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Consolidated Design of the HCPB Breeding Blanket for the pre-Conceptual Design phase of the EU DEMO and Harmonization with the ITER HCPB TBM Program

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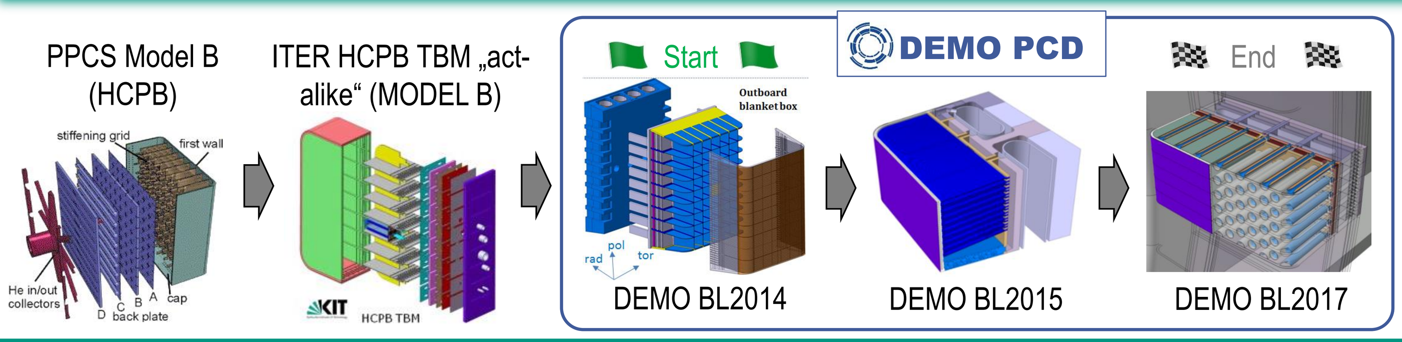
Introduction: HCPB Design Evolution in the PCD Phase

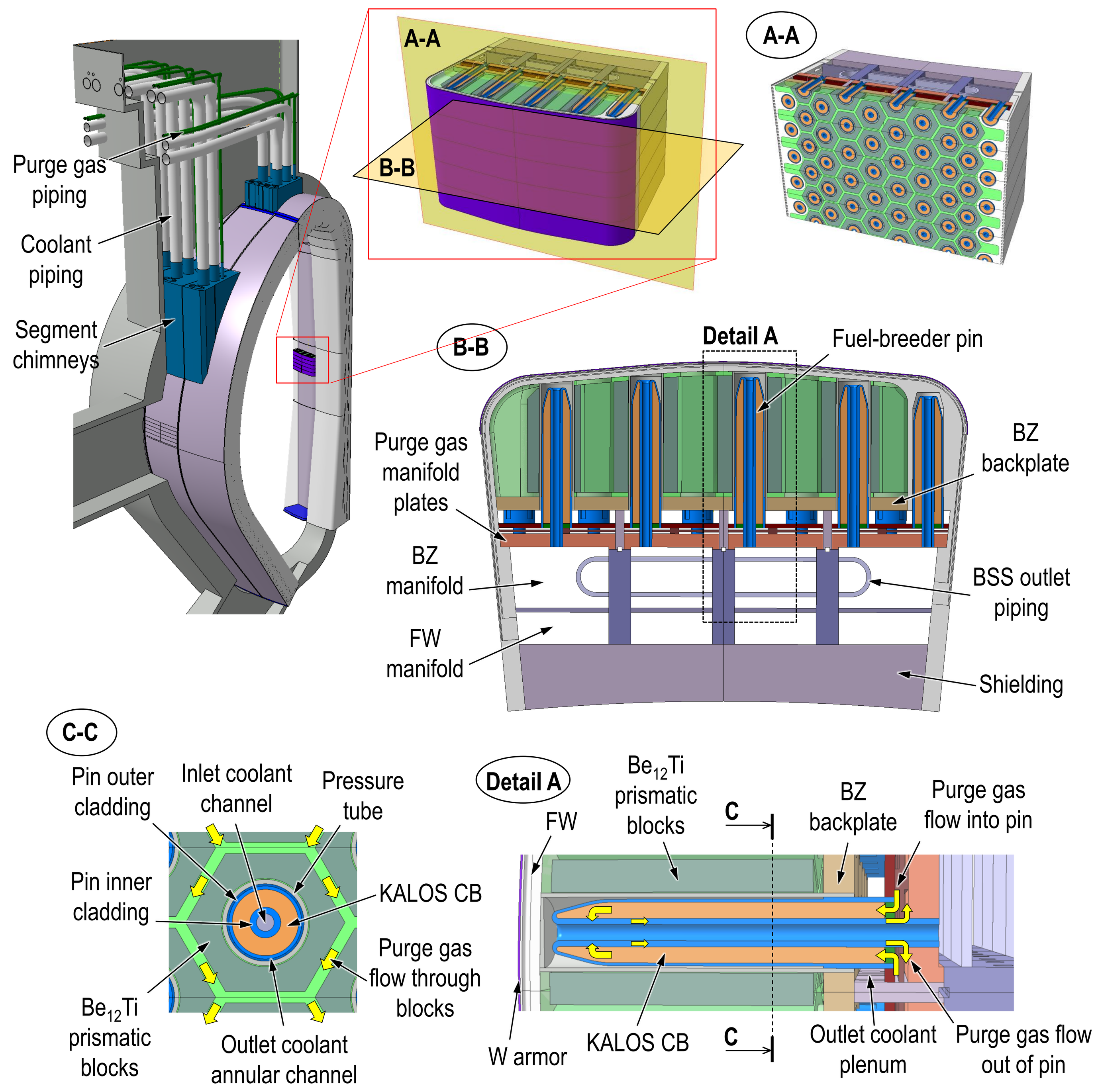


- EU-DEMO currently ongoing its pre-Conceptual Design (PCD) phase.
- Starting point for the HCPB in the PCD: ITER TBM HCPB „act-alike" from PPCS Model B (HCPB „beer-box" conceptual design).
- Highlight of the PCD: holistic design approach.
- Consequence: several major design iterations in order to not only adjust the design to new, challenging DEMO requirements but also to have an harmonic integration with BB interfaces.

HCPB BL2017 v1: General Architecture and Performance Figures

Neutronics

- BB segments architecture: SMS, 16 sectors (DEMO tokamak BL2017)
- 1 segment: 3x outboard (OB) + 2 inboard (IB) segments
- Segment coolant feedpipes: DN250 IB inlet, DN300 IB outlet & OB inlet, DN350 OB outlet
- Segment purge gas feedpipes: DN80 IB & OB inlet & outlet
- BZ architecture: radial fuel-breeder pin bundles connecting FW and BZ backplate; BSS allocating segment coolant manifolds.
- Fuel-breeder pin containing KALOS ceramic breeder pebble bed (Li_4SiO_4 + 35%mol Li_2TiO_3) and inserted into a hexagonal $Be_{12}Ti$ neutron multiplier prismatic block.
- He coolant @80 bar, 300-520°C.
- Purge gas: He + 0.1%vol H_2 (H_2O as alternative doping agent)



Neutronics

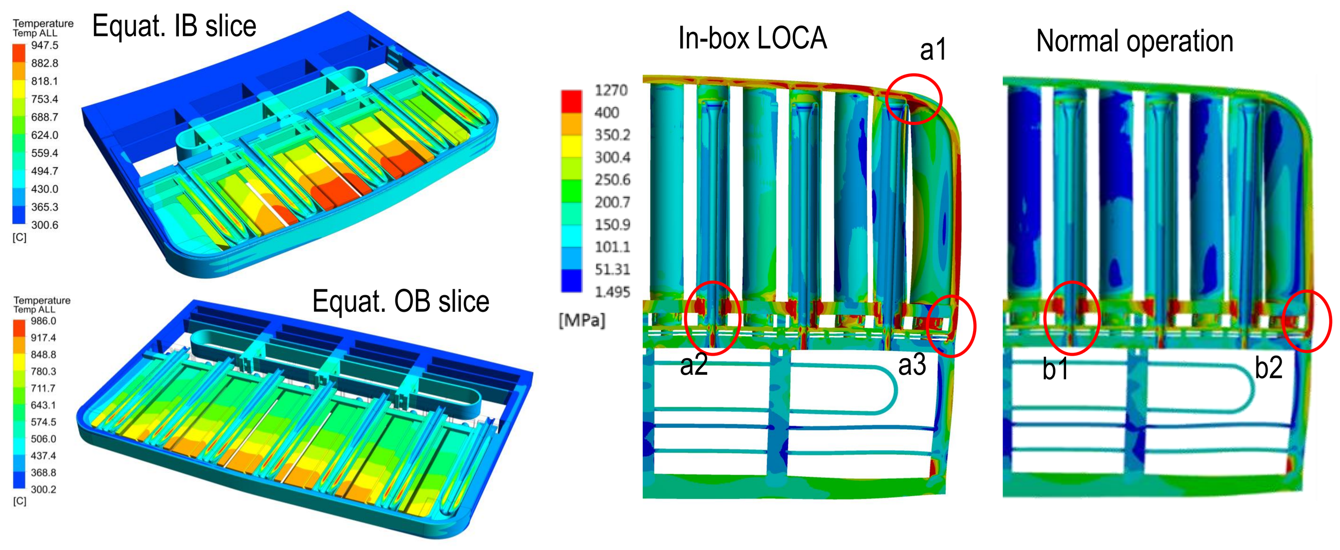
- TBR = 1.20 in a very compact BB config. (1m thick max.)
- n-shielding can be enhanced 10x using 18cm $ZrH_{1.6}$/ $YH_{1.75}$

Local and global thermo-hydraulics

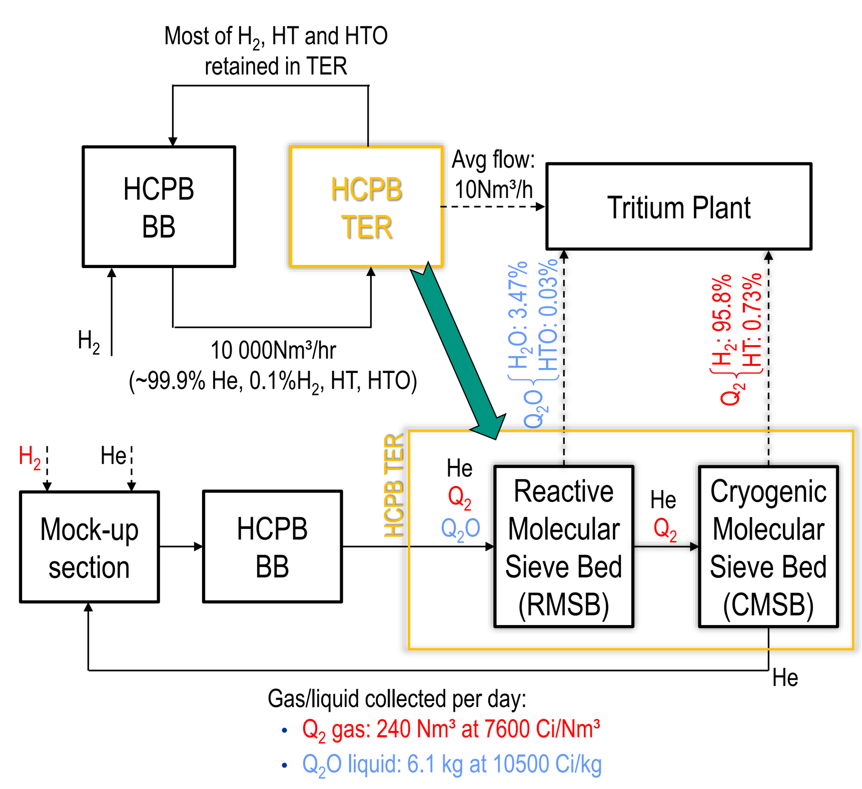
- FW and BZ relying on turbulence promoters; HHF 1.2 MW/m²
- Very low total in-vessel Δp ≈0.8 bar
- The new architecture is based on a layered („sandwich") repeating structure of CP and alternate pebble beds of Li_4SiO_4 and Be.

Local and global thermo-mechanics

- RCC-MRx assessment: correct global structural behavior, but still local issues to be solved for CD phase.

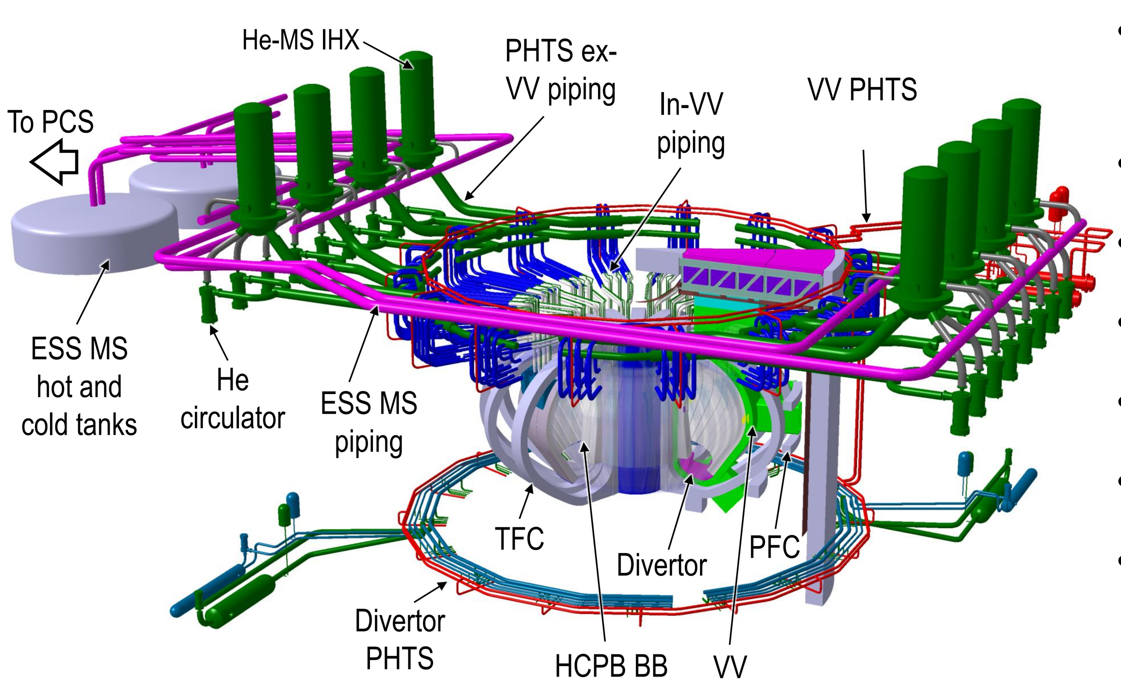


Plant Integration: Tritium Extraction and Removal (TER)



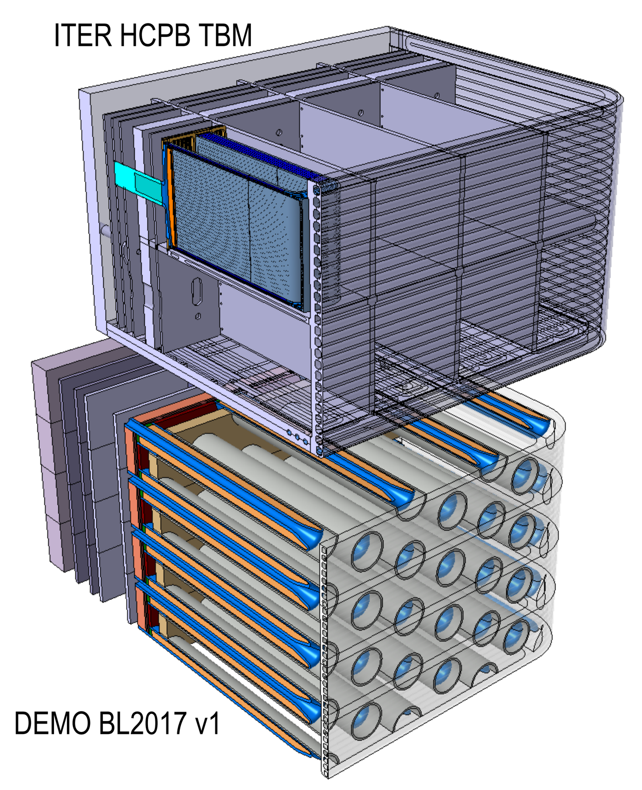
- Selected HCPB TER technology: cryogenic approach due to high technology readiness.
- Total purge gas flow: 0.5 kg/s (10000Nm³/hr)
- 2 step process: (1) absorption/trapping of Q_2O in RMSB + T recovery via catalytic isotope exchange between Q_2O and H/D gas, (2) adsorption of Q_2 in CMSB at 77K + T recovery by regeneration at 400K.
- Possiblility to reduce flow up to 6000Nm³/hr
- Parallel R&D: (1) TER based on wet purge gas (T permeation advantage) and (2) possibility to work with high pressure purge gas (potential key RAMI advantage)

Plant Integration: Balance of Plant



- Development target: maximization of HCPB PHTS and BoP TRL
- TRL driven by $W_{circ,elec}$ (< 6 MW)
- PHTS: 8x (1 IHX + 2 circulators)
- 1 PHTS loop = 2 sectors, OB + IB
- $\Delta p_{in\text{-}VV}$ = 0.8 bar, $\Delta p_{ex\text{-}VV}$ = 1.9 bar
- $W_{total,elec}$ ≈ 90 MW, $W_{circ,elec}$ ≈ 5 MW
- Still high potential to improve some parts of the PHTS to keep lowering $W_{total,elec}$ and $W_{circ,elec}$

DEMO Relevancy of the ITER HCPB TBS



Despite differences in HCPB TBM and ITER HCPB TBS, commonalities identified:

- Same structural material EUROFER97
- Very similar tritium breeder (Li_4SiO_4) in same form (pebble beds) and presence of ^{6}Li enrichment (90%)
- Same primary coolant, same pressure and nearly same temperature window (300-500°C).
- Same T extraction from ceramic breeder, based on low pressure He+0.1-1%H_2
- Similar temperature field in structural material with same design limits
- Similar temperature field in both breeder and neutron multiplier functional materials

Conclusion: it can be expected that the contribution from the EU TBM to the EU DEMO will be very relevant in terms of RoX, as recognized in the past, not reduced by the elements of design novelty in the DEMO HCPB BL2017

Conclusion and Outlook towards the CD Phase

- A consolidated design of the HCPB with SMS segments and hexagonal bundles of fuel-breeder pins embedded in $Be_{12}Ti$ prismatic blocks has been reached and it is presented here.
- Key neutronic, thermo-hydraulic and thermo-mechanical performance figures, together with a more harmonic plant integration assuming matured technologies, converts this HCPB concept to a mature option to be further developed in the next CD phase (2020 - 2024).

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