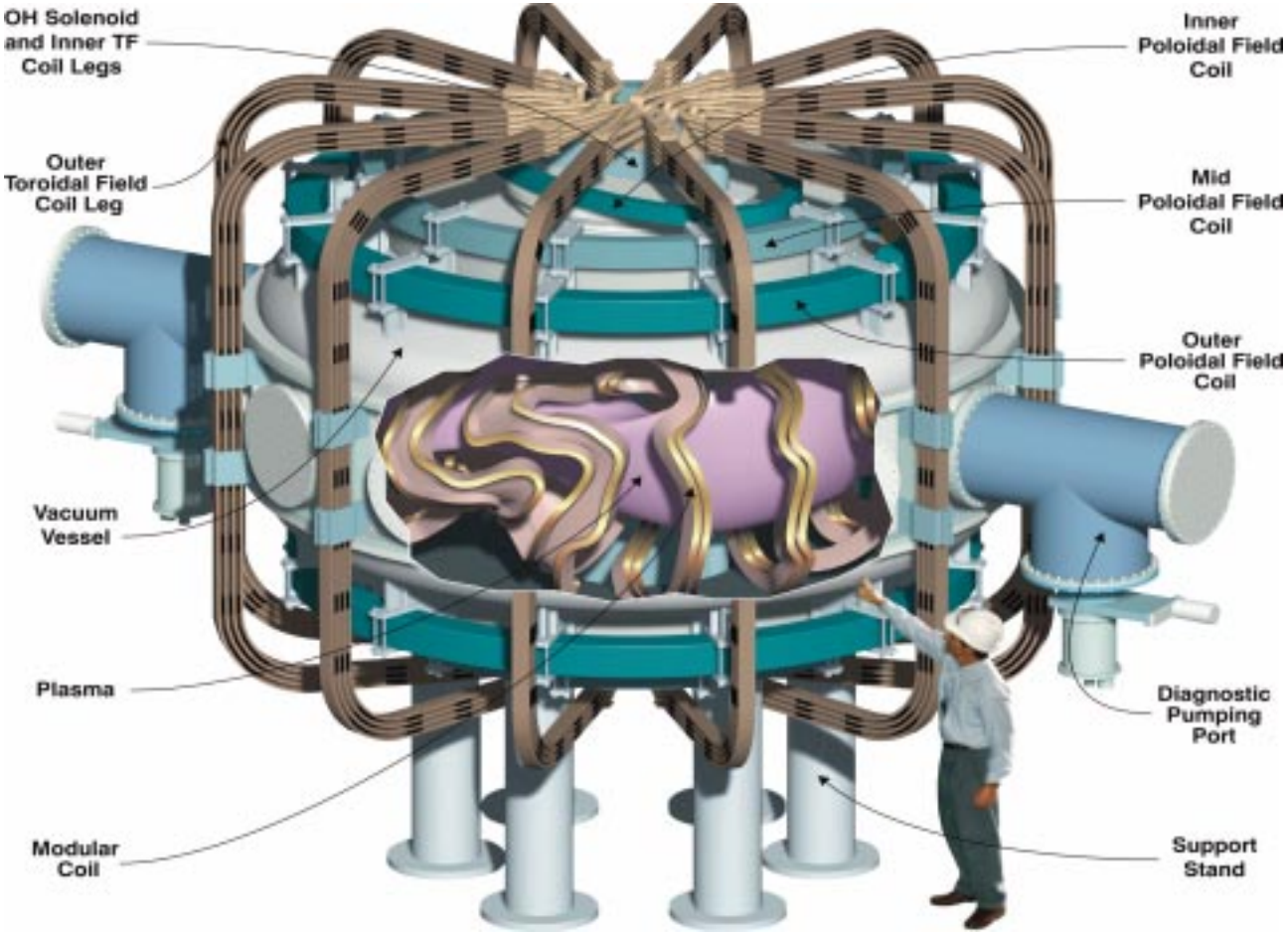
Overview of the QPS Project



- $\langle R_0 \rangle = 0.90$ m
- $\langle a_p \rangle = 0.33$ m
- $\langle B_0 \rangle = 1$ T ± 0.2 T for 1 s
- $I_{plasma} \leq 150$ kA
- $P_{ECH} = 0.6–1.2$ MW
- $P_{ICRF} = 1–3$ MW

Multi-Laboratory Design Team; Project Coordinator – J.F. Lyon, ORNL

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QPS Objectives and Plans

QPS Program Objectives

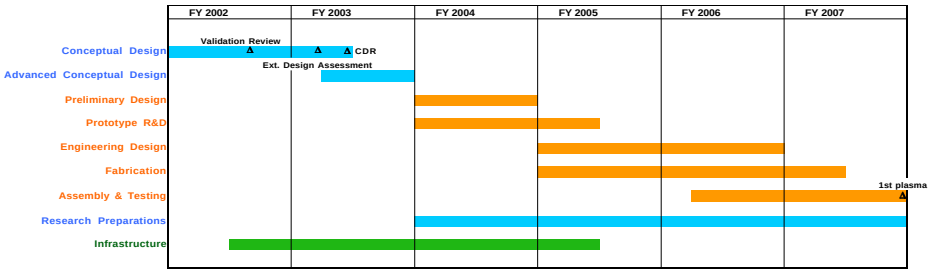
- **Confinement understanding**
  - Anomalous transport, internal transport barriers, and flow shear in low-*R*/*a* configurations with quasi-poloidal symmetry
  - Reduction of neoclassical transport due to near alignment of *B* and ∇B
  - Impact of poloidal flows on enhanced confinement
  - Equilibrium quality (islands, ergodic regions) and its repair at *R*/*a* ~ 2.7; robustness with β and dependence of bootstrap current on configuration properties
  - Understand β limits and limiting mechanisms for quasi-poloidally symmetric configurations at very low *R*/*a*
- **Explore physics not obtainable from other stellarator experiments and theory**
  - effect of strong toroidal coupling
  - significant bootstrap current in quasi-poloidal geometry
  - different neoclassical transport reduction mechanism
- **Study fundamental issues common to low-β and high-β quasi-poloidal configurations**
  - scaling of the bootstrap current with β
  - reduction of H-mode power threshold
  - flux surface robustness as beta increases due to reduced parallel bootstrap current
  - ballooning instability character and limits

QPS Improvements Over Last Year

- Neoclassical losses reduced by factor 19, at same level as in W 7-X with 4 x *R*/*a*
- Departure from quasi-poloidal symmetry reduced by factor 2.7
- Space in middle increased to accommodate TF coil legs and OH solenoid
- Increased plasma-coil and coil-coil spacings
- Modular coils modified to reduce errors in reconstructing B field by factor 2.2
- Smaller vacuum vessel; modified to eliminate eddy currents induced by PF system

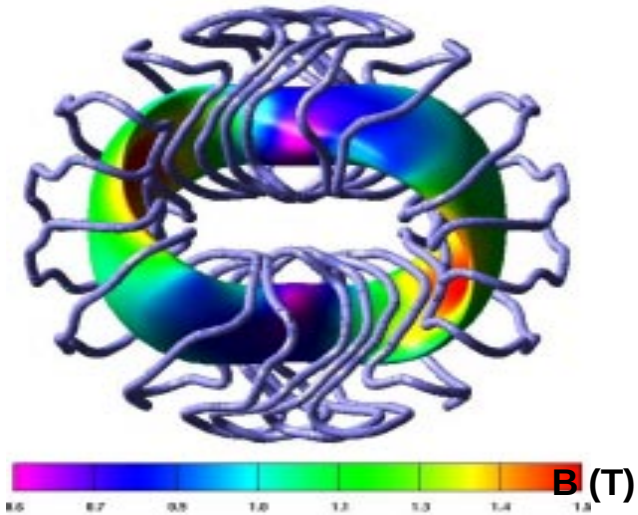
Status and Plans

- Successful Physics and Project Validation reviews
- Complete assessment of QPS physics properties
- Improve engineering design and cost estimate
- April 2003: Design, Cost & Schedule Review
- 2003-2007: R&D, design and construction
- Sept. 2007: First plasma

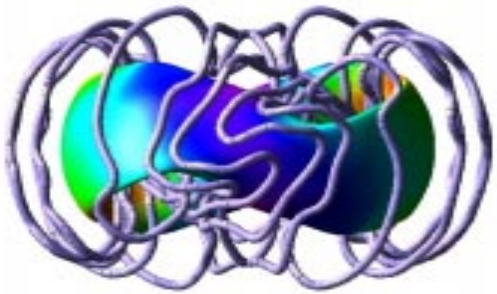


QPS: A New *R/a* = 2.7 Quasi-Poloidal

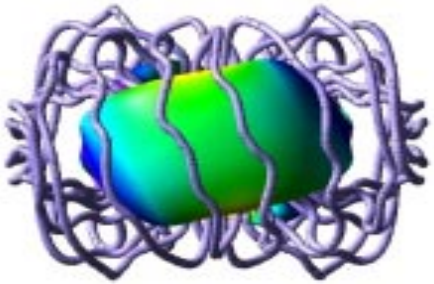
Top View of Plasma and Coils



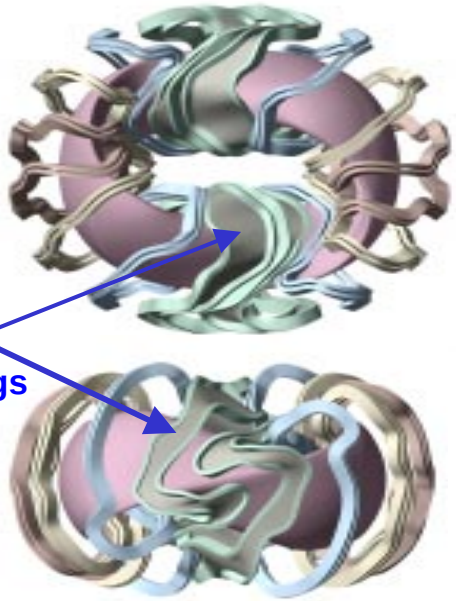
Side View from Middle



Side View from End

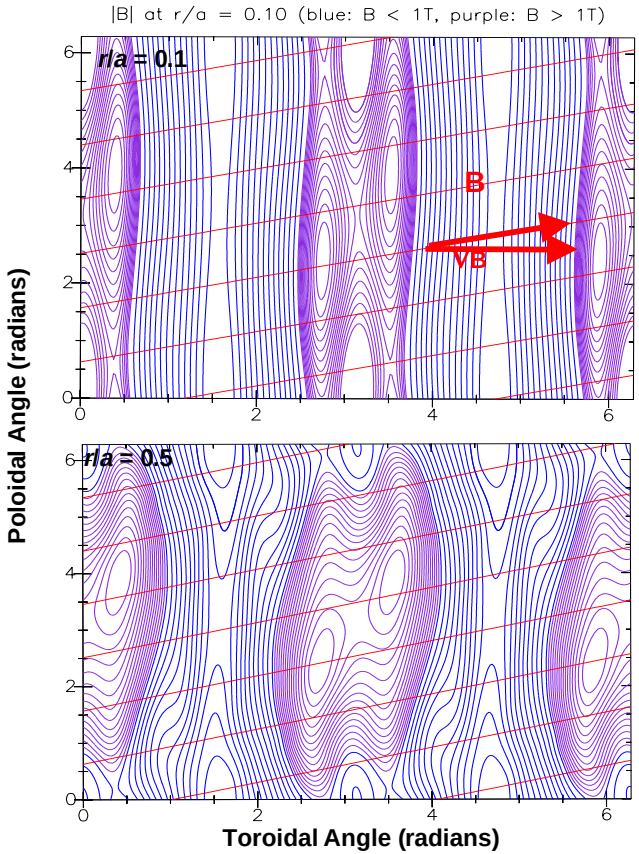


Actual Coils



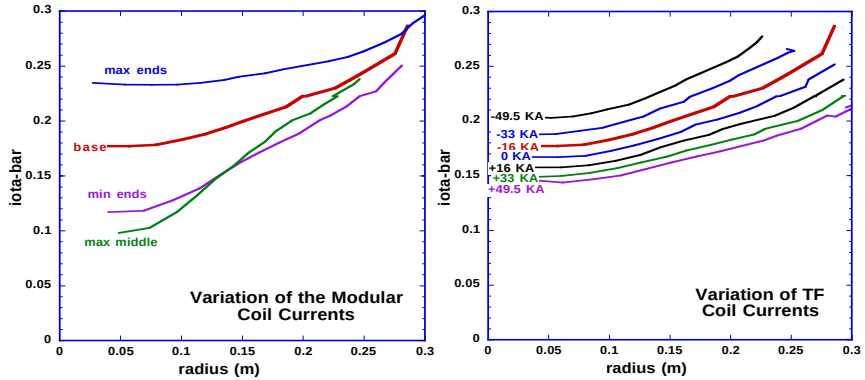
Split windings for coil type 4

|B| Contours illustrate quasi-poloidal |B| structure

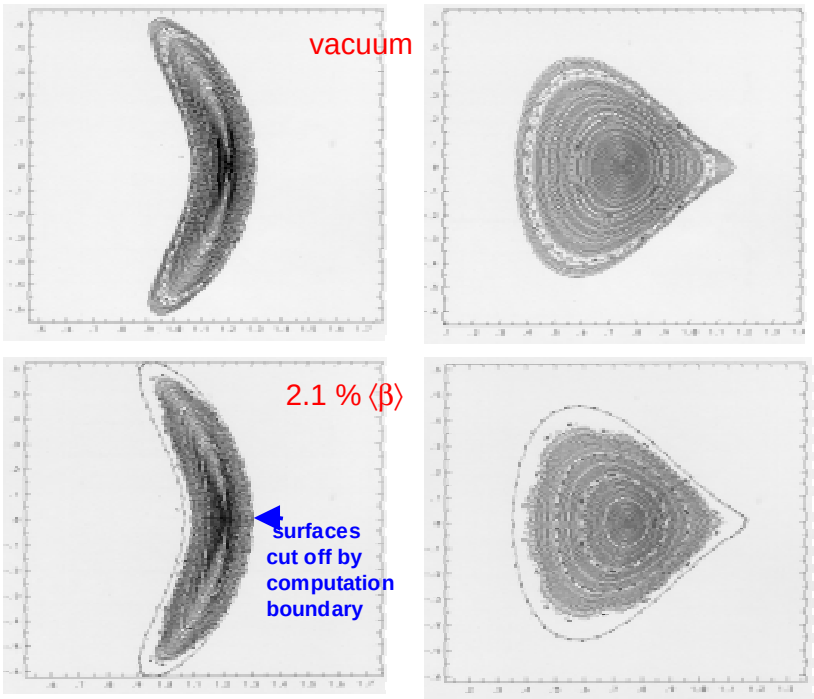


QPS Configuration Properties

QPS Coils Allow Variation of Rotational Transform and Shear

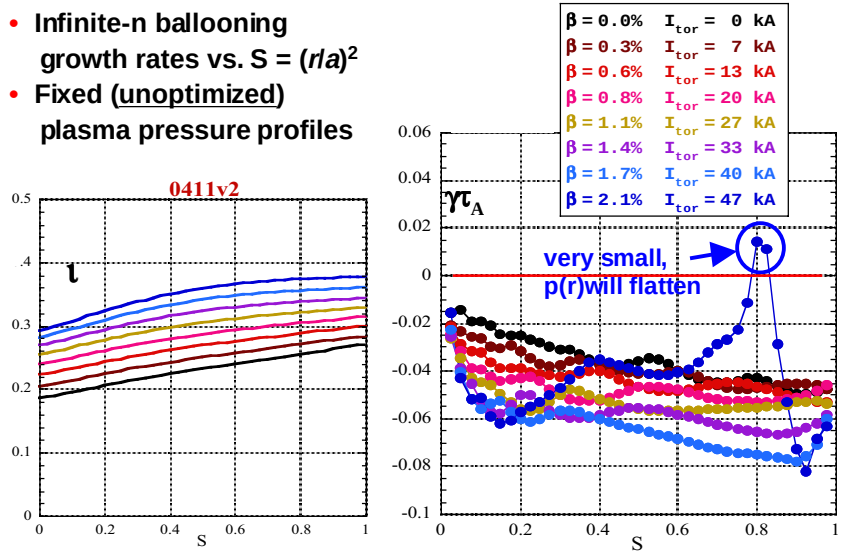


Finite-β Flux Surfaces Do Not Require Healing



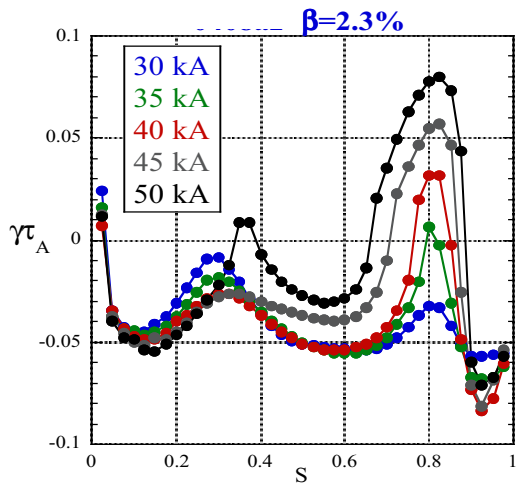
A Stable Path Exists from Vacuum to β = 2.1%

- Infinite-n ballooning growth rates vs. S = $(r/a)^2$
- Fixed (unoptimized) plasma pressure profiles



Infinite-n Ballooning Limits Likely to be Exceeded

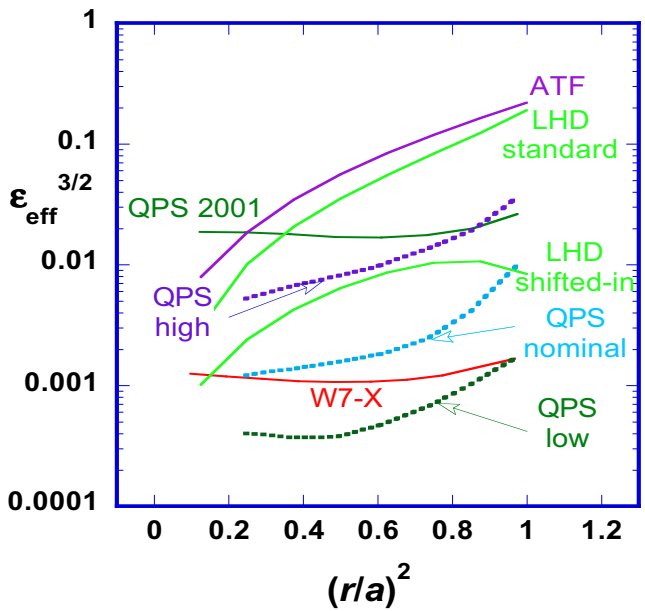
- NCSX stability calculations indicate that finite-n ballooning limits are typically ~50% higher than infinite-n limits
  - have not yet explored reduction of second stability "gap" with finite n or path around it
- Bootstrap current is overestimated
  - lower plasma current leads to higher β limits



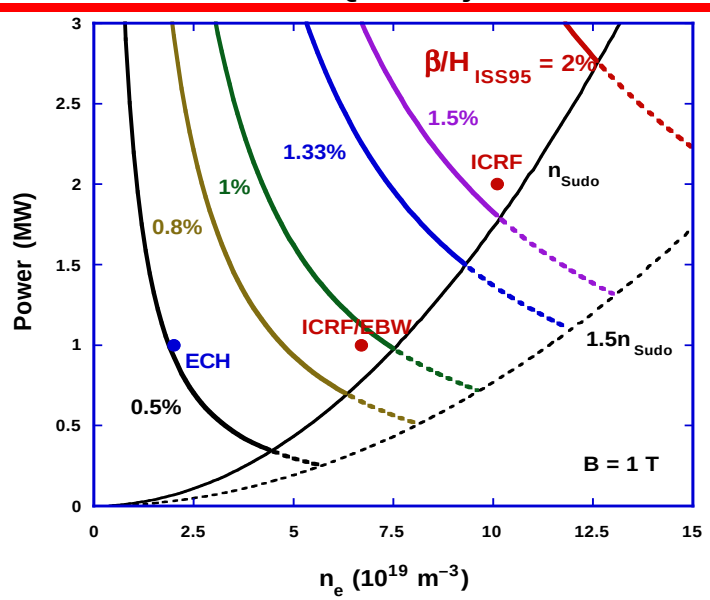
Low-Bootstrap Current Stellarator

QPS Coil Set Allows Testing Neoclassical Transport

- Changing currents in QPS coils varies neoclassical transport by factor 8-20
- Can change from neoclassical being dominant over plasma core to not being significant
- Base QPS is ~10x better than 2001 version, ~ W 7-X value



P = 1-3 MW Gives the Parameters Needed for the QPS Objectives

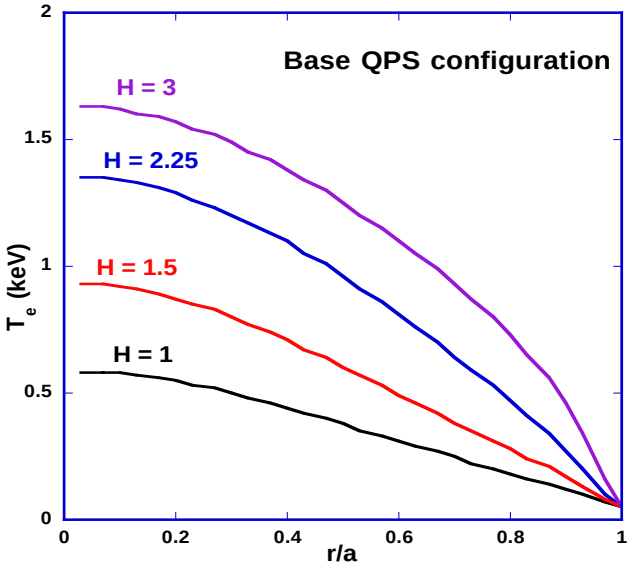


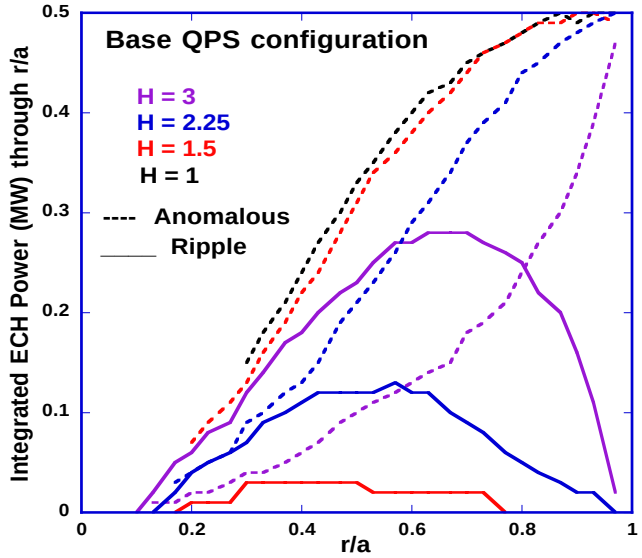
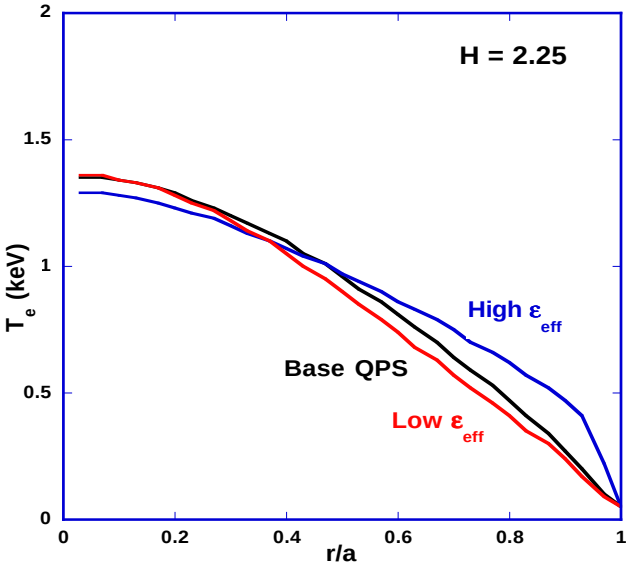
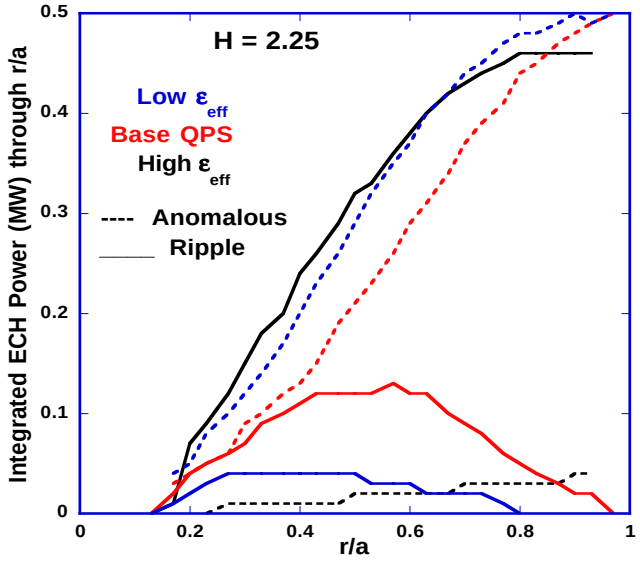
Multiply contour values by H_{ISS95} (= 1-2.5 in experiments)

QPS parameter space for B = 1 T

1-D Transport Calculations

Variation with ISS-95 Confinement Multiplier





Variation with Effective Ripple