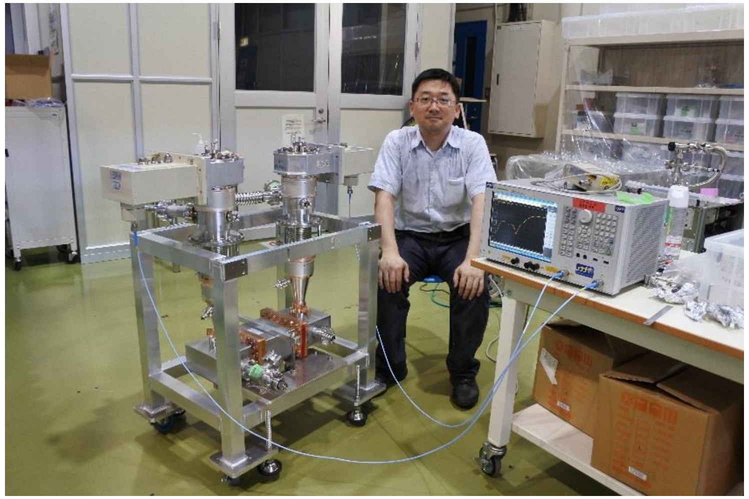
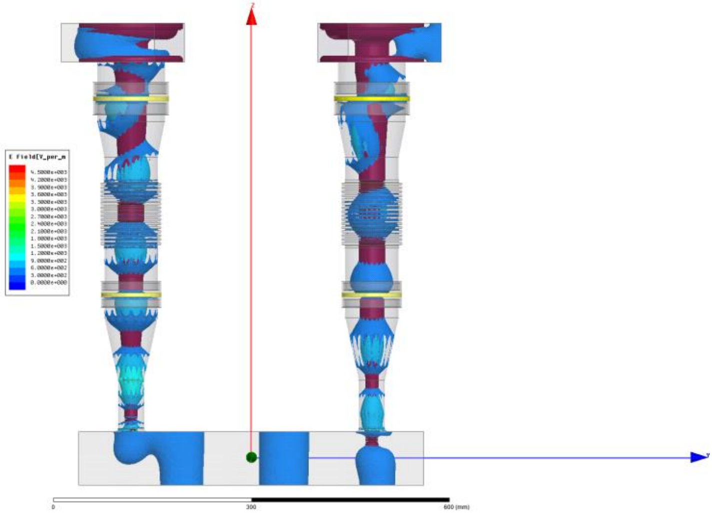


Recent Progress of STF Coupler R&D for the ILC



Akira Yamamoto, Kirk, Charles Julie, Eric Montesino, Toshihiro Matsumoto, Eiji Kako

Outline

- ILC-TDR
- Motivation
- RF design by HFSS
- Fabrication processes
- Incoming inspection
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ILC-TDR (for Power coupler specification)

These figures are shown on Page 35 in ILC-TDR Vol.3 Part-II.

Figure 3.6
Schematic drawing of TTF-III (XFEL) input coupler.

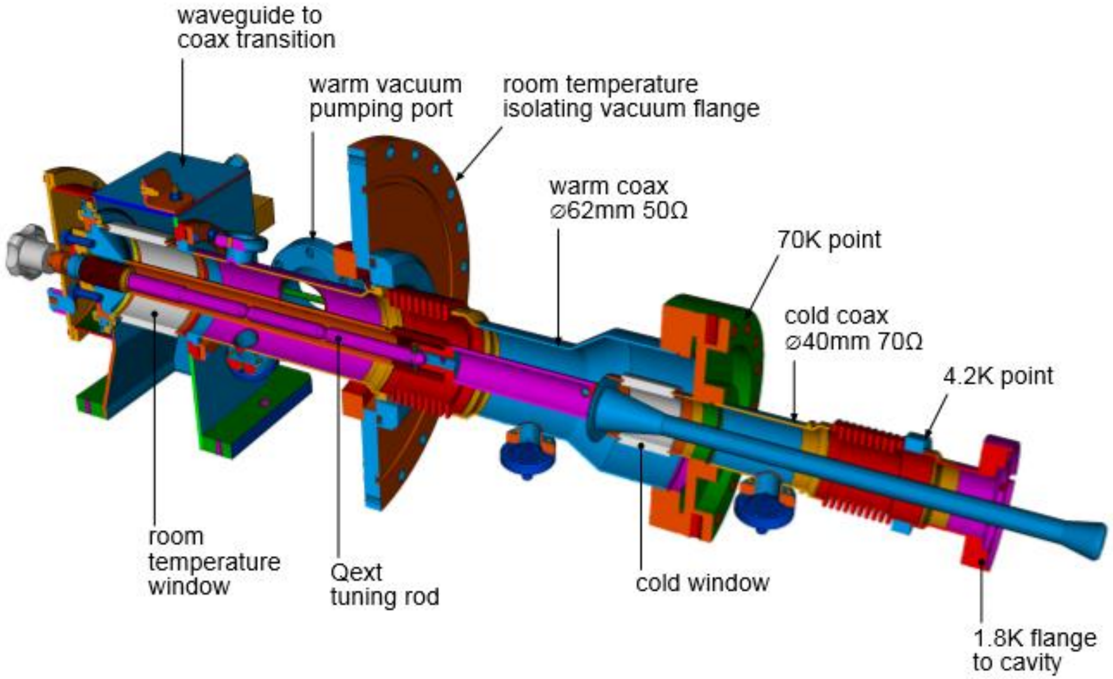

Table 3.7
Main specifications of the input coupler. The parameters represent the approximate maximum expected values during operation, including possible upgrades.

Parameter	Specifications
Frequency	1.3 GHz
Operation pulse width	1.65 ms
Operation Repetition rate	5 Hz / 10 Hz
Maximum beam current	8.8 mA
Accelerating gradient of cavity	31.5 MV/m $\pm$ 20%
Required RF power in operation	$\sim$ 400 kW
Range of external Q value	(1.0 $\sim$ 10.0) $\times 10^6$ (tunable)
RF process in cryomodule	$>$ 1200 kW for $\leq$ 400 µs pulse width
	$>$ 500 kW for $>$ 400 µs pulse width
RF process with reflection mode in test stand.	$>$ 600 kW for 1.6 ms pulse width
RF process time	$<$ 50 hours in warm state
	$<$ 20 hours in cold state
Approximate heat loads	$<$ 0.01 mW (2K static)
	0.07 W (5K static)
	0.6 W (40K static)
	$<$ 0.02 W (2K dynamic)
	0.12 W (5K dynamic)
	1.6 W (40K dynamic)
Number of windows	2
Bias voltage capability	Required

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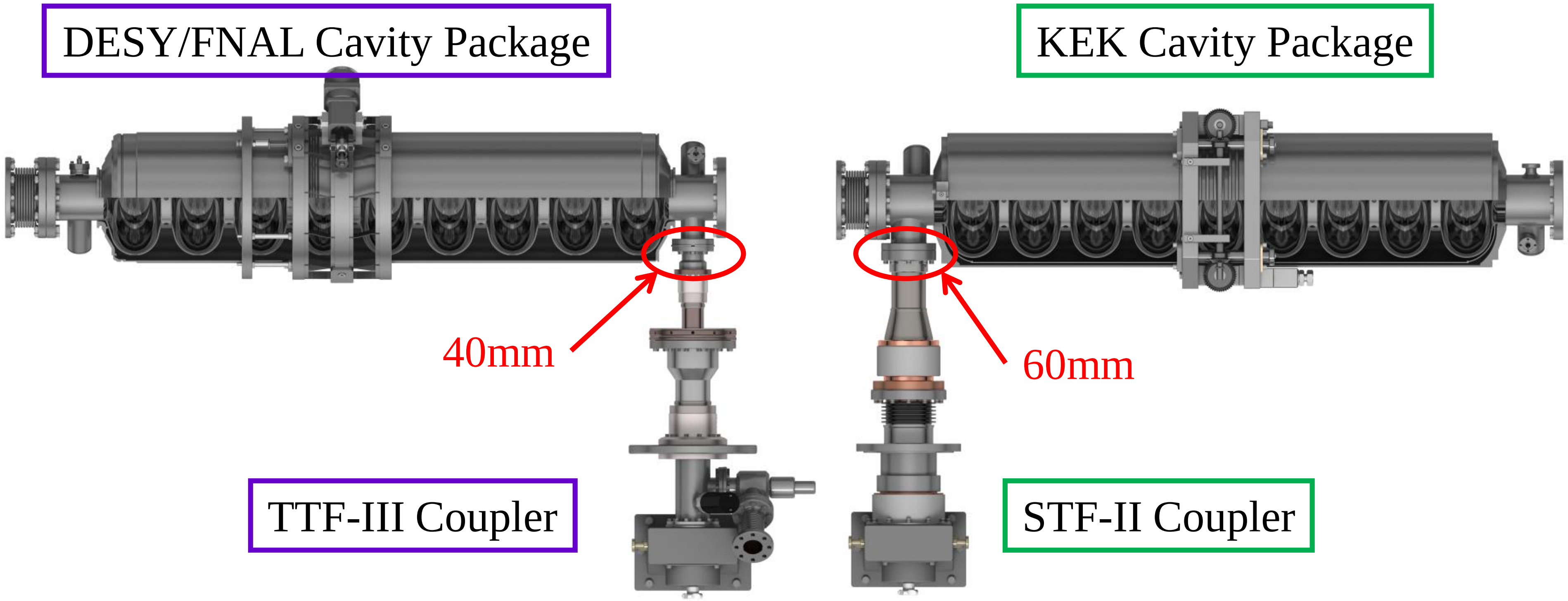
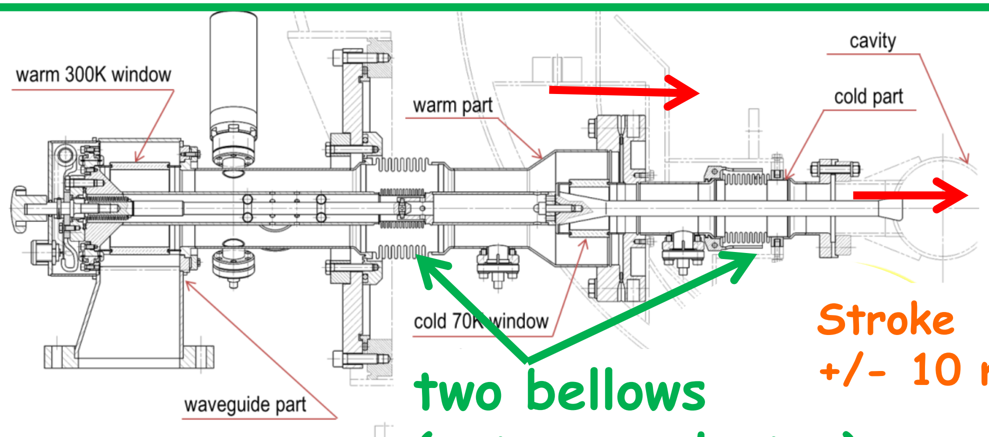
Motivation



In view of “Plug compatibility”, the use of STF-II coupler has to be evaluated for 40mm diameter.

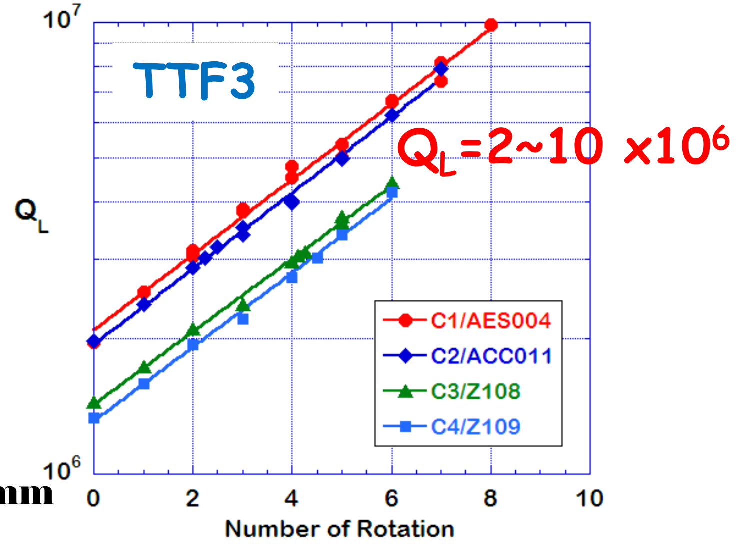
What is the most simple way for this change?

Input coupler performance in S1-G



two bellows
(outer conductor)

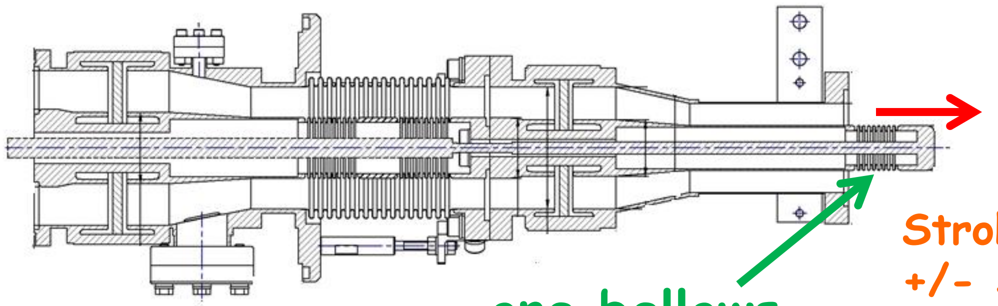
Stroke
+/- 10 mm



内導体外径**12.4mm**
先端部**20.7mm**

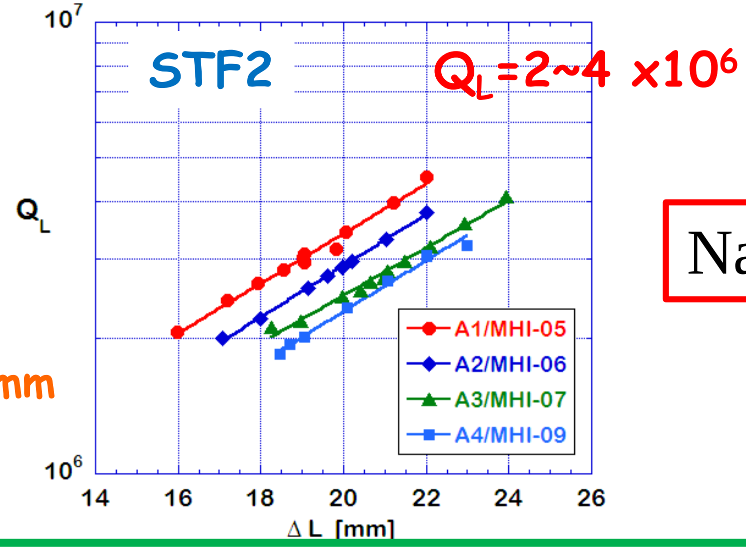
TTF3 Input Coupler

STF2 Input Coupler



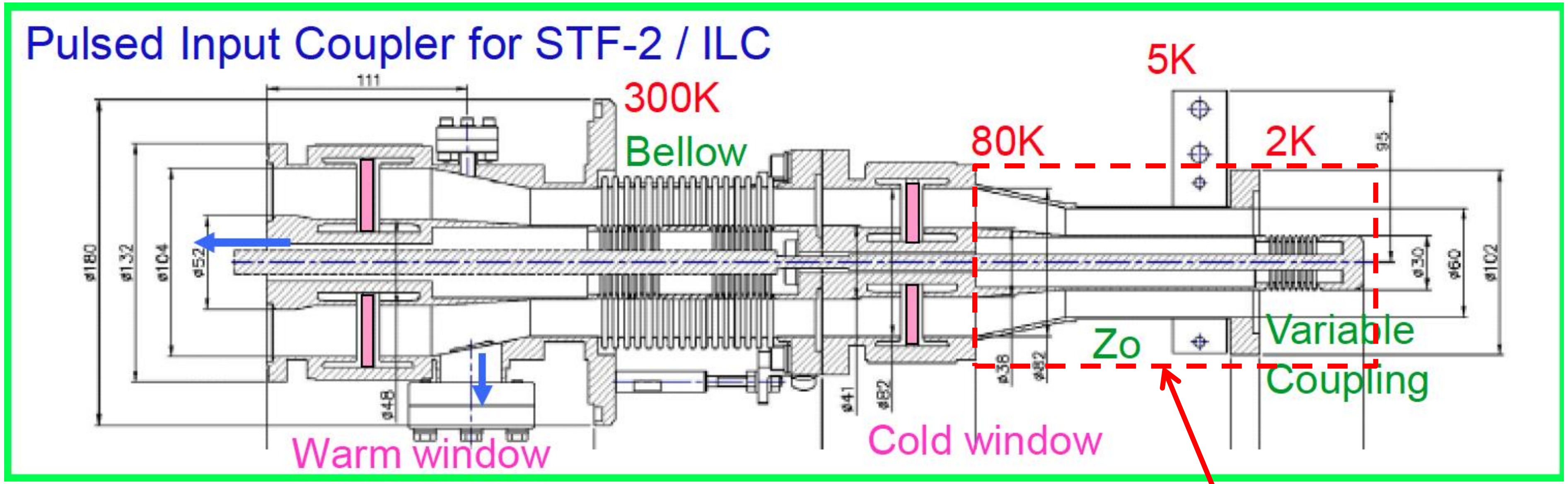
Stroke
+/- 3 mm

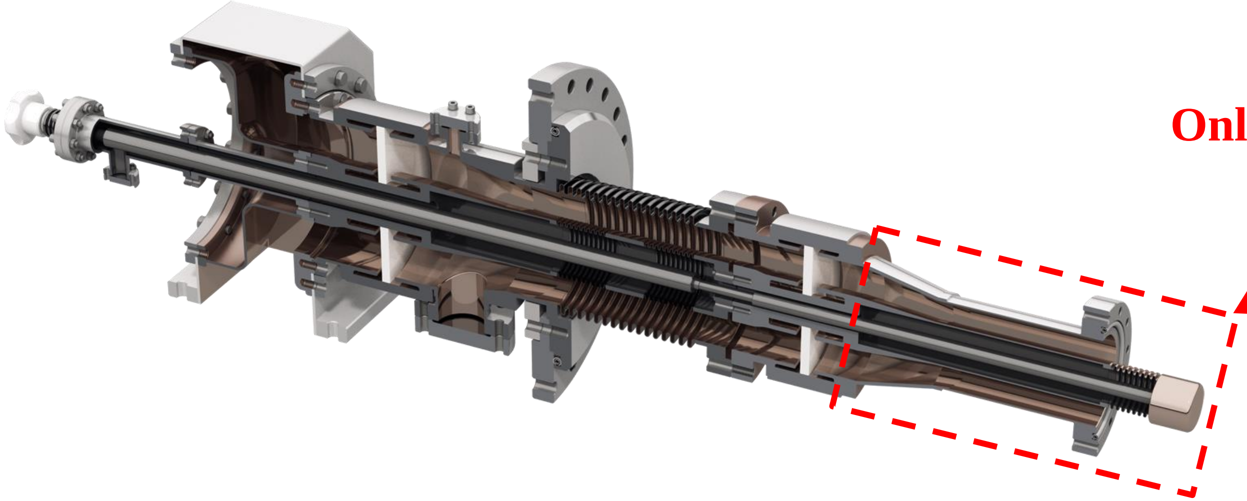
one bellows
(inner conductor)



Narrow range

Design of 40mm STF2 Coupler





Only this part should be changed!

- Longer tapered pipe to 40mm diameter
- Thinner inner conductor
- Longer bellows
- Plug-compatible to TESLA input flange

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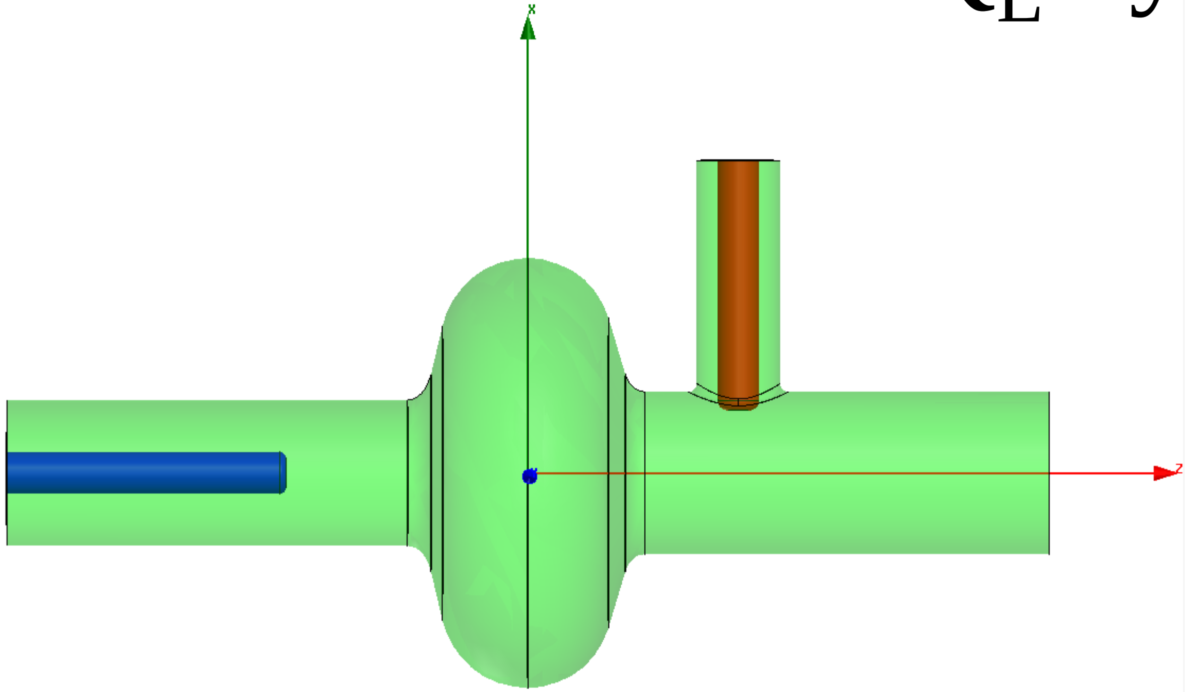
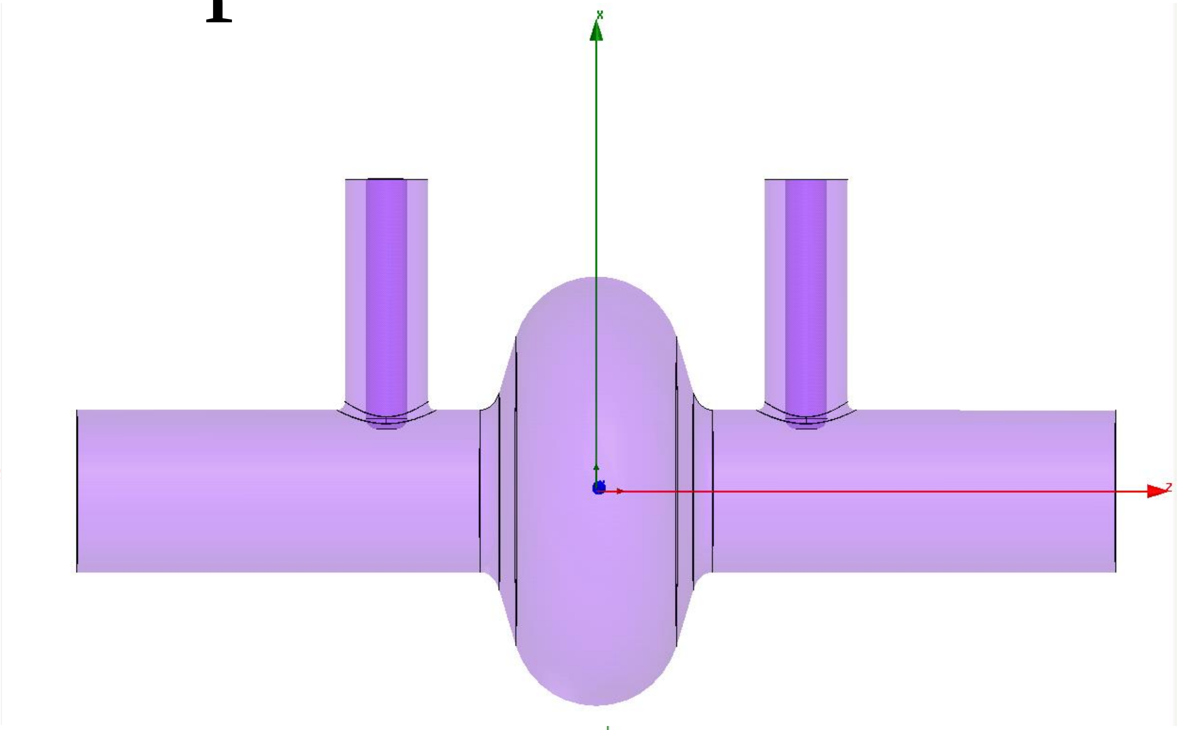
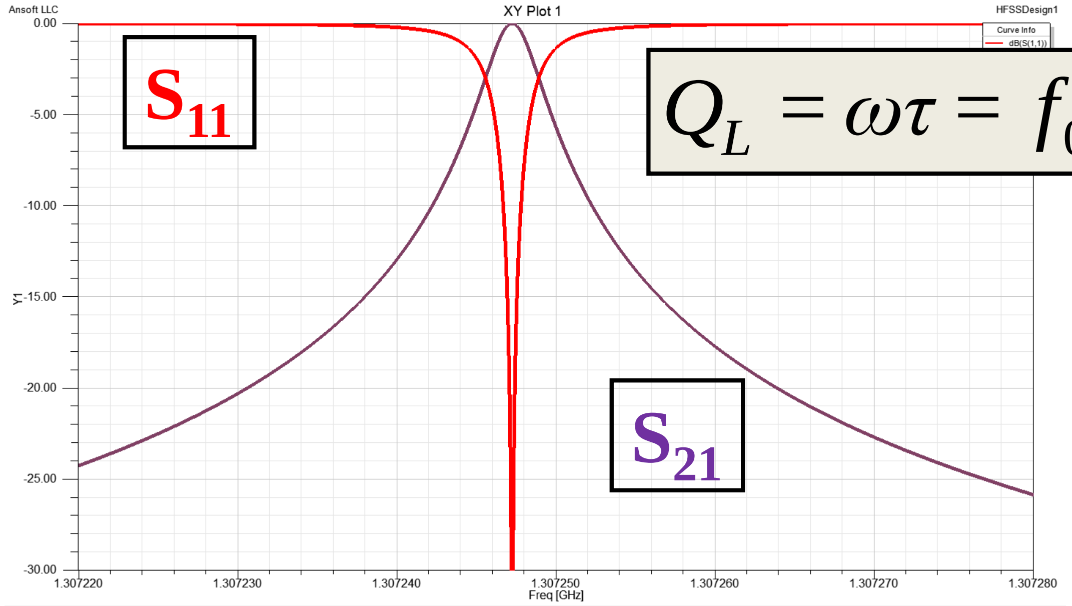
RF Design by HFSS

- ◆Stroke of Q_L
- ◆Full simulation for test stand model
- ◆Full simulation for “Real” bellows model

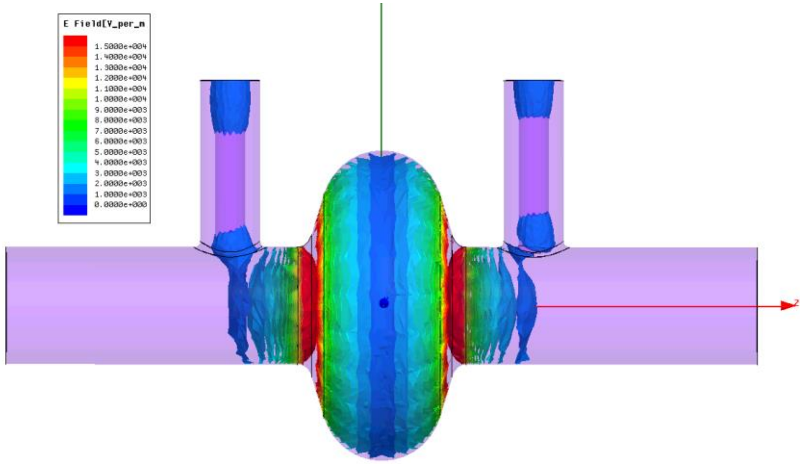
Stroke of Q_L by simple model





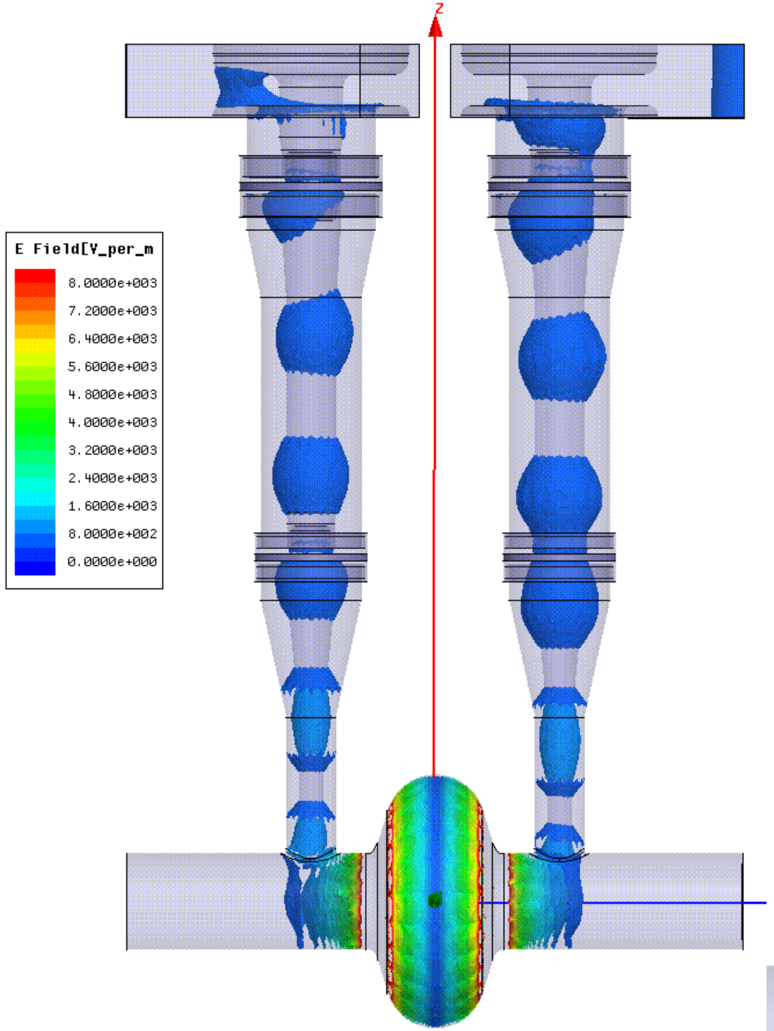


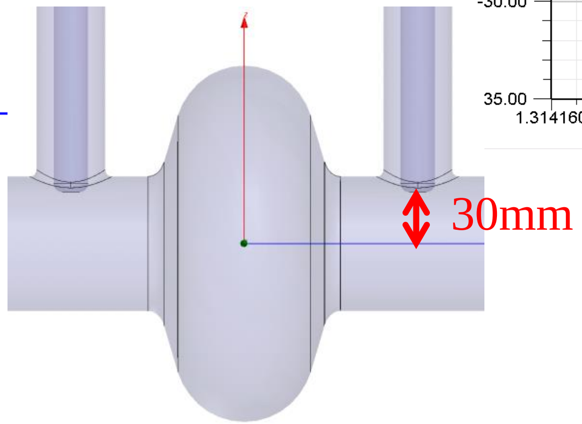
$$Q_L = \omega\tau = f_0 / \Delta f$$

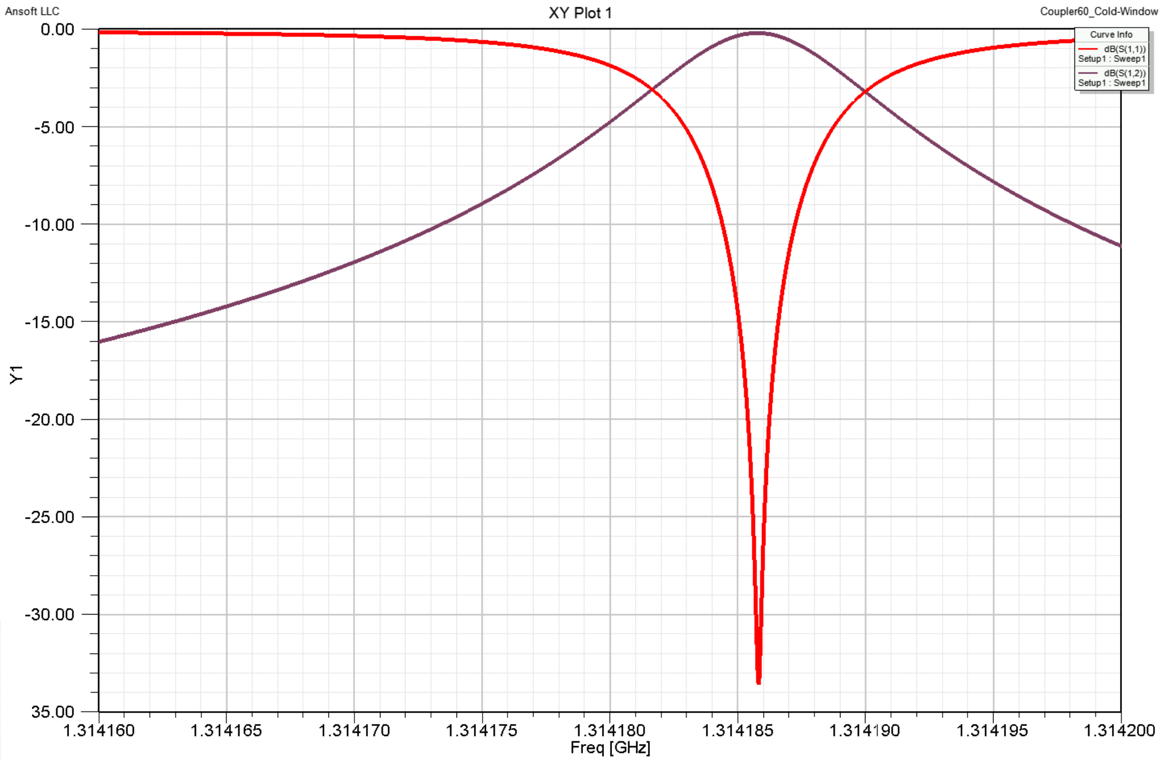


Stroke of Q_L by full model

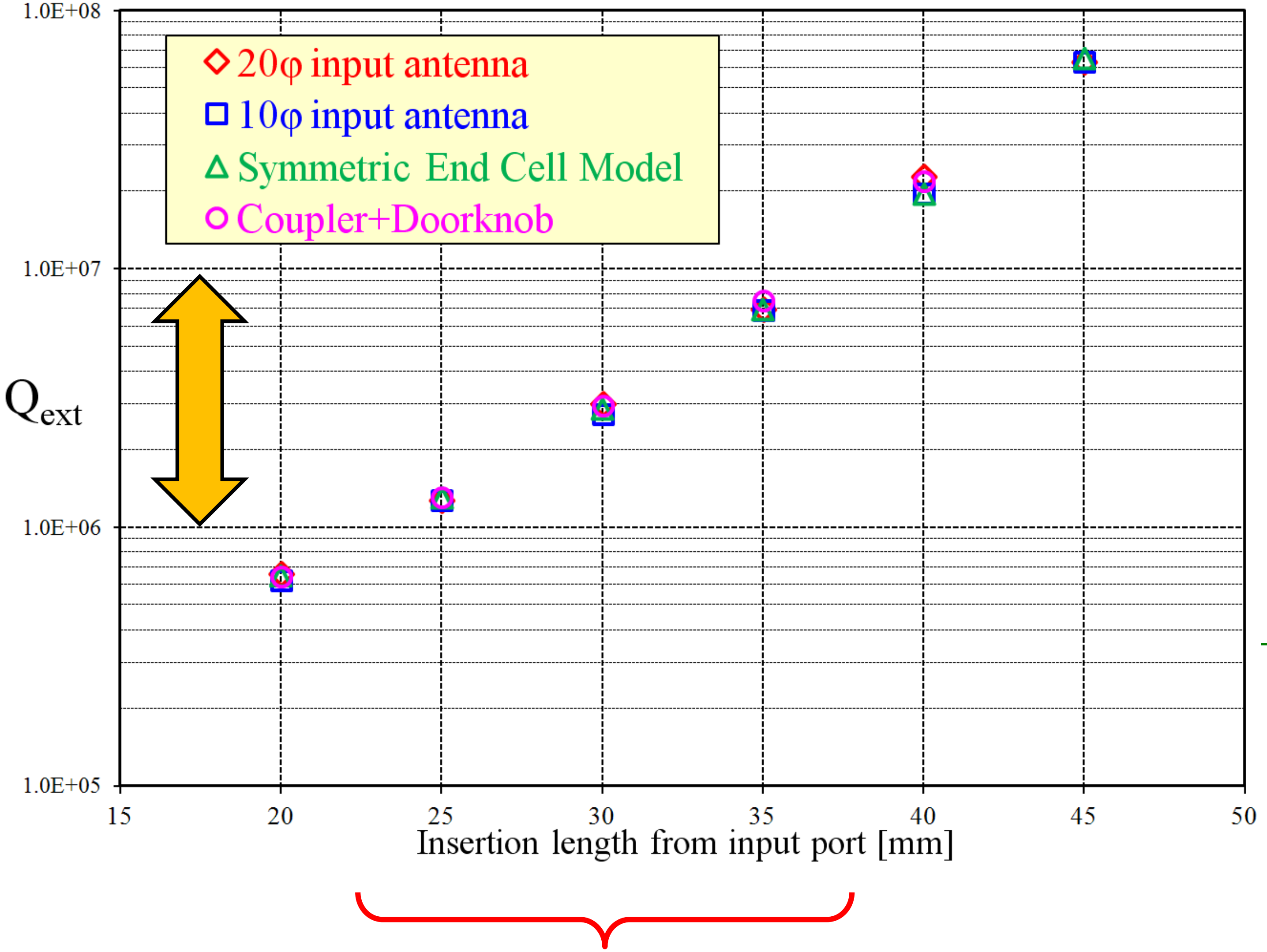
doorknob parameter : h, D, L = 25, 158, 88mm
fillet radius : 8/8mm (in/out)
insertion length : 30mm

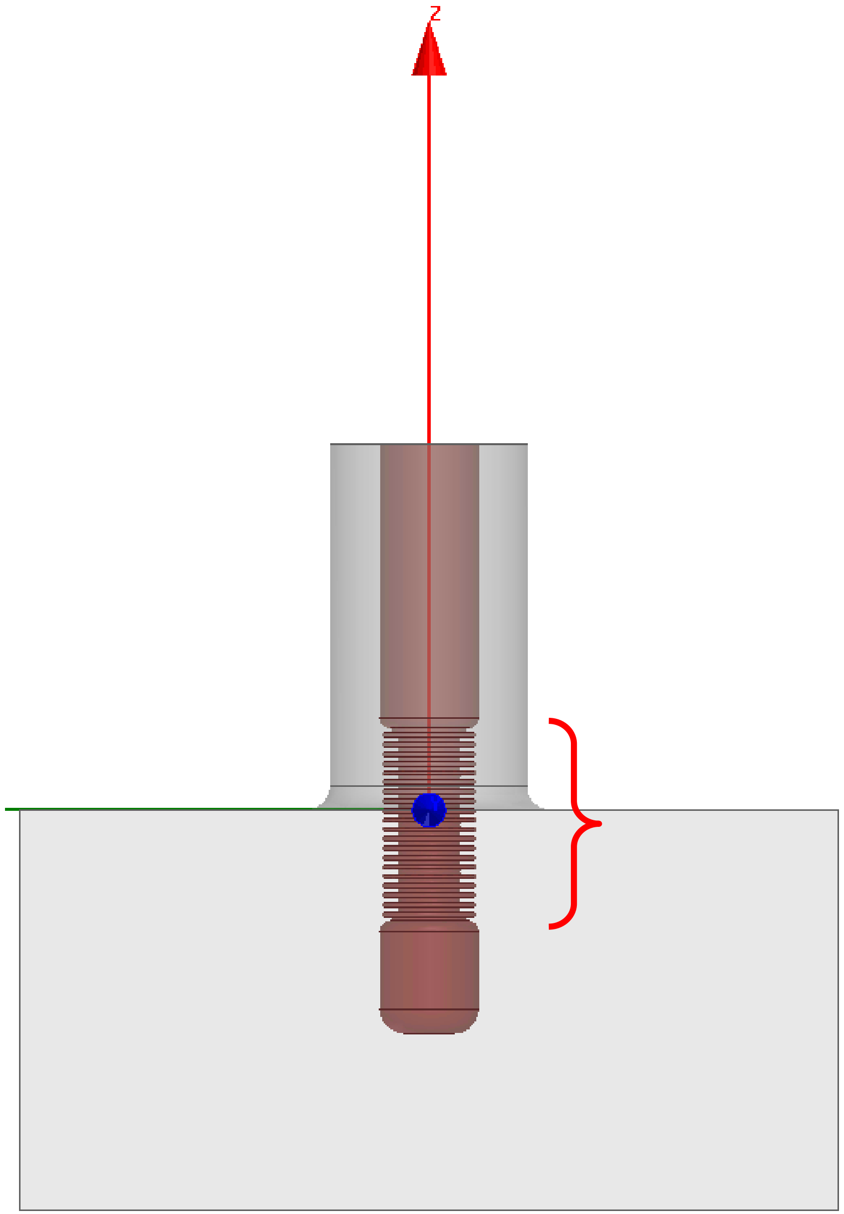






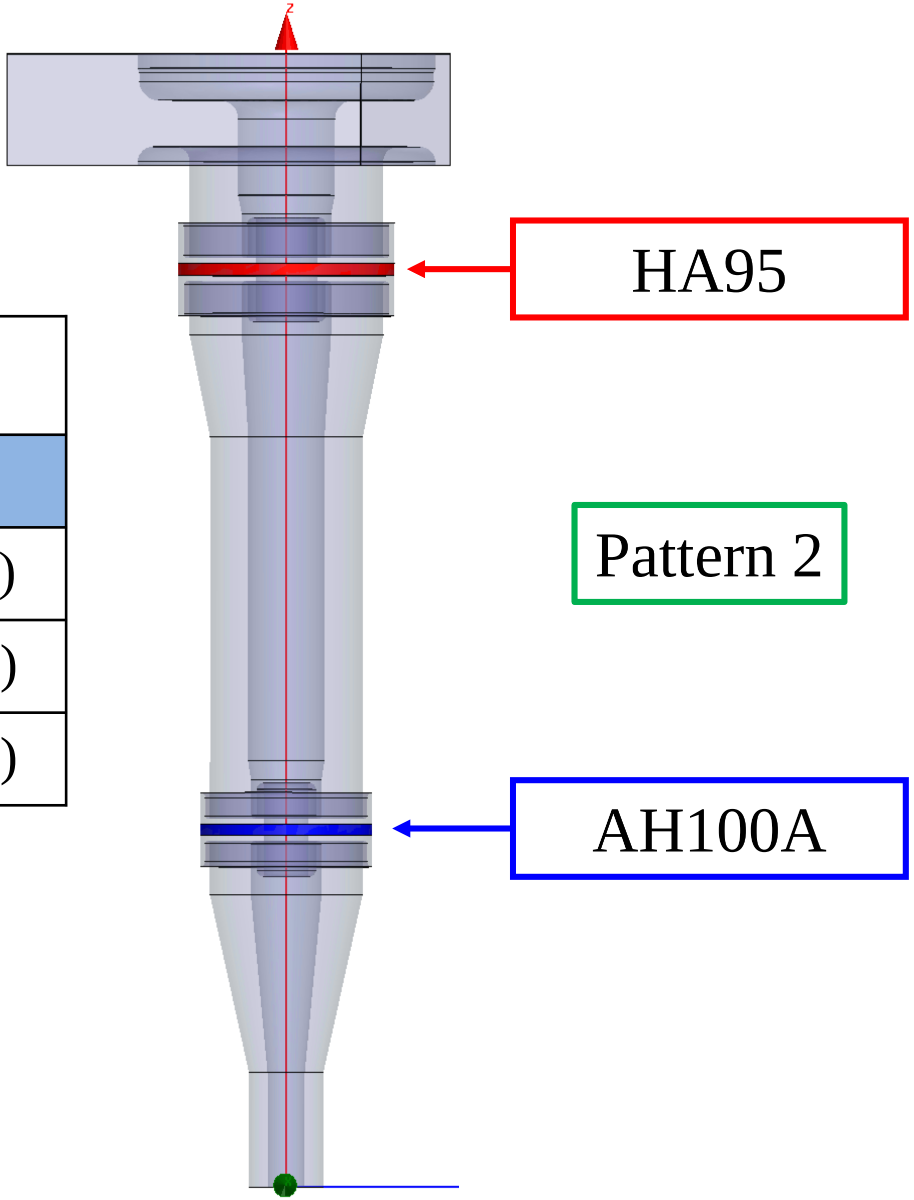
Result of Q_L stroke simulation





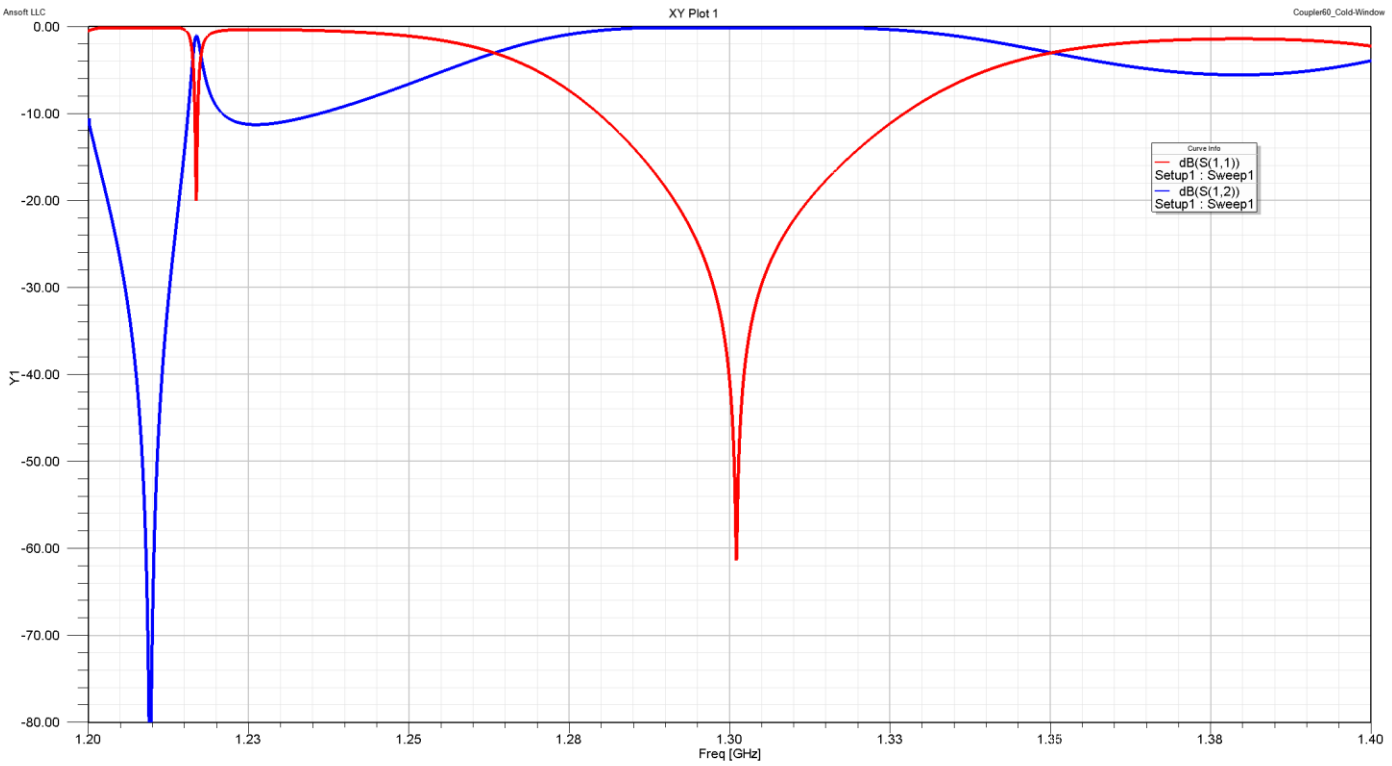
Full simulation for test bench model

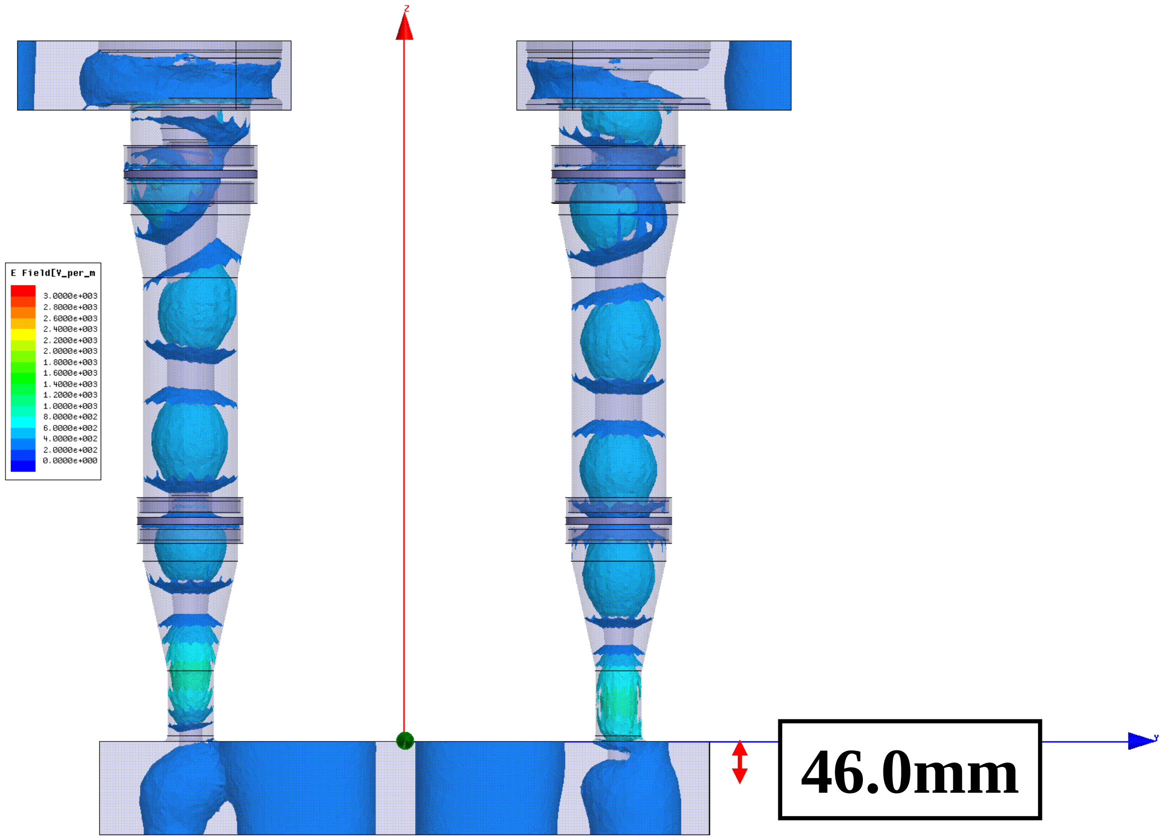
Pattern of ceramic type		
	Warm	Cold
Pattern 1	HA95 (NGK/NTK)	HA95 (NGK/NTK)
Pattern 2	HA95 (NGK/NTK)	AH100A (Kyocera)
Pattern 3 (virtual)	AH100A (Kyocera)	AH100A (Kyocera)



Full simulation for test bench model

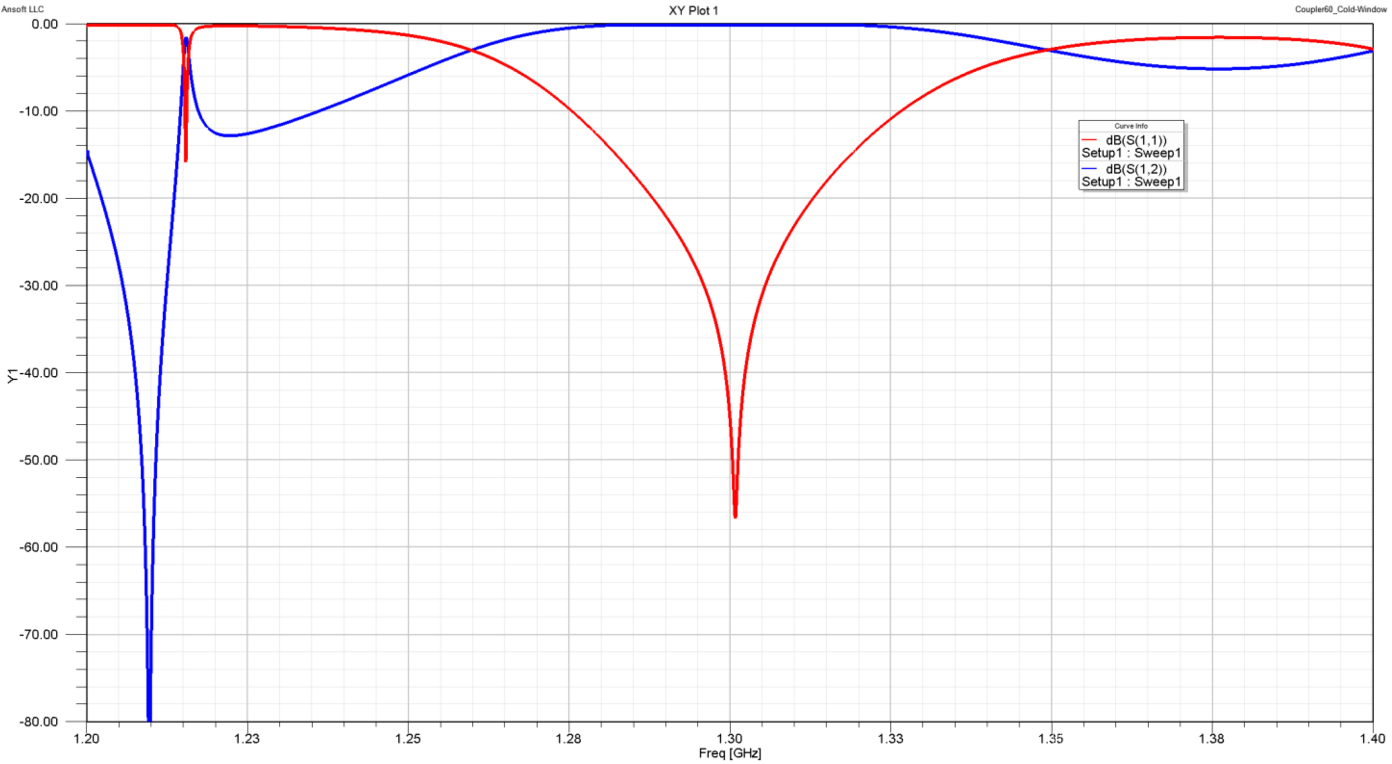
Pattern 1

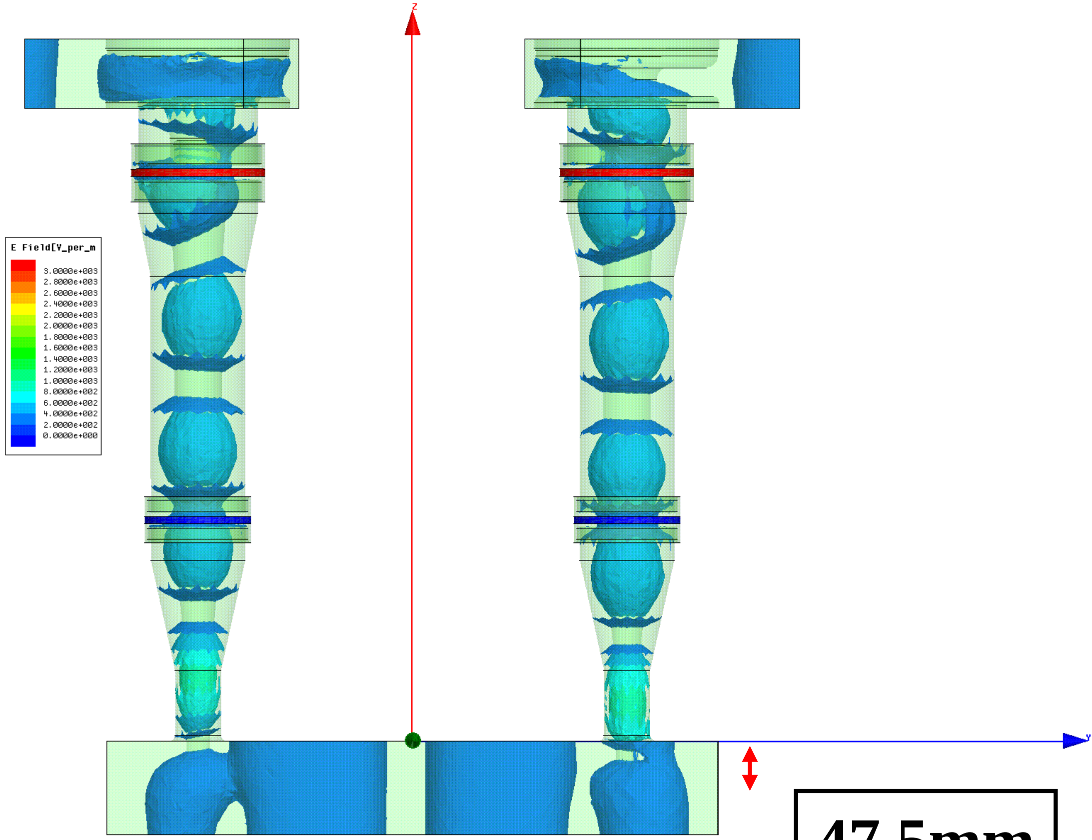




Full simulation for test bench model

Pattern 2

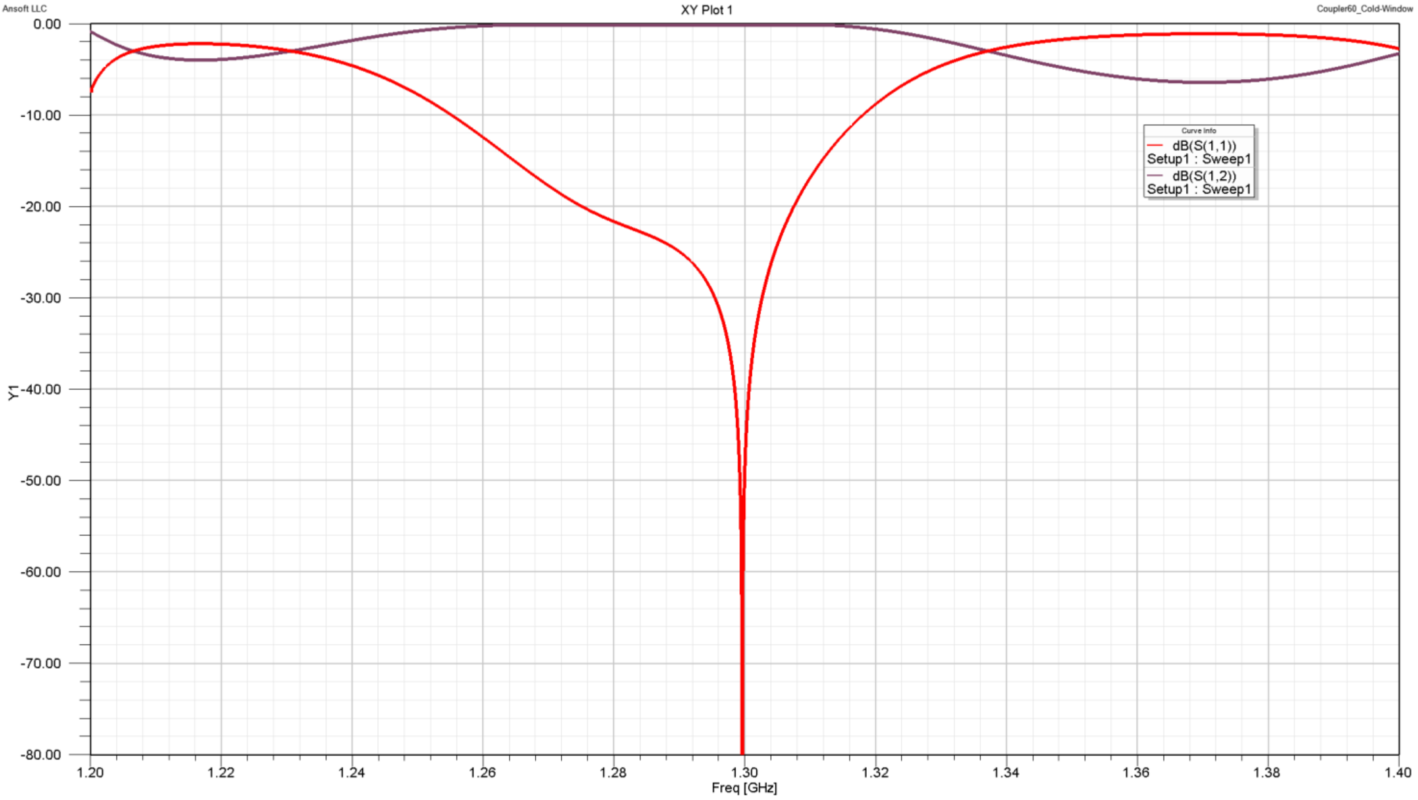


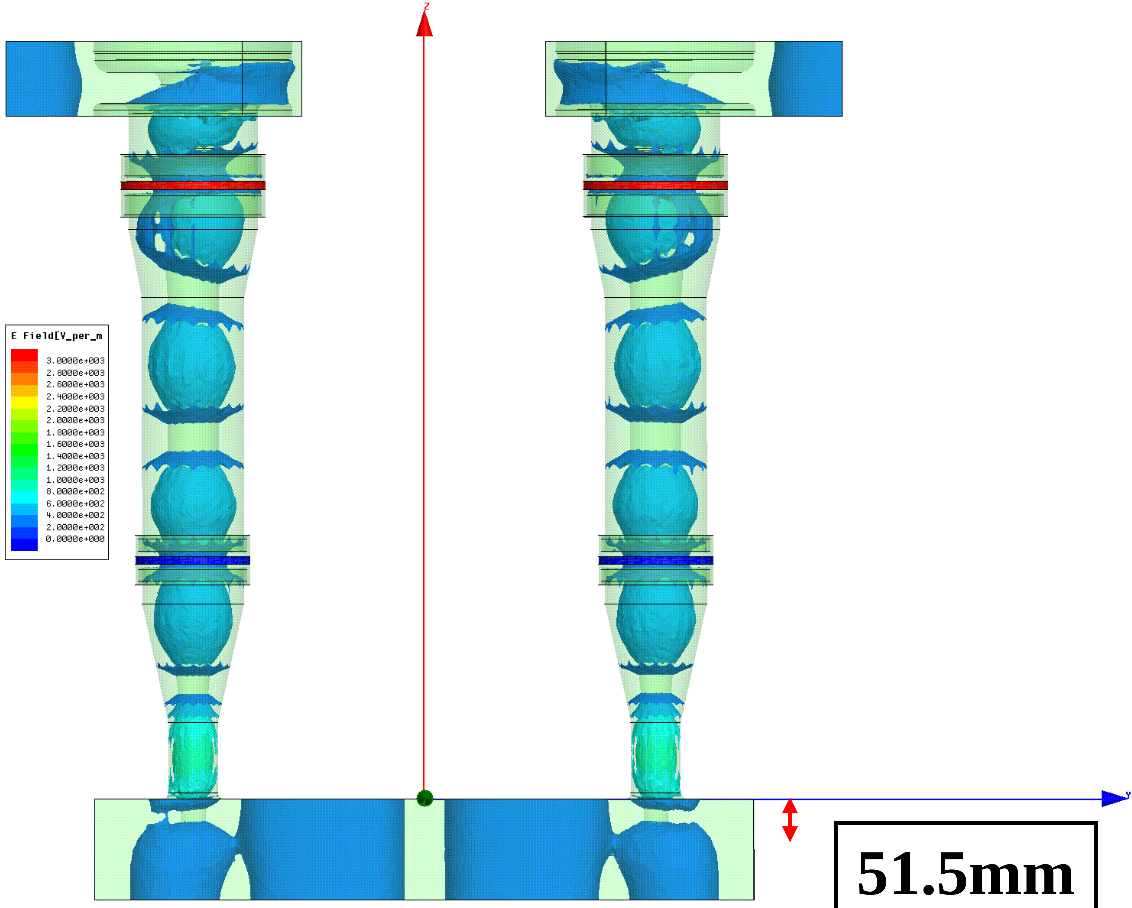


47.5mm

Full simulation for test bench model

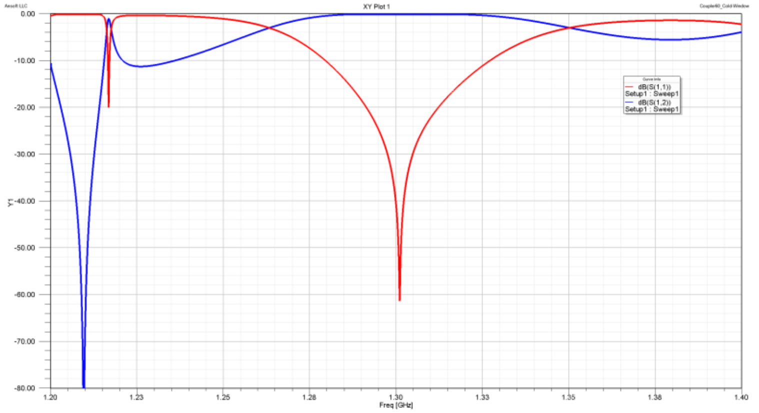
Pattern 3





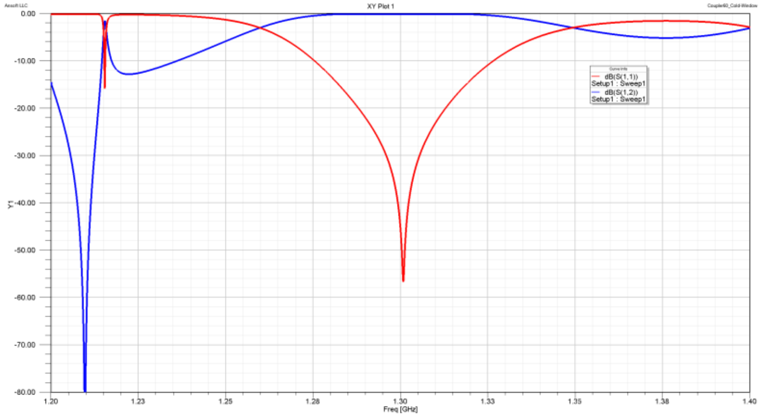
51.5mm

Comparison of two types of ceramics

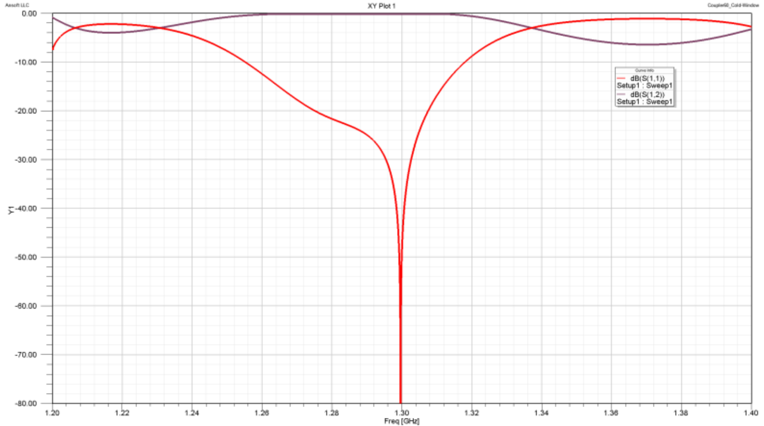


HA95/HA95 (46.0mm)

窓を**AH100A**に変更する度に、突き出し量が増加していく傾向があることが分かる。**Cold**側よりも**Warm**側の影響の方が大きいようである。



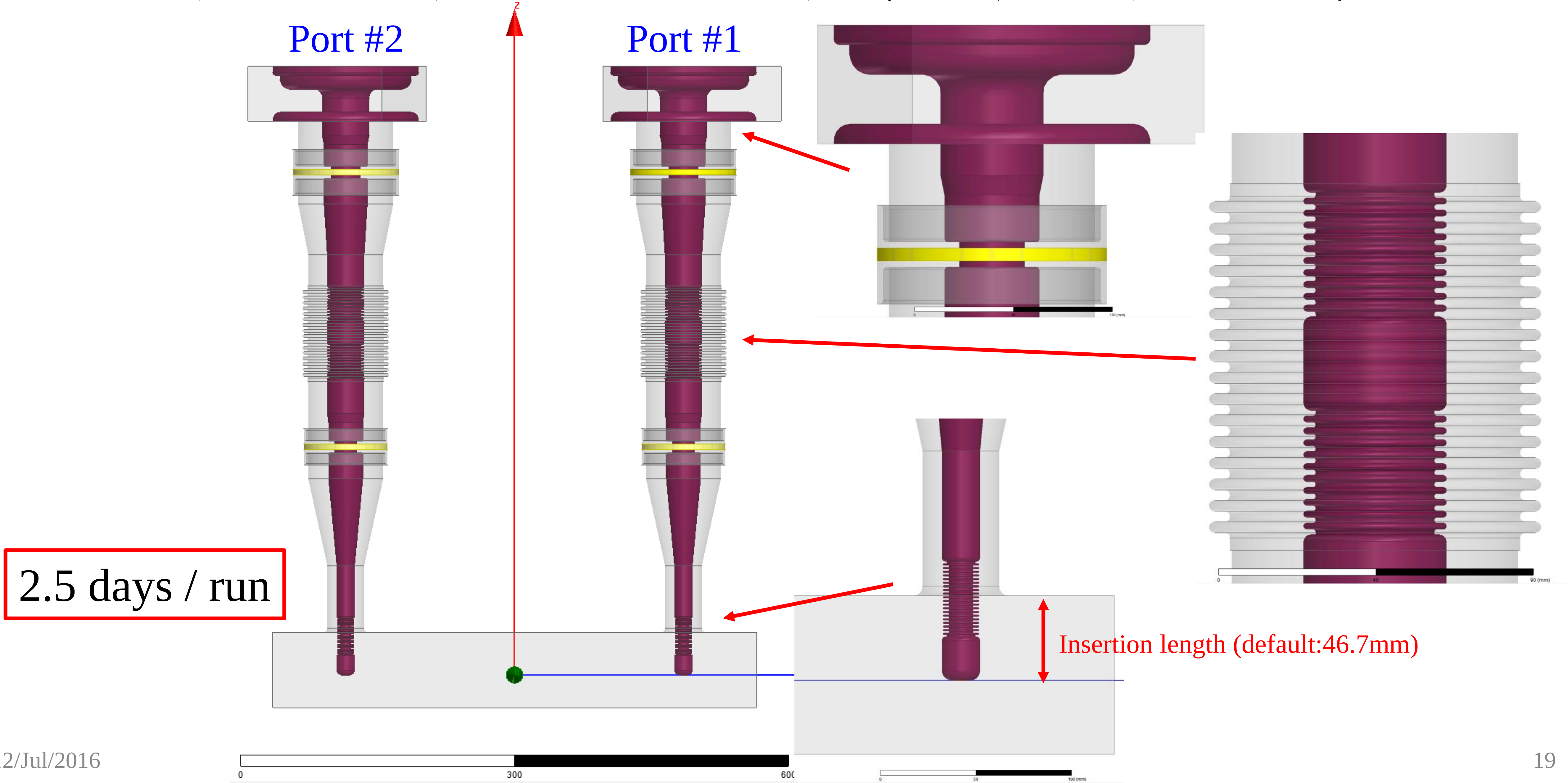
HA95/AH100A (47.5mm)



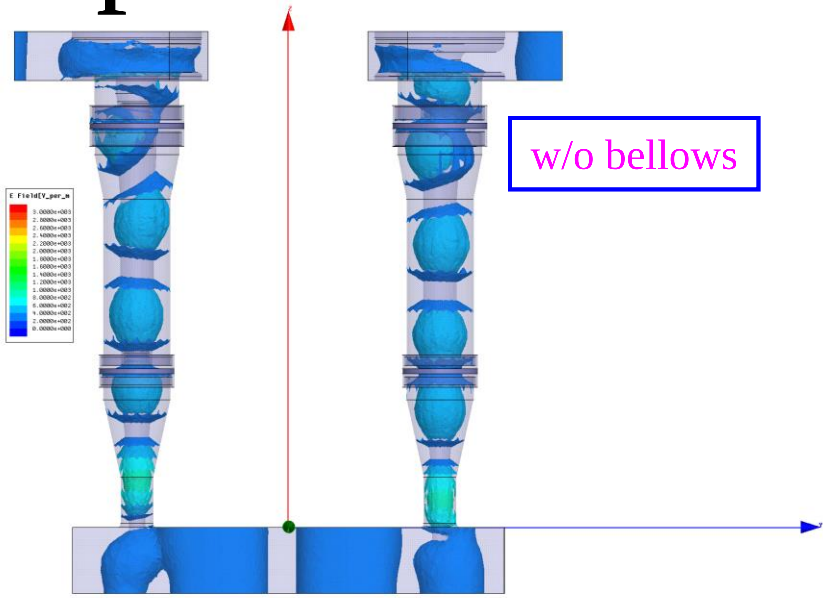
AH100A/AH100A (51.5mm)

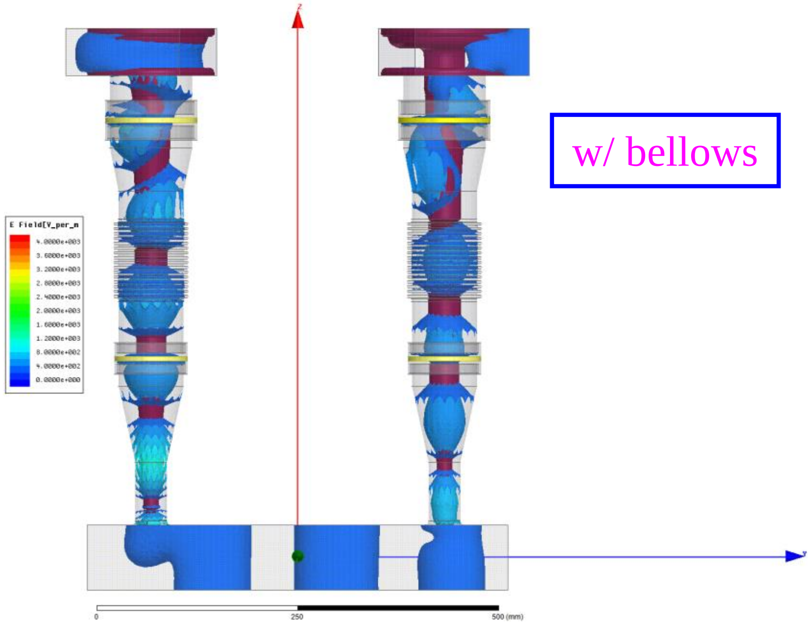
Full Test bench with “real” bellows model

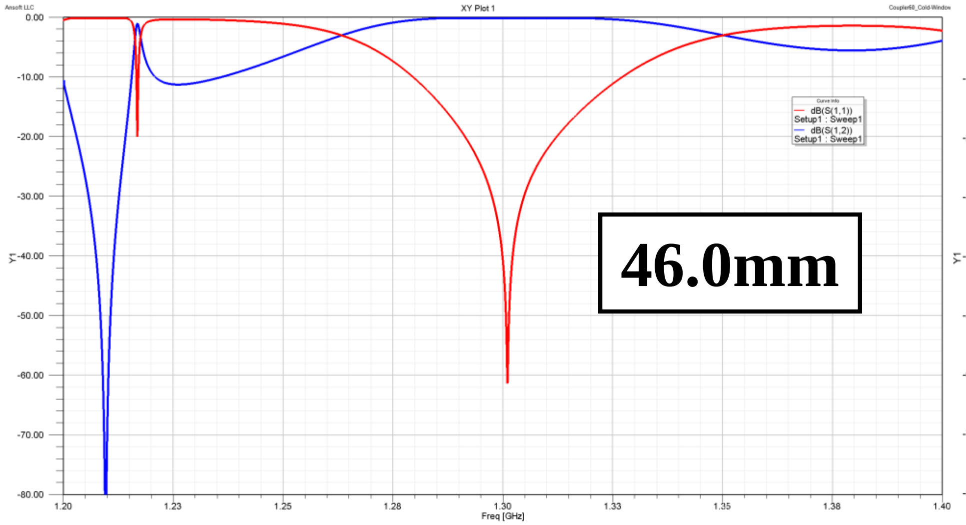
実際のベローズ付きの完全なテストベンチモデルで計算する。ただし、テフロン板は入っていない。

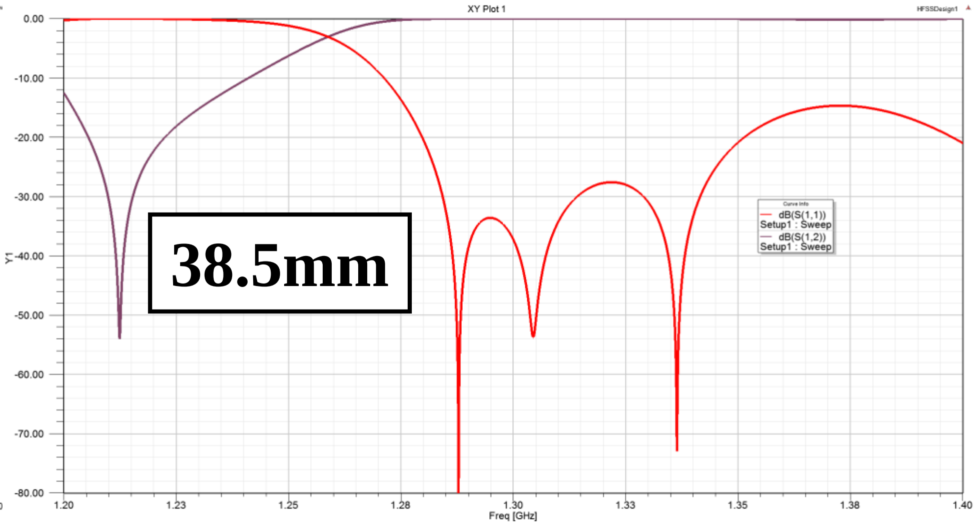


Comparison of w/ and w/o bellows









ベローズの有り無しで**内導体の突き出し量が7.5mm**も異なっている。また、透過特性もかなり異なるのが分かる。

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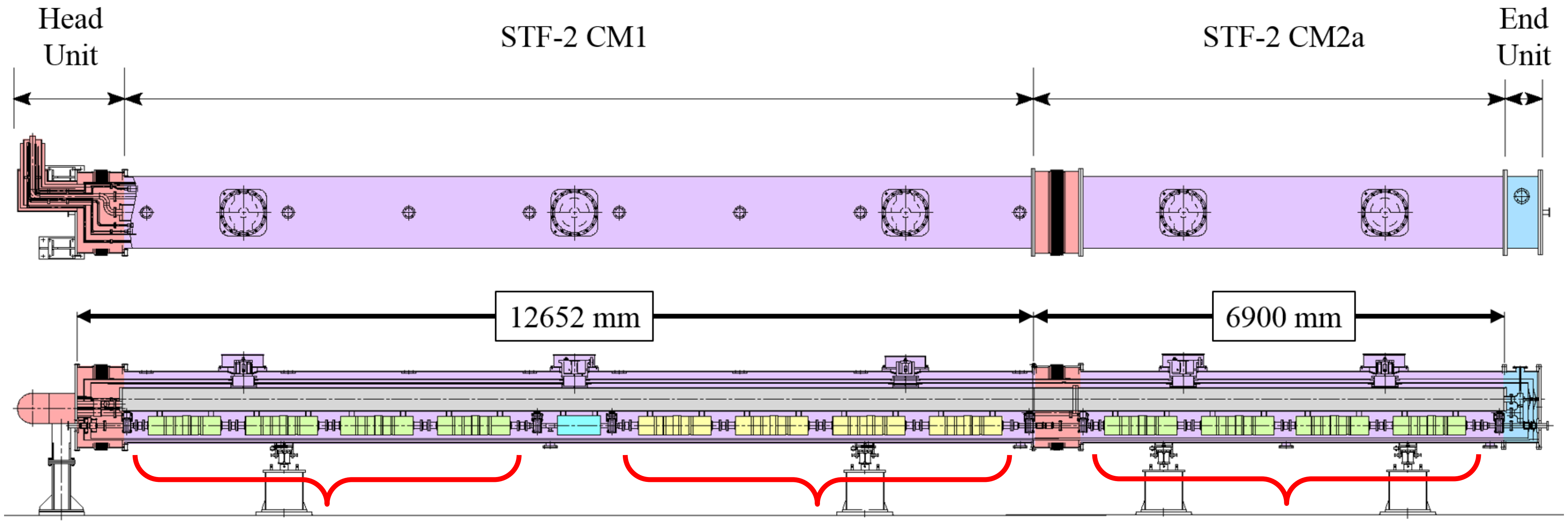
Copper plating condition for STF-2 couplers



12 cavities
12 couplers

Module	CM1								CM2a			
Coupler #	11	12	13	14	15	16	17	18	21	22	23	24
Cold coupler												
Copper plating [μm]	20 (inner)	20	20	20	20	20	20	20	25	25	25	25
	3 (outer)	3	3	3	5	5	5	5	10	10	10	10
Warm coupler												
Copper plating [μm]	10 (inner)	10	10	10	20	20	20	20	25	25	25	25
	10 (outer)	10	10	10	20	20	20	20	25	25	25	25

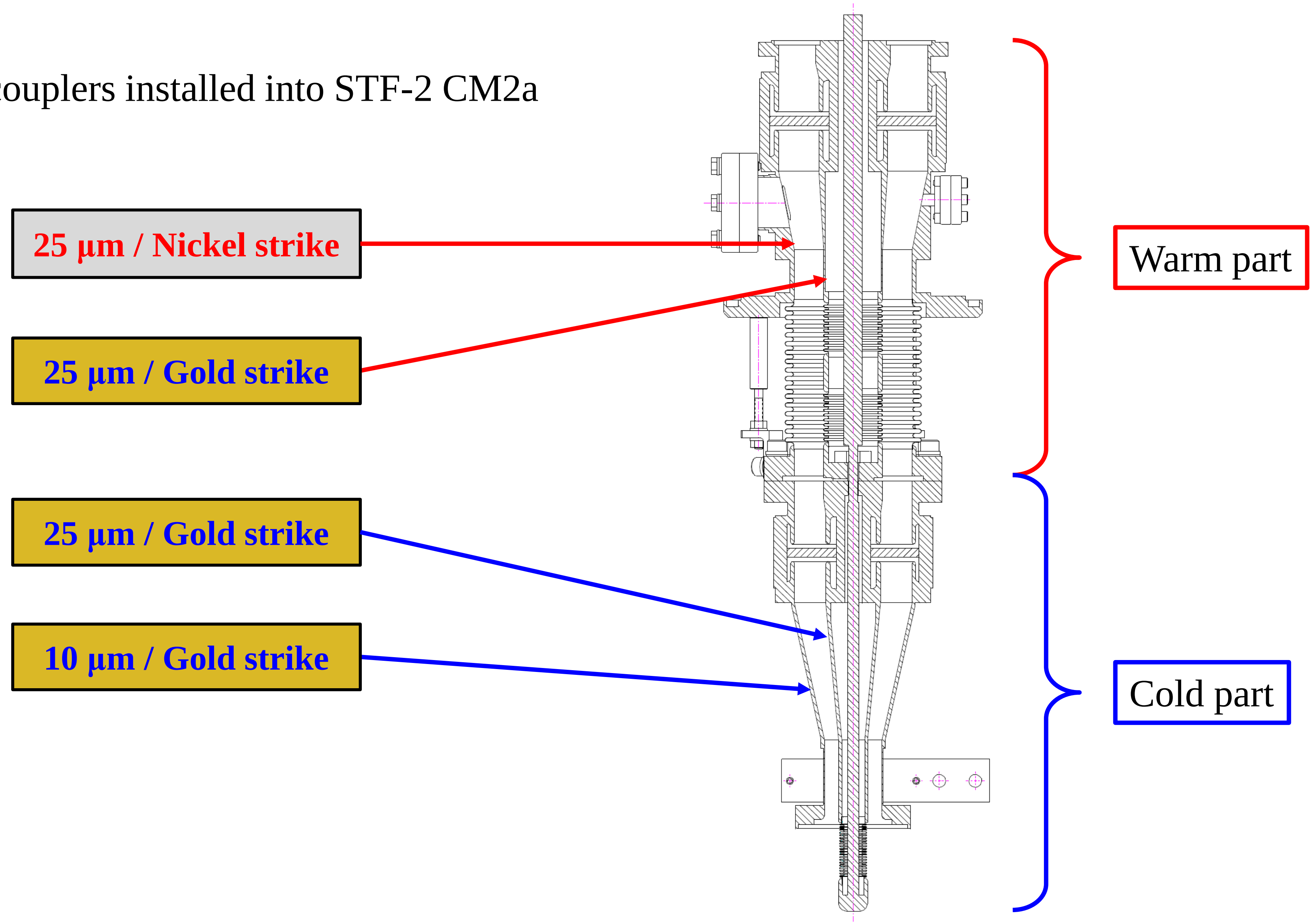
Gold strike plating

Nickel strike plating

Unit: μm

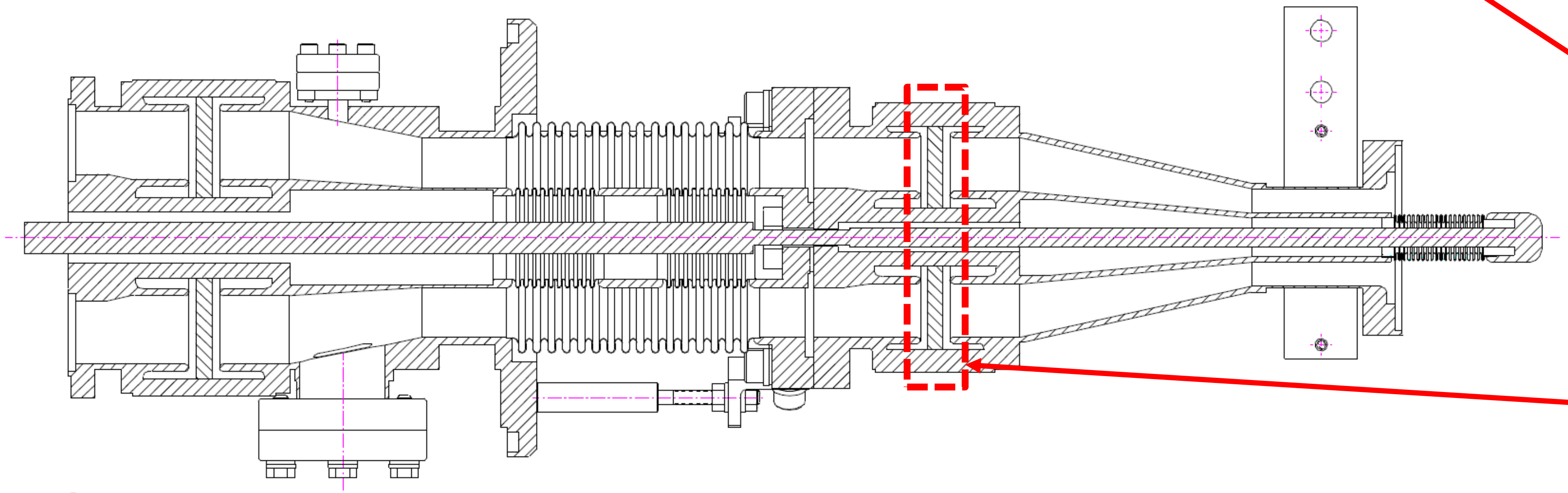
Copper plating condition for 40mm STF coupler

Same condition as couplers installed into STF-2 CM2a

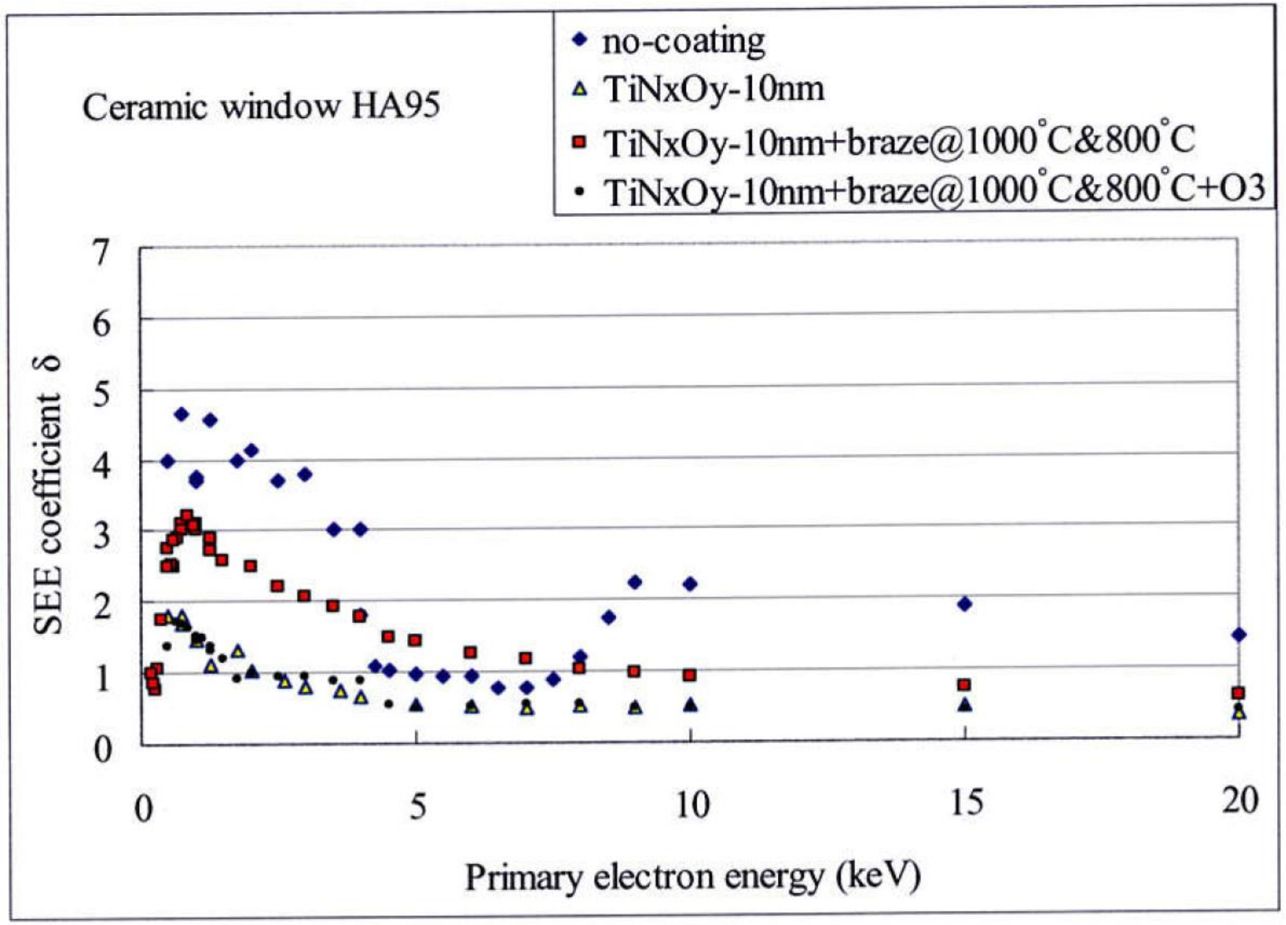


Specification of 40mm Couplers

Coupler (TOSHIBA)	Product No.	Serial No.	Ceramic company	Ceramic color	Ceramic coating	Plating (for outer/inner conductor)
Warm #1, #2 (normal)	E42130	14L001 14L002	NGK/NTK	White	TiN	Copper
Cold #1, #2 (normal)	E42130	14L001 14L002	NGK/NTK	White	TiN	Copper
Cold #3, #4 (new)	E42130	14L003 14L004	KYOCERA	Gray	free	Copper



Reference on HA95 Ceramic (Kijima-san's Paper)



KEKB method	**STF method**
As fabricated (No-coating)	As fabricated (No-coating)
↓	↓
TiN coating (10nm)	TiN coating (10nm)
↓	↓
Brazing @800℃	Brazing @800℃
↓	↓
O_3 rinsing	Ultra-pure water rinsing

We need to measure SEE of AH100A in various steps.

What's the difference among three rinsing processes?

- O_3 rinsing (KEKB)
- Ultra-pure water rinsing (STF)
- Ultrasonic rinsing (EU-XFEL)

⇩

We will also try three rinsing processes in STF.

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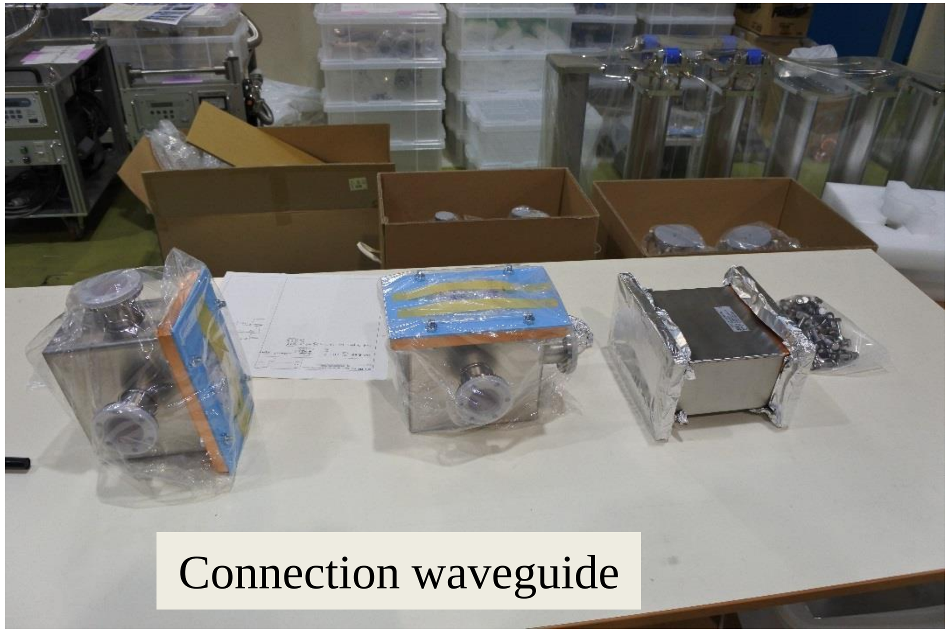
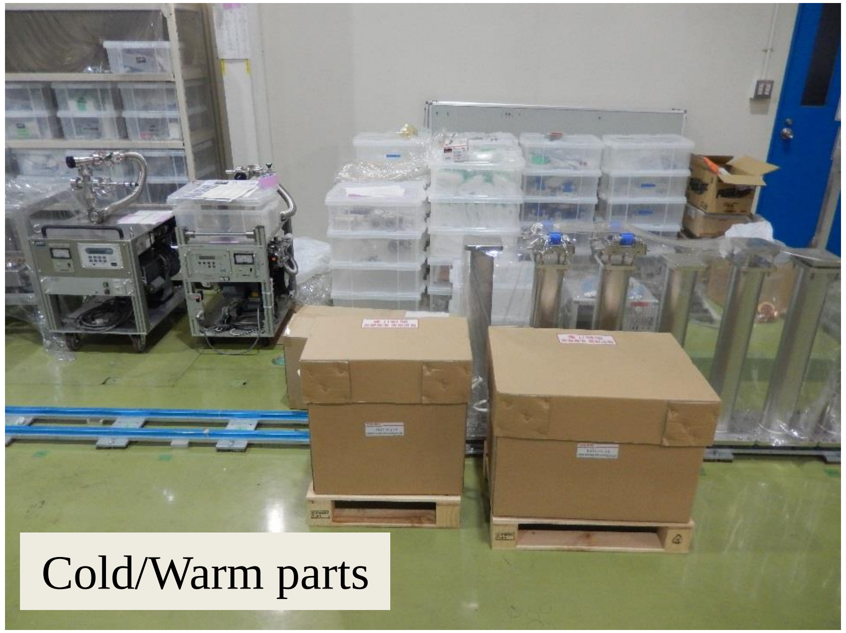
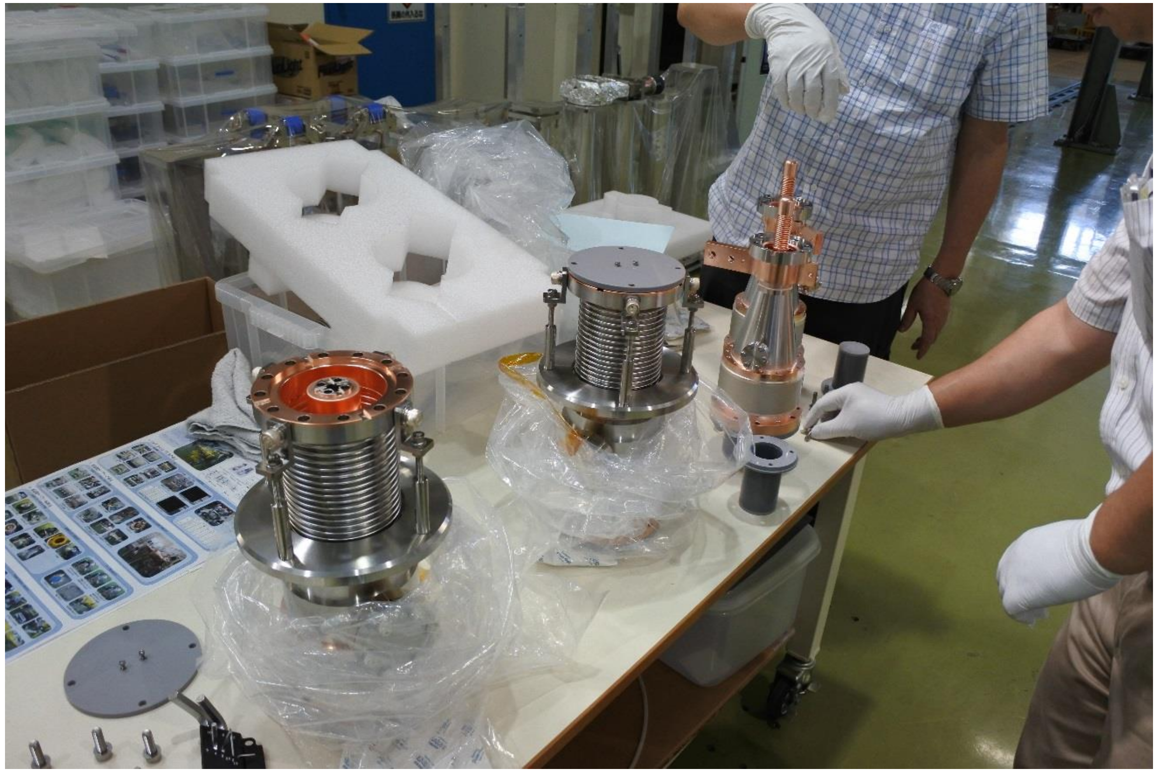
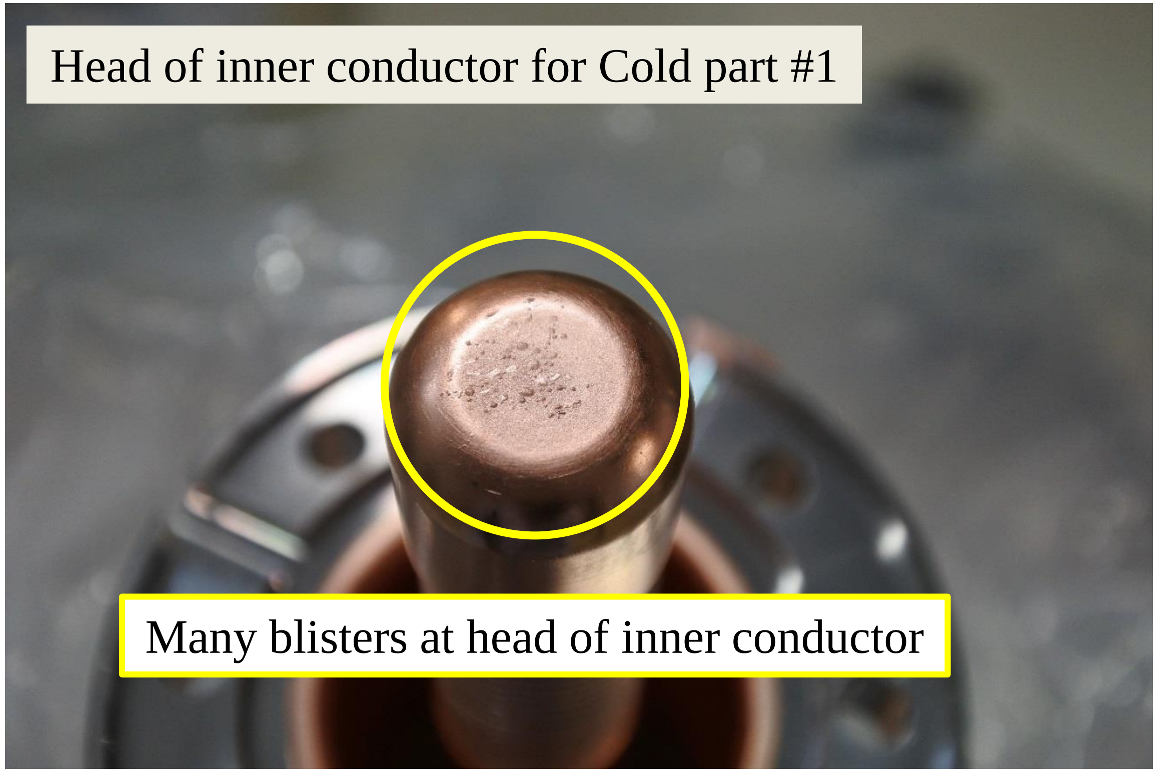
Delivery items





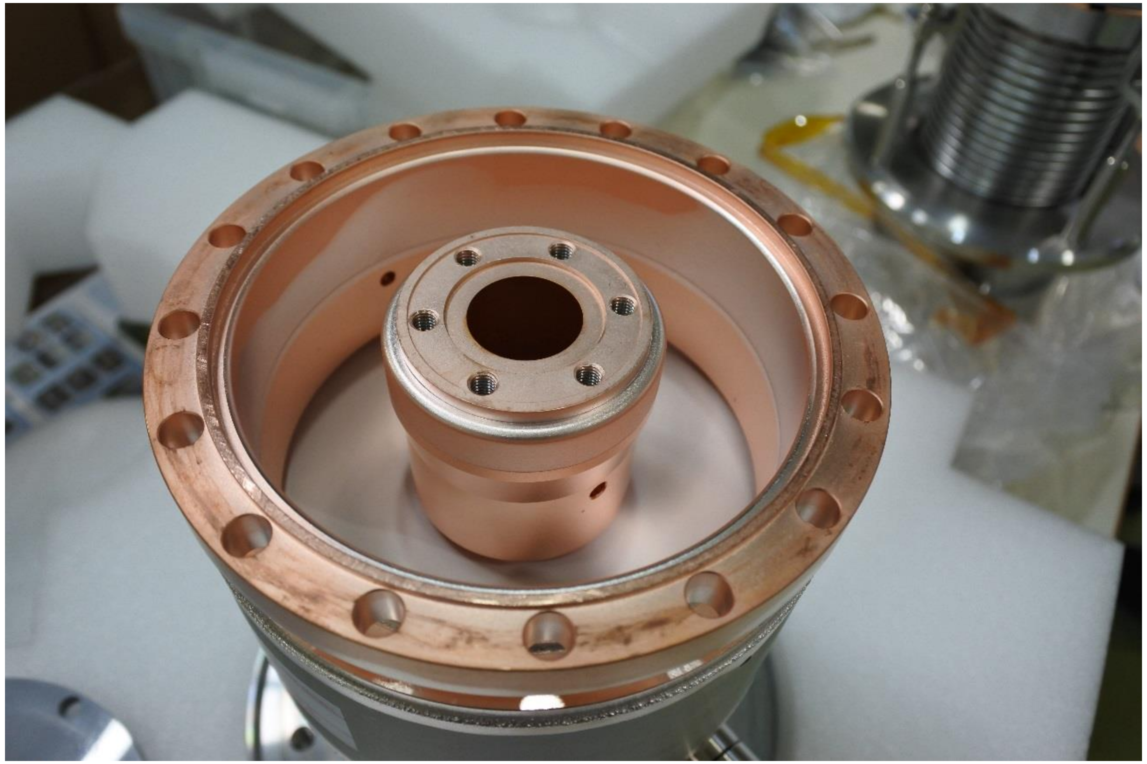
Incoming inspection

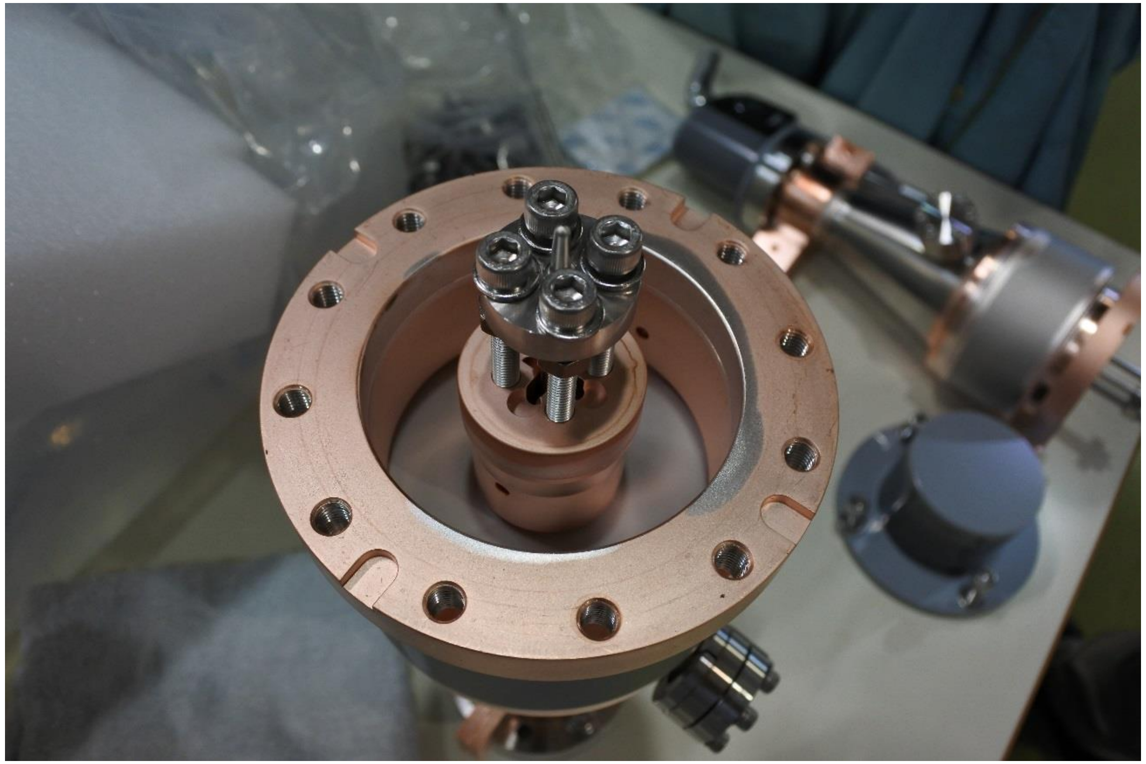




Big problem (To be sent back to TOSHIBA) → But, no time to refabricate → Go forward

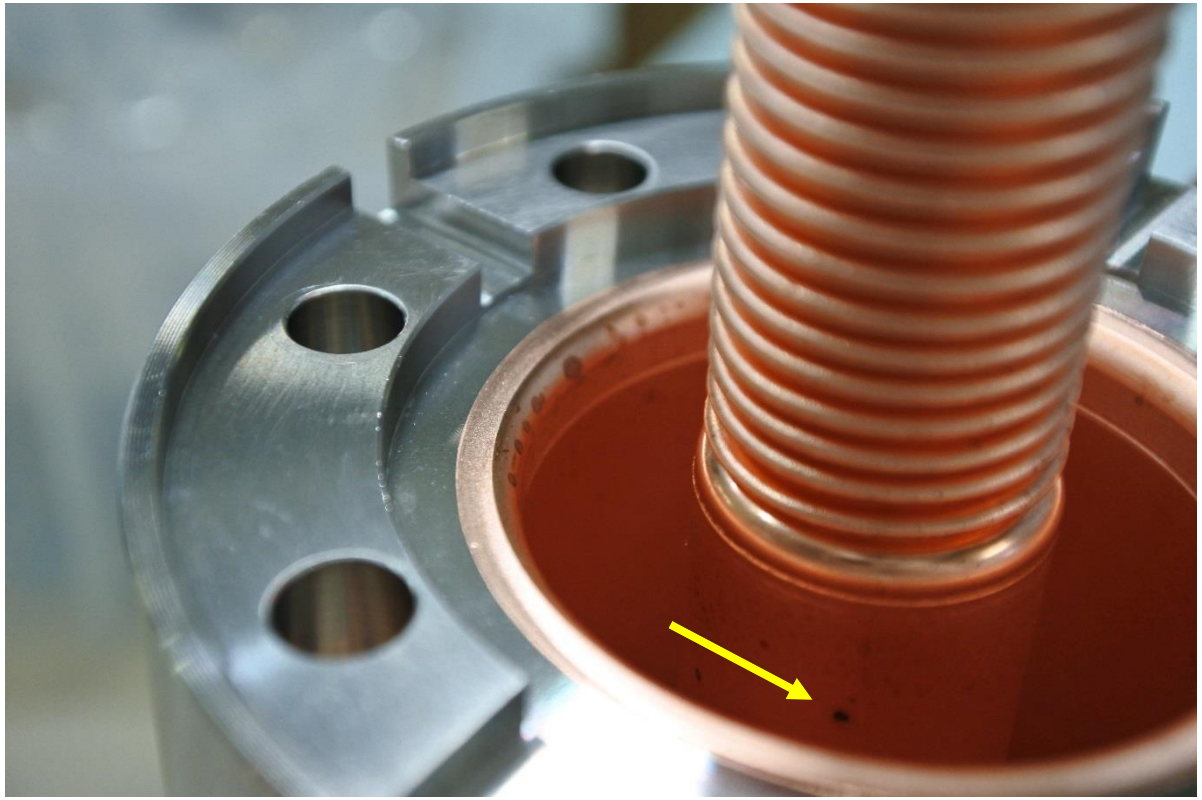
Incoming inspection

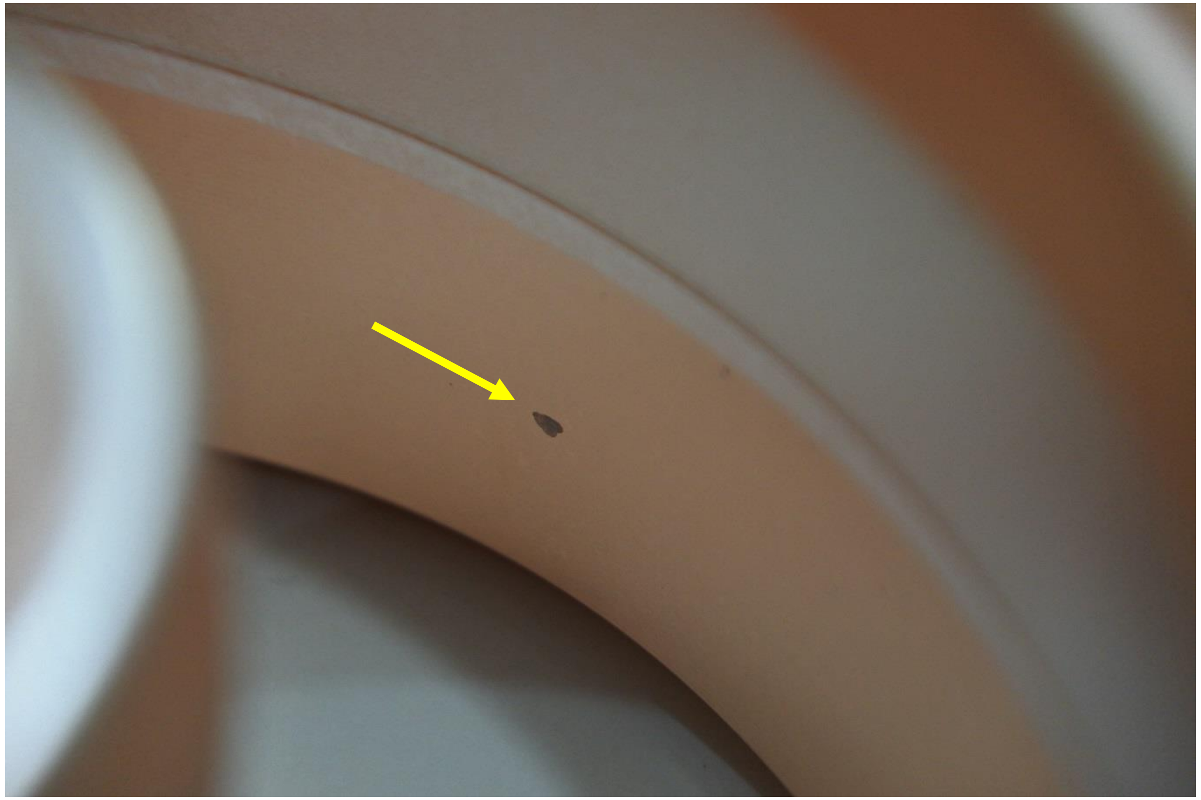




Silver trace existed after brazing process → No problem

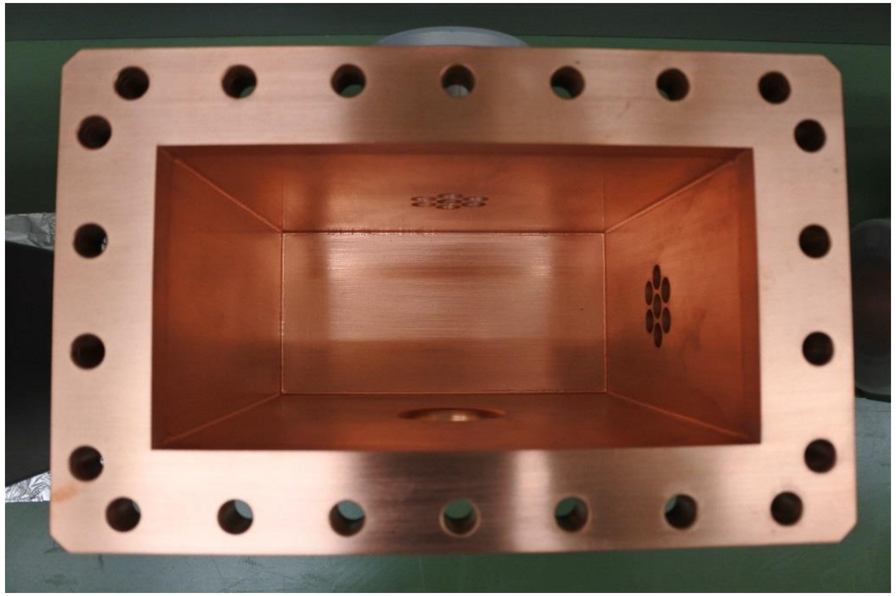
Incoming inspection



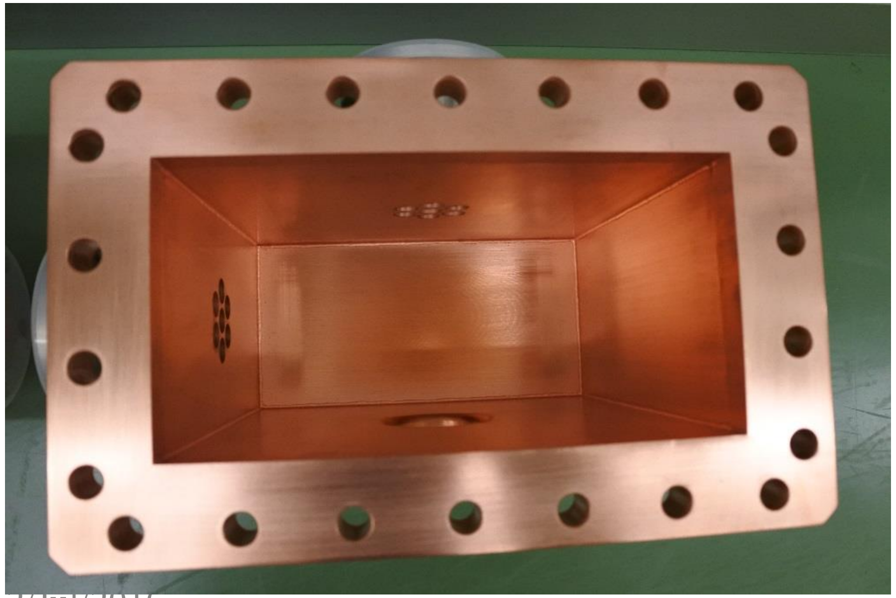


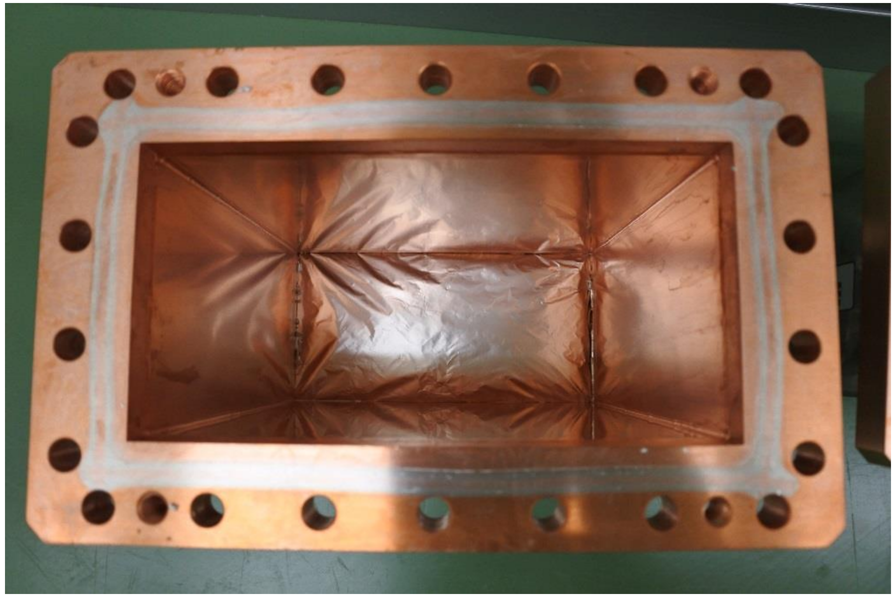
Some black stains existed (maybe after chemical process) → No problem

Incoming inspection



Waveguide system is fabricated by Furukawa C&B.
They had Good copper plating.





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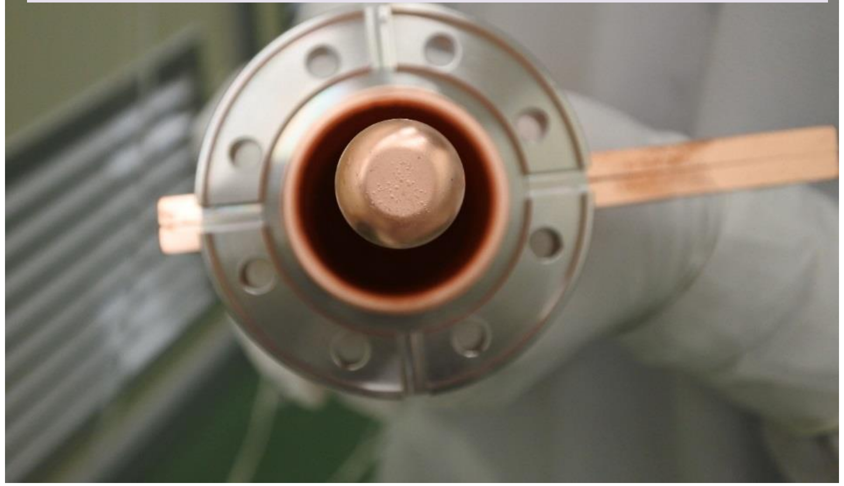
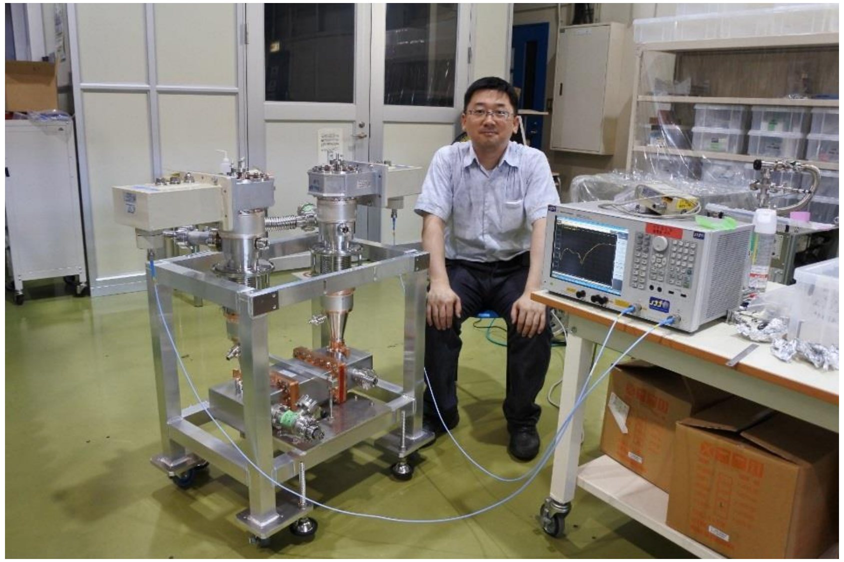
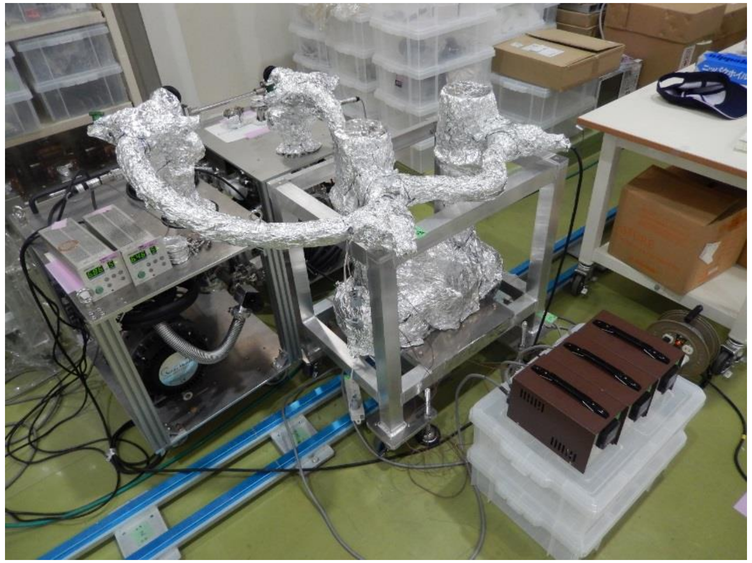
Cold part #1 has problematic copper plating.
But, as now, it’s not significant in high power test!



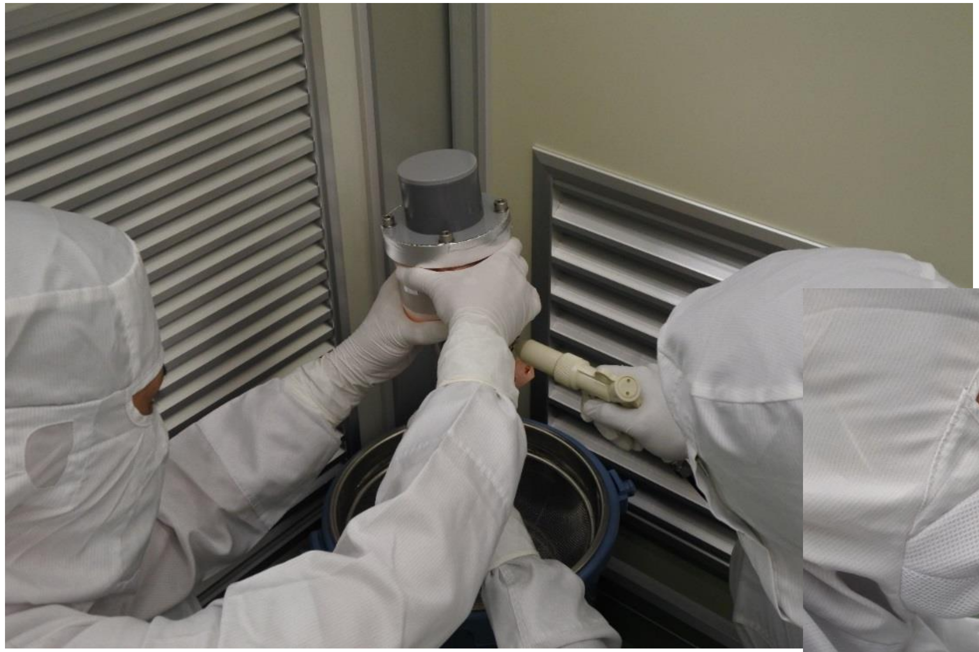
Ultra-pure water rinsing → assembly work in Class10 → Leak check → Low power test → Baking

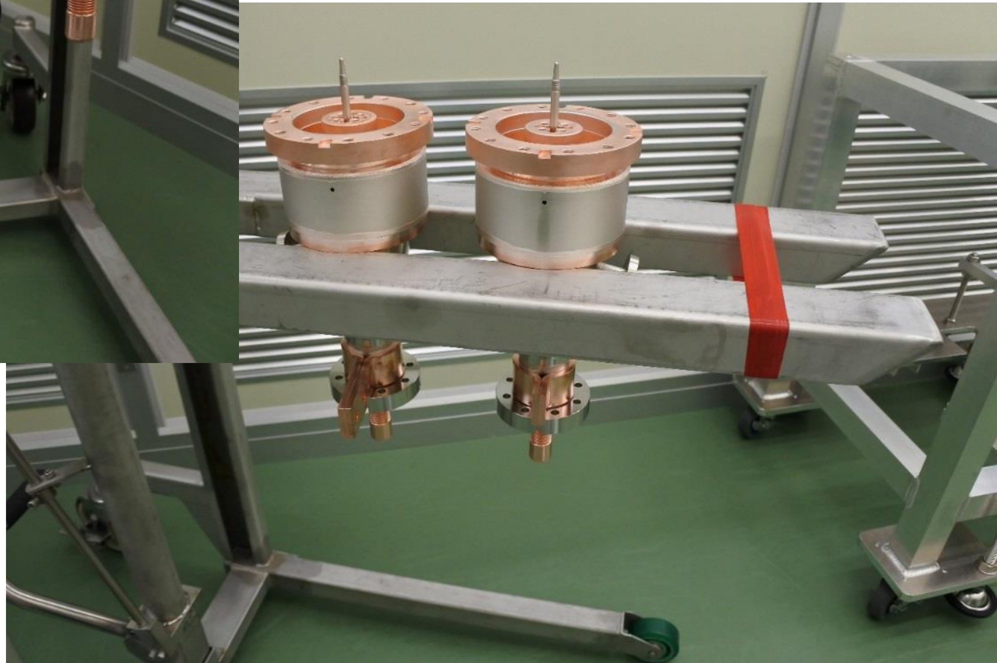




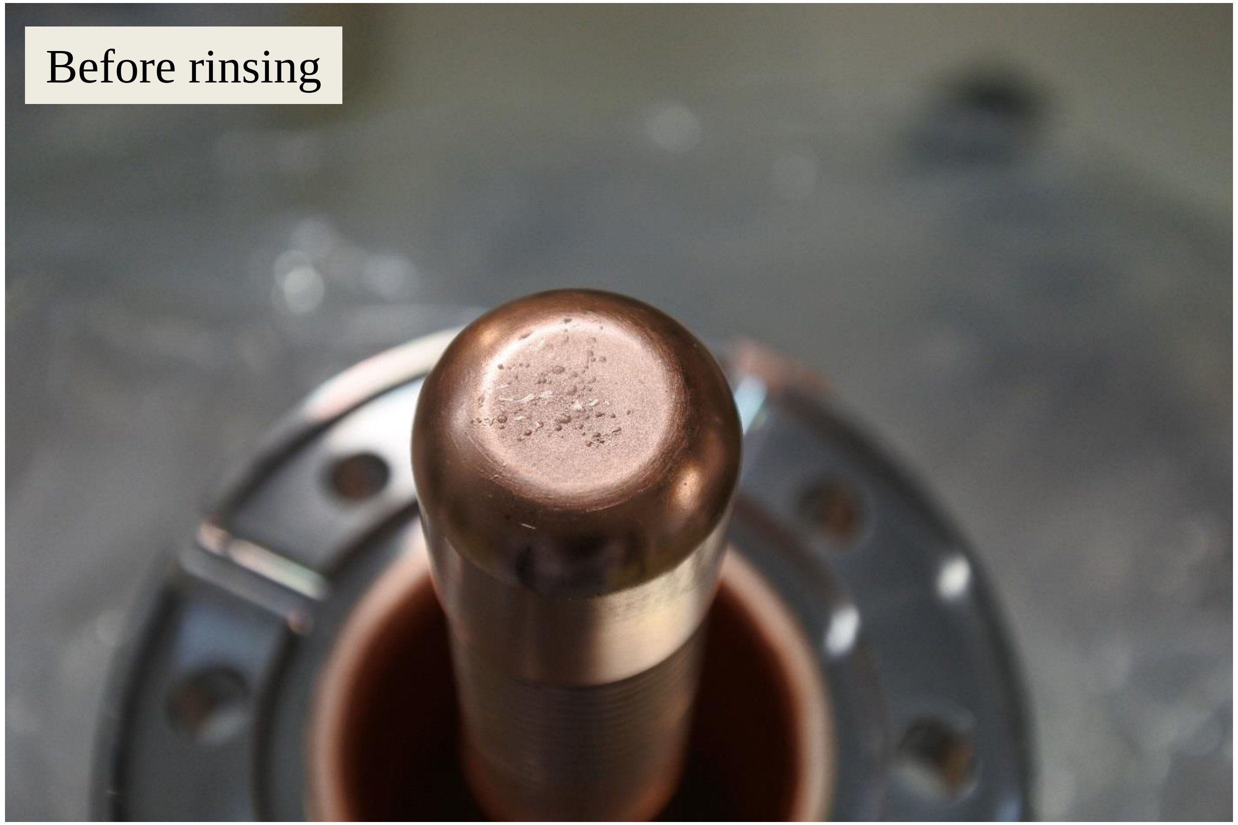
Rinsing cold part by ultra-pure water

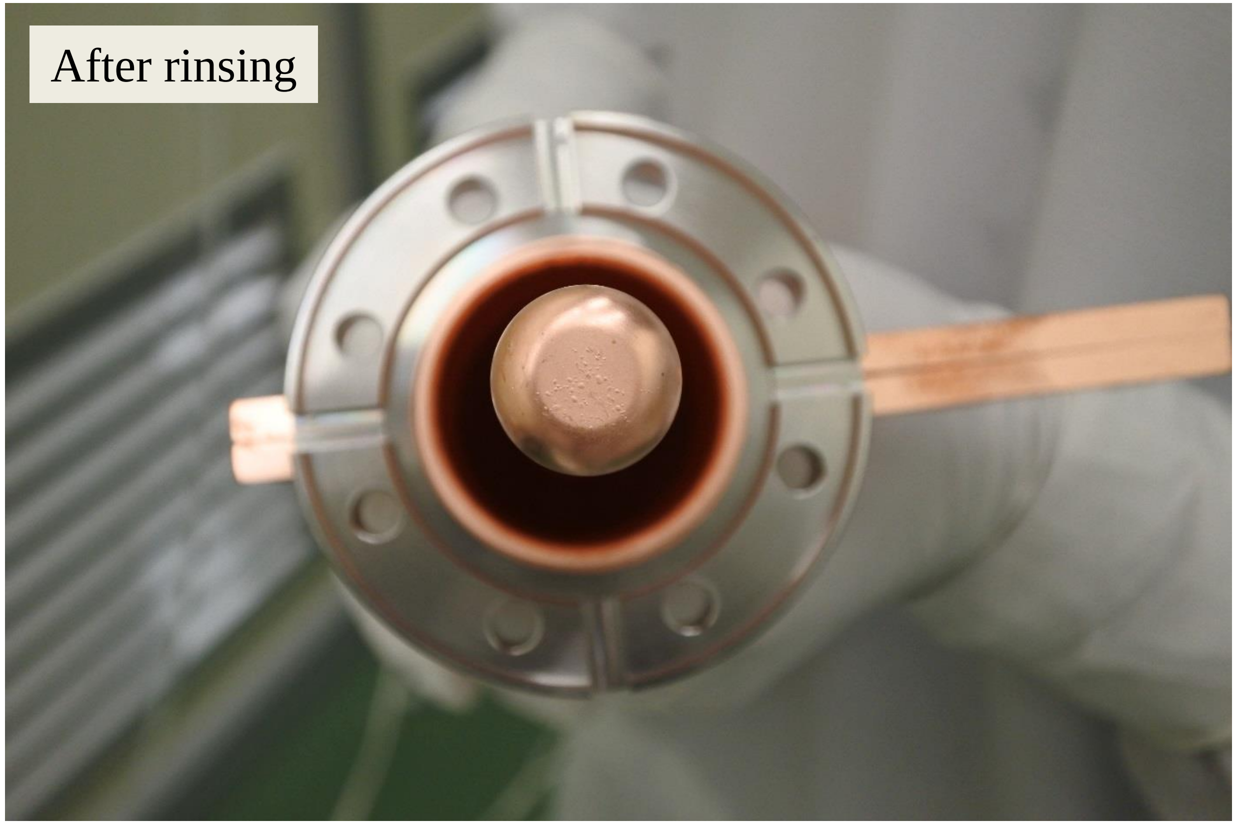
Drying cold part in Class 10





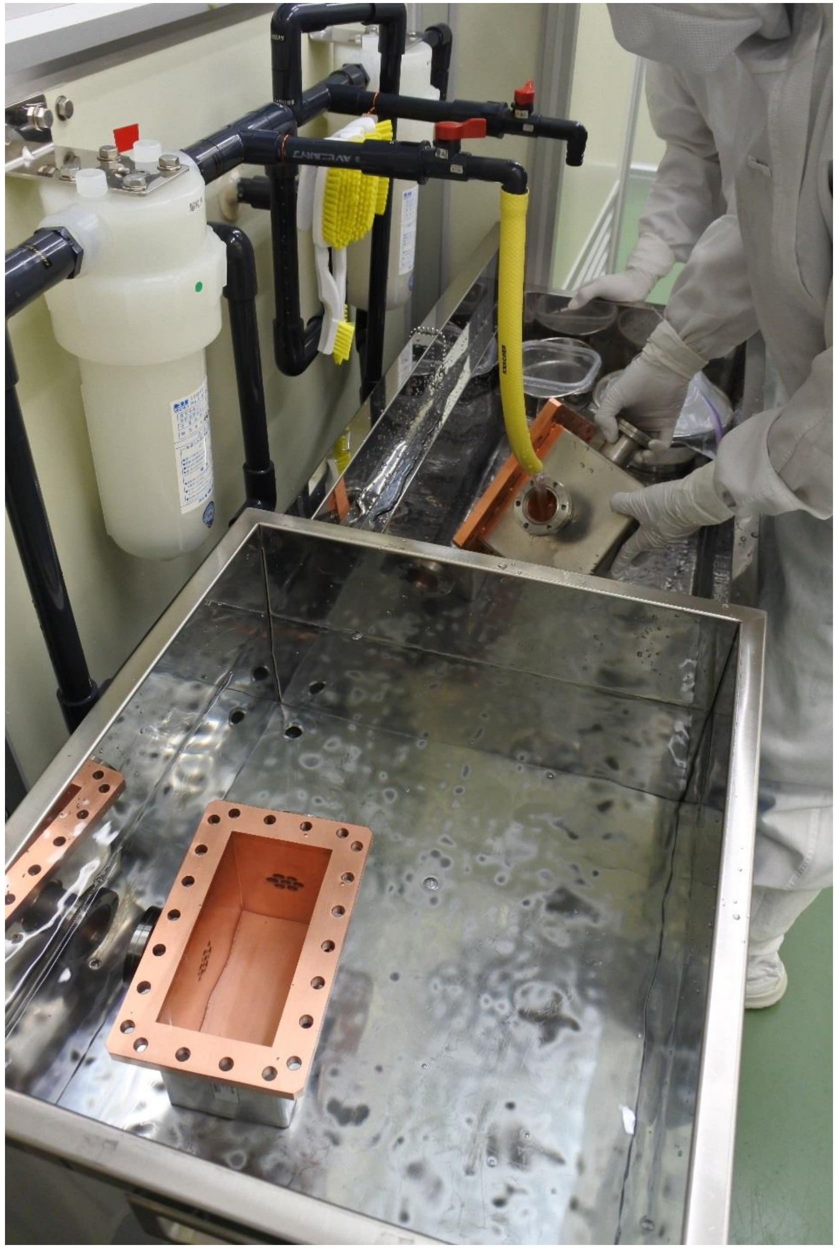
Head of inner conductor before/after rinsing





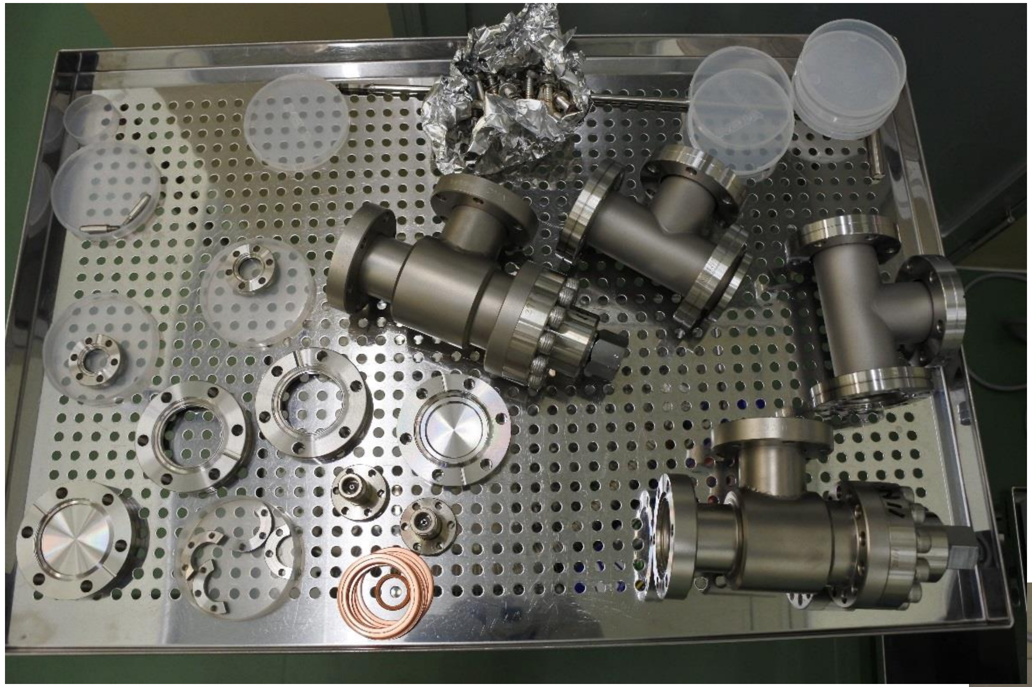
Never changed after ultra-pure water rinsing

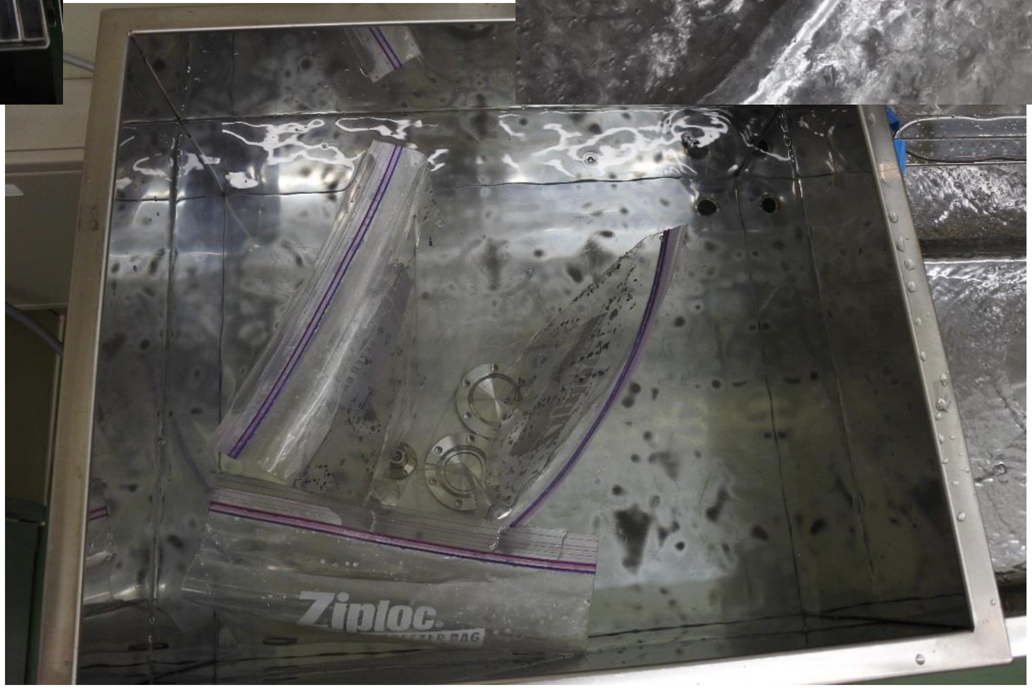
Rinsing waveguide by ultra-pure water/ultra-sonic



Drying waveguide by ion gun in Class 10

Rinsing vacuum parts by ultra-pure water/ultra-sonic

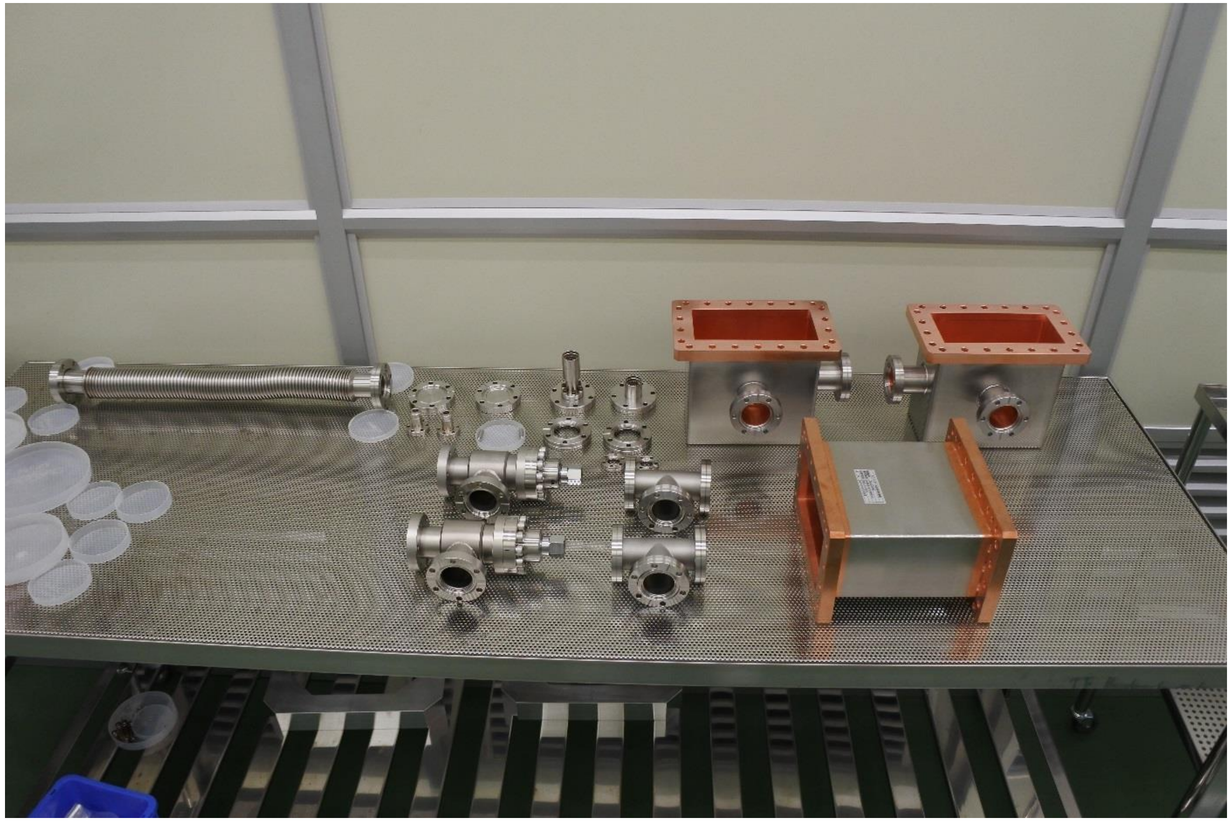




Rinsing vacuum parts by ultra-pure water/ultra-sonic

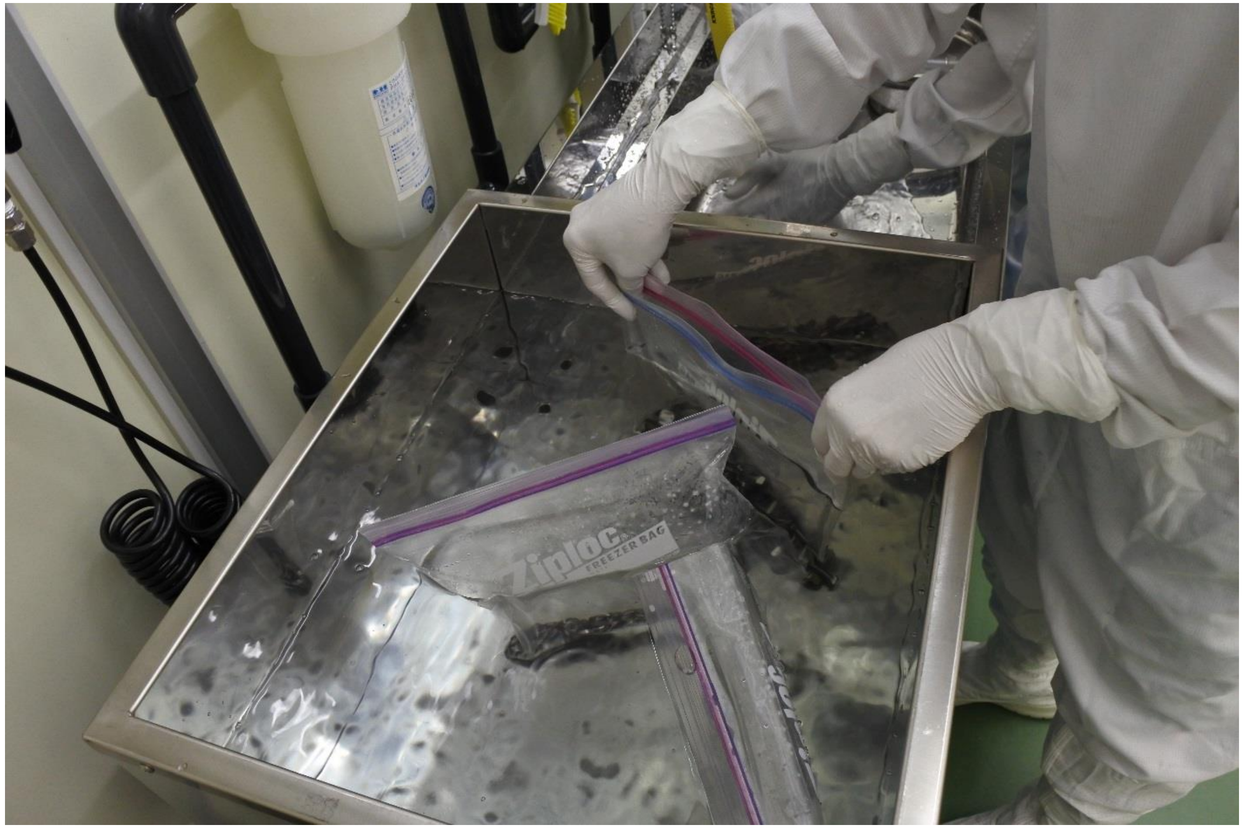
Drying vacuum parts by ion gun

Status in Class 10 at 1st day

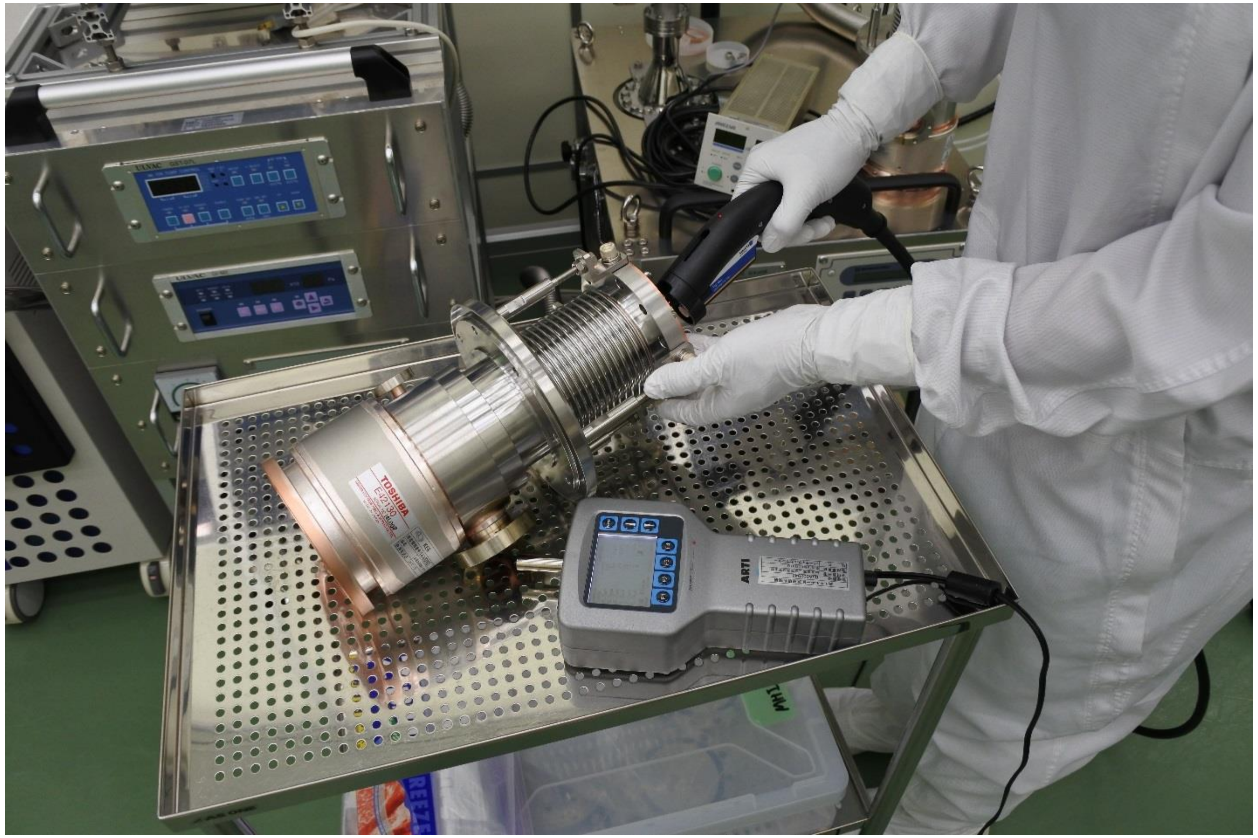


Cleaning up warm part by air blow

Rinsing bolt/nut by ultra-pure water/ultra-sonic

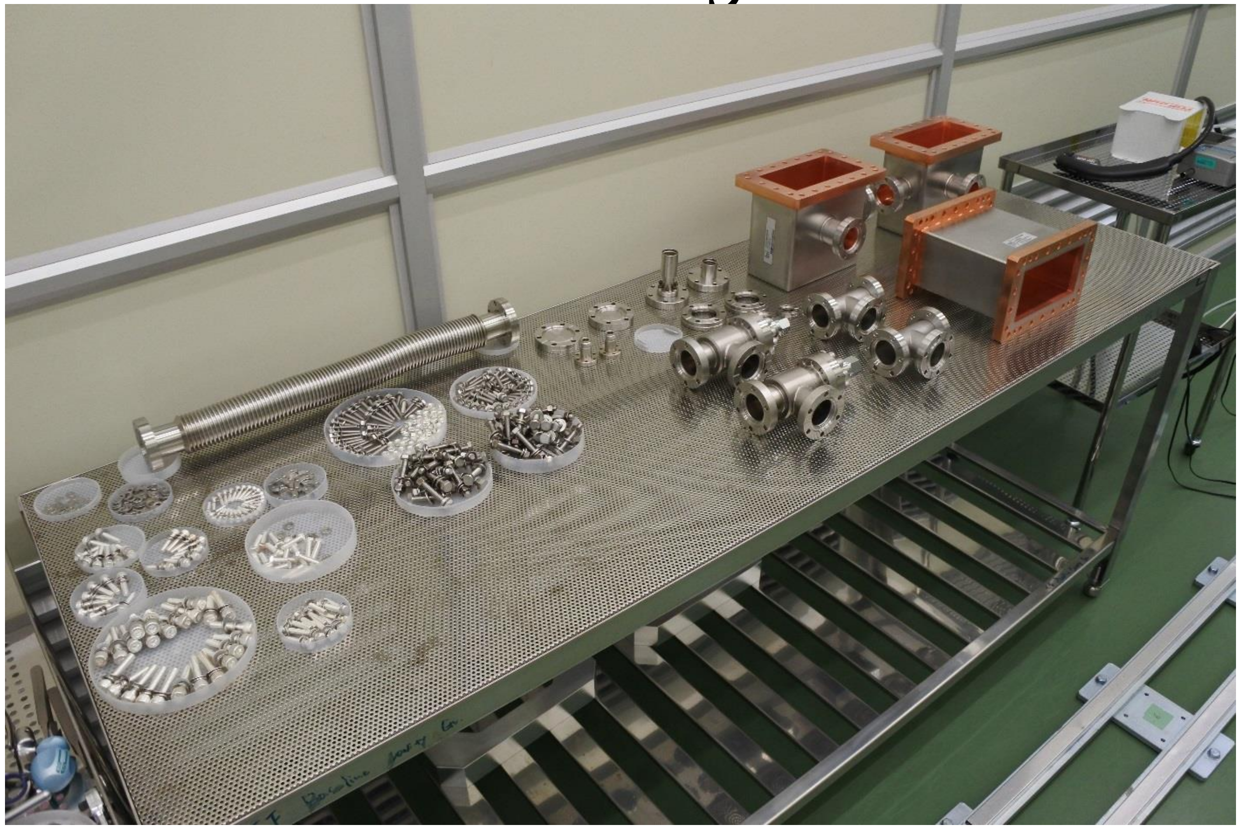


Cleaning up warm part by ion gun

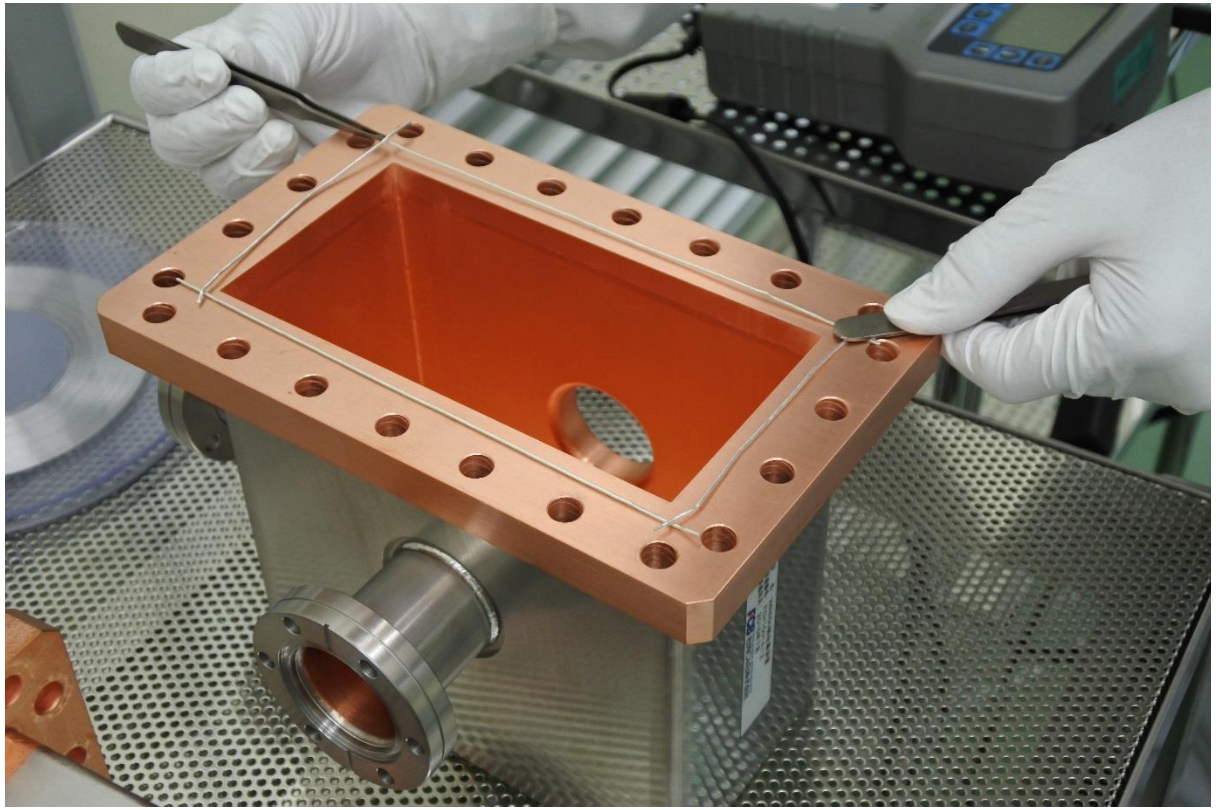


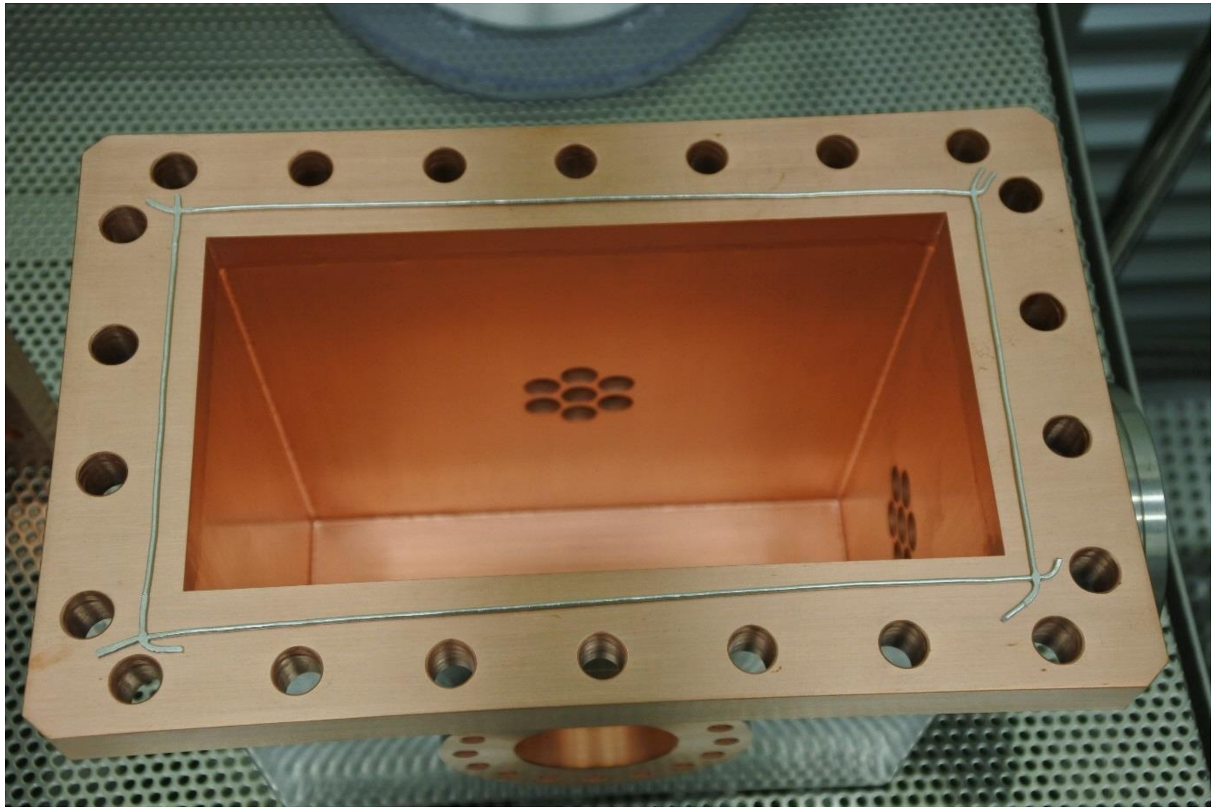
Putting bolt/nut in order

Status in Class 10 at 1st day

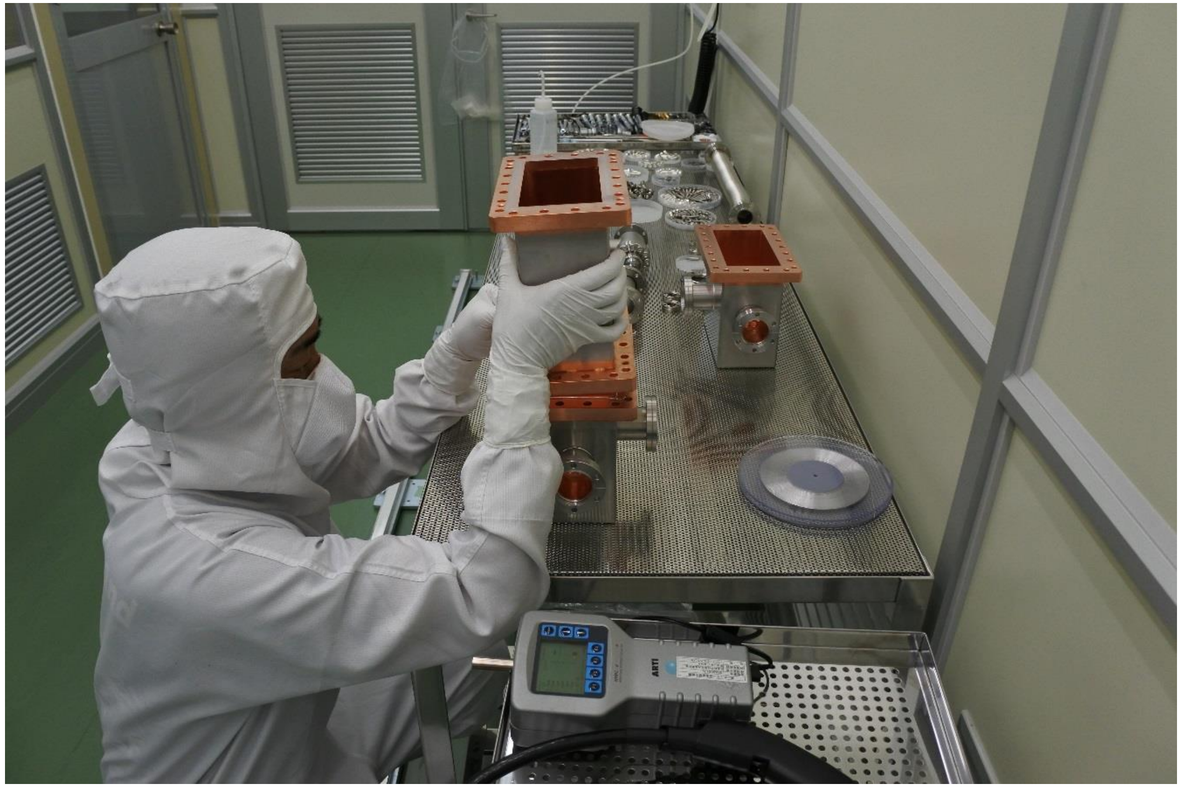


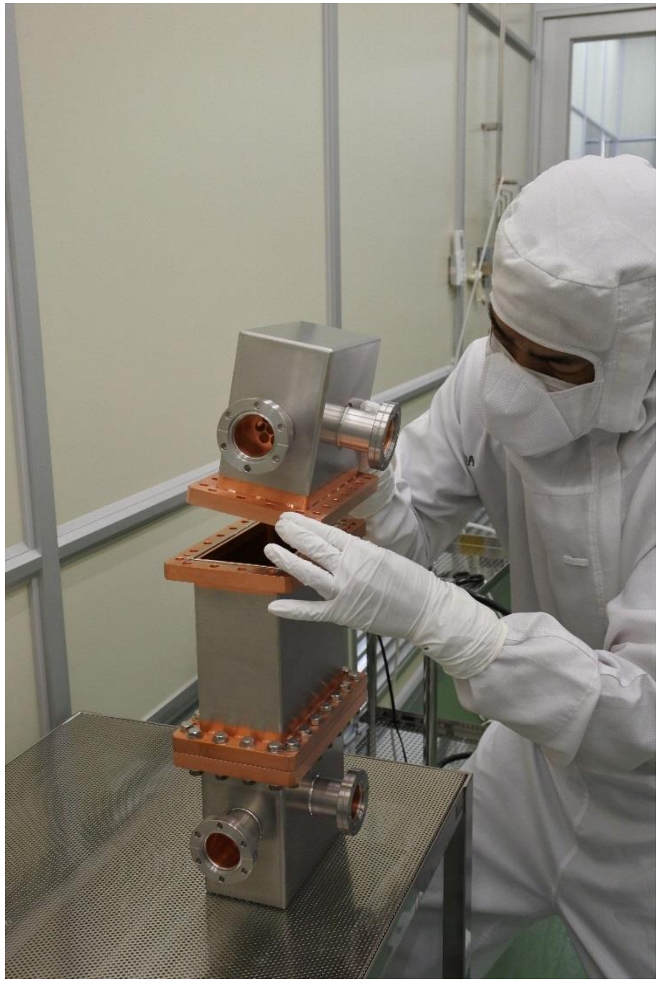
Putting indium wire



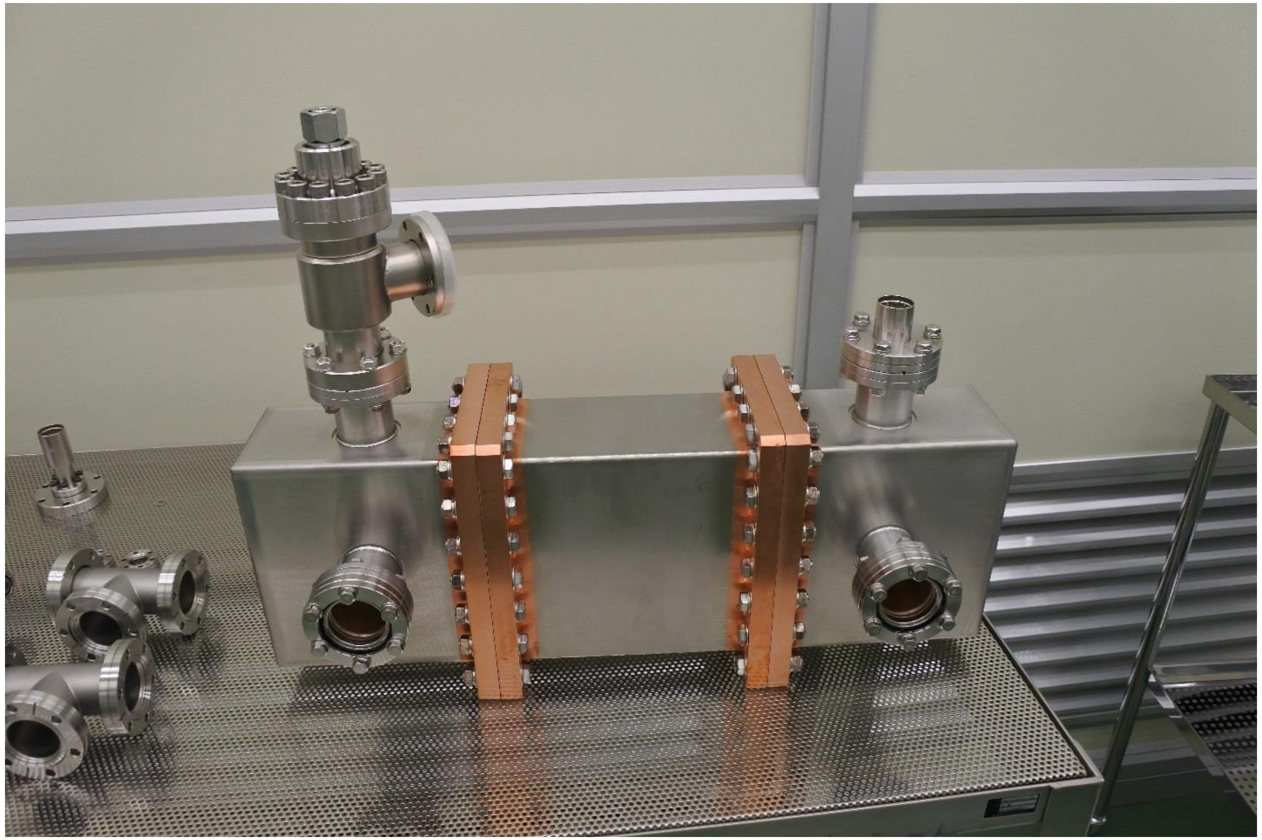


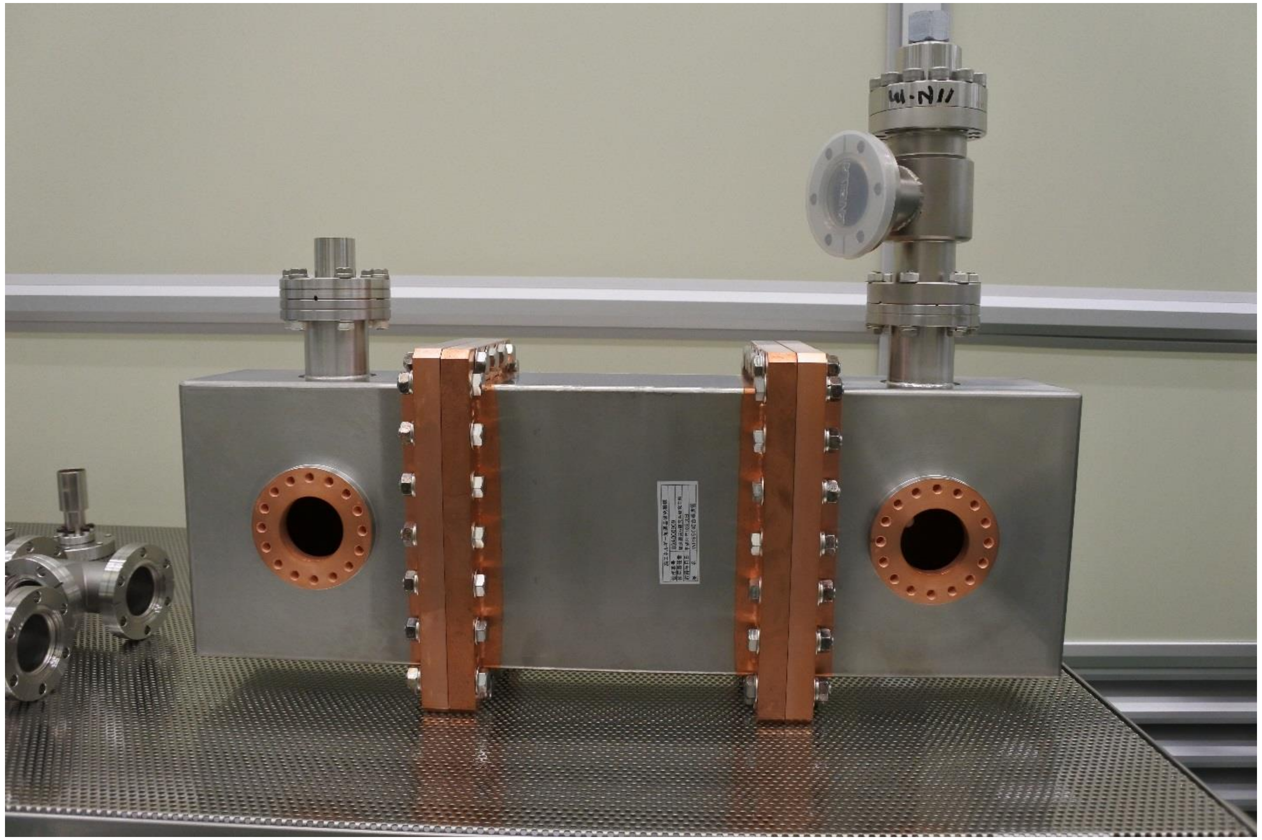
Connection of waveguide



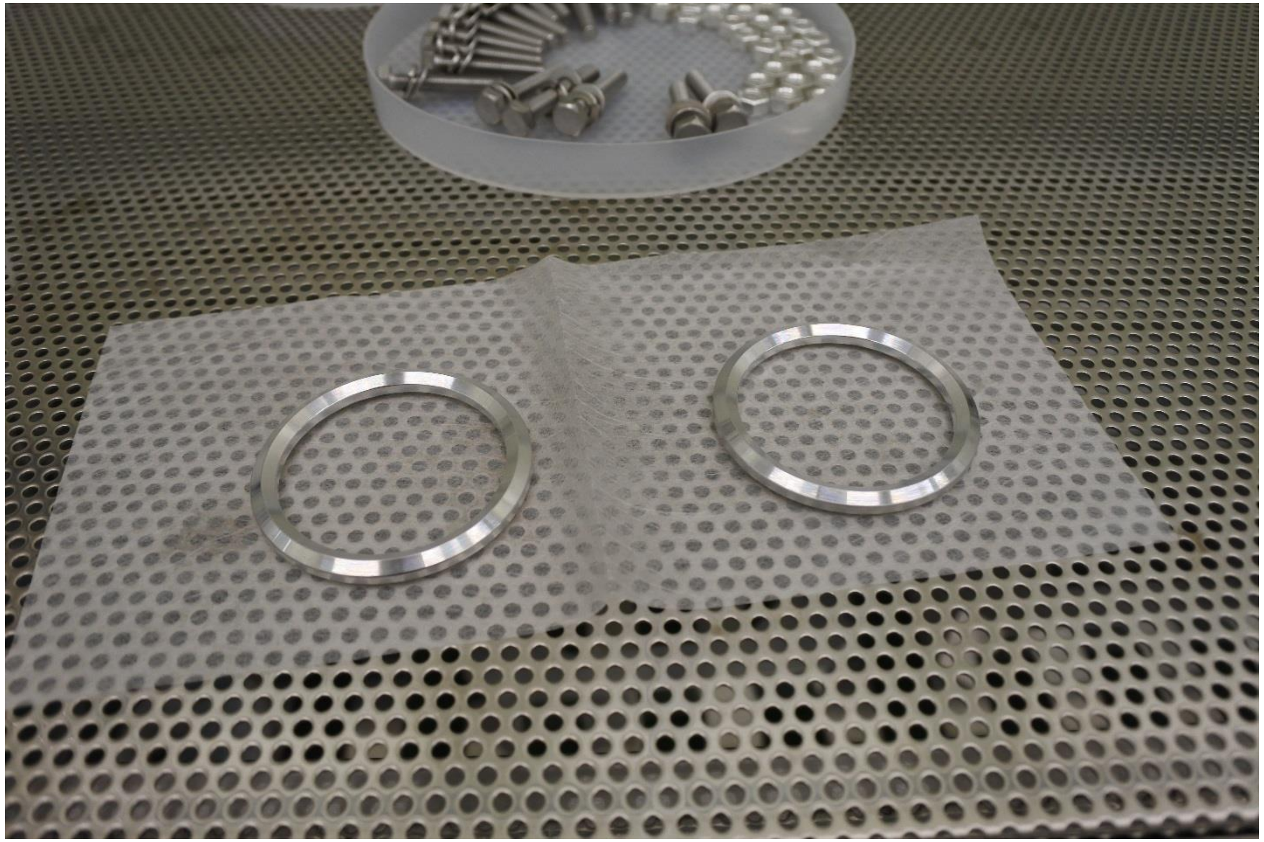


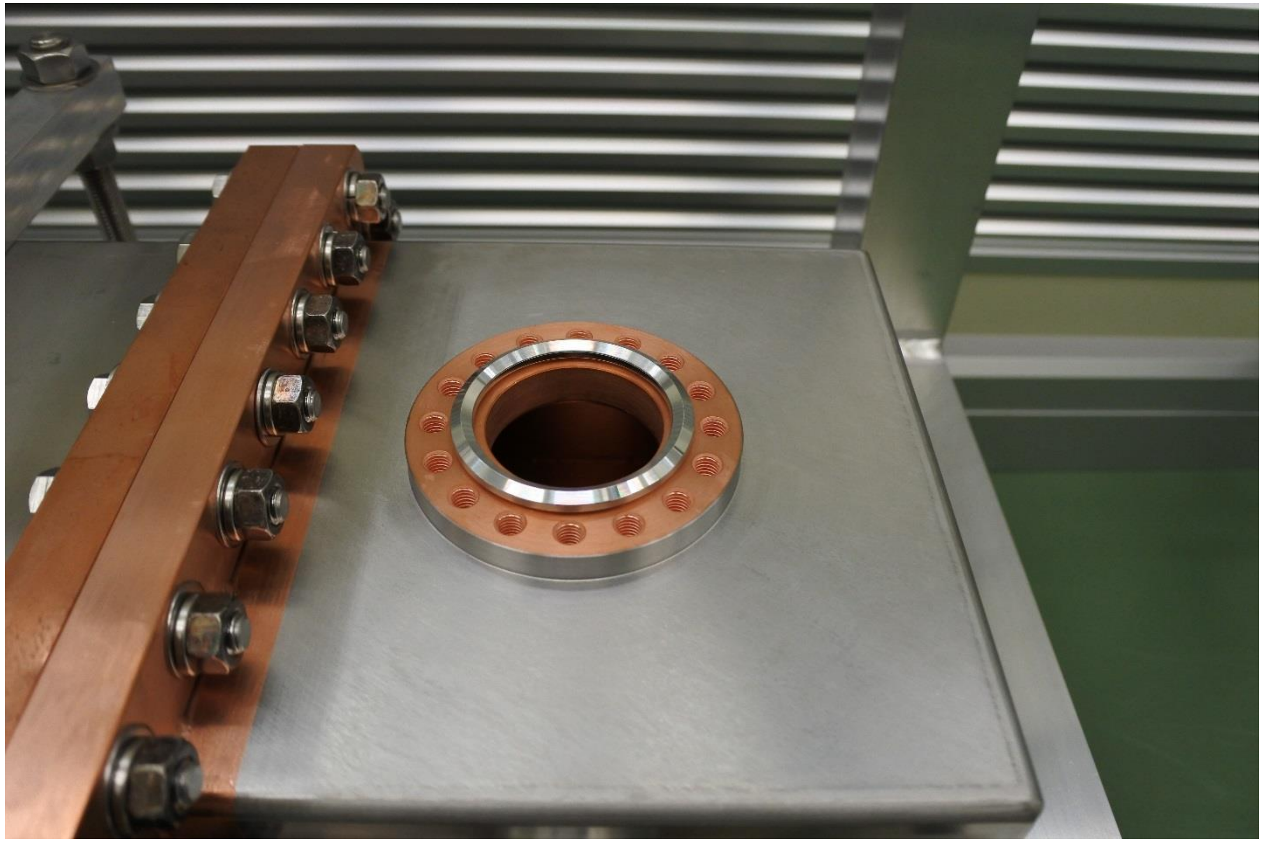
Attachment of metal valve/vacuum gauge





Hexagonal seal





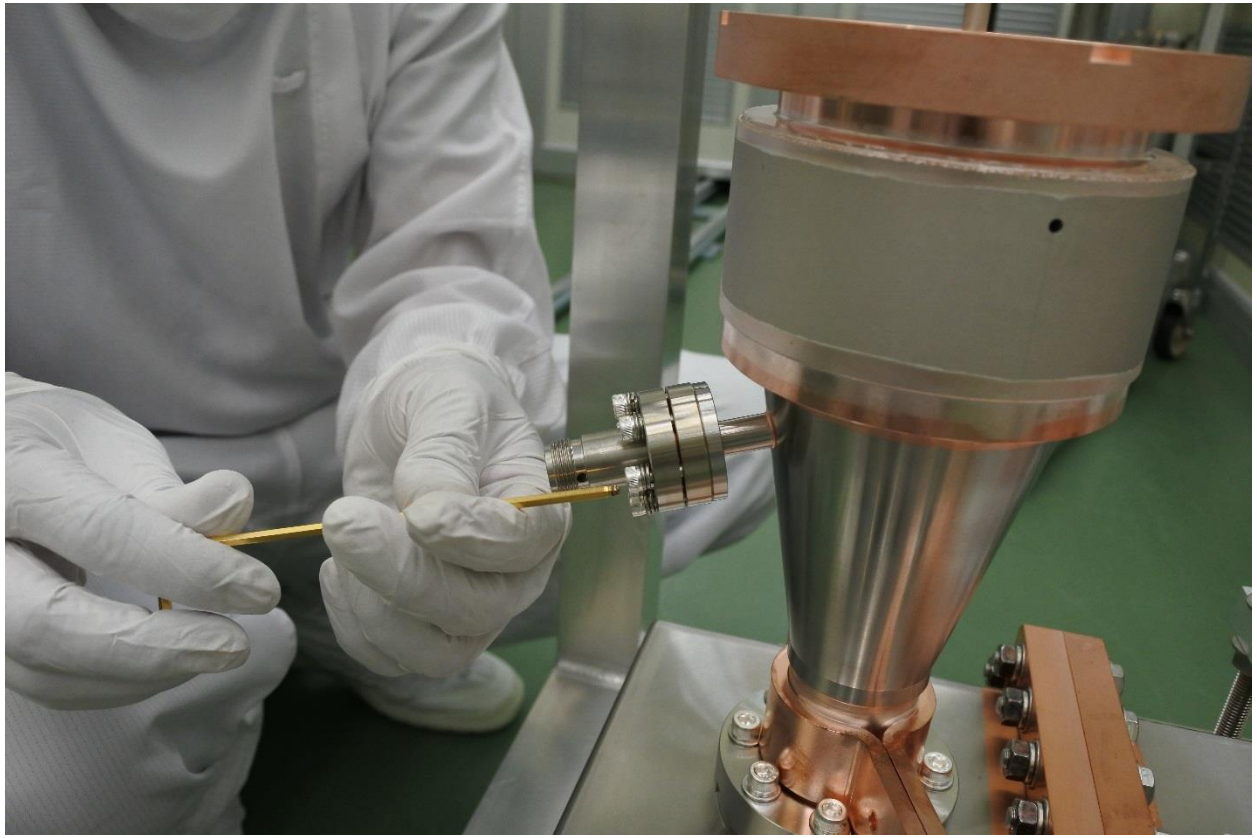
We used Hexagonal seal for the first time!

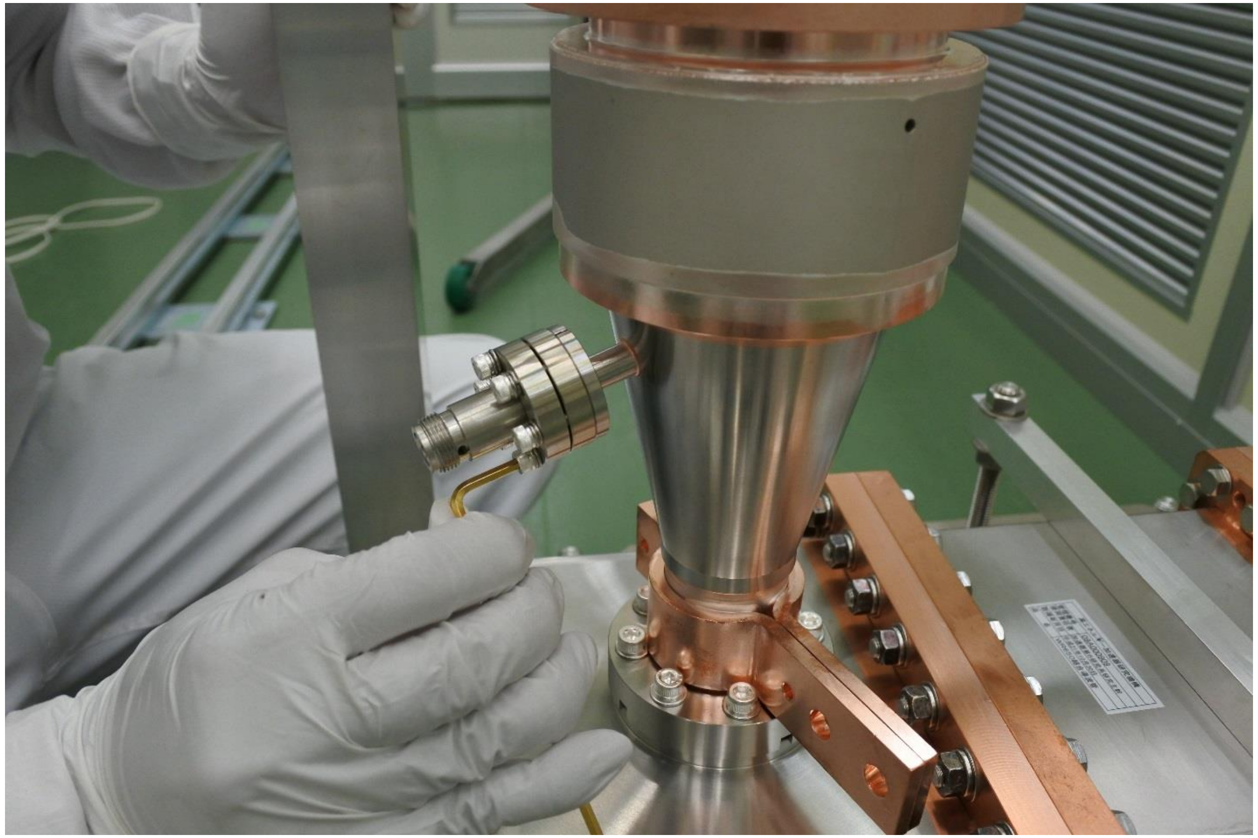
Cleaning up/jointing cold part

Jointing cold part

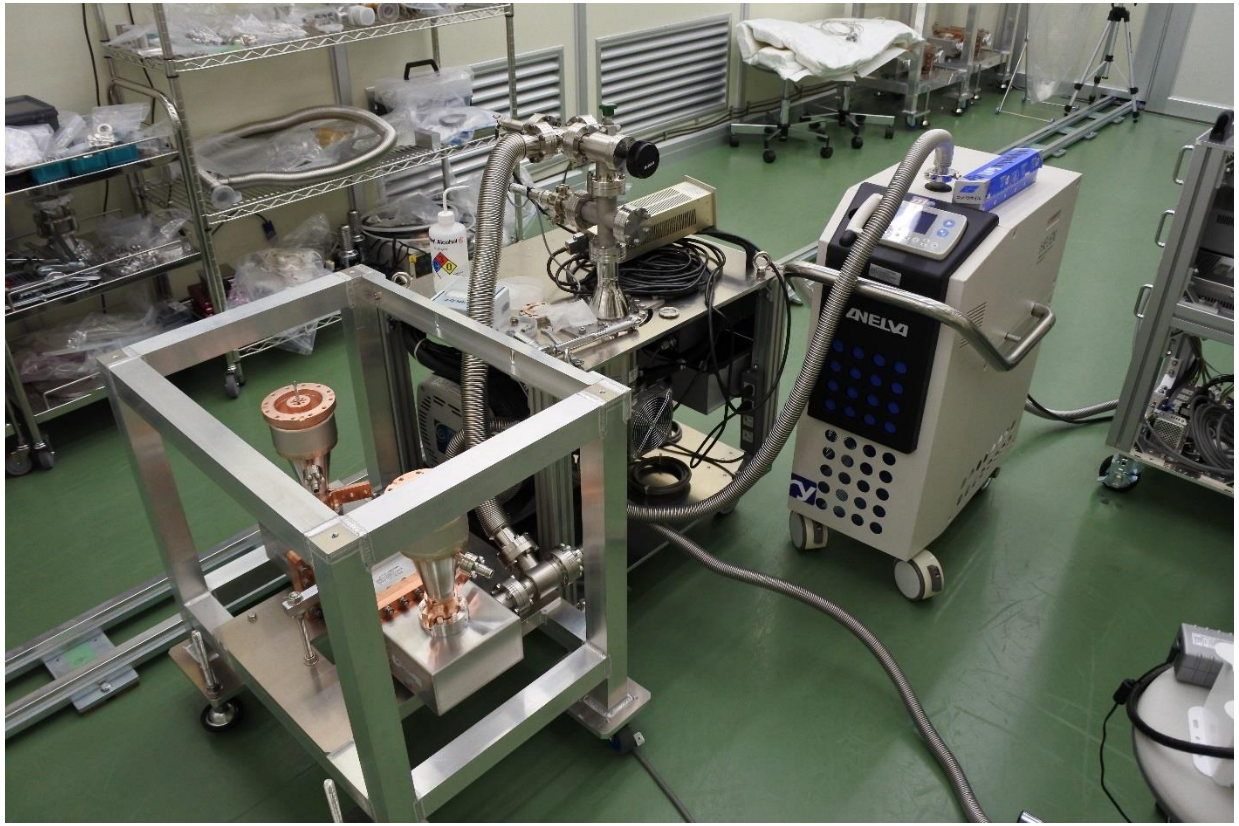
Torque: 7→9→11→13N•m (two turns)

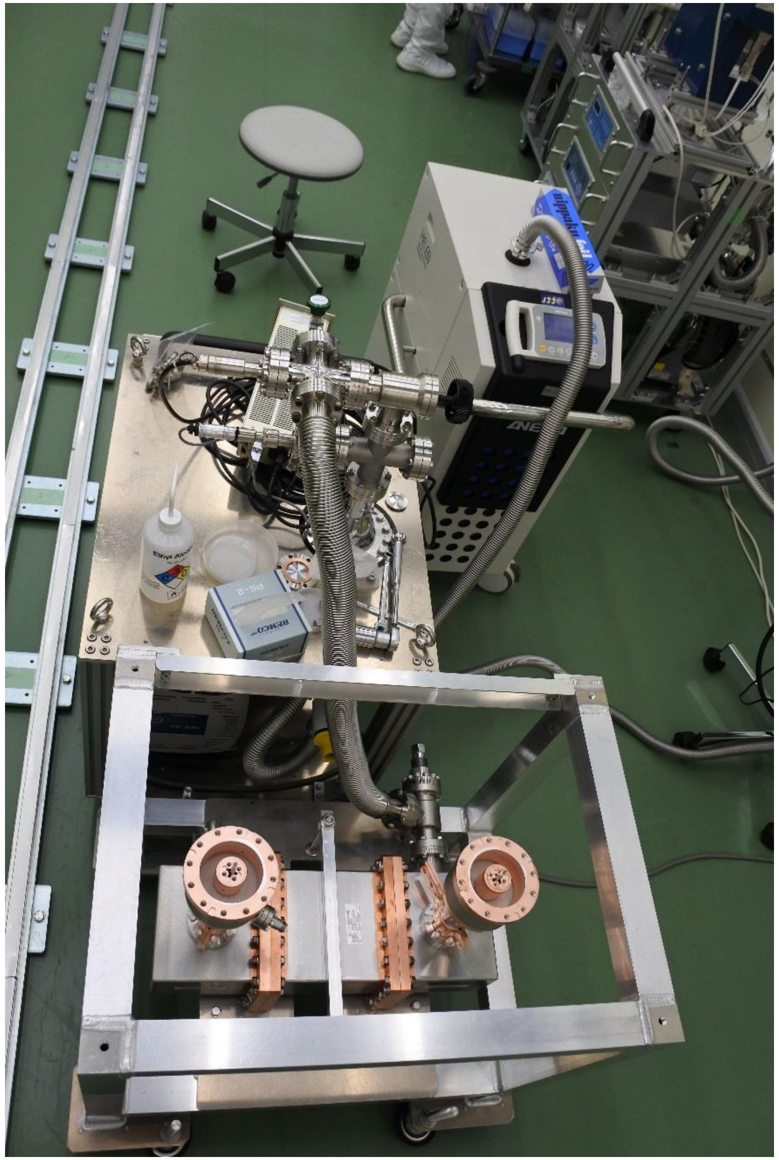
Attachment of electron probe



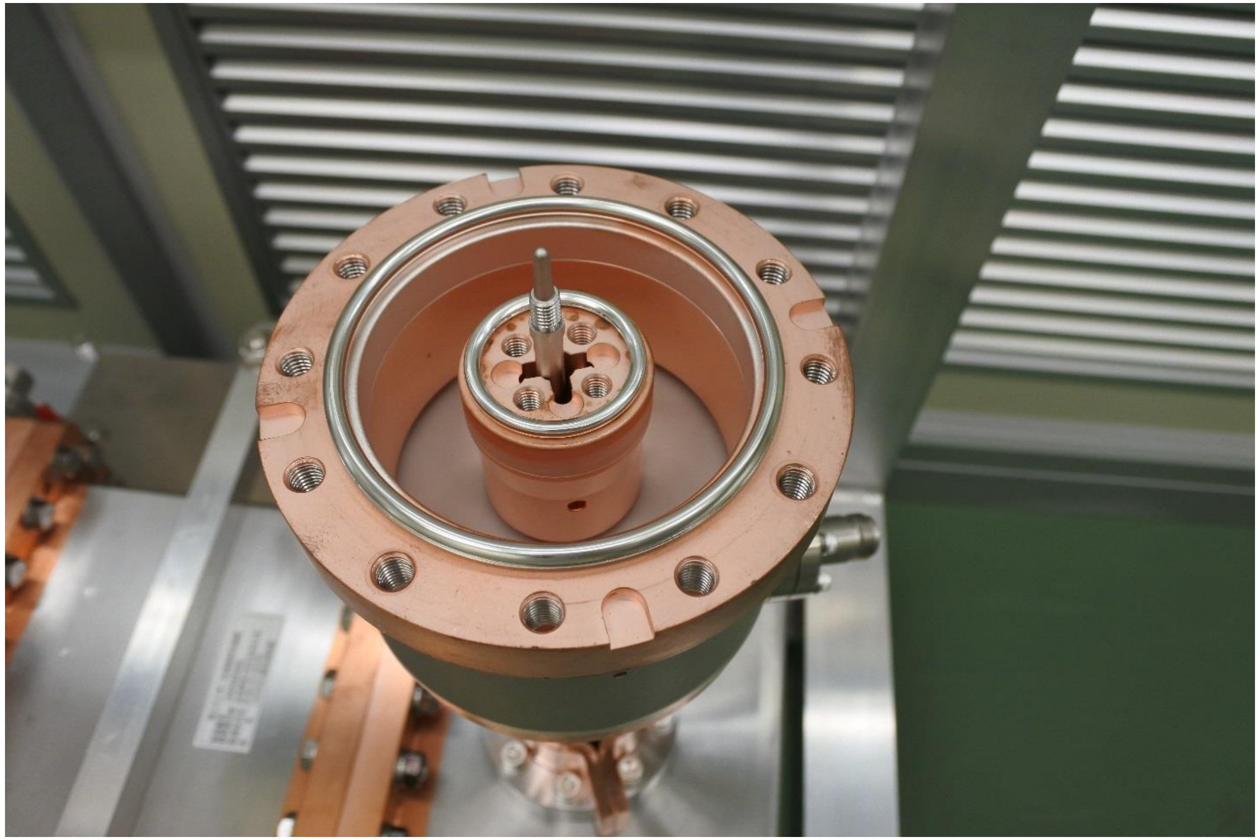


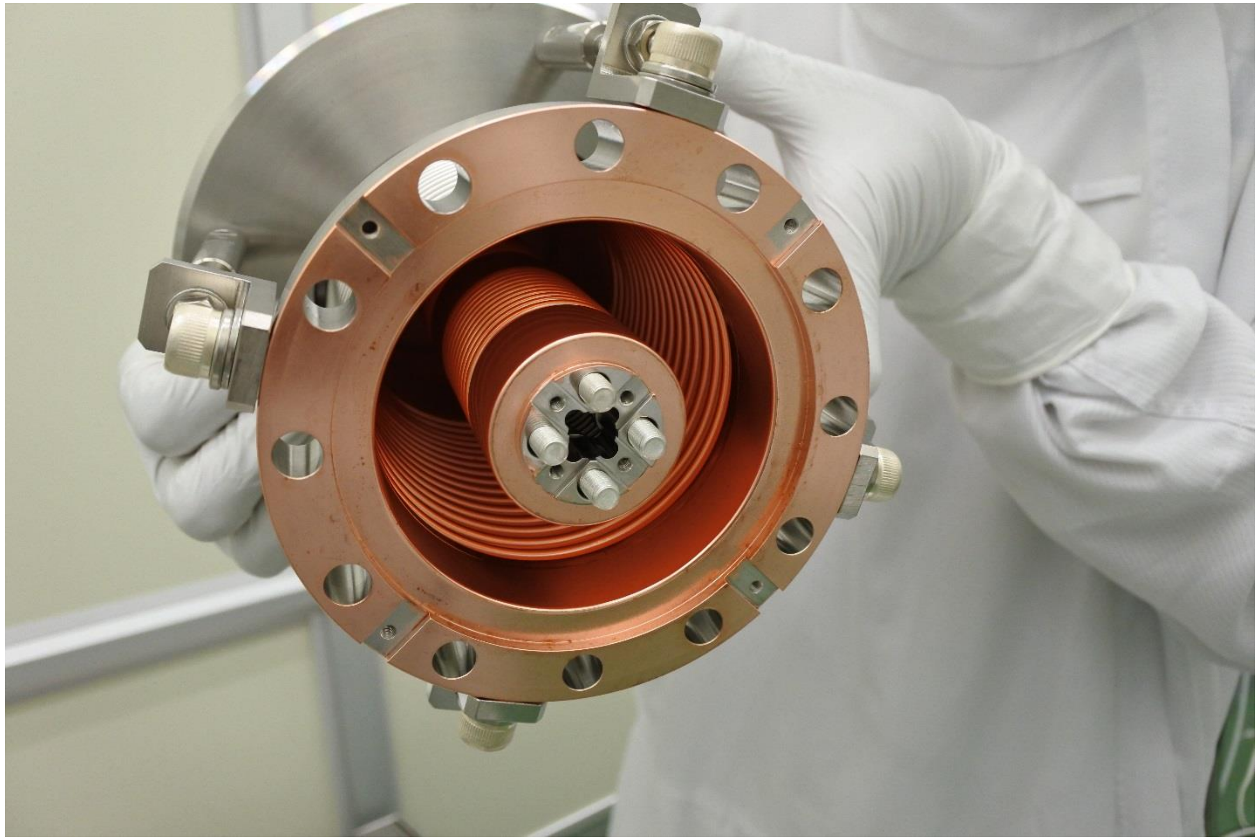
Leak check setup



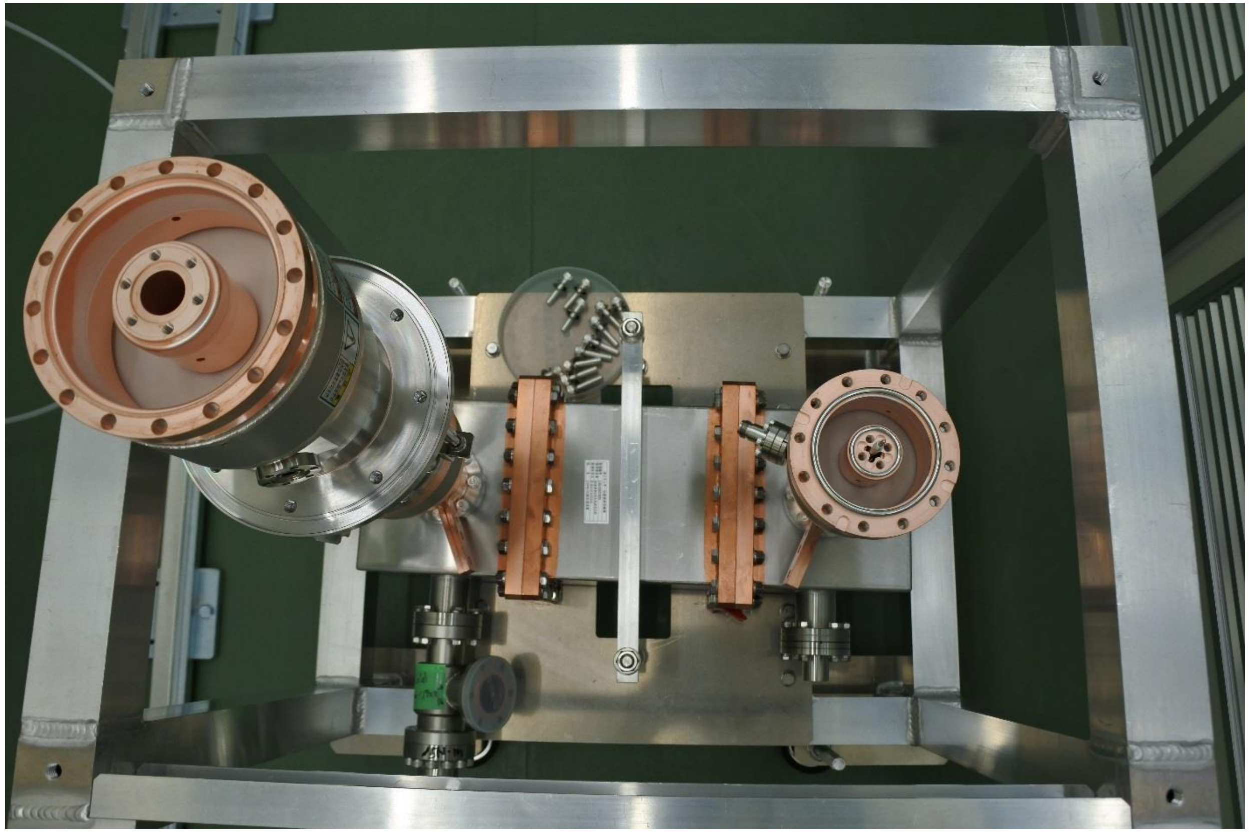


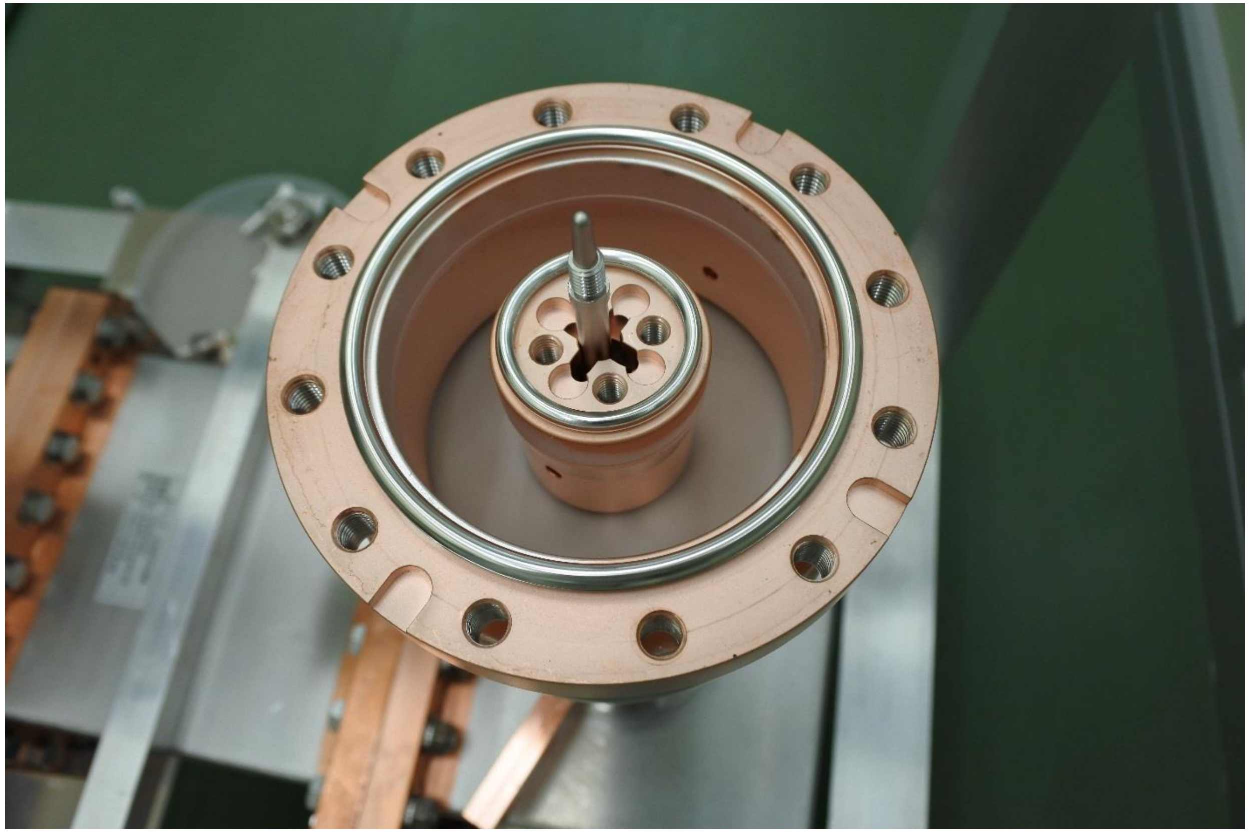
Jointing warm part



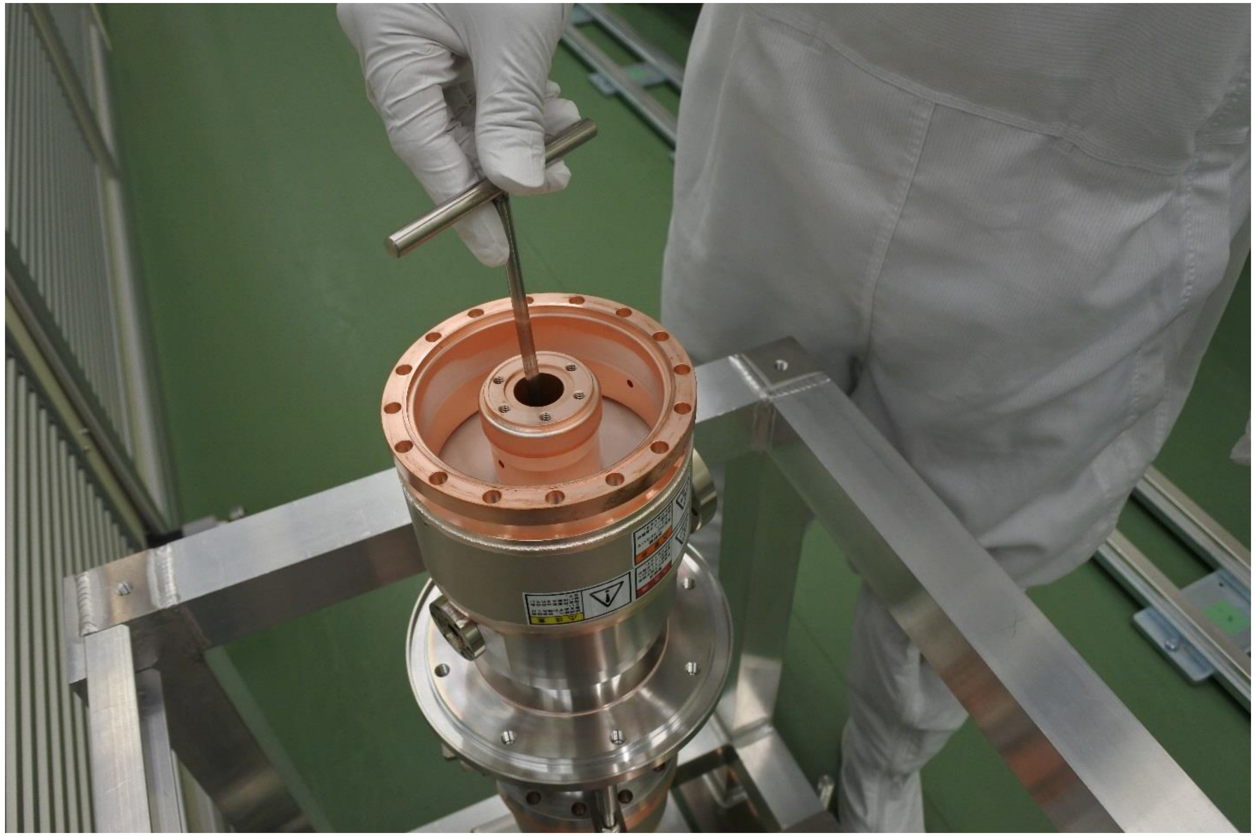


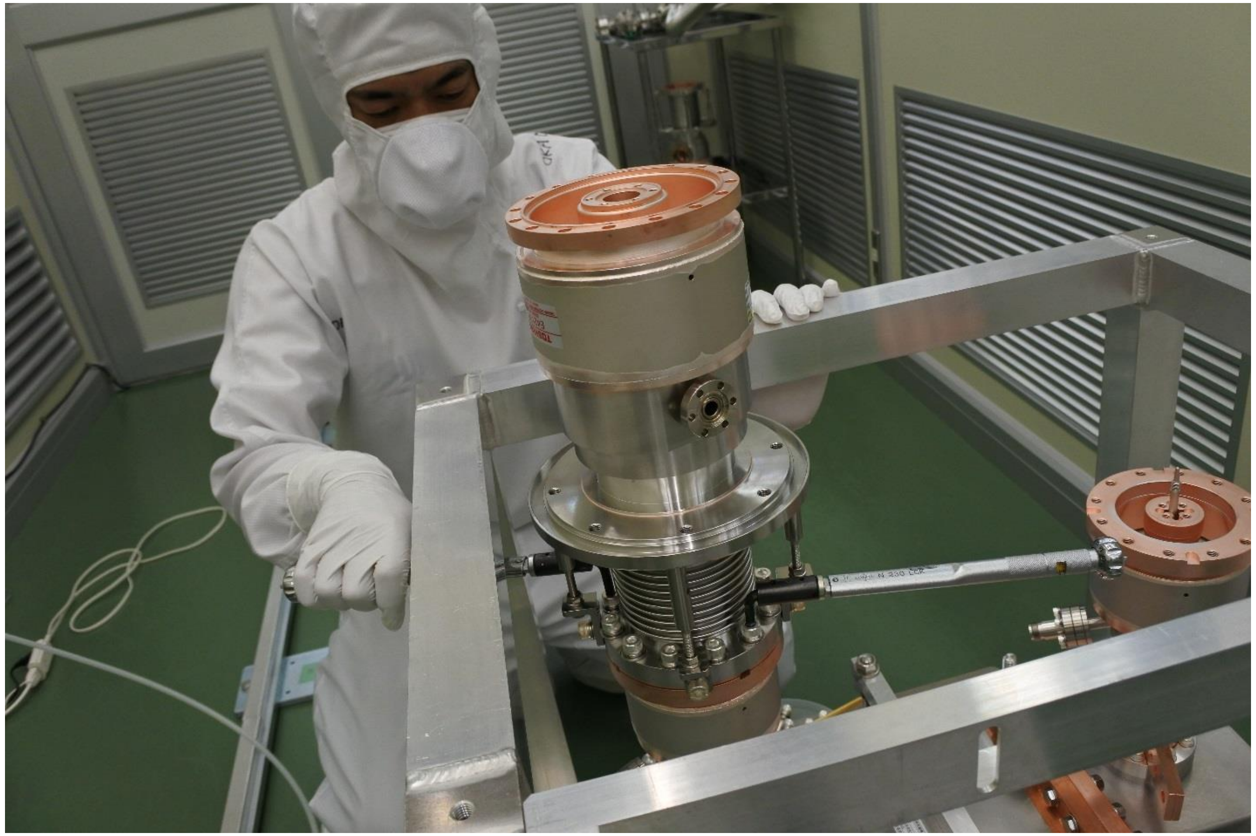
Jointing warm part



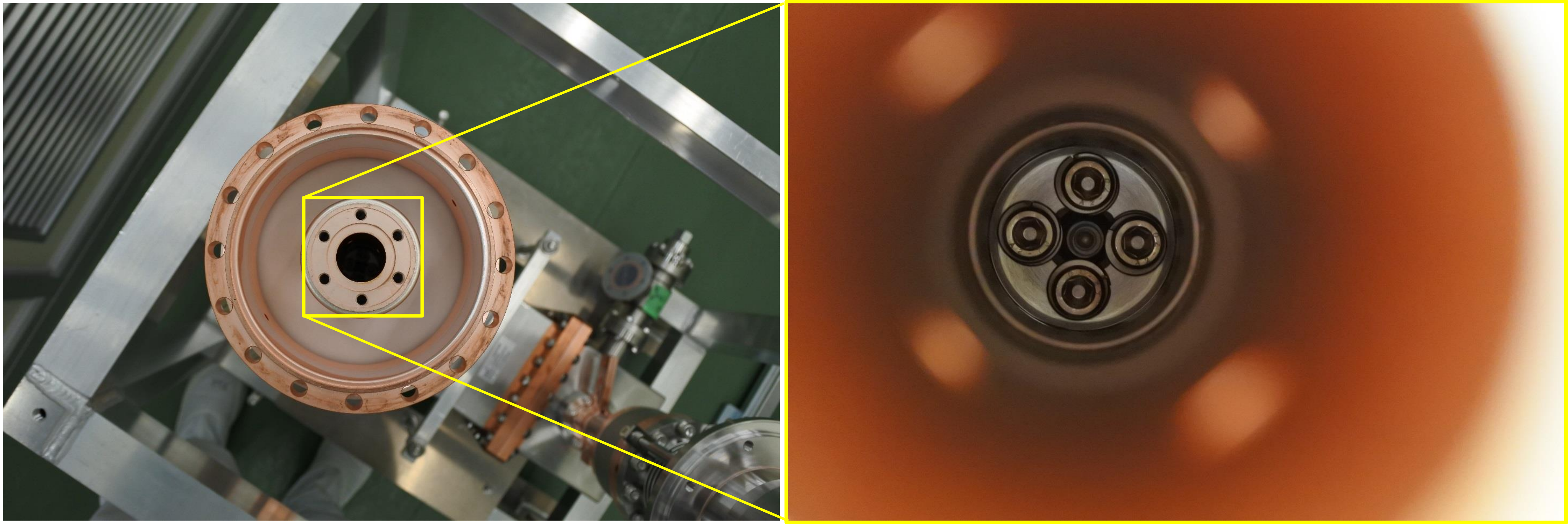


Jointing warm part





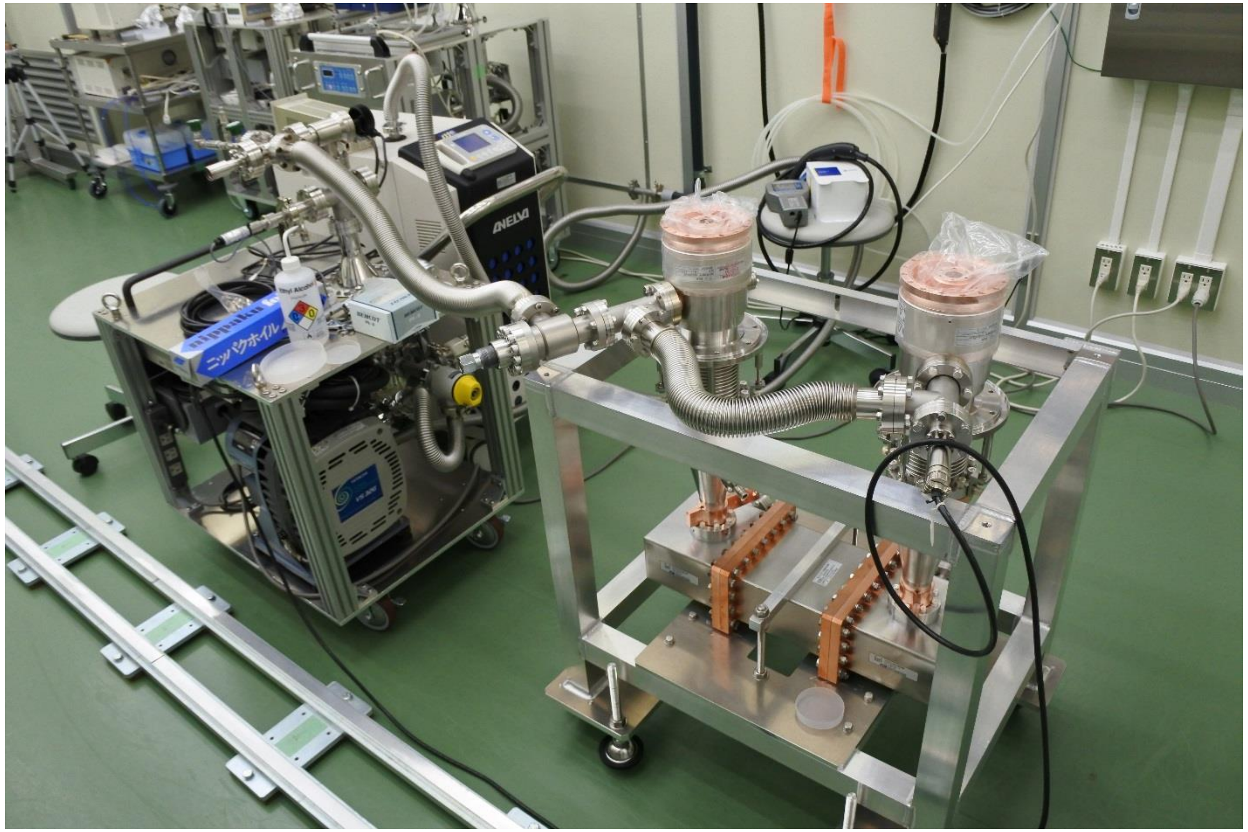
Jointing warm part



Attachment of bellows pipe

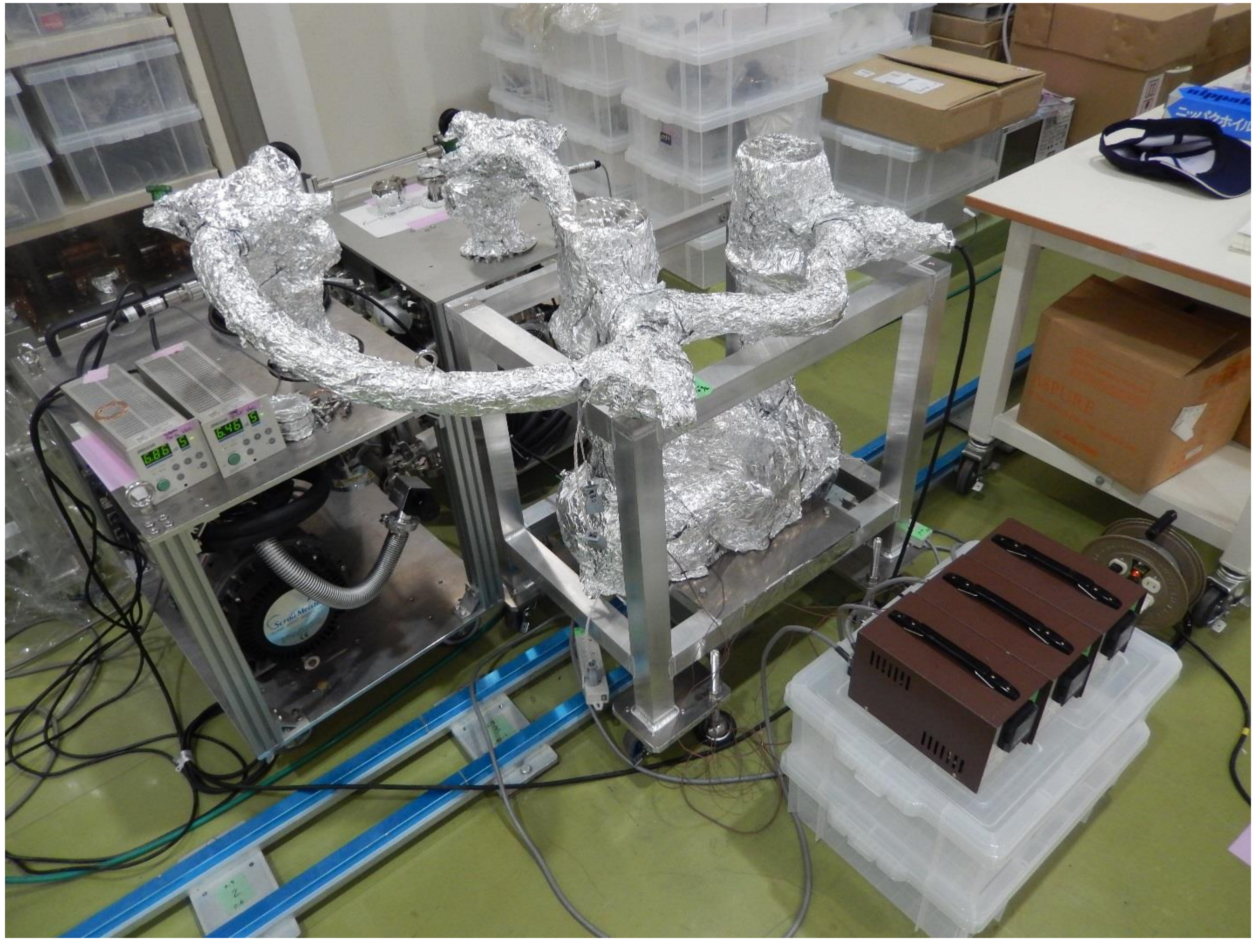
Warm parts are connected each other for common vacuum.

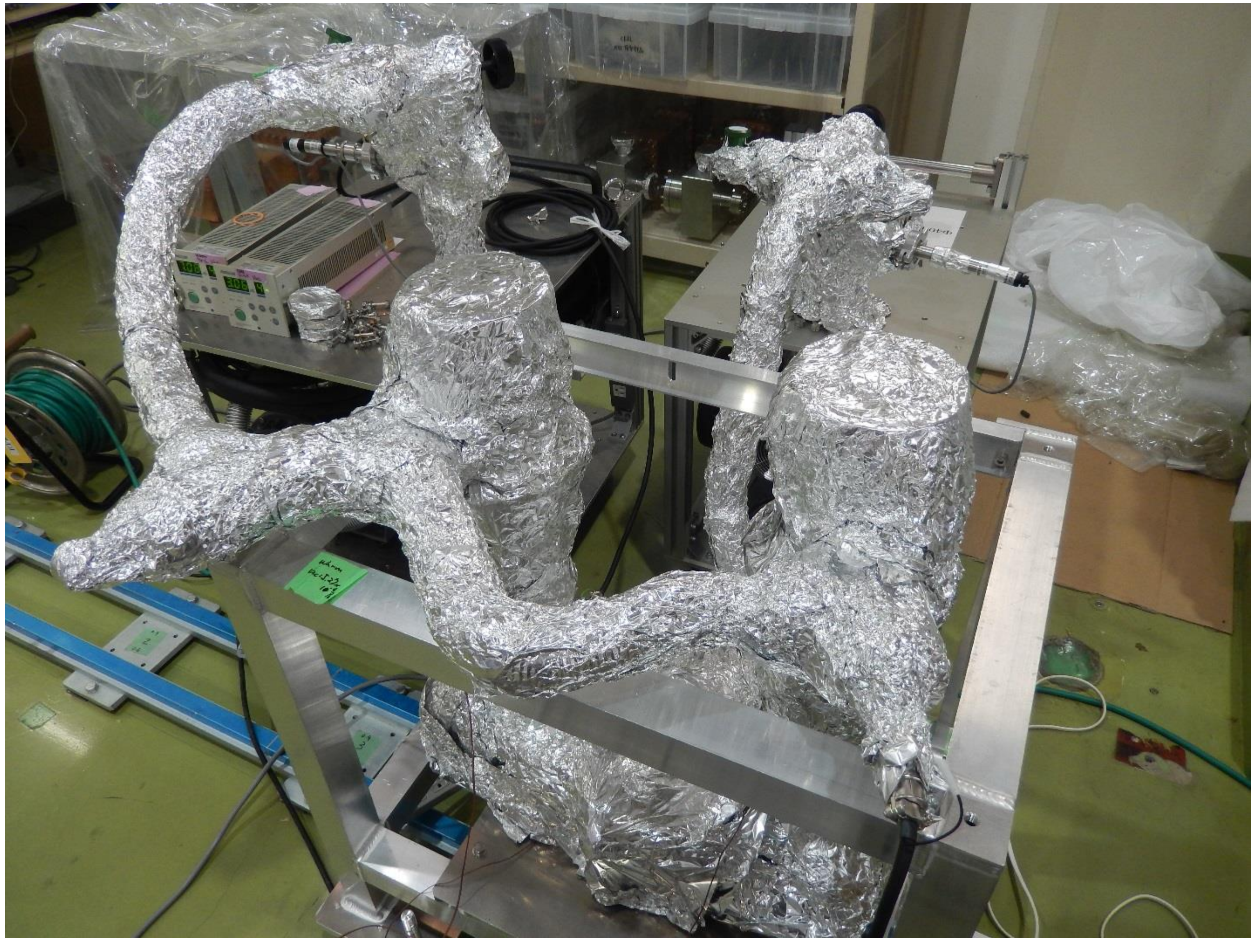
Leak check for warm part



Leak rate : 8.9 x 10^{-11} [Pa•m^3/sec] (before baking)
Back Ground : 8.2 x 10^{-11} [Pa•m^3/sec]

Pumping/Baking



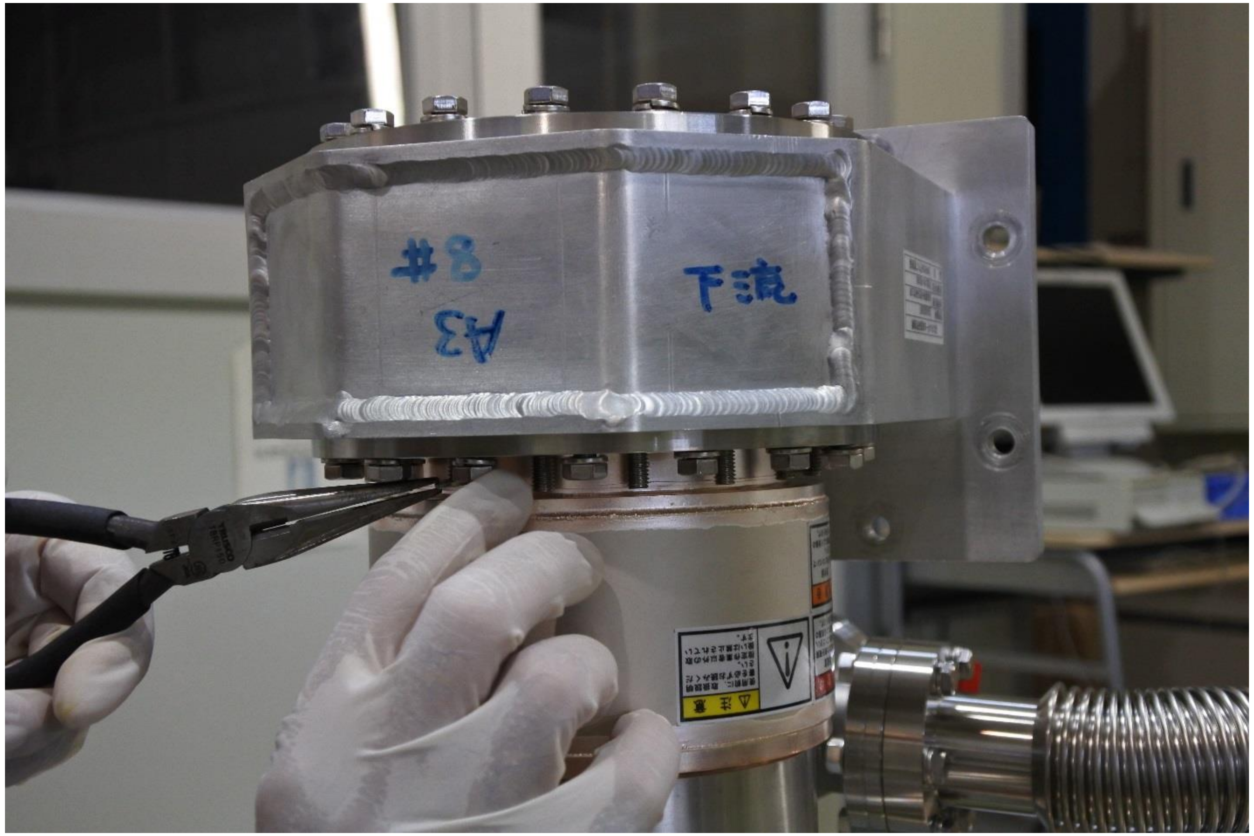


100°C for 48 hours

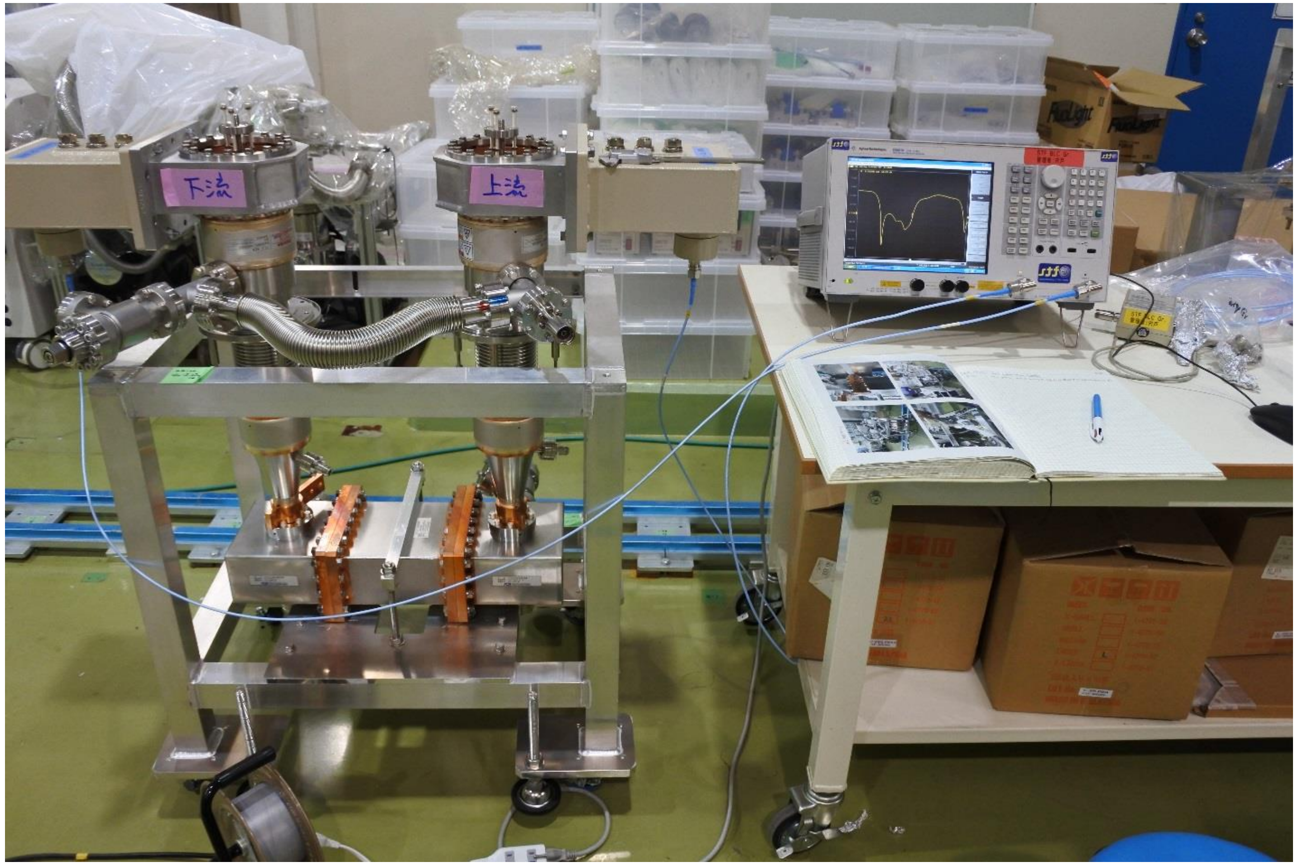
Outline

- ILC-TDR
- Motivation
- RF design by HFSS
- Fabrication processes
- Incoming inspection
- Assembly work in clean room
- **Low power test / Adjustment of inner conductor for lowest S_{11}**
- High power test at test bench
- Inspection for heating area
- More inspection / Identification of cause for heating
- Summary / Future plan

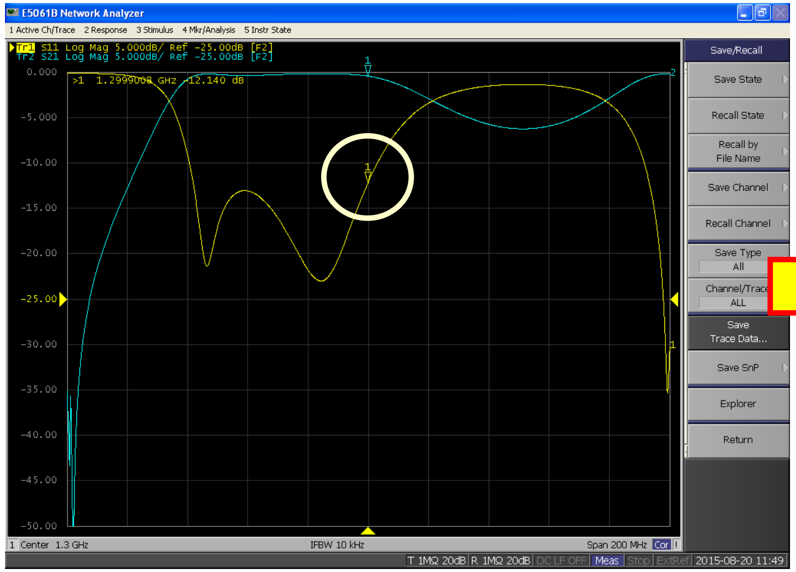
Attachment of doorknob

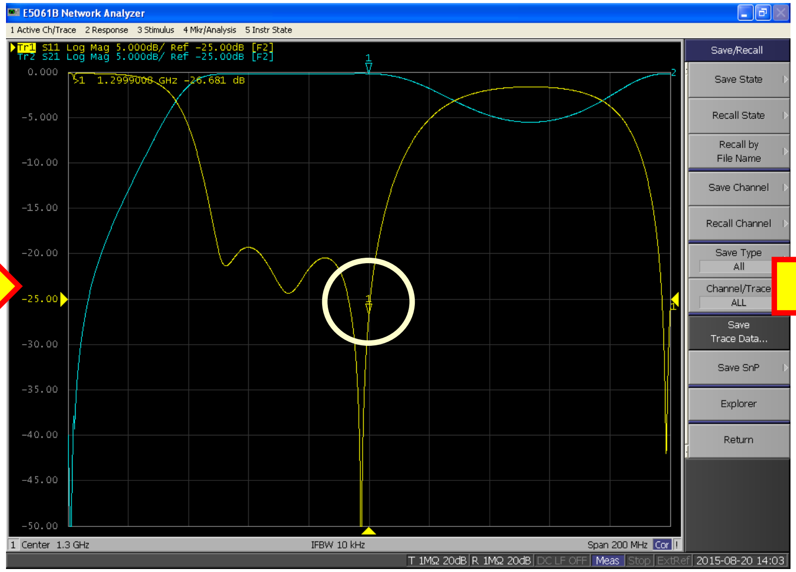


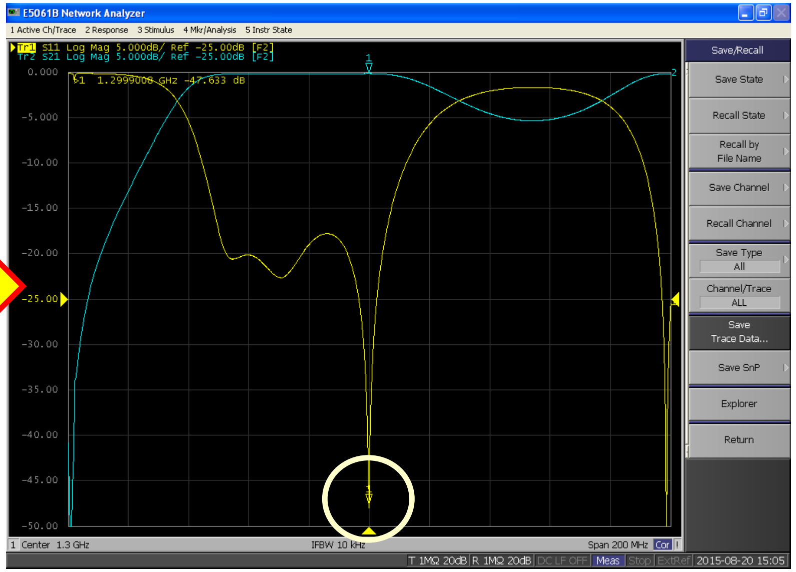
Low power test by N.A.



Adjustment of inner conductor



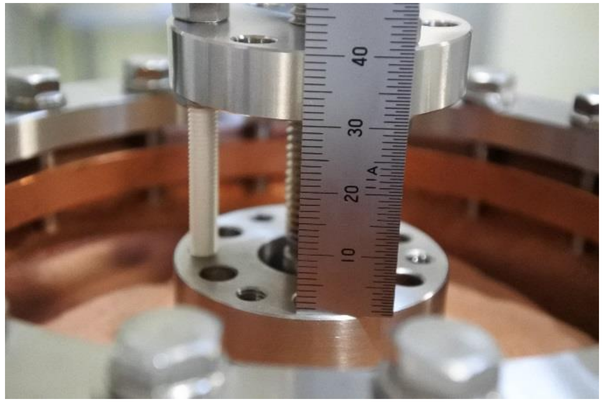


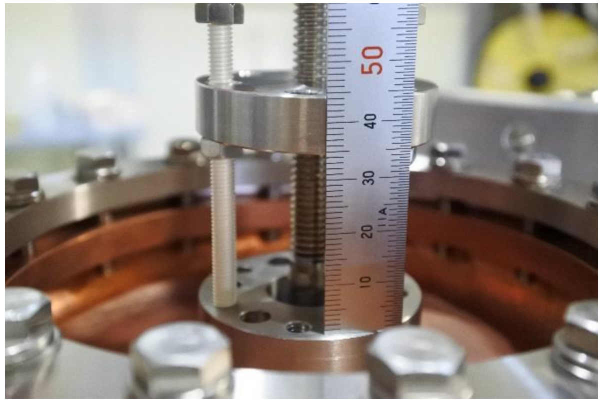


Initial state : 0.0mm
S_{11} : -12.23 dB @1.3GHz
S_{21} : -0.406 dB @1.3GHz

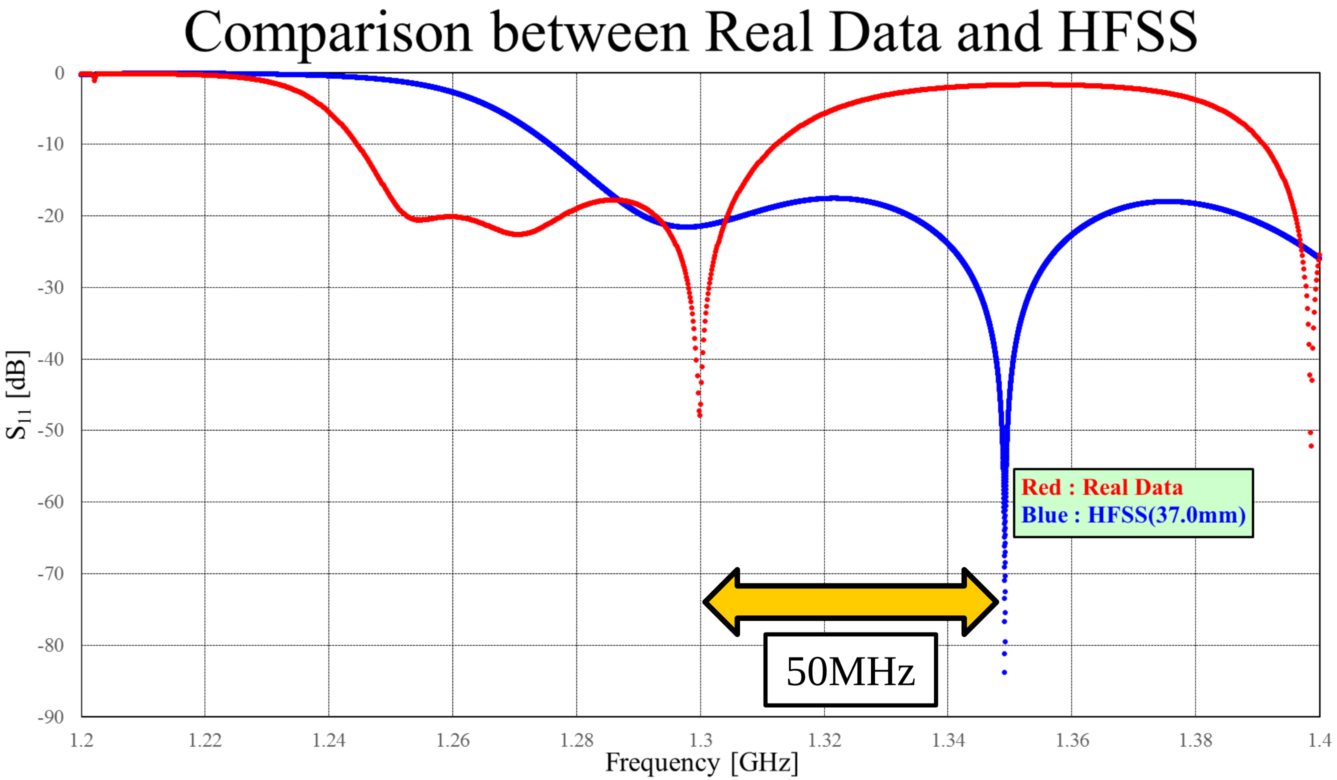
Intermediate state : -3.0mm
S_{11} : -26.68 dB @1.3GHz
S_{21} : -0.135 dB @1.3GHz

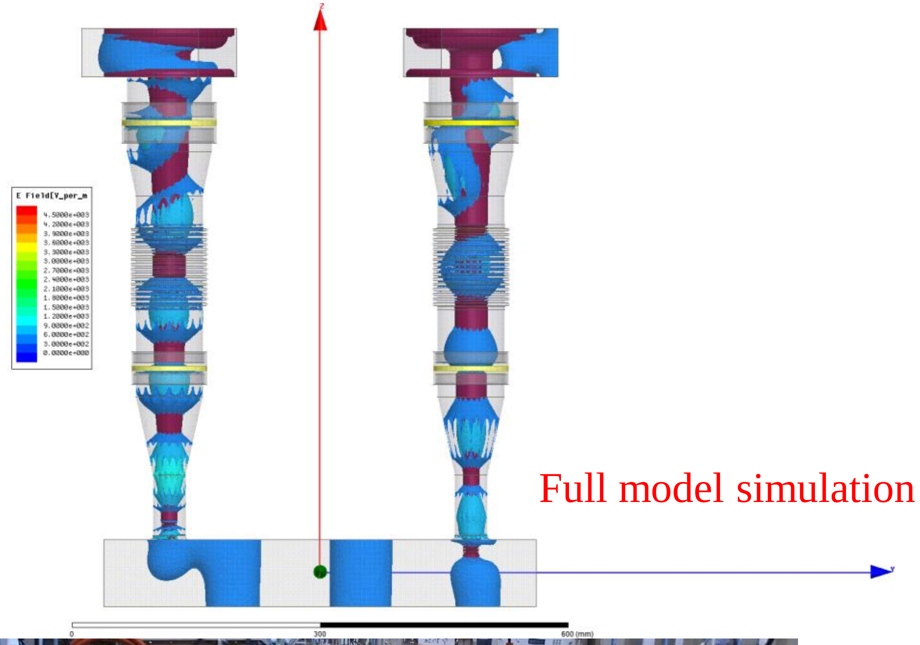
Final state : -3.3/-4.0mm
S_{11} : -47.57 dB @1.3GHz
S_{21} : -0.126 dB @1.3GHz

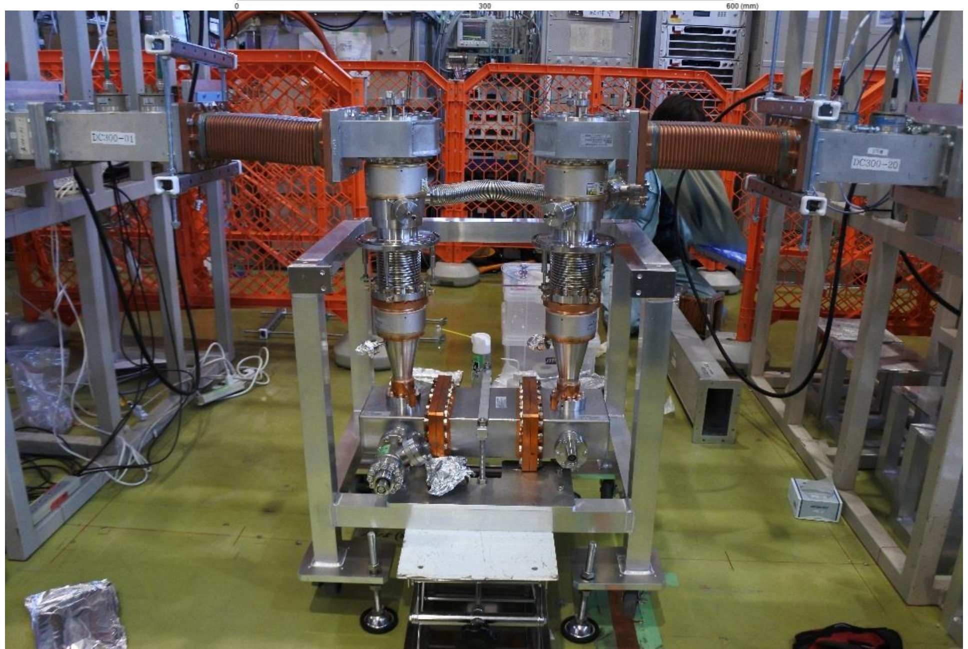




Comparison between Real data and HFSS







They are consistent or quite different each other?

There maybe some fabrication errors or unknown reasons.

Outline

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Goal for each RF condition at test bench

RF Pulse Width [μsec]	RF Repetition Rate [Hz]	Max. Power [kW]
10	5	1200
30	5	1200
100	5	1200
500	5	1200
1500 (RDR spec.)	5	800
1650 (TDR spec.)	5	800

Max. power for above 1500μsec depends on vacuum level

Interlock List in High Power Test of 40mm Input Coupler

I/L Item	mps #	Threshold
Cooling water I/L	mps 60	
Arc I/L #1 (up W.G.)	mps 90	2000 / 6500
Arc I/L #2 (upstream)	mps 91	2000 / 7250
Arc I/L #3 (downstream)	mps 92	2000 / 7480
Arc I/L #4 (down W.G.)	mps 93	2500 / 6550
Vacuum I/L	mps 103	2×10^{-4} [Pa]
VSWR V3 I/L	mps 100	P_{for} < 1.3 [MW] @upstream
VSWR V3 I/L	mps 101	P_{back} < 10 [kW] @upstream
VSWR V3 I/L	mps 102	VSWR < 1.4 @upstream
VSWR V4 I/L	mps 110	P_{for} < 1.3 [MW] @downstream
VSWR V4 I/L	mps 111	P_{back} < 10 [kW] @downstream
VSWR V4 I/L	mps 112	VSWR < 1.4 @downstream

$$VSWR = \frac{1+\sqrt{\dfrac{P_{backward}}{P_{forward}}}}{1-\sqrt{\dfrac{P_{backward}}{P_{forward}}}}$$

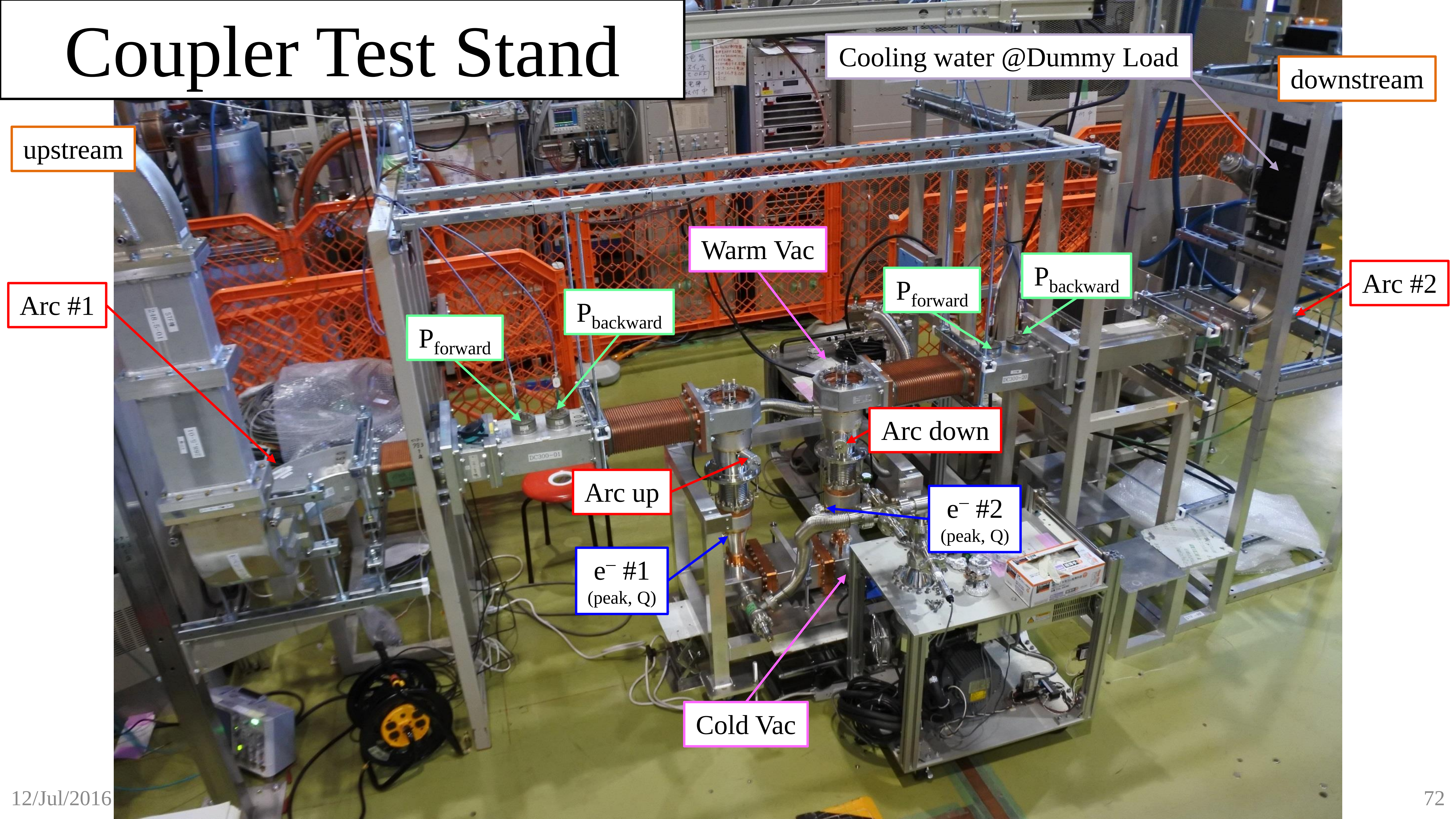
$$VSWR = 1.2 \Rightarrow \frac{P_{backward}}{P_{forward}} \cong 0.01$$

$$VSWR = 1.4 \Rightarrow \frac{P_{backward}}{P_{forward}} \cong 0.028$$

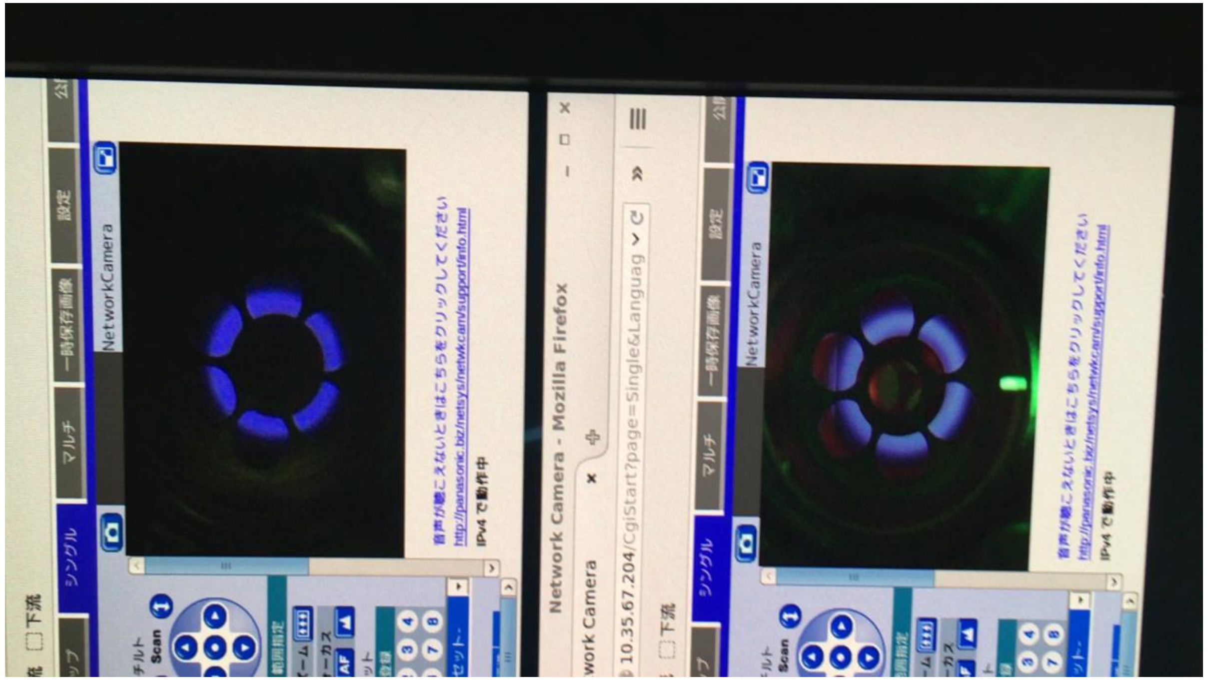
$$VSWR = 2.0 \Rightarrow \frac{P_{backward}}{P_{forward}} \cong 0.111$$

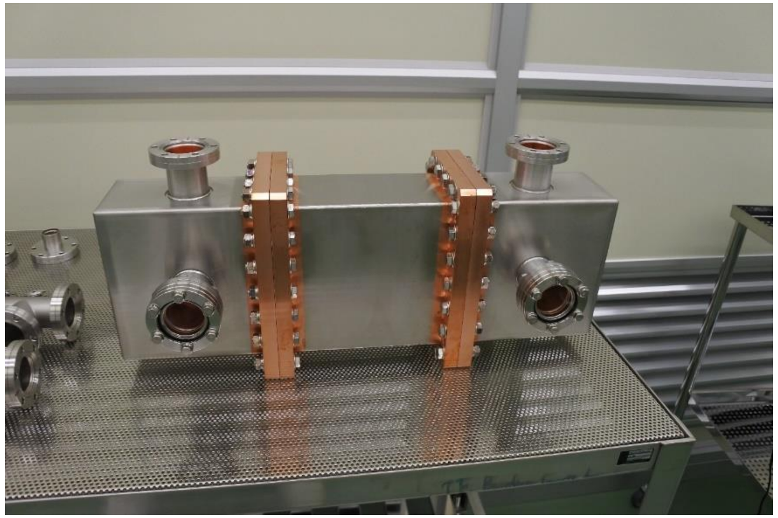
Connection to waveguide system
Pumping restarts
(coupler has been under vacuum
after assembly work in clean room)

Coupler Test Stand

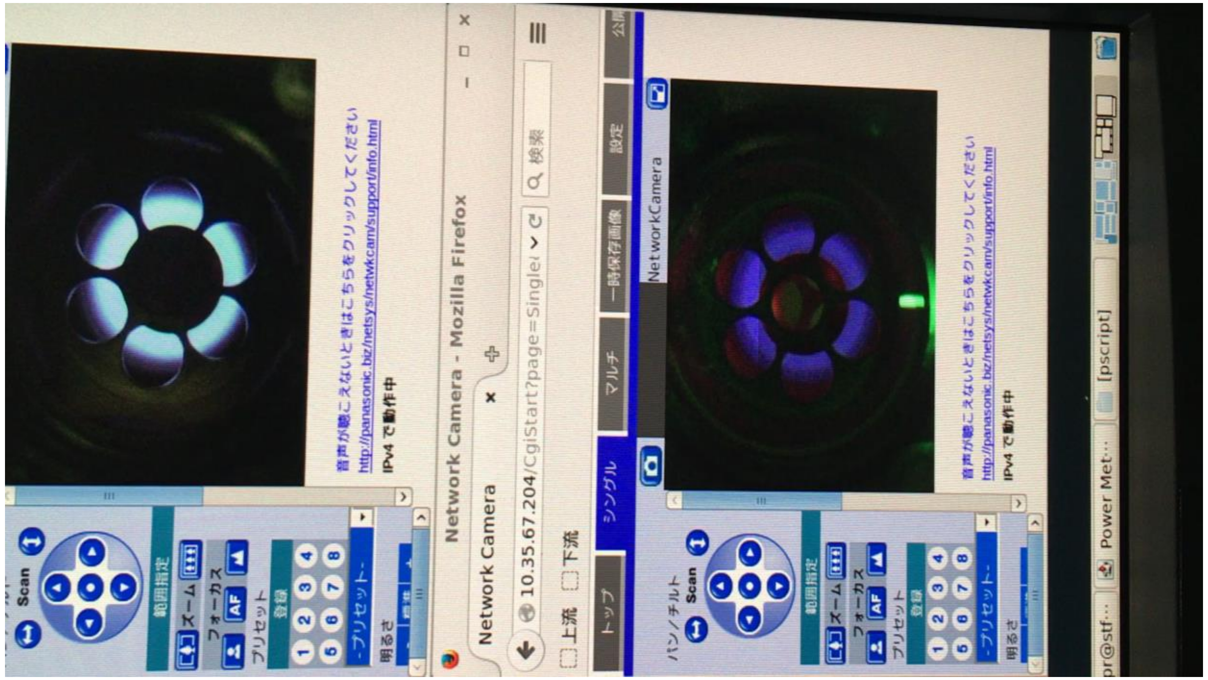


30 µsec / 5 Hz





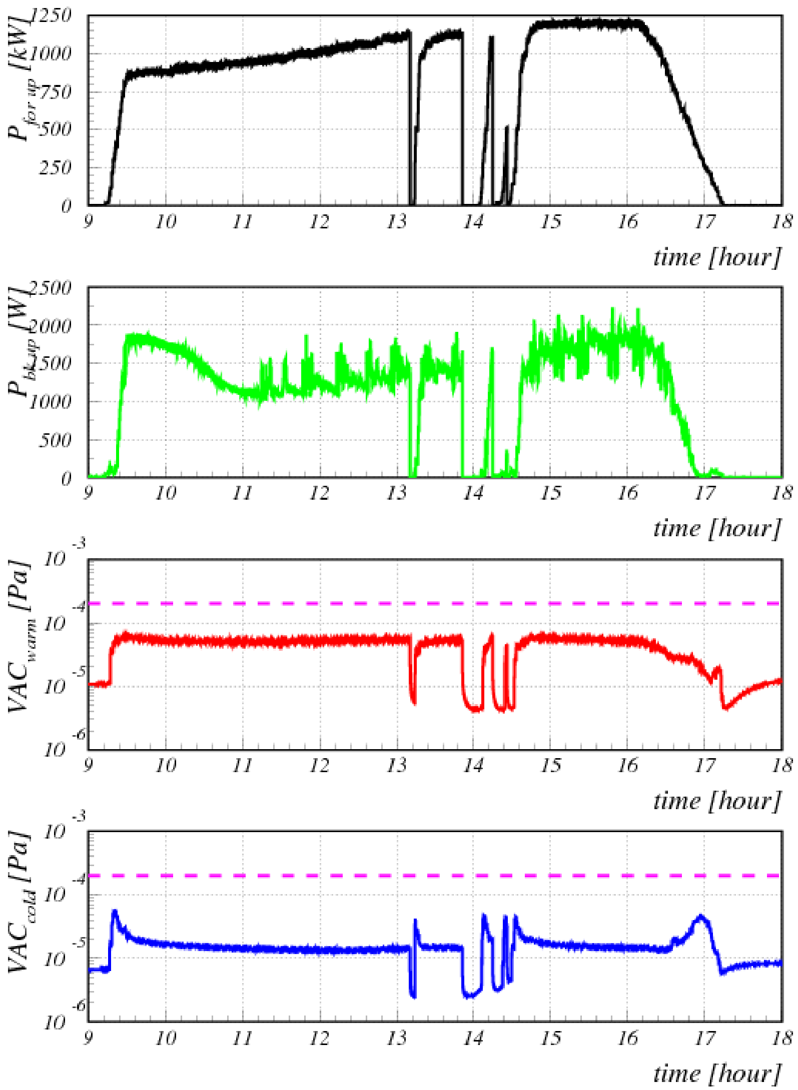
1650 µsec / 5 Hz



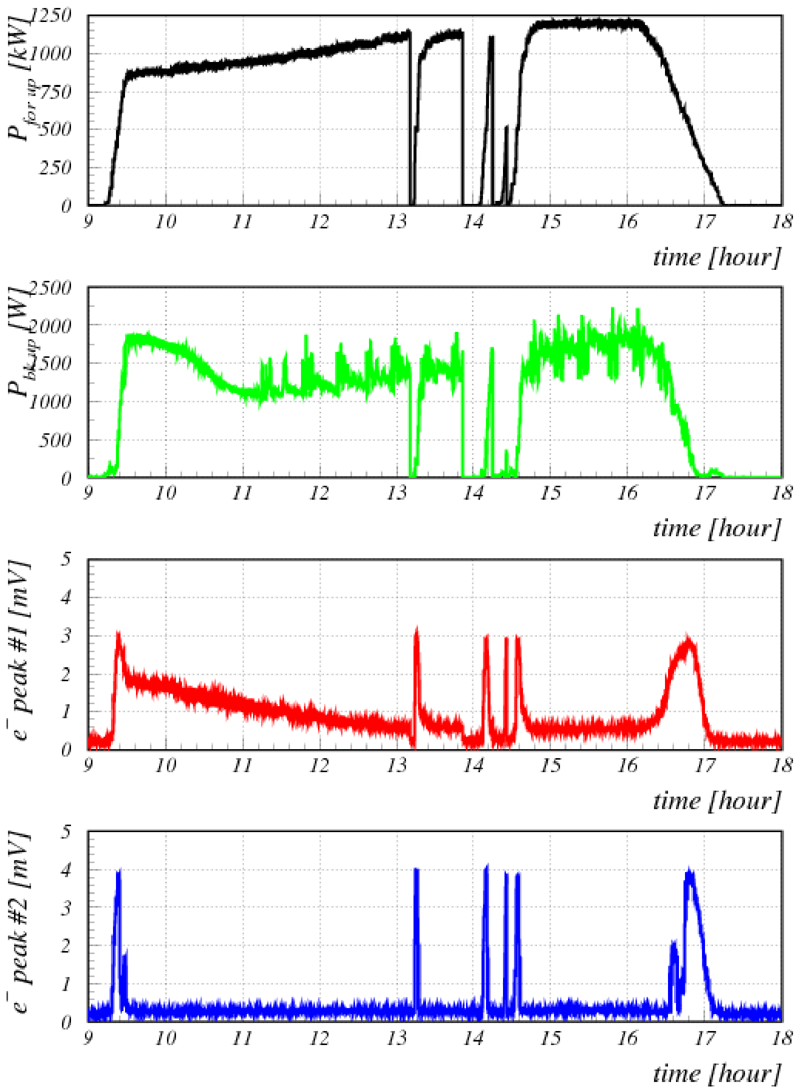
One-day trend graph for coupler conditioning (normal ceramic)

Pulse width : 10 [μsec]
Rep. frequency : 5 [Hz]

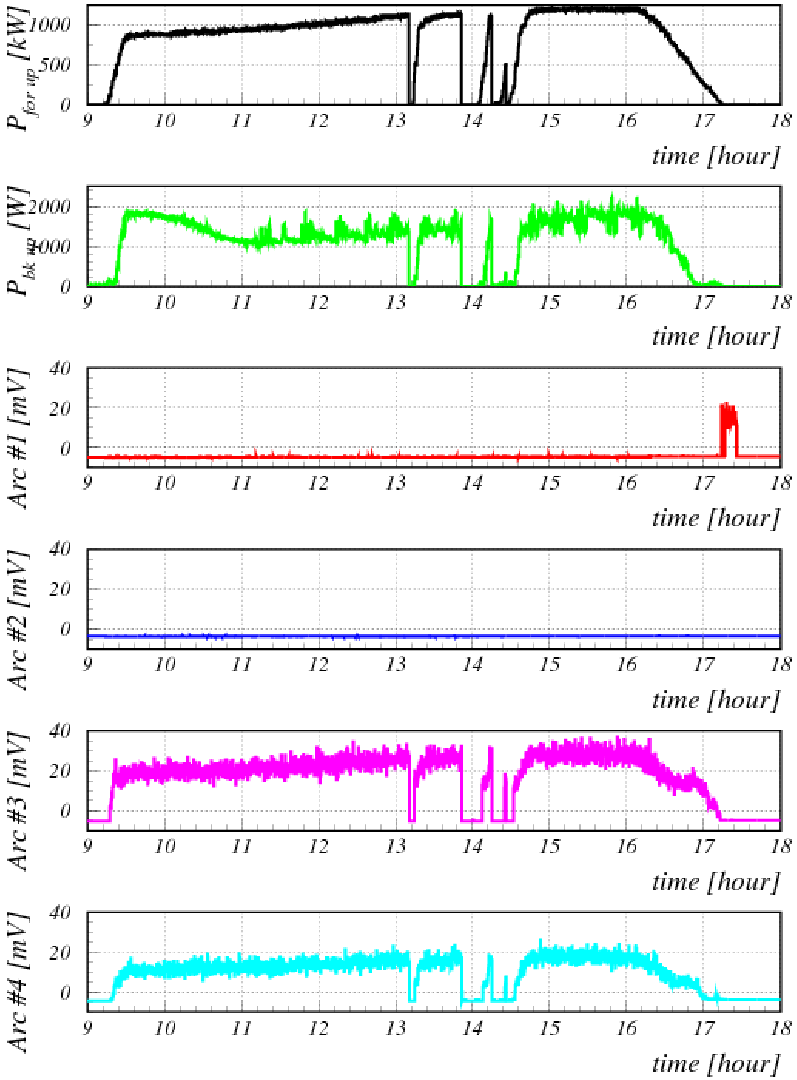
Log Trend of 40Φ Input Coupler Conditioning ('16/1/27)

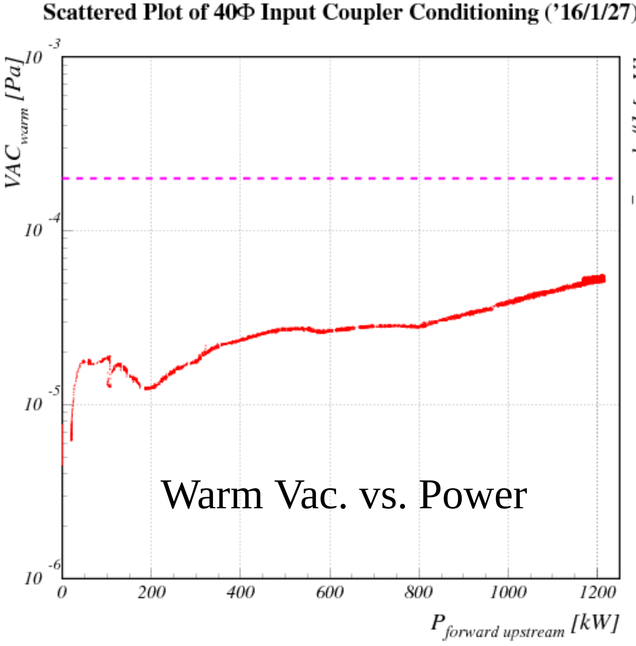


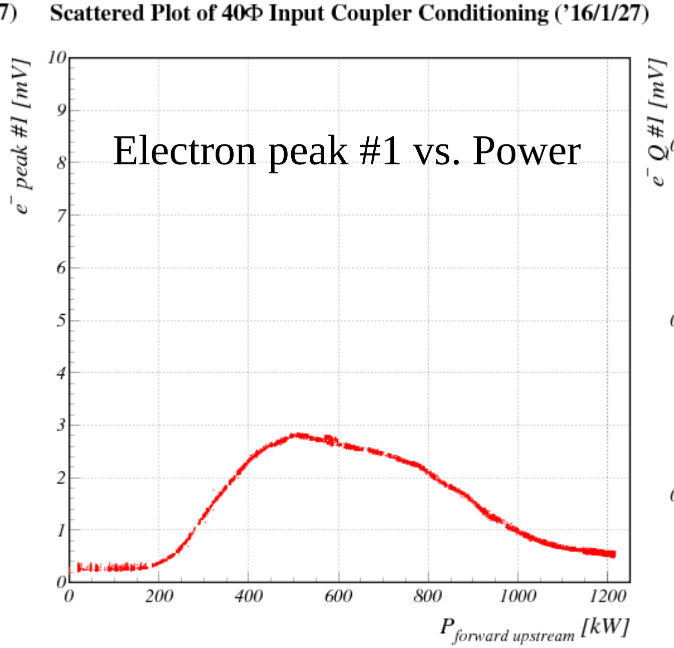
Log Trend of 40Φ Input Coupler Conditioning ('16/1/27)

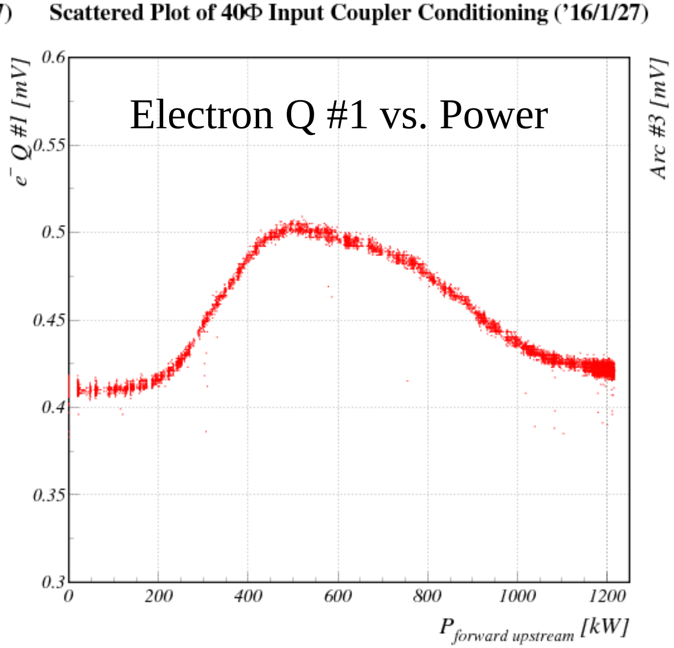


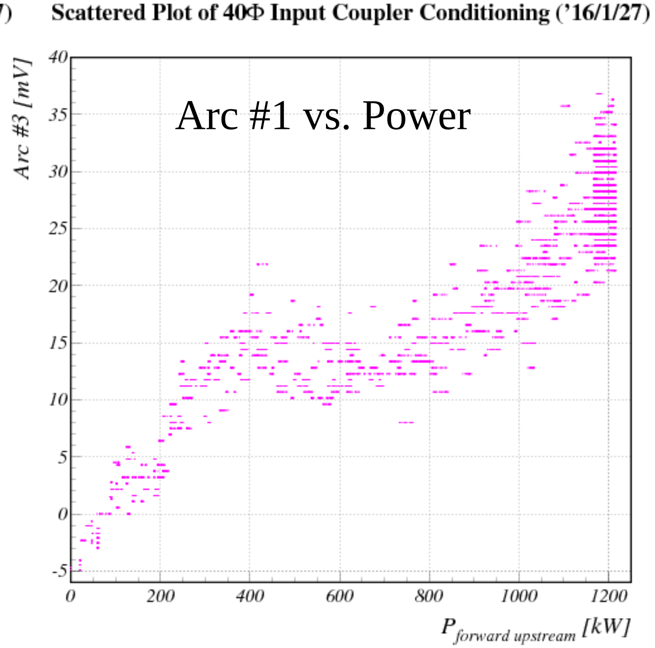
Log Trend of 40Φ Input Coupler Conditioning ('16/1/27)

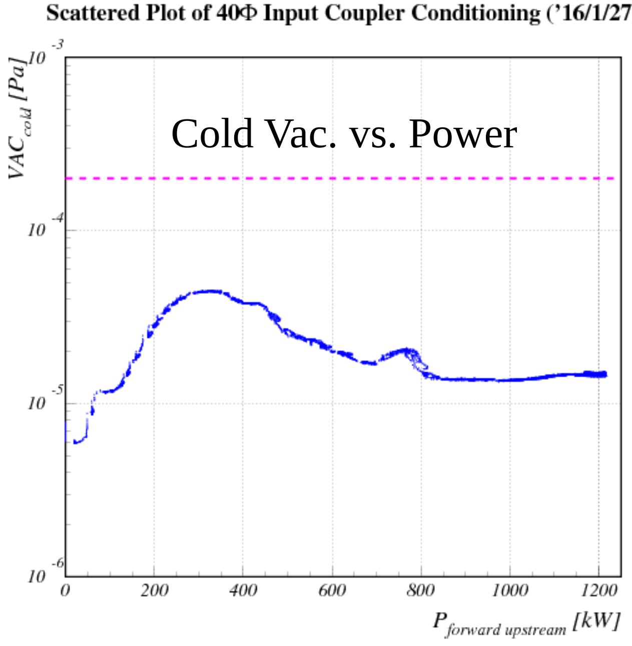


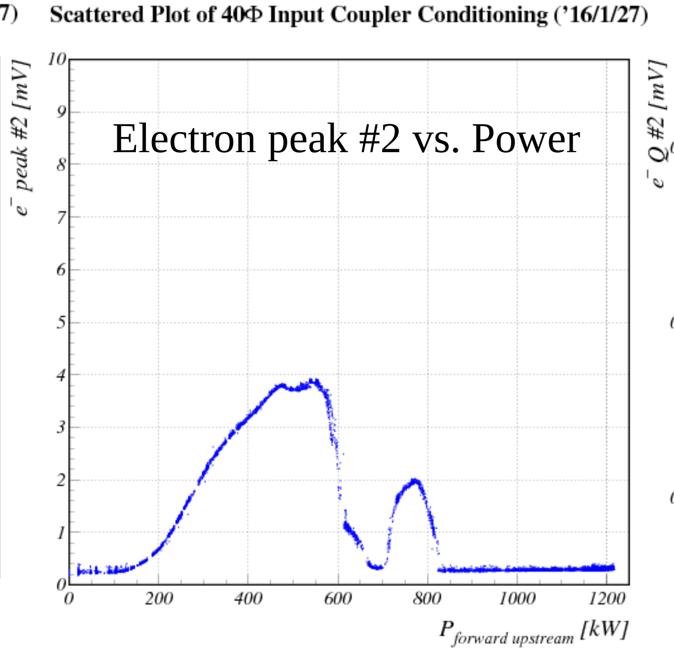

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Warm Vac. vs. Power
VAC_{warm} [Pa]
$P_{forward\ upstream}$ [kW]

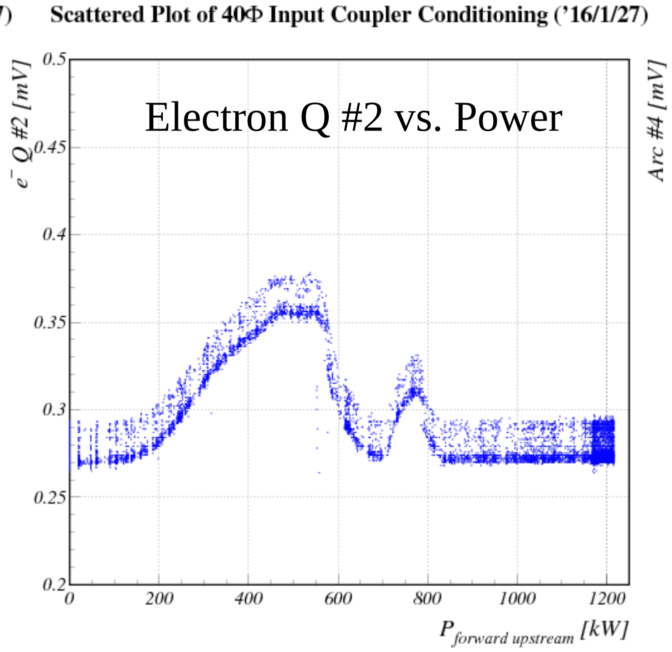

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Electron peak #1 vs. Power
e^- peak #1 [mV]
$P_{forward\ upstream}$ [kW]

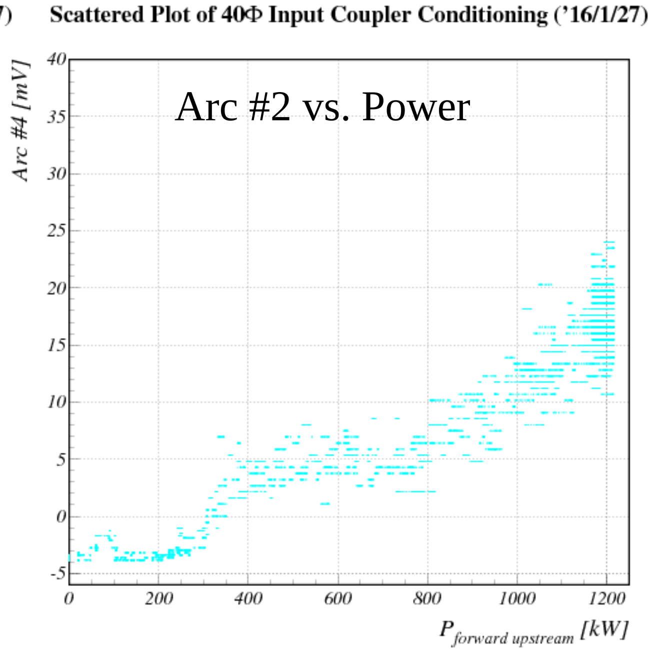

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Electron Q #1 vs. Power
e^- Q #1 [mV]
$P_{forward\ upstream}$ [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Arc #1 vs. Power
Arc #3 [mV]
$P_{forward\ upstream}$ [kW]

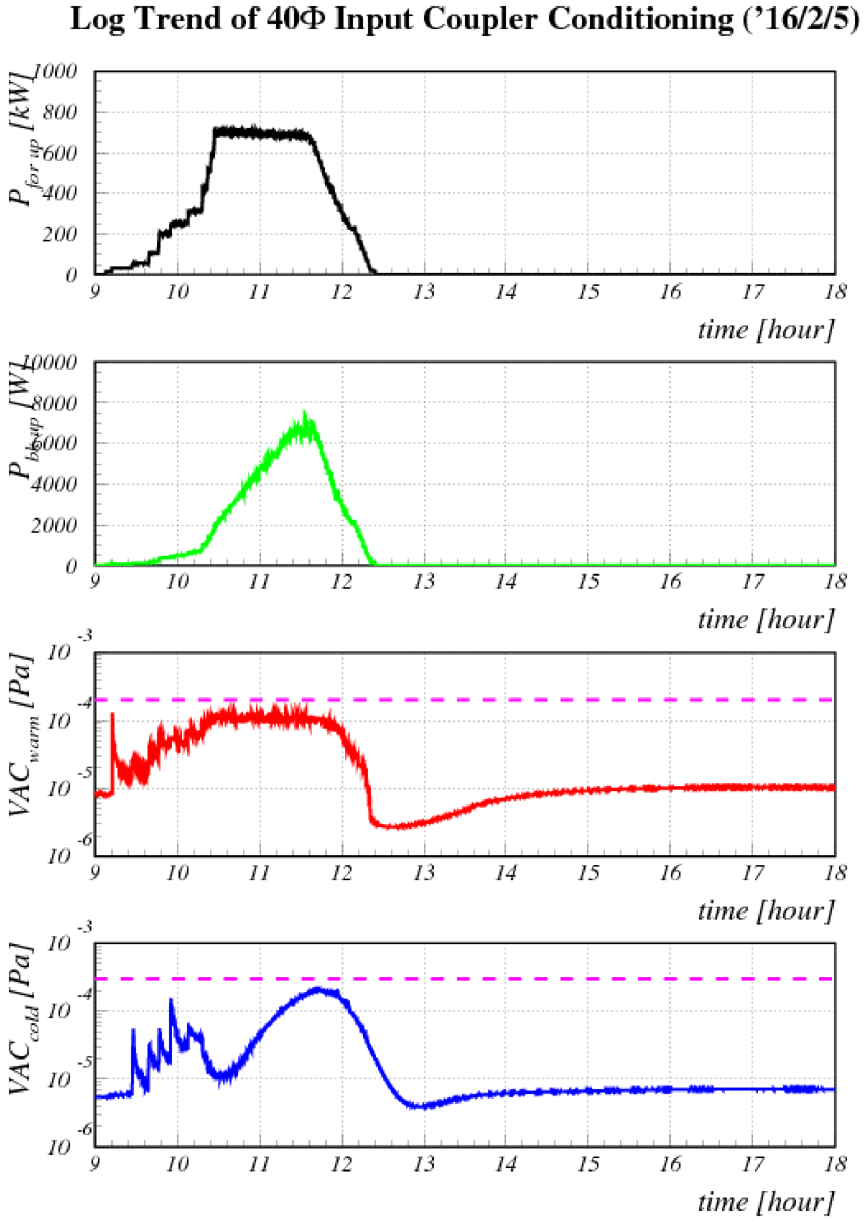

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Cold Vac. vs. Power
VAC_{cold} [Pa]
$P_{forward\ upstream}$ [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Electron peak #2 vs. Power
e^- peak #2 [mV]
$P_{forward\ upstream}$ [kW]

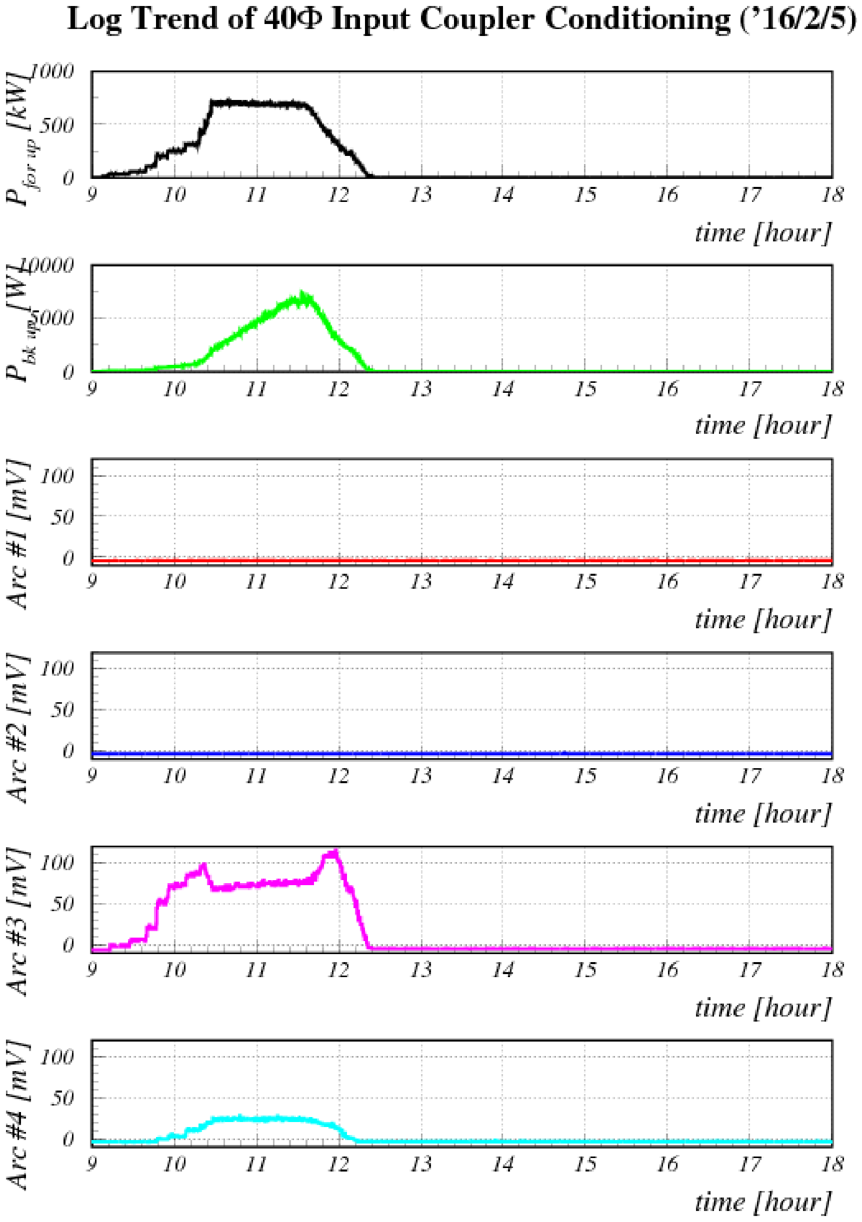

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Electron Q #2 vs. Power
e^- Q #2 [mV]
$P_{forward\ upstream}$ [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)
Arc #2 vs. Power
Arc #4 [mV]
$P_{forward\ upstream}$ [kW]

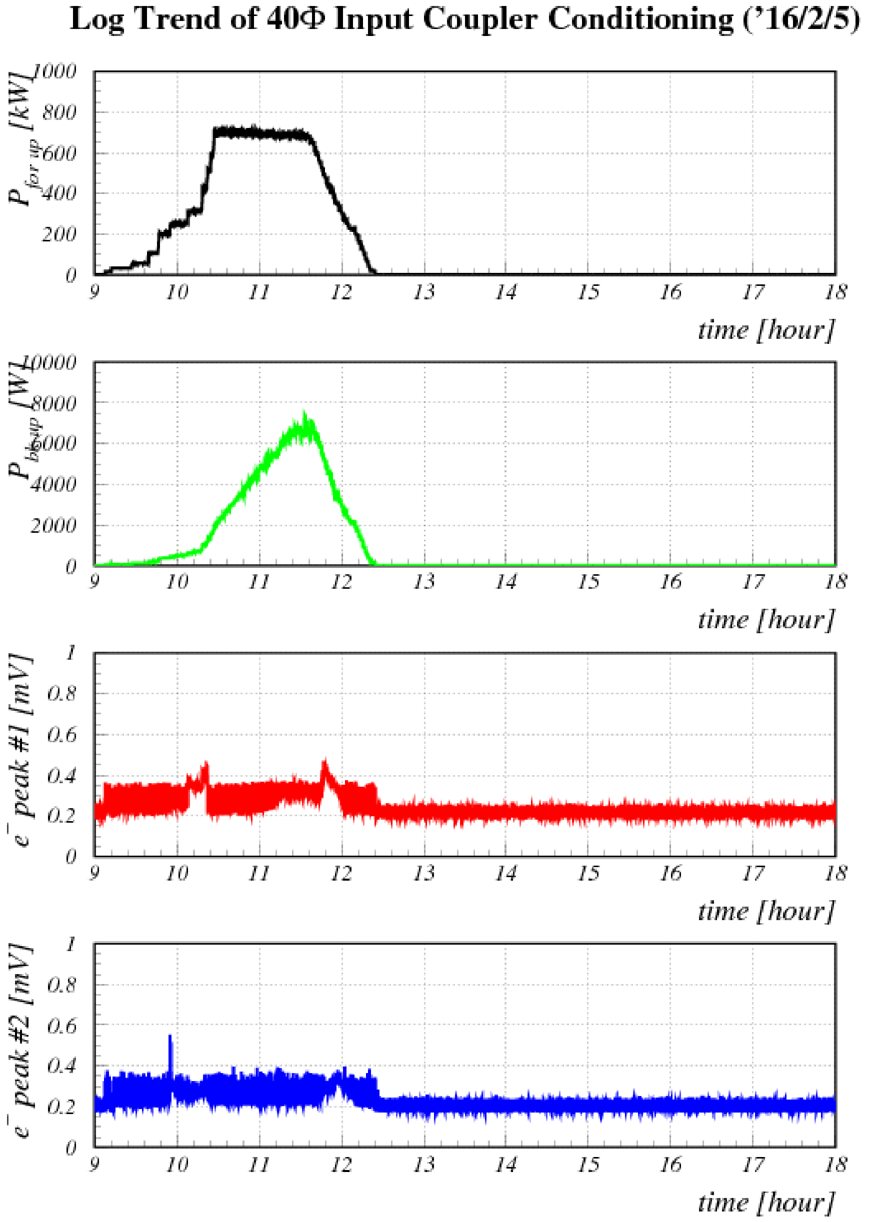
One-day trend graph for coupler conditioning (normal ceramic)



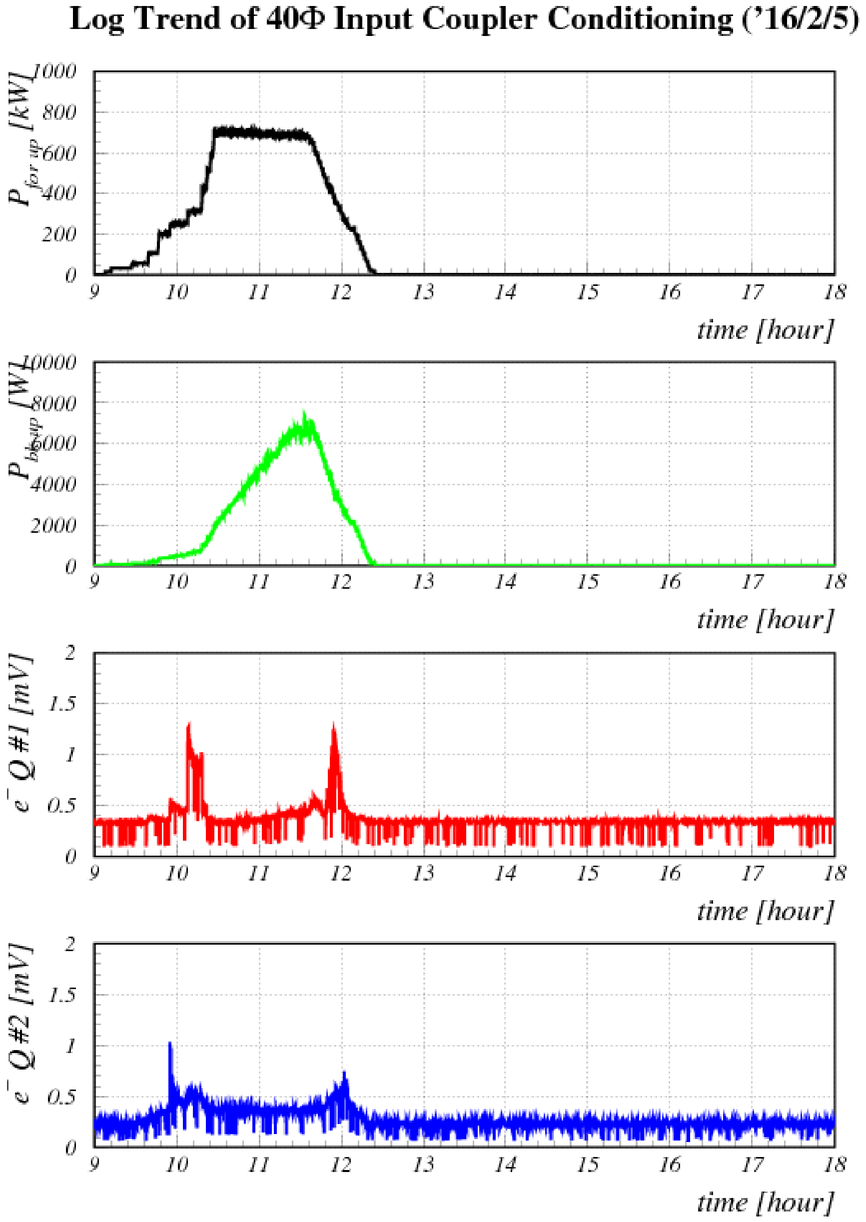
Pulse width : 1650 [μsec]
Rep. frequency : 5 [Hz]

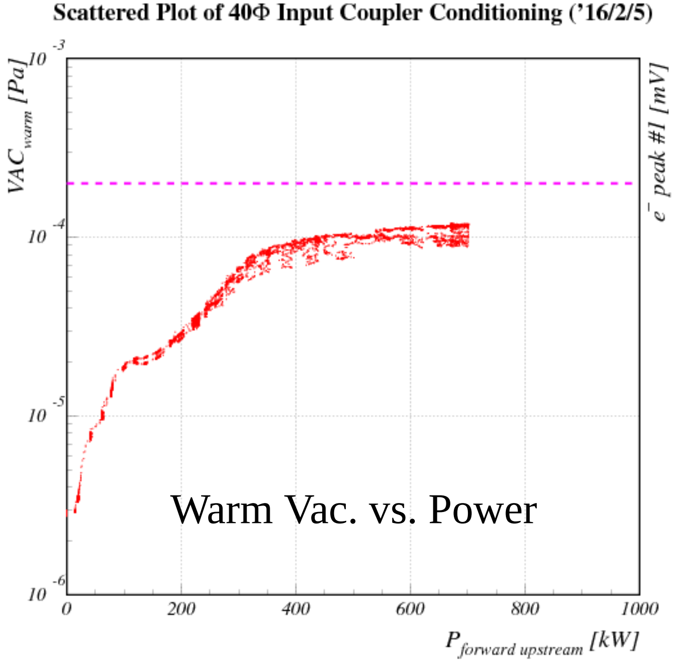


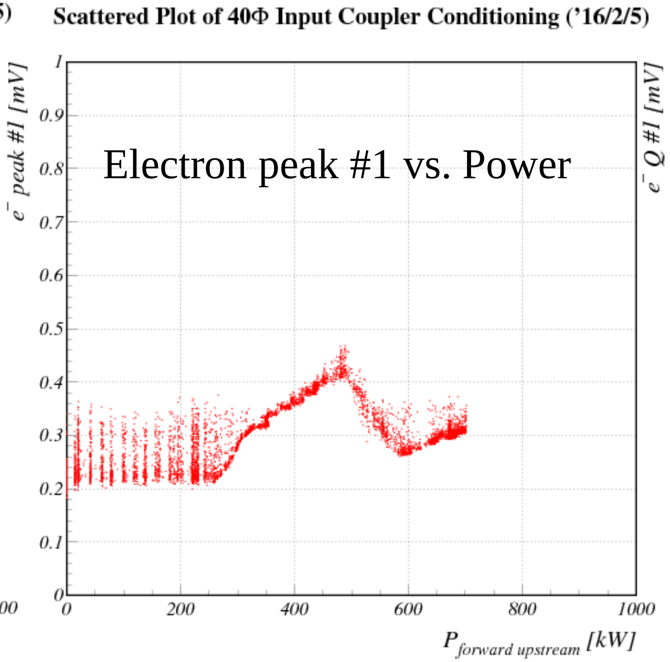
One-day trend graph for coupler conditioning (normal ceramic)

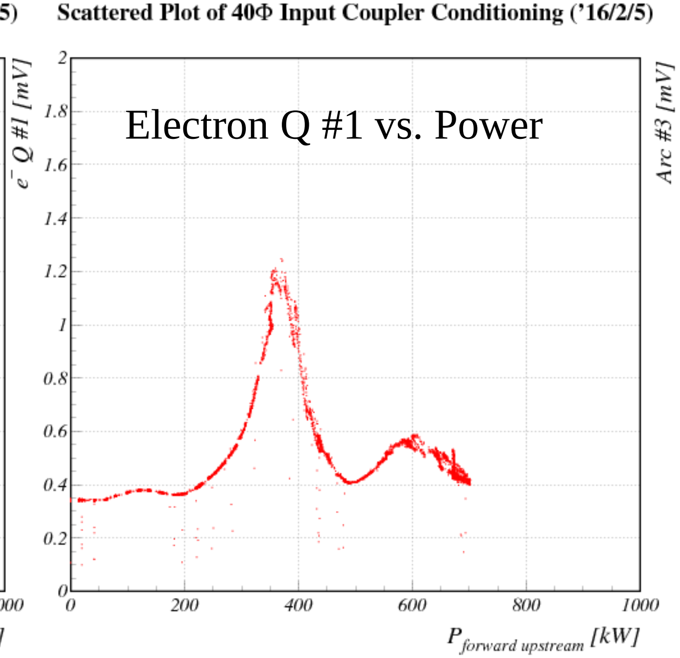


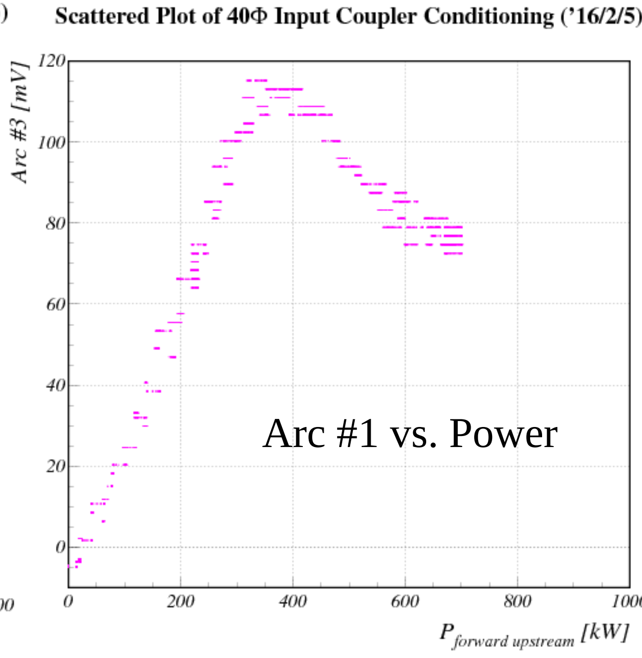
Pulse width : 1650 [μsec]
Rep. frequency : 5 [Hz]

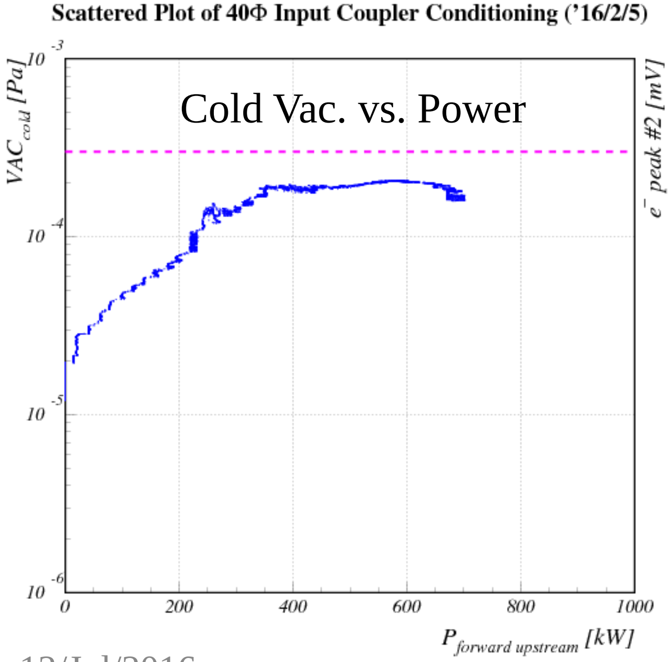


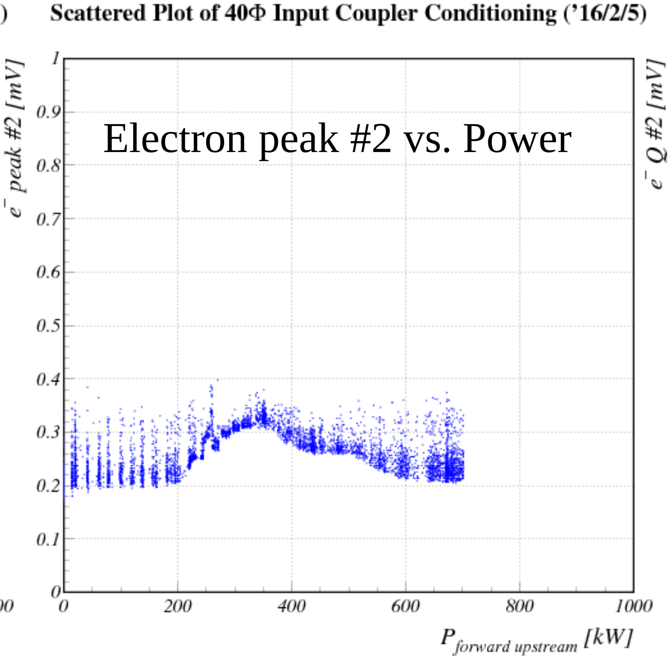

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Warm Vac. vs. Power
VAC_warm [Pa]
P_forward upstream [kW]

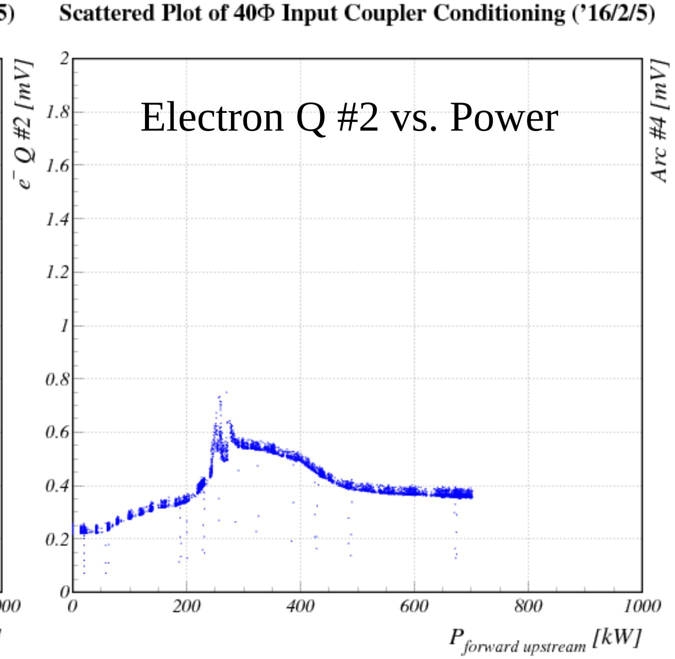

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Electron peak #1 vs. Power
e⁻ peak #1 [mV]
P_forward upstream [kW]

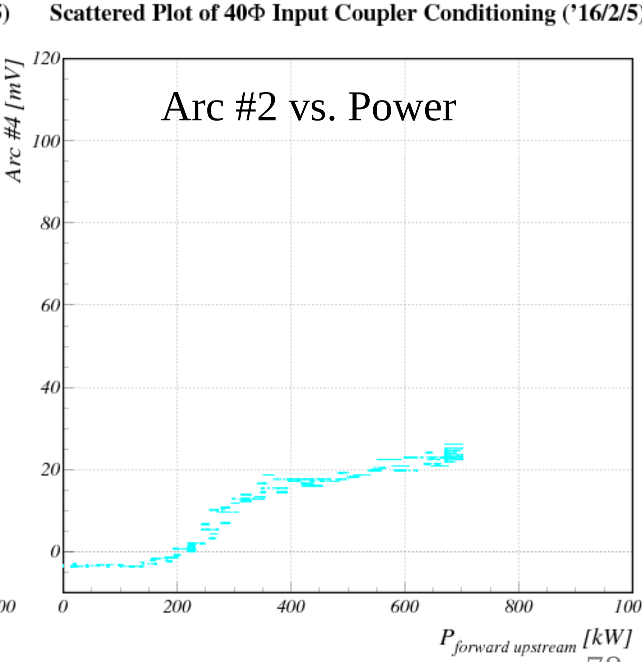

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Electron Q #1 vs. Power
e⁻ Q #1 [mV]
P_forward upstream [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Arc #1 vs. Power
Arc #3 [mV]
P_forward upstream [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Cold Vac. vs. Power
VAC_cold [Pa]
P_forward upstream [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Electron peak #2 vs. Power
e⁻ peak #2 [mV]
P_forward upstream [kW]


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Electron Q #2 vs. Power
e⁻ Q #2 [mV]
P_forward upstream [kW]

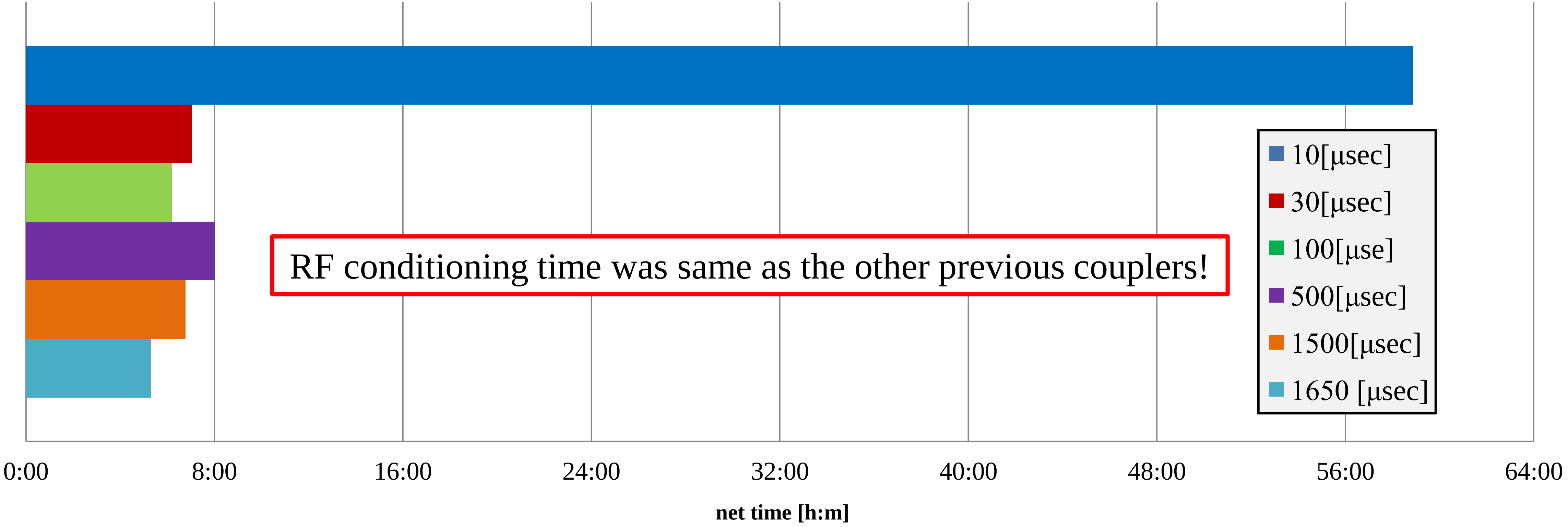

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/5)
Arc #2 vs. Power
Arc #4 [mV]
P_forward upstream [kW]

History of RF Conditioning for Normal ceramic coupler

Date	Content	Result
12/Jan	Preparation work	
15/Jan	Klystron #2 ON, RF ON, Power meter setting	27.9 kW @10μsec/5Hz
18/Jan		43.0 kW @10μsec/5Hz
19/Jan		61.0 kW @10μsec/5Hz
20/Jan		149 kW @10μsec/5Hz
21/Jan	Arc I/L ON	207 kW @10μsec/5Hz
22/Jan		312 kW @10μsec/5Hz
25/Jan		500 kW @10μsec/5Hz
26/Jan		861 kW @10μsec/5Hz
27/Jan	10μsec/5Hz finished	1200 kW (1hour keep) @10μsec/5Hz
28/Jan		1211 kW (1hour keep) @30μsec/5Hz
29/Jan	30μsec/5Hz finished	1215 kW @100μsec/5Hz
1/Feb	100μsec/5Hz finished	1216 kW (1hour keep) @100μsec/5Hz, 604 kW @500μsec/5Hz
2/Feb	500μsec/5Hz finished	1200 kW (1hour keep) @500μsec/5Hz
3/Feb	Fan x 2 ON	818 kW (1hour keep) @1500μsec/5Hz
4/Feb	Fan x 4 ON, 1500μsec/5Hz finished	607 kW @1650μsec/5Hz
5/Feb		708 kW (1hour keep) @1650μsec/5Hz

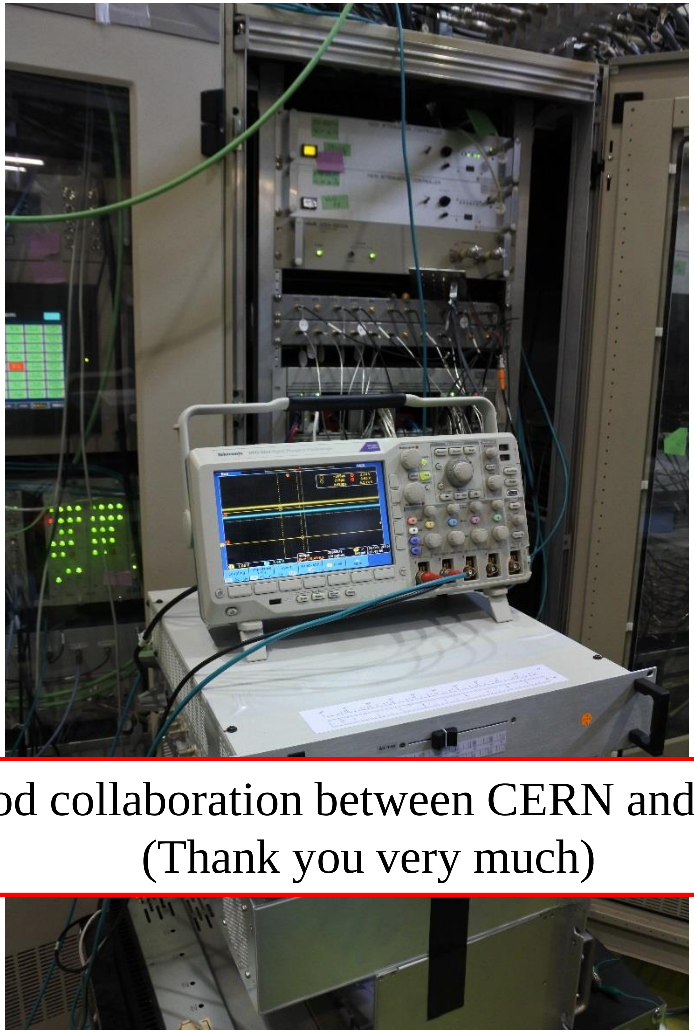
Summary of Conditioning time for each parameter (Φ40mm No, 1 & 2)

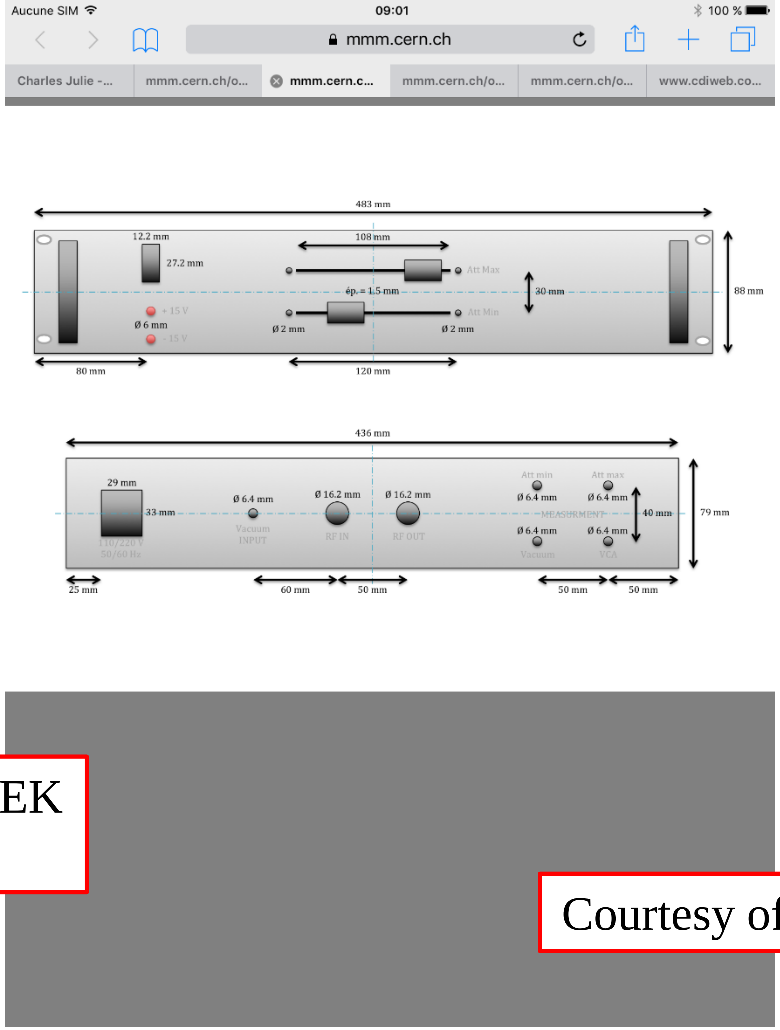
Δt [μsec]([Hz])	Pf1 MAX [kW]	net time [h:m]	keep Pf1 Max[kW]	Keep time @Pf max [h:m]	Elapsed time [h:m]
10 (5)	1200	58:52	1200	1:00	61:12
30 (5)	1200	7:03	1200	1:00	8:03
100 (5)	1200	6:11	1200	1:00	6:11
500 (5)	1200	8:01	1200	1:00	11:23
1500 (5)	800	6:46	800	1:00	7:32
total	-	86:53	-	-	94:21
1650 (5)	700	5:18	700	1:00	7:14
total	-	92:11	-	-	101:35

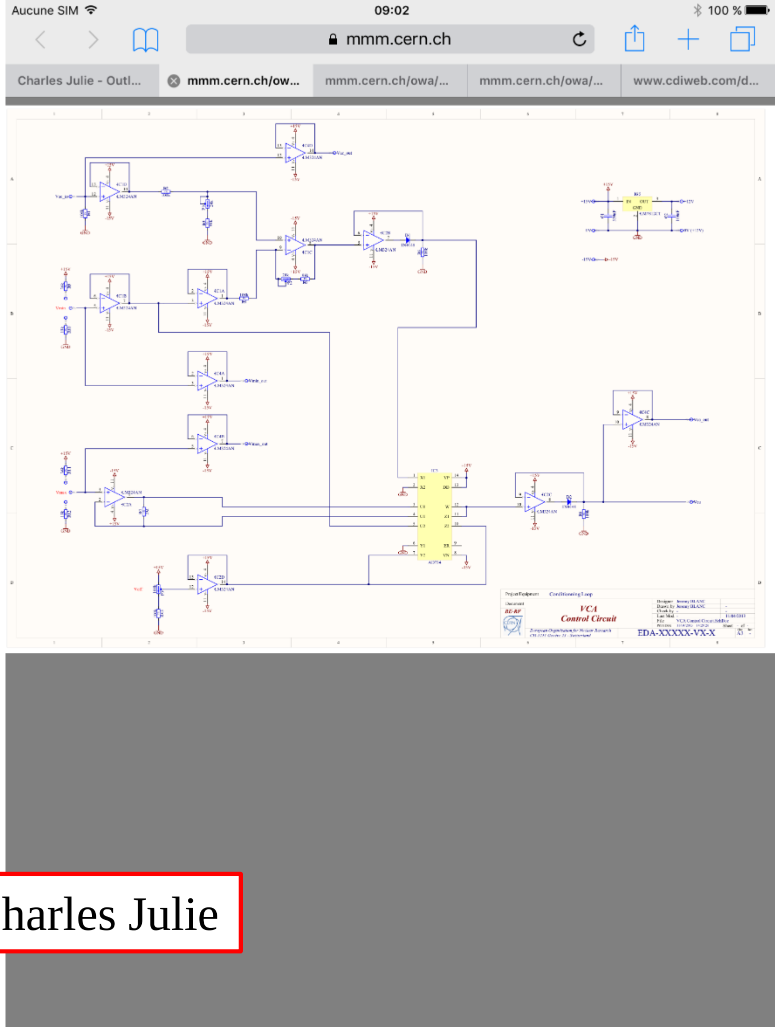


We moved to RF conditioning for new ceramic couplers,
but, before that,
we introduced two useful devices from CERN

Auto-conditioning Module by CERN





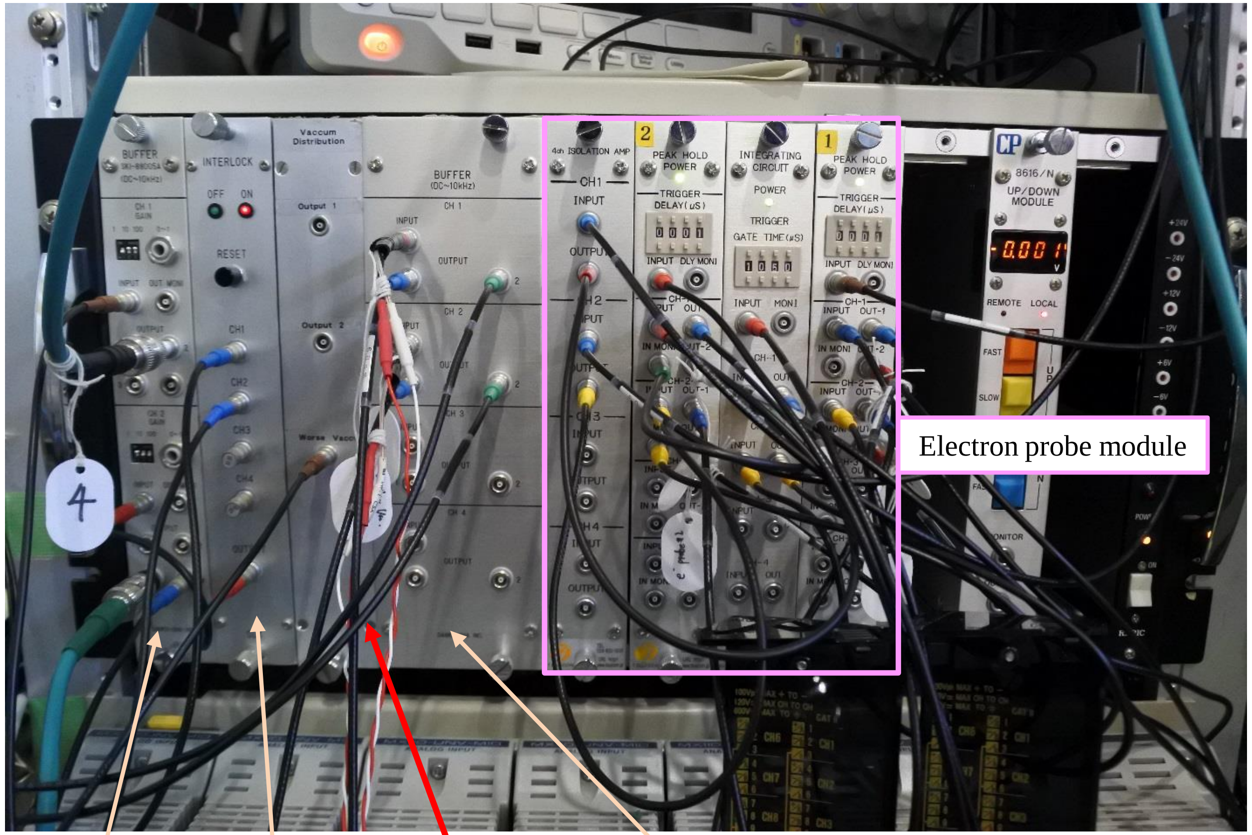


Good collaboration between CERN and KEK
(Thank you very much)

Courtesy of Charles Julie

We connected RF_{in}, RF_{out} and Vacuum output (only one ch.) to this module.
Mr. Charles Julie came to KEK, and helped us very well!

Vacuum Distributor by CERN



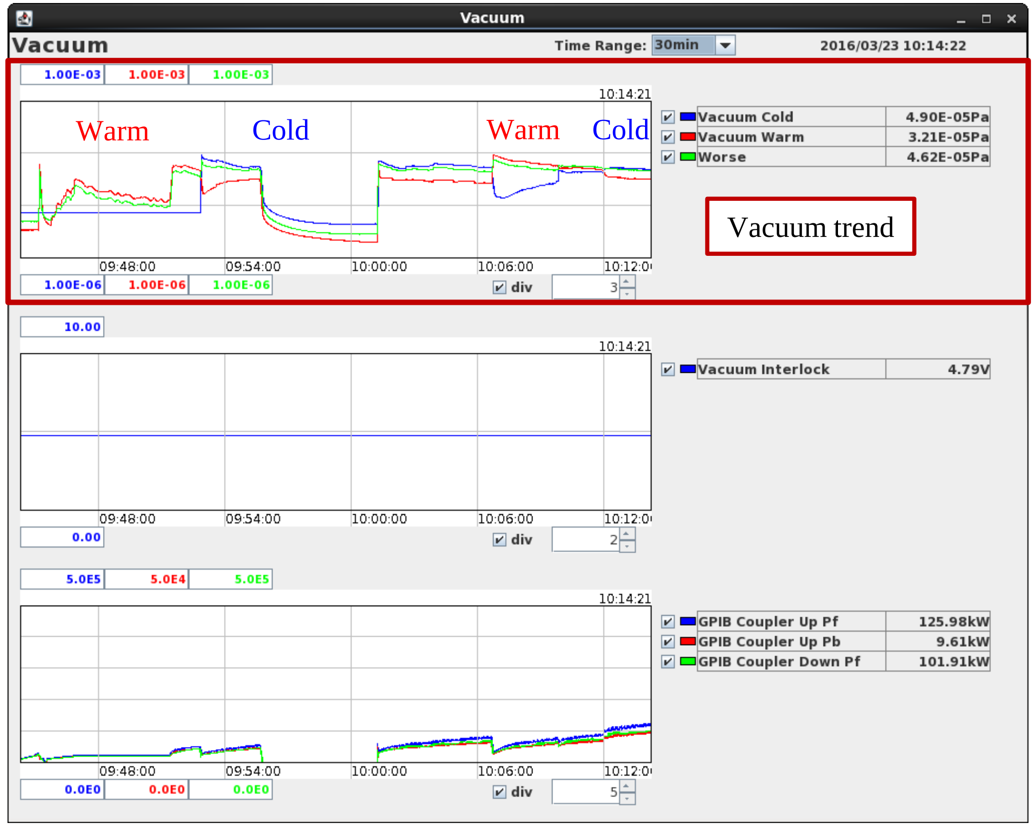
Vac. I/L module

Buffer Amp.

Variable Buffer Amp.

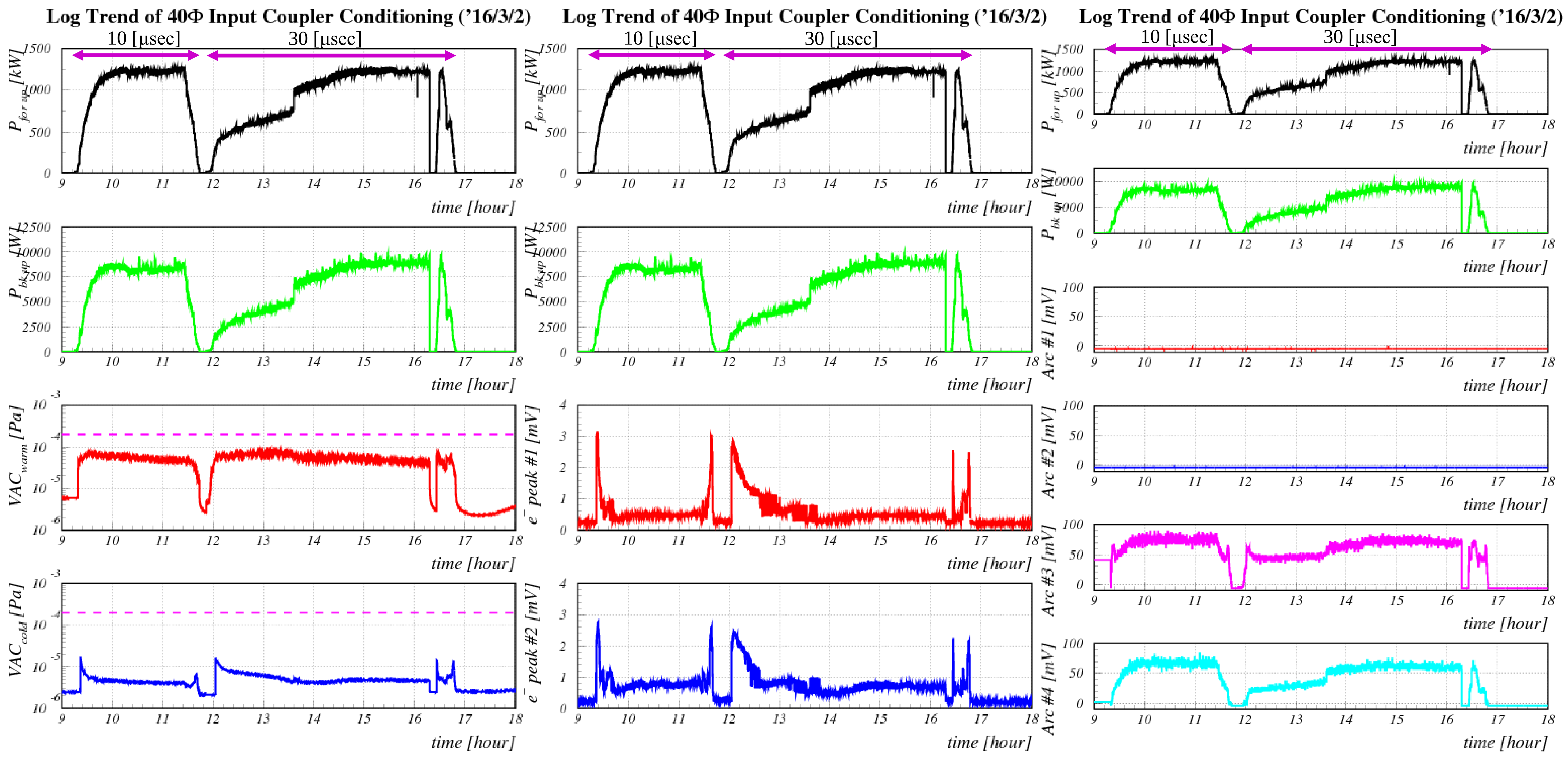
Vacuum Distributor

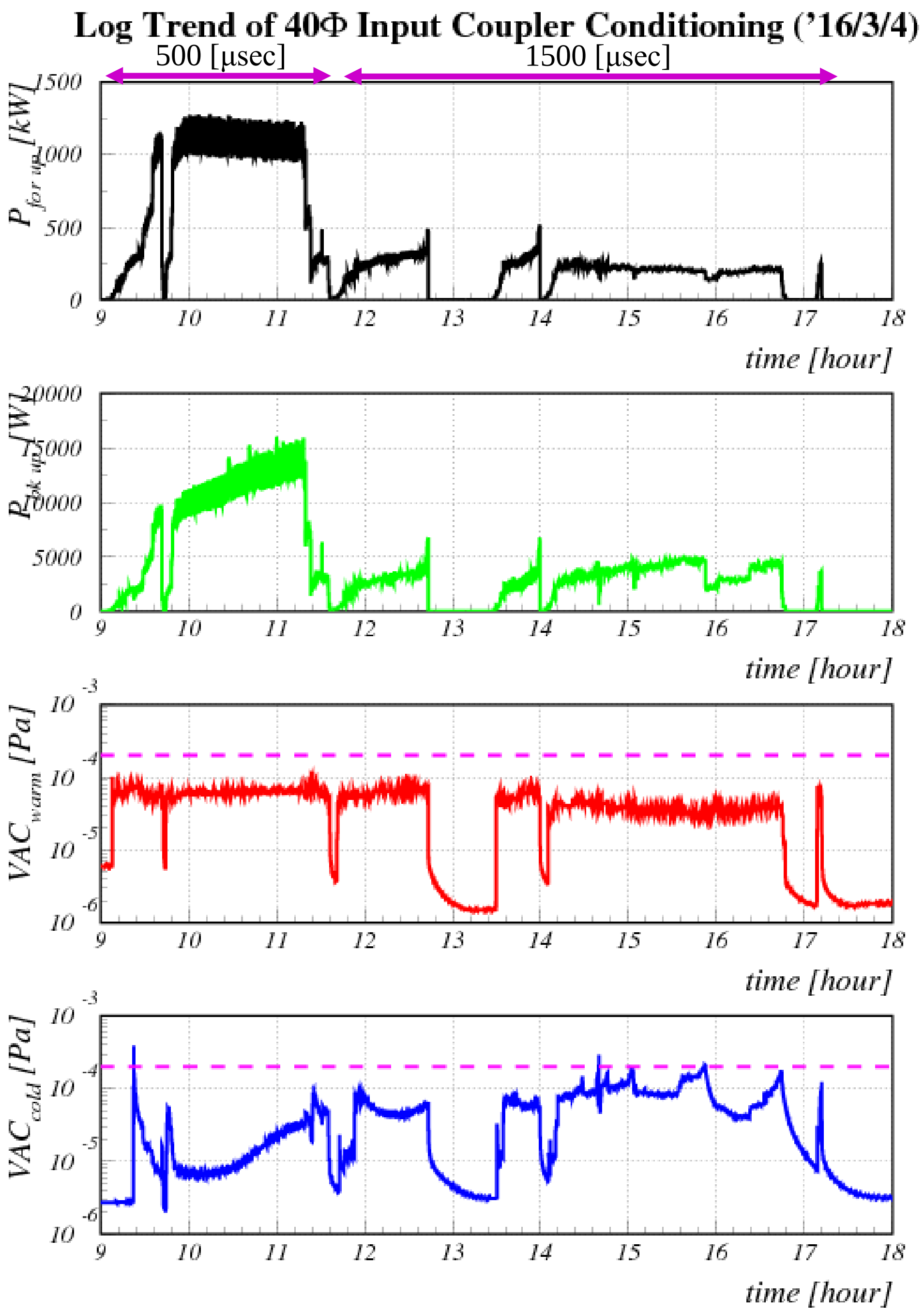
Good collaboration between CERN and KEK
(Thank you very much again)

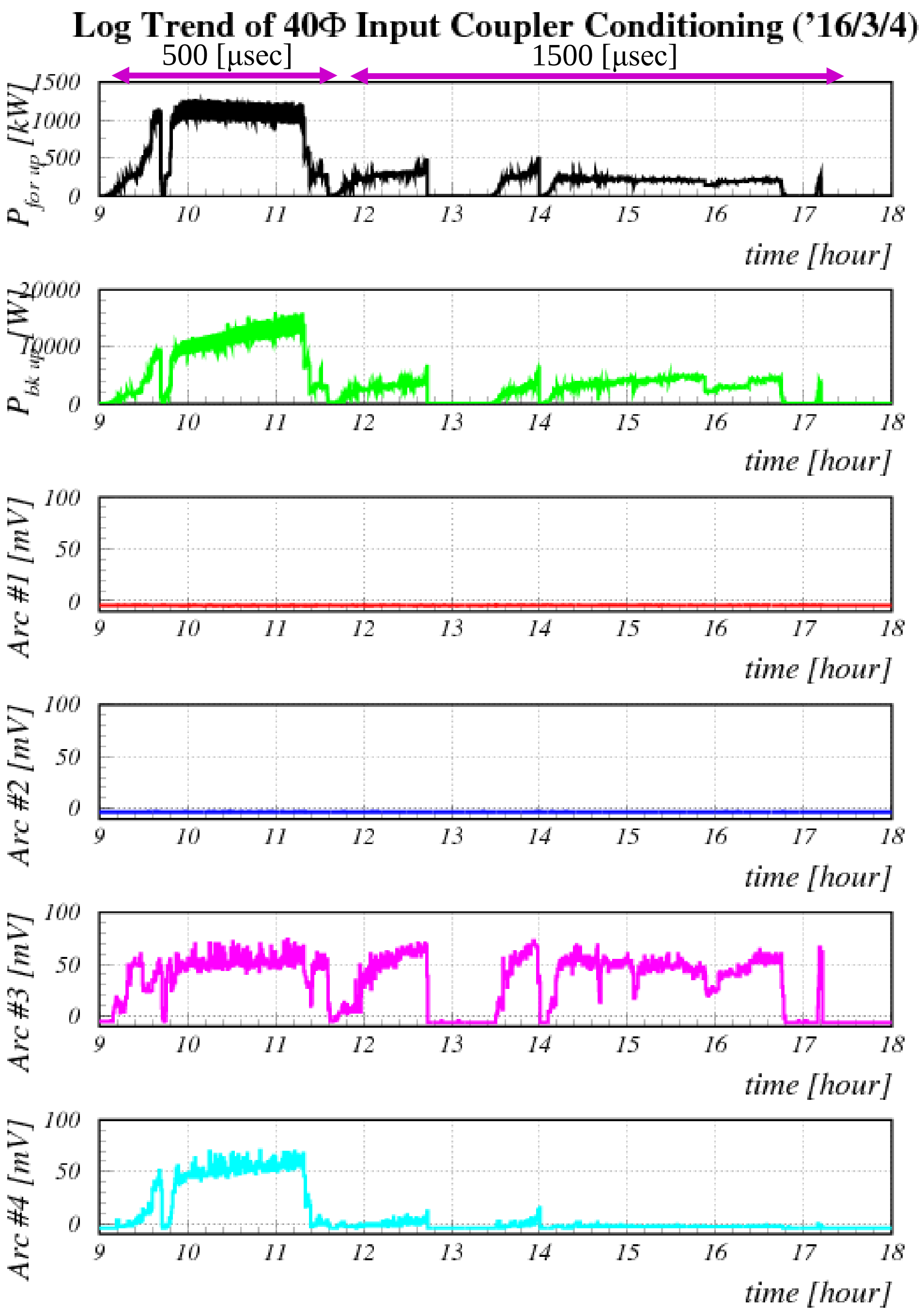


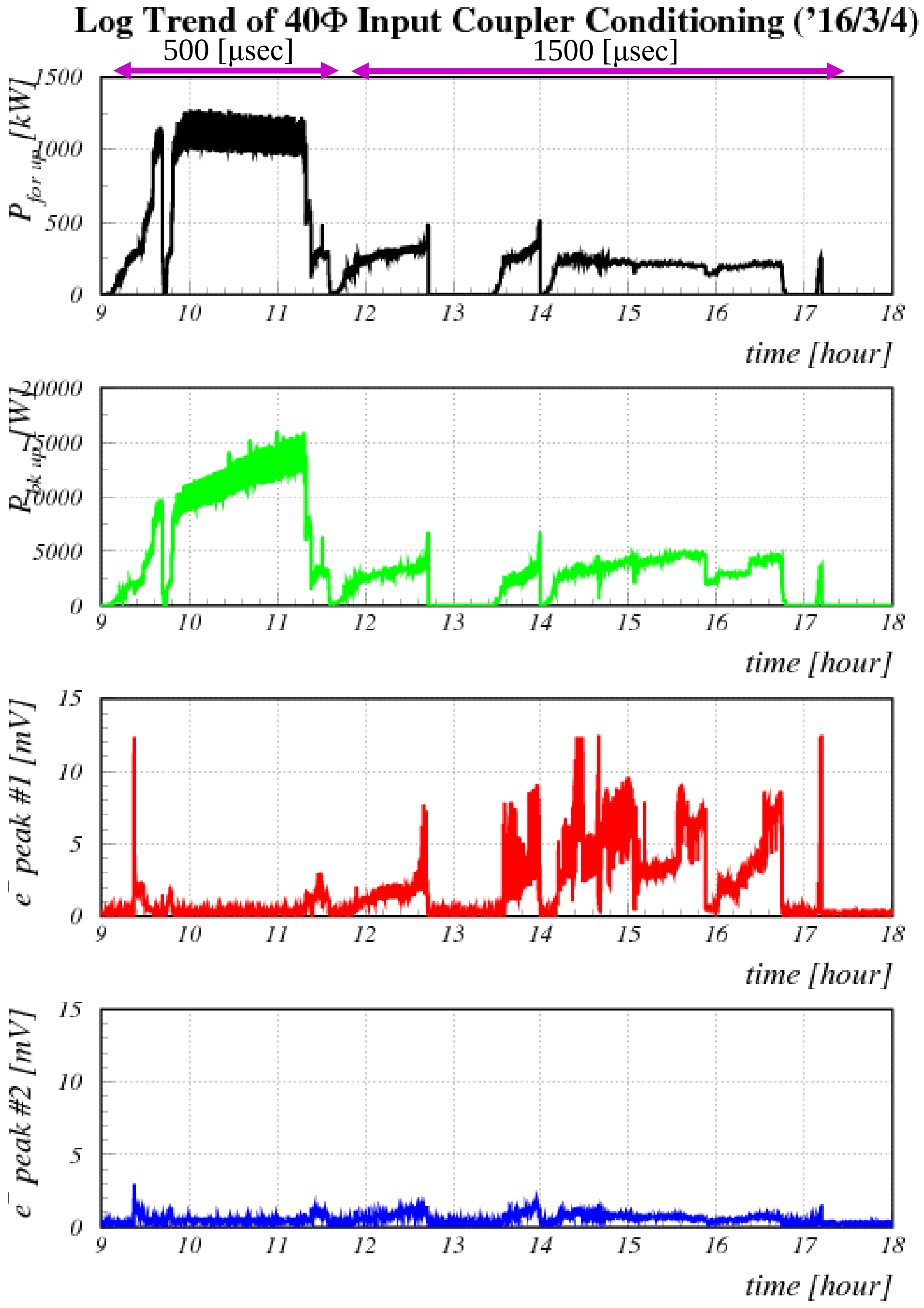
Vacuum distributor follows up the worse vacuum well!
But, there is a little bit difference between actual and worse vacuum.

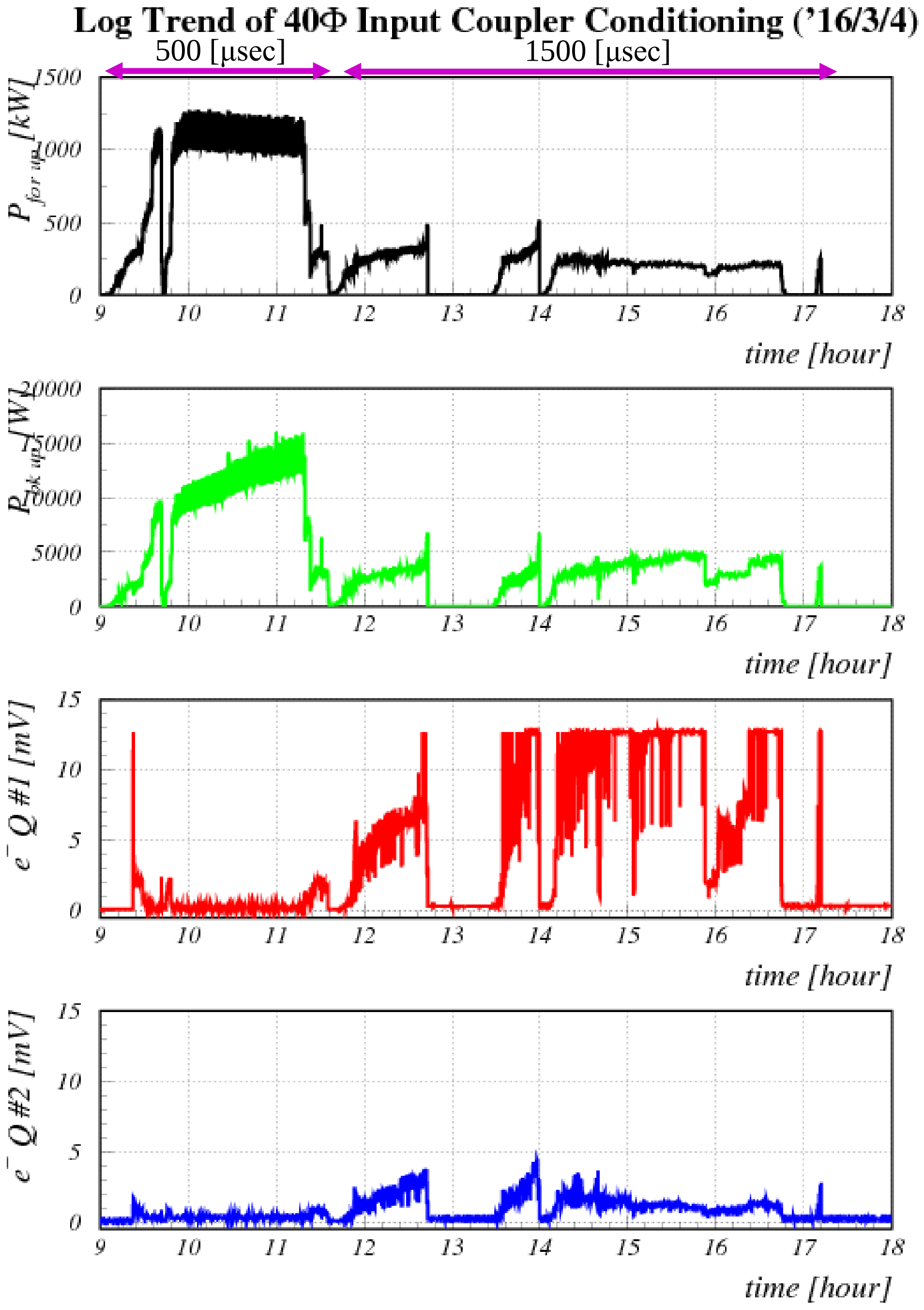
One-day trend graph for coupler conditioning (new ceramic)




Log Trend of 40Φ Input Coupler Conditioning ('16/3/4)
500 [μsec]
1500 [μsec]
P for up [kW]
P bk up [W]
VAC warm [Pa]
VAC cold [Pa]
time [hour]


Log Trend of 40Φ Input Coupler Conditioning ('16/3/4)
500 [μsec]
1500 [μsec]
P for up [kW]
P bk up [W]
Arc #1 [mV]
Arc #2 [mV]
Arc #3 [mV]
Arc #4 [mV]
time [hour]

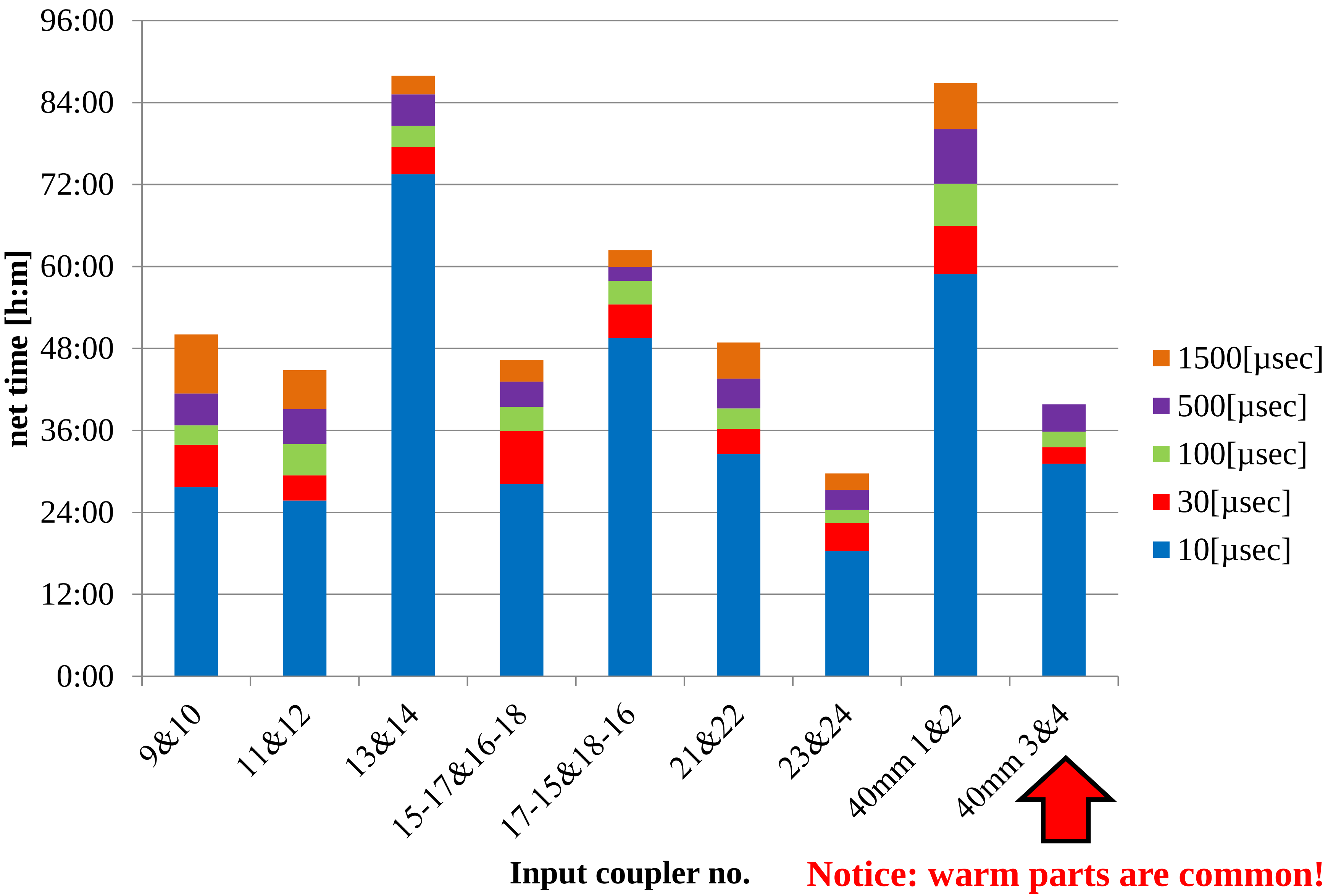

Log Trend of 40Φ Input Coupler Conditioning ('16/3/4)
500 [μsec]
1500 [μsec]
[kW]
time [hour]
[W]
time [hour]
e⁻ peak #1 [mV]
time [hour]
e⁻ peak #2 [mV]
time [hour]


Log Trend of 40Φ Input Coupler Conditioning ('16/3/4)
500 [μsec]
1500 [μsec]
[kW]
time [hour]
[W]
time [hour]
e⁻ Q #1 [mV]
time [hour]
e⁻ Q #2 [mV]
time [hour]

Comparison of RF Conditioning History for Both Couplers

Date	Result for Normal Ceramic	Date	Result for New Ceramic
18/Jan	43.0 kW @10μsec/5Hz	24/Feb	56.0 kW @10μsec/5Hz
19/Jan	61.0 kW @10μsec/5Hz	25/Feb	66.0 kW @10μsec/5Hz
20/Jan	149 kW @10μsec/5Hz	26/Feb	156.0 kW @10μsec/5Hz
21/Jan	207 kW @10μsec/5Hz	29/Feb	342.0 kW @10μsec/5Hz
22/Jan	312 kW @10μsec/5Hz	1/Mar	930.0 kW @10μsec/5Hz
25/Jan	500 kW @10μsec/5Hz	2/Mar	1200.0 kW @10μsec/5Hz 1200.0 kW @30μsec/5Hz
26/Jan	861 kW @10μsec/5Hz	3/Mar	1200.0 kW @100μsec/5Hz 1100.0 kW @500μsec/5Hz
27/Jan	1200 kW (1hour keep) @10μsec/5Hz	4/Mar	1200.0 kW @500μsec/5Hz 483 kW @1500μsec/5Hz
28/Jan	1211 kW (1hour keep) @30μsec/5Hz	7/Mar	
29/Jan	1215 kW @100μsec/5Hz	8/Mar	
1/Feb	1216 kW (1hour keep) @100μsec/5Hz, 604 kW @500μsec/5Hz	9/Mar	
2/Feb	1200 kW (1hour keep) @500μsec/5Hz	10/Mar	
3/Feb	818 kW (1hour keep) @1500μsec/5Hz	11/Mar	
4/Feb	607 kW @1650μsec/5Hz	14/Mar	
5/Feb	708 kW (1hour keep) @1650μsec/5Hz	15/Mar	

No Update!



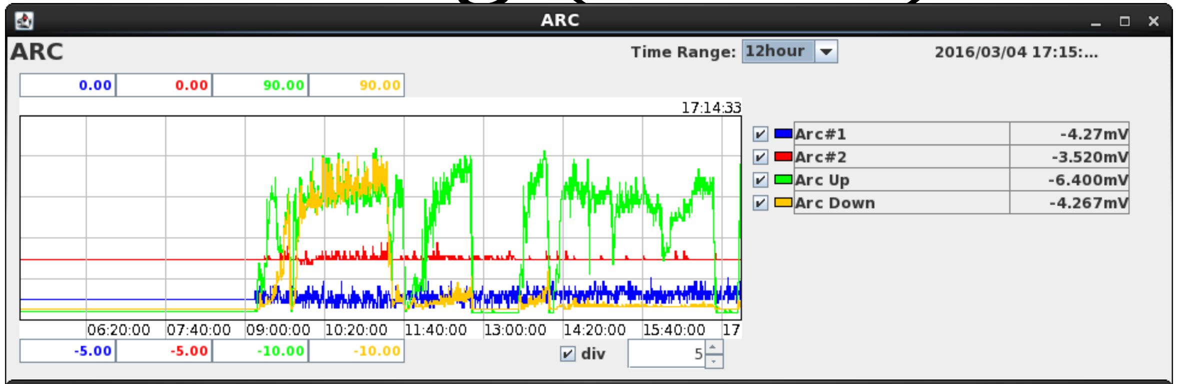
Notice: warm parts are common!
Conditioning time is possibly shorter

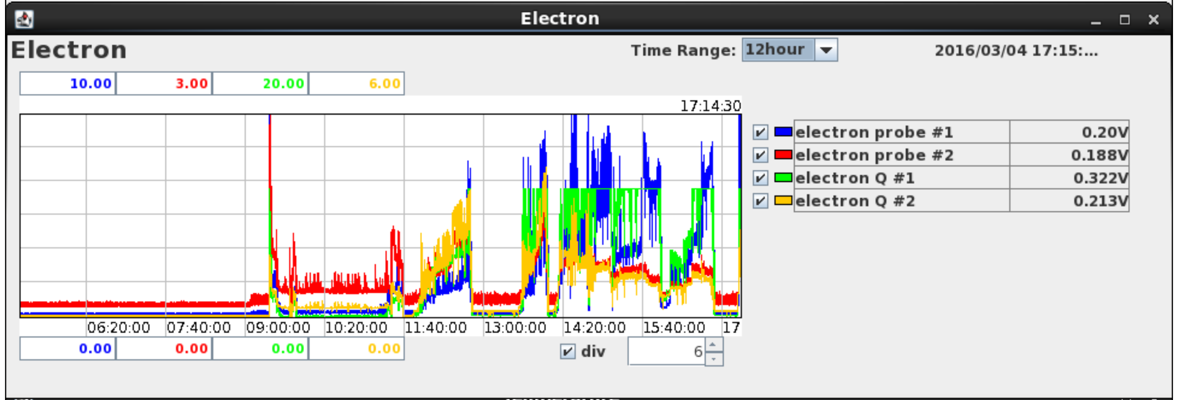
Outline

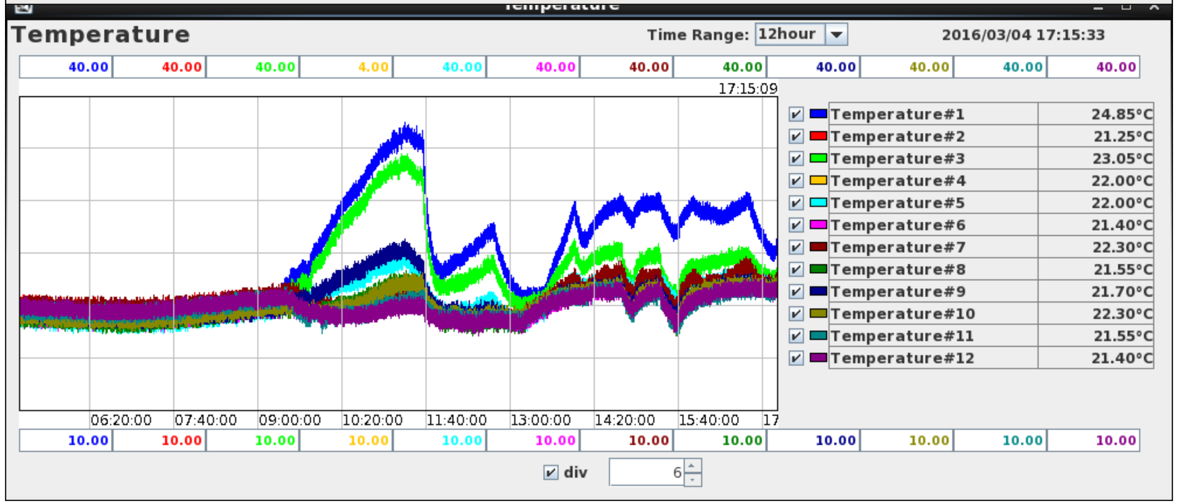
- ILC-TDR
- Motivation
- RF design by HFSS
- Fabrication processes
- Incoming inspection
- Assembly work in clean room
- Low power test / Adjustment of inner conductor for lowest S_{11}
- High power test at test bench
- **Inspection for heating area**
- More inspection / Identification of cause for heating
- Summary / Future plan

Daily Status of conditioning (4/Mar)

Pulse width : 500→1500 [μsec]
Repetition rate : 5 [Hz]



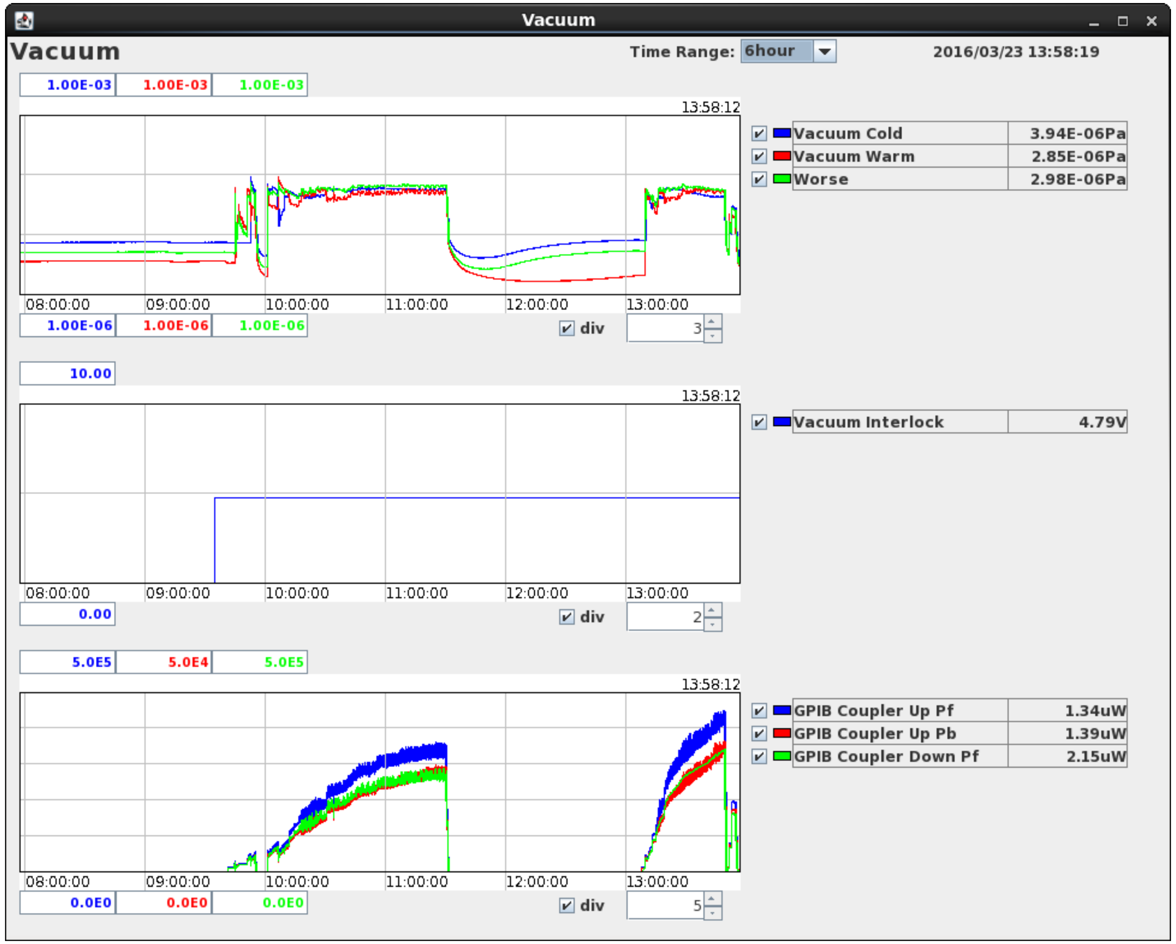




During 1.5ms RF conditioning, cold vacuum was suddenly worse.
Then, we could not do power rise more.
We observed unusual heating around tapered pipe of cold part #3.
It never changed even in lower RF duty cycle.
After disassembly of coupler, we didn't find anything.

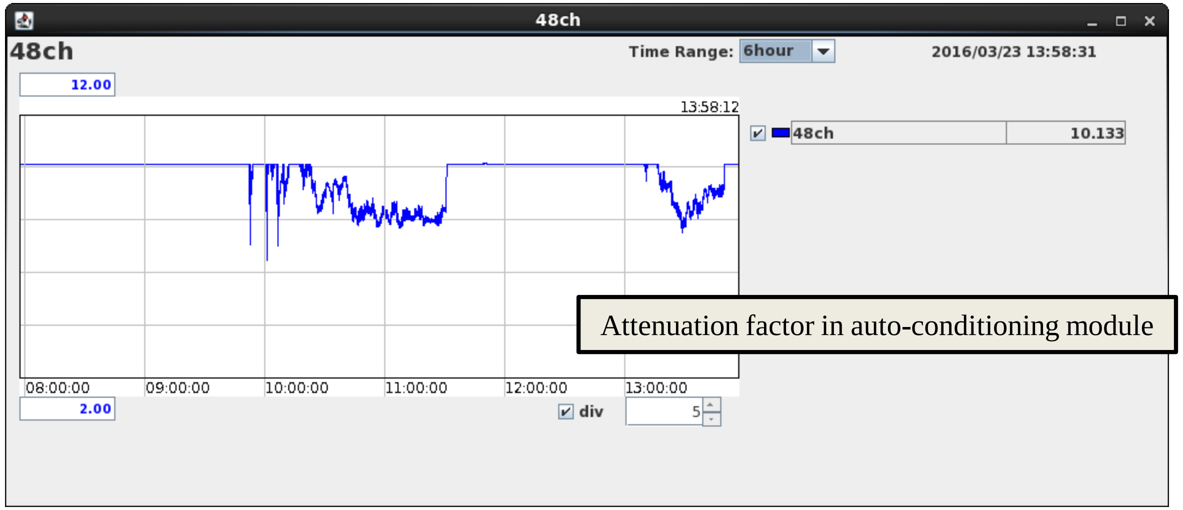
Daily Status of conditioning (23/Mar)

Pulse width : 500 [μsec]
Repetition rate : 5 [Hz]

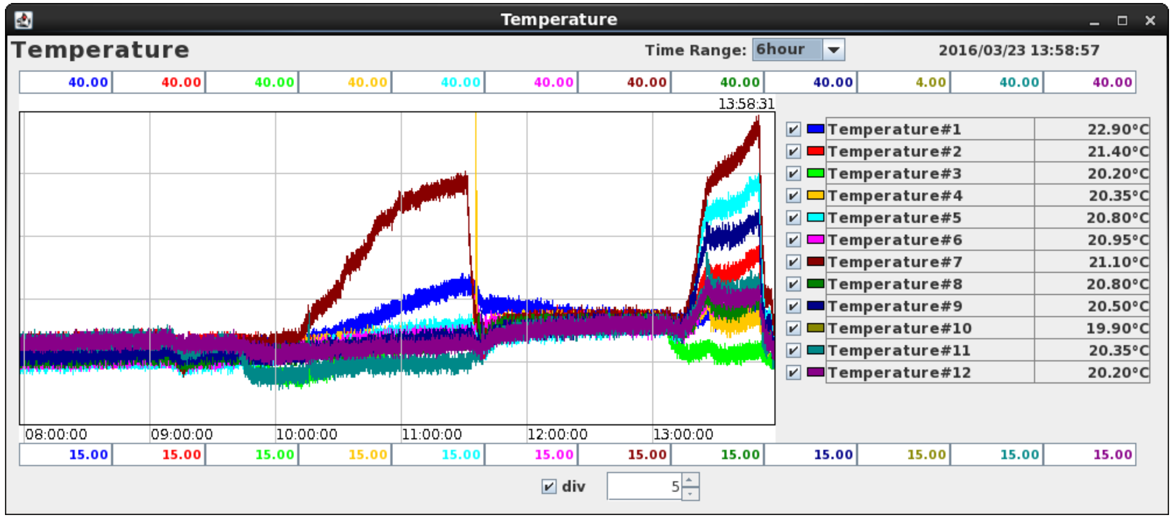


500μsec/5Hz

500μsec/5Hz
(detailed inspection by T-mapping)



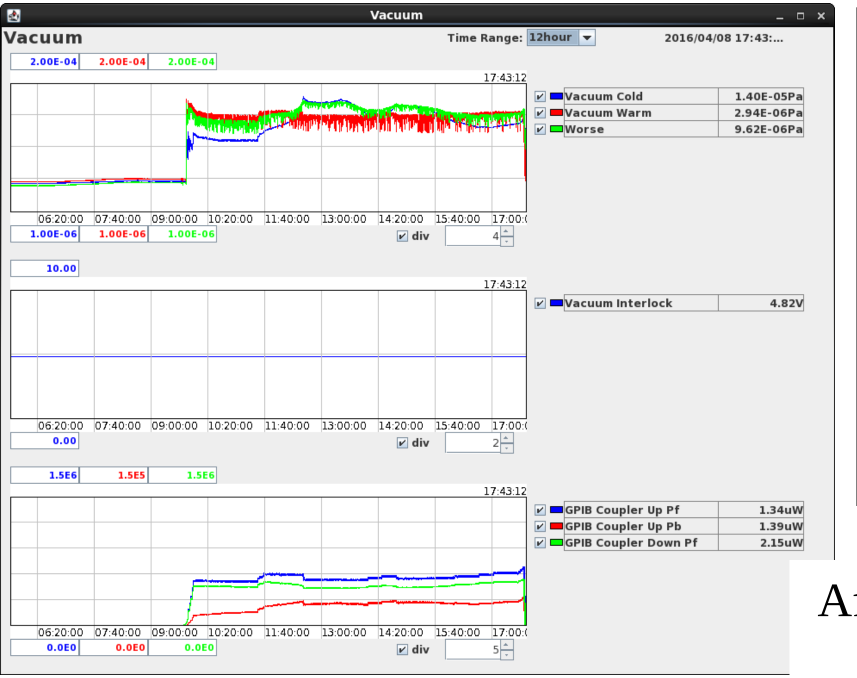
Attenuation factor in auto-conditioning module

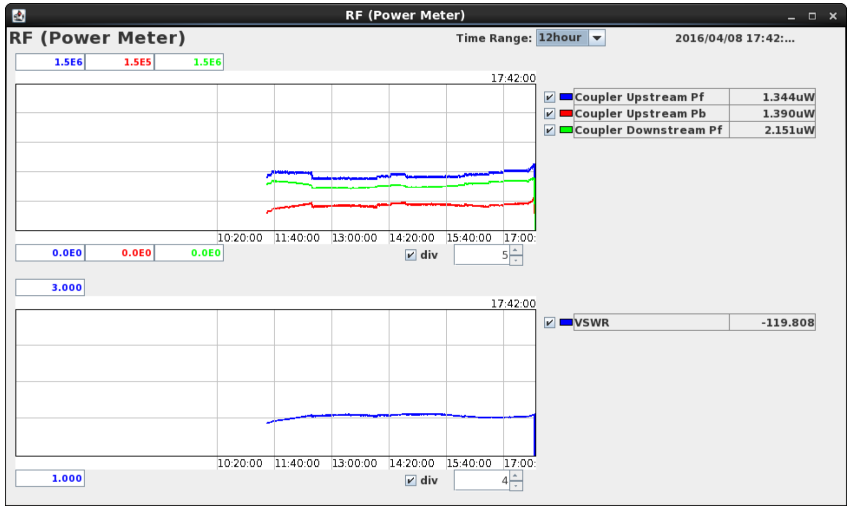


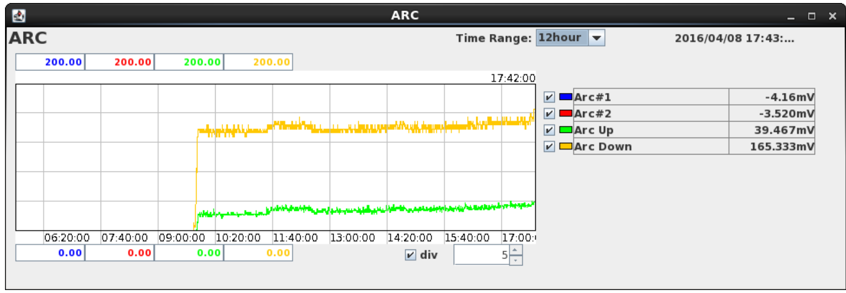
Unusual heating occurred at same position again after reversing coupler test stand!

Daily trend graph @8/Apr

500μsec/5Hz





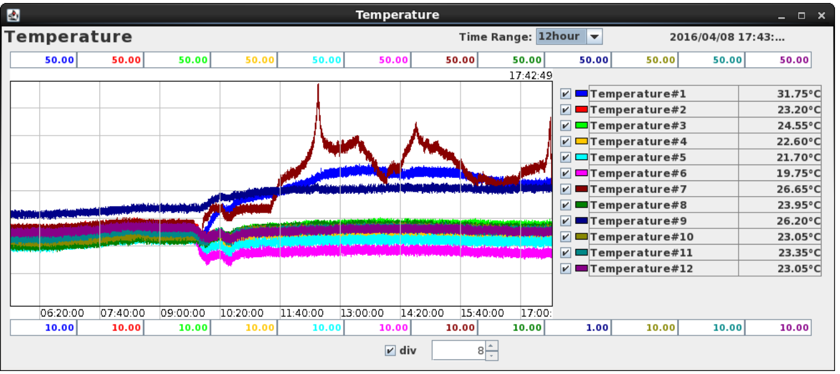


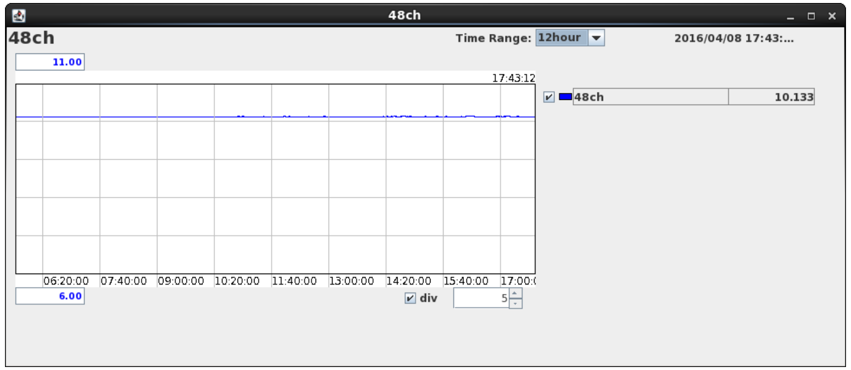
After cold part #3 was replaced to cold part #2, unusual heating occurred at cold part #4.

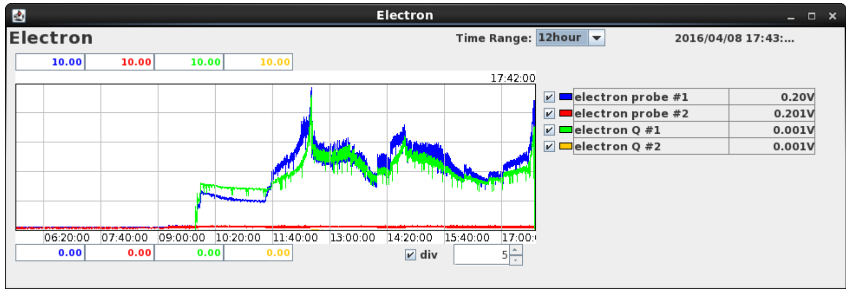
↓

Both of new ceramic couplers had some problem!

Temperature at cold #4 taper increased!



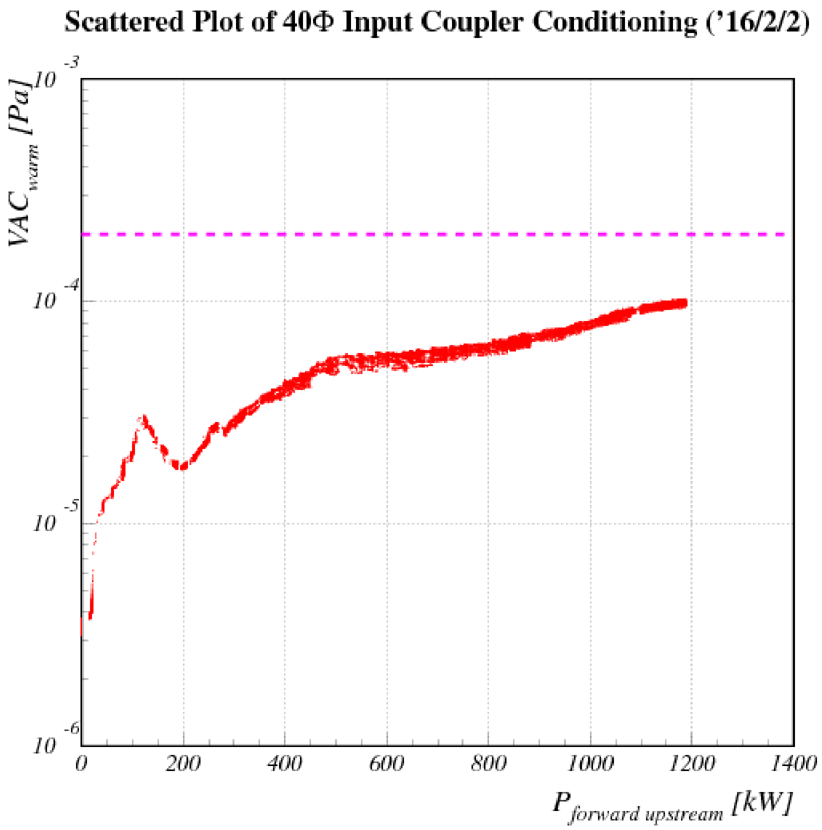




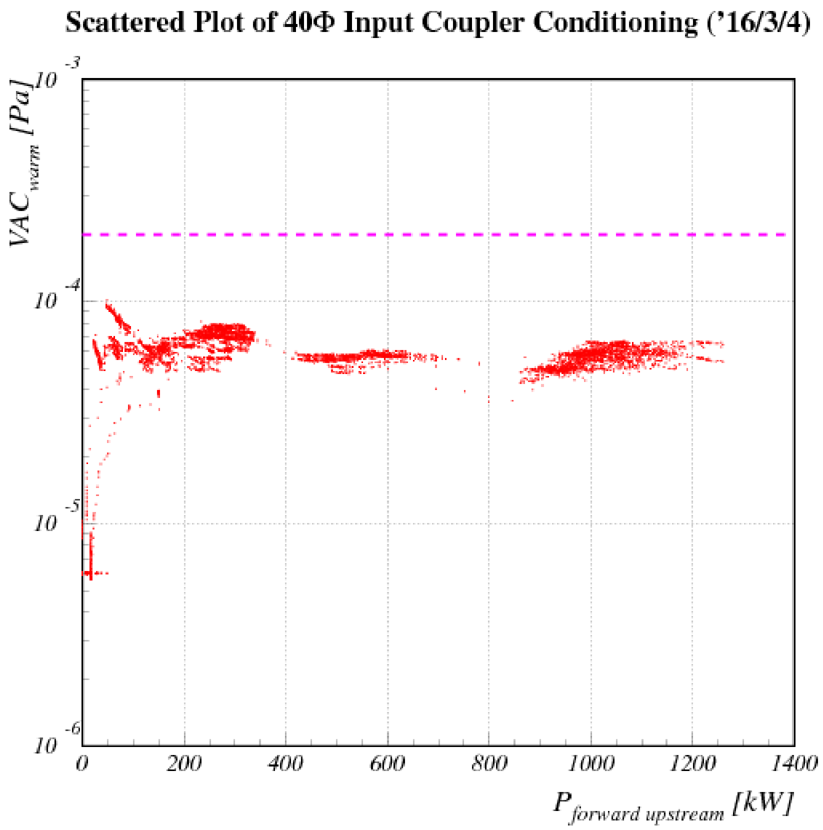
Warm Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

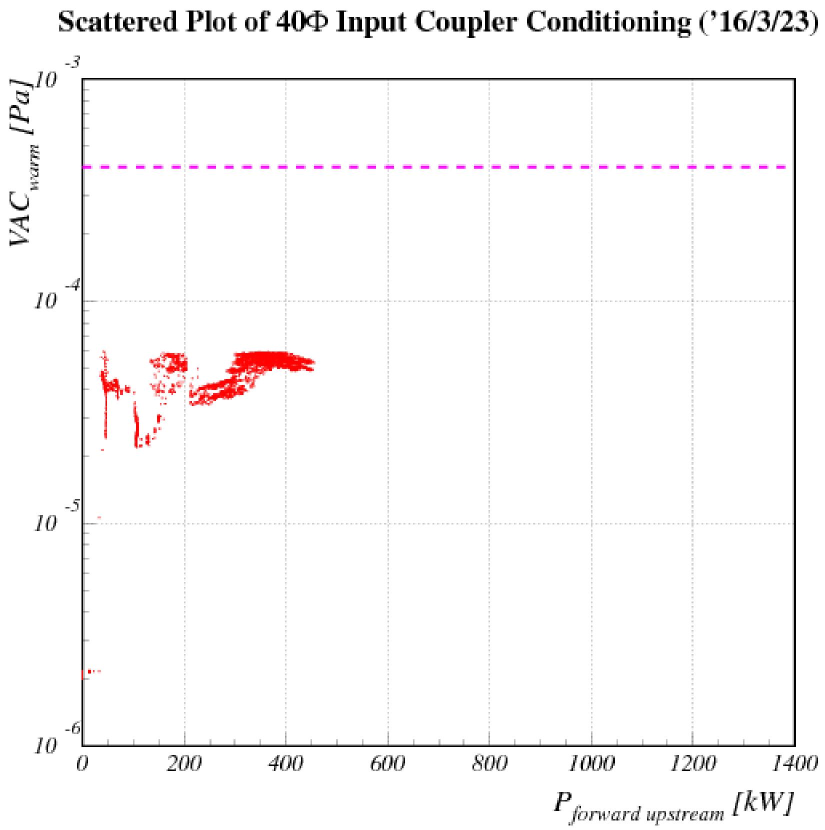
Normal ceramic



New ceramic



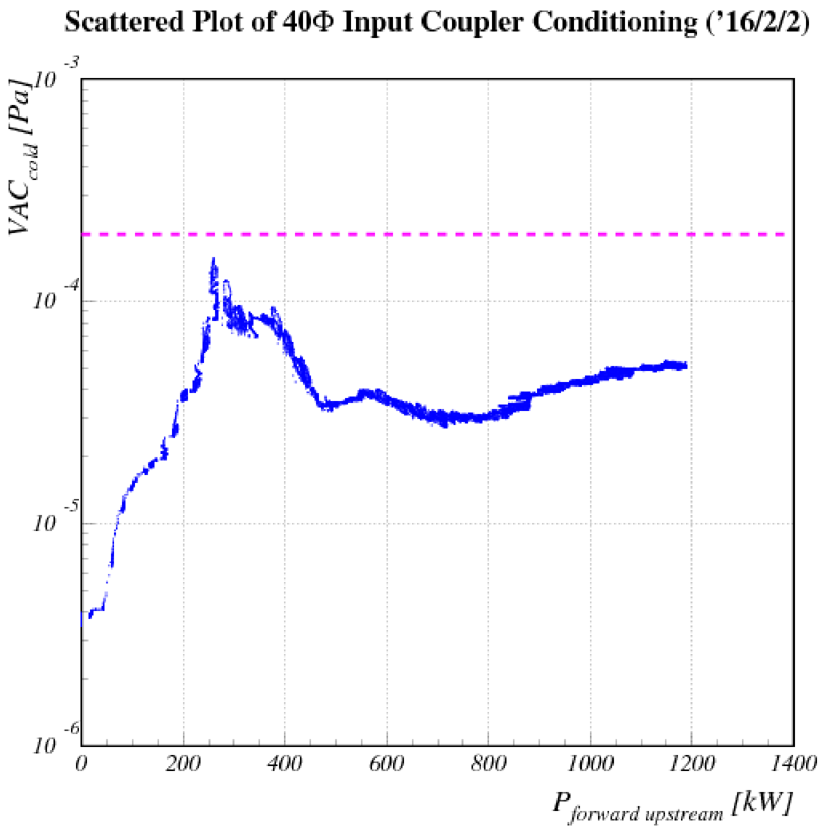
New ceramic



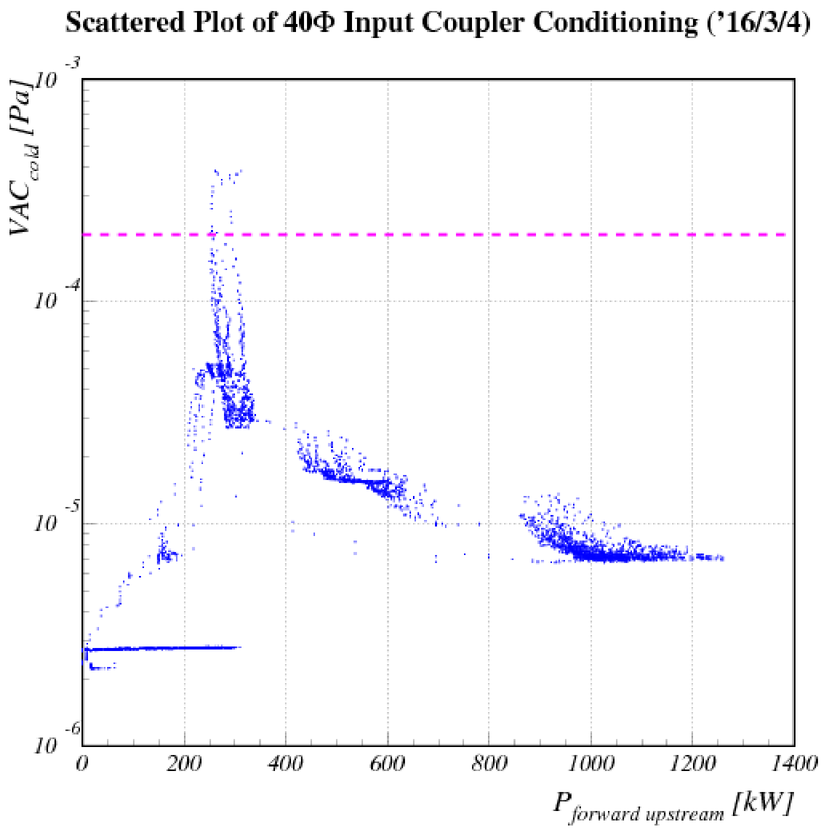
Cold Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

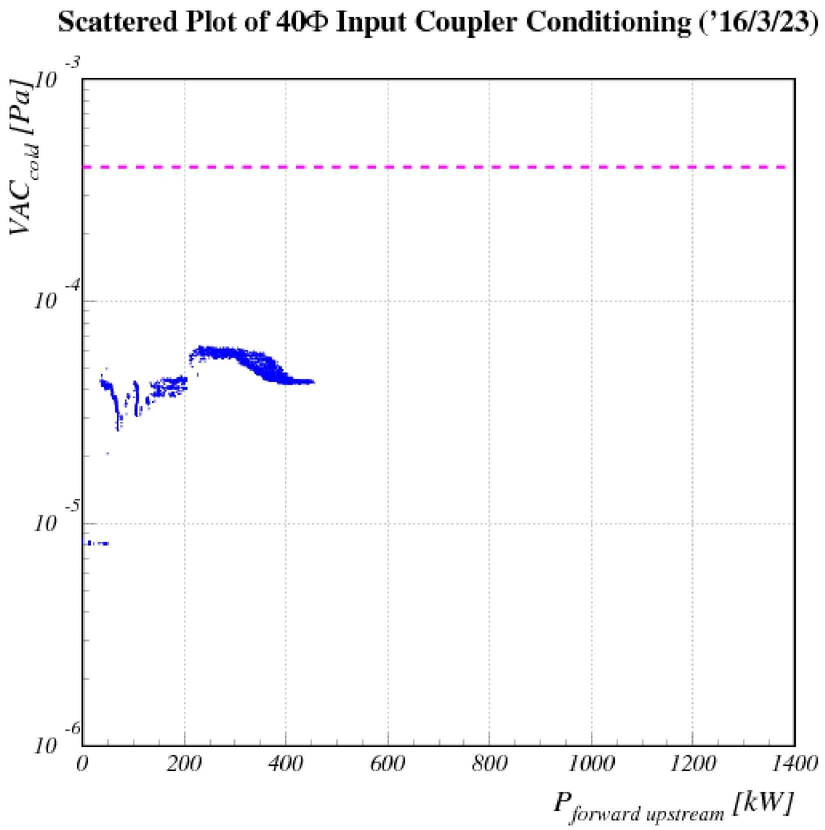
Normal ceramic



New ceramic



New ceramic

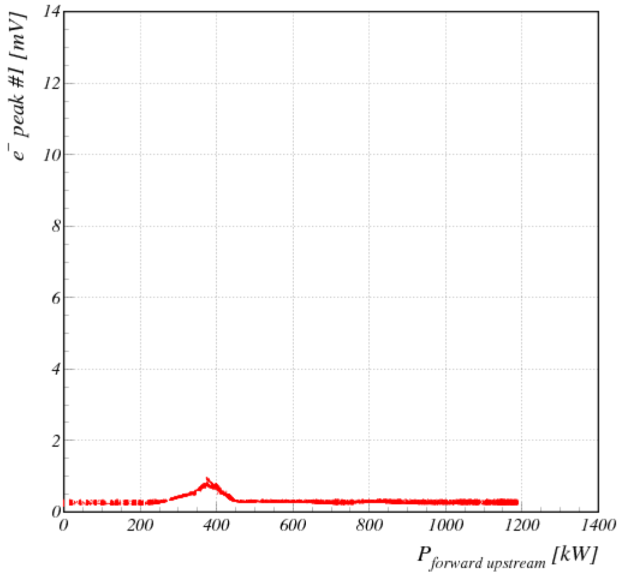


Electron peak vs Power

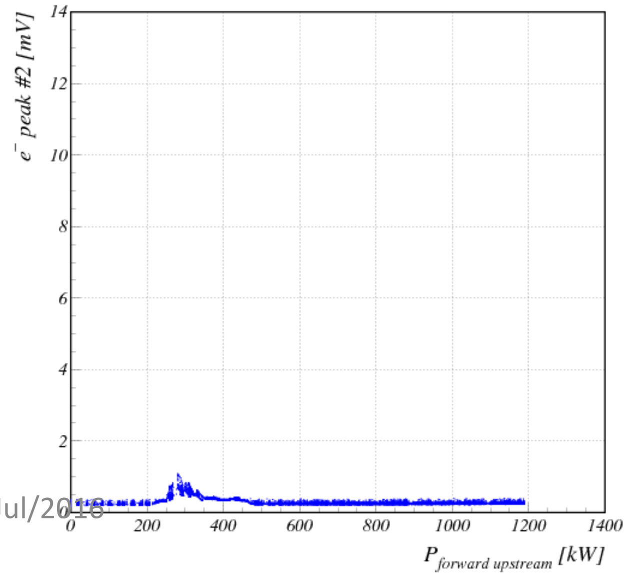
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

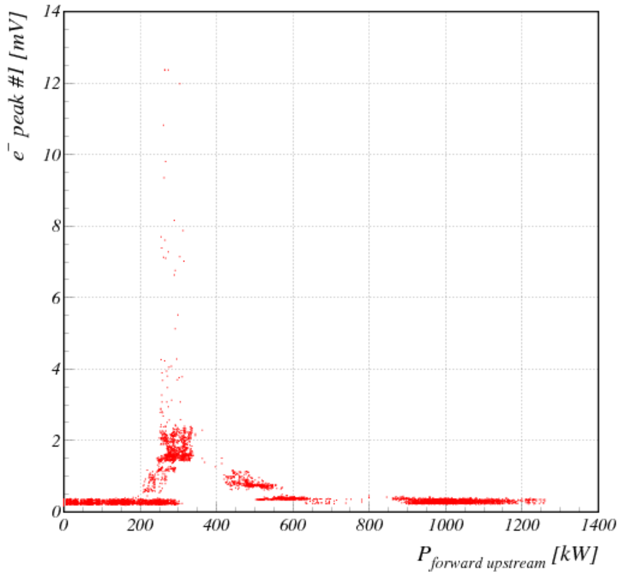


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

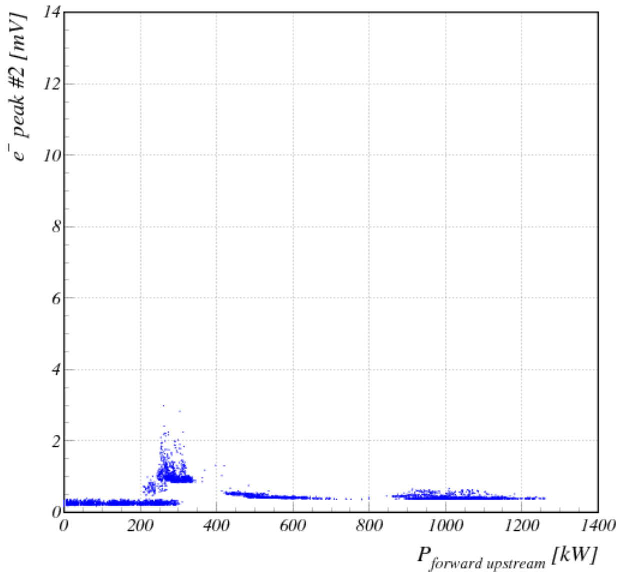


New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

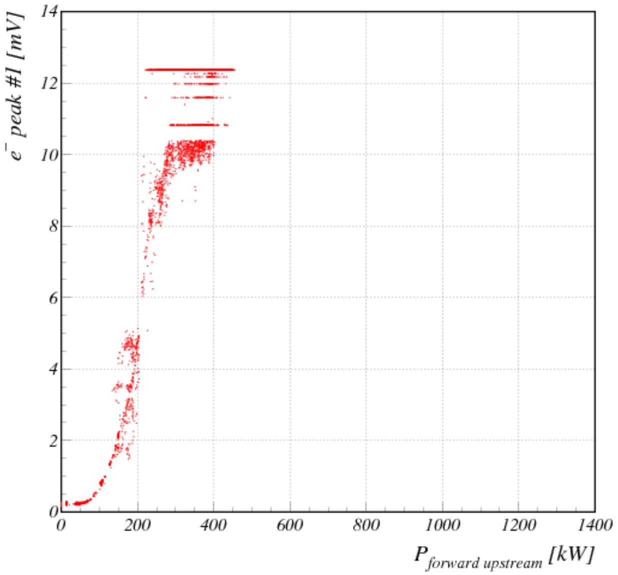


Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

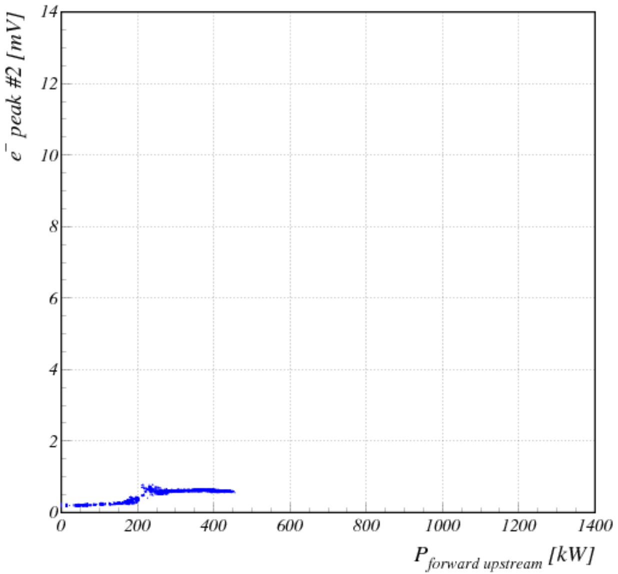


New ceramic

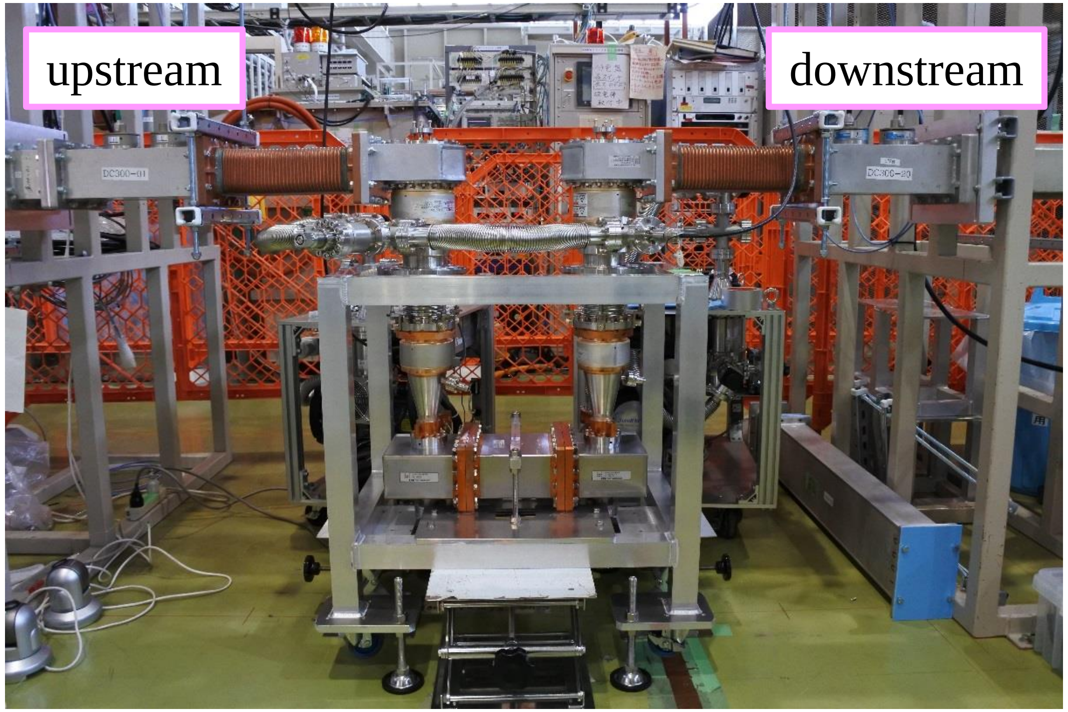
Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)



Heating at Cold Part w/ New Ceramic Coupler



- Only new ceramic coupler
- Only tapered pipe at cold part
- No changed after long RF conditioning
- Many electron emission and worse vacuum as heating occurred
- No worse vacuum at warm part

We asked to TOSHIBA, “What’s differences between them?”

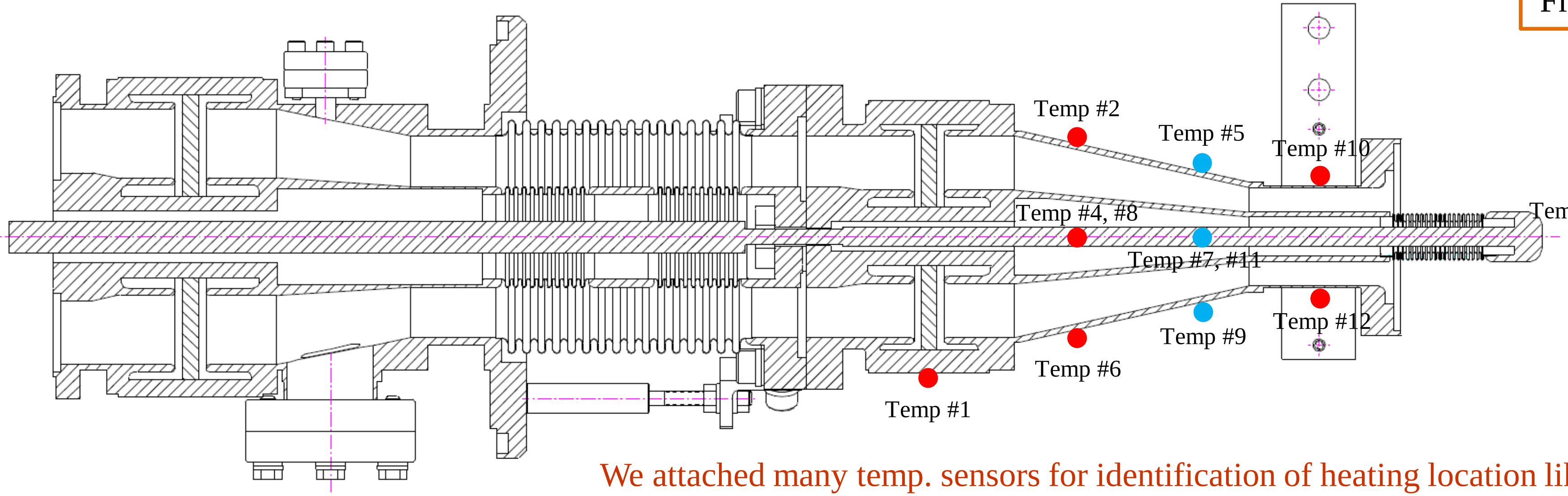
↓

Their answer is…

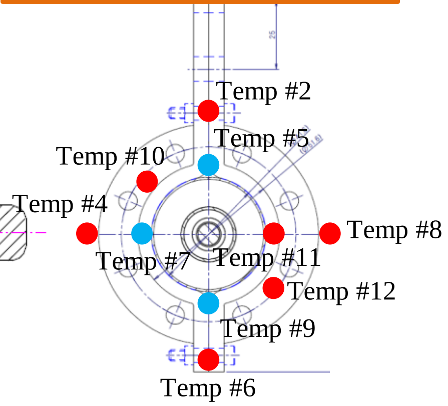
“Both couplers were fabricated by same method”

Test Series #	Upstream coupler	Downstream coupler	Heating location
1	Cold #1 (normal)	Cold #2 (normal)	No heating, but no monitoring
2	Cold #3 (new)	Cold #4 (new)	Cold #3 heating, Cold #4 no heating
3	Cold #4 (new)	Cold #3 (new)	Cold #3 heating, Cold #4 no heating
4	Cold #4 (new)	Cold #2 (normal)	Cold #4 heating, Cold #2 no heating
5	Cold #2 (normal)	Cold #4 (new)	Cold #4 heating, Cold #2 no heating
6	Cold #3 (new)	Cold #4 (new)	Cold #3 heating, Cold #4 no heating

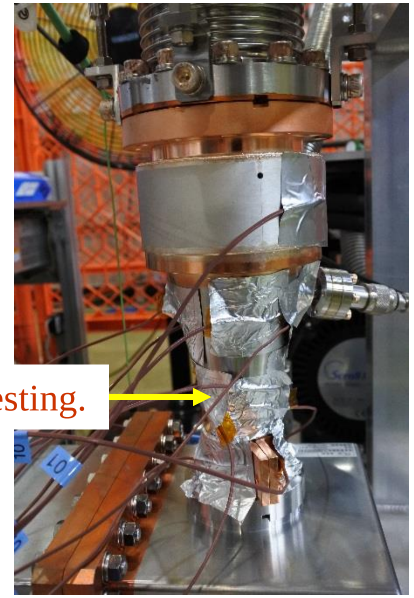
Detailed inspection for unusual heating in Cold #3



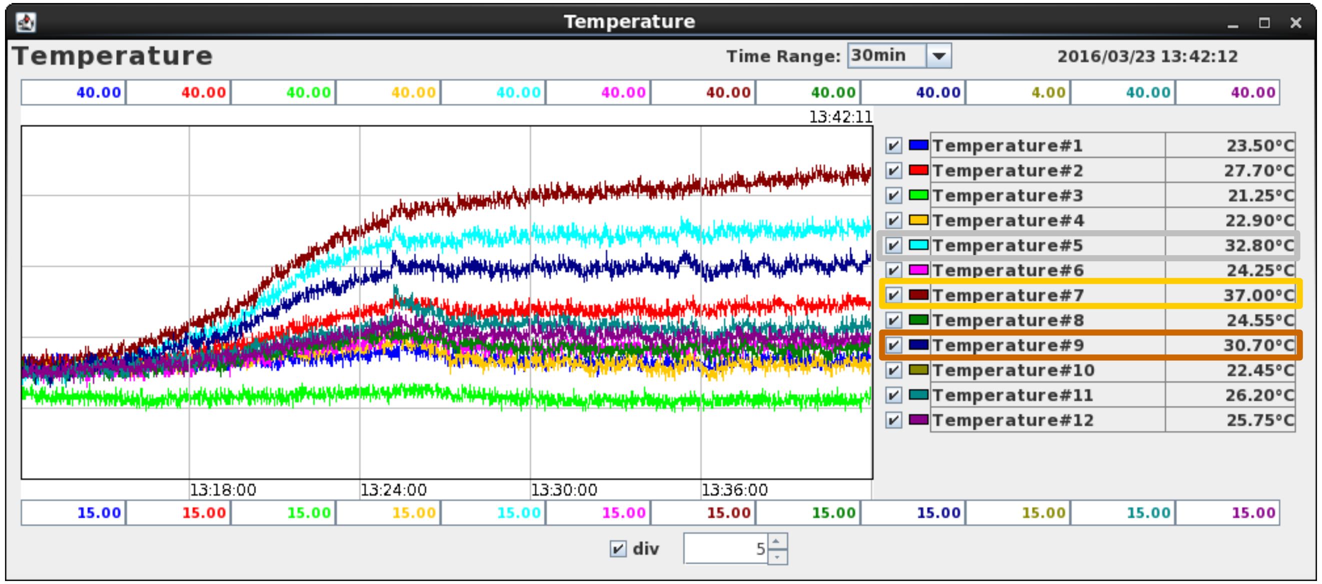
From view of head side

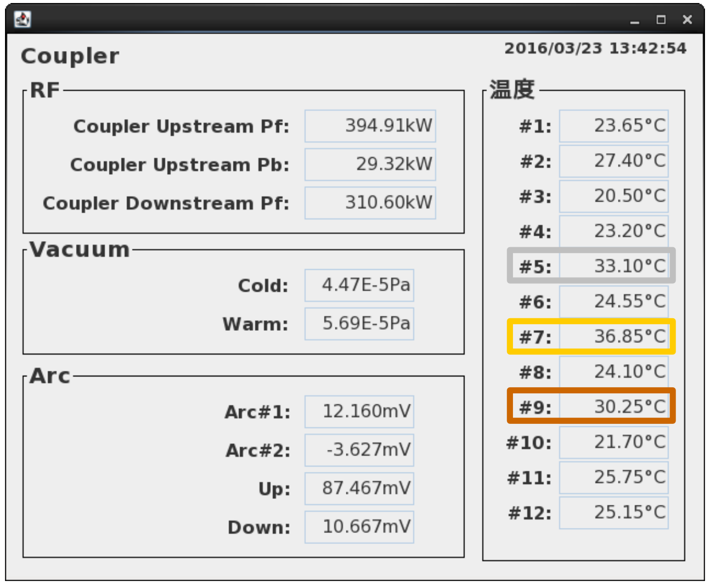


T-mapping for coupler



We attached many temp. sensors for identification of heating location like T-mapping for cavity testing.



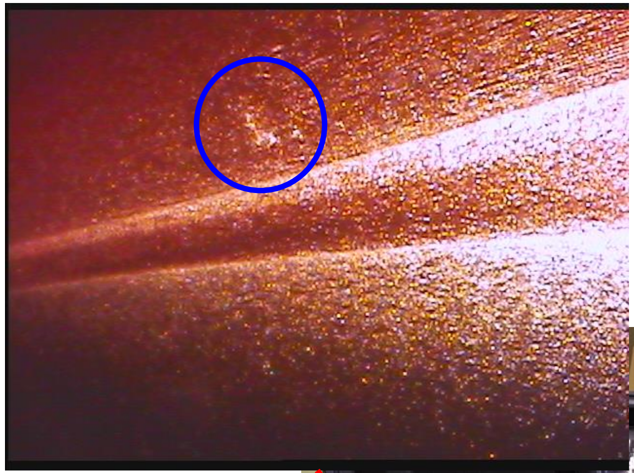


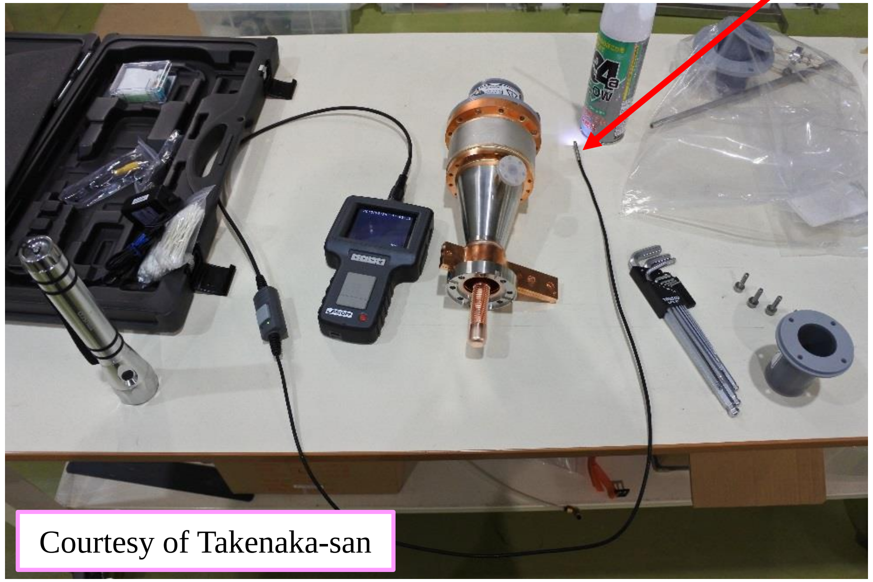
We identified the highest heating location, and inspected there by some fiber-scopes.

Inspection tools for Cold part #3

- Digital borescope (J-SCOPE)
- Rigid borescope (OLYMPUS)
- Digital borescope (OLYMPUS)

Small blisters existed around heating area,
but probably no correlation.
Because, there was no evidence for cold part #4.





Courtesy of Takenaka-san

Most clear picture!
(but no digital data)

Courtesy of Higo-san

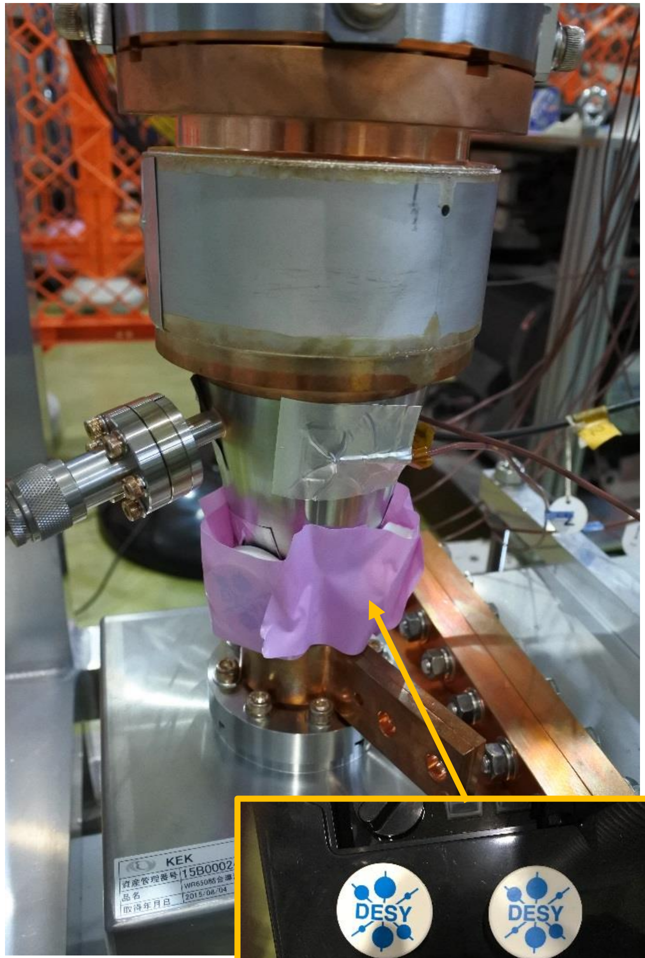
Courtesy of Tanaka-san

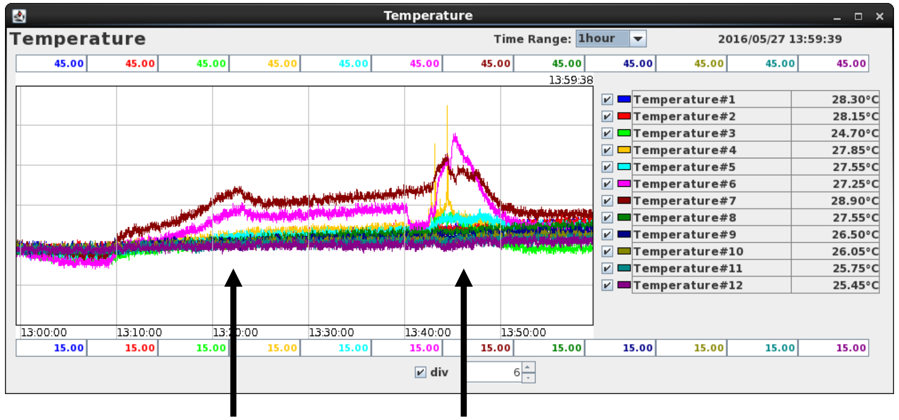
Outline

- ILC-TDR
- Motivation
- RF design by HFSS
- Fabrication processes
- Incoming inspection
- Assembly work in clean room
- Low power test / Adjustment of inner conductor for lowest S_{11}
- High power test at test bench
- Inspection for heating area
- **More inspection / Identification of cause for heating**
- Summary / Future plan

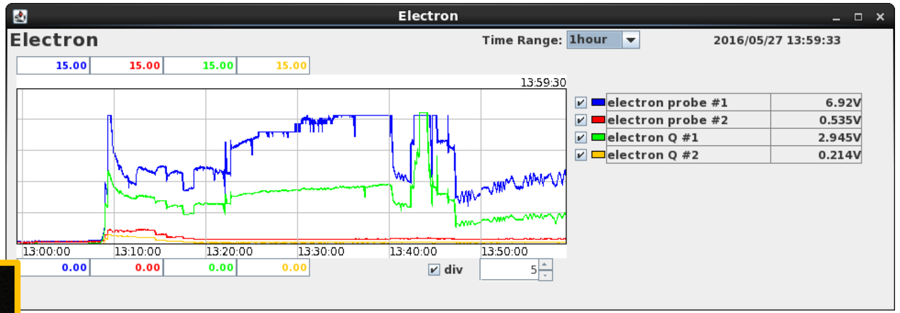
Inspection for unusual heating by DESY magnet

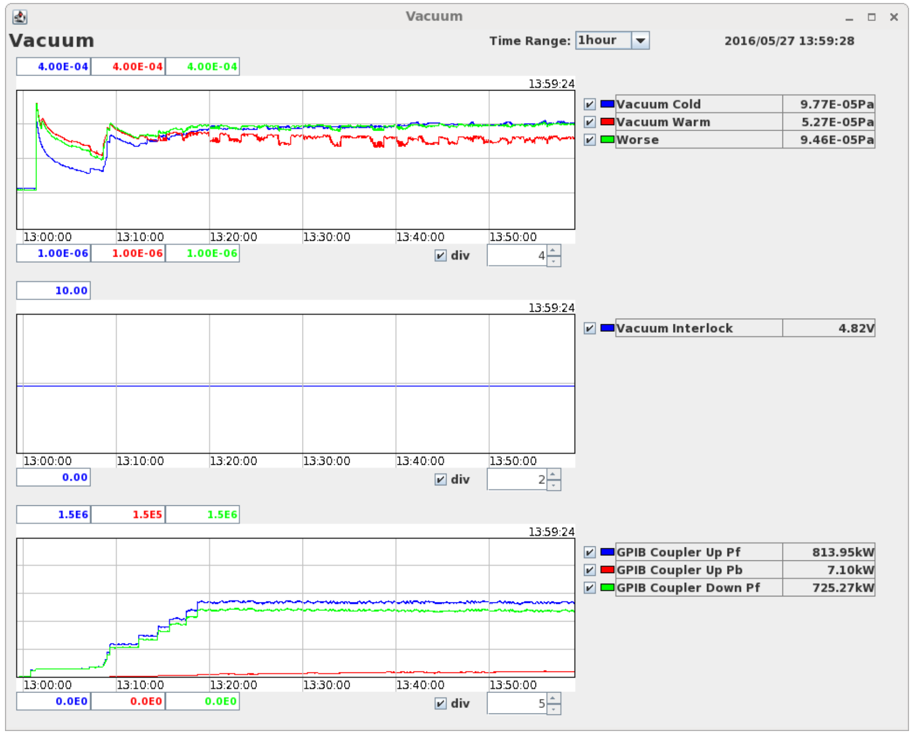
I attached small DESY magnets around tapered pipe.





Only one mag. Four magnets





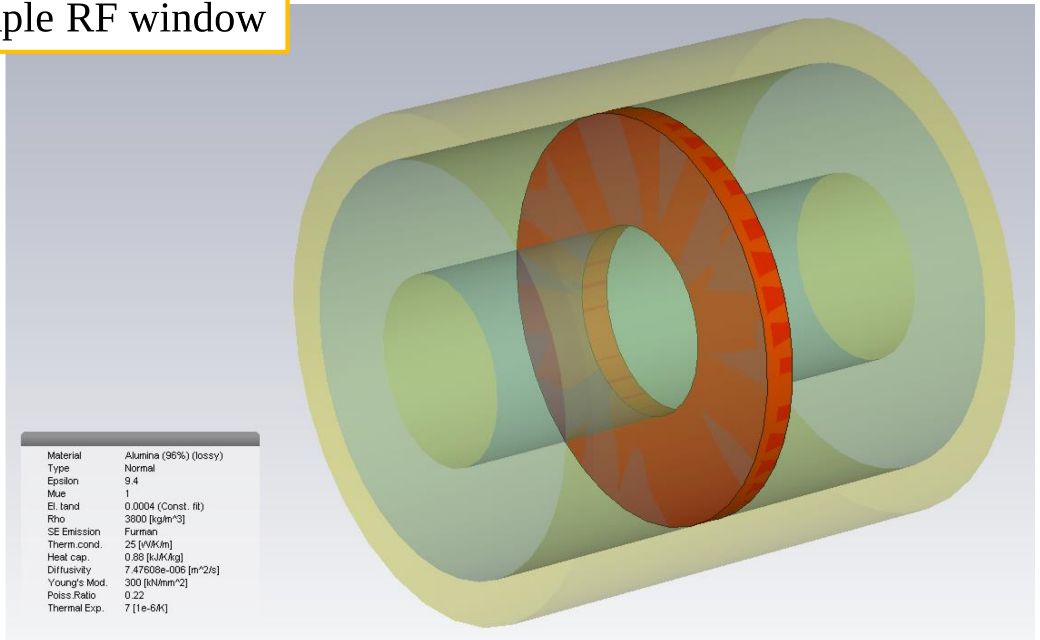
Just after magnets attachment, temperature rise stopped and decreased.
But, when RF pulse width changed from 400 to 500μsec, there was no effect

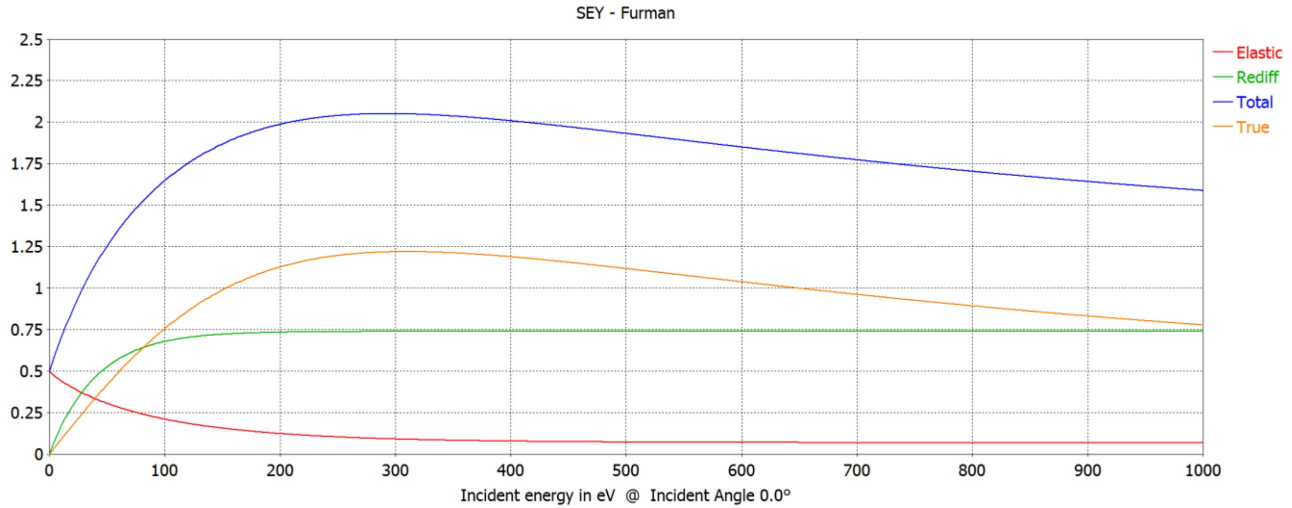
↓

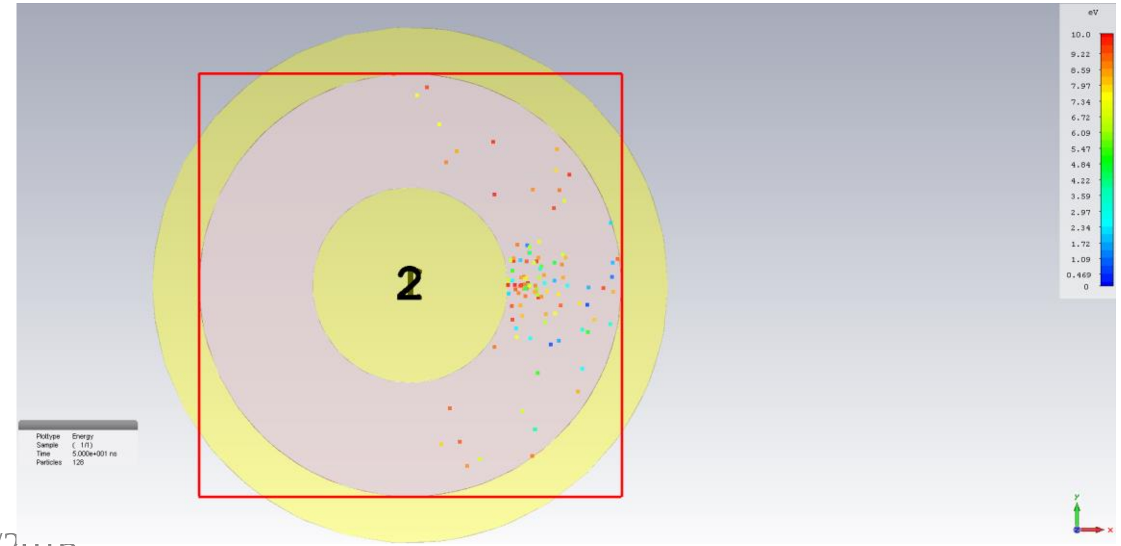
Many electrons directly hit at tapered pipe! (No thermal conductivity)

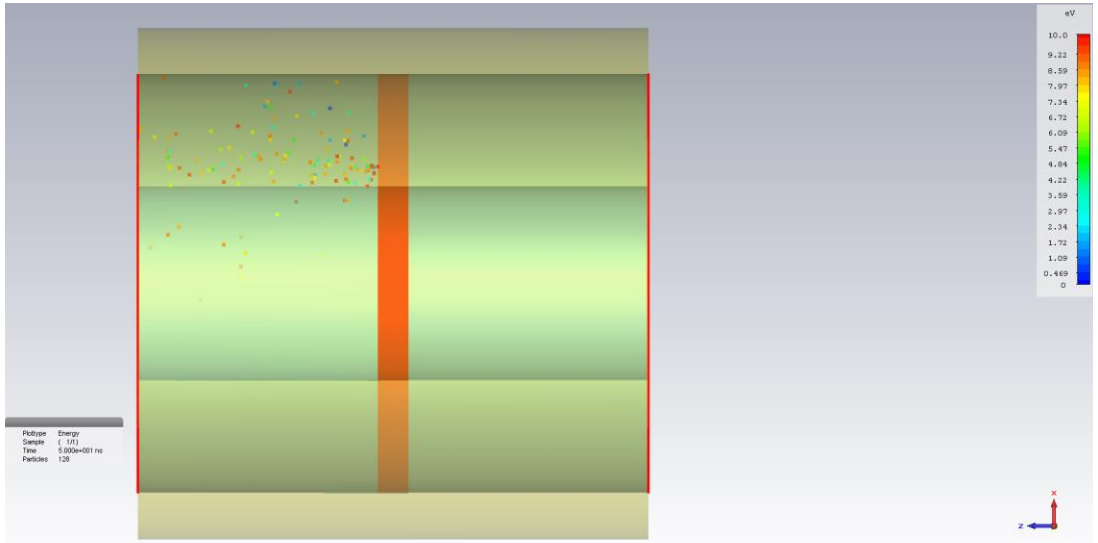
CST simulation just recently started!

Simple RF window









Outline

- ILC-TDR
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- More inspection / Identification of cause for heating
- **Summary / Future plan**

Summary & Future Plan

- Plug-compatibility for STF-II coupler with normal ceramic is no problem
  - RF conditioning time is comparable for previous couplers
  - RF property is no problem, but Q_L measurement is not done yet
- New ceramic coupler had significant heating problem
  - This was observed for Only tapered pipe at cold part
  - Many electrons directly hit at tapered pipe

- Rinsing study (Ultrasonic or O_3) will be done (early next year)
- Range of Q_L will be checked

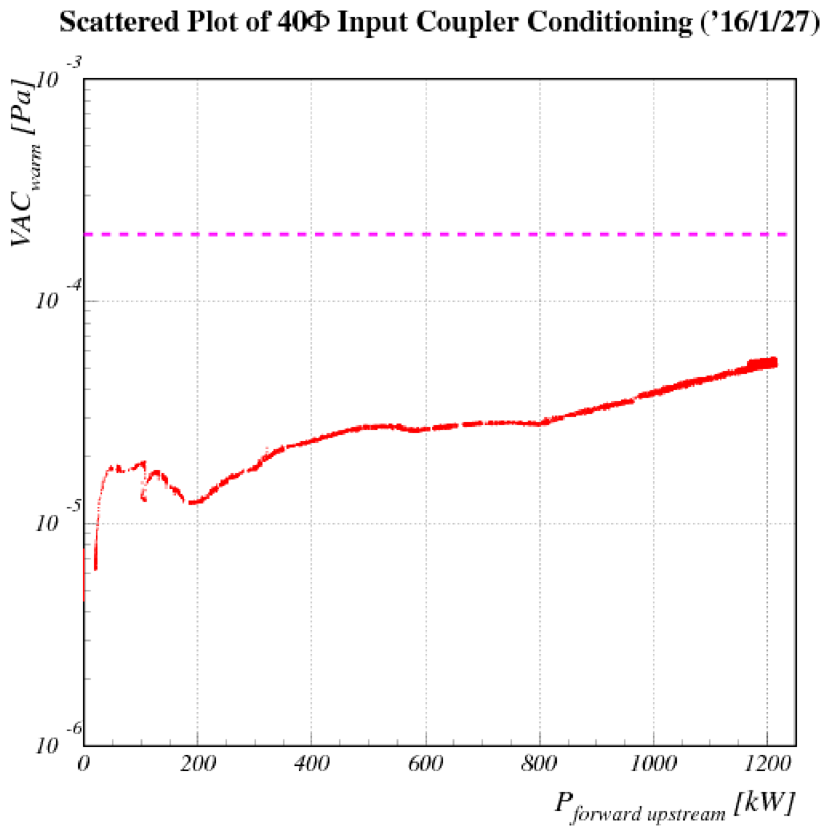
Comparison of Normal/New ceramic coupler

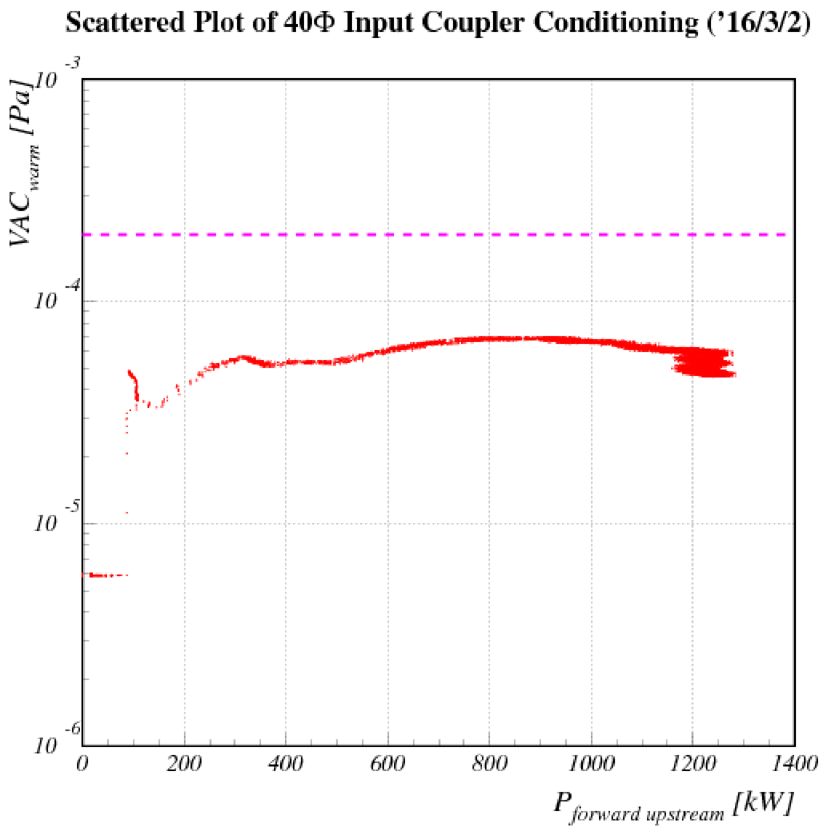
Warm Vac vs Power

Normal ceramic

Pulse width : 10[μsec]
Rep. frequency : 5 [Hz]

New ceramic





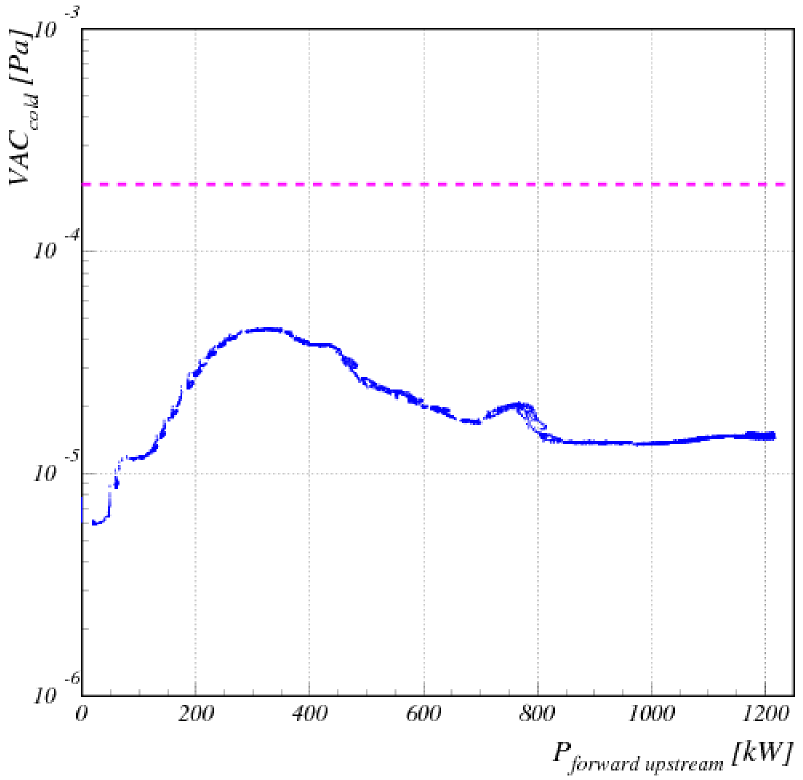
Comparison of Normal/New ceramic coupler

Cold Vac vs Power

Pulse width : 10[μsec]
Rep. frequency : 5 [Hz]

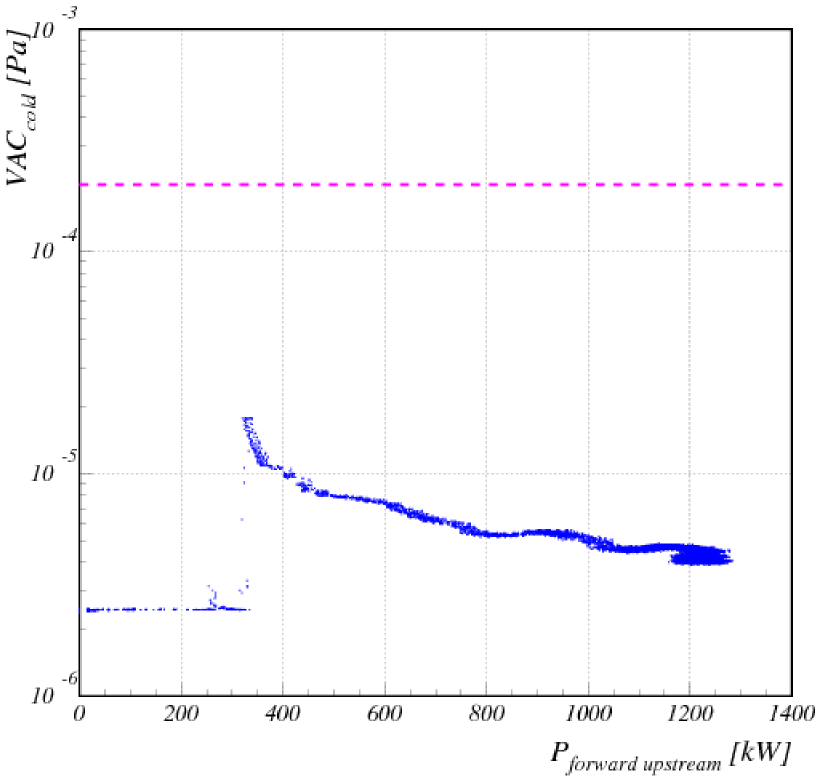
Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)



New ceramic

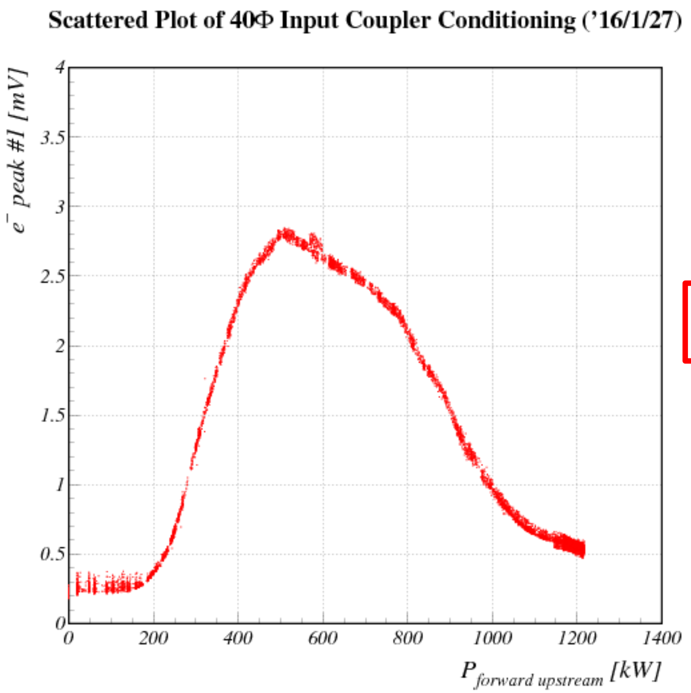
Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/2)

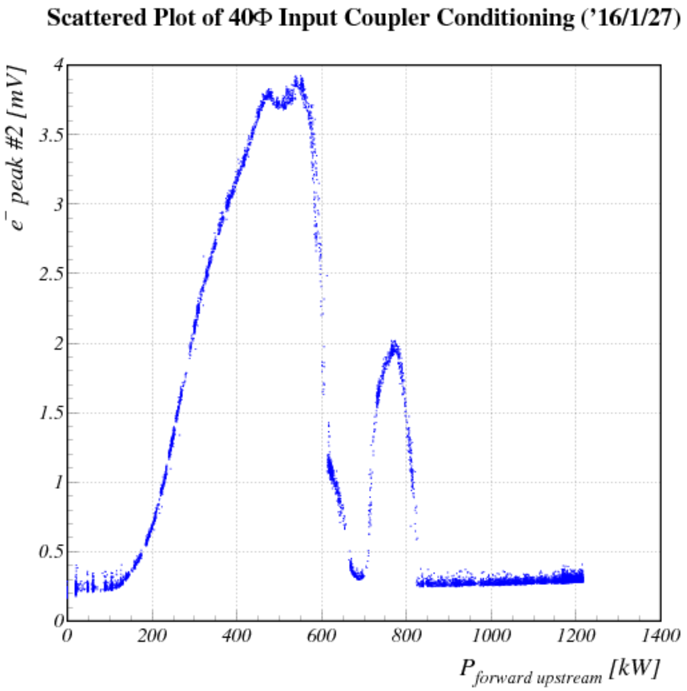


Electron peak vs Power

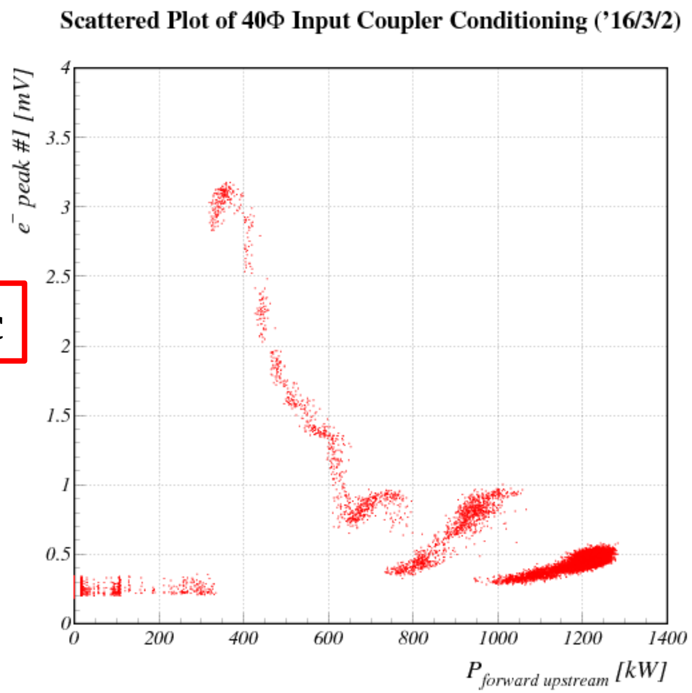
Pulse width : 10[μsec]
Rep. frequency : 5 [Hz]

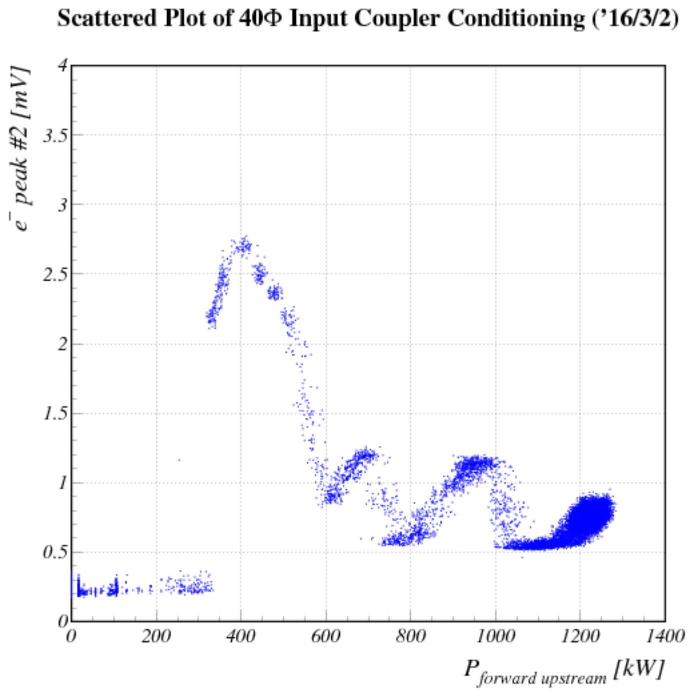
Normal ceramic





New ceramic

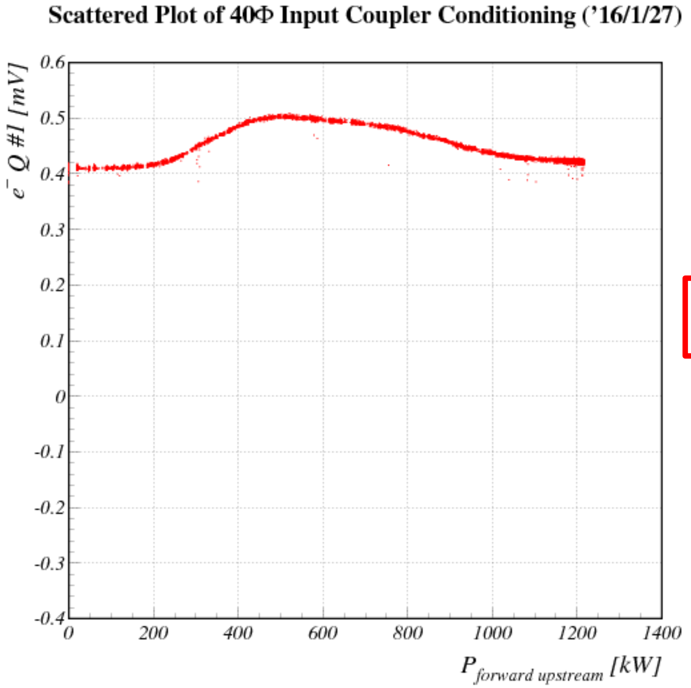


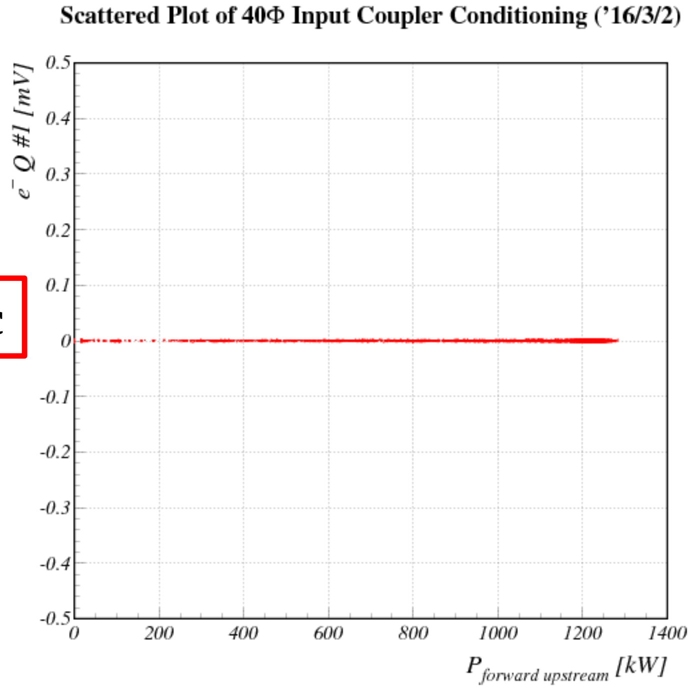


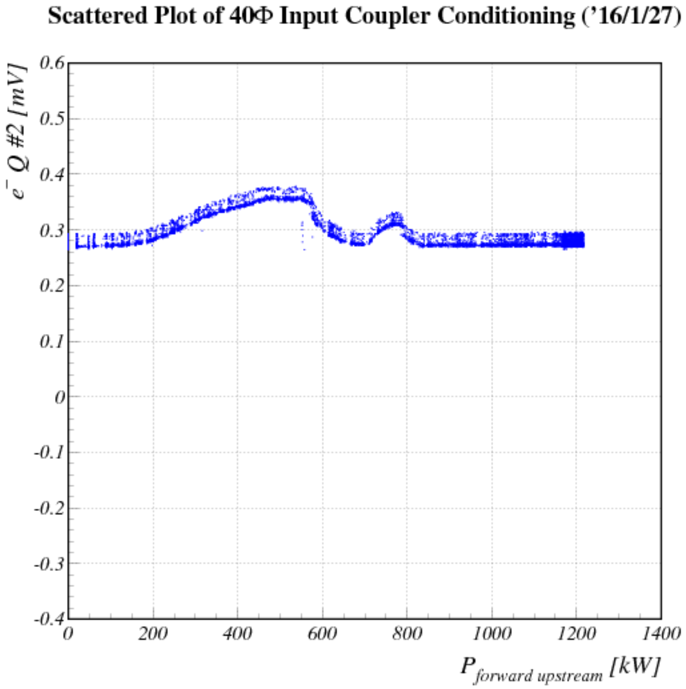
Electron Q vs Power

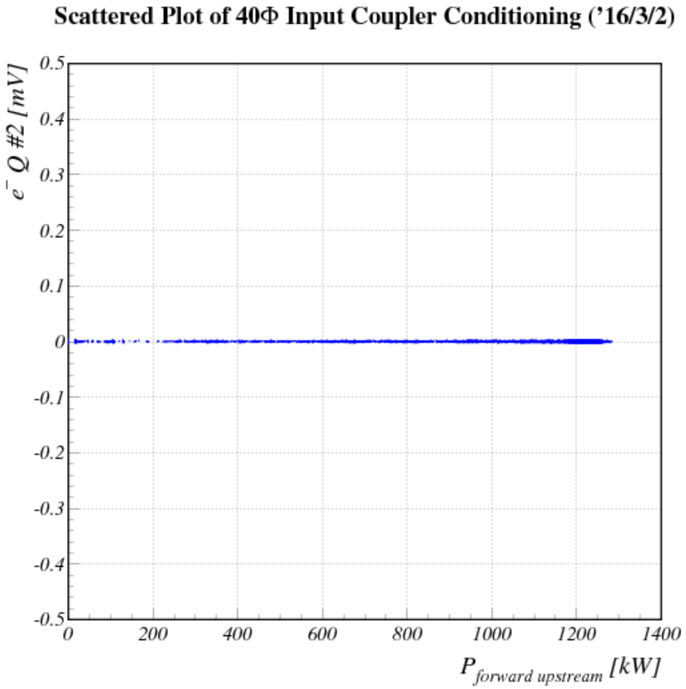
Pulse width : 10[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**





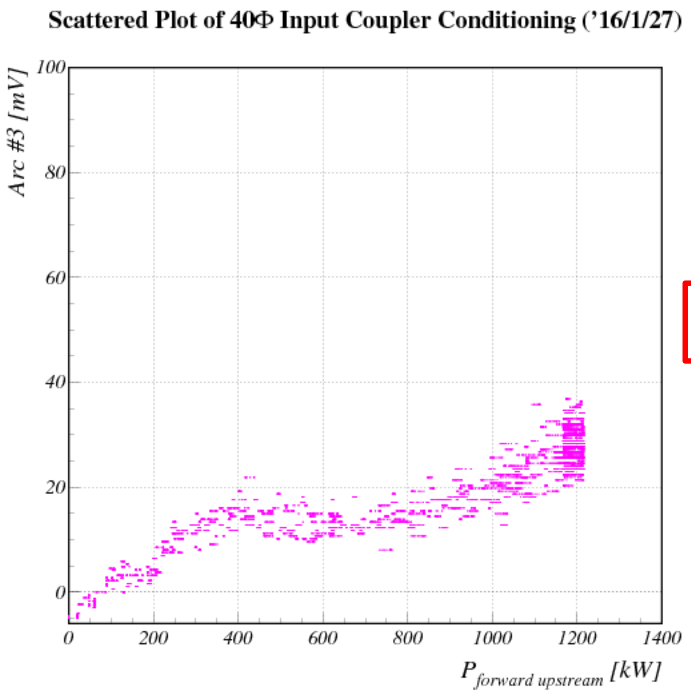


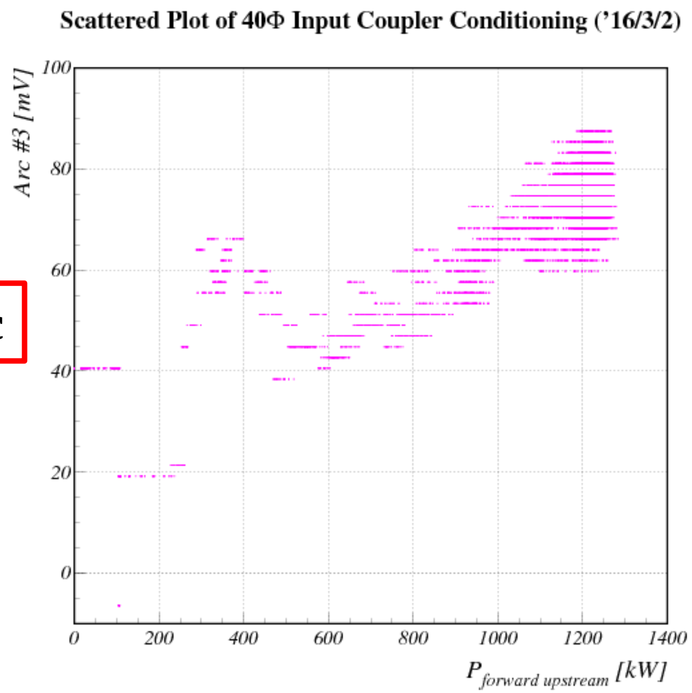


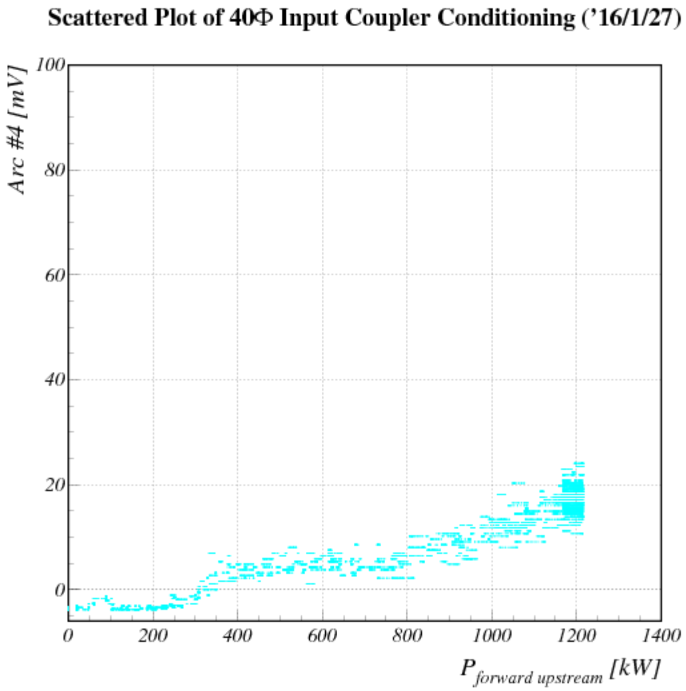
Arc vs Power

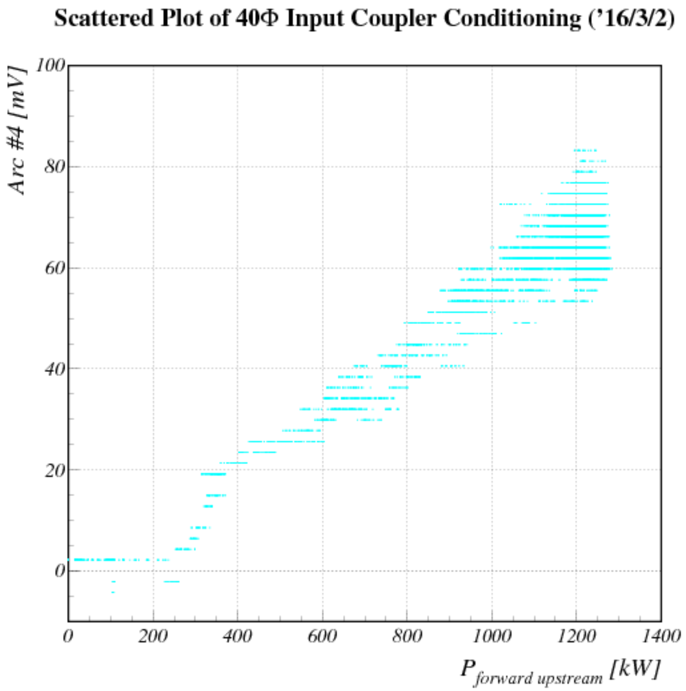
Pulse width : 10[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**







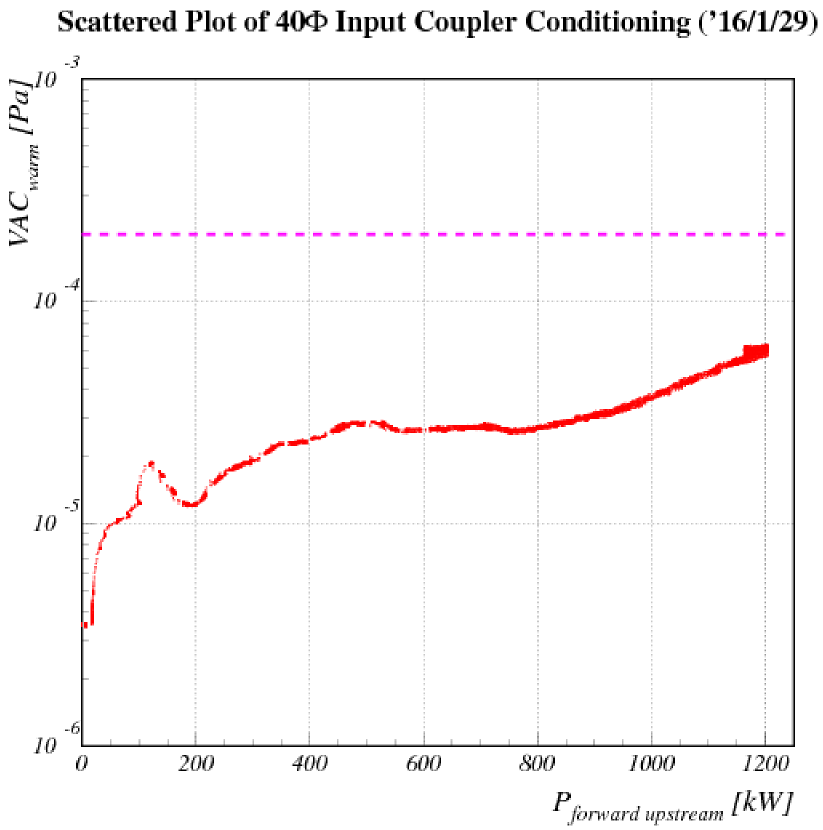


Comparison of Normal/New ceramic coupler

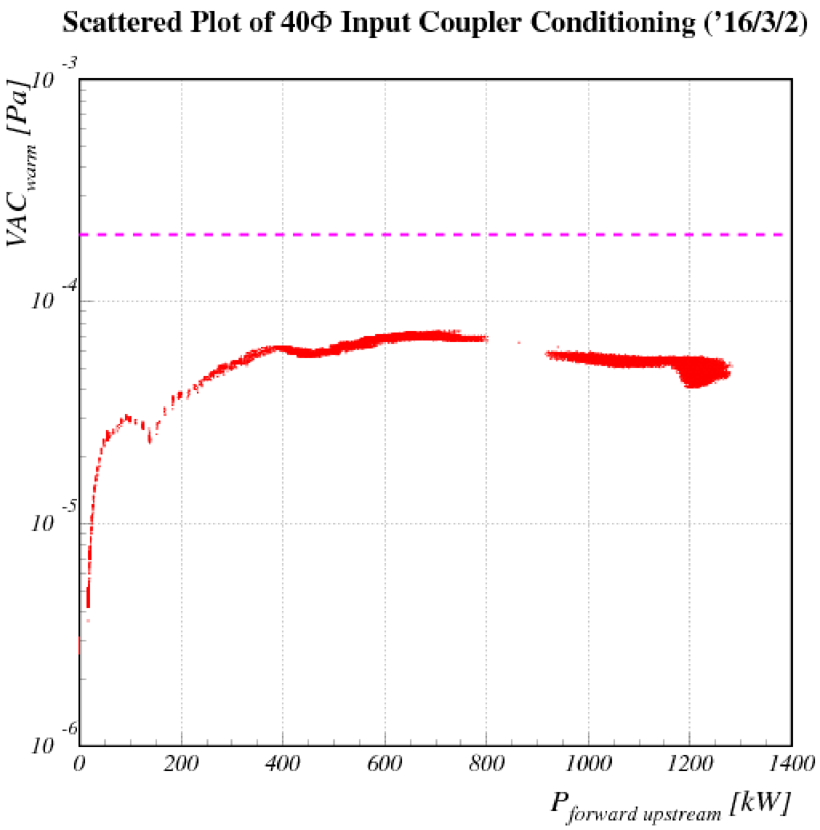
Warm Vac vs Power

Pulse width : 30[μsec]
Rep.   frequency : 5 [Hz]

Normal ceramic



New ceramic

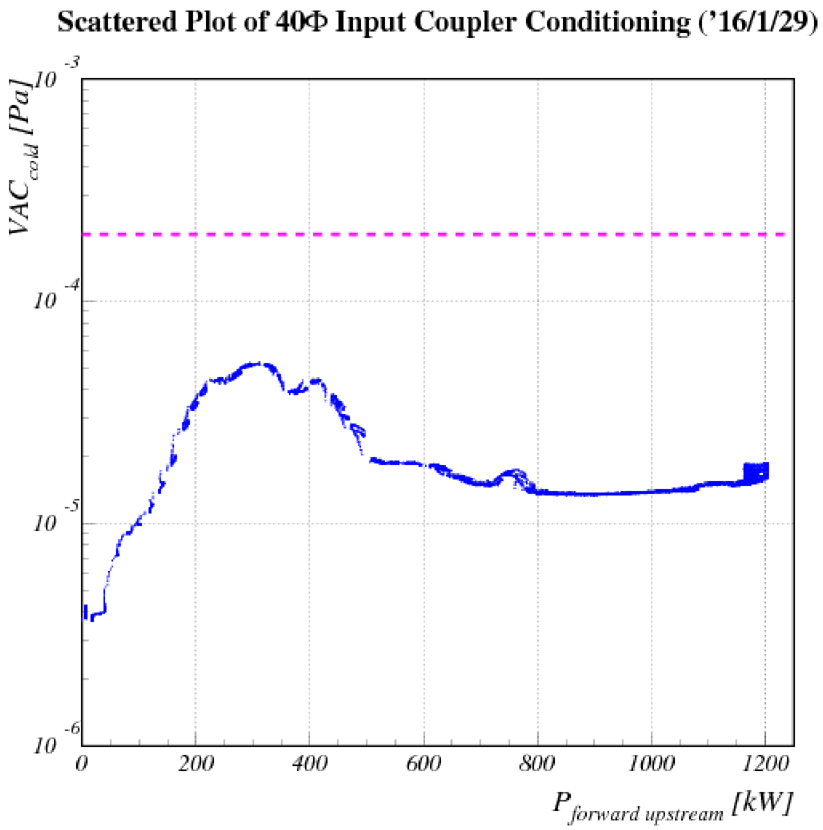


Comparison of Normal/New ceramic coupler

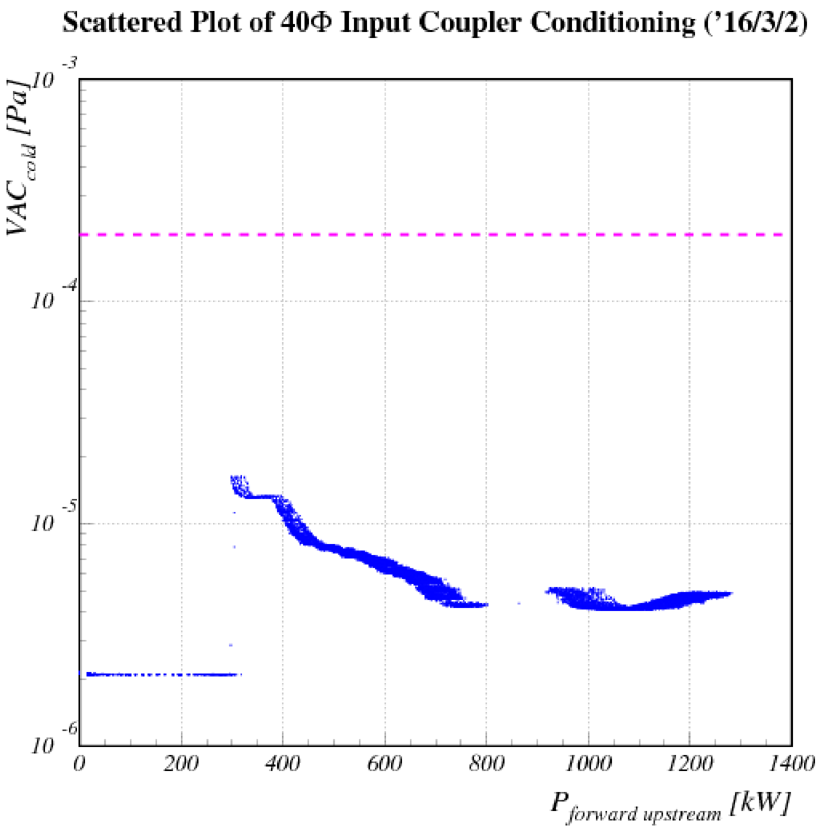
Cold Vac vs Power

Pulse width : 30[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic



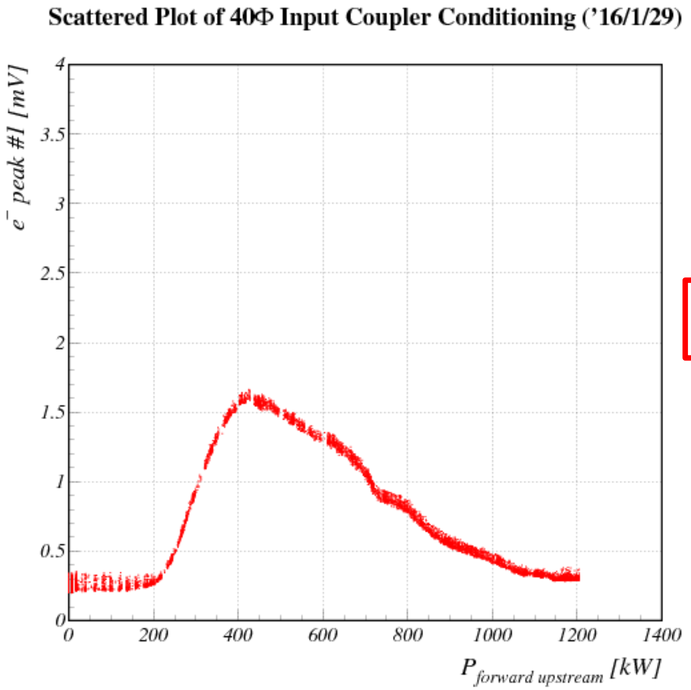
New ceramic

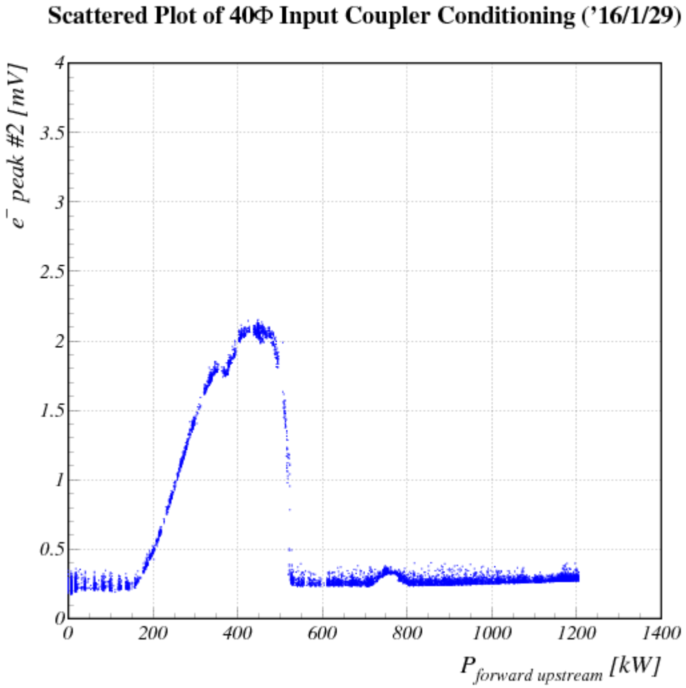


Electron peak vs Power

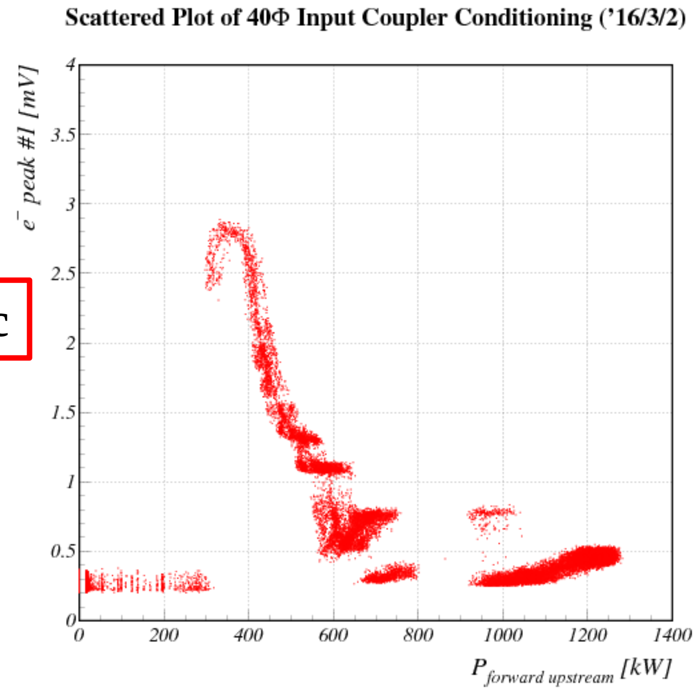
Pulse width : 30[μsec]
Rep. frequency : 5 [Hz]

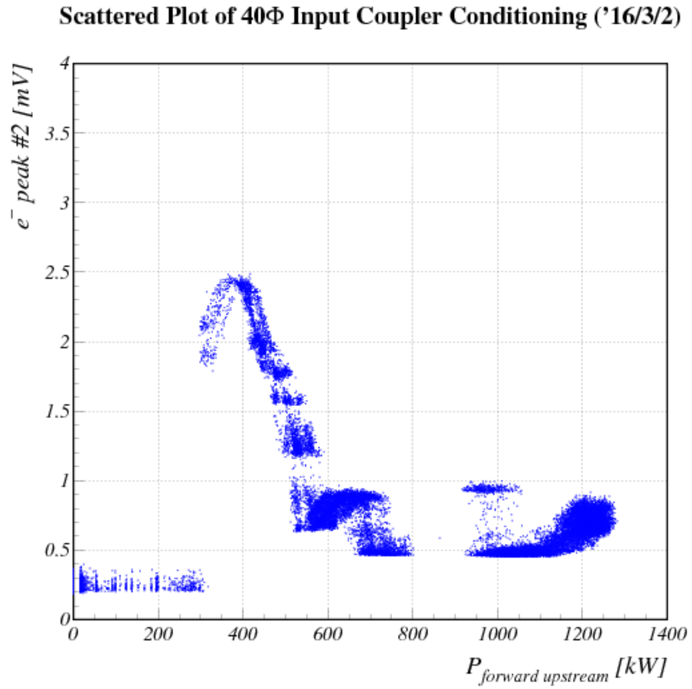
Normal ceramic





New ceramic

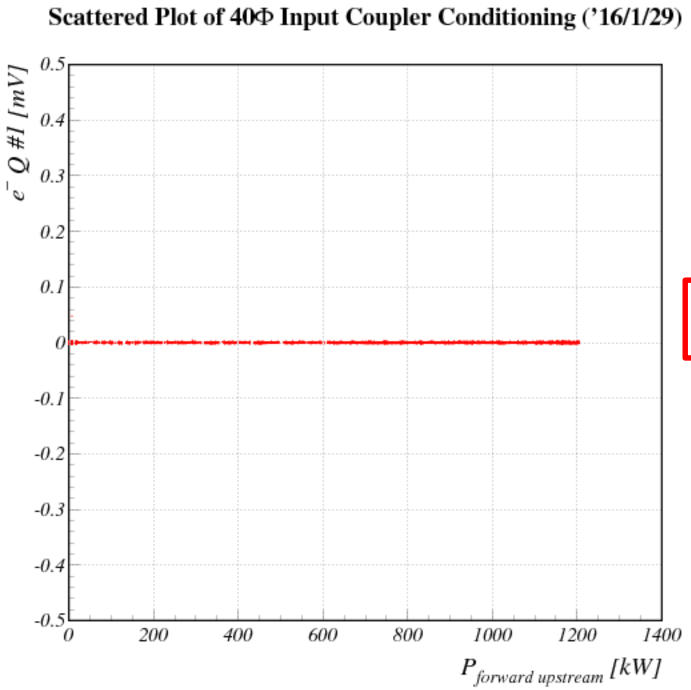


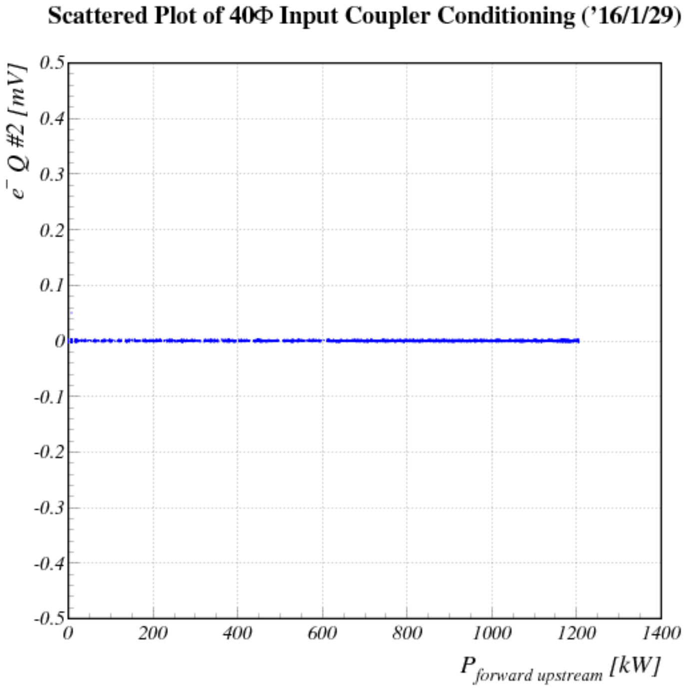


Electron Q vs Power

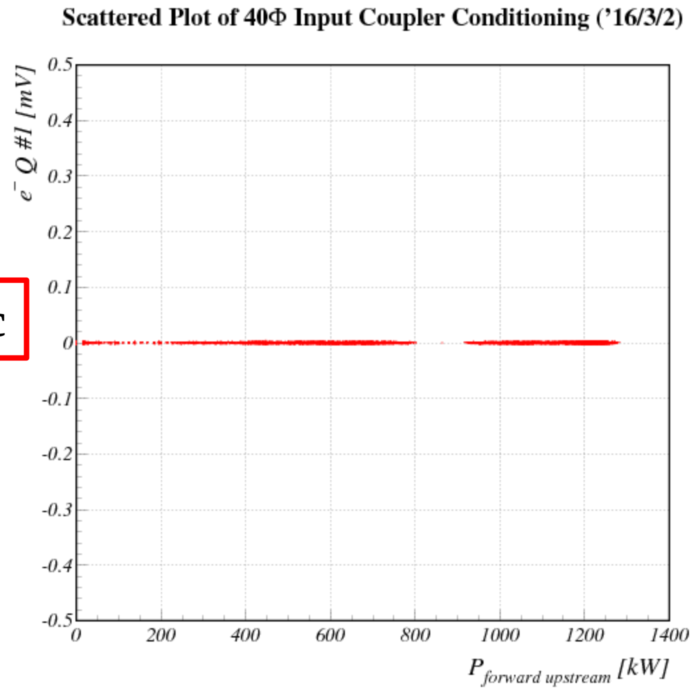
Pulse width : 30[μsec]
Rep.   frequency : 5 [Hz]

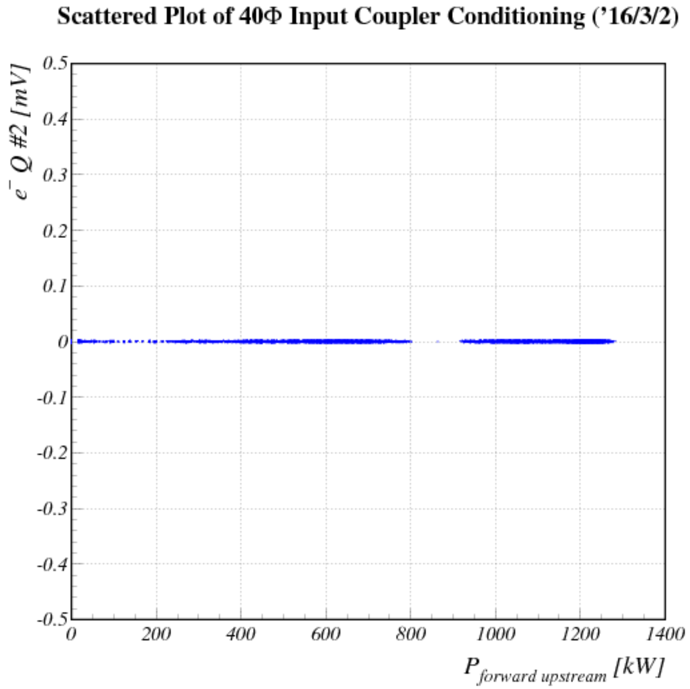
Normal ceramic





New ceramic



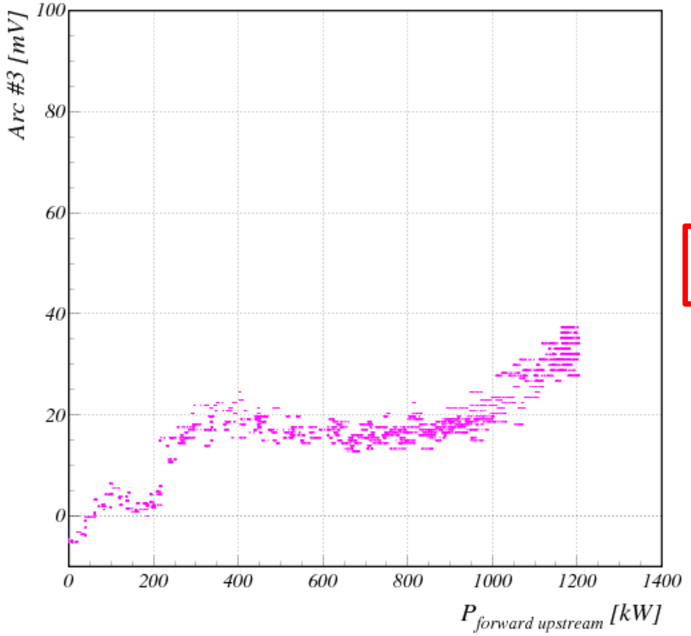


Arc vs Power

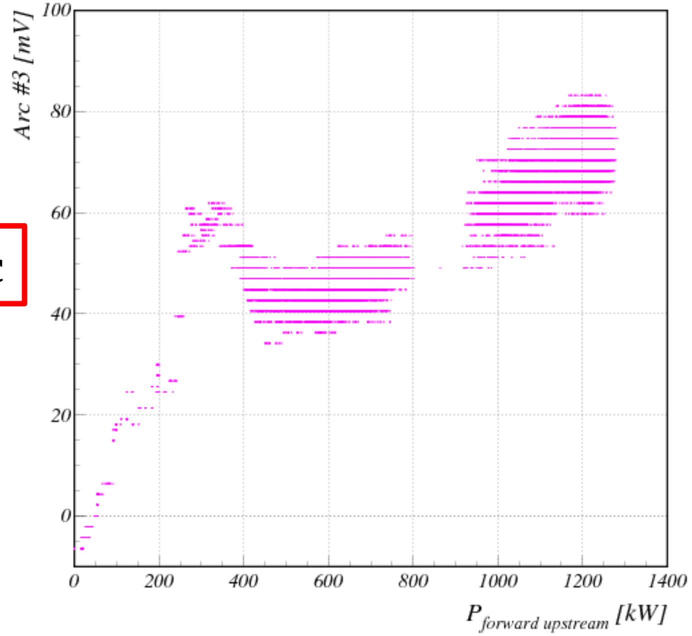
Pulse width : 30[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**

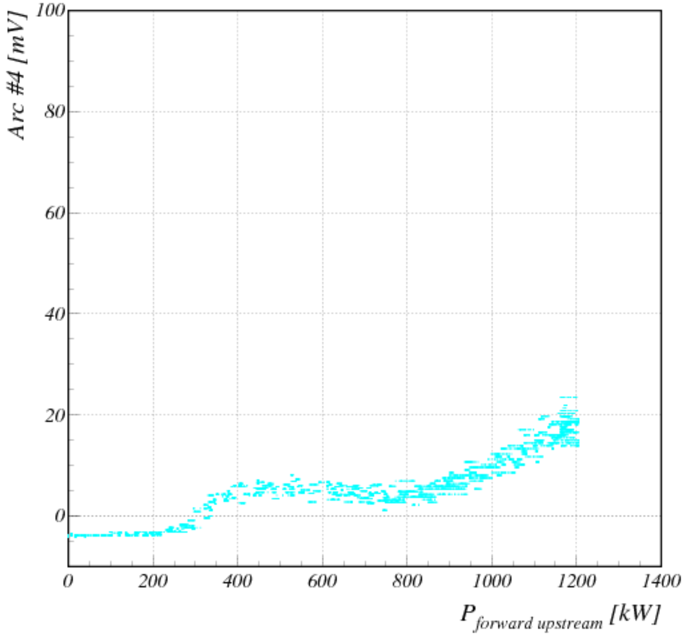
Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/29)



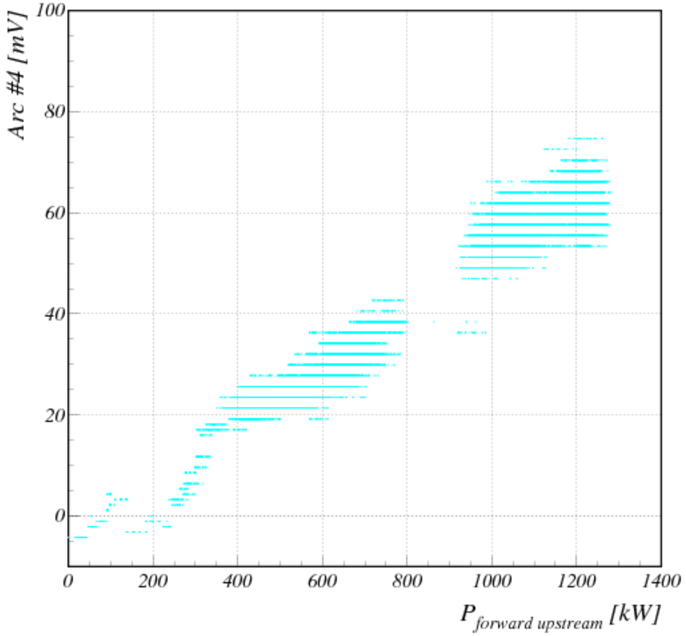
Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/2)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/29)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/2)



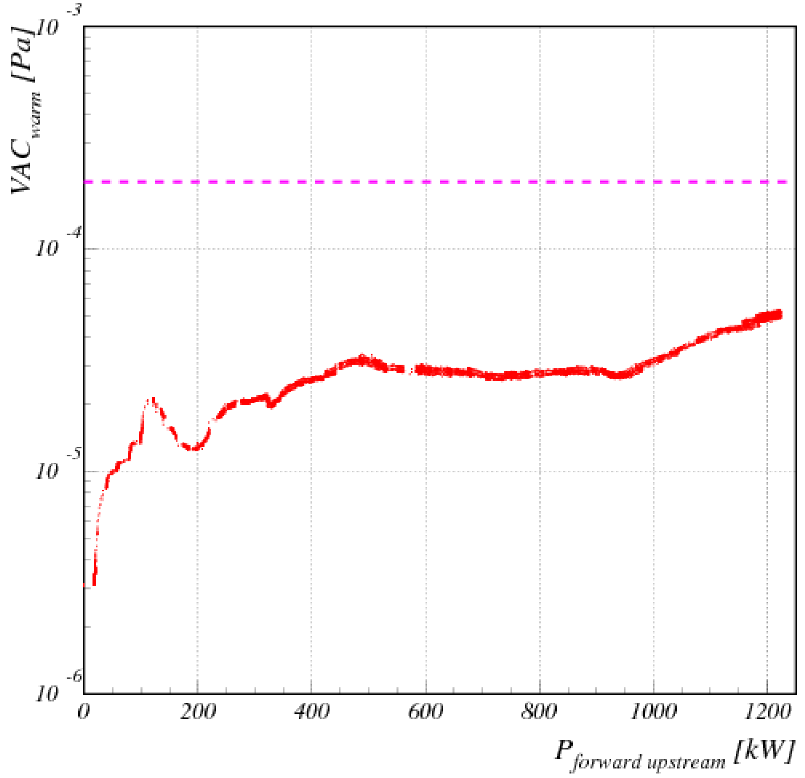
Comparison of Normal/New ceramic coupler

Warm Vac vs Power

Pulse width : 100[μsec]
Rep. frequency : 5 [Hz]

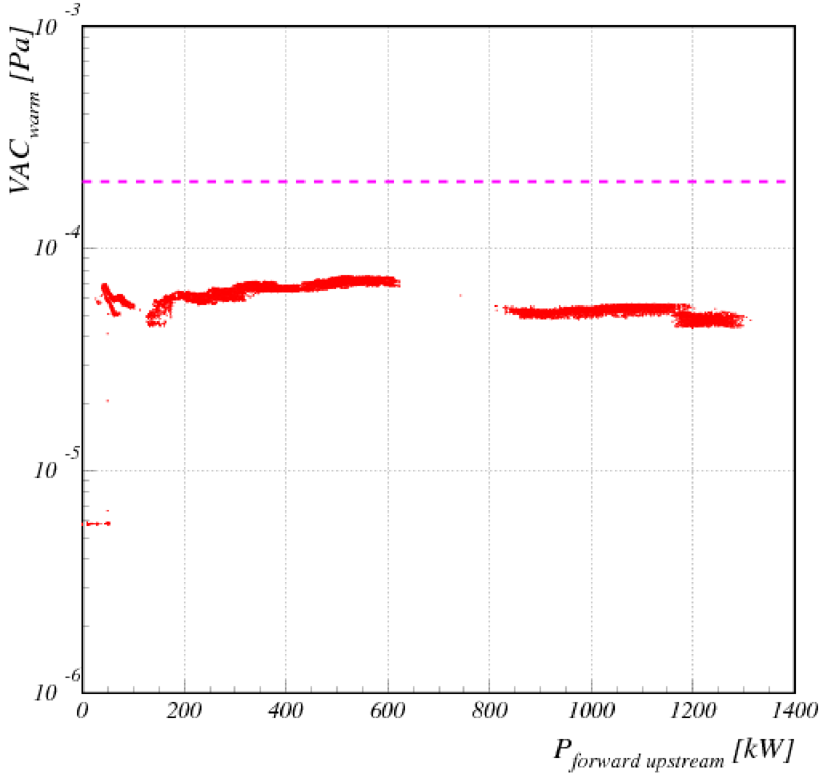
Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/1)



New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/3)



Comparison of Normal/New ceramic coupler

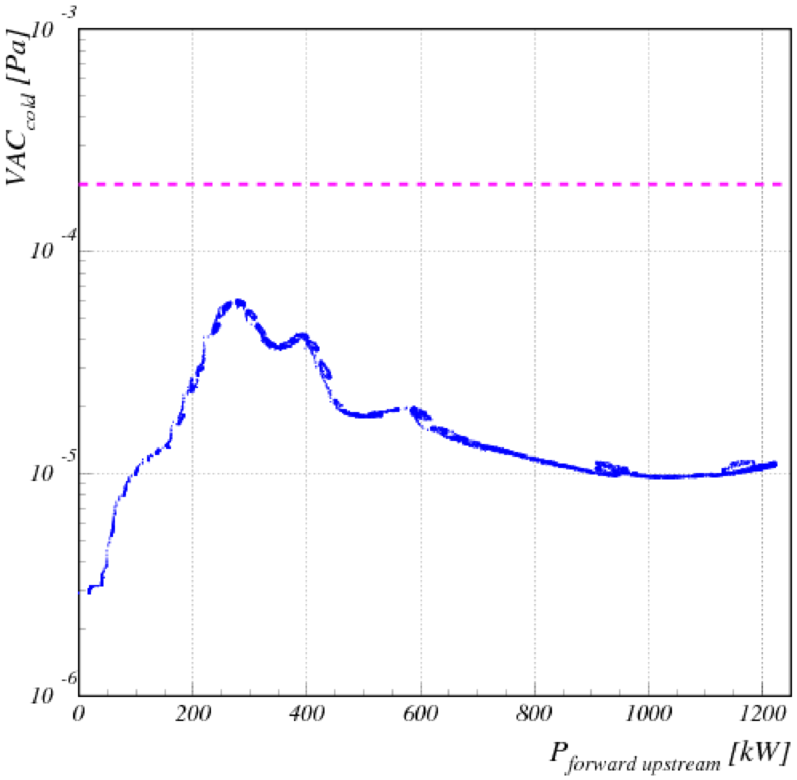
Cold Vac vs Power

Normal ceramic

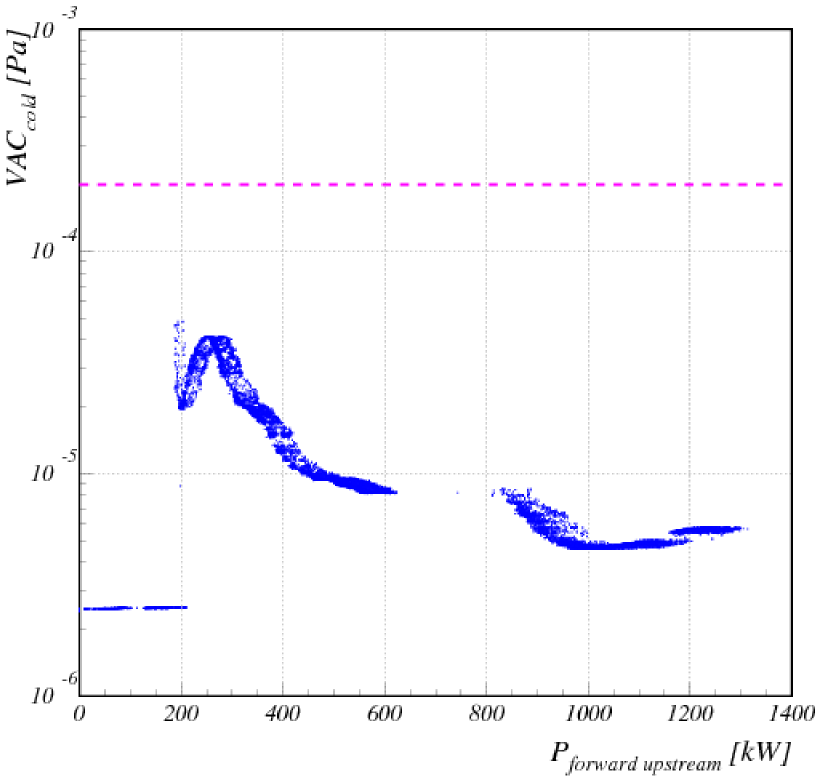
Pulse width : 100[μsec]
Rep. frequency : 5 [Hz]

New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/1)



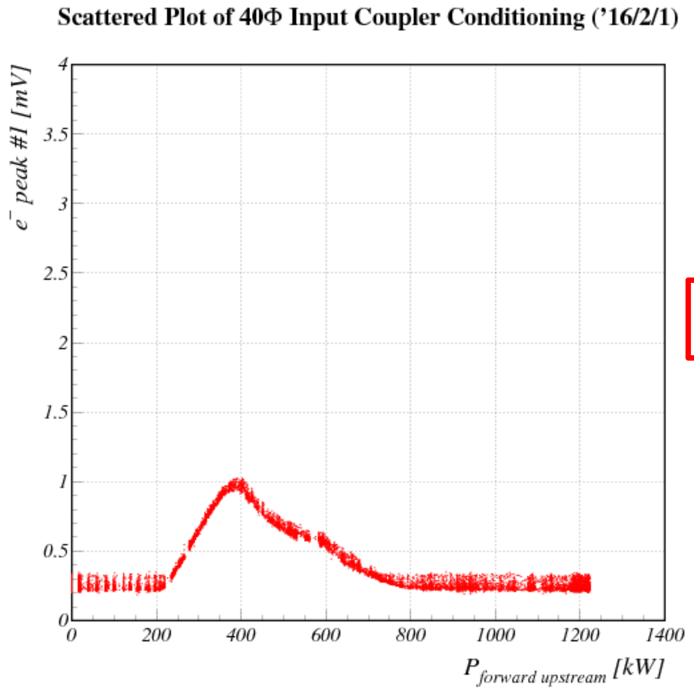
Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/3)

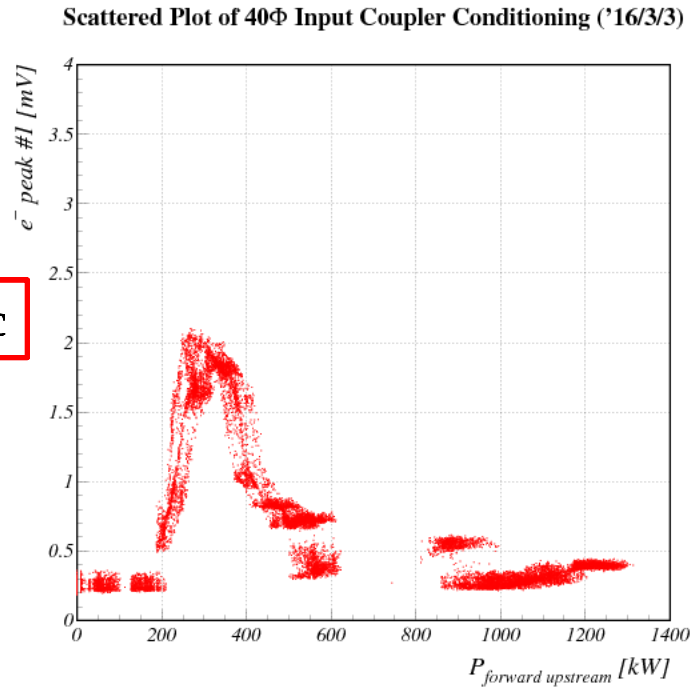


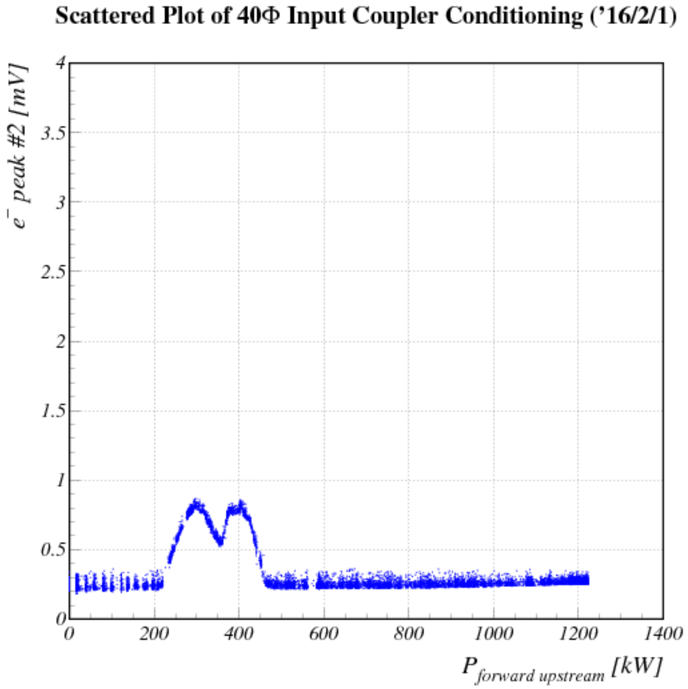
Electron peak vs Power

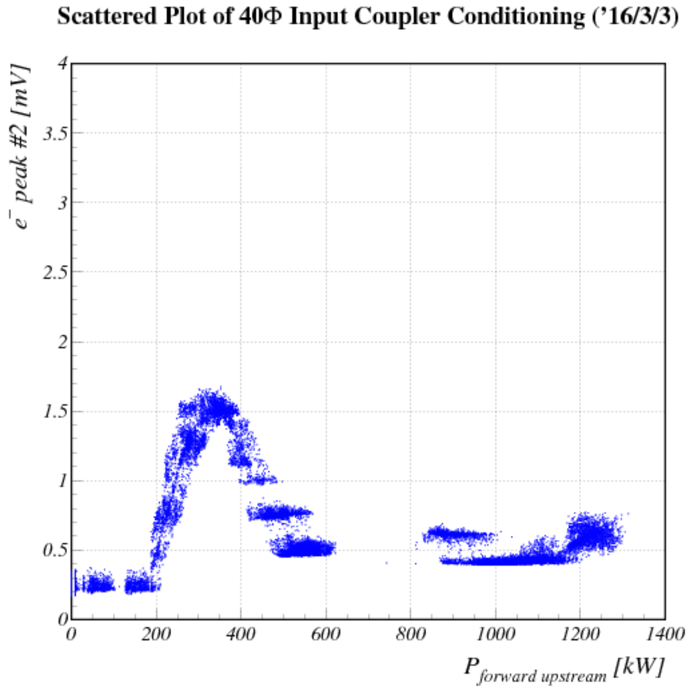
Pulse width : 100[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**





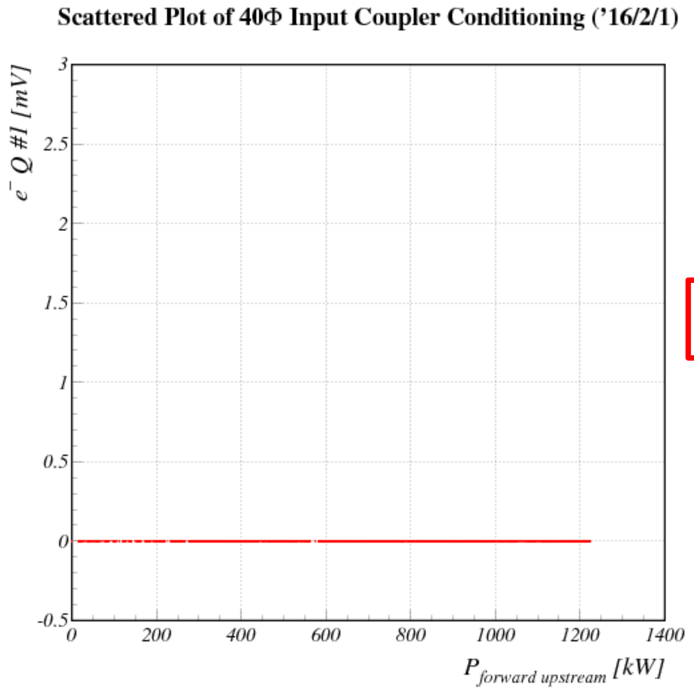


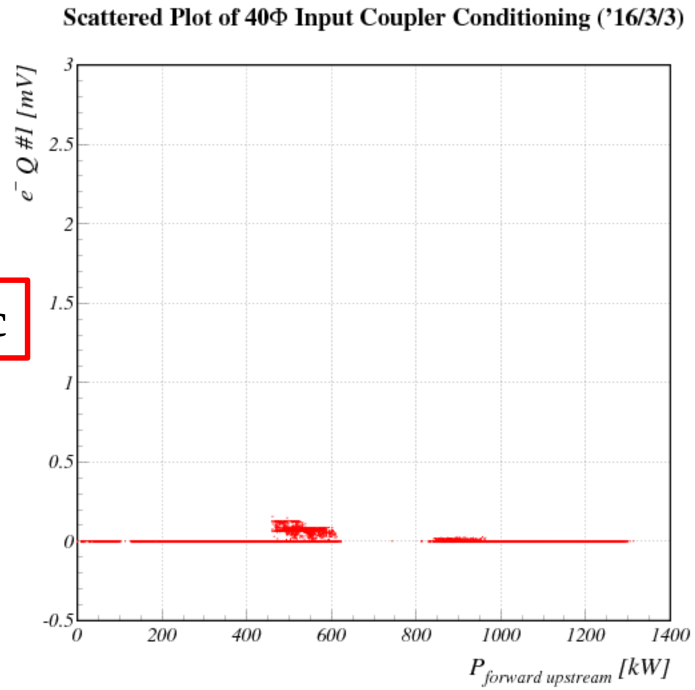


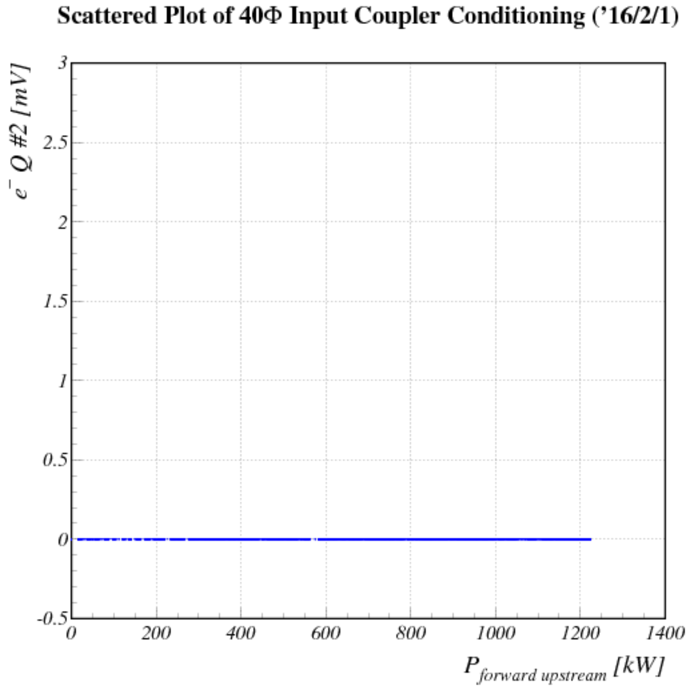
Electron Q vs Power

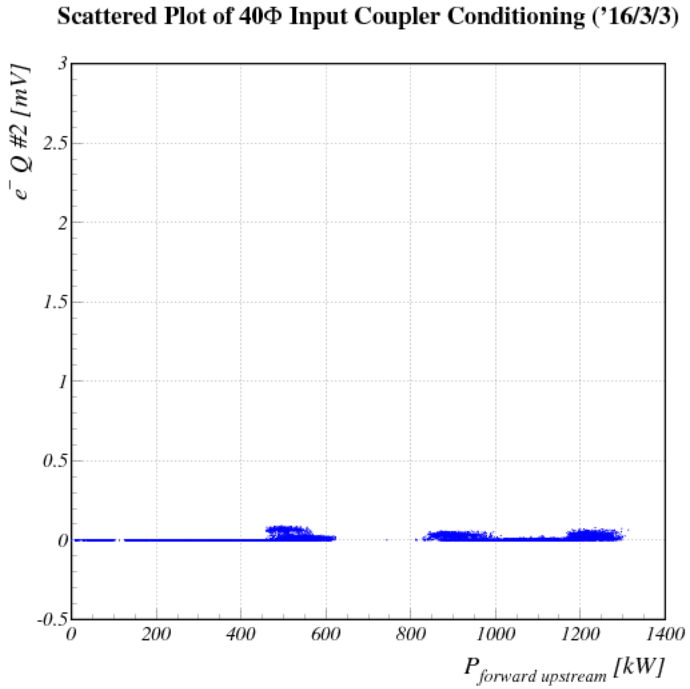
Pulse width : 100[μsec]
Rep.   frequency : 5 [Hz]

Normal ceramic | **New ceramic**





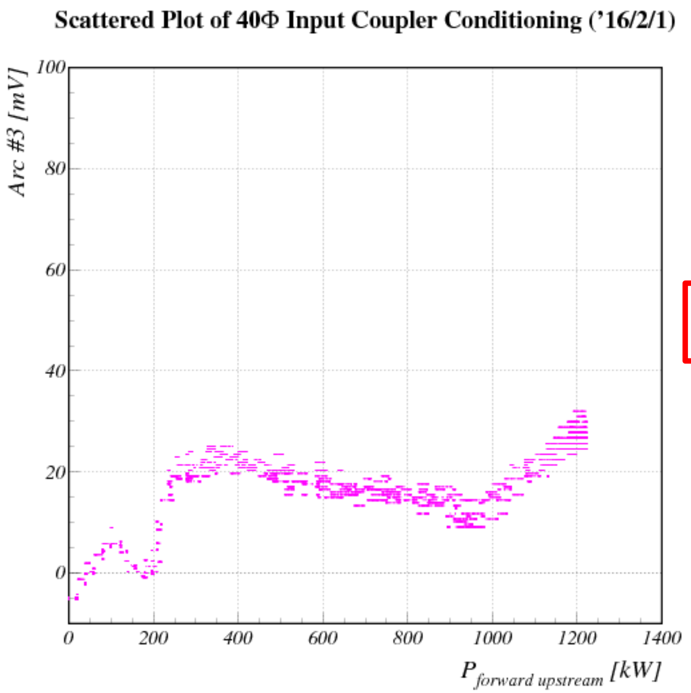


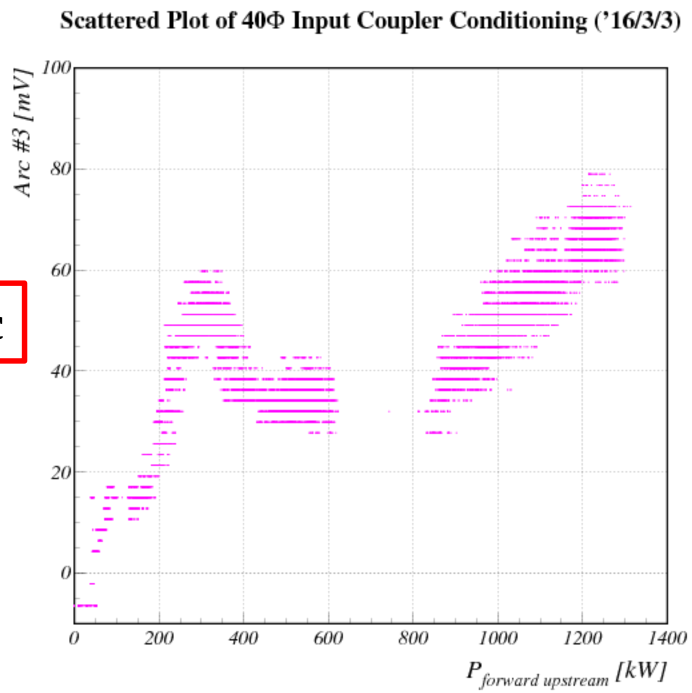


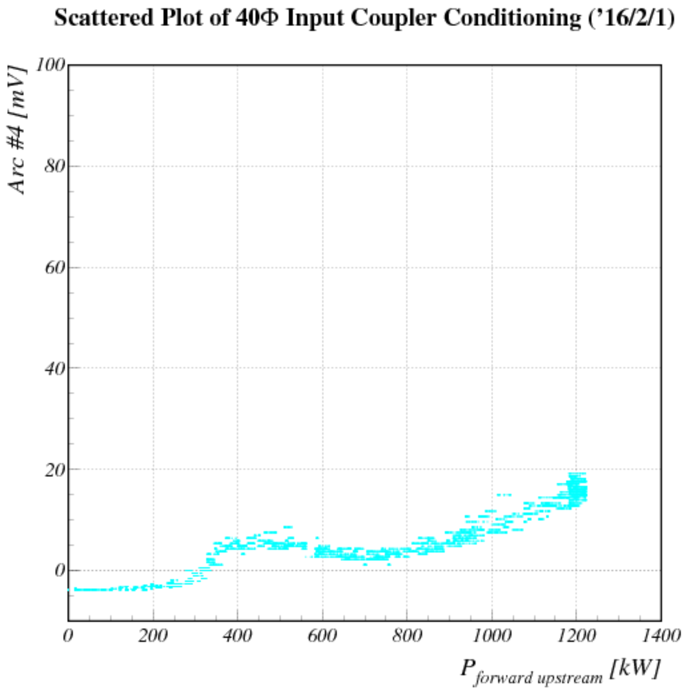
Arc vs Power

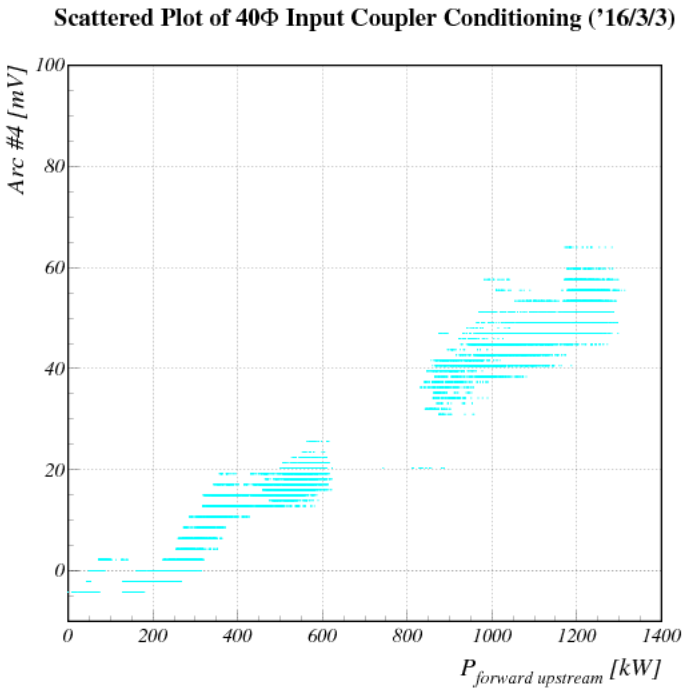
Pulse width : 100[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**









Comparison of Normal/New ceramic coupler

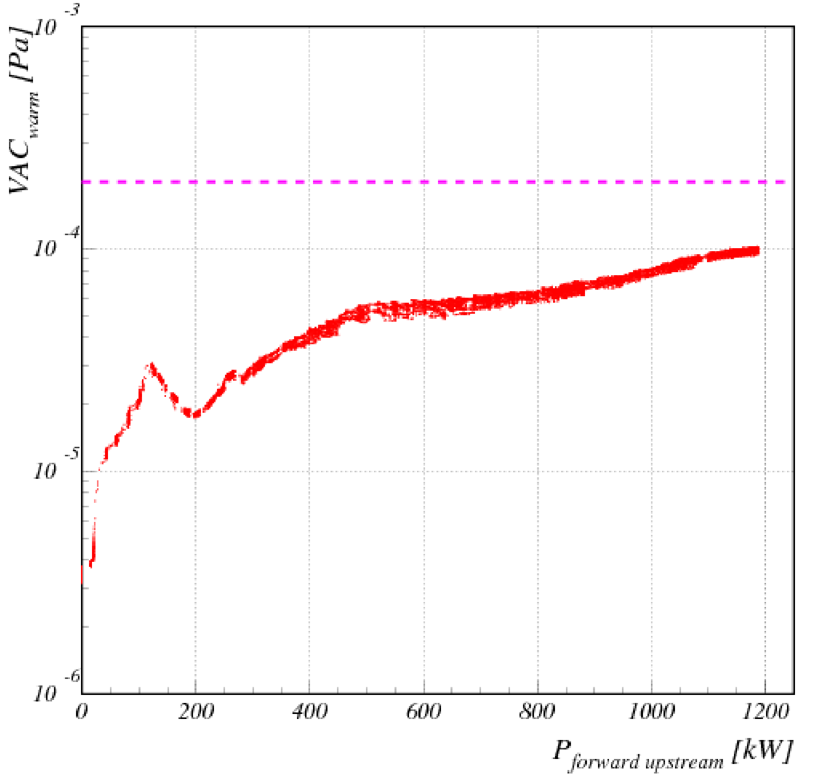
Warm Vac vs Power

Normal ceramic

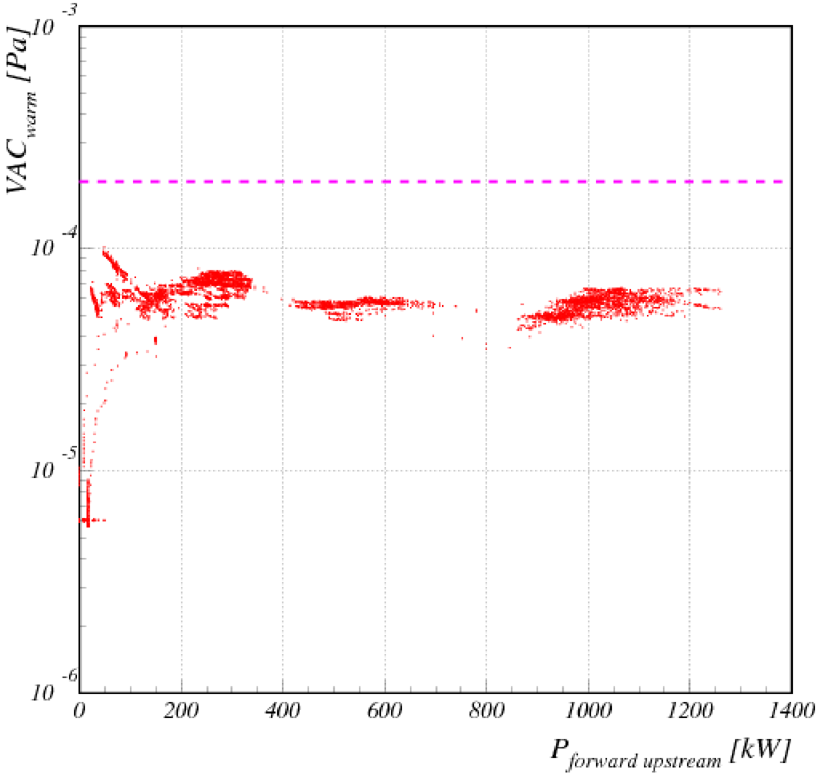
Pulse width : 500[μsec]
Rep.   frequency : 5 [Hz]

New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

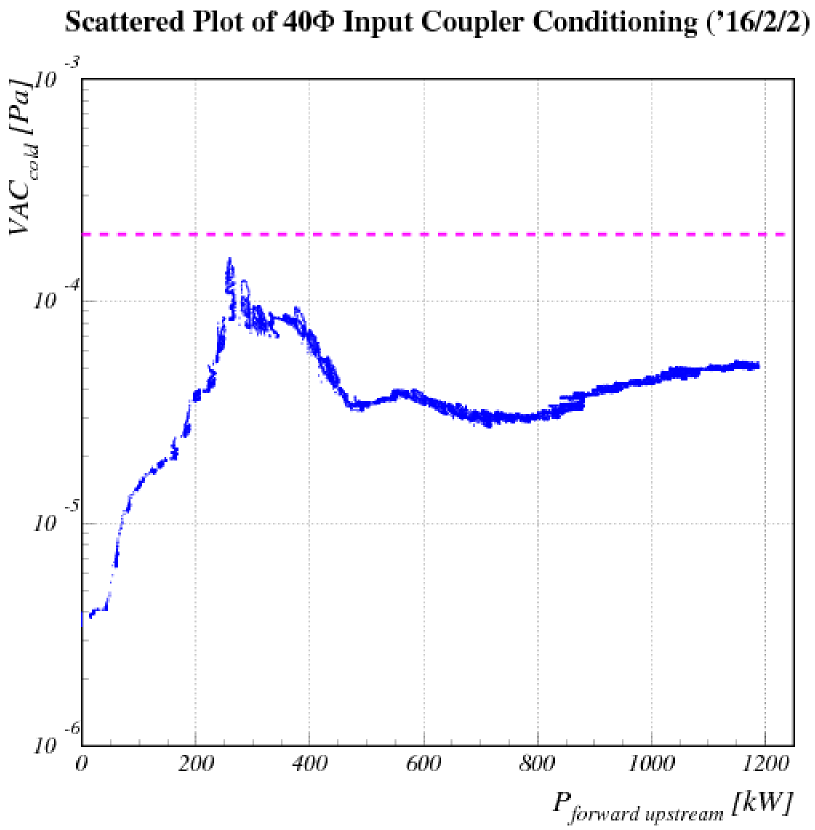


Comparison of Normal/New ceramic coupler

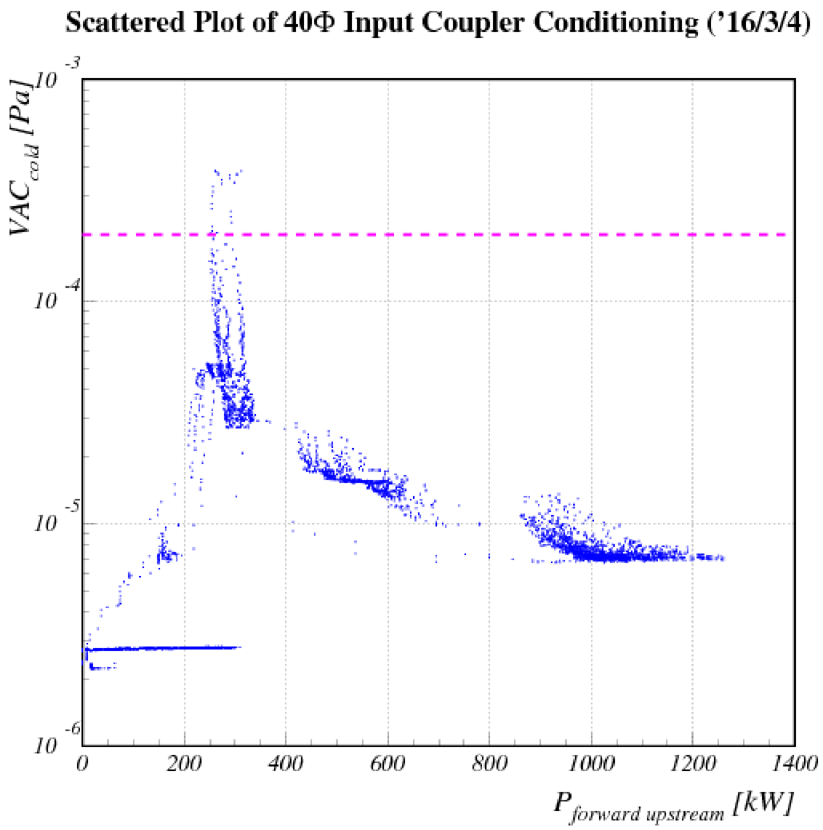
Cold Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic



New ceramic

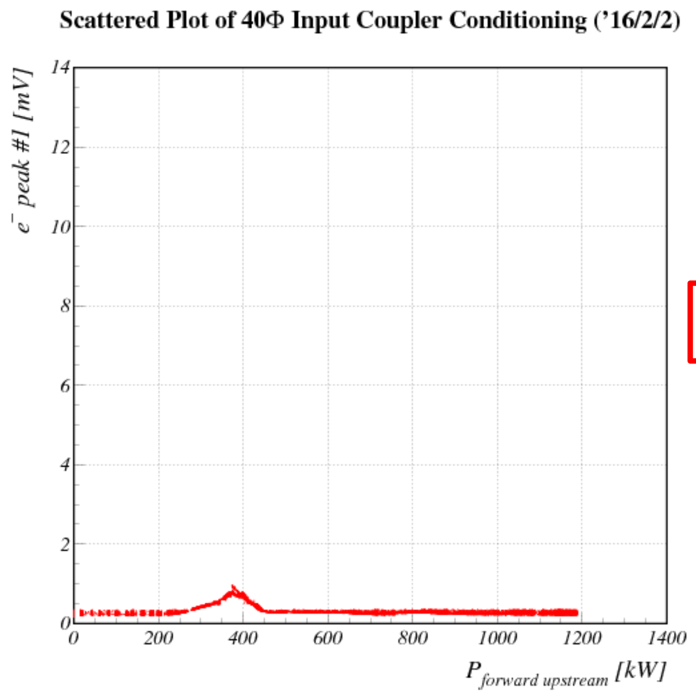


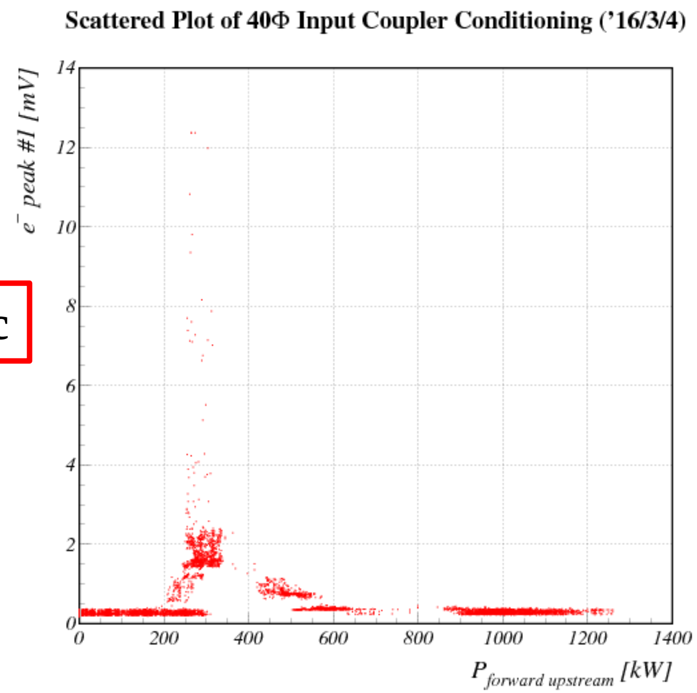
Electron peak vs Power

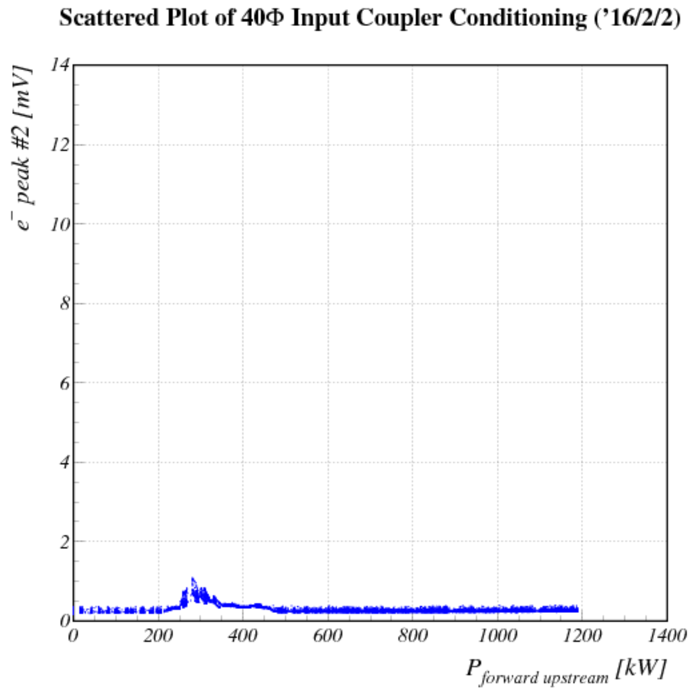
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

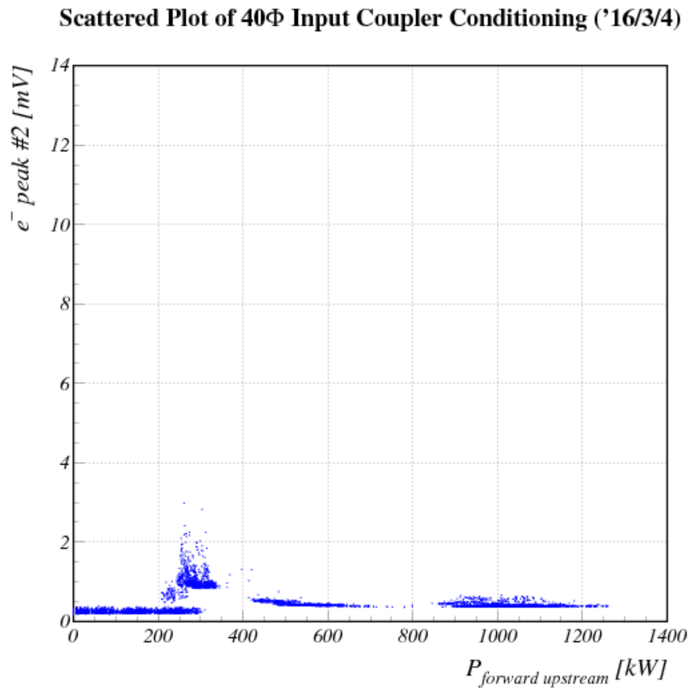
Normal ceramic

New ceramic





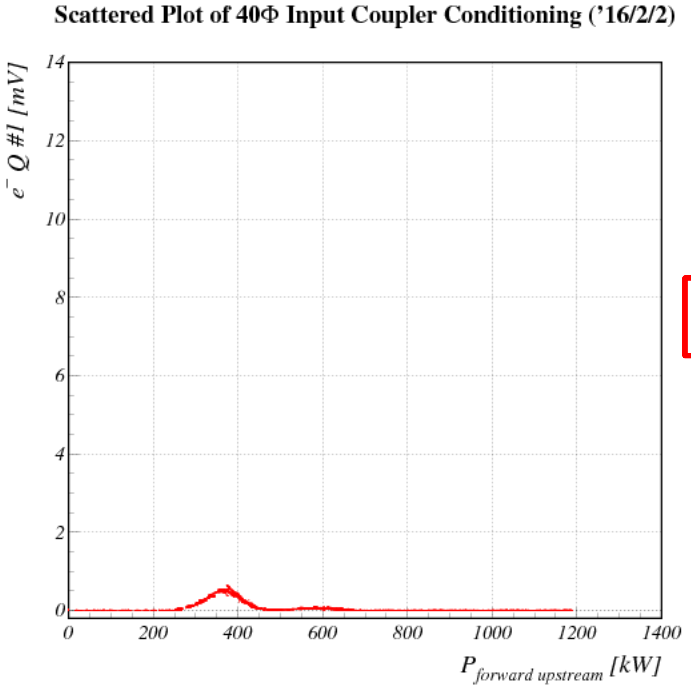


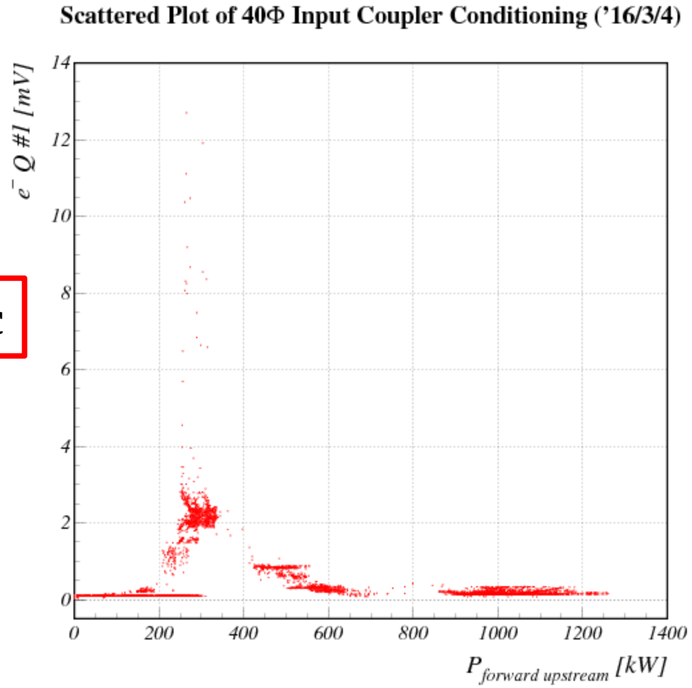


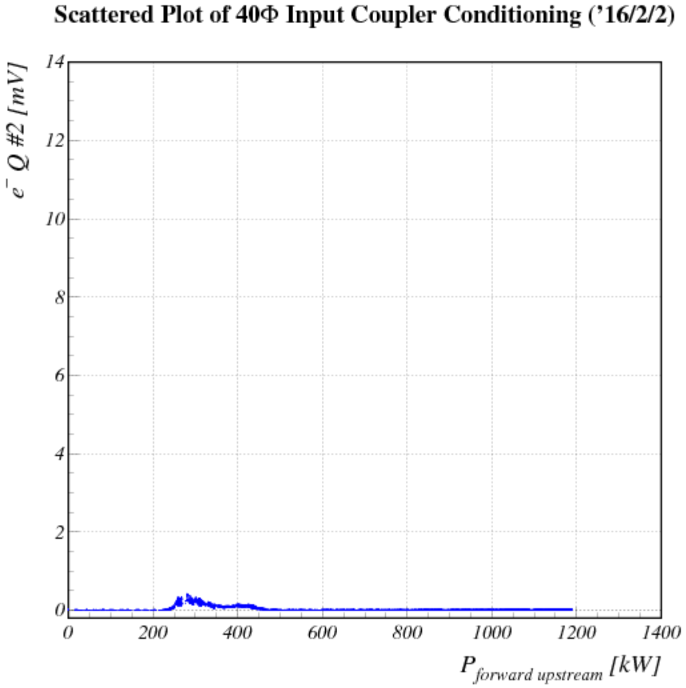
Electron Q vs Power

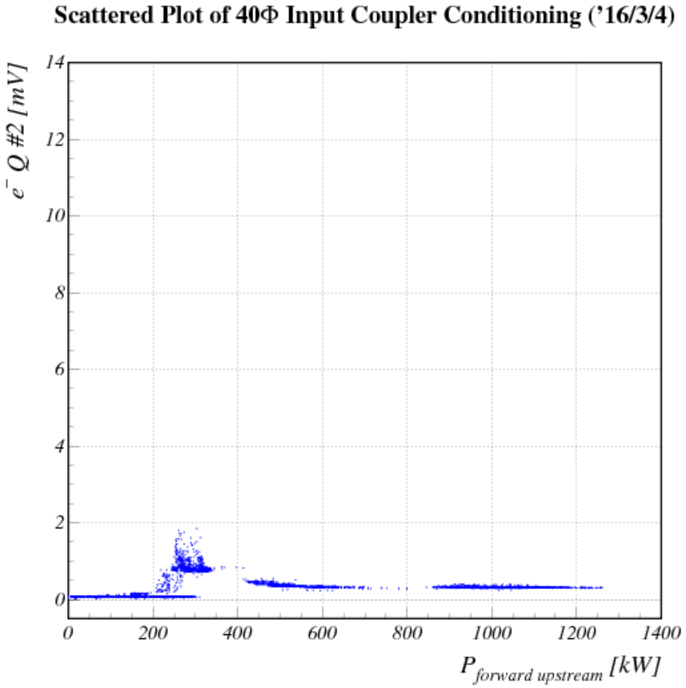
Pulse width : 500[μsec]
Rep.   frequency : 5 [Hz]

Normal ceramic | **New ceramic**





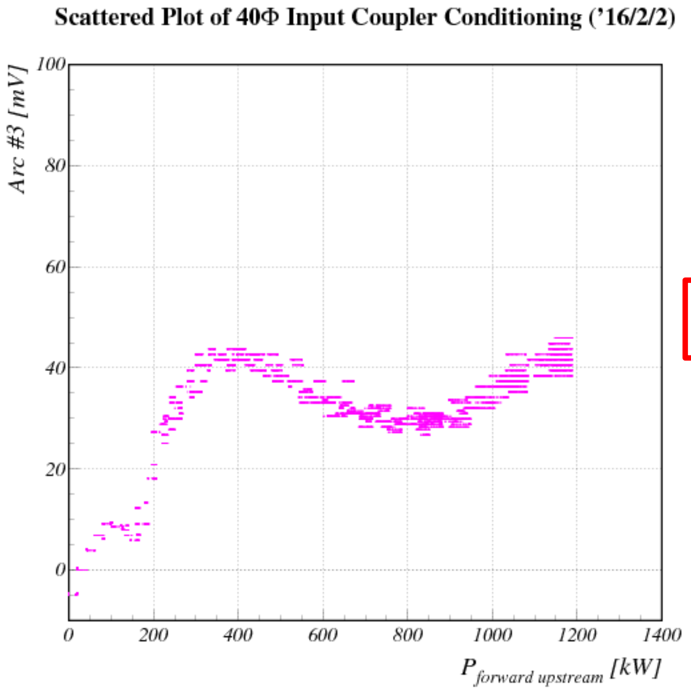


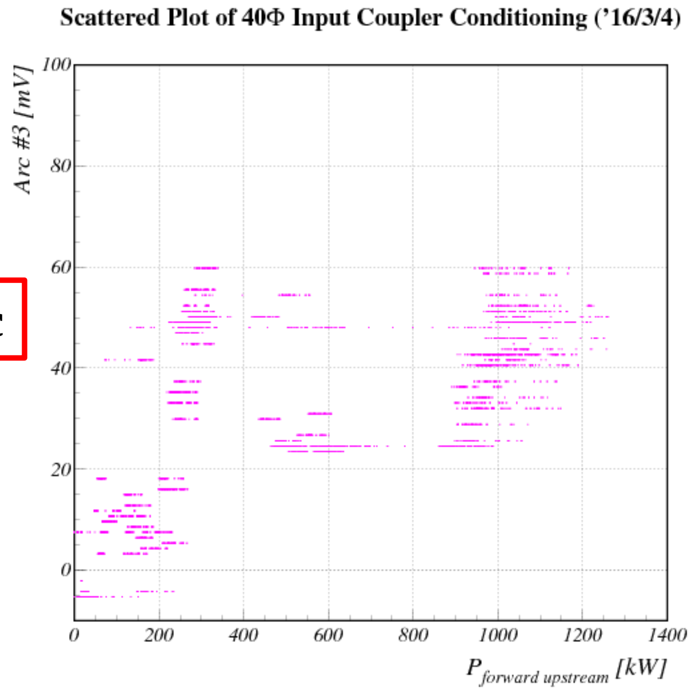


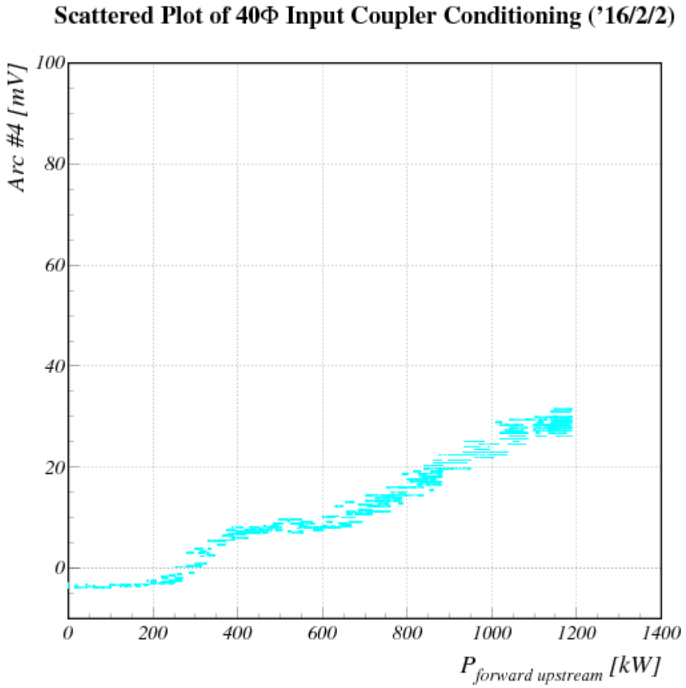
Arc vs Power

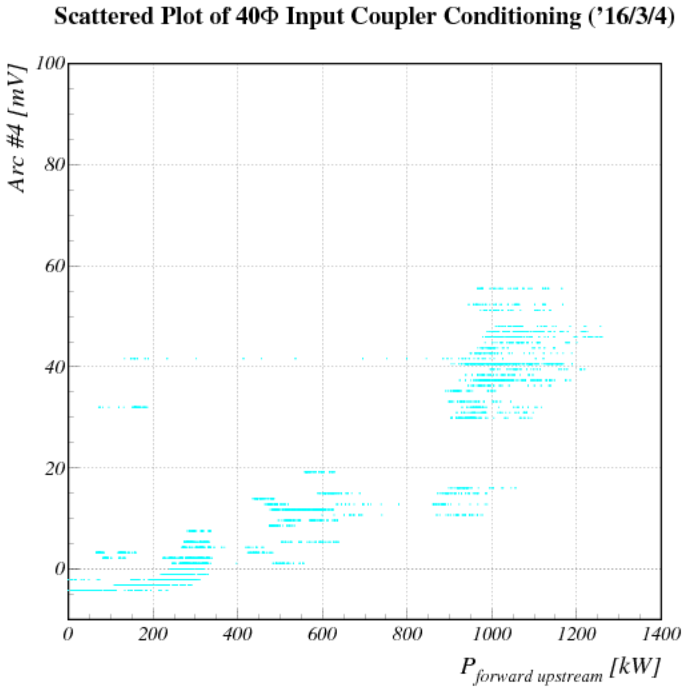
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic | **New ceramic**









Normal ceramic

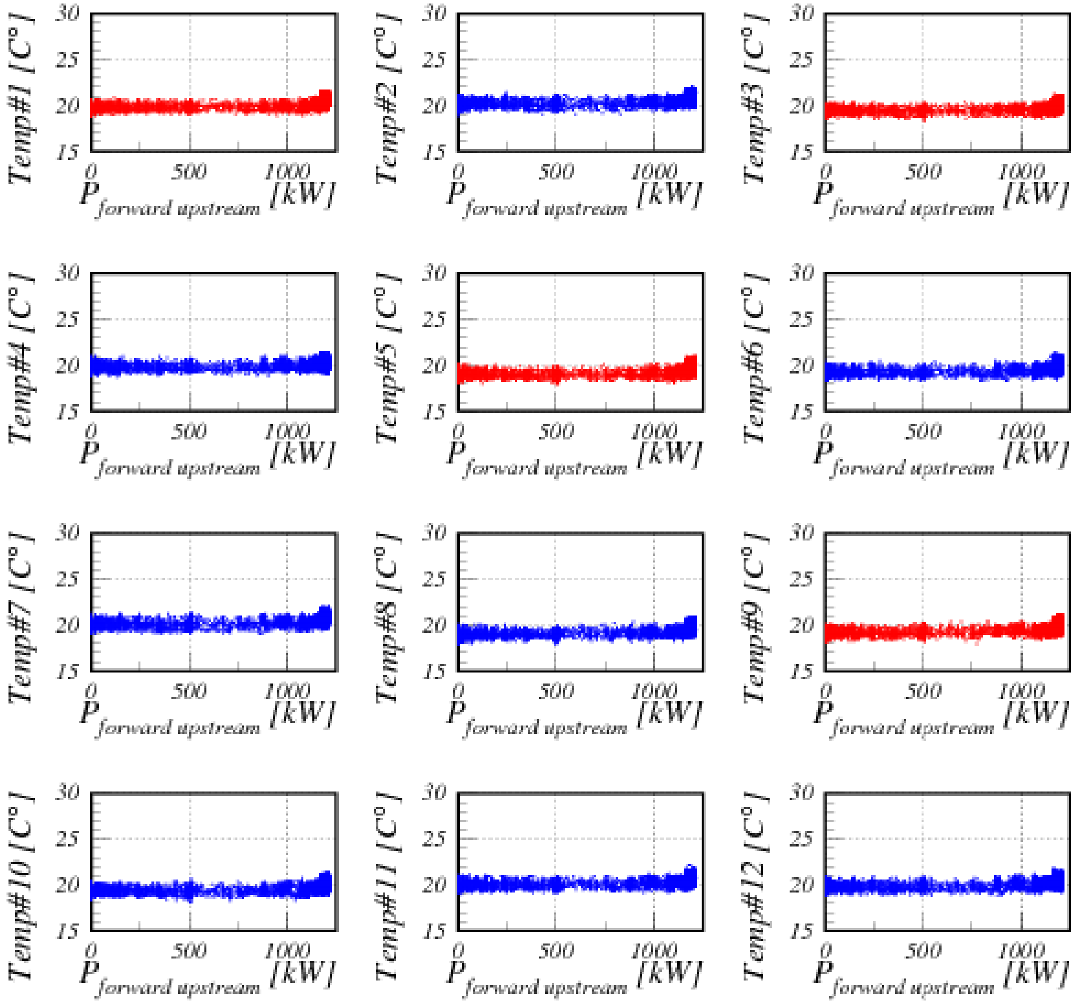
Pulse width : 10[μsec]
No fan

temperature

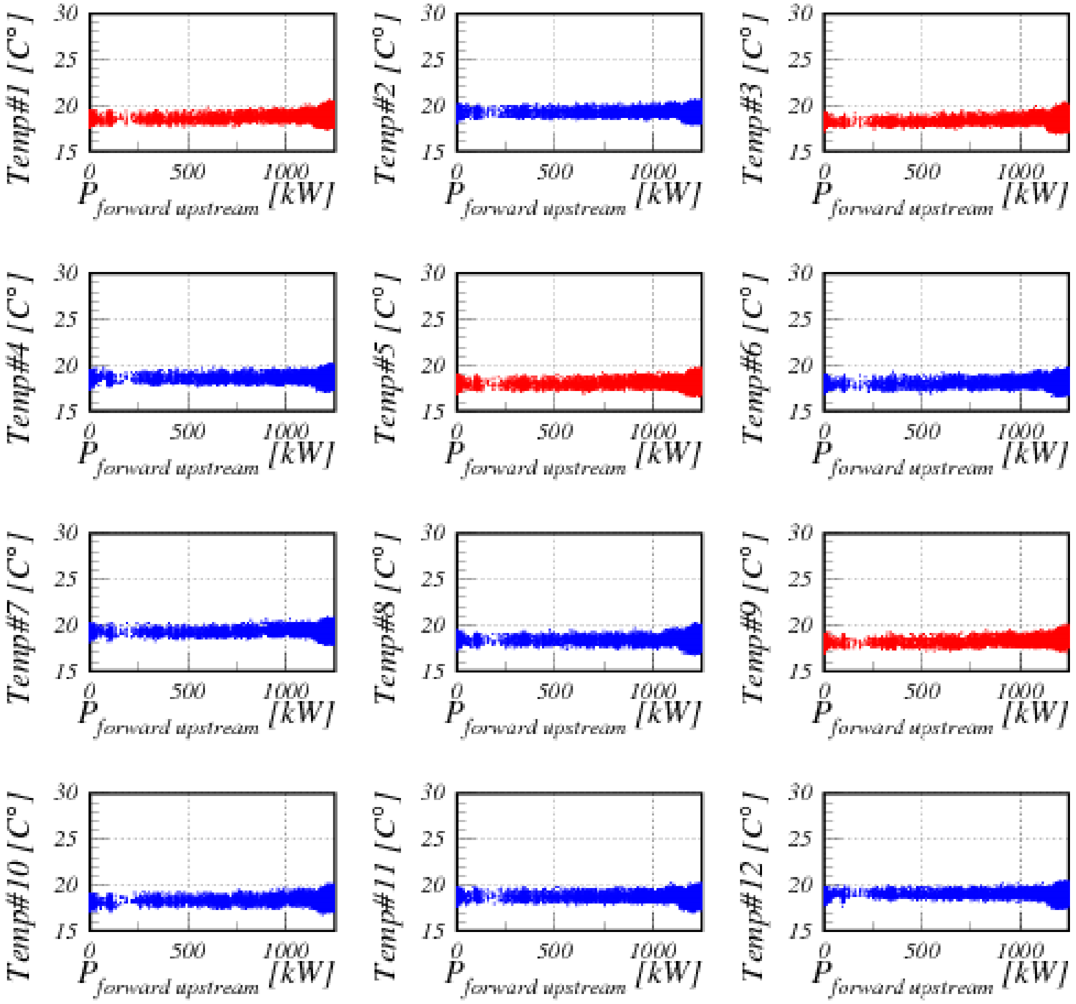
New ceramic

Pulse width : 10[μsec]
No fan

Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/27)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/2)

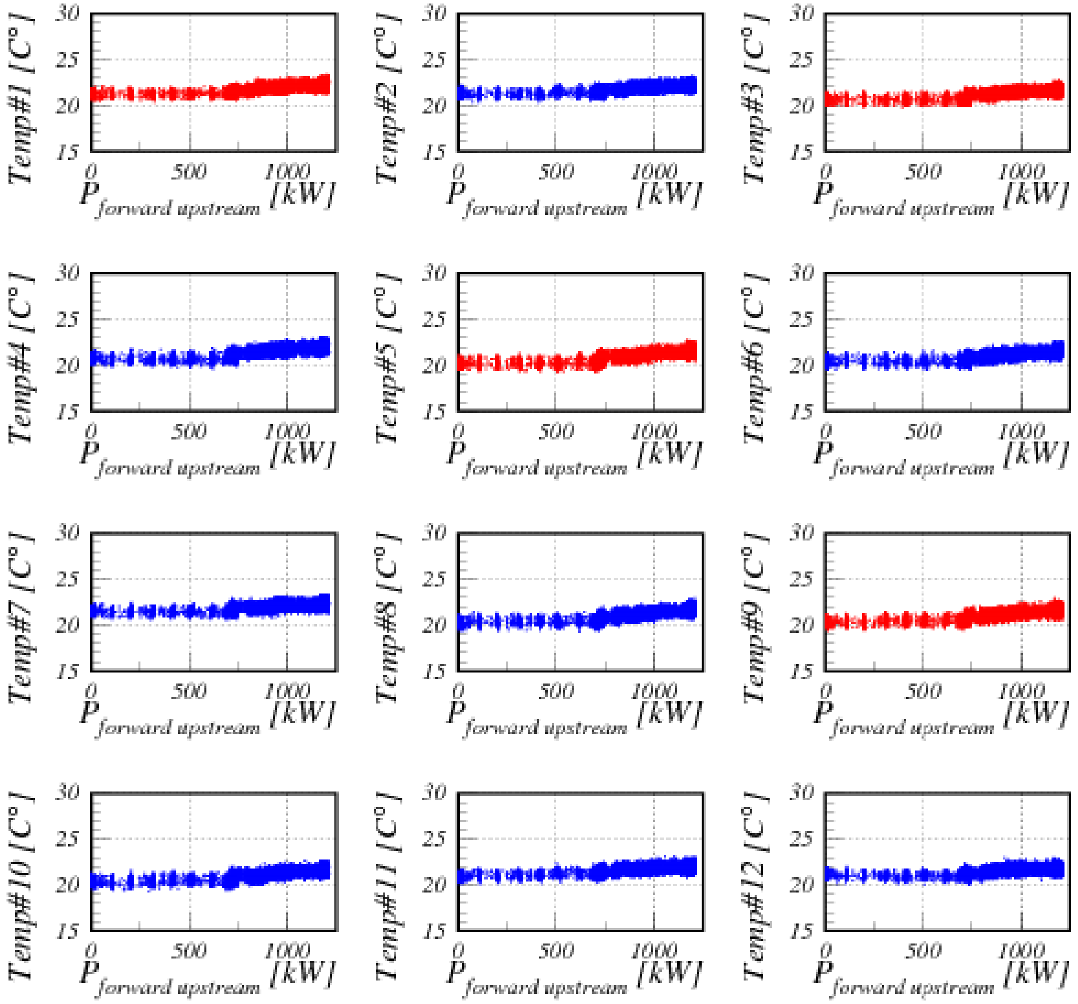


temperature

Normal ceramic

Pulse width : 30[μsec]
No fan

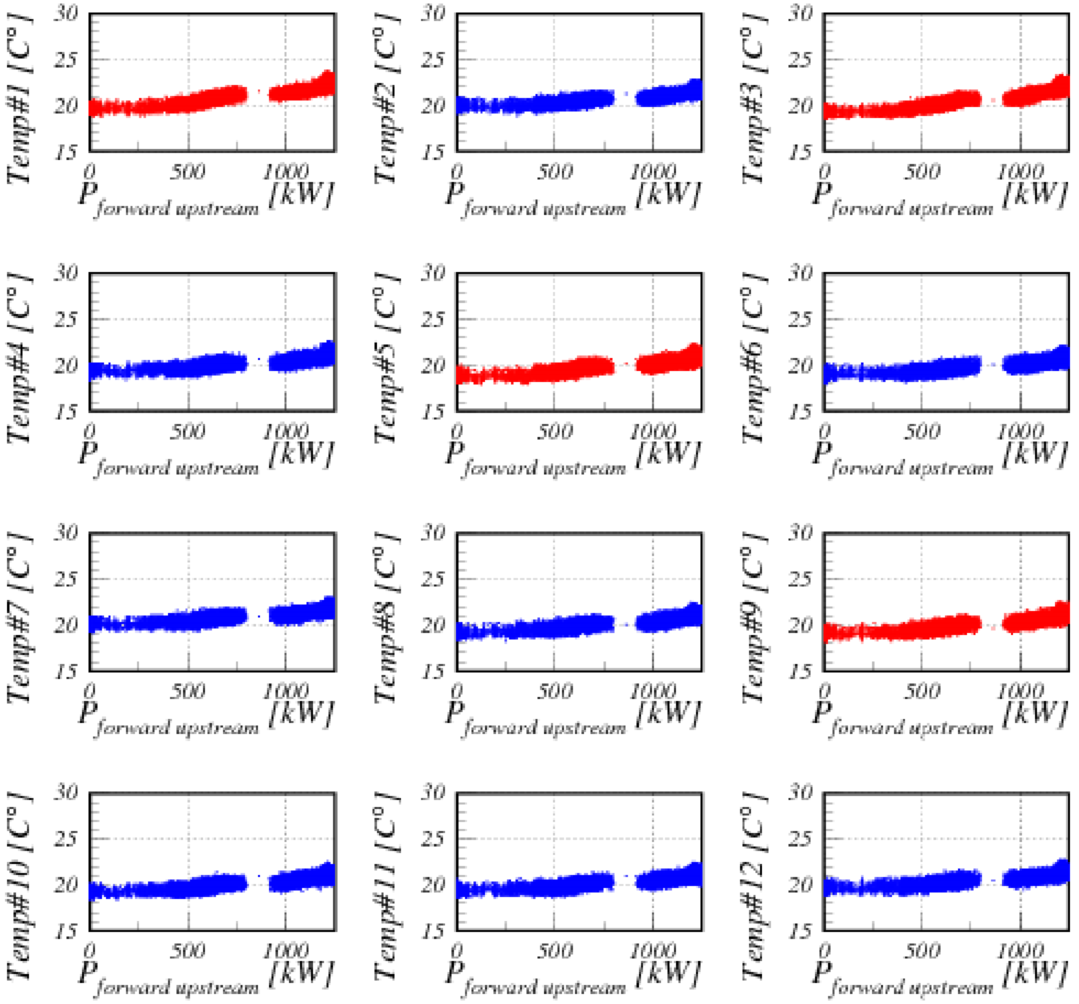
Scattered Plot of 40Φ Input Coupler Conditioning ('16/1/28)



New ceramic

Pulse width : 30[μsec]
No fan

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/2)

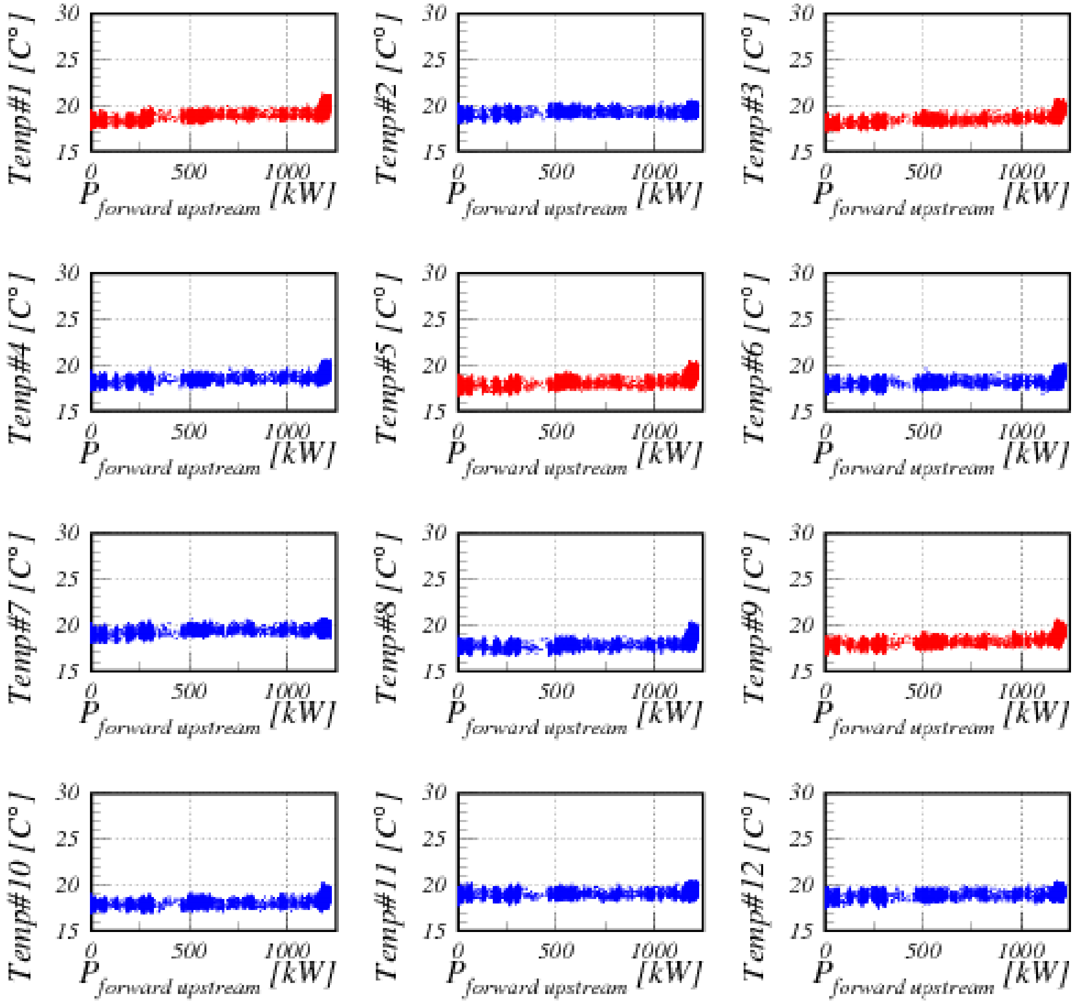


temperature

Normal ceramic

Pulse width : 100[μsec]
No fan

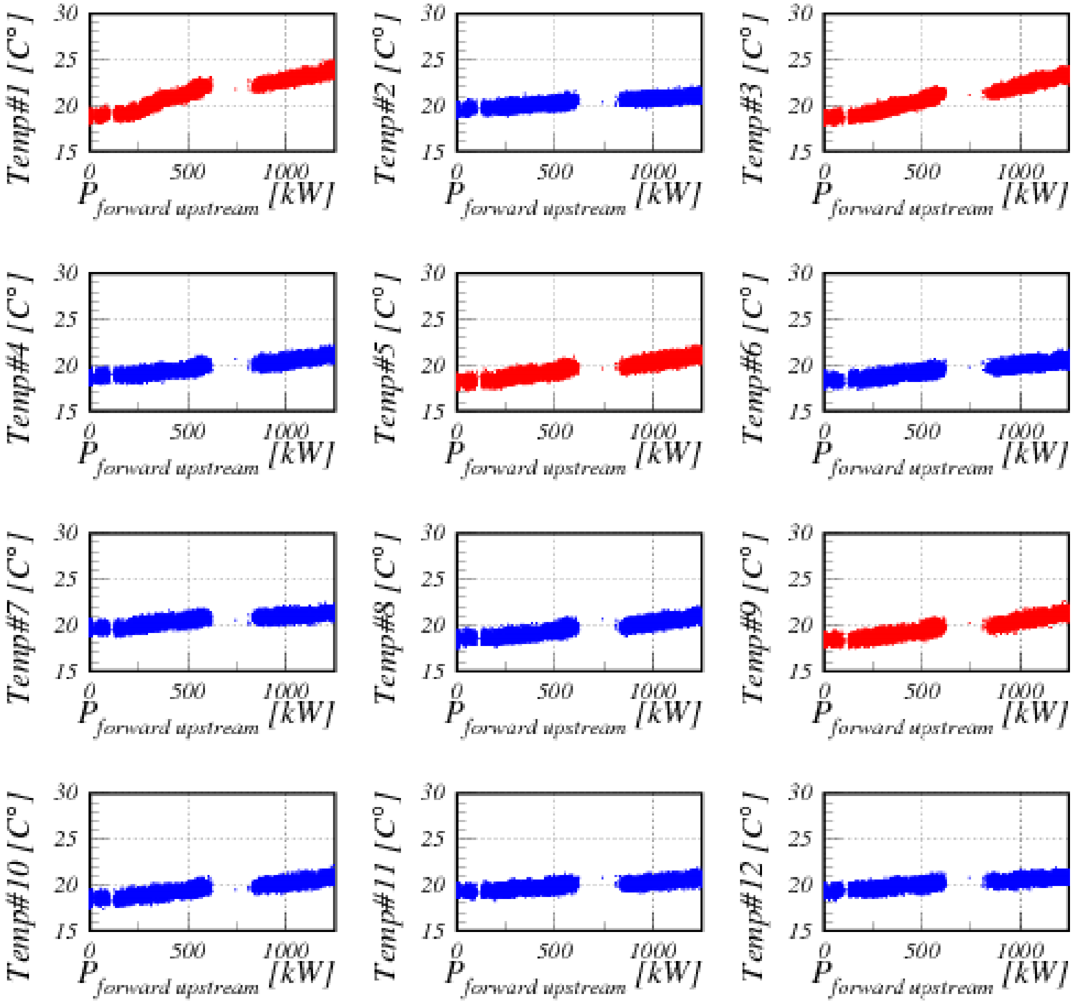
Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/1)



New ceramic

Pulse width : 100[μsec]
No fan

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/3)



Normal ceramic

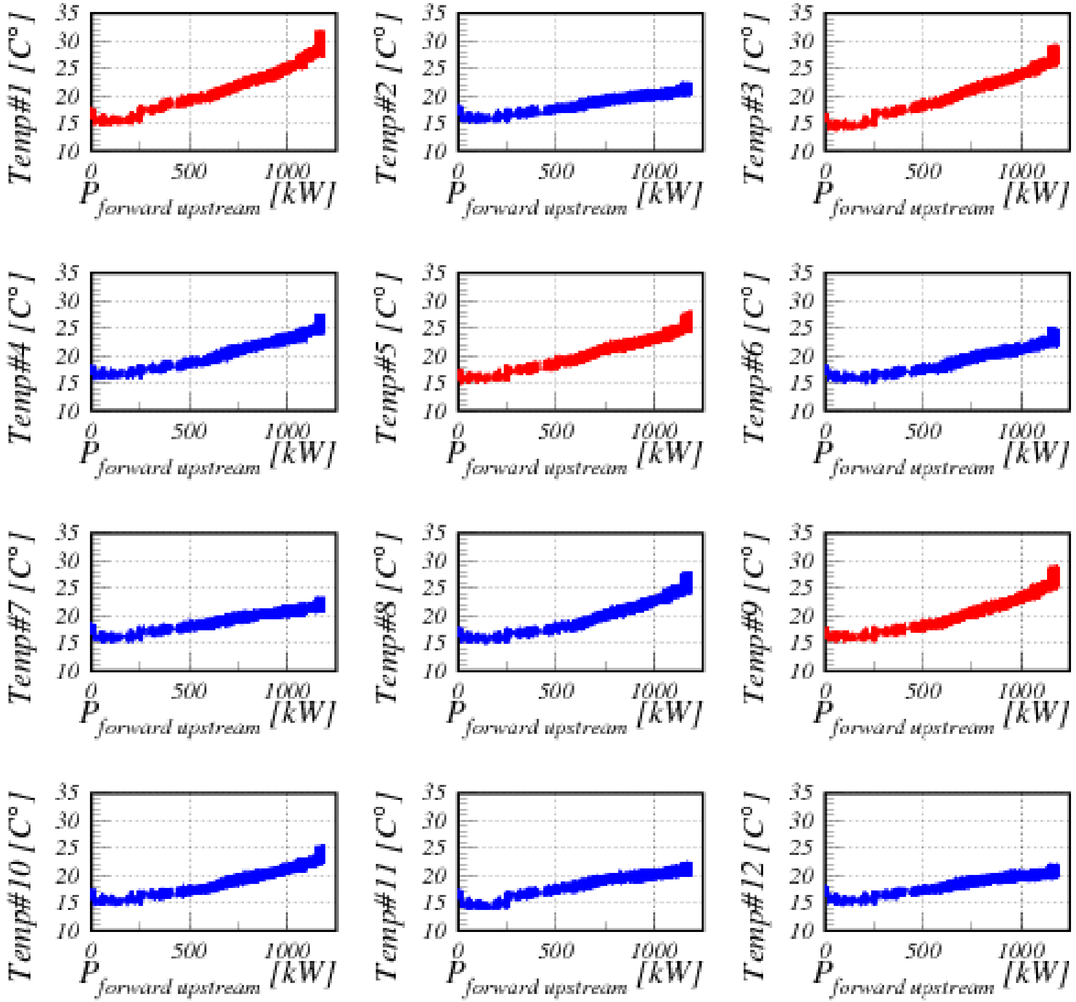
Pulse width : 500[μsec]
No fan

temperature

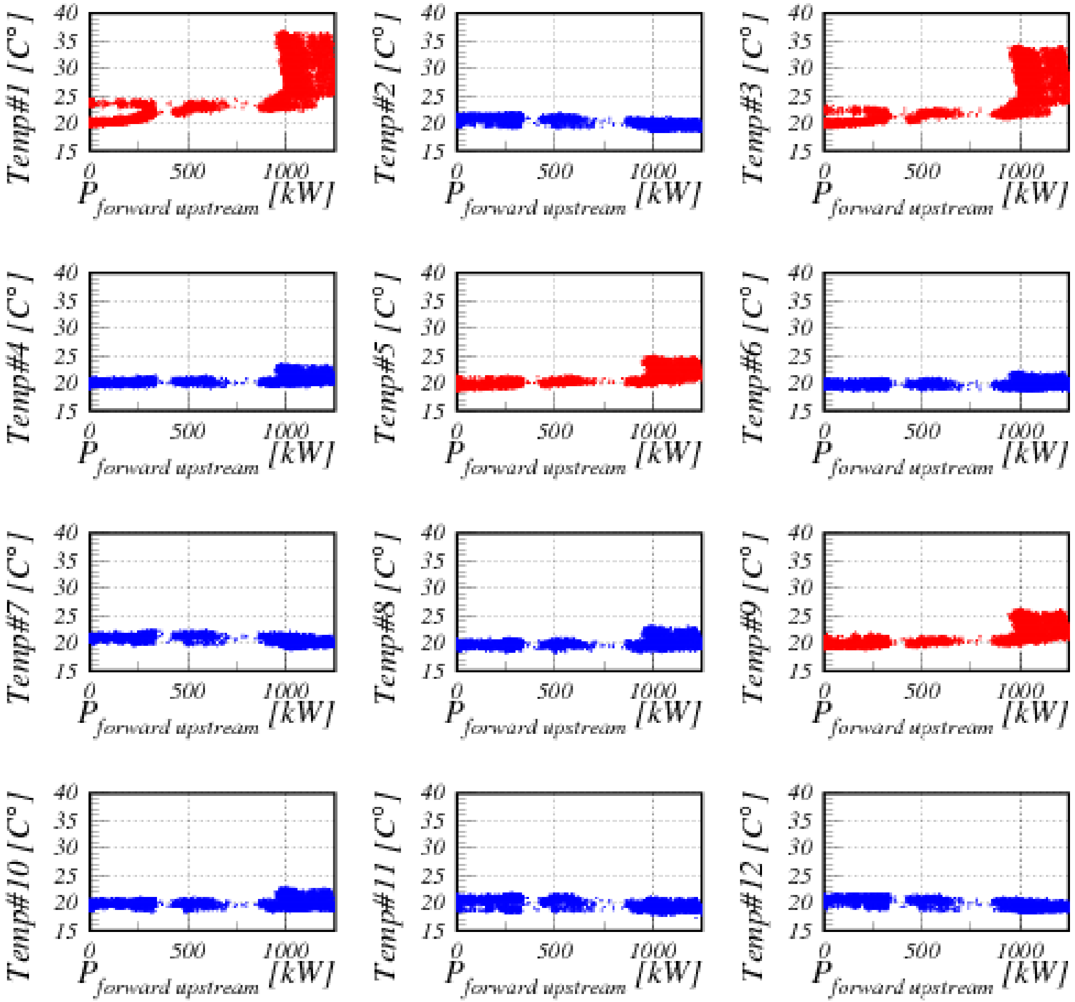
New ceramic

Pulse width : 500[μsec]
No fan

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

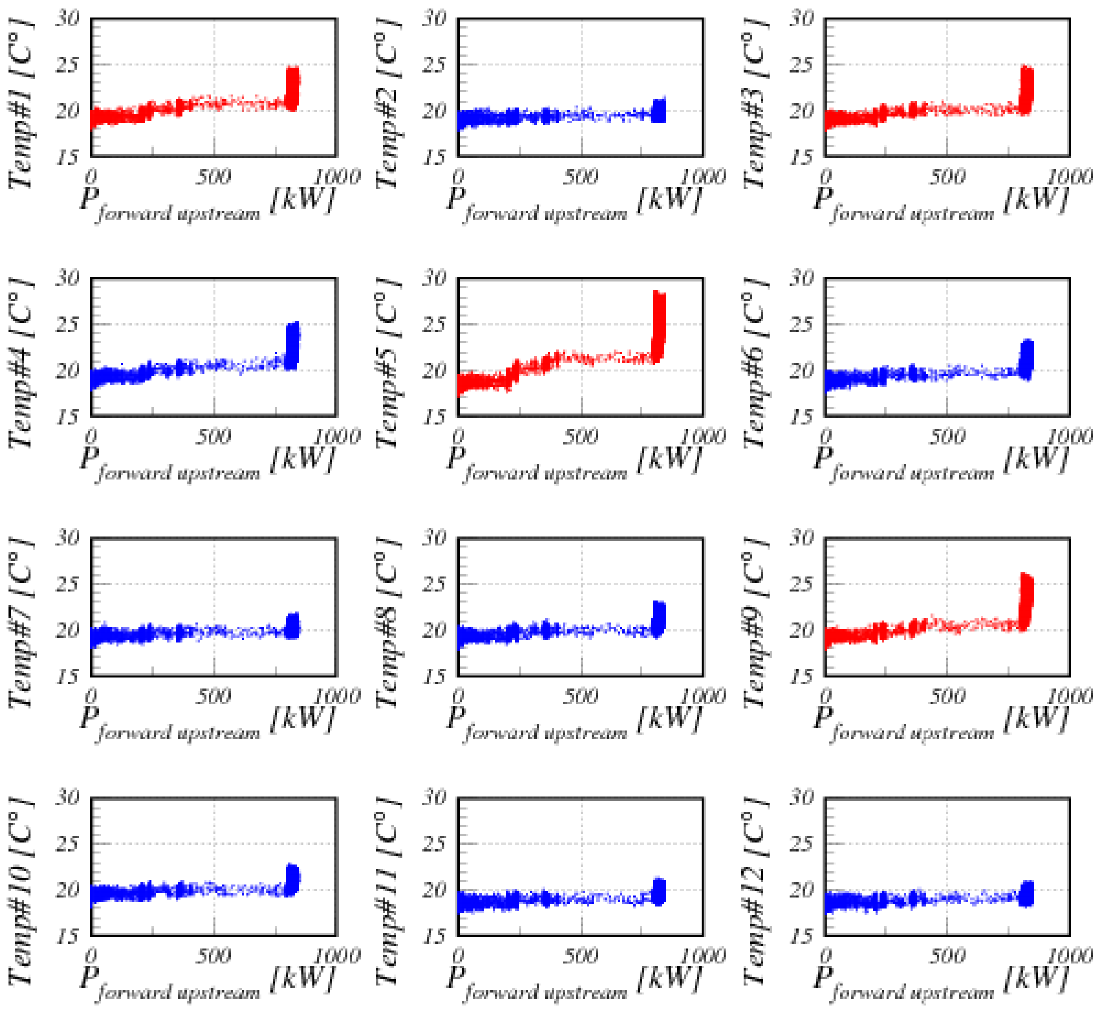


temperature

Normal ceramic

Pulse width : 1500[μsec]
3 fans

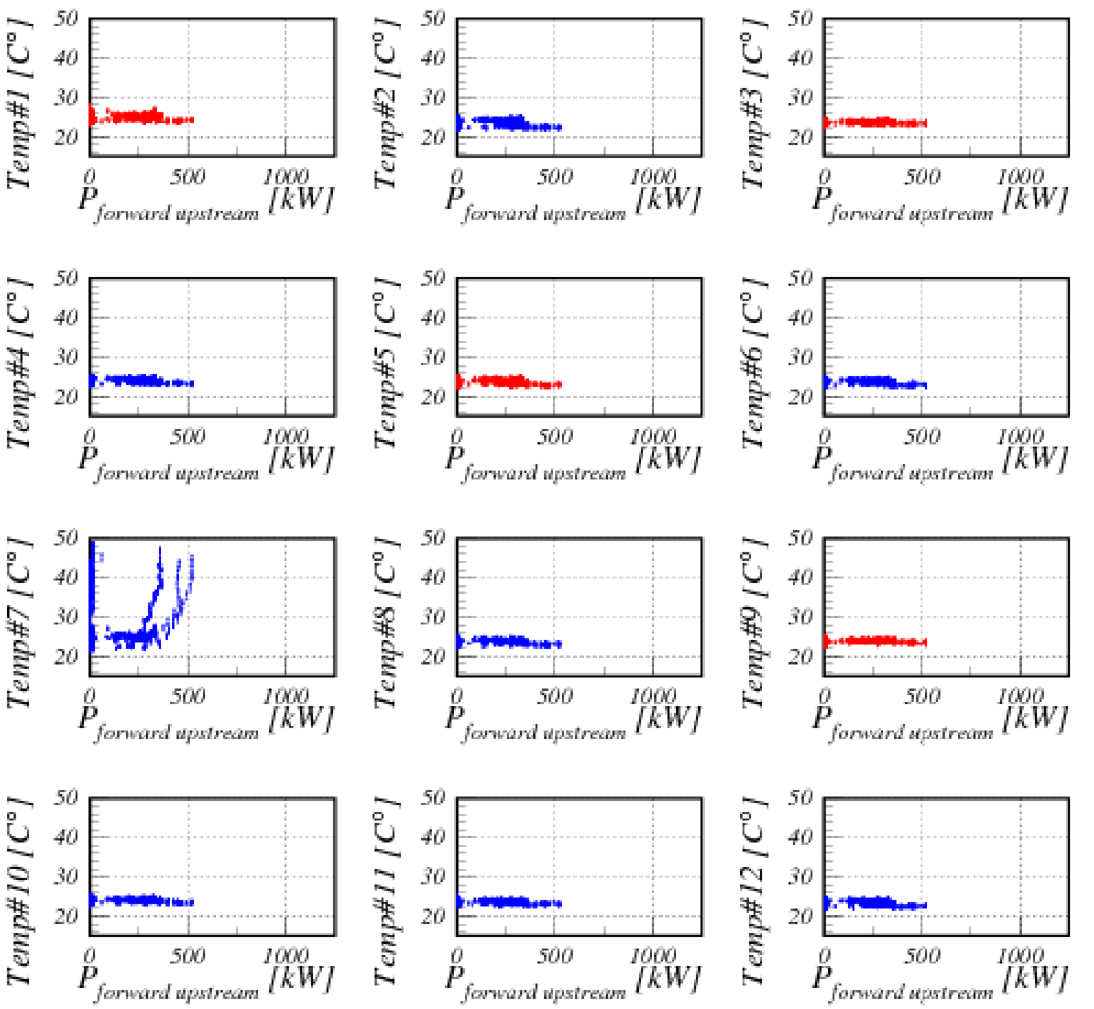
Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/4)



New ceramic

Pulse width : 1500[μsec]
2 fans

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/7)

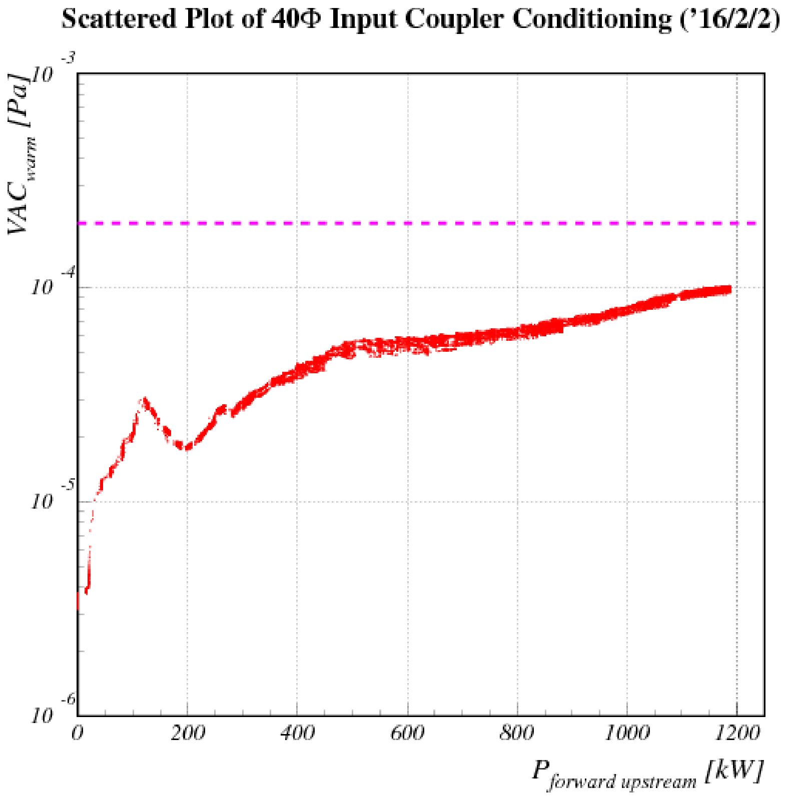


Comparison of Normal/New ceramic coupler

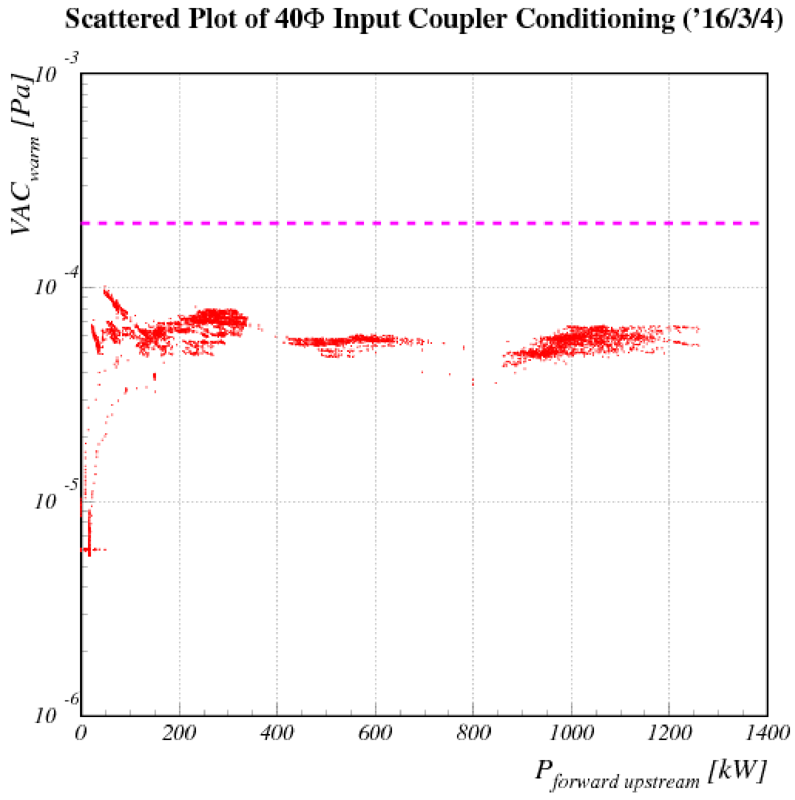
Warm Vac vs Power

Pulse width : 500[μsec]
Rep.   frequency : 5 [Hz]

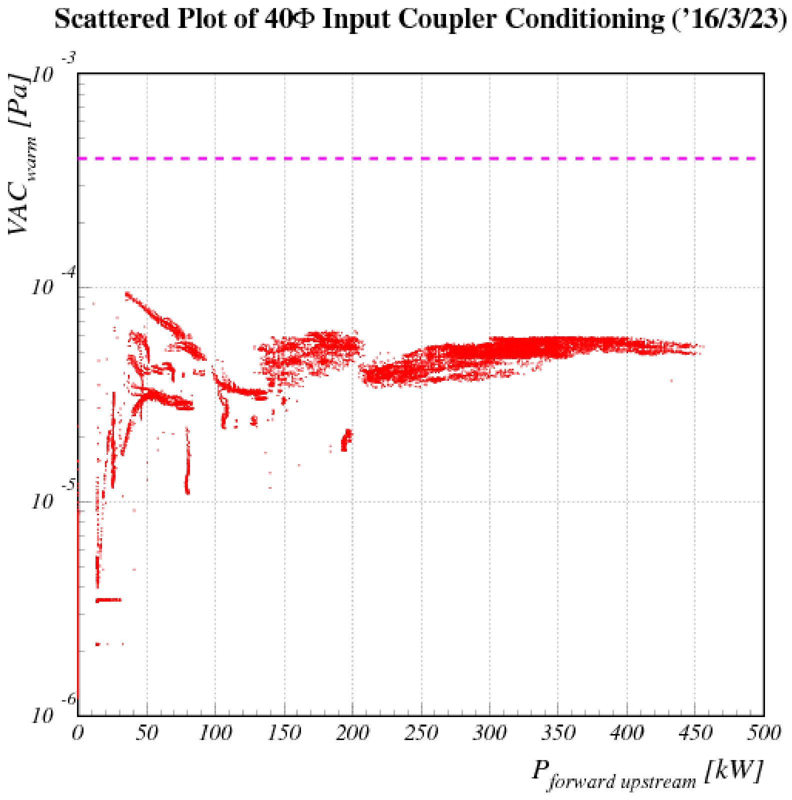
Normal ceramic



New ceramic



New ceramic



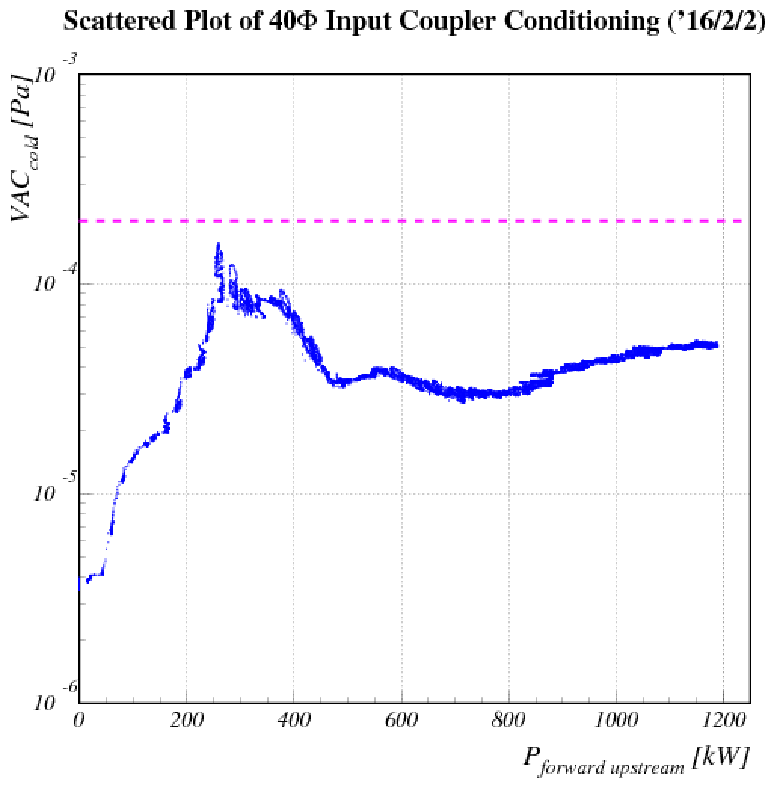
横軸のスケールが異なることに注意

Comparison of Normal/New ceramic coupler

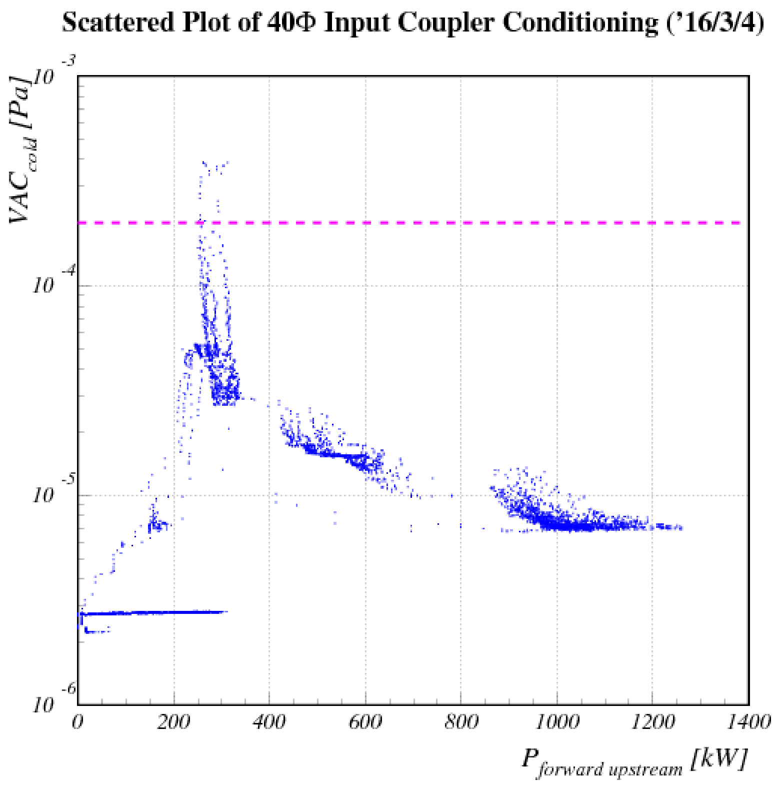
Cold Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

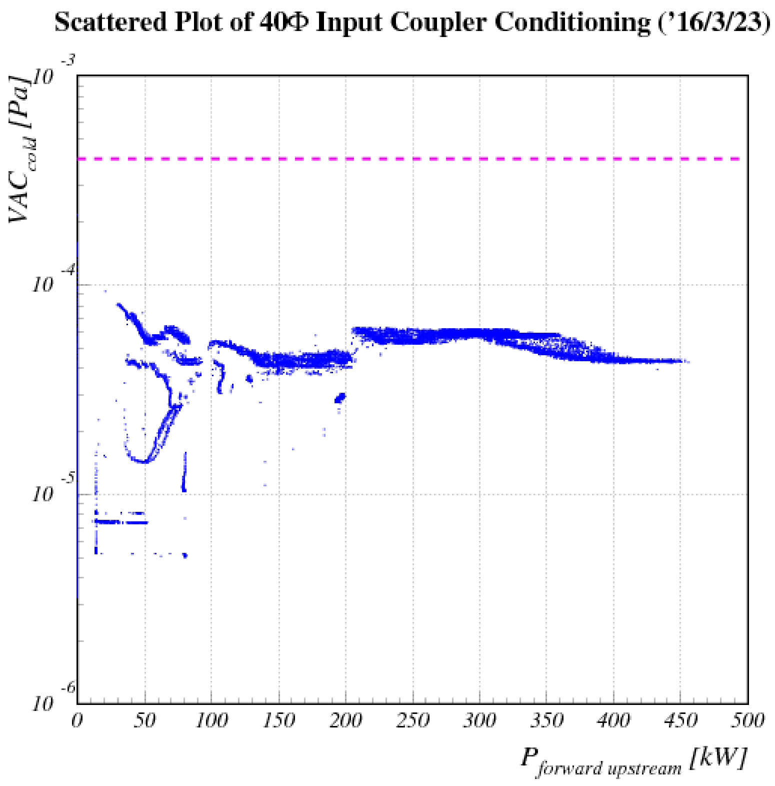
Normal ceramic



New ceramic



New ceramic

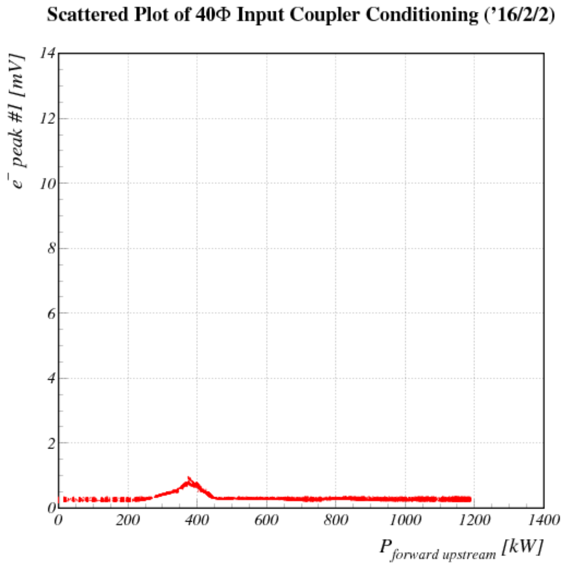


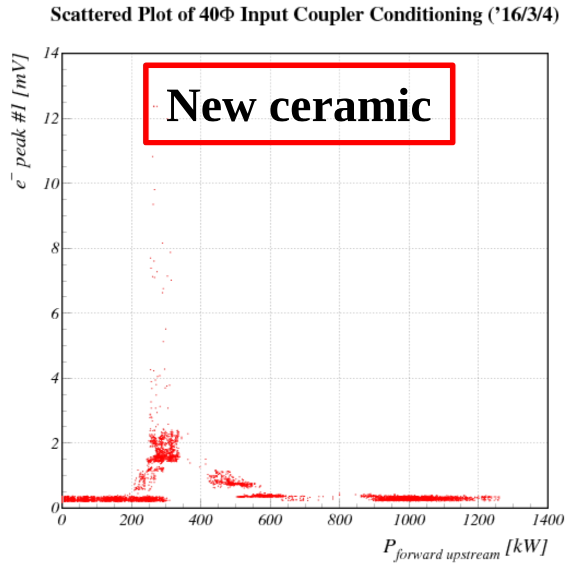
横軸のスケールが異なることに注意

Electron peak vs Power

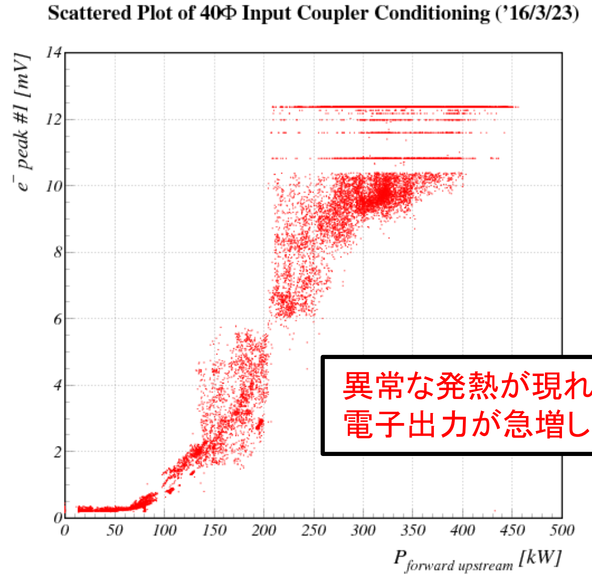
Pulse width : 500[μsec]
Rep.   frequency : 5 [Hz]

Normal ceramic



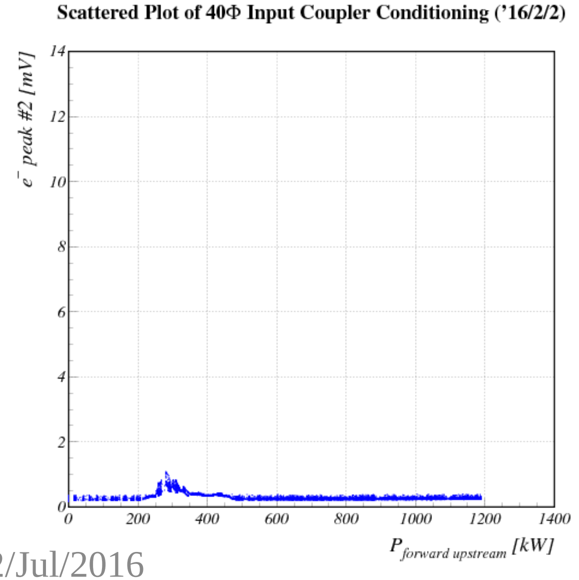


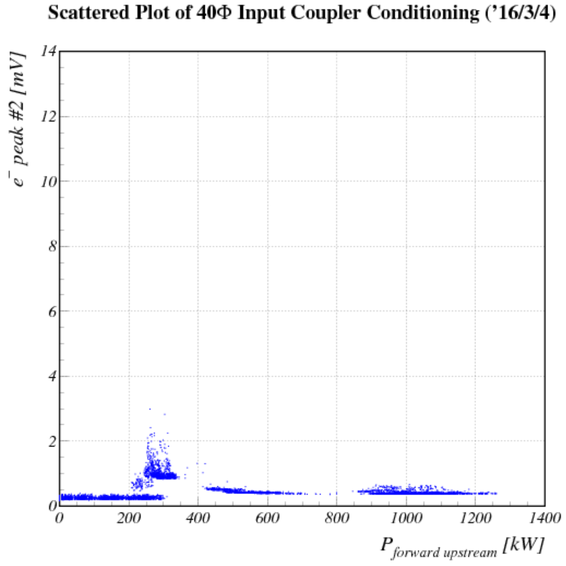
New ceramic

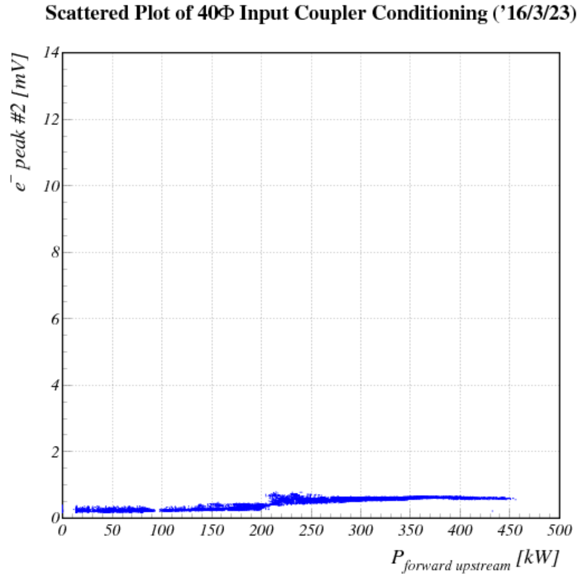


異常な発熱が現れた後から
電子出力が急増している

横軸のスケールが異なることに注意



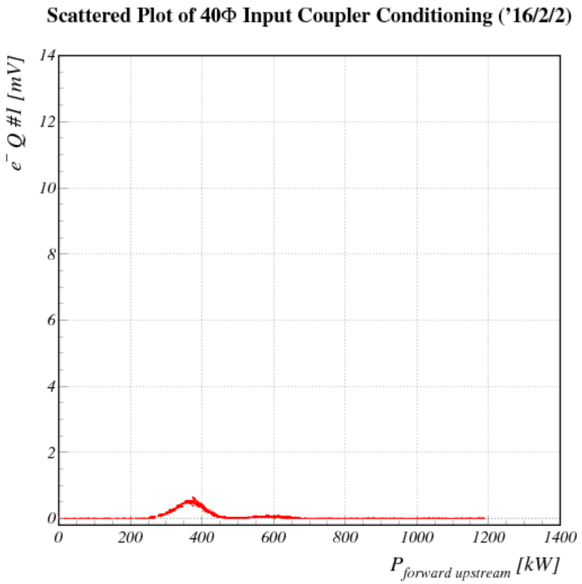


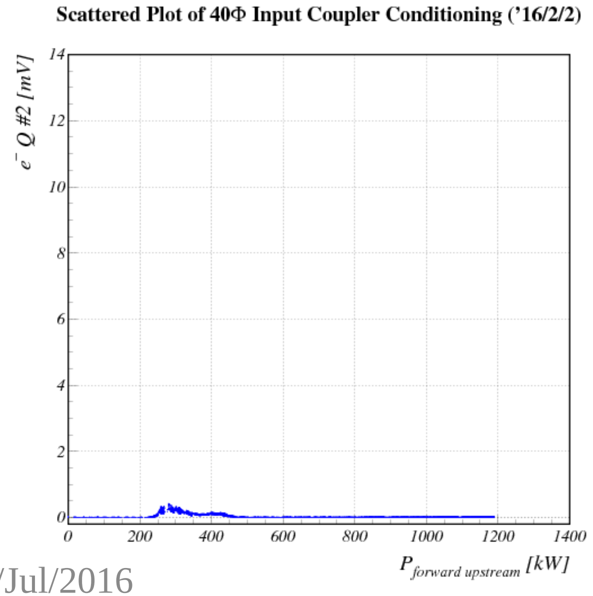


Electron Q vs Power

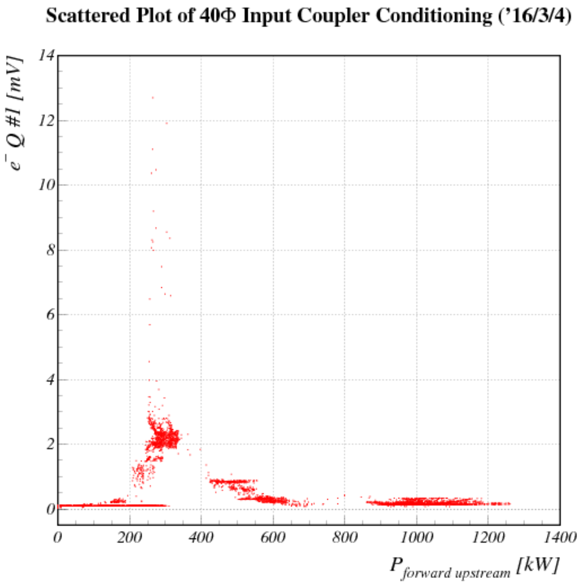
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

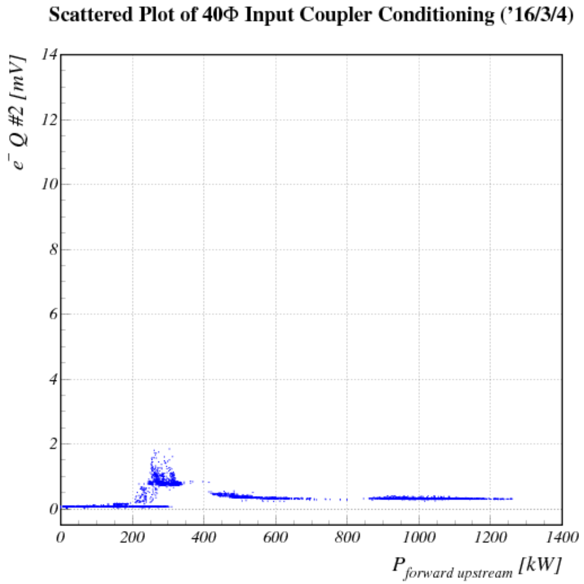
Normal ceramic



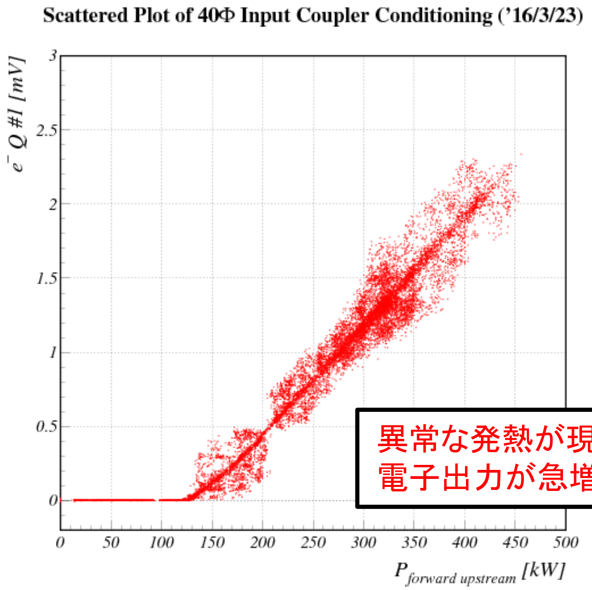


New ceramic

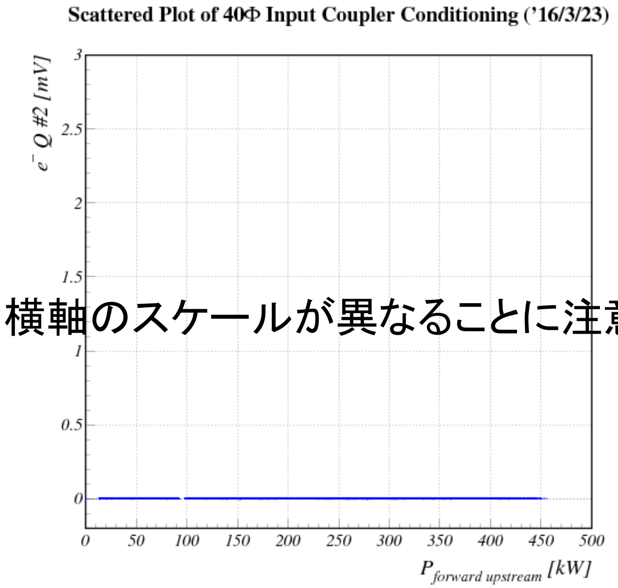




New ceramic



異常な発熱が現れた後から
電子出力が急増している

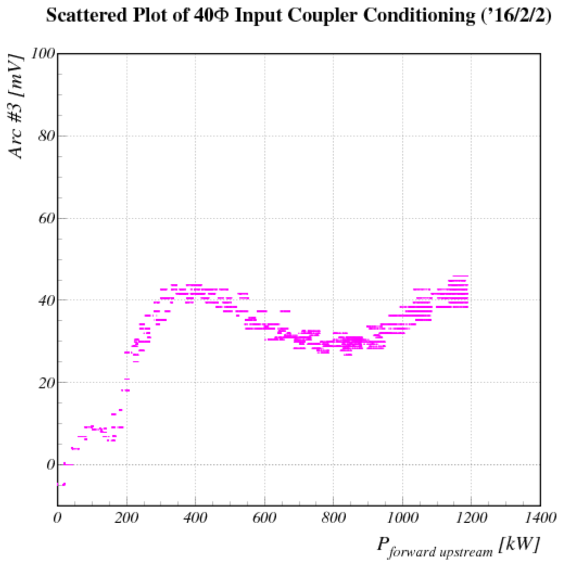


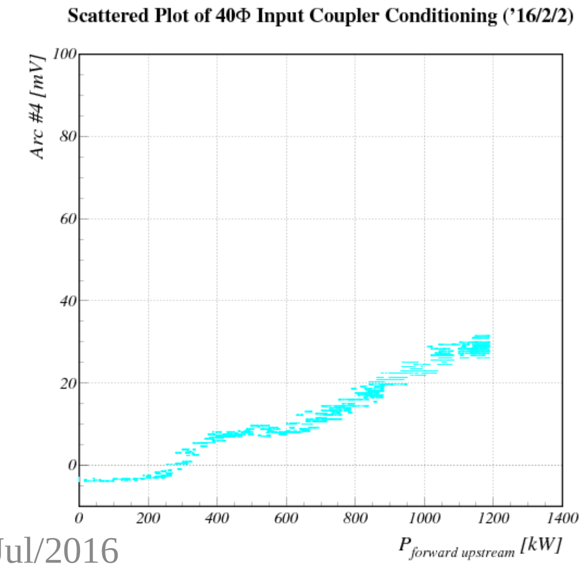
横軸のスケールが異なることに注意

Arc vs Power

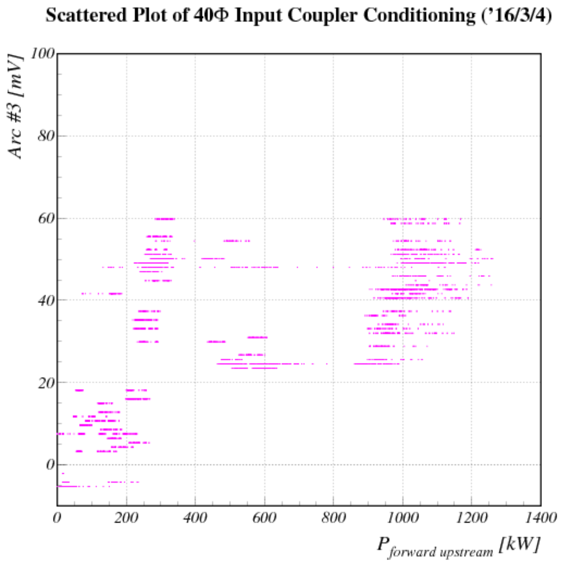
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

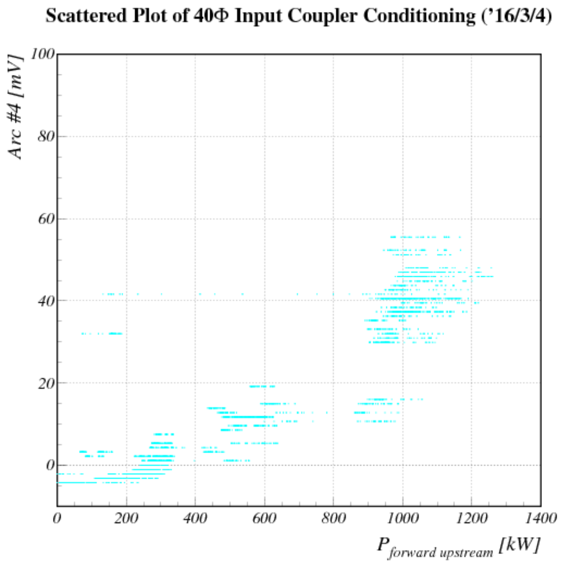
Normal ceramic



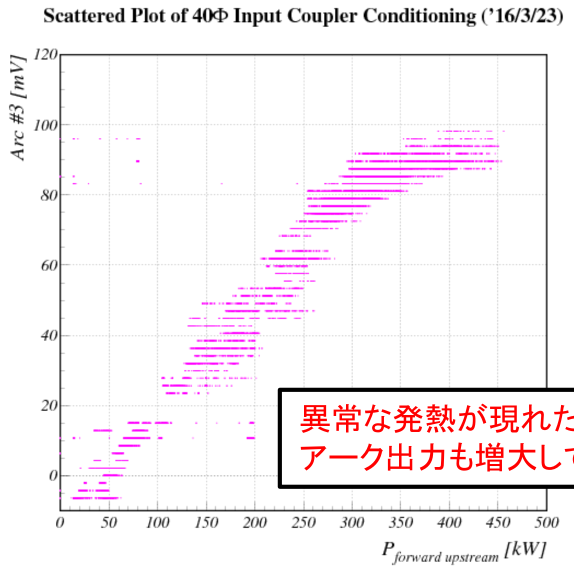


New ceramic



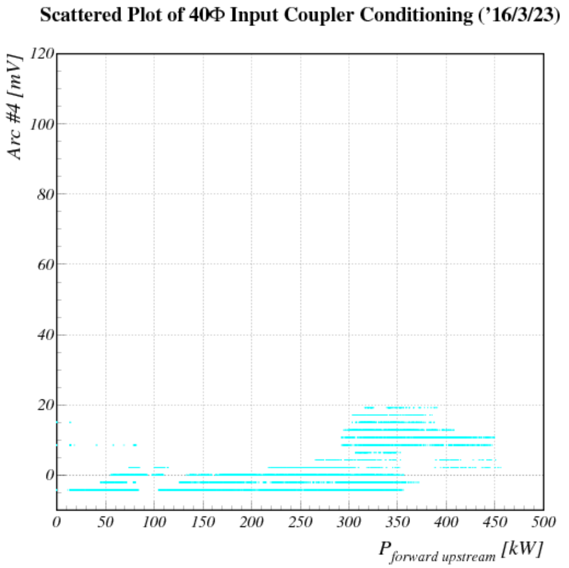


New ceramic



異常な発熱が現れた後から
アーク出力も増大している

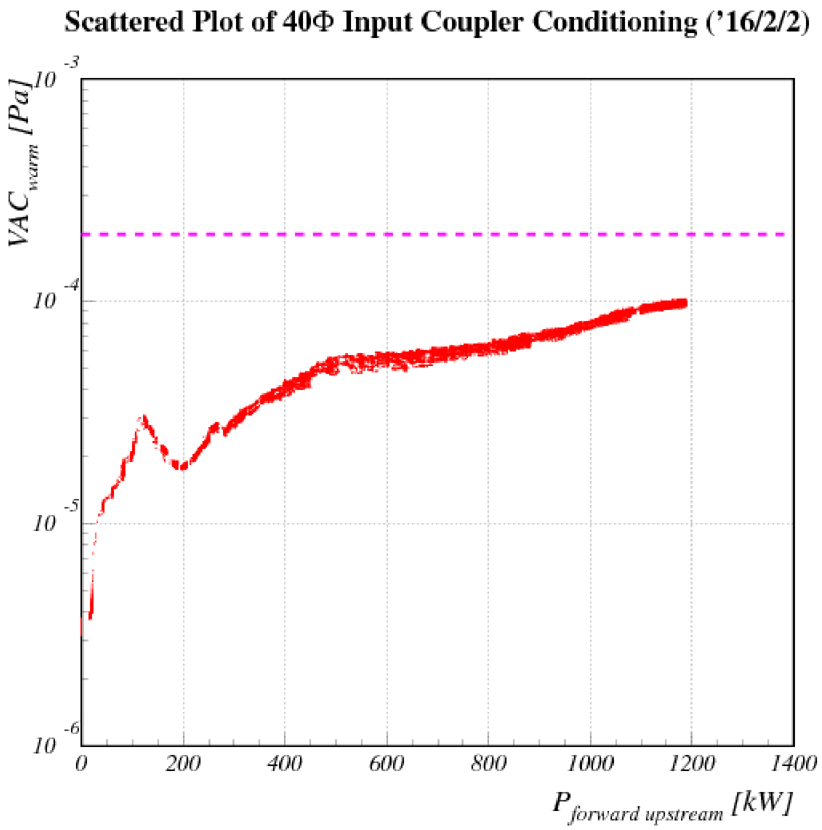
横軸のスケールが異なることに注意



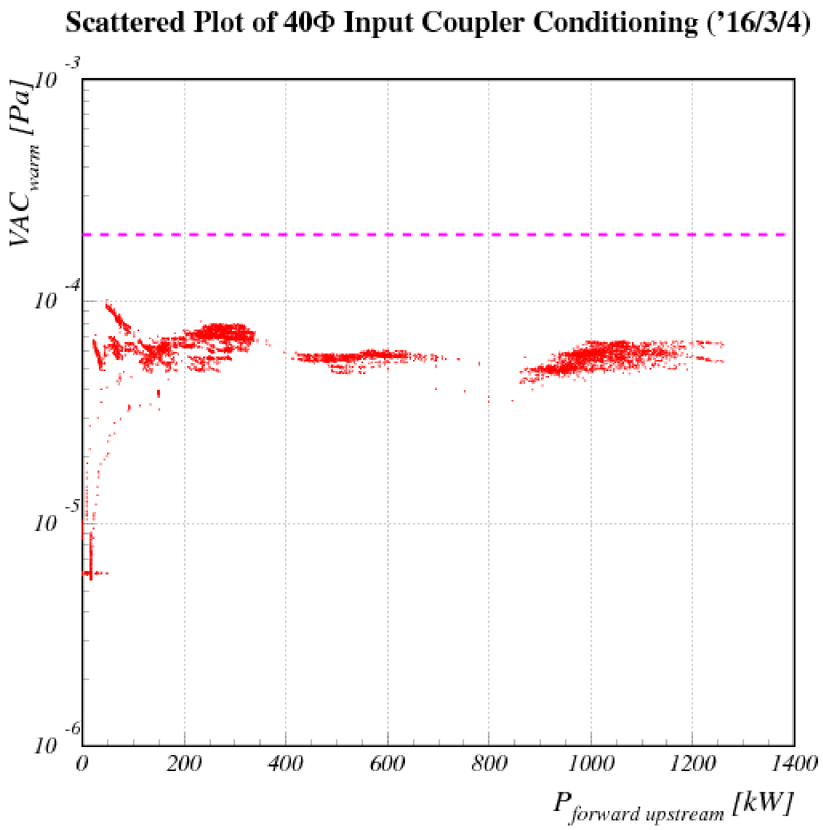
Warm Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

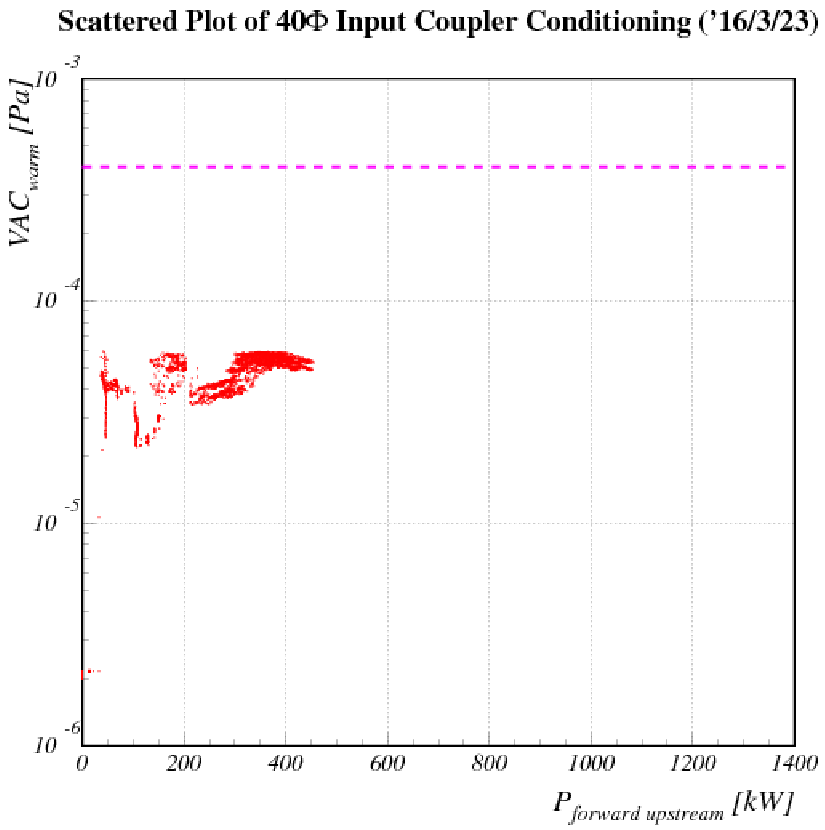
Normal ceramic



New ceramic



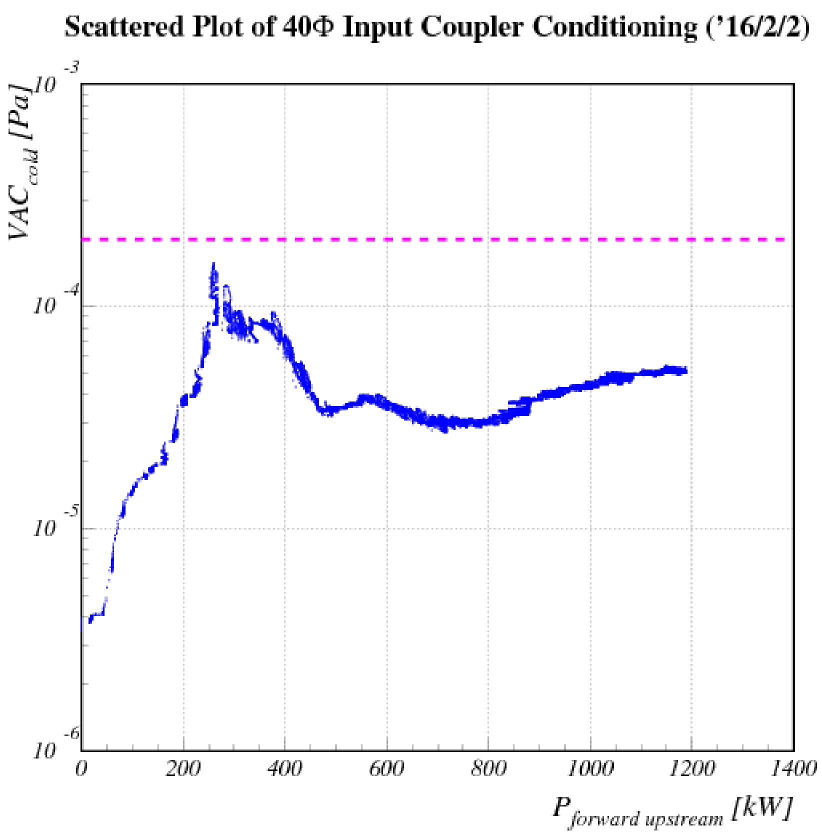
New ceramic



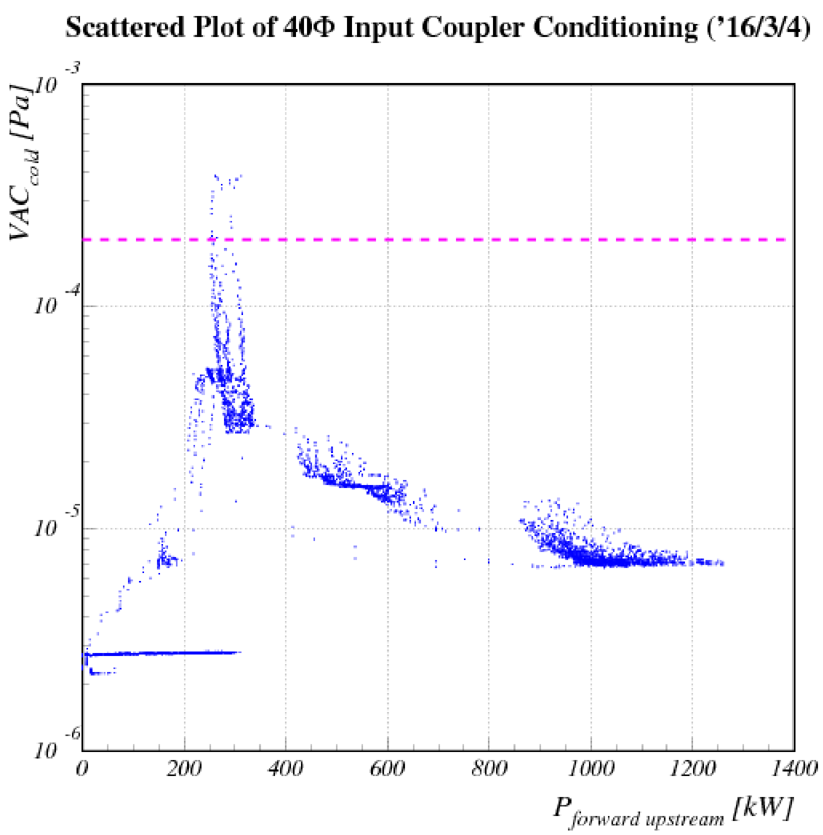
Cold Vac vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

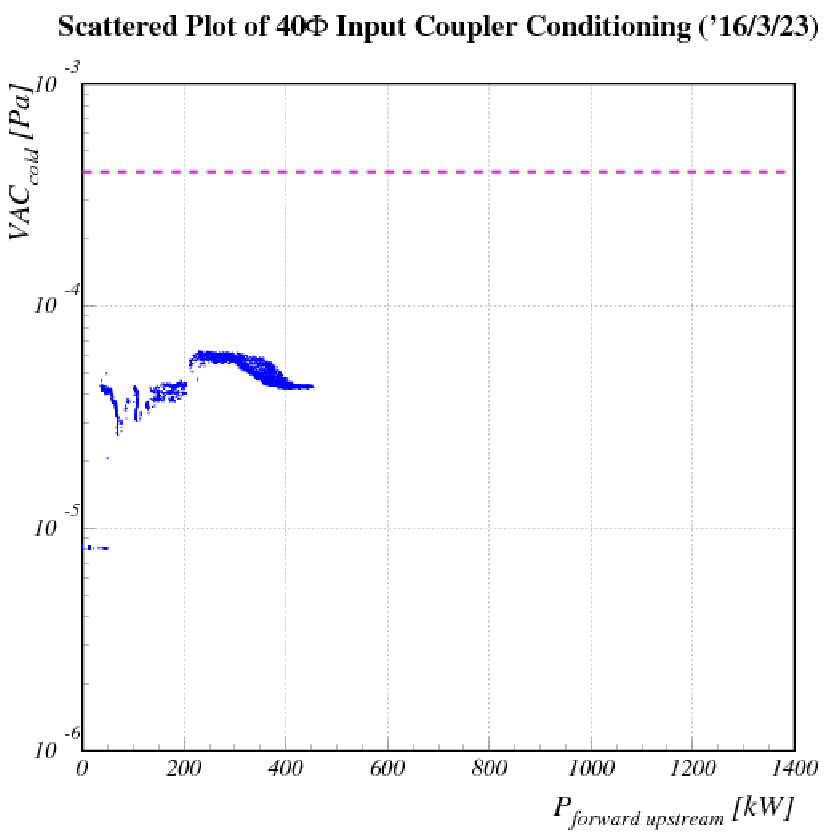
Normal ceramic



New ceramic



New ceramic

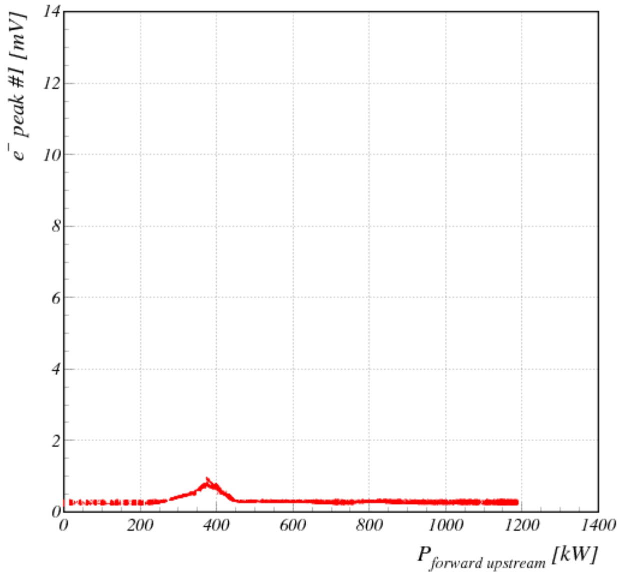


Electron peak vs Power

Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

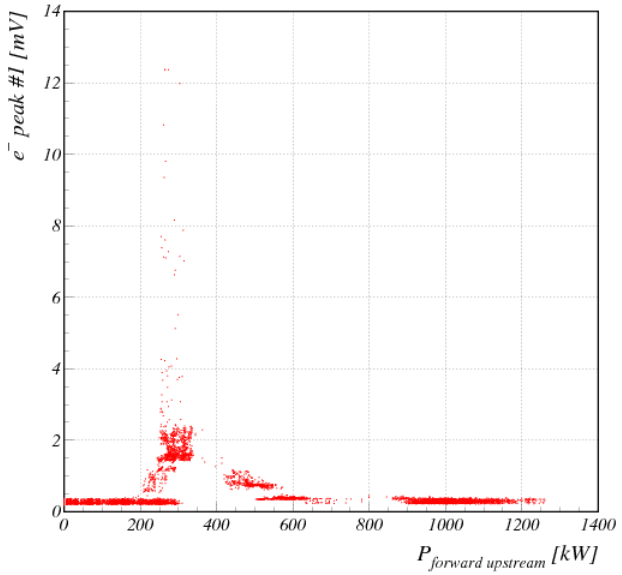
Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)



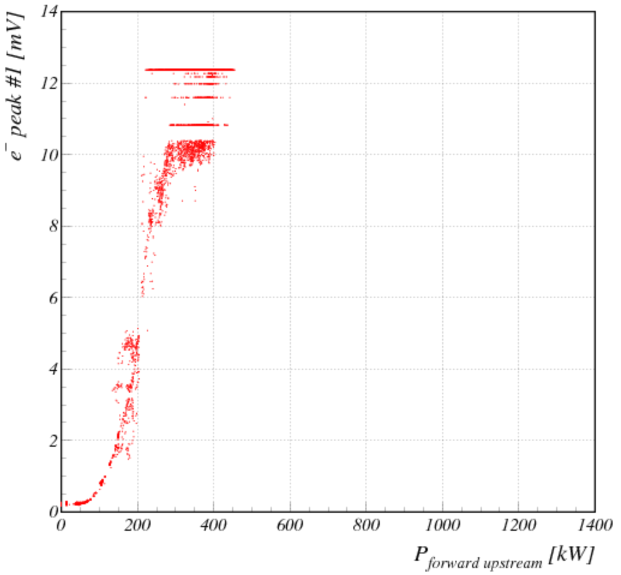
New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

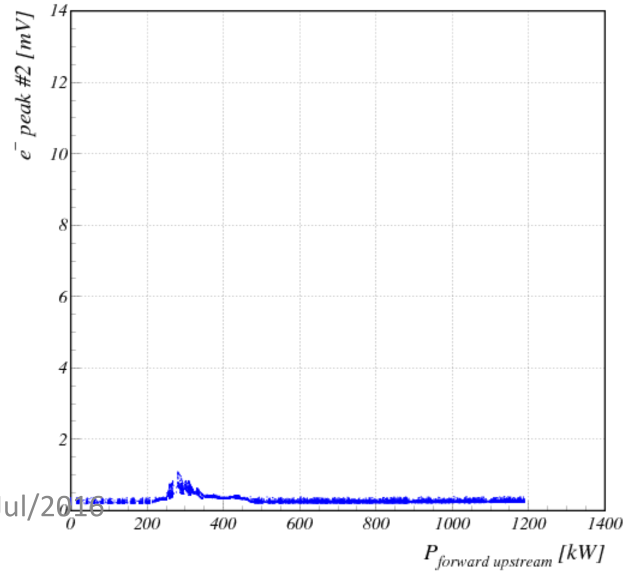


New ceramic

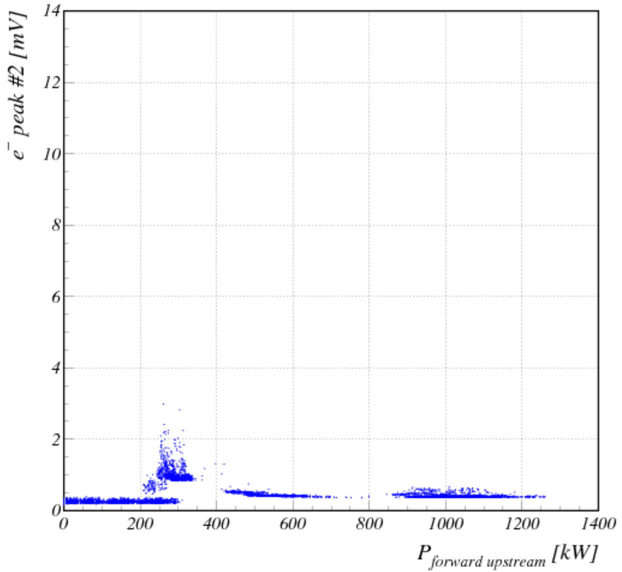
Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)



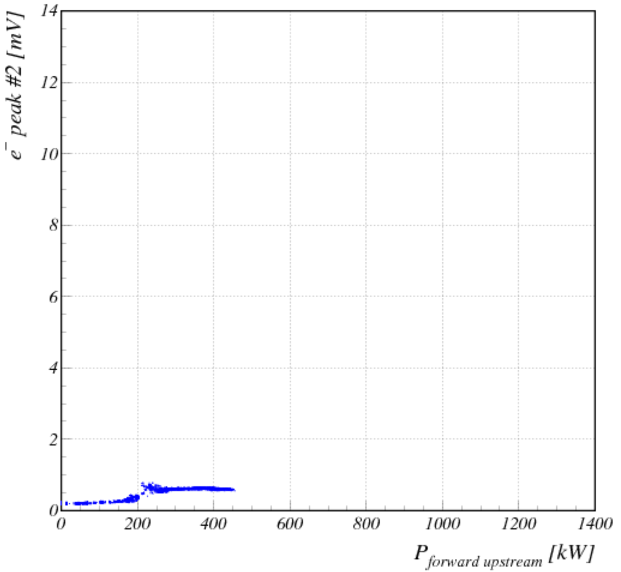
Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)

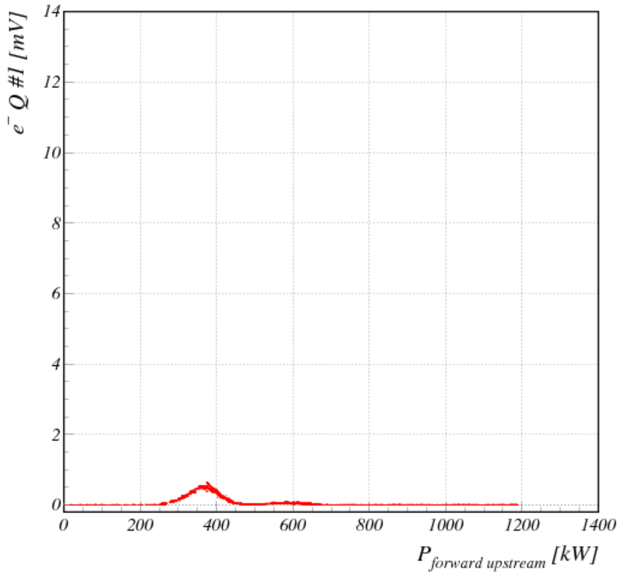


Electron Q vs Power

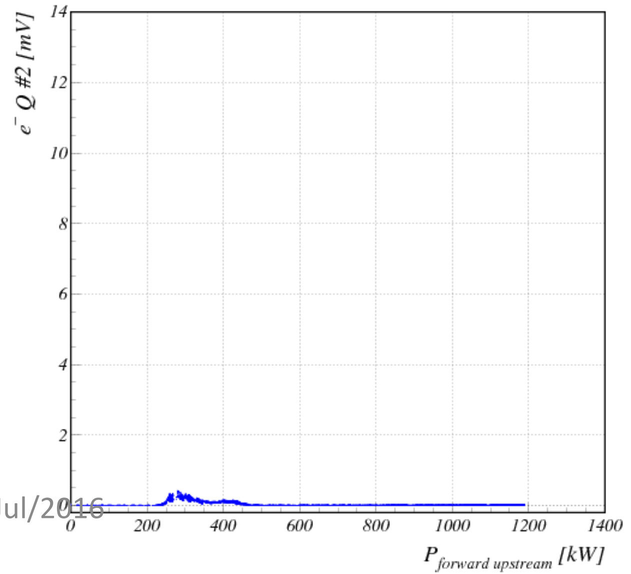
Pulse width : 500[μsec]
Rep. frequency : 5 [Hz]

Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

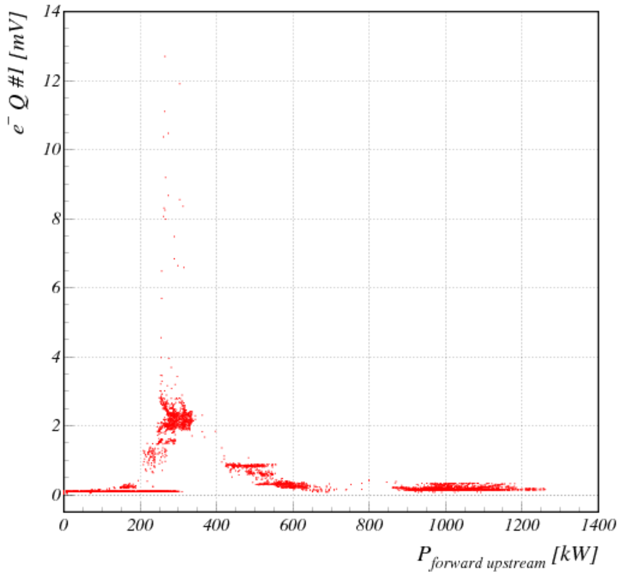


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

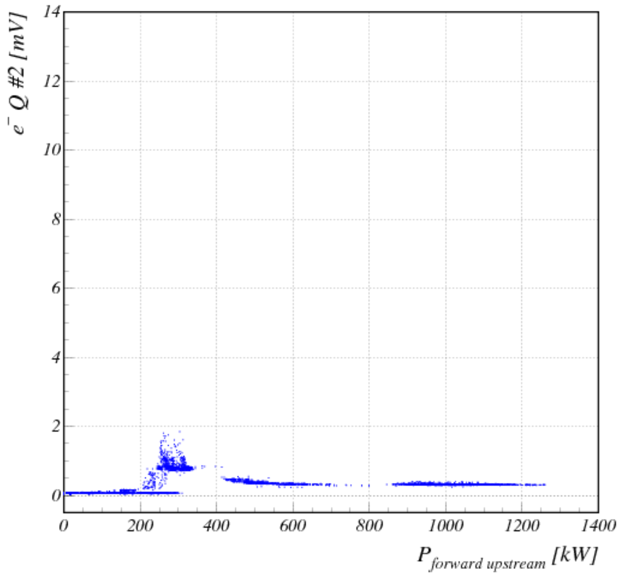


New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

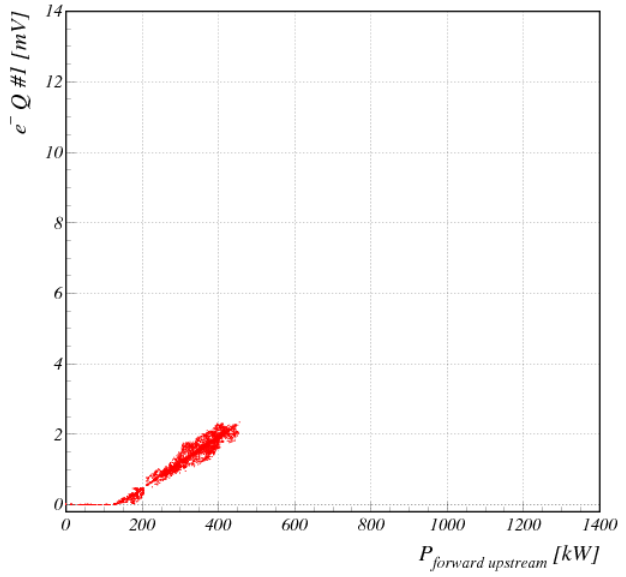


Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

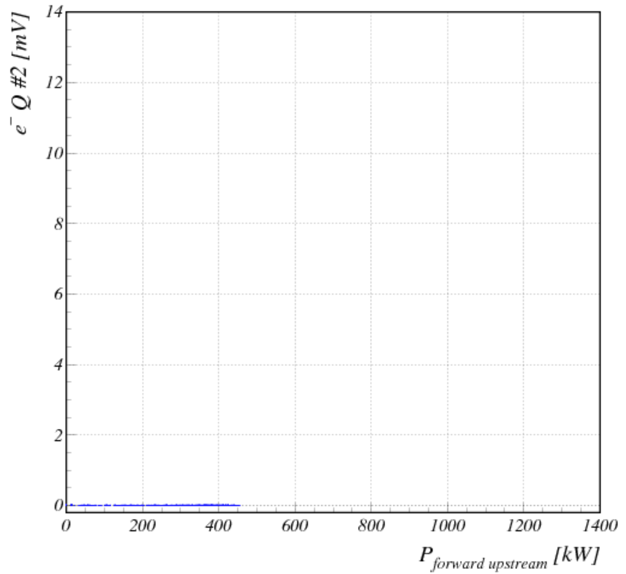


New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)

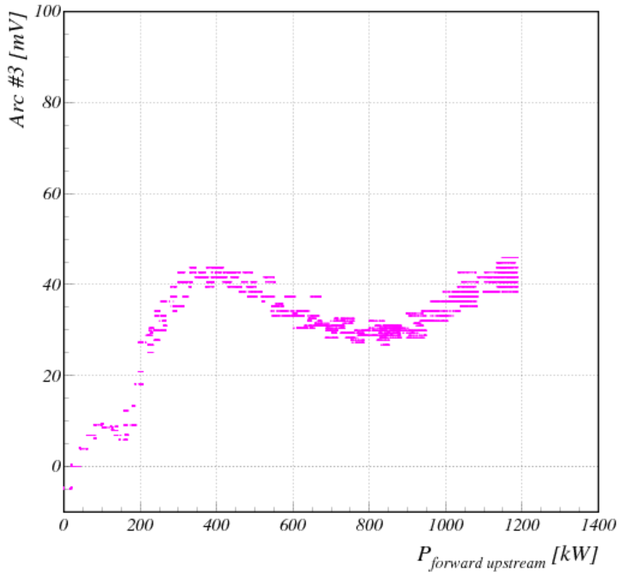


Arc vs Power

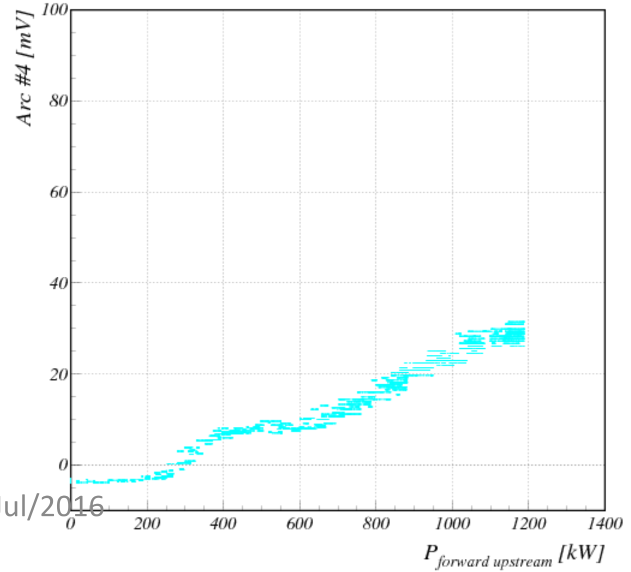
Pulse width : 500[μsec]
Rep.   frequency : 5 [Hz]

Normal ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

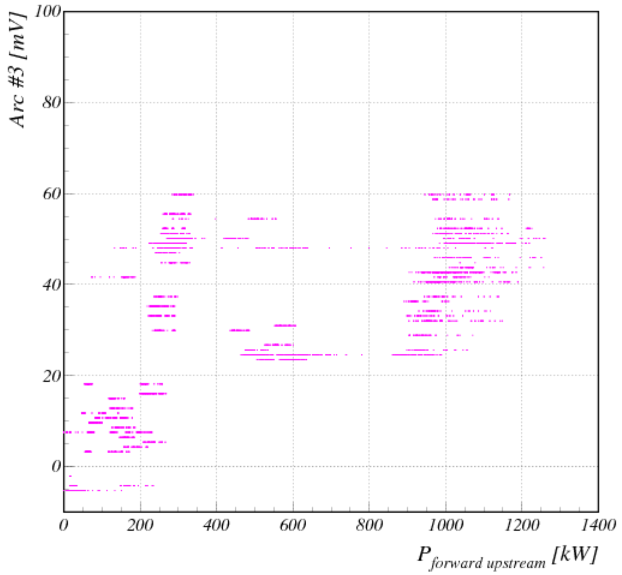


Scattered Plot of 40Φ Input Coupler Conditioning ('16/2/2)

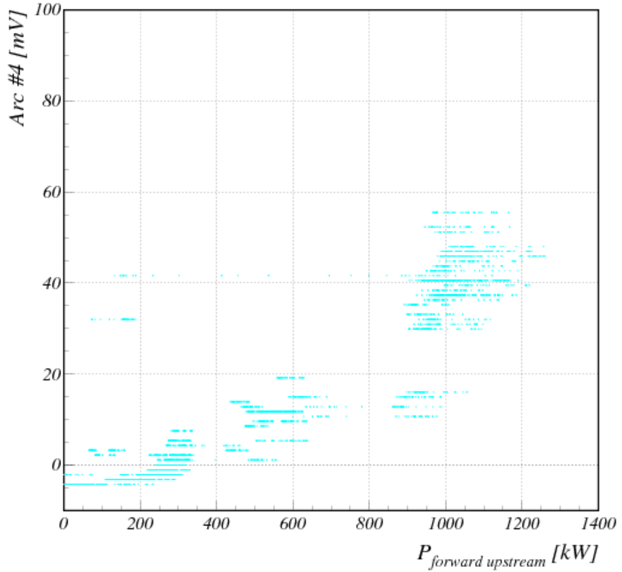


New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)

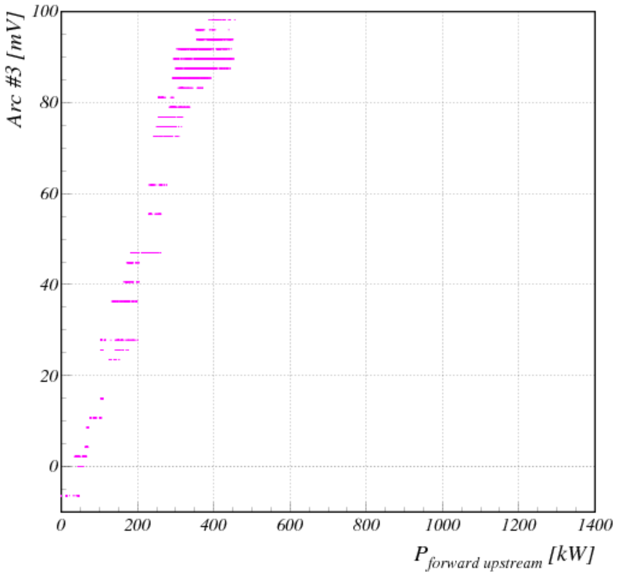


Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/4)



New ceramic

Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)



Scattered Plot of 40Φ Input Coupler Conditioning ('16/3/23)