Recent Progress in Configuration Development for Compact Stellarator Reactors

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Overview of Progress Since January

- Provided an 8.25-m major radius machine description for power plant studies. The device is based on the present (as of January) NCSX plasma configuration and coil geometry.

- Broadened the space of optimization to search for configurations with better reactor performance.

- Initiated efforts to understand what makes a "good" configuration good.

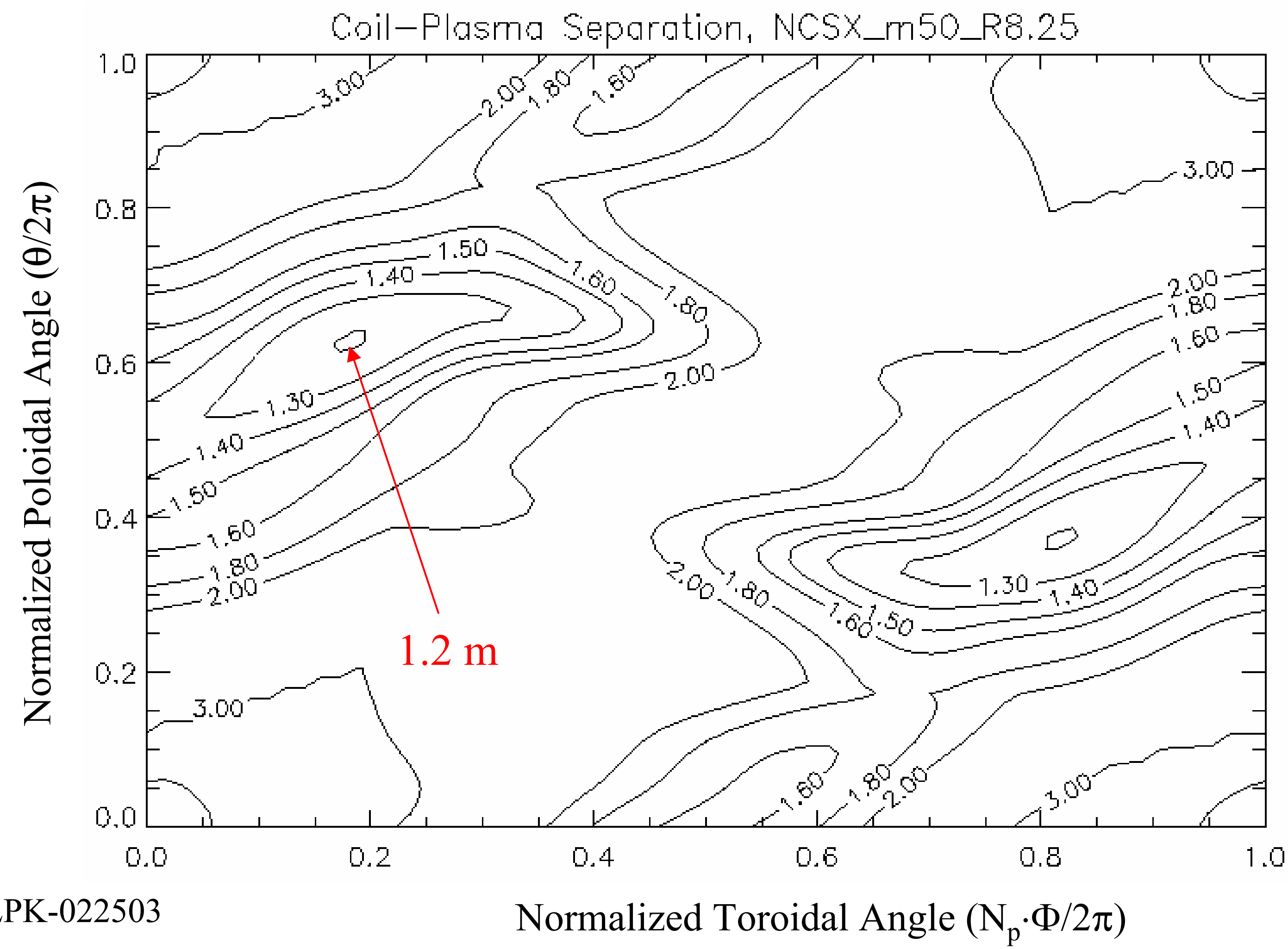
- Started investigating the effects of temperature, density and the corresponding plasma current profiles on QA and MHD stability.

A Reactor Based on NCSX

- M50 coils (version z01), and the reference plasma state they produce, are scaled to a size expected to yield a fusion power of ~1GWe.
  - Purpose is to provide a starting point for studying issues/problems and ways to resolve/solve them. A few iterations expected.
  - Caution: NCSX modular coils are designed using Cu conductors and LN cooling. Optimized coil geometry (coil-coil spacing, bend radii, NB access) would be different for larger sized machines.
  - Simple scaling used based on data in SPPS (Ku to Raffray, 1/31/03).
  - R=8.25 m, A=4.5, B=5.3 T, β=4.1%, Ip=3.5 MA
  - Minimum Δ(coil-plasma)=1.2 m, Γn~2.0 MW/m^2.

- Two new tools have been developed to assist in the design of blank/shield/energy removal and coils:
  - (1) provide a complete map of coil-plasma spacing,
  - (2) calculate maximum magnetic field intensities in coils.

Contours of coil-plasma spacing are constructed to assist in design studies of blanket/shield, heat removal and remote maintenance.



A simple code is assembled to calculate the magnetic field intensity in coils for sizing, finding the maximum field, and estimating body forces.

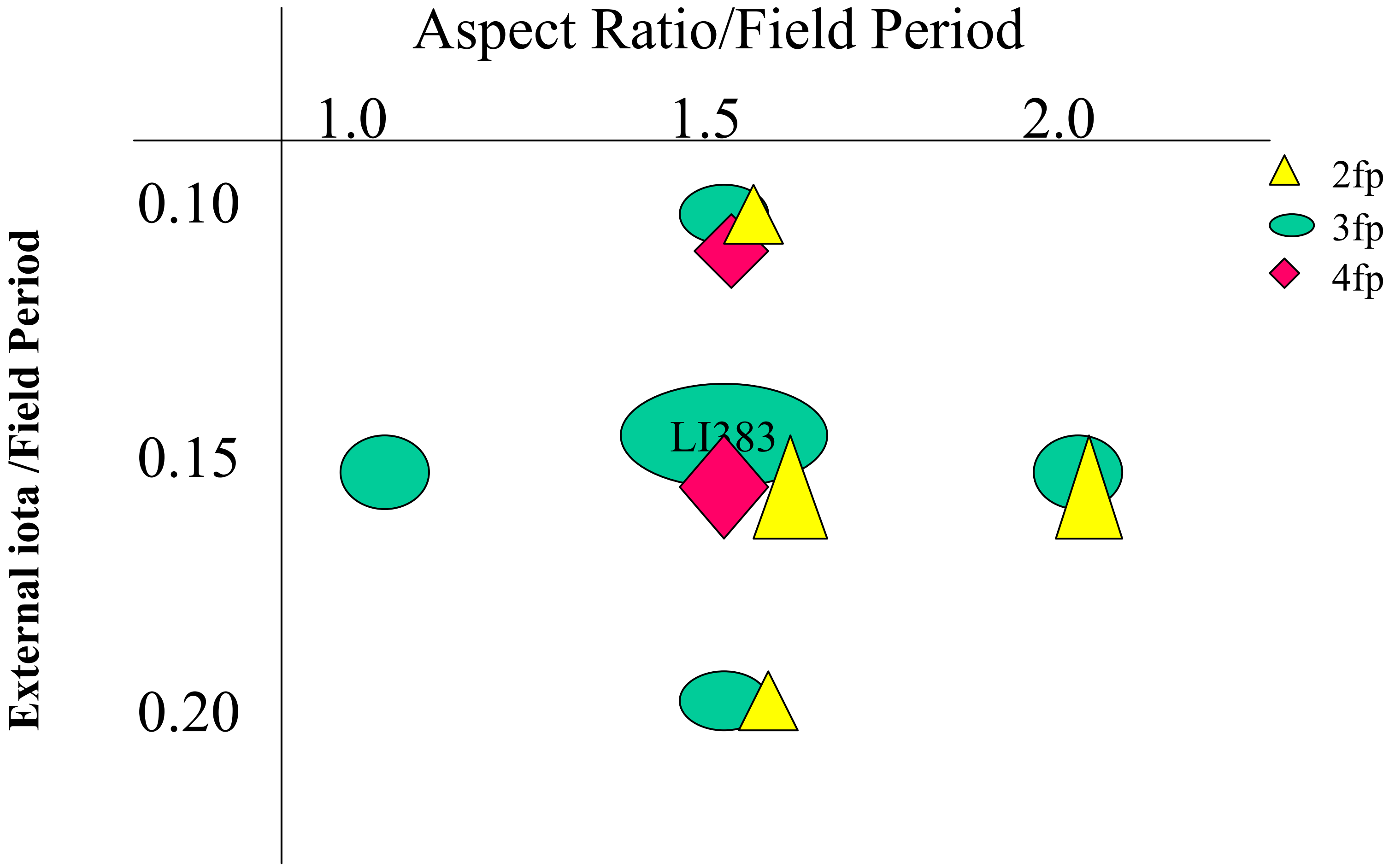
Conductor current density and maximum field intensity for modular coil #3, Ip=13 MA.

conductor cross section (m × m)	conductor current density (MA/m^2)	B_{max} (T)
0.2 x 0.2	$3.3 \cdot 10^2$	16.1
0.3 x 0.3	$1.4 \cdot 10^2$	11.6
0.4 x 0.4	$8.1 \cdot 10^1$	9.7
0.5 x 0.5	$5.2 \cdot 10^1$	8.8
0.6 x 0.6	$3.6 \cdot 10^1$	8.2

The Search for Better Reactor Configurations Is Continuing.

- Optimization space broadened to include wider ranges of external rotational transforms and number of field periods.
  - Effects on plasma shaping (with same QA and stability constraints)
  - Iota dependence of particle confinement
  - Also under way is the effort to simplify shaping – hopefully will lead to simpler coils
- Efforts started to systematically study underlying magnetic field structures and lost particle trajectories.
  - To uncover features configurations with “good” α confinement must possess

The broadened configuration optimization space now encompasses wider ranges of iota and field periods.

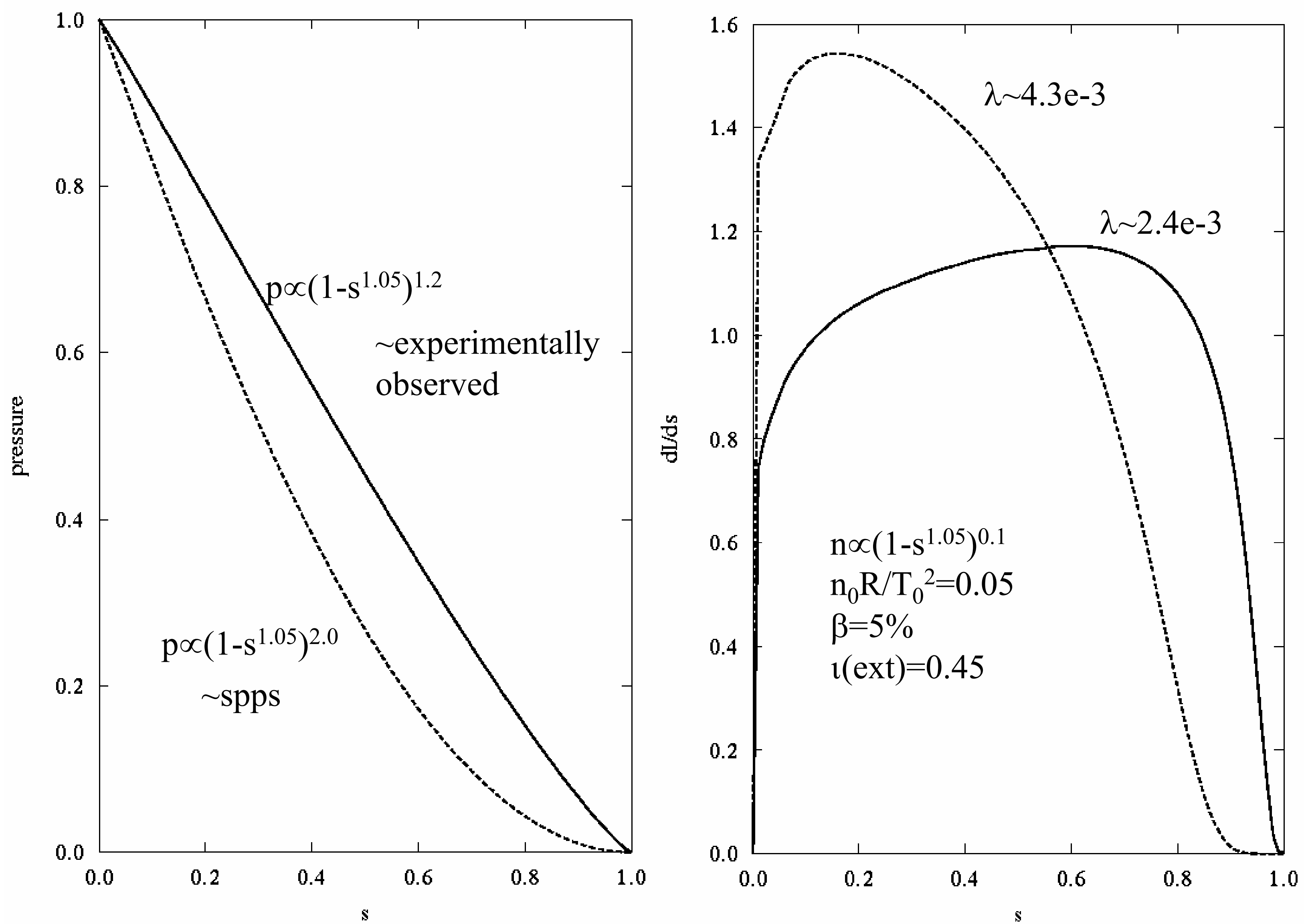


Pressure Profiles and Bootstrap Current Density — Additional Parameters To Be Considered in Configuration Optimization

- Re-activated a bootstrap code that allows input of external rotational transform and a fully three-dimensional description of the plasma field.
  - Calculation encompasses all collisionality regimes.
  - Previously benchmarked, but needs more work.
  - Only axi-symmetric fields are used in bootstrap calculations.

- Effects of a wide range of pressure profiles have been examined for N3AEC (A=4.4, 3 field-periods, ι_{ext}~0.45) at 5% beta.
  - Experimental, SPPS, extremely broad.
  - Flat and not-so-flat density profiles.
  - Various central collionalities.

Effects of pressure and bootstrap current profiles used in equilibrium calculations on the n=1 kink stability in N3AEC-like configuration.



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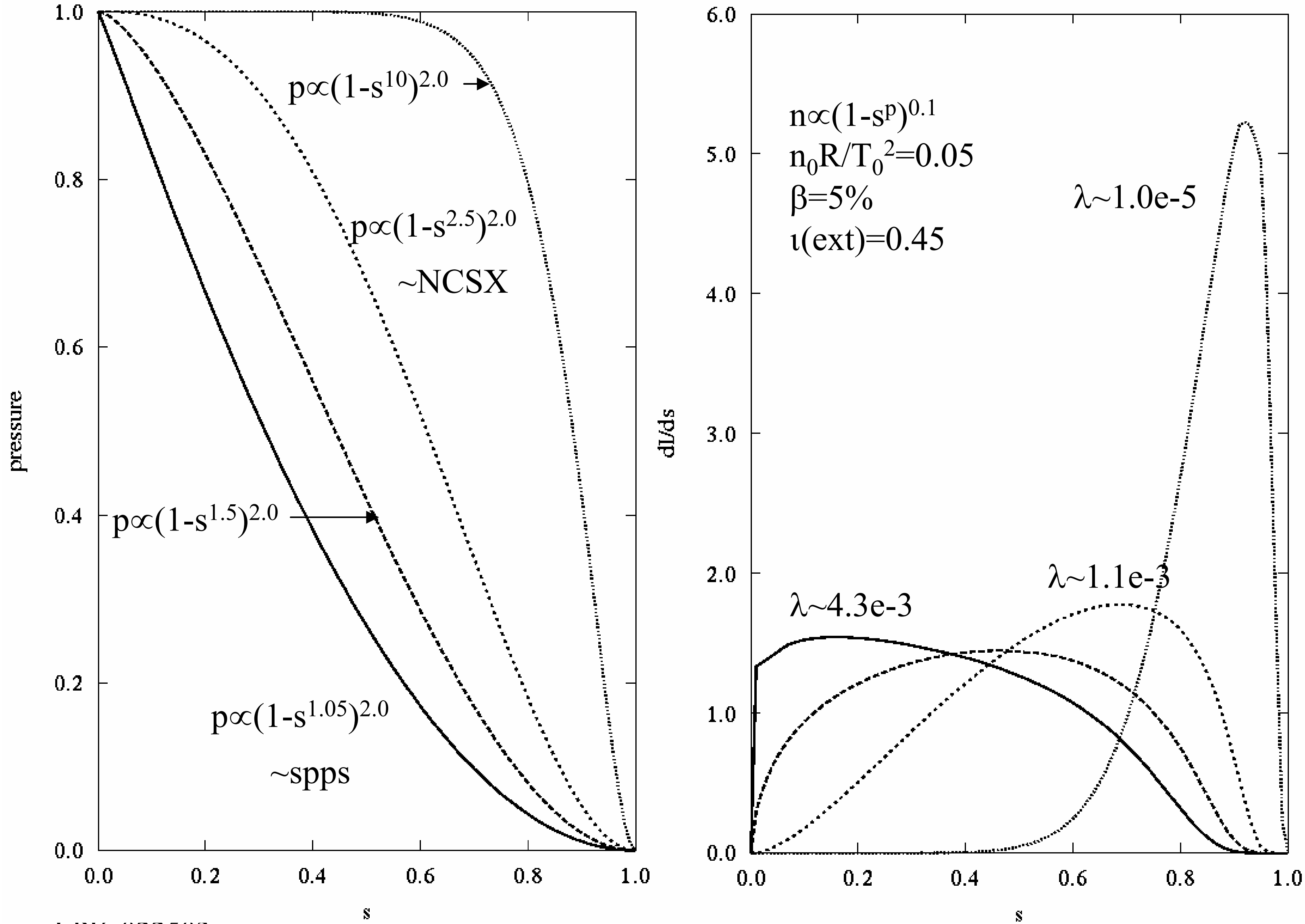

Concluding Remarks

- In configuration optimization, we have been following the path laid out in January project meeting. We expect to continue marching on in the same direction in the next few months. Lots of data need to be analyzed and much more developments need to be carried out.

- We have provided an initial cut of a CS reactor. We expect to iterate on the plasma and coil parameters as the design exercise moves on in the coming months.