Status of 3-D Analysis, Neutron Streaming through Penetrations, and LOCA/LOFA Analysis

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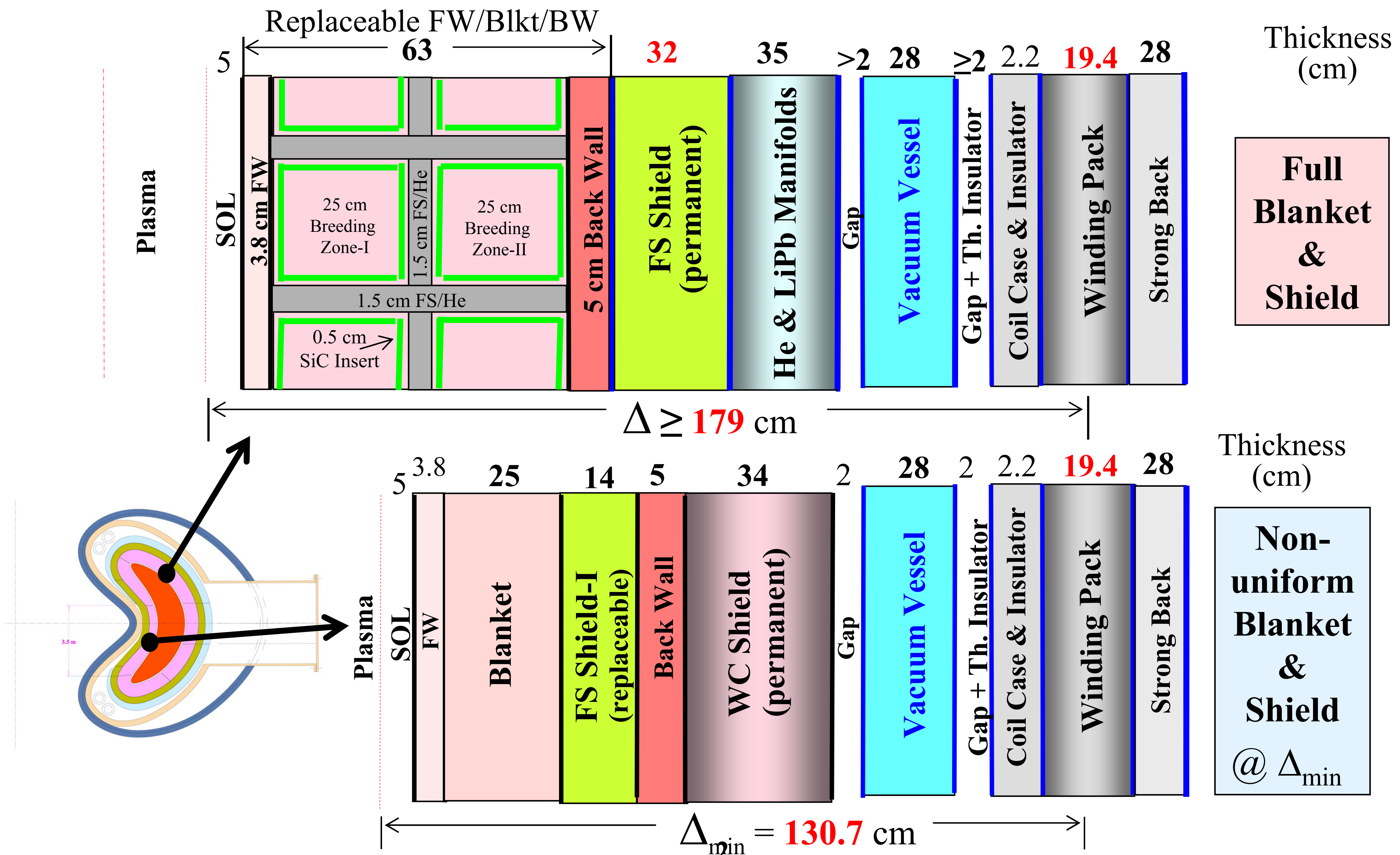
PPPL

Final Radial Build

(http://fti.neep.wisc.edu/aries-cs/builds/build.html)

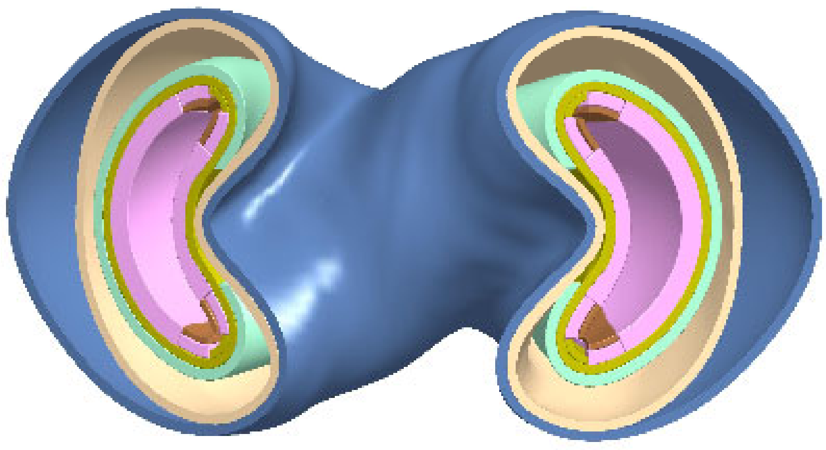
($5.3\ MW/m^2$ Peak NWL)



Status of 3-D TBR Analysis

Purpose: compute overall TBR and M_n

CAD model received from UCSD on 9/19/06 including:
- FW/Blanket/BW
- Shield
- Manifolds
- VV
- Magnet
- Divertor
- No penetrations!



Essential components for TBR and M_n will be included in 3-D model:
- FW/Blanket/BW
- Shield
- Manifolds (continuous)
- Divertor
- ECH ducts (to be added by UW).

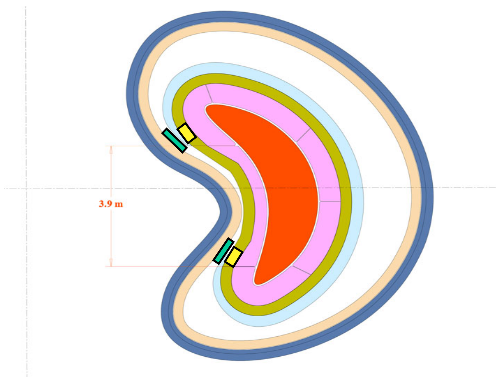
Status of 3-D TBR Analysis (Cont.)

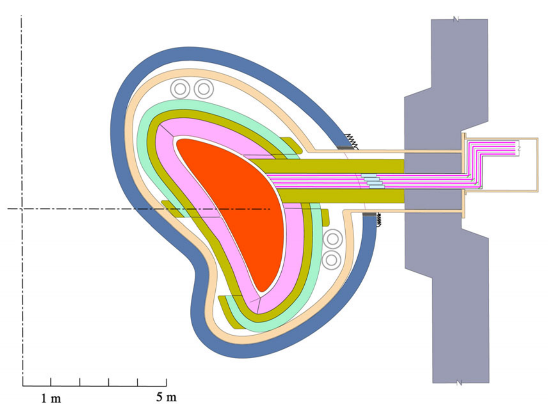
- Complex 3-D problem, requiring many time-consuming iterations.
- UW had difficult time transferring UCSD model into ACIS.
- UW manipulated UCSD geometry to merge properly even though Xueren tried improving accuracy settings in Pro/E.
- Clean model shows no sign of overlapping. **3-D analysis in progress**.
- Future ARIES modeling work should be produced in ACIS*.

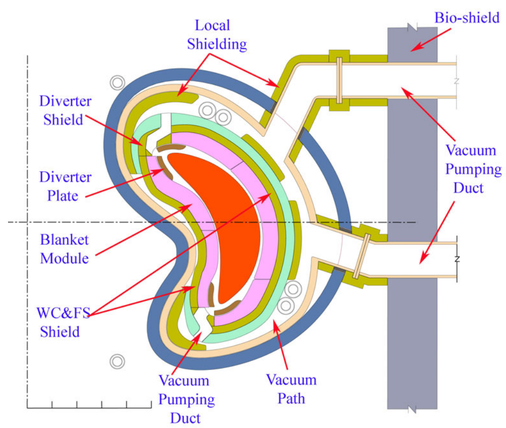
* Commercial solid modeling engine underlying CGM and CUBIT, analogous to what's under Pro/E.

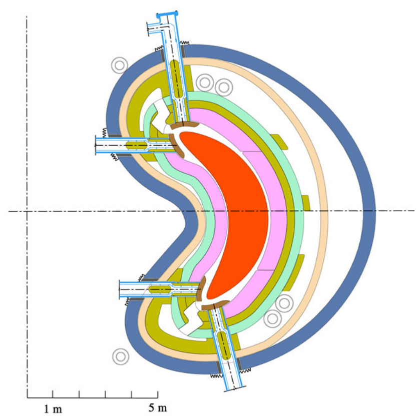
Neutron Streaming through Penetrations

- **Neutron streaming through penetrations compromises shielding performance.**
- **ARIES-CS 7 types of penetrations**:
  - √ – 198 He tubes for blanket (32 cm ID)
  - √ – 24 Divertor He access pipes (~30 cm ID)
  - – 30 Divertor pumping ducts (42 x 120 cm each)
  - – 12 Large pumping ducts (1 x 1.25 m each)
  - – 3 ECH ducts (24 x 54 cm each).
  - – 6 main He pipes - HX to/from blanket (72 cm ID each)
  - – 6 main He pipes - HX to/from divertor (70 cm ID each)
- **Potential solutions**:
  - Local shield behind penetrations
  - He tube axis oriented toward lower neutron source
  - Penetration shield surrounding ducts
  - Replaceable shield close to penetrations
  - Rewelding of VV and manifolds avoided close to penetrations
  - Bends included in some penetrations.







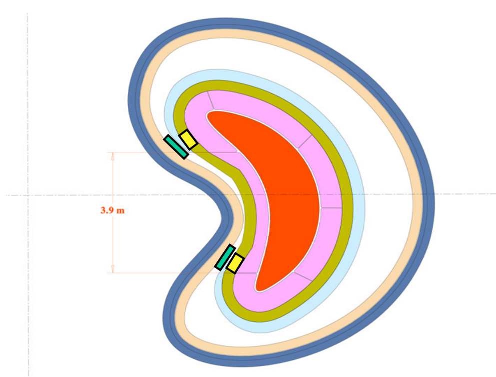


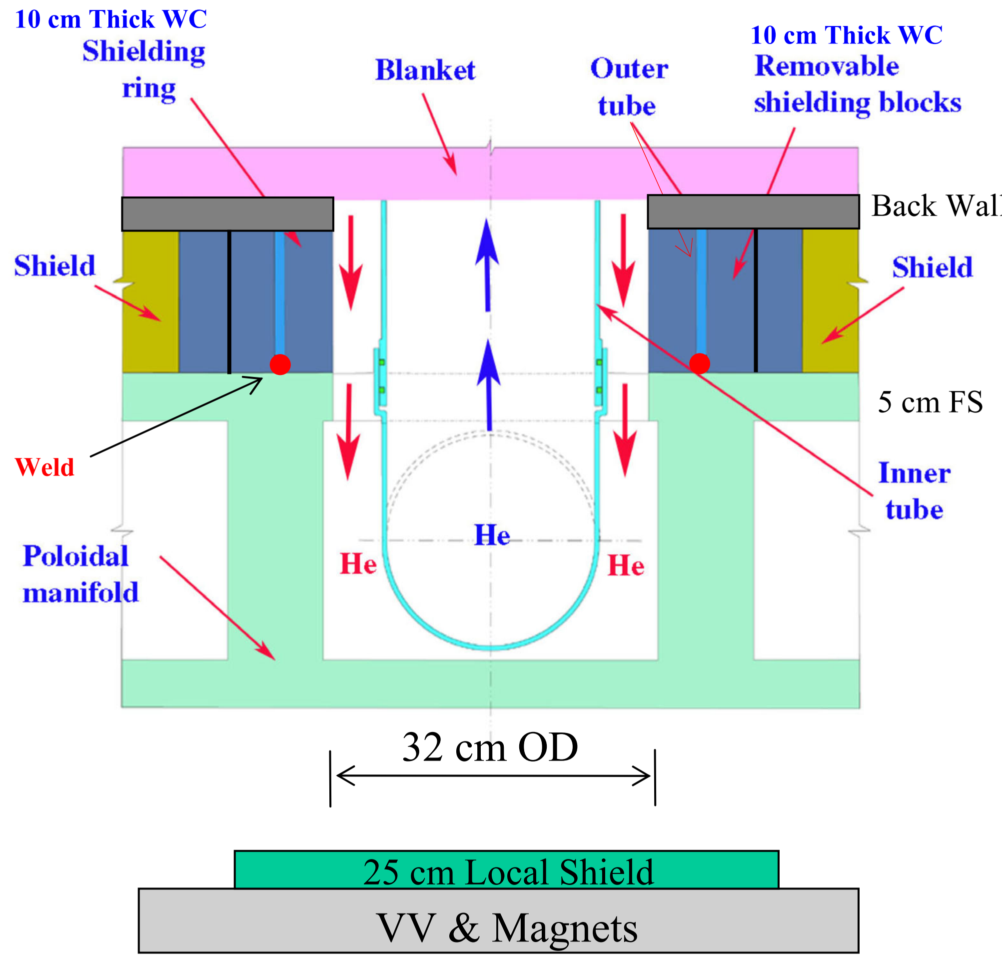
Streaming through Blanket He Tubes
(9/15/05 Presentation)

- 198 He tubes (30 cm ID) connect manifolds to blanket modules.

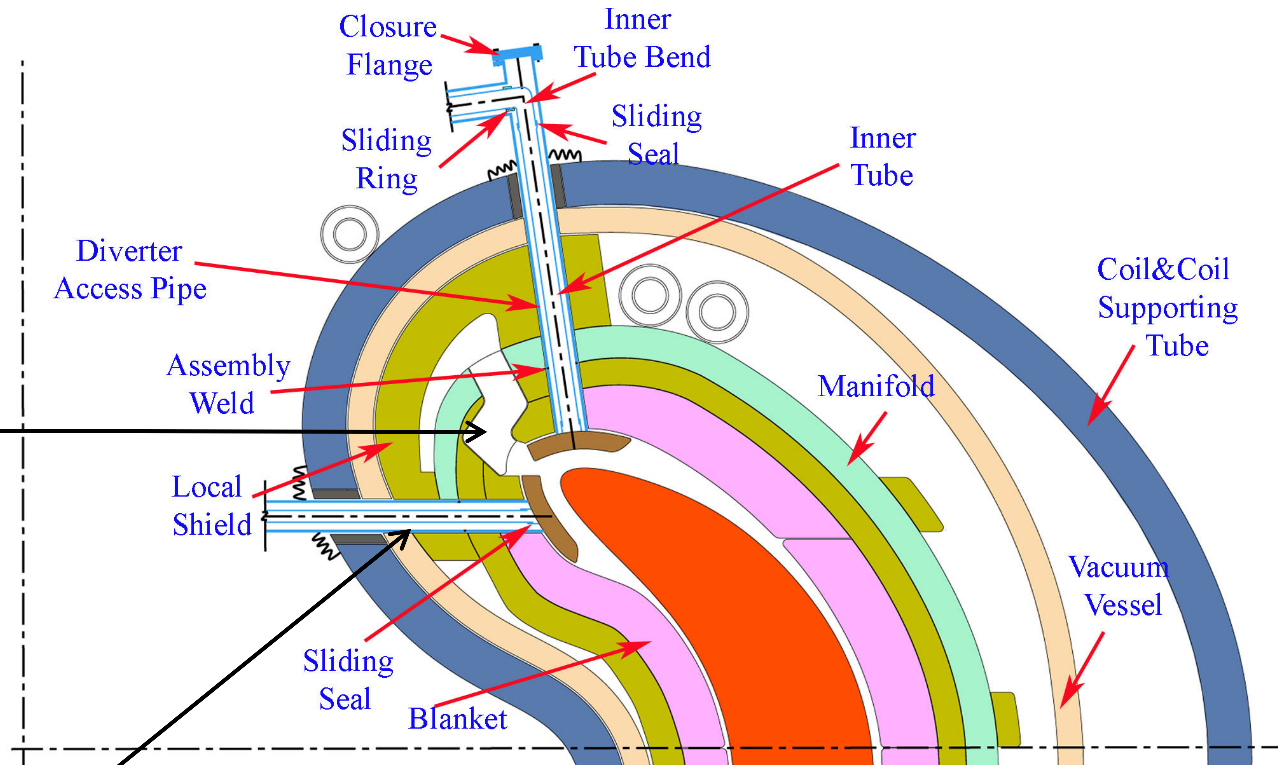
- **2-D results:**
  - High damage at tube wall
  - High damage at VV and magnet behind tubes.

- **Solutions**:
  - Orient tube toward lower n source
  - Avoid welding near tube wall
  - Replaceable shield close to tube
  - Local shield behind tube to protect VV and magnet.





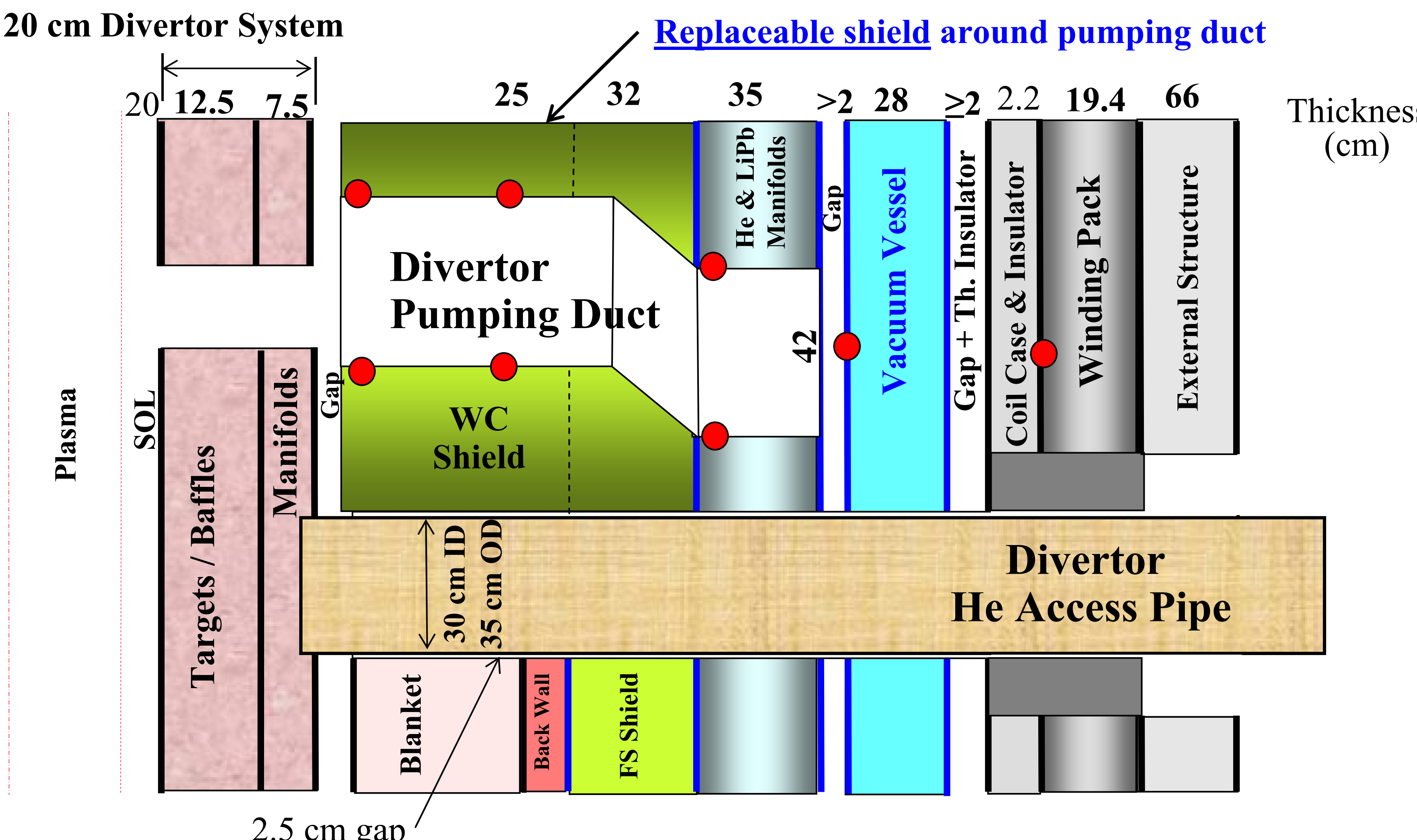
Streaming through Divertor System



30 pumping ducts
(42 x 120 cm each)

24 He access pipes
(~30 cm ID)

Streaming through Divertor Pumping Ducts



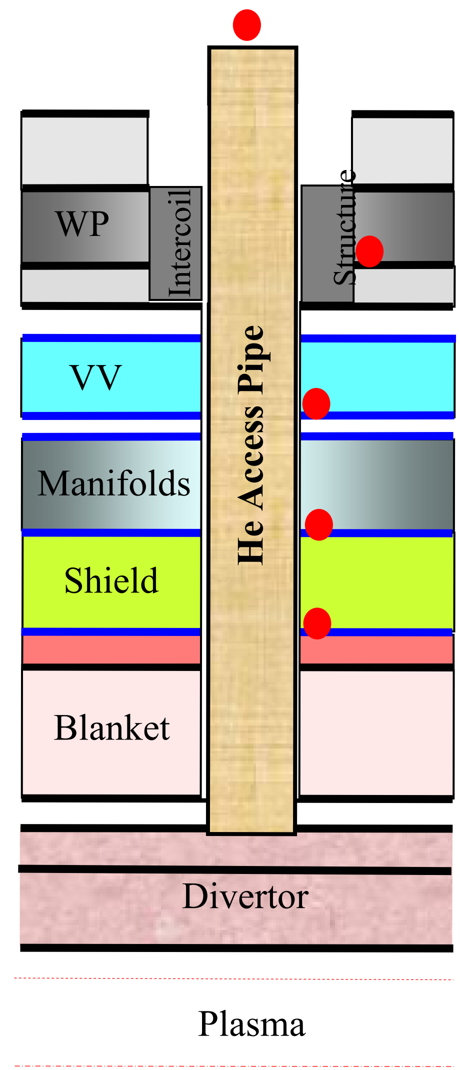
Local shield behind ducts needed to protect VV & magnet

Effect of Streaming through Divertor
He Access Pipes

NWL near pipes= 0.5 - 1 MW/m^2.

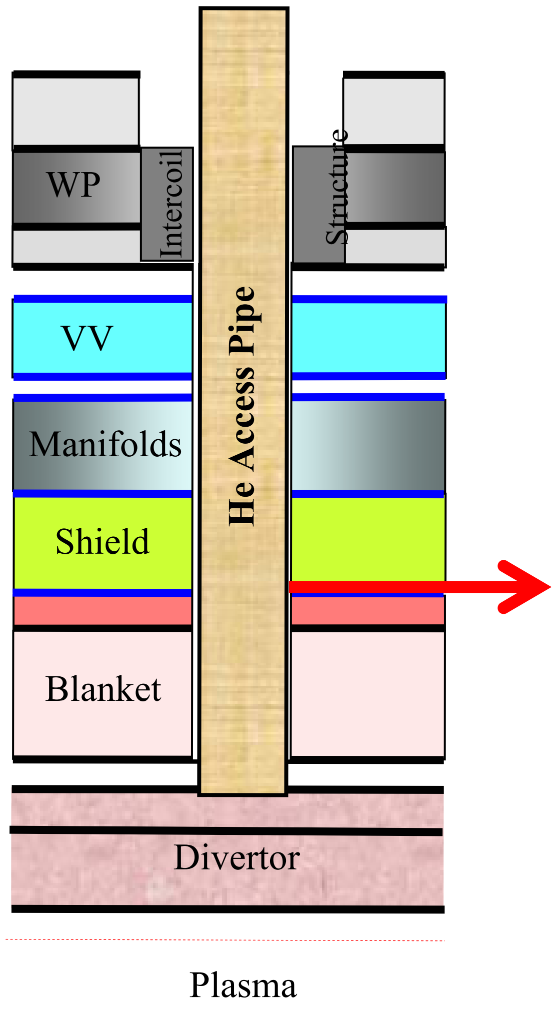
2-D model of pipe estimated:

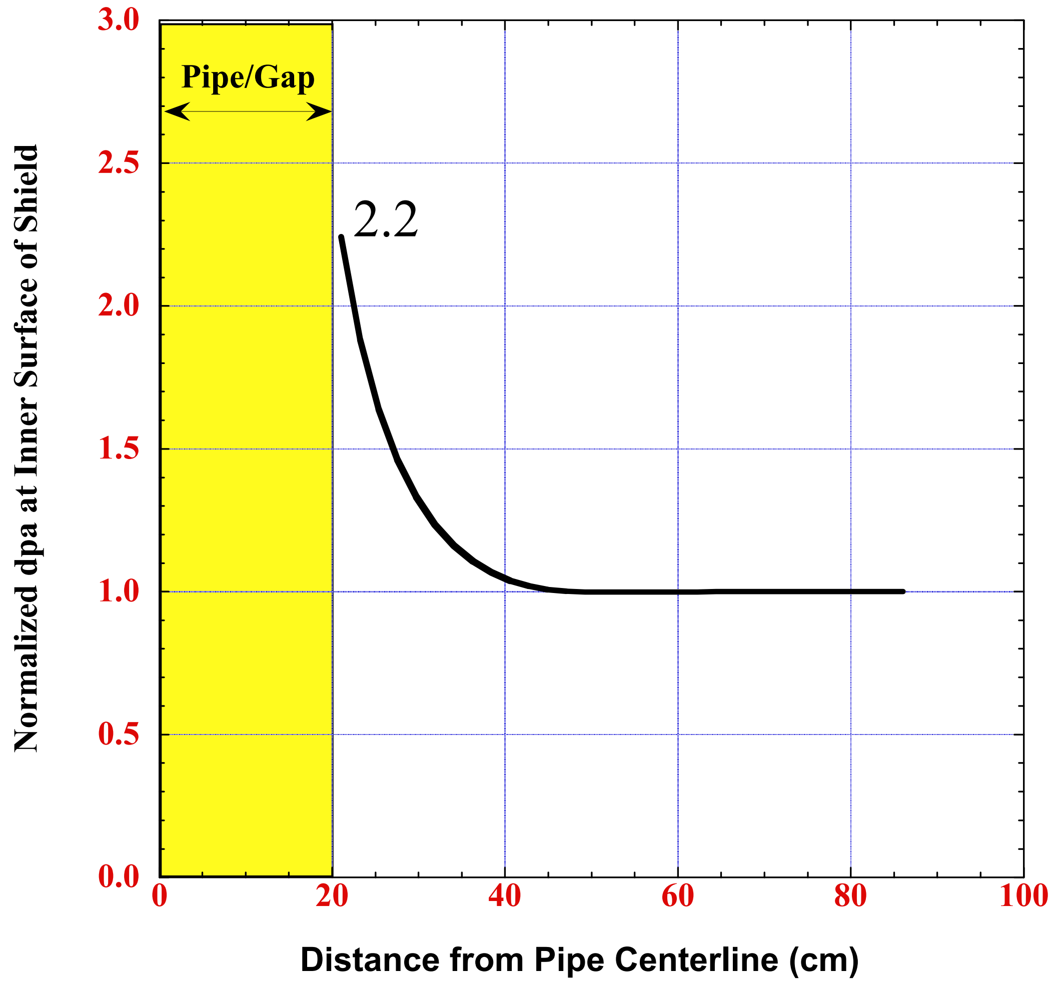
- dpa at shield
- He production at manifolds
- He production at VV
- Fast neutron fluence at WP
- Flux behind pipe
- dpa & He production along pipe wall.



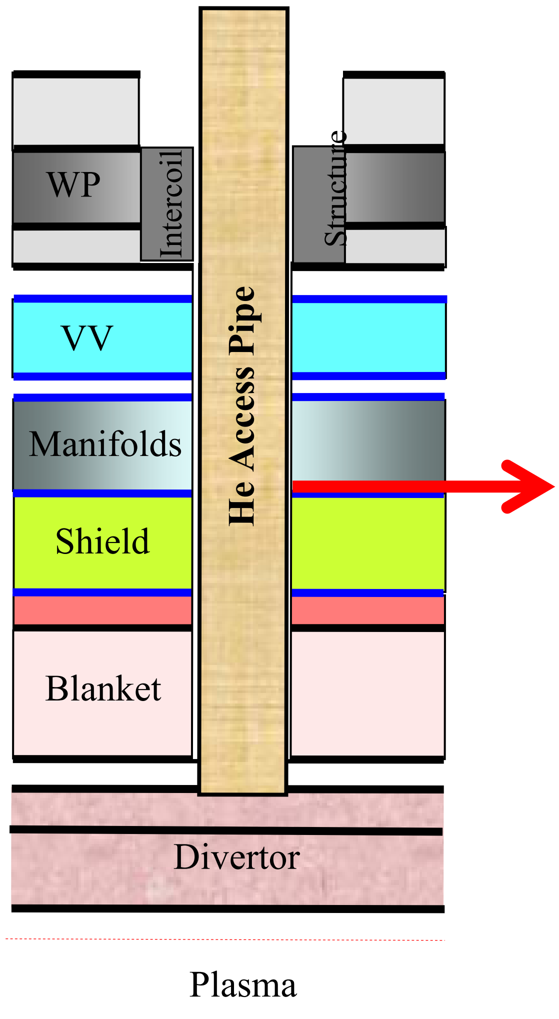
3-D streaming analysis is underway using Attila code.

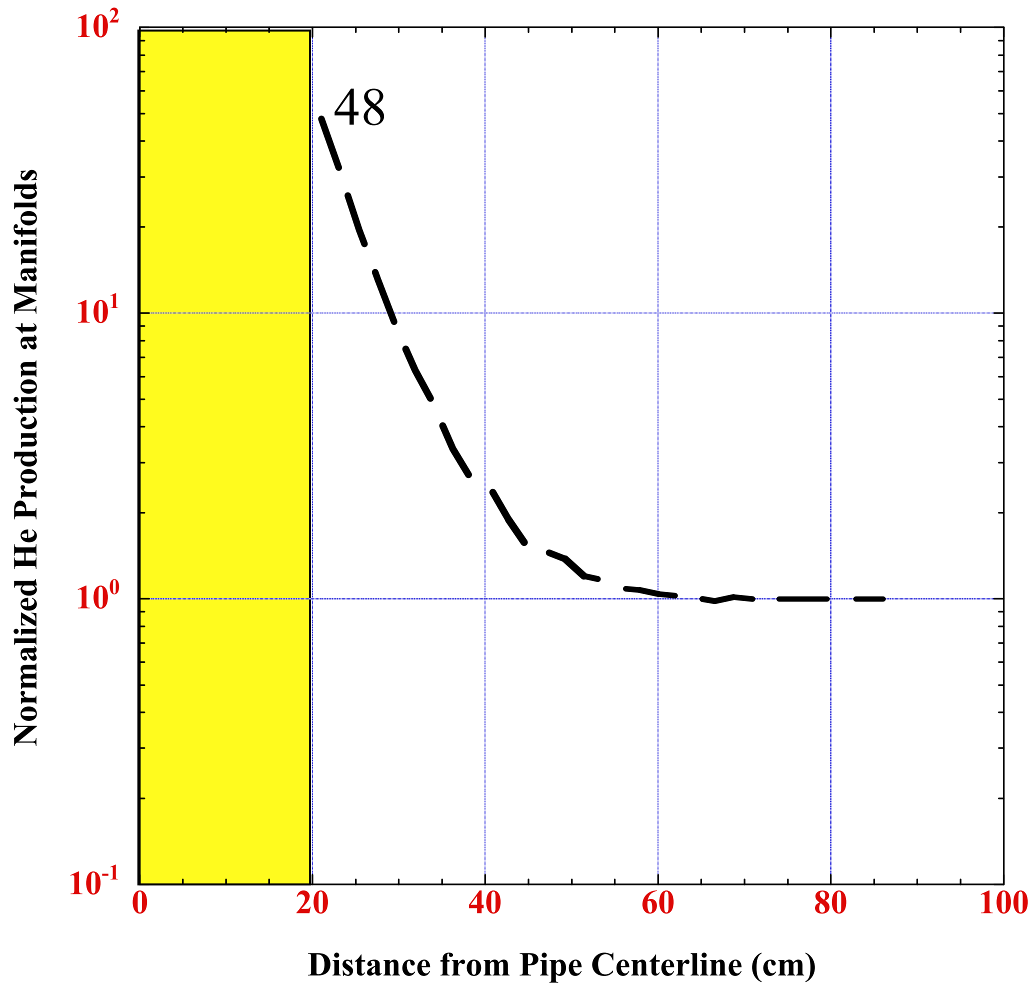
Part of Shield Surrounding Pipe Should be Replaceable



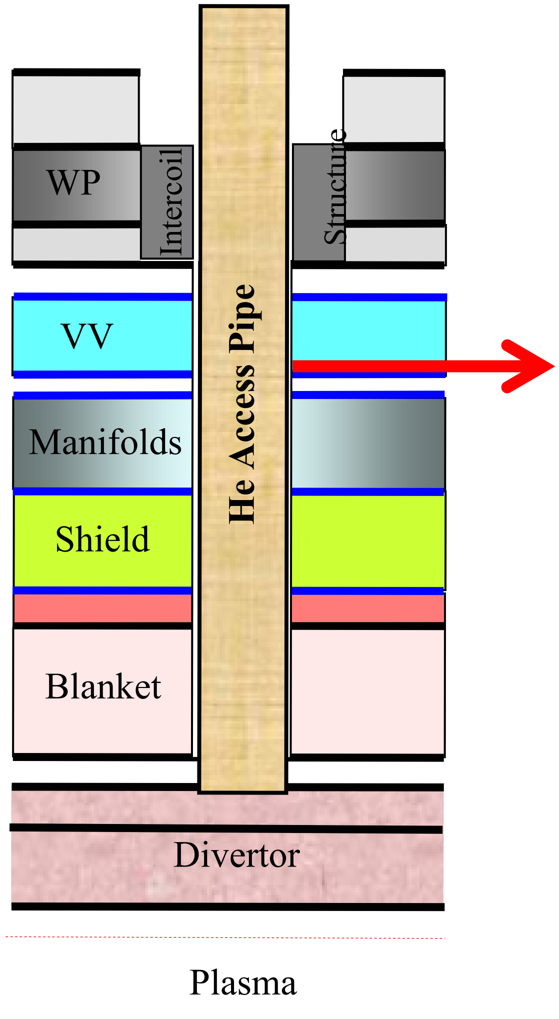


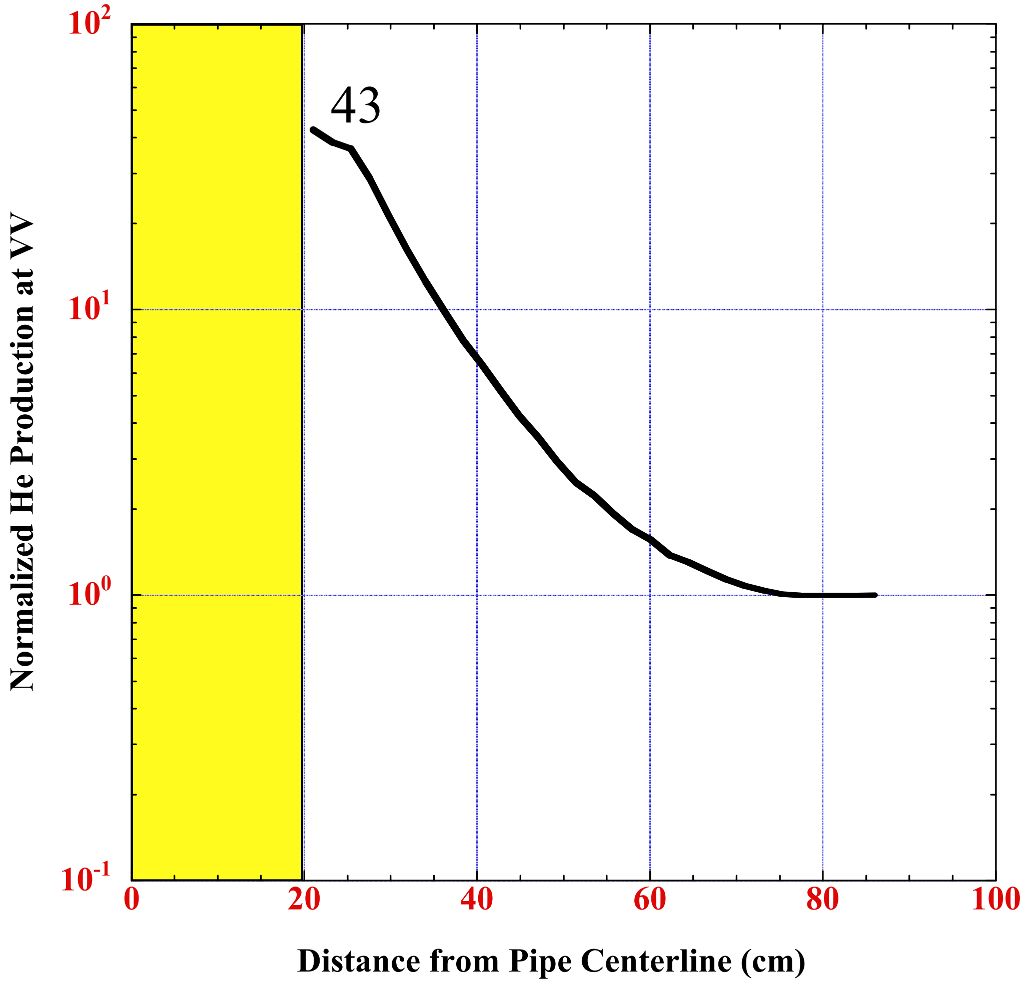
Part of Manifolds Surrounding Pipe Cannot be Rewelded



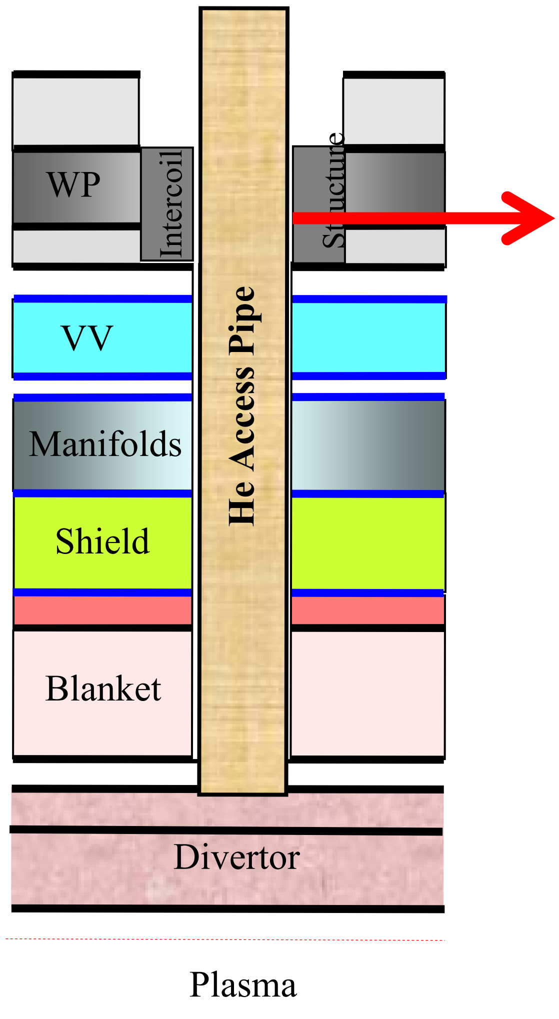


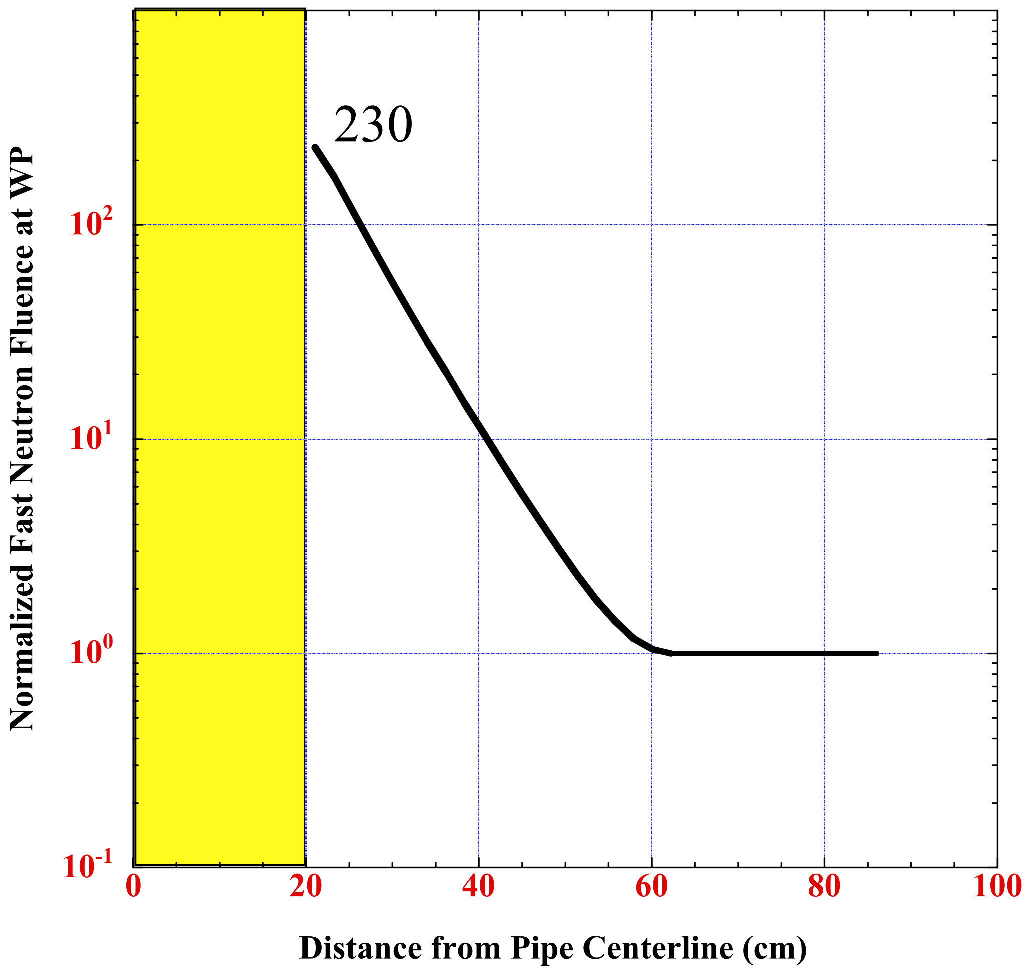
Part of VV Surrounding Pipe Cannot be Rewelded



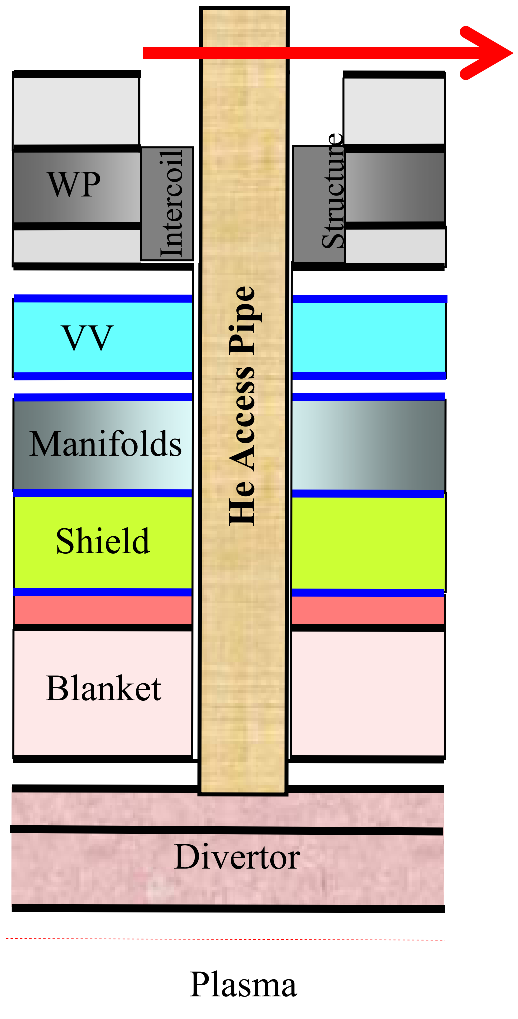


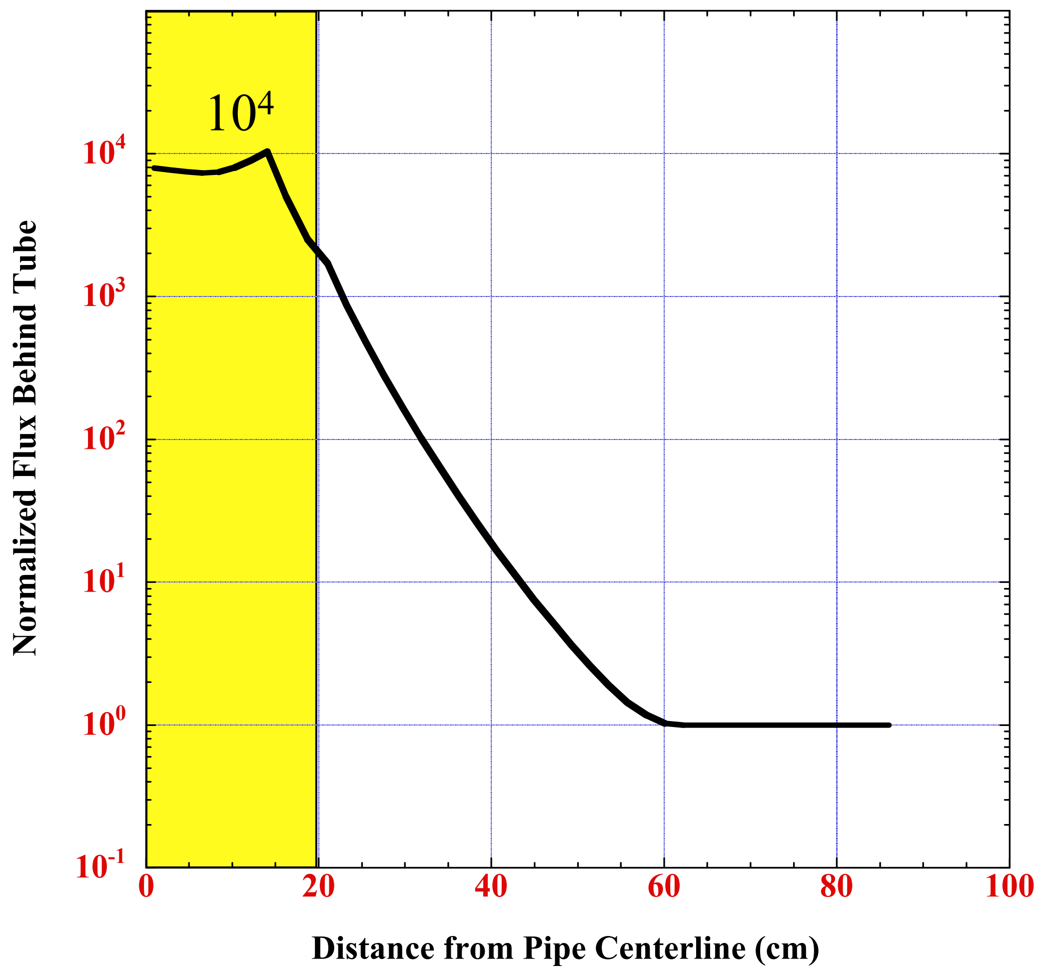
30-40 cm Inter-coil Structure around Pipe Protects Sides of WP



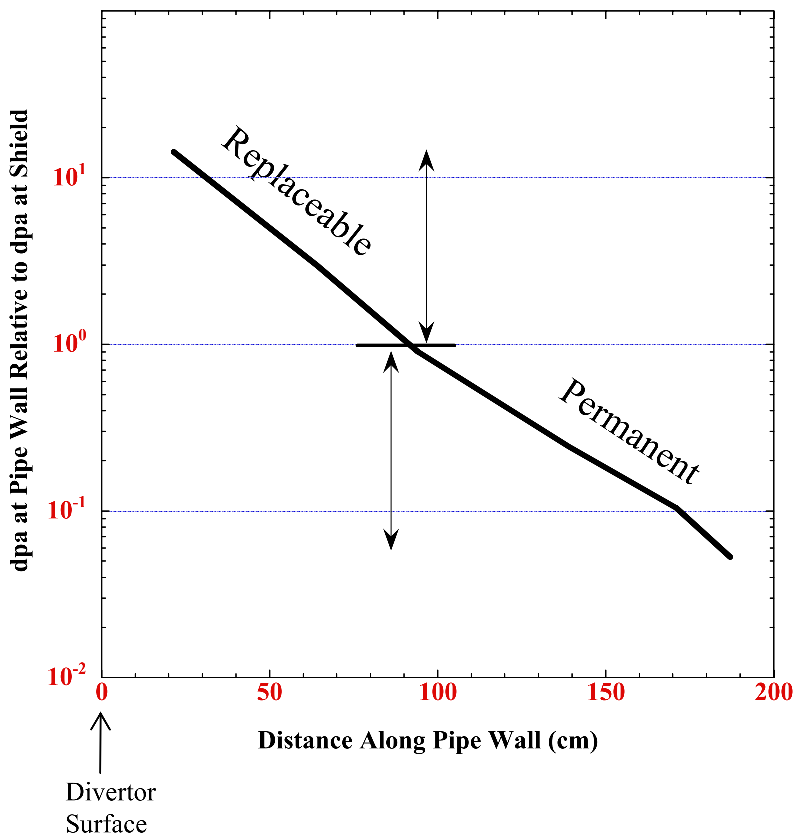


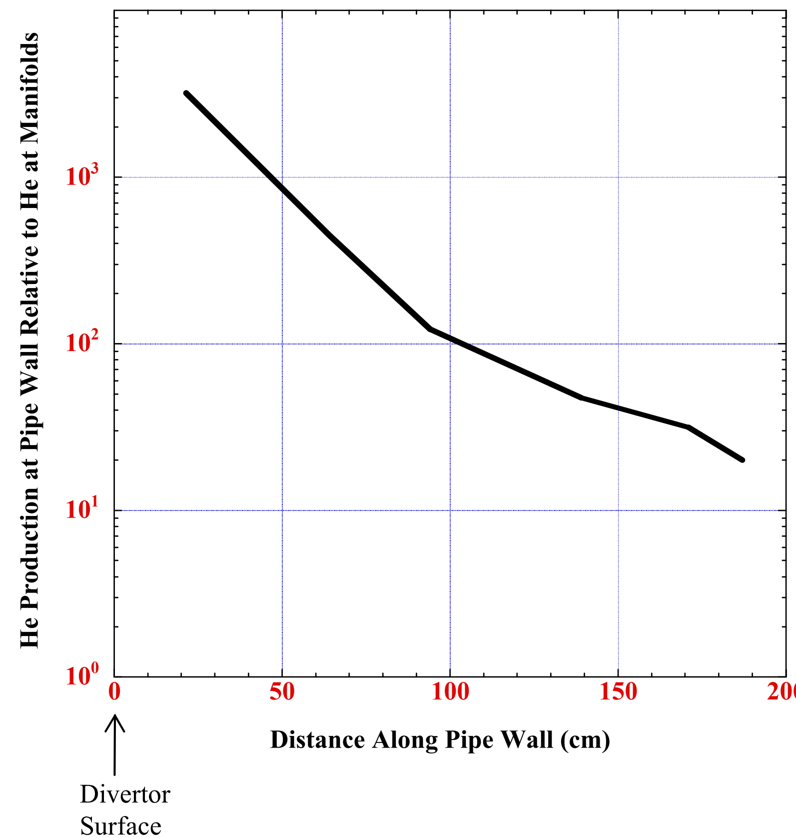
High Flux Behind Pipe Calls for Local Shield to Protect Externals





Pipe Wall

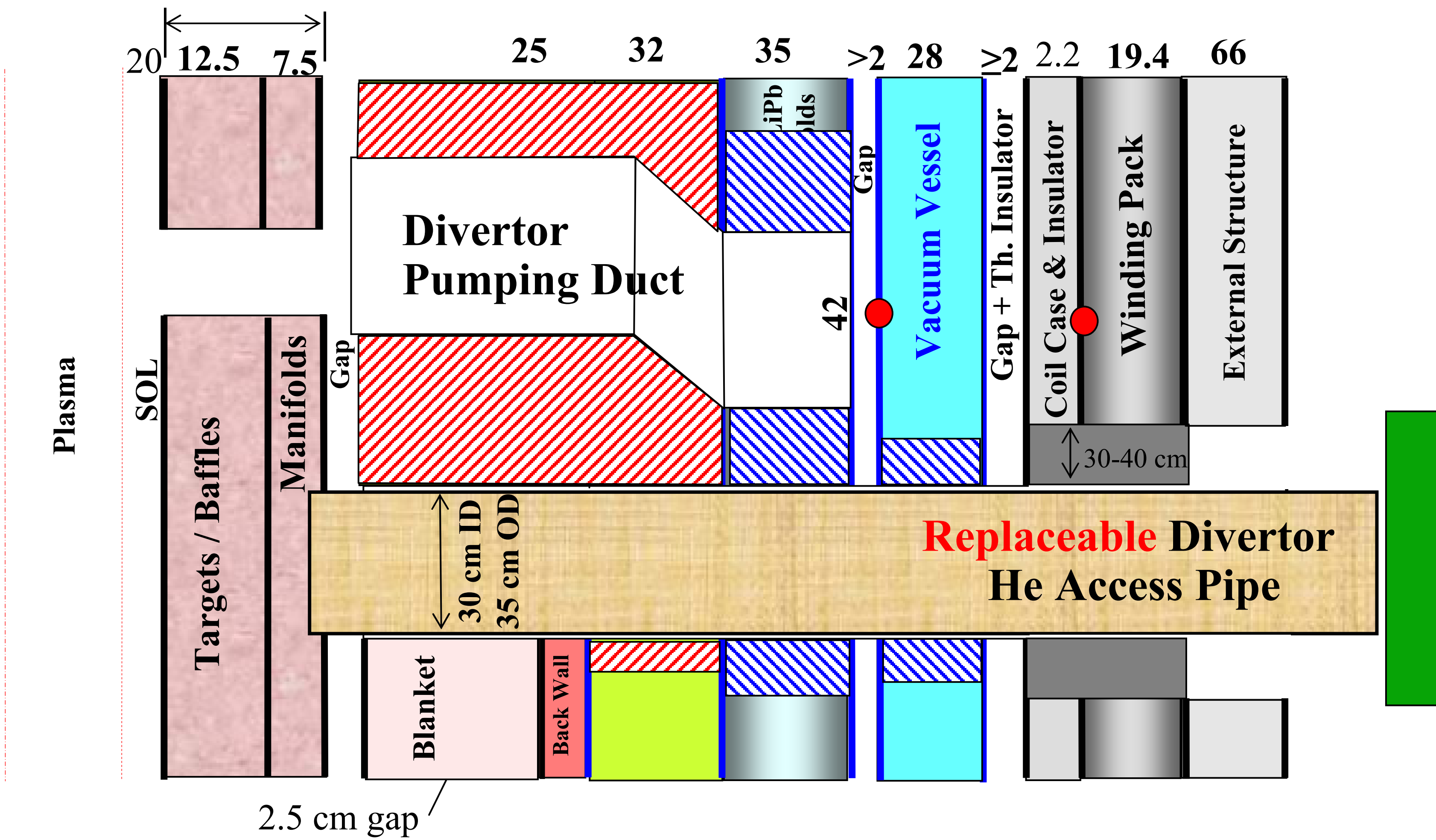




Front part of pipe wall should be replaceable

Pipe wall is not reweldable
$\Rightarrow$ Replace pipe with divertor

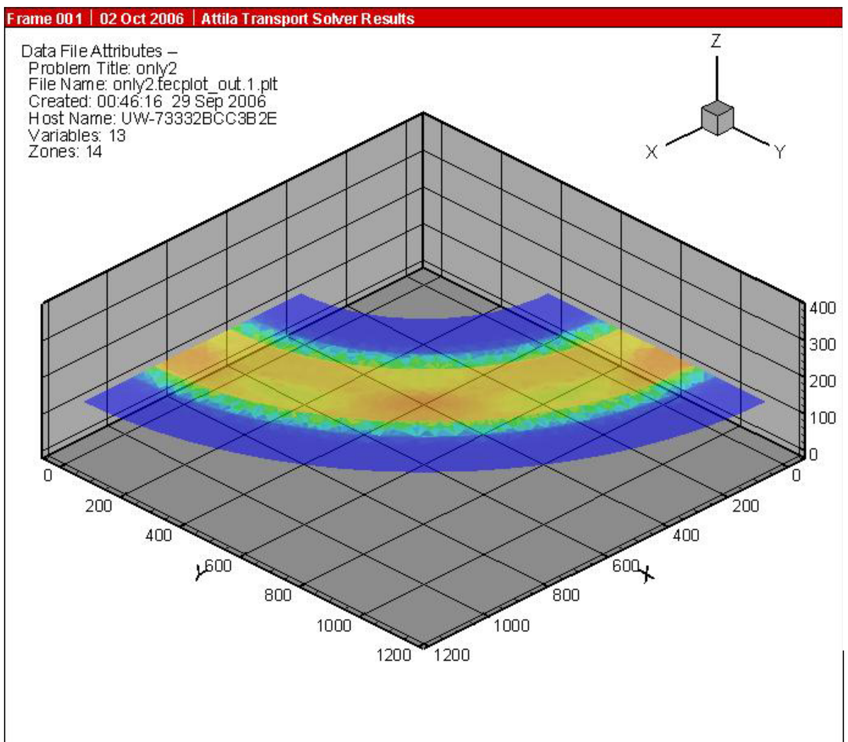
Recommendations



Replaceable Shield   Not Reweldable   Local Shield

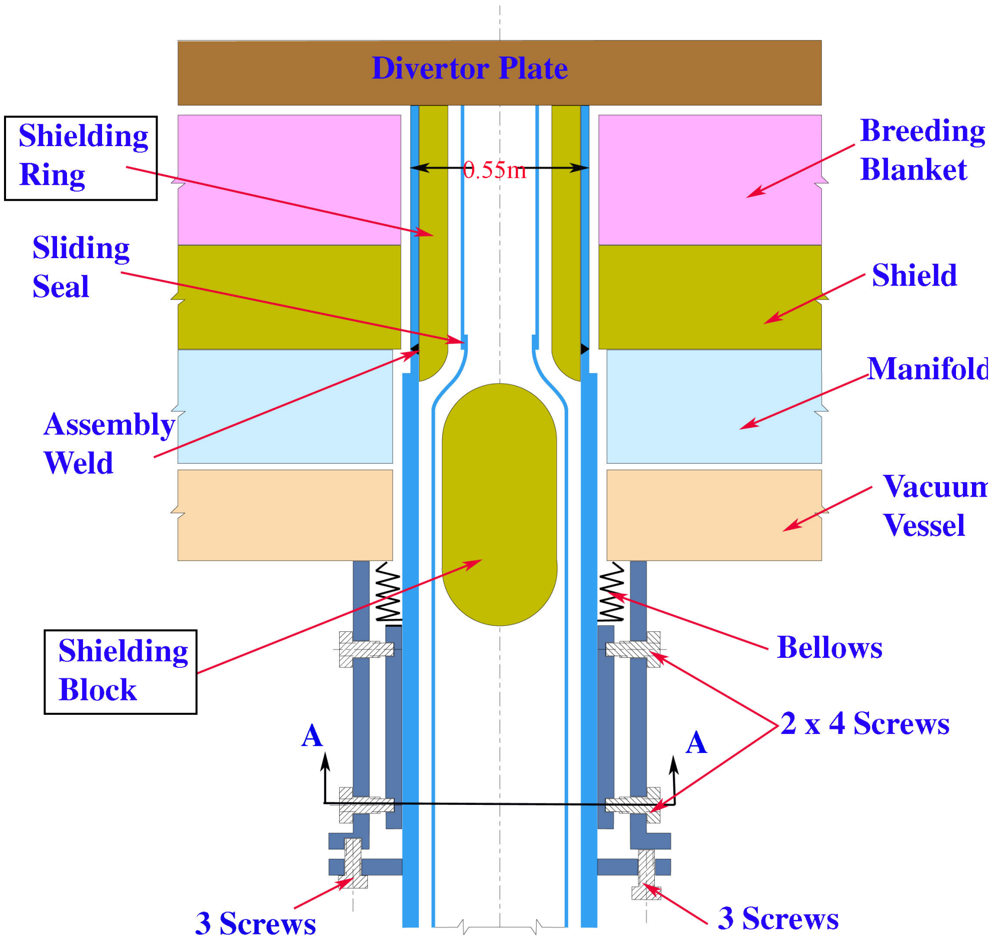
Ongoing 3-D Streaming Analysis Using Attila Code

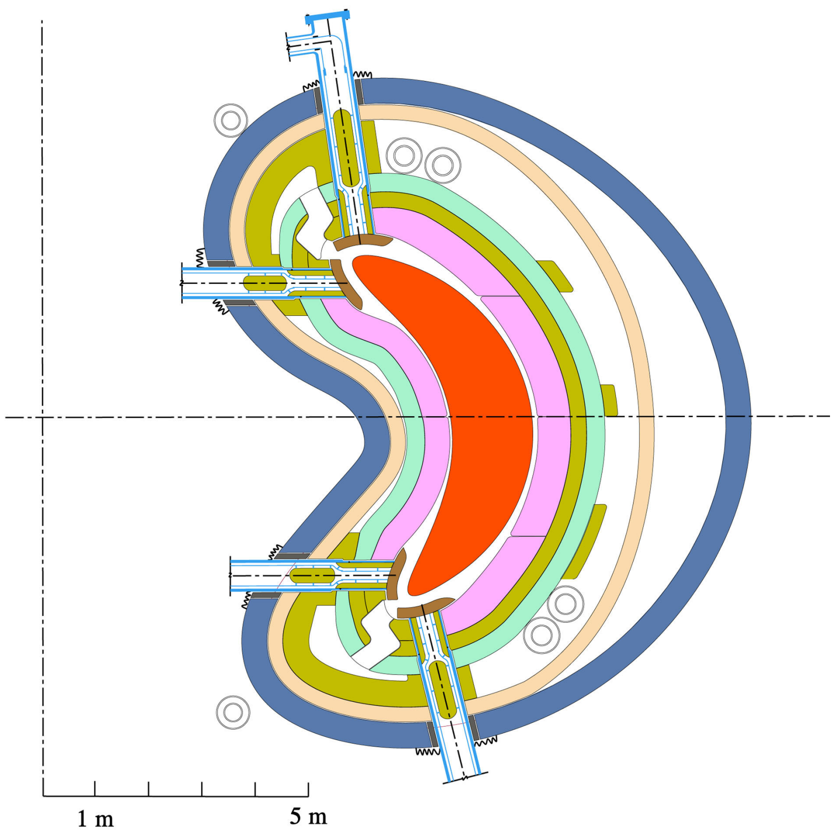
Purpose: Determine dimensions of replaceable shield, non-reweldable manifolds and VV, and local shield.



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Alternate Pipe Design
(S. Malang)



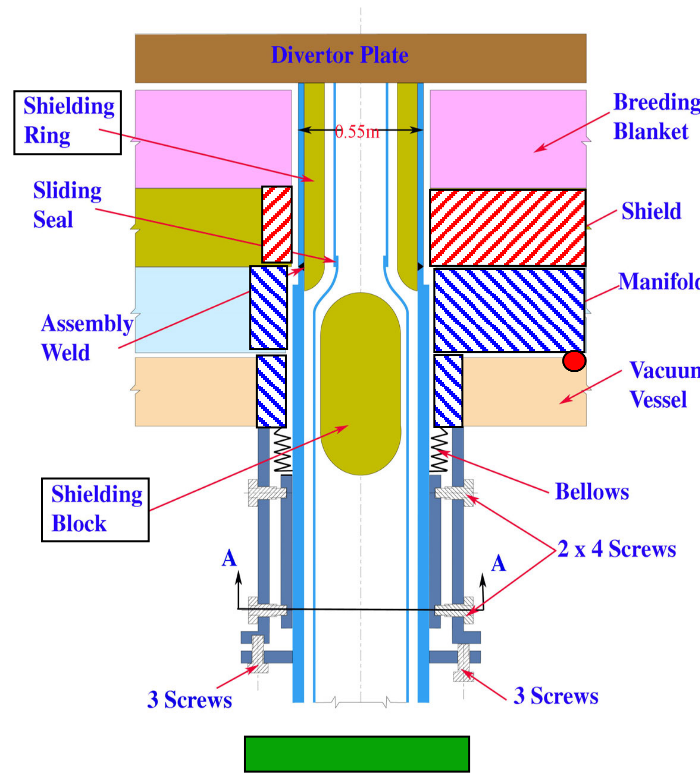


Comments on Alternate Pipe Design

- Shielding ring and block do not solved streaming problem entirely:
  - 10 cm thick WC **shielding ring** is insufficient to protect pipe wall, bulk shield, and manifolds
    - ⇒ Parts around pipe should be replaceable and cannot be rewelded.
  - **Shielding block** will not attenuate flux behind pipes by 4 orders of magnitude
    - ⇒ Local shield behind pipe is still needed.

- Sizable WC shield added:

Mass / pipe (ton)	**Alternate Design**	**Baseline Design**
Shielding Ring	~1.6	---
Shielding Block	~1	---
2.5 cm FS Pipe Wall	0.6	0.4
Total mass - 24 pipes	~77 ton	~10 ton



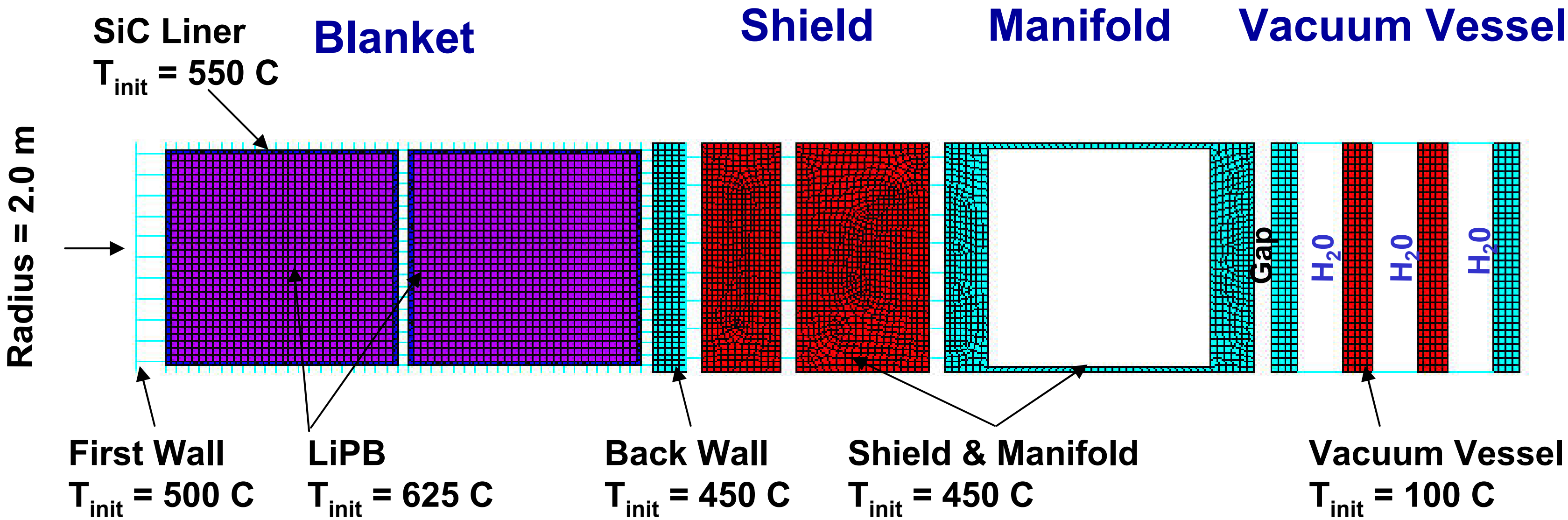
LOCA / LOFA Analysis

(2.6 MW/m^2 Ave. NWL; 0.5 MW/m^2 Surface Heat Load)

Initial temperatures at onset of LOCA/LOFA:

FW	500 ^{o}C	Shield & Manifolds	450 ^{o}C
SiC	550 ^{o}C	VV	100 ^{o}C
Back wall	450 ^{o}C	LiPb average temp	625 ^{o}C

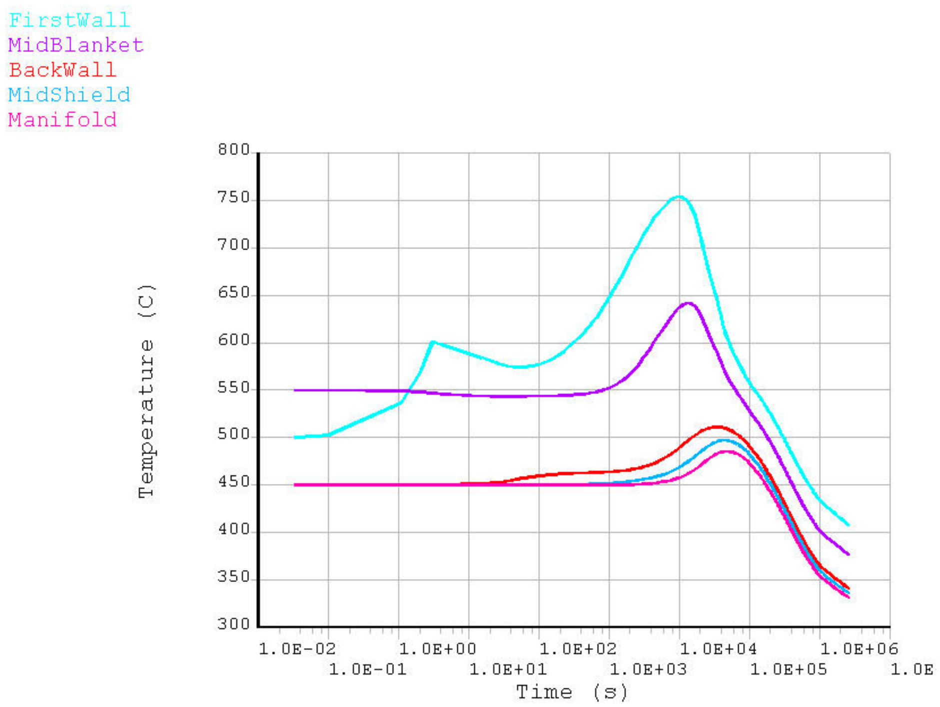
Assumptions: Plasma on for 3 s; Instantaneous loss of coolant.



Uniform Blanket and Shield

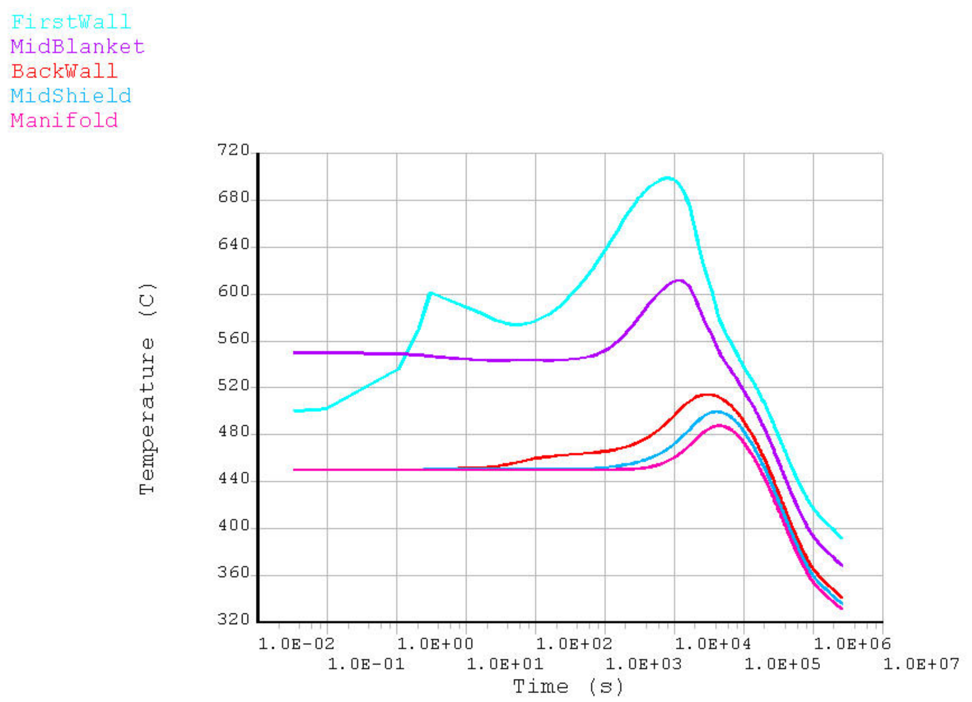
(He & LiPb LOCA in all Modules; H_2O LOFA in VV)

$\varepsilon = 0.3$ all surfaces



Max temp = 753 ºC

$\varepsilon = 0.5$ for SiC

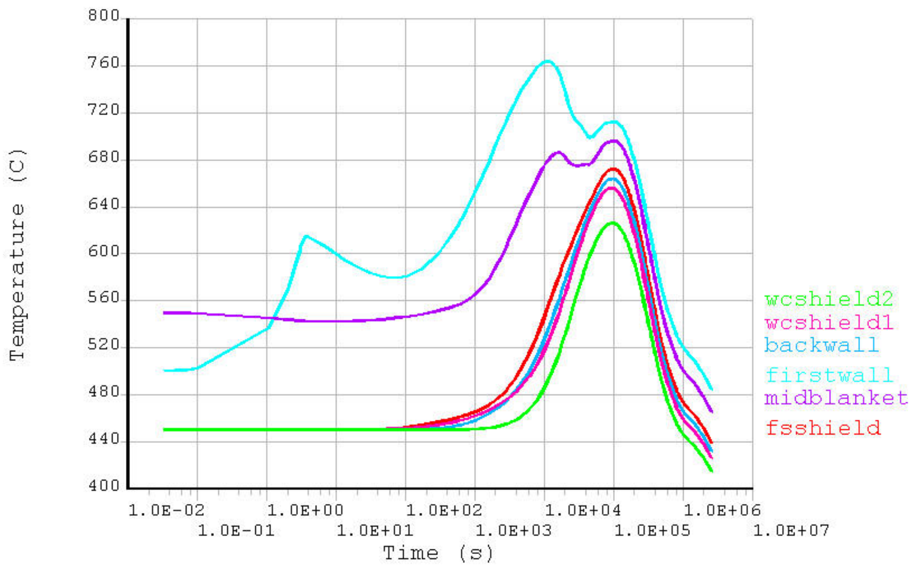


Max temp = 700 ºC

Non-uniform Blanket and Shield

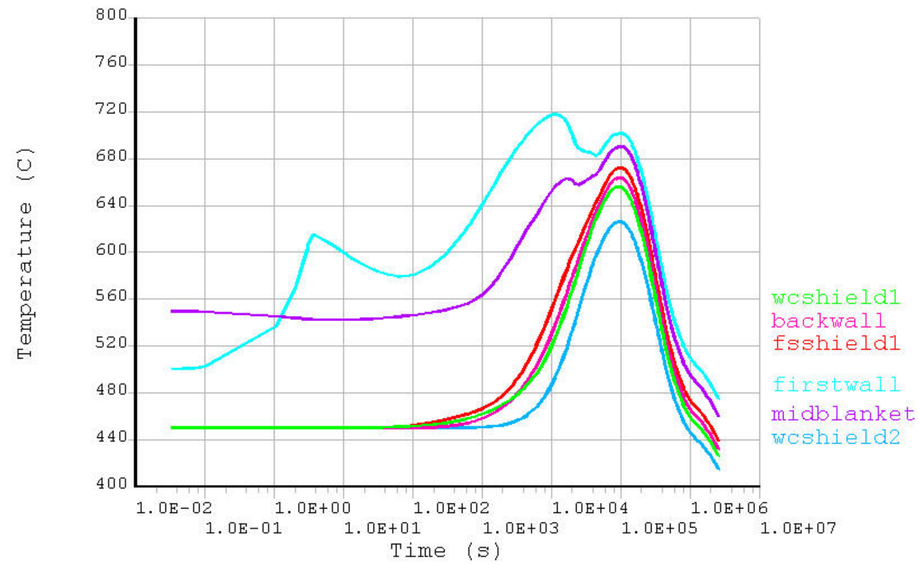
(He & LiPb LOCA in all Modules; H_2O LOFA in VV)

ε = 0.3 all surfaces



Max temp = 762 ^oC

ε = 0.5 for SiC



Max temp = 720 ^oC

Summary and Conclusions

- 3-D TBR and streaming analyses are underway.
- No shielding ring or block should be included in divertor He access pipes.
- Ongoing 3-D streaming analysis will determine size of replaceable shield and non-reweldble manifolds/VV around pipes.
- More realistic LOCA/LOFA assumptions help reduce temperature during accident.