21st Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating – June 20-24, 2022, IO, France

High power mm-wave loss measurements of ITER ex-vessel waveguide component prototypes at the FALCON test facility in Lausanne Switzerland

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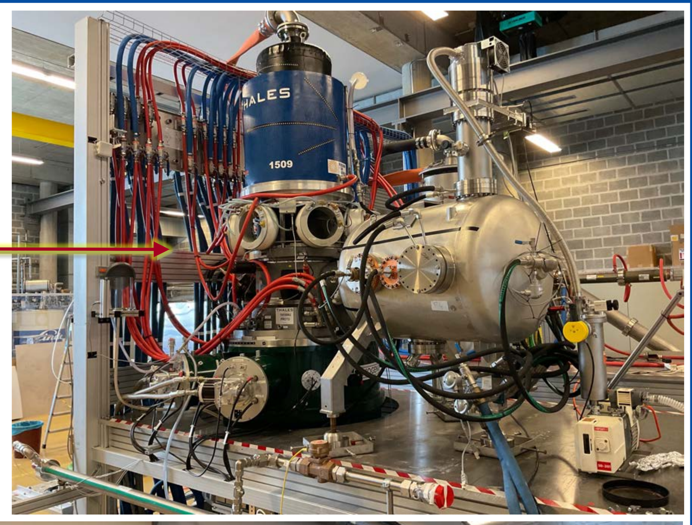
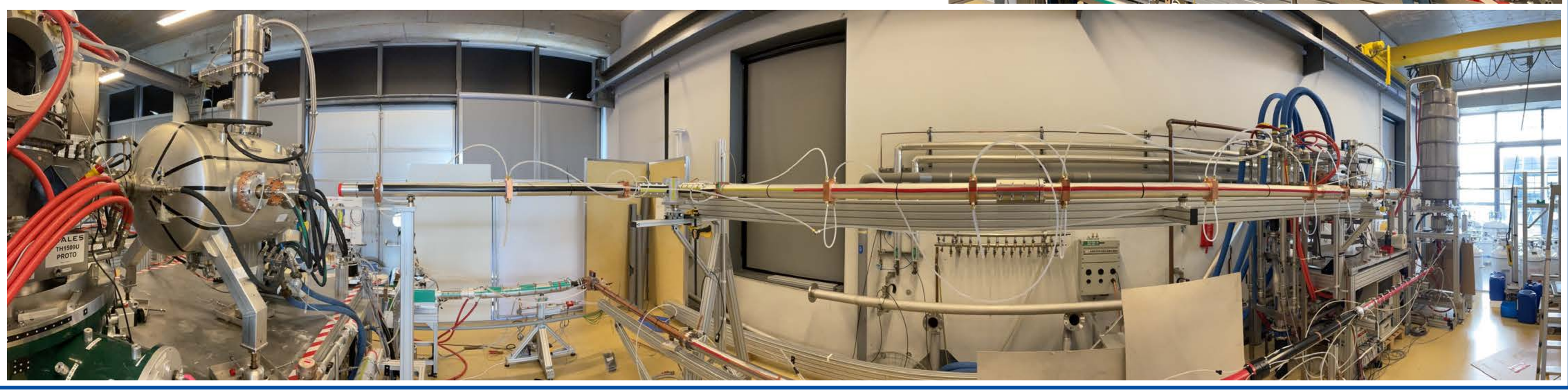
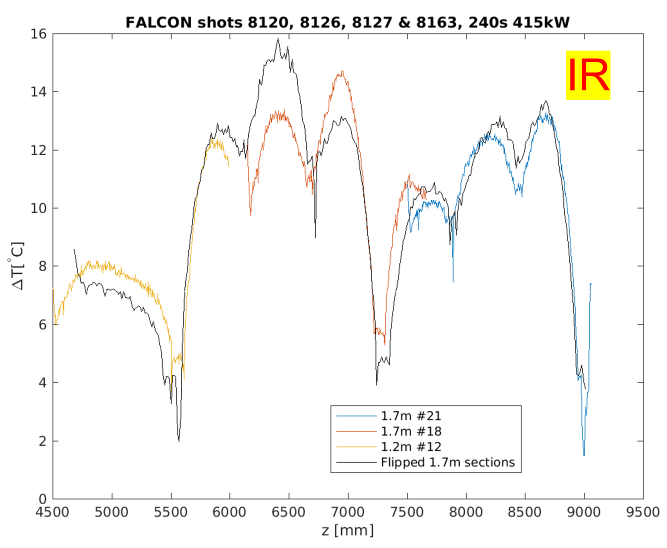
1 FALCON Test Goals

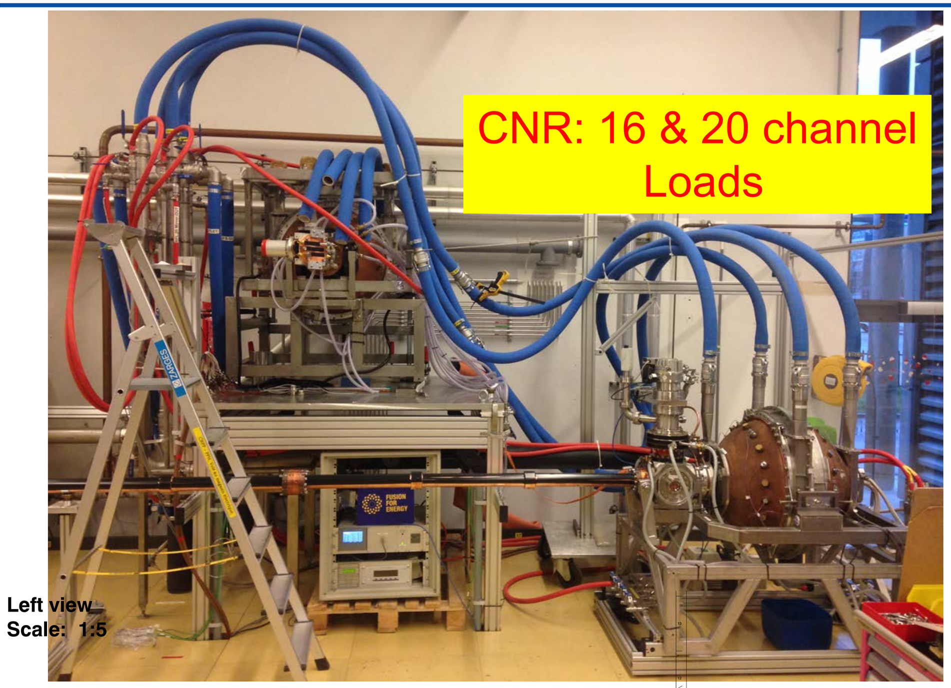
- Components for ITER Upper Launcher (includes ex-vessel waveguides and Calorimetric Loads)
- ITER EU gyrotron
- Control system for EC gyrotrons
- EC system components for other ITER partners
- Training for staff from ITER and DTT: operations ➛ acceptance testing

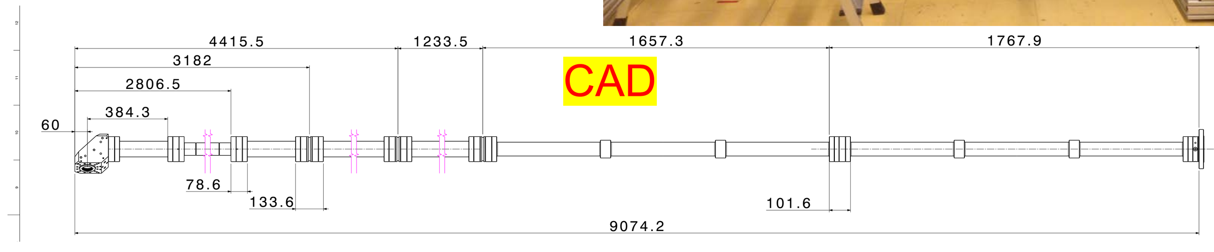




2 Configurations



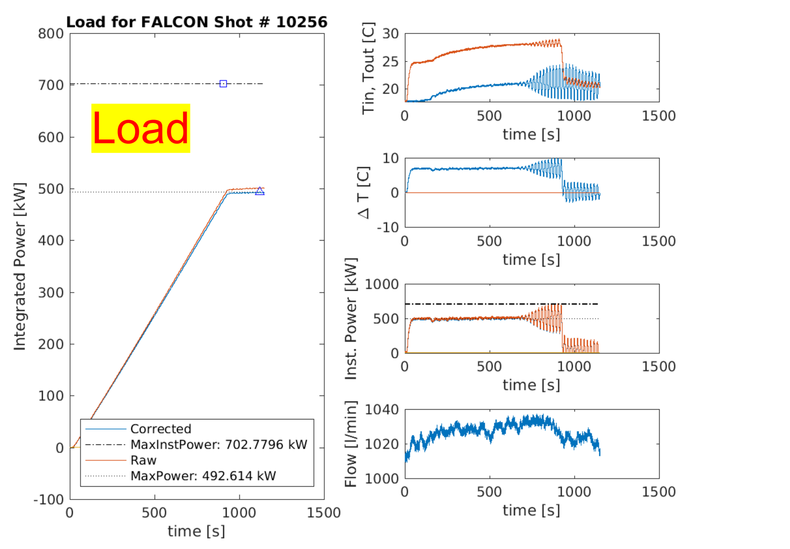




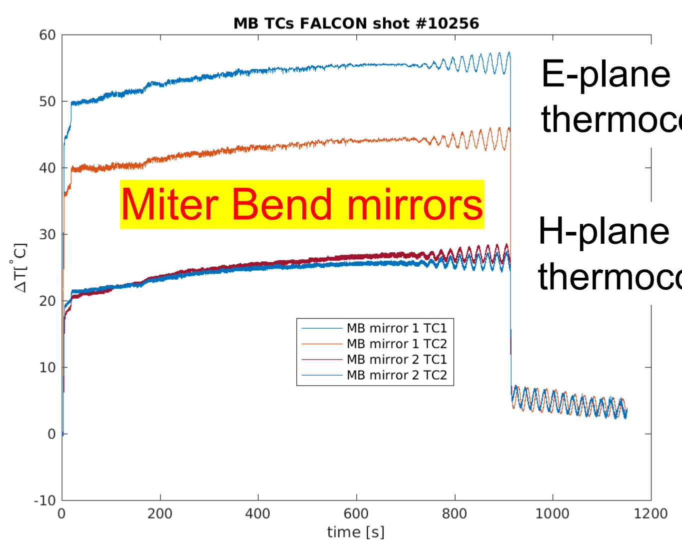
18 config.s used to date

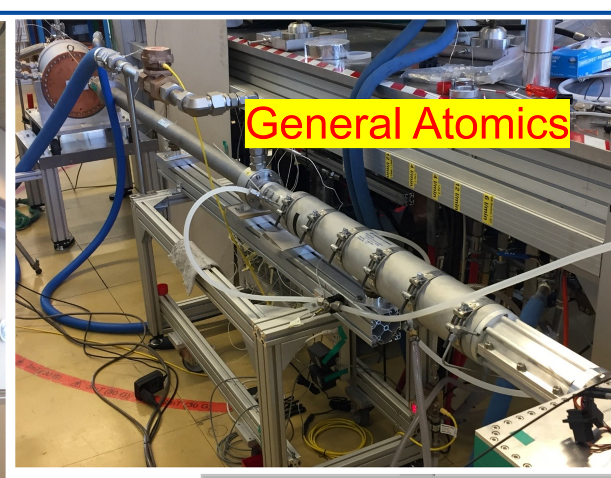
3 Load / Miter Bend results

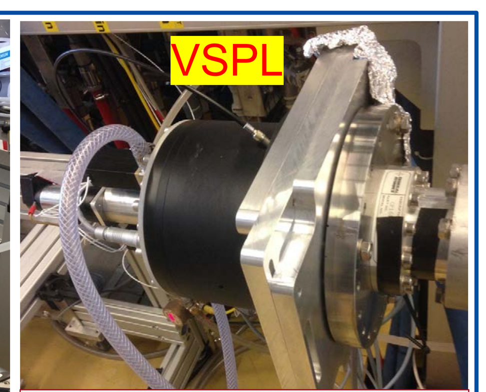
Calorimetry of 0.5MW and ~1000s pulse



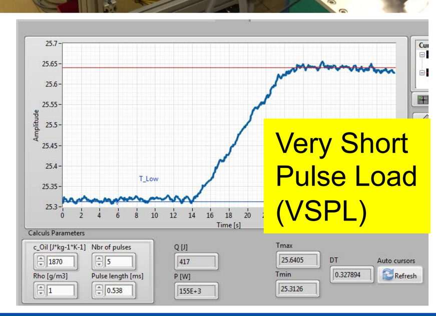
Temperature oscillations water and metal result from heat exchanger feedback loop.

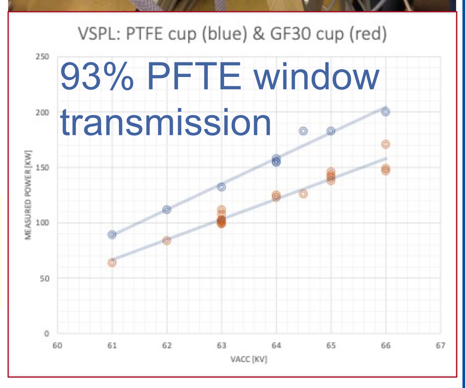




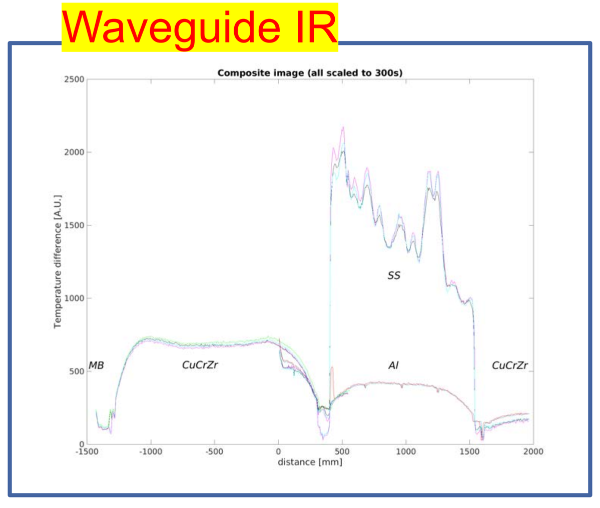


5 pulses of 538µs





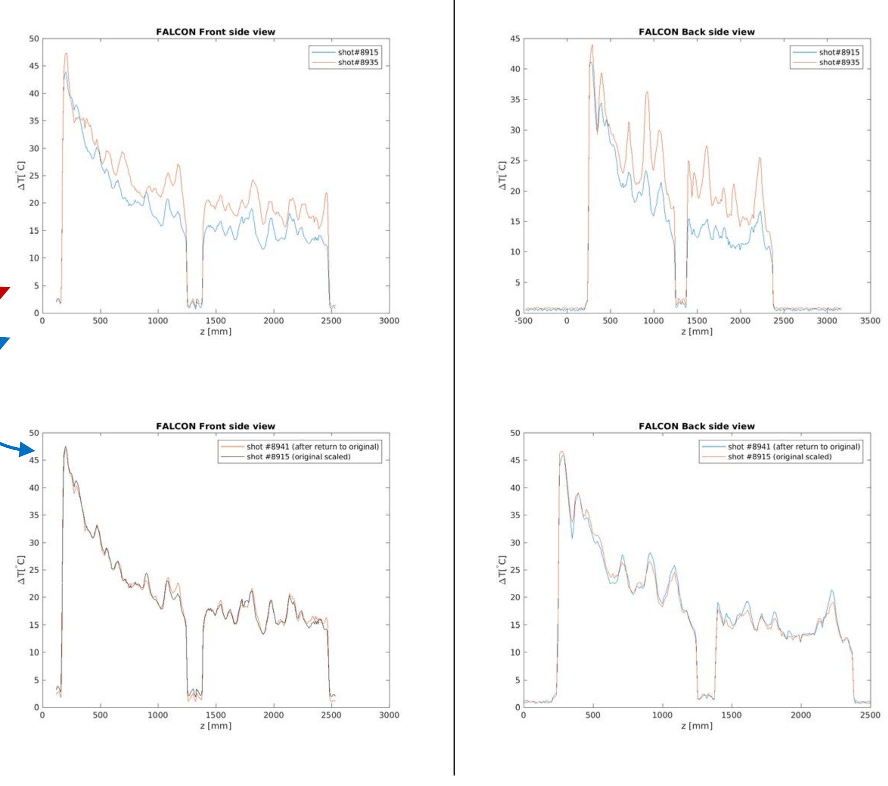
4 WG results



A

- Various WG materials, lengths & diameters, location relative to the MB.
- Stainless steel (ss): bumpy temperature profile.
- High diffusivity Al or CuCrZr: no bumps

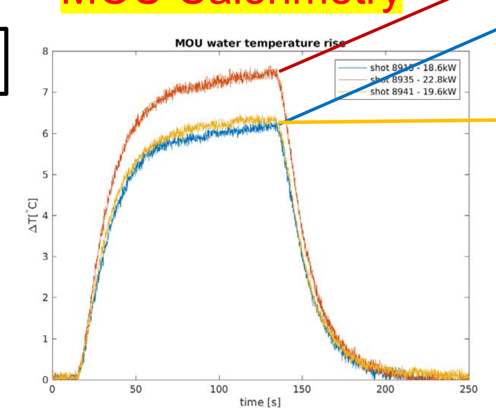
Front side | Back side



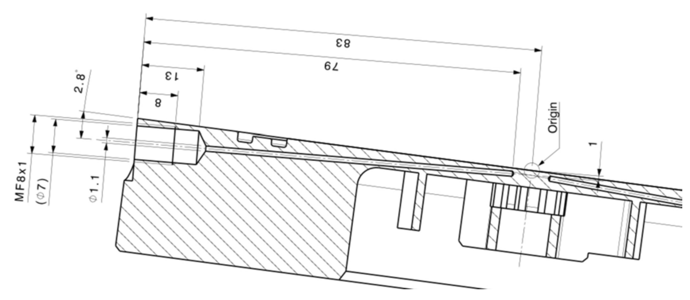
The **modified** MOU mirror angles change the modes in the TL: seen on the front and back side of the SS waveguide.

Original MOU mirror alignment is recovered as evidenced by the return to the previous WG heating pattern (front and back).

B



- Bumps due to known [1] off-axis heating on the MB?
- **Test**: Change MOU mirror angle
- **Results**:
  - Power lost in the MOU **increases**
  - Lower loss **recovered** when moved back



MB mirror design

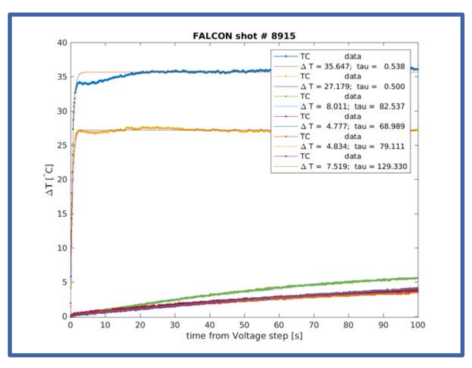
C

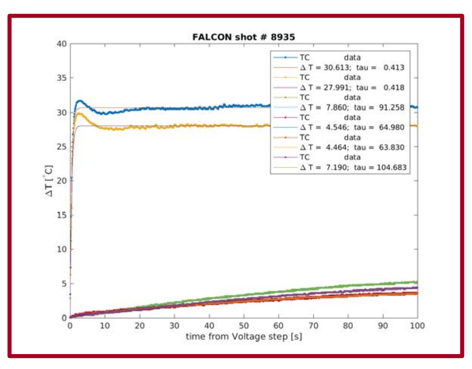
2 thermocouples (TCs) embedded in mirror: 4mm from center; 1mm behind the reflecting surface.

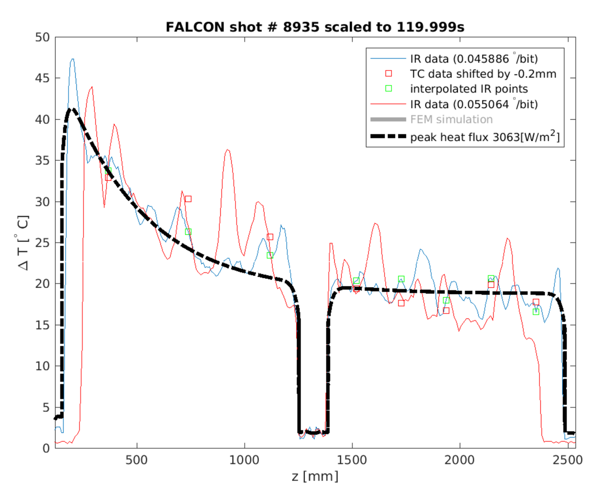
D

Original angles: higher temperature difference between TCs
Modified angle: decreased temperature difference ➛ beam more centered

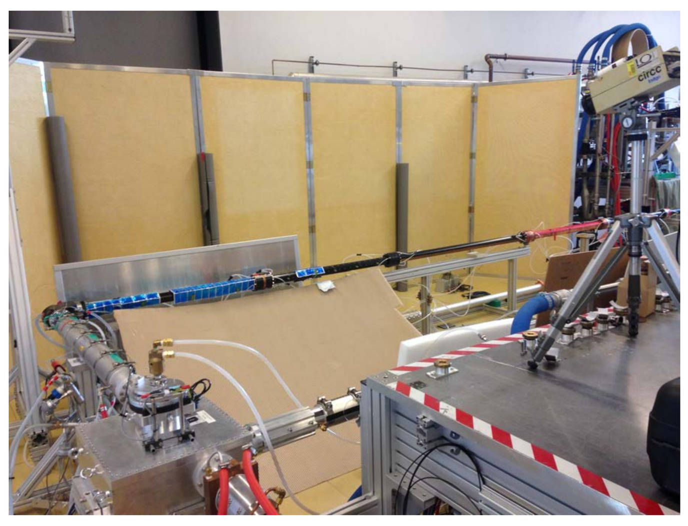
Miter Bend Thermocouples







Modeled with COMSOL: smooth exponentially-decaying heat flux + constant baseline.



5 Conclusions

- Successful ~0.5MW testing of ITER UL components; Successful 1MW eligibility tests of Thales Electron Devices TH1509 for ITER and DTT.
- The 4 loads tested measure the same power (within ~4%) at the same gyrotron operating point in very long (100s of seconds) and very short (100s of µs) pulses.
- SS WG evidences Higher Order Modes in the waveguide through “frozen in” heating pattern; High conductivity materials do not show detailed patterns.
- SS has shorter exponential decay from MB than previously reported [2,3] in larger diameter Aluminum transmission lines.
- Misaligning the beam in the MOU, centers the beam on the MB mirror, changes the local HOM heating pattern, but does not strongly change the total TL losses.
- MB diffraction losses exceed pure HE11-mode theory by a factor of 1.3 to 2.3 times, depending on the MOU alignment.
- WG losses (far from MBs) exceed pure HE11-mode theory by a factor of 7.3 to 8 times, depending on the MOU alignment.

References

[1]	A. Xydou, *et al.*, Fusion Engineering and Design 170 (2021) 112457
[2]	K. Takahashi, *et al.*, Rev. Sci. Instrum. 82, 063506 (2011); https://doi.org/10.1063/1.3599418
[3]	T. Kobayashi, *et al.*, Fusion Engineering and Design 175 (2022) 113009

This work was supported in part by the Swiss National Science Foundation. This work has been carried out in the context of F4E-OFC-671-03/04 task orders which has been funded with support from Fusion from Energy. The views and opinions expressed herein do not necessarily reflect those of the European Commission, Fusion for Energy or the ITER organization.

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