國家同步輻射研究中心
National Synchrotron Radiation Research Center

Operation of TLS and Progress of TPS

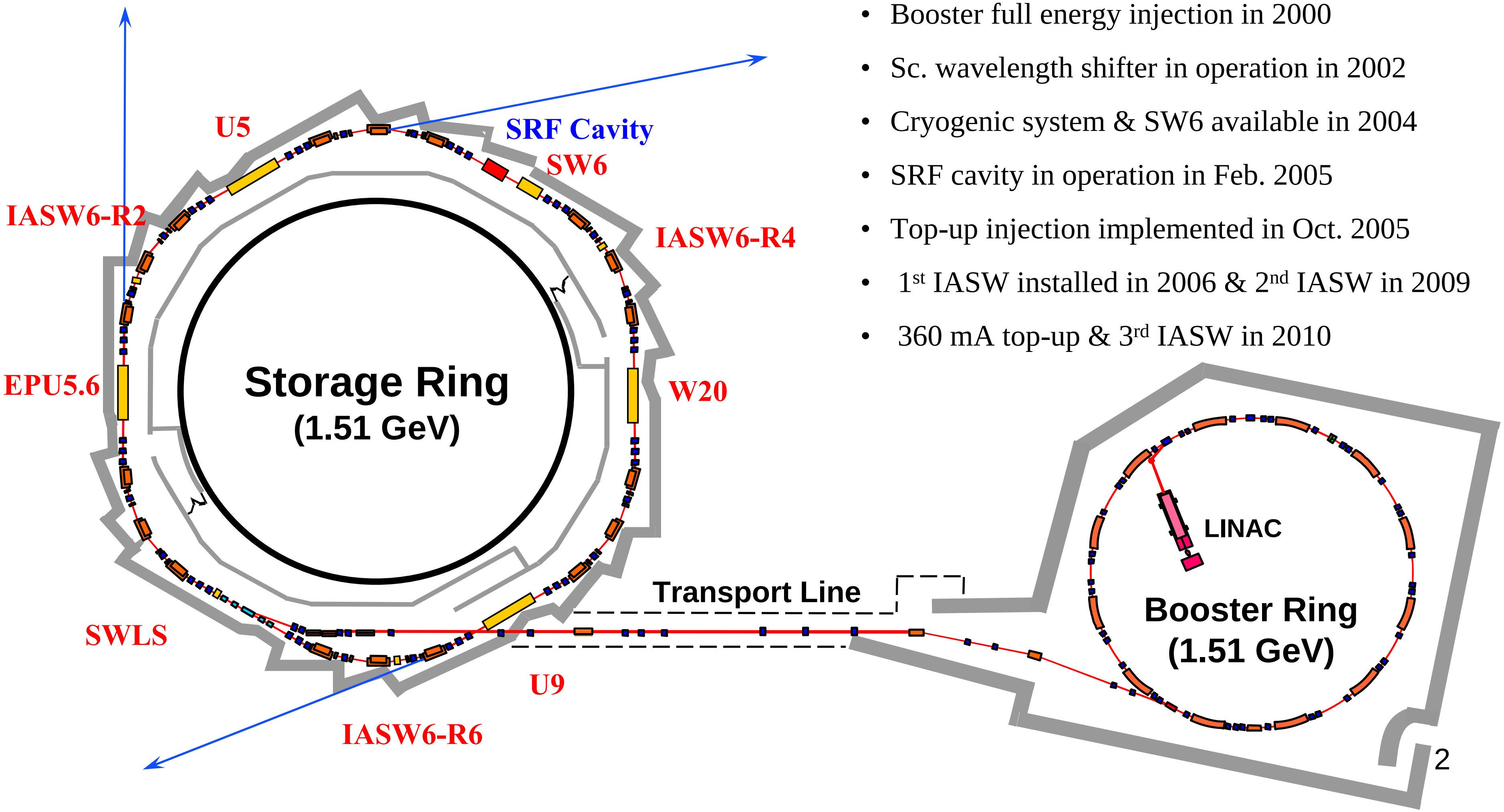
Gwo-Huei Luo on behalf of
Accelerator Divisions

EPICS Collaboration Meeting
June 13-17, 2011

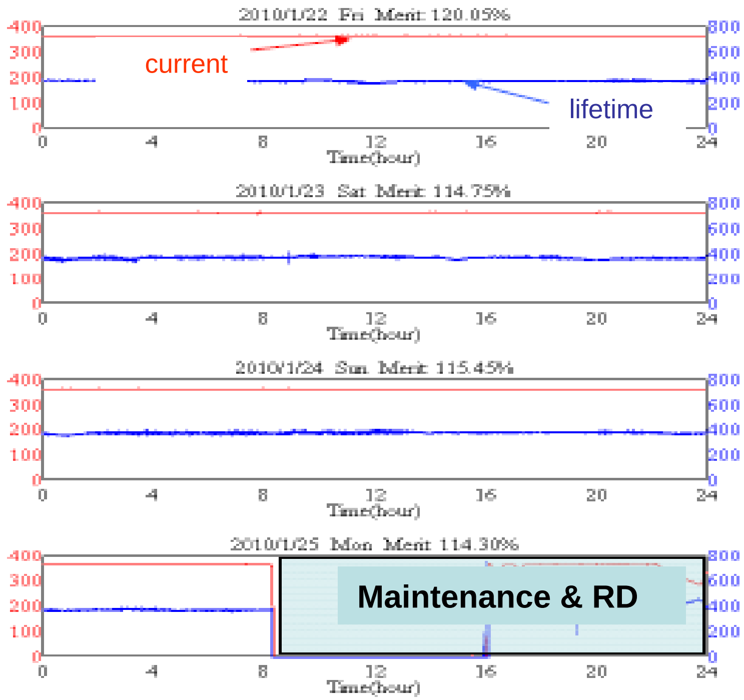
TLS accelerator layout and key milestones

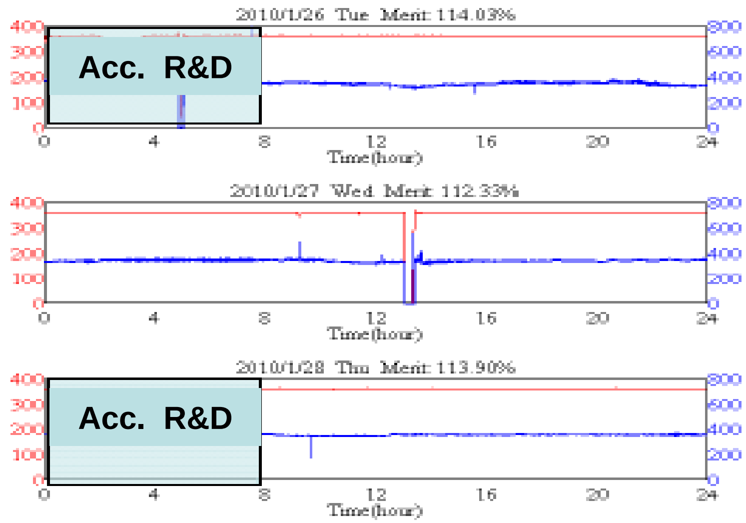
The most densely-packed SR ring with the highest number of superconducting IDs!

- Commission in Apr. & open to users in Oct. 1993
- 1.3 to 1.5 GeV ramping in operation in 1996
- 240 mA operation beam current in 1996
- Booster full energy injection in 2000
- Sc. wavelength shifter in operation in 2002
- Cryogenic system & SW6 available in 2004
- SRF cavity in operation in Feb. 2005
- Top-up injection implemented in Oct. 2005
- 1st IASW installed in 2006 & 2nd IASW in 2009
- 360 mA top-up & 3rd IASW in 2010



Weekly report and accumulated dosage

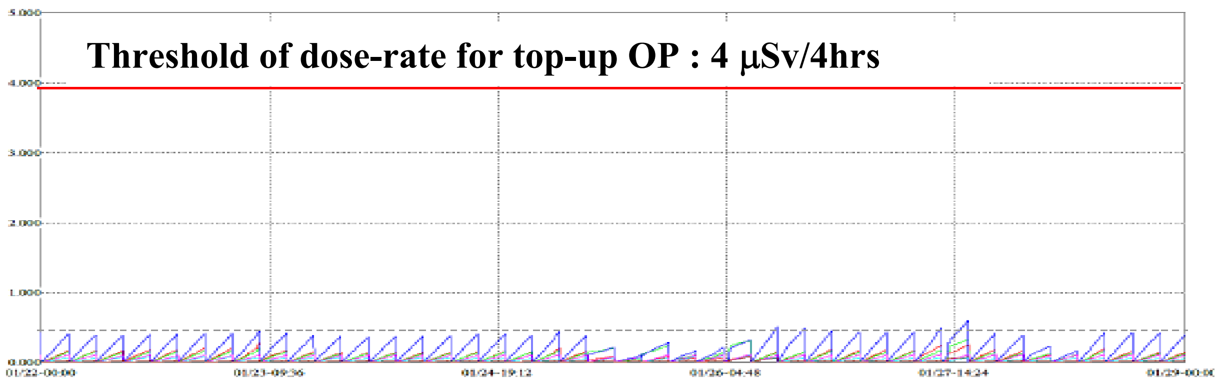




Beam Current(mA)
Life Time(min)

Available(Working day) use ratio:99.19%

Fri 0:24(100.00%)	Tue 8:24(99.10%)
Sat 0:24(100.00%)	Wed 0:24(96.52%)
Sun 0:24(100.00%)	Thu 8:24(98.72%)
Mon 0:8(100.00%)	

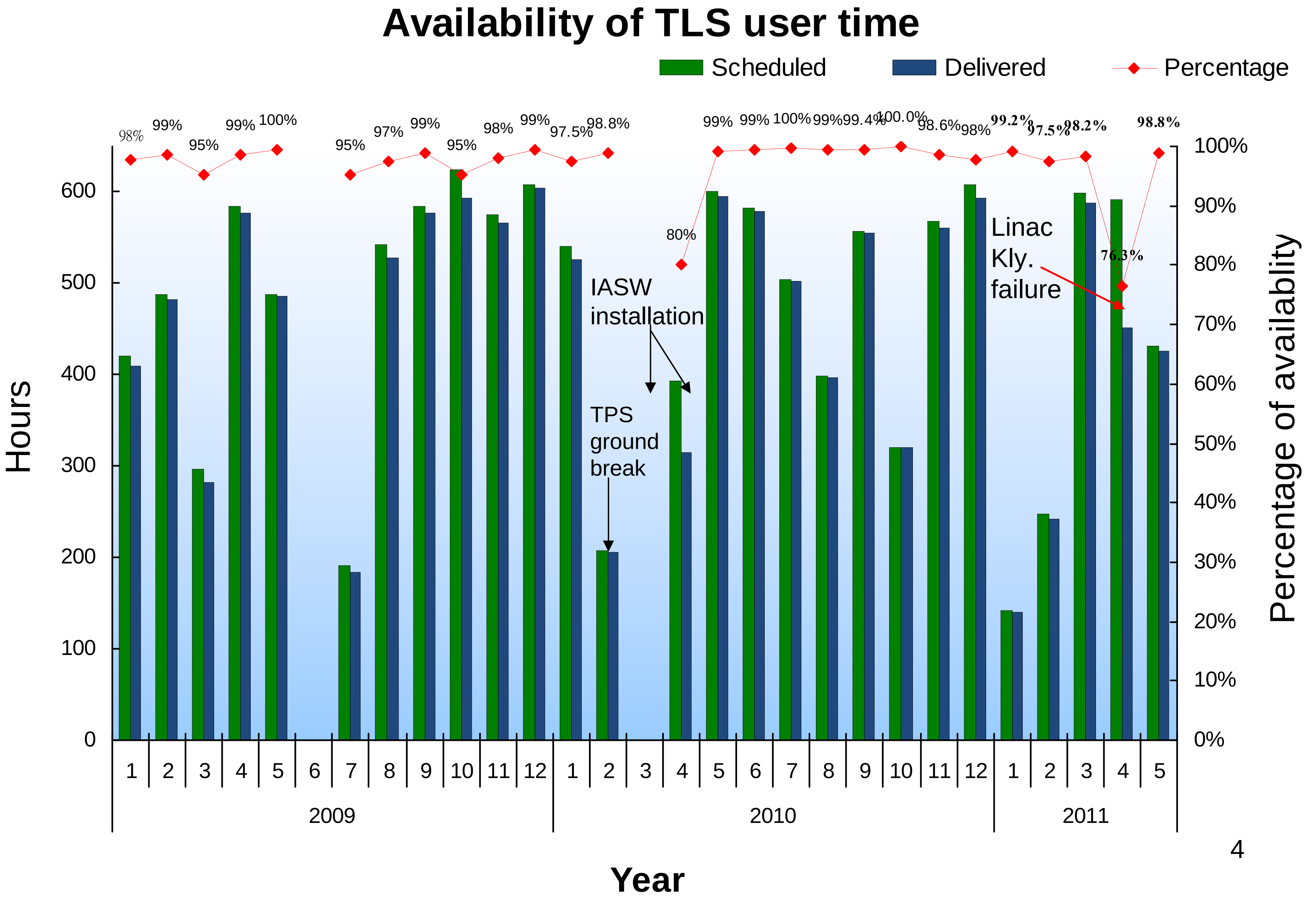


Signal Name	Max	Min	Dif	Avg	Sum
gS1.1 (uSv/h)	0.270	0.001	0.269	0.075	4562.552
gS2.2 (uSv/h)	0.330	0.001	0.329	0.080	4817.066
gS3.3 (uSv/h)	0.600	0.001	0.599	0.192	11592.971
gS4.4 (uSv/h)	0.100	0.001	0.099	0.030	1818.190
gS5.5 (uSv/h)	0.110	0.001	0.109	0.048	2909.204
gS6.6 (uSv/h)	0.080	0.001	0.079	0.010	585.241

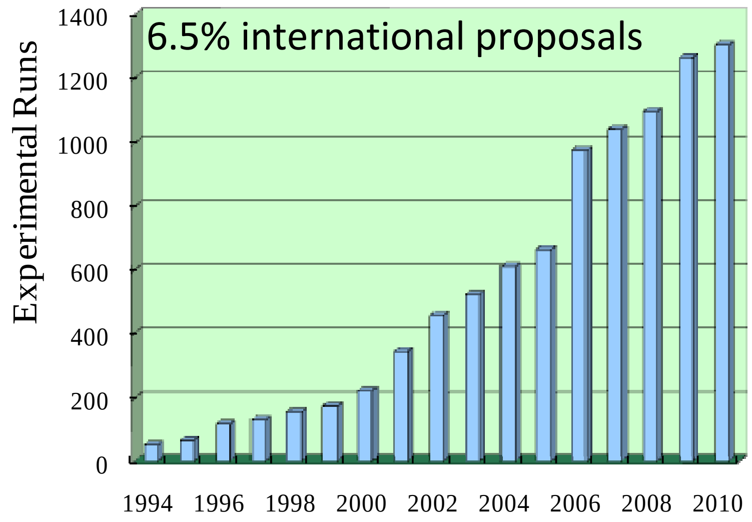
Annual dosage limit for NSRRC staff < 2 mSv/yr.

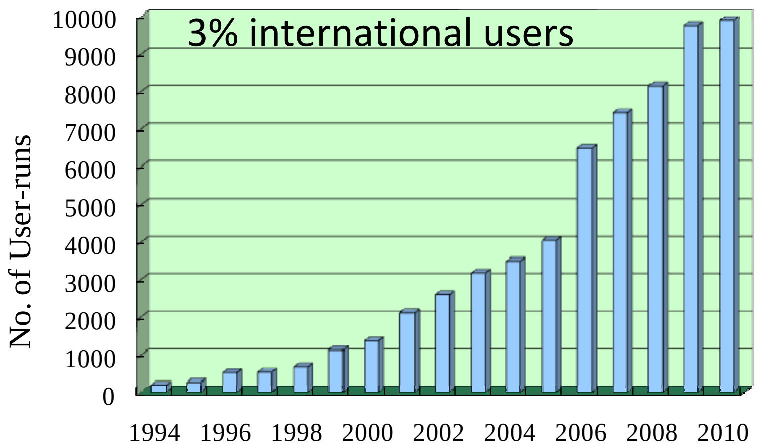
Atomic Energy Council annual dosage < 50 mSv/yr. (rad. worker)

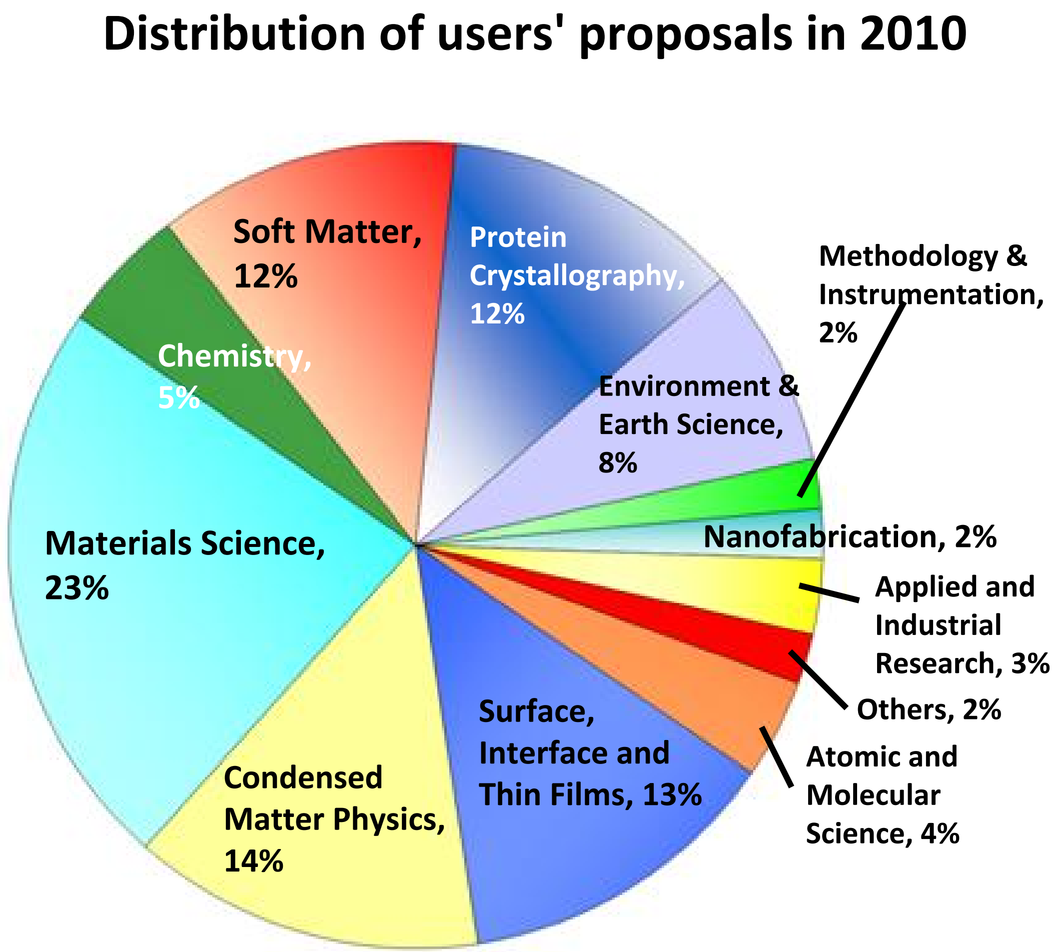
Operation statistics during user shifts



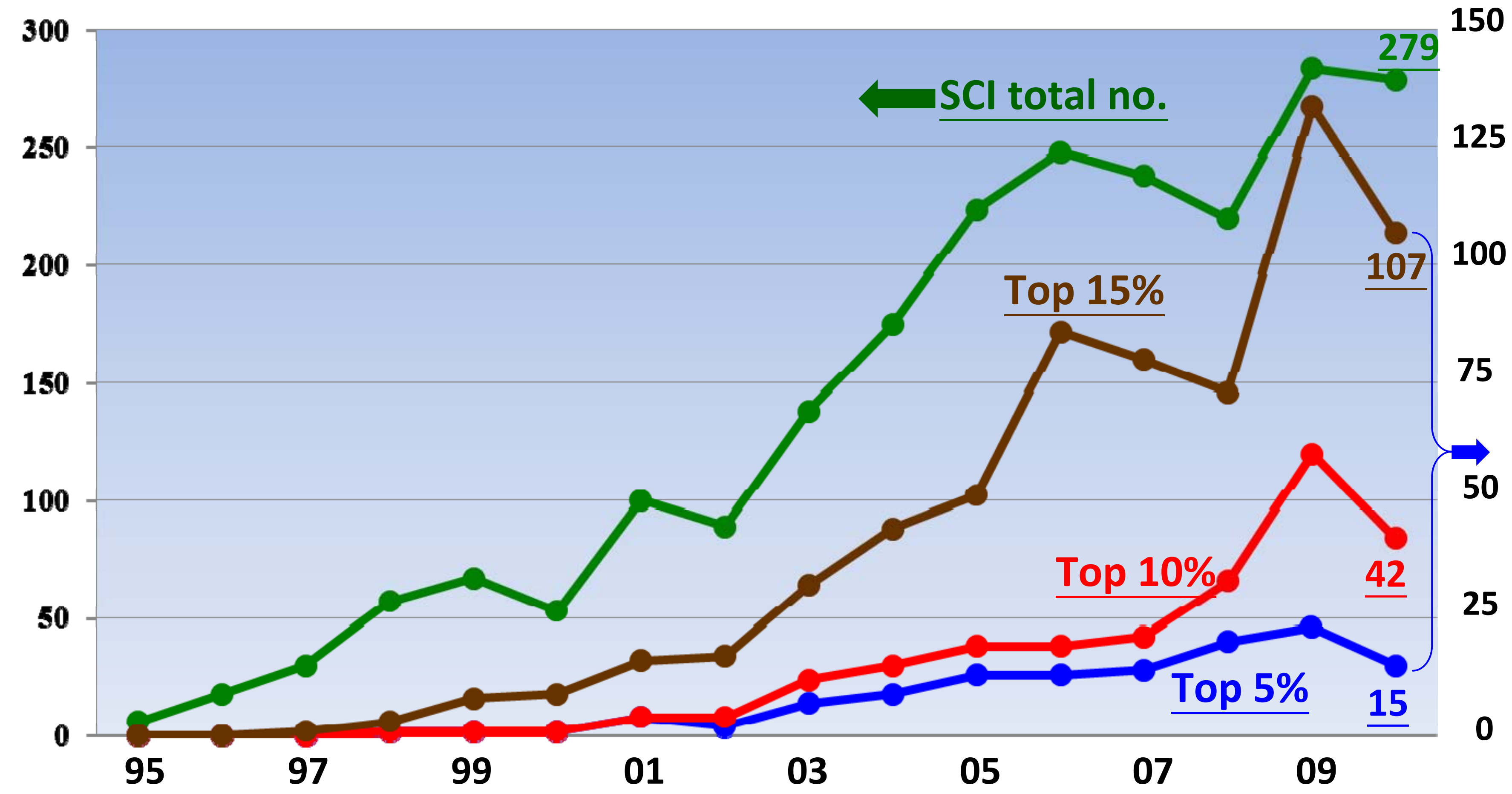
Users Distribution







SCI Publication Statistics



Remark:

1.Top 5%、10% and 15% include SCI paper in the field of natural science and life science.

2.Top 5%: IF ≥ 6.0 in natural science, and IF ≥ 9.0 in life science.

3.Top 10%:IF ≥ 4.5 in natural science ，IF ≥ 6.0 in life science 。

4.Top 15%:IF ≥ 3.5 in natural science ，IF ≥ 4.8 in life science 。

5. 92年(含)前所有年度之IF值皆以93年之IF值為統計標準，其餘年度皆依據該年度之IF值為統計標準。

6. 以上為截至100年6月上旬之資料。相關統計仍持續進行中。

Status and Progress of TPS

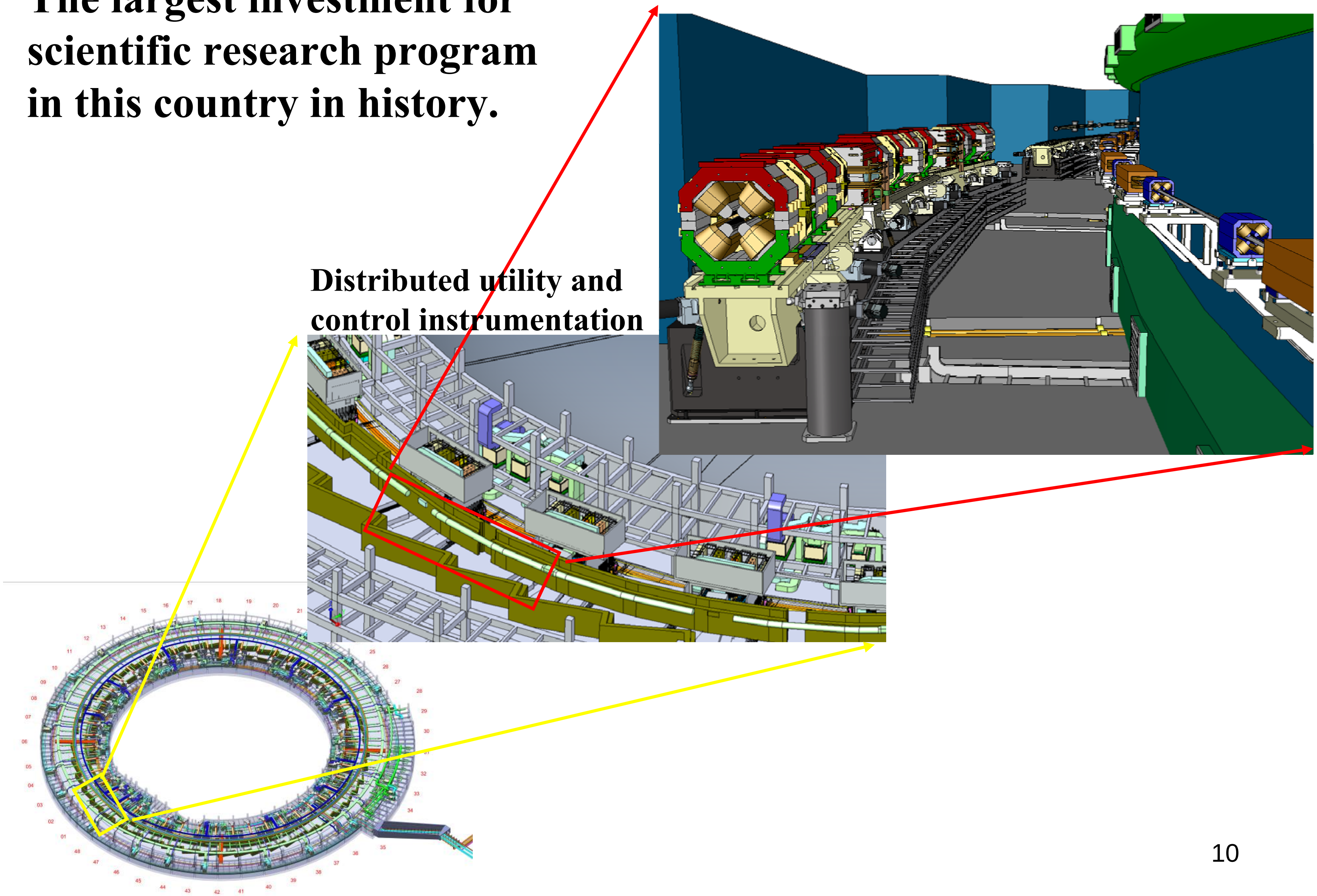
Major Parameters of Taiwan Photon Source

Energy	3 GeV (maximum 3.3 GeV)
Current	500 mA at 3 GeV (Top-up injection)
SR circumference	518.4 m (h = 864 = $2^5 \cdot 3^3$, dia.= 165.0 m)
BR circumference	496.8 m (h = 828 = $2^2 \cdot 3^2 \cdot 23$, dia.= 158.1 m)
Lattice	24-cell DBA
Straight sections	12 m x 6 (σ_v = 12 μm, σ_h = 160 μm) 7 m x 18 (σ_v = 5 μm, σ_h = 120 μm)
Bending magnets	48
Emittance	1.6 nm·rad at 3 GeV (Distributed dispersion)
Coupling	1 %
RF frequency	500 MHz
RF gap voltage	2.8~3.5 MV (3 SRF cavities)
RF power	750 kW (3 SRF cavities)
Location	No. 101, Hsin-Ann Road, Hsinchu, Taiwan
Building	Outer diameter 210 m ; Inner diameter 129 m

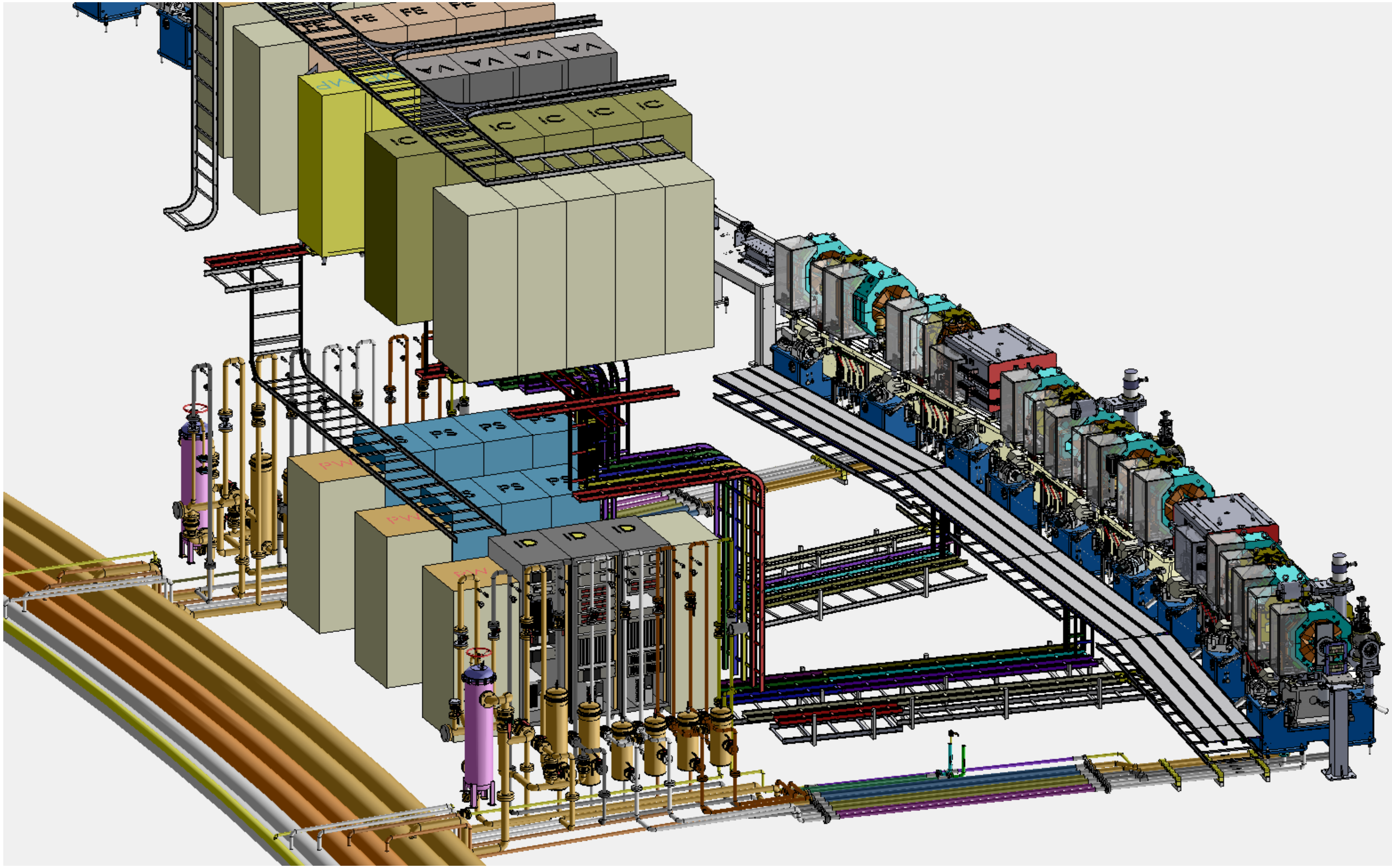
Taiwan Photon Source (TPS)

3D Aerial View of NSRRC

The largest investment for scientific research program in this country in history.



Utility, control and instrumentation for one cell lattice

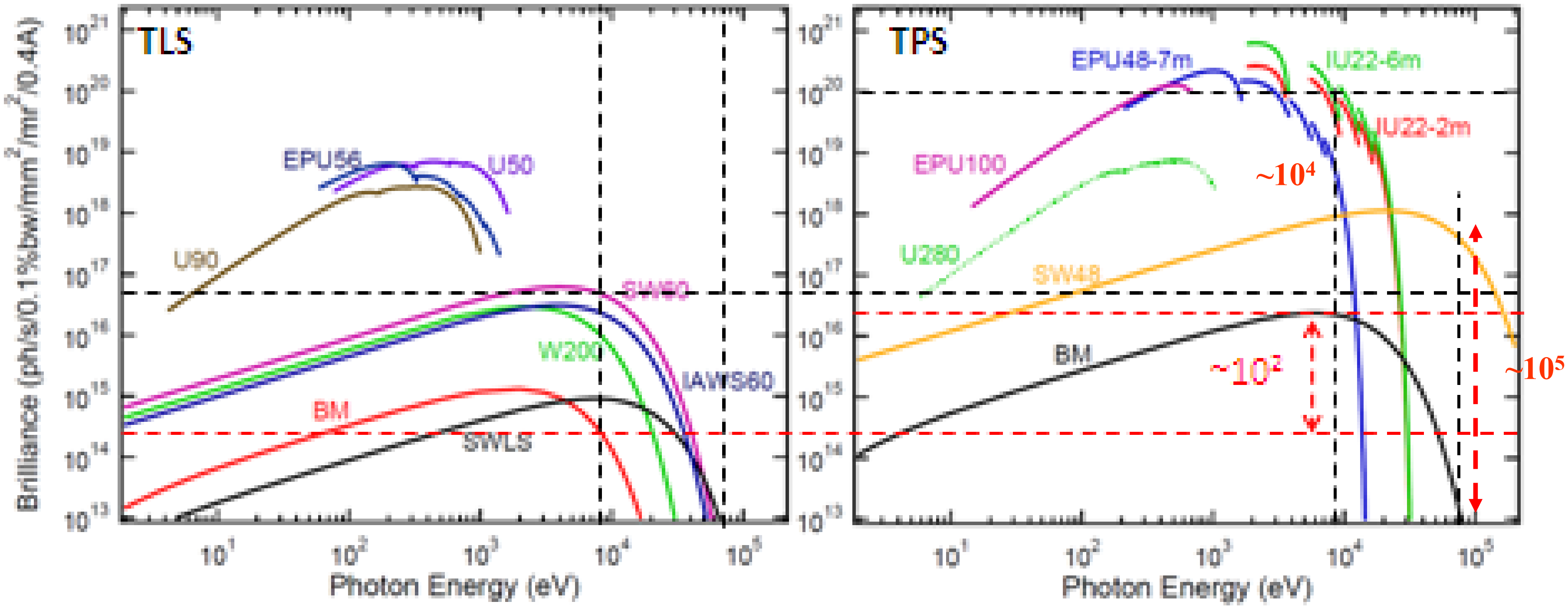


Comparison of brightness between TLS and TPS

The X-ray spectrum (photon energy 8 keV ~ 70 keV):

the brightness of bending magnet >10^2.

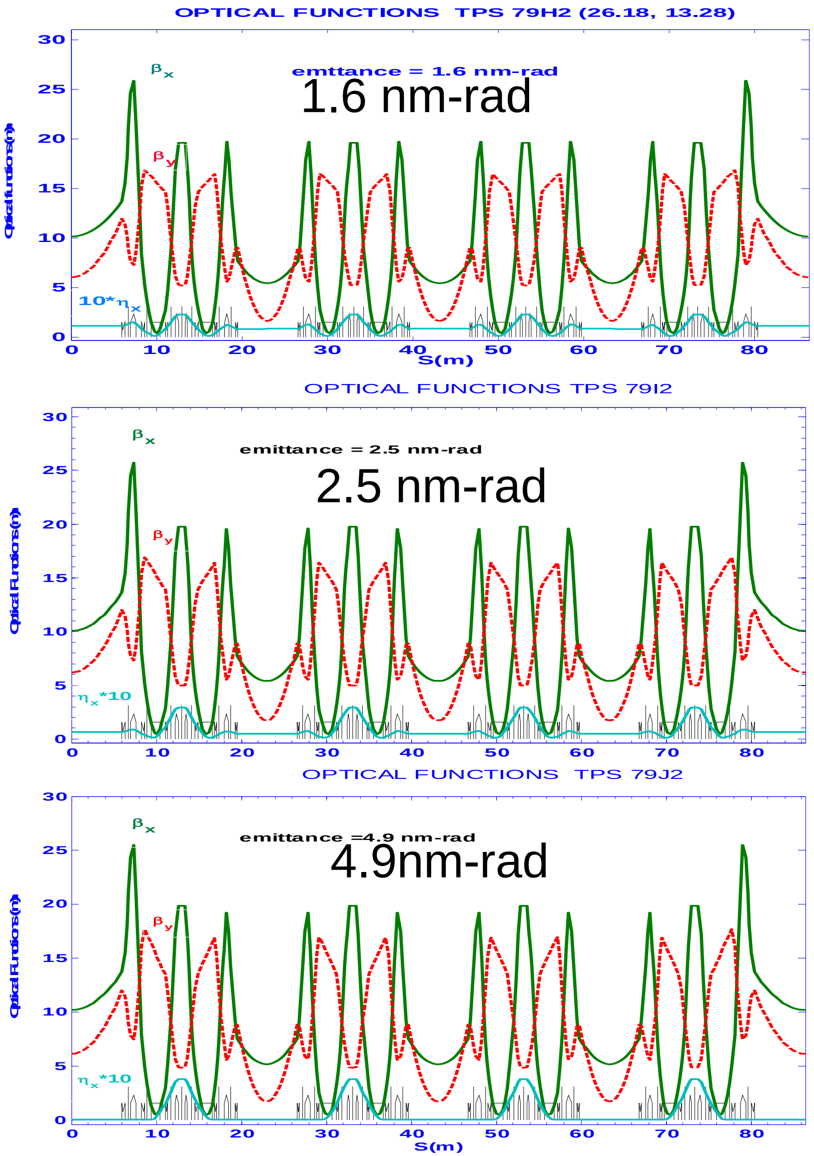
the brightness of IDs: 4~6 orders of mag.

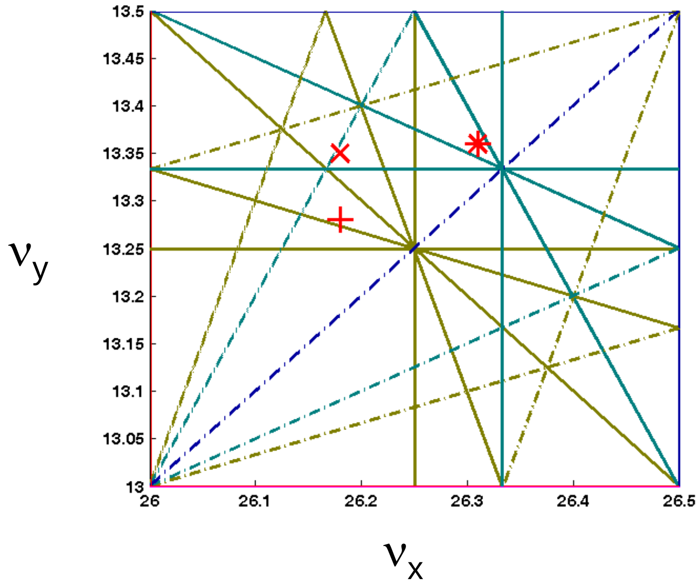


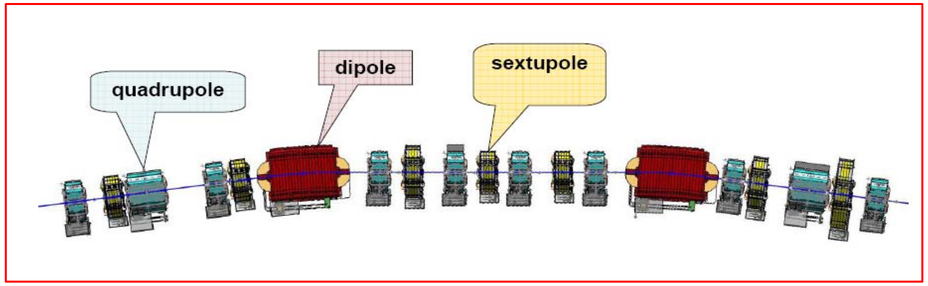
Major parameters of TPS storage ring

Circumference C (m)	518.4
Energy E (GeV)	3.0
Beam cuurent (mA)	400
Natural emittance ε_{x0} (nm-rad)	1.6
Straight sections (m)	12 (x6) + 7 (x18)
Radiofrequency (MHz)	499.654
Harmonic number h	864
RF voltage (MV)	3.5
Energy loss per turn (dipole) (MeV)	0.85269
Betatron tune ν_x/ν_y	26.18 /13.28
Momentum compaction (α_1, α_2)	2.4×10^{-4}, 2.1×10^{-3}
Natural energy spread σ_E	8.86×10^{-4}
Damping time $\tau_x/\tau_y/\tau_s$ (ms)	12.20 / 12.17 / 6.08
Natural chromaticity ξ_x/ξ_y	-75 / -26
Synchrotron tune ν_s	0.00609
Bunch length (mm) σ_l	2.86

TPS storage ring lattice functions







24 DBA cells

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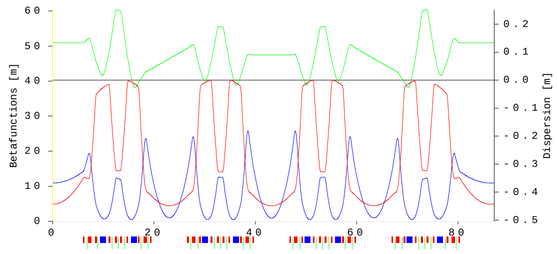
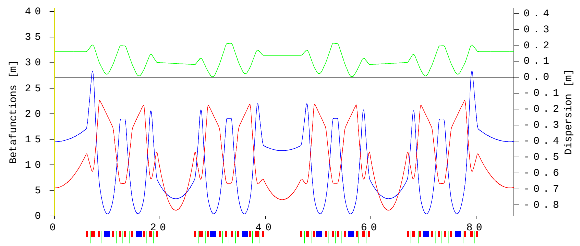
Alternative lattice configurations

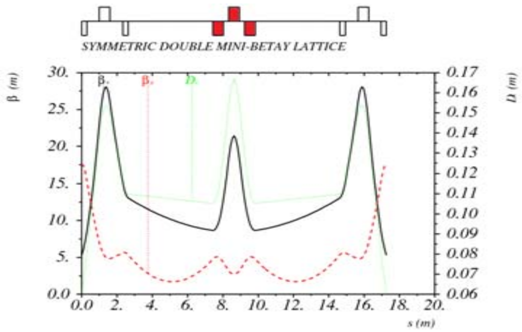
- Low α short bunch -- reduce 1st –order α so that bunch length can be reduced by a factor of 5 (a few ps).
- High/low β_x in the straight -- provide tuning flexibility for optimizing photon beam properties for the experiments.
- Double mini- β_y in the long straight – accommodate two mini-gap insertion devices in a long straight.

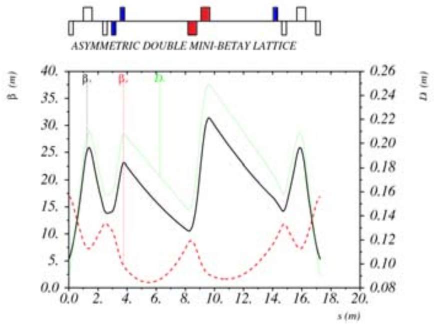


α_1 = 7.3e-6
ε_x= 2.8 nm-rad.



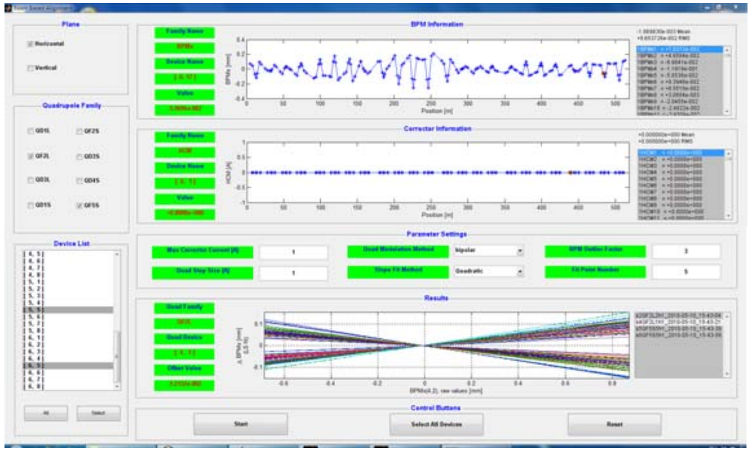
ε_x= 1.6 nm-rad



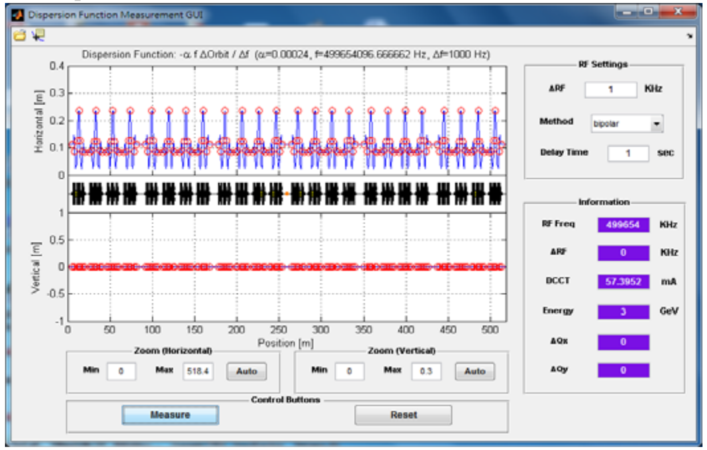


Accelerator application tools for beam commissioning and operation

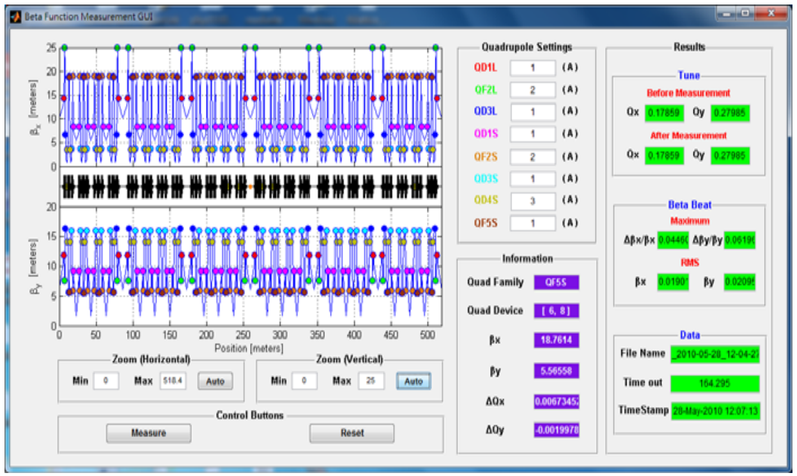
Beam Based Alignment



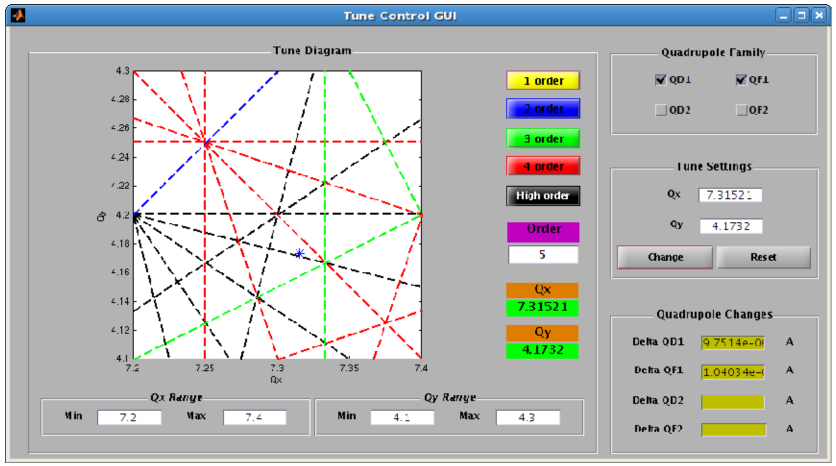
Dispersion Function Measurement



Beta Function Measurement



Tune Control



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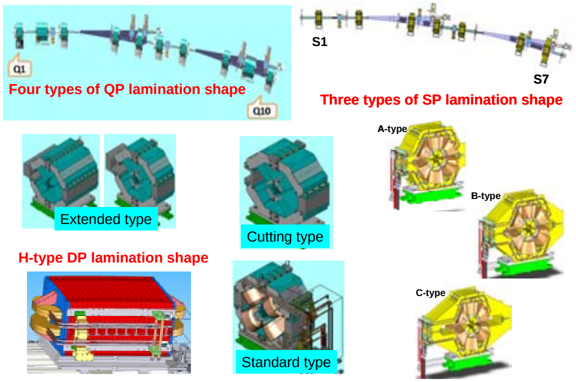
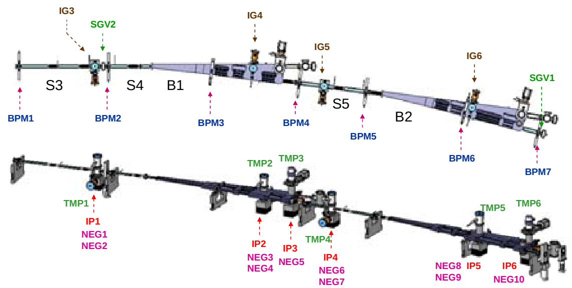
TPS Sub-system design and prototype

二極、四極與六極磁鐵



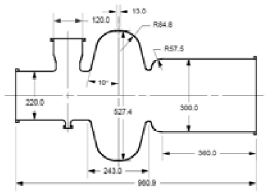
真空系統設計與射束診斷安排

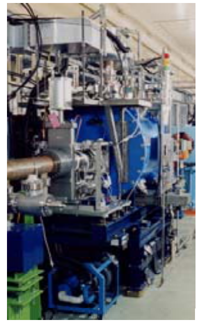


超導高頻共振腔

KEKB Type SRF Module

- Installed at KEKB (508 MHz) and BECP-II/IHEP (500 MHz)





修正磁鐵電源供應器原型

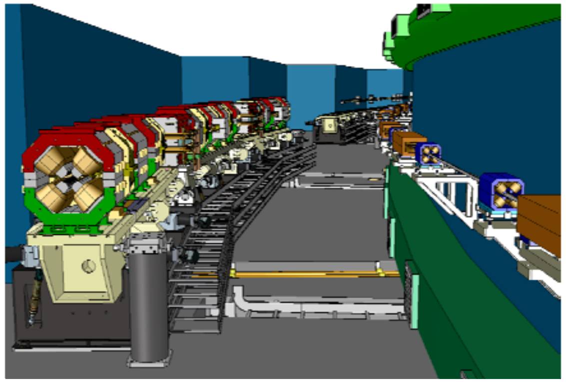
(與工研院合作開發)

Specification

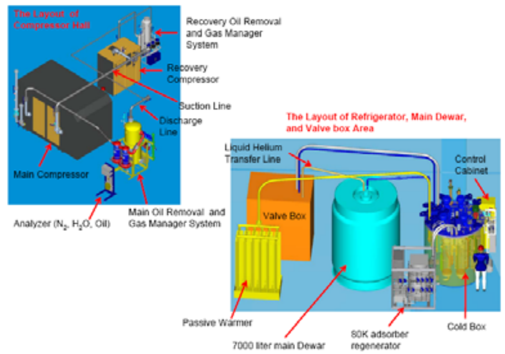
Max. volt/cur.:	±50V/±10A
Current ripple:	10 ppm
Short term stability:	5 ppm
Long-term stability:	10 ppm

Total 750 units to be fabricated by local company

屏蔽牆內儲存環與增能環結構

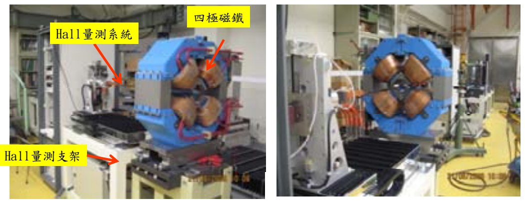


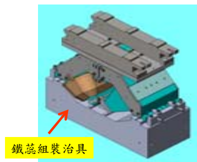
700 W液氦低溫系統配置

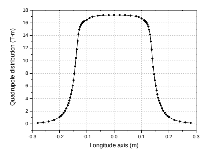


TPS儲存環1/24段實體照片

四極磁鐵原型及量測平台

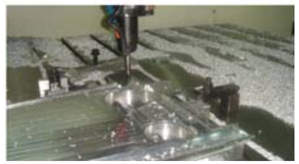






沿軸向四極鐵磁場強度測試
- 四極成分達設計值
- 八、十二極分量超出規格
- 工程精度需提昇(底座等)
- 品質需強化(線圈溫升)

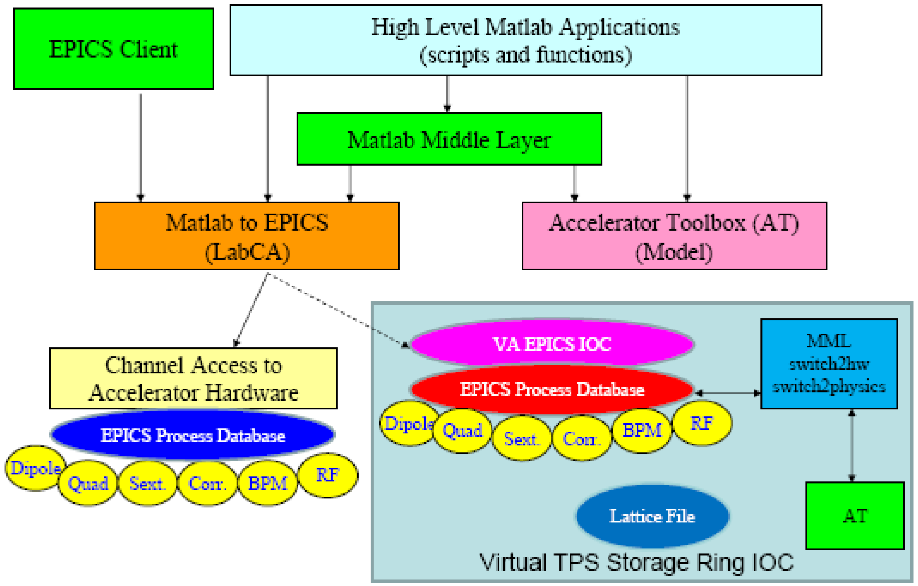
潔淨室無油加工鋁質二極真空腔



3D dipole Al chamber machining
1. In clean room
2. Oil free environment
3. High precision on profile

Software development for the accelerator control

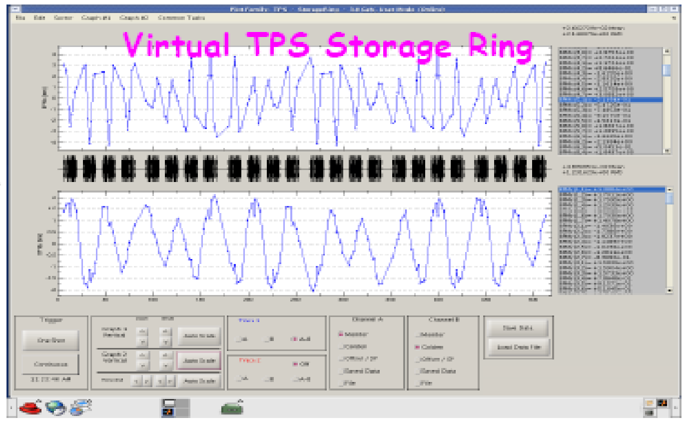
TPS虛擬加速器與EPICS介面控制系統



加速器應用軟體開發與虛擬加速器

- To enable early testing of applications through the control system, a virtual accelerator has been implemented to give simulation of the accelerators though the intended EPICS PV interface. Prototype was set up by the help from DLS.
- Current version is AT/MML version.
- Virtual booster and linac are also possible near future!
- Many facility have such kinds activities: SNS, KEK, J-PARC, DLS, … many others!

TPS Storage Ring
(Lattice designed by BD Group)



Parameters of GHe tanks (completed)

Cryogenic System for SRF Cavities			
Parameters	**Base Value (TPS)**	**Unit**	**Comment**
Cold box			
Maximum refrigeration capacity	700	W	at 4.5K
Inlet GHe temperature	300	K	
No. of turbines	2		
No. of heat exchangers	5		
No. of 80K absorbers	2		
O2 impurities	0.01	ppm	
N2 impurities	3.6	ppm	
No. of 20K absorbers	1		
Pressure drop of return gas thru HEXs	<120	mbar	at 700W
Helium storage tanks			
No. of tanks	4		
Volume	100	m^3	
Design pressure	20	barg	
Operation pressure	2~9.5	barg	

1. Welding

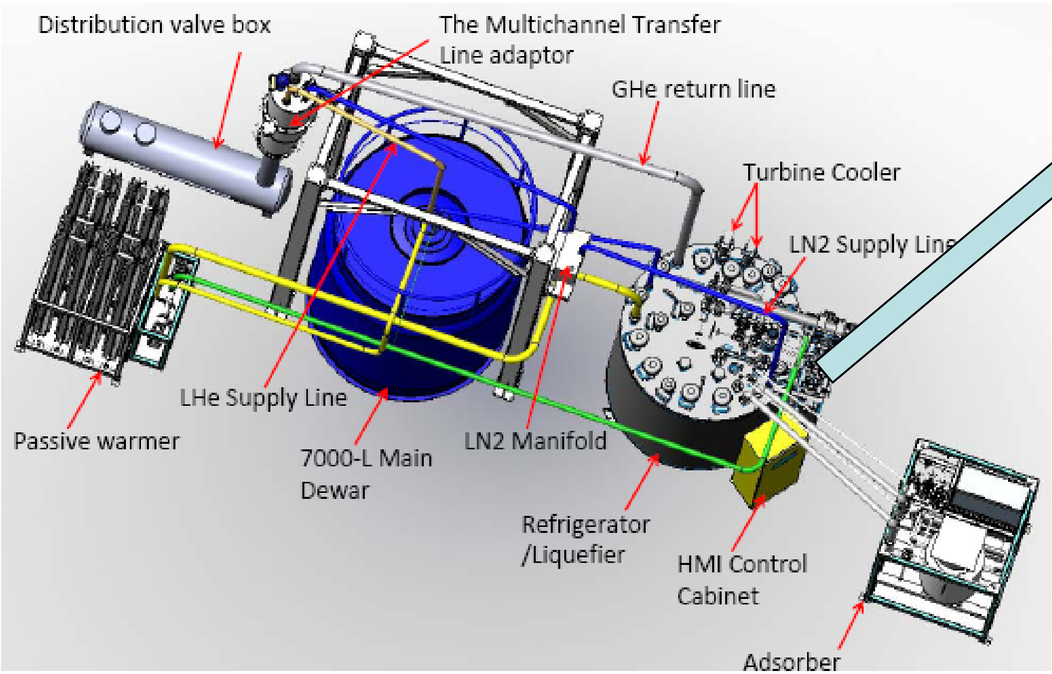
TPS氦氣儲槽製造

3. Sand Blasting

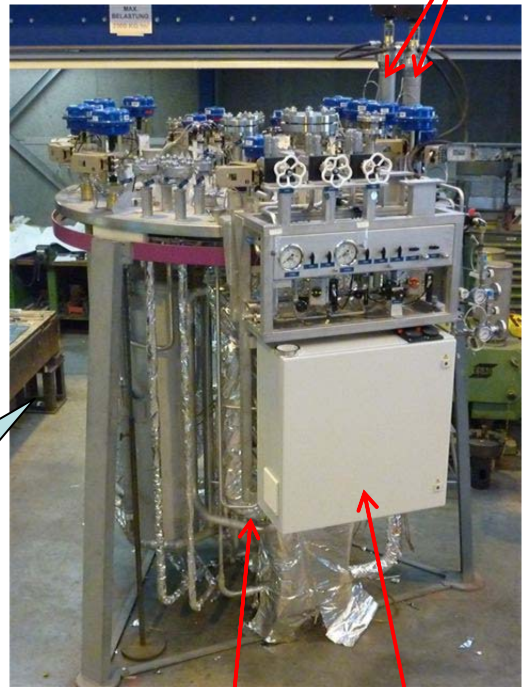
2. He leakage rate test at 18 barg mixing gas (3 barg He and 15 barg N_2)

Basic parameters of 700 W LHe cold box (delivery in July, 2011)

Cryogenic System for SRF Cavities			
Parameters	Base Value (TPS)	Unit	Comment
Cold box			
Maximum refrigeration capacity	700	W	at 4.5K
Inlet GHe temperature	300	K	
No. of turbines	2		
No. of heat exchangers	5		
No. of 80K absorbers	2		
O2 impurities	0.01	ppm	
N2 impurities	3.6	ppm	
No. of 20K absorbers	1		
Pressure drop of return gas thru HEXs	<120	mbar	at 700W



Refrigerator/Liquefier for TPS



RF system

KEK type SRF module：

Contracted to MHI

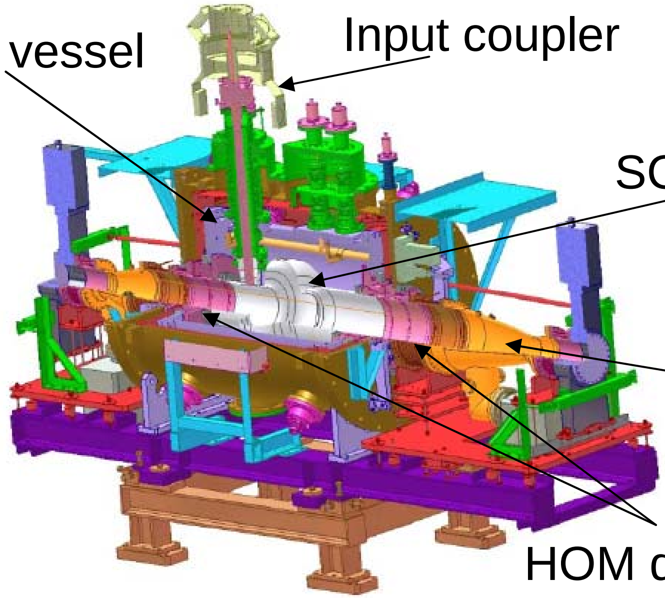
DDR review on Dec. 2010

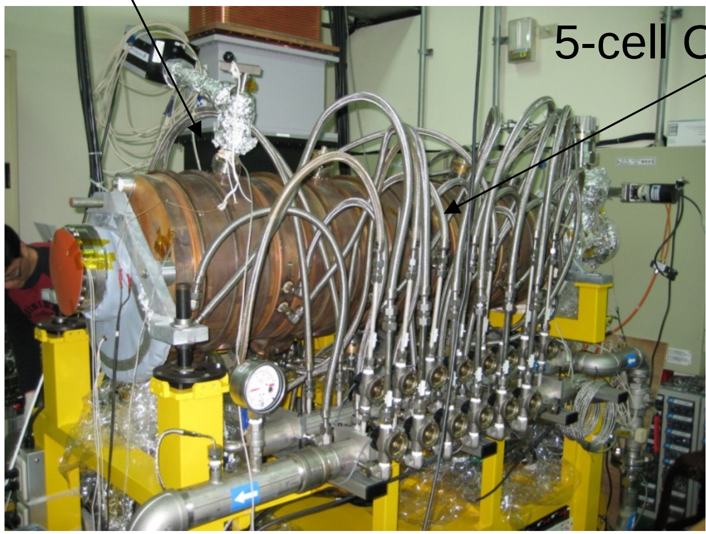
Petra Cavity module：

High power processing

300kW RF transmitter：

1. 2 sets of transmitter and 2 spare klystrons pass acceptance test
2. Re-assembly for all modules
3. Waveguide, ferrite load and cooling units ready
4. high power and acceptance test – 305 kW reached





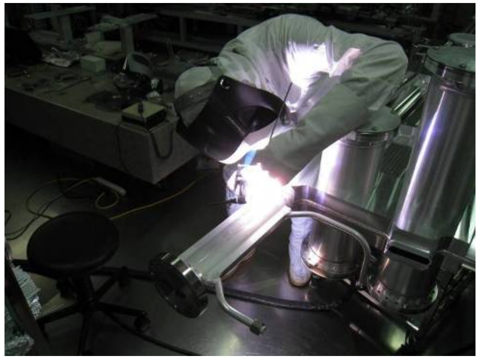
Process welding of BC in Chu-Tung

Upper and lower leaf of BC

Welding pumping port

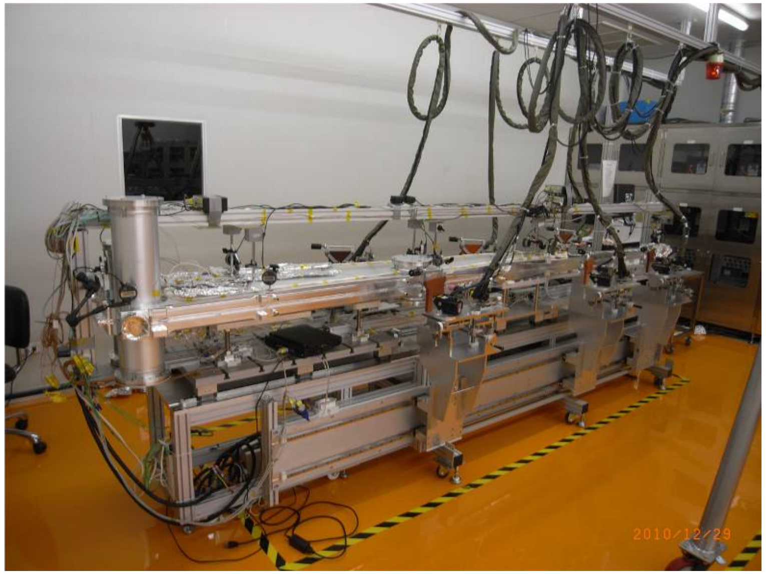
Alignment for the bending chamber

Bending chamber in auto-welding stage



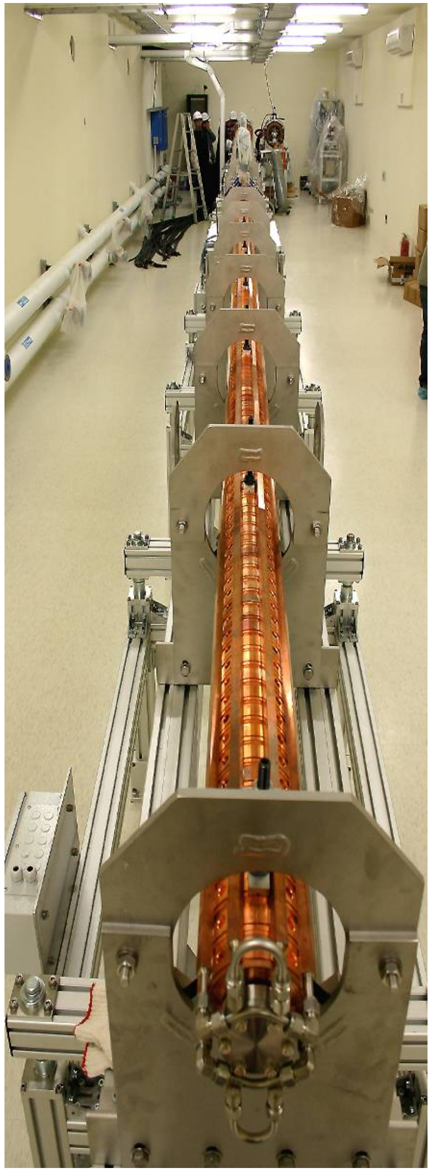
Assembly of vacuum system and storage in Chu-Tung



(2010.12.30)

Assembly and acceptance test of 150 MeV linac



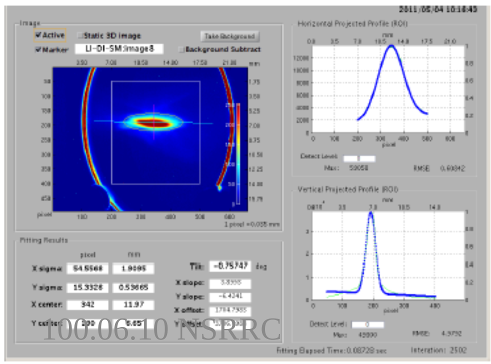
Beam parameters of 150 MeV linac

Single-bunch Mode

Parameter	Specification-SBM	Measurement
Bunch train length (μs)	≤ 1 ns	0.7
Charge in bunch train (nC)	≥ 1.5 nC	>1.5
Energy (MeV)	≥ 150	153
Pulse to pulse energy variation (%)	≤ 0.25 (rms)	0.08
Relative energy spread (%)	≤ 0.5 (rms)	0.2
Normalised emittance (1σ) (πmm mrad)	≤ 50 (x plane)	41
	≤ 50 (y plane)	36
Repetition rate (Hz)	1 to 5, adjustable	1.2 to 5
Pulse to pulse time jitter (ps)	≤ 100	29
Single bunch purity (1%)	better than 1	0.7%

Energy and Energy Spread-SBM

Spec.: >150 MeV; spread < 0.5%



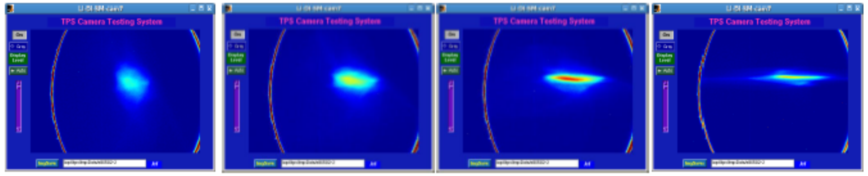
I=46A, E=153 MeV

$\Sigma^2 = \sigma_x^2 + D^2 (\Delta E/E)^2 > D^2 (\Delta E/E)^2$

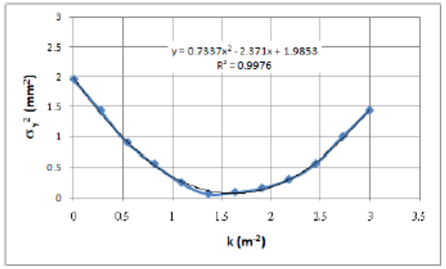
$1.9^2 > 1000^2 ((\Delta E/E)^2$

$0.2\% > \Delta E/E$

Emittance-vertical (SBM)



K=0 K=0.54 (4 A) K=1.09 (8 A) K=1.63 (12 A)

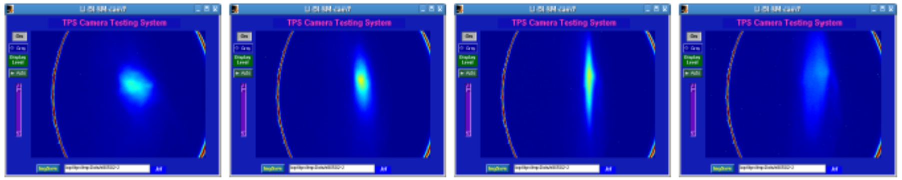


Spec.: < 50 π mm mrad

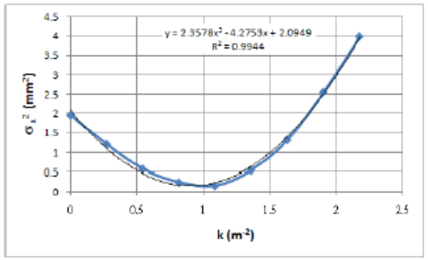
Vertical emittance analysis:

$\varepsilon_{y,rms,norm}$ = 36 π mm mrad

Emittance-horizontal (SBM)



K=0 K=0.54 (4 A) K=1.09 (8 A) K=1.63 (12 A)



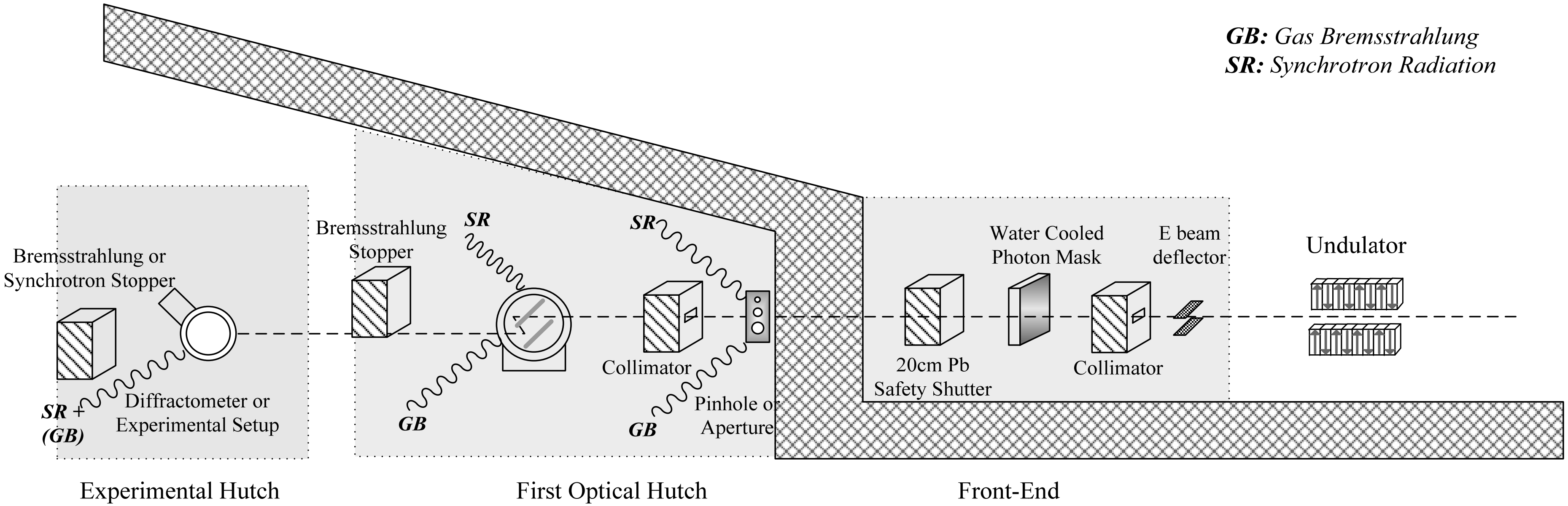
E=153 MeV, 2nC

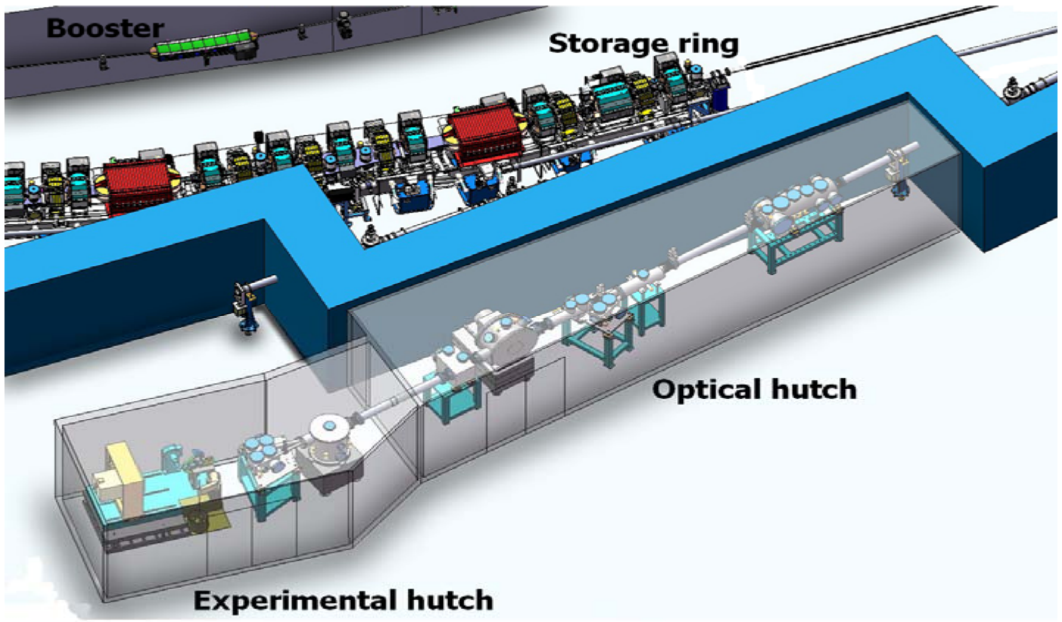
Spec.: < 50 π mm mrad

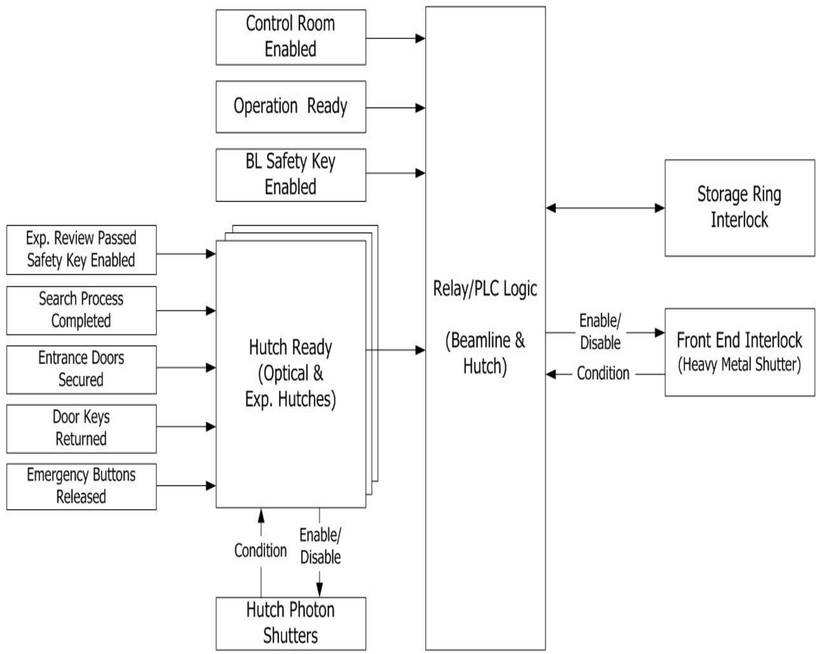
Horizontal emittance analysis:

$\varepsilon_{x,rms,norm}$ = 41 π mm mrad

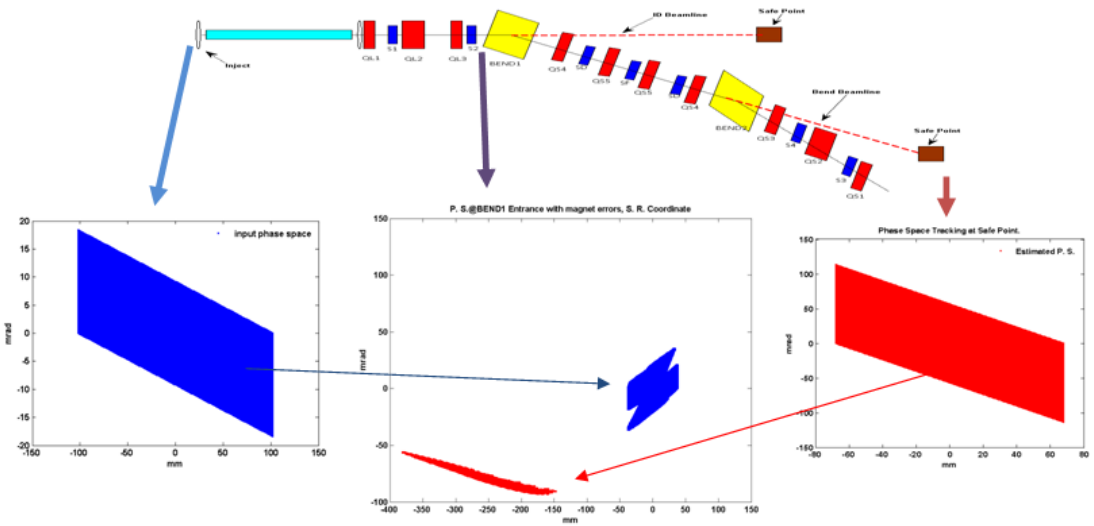
Shielding design for BL and end-station



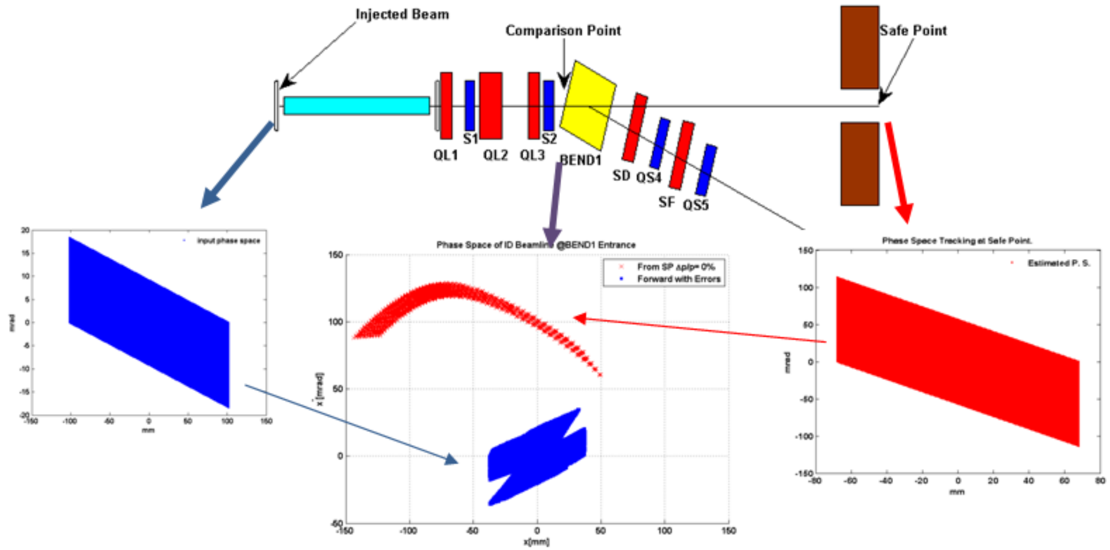




TPS phase space tracking for top-up injection



Forward and backward tracking in phase space for bending magnet's beamline



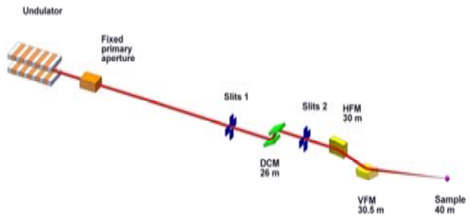
Forward and backward tracking in phase space for insertion device's beamline

The First-Phase BL's Proposals for TPS

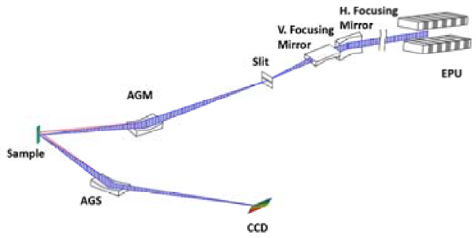
- *μ-focus macromolecular crystallography* (2013)
  (微聚焦巨分子結晶學光束線)
- *High resolution Inelastic soft-x-ray scattering* (2013)
  (高解析非彈性軟X光散射學光束線)
- *Sub-μ soft x-ray photoelectron & fluorescence emission* (2013)
  (次微米軟X光能譜學光束線)
- *Soft matter small angle scattering* (2014)
  (軟物質小角度散射學光束線)
- *Sub-μ x-ray diffraction* (2014)
  (次微米繞射光束線光束線)
- *Nano-probe x-ray diffraction* (2014)
  (奈米探針光束線)
- *Multi-purpose coherence x-ray scattering* (2014)
  (多用途同調性散射光束線)

Conceptual design of first-phase beamlines

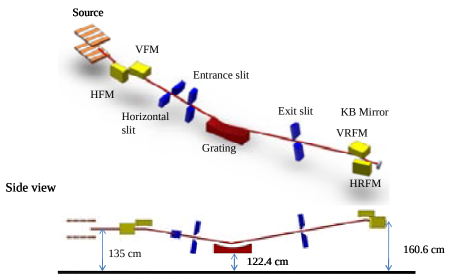
微聚焦巨分子結晶學光束線
(μ-focus macromolecular crystallography)



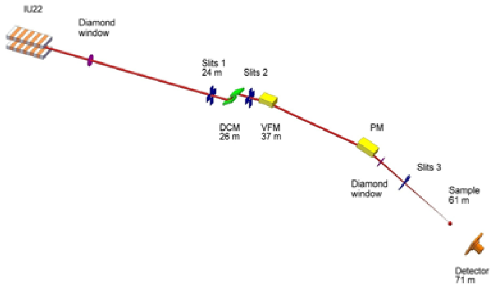
高解析非彈性軟X光散射學光束線
(High resolution Inelastic soft-x-ray scattering)



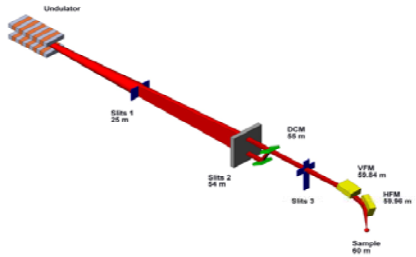
次微米軟X光能譜學光束線
(Sub-μ soft x-ray photoelectron & fluorescence emission)



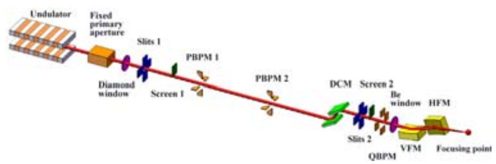
軟物質小角度散射學光束線
(Soft matter small angle scattering)



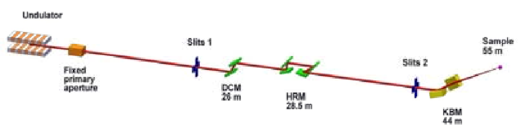
次微米繞射光束線
(Sub-μ x-ray diffraction)



奈米探針光束線
(Nano-probe x-ray diffraction)



多用途同調性散射光束線
(Multi-purpose coherence x-ray scattering)



NSRRC site image from satellite (by National Space Center)

2010-02-10

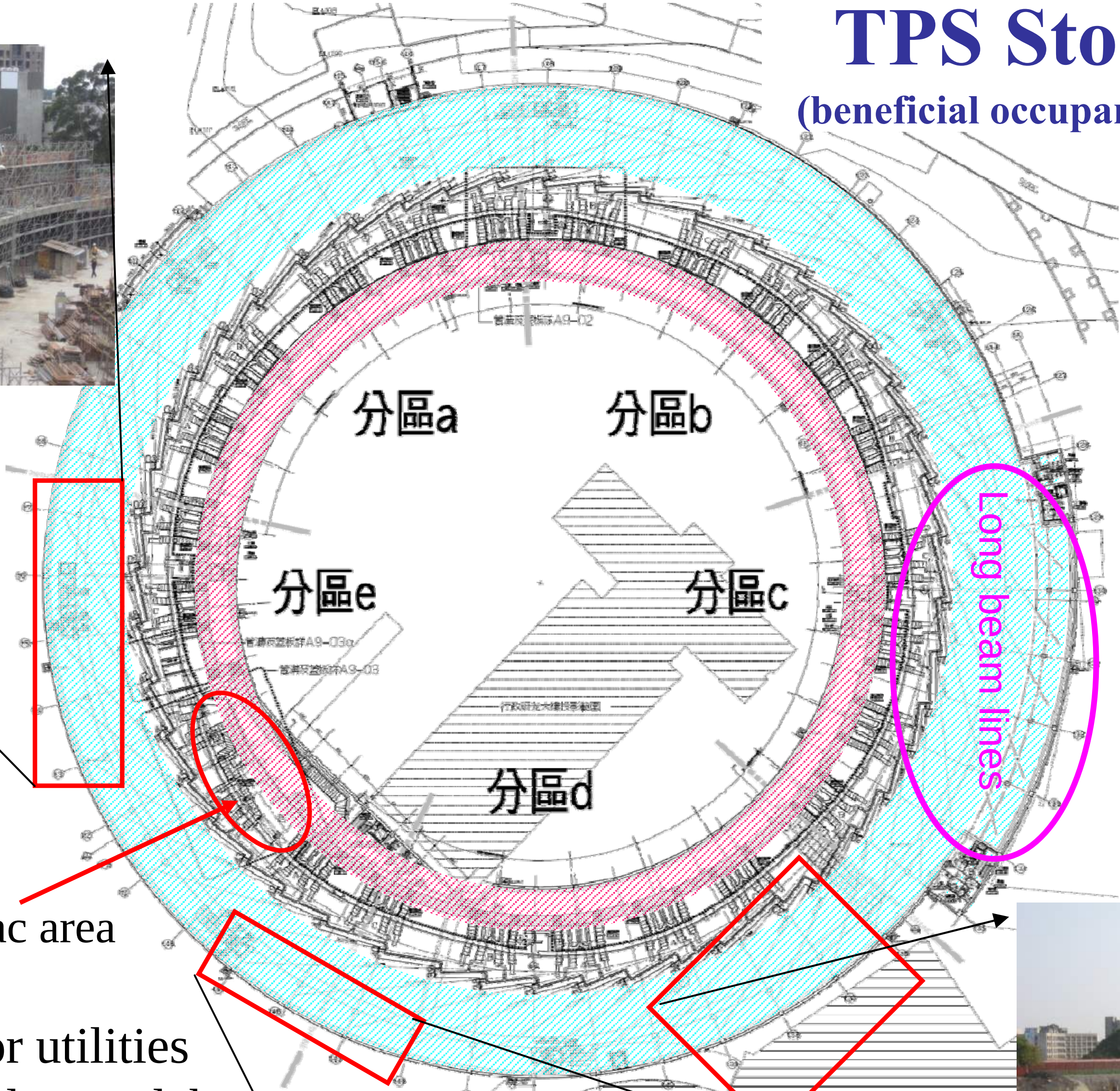
2010-05-21

2010-08-04

2011-02-05

TPS Storage ring

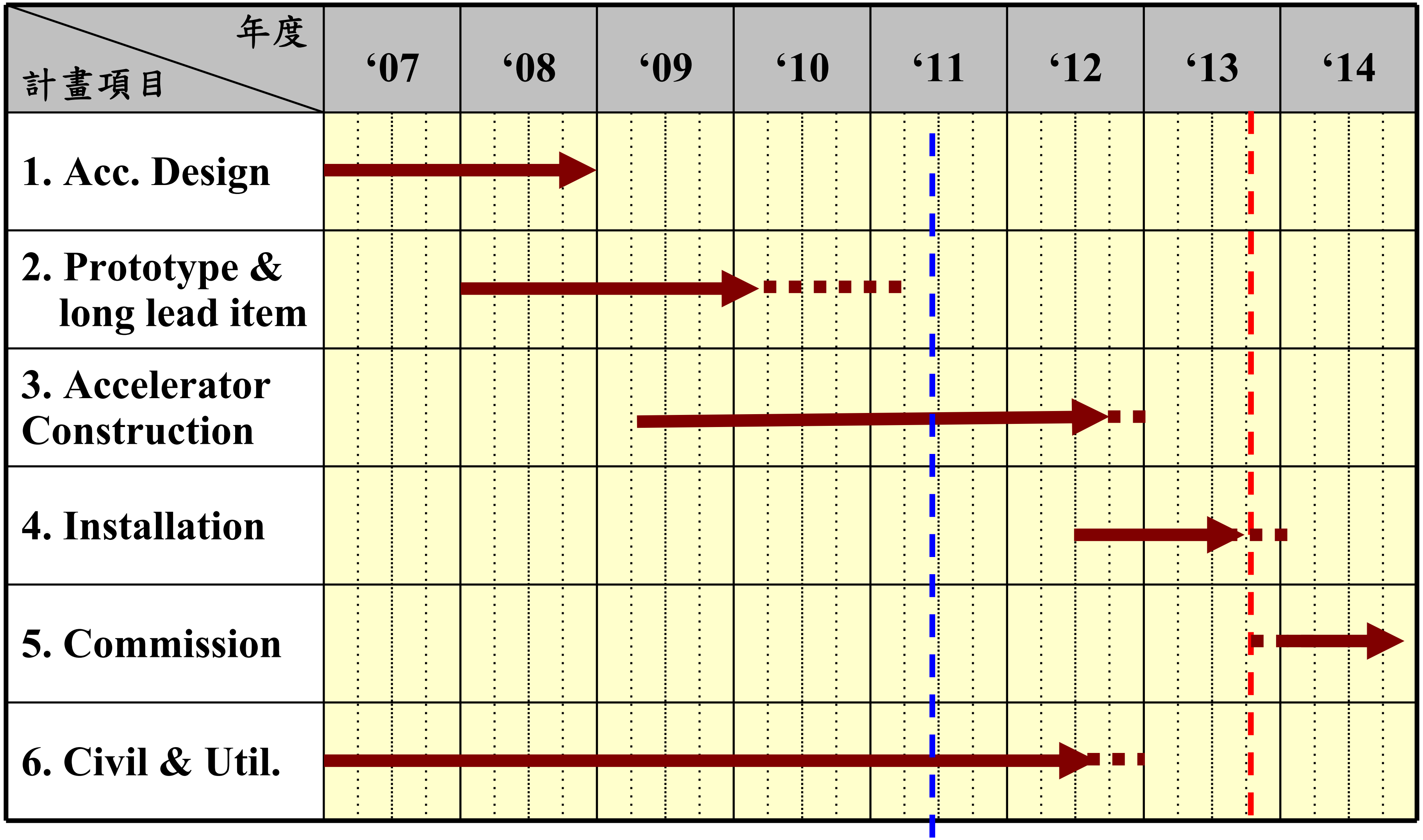
(beneficial occupancy plan in Q2, 2012)



Space for utilities and accelerator lab.

Experimental Area for 50 m beamlines and five 70 m beamlines

TPS construction schedule



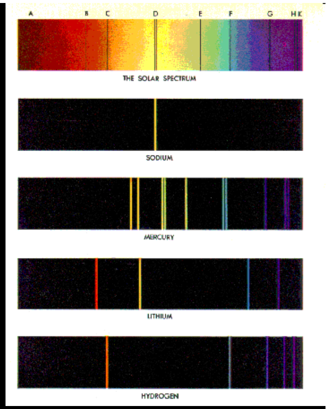
Installation pedestal and girder in Q2, 2012

Booster and storage ring commissioning in Q4, 2013.

Summary

- **Taiwan Light Source**
  - 1.5 GeV beam energy provides more than 5500 hrs with 360 mA top-up to users. Photon energy can be up to ~30 keV by SC wigglers.
  - Beamlines in SPring-8 provide hard x-ray to users.
- **Taiwan Photon Source**
  - 3 GeV storage ring with 500 mA as design goal. Seven beamlines are under design for Phase-I operation.
  - Subsystems of accelerator are delivering to NSRRC for acceptance test and installation.
  - The installation will start in the 2nd quarter of 2012.
  - Booster and storage ring commission are planned before the end of 2013.

Taiwan Photon Source (**TPS**)



Thank you for your attention!