SRF Operation Status of SSRF

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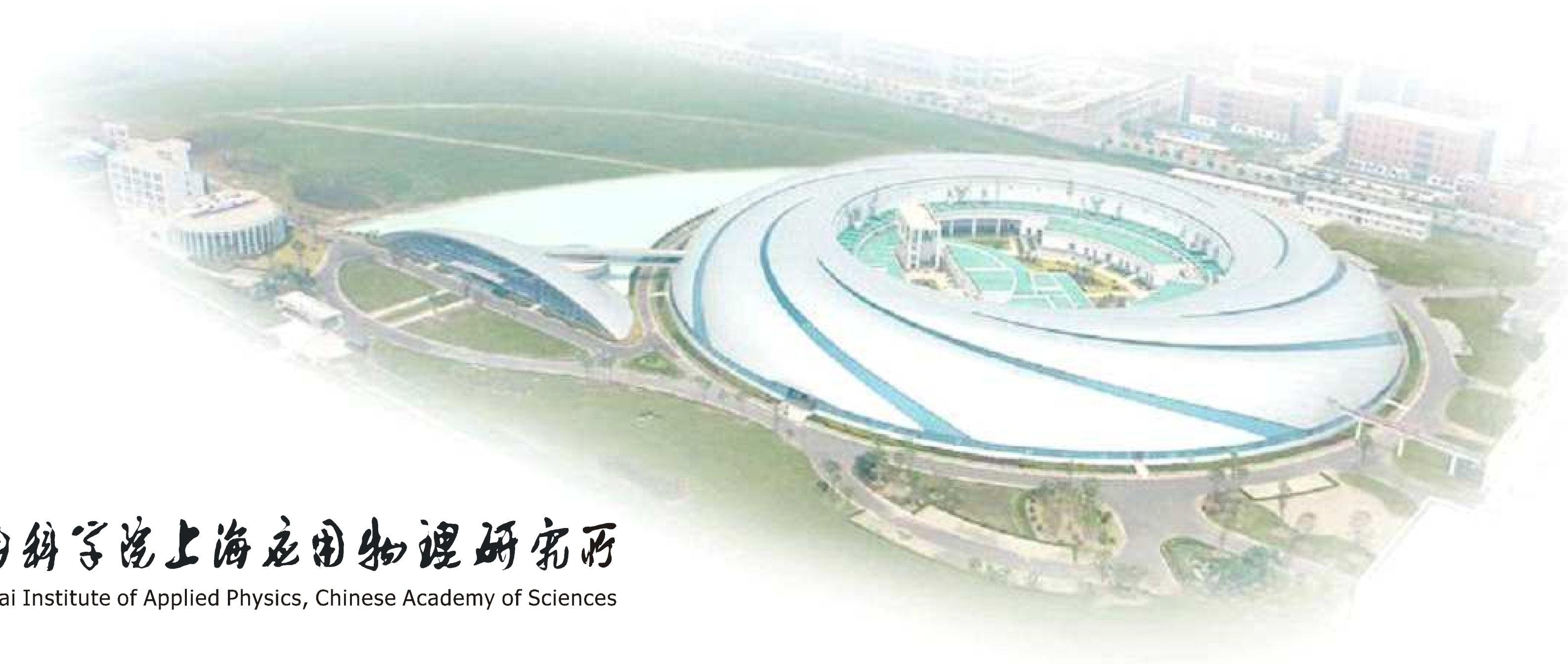

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Contents

- Overview of Shanghai Light Source (SSRF)
- Booster's RF System
- Storage Ring's SRF System
- Cryogenic System
- Operation Status of SRF System

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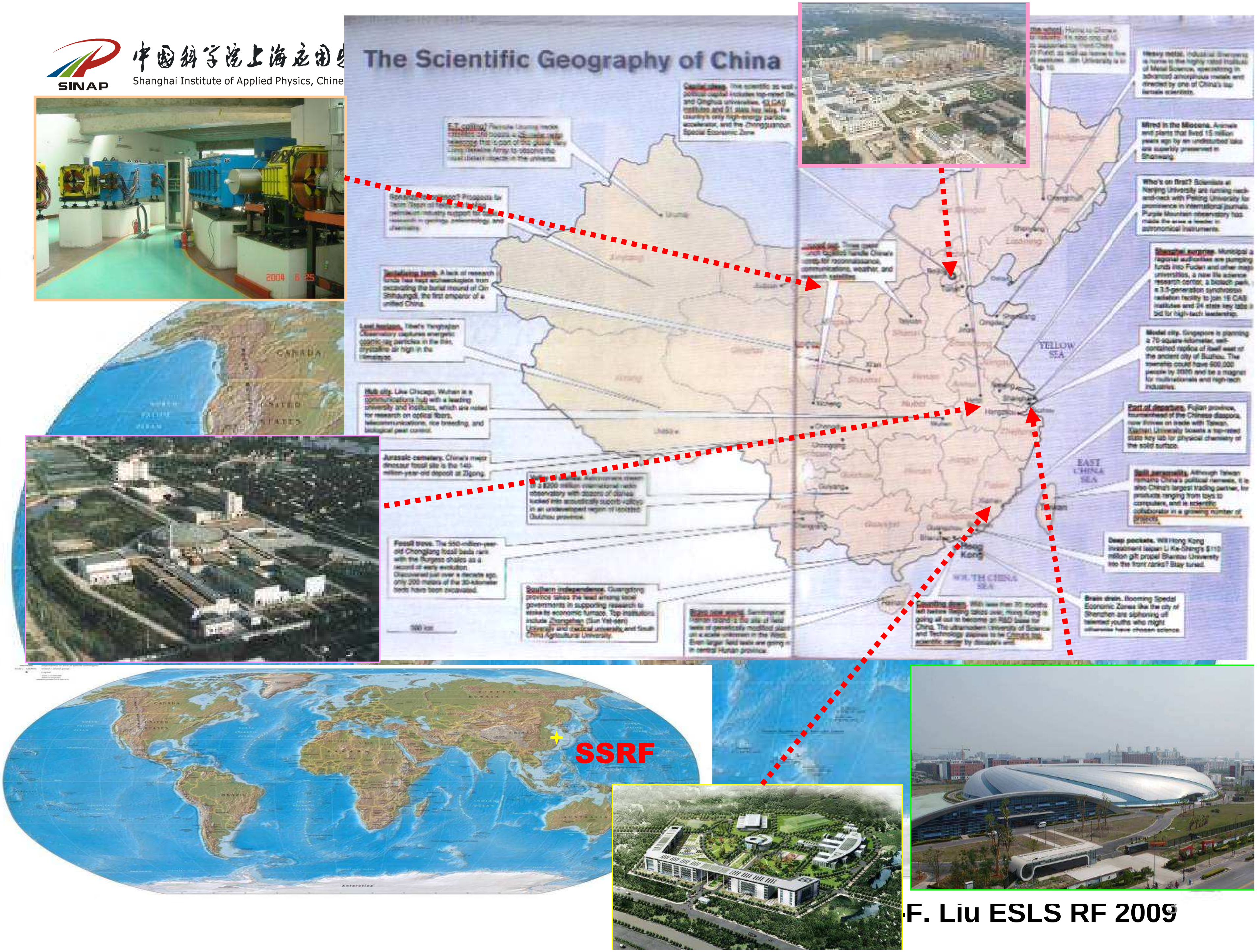

The Location of SSRF Site in Shanghai

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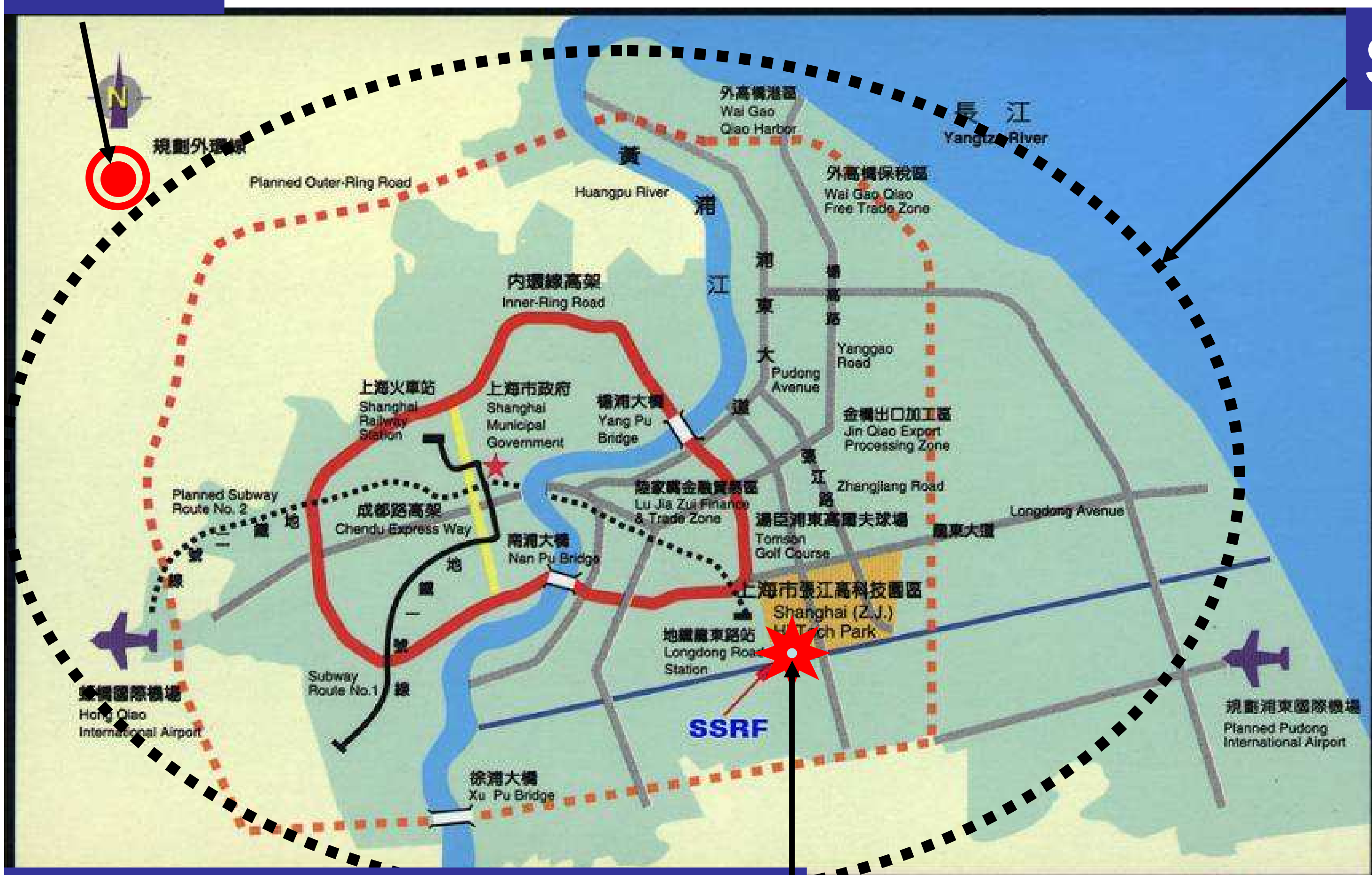
Shanghai



Shanghai Light Source

Trumpet shell

Bird-view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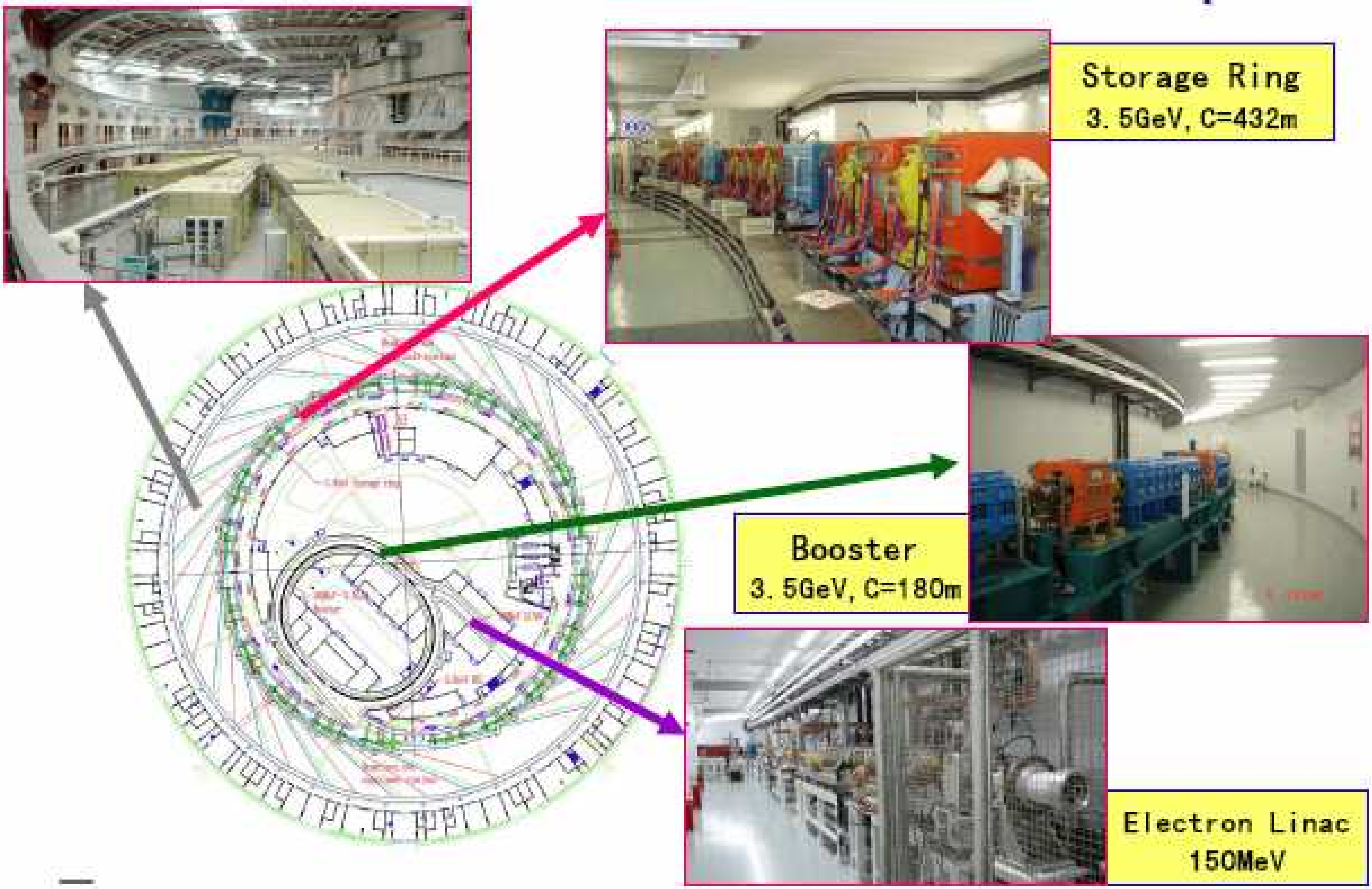
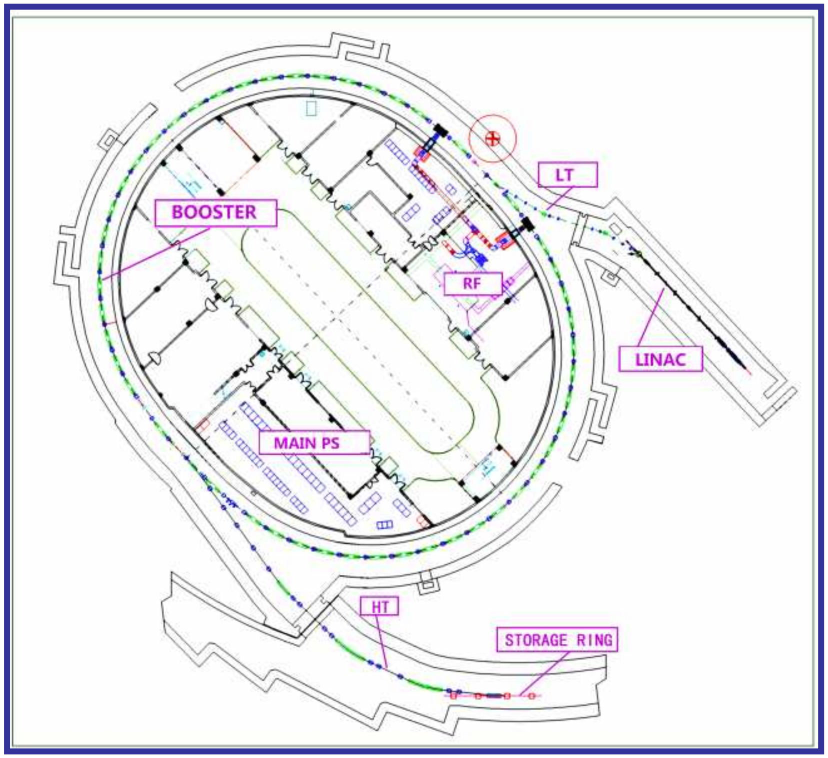
Layout of the SSRF complex

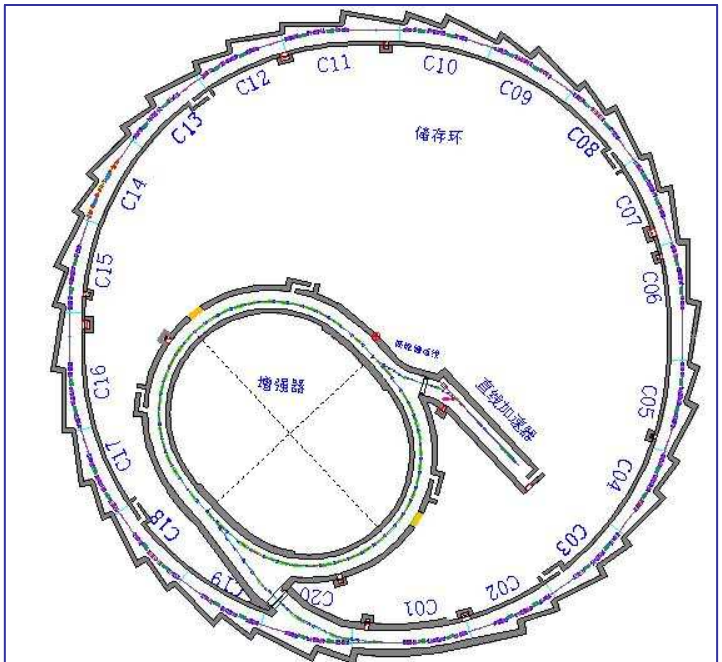


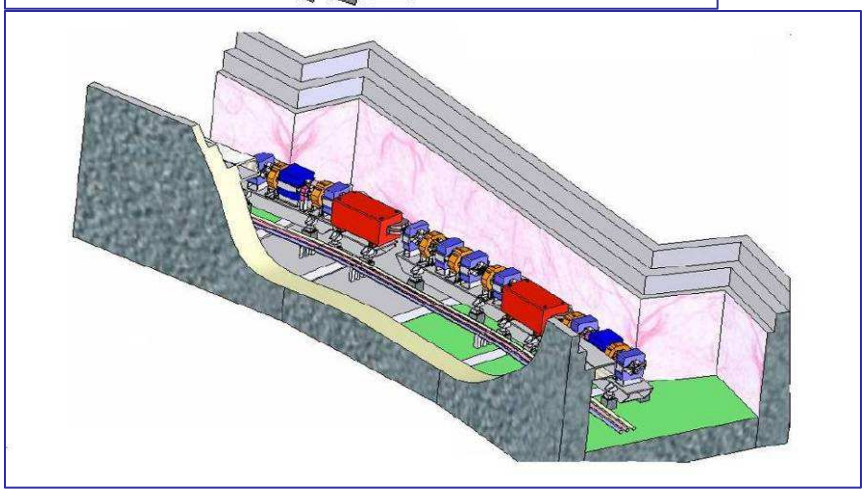
SSRF Booster

- Full energy booster ,optimized for top-up injection;
- Two super-fold and 28 cells FODO with 8 missing dipole magnets;
- Beam emittance about 100 nm-rad @3.5 GeV for clean top-up operation;
- A circumference of 180m and a injection energy of 150MeV;
- Repeat rates up to 2Hz;

Booster Layout







Storage Ring

- Main paramaters:
- Energy：3.5 GeV；
- Circumference：432m；
- Current：5/300 mA (S/M bunch)；
- emittance：3.9 mm-mrad；
- Strait section：4*12m，16*6.5m；
- RF voltage：4-6 MV
- Max Power：~600kW
- Orbit Stability：<10% beam size

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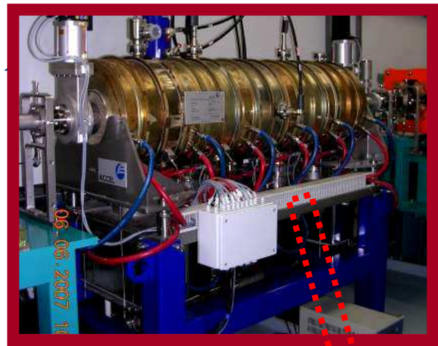
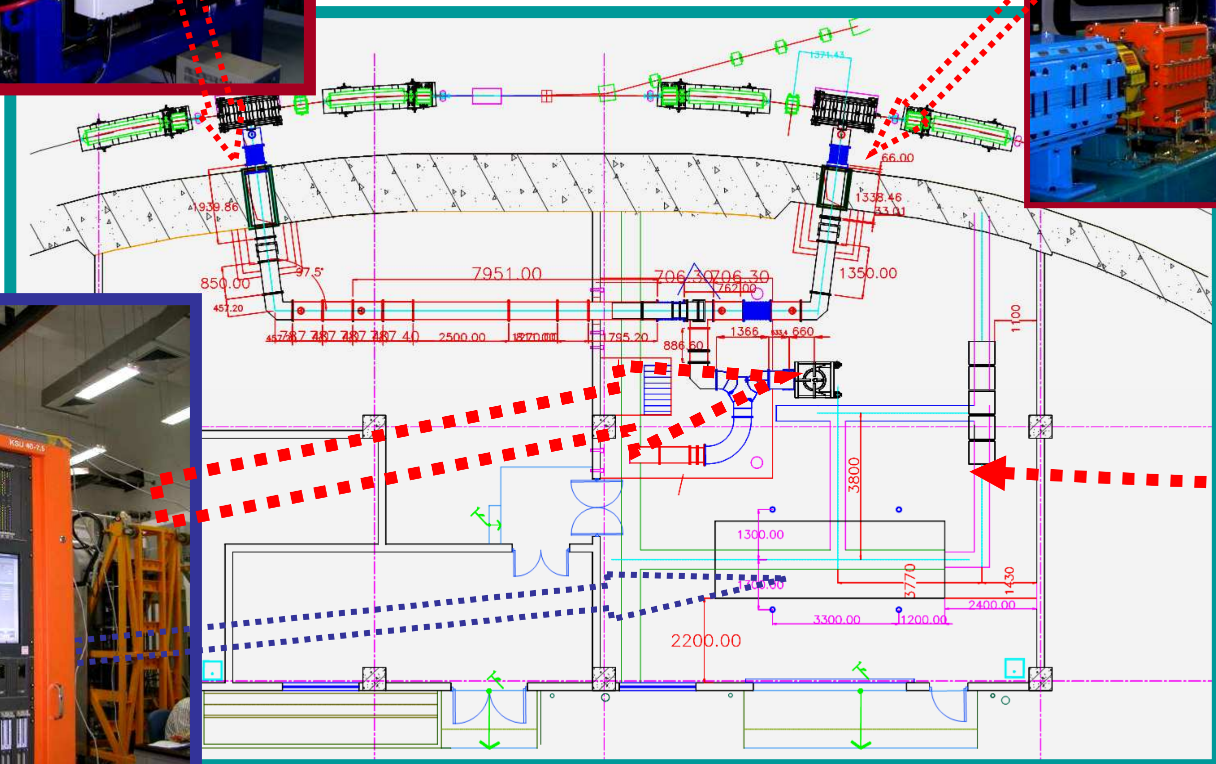
The layout of the booster RF system





1. One 180KW transmitter feeds power to two normal conducting 5-cell cavities, ramping energy from 150 MeV to 3.5 GeV, and its LLRF is analog I/Q from ACCEL company.
2. It has been commissioned successfully in June of 2007

Measured parameters of booster cavities

Parameter	Specified Value	Measured cavity1/cavity2	Unit
Resonant frequency	499.654(30° C)	499.747(19° C)/499.749(18.7° C)	MHz
Coupling factor	1~1.2	1.092/1.068	
Unload quality factor	>29000	29618/29386	
Tuning-range	>+/-0.2	+0.9325/-0.2537, +0.9337/-0.2450	MHz
Tuning-precision	<100	2.08Hz/2.13	Hz
Tuning-speed	>1	2.773/2.80	kHz/s
Field flatness at 499.654MHz	<+/-5	<+/-1	%

Main Designed and Measured Parameters of Booster RF System

Parameter	Value	Unit
RF frequency	499.654	MHz
Beam energy	3.5	GeV
Energy loss per turn	0.915	MeV
Single/Multi-bunch mode beam current	2/10	mA
Beam power (Multi-bunch)	9.15	kW
RF voltage	1.80	MV
RF Phase Stability	<±1	o
RF Amplitude Stability*(*Ramping)	<±1	%

The achieved parameters of booster RF system

Mode	Phase(close loop)	Amplitude(close loop)
CW(0.1MV)	Peak-to-peak = 2.5° ; RMS= 0.5°	Peak-to-peak=4.8%; RMS= 0.96%
CW(2MV)	Peak-to-peak = 0.5° ; RMS= 0.1°	Peak-to-peak=0.35%; RMS= 0.07%
Ramp(0.1 MV~2 MV) (8 Hours stability)	Phase stability : 0.17° RMS	Amplitude stability : 0.2% RMS

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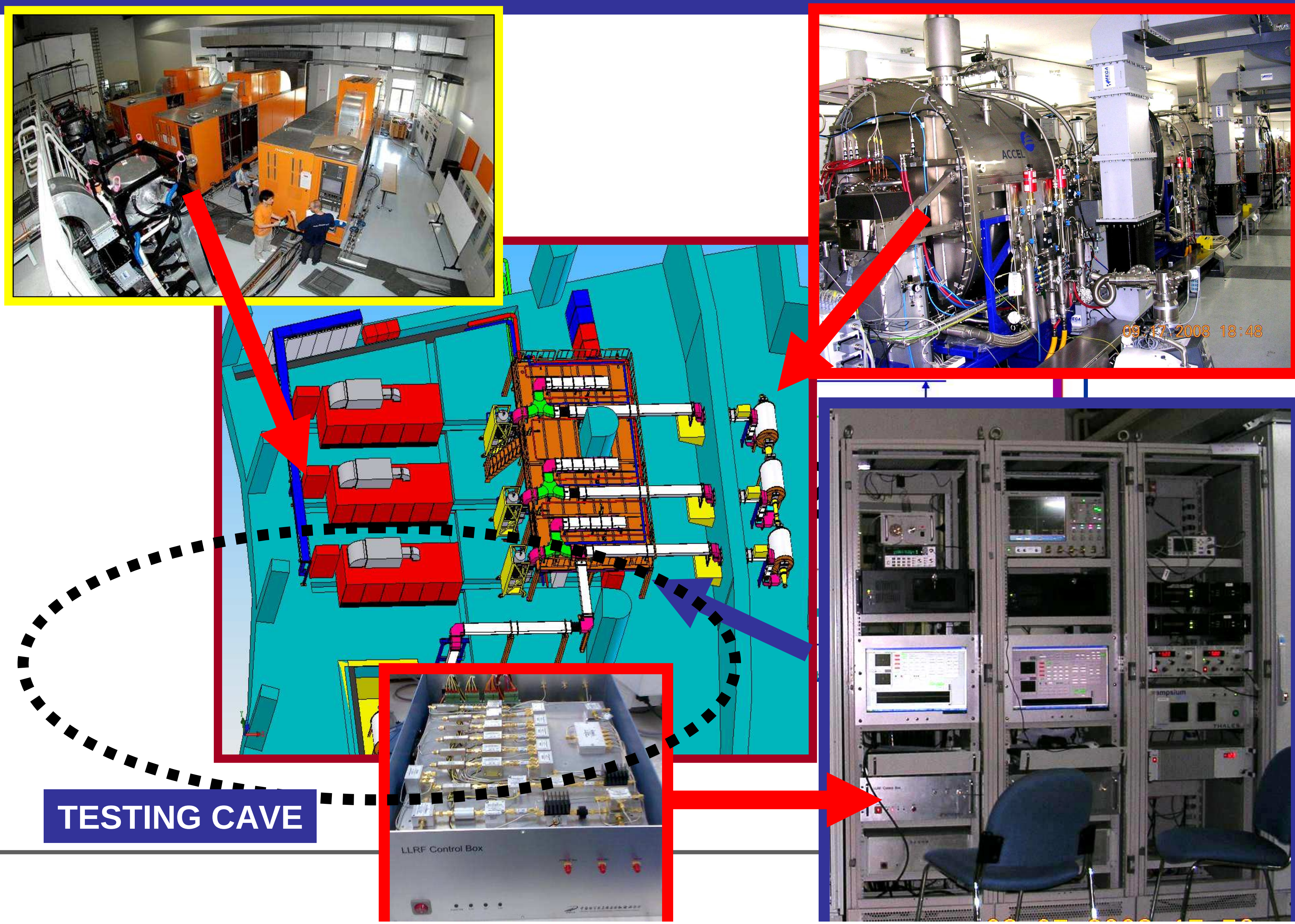
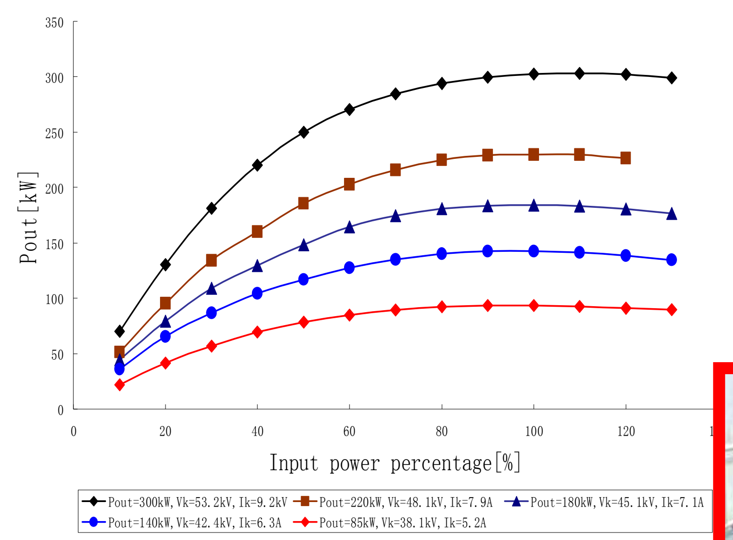
Main requirements of SRF for SSRF storage ring

RF frequency	499.654 MHz
RF voltage	≥4.0MV (5.0MV*)
RF phase stability	≤±1°
RF amplitude stability	≤ ±1%
Beam power	491 (625*) kW

The layout of the storage ring SRF system





Main parameters of Klystrons :

RF output power: > 300 kW CW
RF drive power: < 31 W
Instantaneous bandwidth (-1 dB): > 2 MHz
Gain: > 40 dB
Efficiency: > 63 %

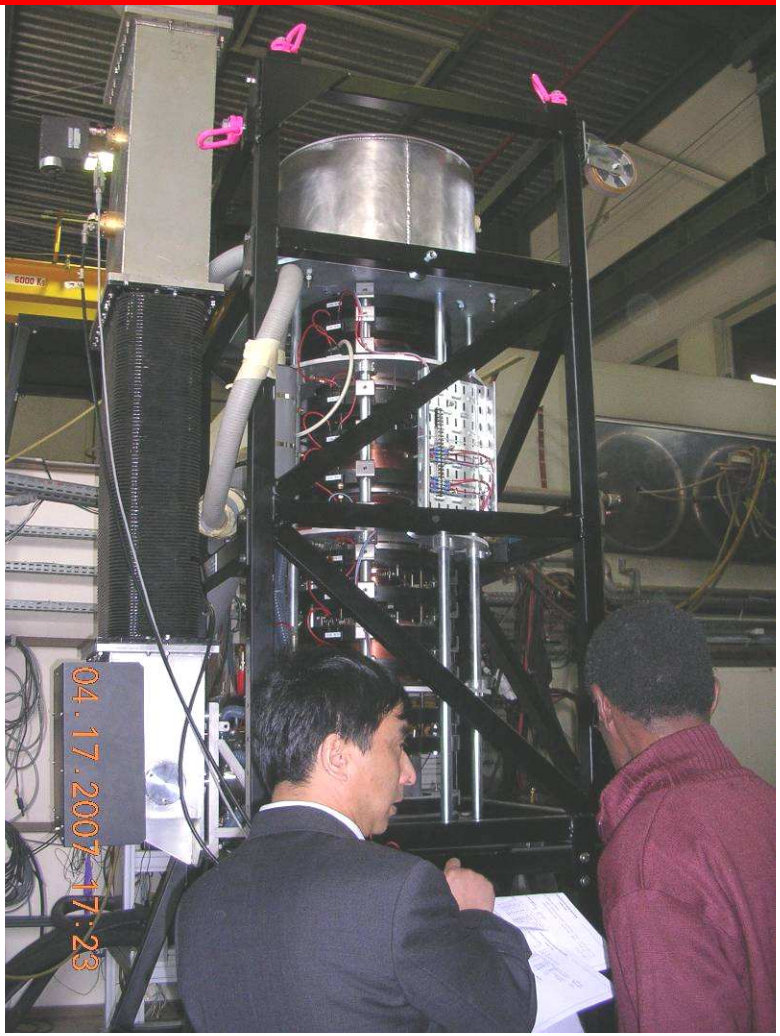
Main parameters of the circulators:

Forward power	**350 kW CW**
Reflected power at any phase	**350 kW CW**
Insertion loss at center frequency	**> 26 dB**
Insertion loss in bandwidth	**> 20 dB**
Isolation at center frequency	**> 26 dB**
Isolation in bandwidth	**> 20 dB**
Return loss at center frequency	**> 26 dB**
Return loss in bandwidth	**> 20 dB**
Bandwidth	**+/- 2 MHz**

Main parameters of the 350 kW loads:

Average power	**350 kW CW**
Return loss	**> 30 dB**

FAT of Klystrons



Milestone of RF Transmitters

- **June-July 2005** **Call for tender**
- **Sept. 2005** **Contract for RF power system**
- **Feb. 2006** **Final design review of amplifiers**
- **Oct. 2006** **FAT of 1st klystron**
- **Feb. - March 2007** **SICAT of 1st amplifier**
- **March 2007** **Test of 1st circulator**
- **April 2007** **FAT of 2nd & 3rd klystron**
- **July-Oct. 2007** **SICAT of 2nd & 3rd amplifiers**
- **Oct. 2007** **Test of 2nd & 3rd circulators**

KSU installation and commissioning

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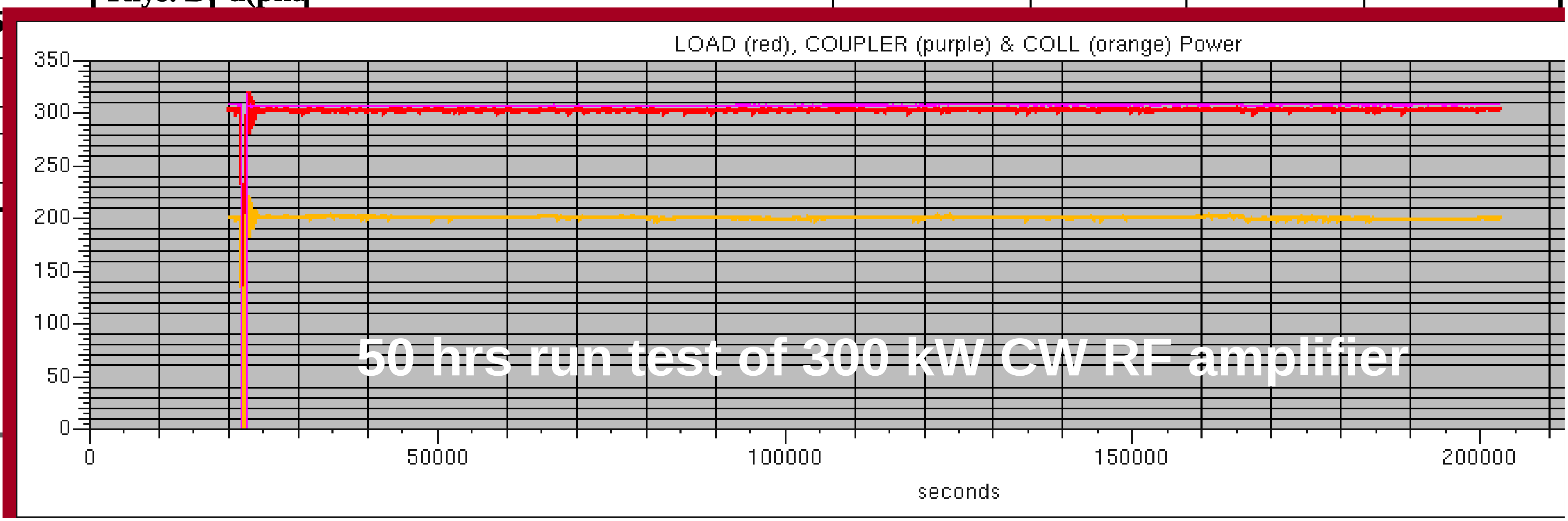
Results of SAT of 3 sets of 300 kW RF Amplifiers

Parame… | Design | Test results
Freque…
Pout C…
Pin
Gain
Efficien…
2nd har…
3rd har…
Attenua…
5…
1…
1…

Parameter | Design | Test results
Klys. C…
Klys. A…
Klys. Fi…
Klys. F…
Klys. F…
Klys. Io…
Klys. Io…
Klys. B…

Parameter	Design Value	Test results		
		1st set	2nd set	3rd set
HV te…				
HV te…				
d(pha…				
d(pha…				

Parameter	Design Value	Test results		
		1st set	2nd set	3rd set
Efficiency of HVPS @ 300 kW [%]	≥ 96	96.3	96.7	96.3
Power factor of HVPS @ 300 kW	≥ 0.96	0.96	0.96	0.96
Efficiency of HVPS @ 150 kW [%]		97.4	96.3	96.8



Superconducting RF Cavities

Vertical Tests in Cornell University

Main Spec.

- Q_0>1E9 @ Vacc ≤2MV
- Q_0>0.5E9 @ Vacc>2.8MV.
- Qext = 1.7E5+/- 0.3E5

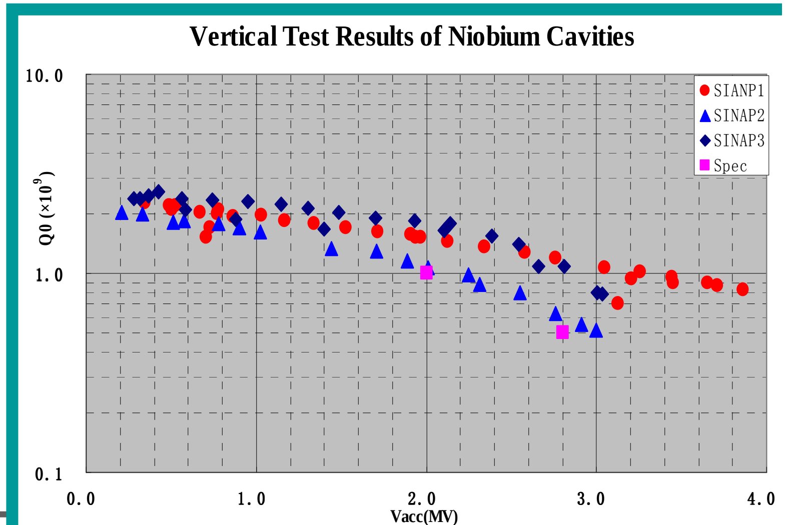
Window:

- 250 kW in traveling wave cw .
- 120 kW standing wave cw at full reflection,
- 400 kW in traveling wave at >20% duty cycle.

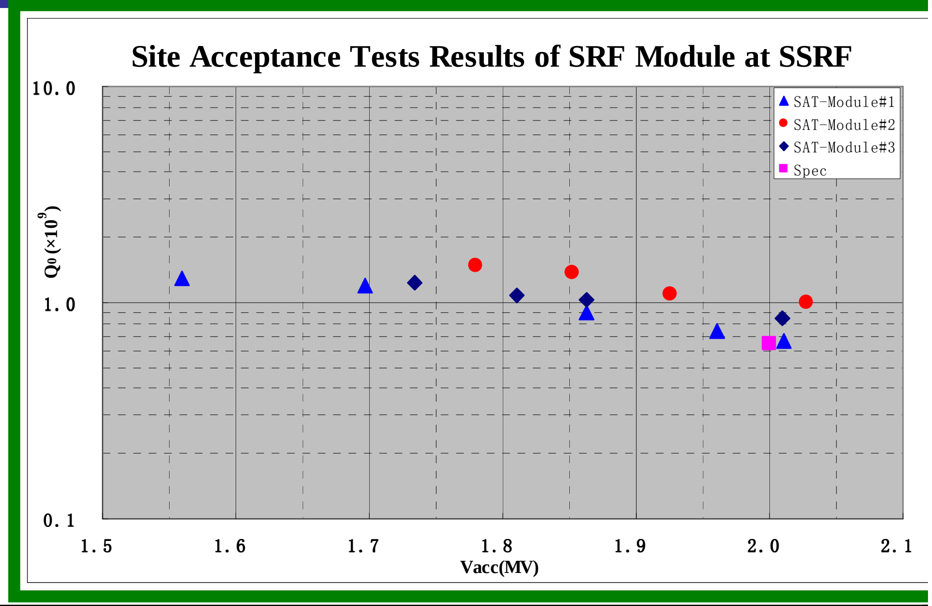
P_{rf} @ 2MV < 70W

P_{static} < 30W

Module NO.	Q0 @ V_{acc} =2MV	Q0 @ V_{acc} >2.8MV
#1	1.45E9 @ V_{acc} =2.13MV	1.07E9 @ V_{acc} =3.05MV
#2	1.07E9 @ V_{acc} =2.0MV	5.88E8 @ V_{acc} =2.86MV
#3	1.52E9 @ V_{acc} =2.04MV	7.88E8 @ V_{acc} =2.84MV



Horizontal Tests on SSRF Site



Parameter	Guarante Value	Measured value		
		M#1	M #2	M #3
$Q_{external}$	1.7 E5 +/- 0.3 E5	1.6E5	1.78E5	1.75E5
V_{acc}	> 2.0 MV	2.1 MV	2.03 MV	2.02 MV
P_{diss} @ Vacc = 2MV	< 70 W	60 W	46 W	< 55 W
Static losses	< 30 W	< 30 W	< 30 W	< 30 W
Total losses @ Vacc = 2MV	< 100 W	< 90 W	< 80W	< 85 W
RF in SW off resonance	120 kW	110 kW*	120 kW	120kW

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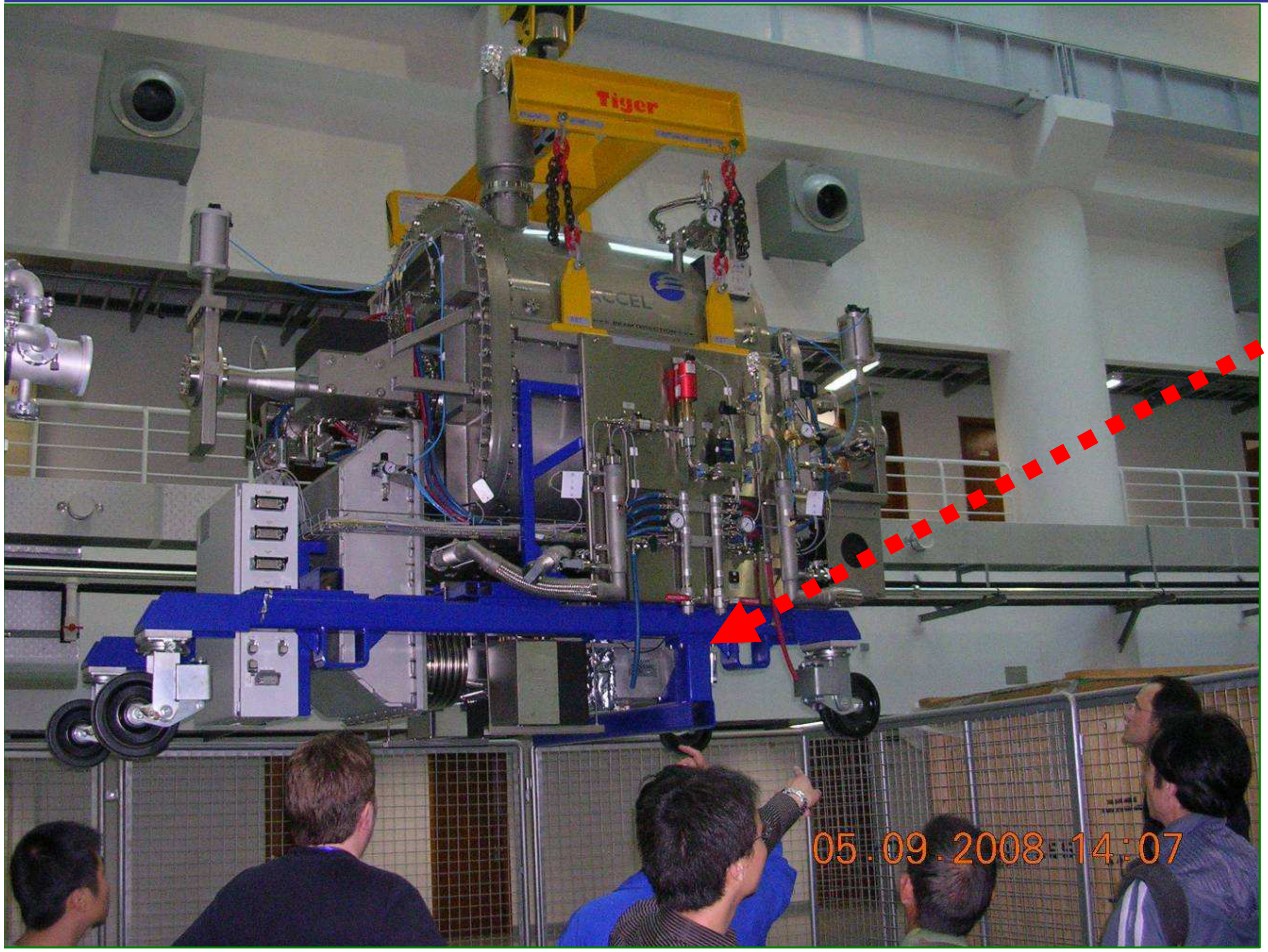
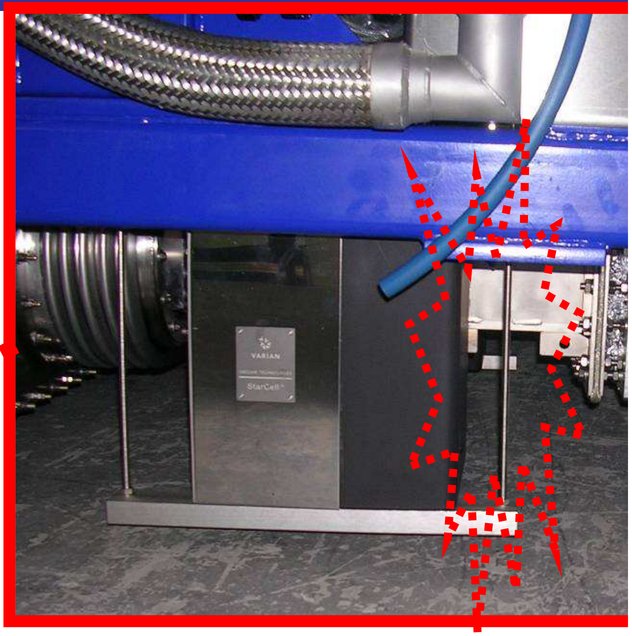
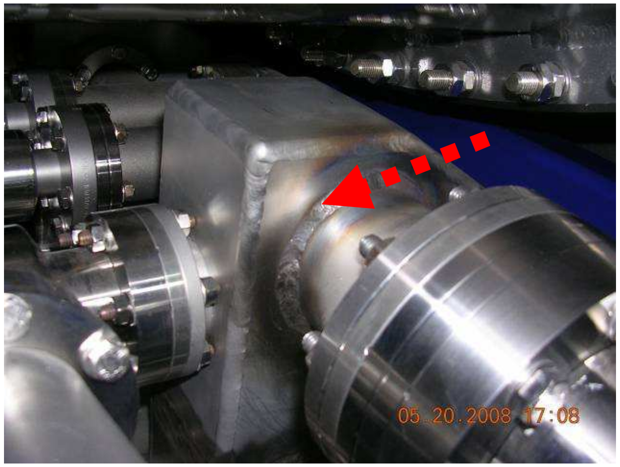
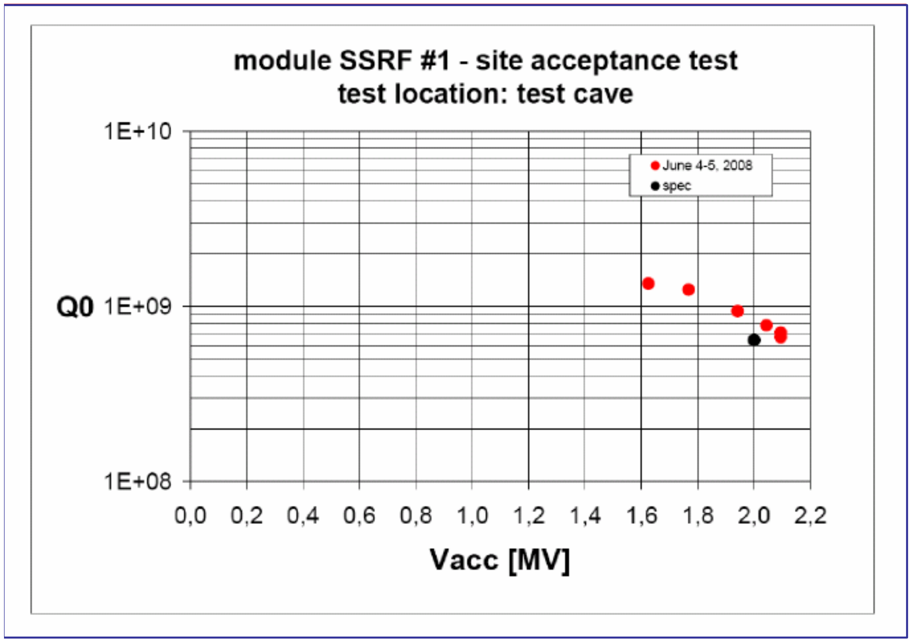
Leakage Happened During Shipping

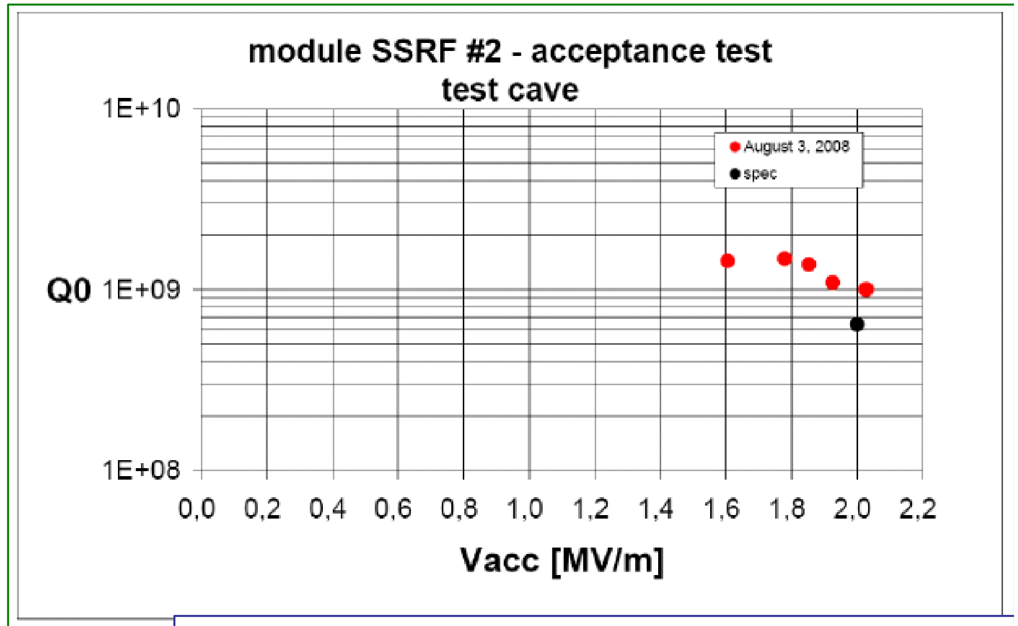






June 6, 1st Module SAT
Aug. 3, 2nd Module SAT
Sept. 13, 3rd Module SAT



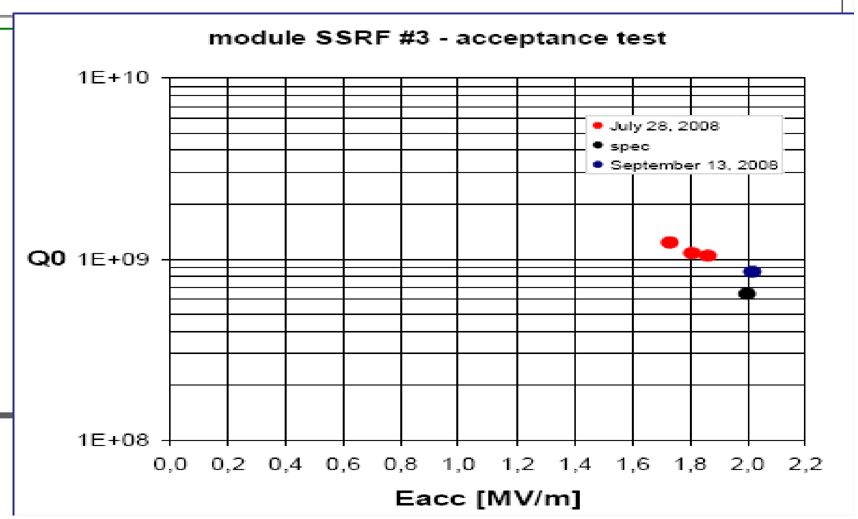


Parameter	Guaranteed Value	Achieved value
$Q_{external}$	$1.7 \cdot 10^5 \pm 0.3 \cdot 10^5$	$1.6 \cdot 10^5$
V_{acc}	>2.0 MV	2.1 MV
P_{diss} @ V_{acc} = 2.0 MV	< 70 W	60 W
Static losses	< 30 W	< 30 W
Total losses @ V_{acc} = 2.0 MV	< 100 W	< 90 W
RF power in SW off resonance	120 kW	110 kW *

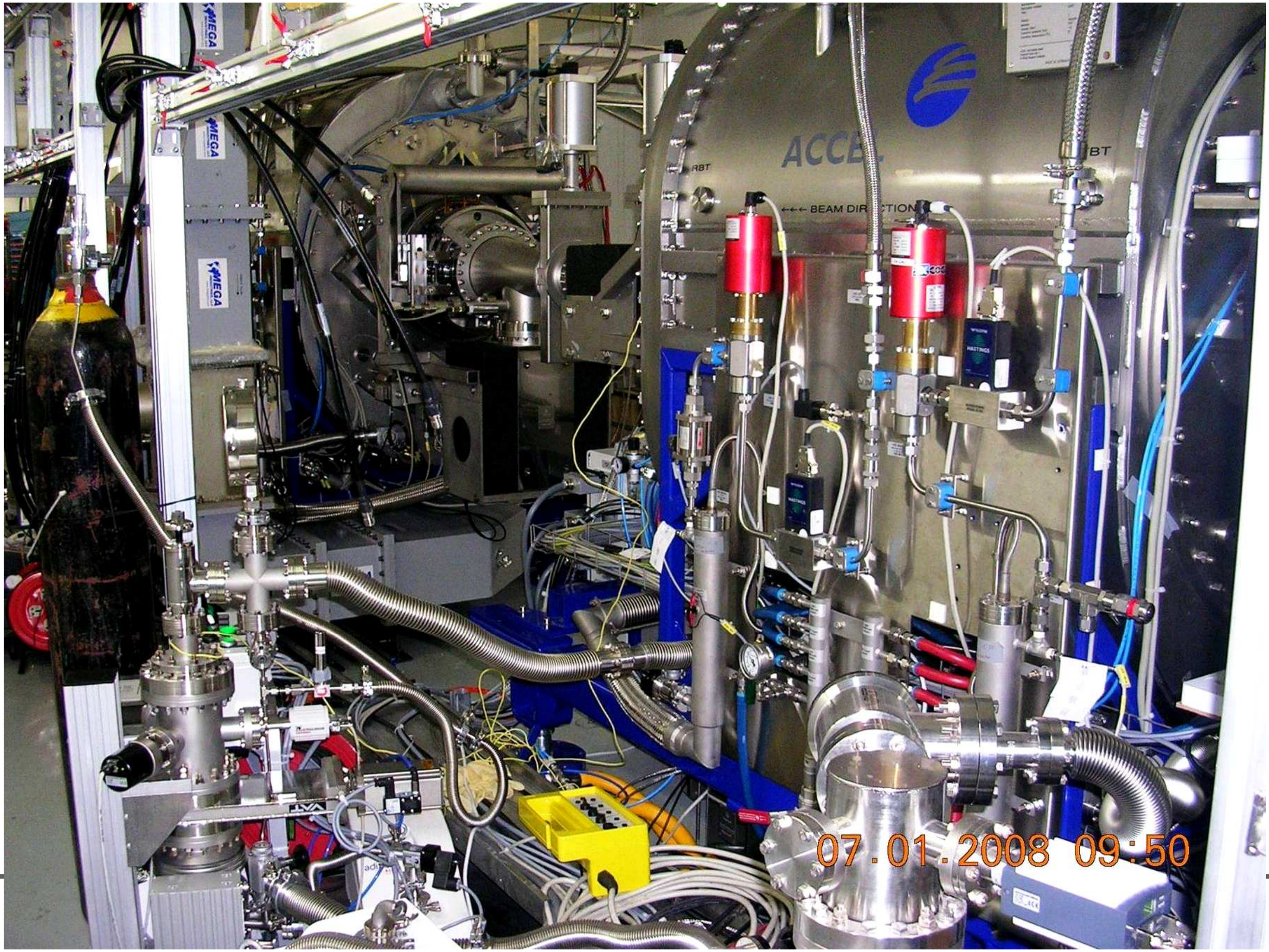
No vacuum leaks where found with the cavity warm and cold.

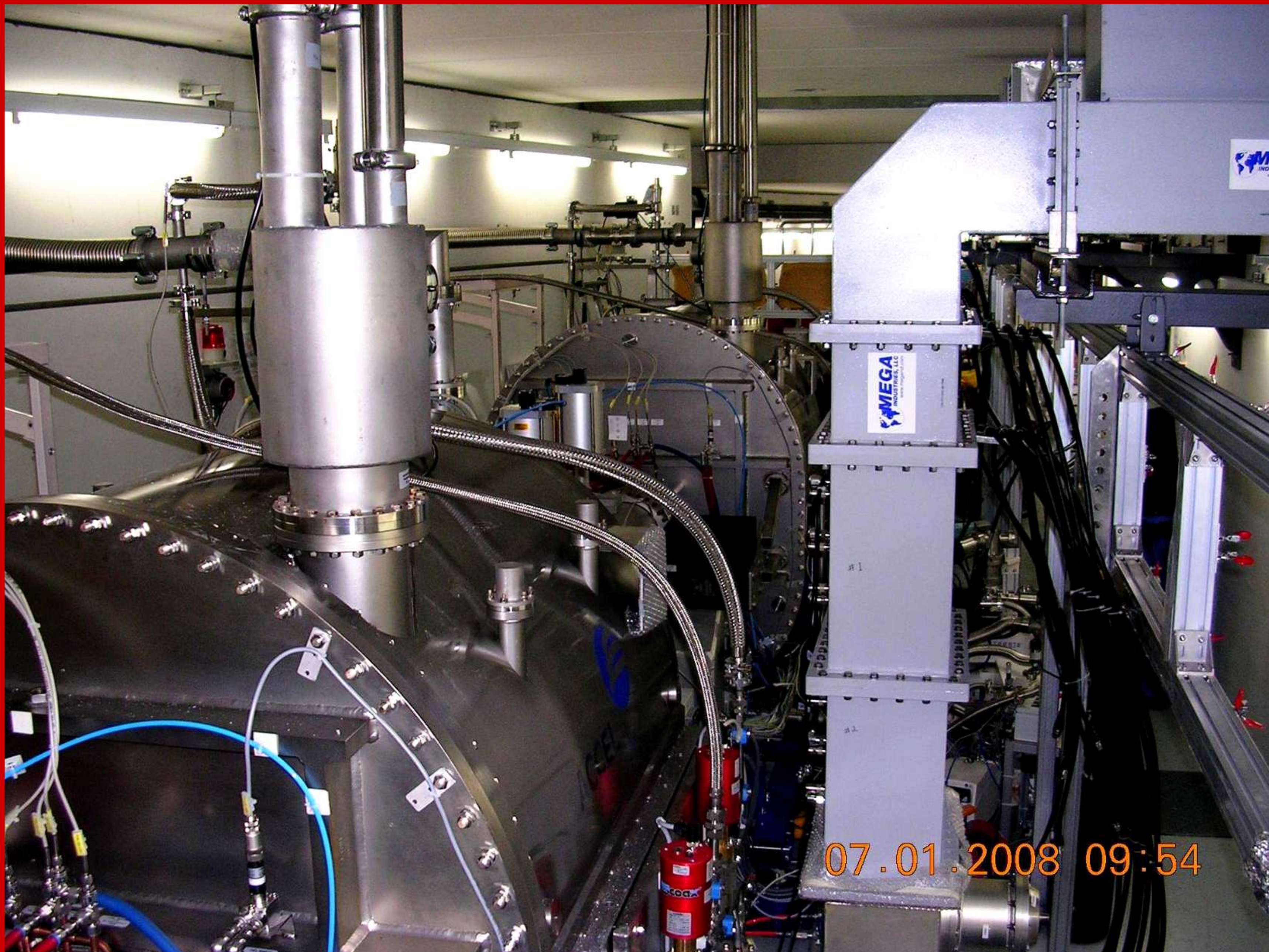
The control system and all PID loops are working properly.

*) as agreed upon



At July 1st, two sets super. cond. modules were installed to the final location in tunnel




MEGA
#1
#2
07.01.2008 09:54

From Sept. 17, 3 sets superconducting modules have been put into operation.

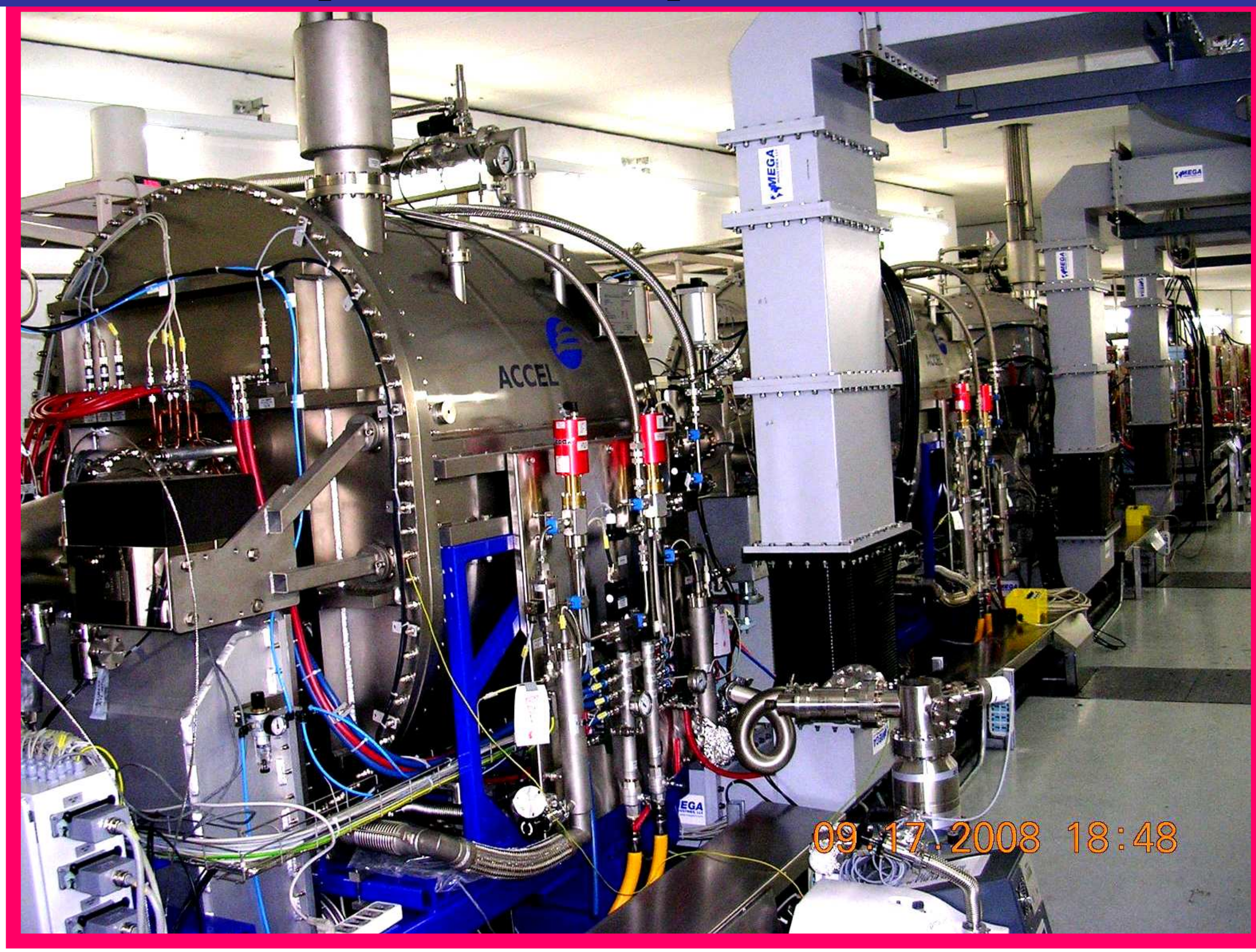
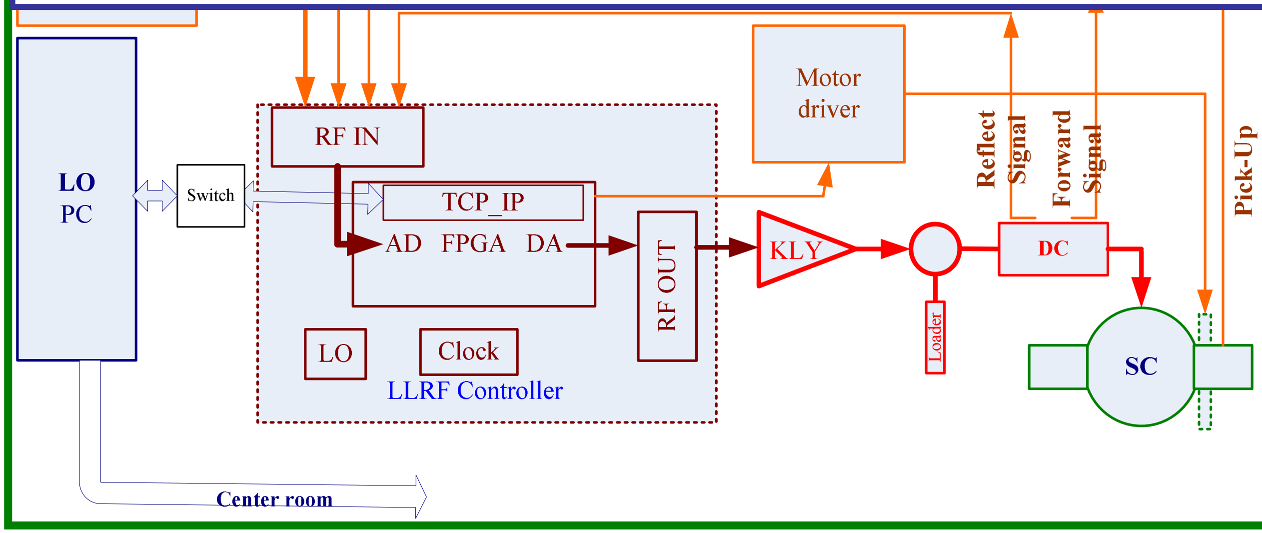
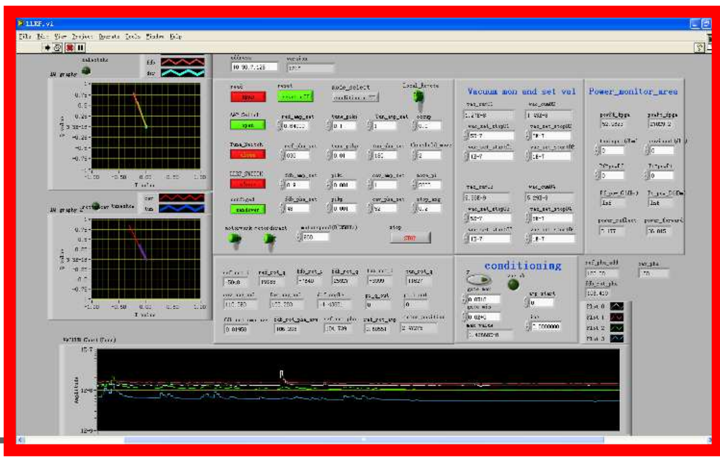


Diagram of SSRF_SR_LLRF

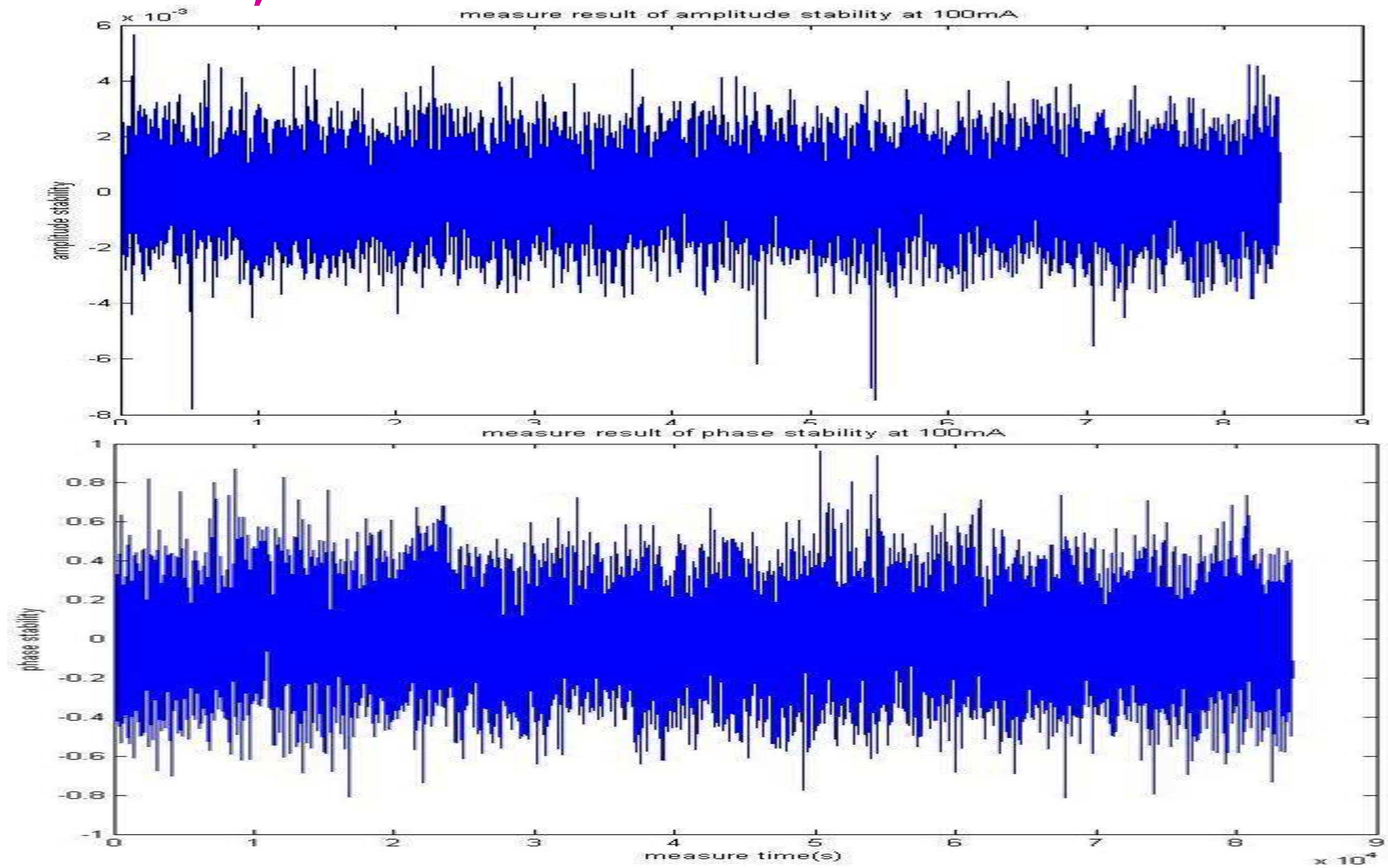
SINAP has successfully developed its own digitalized LLRF system. Its operation was stable and reliable both for backup system and superconducting modules.





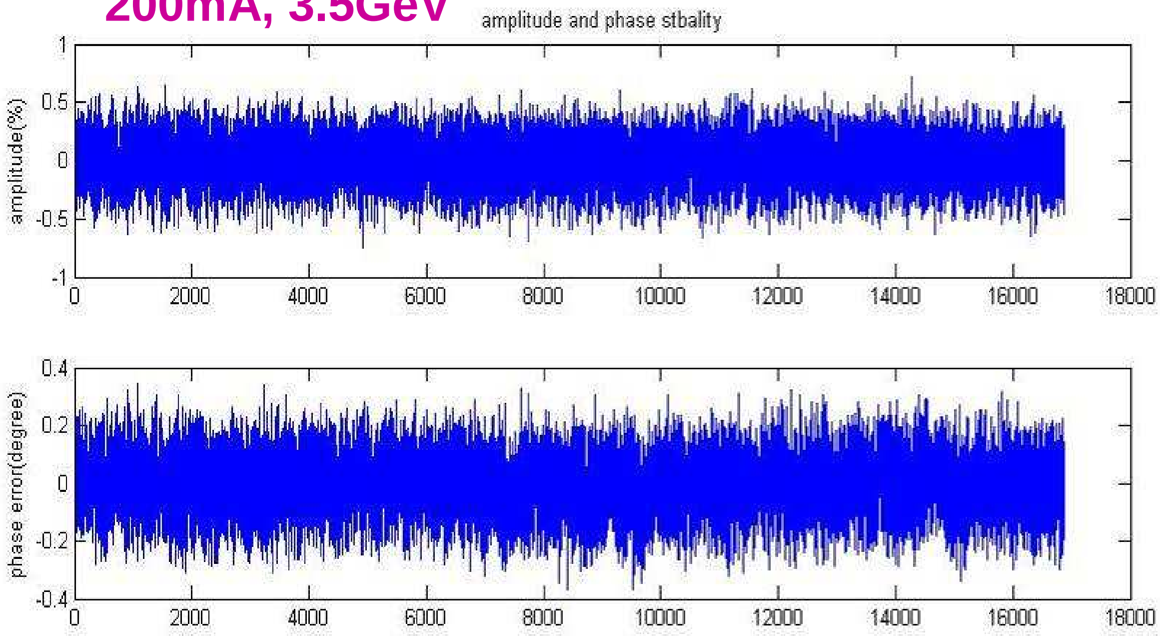
Stability of Amplitude and Phase with NC

100mA, 3GeV



Stability of Amplitude and Phase with SC

200mA, 3.5GeV



RF frequency	**499.654 MHz**
RF phase stability	**≤±1°**
RF amplitude stability	**≤ ±1%**

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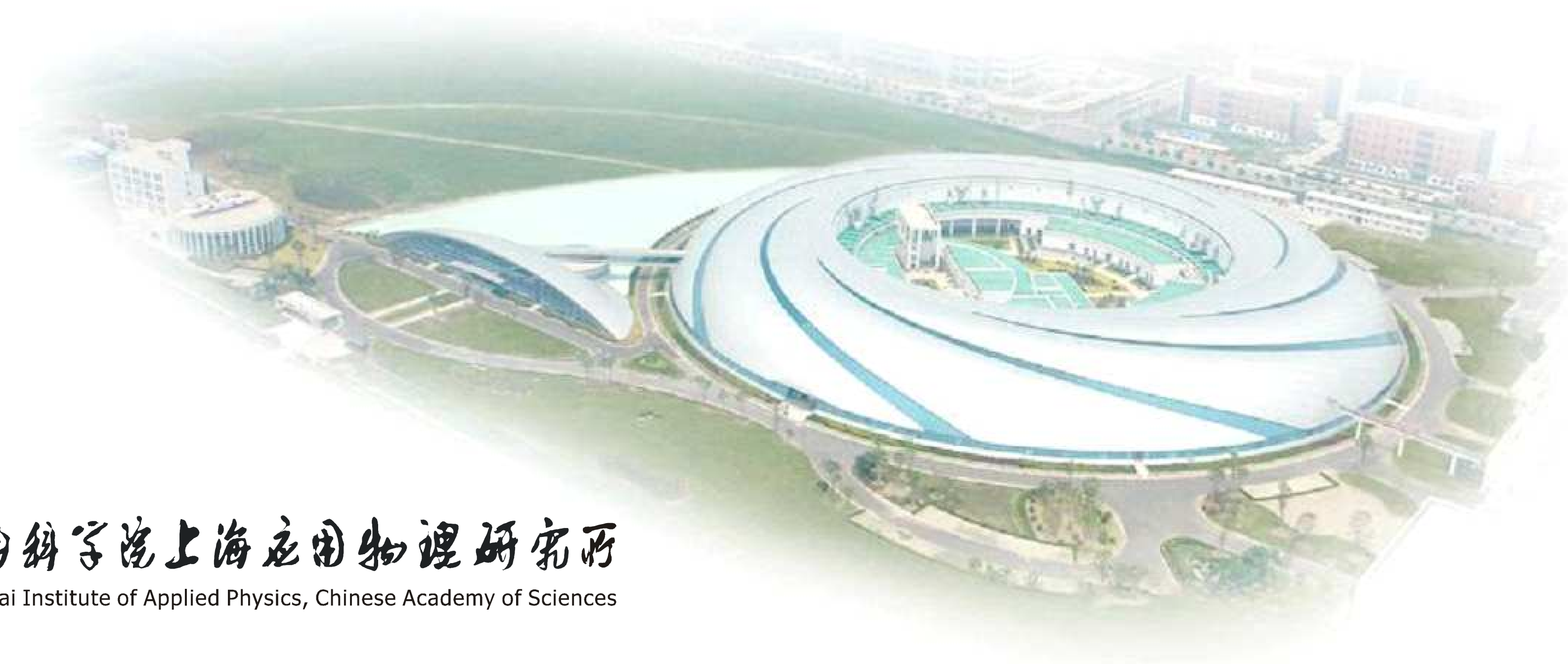
Cryogenic System

Courtesy of **Cryogenic Group**



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Contents of Cryo-plant

- *Specifications of Cryogenic System*
- *Flow Diagram of Cryogenic System*
- *Layout of Maim Equipments*
- *Commissioning and Test Results*
- *Milestones of Cryo-plant*

Specifications of Cryogenic System

1. Capacity of cryogenic plant

   Refrigeration mode: ⩾ 650 W/4.5K

   ⩾ 600W/4.5K

   (In normal operation condition)

2. Pressure fluctuation in LHe dewar: ⩽±3.0 mbar

3. Helium level fluctuation in the dewar: ⩽ 1%

4. Continuous operation time: ＞ 8000 hours

4K Cooling Requirements from SRF Cavities

Three Cavity Cryostats	Static load	3×30 W = 90 W
	Dynamic load	3×70 W = 210 W
	Cooling coupler	3×4 L/hr =12 L/hr
MCTL		17.5 W
MCTL (Air Liquid supply)		5 W
SCTL (Rigid section)		18 W
SCTL (Flexible section)		6 W
2000L dewar		20 W
Valve Box		3×10 W = 30 W
Total		397 W + 12 L/hr ≈ 440 W
Safety margin		650W / 440W ≈ 50%

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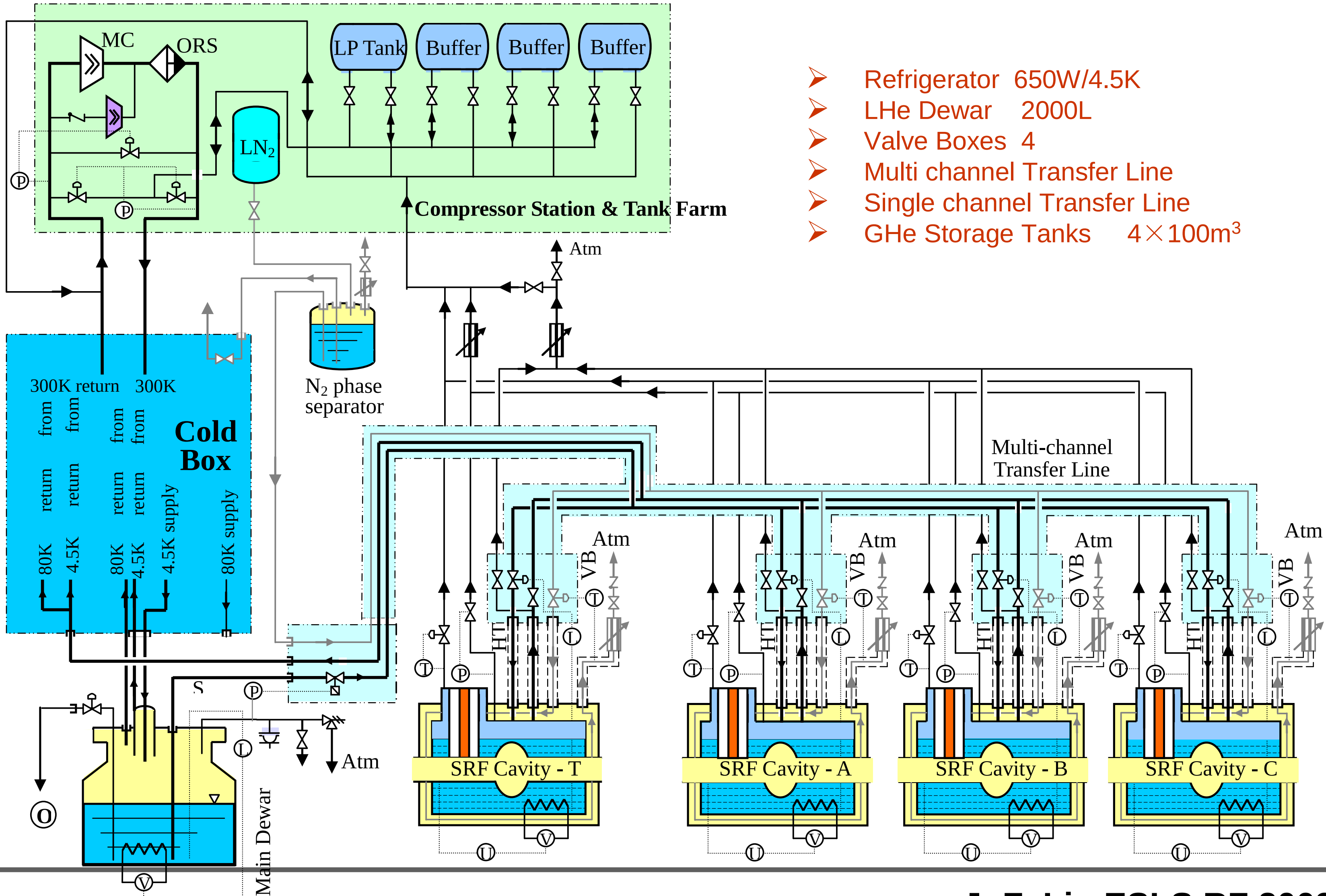
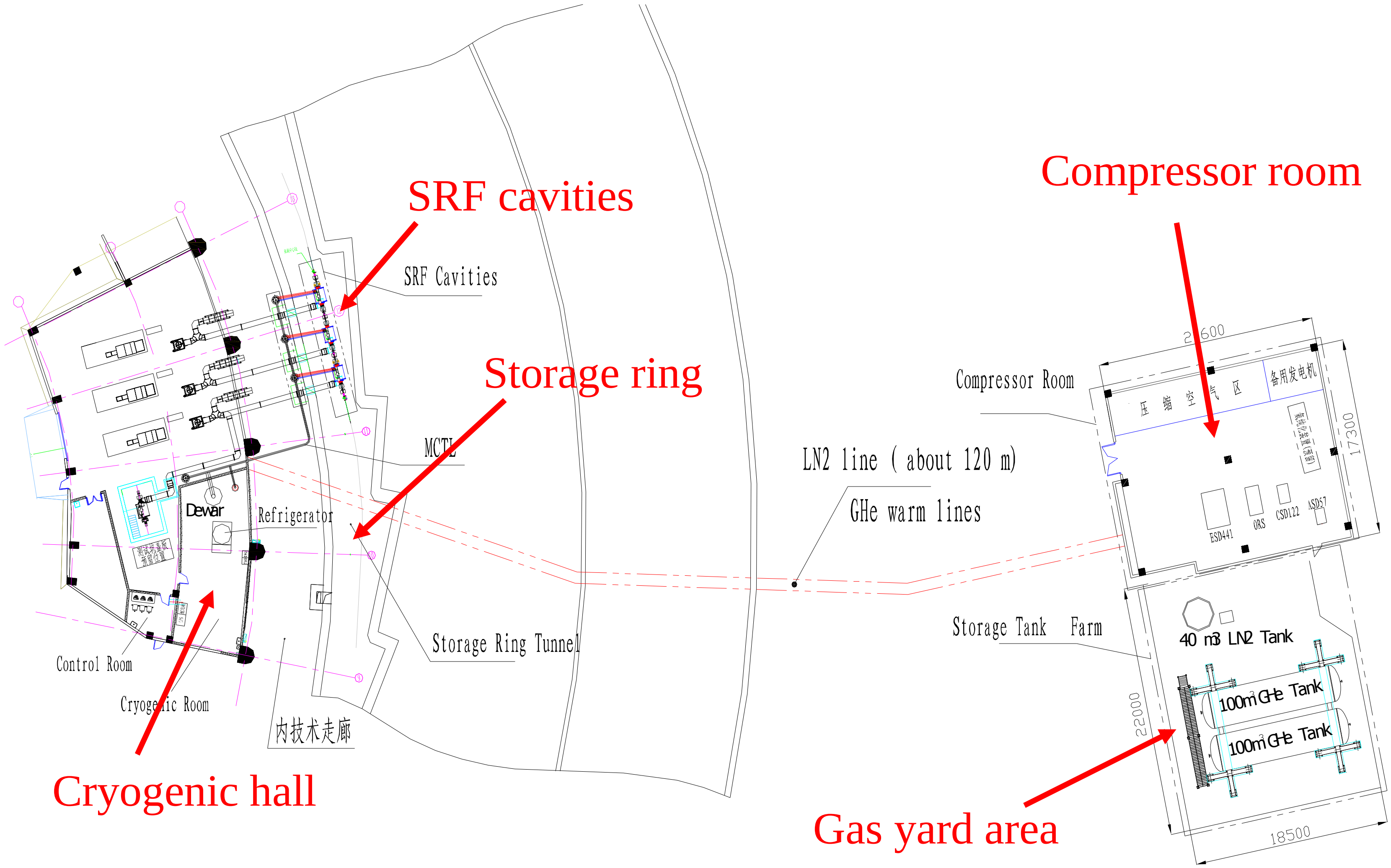
Courtesy of **Cryogenic Group**

Flow Diagram of Cryogenic System



- Refrigerator 650W/4.5K
- LHe Dewar 2000L
- Valve Boxes 4
- Multi channel Transfer Line
- Single channel Transfer Line
- GHe Storage Tanks 4$\times$100m^3

Layout of Main Equipments



Courtesy of Cryogenic Group

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The Cold Box of HELIAL2000 and the 2000L dewar

HELIAL refrigeration system is based on a 2-turbine-in-series Claude cycle which is a combination of a Brayton and Joule Thomson cooling cycle.

HELIAL is a full automatic refrigerator.

Main Parameters of HELIAL 2000

Cooling Capacity	**650 W @4.5 K**
HP	**13.43 bara**
LP	**1.2 bara**
He mass flow rate	**100 g/s**
LN_2 consumption	**5.6 g/s**

Note: With LN_2 Precooling

Main Parameters of 2000L LHe Dewar

Capacity	2000 L
Boil off rate	< 1 %
Electrical heater power	700 W
helium level fluctuation	±3 mbar

Compressors and Oil Removal System

Main Parameters of Compressors

Function	Main		Recovery
Model	ESD 441	CSD122	ASD 57
Mass fow rate (g/s)	80	21	9.4
Suction pressure (bara)	1.05	1.05	1.05
Discharge pressure (bara)	15	15	15
Electrical motor rating (kW)	265	75	30
Cooling water consumption (m^3/h)	25	4.3	
Cooling air consumption (m^3/h)	9500 m3/h	1400 m3/h	5300 m3/h
Other	VFD		

Gas Yard Area

Parameters of GHe Storage Tanks

Quantity	4
Capacity	100 m^3
Design pressure	1.8 MPa gauge
Working pressure	1.35 Mpa gauge
Working temperature	-10～70（℃）

Parameters of the LN_2 tank

Capacity	40 m^3
Design pressure	0.8 MPa gauge
Working pressure	0.08~0.4 MPa gauge
Working temperature	77～350 K
Boil off rate	< 0.5 %

Multi Channel Transfer Line

Courtesy of Cryogenic Group

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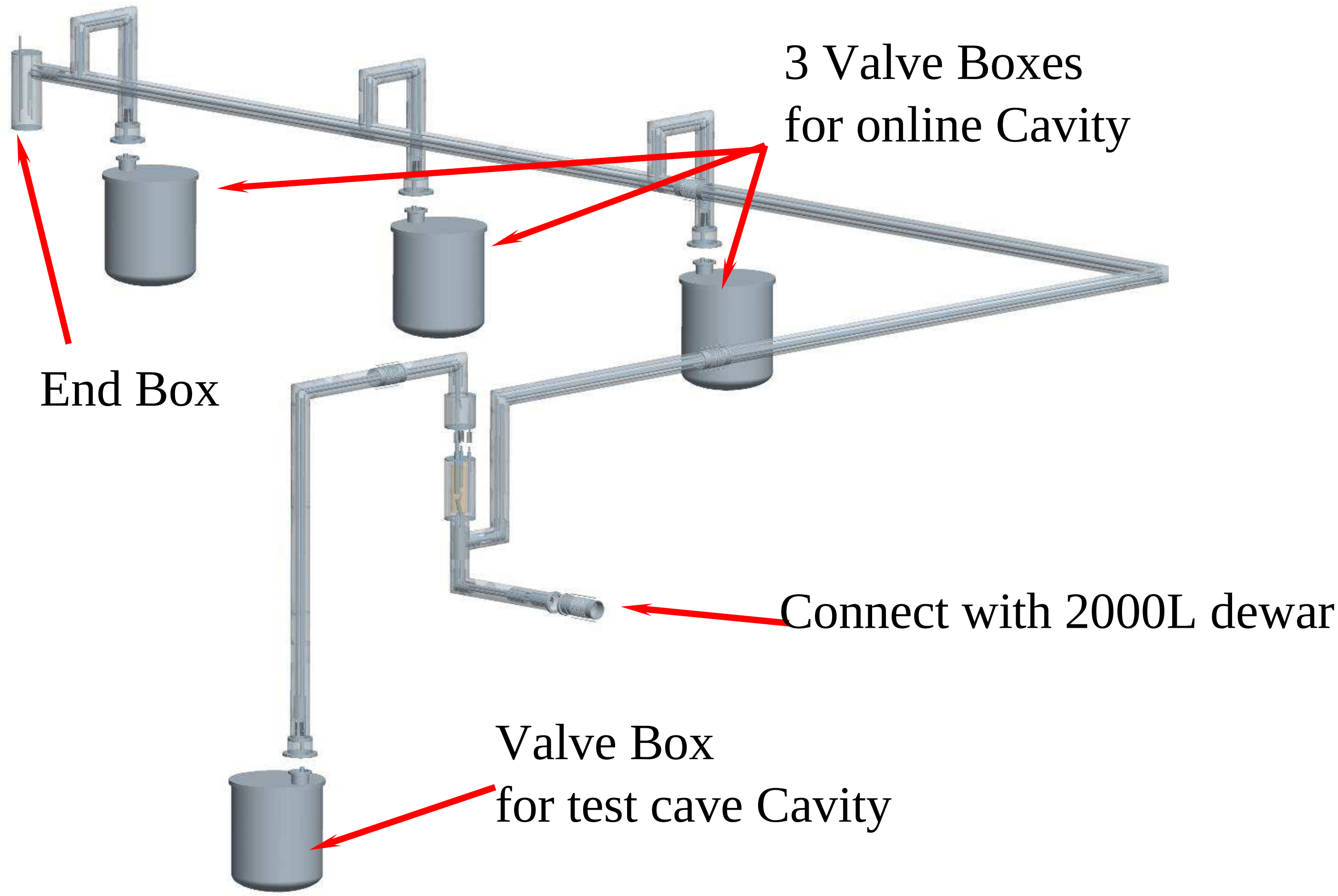
Bird view of Multi Channel Transfer Line



Commissioning and Test Results

Capacity measured at the main dewar

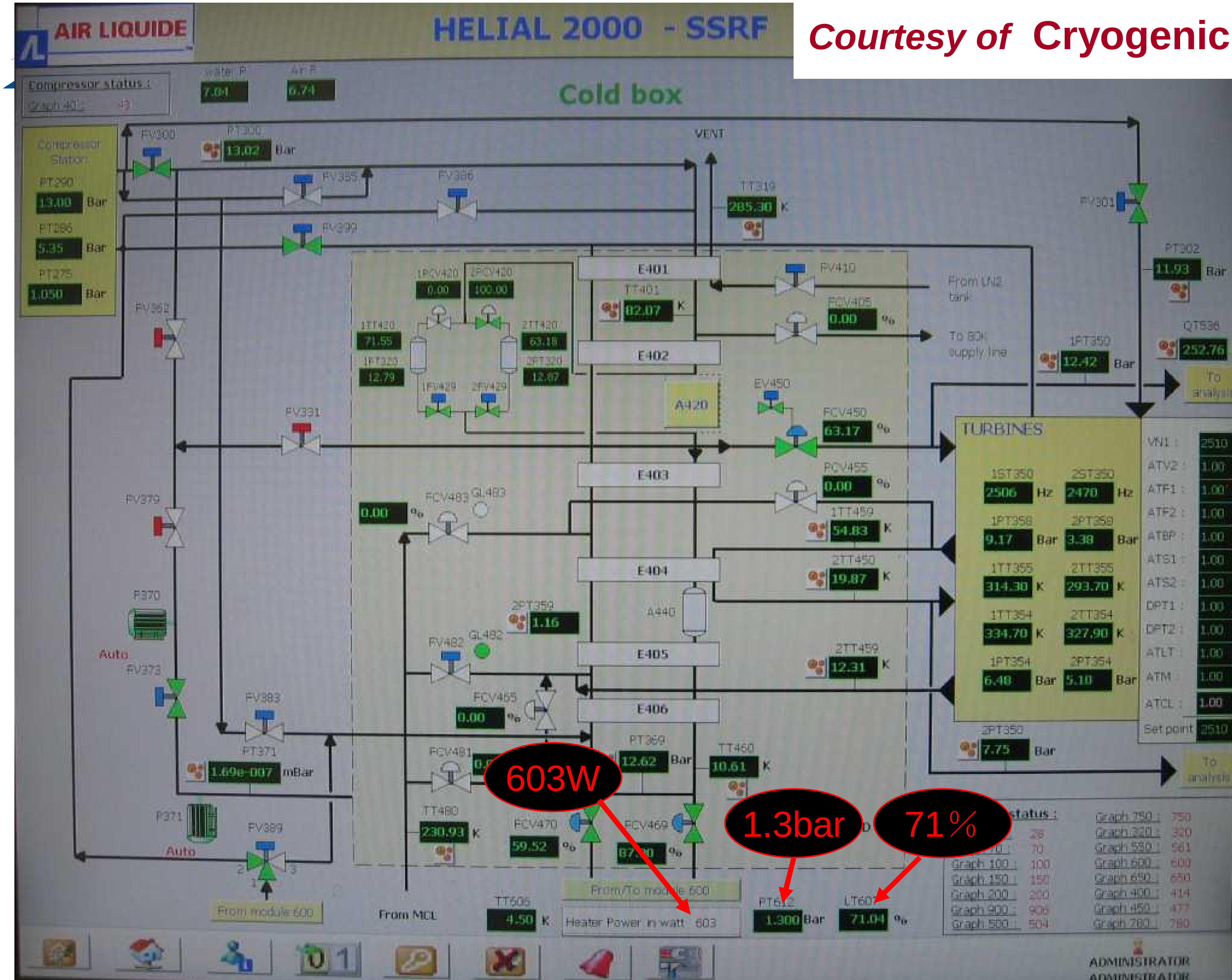
Operation condition	Heat Power In the dewar	Operation time	Equivalency Capacity*	Design Capacity
Maximum	635W	8 hours	657W	650W
Normal	603W	72 hours	625W	600W

***Equivalency capacity = Heat power + Heat leak of the dewar and transfer line.**

Stability measurement

	Design value	Test result
Suction line pressure fluctuation	±3 mbar	±0.3 mbar
Main dewar pressure fluctuation	±3 mbar	±0.2 mbar
He Level fluctuation	±1 %	±0.3 %

Courtesy of **Cryogenic Group**



Capacity test result

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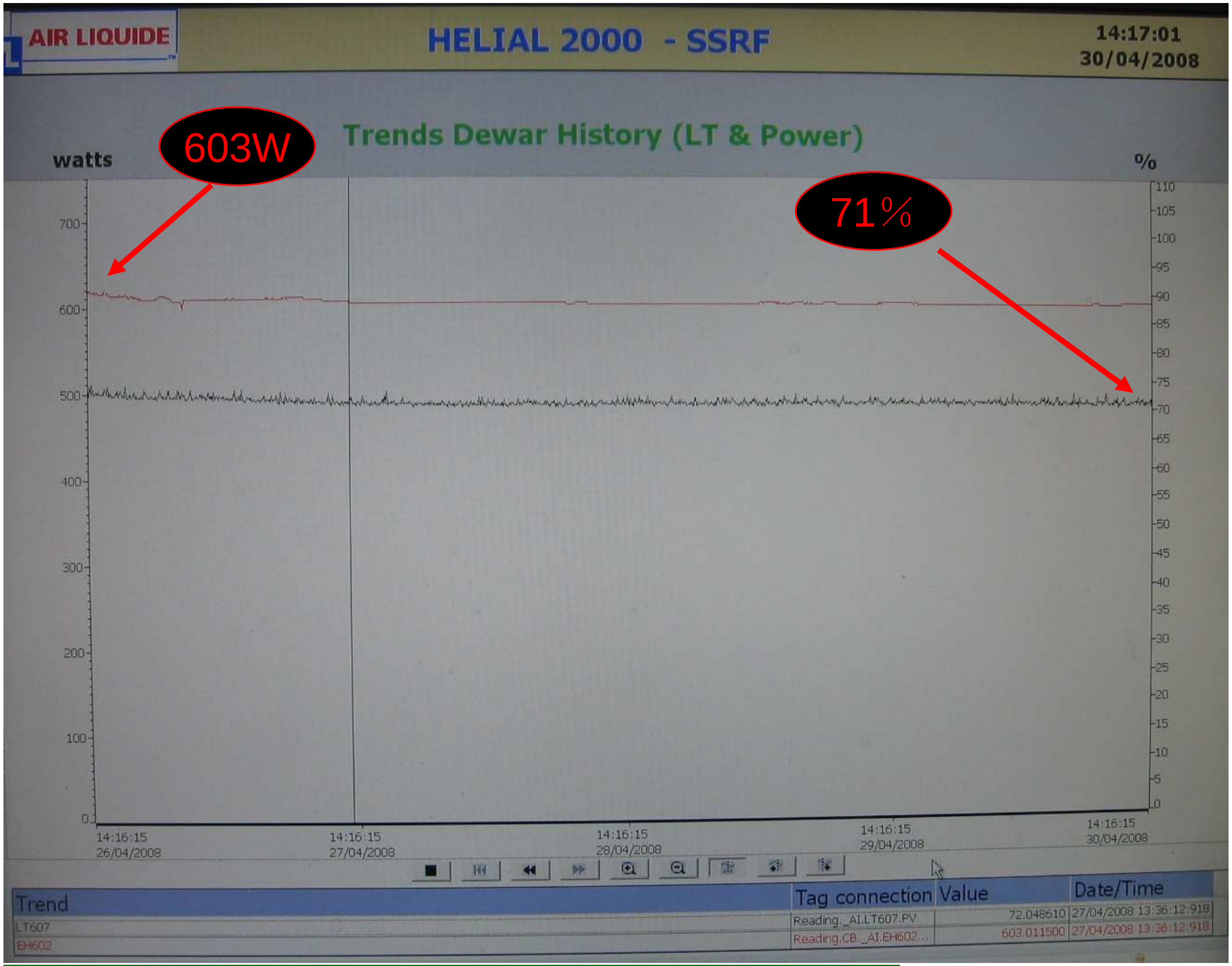
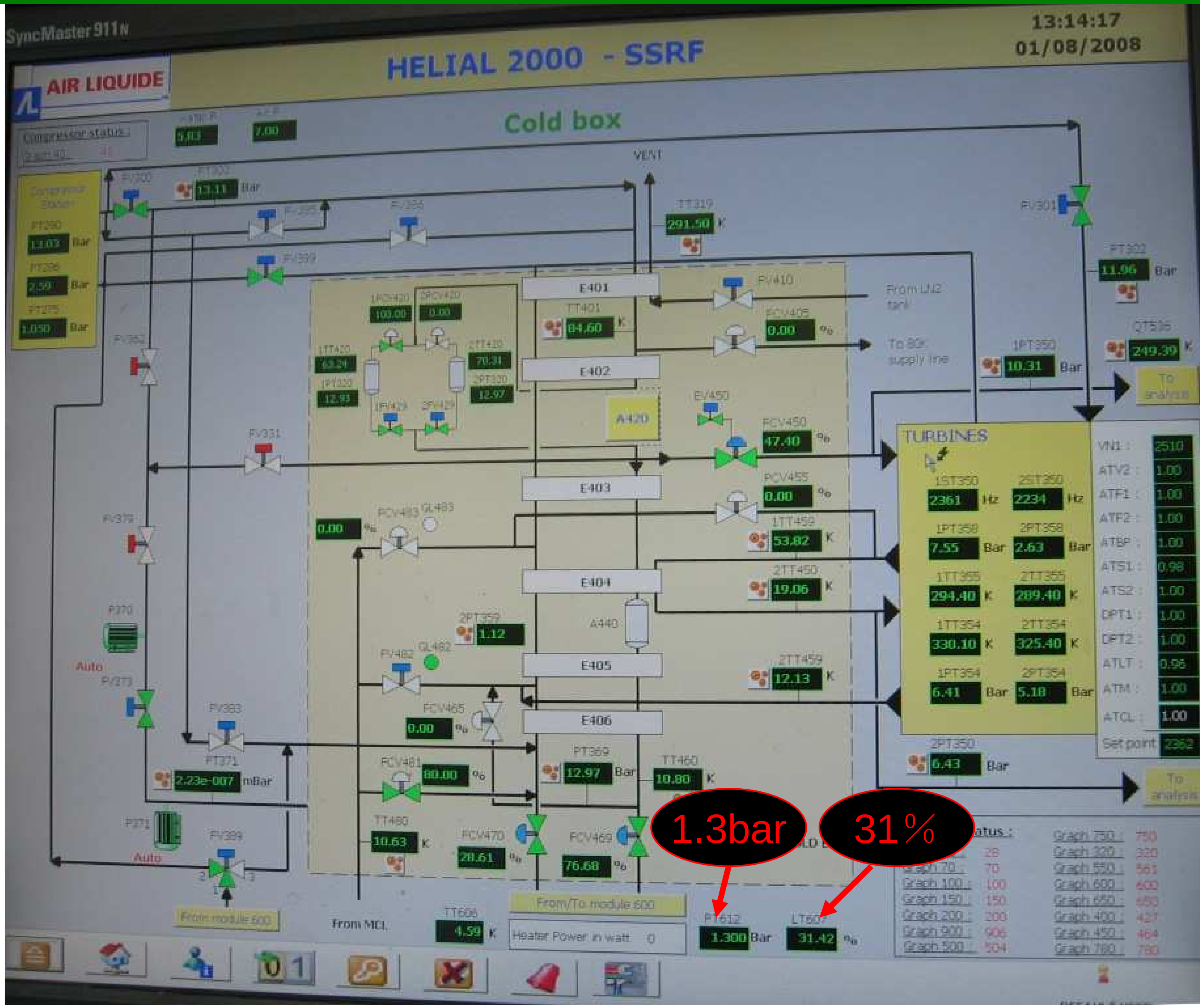


Capacity test result

Operation with three cavities (Aug. 1, 2008)



Courtesy of **Cryogenic Group**

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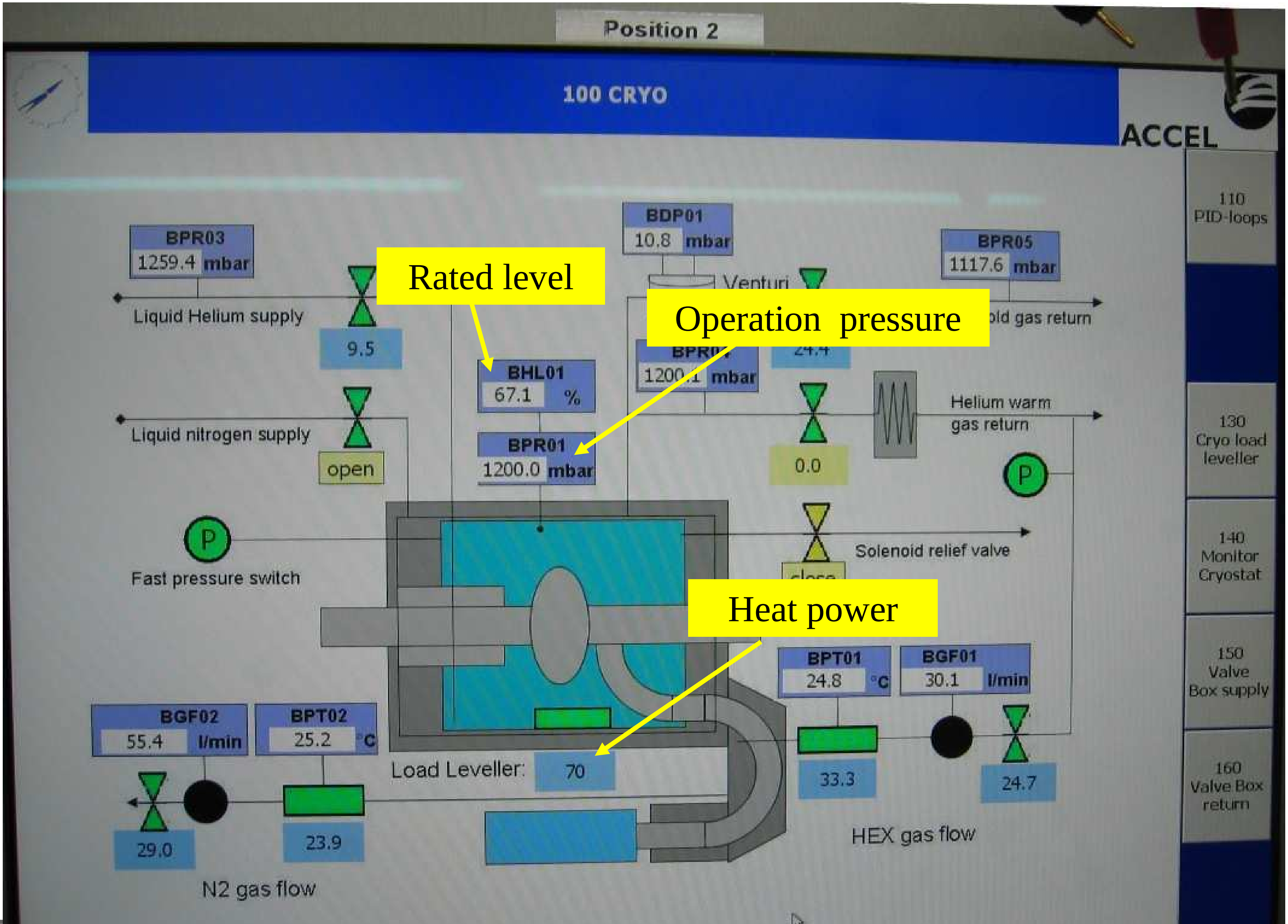


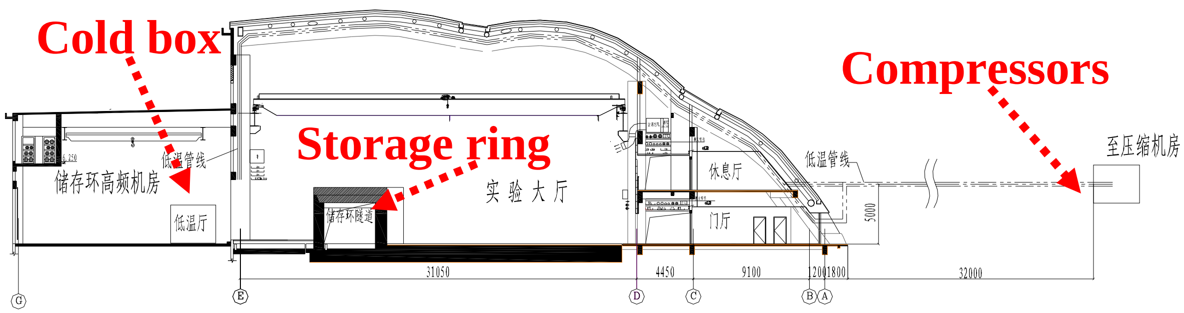
SRF cavity status (Aug. 1, 2008)

Milestones of Cryogenic System

A emergency backup rf system was launched up in the middle of October 2007 by **RF Group**

- ***Nov. 2005*** **Contract the refrigerator to Air Liquide**
- ***Feb. 2007*** **Installation of the refrigerator**
- ***Nov.*** **Installation of the MCTL**
- ***Apr. 2008*** **Acceptance of the refrigerator**
- ***Jun.*** **Cooling down the first SRF cavity**
- ***Aug.*** **Operation with two cavities**
- ***Sep.*** **Operation with three cavities**

Apr. 2007



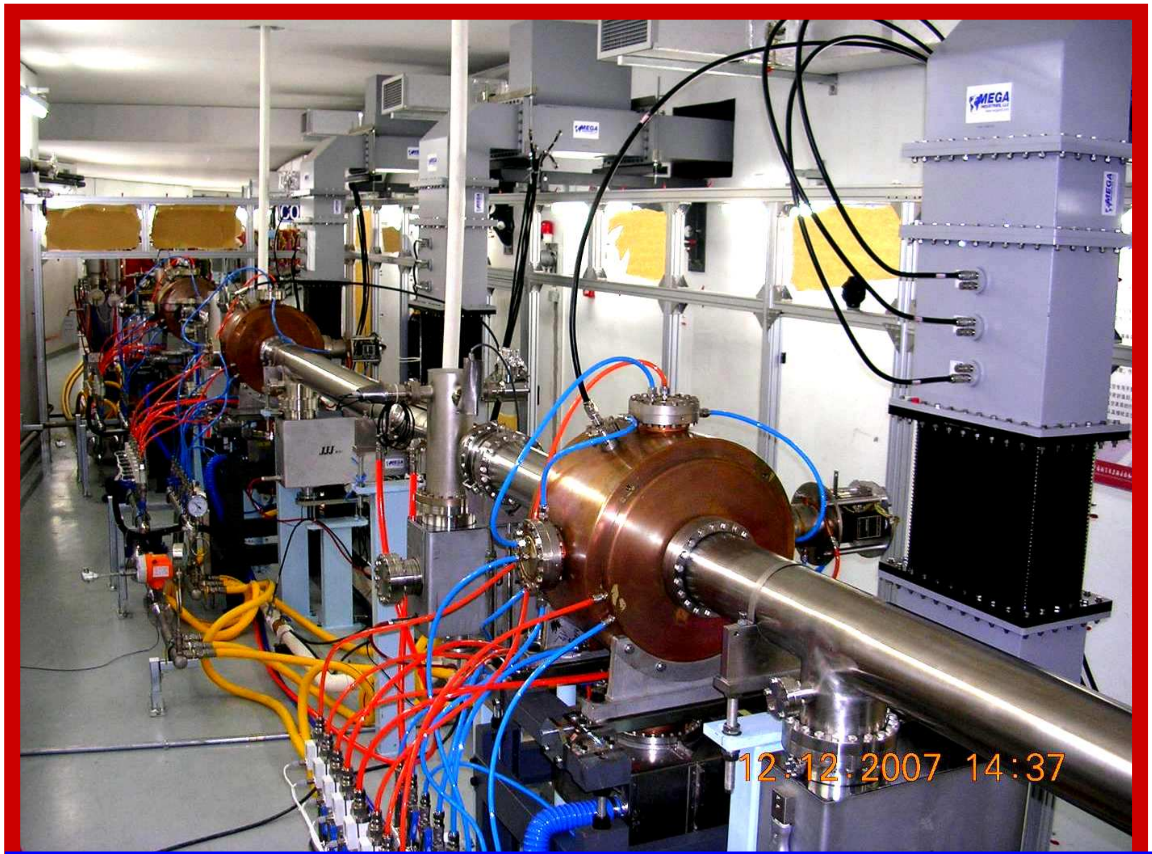
GHe Transfer Line
(Installed in the No2. Underpass)

NC backup

A Backup RF When a Delay of Cryo happened

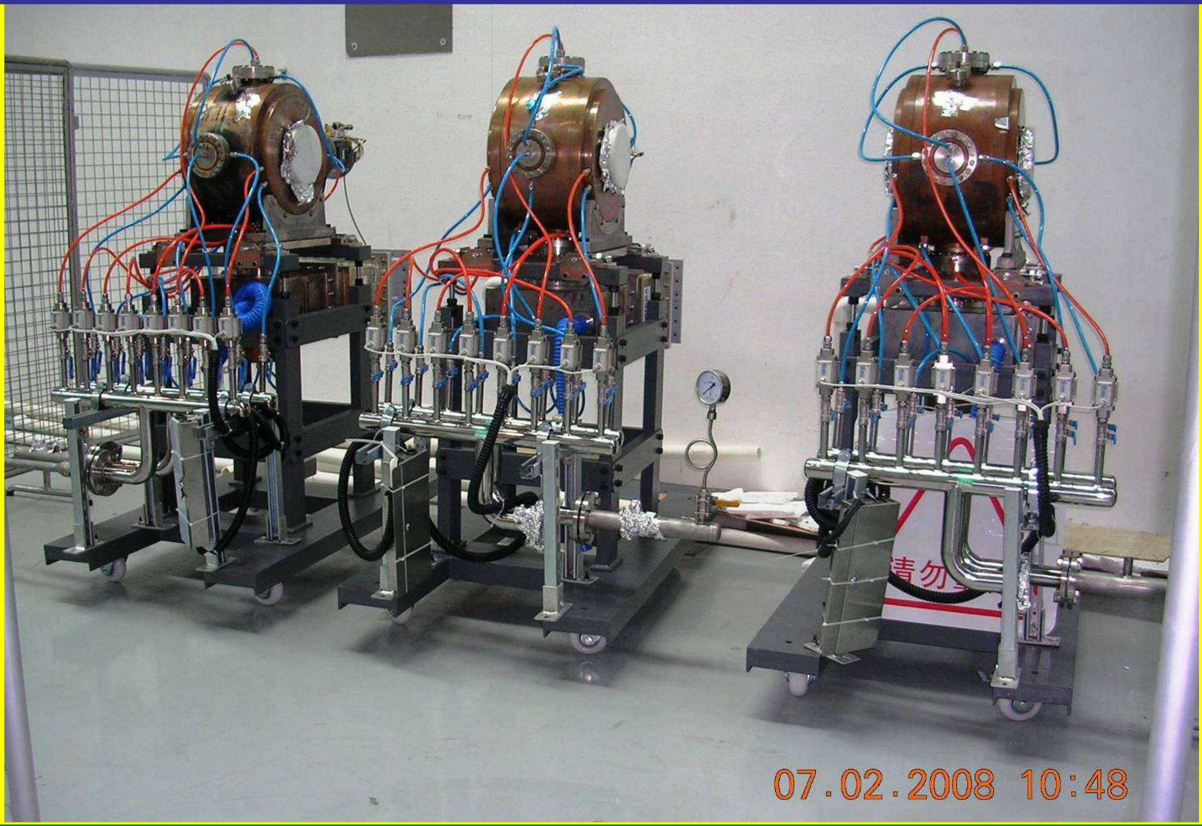
4 cavities Rent from PF of KEK

A installed Supercon. Cavity Was Removed from the Tunnel in Nov. 2007



At Dec. 12, 2007, 3 sets normal cavaties

June 20, 2008, NC cavities operated for 6 months was removed and replaced with two SC modules



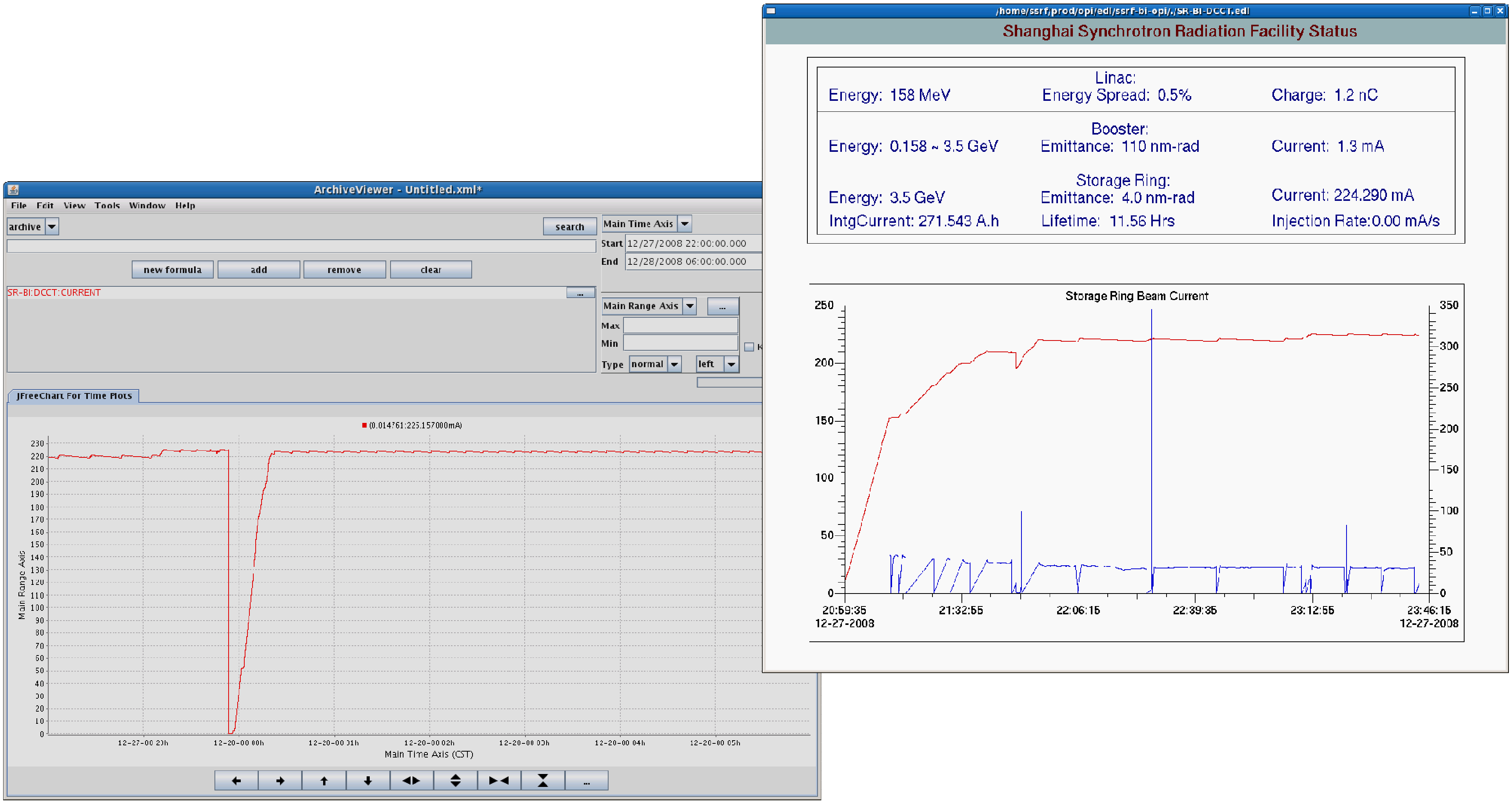
With 3 sets Normal Cavities, we successfully got：

- ✓ **3.0GeV Commissioning，**
- ✓ **100mA@3.0GeV、**
- ✓ **200mA@2.0GeV、**
- ✓ **300mA@1.5GeV**

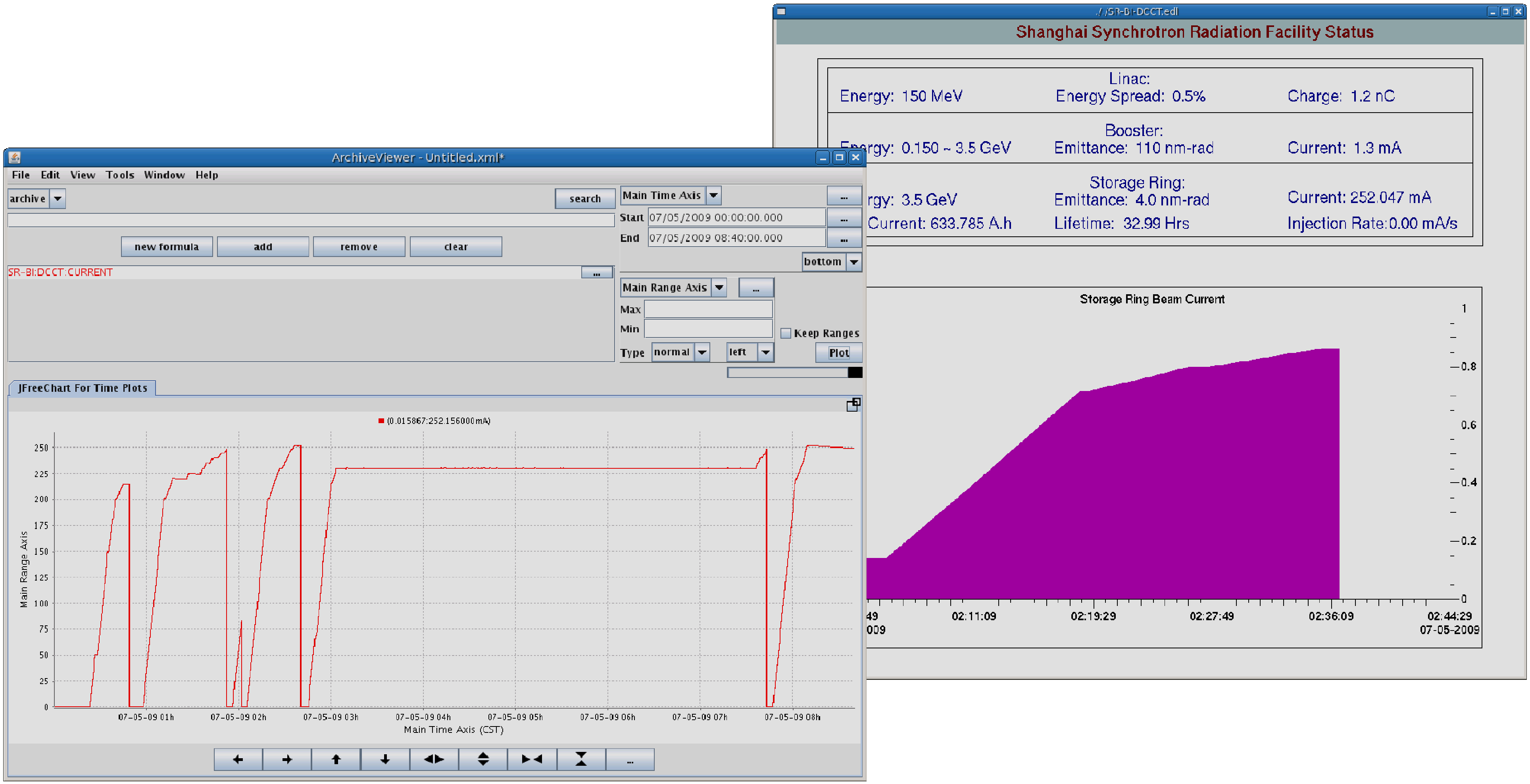
Contents

- Overview of Shanghai Light Source (SSRF)
- Booster's RF System
- Storage Ring's SRF System
- Cryogenic System
- Operation Status of SRF System in SSRF

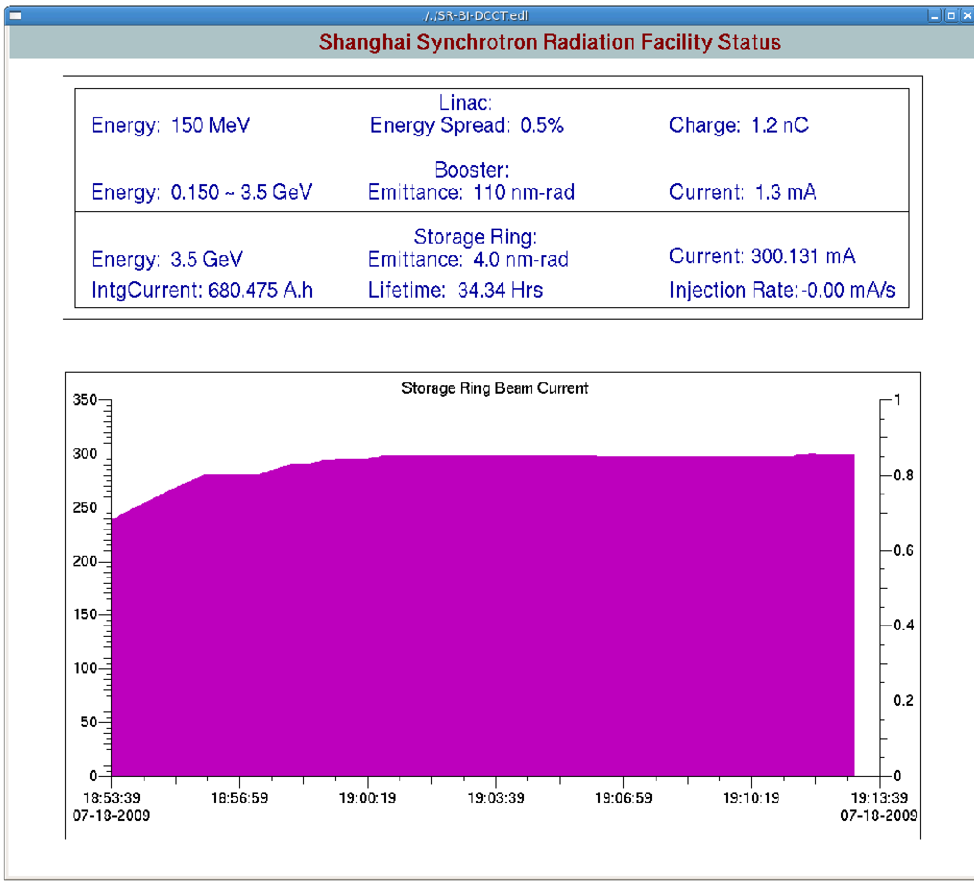
27/12/2008 Beam Current 224mA

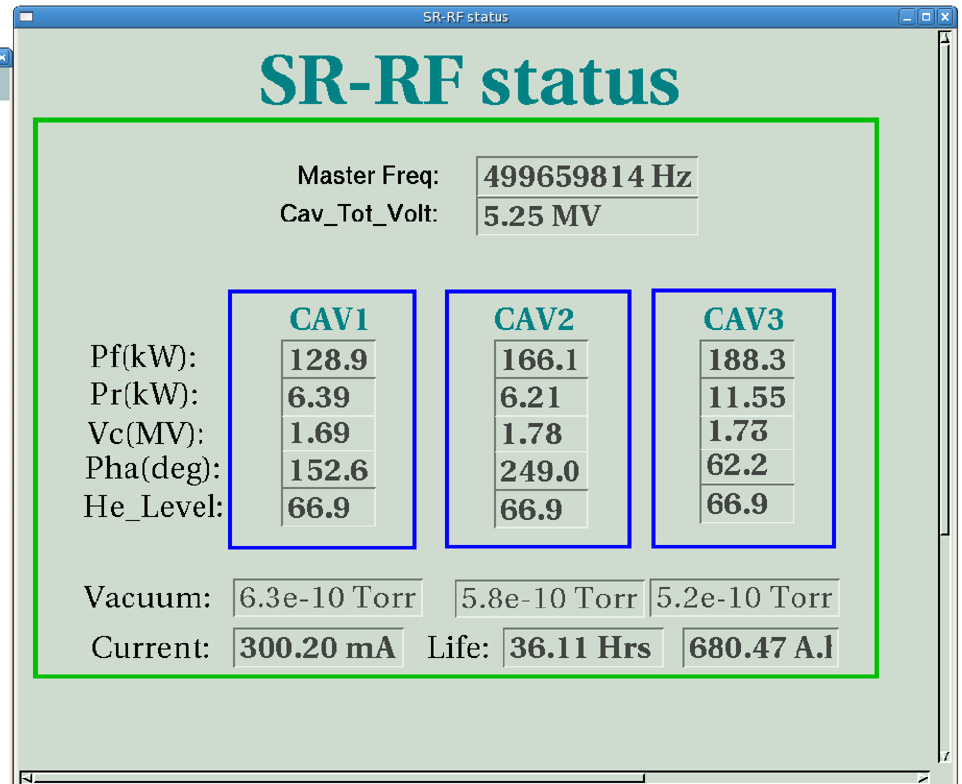


5/7/2009 Beam Current 252 mA

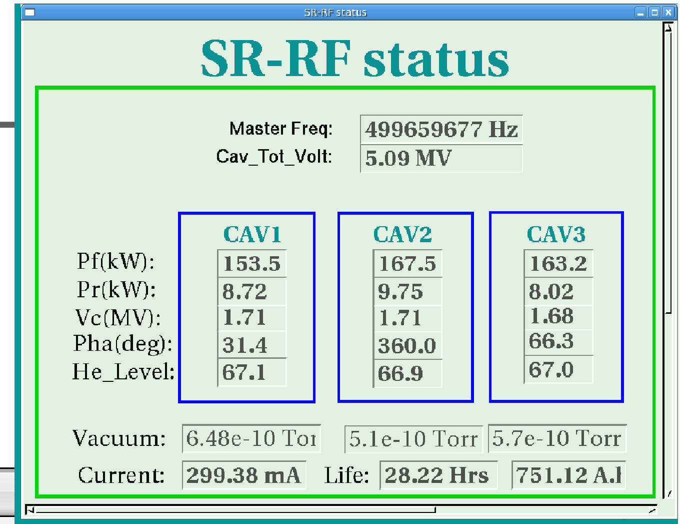


18/7/2009 Beam Current 300mA
--the Maximum Designed Beam Current--

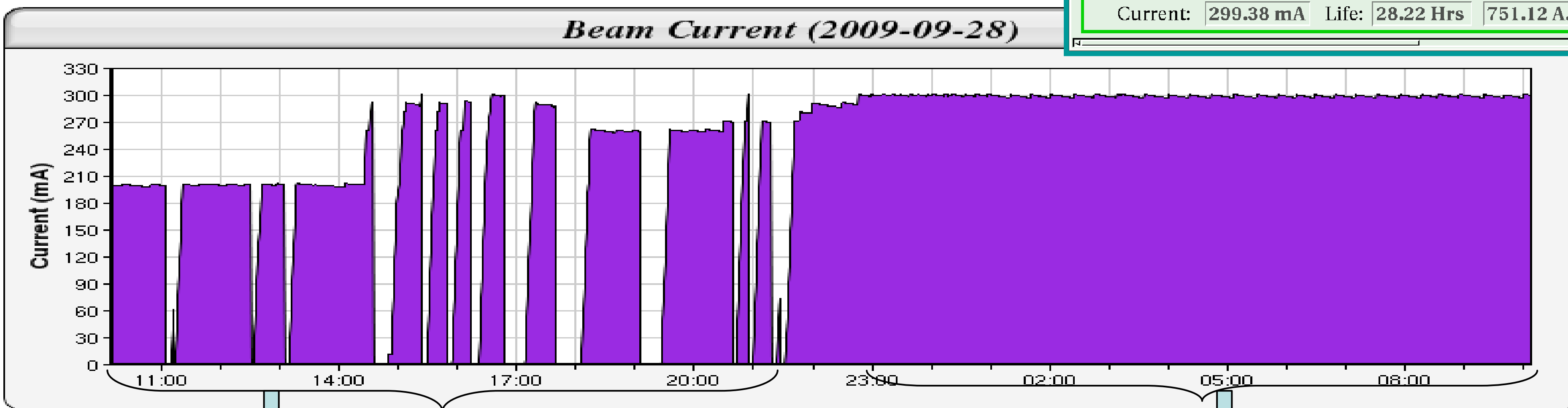




中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences



28/9/2009, 24 hours beam conditioning, and operated at beam current 300mA for 12 hours



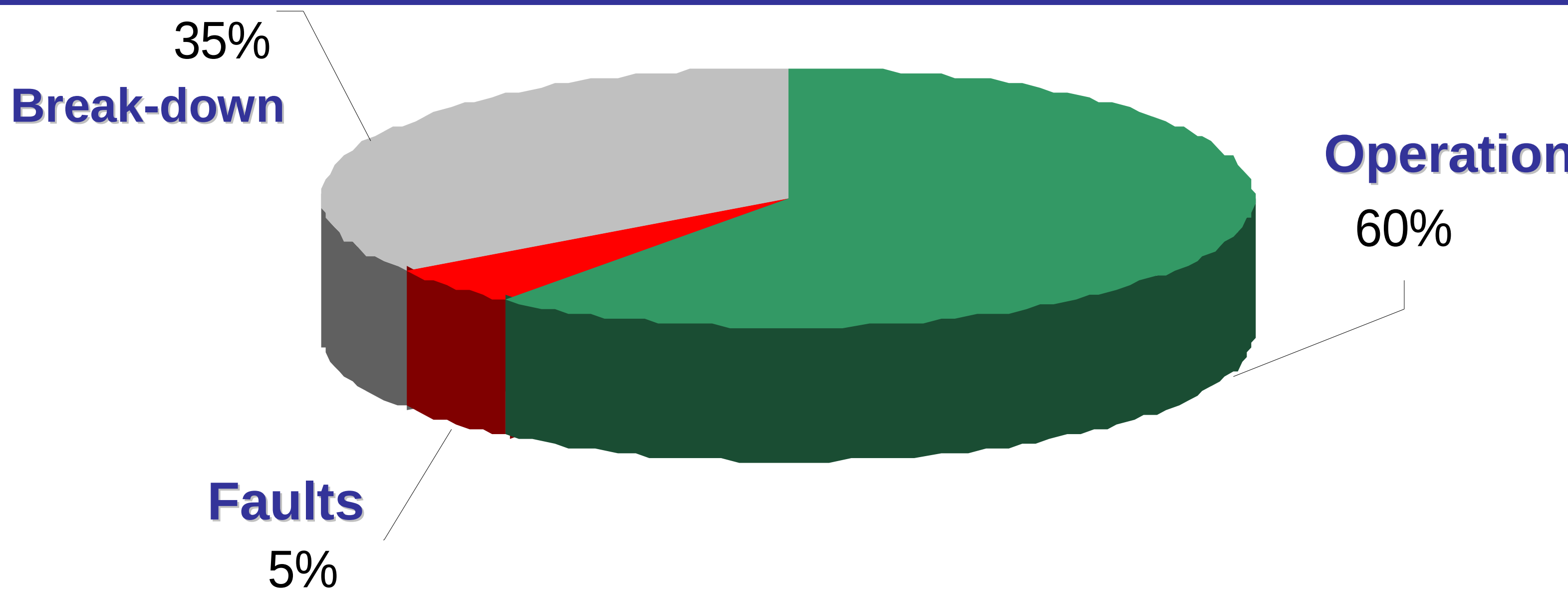
Trip during beam conditioning

- Vacuum interlock on beam tube
- Quench caused by fluctuation of LLRF
- Machine protection signal
- Temperature interlock on beam tube FBT and RBT

300mA top-up

Operated for 12 hrs tripped by vacuum near RF window of module #1

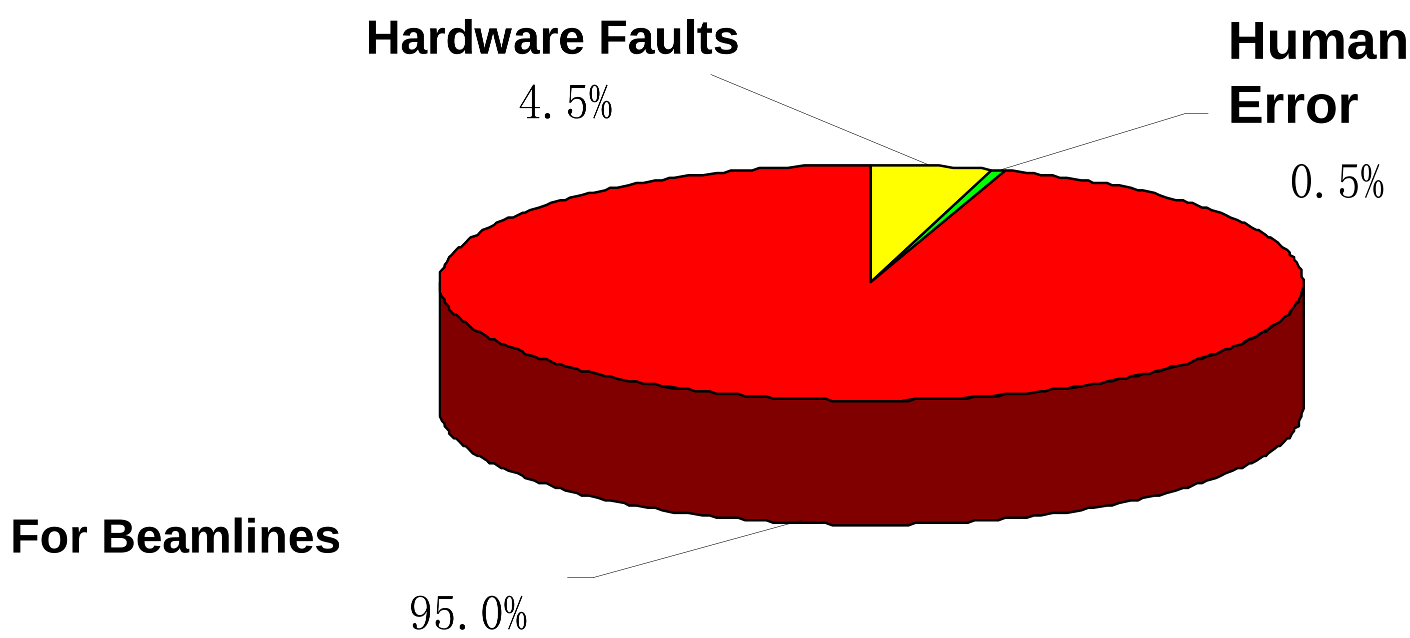
The ratio of break-down time 2008



- Scheduled Operation Time 5300 hours
- Break-down: 437.8 hours
- Machine shutdown : 3050.5 hours
- For Beamlins commissioning : 1152 hours

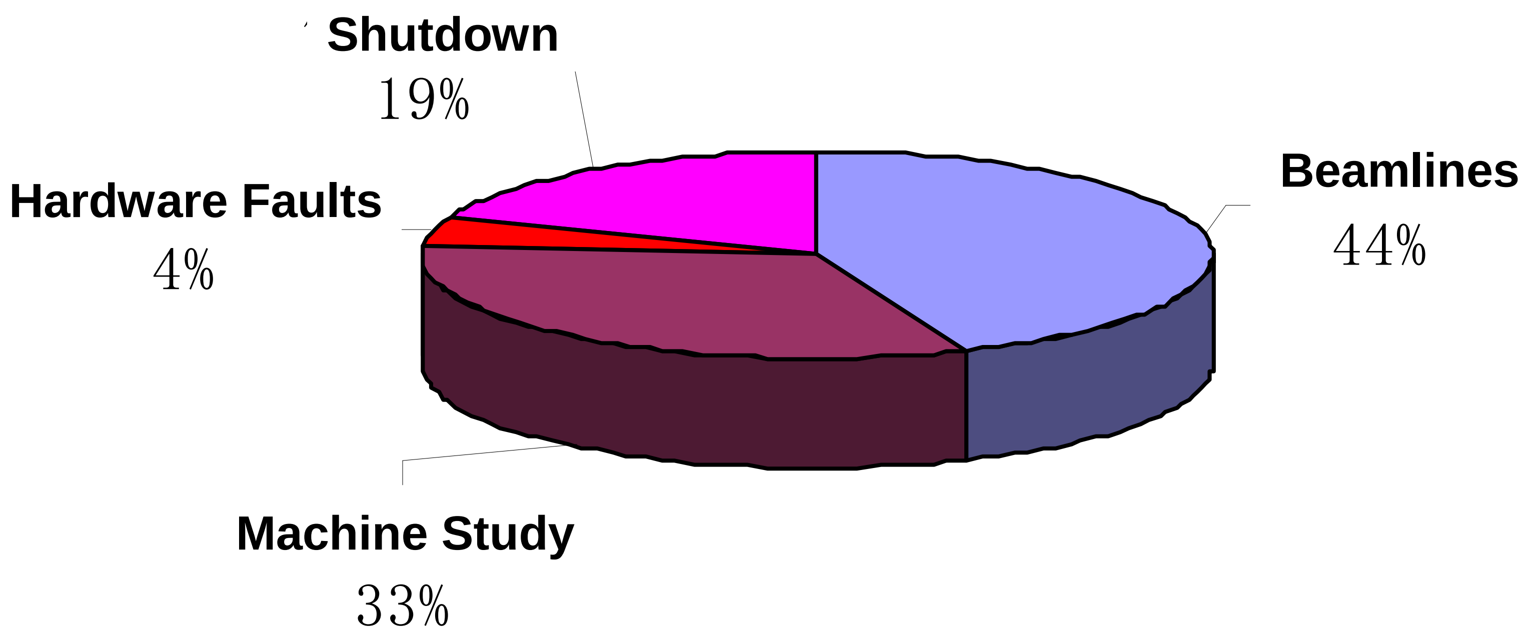
The ratio of break-down time during the beamlines commissioning 2008

- May 7~Beamlines commissioning @3.0GeV， 340.7 hours
- August 19~ 7~Beamlines commissioning @3.5GeV, 811.3 hours



The Ratio of Break-down Time January ~ April 2009

- For Beamines Commissioning: 1263 hours
- Machine Study: 948.6 hours, Faults: 5.5%
- Hardware Faults: 121.75 hours
- Machine Shutdown: 546.7 hours
- Availabilty 96%

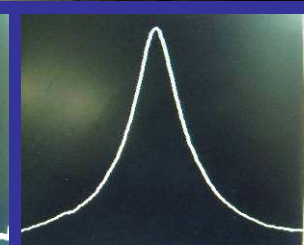


PB#1: Trips by Vacuum near by RF Window

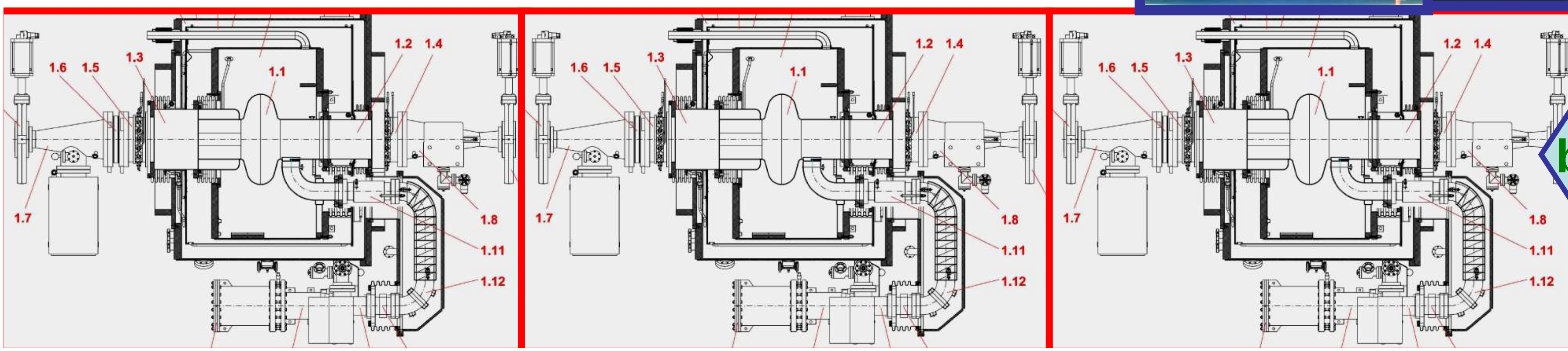
RF trips other than vacuum (3 cavities)			
	Transmitters' fault	LLRF down	unknown
6 weeks	4	1	2

?

Date		C#1			C#2	C#3
		C#1 Total	MS time	SR time	Vacuum	Vacuum
1st week	March 3-14	8	4	4	0	0
2nd week	March 15-21	3	2	1	0	0
3rd week	March 22-28	2	1	1	0	0
4th week	March 29-April 4	7	6	1	0	0
5th week	April 5-11	4	3	1	0	0
6th week	April 12-18	2	1	1	0	0

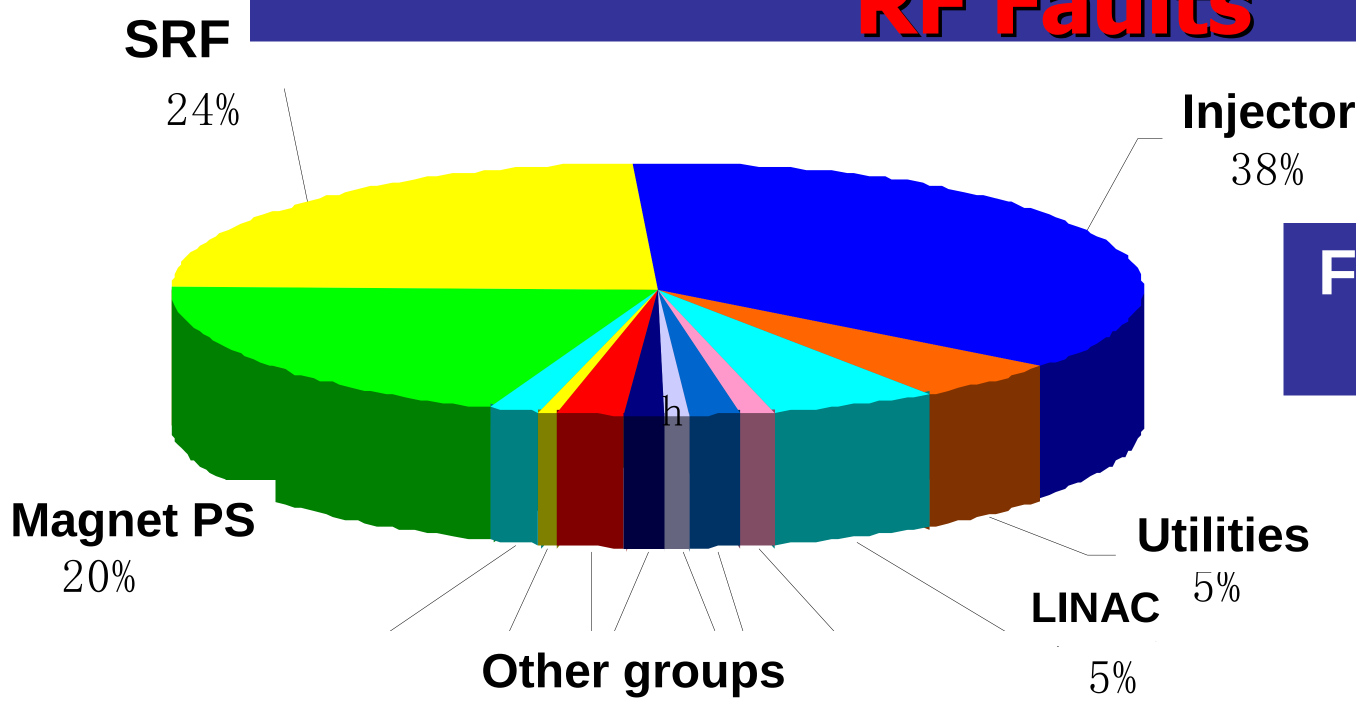


1, Cavity #2 & #3 from July, C#1 from Sept. 20
2, Once standby at 4.5 K because of its tuner
3, Parameters not optimized
4, Aging not enough (Window)
5, Bad lucky of its location just after the bending magnet



beam

May—July 20, 2009, Ratio & Lists of RF Faults

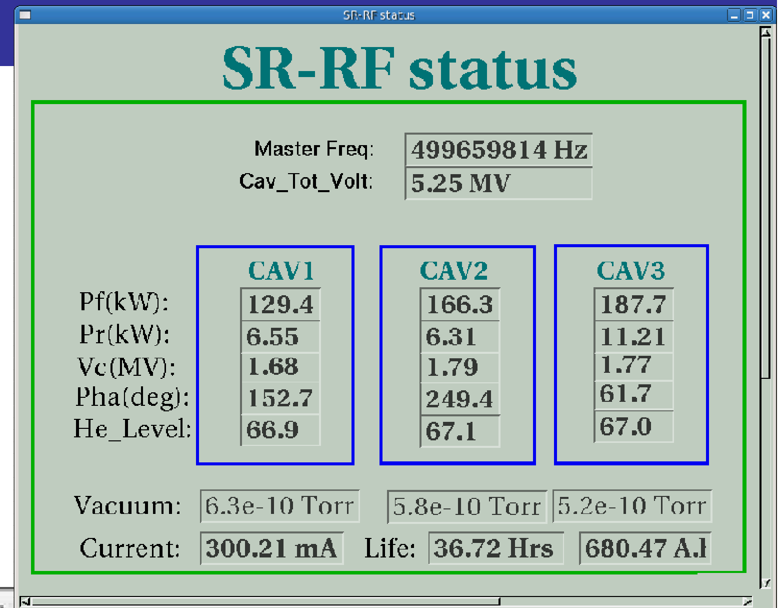


From May 6th, 2009 Open to USERS

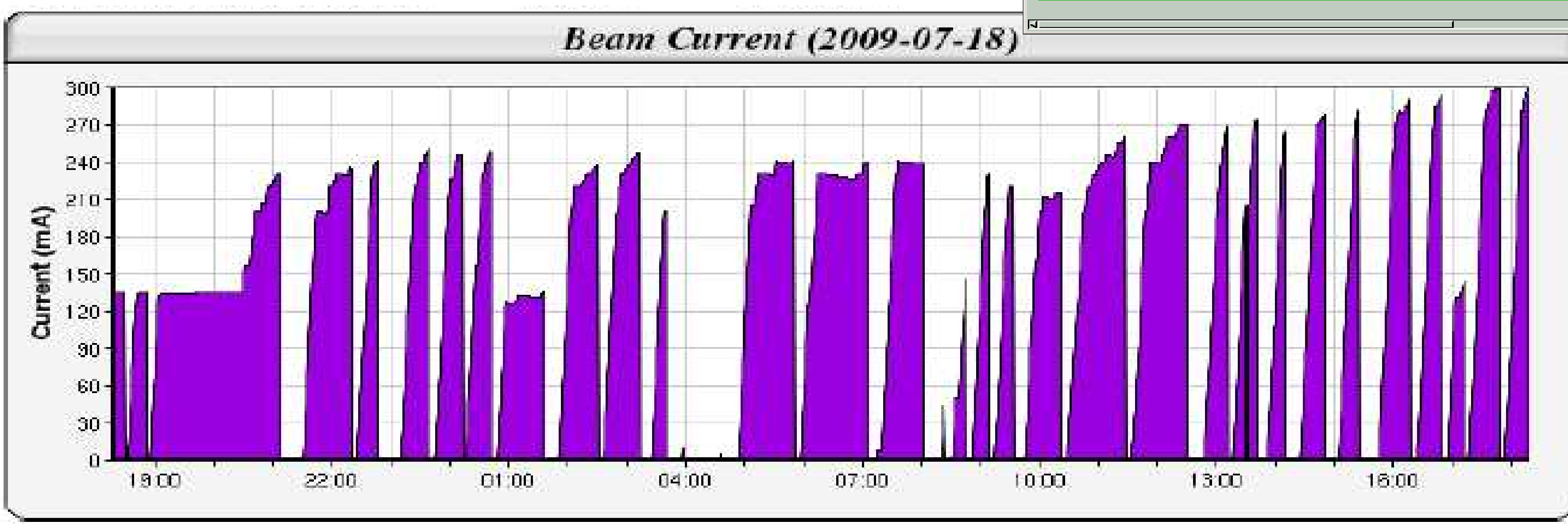
- Vacuum of RF window nearby of cavity #1
- Controller of insulation vacuum
- Water flowmeter of RF window SRF
- Water flowing switch of #1 transmitter
- Air-filter of #2 transmitter
- Cooling water cond. of circulator
- Fluctuation of cavity voltage when heavy beam loading
- Hardware of LLRF controller

8 times over 11 weeks due to SRF except for RF conditioning

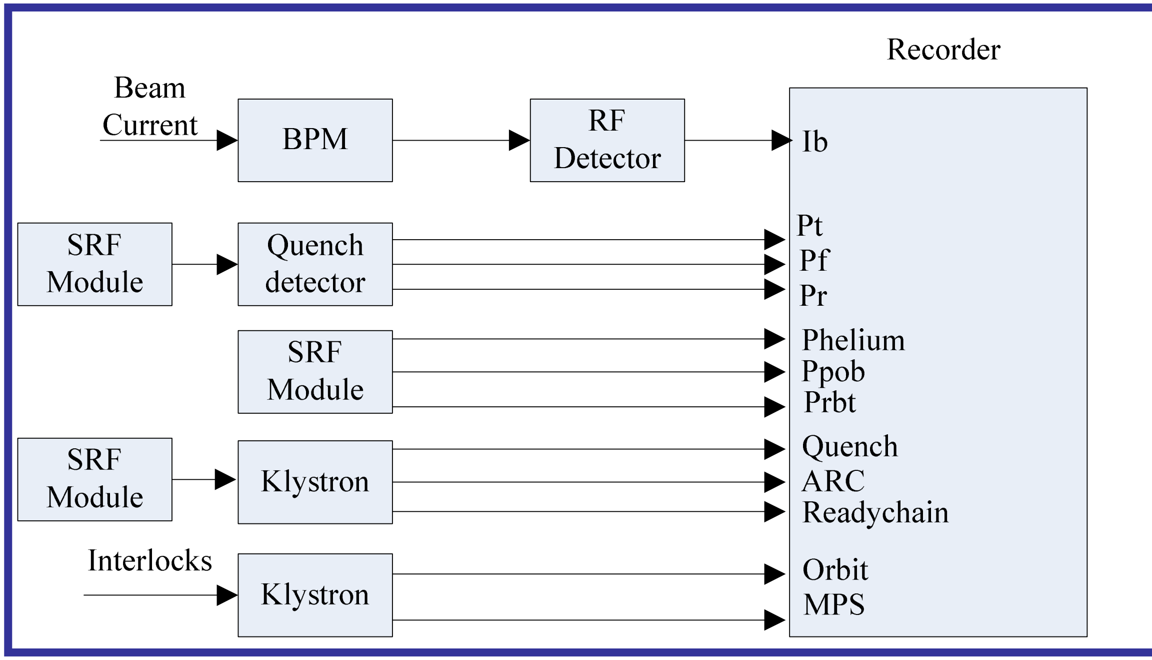
May ~July 2009, SRF Conditioning 235 hours

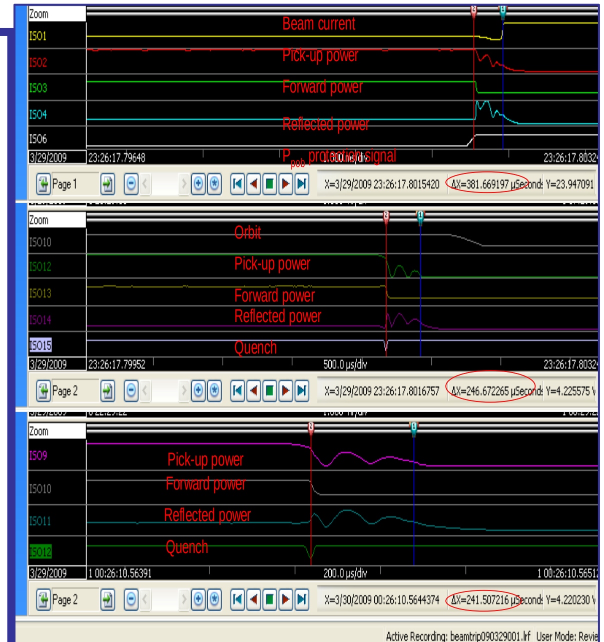


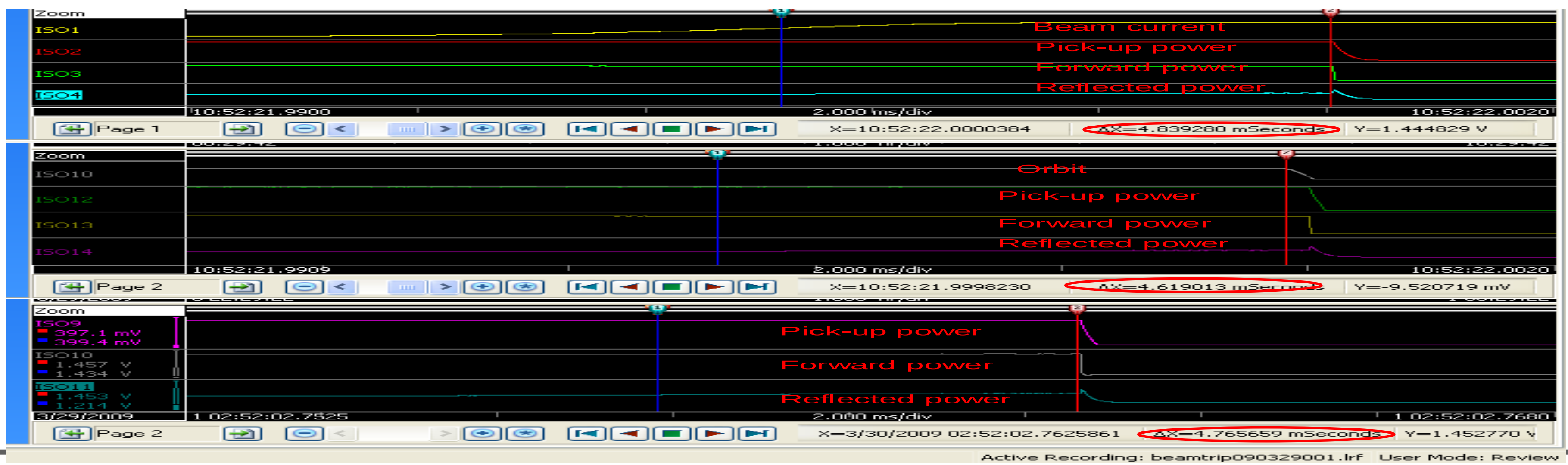
May	29 hours
June	80 hours
July	126 hours



Trip diagnostic system

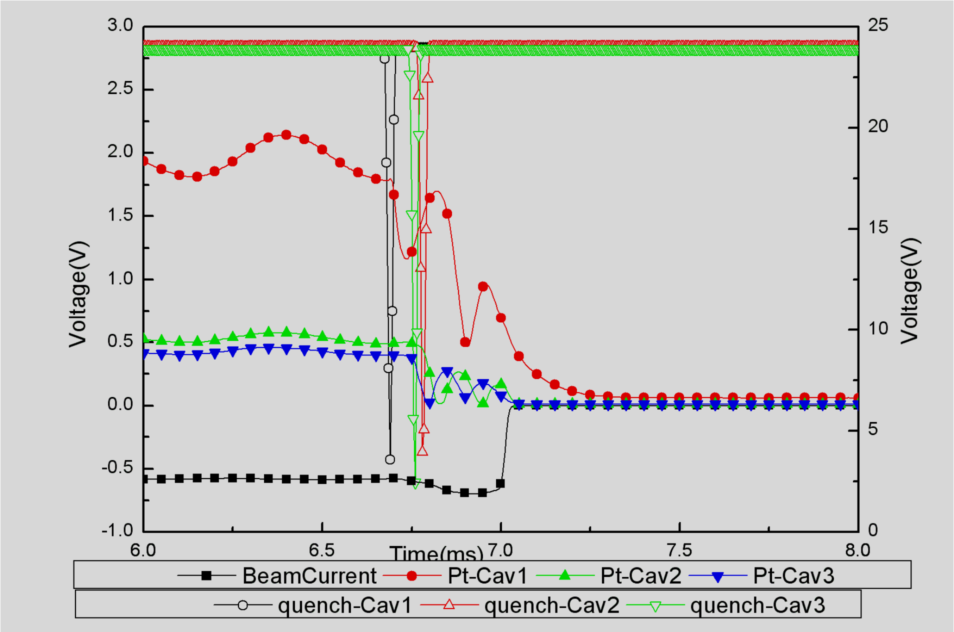


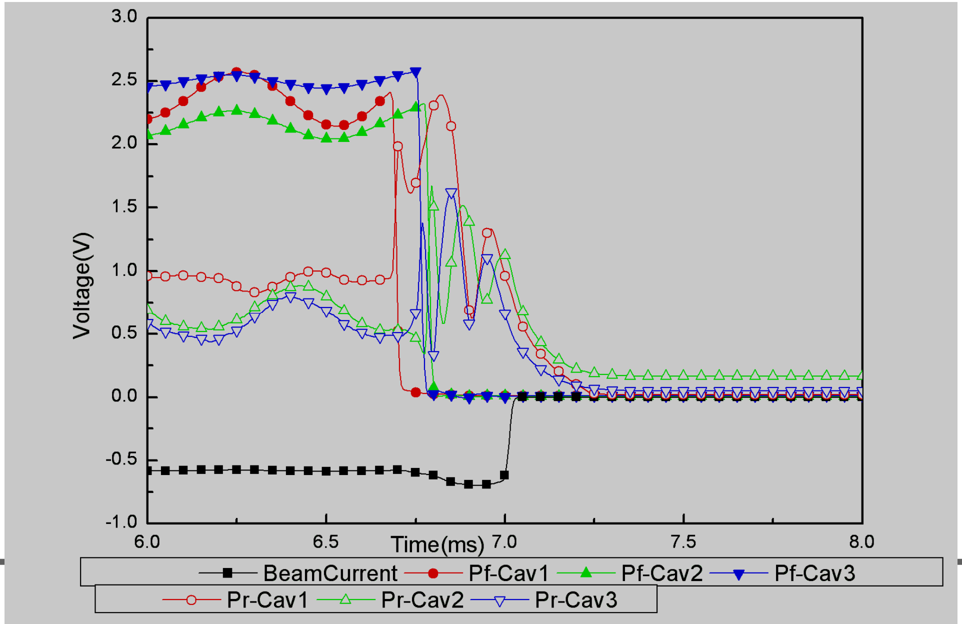




2009-06-19-16pm: Cavity #1 quench first

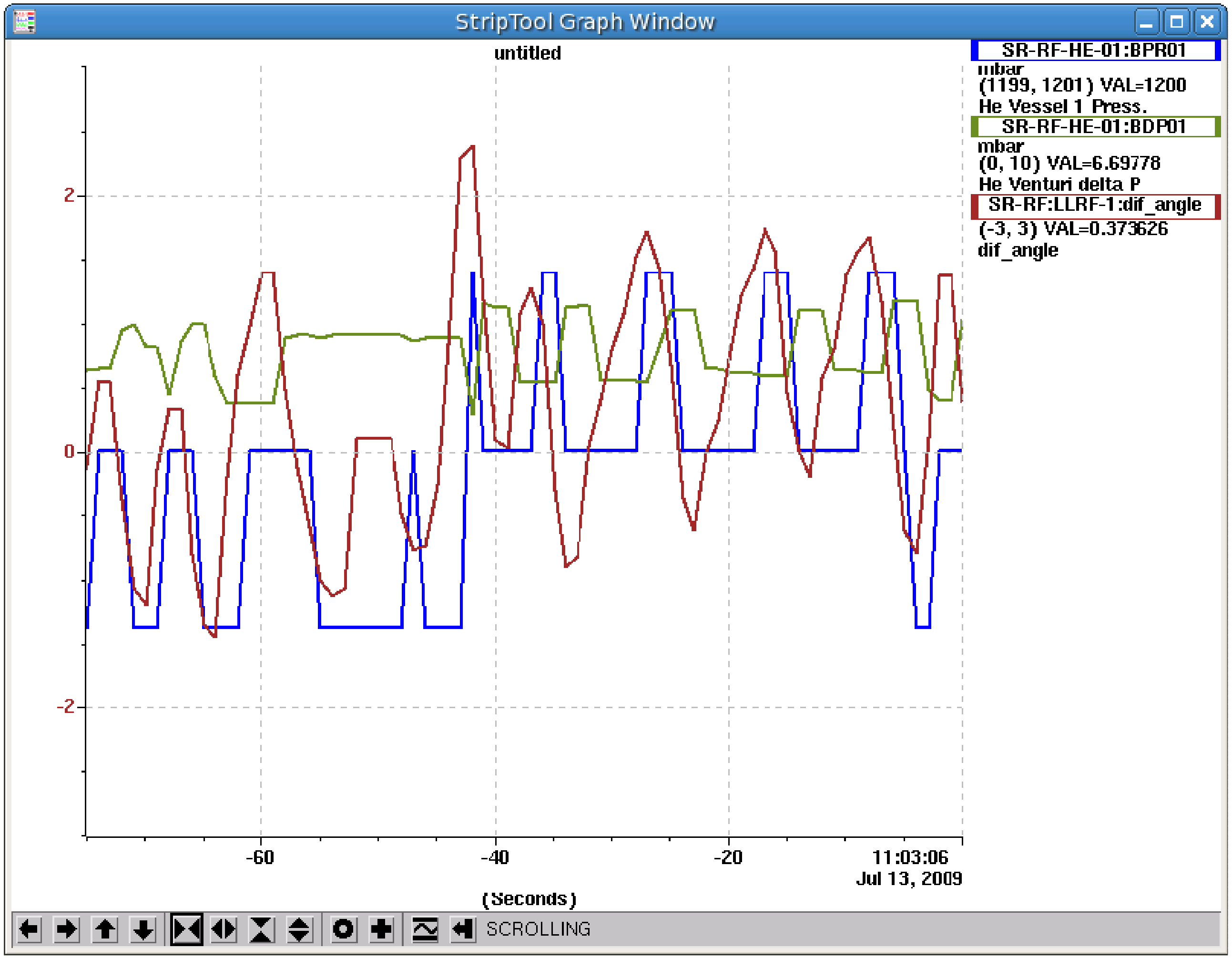
PB#2:





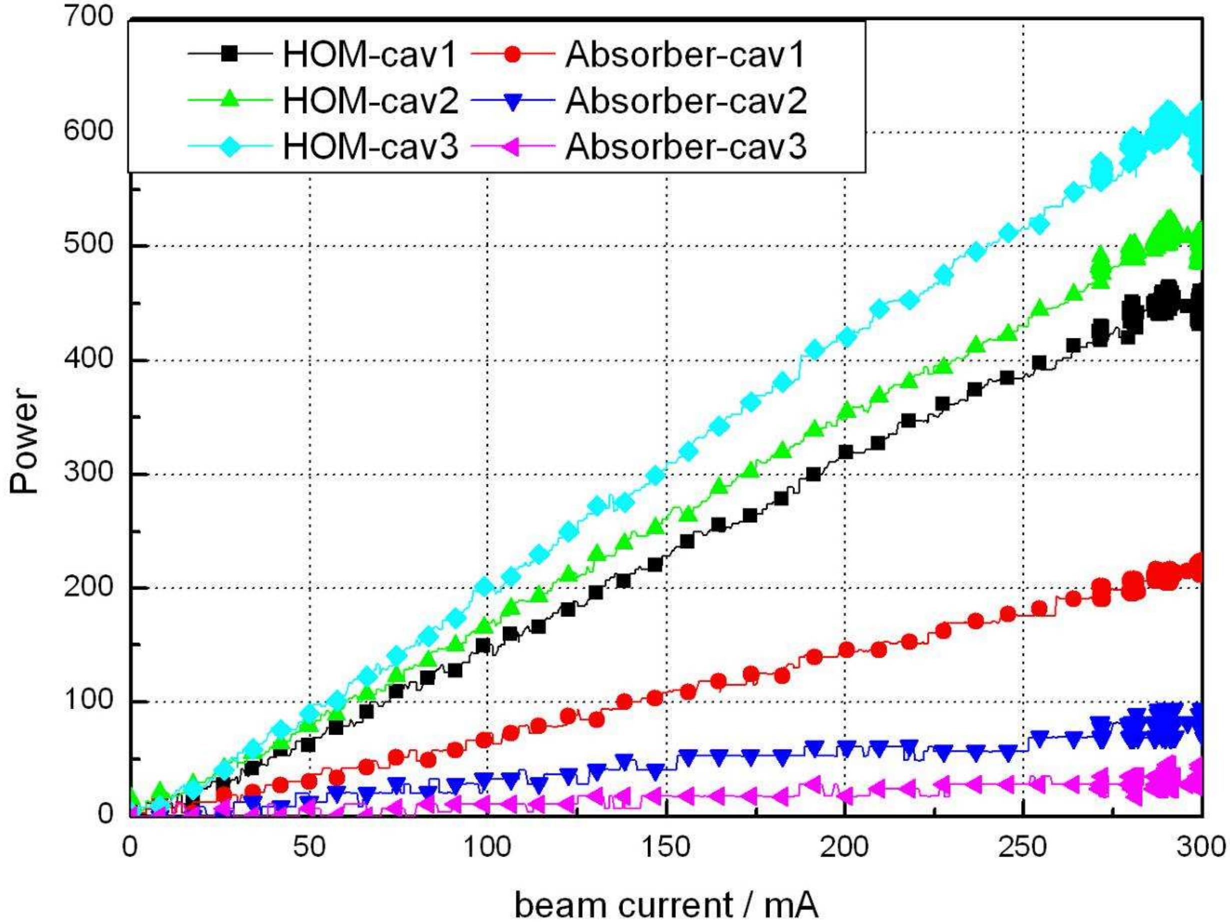
Further SRF system commissioning

PB#3:



PB#4:

Power of HOM and absorber



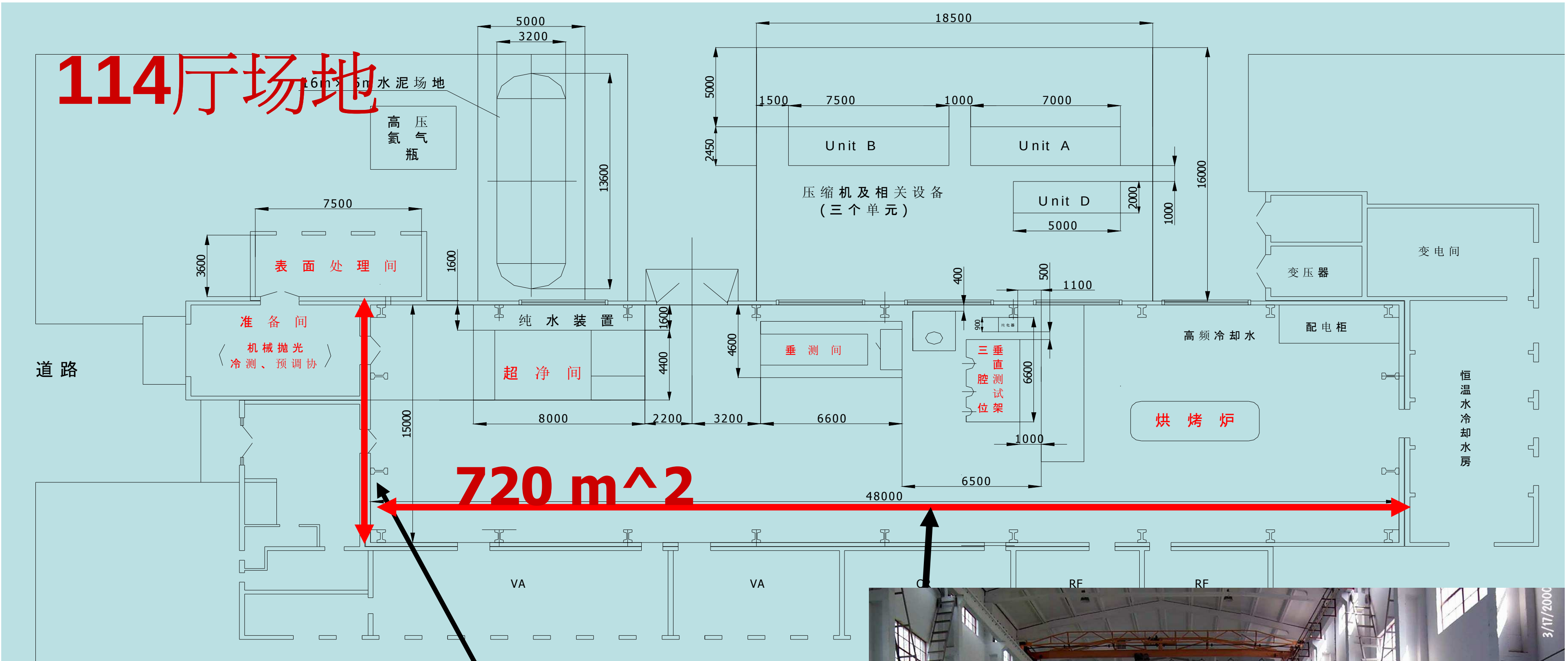
PB#5: IF Cryo-plnat is shutoff by Elec or others, what can we do? Just watching?

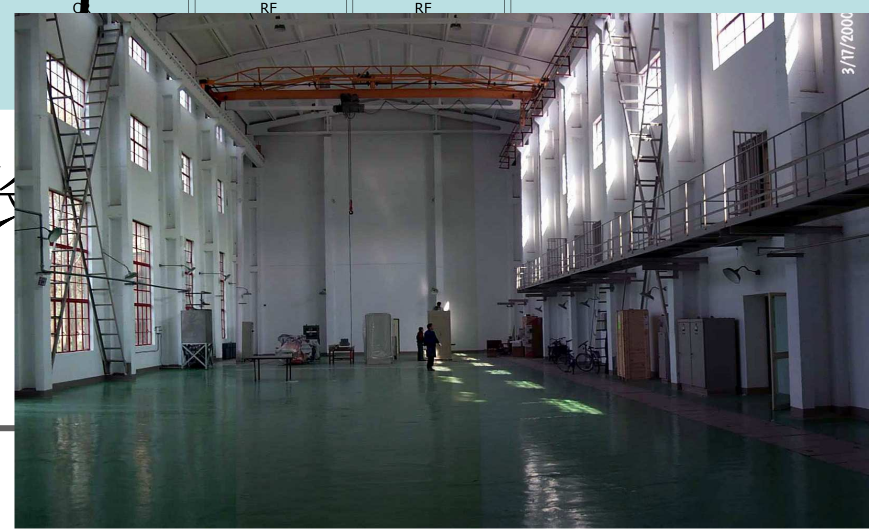
Twice happened since Jan. 2008

Electricity was off, cryoplant was down suddenly, return lines of helium vessel were closed. IS THERE OTHER BETTER SOLUTION except watching?

NEXT STEPS

Shanghai Key Lab for Cryogenics & SRF Technology

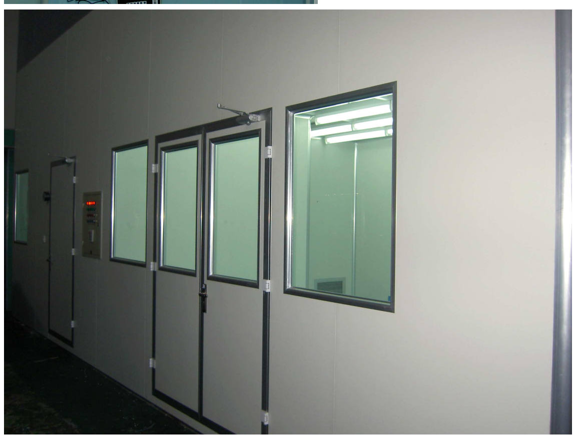




宽15米 长

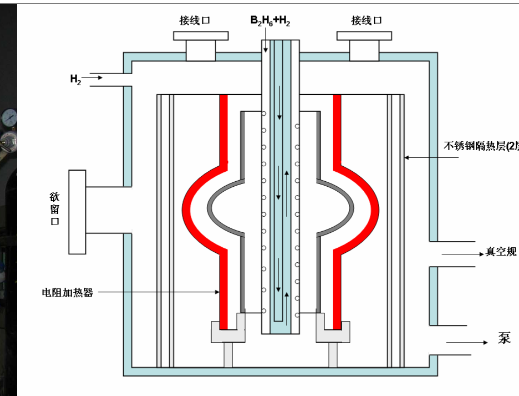
NEXT STEPS

Shanghai Key Lab for Cryogenics & SRF Technology



NEXT STEPS

Shanghai Key Lab for Cryogenics & SRF Technology

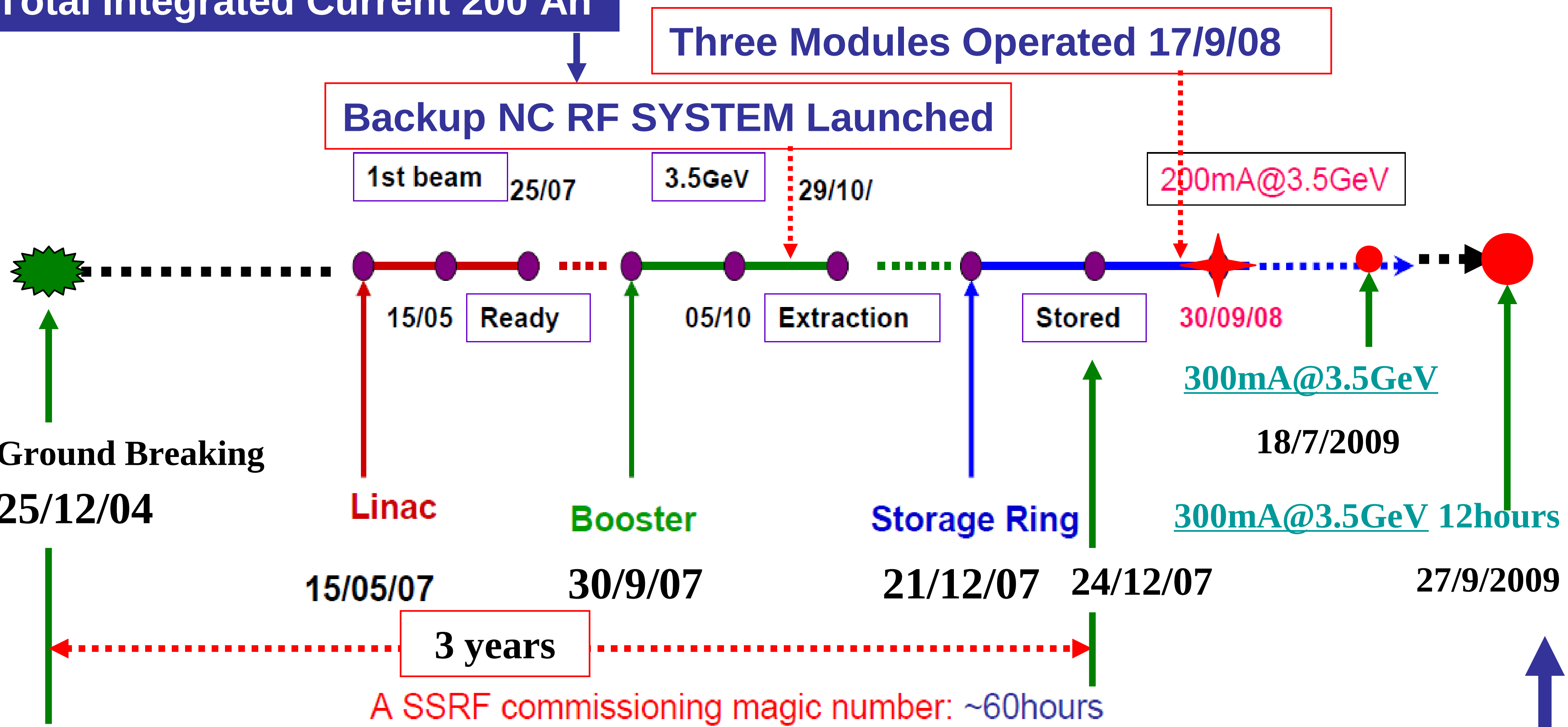


1. **MgB2 cavity to be studied**
2. **Single Cell 500MHz Cryo-Module as a spare one (Budget is READY)**
3. **Multi Cell 500 MHz Cryo-Module for Prototype of ERL (Building is under construction)**

SUMMARY Key Dates of the SSRF Commissioning

Commissioning SSRF. Cleaning the vacuum chamber. Stabling software & hardware. Speeding up SRF commissioning.

6-months Operation with NC
Total Integrated Current 200 Ah



Further studies HAVE TO be done to operate stably

J.-F. Liu ESLS RF 2009


Thanks