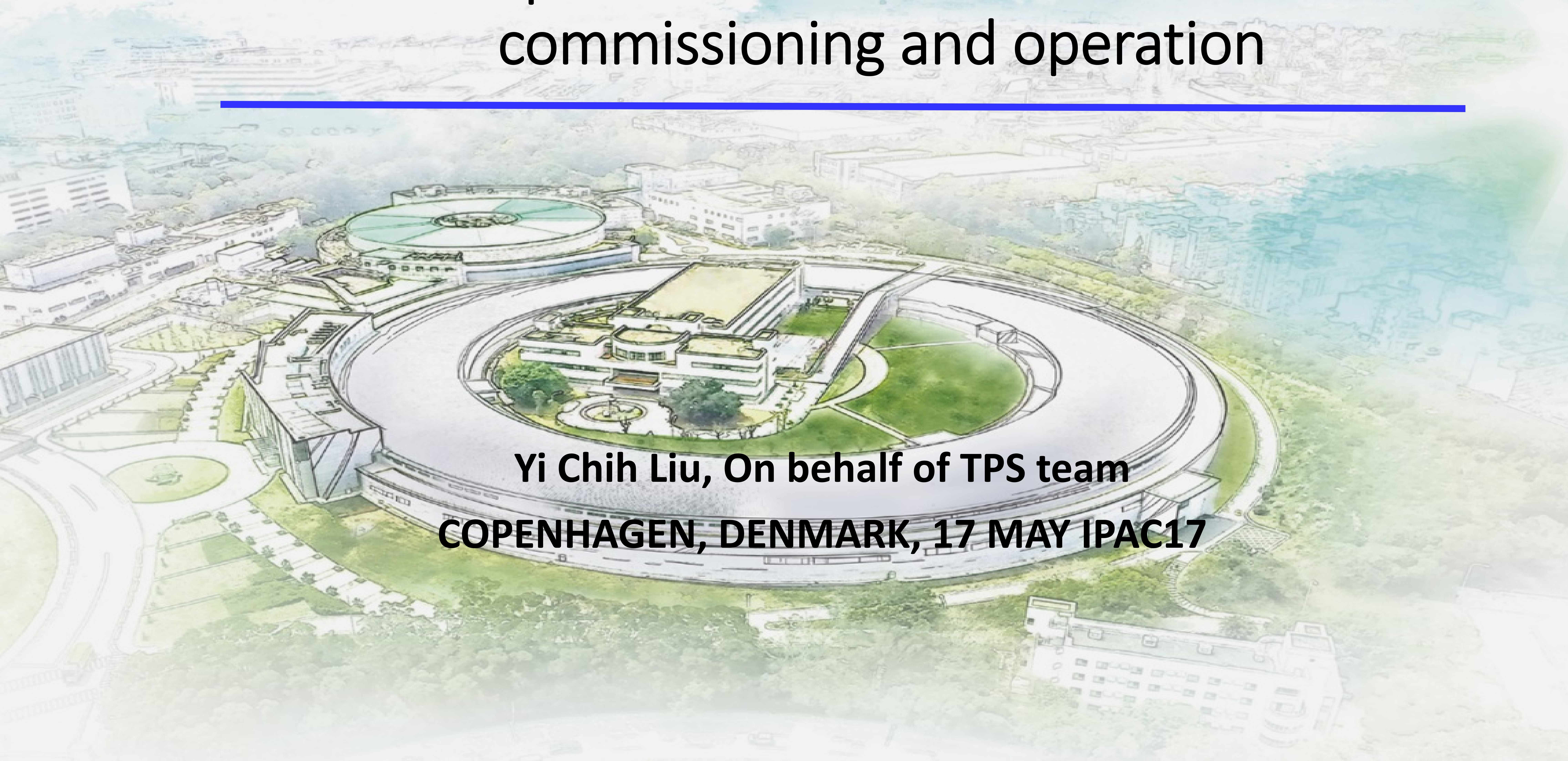
The experience of Taiwan Photon Source commissioning and operation



Yi Chih Liu, On behalf of TPS team

COPENHAGEN, DENMARK, 17 MAY IPAC17

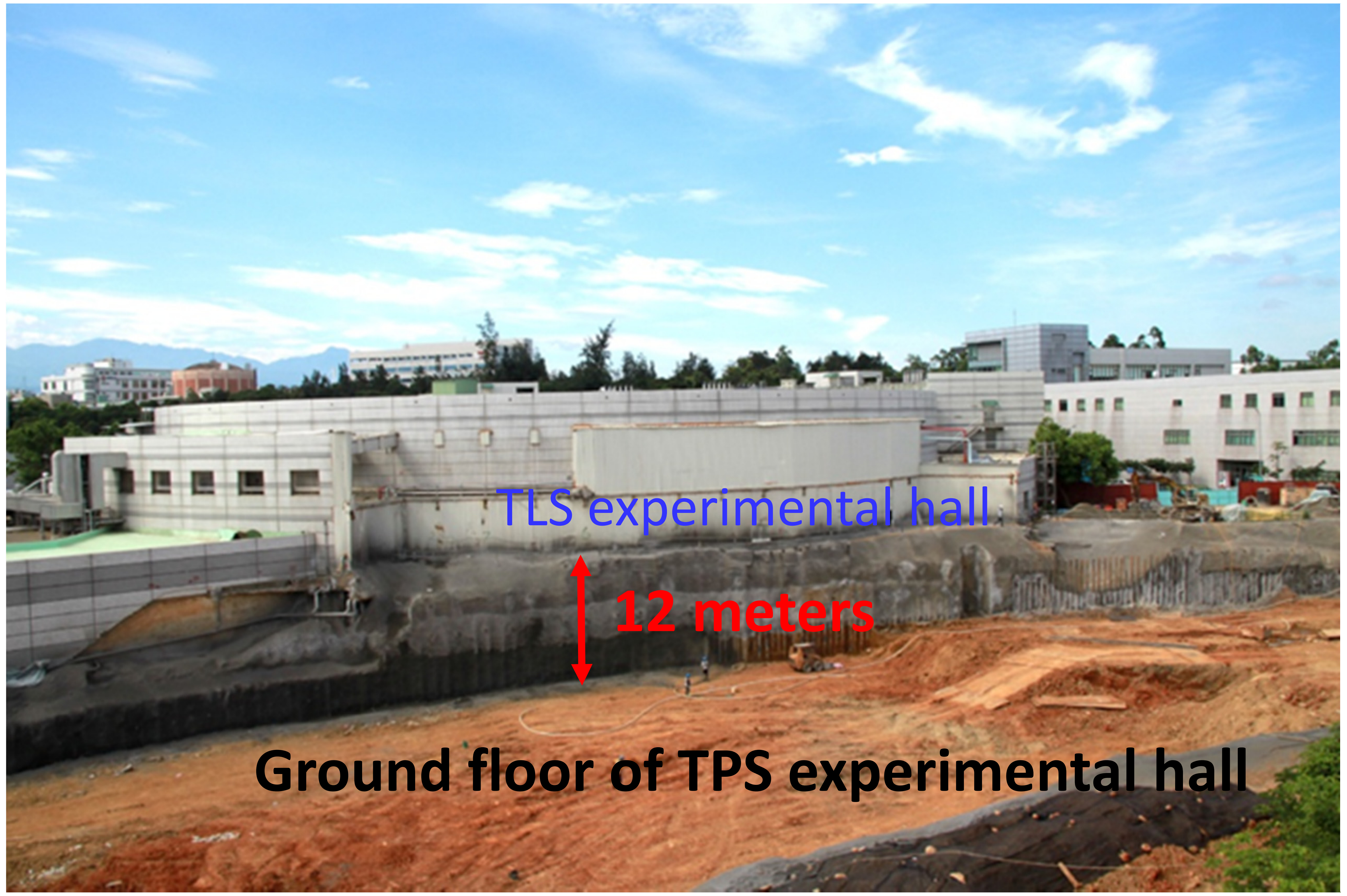
Outline

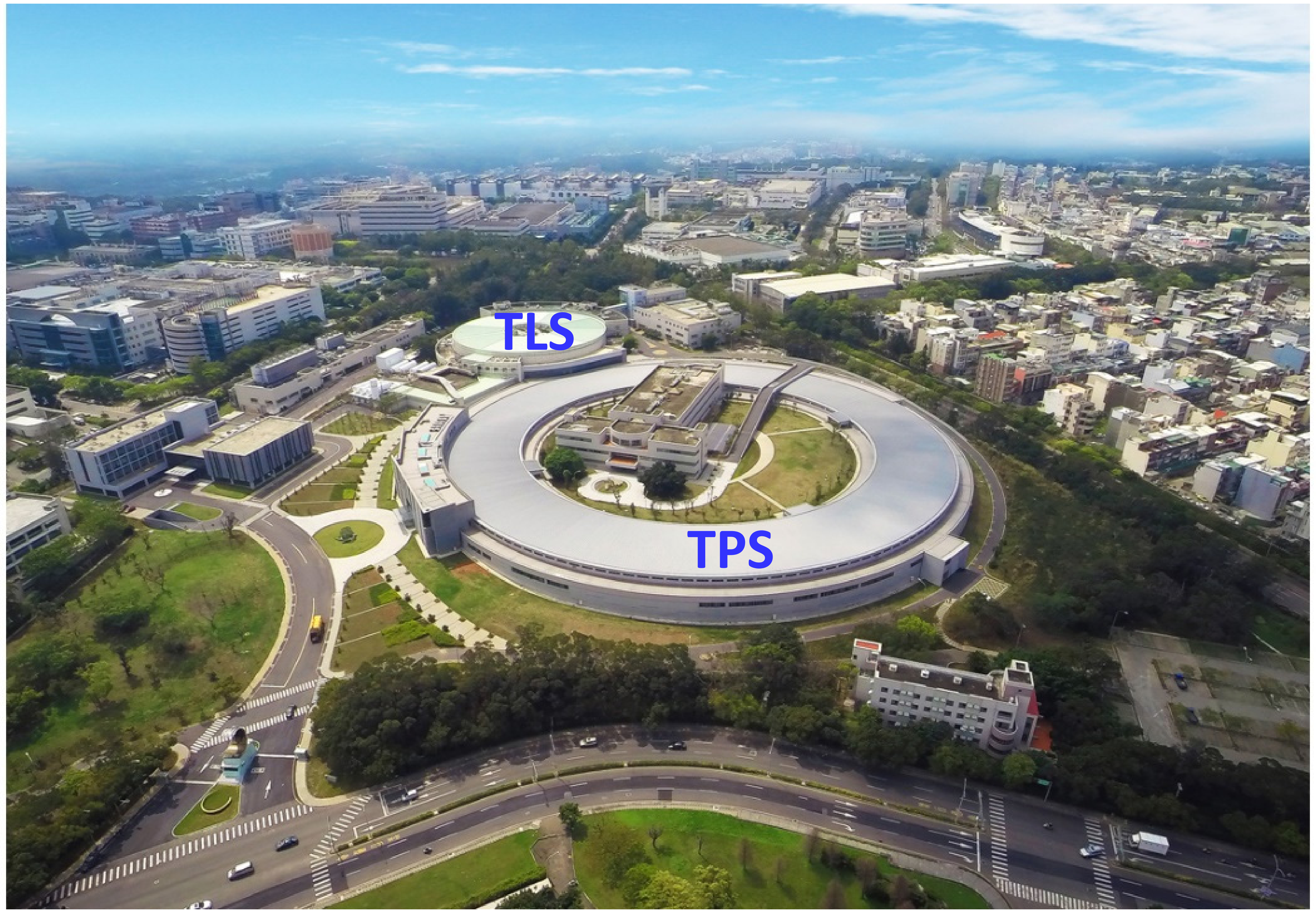
- Overview of TPS
- TPS commissioning experience
- TPS user operation
- Discussion

Milestone of TPS

- Started accelerator installation in Oct. 2013
- Started System test and booster beam commissioning in Aug. 2014
- Stored beam and first light in storage ring on 31 Dec. 2014
- Completed phase I commissioning (35 A‧H vacuum cleaning) in Apr. 2015
- Achieved 520 mA stored beam in Dec. 2015
- Started pilot run (150 mA top-up) for beamline commissioning in Mar. 2016
- Started 300 mA top-up operation in May 2016
- Opened to general users in Sep. 2016

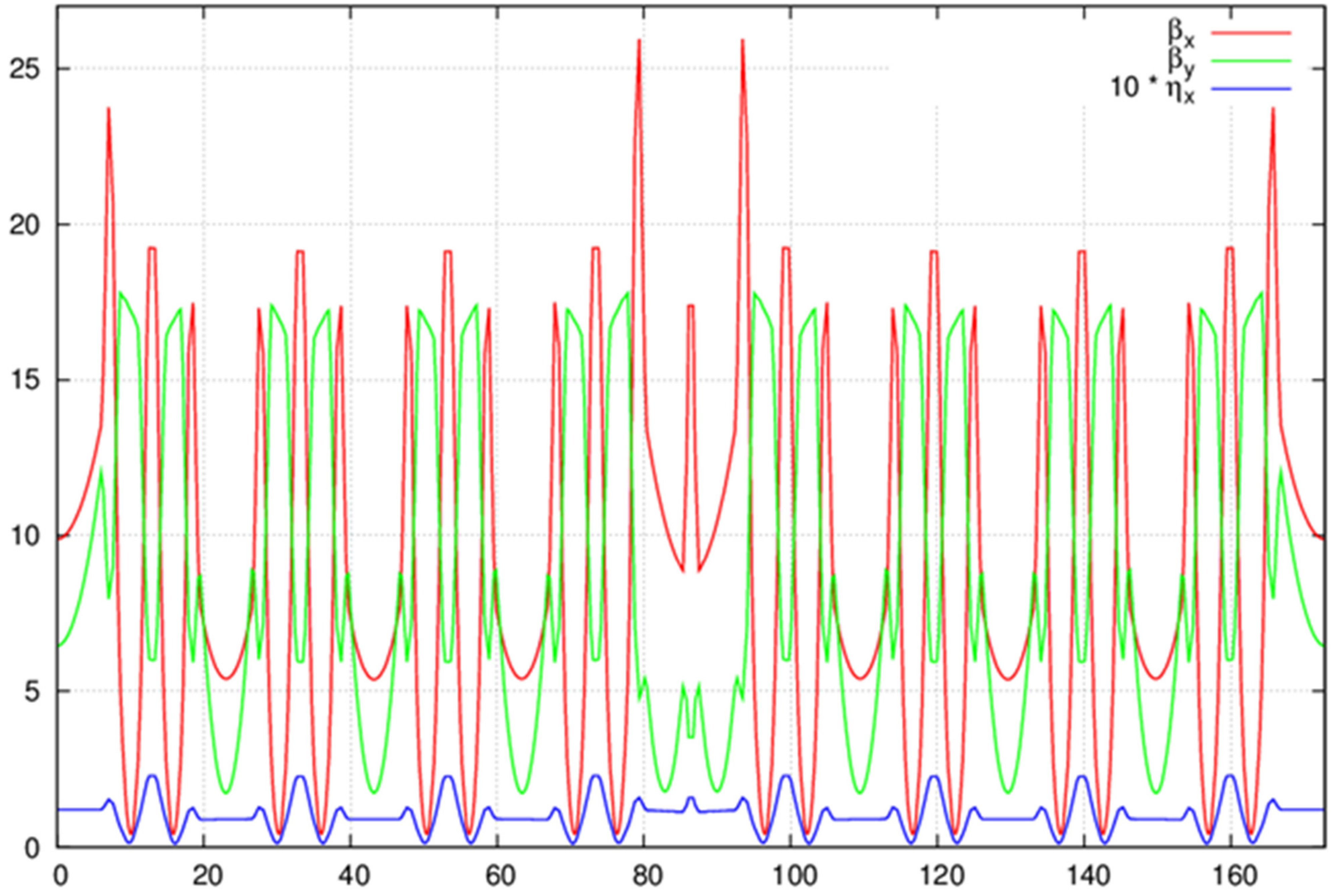
The change of NSRRC campus





Storage ring parameters

Energy (GeV)	3
Current (mA)	500
Periodicity	6
Straight section (m)	18 x 7 + 6 x 12
Bare lattice emittance (nm-rad)	1.6
Betatron tune (ν_x/ν_y)	DMB 26.18 / 13.28 Bare lattice (24.18/14.24)
Natural chromaticity ξ_x/ξ_y	-75/-26
Circumference (m)	518.4
Bending radius (m)	8.40338
Natural energy spread	8.86×10^{-4}
Momentum compaction α_1/α_2	$2.4x10^{-4}/2.1x10^{-3}$
Revolution frequency (kHz)	578.3
RF frequency (MHz)	499.654
Harmonic number	864
Synchrotron tune	0.00609
Bunch length (mm)	2.86

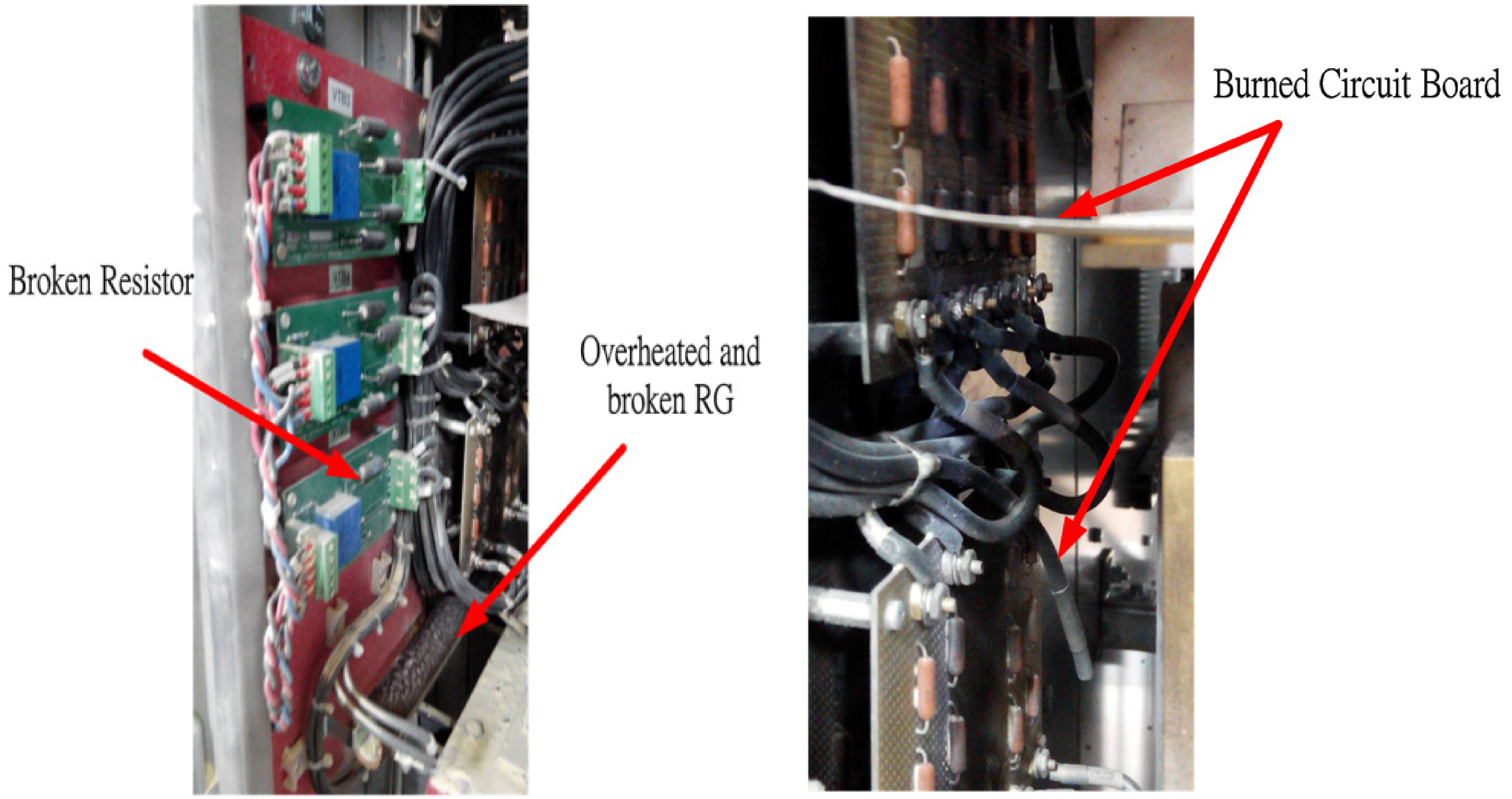


Double Minimum Beta Y lattice
Two IDs sited in the 12-meter long straight section

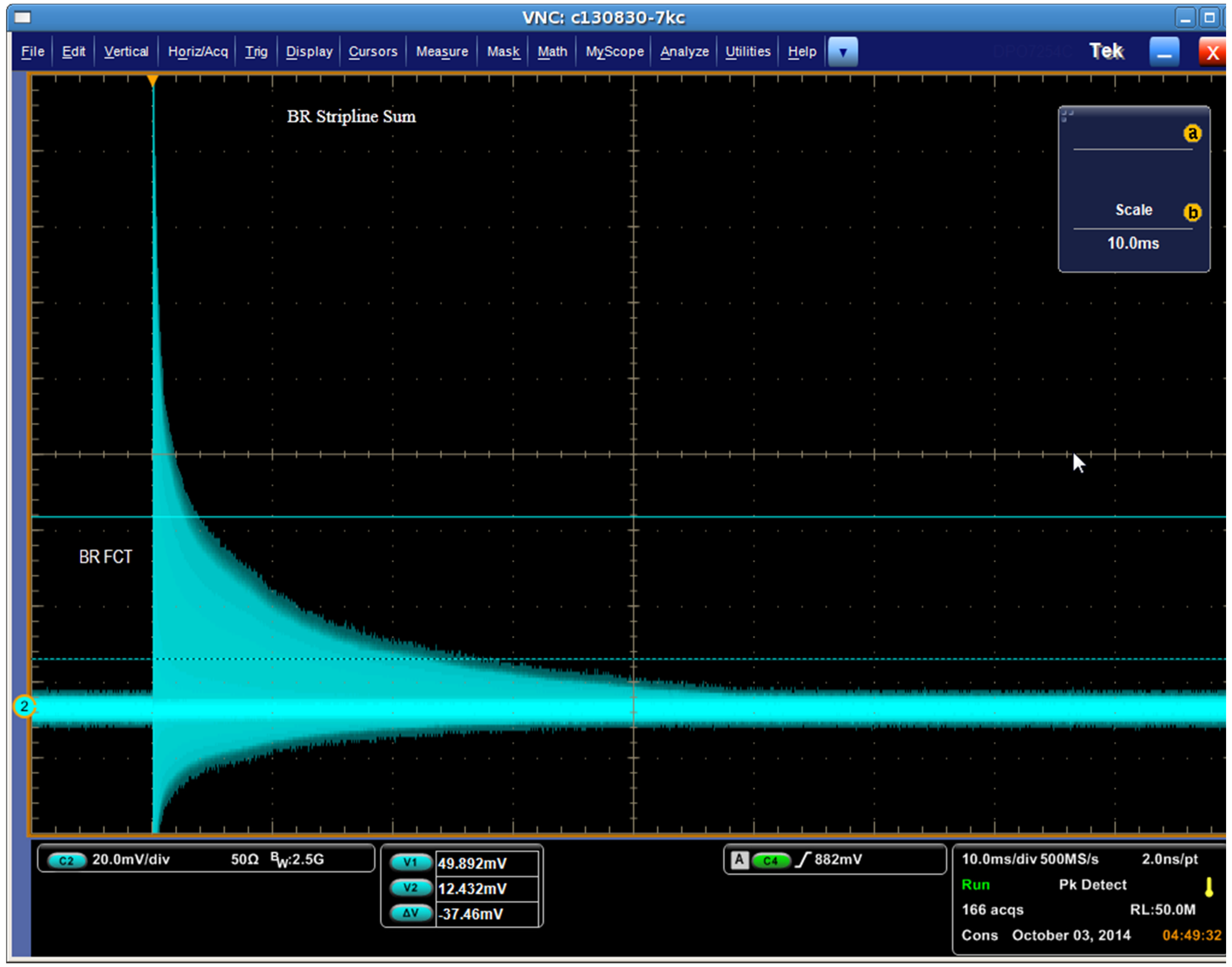
TPS 09A
TPS 25A

TPS 41A

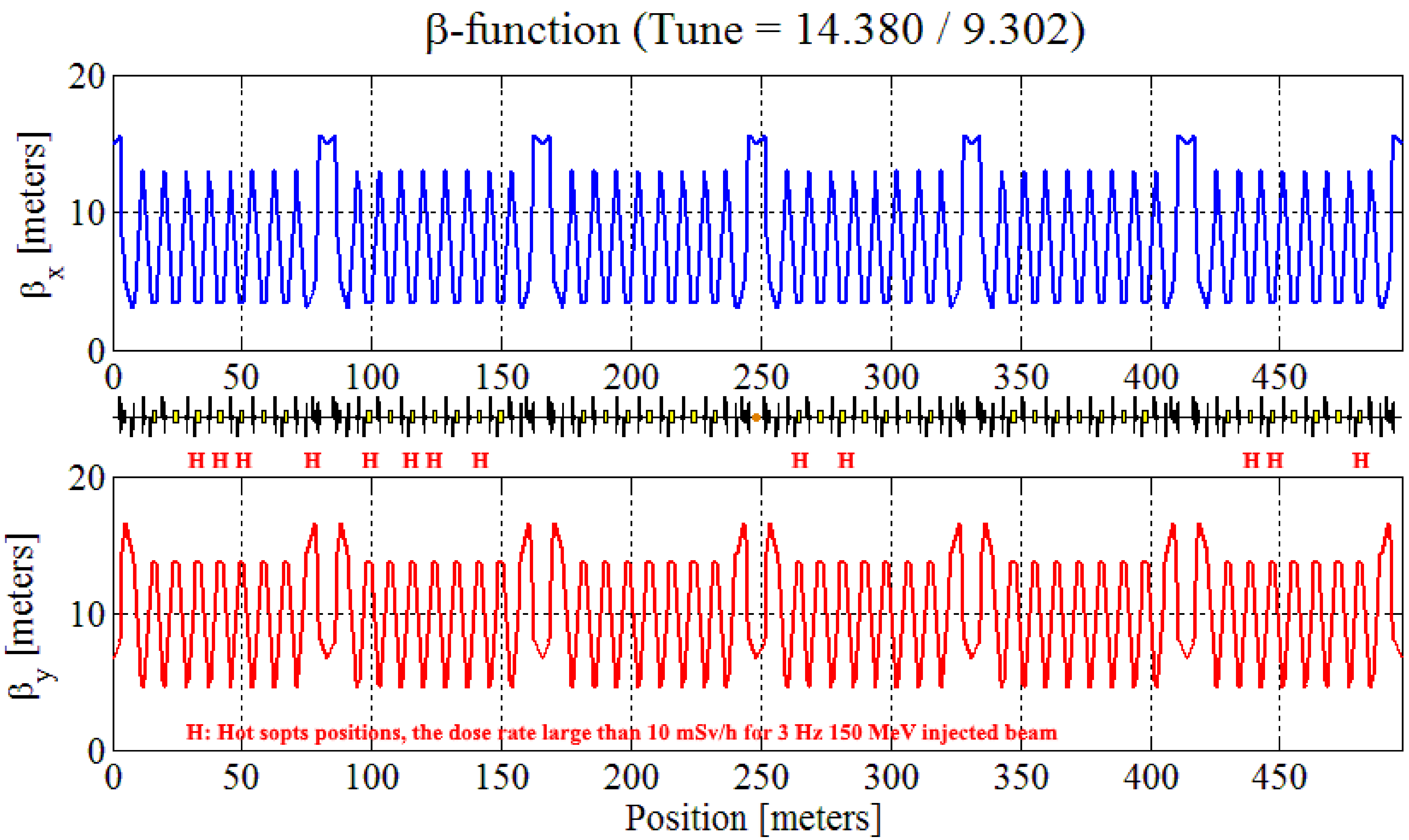
The first day of booster commissioning



Struggled booster commissioning in next three months



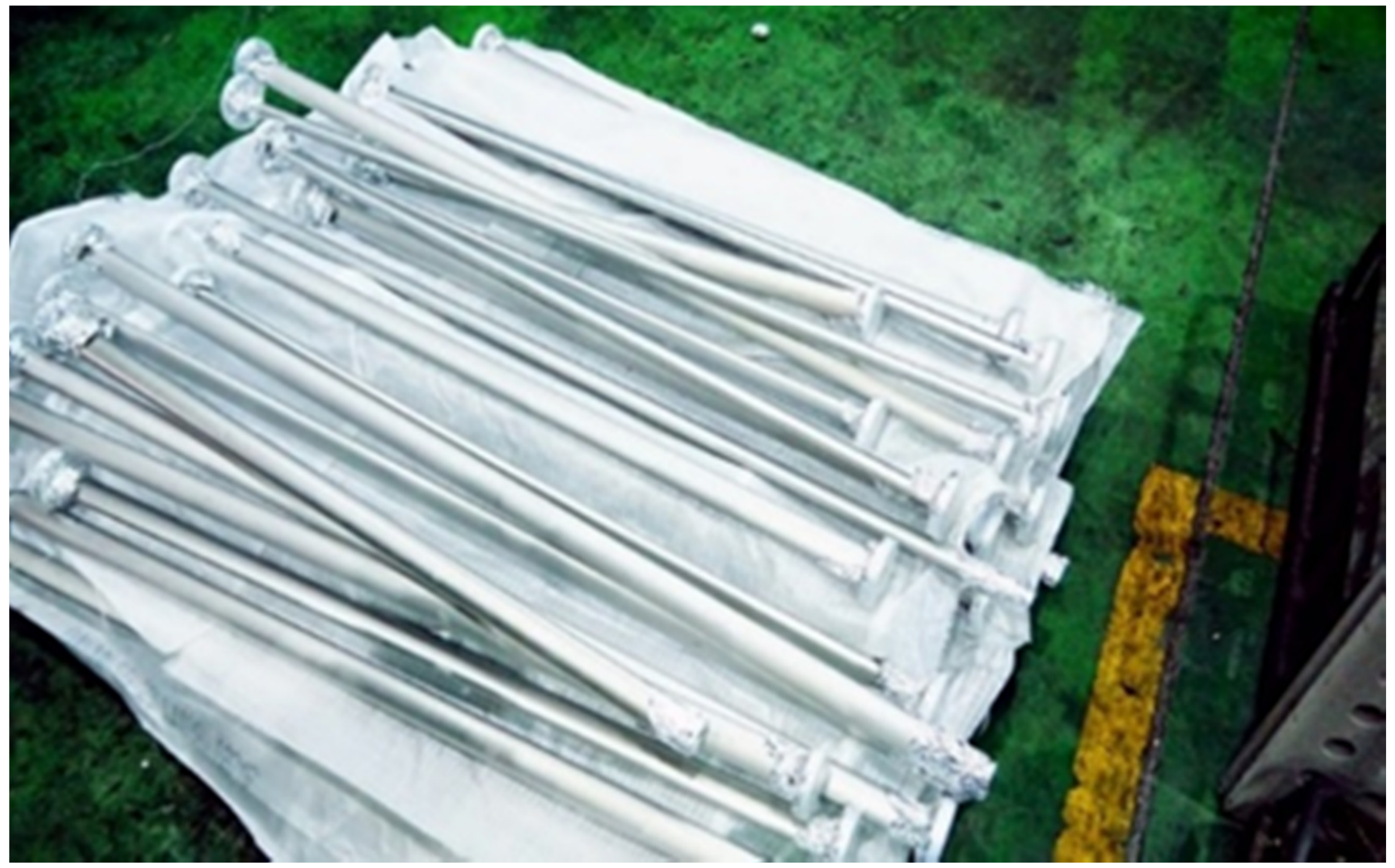
No stored beam



Random radiation hot spots in the location of combined function dipole

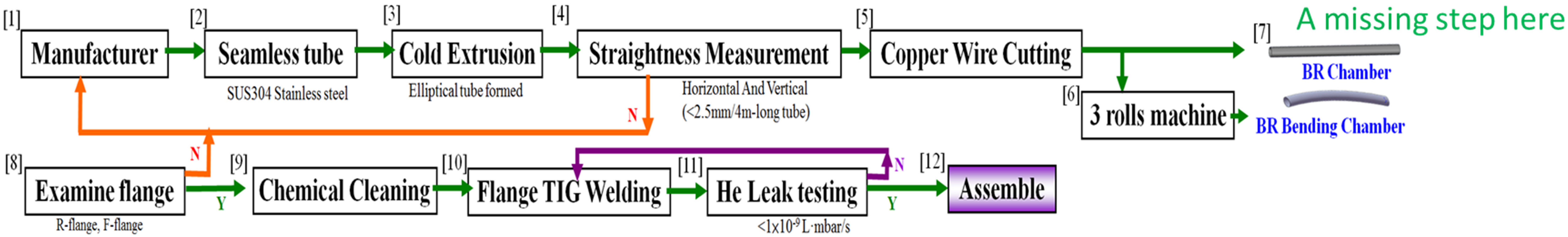
The vacuum chamber had magnetism

Found the problem



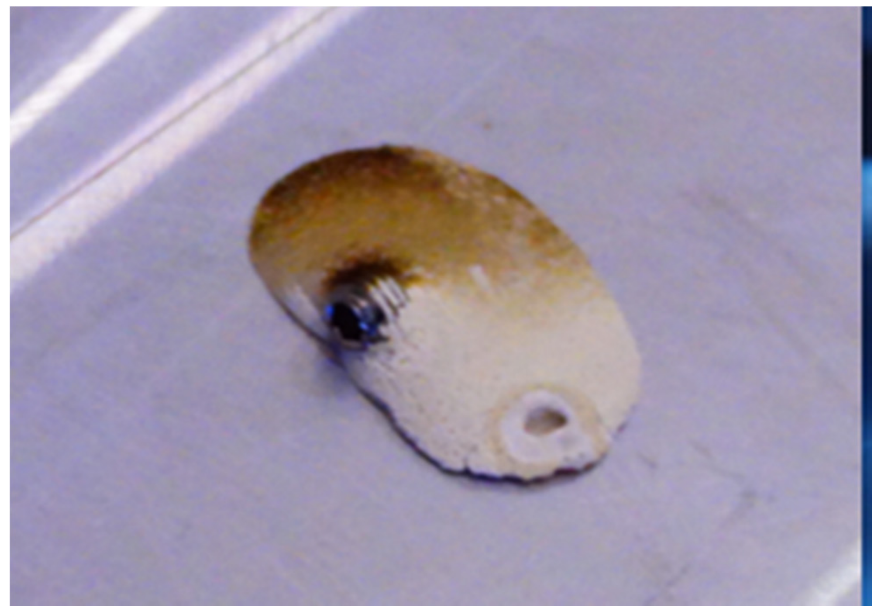
cut vacuum chamber to fit the furnace

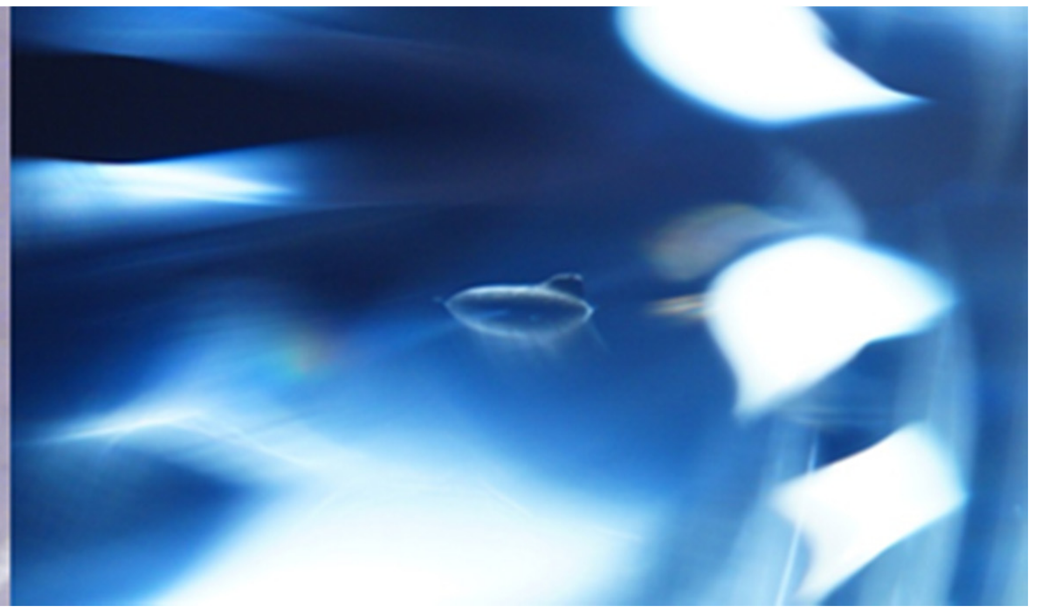
TPS project director sighed with relief after demagnetizing the vacuum chamber



The contamination of cell 02 vacuum chamber

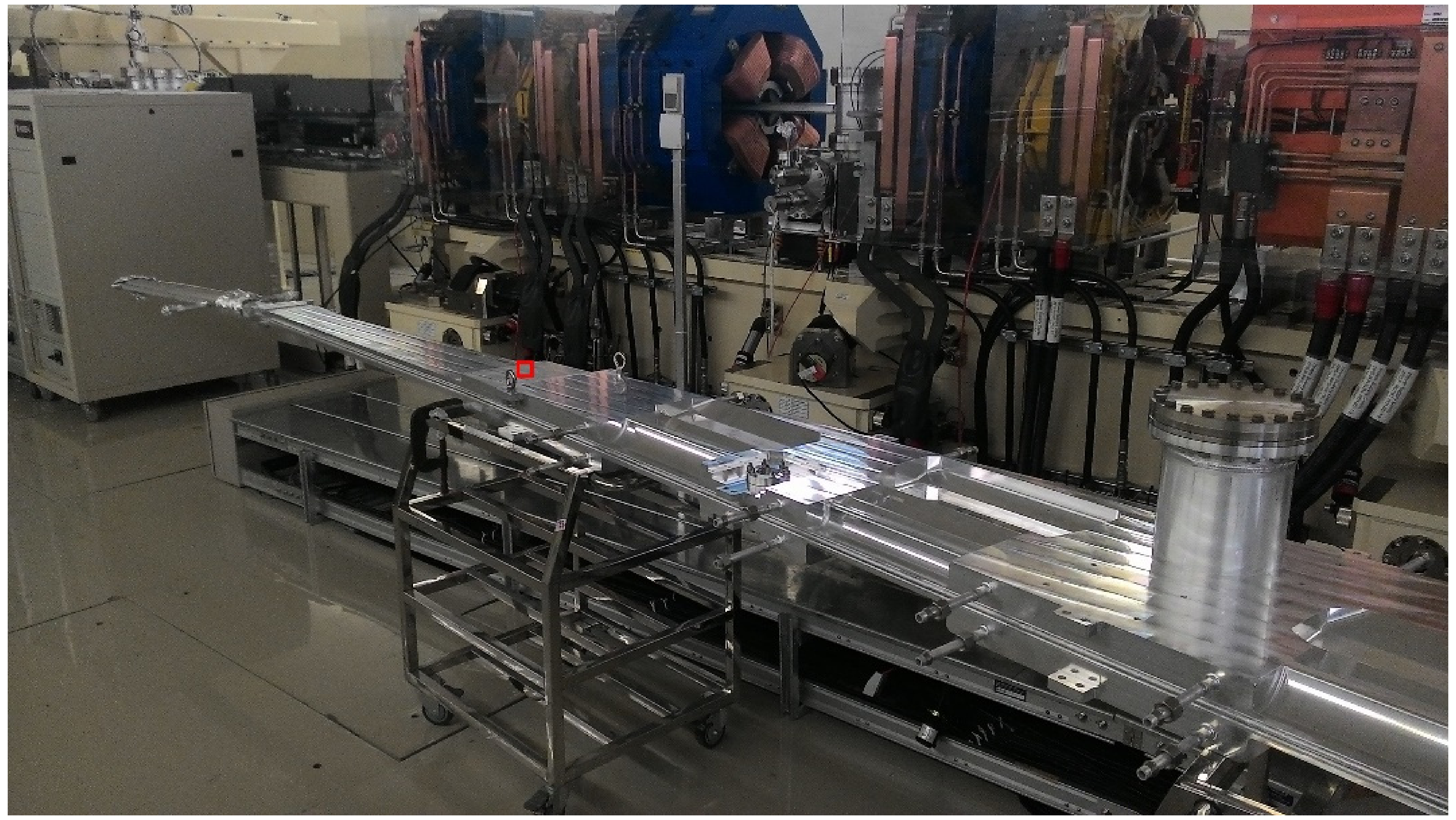
https://www.youtube.com/watch?v=eae-oWT9hqg



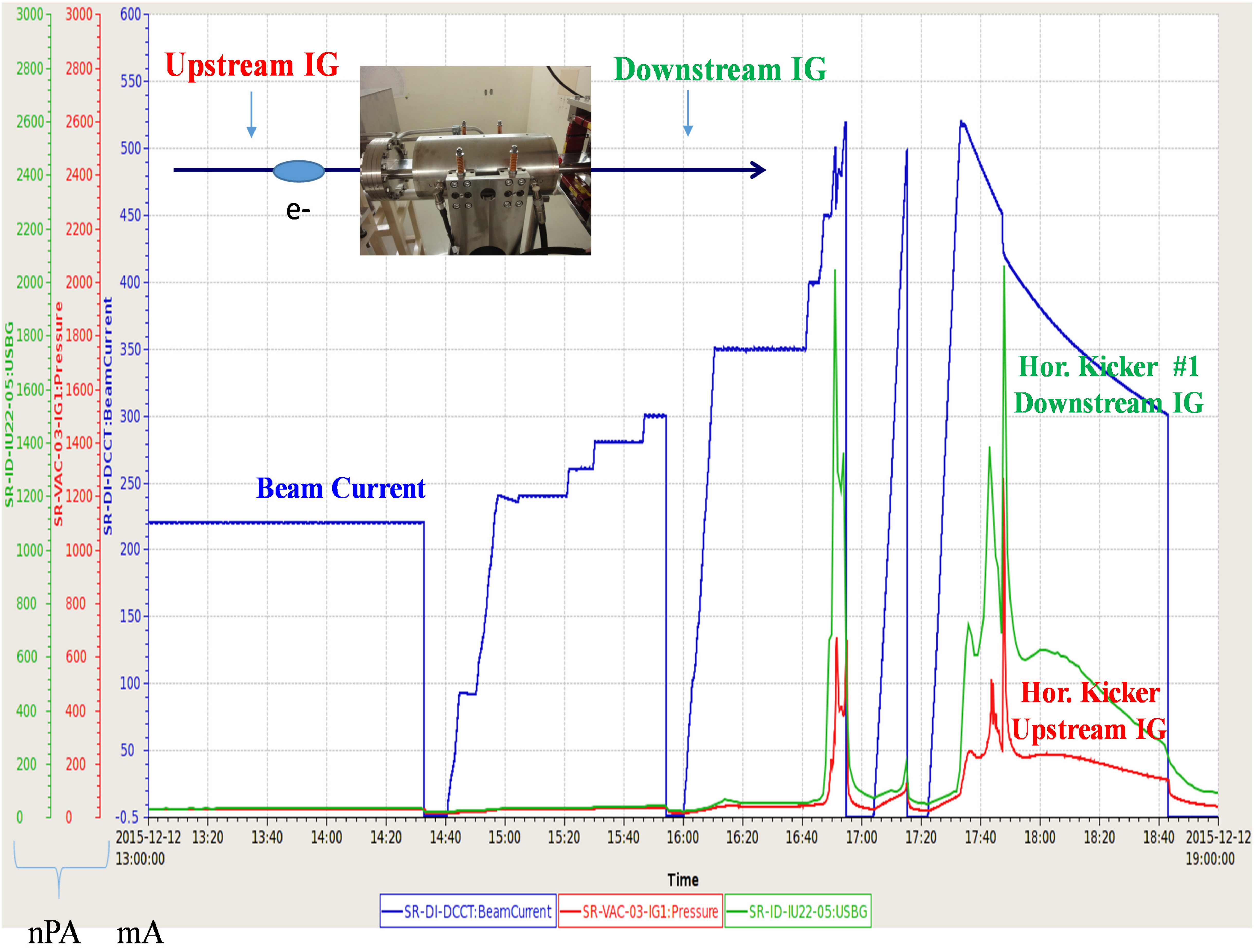


The PVC pad with a screw

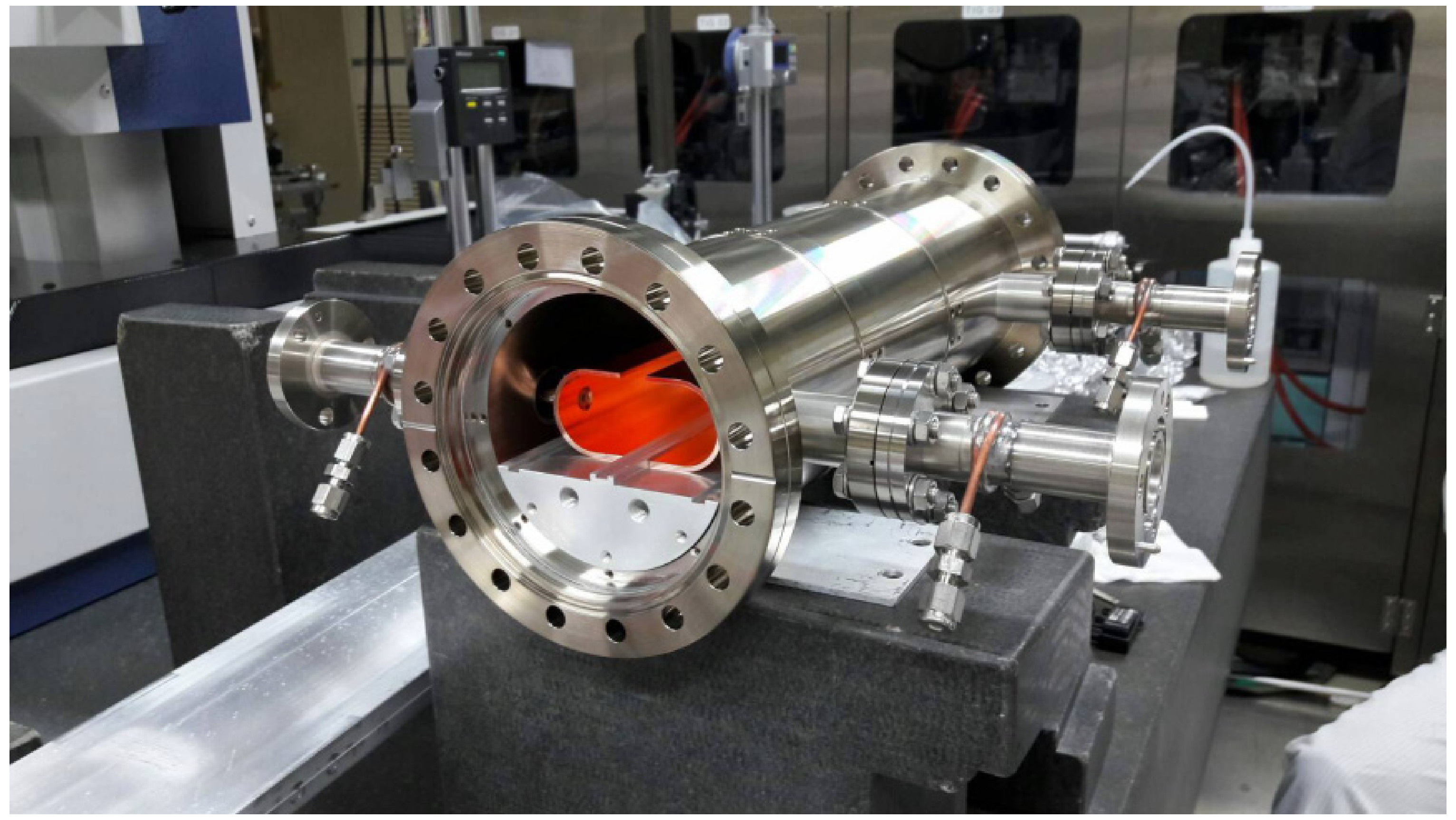
The position of the pad inside the vacuum chamber



Vacuum burst in stripline kicker



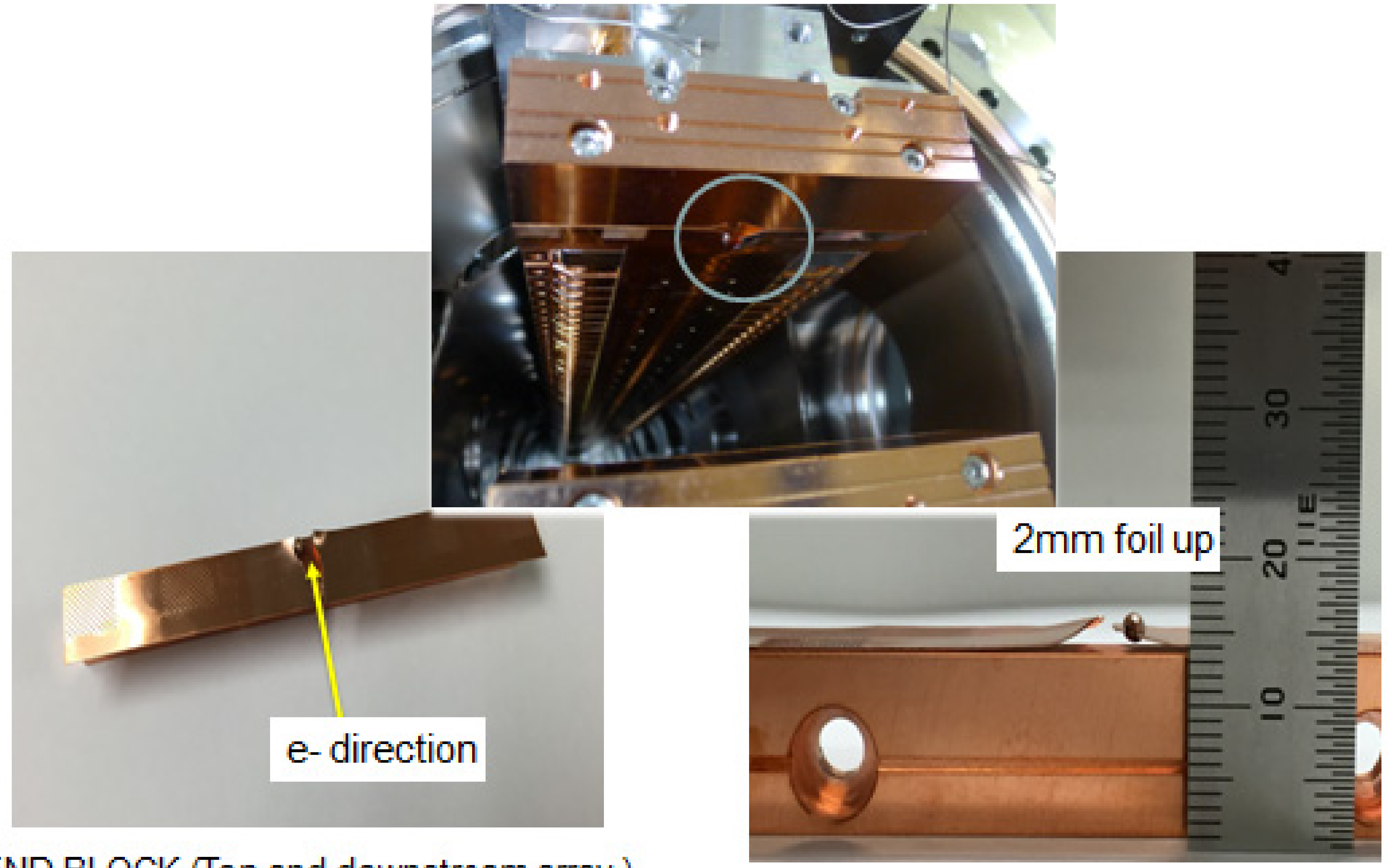
The heating problem will be obstacle for high current operation



New stripline kicker
Better impedance matching
Smaller loss factor

TUPIK105

Foil damage of IU22B-09



END BLOCK (Top and downstream array)

Injection to 30 mA
Orbit correction to golden orbit
FOFB and RF feedback on
Orbit interlock on (actual orbit)
IDs gap closed to small gap
Injection to 300 mA

Injection to 30 mA
Orbit correction to reference orbit
Injection to 300 mA
Orbit interlock on (reference orbit)
FOFB and RF feedback on
IDs gap closed to small gap

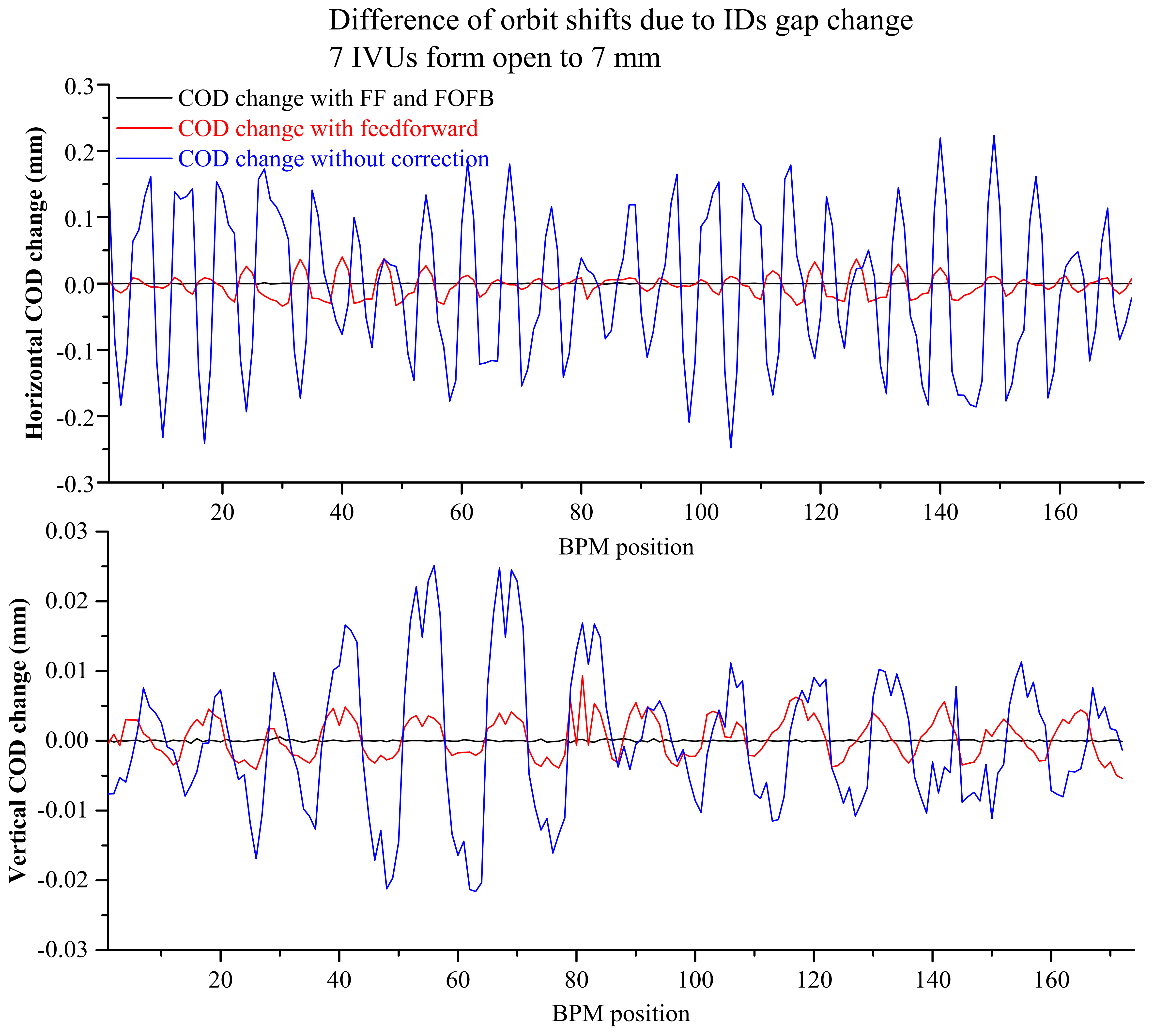
TPS phase I beamlines

Beamline	Beamline name	Type	IDs number	Effective length (m)	Magnet period (mm)	Number of period	Small magnet gap (mm)	Maximum magnetic field (T)	Largest deflection parameter	Range of photon energy (keV)
05A	Protein micro-crystallography	IVU	1	3.08	22	140	7 (5)+	0.76	1.56	5.7-20
09A	Temporally coherent X-ray diffraction	IVU	2	3.08 2.09	22	140 95	7 (5)+ 7	0.76 0.74	1.56 1.52	5.6-25
21A	Submicron X-ray diffraction	IVU	1	3.08	22	140	7 (5)+	0.76	1.56	7-25
23A	X-ray Nano probe	IUV	1	3.08	22	140	7 (5)+	0.76	1.56	4-15
25A	Coherent X-ray scattering	IUV	2	3.08 2.09	22	140 95	7 (5)+ 7	0.76 0.74	1.56 1.52	5.5-20
41A*	Resonant soft X-ray scattering	EPU	2	3.77 3.77	48	68	13 13	V:0.83 H:0.55	V:3.72 H:2.47	0.4-1.2
45A*	Submicron soft X-ray spectroscopy	EPU	1	3.22	46	82	14	V:0.73 H:0.47	V:3.14 H:2.02	0.28-1.5

* Not commissioning

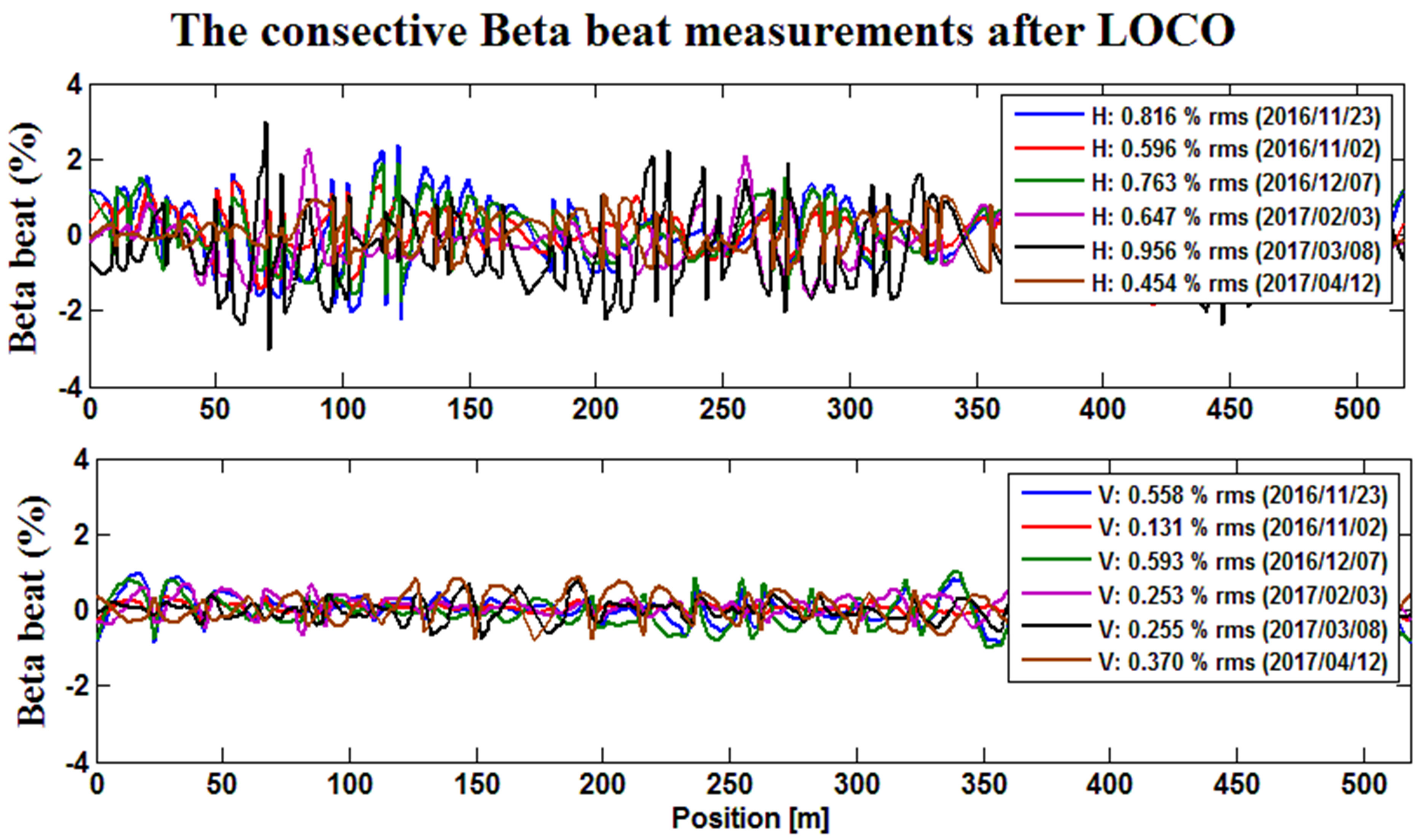
+ Ultimate goal

Difference orbit shift of IVUs



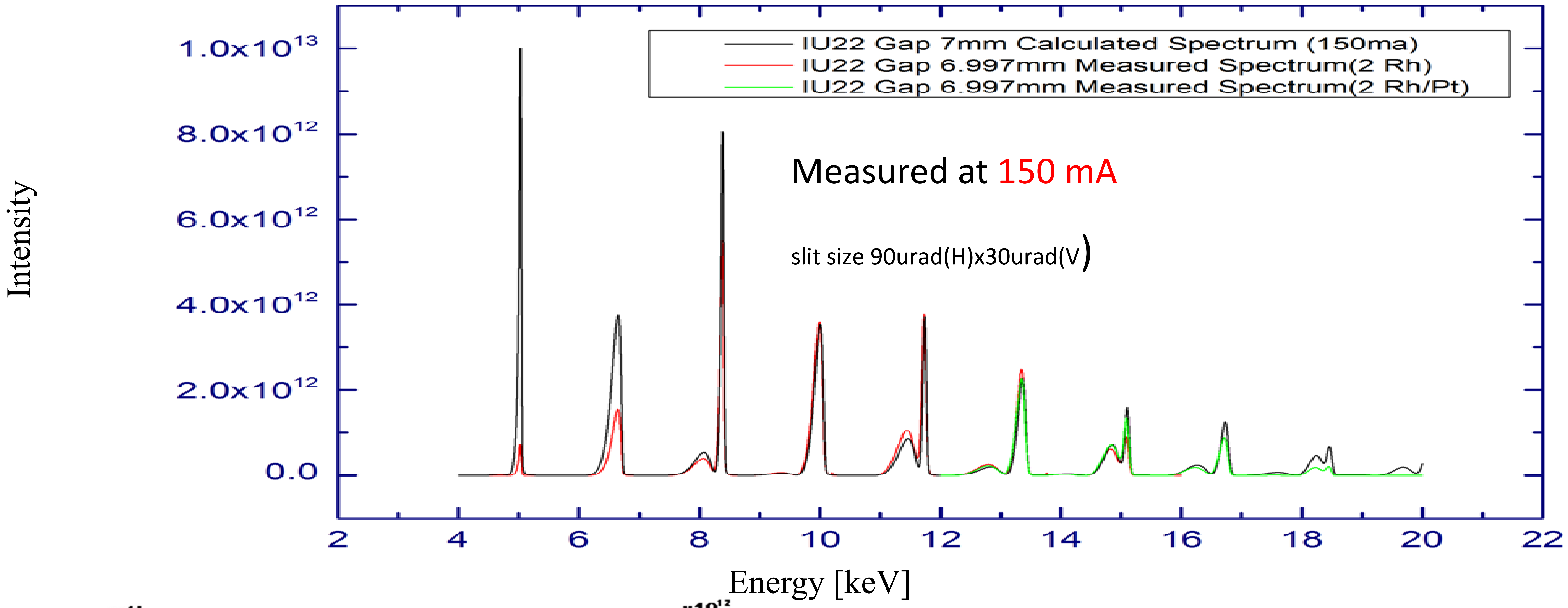
The COD (rms) from insertion devices			
ID name	Ref. (mm)	Min. gap (mm)	X/Y (um)
IU22-05	40	5.6	39/6
IU22A-09	40	5.5	75/6
IU22B-09	40	7	16/5
IUT22-21	40	5.5	10/4
IU22-23	40	5.5	41/15
IU22A-25	40	5.5	41/7
IU22B-25	40	7	18/5
EPU48A	45	13	70/24
EPU48B	45	13	137/29
EPU46	45	14	65/72

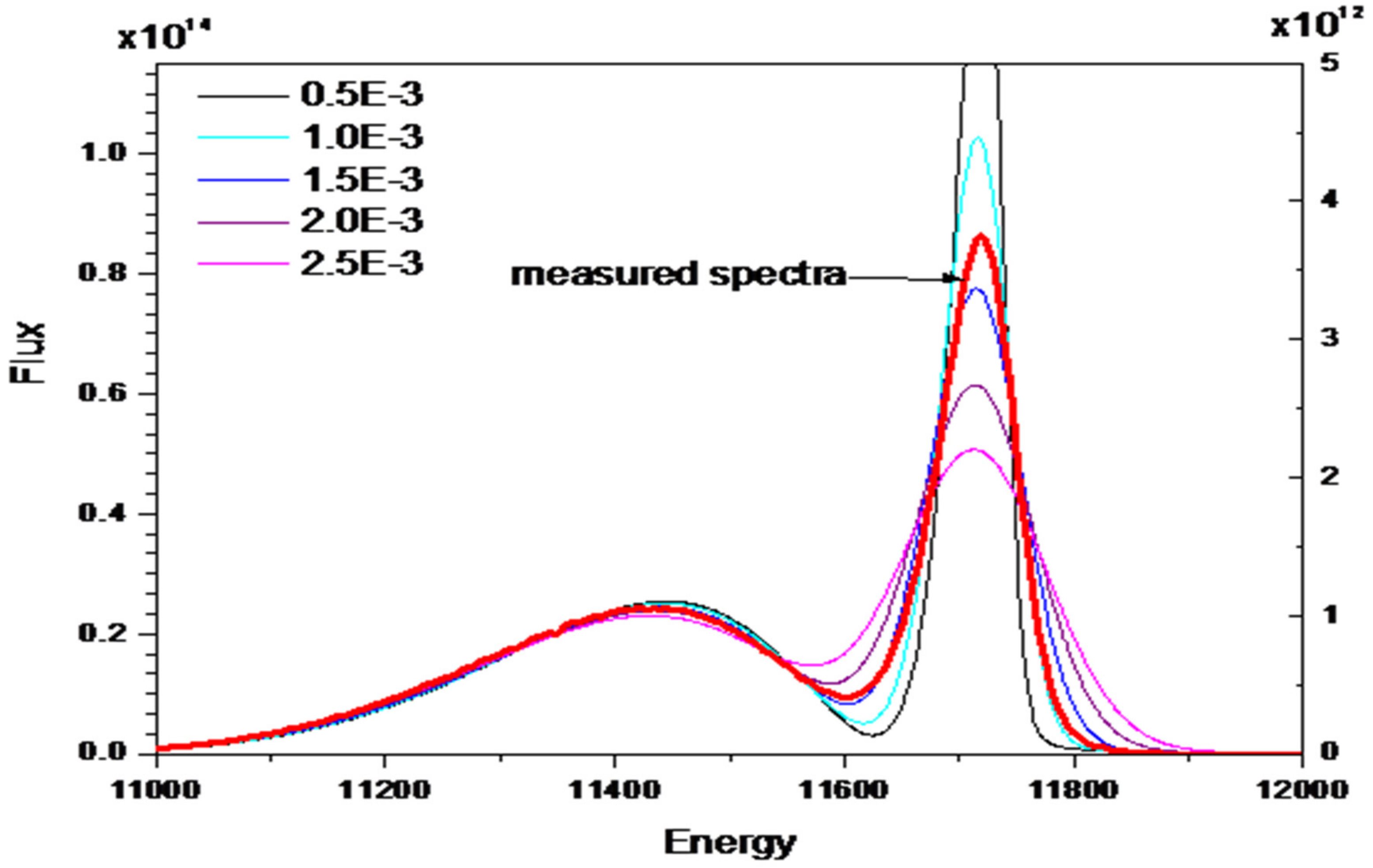
Some basic beam parameters for user operation



- Measured horizontal emittance 1.64 nm·rad for bare lattice
- Chromaticity are (3.7, 2.1), both horizontal and vertical stripline kicker for bunch-by-bunch feedback
- X-ray pinhole photon beam size from bending magnet σx = 57 um σy = 34 um, the related electron beam size σx = 46 um σy = 17 um
- Electron beam size σx = 121 um σy = 5 um for 7 m straight section , σx = 165 um σy = 10 um for 12 m straight section
- The FOFB bandwidth is around 250 Hz for horizontal plane and 300 Hz for vertical plane

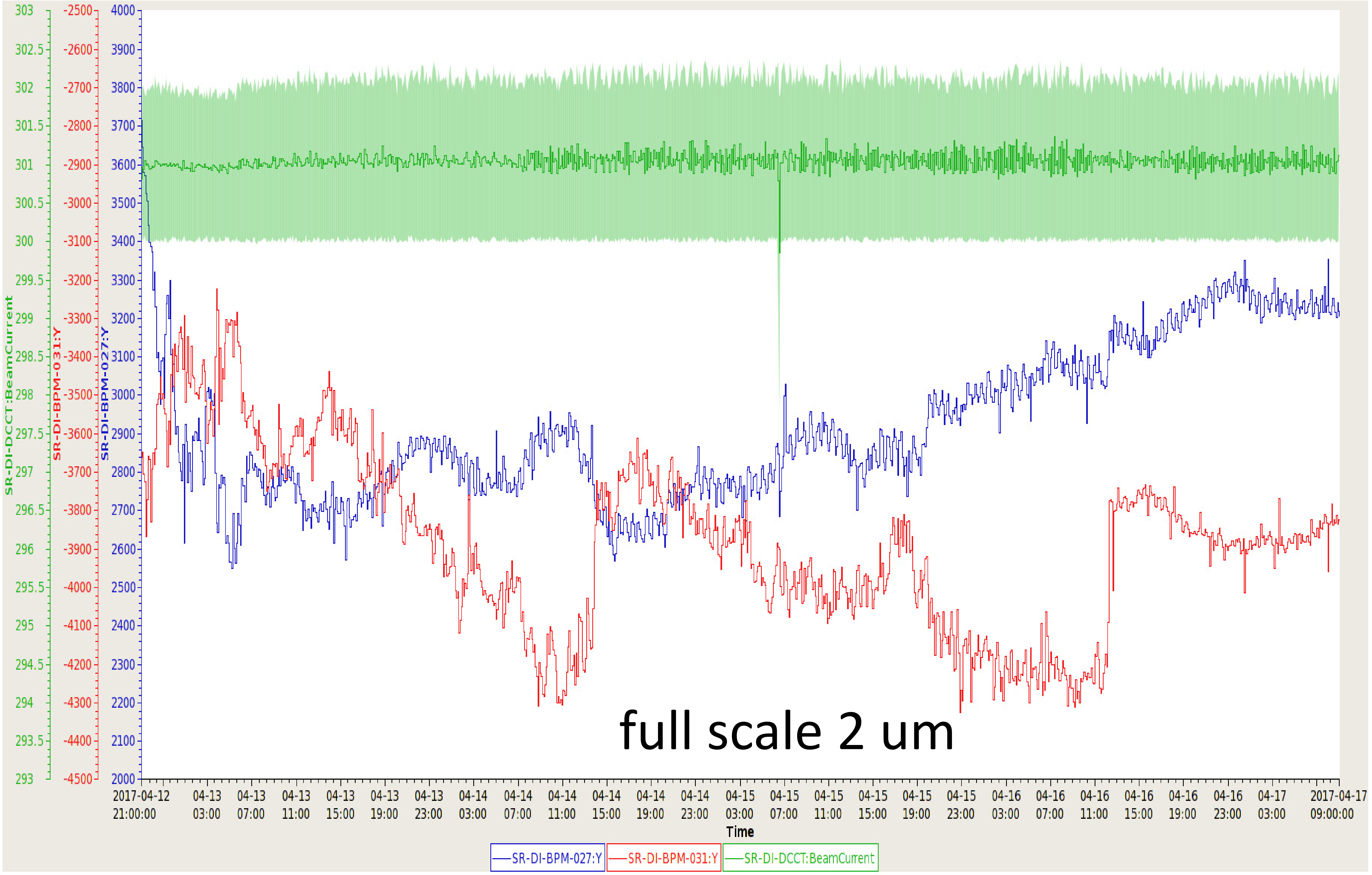
TPS 05A spectrum

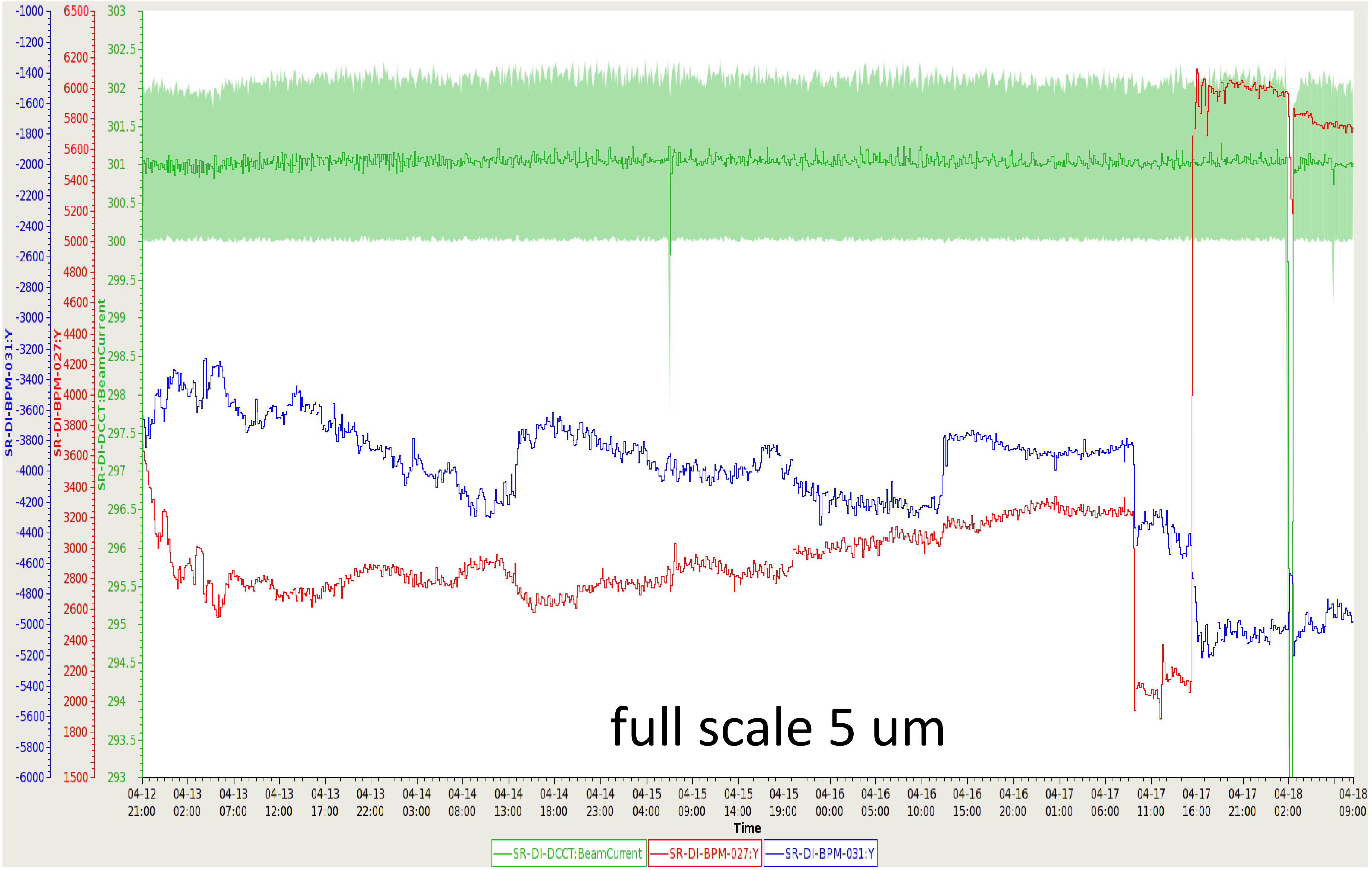




The measured spectra shows 1.3e-3 energy spread @ 7th harmonics

TPS05A vertical orbit stability (σy=5 um)



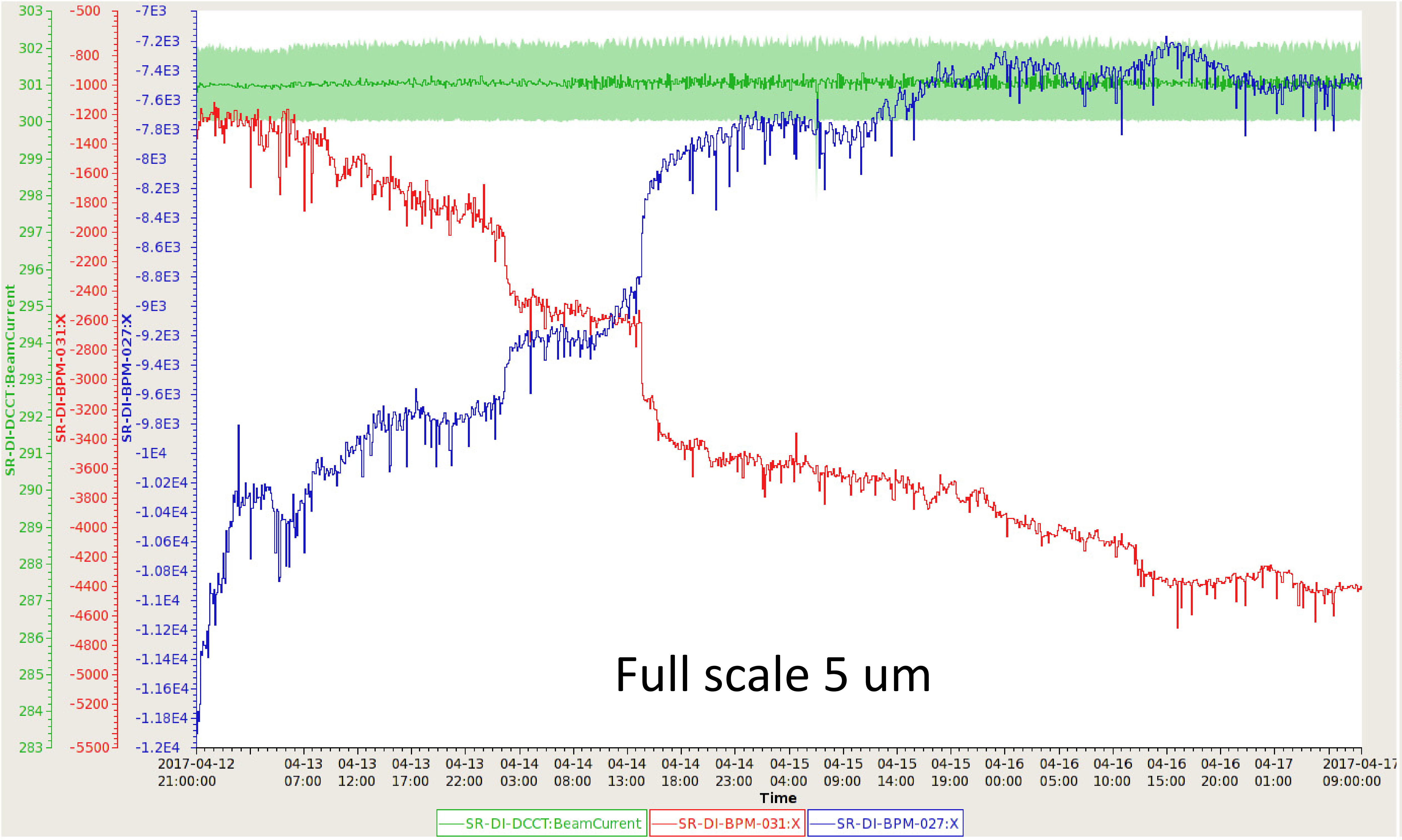


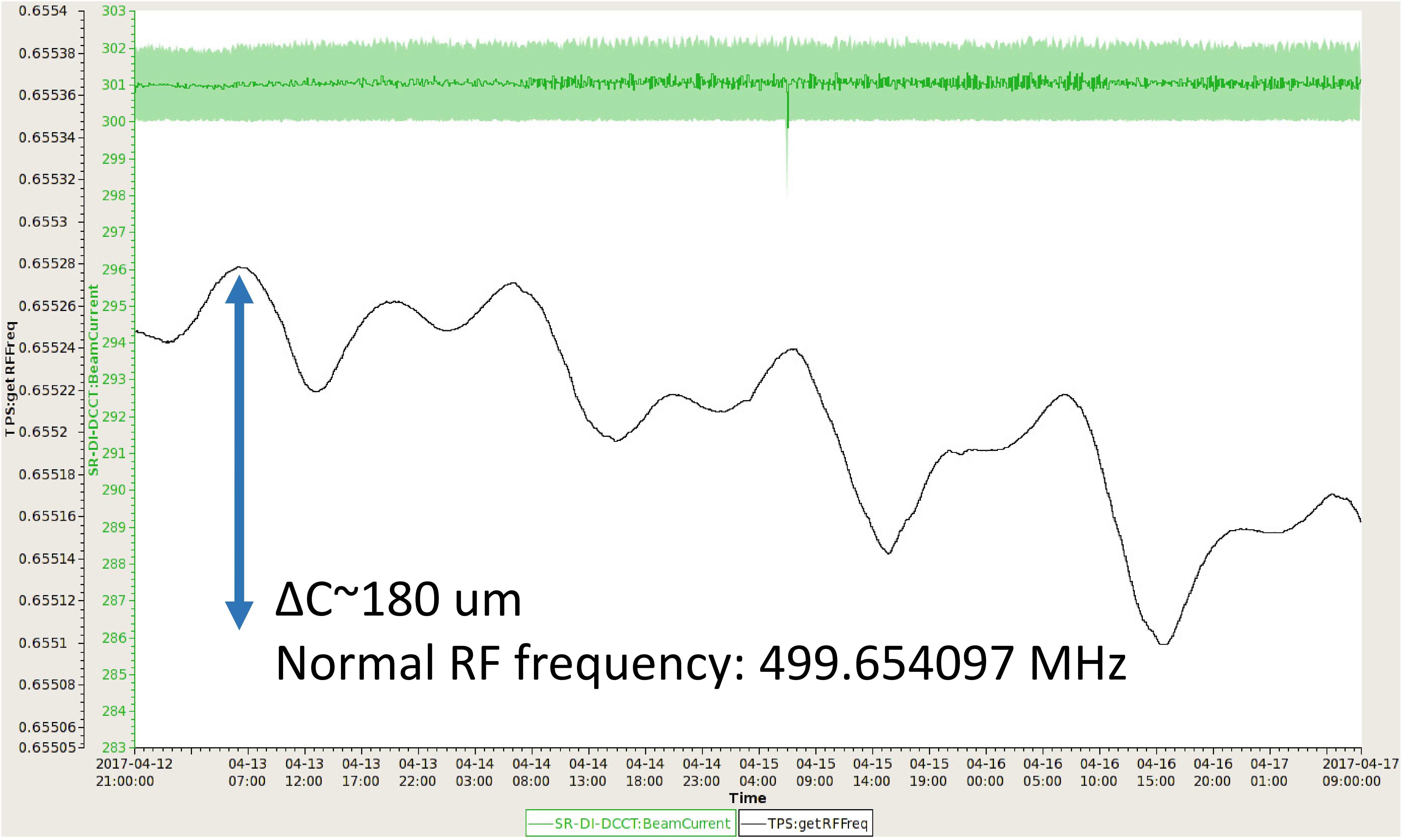
Normal case

0.1 Hz archived data

Worse case

TPS05A horizontal orbit stability (σx=121 um)



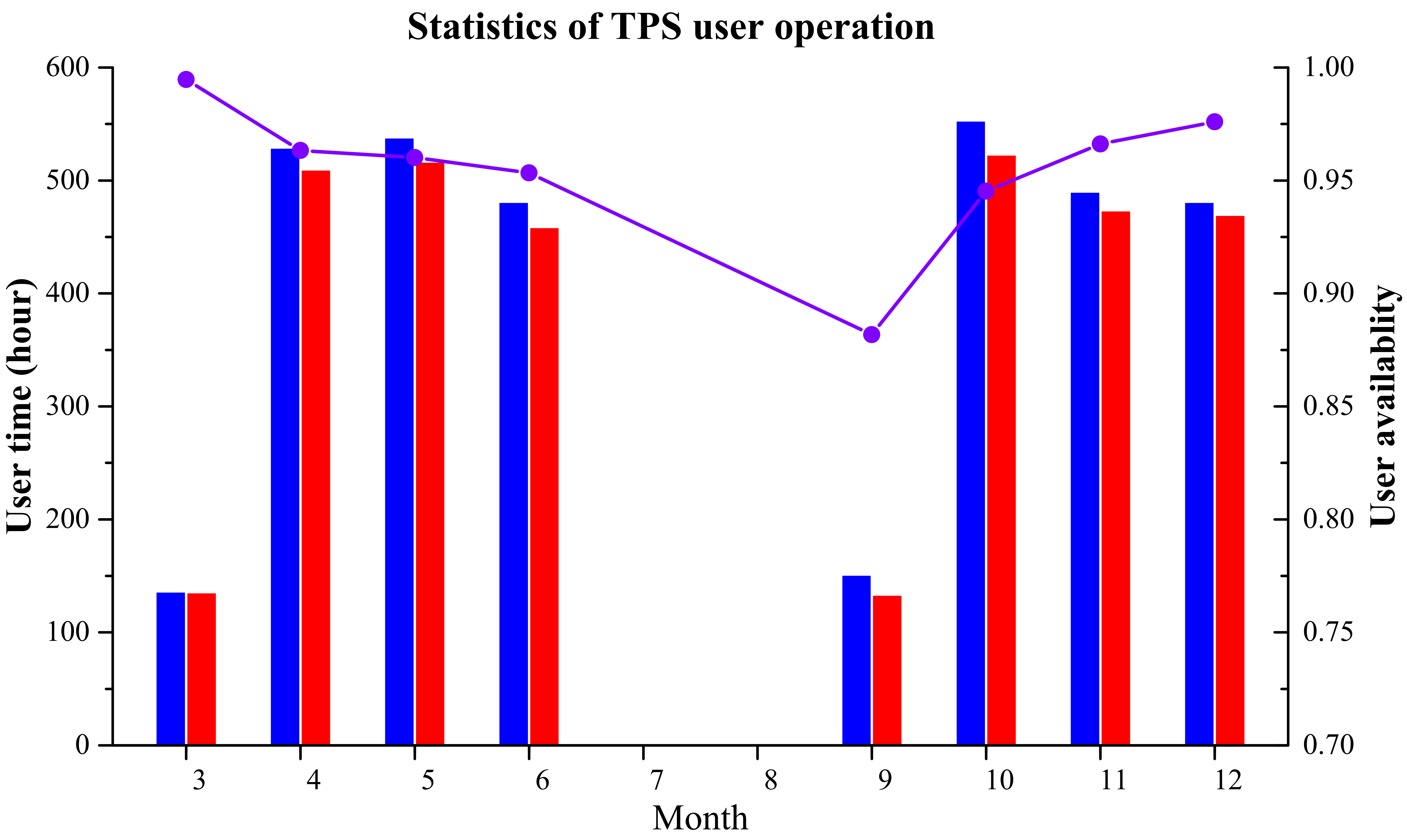


TUPAB103

The FOFB bandwidth is around 250 Hz for horizontal plane and 300 Hz for vertical plane

The RF frequency feedback uses the inverse dispersion matrix @ 0.1 Hz

TPS user availability in 2016

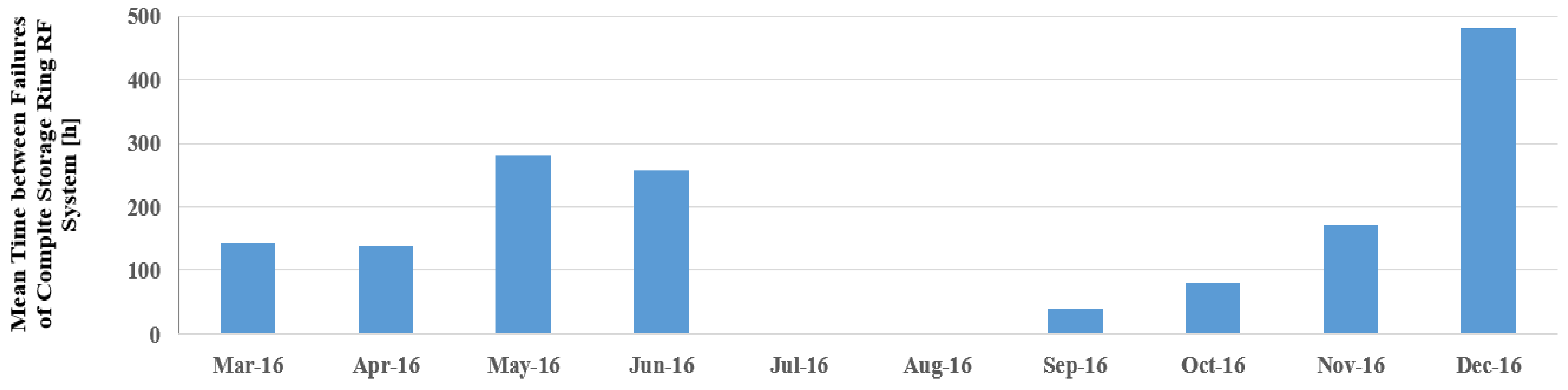


Scheduled user time: 3351 hours
Delivered user time: 3210 hours
Availability: 95.8 %
MTBF: 53.2 hours
MTTR: 2.15 hours
Total trips: 64

Failure categories

Magnet	5
MPS (vacuum)	1
MPS (beamline & FE)	9
MPS (orbit interlock)	5
Pulser	4
RF	17
I&C	6
OP	2
PS	7
Other (Earthquake)	2
Other (Voltage dip)	2
Other (EMI-induced kicker miss-fire)	4

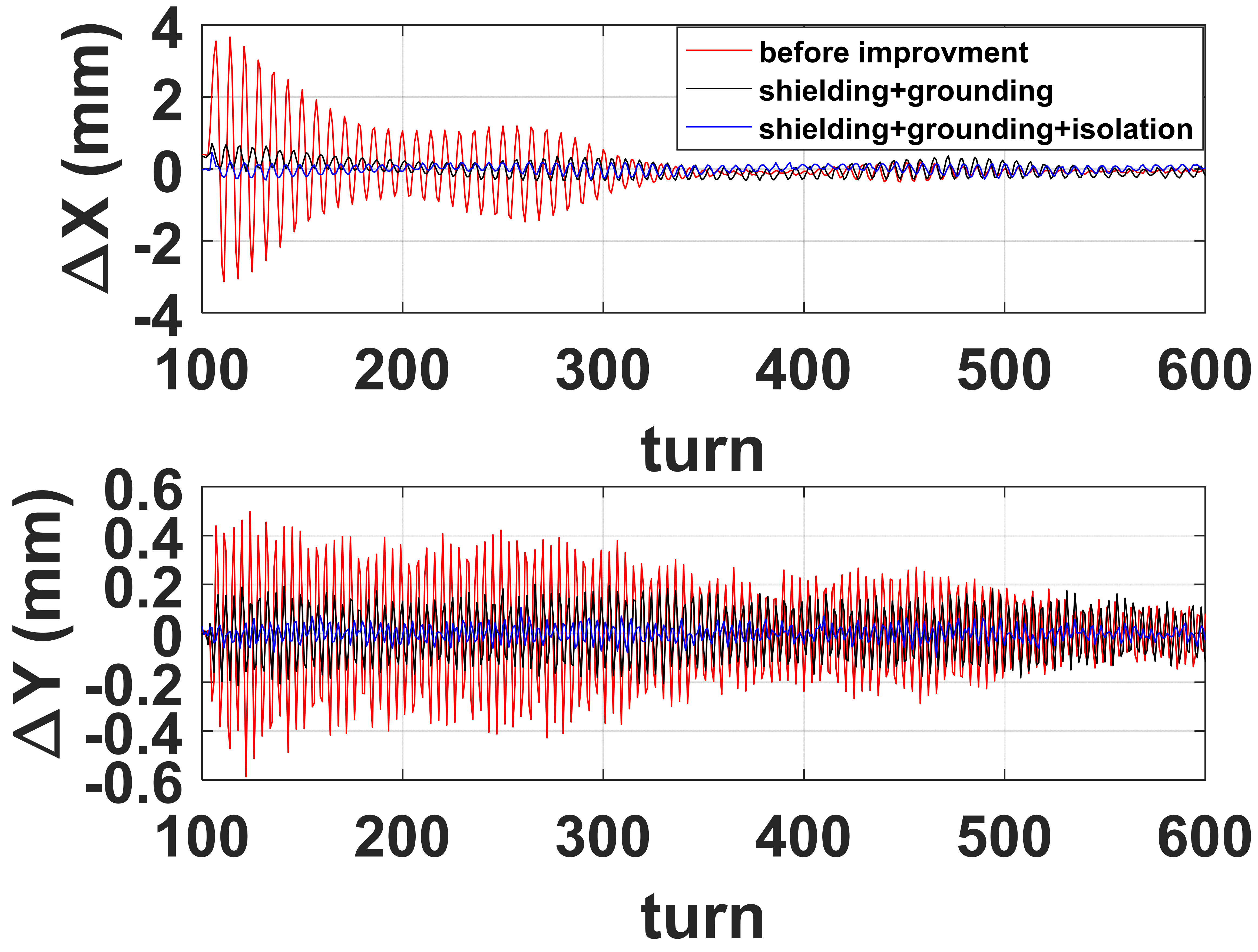
Experience of SRF operation



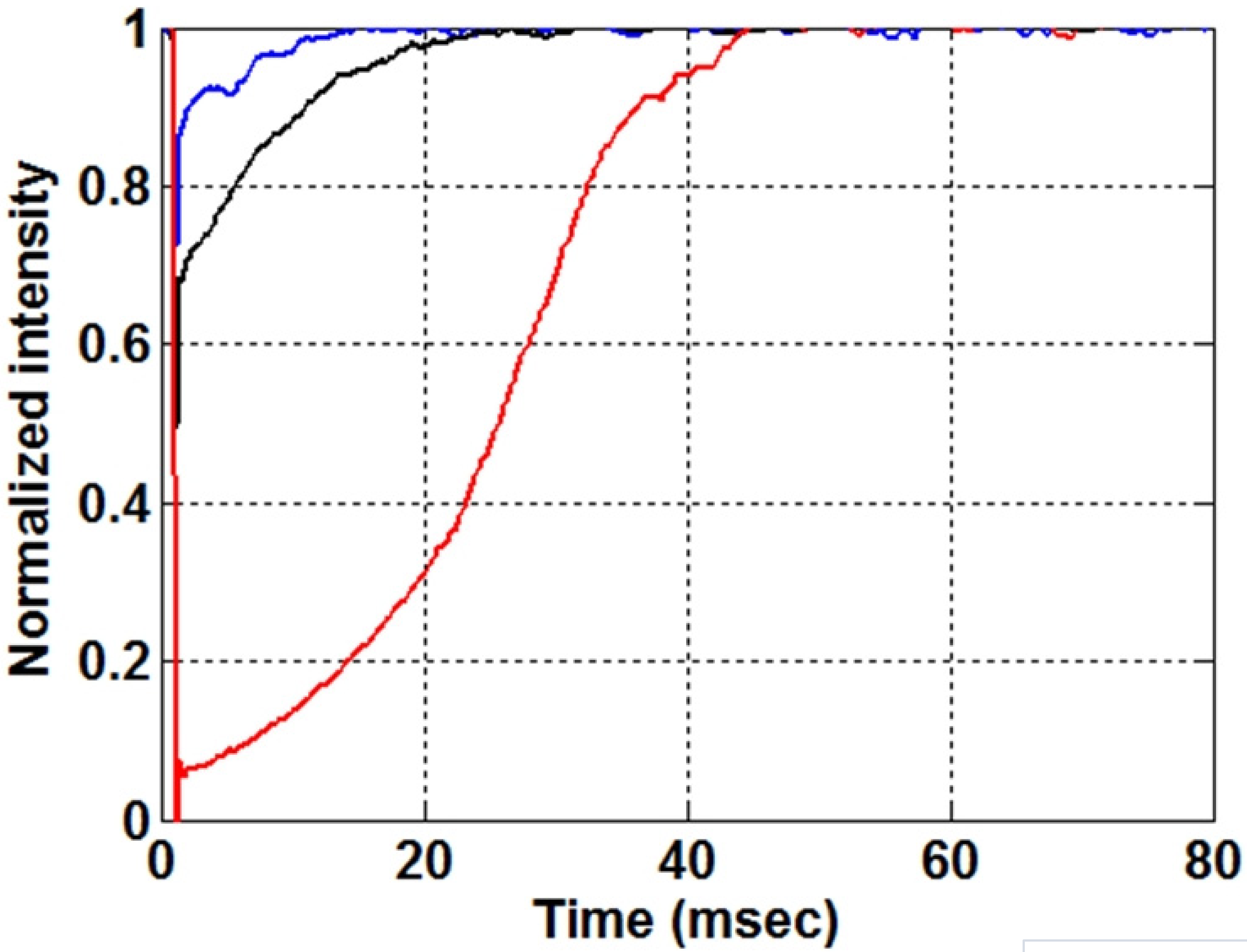
RF source (x2): 300 kW Thales klystron + Thomson solid state HVPSs
LLRF (x2): home made analog system
RF cavity (x2): 500 MHz SRF modules of KEKB design
300 mA top-up operation @ 2800 kV gap voltage
Mitigate coupler multipacting by new developed processing technique (multipacting free operation)

MOPVA098

Injection transient improvement



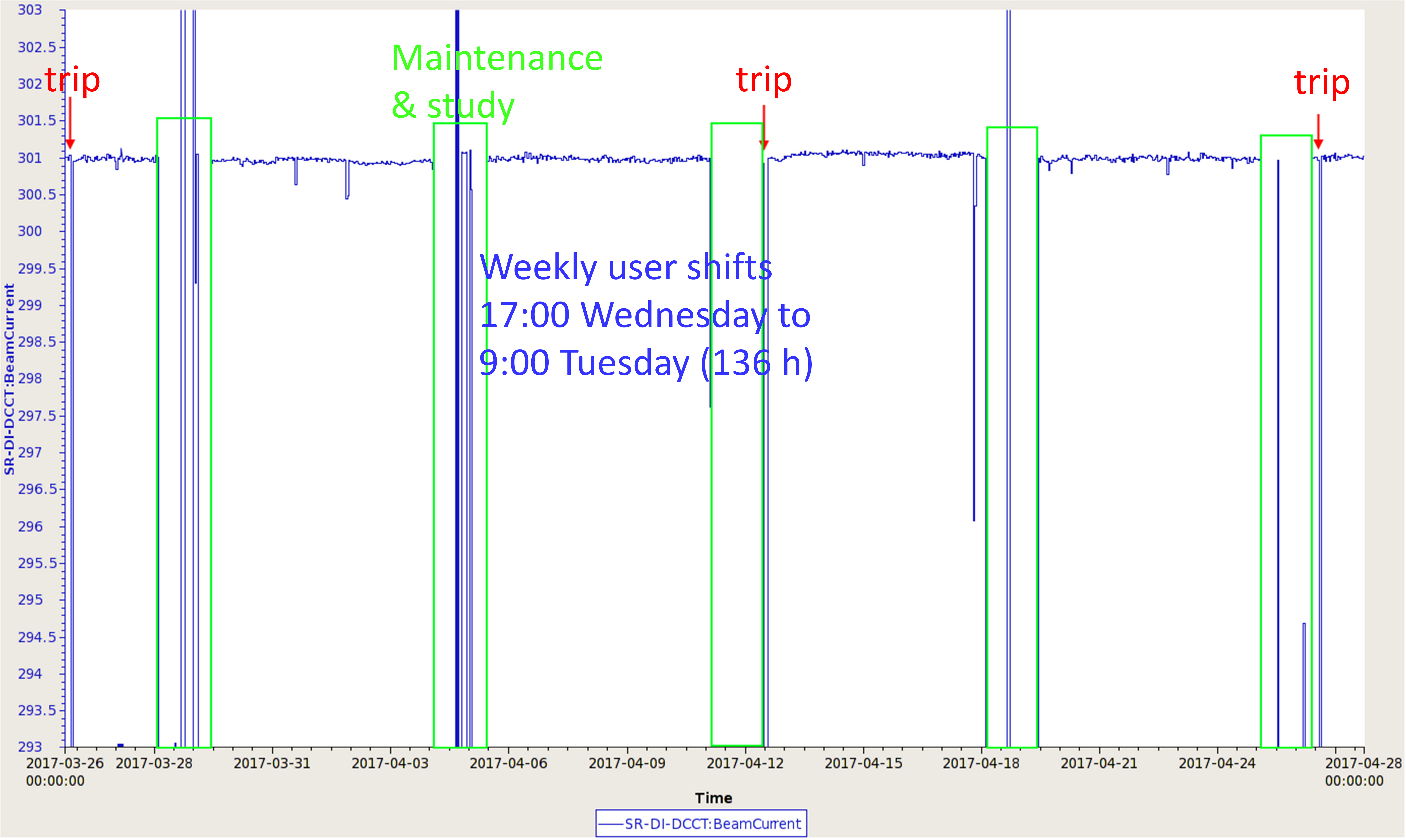
From BPM



From beamline QBPM

MOPIK105

Current status of user operation



More than 200 hours MTBF

Two similar trip were caused by EMI induced kicker mis-fire

One trip was caused by human error after machine study

Estimated performance
Availability: 99 %
MTBF: 200 hours
MTTR: 1 hours

Discussion

- Incomplete system integration can cause many other problems
- Push to high current operation during the early stages of commissioning to get early signs of problems and giving time to plan for their solutions
- Every problem that we found during TPS commissioning and operation drives us to improve the performance of TPS, and it can provide higher availability and better beam quality to user operation

ACKNOWLEDGEMENT

It is a pleasure to thank Professor S. Y. Lee for useful discussions, and Dr. Hitoshi Tanaka and the SPring-8 expert team for useful technical suggestions to reduce injection transients.
All staffs of machine division

Thank you

We are welcome you