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Neutronic Analyses for ITER Diagnostic Port Plugs

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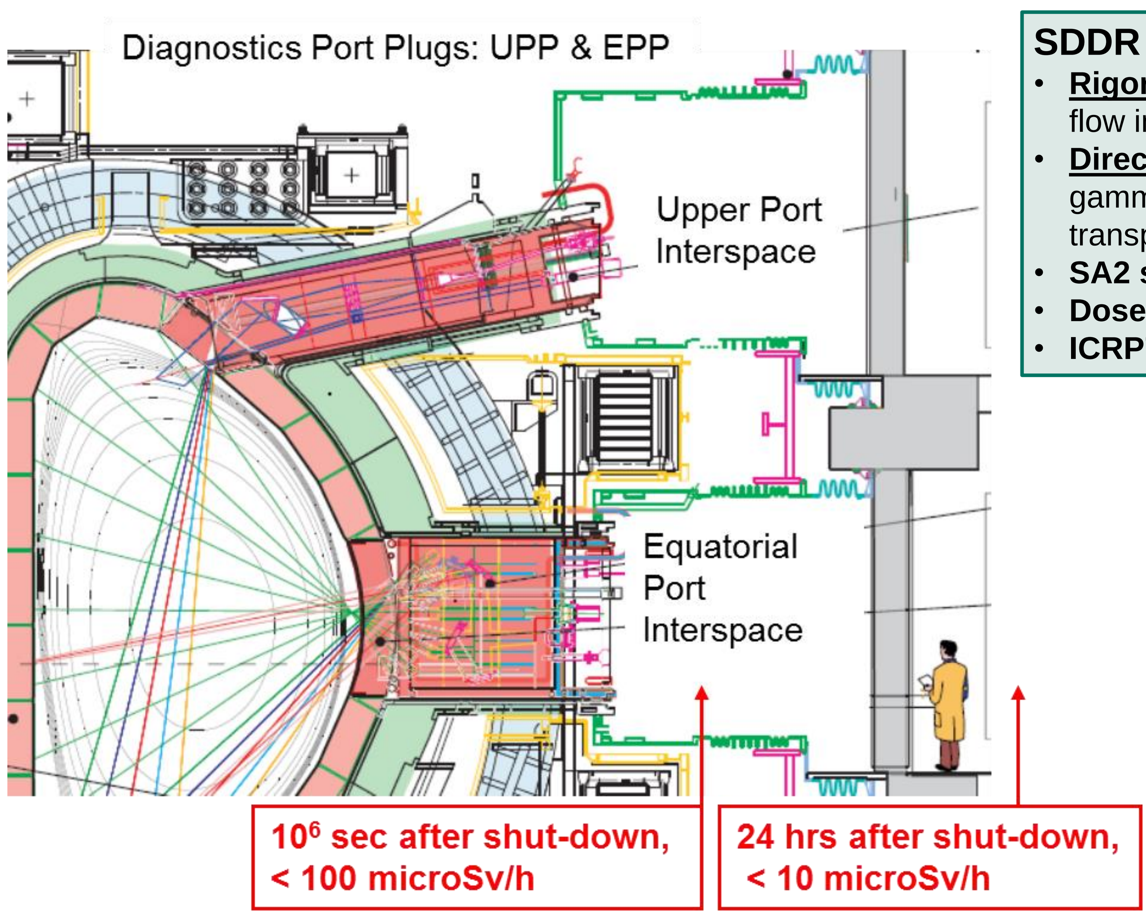
Aims and Strategy for Port Plug Neutronics Analysis

Aims

- Provide neutronics support for the ITER Equatorial and Upper Port Plug design development;
- Check the current design to satisfy the ITER radiation requirements;
- Find design solutions for possible shielding improvements in accordance with **ALARA principle** – for the **Shut-Down Dose Rate (SDDR)**

Strategy

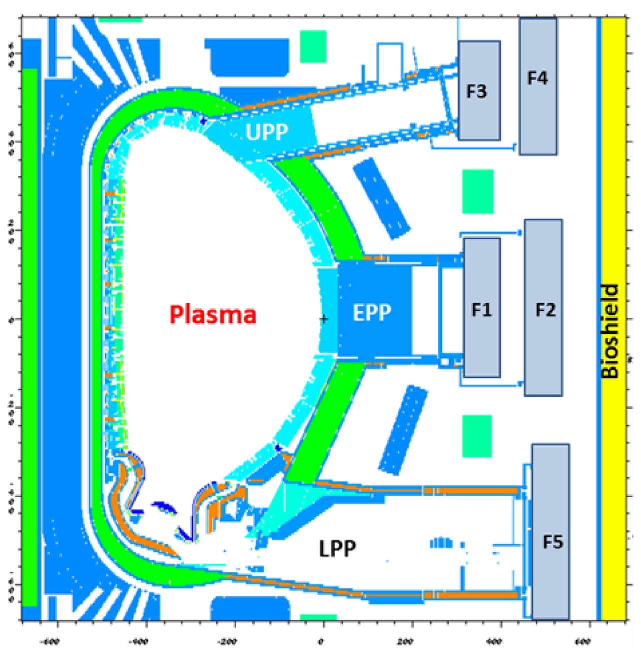
- Understanding the physical phenomena of the problem (radiation transport and activation) – usually steel/water plugs with gaps.
- Choose the best available neutronics model of ITER (B-lite ver. 2 & 3) and modeling approximations (material homogenization, boundary conditions, impurities):
  - **Examine basics principles** on Local models;
  - **Parametric analysis** of the model characteristics in Local model;
  - **Optimization** of the model geometry / material for **Shut-Down Dose Rate** (**SDDR**) as a target parameter;
  - **Integration** of the Local MCNP model into the General ITER model (B-lite).



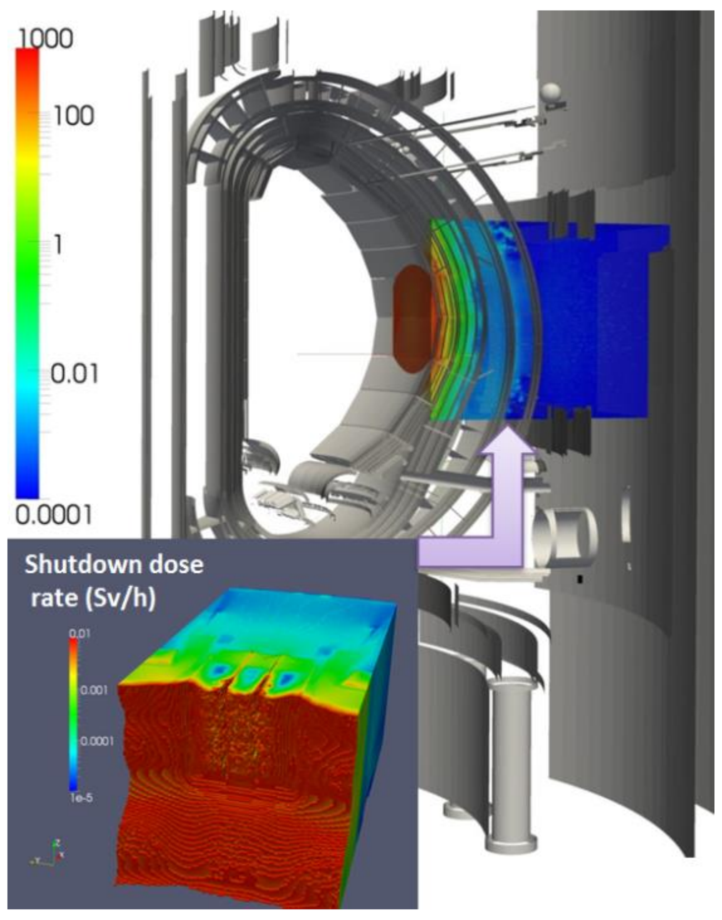
SDDR modeling assumptions:

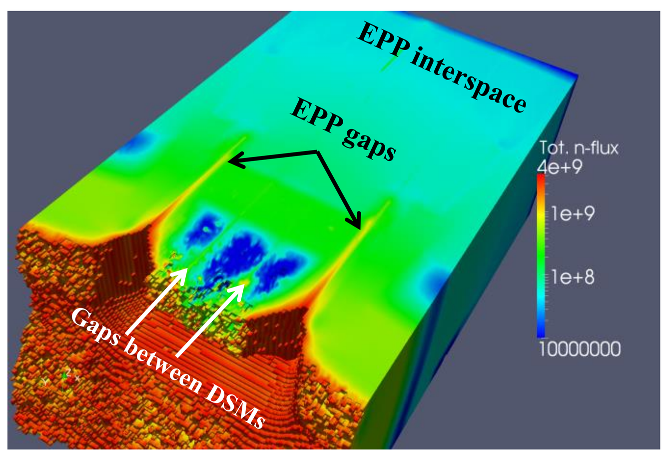
- **Rigorous 2 Step mesh (R2Smesh)** method: data flow interface between MCNP and FISPACT;
- **Direct 1-Step (D1S) method**: couples the decay gammas emission and propagation with the neutron transport in the same MCNP run
- **SA2 safety scenario** for neutron irradiation
- **Dose rate at 1e6 s** after the ITER shutdown
- **ICRP74 photon-to-dose** conversion factors

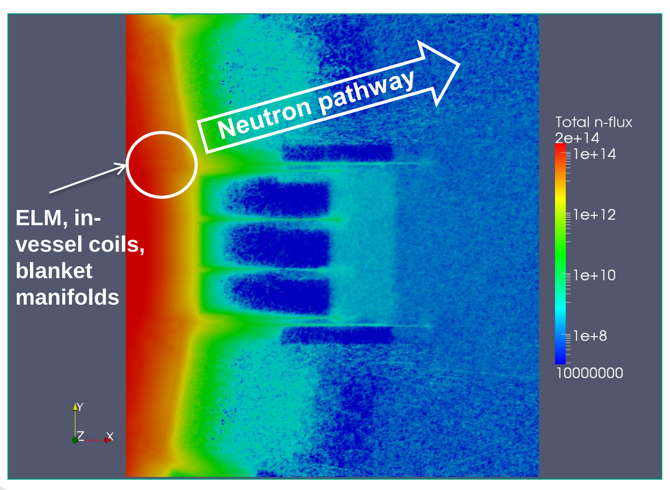
B-lite version 2 MCNP model



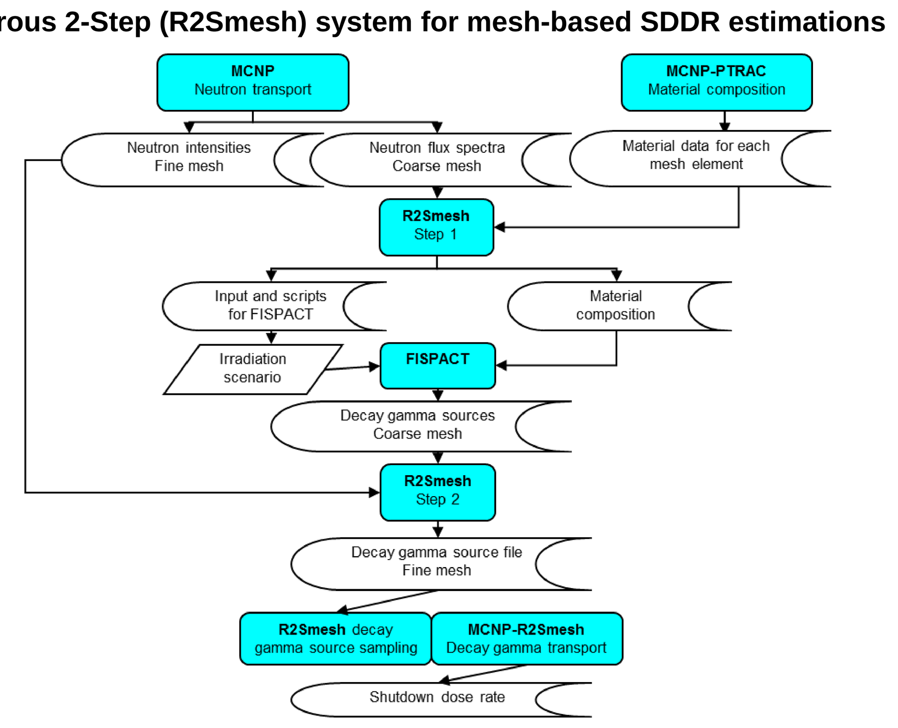
Diagnostics Equatorial Port Plug (EPP)



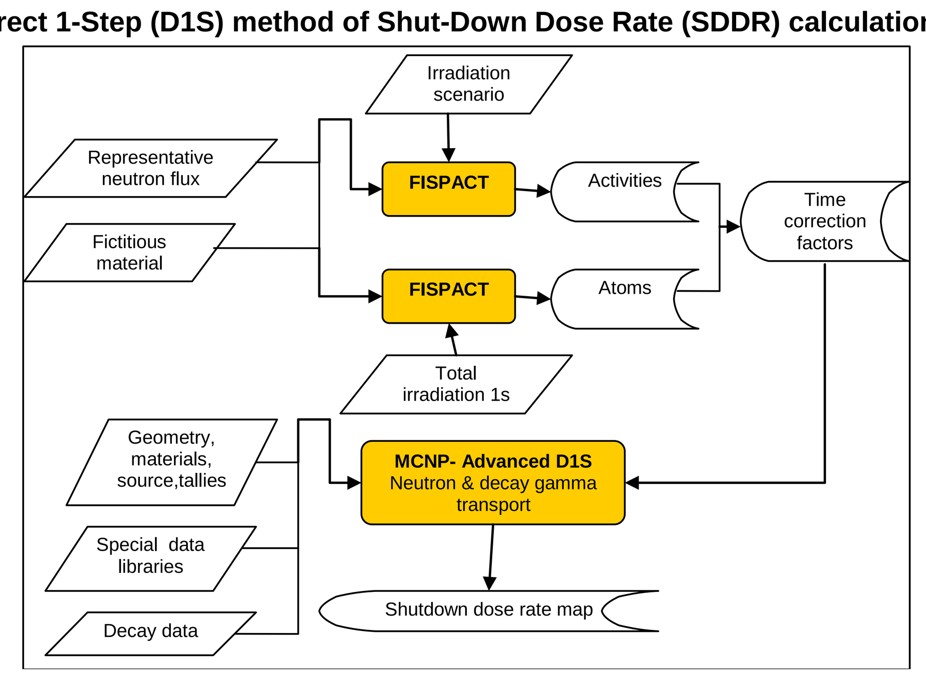




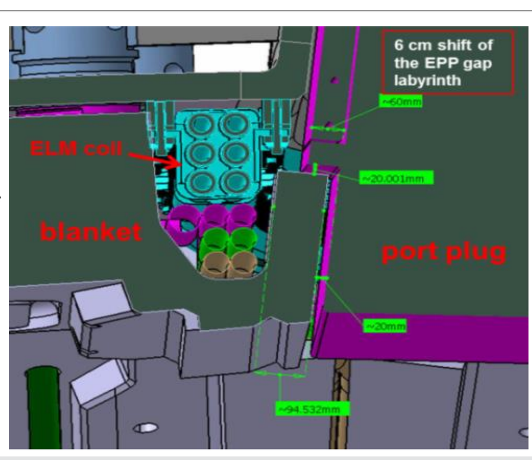
Rigorous 2-Step (R2Smesh) system for mesh-based SDDR estimations



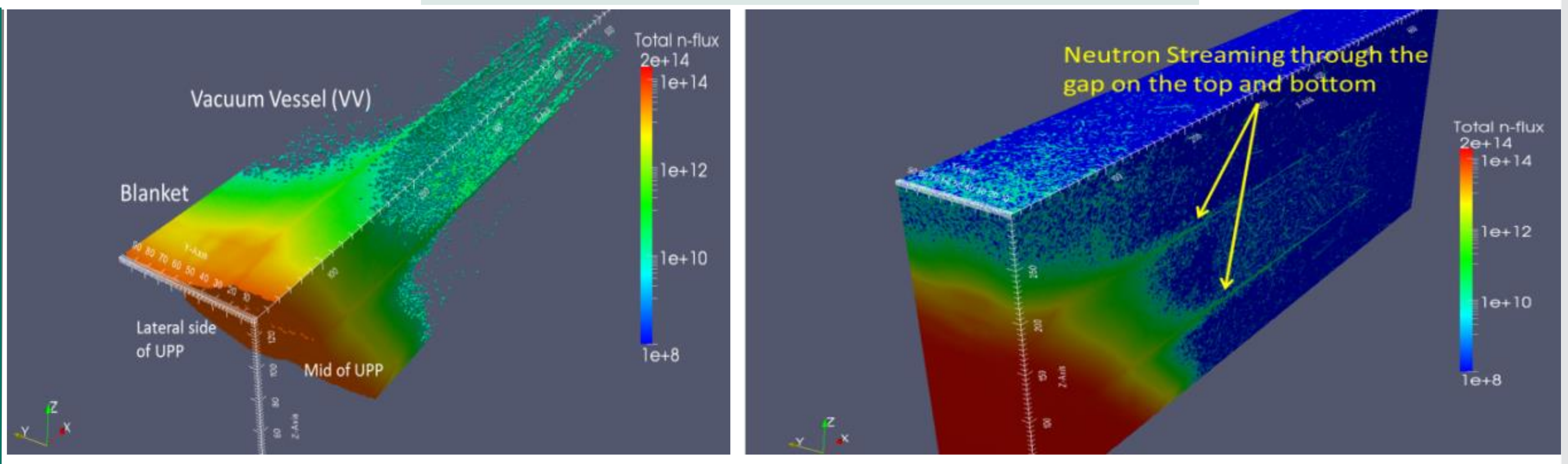
Direct 1-Step (D1S) method of Shut-Down Dose Rate (SDDR) calculations



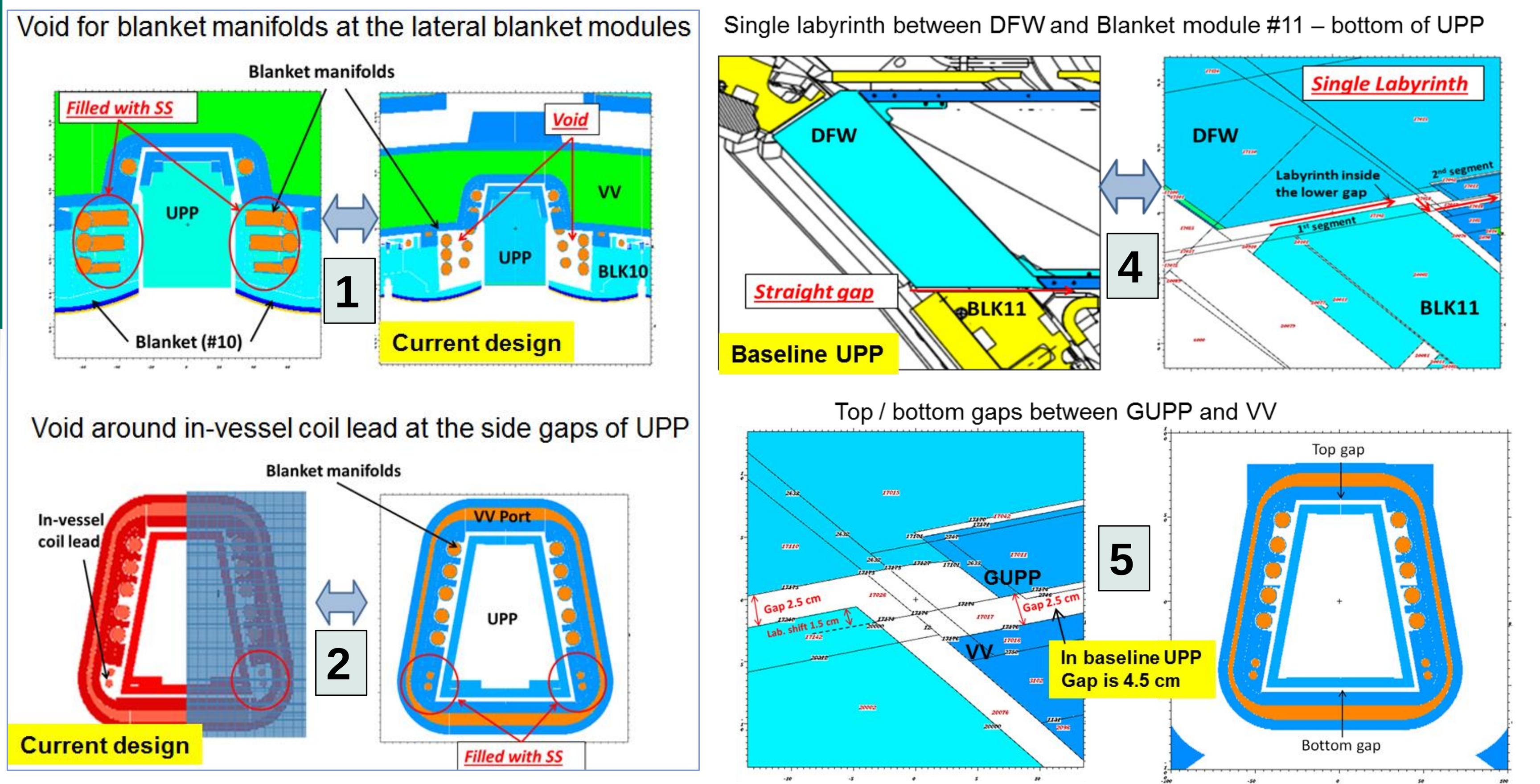
This is the reason why we do have weakened radiation shielding on the sides of EPP



Diagnostics Upper Port Plug (UPP)



5 shielding options affect the SDDR inside UPP interspace



Parametric study for SDDR – shielding improvements for the Generic UPP

We are here

Shielding options	UPP current design	Design cases						Green - Desired UPP
		1	2	3	4	5	6	
1) Void for blanket manifolds in the lateral blankets *	No shielding	No shielding	No shielding	No shielding	No shielding	No shielding	Filled with SS	No shielding
2) Void around in-vessel coil lead in the side gap of UPP **	No shielding	No shielding	Filled with SS	No shielding	No shielding	Filled with SS	Filled with SS	Filled with SS
3) Inconel-718 bolts in the back flange ***	Yes (25%)	Yes (25%)	Yes (25%)	No	Yes (25%)	Yes (25%)	No	No
4) Single labyrinth at bottom gap ****	No	No	Yes	No	Yes	Yes	No	Yes
5) Top/bottom gap around GUPP [mm]	45	25	45	25	25	25	25	25
SDDR at GUPP interspace [microSv/h] -(dose decrease)	108	95 (-13)	80 (-28)	76 (-32)	75 (-33)	67 (-41)	56 (-52)	48 (-60)

Minimization (ALARA principle) of the SDDR at GUPP interspace

* Improvement of shielding in the blanket manifold connection area is difficult – at Blanket back side
** Improvement of shielding in the feeders at the side gap area of UPP is possible – at Vacuum Vessel
*** There is an agreement to change the material of the rear-flange bolts: from Inconel alloy 718 bolts to steel SS-660
**** No difficulty to implement the dogleg single labyrinth for diagnostics UPP

Influence to SDDR inside the UPP interspace

Parameter of UPP Stricture / Environment	(μSv/h)	Environment or UPP structure
• Single labyrinth at the UPP bottom gap	-20	Interface with environment
• Inconel-718 bolts at UPP back-flange	+19	UPP structure
• Increased top/bottom gap around UPP from 25 mm to 45 mm	+13	Interface with environment
• Void in blanket manifolds	+12	Environment
• Diagnostics apertures of the UPP18	+9	UPP18 structure
• Void around in-vessel coil manifolds and ELM feeders on the lateral sides of UPP	+8	Environment

- In summary, environment features contribute **53** microSv/h, UPP structure 19 microSv/h, UPP18 diagnostics apertures deposit 9 microSv/h to SDDR at 10^6 s after ITER SA2 irradiation scenario.
- SDDR depends mainly on the environment, not on the UPP structure itself.
- By using feasible shielding improvements it is possible to reduce **SDDR from 95 microSv/h (current UPP design) to 48 microSv/h (desired design of UPP and adjacent environment).**
- Nuclear heating is mostly deposited by secondary photons in DFW, accounted for 342 kW among 355 kW of total heating inside the UPP.
- Neutron streaming through the gaps around the UPP could be reduced:
  - on the lateral sides by insertion of fillers between the tubes of in-vessel coil manifolds and ELM feeders;
  - on the bottom side by the single dogleg labyrinth;
  - by keeping nominal 25 mm gaps on the top and bottom sides.

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