3-D Assessment of Neutron Streaming through Inboard Assembly Gaps

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Outline

- Introduction
- 3-D Model used
- Results
- Conclusions

Introduction

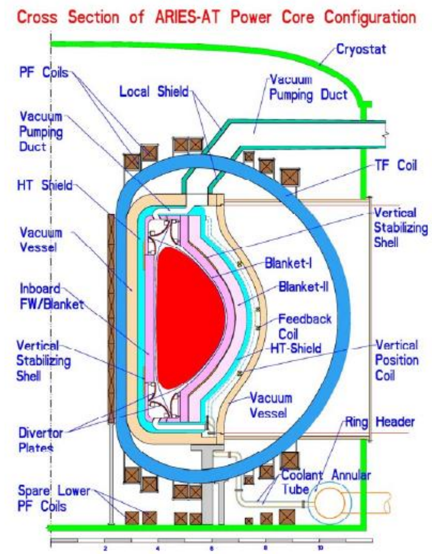
- Assembly gaps between modules allow increased levels of radiation to reach components
- Radiation streaming through these gaps needs assessment to be sure components are well protected
- Previous Work:
  - T.D. Bohm, M.E. Sawan, P. Wilson, "Radiation Streaming in Gaps between ITER First Wall Shield Modules", *Fusion Science and Technology*, in press 2009
  - L.A. El-Guebaly, M.E. Sawan, "Shielding Analysis for ITER with Impact of Assembly Gaps and Design Inhomogeneities", Proc. 8th International Conference on Radiation Shielding, Arlington, Texas, 24-28 April 1994, p. 1047, 1994

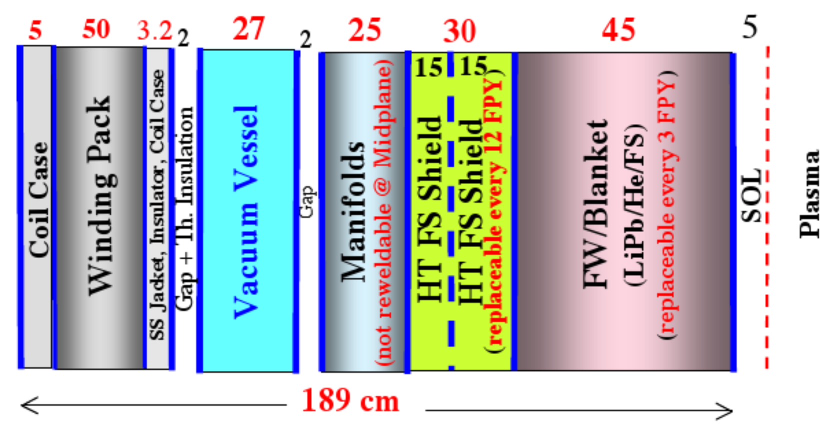
Introduction continued

- During operation, gaps will close due to thermal expansion and neutron induced swelling
- Will examine range of gap sizes from no gap to some reasonable maximum gap size

ARIES 3-D Inboard Model

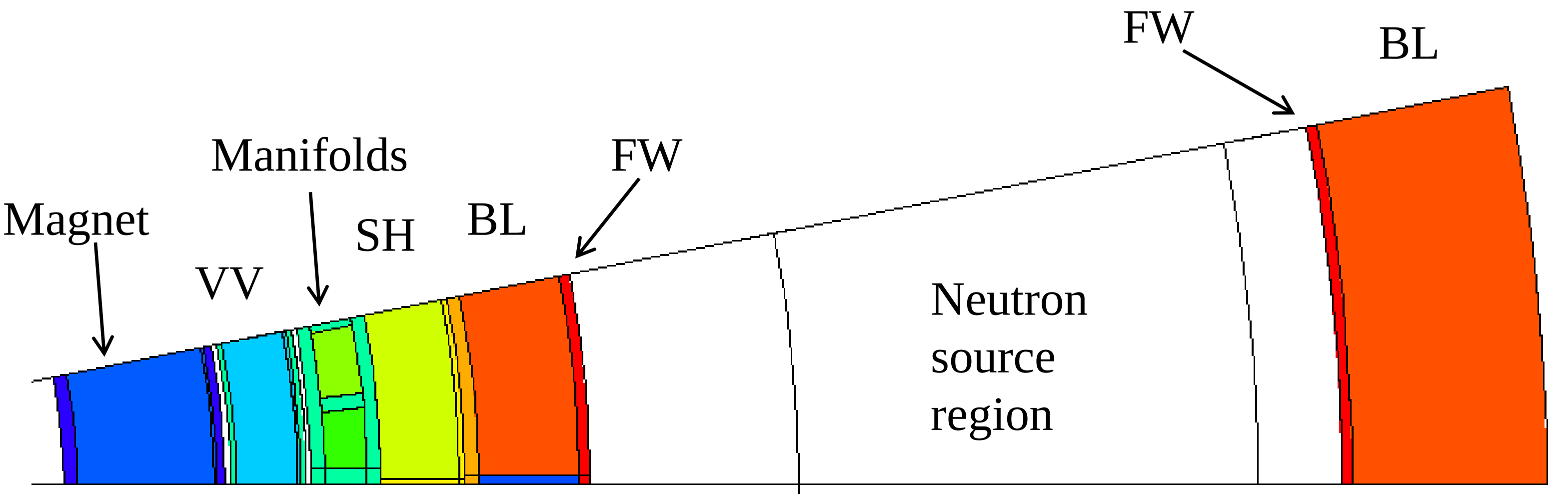
- Basis is ARIES-AT DCLL radial build by El-Guebaly (1/21/2009 presentation)
- MCNPX v27a 3-D Monte Carlo transport code
- FENDL v2.1 cross section library





3-D Model

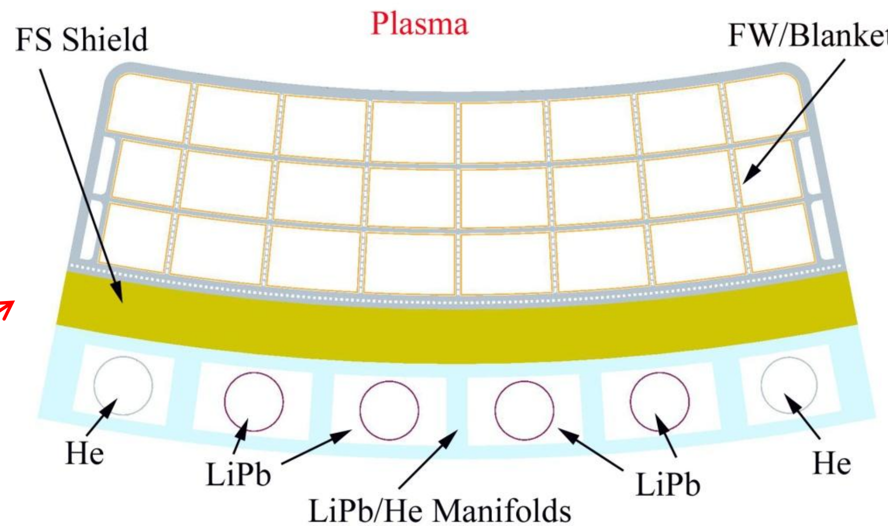
- 3-D partially homogenized model
- 11.25° sector (1/2 module) (w/ reflecting boundaries)
- Vertical extent 100 cm (w/ reflecting boundaries)
- Uniform volumetric source r=460-625 cm
  - IB NWL =3.4 MW/m^2



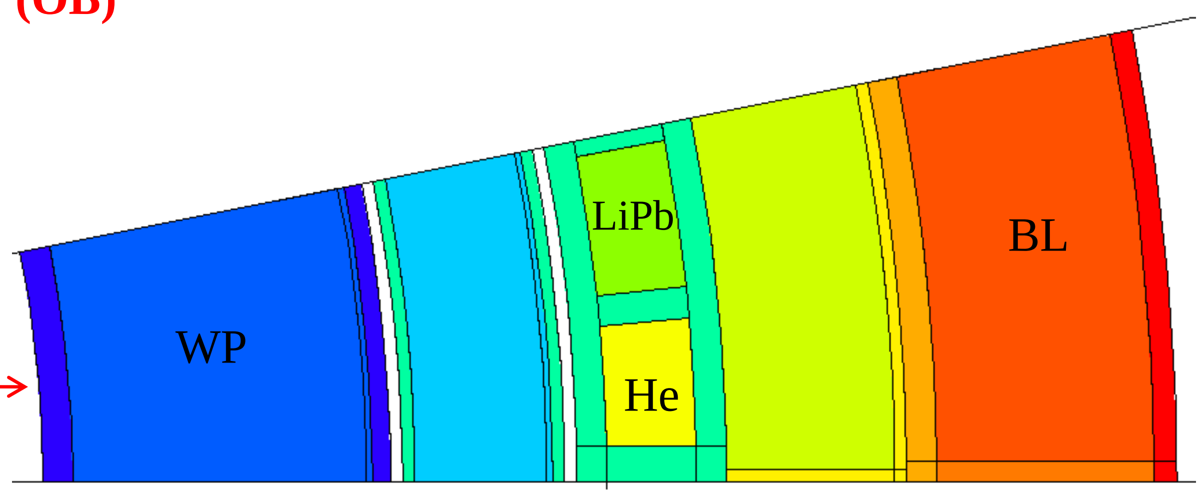
No gap model

- Sidewalls included
- Manifolds included

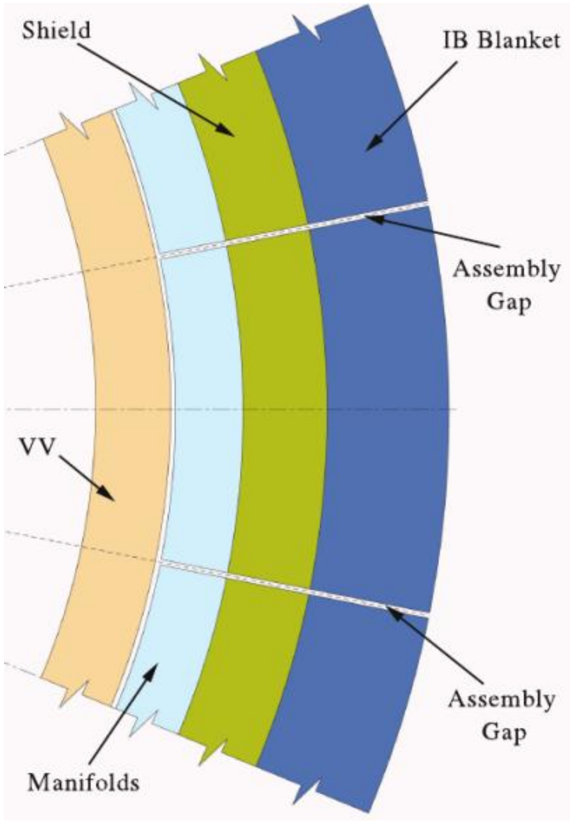
CAD detail (OB)



3-D Model

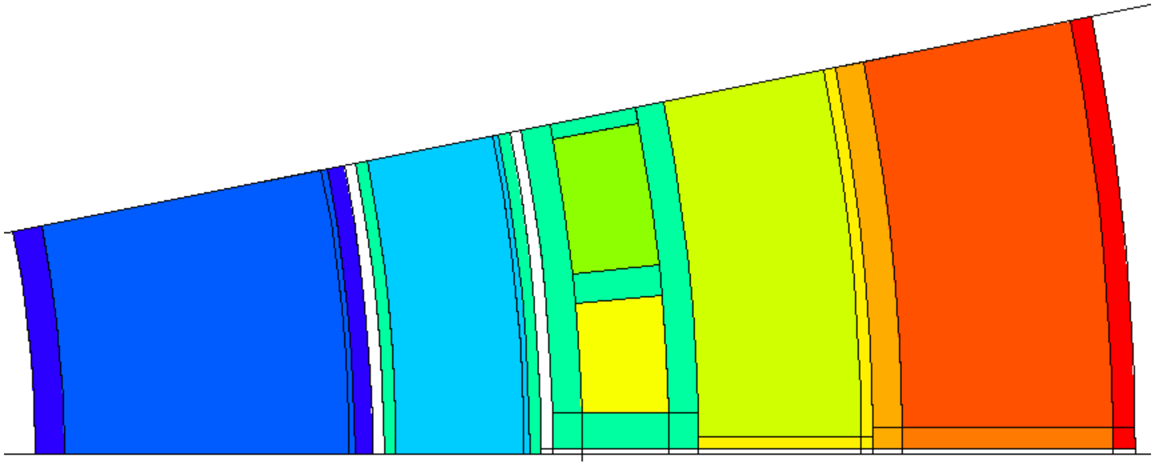


Straight gap model

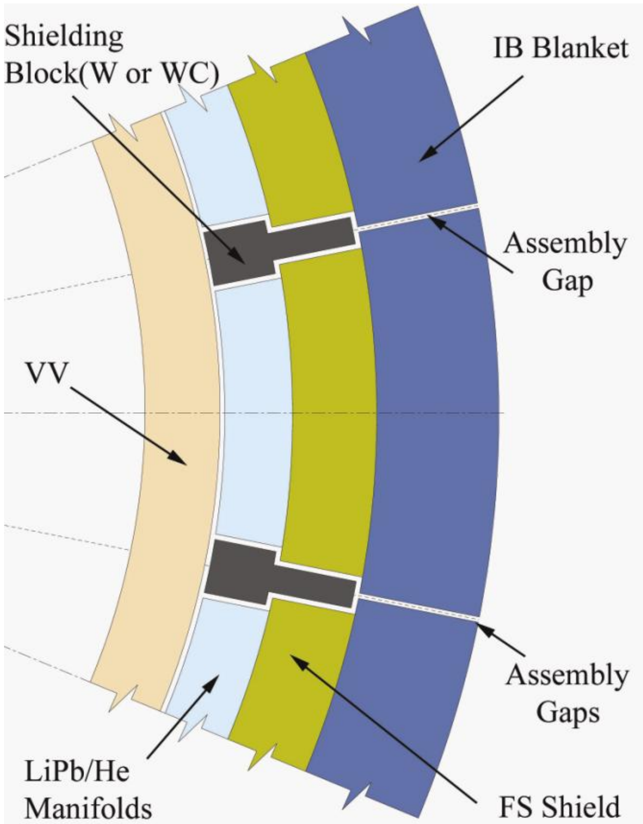


- 1, 2 cm gaps examined
- Gap reaches vacuum vessel

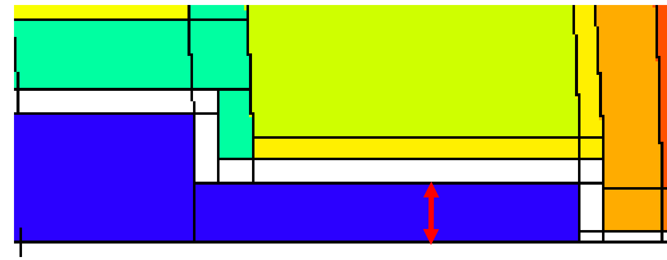
3-D Model →



Stepped gap model

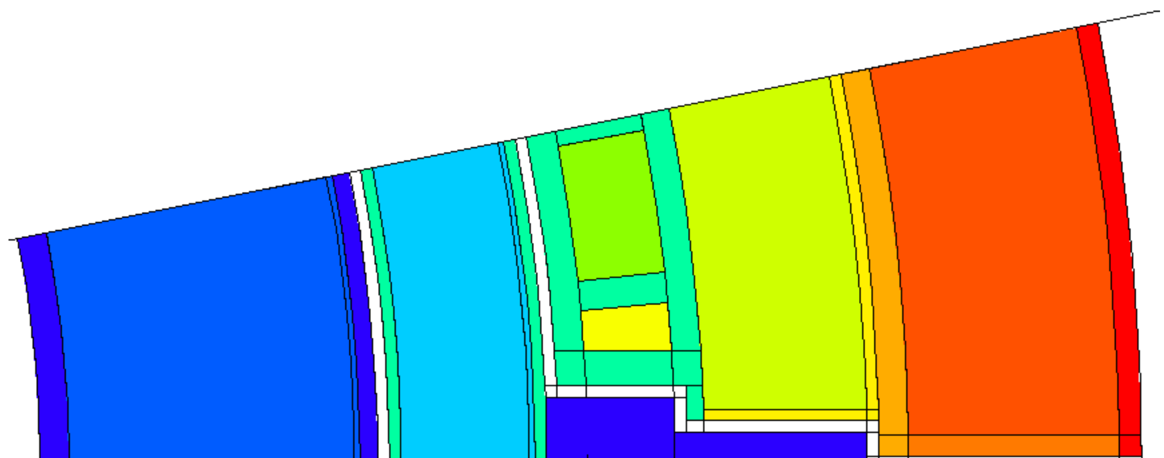


- 1, 2 cm gaps
- Double step
- WC block
- Offset 5 cm



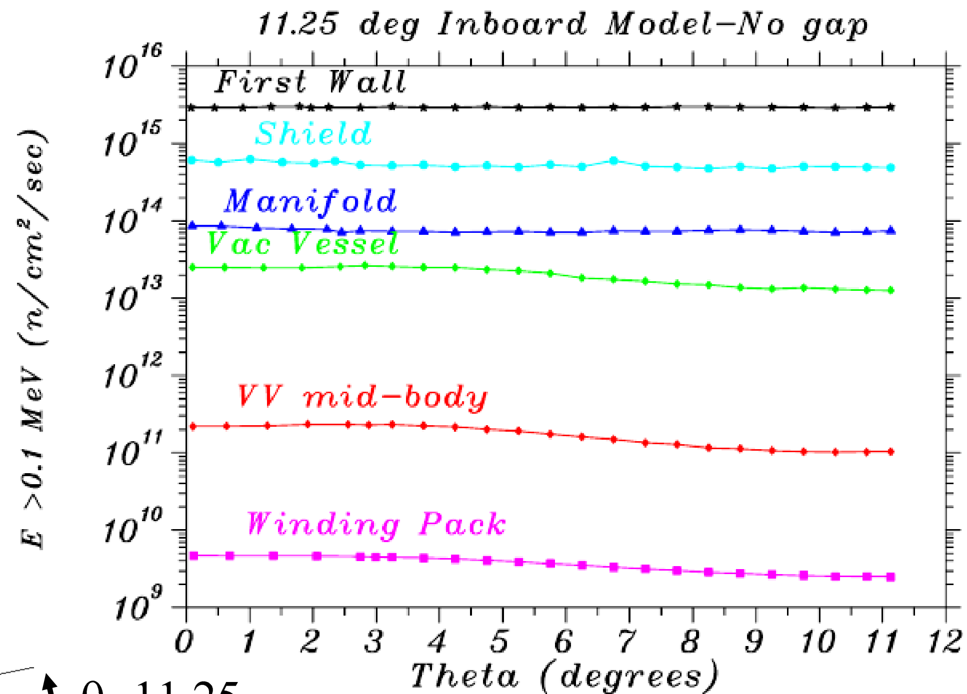
Offset 5 cm

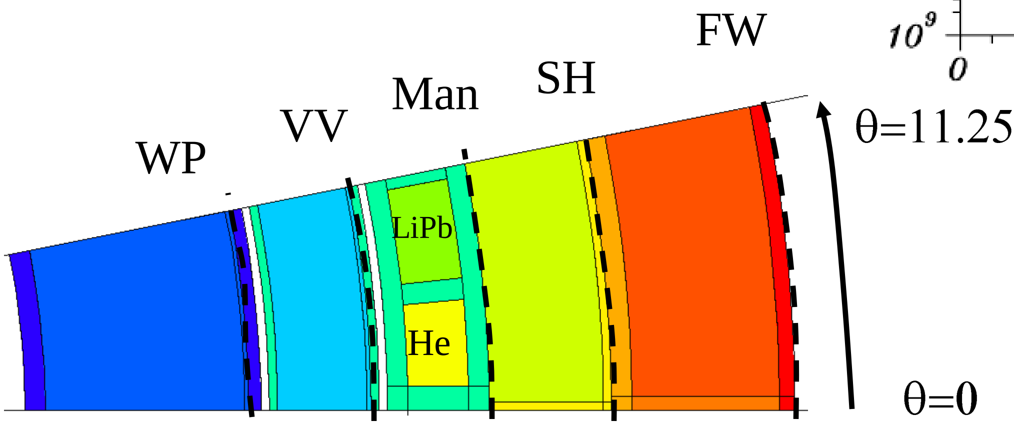
3-D Model →



No gap-Overall IB flux levels

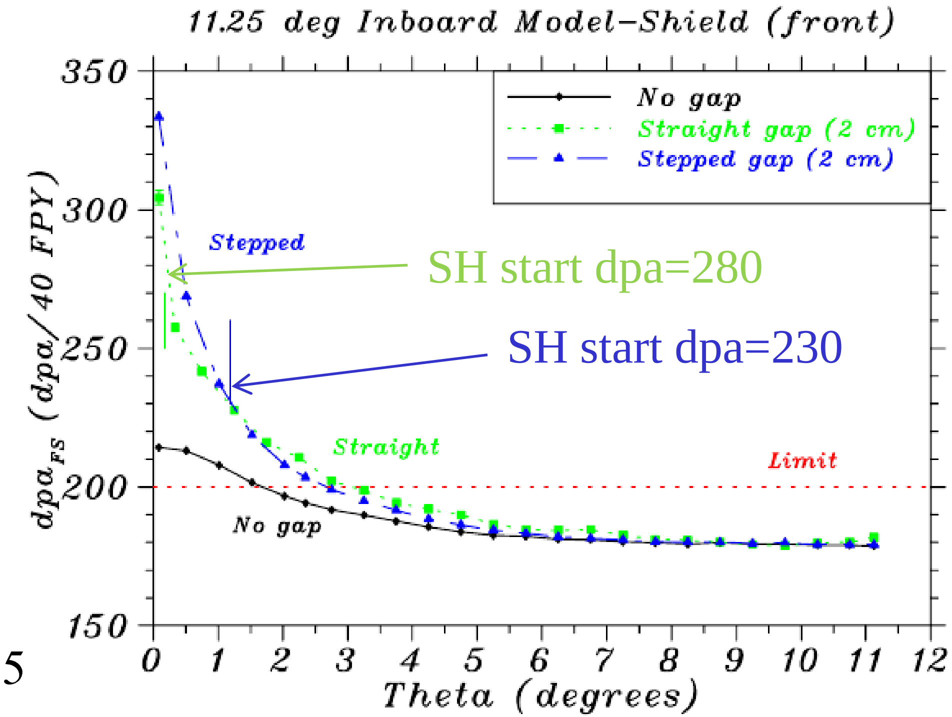
- Almost 6 orders of magnitude attenuation
- Increased levels behind He manifolds (e.g. WP ~2x)

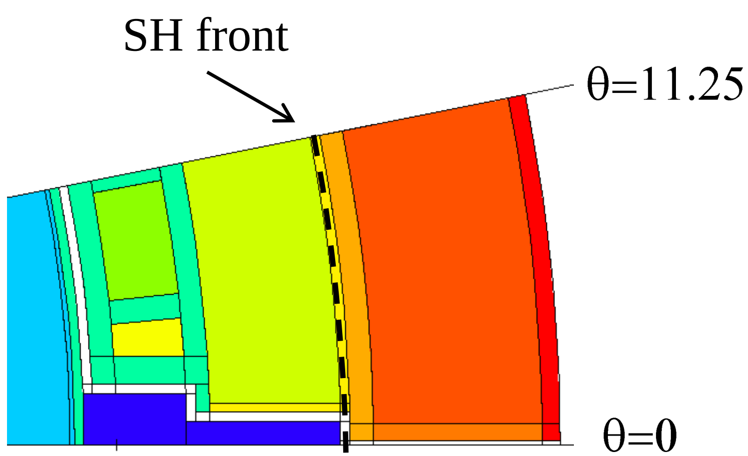




dpa Shield Front (2 cm gaps)

- Both gaps lead to strong peaking
  - Straight Gap $(\text{gap/nogap})_{max}=1.3$
  - Stepped Gap $(\text{gap/nogap})_{max}=1.1$

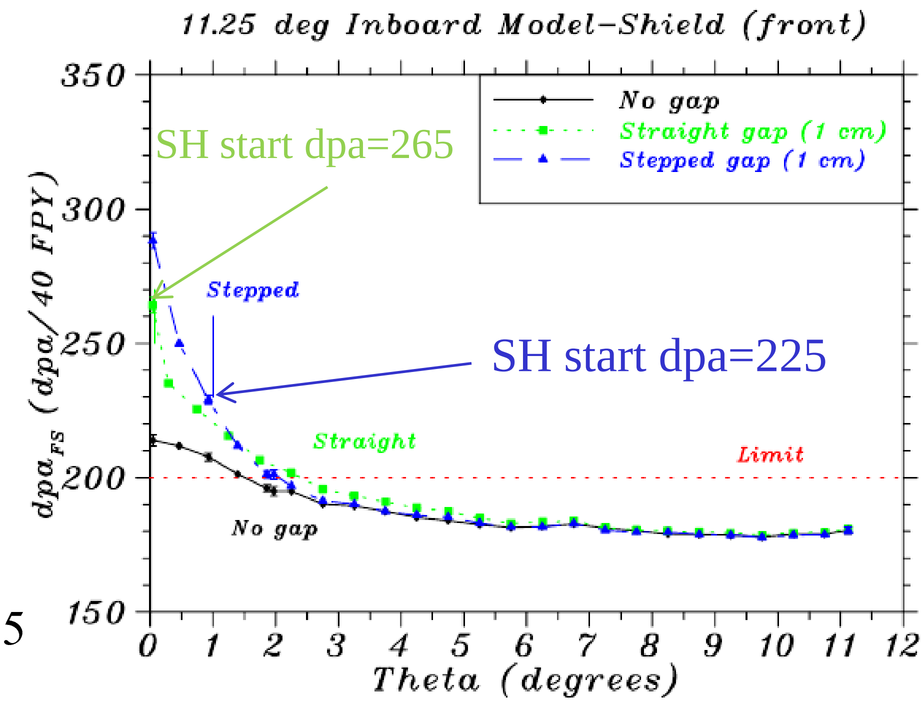


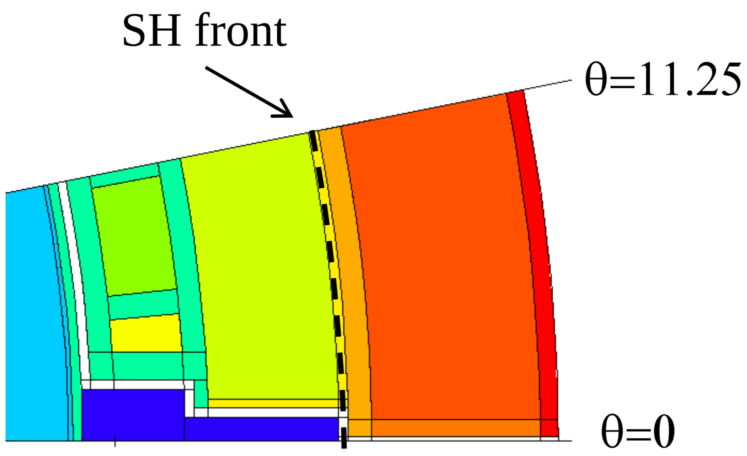


All cases exceed the dpa limit so the front part of shield must be replaceable

dpa Shield Front (1 cm gaps)

- Reduced dpa levels and peaking compared to 2 cm gaps
- Still exceed the limit

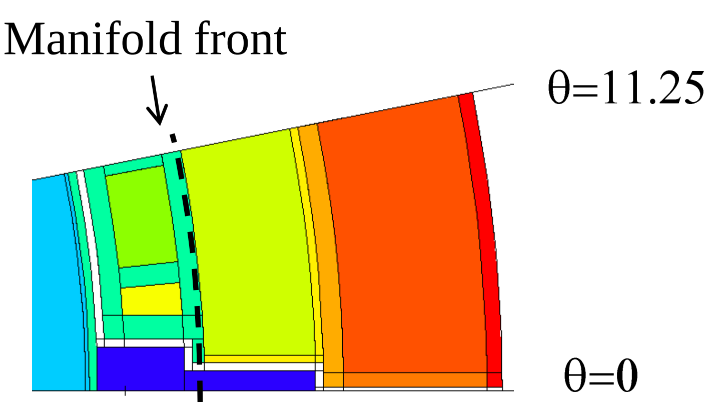


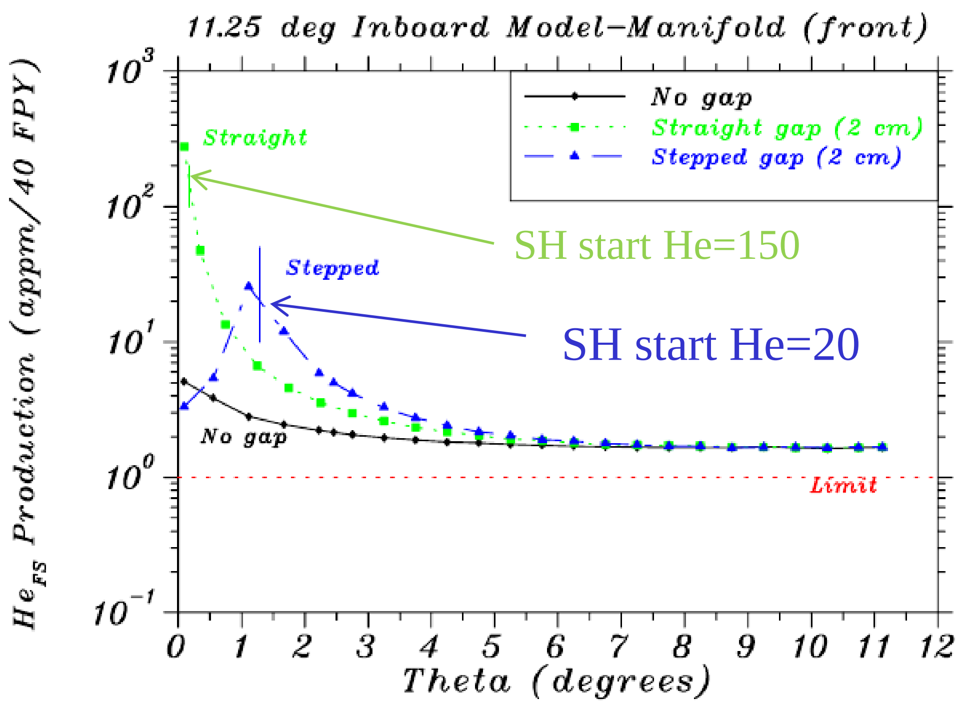


All cases exceed the dpa limit so the front part of the shield must be replaceable

He production Manifold Front (2 cm gaps)

- Both gaps lead to very strong peaking
  - Straight Gap $(gap/nogap)_{max}=30$
  - Stepped Gap $(gap/nogap)_{max}=8$
- Stepped gap shifts peak

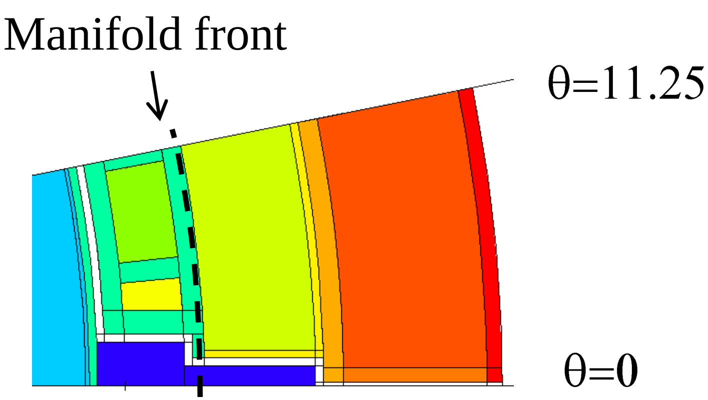


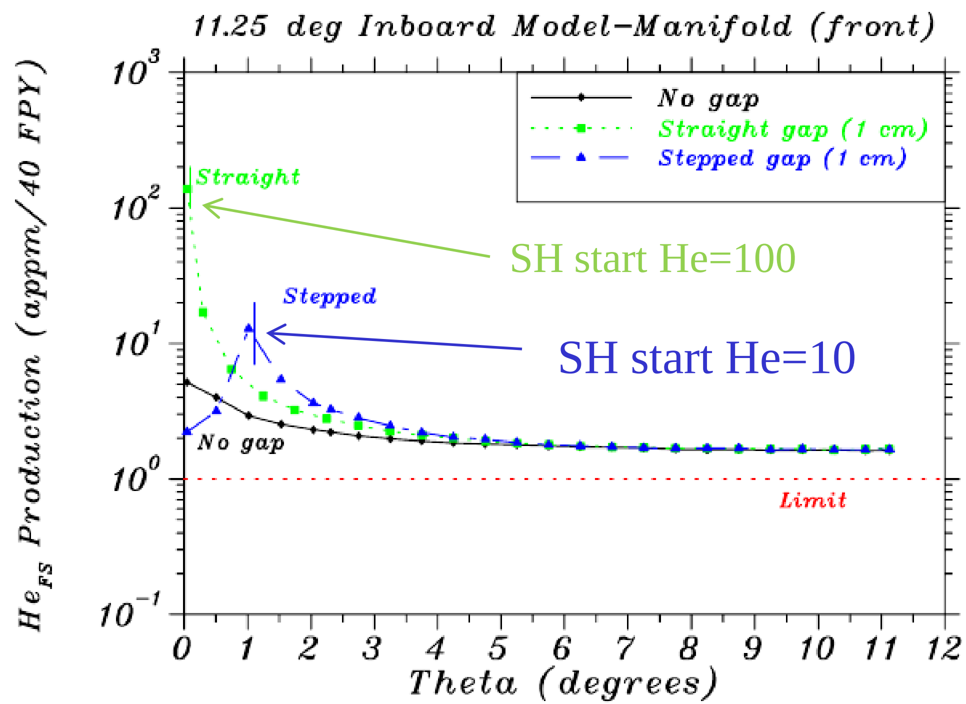


All cases exceed the He production limit so the front part of the manifold is not reweldable (note: new design requires no manifold on IB)

He production Manifold Front (1 cm gaps)

- Reduced He levels and peaking compared to 2 cm gaps

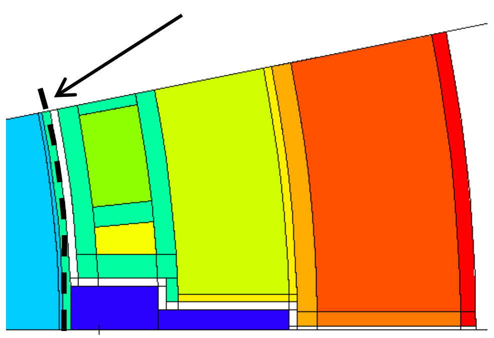


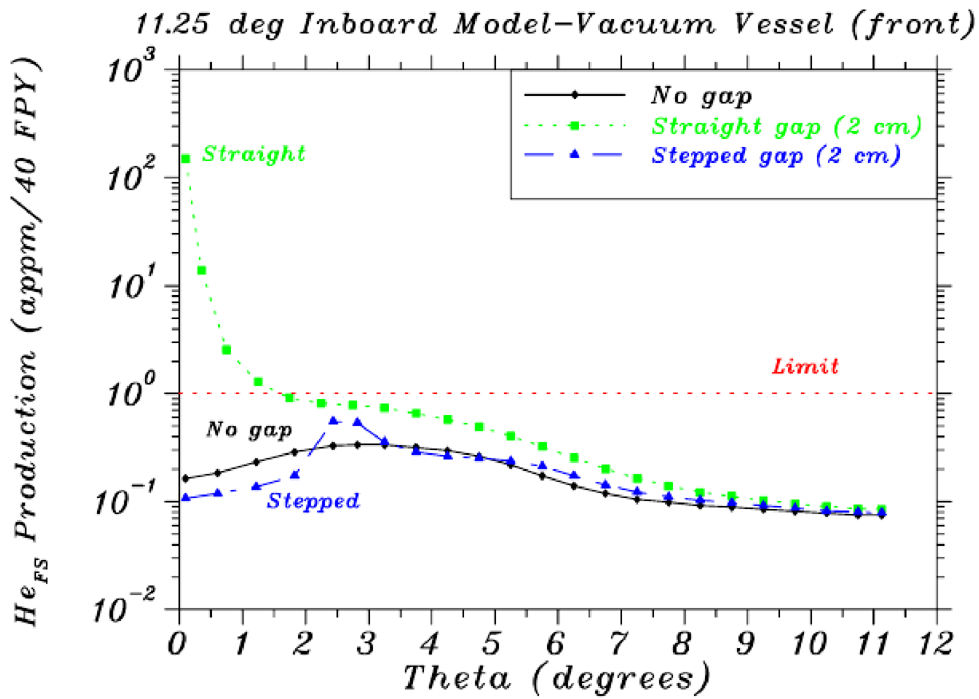


All cases exceed the He production limit so the front part of the manifold is not reweldable

He production Vac Vessel Front (2 cm gaps)

- Straight gap leads to very strong peaking
  - $(gap/nogap)_{max}=900$
- Stepped gap not as strong
  - $(gap/nogap)_{max}=1.7$



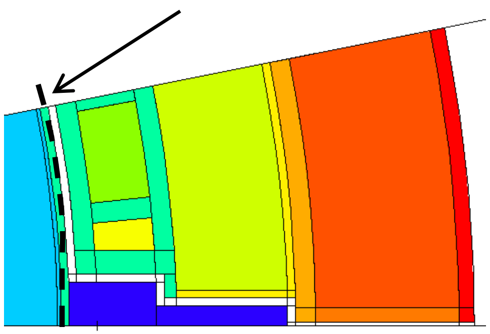


The stepped gap with WC shield block meets the He production limits so the VV is reweldable

He production Vac Vessel Front (1 cm gaps)

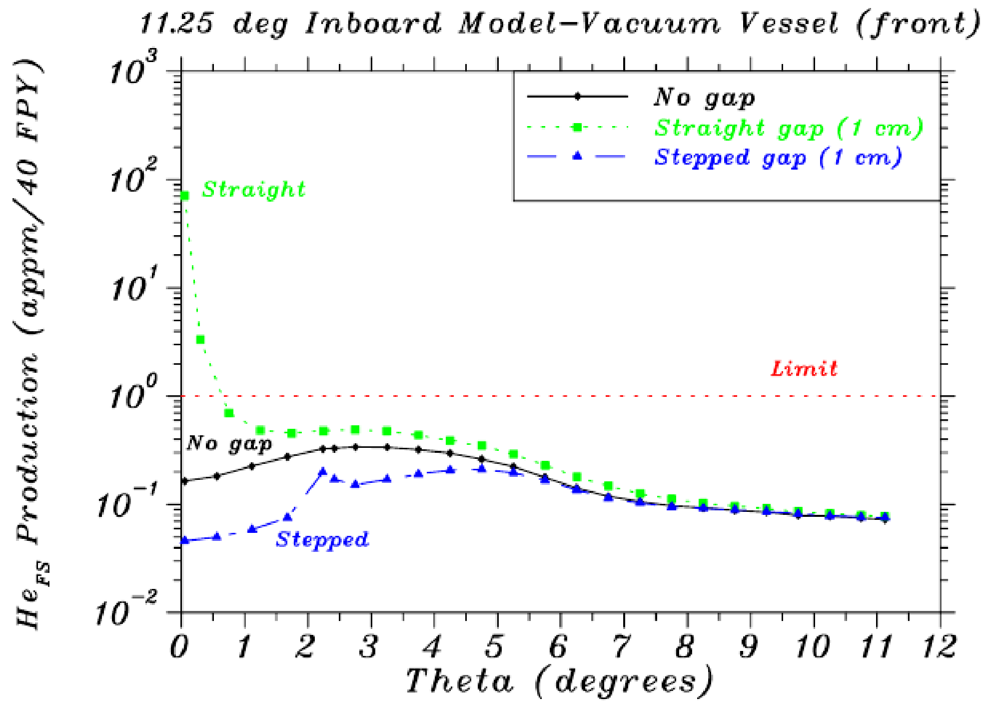
- Reduced He levels and peaking compared to 2 cm gaps

Vacuum Vessel front



θ=11.25

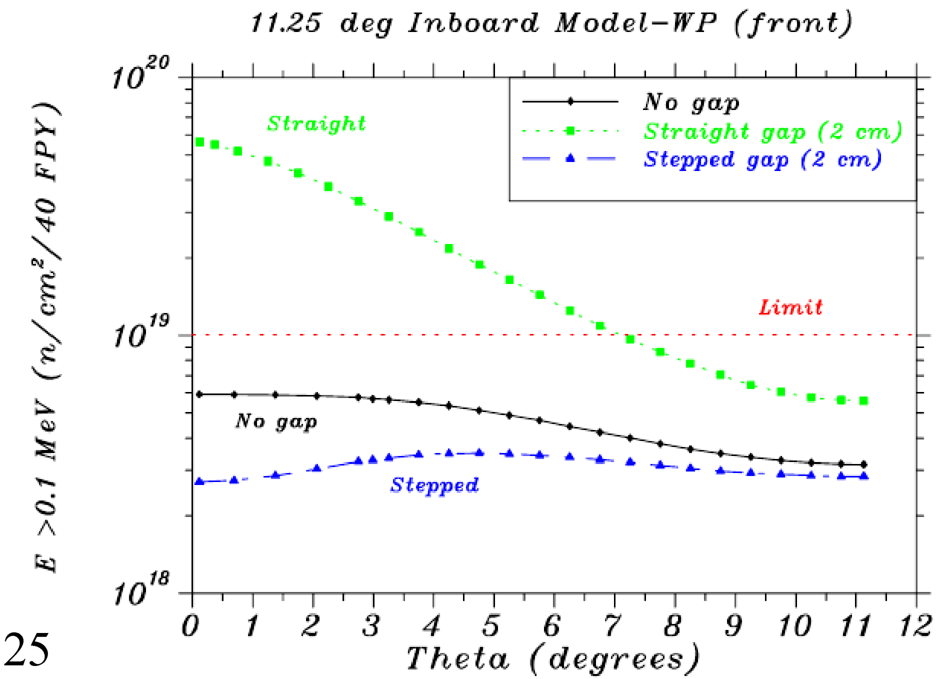
θ=0

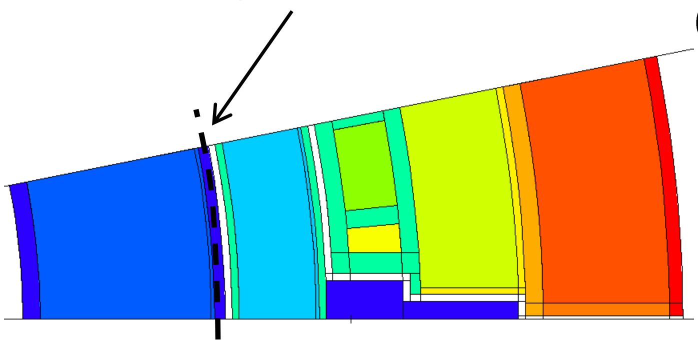


The stepped gap with WC shield block meets the He production limits so the VV is reweldable

Fast Fluence Winding Pack Front (2 cm gaps)

- Smoother peaks due to shielding effect of VV
- Straight gap has significant peaking
  - (gap/nogap)$_{max}$=9.5



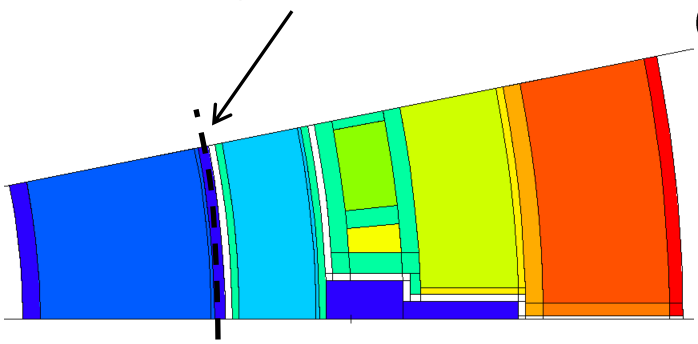


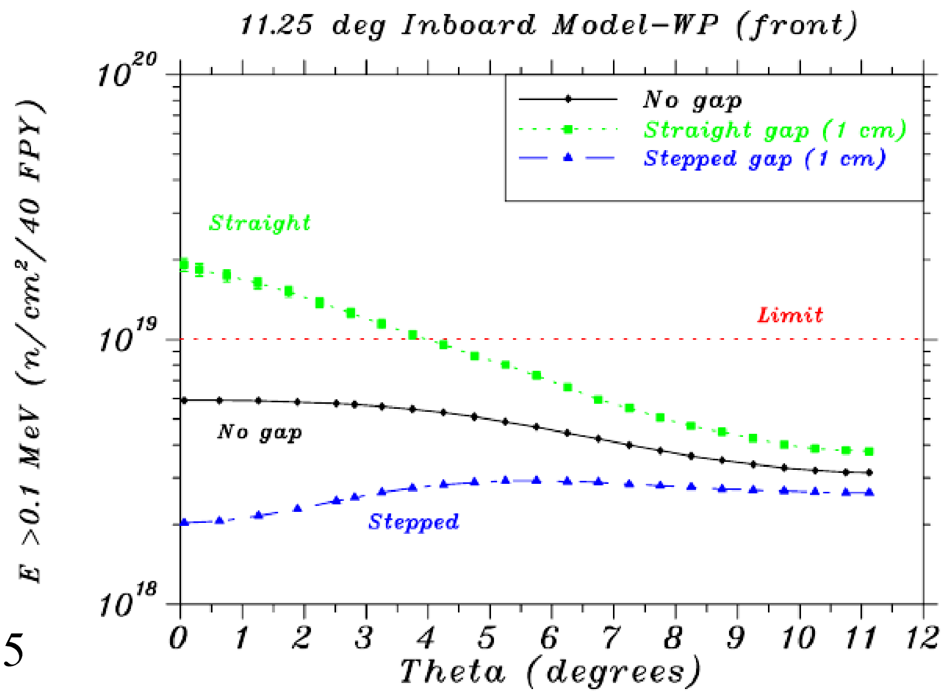
The stepped gap with WC shield block meets the winding pack fast fluence limit

Fast Fluence Winding Pack Front (1 cm gaps)

- Reduced fluence levels and peaking compared with 2 cm gap

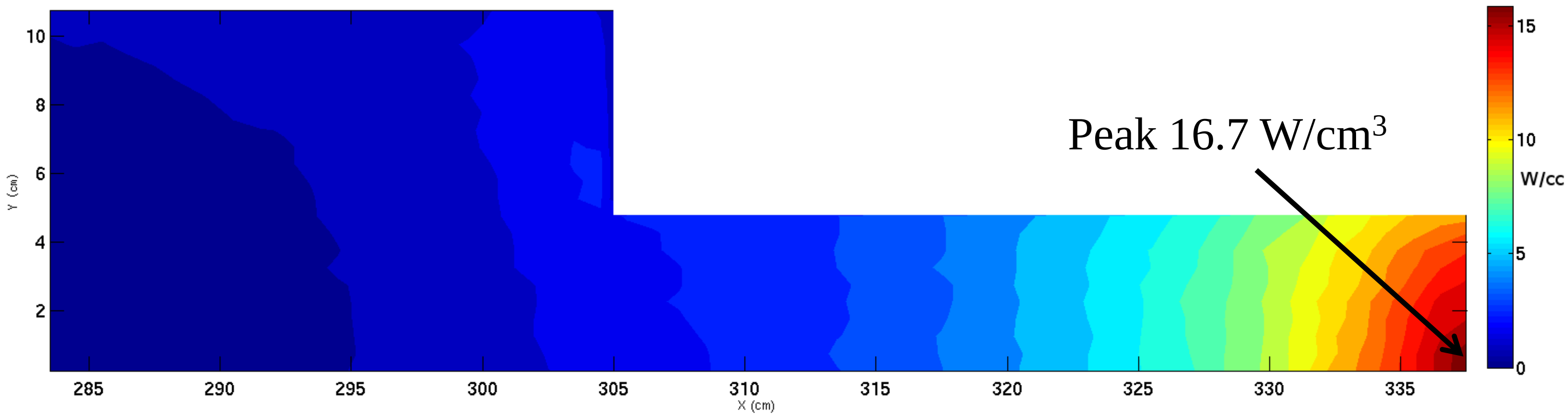
Winding Pack front





The stepped gap with WC shield block meets the winding pack fast fluence limit

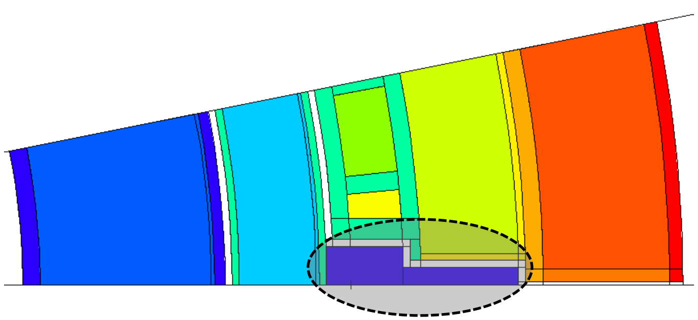
Heating in WC Shield Block (2 cm stepped gap)



Ave. 1.0 W/cm^3

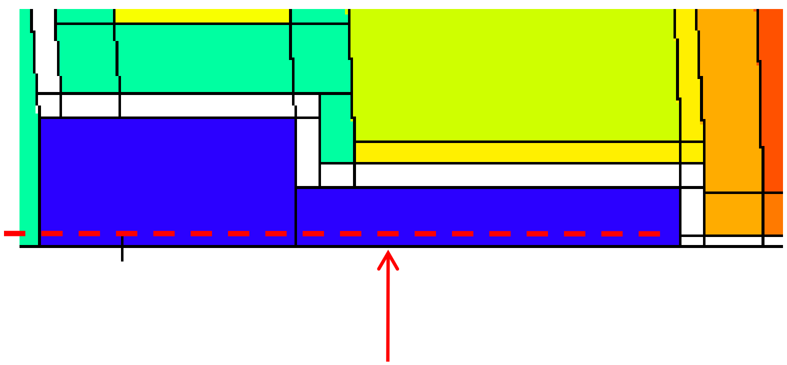
Ave 6.2 W/cm^3

Ave 3.1 W/cm^3

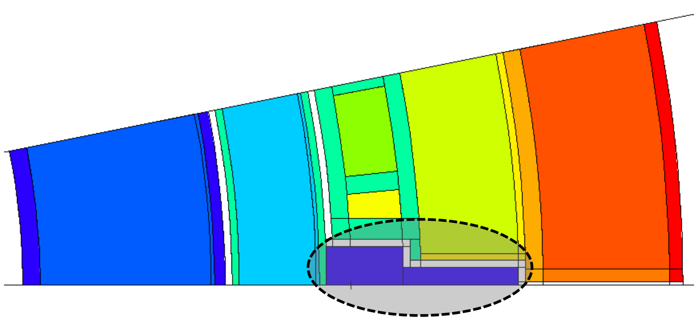


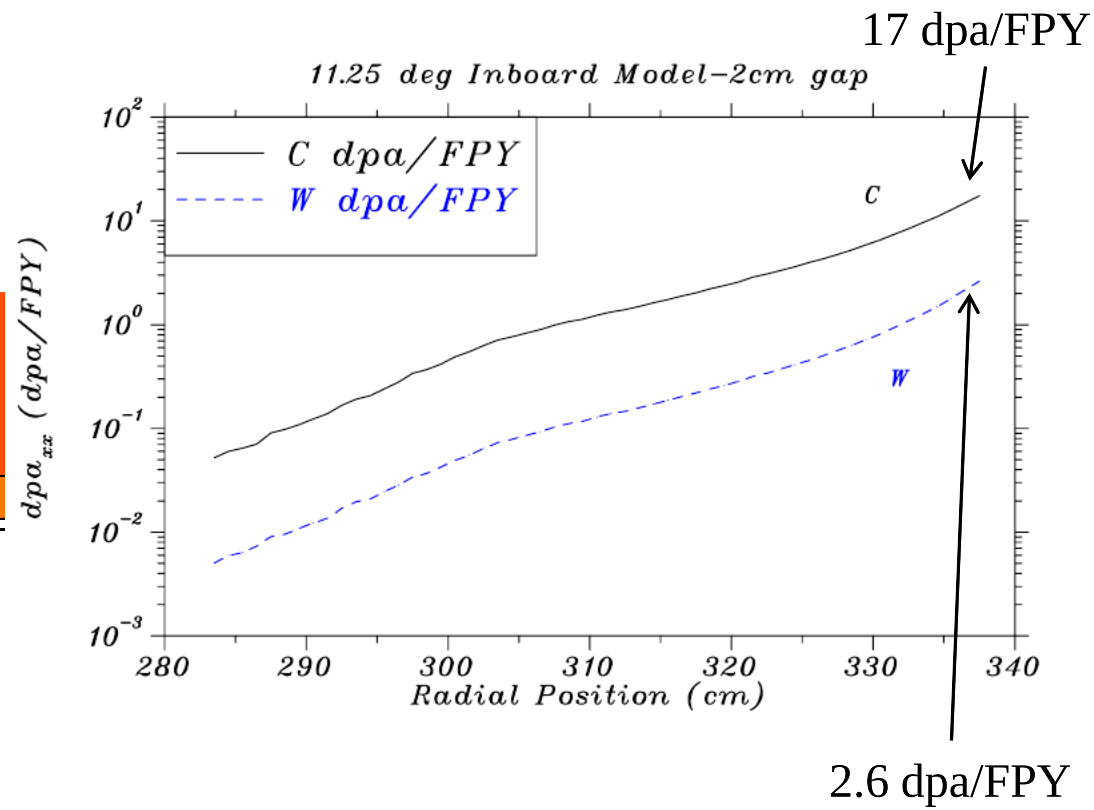
Per S. Malang, radiative cooling is feasible if average heating is below 15 W/cm^3

dpa in WC Shield Block (2 cm gap)



Graph profiles





Materials experts need to decide if WC or W can be used as a structural component

Conclusions

- Straight gaps allow too much radiation to reach components on the IB side for the ARIES-AT DCLL design
- Stepped gaps with WC shield blocks are needed to protect the IB components
- Will need to account for uncertainty in nuclear data
- Safety factor used with 1-D models should be adjusted accordingly