PLS Status and Features of the PLS-II Project

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On behalf of PAL Staffs
Pohang Accelerator Laboratory
POSTECH

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KEK, Tsukuba, Japan

PAL: Geology

POSTECH CAMPUS

PAL: Geology


Pohang Light Source
(2.5 GeV: 3rd Generation Facility)
▪ Total Land Area : 651,031 m²
▪ Total Building Area: 41,846 m²
▪ Number of Building: 15
Utilities
E-Gun
LINAC
Storage Ring
Administration
Beam Lines
(Experimental Station)

PAL: Chronology

I. PLS

▪ Project started	Apr. 1 1988
▪ Ground-breaking	Apr. 1 1991
▪ 2-GeV Linac commissioning	June 30 1994
▪ Storage ring commissioning	Dec. 24 1994
▪ User's service started	Sept. 1 1995
▪ 1st PLS Upgrade Complete	Nov. 1 2002
✓ Energy ramping to 2.5 GeV	Sept. 1 2000
✓ 2.5-GeV injection	Nov. 1 2002

II. 2nd Major Upgrade of the PLS (PLS-II)

▪ 3.0 GeV PLS-II Upgrade begin	Jan. 2009
▪ 3.0 GeV PLS-II Upgrade Complete	Dec. 2011

III. PAL XFEL Proposal

▪ 10GeV Linac Based 0.1 nm x-ray FEL Proposal	2009

PLS STATUS

Pohang Light Source

2.5 GeV Linac

Beam energy (GeV)	2.5
RF (MHz)	2856
Klystron power (MW), max	80
Bunch length (ps)	13
Normalized emittance (nm.mrad)	150
Beam current (A)	1
Energy spread (%), FWHM	0.6
Total length (m)	160

2.5 GeV Storage Ring

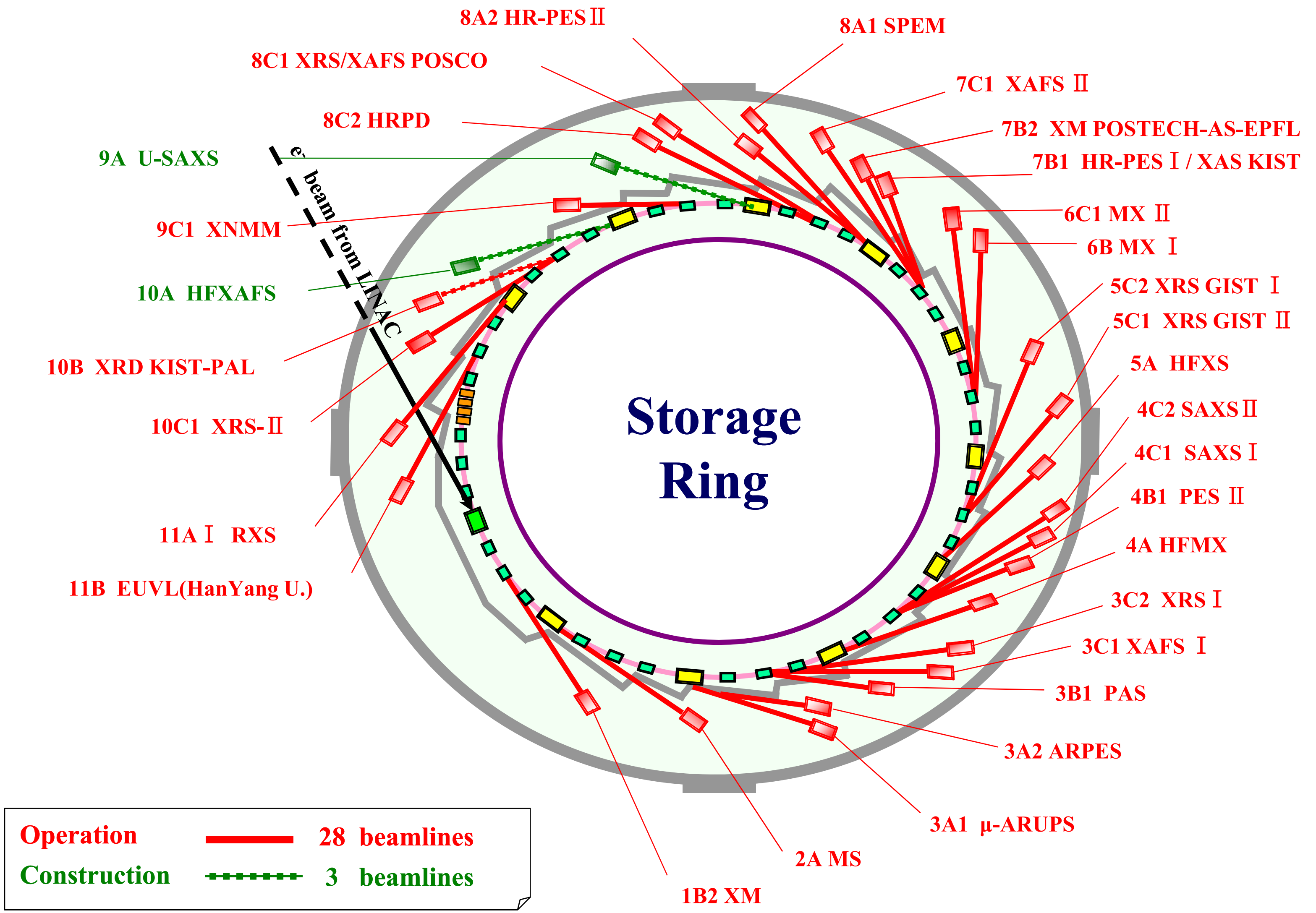
Beam energy (GeV)	2.5
Circumference(m)	280.56
Natural emittance (nm)	18.9
RF (MHz)	500.082
RF voltage (MV)	1.6
Tunes	14.28/8.18
Super-periods	12

Beamlines and Exp. Stations

28 B/L (7 IDs)
3 construction

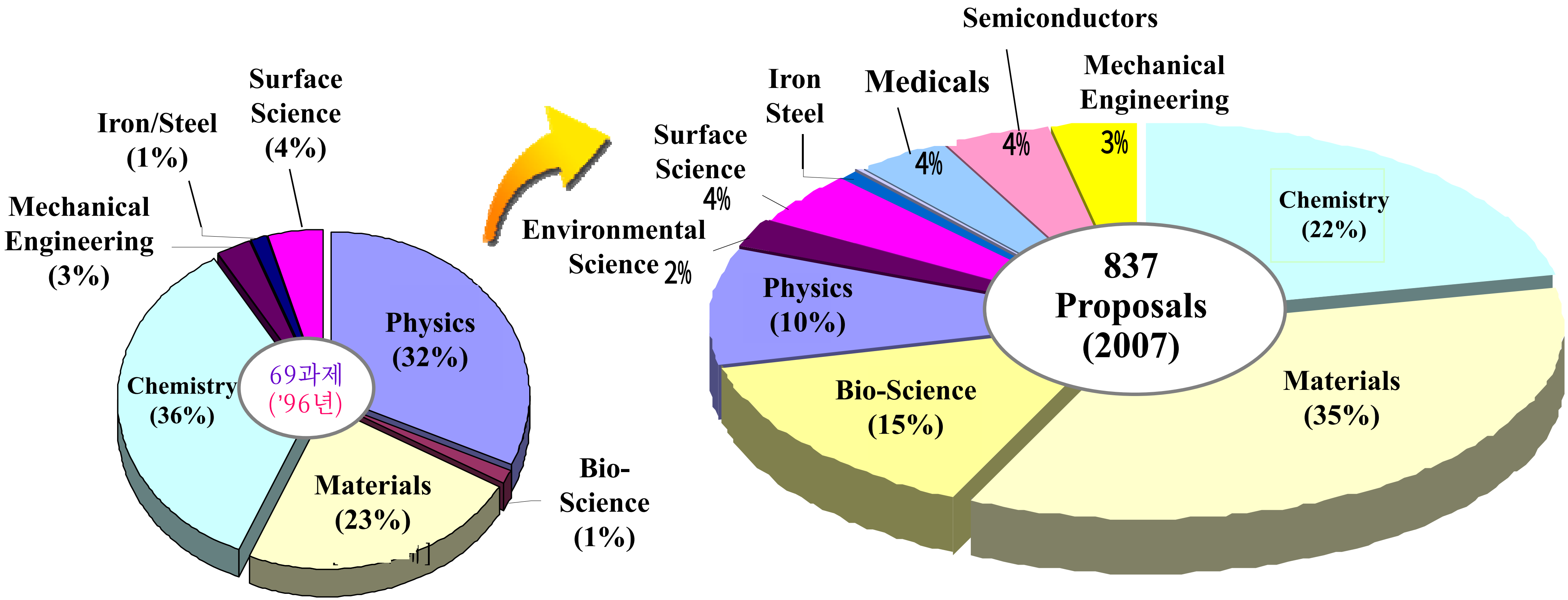
January 2009

PLS Beamline Status



* fs-THz BL : Technical Building II

Massive Increase of PLS Proposals

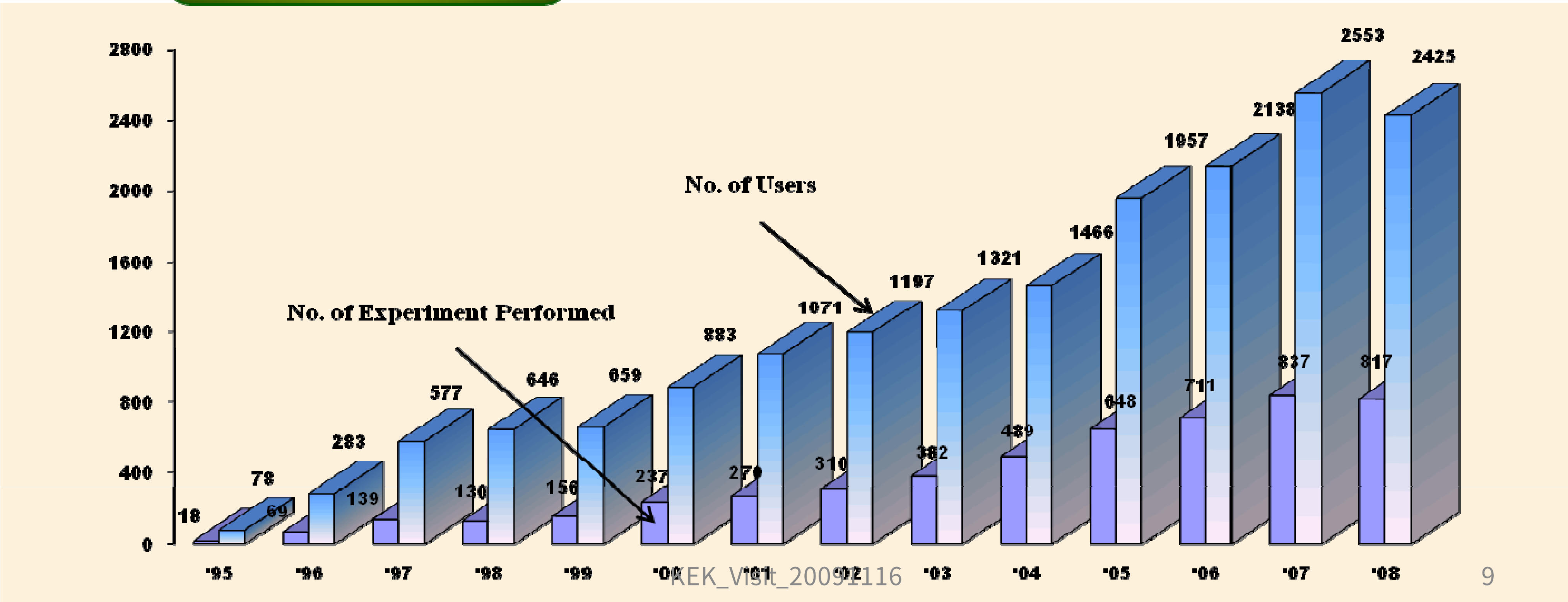


User Statistics

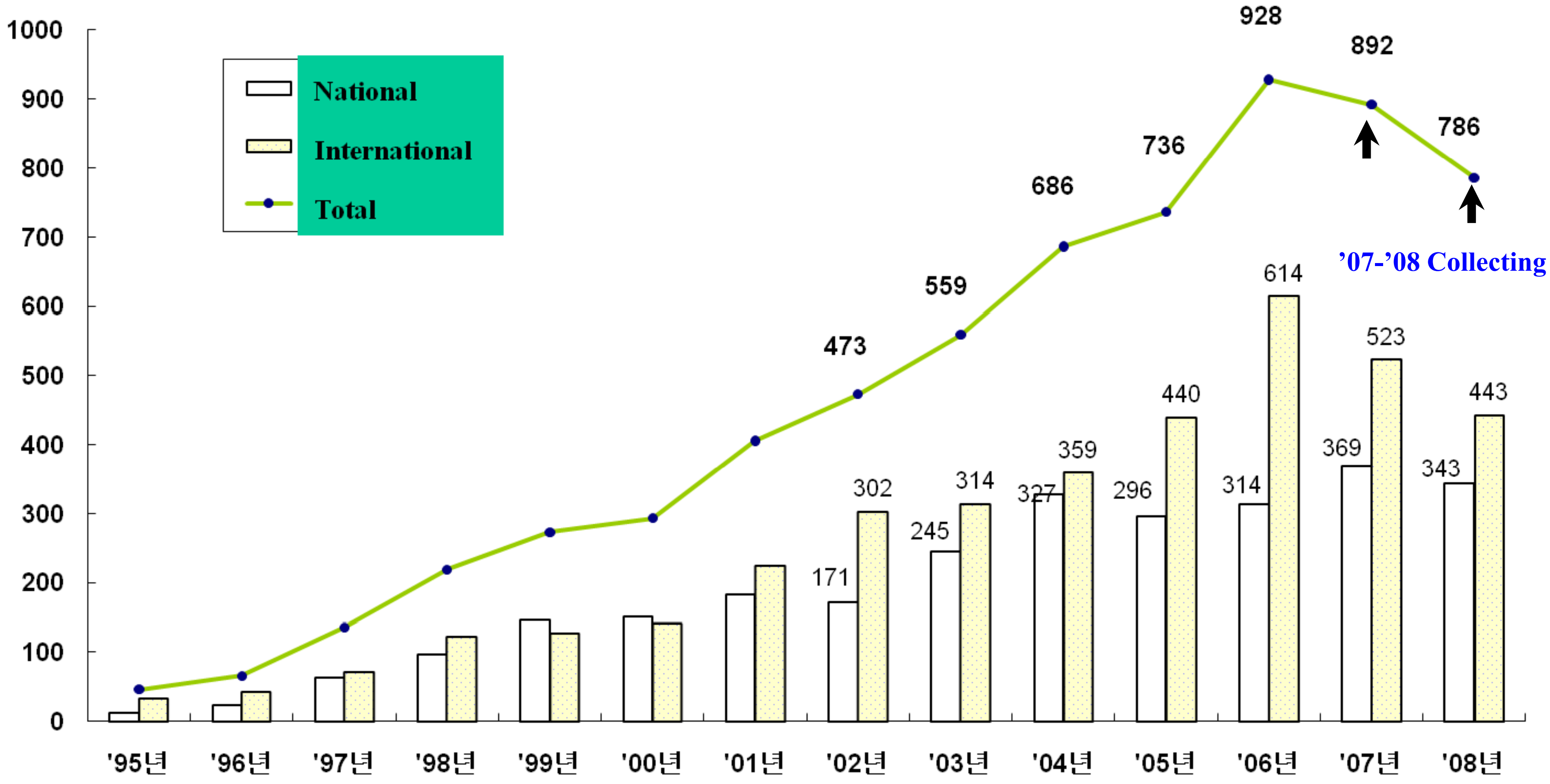
Summary

- More than 2,000 PLS users per year.
- Total 5,213 accumulated experiments (total 17,524 accumulated users) from 1995 opening to 2007.
- More than 20 % yearly increase since Yr 2000.

Statistics

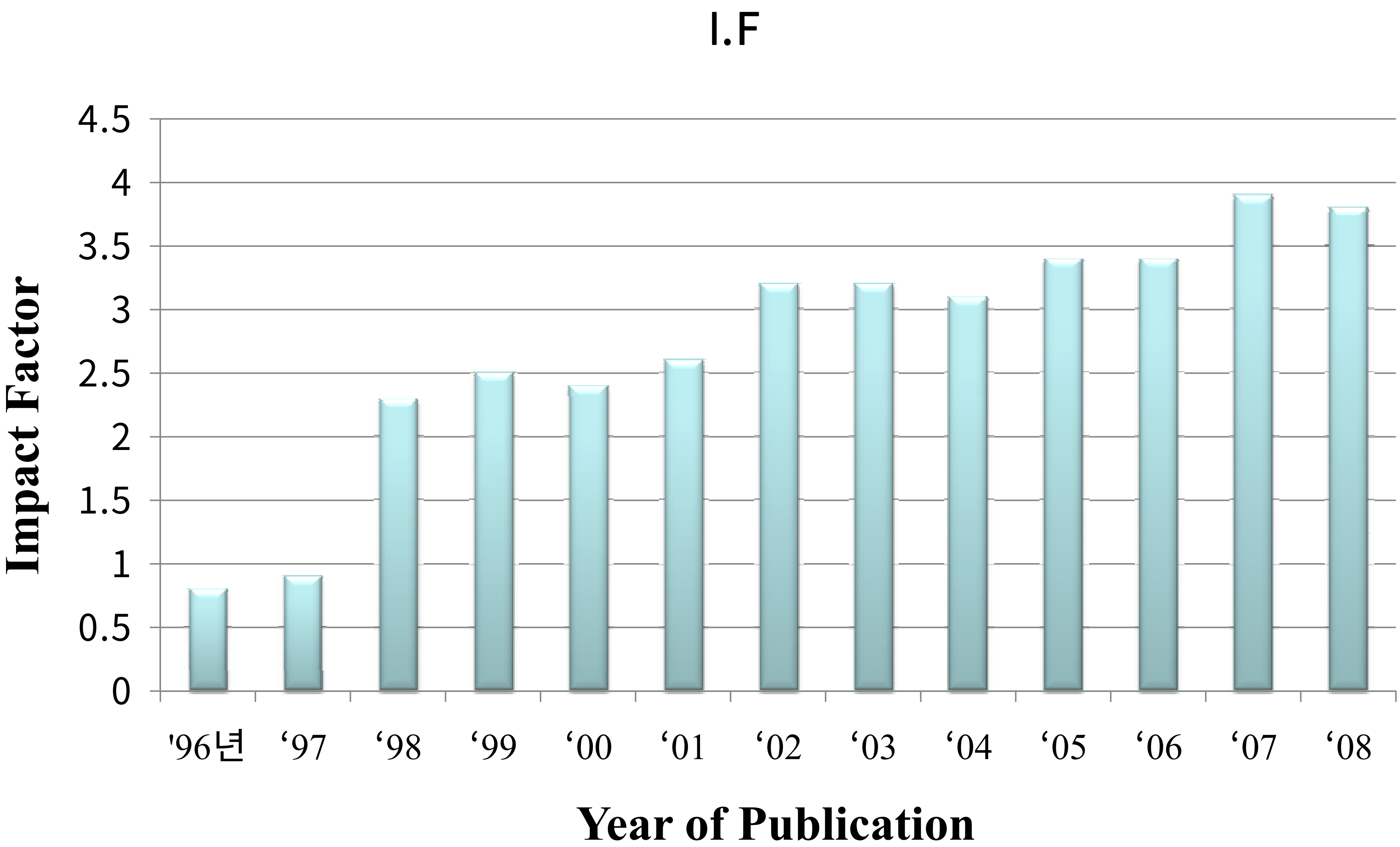


Yearly Publication Statistics



* '07-'08 publication statistics are still under collection.

Average Impact Factor (IF) of Publications



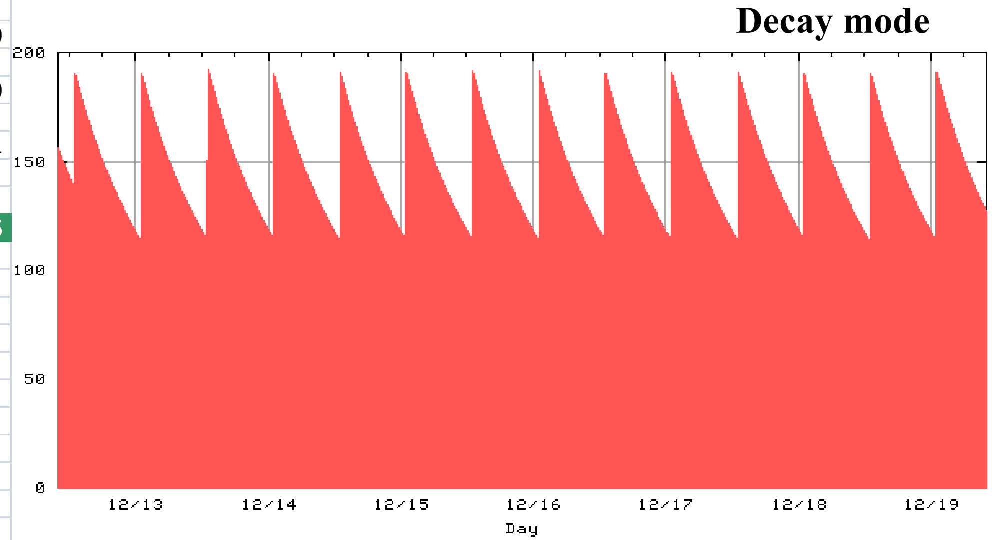
PLS Operation Status

2009 PLS Operation Schedule

- User Beamtime (195 days, 4680 hrs)
- Machine Turn-On & Machine Study (52 days, 1248 hrs)
- Maintenance (108 days, 2592 hrs)
- No Operation (10 days, 240 hrs)

Month	일	월	화	수	목	금	토	
1					1	2	3	
	4	5	6	7	8	9	10	
	11	12	13	14	15	16	17	
	18	19	20	21	22	23	24	
	25	26	27	28	29	30	31	
2	1	2	3	4	5	6	7	
	8	9	10	11	12	13	14	10
	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	10
3	1	2	3	4	5	6	7	
	8	9	10	11	12	13	14	10
	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	10
	29	30	31					
4				1	2	3	4	
	5	6	7	8	9	10	11	10
	12	13	14	15	16	17	18	
	19	20	21	22	23	24	25	15
	26	27	28	29	30			65
5						1	2	
	3	4	5	6	7	8	9	
	10	11	12	13	14	15	16	
	17	18	19	20	21	22	23	14
	24	25	26	27	28	29	30	
	31							
6		1	2	3	4	5	6	10
	7	8	9	10	11	12	13	
	14	15	16	17	18	19	20	10
	21	22	23	24	25	26	27	
	28	29	30					
7				1	2	3	4	10
	5	6	7	8	9	10	11	
	12	13	14	15	16	17	18	10
	19	20	21	22	23	24	25	
	26	27	28	29	30	31		11
8							1	
	2	3	4	5	6	7	8	65
	9	10	11	12	13	14	15	
	16	17	18	19	20	21	22	
	23	24	25	26	27	28	29	
	30	31						
9			1	2	3	4	5	
	6	7	8	9	10	11	12	
	13	14	15	16	17	18	19	
	20	21	22	23	24	25	26	
	27	28	29	30				
10					1	2	3	
	4	5	6	7	8	9	10	
	11	12	13	14	15	16	17	
	18	19	20	21	22	23	24	16
	25	26	27	28	29	30	31	
11	1	2	3	4	5	6	7	
	8	9	10	11	12	13	14	
	15	16	17	18	19	20	21	17
	22	23	24	25	26	27	28	
	29	30						
12			1	2	3	4	5	17
	6	7	8	9	10	11	12	
	13	14	15	16	17	18	19	
	20	21	22	23	24	25	26	15
	27	28	29	30	31			65

Typical Beam Current Pattern during user shift

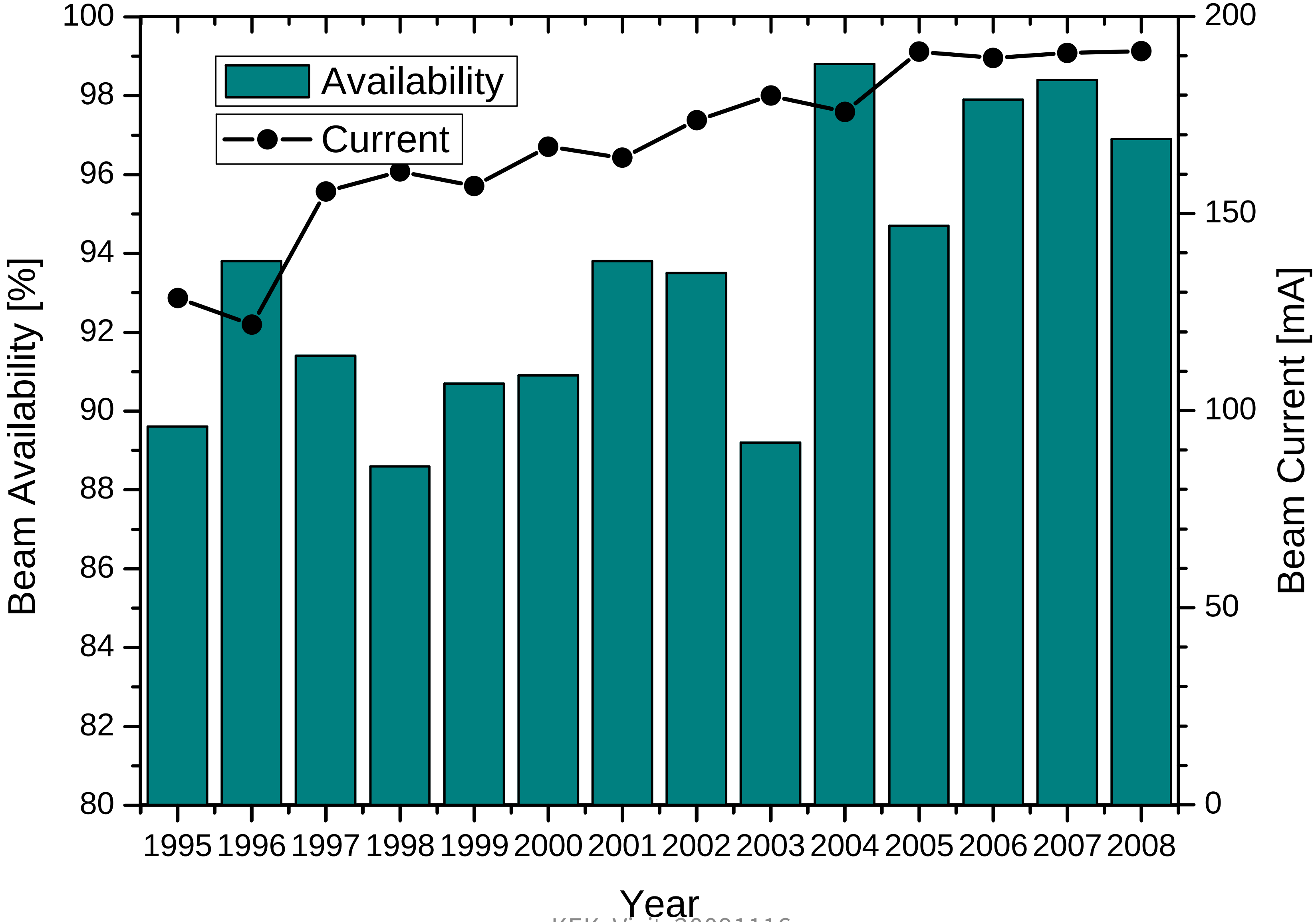


- **Beam injection from 2.5-GeV Linac is done twice a day.**
- **Max. stored beam current is 200 mA.**

2008 OPERATION SUMMARY

		Yr 2007	Yr 2008
• Operation Mode:		2.5 GeV (200 mA)	
• Injection Period:		12 Hours (2 injections/day)	
• Days of Operation per Run:		7-10 Days	
• User Operation:	[Days]	192	195
	[Hours]	4,617	4680
• Turn On and Machine Study:	[Days]	47	53
	[Hours]	1,119	1272
• Upgrade and BL Construction:	[Days]	109	104
	[Hours]	2,616	2,496
• Shut-down:	[Days]	17	13
	[Hours]	408	312
• Beam Availability:	[%]	98.4	97.0

Service Availability Record



Major Ongoing Activities in PLS Machine

- Storage Ring Beam stability
- Linac Beam Stability
- Top-up Operation
- ID Operation Improvement
- Confirm the PLS-II operation conditions in the PLS

FEATURES OF PLS-II PROJECT

PLS-II: Justification

PLS-II Justification

- The PLS was built the first in Korea, and the fifth in the world.
- Since the PLS operation, the number of users and publications increased remarkably (>20%/ yr increase from 2000), and contributed in the improvement of Korean as well as world science and technology.
- So far, the PLS and user community maintain world competiveness.
- Currently, more than 30 third generation light sources are in operation, construction, or plan. Highly competitive.
- To keep the competitiveness and lead this scientific community, the beam quality and number of IDs of the PLS need to be upgraded.
- Thus, the PLS-II is planned.

PLS-II Project Summary

- **Project Period:** 3 years (2009 – 2011)
- **Total Budget:** US 100 M$

- **Yearly Budget: in US M$ (1U$ = 1000 Won)**

Item	Year			Total
	2009	2010	2011	
Storage Ring	15.1	25.11	9.42	49.63
Linac	8.57	5.97	1.6	16.14
Beamline	5.46	11.82	6.62	23.9
Utility	0.87	3.5	5.96	10.33
Total	30.0	46.4	23.6	100.0

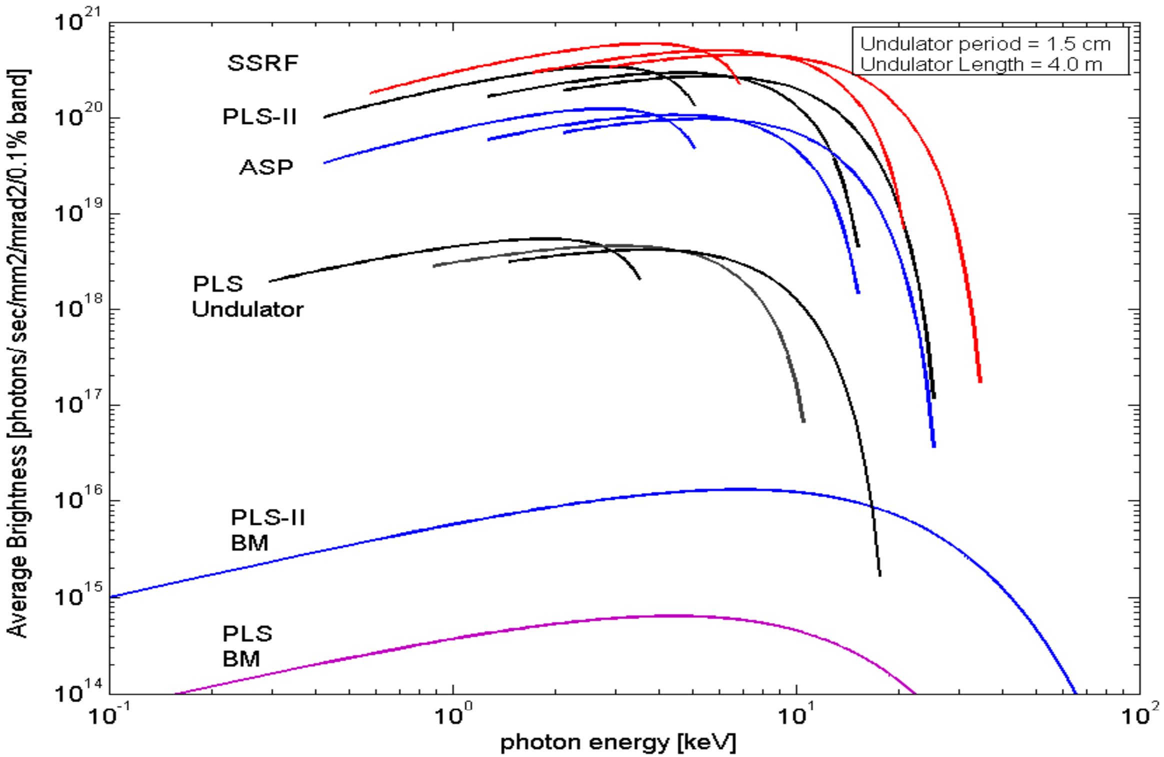
Major Goal of the PLS-II Upgrade

Item	PLS	PLS-II
Increase Energy	2.5 GeV	3.0 GeV
Lower Emittance	18.9 nm·rad	5.6 nm·rad
Increase Stored Beam Current	200 mA	400 mA
Increase No. of IDs	**10**	**>20**
Increase Brightness	**$\sim 2 \times 10^{18}$**	**$\sim 10^{20}$**
Change Lattice Type	TBA	DBA
Change Operation Mode	Decay	Top-up

PLS-II Milestones

	Milestones	Remark
Linac	■ Energy Upgrade 2.5 GeV → 3.0 GeV ■ Improve Energy Stability 0.5% → < 0.2%	■ Improve the injection efficiency for the top-up operation
Storage Ring	■ Achieve Top-Up Operation ■ Increase Stored Current 200 mA → 400 mA	■ Improve beam stabilities by minimizing thermal load variations
	■ Reduce Beam Emittance 18nm·rad → 5nm·rad	■ Results in about 100 times increase in the photon-beam brightness
	■ RF Power Upgrade up to 800kW (663 kW by beam)	■ Compensate for increased radiation losses due to increased currents and ID numbers
	■ Improve Storage Ring Lattice for accommodating more IDs 10 EA → 20 EA	■ Utilize combined-function dipoles to increase straight sections
Beamlines & Infrastuructures	■ Establish Automation System for the Remote Experimentations	■ Improve beamline accessibility and throughput
	■ Reinforce Radiation Shieldings	
	■ Reinforce HLS (Hydrostatic Leveling System)	■ Measure ground movements in real time

Spectral Brightness of the PLS-II



ID radiation brightness from the PLS-II is expected to be 2 x 10^{20} photons/sec/mm²/mrad²/0.1%BW (@ 10 keV (1 Å)) which is about 100 times brighter than the existing PLS.

Linac & BTL

PLS-II Linac

- **Energy Increase: 2.5 to 3.0 GeV**
  - **Add 1 module of klystron and modulator units.**
  - **Increase accelerating gradient**
  - **Add 4 more high gradient accelerating columns**
- **Top-Up Injection**
  - **Improve reliability**
  - **Reduce MTBF**
  - **Improve energy stability and spread**

Performance Upgrade Goal of the PLS-II Linac

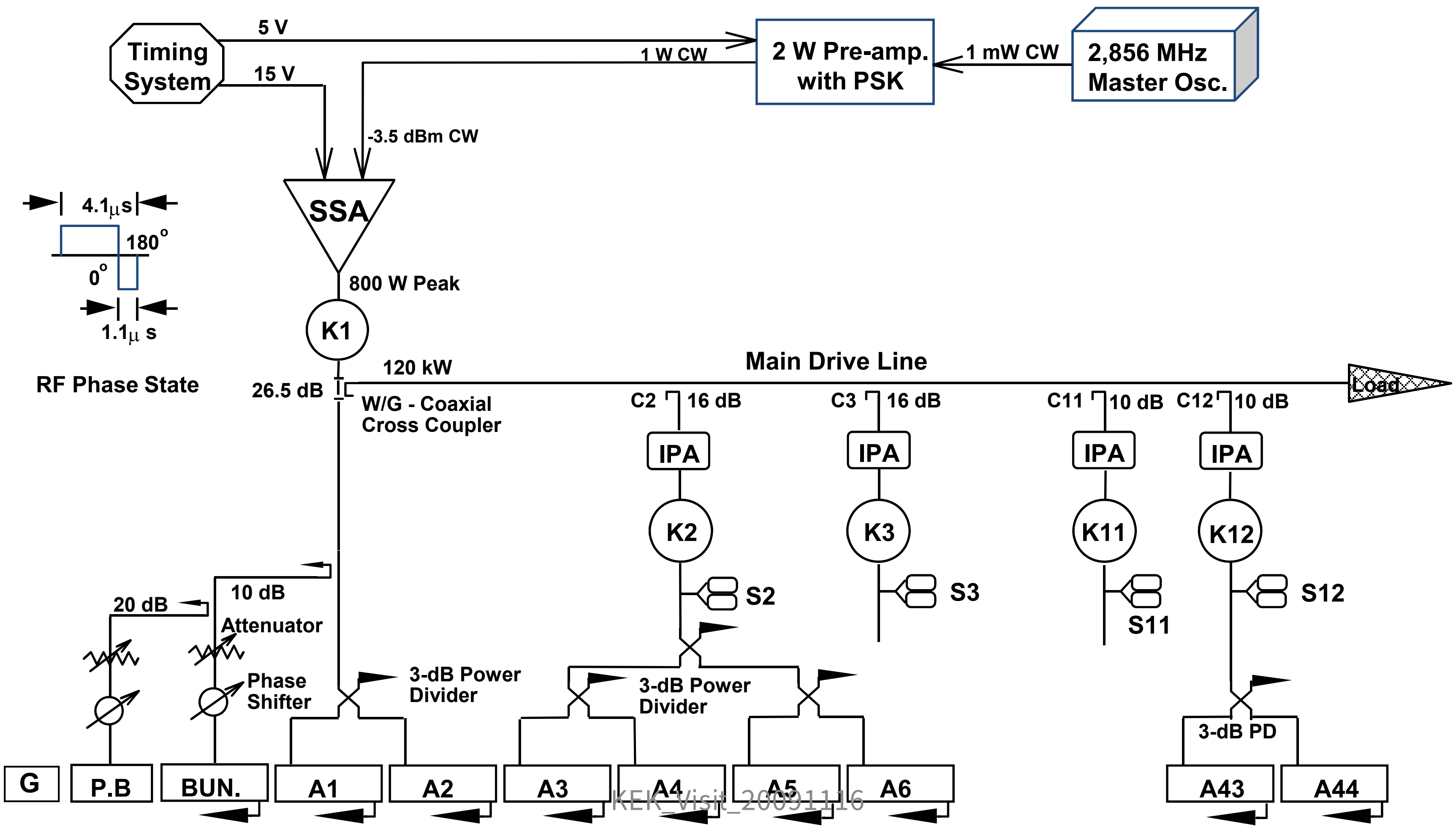
	PLS	PLS-II
Energy	2.5 GeV	3 GeV
Repetition Rate	10 Hz	10 - 30 Hz
Energy Stability	0.5% rms	0.1% rms
Energy Spread	0.6% rms	< 0.2% rms
Emittance (normalized, rms)	150 mm mrad	< 20 mm mrad
Gun Pulse Length	1.5 ns FWHM	~0.5 ns FWHM
Klystron Power (Operating Levels)	50 – 60 MW	70 – 80 MW
SLED Gain	1.5 – 1.6	1.6 – 1.7
Diagnostics	BCMs, BASs, BPRMs	+ BPMs, Slits, Wire Scanners

PLS-II Gun: Comparison of Gun Systems

	PLS	PLS-II
Number of Guns	Single Gun	Single Gun with fast replacement
Beam Energy	80 keV	80 keV
Beam Current	1 A peak	1 A peak
Pulse Length	1.5 ns FWHM	~0.5 ns FWHM
HVPS Type	DC	DC
Beam Transmission	80%	60%

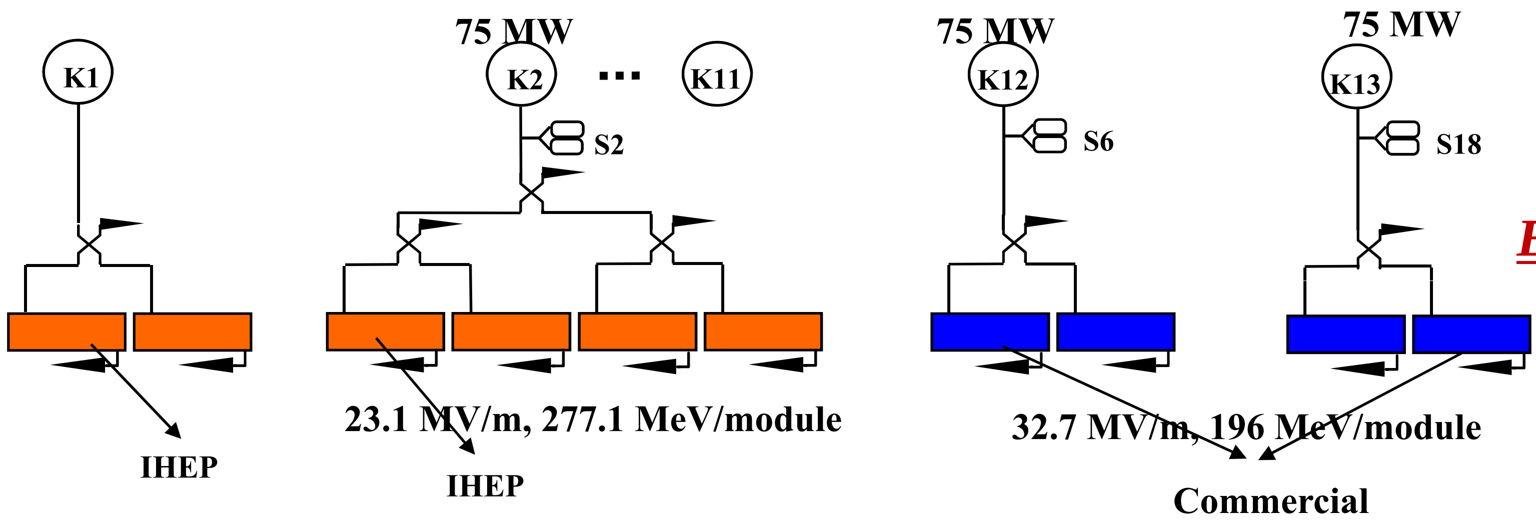
MW System: Current 2.5 GeV Linac

1. 12 klystron&modulator systems
2. MK01&12: two accelerating columns
3. MK2 to MK11: four accelerating columns
4. The klystron drive uses main drive line.
5. Klystron Out Power: 50-60 MW (~19 MV/m)



Linac MW Layout (2.5GeV → 3.0GeV Energy Upgrade)

	MK1 1(set)	MK2 - MK11 10(set)	MK12 – MK13 2(set)
Klystron output power	60 MW	75 MW	75 MW
Model	SLAC5045	Toshiba E3712	
Number of A/C	2	40	4
Type of A/C	IHEP		Commercial
Av. energy gain of SLED	NA	~1.6	
Gradient of A/C		23.1 MV/m	32.7 MV/m



E = 3.273 GeV

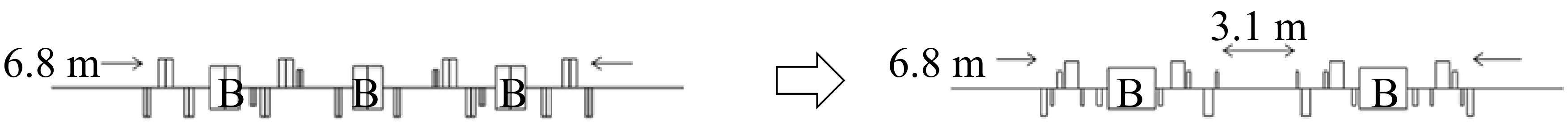
Linac/BTL Beam Instrumentation of the PLS

Instrument	No.		Operation	Remark
	Linac	BTL(BAS)		
BCM	7	5(1)	O	OK
BPRM	4	5(1)	O	OK
BLM	42	12	O	Need controller
BPM	13	13(1)	Linac pickup install(~2009.8)	Need DAQ
			BTL pickup ok	Operation
Beam Charge Monitor		1(1)	ICT install	Need DAQ
YAG screen monitor		1(1)	screen	Need Controller
Gallery environment	1		operation	SLED, gallery, driver line
Beam slit		1(1)	Installed (2009)	Need controller/monitor

Storage Ring

Issues on Lattice Design / Limitations Overcome

Straight section for IDs



12 long straight sections ⇨ 12 long straight sections
12 short straight sections ⇨ 20 straight sections for ID are available!

Usage of present wall

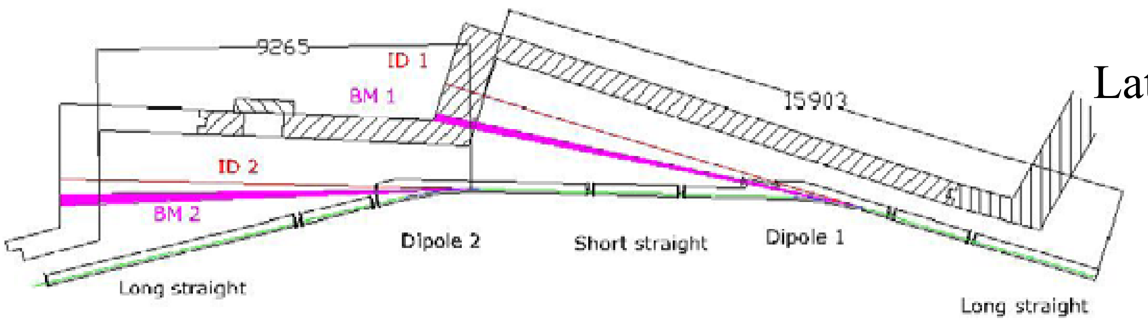
Circumference (m) : 280.56 -> 281.82

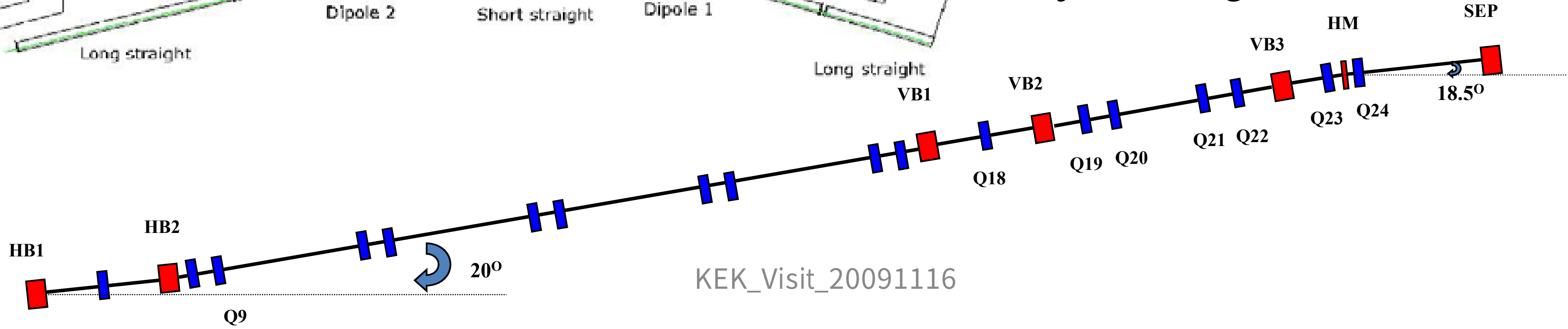
⇩

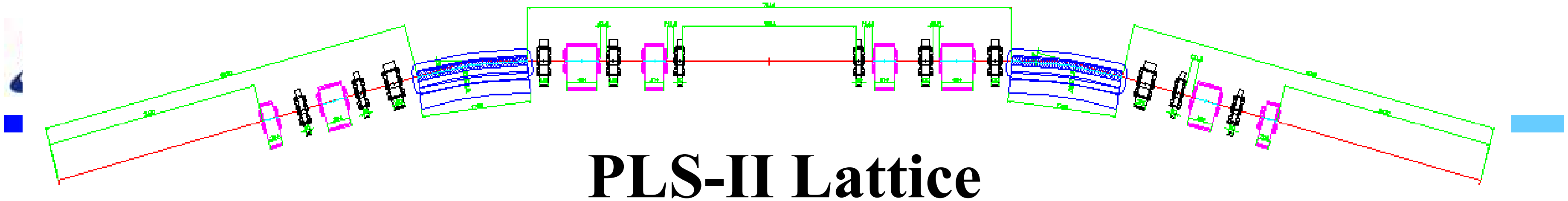
Lattice is rotated by 1.5 degree.

⇩

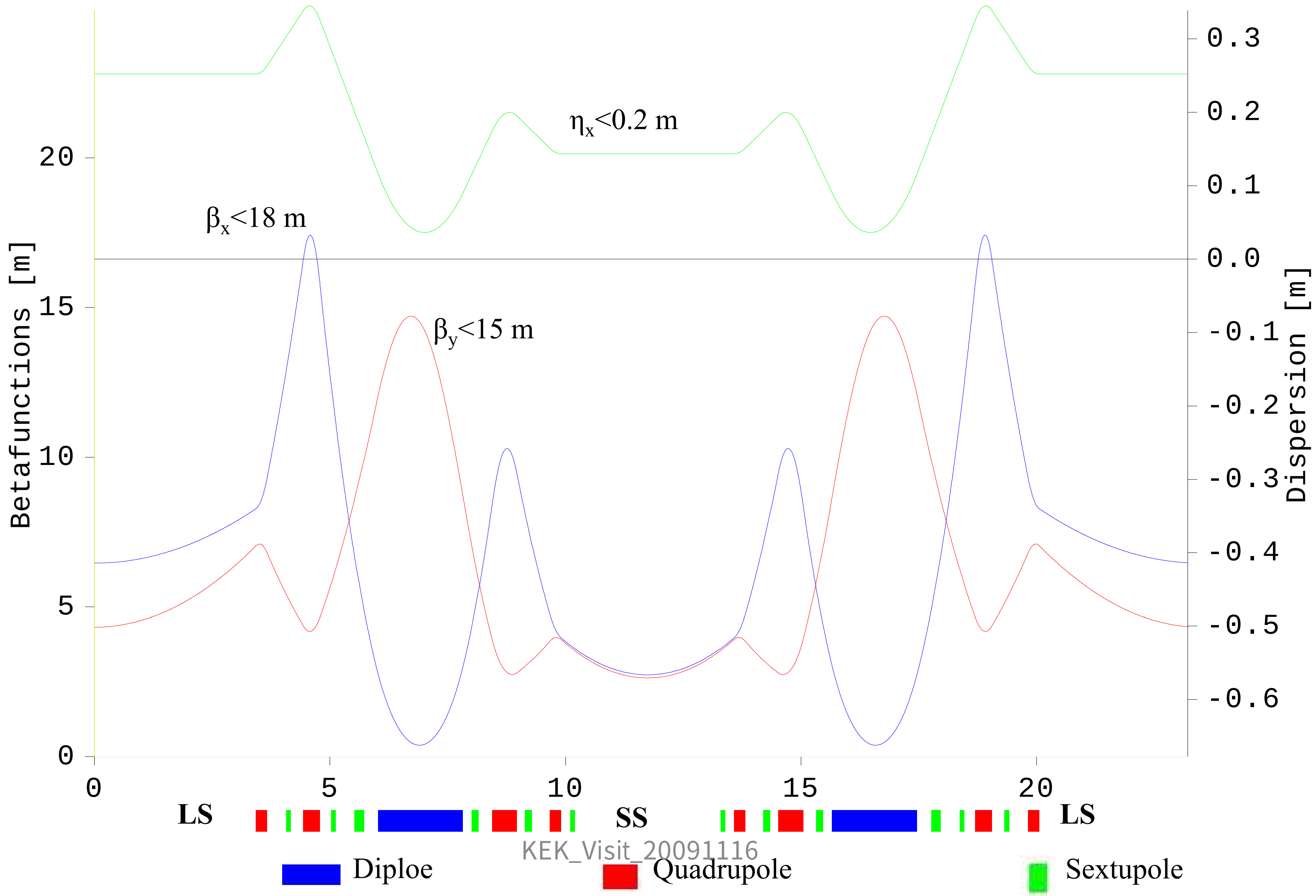
Injection angle is corrected.







PLS-II Lattice



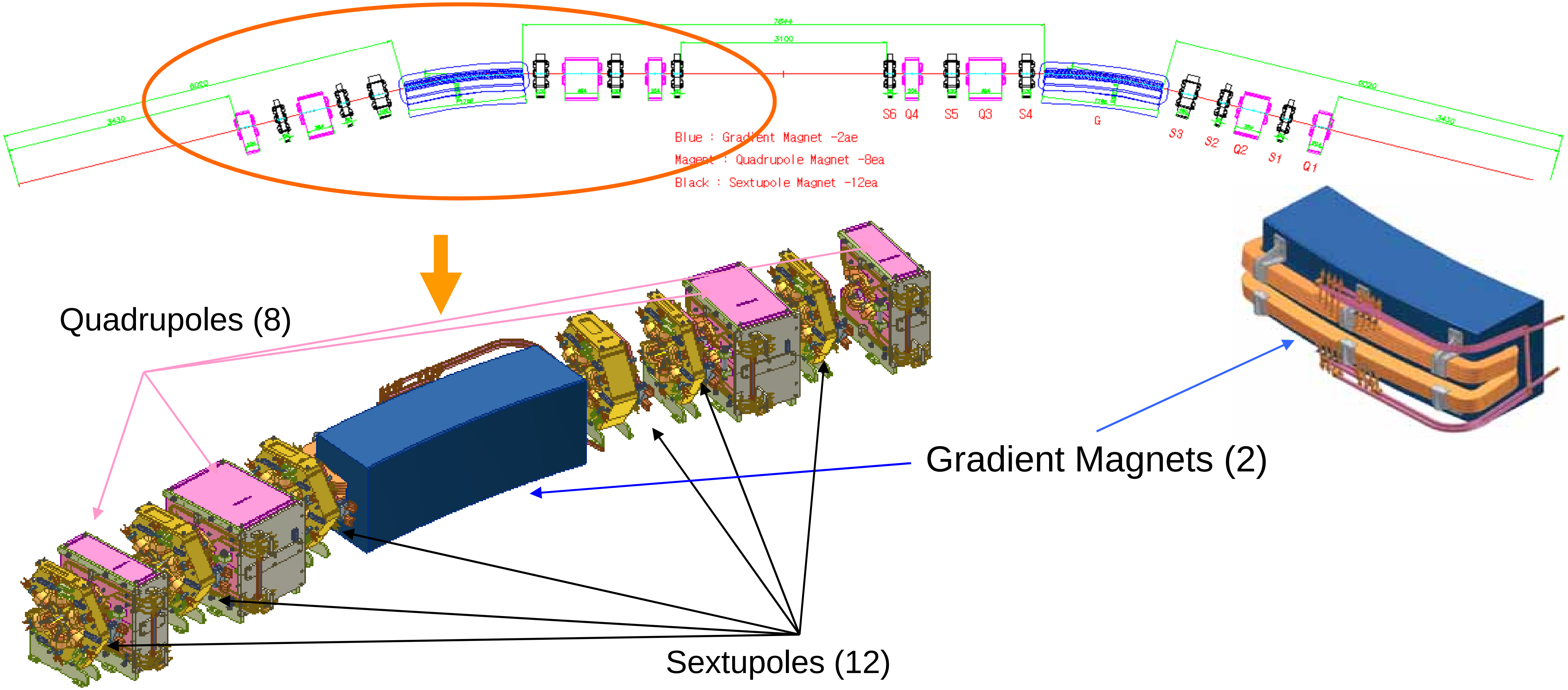
PLS-II Beam Parameters at Photon Source

	Long SS	Short SS	Bending Magnet
Number	9 ID [1 LSS for Injection, 2 LSS for SRF]	11 ID (1 SSS for Instruments)	24
Length or Bending R (m)	6.8	3.1	6.875
β_x (m)	6.16	2.84	0.38
β_y (m)	4.90	2.46	14.14
η_x (m)	0.21	0.17	0.037
$\sigma_x \times \sigma_y$ (μm^2)	234 x 17	167 x 12	47 x 28

Diagnostics in PLS-II

	Monitor	Qty.	Function
Electron	Beam Position Monitor	96	Beam Position
	DC Current Transformer	1	Average Beam Current
	Stripline Electrode	2	Tune, Beam Damping
	Screen Monitor	1	Beam Position (Commissioning)
	Scraper	1	Beam Trimming, Dynamic Aperture
Photon	Photon Beam Position Monitor	36	Frontend Beam Position
	Diagnostic Beamline		
	X-ray	1	Beam Profile, Beam Size
	Visible Light	1	Beam Size, Bunch Length

PLS-II Magnet Layout (Half Cell)



PLS-II Magnets

Type	Number	Key Parameters	Remarks
Gradient	24 (2 X12)	1.4555 T, 4.0028 T/m Gap=34 mm, L_{eff}=1.800 m	All powered in series
Quadrupoles	96 (8 X12)	4 types, Max Gradient 22T/m, R_c=36 mm	Powered in family series with independent aux coils.
Sextupoles	144 (12 X12)	Max B'=550 T/m2 R_c=39 mm, 6 types	SkewQ, V-corrector, H-corrector, combined function
Kicker Magnet	4		Recycle existing one
Lambertson Septum	1	3.0 GeV, 8.8 degree vertical bending,	

PLS-II Magnet Power Supply

<table>
<tr><th colspan="3">PLS-II Magnet Power Supply</th><th colspan="2" rowspan="2">Remarks</th></tr>
<tr><th>Type of MPS</th><th>Quantity</th><th>Connection</th></tr>
<tr><td>Bending Magnet: 900[A], 550[V]</td><td>1 set</td><td>Series</td><td colspan="2">Recycled</td></tr>
<tr><td rowspan="2">Sextupole: 450[A], 300~410[V]</td><td rowspan="2">6 sets</td><td rowspan="2">Series</td><td>A</td><td>3: Recycled, 3: new</td></tr>
<tr><td>B</td><td>New</td></tr>
<tr><td rowspan="2">Quad Main (Q1,Q2,Q3,Q4) — 800[A], 275~475[V]</td><td rowspan="2">1 set/each (4 sets)</td><td rowspan="2">Series</td><td>B</td><td>3: Recycled, 1: New</td></tr>
<tr><td>A</td><td>New</td></tr>
<tr><td>Quad Aux. (Q1,Q2,Q3,Q4) — 20[A], 15~20[V]</td><td>12 sets/each (96 sets)</td><td>Individual</td><td colspan="2">New</td></tr>
<tr><td>Corrector (V/H): 20[A], 30[V]</td><td>V/H (192 sets)</td><td>Individual</td><td colspan="2">102: Recycled, 90: New</td></tr>
<tr><td>Septum: 250[A], 25[V]</td><td>1 set</td><td>Individual</td><td colspan="2">Recycled</td></tr>
<tr><td>Skew: 20[A], 10[V]</td><td>144 sets</td><td>individual</td><td colspan="2">New</td></tr>
<tr><td>BM, Q-main</td><td colspan="2">Location : MPS room</td><td colspan="2" rowspan="4"></td></tr>
<tr><td>Sextupole, septum</td><td colspan="2">Location : Control Shed (1 place)</td></tr>
<tr><td>Corrector, skew,</td><td colspan="2">Location : Control Shed (12 places)</td></tr>
<tr><td>Q-Aux.</td><td colspan="2">Location : Control Shed (12 places)</td></tr>
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PLS-II Vacuum Chamber

Gr
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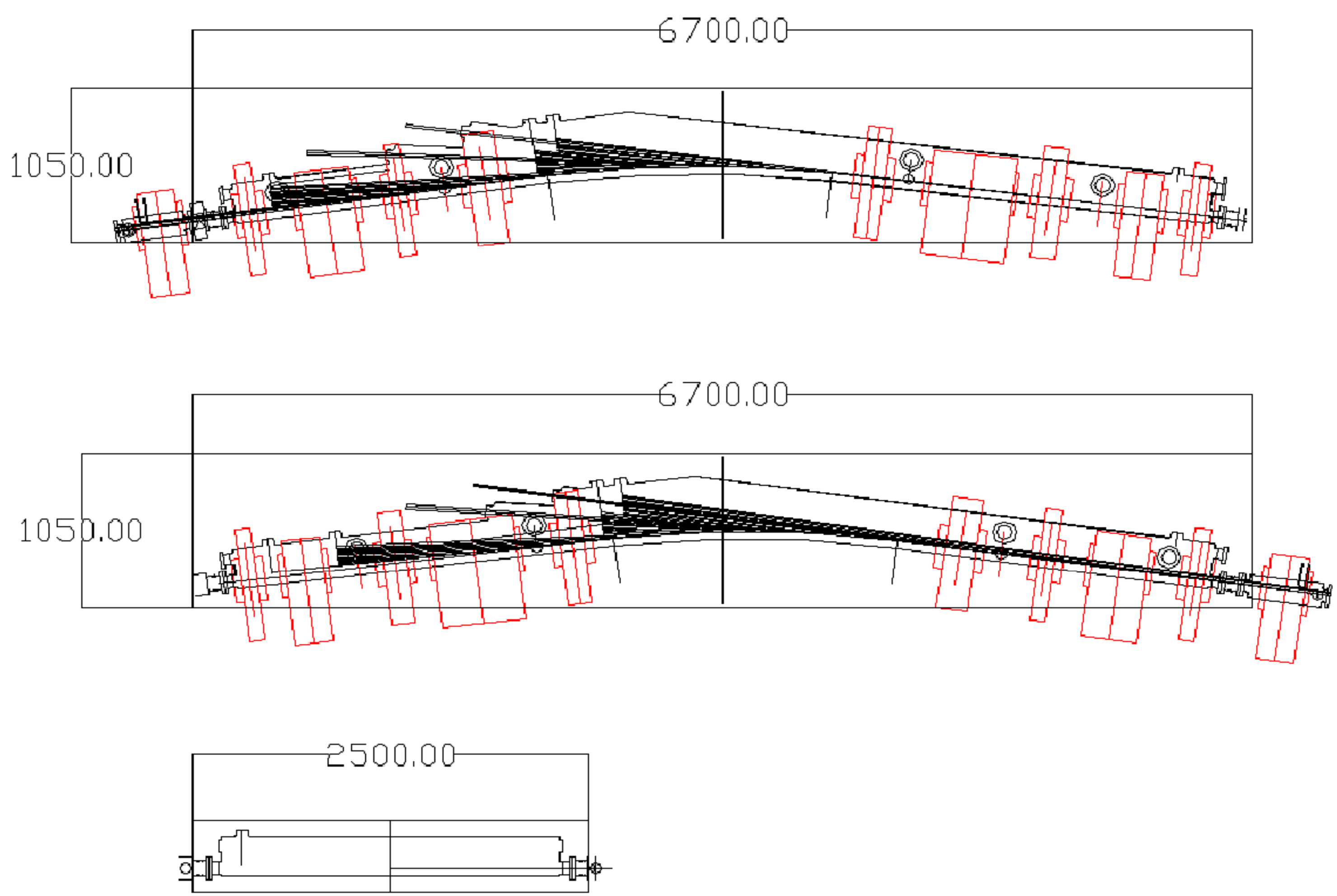

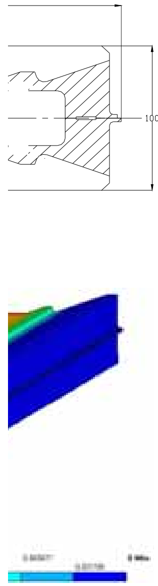

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PLS-II RF system

Parameters	PLS-II RF	PLS RF
Current [mA]	**400**	**200**
RF frequency [MHz]	499.66	500.082
Total beam loss power (kW)	**663**	**130.2**
Accelerating Voltage [MV]	**3.3**	**1.6**

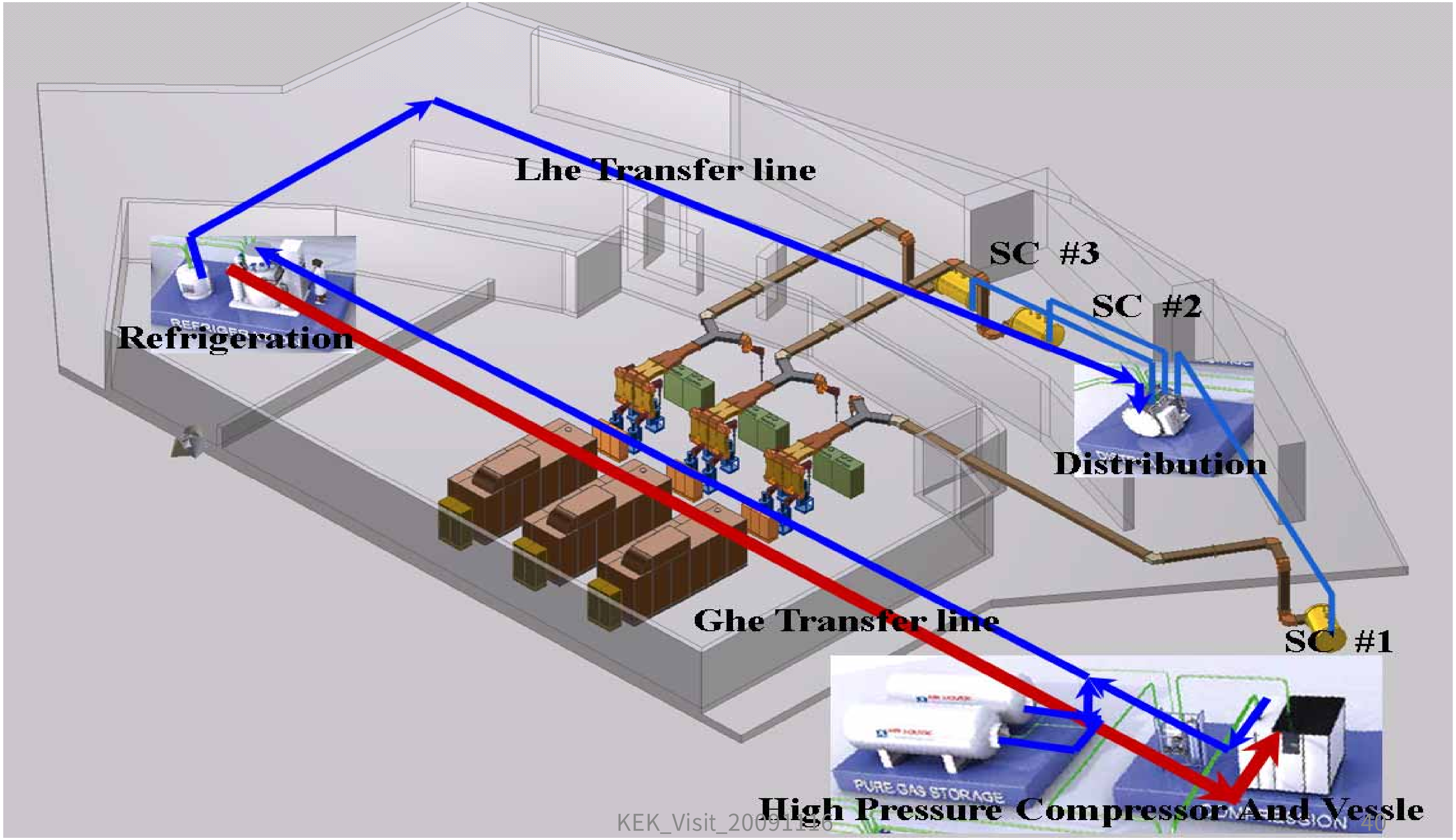
- To provide the required RF power and control beam instabilities at higher energy and beam currents with more high field IDs, the current PLS RF system needs to be fully replaced with a new superconducting RF system.

PLS-II SC RF System Specification

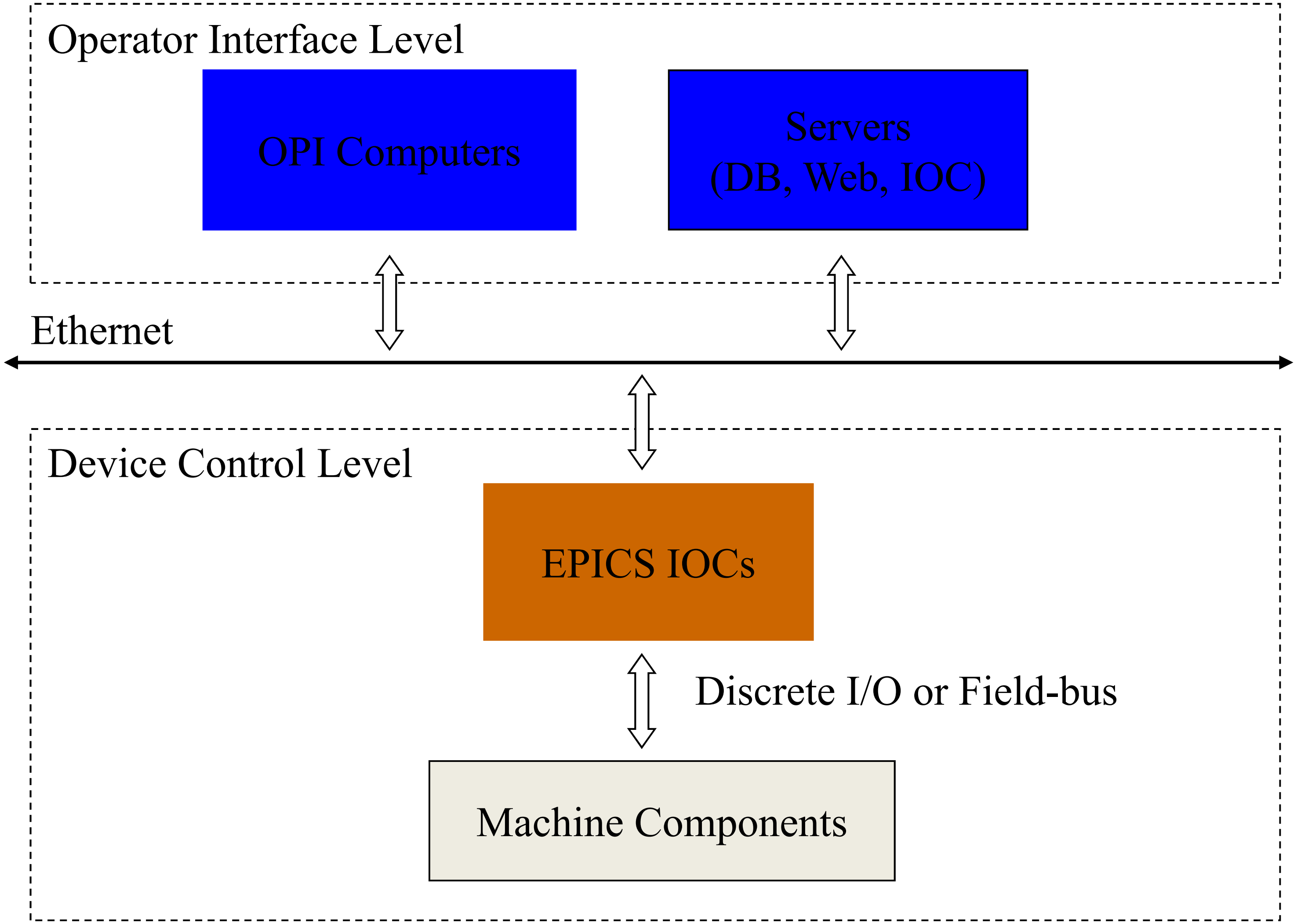
	SC
Number of cavity	3
RF voltage per cavity [MV]	1.1
Wall loss power per cavity [kW]	0.013
Beam load power per cavity [kW]	223
RF Power need per cavity [kW]	232
Number of high power system	300 kW × 3
Number of LLRF system	3
Cryogenic heat load power (W)	650
Need for the storage ring tunnel space	1.5Long-SS

PLS-II RF system

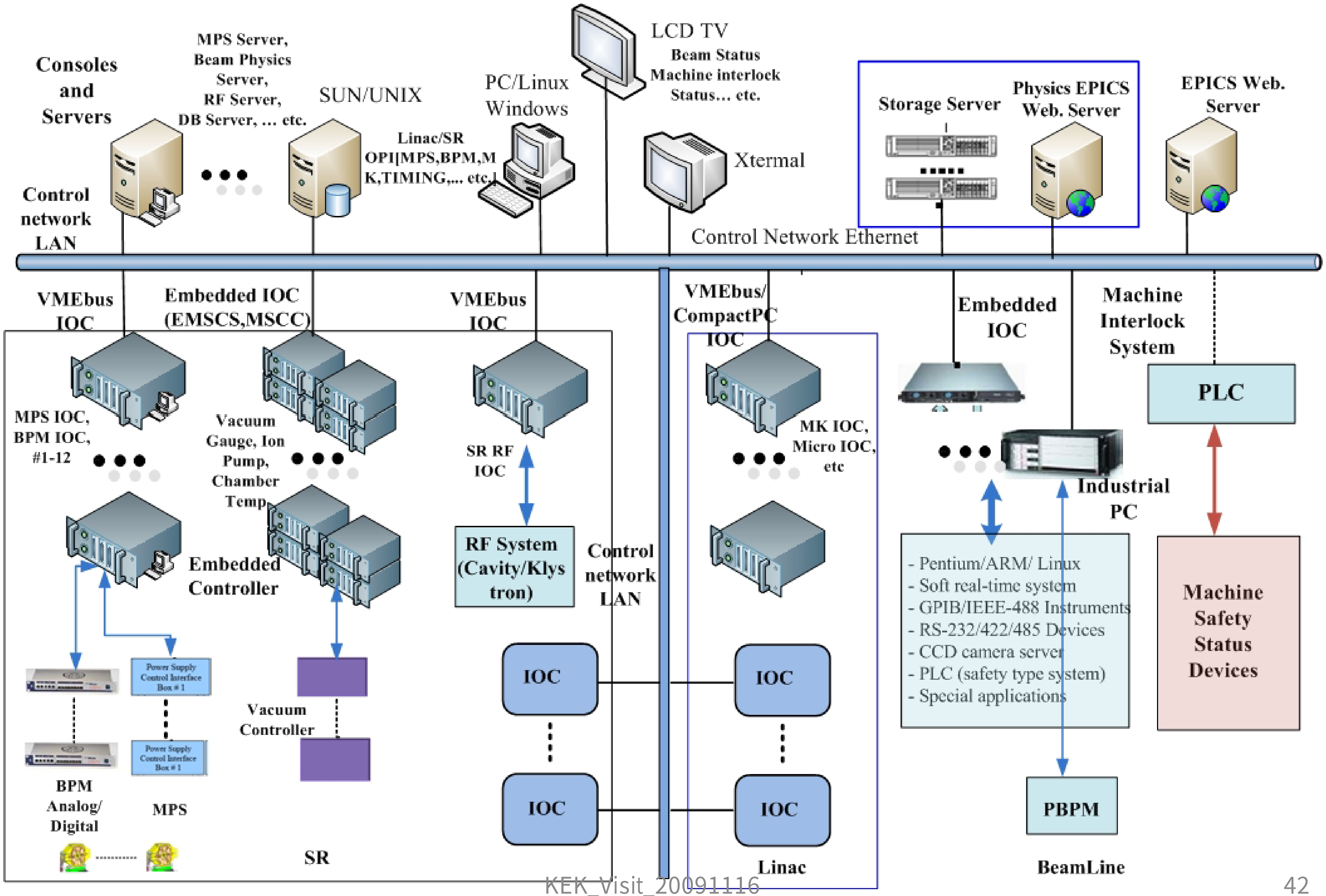
3 sets of superconducting RF system (2 set in Phase-I).



Control System Standard Open Architecture



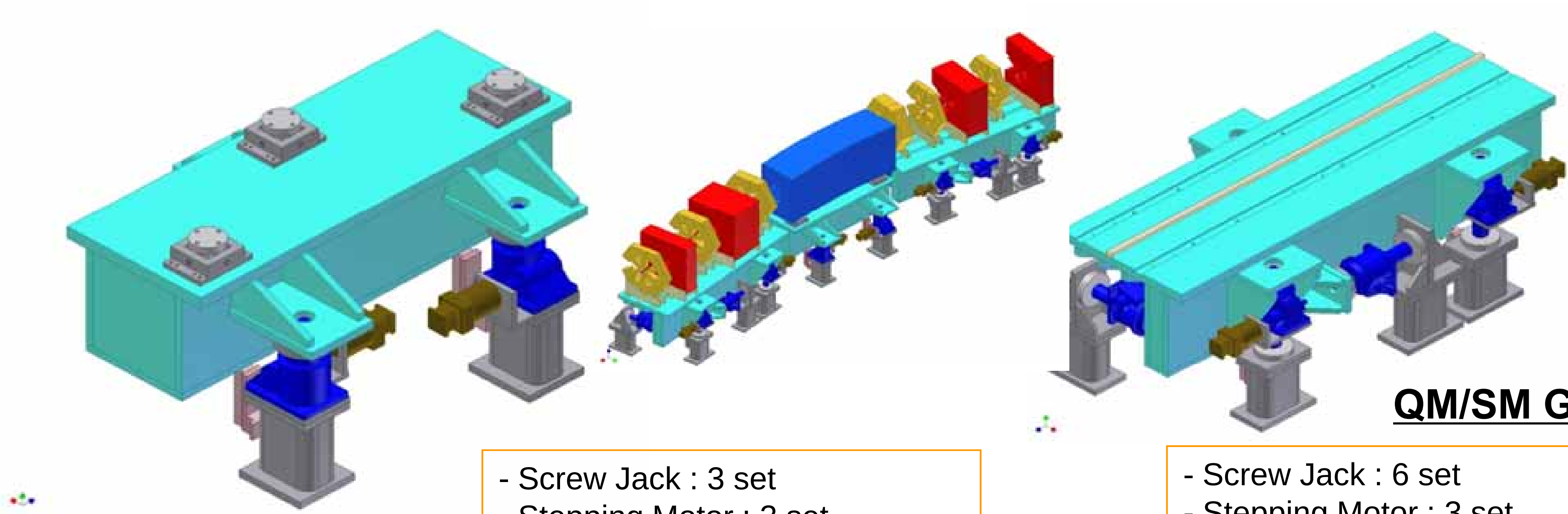
Control System : Overall Configuration



PLSII Girder System

Design Consideration

- Girder Elevation: 1,400 mm from the SR tunnel floor
- Higher natural frequency : >30 Hz (Goal)
- Allow the active adjustment in vertical direction: ±50 mm (> 25 year coverage)
- Girder Deformation : < ±30 ㎛
- Instruments: HLS, HPS, LVDT



BM Girder

- Screw Jack : 3 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 2.0 ton

QM/SM Girder

- Screw Jack : 6 set
- Stepping Motor : 3 set
- Linear Absolute Encoder : 3 set
- Total weight : 3.0 ton

Beamline

PLS-II ID SELECTION: Procedure

Six Divisions of User association and proposed ID beamlines

► XRD & Topography	► XAFS
Coherent & nano-beam X-ray scattering	*Time-resolving XAFS*
High energy High flux materials Science	*Nano-proving XAS*
► SAXS	**► Bio-macromolecular Crystallography**
Micro-beam SAXS	*High Flux nano-crystallography*
Anormalus SAXS	*Micro-crystallography*
► Photoemission	**► Biomedical Imaging**
Nanoscope	*Medical Imaging*
Middle energy spectroscopy	*Nanoscopy*

PLS-II ID SELECTION: Priority

1. **Scientific Importance**
2. **Technical feasibility**
3. **The compatibility with the upgraded performance**
4. **The size and potentials of the relevant user community**
5. **The difference from the present beamlines**

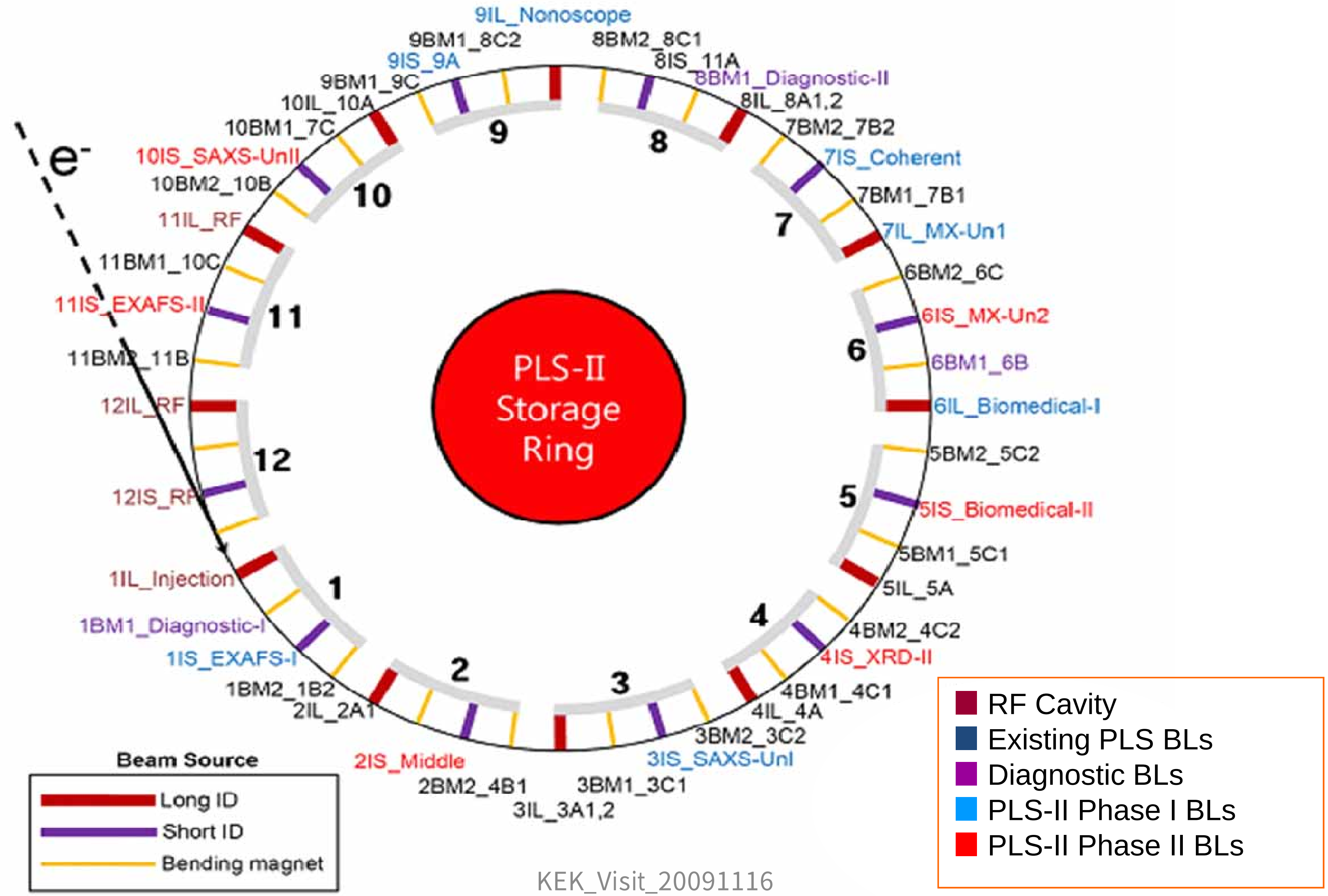
Phase I	Phase II
Micro-beam SAXS	*High energy high flux materials science*
High Flux nano-crystallography (MX)	*Middle energy spectroscopy*
Coherent & nano-beam X-ray scattering	*Nano-proving XAS*
Medical Imaging	*Anomalus SAXS*
Time-resolving XAFS	*Nanoscopy (Biomedical)*
Nanoscope (Photoemission)	*Micro-crystallography*

PLS-II ID SELECTION: Tentative List

	Beamline	Energy range	ID (PLS)	ID (PLS-II)		
1	2A Magnetic Spectroscopy	0.1~1.5 keV	2 m EPU	5 m EPU	In operation	1 In-vac. 2 MPW 3 Undulator
2	3A Angle Resolved PES	0.01 ~ 1 keV	2 m PU	5 m EPU	In operation	
3	4A Protein Crystallography	5 ~ 17 keV	2m MPW	2m MPW	In operation	
4	5A High flux Mat. Science	5 ~ 20 keV	2m MPW	2m MPW	In operation	
5	8A Nano PES	0.1 ~ 1.5 keV	4.5 m PU	4.5 m PU	In operation	
6	11A Resonant Scattering	4 ~ 13 keV	1 m Rev.	1 m Rev.	In operation	
7	9A U-SAXS	5 ~ 20 keV	2m In-vac.	2m In-vac.	Constructing	2 In-vac. 3 MPW 3 Undulator
8	10A XAFS	5 ~ 50 keV	2m MPW	2m MPW	Constructing	
9	Microbeam-SAXS	5 ~ 25 keV		2m In-vac.	PLS-II-1st	6 In-vac. 4 MPW 4 Undulator
10	High Flux nano MX	4 ~ 14 keV		2m In-vac.	PLS-II-1st	
11	Coherent & Nano scatt.	5 ~ 20 keV		2m In-vac.	PLS-II-1st	
12	Medical Imaging	4 ~ 50 keV		2m MPW	PLS-II-1st	
13	Time-Res. EXAFS	5 ~ 15 keV		2m In-vac.	PLS-II-1st	
14	Nanoscope	0.1 ~ 1.5 keV		5 m EPU	PLS-II-1st	
15	High Energy Scattering	5 ~ 50 keV		2m MPW	PLS-II-2nd	8 In-vac. 7 MPW 5 Undulator
16	Middle Energy Spectro.	0.5 ~ 3 keV		5m EPU	PLS-II-2nd	
17	Nano-probe XAS	5 ~ 20 keV		2m MPW	PLS-II-2nd	
18	A-SAXS	5 ~ 30 keV		2m MPW	PLS-II-2nd	
19	Medical Nanoscopy	4 ~ 13 keV		2m In-vac.	PLS-II-2nd	
20	Micro MX	6 ~ 18 keV		2m In-vac.	PLS-II-2nd	

PLS-II Beamline Arrangement (Tentative)

Re-distribution of PLS-II Beamlines



Summary

- PLS-II has completed its major design and started component purchase.
- Final detail design was reviewed by the PAL international advisory committee (IAC) on June 6~7, 2009.
- TDR will be published in November 2009.
- The project is expected to finish on time and budget.

Future Plans of PAL

PAL XFEL

XFEL (X-ray Free Electron Laser) Facility (4th Generation)

- **Coherent X-ray Beam (X-ray Laser)**
- **Super-high Beam Flux**
- **Nanoscale Beam Size**
- **Femtosecond Pulse X-ray Beam**

- **Energy: 10 GeV (0.1 nm)**
- **3 X-ray BLs & 3 VUV BLs (Start with 3 X-ray BLs)**
- **Budget: U$ 400 M**
- **Project Period: 2011-2014**

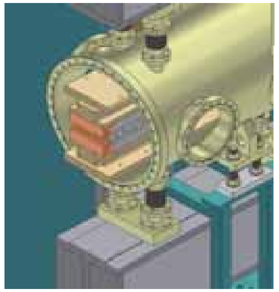
PLS XFEL Project (2011-2014)

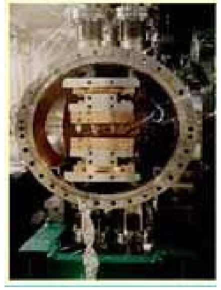
Key Parameters

1. **Wavelength:**
   0.1 nm, 1-4 nm, > 10 nm

2. **Electron beam energy** :
   10 GeV (~550 m)

3. **Undulator:**
   in-vacuum, g_u= 5.3 mm (~100 m)





High-Tech Medical Cluster Project in Korea

- ✓ Korean government initiated project

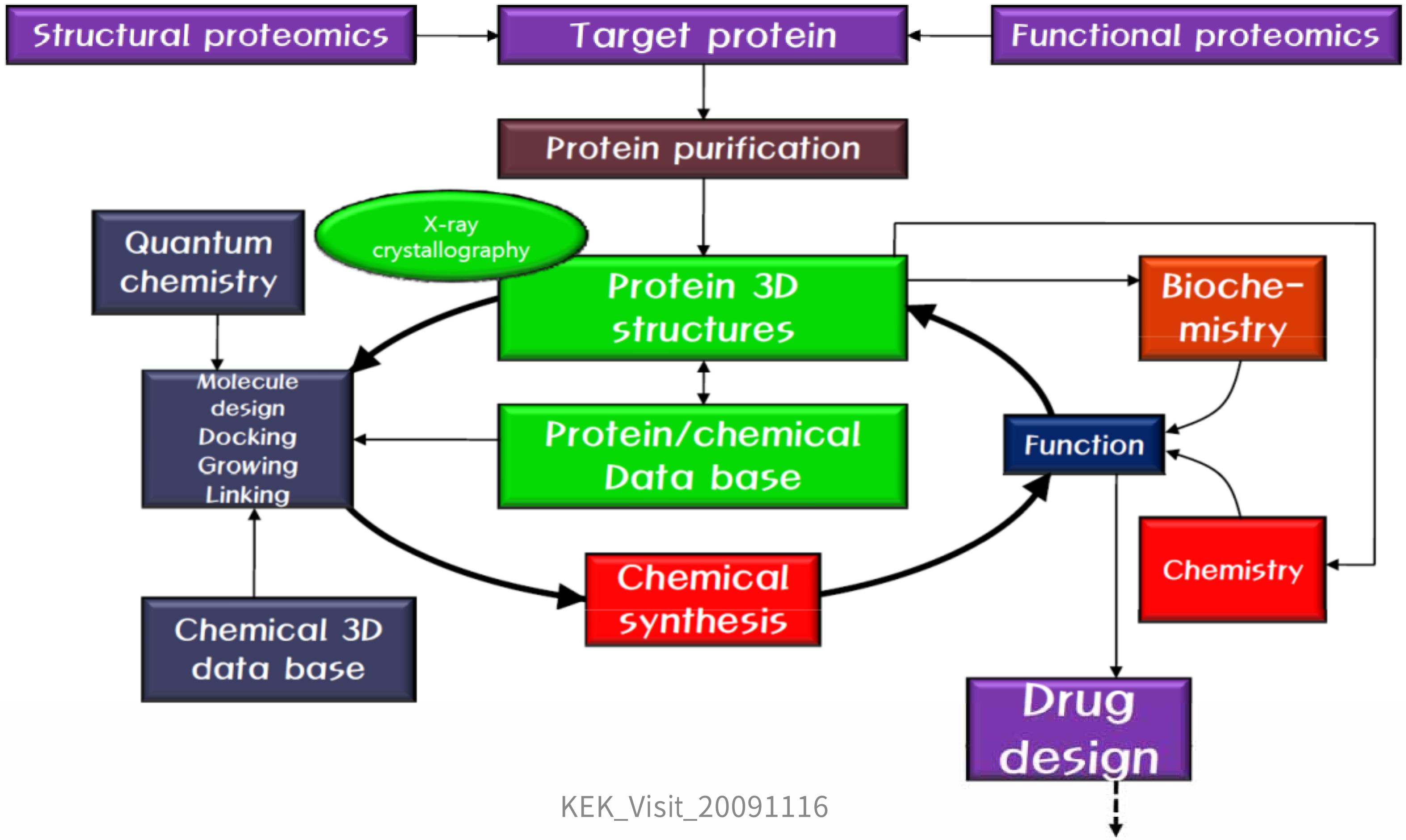
- ✓ Selected two high-tech medical clusters:
  - Daegu and KyungBuk (PAL involved)
  - Osong in ChungBuk

- ✓ Plan to invest ~ U$ 5 billion in 30 years (to 2038)

- ✓ Major Contents
  - Advanced medical service
  - Novel drug discovery and development
  - High-tech medical instrument development
  - Global medical network

PAL Involvement in the Medical Cluster

- ✓ In proposal to establish a drug discovery center to support the Daegu and KyungBuk medical cluster
- ✓ Budget: U$ 100 million



Thank you!