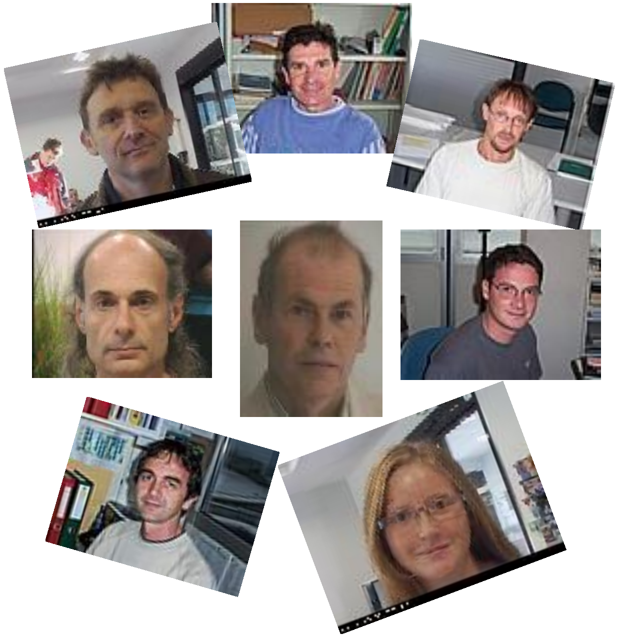
ESRF | The European Synchrotron

Coaxial tunnel roof feed-through and its cooling



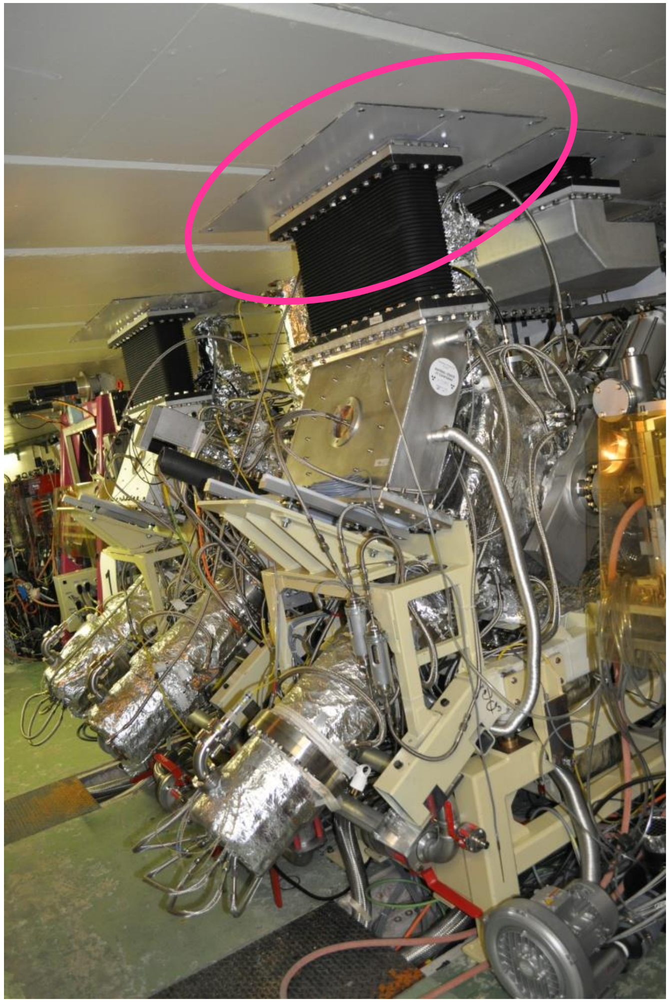
Participants:

- ➢The RF group with special thanks to Pierre Barbier, Vincent Serriere, Philippe Chatain, Claude Rival, Didier Boilot and Bernard Cocat.
- ➢Perrine Ponthenier for her large input in the mechanical design.

Coaxial tunnel roof feed-through and its cooling

Motivation: decrease the size of the holes in the tunnel roof

✓Easier X-ray shielding
✓Stronger concrete roof



ESRF operates at 352.2 MHz.
The waveguide size is WR2300 half height in the tunnel and WR2300 full height above the tunnel.
The EBS upgrade will feature series of 5 cavities side by side.
Going through the roof with a coaxial line seems an interesting alternative.

Power specifications:

- ✓These cavities can sustain 110 kW with the present coupling.
- ✓The ELTA SSA are designed for 150kW.

mode	FWD P	REF P	VSWR	Eq. power
multi-bunch	110.0 kW	15.5 kW	2.2	208.0 kW
16 bunches	84.1 kW	24.2 kW	3.31	198.4 kW
4 bunches	69.9 kW	25.9 kW	4.11	180.9 kW

mode	FWD P	REF P	VSWR	Eq. power
multi-bunch	150.0 kW	21.1 kW	2.2	283.6 kW
16 bunches	114.7 kW	33.0 kW	3.31	270.6 kW
4 bunches	95.3 kW	35.3 kW	4.11	246.6 kW

$$P_{VSWR} = P_{VSWR=1} * \left(\frac{VSWR+1}{2*VSWR} \right)^2 = \left(\sqrt{P_{FWD}} + \sqrt{P_{REF}} \right)^2$$

6”1/8 or 100/230

6”1/8:

manufacturer	Peak power	CW Power
SPINNER	7 MW	118 kW
MEGA	3 MW	100 kW

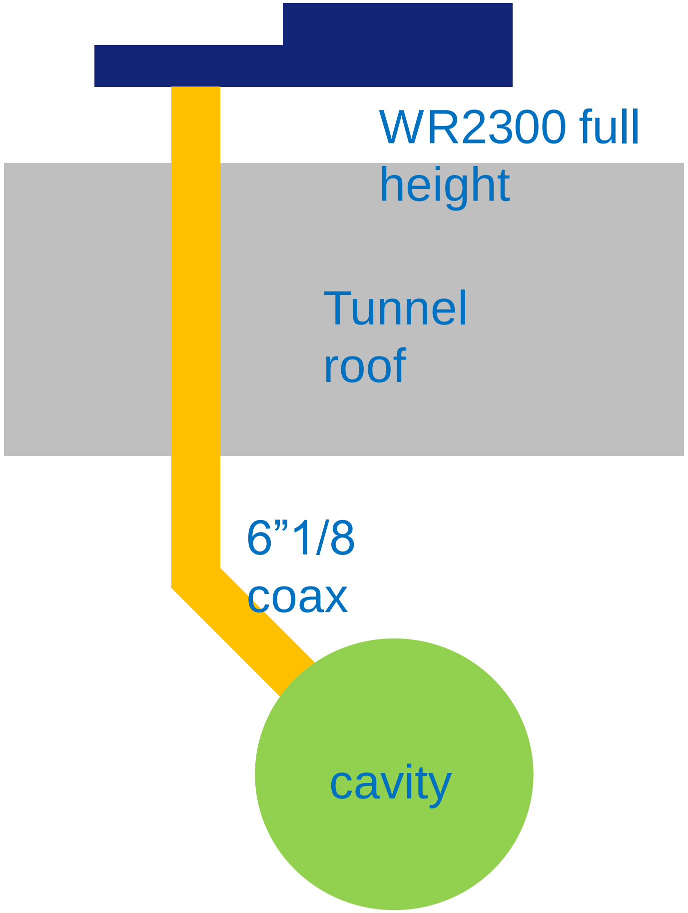
100/230:

manufacturer	Peak power	CW Power
SPINNER	15MW	260 kW
MEGA	6MW	200 kW

FORCED COOLING is MANDATORY!

Coaxial tunnel roof feed-through and its cooling

A single waveguide to coax transition could be enough.



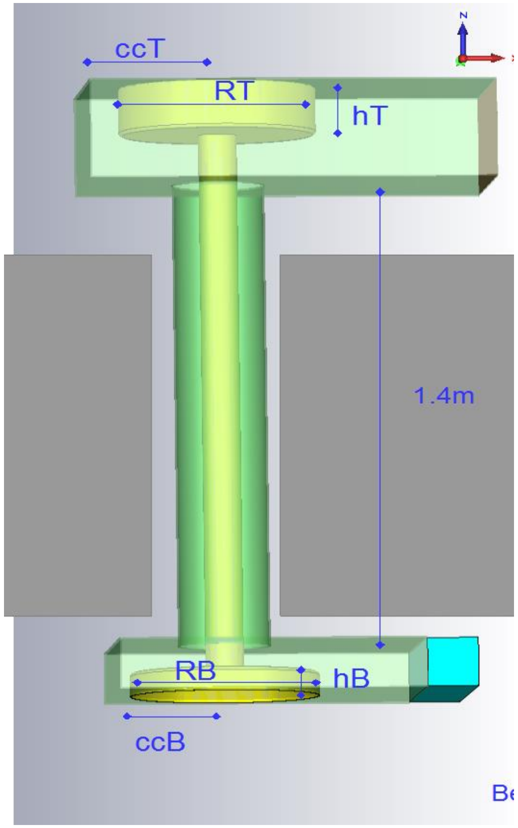
This solution would include a change of all ESRF couplers and would hence be expensive.

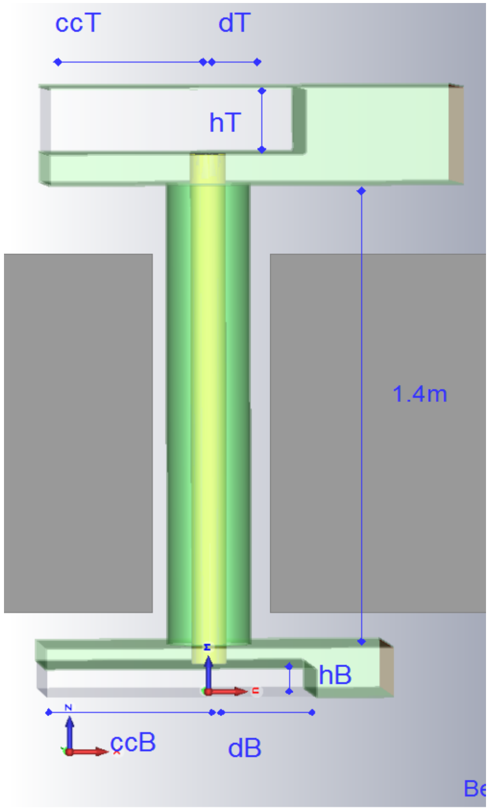
Coaxial tunnel roof feed-through and its cooling

The tunnel feed-through must comply with 2 constraints:
- ✓matching
- ✓temperature

4 options were studied

Coaxial size: 6”1/8 or 100/230
Matching: door knob or step

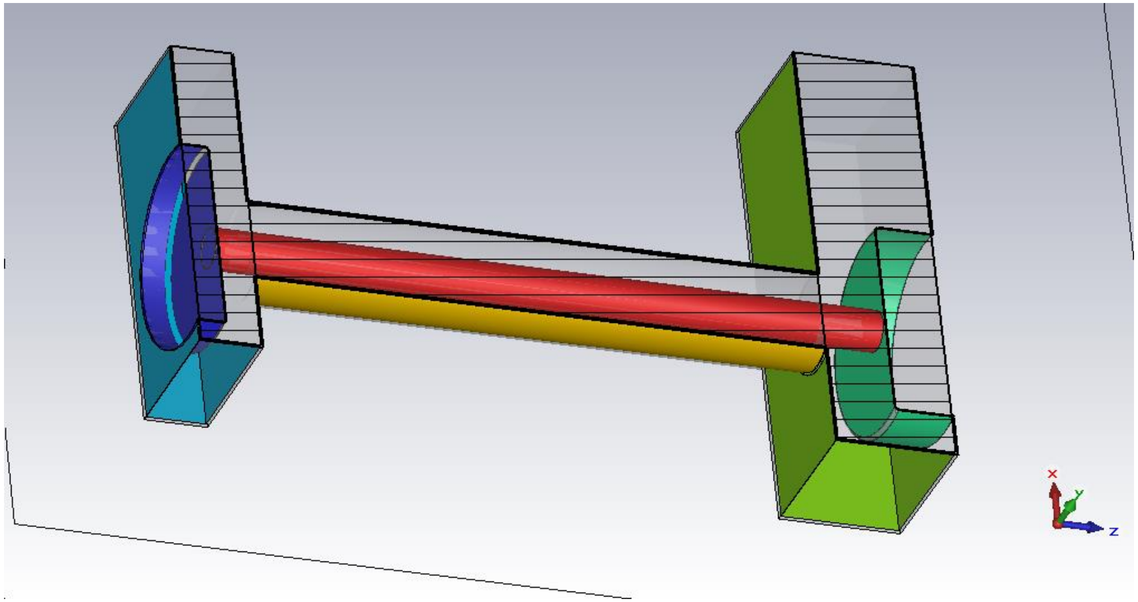


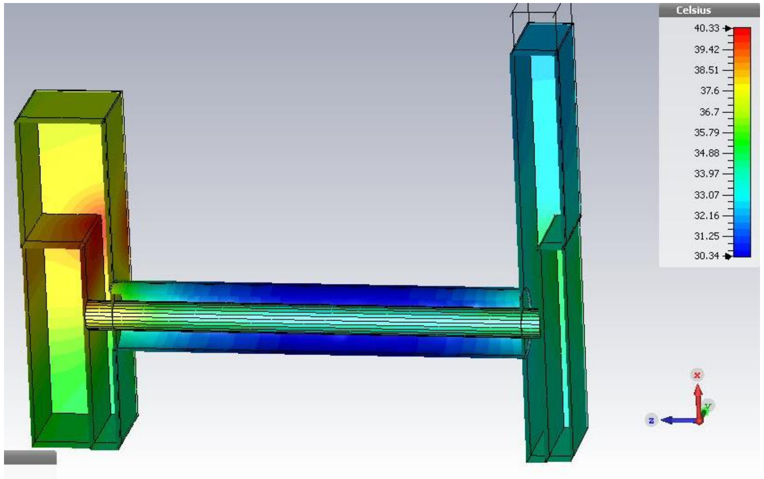


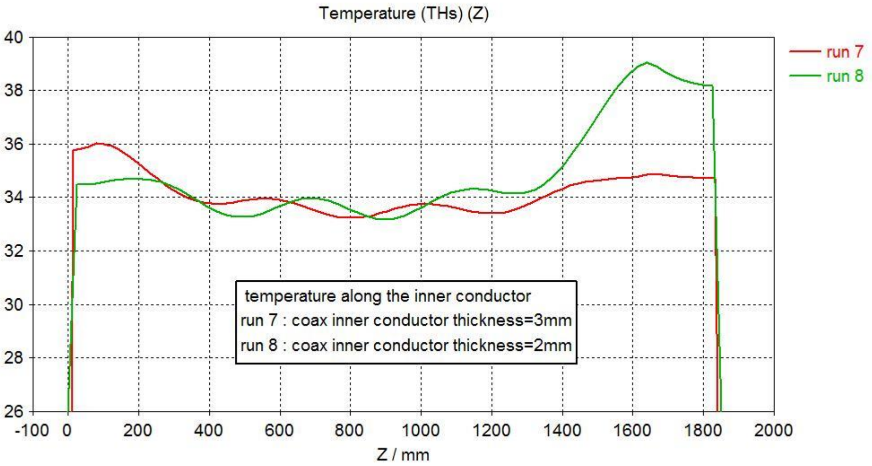
Coaxial tunnel roof feed-through and its cooling

Computation with CST µwave.

✓Frequency solver
✓Tetrahedral auto adaptive mesh
✓Multi-physic solver taking the RF currents into account with the capability to enter heat exchange factors and thermal boundaries with fixed temperatures.

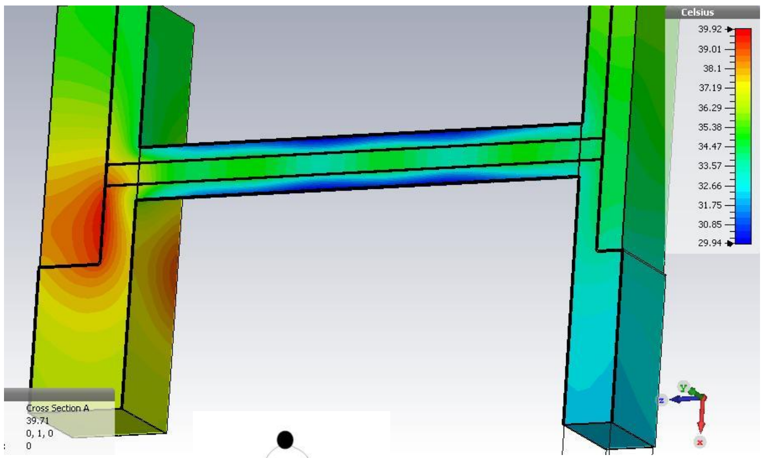






Coaxial tunnel roof feed-through and its cooling

The simulation of the VSWR was made with a variable length of absorber. Its phase was depending on its location. All the following results were computed with 500m3/h of air cooling.



Max temperatures

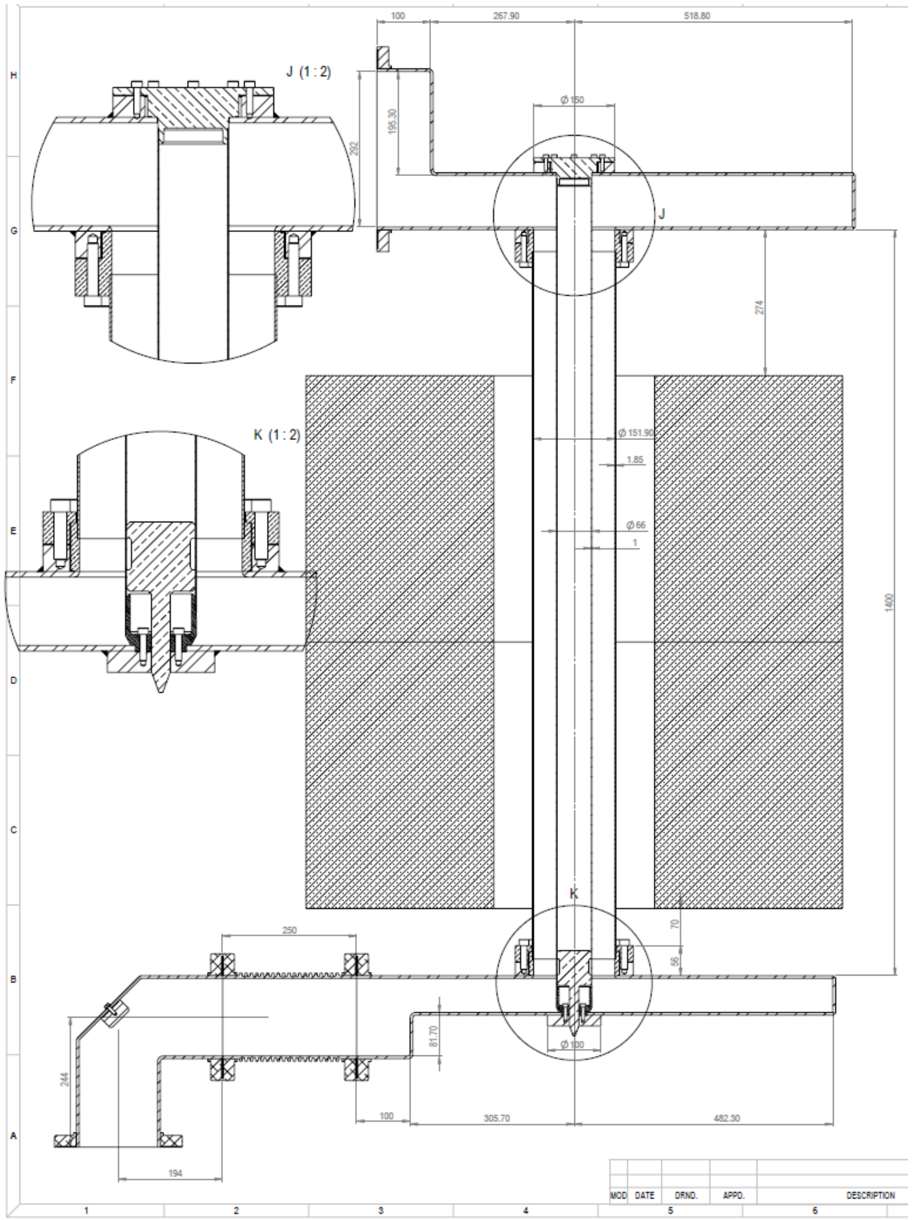
COAX	110kW REF -8.5dB		150kW REF -8.5dB	
	cylinder	parallepi.	cylinder	parallepi.
100/230	40.8C	40.3C	46.2C	45.5C
6”1/8	37.5C	41.6C	39.9C	45.0C

Max field at 110 kW

COAX	Bottom		Top	
	cylinder	parallepi.	cylinder	parallepi.
100/230	213 kV/m	239 kV/m	212 kV/m	259 kV/m
6”1/8	184 kV/m	225 kV/m	175 kV/m	256 kV/m

All 4 options were technically viable. The 6”1/8 is chosen because the hole in the roof is smaller. A step matcher is far less expensive than a door knob matcher.

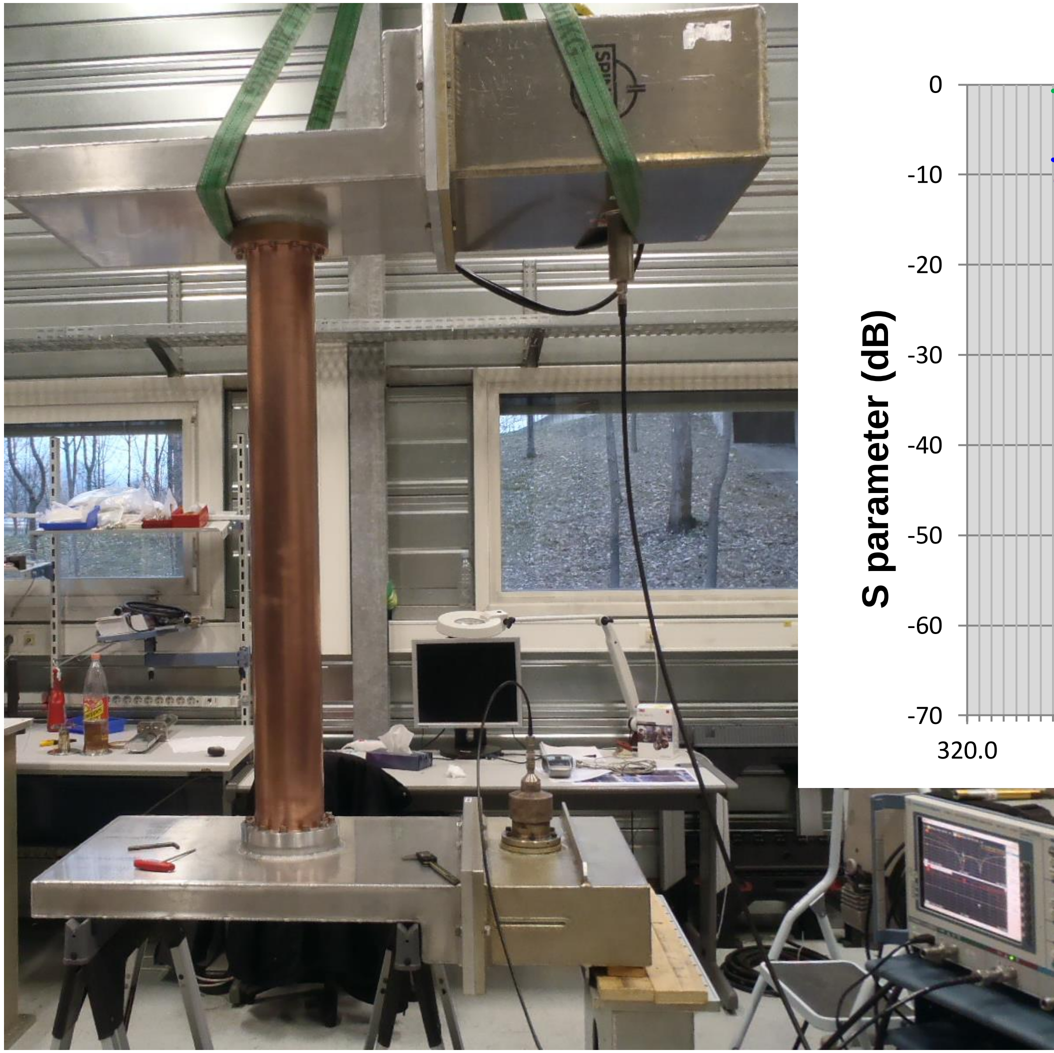
Coaxial tunnel roof feed-through and its cooling



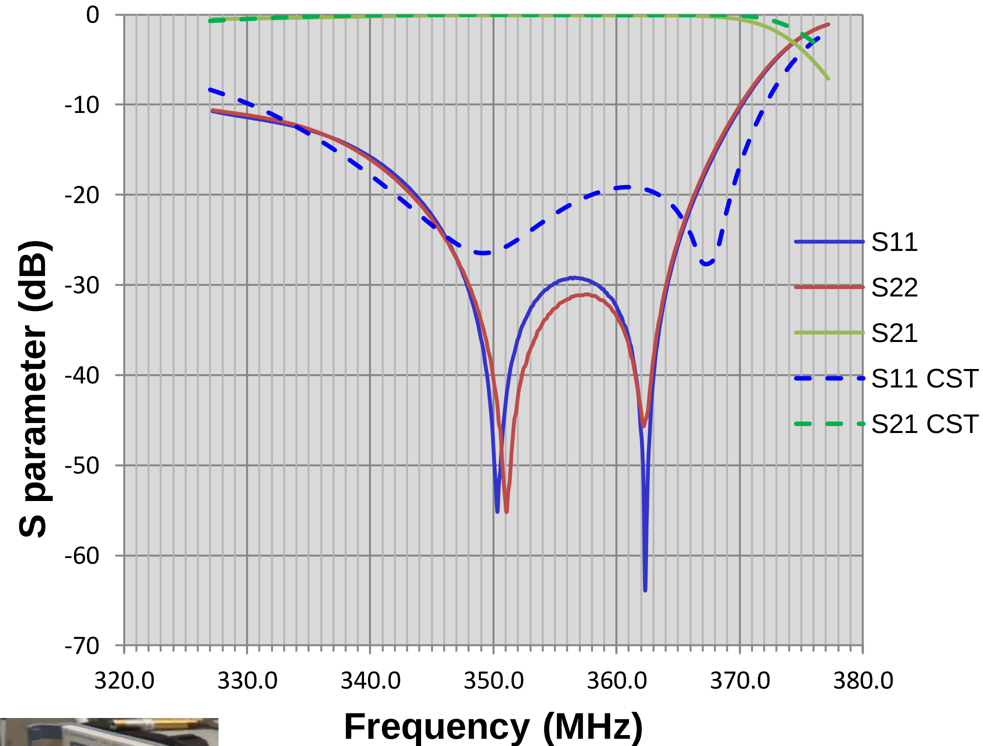
Design peculiarities:

✓No PTFE spacer
✓6"1/8 coax line from SPINNER
✓Rings on inner and outer coaxial line soldered with Sn-Pb
✓Bottom anchor from SPINNER

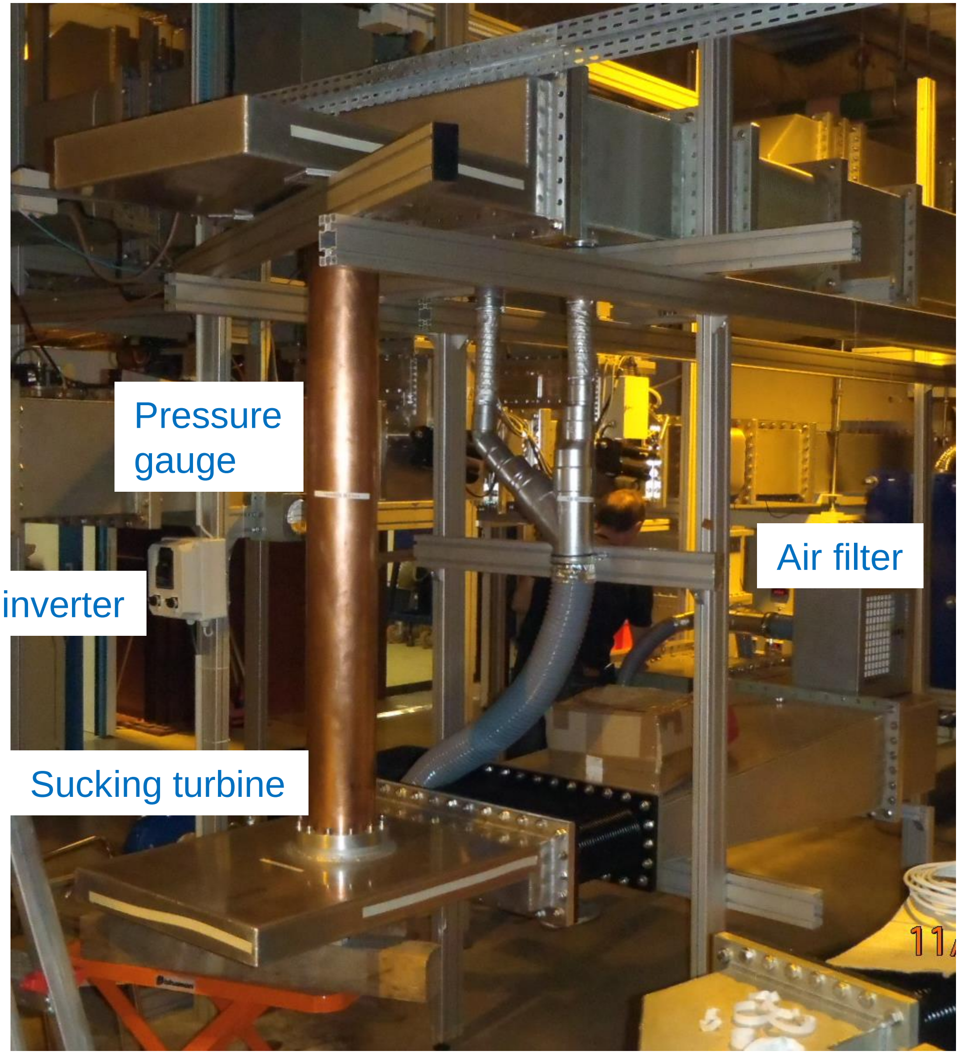
Coaxial tunnel roof feed-through and its cooling

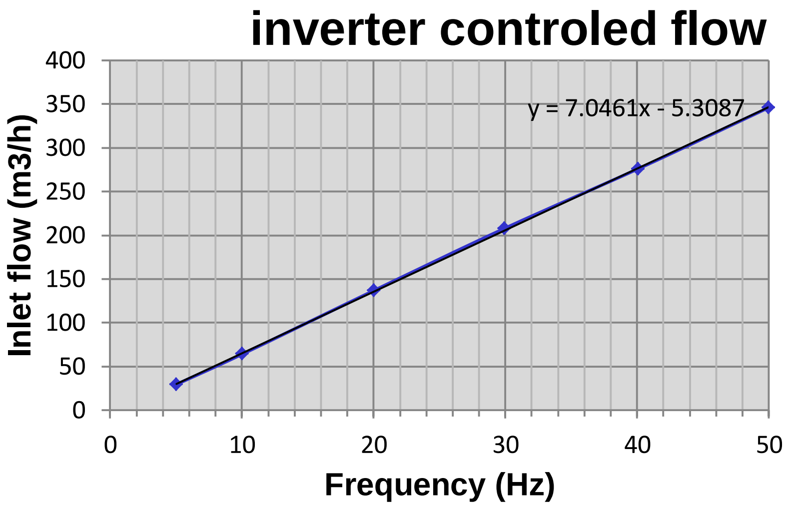


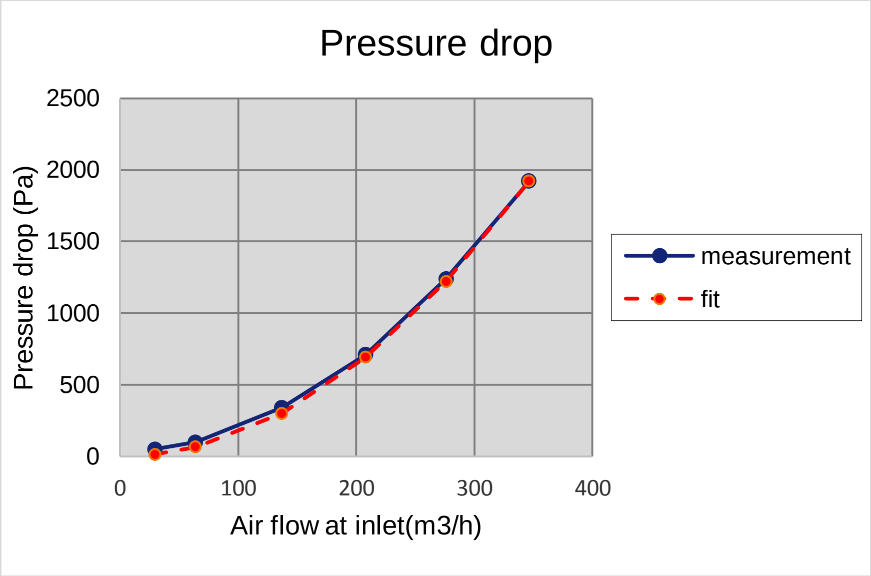
coax transition S parameters



Coaxial tunnel roof feed-through and its cooling





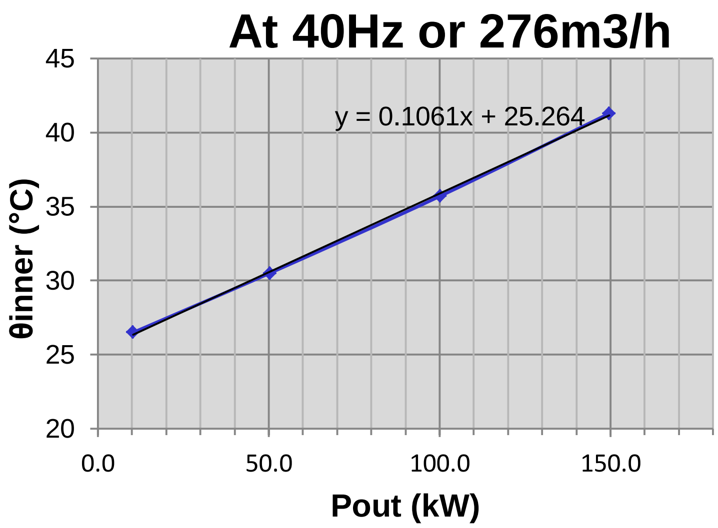


Air flows are really difficult to evaluate.

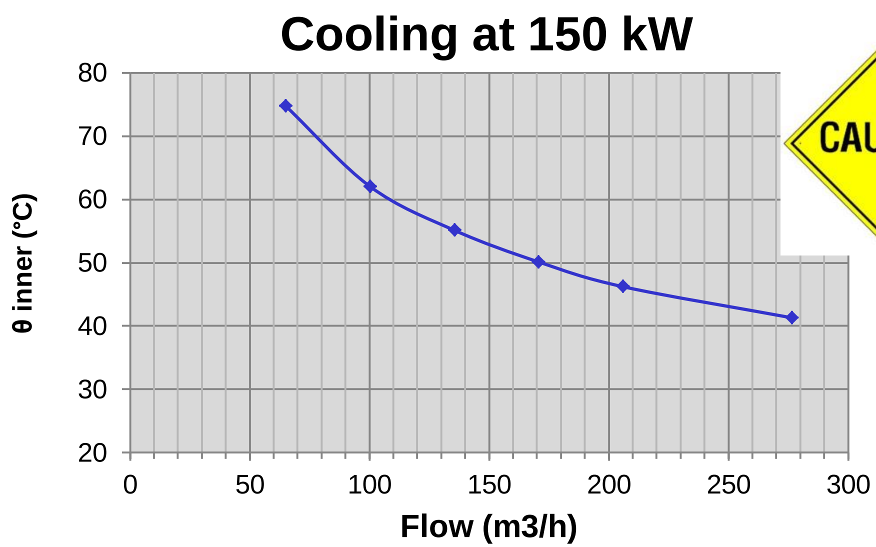
Coaxial tunnel roof feed-through and its cooling

Power tests in matched condition:

	Inlet A	Inlet B	Outlet A	Outlet B
Radiation leakage	2 µW/cm²	0.4 µW/cm²	0.6 µW/cm²	1.5 µW/cm²



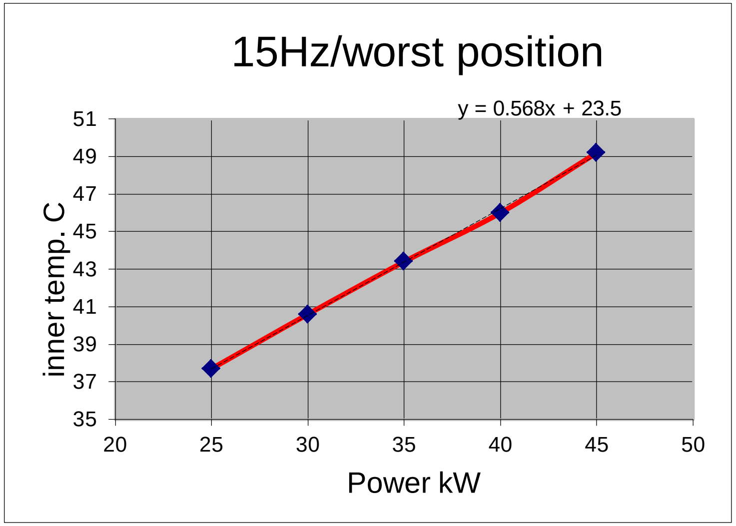
There is a linear dependency between the temperature of the inner conductor and the power.
The inner conductor temperature was measured with an optic fiber probe.

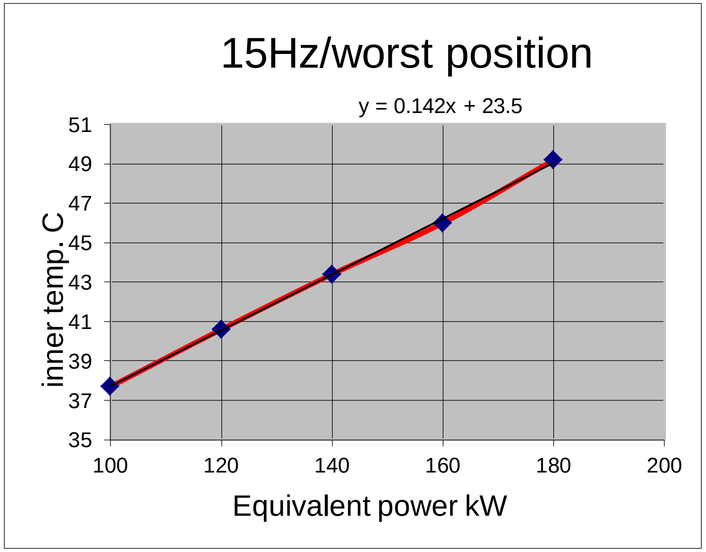


The temperature rises quickly if the air flow is less than 100m3/h.
Turbulent → laminar?

Coaxial tunnel roof feed-through and its cooling

Power tests <u>with full reflection</u> performed at 15Hz (about 100 m3/h): achieved with a tunable short termination





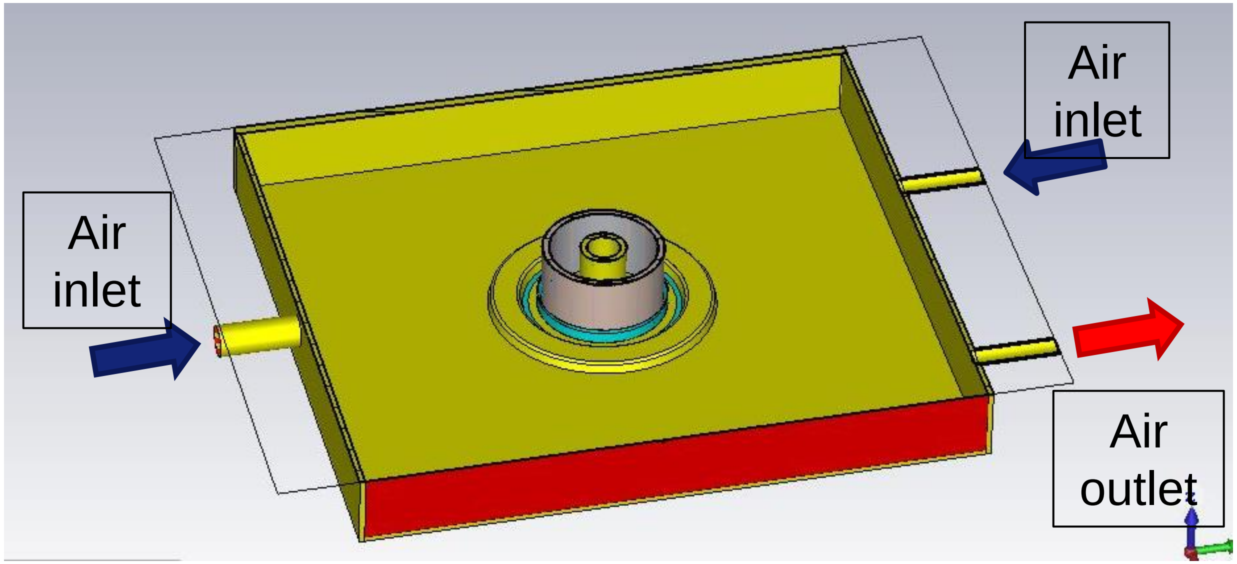
As the temperature probe could not be moved, the temperature depends on the short-circuit setting.

$$P_{eq} = \left(\sqrt{P_{FWD}} + \sqrt{P_{REF}}\right)^2$$

With an equivalent power of 283 kW, the temperature would not rise above an acceptable 64º.

Coaxial tunnel roof feed-through and its cooling

Present cooling scheme:



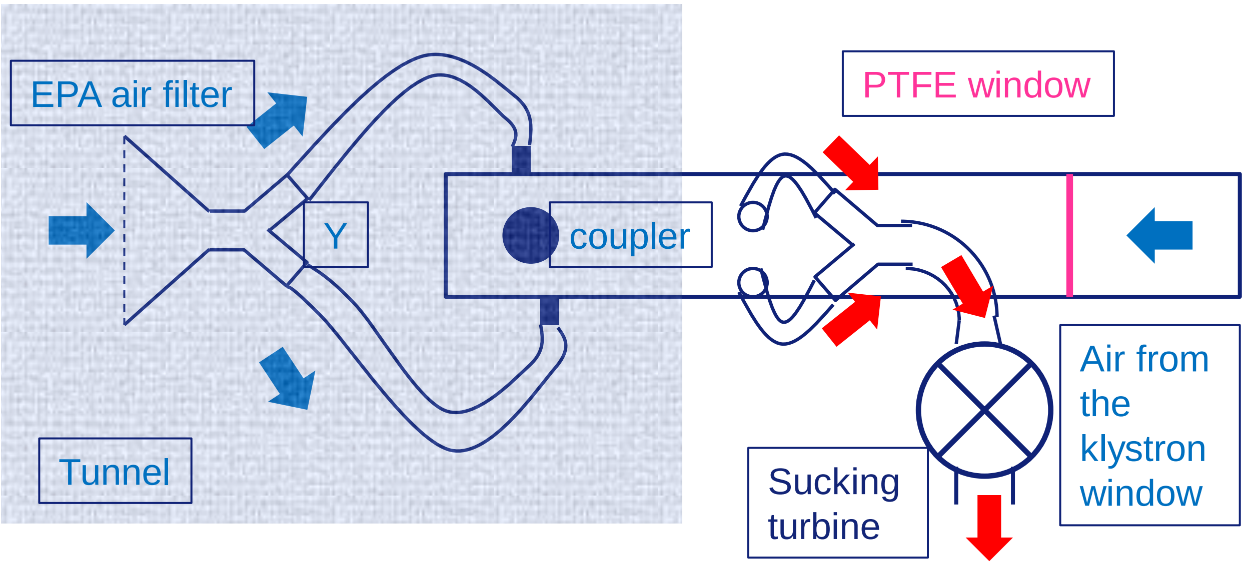
The air is taken in the tunnel, filtered with a truck filter, compressed with an ELMO-RIETSCHLE turbine, divided with a T and blown on the coupler insulator. The exhaust is in the tunnel. The pressure drop is high, due to the small diameter of the inlet and outlet pipes (26mm ID).

	Single cell cavity	5 cells cavity
Air flow	100 m3/h	50m3/h

The air speed is measured with a Pitot tube at the outlet and integrated.

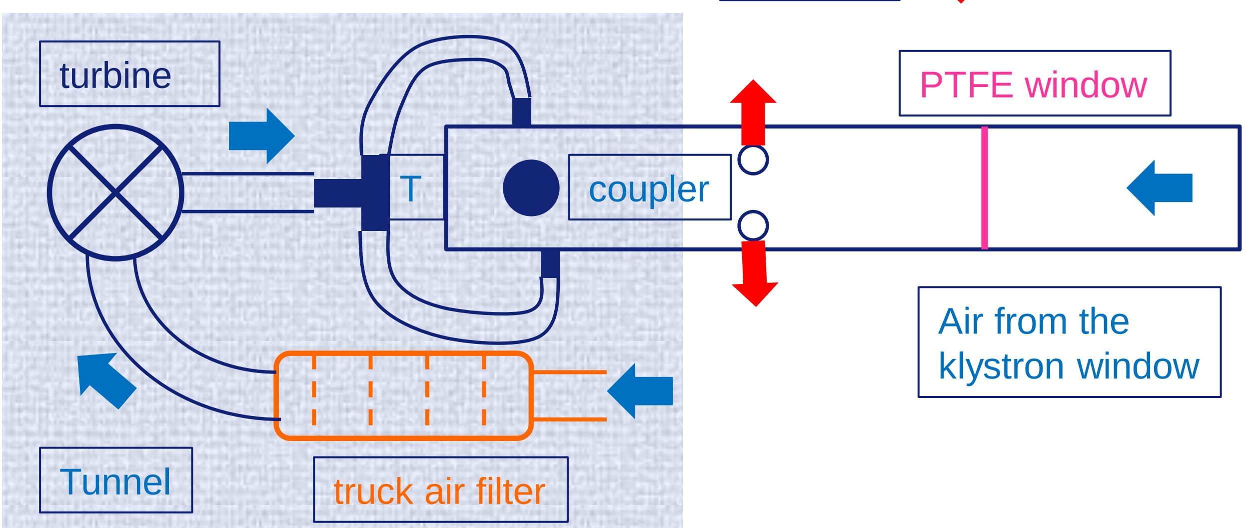
Coaxial tunnel roof feed-through and its cooling

Cooling schemes:



The air is taken from the tunnel, divided with a Y and blown on the coupler insulator. It cools the waveguide including the coaxial line, is sucked by a turbine outside the tunnel

✓Low pressure drop due to bigger IDs.
✓The heat is rejected out of the tunnel.
✓Easier maintenance of the turbine.

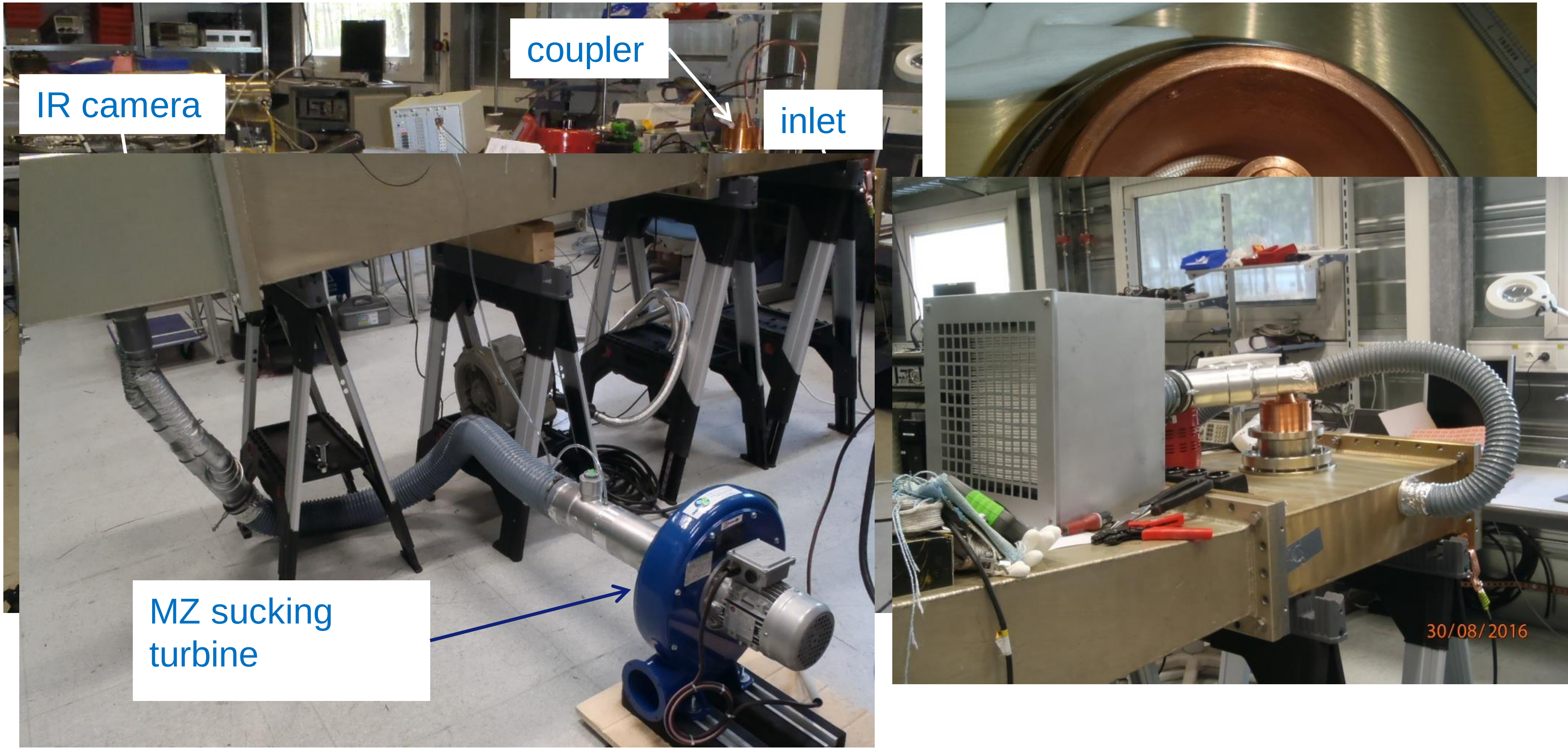


The air is taken in the tunnel, compressed with a turbine and blown on the coupler. It cools the waveguide including the coaxial line and escapes out of the tunnel.

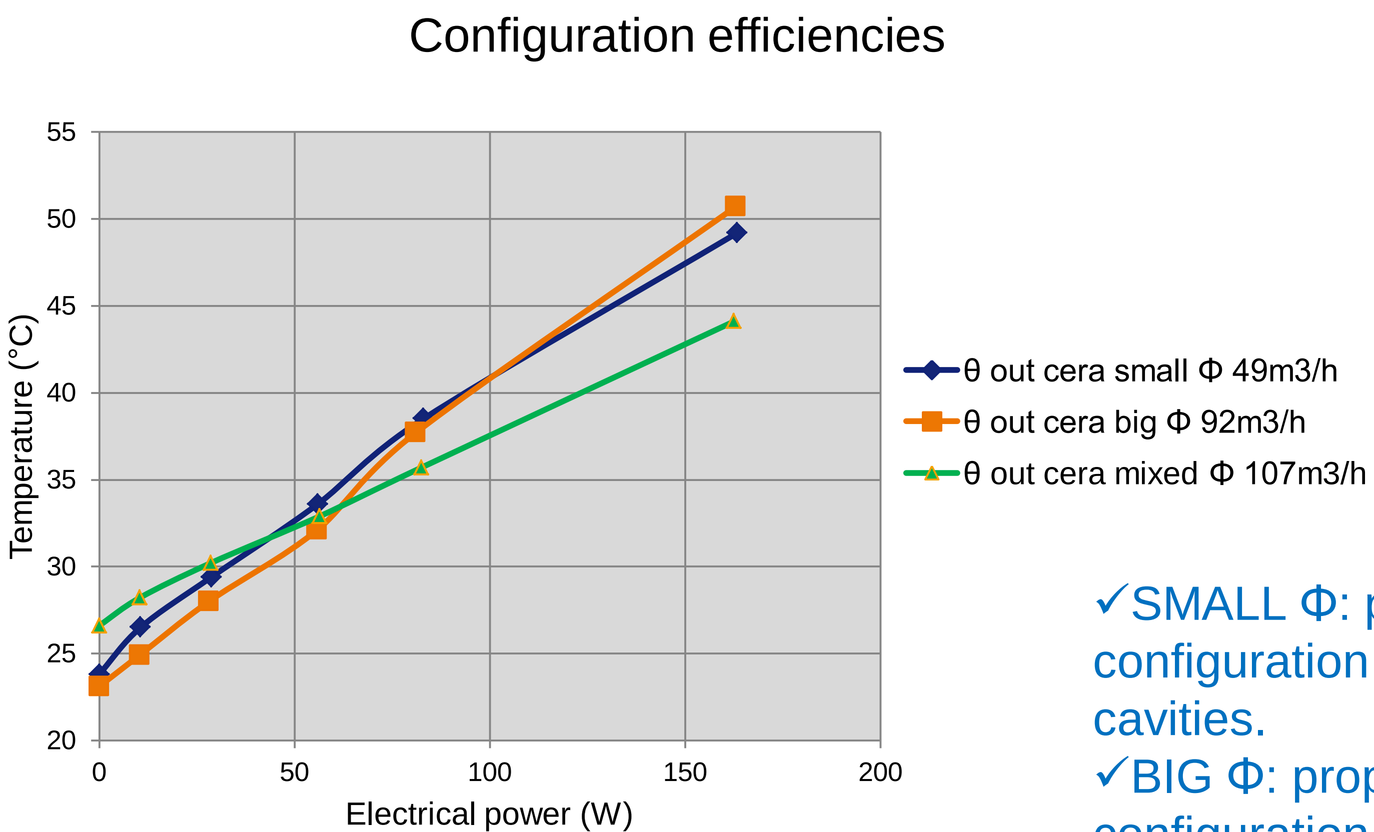
✓Part of the heat is rejected out of the tunnel.

Coaxial tunnel roof feed-through and its cooling

An experimental set-up was installed in the lab to assess cooling efficiency

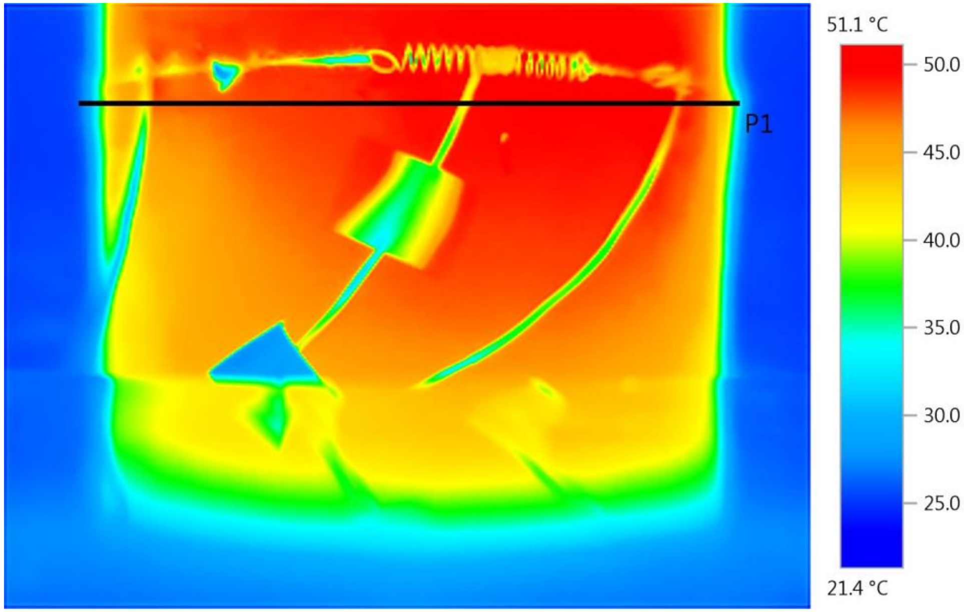


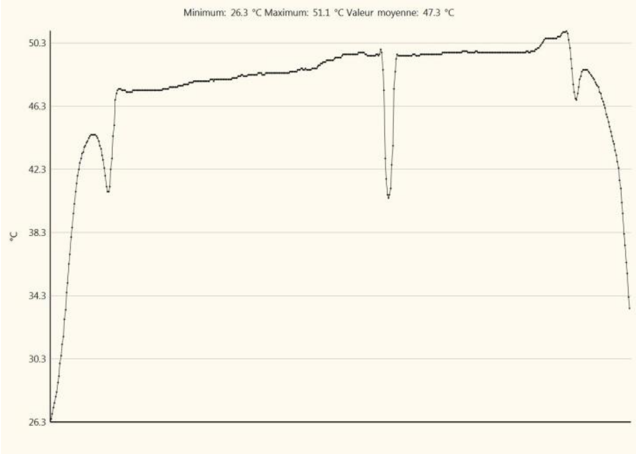
Coaxial tunnel roof feed-through and its cooling



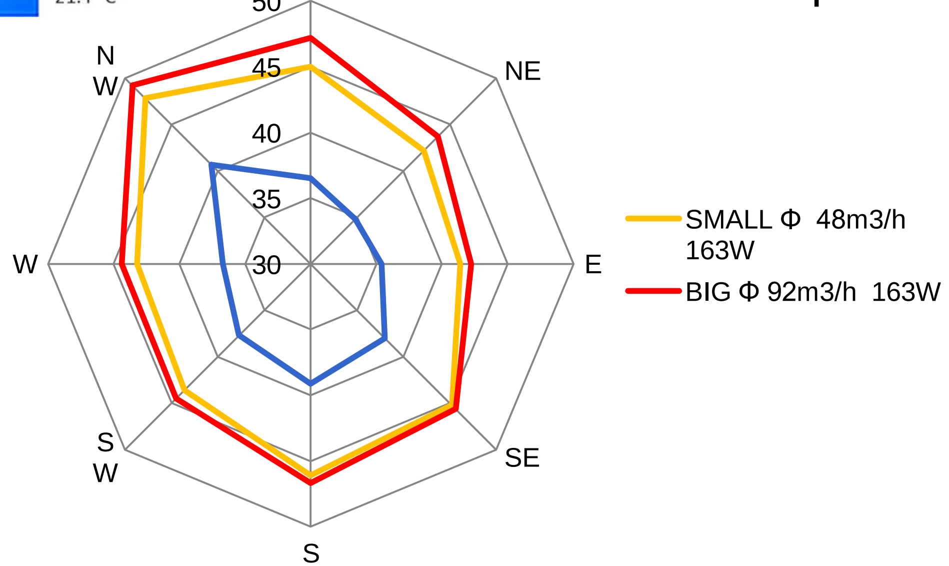
- ✓SMALL Φ: present configuration on 5 cells cavities.
- ✓BIG Φ: proposed configuration with sucking turbine.
- ✓MIXED Φ: proposed configuration with compressor.

Coaxial tunnel roof feed-through and its cooling



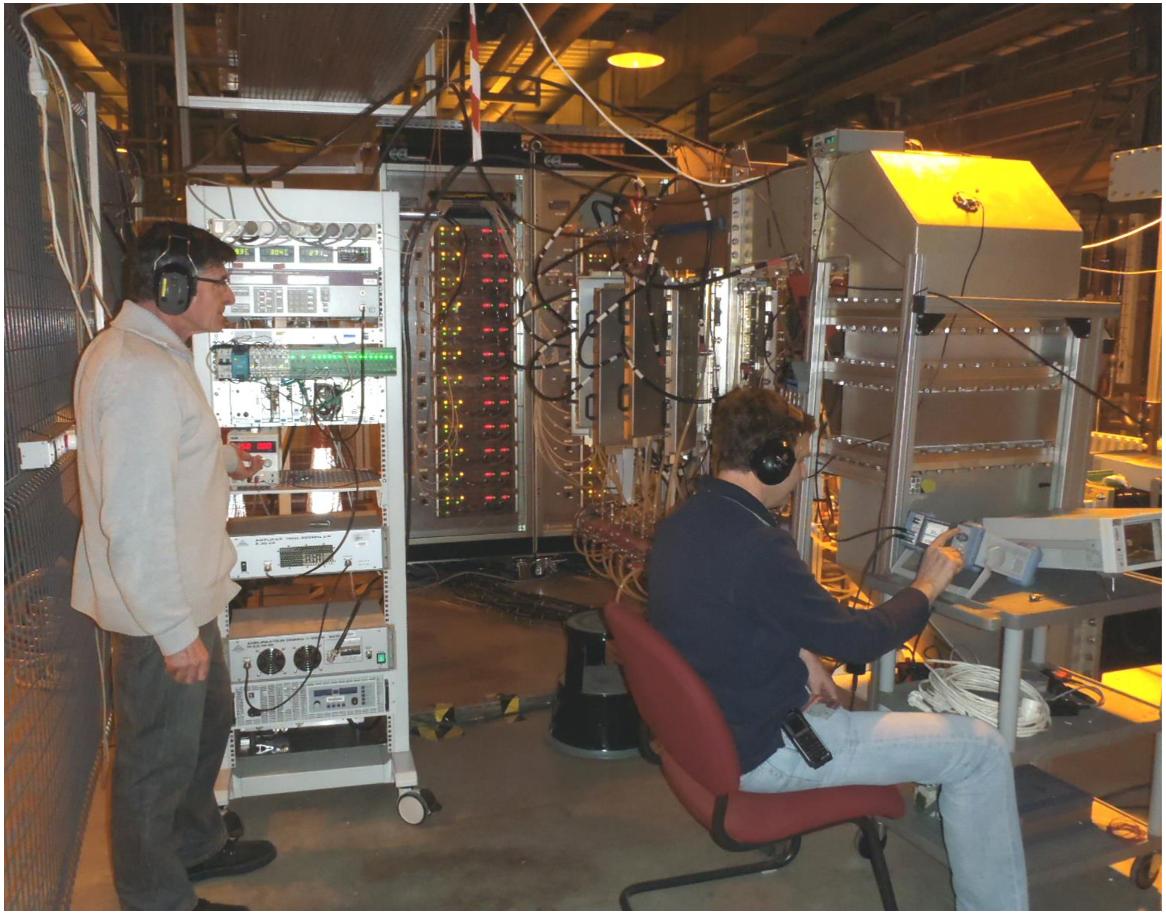


Insulator outer temperature



Temperature distribution measured with IR camera and optic fiber probes

WHAT'S NEW ON THE CAVITY COMBINER?

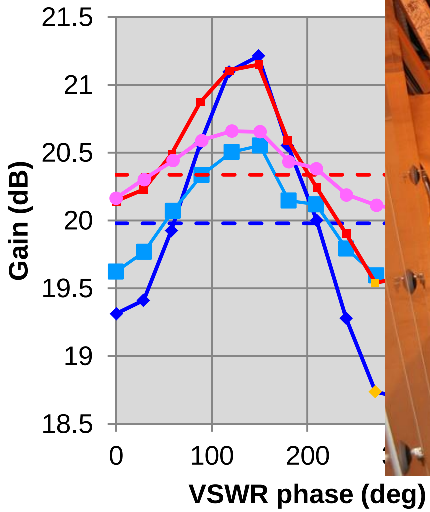


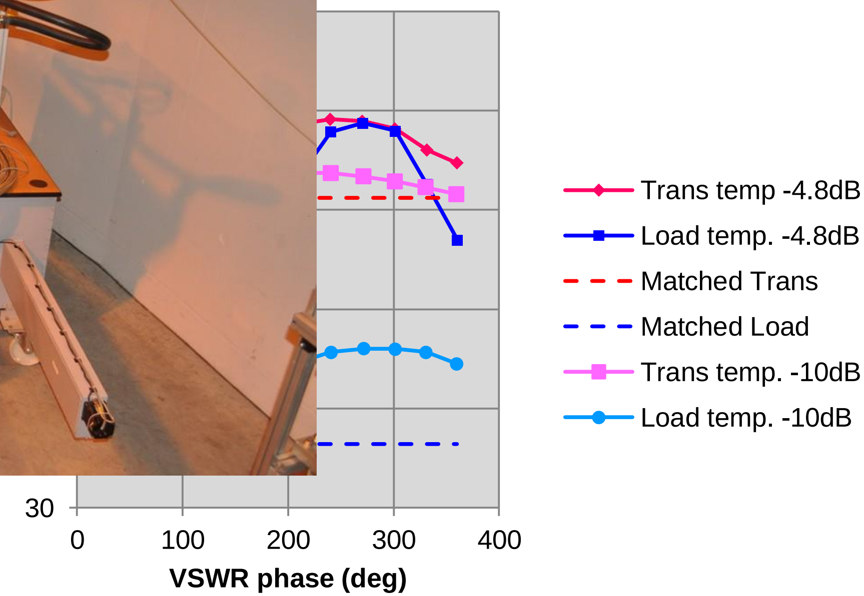
Reminder: we designed and built an RF amplifier at 352 MHz based on a cavity combiner (see CWRF presentation).

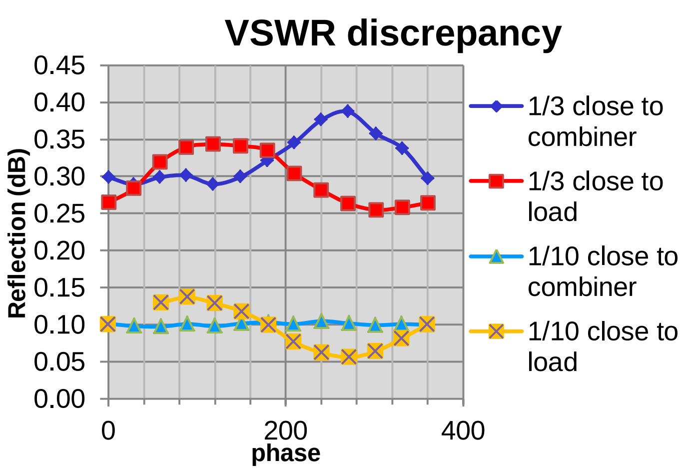
Its nominal power is 85 kW.

Its drain efficiency at 85 kW is 62%.

VSWR tests at 75 kW / -4.8dB (1/3) and -10dB (1/10)



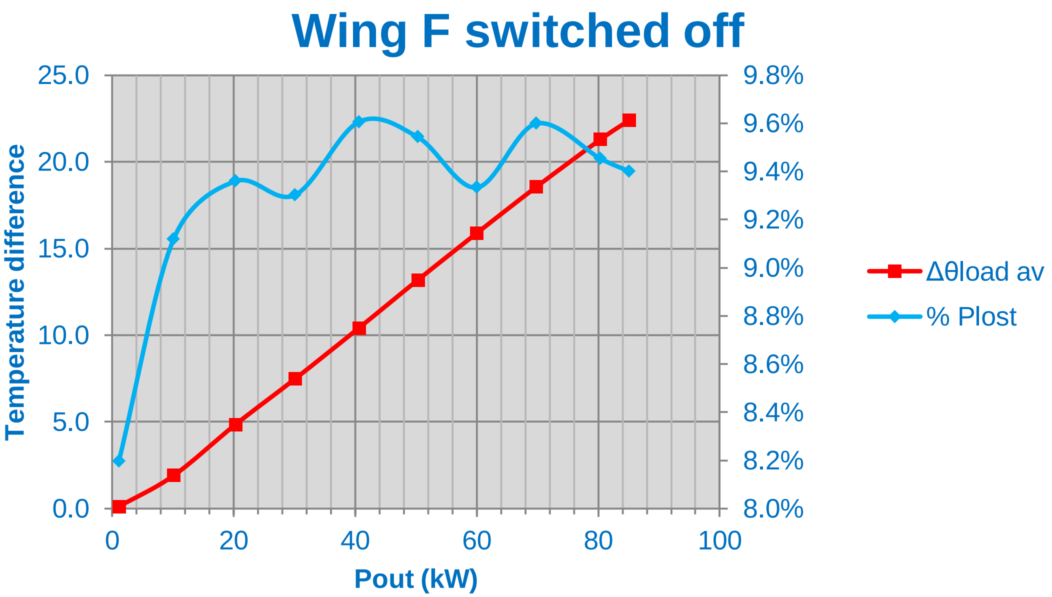




When the output circuit has turns and bends, it is difficult to get the same VSWR value at 2 different locations. (Yes, we were careful with directivities)

WING OFF

Switching off the supply of one wing (over 22) with RF on

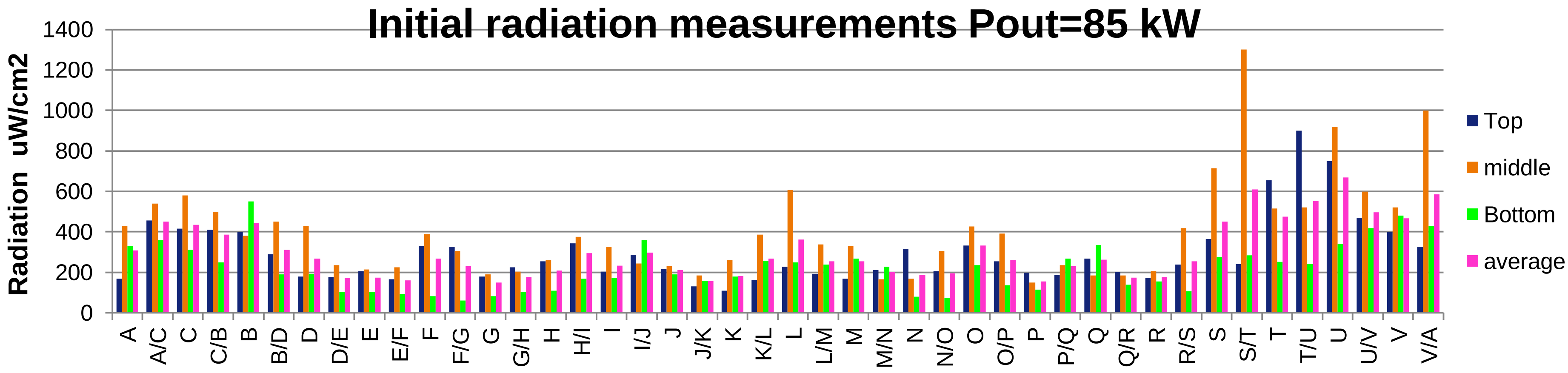


No problem for surviving!

Reminder: 1/22=4.5%

RF LEAKAGE

RF leakage measured with field probe

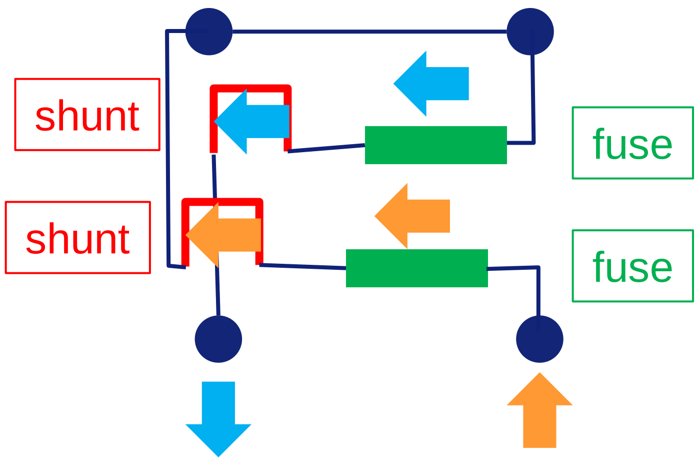


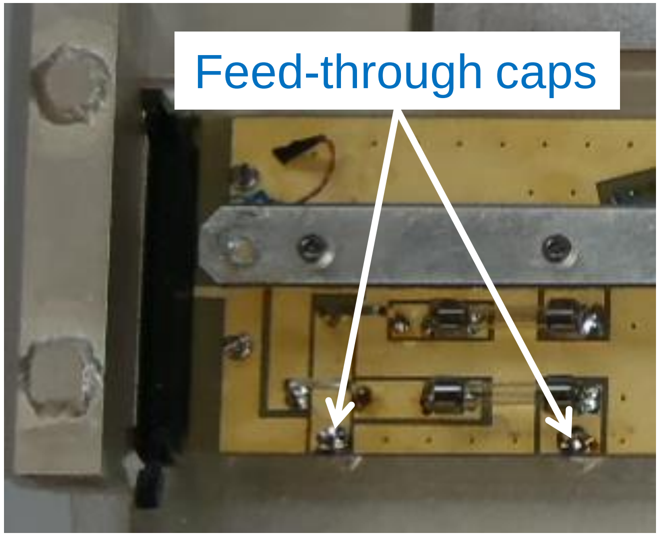
Mitigation and results

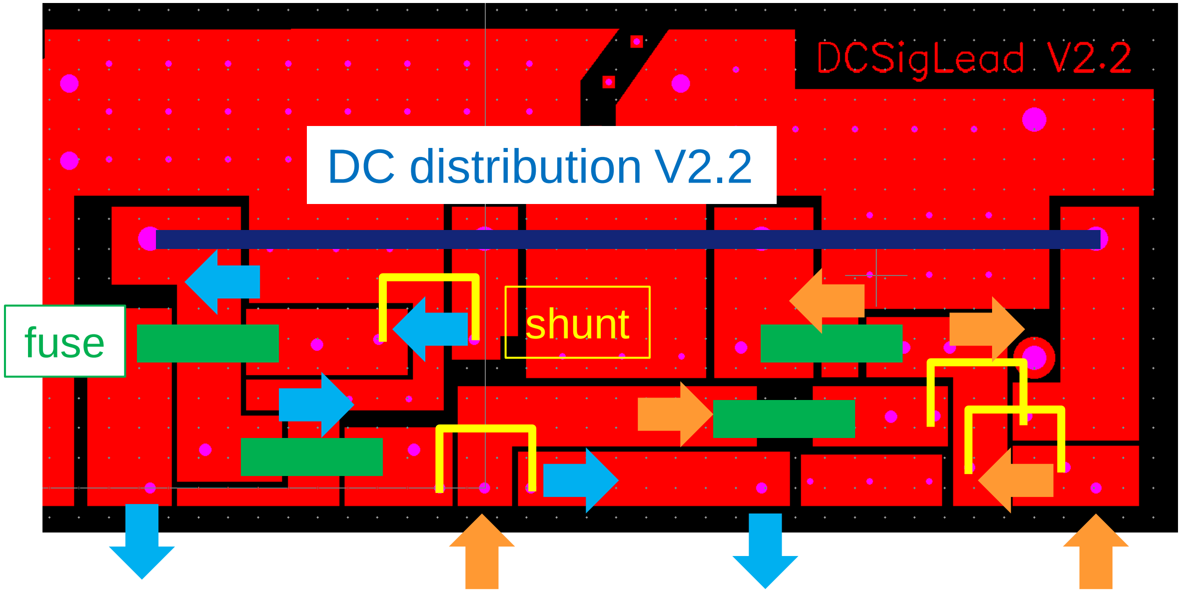
✓Copper tape between wings	No change
✓Large copper ground between LLRF and combiner	No change
✓DC voltage distribution board	Fitted, untested
✓Copper tape between combiner and waveguide	To be tested
✓RF cables from splitters to wings	To be tested
✓Covers	Drawn, to be purchased
✓Splitters on the wing	Computed as negligible

DC BOARD CHANGE

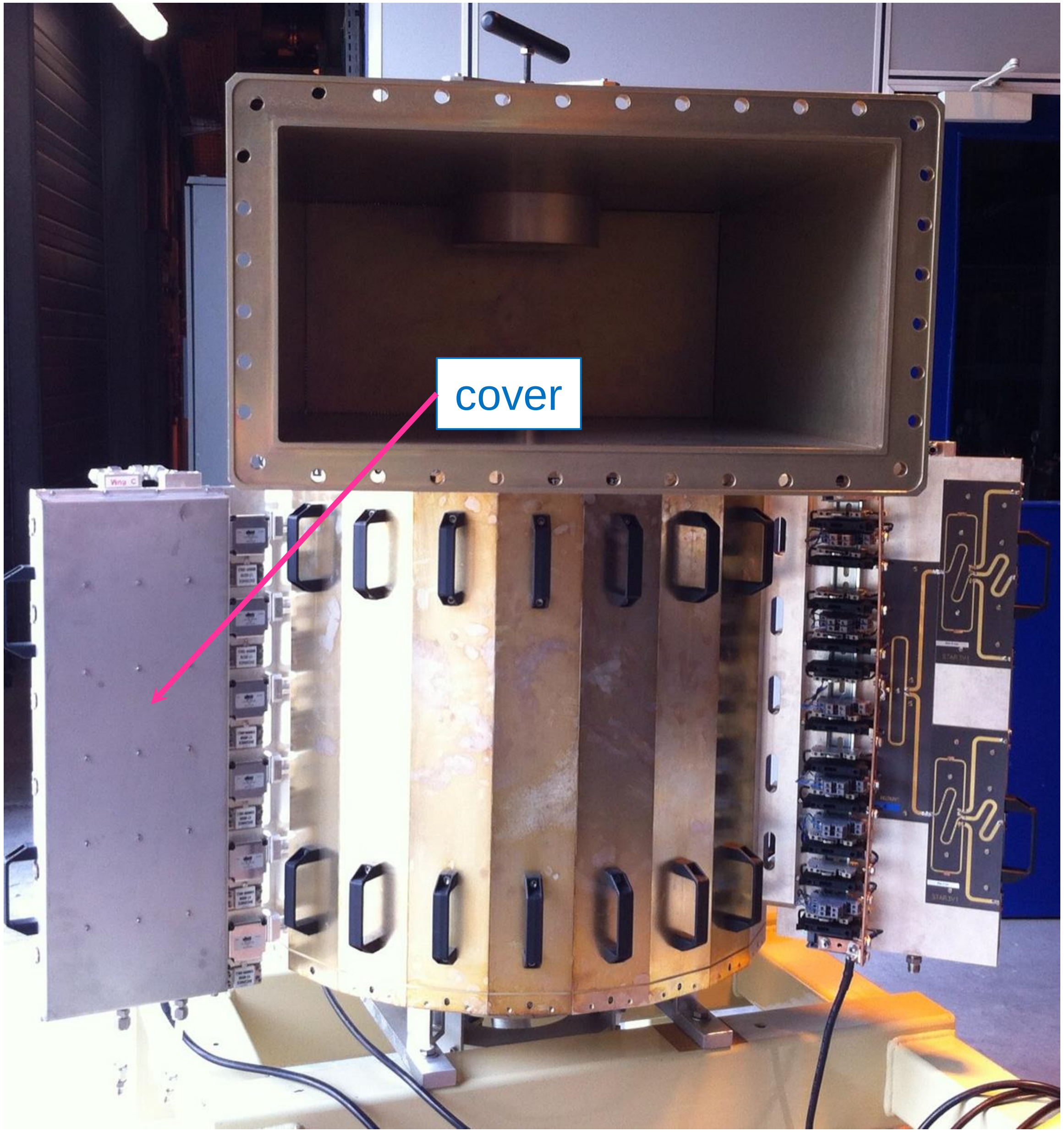
DC distribution V2.0







COVERS



Thanks

for your (hopefully) kind attention