Recent research on the DCLL and PbLi based blanket concepts

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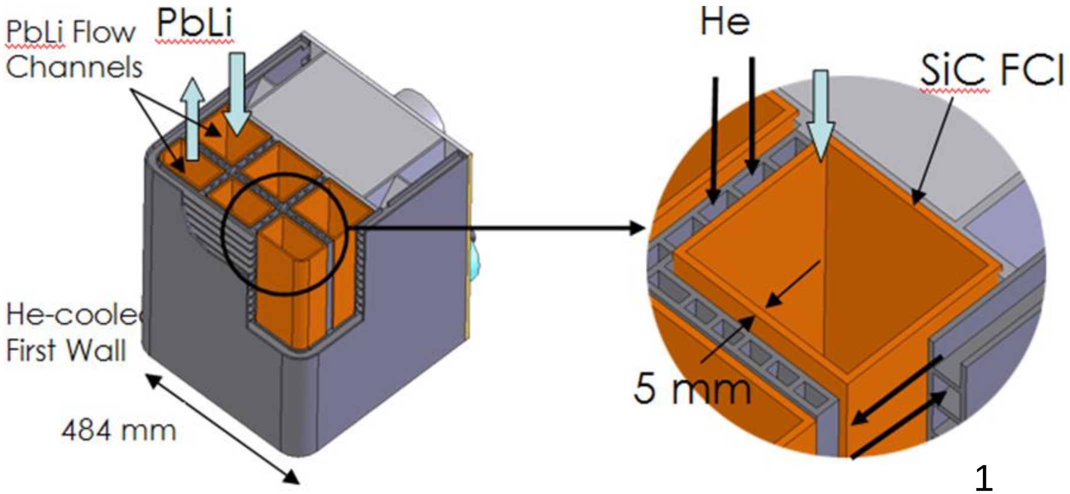
FESS-FNSF Meeting
ORNL
Feb 17-19, 2015



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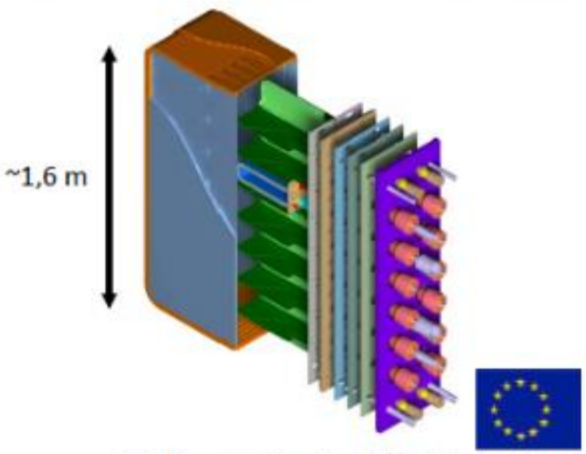
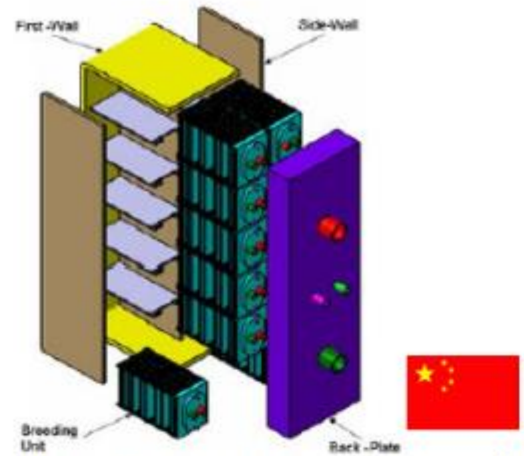
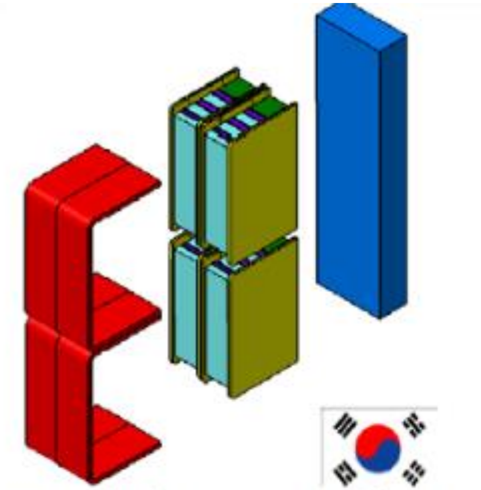
Test Blanket Modules (TBMs) for Testing in ITER



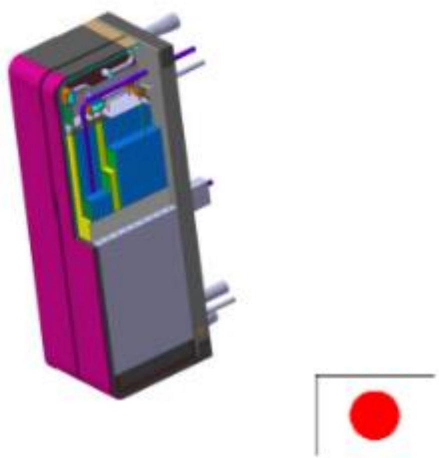
Helium-Cooled Pebble-Bed



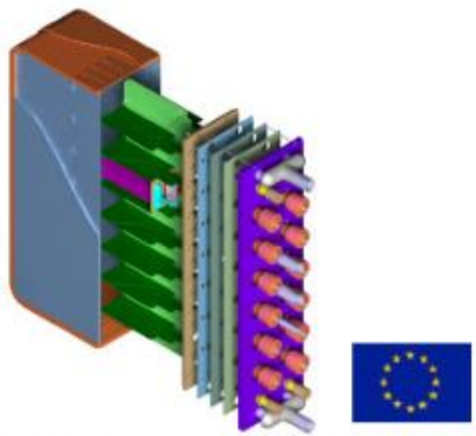
Helium-Cooled Ceramic Breeder



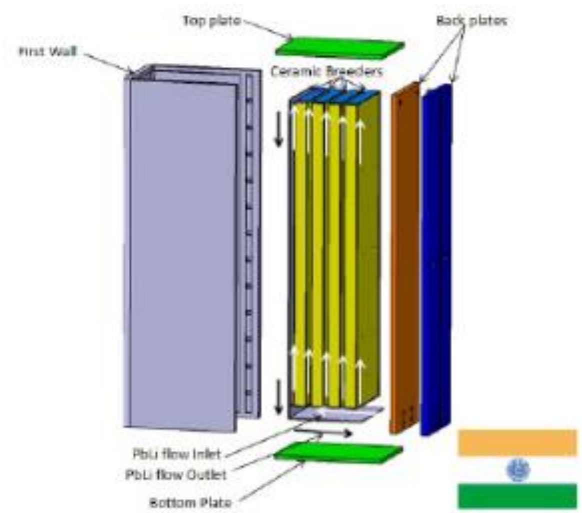
Helium-Cooled Ceramic



Water-Cooled Ceramic Breeder



Helium-Cooled Lead-Lithium



Lead-Lithium Ceramic-Breeder

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Status of ITER TBMS – Three ceramic breeder based systems have conducted conceptual design review (CDR) by IO, LM blankets have not

	KO -HCCR	JA-WCBB	CN- HCCB
Category I Chit	1	4	5
Category II Chit	27	36	37
Category III Chit	2	2	12

CDR Topics

- Requirements & Assumptions
- Load Specifications & Conceptual Designs Descriptions
- Materials
- Analyses Report for Port Plugs
- Analyses Report for Ex-Vessel Components
- Maintenance Operations, RH, Assembly
- Maintenance Tools and Equipment
- Instrumentations & Control
- Safety Analyses and Safety Functions
- Interfaces
- RAMI

- Conceptual Design Approval is accomplished after resolution of Chits 1 and approval of Action Plan for each Chit 2.

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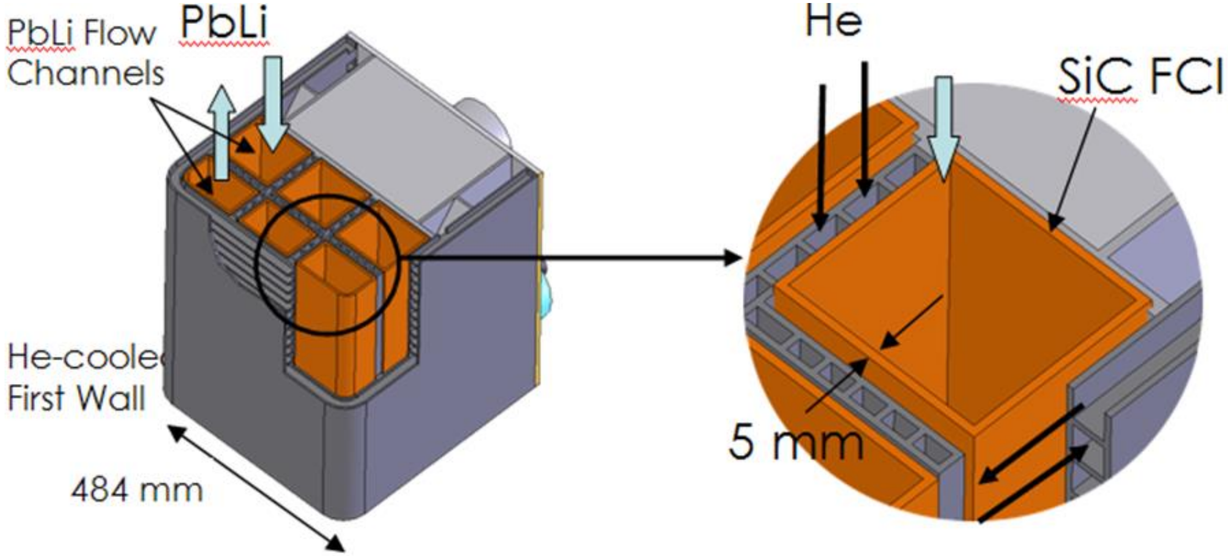
Why DCLL promising solution towards high-temperature (T~700°C), high-efficiency (η>40%) blanket system with near term materials

- **Current generation RAFM steel is used as structural material**
- **High-temperature PbLi is used as breeder/coolant**
- **Flow Channel Insert (FCI) of SiC serves as electrical, thermal insulator**



or sandwich FCI (RAFM-alumina-RAFM) as lower temp option

- **PbLi flows slowly (V ~ 10 cm/s) in large poloidal rectangular ducts (D ~ 20 cm) to remove the nuclear heat at high temp and produce/remove tritium**
- **Pressurized He gas (~ to 8 MPa) is used to remove the surface heat flux and and nuclear heat in other steel structures**

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Why DCLL Other blanket options have less potential long term attractiveness and perceived greater feasibility issues

Options evaluated over the past 10 years:

- Helium Cooled Ceramic Breeder
  - Long term breeder thermomechanics under long term irradiation
  - Low power density, high structural content, high number welds
  - Still main world choice -- Selected as primary US backup
- Self Cooled Li/V
  - Vanadium development, insulator coating development
  - Li reactivity (all variety of Li based systems)
- Molten salt based blankets
  - High melting point, small temperature window with existing materials
  - Low breeding potential, additional Be required
  - High viscosity, low thermal conductivity coolant, MHD interactions
  - REDOX control in irradiation environment, high cost for chemistry control development

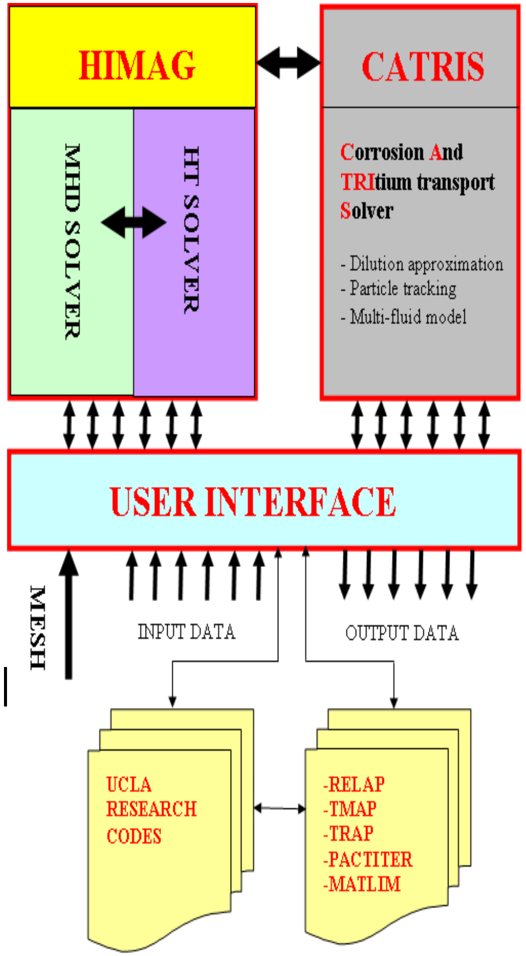
R&D areas pursued at UCLA for DCLL development

Motivated by need to better understand and predict the complex MHD flow and coupled transport processes and LM-MHD effects on material interactions

1. **LM MHD fluid dynamics and heat transfer**
2. **Corrosion of RAFM steel and transport of corrosion products**
3. **SiC FCI performance in LM-MHD environment**
4. **Tritium transport and permeation in DCLL**

To do this R&D we use computational tools developed/modified for DCLL simulations at UCLA

- **HIMAG** (HyPerComp Incompressible MHD Solver for Arbitrary Geometry) is a 3D, MHD, multi-material unstructured mesh, MHD/Heat Transfer parallel code.
- **CATRIS** (Corrosion and Tritium Transport Solver) is a *mass transfer solver* coupled with HIMAG. Various models, such as "dilution approximation" and "particle tracking"
- **TRANSMAG** (Transport Phenomena in Magnetohydrodynamic Flows) is corrosion corrosion products transport code for in laminar and turbulent MHD flows.
- **DNS-MHD** Research codes for direct numerical simulation of 2D turbulence using spectral methods
- **Stream/SC-Tetra –** commercial 3D thermofluid and transport code modified for tritium transport at interfaces and through materials



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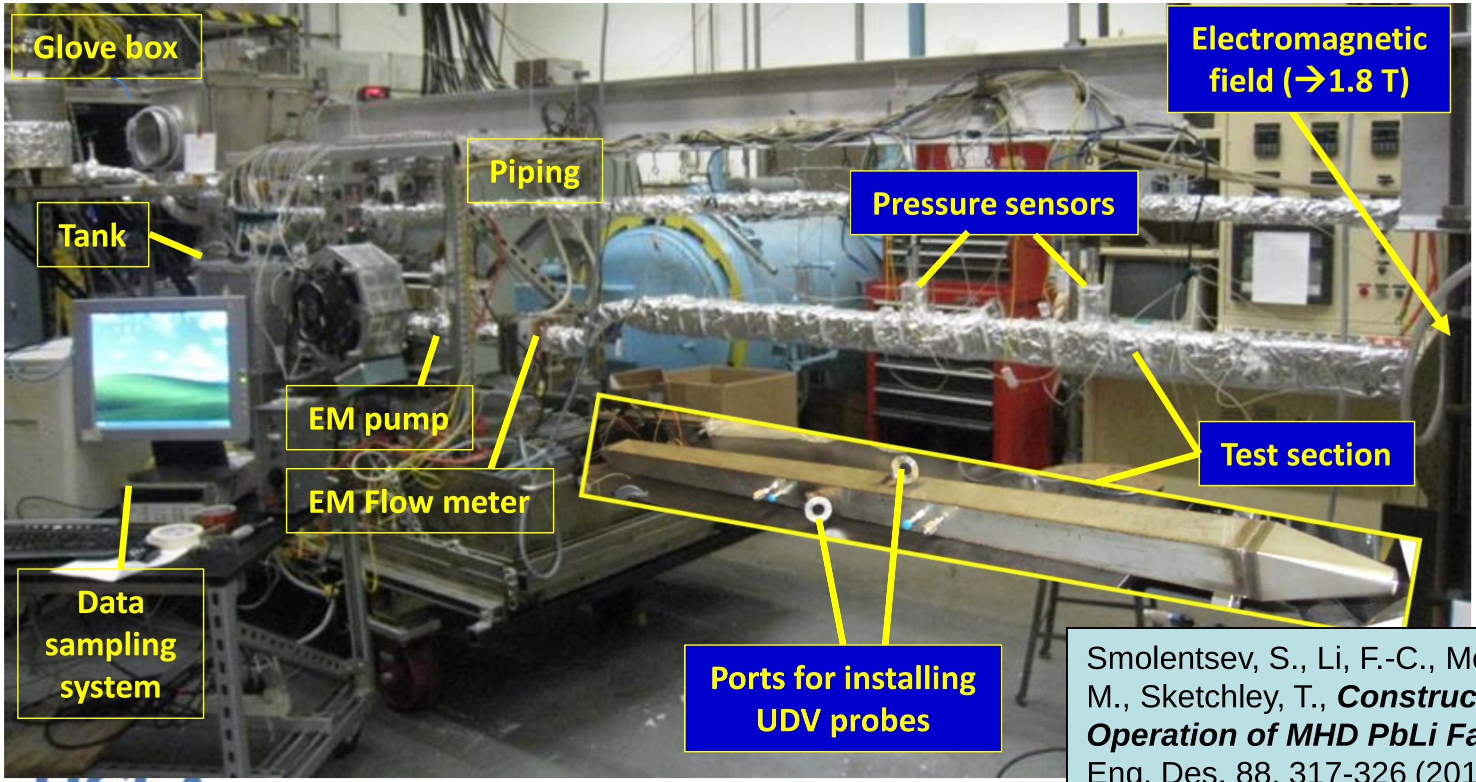
And we use a PbLi MHD loop and simulant LM loops at UCLA for the experiments to study DCLL

MaPLE – MAgnetohydrodynamic PbLi Experiment in the MTOR lab

- First run in July 2011
- The only PbLi MHD facility in the US, one of a few in the World
- To address MHD PbLi flows and flow-material (PbLi-RAFM/SiC) interactions
- To develop and test new flow instrumentation

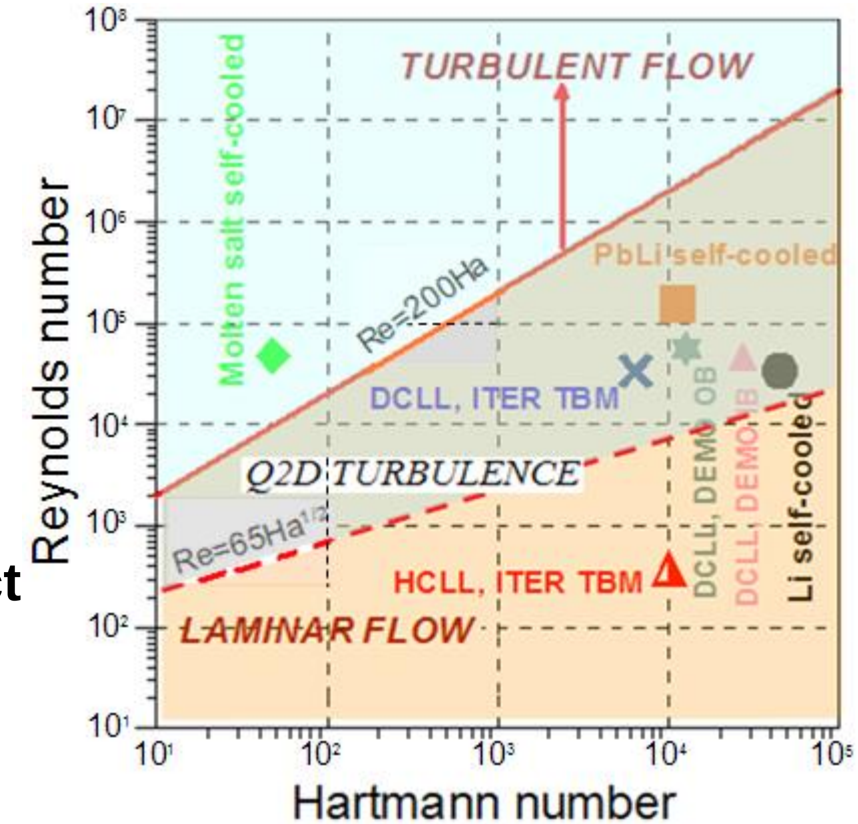


- Q=50 l/min
- M=100 kg PbLi
- B=1.8 T
- V=15x15x80 cm^3
- DP=0.15 MPA
- T=400°C

Smolentsev, S., Li, F.-C., Morley, N., Ueki, Y., Abdou, M., Sketchley, T., ***Construction and Initial Operation of MHD PbLi Facility at UCLA***, Fusion Eng. Des. 88, 317-326 (2013).

(1) LM MHD fluid dynamics and heat transfer

- **Beyond the MHD pressure drop, there is strong uncertainty about how MHD flow phenomena will affect the structure and FCI temperature, flow distribution, and tritium transport in the DCLL**
- **These complex MHD flow processes can affect transport properties of MHD flows in drastic ways and have a significant impact on blanket operation and performance.**
- **Examples here focus on:**
  - **Instabilities, transitions and Quasi-Two-Dimensional (Q2D) turbulence that affect transport**
  - **MHD Flow in FCI configuration**



Ha-Re diagram for a fully developed MHD flow in insulating rectangular duct suggests that in almost all LM blankets, flows will have a special form of *Quasi-Two-Dimensional (Q2D) turbulence*

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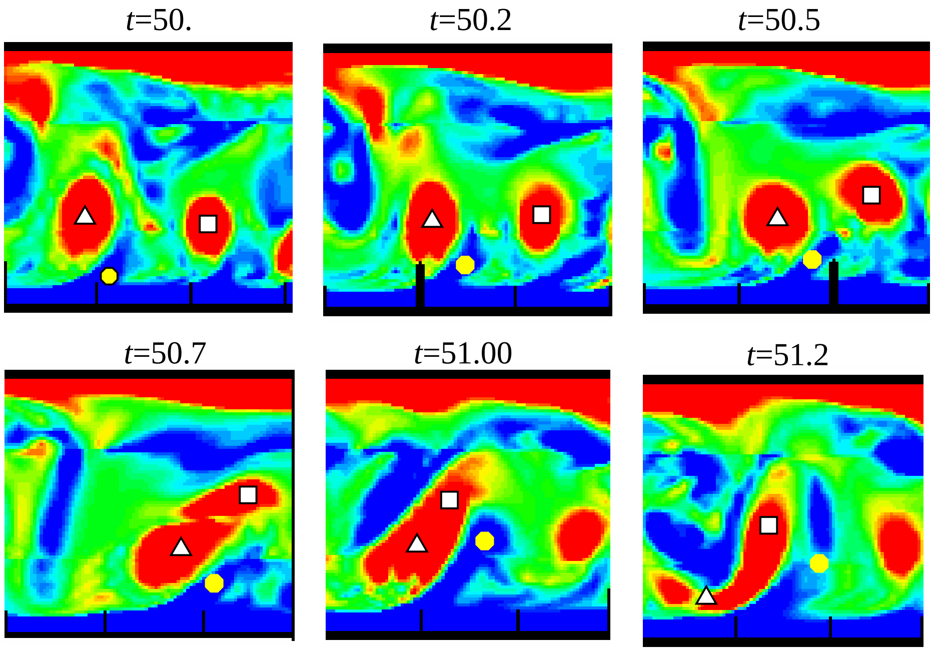
Hydrodynamic stability, laminar-turbulent transitions and Q2D turbulence



The transport processes are controlled via various vortex-wall and vortex-vortex interactions. Vorticity snapshots are shown for Ha=100, Re=5000. (S. Smolentsev et al., PoF, 2012)

Instability and transition to Q2D turbulence occurs as a two-step process. First bulk vortices appear at the vicinity of the inflection point. Then, the bulk vortices interact with the side-wall boundary layer (at the wall parallel to the magnetic field) causing its destabilization and eventually turbulence.

- **Frequent view on MHD turbulence in a LM blanket is that it may develop in the Hartmann layers but suppressed by a strong reactor B field: Re_{cr}~200Ha.**
- **In the DCLL blankets, the Hartmann layers remain stable while turbulence will most likely develop near the side walls in the special form of *quasi-two-dimensional* (*Q2D*) turbulence.**
- **Due to their special topology (stretching along the B field), size and location, the Q2D turbulent vortices may strongly affect transport phenomena (heat transfer, corrosion, T transport).**

S. Smolentsev, N. Vetcha, R. Moreau, ***Study of instabilities and transitions for a family of quasi-two-dimensional magnetohydrodynamic flows based on a parametric model***, Phys. Fluids 24, 024101 (2012).

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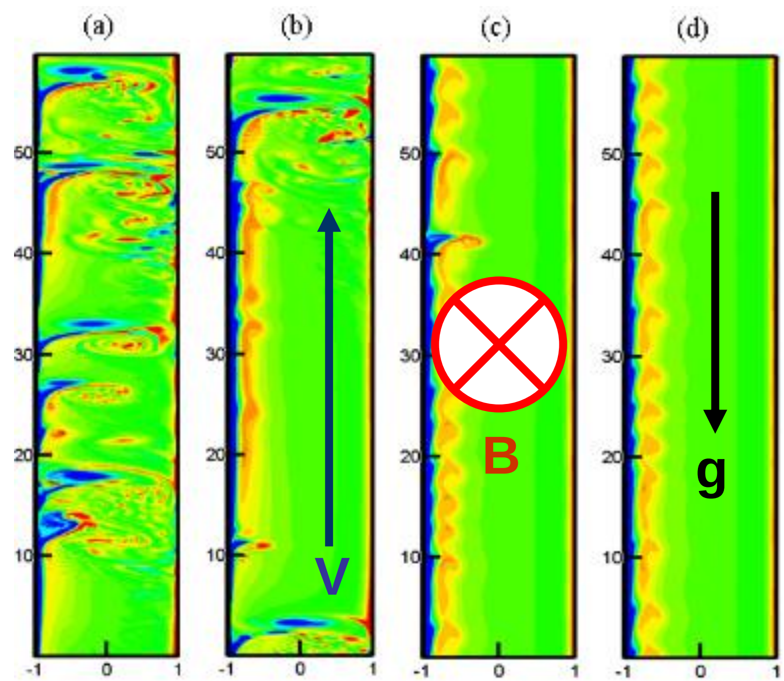
Our studies of vertical MHD flows with reactor-type volumetric heating suggest that in DCLL, Q2D turbulence will appear either as “weak” or “strong”

- **In poloidal flows, buoyancy forces are caused by radial temperature gradients due to exponentially varying volumetric heat. The buoyant flows superimpose on the forced flow. Such mixed-convection flows are foreseen to be hydrodynamically unstable and eventually turbulent.**
- **For DCLL, our DNS studies and stability analysis suggest two types of instability: (1) *primary inflectional instability* and (2) *secondary instability* due to vortex-wall interactions**
- **Two turbulence regimes have been identified. In “*weak turbulence*,” eddies remain localized near the inflection point. In “*strong turbulence*,” bulk eddies interact with the side-wall boundary layer causing its instability and formation of secondary vortices.**

N. Vetcha, S. Smolentsev, M. Abdou, R. Moreau, ***Study of instabilities and quasi-two-dimensional turbulence in volumetrically heated MHD flows in a vertical rectangular duct***, Phys. Fluids 25,024102 (2013).



Vorticity snapshots in a turbulent mixed-convection flow at *Re* = 5000 and *Gr* = 10^8.
Strong turbulence: (a) *Ha* = 50, and (b) *Ha* = 60.
Weak turbulence: (c) *Ha* = 100, and (d) *Ha* = 120.

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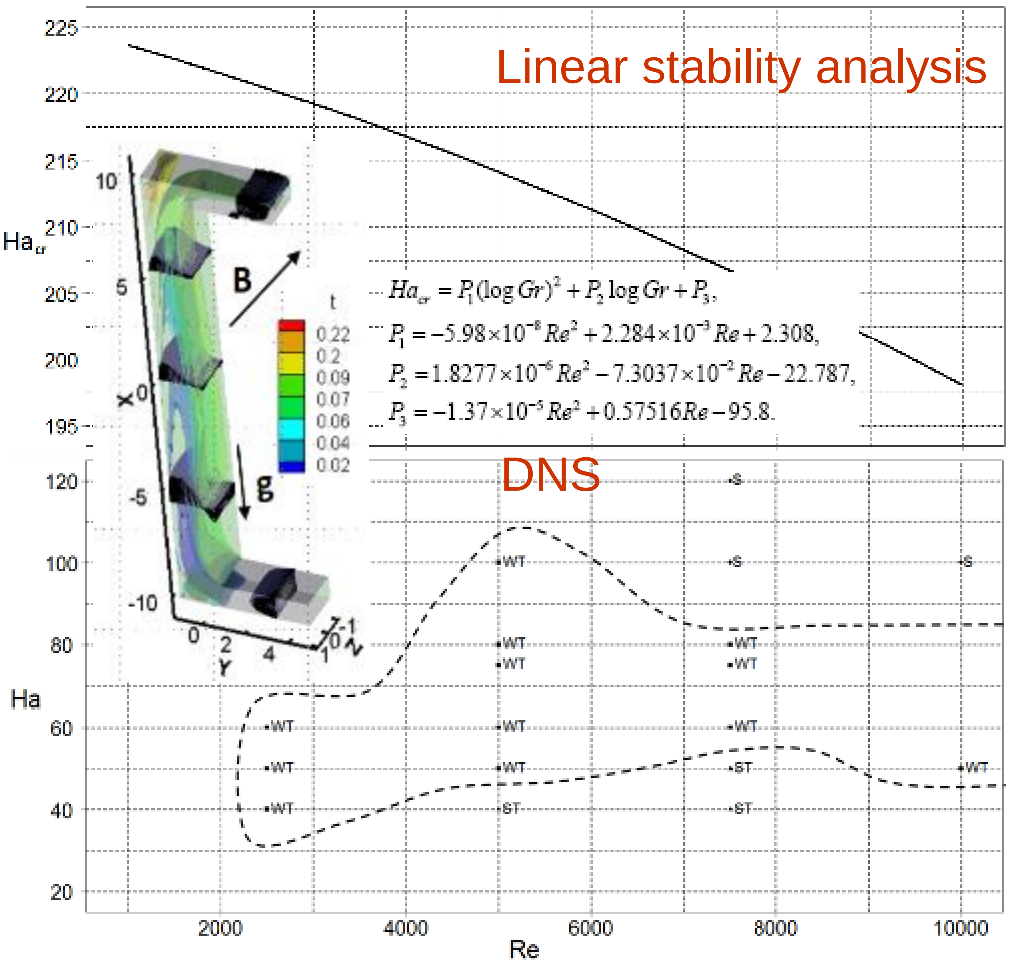
Stability threshold for mixed-convection flows has been evaluated using linear stability analysis and MHD DNS

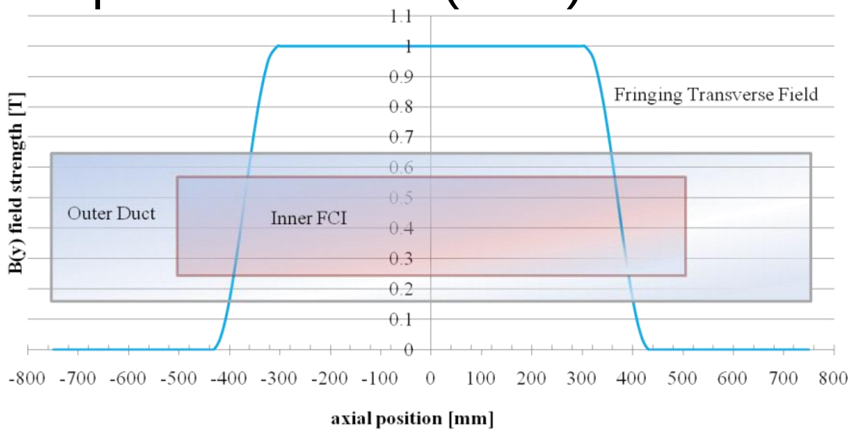


Bottom: Flow map showing stable laminar (***s***) and two turbulent regimes (***wt*** and ***st***) in the *Ha – Re* plane for $Gr = 5x10^7$.
Top: Predictions of the critical Ha number with the linear theory.

- We develop new critical limits that involve **Ha**, **Re** and **Gr** (as a measure of buoyancy forces versus viscous forces).
- We built flow maps (Ha-Re-Gr) using DNS and construct critical Ha number using linear stability analysis to predict transitions and specify turbulence modes. **These results suggest that in DCLL blanket (DEMO, Gr~10^{12}) turbulence can appear due to buoyancy effects.**
- Linear stability analysis overpredicts stability limits compared to DNS studies. Need for energy stability analysis and experiments. Such experiments are being prepared at UCLA.

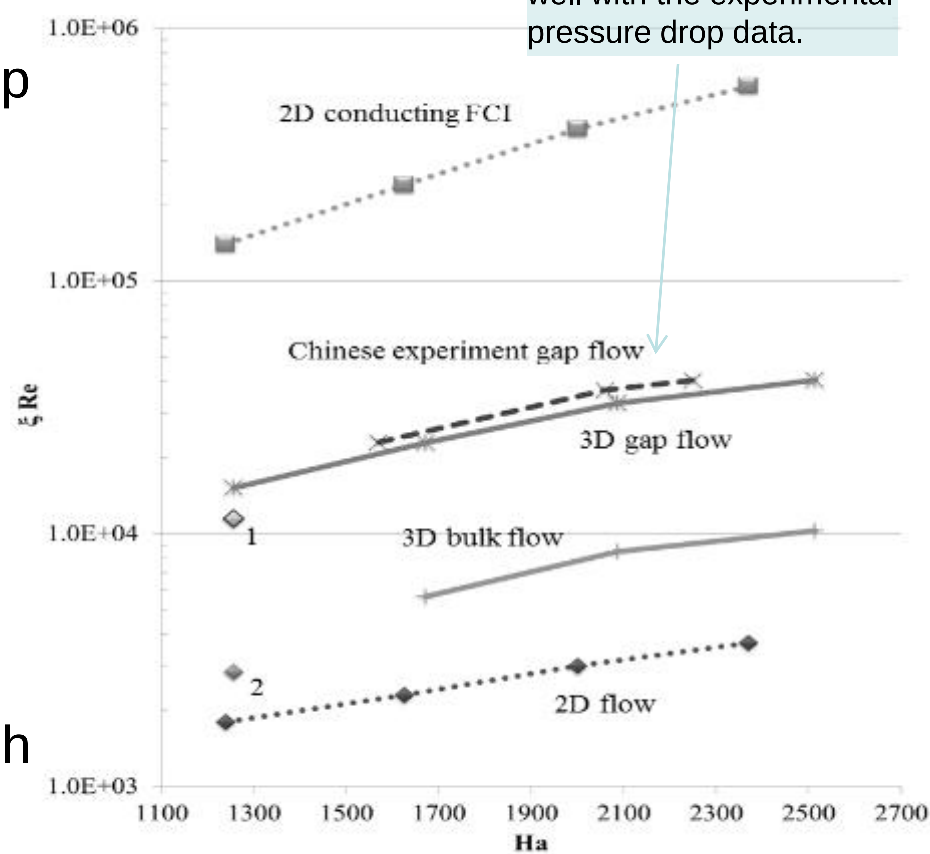
MHD pressure drop reduction using FCI, and validation of MHD simulations

- An In-Ga-Sn MHD experiment at Southwest Institute of Physics (SWIP) measured the pressure drop along a ideal epoxy flow channel insert (FCI) with a pressure equalization slot (PES)



- 3D simulations done at UCLA match well to experimental results
  - 3D is considerably better than 2D results (where pressure is uniform in the cross-section).

3D calculations match well with the experimental pressure drop data.



1: 3D gap flow without slot,
2: 3D bulk flow without slot.

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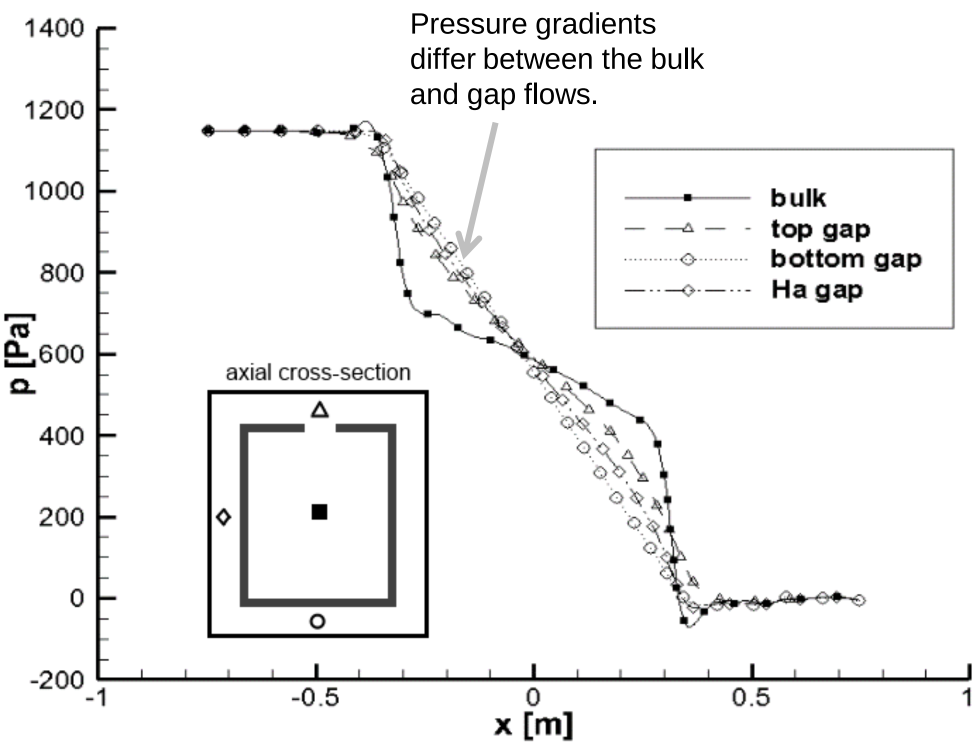
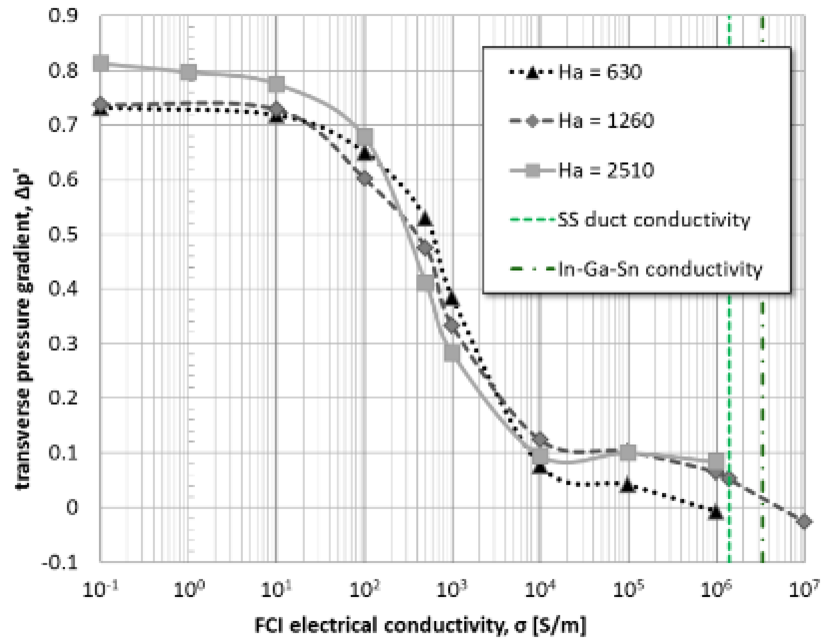
Pressure inside the FCI is quite different than in the gap regions between the FCI and the wall





D. Sutevski, S. Smolentsev, M. Abdou, 3D numerical study of pressure equalization in MHD flow in arectangular duct with insulating flow channel insert Fusion Engineering and Design 89 (2014) 1370–1374

Electromagnetic pressure equalization (current penetrating the FCI)

- In the range of FCI conductivity <10^2 S/m. There is very little EM pressure equalization taking place and impact of Ha is small
- At higher conductivity the pressure difference goes to zero

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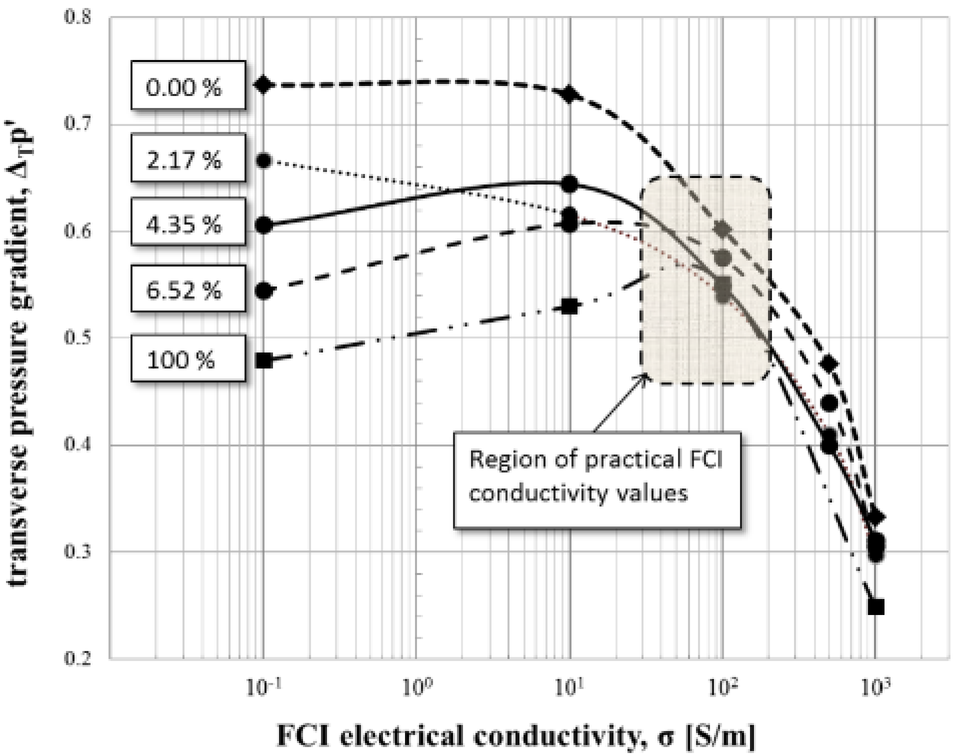
Pressure equalization slot is only weakly effective, especially as FCI conductivity increases

Hydrodynamic Equalization
(having a slot in the FCI to allow pressure to equalize):

- A slot in the FCI can serve as a pressure equalization mechanism, generally this slot is rather small to prevent heat leakage
- Although the pressure drop gradient differs for slot widths with a nearly ideally insulating FCI, as the conductivity approaches practical values, the four cases approach the same curve, that of the simulation with no slot.
- This is a weak control mechanism in achieving pressure equalization in the flow.



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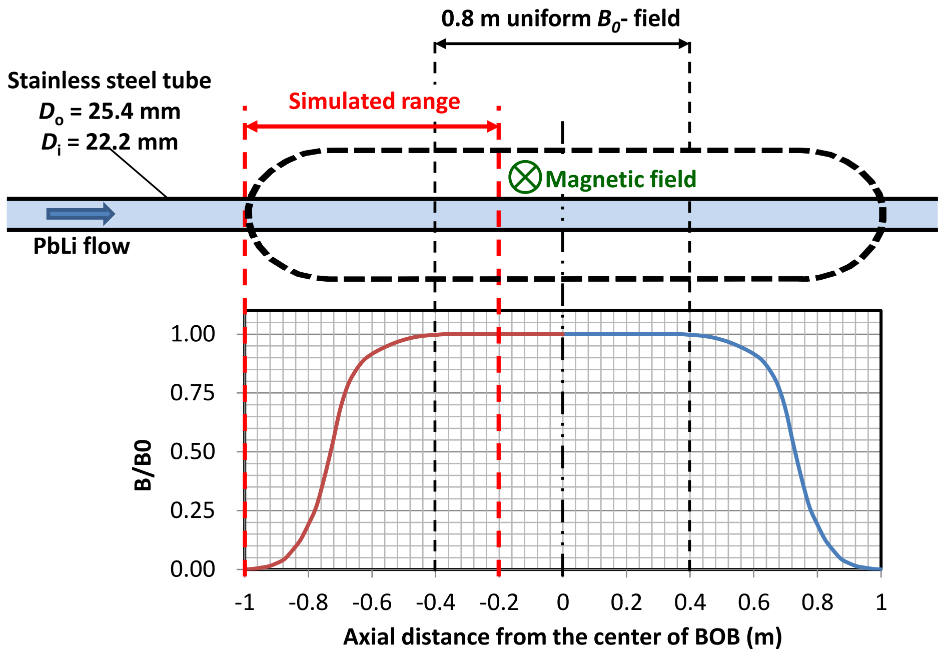
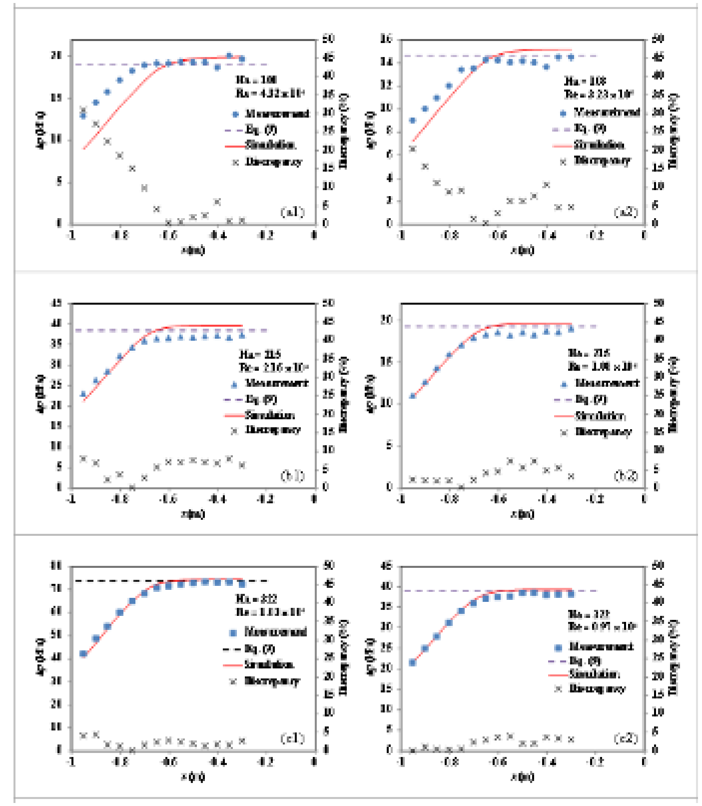
PbLi MHD flows test in a conducting pipe under fringing magnetic field are consistent with simulations



DP is taken from two 0.6 m separated pressure taps

Runs	*Ha* = 108		*Ha* = 215		*Ha* = 322	
	Re	*N*	*Re*	*N*	*Re*	*N*
1	5.40 × 10^4	0.22	3.23 × 10^4	1.43	1.83 × 10^4	5.66
2	4.32 × 10^4	0.27	2.70 × 10^4	1.71	1.40 × 10^4	7.41
3	3.23 × 10^4	0.36	2.16 × 10^4	2.14	0.97 × 10^4	10.69
4	2.16 × 10^4	0.54	1.62 × 10^4	2.85	0.64 × 10^4	16.20
5	1.08 × 10^4	1.08	1.08 × 10^4	4.28	0.26 × 10^4	39.87

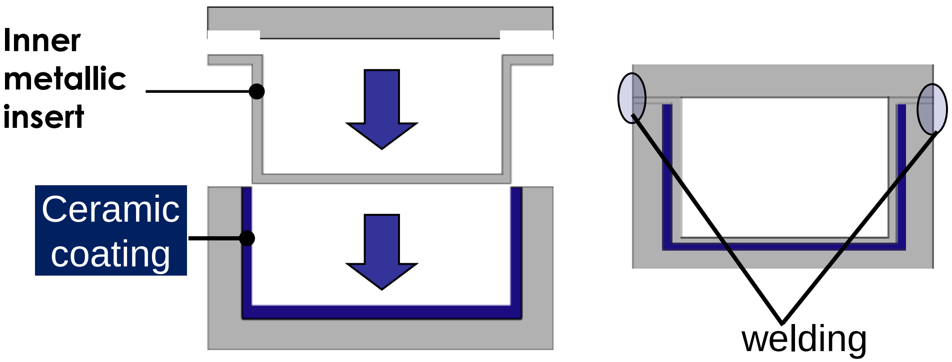
Comparison of measured DP with analytical predictions and 3D numerical simulations by HIMAG



- **Good match with 3D computations**
- **Validation of pressure diagnostics**
- **Similar to room-temperature LMs, PbLi can be used in bulk MHD experiments**

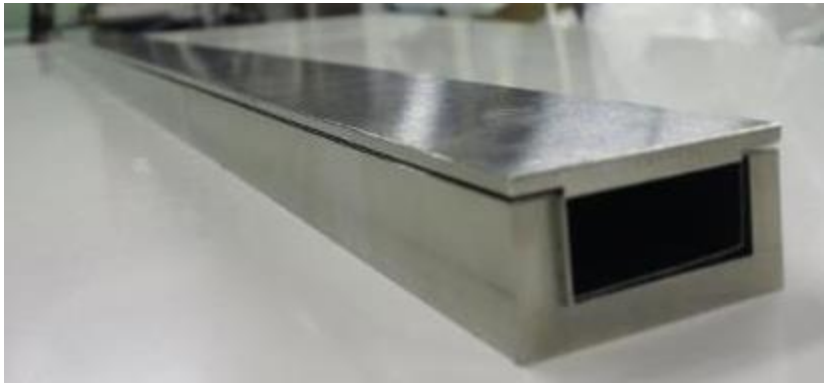
MHD pressure drop reduction in PbLi MHD flow in conducting rectangular duct with laminated walls

Idea of MHD pressure drop reduction (laminated walls BCSS, 1984; recently- Hashizume, JA)



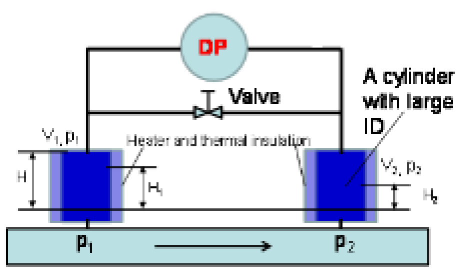
Fabrication process

Test-section fabricated at Tohoku Univ.,

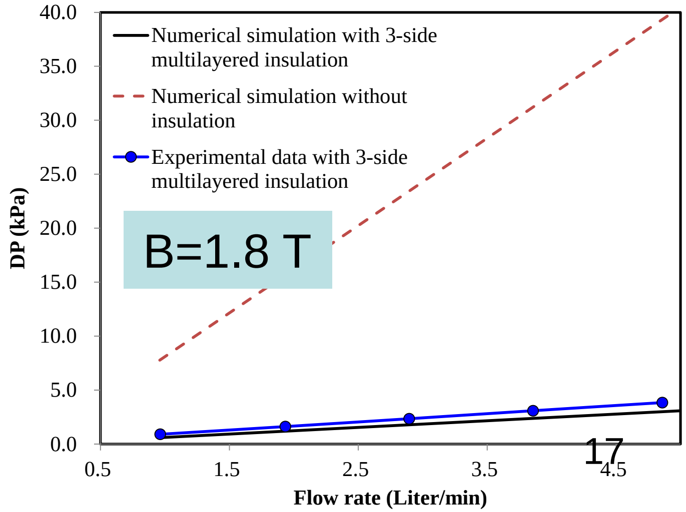


Tests performed at UCLA,

Experiments conducted with New pressure diagnostics developed at UCLA

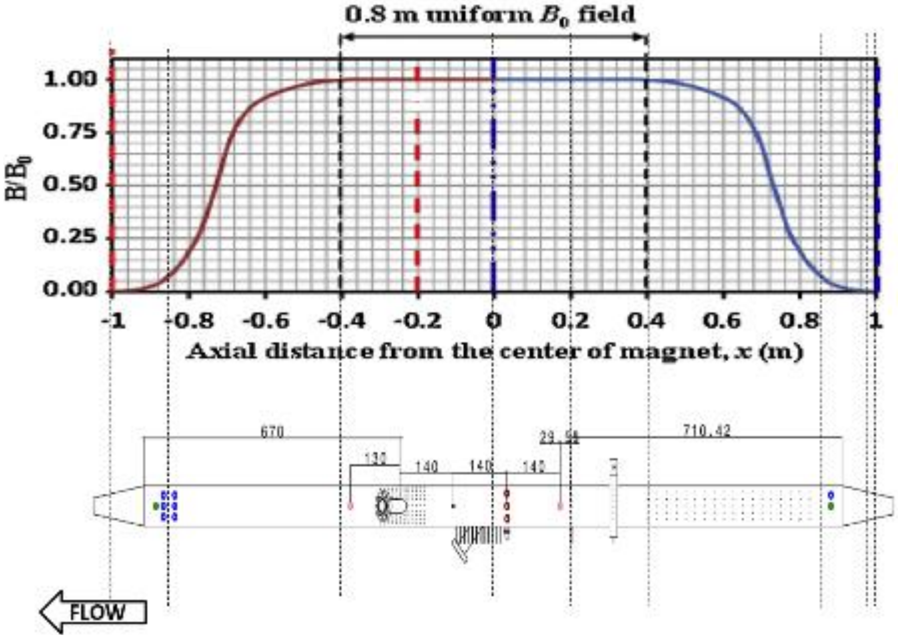


ΔP reduction by a factor of ~10 in agreement with computations



More work on flow diagnostics for PbLi is planned in 2015

- Even "standard" diagnostics may require significant modifications and extra testing for HT PbLi flows to take into account specific effects associated with the use of PbLi.
- **Electric potential**: SWP (surface welded pin) ~200, LTP (liquid touching pin) ~3, MPP (moving potential pin) ~10
- **Temperature**: Thermocouples of type E, K and N
- **Flow-rate**: Newly design Faraday flow-meter
- **Pressure**: HT absolute pressure transducers by Keller
- **Velocity field**: LEVI probes



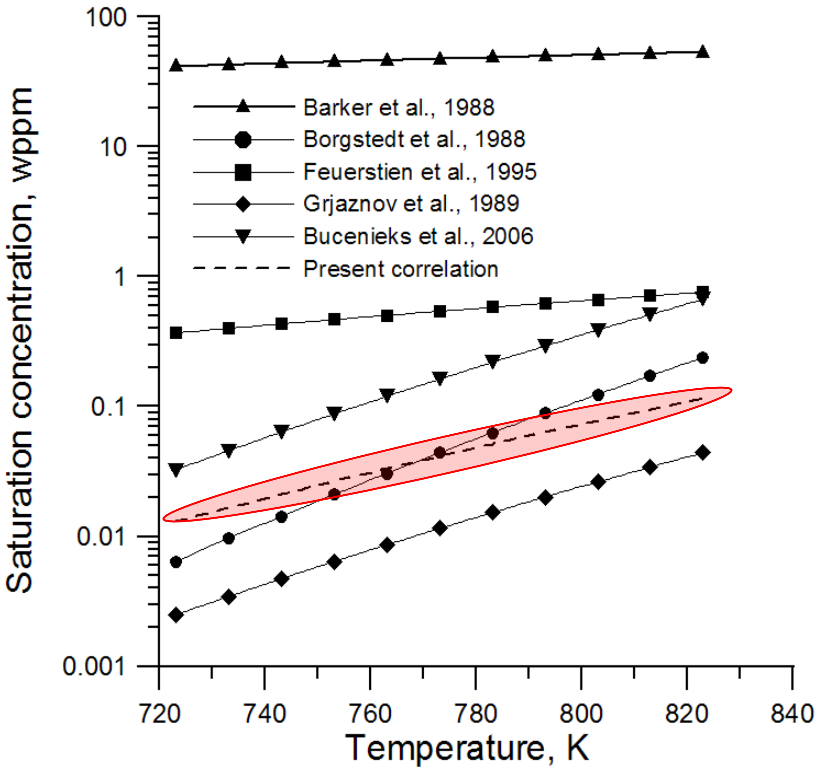
A sketch of the rectangular duct test section with installed flow diagnostics (electric potential pins, thermocouples, pressure sensors and LEVI probes) with respect to the applied magnetic field of the BOB magnet.

(2) MHD corrosion of RAFM steel and transport of corrosion products

UCLA MHD mass transfer code TRANSMAG addresses corrosion in PbLi-RAFM system

- To solve the mass transfer problem, equations for MHD flow are coupled with energy and mass transfer equations
- Assumed corrosion mechanism - *mass-transfer controlled dissolution of steel in flowing PbLi*
- Both laminar and turbulent (k-epsilon model) flows with and without a magnetic field are covered
- First ($C_{wall}=C_s$) or third type ($D*dC/dn=K*(C_s-C_{bulk})$) BC are used
- Code has been intensively tested against various experimental data on corrosion of RAFM in PbLi

S. Smolentsev, S. Saeidi, S. Malang, M. Abdou, ***Numerical Study of Corrosion of Ferritic/Martensitic Steels in the Flowing PbLi with and without a Magnetic Field***, J. Nuclear Materials, 432, 294-304 (2013).



Saturation concentration C_s of iron in PbLi is important parameter that enters BC. Available experimental data scatter by 4 orders of magnitude that makes computations meaningless. A new correlation has been reconstructed from the experimental data by solving an "inverse mass transfer problem".

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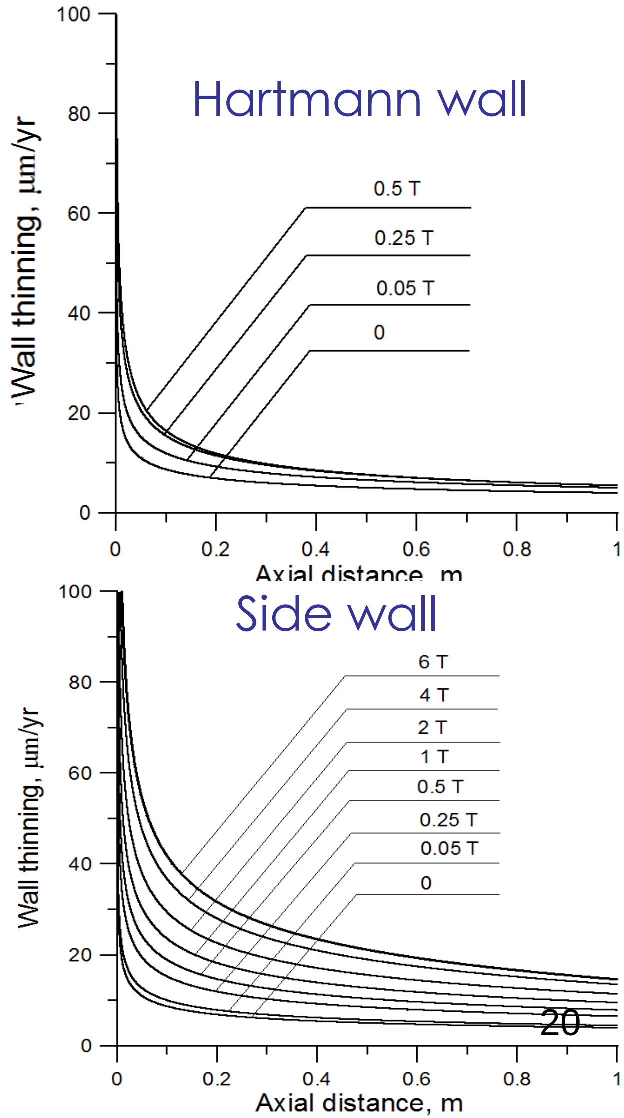
Computations of corrosion of RAFM in PbLi show strong enhancement in B field

- **<u>Riga experiment (2009):</u> *corrosion on Hartmann walls is doubled due to the B-field effect*. No experimental or modeling results for the side walls (parallel to B field).**
- **We analyze effects of B field on corrosion on both Hartmann and side walls using TRANSMAG code**
- **For the Hartmann walls are consistent with the Riga data.**
- **The side wall predictions show 2-3 times (!) higher corrosion rate compared to the Hartmann walls due to formation of velocity jets**



Magnetic field: 0-6 T (Ha=0-1325)
Flow velocity: 1, 2, 3 cm/s (max Re=5580)
Temperature: 400-550°C

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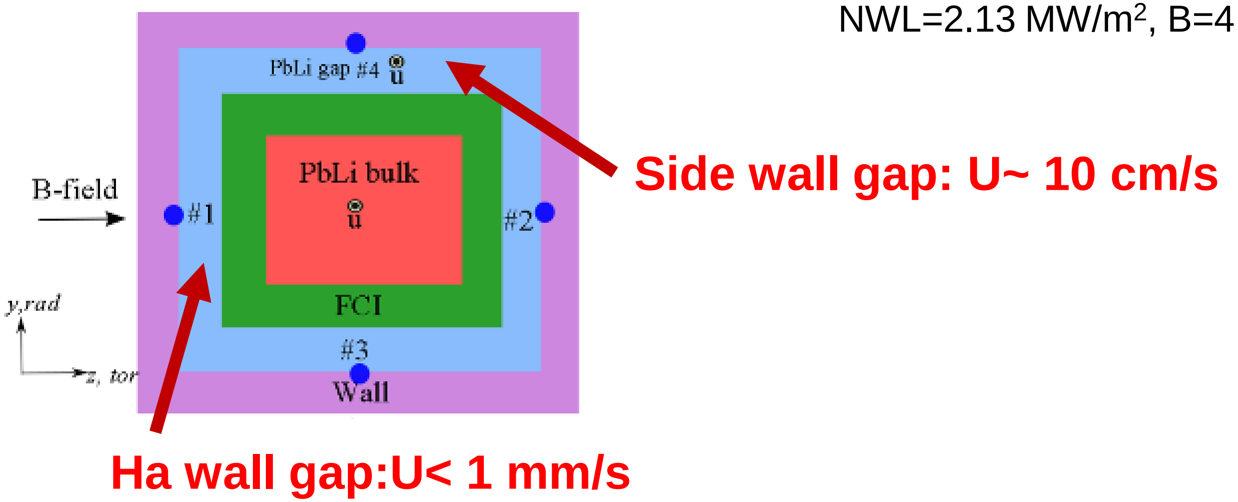
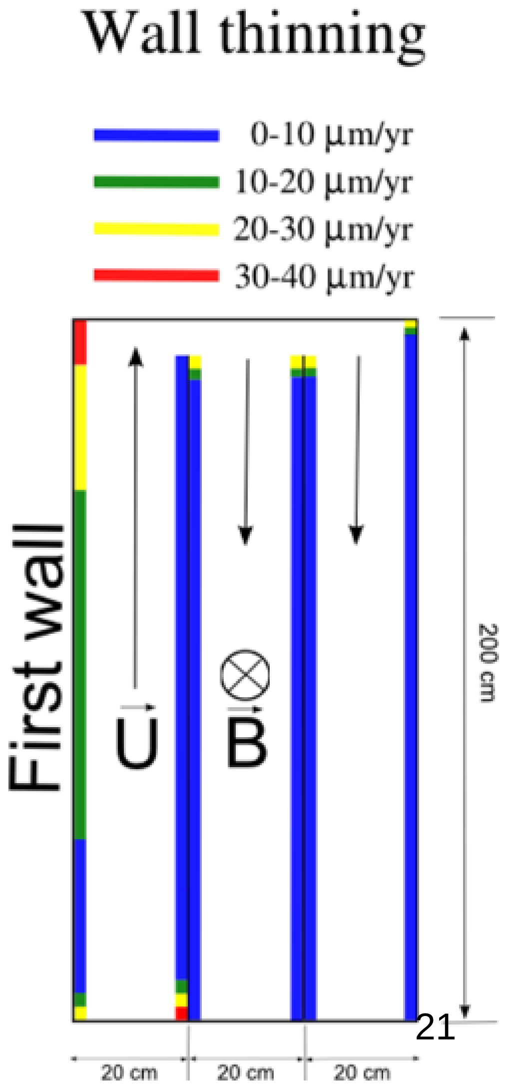
Computations of corrosion for DCLL with FCI

US DCLL (DEMO) OB blanket, 2006 : PbLi T_in/out=460/700°C,
He T_in/out=300/480°C,
NWL=2.13 MW/m², B=4 T



- Most of corrosion occurs in the side-wall section of the gap
- Average wall thinning < 20 μm/yr
- Maximum wall thinning ~ 35 μm/yr



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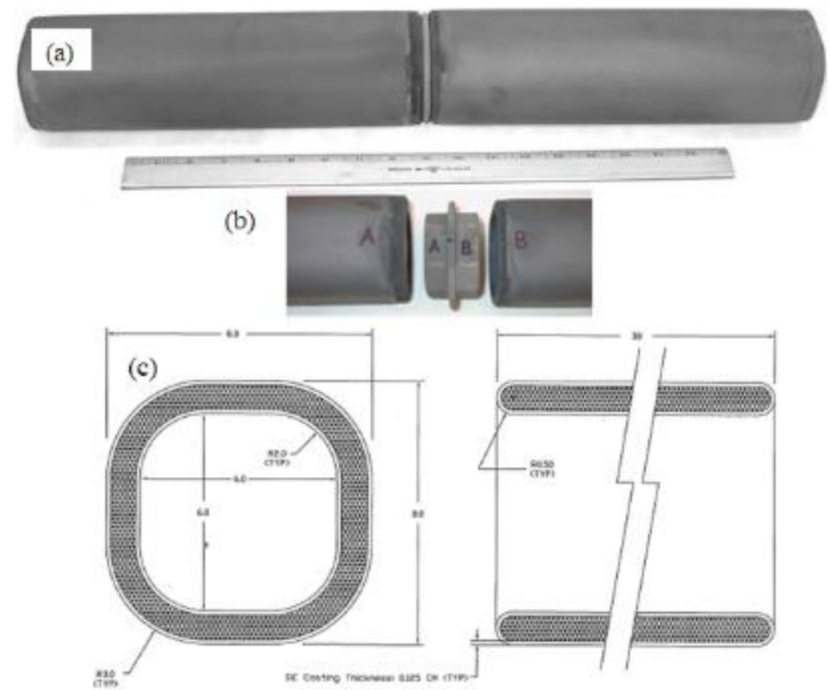
(3) SiC FCI performance in LM-MHD environment

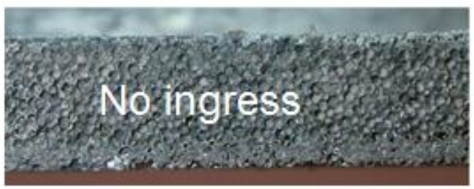
- The goal is low thermal (1-2 W/m-K) and electrical (~1 S/m) conductivity for IB blanket. Higher electrical conductivities of about 50 S/m are allowed for lower magnetic field OB blanket. The expected MHD pressure drop reduction in poloidal flows is 50-100 times compared to bare ducts.
- Two different approaches to development of SiC materials and fabrication of FCI parts are presently considered:
  - 2D fiber-reinforced SiC composite,
  - foam-based SiC.
- In the SBIR program, more focus is recently placed on the development and characterization of foam-based SiC FCI.



Foam-based SiC FCI by ULTRAMET:
(a) Two segments connected together
(b) Connecting FCIs with a T-bracket
(c) FCI cross-section

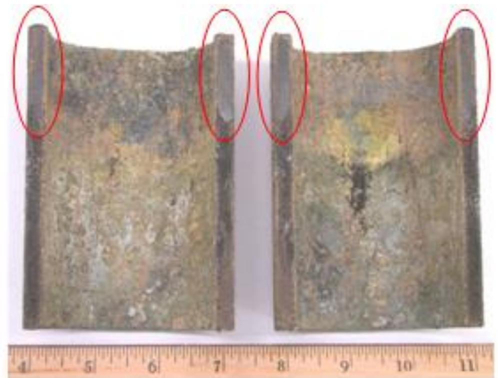
First results of static testing of foam-based SiC FCI samples (ULTRAMET) in PbLi look promising

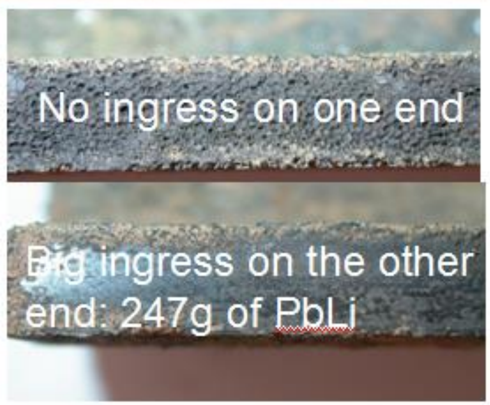
15 vol% dense, 85% porosity filled with aerogel



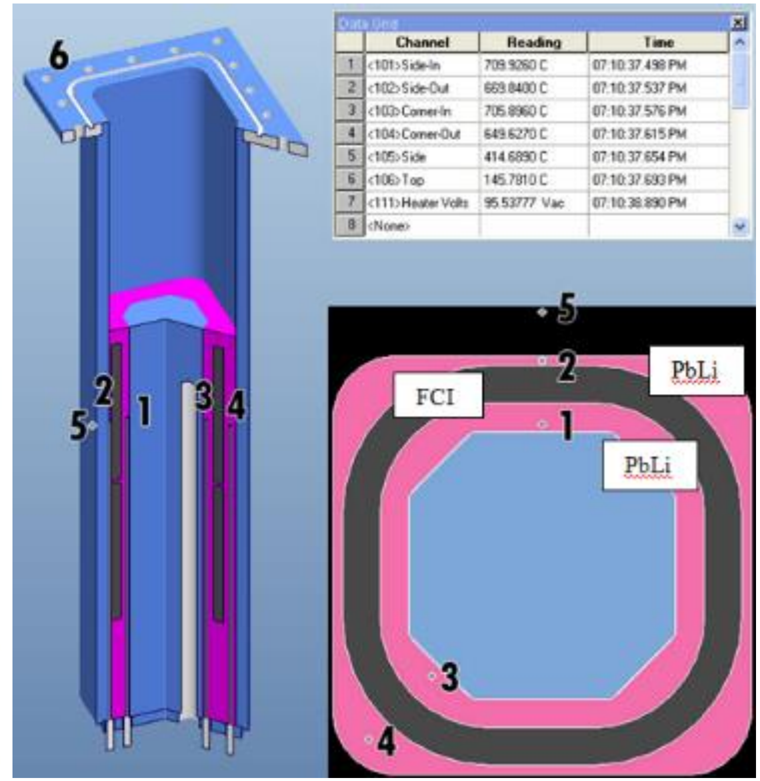
P/N 28A (4.5" long SiC foam infiltrated with carbon aerogel) after 700˚C PbLi exposure for 100 hours at 0.1 MPa

Similar results observed at 0.5 MPa





P/N 49A (4.5" long SiC foam infiltrated with silica aerogel) after 700˚C PbLi exposure for 100 hours at 0.1 MPa



Static test device at UCLA

- Annular cavity PbLi bath
- Heated from inside FCI
- Cooled from outside FCI
- Gas over pressure

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Tests of foam-based SiC FCI samples by in flowing PbLi conditions

- FCI samples filled with Silica or Carbon aerogel: 8 cm x 8 cm, L=12, 30 cm, tw=1 cm. Some samples are CVD coated.
- Dynamic testing in MaPLE: 300°C, Pmax=0.1 Mpa, Umax~10 cm/s, ~ 10 months.
- PbLi ingress was observed in dynamic testing and pressure drop was not reduced
- Brian Williams (Ultramet):
  "My conclusion was that if the aerogel is dense enough, it can prevent metal ingress but more optimization of the aerogel density is needed."

A SiC sample before and after testing

(4) Tritium Transport, Permeation, and Recovery

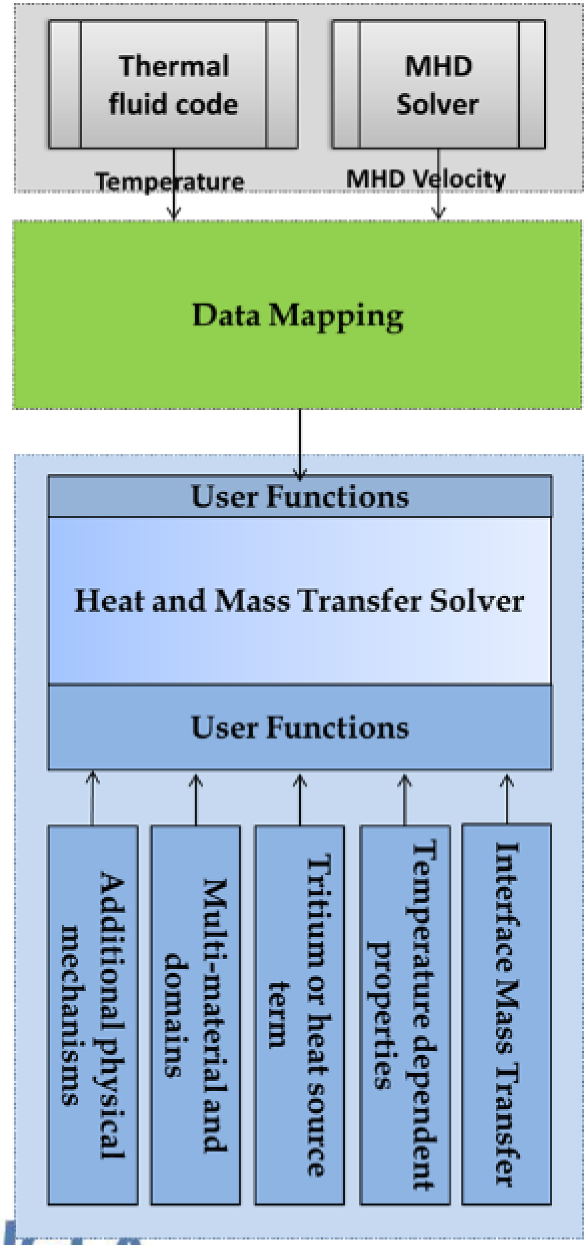
Current Objective: Develop tritium transport modeling code using state-of-the-art CAD based, multi-physics software to investigate geometric and flow complexity on tritium permeation

- Implemented numerical schemes in a commercial thermo-fluid, mass transfer code for calculating mass transfer across material interfaces
  - Ensured flux continuity obeying Sieviet law at the PbLi-Solid/Solid-Solid interfaces
  - Recombination boundary condition at the Solid-He interface
  - Adopted equilibrium reaction rate for chemical reaction and addressed isotope swamping effect
- Established code integration frame work and data mapping
- Performed first-order validations
- Quantified effects of the MHD velocity characteristics as seen in the PbLi based blankets

Hongjie Zhang, Tritium Transport in Multi-Region Lead-Lithium Liquid Metal Blankets, Doctoral Thesis, 2014

Numerical Methodology

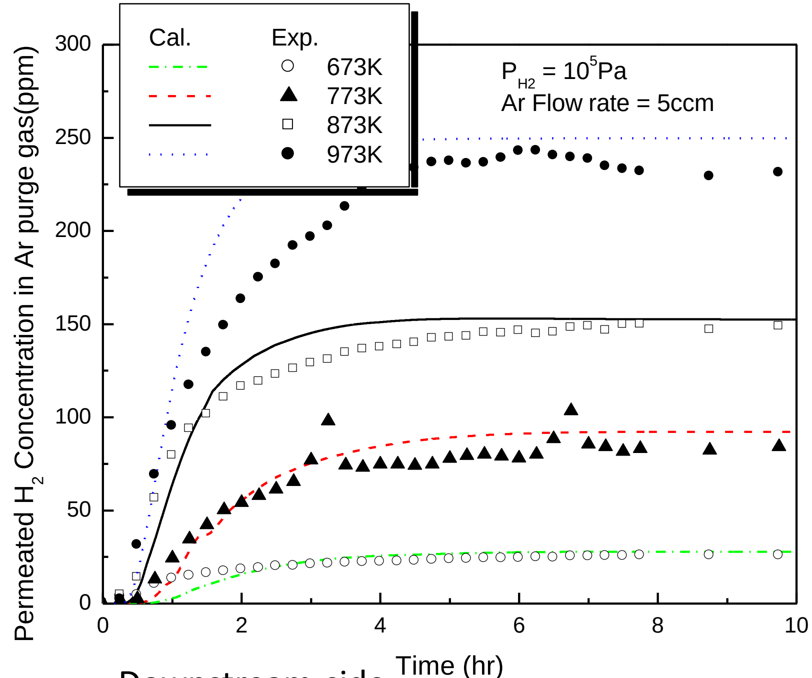
Integrate different solvers for different phenomena, with a utility developed for passing data between solvers

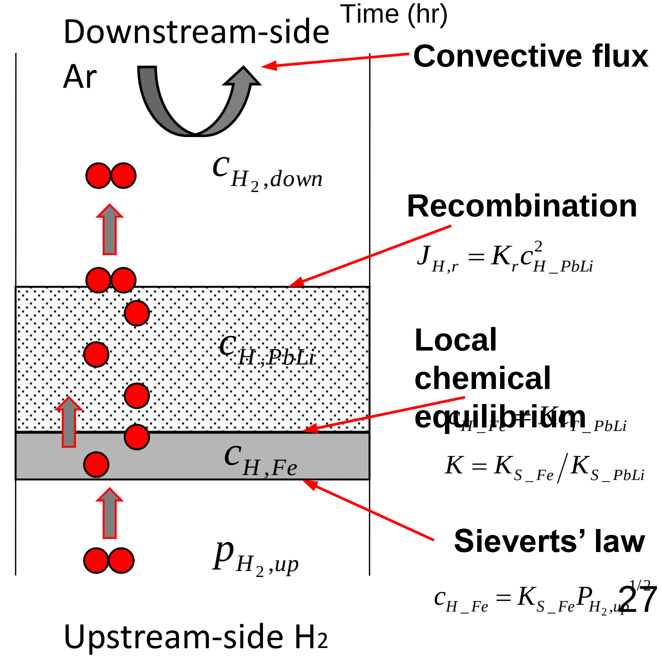


- **MHD solver**
  - HiMAG – 3D Finite volume method, Structured grids, UCLA
  - Stream -- Finite volume method, Structured grids, Cradle Japan (can also solve temperature in the case of mixed convection)
- **Primary Mass transfer solver**, Sc/Tetra -- Finite volume method, Unstructured grids, Cradle Japan
  - Build and solve the proper tritium transport equations in Sc/Tetra
  - Solve the temperature profiles.
  - Handle the blankets geometry complexity.
  - Write and build our own **user functions (in c++)** into the mass transfer solver considering the factors: (1) multiple domains, (2) coupling through the material interfaces, (3) temperature-dependent transport properties, and (4) space-dependent tritium source terms.
- **Data Mapping**
  - Mapping the MHD data into the Sc/Tetra solver using the user-defined function.

Code validations cases

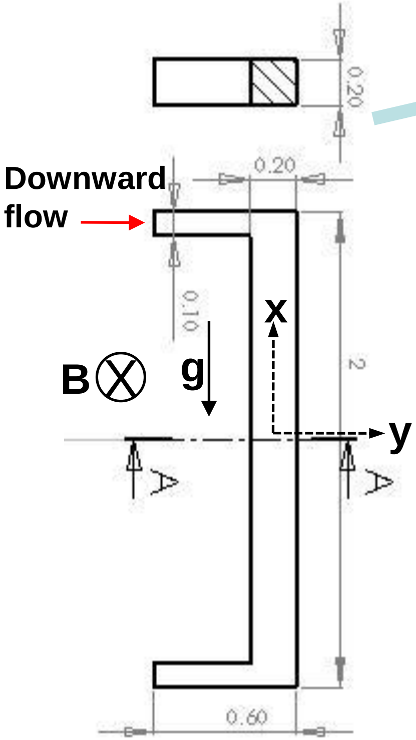
- Validated with co-permeation of Deuterium and Hydrogen through Pd from experiments by K. Kizu, A. Pisarev, T. Tanabe, J. of Nuclear Materials, 289 (2001) 291-302
- Validated with US-JA TITAN experiment of **tritium/hydrogen permeation through α-Fe/PbLi sample**, collaboration between INL and the University of Tokyo.
- Validated with in-reactor tritium release experiment from lithium-lead with tritium generation source term, conducted in the fast neutron reactor “YAYOI” of the University of Tokyo
- Validated with analytical solution of mass transfer in a absorption-convection-permeation problem



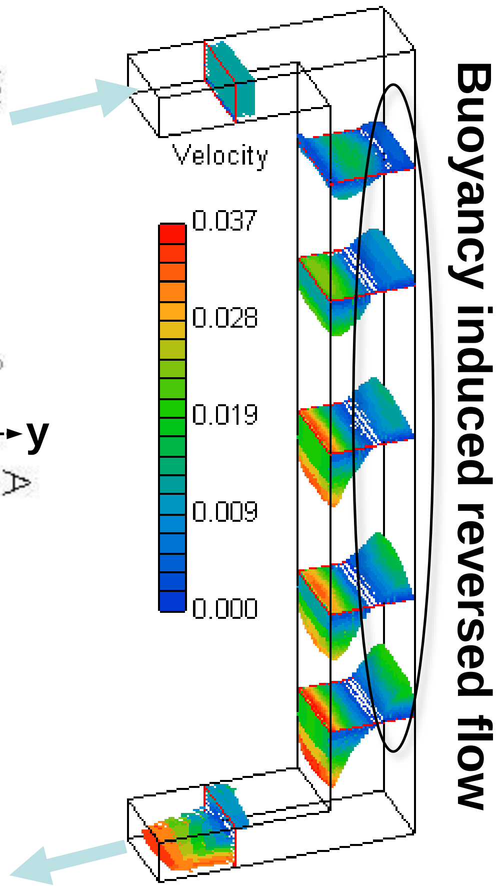


UCLA

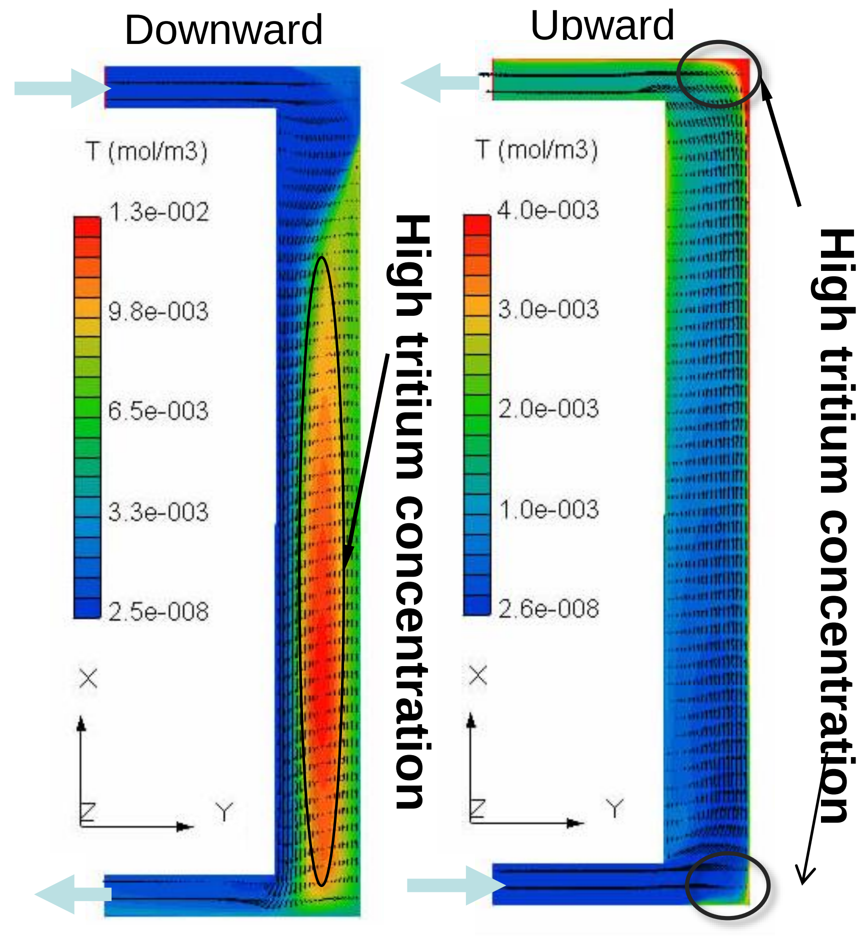
Tritium Transport in Buoyancy Affected PbLi MHD flows



Re=1E4
Gr=1E8
Ha=400



Velocity Profile (m/s)



Tritium concentration (mol/m^3)

Using analyzed parameters	Tritium generation rate (mol/s)	Permeation rate (mol/s)	Permeation Percentage (%)	Inventory (mol)
Downward Flow	3.778e-7	1.885e-8	5.0	4.71e-4
Upward Flow	3.778e-7	1.552e-8	4.1	9.53e-5

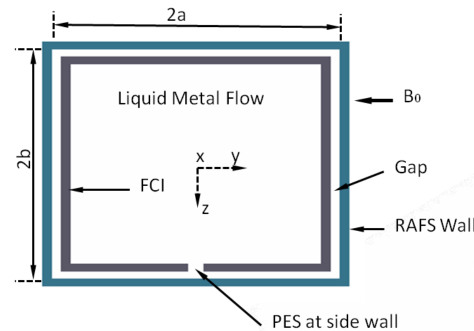
UCLA

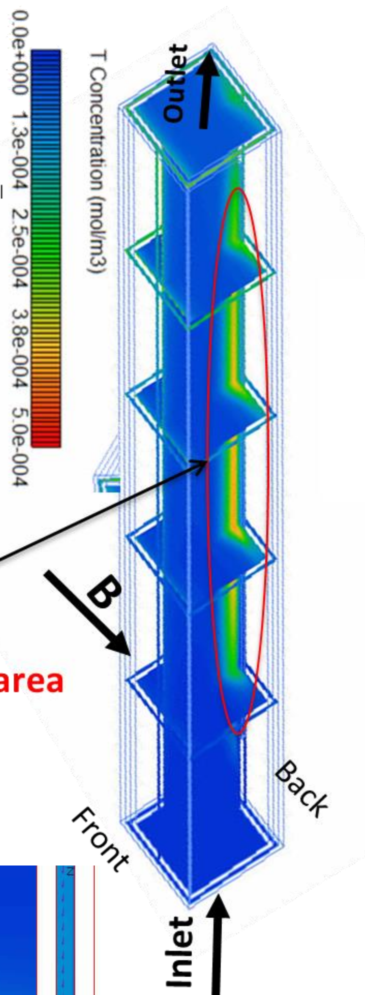
Tritium transport in a DCLL-type poloidal duct with FCI and pressure equalization slot

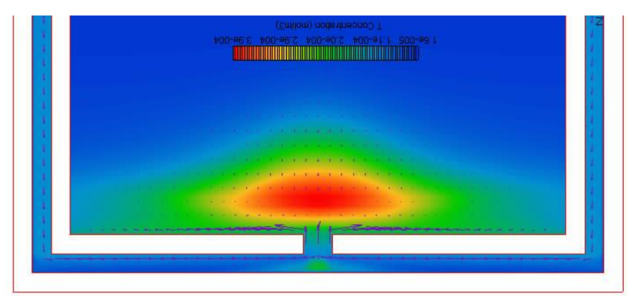
Tritium Losses for Three PES Configurations

	No PES	PES in the wall // B	PES in the wall ⊥ B
generation (mol/s)	1.406e-8	1.410e-8	1.412e-8
permeation (mol/s)	1.76e-10	1.99e-10	1.87e-10
Losses	1.25%	1.42%	1.32%

- If a PES is on the wall parallel to the magnetic field, tritium loss rate increases by 15% because the velocity is reduced near the front wall.
- Tritium loss rate drops slightly 10% with increasing Ha number over the range 500-1500
- Over the range of reference electric conductivity of the FCI from 5 to 500 $\Omega^{-1}m^{-1}$, tritium permeation rate decreased by about 46%.

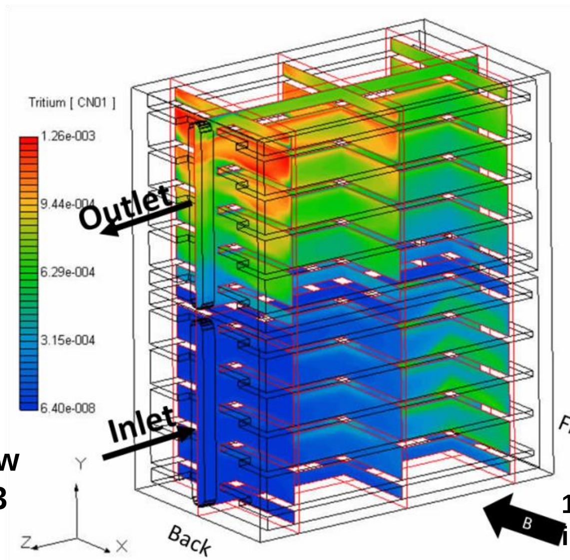






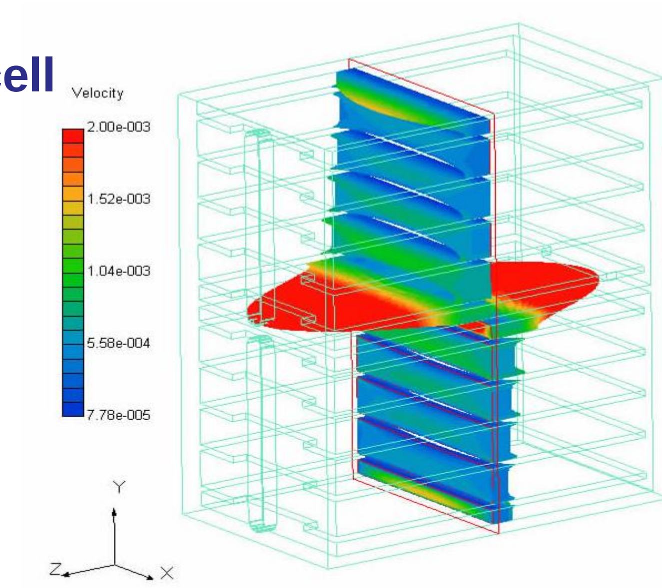
Higher PbLi flowrate in DCLL for heat removal results in a lower tritium permeation compared with HCLL

Mass flow rate: 0.33 kg/s



1.8 T used in the analysis

HCLL unit cell geometry



Case	Average PbLi velocity in channel	Total tritium generation in domain	Tritium exit from outlet	Integrated permeation to coolant	% loss due to permeation
DCLL duct	7 cm/s	1.409e-8 mol/s	1.387e-8 mol/s	2e-10 mol/s	1.8
HCLL BU (2)	0.8 mm/s	2.494e-8 mol/s	2.063e-8 mol/s	4.308e-9 mol/s	17

Right now we are increasing our basic understanding, but cannot predict how the blanket/FW will work in the fusion nuclear environment of FNSF/DEMO

- These R&D results shown above are all at limited parameters in idealized geometry and conditions
  - the fusion nuclear environment has many fields with steep gradients (magnetic, neutrons, nuclear heating, …)
  - the blanket has many functions, conditions, materials, and interfaces
- There are many yet undiscovered phenomena caused by multiple effects/multiple interactions and synergetic effects in the blanket/FW
- MTBF for Blanket/FW in any FNSF is estimated to be very short while MTTR is predicted to be months – leading to low availability of only a few percent
- Therefore, predicting prompt response and behavior of systems in the fusion nuclear environment in the very early life must be the highest priority
  - We need to go to higher parameters (Ha, Re, Gr, …) by overcoming computational challenges and increasing multiphysics integrations
  - We need to perform multiple effect experiments including high magnetic field and simulated bulk and surface heating with gradients with prototypic materials and configurations

We envision a series of **three progressively more integrated thermofluid MHD facilities** prior to FNSF, each with a specific mission and design

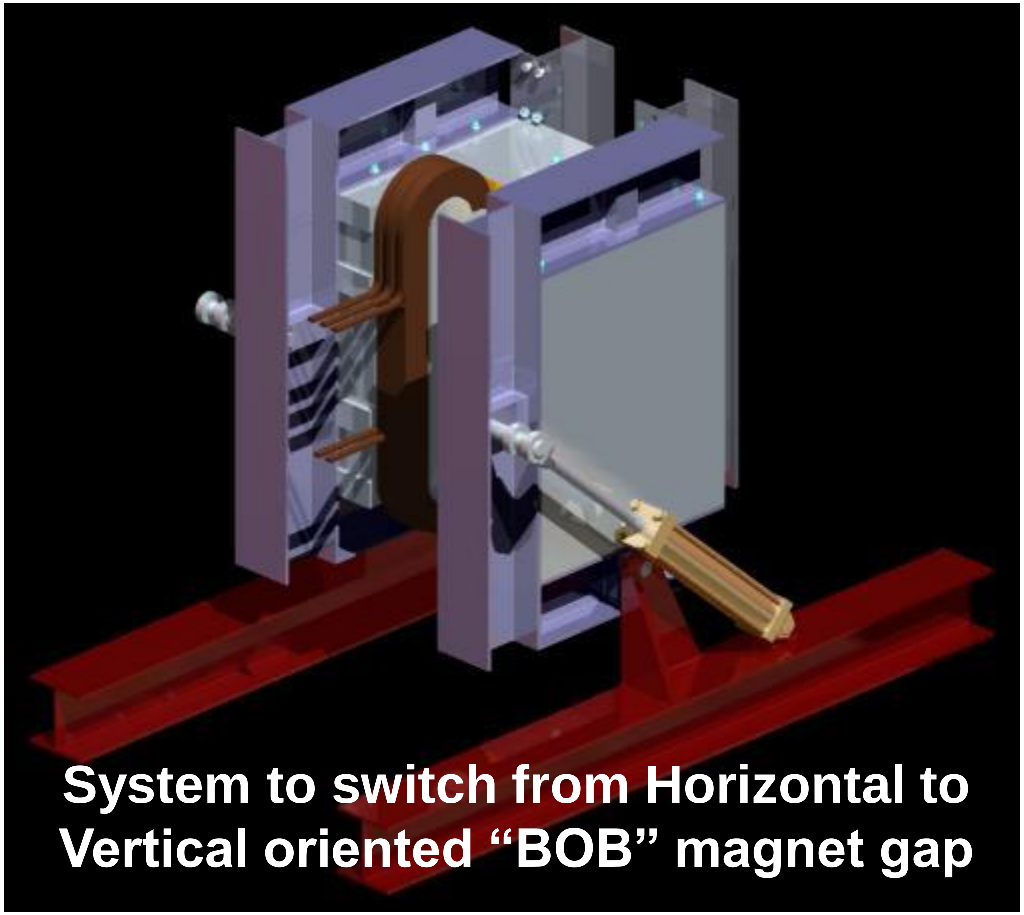
1. **UCLA Scientific Exploration Research Facility.** A expansion of capabilites in the existing MTOR and MaPLE facilities, including: increased operation temperature of the PbLi system to 550C, introduce flexibility of magnet gap orientation to gravity, and adding heating and instrumentation to test sections

2. **Multiple Effect/Multiple Interactions Blanket Facility.** This intermediate facility will explore more reactor relevant critical parameters such as stronger magnetic field beyond 2T, larger volume and prototypical field gradient and simulated surface and volumetric heating and gradients in nearer to full sized blanket channels/submodules.

3. **Partially Integrated Blanket Facility.** Bring together all simulated conditions affecting thermofluid/thermomechanical blanket/FW performance to the maximal practical degree prior to FNSF. For example, a full toroidal and poloidal magnetic field simulation that can accommodate near full size test articles in multiple poloidal orientations with respect to gravity operated for long periods of time (~years)

Upgrades for MaPLE loop and BOB magnet

- Higher flowrate and temperature PbLi
- Strong test section heating
- Flexible B gap orientation for proto-typic buoyancy
- Better Purification and Instrumentation

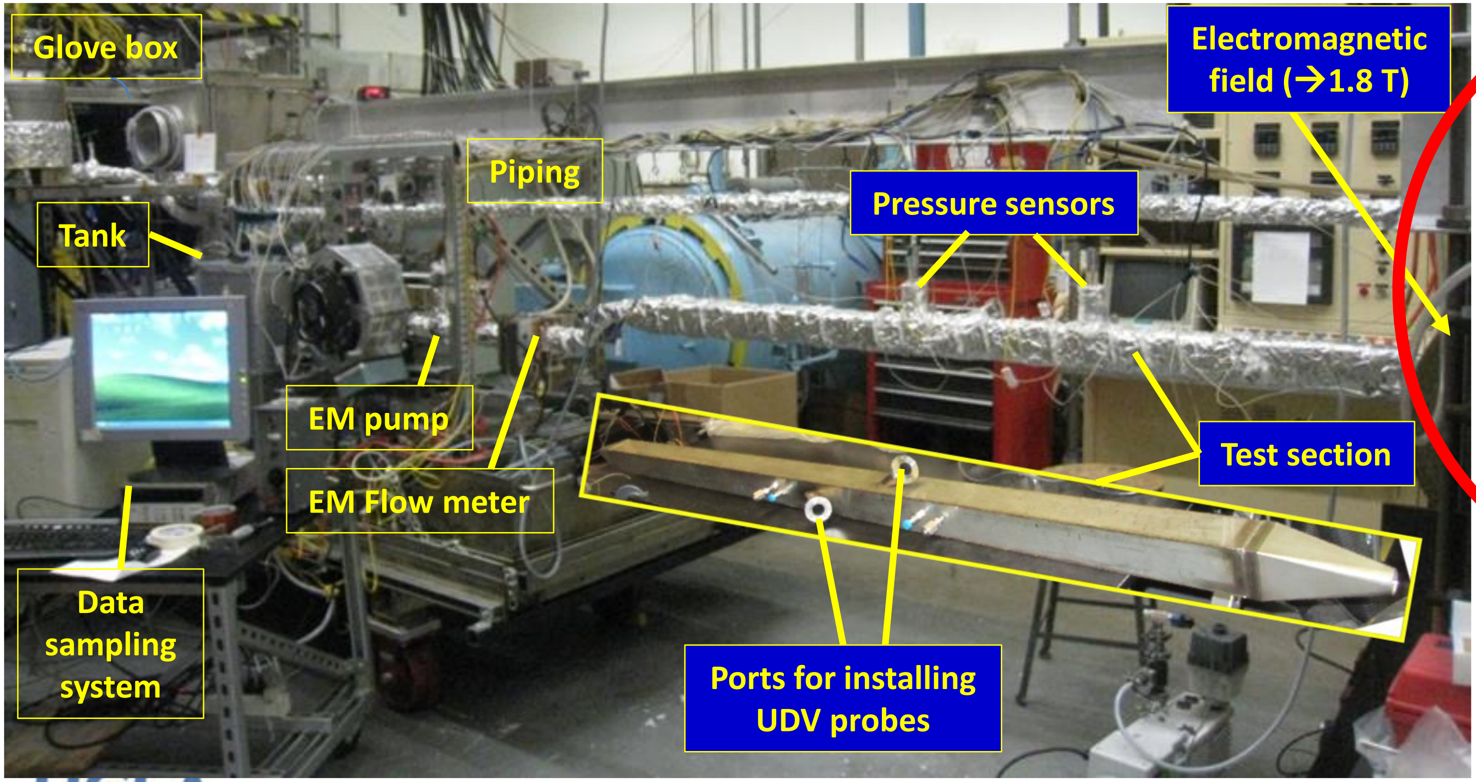


System to switch from Horizontal to Vertical oriented “BOB” magnet gap

And we use a PbLi MHD loop and simulant LM loops at UCLA for the experiments to study DCLL

MaPLE – MAgnetohydrodynamic PbLi Experiment in the MTOR lab

- First run in July 2011
- The only facility of this class in the US, one of a few in the World
- To address MHD PbLi flows and flow-material (PbLi-RAFM/SiC) interactions
- To develop and test new flow instrumentation



- Q=50 l/min
- M=100 kg PbLi
- B=1.8 T
- V=15x15x80 cm^3
- DP=0.15 MPA
- T=400°C