Fusion Neutronics Activities in USA

Reported for the Neutronics Groups at
UCLA, UW, and TSI Research, Inc.

by

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Workshop on Sub-Task Fusion Neutronics
under IEA Implementing Agreement on a Co-operative Program on the
Nuclear Technology of Fusion Reactors

21 September 2004 (SOFT)

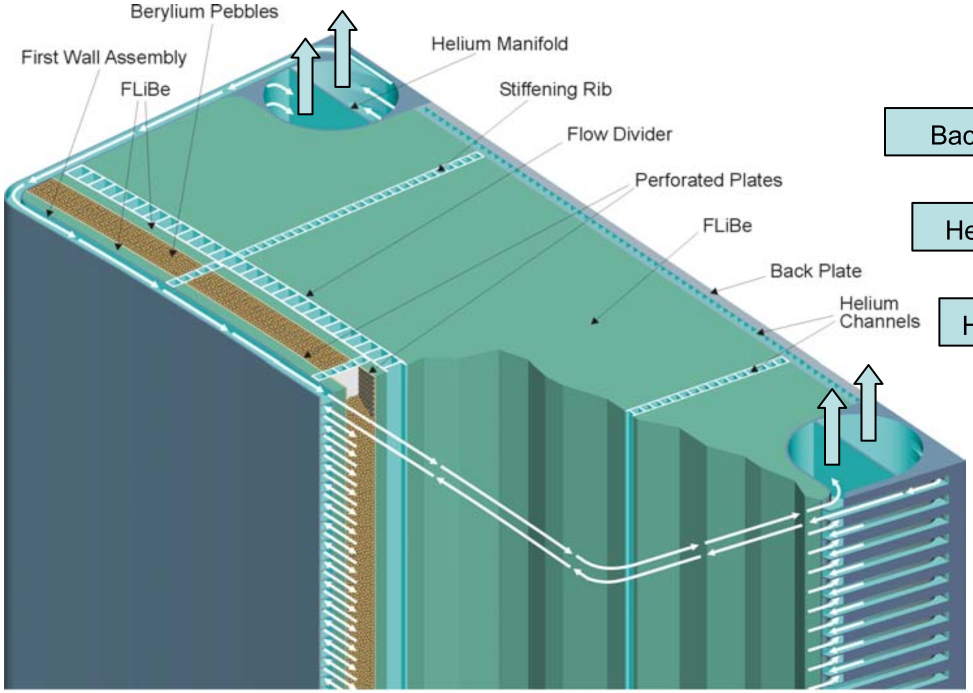
Venice, Italy

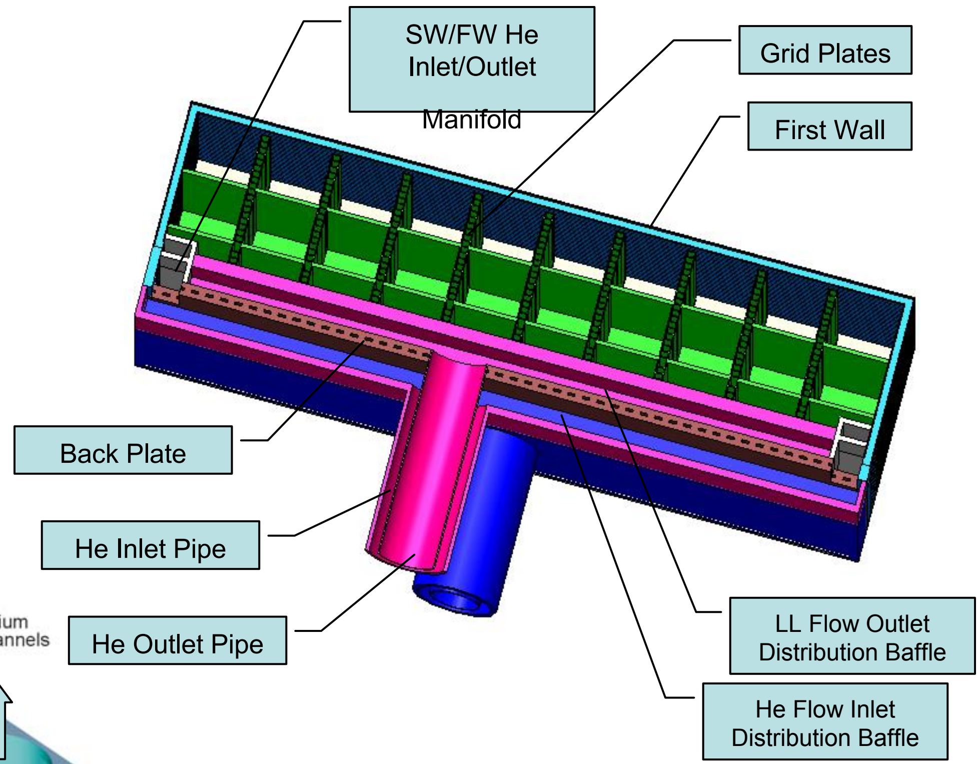
Fusion Neutronics Activities at the University of Wisconsin at Madison

- Neutronics Analysis in Support of ITER Test Blanket Modules
  - Assessment of Dual Coolant Liquid Breeder Blankets, Molten Salts and PbLi
  - Three Dimensional Modeling and Calculations
- Development of CAD-based MCNP
- Development of Activation Code, ALARA
  - Availability: Distribution by RSICC (ORNL)

Assessment of Dual Coolant Liquid Breeder Blankets in Support of ITER TBM

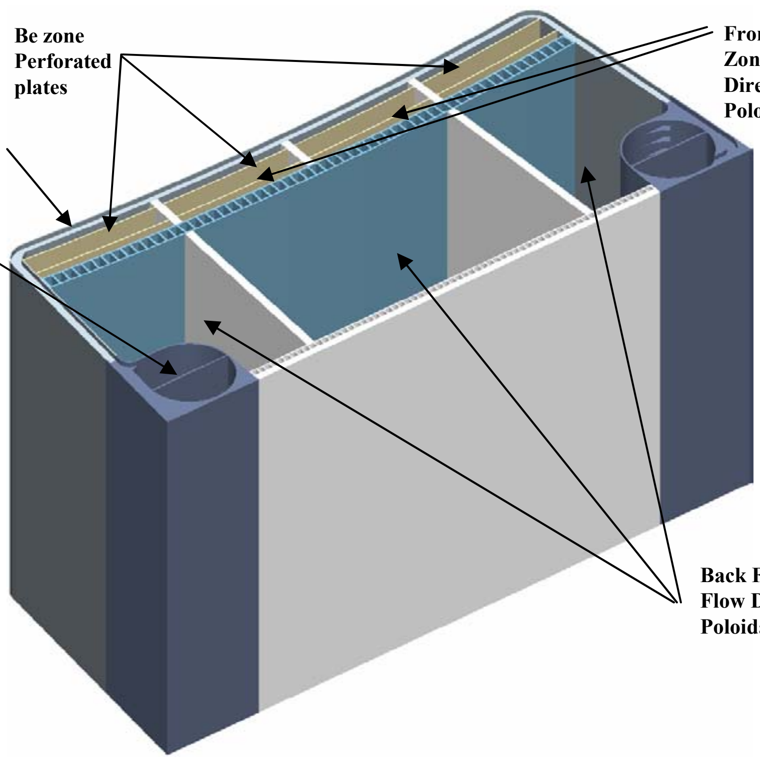
DC-Molten Salt

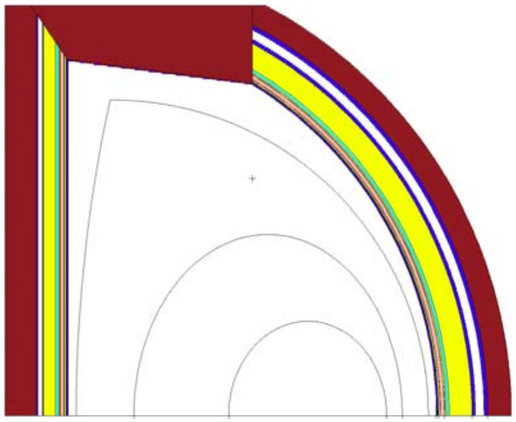


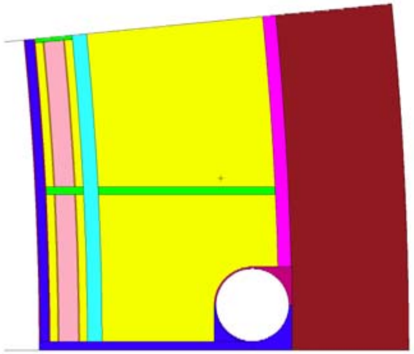


DC-PbLi

3-D Calculation for DC MS







Cross section in OB blanket at mid-plane

- Total TBR is 1.07 (0.85 OB, 0.22 IB). This is conservative estimate (no breeding in double null divertor covering 12%)
- 3-D modeling and heterogeneity effects resulted in ~6% lower TBR compared to estimate based on 1-D calculations
- Peaking factor of ~3 in damage behind He manifold

THE UNIVERSITY of WISCONSIN MADISON

Preliminary Neutronics for DC PbLi Blanket

Blanket thickness

OB 75 cm (three PbLi channels)
IB 52.5 cm (two PbLi channels)

Local TBR is 1.328

OB contribution	0.995
IB contribution	0.333

If neutron coverage for double null divertor is 12% ***overall TBR will be ~1.17*** excluding breeding in divertor region

Shield is lifetime component

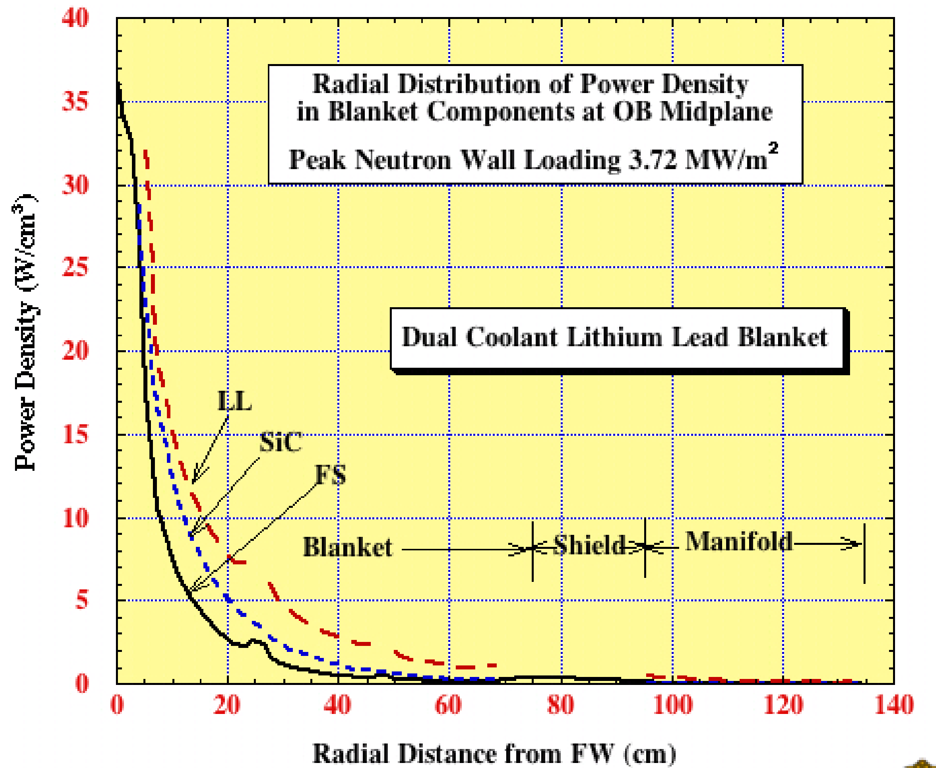
Manifold and VV are reweldable

Magnet well shielded

Nuclear energy multiplication is 1.136

Peak nuclear heating values in OB blanket

- FS 36 W/cm^3
- LL 33 W/cm^3
- SiC 29 W/cm^3

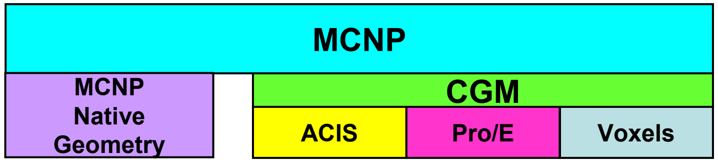


Fusion Technology Institute

CAD-Based MCNP

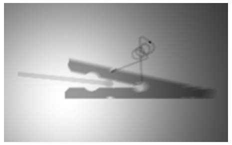
Parallel Computing Sciences Department

- **Use Sandia's CGM interface to evaluate CAD *directly* from MCNP**
  - » CGM provides common interface to multiple CAD engines, including voxel-based models



- **Benefits:**
  - » Dramatically reduce turnaround time from CAD-based design changes
    - – *Identified as key element of ITER Neutronics analysis strategy*
  - » No translation to MCNP geometry commands
    - – Removes limitation on surface types
    - – Robustness improved by using same engine for CAD and MCNP
  - » Can handle 3D models not supported in MCNP

Clothespin, w/helical spring surface



ARIES-CS Plasma

- **Status: prototype using direct CAD query from MCNP**

- **Issues/plans:**
  - » *(Lack of) speed: 10-30x slower than unmodified MCNP*
  - » Key research issue: ray-tracing accelerations (lots of acceleration techniques possible)
  - » Support for parallel execution (CGM already works in parallel)
  - » *Goal: speed comparable to MCNP, but using direct CAD evaluation*

Activation Code Development

Fusion Technology Institute

- ALARA - Version 2.7 available for use
  - Exact modeling of pulsed/intermittent sources
  - “Reverse” mode for efficient calculation of rare products
  - Direct calculation of:
    - Waste disposal rating
    - Contact dose
    - Total shutdown heating
    - Biological dose (requires source-to-dose adjoint calc)
  - Continuing development:
    - Sequential charged particle reactions
    - More data format/type support
- Monte Carlo activation code under development

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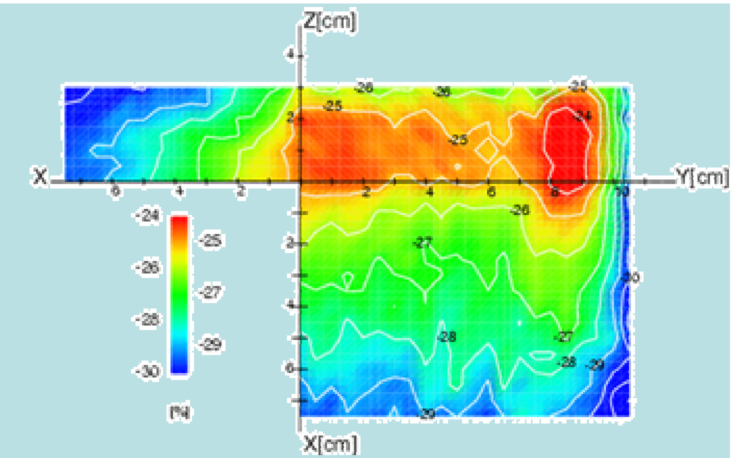
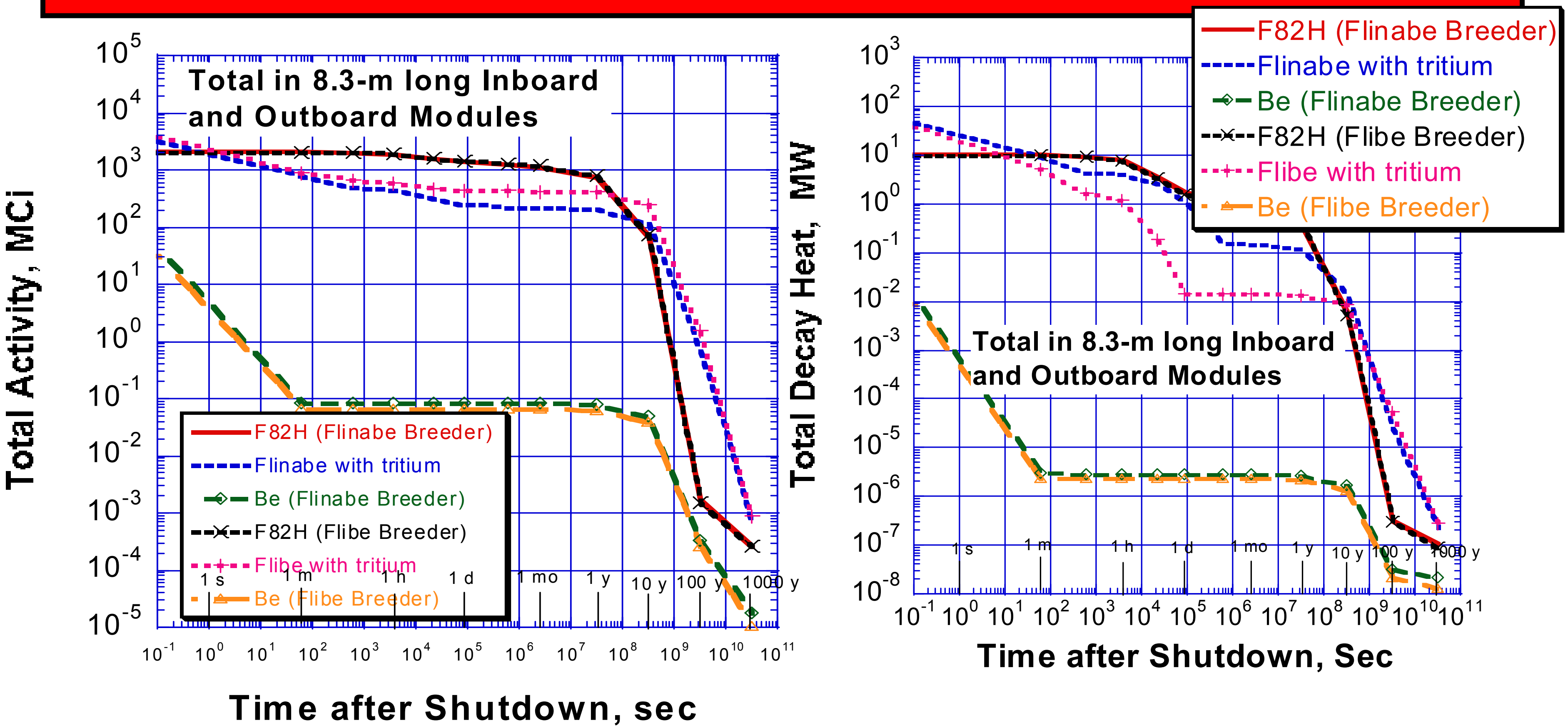


Relative difference between EAF and IEAF decay heat calculations in IFMIF HFTM

Fusion Neutronics Activities at the University of California at Los Angeles

- Neutronics Analysis in Support of ITER Test Blanket Modules
  - Activation Analysis of Dual Coolant Molten Salt Liquid Blankets
  - Design Analysis of Solid Breeder, Pebble-Bed Test Blanket Modules
  - Two Dimensional Discrete-Ordinates Code, DORT

Comparison Between Total Activity and Decay Heat in Each Material in the Flibe and Flinabe Dual Coolant Blankets

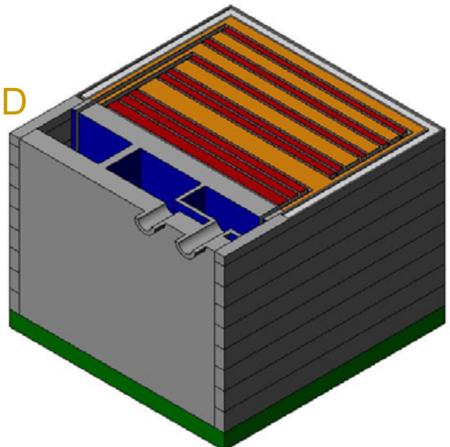


•*The activity generated in Flibe is larger than in Flinabe by a factor of 1.5-2 in the time frame of few days to few years after shutdown. However, there is an appreciable contribution to the total decay heat in Flinabe that is attributed to the generation of Na-24, up to few hours, and to the production of Na-22 up to several years following shutdown.*

Two Types of Helium-Cooled SB PB modules under consideration for Testing in ITER

Type 1: Parallel Breeder and Multiplier:

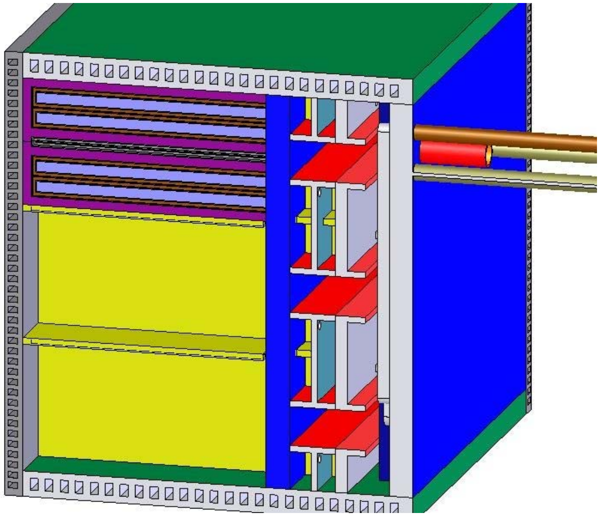
Local TBR: 1.2
In Demo
Configuration- 1-D



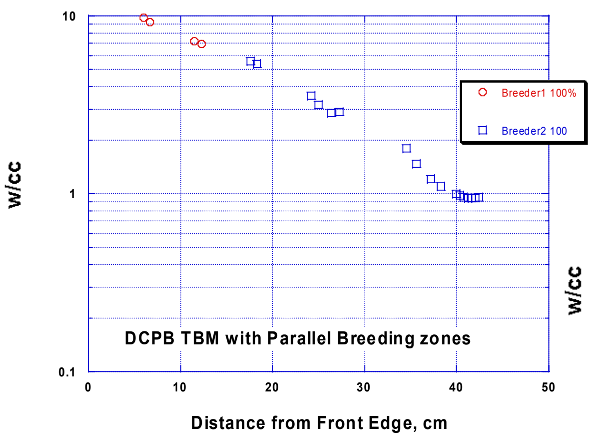
NWL 0.78 MW/m^2
75% Li-6 enrichment
Packing factor for Be and Li4SiO4 Pebble beds 60%

Type 2: Edge-On configuration

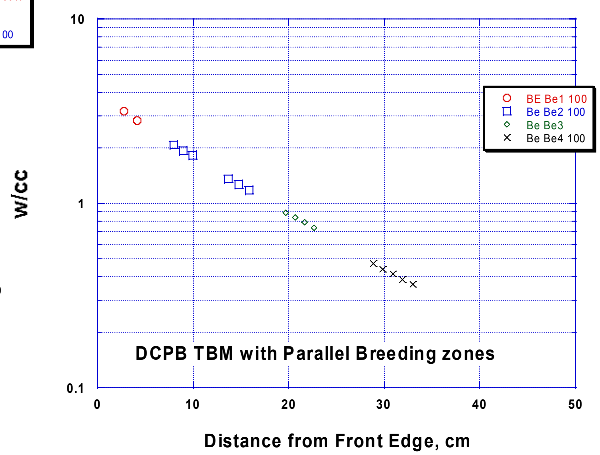
Local TBR: 1.04
In Demo
Configuration- 1-D



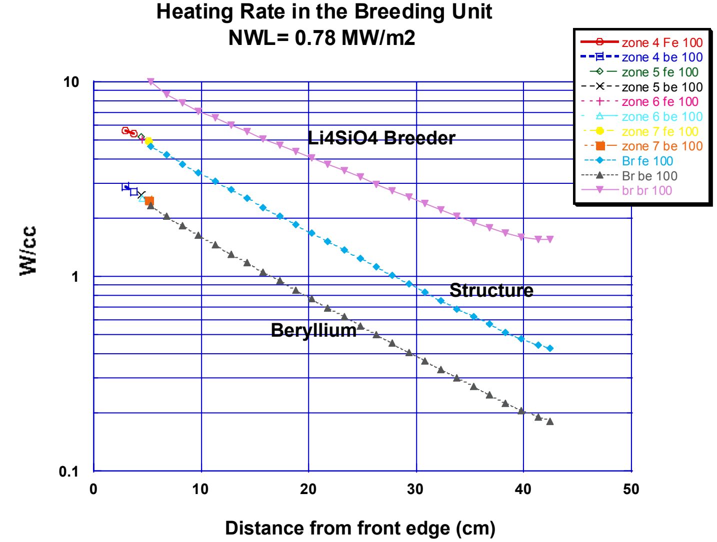
Nuclear Heating Rate in the Li4SiO4 Breeder
Wall Load= 0.78 MW/m2



Nuclear Heating Rate in the Beryllium Multiplier
Wall Load= 0.78 MW/m2



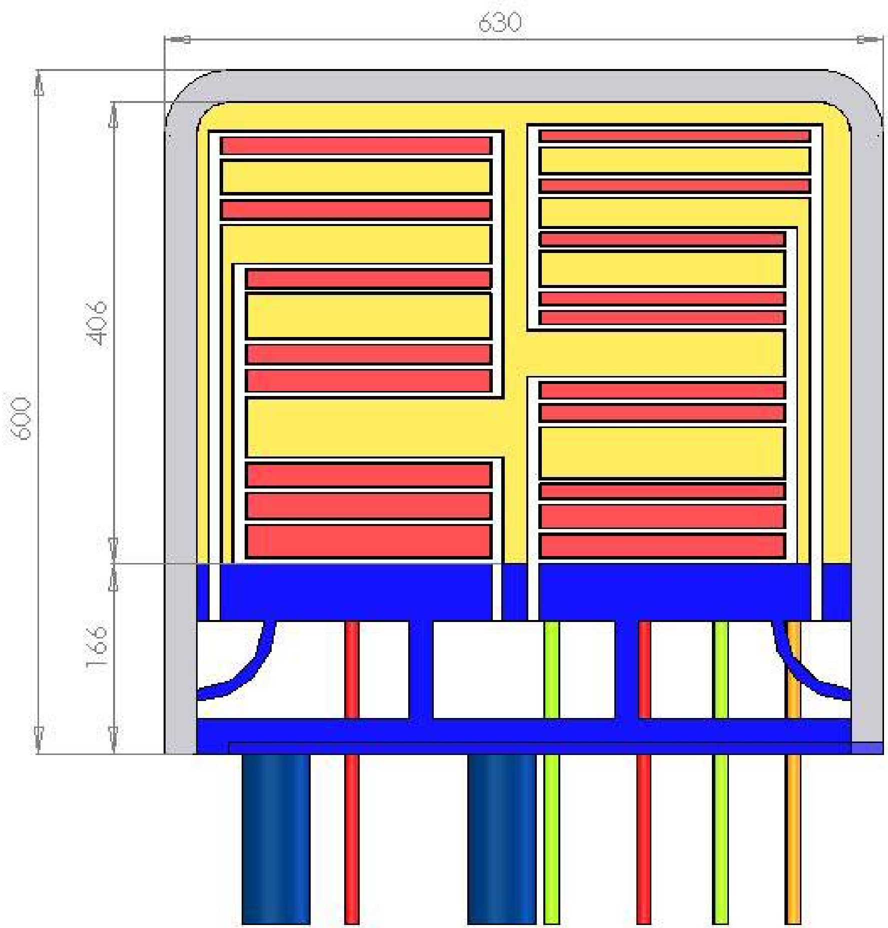
Heating Rate in the Breeding Unit
NWL= 0.78 MW/m2



Neutronics module under evaluation to ensure that design goals are met

Goals

- To determine geometrical size requirements such that high spatial resolution for any specific measurement can be achieved in scaled modules
- To allow for complexity, to maximize data for code validation

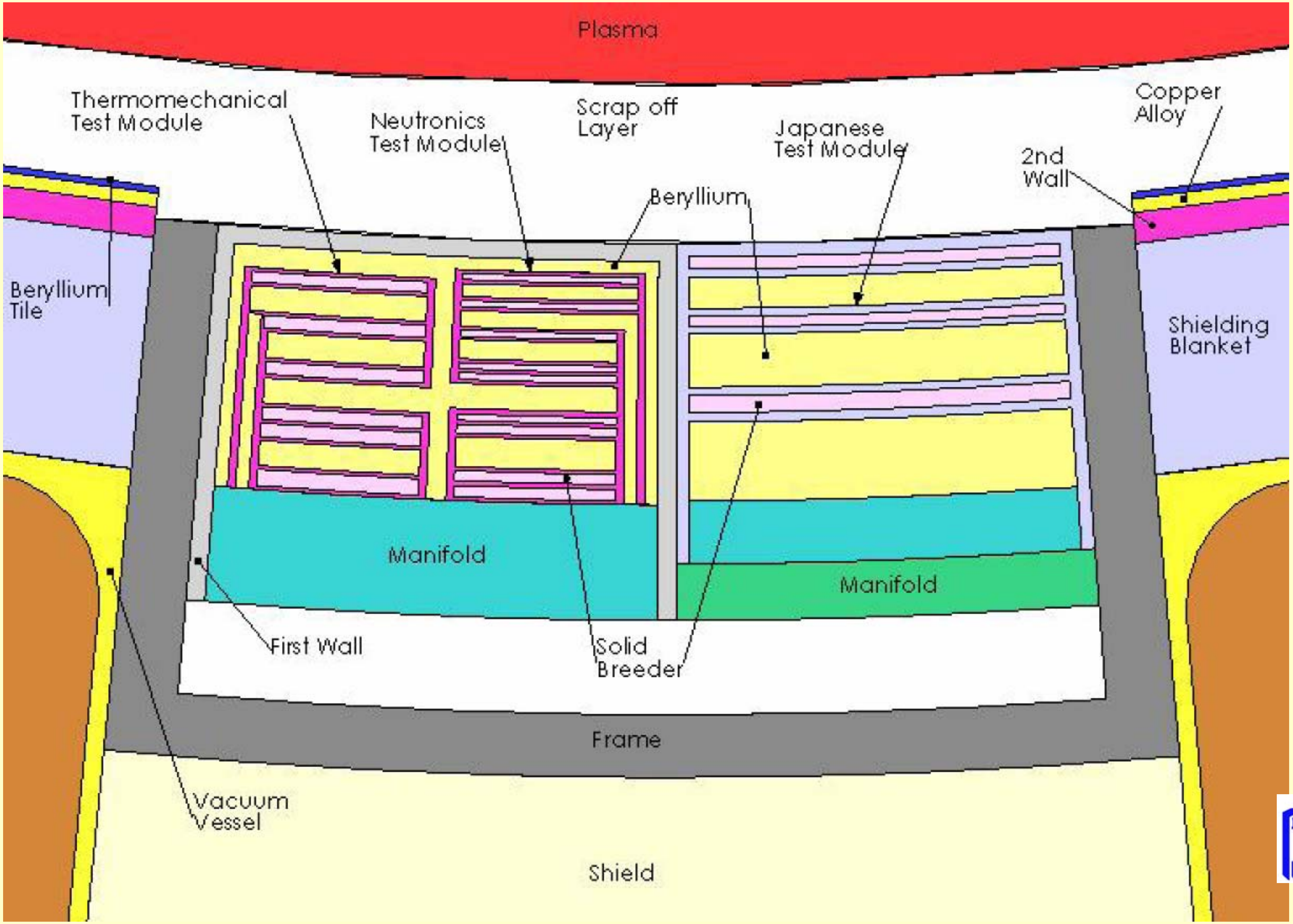


Proposed scheme is to evaluate two design configurations **simultaneously;** however 2-D (3-D) neutronics analysis must be performed to ensure that design goals are met.

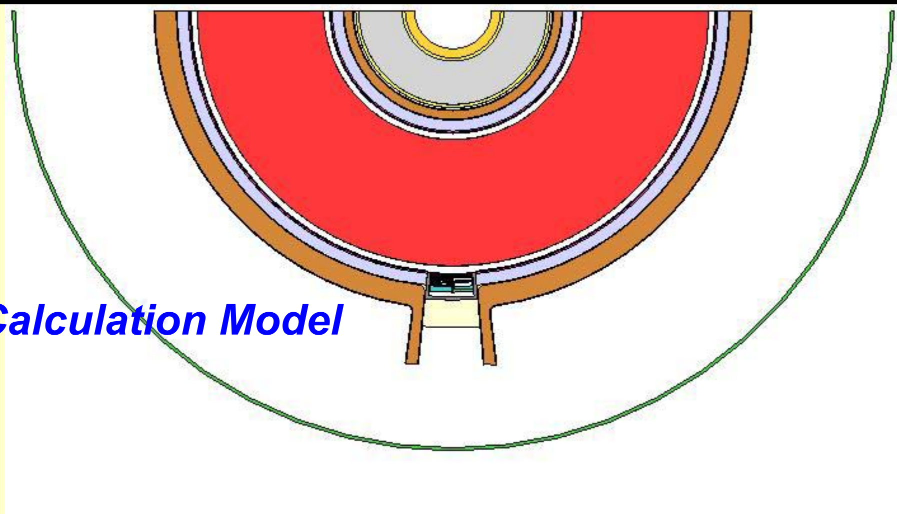
Demo Act-alike versus ITER-optimized designs

- **Structural fraction:**
  - ~ 23% Demo Vs. ~21% ITER
- **Total number of breeder layers/layer thickness:**
  - 10 layers/13.5 cm Vs. 8 layers/14.9 cm
- **Beryllium layer thickness:**
  - 19.1 cm vs. 17.9 cm

Top View of the U.S. and Japan Test Blanket Modules Placed in a ½ Port in ITER



2-D R-theta Neutronics Calculation to Analyze the Nuclear Performance of the US TBM with Actual Surroundings

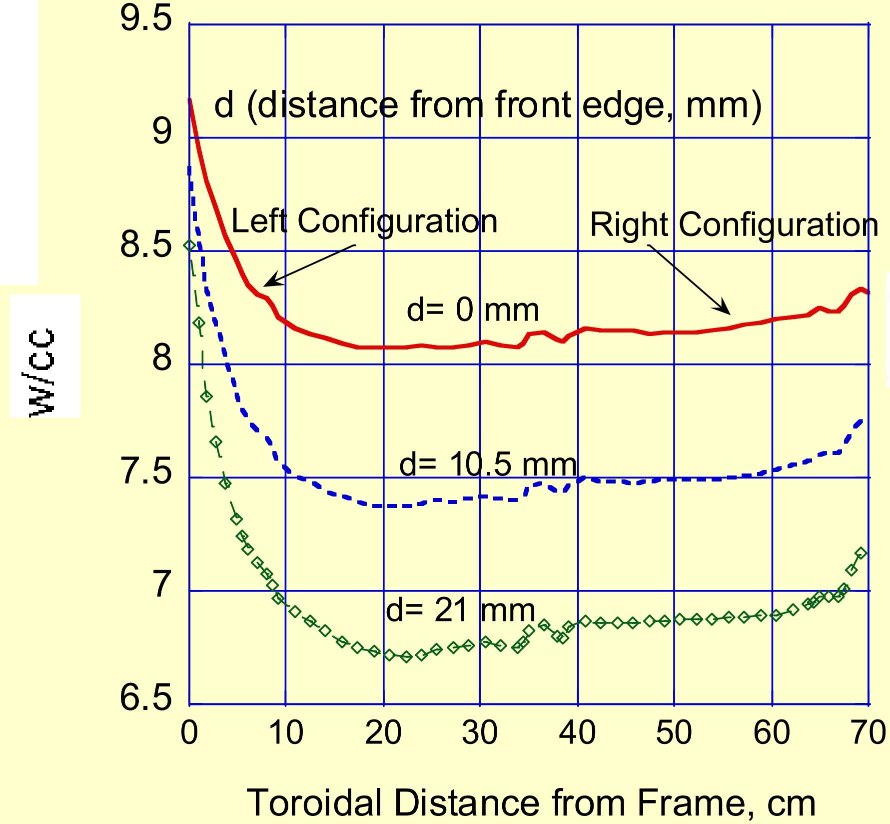


Calculation Model

- ***Toroidal heating rate is nearly flat over a distance of ~10-14 cm (left Config.) and ~16-20 cm (right Config.)***

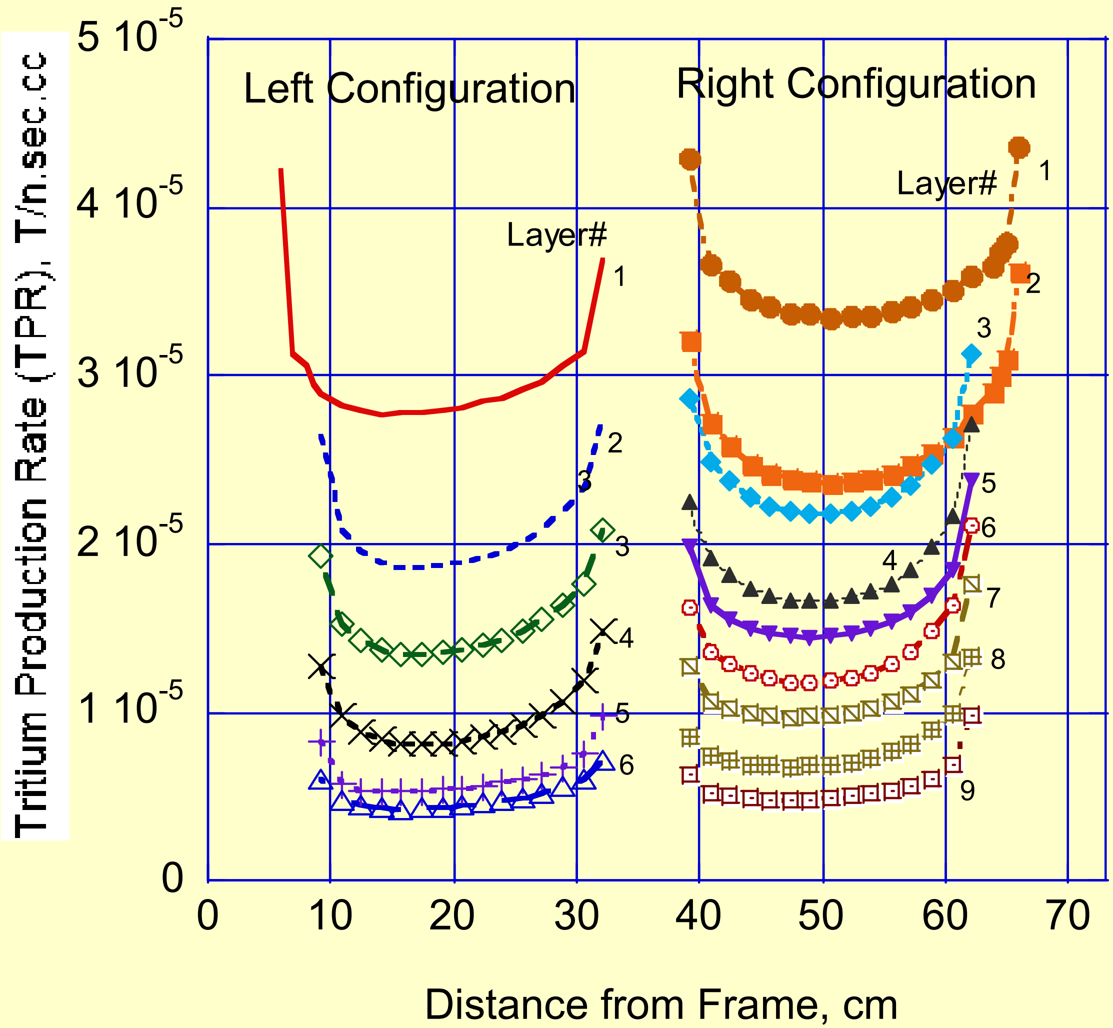
- ***Heating rate measurements could be performed over these flat regions with no concern for error due to uncertainty in location definition***

Calculation by DORT-Discrete Ordinates Transport Code, 46 neutron-21 gamma groups



Nuclear Heating in the First Wall of the Two U.S. Test Blanket Configurations in the Toroidal Direction

Toroidal Profile of Tritium Production Rate (TPR) in each Breeder Layer of the Two Test Blanket Configurations



- Profiles of the TPR is nearly flat over a reasonable distance in the toroidal direction where measurements can be performed (10-16 cm in the left Config. and 10-20 cm in the right Config.).
- Steepness in the profiles near the ends is due to presence of Be layer and reflection from structure in the vertical coolant panels (VCP). This is more pronounced at the outer VCP.

Fusion Research and Neutronics Activities at TSI Research, Inc.

- Application of Fusion Neutrons
  - Transmutation of Spent Fuel Actinides
  - U238 Burning Power Plants
  - Performance of Sub-criticality of Actinides in Equilibrium in Fusion Blankets
- Nuclear Data for Fusion
  - Nuclear Data Needs Activities
  - Review of Helium Generation Data for IFMIF (ANLNDM-158, by Donald L. Smith)