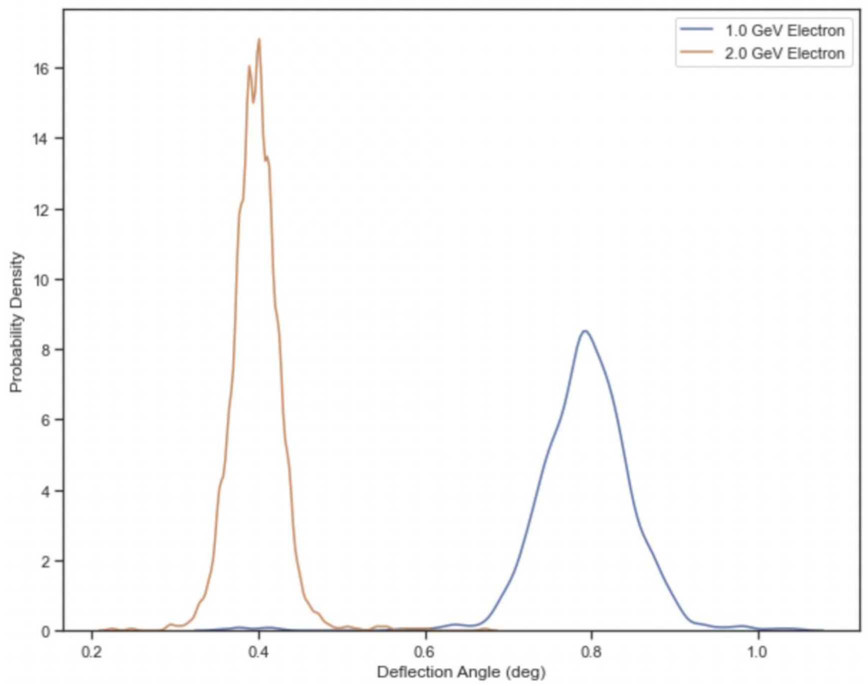


Figure 10: GEANT4 simulation: Normalized deflection angle distributions at 1.0 GeV and 2.0 GeV passing through the mangle dipole configuration.