Towards a finite beta equilibrium

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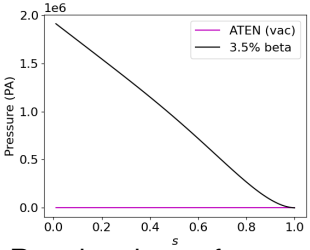
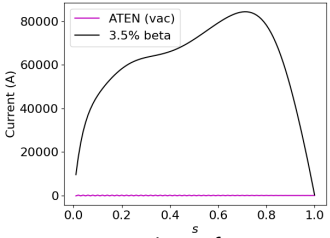
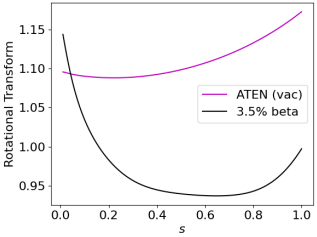
Goal: Optimize equilibria at ”reactor-relevant” pressures

- ARIES-CS scale temperature and density and 8 T operation yield about 3.5% β
- Start with ATEN equilibrium and add ARIES-like profiles, calculate bootstrap current
- Keep current fixed and optimize for QS, Γ_c and ι
- Recalculate bootstrap current
- Repeat last two steps until equilibrium is satisfactory

Step 1: Add current to vacuum config

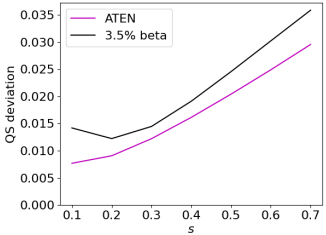


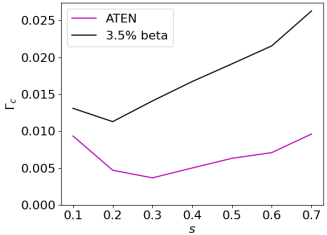


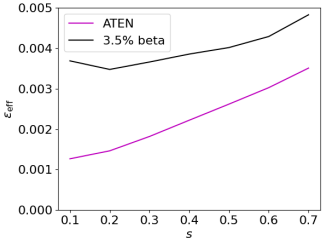


Rotational transform profile crosses $\iota = 1$ surface.

Step 1: Derived quantities

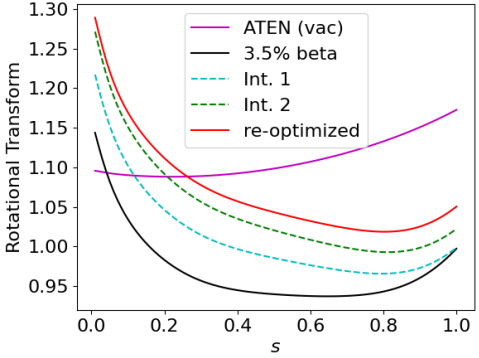


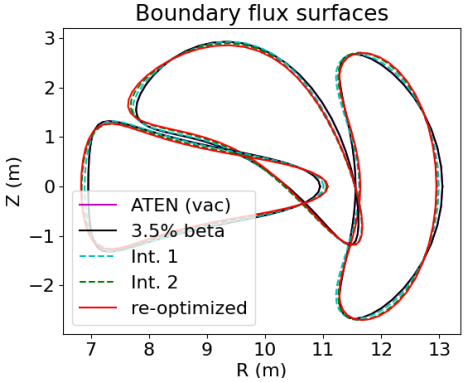




Derived quantities degrade, especially Γ_c

Attempting to move the rotational transform





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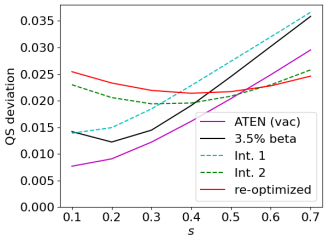
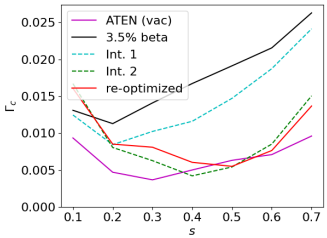
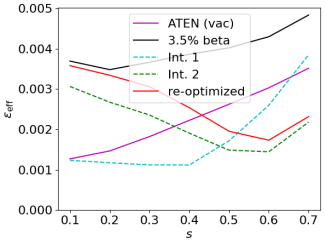
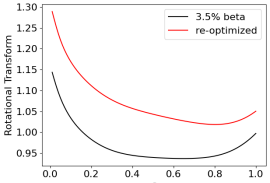


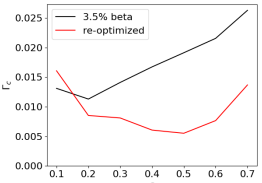


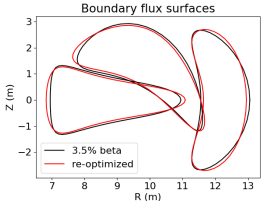


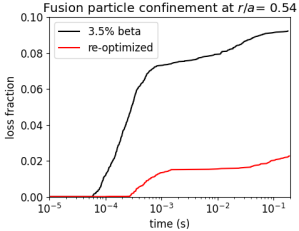
Quasi-symmetry profile different than ATEN, Γ_c mostly recovered

Including finite pressure in the optimization



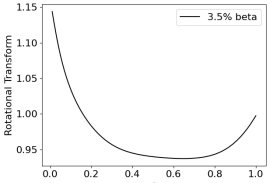


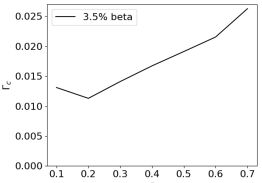


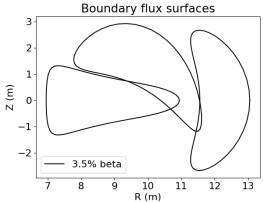


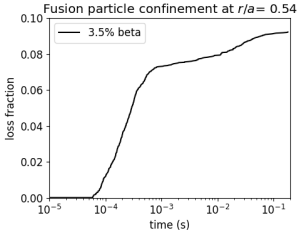
- Optimization is able to reduce the losses somewhat

Further optimization with finite pressure



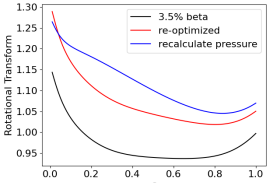


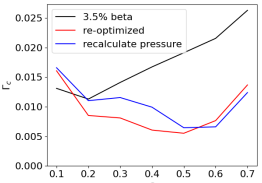


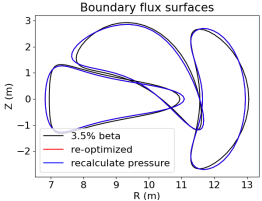


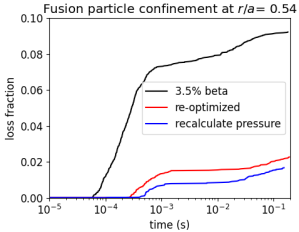
- Adding pressure changes the rotational transform profile - crosses $\iota = 1$ resonance surface (bad)
- Goal: optimize equilibrium to avoid rational surfaces and keep good energetic particle transport

Further optimization with finite pressure



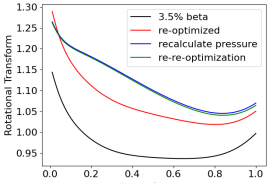


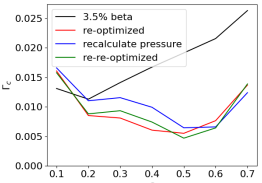


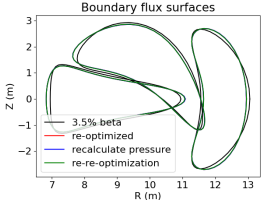


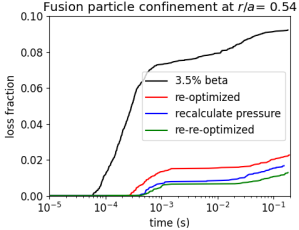
- Recalculating the pressure actually improves confinement slightly
- Can we do better still?

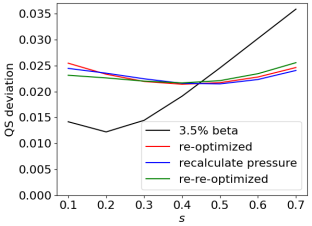
Further optimization with finite pressure



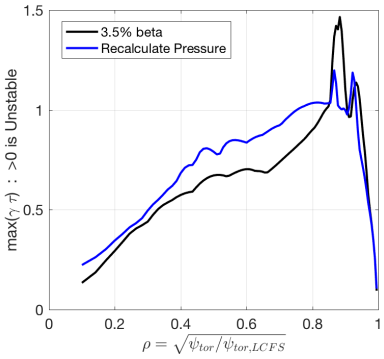








Ballooning stability is a problem



- Ballooning stability is lost over the entire volume.
- Profile shaping: Initial results (not shown) suggest that profile shaping can help stabilize the core, but the edge region is problematic.
- Shear $\sim$ 0 region ALWAYS exists between $0.7 < \rho < 0.9$ in ATEN-like finite beta configurations.
- Finite-beta, 0-current (no bootstrap) optimization showed that Ballooning stability can be attained, but the shear must be increased. This is a problem for ATEN-like finite beta with bootstrap current because a shear reversal ALWAYS happens between $0.7 < \rho < 0.9$.

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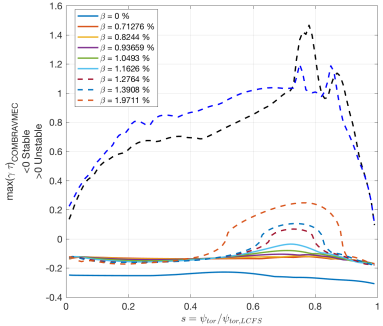

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Other issues

- Coils will be more difficult due to bootstrap current unwinding transform
- Turbulence optimization not yet attempted
- Do we care about other stability metrics (Mercier?)
- Need to figure out path from vacuum to optimized equilibrium (perhaps with control from aux coils)