TSVV-i: Stellarator Optimization

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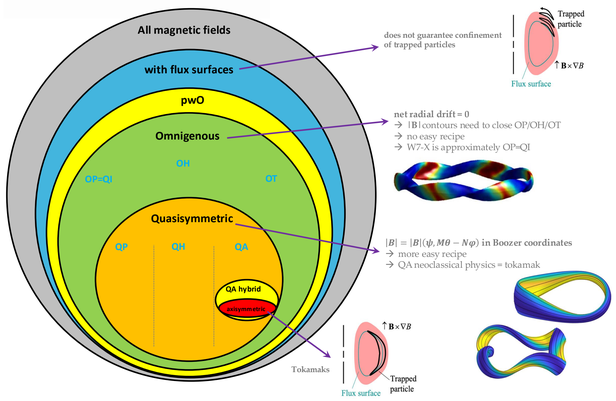
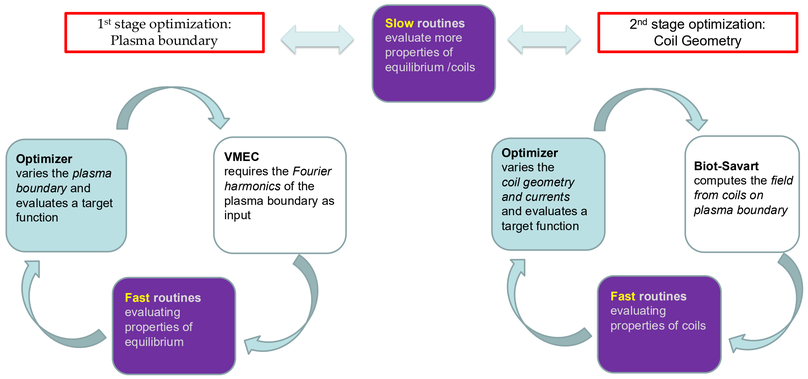
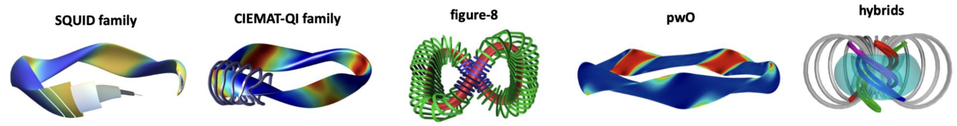
THE SPACE OF MAGNETIC FIELDS



OPTIMIZATION METHODS: HOW DID WE FIND BETTER DESIGNS?





- ❑ Much **faster computing leveraging parallelism** (can explore larger configuration space)
- ❑ Devised **efficient recipes** for finding QI and QS (better target functions)
- ❑ Developed **faster algorithms & improved numerics** (more evaluations inside optimization loop)
- ❑ Derived new **reduced models** (more physics in optimization loop)
- ❑ Combined plasma-coil optimization or "**single-stage**" (access to better optimum)

PLANS FOR 2026 / 2027

Develop state-of-the art codes & new optimization tools

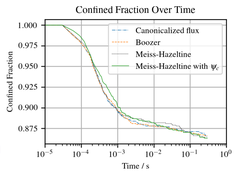
❑ Equilibrium codes with and without nested surfaces (SD1)

SD1.1 New SPEC solver
SD1.2 Interface SIMSOPT-GVEC
SD1.3 Free-boundary optimization with SIMSOPT-GVEC

➢ *G-frame allows GVEC to explore unprecendented configuration space*

❑ Fast particle and neoclassical codes (SD2)

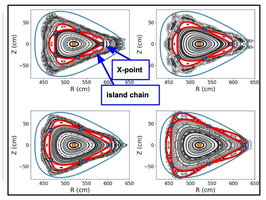
SD2.1 Extension of SIMPLE to support GVEC/SPEC equilibria
SD2.2 New solver for fast bootstrap evaluation beyond 1/nu regime
SD2.3 Interface SIMPLE-SIMSOPT to treat regions beyond LCFS
SD2.4 Extension of SIMPLE to treat divertor region and evaluate wall losses
SD2.5 New 2D drift-kinetic solver for arbitrary E-fields



➢ *SIMPLE code evaluates α losses in SQUIDs*

❑ New optimization tools to control the edge magnetic topology (SD3)

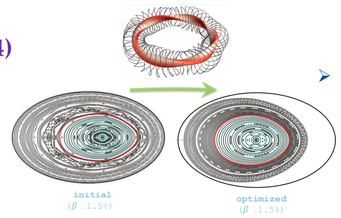
SD3.1 Optimization tools to control magnetic topology in the edge
SD3.2 Database of W7-X topological features versus coil currents
SD3.3 W7-X configurations optimized for the generation of transport barriers



➢ *Topological optimization tools guide the control of the divertor island in W7-X*

❑ New optimization tools to control quality of pwO & hybrid QAs (SD4)

SD4.1 Efficient metrics for the optimization of pwO fields
SD4.2 Optimization tools for converting a tokamak into a QA hybrid



➢ *SIMSOPT optimizes coils to remove chaos using SPEC at $\beta > 0$*

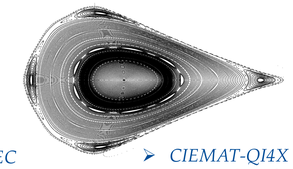
❑ New tools for analyzing the nonlinear stability of MHD modes (SD5)

SD5.1 SPEC-based algorithm that predicts nonlinear saturation of MHD modes

Generate and characterize new optimized stellarator configurations

❑ New QI stellarator configurations (SD6)

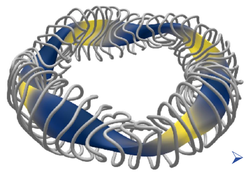
SD6.1 Extended database of different CIEMAT-QI configurations
SD6.2 Direct-from-coils optimization of divertor topology at finite beta
SD6.3 Effect of turbulence optimization on turbulent transport in CIEMAT-QI
SD6.4 Structured database of near-axis QI configurations
SD6.5 Tradeoffs of physical properties in QI configurations
SD6.6 Different optimized divertor topologies for SQUID configurations
SD6.7 New optimized QI configurations using reduced models for turbulence
SD6.8 EMC3-EIRENE performance prediction in divertors with unpaired x-points
SD6.9 Effect of edge optimization on divertor performance



➢ *CIEMAT-QI4X design with improved surface quality and resilient divertor island*

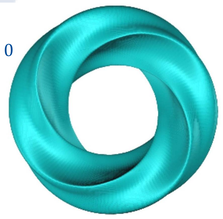
❑ New pwO and hybrid QA stellarator configurations (SD7)

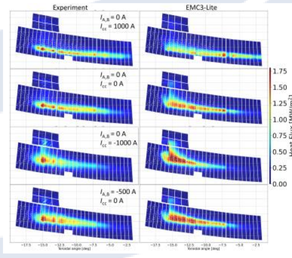
SD7.1 Feasibility assessment of tokamak-pwO hybrid
SD7.3 Coil feasibility and coil simplicity study for pwO fields
SD7.2 Characterized pwO configuration space
SD7.4 Divertor concept for a tokamak-QA hybrid



➢ *SQUID-τ design with improved fueling via turbulent pinch*

➢ *QA hybrid design at $\beta > 0$ and compatible with coils*





➢ *EMC3-Lite quickly predicts the heat flux pattern for different W7-X configurations*

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