Perspective of SPring-8/SACLA complex

1. SPring-8's Strategy for Light-Source Upgrade
2. Current Status of SACLA
3. Current Status of SPring-8 Upgrade

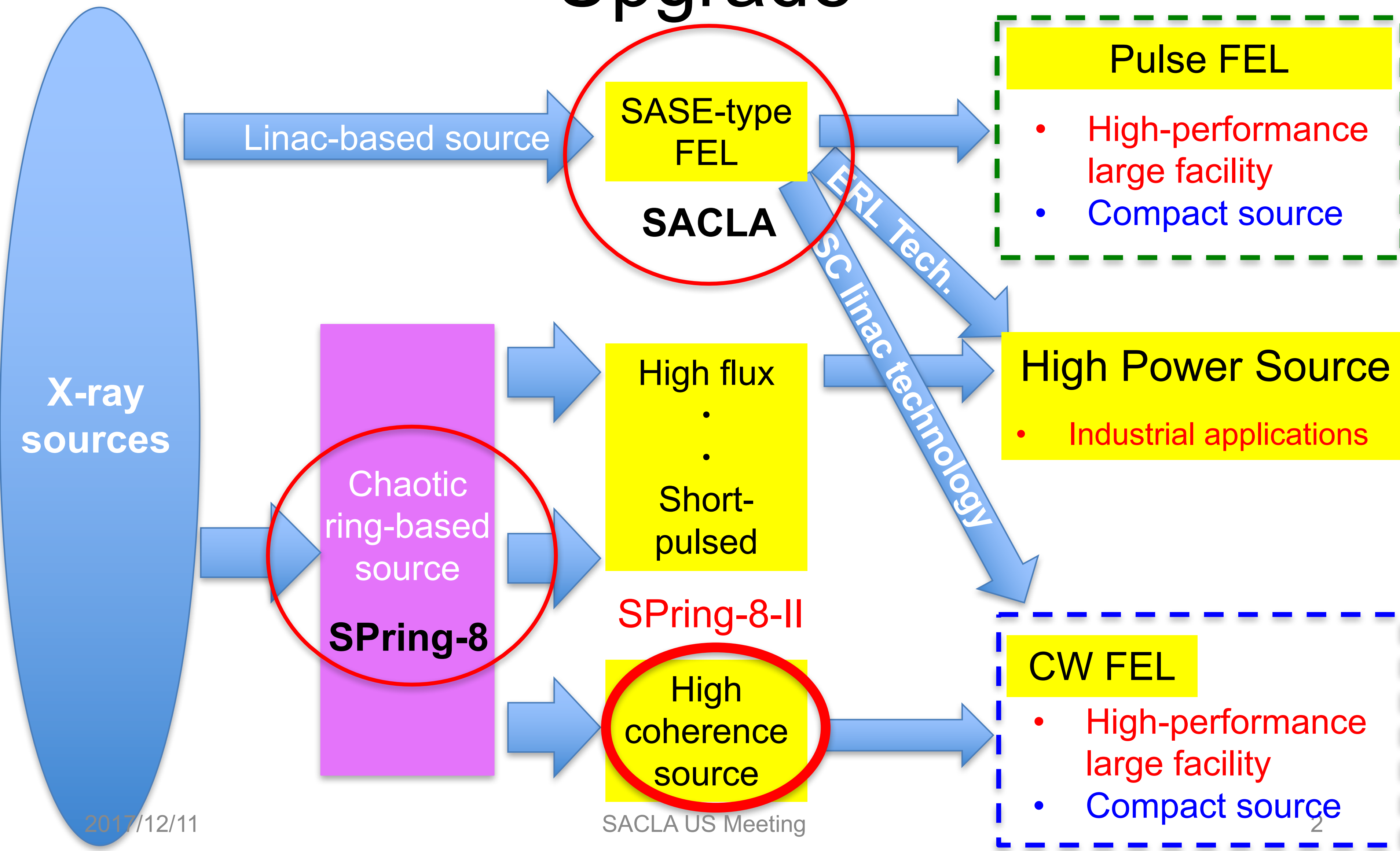
RIKEN SPring-8 Center

XFEL Research & Development Division

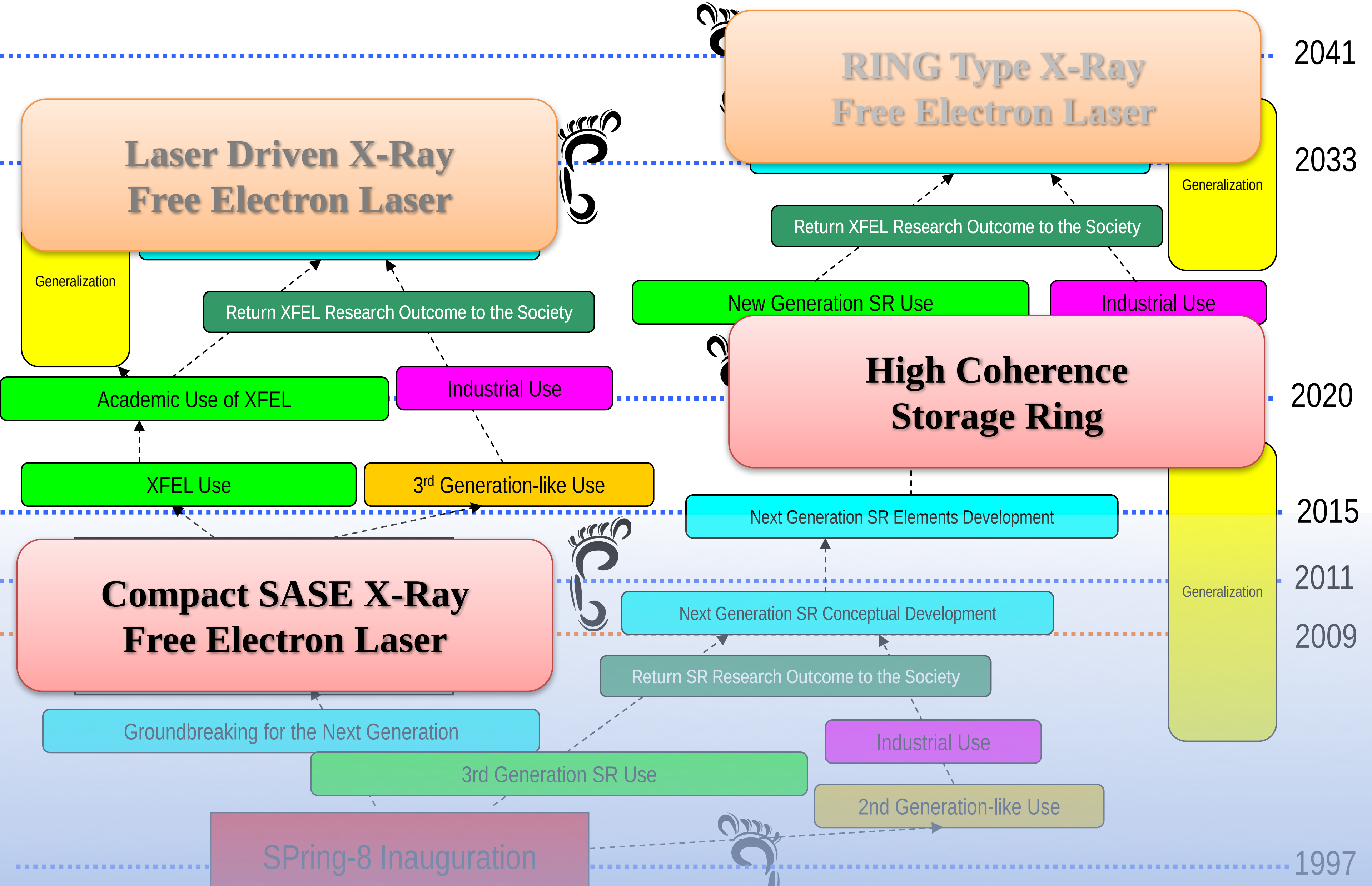
Diffraction Limited SR Source Design Group

Hitoshi Tanaka

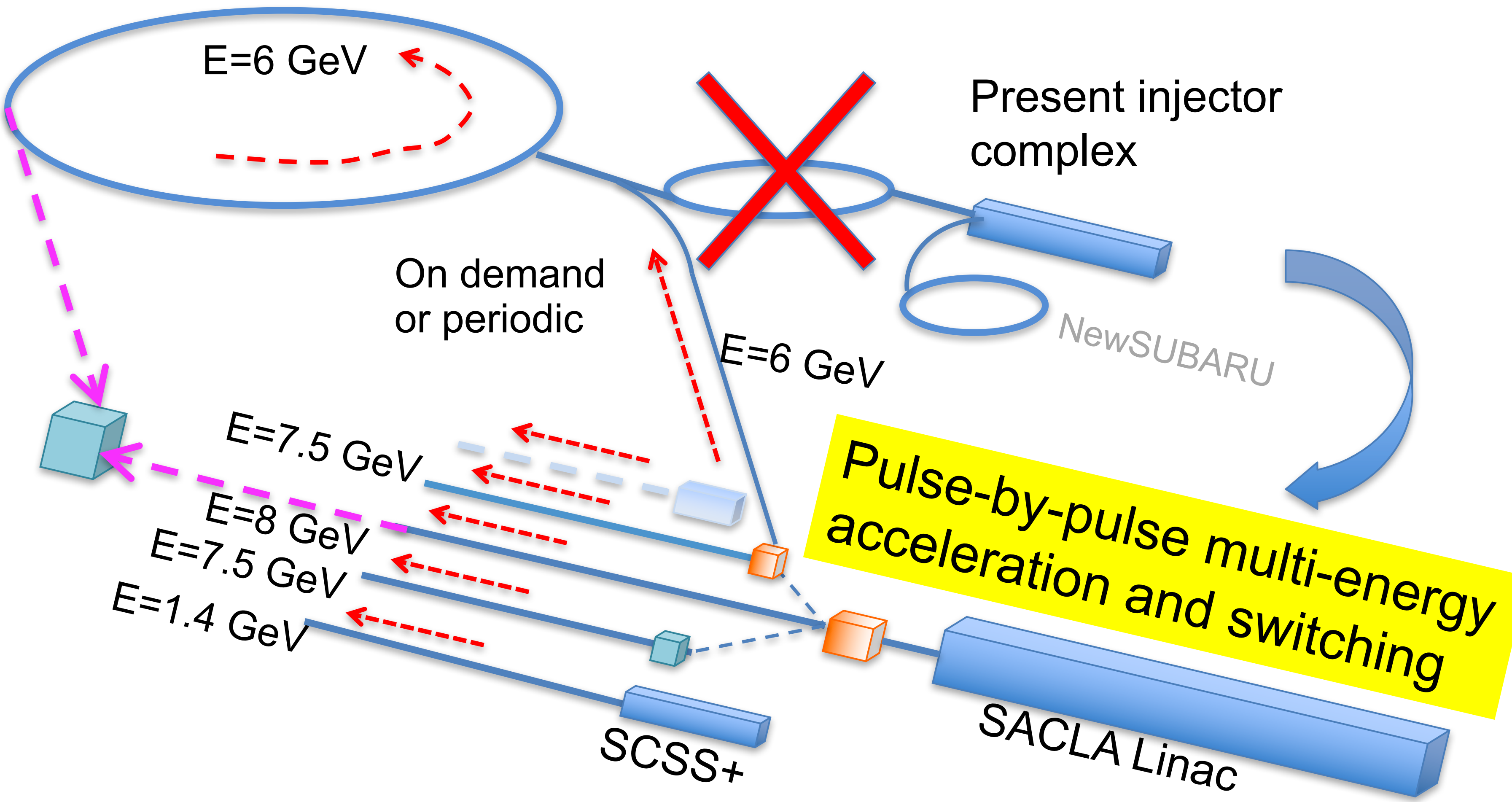
SPring-8's Strategy for Light-Source Upgrade



SPring-8's Strategy for Light-Source Upgrade

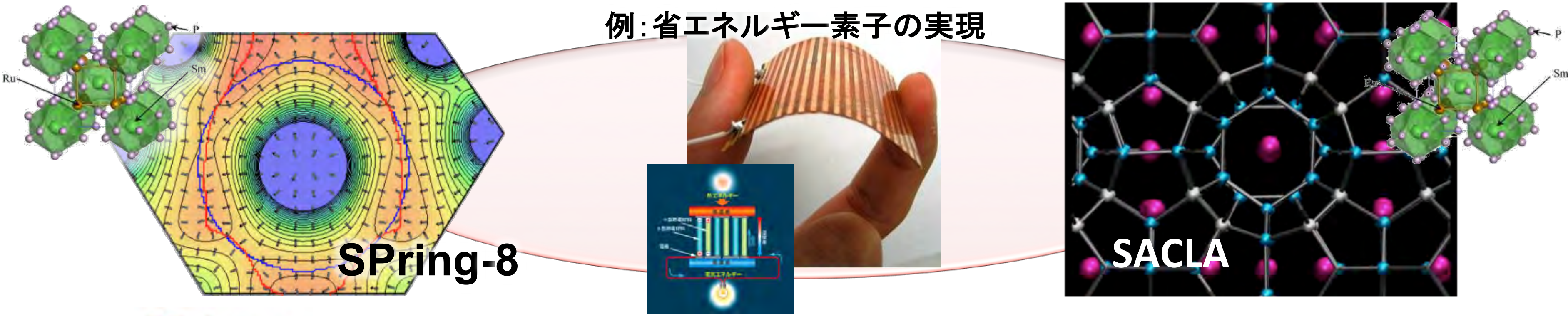


Mid-Term System Integration at SPring-8



Understanding functions with atomic resolution

SPring-8+SACLA enables to bridge an information gap between a <u>macroscopic slow phenomenon of the system</u> and <u>Microscopic ultrafast changes of atoms and molecules</u>



Upgrading both SPring-8 & SACLA has been extending capability of whole the facility.

<u>Rational role-sharing is critically important</u>

1. SPring-8's Strategy for Light-Source Upgrade

2. Current Status of Status

3. Current Status of SPring-8 Upgrade

Concept of SACLA

High performance compact XFEL source with moderate Construction/operation cost, based on Japanese Technologies

Lower Beam Energy

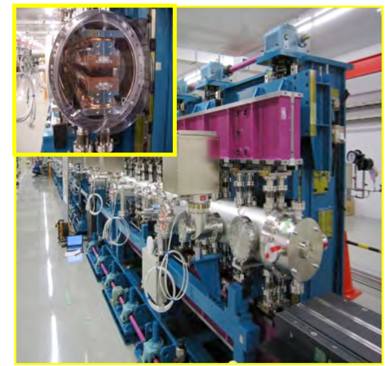
Size Reduction

\+

Efficient Acceleration

Further Size Reduction

Smaller Normalized Beam Emittance

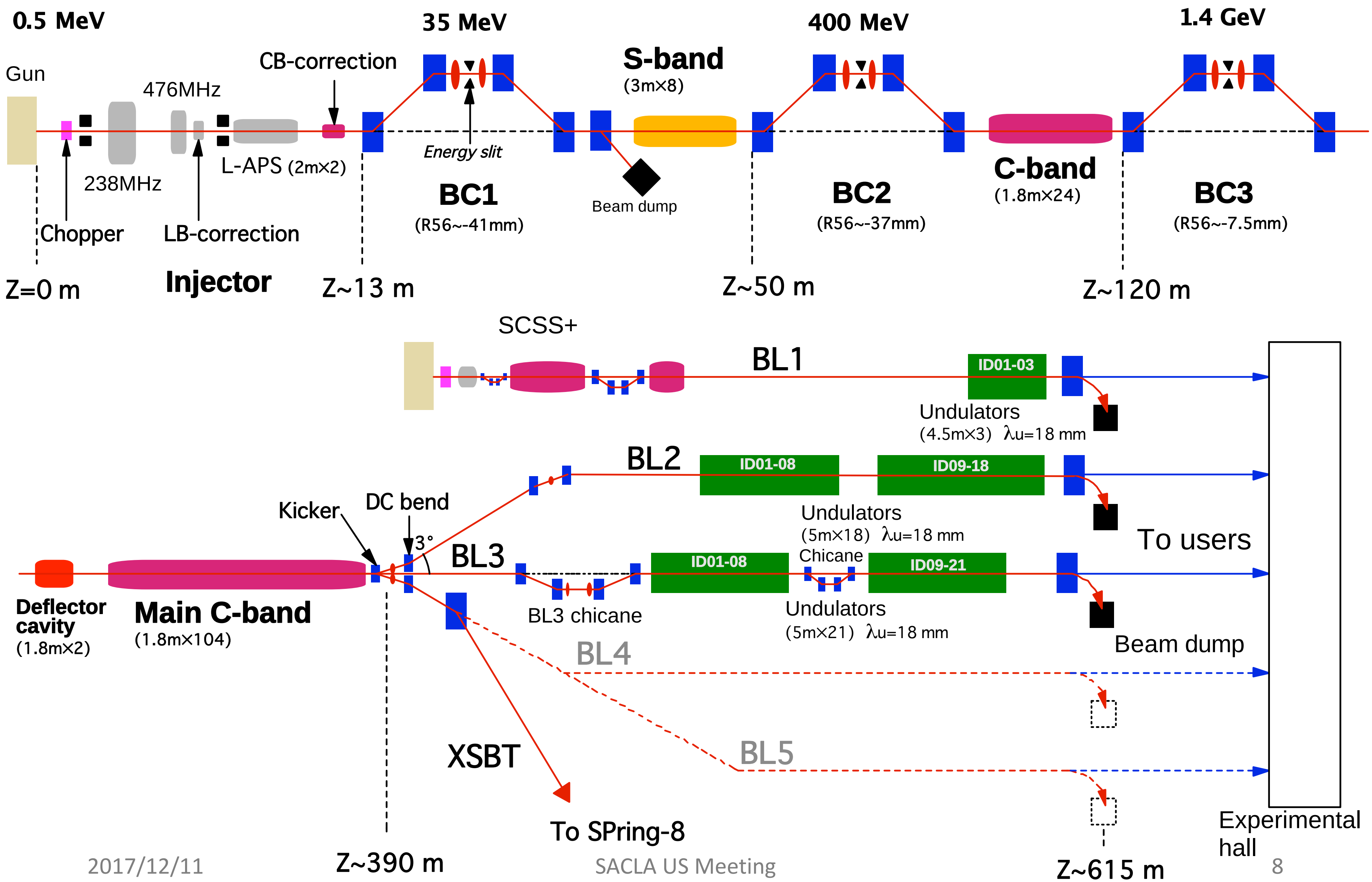


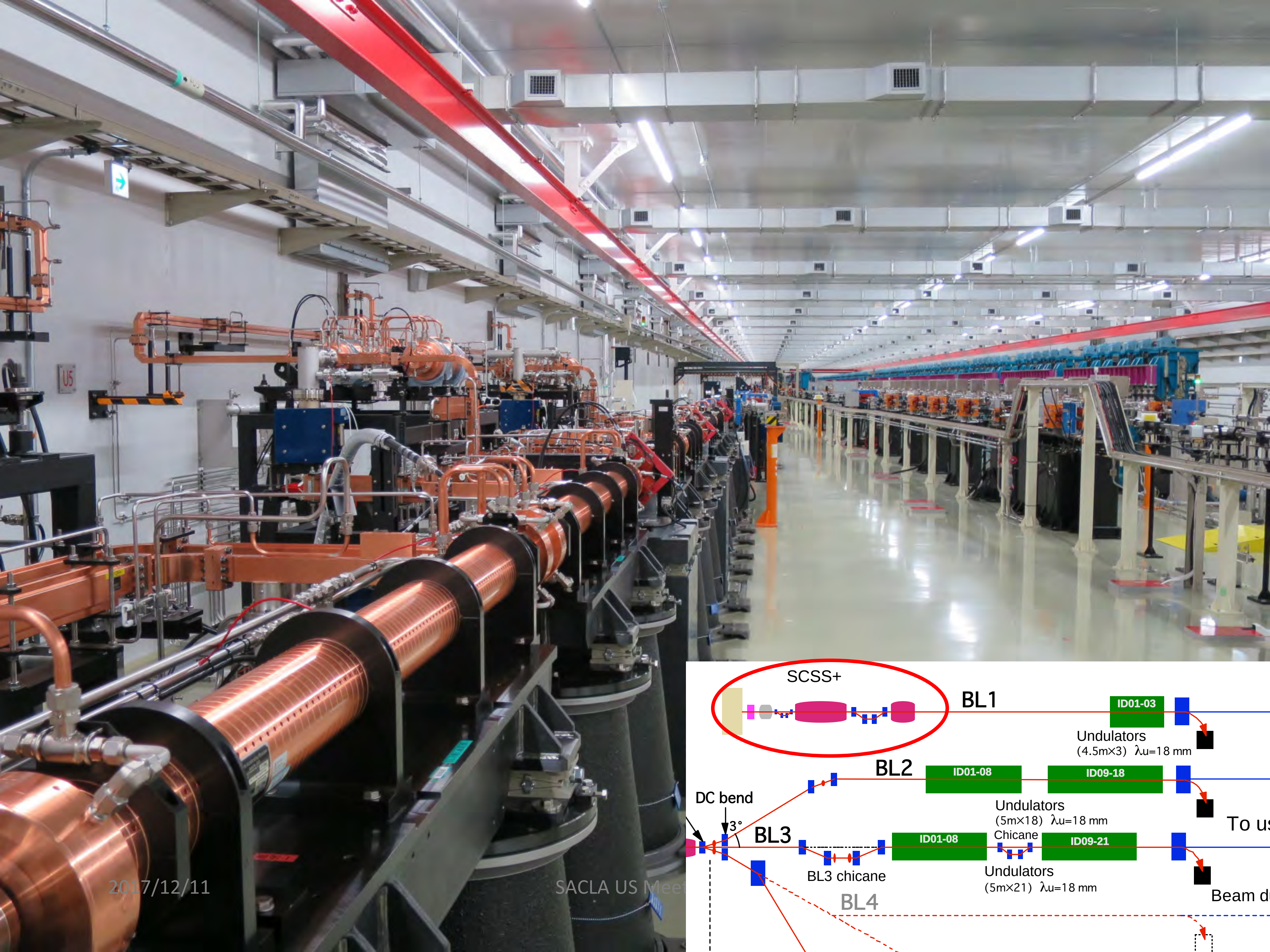
Short period in-vacuum undulator

C-band high gradient acceleration system

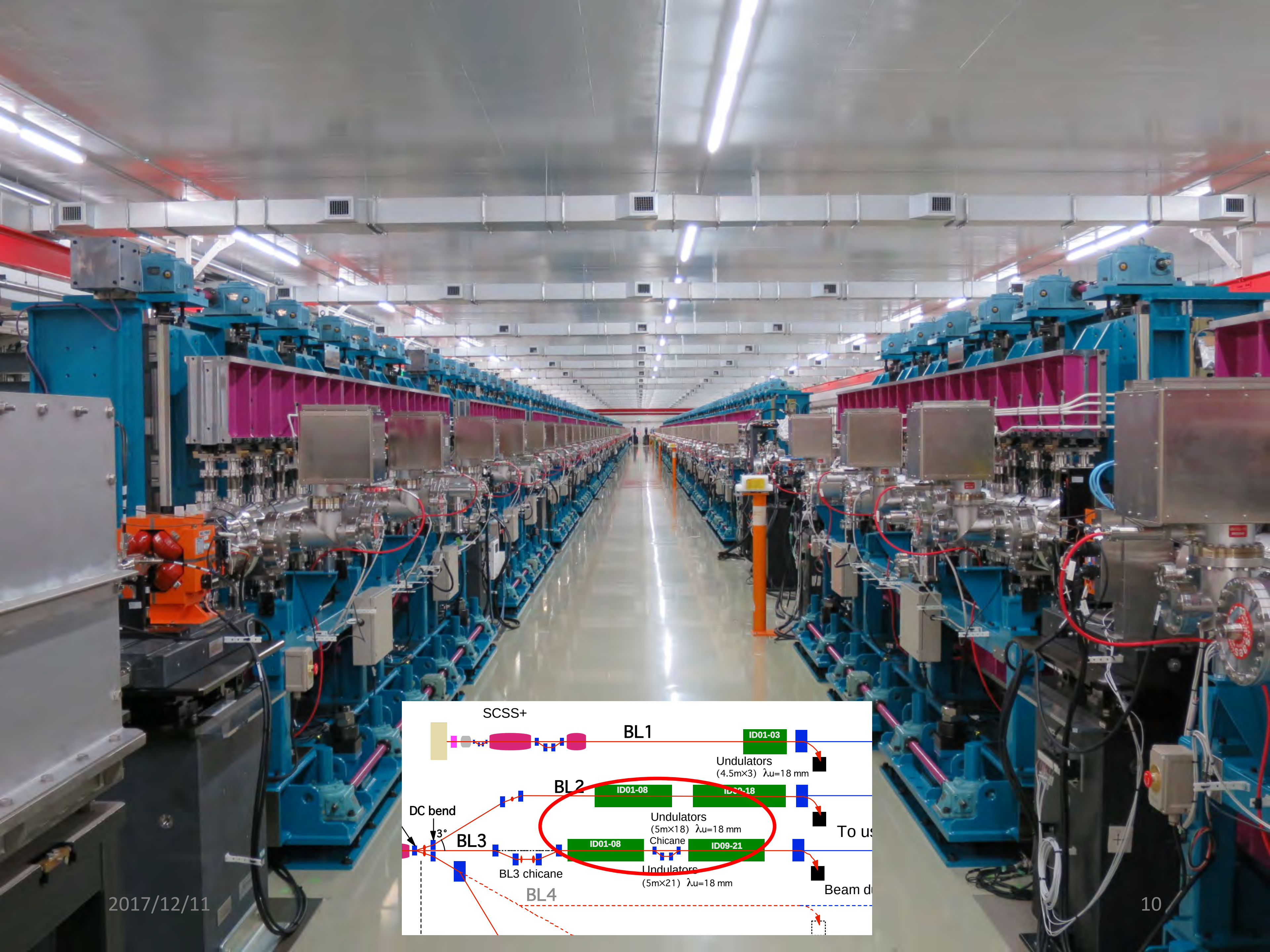
Themionic gun based low emittance injector

2 XFEL and 1 SXFEL Beamlines Now Available





SCSS+
BL1
ID01-03
Undulators
(4.5m×3) λu=18 mm
BL2
ID01-08
ID09-18
Undulators
(5m×18) λu=18 mm
DC bend
3°
BL3
Chicane
ID01-08
ID09-21
BL3 chicane
Undulators
(5m×21) λu=18 mm
BL4


SCSS+
BL1
ID01-03
Undulators
(4.5m×3) λu=18 mm
BL2
ID01-08
Undulators
(5m×18) λu=18 mm
DC bend
3°
BL3
ID01-08
Chicane
ID09-21
BL3 chicane
(5m×21) λu=18 mm
BL4

Current Laser Performance

	BL3	BL2	BL1
Max. Electron Energy (GeV)	8	8	0. 8
Number of Undulators	21	18	3
Photon Energy (keV)	4~15	4~12	0.02~0.1
Intensity (mJ/pulse)	0.4~0.7	0.4~0.5	~0.1
Peak Power P (GW)	P > 30	P < 30	
Repetition (Hz)	Max. 60	Max. 60	Max. 60
Pulse Width (fs; FWHM)	<< 10	<< 10	
Stability Intensity $s_{dI/I}$ (%) Pointing s_{dz}/z(FWHM) (%) Wavelength s_{dl}/Dl(FWHM) (%)	 ≤ 10 3 ~ 7 0.1	 ≤ 10 3 ~ 7 0.1	 10~20 - 0.3
Two Color SASE	Available	not yet	not yet

Operation Statistics

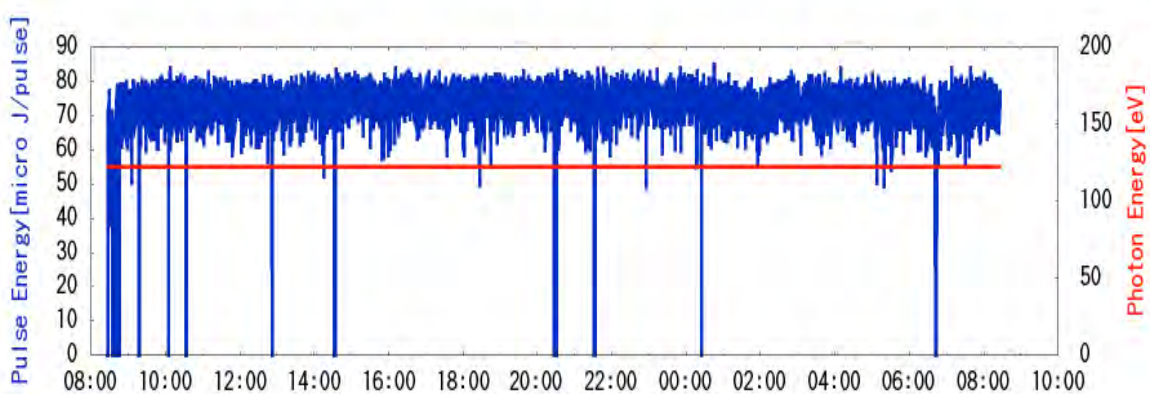
Item	FY2012	FY2013	FY2014
Operation Time (hr)	7016	7017	6258
User Time (hr)	3152	3459	3600
Laser Availability (%)	92.3	92.7	93.4
Item	**FY2015**	**FY2016**	**FY2017**
Operation Time (hr)	6483	5934	-
User Time (hr)	3924	4026*	-
Laser Availability (%)	96.1	96.7	-

*BL1 user time included

BL1 SXFEL Intensity Trend

2017/11/29	SACLA Operation Status	08:26:20

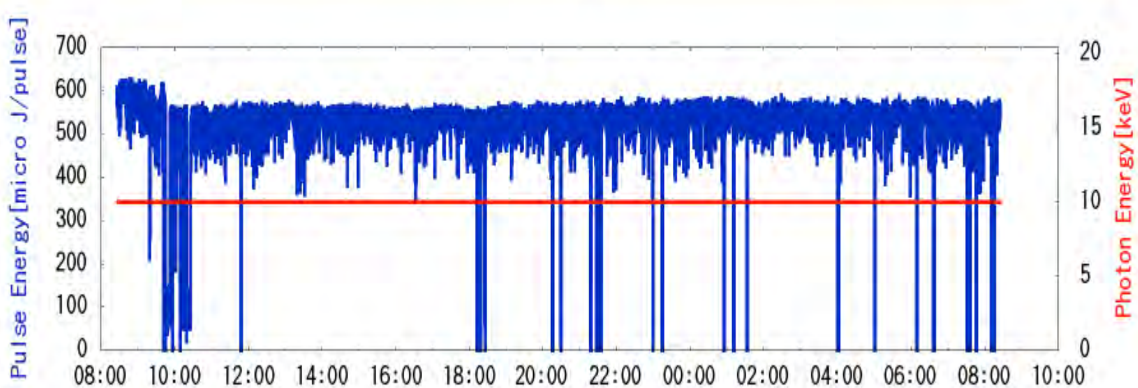
Operation Mode	
BL1 Study	
Hutch in Use	
BL1 EH4a	
Pulse Energy	Photon Energy / Wavelength
72.2 micro J/pulse	122.3 eV / 10.1 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
60 Hz	19.2 %



BL2 XFEL Intensity Trend

2017/11/29	SACLA Operation Status	08:25:40

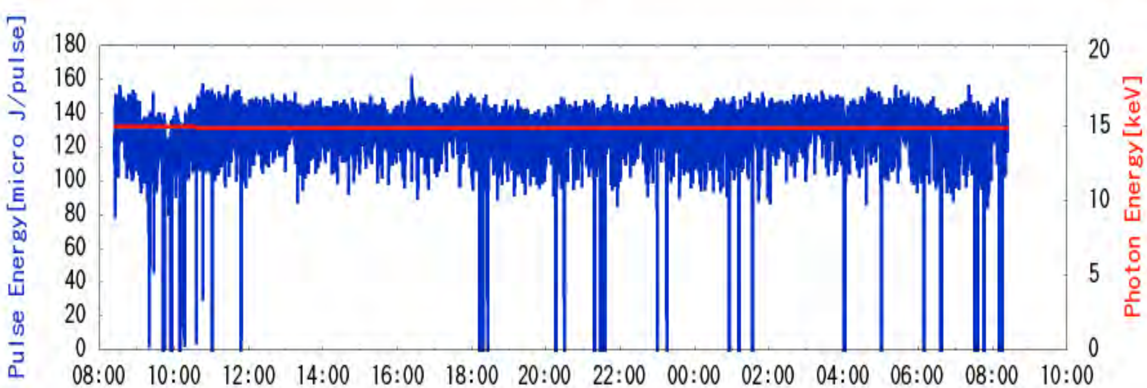
Operation Mode	
BL2 User Operation	
Hutch in Use	
BL2 EH3,4b	
Pulse Energy	Photon Energy / Wavelength
568.3 micro J/pulse	10.0 keV / 0.124 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	7.6 %



BL3 XFEL Intensity Trend

2017/11/29	SACLA Operation Status	08:24:30

Operation Mode	
BL3 User Operation	
Hutch in Use	
BL3 EH4	
Pulse Energy	Photon Energy / Wavelength
133.5 micro J/pulse	14.9 keV / 0.083 nm
Repetition Rate	Intensity Fluctuation in 30 shots (STD)
30 Hz	17.0 %

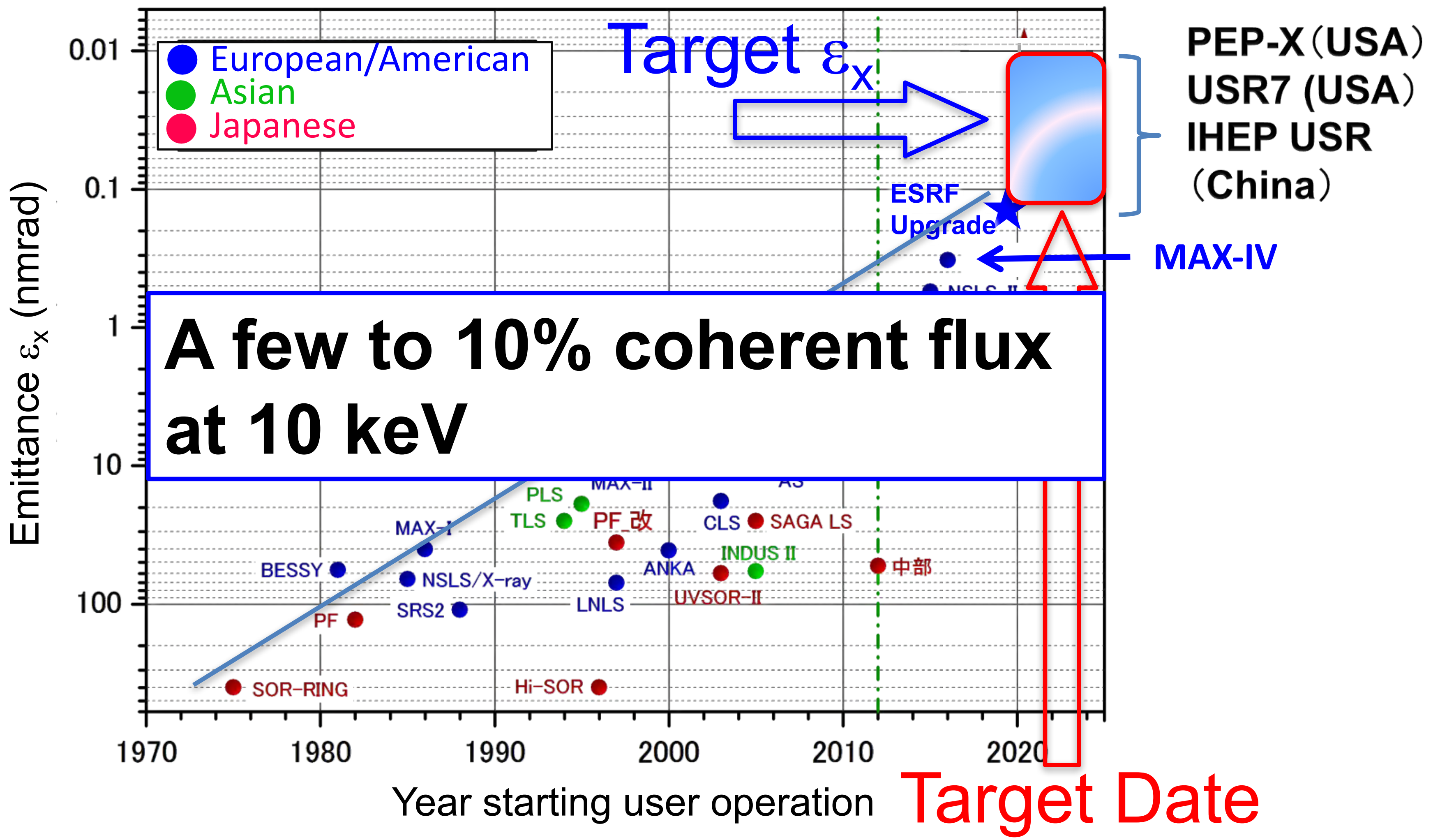


Short and Mid-Term Upgrade Targets

- To establish stable and easily reproducible "self-seeding" scheme
- To improve SASE-XFEL performance by using e.g., "harmonic lasing"
- To construct BL4, third XFEL beamline
- To increase a XFEL repetition rate from 60 to 120 pps until 3 XFEL beamlines are available

1. SPring-8’s Strategy for Light-Source Upgrade
2. SACLA Status
3. Progress on SPring-8 Upgrade

Target Beam Performance

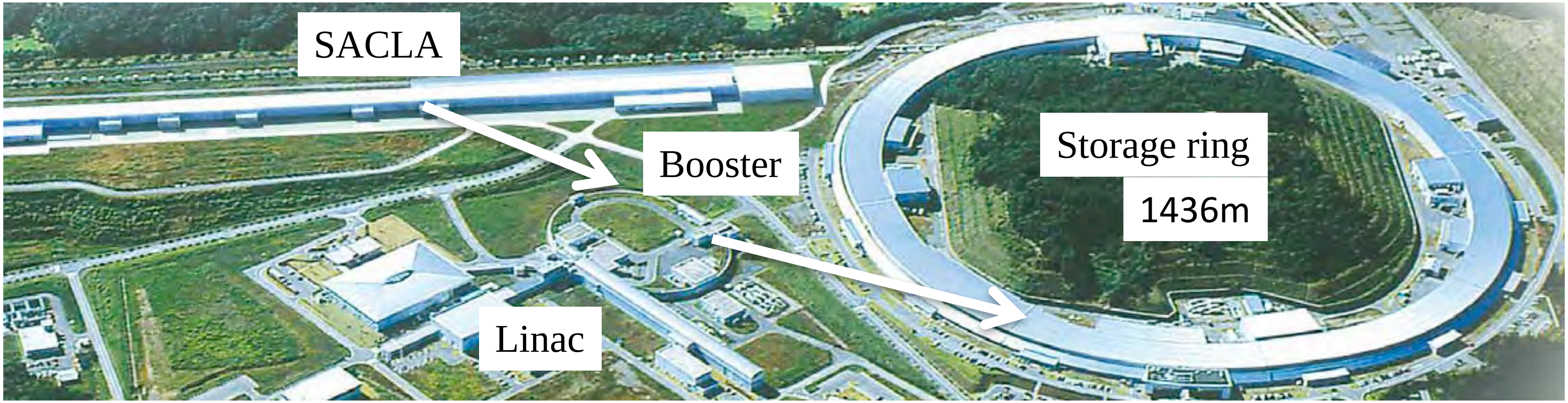


Condition, Consideration, Strategy

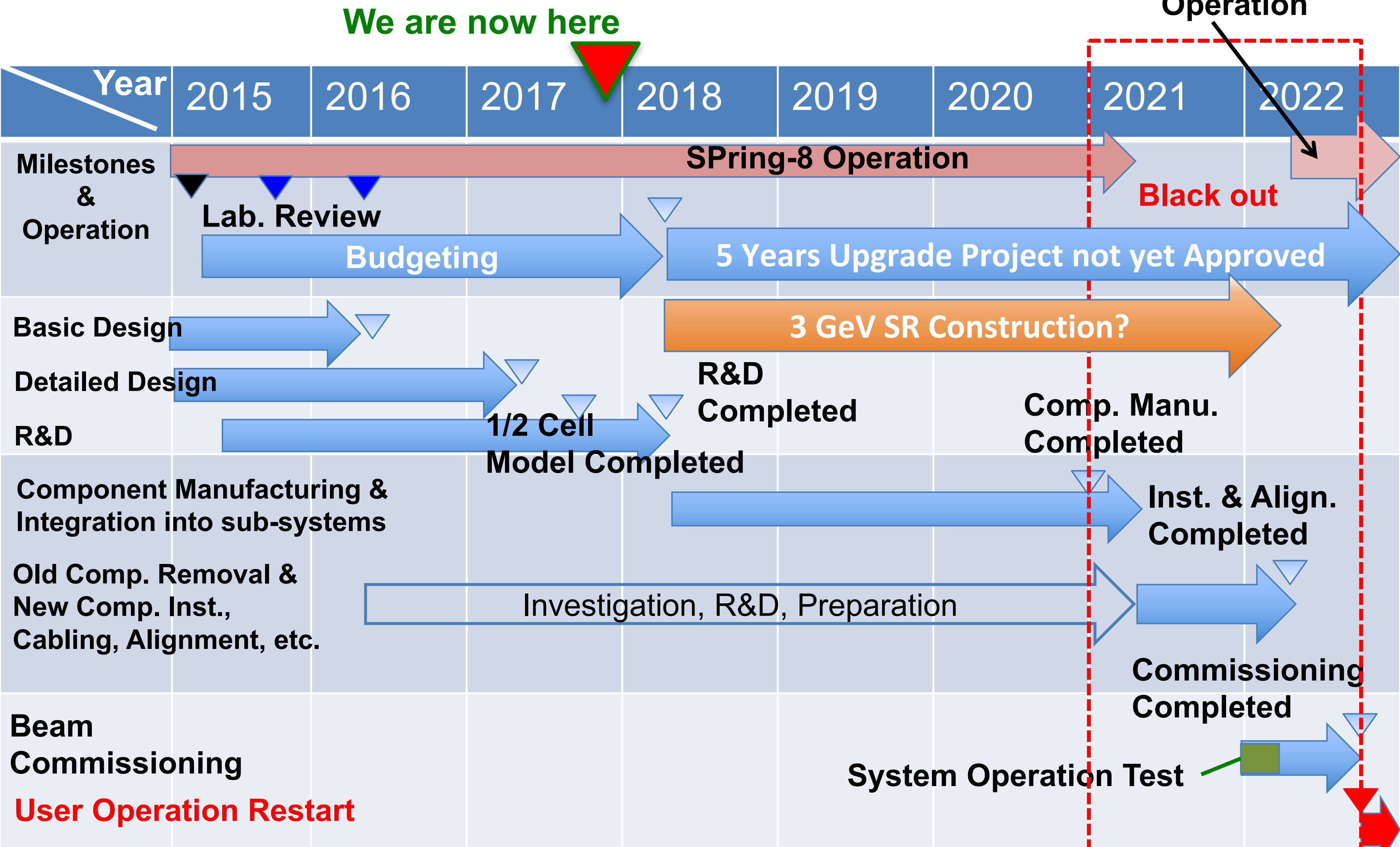
- Approx. one-year shutdown in early 2020's (not yet fixed) → Shutdown procedure should be well considered
- Replace existing ring
- ID position fixed

→ Same circumference
Same cell length

- Take full advantage of existing resources (including human resources) → Low emittance e-beam injection from SACLA
- Better performance, less energy → 6 GeV
Permanent magnet
- Important: stability, reliability



Time Schedule Predicted



Less than 2 years from the shutdown to the restart of the user operation

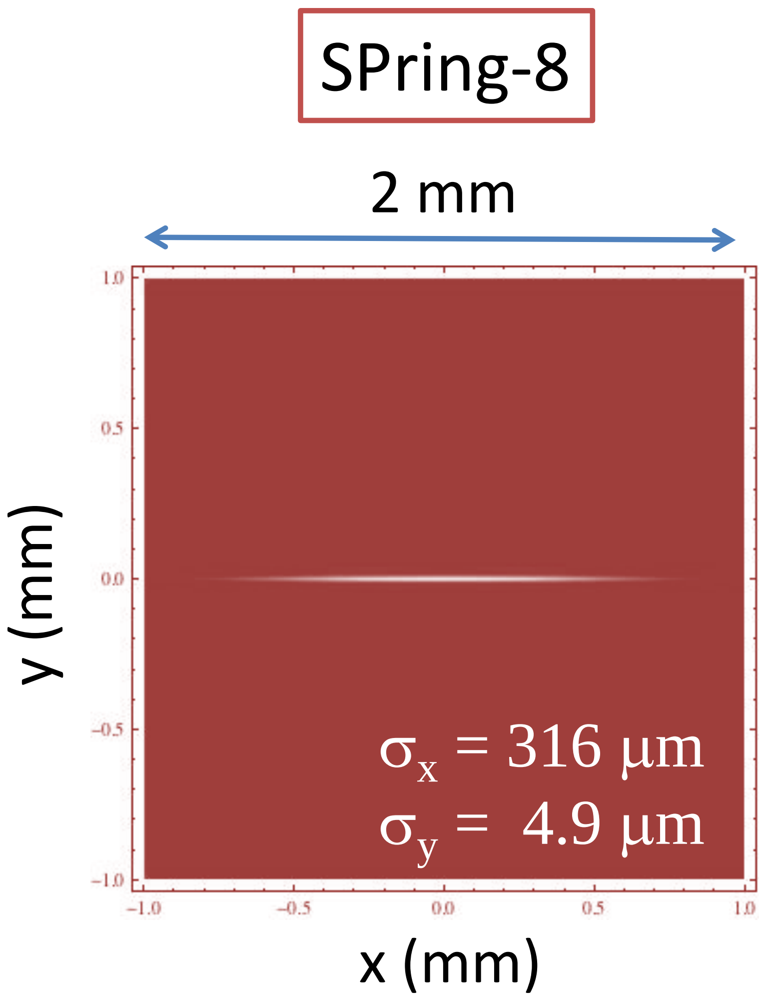
Ring Design Parameter (Preliminary)

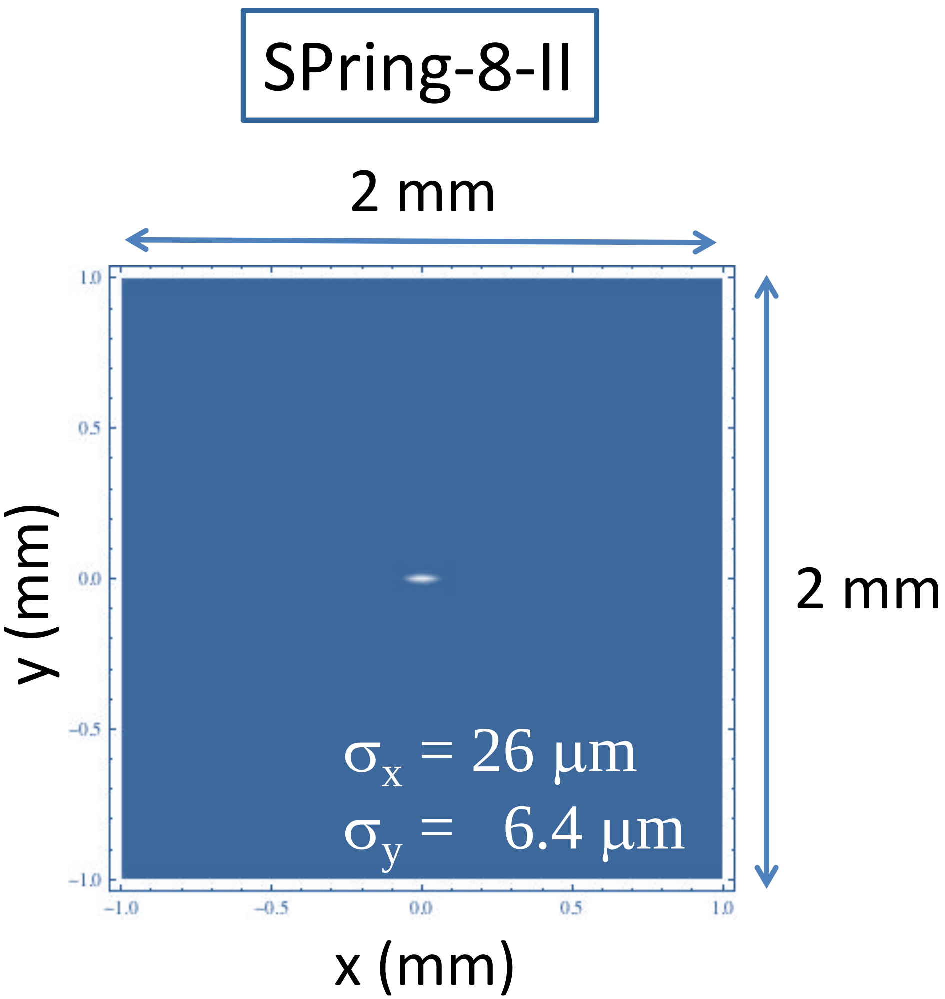
	New Optics	Present Optics
Energy (GeV)	**6**	**8**
Circumference (m)	**1435.4**	**1436.0**
Unit cell structure	**5 BMs**	**2 BMs**
Ring structure	**2 Inj + 42 Unit + 4 Str Cells**	**44 Unit + 4 Str Cells**
Length of ID straight (m)	**4.684**	**6.65**
Natural emittance (nmrad)	**0.15 (Achro, w/o und)** **~0.10 (Achro, w und)**	**2.4 (NA)** **6.7 (Achro)**
Coupling ratio (%)	**10**	**0.2**
Tune (ν_x, ν_y)	**(109.14, 42.34)**	**(41.14, 19.35)**
Natural chromaticity (ξ_x, ξ_y)	**(-154, -142)**	**(-117, -47)**
Momentum compaction α_0	**3.26×10^{-5}**	**1.59×10^{-4}**
Beam lifetime (hr)	**~10**	**10~100**
Stored current (mA)	**200**	**100**

Ring Design Parameter (Preliminary)

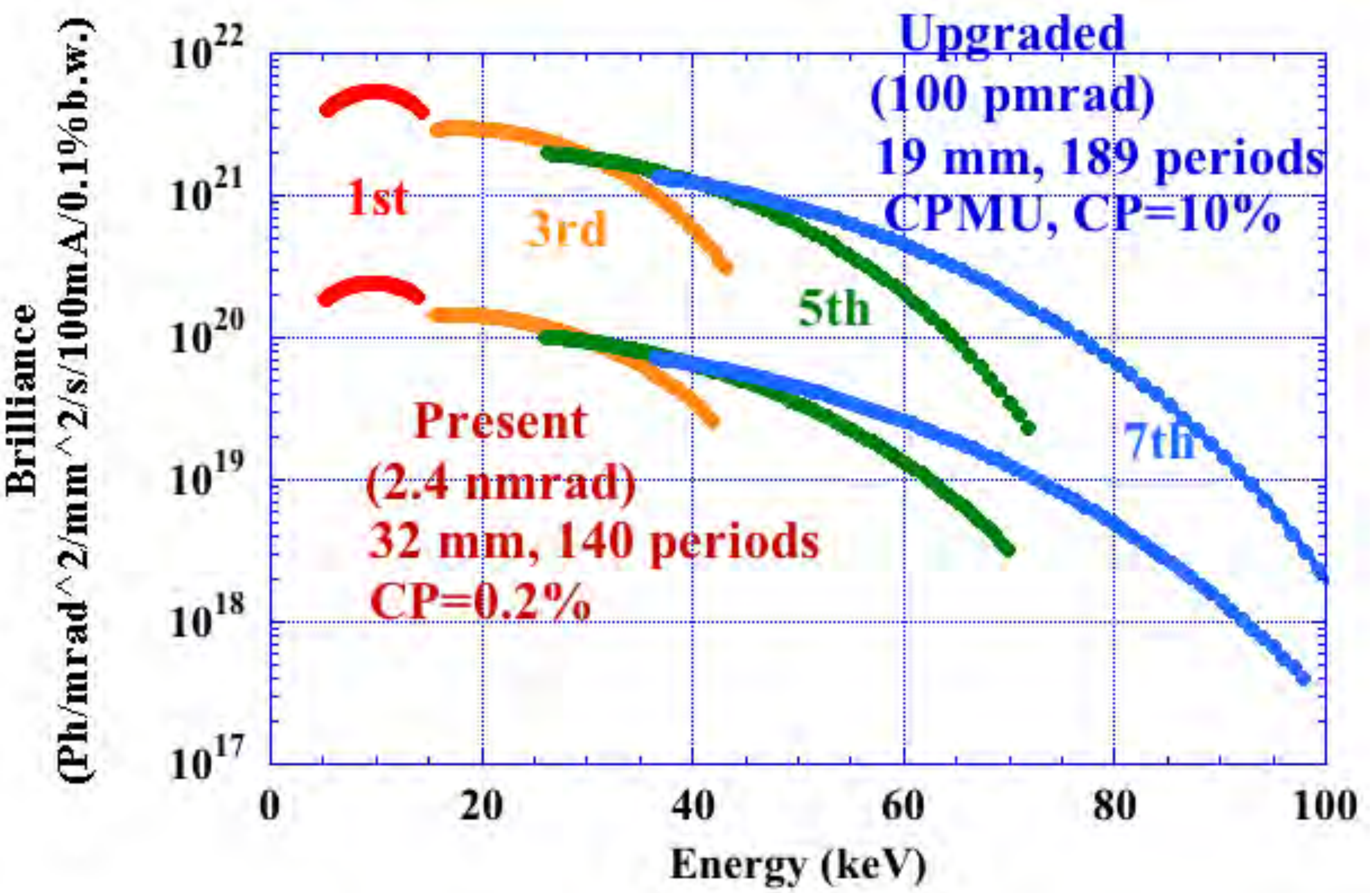
	New Optics	Present Optics
ID straight		
β Function @ID (β_x, β_y) (m)	**(5.5, 3.0)**	**(31.2, 5.0)**
Dispersion η_x @ID (m)	**0.0**	**0.146**
Beam sizes @ID (σ_x, σ_y) (μm)	**(26.0, 5.6)**	**(316, 4.9)**
Angular div. @ID ($\sigma_{x'}$, $\sigma_{y'}$) (μrad)	**(4.4, 1.86)**	**(8.8, 1.0)**
Bending magnet BM1		
Critical photon energy (keV)	**13.9**	**28.9**
β Function (β_x, β_y) (m)	**(1.8, 14)**	**(2.9, 28)**
Dispersion η_x (m)	**0.00016**	**0.039**
Bending magnet BM2		
Critical photon energy (keV)	**22.8**	**28.9**
β Function (β_x, β_y) (m)	**(0.9, 1.9)**	**(2.4, 31)**
Dispersion η_x (m)	**0.0016**	**0.059**

Source Size at Undulators





Undulator Radiation Spectra

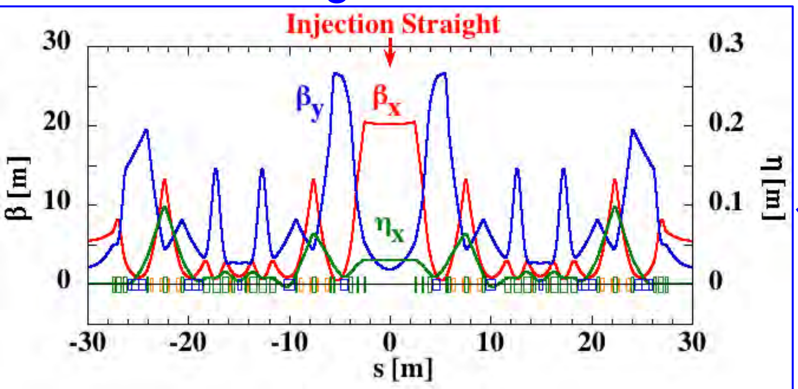


Challenge in Electron Optics

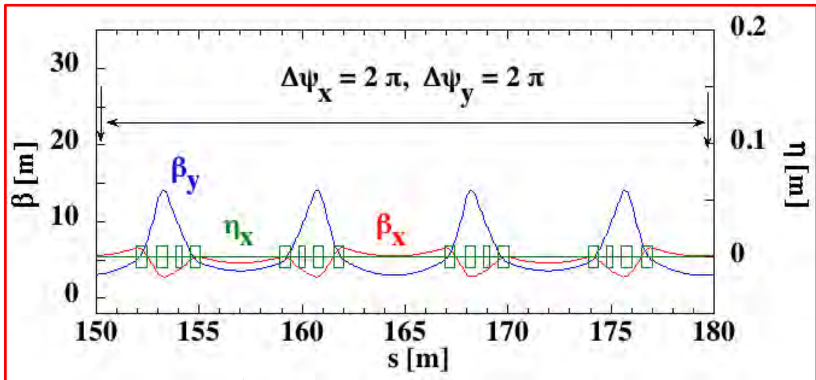
- Small beta-functions at dispersion-free ST for IDs
- No-symmetric optics with a special beam injection section
- Multi-Bend Achromat (5BA) design matched to a limited space
- Non-linearity optimization to assure stable beam injections and storage

Optics and Ring Structure

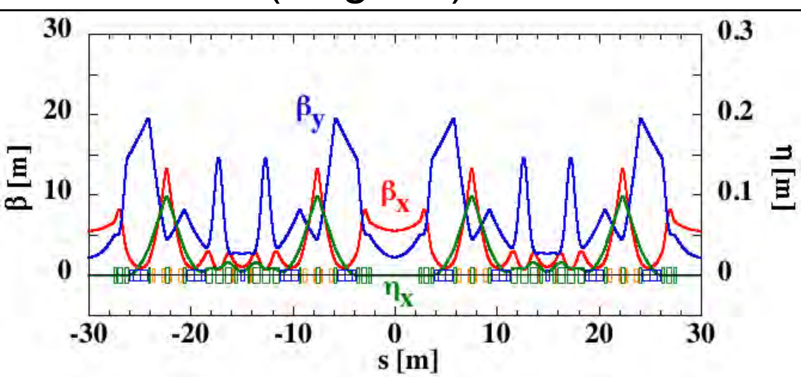
Matching Cells with IP

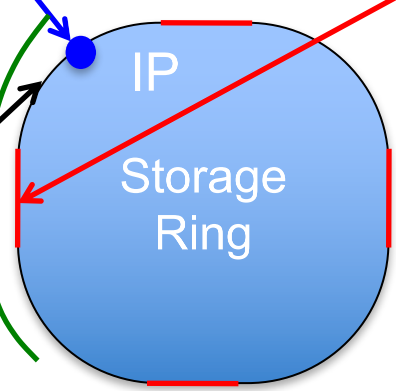


Long Straight Cell (LSS)

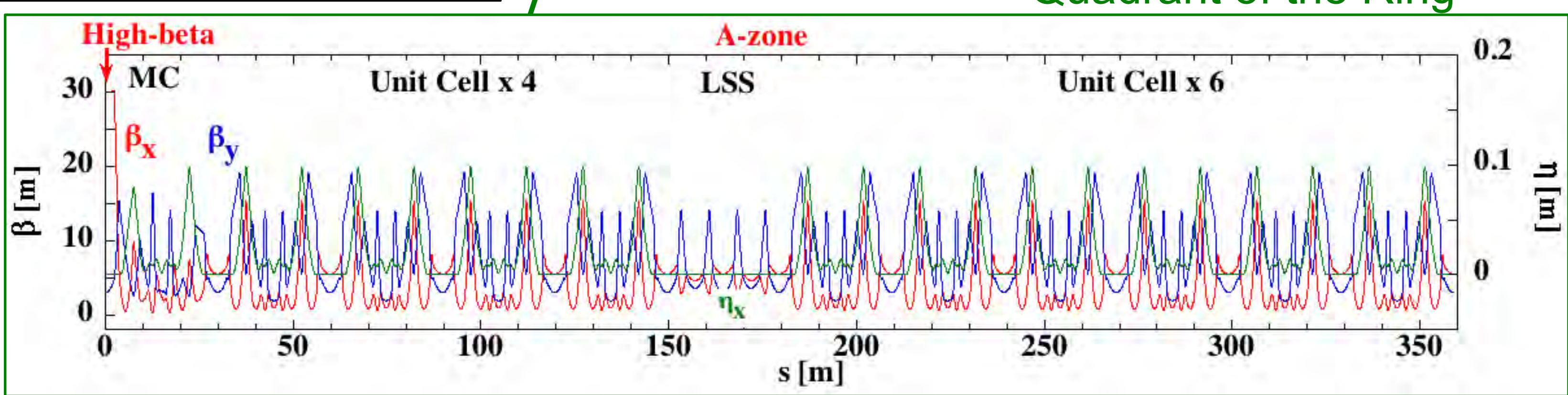


Unit (Regular) Cell





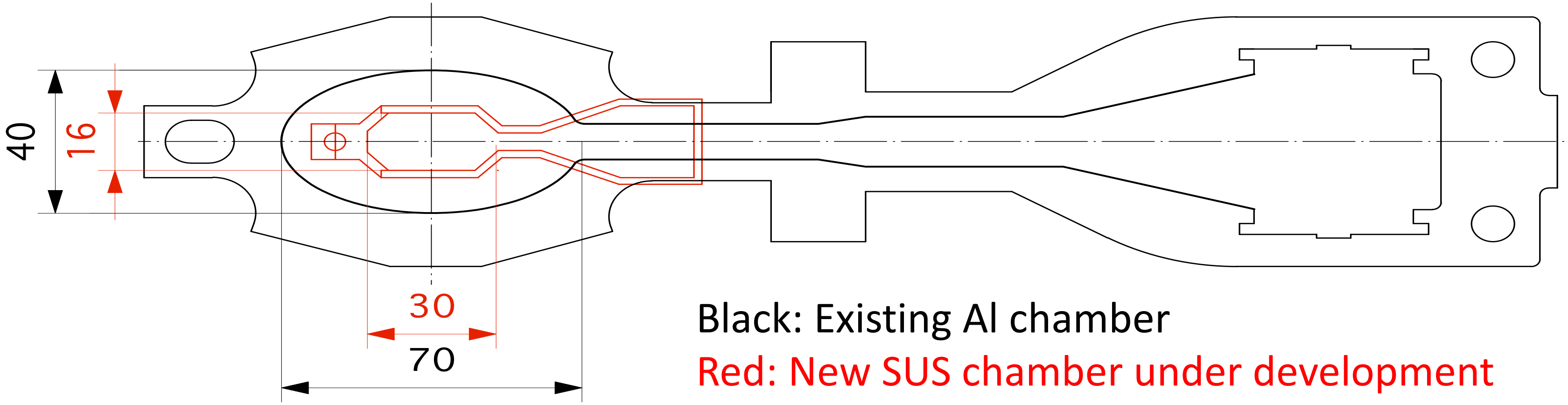
Quadrant of the Ring



Challenge in Component Design

- Compact Magnet System
    - Permanent-magnet based dipoles
    - Compact multi-pole magnets with smaller bore radii
- Compact Vacuum System
    - Narrow cross-sectional vacuum chambers
    - In-situ baking-free vacuum system
- High Performance Beam Injector
    - New timing system between SACLA and the ring
    - On-demand top-up injection from SACLA to the ring
- Invisible Beam Injection Scheme
    - Off-axis in-vacuum beam injection using linear π bump driven by stable solid-state PS

Vacuum System



Black: Existing Al chamber

Red: New SUS chamber under development

- Critical condition
  - Compact system (Beam room cross section ~1/5 of the present one)
  - Smaller total space for vacuum equipment (bellows, flanges, etc)
  - Only 1 year's blackout period
- Three key developments
  - 12 m long SUS chamber with a smaller aperture
  - Compact descrete absorbers（3-times large in number)
  - In-situ baking-free vacuum system

Where we are

- We will finish 3-years R&D on all the necessary components in FY2017 by completing a test half-cell
- In FY2018, two operation teams working in each control room will be unified into a single team in the central operation room toward at system integration
- We will also test beam injections from SACLA to the current storage ring in FY2018

In FY2019, we will be ready for starting SPring-8-II upgrade project

Thank you for your attention!