Future Government Founded Accelerator Projects in Asia

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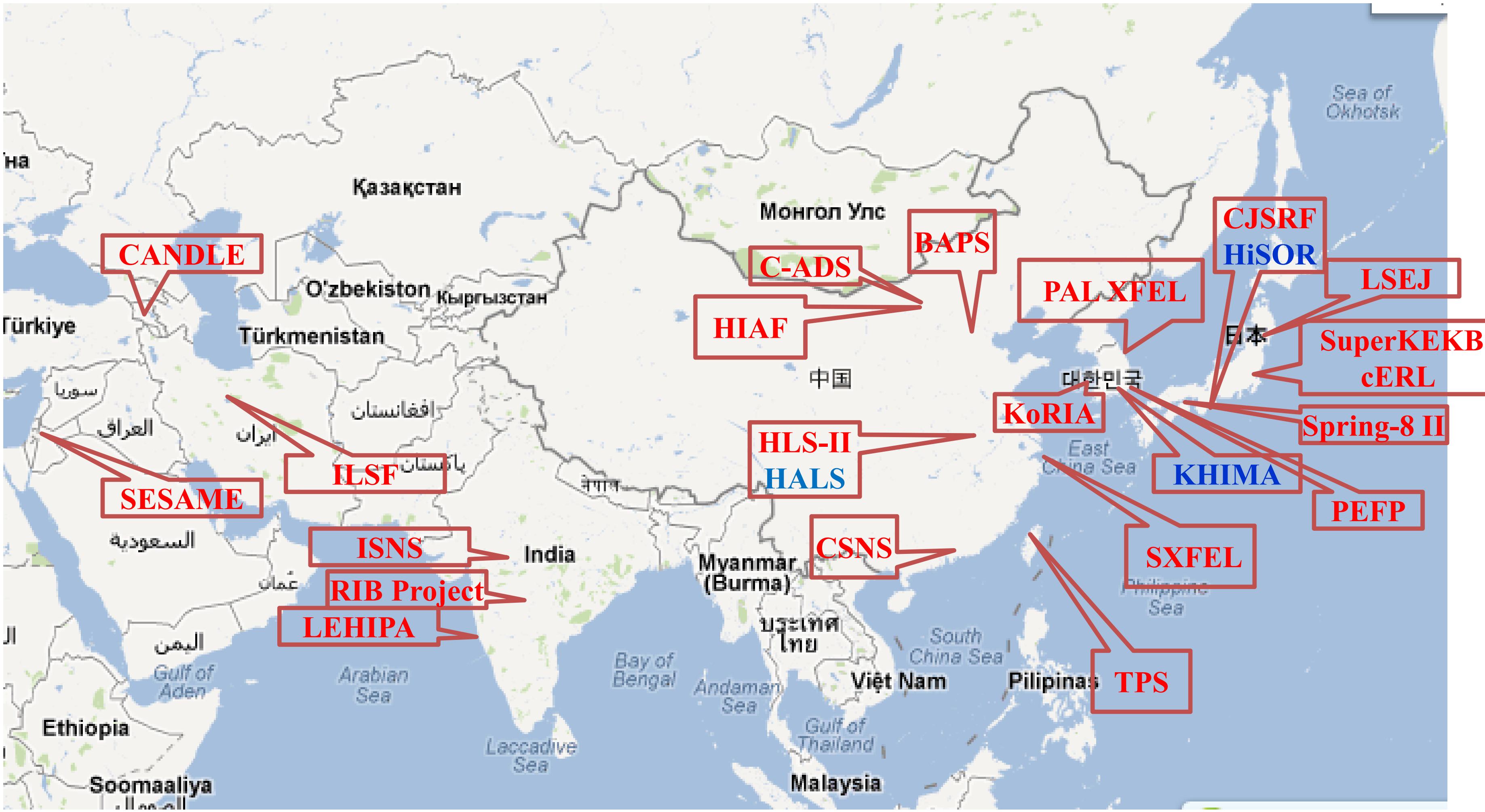
Outline

Reporting the accelerator projects not commissioned, which are or will be funded by central/local governments; The medical and industrial accelerator projects are not included.

- **Electron Accelerator Projects**
- **Proton Accelerator Projects**
- **Rare Isotope and Heavy Ion Accelerator Projects**

Future Accelerator Projects in Asia



Electron Accelerator Projects

- Electron-Positron Collider: 1

 - SuperKEKB

- Synchrotron Light Sources： 11

 - TPS, SESAME, CJSRF, ILSF, LSEJ, CANDLE, HiSOR, HLS-II and HALS

 - SPring-8 II, BAPS

- Free Electron Lasers: 2

 - PAL-XFEL

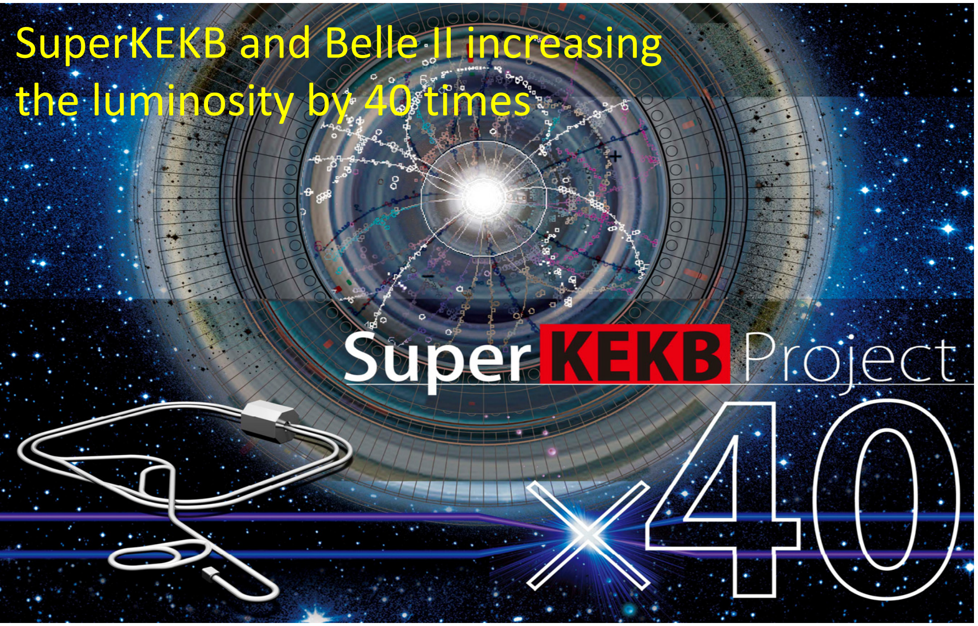
 - SXFEL: Shanghai X-ray Free Electron Laser Test Facility

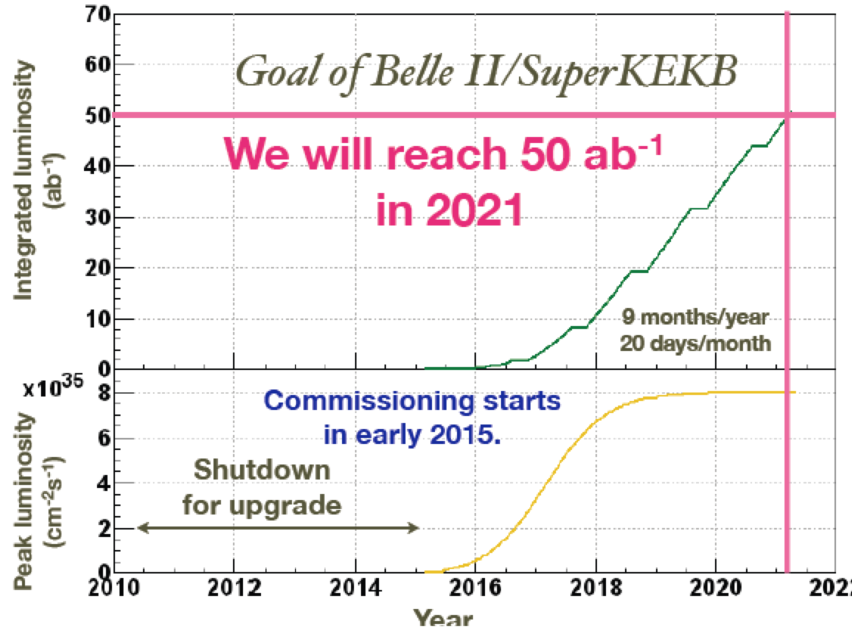
- Energy Recovery Linac: 2

 - cERL

 - 3GeV KEK-ERL

SuperKEKB Project (2010-2015)



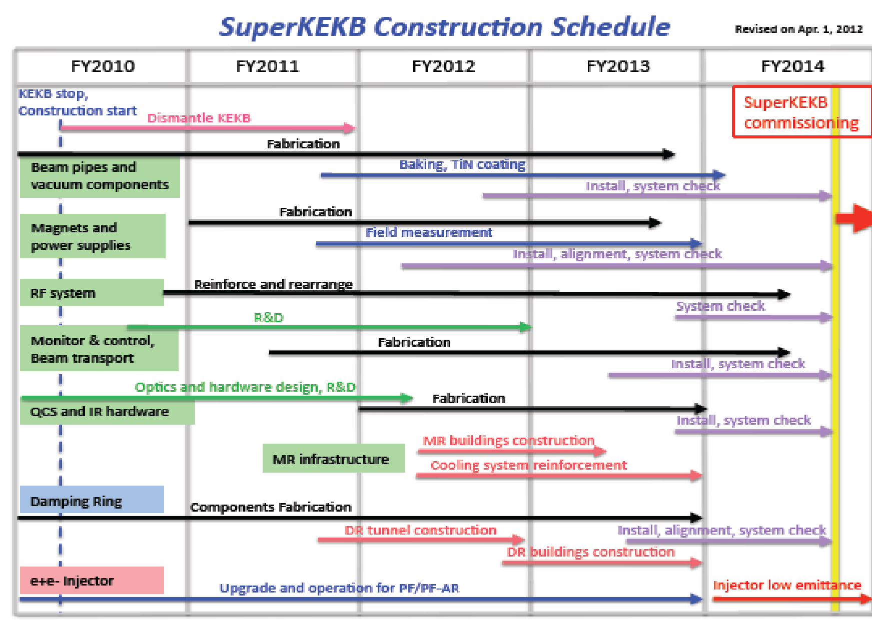


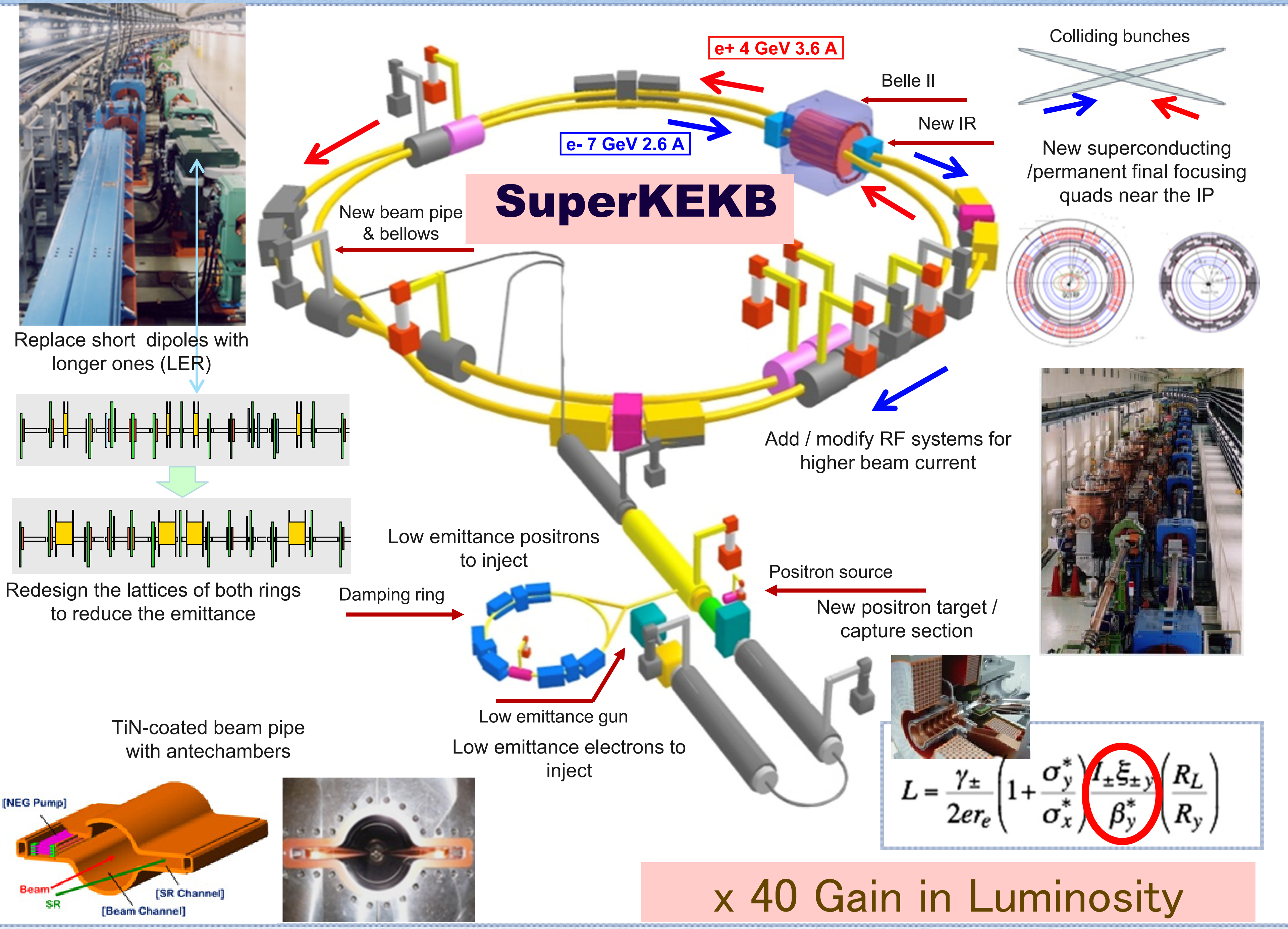
Cost estimation

1 (Oku-Yen) = 1.1 M USD = 0.8 M EUR (as of 12 Feb, 2010)

Components	Cost (Oku-Yen)	Remarks
Linac upgrade and Damping Ring	31	e+ matching and L-band acc., RF-gun and laser system, Damping Ring components
Vacuum System	135	beam pipes (ante-chambers, electrodes, etc), pumps and other vacuum components for 3km x 2 rings
Magnet System	93	magnets, power supplies, cables
IR upgrade	20	QCS and other hardware
RF System	25	add 9 RF stations, improve cavities (coupler, HOM damper)
Beam monitor and control	32	BPM, SRM, feedback, control system, etc.
Belle upgrade	14.7	
Total	350.7	

- Cost for DR tunnel construction is not included in the list. Also cost for buildings and facilities for Linac, DR and MR is not included. These costs are about 30 Oku-Yen in total.
- This list is what went to MEXT last year. According to recent estimation, cost for some components increases, but some others decrease.





SuperKEKB
e+ 4 GeV 3.6 A
e- 7 GeV 2.6 A
Belle II
New IR
Colliding bunches
New superconducting /permanent final focusing quads near the IP
New beam pipe & bellows
Replace short dipoles with longer ones (LER)
Redesign the lattices of both rings to reduce the emittance
Add / modify RF systems for higher beam current
Low emittance positrons to inject
Damping ring
Positron source
New positron target / capture section
Low emittance gun
Low emittance electrons to inject
TiN-coated beam pipe with antechambers
[NEG Pump]
Beam
SR
[SR Channel]
[Beam Channel]
$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$
x 40 Gain in Luminosity

Main Parameters of SuperKEKB

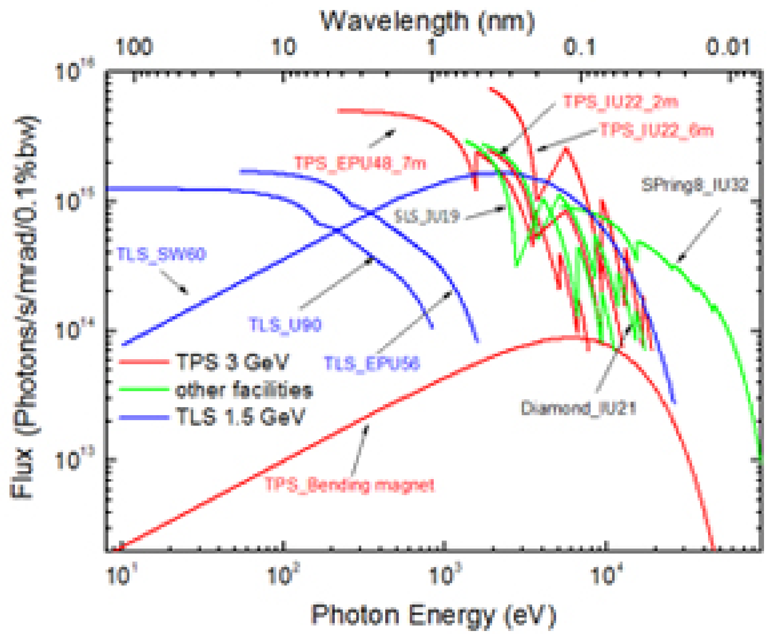
	LER (e+)	HER (e-)	units
Beam energy	4	7.007	GeV
Circumference	3016.315		m
Half crossing angle θ_x	41.5		mrad
Piwinski angle	24.6	19.3	rad
Horizontal emittance	3.2 (1.9)	4.6 (4.4)	nm
Vertical emittance	8.64	11.5	pm
Coupling	0.27	0.28	%
Beta function at IP (x/y)	32 / 0.27	25 / 0.30	mm
Vertical beam size at IP	48	62	nm
Energy spread	8.14	6.49	10^{-4}
Beam current	3.60	2.60	A
Number of bunches	2500		
Energy loss/turn	1.87	2.45	MeV
RF frequency	508.9		MHz
RF voltage	9.4	15.0	MV
Bunch length	6.0	5.0	mm
Beam-beam param. (x)	0.0028	0.0012	
Beam-beam param. (y)	0.088	0.081	
Total beam lifetime	324	357	sec
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$
Integrated luminosity	50		ab^{-1}

TPS: Taiwan Photon Source（2010-2014）

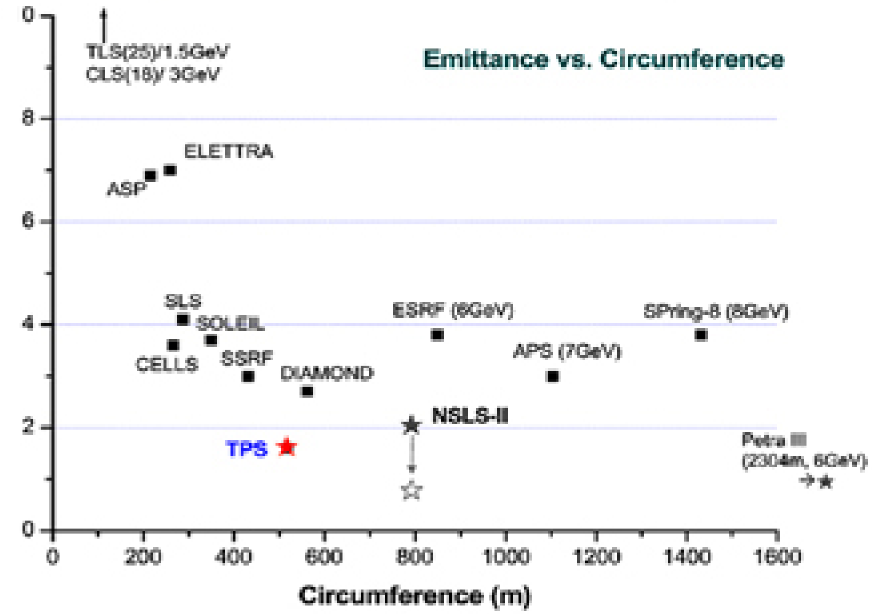
2010 Groundbreaking
2011 Linac pre-test
2012 Accelerator installation
2013 Accelerator commissioning
2014 users run

Ring: 3.0GeV, 518m,1.6nm-rad
Booster: 3Hz, 496.8m, 10nm-rad
Linac: 150MeV

Flux of TPS



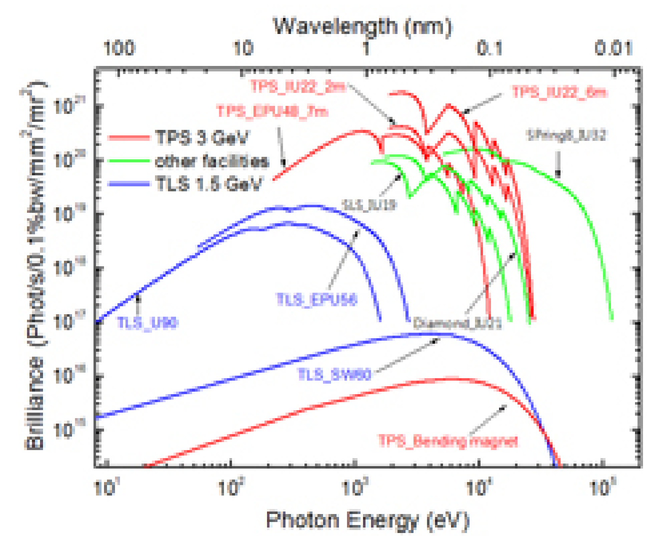
Emittance vs. Circumference



Parameters of TPS Synchrotron Facility

Energy	3 GeV
Beam Current	400 mA at 3 GeV (300 mA in 1st-phase)
C of the Storage Ring	518.4 m (h = 864)
C of the Booster	496.8 m (h = 828)
Cells	24-cell DBA
Long Strait	12 m x 6 (σ_v = 9.8 μm, σ_h = 165.1 μm) 7 m x 18 (σ_v = 5.1 μm, σ_h = 120.8 μm)
Emittance	1.7 nm·rad at 3 GeV (Distributed dispersion)
RF frequency	500 MHz
RF Voltage (1st-phase)	6.4 MV (4 SRF cavities)
RF Power (1st-phase)	720 kW (4 SRF cavities)

Brightness of Synchrotron Light Sources



Central Japan Synchrotron Radiation Research Facility

(2010-2013)

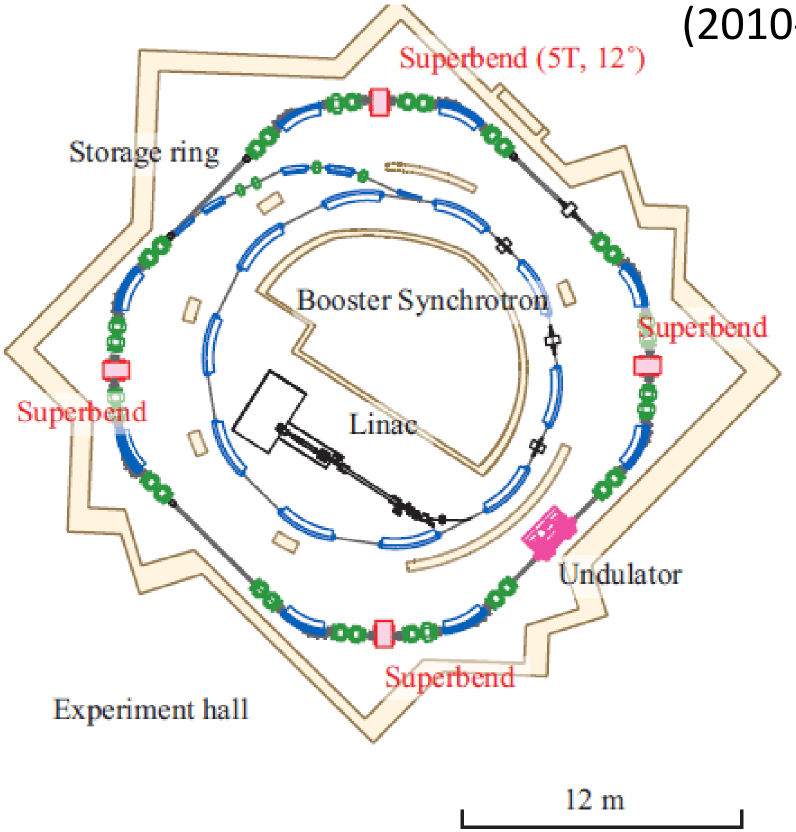
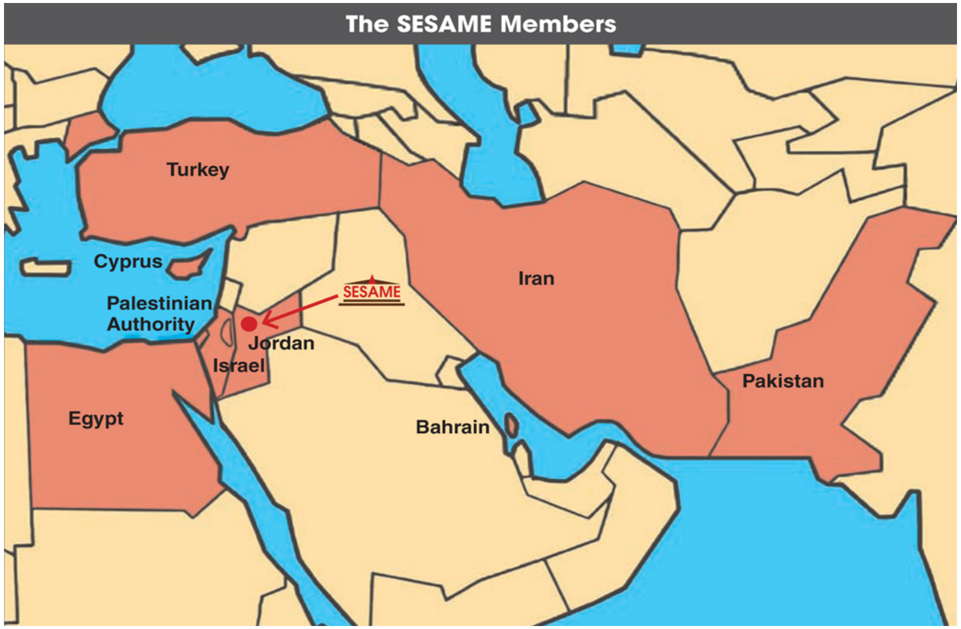


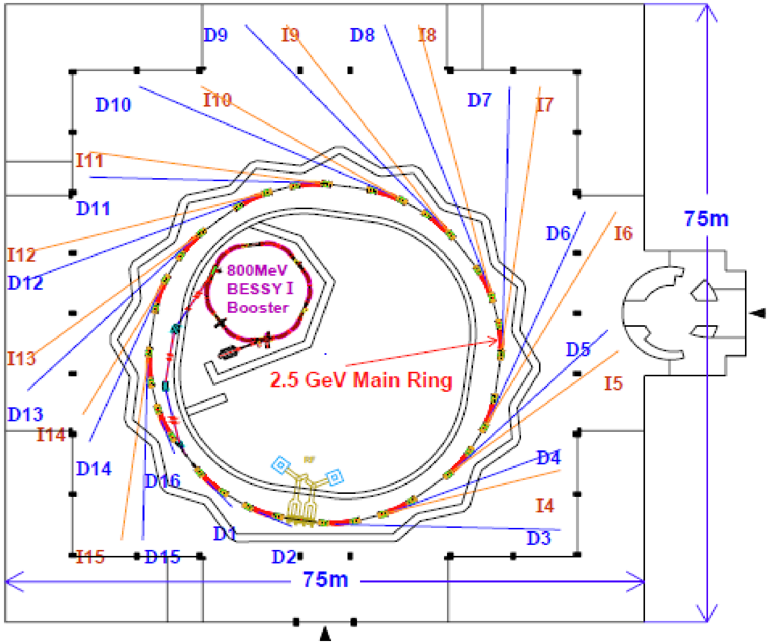
Table 1: Parameters of Accelerators

Storage ring	
Electron energy	1.2 GeV
Circumference	72 m
Current	>300 mA
Natural emittance	53 nm-rad
Betatron tune	(4.72, 3.23)
RF frequency	499.654 MHz
RF voltage	500 kV
RF bucket height	>0.990 %
Harmonics number	120
Energy spread	8.41×10^{-4}
Magnetic lattice	Triple Bend Cell × 4
Normal bend	1.4 T, 39°
Superbend	5 T, 12°
$(\beta_x, \beta_y, \eta_x)$ @superbend	(1.63, 3.99, 0.179)
$(\beta_x, \beta_y, \eta_x)$ @straight section	(30.0, 3.77, 1.20)

Designed at the Nagoya University Synchrotron Radiation Research Center (NUSRC) in collaboration with Aichi prefectural government, Aichi Science & Technology Foundation, industries, and other universities in the area. Commissioning will be made in 2012

SESAME (9 members, 12 observers)





Energy; *2.5 GeV*

Circumference; *133m*

Emittance; *26 nm-rad*

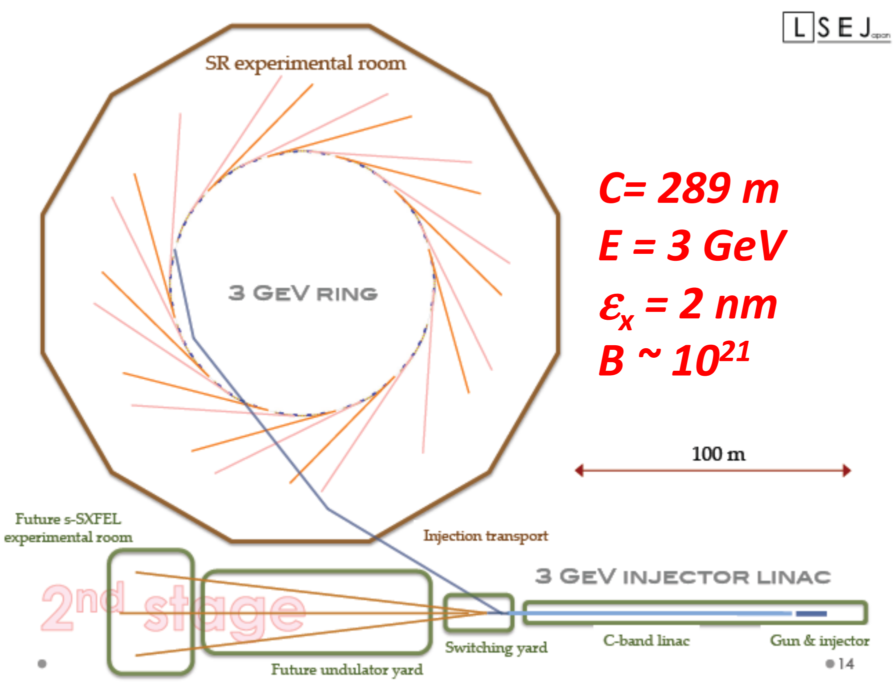
12 Insertion Devices

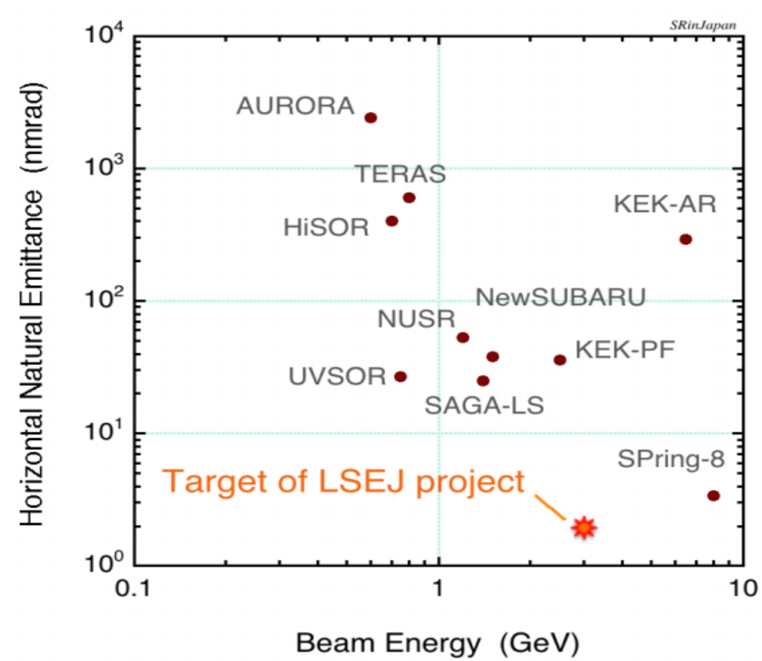
13 Bending Magnet beam lines

Maximum beam line length; 37m

LSEJ$_{apan}$: Light Source in East Japan

- Need another mid-Energy high brightness source in Japan
- Supported by 7 national universities
- 3-GeV C-band linac injector (could be soft-XFEL driver)
- 12-cell, QBA as baseline
- Needs at least 250 M$-- will abandon proposal if funding not approved in 2 years (before KEK ERL, SPring-8 II funding)





ILSF: Ilran Light Source Facility (2011-2018)

Storage Ring

- 3 GeV, 297.6m circumference, 3.3 nm-rad, four-fold symmetry, with 4×8m, 20 X4m 12 × 2.8m straight sections ;

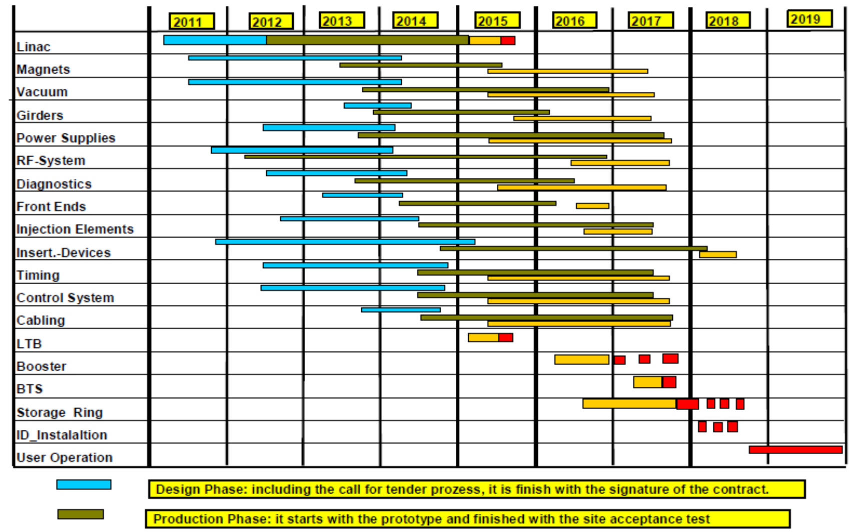
Booster Ring

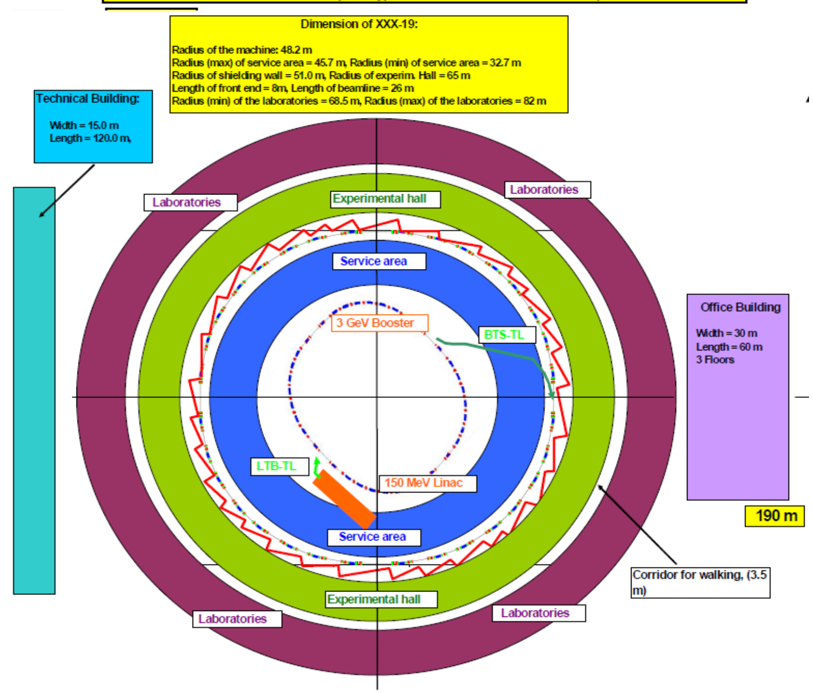
- 144m Circumference, 14nmrad, 1Hz;

Linac

- 150 MeV , Electron gun 90kV

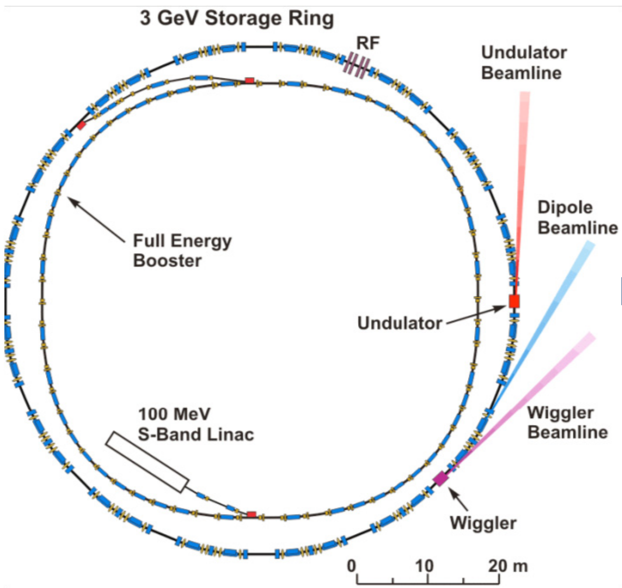
Parameter	Unit	Value
Energy	GeV	3
Circumference	m	297.6
Number of super-periods	-	4
Current	mA	400
Horizontal Emittance	nm-rad	3.278
Harmonic number	-	496
RF frequency	MHz	500
Tune (Q_x/Q_y)	-	18.2656/11.324
Natural energy spread	-	1.0408E-03
Natural chromaticity (ξ_x/ξ_y)	-	-34.560/-28.02
Momentum compaction (α_c)	-	7.621E-04
Radiation loss per turn	MeV	1.0167
Beta function at center of medium straight sections (β_x/β_y)	m	2.3/1.4
Beam size at center of medium straight section ($\sigma x/\sigma y$)	µm	156.18/6.84
No. of dipoles	-	32
No. of quadrupoles	-	104
No. of sextupoles	-	128
Dipole magnetic field	T	1.42
Dipole field gradient (matching/unit)	T/m	-3.83/-5.83





CANDLE and HiSOR-II

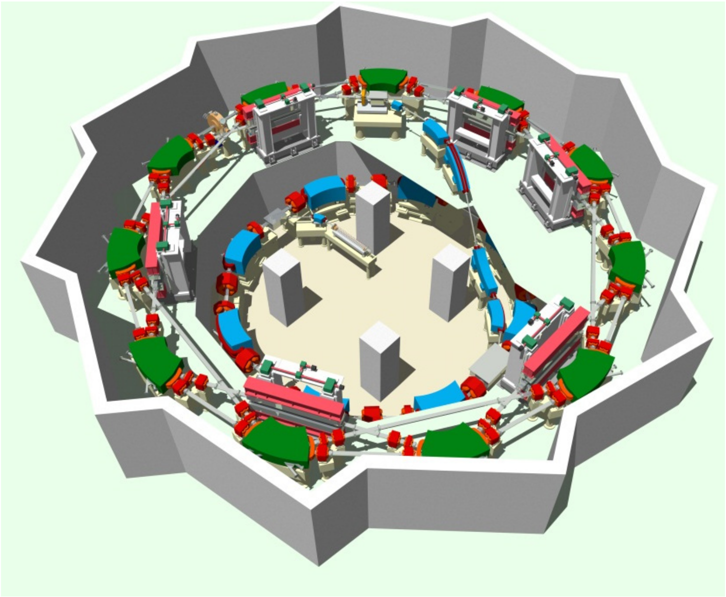
CANDLE
3GeV, 8 nm-rad
216m, 16×4.8m



Parameter	Value
Energy E (GeV)	3
Circumference (m)	216
Current I (mA)	350
Horizontal emittance (nm.rad)	8.4
Vertical emittance (nm.rad)	0.084
RF frequency (MHz)	499.654
Harmonic number	360
Number of lattice periods	16
Straight section length(m)	4.8

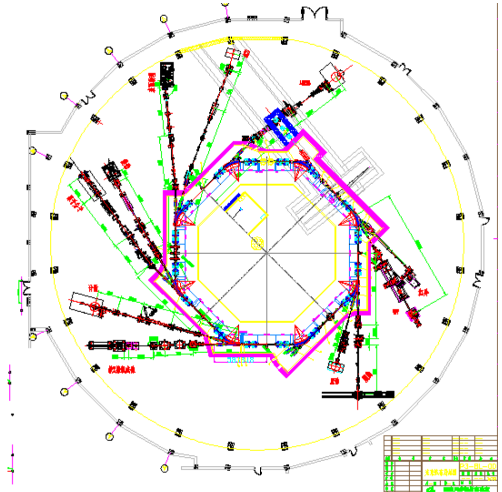
HiSOR-II
0.7GeV, 18 nm-rad
46m, 11×3.6m,
11×1.7m

Perimeter	45.97 m
Orbit shape	(11,3) Torus knot
Perimeter	45.97 m
Orbit length	130.187 m
Beam energy	700 MeV
Straight sections	3.614 m ×11 1.728 m ×11
Harmonic number	88
RF frequency	202.645 MHz
Betatron tune	(10.362, 7.807)
Natural emittance	17.9 nmrad
Chromaticity	(+1.0, +1.0)



HLS-II and HALS: Hefei Light Source Upgrade Projects

HLS-II (2010-2013)

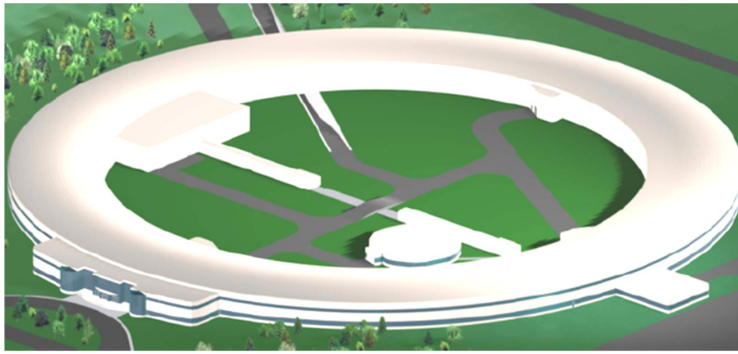


	HLS	HLS II
Beam energy	800 MeV	
Circumference	66.13 m	
Magnet lattice	TBA	DBA
Super-period	4	
Natural emittance	160 nm·rad	<40 nm·rad
Beam intensity	250 mA	300 mA
Transverse tunes	3.54/2.60	4.41/2.80
Beam lifetime	>10 h	>5 h
RF frequency	204 MHz	
RF voltage	150 kV	250 kV
Harmonic number	45	
Critical 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	<25μm（V）	<5μm（V）

HALS

Ultra-low emittance storage ring

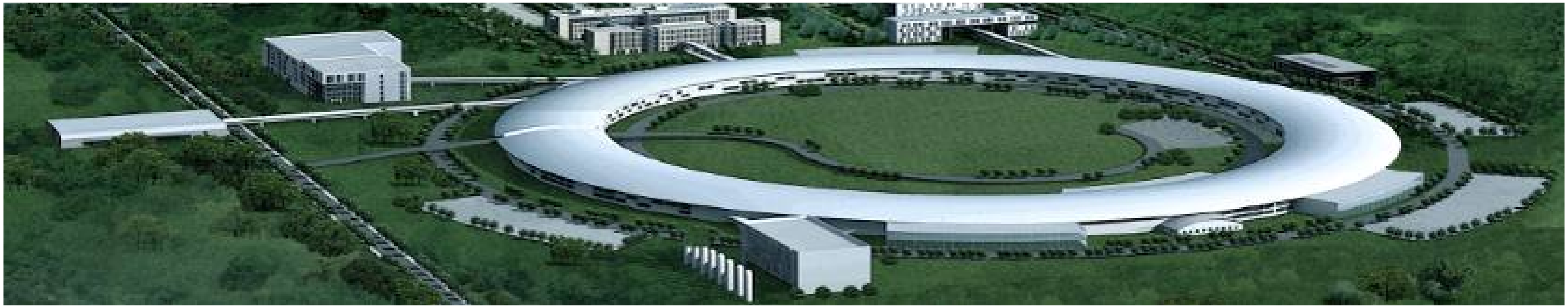
- Beam energy： 1.8 GeV
- Circumference： 480 m
- Beam intensity： ~500 mA
- Beam emittance： ~80 pm·rad (low beam current) ~40 pm·rad
- Critical wavelength： 1.66 nm
- Magnet lattice: Six Bend Achromat
- Straight section : 20×6.5 m
- Beam lifetime： Top-off
- Natural bunch length:~40 ps



BAPS: Beijing Advanced Photon Source

- 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



SPring-8 II

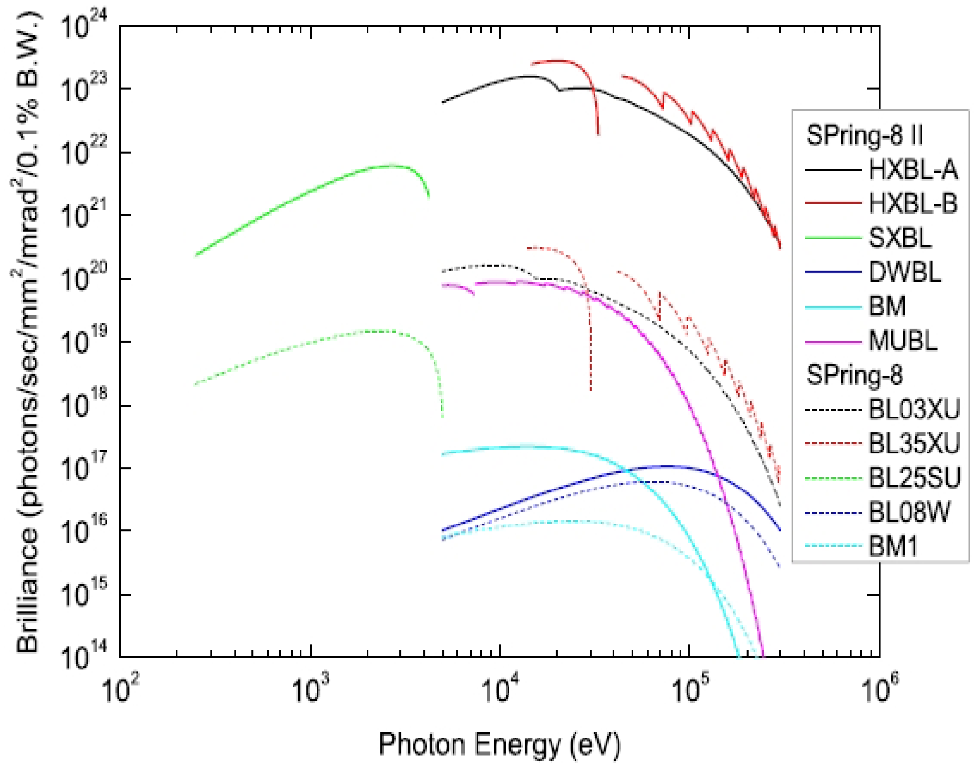
Road map for SPring-8 II

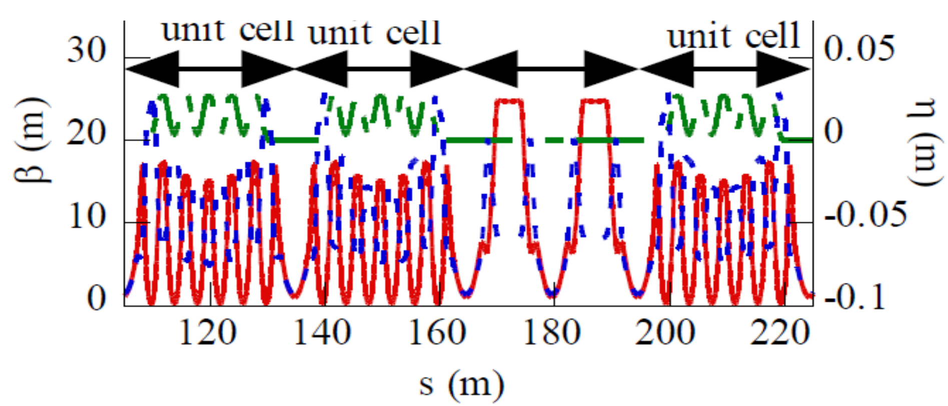
- Two big light source on one site.
- SPring -8 is planed to upgrade to Ultimate ring

Main Performance of SPring-8 II

- Energy : 6 GeV
- Emittance: 67.5 → 10 pm-rad
- New injection scheme

	New Ring	Present Ring
Lattice Type	6 Bend	Double-Bend
Unit Cell Length [m]	29.92	29.92
Ring Circumference [m]	1435.95	1435.95
Beam Energy [GeV]	6	8
Natural Emittance [pm.rad]	67	3400
Energy Spread [%]	0.096	0.109
Dispersion Func. [m] at Straights	0	0.107
Betatron Func. [m] at Straights (H/V)	1.0 / 1.2	22.6 / 5.6
Betatron Tune (H/V)	141.80 / 38.25	40.14 / 18.35
Natural Chromaticity (H/V)	-473 / -199	-88 / -42
Momentum Compaction Factor	1.55×10^{-5}	1.68×10^{-4}
Radiation Loss [MeV/turn]	4	9
Number of Magnets per Cell		
(Bending / Quadrupole / Sextupole)	6 / 26 / 23	2 / 10 / 7
Bending Field [T]	0.70	0.68
Max. Strength of Quadrupoles [m^{-1}]	1.52	0.40
Max. Strength of Sextupoles [m^{-2}]	120	6.2

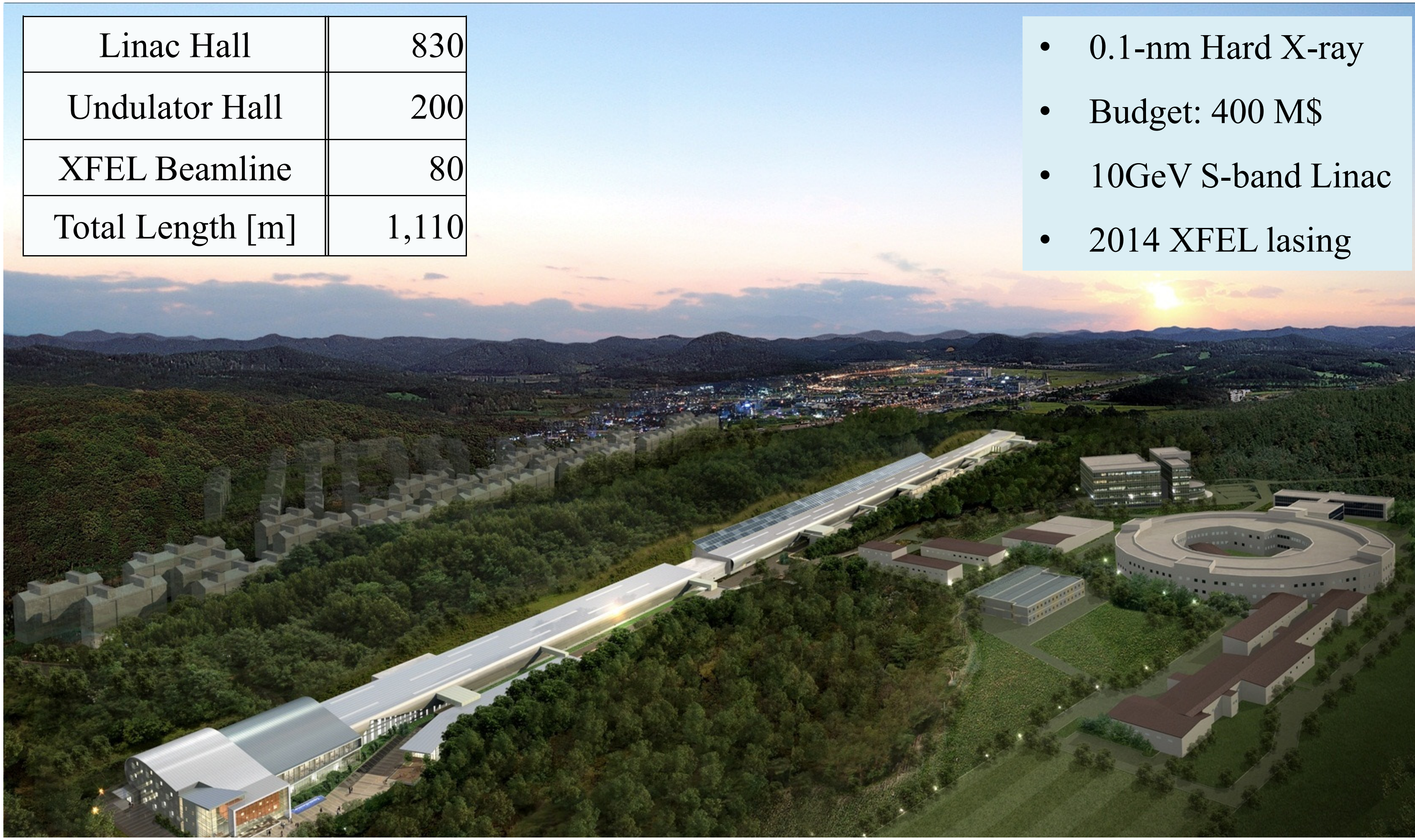


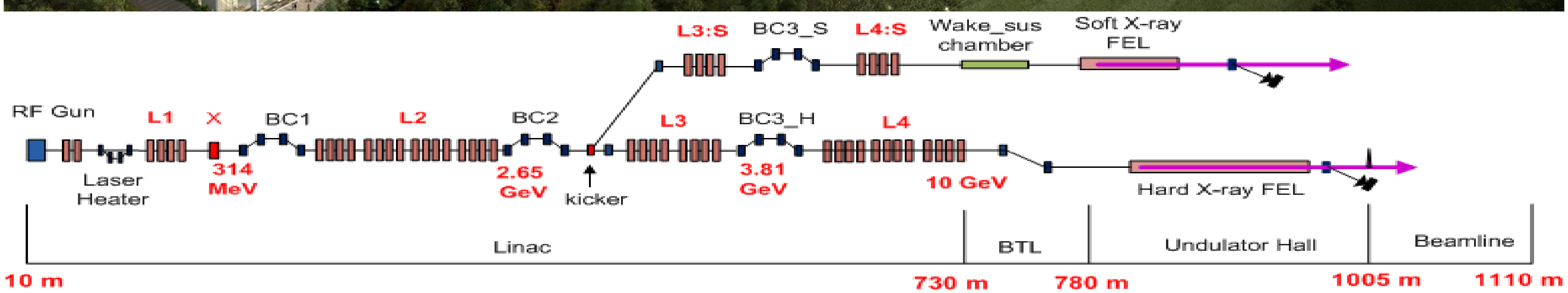


PAL-XFEL (2011 -2014)

Linac Hall	830
Undulator Hall	200
XFEL Beamline	80
Total Length [m]	1,110

- 0.1-nm Hard X-ray
- Budget: 400 M$
- 10GeV S-band Linac
- 2014 XFEL lasing

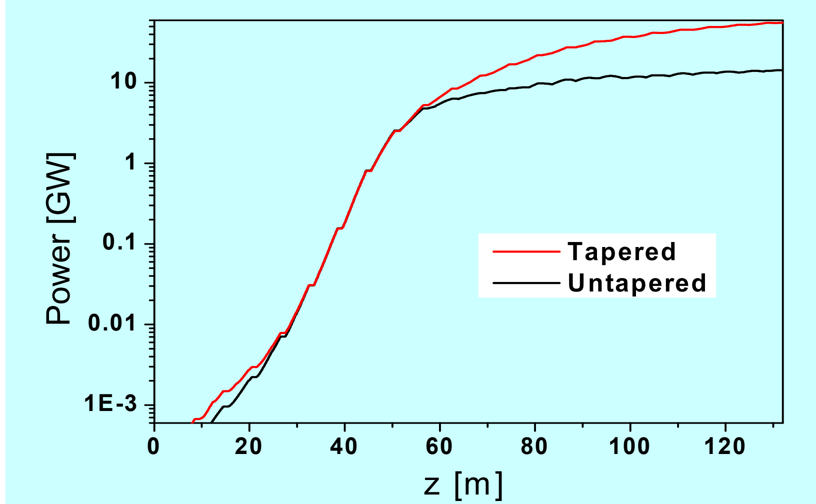




PAL XFEL: Main Parameters

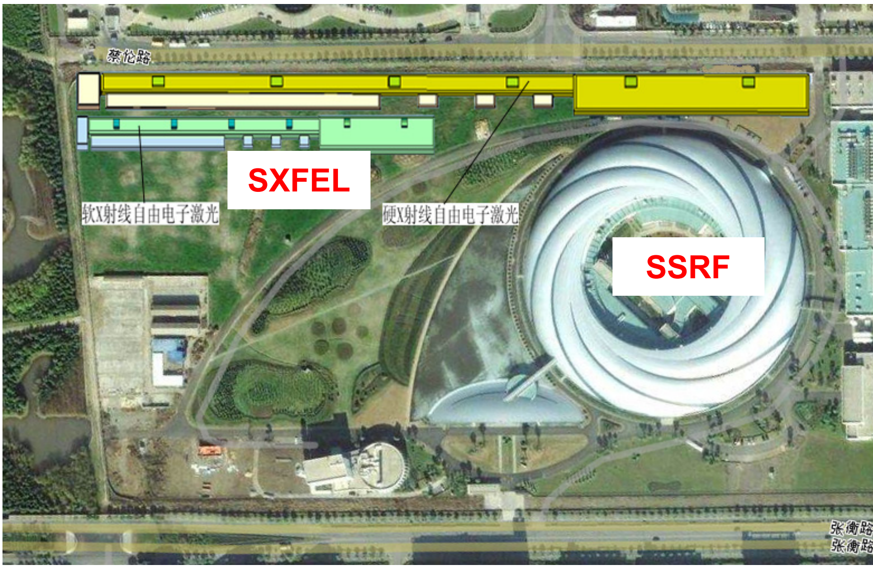
	FEL wavelength [nm]	0.1
Electron Linac	Beam energy [GeV]	10
	Beam charge [nC]	> 0.2
	Beam emittance [mm-mrad]	< 0.5
	Injector Gun	Photocathode RF-gun
	Peak current at undulator [kA]	> 3
	Repetition rate	120 Hz
	Number of bunches	Single or Two
	Linac structure	S-band
Undulator	Undulator type	Out-vacuum
	Undulator period [cm]	2.46
	Undulator gap [mm]	6.8
	Undulator parameter, K	2.076
	Saturation length [m]	56
FEL	FEL radiation power [GW]	> 29
	Photon beam length [fs]	60
	FEL photons/pulse	> 1.0 E+12

- **Wavelength**
  - **Soft x-ray: 1 nm ~ 10 nm**
  - **Hard X-ray: 0.7 ~ 0.1 nm**
    - **Extended to 0.06 nm**
- **Photon beam Length**
  - **Nominal : 30 ~ 100 fs (200 pC)**
  - **Short : < 5 fs (20 pC)**
  - **Ultra short: < 0.5 fs by ESASE scheme**
- **Undulator Beamline**
  - **3 Hard X-ray / 2 Soft X-ray lines**

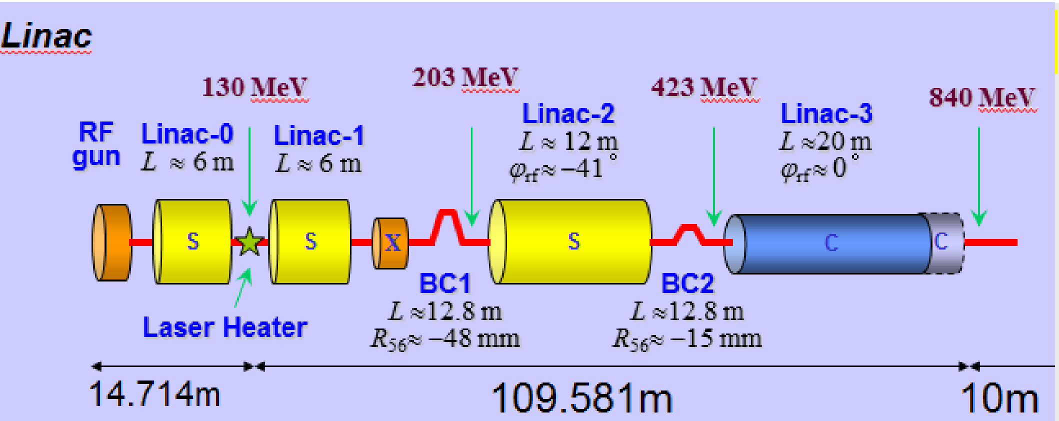


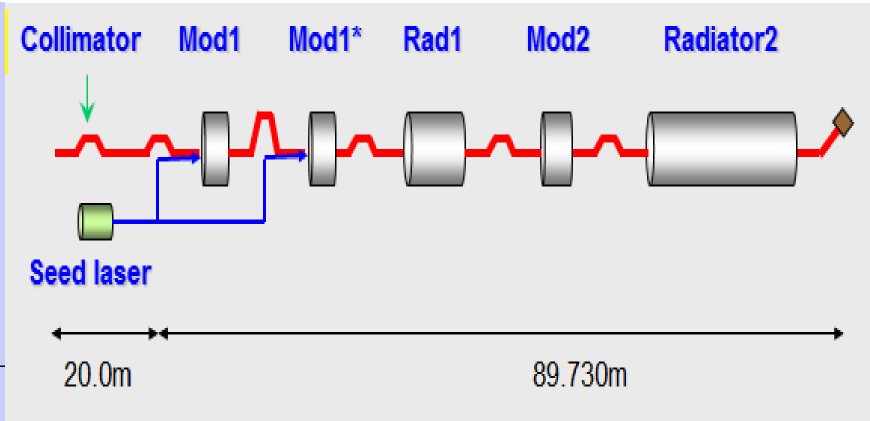
- Radiation Power of 0.1 nm @Z=132 m
- Untapered : 14 GW (4.7E+11 photons)
- Tapered : 55 GW (1.8E+12 photons)

SXFEL: Shanghai XFEL Test Facility (2012-2015)

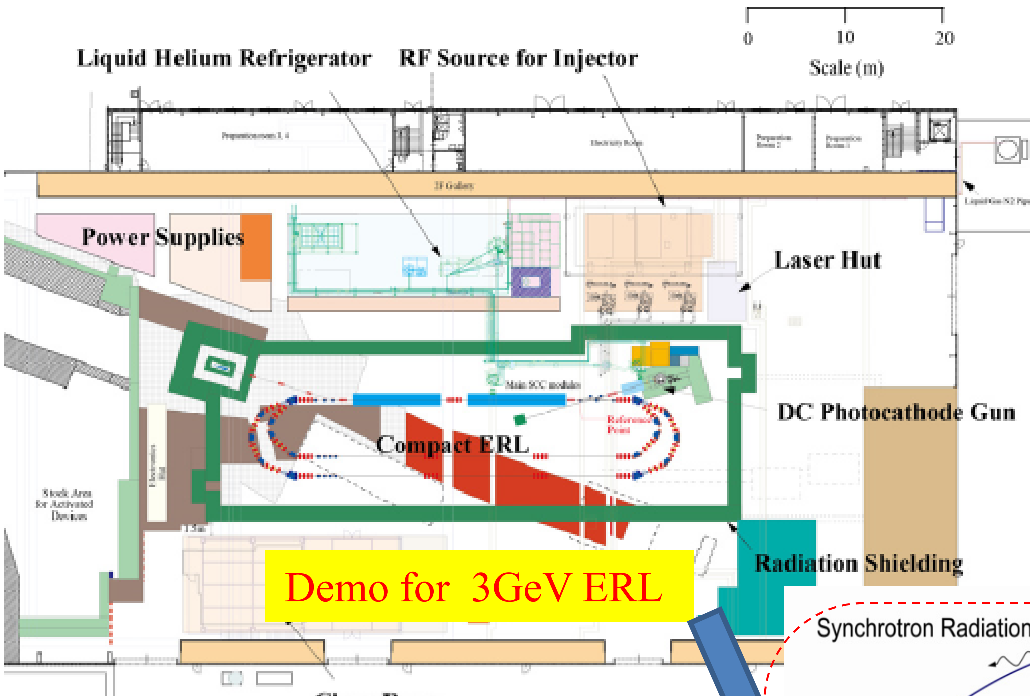


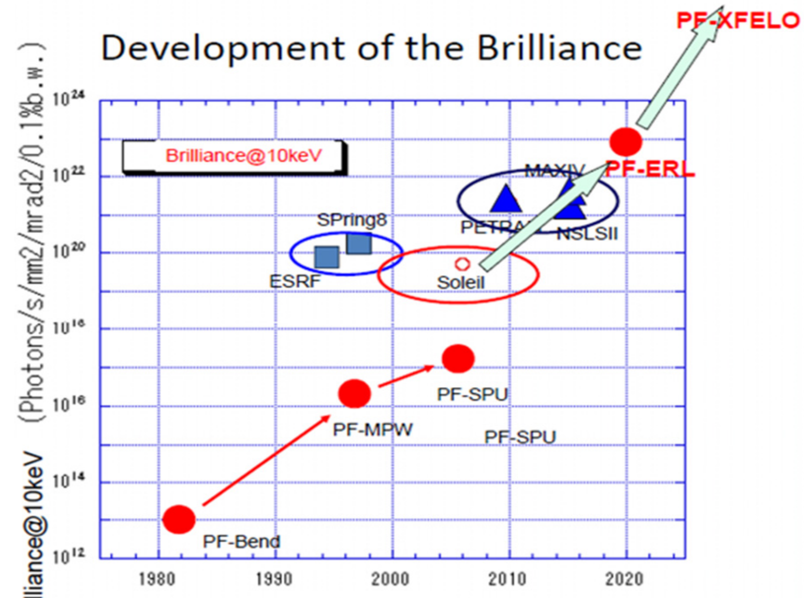
Parameters	HGHG	Upgrade	Unit
Output Wavelength	9	3	nm
Bunch charge	0.5~1	0.5~1	nC
Energy	0.84	1.2~1.3	GeV
Energy spread	0.1~0.15%	0.15%	
Energy spread (sliced)	0.02%	0.03%	
Normalized emittance	2.0~2.5	2.0~2.5	mm.mrad
Pulse length (FWHM)	1.	1	ps
Peak current	~0.5	0.5	kA
Rep. rate	1~10	1~10	Hz

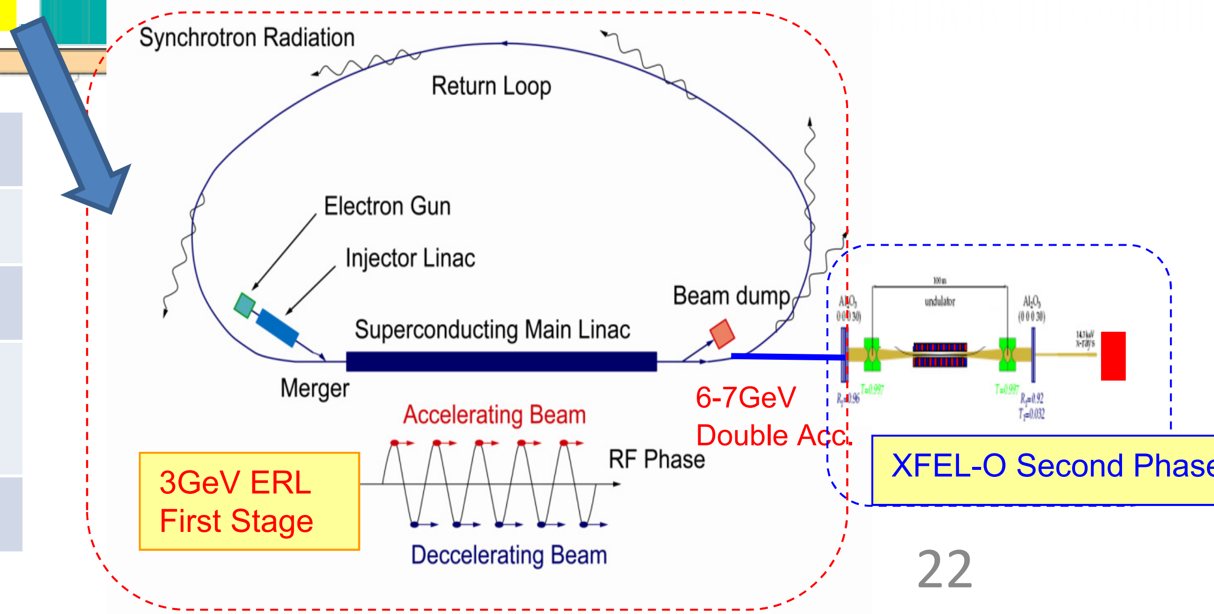




cERL →3GeV ERL@ KEK







Injection energy	5- 10 MeV
Full energy	245 MeV
Electron charge	77 pC
Normalized emittance	< 1 mm-mrad
Bunch length	1-3 ps

Proton Accelerator Projects

- Spallation Neutron Source: 2

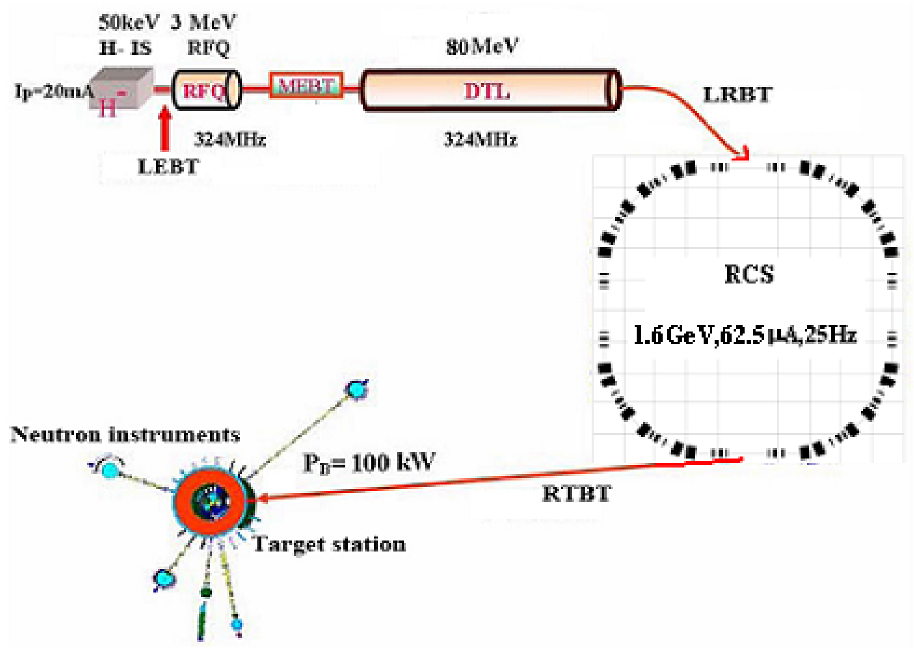
- CSNS: China Spallation Neutron Source ;
- ISNS: India Spallation Neutron Source;

- High Power Proton Linac： 3

- PEFP: Proton Engineering Frontier Project
- C-ADS: China Accelerator Driven System
- LEHIPA: High Intensity Proton Accelerator

CSNS: China Spallation Neutron Source
(2011-2018)

- CSNS project is under construction under the collaboration between CAS and Guangdong local government, it will be completed in 2018;
- The investment is from central government and local government (Gunagdong/Dongguan). CAS covers the manpower costs;
- R&D started in 2006, construction began in 2011;
- Beam power in phase I is 100kW, upgradable to 500kW.



Main Parameters of CSNS

- Repetition rate： 25 Hz
- Average proton current： 62.5 μA
- Proton kinetic energy： 1.6 GeV
- Average beam power： 100 kW
- Target: Tungsten
- Moderators(wing,three): H_2O,LCH_4 ,LH_2
- Spectrometers:

  HRPD (high resolution powder diffractometer)

  HIPD (high intensity powder diffractometer)

  Reflectometer,

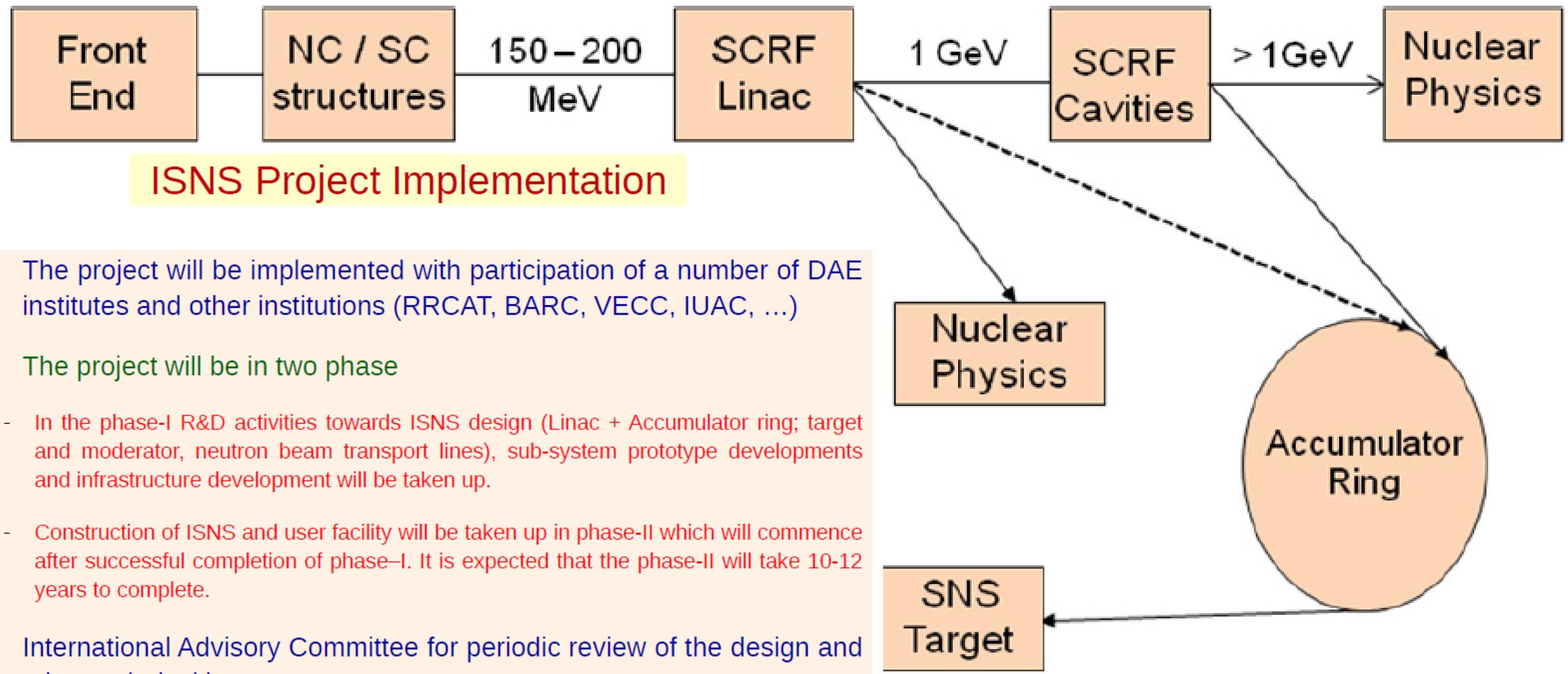
  SANS (small angle diffractometer),

  Direct-geometry inelastic spectrometer

  Engineering powder diffractometer (Northeastern Univ.)

  High-pressure powder diffractometer (Jilin Univ.)

ISNS: Indian Spallation Neutron Source



ISNS Project Implementation

- The project will be implemented with participation of a number of DAE institutes and other institutions (RRCAT, BARC, VECC, IUAC, …)
- The project will be in two phase
  - In the phase-I R&D activities towards ISNS design (Linac + Accumulator ring; target and moderator, neutron beam transport lines), sub-system prototype developments and infrastructure development will be taken up.
  - Construction of ISNS and user facility will be taken up in phase-II which will commence after successful completion of phase–I. It is expected that the phase-II will take 10-12 years to complete.
- International Advisory Committee for periodic review of the design and other technical issues
- Development of Indian industry will be a key factor

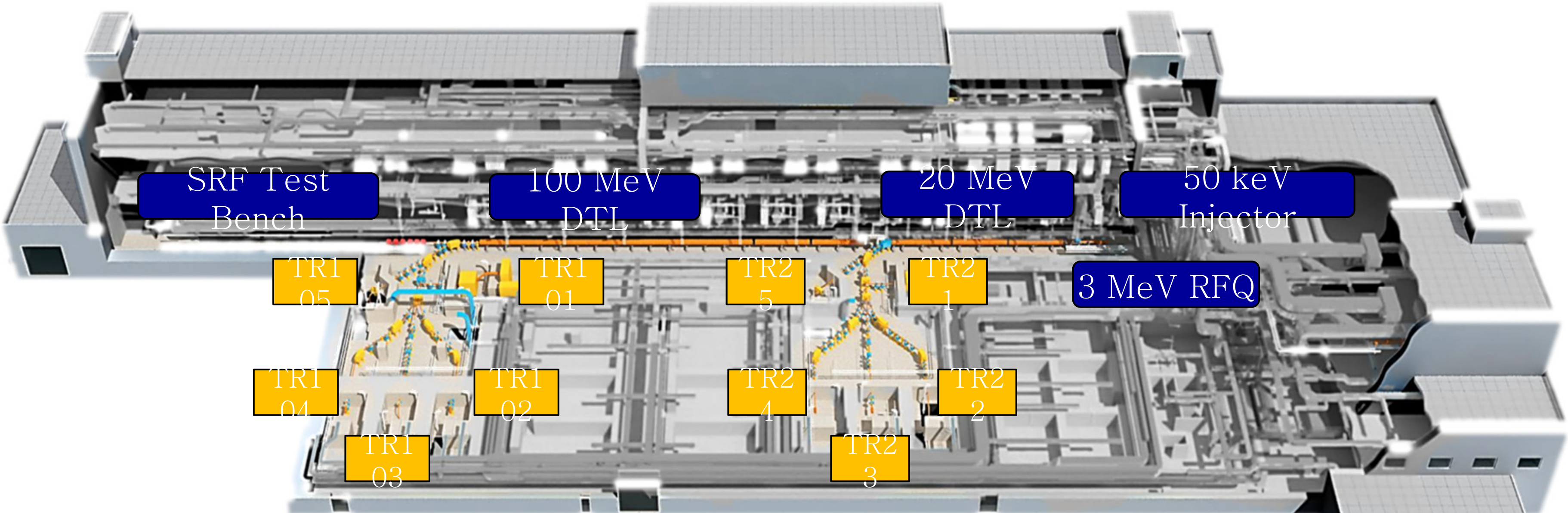
Indian Spallation Neutron Source (ISNS) at RRCAT, 1 GeV, 1 mA protons.

PEFP: Proton Engineering Frontier Project

- High-Power Proton Accelerator: Staged construction of 1.0 GeV, 20 mA proton linac
  - 20 MeV: National Nuclear R&D Program (1997-2002)
  - 100 MeV: New Frontier Program (2002-2012)
  - 1.0 GeV: Under R&D Study
- Government decided the construction site in Gyeongju
  - Near KTX station (March 2006)

- National Users' Facility: Intense neutron source for basic and applied science research
- Lead Lab.: Korea Atomic Energy Research Institute (KAERI)

PEFP 100-MeV Proton Linac (2002 – 2012)

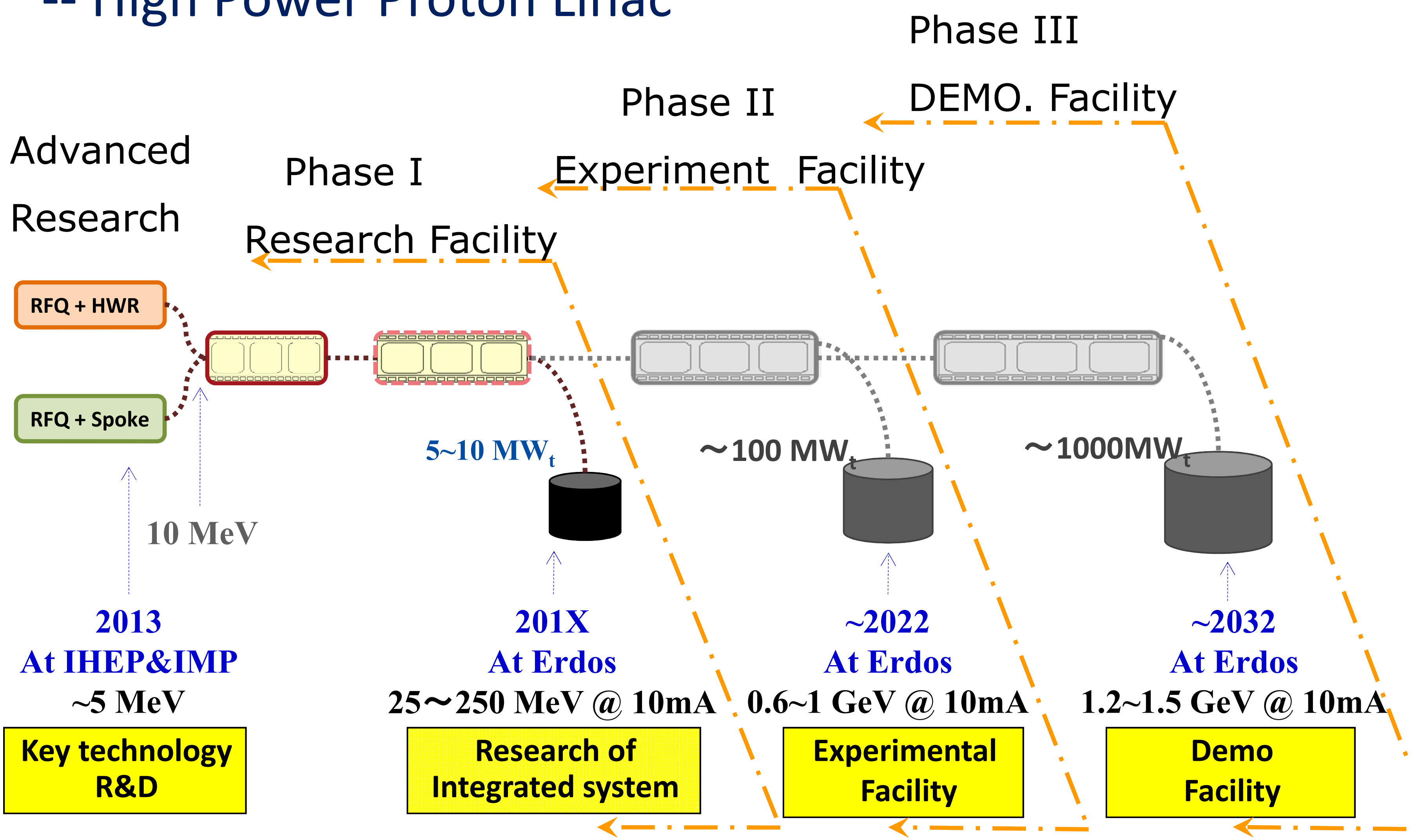


100 MeV Beamlines				
Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR101	Radio Isotopes	60Hz	0.6mA	Hor. Ext. 100mmØ
TR102	Medical Research (Proton therapy)	7.5Hz	10μA	Hor. Ext. 300mmØ
TR103	Materials, Energy & Environment	15Hz	0.3mA	Hor. Ext. 300mmØ
TR104	Basic Science Aero-Space tech.	7.5Hz	10μA	Hor. Ext. 100mmØ
TR105	Neutron Source Irradiation Test	60Hz	1.6mA	Hor. Vac. 100mmØ

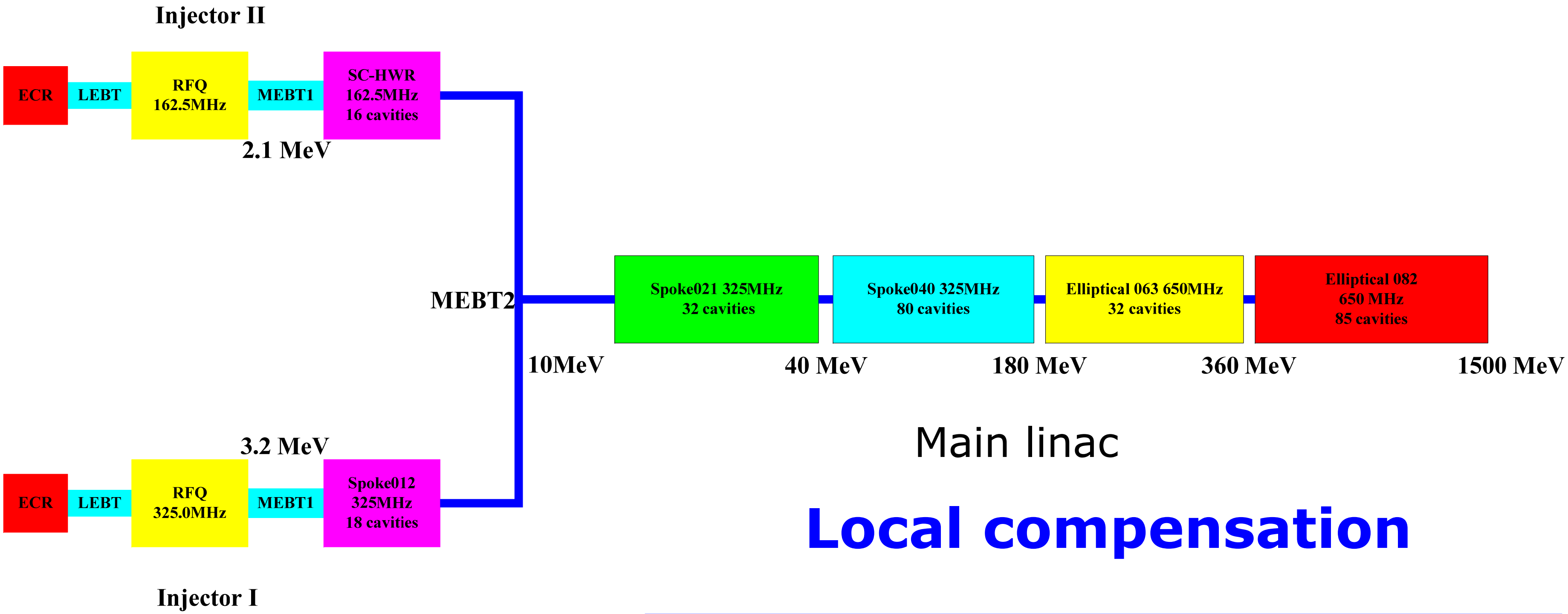
20 MeV Beamlines				
Beam Line	Application Field	Rep. Rate	Avg. Current	Irradiation Condition
TR21	Semiconductor	60Hz	0.6mA	Hor. Ext. 300mmØ
TR22	Bio-Medical Applications	15Hz	60μA	Hor. Ext. 300mmØ
TR23	Materials, Energy & Environment	30Hz	0.6mA	Hor. Ext. 300mmØ
TR24	Basic Science	15Hz	60μA	Hor. Ext. 100mmØ
TR25	Radio Isotopes	60Hz	1.2mA	Hor. Vac. 100mmØ

C-ADS: China Accelerator Driven System

-- High Power Proton Linac



Layout of the C-ADS linac



Local compensation

'Hot stand-by'

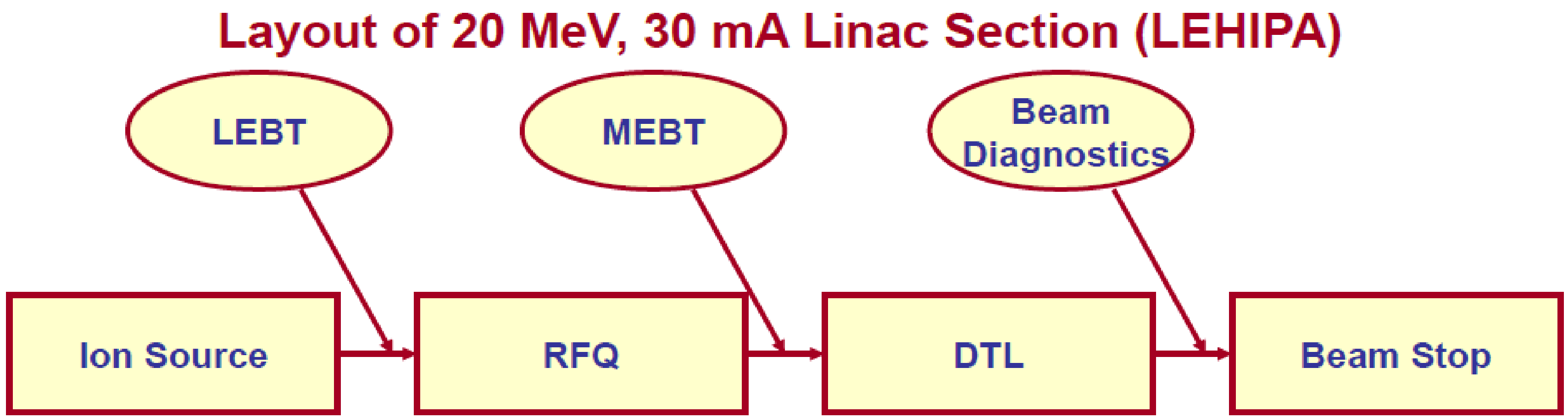
Two injectors are on line, either with injector-1 or with injector-2

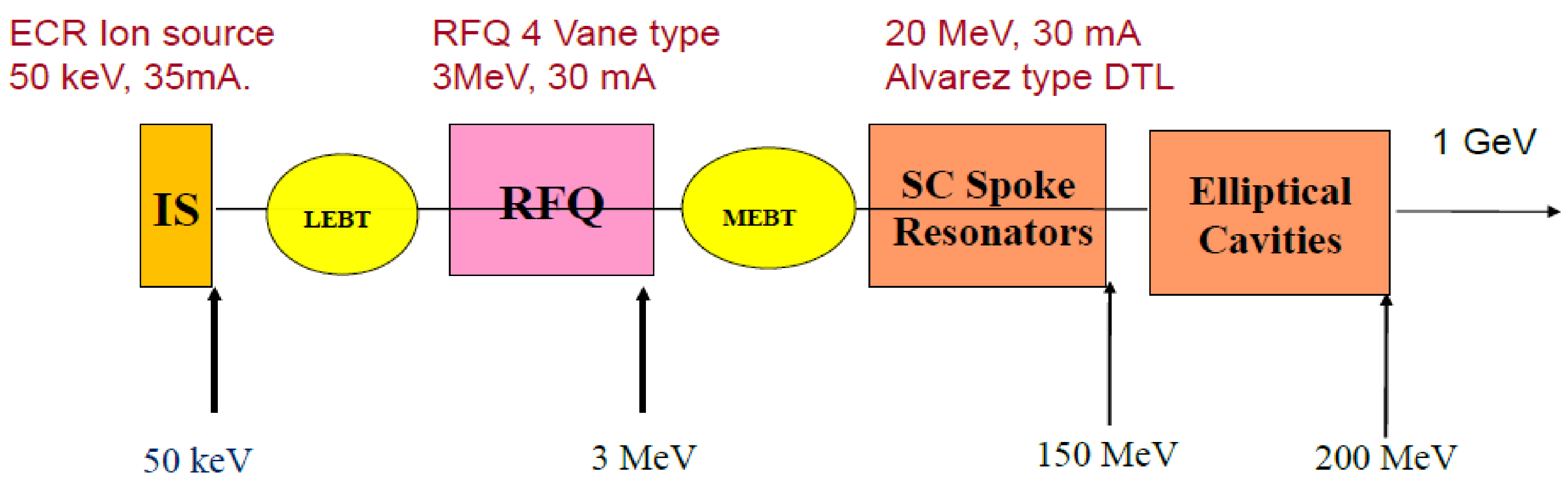
Main specifications of the C-ADS driver linac

Particle	Proton	
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
Frequency	162.5/325/650	MHz
Duty factor	100	%
Beam Loss	<1 (0.3)	W/m
Beam trips/year	<25000 <2500 <25	1s<t<10s 10s<t<5m t>5m

LEHIPA: 200MeV/10-30mA Proton Lianc for ADS

(Bhaba Atomic Research Center, Munbai)





Rare Isotope and Heavy Ion Accelerator Projects

- KoRIA: Korea Rare Isotope Accelerator
- Rare Isotope Accelerator Project
- Heavy Ion Accelerator Facility

KoRIA: Korea Rare Isotope Accelerator

- High intensity RI beams by ISOL & IFF
  - 70kW ISOL from direct fission of ^{238}U induced by 70MeV, 1mA protons → ~MW ISOL upgrade
  - 400kW IF by 200MeV/u, 8pμA ^{238}U

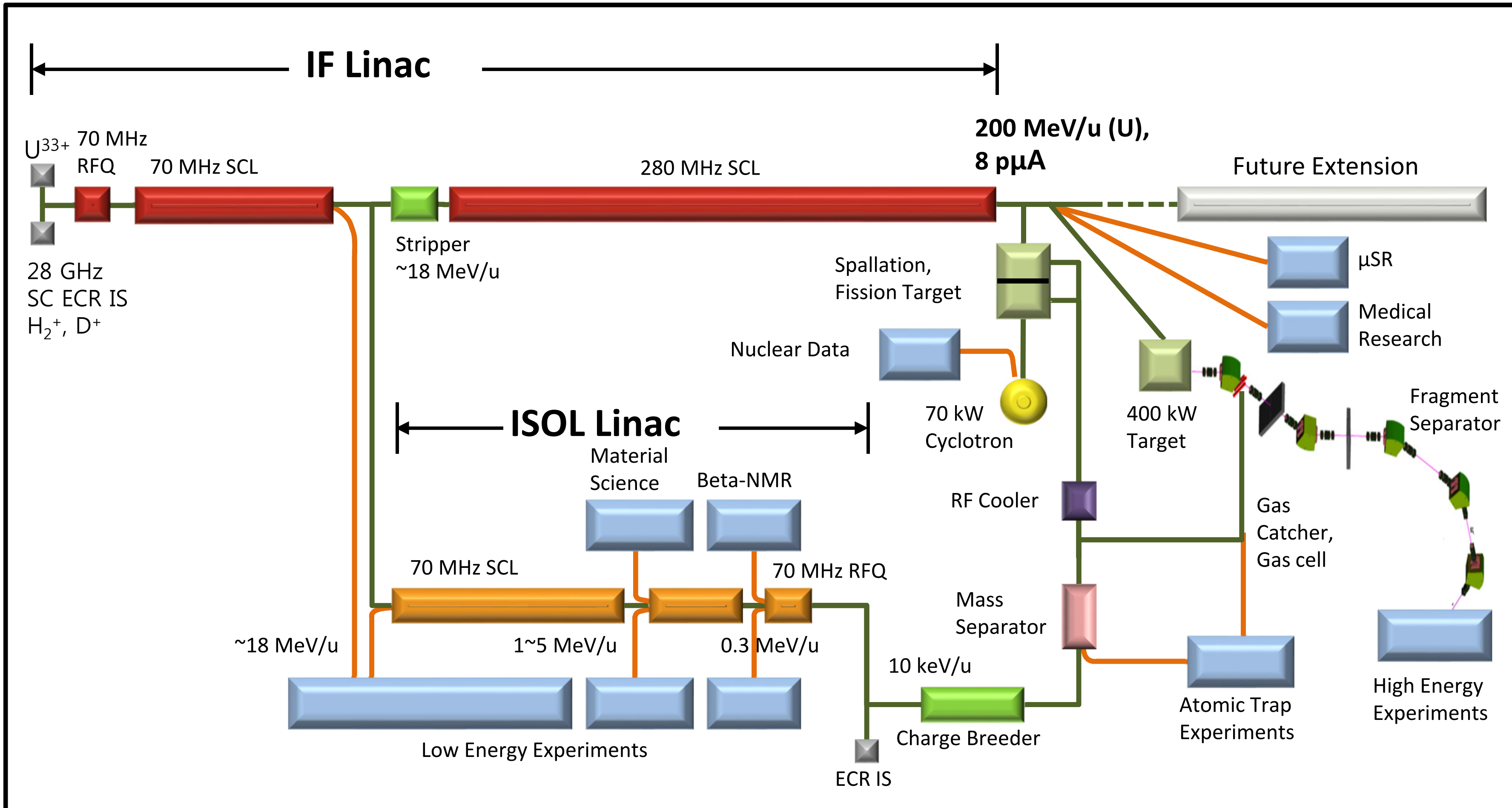
- High energy, high intensity & high quality neutron-rich RI beams
  - ^{132}Sn with ~250MeV/u, up to 9×10^8 pps

- More exotic RI beams by ISOL+IF+ISOL(trap)

- Simultaneous operation of ISOL and IFF for the maximum use of the facility

Schematic Diagram of KoRIA

For the basic and applied science with stable and unstable isotopes



ISOL: Isotope separation on line
IF : In-flight fragmentation

Main Parameters of KoRIA

- Beam species/energy: proton/600 MeV ~ Uranium/200 MeV/u
- Beam power: 400 kW

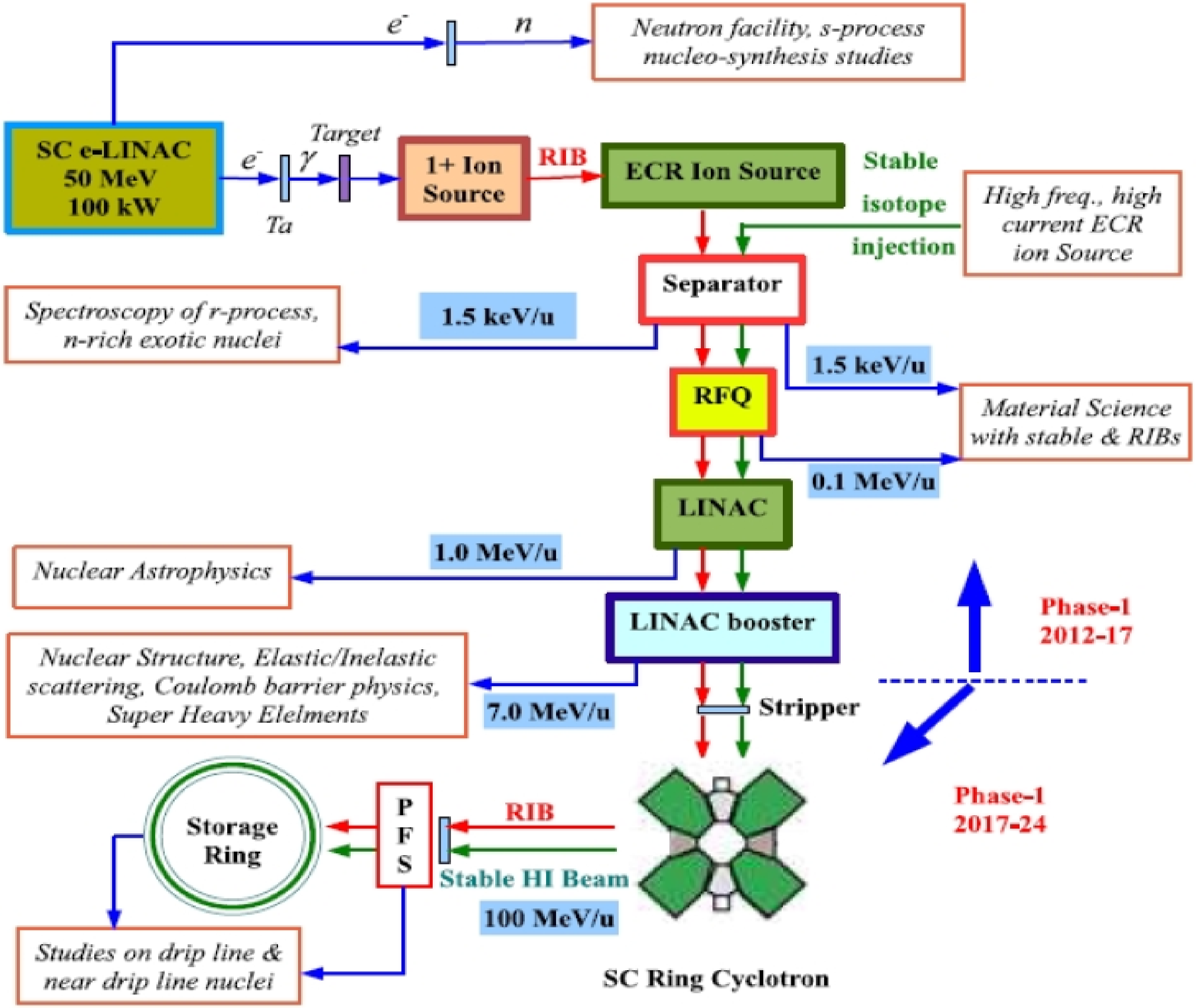
⇨ SC linac with 2-gap cavities (QWR and HWR)
Acceleration with multiple charge states for heavy ions

Beam Specification

Ion Species	Z/ A	SC Linac input			SC Linac output			
		Charge	Current (pμA)	Energy (MeV/u)	Charge	Current (pμA)	Energy (MeV/u)	Power (kW)
Proton	1/1	1	660	0.3	1	660	610	400
Ar	18/40	8	42.1	0.3	18	33.7	300	400
Kr	36/86	14	22.1	0.3	34-36	17.5	265	400
Xe	54/136	18	18.6	0.3	47-51	12.5	235	400
U	92/238	32-34	10.0	0.3	77-81	8.4	200	400

RIB Accelerator Project in India

Variable Energy Cyclotron Centre, Kolkata, RIB Project



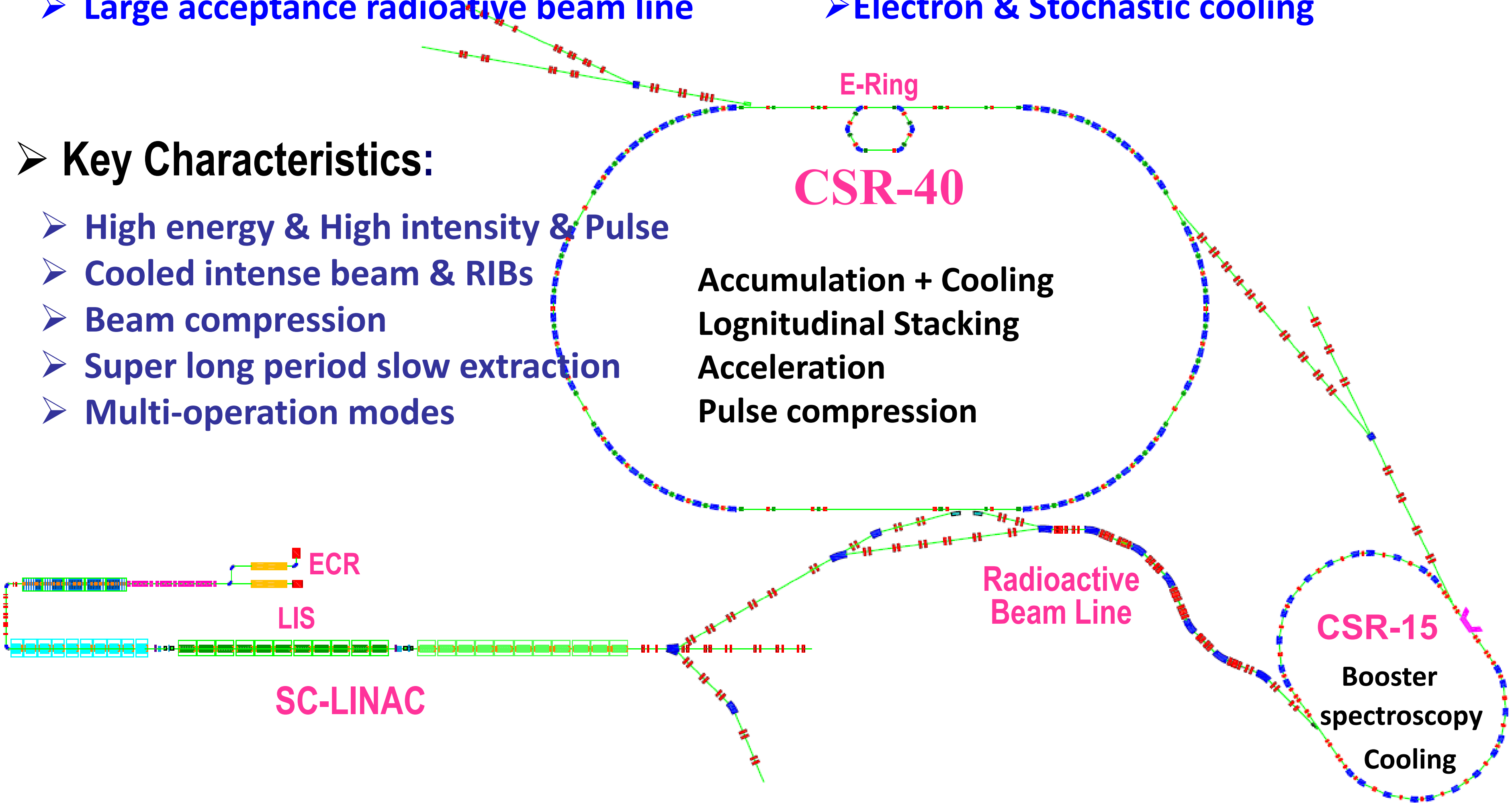
The HIAF Complex

Accelerator Components:

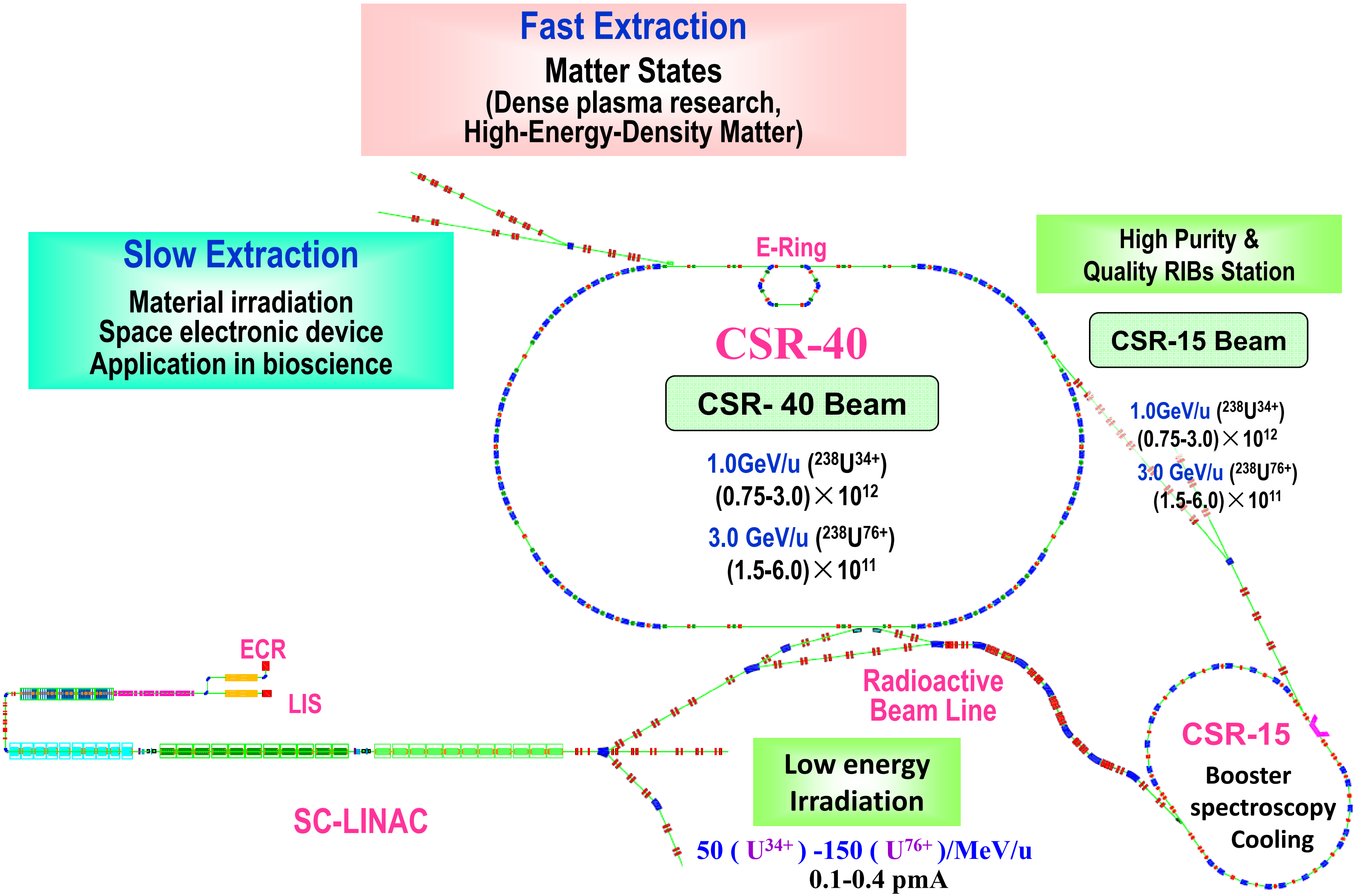
- High intensity ion source
- High intensity pulse SC-Linac
- Large acceptance radioative beam line
- High energy & Intensity synchrotron
- Multi-function circular spectroscopy
- Electron & Stochastic cooling

Key Characteristics:

- High energy & High intensity & Pulse
- Cooled intense beam & RIBs
- Beam compression
- Super long period slow extraction
- Multi-operation modes



Experiment Terminals of HIAF



Main Parameters of HIAF

	CSR-40	CSR-20 (Booster)
Circumference (m)	~800	~250
Energy	3.0GeV/u for $^{238}U^{76+}$ 5.0GeV/u for $^{12}C^{6+}$	1.0 GeV/u
Max. Rigidity (T.m)	40	20
Function	Accumulation + Cooling Longitudinal RF Stacking Acceleration Pulse compression Electron + Stochastic cooling	Acceleration Spectroscopy Cooling
Experiment type	Matter states Dense plasma research High Energy Density Matter Material irradiation Space electronic device	High Purity & Quality RIBs Station

Summary

- More than 20 accelerator projects are planned and constructed in Asia, including light source, proton, rare isotope and heavy ion accelerator facilities;
- Superconducting accelerator technology is widely used in these future accelerator projects;
- Local government supports help greatly the project getting approval and funding.

Acknowledgement

Many thanks to B. C. Jiang, S.I.Kurokawa, W.M. Li, L. Ma, W. Namkung, K.Oide, H.Okuma, W.M. Pan, Q.Qin, A.Roy, H.P. Yan, H.W. Zhao, W.Z. Zhang and many other colleagues for their valuable helps and information.

I cannot make an exhausted survey of the accelerator projects in Asia in a short time, and I may miss some projects due to my limited information and knowledge.

Thank you for your attention!