

Effect of Magnetic Perturbations Produced by a Divertor Control Coil on the Flux Surfaces in the W7AS Stellarator

Presented by Allan Reiman¹

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Monticello¹, and the W7-AS Team²

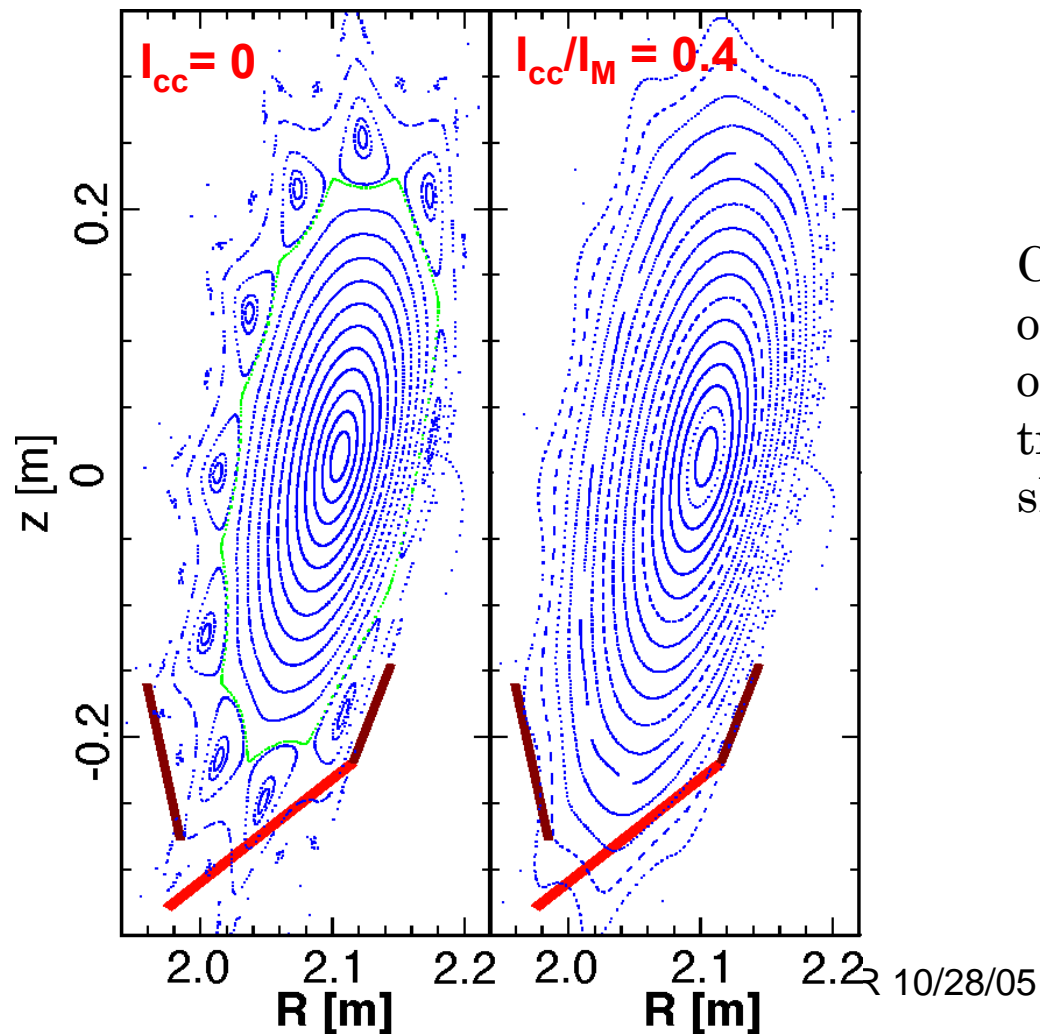
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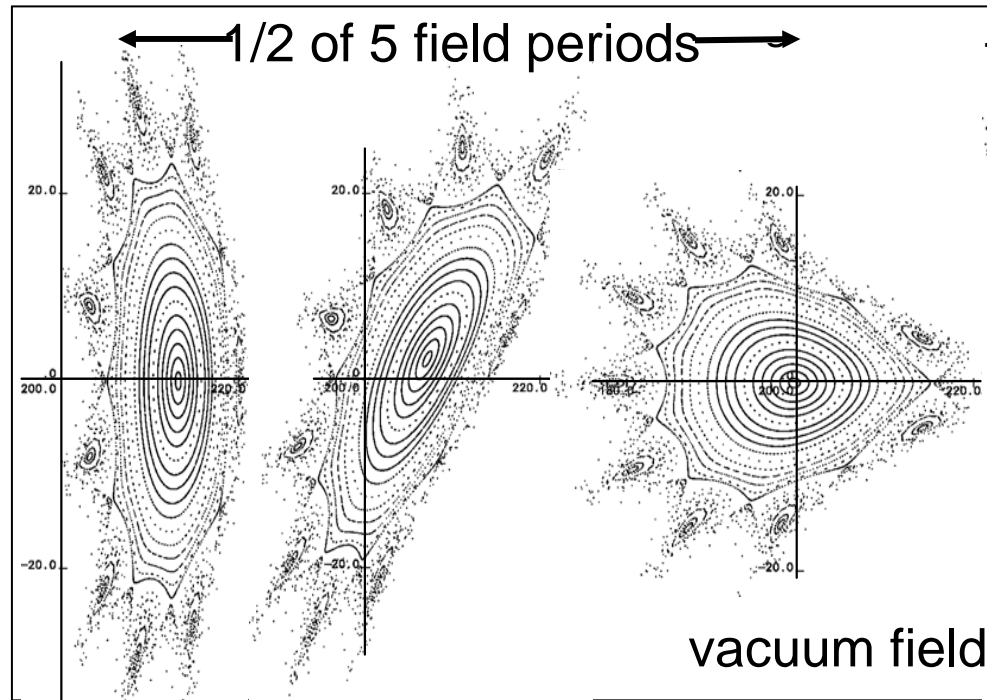
Divertor control coil on W7AS stellarator designed to control resonant magnetic field near plasma edge.

Calculated Vacuum Surfaces

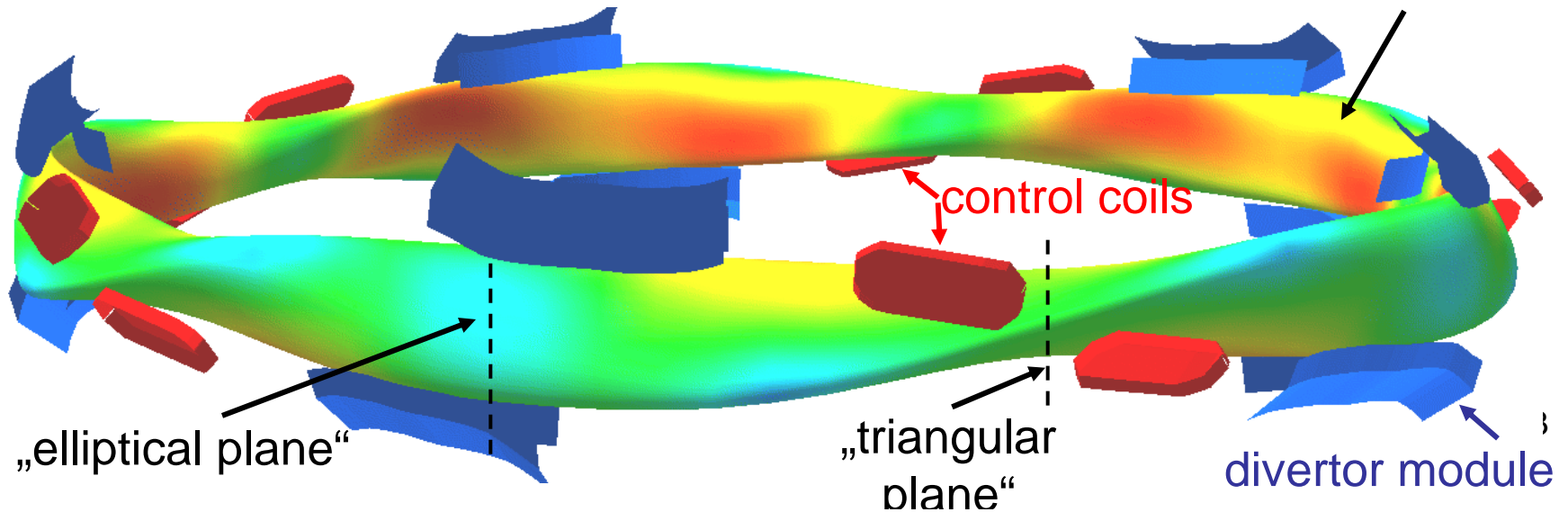


Coil calculated to have little effect on rotational transform ($\equiv \iota \equiv 1/q$), or on neoclassical ripple transport, or on magnetic axis shift.

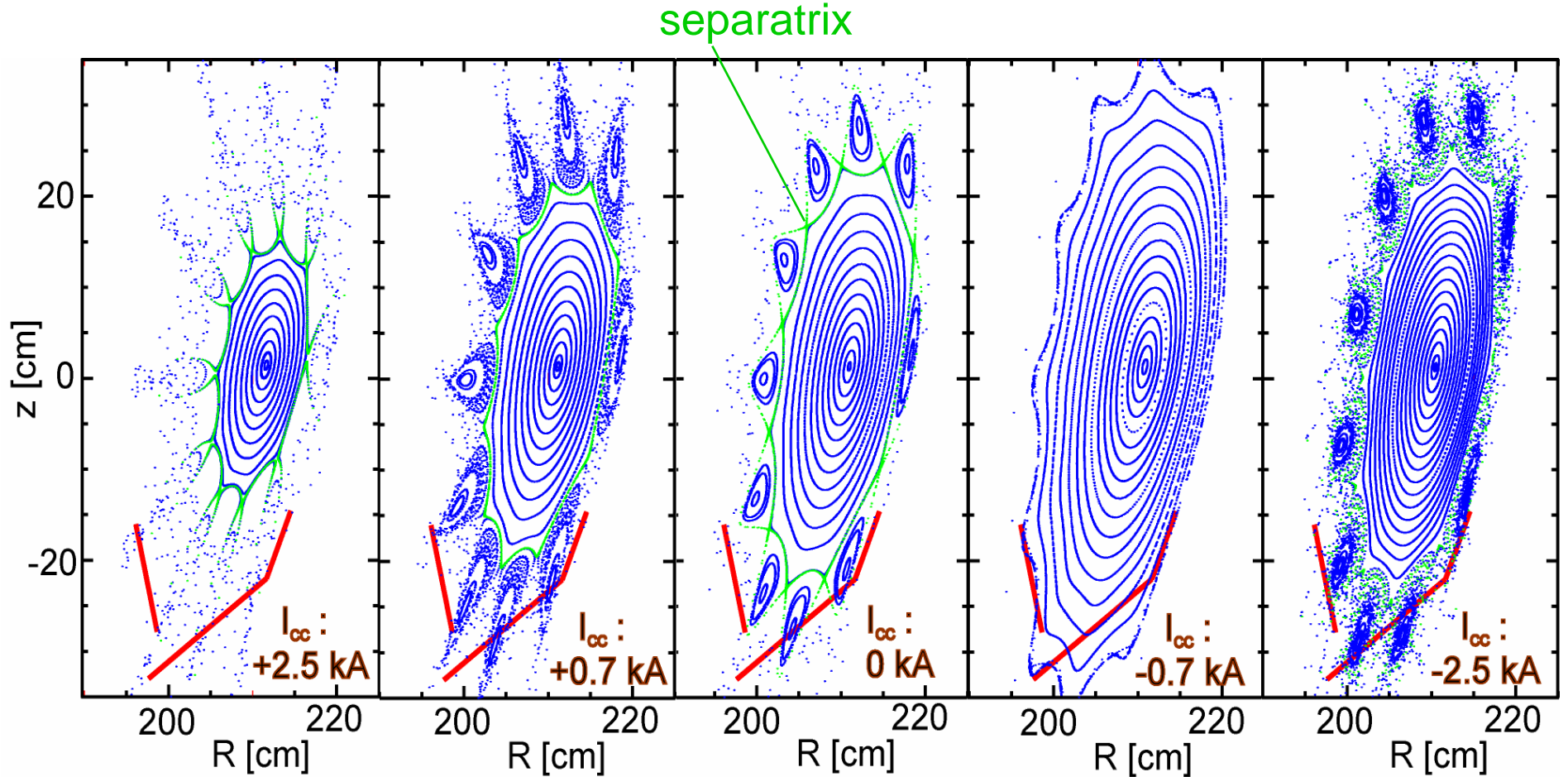
Magnetic Configuration, In-Vessel Comp.



|B| (color) on magnetic surface



Effect of Control Coils (Vacuum Configuration $iota \approx 1/2$)



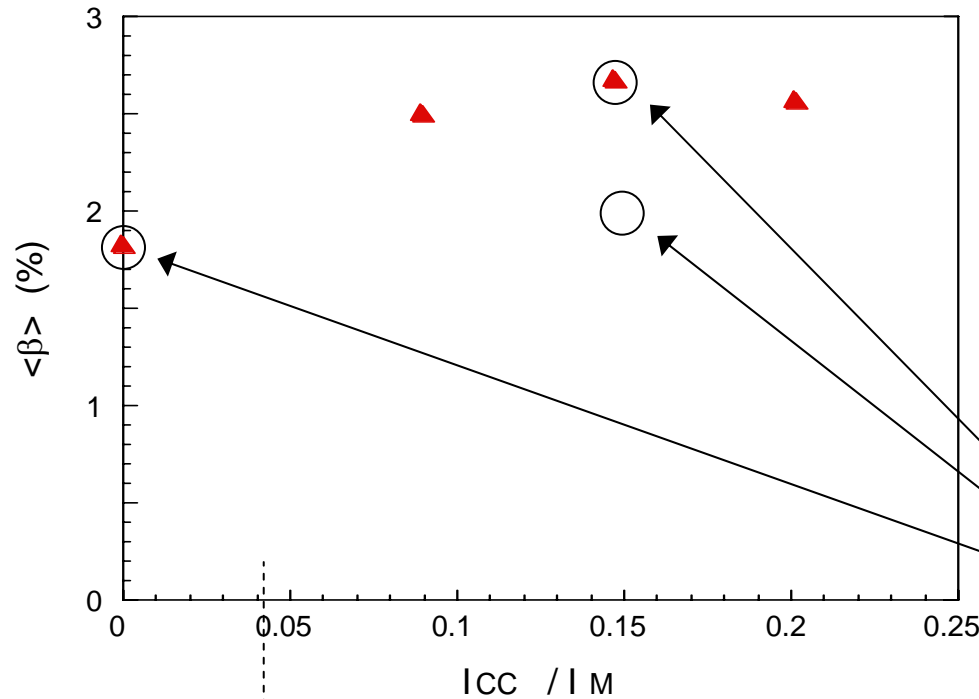
← „Divertor-Configurations“

AHR 10/28/05

→ „High- β -Configurations“
(Divertor used as Limiters)

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The control coil substantially affects the achievable β on W7AS.



Variation of peak- $\langle \beta \rangle$ versus the divertor control-coil current I_{CC} normalized by the modular coil current, for $B=1.25$ T, $P_{NB} = 2.8$ MW absorbed and $t_{vac} = 0.44$.

PIES code run for these parameters.

Island width zero for vacuum field.

Vacuum island width does not provide useful guide for choice of optimal I_{cc} .

PIES code has been modified to allow specification of experimentally determined pressure profile.

- PIES code solves 3D MHD equilibrium equation using general representation of magnetic field.
Can handle islands and stochastic regions.
- Initial implementation of code assumed flat pressure and current profiles in islands and stochastic regions.
- For modeling W7AS experimental data, code modified to allow specification of pressure profile in edge stochastic region.
Finite pressure gradient reasonable when particle mean free paths \ll field line connection length to wall.

Pfirsch-Schlüter current:

$$\mathbf{j} \equiv \mathbf{j}_{\perp} + \mu \mathbf{B}$$

$$\mathbf{j}_{\perp} \times \mathbf{B} = \nabla p \Rightarrow \mathbf{j}_{\perp} = \mathbf{B} \times \nabla p / B^2$$

$$\nabla \cdot \mathbf{j} = 0 \Rightarrow \mathbf{B} \cdot \nabla \mu = -\nabla \cdot \mathbf{j}_{\perp}$$

Pfirsch-Schlüter Current (continued)

On good surfaces, magnetic coordinates give:

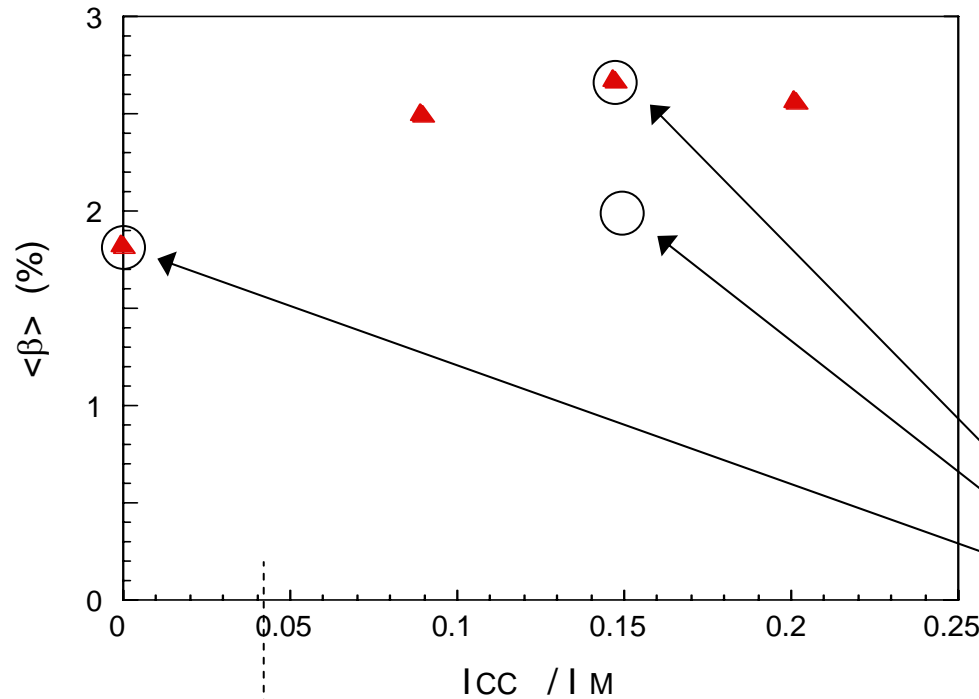
$$\mu_{nm} \propto \frac{dp}{d\psi_t} \left(\frac{1}{B^\phi} \right)_{nm}$$

- Crude model: Scale $\mu_{nm} \propto dp / d\psi_t$
- Improved model being incorporated:
 - o Fourier decompose along field line.
 - o Phase mixing causes integrals to vanish for wavelengths \gg autocorrelation length of field line. (A resonance broadening effect.)

W7AS modeling uses experimentally determined profiles

- Optimizer used to construct VMEC equilibrium which provides best fit to experimental data.
- VMEC reconstructed equilibrium used as starting point for PIES calculation. Pressure profile preserved, with no flattening in edge stochastic region.
- Assume zero net current ($\mu_{00} = 0$).

The control coil substantially affects the achievable β on W7AS.



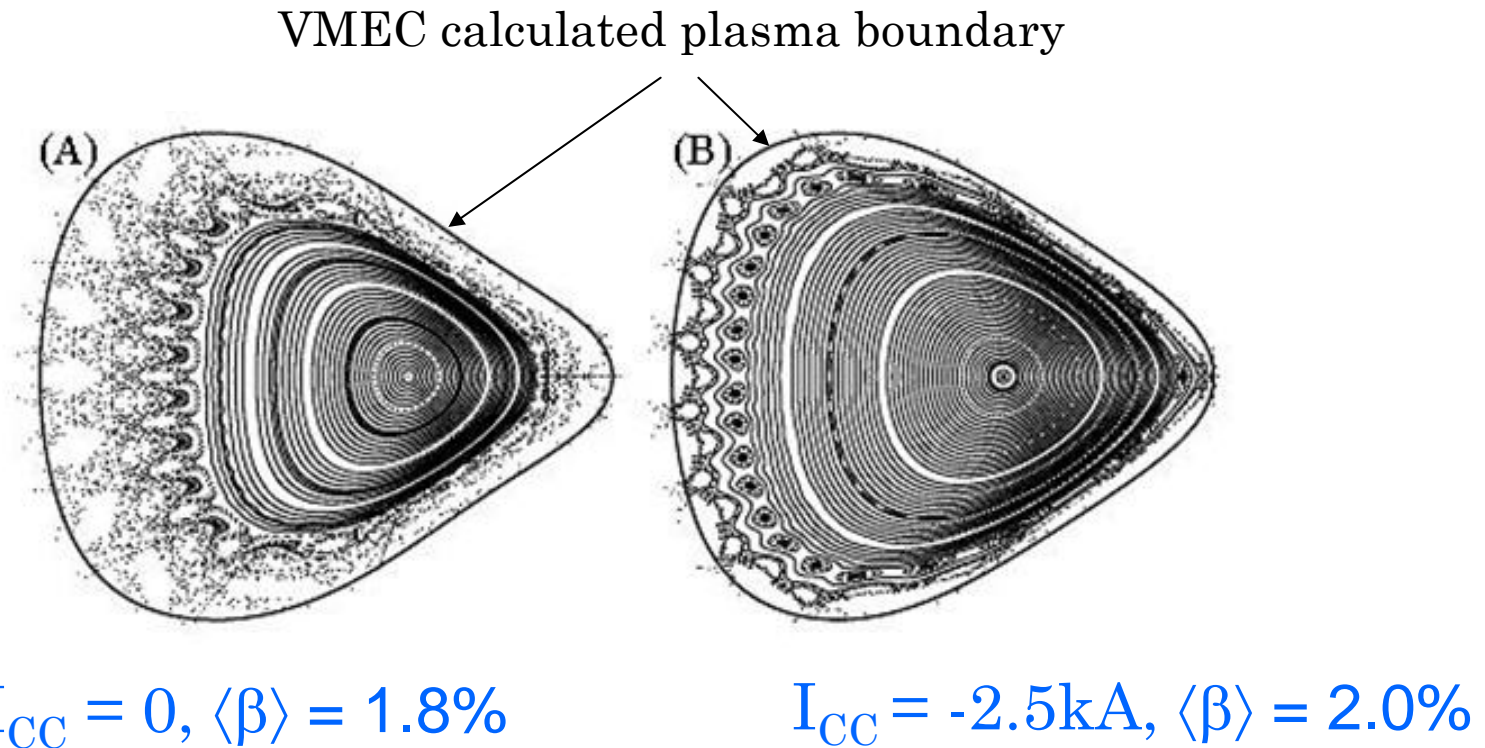
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Island width zero for vacuum field.

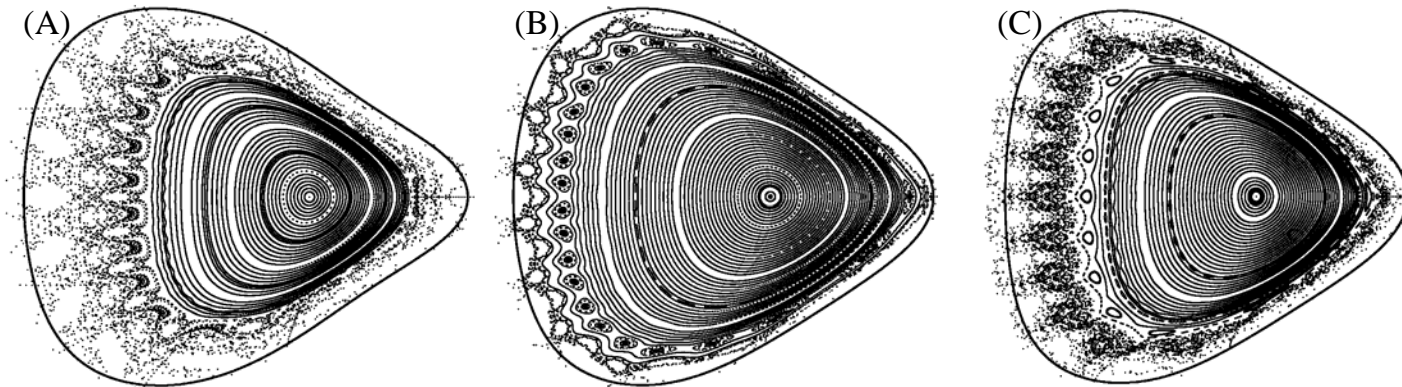
Vacuum island width does not provide useful guide for choice of optimal I_{cc} .

PIES calculations for two different values of control coil current are consistent with observed trend.



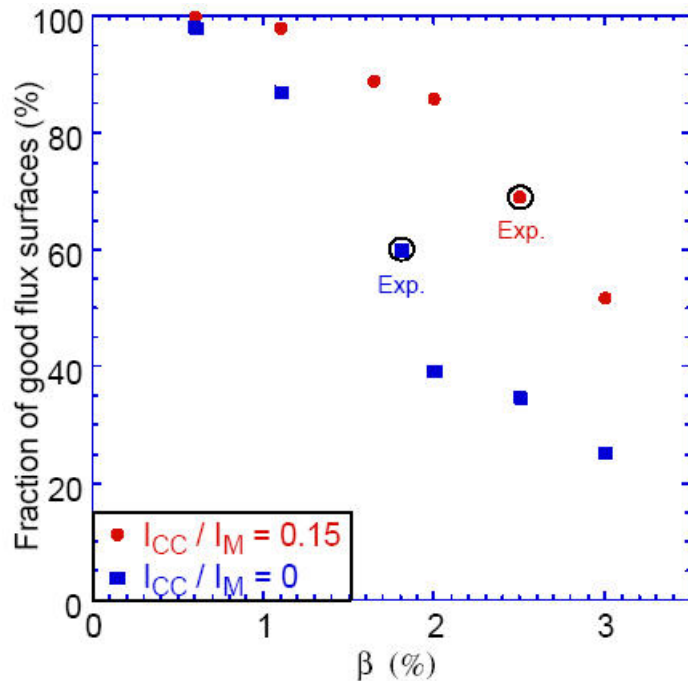
Width of stochastic region larger for $I_{CC} = 0$, even though it has somewhat lower β .

Experimentally achieved β in each case corresponds to loss of about 1/3 of the minor radius.



PIES calculated flux surface topologies at the triangular symmetry plane for: (A) ICC=0 and $\langle\beta\rangle = 1.8\%$, (B) ICC=-2.5kA and $\langle\beta\rangle = 2.0\%$, (C) ICC=-2.5kA and $\langle\beta\rangle = 2.7\%$. In each case, the dark line is the VMEC calculated plasma boundary.

Same trend emerges from PIES β scan for two different values of control coil current.



Fraction of good flux surfaces versus β as predicted by PIES for two different values of the control coil current for the W7AS stellarator. The circles indicate the PIES calculations done for the experimentally achieved value of β .

PIES results sensitive to pressure profile in stochastic region. Stochastic region collapses inward if pressure flattened there.

Summary and Conclusions

- Divertor control coil strongly influences width of stochastic region at edge of W7AS stellarator.
- Control coil designed to influence resonant field near plasma edge, with little effect on ι ($= 1/q$) or on Shafranov shift.
- Effect of control coil on vacuum field does not provide adequate guide to effect at finite β .
- Rule of thumb that assumes that equilibrium β limit corresponds to magnetic axis shift of approximately $\frac{1}{2}$ minor radius does not adequately characterize observations.
- PIES calculations consistent with experimental observations.
 - More detailed comparison to be pursued.
 - Improved model for Pfirsch-Schlüter currents being implemented.