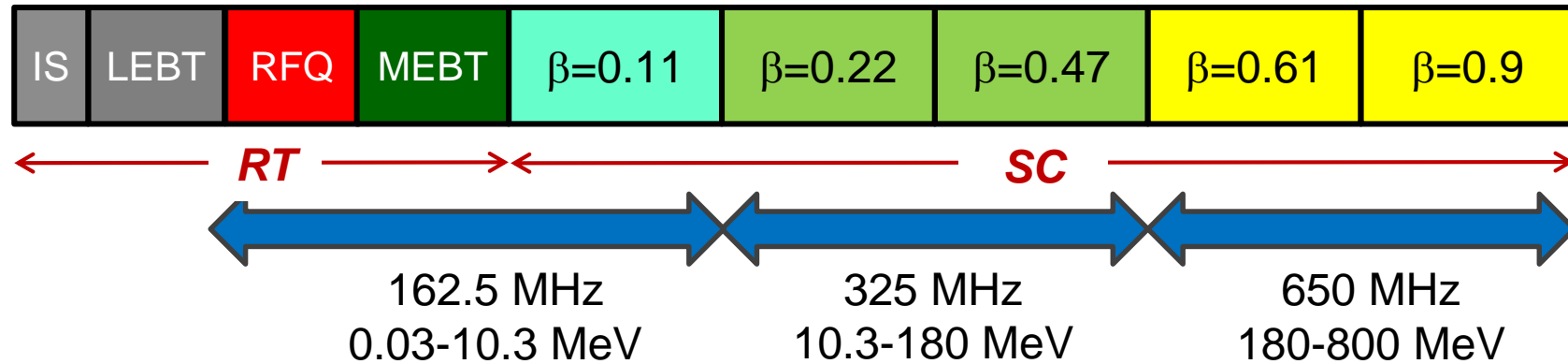


PIP-II coupler design

S. Kazakov

06/23/2015

PIP-II Linac Technology Map



Section	Freq	Energy (MeV)	Cav/mag/CM	Type
RFQ	162.5	0.03-2.1		
HWR ($\beta_{opt}=0.11$)	162.5	2.1-10.3	8/8/1	HWR, solenoid
SSR1 ($\beta_{opt}=0.22$)	325	10.3-35	16/8/ 2	SSR, solenoid
SSR2 ($\beta_{opt}=0.47$)	325	35-185	35/21/7	SSR, solenoid
LB 650 ($\beta_{opt}=0.65$)	650	185-500	33/22/11	5-cell elliptical, doublet*
HB 650 ($\beta_{opt}=0.97$)	650	500-800	24/8/4	5-cell elliptical, doublet*

*Warm doublets external to cryomodules

All components CW-capable

RF Power Requirements

- RF power requirements include
 - Up to 20 Hz microphonics driven detuning
 - 1 dB allowance for regulation
 - Power transfer inefficiency:
 - 0.5dB - HWR&SSR (coaxial);
 - 0.25 dB – LB&HB (wave guide)

CM type	Power transferred to beam per cav. (kW)	Cavity half-bandwidth, $f / 2Q_L$, (Hz)	Peak RF power per cavity (kW)
HWR	4	33	6.5
SSR1	4.1	43	6.1
SSR2	10	28	17
LB 650	23.8	29	38
HB 650	39.8	29	64

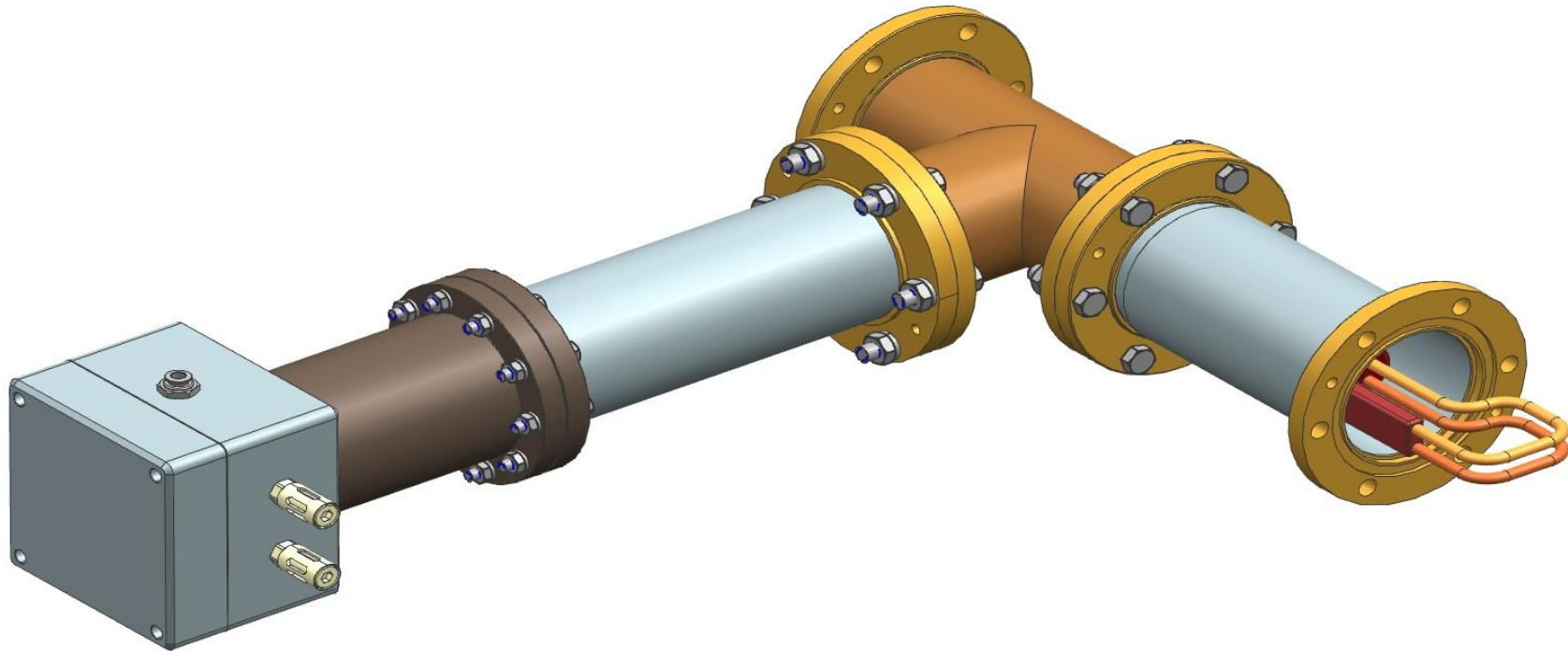
Number of couplers and requirements

Coupler	Nmb.	Pulse power, kW	Av. power, pulse mode, kW	CW mode (future), kW	Responsibility
162.5 MHz, RFQ	2	50	50	50	FNAL
162.5 MHz, HWR	8	6.5	6.5	6.5	ANL
325 MHz, SSR1, SSR2	51	17	2.1	17	FNAL
650 MHz, LB, HB	57	64	7.7	64	FNAL

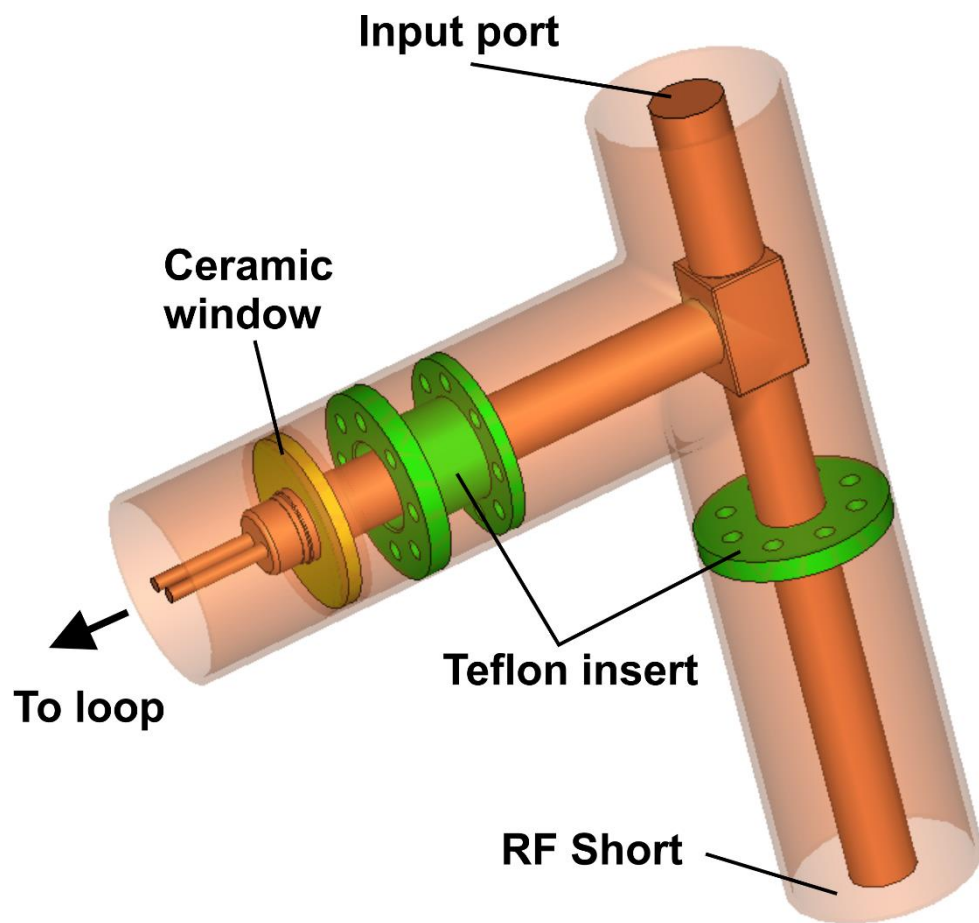
Design goal

Total number of couplers - 118

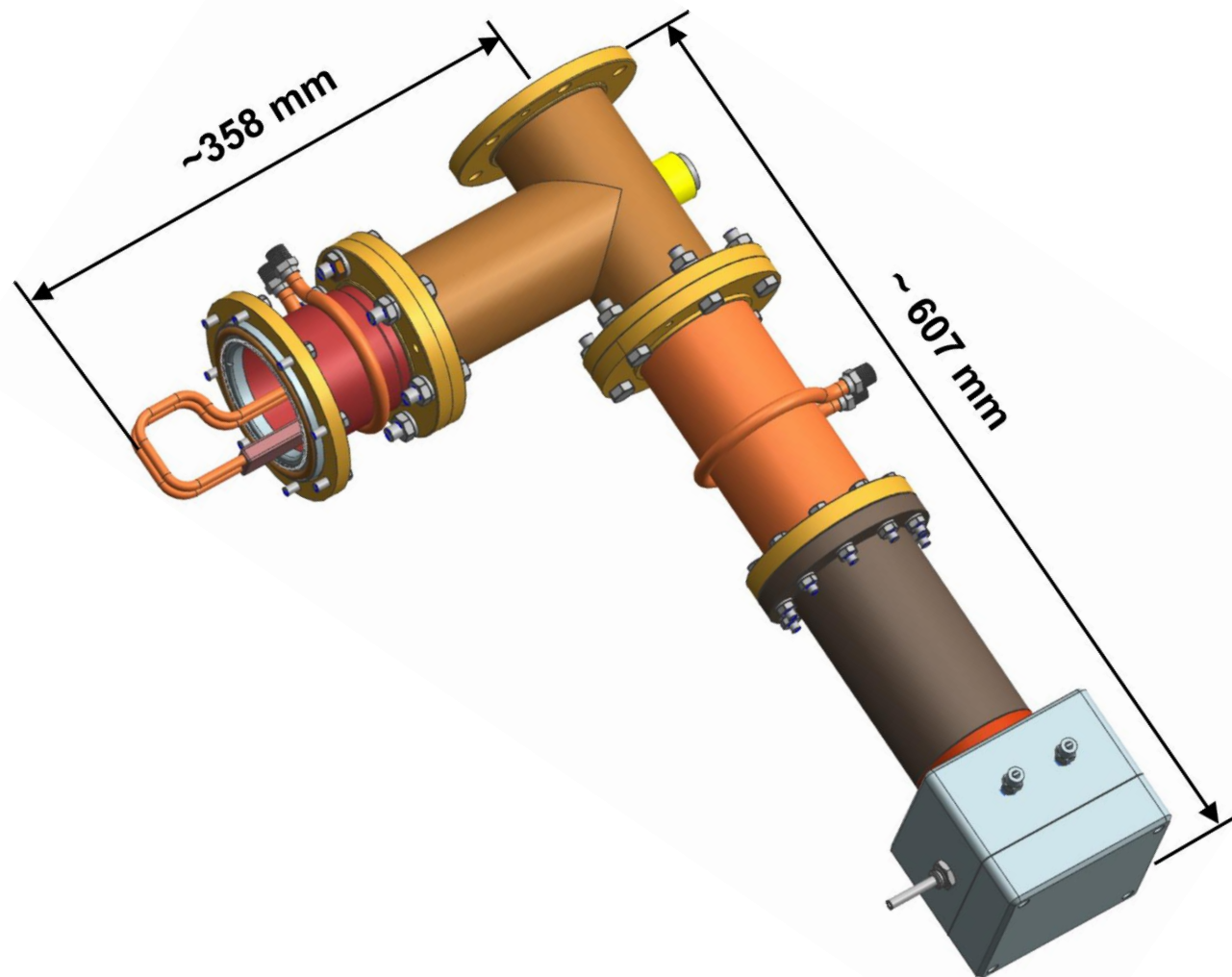
162.5 MHz Coupler for RFQ



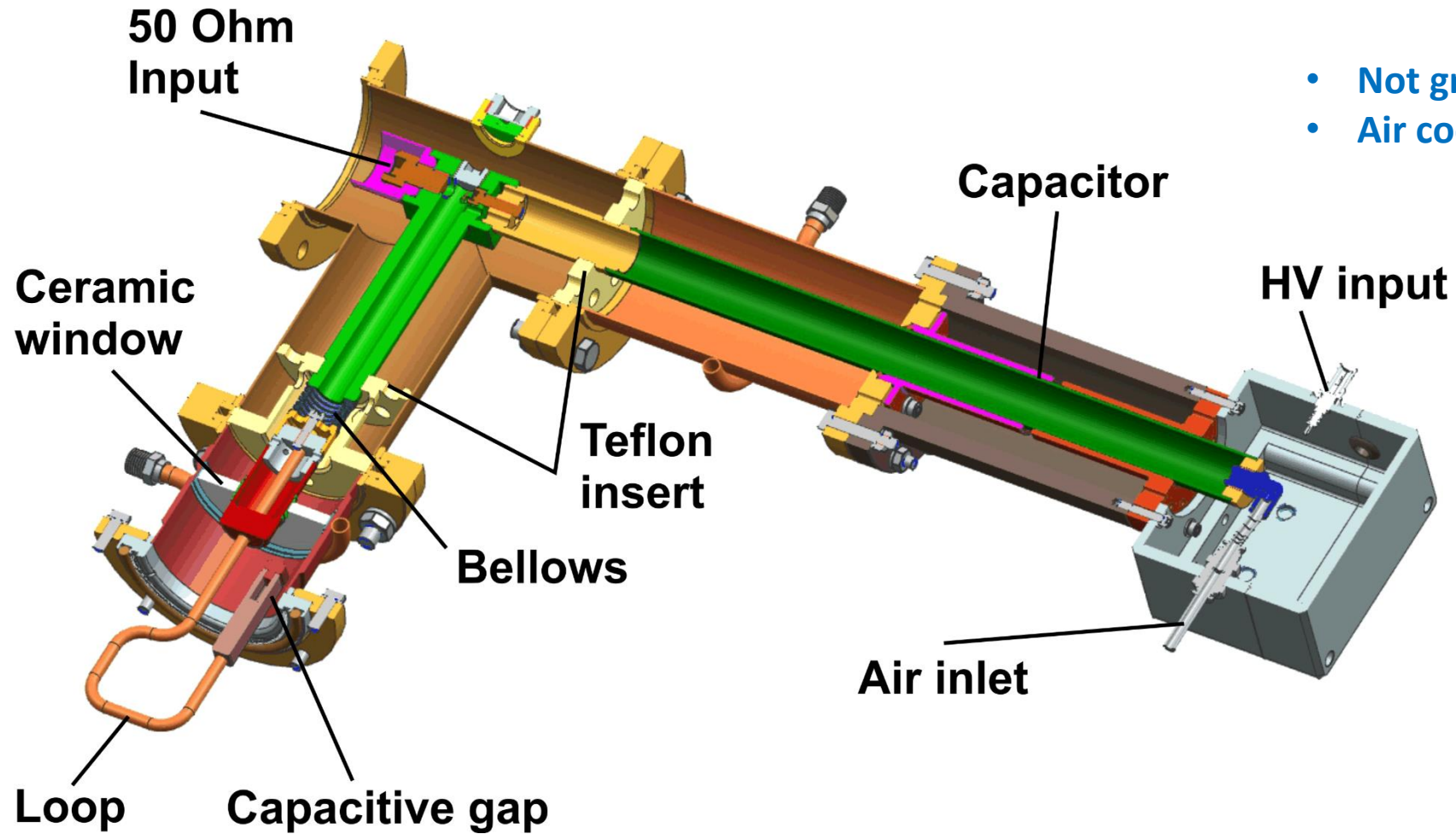
Electrical configuration



Overall sizes



RFQ coupler structure

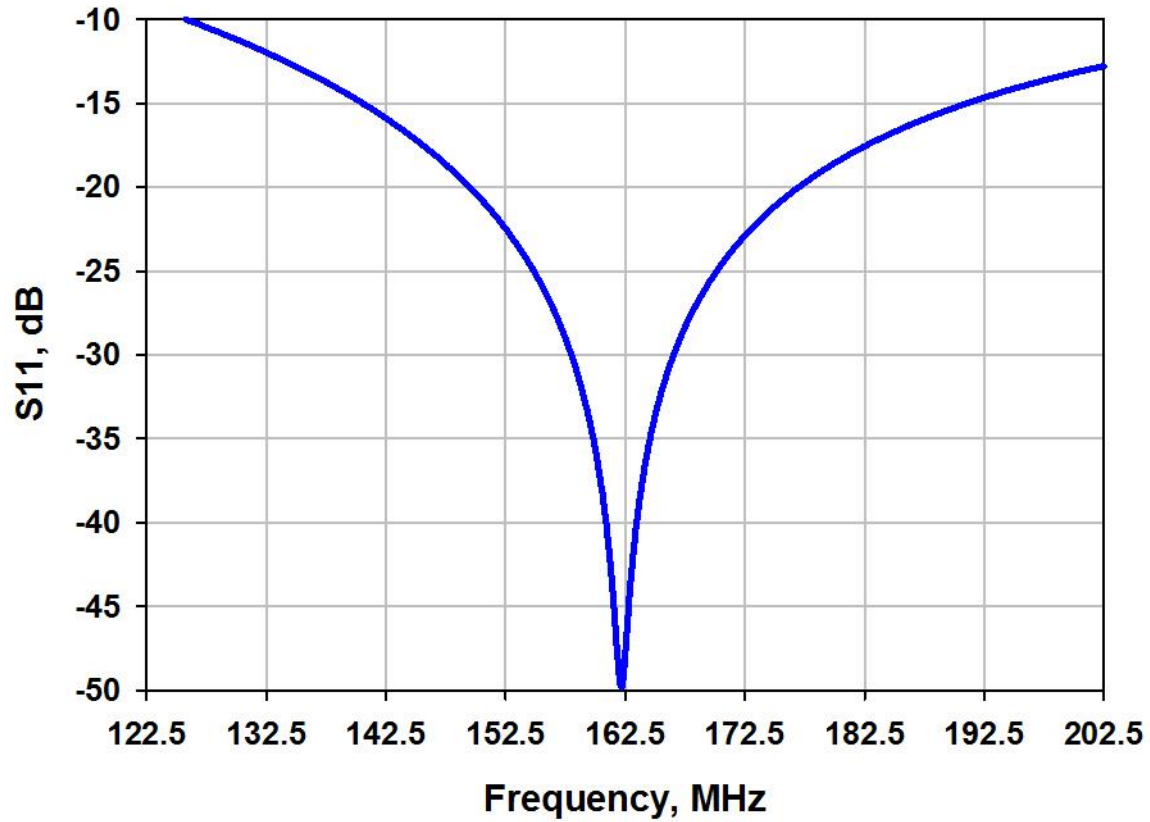


Some features of RFP coupler:

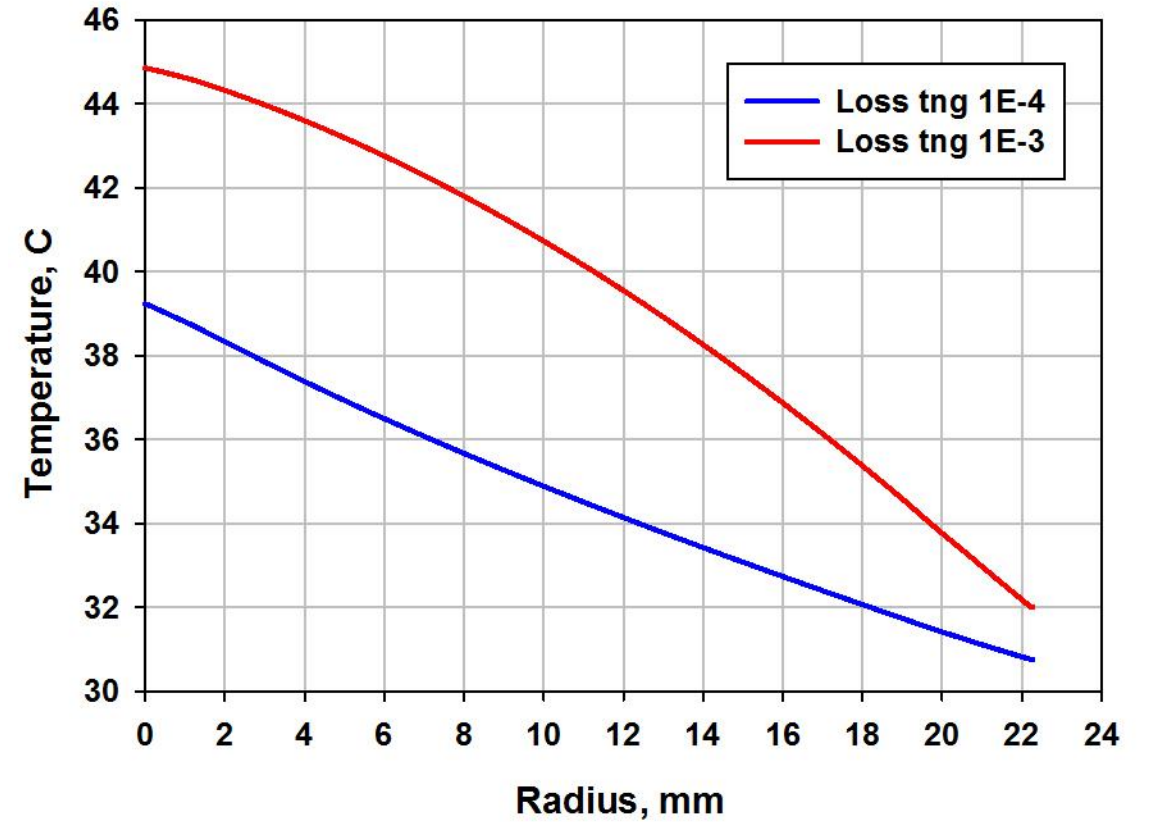
- Not grounded loop (HV bias applicable)
- Air cooling

Input power - 80 kW, TW

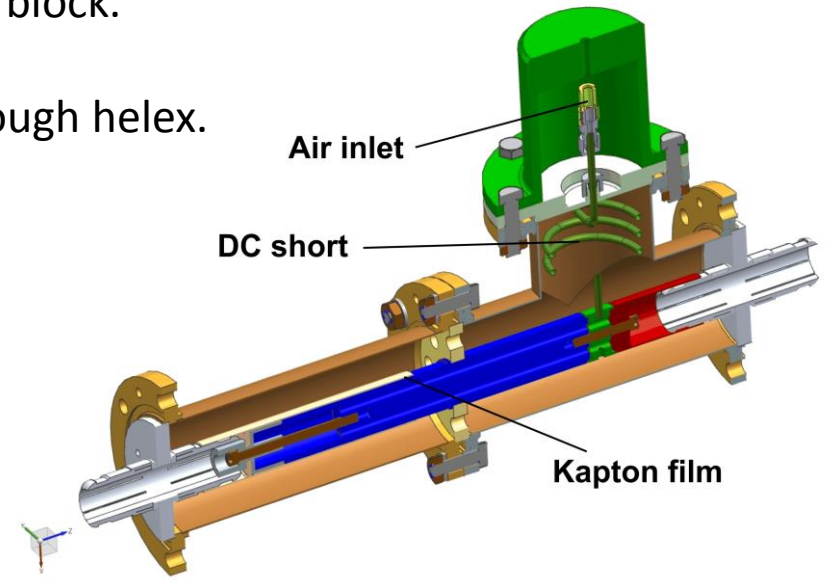
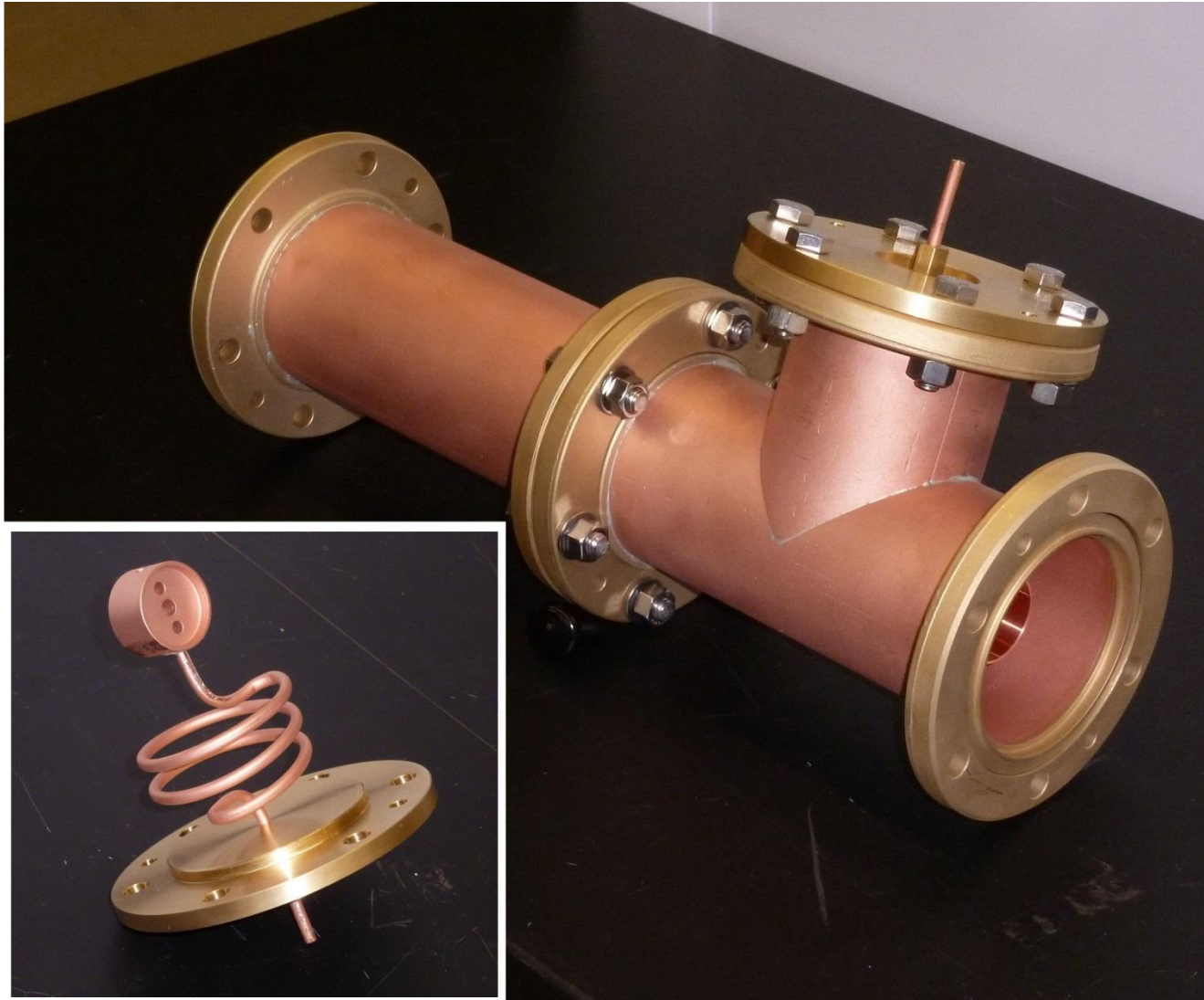
Passband of RFQ coupler



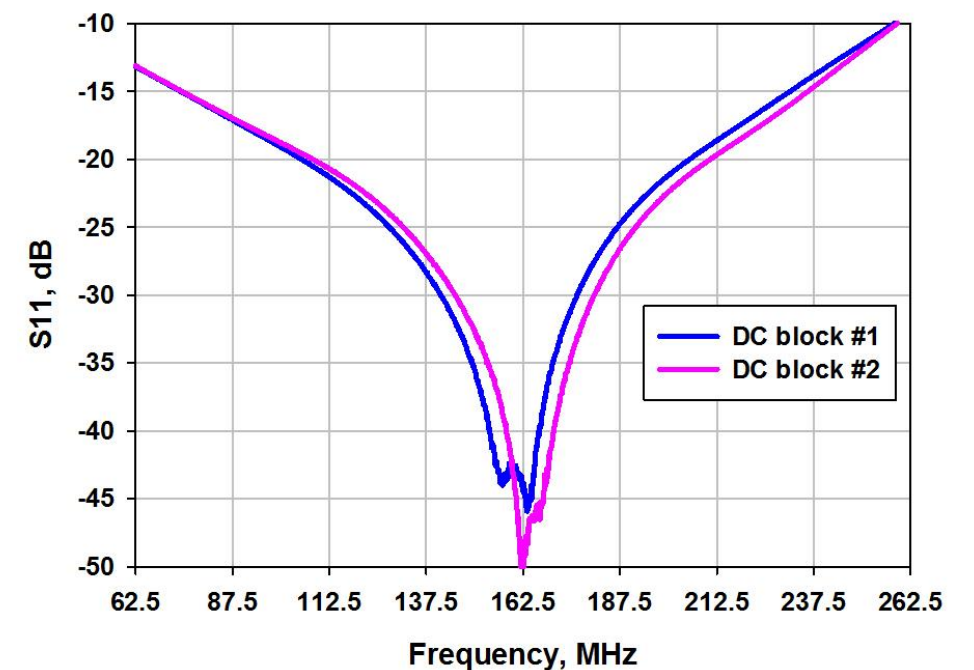
Temperature along ceramic



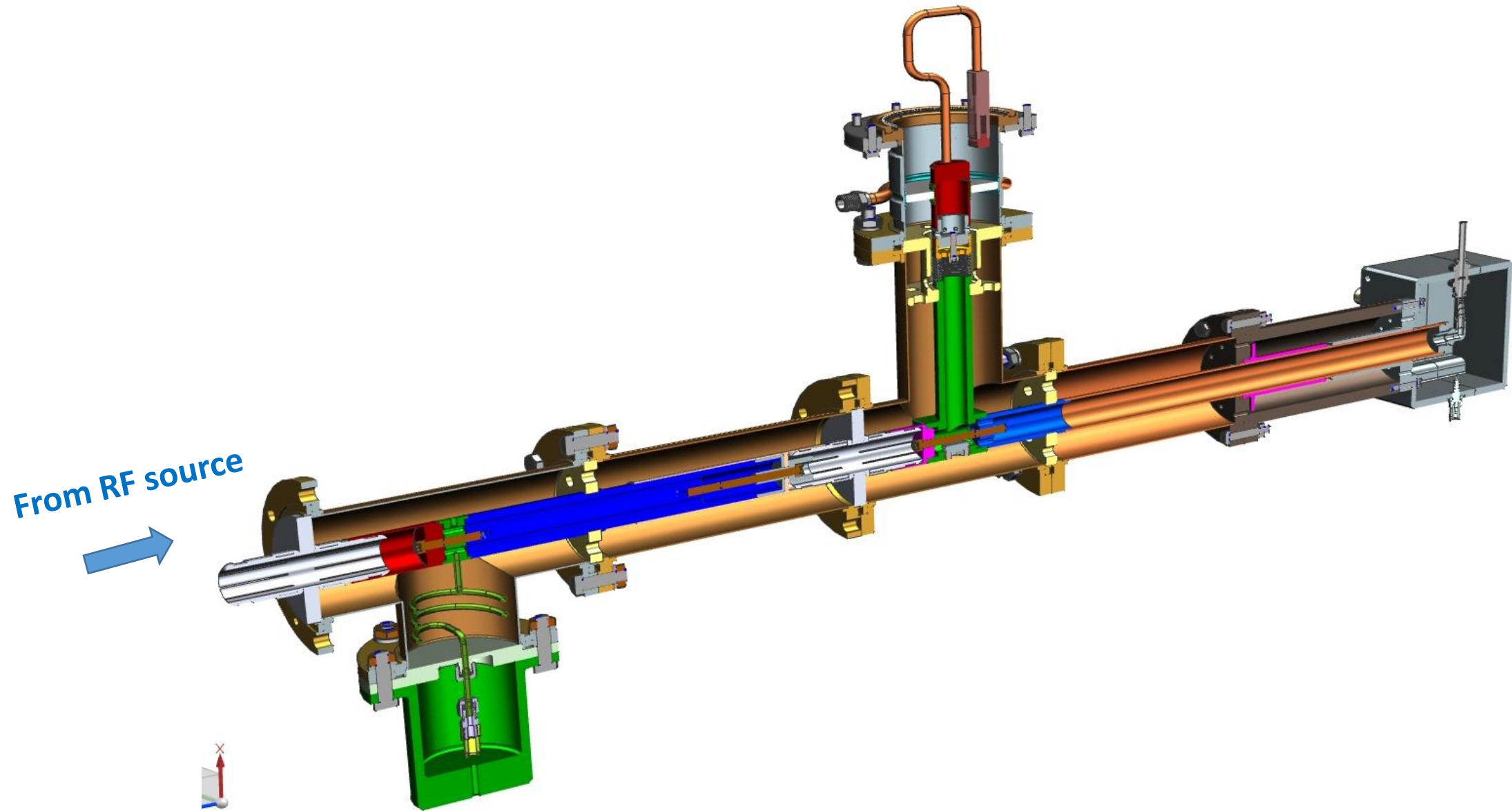
To apply HV bias the couple is connected to feeding coaxial line through DC block.
DC block transmits RF and blocks DC current.
To protect RF source the central conductor from source side is grounded trough helix.



162.5 MHz DC blocks, measured passbands



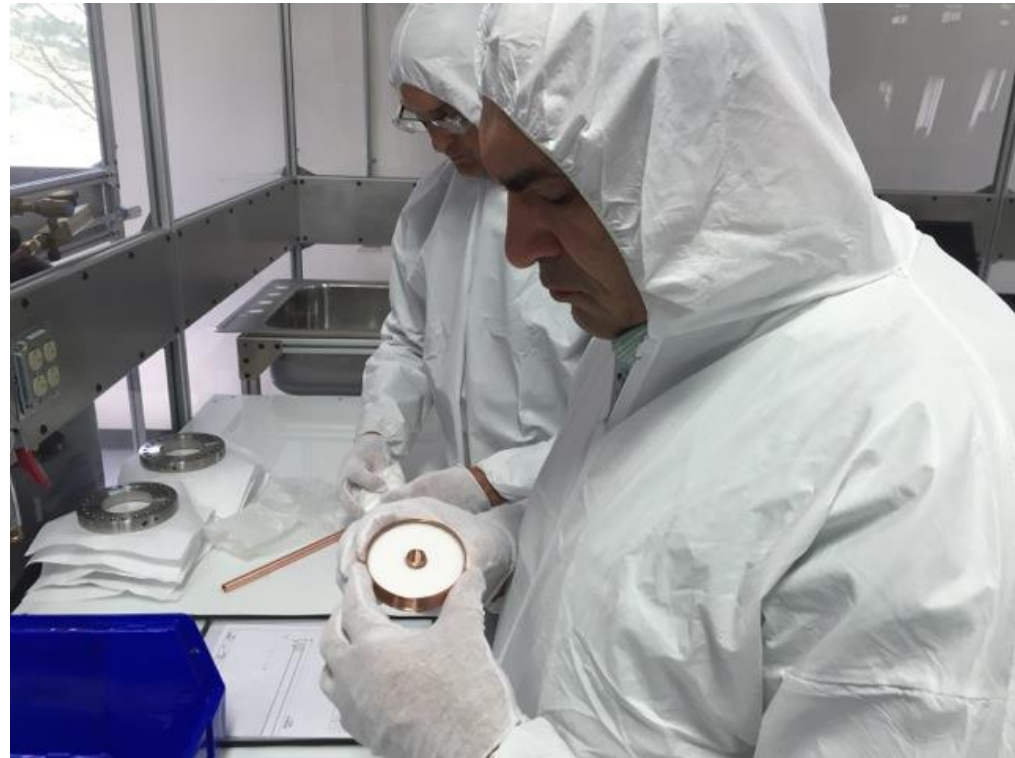
DC Block with 162.5 MHz Power Coupler





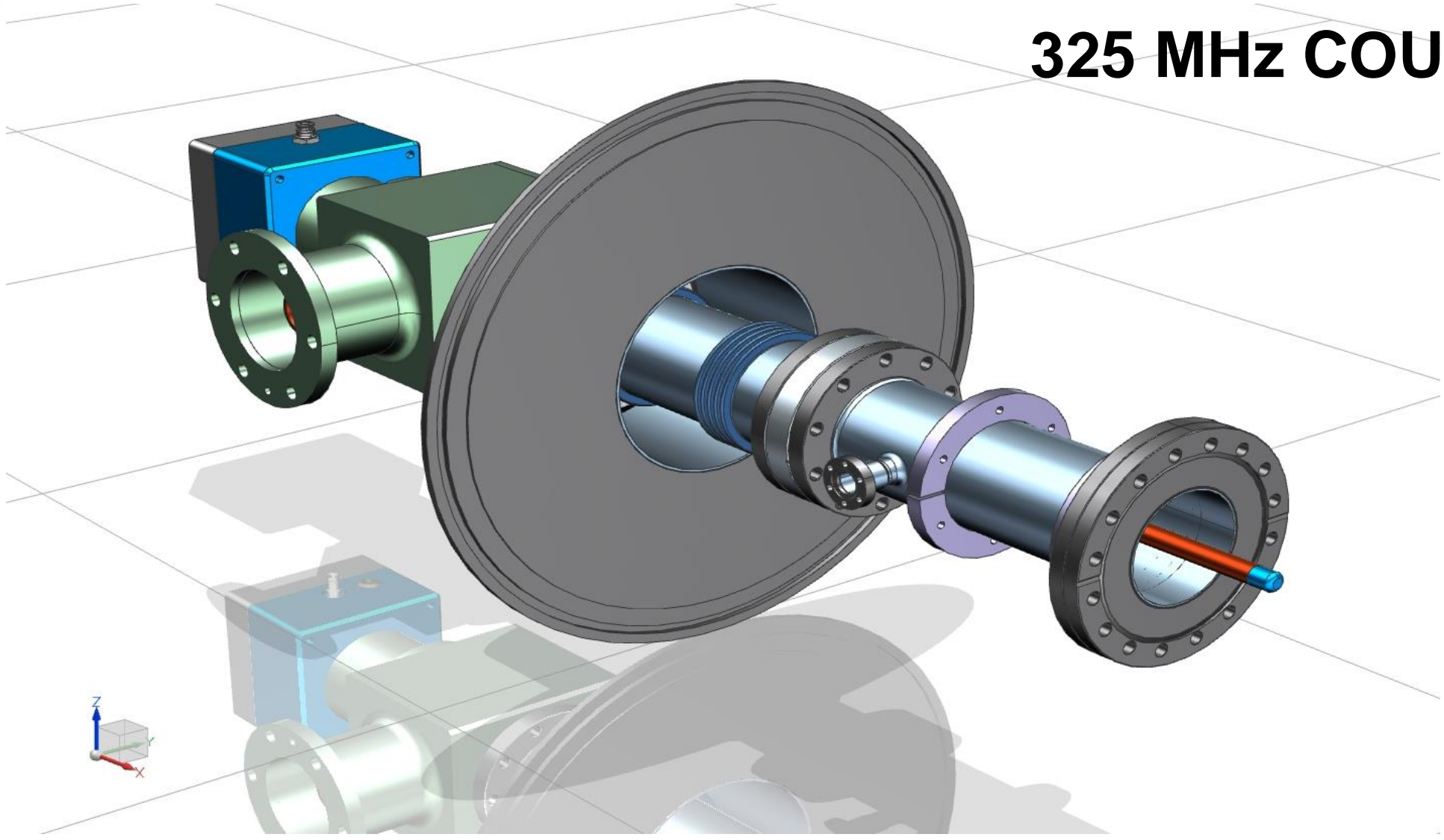
Current status:

Two couplers are under production in Mega Industries.
Expected delivery time is August.

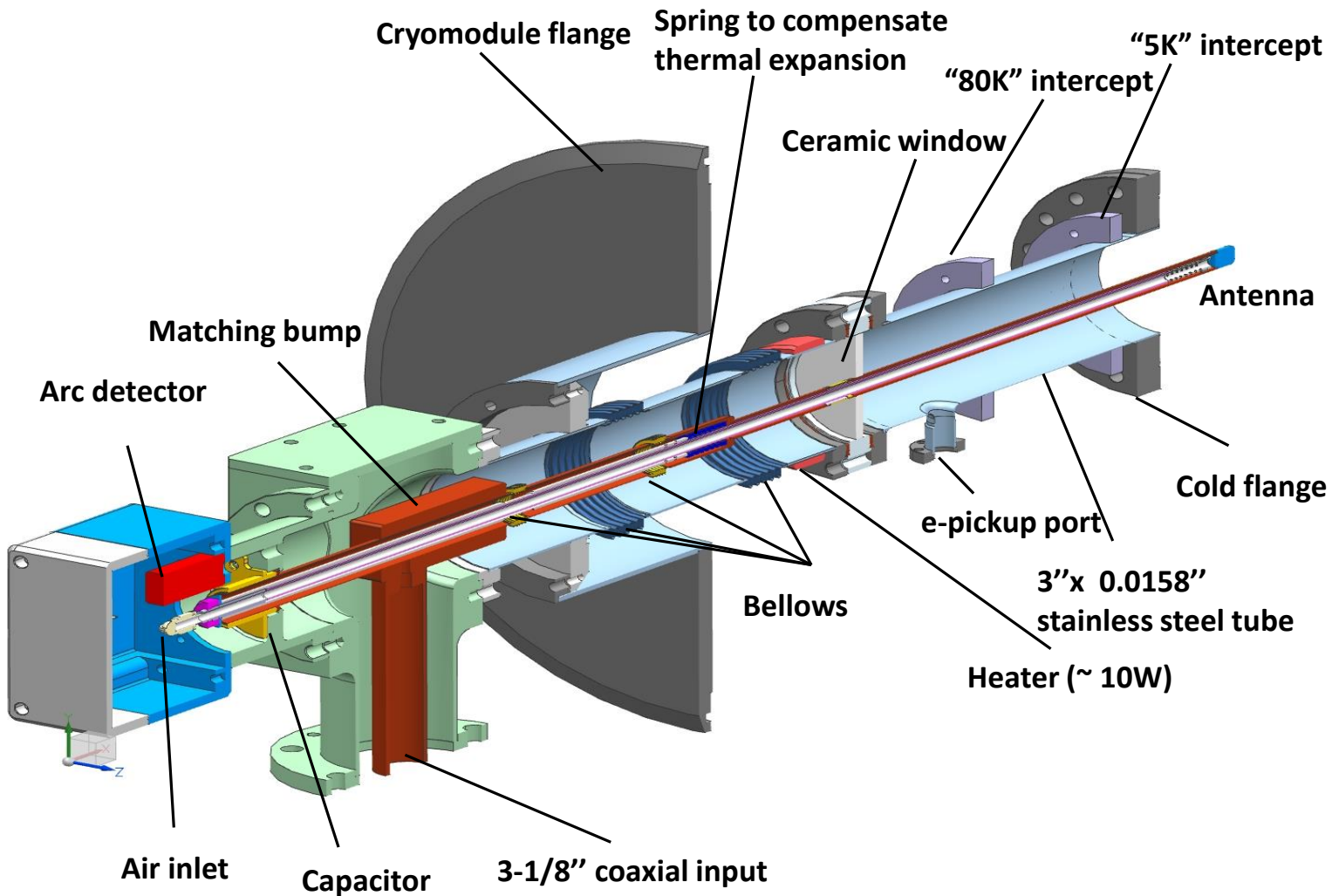




325 MHz COUPLER



Cut view of 325 MHz coupler



Cryogenic loading by coupler

325 MHz Coupler FRS:

Parameter	Value
Frequency	325 MHz
Pass band ($S_{11} < 0.1$)	> 1 MHz
Operating power (CW, any refl.)	25 kW
HV bias	~ 2 kV

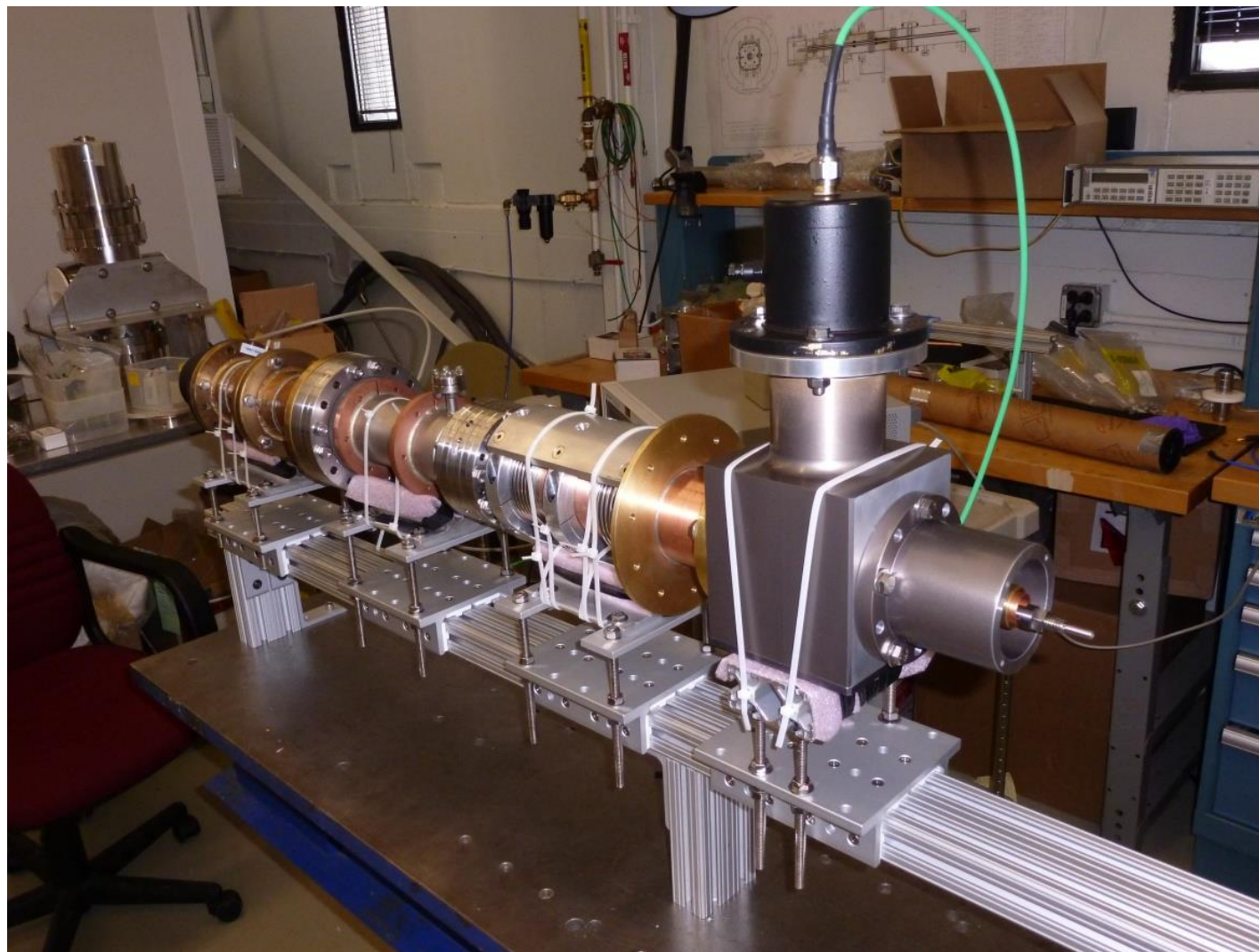
Parameter	Value
Input	3-1/8" , 50 Ohm coaxial
Output	3-1/8" coaxial, SSR1/SSR2 flng.
RF window	Single, room temperature
Cold flng. relative displacement	+3 mm
Vibration and shock	Up to 3 g in any direction

P, kW	2K / PI, W	15K / PI, W	125K / PI, W
0	0.06 / 52	0.58 / 151	2.02 / 40
3	0.10 / 86	0.81 / 211	2.35 / 47
6	0.15 / 129	1.03 / 268	2.68 / 54
20	0.35 / 301	2.07 / 538	4.25 / 85
30	0.50 / 430	2.82 / 733	5.36 / 107

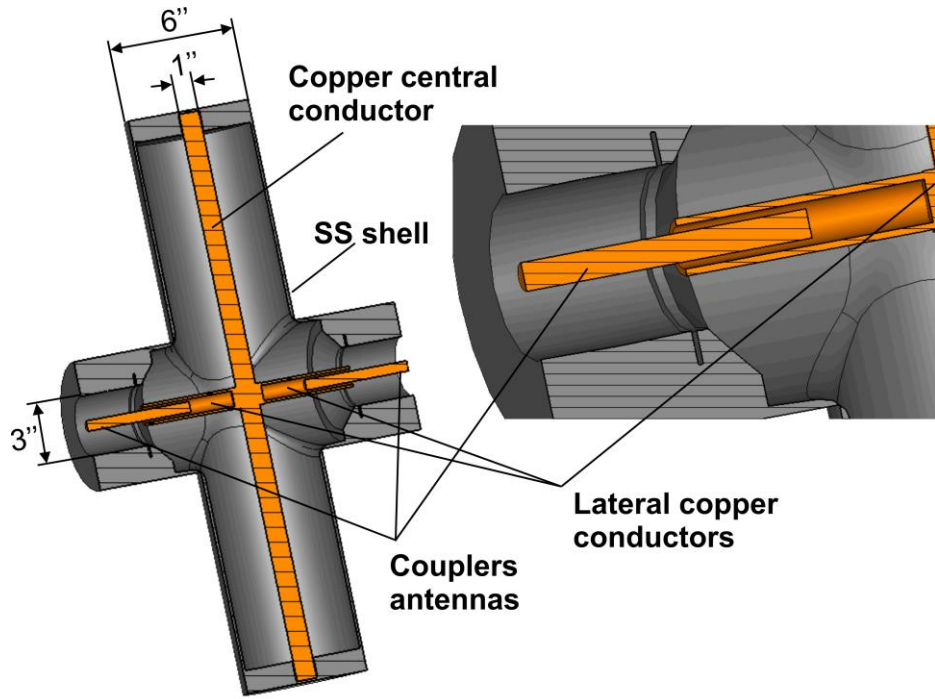
Three coupler were fabricated:



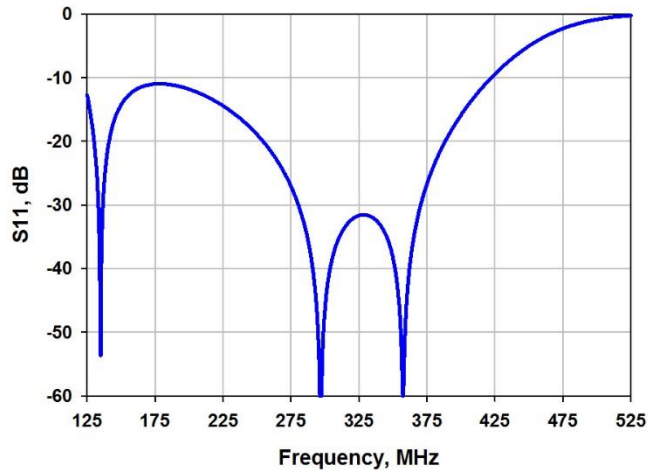
Checked and tuned at the test bench:



SS HW cavity under vacuum:

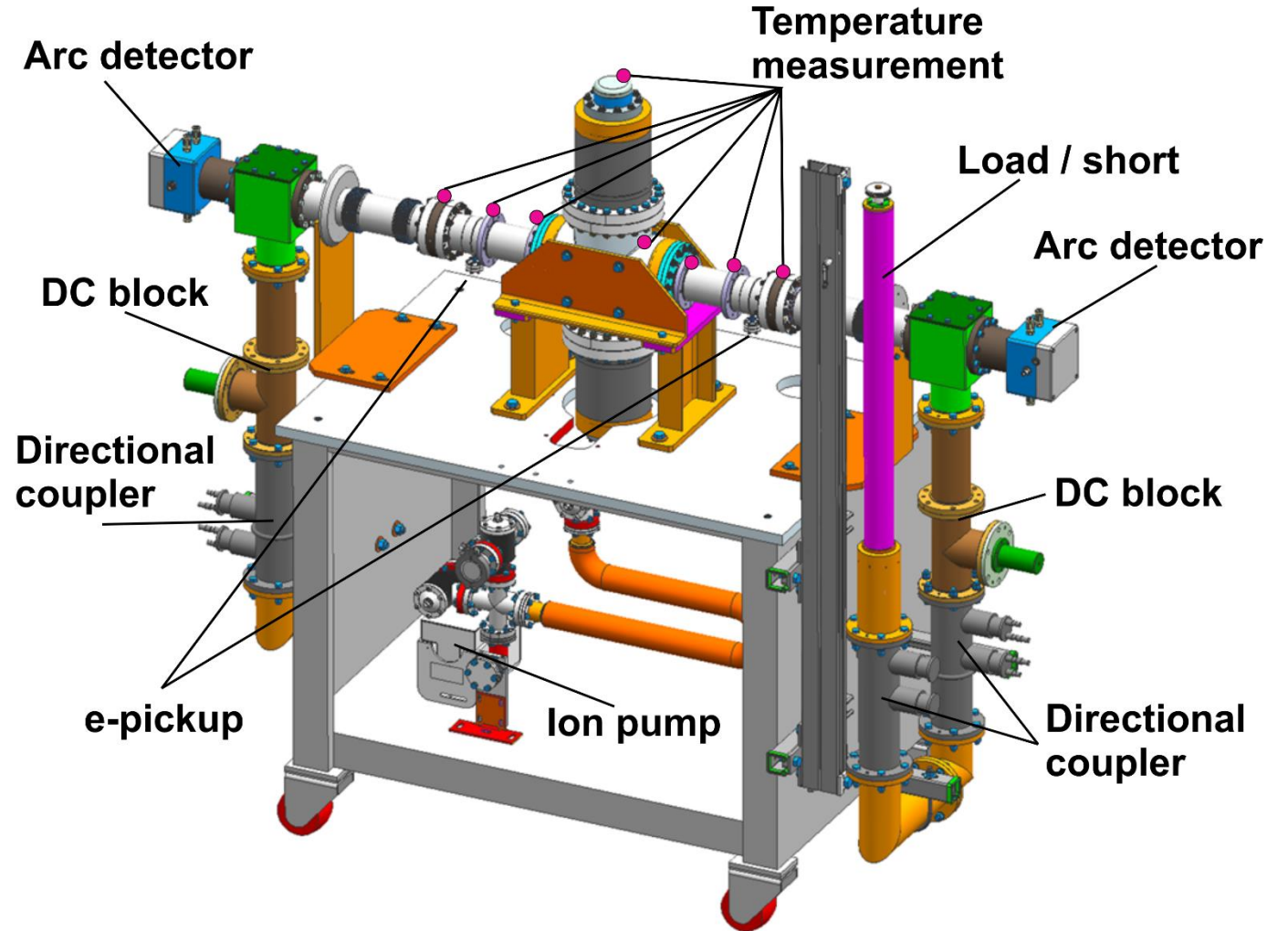


Passband of test cavity

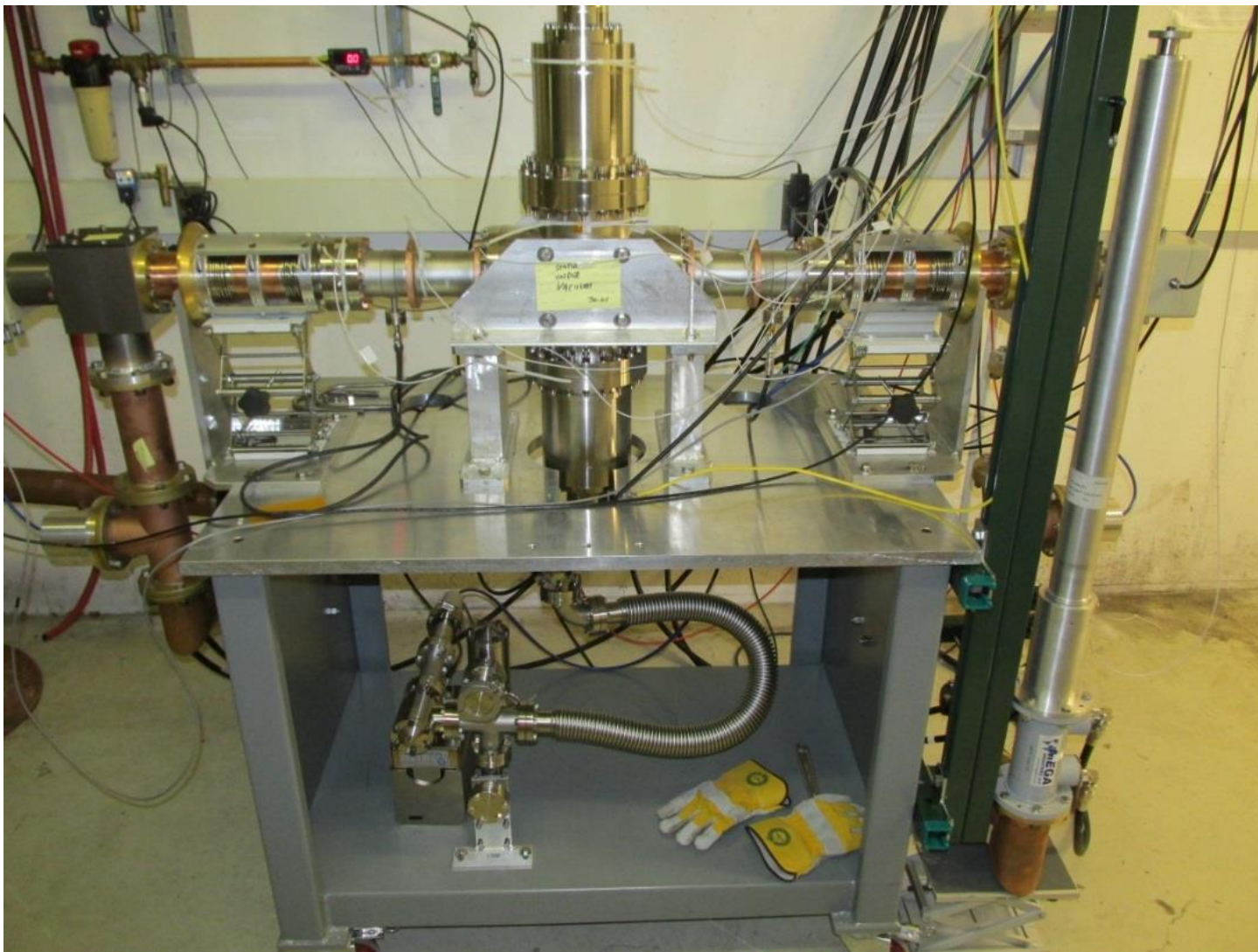


Coupler test stand was designed

325 MHz coupler test stand configuration:



Two couplers were tested:



Tests were successful – we burned everything except couplers.

Power limitation: maximum RF power of source is 10 kW, CW.

About 8 kW can reach the couplers through circulator and long cable.

Run 1: TW configuration (matching load at the end).

Within one day multipactor was conditioned up to maximum power.

Next day couplers were run 7 hours at maximum power. There was no trips.

Temperature rise (windows and SS outer conductors) was small, ~ 5C

Run 2: SW configuration (movable short at the end, full reflection).

Multipactor started at ~ 3.5kW and it was more significant. We managed to

condition up to maximum power at 5 positions (step – 5 cm) of moveable short at CW mode. Vacuum activity was presented till the end, but vacuum was better than $1e-6$ Torr. It means weak multipactor existed. Rise of temperature was moderate ~ 10C. Then cable between RF amplifier and couplers was burned.

Run 3:

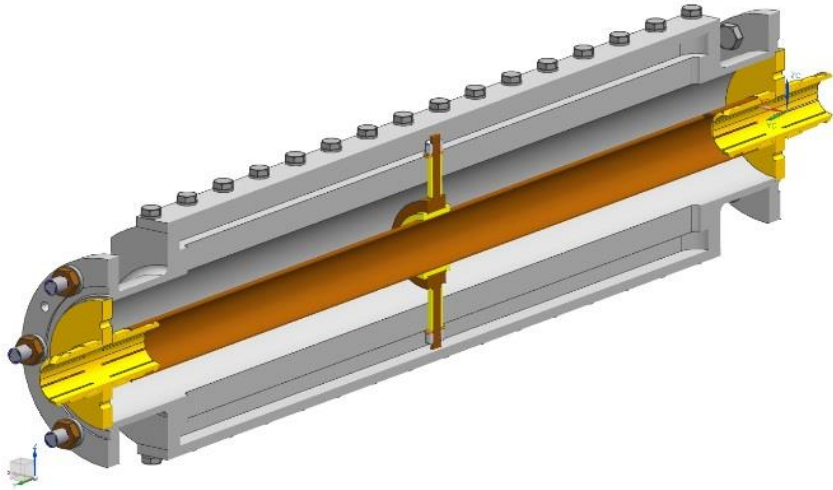
Cable was repaired. We continued work in configuration with HV bias.

Because of cable limitation it was pulse mode with pulse duration 0.5s and 1pps.

Bias works well. Multipactor was suppressed by +1.5 kV (“+” at the antenna) up to maximum power at any position of moveable short (no vacuum activity, no signals from e-pickups.) Negative bias voltage is not so effective. It requires about – 3kV to suppress multipactor.

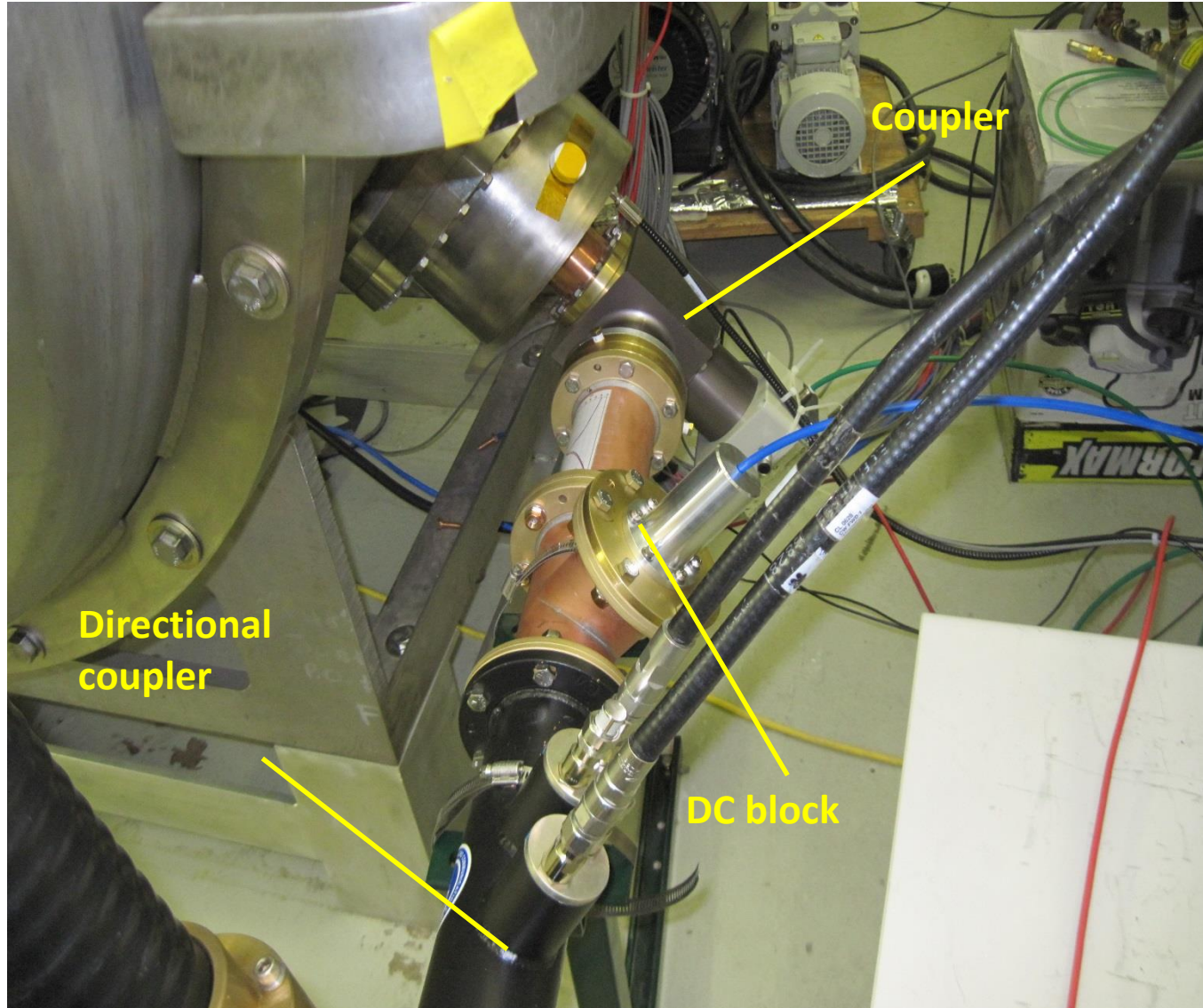
DC blocks and movable short work well at power level ~8 kW, TW.

Run 4: Cable was change for more powerful one. To increase the power we organized resonance scheme using a movable reflector. Reflector has reflection about -4 dB. It allows to increase RF power in resonance scheme about 4 times. So coupler ca be tested up to ~ 30 kW CW in SW configuration



Movable short was burned immediately and was replaced with set of coaxial waveguides. Then there were some discharges in reflector and DC blocks. Reflector and DC block were modernized. After that couplers were run about 1 hour at ~ 30 kW, SW. Then DC block was burned again and needs some modernization. Couplers survived. Test will be continued soon.

Third coupler was installed in cryomodule of STC with SSR1 cavity.
Coupler works well.



Current results:

Detuned cavity (full reflection):

- Coupler was conditioned up to maximum power (~ 10 kW from RF source). No multipactor (it was conditioned out).
- Window temperature rise ~ 25 C at maximum power (more than 2 hour CW operation).
- Window temperature without RF < 0 C (~ 270 K).

Tuned cavity:

- Multipactor appears at ~ 18 MV/m. There is signal from coupler e-pickup. It provokes X-radiation from cavity.
- HV bias suppresses multipactor (no signal from e-pickup) and no X-radiations.
- X-radiations appears again at ~ 21 MV/m, but it is originated not by multipactor (no signal from e-pickup).

The designed 325 MHz coupler satisfies PIP-II requirements (17 KW, CW).

Next 10 couplers are under fabrication in Mega Industries.

Fist 4 will be delivered in August.

We continue works for 650 MHz, 1.3 GHz, 3.9 GHz couplers. But they are still in paper work stages.
We will discuss them in next time.

Thank you!