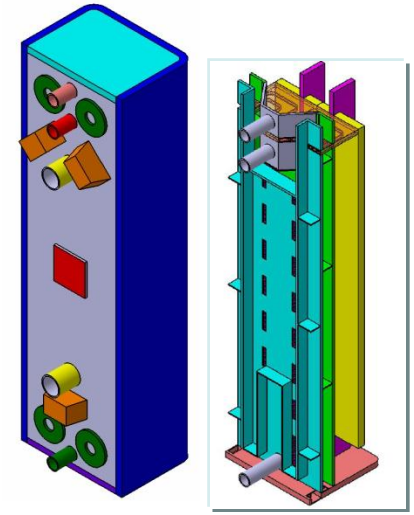
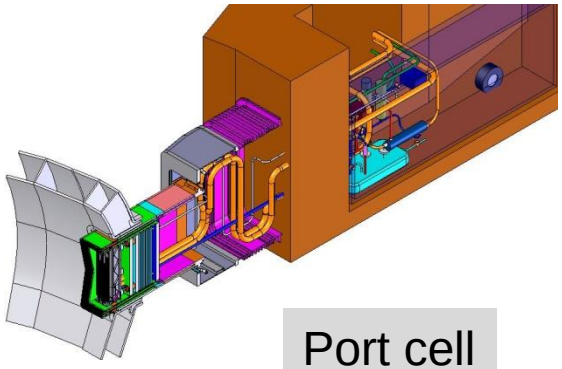
# US DCLL TBM Status



**Clement Wong, General Atomics**
**For the U.S. DCLL TBM Team**



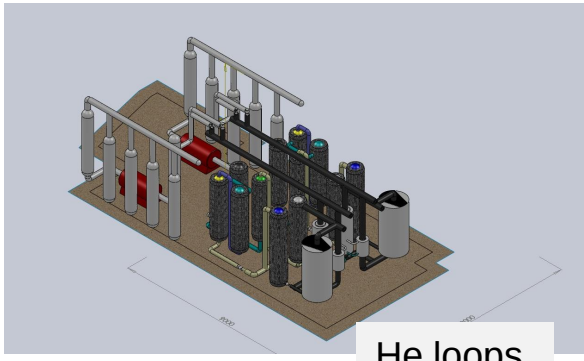
TBM



Port cell

Hot cell

Tritium building



He loops

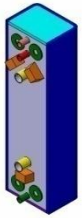
Ancillary systems

**Plus R&D**

**Interaction with IO**

**VLT Conference Call, March 17, 2010**

# US DCLL TBM Team





**M. A. Abdou, M. Dagher, A. Ying, N.B. Morley, S. Smolentsev,**

**K. Messadek, S. Sharafat, A. Aoyama, M. Youssef – UCLA**

**C. Wong, M. Schaffer – GA**

**B. Merrill, L. Cadwallader , P. Sharpe – INL**

**R. Kurtz, G. E. Youngblood – PNL**

**M. Sawan, E. Marriott, P. Wilson, B. Smith – UW**

**Y. Katoh, A. Lumsdaine – ORNL**

**D. K. Sze – UCSD**

**S. Willms – LANL**

**M. Ulrickson, R. Nygren, D. Youchison– SNL**

**S. Malang – Consultant, Germany**

**R. Munipalli, P. Huang – Hypercomp**

**B. Williams – Ultramet; R. Shinavski – Hypertherm HTC**

# The US-Selected DCLL Concept for DEMO

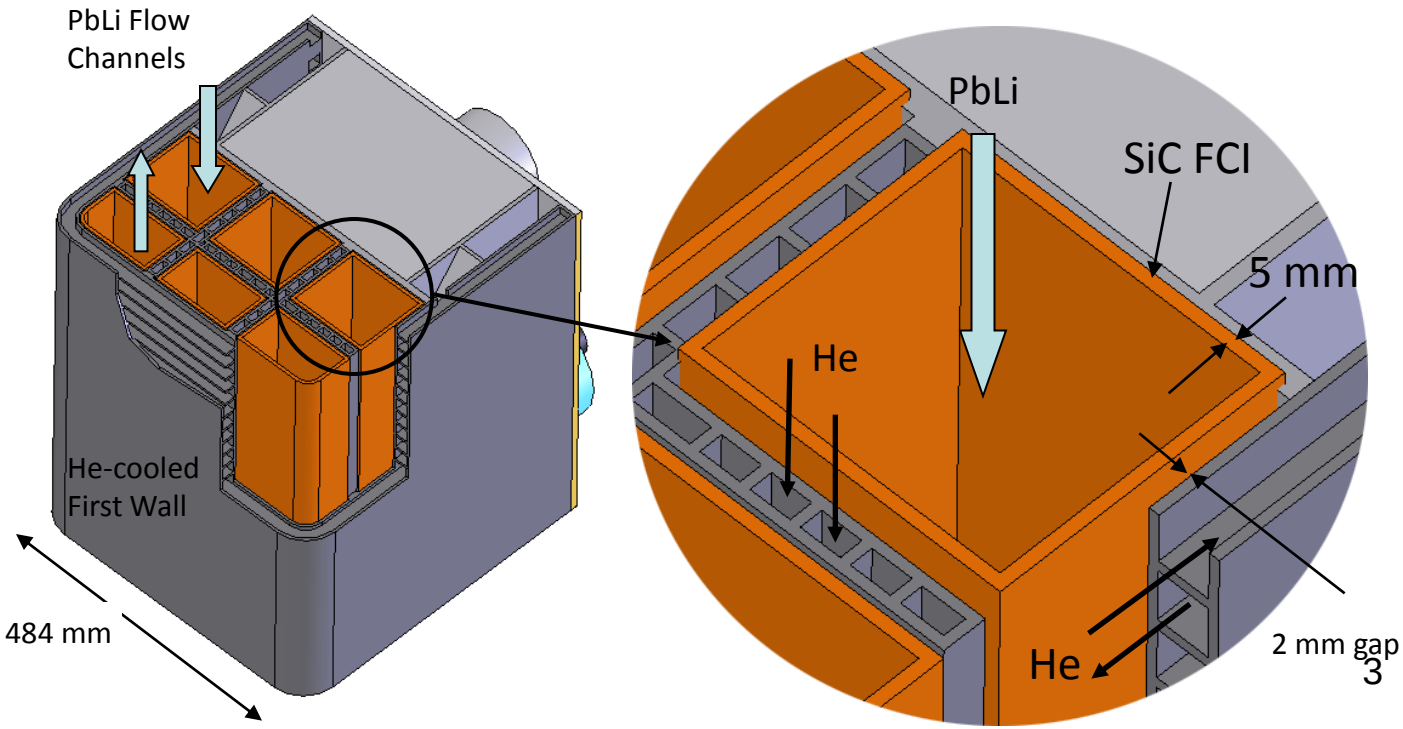
US DCLL TBM

**The US-Selected Dual Coolant (He & PbLi) Lead Lithium (DCLL) TBM concept provides a pathway to high coolant outlet temperature using current generation of structural materials:**

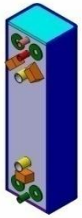
- **Use of RAF/M steel with He cooling and SiC for flow channel insert (FCI) for thermal and electrical insulation between PbLi and RAF/M steel structure**
- **Breeder PbLi moves at a slow velocity of < 10 cm/s, leading to Tout @ 700° C and combined gross ηth > 40% with the use of CCGT**

***DCLL Evolution:***

- ***Developed in ARIES-ST US-APEX and in the EU-PPS***
- ***Adopted for ARIES-CS***
- ***Similar concept considered in US-IFE-HAPL program***



# Recent Actions on ITER TBM

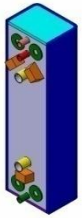




- The ITER TBM program has been formalized by the ITER Council as an important part of ITER and as essential to ITER achieving its objectives.
- A TBM program committee (TBM-PC)* was formed with official participation by the 7 parties
- TBM-PC reports directly to the ITER Council
- TBM-PC-1 met March 2009
- TBM-PC-1 assigned half-port in ITER to test DCLL. The US agreed to serve as "interface coordinator" for this DCLL half-port.
  - US "interface coordinator" function is similar to that of a "concept leader", but with the understanding that the US does not have the resources at present to fulfill the responsibilities of a concept leader. The US will do only limited effort – often on delayed time schedule, and will seek support from other parties.

*TBM-PC US: Member: J. Hoy
Experts: M. Abdou, M. Hechler, L. Leiken "DOE lawyer", R. Goldston

# TBM Concepts and Port-Sharing



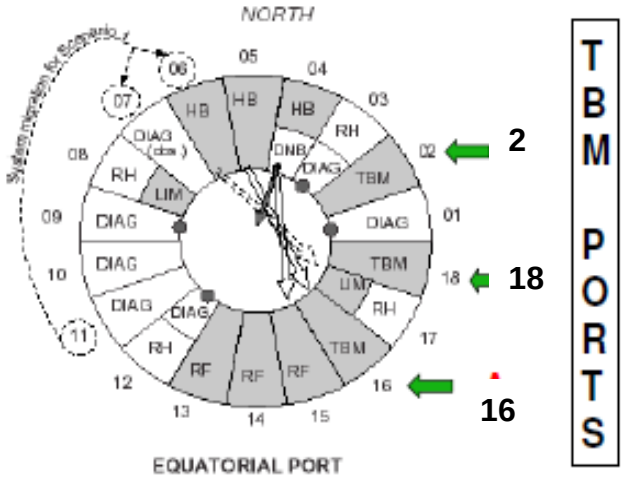
US DCLL TBM

**The proposed six TBM systems to be installed in ITER in the initial ITER H-operation are the following**

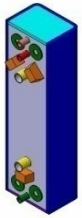
| Port No. and PM | TBM Concept | TBM Concept |
|---|---|---|
| 16 (PM : EU) | HCLL (TL : EU) | HCPB (TL : EU) |
| 18 (PM : JA) | WCCB (TL : JA) | DCLL (InCo : US (KO))* |
| 2 (PM : CN) | HCCB (TL : CN) | LLCB (TL : IN) |

*Interface Coordinator (acting as provisional TBM Leader), PM: Port Master, TL: TBM Leader

HCLL : Helium-cooled Lead Lithium
HCPB : He-cooled Pebble Beds (Ceramic/Beryllium)
WCCB : Water-cooled Ceramic Breeder (+Be)
DCLL : Dual Coolant (He & PbLi) Lead Lithium
HCCB : He-cooled Ceramic Breeder (+Be)
LLCB : Lithium-Lead Ceramic Breeder
(DC type, He & PbLi)



# US DCLL TBM Approach, August 2009





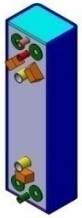
- The US serves as interface coordinator (InCo) and will do its best to fulfill this function. In 09 we had good meetings with EU, Japan and Korea
- The US will need support from other parties with expertise and interest in lead-lithium blanket in developing the interface information for integration in ITER
- We continue the DCLL TBM design with focus on the last DT module, address critical issues for DEMO and technology and scientific challenges via R&D tasks

**For InCo, the most urgent duties are :**

- Interact with IO technically and on interfaces in a timely manner
- participate in the required integration effort with other ITER systems
- participate in the review process of all ITER-TBM documents
- provide information to IO on the corresponding TBM R&D programs
- for the TL and InCo, interact with the corresponding PM to allow the PM to perform his duties

# Immediate Activities and Events



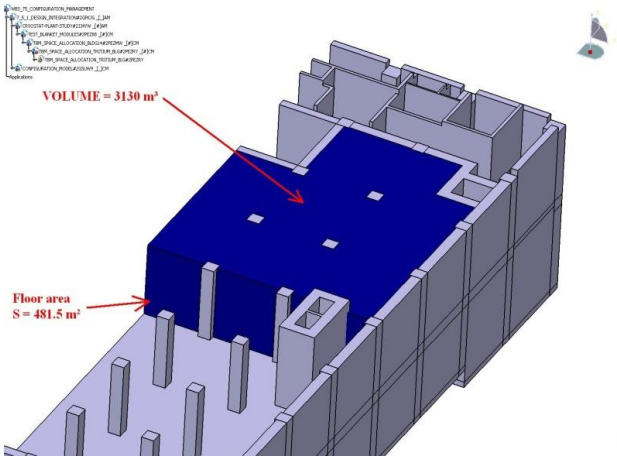


1. Complete the equipment layout of our helium loop equipment in the assigned TBM Tokamak Cooling Water System (TCWS) area
2. Complete the equipment layout of all Ancillary Equipment Unit (AEU) equipment with the new port cell details
3. Complete the design and analysis of all helium pipes from the port cell to the TCWS area
4. Support the maintenance procedure review of different systems
5. Complete the RPrS report (Preliminary Safety Report)
6. Complete the 2010 DDD report

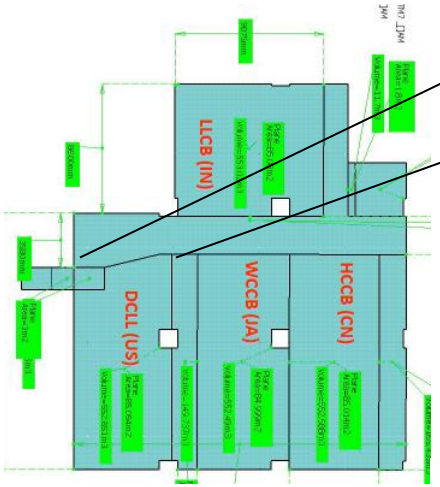
**TBM FS impacts meeting will be held in Cadarache on April 13-15.**

**PMG-18-3 meeting will be held in Cadarache on April 16, with focus on the RPrS details and program up-date**

# TBM Building and DCLL He Cooling System

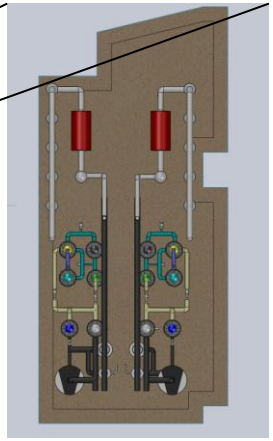



TCWS vault annex



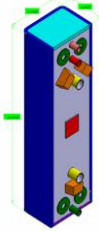

Top view TCWS area

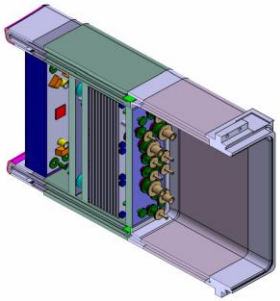
US DCLL TBM



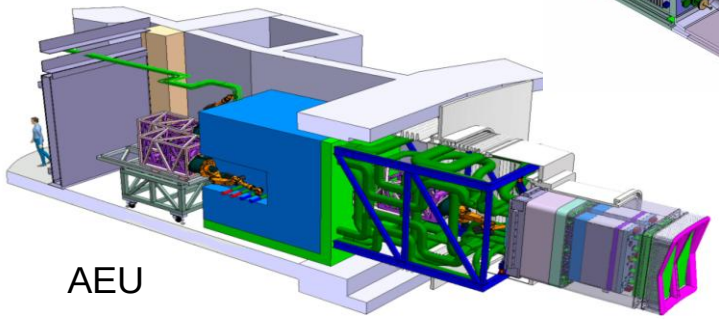
TCWS
vault annex

**DCLL TBM**





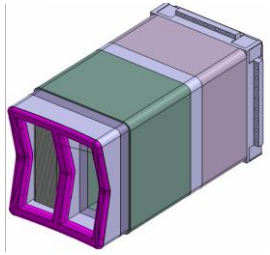

Port cell area



AEU

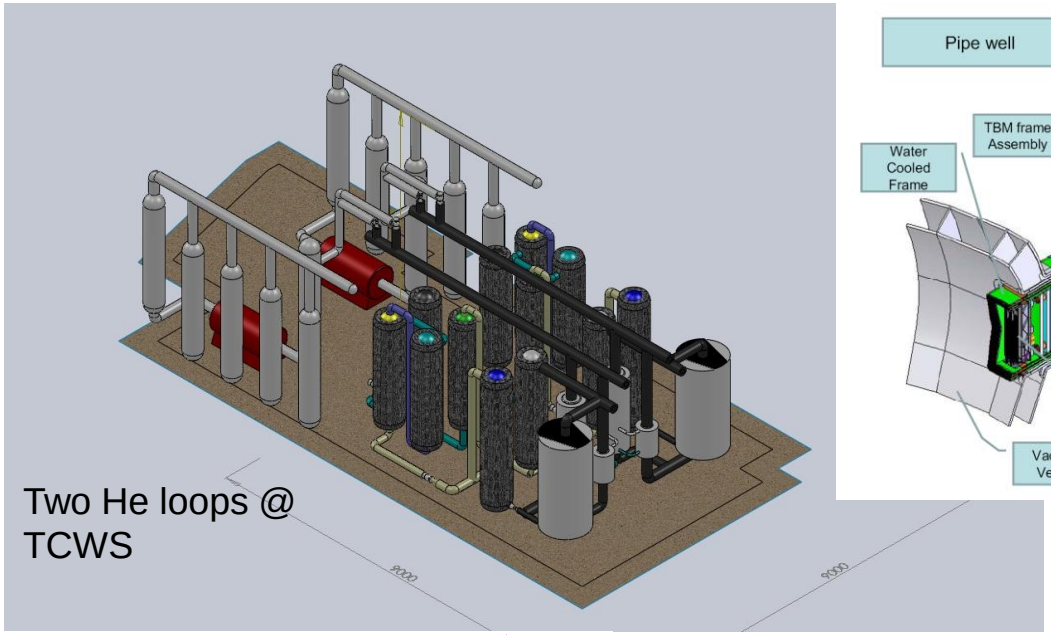
Tube forest

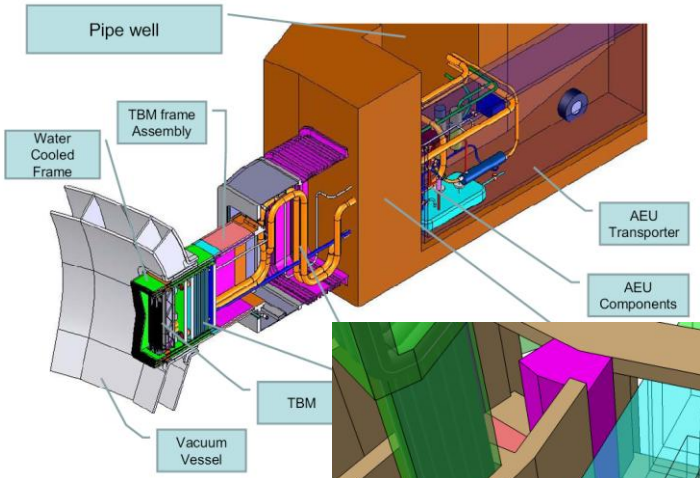
Port plug



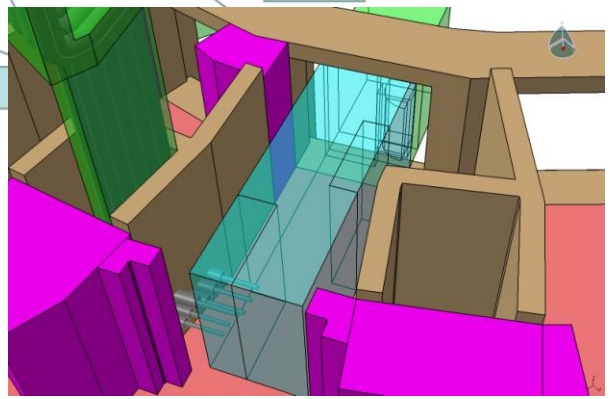
Port plug

# We are working on the He loop details and AEU equipment to fit into available space

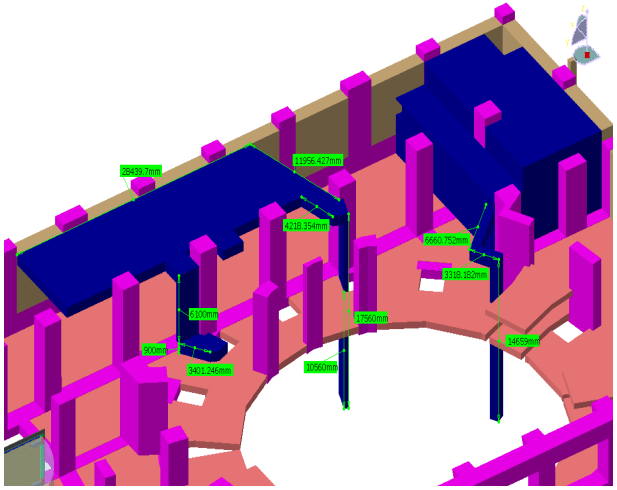


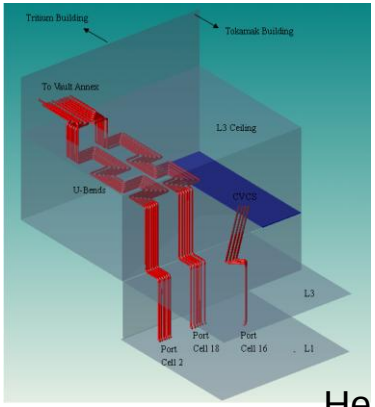



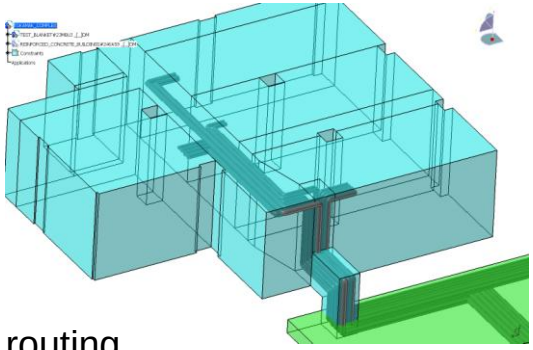

Port Plug & AEU



AEU backside

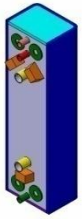




He pipe routing

# Reviewed PBS-56 ICDs and ISs



US DCLL TBM

| PBS | Link on IDM | ICD Status | Number of associated ISs | ISs: status and due dates | Comments |
|---|---|---|---|---|---|
| **15** (Vacuum Vessel) | ITER_D_2V38KU - Interface Control Document (ICD) - Vacuum Vessel (PBS-15) - Test Blanket Modules System (PBS-56) | Approved 08/10/09 | 3 | 10/09 (not yet done) | Not involving TBSs |
| **22** (Machine Assembly and Tooling) | N/A | TBD | ? | | To be done soon (2010?) |
| **23** (Remote Handling) | N/A | | | | |
| **26-PH, -CV, -DR, -DY** (TCWS) | ITER_D_2V7HG - Interfaces Control Document (ICD) between Tokamak Cooling Water System (PBS 26-PH,-CV,-DR,-DY) - Test Blanket Modules System (PBS 56) | | | | |
| **26-CC** (Component), **26-CH** (Chilled) Cooling Water Sytems | ITER_D_2Y2VG3 - Interfaces Control Document (ICD) between Component & Chilled Cooling Water Systems (PBS 26-CC, -CH) - TBMS (PBS 56) | | | | |
| **31** (Vacuum Pumping) | N/A | | | | |
| **32** (Tritium Plant) | N/A | | | | |
| **43** (Electrical Power Network) | ITER_D_2KSJ89 - Interface Control Document (ICD) between SSEN (PBS43) - Test Blanket Modules (PBS56) | | | | |
| **44** (Cable Management) | N/A | | | | |
| **45** (CODAC) | ITER_D_2UQDWN - S-ICD PBS-PS6 | | | | |
| **46** (Central Interlock System) | ITER_D_2LGKPC - Interface Control Document (ICD) Central Interlock System (PBS 46) - Test Blanket Modules (PBS 56) | | | | |
| **47** (Plasma Control) | N/A | TBD | ? | | ICD needed in 2010? |
| **48** (Central Safety System) | ITER_D_2MBELA - Interface Control Document (ICD) Central Safety System (PBS 48) - Test Blanket Modules (PBS 56) | Reviewed | 18 | 06/11 Linked with CD | Waiting for revised version |
| **55** (Diagnostics) | N/A | TBD | ? | | Is ICD needed? |
| **58** (Port Plug Test Facility) | N/A | TBD | ? | | ICD needed in 2010? |
| **62-11, 62-14** (Tokamak & Tritium Buildings) | ITER_D_2EQ892 - 000000-CCS-KA0-35 Interface Control Document (ICD) between Tokamak & Tritium Buildings (PBS 62-11 & PBS 62-14) - Test Blanket Modules (PBS 56) | Approved 05/05/09 | 10 | 12/09 | Detailed interfaces table under preparation (may be used as ISs?) |
| **62-21** (Hot ) | ITER_D_2EPR92 - 002100-CCS-KA0-13 Interface Control Document (ICD) between Hot Cell Building (PBS 62-21) - Test Blanket Modules (PBS 56) | Approved 05/05/09 | 2 | 12/09 | |
| **62-71** ( ) | N/A | Unknown | ? | | Is ICD needed? |
| **64** (Radiological Protection) | N/A | TBD | ? | | ICD needed in 2010? |
| **65-CA** (Compressed Air) | ITER_D_2EQ7CG - 0000CA-CCS-KA0-19 Interface Control Document (ICD) between Compressed Air (PBS 65-00-CA) - Test Blanket Modules (PBS 56) | Approved 30/04/09 | 1 (under preparation) | 12/09 | More than one IS may be needed for taking into account different locations and different TBSs |
| **65-NG** (Liquid and Gaseous Nitrogen) | ITER_D_2MKDR2 - 0000NG-CCS-KA0-17 Interface Control Document (ICD) between Nitrogen Distribution (PBS 65-00-NG) - Test Blanket Modules (PBS 56) | Approved 30/04/09 | 1 (under preparation) | 12/09 | More than one IS may be needed for taking into account different locations and different TBSs |
| **65-HE** (Helium Gas) | ITER_D_2MYPGQ - 0000HE-CCS-KA0-10 Interface Control Document (ICD) between Helium (PBS 65-00-HE) - Test Blanket Modules (PBS 56) | Approved 30/04/09 | 1 (under preparation) | 12/09 | More than one IS may be needed for taking into account different locations and different TBSs |
| **65-BA** (Breathing Air) | N/A | TBD (urgent) | ? | | ICD may be urgently needed – under discussion |
| **66** (Radwaste Treatment and Storage) | N/A | TBD | ? | | |
| **67** (Hot Cell Facility) | ITER_D_2VVBNS - Interface Control Document (ICD) Test Blanket Modules System (PBS 56) - Hot Cell Facility (PBS 67) | Approved 18/10/09 | 6 | 09/10 | |

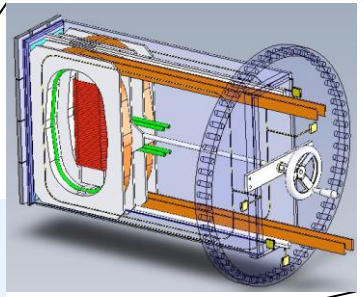
| | |
|---|---|
| **62-11, 62-14** (Tokamak & Tritium Buildings) | ITER_D_2EQ892 - 000000-CCS-KA0-35 Interface Control Document (ICD) between Tokamak & Tritium Buildings (PBS 62-11 & PBS 62-14) - Test Blanket Modules (PBS 56) |
| **62-21** (Hot ) | ITER_D_2EPR92 - 002100-CCS-KA0-13 Interface Control Document (ICD) between Hot Cell Building (PBS 62-21) - Test Blanket Modules (PBS 56) |

ICD: ITER control document
IS: Interface document
PBS-56: is the PBS for TBM

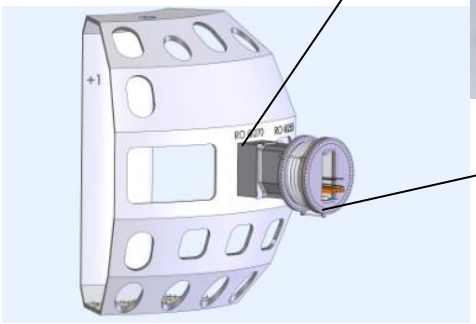
# Impact of TBM ferromagnetic effects on ITER performance

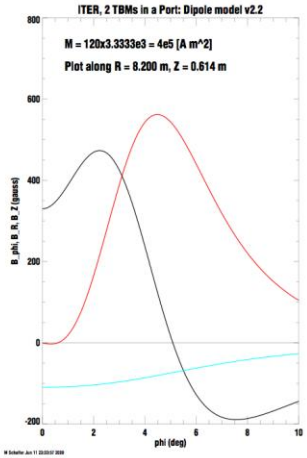
**Experimentally assessed in DIII-D in Nov. 2009**
**A community meeting is organized for April 13-15, 2010**
**A presentation will be made at the June VLT conference call**

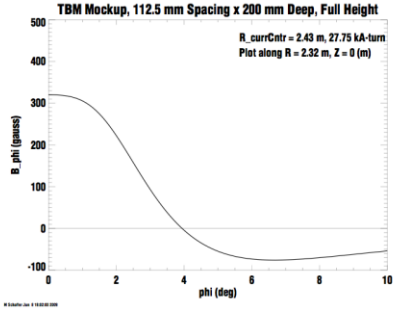
US DCLL TBM

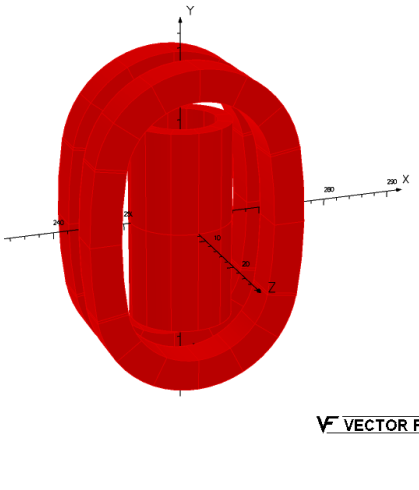


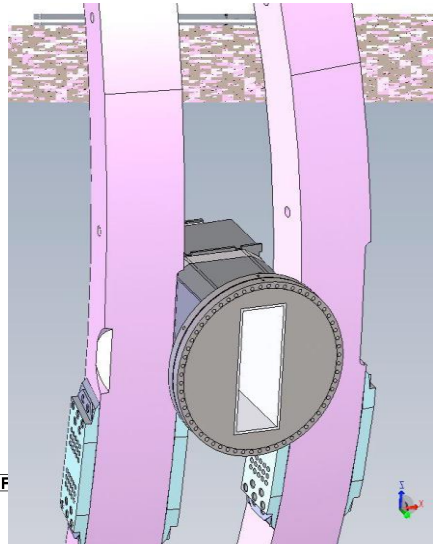
**DIII-D**





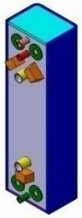



**ITER Bphi**

**Mockup Bphi in DIII-D**

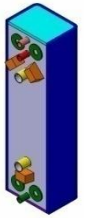
# Main DCLL Related R&D Topics



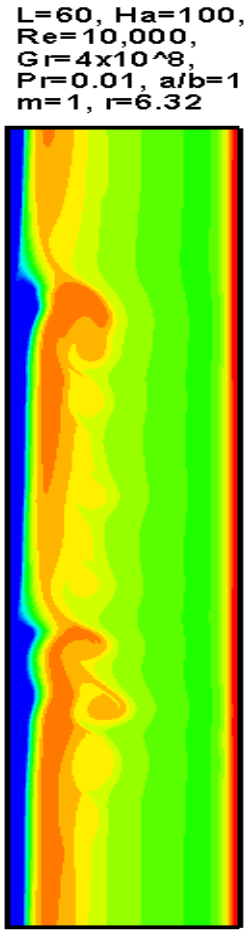
US DCLL TBM

- MHD flow and heat transfer and mass transfer for liquid metal blankets (UCLA: Smolentsev, Messadek, Morley, Ying; SBIRS: Hypercomp)
- Tritium permeation and recovery (INL: Sharpe, Calderoni; UCLA: Ying)
- Safety analysis and modeling (INL: Merrill, Sharpe)
- FCI material/component development & properties (ORNL: Katoh, PNL: Youngblood; SBIRS: Ultramet, Hypertherm)
- Irradiation effects in RAF/M steels and SiC (Materials program in general)
- Integrated modeling / Virtual TBM (UCLA: Ying, Liu; UW: Sawan, Marriott, Hypercomp)
- Beryllium armor joining to RAF/M steel (UCLA: Ying, Hunt)
- Interfacial phenomena, Compatibility, Corrosion (ORNL: Pint; UCLA: Smolentsev; SBIRS: Ultramet, Hypertherm)

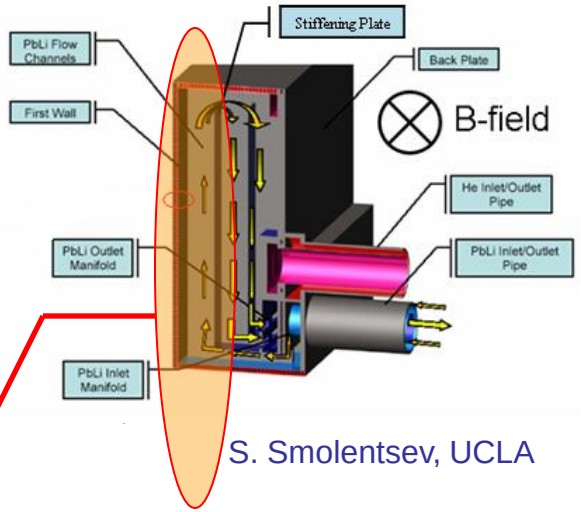
# Impact of Buoyancy effects in blanket thermal performance and tritium transport



US DCLL TBM




DCLL DEMO blanket, US




S. Smolentsev, UCLA

| Parameter | ITER | DEMO OB |
|---|---|---|
| Ha | 6500 | 12,000 |
| Re | 30,000 | 60,000 |
| Gr | $7.0\times10^{9}$ | $3.5\times10^{12}$ |

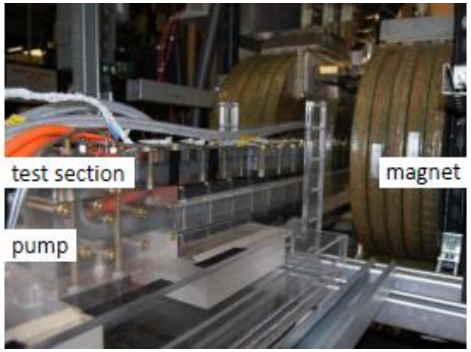
Vorticity distribution in the buoyancy-assisted (upward) poloidal flow

Investigated by Buhler and others in the EU for impact on HCLL heat and mass transfer

In the DCLL, can be 2-3 times stronger than forced flows. Forced flow: 10 cm/s. Buoyant flow: 25-30 cm/s

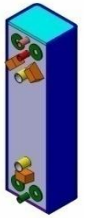
In buoyancy-assisted (upward) flows, buoyancy effects may play

- a positive role on FCI peak temperature due to the velocity jet near the “hot” wall, reducing the FCI $\Delta T$
- a negative effect on heat loss from hot PbLi to colder He coolant
- Effect on tritium transport and permeation, FCI compatibility, RAFS compatibility still unknown




At UCLA experimental facility is used to address fundamental MHD critical areas

# Flow Channel Insert (FCI) Material Options



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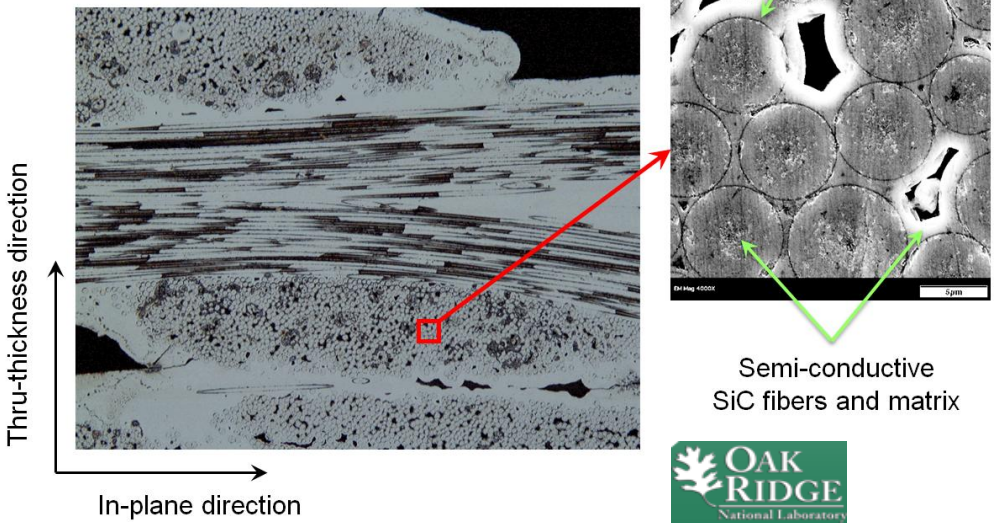
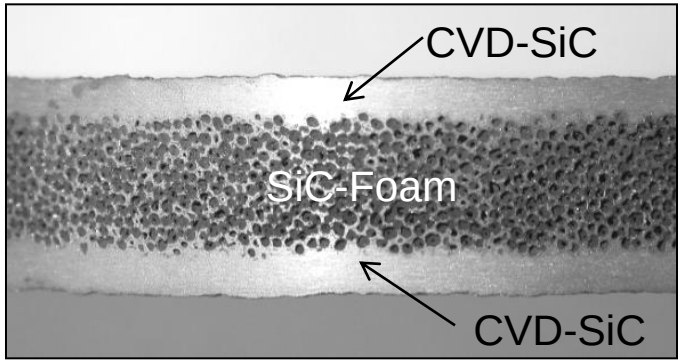
- SiC-fiber/SiC-matrix composites are promising candidates
- Other forms of SiC (porous SiC), such as SiC-Foam are alternatives




**CVD SiC**
**Closeout Layers/SiC foam (5X)**




ULTRAMET
ADVANCED MATERIALS SOLUTIONS

# Tritium Transport Experiments (INL)

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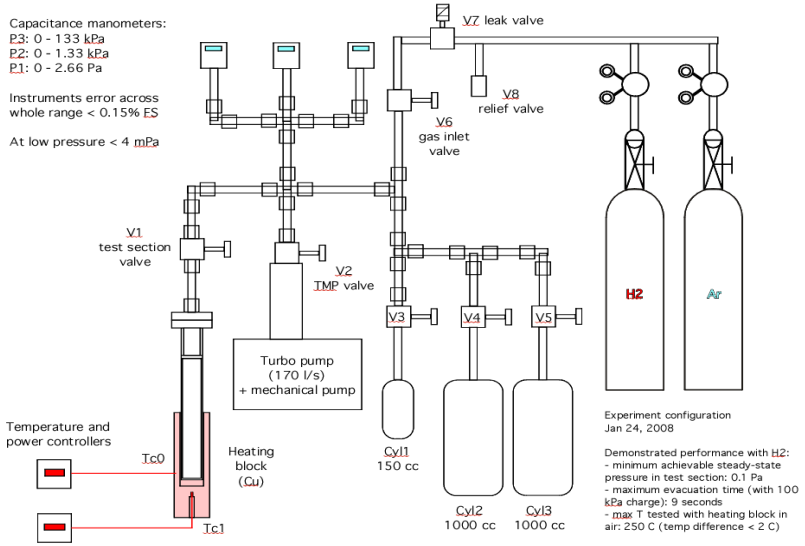
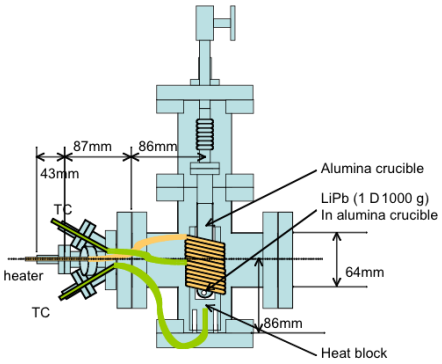
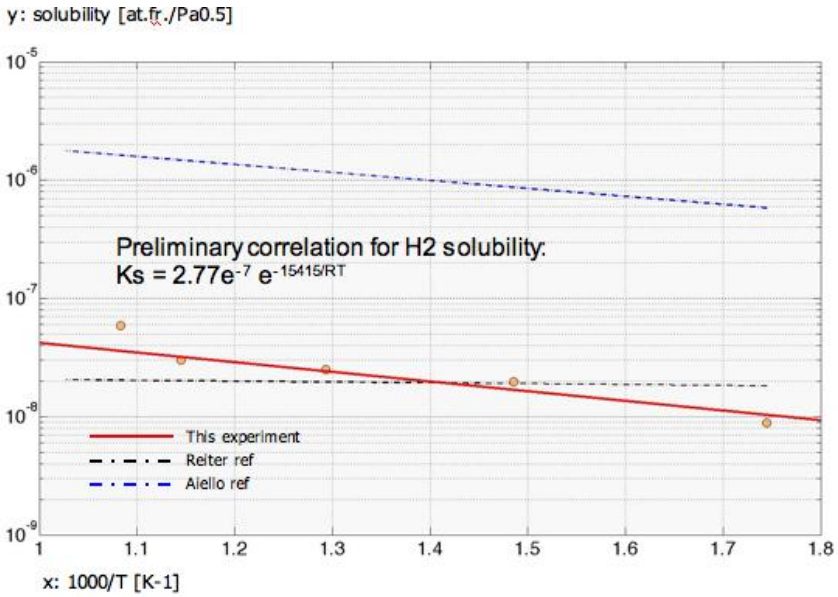
## Hydrogen isotope solubility in PbLi Eutectic (LLE):

*Adsorption/desorption system for solubility measurements*



# US DCLL TBM Status Summary



## We are ready to go