Status of the RIKEN Linac upgrade

N. Sakamoto

RIKEN Nishina Center, Wako, Japan

Contents

RIKEN RI-BEAM FACTORY

Mission : Expand the availability of **heavier RIB**

Wide Mass Range: from deuteron to uranium

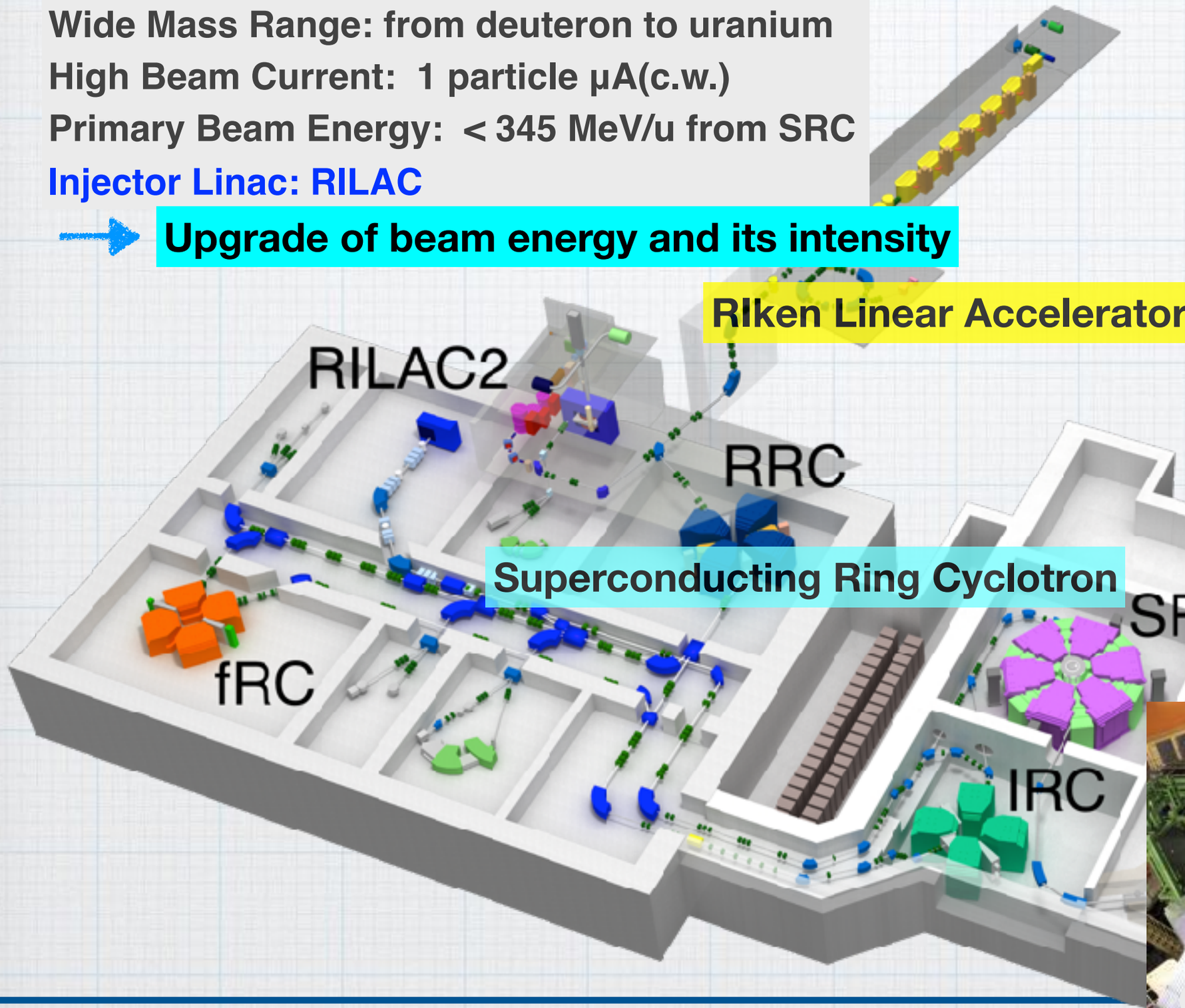
High Beam Current: 1 particle μA(c.w.)

Primary Beam Energy: < 345 MeV/u from SRC

Injector Linac: RILAC

→ **Upgrade of beam energy and its intensity**

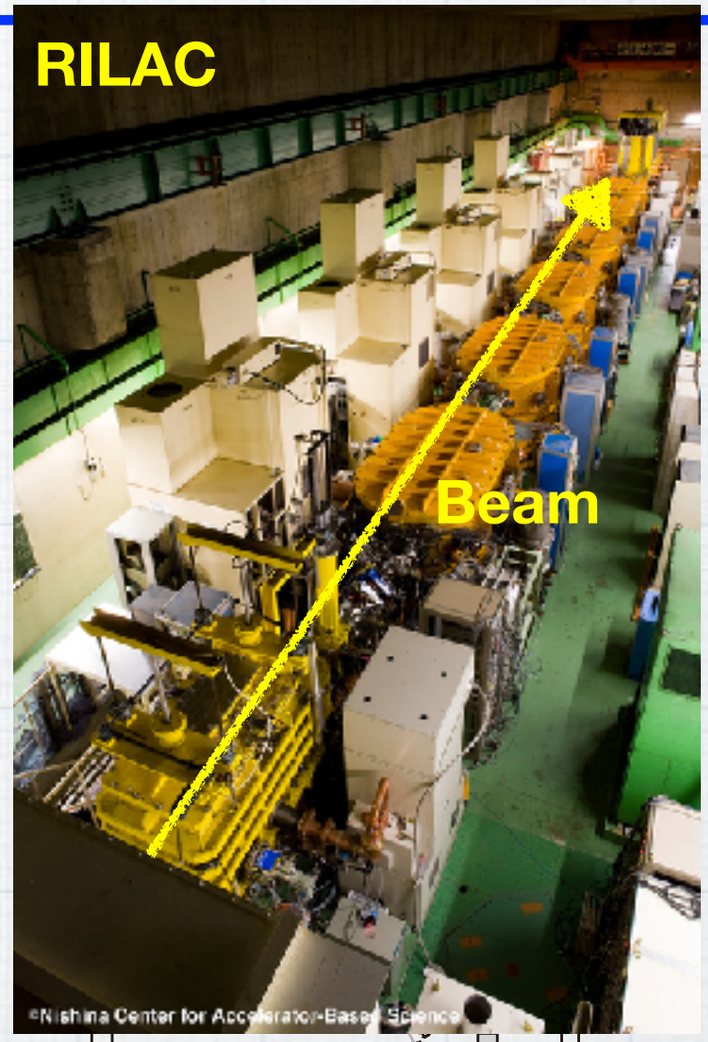
RIken Linear Accelerator

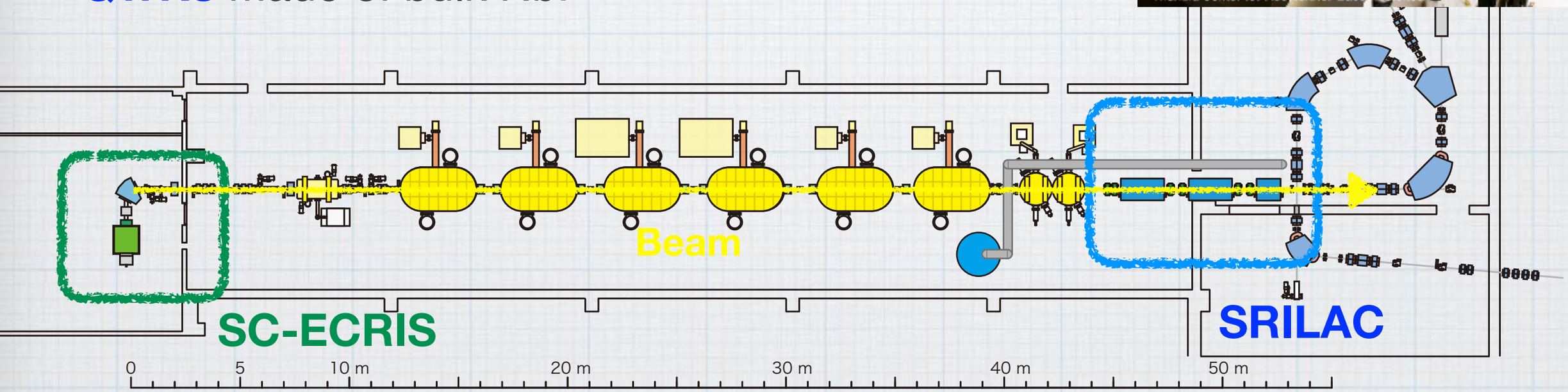


Superconducting Ring Cyclotron

Upgrade of the RIKEN Heavy Ion LINAC (SRILAC)

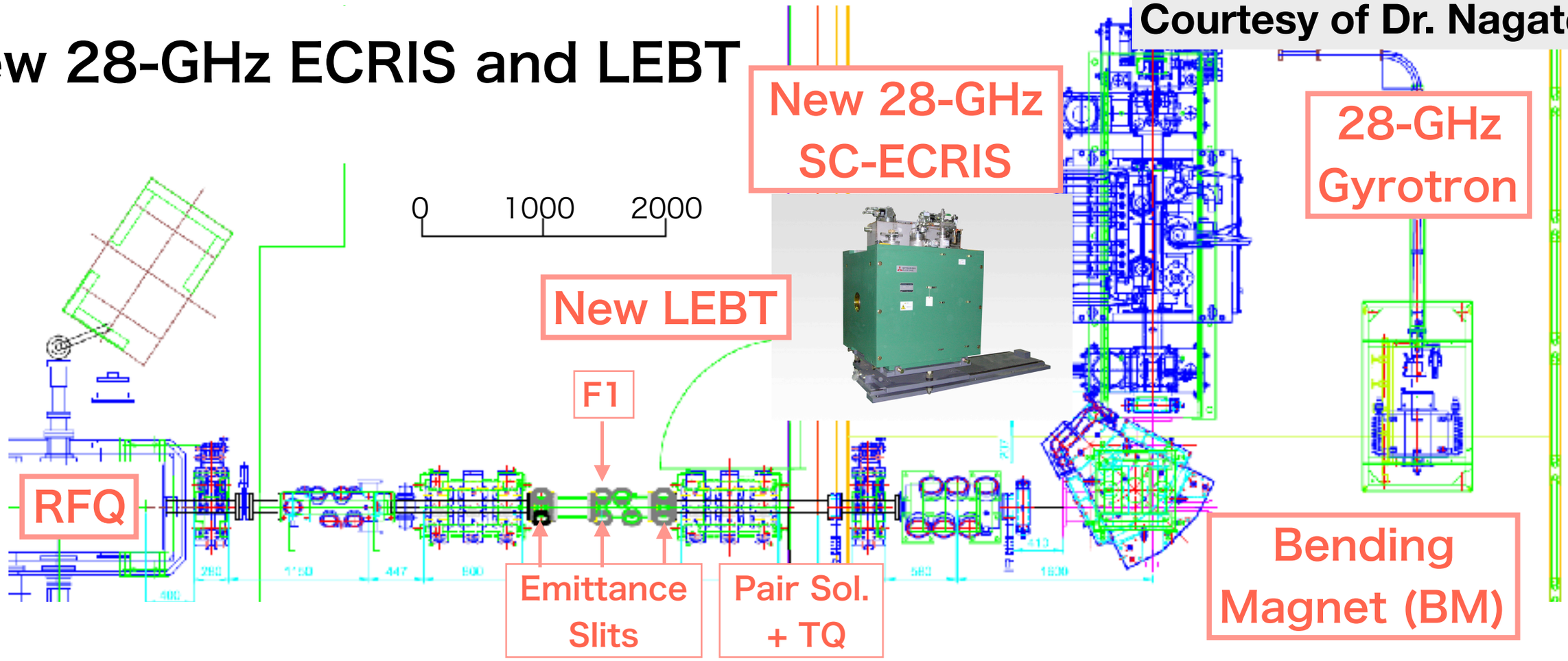
- The RILAC is going to have upgrade aiming to provide intense heavy-ion beams to continue the experiment of **super heavy element** (SHE) synthesis challenging the 8th row of the periodic table of elements (A>=119).
- The intense beams of **q/A larger than 1/5** provided by newly constructed **SC-ECRIS** with 28 GHz rf source will be accelerated up to **6.5 MeV/u**.
- The superconducting linac (**SRILAC**) consists of three cryomodules based on **QWRs** made of bulk Nb.





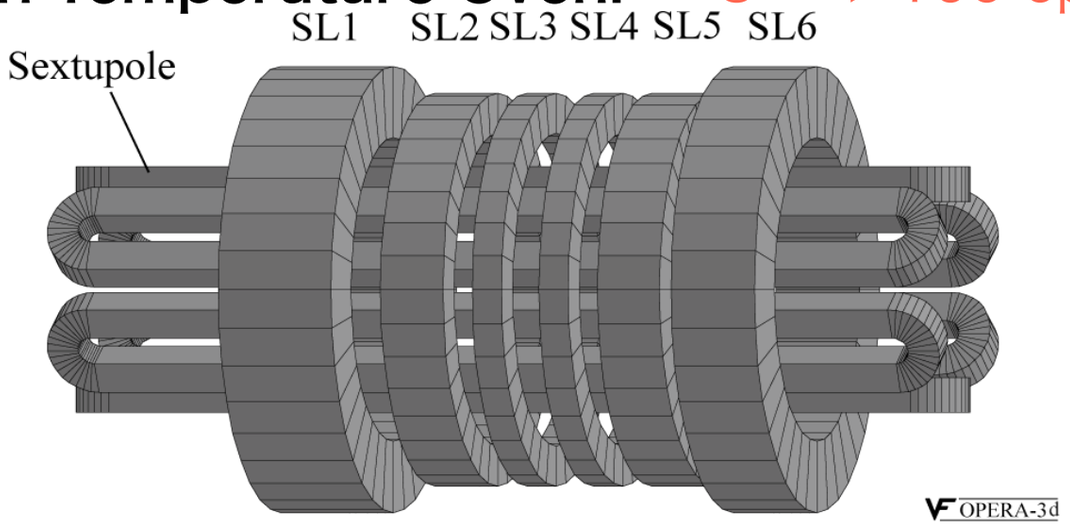
New 28-GHz ECRIS and LEBT

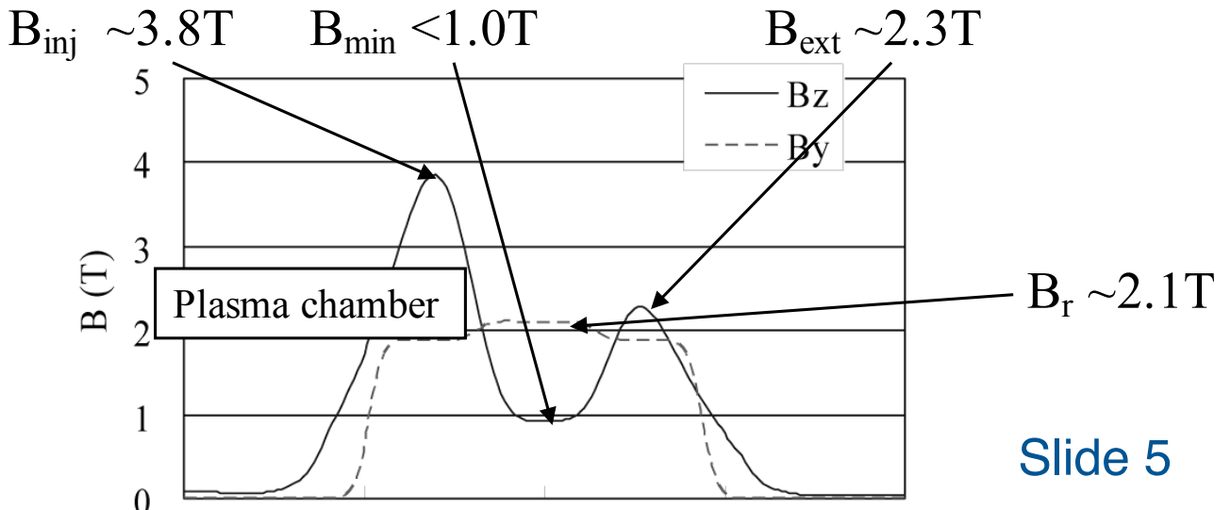
Courtesy of Dr. Nagatomo



NEW 28-GHz SC-ECRIS (basically same as the RIBF ECRIS)

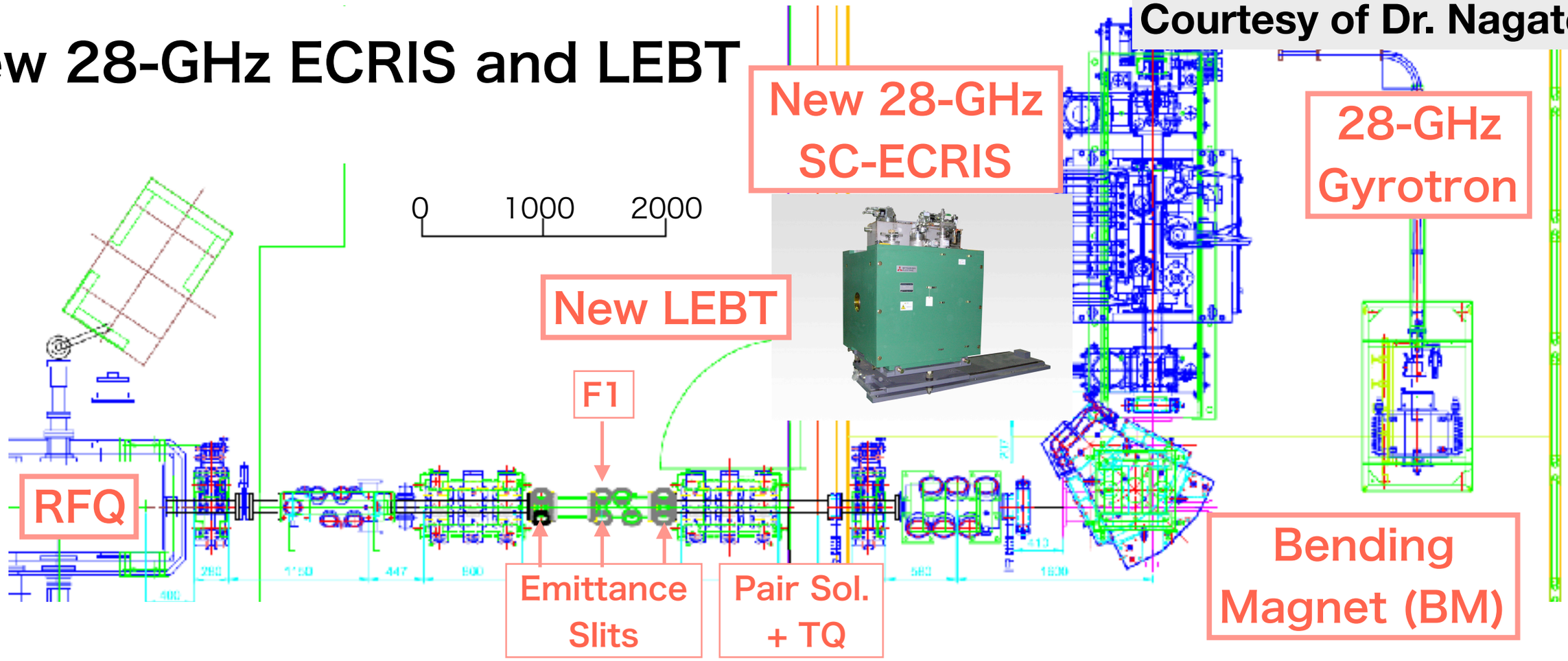
1) **All Superconducting Mirror System:** 6 solenoids (< 4T) and 1 hexapole (< 2T).
2) **Powerful microwaves:** 28-GHz Gyrotron (> 5 kW) and 18-GHz Krystron (>1kW)
3) **Large Volumes of Plasma Chamber:** 10L, 575mm
4) **High Temperature Oven:** $^{238}U^{35+}$ > 100 eμA, $^{51}V^{13+}$ > 100 eμA (Higurashi et al, 2017)





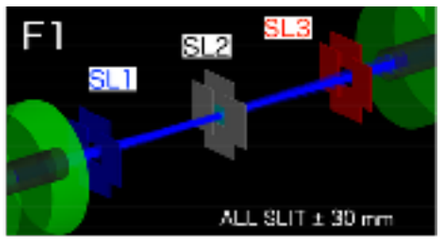
New 28-GHz ECRIS and LEBT

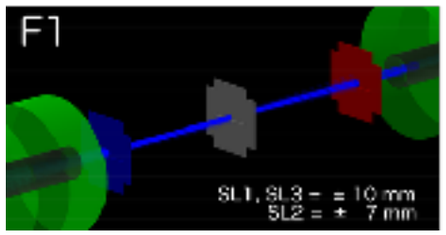
Courtesy of Dr. Nagatomo

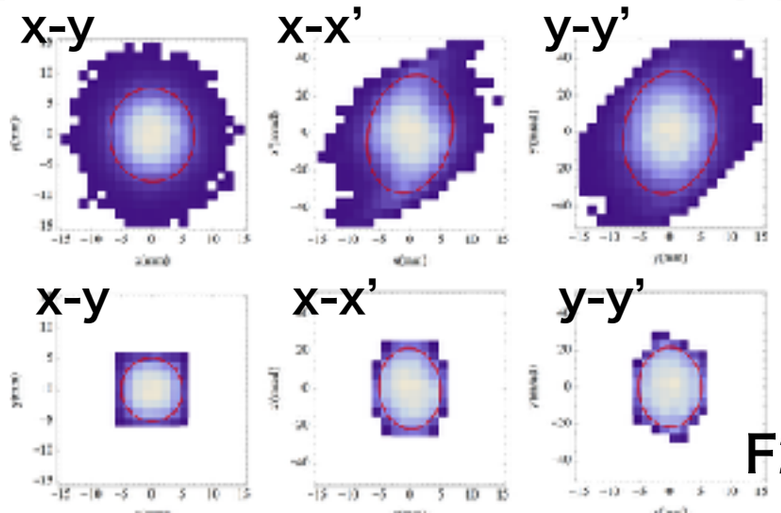


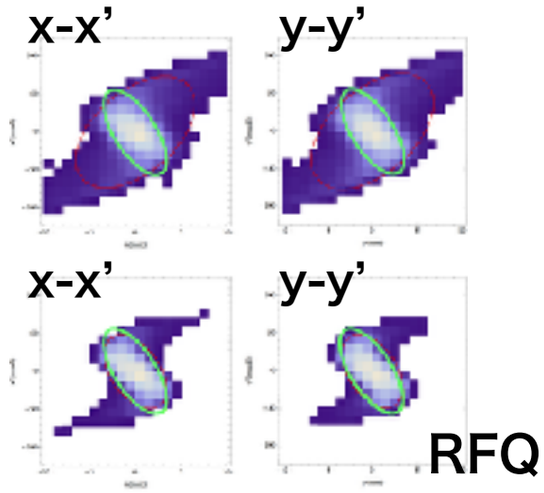
NEW LEBT (BM - Pair Sol.+TQ - TQ - Pair Sol.)

1) **Aberration Corrected BM:** Special pole face to cancel the hexapole component.
2) **Pair Sol. + TQ:** Tune the arbitrary transverse emittance to the beam acceptance at F1.
3) **Emittance Slits at F1:** A set of three slits limits the angle as well as the spatial spread.
4) **Pepper-pot-type Emittance meter:** {x,x',y,y'} correlations from only 1 beamlet image.









ε_{4rms} ~250 πmm*mrad→
RFQ Acceptance: 144 πmm*mrad

SRILAC

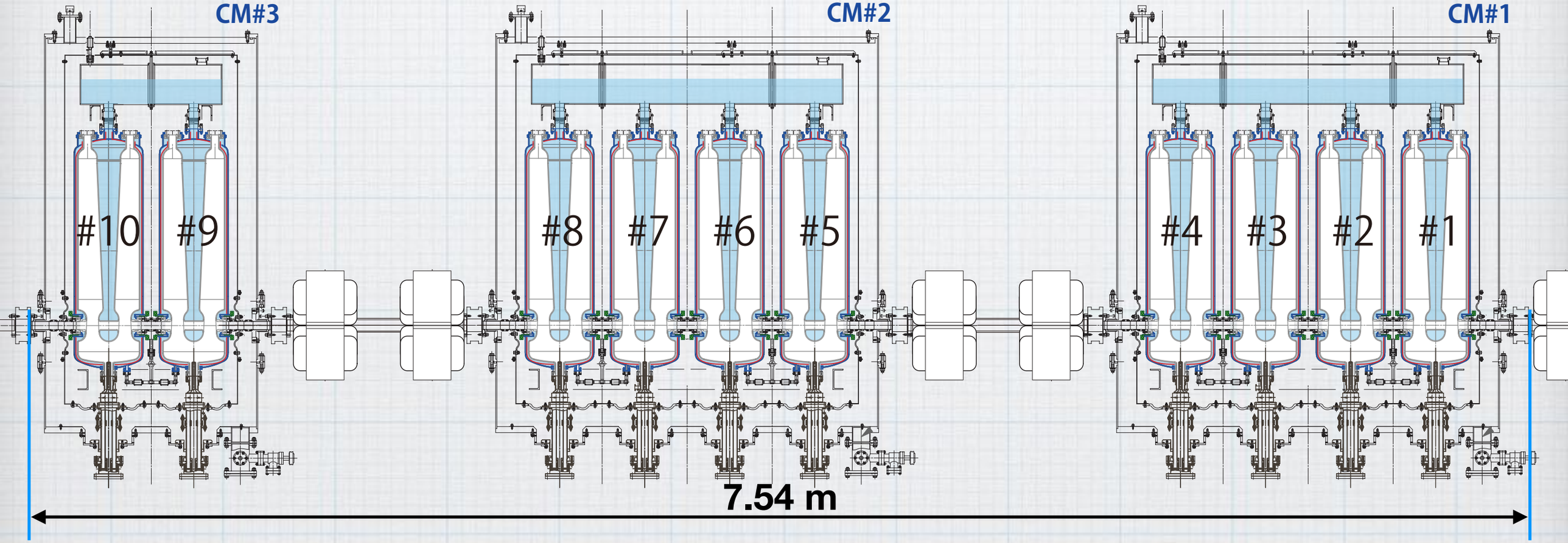
- 4 RT DTLs will be replaced by three CMs with 4.5K helium.
- Energy upgrade:

  5 MeV/u (M/q=5) → **6.5 MeV/u (M/q=5)**

  7.5 MeV/u (M/q=4)

  12 MeV/u (M/q=4)

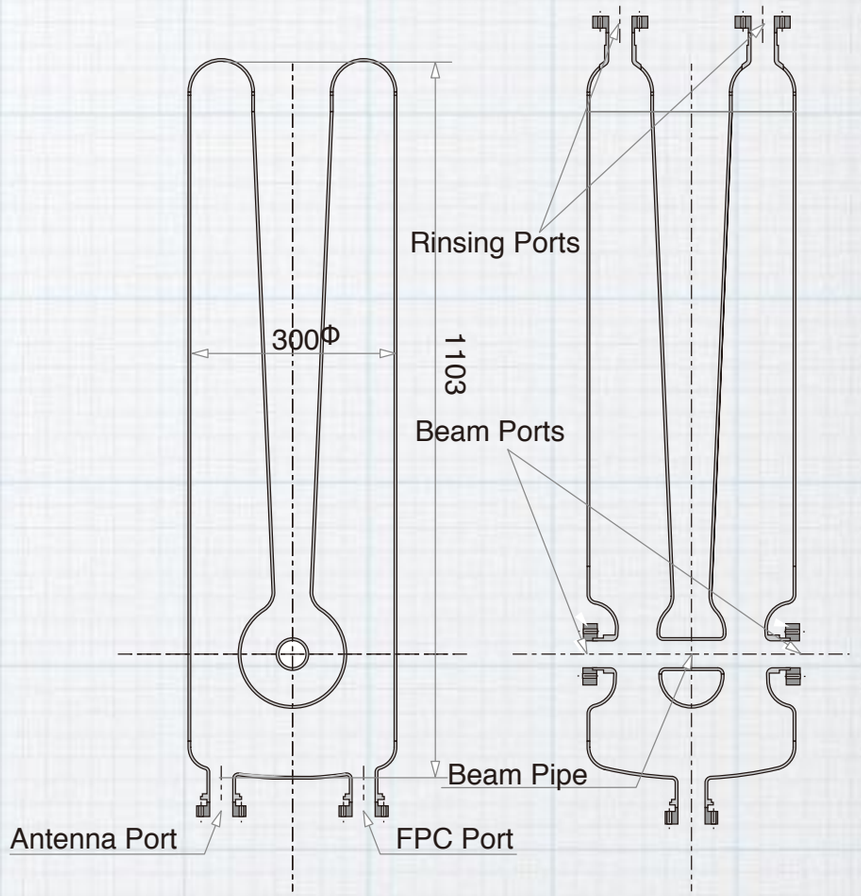
- Total length of the superconducting part is about 7.5 m.
- Focusing element of RT Q-magnets are installed between CMs.



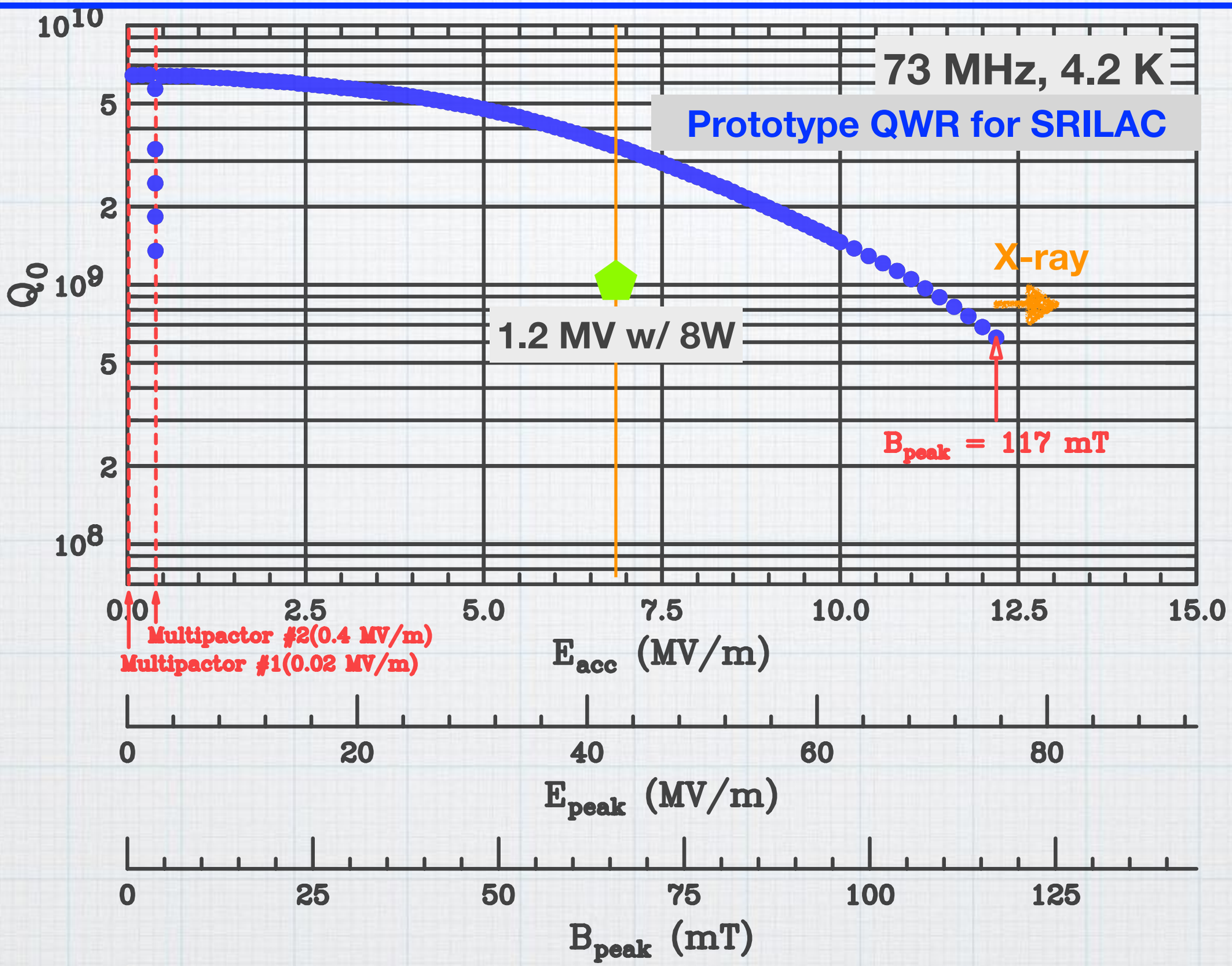
Superconducting Cavity

- The first prototype cavity with 73 MHz was produced before prior to series of the ten cavity production.
- The first VT was performed in October 2017 at KEK.

Operational Parameters	
Number of cavities	10 QWRs 73.0 MHz (C.W.)
Voltage (E_{acc})	1.2 MV/gap (6.75 MV/m)
Q_0	9×10^8 at 4.5K
E_{pk} / E_{acc}	6.2
B_{pk} / E_{acc}	9.6 mT/(MV/m)
Beam Current	<100 μA
Variable Q_{ext}	1×10^6 to 1×10^7



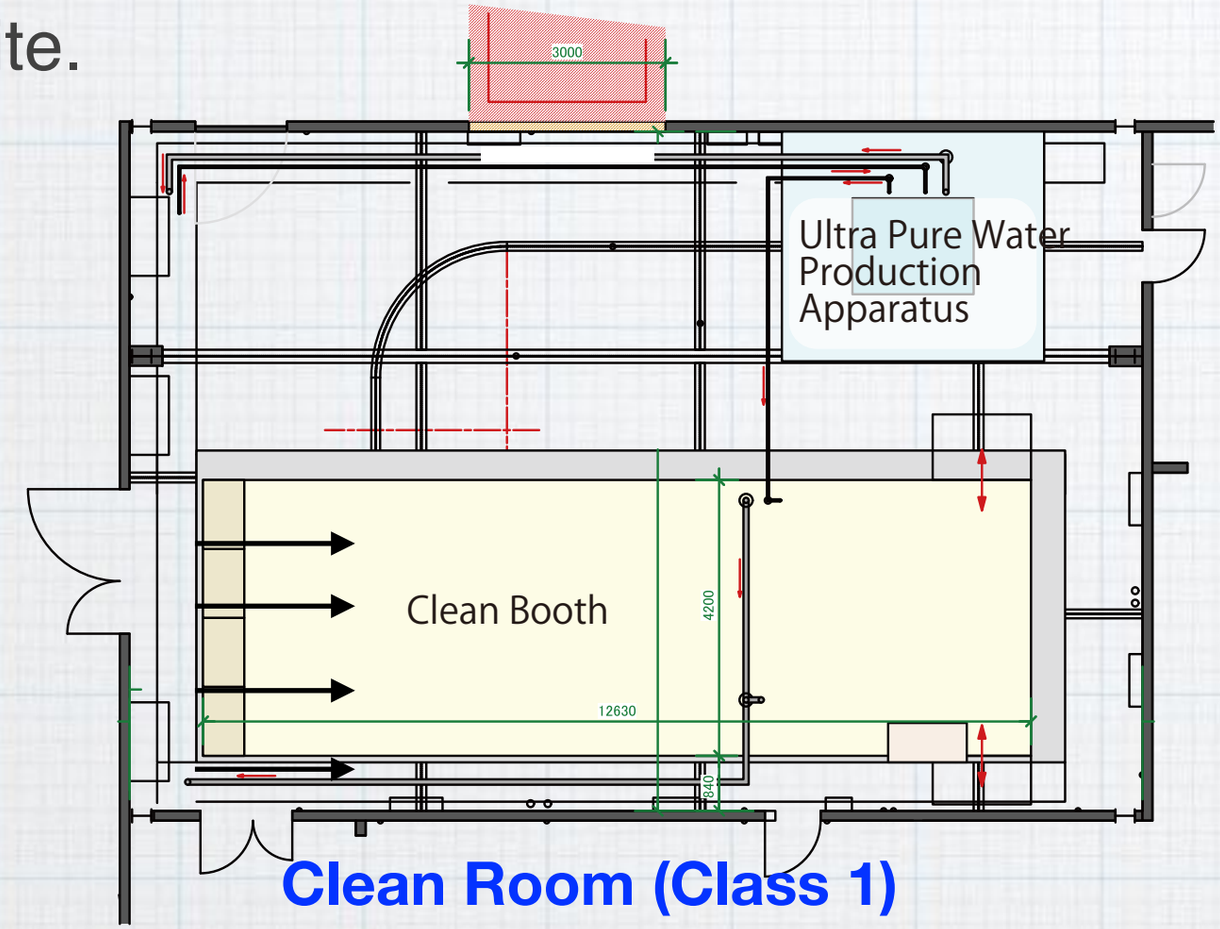
Q_0 measurement at KEK



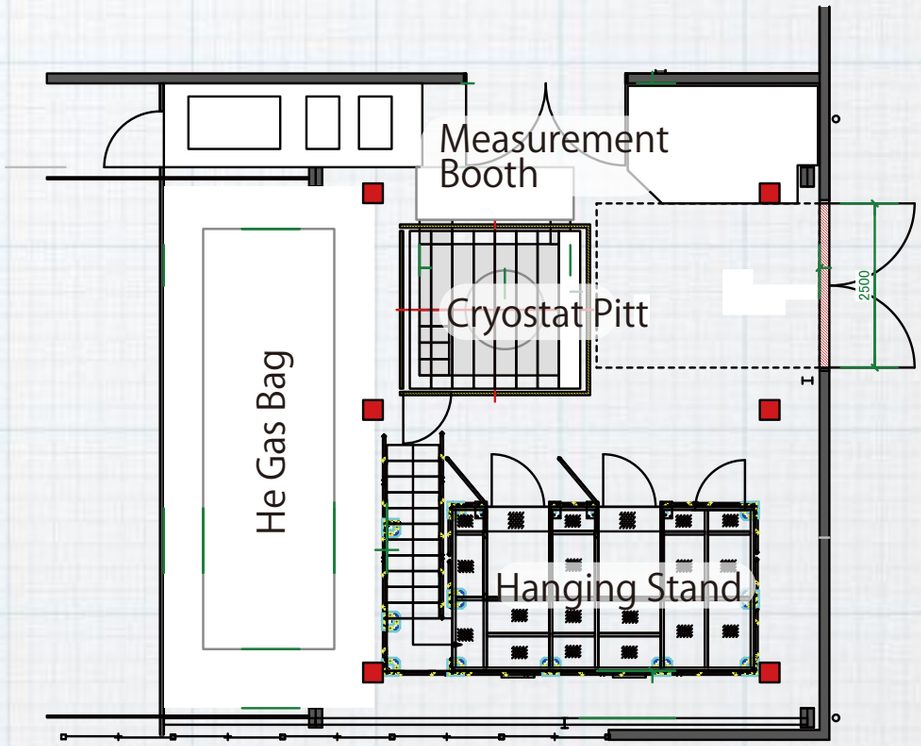
Q_o of 3.5E9 was obtained at E_{acc} of 6.8 MV/m at 4.2 K.

SRF Facility in RIKEN

■ To accept ten sc-cavities a VT facility (under construction) and a Clean Booth (class 1) are under construction in the existing building in RIKEN Wako cite.



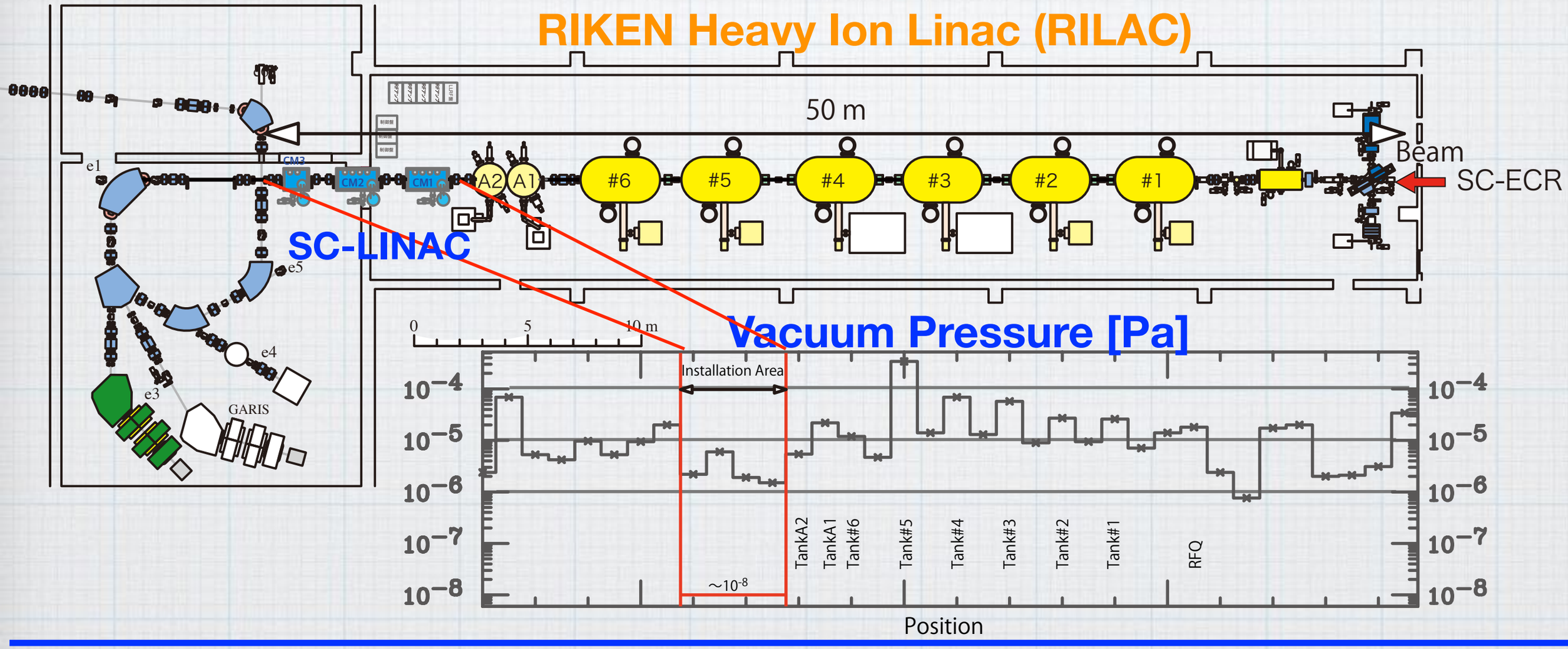
Clean Room (Class 1)



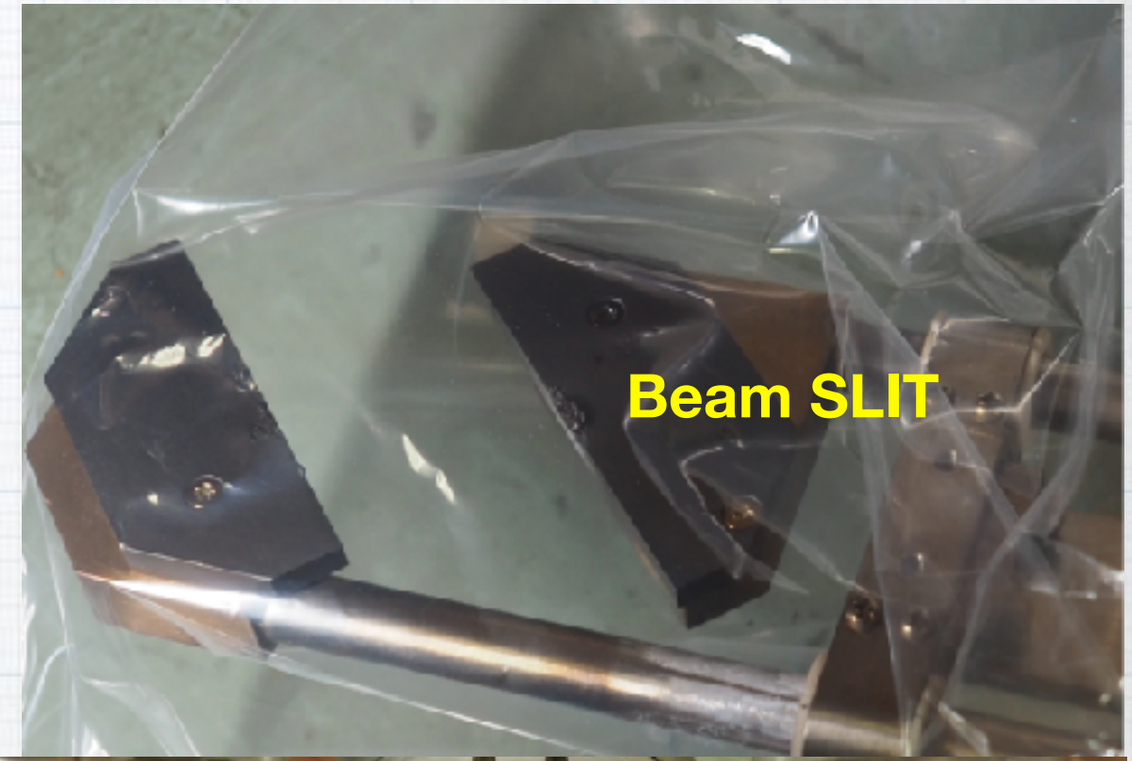
Vertical Test Facility

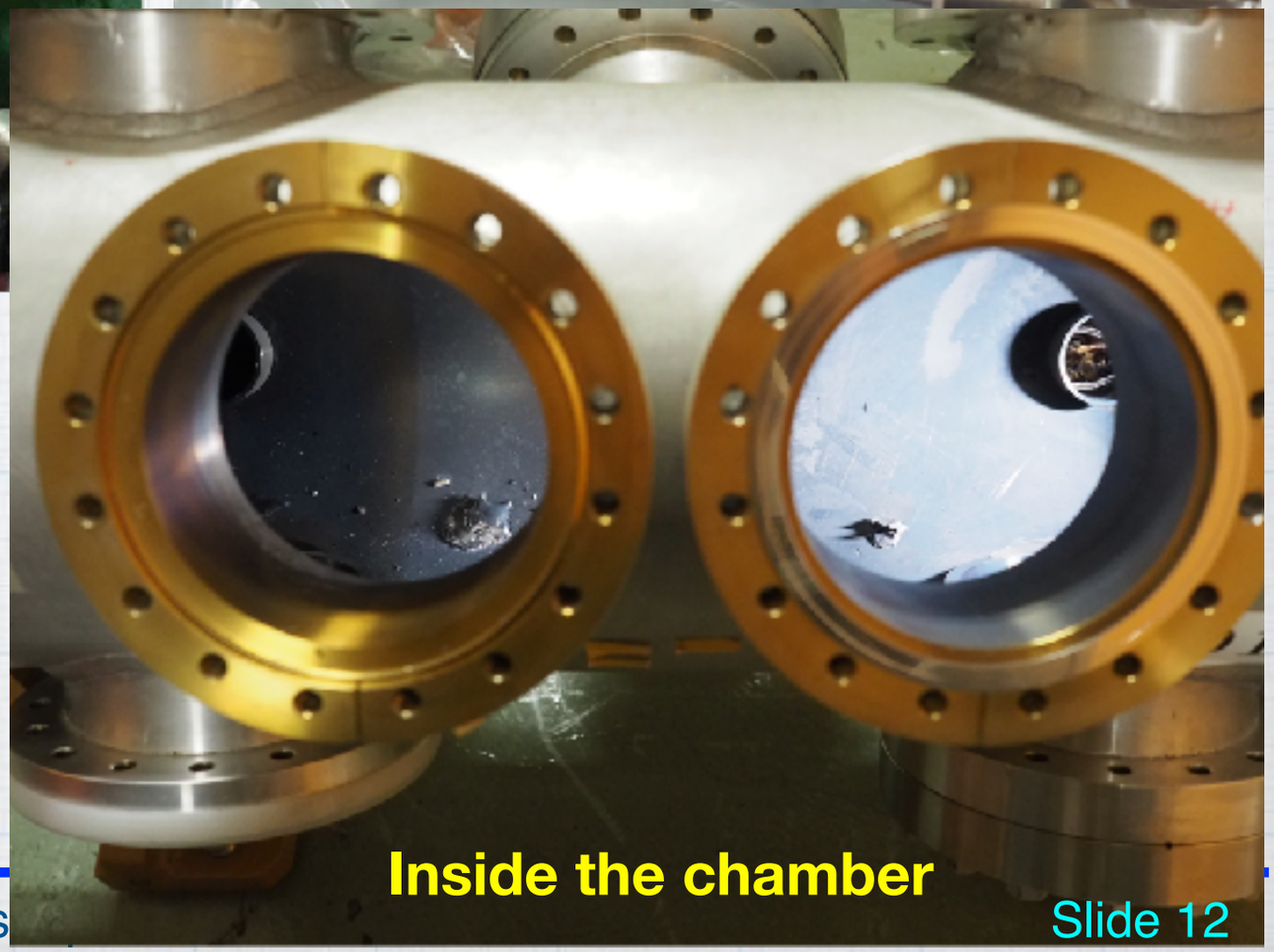
Installation to the existing RT Linac

- RT frequency tunable DTL has large volume with sliding short plate.
- Vacuum level is $1x10^{-6}$ to $1x10^{-4}$ Pa. (Viton O-rings are used at everywhere!)
- Destructive beam diagnostic devices such as Faraday cup, wire scanner cause vacuum deterioration and generate dusts.
- Beam slits and charge stripper carbon-foils also generate particulate.



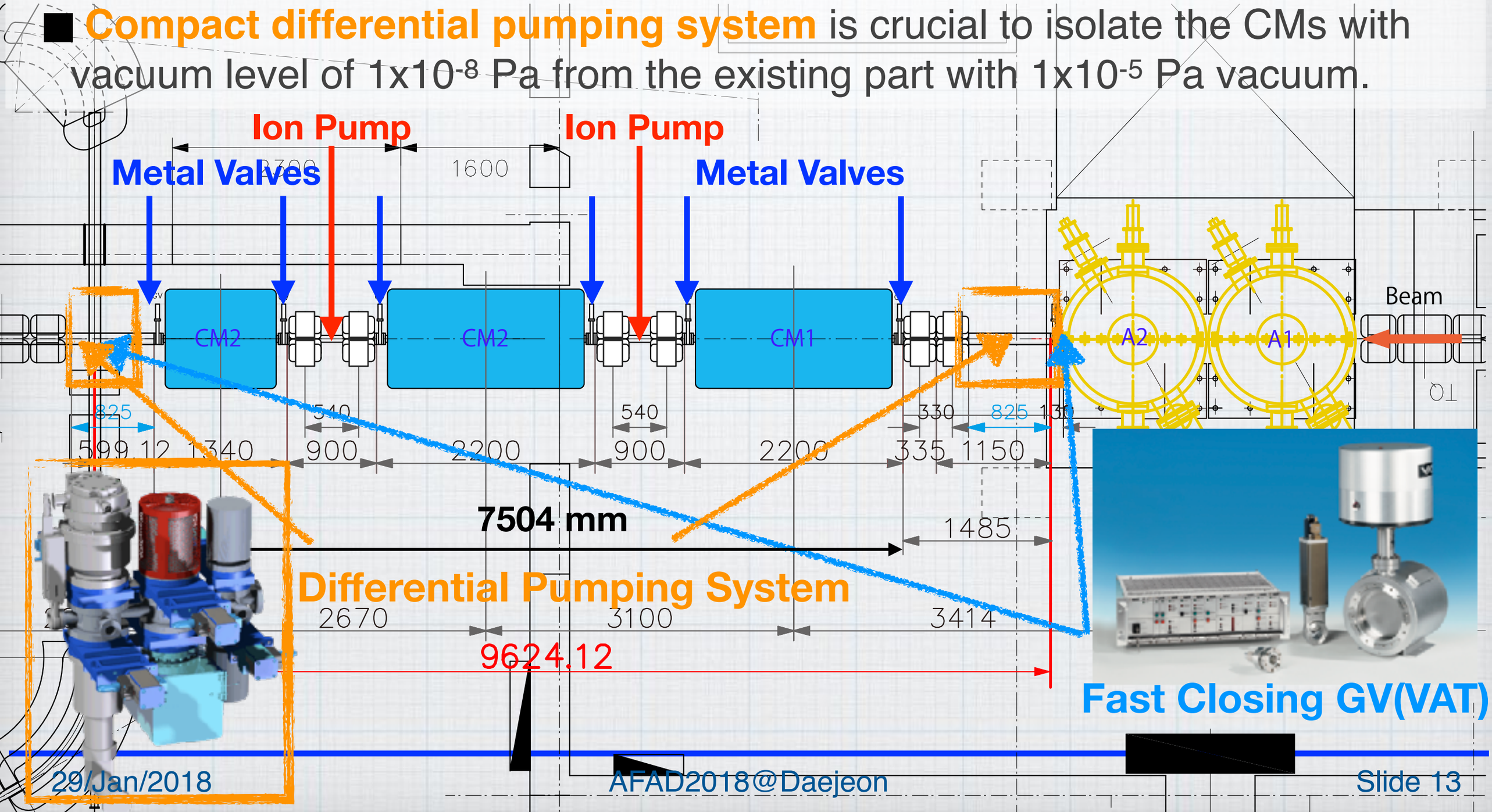
Example of Destructive Beam Diagnostic Devices





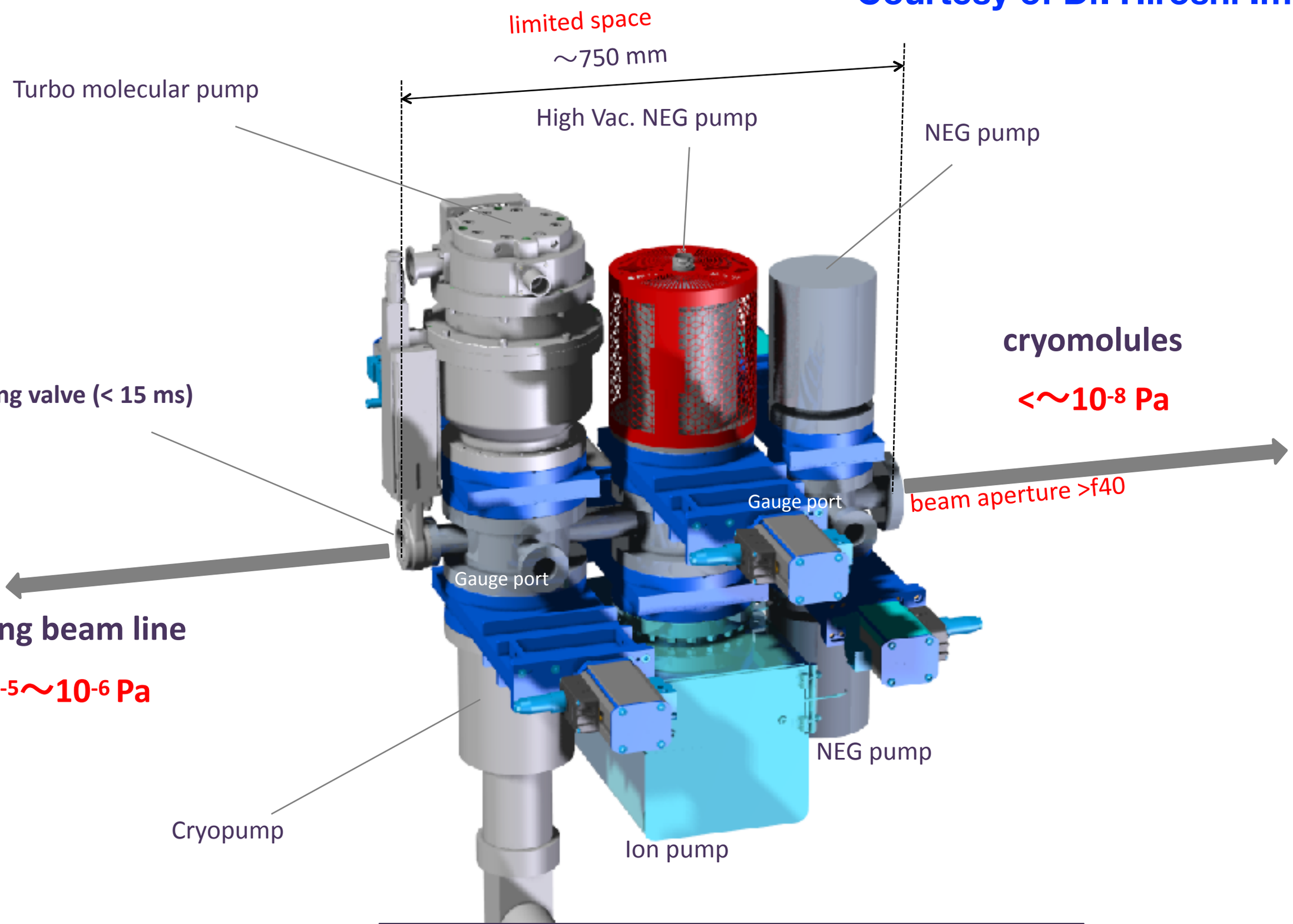
How can we protect CMs?

- The CMs are protected with **metal valves** when beam is off.
- **Fast closing gate valve** provided by VAT responses within 15 ms which is expected to be effective against air-inrush from the experimental stations.
- **Compact differential pumping system** is crucial to isolate the CMs with vacuum level of $1x10^{-8}$ Pa from the existing part with $1x10^{-5}$ Pa vacuum.



Schematic view of optimized differential pumping system

Courtesy of Dr. Hiroshi Imao



3-stage differential pumping system

Construction Schedule

■ Ten QWRs are planned to be tested by the third quarter of FY2018.

Construction Schedule

Items	FY2016								FY2017												FY2018											
	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Cavity	Design																	Now														
	Application for Japan High Pressure Gas regulation																															
	Prototype								VT@KEK											VT@RIKEN												
	Cavity Production #1-4																				VT											
	Cavity Production #5-10																															
	VT#5-10																															
Coupler	Design																															
	Production#1-10																															
	Test#5-10																															
Cryomodule	Design																			Test#1-4												
	Production of Parts																														Cooldown Te	
	Assembly CM1																											Install				
	CM2																												Install			
	CM3																													Install		
	Integration to Liq. He Systen																															

Summary

- RIken Linear-ACcelerator (RILAC) will have upgrade replacing four DTLs by three superconducting cryomodules which consists of **ten QWRs with a frequency of 73 MHz**. RT focusing elements will be installed between CMs.
- **SC-ECRIS** w/ 28 GHz Gyrotron is under construction. Beam commissioning is scheduled in July 2018.
- **Prototype QWR** was designed and fabricated to obtain fundamental data of cavity production.In VT performed at KEK, measured Q_0 was as large as 3.5E9 at the acceleration gradient of **6.8 MV/m. i.e. 1.2 MV w/ 2.3W**
- Connection between unclean part and clean part will be realized by introducing **compact differential pumping systems** to intercept particulate by reducing the gas flow into SC part.
- Upgrade of the RILAC will be completed by the end of FY2018 aiming to start the SHE experiment in FY2019.

Acknowledgement:

This project is realized by collaboration with KEK SRF group.

Authors are grateful to staffs of NAT (KEK) for helping us during VT at KEK.