Stellarator Simplification using Permanent Magnets

BETHE Kickoff Virtual Workshop
Aug. 11–12, 2020

PI: David Gates, Head of Advanced Projects, Princeton Plasma Physics Laboratory
Co-PI: Robert Mercurio, President, SABR Enterprises
Co-PI: Prof. David Maurer, Auburn University

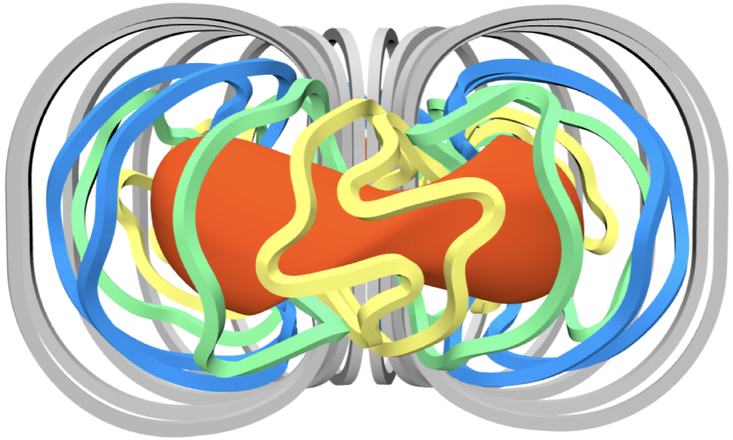
SABR Enterprises

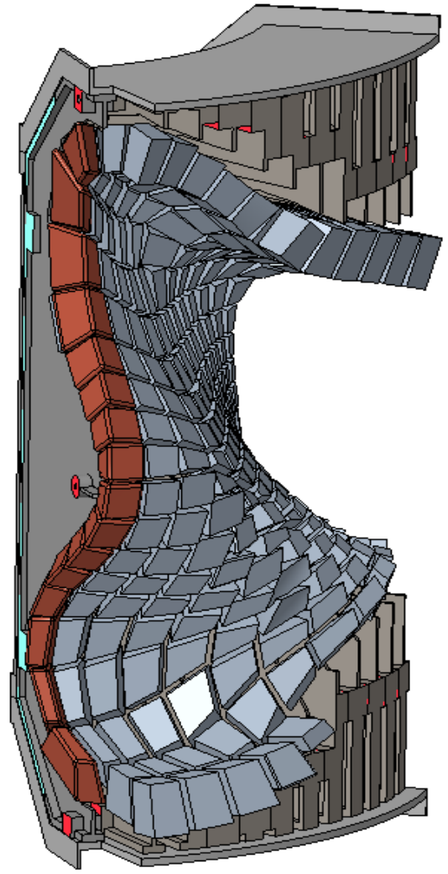
Team members and roles

- PPPL Team Members
- PI (PPPL)
  - David Gates
- PPPL Chief Scientist
  - Mike Zarnstorff
- Staff Scientists
  - Ken Hammond
  - Caoxiang Zhu
- PPPL Engineers
  - Keith Corrigan (analysis and design)
  - Tom Brown (design)
  - Art Brooks (analysis)
- SABR Enterprises Team Members
- Co-PI SABR
  - Robert Mercurio (president, engineer)
- SABR engineer
  - Robert Lown
- Auburn University Team Members
- Auburn Co-PI - Dave Maurer
- Auburn scientists
  - Greg Hartwell (Assoc. Prof.)
  - John Schmitt

High-level motivation and goals - PM4-Stellarators

- Stellarators have intrinsic advantages
  - Steady state, disruption free, no hard density limit
- Stellarator coils are complex
- Complexity leads to higher costNew idea: Use permanent magnets to provide 3D shaping field!
  - Helander, et al., PRL 2019
- Technical goal –
  - demonstrate that shaping fields required to create an optimized stellarator can be built
  - meet required accuracy (~10^{-3} error)





Major tasks, risks, milestones, and desired project outcomes

- Develop detailed design
  - Combine stellarator design tools with engineering models
  - Develop tooling and assembly concepts
  - Complete safety analysis of assembly plan
  - Develop error field (major risk) mitigation scheme (mechanical adjustment)
  - Build small test assembly
  - Go/No-go decision at completion of Final Design Review
- Procure materials, fabricate and assemble device
  - Verify magnet sub-assemblies during fabrication
- Measure resultant fields
  - Verify field errors meet tolerance
  - Adjust magnets to minimize errors
- Product = ½ period of a 3-period optimized stellarator with verified magnetic fields

Key techno-economic metrics of the project (and, if applicable, its commercial fusion-energy application)

- Using adjustable mechanical assemblies of permanent magnets reduces the cost of stellarator field coils
  - NdFeB costs $14/lb and has been used to create fields up to 4T
  - Can be immersed in fields up to 7T (when cooled)
  - Estimate 20-30% reduction in cost of coils by using only planar coils+ permanent magnets
  - Can also use magnets to reduce amount of non-planarity
- Addresses the main perceived issue for stellarators