

New Results for Plasma and Coil Configuration Studies

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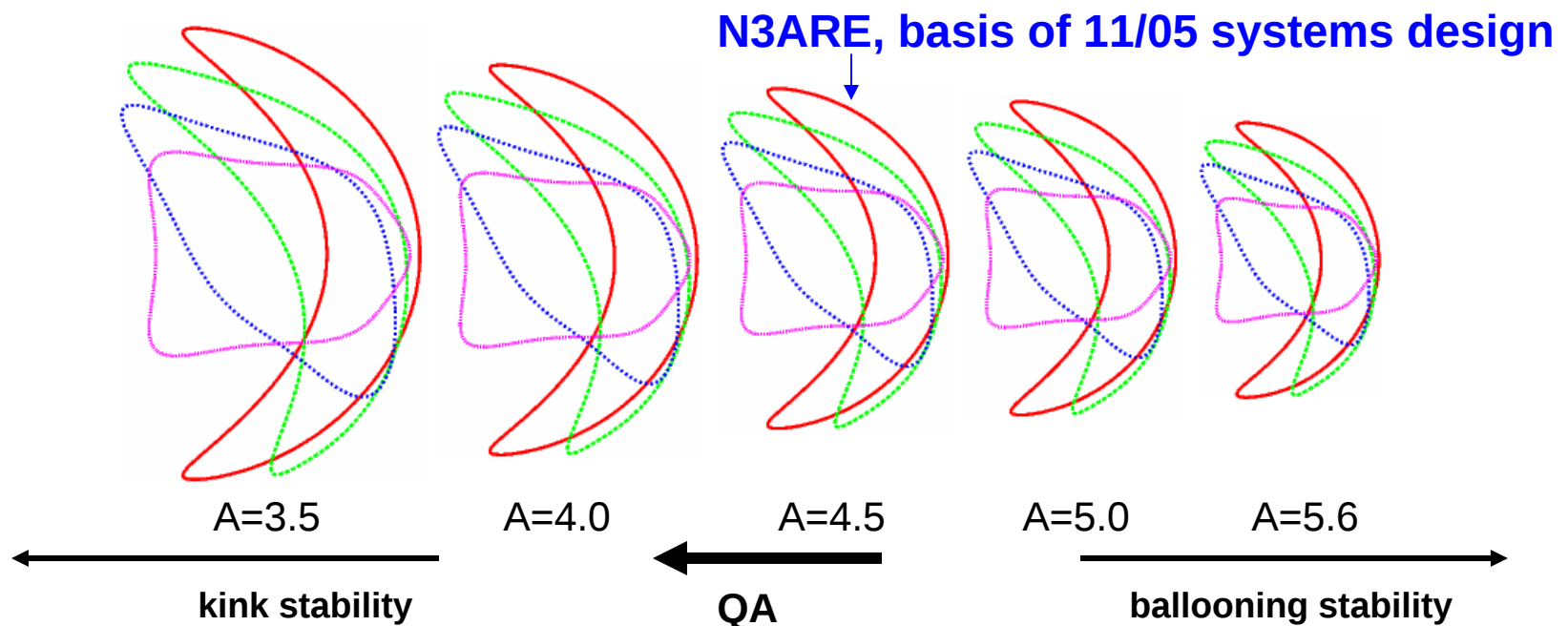
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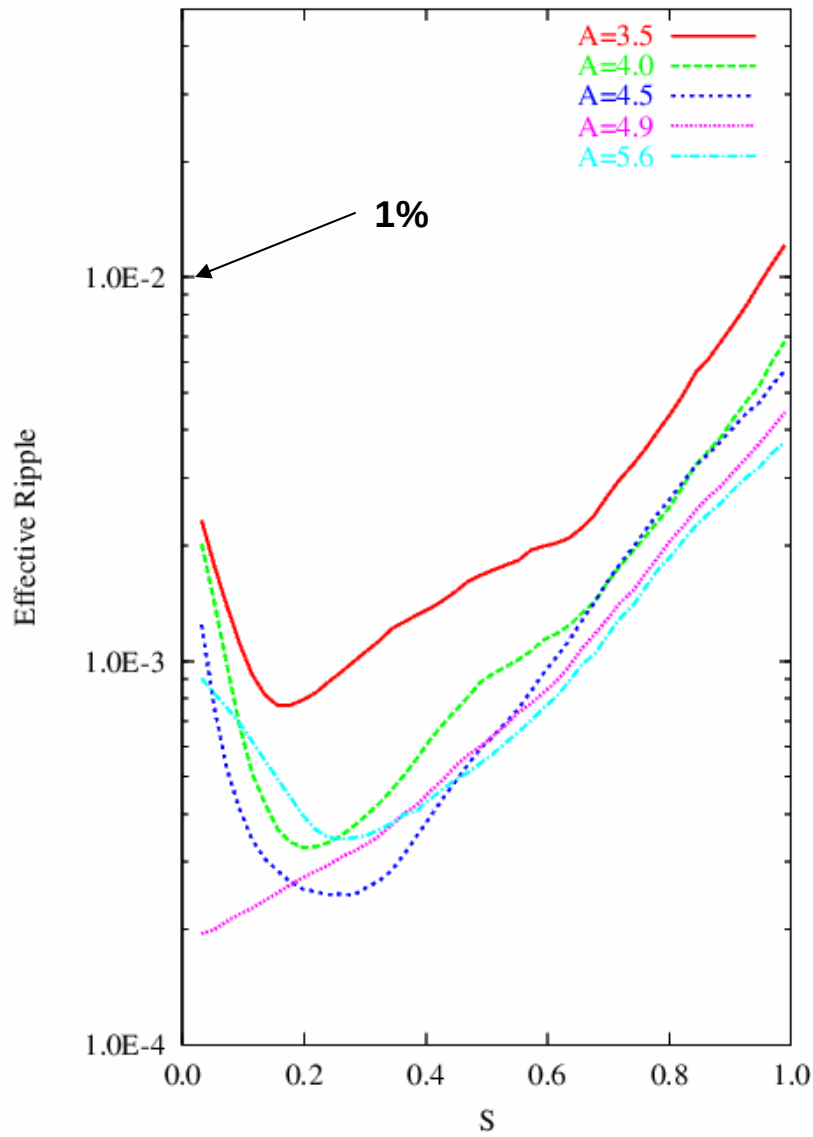
Topics

- **Surface quality of the 3-field period configuration N3ARE.**
- **Size, B, and collisionality scaling of α loss.**
- **Initial physics analysis using density and temperature profiles consistent with the systems code for the 11/05 reference design.**

Configurations of the NCSX-class, for example, N3ARE, with a small but non-negligible mirror component introduced in the magnetic spectrum, have “all around” good physics properties desirable for power producing reactors.

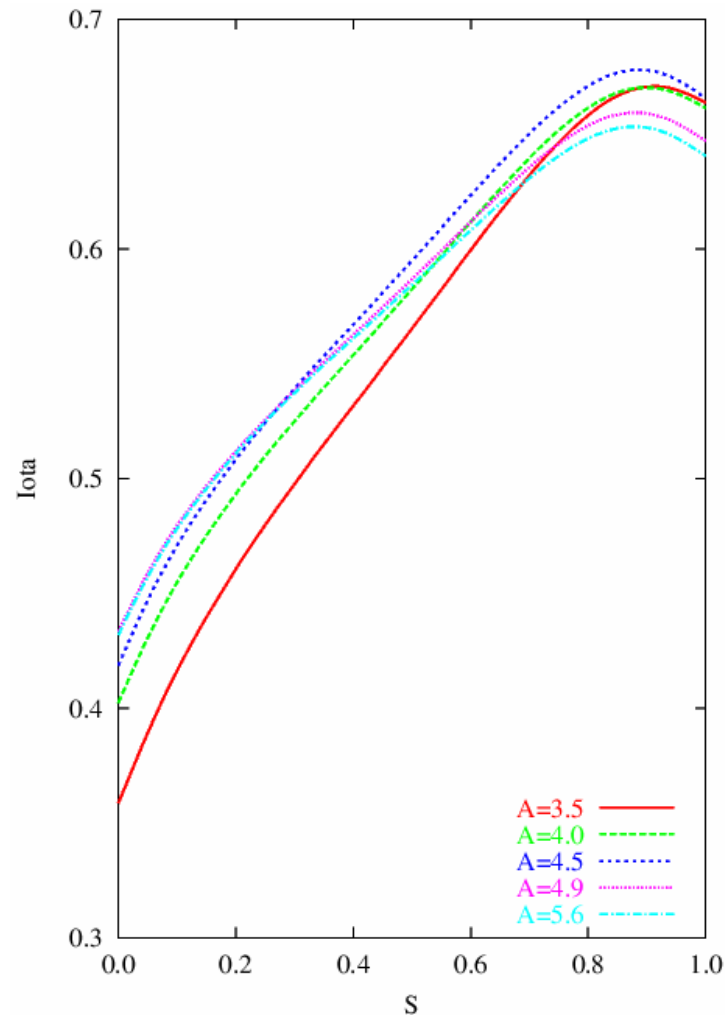
- Studies indicate that the plasma aspect ratio ~ 4 -5 is a good choice for the three field-period system from the viewpoint of configuration optimization.



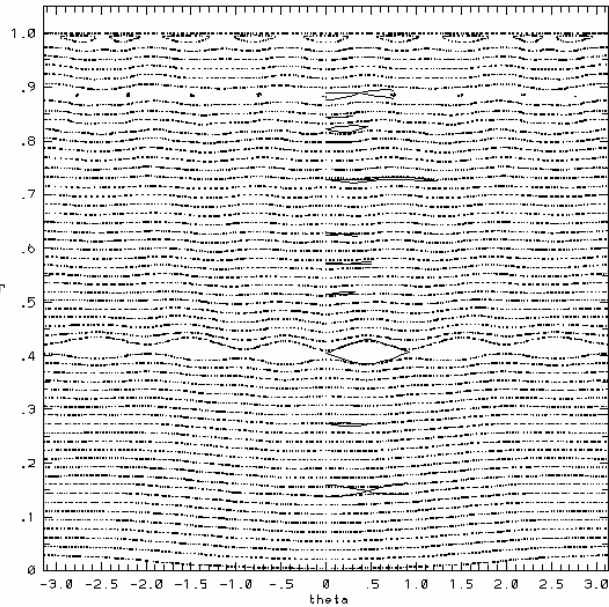


Very low effective ripples (ε -eff) in this class of configurations are found, particularly for $A > 4$, while they maintain favorable MHD stability properties (external kinks, ballooning and Mercier). For example, N3ARE has been “calculated” to be stable at 4-5% β .

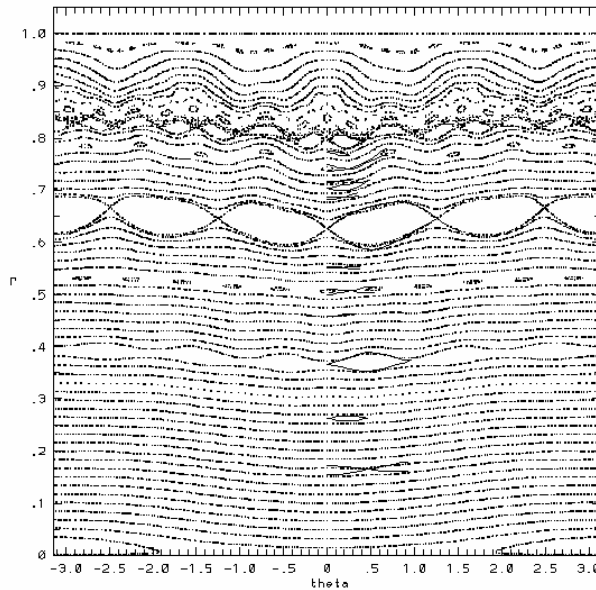
The rotational transform profile of these configurations is similar to that of NCSX at the same β when the same pressure and current profiles are assumed. The quality of equilibrium flux surfaces is expected to be similar as well.



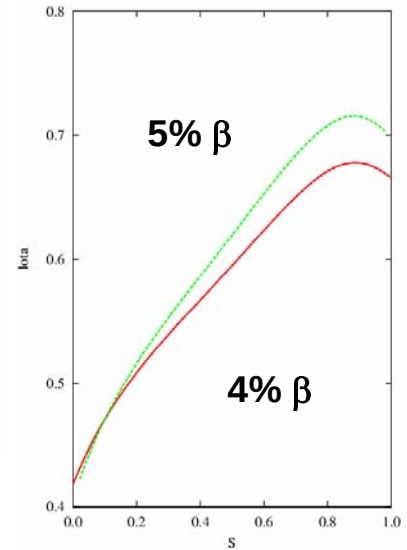
Here we show results of PIES equilibrium calculations (fixed boundary) for N3ARE, illustrating the quality of flux surfaces both at 4 and 5% β using the NCSX pressure and current profiles.



4% β



5% β

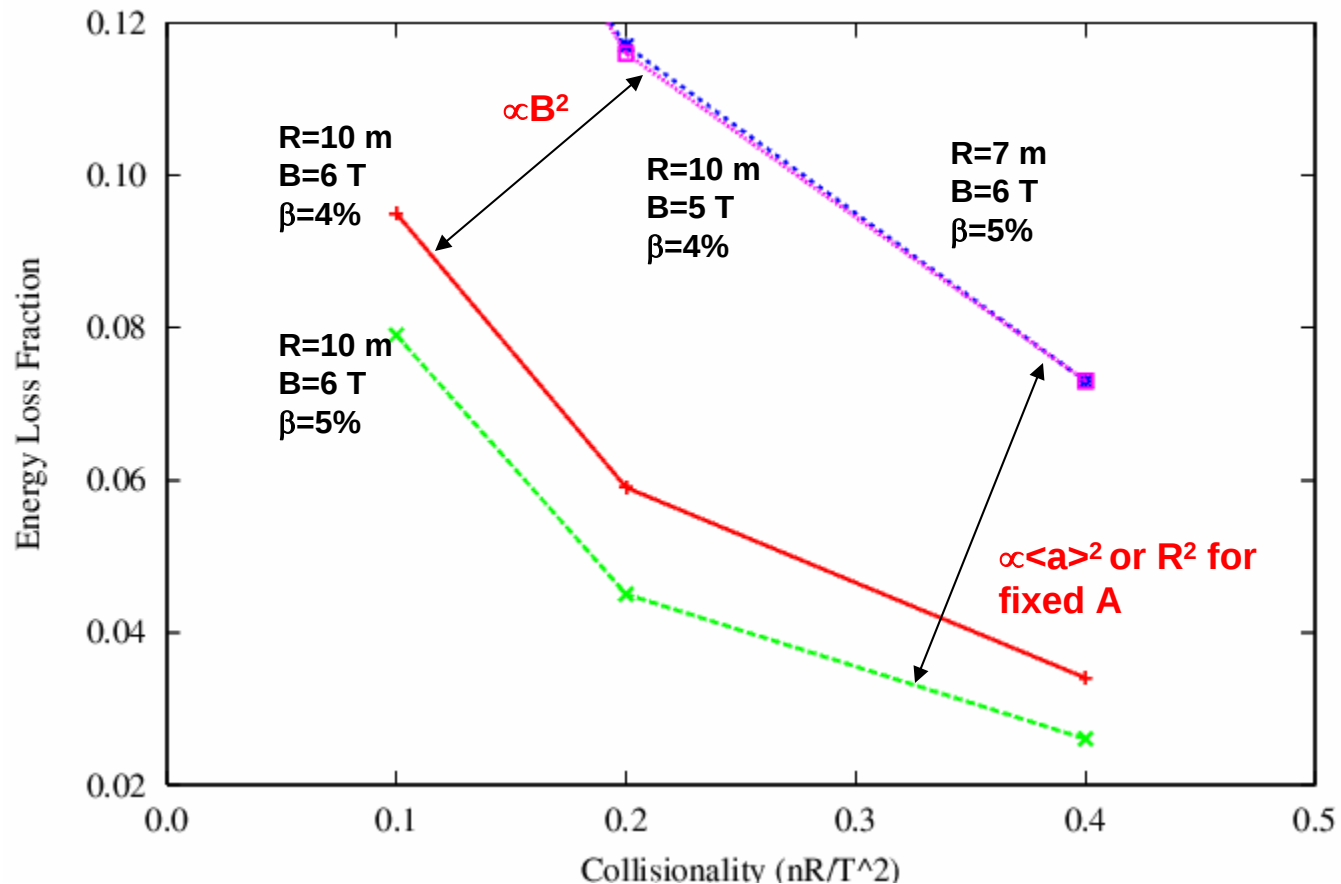


Collisionality, β and R scaling of α loss

- The loss of α depends on equilibrium characteristics of a configuration and also on some other parameters . It tends to be smaller if the field is higher and/or the overall collisionality with the background ions is larger.
- The collisionality can be increased with higher n and lower T . The 11/05 design point at 5% β has $n_0 R/T_0^2 \sim 0.4$ and $B_0 \sim 6$ T, limited by the $B_{\max}$ allowed in the coil.
- Previous calculations of α loss have always been normalized to a volume of 1000 m^3 , or $R \sim 10$ m for $A=4.5$ configurations. The 11/05 design point has a major radius $R \sim 7$ m, resulting in the increased loss compared to our previous reference calculations.
- Because of the large $n_0 R/T_0^2$ and good QA at higher β , the α energy loss of the 11/05 design is still $< 10\%$.

Calculations of α energy loss for N3ARE show strong v , B and R dependence.

Note: $(1-s)^8$ birth distribution, parabolic distribution for background ions.



Initial results of calculations using density and current profiles consistent with those in the systems code for N3ARE at 5% β (without re-optimization) indicate that QA, MHD stability and surface quality of the configuration remain similar to those calculated with the assumed NCSX profiles.

- The 11/05 design point uses

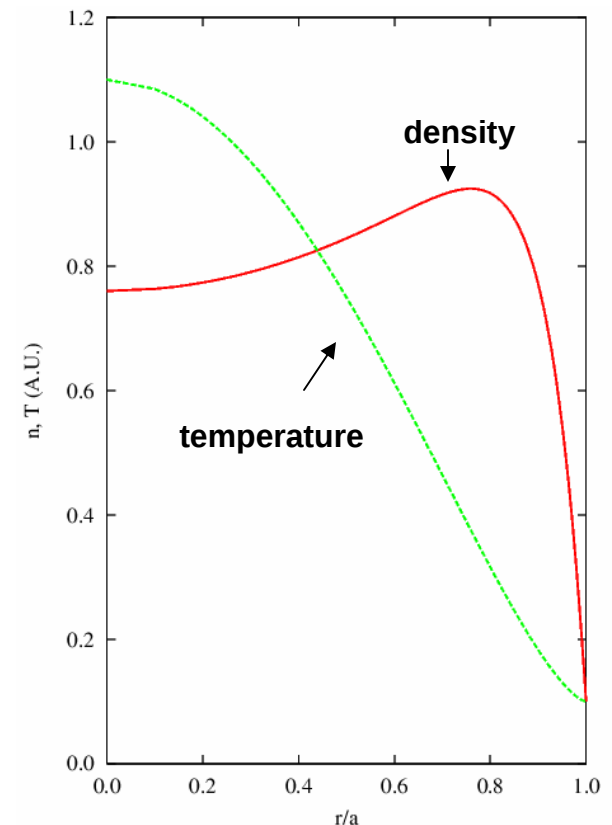
$$n(x)/n(0) = (1 - x^{y_n}) \cdot \{f + (1 - f)x^2\} + n(\text{edge})/n(0),$$

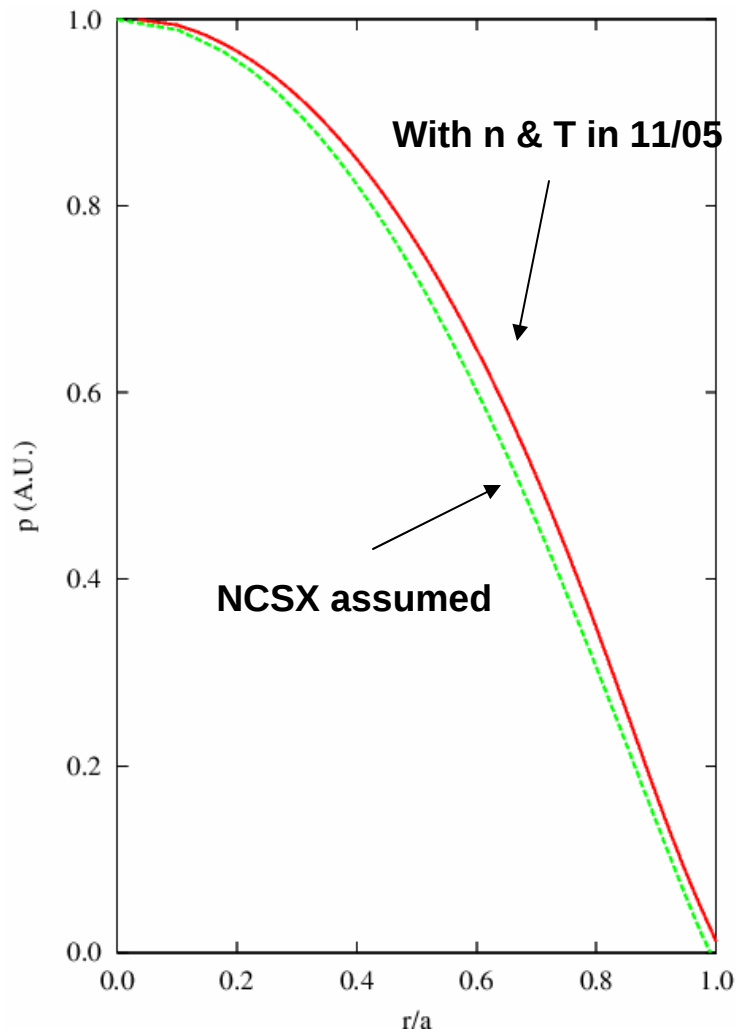
$$T(x)/T(0) = (1 - 0.999999x^{y_t})^{x_t} + T(\text{edge})/T(0)$$

$$y_n = 12, f = 0.66, y_t = 2, x_t = 1.5,$$

$$n(\text{edge})/n(0) = 0.1, T(\text{edge})/T(0) = 0.1.$$

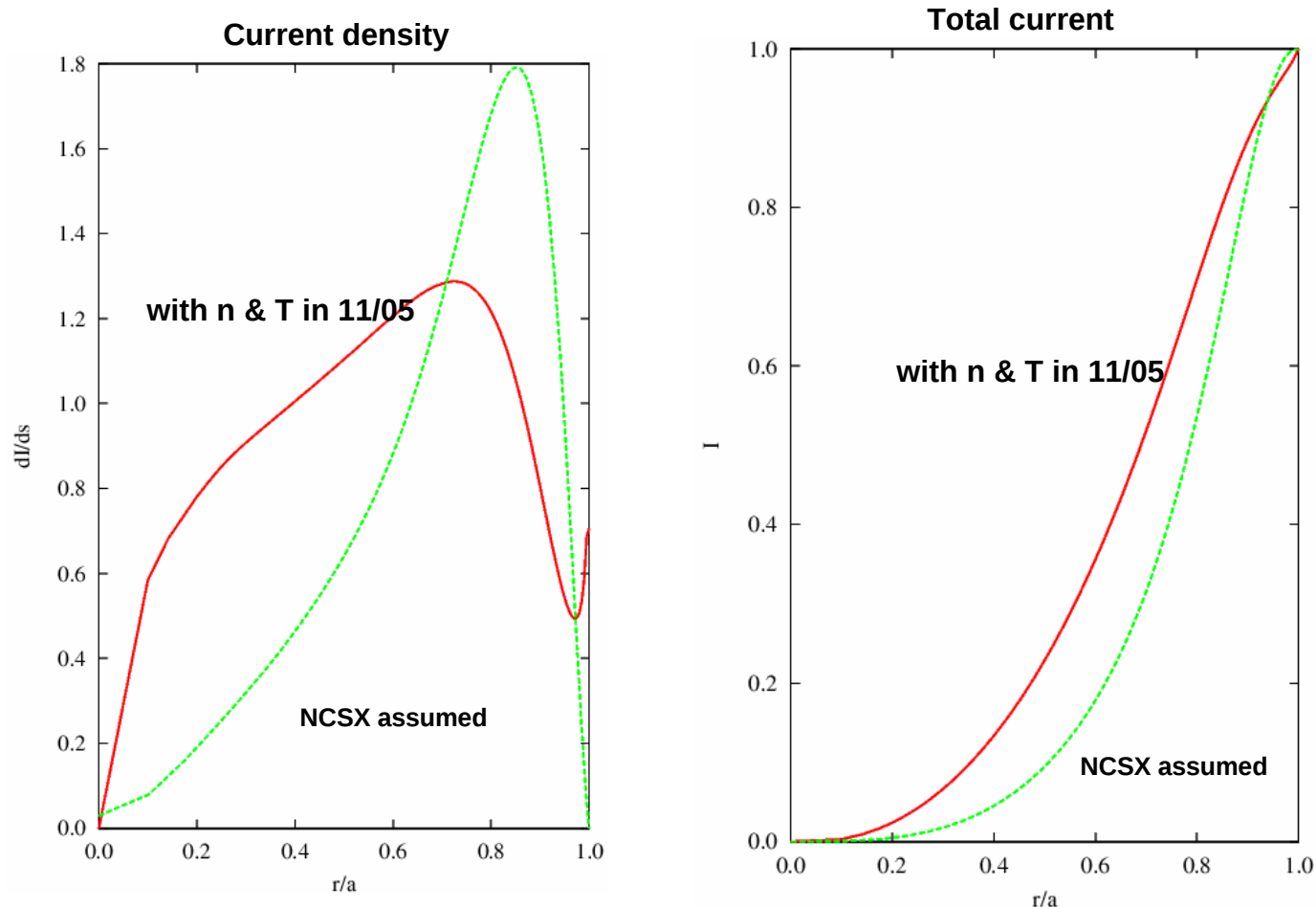
- Also,
 $\langle n \rangle = 4.59 \cdot 10^{20} \text{ m}^{-3}$, $R = 6.93 \text{ m}$, $B = 6.28 \text{ T}$ and $\beta = 5\%$.
 $\Rightarrow n(0) \sim 5.8 \cdot 10^{20} \text{ m}^{-3}$, $T(0) \sim 10.2 \text{ keV}$

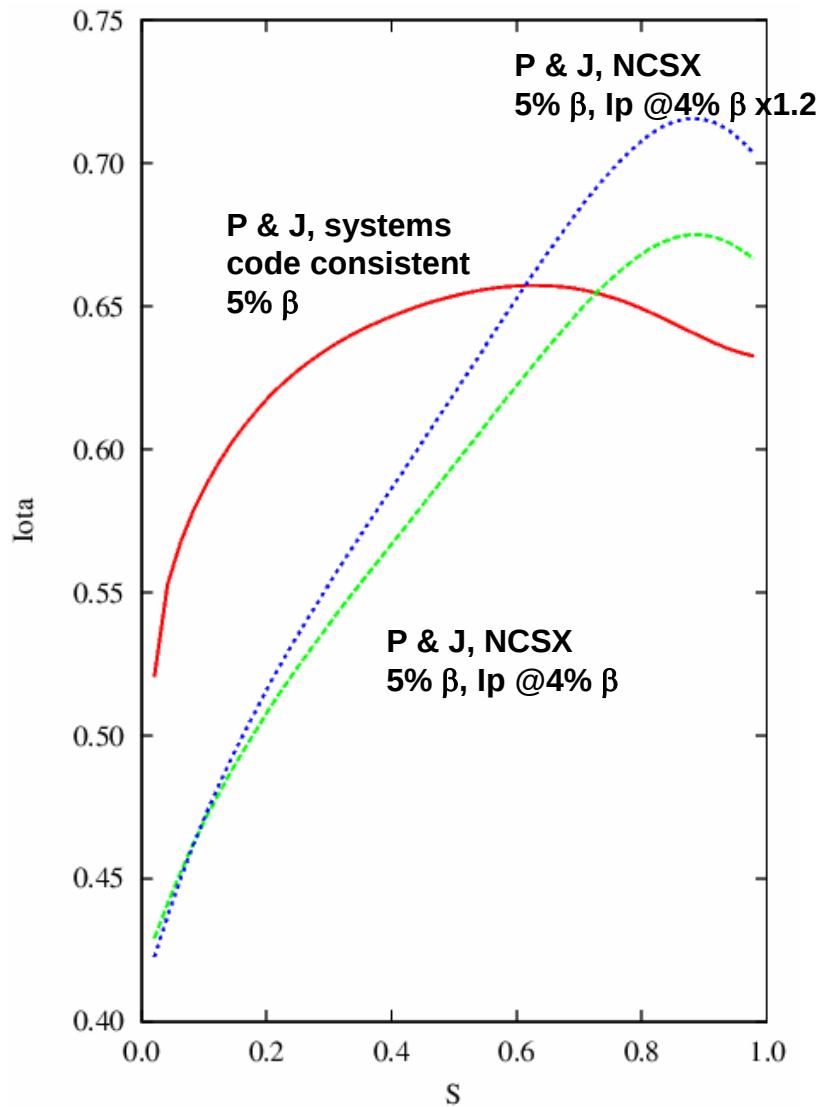




The resulting pressure profile using n and T which are consistent with the systems code is a little broader than the one used in our previous calculations.

The bootstrap current profile, calculated by JBSC^{*†}, is also broader with the peak shifted slightly inward. The result is preliminary. More convergence studies are needed.



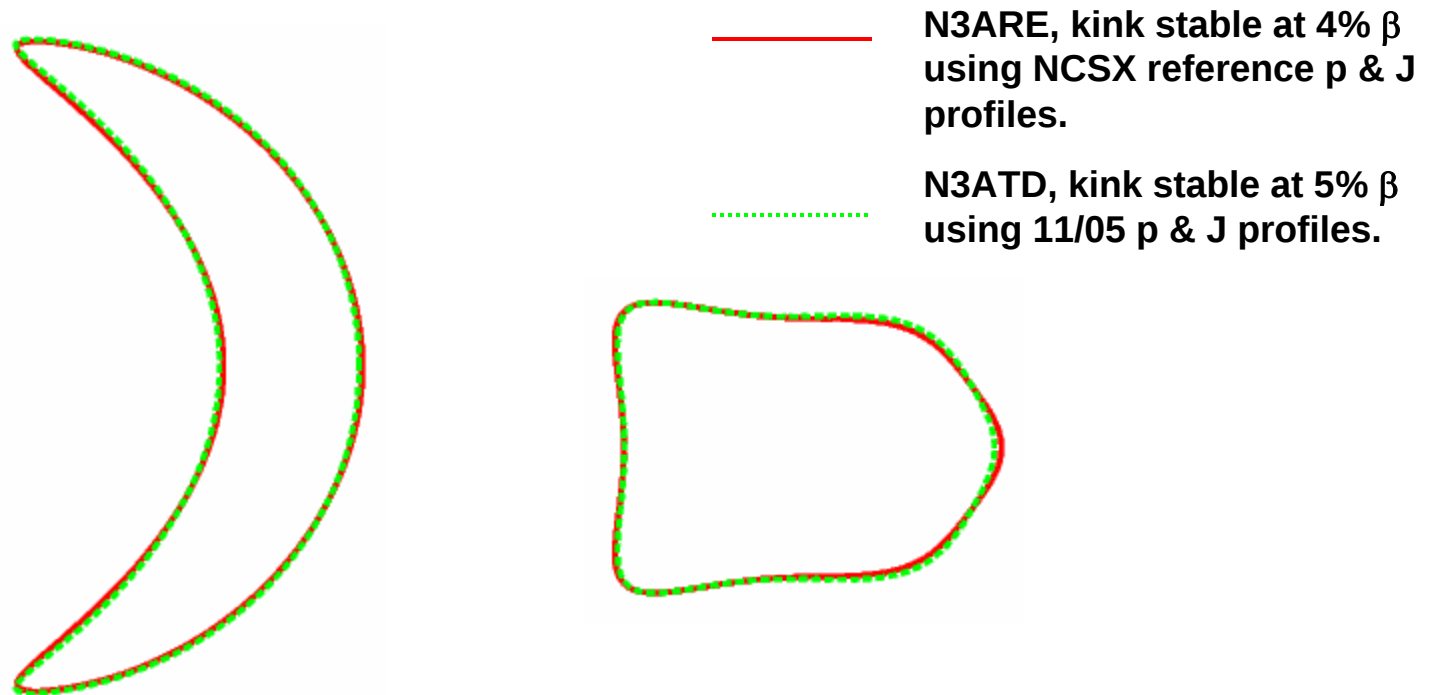


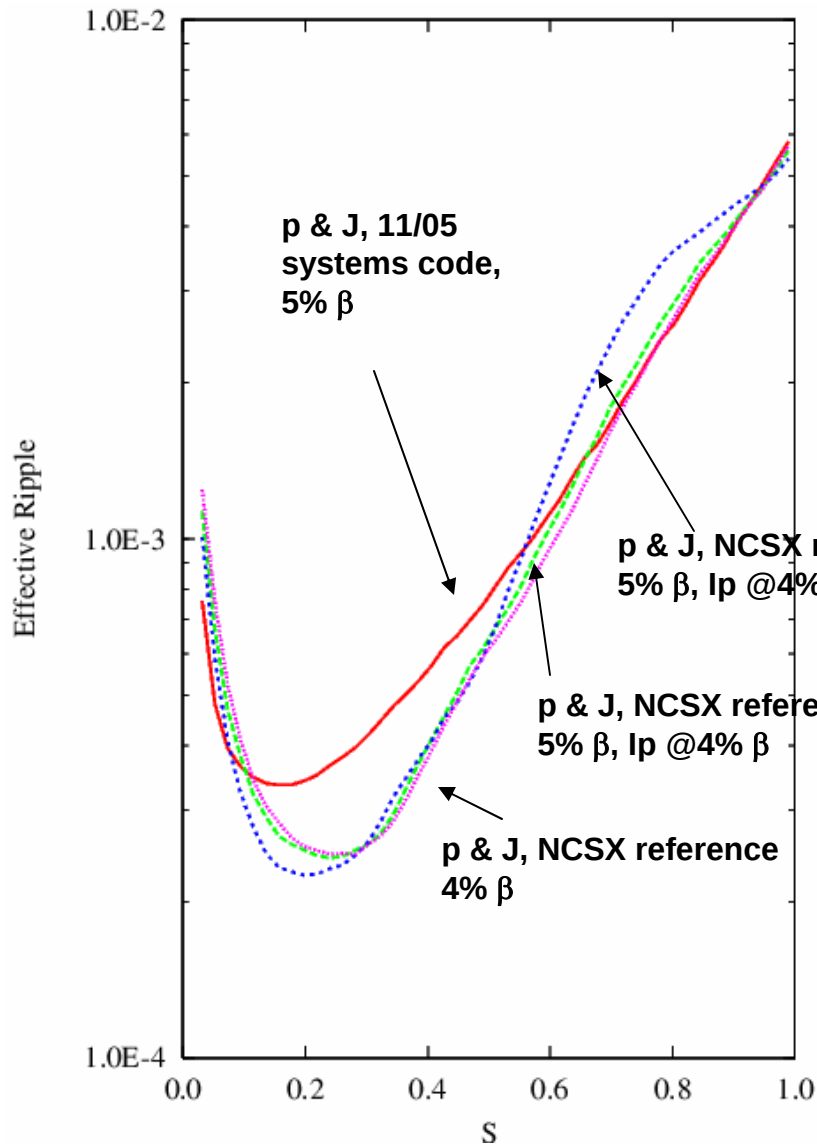
The rotational transform profile is quite different from that based on the NCSX reference profiles with the magnetic shear weakened over a large region.

Because of the larger nR/T^2 of the new profiles, the magnitude of the bootstrap current will be smaller. At 5% β it is calculated to be about the same as the level at 4% β when the NCSX reference profiles are used.

The MHD stability properties, such as the infinite- n ballooning and external kink modes, calculated by numerical codes, are not made worse, however.

And, a small modification of the plasma shape will make the configuration kink stable at 5% β using profiles consistent with the 11/05 design point from the systems code (without degrading QA).

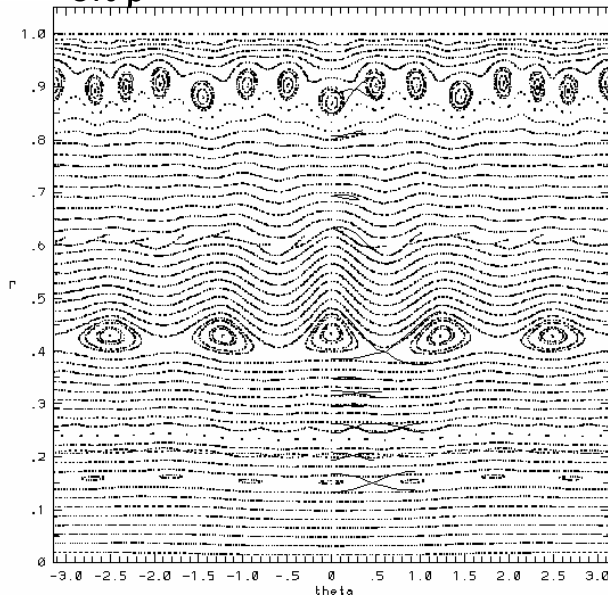




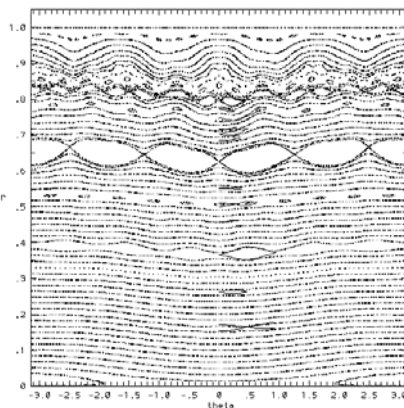
There is no significant change in the effective ripple (the epsilon-effective) due to changes in the pressure and current profiles. The difference in the loss of α is also statistically insignificant. Thus, the overall transport property is little changed.

PIES calculations (fixed boundary) indicate that the quality of the flux surfaces using the new profiles are comparable to that using the NCSX reference profiles.

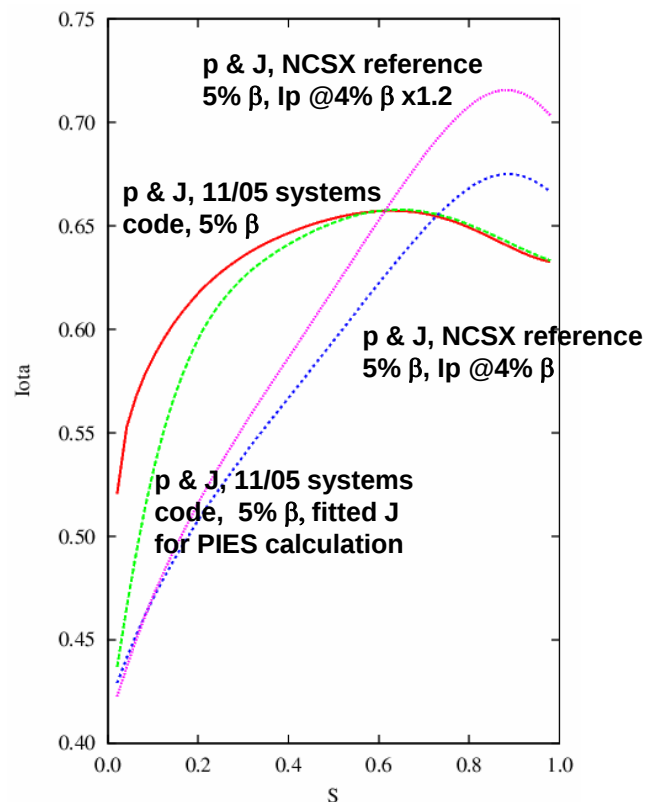
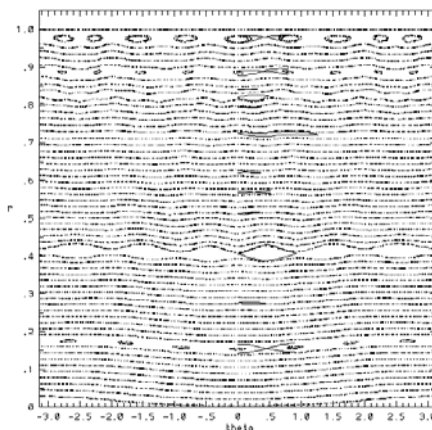
**p & J, systems code consistent
5% β**



**p & J, NCSX reference
5% β , I_p @4% β x1.2**



**p & J, NCSX reference
5% β , I_p @4% β**



Summary and Conclusions

- **The initial analysis indicates that, when the pressure and current profiles consistent with the systems code are used, the physics properties of the 3 field-period configuration, N3ARE, are not significantly different from those reported previously. The previous results were based on the assumed profiles of NCSX.**
- **The confinement of α particles in configurations which are designed to minimize the prompt loss depends strongly on the device size. To maintain the energy loss $<10\%$ in our configuration, high field and high particle density consistent with $B_{\max}$ allowable in the coil and the density limit, if there is one, are desirable. Also, reducing plasma aspect ratio may be helpful.**

Work Plans

- **Continue to examine physics aspects of the designs from the systems code. Additionally, expand the study to include the $A=4$ configuration with three periods since there may be advantages to lower the aspect ratio.**
- **Optimize internal transforms by varying p and J profiles.**
- **Continue the effort of using biased magnetic spectrum to improve configurations.**
 - **Add iota constraint for surface quality improvement**
 - **Study coil complexity and plasma aspect ratio**