THEA ENERGY

Physics Design of the Eos Neutron Source Stellarator

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Introduction

Thea Energy will build a mid-scale planar coil stellarator, called Eos, which will be used as a neutron source for tritium and medical isotope production. Thea Energy's novel design concept will generate optimized stellarator magnetic fields without complex, expensive, 3D modular coils, while retaining all the advantages of the inherently steady-state stellarator approach. The DESC code is used in a single stage to optimize a quasi-axisymmetric stellarator magnetic field geometry. A set of encircling planar coils and another set of small planar shaping coils provide an on-axis field of 5 Tesla . Electron cyclotron heating will generate deuterium plasma with a central electron temperature of ~ 13 keV. A pebble-based renewable wall will aid in removing particles and heat from the non-resonant divertors. Two negative ion deuterium neutral beams of energy with energy of ~ 1 MeV will be injected into the deuterium plasma to generate D-D neutrons with energy ranging from 2 to 4 MeV, resulting a steady state neutron flux of ~ $1{\times}10^{17}$ neutrons/sec. It is estimated that ~0.2 grams/day of tritium will be generated.

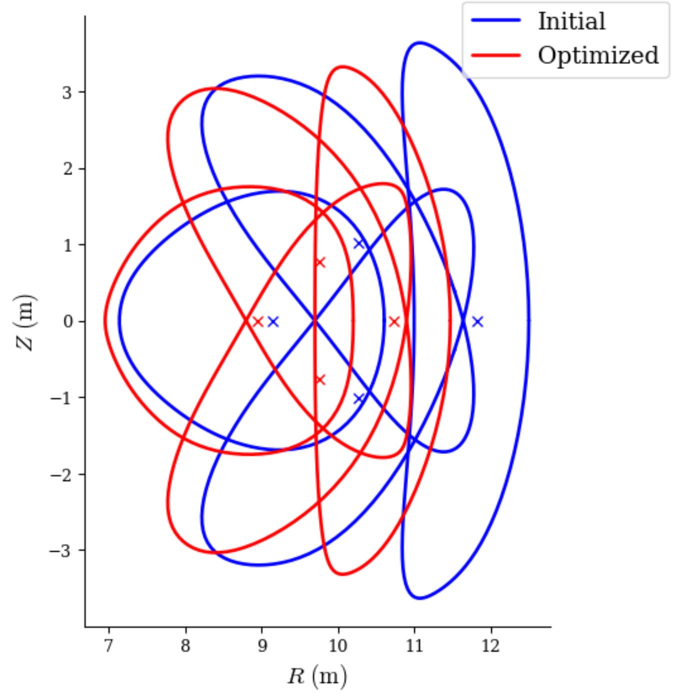
Stable Equilibrium with MHD stability

Equilibrium optimization is done using the DESC [1]. Optimization included objectives for:

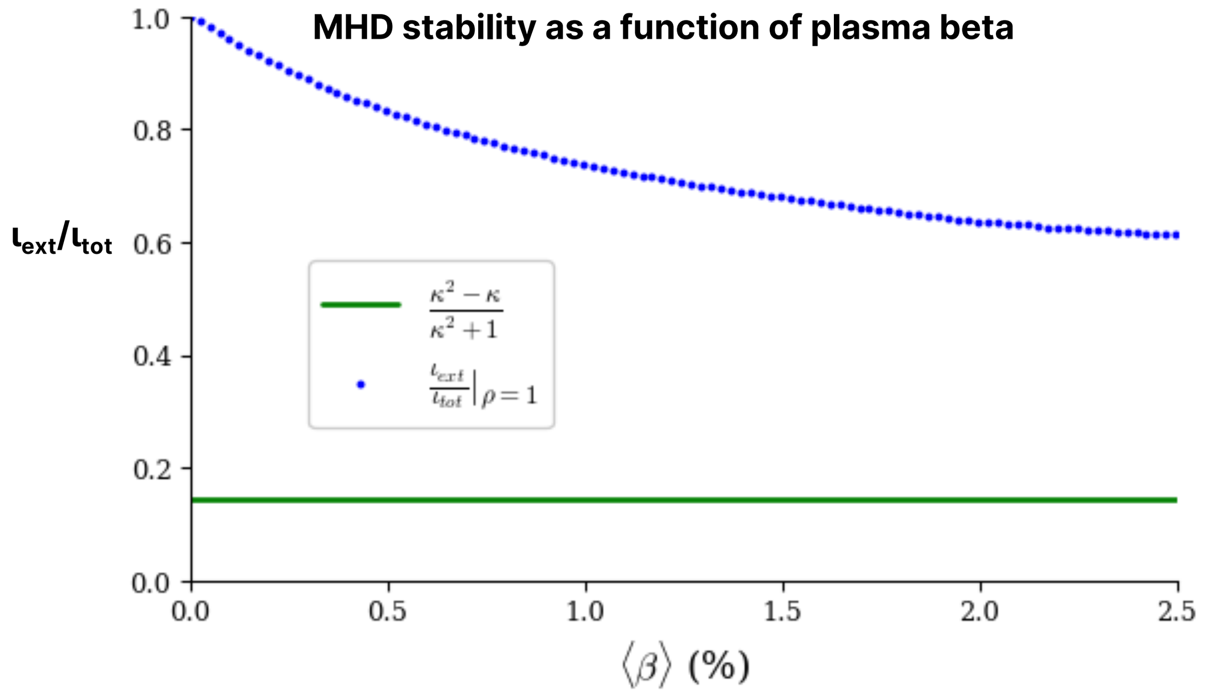
A. Aspect ratio, average magnetic field, plasma beta, elongation, iota profile.
B. Quasi-axisymmetry metric.
C. Bootstrap current self consistency.
D. Ideal MHD linear stability using TERPSICHORE [2].

For details, see poster by D. Dudt *et. al.*

Eos parameters	
Field period	2
Aspect ratio	6
Average major radius	3.24 m
Magnetic field strength <B>	~5 T
Plasma beta (β)	2.5 %
Heating	ECRH
Core electron temperature	~13 keV
Core ion temperature	~3 keV
Core density	1e20 /m³



Candidate Eos equilibrium



The minimum value of ι_{ext}/ι_{tot} is plotted . The green line is the minimum required external rotational transform from Fu *et.al.* [3] that guarantees vertical stability.

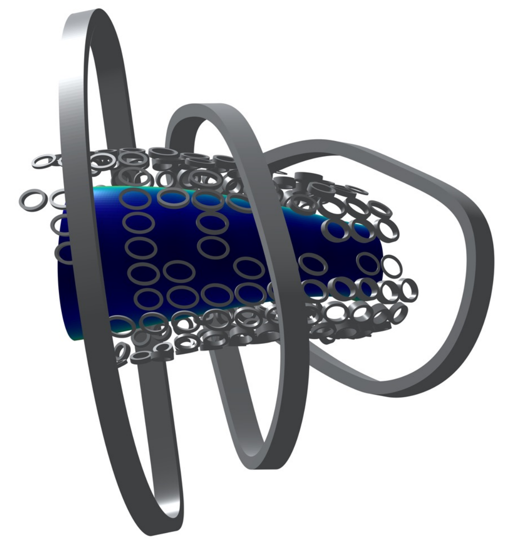
For details, see poster by M. Martin *et. al.*

Planar Coil Optimization with < 1% Max Field Error

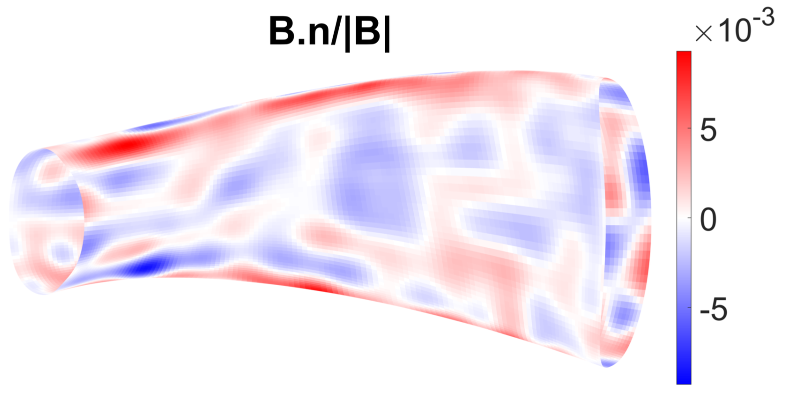
Planar coil optimization is done in multiple stages:

A. Preliminary encircling coil optimization. Optimized encircling coils generate about 97% of the confining field. Maximum field error ~14%.
B. Preliminary shaping coil optimization brings the maximum field error to ~1.1 %.
C. Final stage of combinatorial optimization brings the maximum field error to around 0.9%, with fewer number of shaping coils. Average field error ~0.15%.
D. Optimize for finite-build quantities (HTS critical current, tape length).

For details, see poster by T. Kruger *et. al.*



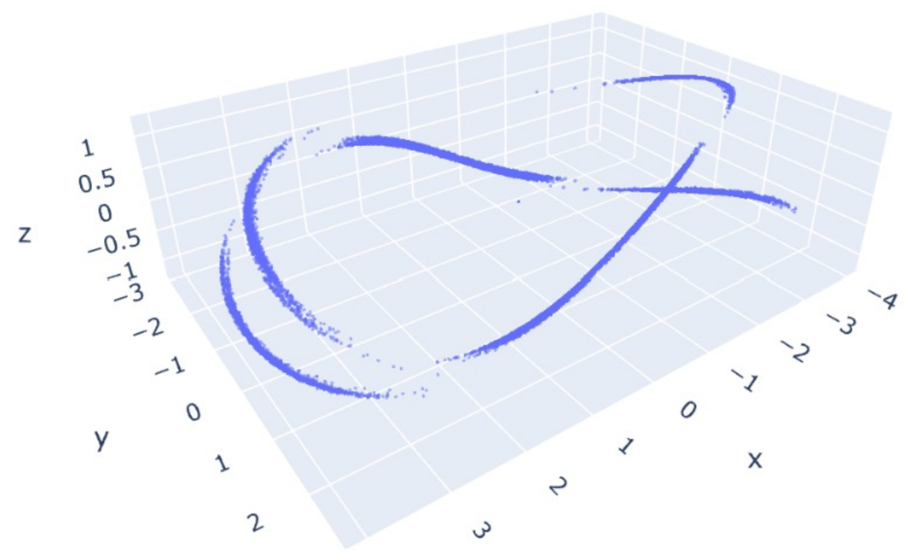
Encircling and shaping coils



Field error from combinatorial optimization

Renewable Divertors for High Heat Flux Operation

- A non-resonant divertor system is being designed.
- Strike point patterns and their resiliency are being studied using FIELDLINES [4] and DIV3D [5] codes.
- A boron pebble based renewable divertor is being designed in collaboration with UCSD.

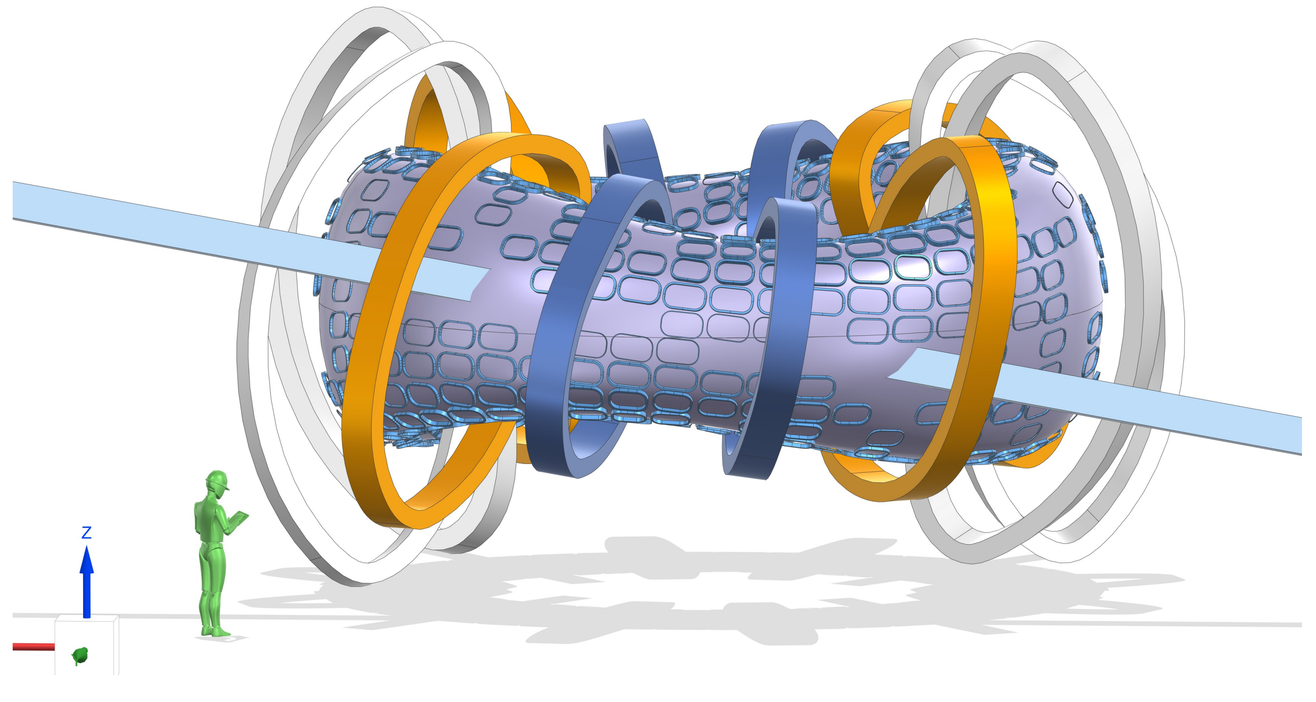


3D plot of Strike point pattern

Boron pebble rod developed by UCSD team to do high heat flux tests

For details, see poster by L. Tang *et. al.*

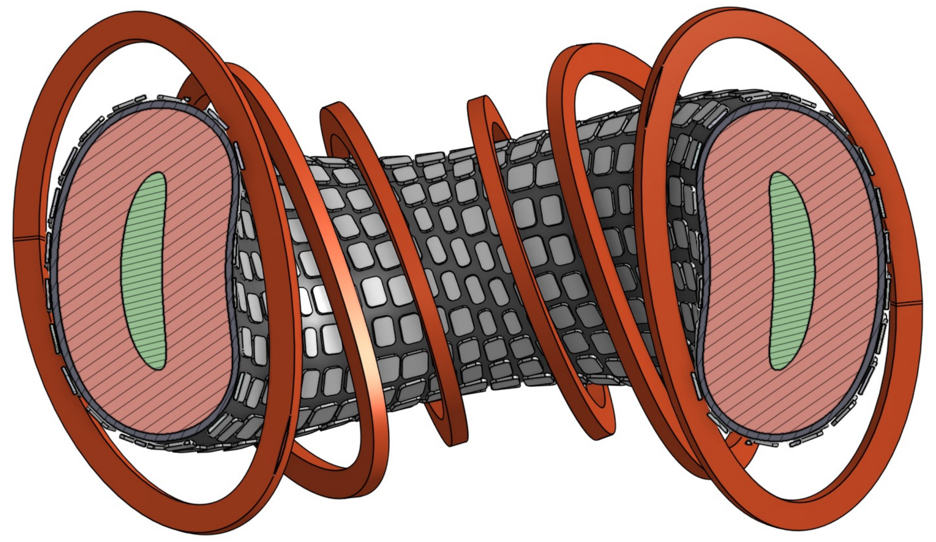
Negative Ion Neutral Beam for D-D Fusion



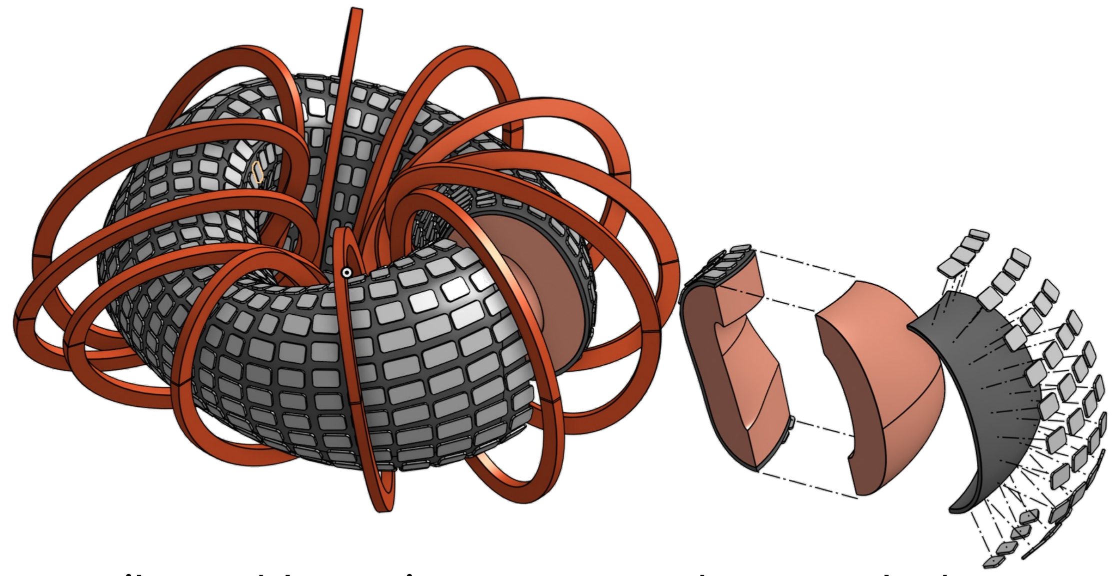
Two negative ion deuterium neutral beams (only one shown in the figure) of energy with energy of ~ 1 MeV will be injected into the deuterium plasma to generate D-D neutrons.

For details, see poster by C. P. S. Swanson *et. al.*

Advantages for Blankets & Sector Maintenance



Quasi-axisymmetry provides ample room for blanket system between plasma and magnet systems



Planar coils enable easier access to the vessel where remote manipulators can remove and maintain entire sectors of the system

Summary

Thea Energy will build a mid-scale planar coil neutron source stellarator. Optimized Quasi-axisymmetric stellarator magnetic fields are generated using planar encircling coils and smaller planar shaping coils. The optimization is done in single stage using the DESC code. A pebble-based renewable wall is being designed. Two negative ion deuterium neutral beams will be used for D-D neutron production.

References

1. D.W. Dudt et al., 2023 *J. Plasma Phys.* 89
2. D.V. Anderson et al., 1990 Int. J. Supercomput. Appl. 4 34
3. G.Y. Fu, Phys. Plasmas 7, 1079–1080 (2000)
4. Lazerson, S.A. et al. Nuclear Fusion 56, 106005 (2016)
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66th APS-DPP, October 7-11, 2024, Atlanta, GA

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