Development of a charged-particle accumulator using an RF confinement method

FA4869-08-1-4075

Ryugo S. Hayano, University of Tokyo

1 Impact of the LHC accident

This project, development of a charged-particle accumulator using an RF confinement method, is recognized at CERN as one of the important R&D projects. Technical support is thereby provided by CERN's cryogenic laboratory, central workshop, radio-frequency group, brazing and surface treatment laboratories. However, due to the accident in the LHC (Large Hadron Collider) tunnel (September 2008), most of the CERN technical personnel must now concentrate on the LHC repair, which is expected to continue until the fall of 2009. Inevitably, the level of technical support we obtain from CERN is to be reduced. This is causing significant delays of the present project. Despite the LHC accident, we have managed to make a significant progress as presented below:

2 Paul trap cryostat – completed

The cryostat for the Paul trap has been assembled in the CERN Cryolab, as shown in Fig. 1, and has been tested for vacuum tightness. A helium pumping line for cool-down test is being assembled in the Cryolab, but will still take some time before completion due to the increased work load to the CERN cryogenic group caused by the LHC accident.

3 Heat exchanger and cooling system – completed

Figure 2 schematically shows a cut-away view of the cryostat, which illustrates how the so-called "LHC" helium heat exchanger (the same type as used to cool down the LHC accelerator) is installed in the cryostat. The heat exchanger is used to make superfluid helium to cool down the Paul trap electrode to the superconducting temperature of 1.5 K. The heat exchanger has already been installed in the cryostat (Fig. 1).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **29 SEP 2009**	2. REPORT TYPE **Final**	3. DATES COVERED **10-04-2008 to 09-05-2009**

4. TITLE AND SUBTITLE **Development of a Charged-Particle Accumulator Using an RF Confinement Method V**	5a. CONTRACT NUMBER **FA48690814075**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Ryogo Hayano**	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Tokyo,7-3-1 Hongo, Bunkyo-ku,Tokyo 113-0033,Japan,NA,NA**	8. PERFORMING ORGANIZATION REPORT NUMBER **N/A**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **AOARD, UNIT 45002, APO, AP, 96337-5002**	10. SPONSOR/MONITOR’S ACRONYM(S) **AOARD**
	11. SPONSOR/MONITOR’S REPORT NUMBER(S) **AOARD-084075**

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report describes the excellent progress made in constructing a Paul Trap, despite all the difficulties encountered by researchers at CERN.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Fig.1 The cryostat for the Paul trap has been completed in the CERN Cryolab.

4 Helium distributor - mechanically completed awaiting surface treatment

The left panel of Fig. 3 shows where a superfluid helium distributor is installed in the cryostat, and the right panel shows what it looks like. The distributor as shown is made of copper, whose surface needs to be coated by niobium by the sputtering method.

The helium distributor' s copper plate has been Nb-sputtered twice, but failed each time (the Nb layer came off). The surface treatment laboratory of CERN has since then invented and tested a new method, which gives sufficient results.

5 Baseplate heat load problem - solved by adding a shield

The top two panels of Fig. 4 show the geometries of the base plate (the oval plate shown at the bottom), resonator coils (the two coils on top of the base plate), and the four electrodes of the Paul trap, used in the ohmic-loss simulations. The left panel is the original configuration

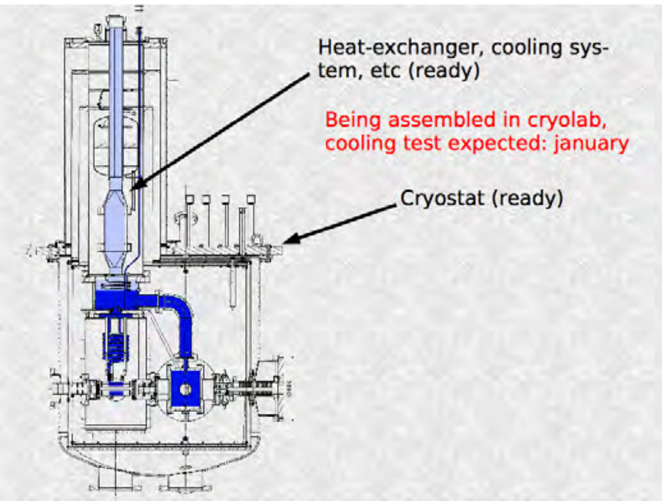

Fig.2 Heat exchanger inside the cryostat is used to make superfluid helium. This is also ready.

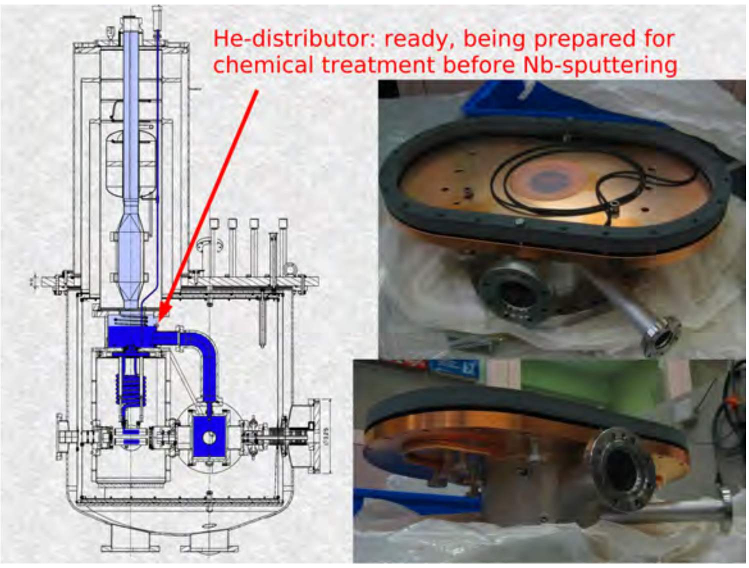

Fig.3 Superfluid helium distributor has been constructed, and is being prepared for chemical treatment before niobium sputtering.

and the right panel is a revised design with an additional shielding plate.

In the original configuration, the ohmic loss of the RF electric current in the copper base plate is more than 1.5W (more than the estimated cooling power of the cryostat). By adding a shielding plate as shown in the top-right panel, the loss was reduced by a factor 25 to < 0.1 W.

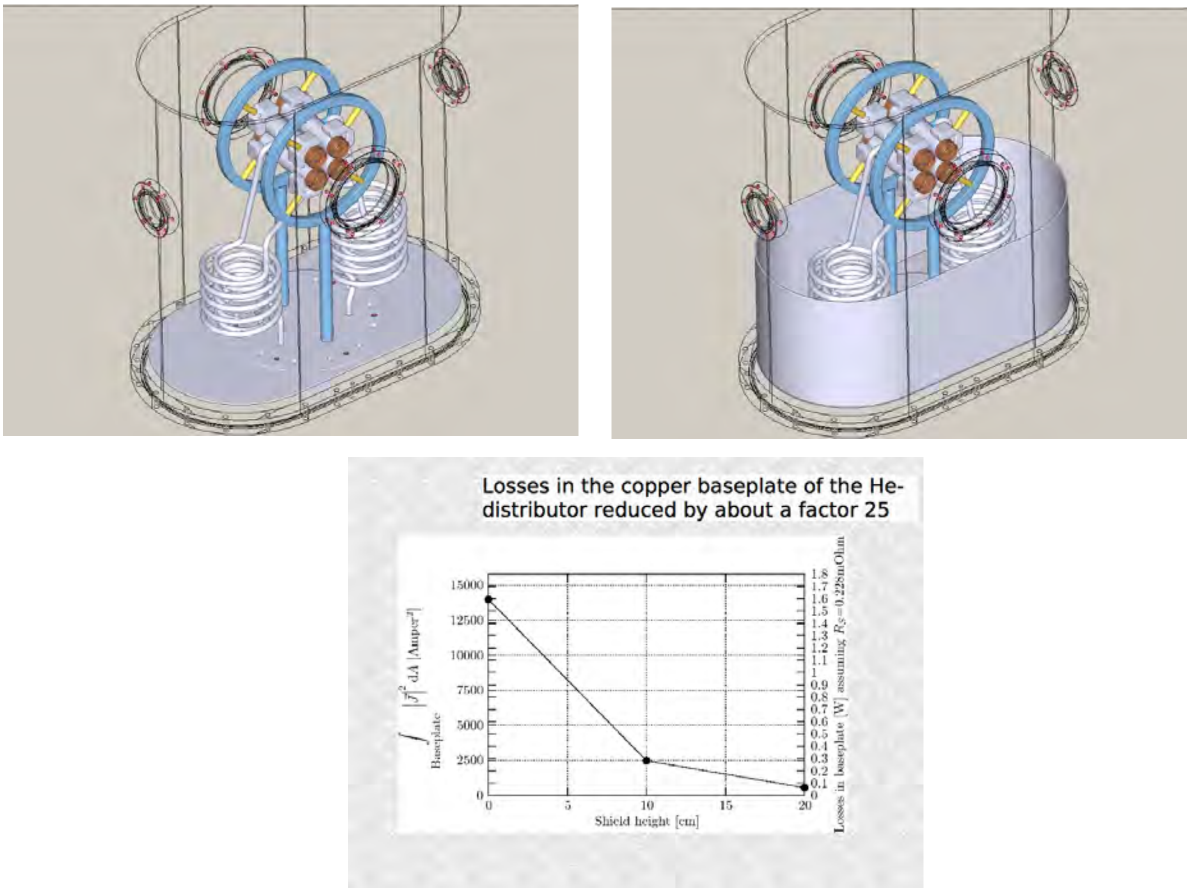

Fig.4 Simulations revealed that the RF electric current in the copper base plate (top left) causes more the 1.5W of ohmic loss. By adding a shielding plate (top right), the loss can be reduced by a factor 25 (bottom) to less than 0.1 W.

6 Test superconducting cavity – Resonance quality factor (Q) reached $2.5 - 3 \times 10^6$

In order to perfect the technology of fabricating superconducting cavities, a test cavity (shown in Fig. 5 has been used to measure the Q-factor of the cavity.

What has been achieved so far is a Q factor of $2.5 - -3 \times 10^6$ and the peak-to-peak voltage of 27 kV. Although both of these are satisfactory in terms of the cavity performance and its cooling characteristics, the Q factor is still more than an oder of magnitude less than the design value. This is considered to be due to the imperfection in the niobium surface treatment. Further tests are being conducted.

TESTCAVITY: version #N+1

- New outer coil
- All bad welds removed and rewelded
- Visibly perfect, shiny surface
- **$Q=2.5\text{-}3 \times 10^6$** @ highest levels (still too low by x10-50, reasons unknown)

(✓)-cryostat can handle

- Highest reached CW level: **27 kV** ✓

Fig.5 Superconducting test cavity (after many iterations) has now reached $Q = 2.5 - 3 \times 10^6$ and can sustain a peak-to-peak voltage of 27 kV.

7 End-cap electrode design and fabrication

Electrostatic potential applied to a pair of end-cap electrodes longitudinally confine charged particles in Paul traps. This is technically challenging since the end-cap electrodes must be placed very close to the Paul trap quadruple rods (to which high RF power is applied).

The endcap (see Fig. 6 is isolated from the main body of the electrode via a high-Q, about 400 pF capacitance consisting of 4 sapphire disks of thickness 0.2mm, diameter 25mm, to be on the (almost) same RF potential as the electrode, but to be biased to -2 kV DC.

It could stand 3 kV DC before any cleaning. RF properties is yet to be tested in the test cavity.

Fig.6 The endcap (left photo) is isolated from the main body of the electrode (right photo, center object) via a high-Q, about 400 pF capacitance consisting of 4 sapphire disks of thickness 0.2mm, diameter 25mm, to be on the (almost) same RF potential as the electrode, but to be biased to -2 kV DC.