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Fifteen Years Operation Experiences of TLS Vacuum System

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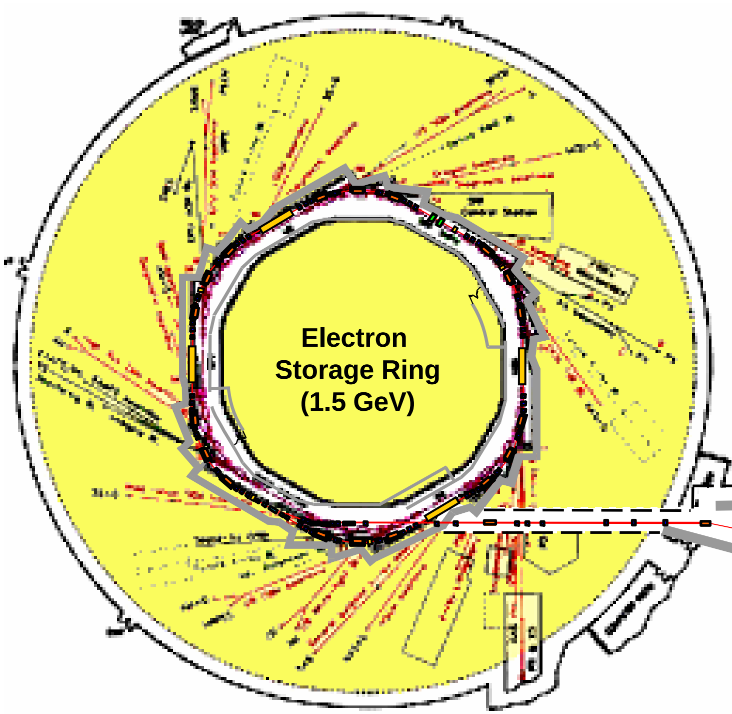
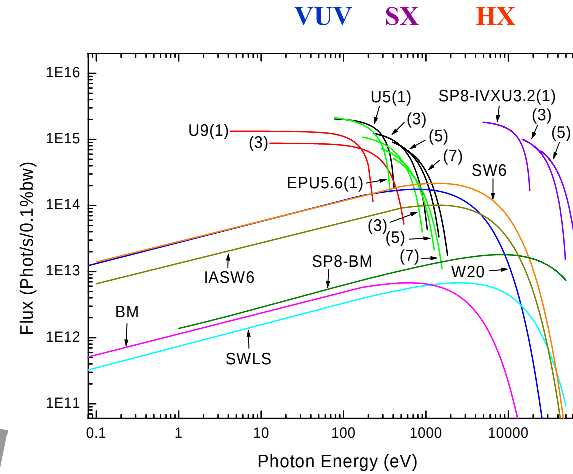
(on behalf of Vacuum Group)

2009.05.06

Taiwan Light Source (TLS)



Hsinchu Science Park

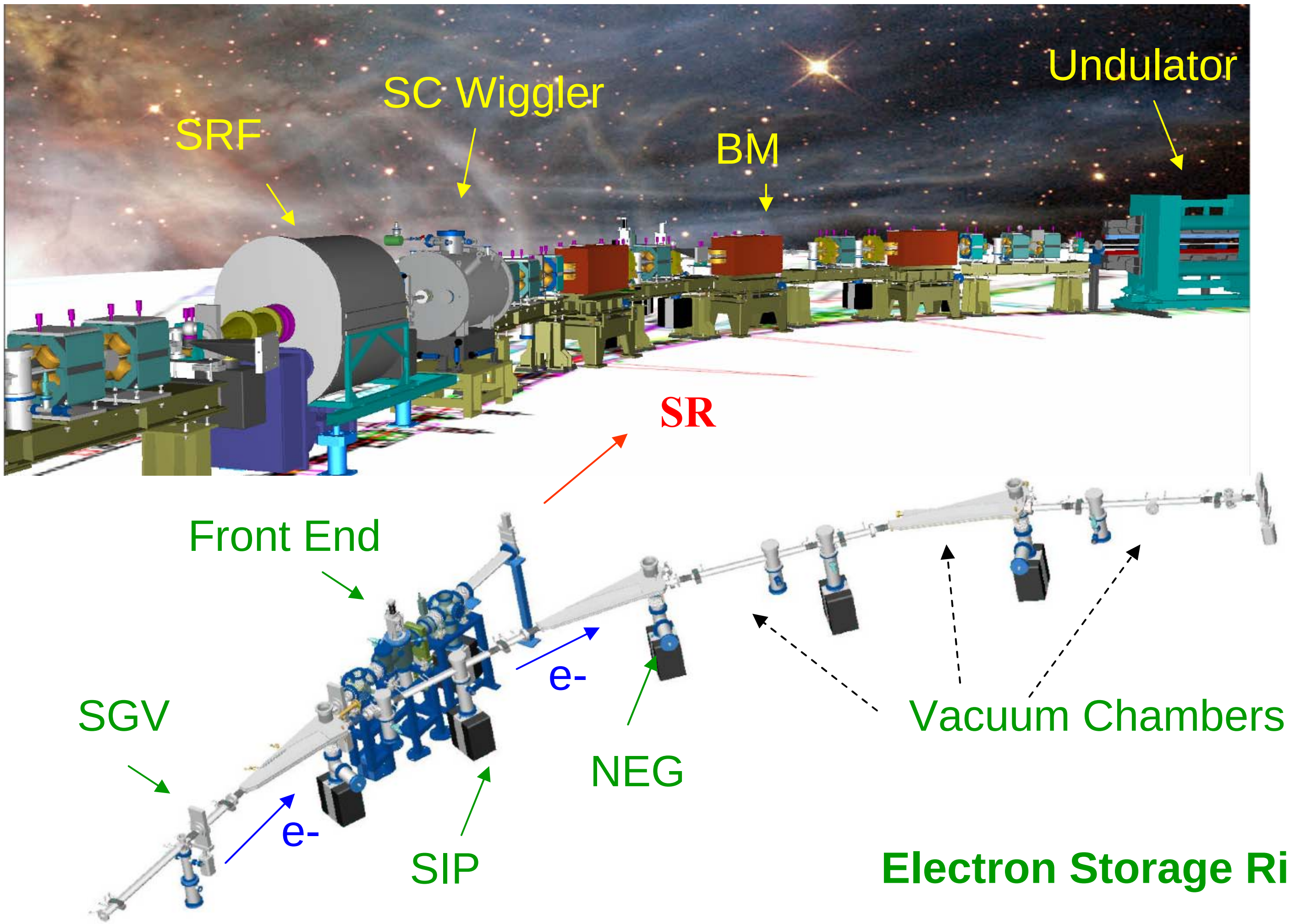


- 1993 – Operation 1.3 GeV
- 1996 – Ramping to 1.5 GeV
- 2000 – 1.5 GeV Full Energy Injection (200 mA)
- 2004 – Operation with Superconducting RF Cavity
- 2005 – Top-up Injection at 300 mA

- Circumference – 120 m
- Critical Energy – 2.14 keV
- Natural Emittance – 25 n mrad
- Average Pressure (200 mA) – 0.68 nTorr
- Accumulated Dose > 8000 Ah
- Life Time – 10 h

HX	W20	(1995)	4 ~ 15 keV
VUV	U10	(1995)	3 ~ 500 eV
SX	U5	(1997)	60 ~ 1500 eV
VUV	U9	(1999)	4 ~ 100 eV
SX	EPU5.6	(1999)	60 ~ 1400 eV
HX	SWLS	(2002)	4 ~ 30 keV
HX	SW6	(2004)	6.5 ~ 19 keV
HX	IASW6	(2006)	6.5 ~ 19 keV
HX	2nd IASW6	(2009)	
HX	3rd IASW6		
SX	EPU4.6		

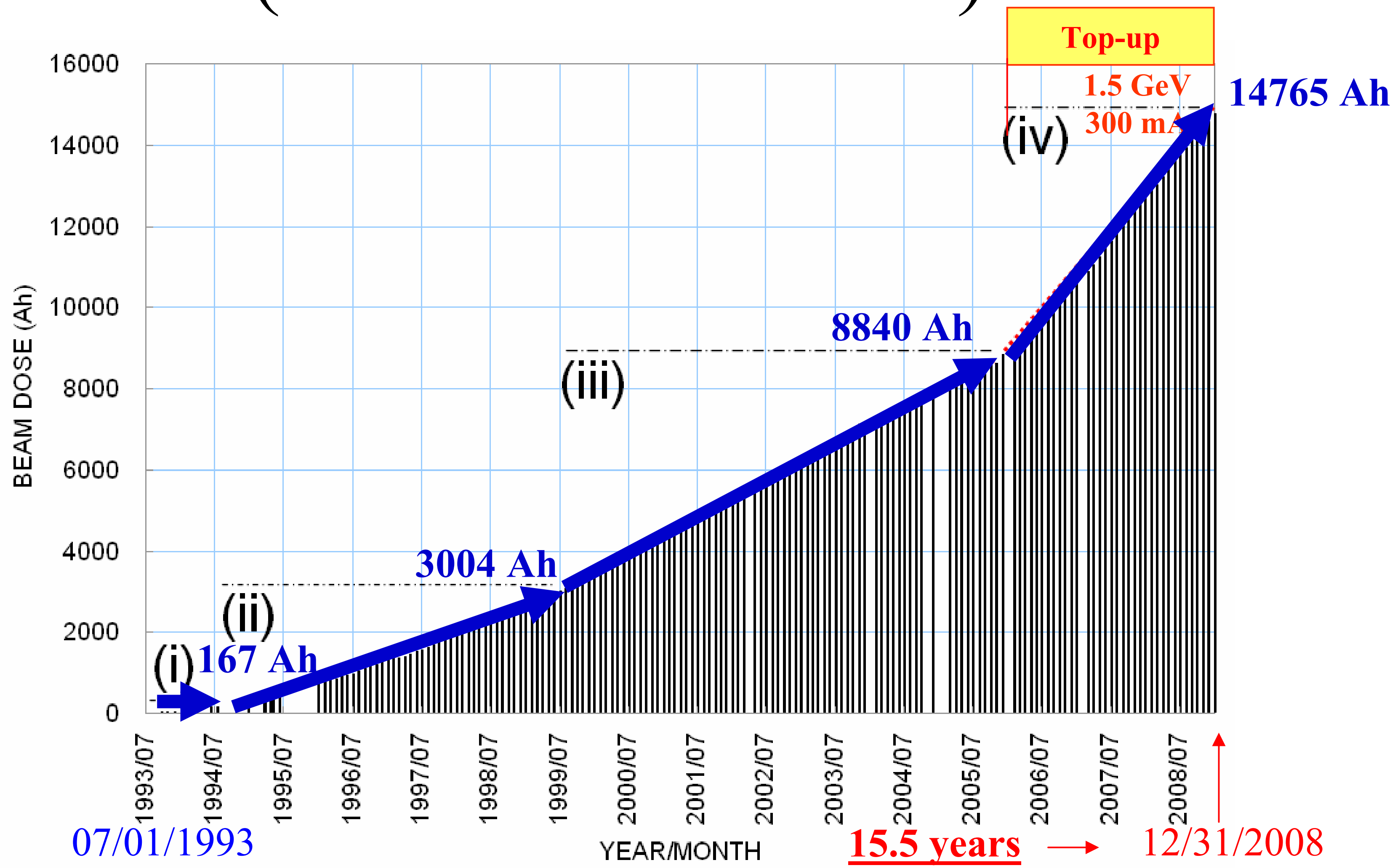
Vacuum System for TLS



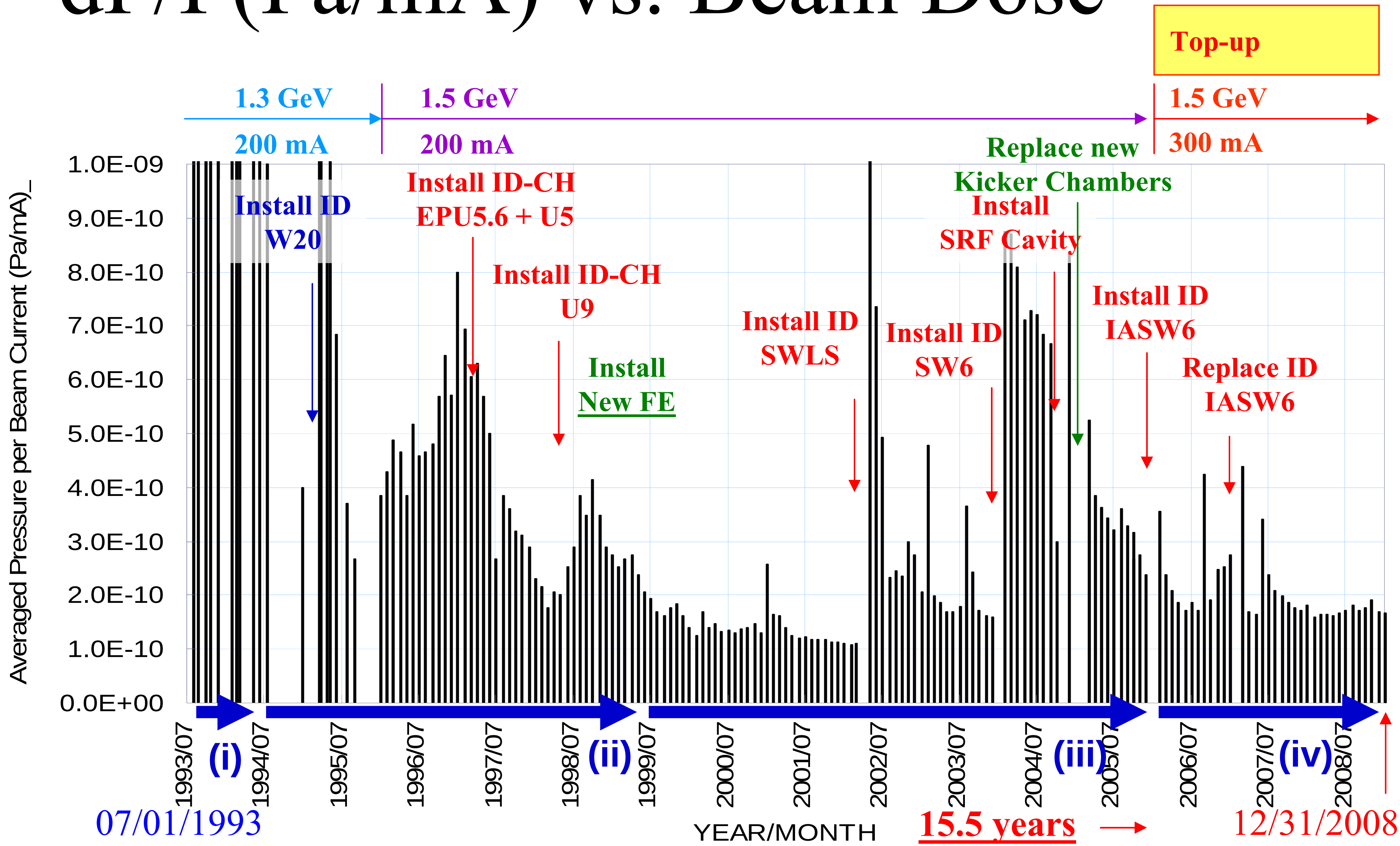
Four stages of operation of TLS in 1993 ~ 2008 (15 years)

Years of Stages	E(GeV)/ I(mA)	Accumulated Beam Dose (Ah)	Insertion Devices
(i) 1993~1994 Commissioning	1.3 / 200	167	Not Available
(ii) 1994~1999 New ID and Front Ends Upgrade Booster	1.3 / 200	3004	W20 (03/1995) U5 (03/1997) EPU5.6 (03/1997) U9 (06/1998)
(iii) 1999~2005 1.5 GeV New SC Wigglers	1.5 / 200	8840	SWLS (04/2002) SW6 (12/2003)
(iv) 2006~2008 SRF, IASW6	1.5 / 300 (on Top-up)	14765	IASW6 (01/2006)

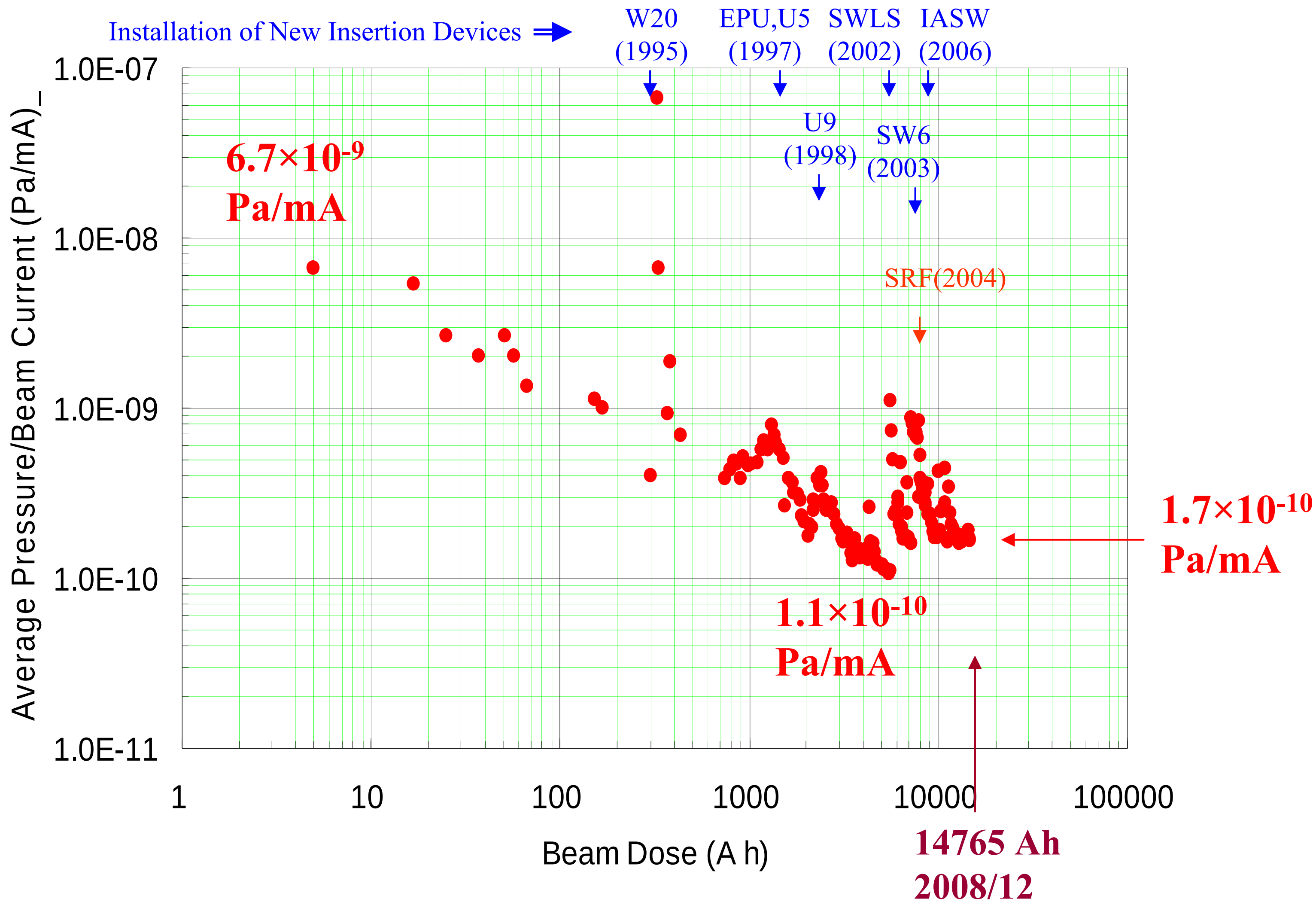
Roadmap / Accumulated Beam Dose (1993.07 ~ 2008.12)



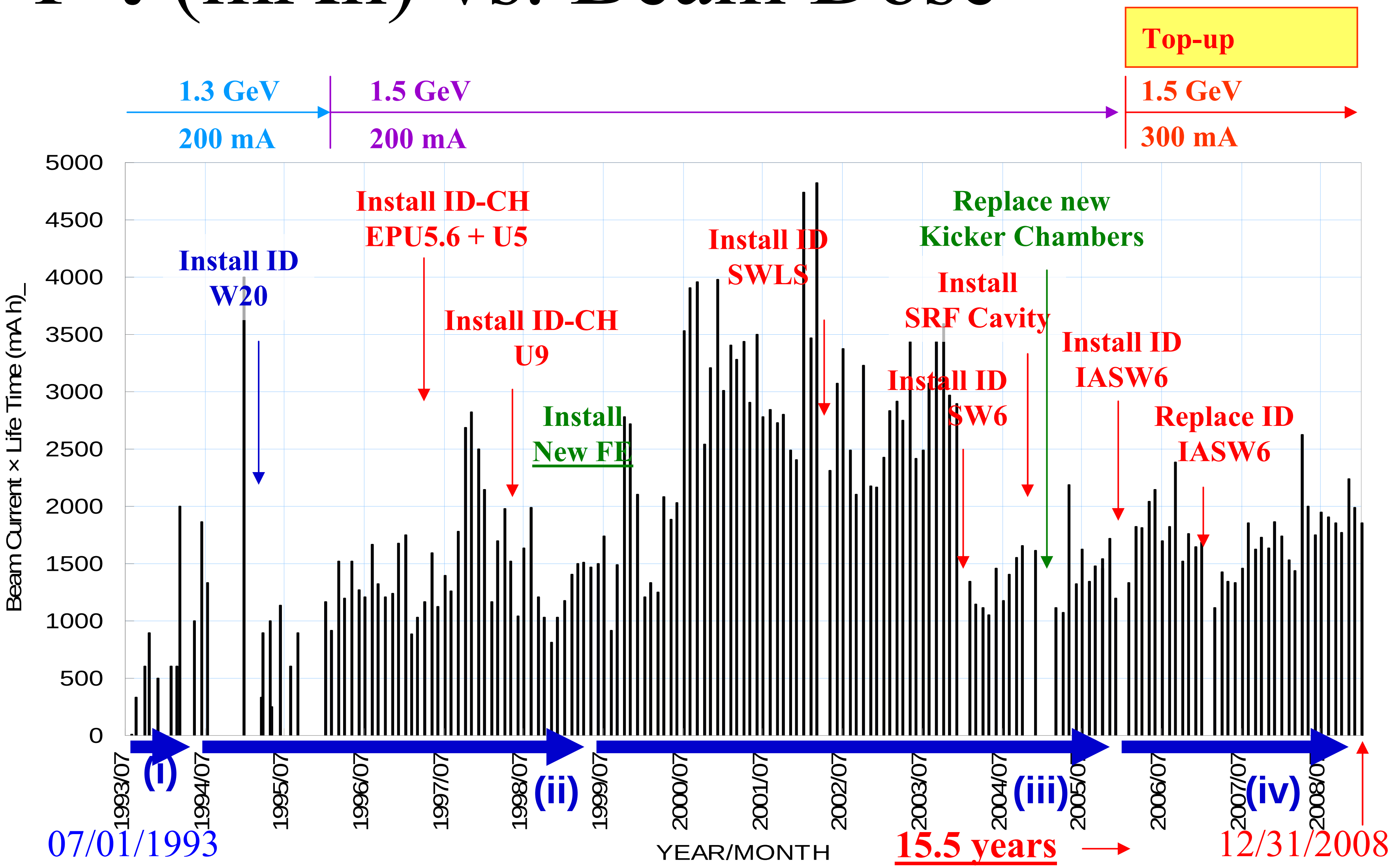
dP/I (Pa/mA) vs. Beam Dose



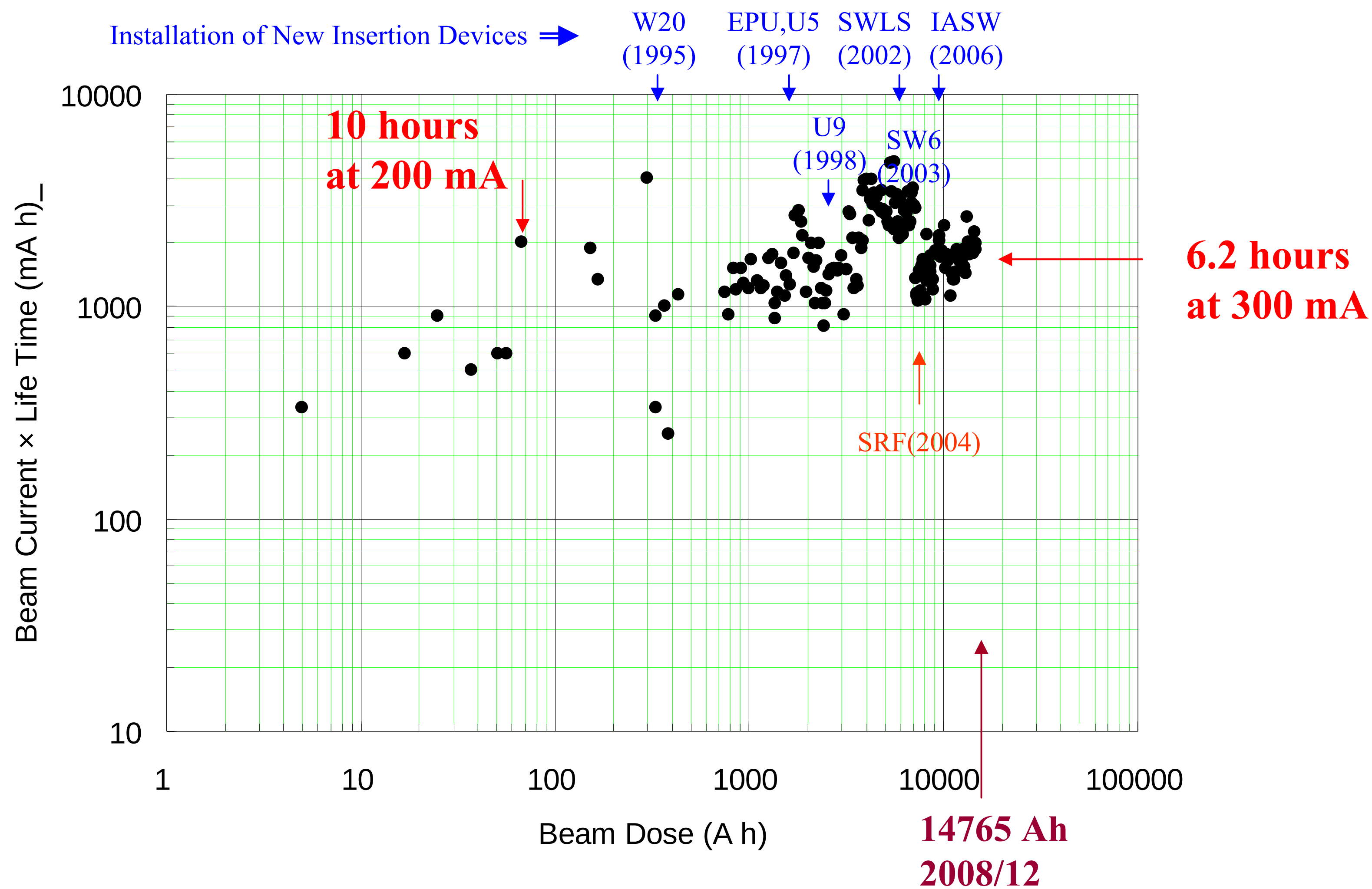
dP/I (Pa/mA) vs. Beam Dose



I ·τ (mAh) vs. Beam Dose



I ·τ (mAh) vs. Beam Dose



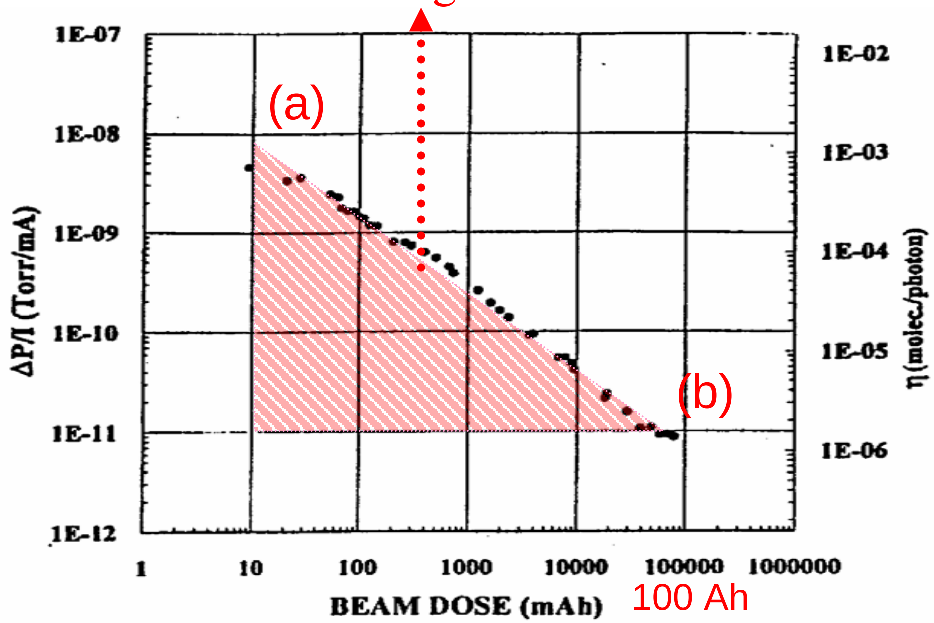
(i) Commissioning

- 1993/07 ~ 1994/07 (~ 1 year)
- Beam Dose ~ 167 Ah
- dP/I ~ 1 nPa/mA

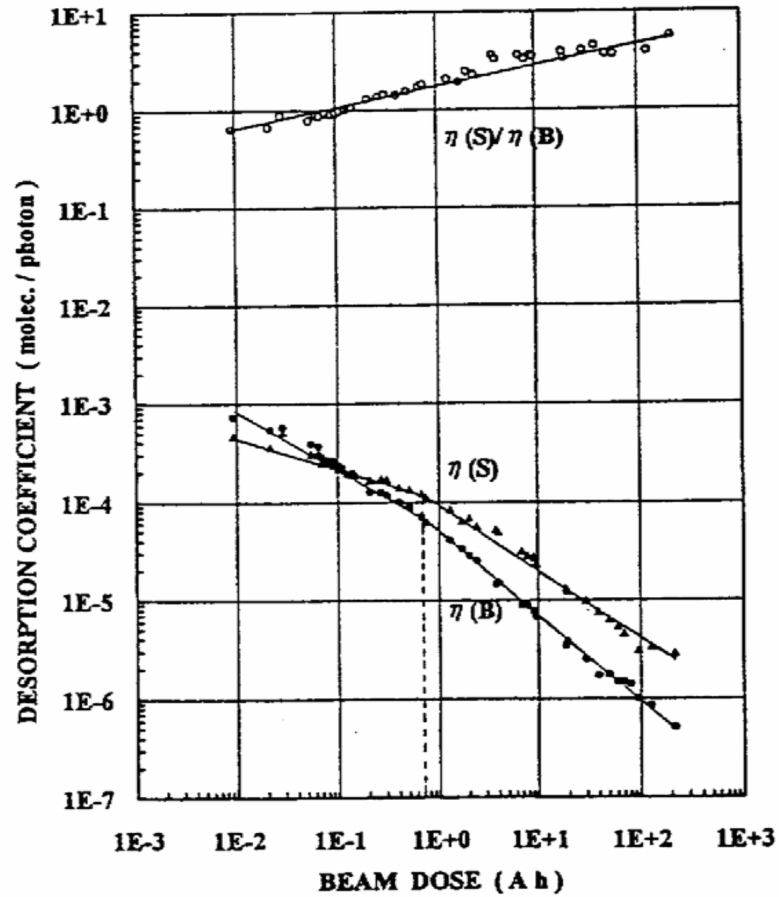
Beam cleaning to reduce the PSD yields

Pressure rise per beam current and Desorption coefficient in B-ch (η_B) during beam cleaning.

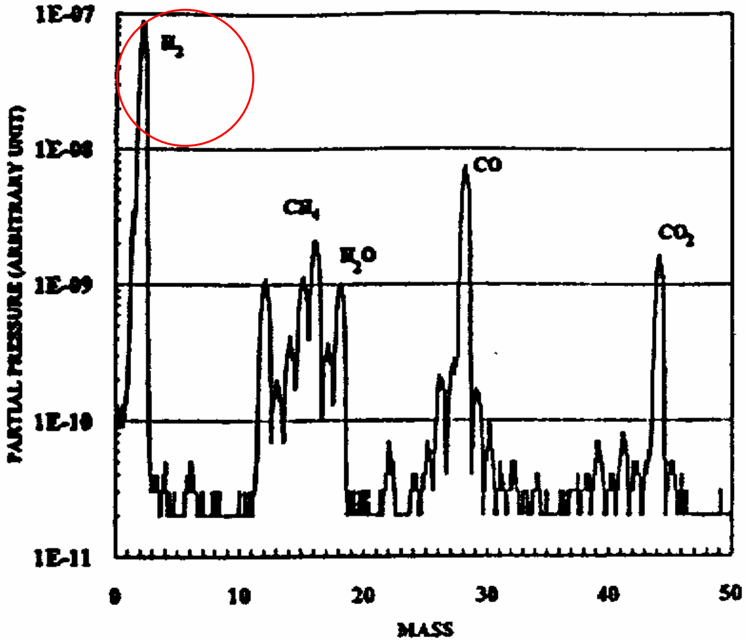
TMP pumps were useful for removing the large amount of PSD outgas during the commissioning.

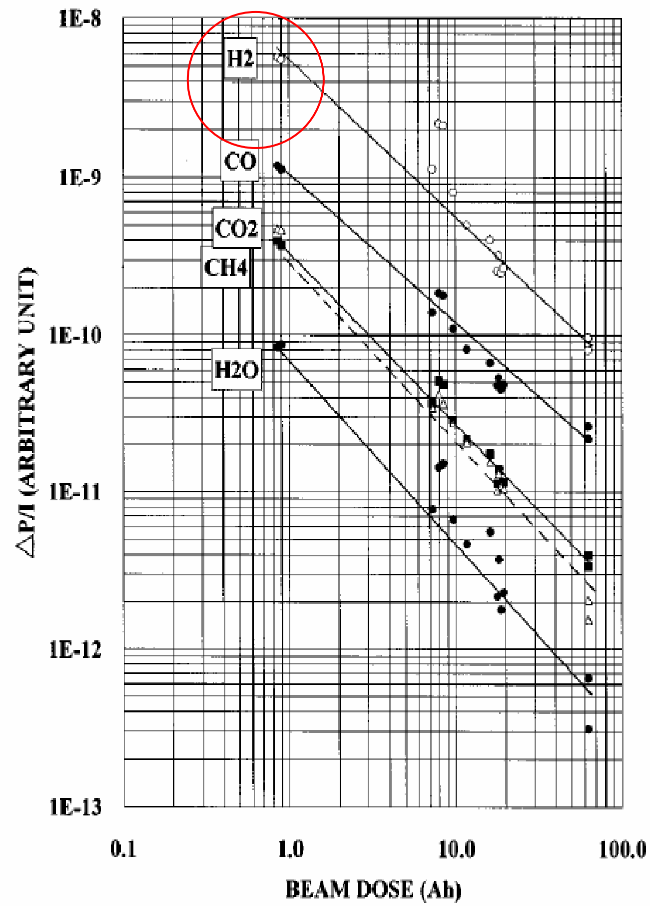


Desorption coefficient at S-ch (η_S) and B-ch (η_B)



Residual Gases of PSD from TLS





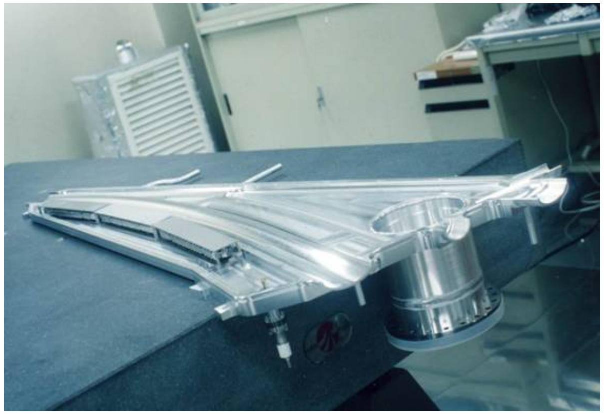
Major PSD Outgas :

H_2 (93%) > **CO (4.4%)** > CO_2 (1.2%) > CH_4 (0.5%) ~ H_2O (0.5%)

(ii) Installation of new ID and FE

- 1994/07 ~ 1999/07 (~ 5 year)
- Beam Dose ~ 3004 Ah
- dP/I ~ 0.17 nPa/mA

Aluminum Alloys (Al) Vacuum Chambers for the Storage Ring

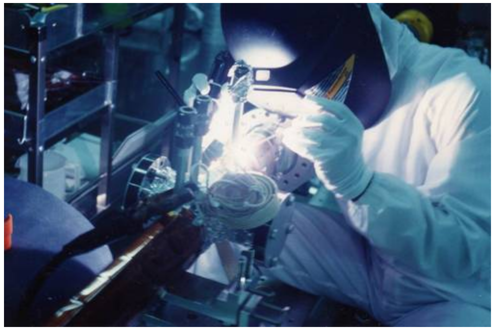


B-Chamber

•CNC machining in pure alcohol

•Distributed Ionization Pump

•TIG welding in clean room



S-Chamber

•Al Extrusion

•Chemical cleaning by acid

•TIG welding in clean room

ID-Chamber

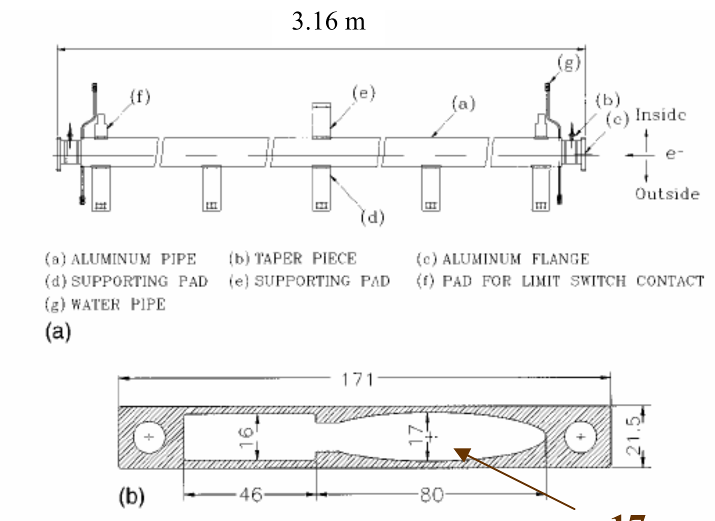
•Surface finishing by CNC machining after TIG welding

Specifications for the ID Chambers

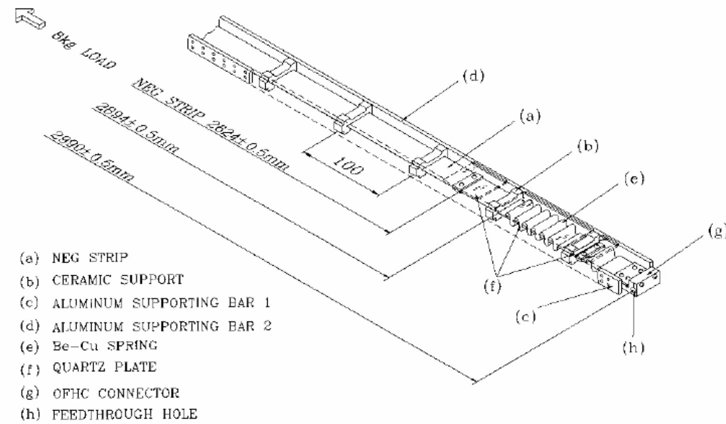
Name of Straight Section	R1	R2	R3	R4	R5	R6
Name of Insertion Device	**SWLS**	**EPU5.6**	**U5**	**SW6**	**W20**	**U9**
Minimum Pole Gap mm	55 mm	18 mm	18 mm	18 mm	22.5 mm	18 mm
Length of ID m	0.835 m	3.9 m	3.9 m	1.405 m	3.1 m	4.5 m
Length of ID Chamber (m)	**0.84 m**	**4.16 m**	**4.16 m**	**1.4 m**	**3.16 m**	**4.76 m**
Outside Vertical Height (mm)	**28 mm**	**17 mm**	**17 mm**	**13.4**	**21.5 mm**	**17 mm**
Inside Vertical Height (mm)	**20 mm**	**13 mm**	**13 mm**	**11**	**17.5 mm**	**13 mm**
Inside Horizontal Width (mm)	**100 mm**	**80 mm**				
Material of ID Chamber	**Aluminum Alloys (A6063T5)**					
Machining of ID Chamber	Extrusion					
Outside Surface Finishing	CNC Machining (in Ethanol)					
Flatness after Surface Finishing	< ±0.2 mm	< ±0.2 mm	< ±0.2 mm	< ±0.2 mm	< ±0.2 mm	< ±0.2 mm
Cooling Channel	NA	Outboard	Outboard	NA	Both Sides	Outboard
Pump inside ID Chamber	NA	Strip Type NEG (ST707)		NA	Strip Type NEG (ST707)	
Length of NEG Pump	NA	3.54 m	3.54 m	NA	2.62 m	4.14 m
Time of Installation Chamber	April, 2002	March, 1997	March, 1997	Dec., 2003	March, 1995	June, 1998

W20 Vacuum Chamber

1995
March



17 mm



Strip-type NEG pump

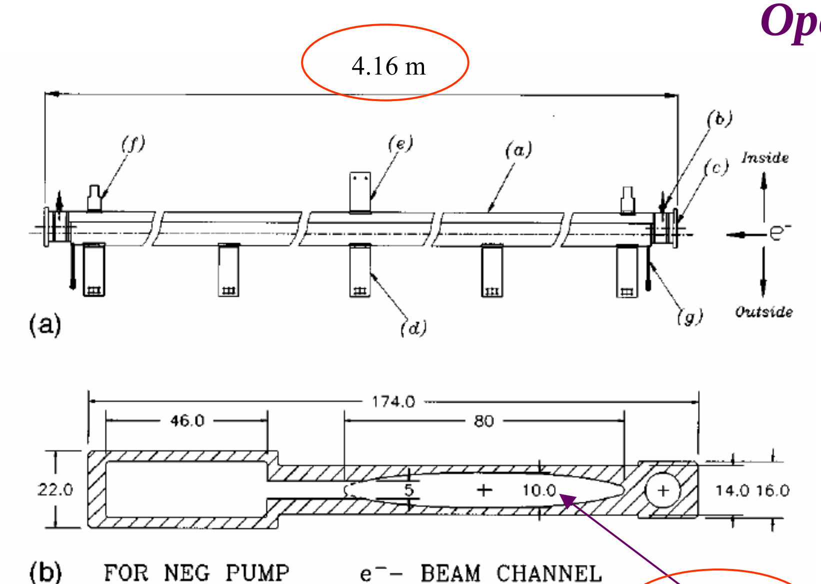
<u>Al Chamber – manufacturing processes</u>

1. Extrusion of the pipe
2. Machining the welding edges and cooling edges
3. Chemical cleaning by acid
4. TIG welding the supporting pads, cooling joints, tapers, and flanges
5. Surface finishing by CNC machining in ethanol
6. Insert NEG strip assemblies and feedthroughs

14 mm prototype U5 Chamber

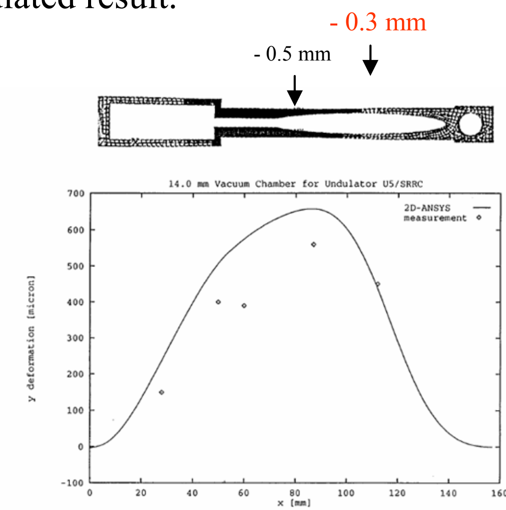
1996 Feb.

Operation in March ~ June, 1996



ANSYS Simulation and Measurement

The measured 0.3 mm deformation on upper and lower surfaces near the beam center is similar with the simulated result.



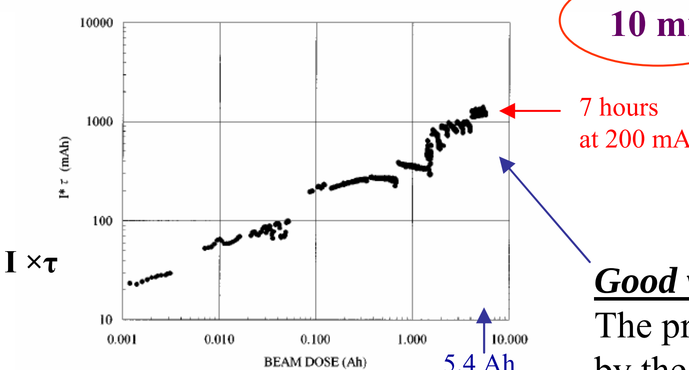


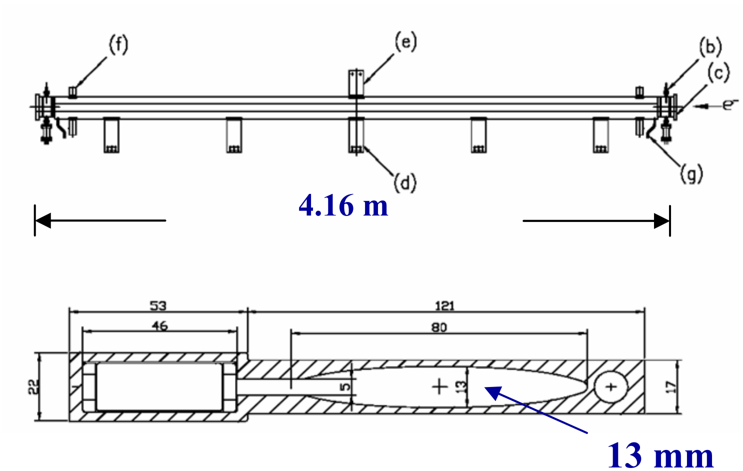
Fig. 4. The product of the electron beam current I and the beam lifetime τ vs the accumulated beam dose from 1 March to 3 March.

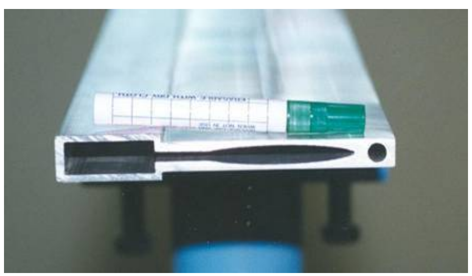
Good vacuum has been achieved in two days of beam cleaning

The pressure of 14 mm U5 chamber has been improved efficiently by the beam cleaning in two days. However, the beam lifetime is still limited due to the smaller dynamical aperture.

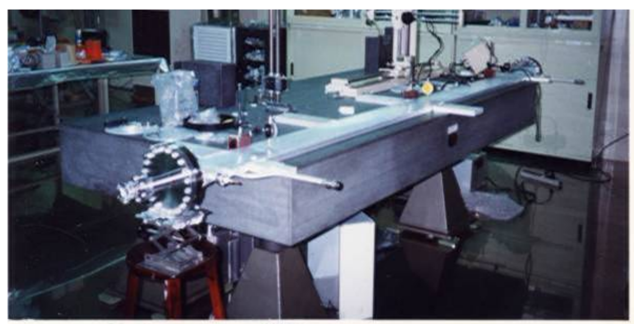
EPU5.6, U5 Vacuum Chambers

1997 March

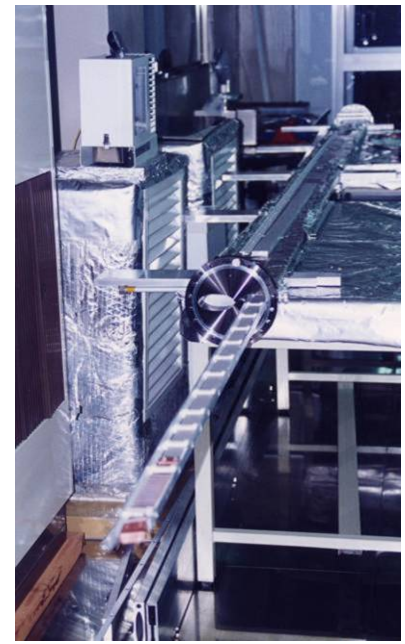




Cross section of ID chamber



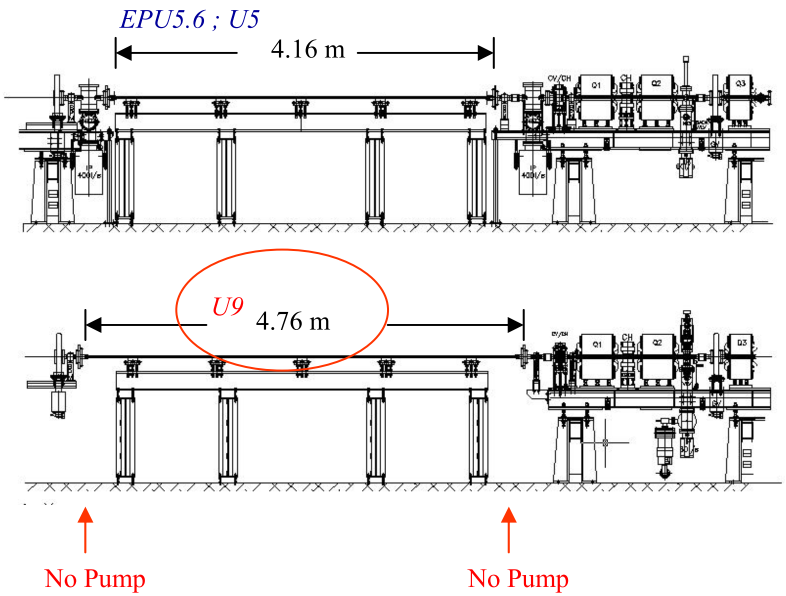
ID chamber assembly



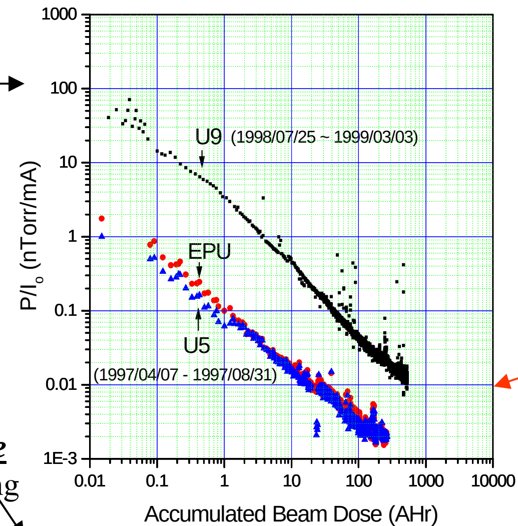
NEG strip assembly

U9 Vacuum Chamber

1998 June

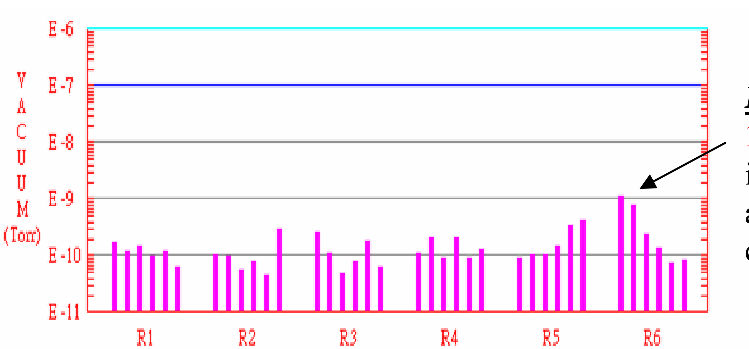


Pressure rise
(dP/I) near U9 chamber is ~ 50 times higher than that of U5 & EPU5.6 chambers.

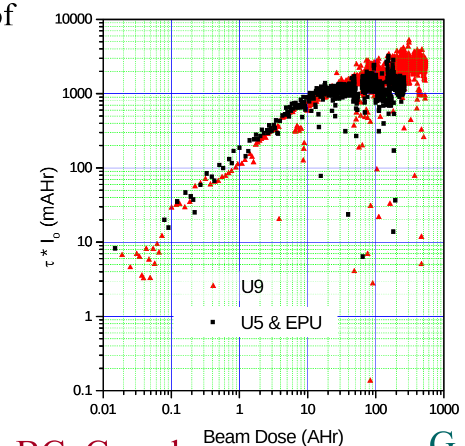


1 ×10^{-11} Torr/mA

Current × Lifetime
(I ×τ) after installing the U9 chamber is similar with that of U5 & EPU5.6.

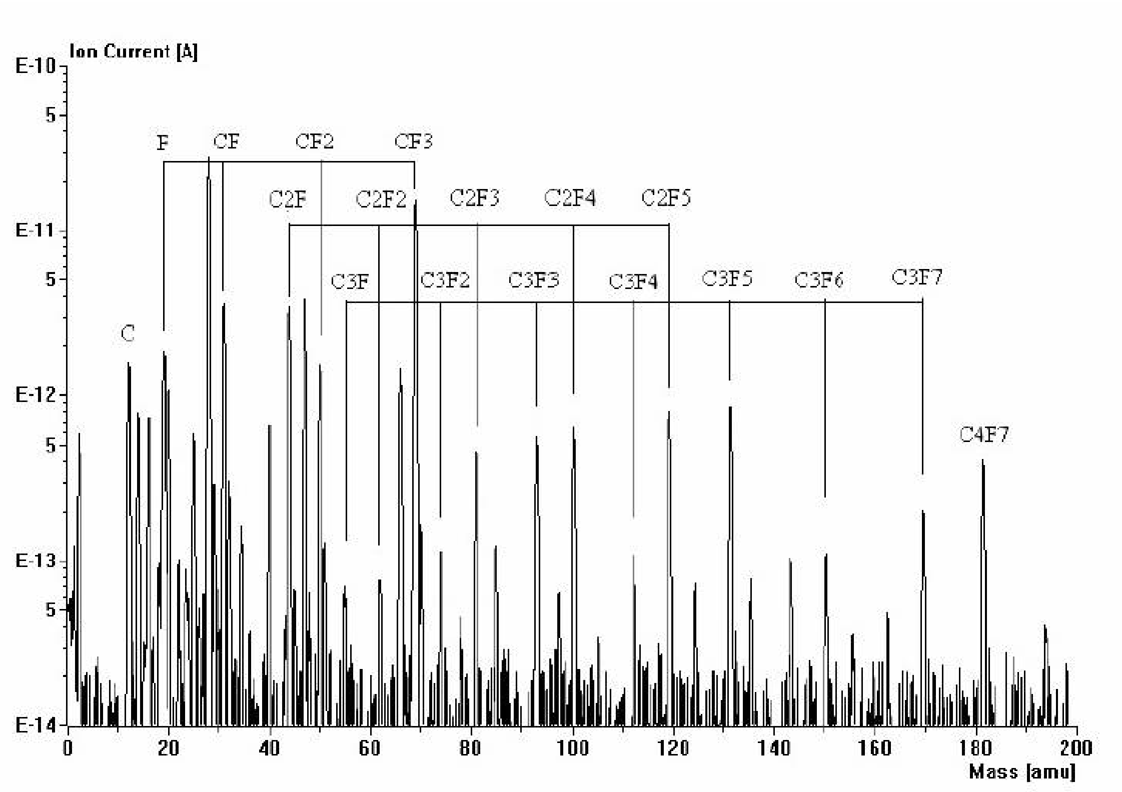


Highest pressure
1 ×10^{-9} Torr
in the storage ring addresses near U9 chamber



Most of the vacuum problems caused by the baking during maintenance in the Tunnel

Synchrotron Radiation Hitting Problems



Mass spectrum near a B-chamber shows CxFy contamination from the O-ring sealed Beam Line gate Valve (BLV). The O-ring had stuck on the wall of BLV due to over baking, hit by synchrotron light and broken, and released the CxFy outgas. All the BLV's have been replaced by all metal ones.

High Temperature Baking Problems

A feedthrough of the ion pump was broken due to high voltage sparking when degassing during the baking. Number of times for switching the IP on are reduced to < 3 times.

Problem of Over Heating

A photon aperture, horizontally installed in a front end, was melt down due to insufficient water cooling. Each loop of cooling water pipes for the absorbers or masks should connect the flow rate meter and link to the interlock system.

Radiation Damage Problems

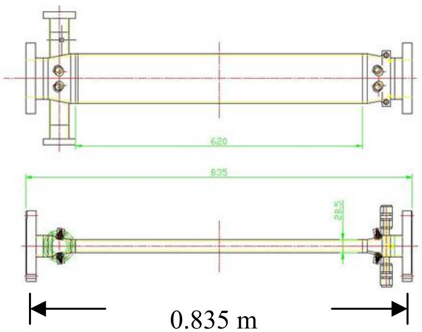
An O-ring for a turbo-molecular pump located near the extraction septum chamber of 1.5 GeV booster synchrotron was damaged after high dosage rate irradiation. The pumps with O-ring contained has been removed from high dosage area after using.

(iii) Installation of SC Wigglers

- 1999/07 ~ 2005/12 (~ 6.5 year)
- Beam Dose ~ 8840 Ah
- dP/I ~ 0.11 nPa/mA

SWLS Vacuum Chamber

2002
April

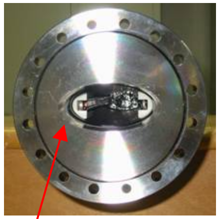


SWLS beam duct

SWLS

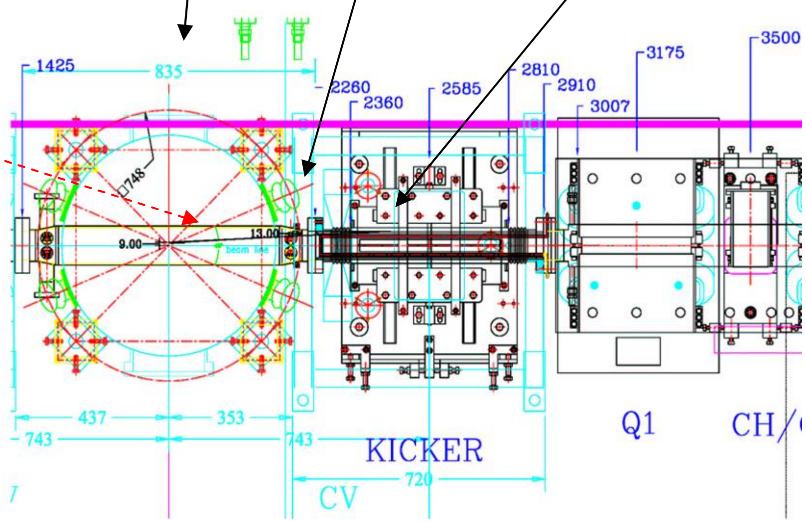
Pre-absorber in flange to protect the downstream bellows

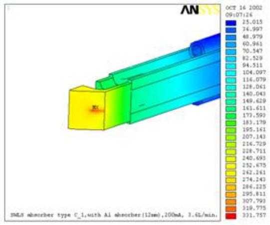
Absorber inside the 4th kicker chamber



Ceramic insulators on top of absorber to avoid the arcing during kicker firing.

The SR light emitted from SWLS (6T), with 130 mrad photon span and 9 mm offset, will hit on the downstream kicker ceramic chamber.





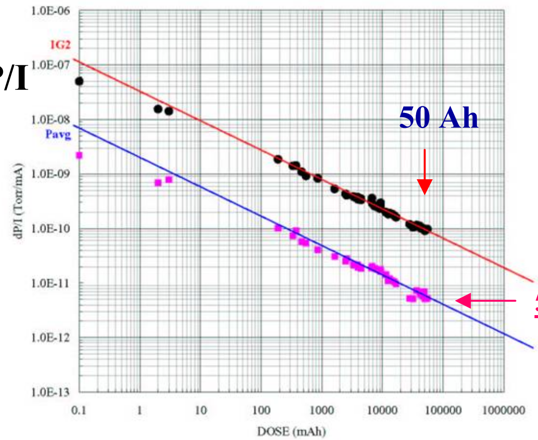
ANSYS Thermal Analysis

330°C hot spot near Cu cold head cover of absorber with upstream pre-absorber (5.3 T)

SWLS operating at 5.3 T

2002
May

dP/I

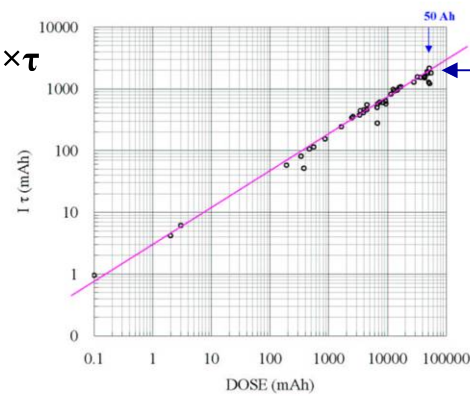


50 Ah

5×10^{-12} Torr/mA

Pressure rise
(dP/I) for IG2 and Pavg.
Pavg/I reaches 5×10^{-12} Torr/mA at 50 Ah beam dose.

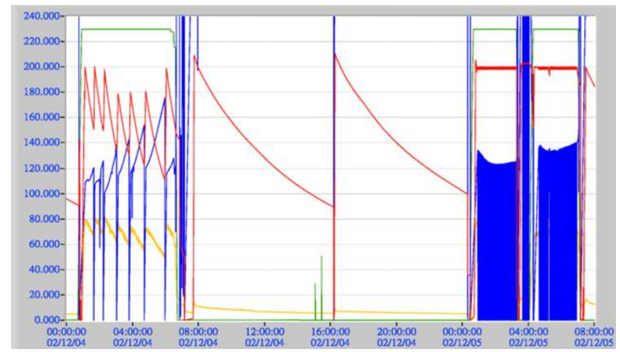
I ×τ

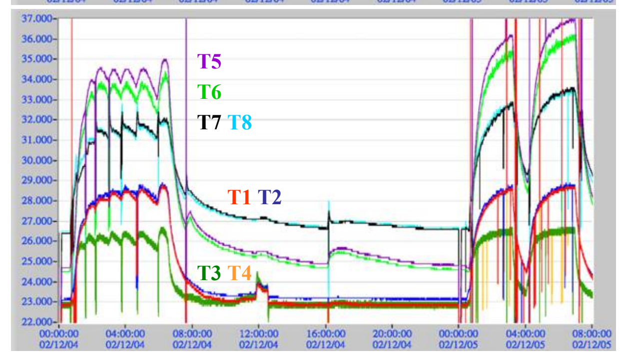


10 hours at 200 mA

Beam Dose

Current × Lifetime
(I ×τ) reaches 10 hours at 200 mA at 50 Ah beam dose.





Temperature rise
near SWLS and downstream kicker chamber. T1 ~ T4 represent the temperature near both sides of taper and flange downstream the SWLS, while T5, T6 and T7, T8 near upstream and downstream of kicker chamber respectively.

Aluminum Beam Duct for SW6

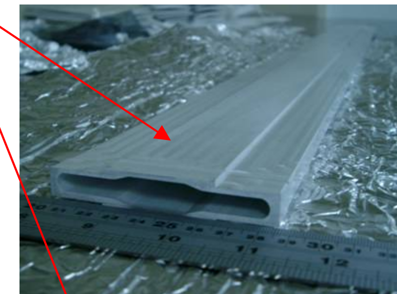
2003 Dec.

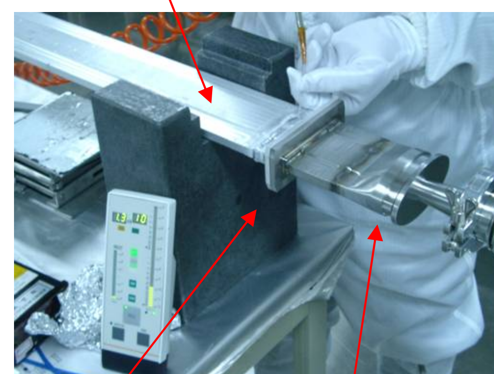
Al Beam duct

1. Length: 1.1 m
2. Inner width: 80 mm
3. Inner height: 11 mm
4. Outer height: 13 mm
5. Operating temperature: 100 K
6. Higher thermal conductivity
7. Lower emissivity

Bimetal LN_2 Test

(1) Al Beam duct

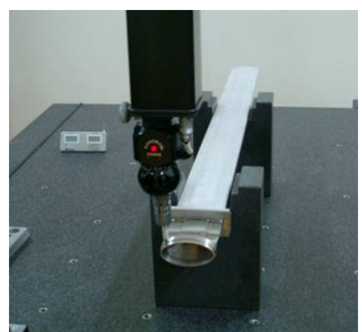




(2) Al / S.S. Bimetal Adaptor

(3) S.S. Taper

Leakage Check



Flatness Check

SW6 Vacuum Chamber Welding

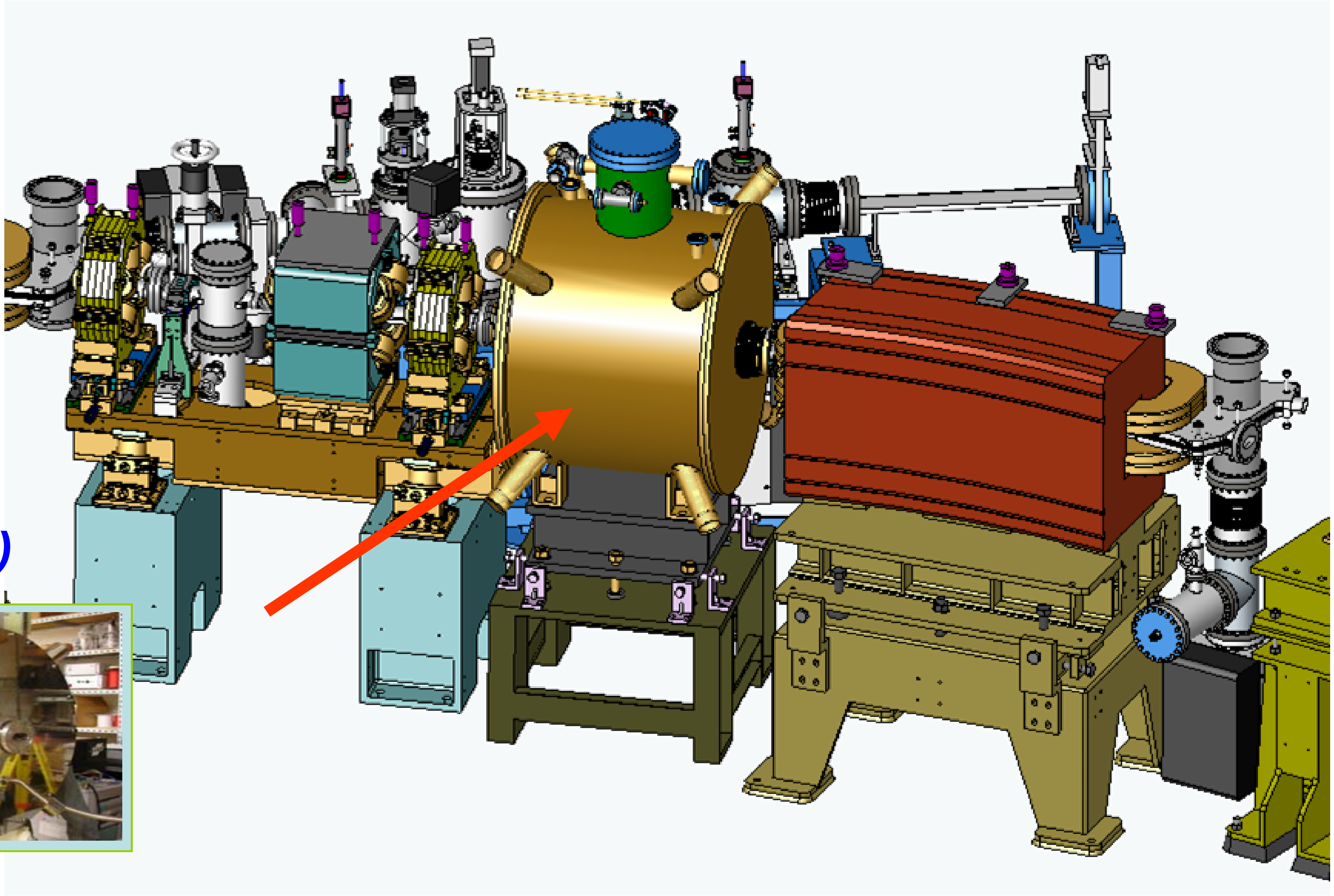
TIG Welding for Al beam duct

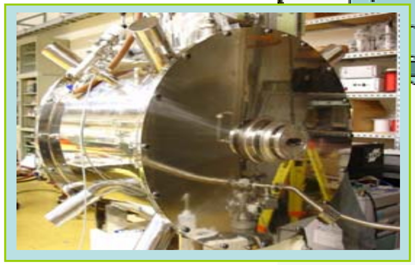
Commissioning of TLS with SW6 is successful. (April 2004)

In-Achromat Superconducting Wiggler (IASW6)

2005
Dec.

IASW6 (3.1 T)





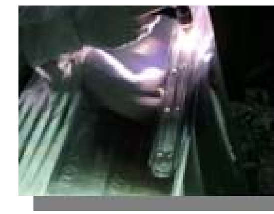
Oil-free manufacturing process for Al Bending chambers provides high reliability

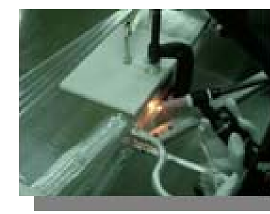
1) NC Machining with Ethyl Alcohol

2) Dimension Check After Machining

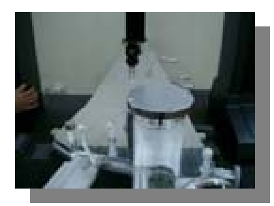
3) Surface Cleaning

4) DIP Installation





5) Welding in Clean Room



6) Deformation Check After Welding

7) Leak Test

8) Pre-assembly In Lab

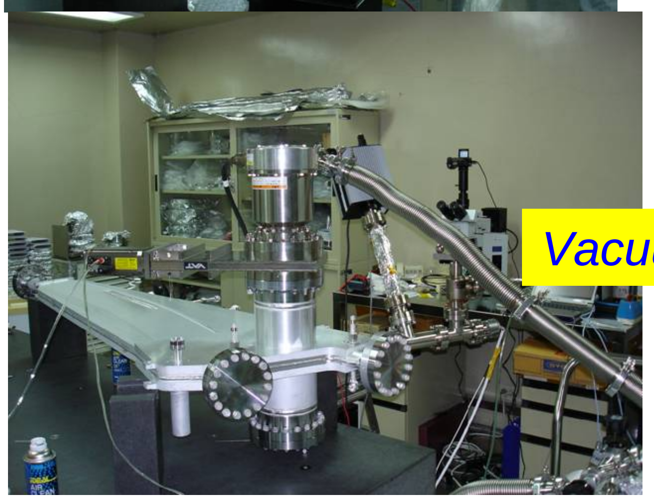
9) Installation in the Tunnel

Assembly, Welding and Testing (at NSRRC) for the B-Chamber

Assembly

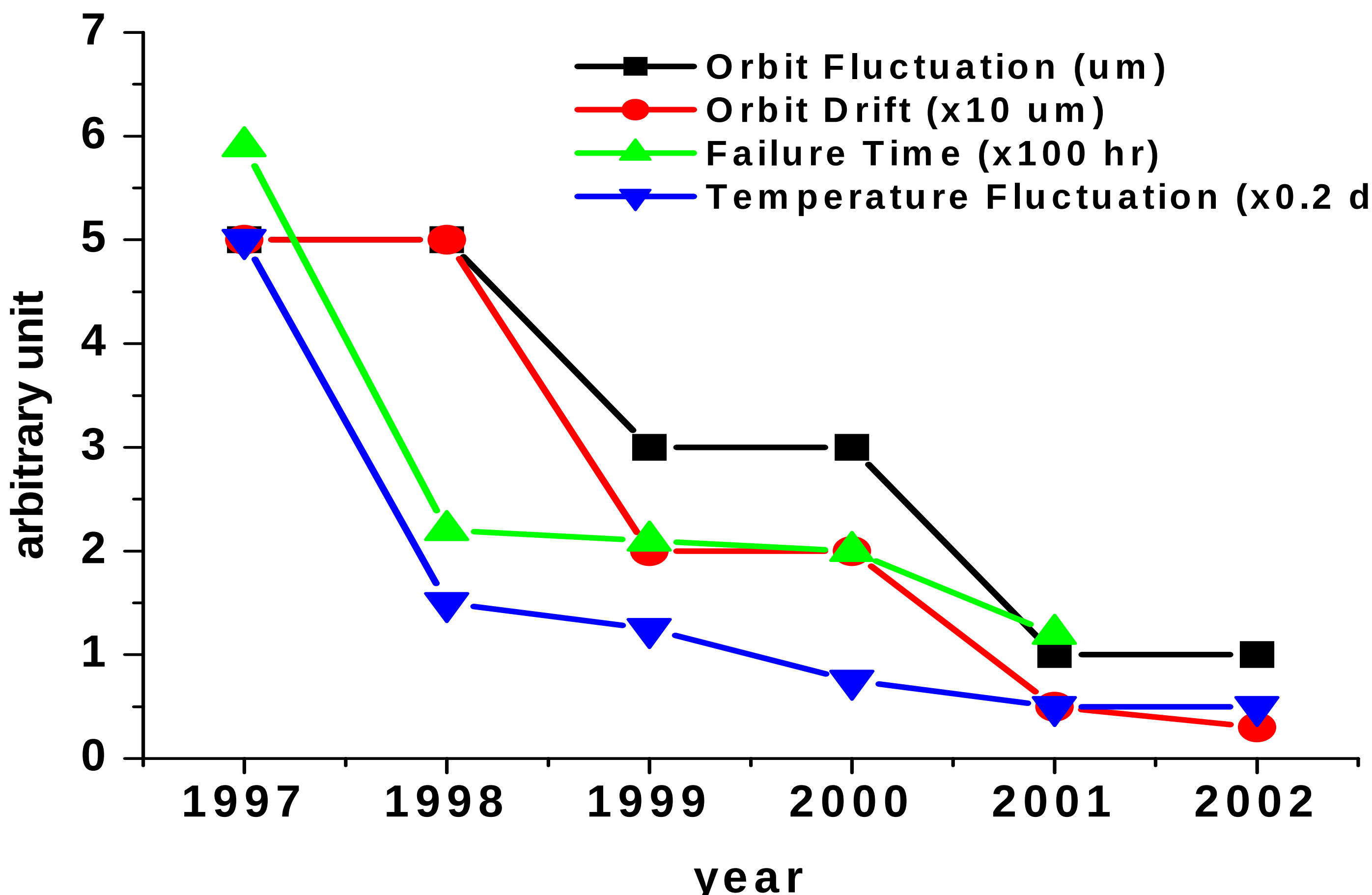
TIG Welding

Vacuum Test



TLS Improvement (I) (1997-2002)

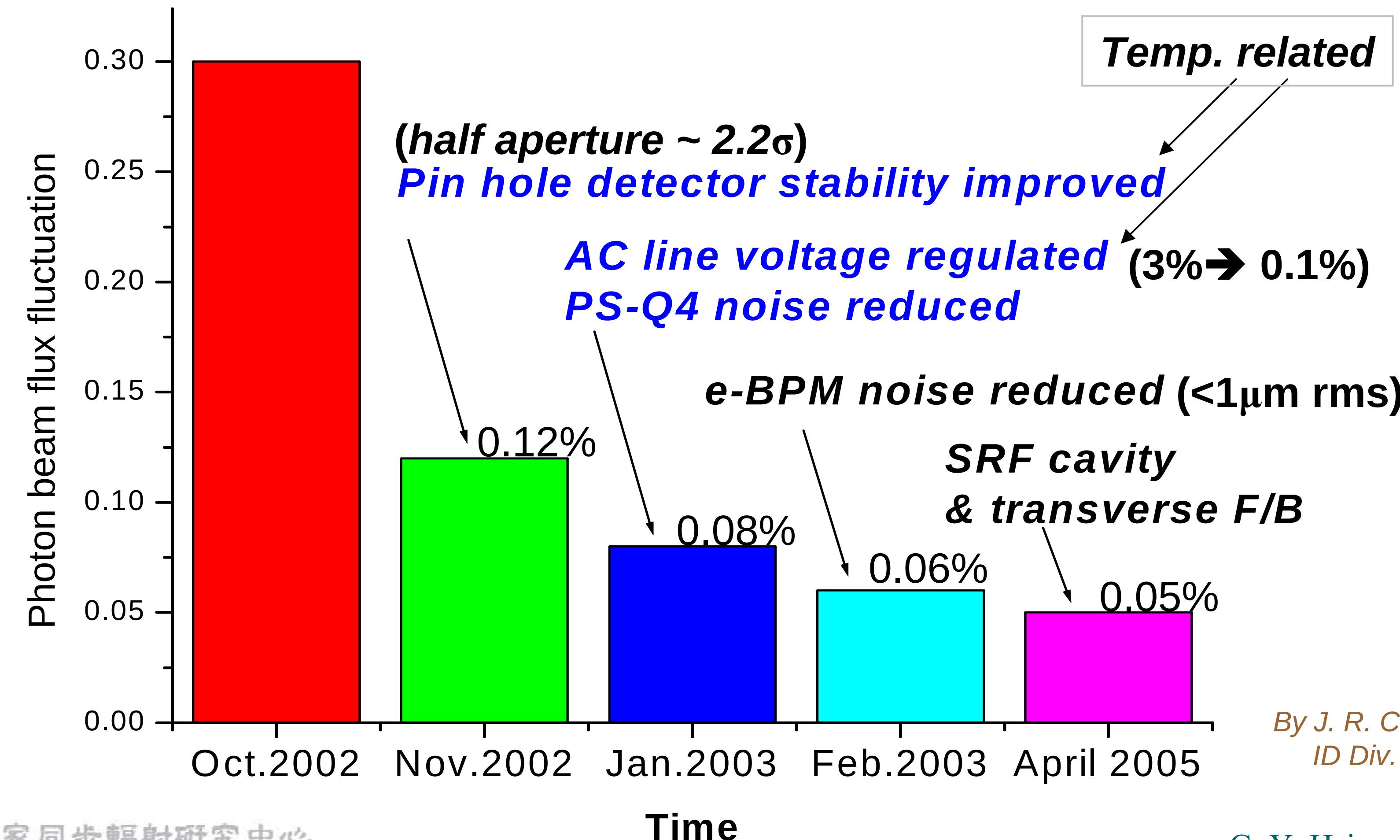
Improvement on Utility systems



By J. R. Chen
ID Div.

TLS Improvement (II) (2002-2005)

Improvement on Noise and Stabilities of Monitors

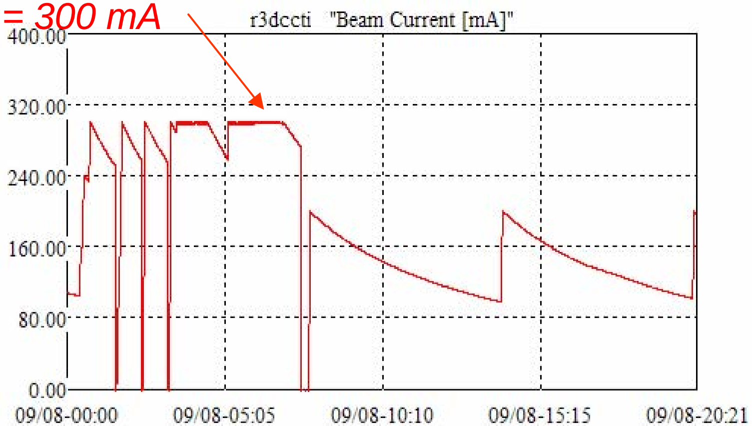


By J. R. Chen
ID Div.

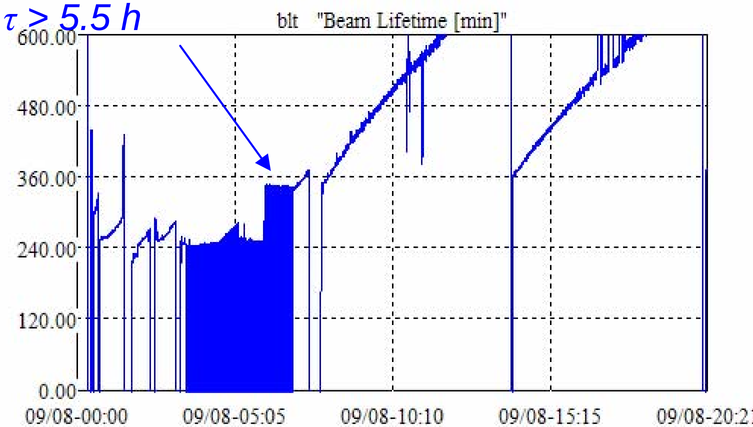
Top-up Injection at 300 mA
(routine operation before Dec. 2005)

2005

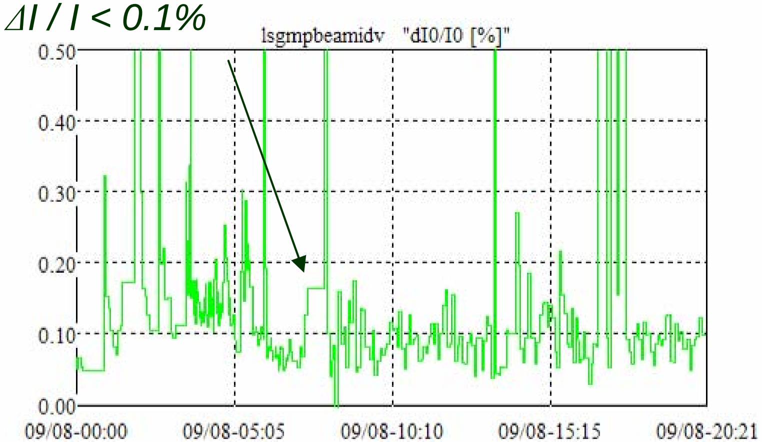
Beam current
I = 300 mA



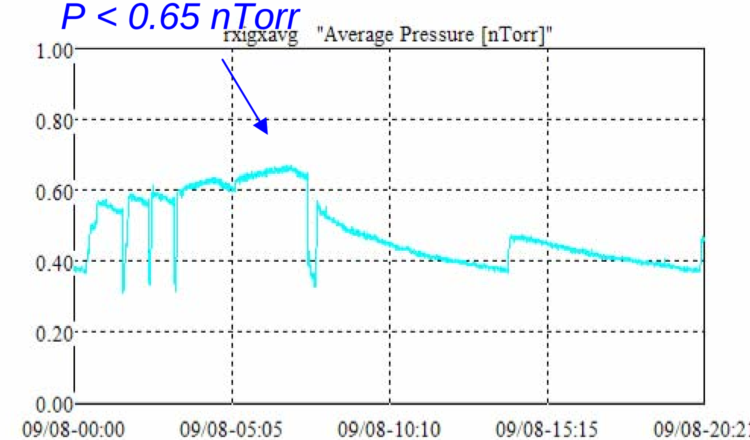
Life time
τ > 5.5 h



Variation of Photon flux
$\Delta I / I < 0.1\%$

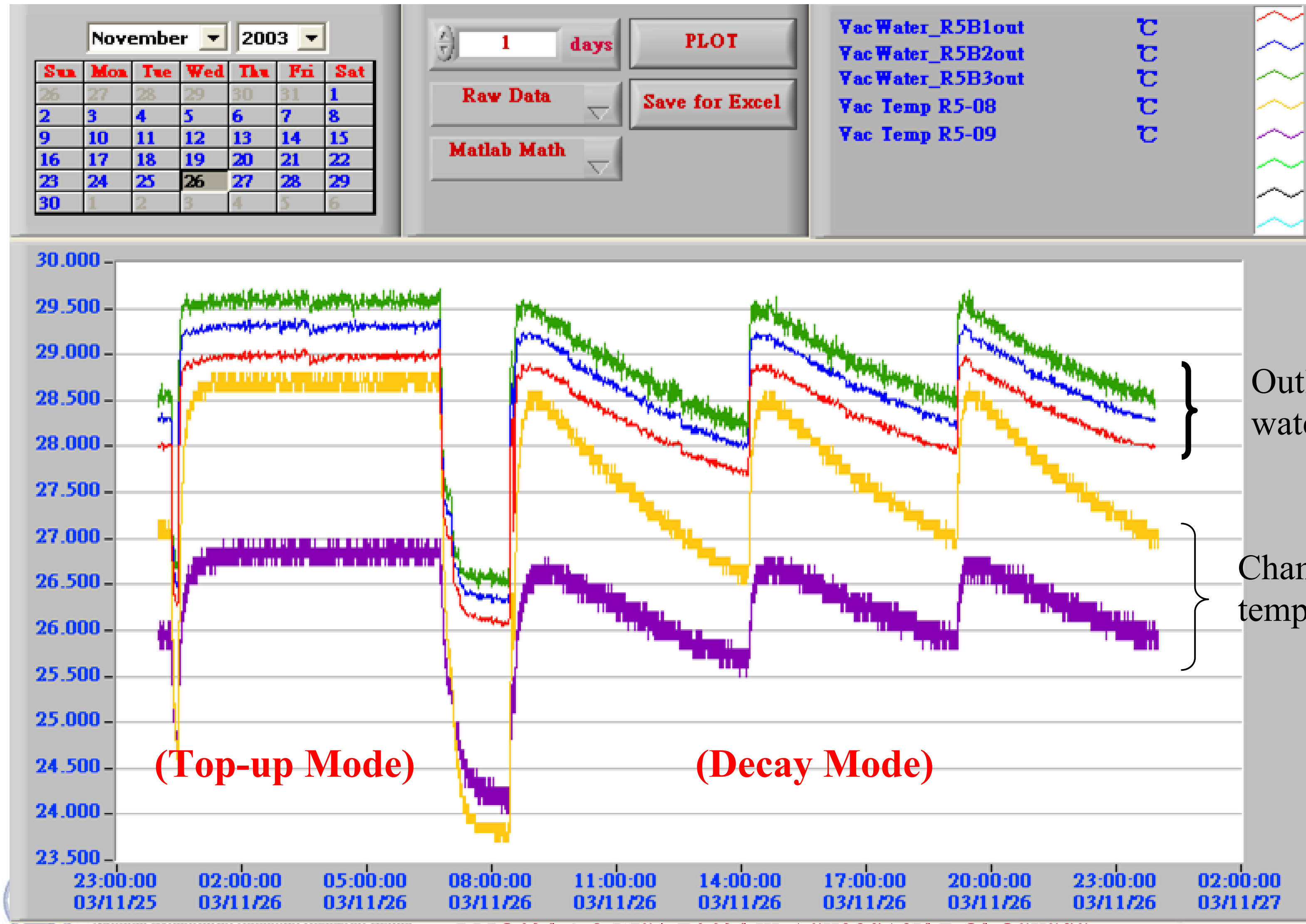


Average Pressure
P < 0.65 nTorr



Top-up Test
(Constant Flux & Temperature)

2003



(iv) Raise the Beam Current and Top-up Operation

- 2006/01 ~ 2008/12 (~ 3 year)
- Beam Dose ~ 14765 Ah
- dP/I ~ 0.17 nPa/mA
- Beam current increased to 300 mA

Top-up injection at 300 mA routinely

- 2008.03.05

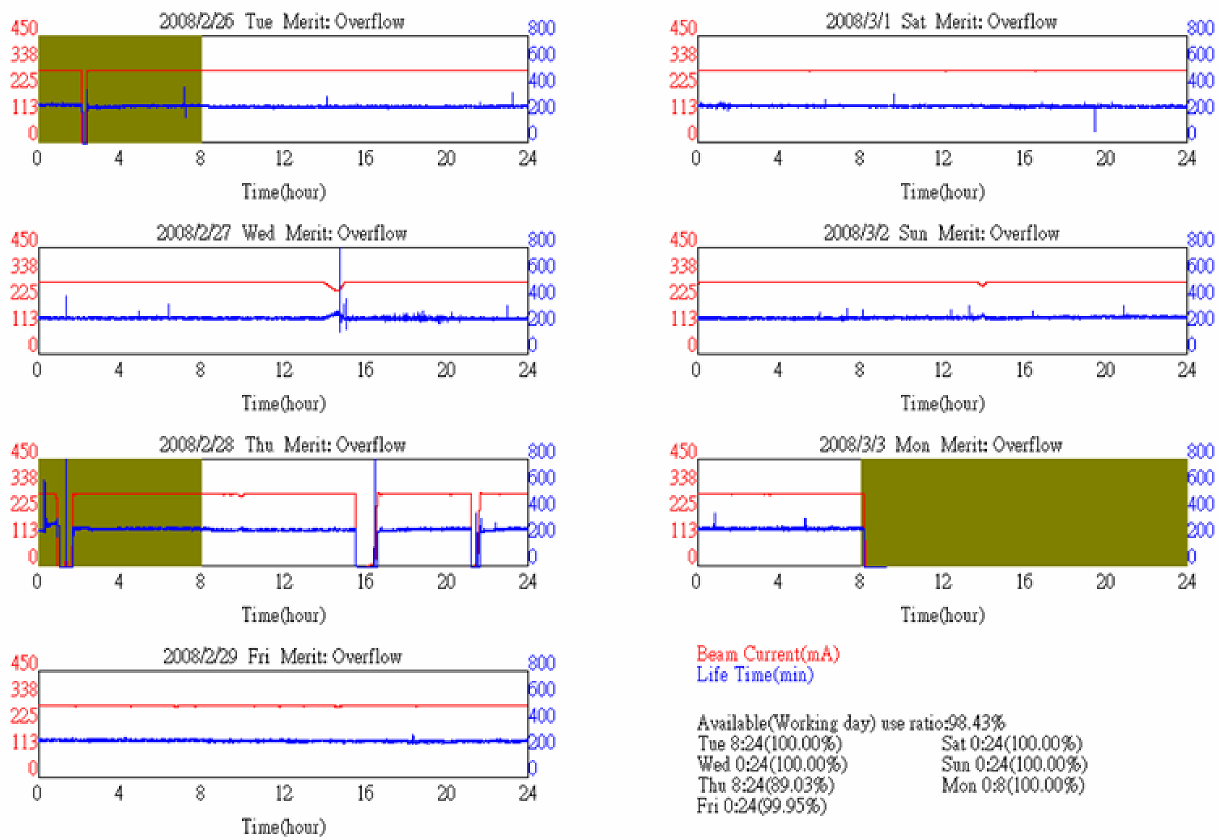
Operation status of the weeks: 02/26(Tuesday) ~ 03/03 (Monday)

1. User availability

One week data

I = 300 mA

τ = 3.5 h



Beam Current(mA)
Life Time(min)

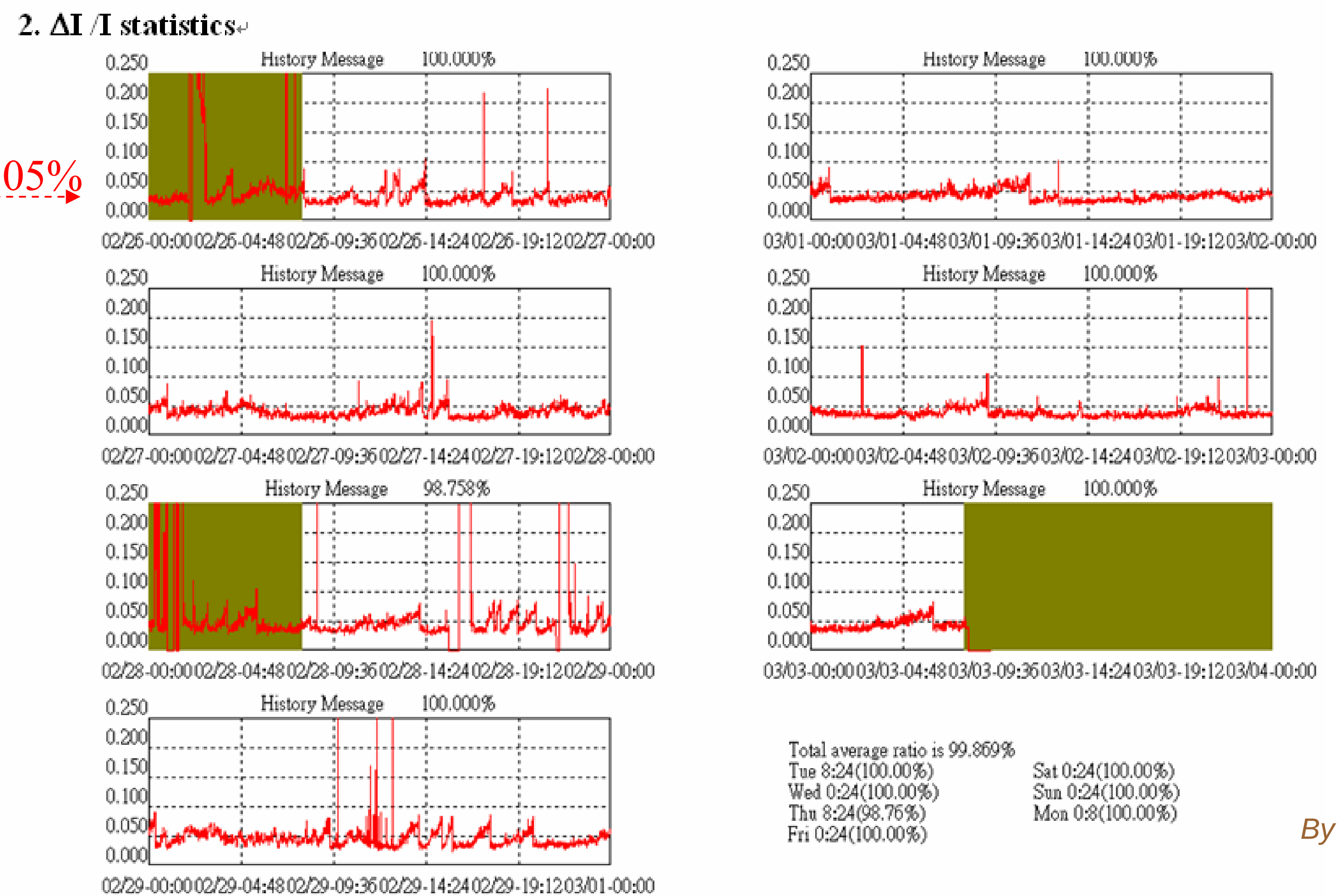
Available(Working day) use ratio:98.43%

Tue 8:24(100.00%)
Wed 0:24(100.00%)
Thu 8:24(89.03%)
Fri 0:24(99.95%)
Sat 0:24(100.00%)
Sun 0:24(100.00%)
Mon 0:8(100.00%)

By Y.C. Liu (Op. Gr.)

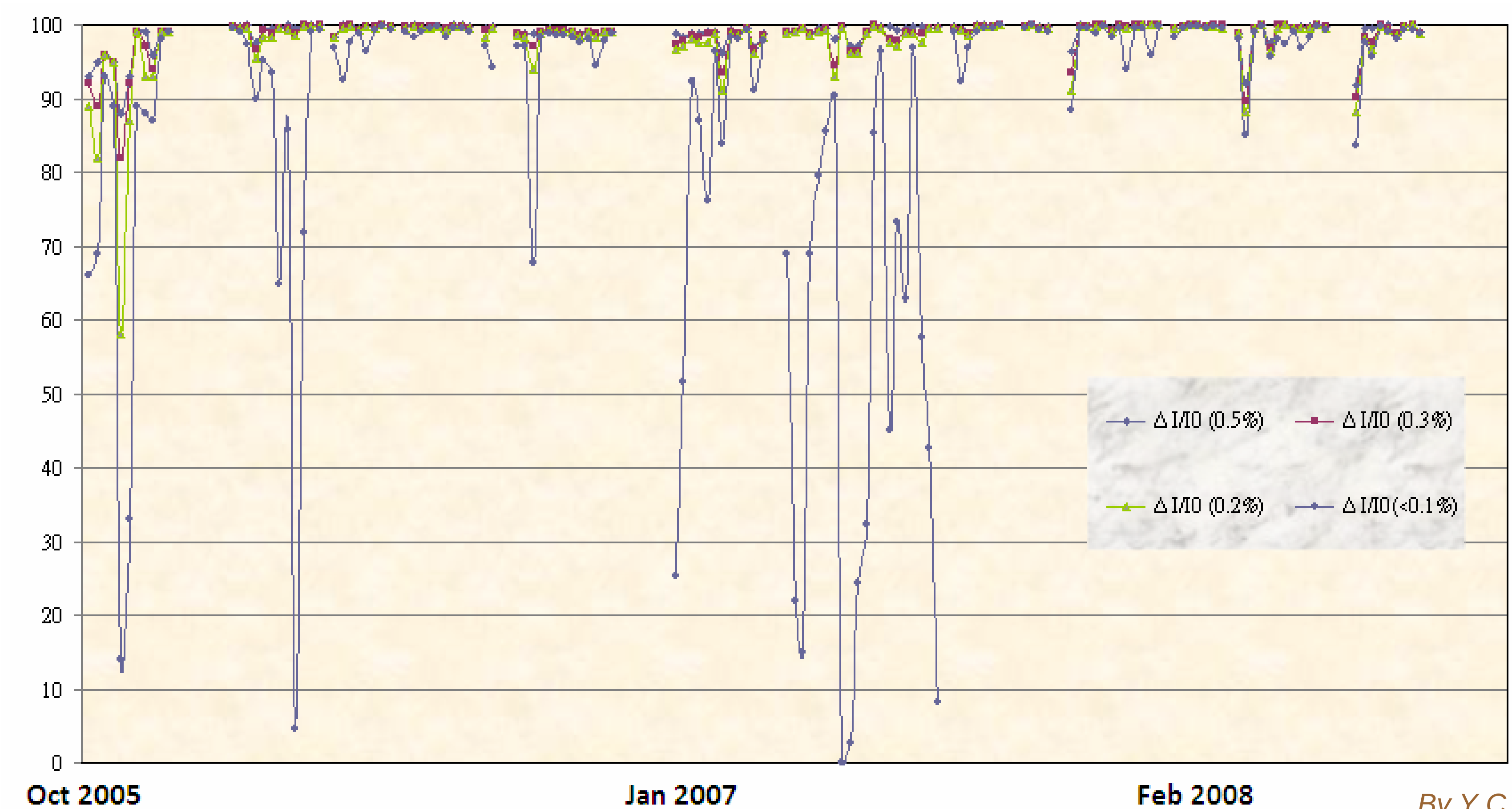
Fluctuation of photon flux (dI/I) < 0.05%

dI/I < 0.05%



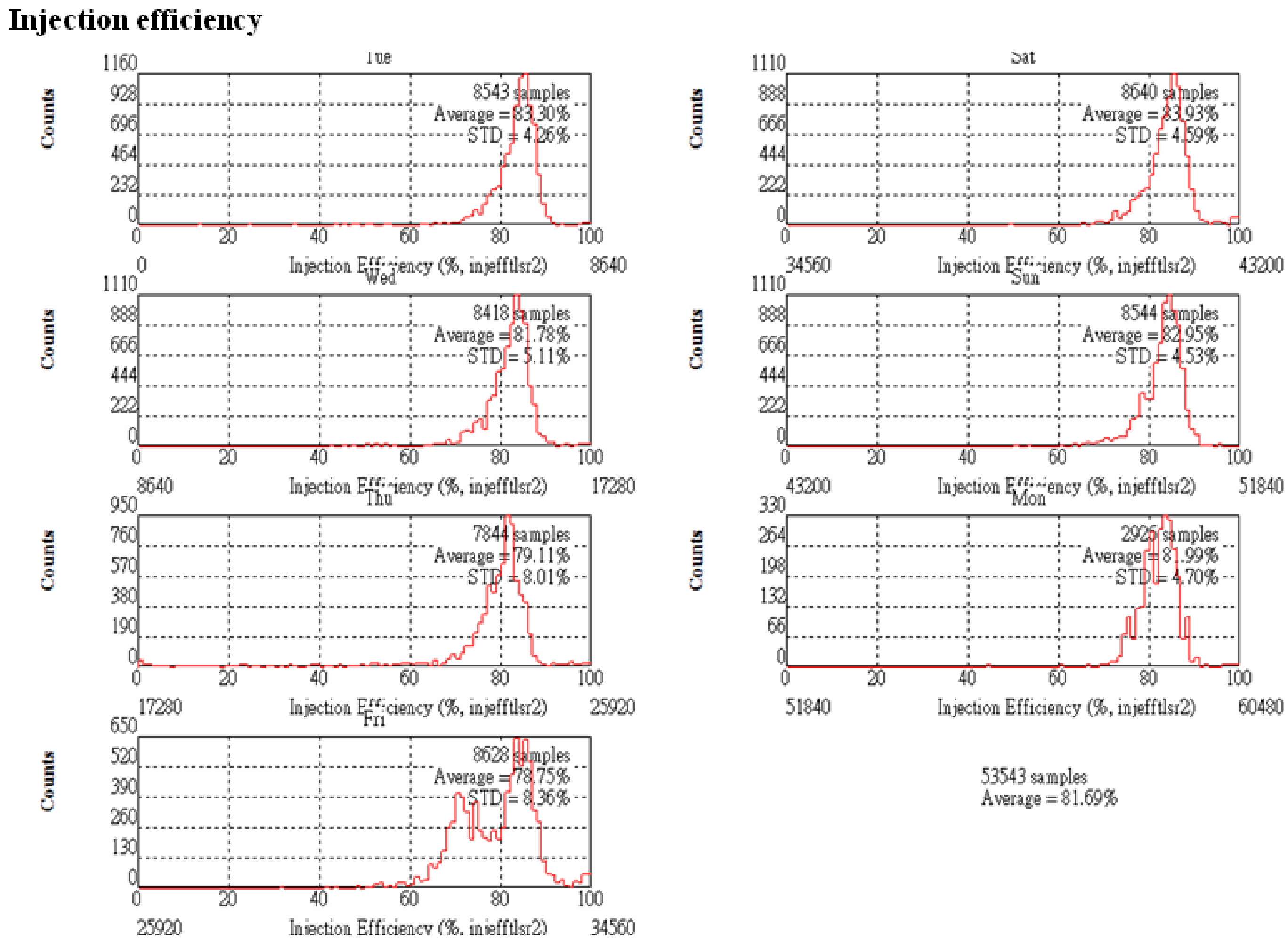
By Y.C. Liu
(Op. Gr.)

dI/I < 0.1 % available at > 95% of Operational User Beam Time



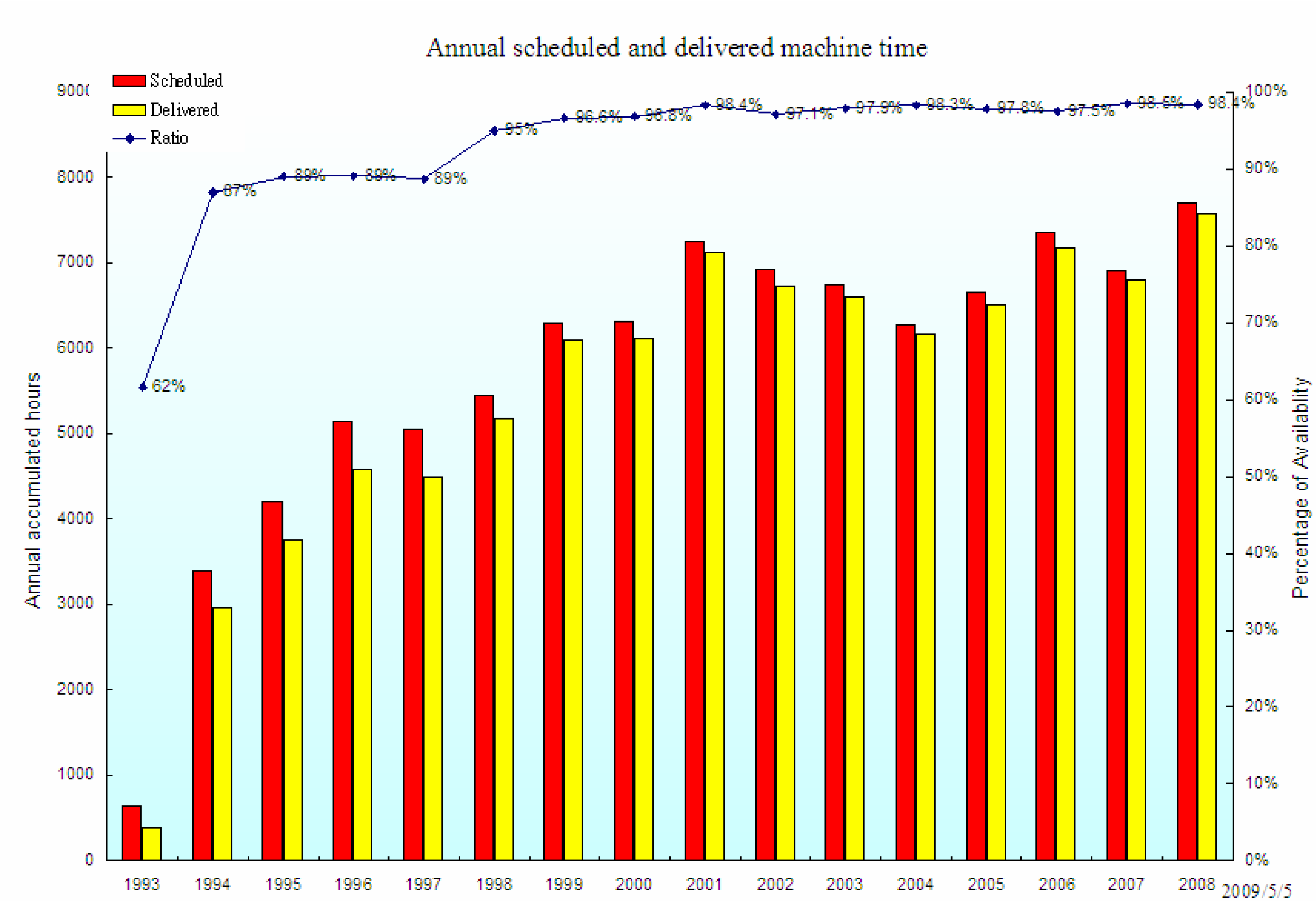
By Y.C. Liu (Op. Gr.)

Injection efficiency > 80%



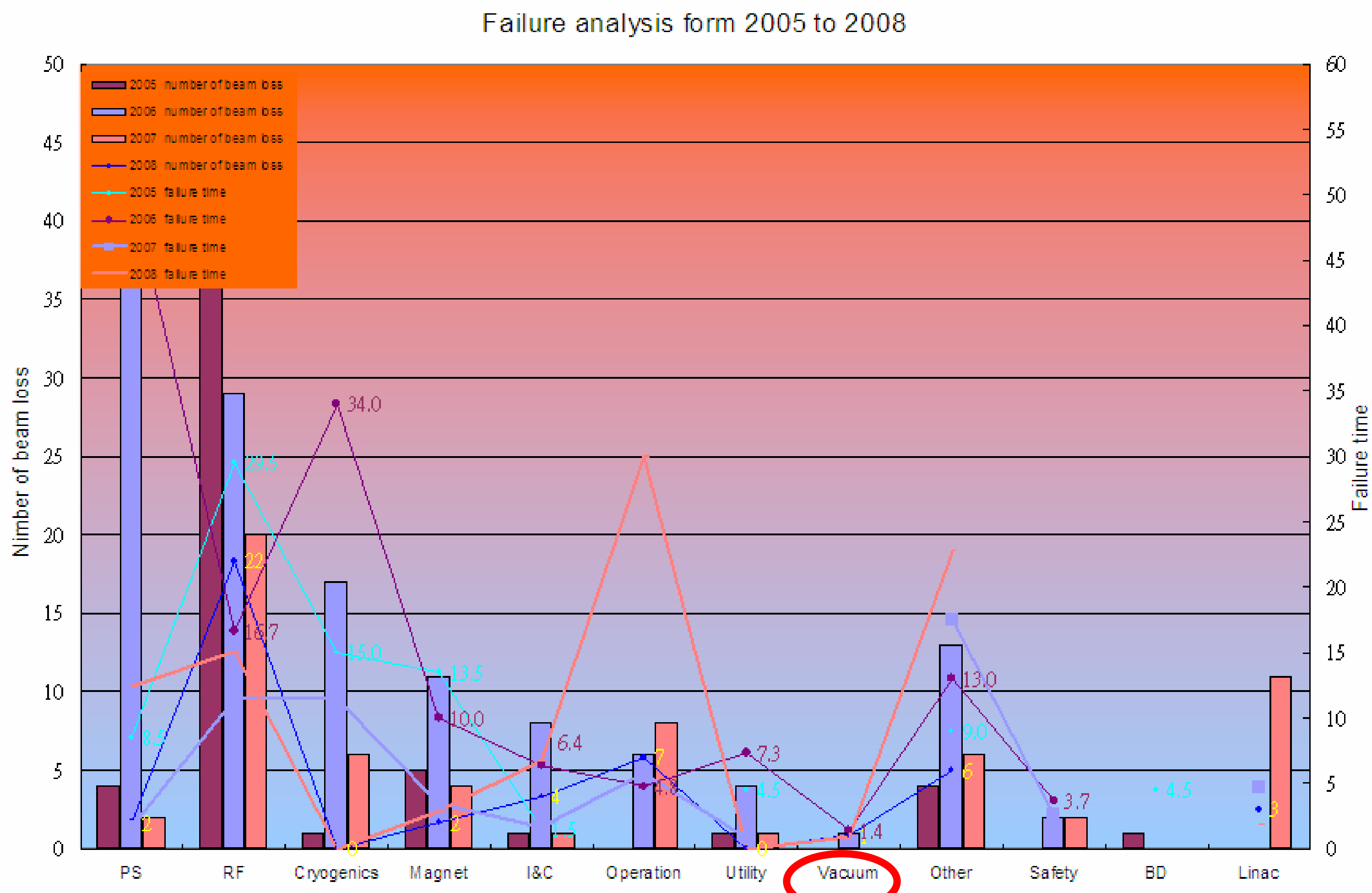
By Y.C. Liu (Op. Gr.)

Scheduled time delivered to the Users > 98%



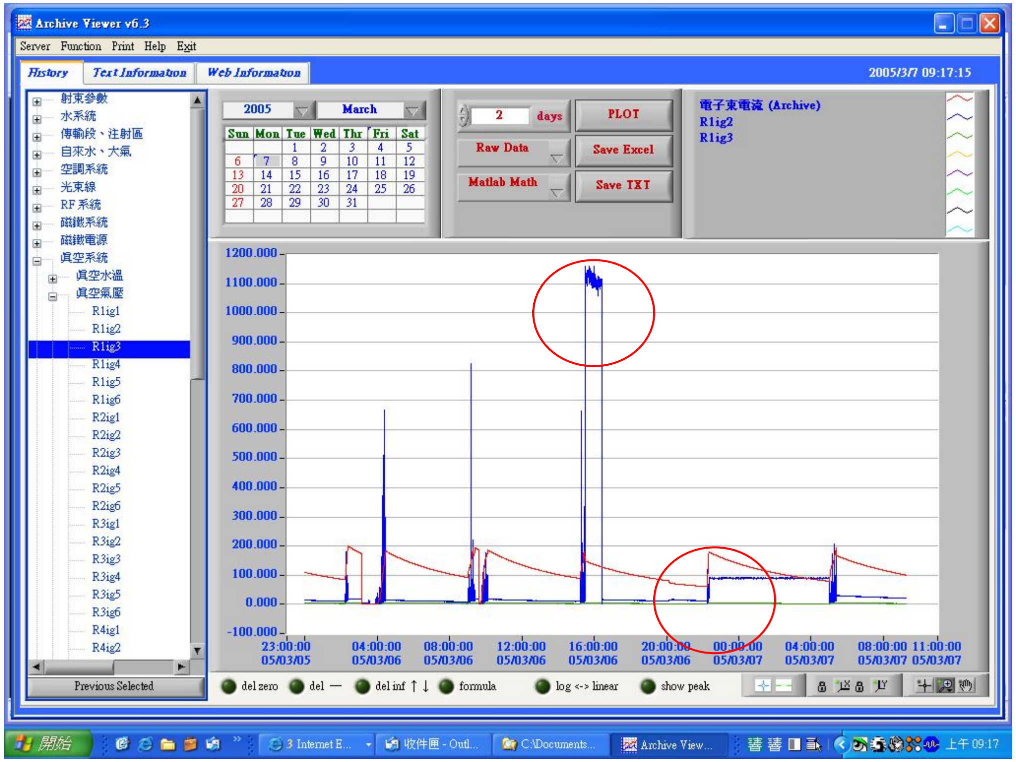
By Y.C. Liu (Op. Gr.)

Failure Analysis in 2005-2008
Vacuum trip < 1.4 events per 4 years



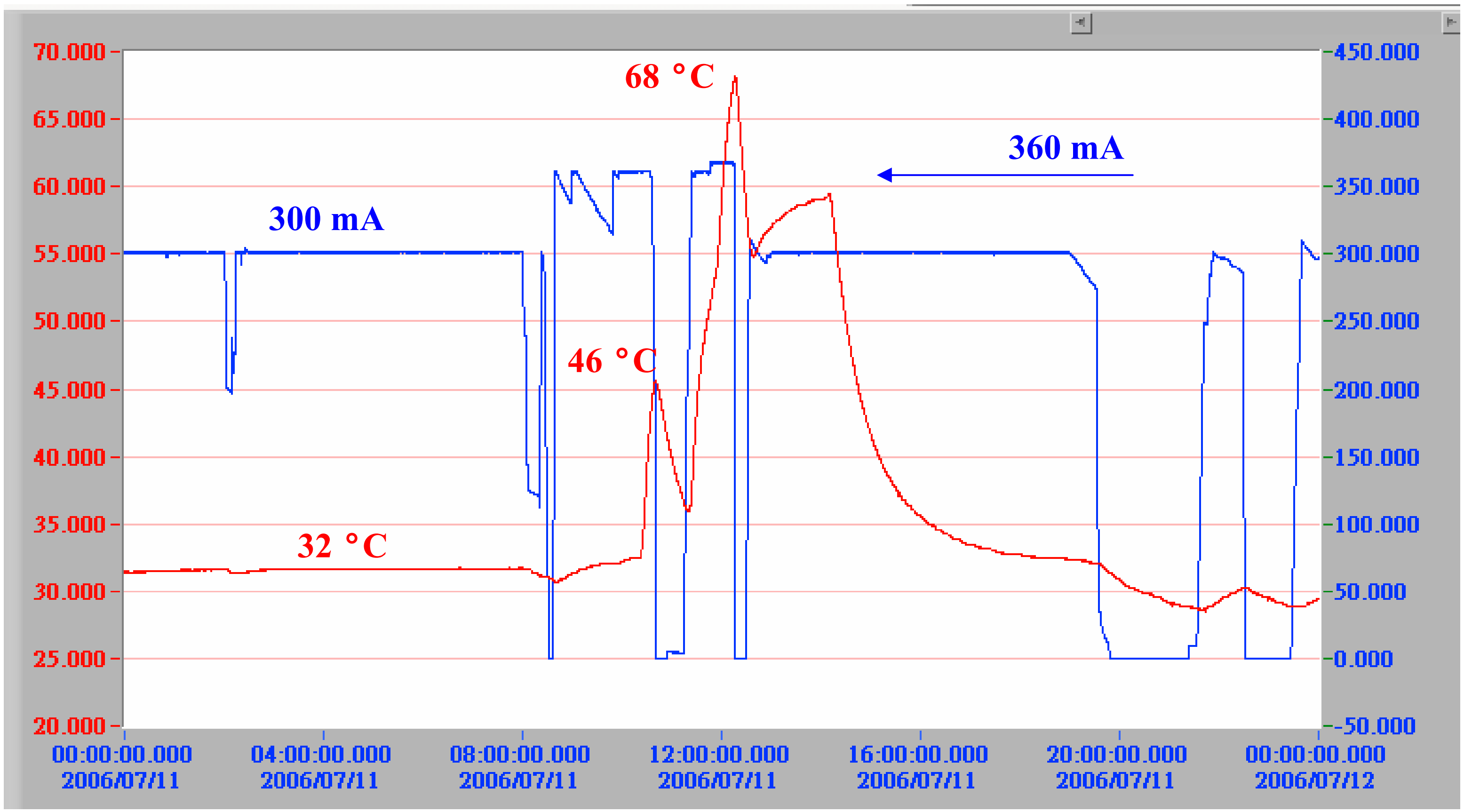
By Y.C. Liu
(Op. Gr.)

Noise pickup to the gauge

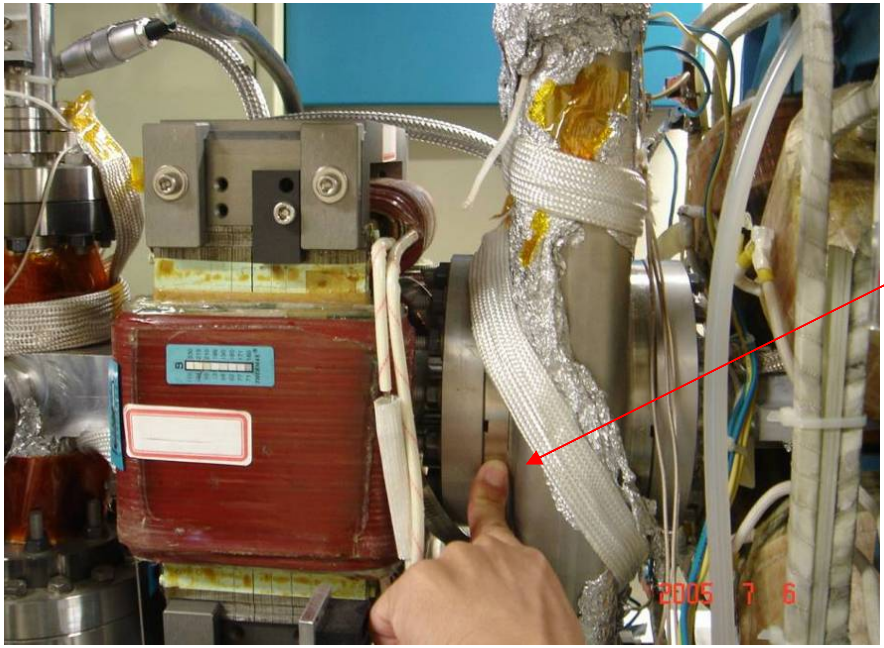


The readings of the ion gauge near a kicker pulsed magnet were instantly changed and hung due to the noise pickup during kicker firing. It has been solved by wrapping the gauge sensor with EM shielded clothes and the cable with Al foil. The grounding of the chamber is isolated from that of pulsed magnets.

It has been found the irregular temperature rise near the Sector Gate Valve (SGV) when beam current is raised higher than 360 mA.



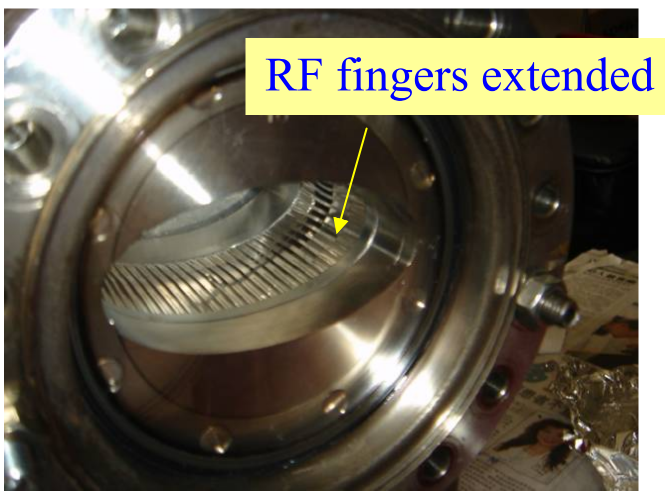
The SGV (VAT 47 Series) installed in the TLS storage ring

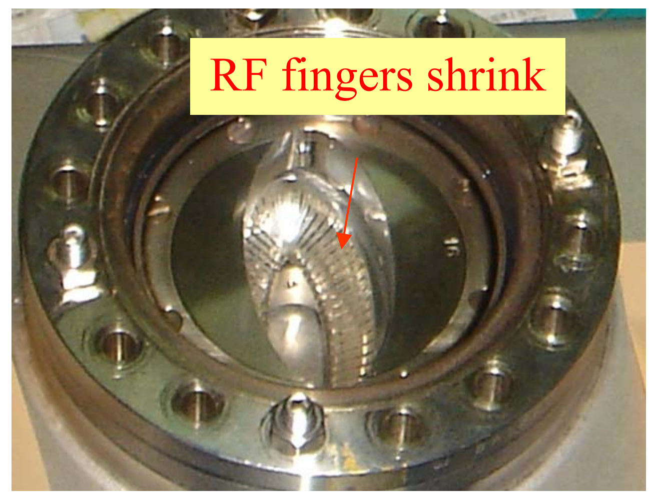


The flange of SGV is hot after interrupting the stored beam.

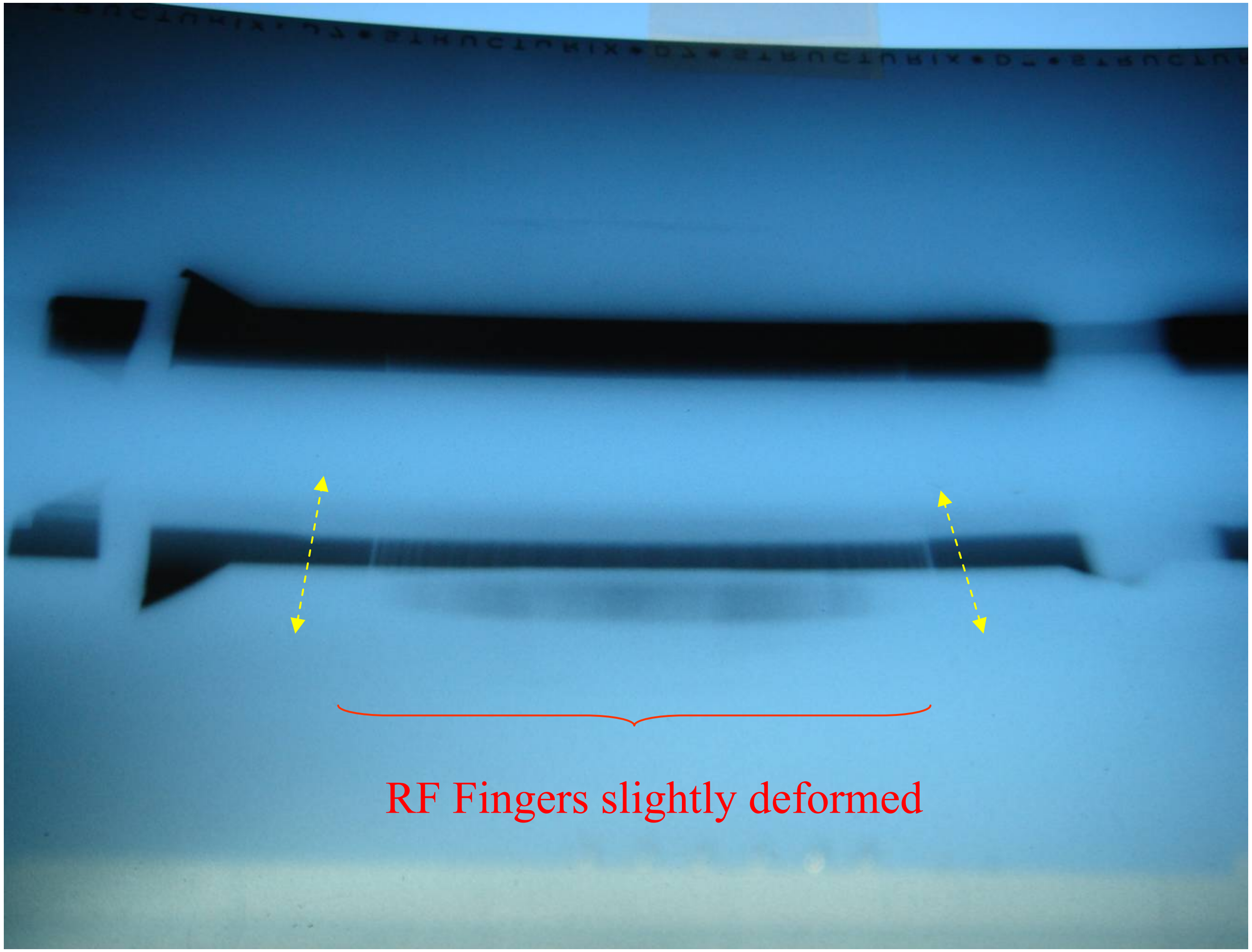
1. The irregular temperature rise (> 68 °C) on SGV at beam current > 360 mA can not be explained by irradiation heating from upstream synchrotron light which keeps the temperature of SGV stable (~ 32 °C) at 300 mA.
2. The possible reason of irregular temperature rise might come from the higher impedance of RF shielding structure caused by the operation parameters of beam.

X-ray Photographs of SGV





R3SGV2 (RF fingers slightly deformed)



Conclusions

1. The TLS vacuum system is getting reliable after 15 years operation.
2. Aluminum beam ducts illustrate good performance for TLS.
3. TMP pumps for PSD beam cleaning at commissioning is efficient.
4. Gas load to the IP and NEG after beam cleaning is significantly reduced which keep the getter materials fresh and longer life time.
5. Non-metal sealed valves are not adequate for high reliable light source.
6. In-situ baking not only causes the problems of damage the vacuum components or positional shift due to thermal expansion, but also leave the heavy work loads and long time for the maintenance inside the tunnel. It is better to complete the baking for the vacuum components outside the tunnel and assure the good ultrahigh vacuum qualities being achieved, then using the super-dry N_2 purging and super-dry ambient air shower exposing system and procedure for the installation of UHV components to avoid the in-situ baking inside the tunnel.

Thanks for your attention!