

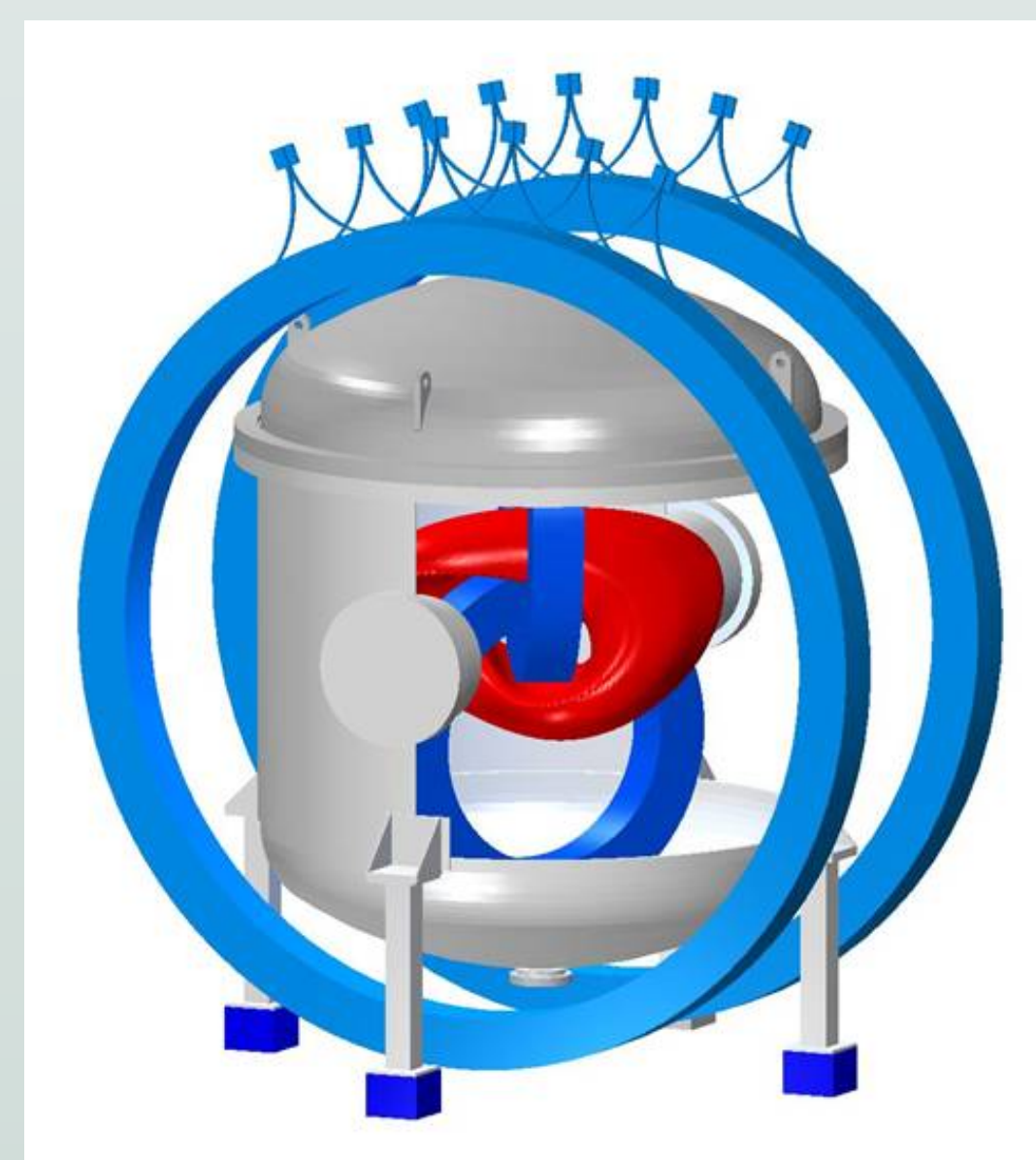
Jared Carlson (MCC), Arturo Dominguez (PPPL)

Goals

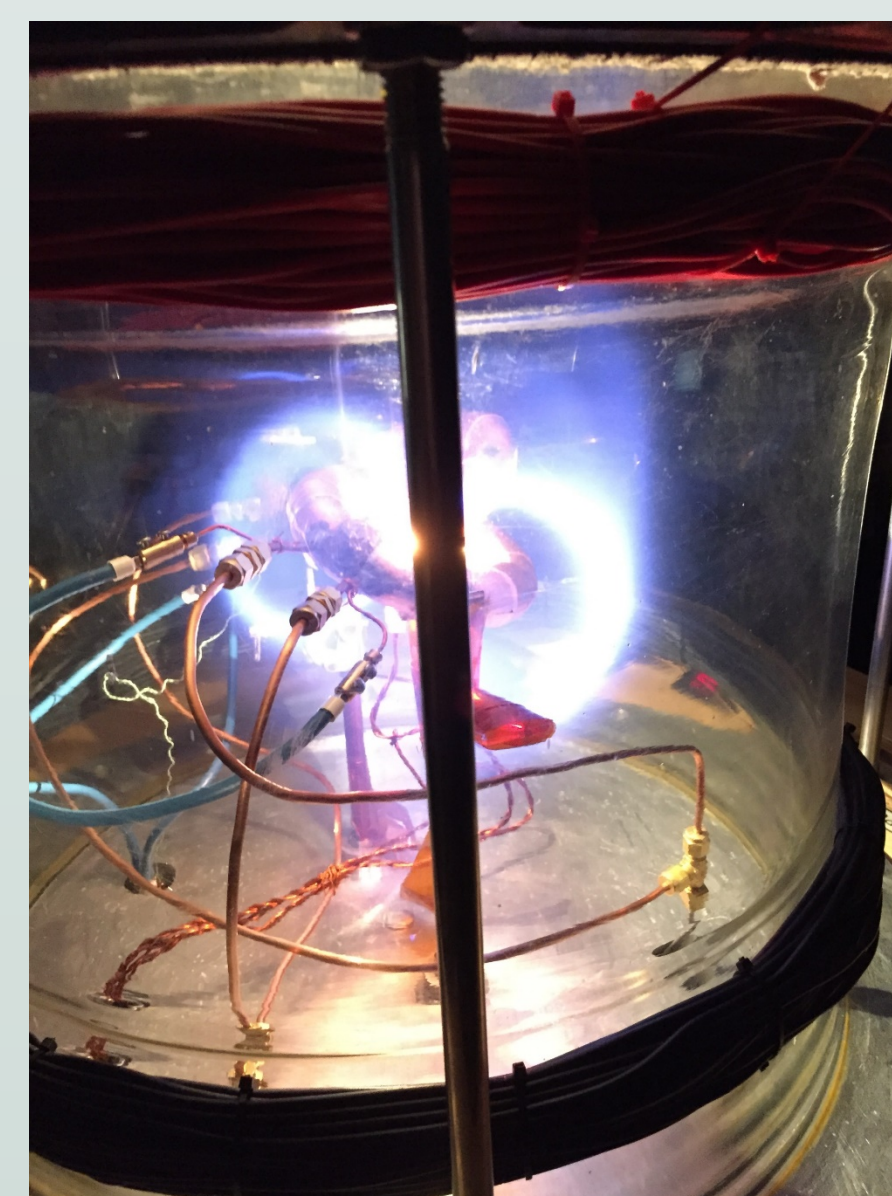
- **Design an interlocking coil Stellarator configuration that:**
 - Is tabletop size
 - Provides a visually engaging demonstration of Stellarator physics to the public.
 - Facilitates graduate and undergraduate experiments.

Background

- A Stellarator is a toroidal plasma confinement device that utilizes electromagnetic coils to magnetically confine plasmas without the need for a toroidal current within the plasma.
- The PASEO is based on the design of the Columbia Non-Neutral Torus (CNT)¹, which was originally designed to study magnetic surfaces. Smaller versions, called mini-CNTs², have also been built.



Model of the CNT, magnetic surface in red



Mini-CNT in operation at IPP

- The PASEO builds off of the CNT and mini-CNT by combining the experimental and public display components of both into a single device.

PASEO's Physical Design

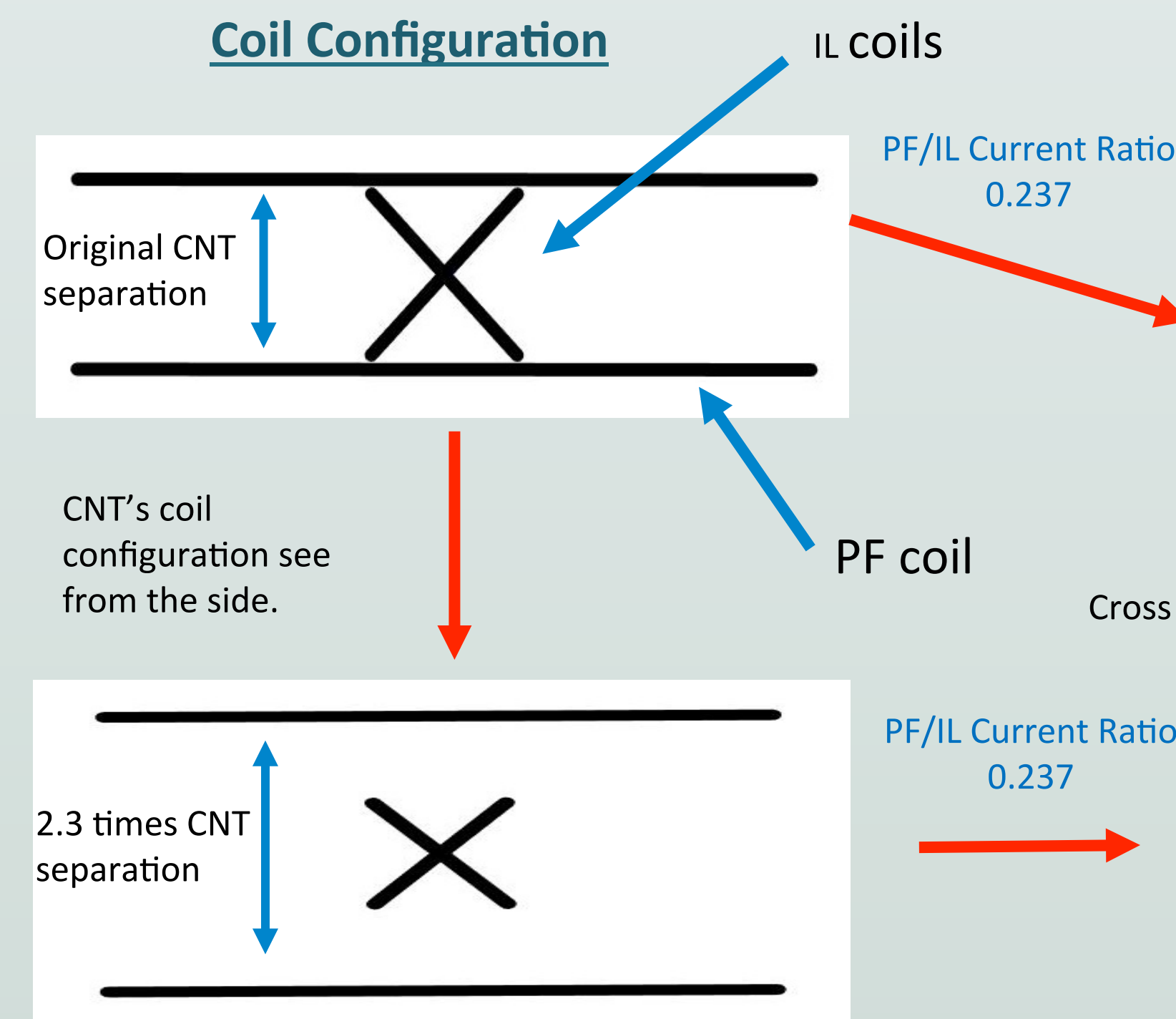
- The PASEO consists of 4 coils:
 - Two interlocking coils (IL)
 - Two poloidal field coils (PF)
- The vacuum chamber is made of a cylindrical cut of Borosilicate glass to increase outside visibility.
- The IL coils will be provided for by Thomas Pedersen at IPP, who has helped in the development of PASEO's design.

- Adjustable components:
 - Currents in coils (up to 2k amp-turns)
 - Vacuum pressure (0.1 - 10 mTorr)
 - Vertical displacement of PF coils
 - Tilt angle of IL coils
- Expected values for PASEO
 - IL coil radius: 0.088 m
 - PF coil radius: 0.23 m
 - $\langle |B| \rangle$: 75 Gauss
 - $\langle \rho_e \rangle_{\text{surface}}$: 0.3 mm
- The adjustability of the physical design allows for PASEO to be configured for both public outreach and student experiments.

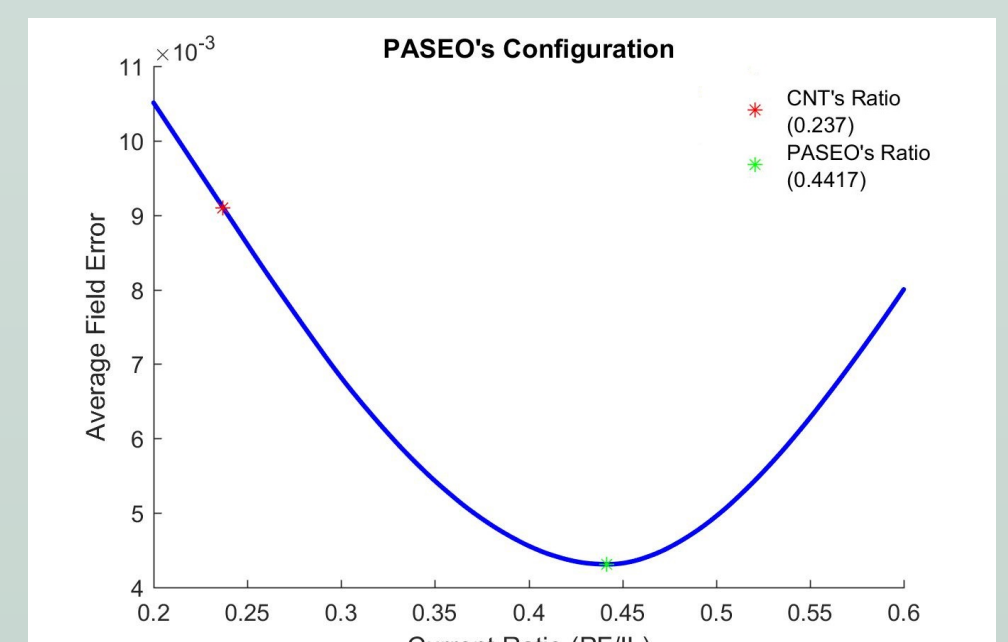
Modeling the PASEO

- Due to the customizable nature of PASEO, codes were developed to find optimal current ratios at varying coil distances and angles to increase the size of magnetic surfaces.

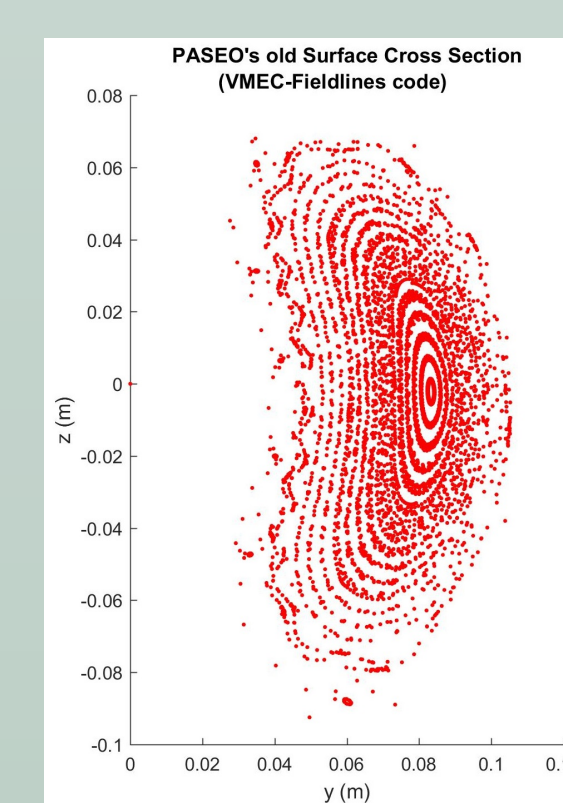
Coil Configuration



PASEO's coil configuration as seen from the side with the PF coils extended for public demonstration.

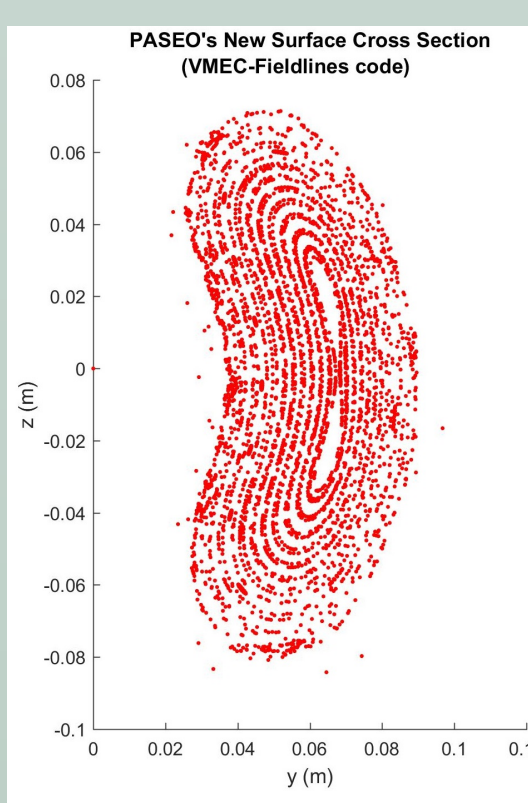


Results of the optimization code for the extended configuration. The lower the error the closer the magnetic field around the coils is to working configuration.

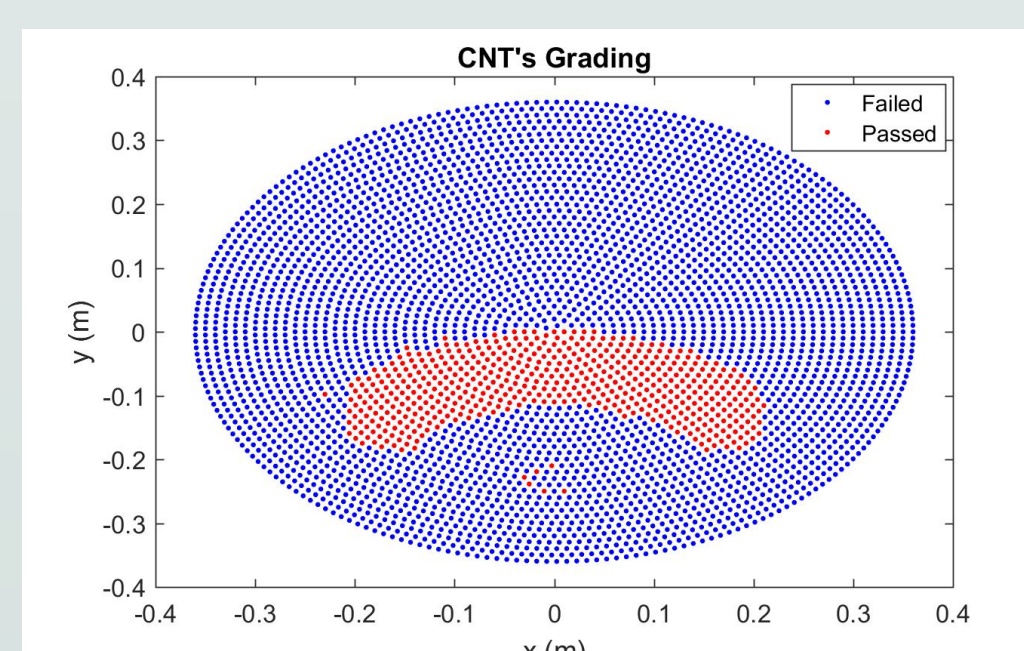


PF/IL Current Ratio: 0.237
PF/IL Current Ratio: 0.4417

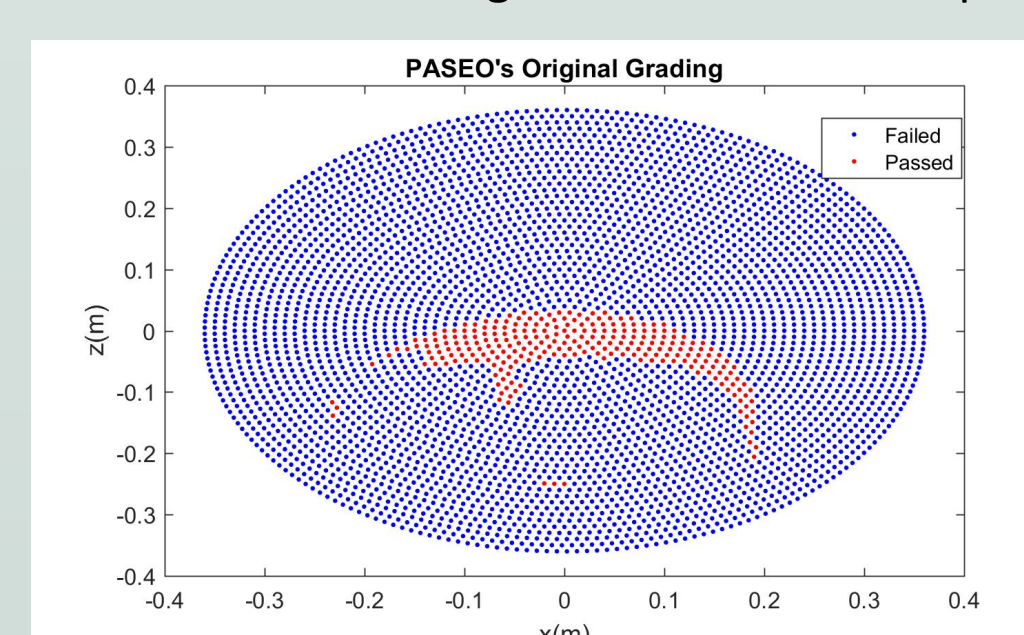
- VMEC Fieldlines⁴ code was run on both variation of current ratio, 0.237(left) and 0.4417(right).
- After optimization, the magnetic surfaces became more distinct.



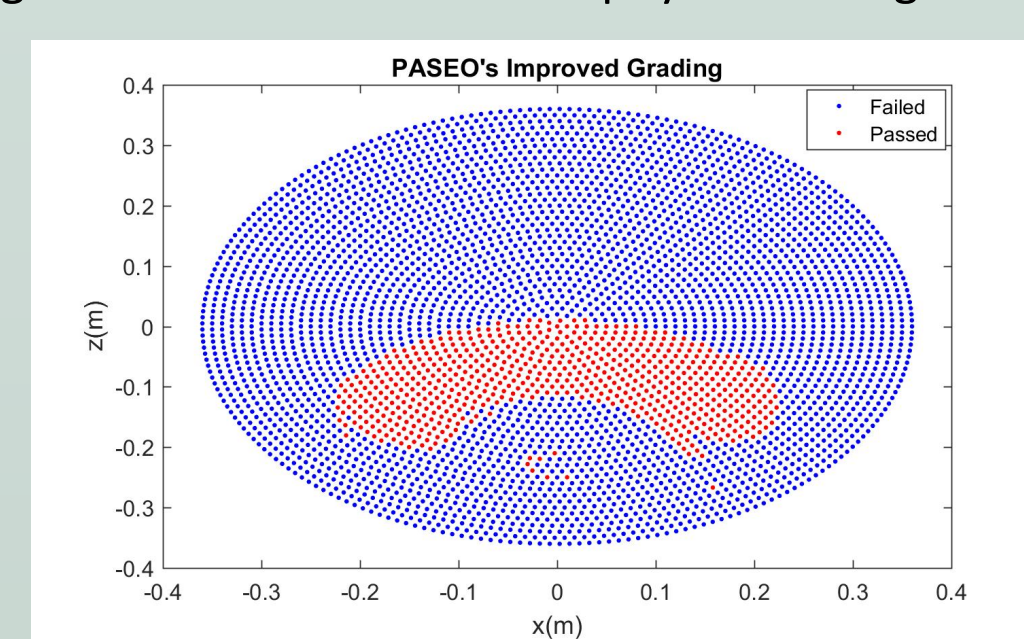
Magnetic Surface Cross Section



Cross sectional area of the magnetic surfaces in the plane of an IL coil.

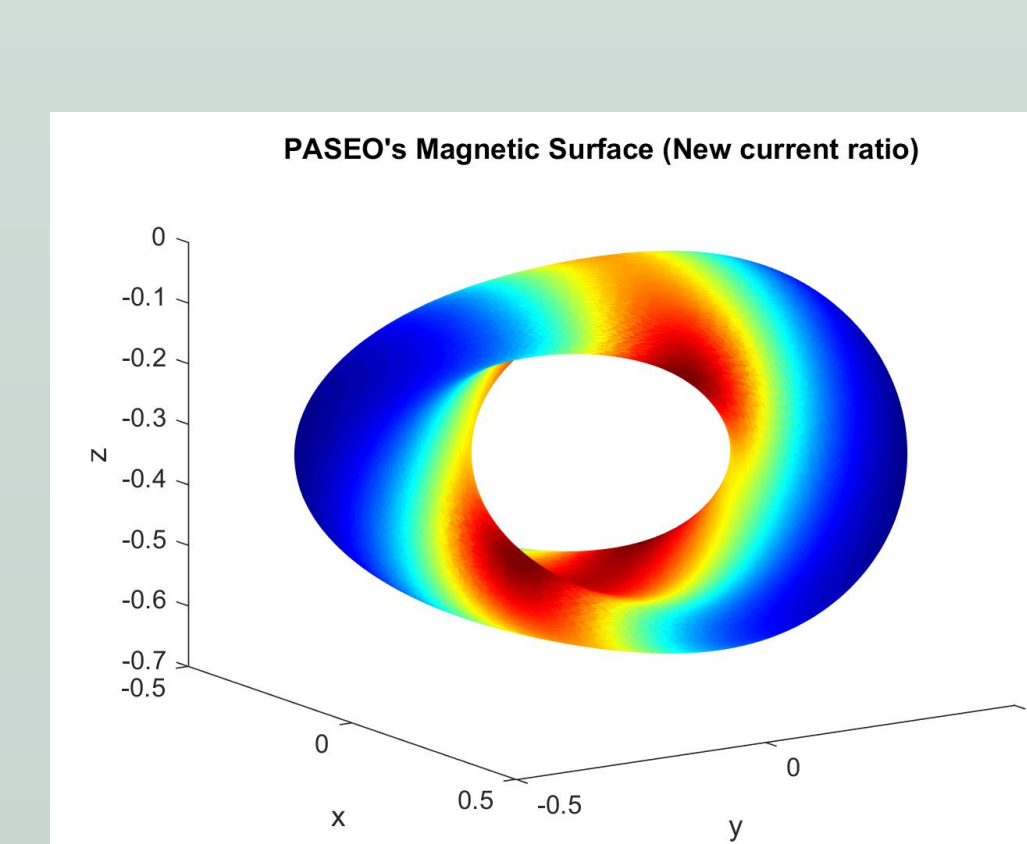
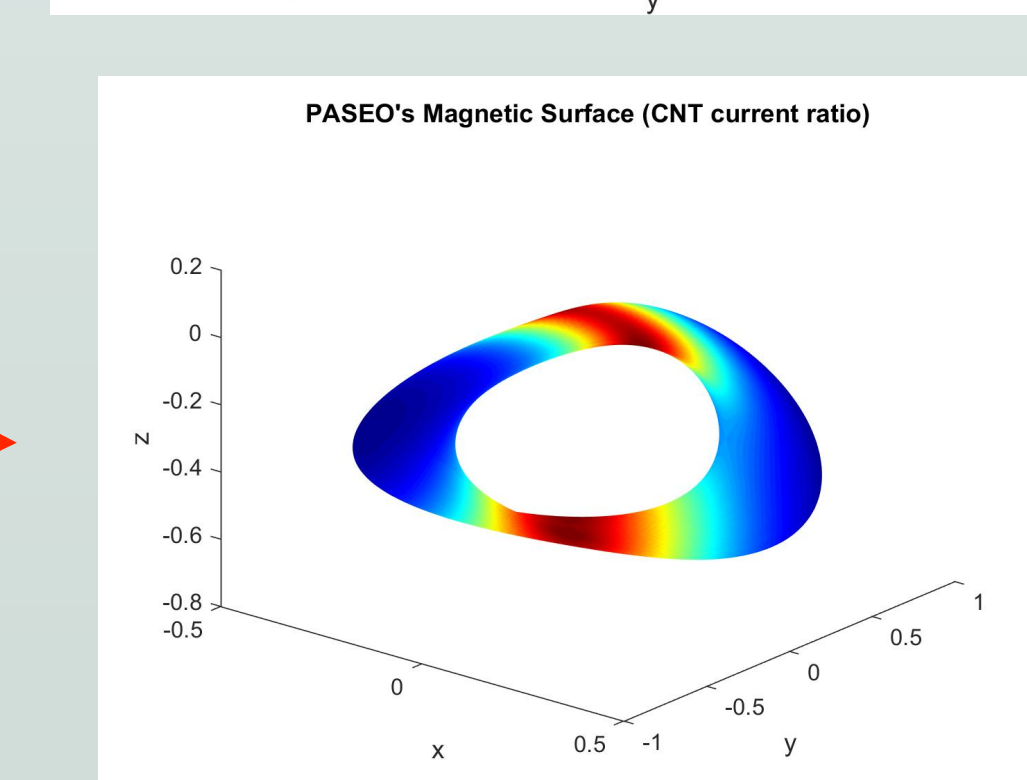
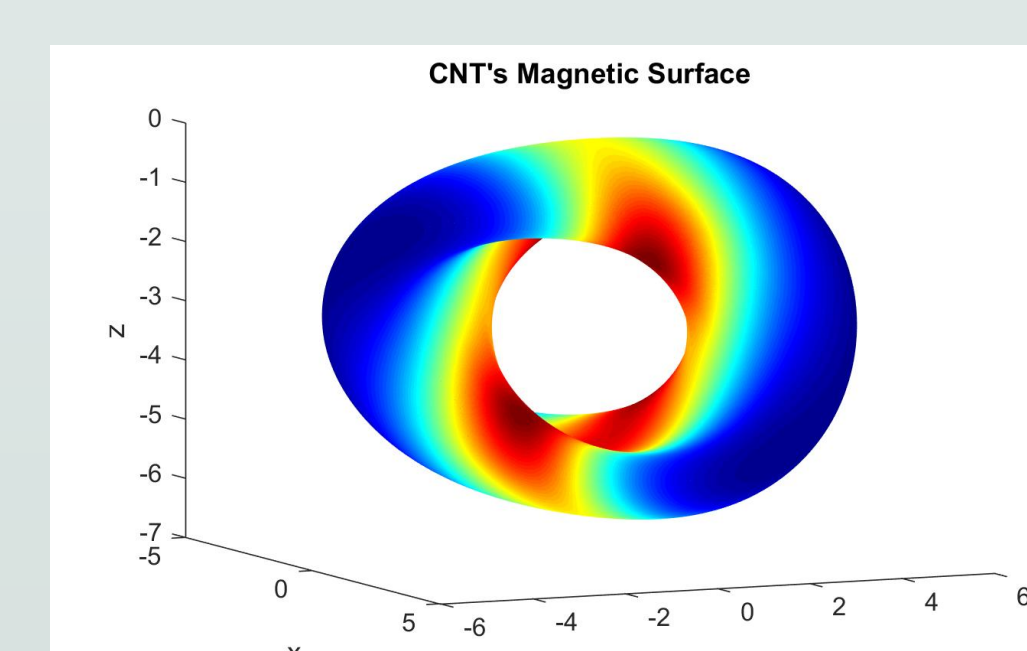


Magnetic surfaces for PASEO's physical configuration.

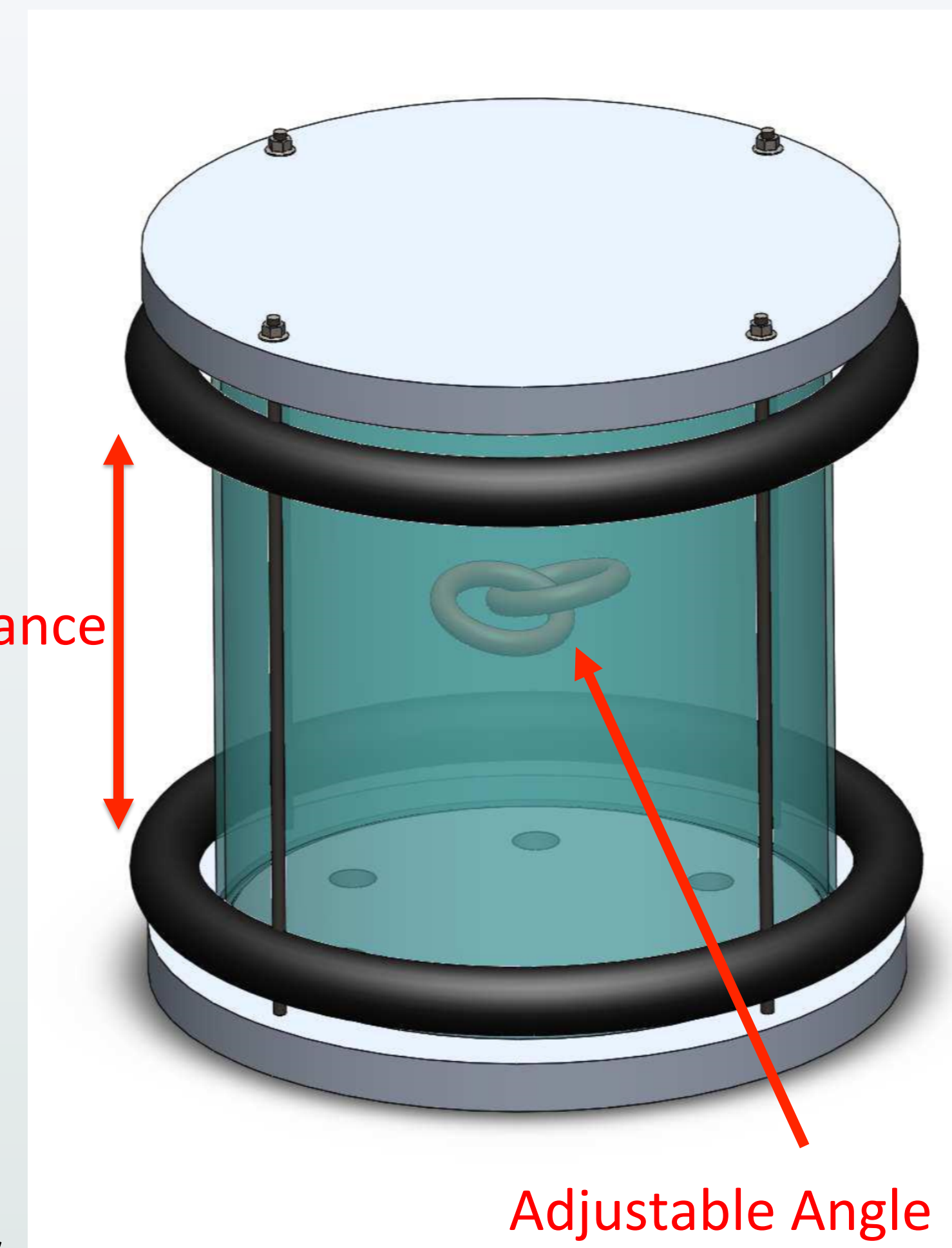


Magnetic surfaces for PASEO's new current configuration.

Magnetic Surface

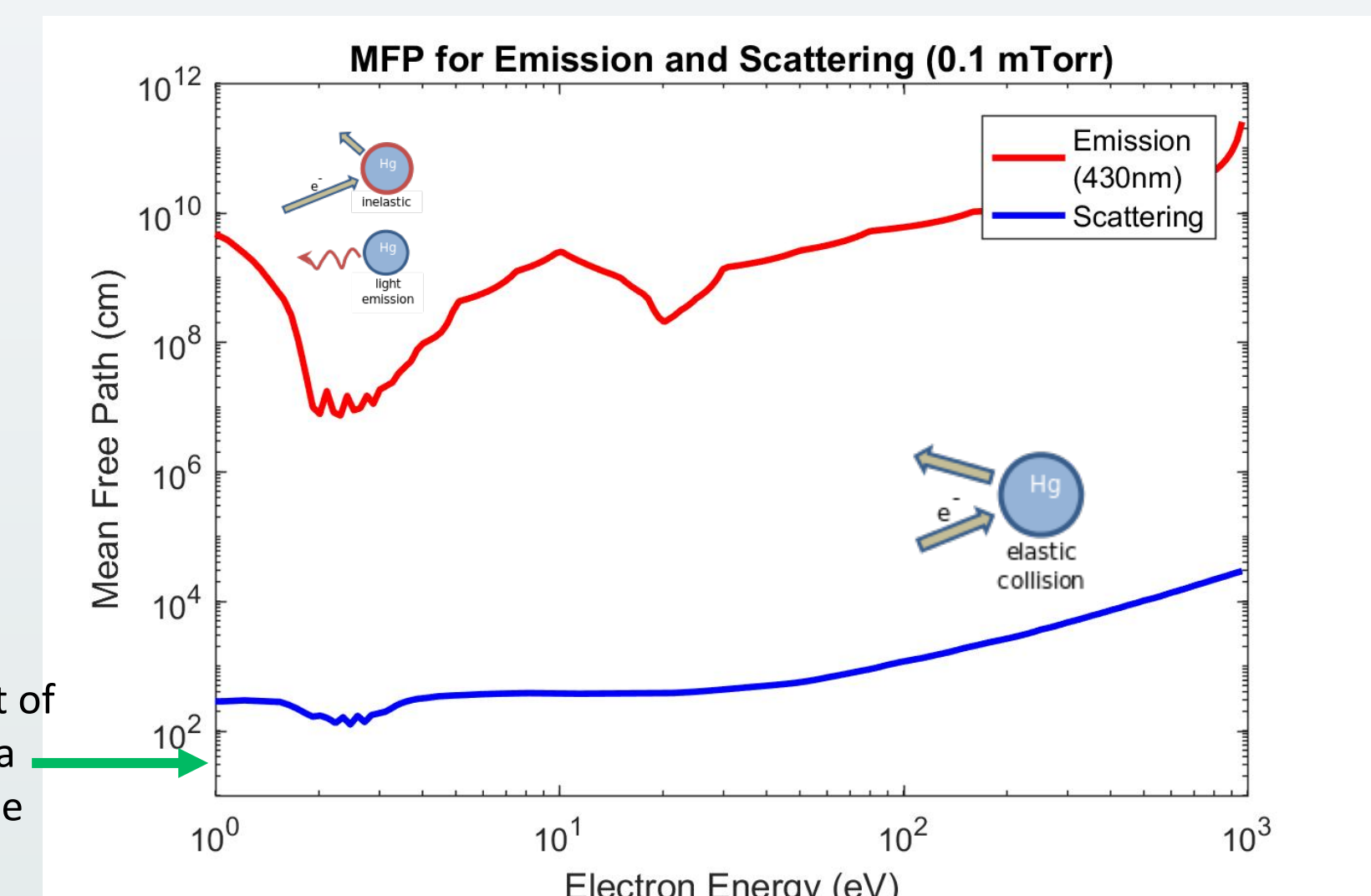


Physical Design of PASEO



Observing Magnetic Surfaces

- To determine the best method to map the magnetic surfaces, the mean free path of electron to molecular Nitrogen collisions was examined.



One toroidal orbit of an electron on a magnetic surface

- Due to the high emission MFP to scattering MFP ratio, observing field surfaces through emissions is not very accurate. This means that at the current scale, measuring magnetic field surfaces may prove difficult. However, at higher pressures, the emission will be observable for public demonstrations².

Conclusions

- PASEO's highly adjustable design accommodates both public demonstrations and student experiments.
- Optimization and modeling codes helped to determine current ratios to maximize the magnetic surfaces' size despite changing coil geometries.
- At the current scale, measuring the field surfaces may prove difficult, but at higher pressures they should be observable through electron neutral collisions.

Future Work

- Building the PASEO.
- Designing experiments that incorporate the PASEO's highly adjustable design.
- Using VMEC codes to model MHD equilibrium, confinement, and coil optimizations.
- Determine methods for measuring PASEO's magnetic surfaces

REFERENCES

1. T.S. Pedersen, et. al, Fusion Science and Technology Vol. 46 July 2004
2. C. Dugan, et. al, American Physical Society; 48th Annual Meeting of the Division of Plasma Physics, October 30-November 3, 2006
3. Biagi database, www.lxcat.net, retrieved on August 3, 2017
4. Lazerson S. VMEC FIELDLINES