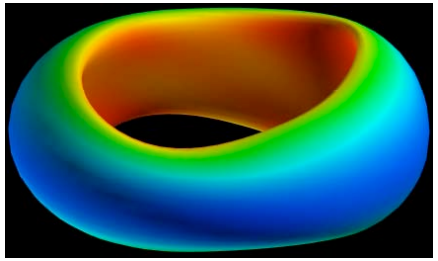
Importance to DEMO of the Quasi-Axisymmetric Extension of Tokamak Operating Space

Allen Boozer, Columbia University

Quasi-axisymmetric (QA) shaping allows tokamak control that is not possible with pure axisymmetric shaping.

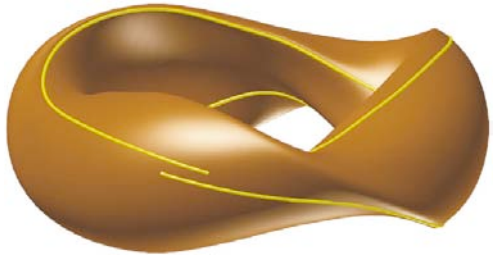
Like elongation and triangularity, it can be applied at any amplitude from zero, a conventional tokamak, to large while preserving the good trajectory confinement.

Addresses a large fraction of the acknowledged ITER to DEMO issues.



ARIES-RS but $\Delta\iota_{vac}/\iota = 20\%$

(L-P. Ku through a Columbia grant)



NCSX with $\Delta\iota_{vac}/\iota = 70\%$

I. Potential benefits at different amplitudes of QA shaping

1. At 1% asymmetry:

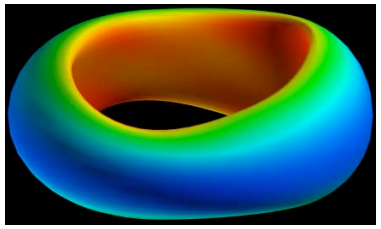
ELM control using low *N* edge perturbations, which allows coils to be far away.

2. At $\Delta\iota_{vac}/\iota = 20\%$ strong centering of plasma in chamber for:

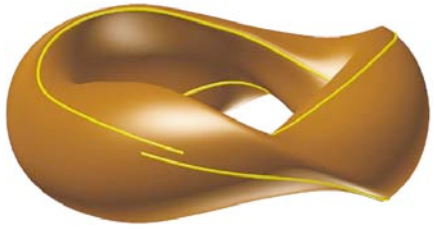
a. disruption avoidance.
b. enhanced vertical stability.
c. easier startup due to vacuum magnetic surfaces.
d. enhanced kink stability. *(Resistive wall mode stability)*

3. For $20\% < \Delta\iota_{vac}/\iota < 70\%$:

a. control of q profile (reversed shear, etc.).
b. density limit raised above Greenwald limit.
c. no need for current drive.
d. low temperature, high density DEMO (eases divertor and α issues).



ARIES-RS but $\Delta\iota_{vac}/\iota = 20\%$



NCSX with $\Delta\iota_{vac}/\iota = 70\%$

II. Research program on quasi-axisymmetry

1. NCSX will give unique information on quasi-axisymmetry.
   Only quasi-axisymmetric machine in world program.
2. Theory/computation should allow interpolation between NCSX and the conventional tokamak. *NCSX is only one element in a broader program.*
3. Implement known methods for reducing technical difficulty of coils.

III. Quasi-axisymmetric (QA) shaping has a unique position for U.S. research going from ITER to DEMO

1. Shaping essential for DEMO *(elongation, triangularity)*. Various levels of QA shaping would provide additional plasma control.
2. QA shaping addresses a large fraction of the acknowledged issues *[N.F. 47 S404, (2007)].*
   Effectiveness demonstrated in stellarator experiments.
3. U.S. has and can keep the dominant position in QA research.

Is it too risky to decide without further research to set all of the quasi-axisymmetric shaping parameters to zero in a tokamak DEMO?