NCSX Facility Design Progress

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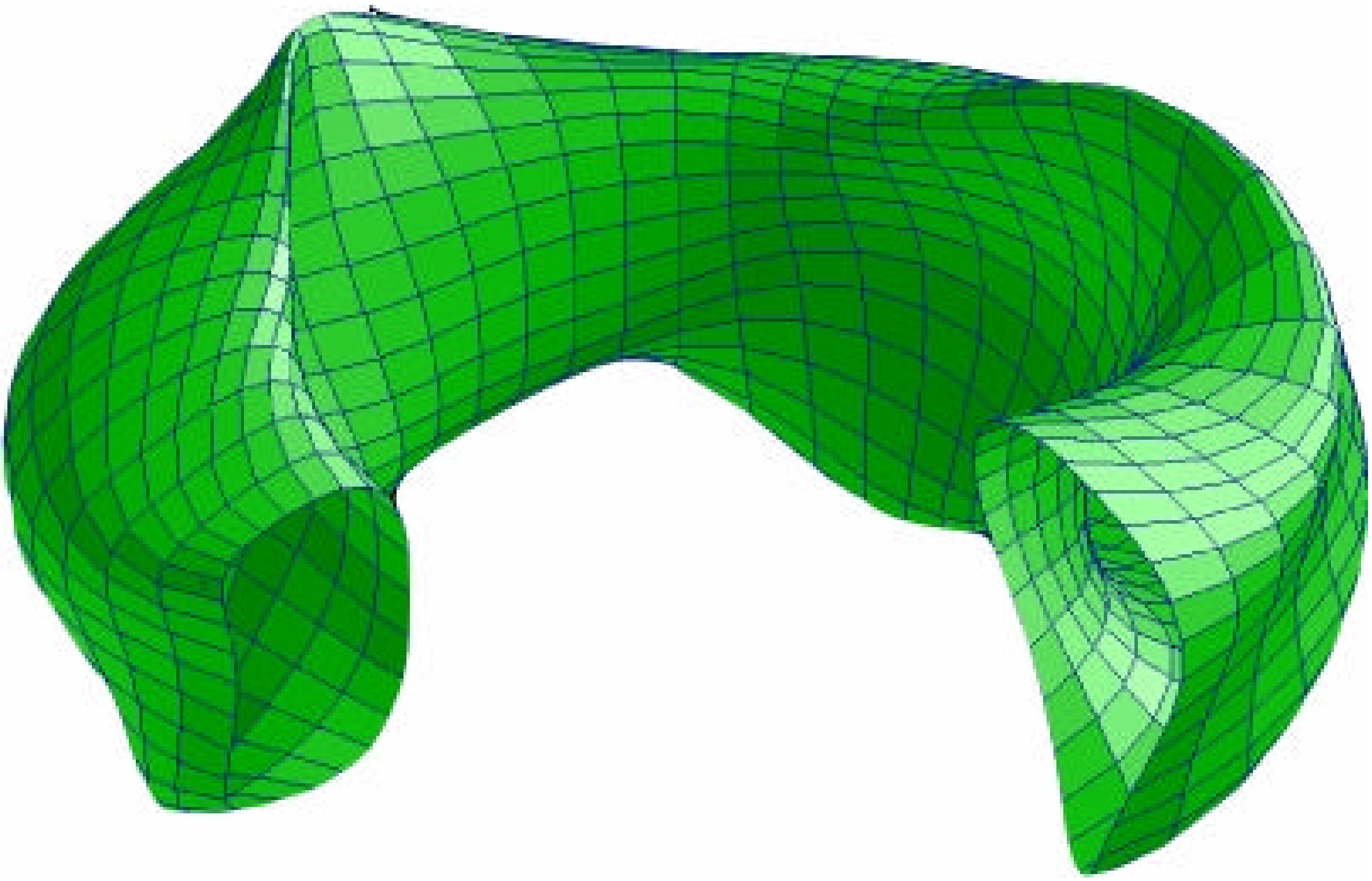
Abstract

In 1999, a point design for the National Compact Stellarator Experiment device was developed. Though not a complete conceptual design for the NCSX, the 1999 point design showed that a high-beta CS plasma configuration that satisfies physics requirements for plasma stability can be realized in a practical device implementation. A key feature of the 1999 design was its use of the existing toroidal and poloidal field coils from the former PBX-M tokamak device to provide a "coarse" background field. Alternative background coil options, including those with all-new coils optimized for NCSX instead of existing ones, are now being explored. Saddle coils and deformed TF and PF coils are options being studied for providing the "fine" corrections needed to produce the required fields with high accuracy. Since the NCSX device must provide access for required heating, diagnostic, and pumping systems in order to fulfill its physics objectives, access is an important criterion for evaluating options. Recent progress in the exploration of optimized coil systems and in the definition and evaluation of access requirements for physics tools will be reported.

NCSX Plasma Configuration "C82" Stable at $\langle\beta\rangle$=4%



- Aspect ratio 3.4
- 3 field periods
- Assumed bootstrap-like current profile.

- Stable to ballooning, kink, vertical, Mercier modes without nearby conducting structures.

Progress in the NCSX Facility Design

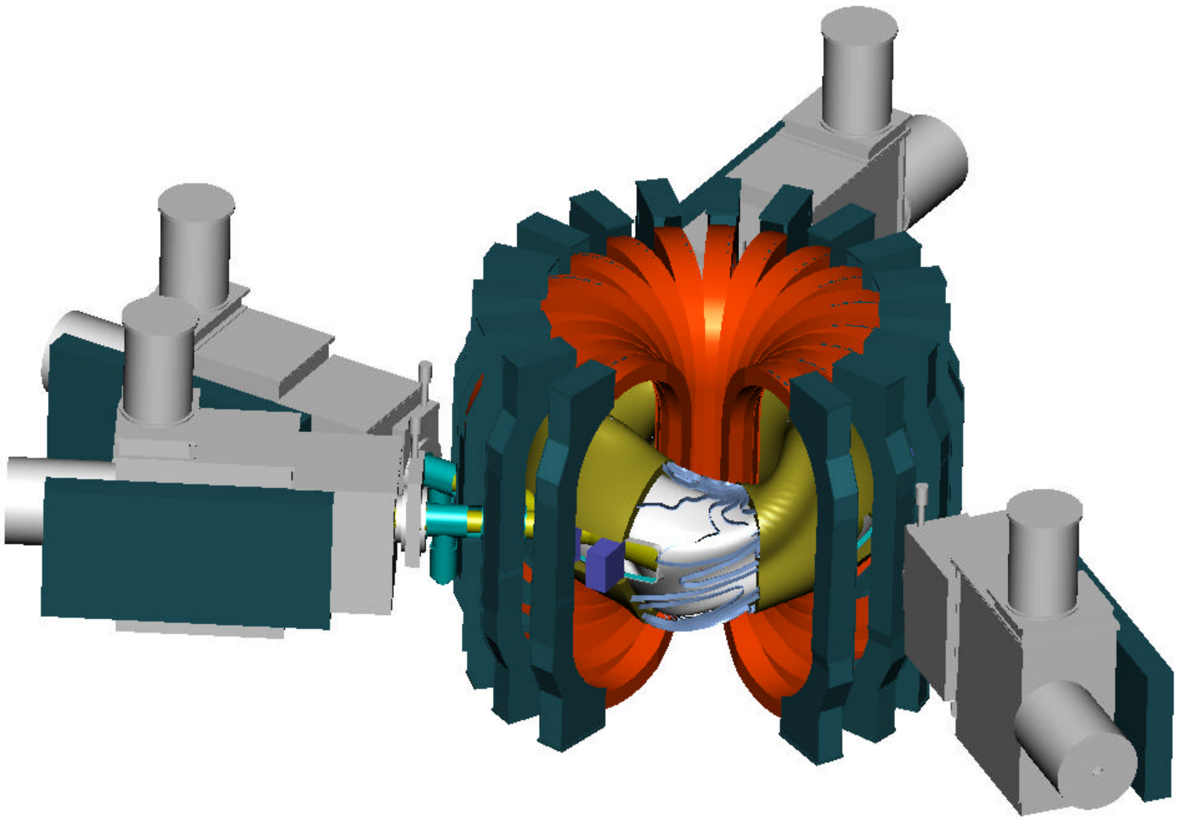
- A Reference Design (June, 1999):
  - Uses existing (PBX-M) background field coils around C82 plasma.
  - Demonstrates a high-beta CS design satisfying stability requirements.
  - Not yet a complete conceptual design.
  - A reference point for further development.

- Current NCSX development activity (FY-2000)
  - Incorporate additional physics requirements into design process: plasma configuration flexibility and robustness, heating and diagnostic access.
  - Define a broader range of machine topology options from which to select.
  - Goal: an updated design by Sept., 2000.

Status Reported Here

- Found promising machine topologies with optimized background coils.
- Found ways to accommodate major access requirements.

NCSX Reference Design (6/1999) Re-Using Major PBX-M Components: TF/PF Coils, Neutral Beams



- PBX TF coils (existing) provide a 1/R background field.
- Conformal coils (new) provide 3D shaping fields.
- Would also use PBX PF coils, neutral beams, and test cell.

Optimization of Background Coils

Motivation

- Provide a better approximation of equilibrium field requirements than 1/R field from TF coils. Reduce or eliminate conformal coil requirements. Potential benefits to heating and diagnostics access, magnetic surface quality, flexibility.

Approach: Background + Conformal Coils

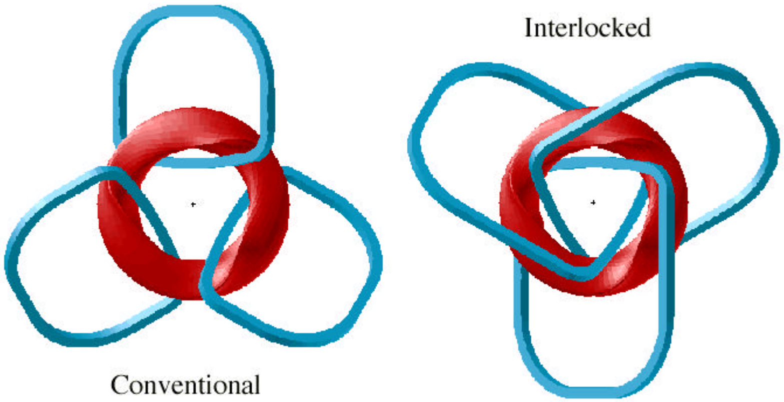
- Select from a library of background coil types described by a few parameters.
- Use NESCOIL suite to find optimum conformal coils for given background.

Background Coil Optimization Objectives

- Physics: reduce max. and mean B_{norm} on plasma boundary.
- Ampere-meters of background coils (cost measure).
- Max. and mean current density on conformal coil surface.
- Complexity of conformal coils.

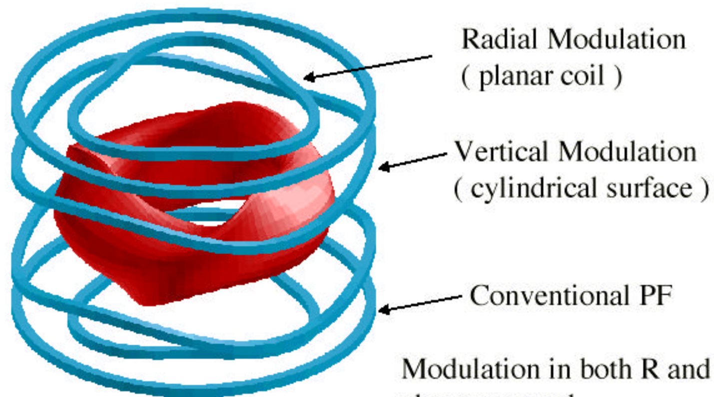
Various Coil Types Are Considered

Tilted Planar TF



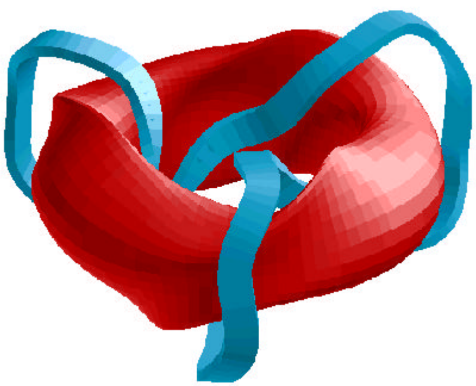
An Interlocked TF is an L=3 Winding

Wavy PF



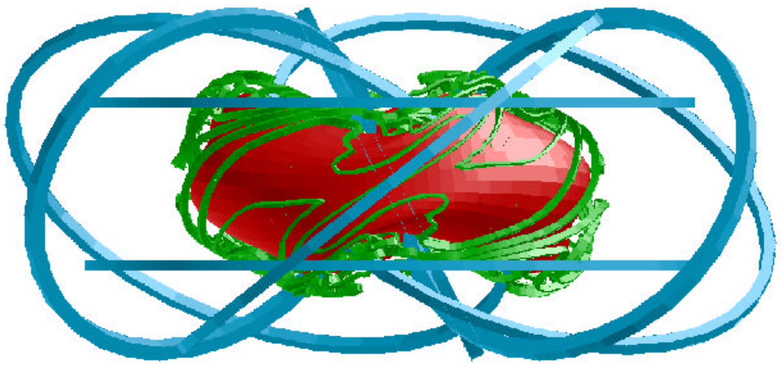
Modulation in both R and Z
also supported

Helical



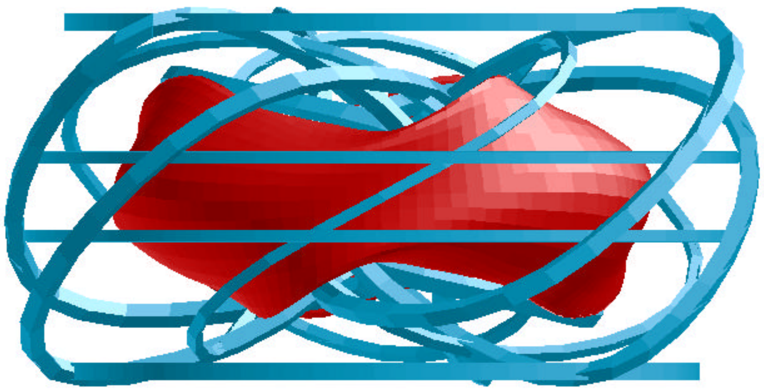
L=1 Torsatron
with modulation
wound on
conformal surface

Optimized Background Coils May Be Advantageous



Simple-shaped background coils

+ Conformal coils



Optimally-shaped background coils

No conformal coils

Physics Benefits Readily Apparent

- Better heating and diagnostic access.
- Increased plasma shape flexibility.

Plan: Evaluate Benefits and Cost Implications for Each Option

Access for Heating, Diagnostics, Pumping

Approach

- Determine requirements.
- Understand factors that restrict access.
- Develop concepts for providing access for each system.

Access Requirements

Neutral Beam Heating (P=6 MW)

- Accommodate all 4 PBX-M beamlines (E_0=50 keV).
- Tangential aiming: R_{tang}=1.5 m desirable.
- Minimized power losses in the duct (geometry, pumping).

High-Frequency Fast Wave RF (P=6 MW)

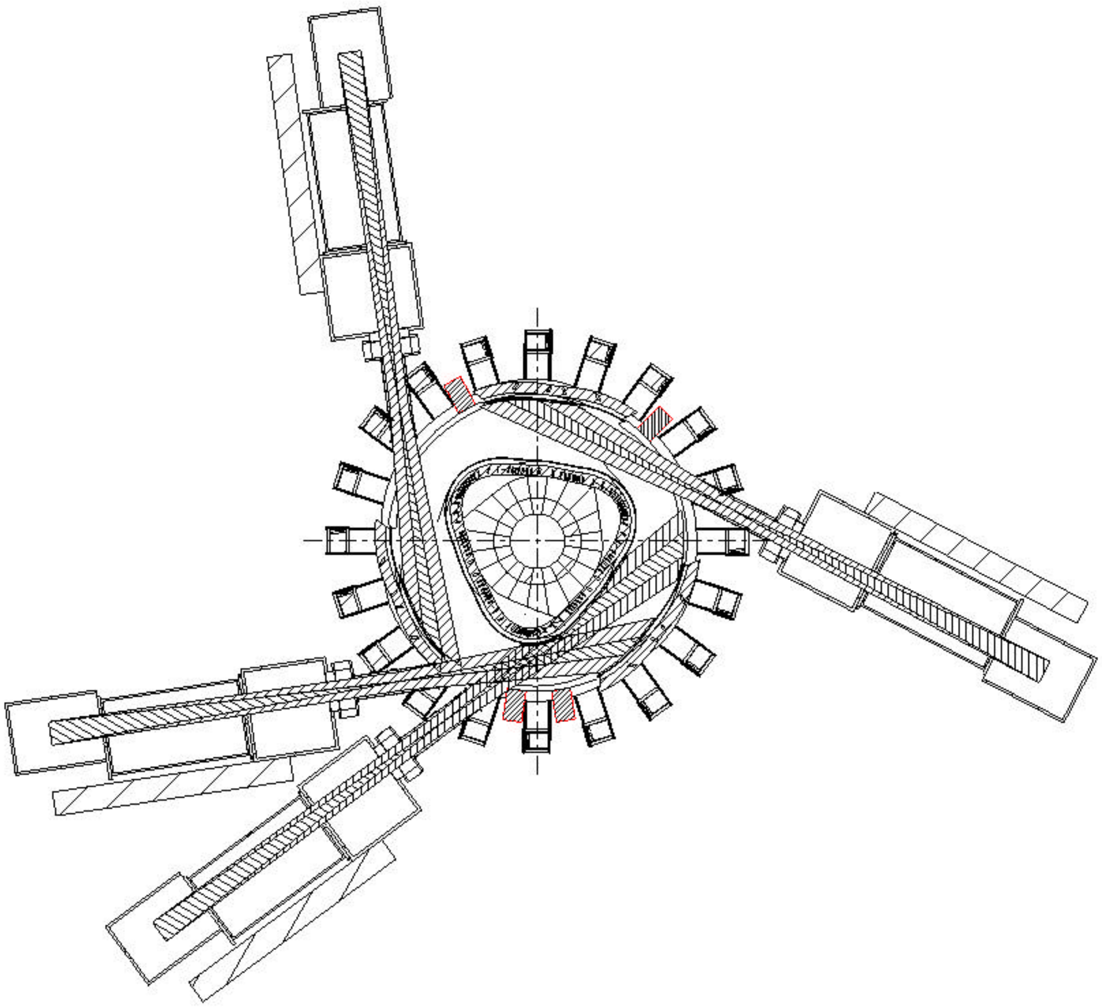
- Assumed scenario: 350 MHz, waveguide-based launchers.
- Accommodate 4 launchers @ 0.24 m × 0.44 m.
- Avoid intercepting neutral beams.

Torus Vacuum Pumping (3,000 l/s)

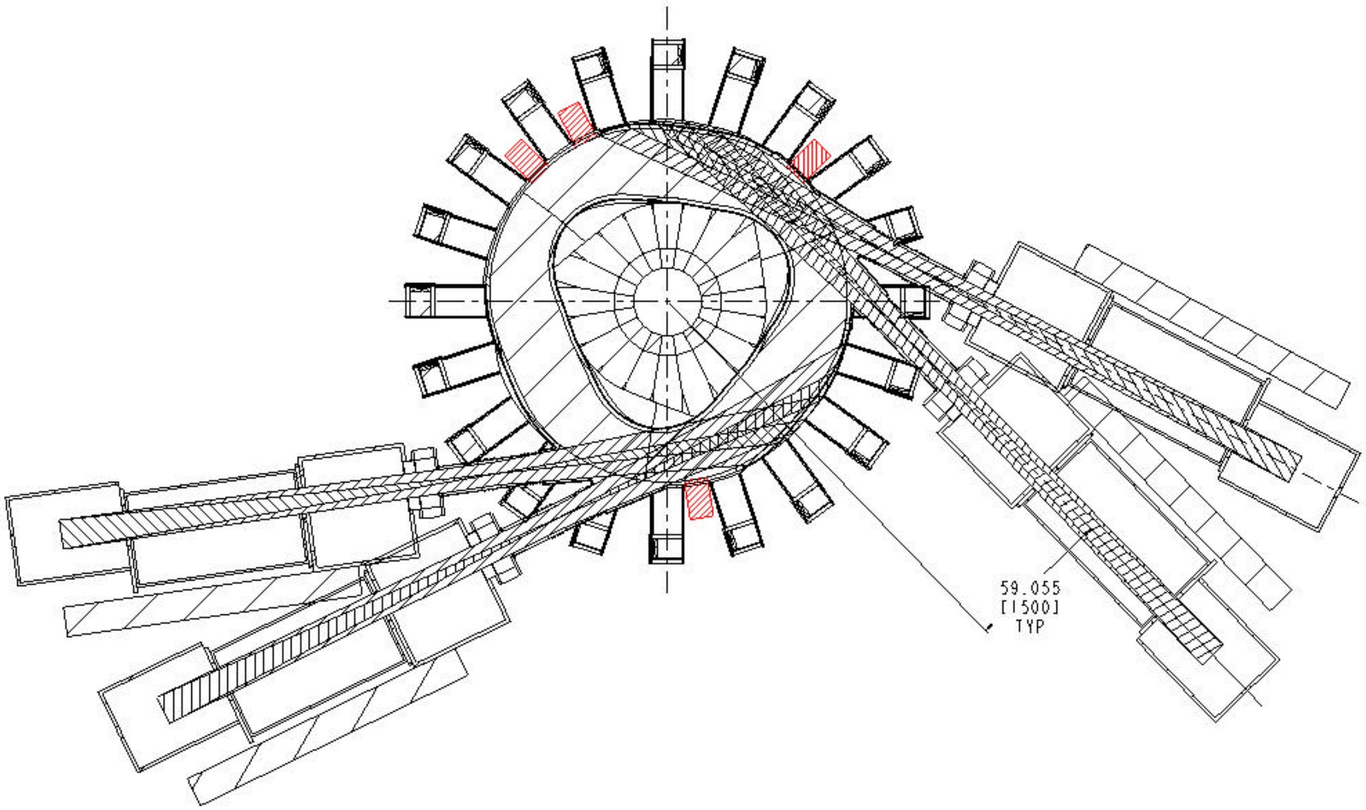
Plan:

- Develop concepts for accommodating each requirement.
- Evaluate the various options.

Neutral Beams and RF Launcher Access Can Be Accommodated Even in the PBX Option



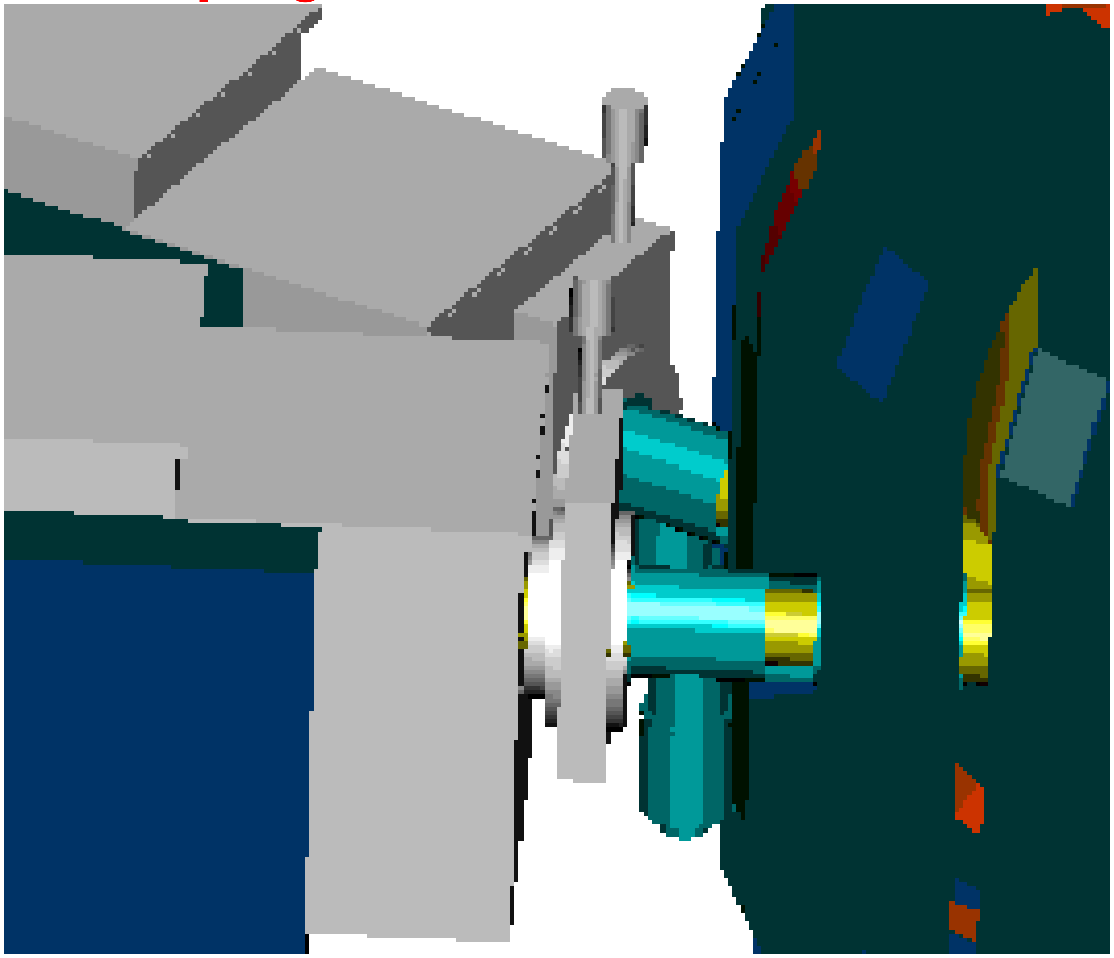
With Modest Structural Modifications, Heating Access Can Be Improved



- All 4 beams at R_{tang}=1.5 m
- Frees up large horizontal port
- Benefits for RF and diagnostics

- Requires “notch” in TF coil, beam-box modification, combined PBX+PLT test cell.

Vacuum Pumping and NBI Ducts Can Be Combined



- Provides high conductance geometry that both systems need.
- Makes efficient use of ports.

Preliminary Assessment of NCSX Diagnostic Port Needs

diagnostic	#ports	size	comments
in-vessel sensors	30	2.75	location dependent on method for mounting sensors, protecting leads
visible cameras	3	6	assumes retractable periscopes for inspection, top best
IR cameras	6	4.5	provide sightlines to limiter, divertor regions, RF antenna, NB armor
interferometer	2	4.5	opposing on line through core will use commercial flapper shutter
x-ray imaging arrays	12	6	part of "tomagraphy" complement
VB array	1	6	part of "tomagraphy" complement
	1	2.75	will use commercial flapper shutter
bolometer arrays	3	6	part of "tomagraphy" complement
VIPS, SPRED, filterscopes	4	6	part of "tomagraphy" complement will use commercial flapper shutter
CHERS/MSE	1	10	shares large miplane slot with NB
	2	2.75	for shutter drive
BES	1	10	shares large miplane slot with NB
	2	2.75	for shutter drive
poloidal CHERS	2	4x10	racetrack shape above/below NB
	2	2.75	for shutter drive
Thomson Scattering	1	2.75	outer midplane, oblate sym. plane
	1	10	top or midplane
	1	2.75	for shutter drive
ECE	2	8	outer midplane, symmetry plane
reflectometry	2	8	outer midplane, symmetry plane
x-ray PHA	1	6	horiz. or vert. flt. tube out of TF
NPA	1	6	horiz. or vert. flt. tube out of TF
fast ion loss probe	1	6	needs clear path to outside of TF
fast scanning probe	1	6	needs clear path to outside of TF
future needs	8	2.75	initially blanked
	4	4.5	part of "tomagraphy" complement
	4	6	initially blanked
	2	8	initially blanked
	2	10	initially blanked

Implications Are Being Evaluated

Summary

- A spectrum of topology options has been identified.

  Having more choices increases capability to find the best solution that:
  - Meets physics requirements including flexibility, robustness, access, and
  - Has acceptable cost and schedule.

- Access requirements have been defined.

  Progress has been made in understanding how to accommodate them:
  - Concept for heating and pumping arrangements defined.
  - Evaluation of diagnostic requirements is in progress.

NCSX Status / Plan

Task for FY-2000: Update NCSX Design to Fully Satisfy Physics Requirements.

Progress to date

- Improved physics capabilities needed to incorporate requirements for flexibility, equilibrium robustness, heating and diagnostic access, into the design process.
- Found promising alternative machine concepts.

Remainder of the year

- Update design using improved tools and expanded option set.

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