Synchrotron Radiation Light Sources at CAS

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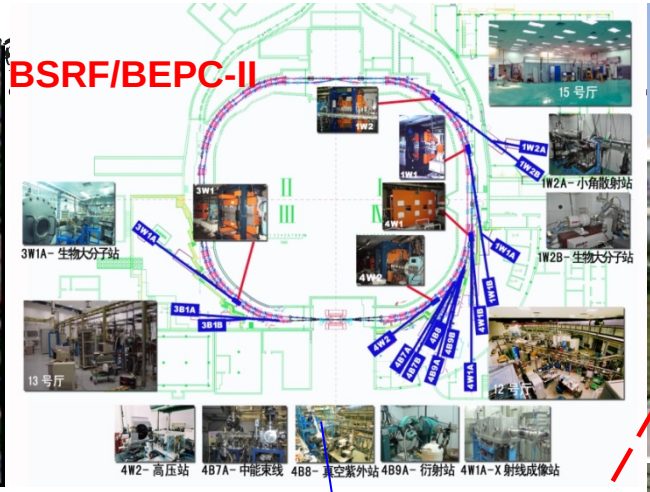
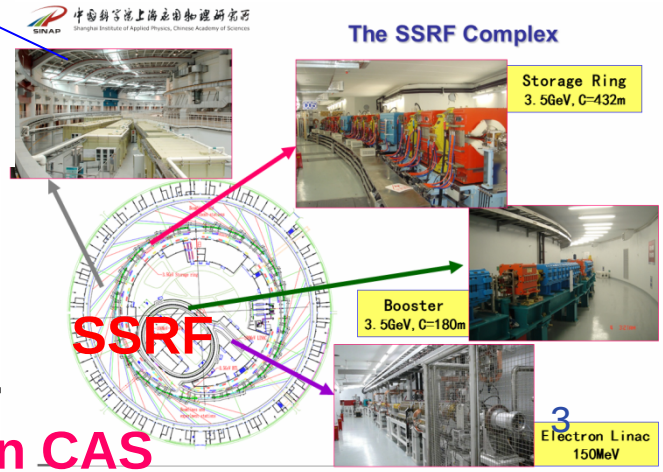
Outline

- Introduction to Light Sources in CAS
- Synchrotron Light Sources in IHEP
- Synchrotron Light Sources in NSRL
- Synchrotron Light Sources in SINAP



BSRF: 2.5GeV
HLS: 0.8 GeV
SSRF: 3.5GeV

Synchrotron Radiation Light Sources in China



List of operational light sources

1	BSRF: Beijing Synchrotron Radiation Facility	IHEP
2	HLS: Hefei Light Source	NSRL, USTC
3	SSRF: Shanghai Synchrotron Radiation Facility	SINAP
4	BFEL: Beijing Free Electron Laser	IHEP
5	SDUV-FEL: Shanghai DUV Free Electron Laser	SINAP

List of planned light sources

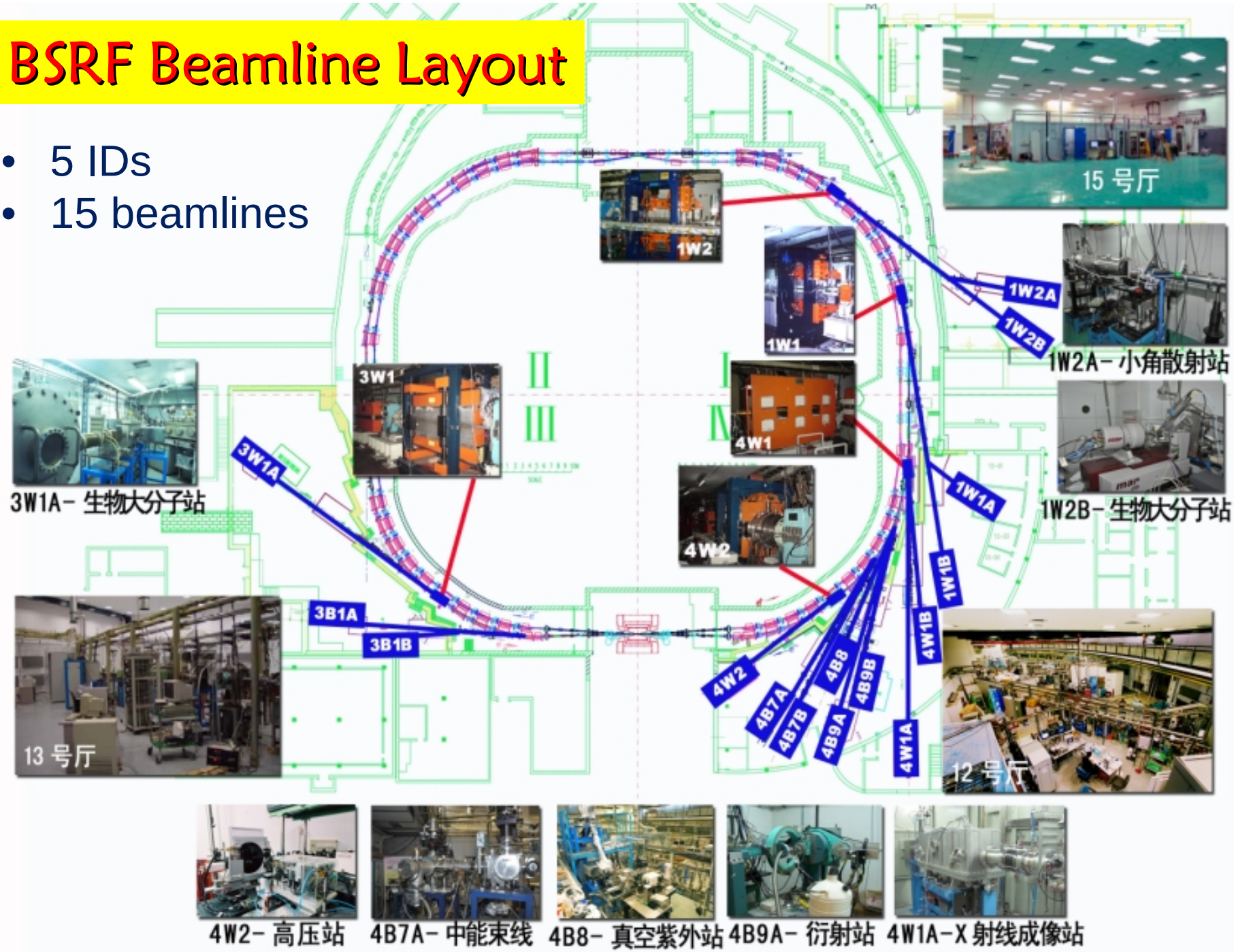
1	SXFEL: Shanghai Soft X-ray Free Electron Laser	SINAP
2	DEUV-FEL: Dalian EUV-Free Electron Laser Facility	DIPC
3	BAPS: Beijing Advanced Photon Source	IHEP
4	HALS: Hefei Advanced Light Source	NSRL, USTC
5	CHXFEL: Compact Hard X-ray Free Electron Laser	SINAP

BSRF: Beijing Synchrotron Radiation Facility

- It is the first synchrotron radiation facility in China, started user operation in 1991.
- Currently it consists of the out ring of BEPC-II and 15 beamlines and end stations. In the dedicated mode, its storage ring operates at 2.5GeV, ~100 nm·mrad and 250-200mA with beam life time >10 hours;
- About 2000 hours/year beam time is operated for the SR dedicated mode;
- And 6 beamlines can be operated in parasitic mode, with the storage ring beam current of 500-700mA (910mA) at the energies depending on the HEP experiments from 1.5GeV to1.9GeV.
- About 1000 users, and 150 publications/year

BSRF Beamline Layout

- 5 IDs
- 15 beamlines



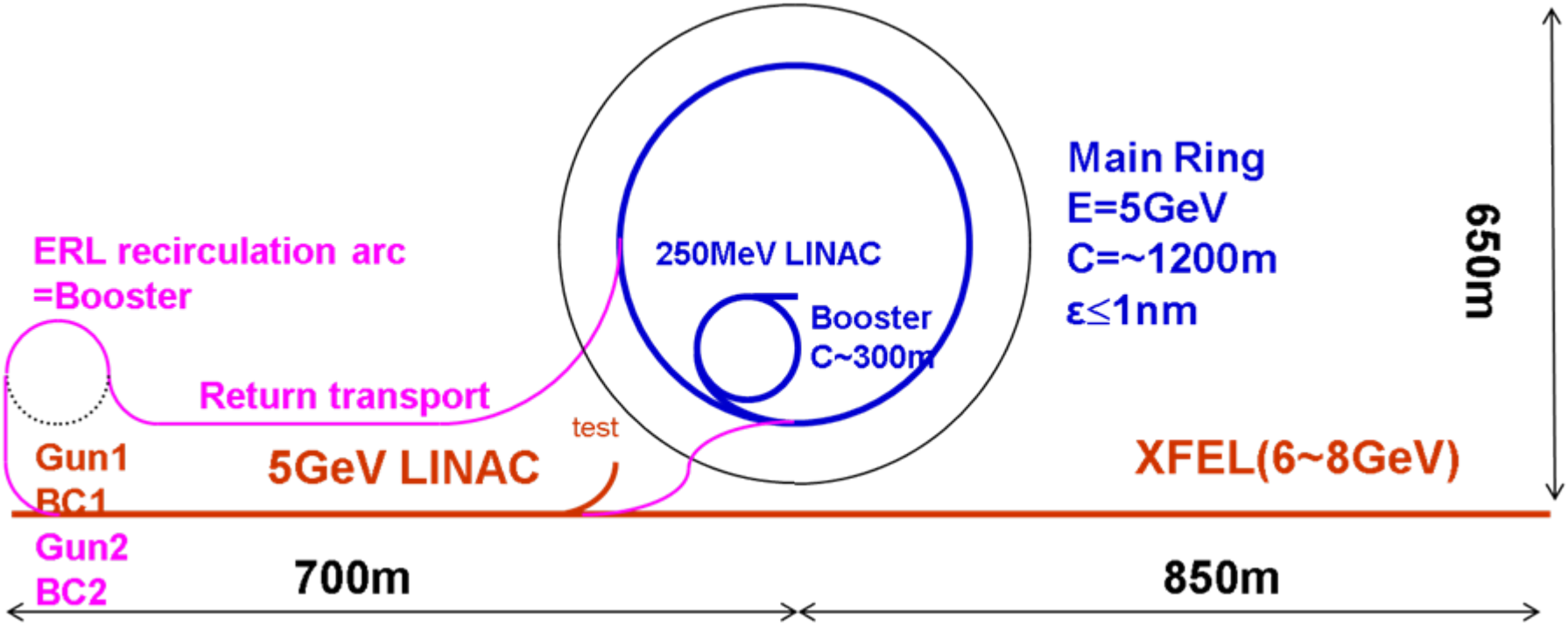
BEPCII – BSRF Parameters

	BSRF (dedicated)	BSRF (parasitic)
Energy（GeV)	2.5	1.89
Current (mA)	250	500-700
Emittance (nm.rad)	100	150
Lifetime (Hr)	~10	~2
Coupling	1%	0.1%
V orbit stability（um)	± 10	±100
Injector energy（GeV）	2.5	1.89

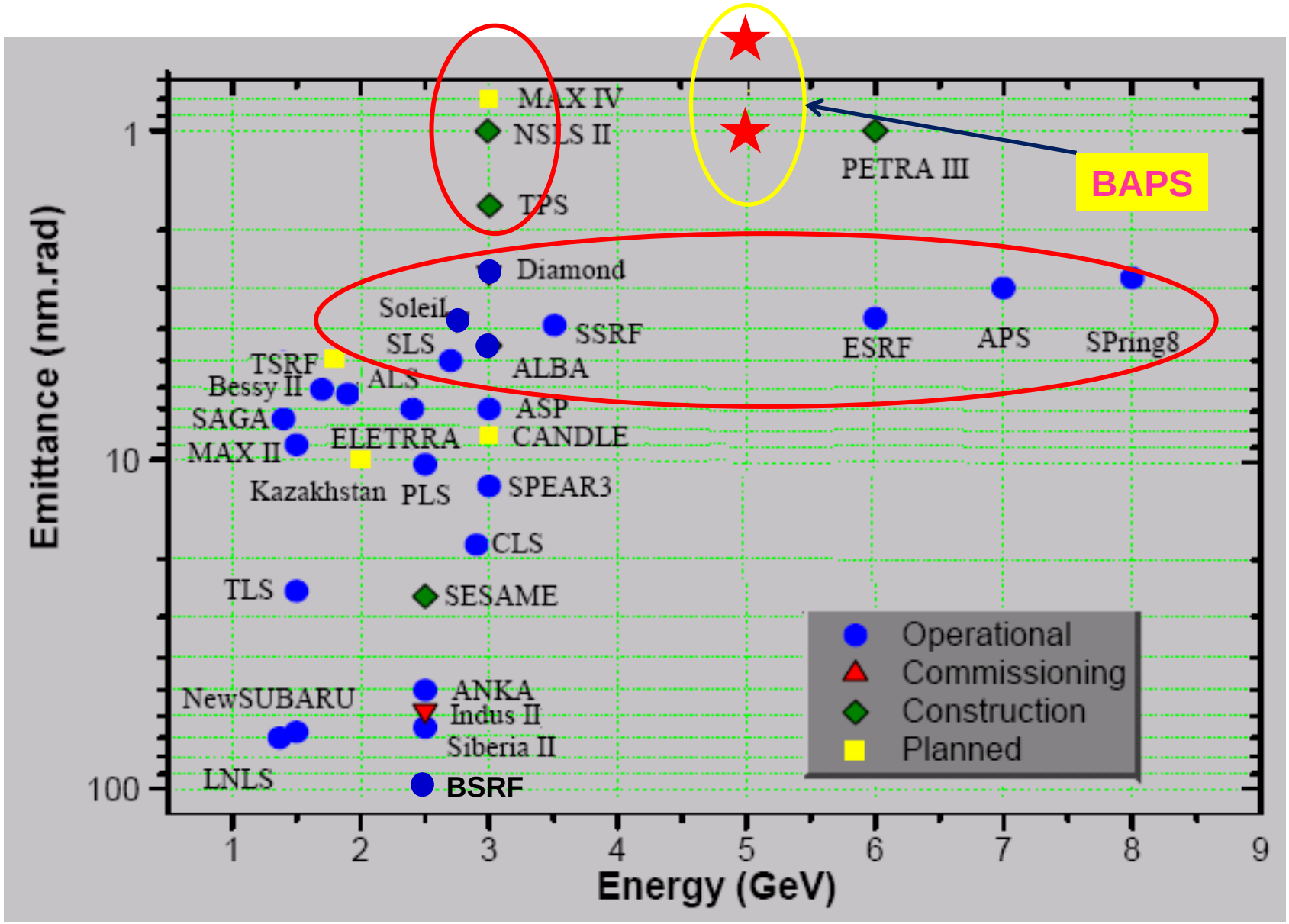
@ 3 months/year for dedicated SR operation

Beijing Advanced Photon Source (BAPS)

- **BAPS — Beijing Advanced Photon Source**
- **A 5-GeV light source, with very small emittance**
- **Potential to have ERL and X-FEL in the future**



A lower emittance, higher brightness light source



Beijing Advanced Photon Source (BAPS)

- High energy X-ray (50-150 keV)
- 0.1μm focus beam for diffraction experiments, especially for the protein crystallography.
- 10nm focus beam for spectroscope experiments
- 1 ps time resolution possible.
- R& D: 2012 – 2015
  Construction: 2016 - 2020

- 5GeV 1200m-Circomference Storage Ring
- 250MeV LINAC
- Lower energy transport line
- 250MeV - 5GeV 300m-Circum booster
- higher energy transport line

- 48 DBA cells, Circumference = 1209.44 m
- 4 straight sections of 14.6 m long
- 44 straight sections of 6.4 m long → 6.9 m
- 96 bending magnets
- Capacity on accommodating more 50 beam lines with insertion devices

Main parameters of storage ring

Beam energy	GeV	5
circumference	m	1209.44
Beam current	mA	200
Emittance（H/V）	nm	1.4/ 0.014(κ =1%) 0.5/0.005 w/ damping wiggler
Energy loss per turn	MeV	1.68
Energy spread	10^{-4}	7.5
Momentum compact	10^{-4}	1.22
Bunch length	ps/mm	8.7/2.61
Trans. tune (H/V)		57.25/29.3
Natural chromaticity		-186.5/- 48.8
Photon critical energy	keV	8.44(main bend) 83.1(5T SC Wig.)
Average brilliances	$Ph/s/mm^2/mrad^2/0.1\%BW$	$\sim 10^{21}$

Technical requirements on BAPS compared with other SR machines

	BAPS	3rd generation SR
Un-uniformity of dipole field	1×10^{-4}	5×10^{-4}
Current ripple of PS	5 ppm	20 ppm
Accuracy of quads' alignment	30 μm	80 μm ~ 150 μm
BPM resolution	~ 0.1 μm	~ 0.3 μm
Stability of beam orbit	~ 0.3 μm	~ 1 μm
Temp. control of cooling water	$\pm0.05^0$C	$\pm0.1^0$C ~ $\pm0.2^0$C
Temp. control of tunnel	$\pm0.1^0$C	$\pm0.2^0$C
Stability of tunnel base	10μm/10m/y	100μm/10m/y

R&D issues of accelerator techniques

- Conception design of 5-GeV accelerator and beam lines
- High precision (<1μm) of beam orbit measurement, control and feedback
- Design of high accuracy of magnet, power supplies and girders
- Design and manufacture of key elements (e.g. BPM)
- Manufacture of cryo-undulator, and superconducting wiggler

HLS: Hefei Light Source

- It is the first dedicated synchrotron radiation facility in China, started user operation in 1991.
- Currently it consists of a 200 MeV Linac functioning as the injector, a transport line, an 800 MeV electron storage ring, 14 beamlines and endstations.
- About 6000 hours/year beam time is operated for user experiements;
- New upgrades HLS-II are underway, constructing a new storage ring with 4 more straights to accommodate more ID beamlines, and an 800MeV linac to be the full energy injector.
- HLS-II will start its user operation with five beamlines in 2013

Phase I Project

Construction time: 1984~1991

Main components:

800 MeV electron storage ring

200 MeV Electron linac

transfer lines

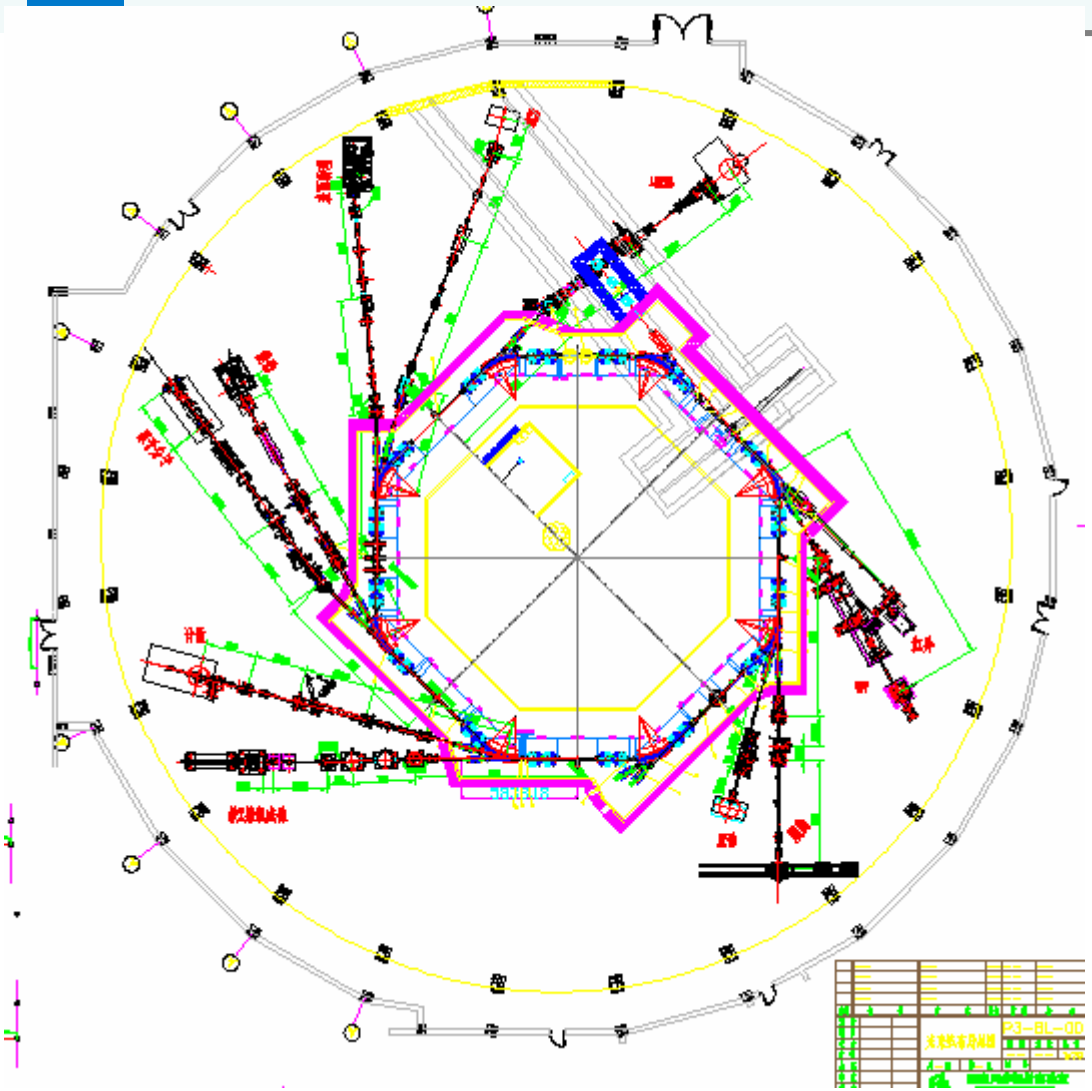
5 beamlines and experimental stations

Phase II Project

Duration: 1998~2004

Improvements: new undulators, 8 new beamlines and experimental stations, Increase reliability and beam stability

Upgrade Project of HLS



BL01B: Infrared

BL02B: VUV

BL03U: Combustion

BL04B: Mass Spectrum

BL07W: Soft X-ray Imaging

BL08B: Metrology

UL09U: Atomic and Molecular Physics

BL10B: Photonemssion

BL11U: Catalysis and Surface science

BL12B: MCD

BL13U: ARPES

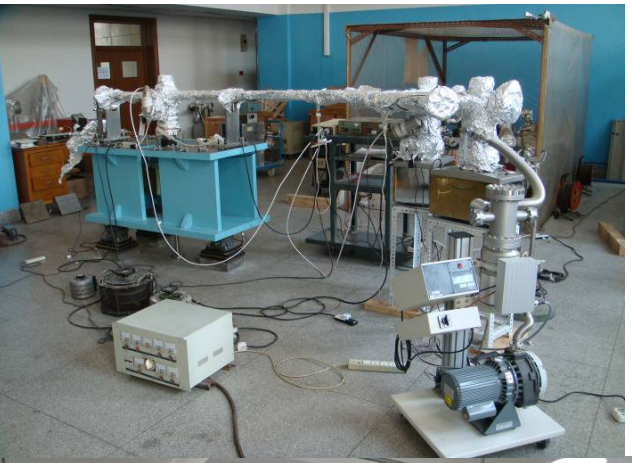
The five ID Beamlines will be operated in the end of 2013

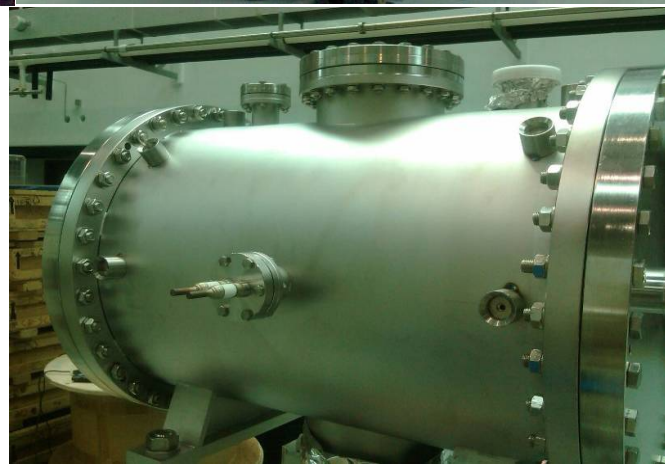
Main Parameters

	HLS	HLS II
Beam energy	800 MeV	
Circumference	66.13 m	
Magnet lattice	TBA	DBA
Super-period	4	
Natural emittance	160 nm·rad	<40 nm·rad
Beam intensity	250 mA	300 mA
Transverse tunes	3.54/2.60	4.41/2.80
Beam lifetime	>10 h	>5 h
RF frequency	204 MHz	
RF voltage	150 kV	250 kV
Harmonic number	45	
Critical wavelength	24.0 Å	23.44 Å
Radiation loss	16.31 keV/turn	16.70 keV/turn
Number of ID	2	6
Slow orbit shifts	<25 μm（V）	<5 μm（V）

2012-05-01

2012-06-01

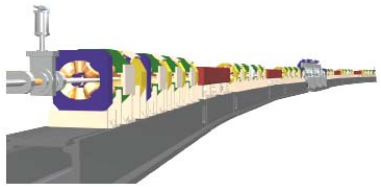


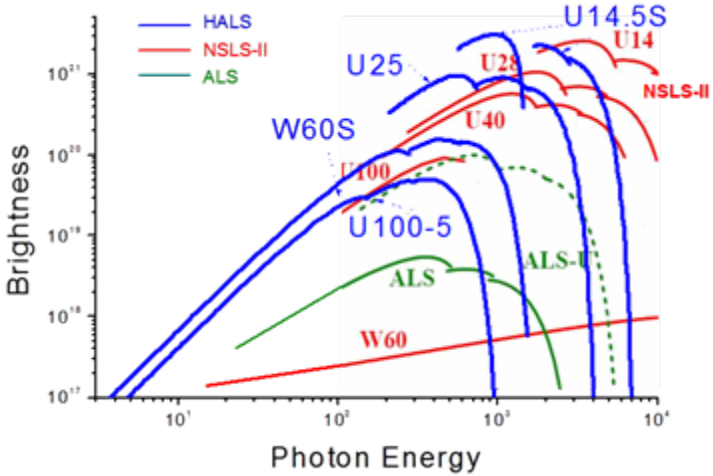


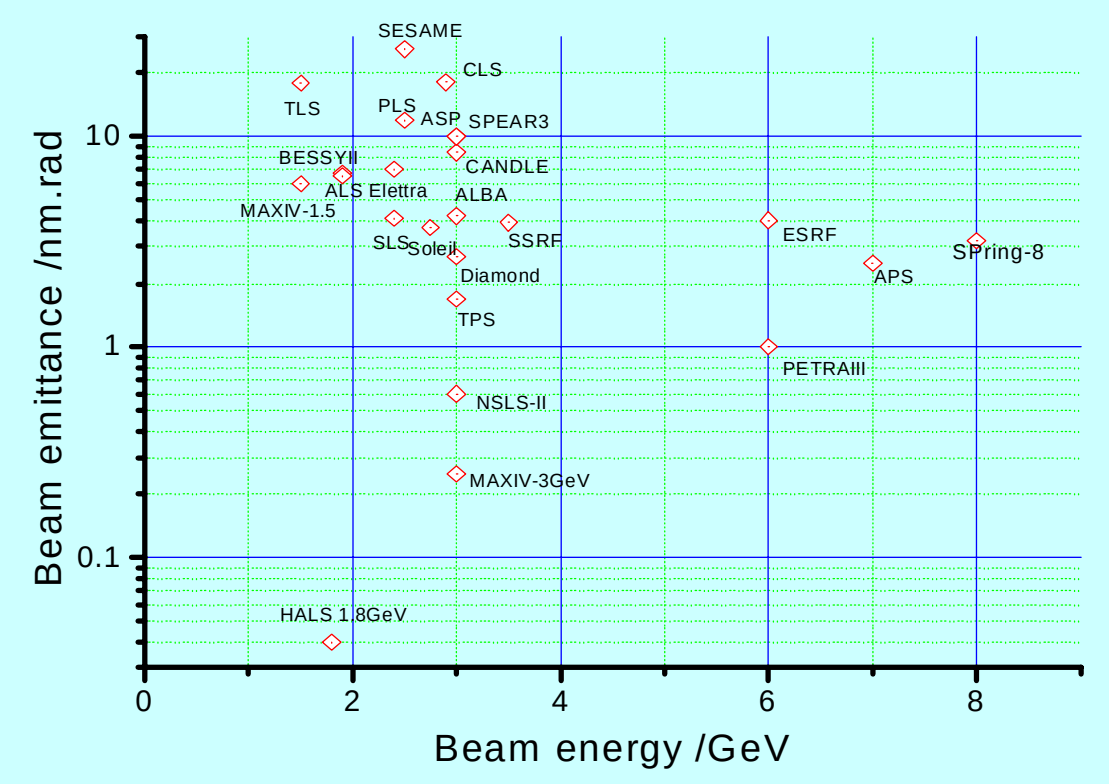
Proposal of Hefei Advanced Light Source (HALS)

Ultra-low emittance storage ring

- Beam energy： 1.8 GeV
- Circumference： 486 m
- Beam current： ~500 mA
- Beam emittance： ~80 pm·rad
  (low beam current) ~40 pm·rad
- Critical wavelength： 1.66 nm
- Magnet lattice: Six Bend Achromat
- Straight section : 20×6.5 m
- Beam lifetime： Top-off
- Natural bunch length:~40 ps





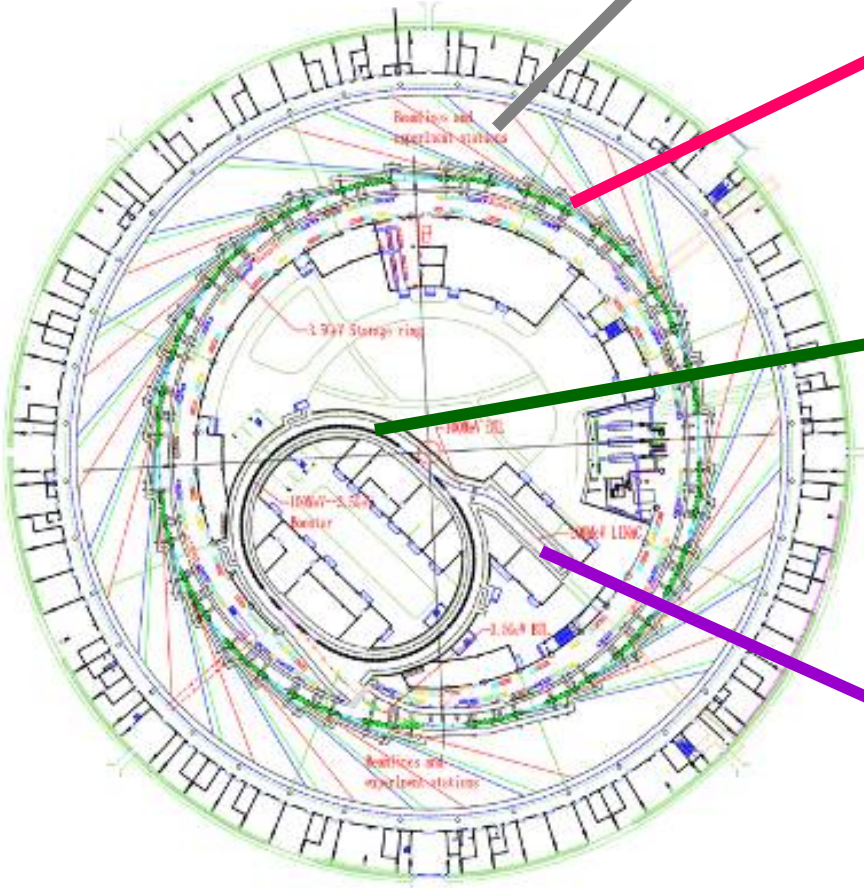


Shanghai Synchrotron Radiation Facility (SSRF)

- SSRF is a 3.5 GeV 3rd generation light source funded by Chinese Academy of Sciences (CAS), Shanghai local government and the central government of China. The total budget of the SSRF is about 200M US$;
- The SSRF project was proposed in 1995, and then a R&D program was carried out from Jan. 1999 to Mar. 2001; Later on this project was proceeded from December 2004 to April 2009.
- The SSRF user operation with 7 beamlines commenced in May 2009.

The SSRF Complex

- Dec. 25, 2004 : Ground breaking
- Dec.24, 2007: First synchrotron light
- Apr. 29, 2009: Dedication of the SSRF
- May 6, 2009: formally open to users
- Jan. 19, 2010: Government acceptance



Beamlines

7 operation
6 construction

Storage Ring
3.5GeV, C=432m

Booster
3.5GeV, C=180m

Electron Linac
150MeV

SSRF Main Parameters

- Storage Ring Energy: 3.5 GeV
- Circumference: 432 m
- Natural Emittance: 3.9 nm-rad
- Beam Current: 200 ~ 300 mA
- Beam Lifetime: ~20 hrs
- Straight Sections: 4×12.0 m, 16×6.5 m
- Max. Beam Power: ~600kW

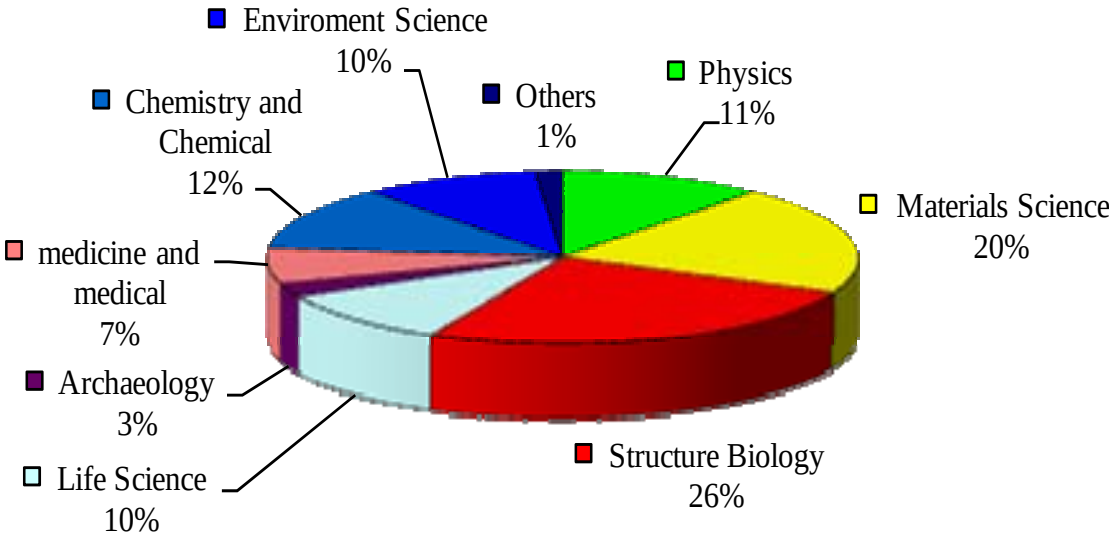
Beamlines in Operation

- Macromolecular Crystallography (In-Vac Und.)
- High-Resolution X-ray Diffraction (Bend)
- X-ray Absorption Fine Structure Spectroscopy (Wiggler)
- Hard X-ray Micro-focus and Application (In-Vac Und.)
- X-ray Imaging and Biomedical Application (Wiggler)
- Small Angel X-ray Scattering (Bend)
- Soft X-ray Microscopy (EPU)

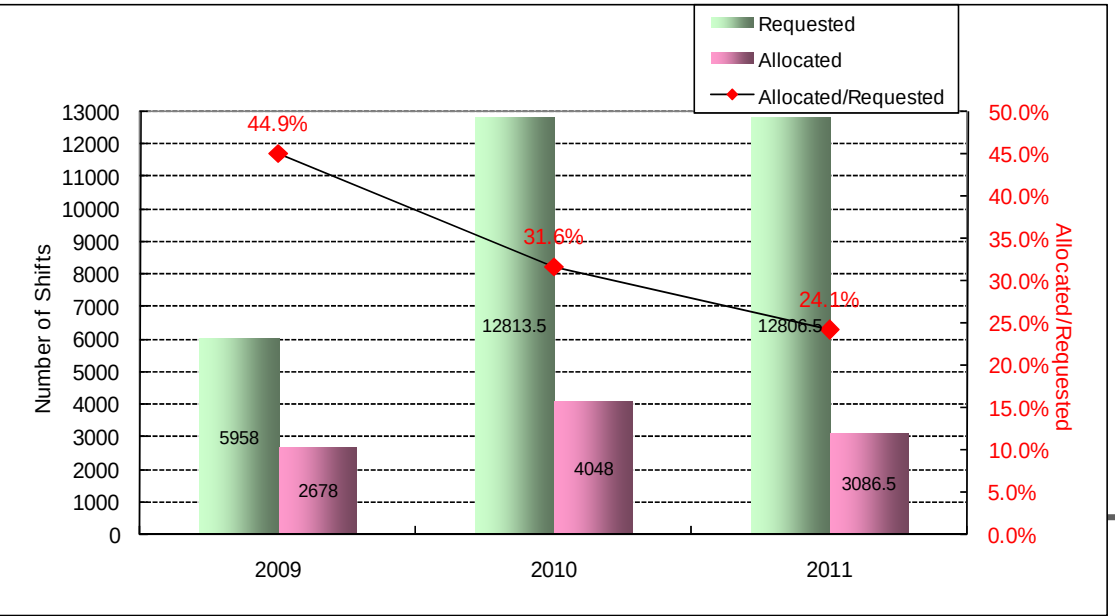
Current User Operation Status

- User operation started from May 6, 2009;
- By July, 2012, more than 4296 users from 251 universities and institutes carried out 2822 experiments at SSRF, on10+ fields: life science, material science, environmental, information, physics, chemistry etc.;
- User demand 4 times more than capacity;
- SR experiment operation time was 2020 hours in 2009 , increased to ~5500 hours in 2011. > 97% availability with MTBF of >50 hrs.
- 14 papers at NCS and 26 papers at NC series (07/12).

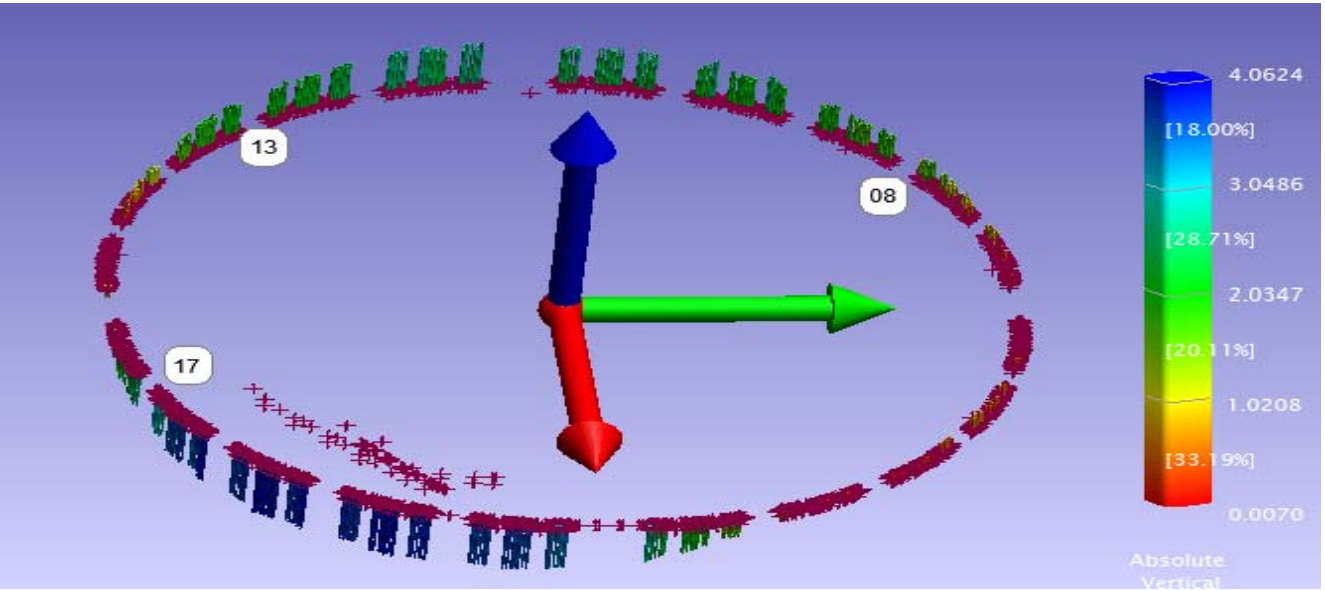
Distribution of user's research fields



Beam time application and approval

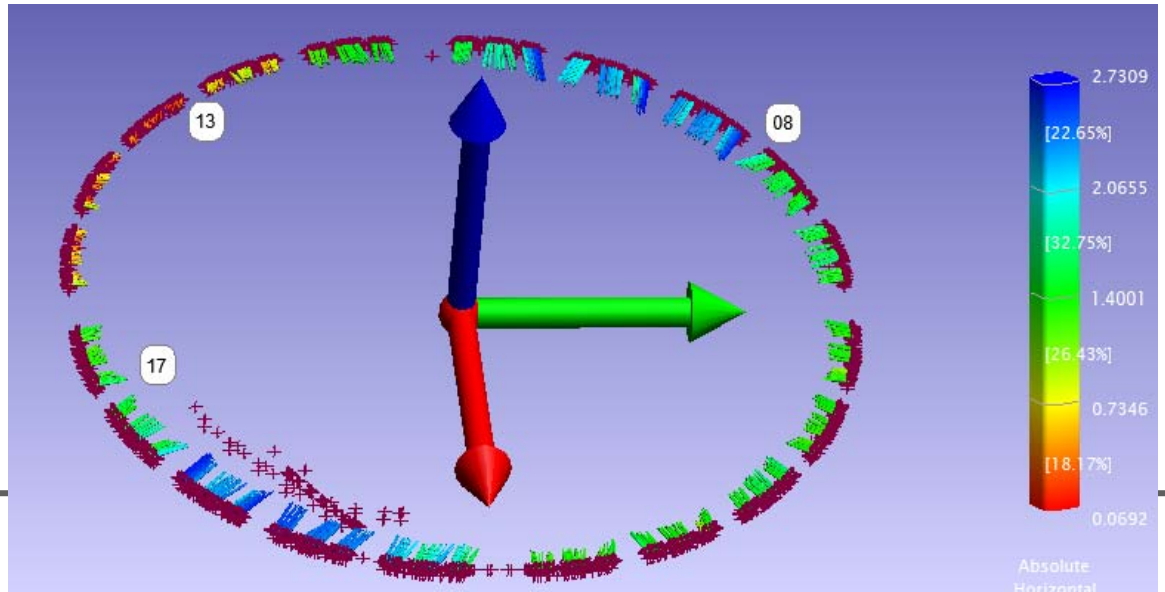


SSRF ring deformation until 2012



ΔY：~7mm

ΔC：~ -11mm



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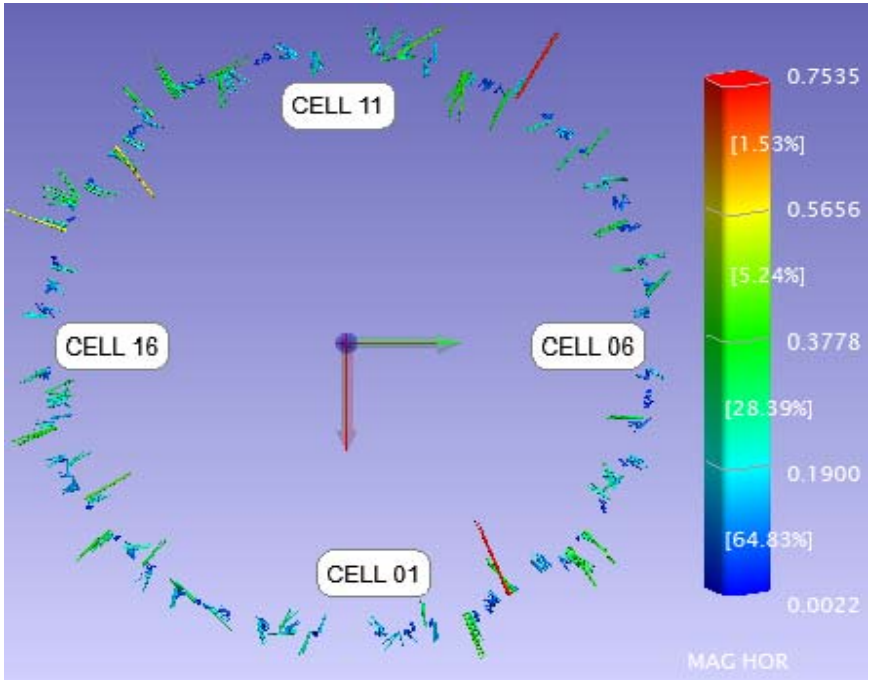
SSRF ring alignment in 2012



Δ Y **Δ H**

COD before alignment: 120 μm (H) ; 200 μm (V)
COD after alignment: 75 μm (H) ; 85 μm (V)

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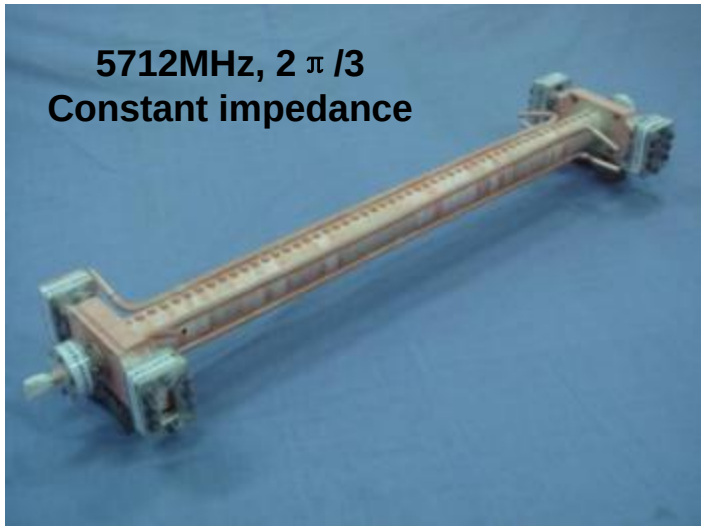
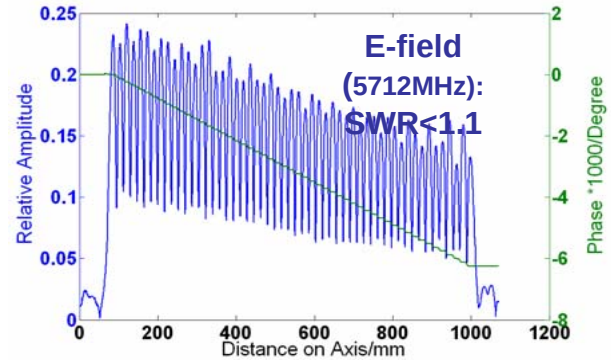
Key Technology Development in recent 2 years

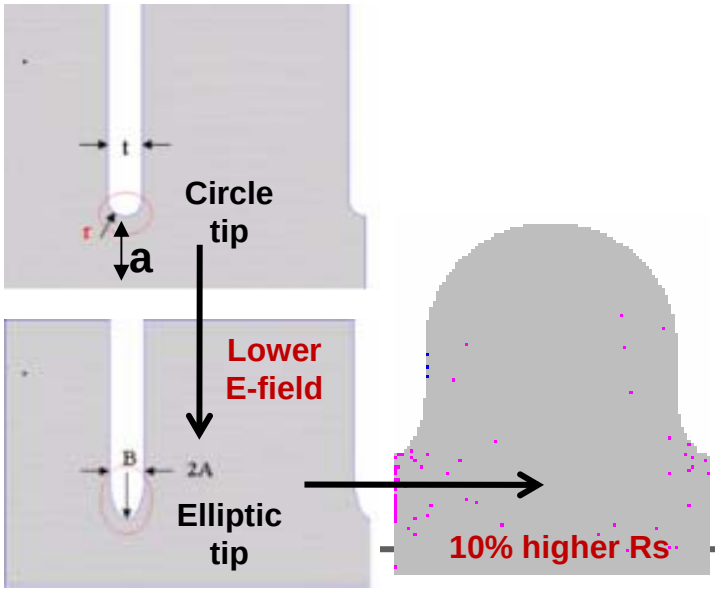
- C-band accelerating structure
- Magnets
- IDs
- SRF cavity
- Super-conducting undulator R&D

C-band Accelerating Structure

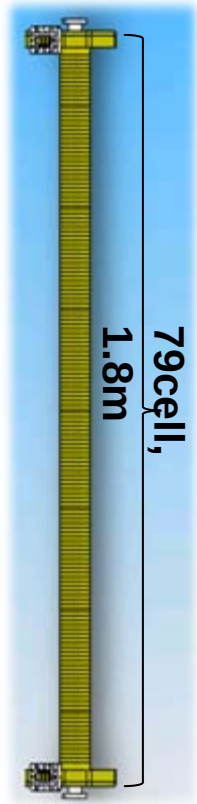


- C-band acc. structure is ready for high power Test.
- High power test setup is conditioning now, and will be connected with C-band acc. structure soon



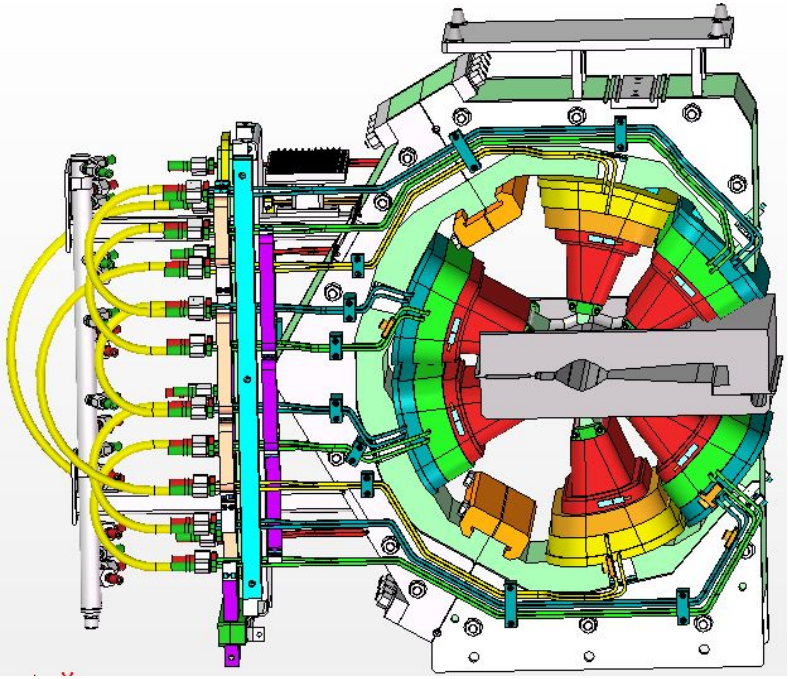


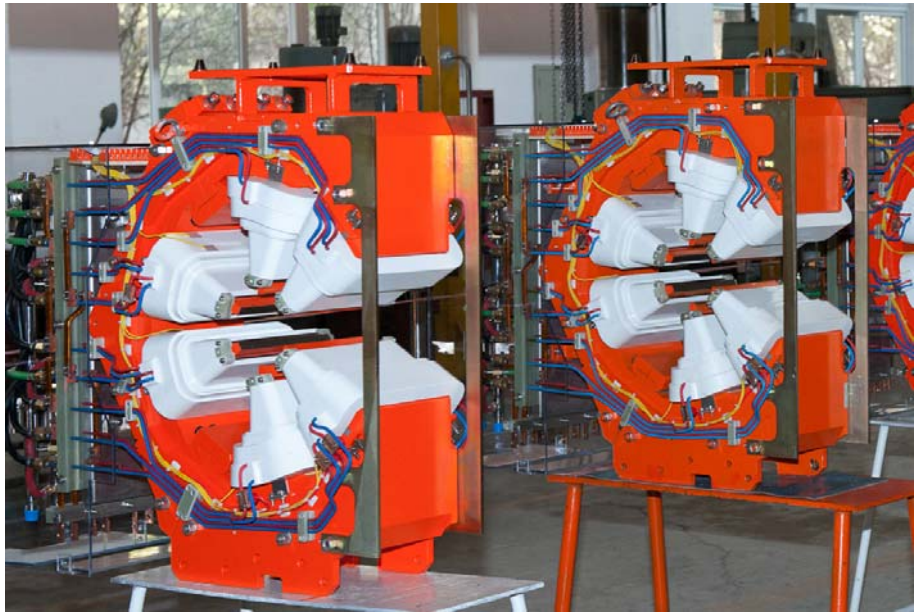
Frequency （MHz）	5712
Phase adv. Per cell	2 π /3
Length (mm)	944.73
Length of cell	17.495
Shunt imp. (M Ω /m)	87.18
Quality factor:	9893
Group velocity/c (%)	1.00
Filling time (ns)	315
Attenuated factor	0.61



Q. Gu, M. Zhao

Combined function SX magnets





SHD-Sextupole Field @96A

	LBNL Spec.		SHD03		SHD04		SHD05	
n	an	bn	an	bn	an	bn	an	bn
1	1.40E-02	2.00E-03	-4.14E-03	-3.02E-03	-4.36E-03	-5.05E-03	-1.01E-02	-1.60E-03
4	1.00E-04	6.00E-04	-2.76E-05	3.37E-04	6.66E-05	4.12E-04	-1.14E-04	2.30E-04
5	1.00E-04	1.00E-04	-3.02E-05	-1.81E-04	-1.11E-04	8.21E-05	-1.52E-04	4.63E-05
6	4.00E-03	1.00E-04	-3.80E-03	6.43E-06	-3.82E-03	2.88E-05	-3.84E-03	-1.05E-05
7	1.00E-04	1.00E-04	5.46E-05	-6.38E-06	6.42E-05	2.63E-05	5.63E-05	1.27E-05
8	1.00E-04	1.00E-04	4.65E-06	1.46E-05	-4.23E-06	2.53E-06	-1.20E-05	-1.24E-05
9	2.50E-03	1.00E-04	-2.43E-03	2.30E-05	-2.43E-03	2.06E-05	-2.45E-03	1.57E-05

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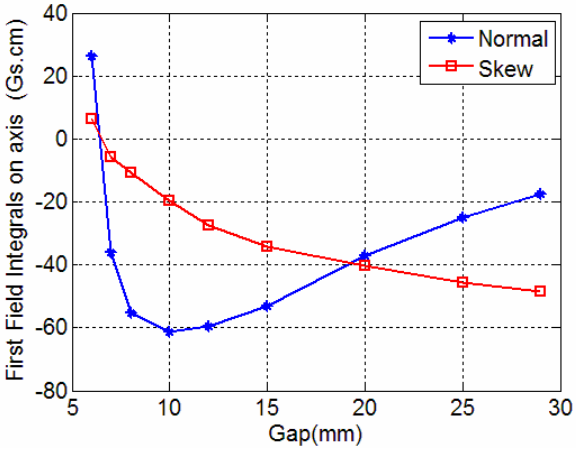
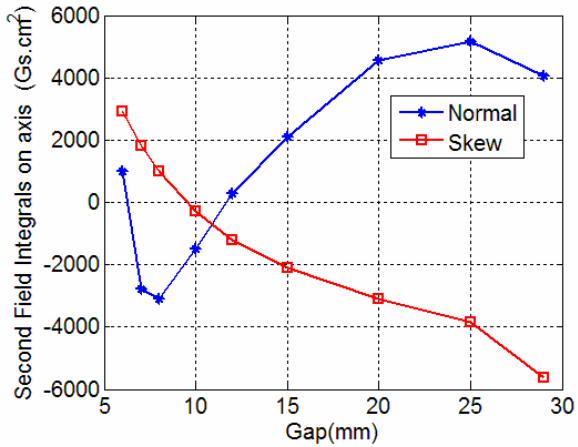
IVUs

IVU40

	IVU20-1,2	IVU25	IVU40
Period length	20mm	25mm	40mm
Period number	80	80	30
Gap	6-16mm	7-16mm	10～30mm
Phase error @x=0	<3°	<3°	< 3°
Average Orbit Off	<1μm	<1μm	
First Field Integral @|x|≤12mm	<50Gs-cm	<50Gs-cm	<100Gs-cm
Second Field Integral @|x|≤12mm	<25000Gs-cm^2	<25000Gs-cm^2	<20000Gs-cm^2



First Field Integral

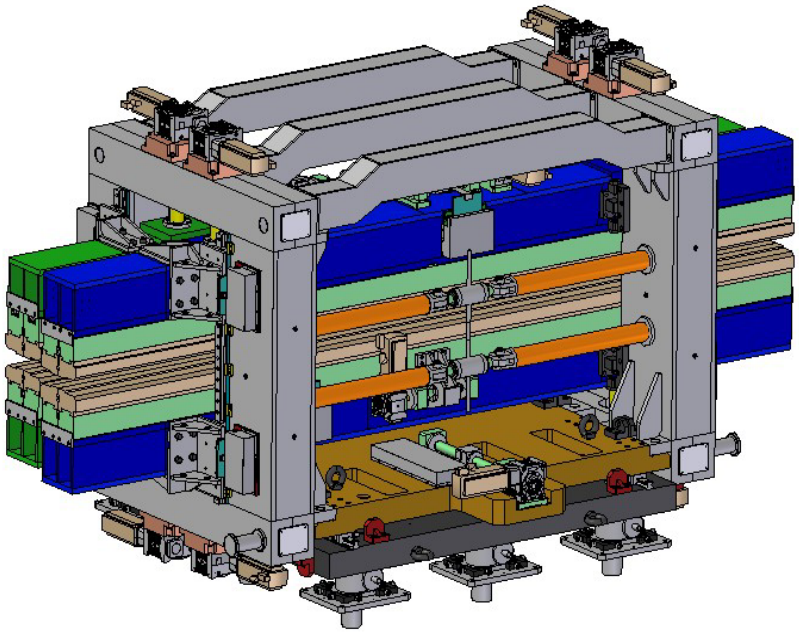


Second Field Integral

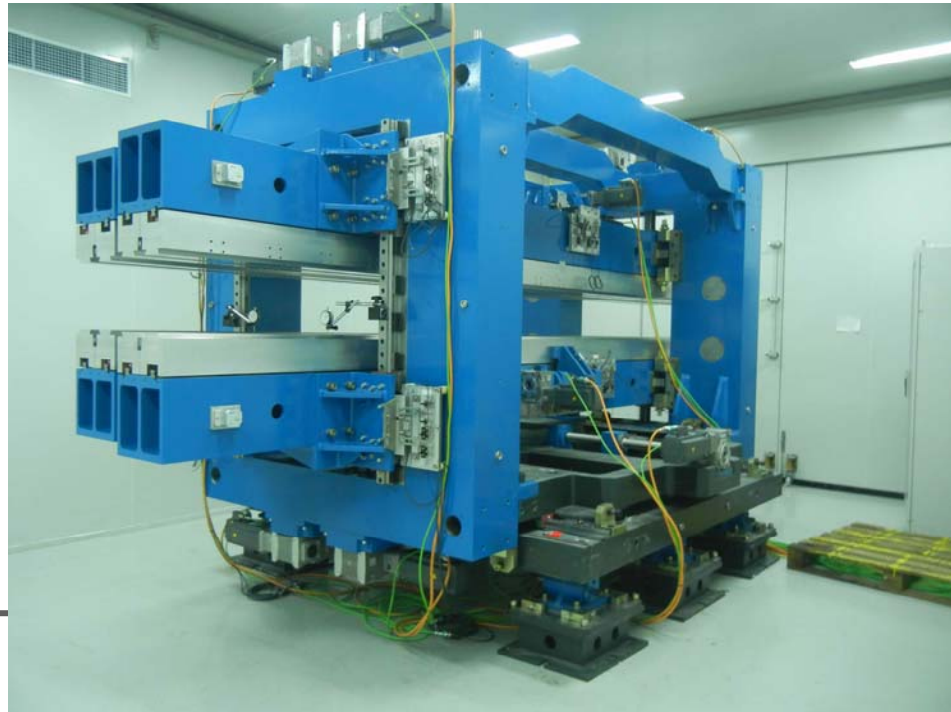
Gap	Peak Field (T)	Phase Error (R.M.S)
5	1.0514	2.50°
6	0.8684	2.29°
8	0.6015	3.13°
10	0.4264	3.22°
12	0.3061	2.41°
16	0.1614	1.50°
20	0.0884	0.94°
29	0.0209	0.46°

Q. Zhou, H. Du

DEPU



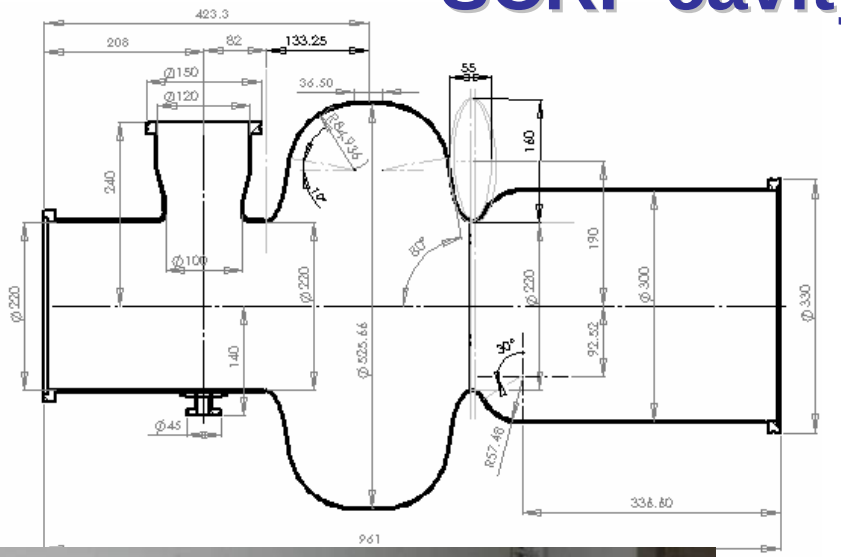
	LEID	HEID
Period length	148 mm	58 mm
Period number	32	84
Gap	22mm	16.5mm
Peak By for H Mode	>0.67 T	>0.78 T
Peak. Bx,y for C Mode	>0.45 T	>0.44 T
Magnet length	4.88 m	4.97 m
Photon energy for H Mode	20- 200 eV	200 – 2000 eV
Photon energy for C Mode	20- 300 eV	300 – 2000 eV

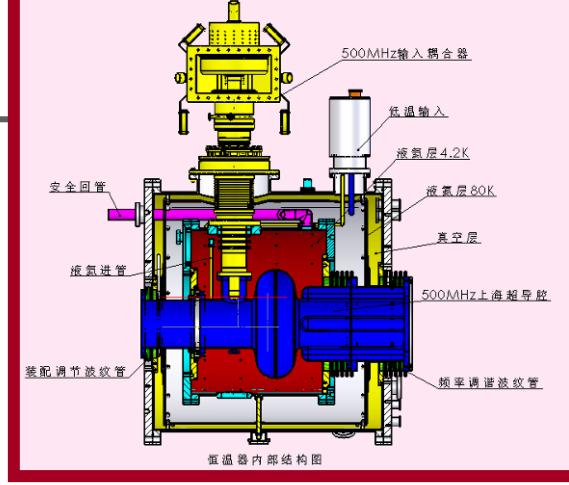


Q. Zhou, R. Deng

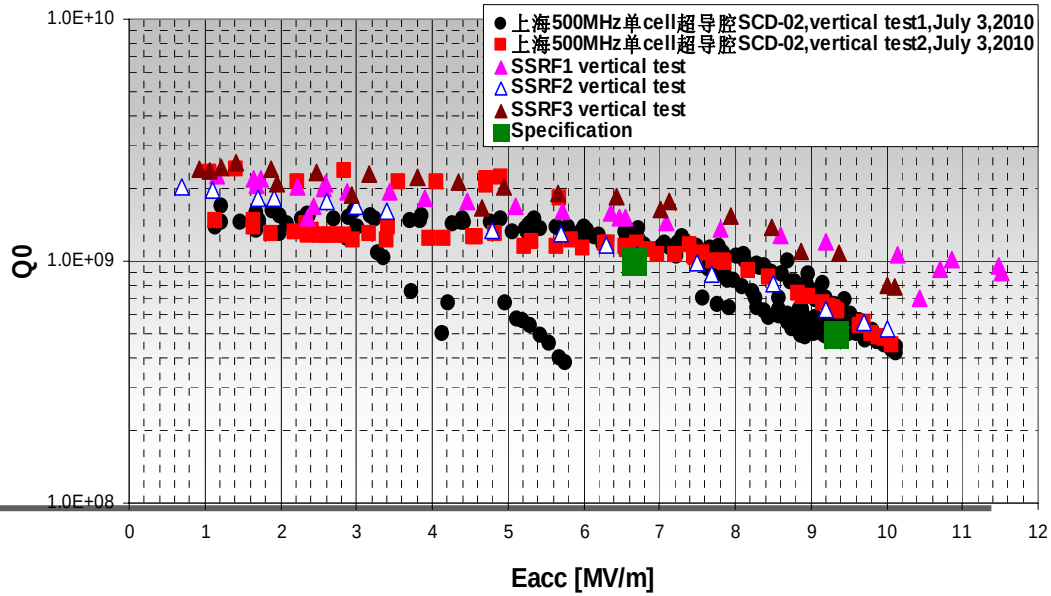
中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

SCRF cavity





Q0 versus Eacc, Cavity SCD-02 tested results Compared with SSRF Cavities

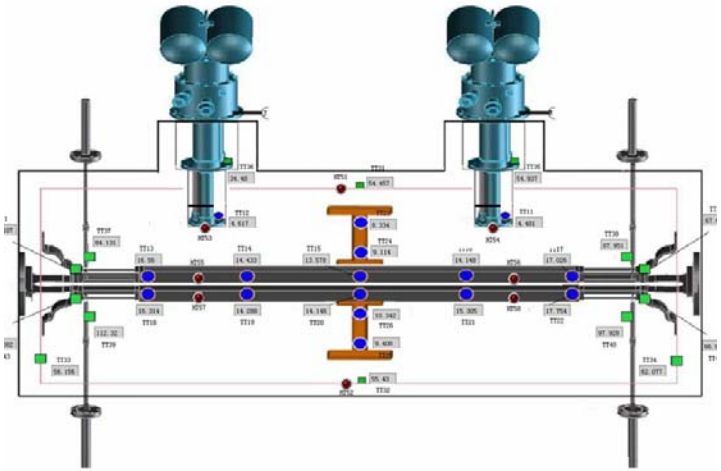


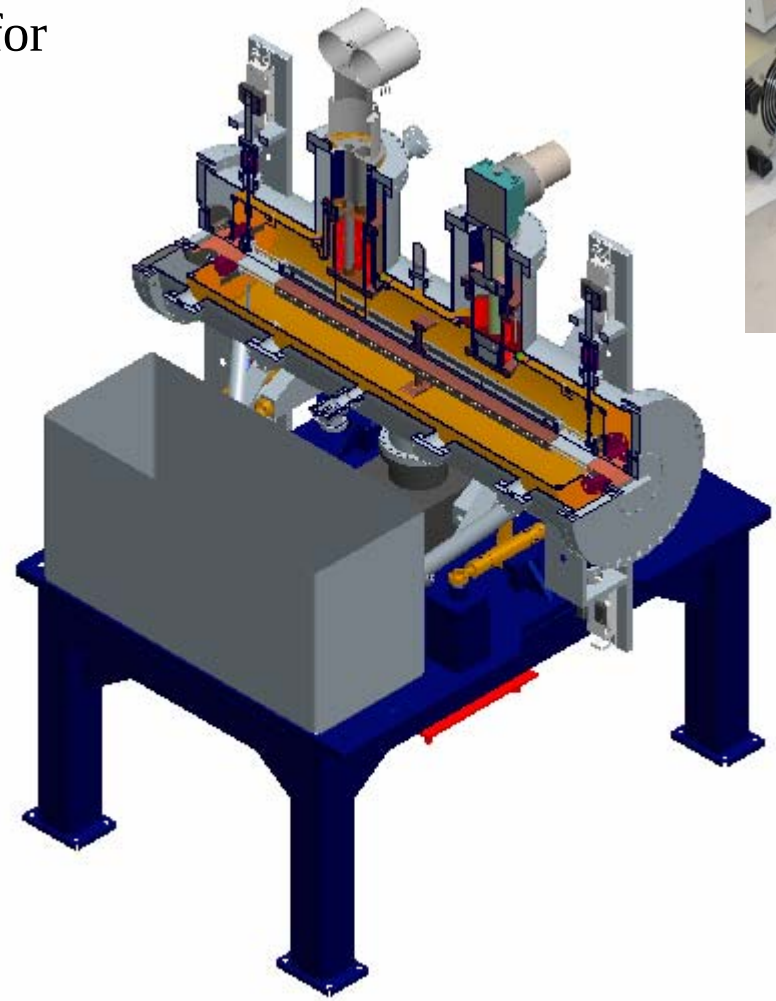
J. Liu

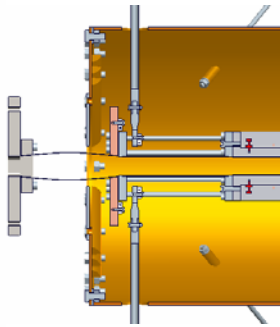
SCRF Laboratory

Cryogenic Calorimeter

- To quantify beam-based heat load for superconducting undulators
- To optimize design of SCU







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Summary

- Three synchrotron light sources, from first generation to third generation, were constructed and operated for users for more than 30 years at CAS.
- Many new technology for light source development are carried out and successfully applied.
- Light sources with very low emittance are proposed and R&D for development and construction are under going.
- Close collaborations and interactions with light sources in the world have been performed since late 1970s. We got a lot of valuable helps from our partners in the design and construction of the CAS light sources
- More closer collaboration are expecting for future light source R&Ds and projects

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Thank you !