



NCSX Coil Configuration

Status and Future Plans

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Need to carefully optimize our coil configuration

- **Achieve performance requirements**
- **Avoid unnecessary technical, cost, and schedule risks**
- **Minimize cost**

Our coil configuration must provide several functions

- **Toroidal field - 1T at 1.5m for 3s, 2T for 0.5s**
- **Inductive current drive - up to 600kA**
- **Shaping and equilibrium fields for reference scenario**
 - Closed surfaces for plasma formation with ECH
 - Inductively drive plasma current to full current
 - Heat plasma to full beta
 - Reduce beta and plasma current to zero
- **Flexibility in iota ($\iota_{\text{ext}}/\iota_{\text{tot}}$, $d\iota/dr$), beta, shape**
- **Control of surface quality**
 - Maintain good transport
 - Control edge shear
 - Introduce island divertors at edge

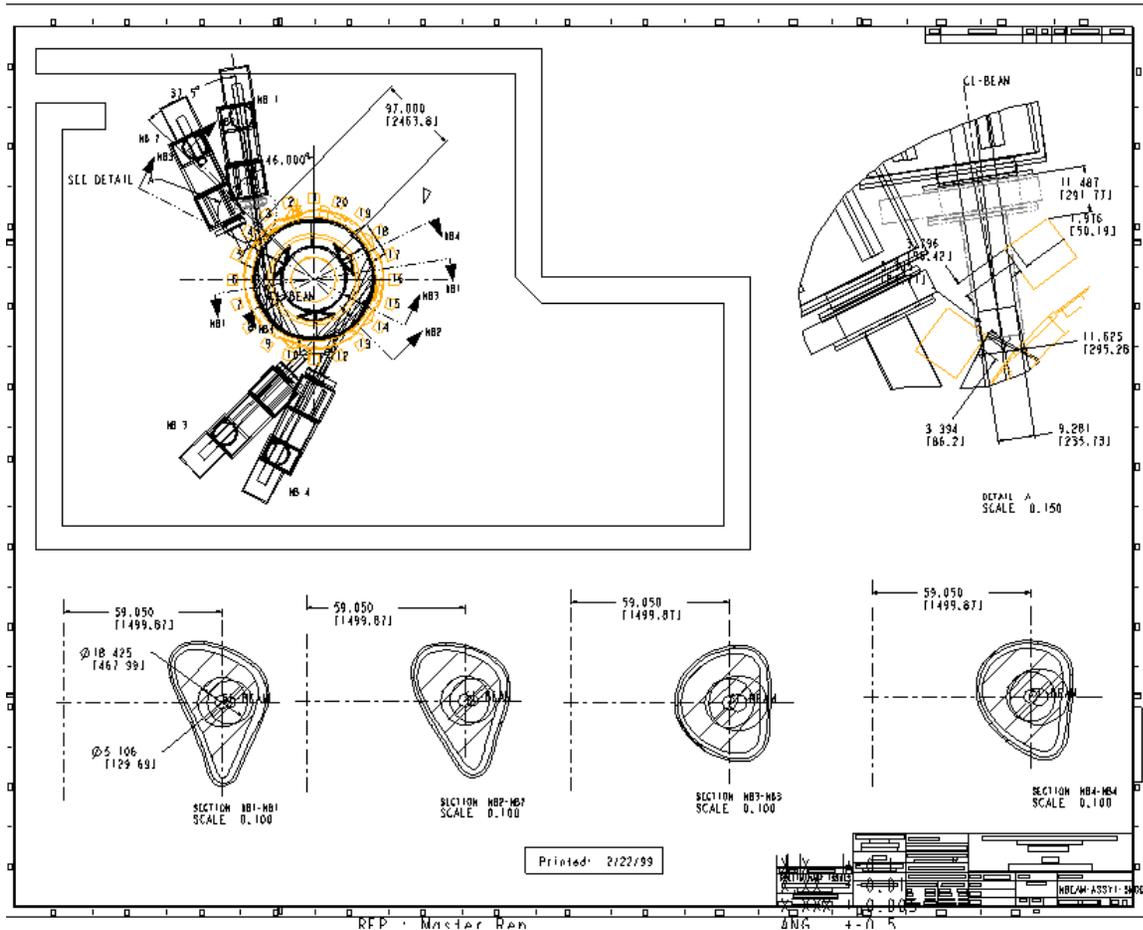
PBX planned as site for NCSX

- **PBX TF and ex-vessel PF coils will be re-used**
- **PBX will be disassembled down to base**
- **Stellarator core installed as a pre-assembled module**
 - **Pre-assembled and tested in a separate building**
 - **Present PBX test cell crane capacity is 30 tons**
 - *Crane can be upgraded to 50+ tons w/o building mods*
 - **Re-assembly of PF and TF follows installation of core**

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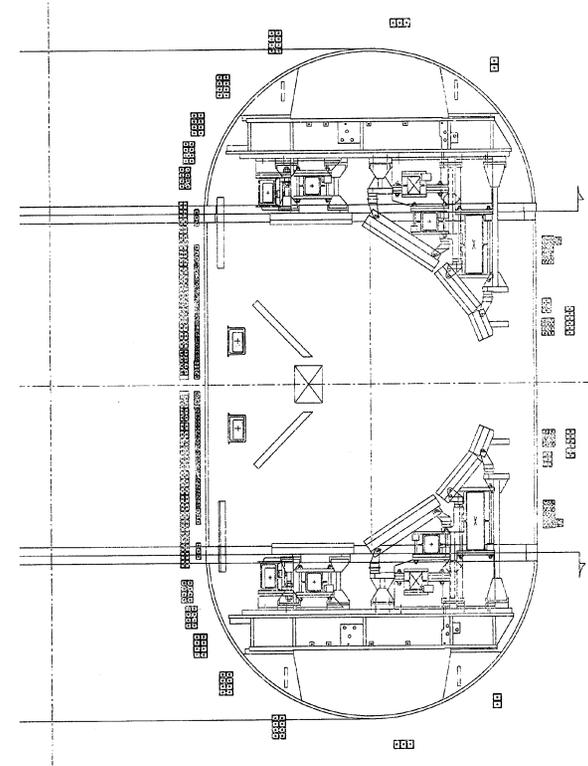
NCSX in PBX facility

- $R_{NBI} = 1.5m$



Re-use of PBX TF/PF coils appears cost efficient

- TF amp-m is much greater than amp-m required for helical fields
- TF can provide a 2s flattop at 2T, 22s at 1T
- OH coils provide inductive current drive
- EF coils provide plasma position control and axisymmetric shaping
- Coils are matched to existing power supplies
- Separation of TF and HF gives flexibility in controlling iota



Negative impacts of PBX siting

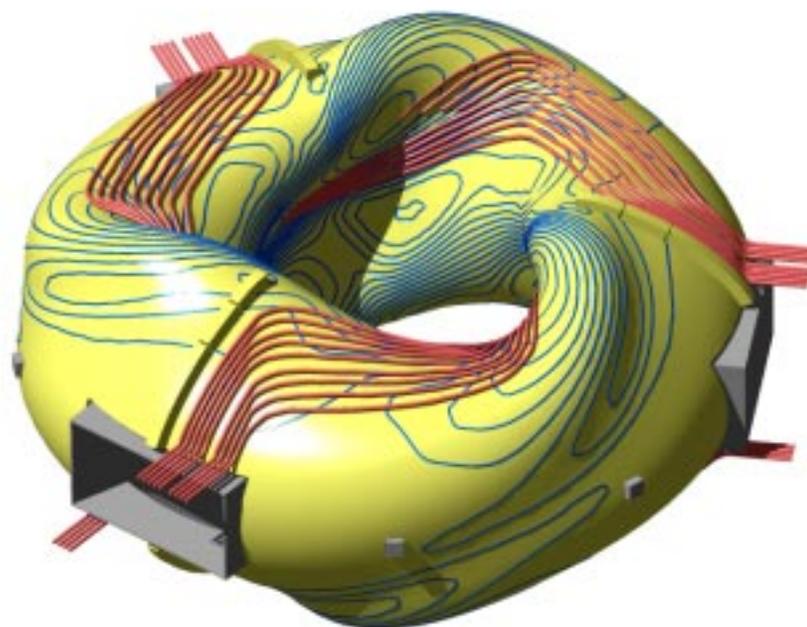
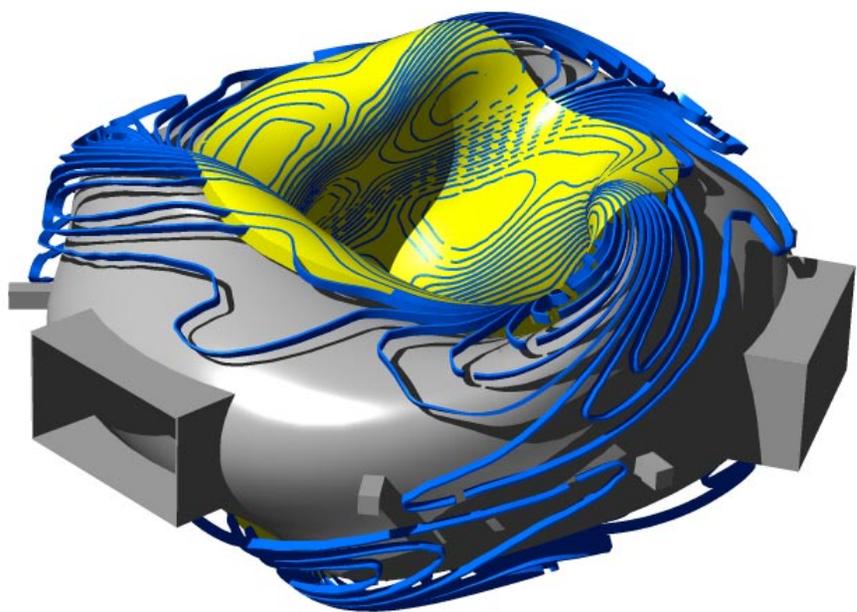
- **Limits plasma aspect ratio to >3.4**
- **3 period plasmas do not have symmetric alignment with 20 TF coils**
- **Limited access for tangential NBI, RF, and diagnostics**
- **Requires close-fitting HF coils, even on the outboard side**
- **Alternatives still need to be explored**

Saddle coils appear to be the natural choice with PBX TF/PF coils

- **Saddle coils have no net poloidal or toroidal current**
- **Adequate for producing helical fields required by plasma**
- **Produce helical fields that are complementary to the toroidal and axisymmetric poloidal fields already provided by PBX TF/PF coils**
- **No net inductive coupling between saddles and TF/PF coils**
- **Reduced net centering force**

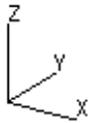
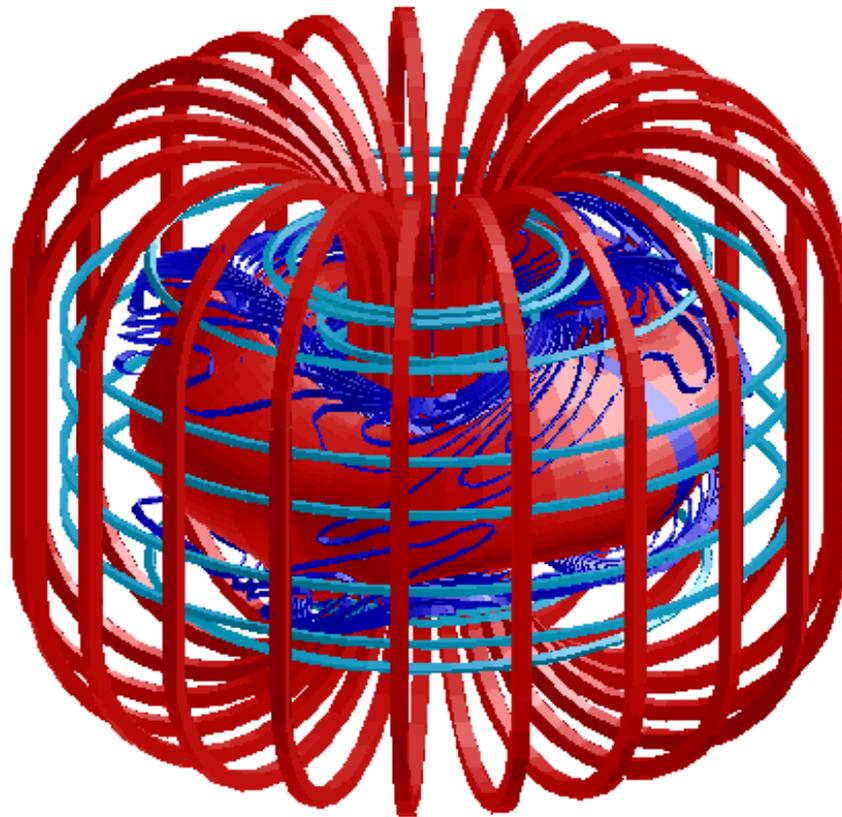
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NCSX saddle coils



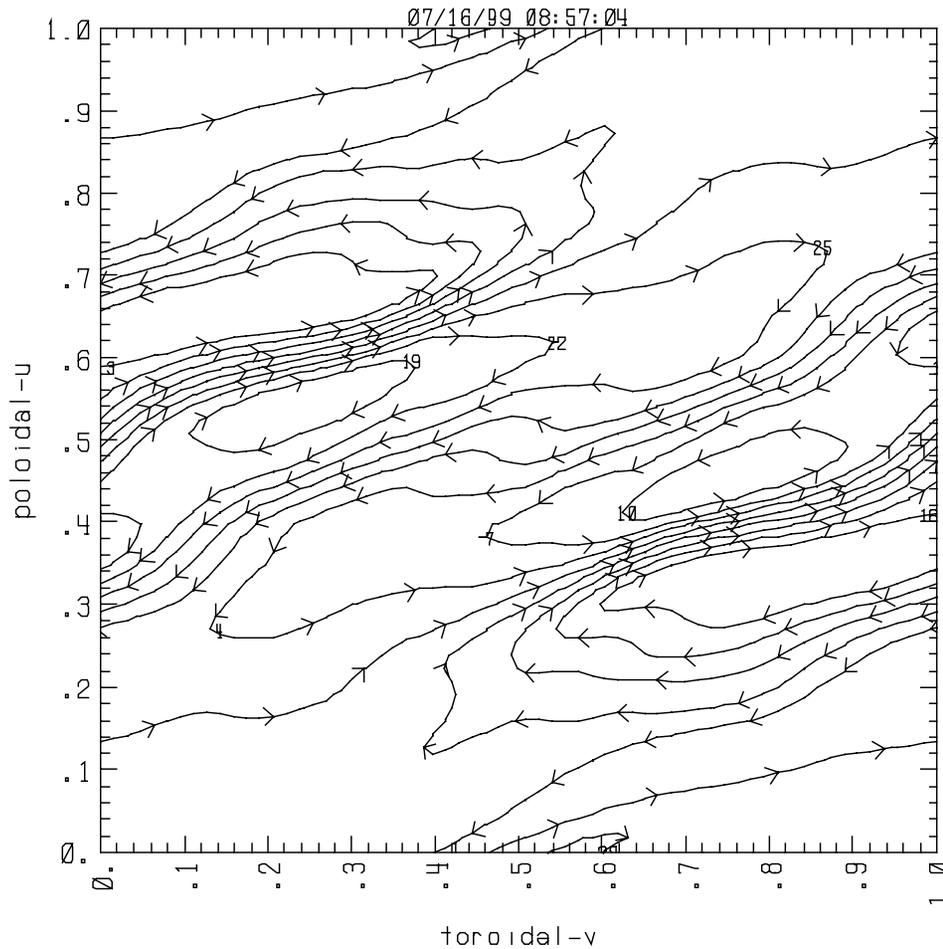
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NCSX with saddle coils plus PBX TF/PF coils



Coil designs with few coils (10 per period) adequately reproduce physics

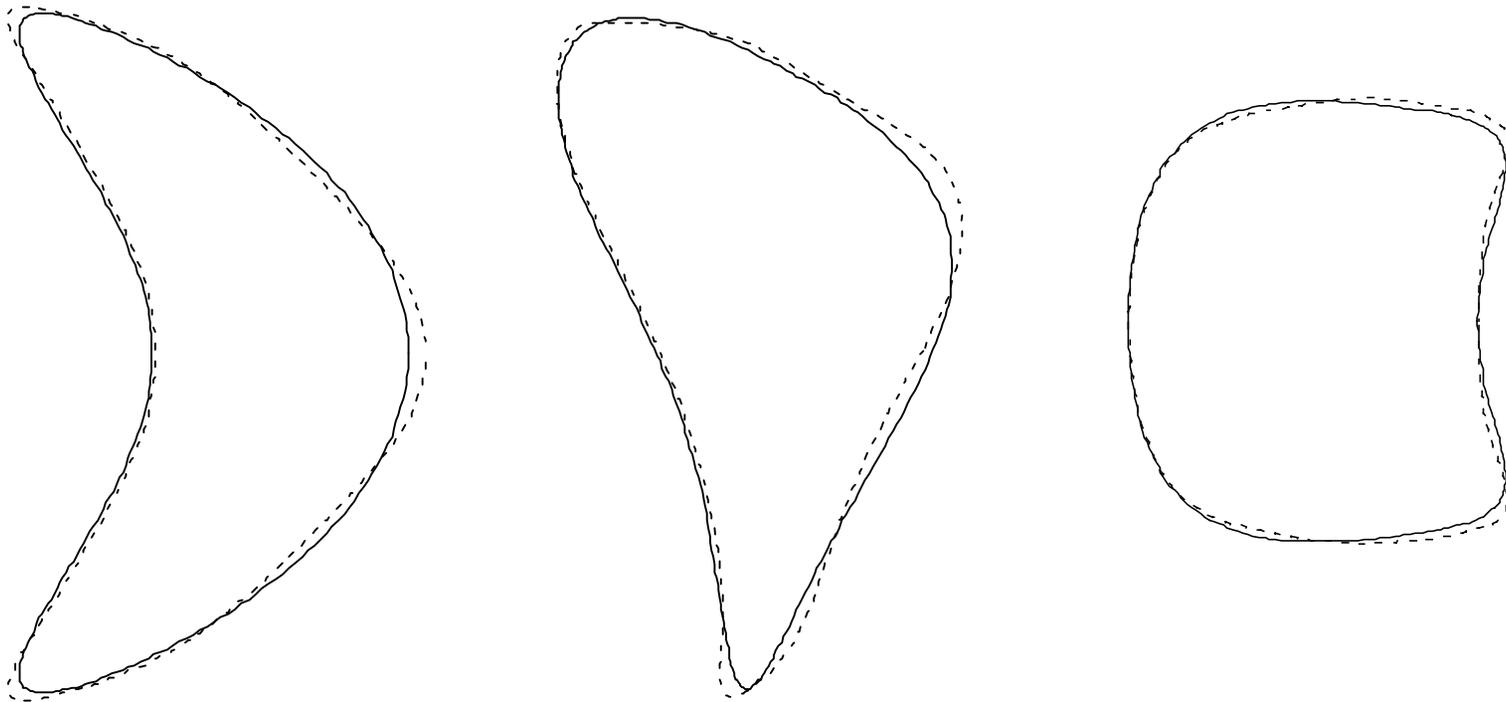
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- **Mean Err = 1.53%**
- **Max Err = 7.13%**
- **Jmax = 12.2 KA/cm²**
- **Quasi-symmetry and kink stability preserved**

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Reconstructed shape approximates original shape



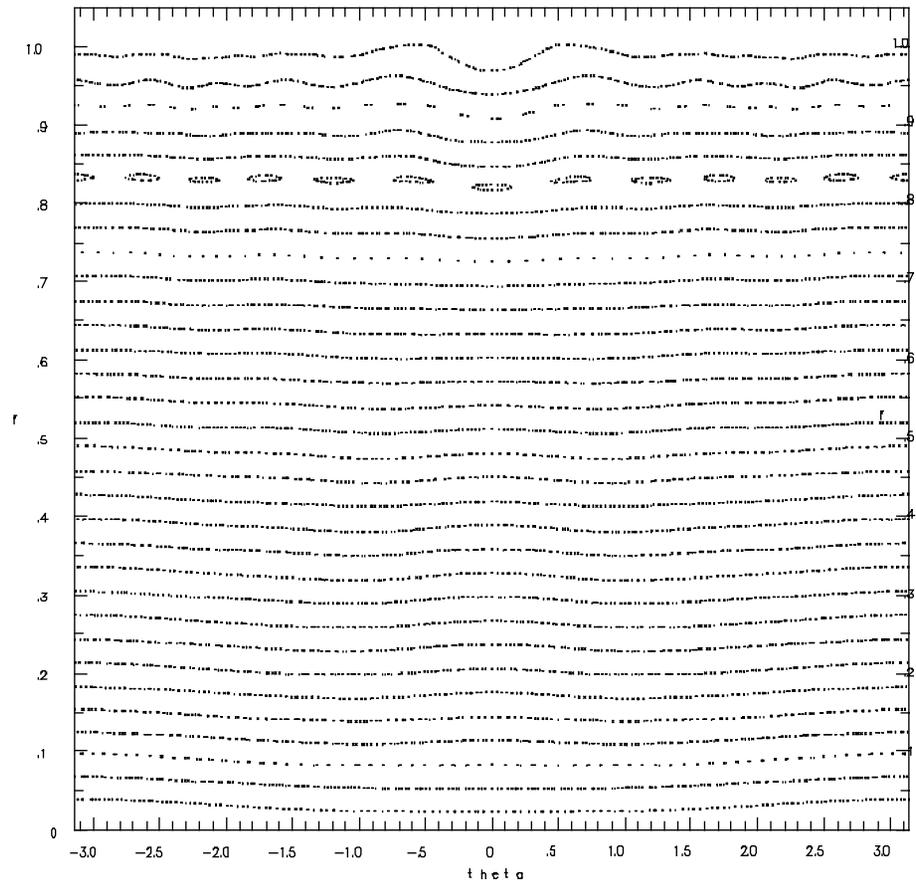
Magnetic surface quality is a concern

- **OK at full current/low β in fixed boundary calculations**
- **Poorer in vacuum and at full current/high β**
- **Vacuum magnetic surfaces can be produced with full current/high β saddle coil currents plus vertical field ($I_{\text{cfs}} \sim 0.15$)**
- **Tools being developed for determining surface quality with finite current and β**



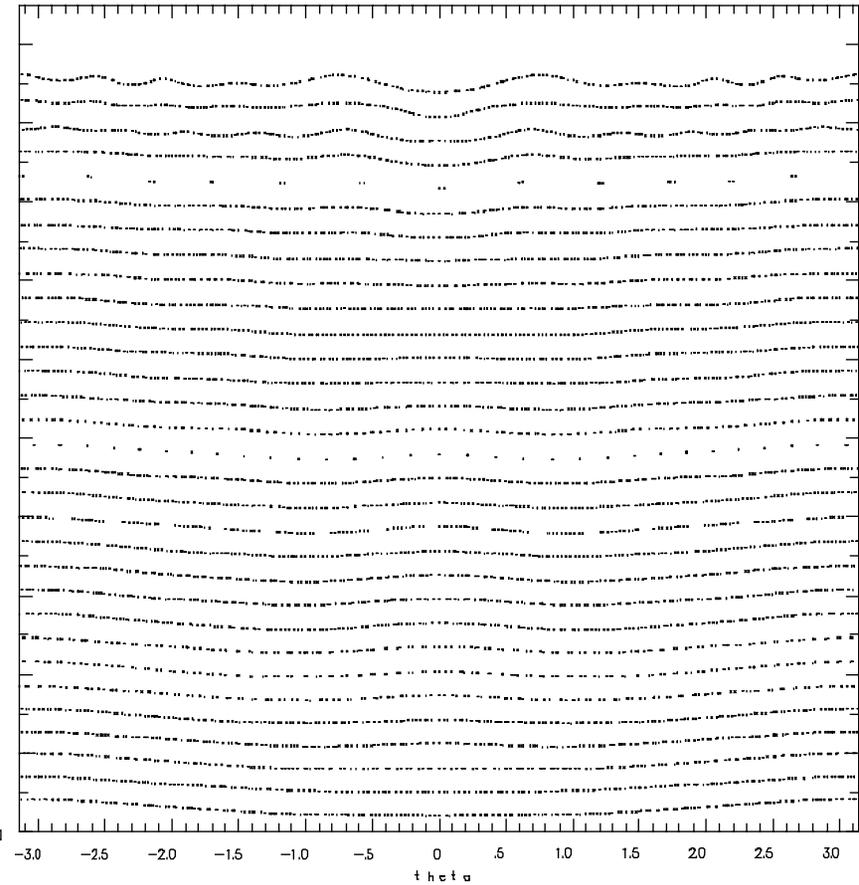
Trim coils planned for suppressing islands

[12,3] Island at $\iota = .25$ w/o trim coils



it= 1 rpoinc: background coordinates

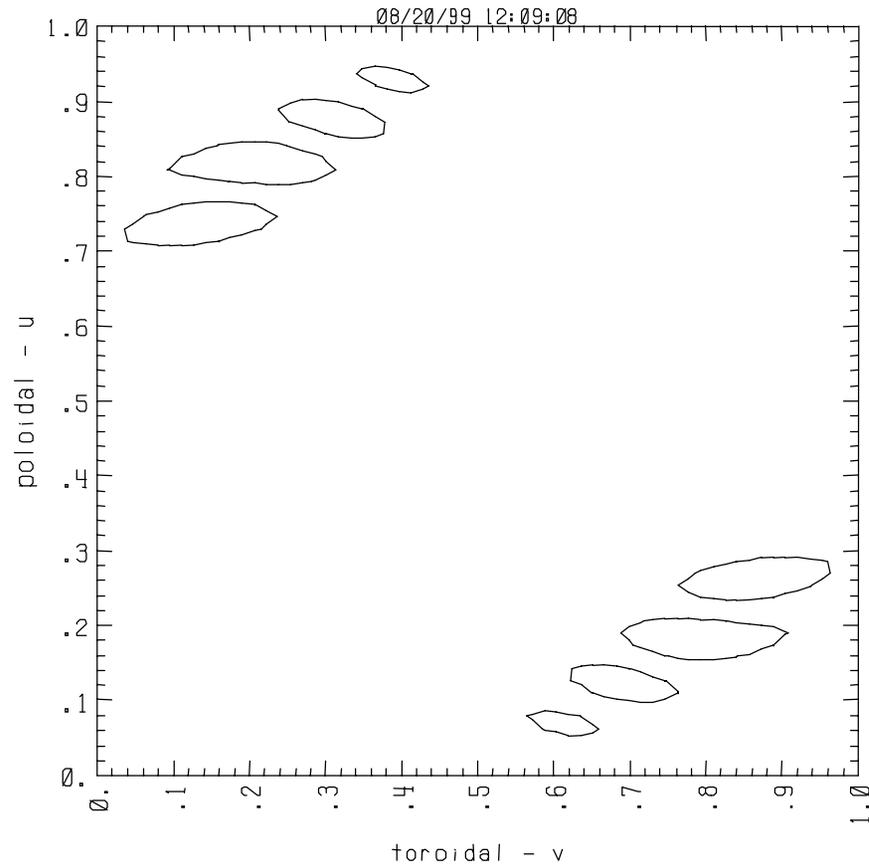
[12,3] Island suppressed w/ trim coils



it= 1 rpoinc: background coordinates

Dipoles mounted on interior surface of shell might work OK

Trim coils
generated to target
[12,3] islands on
 $I=0.25$ in previous
slide



Critical issues

- **Current density**
 - Limits pulse length and max field
 - LN₂ cooling adopted to extend J²t capability
 - Favors fewer coils
- **Access**
 - Difficult to get a tangency radius of 1.5m w/PBX TF coils
 - Saddle coils occlude access in several midplane ports
 - Access remaining for RF, diagnostics, and vacuum pumping is still to be determined
- **Magnetic surface quality**
 - Need tool to assess in free-boundary
 - Coil and plasma configuration impacts TBD
- **Coil requirements for flexibility is still to be determined**

Alternate coil configurations will be explored

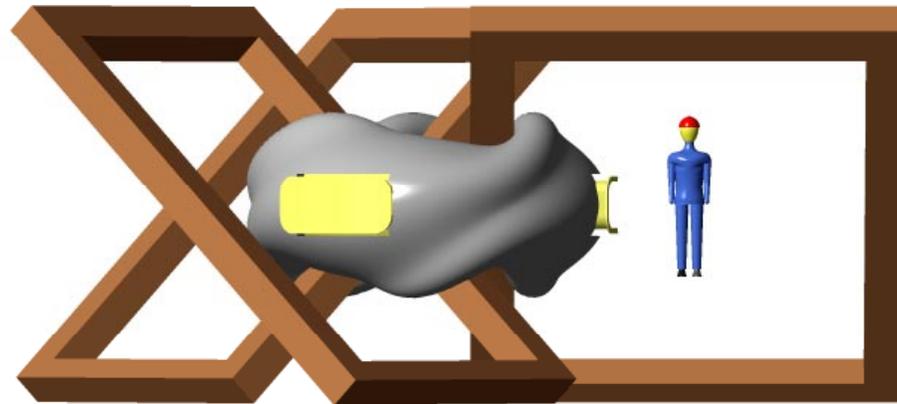
- **Goal is to reduce J , improve access, improve magnetic surface quality, and provide adequate flexibility**
- **Options**
 - **Reduced number of PBX TF coils plus saddle coils**
 - **Tilted, planar TF coils plus saddle coils**
 - **Non-planar TF coils plus saddle coils**
 - **Modular coils**
 - **Torsatron windings**

Tilted TF coils are an interesting option

- **Lowers resonant and non-resonant field errors to be corrected**
- **Decouples inboard and outboard saddles - better flexibility?**
- **Reduces saddle coil current density**
- **Reduces total length of saddle coils - saves \$**
- **Improves access**
- **Planar coils of plate construction should be cheap**

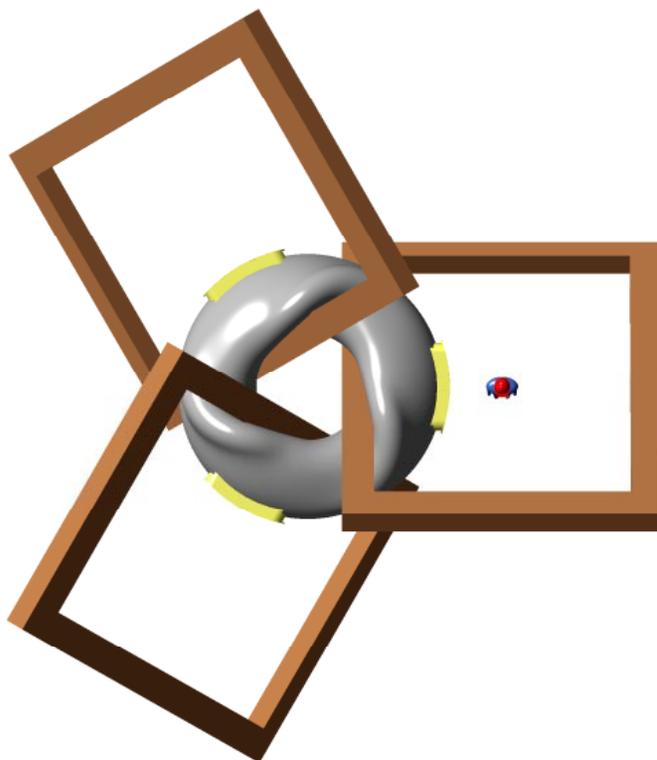
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Tilted TF coils (side view)



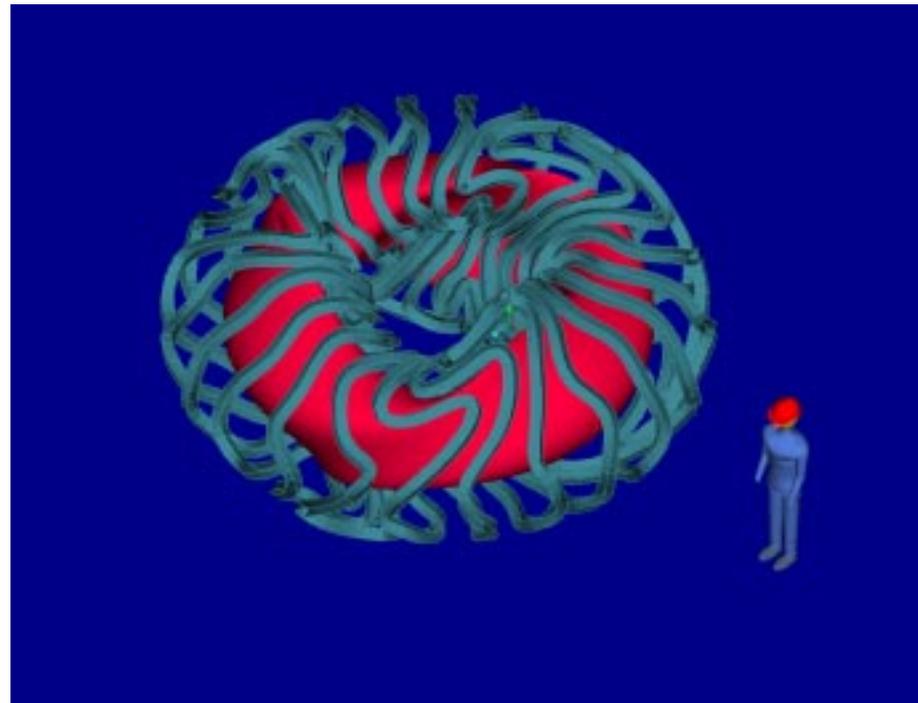
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Tilted TF coils (top view)



Modular coils did not appear compelling but will be revisited

- Modular coils (c10 shown, c82 is worse) appear more contorted than W7-AS, but little work done on optimization
- More (2x) amp-m than saddles
- TF and HF not separated - less flexible?
- Potential for improved access? Lower J? Better magnetic surface quality? More reactor relevance?



Summary

- **The present coil configuration features:**
 - **Saddle coils mounted on a shell that is conformal to the plasma to provide helical field**
 - **TF and PF coils from PBX to provide the toroidal and axisymmetric poloidal fields**
 - **Trim coils, probably mounted on the interior surface of the shell, for suppressing islands**
- **Critical issues are current density, access, magnetic surface quality, and flexibility**
- **Alternate coil configurations will be explored to see if radically different approaches might yield quantum improvements**