Cryomodule design, assembly and installation utilizing ``KOACH'' system

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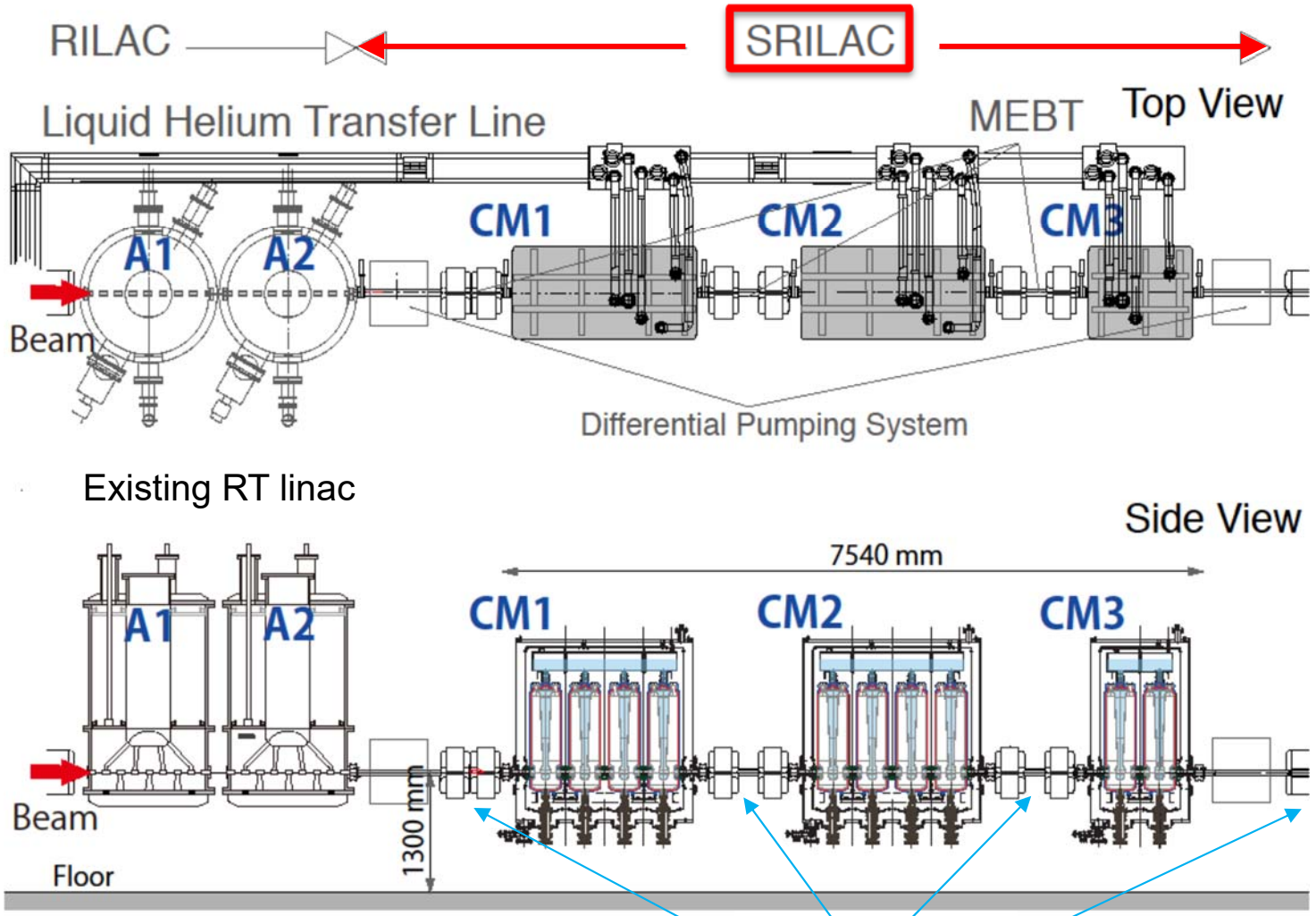
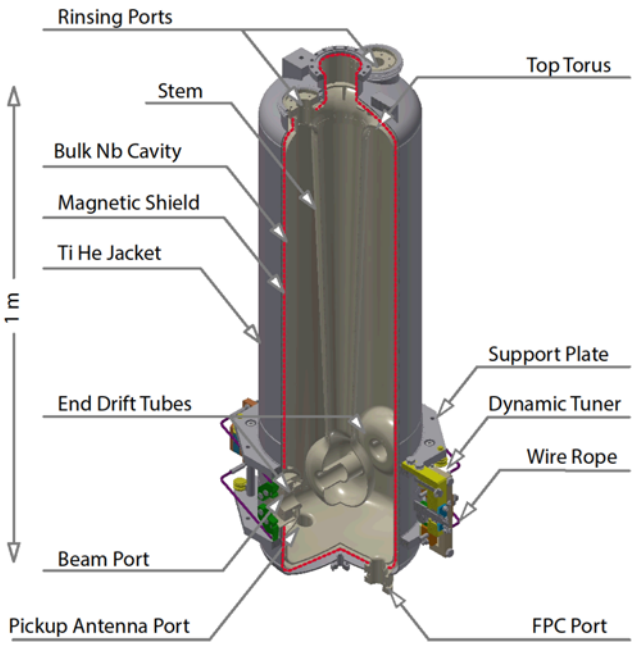
Superconducting RIken Linear Accelerator (SRILAC)

- Superconducting booster linac of existing room-temperature linac
- Just commissioned in Jan. 2020
- 10 SC-QWRs stored in 3 cryomodules (CM1~3), arranged into groups of 4, 4, 2 units
- f_0 = 73.0 MHz, β_{opt} = 0.078, 4.5 K operation
- Energy: 3.6 MeV/u to 6.5 MeV/u for heavy-ions with m/q = 5
- Focusing elements: RT quadrupoles

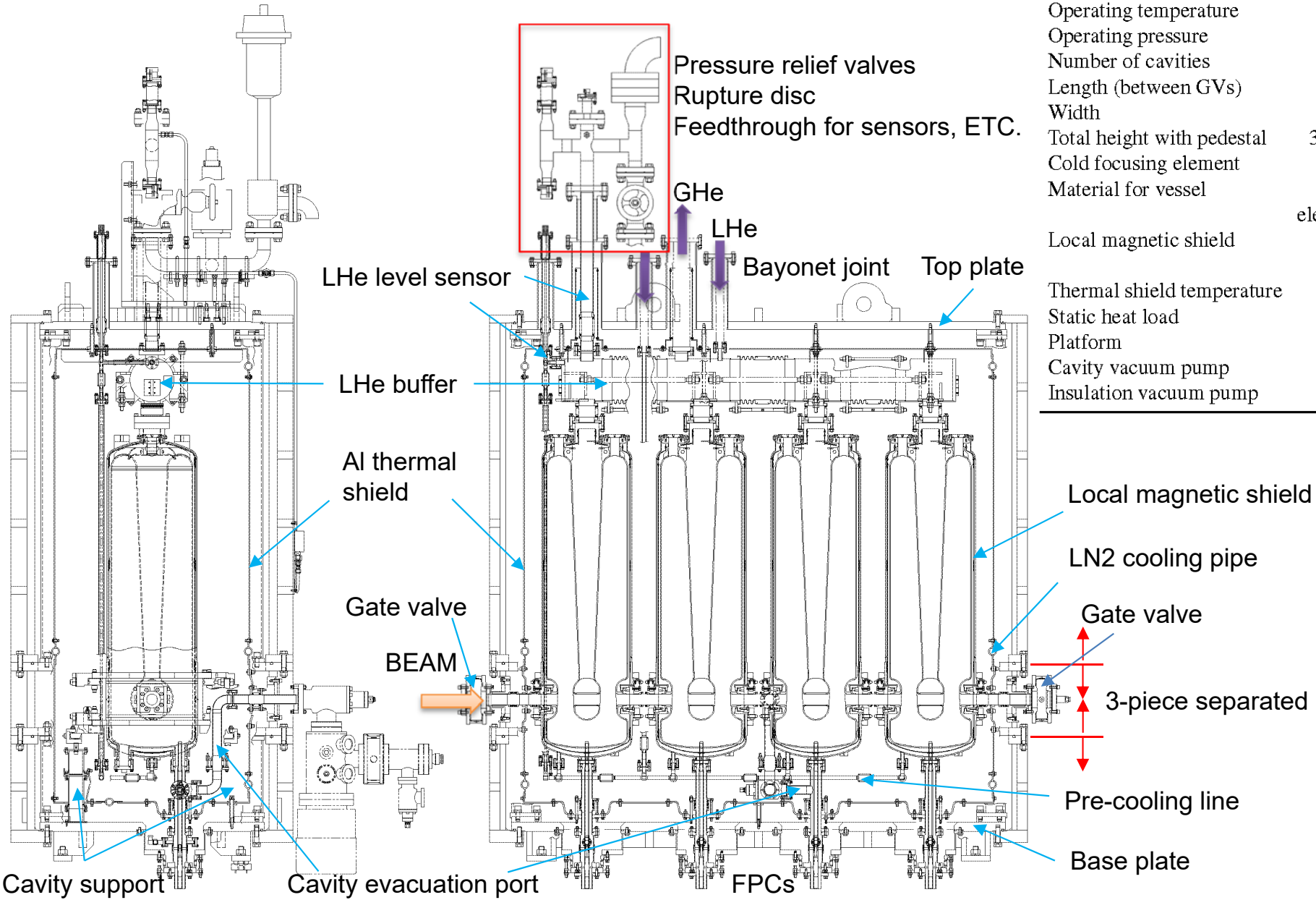




SC-QWR

Design of SRILAC cryomodule

- 3-piece vacuum vessel (upper vessel, center vessel, lower vessel)
- Compatible with high pressure gas safety act in Japan
- Stacking structure on base plate
- CM3 is the half type of CM1 and CM2



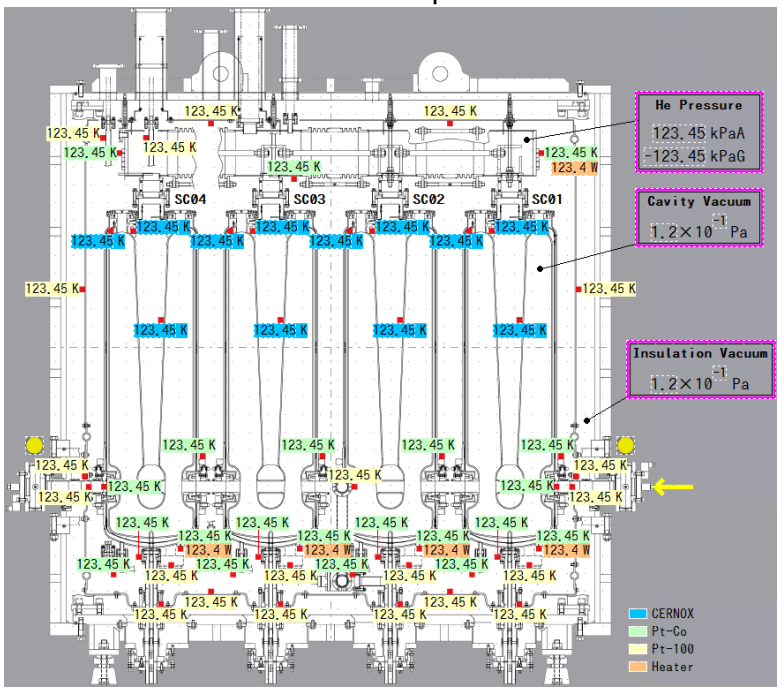
Design parameter of SRILAC cryomodule

Operating temperature	4.5 K
Operating pressure	0.126 MPaA
Number of cavities	4 or 2
Length (between GVs)	2200 or 1340 mm
Width	1060 mm
Total height with pedestal	3907 mm (Incl. valves)
Cold focusing element	None
Material for vessel	Carbon steel with electroless nickel plating
Local magnetic shield	Permalloy 1.5 mm (Inside the He jacket)
Thermal shield temperature	80 K (LN_2 cooling)
Static heat load	18 or 10 W to 4.5 K
Platform	Base plate
Cavity vacuum pump	IP + NEG(ZAO)
Insulation vacuum pump	TMP

Components of cryomodule

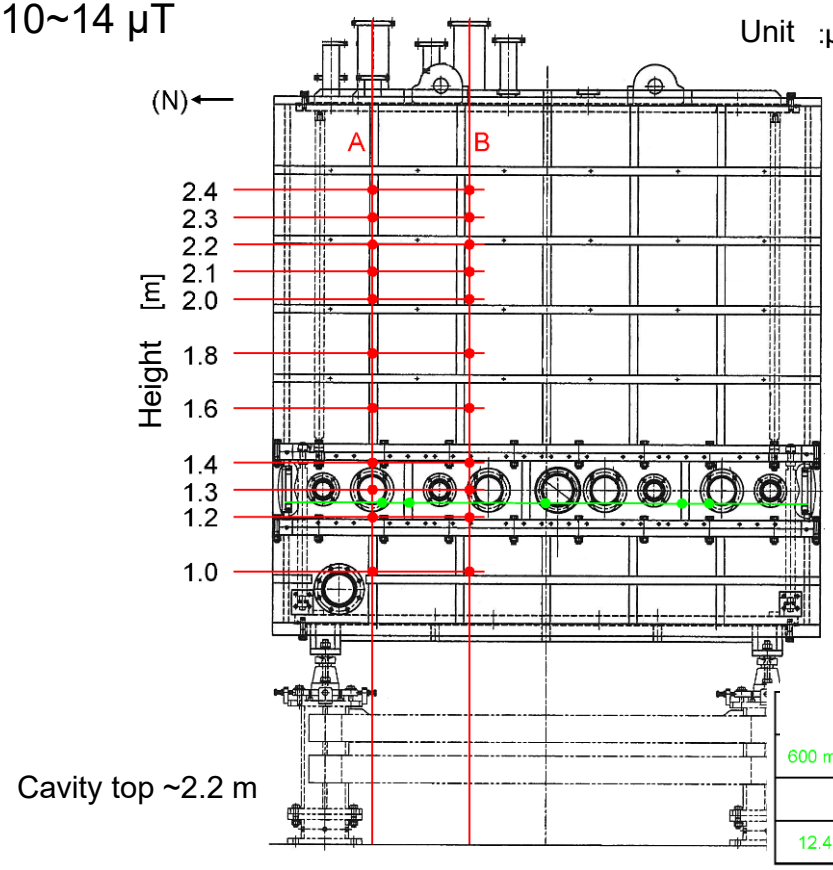
- Thermal sensors (/CM): 12 CERNOX, 21 Pt-Co, 21 Pt100
  6 CERNOX, 10 Pt-Co, 15 Pt100
- Residual magnetic field inside the vessel: 10~14 μT

Thermal sensor position



Unit :μT

(Outside)



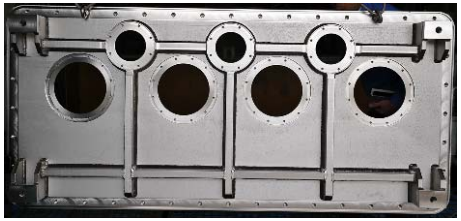
	A	B
2.4	11.53 (39.85)	10.49
2.3	11.23 (39.95)	10.38
2.2	11.33 (39.72)	10.46
2.1	11.56 (40.34)	10.75
2.0	11.83 (39.51)	11.25
1.8	12.06 (40.49)	12.00
1.6	11.99 (40.40)	12.36 (39.40)
1.4	12.03 (40.00)	12.74
1.3	12.32 (41.21)	12.69
1.2	12.88 (41.70)	12.47
1.0	13.56 (41.08)	10.34 (40.94)

Beam line

N		C	S	
600 mm	500 mm		500 mm	600 mm
		12.98	12.49	12.52
12.43	12.45	12.46		

Upper vessel

Top plate



Base plate

Lower vessel and thermal shield of CM3

Assembly procedure of cryomodule

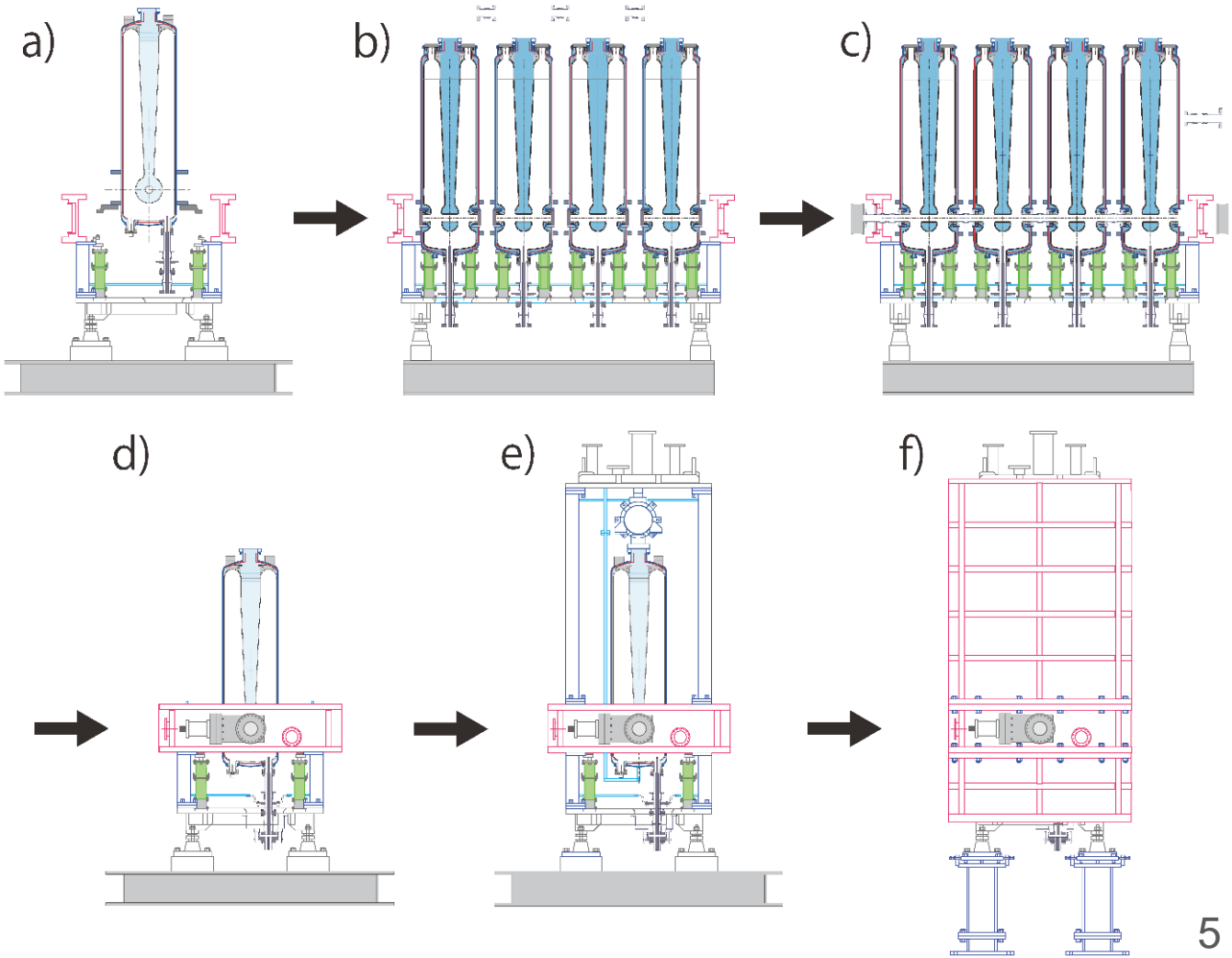
a) Mounting SC-QWRs on base plate
b) Connecting bellows between QWRs
c) Attaching beam pipes, GVs, and vacuum exhaust
d) Assembling tuners, lower cryo pipings, and thermal sensors
e) Mounting top assembly on cryomodule, piping, leak test, inspection, assembling thermal shield, thermal anchors, and SIs
f) Attaching instrumentation, upper thermal shield, upper vessel, and safety elements

Assembling work was performed in each place

・ISO class 8 semi-clean room
for a), d), e)

・ISO class 1 super clean room built in the semi-clean room (KOKEN Floor KOACH)
for b), c)

・Installation site (very dirty)
for f)

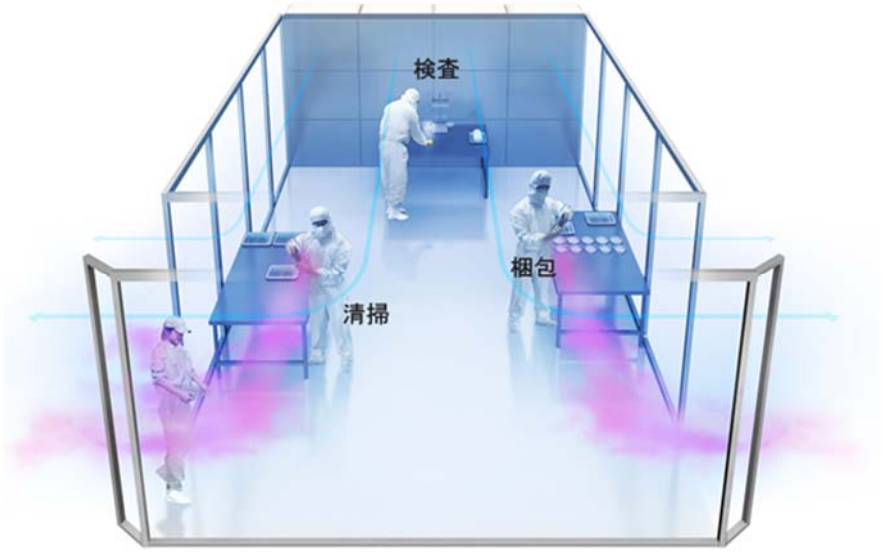


KOKEN KOACH clean system

We introduced KOACH clean system for assembling work.
https://www.koken-ltd.co.jp/english/product/clean/super/

- ISO class 1 super clean environment
- High coherent side laminar flow (wind speed: 0.3~0.5 m/s)
- Short clean-up time
- Short construction period (～1 week) for clean room type
- Reasonable price
- Low running cost

Room type for cryomodule assembly



KOACH F1050-F (Floor KOACH) + guide screen

Clean area: W1050 mm × H850 mm/one module < L20,000 mm

Open zone type for connection in situ

KOACH C900-F (Stand KOACH)

Clean area: W900 mm × H700 mm × L1800～2300 mm

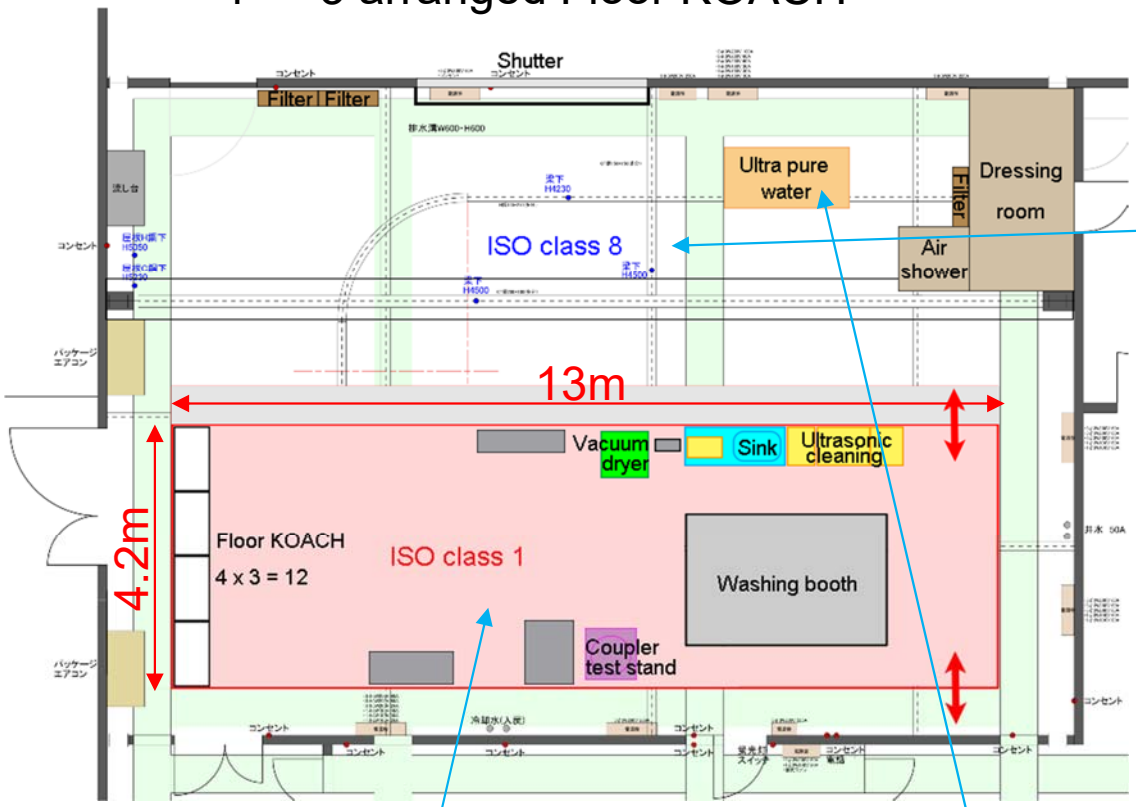
Open tabletop type for VT connection

KOACH T500-F (Table KOACH)

Clean area: W496 mm × H310 mm × L700 mm

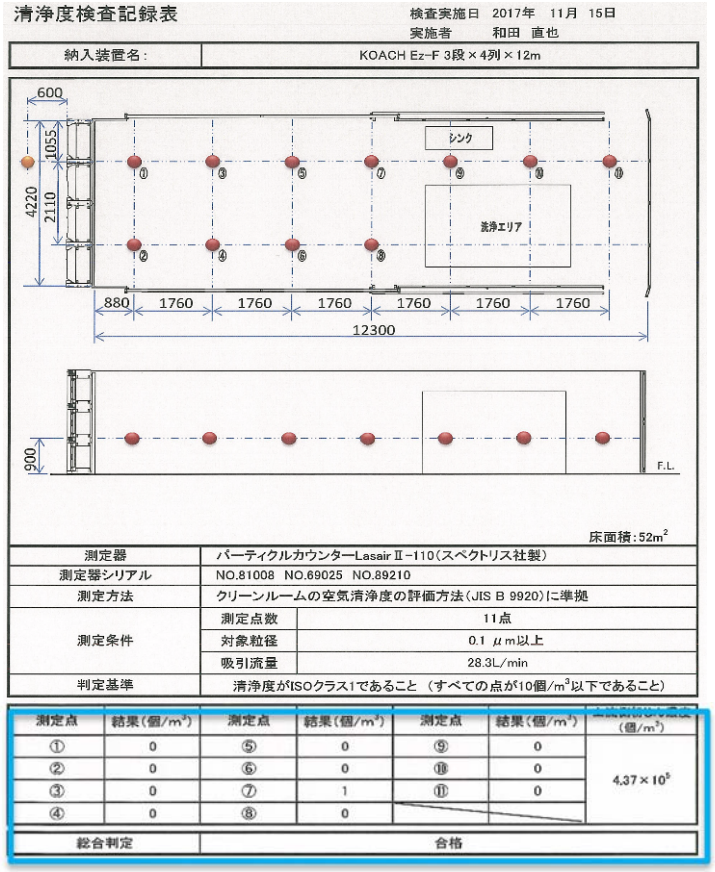
Super clean room in RIKEN

- ISO class 1 super clean room built in ISO class 8 semi-clean room
- 4 × 3 arranged Floor KOACH



Rs: >18 MΩ･cm
0.2 μm Particle: < 1/ml
TOC: ~2 ppb

Inspection record



清浄度検査記録表

検査実施日　2017年　11月　15日
実施者　和田　直也

納入装置名：	KOACH Ez-F 3段×4列×12m

床面積：52m²

測定器	パーティクルカウンターLasair Ⅱ-110（スペクトリス社製）	
測定器シリアル	NO.81008　NO.69025　NO.89210	
測定方法	クリーンルームの空気清浄度の評価方法（JIS B 9920）に準拠	
測定条件	測定点数	11点
	対象粒径	0.1 μm以上
	吸引流量	28.3L/min
判定基準	清浄度がISOクラス1であること（すべての点が10個/m³以下であること）	

測定点	結果（個/m³）	測定点	結果（個/m³）	測定点	結果（個/m³）	平均値（個/m³）
①	0	⑤	0	⑨	0	4.37×10⁵
②	0	⑥	0	⑩	0	
③	0	⑦	1	⑪	0	
④	0	⑧	0			
総合判定	合格					

Assembly and installation of cryomodule

Preparation of SC-QWR

Before connection

After vacuum connection

Assembly in semi-clean room

Transport to installation site

ISO class 1
↓
ISO class 8
↓
Installation site

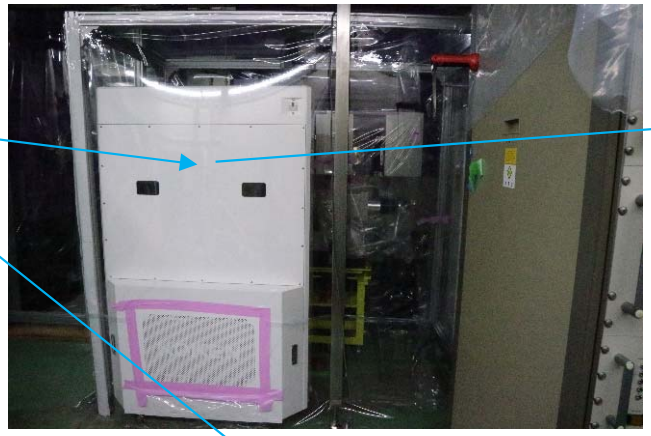
Installation

After alignment

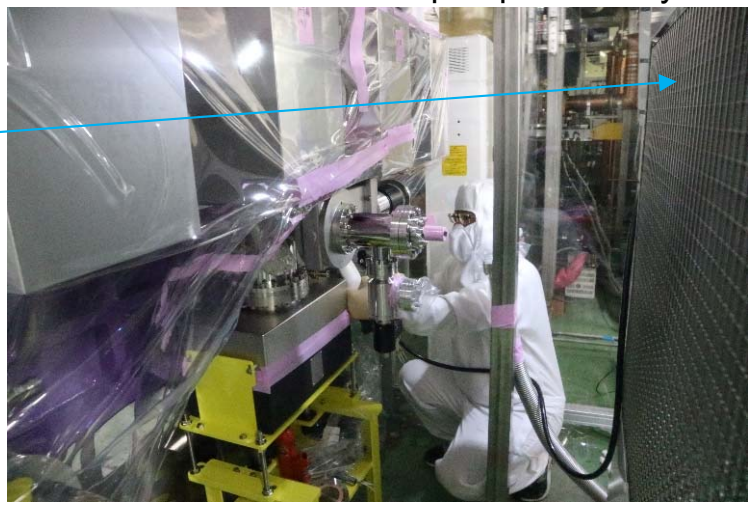
Connection work in situ

One side of Stand KOACH was used with local antistatic-vinyl enclosure.

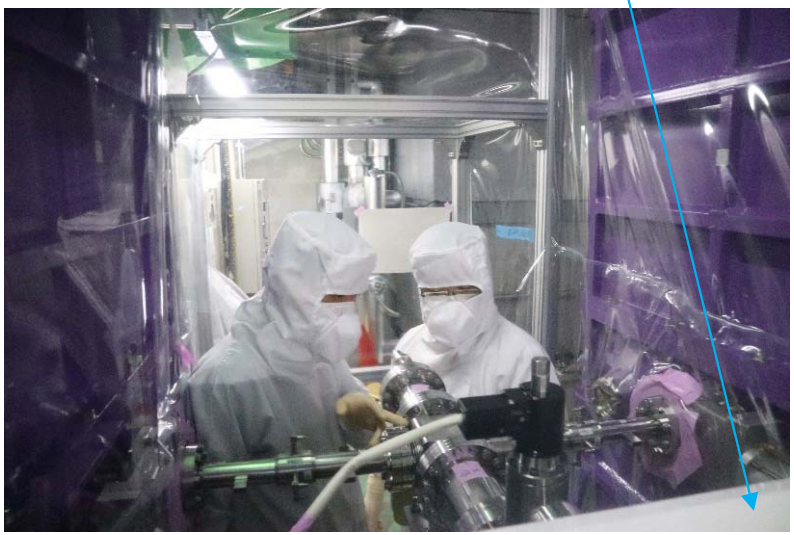
KOACH C900-F (Stand KOACH)



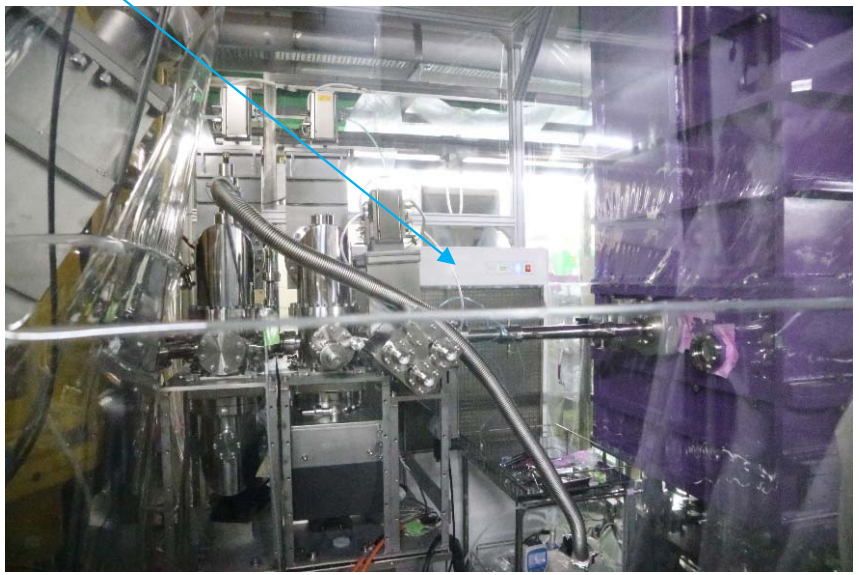
Connection of vacuum pump assembly



Connection between CM1 and CM2

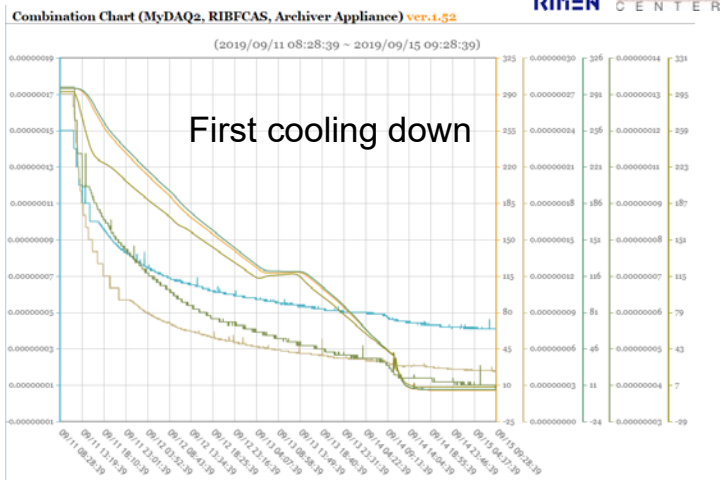


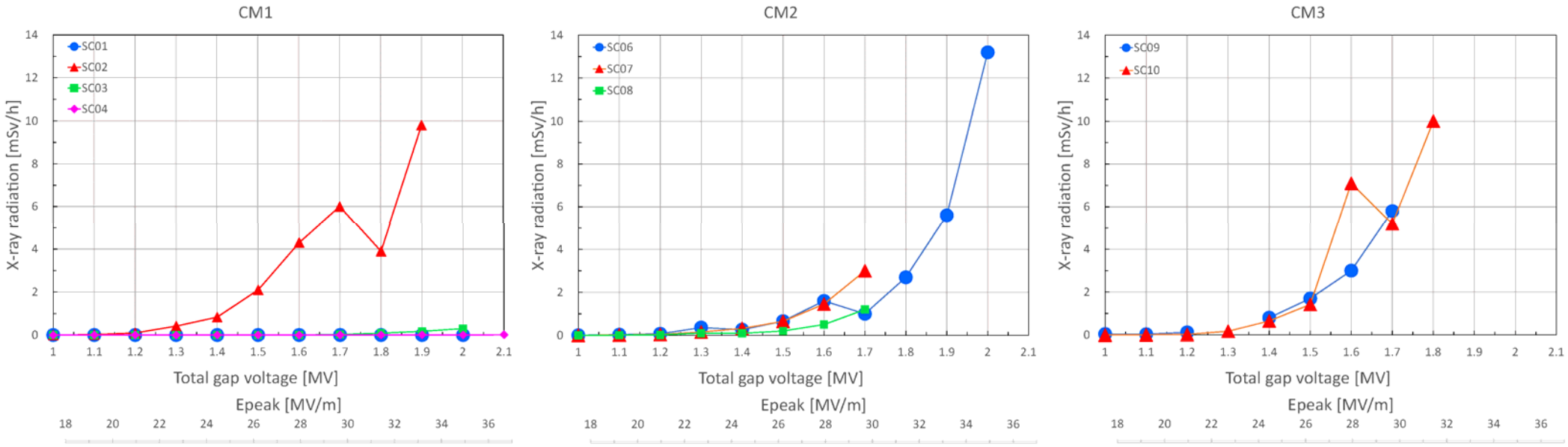
Connection between differential pumping system and CM1



Result of rf excitation test

- Successfully cooled down without any cold leak (Sep. 2019)
- Vacuum leakage from the FPC window (SC05)
  as reported by K. Ozeki, Feb. 04, WG2
- 9 SC-QWRs were excited with rf and X-ray emission
  was measured at each voltage from Dec. 2019
- Assembly order of cryomodule: CM2, CM3, CM1
  (Gate valves have never been opened at this time)





- Last one (CM1) has the best performance → gained experience??
- Cavity with evacuation port seems to be dirty? (SC02)
→ contaminated during slow leak

- Performance of KOACH clean system is sufficient
- Further improvement of working procedure is required

Summary

- 3 cryomodules were assembled and installed by utilizing KOACH clean system
- The first cooling down was successfully performed without any cold leak in Sep. 2019
- 9 SC-QWRs were excited with rf and X-ray emission was measured at each voltage from Dec. 2019
- Performance of KOACH clean system is sufficient

- First beam acceleration has successfully commissioned in Jan. 28, 2020 with 40Ar beam up to E = 6.2 MeV/u

- We will investigate the effect of opening the gate valves and beam acceleration

Collaborators

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