Injector Cryomodule for cERL at KEK

- Cavity 3 2-cell Cavities
- Input Coupler 2 Couplers with water cooling
- HOM Coupler 5 TESLA-like couplers
- Frequency Tuner Slide-Jack Tuner
- Cryostat Under Fabrication

Design Specification for 5GeV ERL Injector

RF Frequency : 1.3 GHz

Beam Current : 100 mA cW

Energy : 10 MeV

Beam Power : 1 MW

Injector Module Parameters

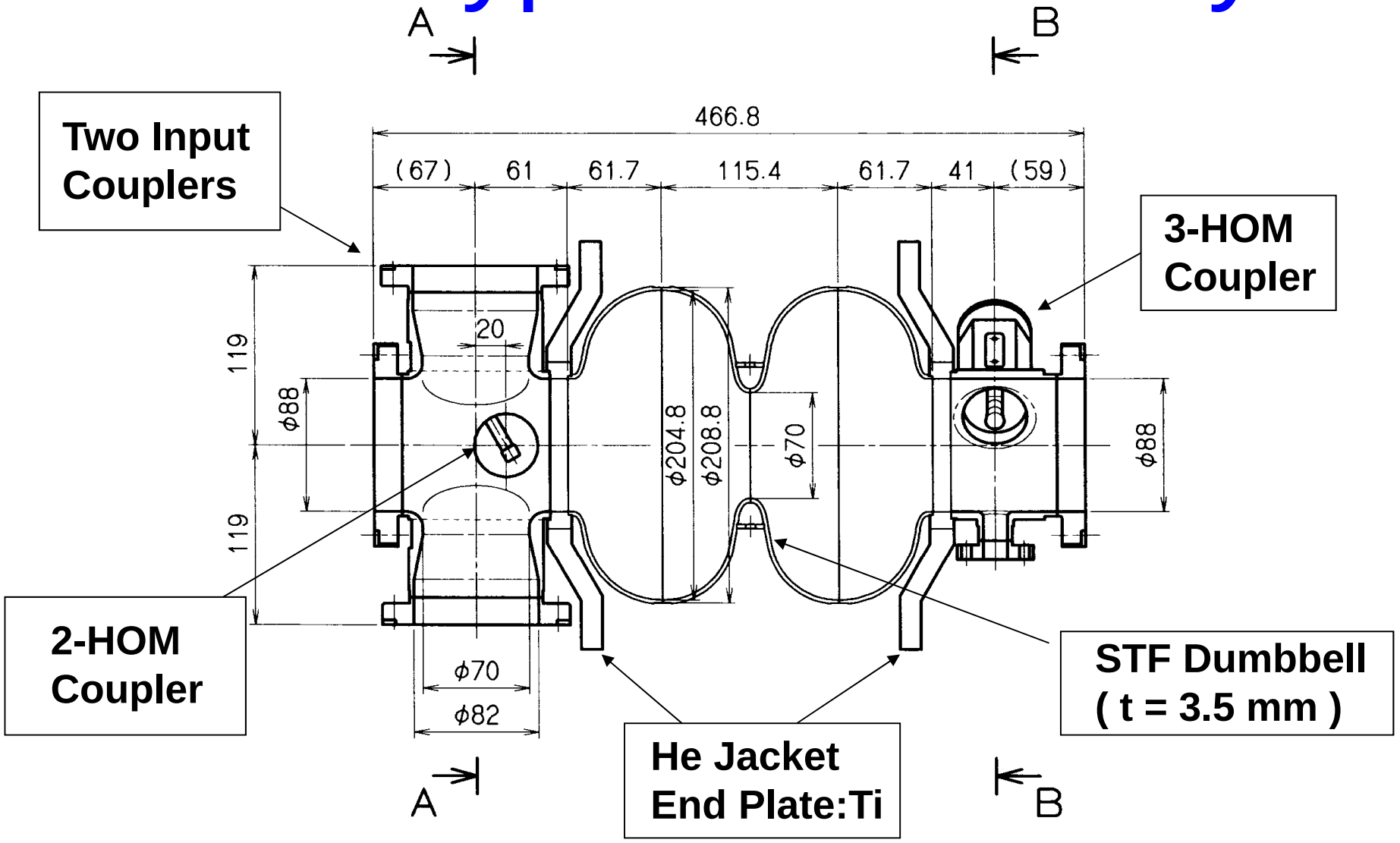
Injector Module Parameters (10 MeV, 100 mA)					
Frequency	1.3 GHz				
Number of cell / cavity (& Cavity)	3 (2)	2 (4)	2 (3)	2 (2)	1 (4)
Effective Length	34.6 cm	23.0 cm	23.0 cm	23.0 cm	11.5 cm
Accelerating Voltage	5 MV	2.5 MV	3.4 MV	5 MV	2.5 MV
Accelerating Gradient	14.5 MV/m	10.9 MV/m	14.7 MV/m	21.7 MV/m	21.7 MV/m
R/Q	300 Ω	200 Ω	200 Ω	200 Ω	100 Ω
Geometrical Factor G	280 Ω	280 Ω	280 Ω	280 Ω	280 Ω
Unloaded Q	$1x10^{10}$	$1x10^{10}$	$1x10^{10}$	$1x10^{10}$	$1x10^{10}$
Cavity Loss	8.3 W	3.2 W	5.8 W	12.5 W	6.3 W
Beam Current	100 mA	100 mA	100 mA	100 mA	100 mA
Beam Power	500 KW	250 KW	340 KW	500 KW	250 KW
Number of Input Coupler	2	2	2	2	2
Optimum Coupler Q	$1.7x10^{5}$	$1.3x10^{5}$	$1.7x10^{5}$	$2.5x10^{5}$	$2.5x10^{5}$
Half Band Width	3.8 kHz	5.0 kHz	3.8 kHz	2.6 kHz	2.6 kHz
Number of HOM Coupler	5	5	5	5	5
2k Load (static)	47 (11) W	59 (17) W	51 (14) W	53 (11) W	63 (17) W
5k Load (static)	64 (22) W	92 (44) W	75 (33) W	58 (22) W	80 (44) W
80k Load (static)	233 (85) W	323 (155) W	270 (120) W	213 (85) W	283 (155) W

Heat Load of Cryomodule (1 MW Beam)

2cell x 3	2k		5k		80k	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Cavity		6 W				
Input Coupler	2 W	2 W	6 W	8 W	20 W	30 W
HOM Cable	1 W	3 W (100 W)	5 W	6 W	15 W	20 W
Sub-Total	3 W	11 W	11 W	14 W	35 W	50 W
Beam Pipe		4 W			10 W	
Others	5 W				5 W	
Module Total	14 W	37 W	33 W	42 W	120W	150 W

Cavity

Prototype 2-cell Cavity



Vertical Tests of prototype 2-cell Cavities

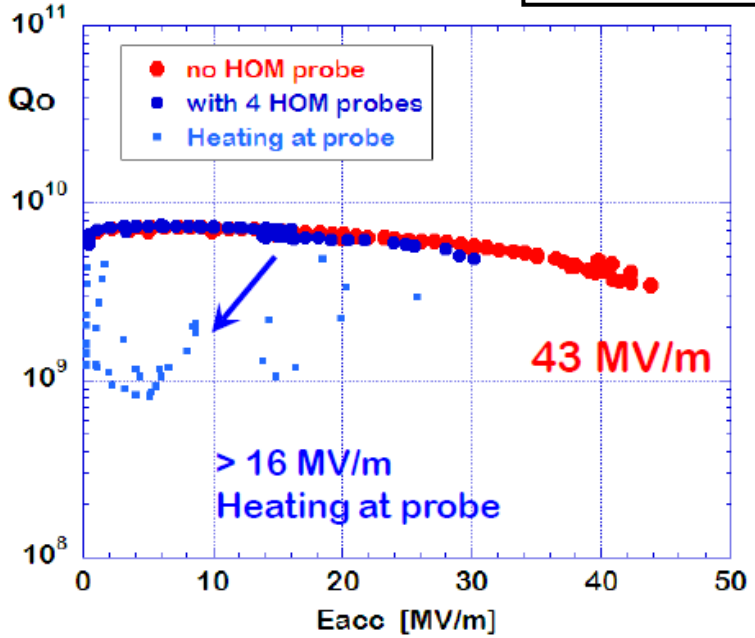
ERL prototype 2-cell #1 Cavity

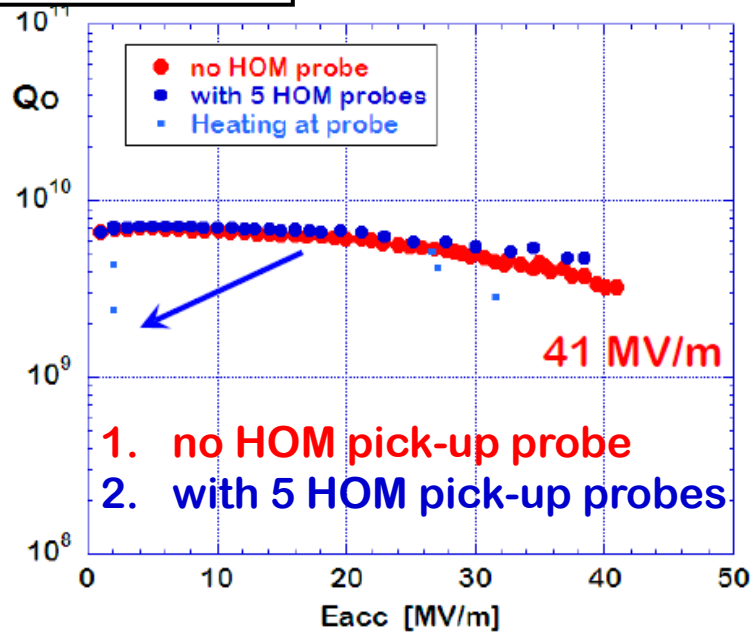
2 loop & 2 antenna-type HOM

ERL prototype 2-cell #2 Cavity

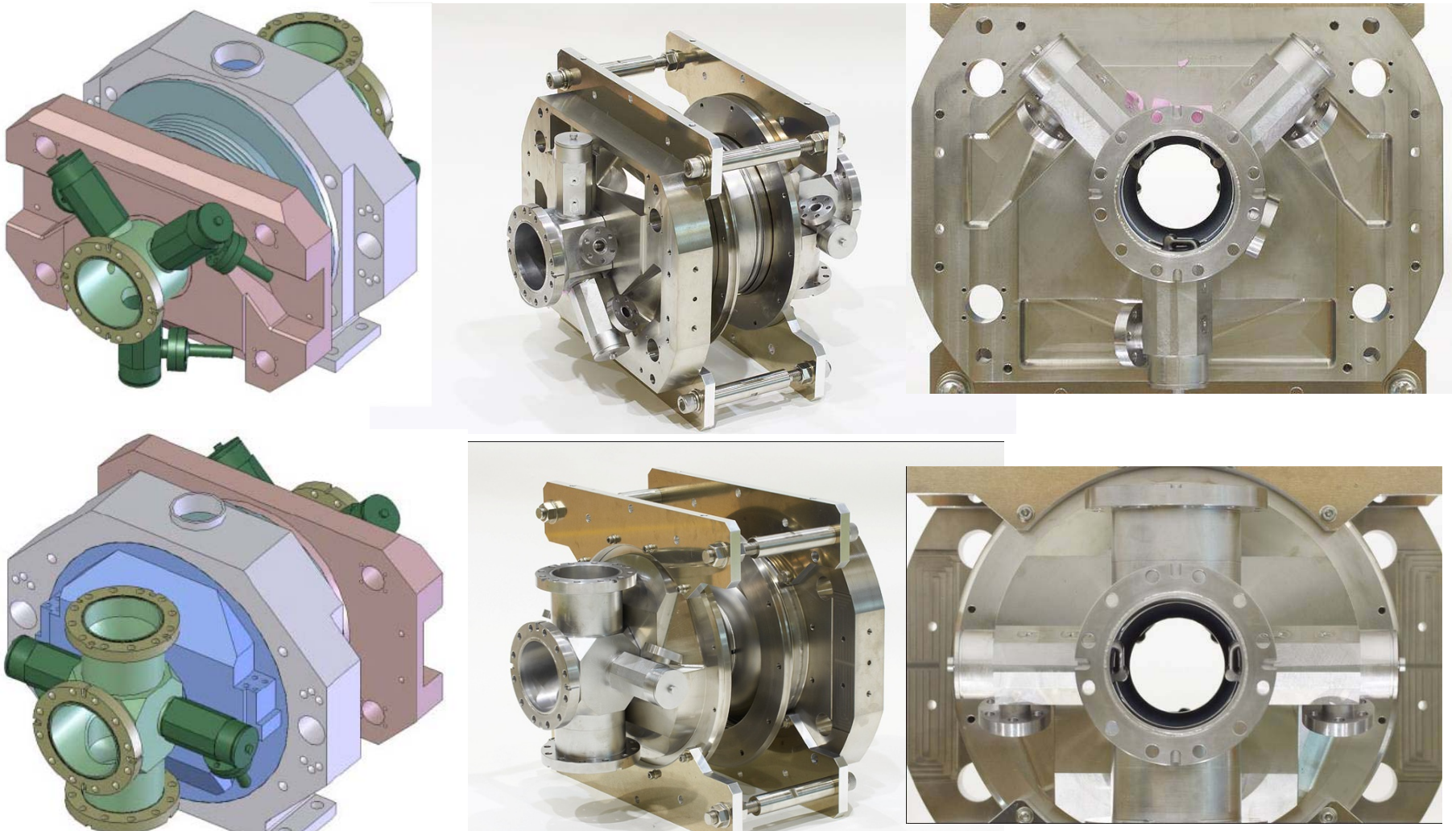
5 loop-type HOM couplers

Rres=38.6nΩ (Flange loss: 23nΩ)





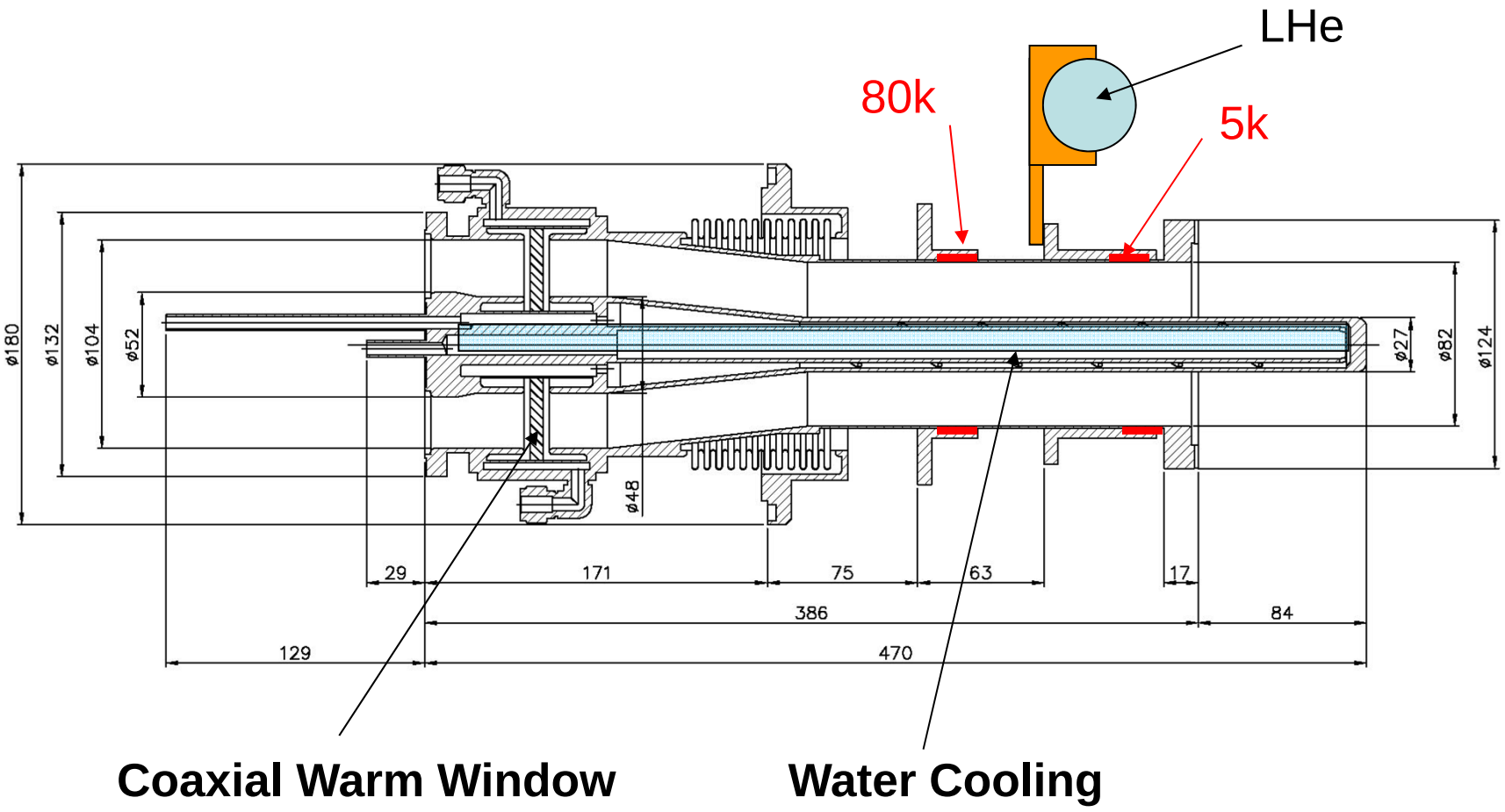
2-cell cavities for cERL Cryomodule



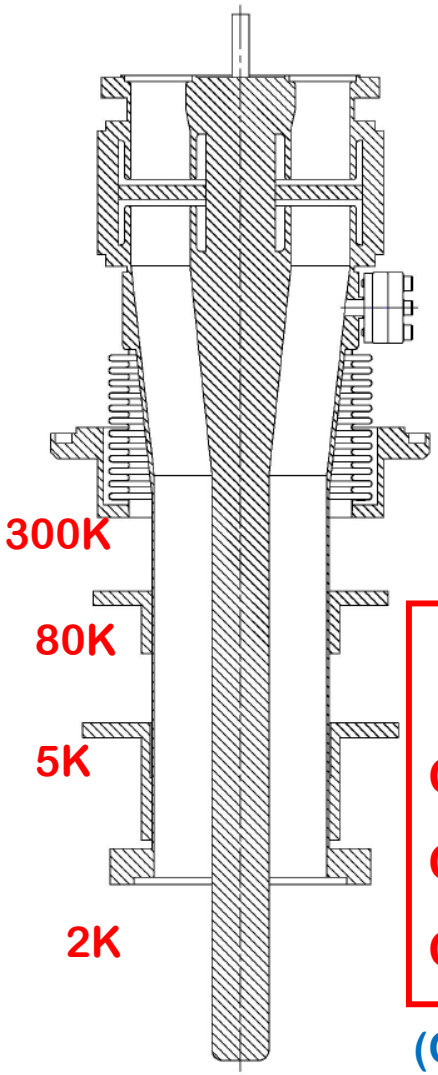
Magnetic Shield is installed inside of He Vessel.

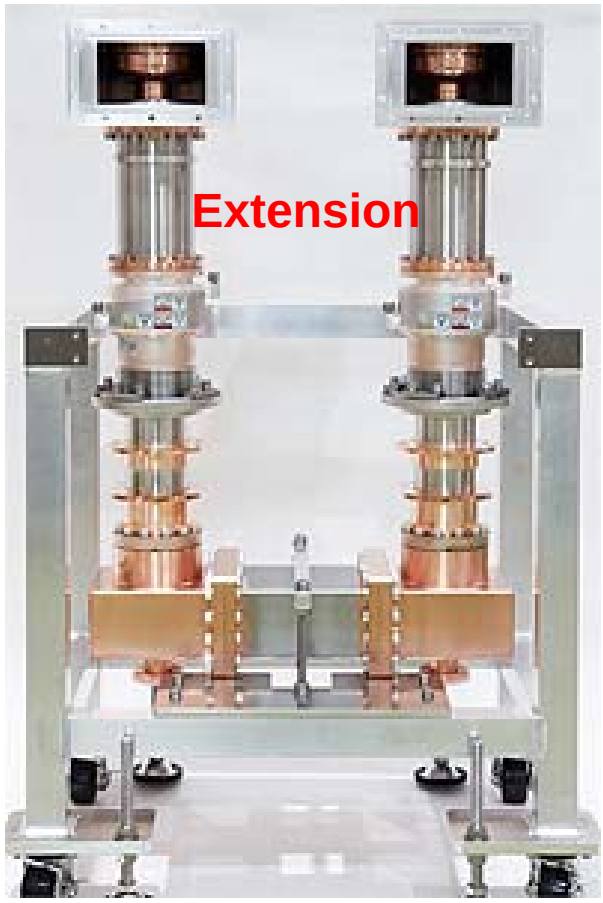
Couplers

Fixed Input Coupler



Design & fabrication of input couplers

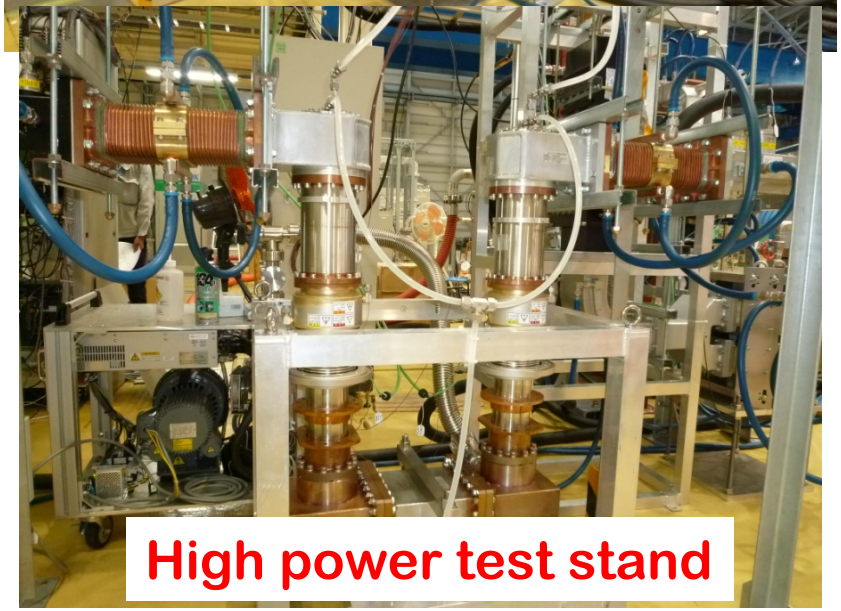


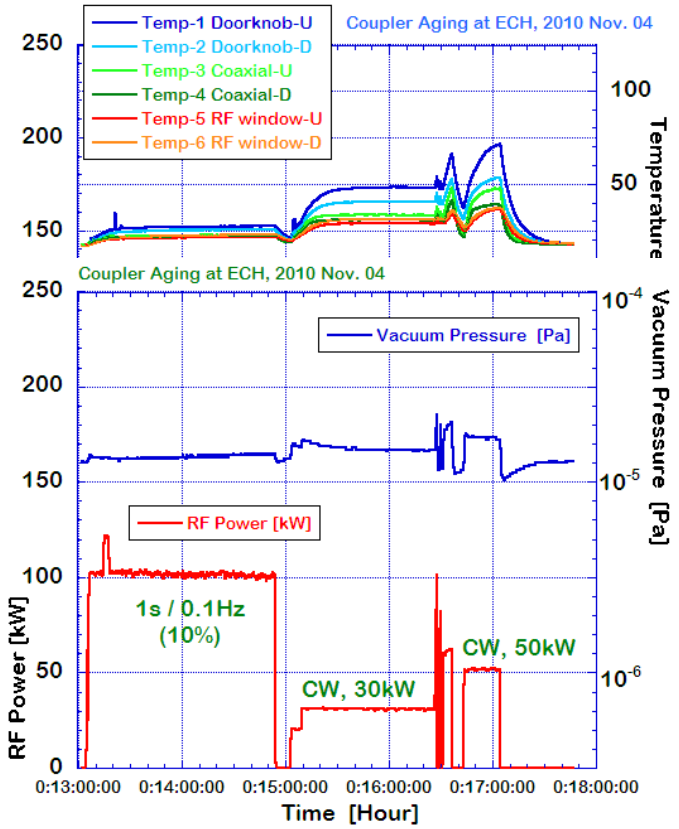


	V_{acc} [MV]	Q_L [x10^5]	P_{rf} [kW]
Cavity-1	1.5	10.	20
Cavity-2	2.5	4.	50
Cavity-3	2.5	4.	50

(Q_L /coupler, P_{rf} /coupler, I_{beam} = 20 mA)

Conditioning of input couplers





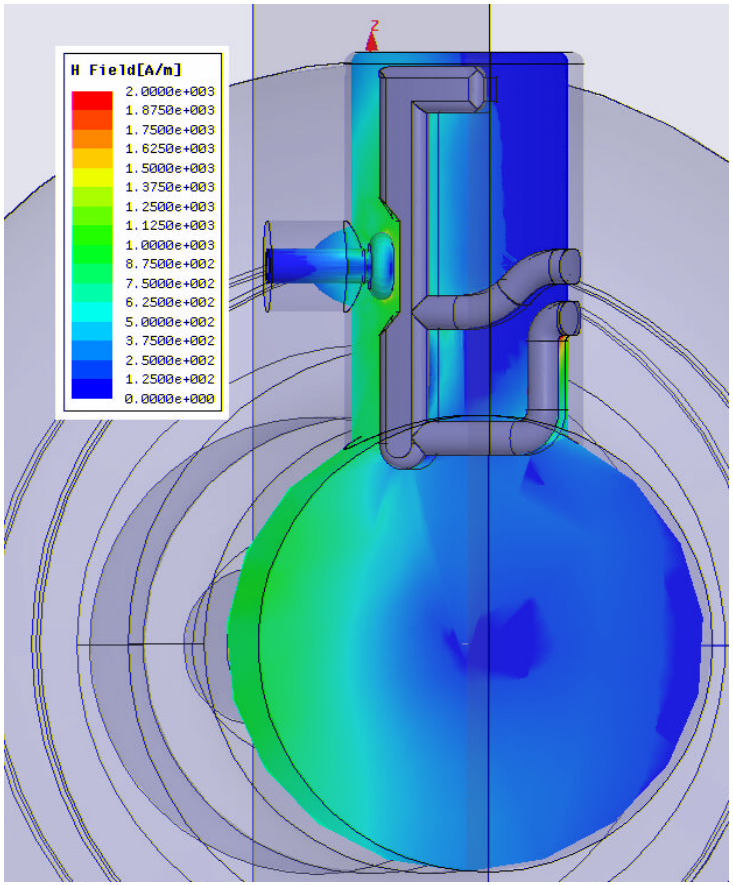
Conditioning Results

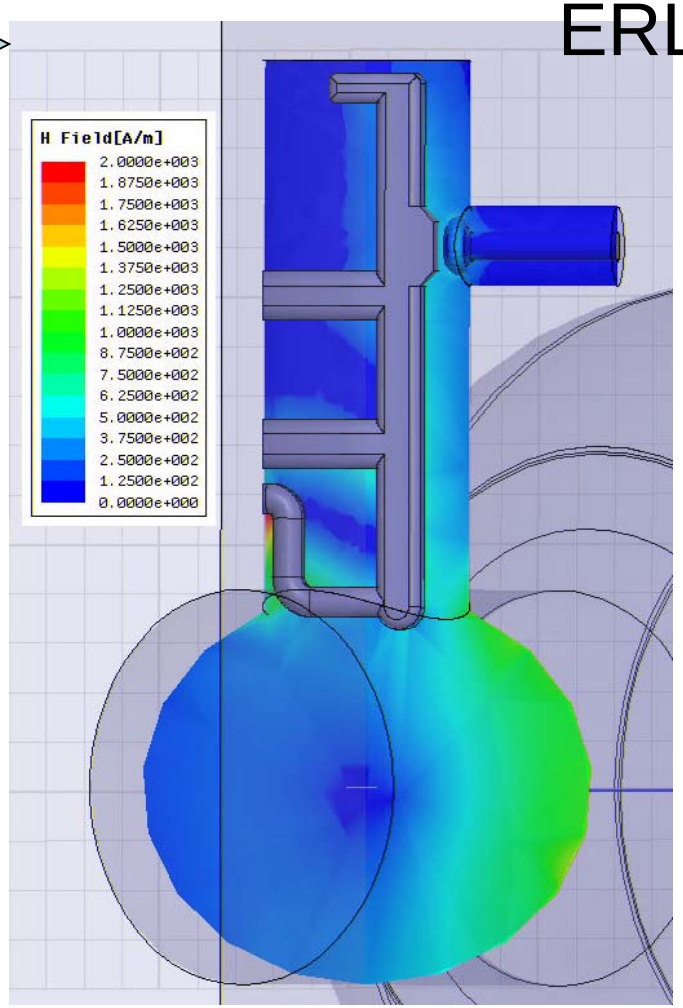
- 1s, 0.1Hz, 100kW for 2h
- cw 30kW for 1.5h
- cw 50kW for 0.5h
- cw 100kW for 1 min

Improved HOM Coupler

TESLA Type

ERL

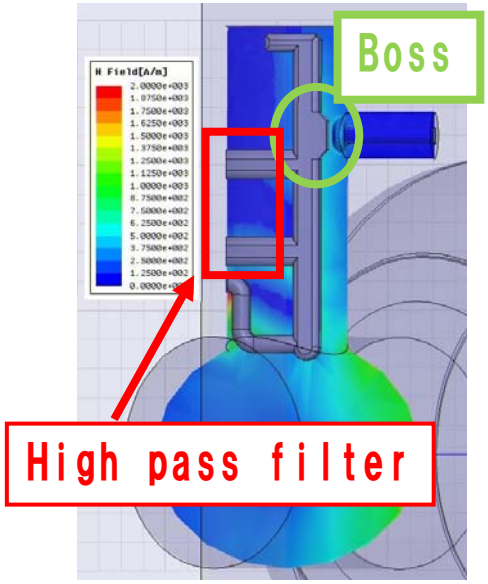




2. Cavity and HOM coupler

- Number of cell : 2 cell
- Number of Input coupler : 2 couplers
- HOM damper : Coaxial type HOM coupler x 5

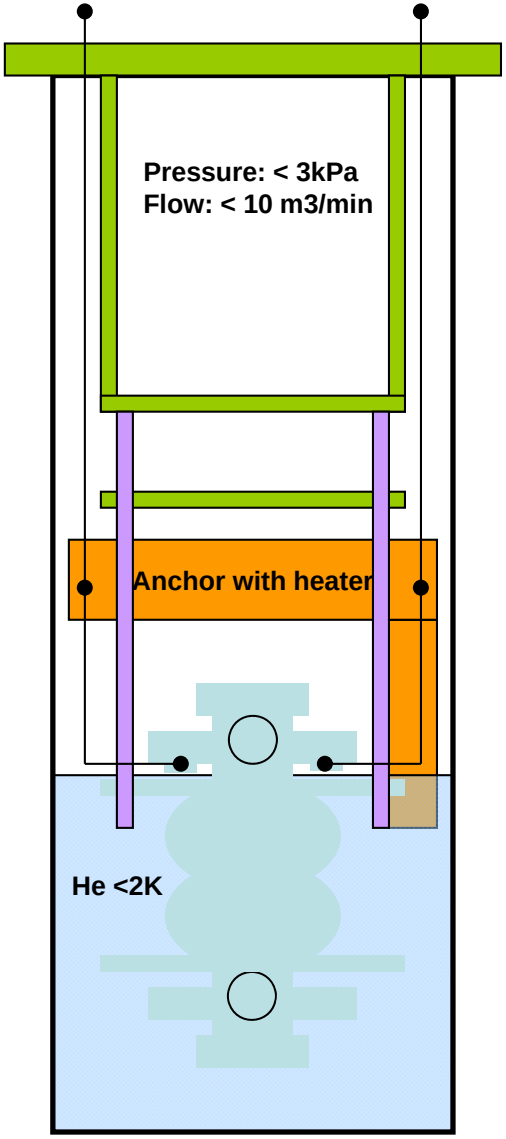
The HOM coupler was designed by based on TESLA type coaxial HOM coupler.
The TESLA type HOM coupler has a heating problem at low field in CW operation.



* Deduce a surface current at HOM coupler to 1/2 by high pass filter and boss.
* The loss also reduces to 1/4.

The cavity performance w/o HOM pick-up was achieved exceed 40 MV/m in liq He. The fabrication of cavity is good quality.
A problem of designed HOM coupler is heating of HOM pick-up antenna at operating field. We need to do development a feed-through with good thermal conductivity.

3. Setup and RF test in vertical test

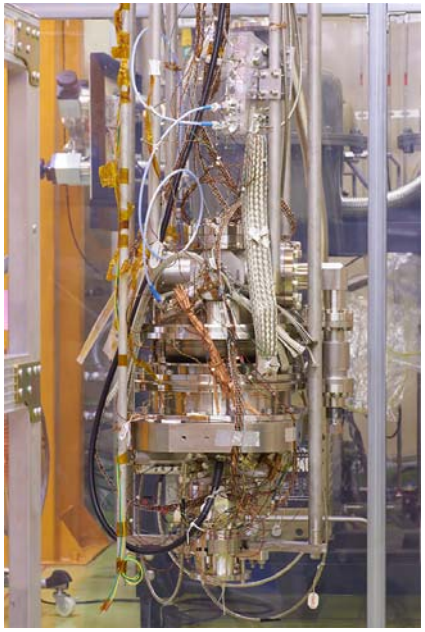


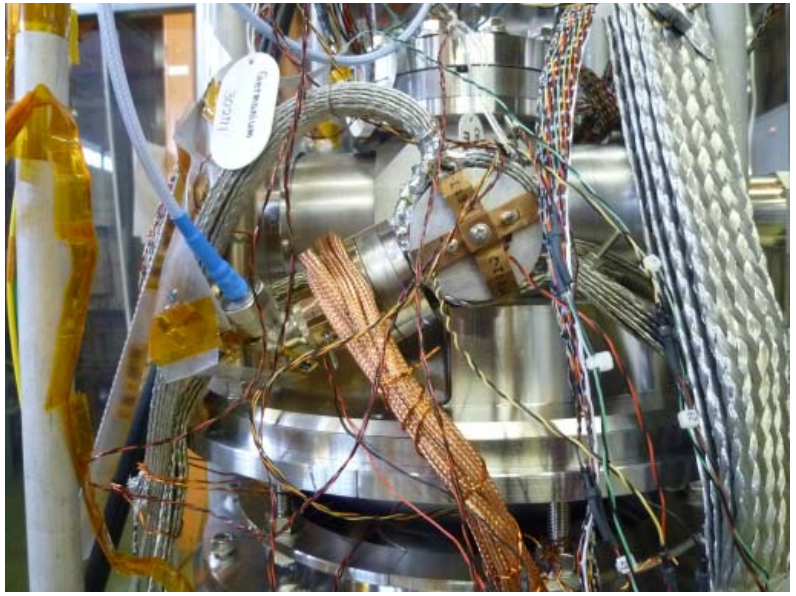
Unfortunately, KEK don't have the CHECIA. We can not test at bad cooling situation before install the real injector cryomodule.

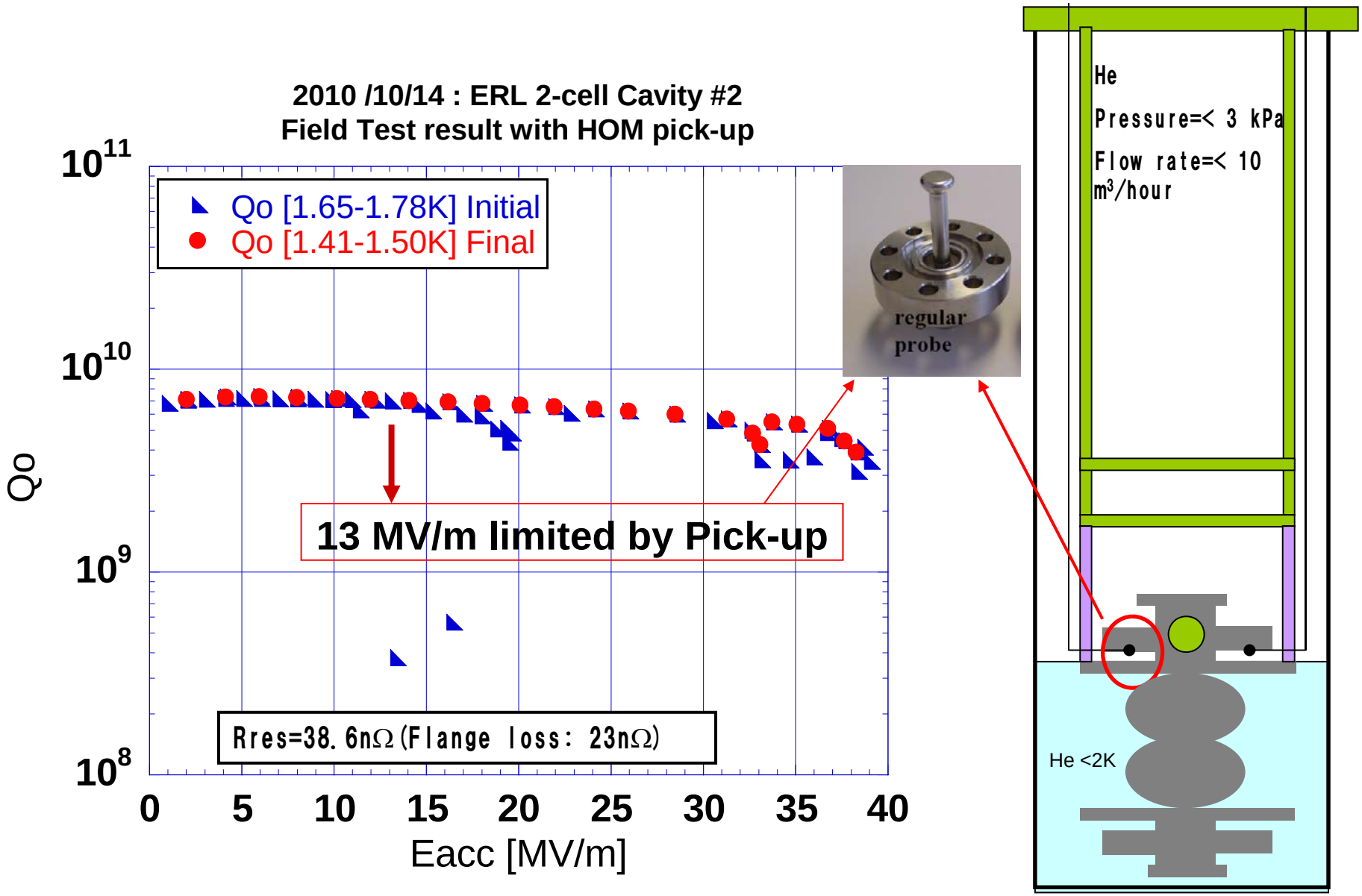
To estimate the cavity performance without the CHECIA, we try to control the liq. He level and flow rate in the Dewar at vertical test. **(make a bad cooling situation)**

And the He level vs the Suitable field at CW measured for it.

Six thermo-sensors attached on each HOM couplers to be monitoring a heating. (Feed-through, Outer conductor and etc…)

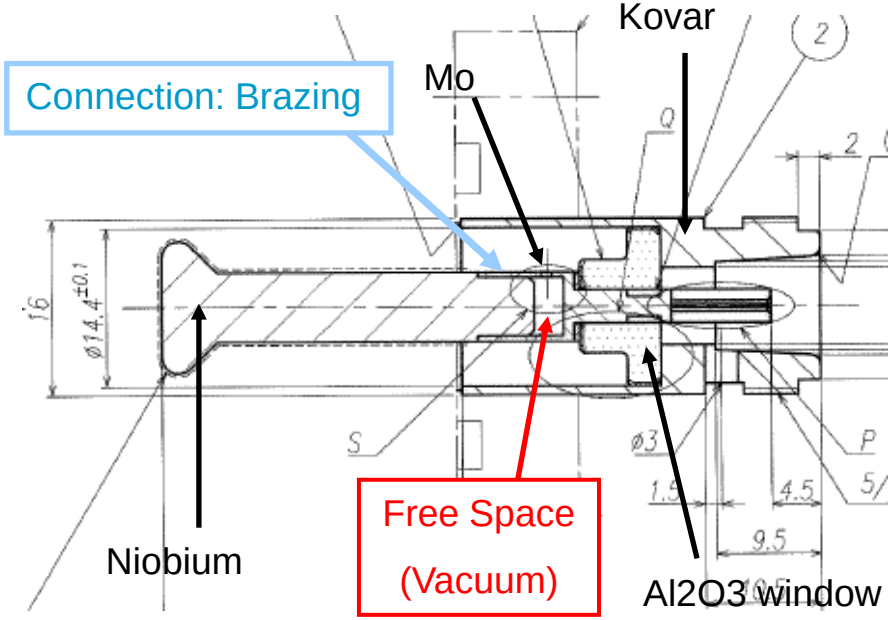




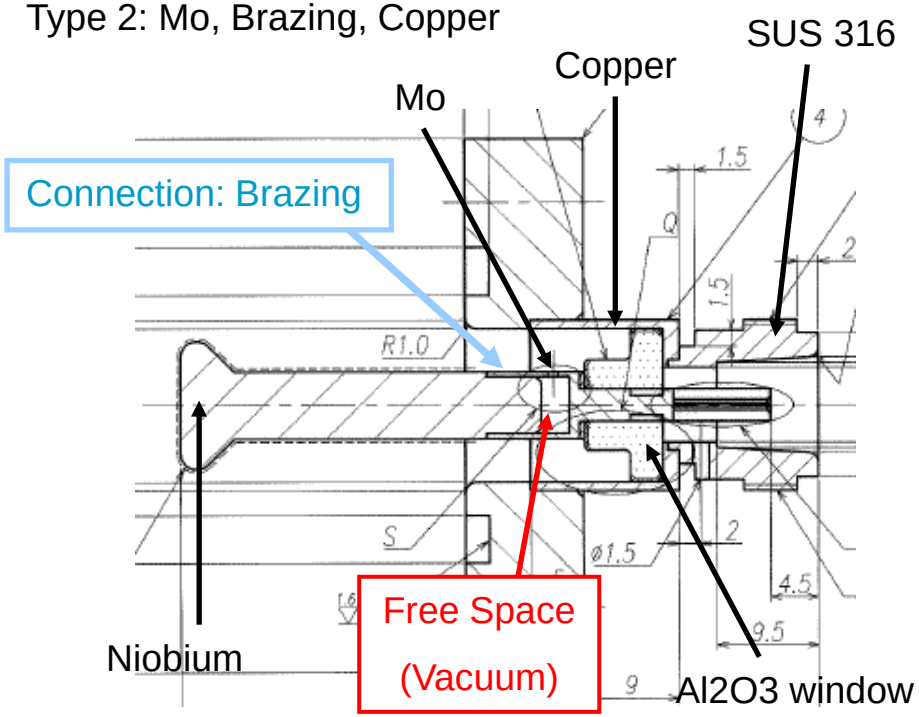

2010 /10/14 : ERL 2-cell Cavity #2
Field Test result with HOM pick-up
Qo [1.65-1.78K] Initial
Qo [1.41-1.50K] Final
13 MV/m limited by Pick-up
Rres=38.6nΩ(Flange loss: 23nΩ)
Qo
Eacc [MV/m]
regular probe
He
Pressure=< 3 kPa
Flow rate=< 10 m3/hour
He <2K

2. Feed-through (2) Modify based on Kyocera N-R type

Type 1: Mo, Brazing



Type 2: Mo, Brazing, Copper

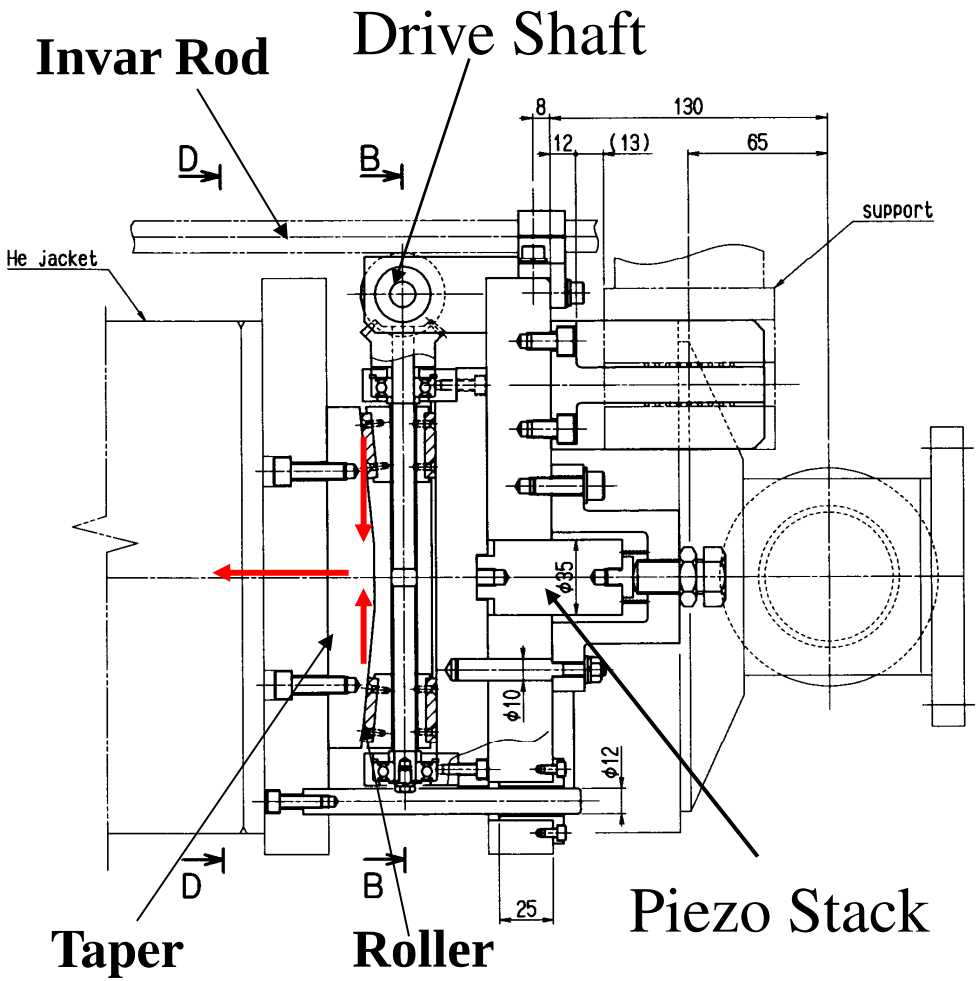


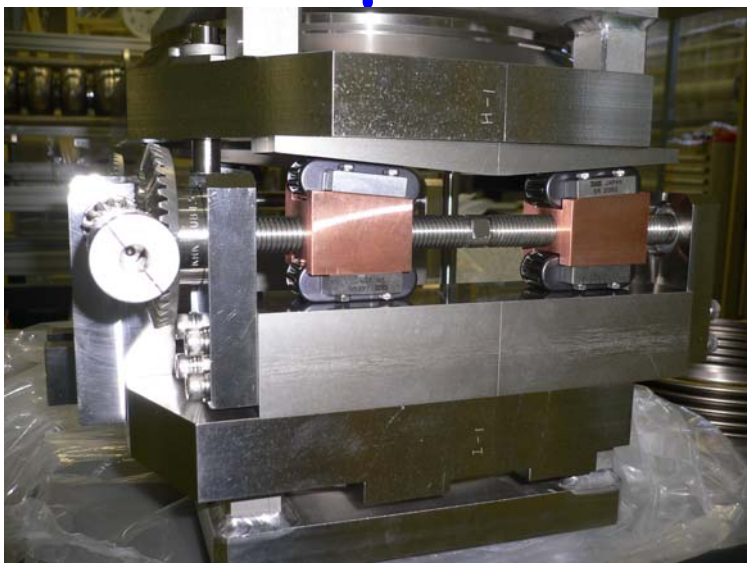
HOM Dumping with 5 Couplers

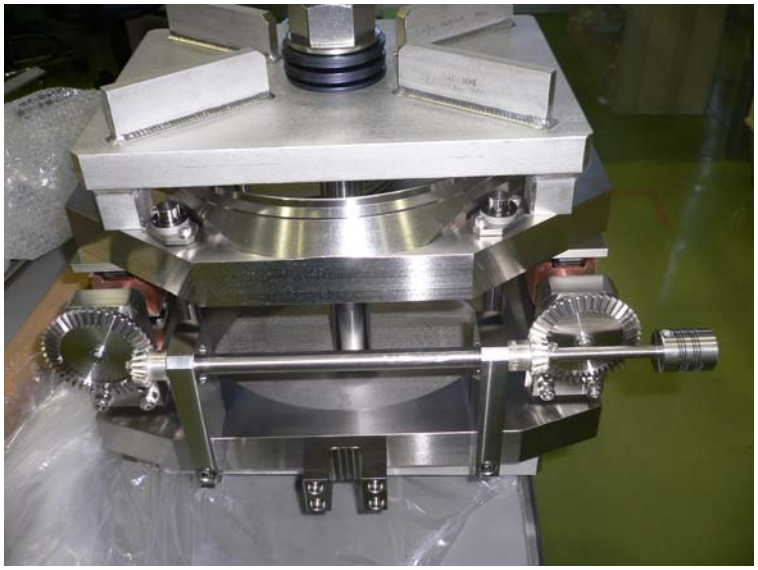
Mode	Frequency	R / Q	Measured Q_L
TE111	1.57GHz	0.59 Ω/cm^2	1000
	1.63GHz	1.8 Ω/cm^2	500
TM110	1.80GHz	4.0 Ω/cm^2	800
	1.88GHz	1.9 Ω/cm^2	1000
TM011	2.28GHz	64 Ω	1000
	2.31GHz	12 Ω	1200
TM020	2.67GHz	0.4 Ω	
	2.69GHz	31 Ω	

Tuner

Slide Jack Tuner 290N/μm





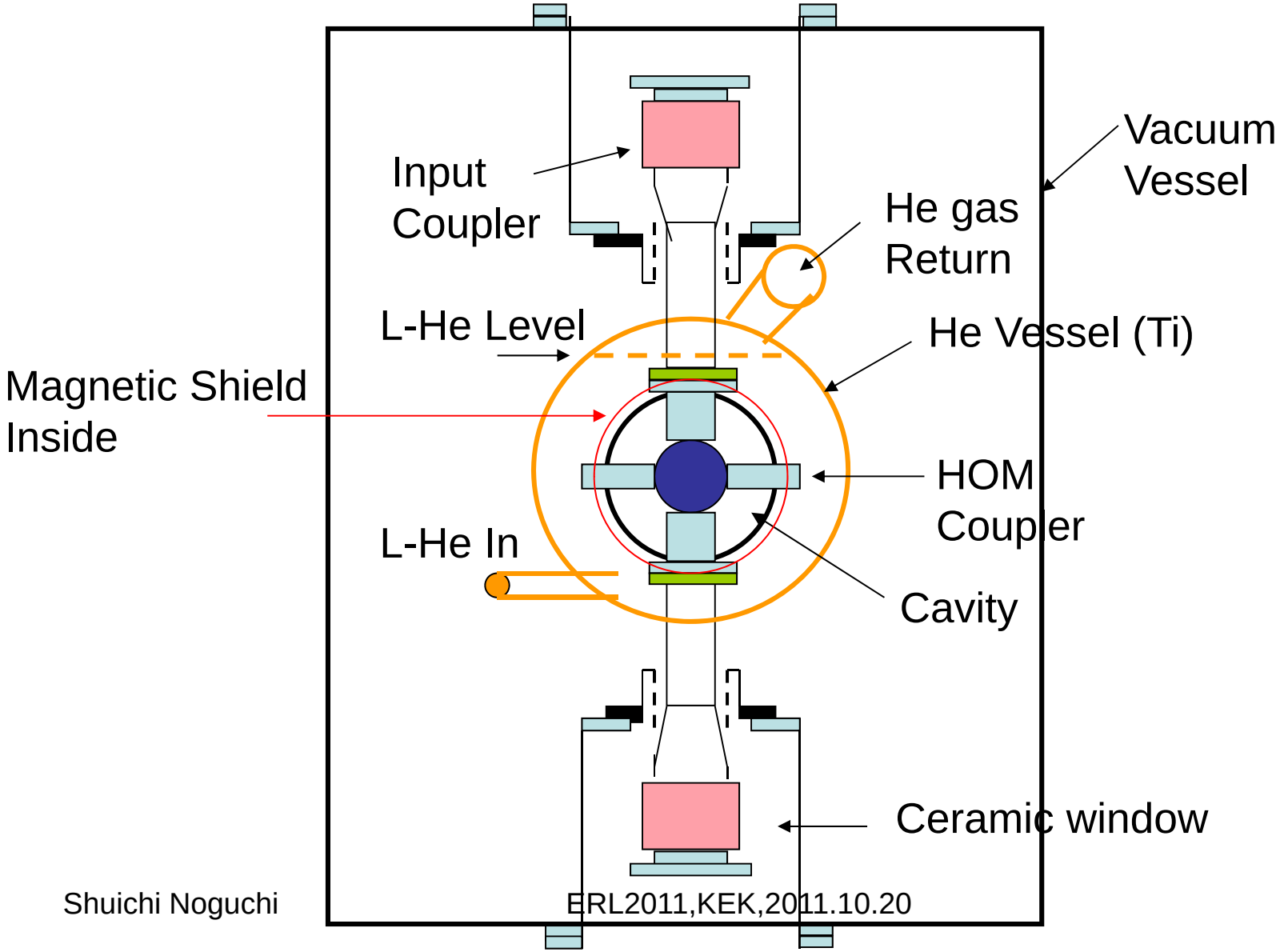


Slid-Jack Tuner Performance

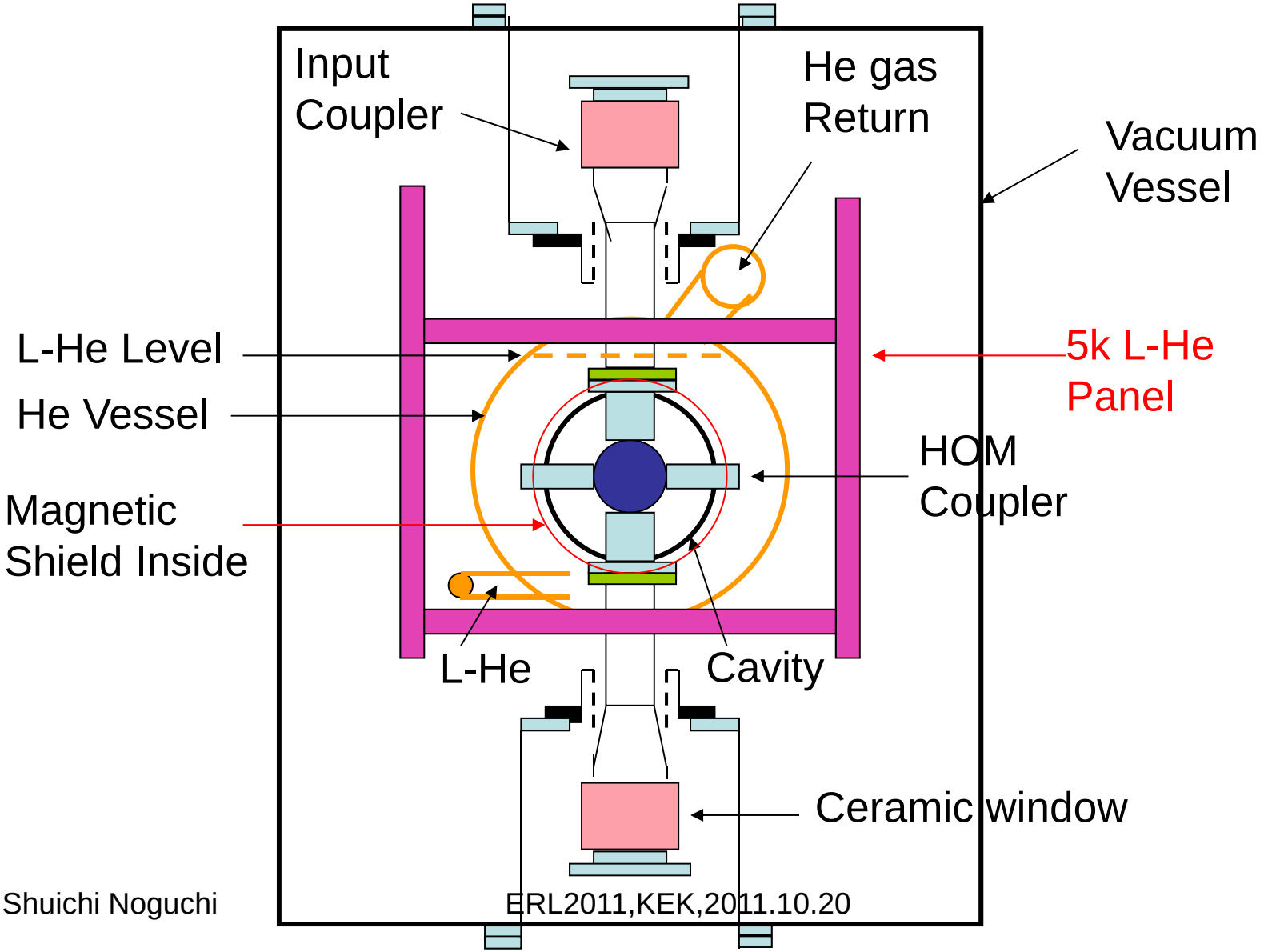
Cavity	Spring Constant	Sensitivity
	18 N/μm	1.3 kHz/μm
Tuner	Type	Stroke
Mechanical	Slid - Jack	1.6 mm 2.1 MHz
Fine Tuner	2 x Piezo (1000 V)	~ 6 μm ~ 8 kHz (2 x HBW)

Cryomodule

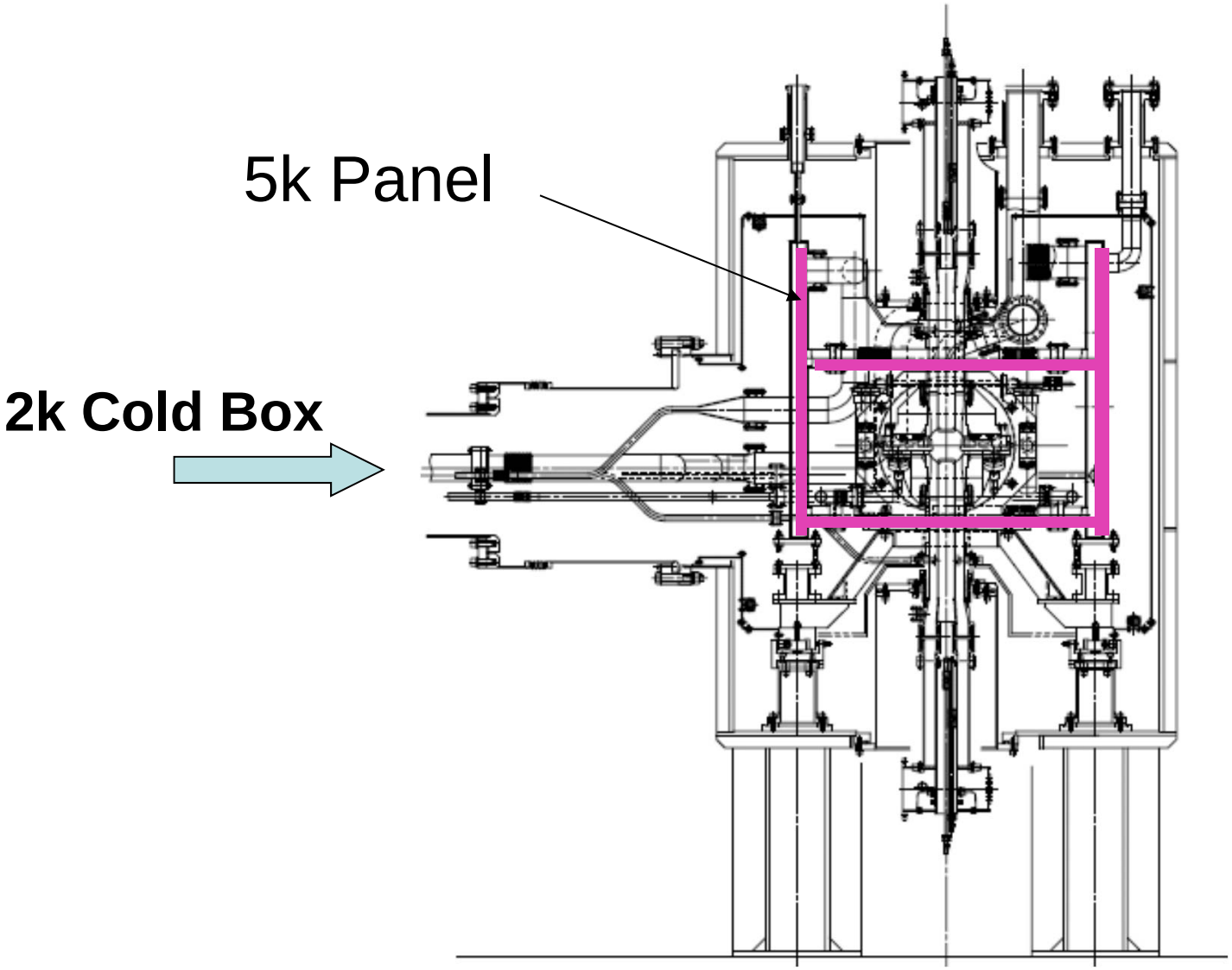
cERL Injector Cryomodule



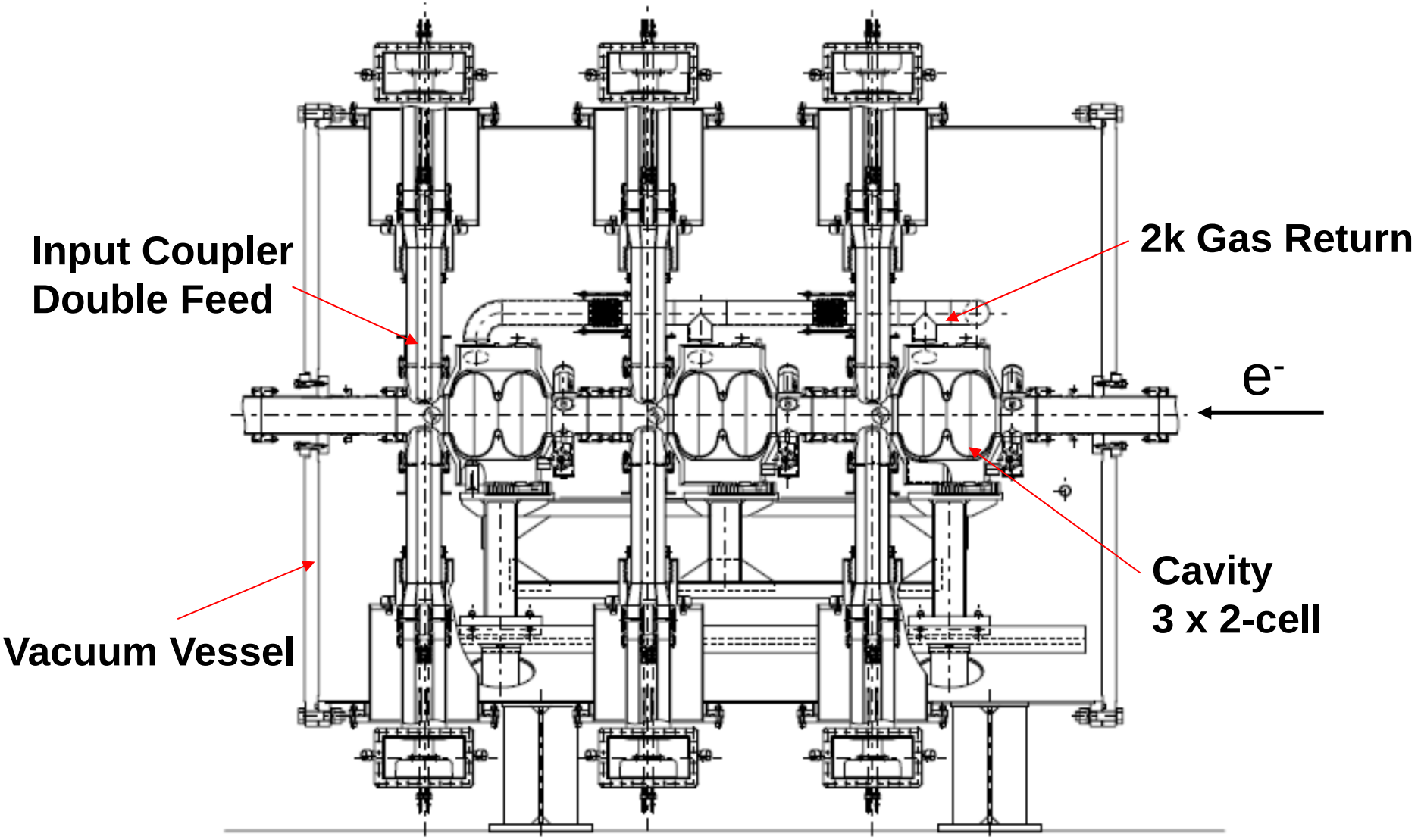
cERL Injector Cryomodule



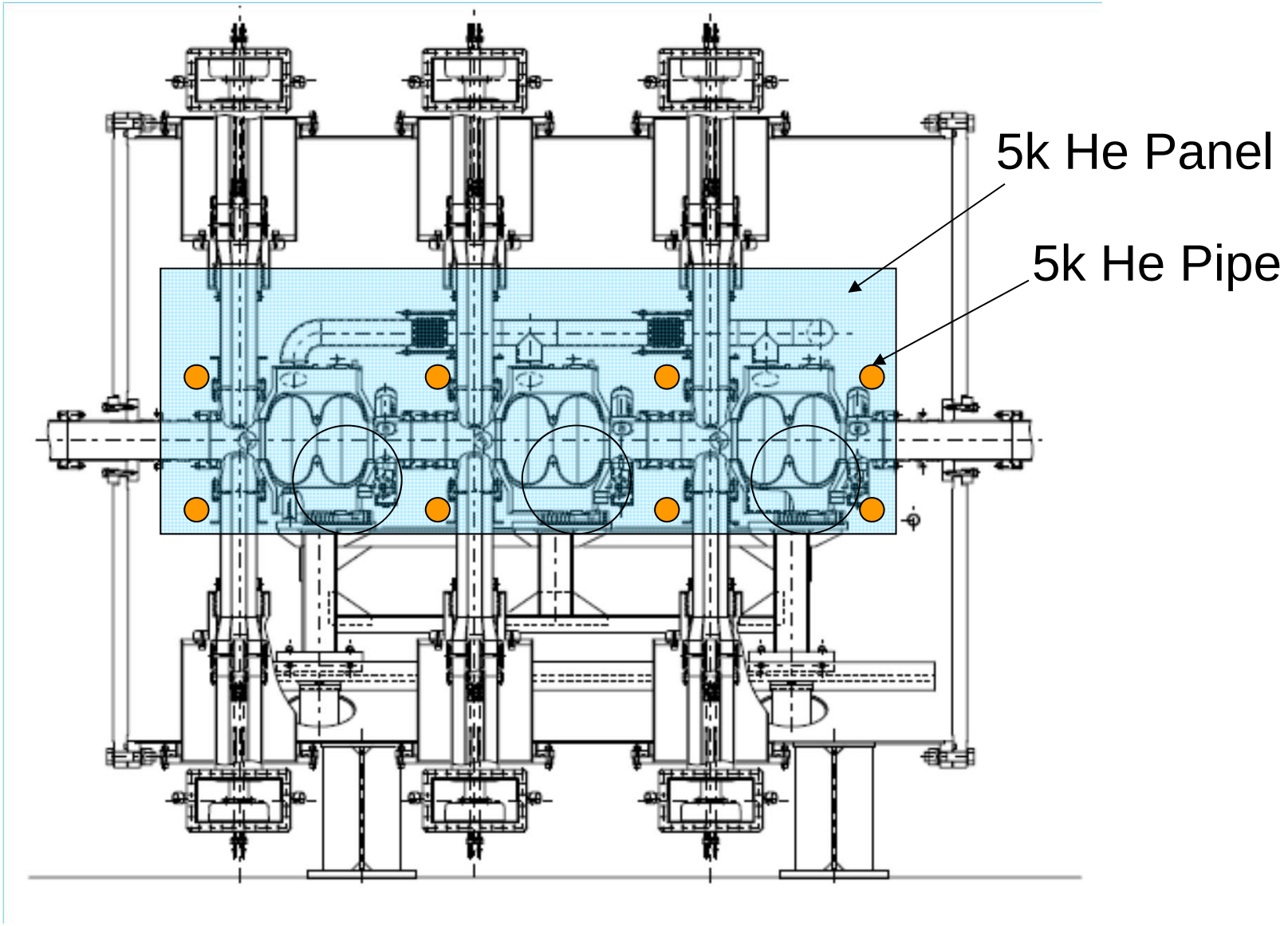
cERL Injector Cryomodule

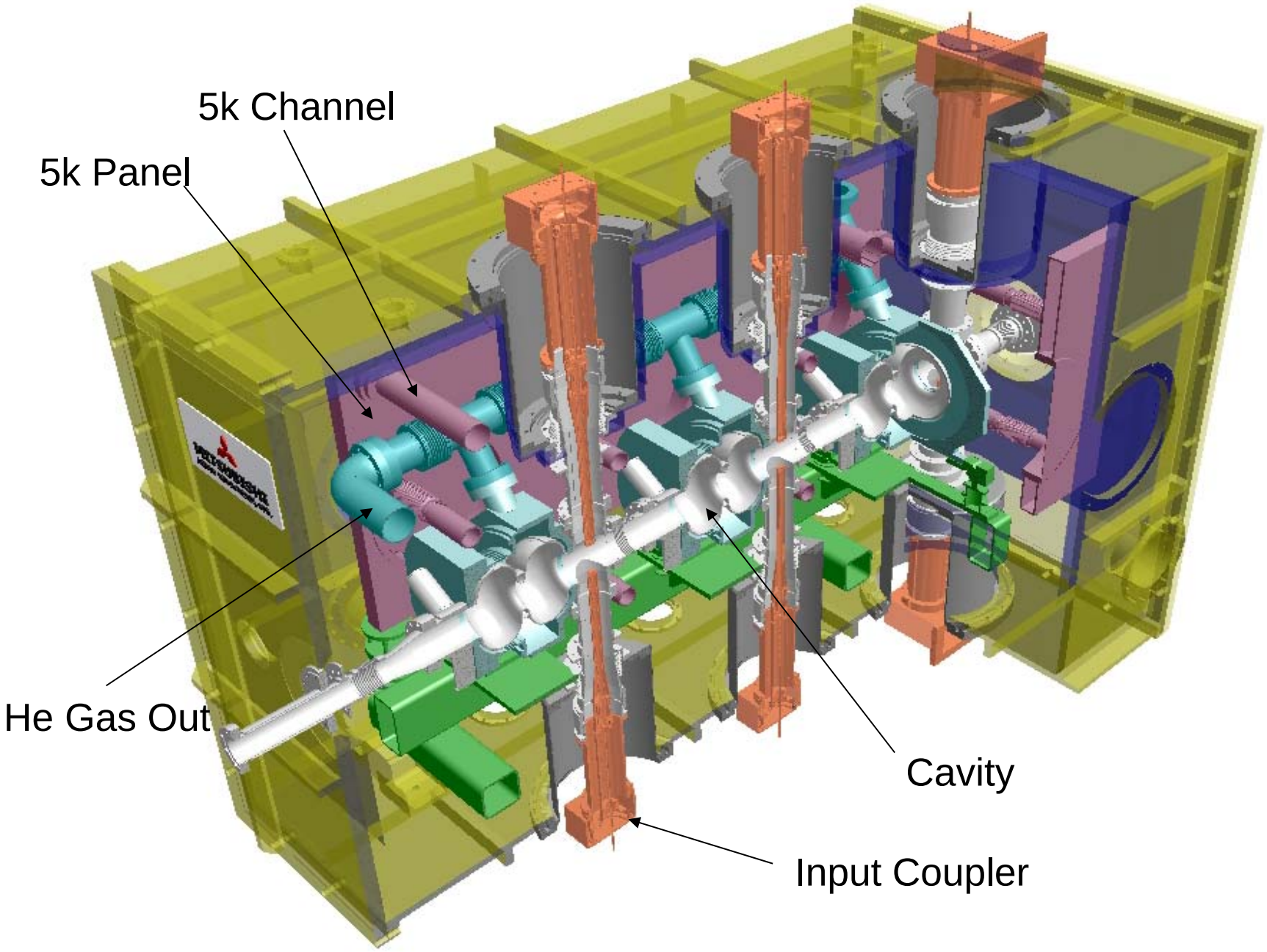


cERL Injector Cryomodule

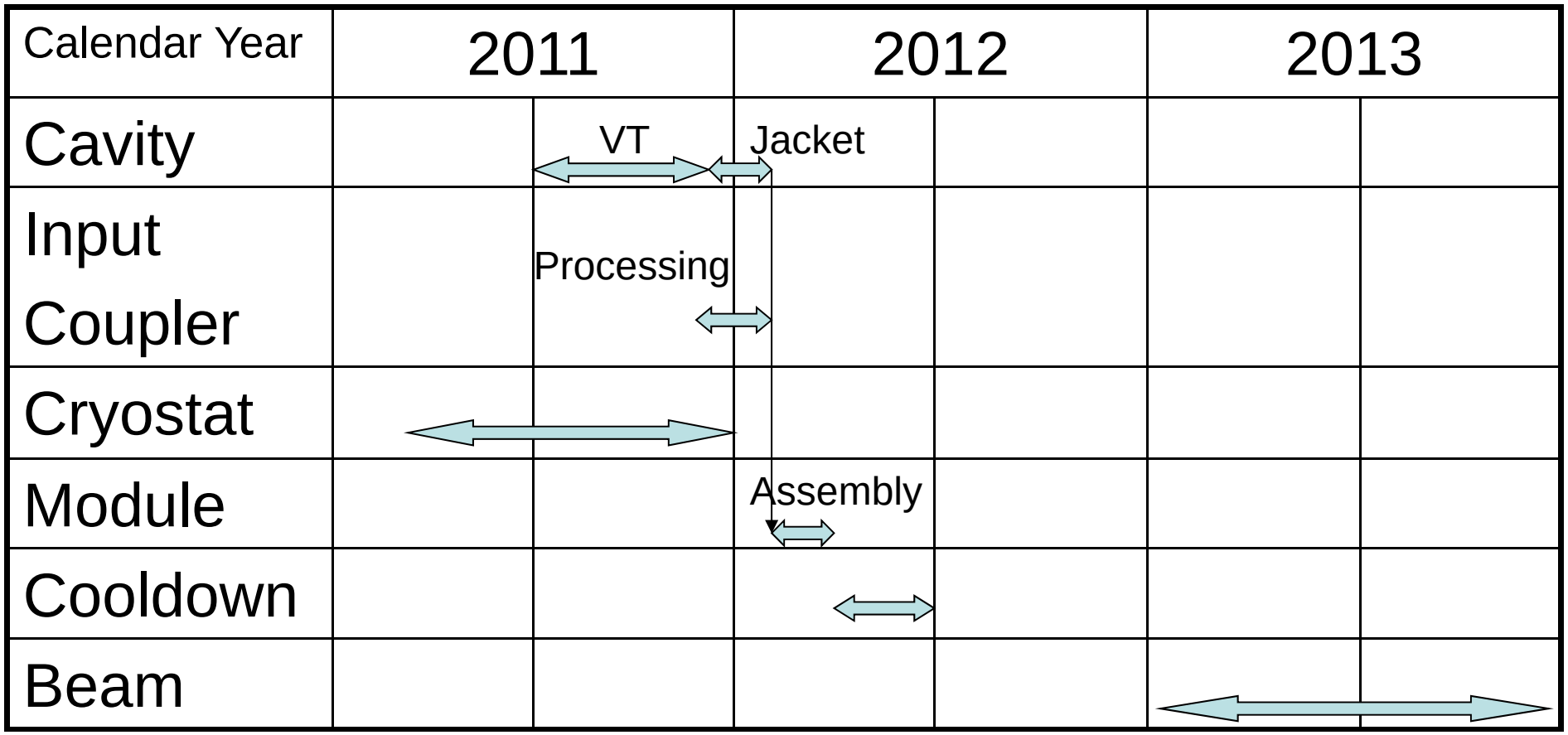


5k Panel




5k Channel
5k Panel
He Gas Out
Cavity
Input Coupler

Schedule


Calendar Year
2011
2012
2013
Cavity
VT
Jacket
Input Coupler
Processing
Cryostat
Module
Assembly
Cooldown
Beam