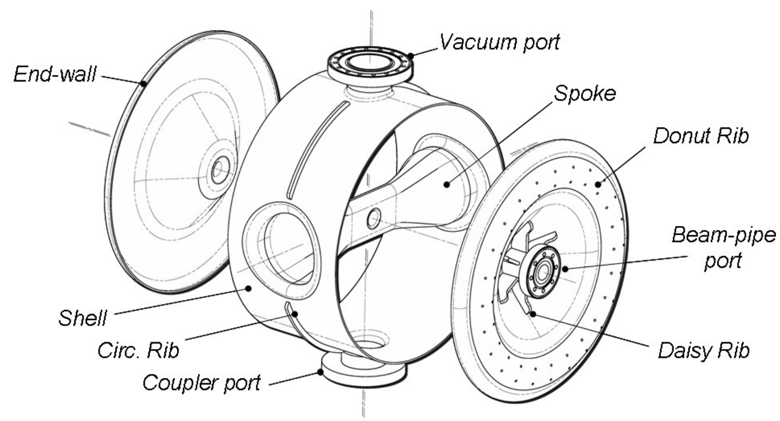
Recent SSR1 Tests

Bob Wagner
T. N. Khabiboulline, R. Madrak, A. Mukherjee,
T. H. Nicol, Y. Pishchalnikov, L. Ristori, W. Soyars,
I. Terechkine, R. Webber

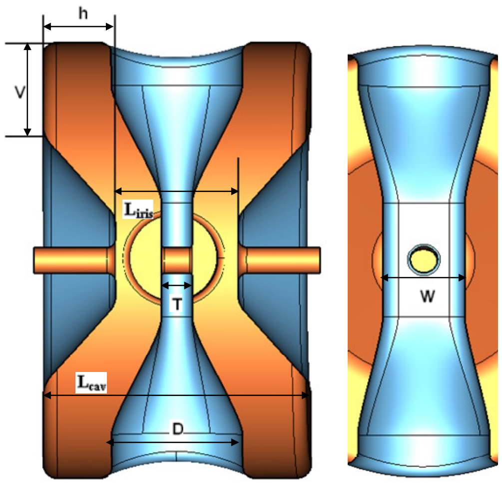
Design and operating parameters of 325 MHz SSR1

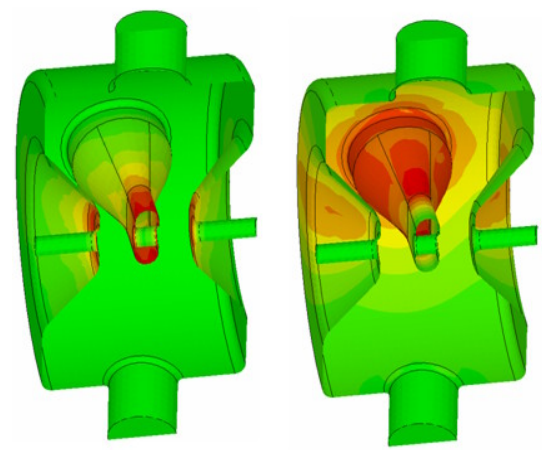
Quantity	Value
Beampipe, shell ID	30 mm, 492 mm
E_{peak}/E_{acc}	2.56
B_{peak}/E_{acc}	3.87 mT/(MV/m)
G, R/Q_0 , $ß_g$	84 Ω, 242 Ω, 0.21
RF structure	1 ms, 9 mA ⇒ CW, 1, 5 mA
Loaded BW	388 Hz ⇒ 43, 215 Hz
He temp, pressure	4.4 K, 900 torr ⇒ 2.0 K, 20 torr
He press variation	±12.9 torr ⇒ ± .25 torr
Accel. Grad., E_{acc}	10 MV/m ⇒ 15 MV/m ?
Q_0 at E_{acc}	> 0.5×10^9 ⇒ ?
LFD co. (jacketed)	3.8 $Hz/(MV/m)^2$ ⇒ Non-issue
df/dp (jacketed)	-210 Hz/torr with present tuner

SSR1-02, the 2nd SSR1 prototype. Fabricated by Roark.



RF design of SSR1





- The above dimensions were varied in MWS to optimize the RF design.
- E_{acc} = Total accelerating voltage divided by $L_{eff} = L_{iris}$ $= (2/3)\beta\lambda$ = 135 mm

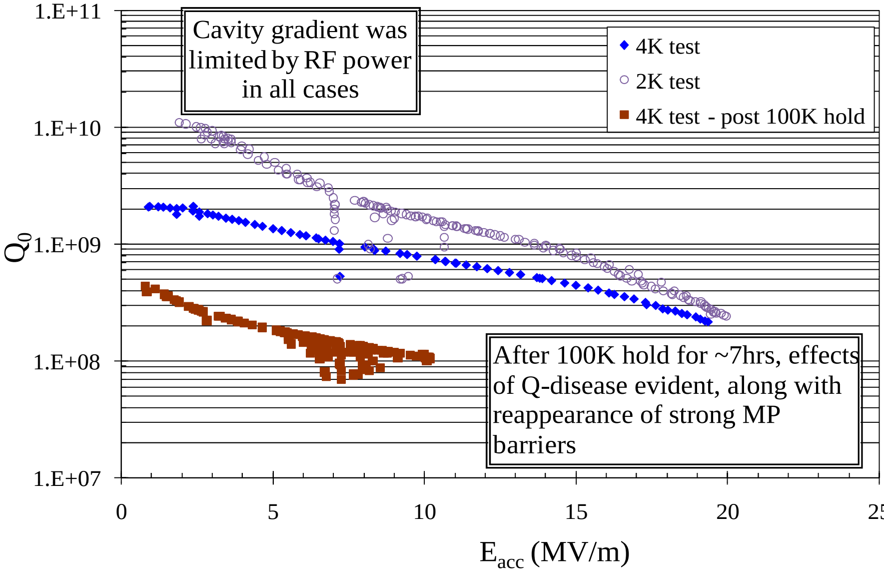
- Surface electric (left) and magnetic (right) fields in SSR1.
- The field strength increases as the color changes from green to yellow to red.

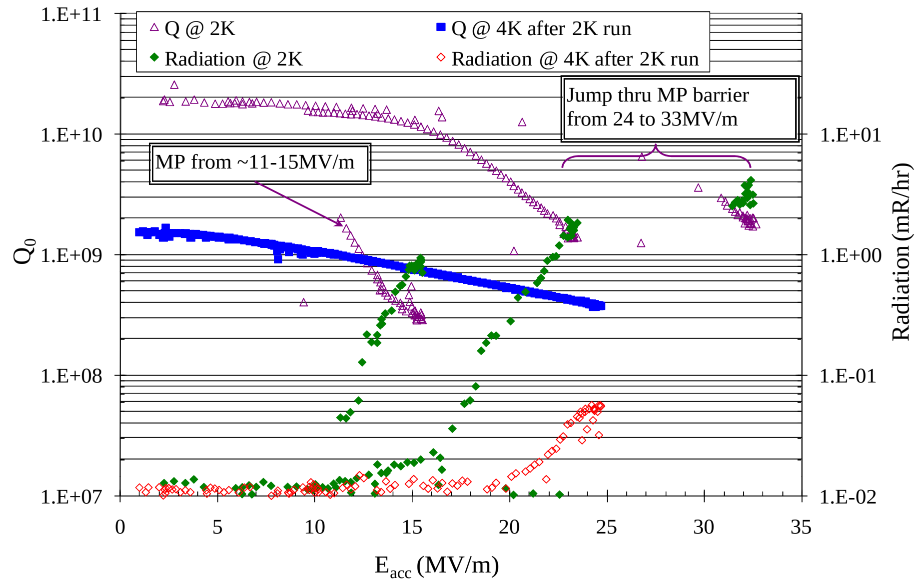
Chemistry and HPR of unjacketed cavities at ANL G150

- BCP: two 80 minute sessions
  - Between sessions, flip top to bottom and replace acid.
- Remove 120 microns at 15-16°C

- HPR: 6 ultra-pure water jets, two each at +40°, 90°, and -40°
- 2 hrs water time with cavity in 8 different orientations.

CW tests of unjacketed SSR1-01 and SSR1-02 in the VTS

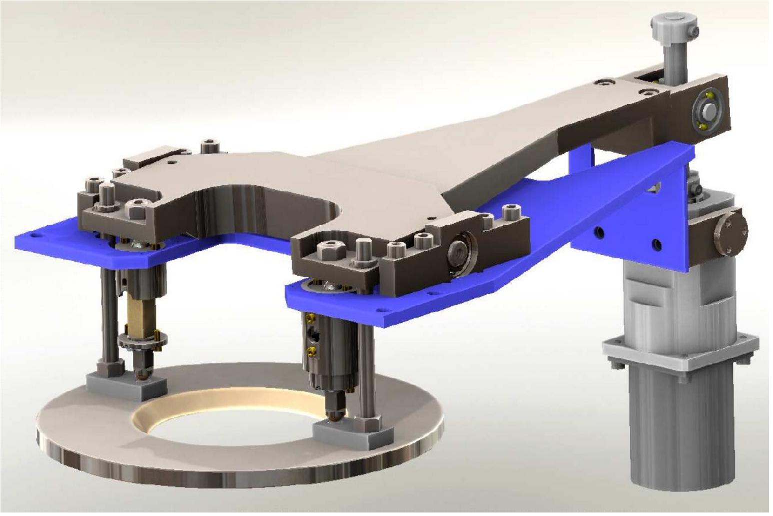




- SSR1-01: Q_0 vs. E_{acc} at 2.0 K and 4.4 K from the fourth cold test.
- During cool down, a 7 hr hold at 100 K produced a large Q_0 drop, confirming Q disease.
- Subsequently baked SSR1-01 at 600 C for 10 hours at Jlab.

- SSR1-02: Q_0 vs. E_{acc} from the first cold test of SSR1-02.
- Effects of Q disease should not appear on first cooldown.
- X-rays increase at MP barriers, then disappear after punch through.

Helium vessel with prototype slow and fast tuner



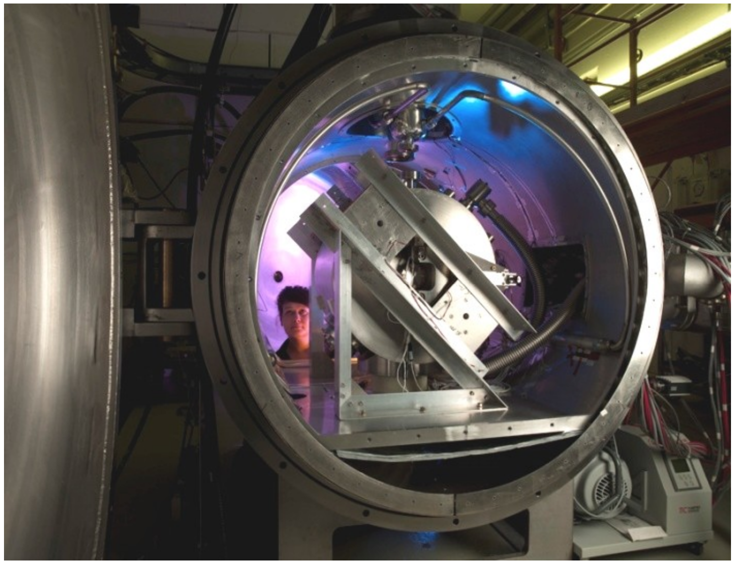
- SSR1-01 inside 316L stainless steel (SS) helium vessel with tuner.
- Vessel TIG welded to SS flanges (brazed to niobium ports).
- Fabricated according to ASME pressure vessel code.
- Bellows between endwall and collar welded to beampipe flange.

- Two piezo actuators “in series” with slow tuner arms (pivot with 5:1 mech. advantage).
- Stepping motor with harmonic drive,1:100 ratio (0.9 Hz/step).
- Present tests with a tuner on each end.
- Low profile along beam required due to close proximity to solenoid.

After VTS CW tests, prepare SSR1-01 for CW and Pulsed tests of jacketed cavity

- 10 hr, 600 °C vacuum bake for hydrogen degassing at Jlab (Thanks Jlab).
- Adjust cavity tune at room temperature: fixture to inelastically stretch or compress at beam pipes (capable of ± 250 kHz).
- Weld on the helium vessel: argon purge and temperature and frequency monitoring.
- Degreasing, flash BCP (20 min at 13 C) and HPR.

Commissioning 325 MHz Spoke Cavity Test Facility(SCTF)



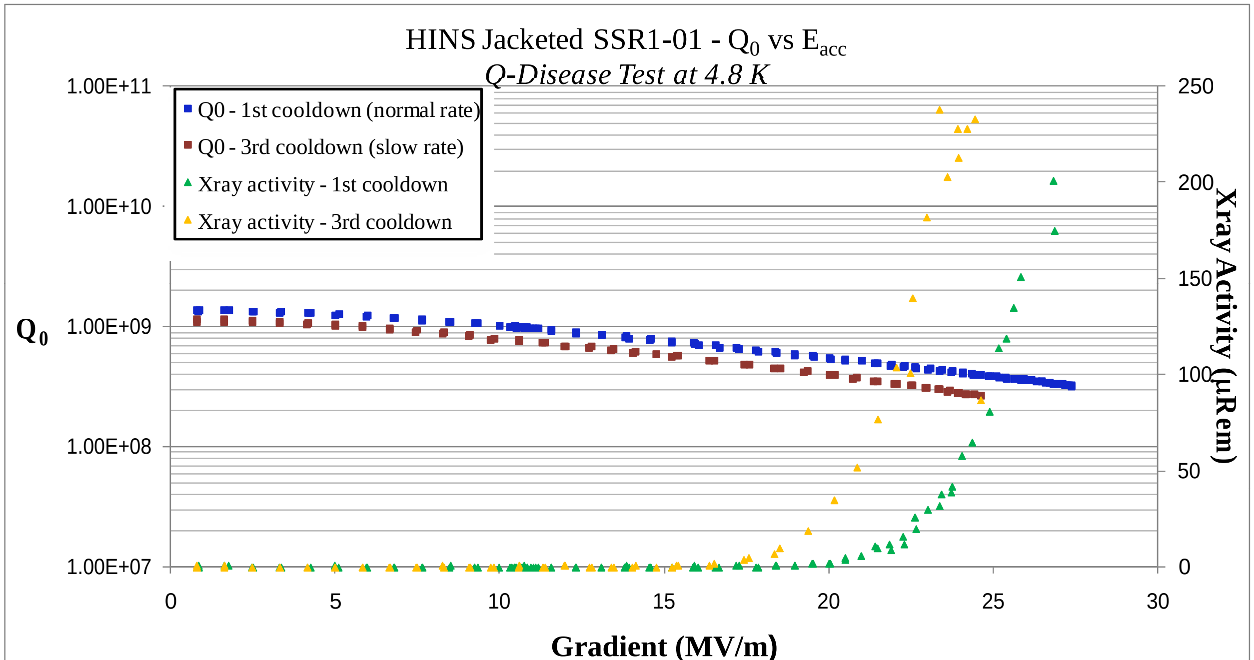
- Cooling to 4.5 K. (2 K upgrade is planned).
- Primary (secondary) pressure relief of 10 (5) psig. Operation near 5 psig.
- 200 W solid state supply for CW.
- 250 kW Klystron for pulsed tests.
- Digital LLRF with GUI interface screens .
- Locks to cavity frequency for CW operation.

- Room temp B shield just inside cryostat wall.
- 80 K thermal shield. Robyn (runs the place).
- Jacketed cavity with tuner. Test magnets.
- X-ray detectors along beam line:
  - Diodes ~10 cm from beampipe flanges
  - Foxes and Chipmunks ~50 cm outside cryostat.
- CW: Drive antenna with $Q_{ext} = 1.5 \times 10^8$

First cold tests of the Jacketed SSR1 with tuner

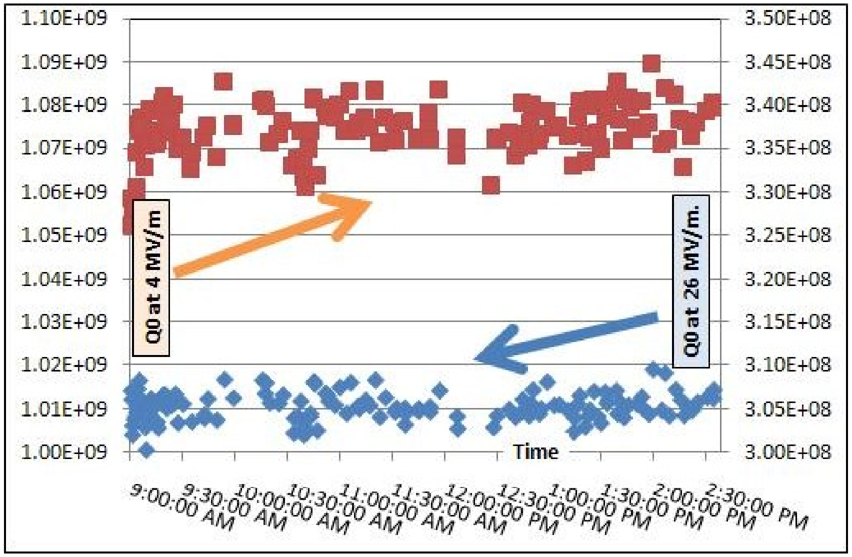
- Cooled down to ~4.5 K (~5 psig) for CW tests with high Q_{ext} drive antenna.
  - Q_0 .vs. E_{acc}, LFD coefficient, pressure sensitivity (df/dp), Q disease status, compensate for pressure variations with fast tuner, sensitivity to B field.
- Minimum cool down time through region sensitive to Q disease, 150 K to 70 K, was limited to 3 hours by the 5 psig secondary pressure relief.
- The resonant frequency was within 20 kHz of the goal when doing the warm inelastic tune of the bare cavity, so there were no surprises when cooling down with the stainless steel jacket.
- After cool down, the tuner arms were run in so that the piezos / bullets contacted the beampipes with 6 kN at each beam pipe (3 kN / piezo).
- Cryo system supported continuous running at ~35 watts. It took ~10 hours to process multipacting (MP) barriers in this mode.
- After the MP processing, the LLRF was upgraded to allow stepping between high and low power, keeping the average power near 35 watts.
  - We believe that the MP processing could go significantly faster with the stepping.
  - Stepping was used when taking subsequent Q_0 .vs. E_{acc} scans in order to keep the helium temperature and pressure as uniform as possible.
- df/dp was measured to be -145 ± 15 Hz/torr with the beam pipes restrained by the tuner, in fair agreement with -210 kHz/torr predicted by simulation.
- The static Lorentz Force Detuning coefficient was measured to be -1.5 ± 0.5 Hz/(MV/m)^2, considerably lower than -3.8 Hz/(MV/m)^2 predicted by simulation.

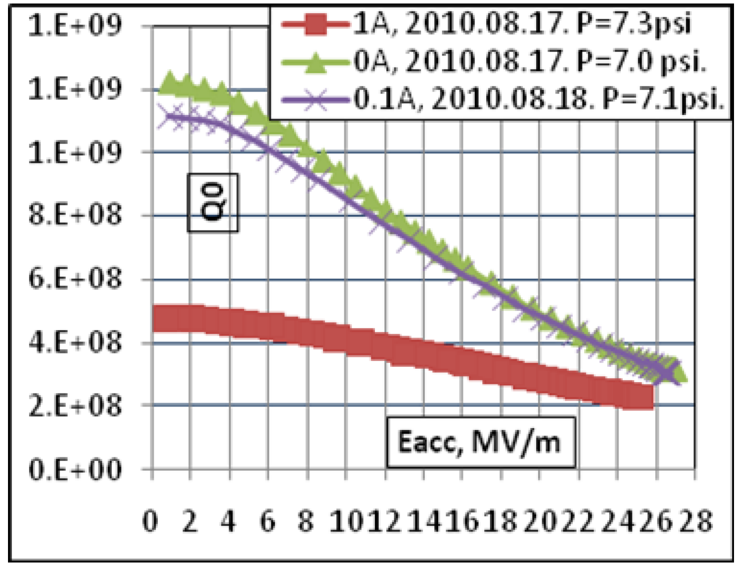
Q_0 .vs. E_{acc} scan in first cooldown and Q disease test



- Scan in first cooldown compares well with first cooldown of bare SSR1-02 in VTS at 4.4 K.
  - Maximum E_{acc} of 27 MV/m is a bit higher. Assume comparable to SSR1-02 at 2 K?
- Within 5% measurement uncertainty, scan was unchanged after a second 3 hour cooldown.
- Third cooldown of 11 hours through sensitive region (150 K to 70 K): Much milder case of Q disease than before degassing: At 10 MV/m, Q_0 decrease of 20% versus 87% for 7 hour hold at 100 K in last VTS test of bare SSR1-01.
- However, 20% decrease at ~4.5 K is about a factor of three decrease at 2 K – Need to test at 2 K.

Effect of fringe field of proposed solenoid focusing



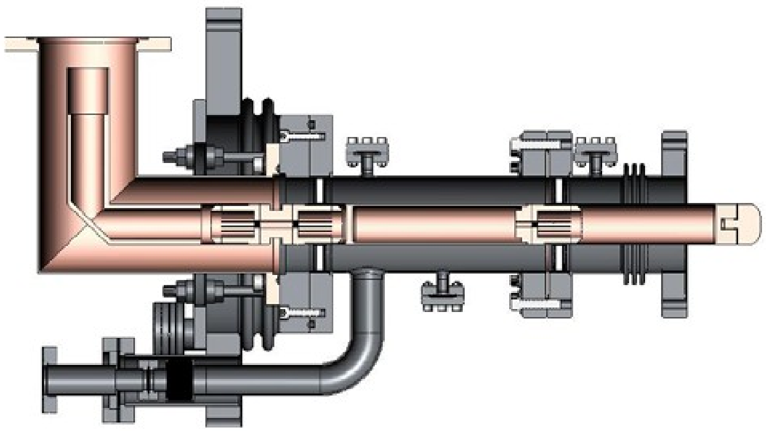


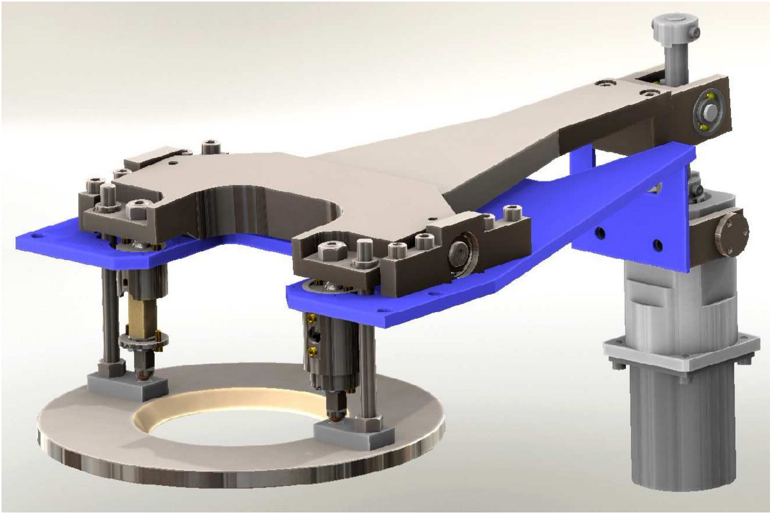
- Expect maximum fringe field of 0.1 G (test solenoid current of 0.05 A).
- At E_{acc} ~ 27 MV/m, cavity quenches almost certainly at spoke.
- At 4-5 A current, quenched 5000 times in ~6 hours with no degradation of Q_0.
- Spoke is very well shielded.

- Also tested cooling through niobium transition point at various fields.
- See an ~10% drop in Q_0 at twice the expected field (likely close to a factor of two drop at 2 K). Should test at 2 K.
- As expected, a much larger drop is seen at twenty times the expected field.

Project X

Some conclusions and upcoming tests





- The SCTF was commissioned successfully with the first jacketed SSR1 at ~4.5 K. The cavity tune, df/dp and static LFD coefficient were reasonable.
- Q_0 .vs. E_{acc} looks fine at 4.5 K. Q disease after hydrogen degassing is much milder and likely manageable at 2 K with a reasonable cool down rate.
- For solenoid focusing, the fringe field does not affect Q_0 at the most likely quench site (spoke).
- Next install the power coupler and test at high field in pulsed mode with Klystron.
- With piezos, further test controlling tune change due to pressure fluctuations. Already achieved control at the 2 Hz level (Warren Schappert and Yuriy Pishchalnikov).
- Upgrade of the SCTF to 2 K should be given high priority.