Discussion of Peer Review Action Plan and Other Key Issues (including IFMIF and Spallation n-sources)

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Fusion Materials Sciences Program Strategic Planning Meeting

August 26-30, 2002

Univ. California-Santa Barbara

Outline

- Discussion of Peer Review Action Plan and Materials Retreat action items
- Program management issues; transition of MASCO from coordinator to advisor role
  - proposed research task group structure
- Materials handbook (migrate to interactive web site system; initially US-only access)
- Fusion materials major facility needs for next 10-15 years (Baker 8/26/02 email)
- US community position regarding IFMIF and Spallation n-sources
  - IFMIF programmatic support for FY03 and beyond
  - US position on spallation neutron sources for October Les Diablerets workshop
- Fusion technology development roadmap:role and staging of IFMIF and VNS/CTF
  - Monitor/participate in FESAC development path activities

Current Action Items (Materials retreat, etc.)

- Encourage “competent” SBIR submissions
- Prepare one or more VGs on Fusion Materials Science program for use by OFES
- Continue to seek opportunities to improve interactions with broader fusion community (plasma physics, fusion technology)
  - Joint town meetings
  - Materials engineer
  - Seminar series
    - Completed: OFES budget meeting (4/01, 4/02), SOFE plenary (1/02), PPPL (5/02)
    - Planned: GA (gro), UT (rjk or sjz), MIT (sjz), UW (sjz)
  - ANS TOFE (11/02) conference organization

Key findings from 2001 peer review

- **Overall scientific quality of research is high**
- **Seven general findings were identified, and an action plan was formulated to address these issues**
  - **Education and training**
  - **Program scope, mission, priorities and balance**
  - **Interaction with other (fusion) programs**
  - **Chemistry and corrosion R&D program**
  - **Coordination of theory and modeling program**
  - **Helium effects research program**
  - **V alloy R&D (fabrication) and MHD insulator program**
  - **External visibility (interaction with fusion community)**

Key findings from 2001 peer review

Review Panel Generalized Findings & Recommendations	Community Comments and Actions
With regard to **education and training,** in light of program restructuring away from fusion energy development and toward science-based research, reassess funding allocations between labs and universities and the effectiveness of university programs for meeting future scientist and other human resource needs of fusion materials research.	The fusion materials sciences program has made a concerted effort to increase the level of participation by university professors and students in the past two years (University funding for fusion materials tripled from 1998 to 2001). We will continue to seek opportunities to attract the highest quality materials scientists, and monitor the university/lab funding ratio (benchmarked against similar ratios in the fusion program).
With regard to **program scope, mission, priorities, balance,** assess whether or not it is possible and advisable to increase the rate of progress toward solving critically important fusion structural material issues by focusing on a smaller set of materials systems, perhaps eliminating research for a period of time on the lowest priority system.	One of the pillars of the reorganized fusion materials science program is an emphasis on cross-cutting materials science phenomena. In the current research program, a limited number of model alloys encompassing a range of compositions are highly valuable in order to assess intrinsic physical phenomena. The topic of research portfolio balance will be discussed in detail by the fusion materials community during a materials program team meeting scheduled for late August, 2002.
With regard to interaction with other programs, identify ways to improve connections with and support for next step burning plasma experiment studies.	The FIRE design team has recently established regular informal communications with the fusion materials science program in order to obtain expert advice on a wide range of materials issues. This activity will also be aided by the newly established materials engineer activities in the materials science program.

Key findings from 2001 peer review (cont'd)

Review Panel Generalized Findings & Recommendations	Community Comments and Actions
With regard to activities in **chemistry and corrosion,** assess the appropriateness of the current level of effort on oxidation/ corrosion studies and review experimental techniques in these studies to determine if improvements should be made.	A discussion of the corrosion research priorities will be held during the fusion materials program team meeting scheduled for late August, 2002.
With regard to activities in theory and modeling, assess the appropriateness of the current level of effort on theory/ modeling and identify ways that theory/modeling activities can work more effectively among each other and with experimental programs.	A theory&modeling/experimental researcher workshop has been organized (May 2002, UCLA) as a first step to enhance the collaborative interactions within the modeling program and between experimental and modeling activities. This topic will be discussed in more detail during the Aug. 2002 fusion materials team meeting.
With regard to helium effects assess the appropriateness of the current level of effort on helium effects and the effectiveness of the approaches being used to evaluate helium effects.	Helium effects are a major focus of the majority of the multi-year proposals funded in the 2001 theory and modeling initiative, and are also the primary focus of the DOE/JAERI collaborative HFIR irradiation program that will begin in the summer of 2002. It is clearly recognized as a very important factor in the development of viable fusion materials.

Key findings from 2001 peer review (cont'd)

Review Panel Generalized Findings & Recommendations	Community Comments and Actions
With regard to activities in vanadium alloys and insulator coatings, assess the appropriateness of the current level of effort on vanadium alloy insulator coating research and review experimental techniques to determine if improvements can be made and if the rate of progress can be increased.	A set of quantitative technical metrics have been developed to aid in the assessment of the performance of the various candidate MHD insulators. A community-led rigorous assessment of the scientific feasibility and technical maturity of the leading candidate MHD insulator coatings will be performed in the summer of 2002. Significant advances in the understanding of the physical metallurgy of the V alloy system have been attained by fusion materials scientists in the past 6 years (when the last US V alloy heat was fabricated), and this improved understanding is being used in a current effort to fabricate high-quality V alloy tubing for an upcoming US/Japan JUPITER-II collaborative irradiation experiment.
With regard to external visibility, present results of fusion materials research to broader audiences, such as at ANS-sponsored meetings	Although researchers on the fusion materials program have been recognized numerous times with national materials science awards, the program has relatively weak connections with the fusion technology and plasma physics communities. In order to enhance the connections with the rest of the fusion program (while maintaining our important strong ties to the broad materials science community), the fusion materials program will work within the VLT and actively participate in few selected fusion technology meetings. A materials/plasma facing components workshop and an advanced ferritic steel materials/chamber technology workshop were held in April, 2002, and a series of fusion materials seminars at plasma physics institutions are being planned, beginning with a PPPL colloquium. Fusion materials scientists will be the lead organizers of the ANS Topical on Fusion Energy to be held in Washington DC in November, 2002.

Fusion Materials Science Program

	Theory-Experiment Coordinating Group*				
	Microstructural Stability	Physical & Mechanical Properties	Fracture & Deformation Mechanisms	Corrosion and Compatibility Phenomena	Fabrication and Joining Science
Materials for Attractive Fusion Energy					
• **Structural Alloys*** - Vanadium Alloys - F/M and ODS Steels - High T Refractory Alloys - Exploratory Alloys					
• **Ceramic Composites*** - SiC/SiC, other CFCs					
• **Coatings**					
• **Breeder/multiplier Materials**					
• **Neutron Source Facilities**					
Materials for Near-Term Fusion Experiments					
• **PFMs (Refractory Alloys, etc.)**					
• **Copper Alloys**					
• **Ceramic Insulators**					
• **Optical Materials**					

*asterisk denotes Fusion Materials Task Group

Fusion Materials Sciences Community Governance

MASCO (MAterials Science COordinators)
S.J. Zinkle (ORNL), chair
N.M. Ghoniem (UCLA)
R.H. Jones (PNNL)
R.J. Kurtz (PNNL)
R. Mattas (ANL)
G.R. Odette (UCSB)
R.E. Stoller (ORNL)
B. Wirth (LLNL)

	Theory/Expt coordinating committee Zinkle*, Kurtz, Odette (steering committee) Ghoniem, Stoller, Wirth
Structural alloys Odette (chair) Hoelzer, Kurtz, others (choose from subject experts on an as-needed basis)	
Ceramic composites Jones (chair) Snead, Lucas, others (choose from subject experts on an as-needed basis)	
Crosscutting Theory & Modeling N.M. Ghoniem (chair)	

*Fusion Materials Sciences program leader

Fusion Materials Sciences Research Task Groups

Topical Team	Team Leader	Proposed Team Members
Experimental Microstructure	Zinkle	Edwards, Gelles, Ghoniem, Hoelzer, Odette, Wirth
Experimental Fracture and Fatigue	Odette	Gelles, Ghoniem, Grossbeck, Klueh, Kurtz, Lucas, Sokolov, Wirth, Yamamoto, Zinkle
Experimental Deformation and Constitutive Law	Lucas	Edwards, Hoelzer, Odette, Wirth, Yamamoto, Zinkle
Deformation and Fracture Modeling	Ghoniem	He, Kurtz, Odette, Osetsky, Wirth, Zinkle
Microstructural, Multiscale-Multiphenomena Modeling	Stoller	Heinisch, Kurtz, Odette, Osetsky, Srolovitz, Wirth, Yamamoto, Zolb, Zinkle
High Temperature Deformation and Fracture	Kurtz	Ghoniem, Grossbeck, Hoelzer, Lucas, Odette, Zinkle,
Processing, Fabrication and Joining	Klueh	Gelles, Grossbeck, Hoelzer, Odette, Zinkle
Coatings and Compatibility	Pint	Jones, Mattas, Natesan, Odette
Materials Design Interface	Ghoniem	Majumdar, Mattas, Odette, Yamamoto, Zinkle
Ceramic Composites	Jones	Lucas, Snead, White, Youngblood
Advanced & Innovative Materials	Hoelzer	Gelles, Klueh, Kurtz, Ghoniem, Odette, Snead, Was, Zinkle
Irradiation Experiments	Zinkle	Kurtz, Ghoniem, Odette, Stoller, Wirth

Task group charter, meeting frequency, membership, etc. still needs to be discussed

Fusion Technology major facility needs for next 10-15 years

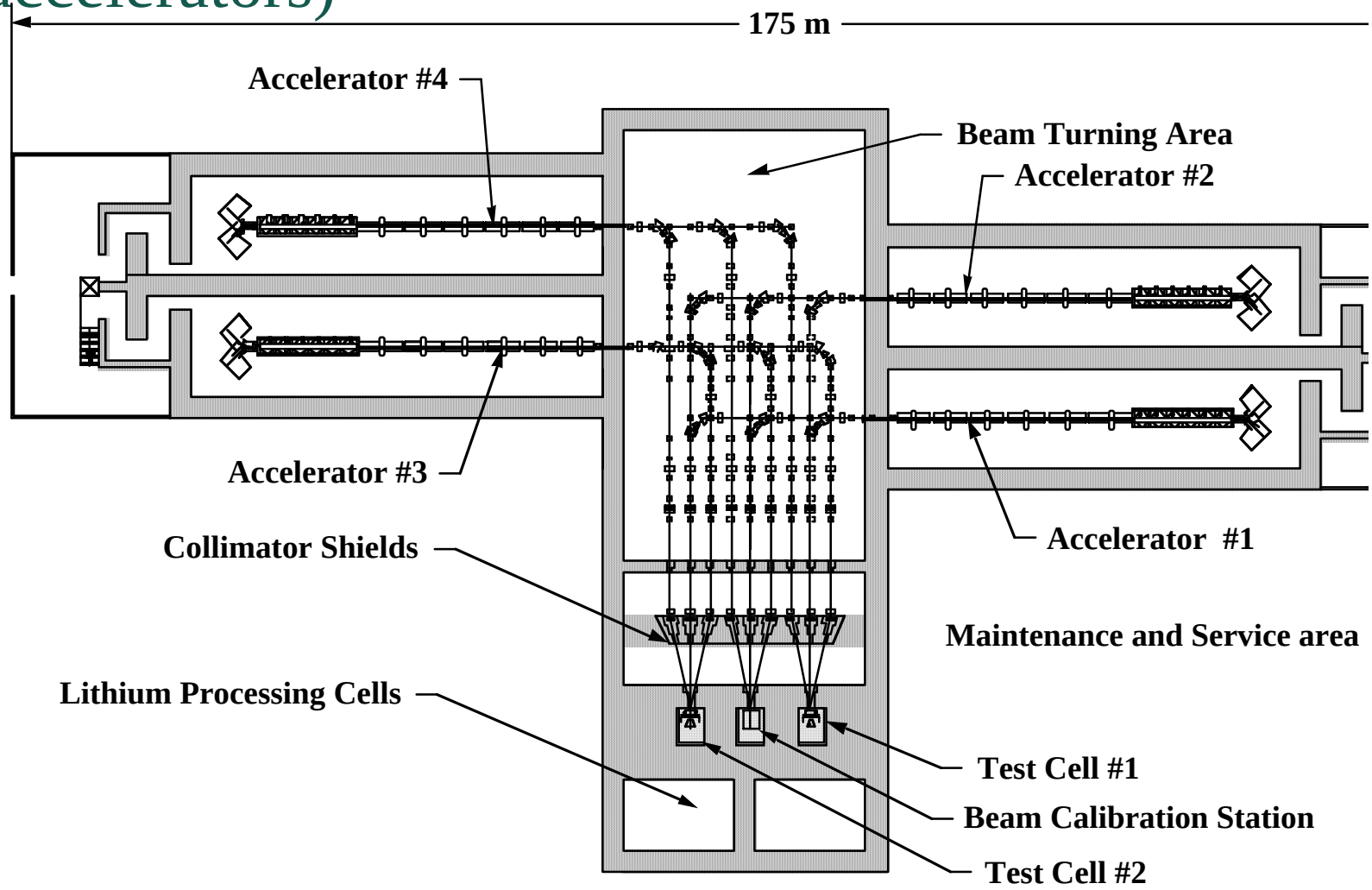
- Input to C.R. Baker requested by October 1, 2002
- Purpose: identify critical new facilities with a possibly shorter time scale and lower costs than ITER, IFMIF, etc.
- Facilities should meet a crucial mission need, should be able to be utilized in the next several years, and should cost in the range of a few to several million dollars (not more than $50M)
- Candidate facilities:
  - Cryogenic irradiation facility (electron/ion/RTNS-II?) to study fundamental defect migration/accumulation phenomena
  - Versatile corrosion loop or thermomechanics facility?
  - Virtual national lab facility for remote experimentation on irradiated materials

Overview of Fission, Spallation, and d-Li Neutron Sources for Fusion Materials R&D

Neutron Source	Advantages	Disadvantages
Fission Reactors	Well-characterized spectra Allows medium-high damage regimes to be investigated in bulk specimens Operating funds provided by multiple users (non-fusion)	Low He/dpa ratio
Spallation	Allows high-He irradiation conditions to be explored Operating costs may be largely provided by non-fusion agencies	Not designed for materials irradiations (physics/ neutron scattering facility)* He/dpa,H/dpa ratio too high Pulsed irradiation; requires detailed analysis
D-Li	Correct He/dpa ratio, etc. Dedicated materials irradiation facility	Operating funds completely provided by fusion

***feasibility of limited-volume "rabbit" irradiation facility in SNS is being explored**

Original IFMIF configuration (2 test cells, 2+2 accelerators)

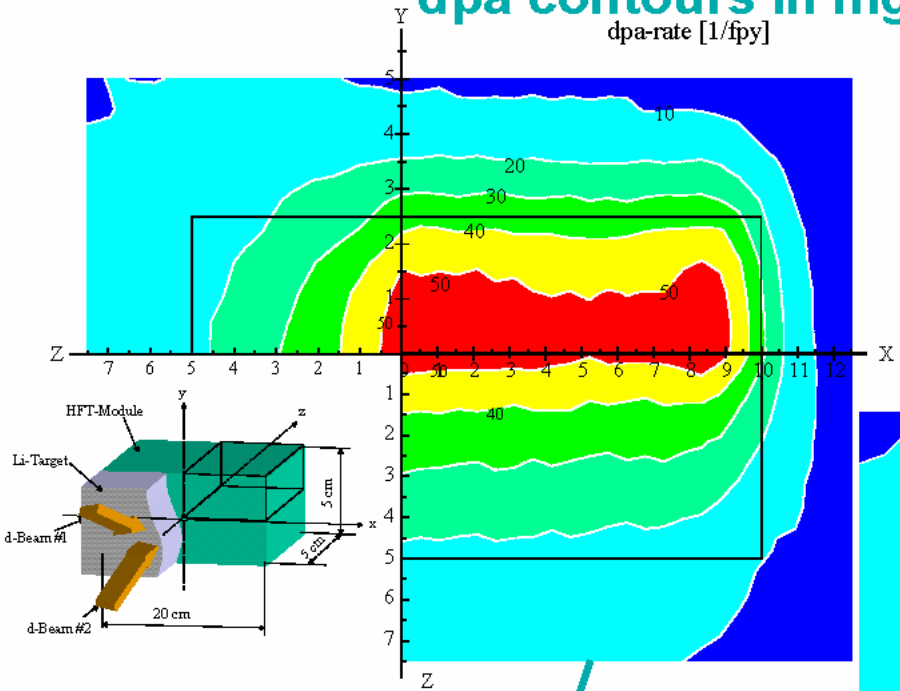


IFMIF CDA report 1996

IFMIF Expanded Configuration

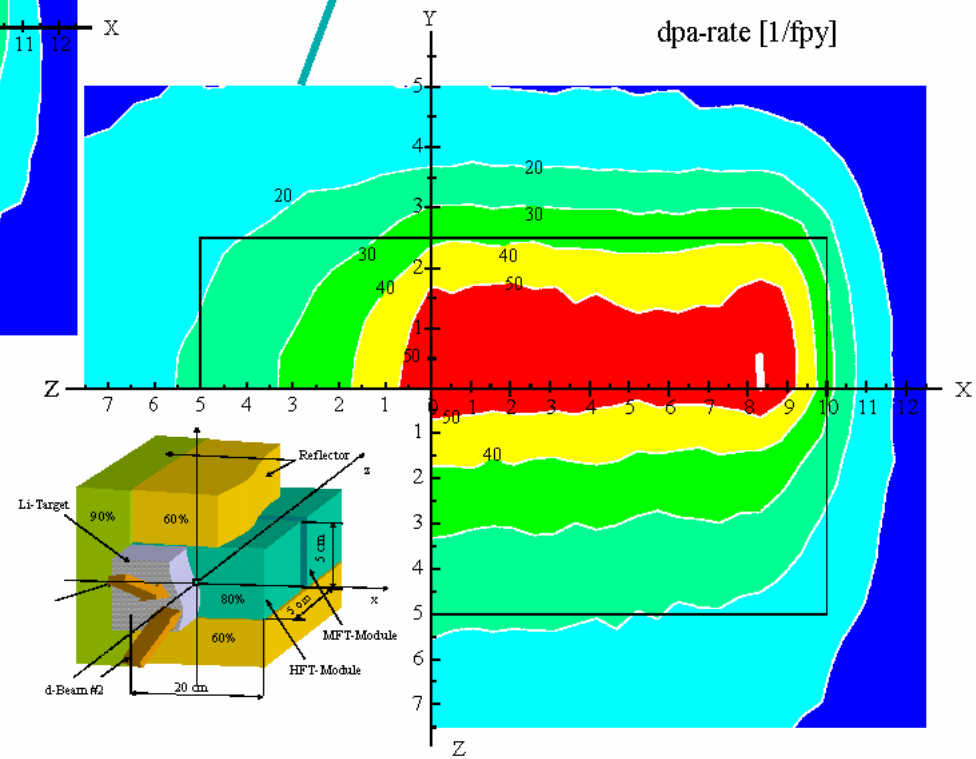
IFMIF Test Facilities

dpa contours in high flux test region

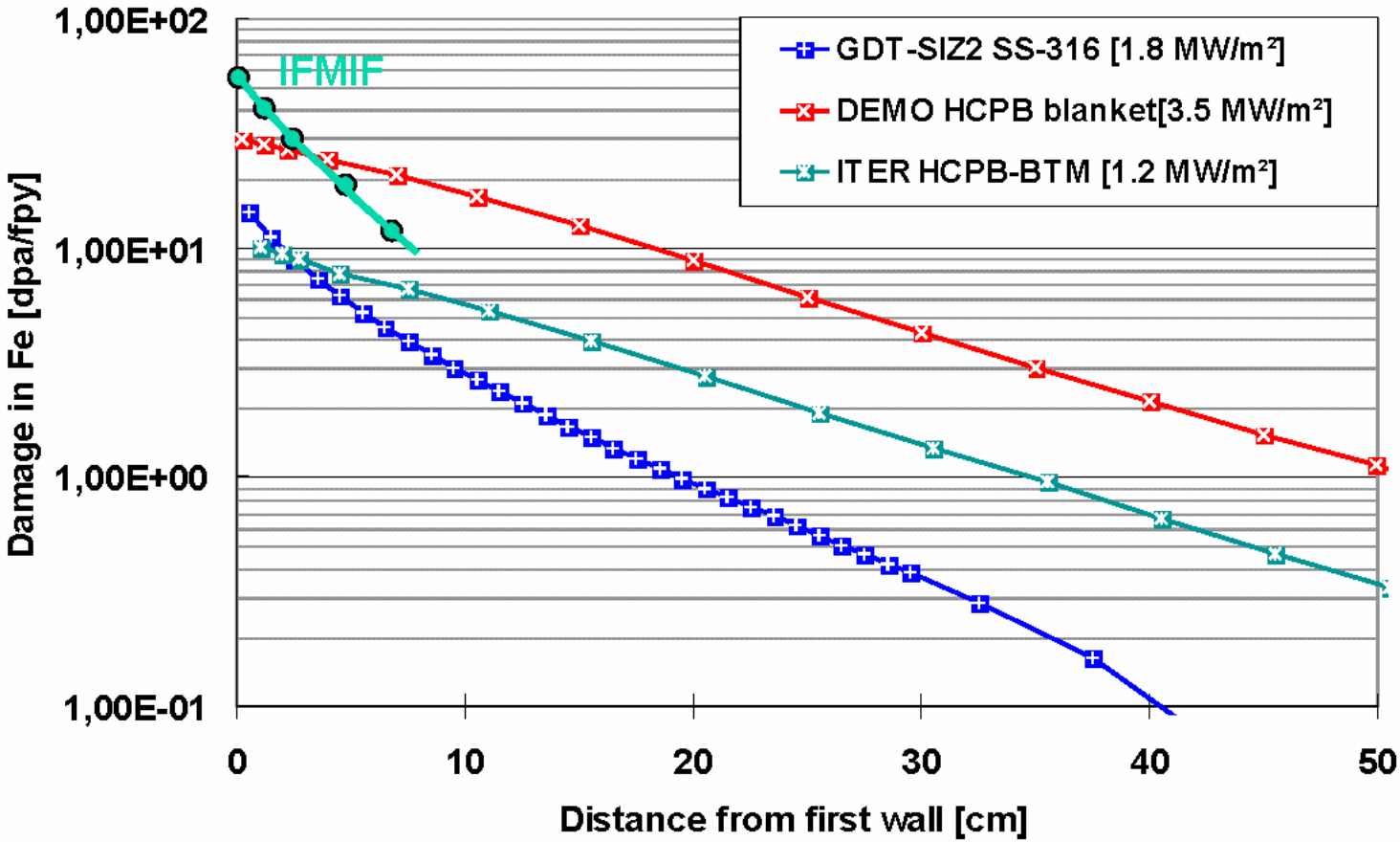


Bare HFTM

HFTM with steel reflector



Comparison of different radial damage profiles



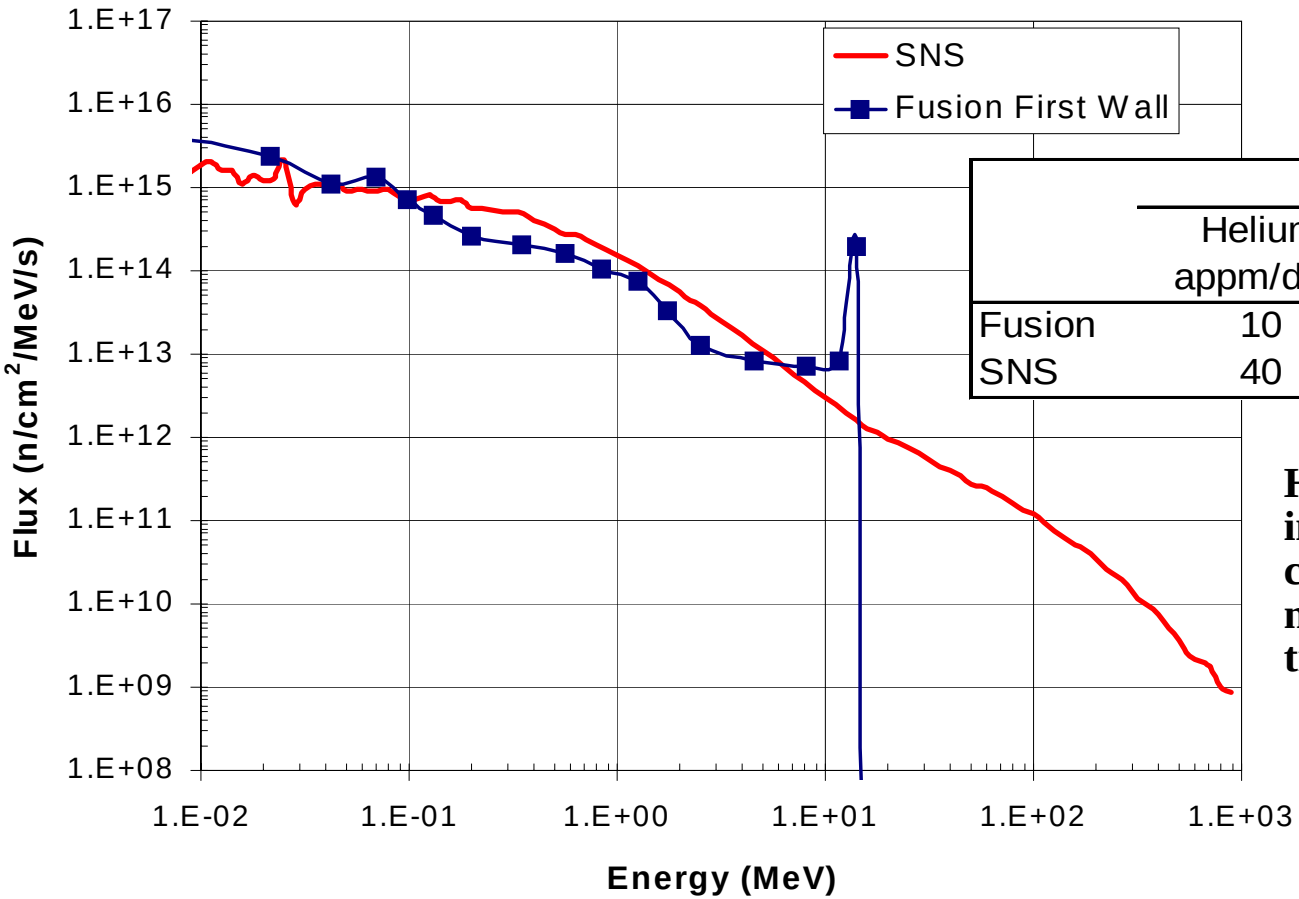
Flux gradients requires miniaturized specimens in all non-volume sources

Spallation Neutron Source
Chestnut Ridge Transformation

Current status (10/2001): design 69% complete; construction 33% complete

Neutron Flux and Gas Production Rate at the Bottom of the Mercury Target

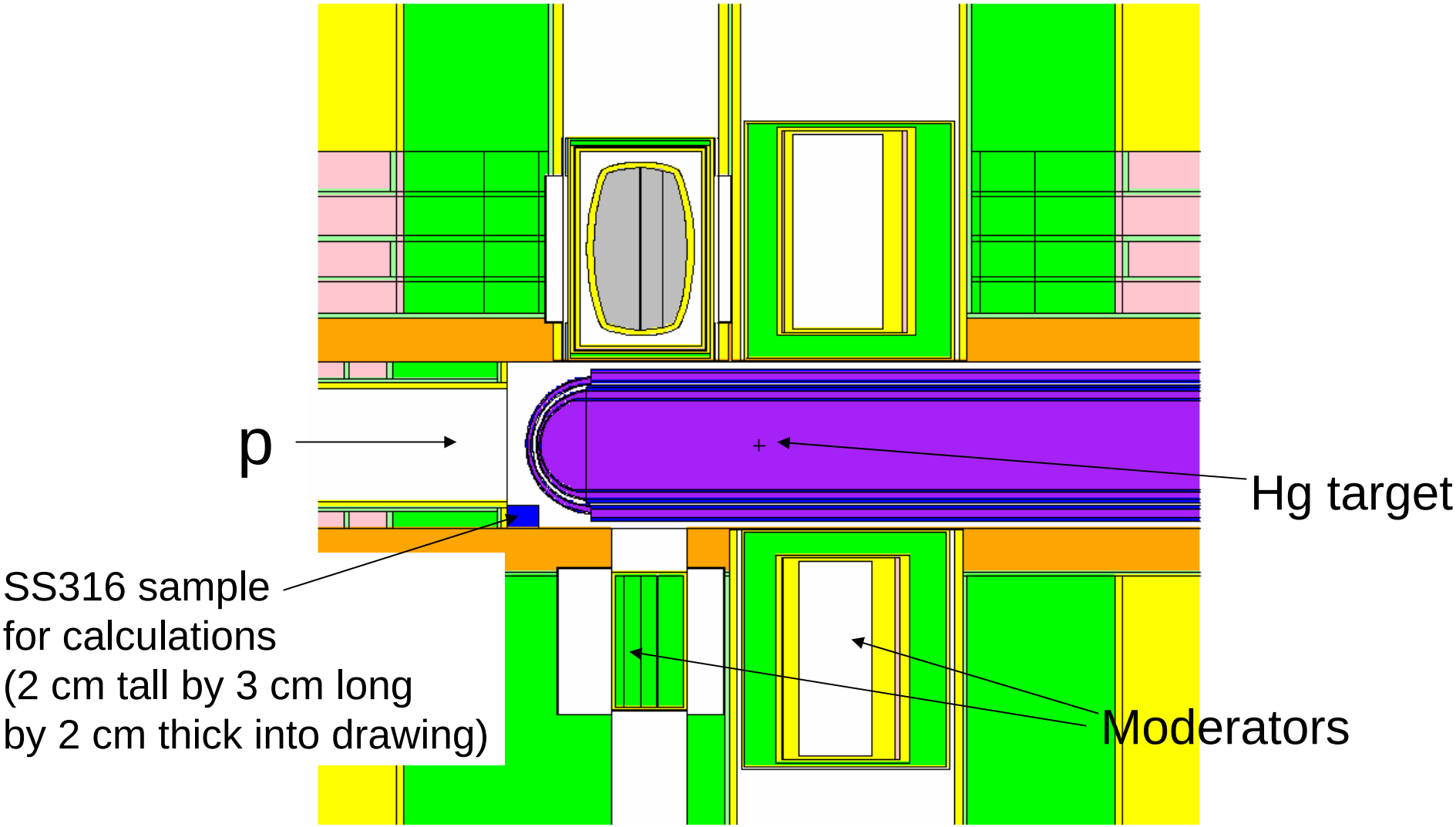
- Flux tally location for SNS is in the bottom of the mercury target near the peak in the axial flux distribution for 2 MW proton beam power
- Fusion FW data for 2 MW/m^2 neutron wall loading taken from ORNL/TM -5956, T.A. Gabriel, B. Bishop, and F. W. Wiffen



	Iron	
	Helium appm/dpa	Hydrogen appm/dpa
Fusion	10	40
SNS	40	600

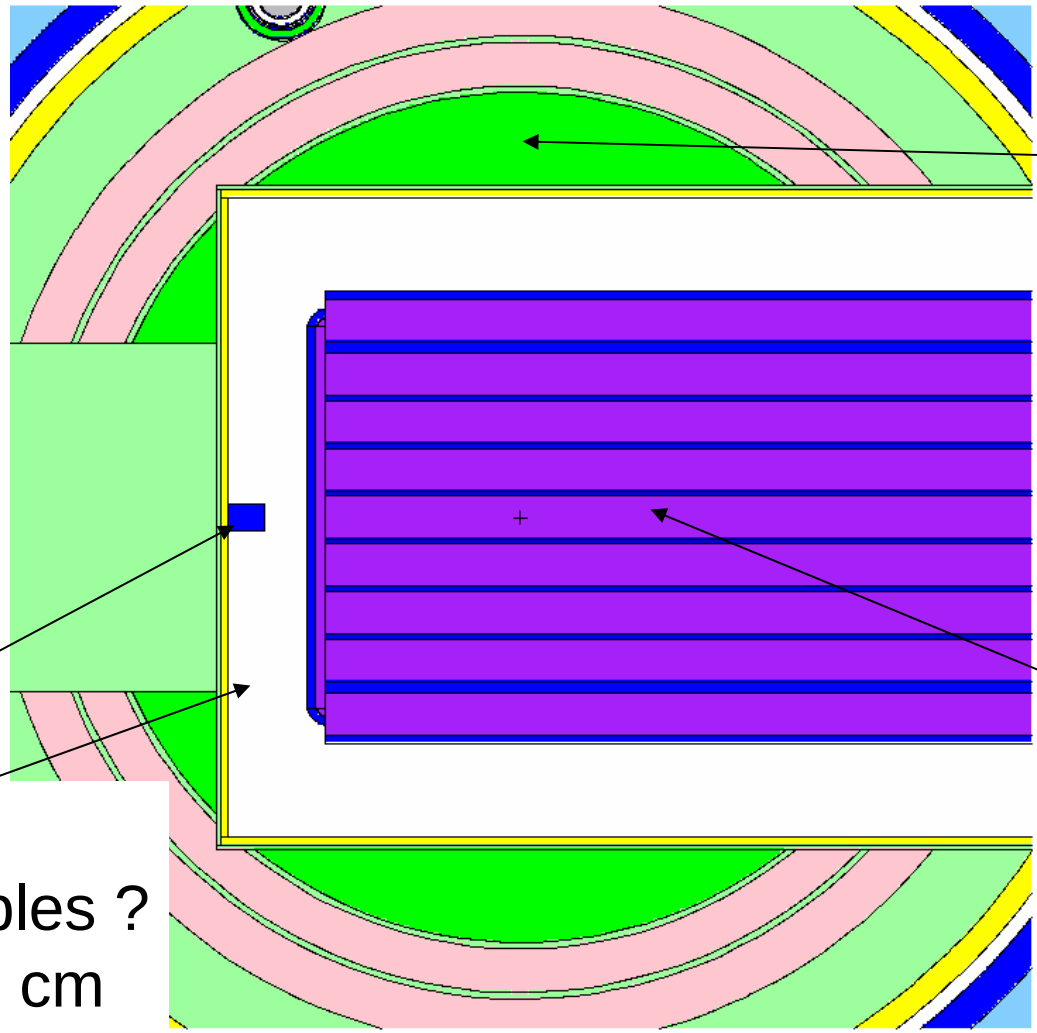
H,He production includes contribution from n- and p- induced transmutations

SNS target system geometry



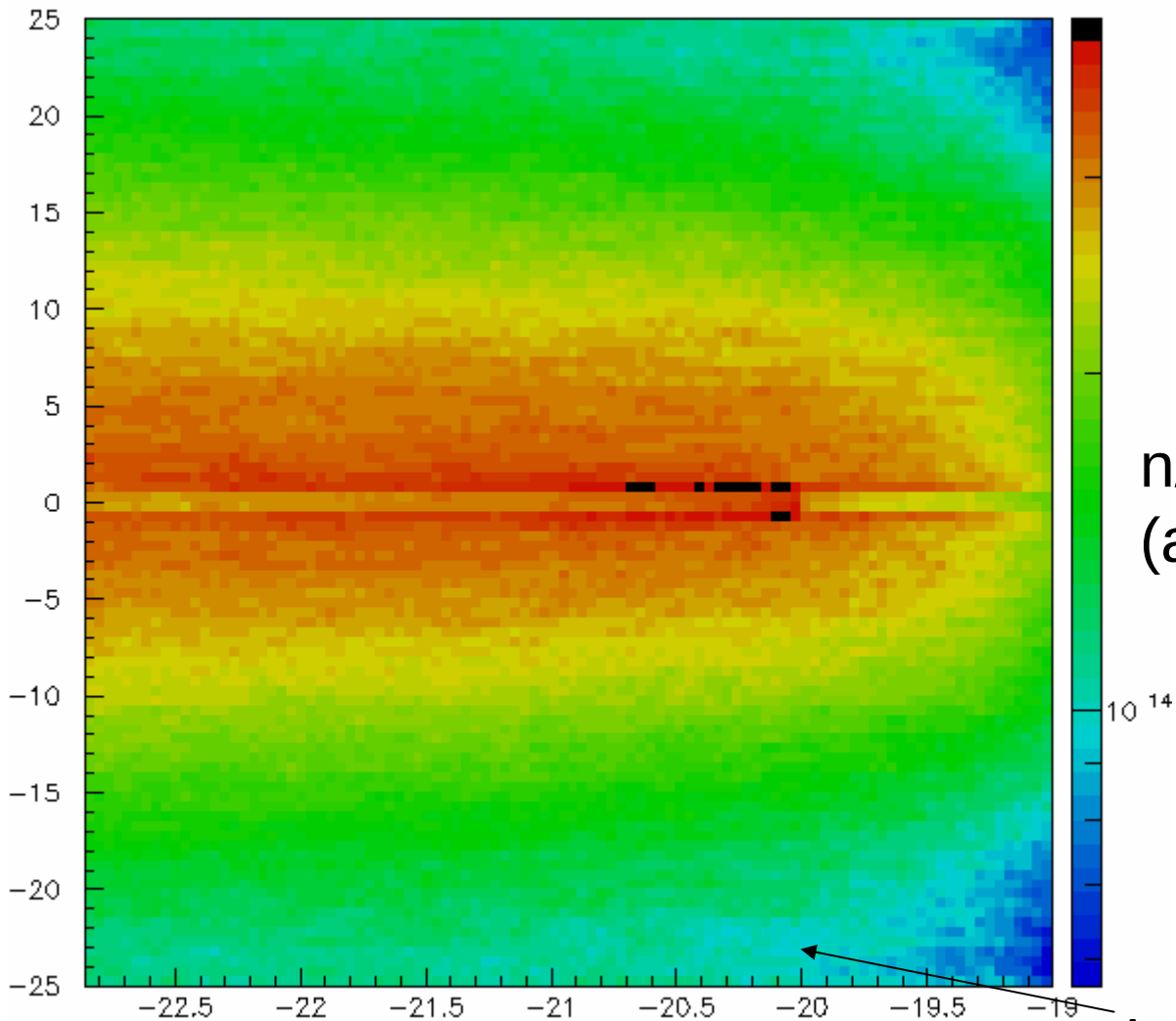
Elevation view

SNS target system geometry (cont.)



Plan view at the elevation of the SS316 sample

Integrated neutron flux



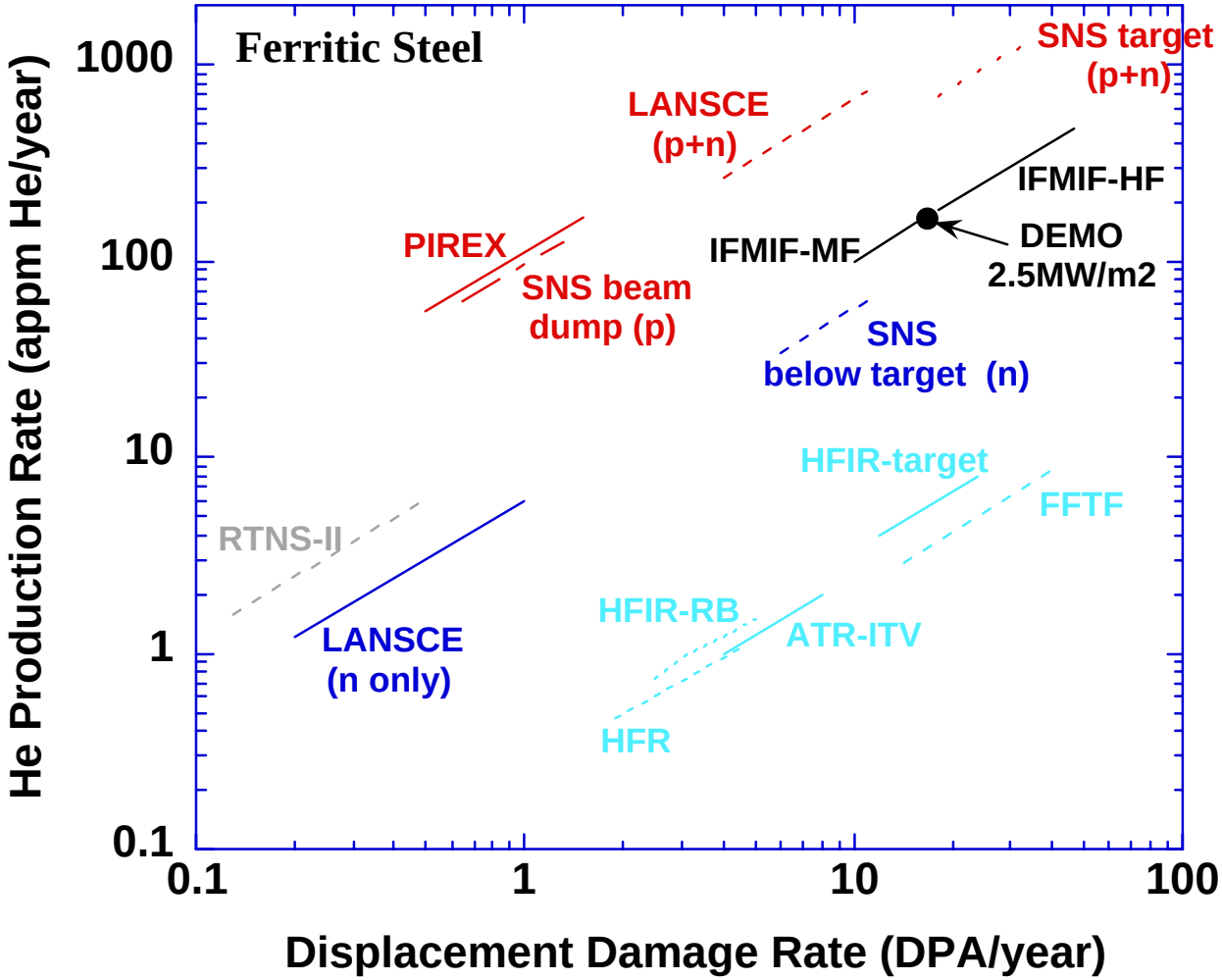
Horizontal position (cm)

Axial position (cm)

n/cm^2-s-2MW (all energies)

Approximate edge of SS316 sample

Comparison of He and Damage Production Rates in Fission, Fusion and Spallation Neutron Facilities



- Notes: PIREX scheduled to shut down in 2003; SINQ not shown on plot; LAMPF availability/costs to fusion need to be investigated

Strawman US position on potential contributions of spallation neutron sources to fusion materials development

- Spallation neutron sources will not replace the need for a dedicated intense fusion neutron source (IFMIF)
- Many helium effects require simultaneous displacement damage and He generation, with He concentrations above 100-1000 appm
  - He preinjection studies have limited (but valuable) contribution
- Spallation vs. fission neutron irradiations do not represent single-variable experiments on He effects
- Extensive modeling and analysis need to be performed to carefully interpret the meaning of the acquired data
  - Pulsed irradiation effects
  - Solute transmutation effects
  - Etc.
- There is value in pursuing a <u>limited</u> test irradiation capability (i.e., temperature controlled rabbit irradiation facility. ~10-30 cm3 in SNS) if…….. low cost and does not seriously impact neutron scattering mission of SNS