WBS3 Diagnostics Planning Update

Presented by B. Stratton

with input from T. Brown, M. Cole, E. Fredrickson, R. Feder, P. Goranson, L. Guttadora, D. Johnson, E. Lazarus, A. Nagy, B. Nelson, H. Takahasi, and M. Zarnstorff

NCSX Engineering Telecon

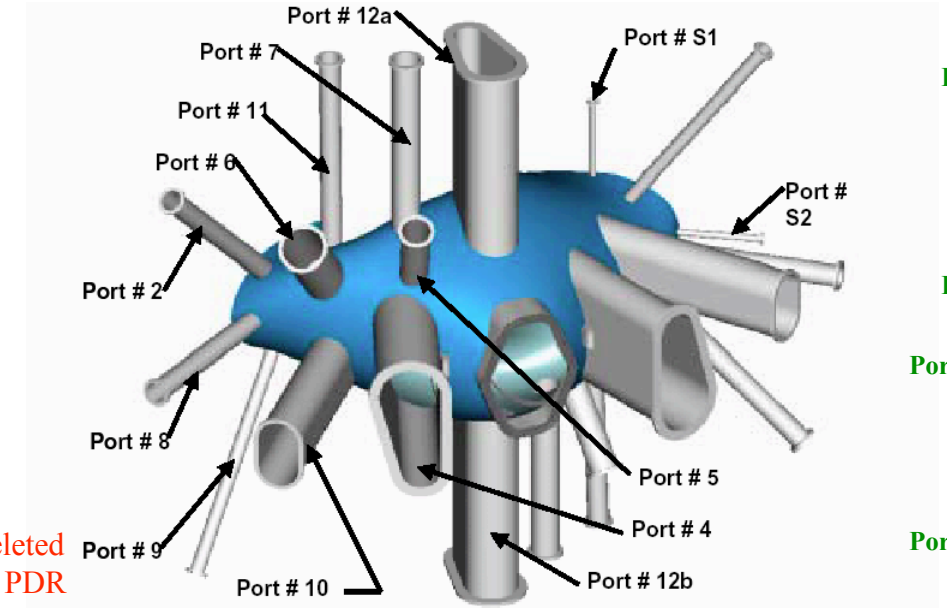
7-30-03

Topics

1. Progress on vacuum vessel port modifications relevant to diagnostics
2. Proposed port naming scheme and diagnostics port assignments
3. Electrical feedthrough requirements for diagnostics
4. Concepts for equilibrium magnetics diagnostics
5. In-vessel space requirements for SXR arrays

Changes in vacuum vessel ports since CDR design

CDR Design



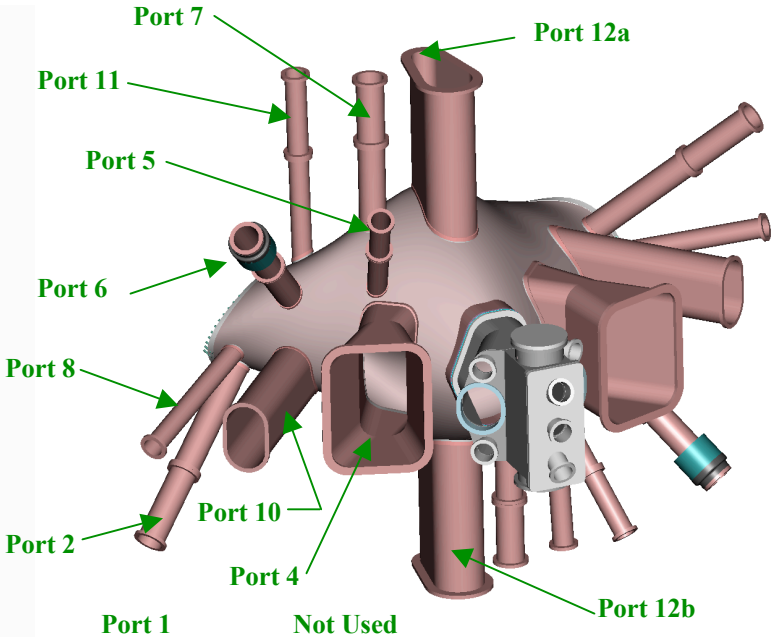
Deleted on PDR

Table 4 Vacuum Vessel Port Dimensions

Port ID	No. per period	O.D. (inches)	total	Port ID	No. per period	O.D. (inches)	total
2	2	4 .	6	10	2	6 x 6 x 8	6
4	2	12 x 18 x 23.25	6	11	2	6	6
5	2	8	6	12	2	9 x 15 x 17.25	6
6	2	12	6	Neutral Beam	1	33 x 23	3
7	2	8	6	S1	2	2	6
8	2	6	6	S2	1	2	3
9	2	6	6	Total number of ports			72

M. Cole

PDR Design



Port 1 Not Used
Port 2
Port 3 Not Used
Port 4
Port 5
Port 6
Port 7
Port 8
Port 9 Deleted
Port 10
Port 11
Port 12

TABLE

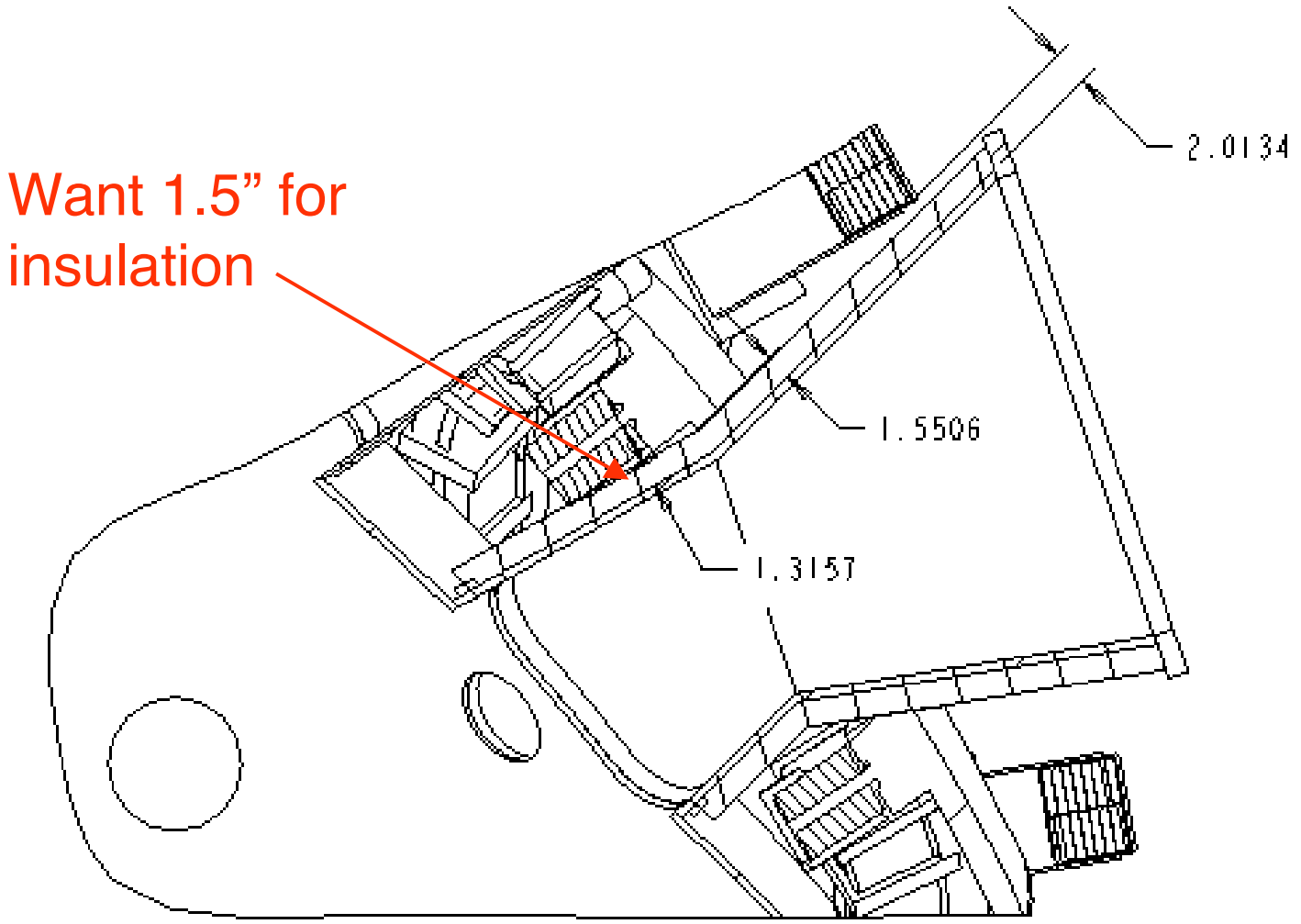
TBD

20030509-cdr-vs-pdr.ppt

Changes to VV design affecting diagnostics

- Several small ports eliminated
  - No major impact on diagnostics
- Changed diameter of some circular ports
  - Increase diameters of ports 2 and 5? (M. Cole)
- Flared port 4 incorporated into VV model
  - Reshape top of port to provide clearance for modular coil insulation-do when changes to coils are finished (M. Cole)
- Can port 10 be flared as well? (R. Feder)
- Reviewed diagnostics port assignments in light of port changes
- Proposing new port naming scheme

Port 4 sections 8-12 inches above midplane show small interference with insulation

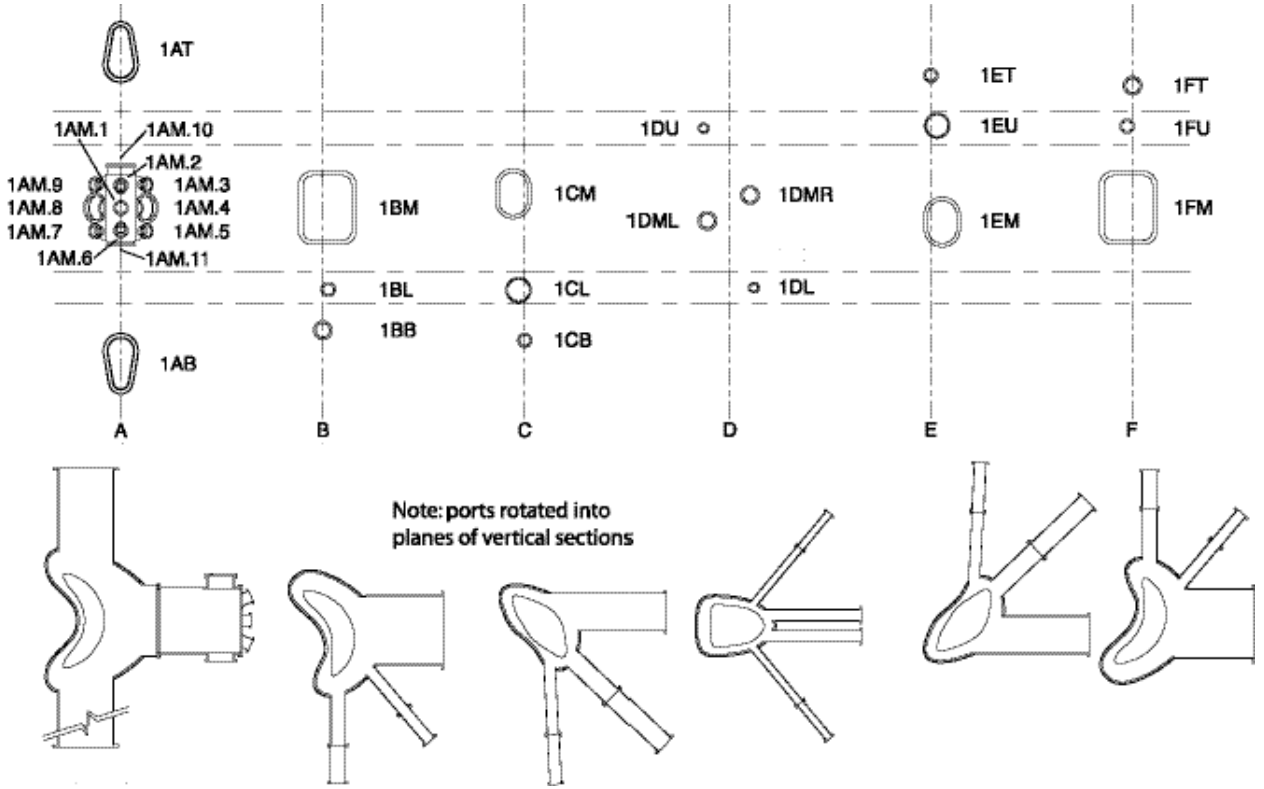


M. Cole

Proposed Port Naming Scheme

- Take advantage of repeated port pattern in each vacuum vessel period:
- Port names look like 1AM.3
  1. Leading number denotes period (1, 2, 3)
  2. First letter denotes bay within period (A…F)
  3. Second letter denotes vertical position within bay (T: top, U: upper, M: midplane, L: lower, B: bottom)
  4. For port covers that have more than one port, number after period denotes specific port on port cover
- Following three slides show concept along with present diagnostics port assignments
  - Make into a controlled document

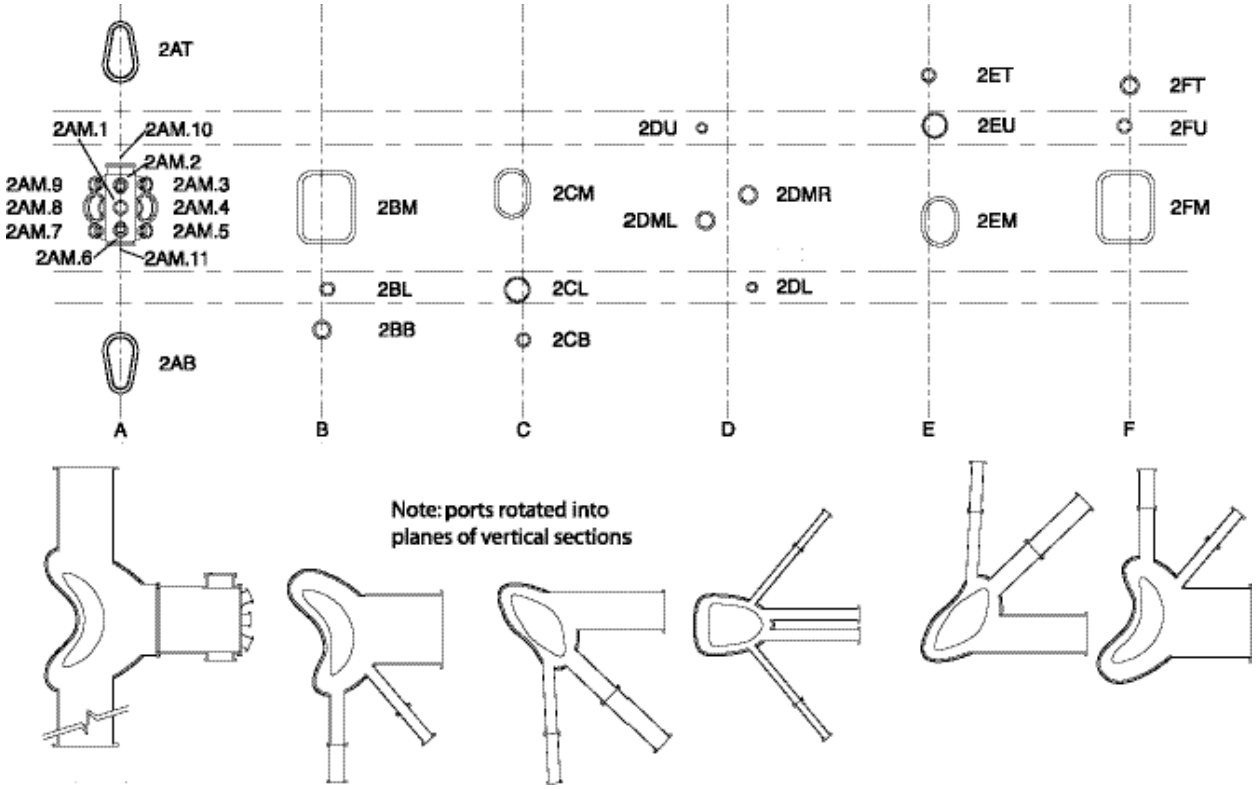
Period 1



A			B	C	D		E	F
	1AT div. bolometer div. camera						1ET equilib. magn. (120 MI)	1FT
	1AM.10				1DU Mirnov coils (90 tp)		1EU	1FU Mirnov (20 tp) thermo (15 tp)
1AM.9 thermocouples (45 tp)	1AM.2	1AM.3						
1AM.8 heating neutral beam	1AM.1 1 mm interferometer	1AM.4 heating neutral beam	1BM fluctuation diag. (BES)	1CM	1DML SXR arrays (180 tp)	1DMR SXR arrays (180 tp)	1EM 1-D filtered (H□, C) camera	1FM CHERS/MSE & He CHERS
1AM.7 fast pressure gauges	1AM.6 divertor UV spectrometer	1AM.5						
	1AM.11 vacuum pump, ion gauge		1BL core UV spectroscopy	1CL visible spectroscopy		1DL fast pressure gauges		
	1AB div. Bolometer div. IR camera		1BB glow probe & 2 filaments (5 c)	1CB equilib. magn. (120 MI)				

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor

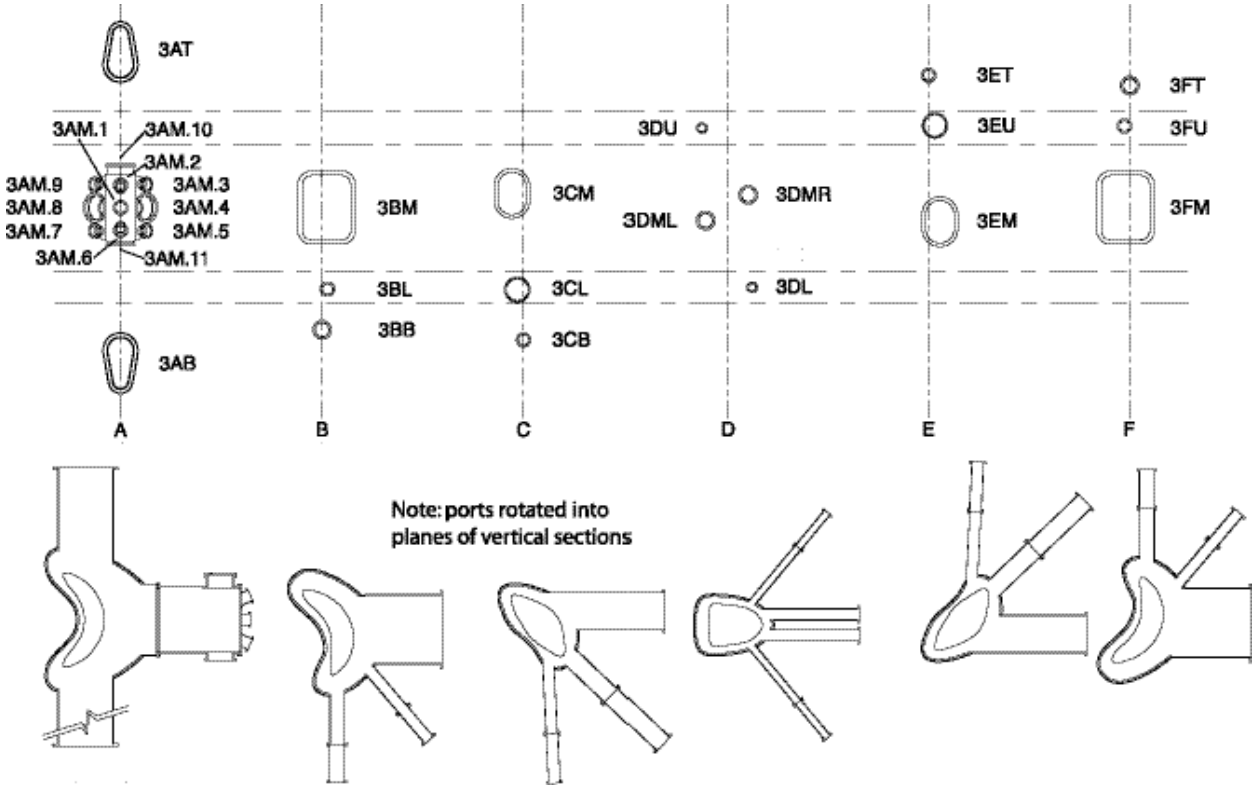
Period 2



A			B	C	D		E	F
	2AT MPTS dump, divertor TS						2ET equilib. magn. (120 MI)	2FT fluctuation diag. (HIBP?)
	2AM.10				2DU Mirnov coils (90 tp)		2EU	2FU Mirnov coils (20 tp)
2AM.9 thermocouples (15 tp)	2AM.2 visible filterscope	2AM.3						
2AM.8 visible camera	2AM.1 diagnostic neutral beam	2AM.4 visible camera	2BM MPTS view	2CM e-beam mapping probe	2DML SXR arrays (180 tp)	2DMR SXR arrays (180 tp)	2EM visible filterscopes	2FM fluctuation diag. (HIBP?)
2AM.7 fast pressure gauges	2AM.6 visible filterscopes	2AM.5 divertor visible camera						
	2AM.11 vacuum pump, ion gauge		2BL core bolometer	2CL fast scanning edge probe		2DL fast pressure gauges		
	2AB MPTS laser, divertor TS		2BB glow probe & 2 filaments (5 c)	2CB equilib. magn. (120 MI)				

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor

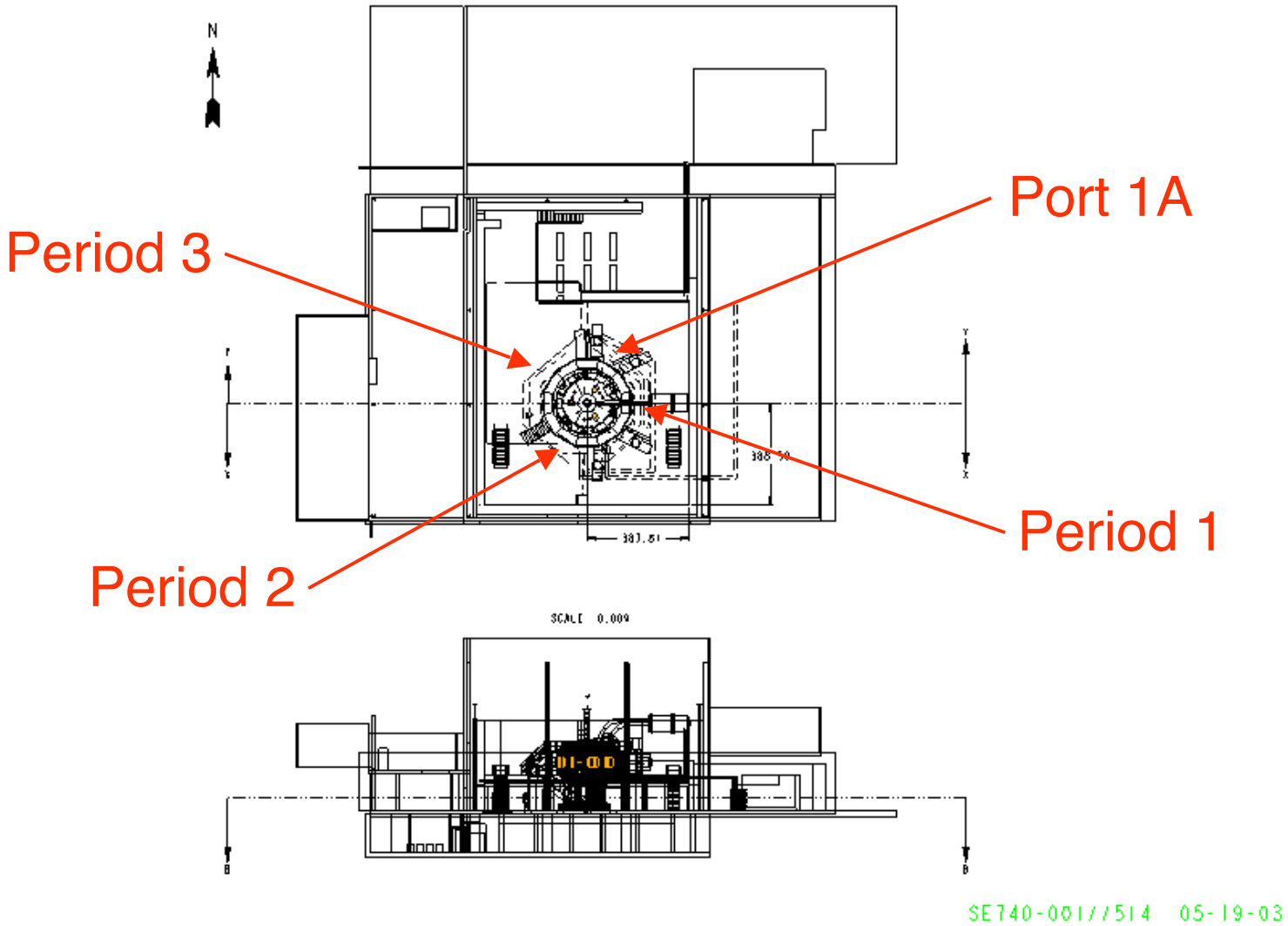
Period 3



A			B	C	D		E	F
	3AT FIR interf./polarim.						3ET equilib. magn. (120 MI)	3FT
	31M.10				1DU Mirnov (90 tp) thermo. (30 tp)		3EU	3FU Mirnov coils (20 tp)
3AM.9 thermo. (15 tp) Lang. Pr. (50 c)	3M.2	3AM.3 fast IR camera						
3AM.8 visible camera	3AM.1 X-ray crystal spectrometer	3AM.4 fast tang. X-ray camera	3BM neutral particle analyzer	3CM	1DML SXR arrays (180 tp)	1DMR SXR arrays (180 tp)	3EM fluctuation diagnostic	3FM e-beam mapping target
3AM.7 fast pressure gauges	3AM.6 X-ray crystal spectrometer	3AM.5						
	3AM.11 vacuum pump, ion gauge		3BL fast ion loss probe	3CL movable Langmiur probe		1DL fast pressure gauges		
	3AB FIR interf./polarim.		3BB glow probe & 2 filaments (5 c)	3CB equilib. magn. (120 MI)				

Electrical feedthroughs: tp=twisted pair, MI=mineral insulated cable, c= single conductor

Propose labeling ports clockwise starting on north side of machine



Large number of electrical feedthroughs needed for diagnostics

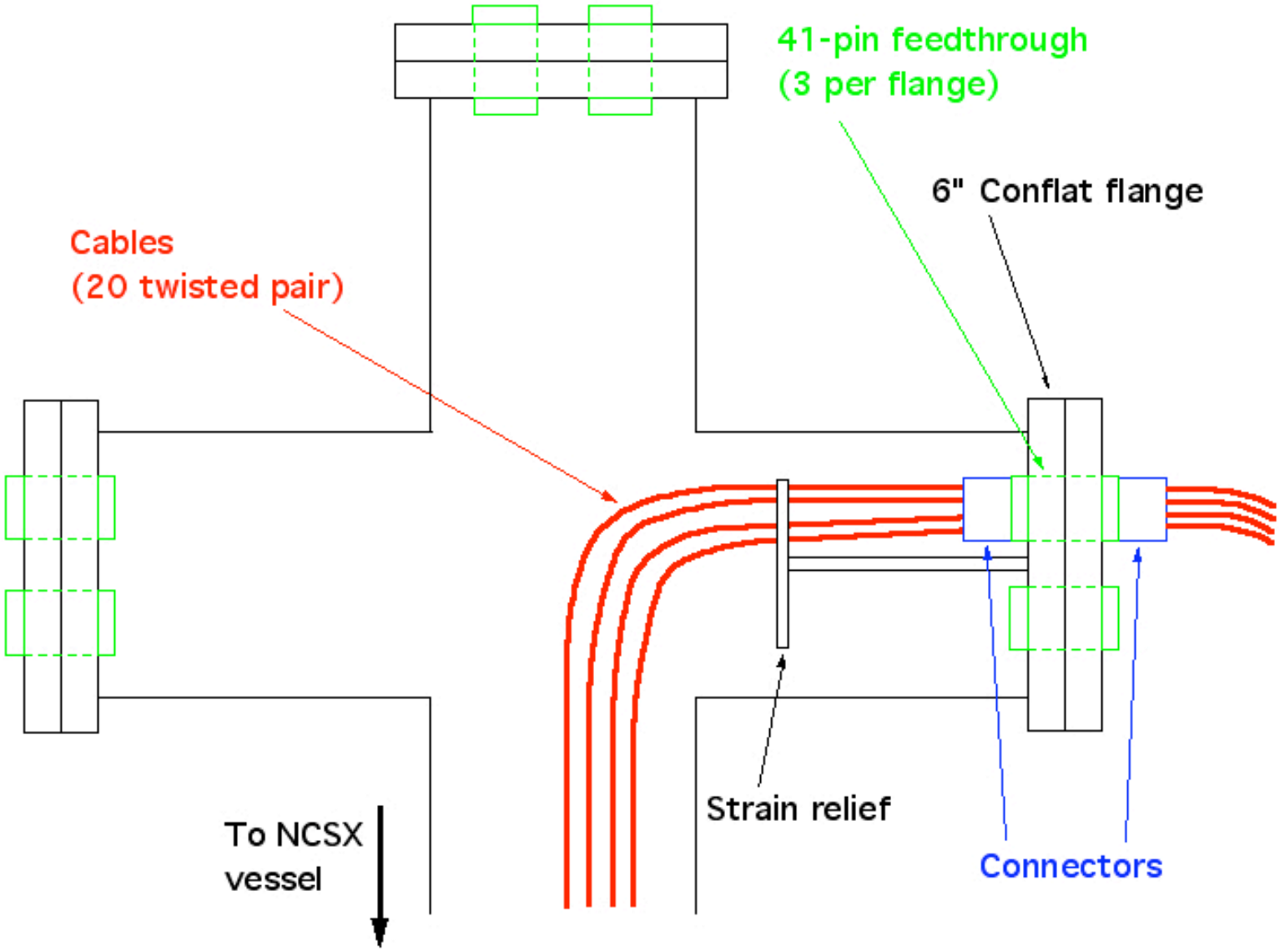
(Liquid and gas feedthroughs not included)

Diagnostic	# Connections	Comments
Equilibrium magnetics:		
360 probes (120 per period)	**720**	
Mirnov coils:		
126 high-freq. poloidal (2-axis)	504	252 connections if 1-axis
36 high-freq. Toroidal (2-axis)	144	72 connections if 1-axis
6 low-freq. (locked-mode)	12	
Total Mirnov coils	**660**	total=336 if 1-axis high-freq. coils
SXR Arrays:		
phase 3: 160 channels (8 20-channel arrays)	360	45 connections per 20-channel array
phase 4: 160 channels (8 20-channel arrays)	360	(IRD AXUV-20EL chip)
Total SXR arrays	**720**	
GDC probes & filaments:		
1 glow probe and 2 filaments per period	**15**	High current feedthroughs required
Thermocouples:		
30 at v=0 & 30 at v=1/2 cross sections in 1 period	120	
15 per NB strike point X 4 strike points=60	120	
Total thermocouples	**240**	
Langmiur probes:		
50 probes	**50**	
Total electrical feedthrough connections:	**2405**	total=2081 if 1-axis high-freq. coils

Diagnostics electrical feedthrough plan

- Can use existing ports and still meet other diagnostic port needs
  - Alternative of putting feedthroughs on blind ports has drawback that repair/modification on outside is extremely difficult
- Large number of electrical connections can be accommodated on crosses or tees using commercial feedthroughs and conflat vacuum hardware
- Use connectorized feedthroughs to simplify assembly and make repair/modification easier
  - Possible exception: mineral-insulated cable for equilibrium magnetics diagnostics may not use connectors on feedthroughs
- Bundle and strain-relieve cables on both sides of feedthroughs
- Most demanding case is 180 twisted pair cables through 6” O. D. port for SXR arrays: for 1/8” diameter cable, 10% of port cross sectional area is occupied by cables-less in other cases
- 9 41-pin circular feedthroughs (1.5” O. D) can accommodate 180 twisted pair cables-mount 3 on each arm of vacuum cross

Feedthrough tee concept



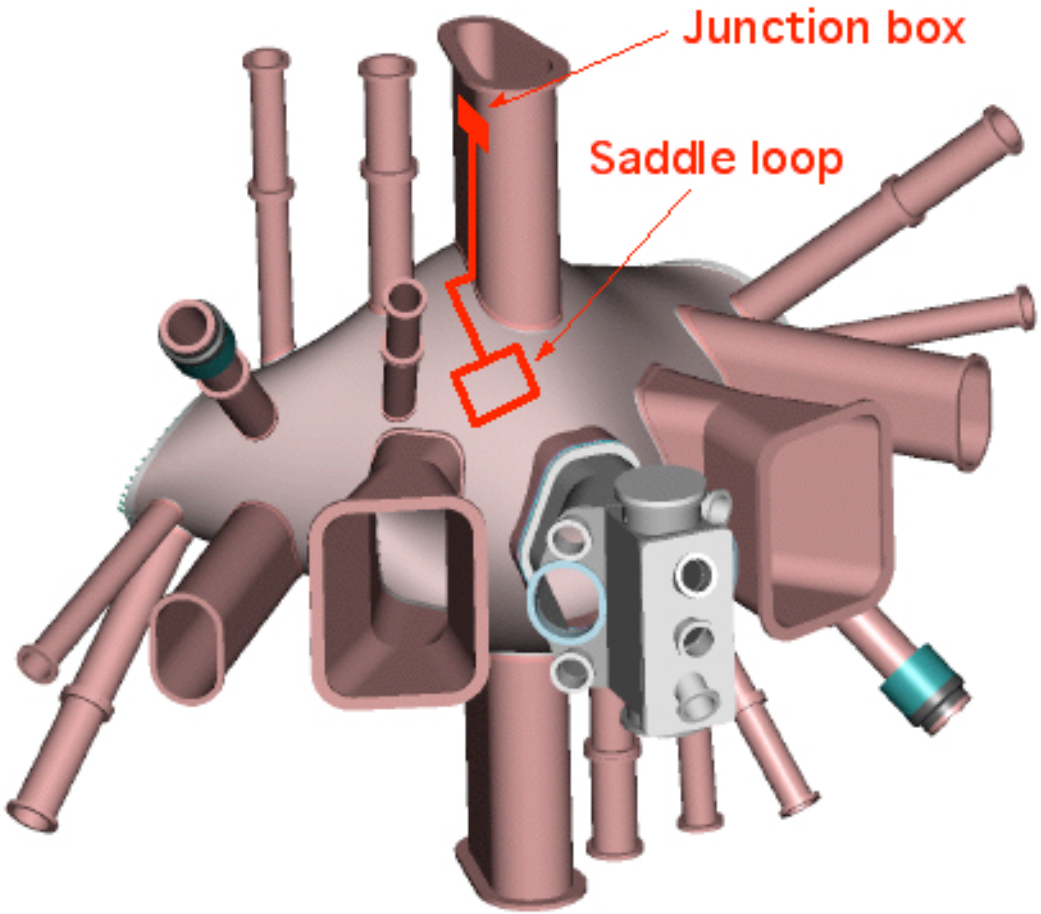
Equilibrium magnetics

- Number of sensors has increased since PDR; modeling study to be completed next winter will provide specific numbers (E. Lazarus)
- Generated ICDs defining requirements for:
  - Co-wound loops on modular and conventional coils
    - To be installed as part of coil fabrication
  - Installation of saddle loops on outer surface of vacuum vessel
    - Issue: clearance with cooling tubes
  - Space envelopes for coils inside vessel
    - Issue: clearance between VV and liner
- Need to re-evaluate installation schedule for internal/external sensors
- Have investigated concepts for
  - Internal coils
  - External saddle loops

Mineral-insulated cable for equilibrium magnetic sensors

- MI cable is coax with solid metal outer jacket and MgO insulator
- Vacuum compatible and tolerant of temperature extremes
- Very reliable in DIII-D internal coils
- Variety of diameters: 1.0-1.5 mm (40-61 mil) used on DIII-D, 0.25 mm (10 mil) diameter used at RFX
- MgO insulator is hydroscopic so ends of cable should be sealed by epoxy potting
- On DIII-D, vacuum seal is made by brazing MI cable to stainless tubes welded into vacuum flange
- Bring terminated MI cables to junction boxes for transition to conventional cables.

External saddle loops



Installation of external saddle loops

- Saddle loops will be installed before installation of cooling tubes on exterior of vessel
- Use template with holes to mark corners of loops
- Attach studs at corners
- Run MI cable around studs to form loop
- Run leads to junction boxes on vertical ports and terminate
- Spot weld thin tabs over MI cable to hold in place
- Install cooling tubes leaving 1/16 inch gap to vessel
- Fill gap with conductive epoxy
- Installation schedule is on critical path; needs to be re-evaluated

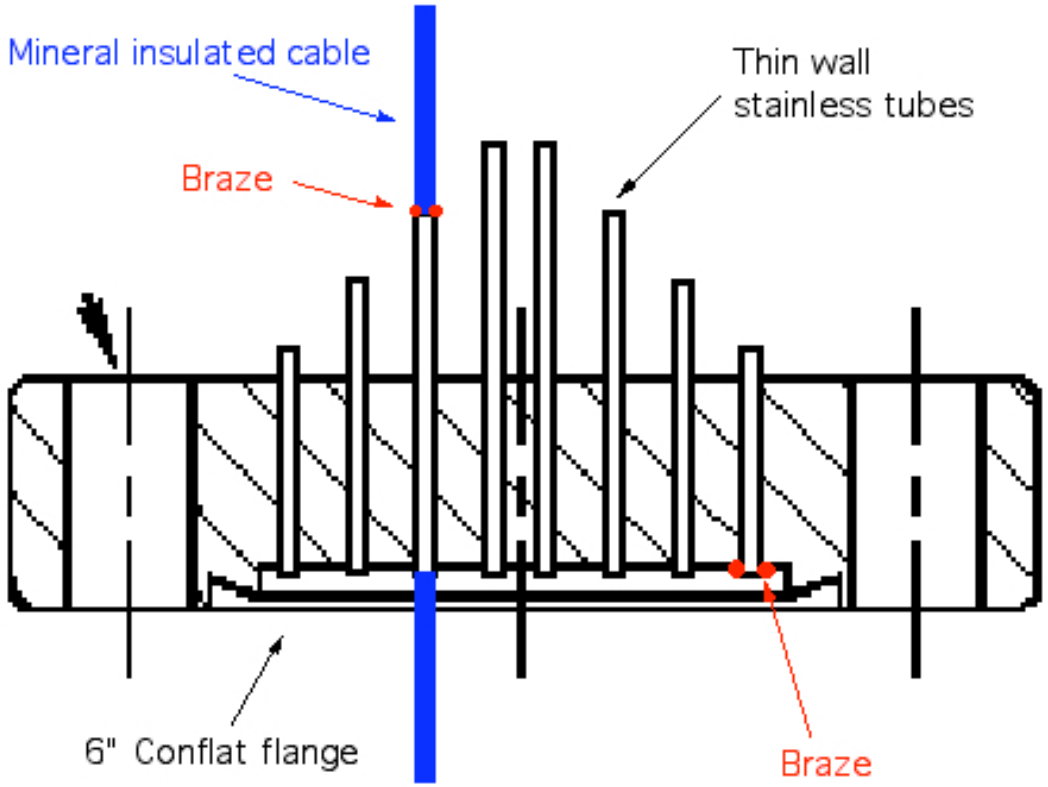
Space envelopes for internal coils

- Before starting design of internal coils, need to know available radial space between inside surface of vacuum vessel and liner. Could be 1 cm or less in some places.
- Compact coils are possible
- May need two coil designs with different radial dimensions

DIII-D magnetic probes

- Made from 1.0-1.5 mm diameter MI cable
- Sturdy design
- Radial build: 2 cm
- Probably too large for some places in NCSX

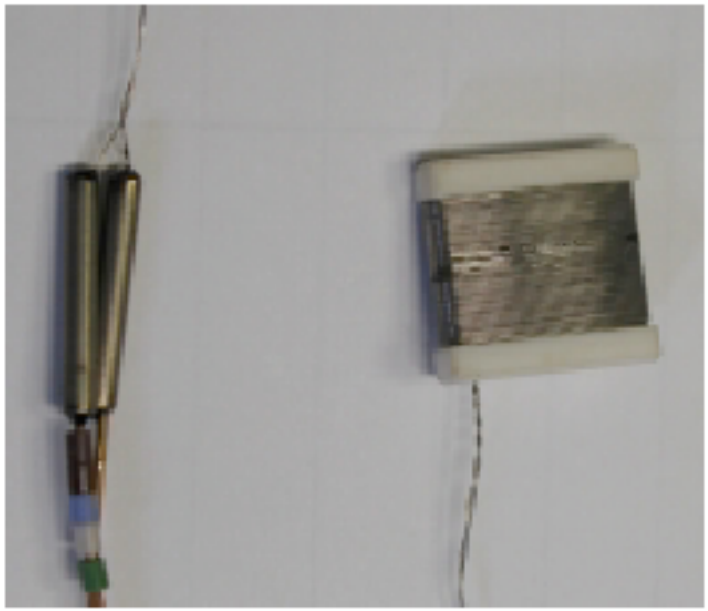
DIII-D mineral insulated cable vacuum flange

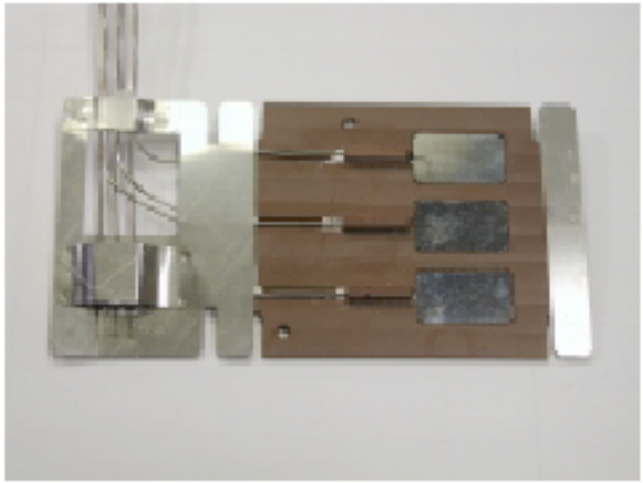


- DIII-D puts 66 MI cables on one 6” Conflat flange
- Terminate on outside using standard connectors

RFX magnetic probes are compact

G. Serianni, et al., 2002 Diagnostics Conference

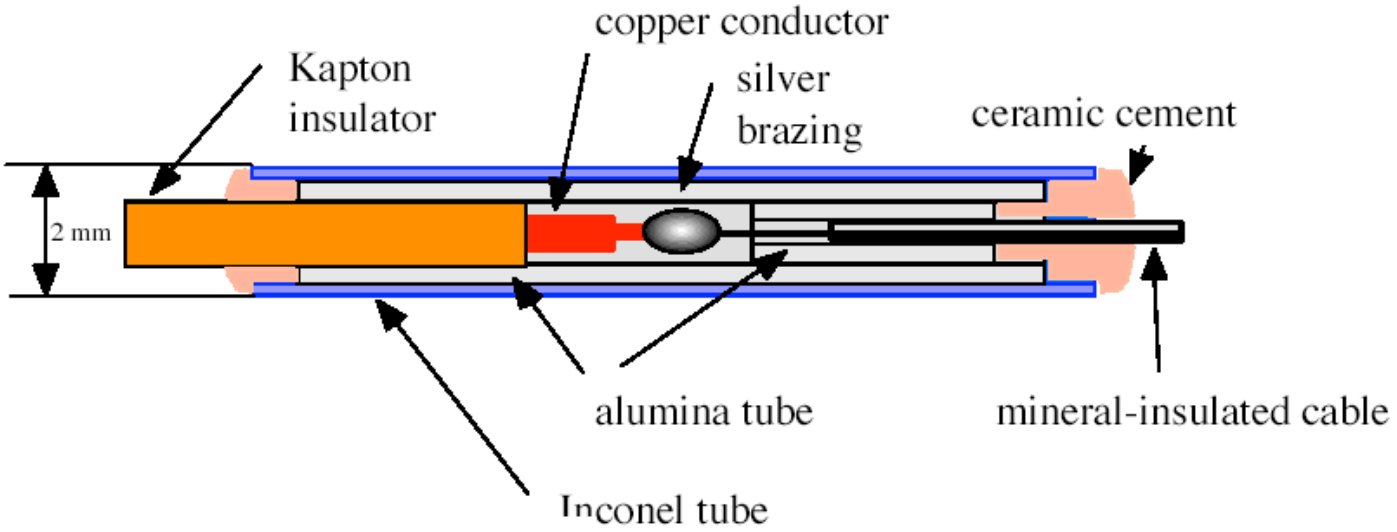


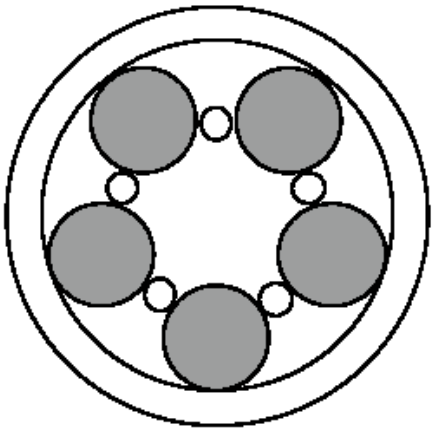


- Ceramic winding form
- Radial build is 5 mm
- 0.25 mm diameter MI cable (too fragile?)
- Transition from MI cable to conventional cable in vacuum allows use of connectorized feedthroughs

Technology for cable terminations

Transition from mineral-insulated cable to conventional cable

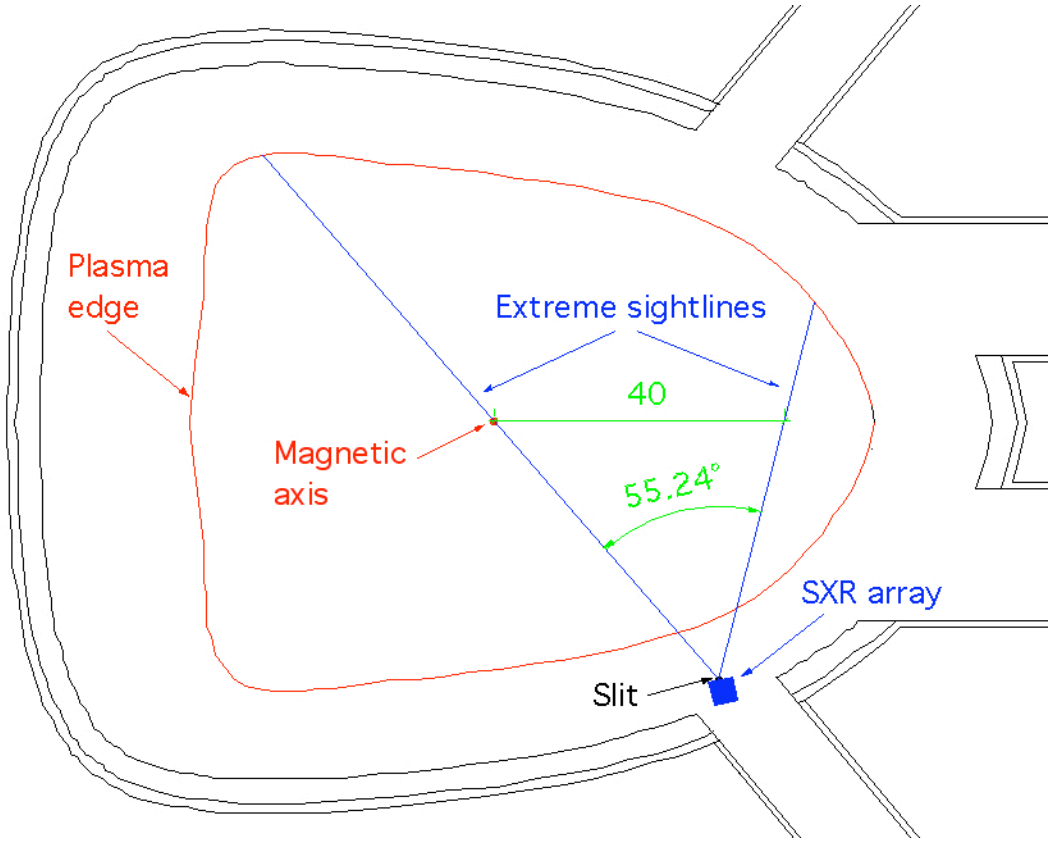




CF63 flange

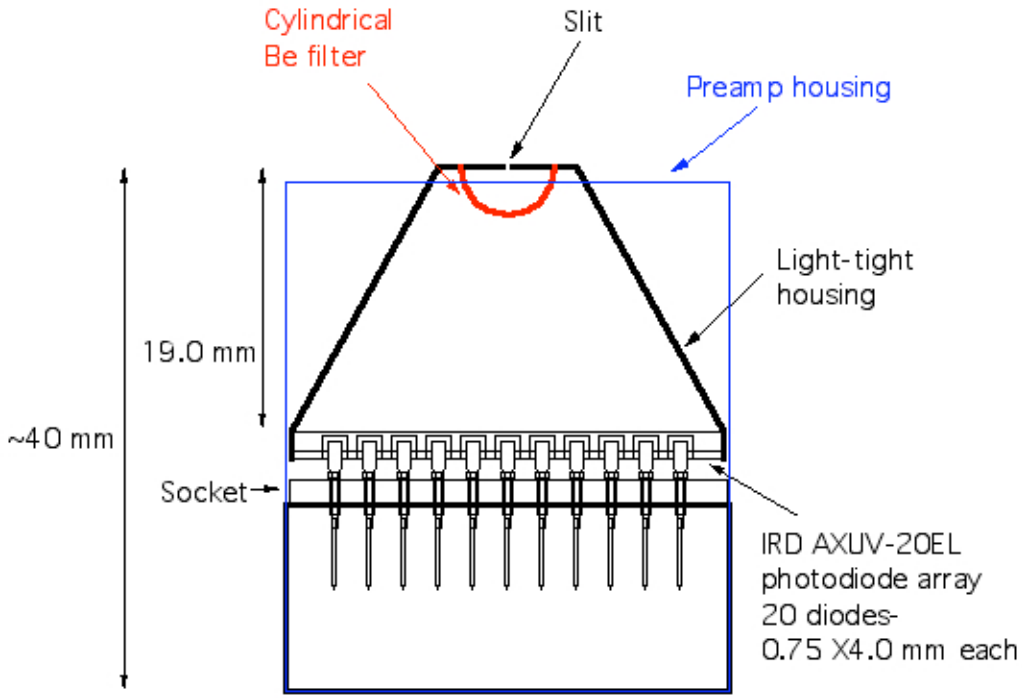
Serianni,et al.

Space envelopes for SXR arrays



- Preferred location for SXR arrays is near bullet-shaped cross section
  - maximizes spatial resolution
- Space envelope determined by desired spatial resolution, need to put preamp in secondary vacuum, and need for cooling

Compact SXR array concept



- Compact array concept requires minimum ~4 cm radial space to give 2 cm spatial resolution in plasma (6 cm radial space required for ~1 cm spatial resolution)
  - Engineering required to determine if array package can be made this small
- Sufficient radial space near vacuum vessel spacers (M. Cole)?
- Interference with RF antennas?