Introduction to SSRF Operation Reliability

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SINAP
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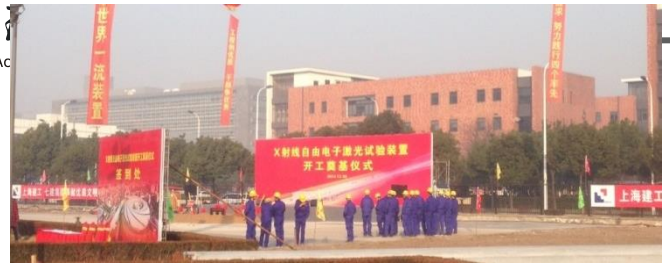
- **Introduction of SINAP**
- **Upgrade and new beamlines of SSRF**
- **Status of SSRF operation**
- **Main failures in Operation**

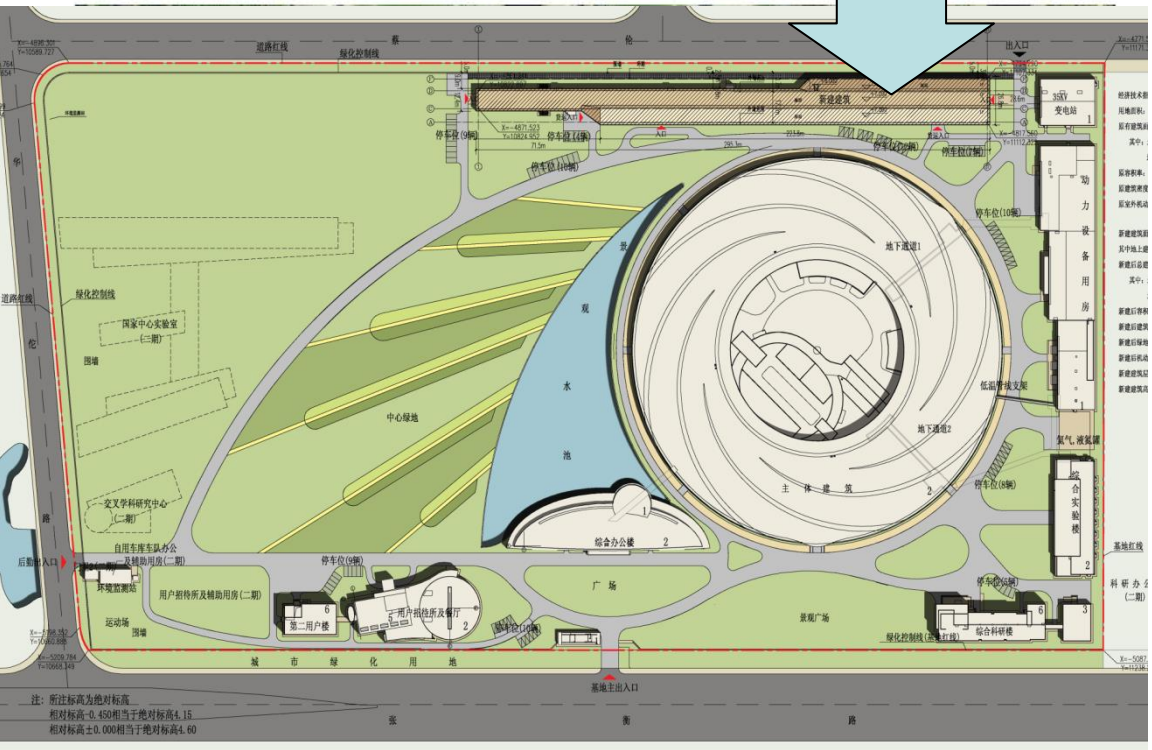
Shanghai Institute of Applied Physics (SINAP)

Site Map



2014.12——2016.12

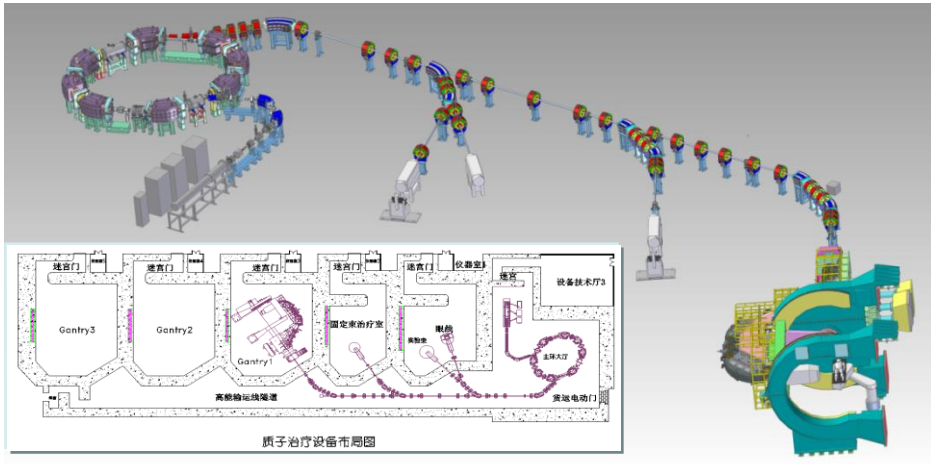
Shanghai Photon Science Center



1. SSRF operation
2. SSRF Phase II , more beamlines construction
3. SXFEL construction
4. Proton Therapy research

Energy	70~235MeV
Energy lamination	~90
Circumference	24.6m
Ramping time	0.7s
Scan area	30cm x 40cm

Proton Therapy

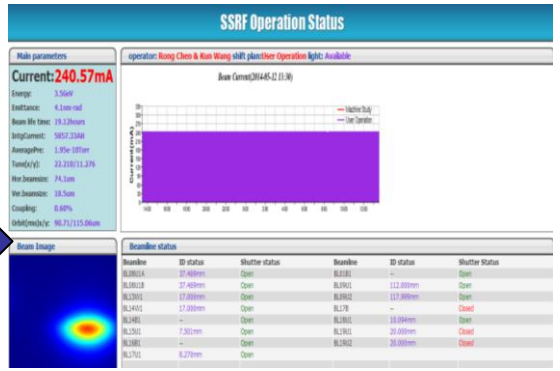


2014.12.30 Foundation of SAPT

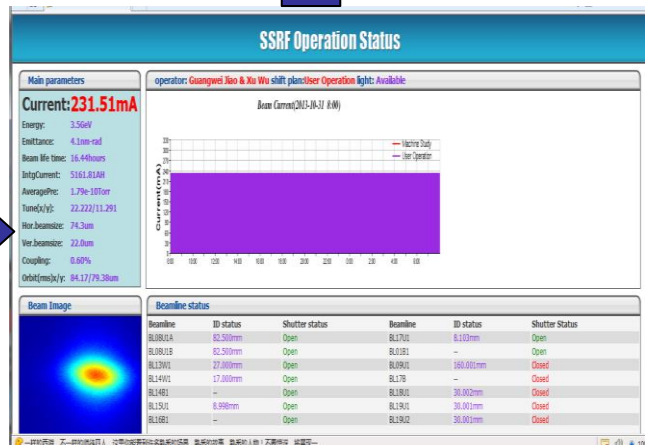
Upgrade and New Beamlines of SSRF

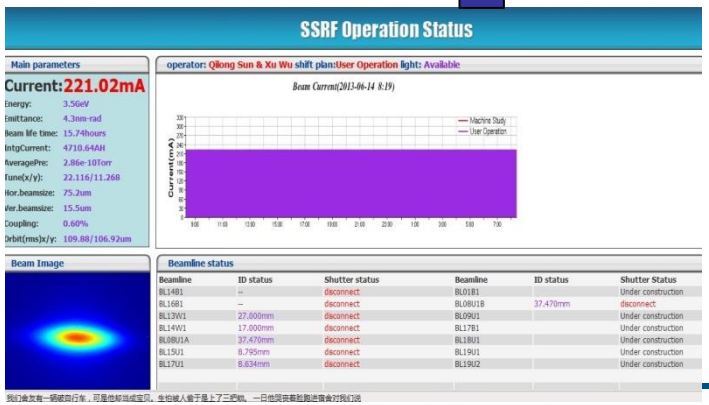
Beam current

3, 2014
240mA

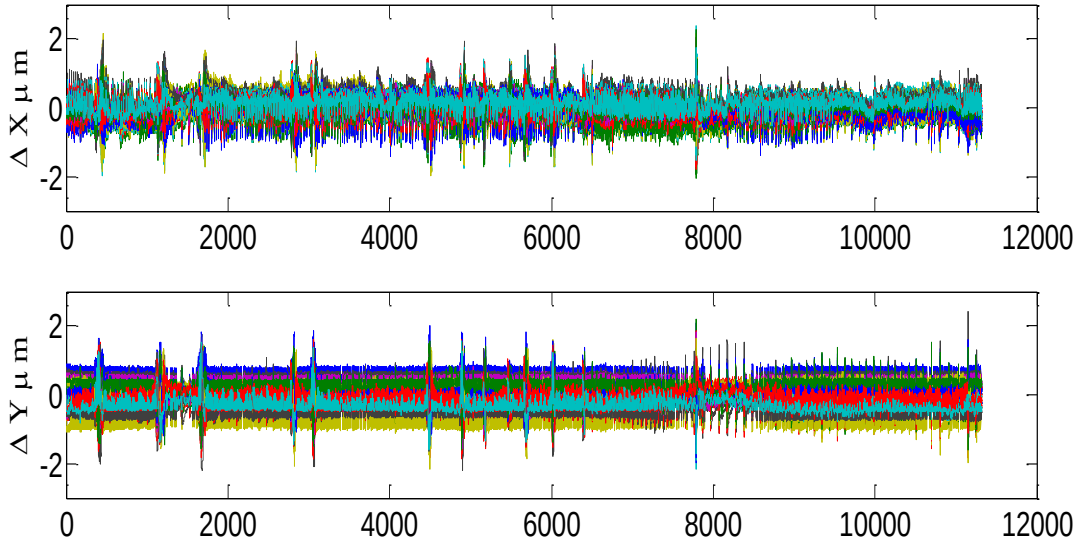


11, 2013
230mA





Fast orbit feedback

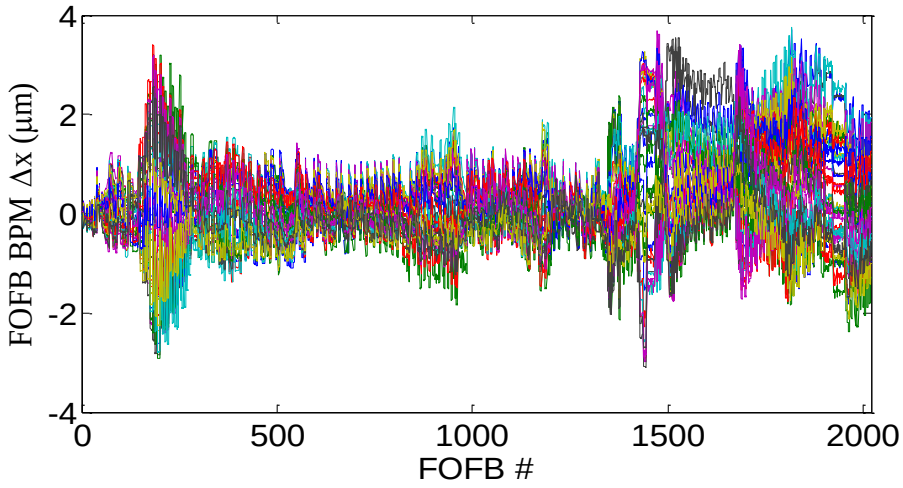


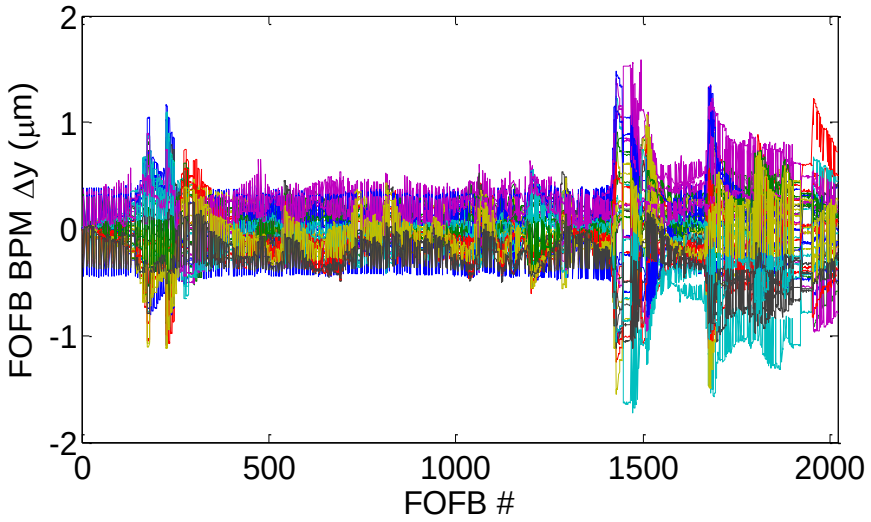
11/7/2013 12:55 to 11/9/2013 9:00 , 45 hours orbit stability

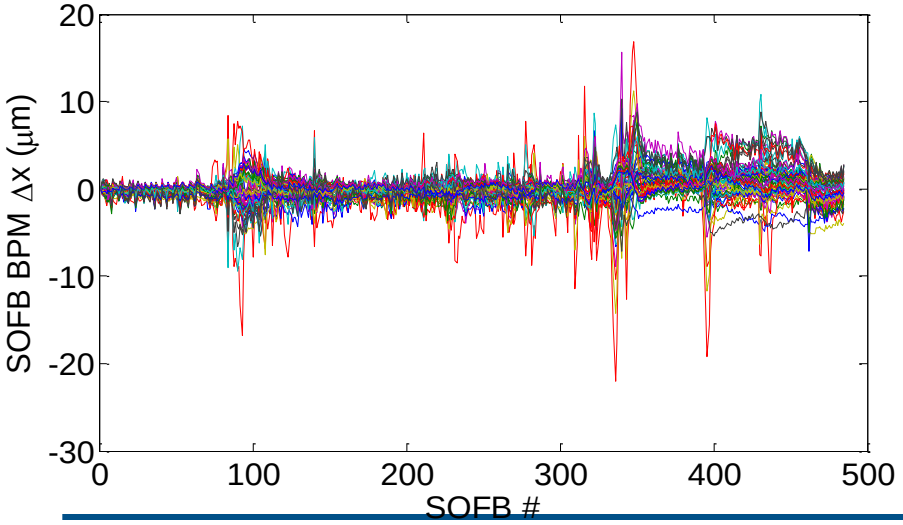
X: 0.26μm（RMS）

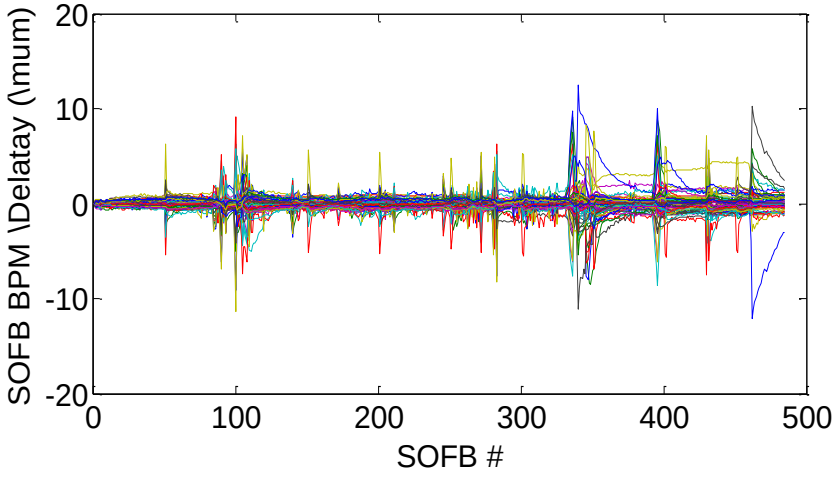
Y: 0.25 μm（RMS）

Fast orbit feedback









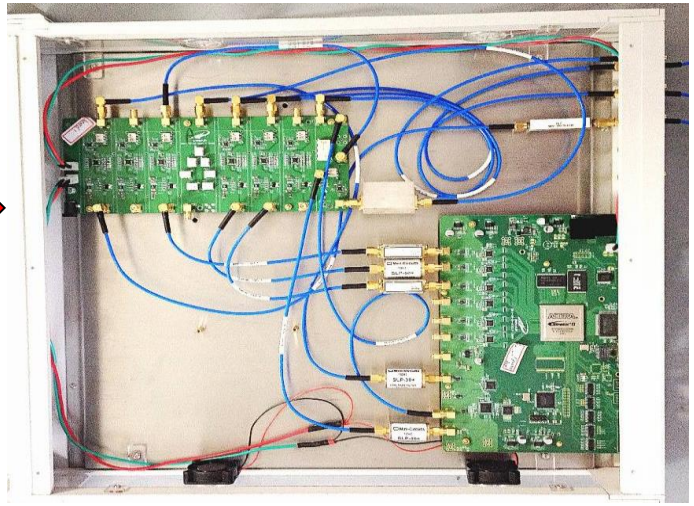
Timing system update

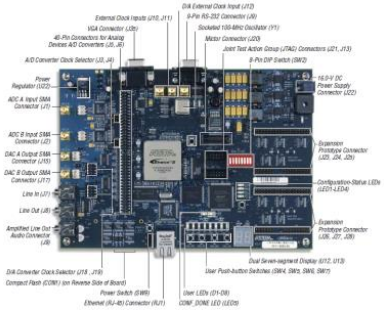
Solving the problem of missing trigger

Replacing linac MRF EVR-230RF and Guntx-200 with SINAP EVO\EVR

- Jitter < 5ps, delay step 2ns, any bucket injection can be realized by one download bucket number table.
- Update low level software of timing system
- Update up level software of injection
- Save the injection time, solve the problem of missing trigger.

LLRF Upgrade





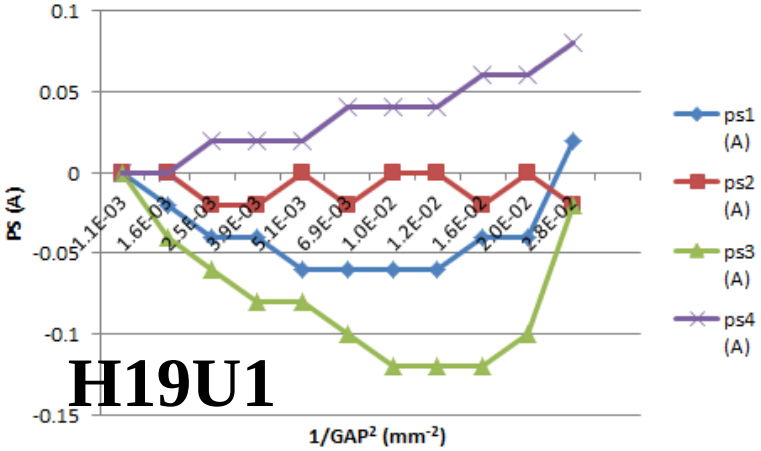
Compact Clock, ADC, DAC, FPGA into one PCB

- Less cable, more reliable
- Easy maintenance

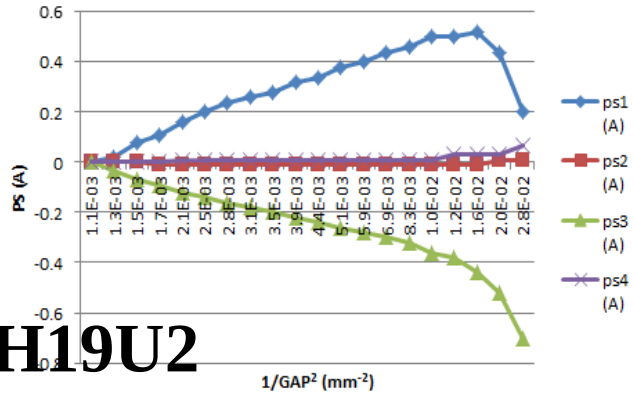
New Insertion devices commissioning

3 in-vacuum undulators for the Protein Research Facility beamlines

Orbit drift caused by the new insert device was corrected by feed forward system.

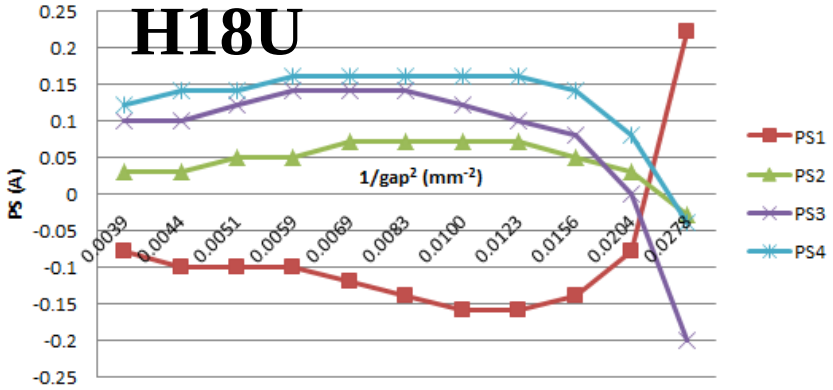


H19U1

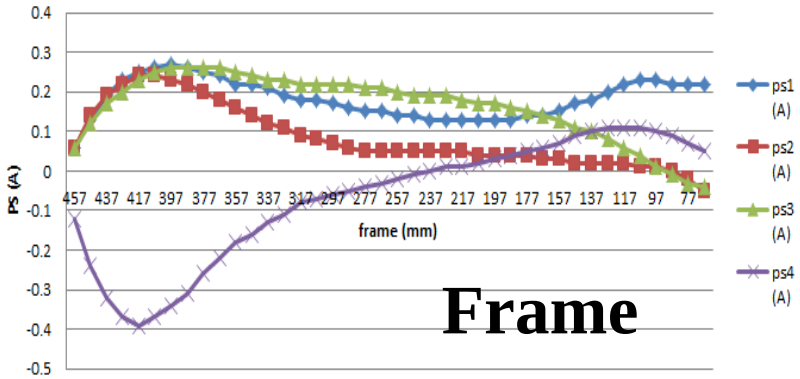


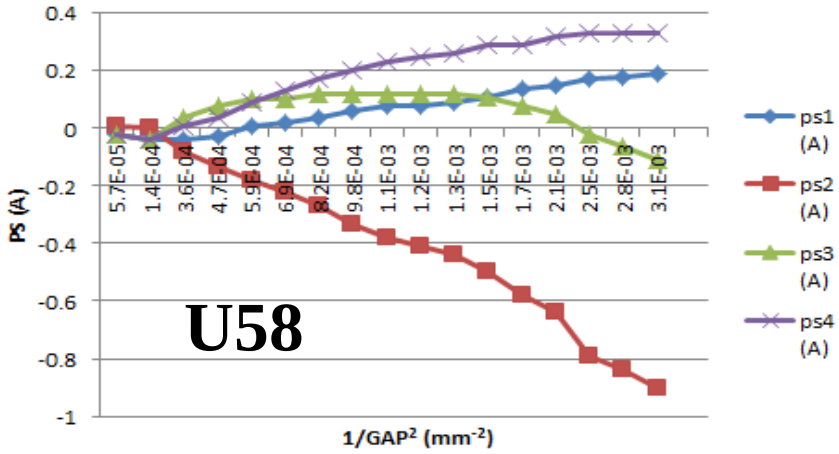
H19U2

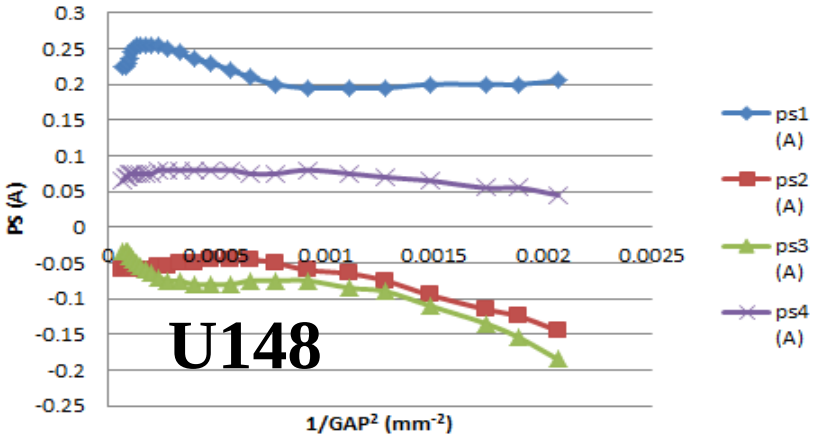
H18U



DEPU for the Dreamline







Machine Study

	Schedule AP	Practiced AP	Insertion device	Rate
Total	756 hrs	856.15 hrs	~ 288 hrs	34%
2013H2	360 hrs	321.75 hrs	~ 60 hrs	19%
2014H1	396 hrs	534.4 hrs	~ 228 hrs	43%

- 30%time: New insertion devices experimented
- 30%time: Accelerator maintenance, LOCO, BBA, beam scraped, etc.
- 30%time: Accelerator physics research, FOFB, coupling, etc.

Status of SSRF operation

Schedule of 2013-2014

Sep			Oct			Nov			Dec		
1	D	D	1	U	U	1	U	U	1	U	U
2	W	A	2	U	U	2	U	U	2	U	U
3	A	A	3	U	U	3	U	U	3	M	A
4	A	A	4	A	A	4	U	U	4	A	A
5	A	A	5	B	B	5	M	A	5	B	B
6	A	A	6	U	U	6	B	B	6	U	U
7	LB	LB	7	U	U	7	U	U	7	U	U
8	LB	LB	8	U	U	8	U	U	8	U	U
9	B	B	9	M	A	9	U	U	9	U	U
10	M	A	10	B	B	10	U	U	10	B	B
11	B	B	11	U	U	11	U	U	11	U	U
12	U	U	12	U	U	12	B	B	12	U	U
13	U	U	13	U	U	13	B	B	13	U	U
14	U	U	14	U	U	14	U	U	14	U	U
15	U	U	15	U	U	15	U	U	15	U	U
16	U	U	16	U	U	16	U	U	16	U	U
17	U	U	17	M	A	17	U	U	17	B	B
18	A	A	18	B	B	18	U	U	18	B	B
19	B	B	19	U	U	19	M	A	19	U	U
20	U	U	20	U	U	20	A	A	20	U	U
21	U	U	21	U	U	21	B	B	21	U	U
22	U	U	22	U	U	22	U	U	22	U	U
23	U	U	23	U	U	23	U	U	23	U	U
24	M	A	24	U	U	24	U	U	24	M	A
25	B	B	25	M	A	25	U	U	25	A	A
26	U	U	26	A	A	26	U	U	26	B	B
27	U	U	27	B	B	27	U	U	27	U	U
28	U	U	28	U	U	28	B	B	28	U	U
29	U	U	29	U	U	29	U	U	29	U	U
30	B	B	30	U	U	30	U	U	30	U	U
			31	U	U				31	U	U
Sep			Oct			Nov			Dec		

Jan			Feb			Mar			Apr			May			June			July		
1	U	U	1	D	D	1	U	U	1	M	A	1	U	U	1	U	U	1	U	U
2	U	U	2	D	D	2	U	U	2	B	B	2	U	U	2	U	U	2	U	U
3	U	U	3	D	D	3	U	U	3	U	U	3	U	U	3	U	U	3	U	U
4	U	U	4	D	D	4	M	A	4	U	U	4	U	U	4	U	U	4	U	U
5	U	U	5	D	D	5	B	B	5	U	U	5	U	U	5	B	B	5	U	U
6	U	U	6	D	D	6	U	U	6	U	U	6	M	A	6	U	U	6	U	U
7	M	M	7	D	D	7	U	U	7	U	U	7	A	A	7	U	U	7	U	U
8	B	B	8	D	D	8	U	U	8	M	A	8	B	B	8	U	U	8	M	A
9	U	U	9	D	D	9	U	U	9	B	B	9	B	B	9	U	U	9	B	B
10	U	U	10	D	D	10	U	U	10	B	B	10	U	U	11	M	M	10	U	U
11	U	U	11	D	D	11	M	A	11	U	U	11	U	U	12	B	B	11	U	U
12	U	U	12	D	D	12	B	B	12	U	U	12	U	U	13	U	U	12	U	U
13	B	B	13	D	D	13	U	U	13	U	U	13	U	U	14	U	U	13	U	U
14	U	U	14	D	D	14	U	U	14	U	U	14	U	U	15	U	U	14	U	U
15	U	U	15	D	D	15	U	U	15	U	U	15	U	U	16	U	U	15	U	U
16	U	U	16	D	D	16	U	U	16	U	U	16	U	U	17	B	B	16	B	B
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21	M	M	21	W	W	21	U	U	21	U	U	21	A	A	22	U	U	21	D	D
22	A	A	22	W	W	22	U	U	22	M	M	22	B	B	23	U	U	22	D	D
23	A	A	23	W	W	23	U	U	23	B	B	23	U	U	24	M	M	23	D	D
24	A	A	24	W	W	24	U	U	24	U	U	24	U	U	25	A	A	24	D	D
25	A	A	25	A	A	25	M	A	25	U	U	25	U	U	26	A	A	25	D	D
26	A	A	26	A	A	26	B	B	26	U	U	26	U	U	27	B	B	26	D	D
27	D	D	27	B	B	27	B	B	27	U	U	27	M	A	28	U	U	27	D	D
28	D	D	28	B	B	28	U	U	28	U	U	28	B	B	29	U	U	28	D	D
29	D	D				29	U	U	29	U	U	29	U	U	30	U	U	29	D	D
30	D	D				30	U	U	30	U	U	30	U	U	31	U	U	30	D	D
31	D	D				31	U	U				31	U	U				31	D	D
Jan			Feb			Mar			Apr			May			June			July		

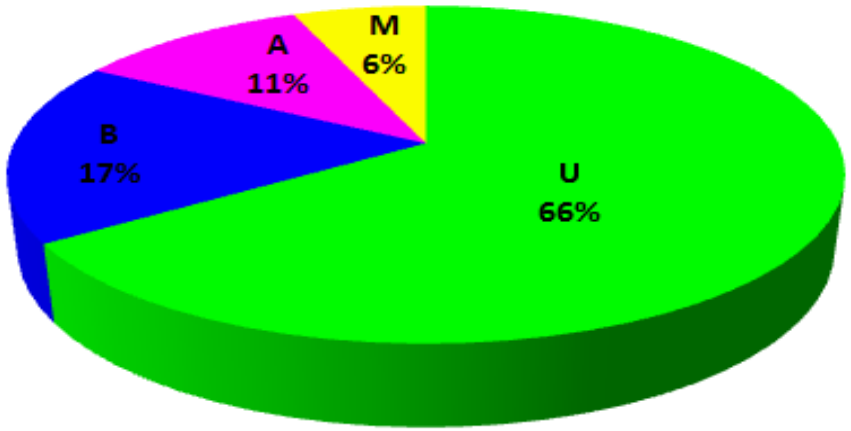
Sep - Dec, 2013

Jan - Jul, 2014

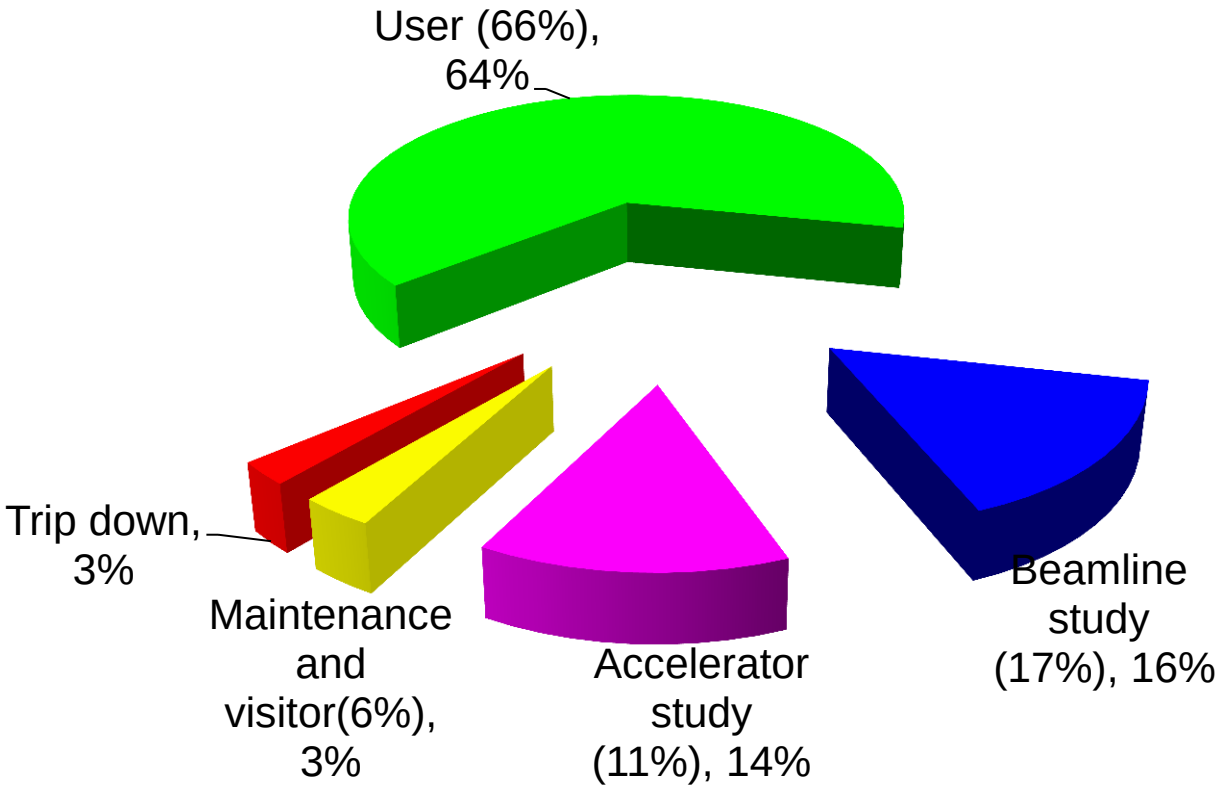
Operation schedule

Operation	Warm up	Shut down
7020 hrs	132 hrs	864 hrs

User	Beamline Study	Accelerator Study	Maintenance
4608 hrs	1224 hrs	756 hrs	432 hrs



Sep, 2013 – Jun, 2014



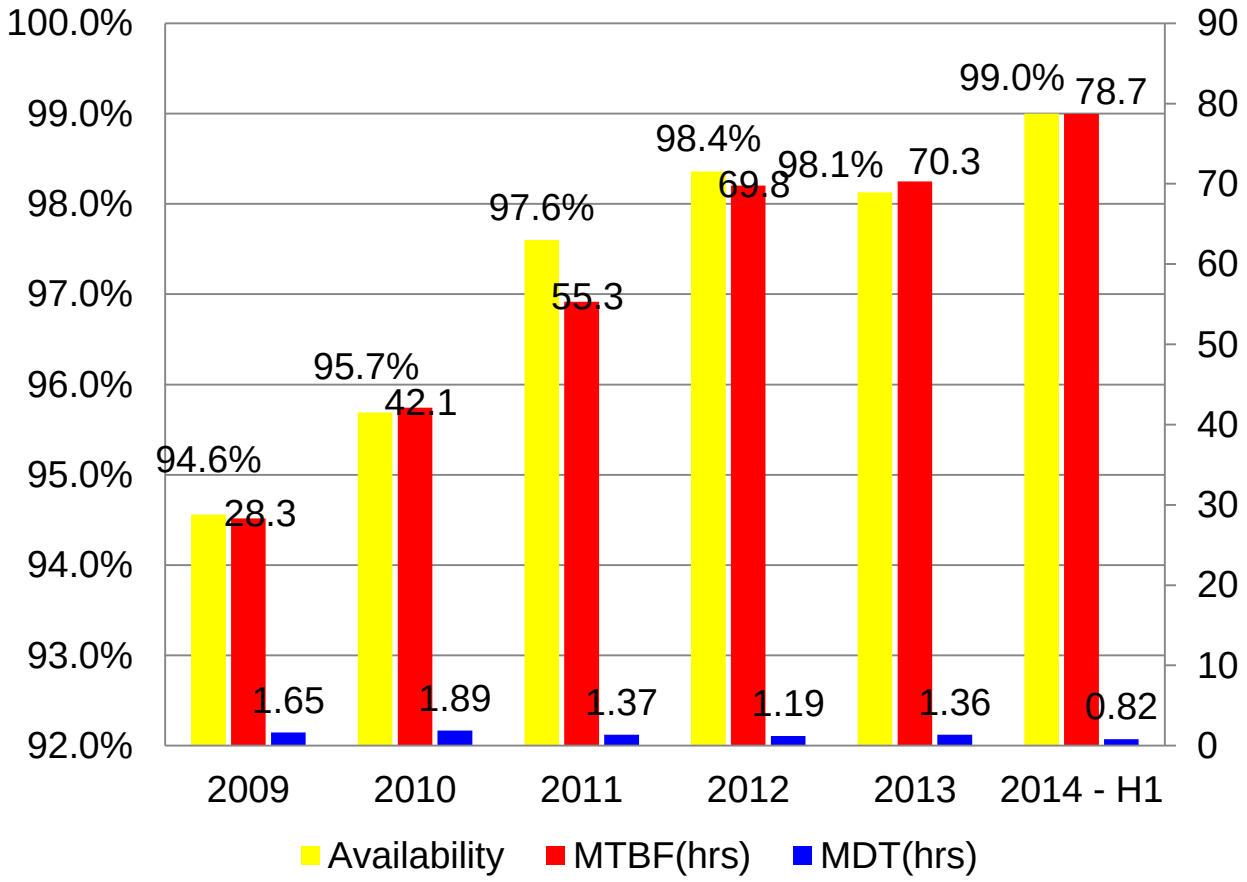
Availability

	时间	供光时间		故障情况		机器性能参数		
		计划	实际	时间	次数	开机率	MTBF	MDT
		U	U	U	U	U	U	U
	1.1 - 1.6	144	144	0	0	**100.00%**	144.00	#DIV/0!
第1轮	1.8 - 1.20	192	188	4	6	97.92%	26.86	0.67
第2轮	2.27-3.3	72	70.15	1.85	3	97.43%	17.54	0.62
第3轮	3.5-3.10	120	117.4	2.6	3	97.83%	29.35	0.87
第4轮	3.12-3.17	120	118.13	1.87	1	98.44%	59.07	1.87
第5轮	3.20-3.24	92.6	92	0.6	1	**99.35%**	46.00	0.60
第6轮	3.26-3.31	96	96	0	0	**100.00%**	96.00	#DIV/0!
第7轮	4.2-4.15	237.33	235.4	1.93	2	**99.19%**	78.47	0.97
第8轮	4.17-4.21	117.34	114.04	3.3	4	97.19%	22.81	0.83
第9轮	4.23-5.5	264	264	0	0	**100.00%**	264.00	#DIV/0!
第10轮	5.8-5.19	240	238.35	1.65	1	**99.31%**	119.18	1.65
第11轮	5.22-5.26	96	96	0	0	**100.00%**	96.00	#DIV/0!
第12轮	5.28 - 6.9	264	264	0	0	**100.00%**	264.00	#DIV/0!
第13轮	6.11 - 6.22	216	213.77	2.23	3	98.97%	53.44	0.74
第14轮	6.25 - 7.7	264	262.5	1.5	1	**99.43%**	131.25	1.50
第15轮	7.9-7.18	168	162.52	5.48	8	96.74%	18.06	0.69
	合计	2703.27	2676.26	27.01	33	**99.00%**	78.71	0.82

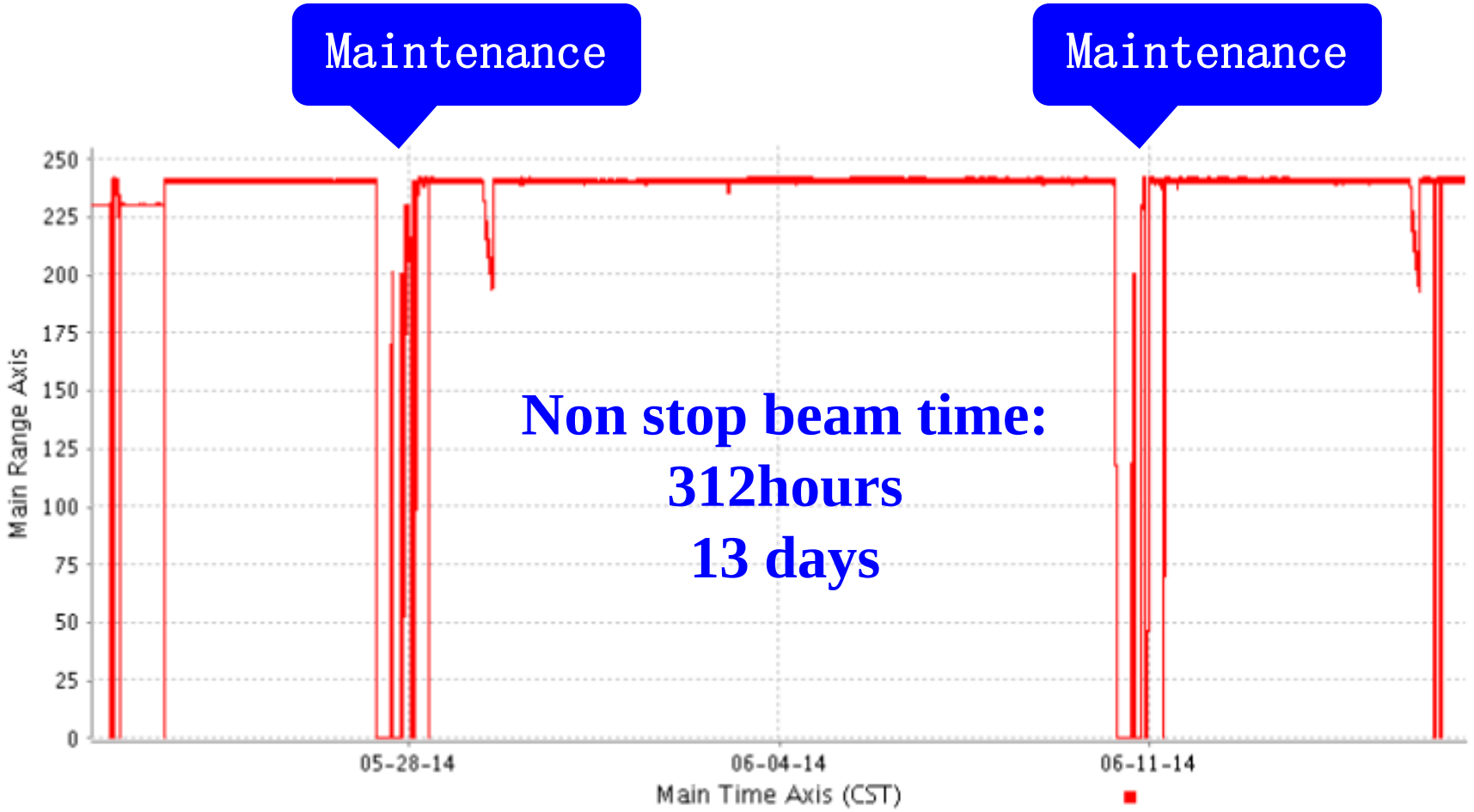
Sep. 2013 – July. 2014 for user

	2013.09-2014.07	2013.09-2013.12	2014.01-2014.07
Schedule for user	4664.14	1960.87	2703.27
Effective for user	4604.41	1928.15	2676.26
Trip down times	57	24	33
Trip down hours	59.73	32.72	27.01
Availability	**98.72%**	98.33%	99.00%
MTBF	**79.39 hr**	77.13 hr	78.71 hr
MDT	**1.05 hr**	1.36 hr	0.82 hr

Availability and MTBF

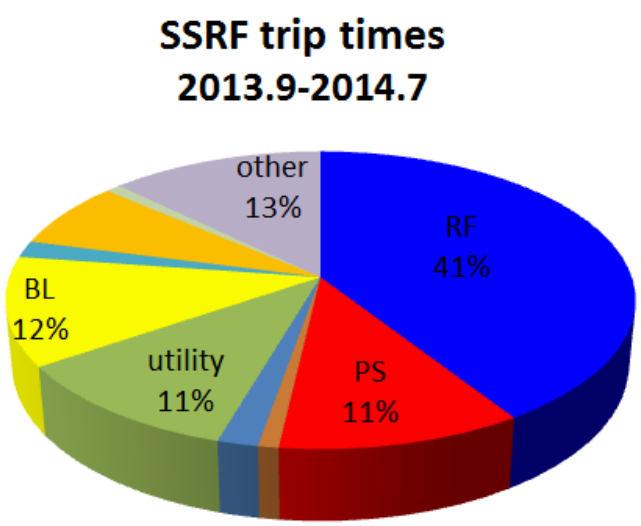


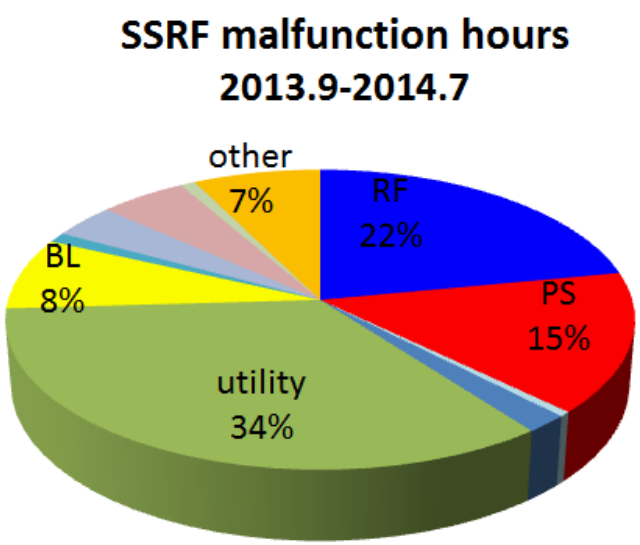
Longest duration of non-stop beam for user operation: 551 hours



Hardware failure（U/B/AP）

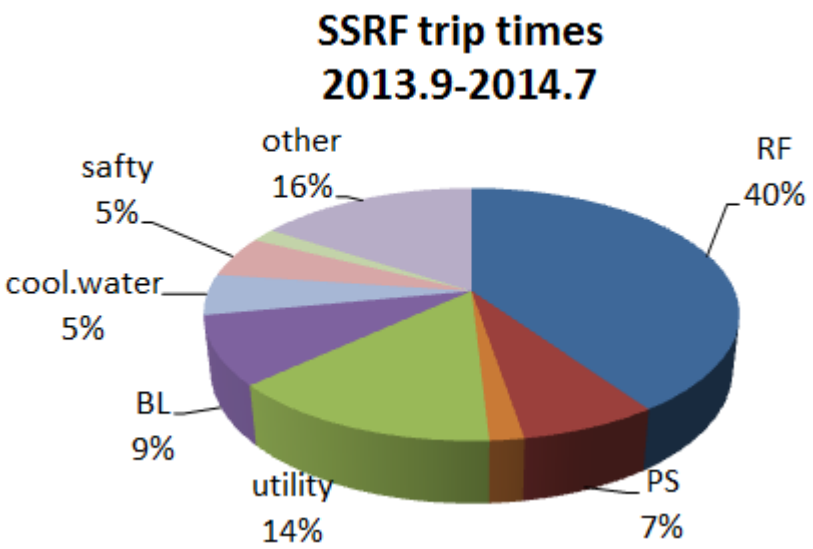
All failures（U/B/AP）	
beam lost times	Beam lost time (hours)
110	183.36

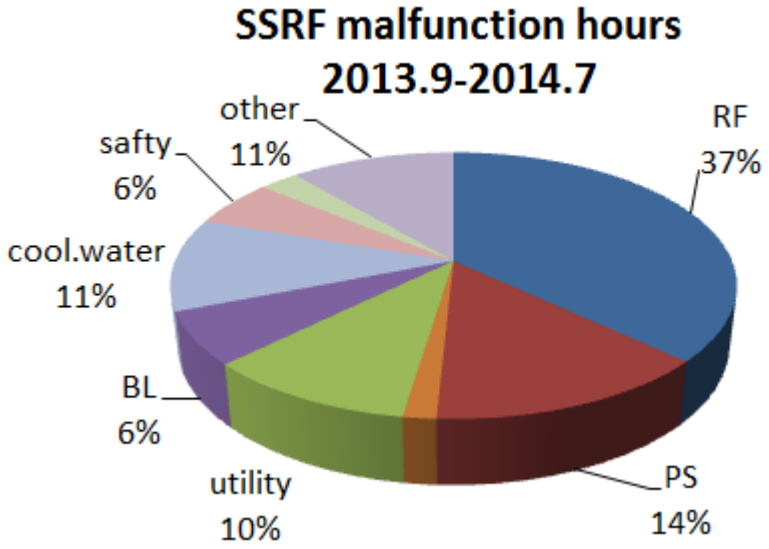




Hardware failure（User operation）

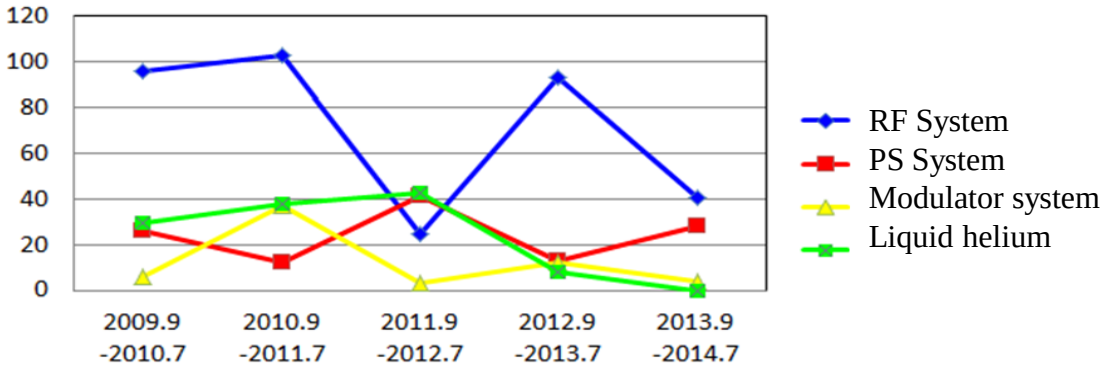
Failures（U）	
Beam lost times	Beam lost time (hours)
57	59.73





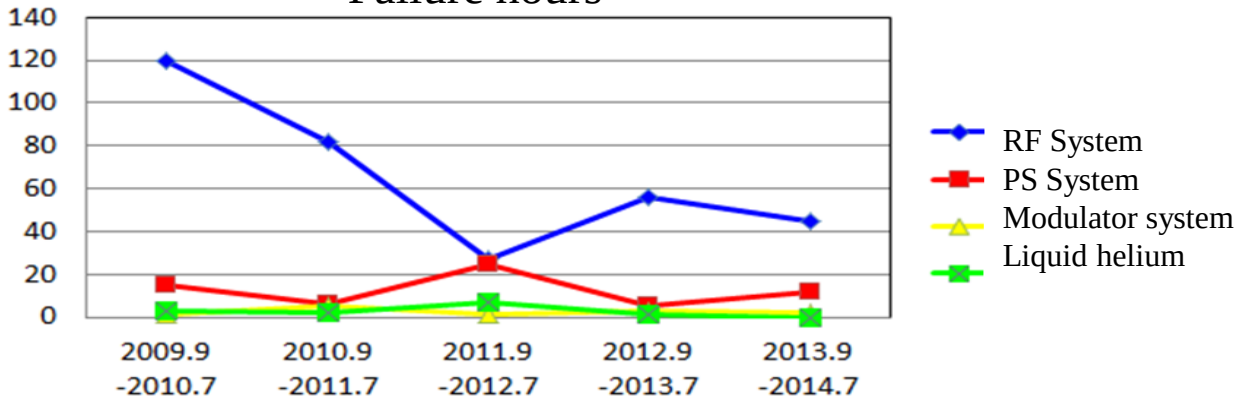
Four high failure systems since 2009

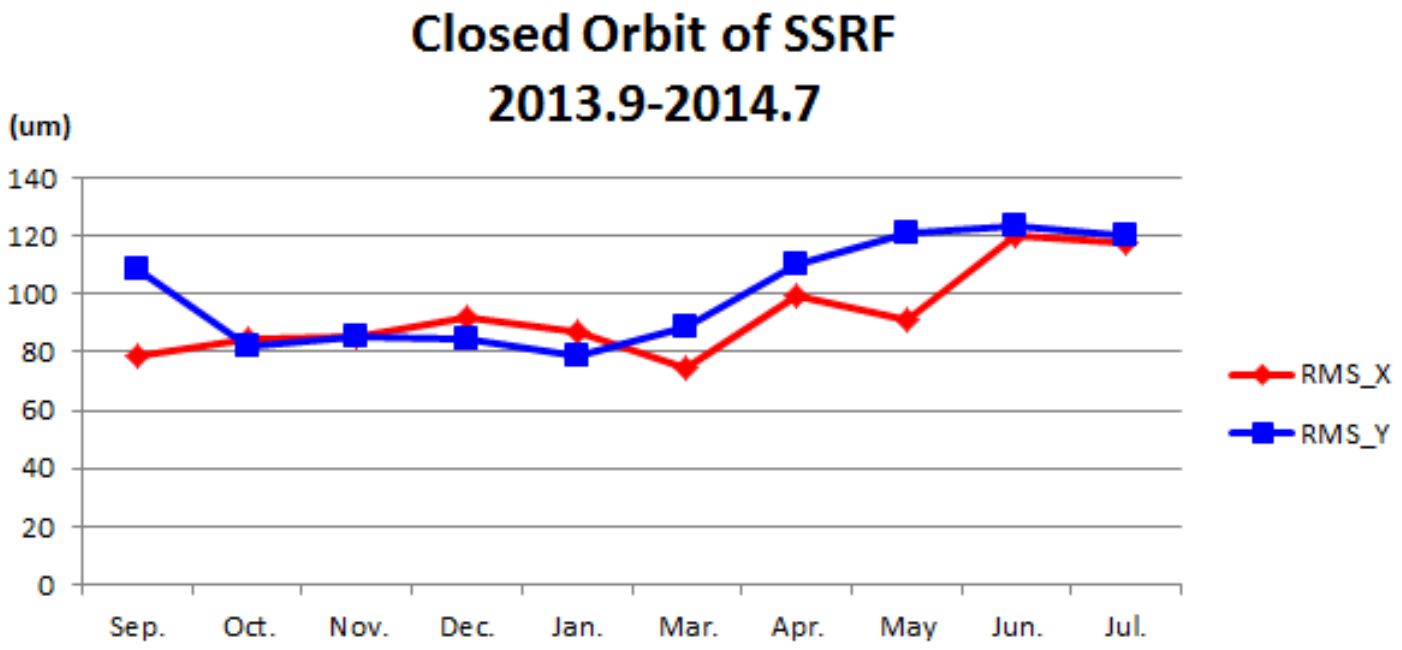
Failure times



●RF：
Thanks for the low level RF failure times and hours, availability got 99% last year.

Failure hours





	Sep.	Oct.	Nov.	Dec.	Jan.	Mar.	Apr.	May	Jun.	Jul.
RMS_X	78.5	84.8	85.5	91.8	87.0	74.9	99.6	90.9	119.9	117.6
RMS_Y	108.6	82.4	85.7	84.7	78.8	88.4	110.3	120.6	123	120.0

Ways to improve reliability

- **Every week**

  Regular operation meeting in every Monday, arranging current week project and doing a summary for last week on operation.
  meeting.

- **Bi-weekly**

  Every one or two weeks, we have one day for maintenance, from 9:00AM to 5:00PM, checking and maintaining, and then warming up to inject beam.

- **Annual**

  Shut down about one month every summer and three weeks at the winter.
  Maintaining work for all the system.
  Upgrade on software and hardware are done constantly by all system.
  Installations include new beamlines and new insertion devices.

- **Elog**

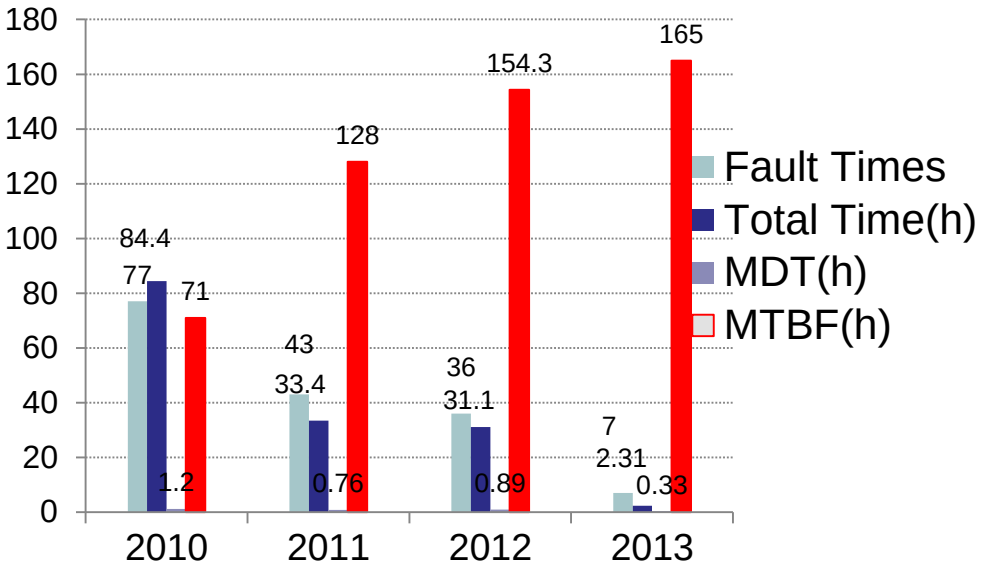
  Every operation staff can sign up and look up machine status. Once any device fails to work, he can get help from it to reduce the time to repair.
  Record and give a report for a update suggestion.

- **Spare parts**

  Liquid helium system has a online spare compressor which can turn to work at any time.
  Real time checking keeps the spare parts enough and ready to be used.

Main Failures in Operation

RF System



Main trips from 2012 to now include:

Trips over: 4 times

FBT Vacuum burst: 11 times;

Insulation vacuum burst: 4 times.

Circulator and load arc: 5 times

Trips with long break-down time:

Damaged kinds of auxiliary power

Total 12hours.

Frequently on SCC2 and SCC3.

Typically shows:

Sudden voltage decrease

Big outgas from FBT or POB

Solution: Thermal cycle / Pulse conditioning / CW conditioning

RF System

- During the 4-years operations of SSRF with users, many trips and problem of storage ring system have been solved, which make the system more reliable and stable for 220mA@3.5Gev beam operation.
- There are still some unsolved trips, like FBT vacuum burst, insulation vacuum burst, vibration of transmitter 3’ s output. We are now trying to find the way to solve them.
- Over 600kW RF power will be demanded by the future SSRF phase-II project, which means each cavity should provide over 200kW power.
- How to overcome the multipacting and window vacuum burst will be the biggest challenge for super-conducting cavities.
- How to keep the high stability with the gradual degradation of devices will be also a big challenge.

Utility

Power grid often had a deep trip and caused the beam trip, sometimes a critical damage, for example:

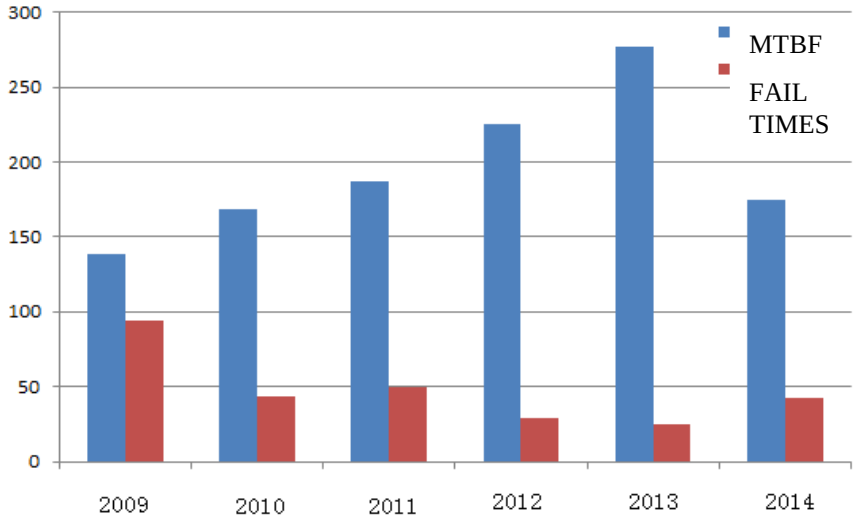
- ✓ 10/26,2013, result liquid helium fail and RF shutdown suddenly, stop beam for 29.5 hours.
- ✓ 4/9,2014, caused beam stop for 13.9 hours.
- ✓ 7/9,2014, caused beam stop 12.03hours.

DATE	TIME	GRID VARY(%)	DURATION (s)
2014.3.13	6:50:26	93.10	0.052
2014.3.16	12:03:32	82.06	0.073
2014.3.19	15:10:57	93.73	0.077
2014.3.23	7:07:16	86.15	0.095
2014.4.06	10:21:59	93.37	0.488
2014.4.09	11:12:02	71.31	0.075
2014.4.26	8:01:45	94.87	0.025
2014.4.27	12:51:28	94.98	0.112
2012.04.30	18:51:20	94.83	0.739
2014.05.11	6:43:45	79.06	0.079
2014.05.20	9:28:04	86.45	0.023
2014.05.23	12:53:06	93.89	0.021
2014.06.15	23:30:00	91.3	0.023S
2014.07.05	18:28:49	94.97	0.03
	21:09:08	94.70	0.03
2014.07.09	14:15:52	68.02	0.09
2014.07.10	12:30:40	91.69	0.334
2014.07.12	11:00:14	81.82	0.34
	12:32:51	91.18	0.315
	20:44:29	80.98	0.247
2014.07.15	4:02:20	89.14	0.062

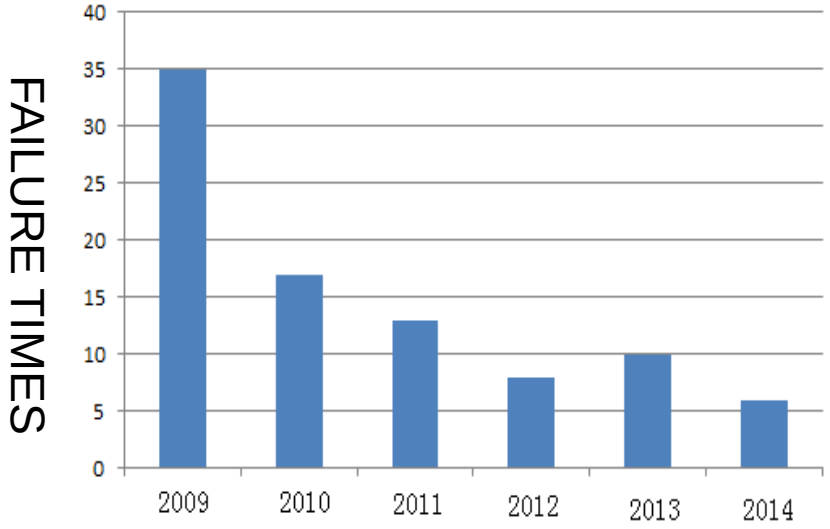
PS system

PS TYPE	Number	Total trip	Converter	Digital cards	Communication broken-link	Repair time	MTBF (hours)	MDT (hours)
Medium PS	623	9	2	1	6	0	653.3	0
SR-Q	200	12	4	2	6	9.65	490	0.8
Huge PS	17	18	10	3	5	12.72	326.7	0.71
Total	840	39	16	6	17	22.37	150.8	0.534

MTBF and failure times of PS

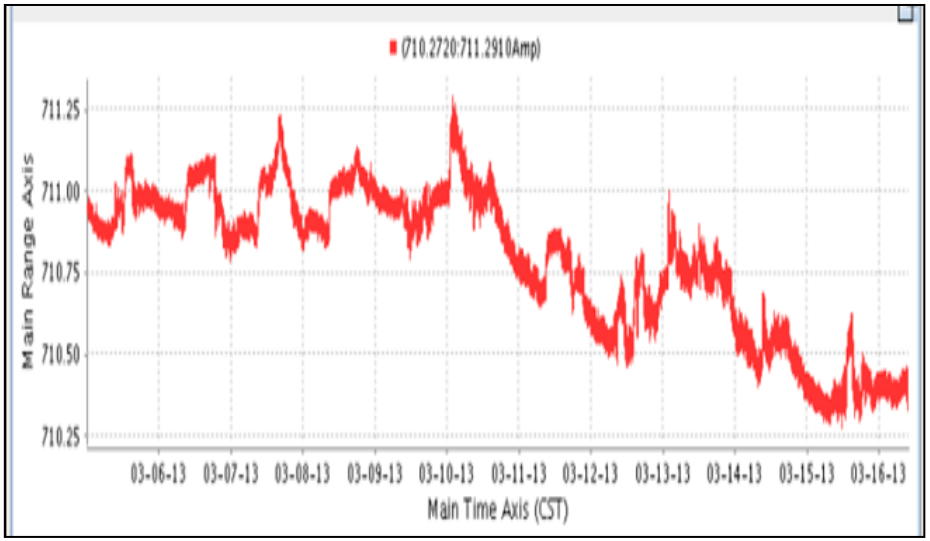


MTBF and fail times of PS

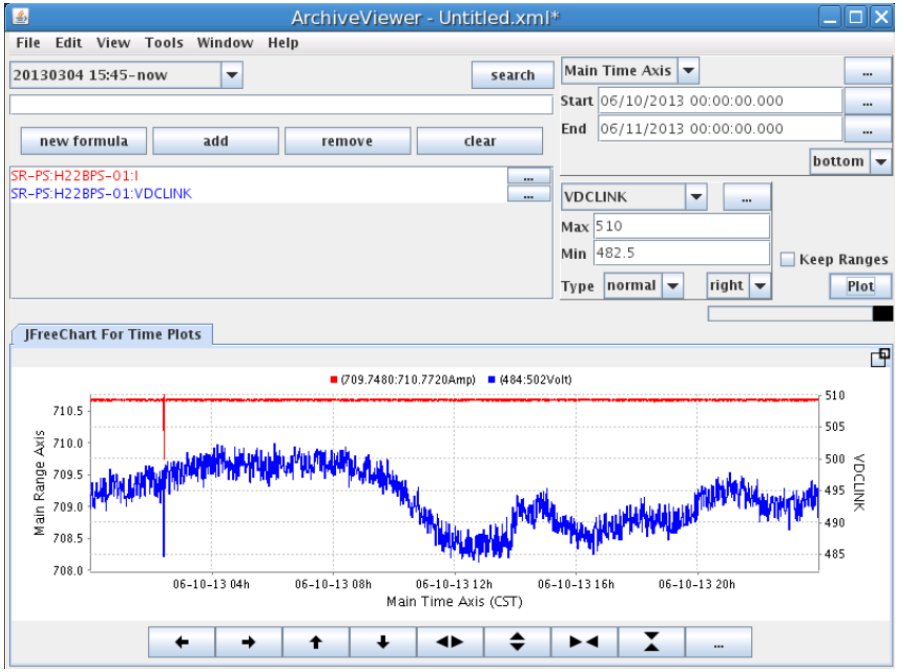


Communication broken-link

SR-B Drift and trip



SR-B current had a long drift caused by ADC fault

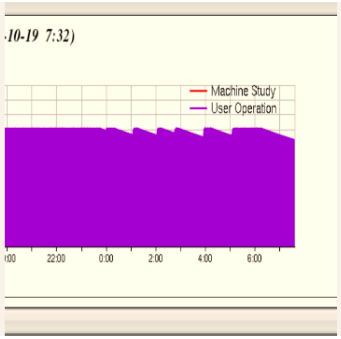


SR-B current trip caused by utility trip, with low open loop gain

Maintenance

Huge power supply, which must be repaired in local, so it is more difficult and spend more time.

Annual clean up for every PS, this type power supply can be exchanged very easy.



Aged cooling water pipes

Summary of power supply system

There are more than 840 power supplies in SSRF, and the MTBF is about 150 hours in 2014.

1. Auxiliary power fails.
2. The handle of the main relay (BS-Q,SR-B) was broken when it was turned on.
3. Cooling water pipe aged and leaked.
4. There are 20 power supplies in booster ring (Q & B) and in storage ring (S & B) . They are cabinet structure and must be repaired in local. SR-B current drifted 0.75A over 5 days. Several ways were tried to find the problem which was caused by ADC card. This was a typical example that some problems were deep hided.
5. All the other power supplies are module structure, which just need exchange a spare module and repair the failure one offline.
6. A good designed power supply should have more margin and consequently reliable.

THANKS