Shielding and Activation Issues for ARIES-AT

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Web address:
http://fti.neep.wisc.edu/FTI/ARIES/AUG99/shield.pdf

ARIES Project Meeting
9 -10 August 1999
UCSD

Contents

- Updated Shielding requirements
- Optimal shield design
- Recommended radial/vertical builds for SiC/LiPb system
- Impact of magnet cryogenic shield on radial standoff
- Comparison between afterheat of WC and FS-based IB shields
- Clearance issues and recommended changes to V.V.

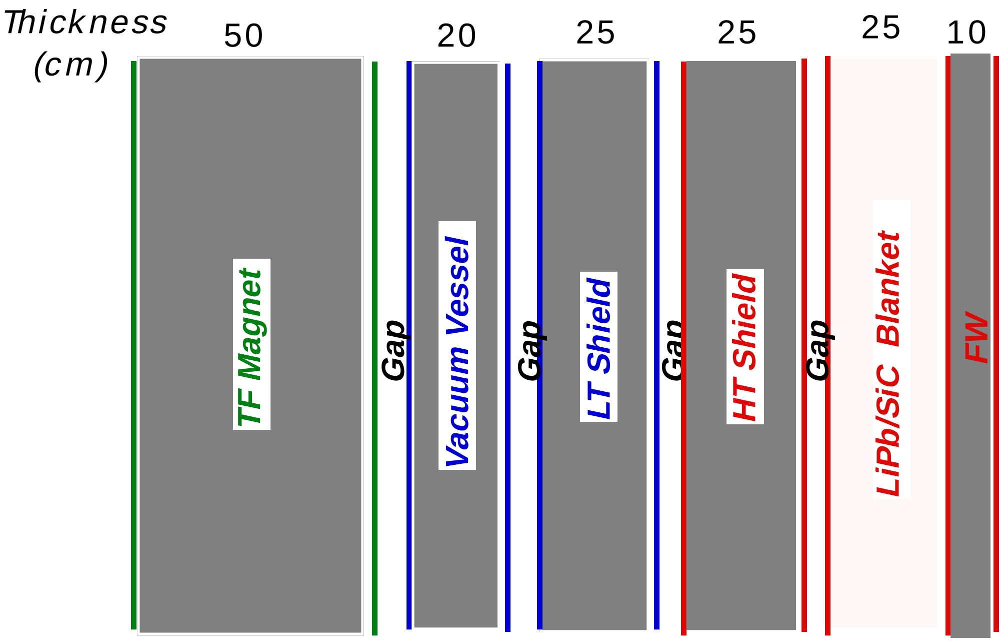
Shielding Requirements

- Provide lifetime protection for HT magnets $< 10^{19}$ n/cm^2
- Provide lifetime protection for V.V. < 1 He appm
- Protect workers/personnel during operation < 2.5 mrem/h
- Power production component
  (< 1% nuclear heating in LT shield)
- OB shield is lifetime component < 200 dpa for FS
  < 3% burnup for SiC
- Reasonable cost
- Attractive safety & environmental characteristics:
  - Low level waste (Class C)
  - No hazardous materials
  - No damage in case of LOCA/LOFA
- Clear as many components as design allows for reasonable cost
- Meet stress and temperature limits
- Reliable, maintainable, replaceable, recyclable

Main Features of Shield/V.V.

- High performance, expensive materials for IB side
- Lower performance, inexpensive materials for OB side
- LiPb-cooled HT shield with SiC structure for self-cooled design
- He-cooled (?) HT shield with SiC structure for dual-cooled design
- H_2O-cooled LT shield and V.V. with FS structure
- ARIES-RS’ V.V. configuration (20 cm IB, 20 cm div., 30 cm OB)

Inboard Radial Build



Components	**Composition**
FW	17% SiC , 26% LiPb, 57% void
Blanket	8% SiC , 92% LiPb
HT Shield	15% SiC, 10% LiPb , 75% **B-FS**
LT Shield	15% FS , 5% H_2O , 80% WC
Vacuum Vessel	35% FS , 40% H_2O , 25% WC

- Shield sized for self-cooled FW/B design
- No significant difference in total FW/B/S/VV thickness between self-cooled and dual-cooled designs
- V.V. and TF magnet radiation limits are all met[*] for peak Γ= 5 MW/m^2
- Higher wall loading requires thicker LT shield
- Old LT magnet info used for shielding analysis (need info on HT magnet)

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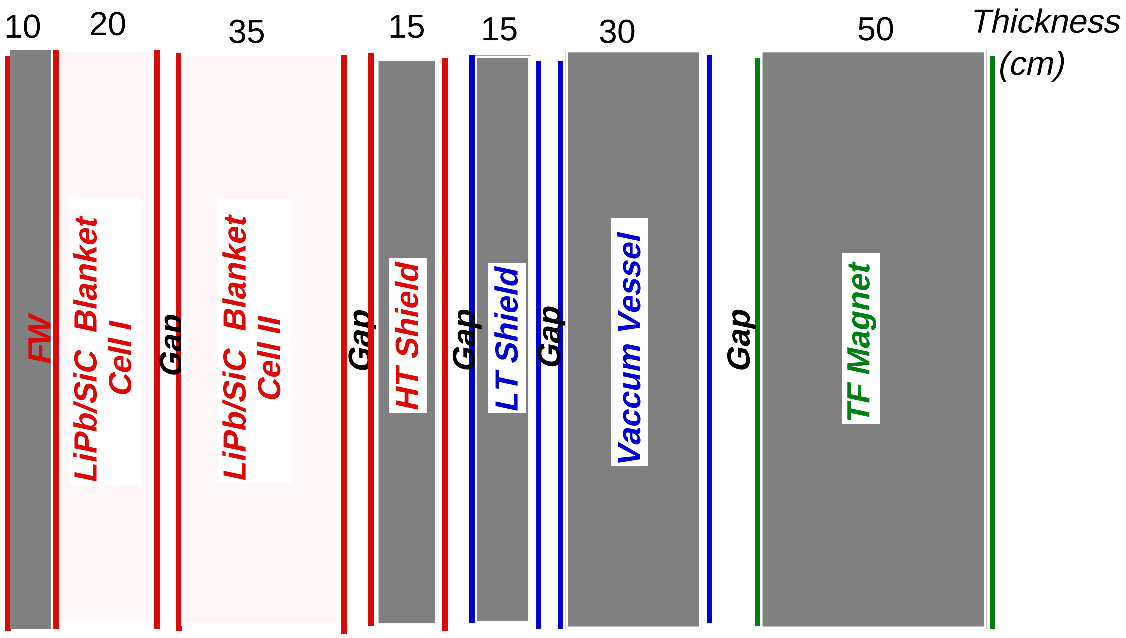
[*] Safety factor of 3 considered in all shielding calculations

Outboard Radial Build



Components	**Composition**
FW	17% SiC , 26% LiPb, 57% void
Blanket	8% SiC , 92% LiPb
HT Shield	15% SiC, 10% LiPb , 75% B-FS
LT Shield	15% FS , 5% H_2O , 80% B-FS
Vacuum Vessel	25% FS , 60% H_2O, 15% B-FS

- Shield sized for self-cooled FW/B design
- Blanket Cell II and HT shield could be combined in a single lifetime component
- No significant difference in total FW/B/S/VV thickness between self-cooled and dual-cooled designs
- V.V. and TF magnet radiation limits are all met[*] for peak Γ= 7 MW/m^2
- Higher wall loading requires thicker LT shield
- Old LT magnet info used for shielding analysis (need info on HT magnet)

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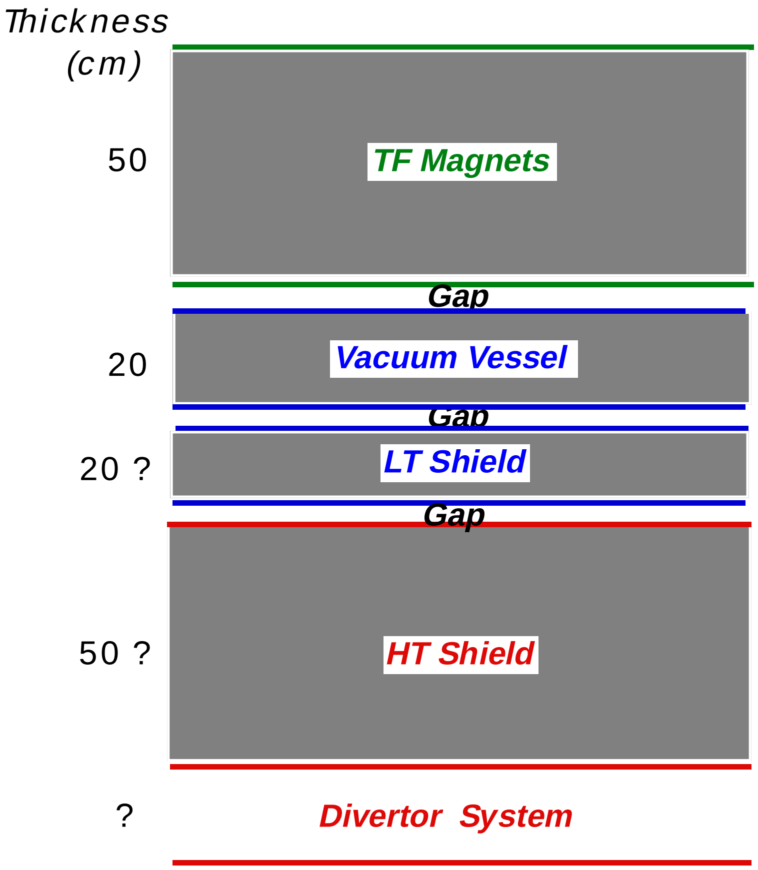
[*] Safety factor of 3 considered in all shielding calculations

Vertical Build



Thickness
(cm)

50 TF Magnets

Gap

20 Vacuum Vessel

Gap

20 ? LT Shield

Gap

50 ? HT Shield

? Divertor System

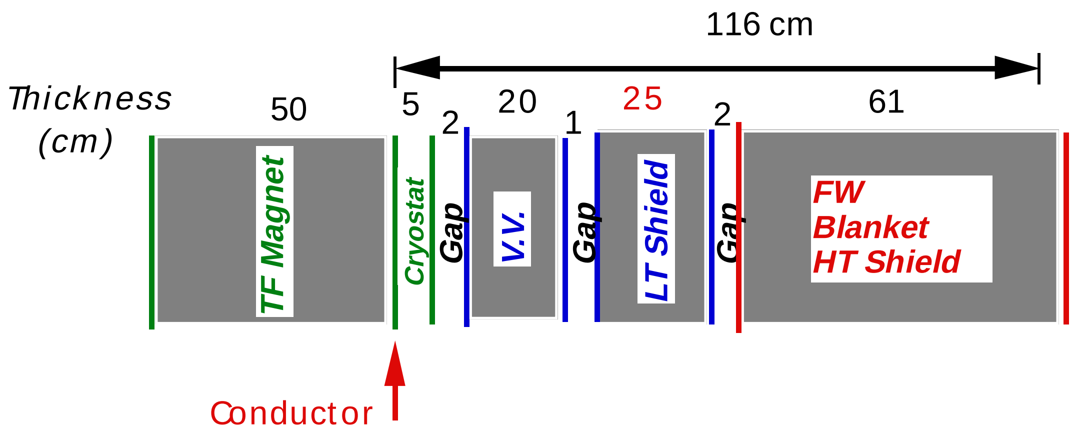
Divertor System	?% SiC , ?% LiPb or He
HT Shield	15% SiC , 10% LiPb , 75% B-FS
LT Shield	15% FS , 5% H_2O , 80% B-FS
Vacuum Vessel	35% FS , 40% H_2O , 25% B-FS

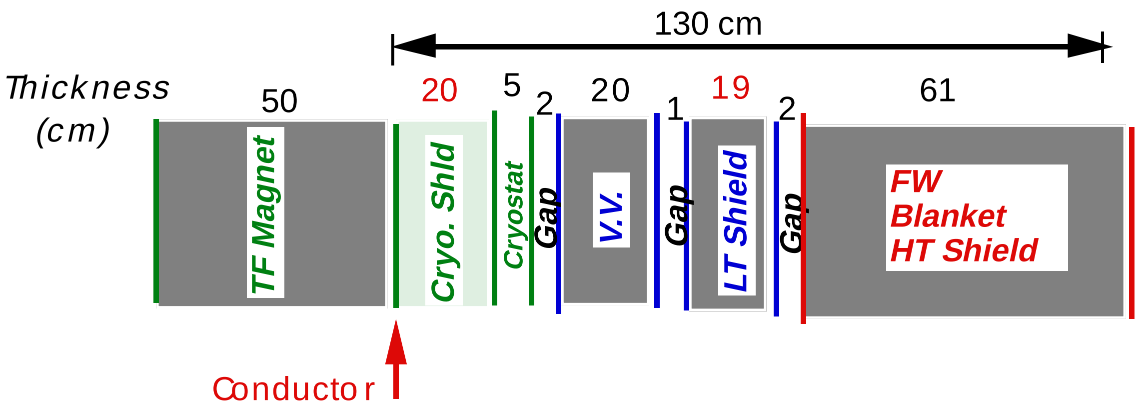
- Shield size depends on divertor system design

Impact of Magnet Cryogenic Shield on Radial Standoff

- Water-cooled WC-based IB shield/V.V. is much more efficient than SS-based magnet cryogenic shield
- Using 20 cm cryogenic shield reduces IB LT shield thickness by 6 cm but increases FW-conductor distance by 14 cm
- Cryogenic shield will not reduce radial standoff between FW and conductor

Reference Design



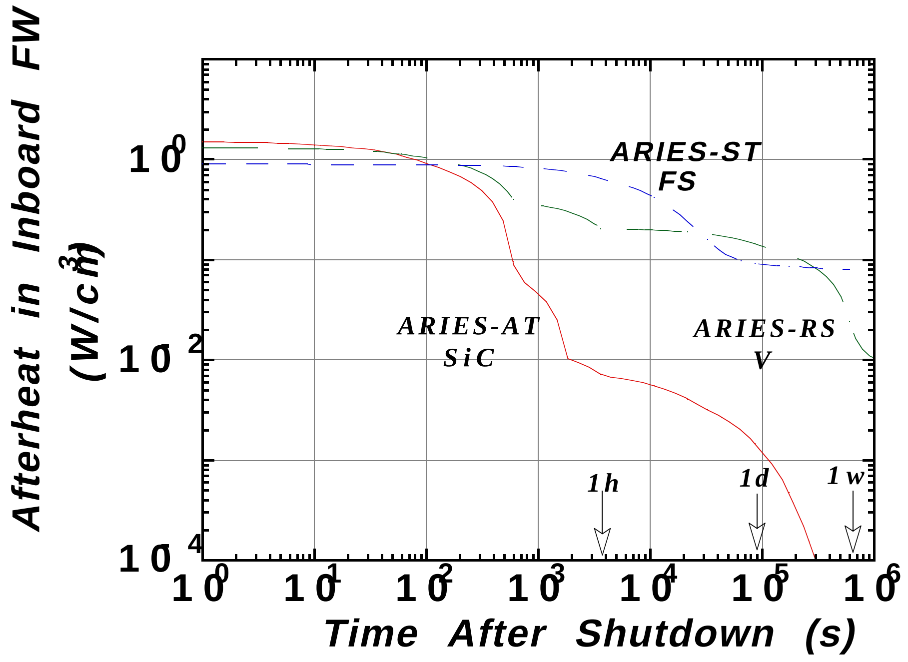


Cryogenic SS shield is not recommended for HT magnets

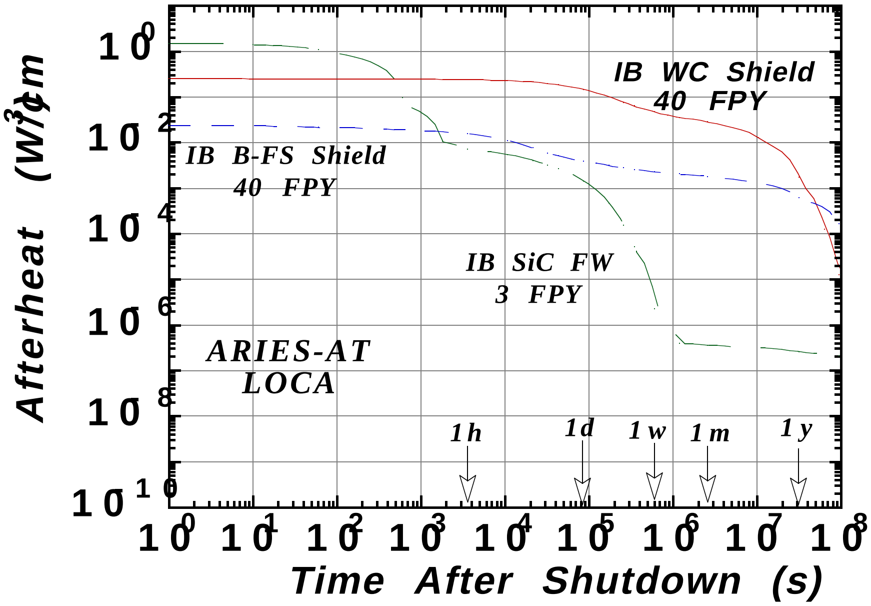
Activation Analysis

- Codes and model:
  - – Activation: ALARA code; FENDL-2 activation library
  - – Flux: 1-D transport DANTSYS code; FENDL-1 Xn data; 175 n and 42 g group structure
  - – 3-D neutron fluxes used to re-normalize 1-D fluxes for all components
  - – Irradiation time: 3 FPY FW, 9 FPY Blanket-Cell I, 40 FPY other components
  - – Continuous operation (need availability to run pulsed case)

- LiPb/SiC System:
  - – SiC structure generates very low afterheat compared to FS and V
  - – LiPb generates higher afterheat than SiC
  - – In ARIES-AT, LOFA is more critical than LOCA
  - – Afterheat calculation is done
  - – Waste disposal and clearance analyses are in progress

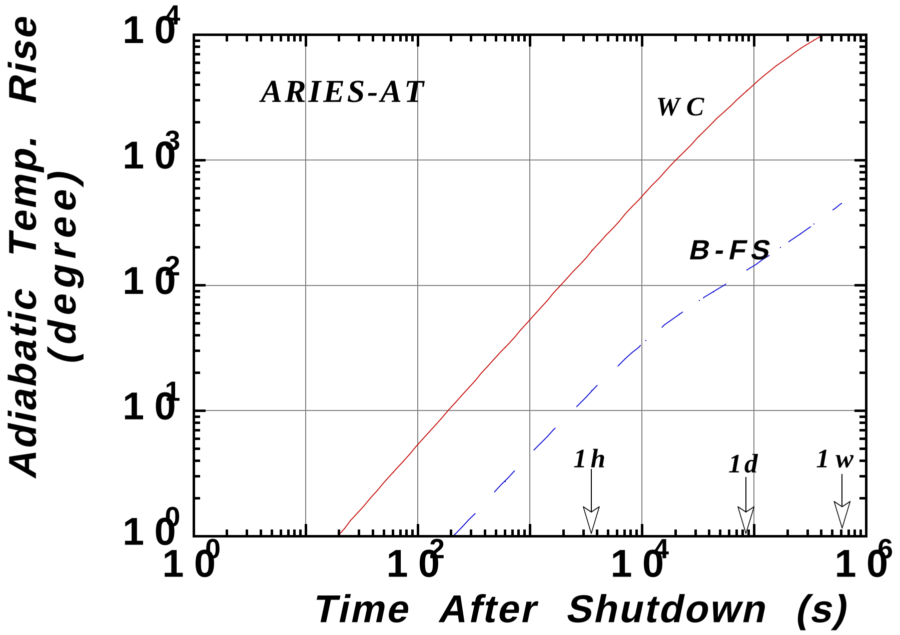


Afterheat Comparison Between WC and FS-based IB HT Shield



WC reduces radial build by ~5 cm but generates higher afterheat than B-FS

Temperature Rise in IB HT Shield During LOCA/LOFA



- Adiabatic calculations indicate excessive temp rise in WC-based IB HT shield after onset of LOCA/LOFA
- Realistic LOCA/LOFA analysis results in lower temp rise
- B-FS filler is recommended for IB HT shield
- What is the max. allowable temp. for SiC (T_m= 2700 C) during LOCA/LOFA?

Clearance Issues

ARIES-RS Design

Components	**Volume** (m^3)	**Clearance Index**	**Cleared?**
Blanket (compact)	25 (2%)	>> 1	no
Shield	560 (46%)	>> 1	no
Vacuum Vessel	175 (15%)	> 1	no
Magnet	440 (37%)	< 1	yes

Magnets (~35%) are always cleared

Blanket and shield (~50%) of all fusion designs will never meet clearance requirement

V.V. could be cleared with thicker shield

Clearance Issues

For VV, clearance limit is more restrictive than reweldability limit

Option I:

Meeting VV reweldability requirement (1 appm He)

⇒ Thin shield not cleared, VV not cleared

Shield volume = V_1
VV volume = V_2
Magnet volume = V_3

Option II:

Meeting VV clearance requirement

- Need 20-30 cm thicker shield
- Thicker shield not cleared, VV cleared
- Larger non-cleared shield volume

Shield volume $> V_1$
VV volume $> V_2$
Magnet volume $> V_3$

⇒ Larger "waste + cleared" volume !

If incremental increase in shield thickness is comparable to V.V. thickness, dispose of V.V. along with shield as Class C radwaste

Option III:

Meeting VV clearance requirement

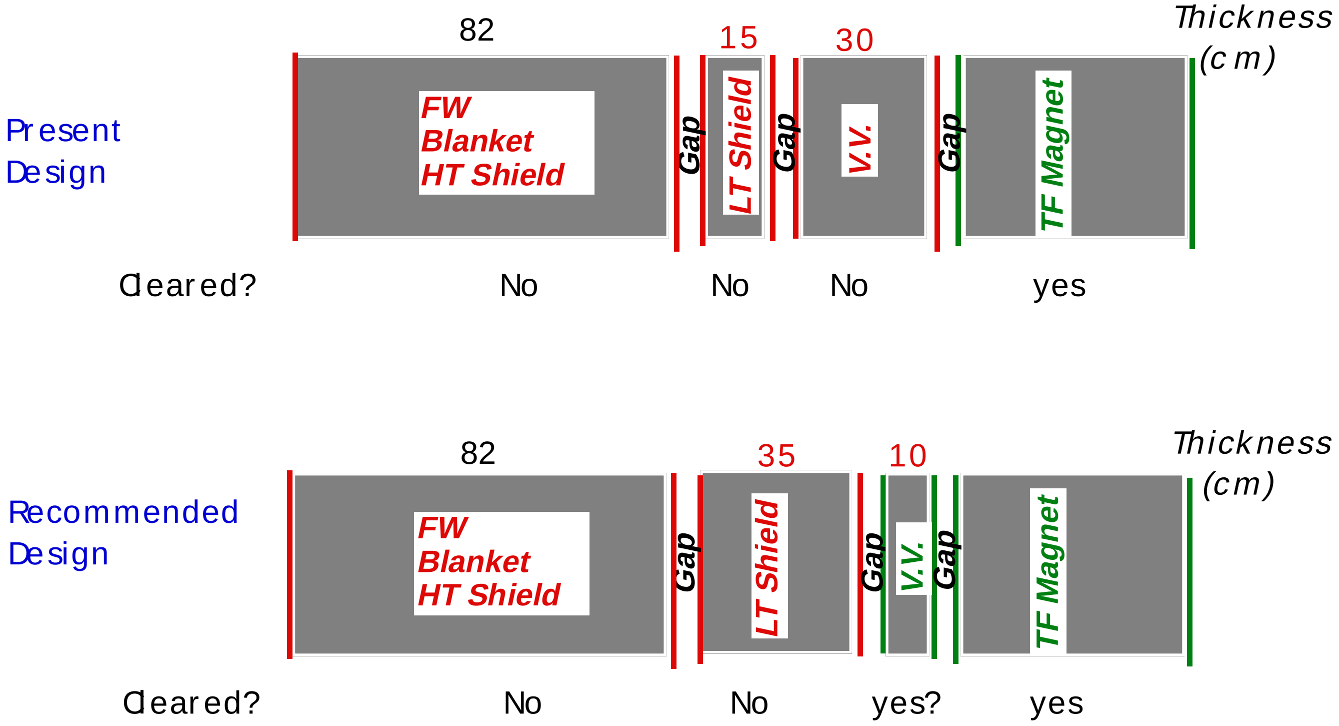
- Need 20-30 cm thicker shield
- Design thin V.V. (~10 cm thick)
- Thicker shield not cleared, thin VV cleared
- Larger non-cleared shield volume

Shield volume $> V_1$
VV volume $< V_2$
Magnet volume $\sim V_3$

⇒ ~ same "waste + cleared" volume

Clearance Issues (cont.)

ARIES-AT Outboard Components



Activation analysis will determine boundary between radwaste and cleared components

How thin the V.V. could be? In ARIES-AT, 10 cm thick V.V. may qualify as cleared component

Shield should help clear as many components as design allows w/o significant increase in radwaste volume or cost