Mechanical Design and Neutronics Analysis for Li Blanket in 10.5 m Chamber

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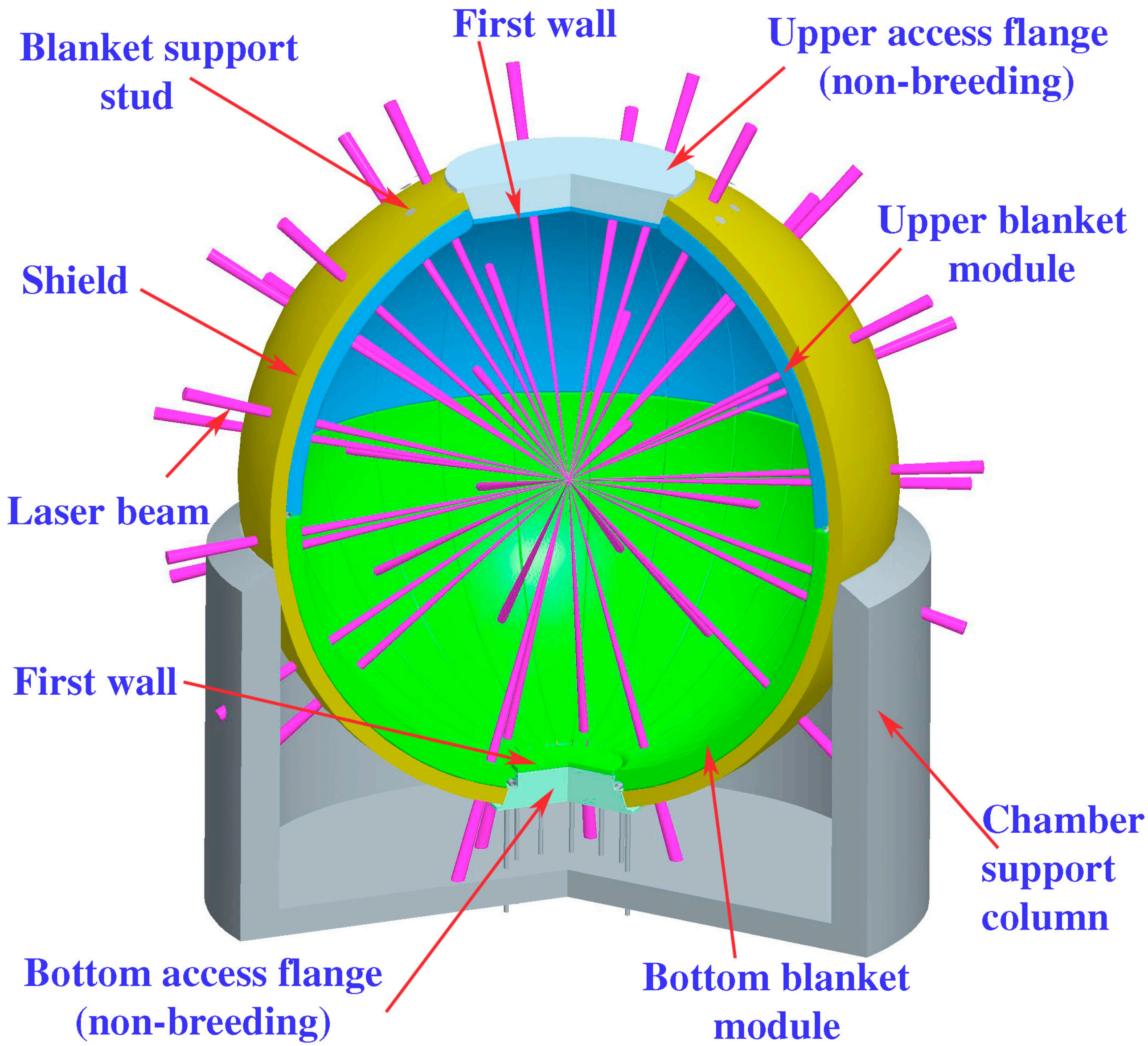
Description of 10.5 m HAPL Chamber

- The chamber is spherical with first wall at 10.5 m radius followed by a Li blanket 60 cm thick at mid-plane, increasing to 82 cm at the extremities
- The blanket is followed by a shield 50 cm thick consisting of curved I-beams oriented vertically with a 3 cm thick plate on the surface behind the blanket and a 10 cm thick plate on the back. The space between the I-beams is filled with balls. Ball material options are FS, W, WC, B_4C, or B-FS. The shield is He cooled
- At the north pole of the chamber there is an access flange 4 m in radius and at the south pole an access flange of 2 m radius. These access flanges are non-breeding and consist of a He cooled FW followed by a shield

10.5 m Radius Chamber Configuration with Li Blanket



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Chamber Weight to be Supported

- ***Blanket*:**
  - Li Blanket — 500 tonnes (10.4 tonnes/module)
  - LiPb Blanket — 8550 tonnes (180 tonnes/module)
  - Drained Blanket — 75 tonnes (1.6 tonnes/module)
- ***Shield*:**
  - Steel — 1820 tonnes
  - B_4C Balls — 1100 tonnes
  - Total — 2920 tonnes

Description of Blanket

- The chamber has two sets of blanket modules, an upper set and a lower set, covering 88.6% of the surface area. The bottom set has Li inlet and outlet connections on the bottom and extends to mid-plane. The upper set starts at mid-plane and extends to the top with Li inlet/outlet connections at mid-plane
- The blanket modules are secured to the shield by the Li supply/return connections on the bottom and with support studs on the top
- The sub-modules consist of two concentric rectangular tubes separated by a constant gap. As the shape of the sub-module changes, the hydraulic diameter is maintained constant

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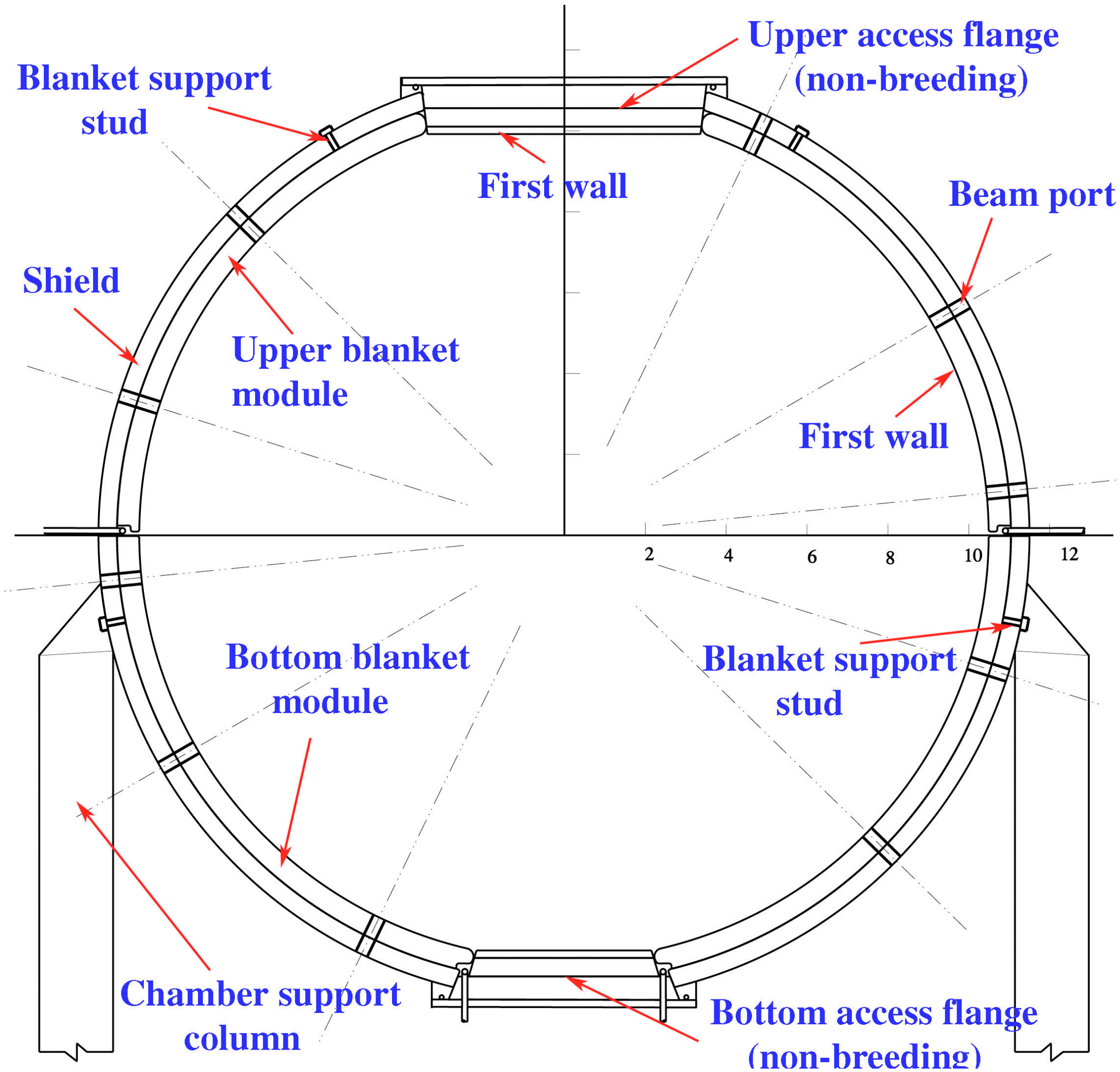
Side View of 10.5 m Radius Chamber



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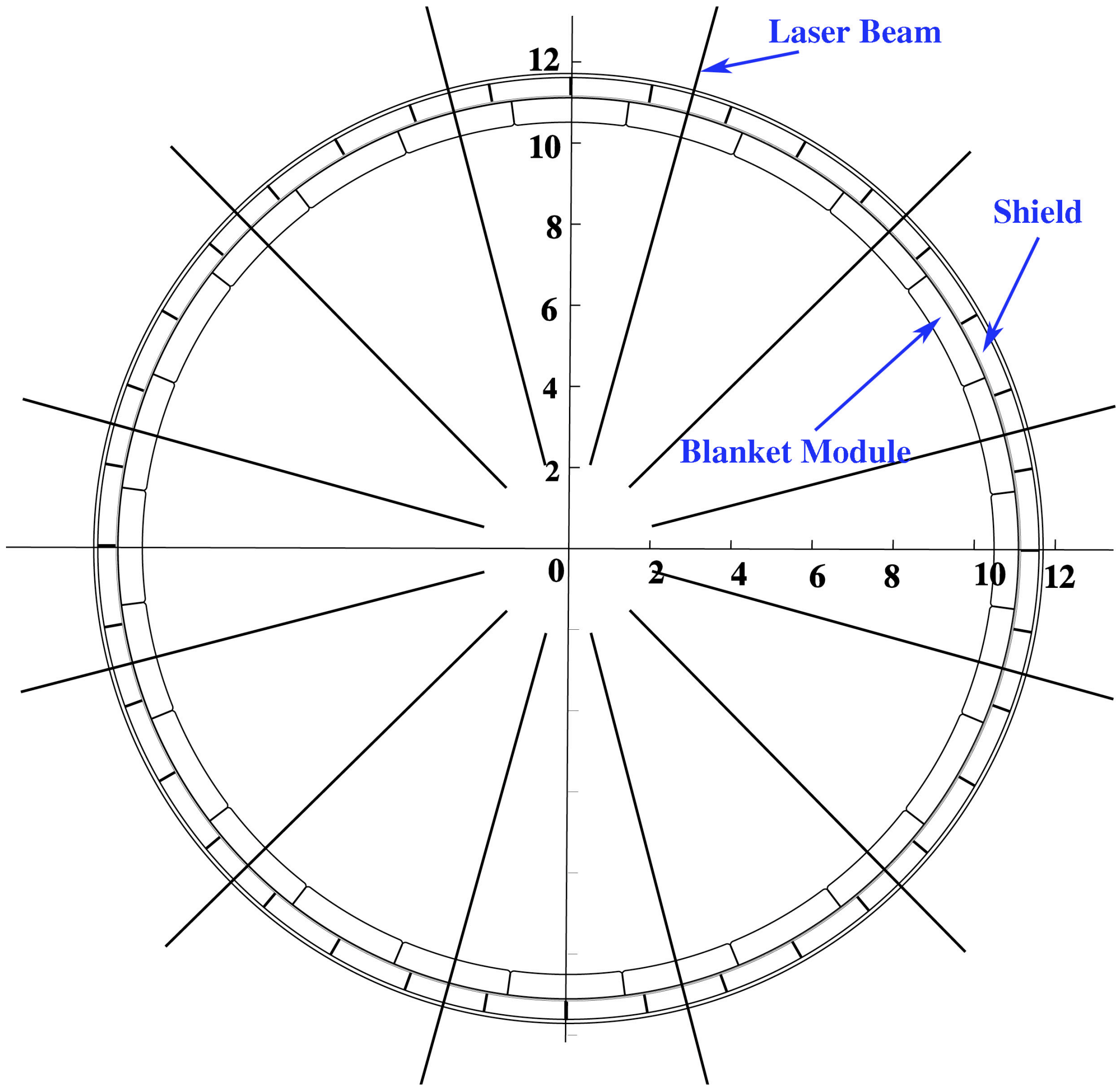
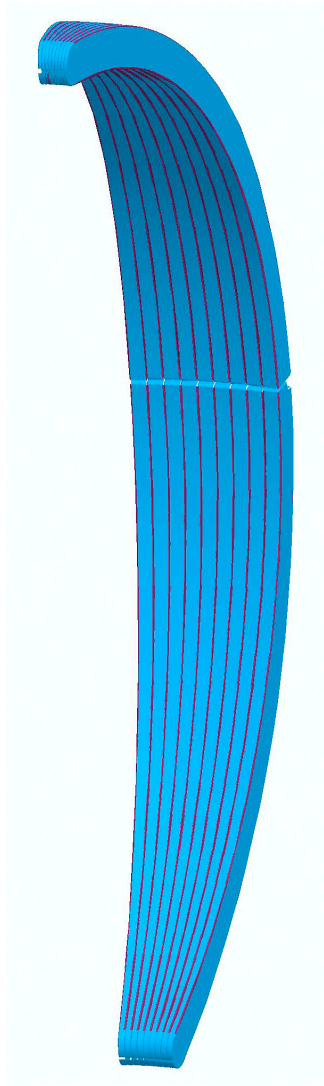
Top View of the Chamber Showing 24 Blanket Modules and 12 Laser Beam Directions

Toroidally the blanket is divided into 24 modules on top and 24 modules on bottom each covering 15° of circumference

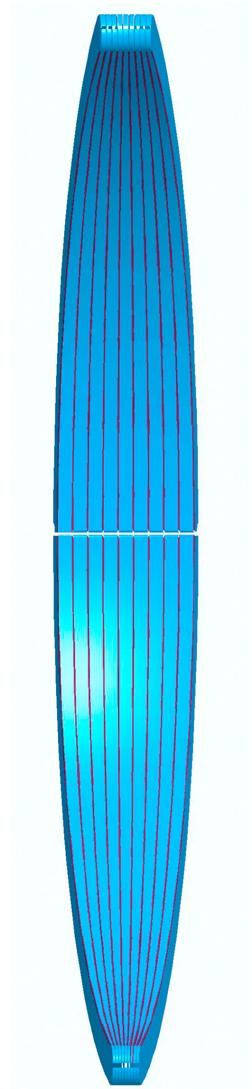


Module Without Laser Beam Ports

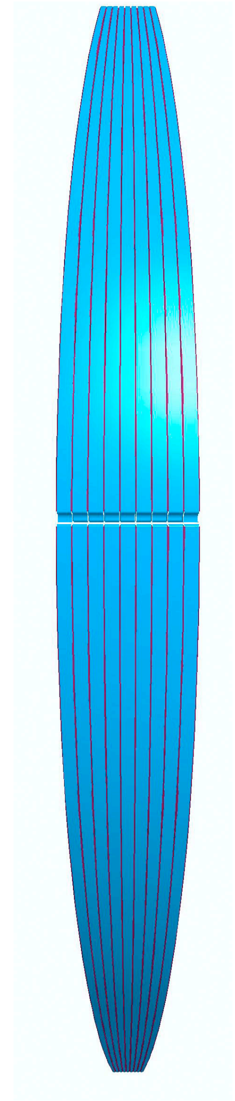
Each module has
9 sub-modules



Side view



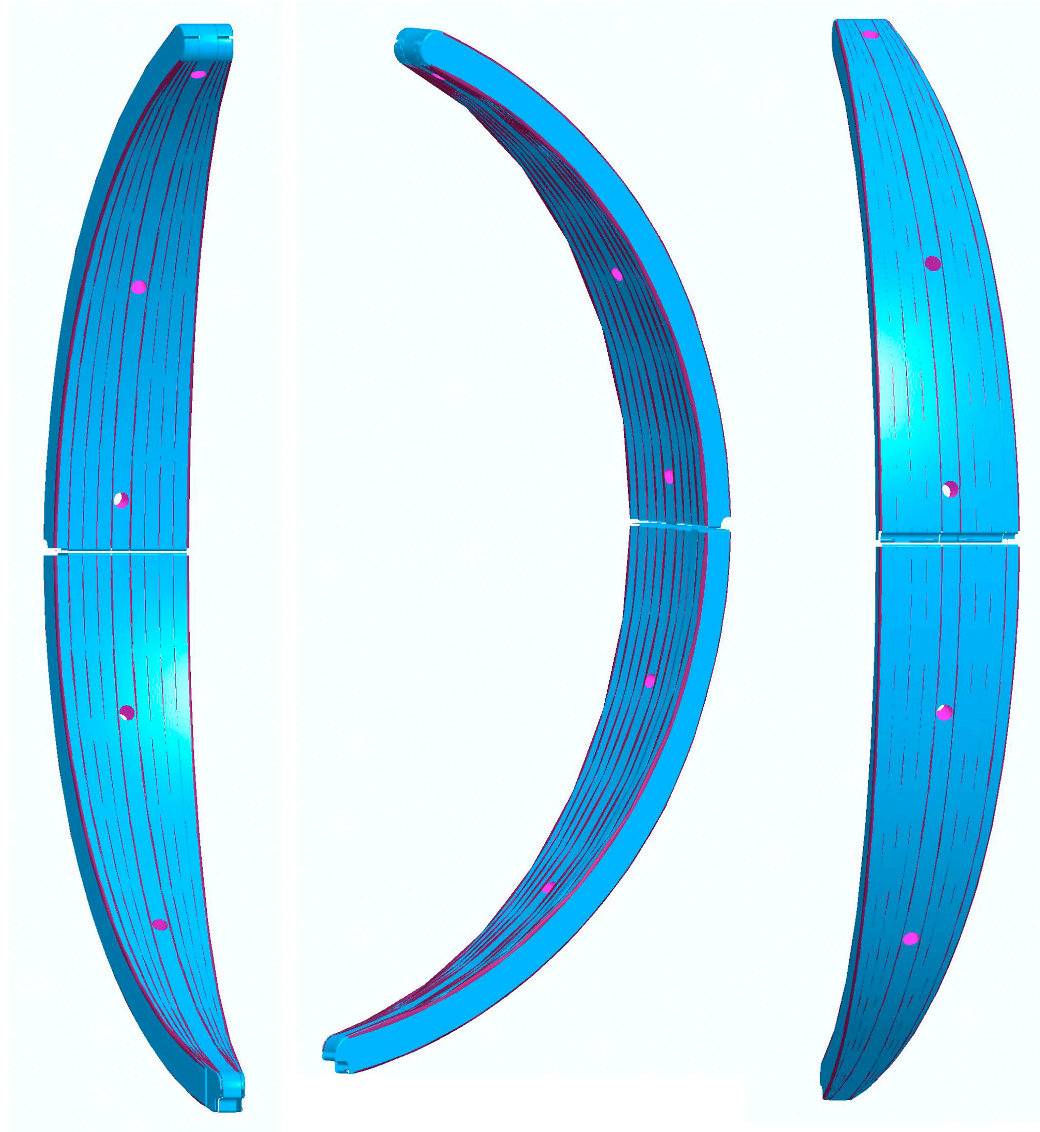
Front view



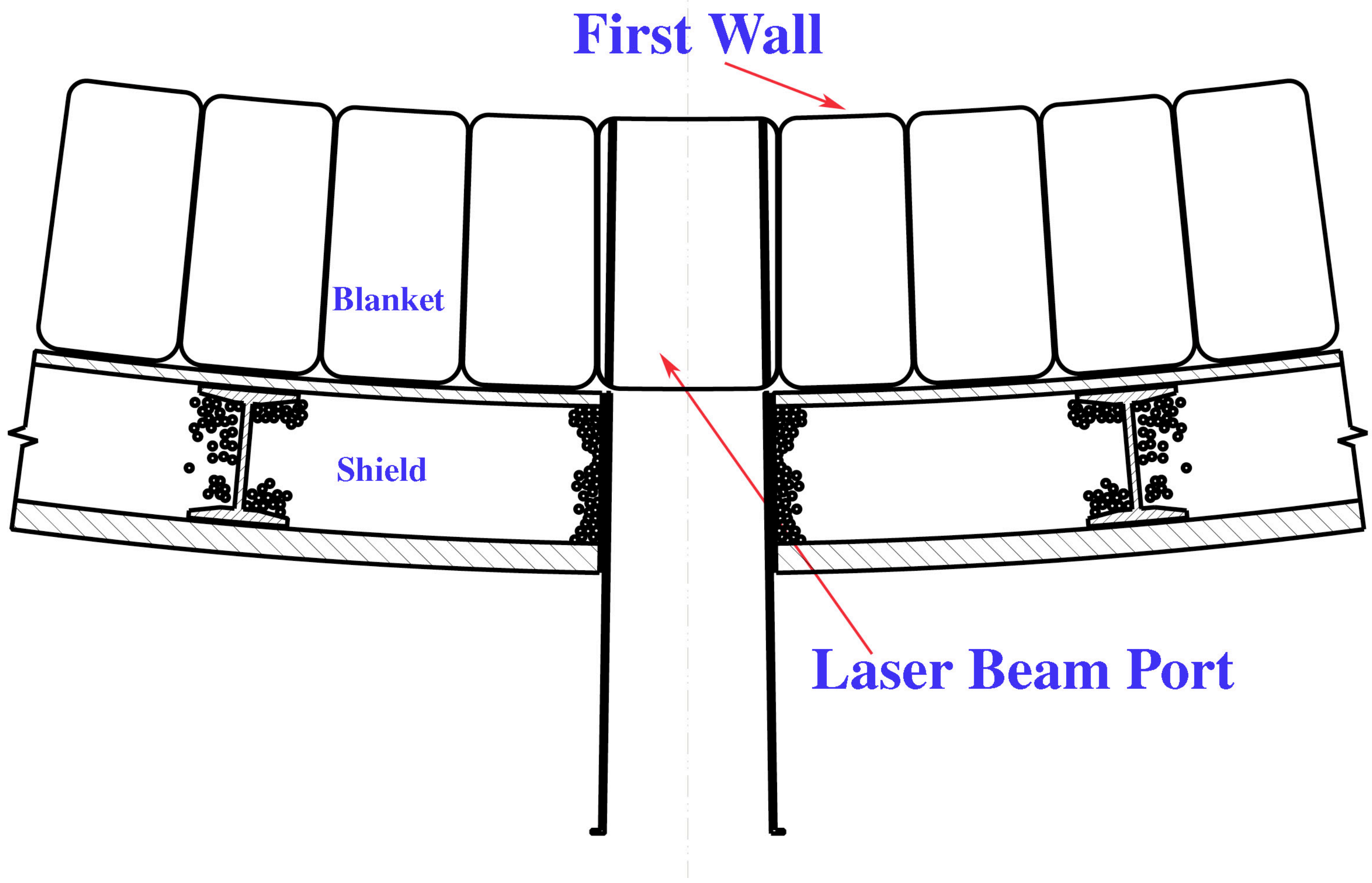
Back view

Module With Laser Beam Ports

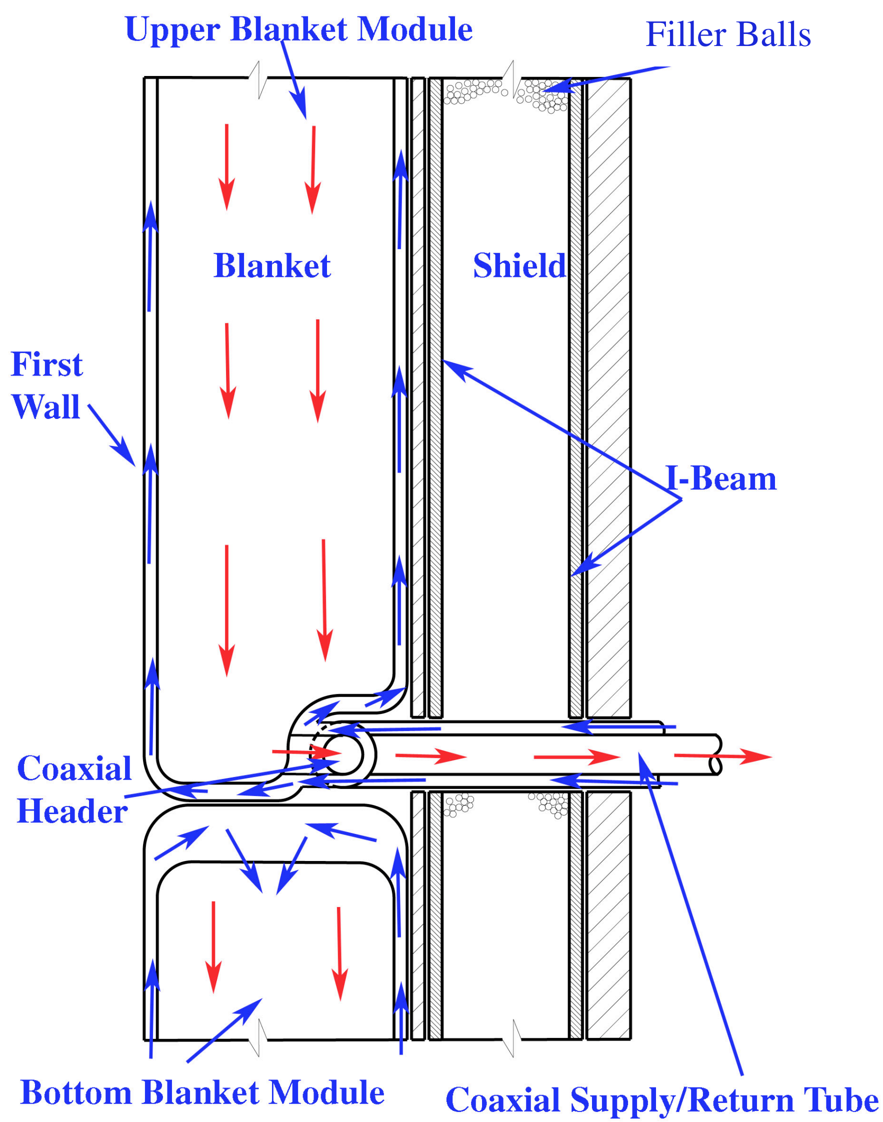
- The laser beams come in at 12 vertical levels around the chamber
- Every other module is specially equipped to accommodate a set of 5 beam ports



View of One Blanket Module at Mid-plane Attached to the Shield Showing a Laser Beam Port



Junction Between Upper and Lower Blanket Modules at Mid-plane

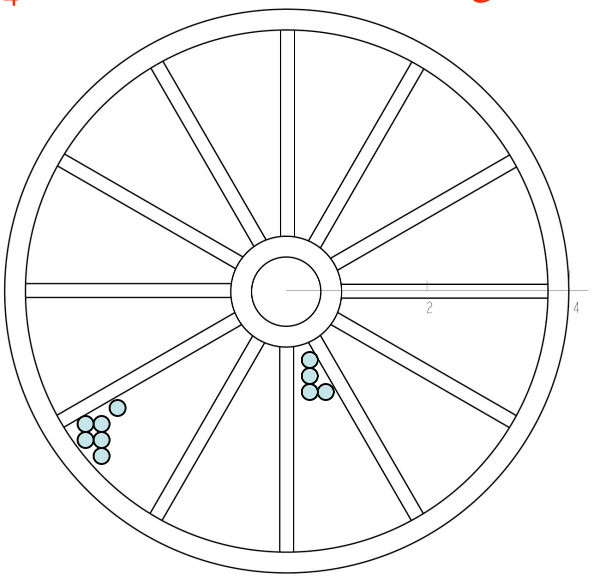


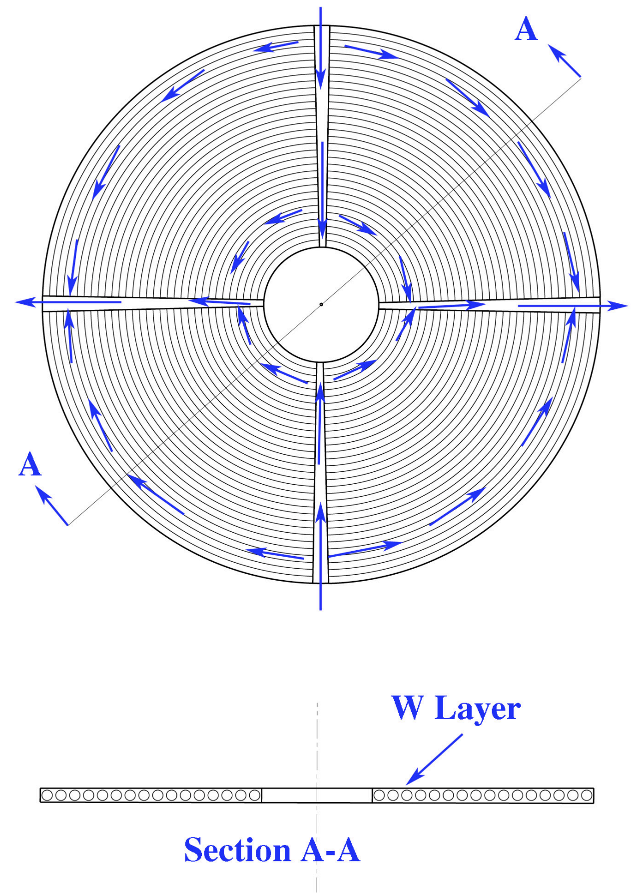
Upper Removable Flange

(bottom flange has same design but smaller)

Shield

I-Beam structure forms the shield. Spaces filled with B_4C balls cooled with He gas





First Wall

FW facing target consists of square coiled channels diffusion bonded to each other and to sheets on both sides. He gas cooling as indicated. Bottom sheet has the W armor bonded to it

Parameters Used for Baseline Chamber Design

- 1 mm W armor on low activation ferritic steel (F82H) FW
- Used target spectrum from LASNEX results (Perkins) for NRL direct-drive target
- 70.5% of target yield carried by neutrons with 12.4 MeV average energy
- Target yield 350 MJ
- 5 Hz rep rate
- 1.75 GW fusion power
- Chamber radius 10.5 m at mid-plane
- Peak neutron wall loading at mid-plane is 0.89 MW/m^2

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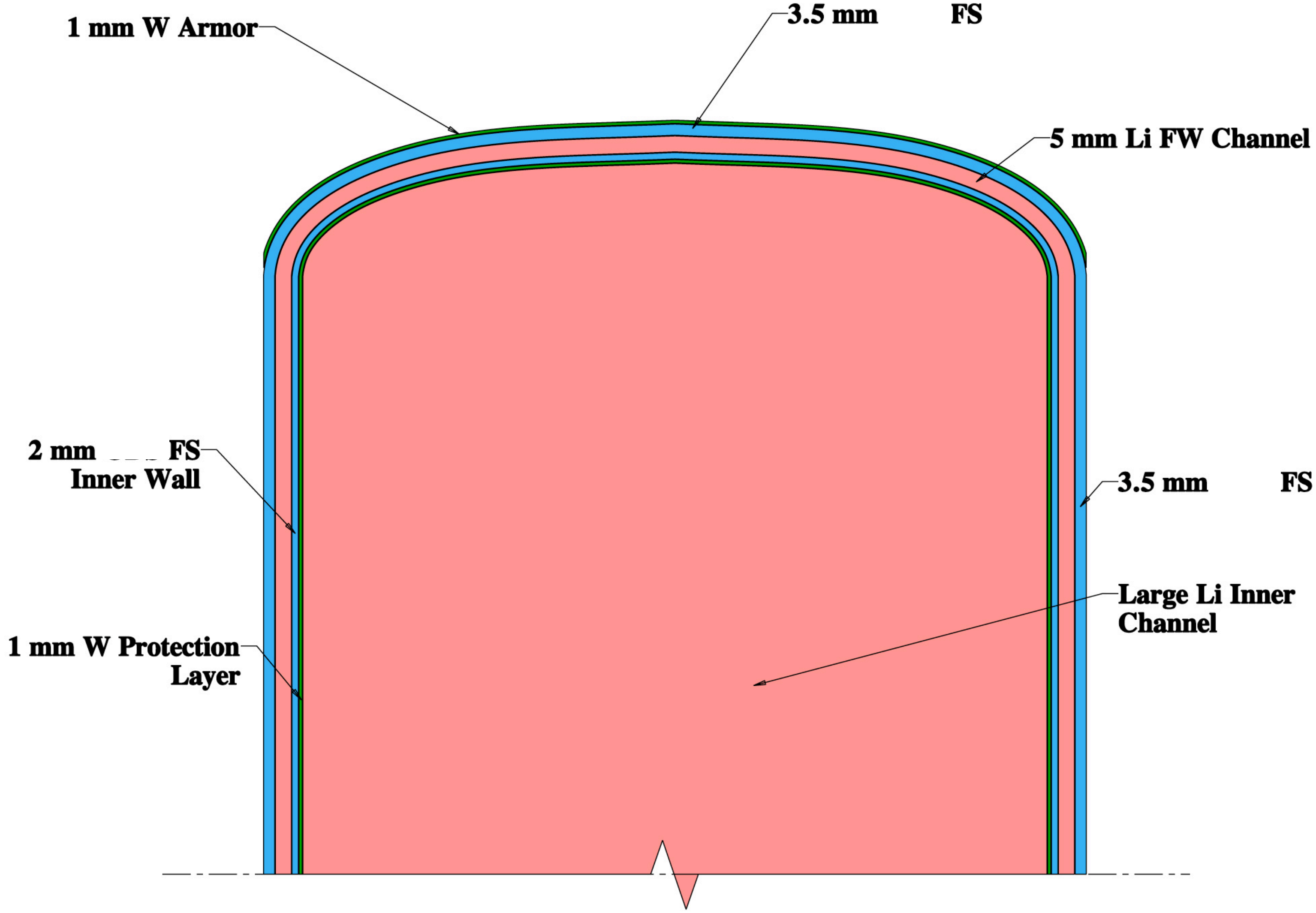
Schematic of Self-Cooled Li Blanket



Radial Build and Material Composition Used in Neutronics Analysis

Zone	Description	Thick (mm)	% W	% FS	% Li	% Filler balls	% He
1	**Armor**	1	100	0	0	0	0
2	**FW**	3.5	0	100	0	0	0
3	**FW Li channel**	3	0	0	100	0	0
4	**Inner wall**	2	0	100	0	0	0
5	**Large Li inner channel**	482	0	0	100	0	0
6	**Back inner wall**	2	0	100	0	0	0
7	**Li channel in back wall**	3	0	0	100	0	0
8	**Back wall**	3.5	0	100	0	0	0
9	**Front plate of shield/VV**	30	0	100	0	0	0
10	**Inner zone of shield/VV**	370	0	2.8	0	66.1	31.1
11	**Back plate of shield/VV**	100	0	100	0	0	0
	Total	**1000**					

- Blanket thickness 50 cm
- Shield/VV thickness 50 cm

Design Requirements

- Overall TBR >1.1 taking into account lost breeding blanket coverage
  - 0.4% beam ports
  - 11% top and bottom access flanges

- End-of-life (40 FPY) peak dpa in shield <200 dpa for shield/VV to be lifetime component

- End-of-life (40 FPY) peak He production at back of shield/VV <1 He appm to allow for rewelding

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Neutronics Parameters

- Used SS filler balls in shield/VV
- Local 1-D TBR is 1.3
- Estimated overall TBR is 1.15
- Peak dpa rate in FS FW is 9.6 dpa/FPY implying a blanket lifetime of 20 FPY and the blanket has to be replaced at least once during the plant lifetime
- End-of-life (40 FPY) peak dpa in shield is 96 dpa implying that it will be lifetime component
- End-of-life (40 FPY) peak He production at back of shield/VV 0.9 He appm allowing for rewelding

- *A major concern is providing support for the large weight of the blanket and shield/VV in the large chamber configuration*
- *We explored using different filler balls to reduce thickness and/or weight of shield/VV*

Impact of Filler Ball Material

Ball material	Density (g/cm^3)	Local TBR	Overall TBR	Peak nuclear heating in balls (W/cm^3)	He appm @40 FPY at back of VV	Reduction in shield/VV thickness (cm)
FS	7.8	1.30	1.15	1.3	0.88	0
W	19.3	1.25	1.11	3.0	0.21	9
WC	15.5	1.23	1.09	2.9	0.25	8
B_4C	2.5	1.12	0.99	2.0	1.36	--
B-FS	7.8	1.22	1.08	1.7	0.69	2

- Using more efficient shielding materials (W, WC) reduced TBR and increased heating to be removed by shield coolant
- The more than a factor of 2 higher density of W and WC combined with the modest shield thickness reduction results in a heavier shield/VV
- B_4C with its low density is an attractive option but TBR is not acceptable and He production at back of VV is excessive
- We recommend using B_4C balls in shield/VV with a 60 cm thick blanket
- This yields overall TBR of 1.1 and 0.88 He appm at VV back

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Summary

- A preliminary design of a 10.5 m radius chamber based on a self-cooled Li blanket has been presented
- Adequate overall TBR of 1.1 and lifetime shield can be achieved with 60 cm thick blanket
- Rewelding is possible at the back of 50 cm thick shield/VV filled with B_4C balls