Preliminary Assessment of Diagnostic Access Needs

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- Preliminary assessment of diagnostic access requirements recently provided in memo dated 01/03/00.
- Assessment was based on list of diagnostics previously established for the project.
- Discussions were held with M. Cole, W. Reiersen, T. Brown, P. Heitzenroeder, and M. Zarnstorff.
- Conclusion: The spatial constraints inherent in the current design concept for the shell and saddle coils, the cryostat, and the heating systems make diagnostic access problematic on NCSX.
- This presentation will address:
  - Spatial constraints on diagnostic access and suggestions for easing constraints
  - Specific listing of diagnostic access needs

Comments on Diagnostic Planning

- Non-axisymmetry generally dictates requirement for more toroidal views of plasma. Likely to be a few well characterized poloidal planes.
- Because of its relatively high aspect ratio, and complicated vessel shape, viewing a given fraction of the inside of the vessel requires many more ports on a stellarator than on a tokamak or an ST. Dedicated views of important regions will be necessary.
- Elimination of vessel entry for installation, calibration, and maintenance will make these activities impossible or very expensive for some diagnostics.
- Close fitting vessel makes in-vessel sensor design challenging.
- To minimize design and fabrication effort in the vessel, shell, and cryostat, 3-fold symmetry should be imposed for all but a few diagnostic penetrations.

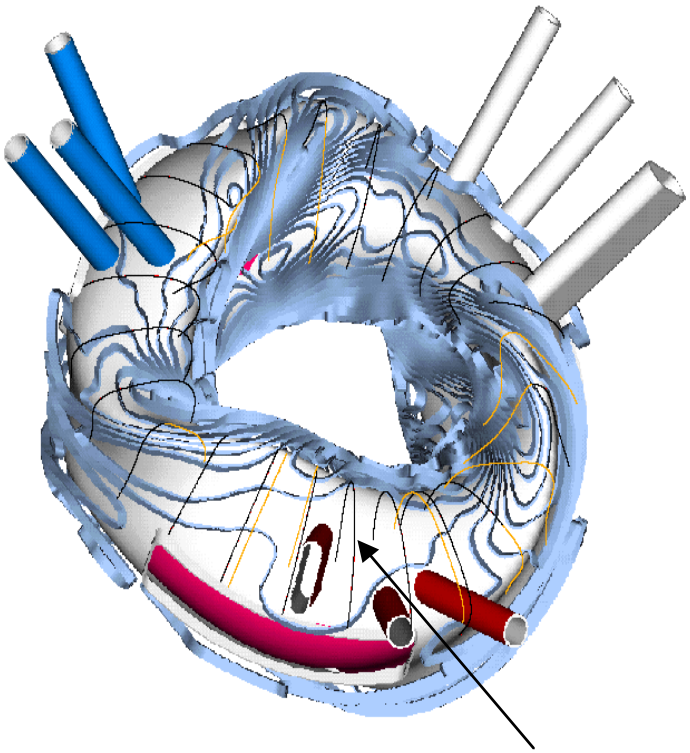
Saddle Coil Concept Greatly Limits Access

- The extensive coverage of the vessel by coils in the shell, and the need to allow a gap between coils and shell penetrations greatly limit space for diagnostic penetrations, particularly large ones.

- If dielectric breaks in the shell must also be avoided, available space is reduced significantly further.

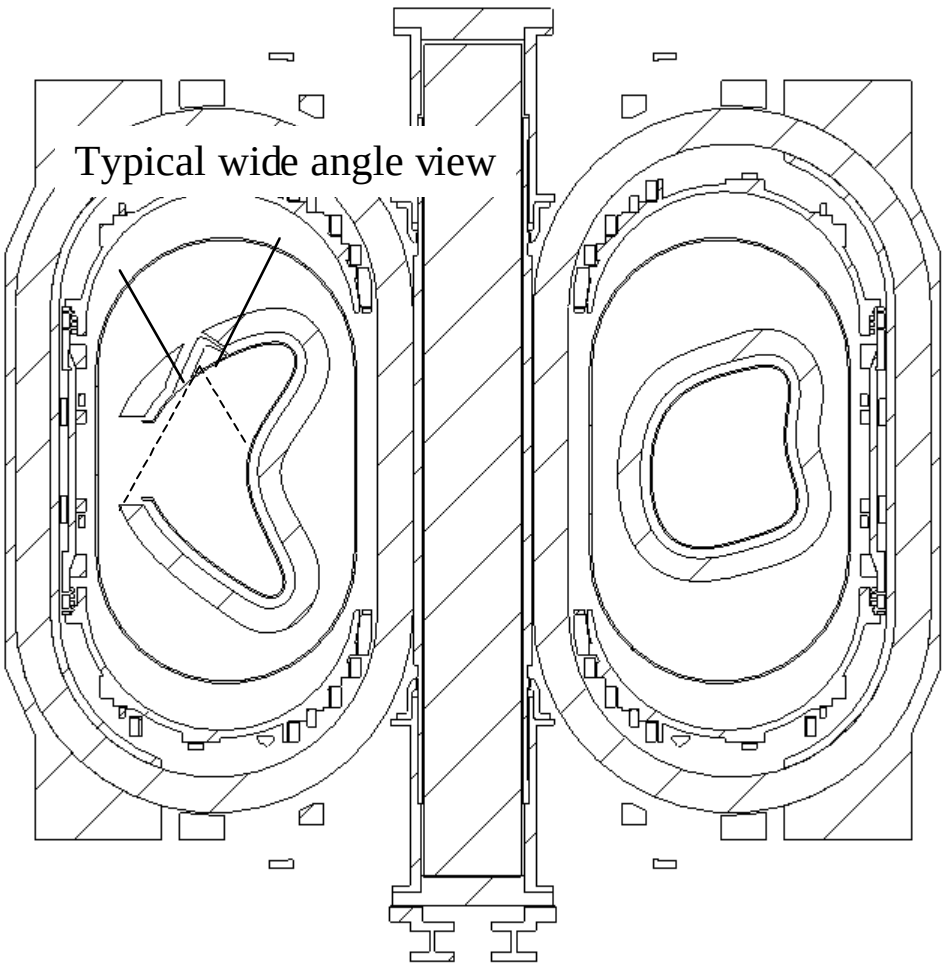
- <u>Suggestion</u> - Permit diagnostic penetrations to cross dielectric breaks in shell.

Note: do not advocate long narrow access ports shown here



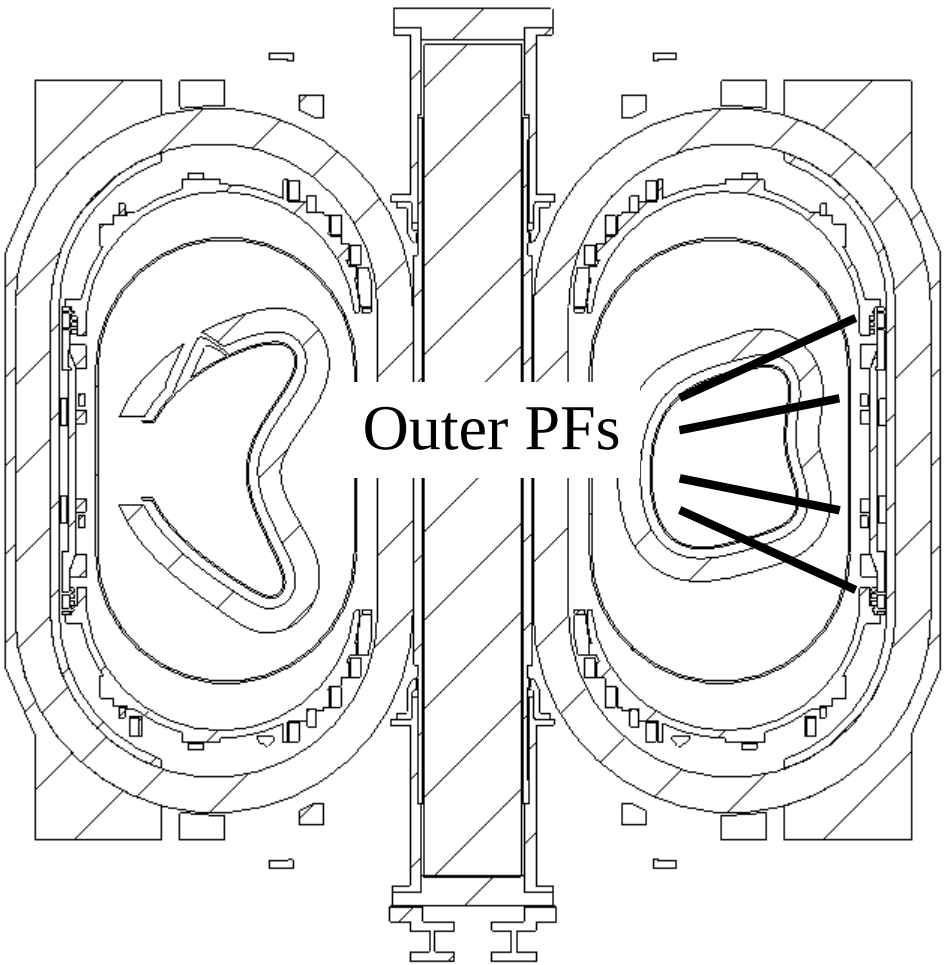
Axisymmetric Cryostat Concept Aggravates Spatial Constraints on Diagnostics

- Many diagnostics will have to be above & below the vessel
- The cryostat currently occupies much of the volume between shell and TF coils
- Penetrations through a “thick’ cryostat will:
  - Limit diag. sensitivity and fields of view
  - Make access for installation and maintenance problematic
  - Be very expensive
- <u>Suggestion</u> - Use conformal cryostat with fiberglass layup



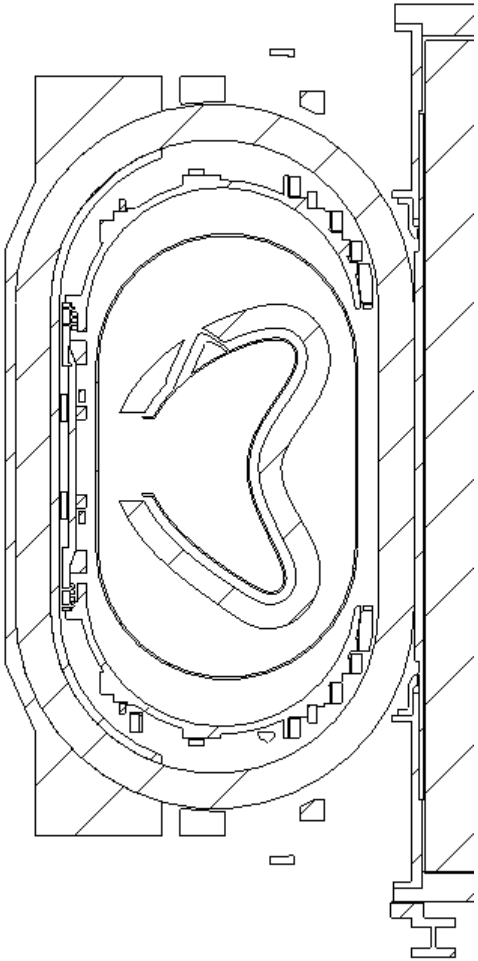
Outer PF Coils Limit Access Above and Below Midplane

- Suggestion - If possible, move or remove outer PFs to provide more space for diagnostic access just above or below midplane



Magnetics and Other In-Vessel Sensors

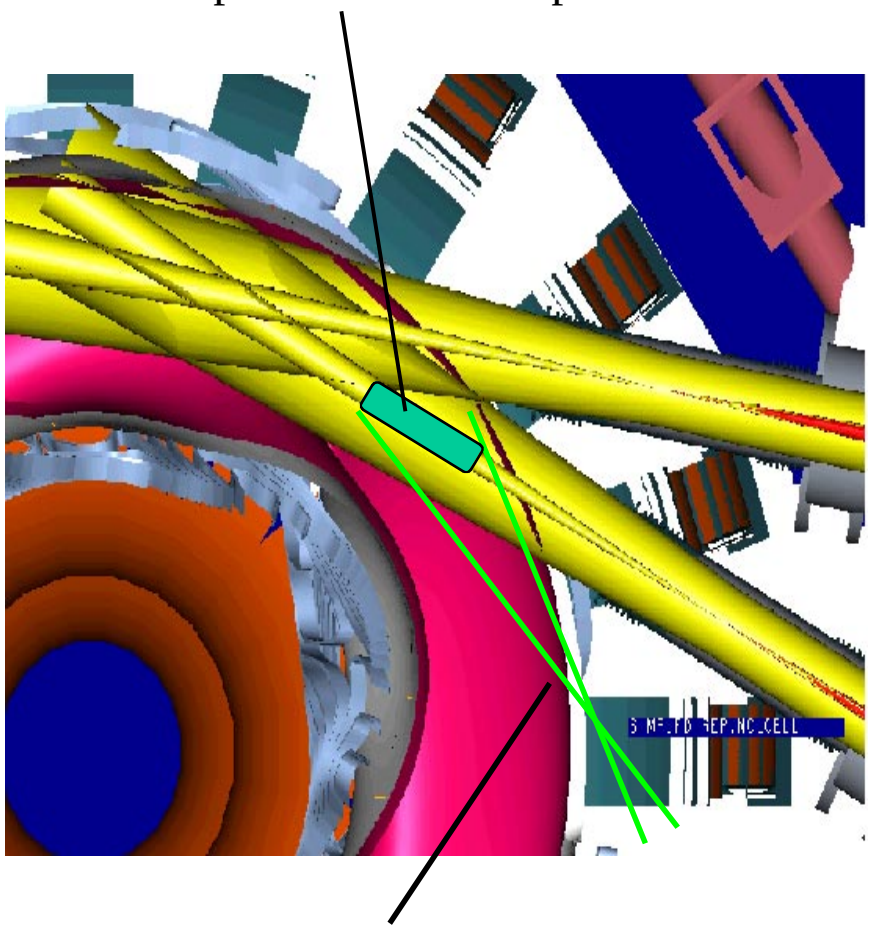
- Sensors include B-dot coils, flux loops, Langmuir probes, thermocouples.
- Strategy for mounting of sensors inside vessel, and for protecting leads needs to be identified. Best if feedthru location can be decoupled from sensor location.
- Systematic physics-based assessment of minimum sensor complement has not been done.
- Projects of this scale typically design for 100-200 in-vessel sensors.
- Each sensor requires 2-3 leads.
- High density feedthrus (NSTX uses 32 per 2.75” flange) are commercially available.
- Plan on ~ 30 2.75” flanges for sensor feedthrus.
- Can be located in ‘non-critical’ areas



Visible and IR Camera Views

- Due to large aspect ratio and complicated vessel shape, viewing a large fraction of the plasma would require many viewports.
- Insertable, steerable periscopes should be used to minimize the number of ports needed to inspect inside of vessel when not operating. Three 6” ports required. May provide limited view of plasma in retracted position.
- Since there is so little room between plasma and vessel, use of re-entrant optics to view at large angles to the port axis during operation may not be feasible.
- IR camera views of limiters, divertors, RF antennas, and neutral beam armor would needed dedicated ports with the proper viewing geometry. Estimate 6 - 4.5” ports needed.

Neutral Beam Spectroscopy Access



- Diagnostics include:

  Tang. CHERS - T_i, tor. rotation

  MSE - J(R)

  BES - Fluctuations

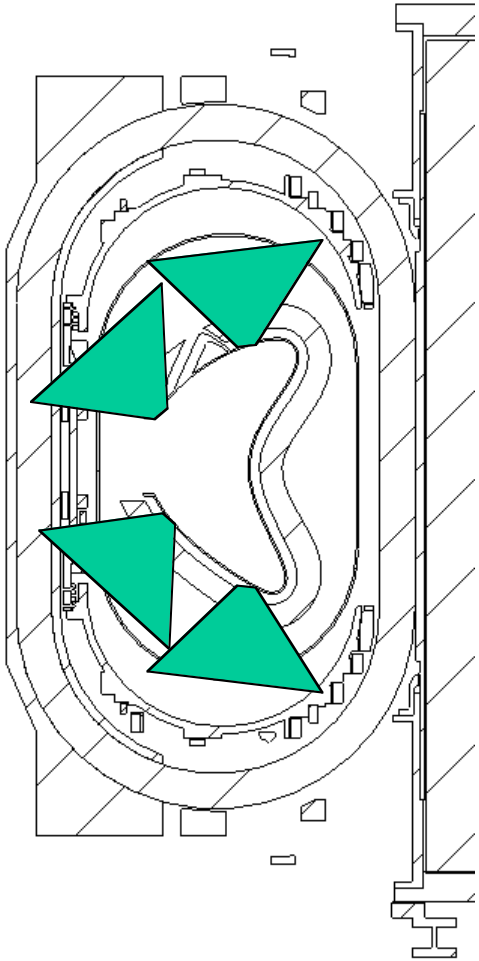
  Pol. CHERS - pol. rotation
- Midplane access is needed for sightlines intersecting the beam approx. tangent to flux surfaces
- Vertical access above and below a beam trajectory would be used for poloidal CHERS
- Prefer location with only 1 beam
- Ports sizes:
  - Tang. CHERS/MSE 8” shared
  - BES 8”
  - Pol. CHERS 2 x 4”x10”

Tomographic Diagnostics

- Multiple poloidal views for tomography are valuable for a number diagnostics.

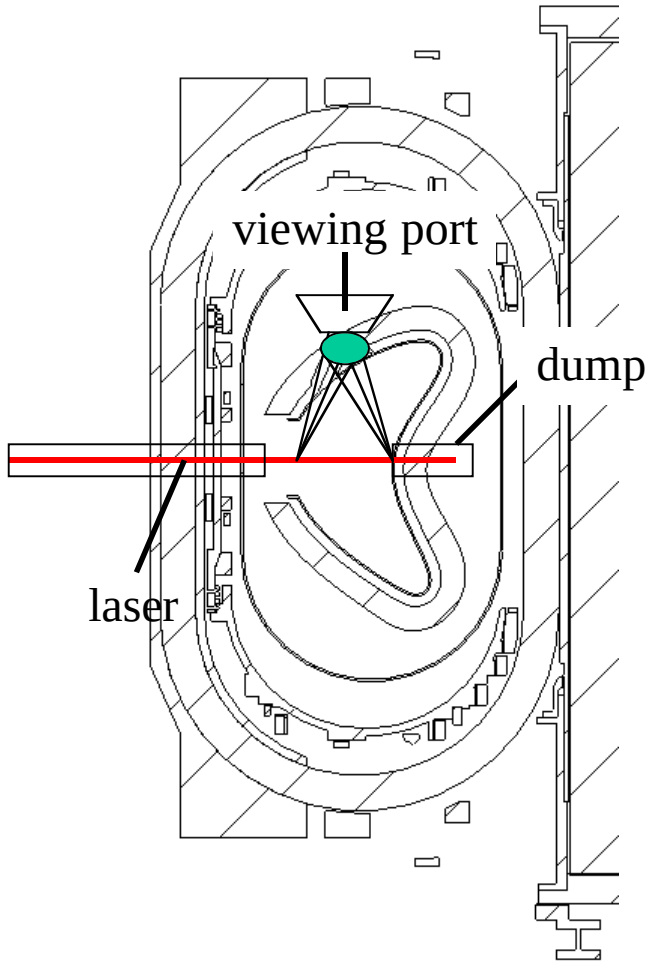
- If 2 poloidal locations on each third of the machine could be found where 4 - 6” ports could be distributed around the outer 2/3 of the perimeter, these requirements could be satisfied.

- Total of 24 - 6” ports:➪
  - X-ray arrays 12 6” ports
  - Bolometry arrays 3 6” ports
  - Spectroscopy - VB array 1 6” ports
  - Visible, UV spectroscopy 4 6” ports
  - Future use 4 6” ports



Thomson Scattering

- Best geometry would be a midplane radial laser beam in a symmetry plane.
- Viewing could be best from above or below. Next best on midplane toroidally displaced from laser
- Beam dump would require small (~ 2” ID x 6” deep) inward extension of vacuum vessel into shell opposite laser beam
- Laser input tube (4” dia.) extends radially outward along beam to window ~ 3 m from vessel
- Port requirements:
  - Laser input tube 2.75”
  - Viewing port 10”
  - Shutter drive 2.75”



Microwave Diagnostics

- ECE diagnostic and reflectometry
  - Preferred geometry - Outer midplane at symmetry plane
  - 4 - 6” ports needed
  - Edge reflectometer should be designed into RF antenna

- Microwave interferometer (possibly FIR system)
  - Opposing views needed on line through plasma core - preferably midplane
  - 2 - 4.5” ports needed

- As future upgrade, may want to consider FIR interferometer/polarimeter with many sightlines in a poloidal plane. (See future needs)

Other Diagnostics Requiring Extensions Beyond TF

- X-Ray Pulse Height Analyser and Neutral Particle Analyser
  - Require vacuum flight tubes extending outside TF with valve, bellows, break, etc. Each will have dedicated pumping system
  - Horizontal or vertical flight tubes preferred.
  - Each needs 6” port

- Fast Scanning Edge Probe and Fast Ion Loss Probe
  - Probes with a 18-24”travel, horizontal preferred
  - Valve, bellows, break, etc. Dedicated pumping systems may be needed.
  - Positioned where the probe drive mechanisms can extend normal to the plasma surface and avoid the TF coils and other structures for a distance of ~ 2 meters from the vessel.
  - Require 6” ports

Preliminary Diagnostic Port Requirements

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 “tomography” complement
VB array	1	6	part of “tomography” complement
	1	2.75	will use commercial flapper shutter
bolometer arrays	3	6	part of “tomography” complement
VIPS, SPRED, filterscopes	4	6	part of “tomography” 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

Preliminary Diagnostic Port Requirements (cont'd)

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 "tomography" complement
	4	6	initially blanked
	2	8	initially blanked
	2	10	initially blanked
total	102		

NCSX Diagnostic Access - Summary

- To accommodate the diagnostics previously established, and provide some capability for adding new measurements, approximately 100 diagnostic ports are needed for NCSX with sizes:

  46 - 2.75” 12 - 4.5” 31 - 6” 6 - 8” 5 - 10”

- Many of these ports have specific geometrical requirements.

- Suggestions to ease spatial constraints on diagnostic access:
  - Use tight fitting, conformal cryostat
  - Permit diagnostic access ports to cross shell dielectric breaks
  - Remove or move some of the outer PF coils
  - Reserve some room on large midplane slots for diagnostics

- Numerous spatial constraints in the current design make diagnostic access a challenging problem which we have only started addressing.