Highlights of
1st IAEA DEMO Programme Workshop
UCLA, Los Angeles, U.S.A.
15-18 October 2012

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VLT Conference Call

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Background

- IAEA established a series of annual DEMO Programme Workshops to facilitate international collaboration on defining and coordinating DEMO programme activities.
- The first IAEA workshop was held at UCLA - October 15-18, 2012
- The objective of this first workshop in the IAEA series, was to discuss a subset of key DEMO scientific and technical issues with the aim of defining the facilities and program activities that can lead to their resolution
- Workshop output, information that could be used by any party as input to the planning of possible roadmaps to DEMO, is documented in summary presentations and (tentatively) a journal publication.
- Workshop information/Presentations/Summary: See web site:

http://advprojects.pppl.gov/ROADMAPPING/IAEADEMO/

Attendees and Organization

- The Workshop was attended by 70 participants from 16 countries or international organizations (e.g., IAEA, EFDA)
- Richard Kamendje was the IAEA person-in-charge
- Hutch Neilson served as the Technical Program Chair.

The Workshop was organized around 3 Topics:

1. Fusion Power Extraction and Tritium Fuel Cycle

   Topic chair: Mohamed Abdou

2. Plasma Power Exhaust and Impurity Control.

   Topic chair: Marco Wischmeier

3. Magnetic Configuration and Operating Scenario for a Next-step Fusion Nuclear Facility.

   Topic chair: Tom Todd

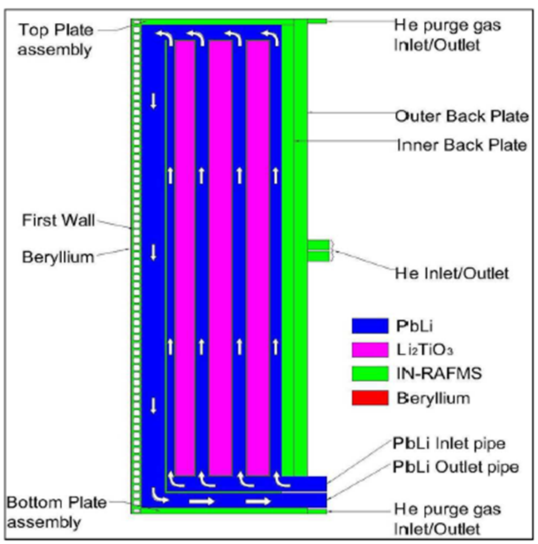
Topic 1: Fusion Power Extraction and Tritium Fuel Cycle

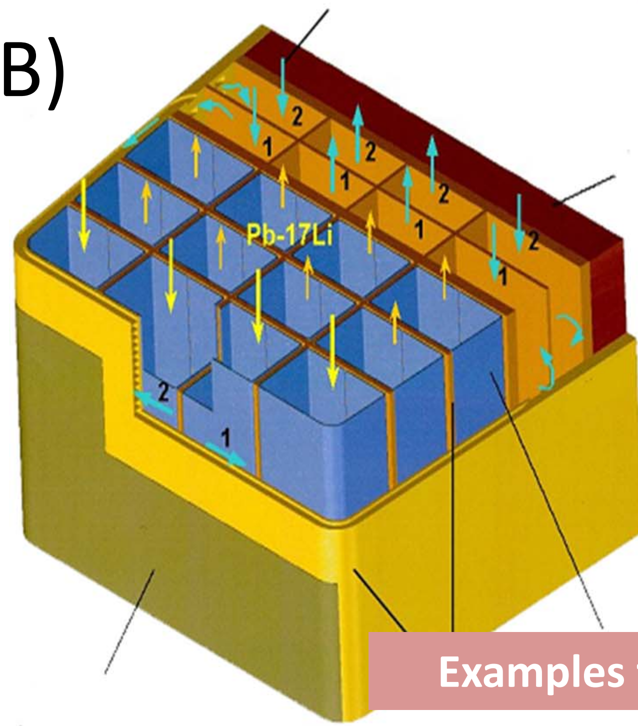
- What choices are available for material, coolant, breeder, configuration and design concepts for fusion nuclear components worldwide (focus on power extraction and tritium fuel cycle)?
- What are the key fusion nuclear science and technology (FNST) issues and challenges?
- What issues can be resolved in non-fusion facilities?
- What issues require experiments in integrated fusion nuclear environment?
- What laboratory facilities need to be upgraded or constructed in the next 10 years?
- What are the major parameters and features required in a next step fusion nuclear facility to resolve the FNST issues and develop fusion nuclear components?
- What is the role of ITER-TBM?
- What are the stages of experiments and development of FNST in a fusion nuclear facility?
- What strategies can be adopted for design, construction and operation of next step fusion nuclear facility(ies) to address the challenges of RAMI and limited availability of external tritium supply?

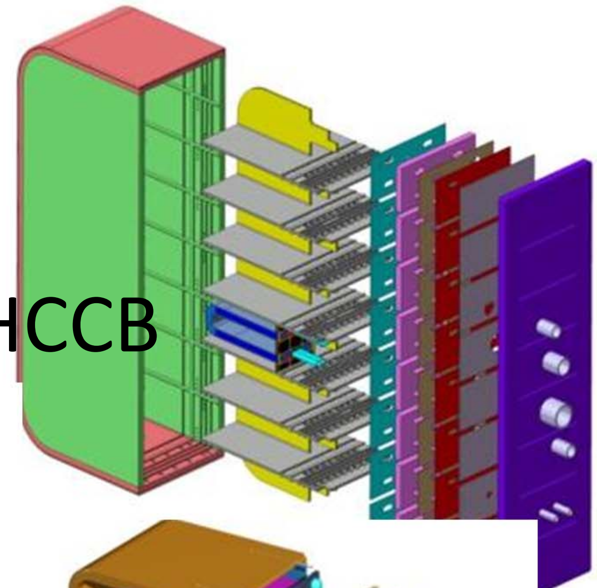
FW/Blanket concepts for fusion power extraction and tritium production

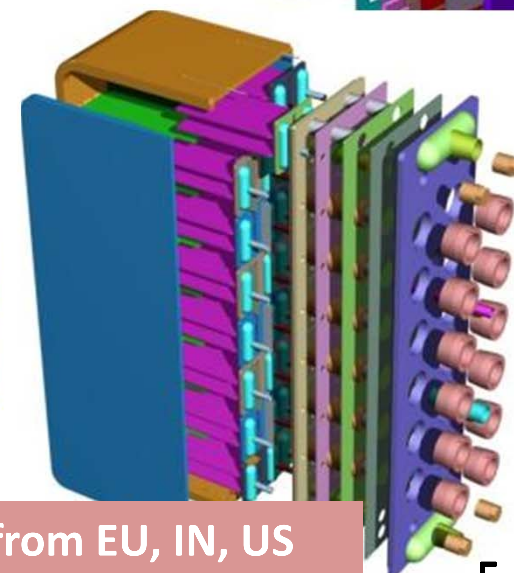
- EU: HCLL, HCPB, WCLL, DCLL
- US: DCLL (HCCB)
- KO: HCCB (LL) CH: HCLL, DCLL, HCCB
- IN: LCCB (HCCB)

LLCB: Lead-Lithium Ceramic Breeder









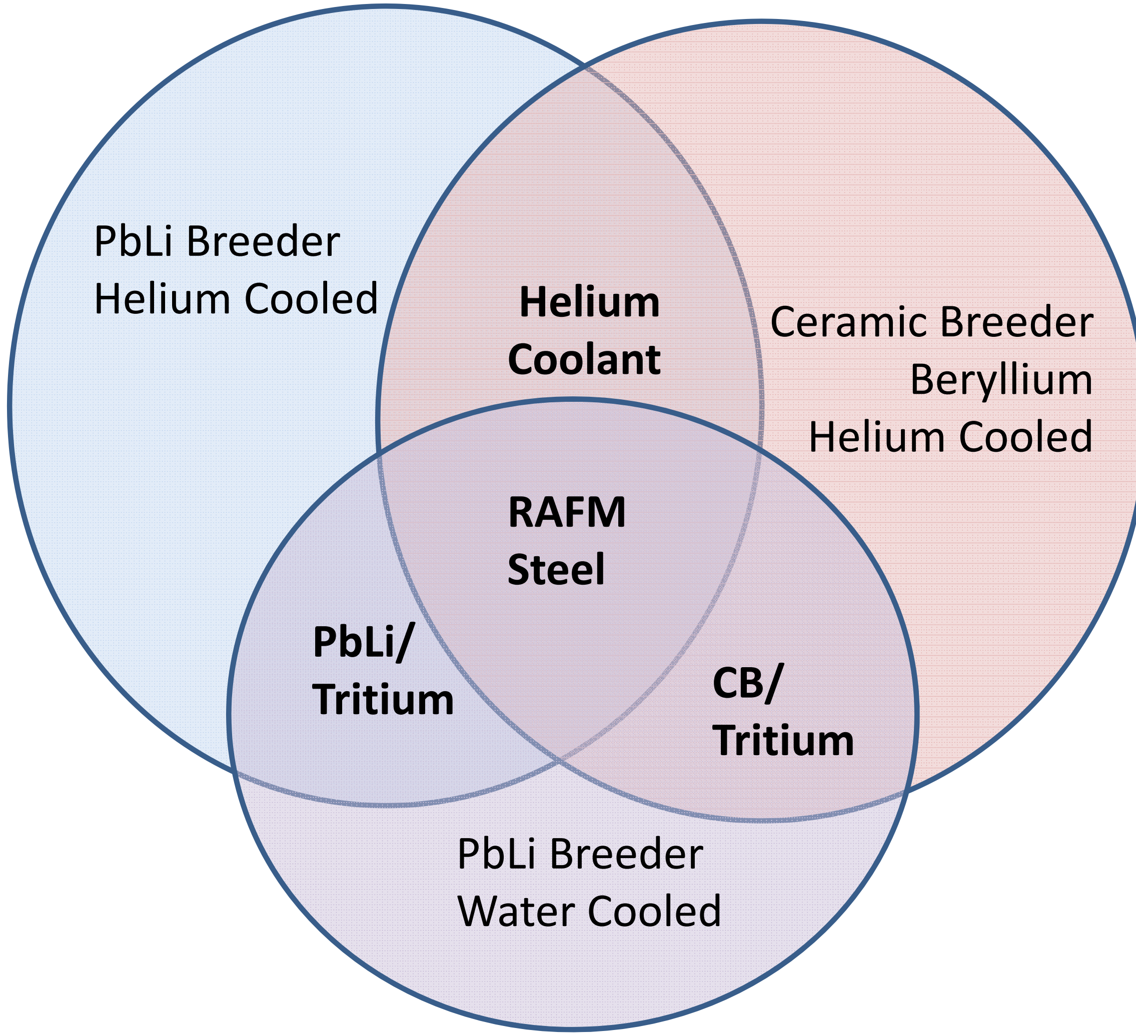
Examples from EU, IN, US

Many "Concepts" discussed — but technologies, issues and therefore R&D and facilities strongly overlap

Two classes of concepts: Liquid Breeder and Ceramic Breeder (using RAFS in common)

Both classes have feasibility issues and selection cannot be made prior to testing in the fusion environment

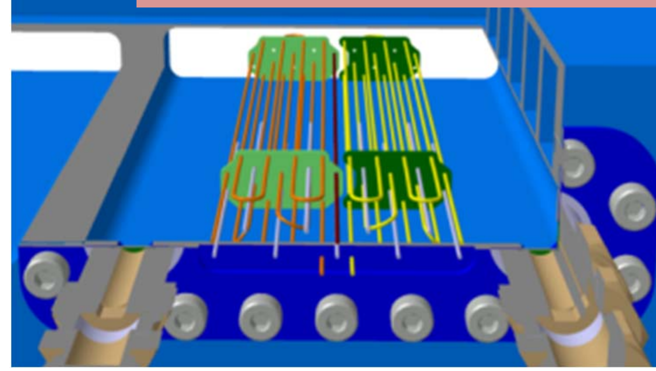
Variations within class have much less impact on the necessary R&D



R&D on Blanket/FW and Tritium for DEMO

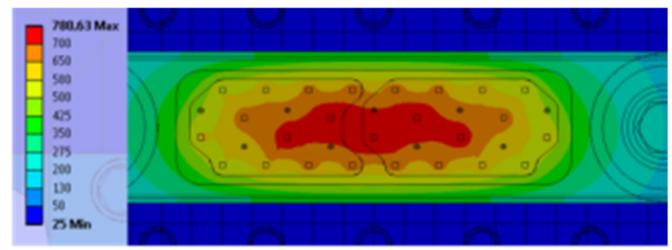
- Extensive programs for the design, analysis, and qualification of the components are needed which requires a number of testing facilities.
- EU described a significant R&D program
  - Spanning all concepts and coolant types including extensive RAFM, instrumentation, modeling
  - Driven by T self sufficiency requirements , risk and mitigation analysis, Eurofer code qualification, ITER and DEMO safety
- IN as well described activities including RAFM/ODS, Pb-Li/LiTiO3, coating, In-RAFM : optimization of W and Ta level
- CN described an ambitious program plan including facilities and integrated modeling
- Other parties R&D was not described in detail in presentations in this workshop

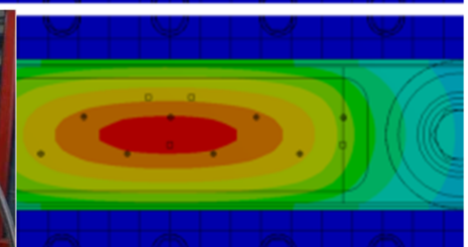
Examples from EU, IN



PREMUX test section 3D cut.

PbLi corrosion at IPR, IN





EU - temperature profile at the measurement section: heater wires (top) and reference neutronic heating (bottom).

Fusion development strategies / DEMO

- **EU, KO** propose DEMO construction in 2030s
  - Operation in not too far future in order to keep relevancy in domestic energy programs (programmatic/political motivation)
  - Initial phase of DEMO used for testing materials and blanket components
- **US, IN, CH, RF** propose a strategy with **Fusion Nuclear Facility (FNSF)** for testing in-vessel components (Blanket/FW/PFC/Tritium/Materials) prior to DEMO
  - Recognition that **experiments in the fusion environment are needed** to show **scientific and engineering feasibility** and perform long **engineering development/reliability growth** phase **prior to DEMO**
  - US has no official schedule for FNSF or DEMO
  - India has SST-2 (FNSF role) project start in 2027 and DEMO project start in 2037
  - China has CFETR in mid 2020's (FNSF role)
  - **All options recognize importance of using small power devices to deal with issue of limited external tritium availability**

* EU and JAPAN do not have Fusion Nuclear Facility for component tests in their roadmap, "scaled-down IFMIF" proposed

Agreement on need for FW/Blanket testing in the fusion environment

- Despite differences in names and size of devices, there is strong recognition of the essential need of component testing in the fusion environment
  - Performance verification, model validation, tritium self-sufficiency, reliability growth
- Vision of multiple phases/stages of component testing with progressively higher fluence
  - 20 dpa, 50 dpa… Stages in both EU/IN/K DEMOs
  - 10 dpa, 20 dpa … Stages in US FSNF
  - **Short MTBF, Long MTTR is Dominant Issue.**
  - **Can goal of MTBF > 40 MTTR be achieved? What is the impact on achievable dpa?**
  - What is ultimate lifetime? Is 50 dpa/500 appm He sufficiently attractive?
  - What is the down/lag time between learning from one stage and implementing improvements in following stage (or leap-frog stages?)
- Although EU and Japan do not have FNSF, they also recognize that the nuclear component tests make the present DEMO roadmap more robust, and have intention to join the research by collaboration if available.

In-vessel components role as confinement barrier (from Neill Taylor)

- Strategy should be decided early
  - Will Vacuum Vessel provide confinement barrier (as in ITER)?
  - Will in-vessel components be considered experimental with no safety function (as in ITER), ***or*** will they have safety function (unlike ITER)?

Role of TBM in these strategies

- What is the role of ITER-TBM in programs
  - Break-in to fusion environment testing in a manageable way, instrumentation development
  - First integrated fusion environment testing to compare with models and partially validate separate effects science/designs
  - Anchor blanket and materials development to reality (fabrication, licensing, safety)
- Why is US not doing TBM?
  - Complex government issues related more to ITER than TBM
  - Emphasis on science and not engineering development in US program
- What is the need for TBM on development plan timing
  - Are early DEMO down select decisions and engineering designs being made prior to ITER-TBM information (the same question applies to DT burning plasma physics testing)?
  - What is the impact of further delays in ITER schedule on DEMO plans?

Discussion Topic – Suggestions on how to better work together

- Countries agree on and take major facilities necessary for fusion development beyond ITER, avoid drifting/waiting in the program where little gets done
- Countries will NOT ever have unified roadmap and development plans, but they can support or present a unified consensus on major facility needs
- Define / divide common work needed in the next 5 years to advance fusion technology development
- Define / catalog existing facilities: What capabilities exist? What is still needed?
  - EU has many facilities, some under-utilized. What are the capabilities that already exist?
- People/expertise are also valuable resources that can be better shared
- EU discussed a small D-D Divertor Test Tokamak, US discussed a small FNSF (CTF) prior to DEMO. Can/should these be a unified facility?
  - Operation in 2020s as plasma/thermal/EM test using H/D, Refitting and operation in 2030s as DT nuclear test facility

Topic 2:
Plasma power exhaust and impurity control

- A smaller fusion device is more economically attractive.
  - However, pushing the major radius to smaller values increases the problems for power exhaust.
- Presentations delivered concerning power exhaust:
  - Issues related to plasma physics
  - The choice of plasma facing components (PFCs)
  - Integration of the PFCs and the coolant system.
- Discussion acknowledged that an integrated approach is needed. This includes consideration of both physics and engineering issues, and parallel development of tools to combine and deliver optimized solutions, on acceptable time scales.
  - Performance of the core physics via the exhaust of power in the plasma edge, Scrape Off Layer and divertor
  - Choice of wall materials
  - Heat removal technologies for PFCs.

Plasma power exhaust and impurity control (cont.)

- Currently, in terms of plasma exhaust physics, no reliable predictive numerical capability exists.
- Exhaust physics in ITER like divertor geometries needs to be further assessed and the potential of alternative solutions need to be investigated, e.g.:
  - Super-X configuration
  - Snowflake configuration
- Better coverage by diagnostics could help accelerate assessments and the development of validated numerical tools that are useful for extrapolating to large scale devices

Plasma power exhaust and impurity control (cont.)

- With respect to PFCs: the principal materials envisioned for a DEMO type device are tungsten and steel.
  - The operational space of tungsten is being extended by developing fiber–reinforced composites and self-passivating alloys in order to overcome the brittleness as well as the fracture toughness.
- Maximum power density that could be handled by an integral engineering approach, combining innovative materials and heat removal technologies under irradiated conditions will be less than **5MW/m^2.**
- Development of advanced materials is problematic

Interesting Points from Topic 3 Discussion

- More than **55** tokamaks were built *for* **physics** research,

  but so far exactly zero are for fusion technology.

  -One on technology in each ITER party would be good!
- Centralized project budget control is much superior to in-kind contributions.
- Anyone not providing a TBM for ITER should not criticise the designs of those who are.
- Small non-nuclear facilities cannot reproduce some features demanded of the fusion nuclear environment, e.g. volumetric heating and temperatures with gradients.
- Many think ITER will consume all the available tritium.
- 10MW of neutrons spread over a $10m^2$ wall area would suffice for testing, not necessarily from a tokamak, which needs some minimum size.
- TBMs only cost <$1M, but the prior R&D is the primary cost.
- We don't know which type of TBM/BBM will really work, so international collaboration is vital. [Only if the IPR is shared!]
- Maybe an FNSF could begin life with DD plasma, just as a divertor test facility.
- The EU is considering building a Divertor Tokamak Test Facility.

"Next" 2nd IAEA DEMO Program Workshop

- Workshop participants agreed to reconvene at IAEA headquarters in Vienna for the next annual meeting to be held in December, 2013.

- Proposed topics for the Workshop include:
  - Computer codes for designing fusion facilities
  - Simulated scenarios for controlling plasma
  - A continuation of the first workshop's discussion of methods for dealing with the heat that strikes the inner walls of fusion facilities
  - Fusion nuclear issues.