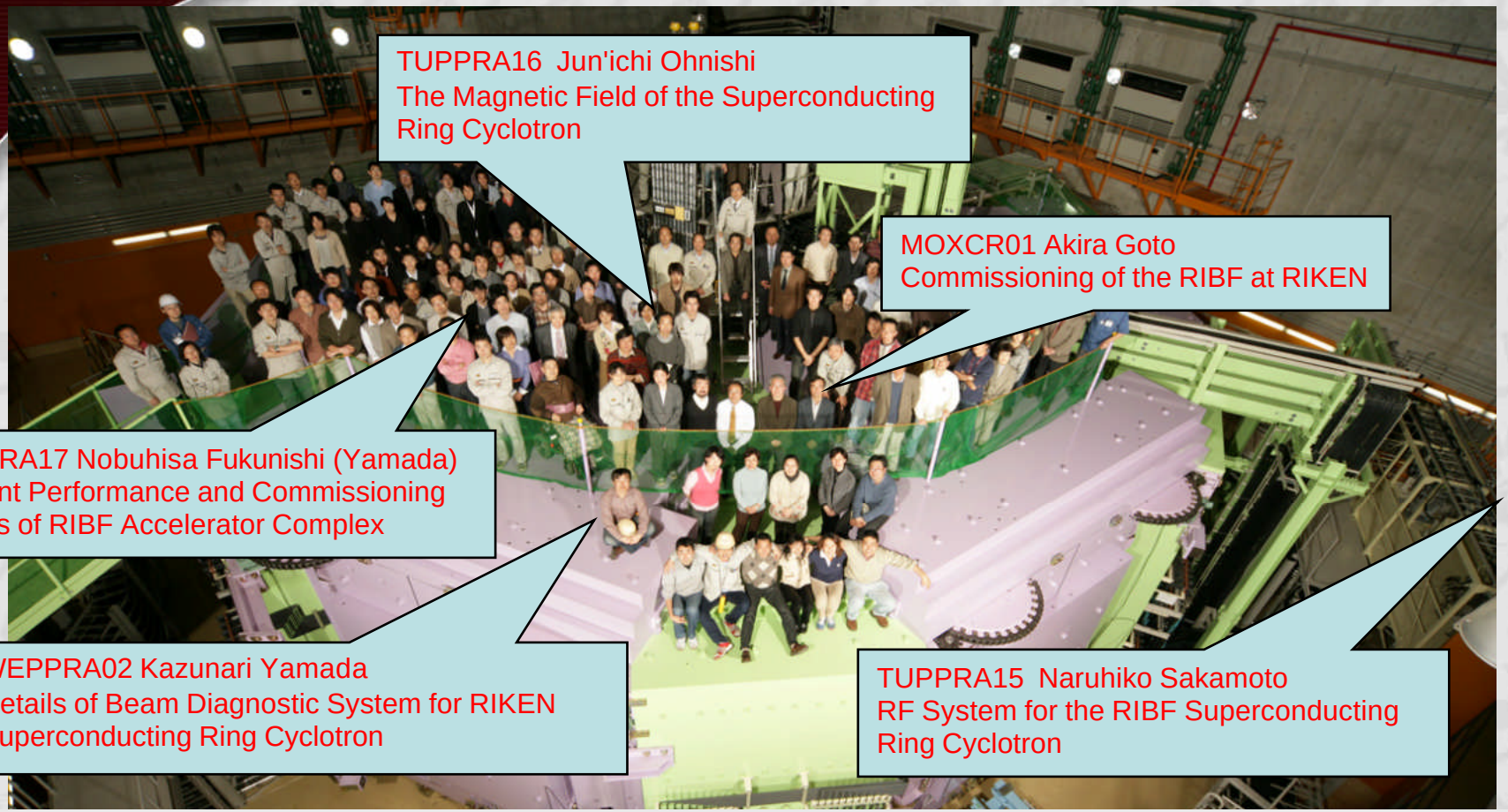
Hardware Commissioning of the RIKEN Superconducting Ring Cyclotron



TUPPRA16 Jun'ichi Ohnishi
The Magnetic Field of the Superconducting Ring Cyclotron

MOXCR01 Akira Goto
Commissioning of the RIBF at RIKEN

TUPPRA17 Nobuhisa Fukunishi (Yamada)
Present Performance and Commissioning Details of RIBF Accelerator Complex

WEPPRA02 Kazunari Yamada
Details of Beam Diagnostic System for RIKEN Superconducting Ring Cyclotron

TUPPRA15 Naruhiko Sakamoto
RF System for the RIBF Superconducting Ring Cyclotron

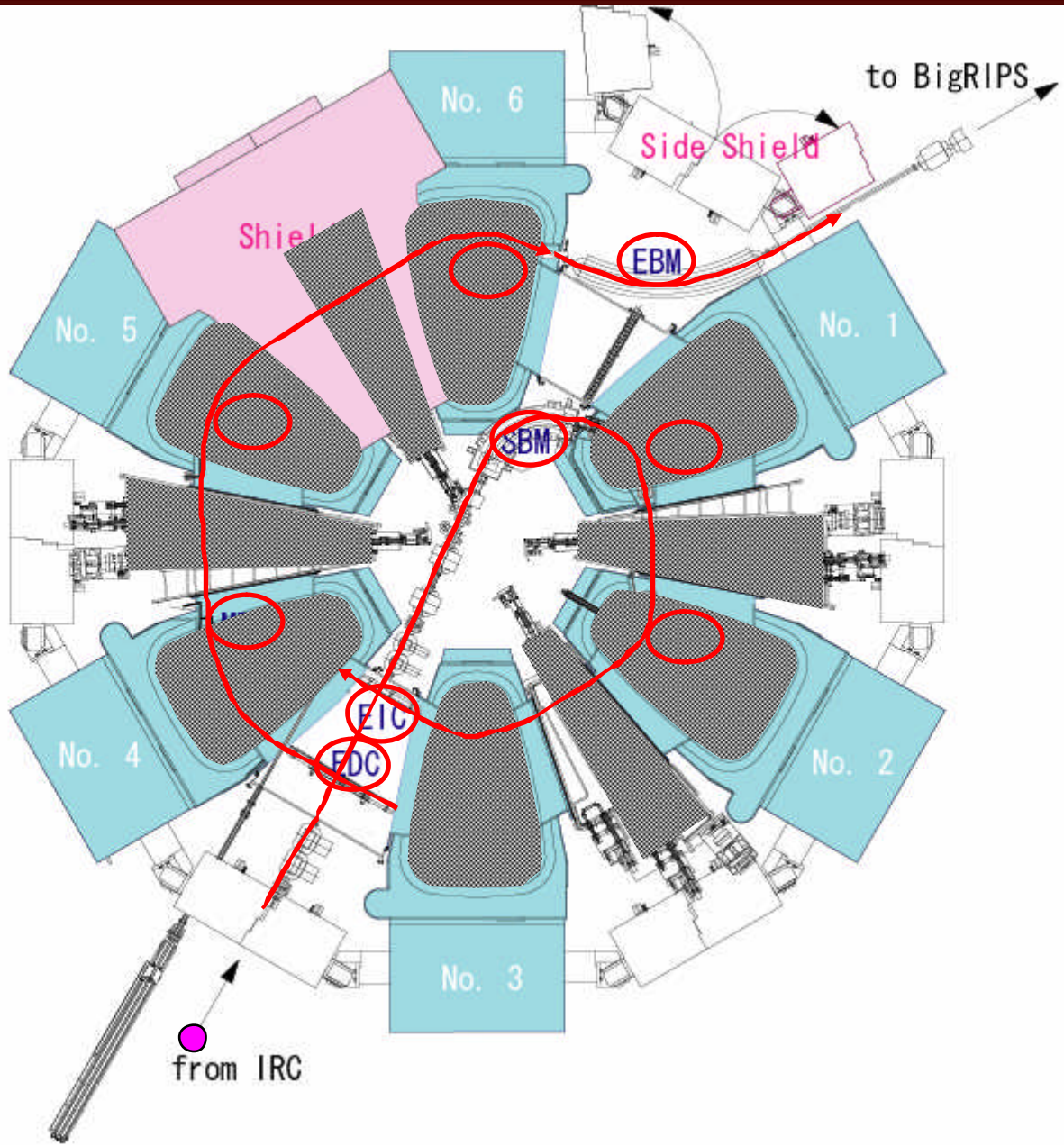
H. Okuno, K. Yamada, J. Ohnishi, N. Fukunishi, N. Sakamoto, O. Kamigaito, M. Fujimaki, H. Hasebe, K. Kumagai, T. Maie, M. Nagase, S. Yokouchi, K. Ikegami, M. Kase, A. Goto and Y. Yano, *RIKEN Nishina Center*

SRC: the World's First Superconducting Ring Cyclotron

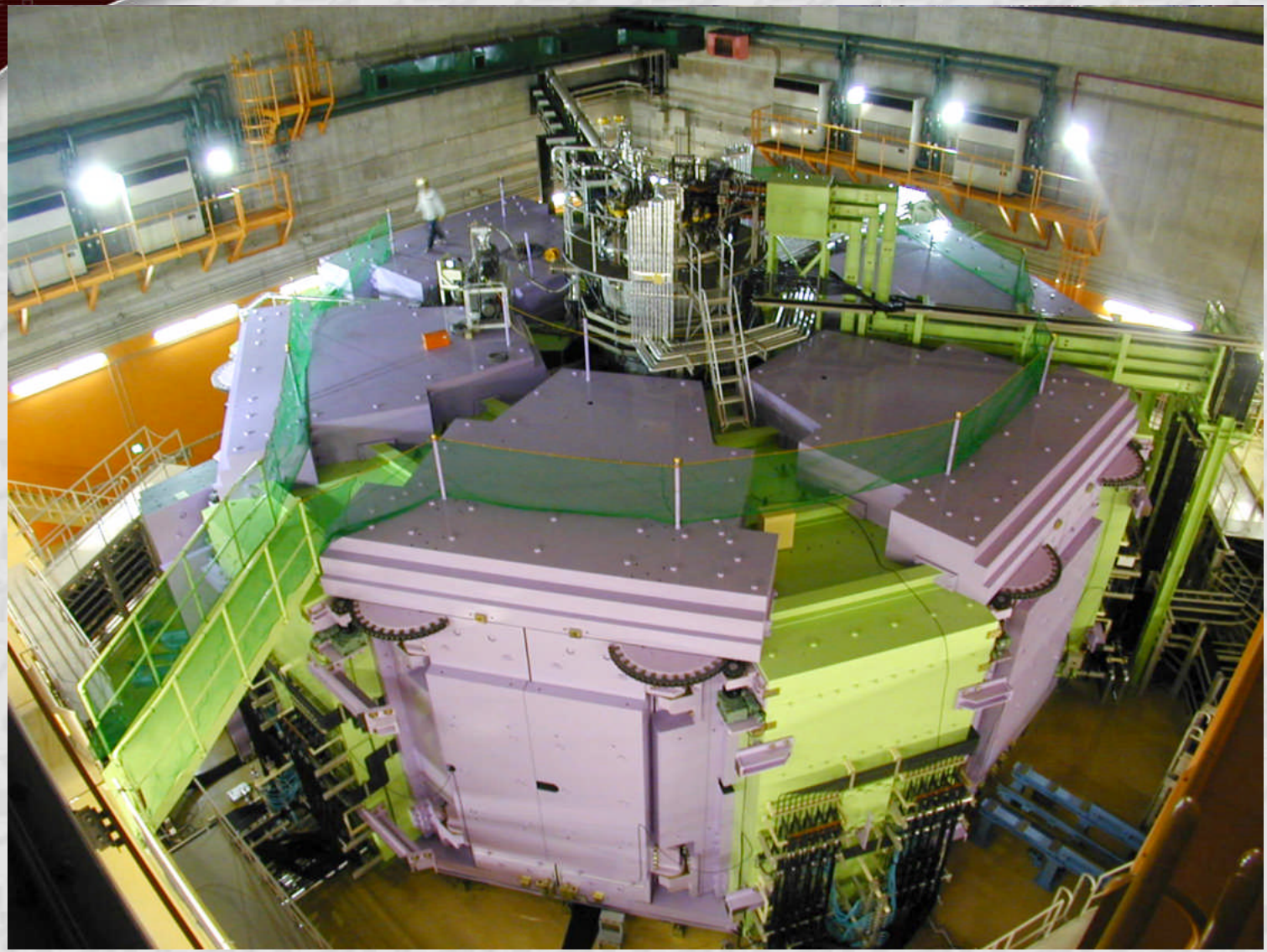
K = 2,600 MeV
Max. Field: 3.8T (235 MJ)
RF frequency: 18-38 MHz
Weight: 8,300 ton
Diameter: 19m Height: 8m

Sector Magnets :6
RF Resonator :4
Injection elements.
Extraction elements.

Self Magnetic Shield
Self Radiation Shield

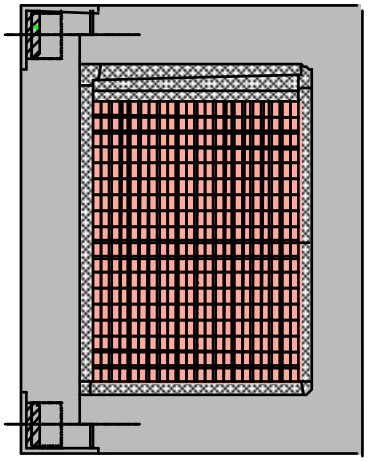


Assembling of SRC in the vault



Cold mass assembly

Main Coil



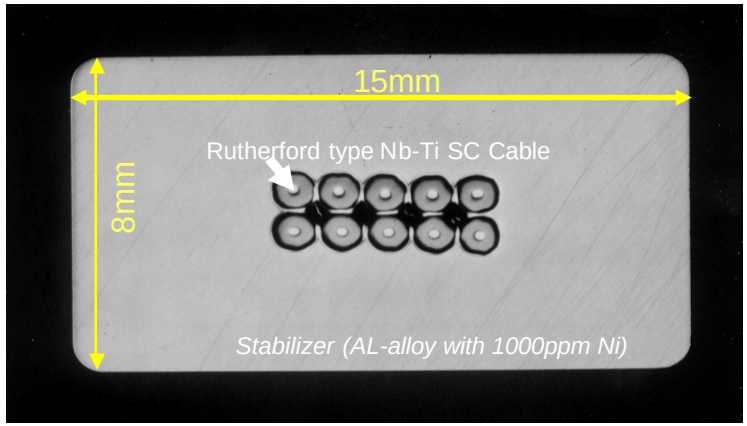
Solenoid winding with 396 turn

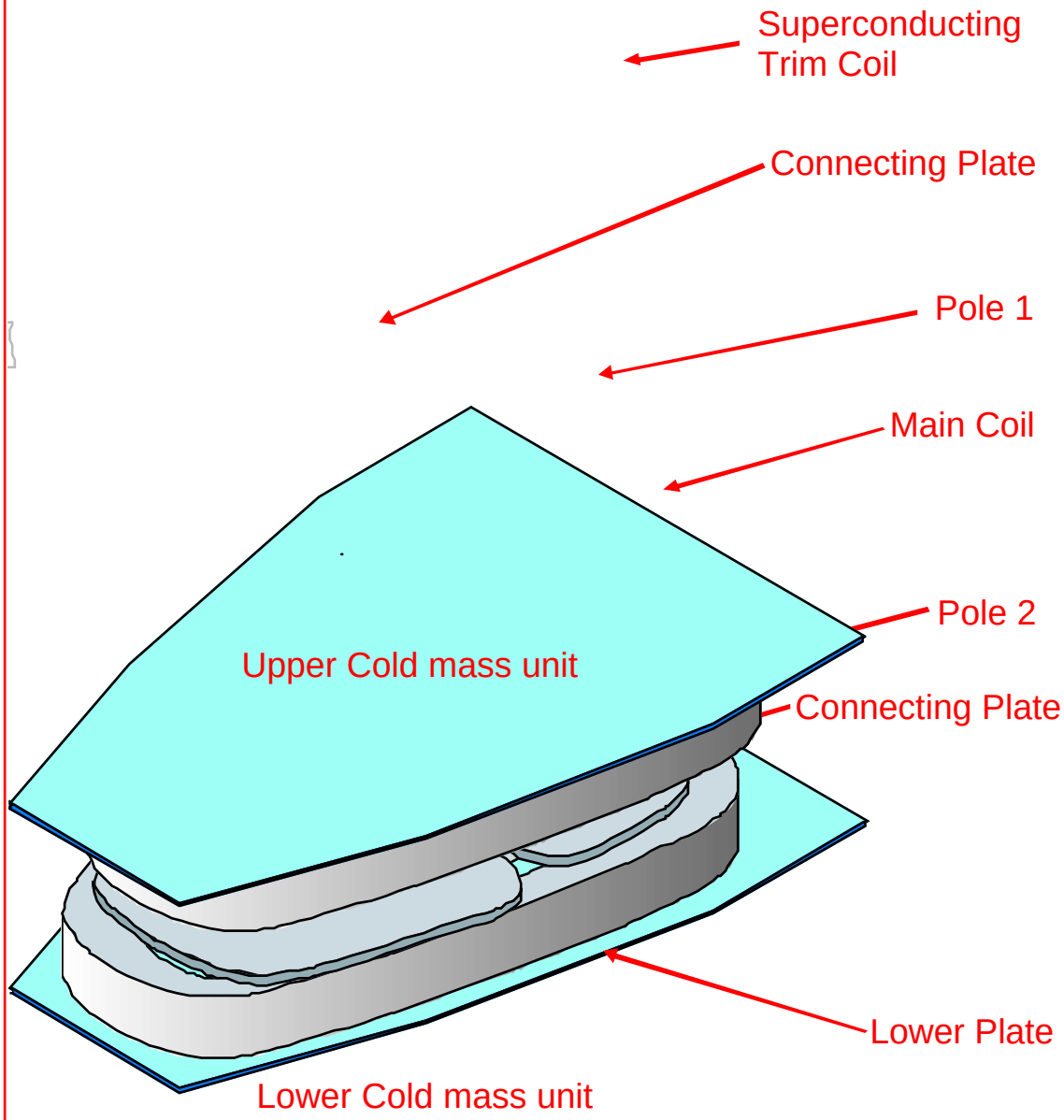
Circumference : 10m

Maximum Current : 5000 A

Bath cooling

Conductor

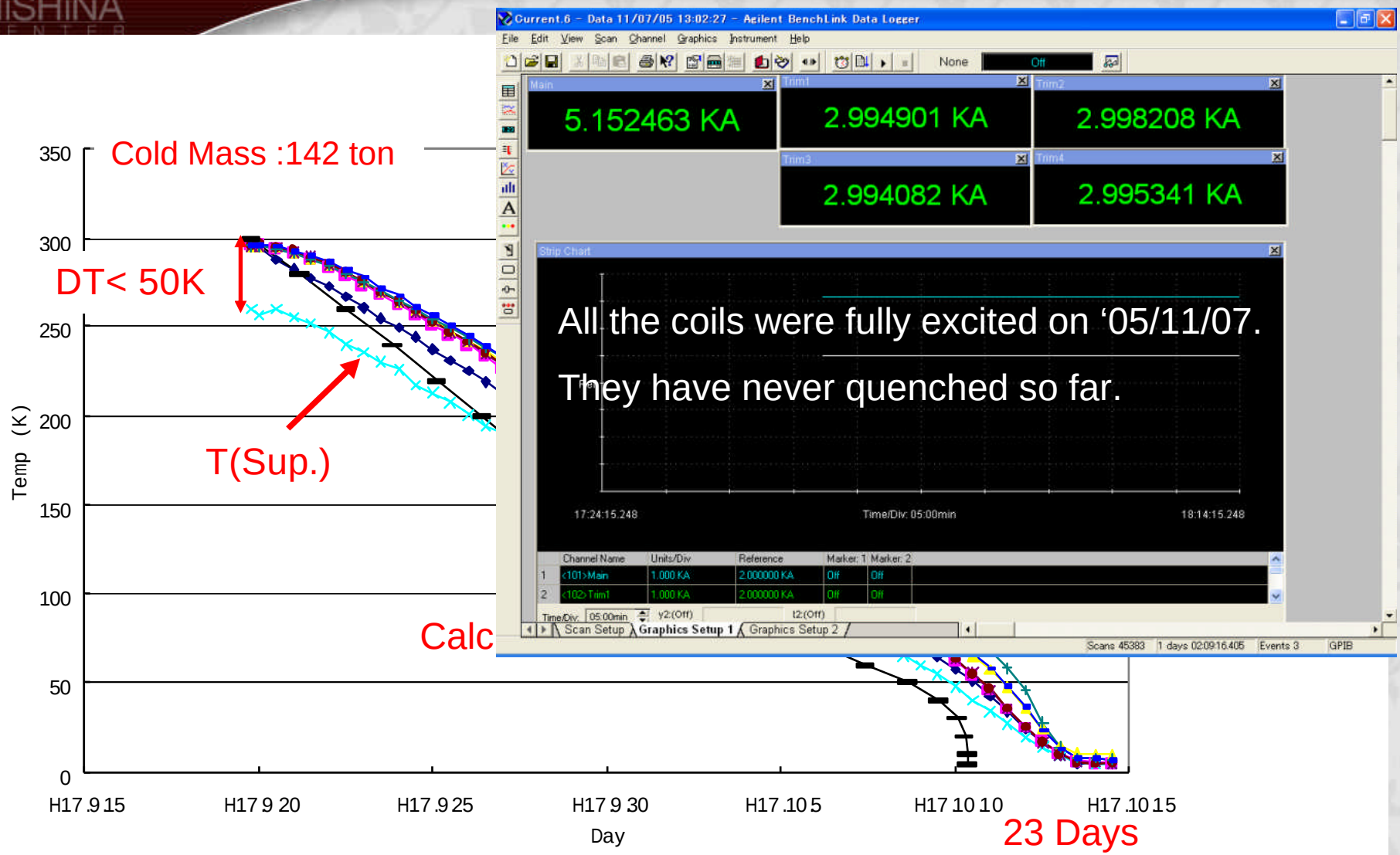




The history of the commissioning

Date	Phase I (Test of the S.C. Magnets)	Date	Phase II (toward the first beam)
05/9/19	The 1st Cool-down started	06/6/24	Arrival of RF resonators
05/10/13 1:00AM	All the main coils transited to superconducting state.		*RF, Beam diagnostics, Vacuum pumping system were installed*
05/11/7	Excitation test (Imain = 5000 A, Itrim = 3000 A)	06/10/18	*Vaccuum for the beam < 10^{-5} Pa*
05/11/8	*Trouble due to a He leak*	06/11/~	*RF conditioning Started.*
06/4/15	Full excitation again	06/12/17	Beam injection to SRC
06/4/17-06/6/14	Magnetic field measurements	06/12/28	The first beam from SRC!
06/6/14	Fast shutdown test from full excitation	07/03/23	The first Uranium beam!
		07/05/~	New isotope search

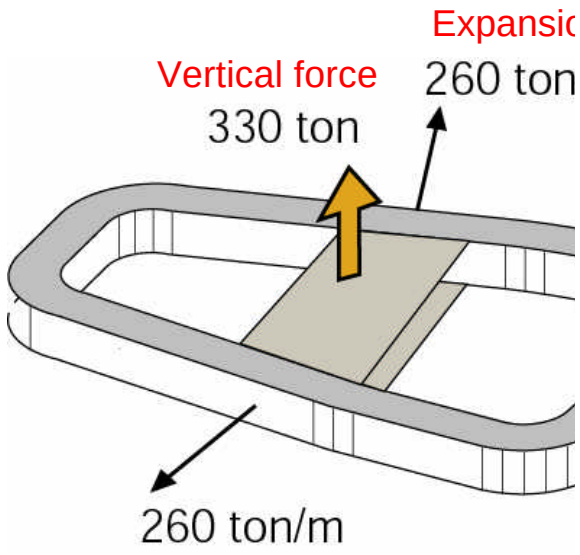
The First Cool-down and Excitation



Magnetic forces in excitation

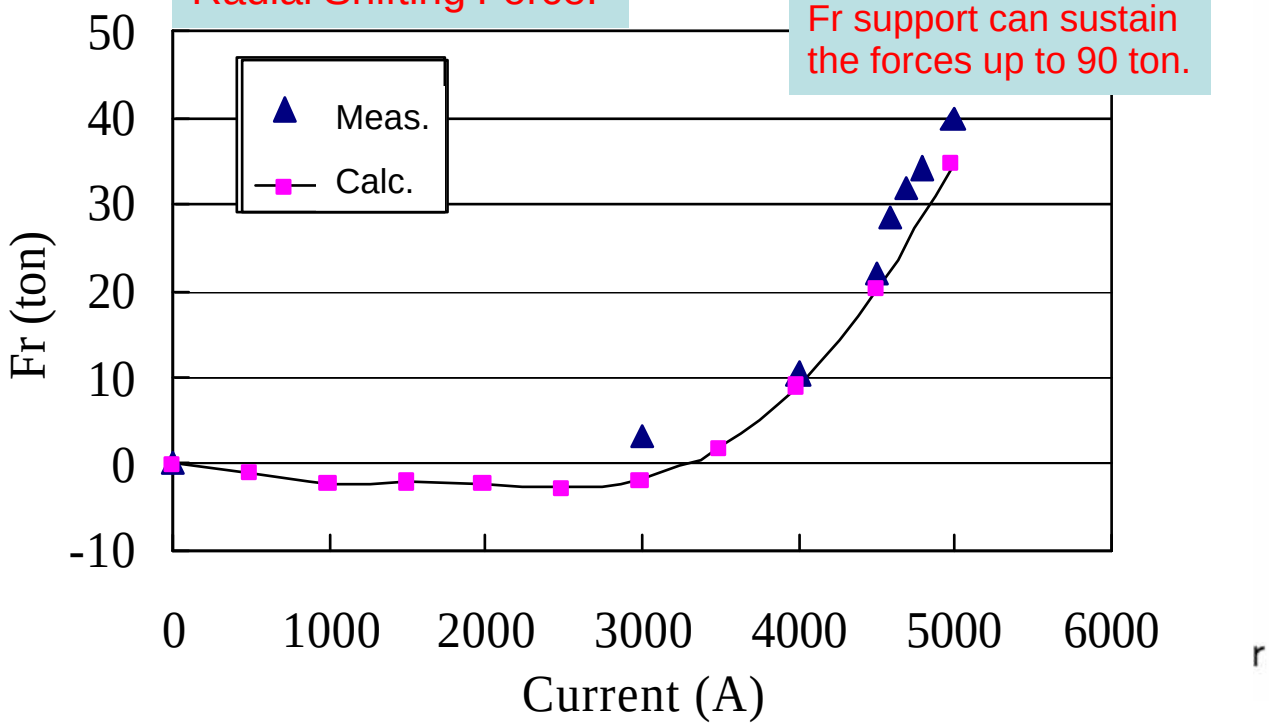
Huge magnetic forces on the coils

Forces on the upper coil (TOSCA calculation)



Radial Shifting Force.

Fr support can sustain the forces up to 90 ton.



Big Errors?

In the excitations, we continuously measured the forces using the strain gauges attached to all the supports, checking whether our calculations are correct or not.

Power supplies and coil protection

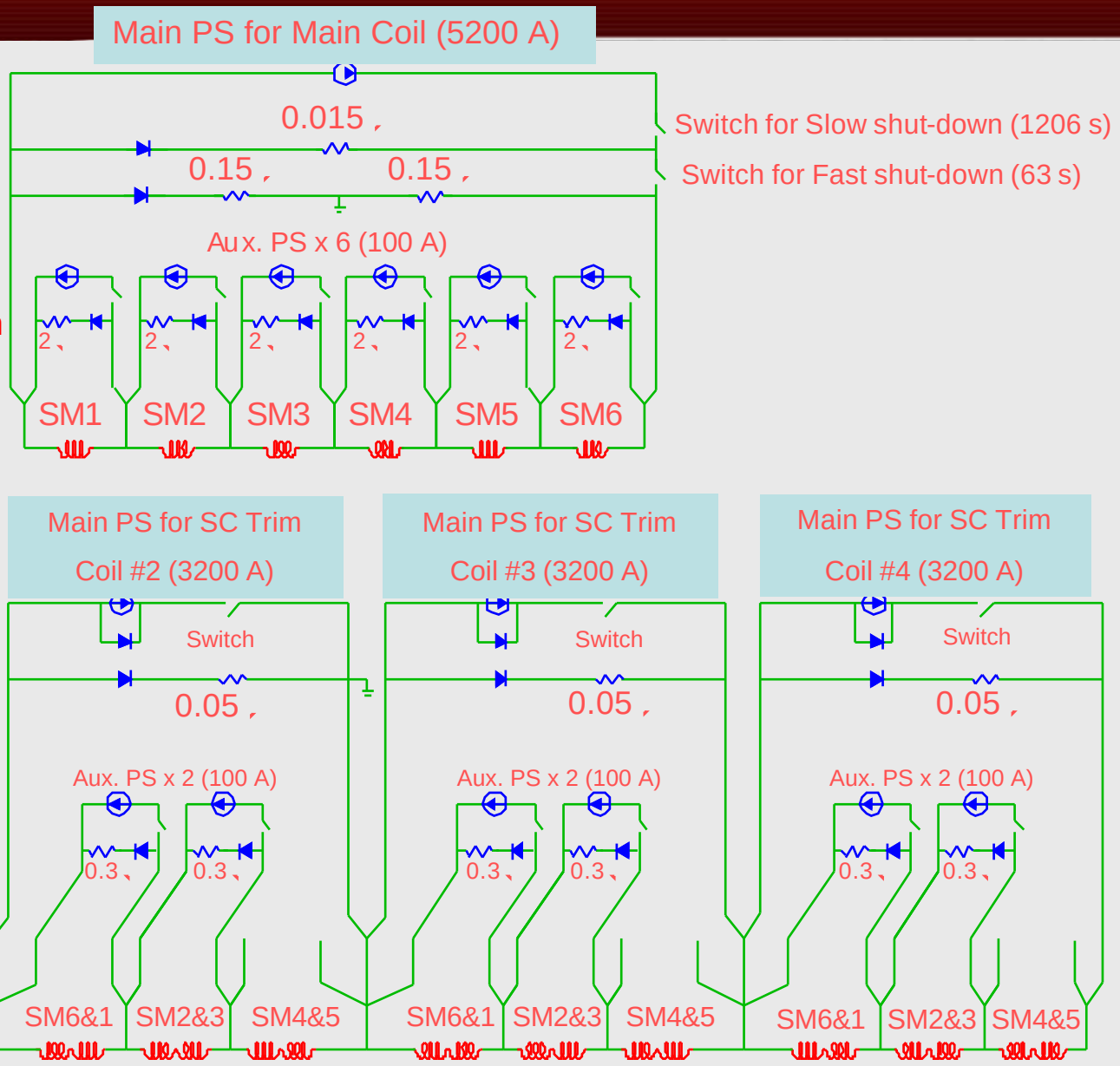
1:Quench characteristic

Current decay: 63 s

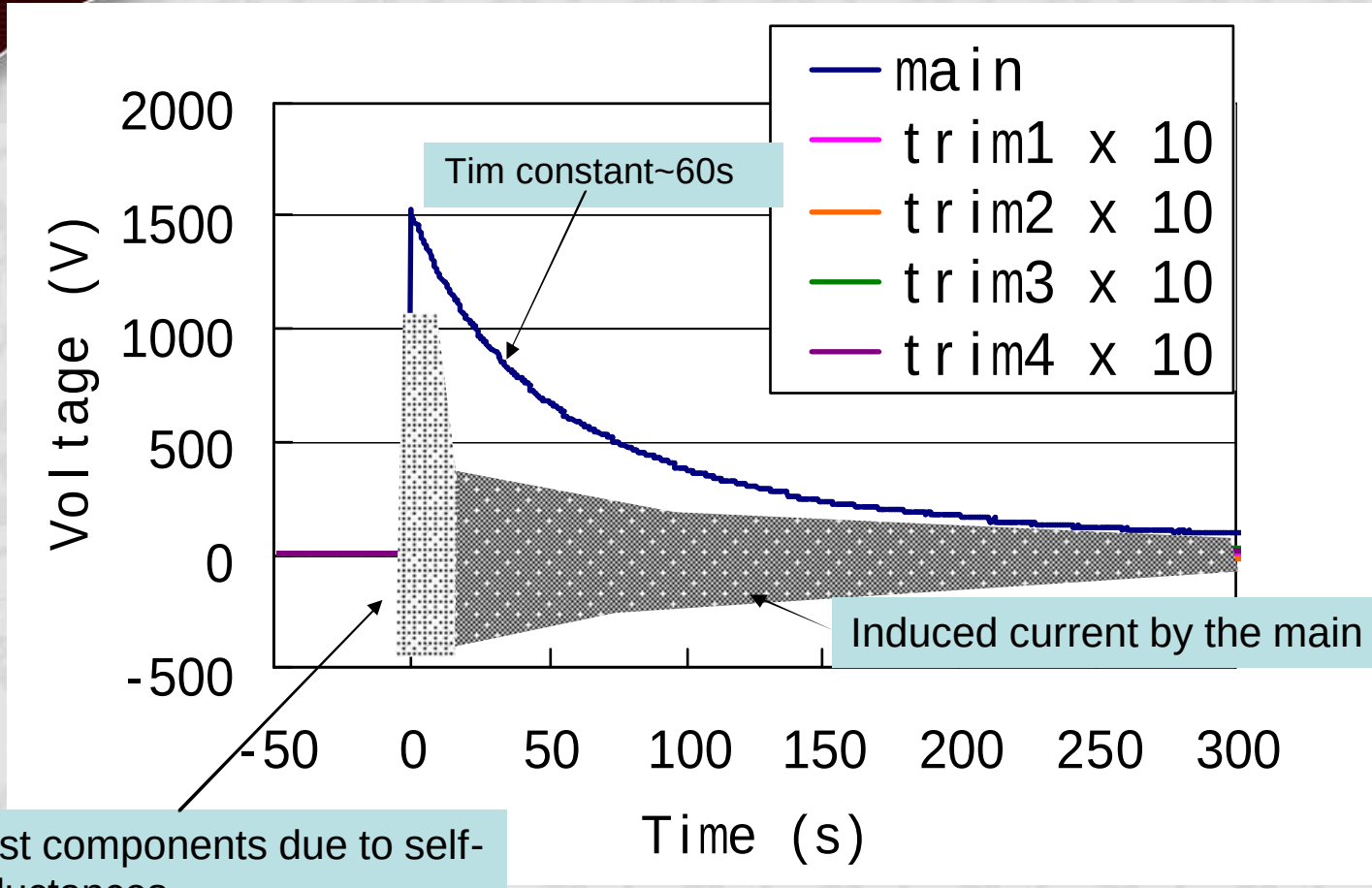
Temp. rise: 140 K

Volt. Development: 1.5 kV/2

2: The main coils and S.C. Trim coils are strongly coupled together due to their relative positions.



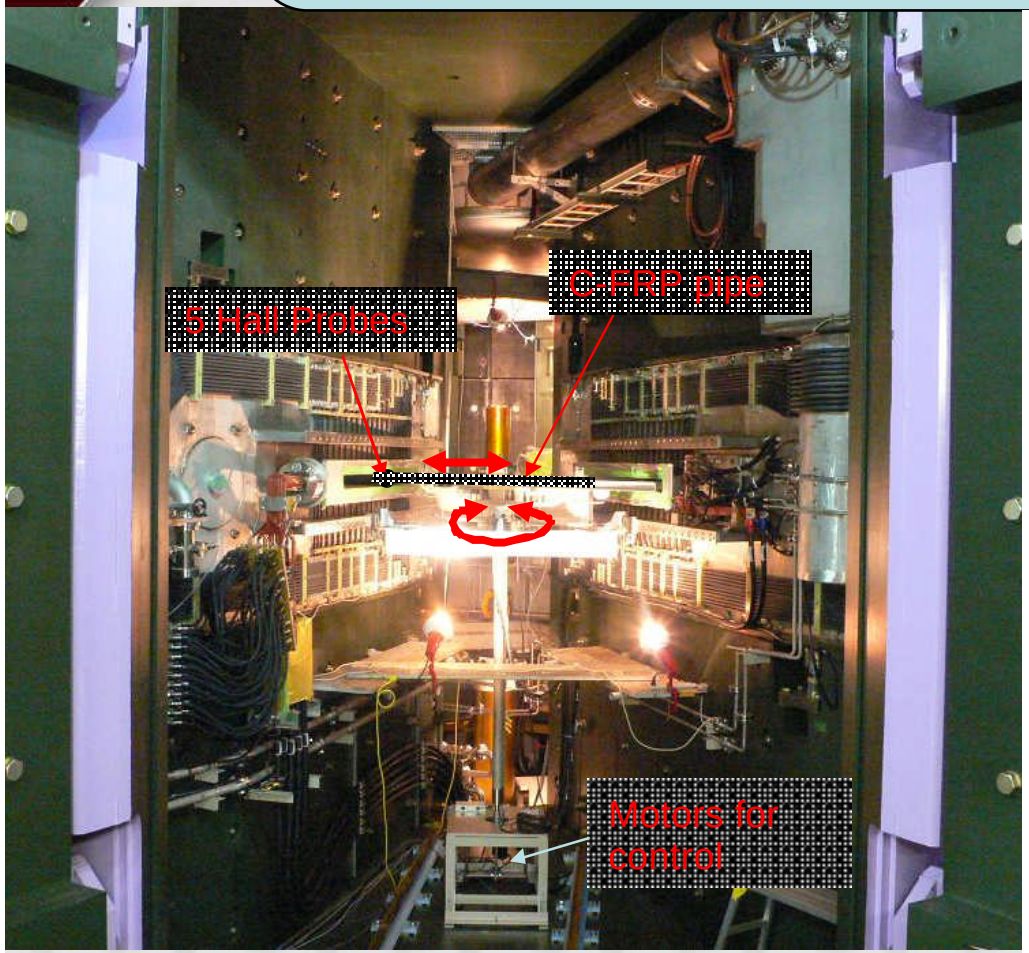
Coil voltages in a fast shut-down test from full excitation

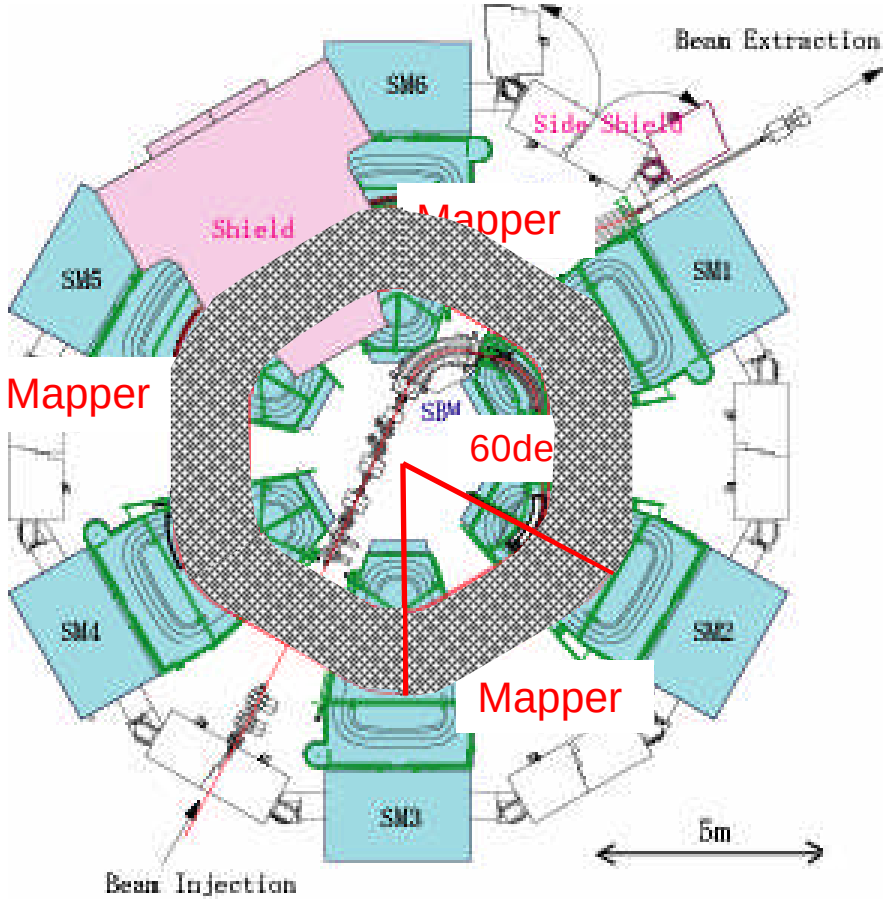


All the coils were safely shut down even in emergency.

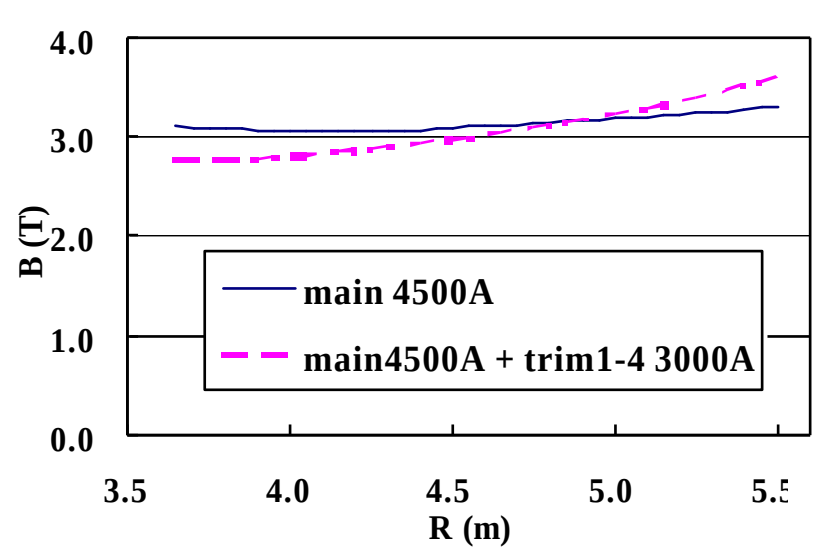
Field mapping over the acceleration region

Field Mapper	3 (60 deg./each)
Hall Probe	5
Control	2axis (Rot./Trans.)
Mesh	about 5cm
Meas. Time	about 3h30m/60deg.





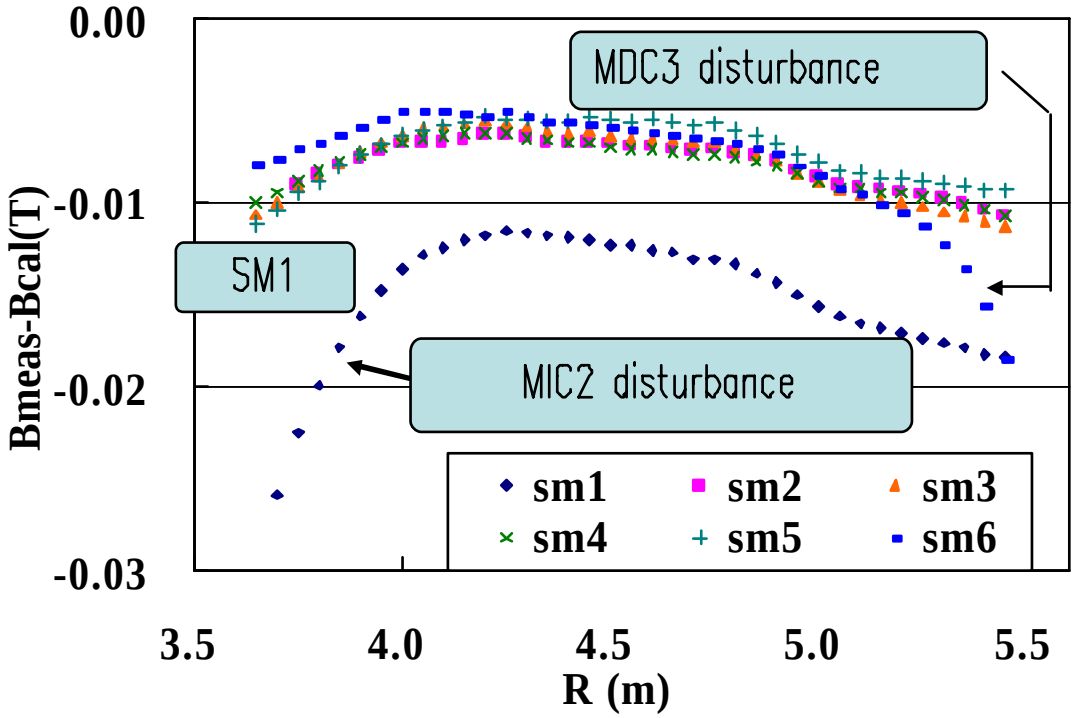
Measured field profiles along the hill axis



Main Coil: Bending power over the acceleration region.

Trim Coil: Isochronous field

Difference between measured and calculated fields



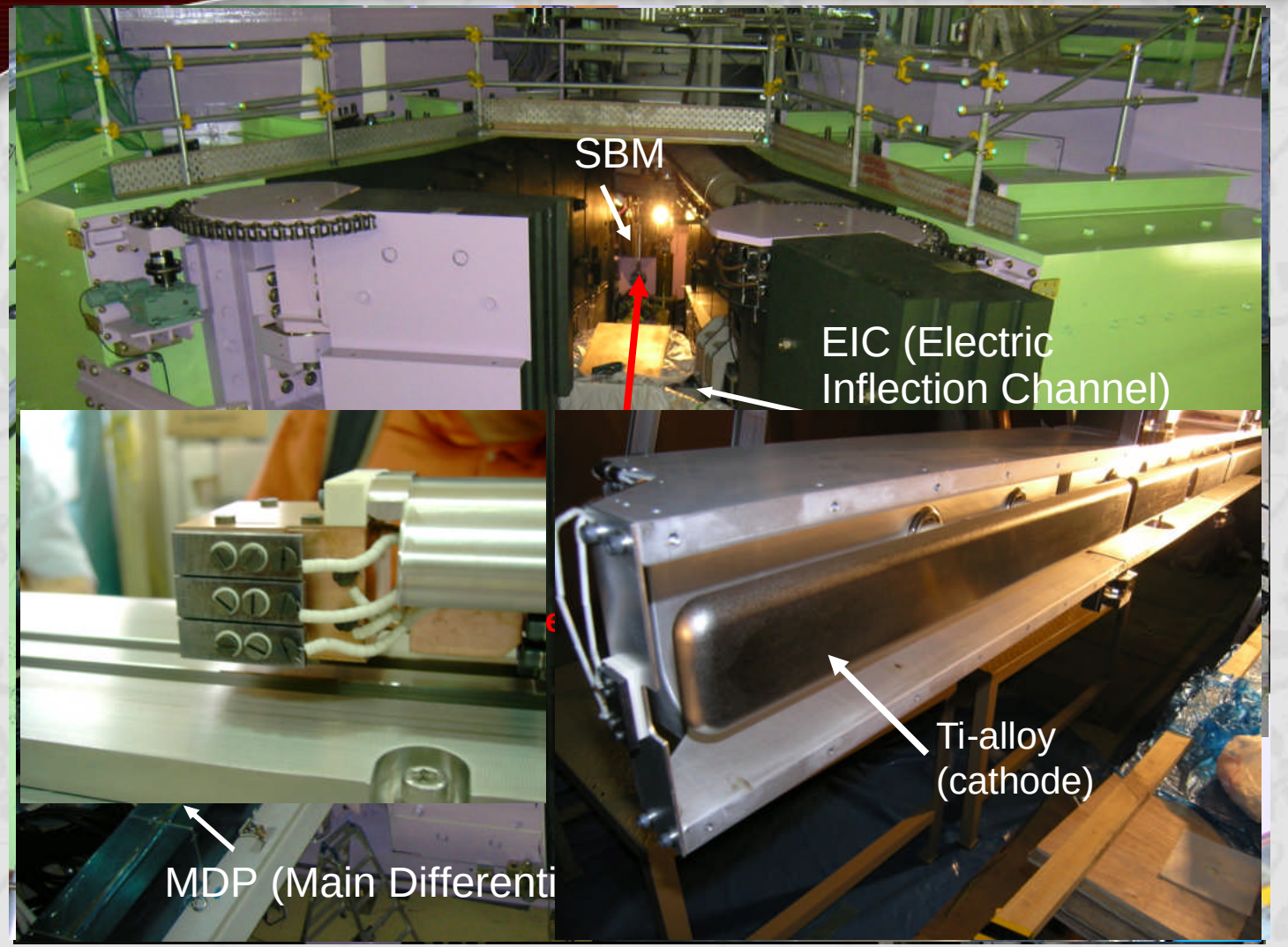
. Good agreement (0.16%~0.35%)
. Small field dispersion among the sectors

Field Disturbances

.SM1 has a slightly different shape.
.Disturbance from MIC2 and MDC3

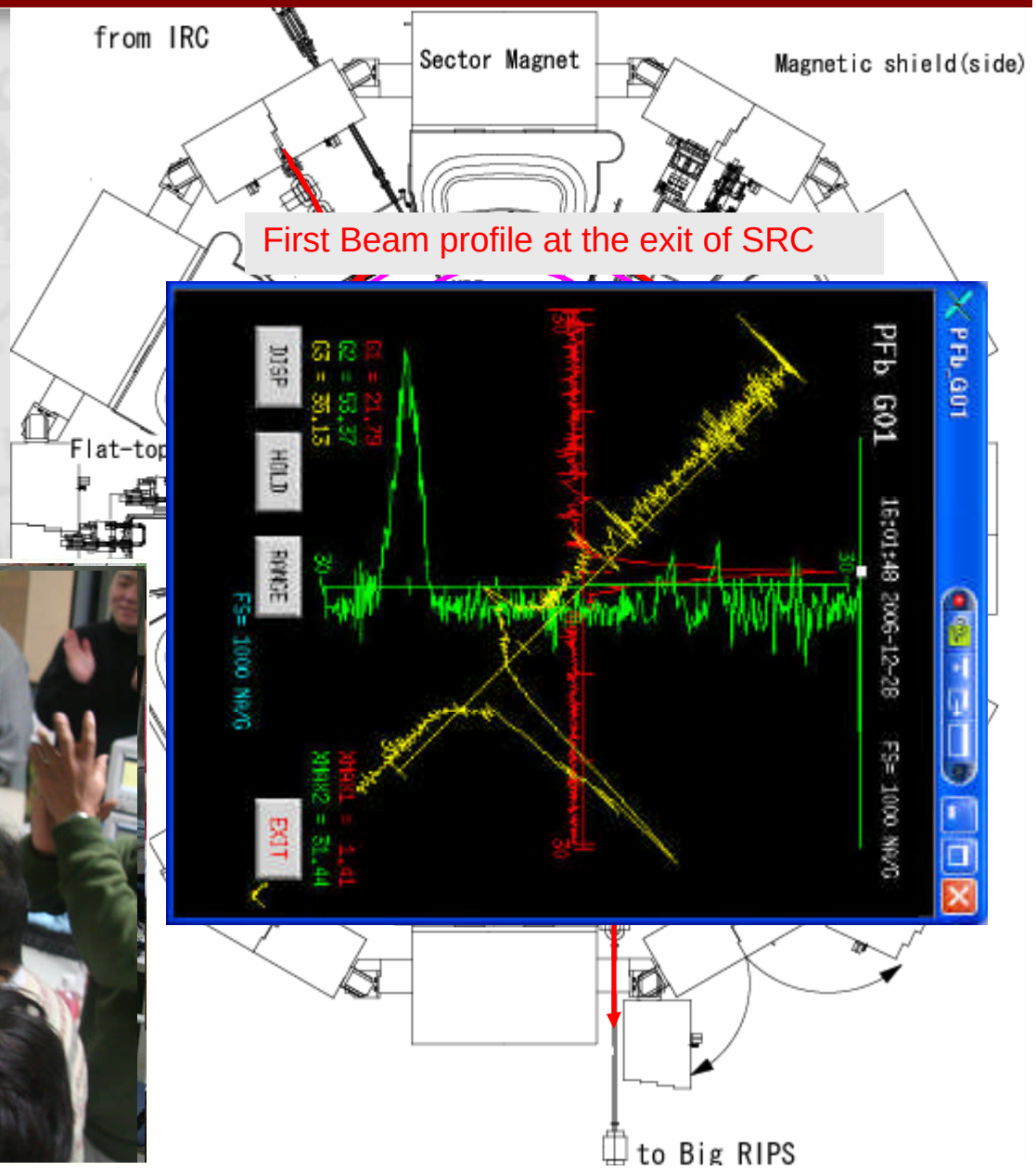
Small enough to be adjusted by the correction coils in the magnetic channels and aux. power supplies of the main and trim coils.

Installation of the parts for the SRC



SRC Beam commissioning
$^{27}Al^{10+}$ 345MeV/u (pilot beam for $^{238}U^{88+}$.

- 12/17 18:20 Al beams were injected to SRC.
- 12/21 16:00 Acceleration Tuning started. (currents of Imain, Itrim, Injection orbits and phase of RF)
- 12/23 21:00 Acceleration up to 10cm from r_{inj}.
- 12/24 02:00 Acceleration up to 100cm from r_{inj}.
- 12/25 23:45 Something @100cm from r_{inj}.
- 12/26 daytime Removal of Q-mass
- 12/28 6:00 Beam injection re-started.
- 12/28 6:08 Acceleration up to the final turns
- 12:28 16:00 The first beam extracted!



First Beam profile at the exit of SRC

After the first beam

To the next stage

2007/3/11 $^{86}Kr^{26+}$ 345MeV/u

(pilot for $^{238}U^{86+}$)

2007/3/23 The first Uranium beam

(TOP priority)

2007/5/ ~ New isotope search

Improvement

- RF resonators
- EIC/EDC (high voltage device)

EIC/EDC

Specification:

120kV 12mm gap

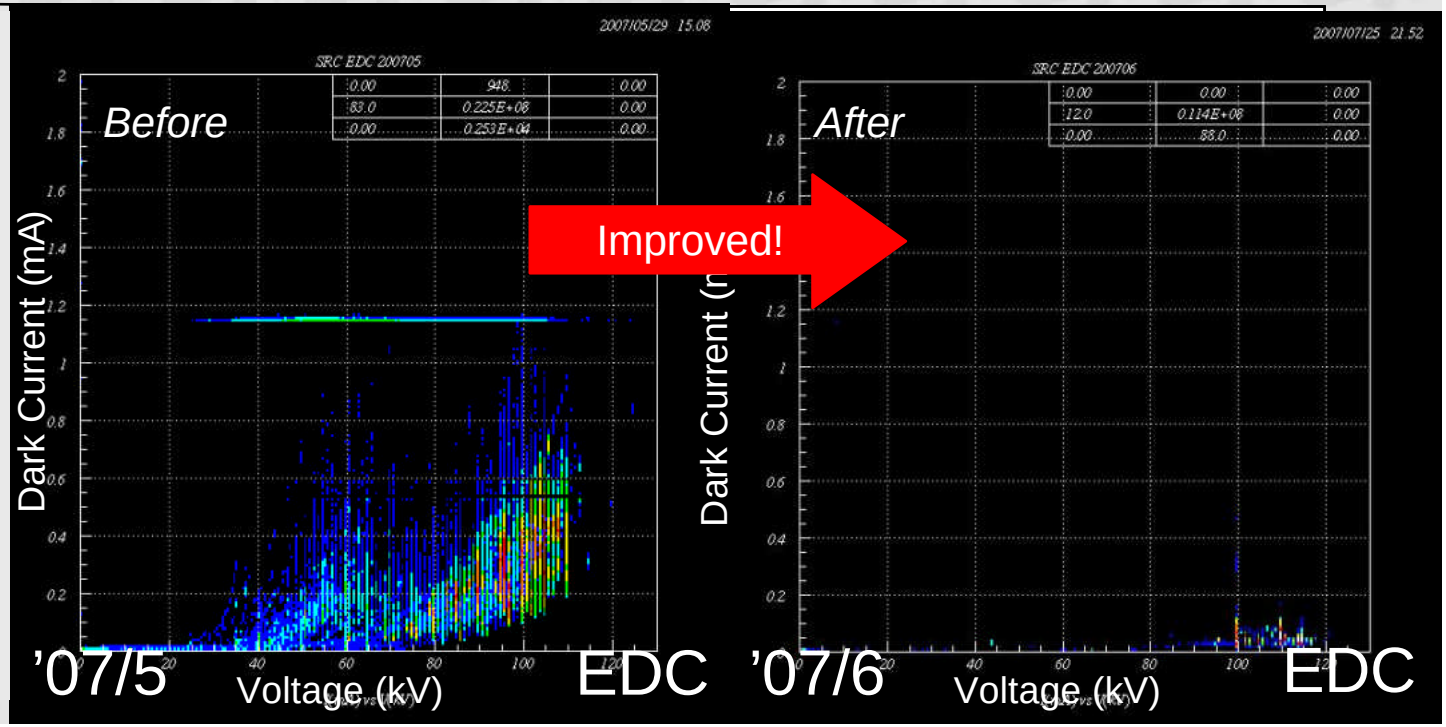
In the first beam

2mA @90kV

Cleaning:

Supersonic cleaning

Buff polishing



Summary

1. **The SRC sector magnets were successfully cooled down and excited without quench.**
2. **Supports against magnetic forces, quench protection, cooling system, etc worked well as designed.**
3. **The field measurement:**
    a. **Field disturbances can be corrected.**
    b. **Data base to create isochronous fields for acceleration.**
4. **RF system, vacuum system and beam diagnostic system were successfully installed and tested under the stray fields arising from the sector magnets.**
5. **The SRC started working as an accelerator from the end of 2006.**