

Current Status of PAL-XFEL Facility

- 0.1-nm Hard X-ray XFEL
- Project Period: 2011 ~ 2015
- Total Budget: 400 M\$
- 10-GeV Electron Linac (Normal Conducting S-band, 60 Hz)
- Total Length: 1.1 km



Heung-Soo Lee,
on behalf of PAL-XFEL Team

Outline

- **Introduction**
- **Current status of linac**
 - Injector
 - High Power RF
 - LLRF
 - Vacuum
 - Diagnostic & magnets
- **Current status of undulator**
- **Current status of beam line**
- **Commissioning schedule**

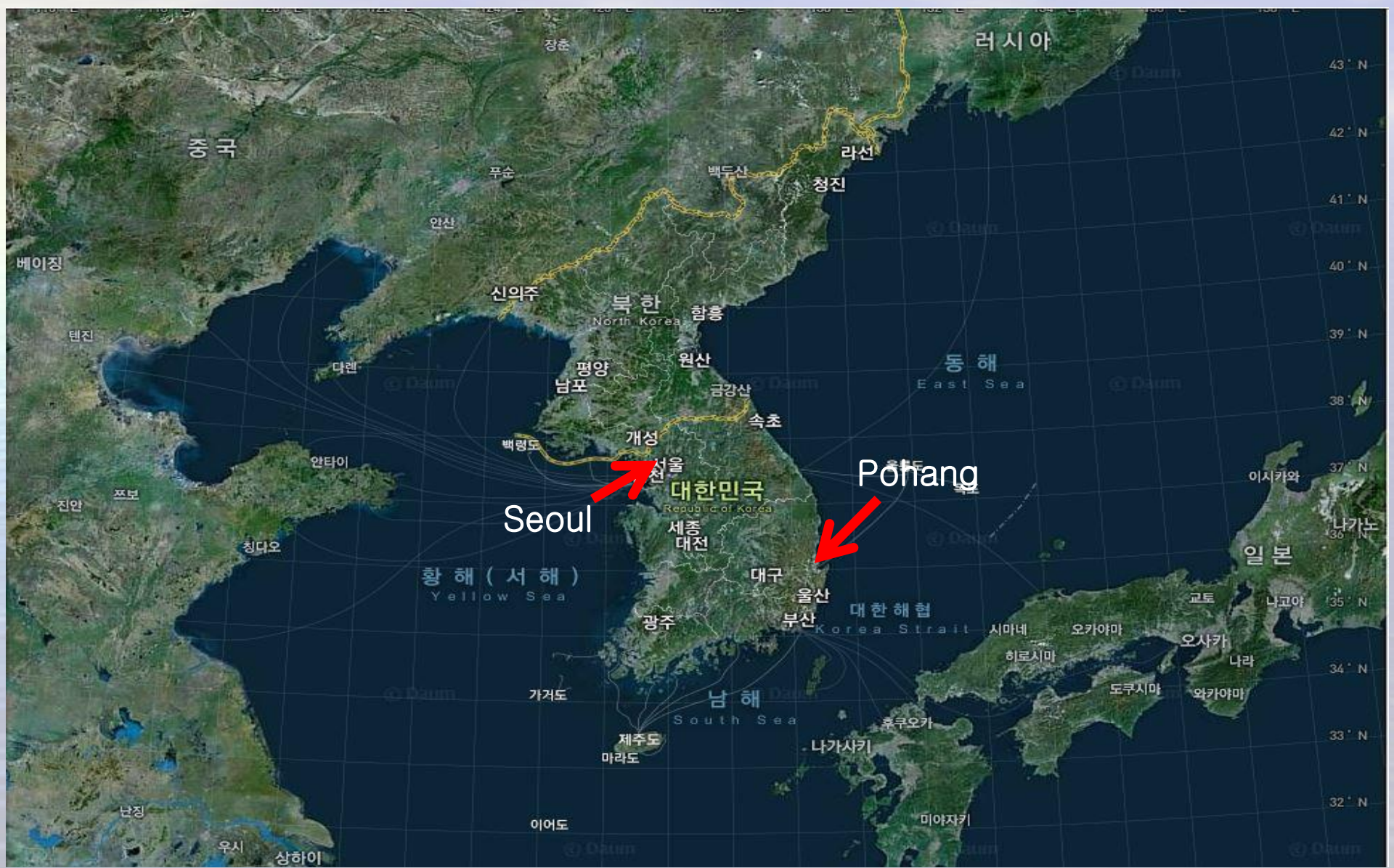
Worldwide FEL Projects



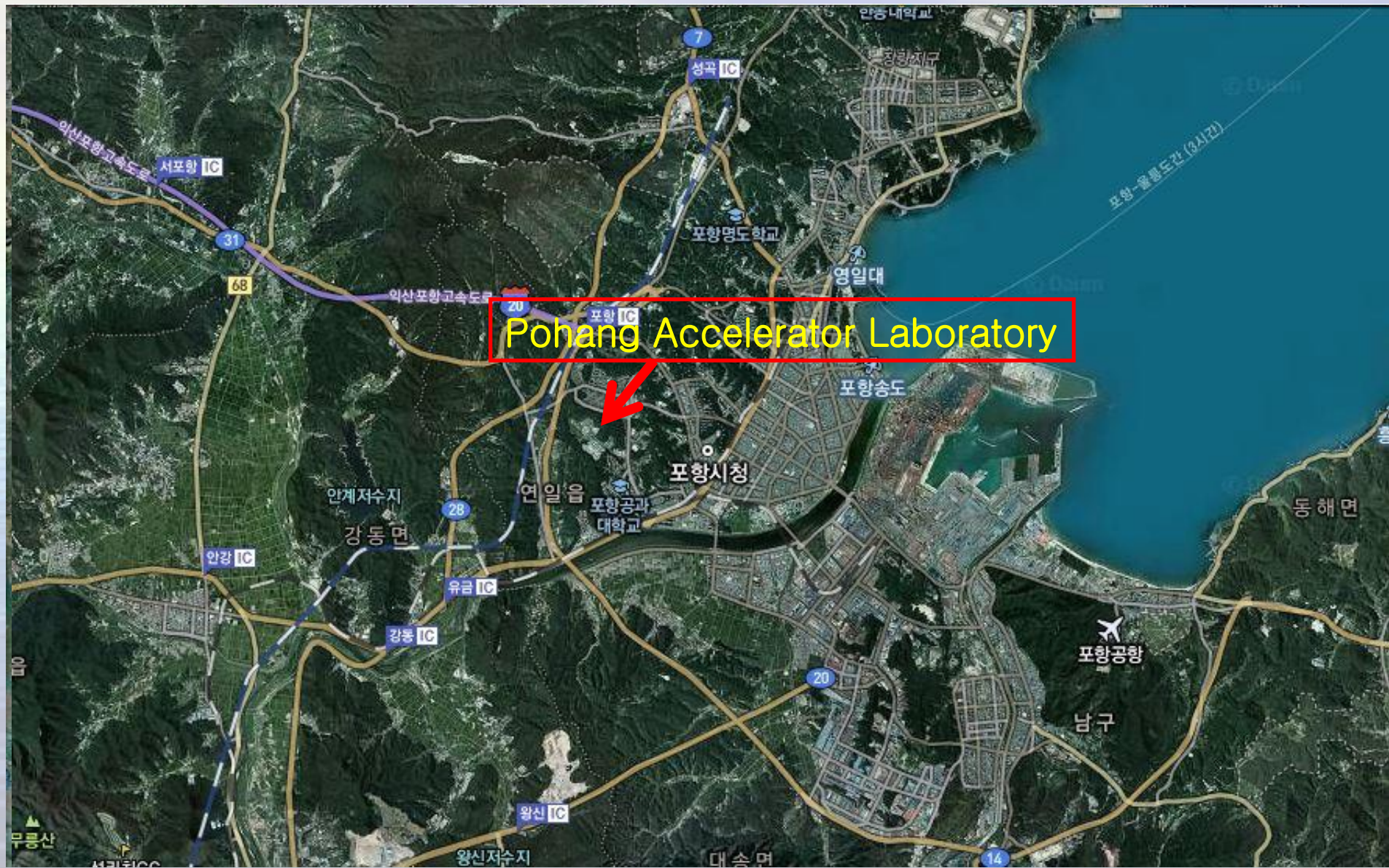
4GLS at Daresbury (124 Å)
TESLA XFEL at DESY (0.86-64 Å)
SASE-FEL at BESSY (12-600 Å)
FERMI at ELETTRA (12-15 Å)
SPARX in INFN Rome (15-135 Å)

PAL XFEL at PAL (1-50 Å)
SACLA at SPring-8 (Å)

Worldwide FEL Projects



Worldwide FEL Projects



Aerial View of PAL



July 2012

Aerial View of PAL



July 2013

Aerial View of PAL



July 2014

Aerial View of PAL

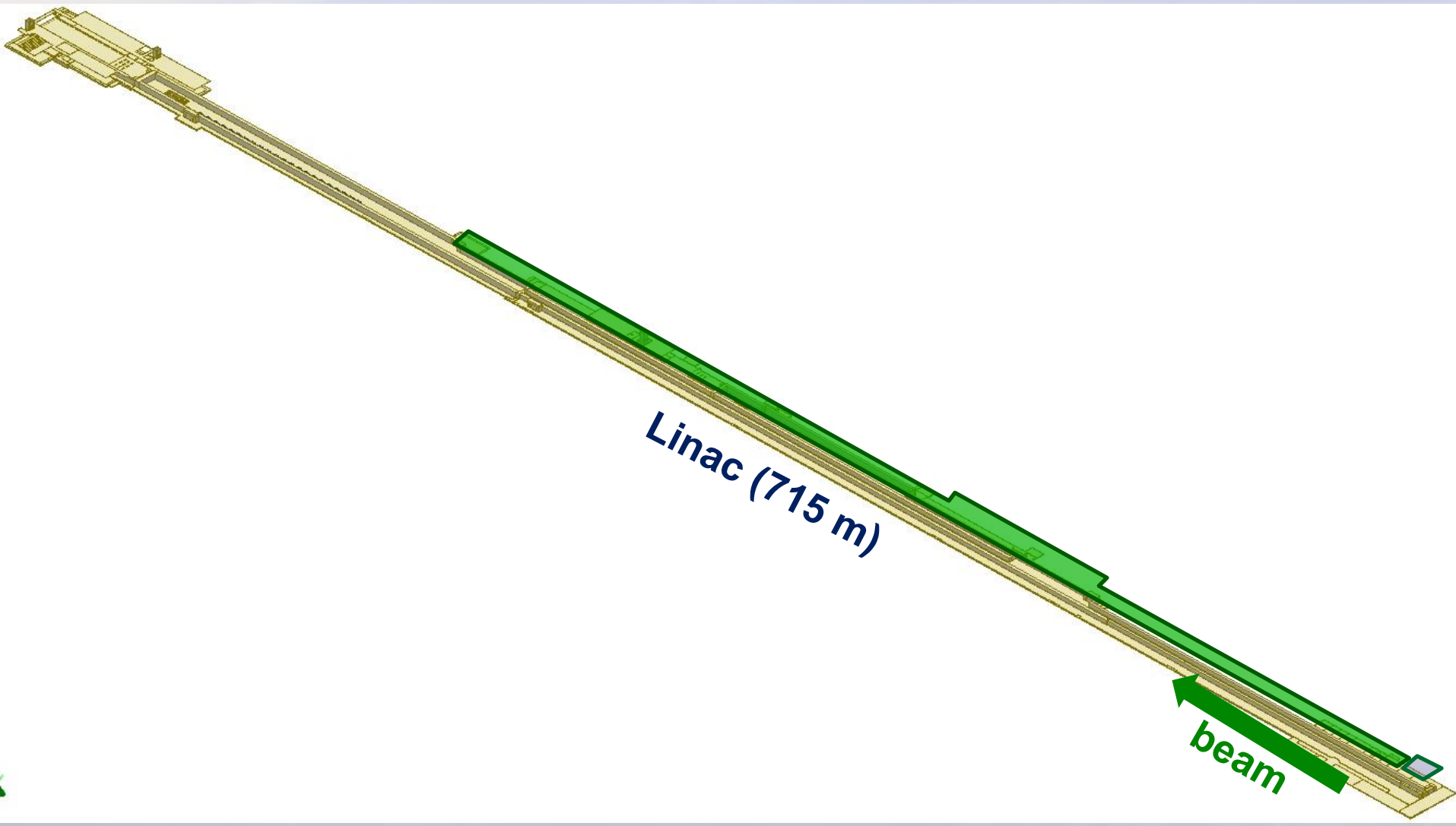


January 2015

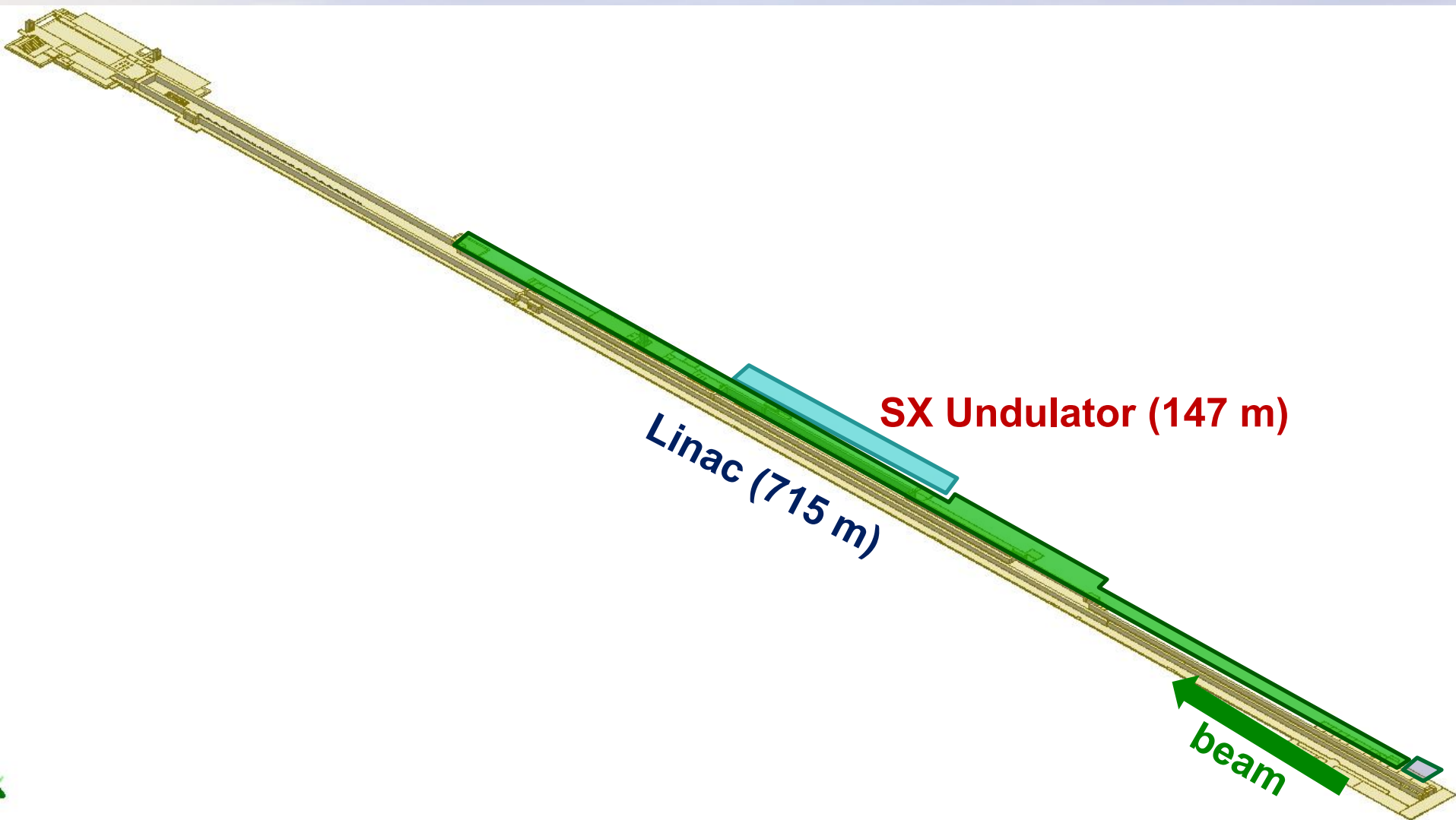
Building Layout



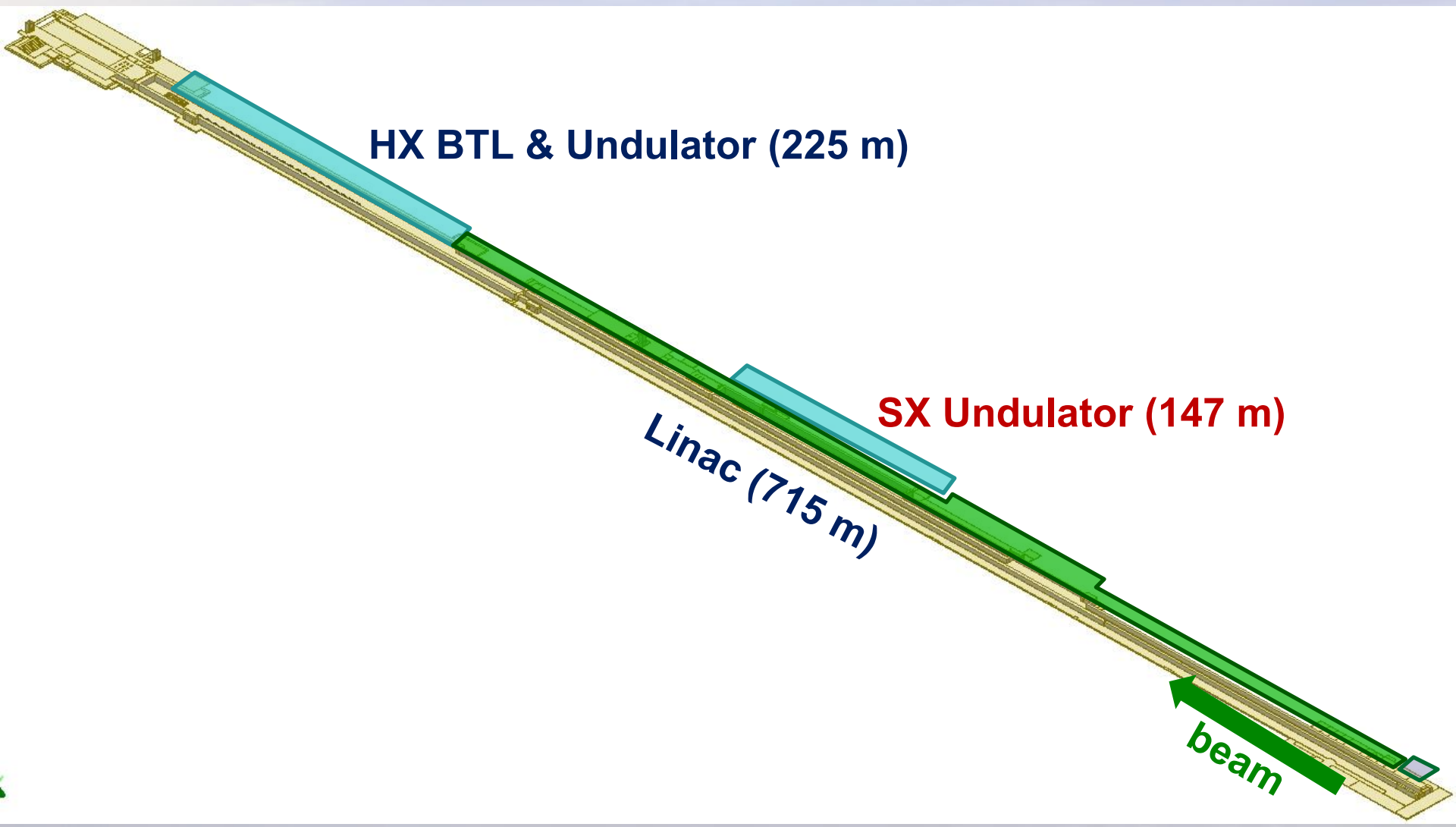
Building Layout



Building Layout



Building Layout



Building Layout

HX Experimental Hall (60 m)

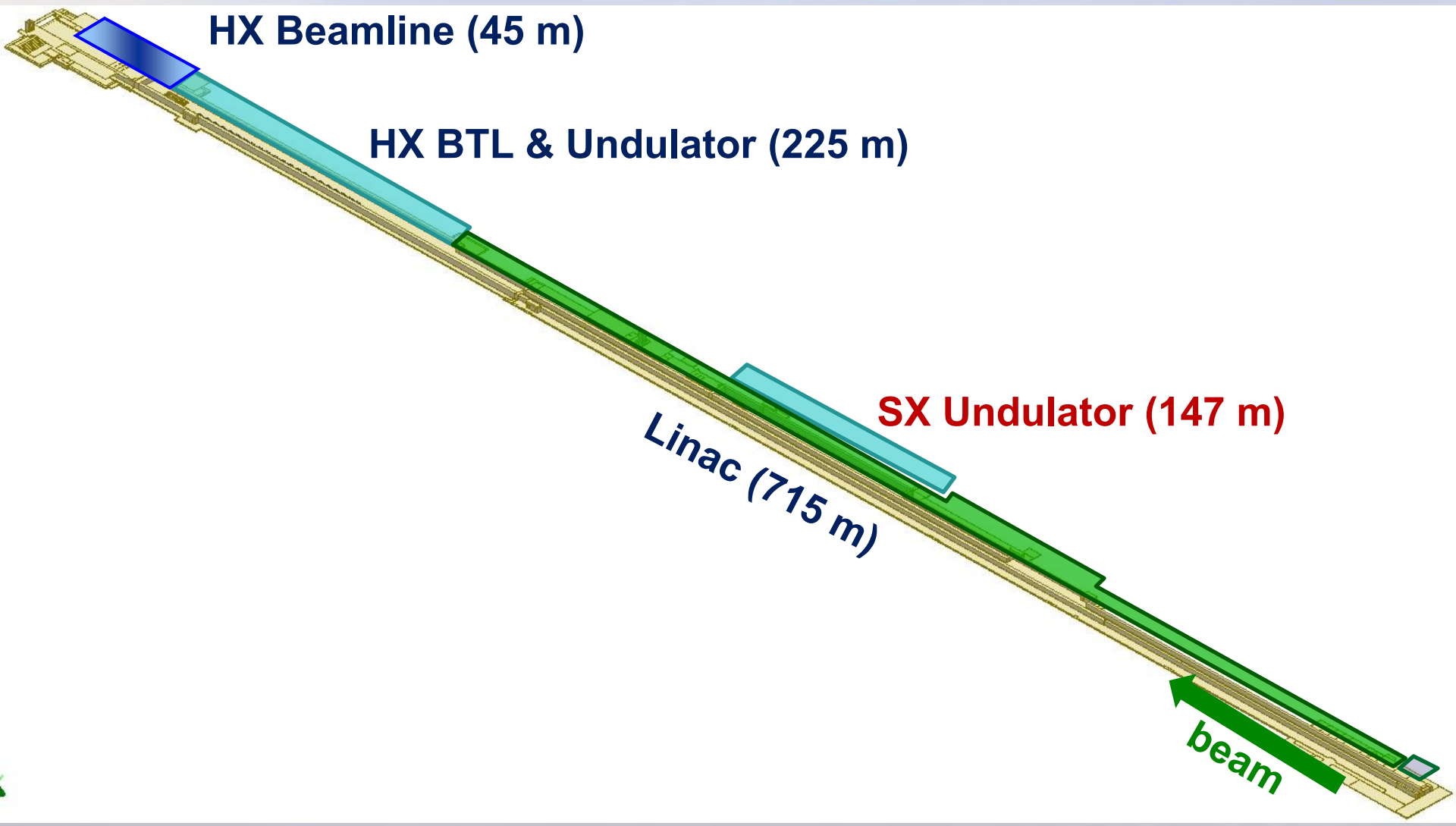
HX Beamline (45 m)

HX BTL & Undulator (225 m)

SX Undulator (147 m)

Linac (715 m)

beam



Building Layout

HX Experimental Hall (60 m)

HX Beamline (45 m)

HX BTL & Undulator (225 m)

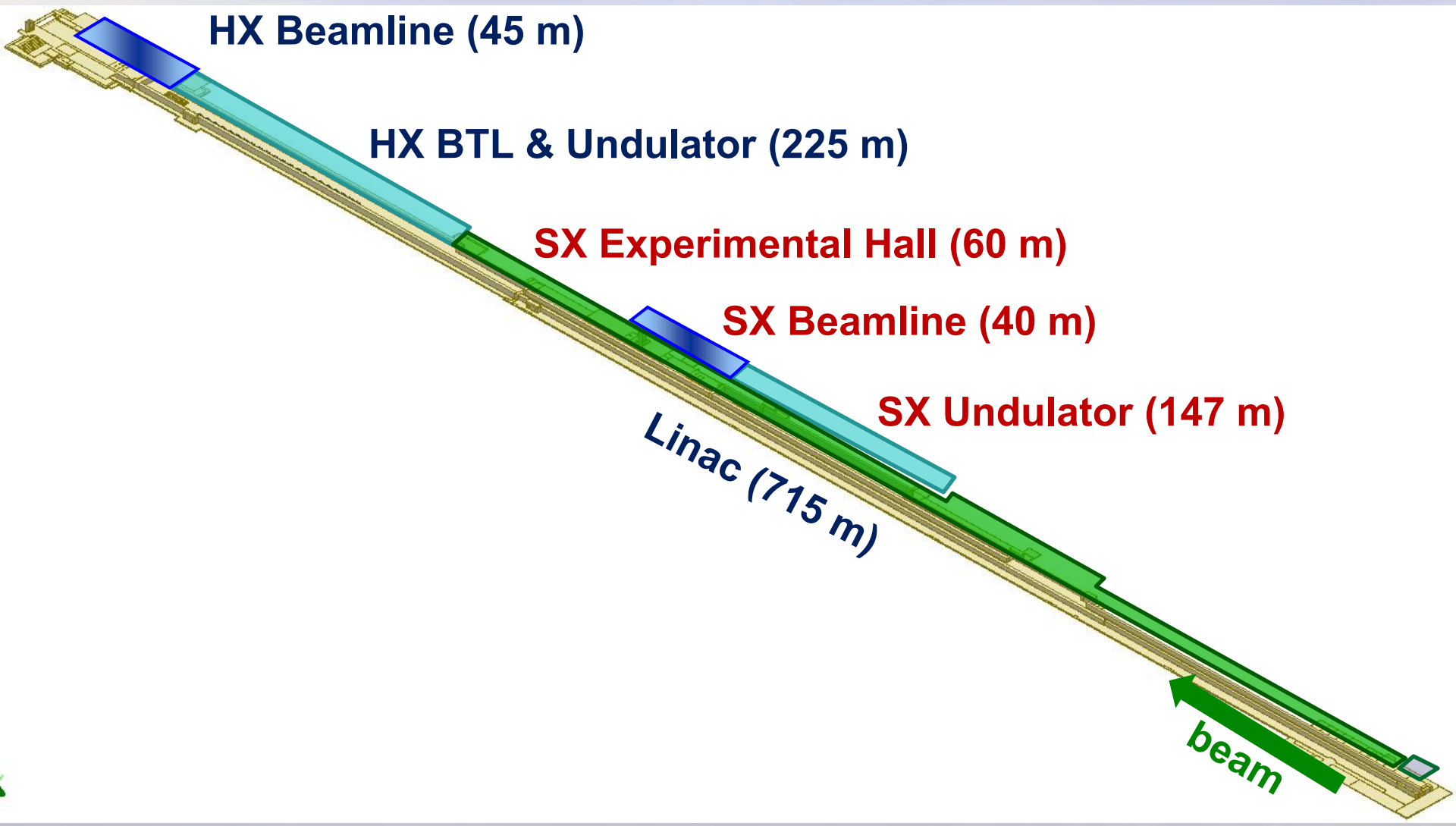
SX Experimental Hall (60 m)

SX Beamline (40 m)

SX Undulator (147 m)

Linac (715 m)

beam



Building Layout

HX Experimental Hall (60 m)

HX Beamline (45 m)

HX BTL & Undulator (225 m)

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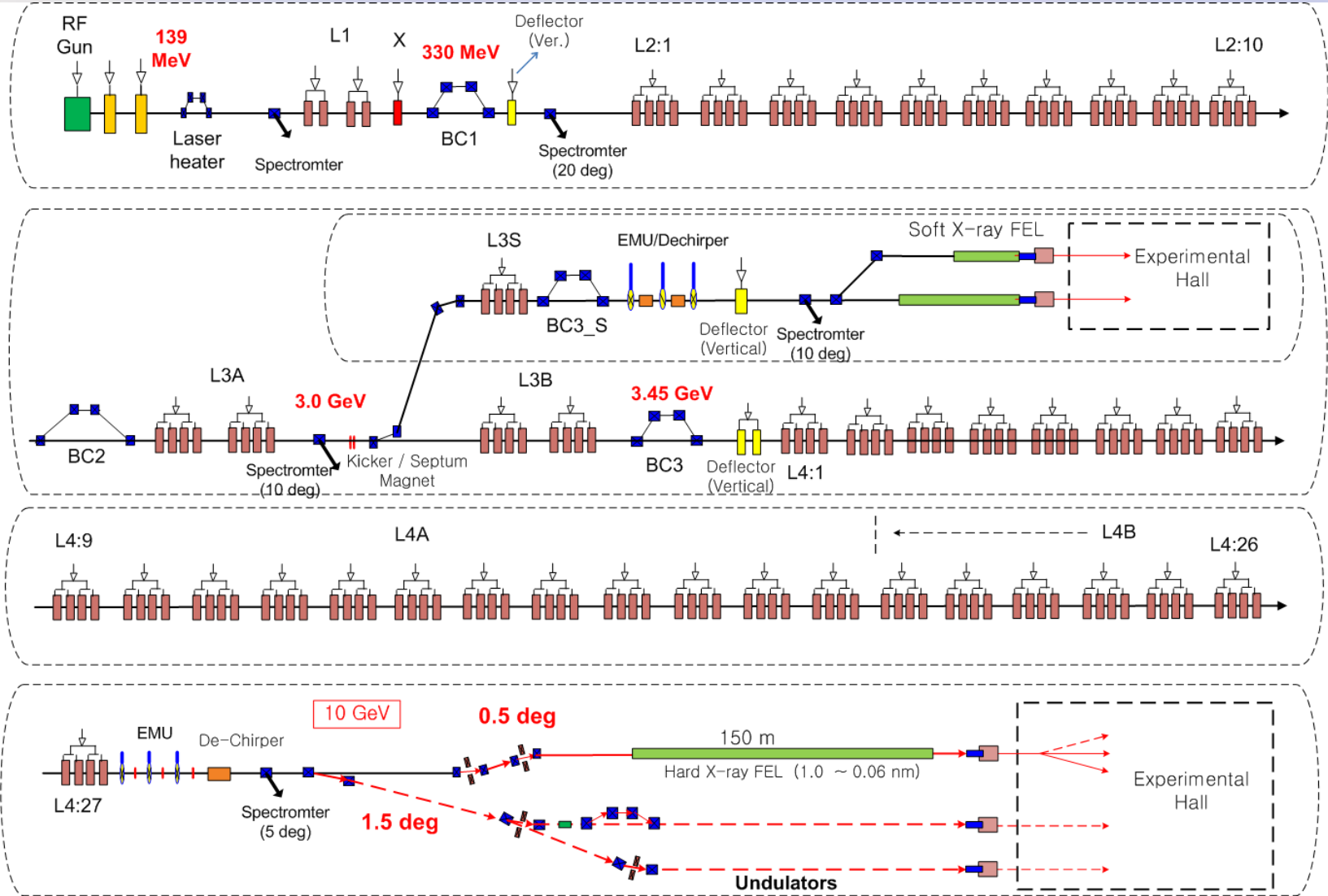
Linac (715 m)

beam

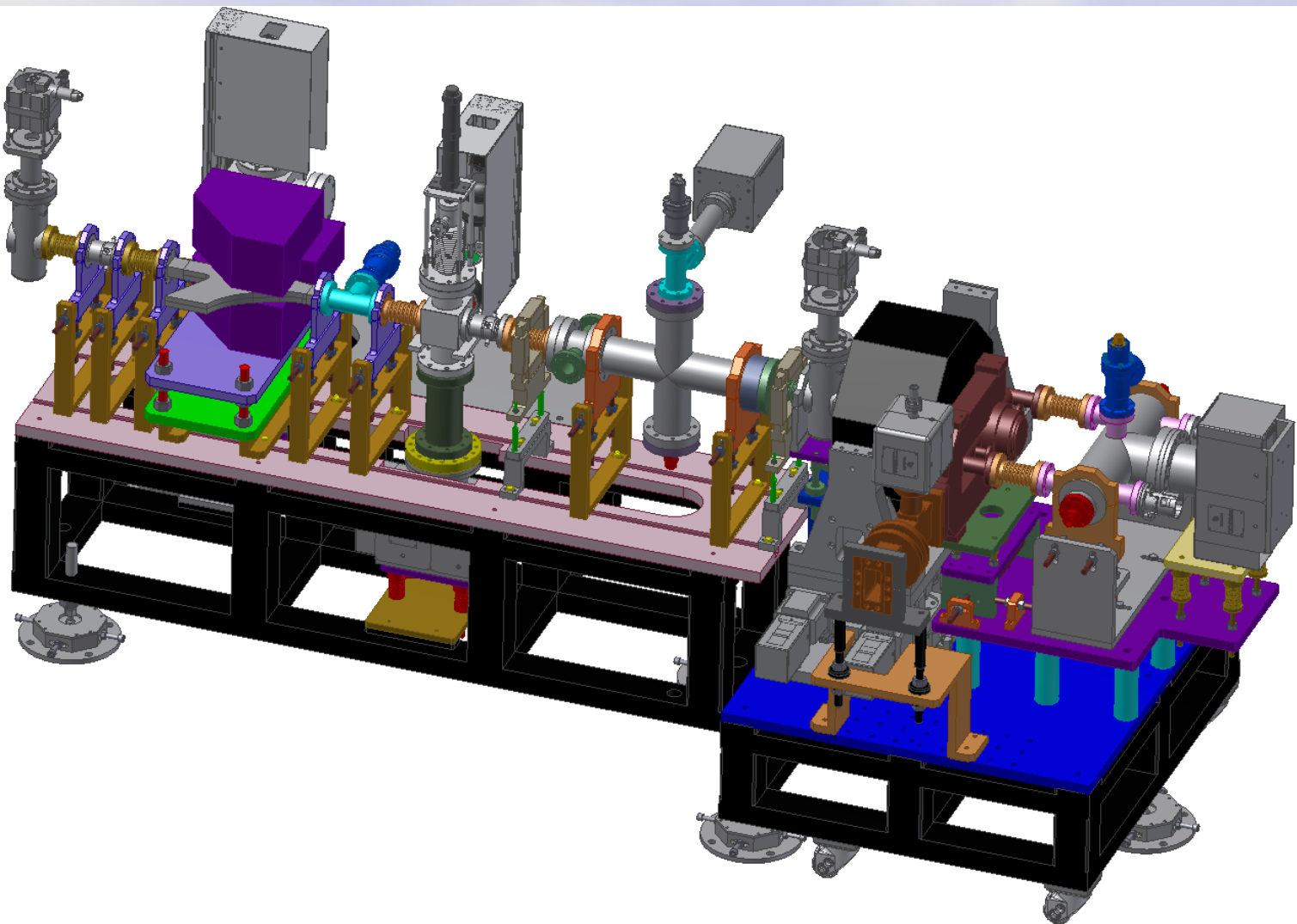
Main parameters

e ⁻ Energy	10 GeV
e ⁻ Bunch charge	20-200 pC
Slice emittance	0.4 mm mrad
Repetition rate	60 Hz
Pulse duration	5 fs – 100 fs
SX line switching	DC (Phase-1) Kicker (Phase-2)

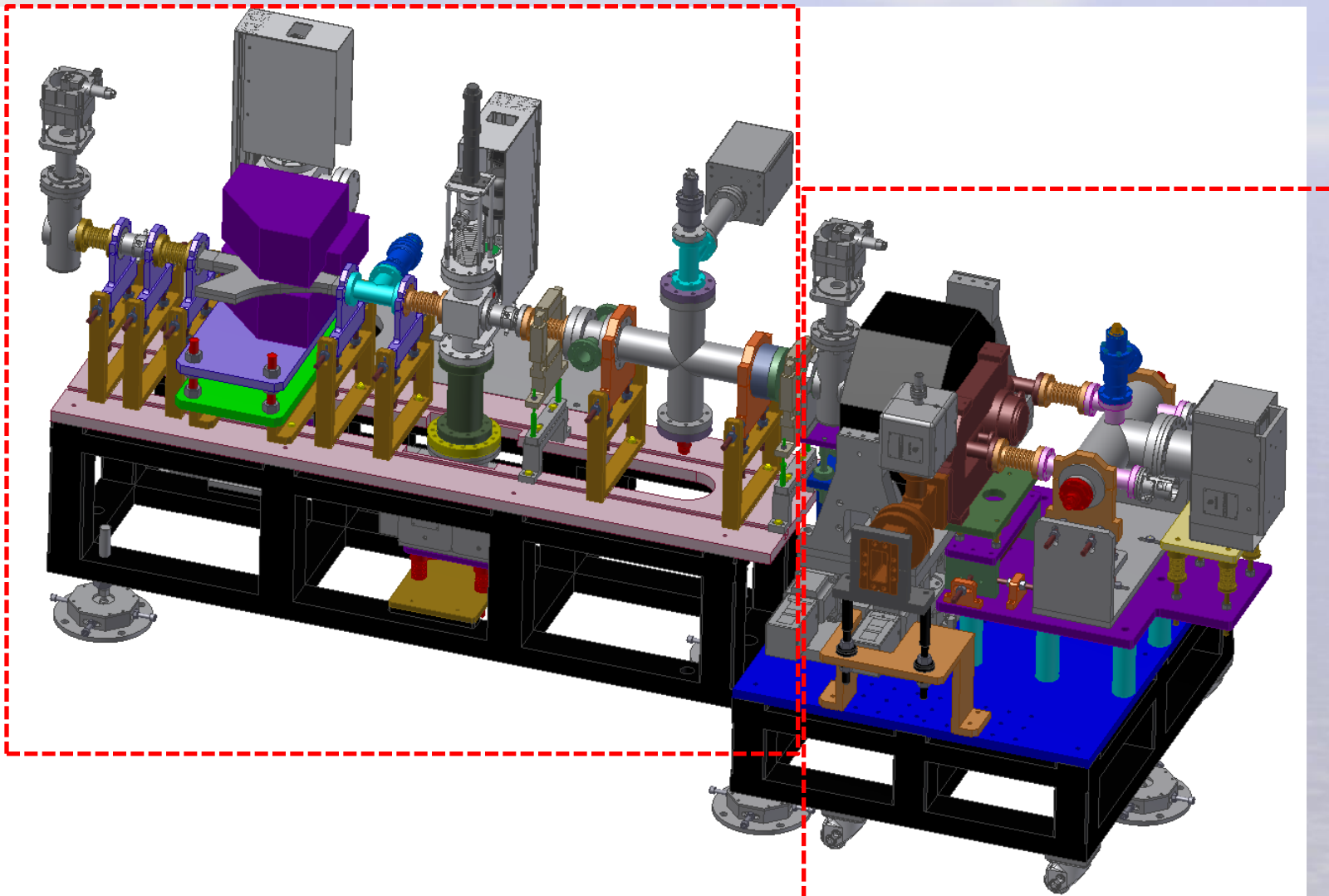
PAL-XFEL Layout



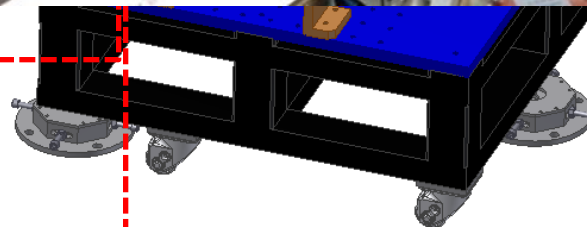
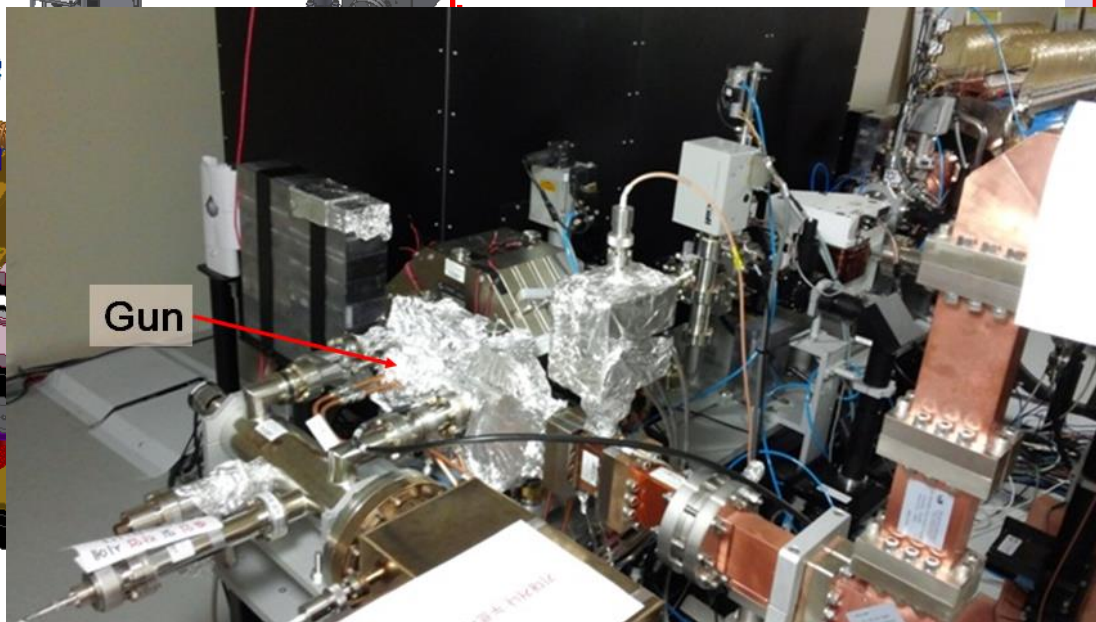
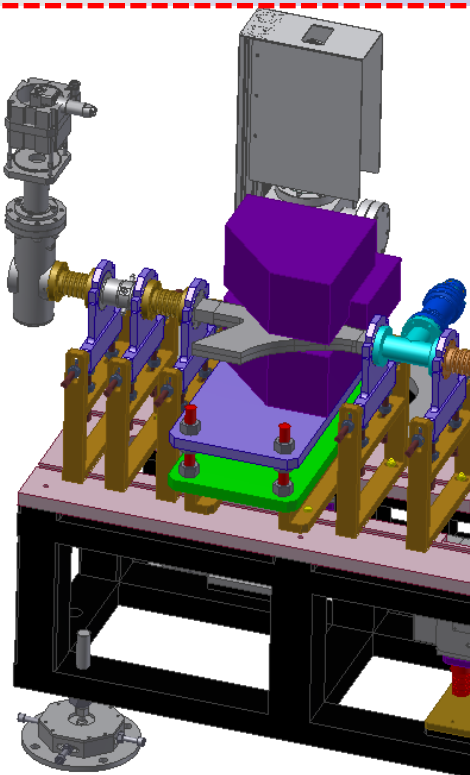
Injector



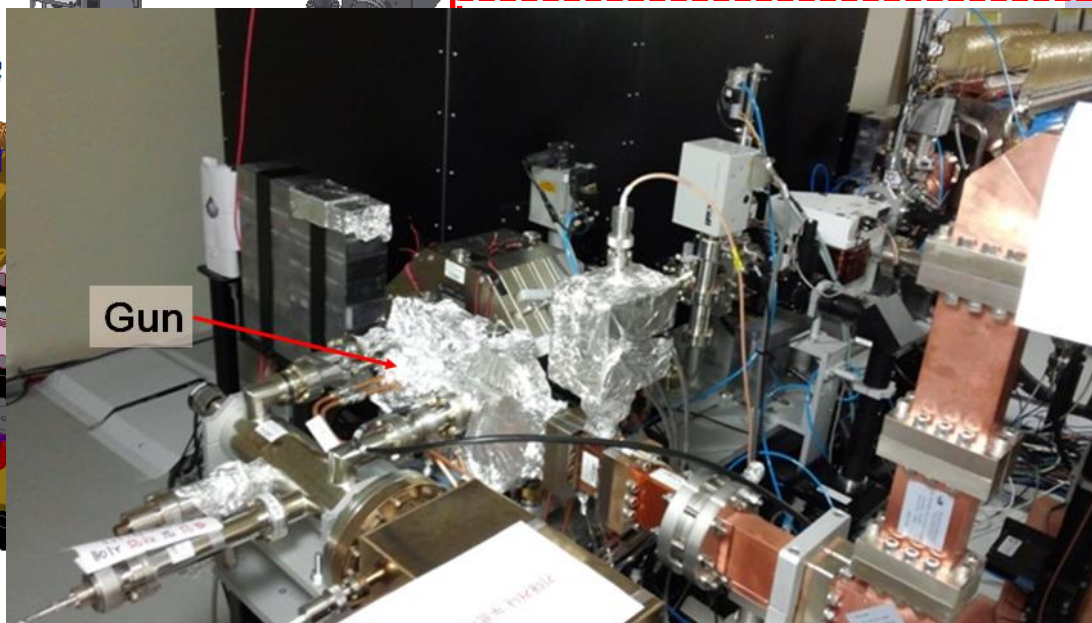
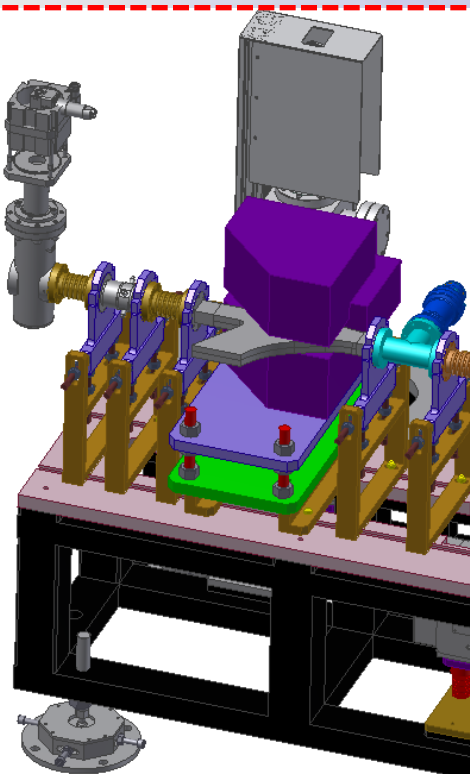
Injector



Injector

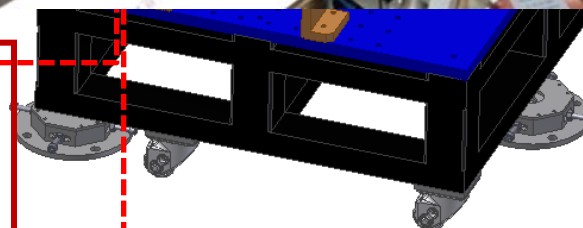


Injector



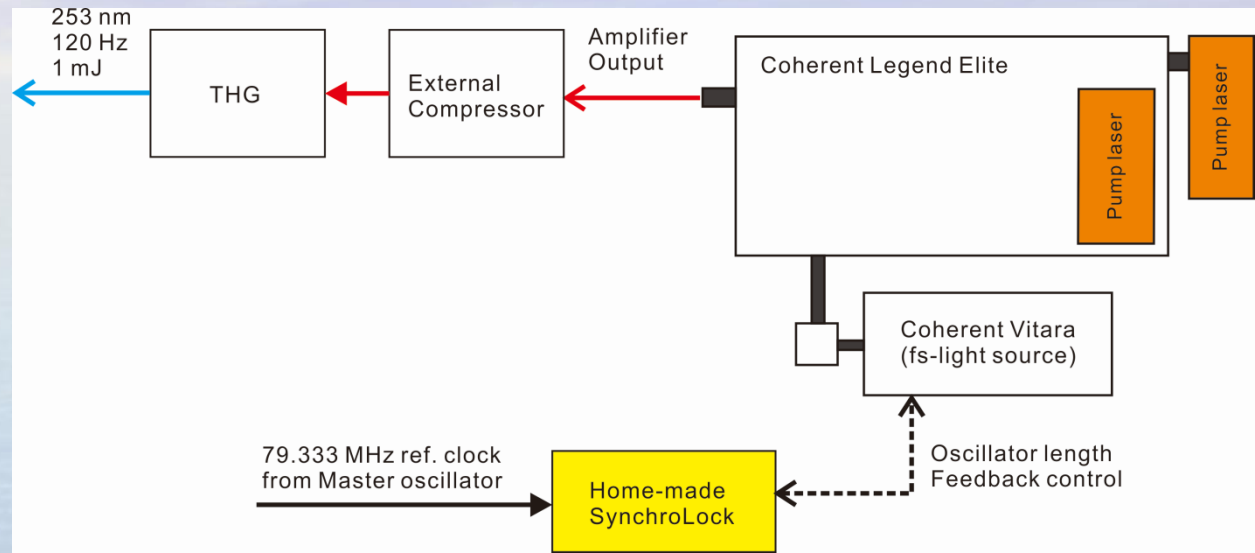
Pressure : $< 5 \times 10^{-11}$ mbar (RF GUN)

Permeability : < 1.03



Layout of Injector Laser

The light source is a commercial regenerative amplifier from Coherent Inc.



IR-light source parameters

Parameter	Value
Oscillator rep. rate	79.333 MHz
Amplifier rep. rate	120 Hz
Center wavelength	760 nm
Pulse duration	~150 ps
Pulse energy	20 mJ
Energy jitter (RMS)	~0.24 %

UV beam parameters

Parameter	Value
Center wavelength	253 nm
Pulse energy (variable)	Up to 1 mJ
Pulse duration (variable)	3~5 ps
Energy jitter (RMS)	~1 %
Beam size at gun (variable)	<1 mm

Layout of Injector Laser

The light source is a commercial regenerative amplifier from Coherent Inc.



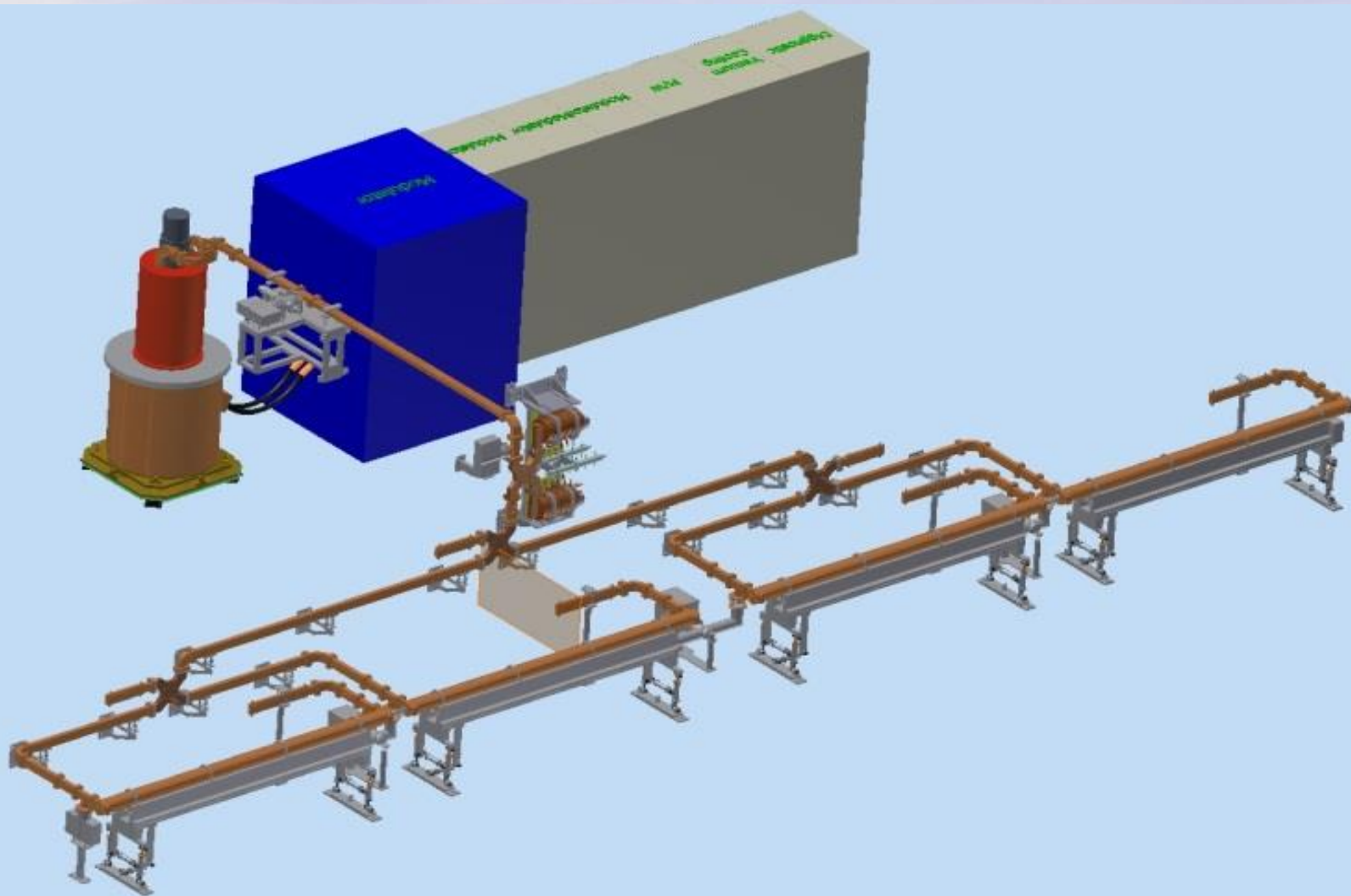
Energy jitter (RMS)

~0.24 %

Number of Major RF Components

Classification	Section	K&M	A/S	Energy Doubler	Energy (GeV)
Injector linac		3	2	0	0.139
Hard X-ray main linac	L1	2	4	0	0.33
	L2	10	40	10	2.52
	L3A	2	8	2	3.0
	L3B	2	8	2	3.45
	L4	27	108	27	10
Soft X-ray linac		1	4	1	3~3.5
Deflector (S-band)	L1, L3	3	4	0	
Linearizer (X-band)	L1	1	1	0	
Total No.		51	180	42	

Number of Major RF Components



Linac Tunnel View (L2-1)



Linac Tunnel View (L2-1)



5/6

Linac Tunnel View (L2-1)



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Linac Tunnel View (L2-1)



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Linac Tunnel View (L2-1)



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Gallery Tunnel View (L2-6)



4/1

Gallery Tunnel View (L2-6)



5/6

Gallery Tunnel View (L2-6)



6/1

Gallery Tunnel View (L2-6)



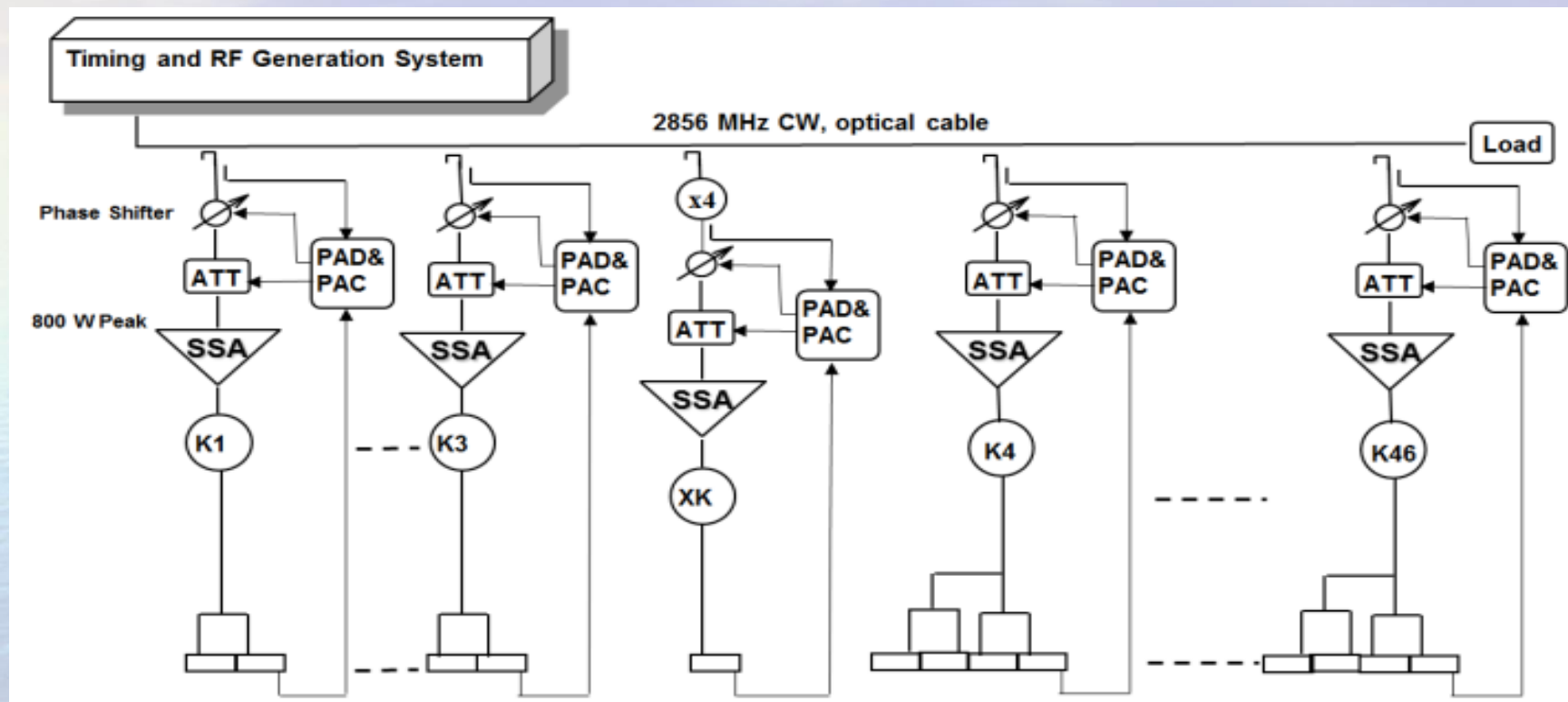
7/1

Gallery Tunnel View (L2-6)

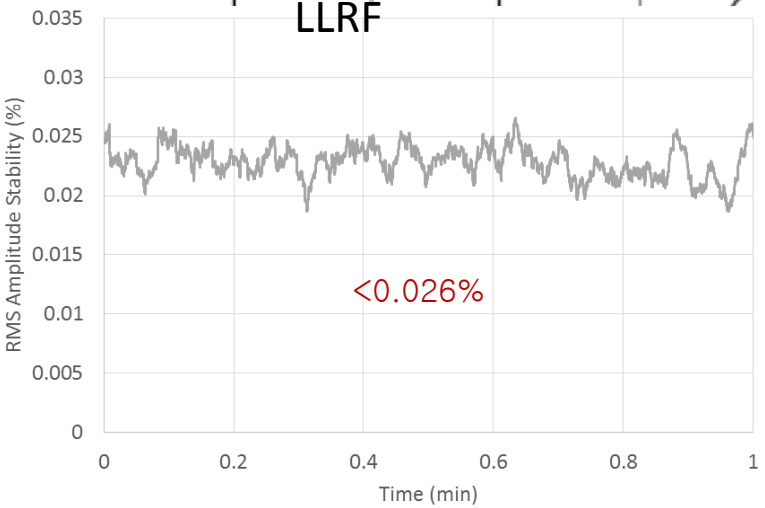
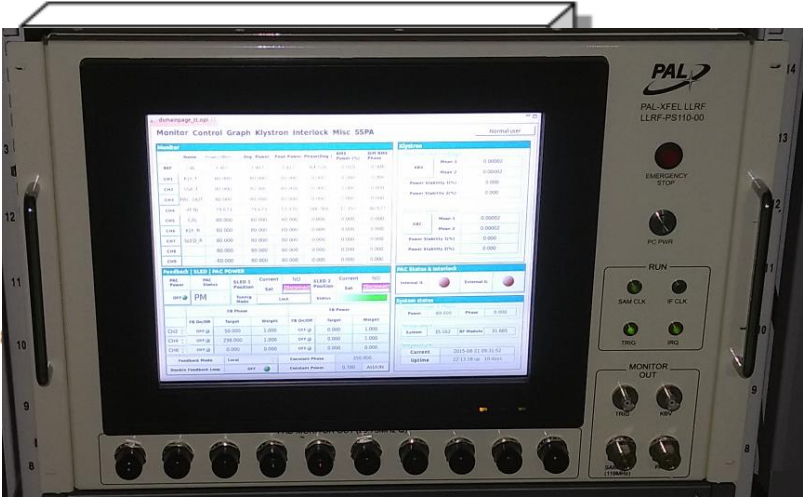


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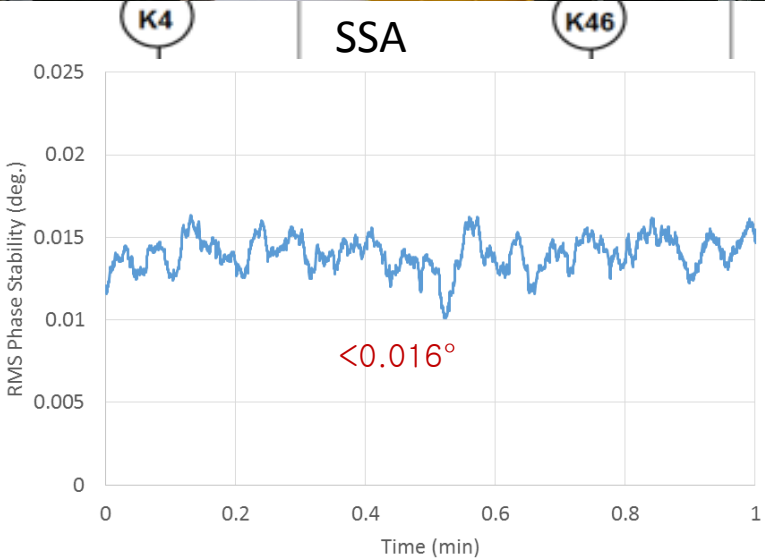
LLRF



LLRF

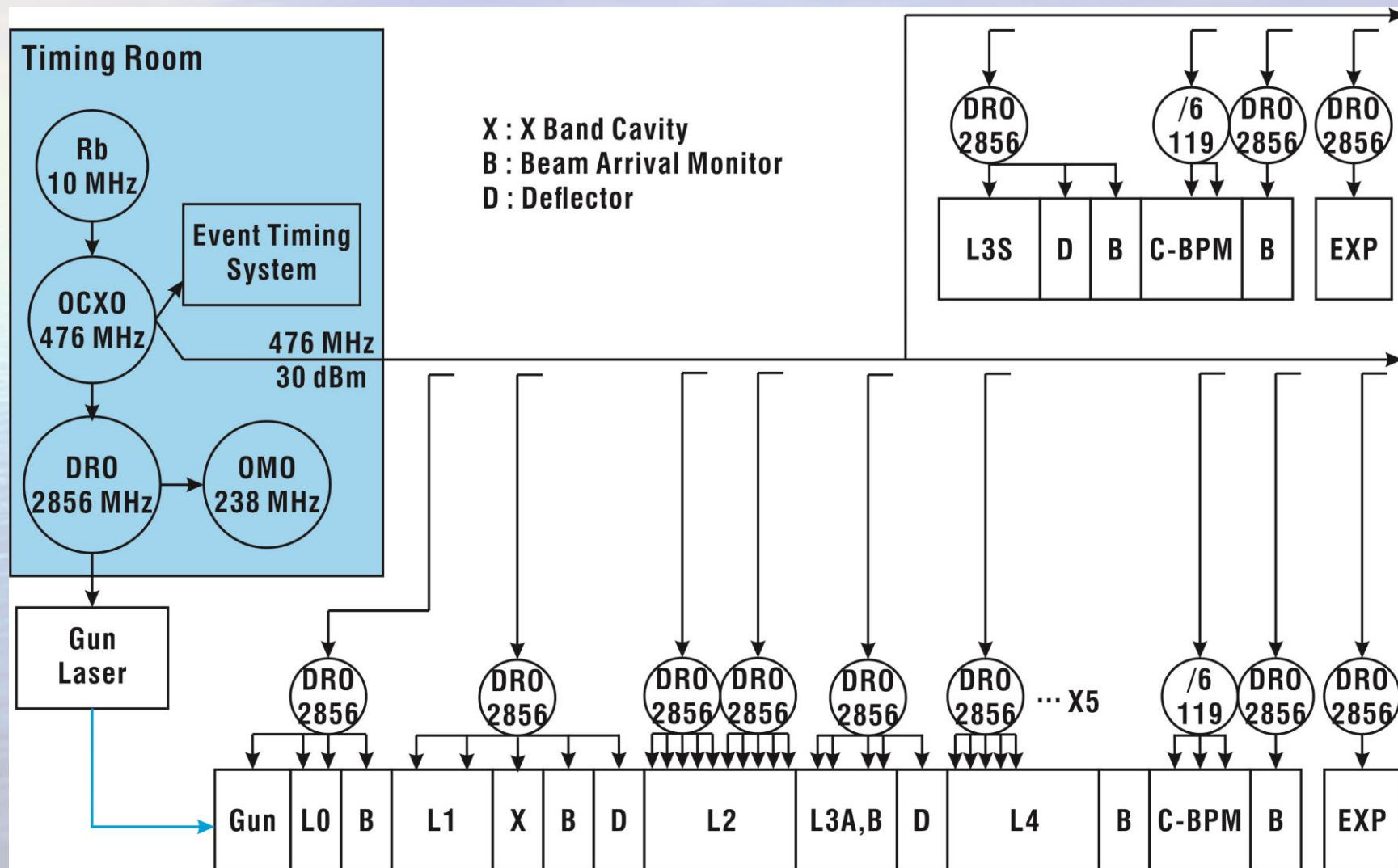


Amplitude Stability @LLRF out

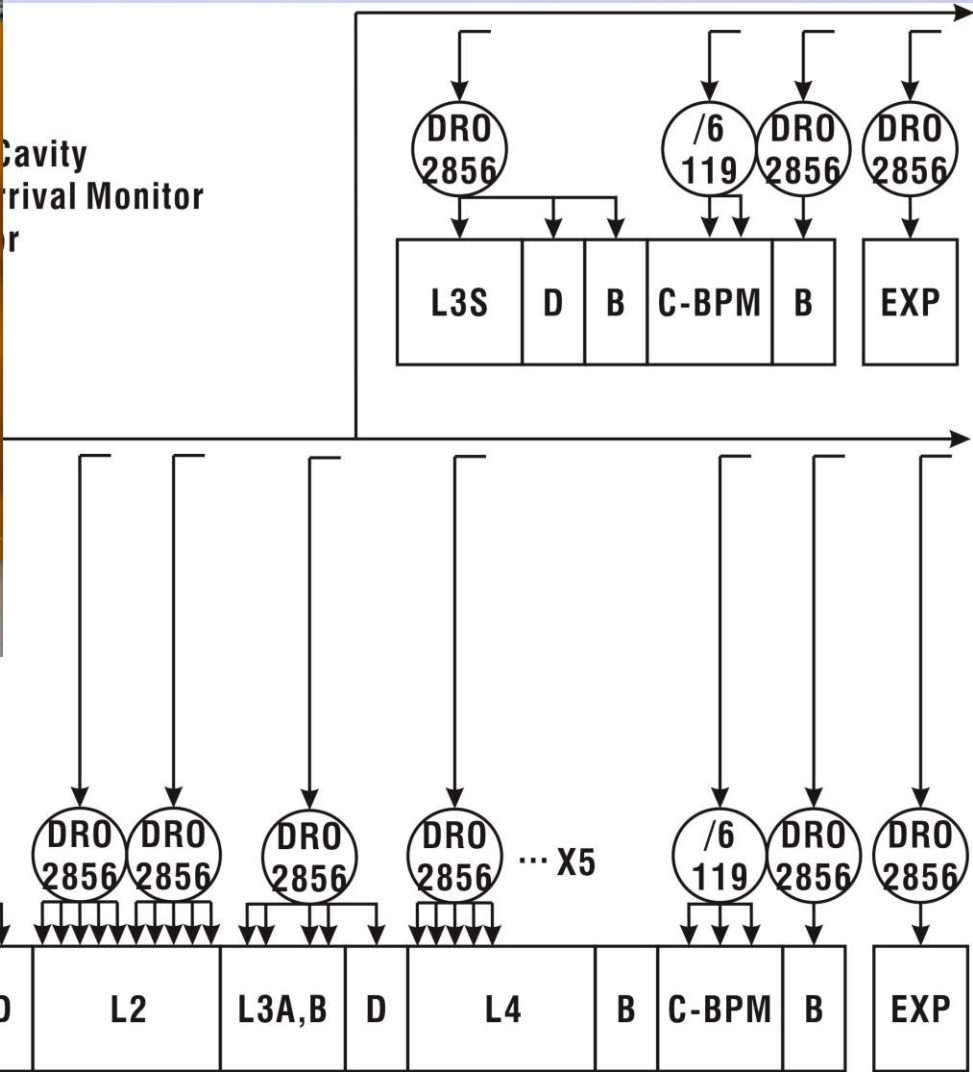


Phase Stability @LLRF out

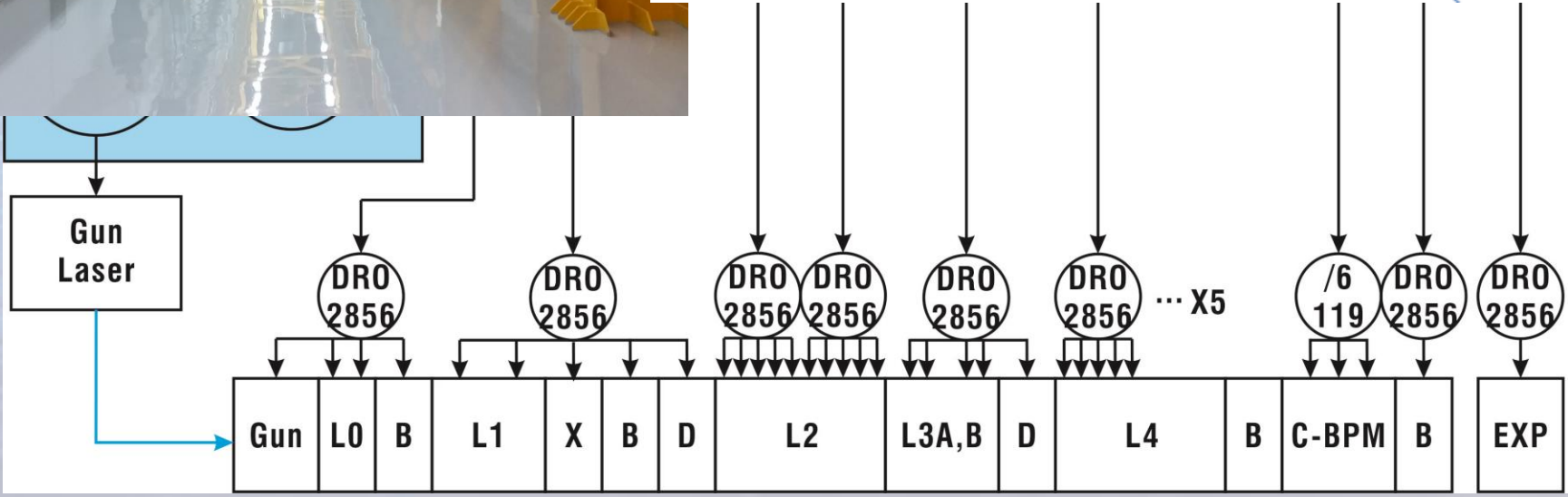
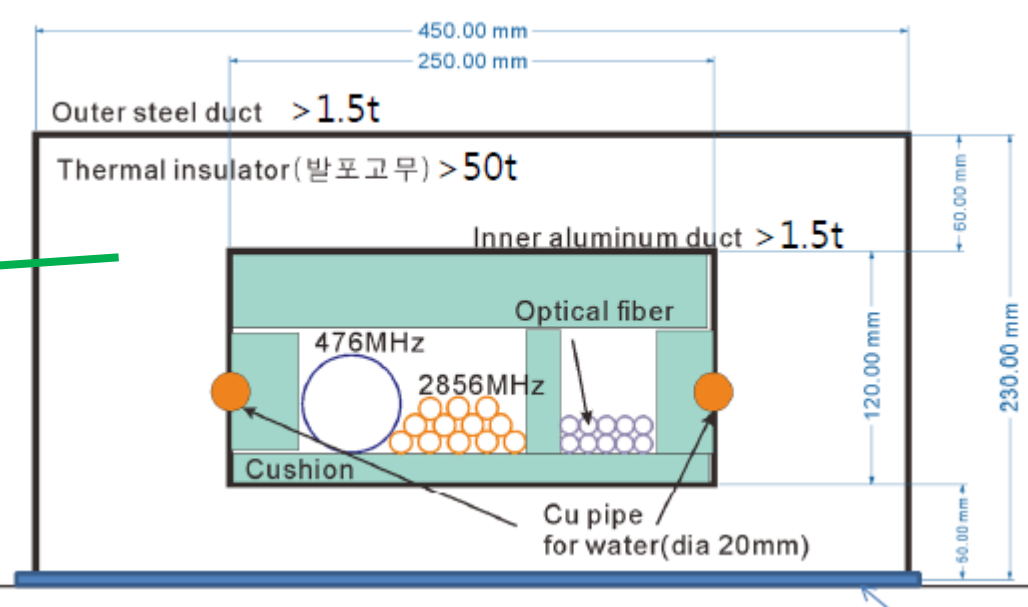
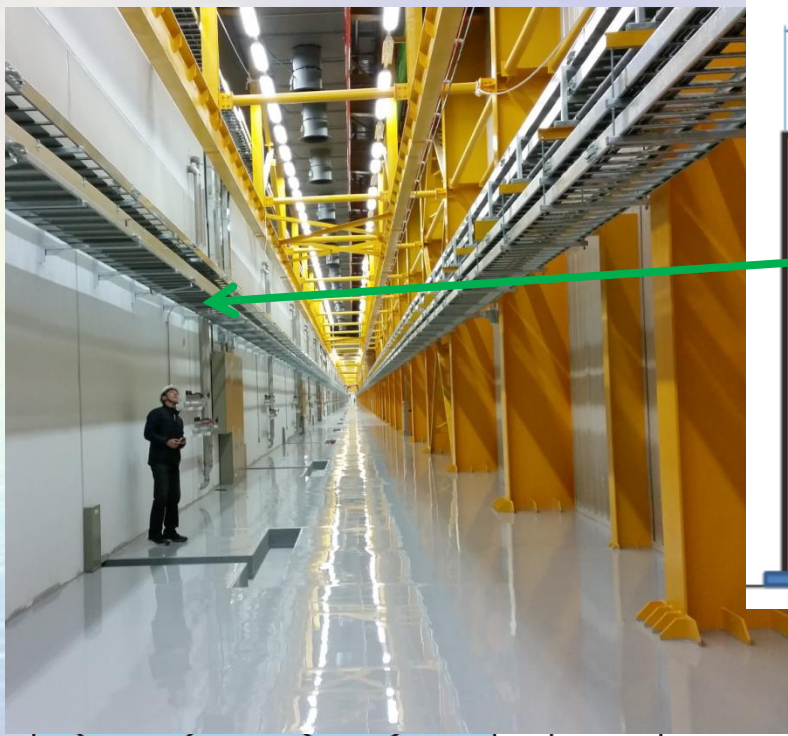
RF Timing Distribution System



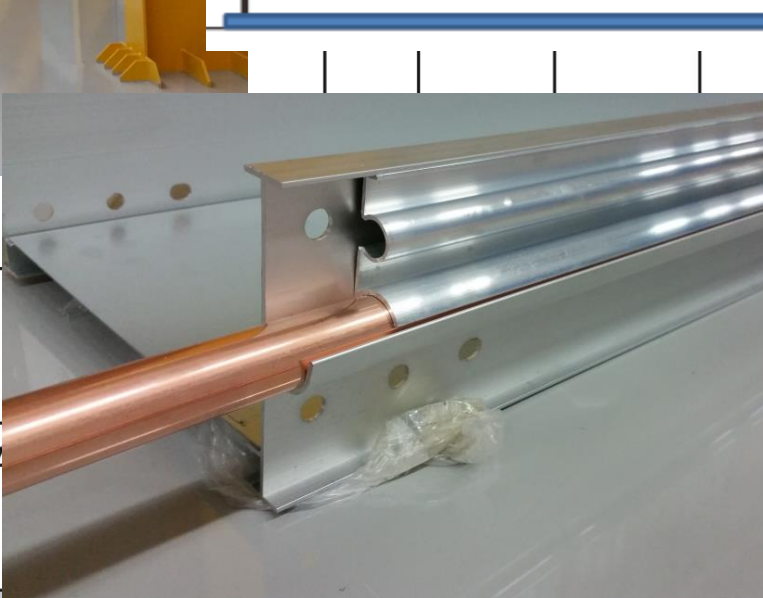
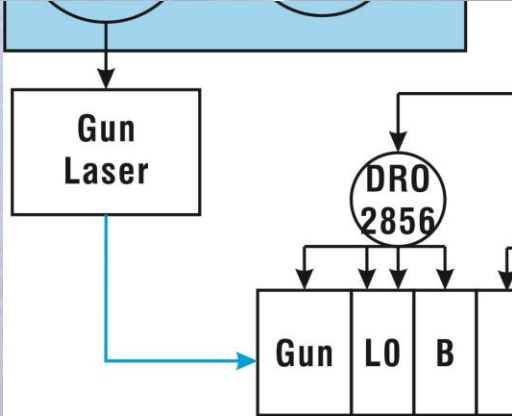
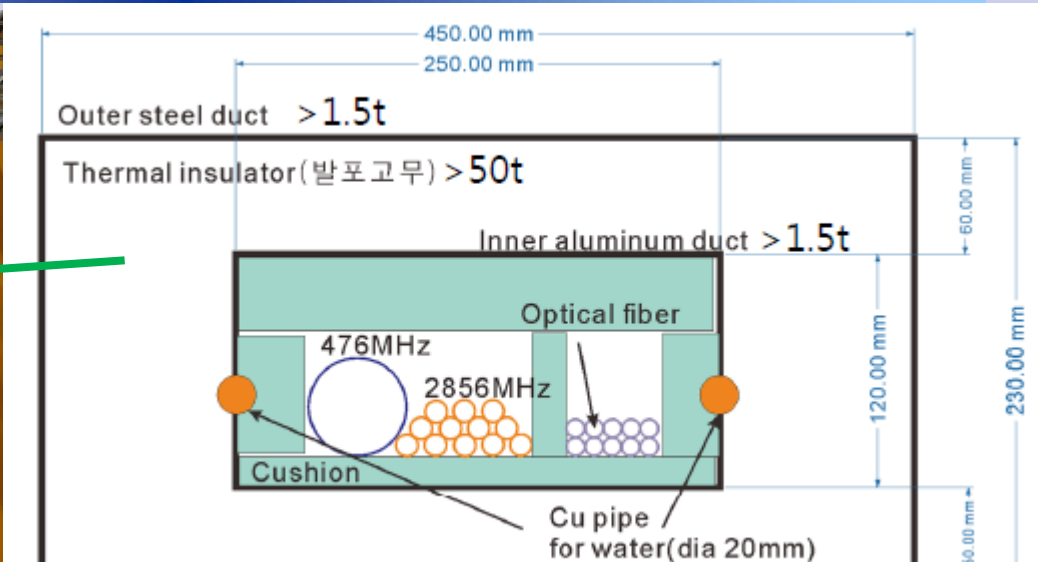
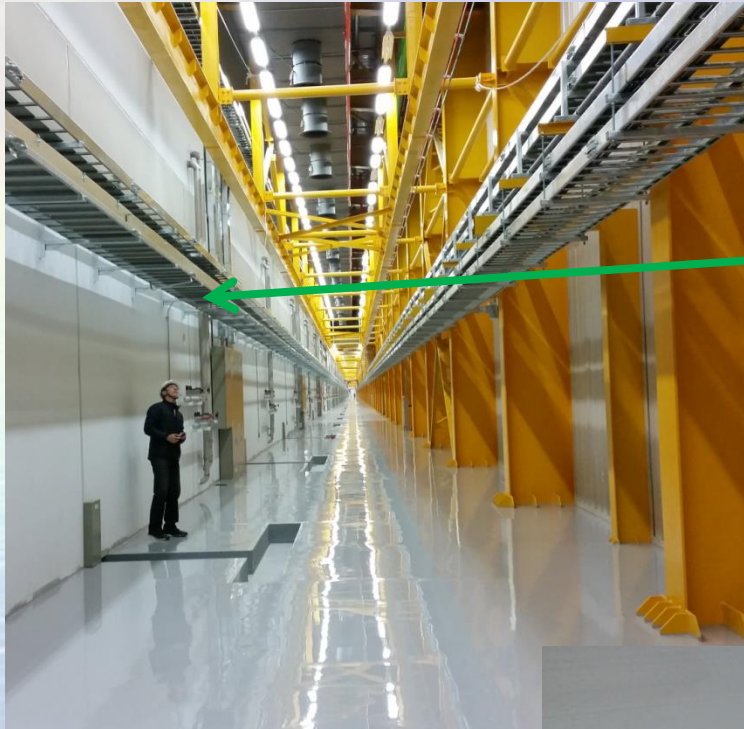
RF Timing Distribution System



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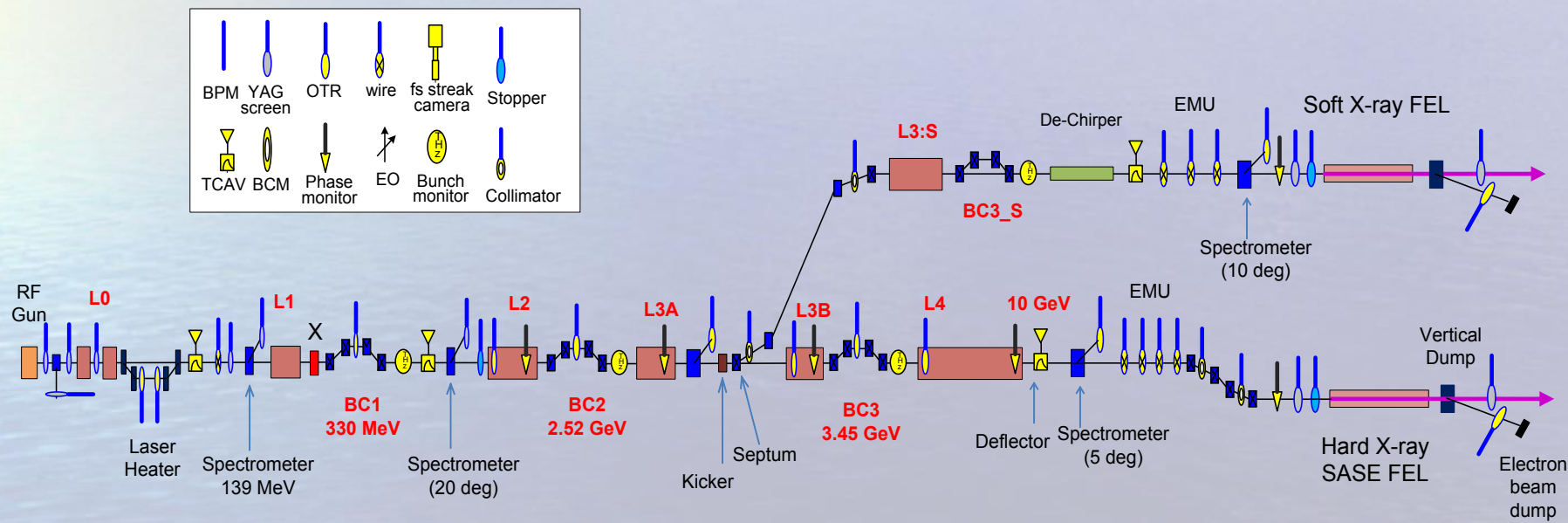
RF Timing Distribution System



Vacuum

Sector	60 l/s	30 l/s	20 l/s	Gauge	Gate Valve
HX Linac	328	27	4	157	60
HX Undulator	0	16	28	17	9
SX Linac	16	6	0	10	5
SX Undulator	0	8	15	5	7
Toatal	344	57	47	189	81

Diagnos



Diagnostics

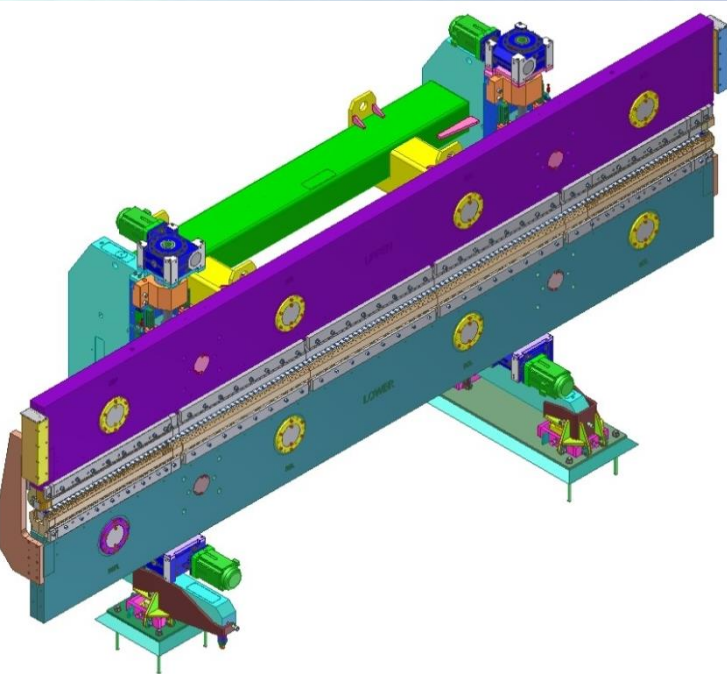
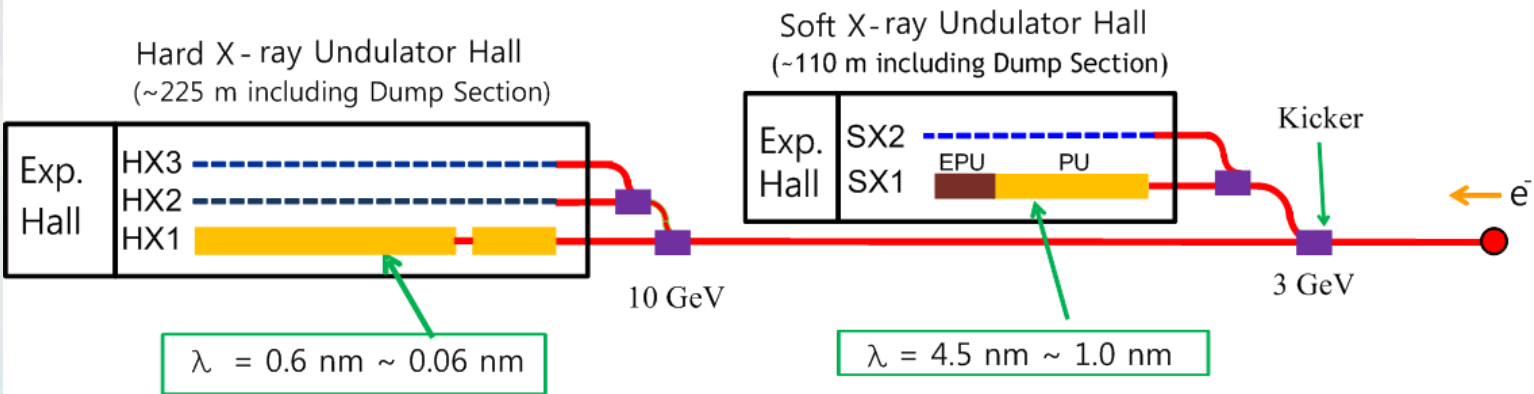
Parameter	Instruments	Number	Resolution
Beam Position & Beam Energy	Stripline BPM	160 (153+7)	< 5 μm
	Cavity BPM	49 (4+45)	< 1 μm
Beam Charge	Turbo ICT	10 (4+6)	< 1 pC
Beam Size	Screen Monitor	54 (47+7)	< 10 μm
	Wire Scanner	9 (7+2)	< 10 μm
Bunch Length	Coherent Radiation Monitor	4 (4+0)	< 50 fs
	Transverse Deflecting Cavity	3 (3+0)	< 10 fs
Beam Arrival Time	Beam Arrival Time Monitor	10 (8+2)	< 20 fs
Beam Loss	Beam Loss Monitor	26 (0+26)	—

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Magnet

Location	Type	Num.
HX Linac	Dipole	19
	Quadrupole	98
	Corrector	16
HX Undulator	Dipole	52
	Quadrupole	17
	Corrector	47
SX Linac	Dipole	33
	Quadrupole	9
	Corrector	11
SX Undulator	Dipole	26
	Quadrupole	5
	Corrector	17

Undulator



Undulator Line	HX1	SX1
Wavelength [nm]	0.06 ~ 0.6	1 ~ 4.5
Beam Energy [GeV]	4 ~ 10	3.15
Wavelength Tuning [nm]	0.6 ~ 0.1 (energy) 0.1 ~ 0.06 (Gap)	4.5 ~ 3 (Beam energy) 3 ~ 1 (Undulator gap)
Undulator Type	Planar variable gap, out-vacuum	Planar + APPLE II variable gap, out-vacuum
Undulator Period / Gap [mm]	26 / 8.3	35 / 8.3
Operation Mode	SASE (2016) Self-Seeding (2017)	SASE

Undulator

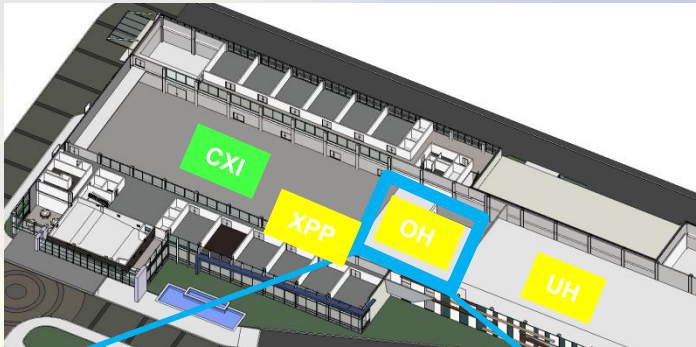
Soft X-ray Undulator Hall



Undulator

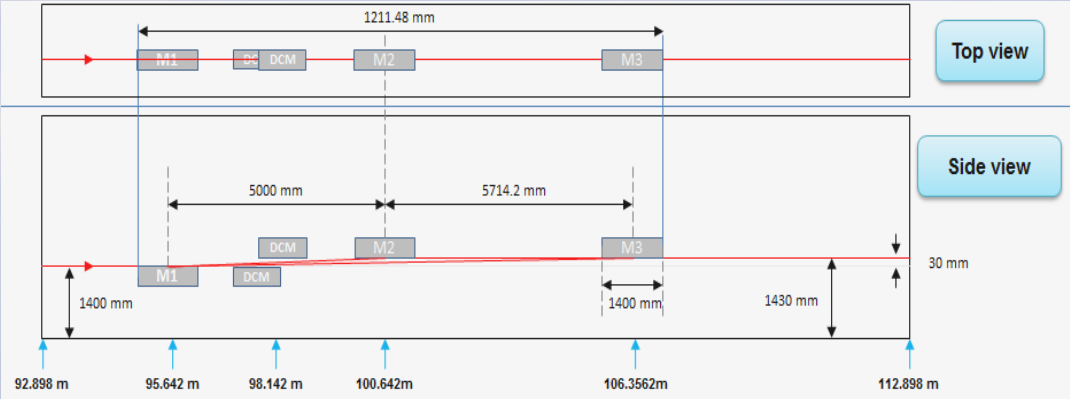
Soft X-ray Undulator Hall





Hard X-ray Optics Hall

Beam Delivery Mode



- Low Energy Mode : 5 – 10 keV (M1+M2)
- High Energy Mode : 10 – 12 keV (M1+M3)
- Narrow Bandwidth Mode : DCM Monochromatic beam

Energy Range		5-12 keV
Optics	Unfocused Beam	200 X 200 micron (FWHM)
	CRL	10 X 10 micron (FWHM)
		3 X 3 micron (FWHM)
		Si(111)
Flux	Chemistry	Si(220)
		Ge(111)
		10 ¹² -10 ¹³ photons/pulse
Energy Bandwidth	Narrow	DCM
	Mid	Offset Mirror
Pulse Width	Tunability	30 fs @ 10 ¹¹ photons/pulse
		100 fs @ 5x10 ¹¹ photons/pulse

Beam Delivery Mode



Hard X-ray Optics Hall

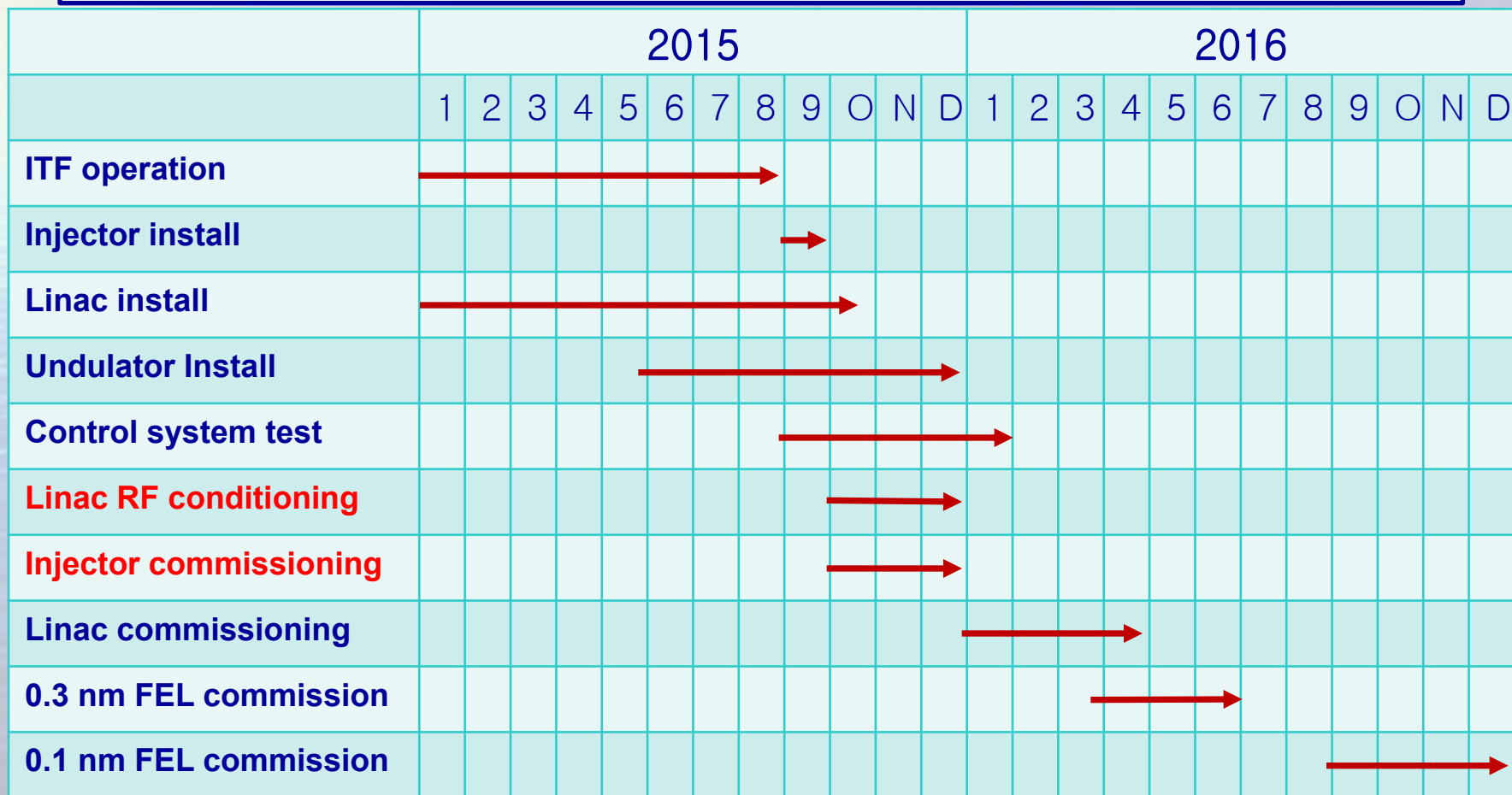
PAL XFEL Accelerator Division

100 fs @ 5×10^{11} photons/pulse

H.S. Lee Pohang Accelerator Laboratory, lhs@postech.ac.kr

Installation & Commissioning

- Linac RF conditioning / Injector commissioning 2015. 10 ~ 2015. 12
- 1st FEL commissioning for 0.3 nm HX @10 Hz 2016. 01 ~ 2016. 06
- 2nd FEL commissioning for 0.1 nm HX @10 Hz 2016. 09 ~ 2016. 12



Thanks for Your Attenuation!

Let's go Brighter !