Liquid Metal Divertor Design for the European DEMO

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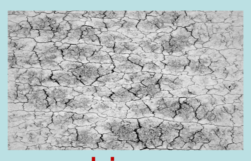
Motivation

Neutrons

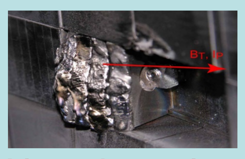
Solid PFC:

Sputtering

Thermal shock/fatigue



Big ELMs/VDEs/disruptions



LM PFC:

Self replenishment
Higher heat fluxes

No cracking
Lower stresses substrate
ELMs possible(?)

Already molten
Vapour protection

Only influences substrate
Separation of PSI from neutron issue

Goal

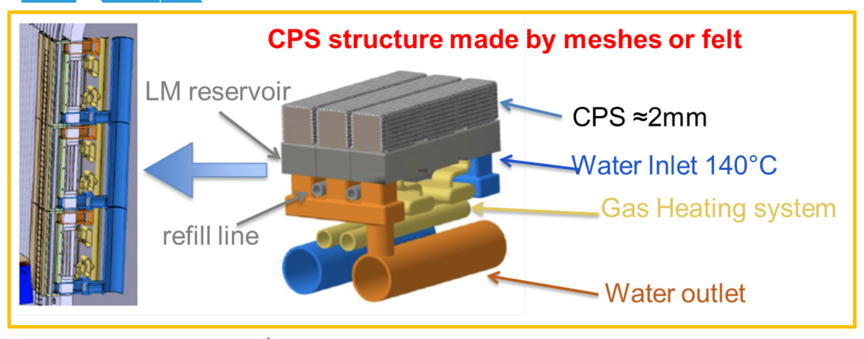
Provide a back-up solution for the baseline (risk mitigation)

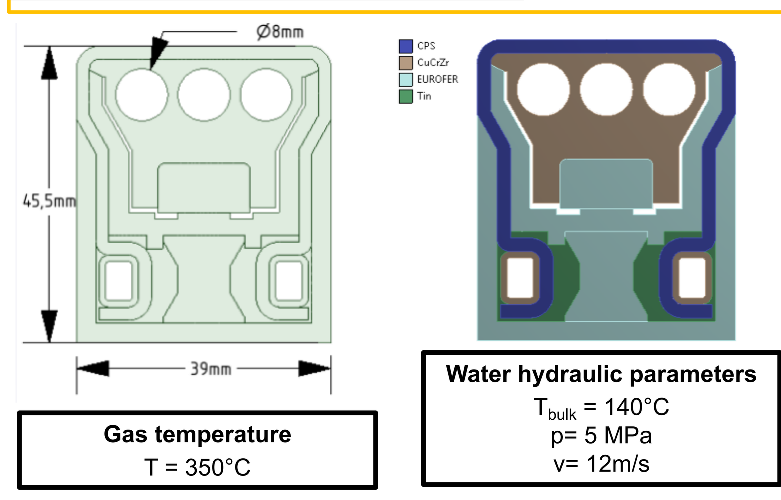
- Fulfil all divertor requirements (heat/particle handling)
- Compliant with plasma (impurity) and scenario
- Compliant with in vessel components, diagnostics…
- Compatibility with baseline cassette design

Solution: Capillary Porous Structure Design using Tin (Sn) as Liquid Metal

LM Divertor Design

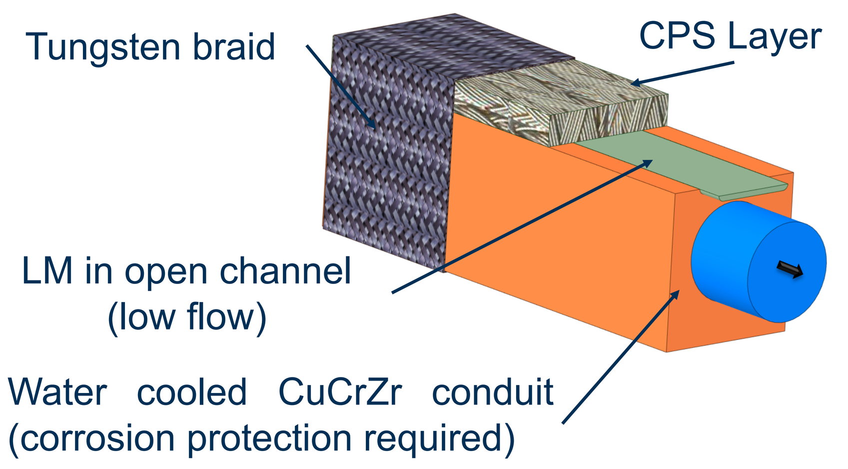
ENEA





CCFE

Water cooled: 250°C, 150bar & 16m/s

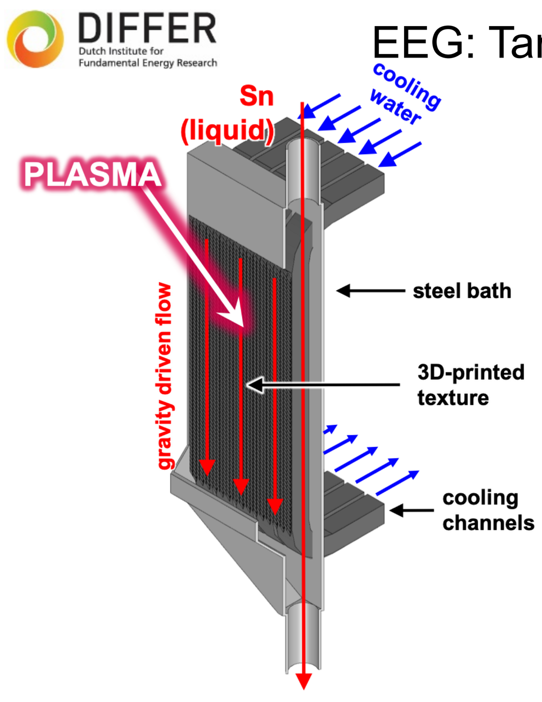


Maximum surface temperature

Design	10 MW m^{-2}	20 MW m^{-2}
ENEA CuCrZr	489 °C	843 °C
ENEA $W_{70\%}Cu_{30\%}$	516 °C	919 °C
DIFFER	600 °C	1020 °C
CCFE	696 °C	1142 °C

DIFFER

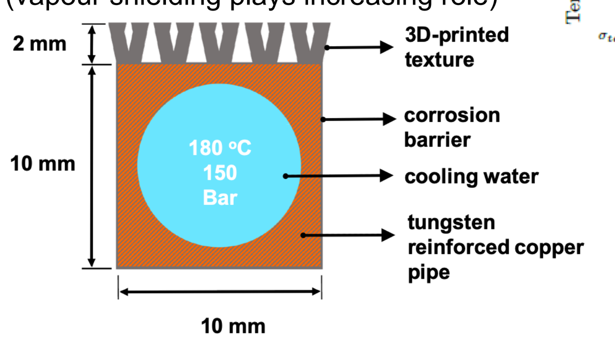
EEG: Target design studies complementary to the WPLMD activities

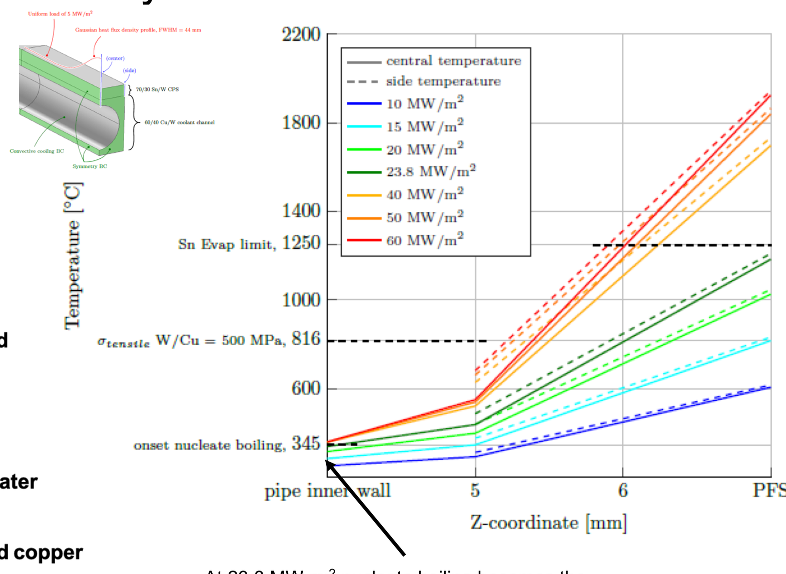


Normal operation up to 24 MW m^{-2} before onset nucleate boiling (slow transient only)

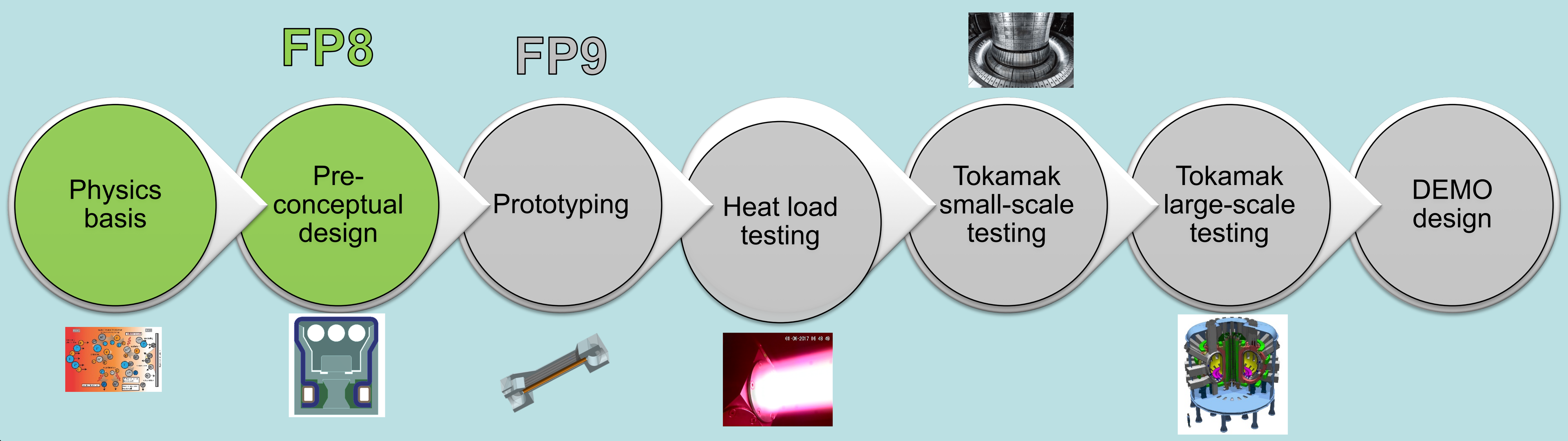
- Temperatures still below Sn evaporation limit

Target only damaged at 56 MW m^{-2} due to CHF reached (vapour shielding plays increasing role)





At 23.8 MW m^{-2} nucleate boiling becomes the limiting factor (only allowed during off normal events)

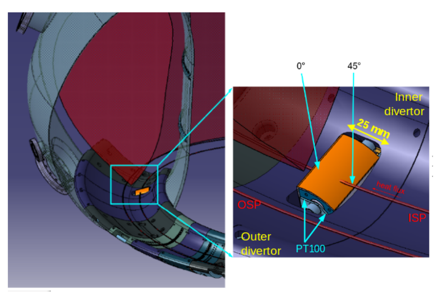


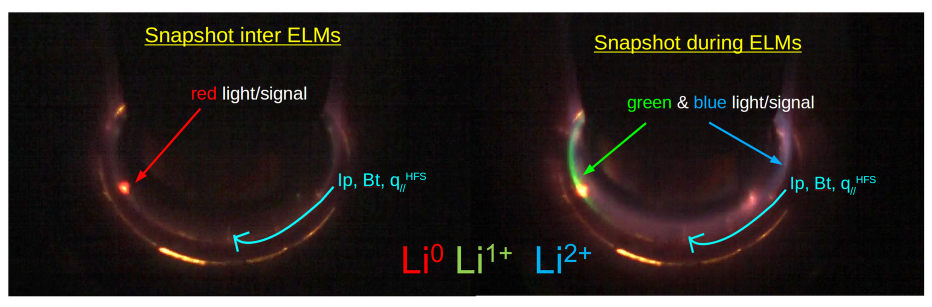
Safety

- Tritium retention
- Safety analysis

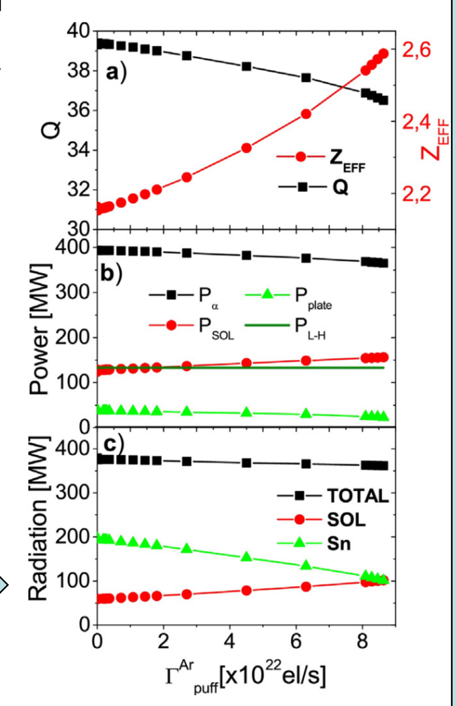
Performance Optimization & Management

- Power handling with Li and LiSn divertor modules in COMPASS under *ELMy H-mode*
  - q// < 25 MW/m^2 (steady-state inter ELMs) and E_{elm} = 15 kJ.m^2 (= ELM peak energy fluence)
  - No mesh damage; good power handling capability for both Li and LiSn up to q_dep = 12 MW/m^2
  - No droplet ejected and no Sn contamination of core/SOL plasmas





- High heat load experiments in quasi-stationary plasma accelerators QSPA Kh-50 and QSPA-M (KIPT)
- Simulations of disruptions (TOKES code: KIT)
- Pumping performance (DIVGAS modelling: KIT)
- Measurement of H solubility in Sn (JSI) IJS
- Influence of seeding impurities on core impurity and fusion performance with LMs:
  - *COREDIV: use of Sn can be compatible with good core performance using Ar seeding* IFPiLM
  - Figure right: deliberate scenario with v. high Sn source (T_{cool}=500 ºC, T_{surf}~2000 ºC)



- Investigate SOL and divertor conditions (TECXY and SOLPS-ITER) IFPiLM ENEA
- MHD stability of pores and dynamics of pore replenishment (NCSRD)
- Study and model microchannel flow and stability (IST & ISSP.UL)

KIT Karlsruher Institut für Technologie

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