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A new HCPB breeding blanket for the EU DEMO: evolution, rationale and preliminary performances

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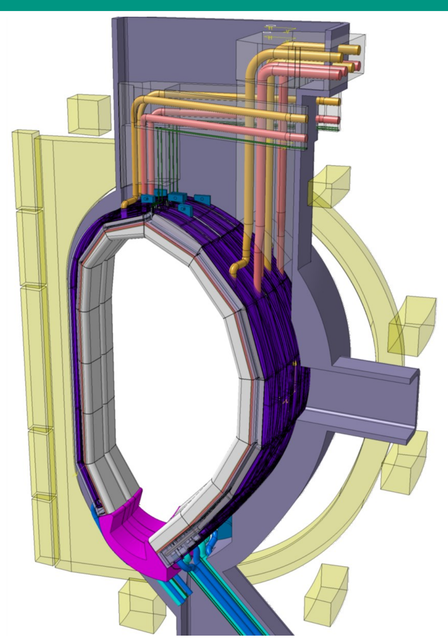
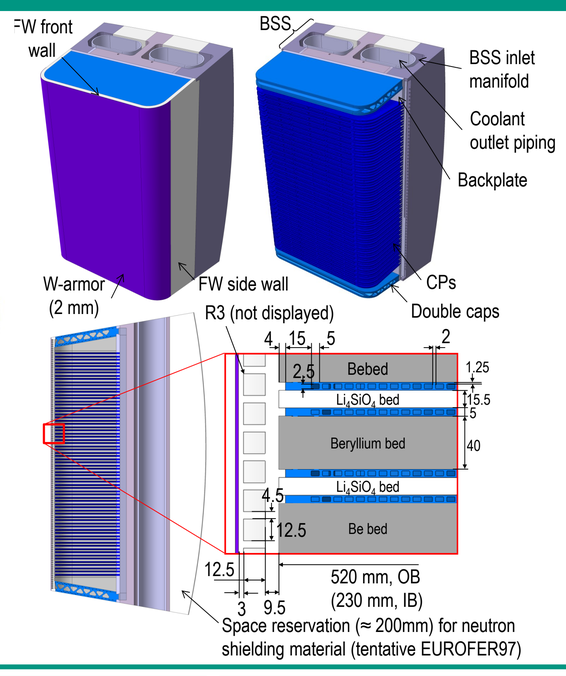
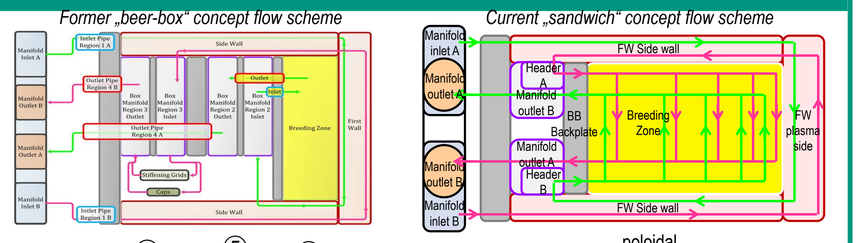
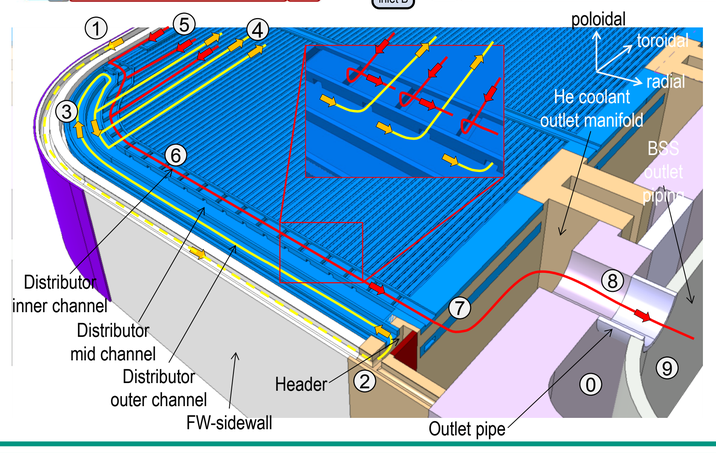
DEMO HCPB breeding blanket: General architecture

- A new HCPB BB architecture for the EU DEMO is presented here.
- The new architecture is based on a layered („sandwich“) repeating structure of CP and alternate pebble beds of Li_4SiO_4 and Be.
- The complex manifold backplate system of the ITER-based former blanket architecture („beer box“) has been simplified and integrated directly in the CP.
- This resulted in a much compact BZ, with more place for shielding and the BSS.



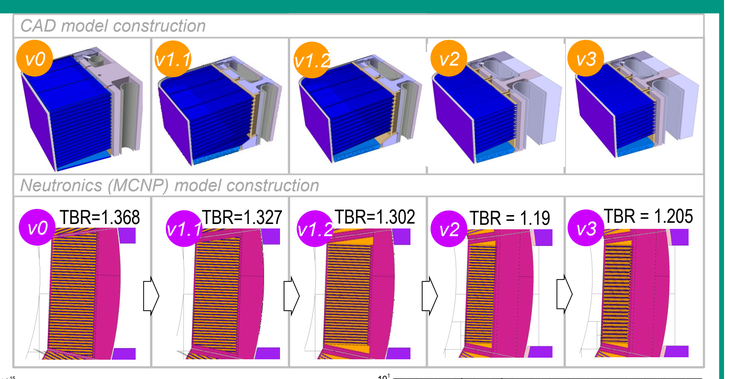


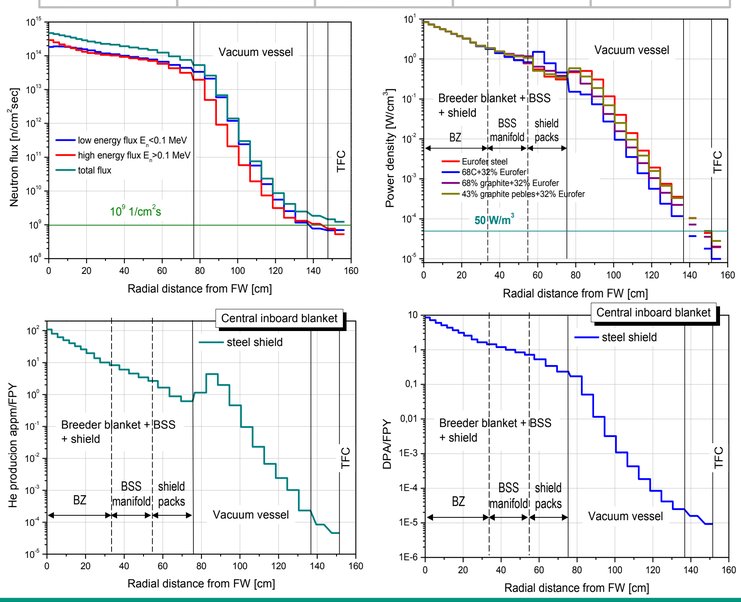




Design Iterations & Neutronics Performance

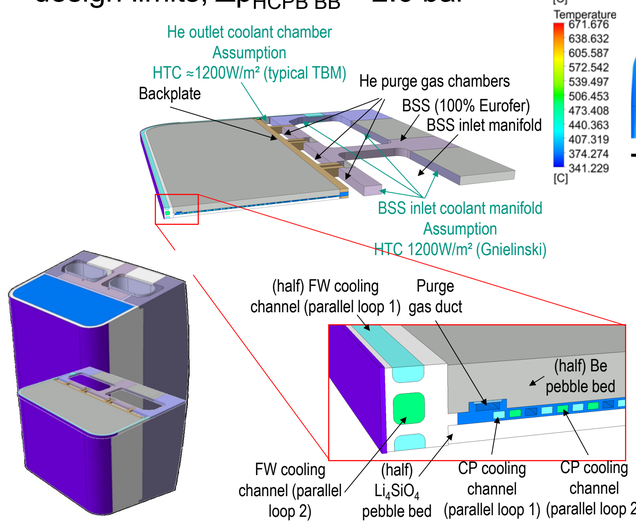
- Maximization of the TBR and shielding capabilities have driven the design iterations with this new architecture:
  - V0: initial configuration, Li_4SiO_4 11mm, Be 33mm, “thin” caps, long BZ, CP in cap region
  - V1.1: same as V0 but „double-caps“
  - V1.2: same as V1.1 but no CP in cap region
  - V2: same as V1.1 but shorter BZs
  - V3: same as V2 but Li_4SiO_4 15.5mm, Be 40mm (baseline)
- Shielding materials at BSS investigated, EUROFER as baseline for simplicity.
- dpa damage ok, He production fine, although local peak of 4 appm.
- The new architecture is flexible enough to mitigate future tokamak configurations that may result in significant loss of blanket coverage.

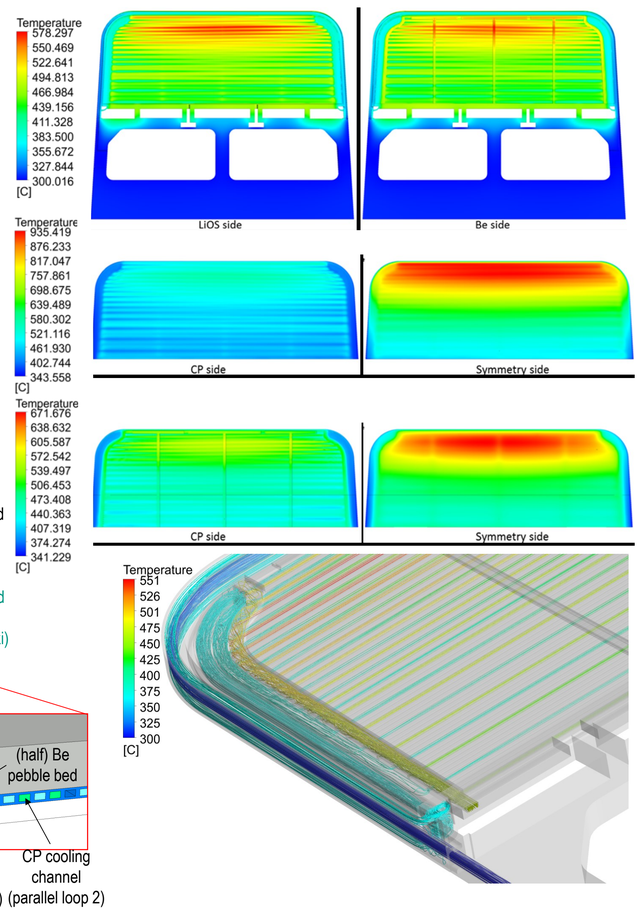




Thermohydraulic Performance

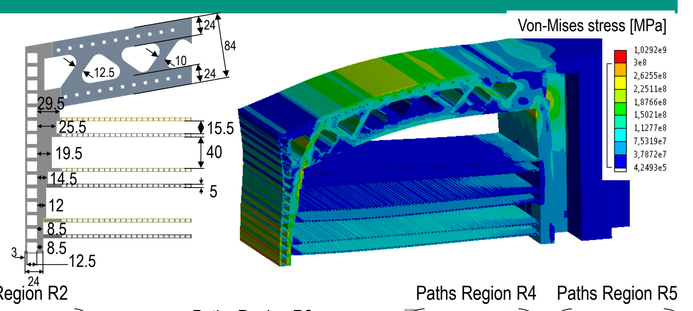
- Input data:
  - DEMO fusion power: 2060 MW
  - HCPB BB thermal power: 2796.4 MW (considering a constant FW heat flux of 0.5 MW/m²)
  - Total HCPB BB mass flow: 2690.4 kg/s
- Comprehensive CFD analyses have been performed to a unit slice of the equatorial OB module
- Temperatures are about the material design limits, $\Delta p_{HCPB\ BB} \approx 2.6$ bar

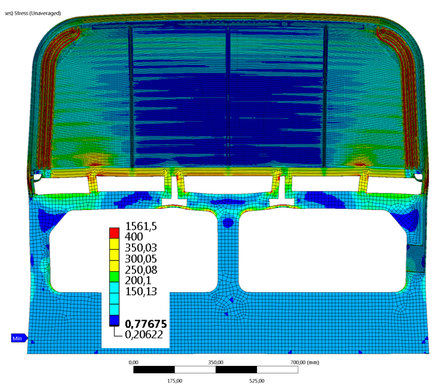


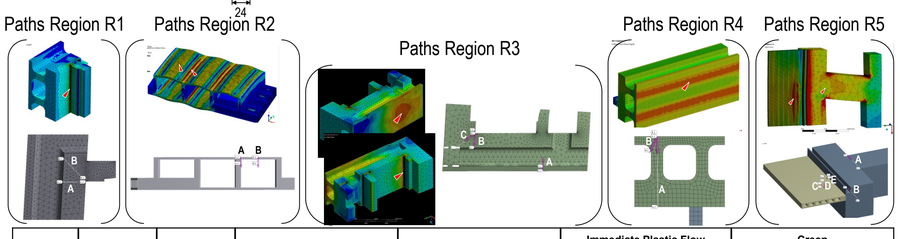


Thermomechanical Performance

- TM assessment with RCC-MRx code.
- In-box LOCA (9 MPa): HCPB fulfills the criteria at level C after implementing a “double-cap” and stepped FW.
- Normal operation: good global behavior at level A, local modifications needed in future consolidated design.







Region		Average path temperature [°C]	Immediate Plastic Collapse			Immediate Plastic Instability			Immediate Plastic Flow Localisation			Creep (2nd blanket, 50dpa, 50.000h)		
			Value [MPa]	Limit [MPa]	Ratio over limit	Value [MPa]	Limit [MPa]	Ratio over limit	Value [MPa]	Limit [MPa]	Ratio over limit	Value [MPa]	Limit [MPa]	Ratio over limit
R1: FW to header	Path A	353.2	109.0	165.0	0.66	250.6	247.5	1.01	268.8	313.0	0.86	212.8	275.8	0.77
	Path B	351.0	107.5	165.0	0.65	122.4	247.5	0.49	230.0	313.0	0.73	141.9	278.1	0.51
R2: Distributor	Path A	372.2	176.2	160.0	1.10	721.9	240.0	3.01	281.2	313.0	0.90	635.4	256.5	2.48
	Path B	368.5	58.1	160.0	0.36	560.2	240.0	2.33	208.1	313.0	0.66	459.5	260.3	1.77
R3: FW to BSS	Path A	310.7	45.7	170.0	0.27	44.4	255.0	0.17	460.6	313.0	1.47	51.2	320.8	0.16
	Path B	347.6	88.9	165.0	0.54	63.5	247.5	0.26	211.2	313.0	0.67	80.2	281.6	0.28
	Path C	344.6	81.9	165.0	0.50	69.8	247.5	0.28	198.0	313.0	0.63	74.6	284.7	0.26
R4: FW plasma side	Path A	406.6	15.7	156.0	0.10	20.4	234.0	0.09	279.2	313.0	0.89	18.4	222.8	0.08
	Path B	457.9	16.4	145.0	0.11	22.4	217.5	0.10	299.5	313.0	0.96	23.5	175.7	0.13
R5: Backplate bridge	Path B	464.9	31.2	139.0	0.22	46.1	208.5	0.22	309.2	313.0	0.99	45.7	169.5	0.27
	Path A	464.9	39.7	139.0	0.29	70.9	208.5	0.34	346.3	313.0	1.11	71.2	169.5	0.42
	Path C	437.8	85.9	148.0	0.58	111.3	222.0	0.50	410.1	313.0	1.31	107.4	193.7	0.55
	Path D	438.8	80.1	148.0	0.54	103.9	222.0	0.47	439.0	313.0	1.40	108.0	192.8	0.56
	Path E	467.6	12.1	139.0	0.09	19.2	208.5	0.09	615.1	313.0	1.97	17.0	167.2	0.10

Conclusions and Outlook

- A new HCPB architecture based on an integrated FW (“HCPB-I”) have released the high potential of the solid breeding blanket for DEMO, which stalled with the ITER-like concept.
- Good neutronic performance figures: TBR≈1.20 in the baseline design; shielding, nuclear heating and dpa under design limits; i.e. this „sandwich“ architecture can mitigate future adverse configurations for the blanket coverage (DN, detached FW, bigger divertor).
- Good overall TH and TM performance figures: temperature peaks in structural and functional materials are localized and can be relatively easily mitigated in a future consolidated design.
- Due to the large uncertainty in the FW heat flux, a variant with a detached FW („HCPB-D“) based on this architecture will be studied thereafter; due to the mechanical separation in the HCPB-D, water can be a coolant option for the detached FW.
- Other functional materials are being studied, with especial attention to alternative neutron multipliers that can potentially replace Be and Be mixtures, eliminating the issues related with the use of this element.

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