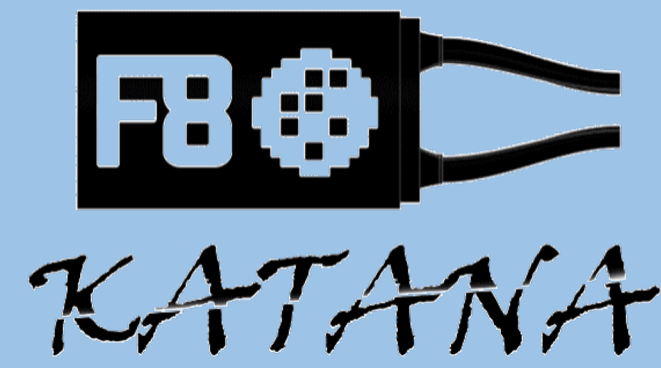


ITER-relevant Irradiation Head of KATANA Water Activation Loop at JSI TRIGA Reactor

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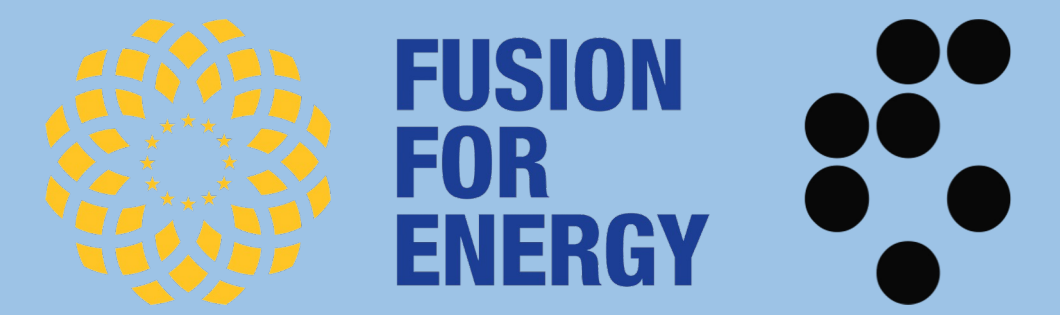
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MOTIVATION

- Lack of **water activation** experiments in **fusion relevant conditions**
- Lack of **experimentally validated** fluid activation codes
- Discrepancies between convectional and CFD-based fluid activation codes
- KATANA water activation facility does not yet replicate exact conditions expected in ITER

OBJECTIVE

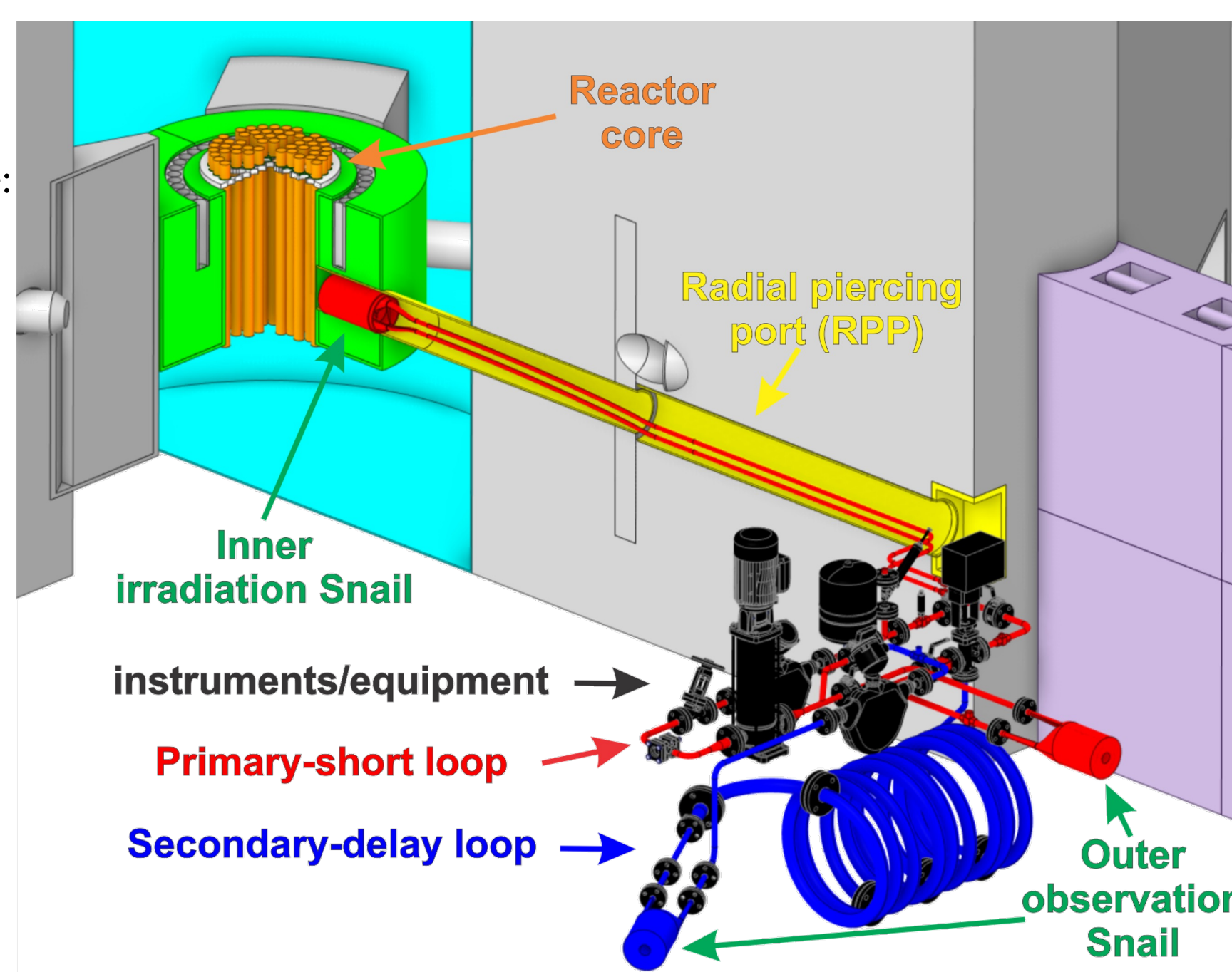
- Replacement of the existing KATANA irradiation Snail head
- Designing a new irradiation head to better reproduce ITER-relevant conditions
- Preserving
 - Hydraulics features
 - Residence time
 - Orientation of neutron flux gradients

CONCLUSION

- Complex design makes manufacturing using 3D metal printing impractical
- Manual CNC-machined modular design has been adopted
- Proposed modular design shows promising feasibility but requires further detailed neutronic and computational fluid dynamics-based analyses before prototype fabrication and experimental validation
- Design finalisation is anticipated for 2027, followed by installation on KATANA and dedicated new experimental campaigns

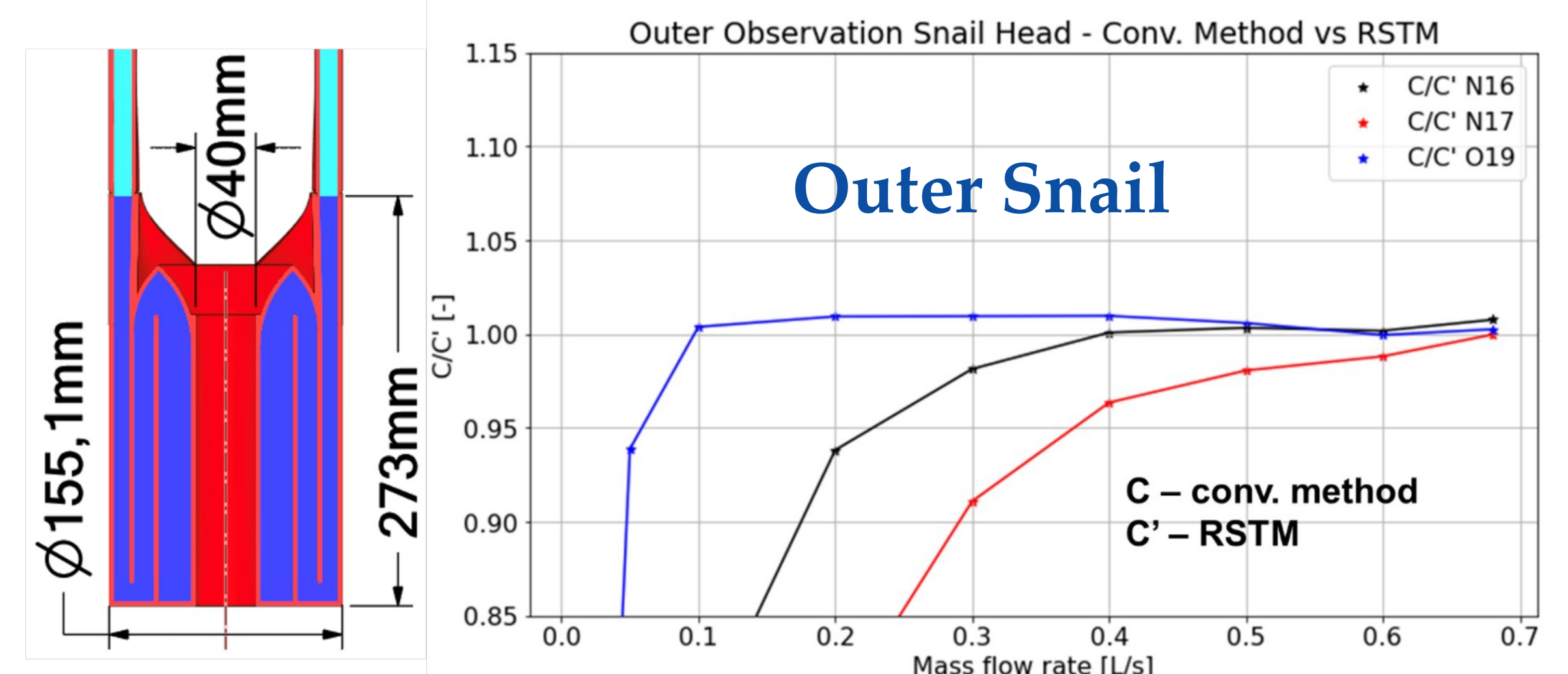
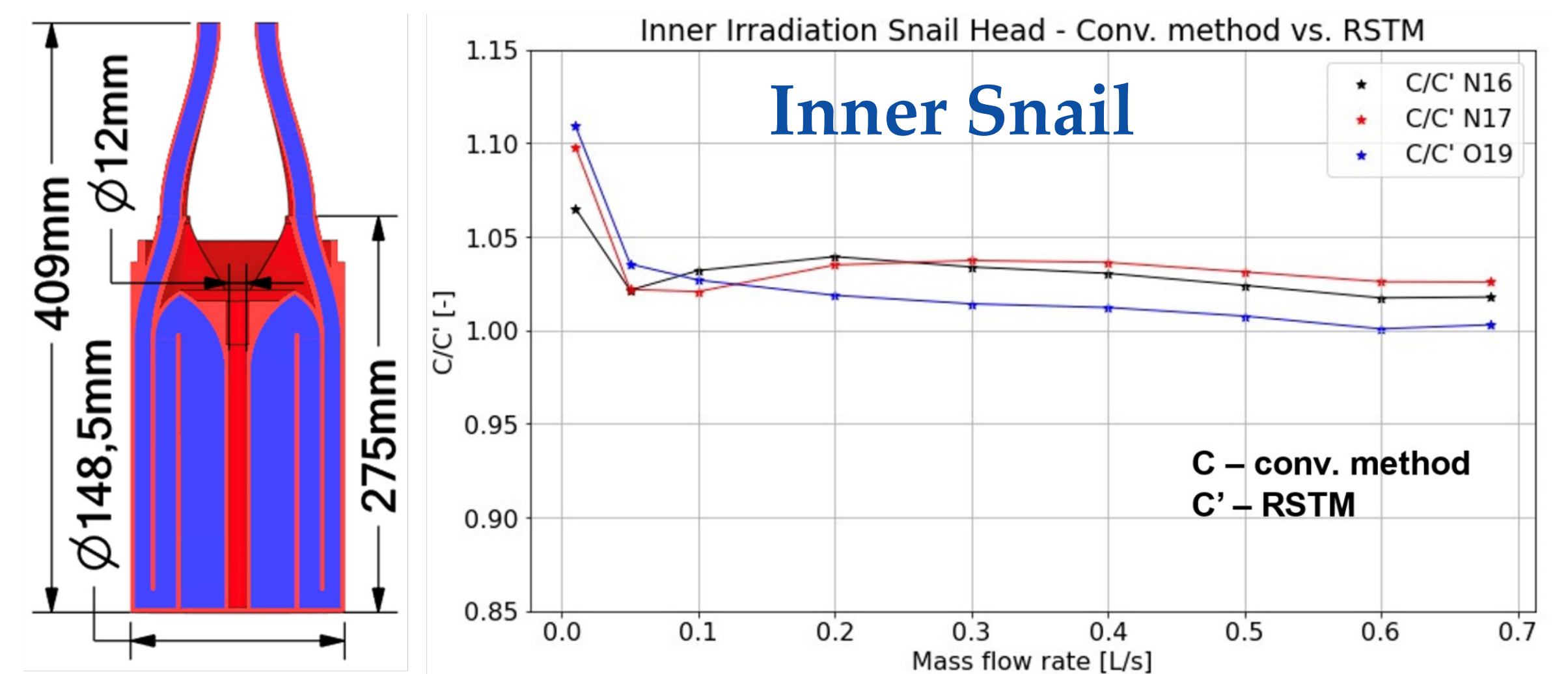
1. KATANA facility

- Well-defined and stable high energy irradiation source:
 - Gamma: 6 MeV – 7 MeV, Neutron: ~1 MeV
- Water activation based experiments (¹⁶N, ¹⁷N, ¹⁹O)
- Experimental validation of fluid activation codes
 - RSTM, FLUNED, ActiFlow & GammaFlow
- Calibration of γ detectors and dosimeters
- Shielding experiments using ITER-relevant materials
- Integral cross-section measurements
- Dose rates and γ spectrum measurement
- relevant conditions



2. Comparison between convectional (non-CFD) method and RSTM code (CFD)

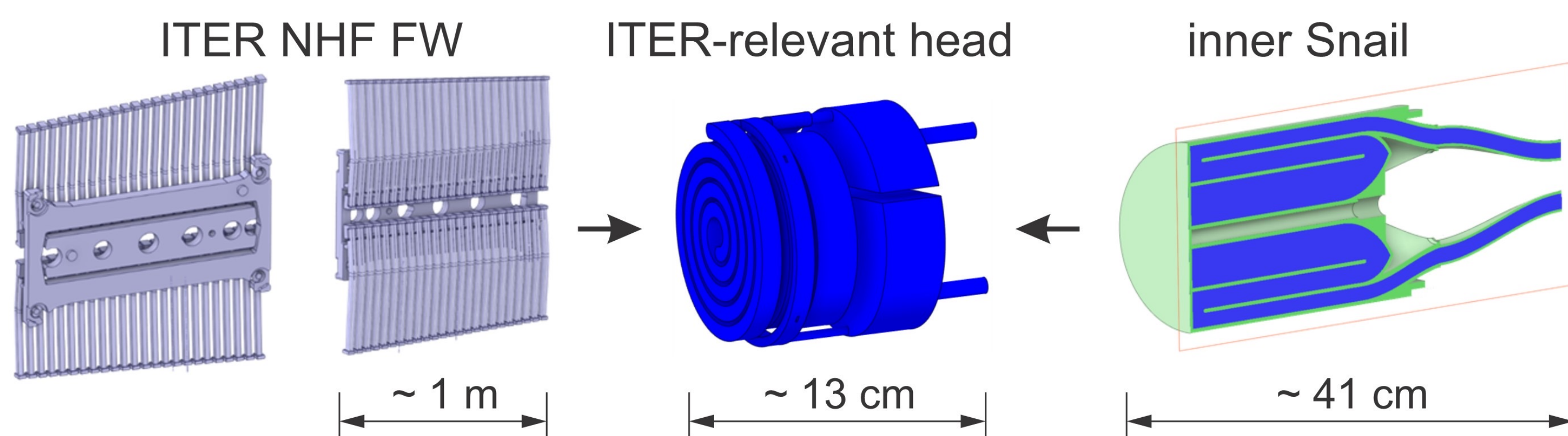
- **RSTM code:** The Radio-Species Transport Model is a simulation tool developed by F4E, coupling fluid activation phenomena and fluid dynamic effects
- Results show a strong coupling between fluid dynamics and neutron activation.
- **Inner irradiation head:** opposing activation and flow effects → small differences (**flat C/C'**)
- **Outer observation head:** decay-only region → fluid effects dominate (**irregular C/C'**)
- Current KATANA configuration can mask important coupled physics
- Motivating the development of an ITER-relevant irradiation head (F4E + JSI) to better capture these effects



3. ITER-relevant irradiation head

- In future, KATANA will focus on:
 - performing experiments more relevant to ITER cooling systems
 - validating general-purpose fluid activation tools also in a **more complex scenario:**
 - approach conditions closer to the breakdown of the conventional (non-CFD) method assumptions and, if possible, to match ITER cooling systems
- Design strategy is to preserve key features of **the ITER First Wall module:**
 - hydraulic features (inlet and outlet pipework, water-boxes and fingers),
 - residence time (via flow rate adjustment while preserving the Reynolds number)
 - orientation of neutron flux gradients (spiral discs instead of back-and-forth routing)

(mean residence time: 11.9 s, Re: 17310, velocity: 0.79 m/s, volume: 55 L, flow rate: 4.7 L/s)



- Several conceptual spiral disc designs are under investigation
- Use one or more spiral disks, water boxes, channels and interconnecting pipes
 - Adjusting the size → volume ratio corresponds to that of a First Wall + size restrictions of dimensions of reactor port

- **3D printing option is unsuitable for spiral disk designs → manual production → remodelling design**
 - standard CNC-technique is proposed: **spiral disks (green), gaskets (red) + bolts-tightening (black)**
 - ❖ Design simplifications lead to deviations from the ideal "on-paper" concept.
 - ❖ Further neutronics/CFD analysis is needed to optimise the design under manufacturing constraints

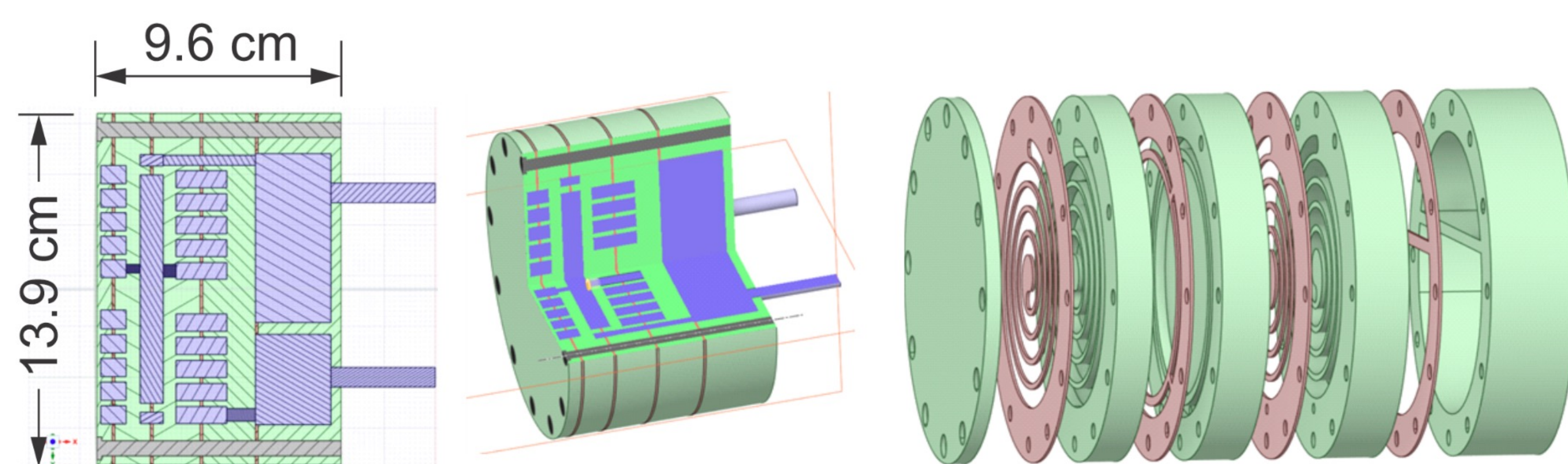


Figure: schematic of the latest design + exploded view

Results/Conclusions

- New ITER-relevant head is under development
- Complex design makes manufacturing using 3D metal printing impractical
- Manual CNC-machined modular design has been adopted → redesigning model
- Proposed modular design shows promising feasibility but requires further detailed neutronic and computational fluid dynamics-based analyses before prototype fabrication and experimental validation
 - calculations of the new reaction rate distributions
 - detailed CFD-based activity calculations along the KATANA circuit
 - calculation of residence time distribution along the head to match ITER FW module characteristics

Acknowledgement

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