National Synchrotron Radiation Research Center

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Operation status and future plans of the SRF module at NSRRC

National Synchrotron Radiation Research Center
RF Group
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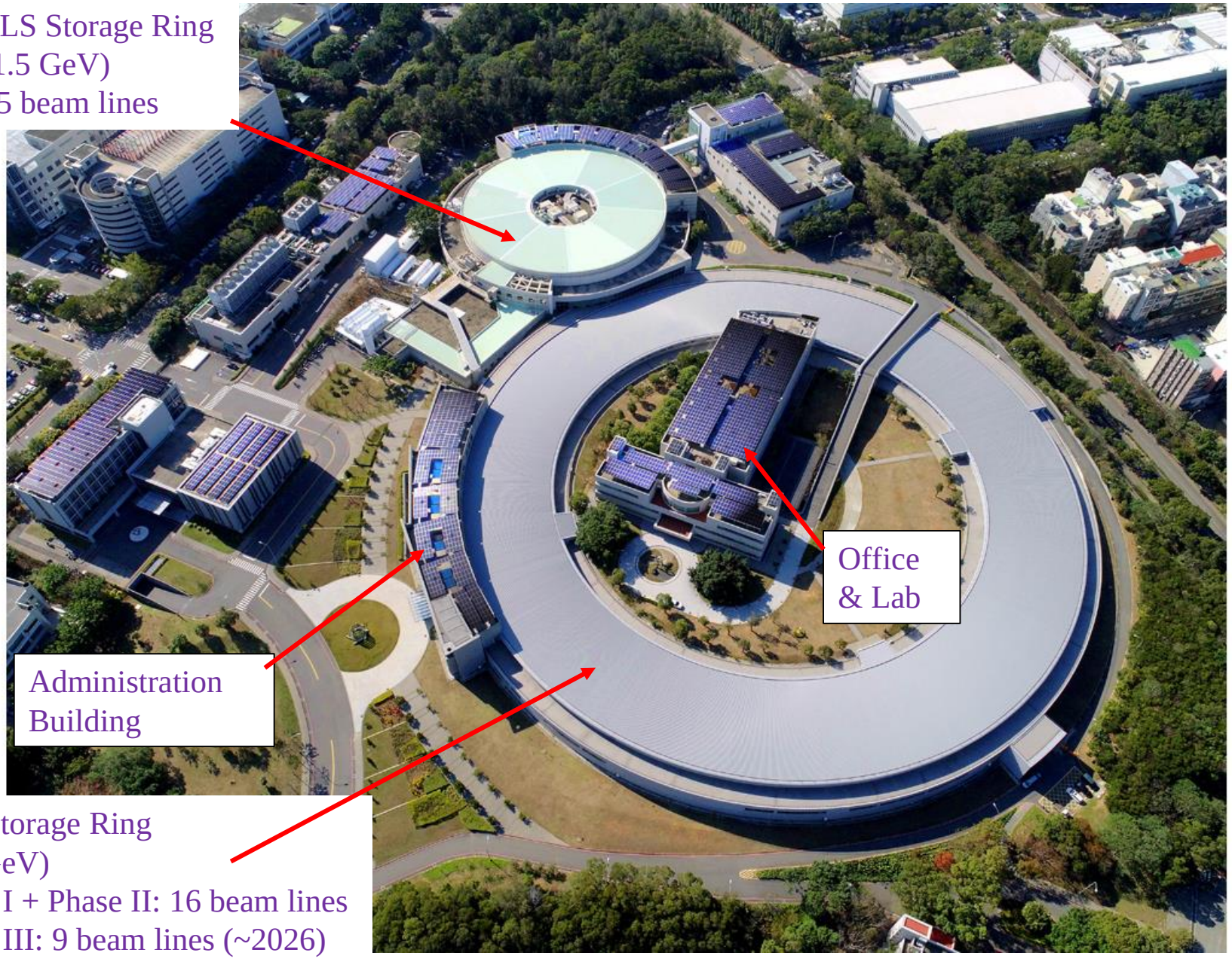
2023/04/12

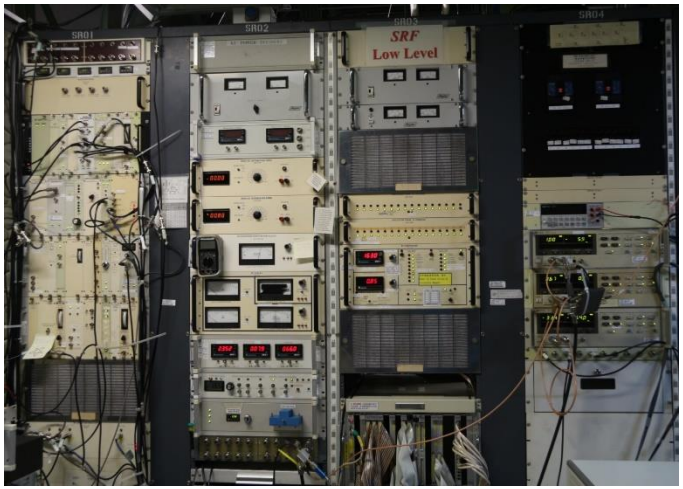
Two Light Sources in NSRRC



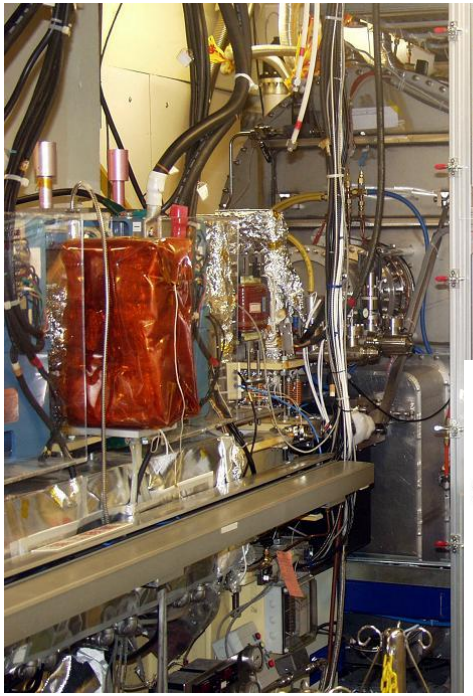
Machine Parameters

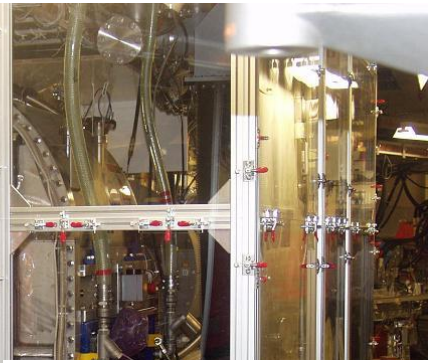
Main parameters	TLS	TPS
Circumference [m]	120	518.4
Beam energy E [GeV]	1.5	3.0
LINAC [MeV]	50	150
Beam current [mA]	360	500
Natural emittance ε_x [nm-rad]	22	1.6
RF frequency [MHz]	499.654	499.654
Harmonic number	200	864
Momentum compaction	6.78×10^{-3}	2.4×10^{-4}
Energy spread σ_E/E	7.56×10^{-4}	8.86×10^{-4}
Energy loss/turn (dipole) [keV]	128	852.7
RF voltage [MV]	1.3	3.0 (1.5x2)
RF Plant	CESR-type SRF module	KEKB-type SRF module
Straight sections [m]	6m X6	12m X6 & 7m X18

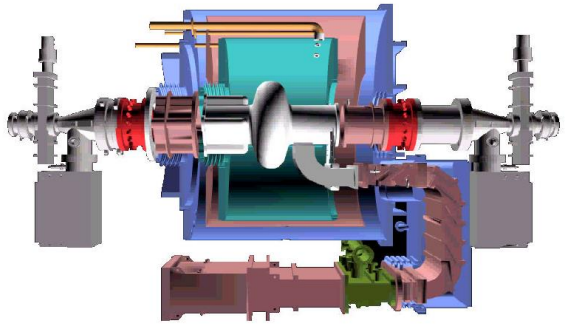
TLS RF System (Storage Ring)



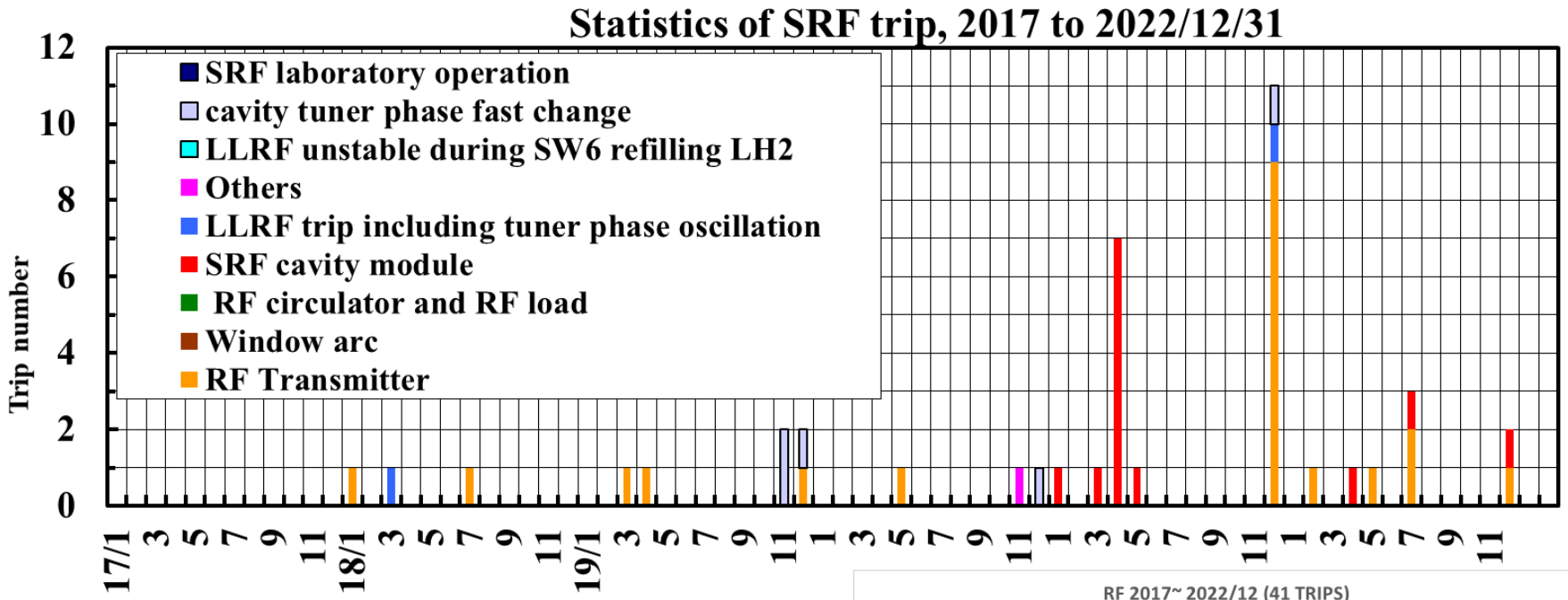
- CESR type SRF Module
- 100 kW klystron transmitter
- Analog LLRF

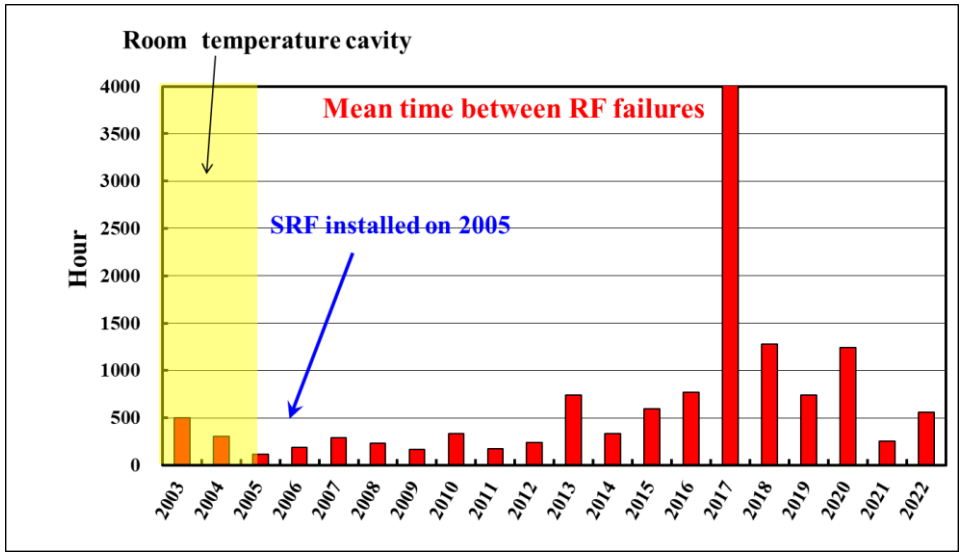


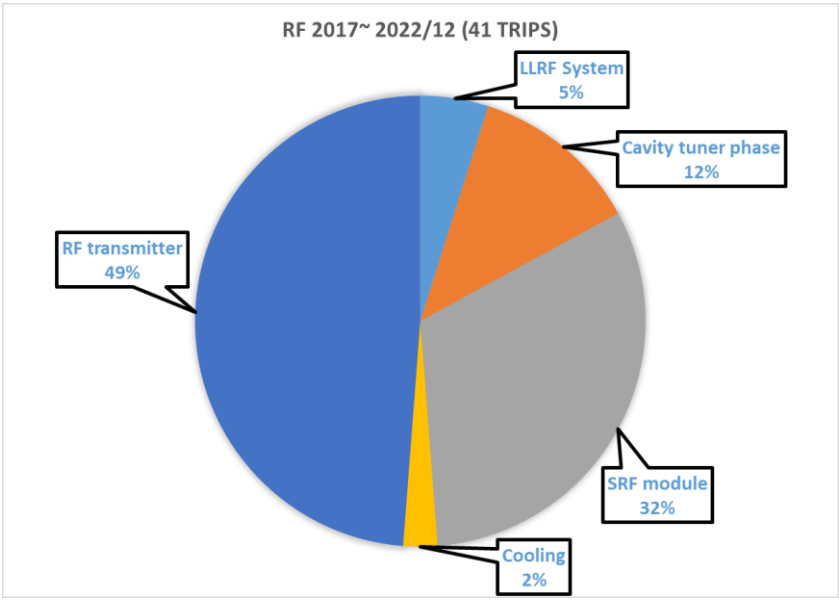




Operation Status of TLS SRF System

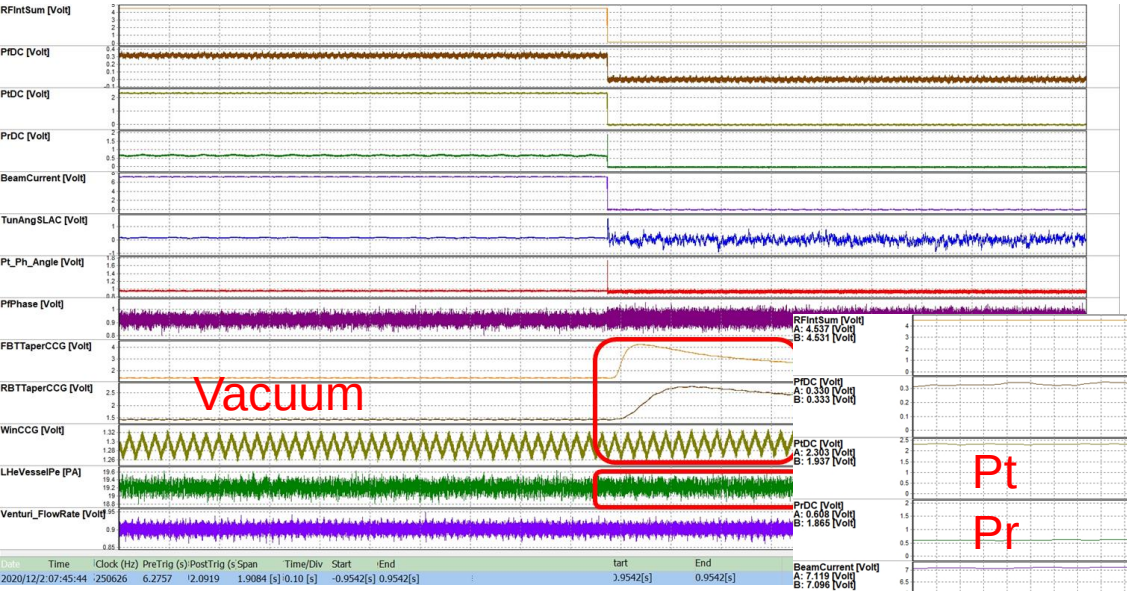




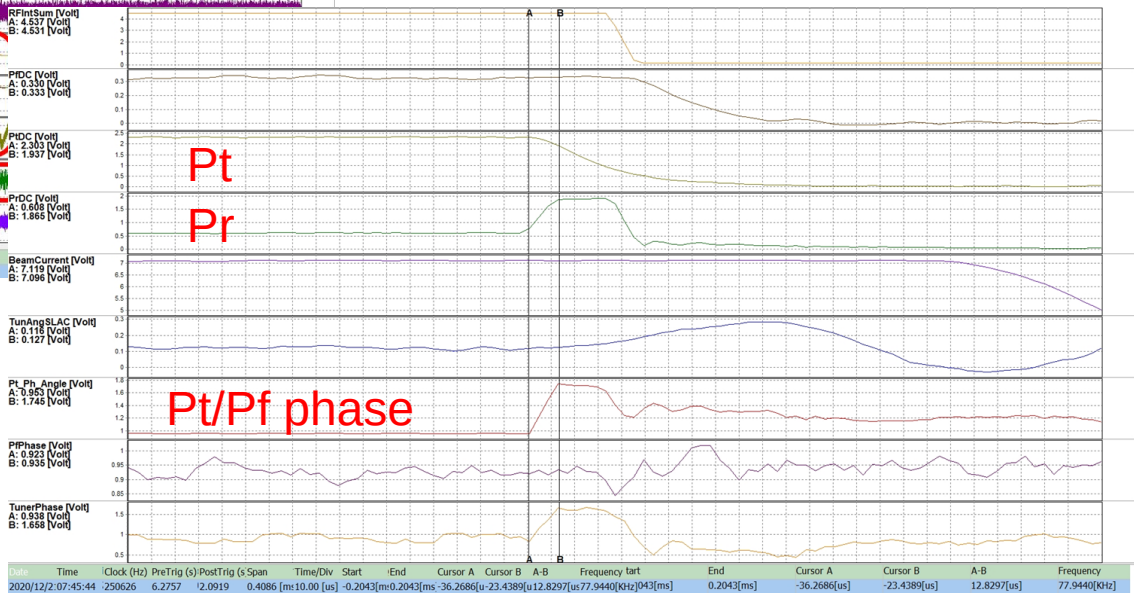


Operation Status of TLS SRF System

- Recent major SRF trip events－unknown quench：
  - ① Vacuum activity in RBT/FBT，but there is no vacuum event in the window.
  - ② LHe pressure does not change.
  - ③ Pt falls rapidly、Pt/Tuner phase changes rapidly、Pr rises rapidly within ~ 12 us.



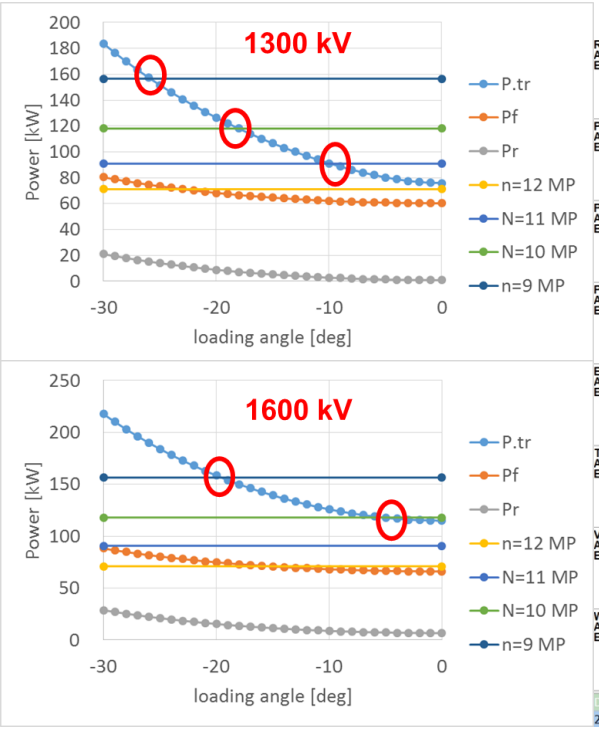
- It may be the arc/MP/other activity in the cavity, which may be related to the heavy gas loading.

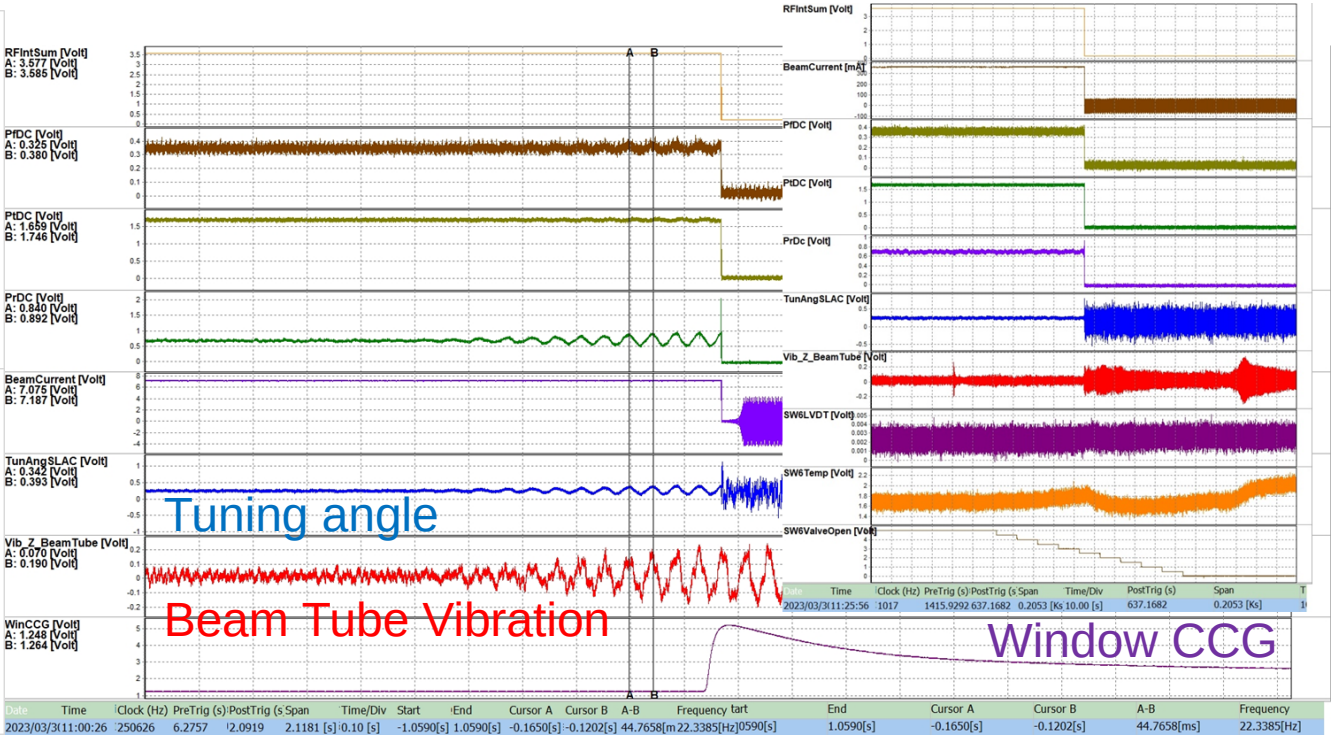


- Partial warm up (to 60 K) and run with lower RF voltage (from 1.6 MV to 1.3 MV).

Operation Status of TLS SRF System

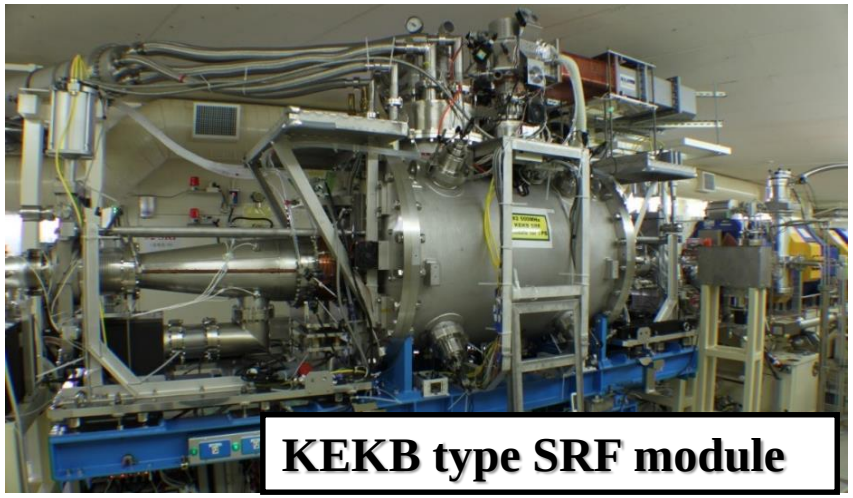
- Recent major SRF trip events－Vacuum burst with tuning angle change：
  - ① During the LHe refilling of a SC wiggler (SW) at the down stream of SRF module.
  - ② There is always a 22 Hz beam tube vibration in Z direction, and resulting in a oscillation of tuning angle.
  - ③ Occurred frequently during 2011~2013 with 1.6 MV operation (solved by optimizing the LHe filling process of SW and applying beam processing/aging).
  - ④ Repeated several times in 2022~2023 with 1.3 MV operation, no vacuum activity during aging/processing. (the original filling process is changed to reduce heat load of SW)





TPS RF System

- Two RF plant in operation
- KEKB type SRF module
- 300 kW klystron transmitter for 1 station
- Analog LLRF



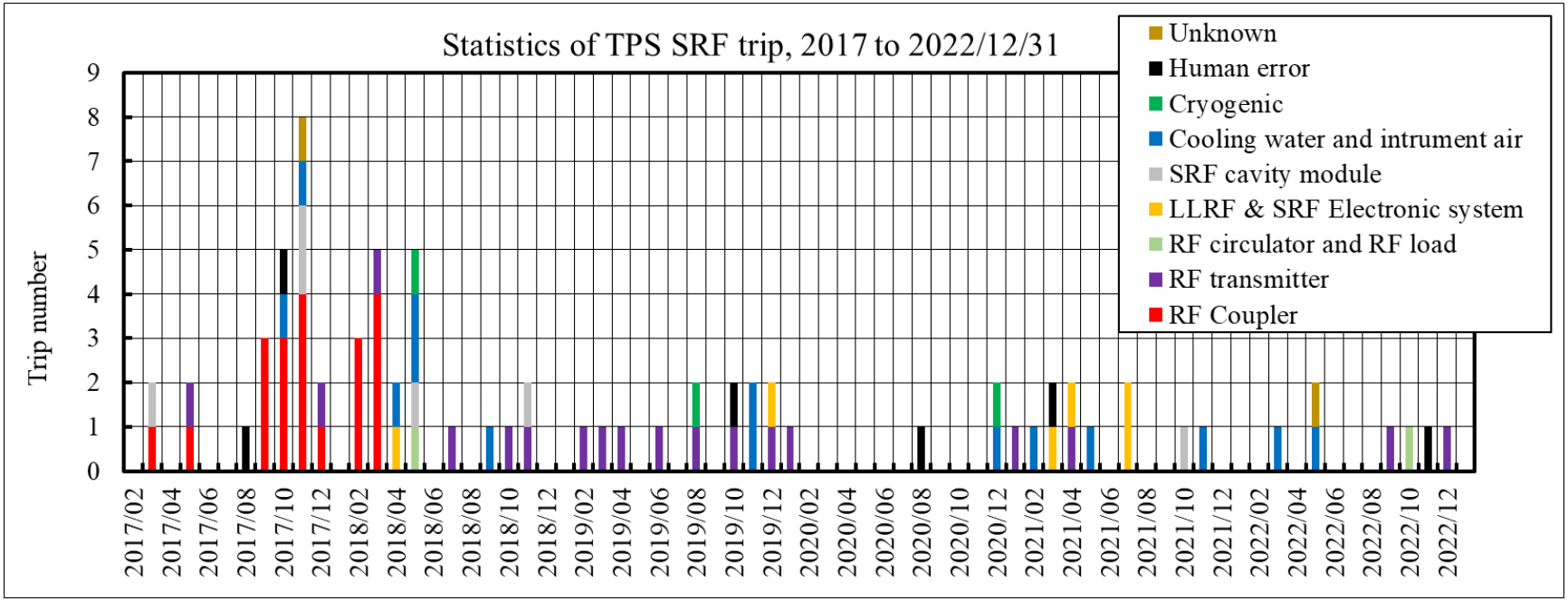
KEKB type SRF module

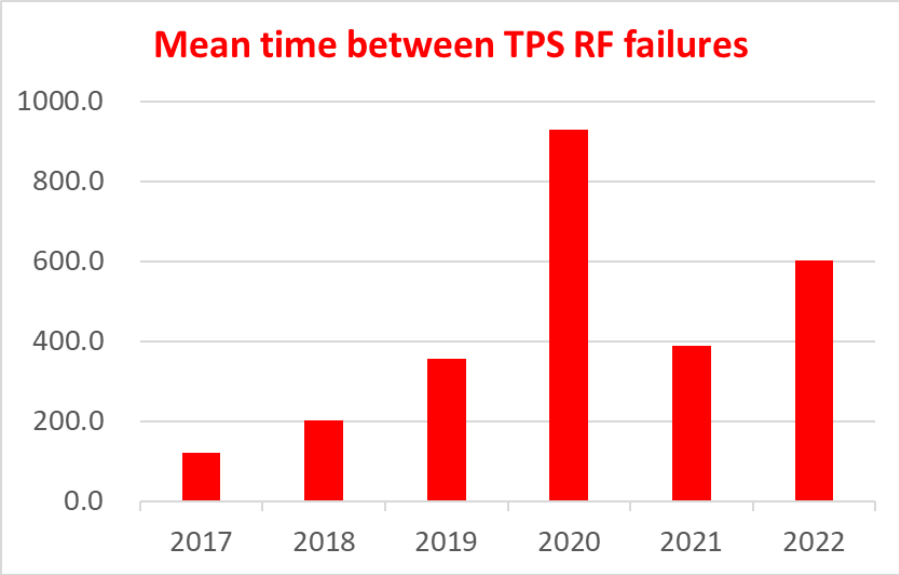
300 kW transmitter & LLRF

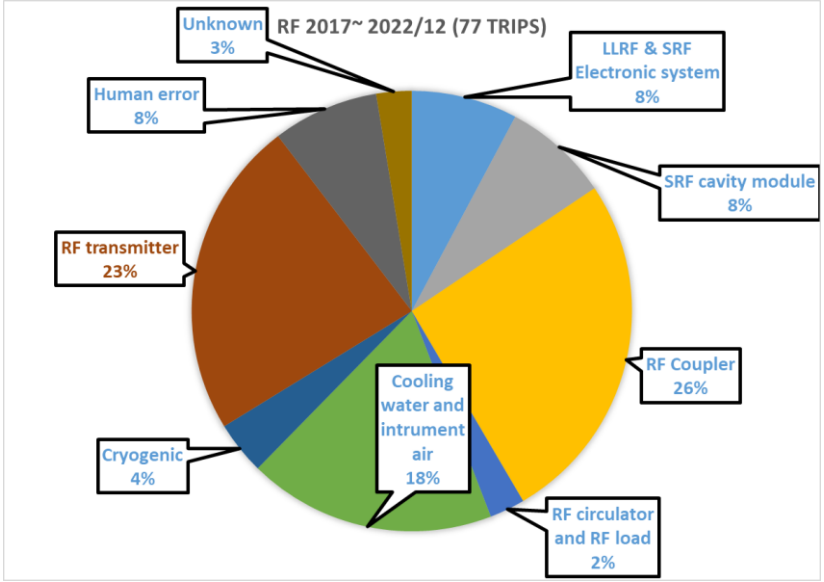
300 kW klystron

SRF electronics

Operation Status of TPS SRF System

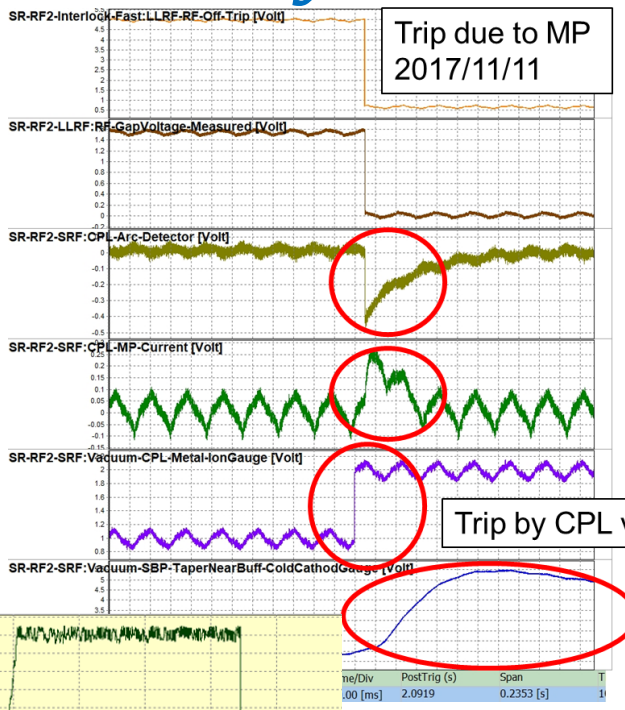






Operation Status of TPS SRF System

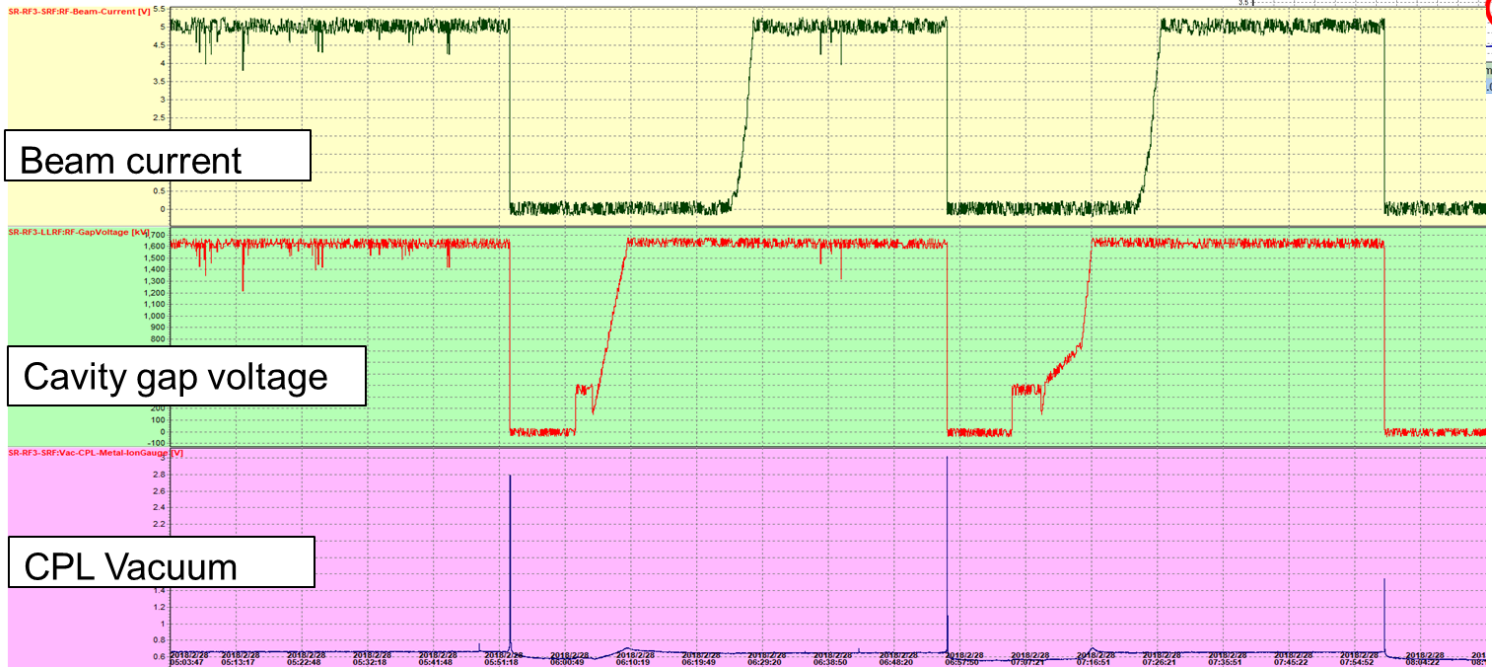
- Trip during early stage of operation：
  - ① Due to Multipacting (MP) in the coupler
  - ② It may continuously cause trip
  - ③ Apply bias voltage (+1000 ~ +1200) to avoid MP



Trip due to MP
2017/11/11

Trip by CPL vacuum

2018 2/28
SRF #3
Vacuum Trip x3 at 300 mA



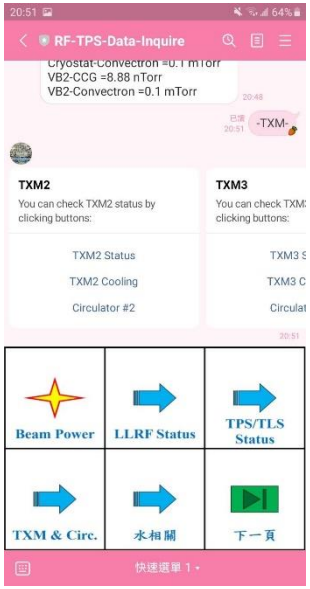
Beam current

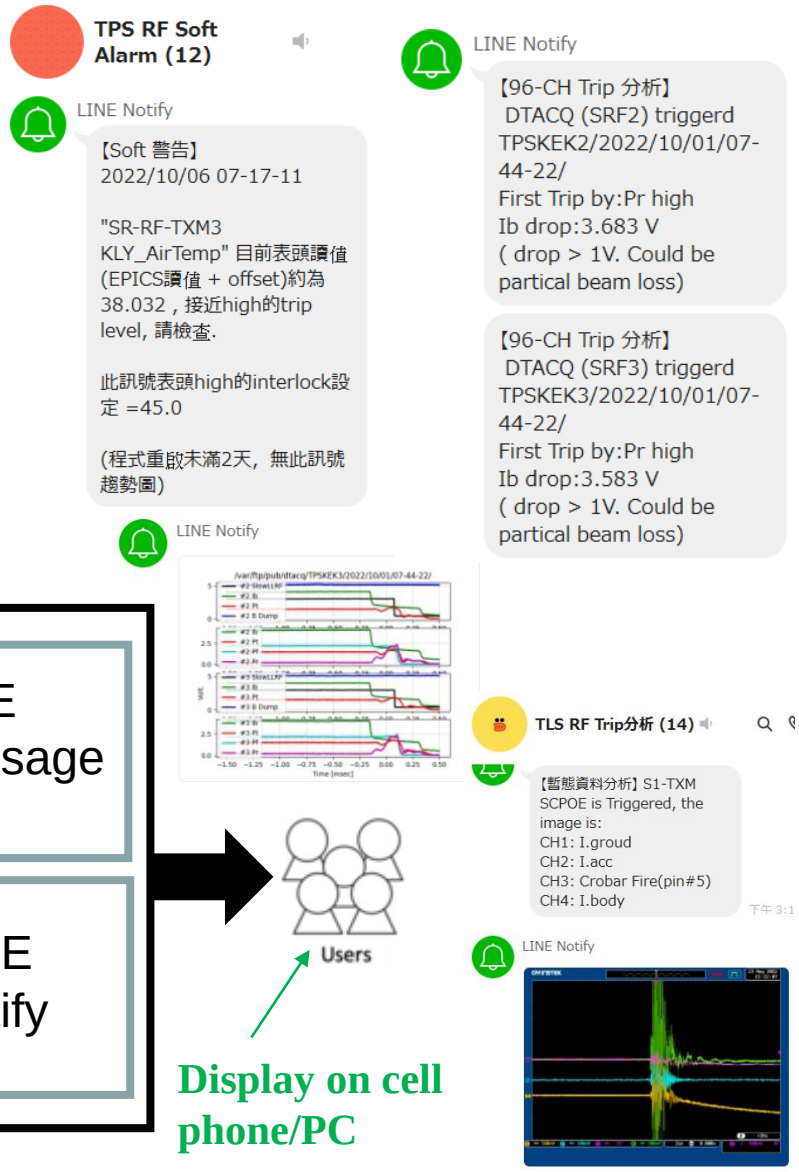
Cavity gap voltage

CPL Vacuum

LINE-based RF Soft alarm System

- Soft alarm system is developed to shorten the downtime and diagnosis time、as well as to improve the reliability (avoid trip due to slow changed signals).
- All messages and figures are sent to user's smart phone and PC via LINE (an instant messaging app.)

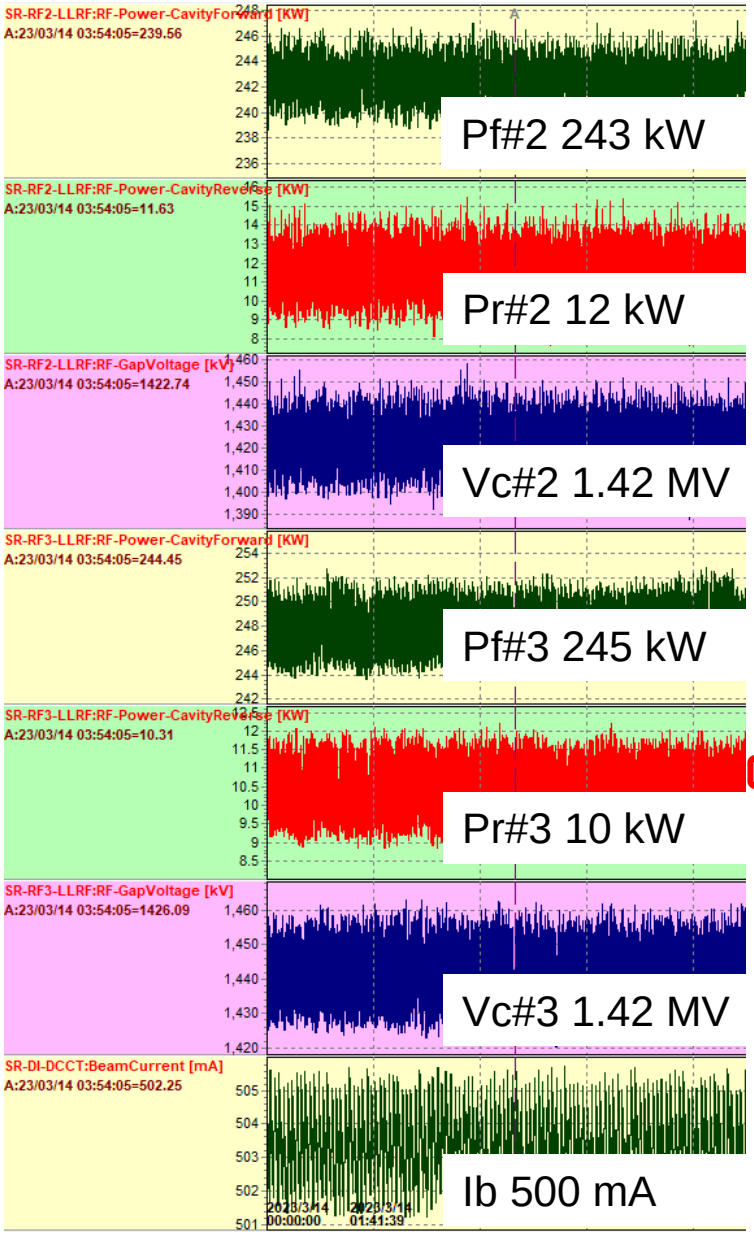




1. **Real time signal inquiry (check message machine status)**

2. **RF soft alarm**
3. **Accelerator operation alarm**
4. **SRF trip indicator**
5. **RF Trip analysis**
6. **Oscilloscope display**

Future Plan (1) —Power Combine

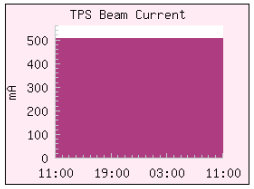


- Stored current reached 500 mA at the end of 2020.
- Several insertion devices will be installed into the storage ring.
- RF power of 2 stations with 300 kW klystron may reach the limit in 3 years.

500 mA	Total Pb	2 x RF
w/o ID	427 kW	213 kW
Phase I	476 kW	238 kW
Phase I+II	526 kW	263 kW
Phase I+II+III	576 kW	288 kW

Taiwan Photon Source

User Beam Time	
Energy	3.01 GeV
Current (H)	501.67 mA
Lifetime	8 h 47 min
Size X	56 μm
Size Y	24 μm

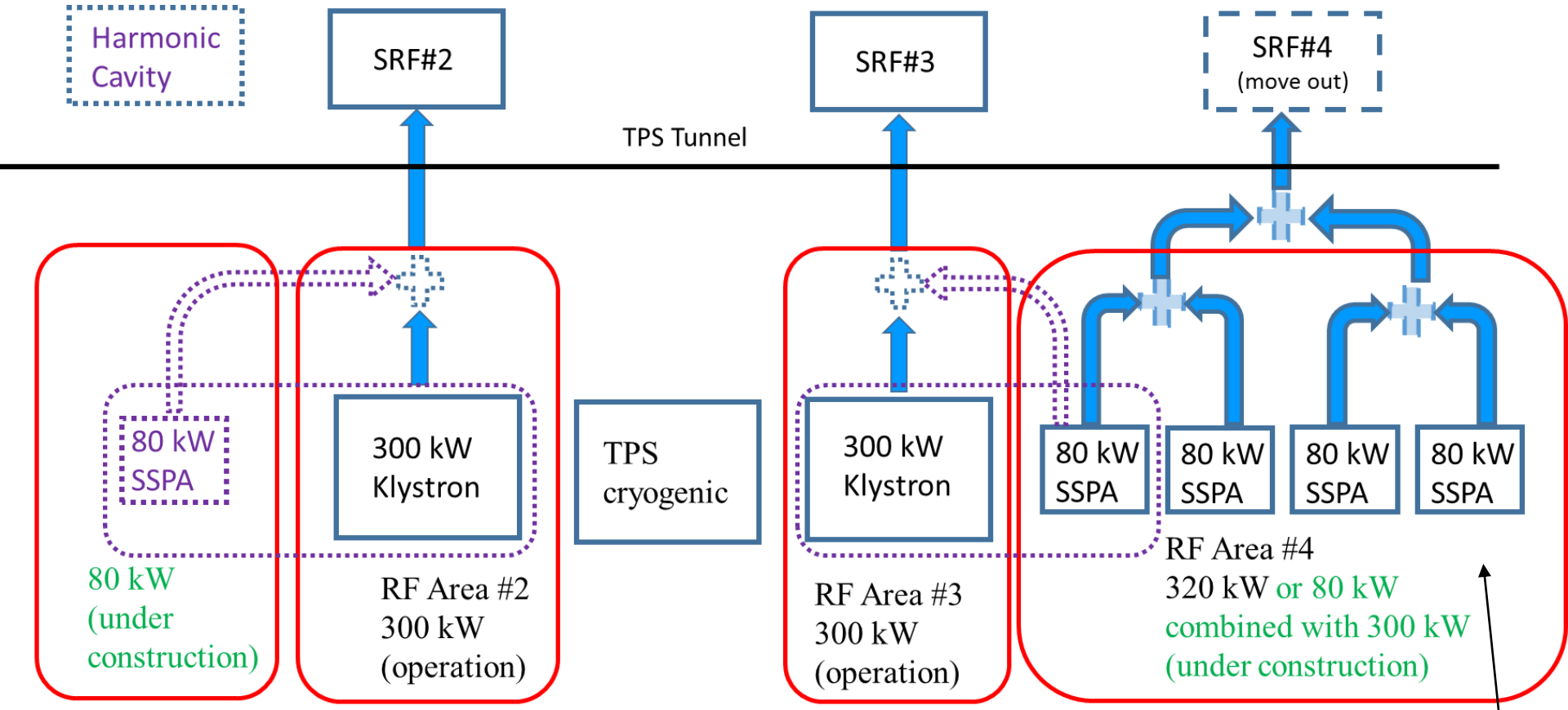


05A (IU22) g	7.27 mm
07A (IU22) g	7.60 mm
09AU (IU22) g	6.92 mm
09AD (IU22) g	40.00 mm
13A (IU24) g	7.58 mm
19A (CU15) g	4.75 mm
21A (IUT22) g	7.31 mm
23A (IU22) g	7.33 mm
25A (IU22) g	6.70 mm
31A (W100) g	14.49 mm
39A (EPU168) g	60.00 mm
39A (EPU168) p	0.00 mm
41AU (EPU48) g	65.00 mm
41AU (EPU48) p	0.00 mm
41AD (EPU48) g	24.55 mm
41AD (EPU48) p	0.00 mm
45A (EPU46) g	28.45 mm
45A (EPU46) p	0.00 mm

Beam power only and with all ID gap close to the minimum.

One solution is: Combination of an 80-kW SSPA to a 300-kW klystron in TPS.

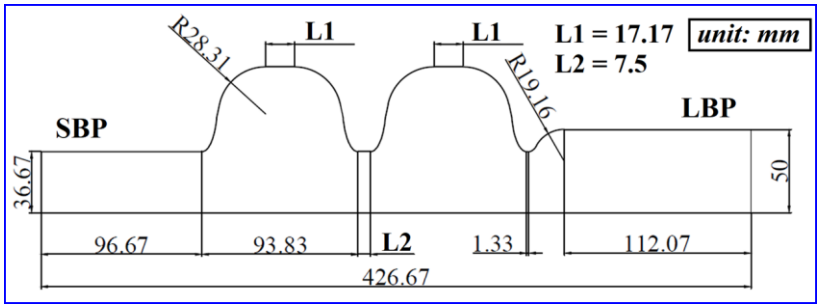
Future Plan (1) —Power Combine



Combine method was tested in the RF Lab.

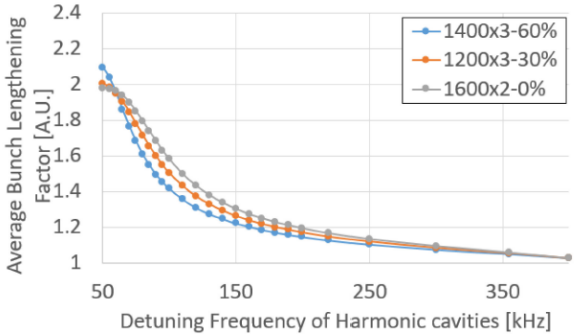
Future Plan (2) —SC Harmonic Cavity

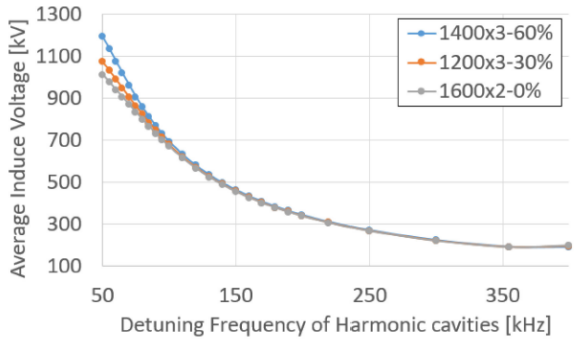
- Bunch lengthening by the passive 3rd harmonic cavities: to reduce the beam-induced heat on magnet arrays of IDs and to improve the beam lifetime.
- 1.5 GHz, Two-cell SRF cavity designed by NSRRC. (2016-2018)
- Niobium cavity contracted to MHI MS, Japan. (2020-2021)

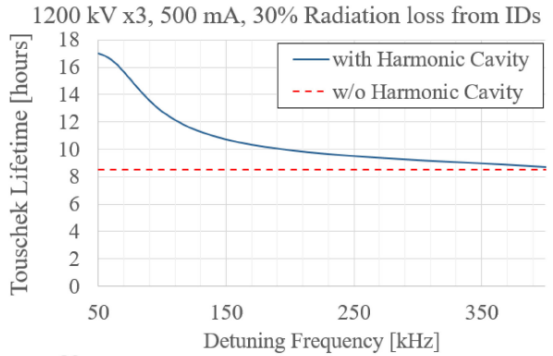


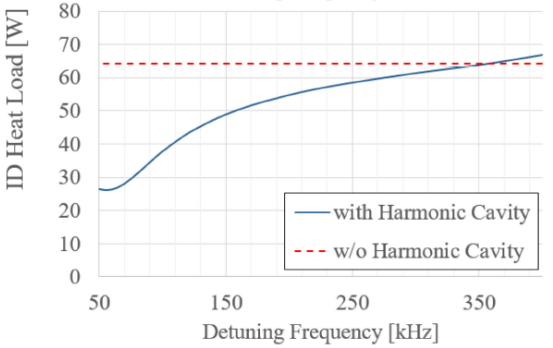
- EPs and annealing to be done at KEK. (2023)
- Cryostat to be designed and assembled by NSRRC. (2022-2023)

- HOM absorbers contracted to RI, Germany. (2022-2024)
- Assembly and integration at NSRRC. (2024-2025)

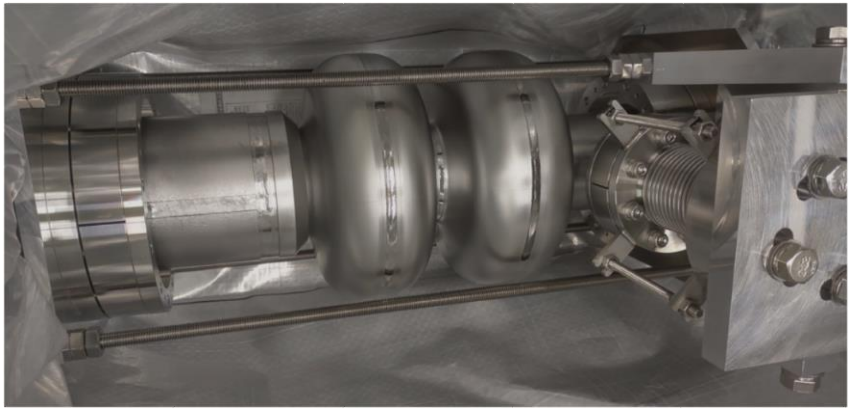


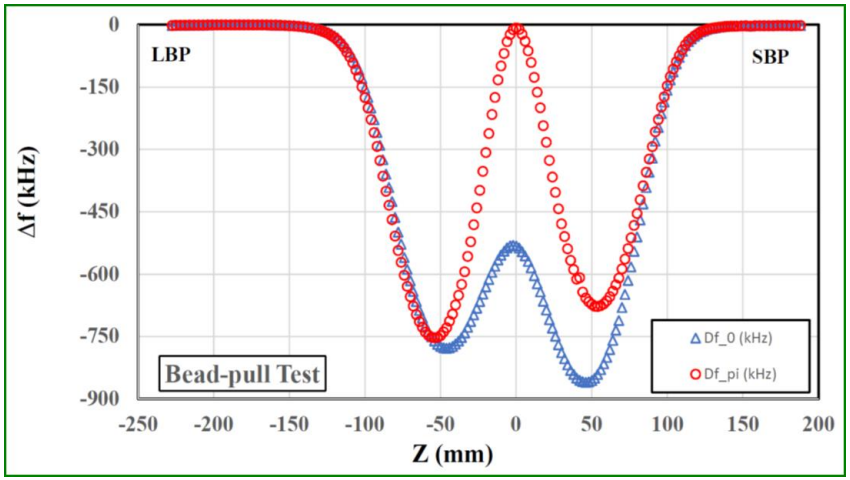






Future Plan (2) —SC Harmonic Cavity

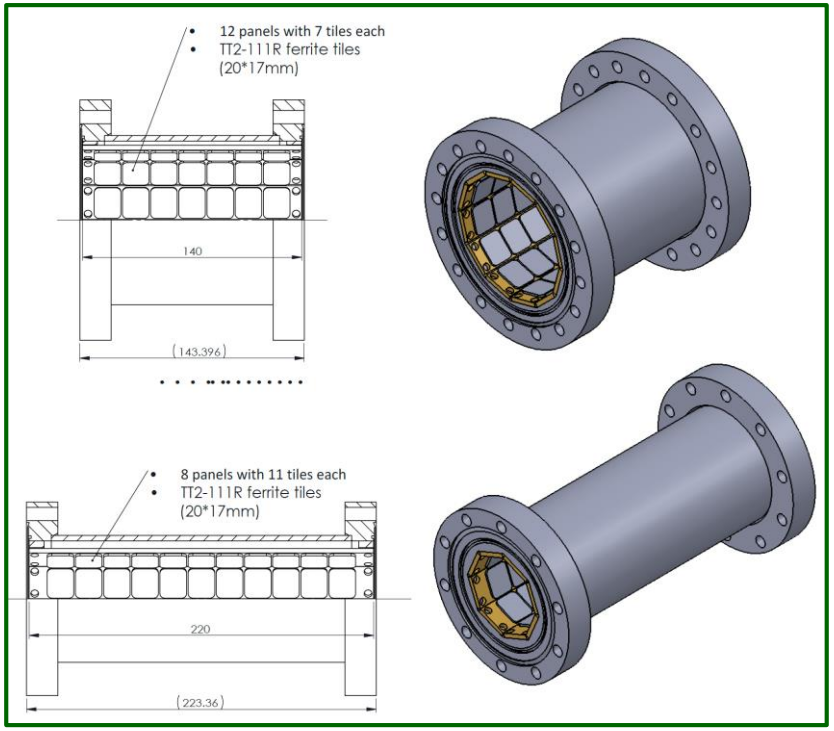




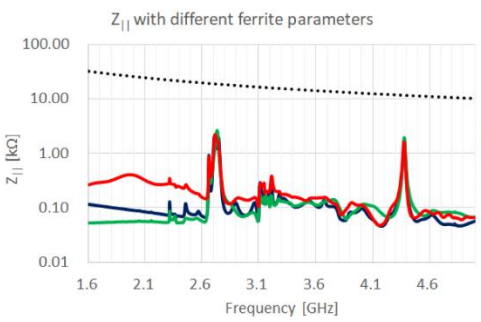
		ANSYS	Measured
f0	o-mode	1.4736 GHz	1.4686 GHz
	π-mode	1.4976 GHz	1.4928 GHz
R/Q	o-mode	0.048	0.034
	π-mode	97.71	98.84
			(9-mm bead)

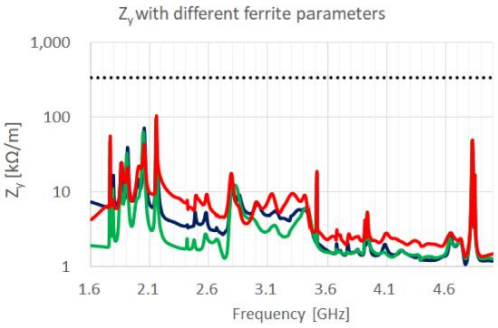
Courtesy of Ming-Chyuan Lin (chyuan@nsrrc.org.tw)

HOM absorbers of panel type:



Courtesy of Chih-Hung Lo (lo.ch@nsrrc.org.tw)





Summary

1. **Two light sources (TLS & TPS) use 500 MHz SRF modules as their accelerating cavity, MTBF of both RF systems are all > 500 hours in 2022.**

2. **Major trip types and improvements in recent years:**
   - **CESR type for 1.5 GeV TLS**
     - ✓ **Unknown quench events: Partial warm up and lower operating RF voltage.**
   - **KEKB type for 3.0 GeV TPS**
     - ✓ **Multipacting in coaxial coupler: applying positive bias voltage.**
     - ✓ **Develop soft alarm system to shorten the downtime and improve the reliability.**

3. **Future plans for TPS SRF activity:**
   - **Power combination for each SRF module.**
   - **SC 3rd harmonic cavity to lengthen the electron bunch.**

Thank you