Preliminary Activation Analysis for LiPb/SiC and LiPb/FS Systems

L. El-Guebaly, P. Wilson, and D. Paige
Fusion Technology Institute
University of Wisconsin - Madison

With input from:
L. Bromberg (MIT)

ARIES-CS Project Meeting
March 8 - 9, 2004
UCSD

Outline

- Activation assessment for two different systems with SiC and FS structures:
  - Activity
  - Decay Heat
  - Waste Disposal Rating (WDR)
- Future plan.

SiC- and FS-Based Systems Selected for Preliminary Activation Analysis

Breeder	Multiplier	Structure	FW/Blanket Coolant	Shield Coolant	VV Coolant
Internal VV:					
Flibe	Be	FS	Flibe	Flibe	H_2O
LiPb	**–**	**SiC**	**LiPb**	**LiPb**	**H_2O**
LiPb	**–**	**FS**	**He/LiPb**	**He**	**H_2O**
External VV:					
LiPb	–	FS	He/LiPb	He/B-H_2O	He
LiPb	–	FS	He/LiPb	He	He
Li	–	FS	He/Li	He	He

Key Activation Parameters

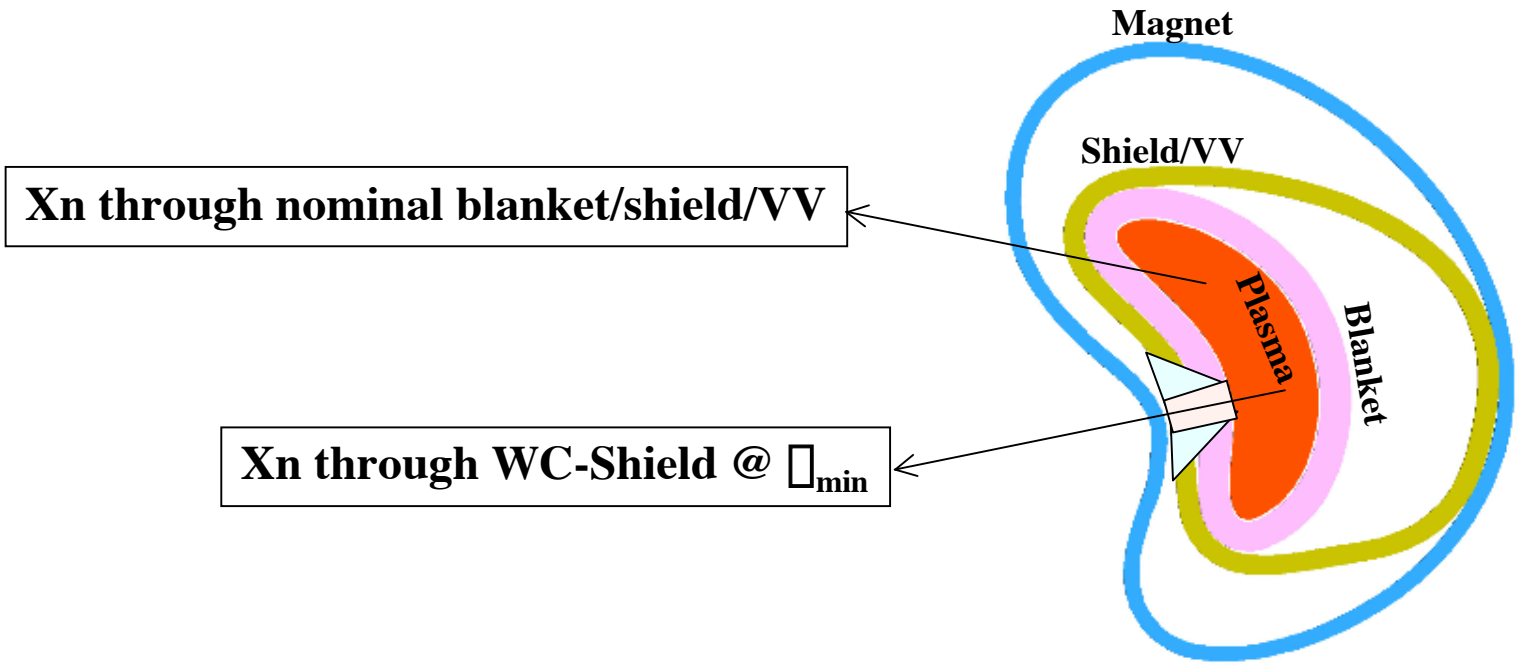
	SiC System	FS System
Average Neutron Wall Loading	2 MW/m^2	2 MW/m^2
FW/Blanket Lifetime	6 FPY	5 FPY
Shield/VV/Magnet Lifetime	40 FPY	40 FPY
Availability	85%	85%

Elements Controlling Activation Results

- **Average neutron wall loading**.
- **Lifetime** of individual components.
- **Thickness** of components

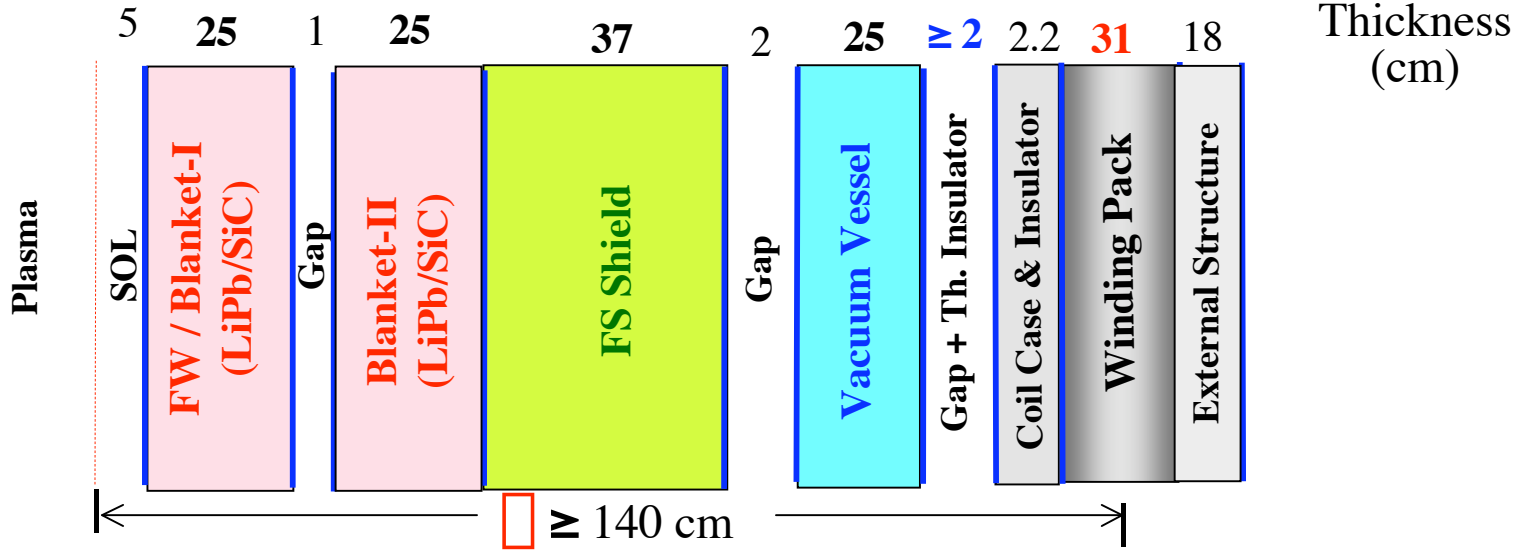
  (large volume lower volume-average responses).
- **Composition**: structural materials, filler, alloying elements, and impurities.
- Neutron **spectrum.**
- **Decay rate** of radioisotopes.
- Waste disposal **limits**.

Analysis Performed at Two Radial Cross Sections

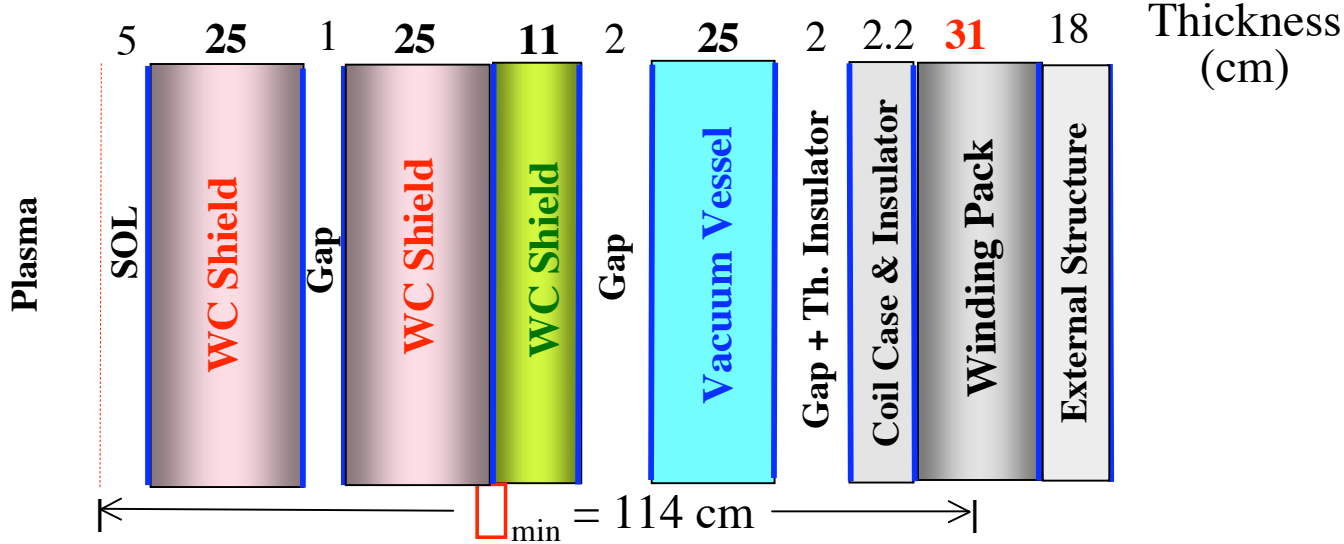


LiPb/SiC Radial Build
(Water-Cooled Internal VV)

Blanket Zones

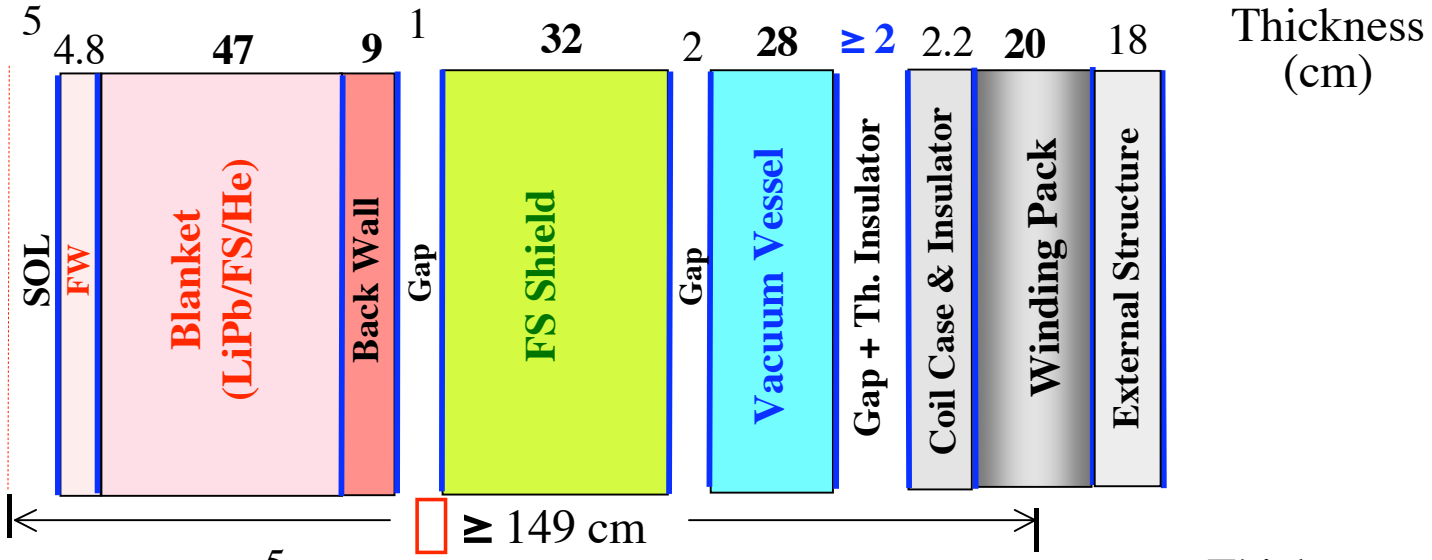


Shield Only Zones

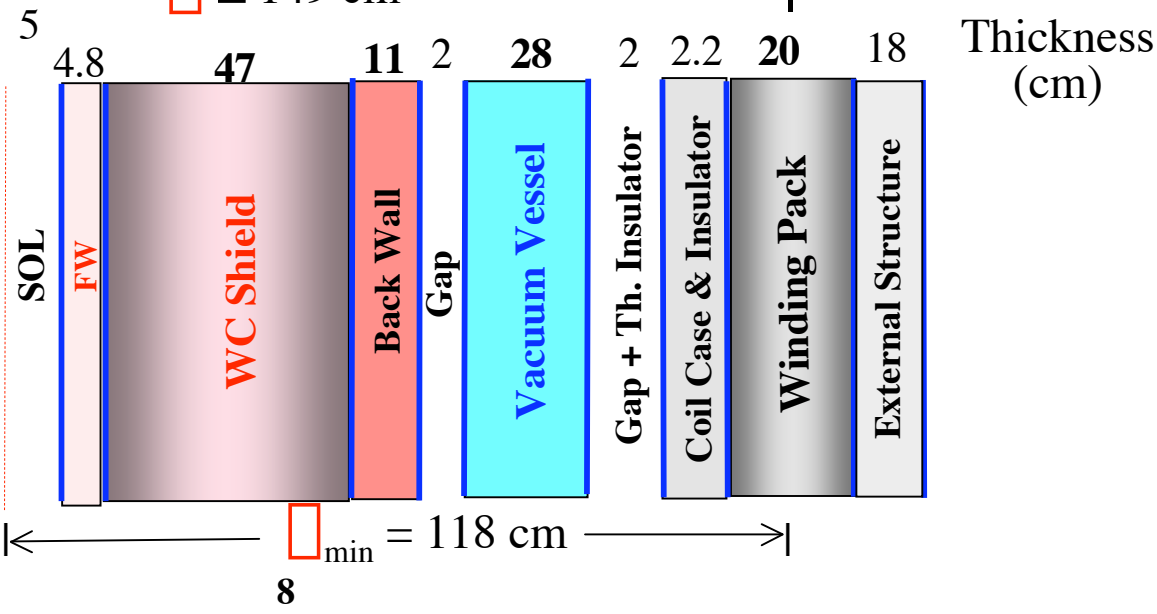


LiPb/FS/He Radial Build
(Water-Cooled Internal VV)

Blanket Zones

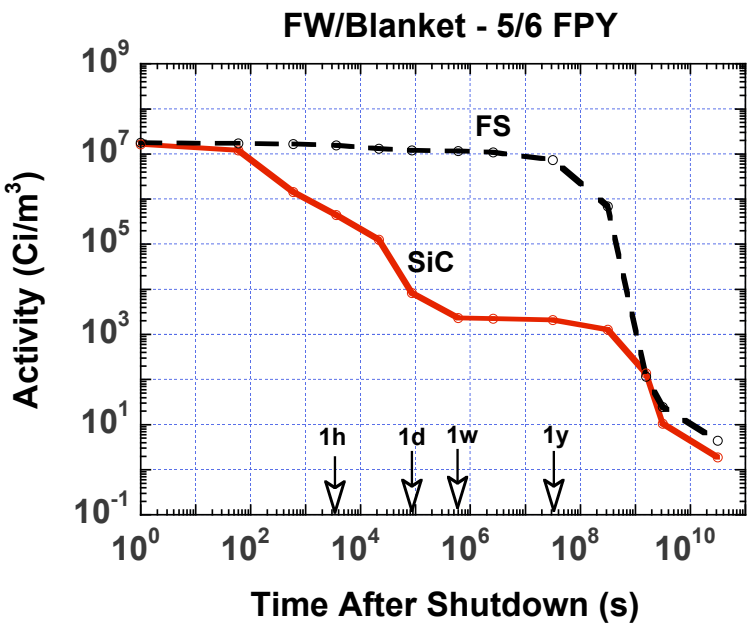


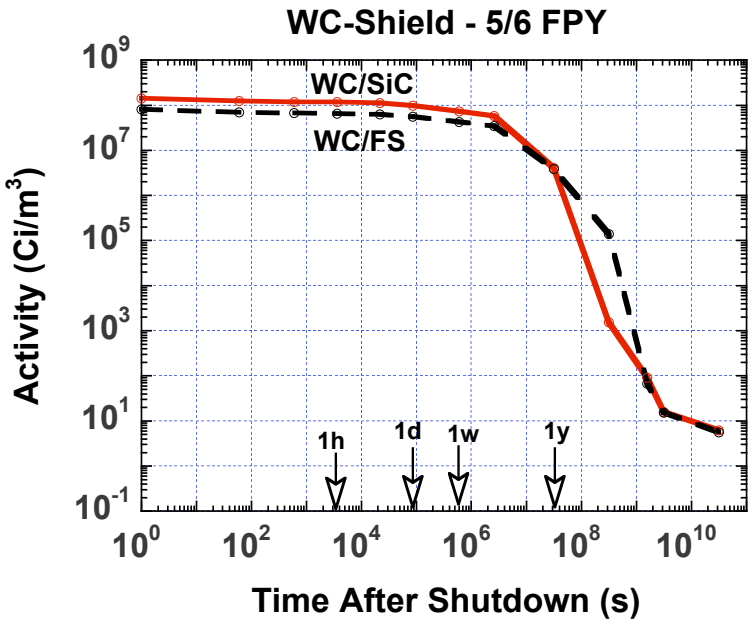
Shield Only Zones



Boundary between WC-shield and back wall will be adjusted to meet design requirements

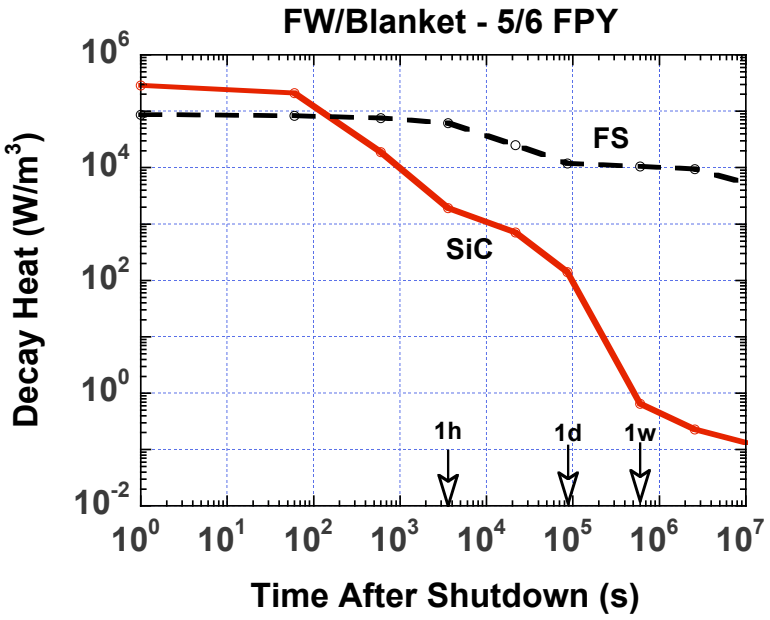
Activity

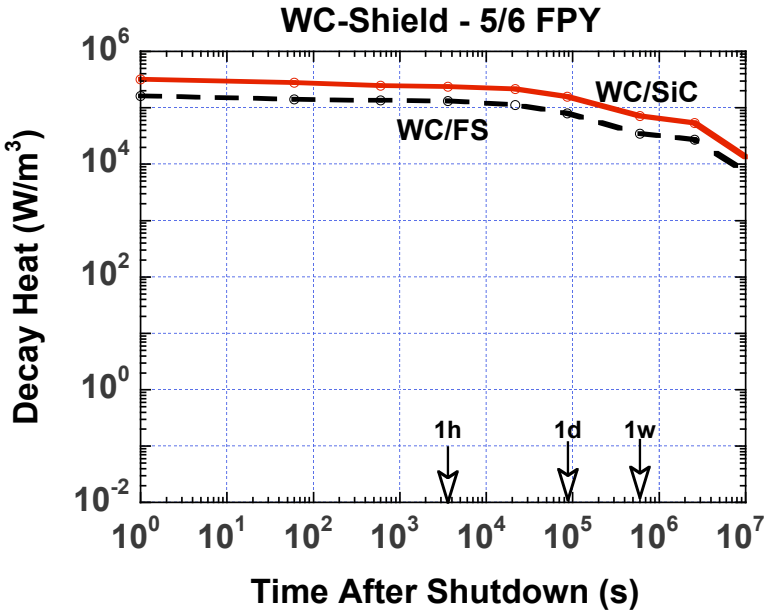




- At intermediate time following shutdown (1 d - 10 y), **SiC** system offers 3-4 orders of magnitude lower activity compared to FS.
- **WC** filler generates highest activity.

Decay Heat





- **SiC** decay heat drops sharply after shutdown.
- **WC-shield** generates **10 - 1000 times higher decay heat** than FW/blanket @ 1 d after shutdown.
- If temperature during LOCA/LOFA exceeds limit, install **special loop** to transport decay heat from WC-shield to surroundings.

Waste Disposal Rating

(Compacted Waste @ 100 y After Shutdown;
Fetter's Class C Limits Unless Indicated)

	SiC System	FS System
Replaceable Components:		
FW/Blanket-I	0.03	0.4
WC-Shield	0.8	0.6
Permanent Components:		
Blanket-II	0.06*	---
Shield	0.5	0.7
Vacuum Vessel	0.02	0.05

* NRC Class C limits

- WDR < 1 ⇒ **Class C Low Level Waste** (LLW).
- **SiC-FW/blanket** and **VV** qualify as **Class A** LLW.

Waste Disposal Rating (cont.)

(Compacted Waste @ 100 y After Shutdown;
Fetter's Class C Limits Unless Indicated)

SiC System	Old Magnet	New Magnet
Coil Case	0.6 (Incalloy*)	**0.02** (316-SS)
WP-I	0.34 (Nb_3Sn)	**0.001** (MgB_2)
WP-II	---	**0.12** (NbTi)
External Structure	0.05 (Incalloy*)	**0.001** (316-SS)

- WDR < 1 ⇒ **Class C LLW**.
- **New magnet** offers lower WDR.
- **Averaging** WDR over WPs and structure qualifies **new magnet as Class A LLW**.

Waste Disposal Rating (cont.)

(Compacted Waste @ 100 y After Shutdown; Fetter's Class C Limits Unless Indicated)

FS System	Old Magnet	New Magnet
Coil Case	0.5 (Incalloy*)	**0.02** (316-SS)
WP-I	0.27 (Nb_3Sn)	**0.001** (MgB_2)
WP-II	---	**0.10** (NbTi)
External Structure	0.04 (Incalloy*)	**0.001** (316-SS)

* Contains 3 wt% Nb.

- WDR < 1 ⇒ **Class C LLW**.
- New magnet offers lower WDR.
- **New magnet** qualifies as **Class A** LLW.

Concluding Remarks

- No major activation problems identified for SiC and FS systems.
- All radioactive wastes qualify as Class C LLW.
- Few components qualify as Class A LLW:
  - SiC Blanket-I&II
  - Vacuum vessel
  - New magnet.
- High decay heat identified for WC-shield
  - Special loop could be installed to automatically transfer decay heat to surroundings if temperature during accident exceeds limit.

Future Plan

- Generate temperature profile during LOCA/LOFA for FS-based system ?!
- Check WDR of divertor as design becomes available.
- Submit two abstracts to 16th TOFE :
  1- **Initial Activation Assessment for ARIES Compact Stellarator Power Plant**
  L. El-Guebaly, P. Wilson, D. Paige and the ARIES Team
  2- **Views on Clearance Issues Facing Radwaste Management of Fusion Power Plants**
  L. El-Guebaly, P. Wilson, D. Paige and the ARIES Team
- Submit invited paper to Int. Symp. on HIF, June 7-11, 2004 @ Princeton, NJ:
  Recycling Issues Facing Target and RTL Materials of Inertial Fusion Designs
  L. El-Guebaly, P. Wilson, M. Sawan, D. Henderson, A. Varuttamaseni
  and the ARIES and Z-Pinch Teams