THAI SYNCHROTRON NATIONAL LAB

SPS-II : A 4th Generation Synchrotron Light Source in Southeast Asia

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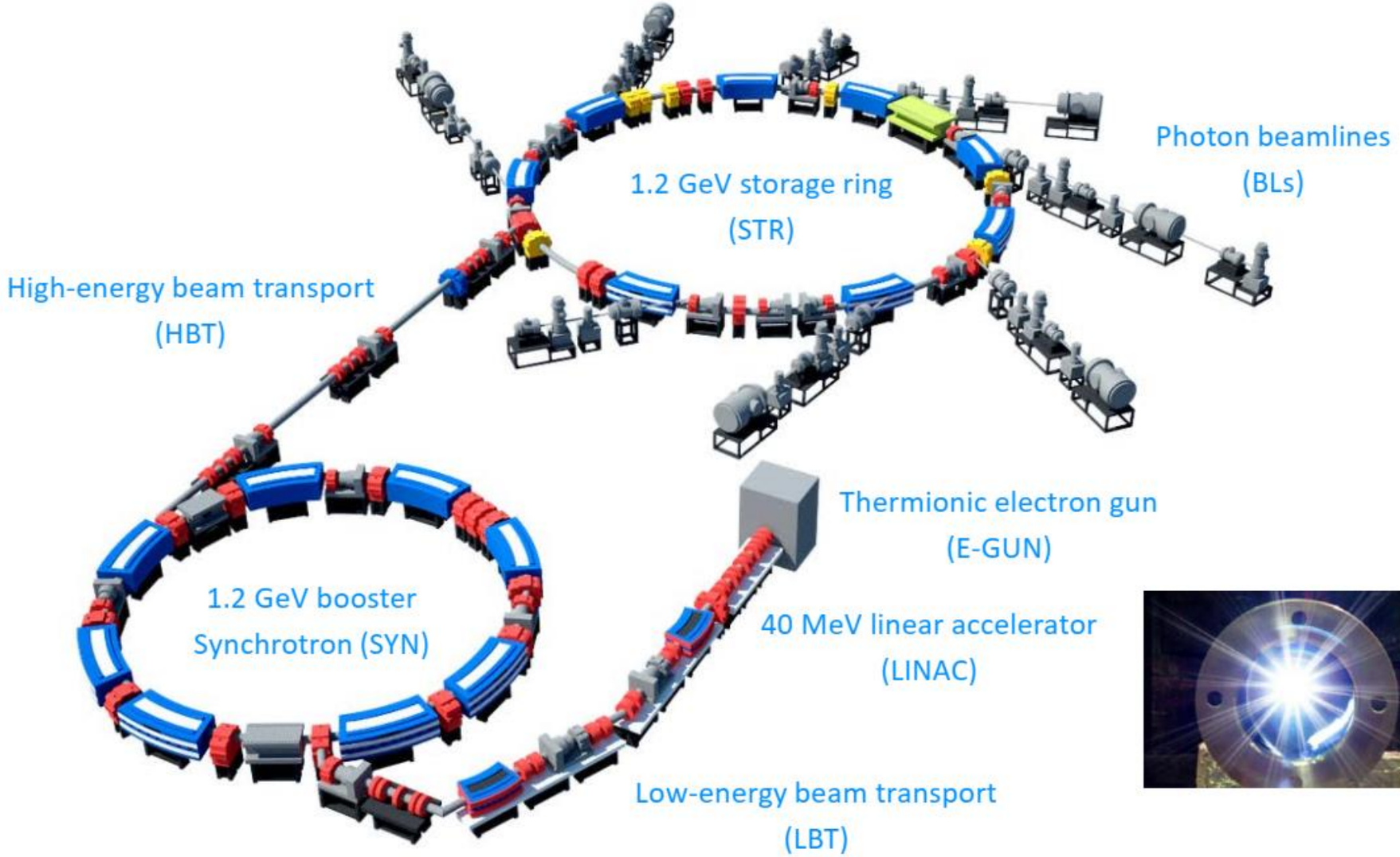
Synchrotron Light Research Institute, Thailand

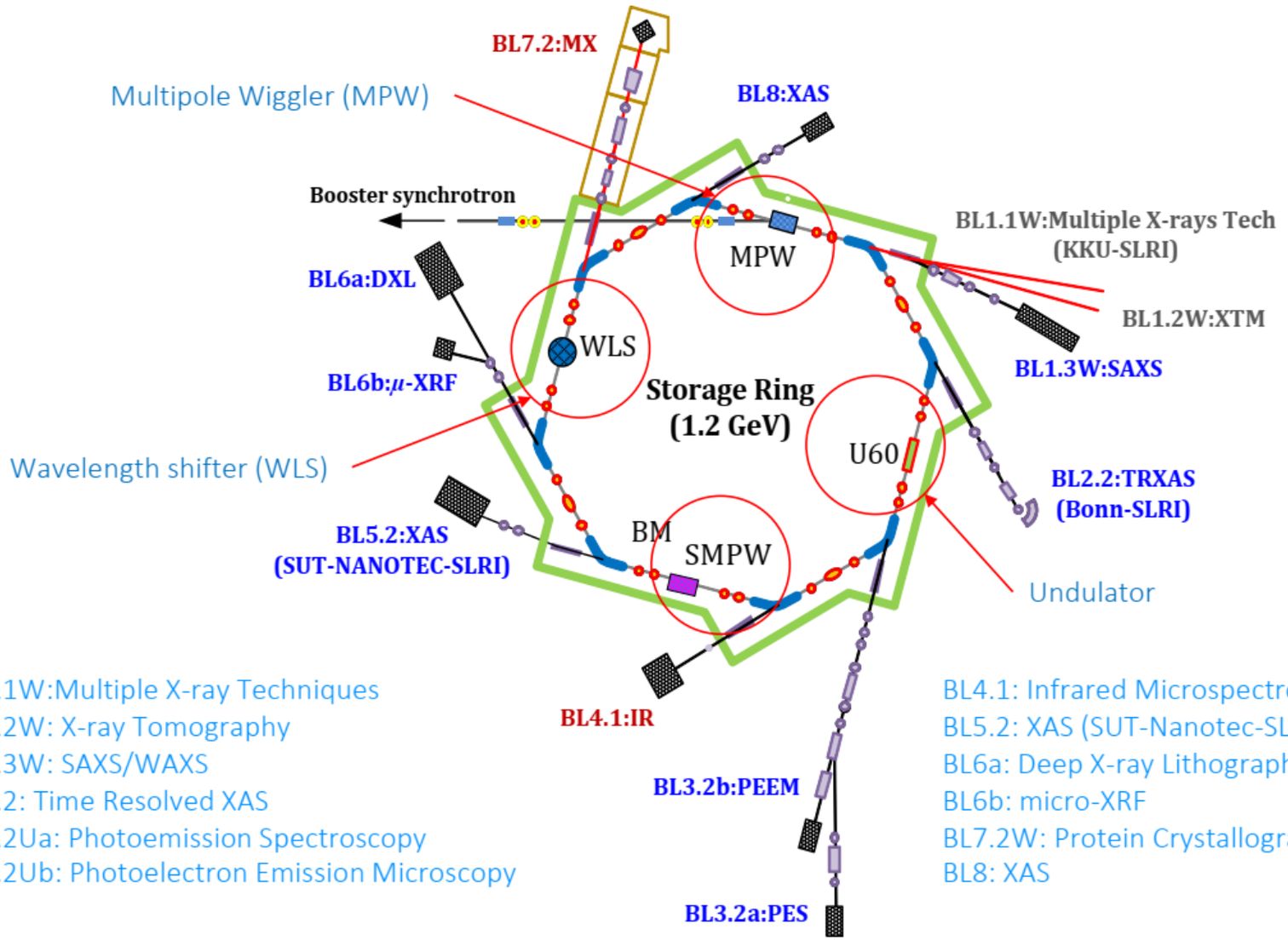
Siam Photon

13 June 2022, IPAC 2022, Thailand

Siam Photon Source - I



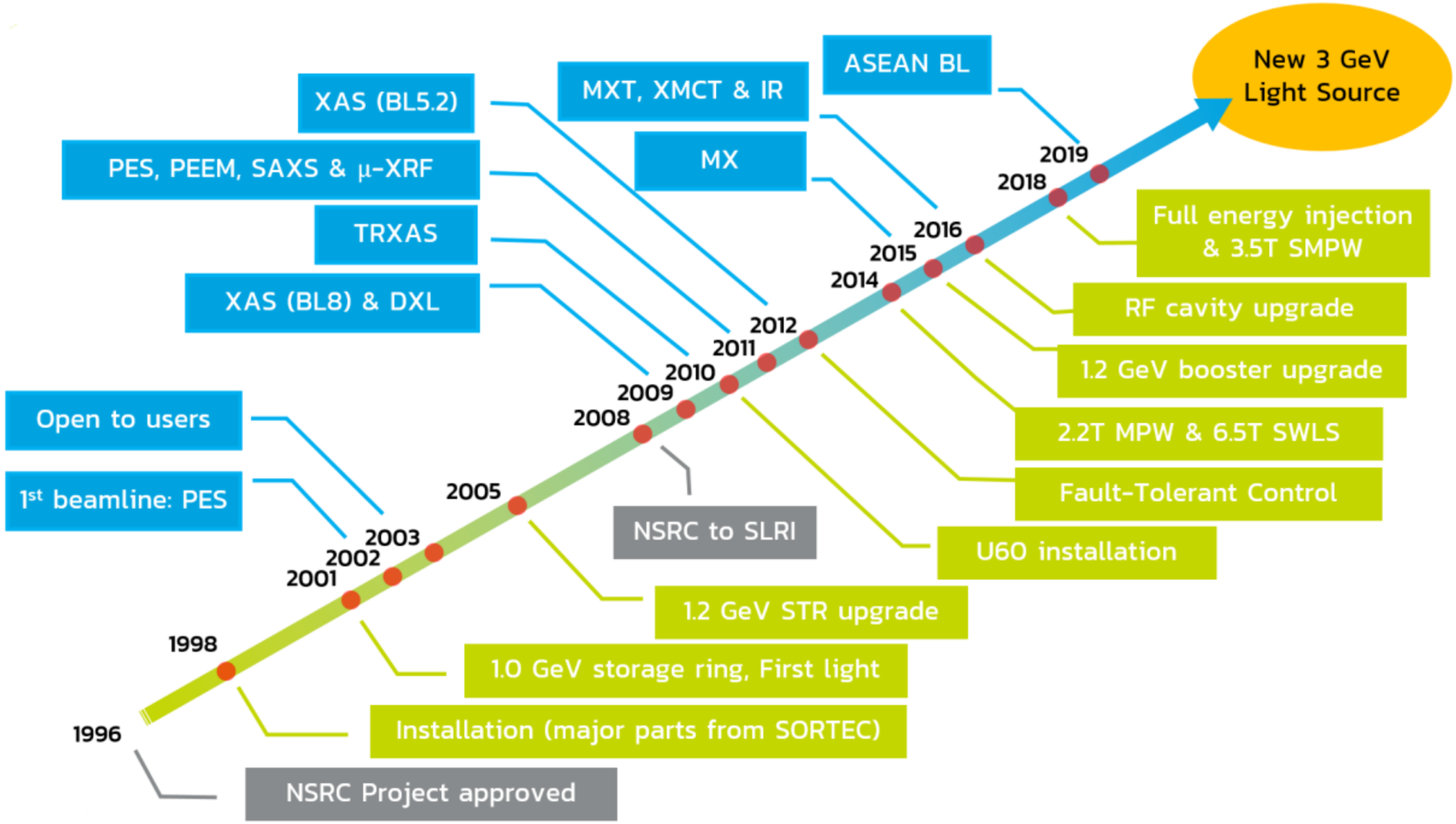
Siam Photon Source - I



BL1.1W:Multiple X-ray Techniques
BL1.2W: X-ray Tomography
BL1.3W: SAXS/WAXS
BL2.2: Time Resolved XAS
BL3.2Ua: Photoemission Spectroscopy
BL3.2Ub: Photoelectron Emission Microscopy

BL4.1: Infrared Microspectroscopy
BL5.2: XAS (SUT-Nanotec-SLRI)
BL6a: Deep X-ray Lithography
BL6b: micro-XRF
BL7.2W: Protein Crystallography
BL8: XAS

Time to go Forward



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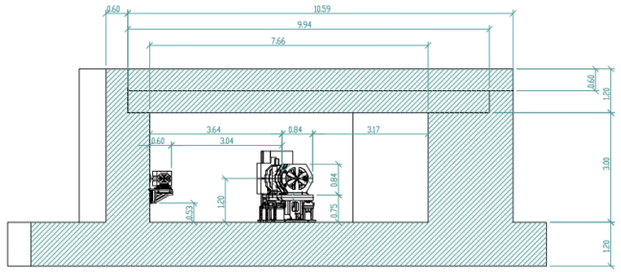
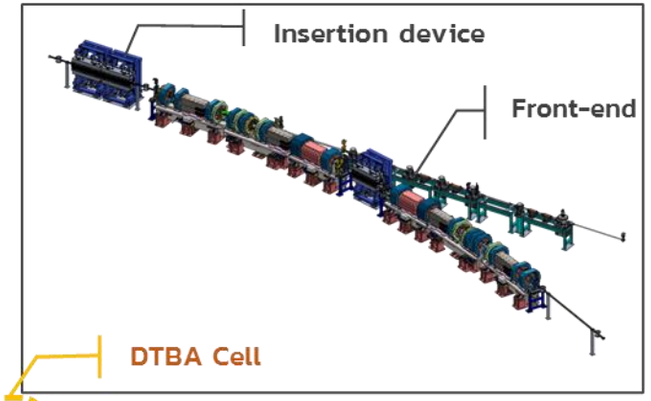
Siam Photon Source - II (SPS-II)

SPS-II Main Components

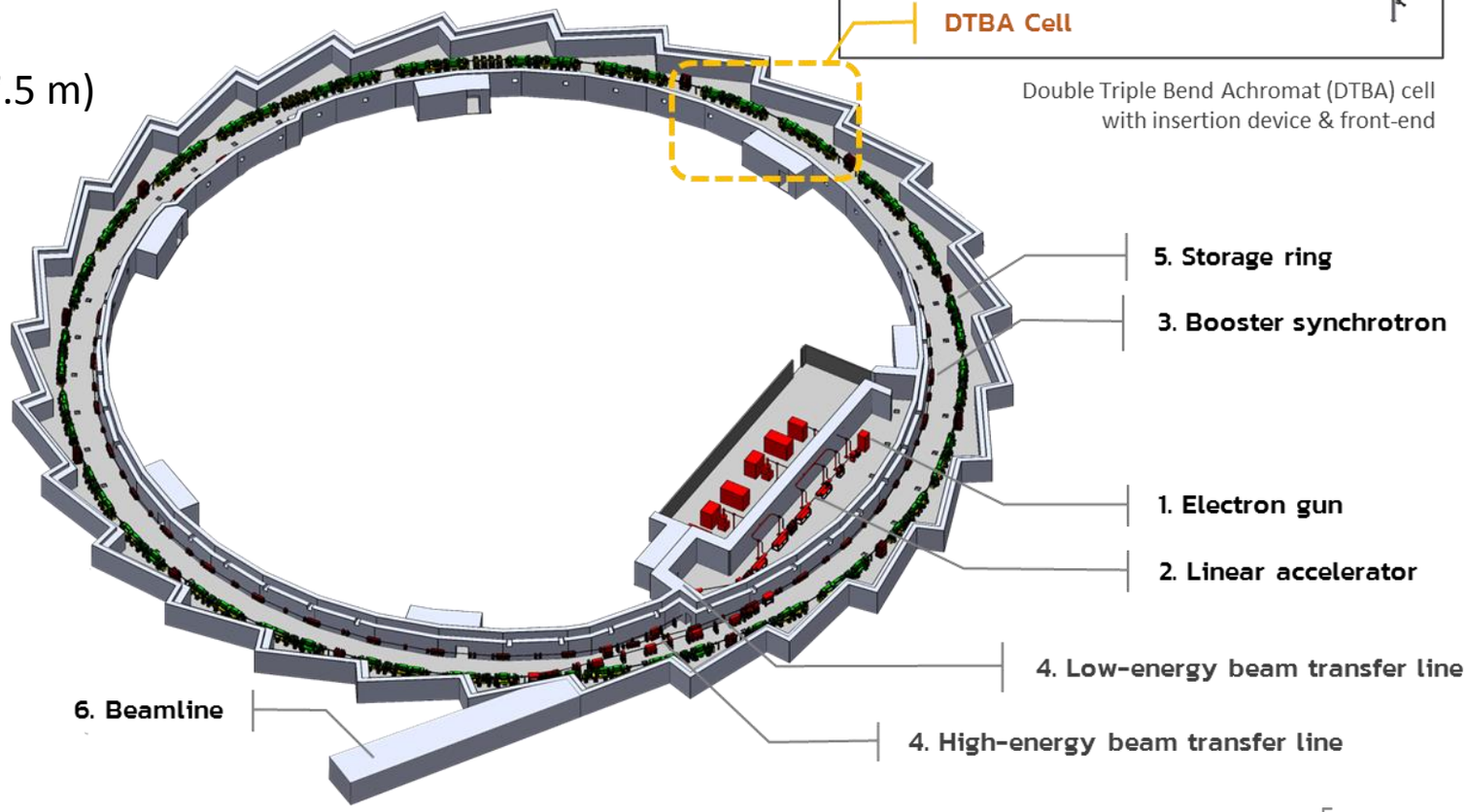
1. Electron gun
2. 150 MeV linear accelerator
3. 3.0 GeV booster synchrotron - (Circumference 304.8 m)
4. Low and high energy transfer line
5. 3.0 GeV storage ring - (Circumference 327.5 m)
6. Beamlines
   - 21 Insertion Device (ID) beamlines
   - 2 infrared beamlines
   - 2 diagnostic beamlines



SECTION A-A
SCALE 1 : 200



Double Triple Bend Achromat (DTBA) cell with insertion device & front-end



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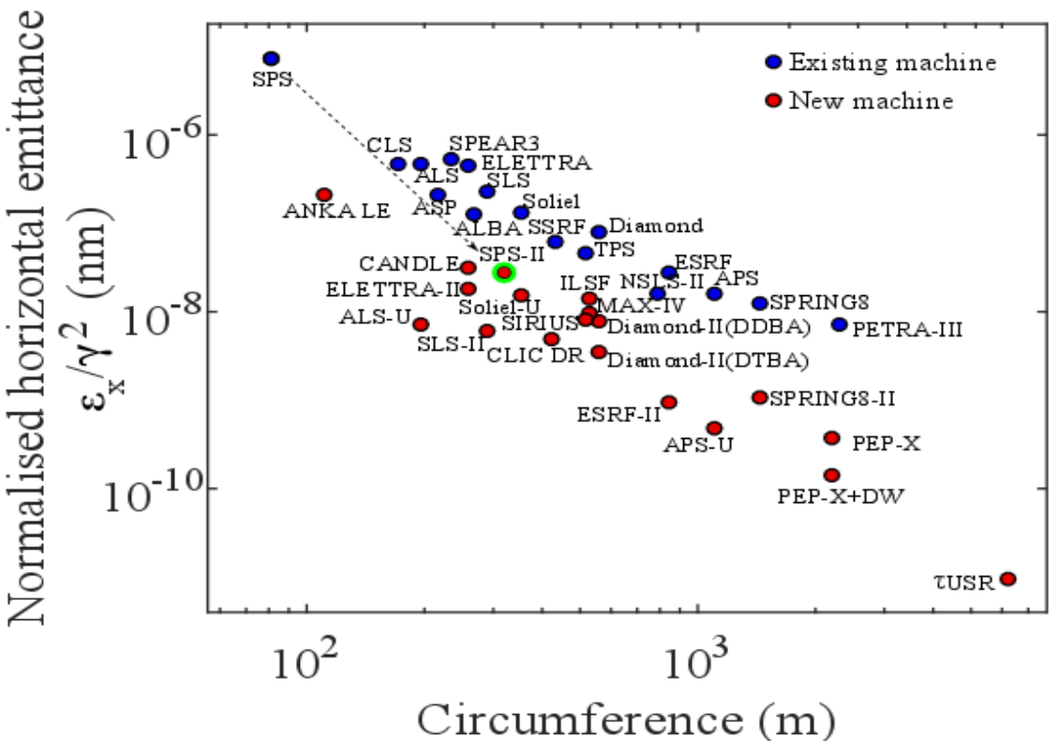
Machine Parameters

Parameters	SPS	SPS-II
Circumference (m)	**81.3**	**327.5**
Energy (GeV)	**1.2**	**3.0**
Relativistic factor γ	2348.34	5870.85
Emittance ε_{x0} (nm·rad)	**41.0**	**0.96**
Beam current (mA)	**150**	**300**
Nat. energy spread σ_E (%)	0.066	0.077
Nat. chromaticity ξ_x/ξ_y	-8.7/-6.4	-65.6/-76.7
Tune Q_x/Q_y	4.75/ 2.82	34.24/12.31
Momentum compaction α_c	1.70e-2	3.33e-4
Damping times hor./ver./long. (ms)	10.7/9.8/4.7	9.7/11.3/6.2
Straight/circumference	**0.33**	**0.35**
Energy loss per turn U_0 (MeV)	0.066	0.577
RF frequency (MHz)	118.00	119.00
RF voltage (MV)	0.3	1.5
Harmonic number	32	130
Overvoltage V/U_0	4.5	2.6
Synchronous phase (degree)	167.29	157.34
Synchrotron tune	0.00460	0.00178
Nat. bunch length (mm)	29.03	7.48
Nat. bunch duration (ps)	96.8	24.9

Larger ring -> More Beamlines

Higher beam energy -> Higher photon energy

Lower emittance
Higher current -> Higher flux, brightness

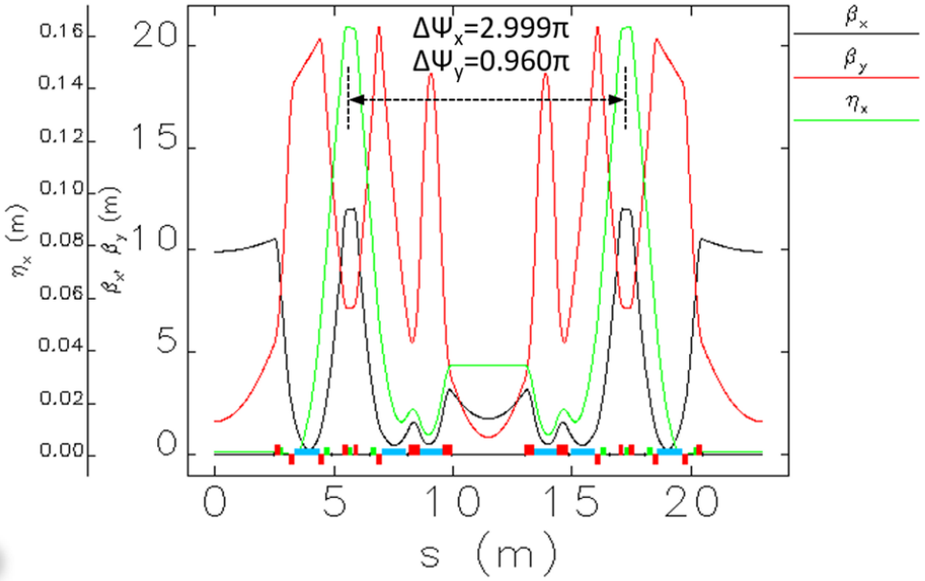


SPS-II Storage Ring

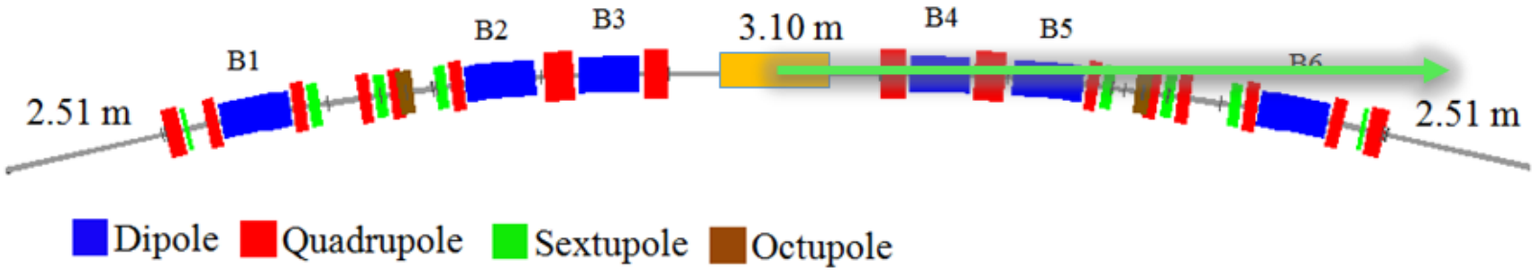
Design concept:

- ✓ Performance --> MBA cell, low emittance (<1nmrad)
- ✓ Feasibility --> Moderate magnets requirement
- ✓ Productivity --> Space usage (>35%)

Odd-pi phase advance

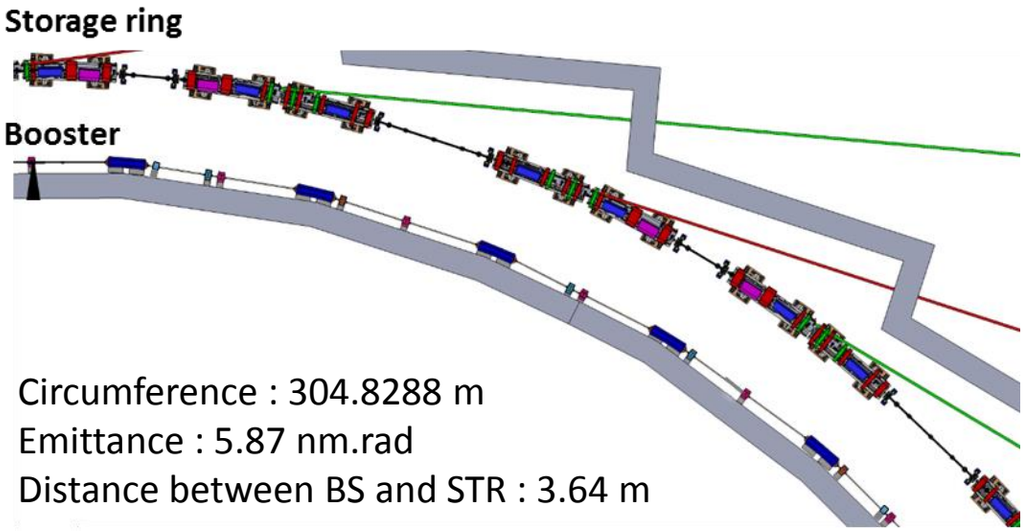


DTBA (Double Triple Bend Achromat)
originated from Diamond Light Source upgrade study



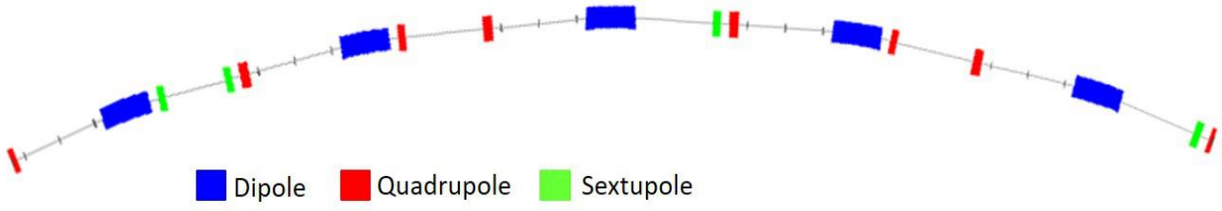
14 Cells -> 28 straights in total

SPS-II Booster Synchrotron



Circumference : 304.8288 m
Emittance : 5.87 nm.rad
Distance between BS and STR : 3.64 m

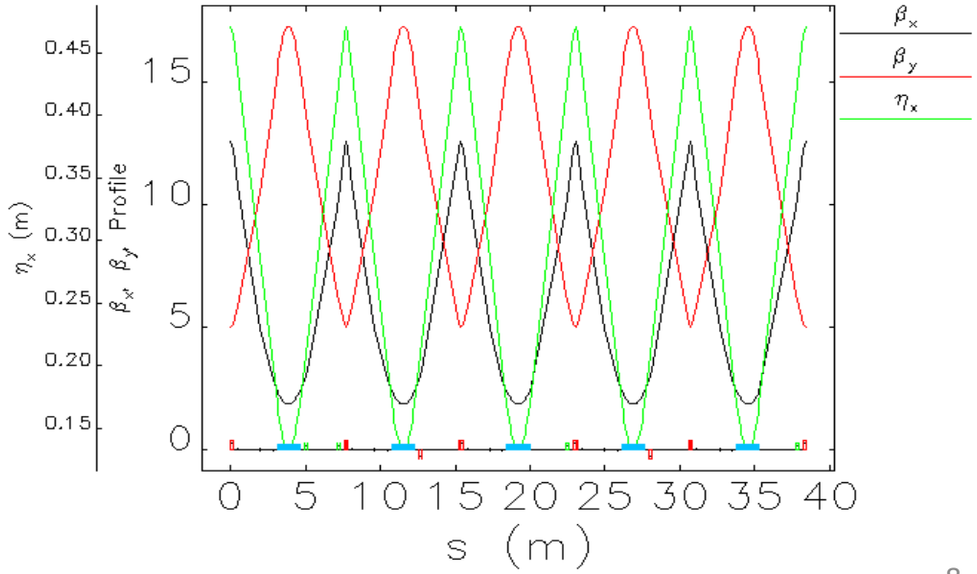
FODO with combined function magnets



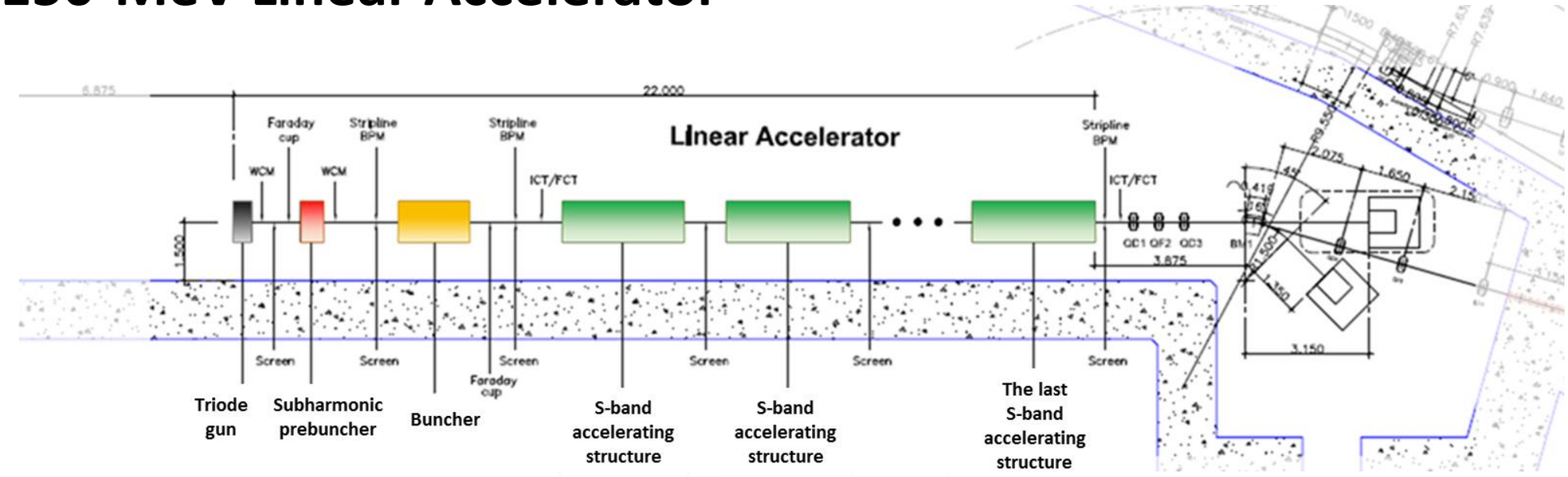
8 Cells in total

Concentric booster

- low emittance for providing a clean injection into the storage ring
- Minimize the building construction cost (substantial saving of building space and shielding)
- Minimize magnet manufacturing cost (small lattice elements, low power consumption)
- Simple transfer line between booster and ring



150-MeV Linear Accelerator



Design considerations:

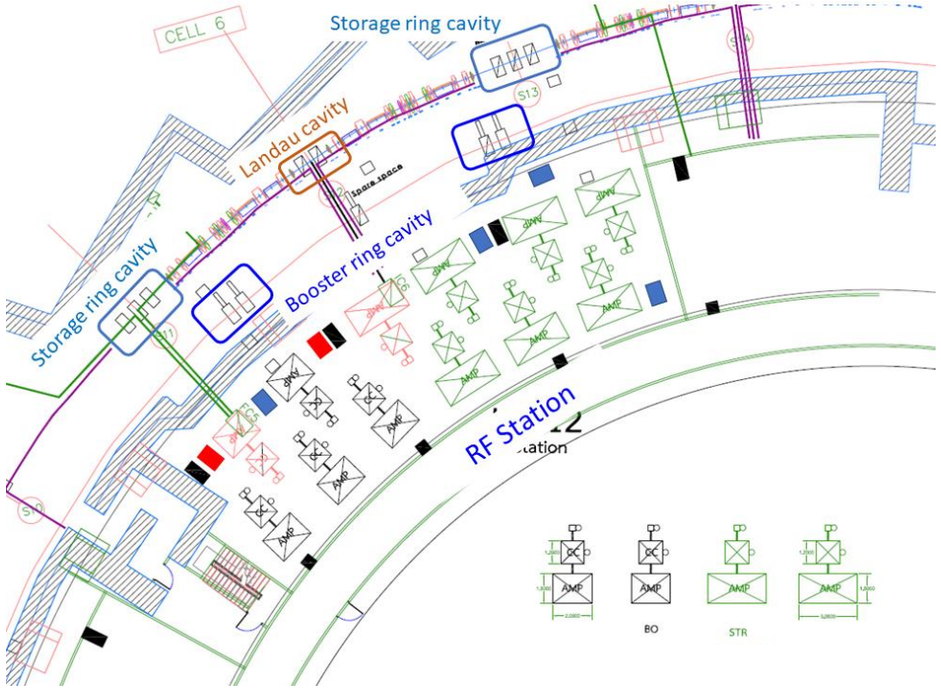
- Target beam energy of 150 MeV
- Total linac length < 25 m
- Compatible with 119-MHz RF system of booster and storage ring

Proposed Components:

- Triode gun with 119-MHz voltage modulation at the grid level to produce a chopped beam
- Subharmonic pre-buncher operating at 476 MHz
- S-band buncher operating at 2856 MHz
- S-band accelerating structures

Parameter	Value
Beam energy	150 MeV
Normalized emittance	≤ 50 mm·mrad
RMS energy spread	≤ 0.5 %
Bunch train charge (MBM)	> 6 nC
Bunch charge (SBM)	≥ 1.5 nC
Bunch train duration (MBM)	150-600 ns
Bunch duration (SBM)	< 1 ns
Repetition rate range	1-5 Hz
Nominal repetition rate	2 Hz

RF System



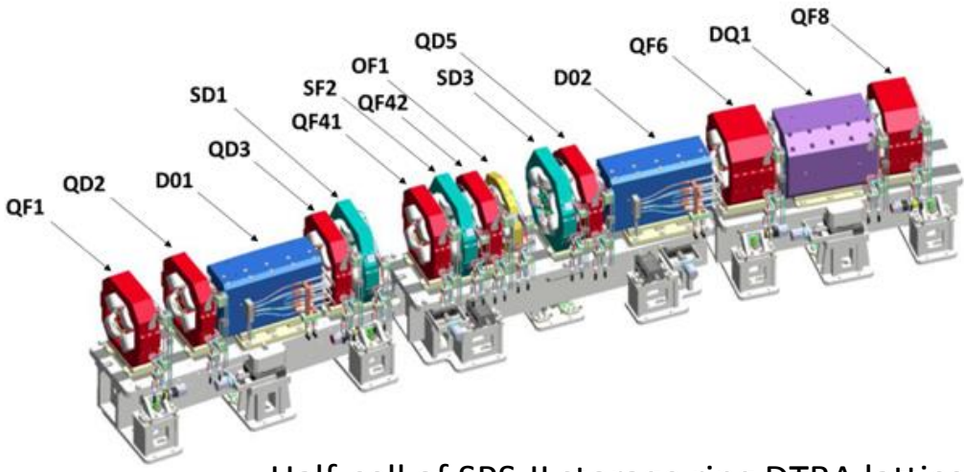
Number of cavity		
- Storage ring	5/6	5 cavities for first phase
- Booster ring	4	
Total RF voltage		
- Storage ring	1.5/1.8 MV	RF acceptance > 4.2%
- Booster ring	1.2 MV	RF acceptance > 1.5%
RF power transmitter		Solid state technology
- Storage ring	135 kW/cavity	
- Booster ring	60 kW/cavity	
LLRF control unit		FPGA base
- Storage ring	3	2 for main RF cavity 1 for Landau cavity
- Booster ring	1	

Frequency 119 MHz

- Require less RF voltage for a high RF acceptance
- Low power consumption to get required cavity voltage
- Low sampling rate of LLRF makes the simple LLRF
- Use coaxial rigid line instead of waveguide for RF distribution
- Need Landau cavity for bunch lengthening

Magnet System

- Moderate requirements
- Offset quadrupole design (ESRF) for combined dipole-quadrupole magnet
- Manufacturing tolerance ± 0.02 mm
- Static deformation of magnet structure < 0.005 mm
- Pulsed multipole magnet (nonlinear kicker) for injection into storage ring
- Magnets for storage ring (solid steel) and booster synchrotron (laminated steel) to be manufactured in Thailand
- Pulsed magnets (septum, kicker) to be purchased as a turnkey system



Half-cell of SPS-II storage ring DTBA lattice

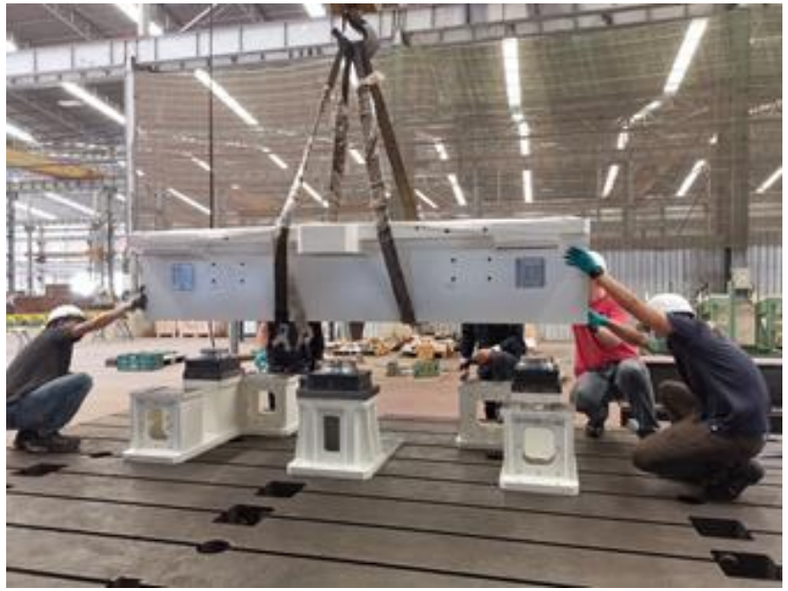
Booster Magnets	Magnetic field	Gap/Bore diameter (mm)	Turn number	Operating current (A)
BD	1.048 T, 3 T/m, 21 T/m^2	30	12	1,071
QF	20 T/m, 64 T/m^2	46	26	173
QD	5 T/m	50	10	130
SF, SD	750 T/m^2	44	8	135

Transfer Line Magnets	Magnetic field	Effective length (m)	Deflecting angle (°)
LTB-QM	5 T/m	0.075 - 0.150	-
LTB-BM	0.33 T	0.419	16
LTB-SEP	0.16 T	0.800	15
BTS-QM	25 T/m	0.200	-
BTS-BM	1.05 T	1.500	9
BTS-SEP	1.3 T	0.800	6

STR Magnets	Magnetic field	Gap/Bore diameter (mm)	Turn number	Operating current (A)
D01, D02	0.87 T	36	24	530
DQ1	0.6 T, 26 T/m	52	50, 10	145
QF1	45 T/m	32	56	85
QD2, QD3, QD5	51 T/m	32	56	100
QF41, QF42	44 T/m	36	56	113
QF6	60 T/m	32	56	112
QF8	50 T/m	32	56	89
SD1, SF2, SD3	1,800 T/m^2	44	32	84
OF1	72,000 T/m^3	56	15	103

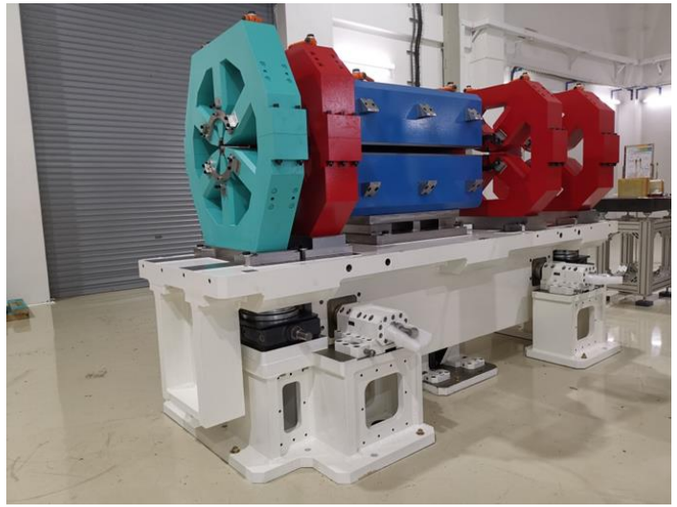
Mechanical Positioning System

Storage Ring Girder

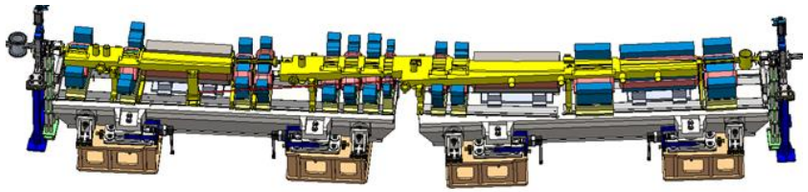


Top plate size	750 x 2,800 mm
Payload (total magnet load)	7 Tons
Levelling adjustment resolution (by motor)	0.004 mm

Assembly

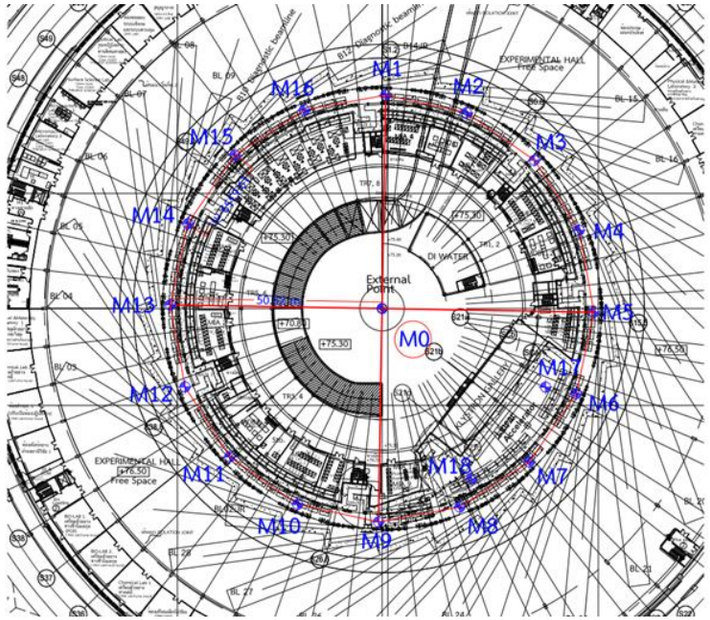


84 STR girders will be assembled and aligned with Magnets in Lab, then transport to STR tunnel for installation.



The magnets will be open for vacuum chamber installation.

Alignment Network



The alignment network is used to provide the precise position for all components.

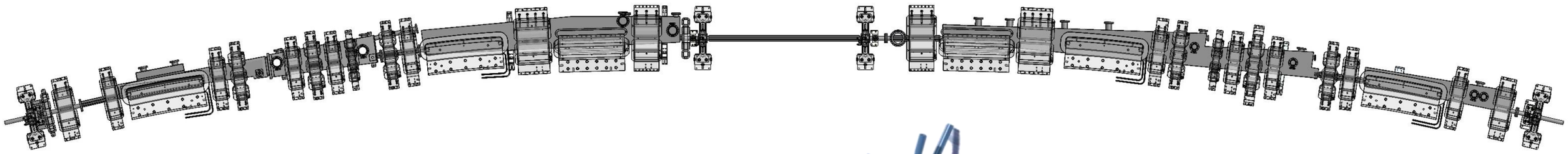
Required positioning tolerances.

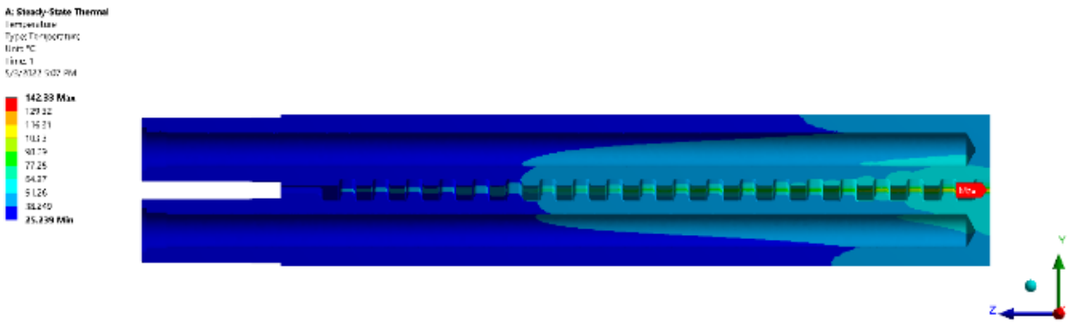
Global tolerance	± 3 mm
Girer to Girder tolerance	100 µm (RMS)

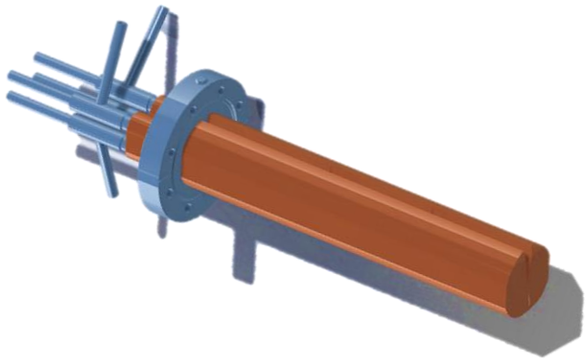
Vacuum System

- Stainless steel vacuum chamber is chosen due to its excellent strength
- Domestical manufacturing - welding technology
- External baking out
- Non-evaporable getter (NEG) cartridges and sputter ion pumps (SIP)

Fabrication tolerances	< 1 mm/m
Taper inclination	< 1/10
The step height	< 1 mm

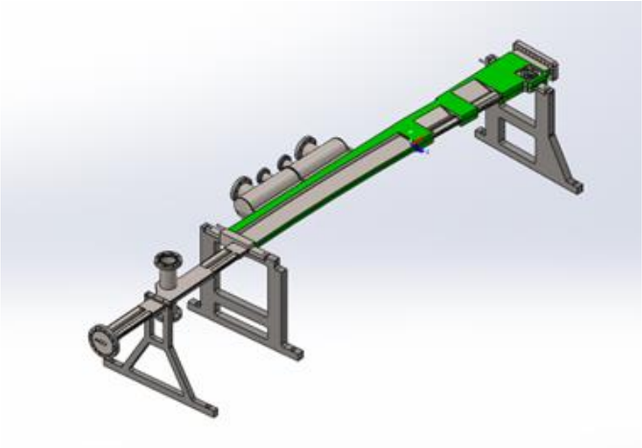


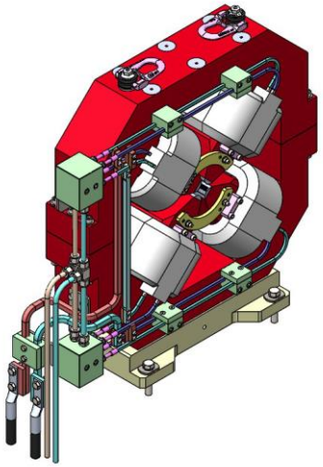


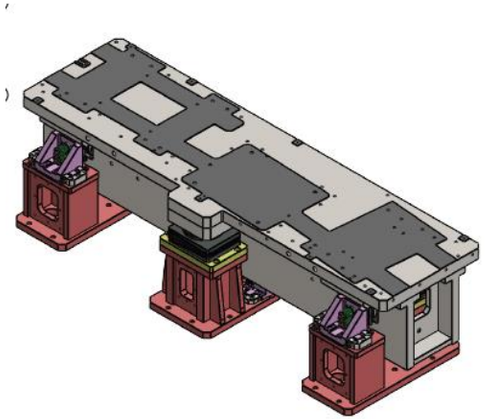


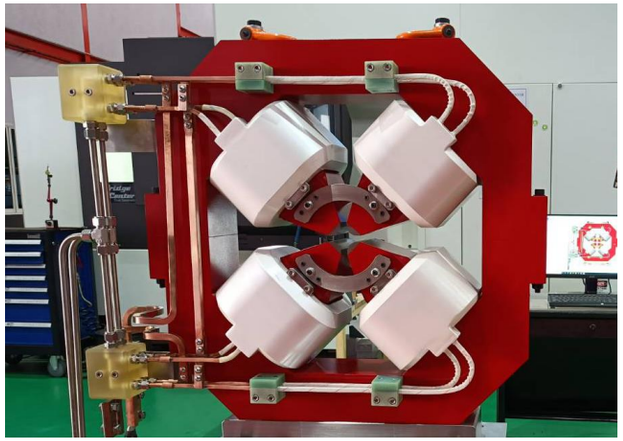
Photon absorbers have been designed to tolerate SR power with the beam current up to 500 mA + 20% margin

Prototype Development (2021 – 2023)







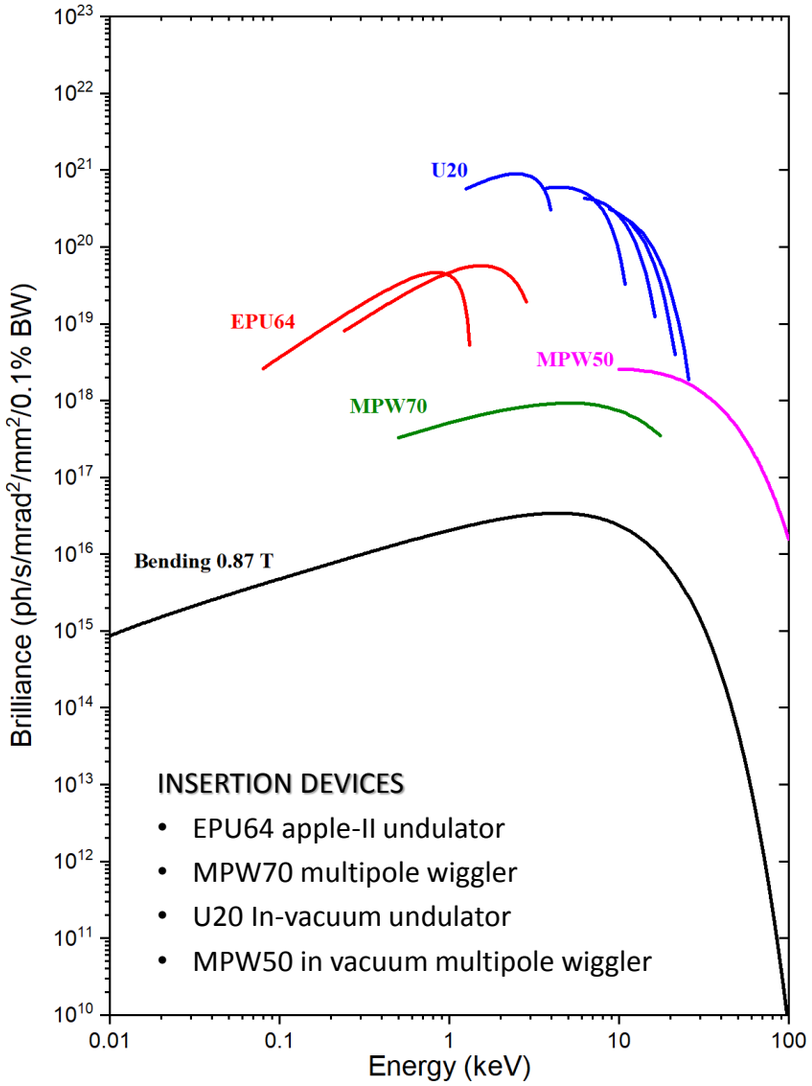


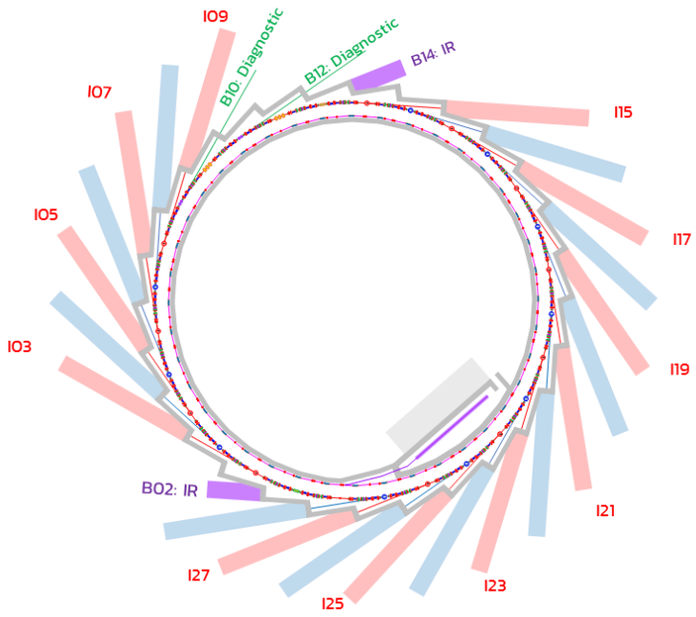
Vacuum chambers

Magnets

Girders

SPS-II Photon Beamlines





IDs	Beamlines	Techniques
EPU64	HRSXS	PES, ARPES, XPS, PEEM, NEXAFS, XMCD
MPW70	TXAS	XANES, EXAFS, XRF
MPW50	HXAS	XANES and QEXAFS, XRF, XES
U20	SWAXS	SAXS, WAXS USAXS, GISAXS
U20	HRXRD	XRD, High Resolution XRD, XRD imaging
MPW50	XMCT	micro-tomography
U20	MX	micro-focused MX MAD and SAD
(BM)	IR	FTIR, IR microspectroscopy / imaging

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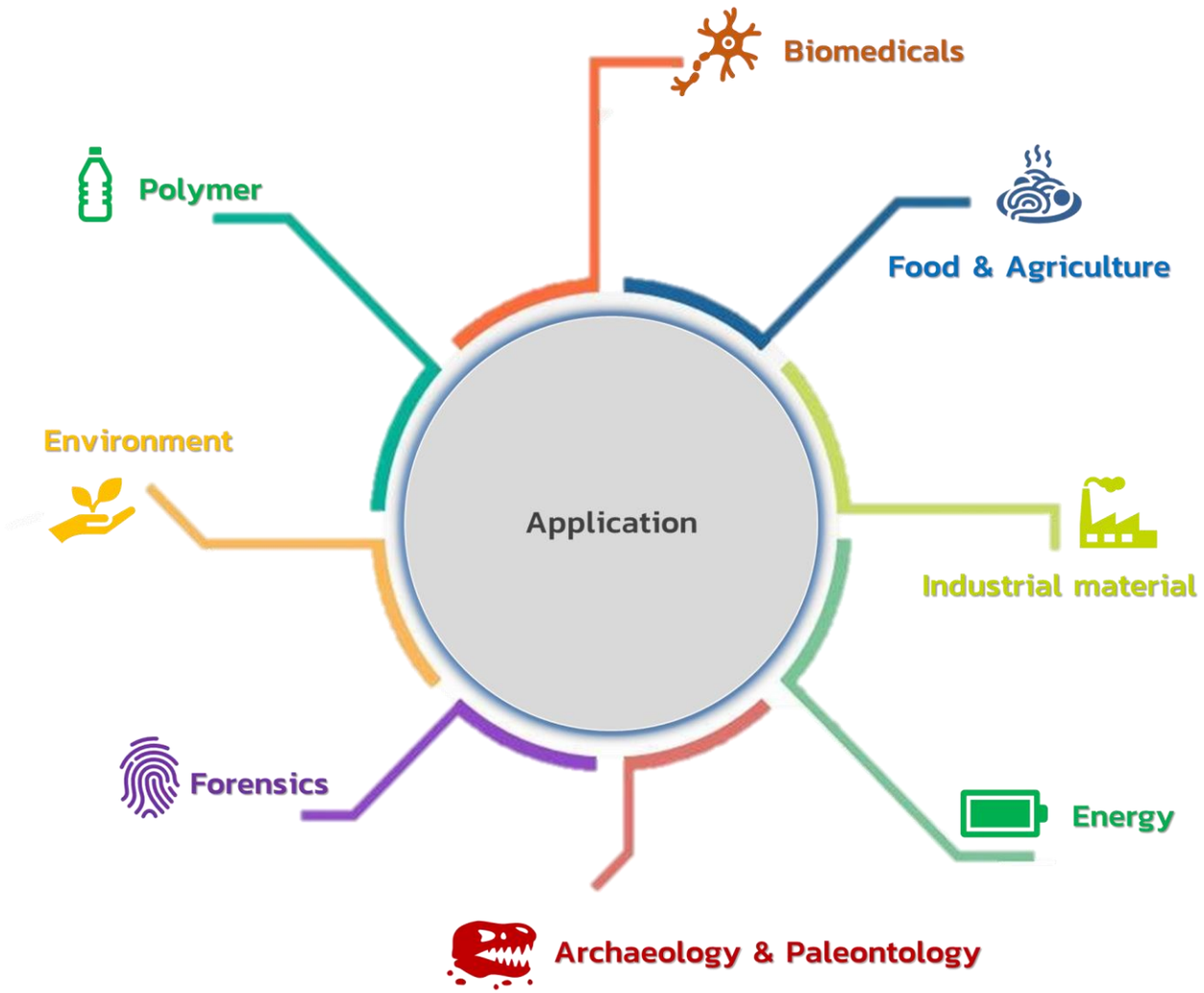
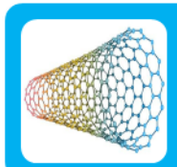
New Opportunities for Research and Industry




Frontier sciences

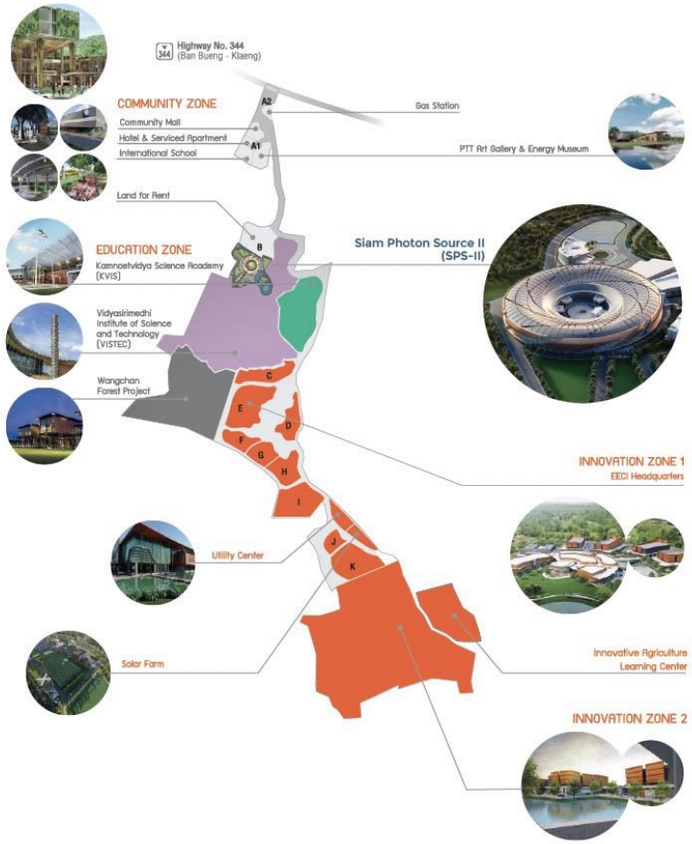

BCG researches


High-valued industries


SME & Start-ups

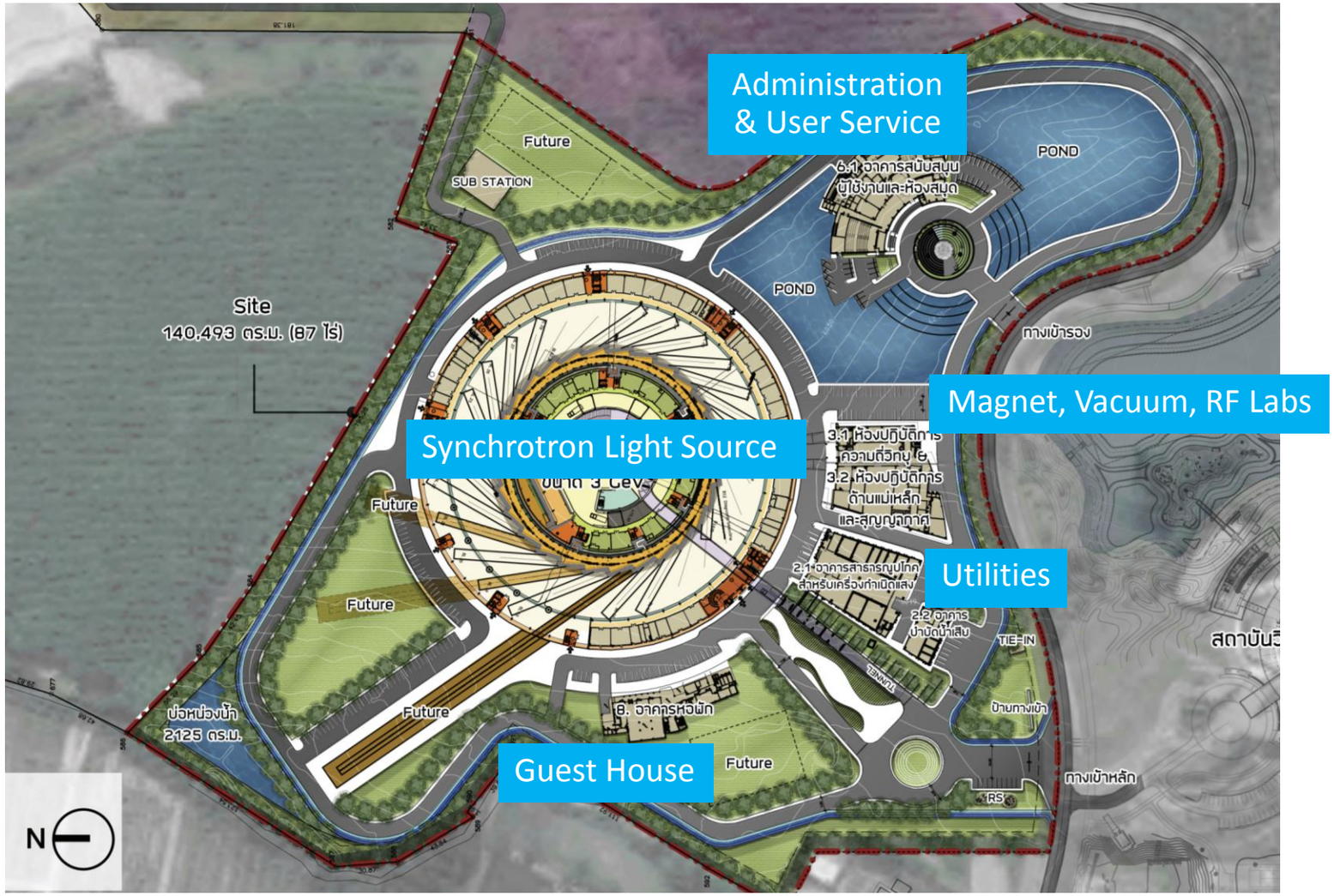

Human development

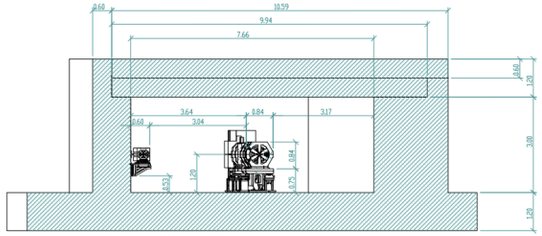
Eastern Economic Corridor of Innovation (EECi)



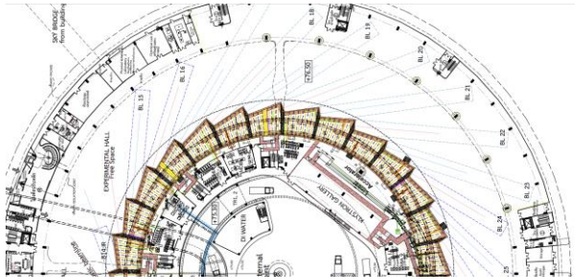
Total Area	3,454	Rai	(552.64 ha)
• Community Zone	178	Rai	(28.48 ha)
• Education Zone	1,186	Rai	(189.76 ha)
• Innovation Zone 1	989	Rai	(158.24 ha)
• Innovation Zone 2	946	Rai	(151.36 ha)
• Innovative Agriculture Learning Center	155	Rai	(24.8 ha)

Buildings and Facilities



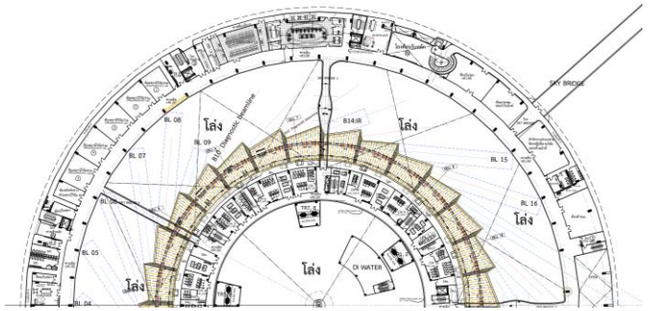


Ring Tunnel



First floor

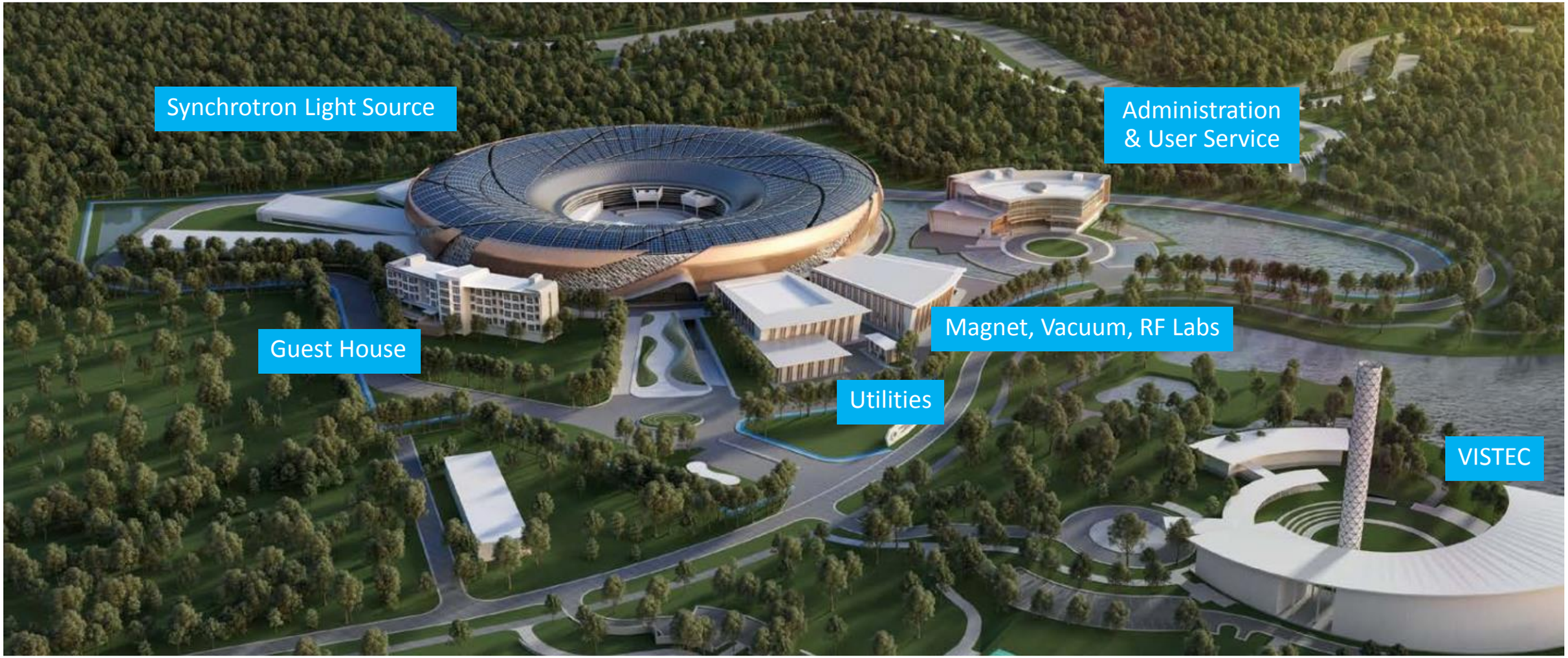
Machine Instrument Area (MIA)



Second floor

Control Instrument Area (CIA)

Building and Facilities



Summary

- SPS-II project was approved in 2019. The project aims to serve the user community in the region with new opportunities for research and industry.
- The SPS-II design concepts considered the performance, feasibility and productivity. The DTBA lattice was chosen.
- Detailed design of the SPS-II machine and the buildings are completed.
- Prototype of magnets, vacuum chambers and girders for half-cell of the DTBA lattice is currently in progress.
- The SPS-II is planned to open for users in 2029.

THANK YOU

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