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

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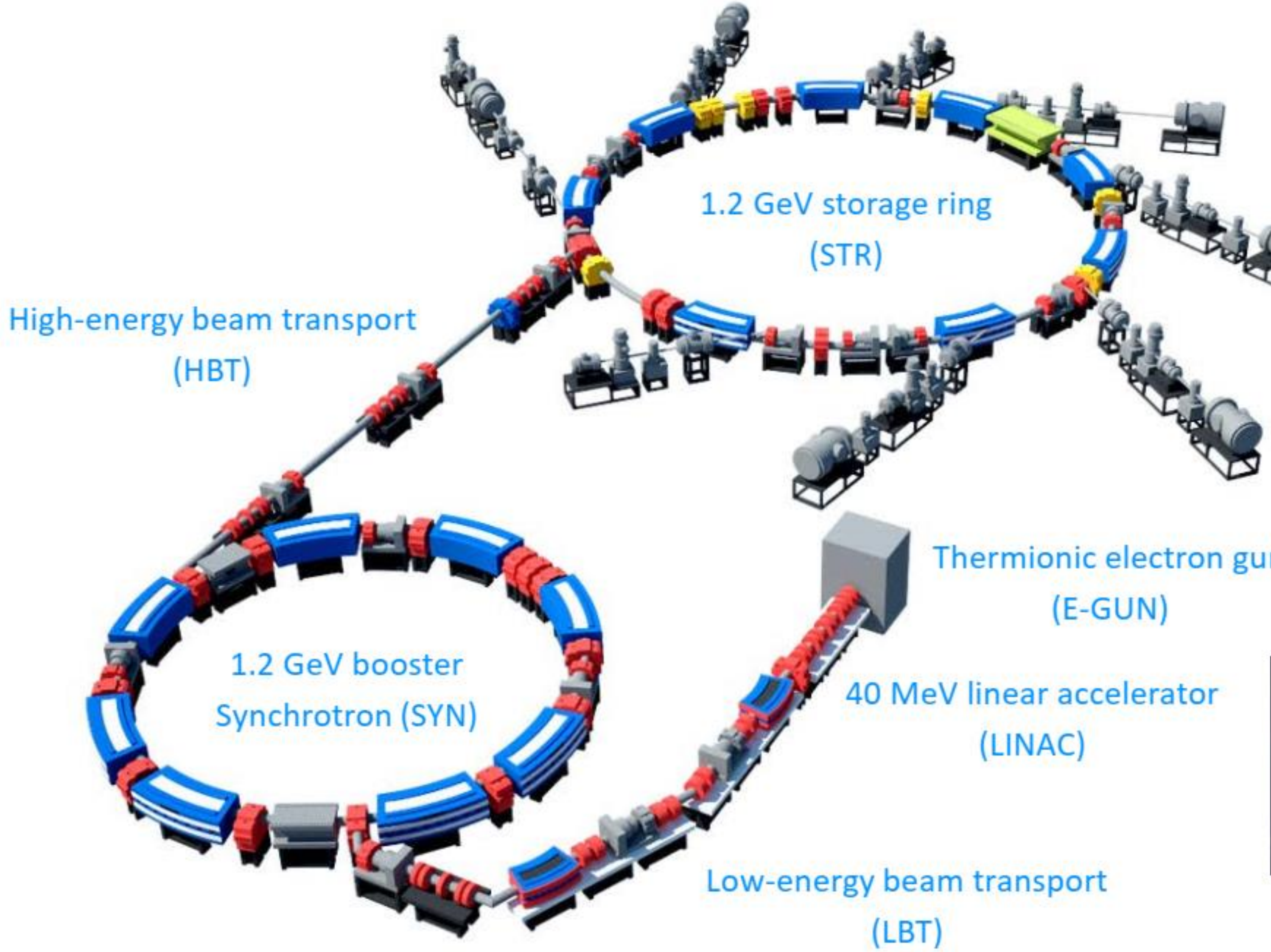
THAI SYNCHROTRON NATIONAL LAB

Siam Photon

13 June 2022, IPAC 2022, Thailand

# Siam Photon Source - I





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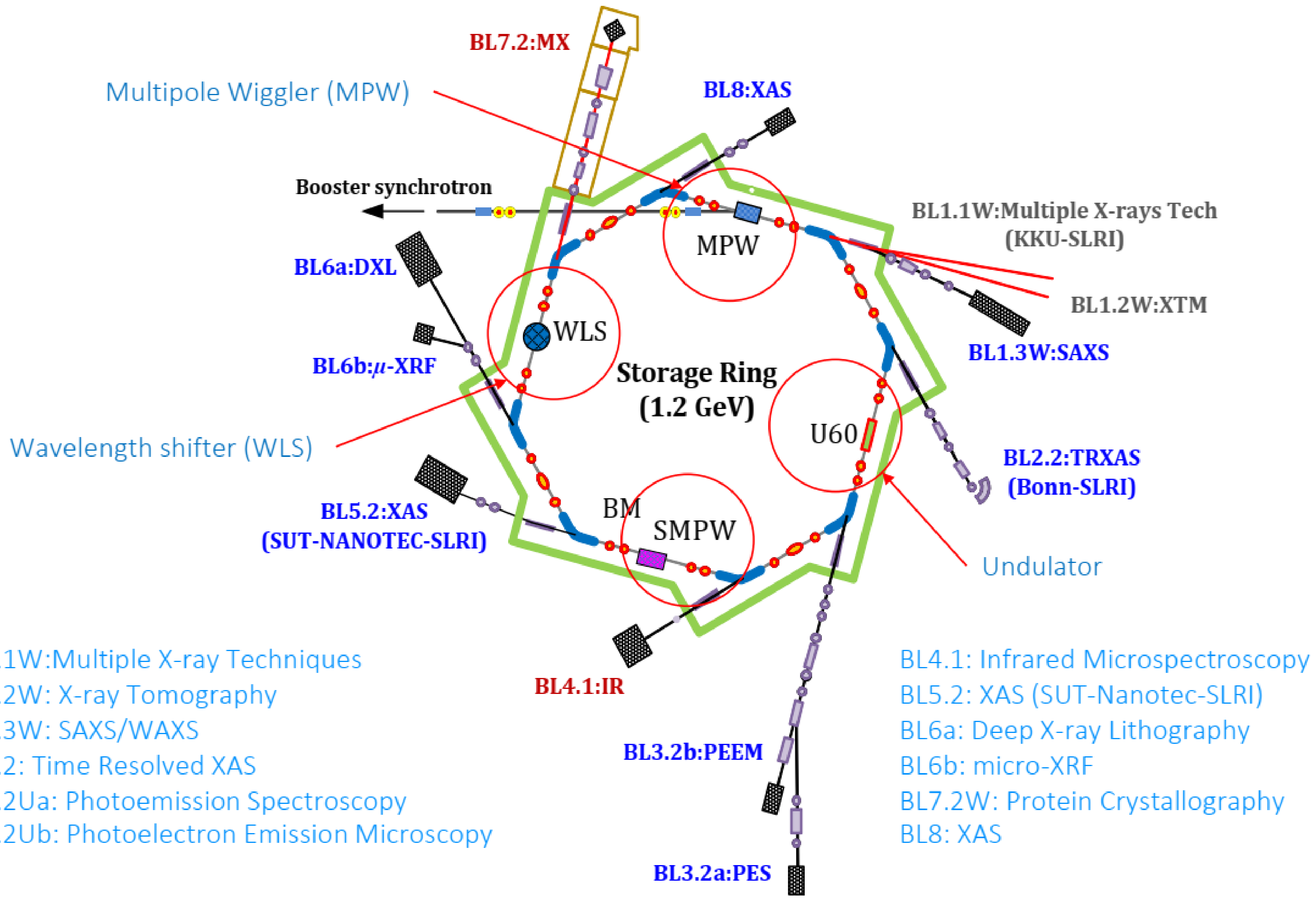
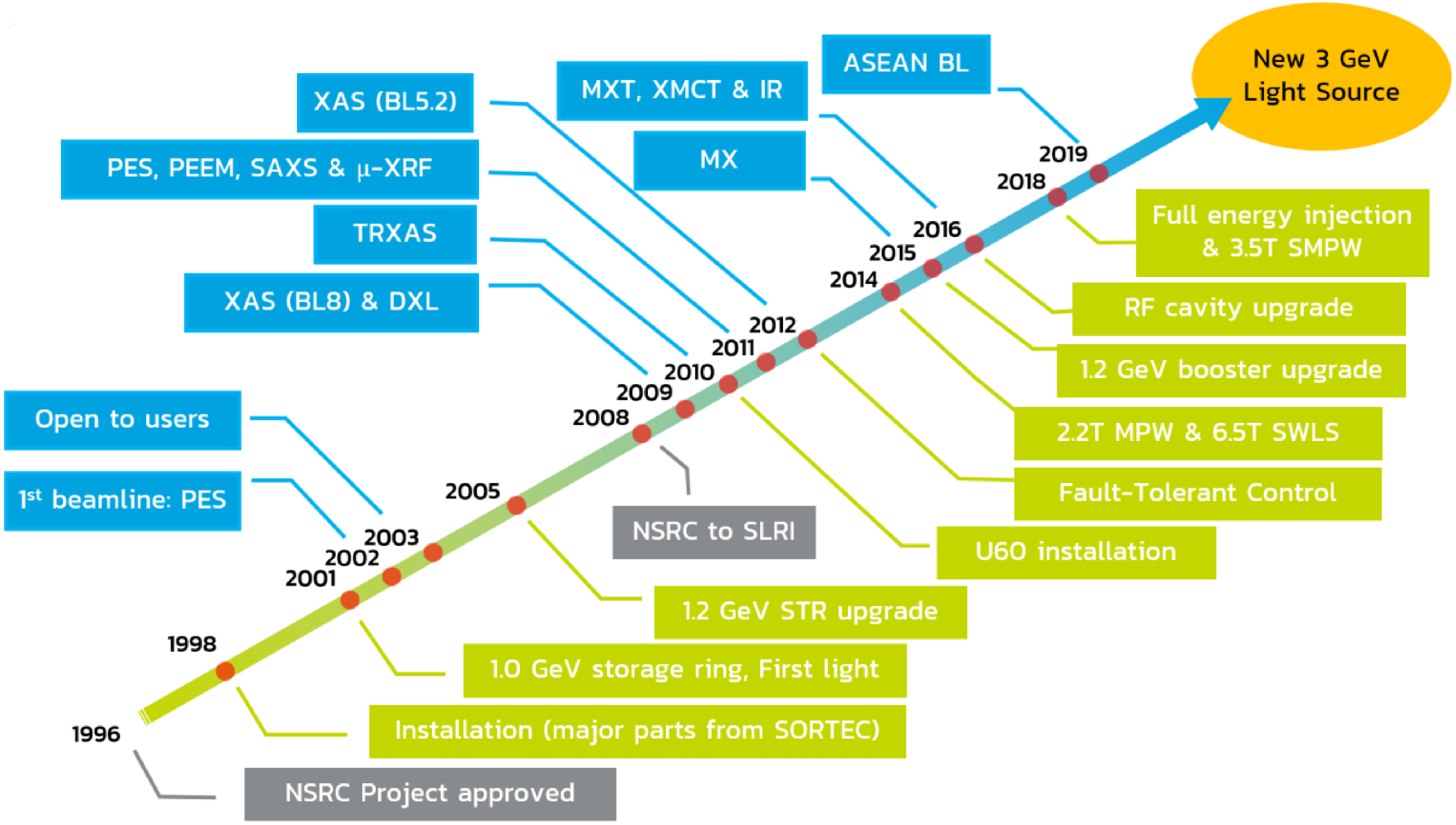



BL1.1W:Multiple X-ray Techniques
BL1.2W: X-ray Tomography
BL1.3W: SAXS/WAXS
BL2.2: Time Resolved XAS
BL3.2Ua: Photoemission Spectroscopy
BL3.2Ub: Photoelectron Emission Microscopy

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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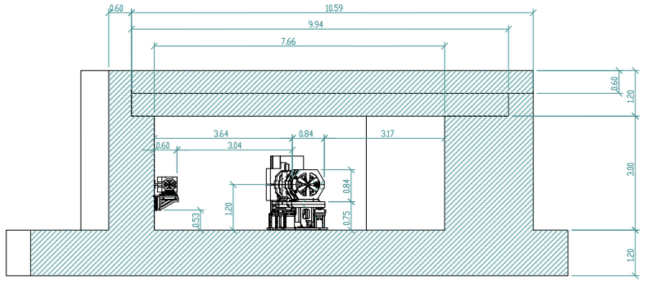
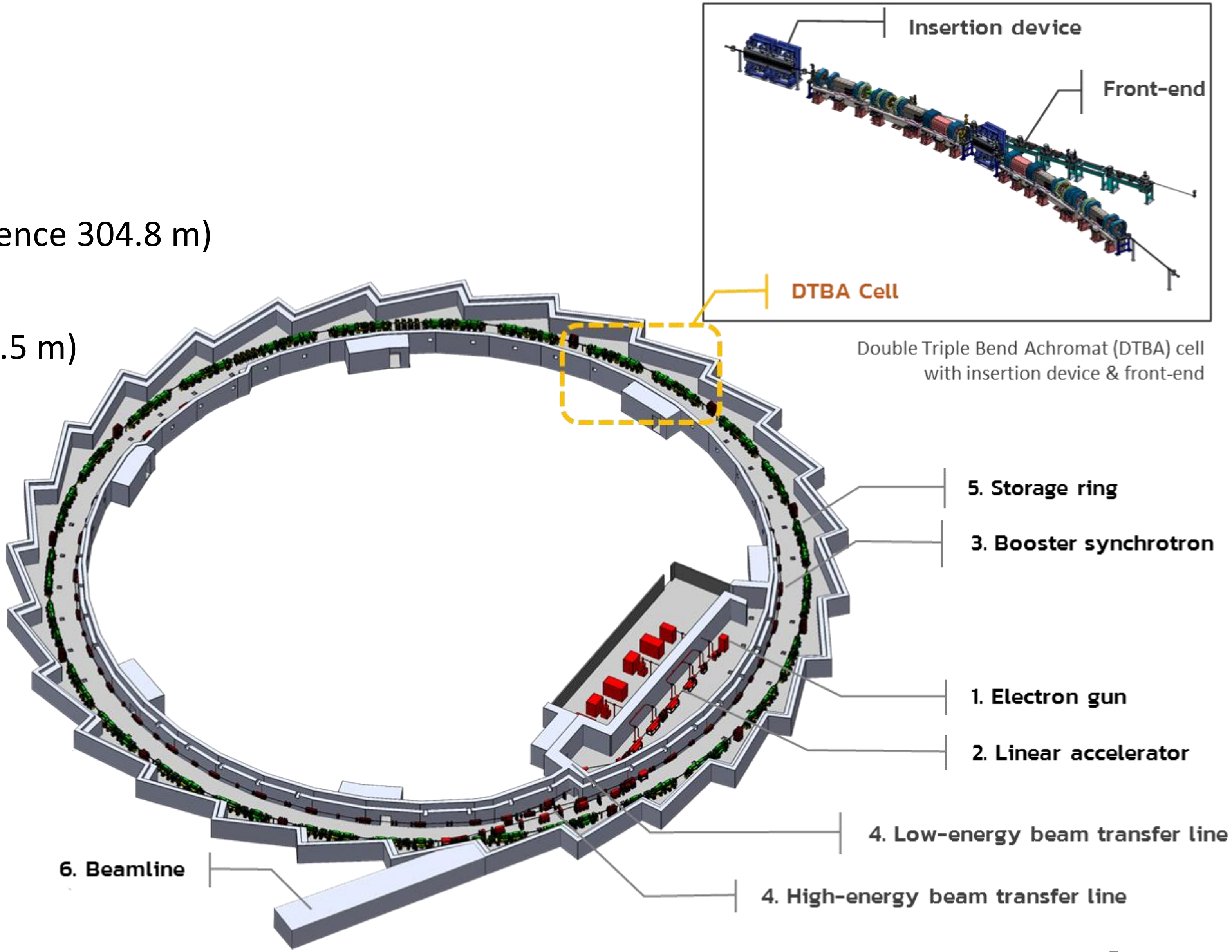
# Siam Photon Source - II (SPS-II)

**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

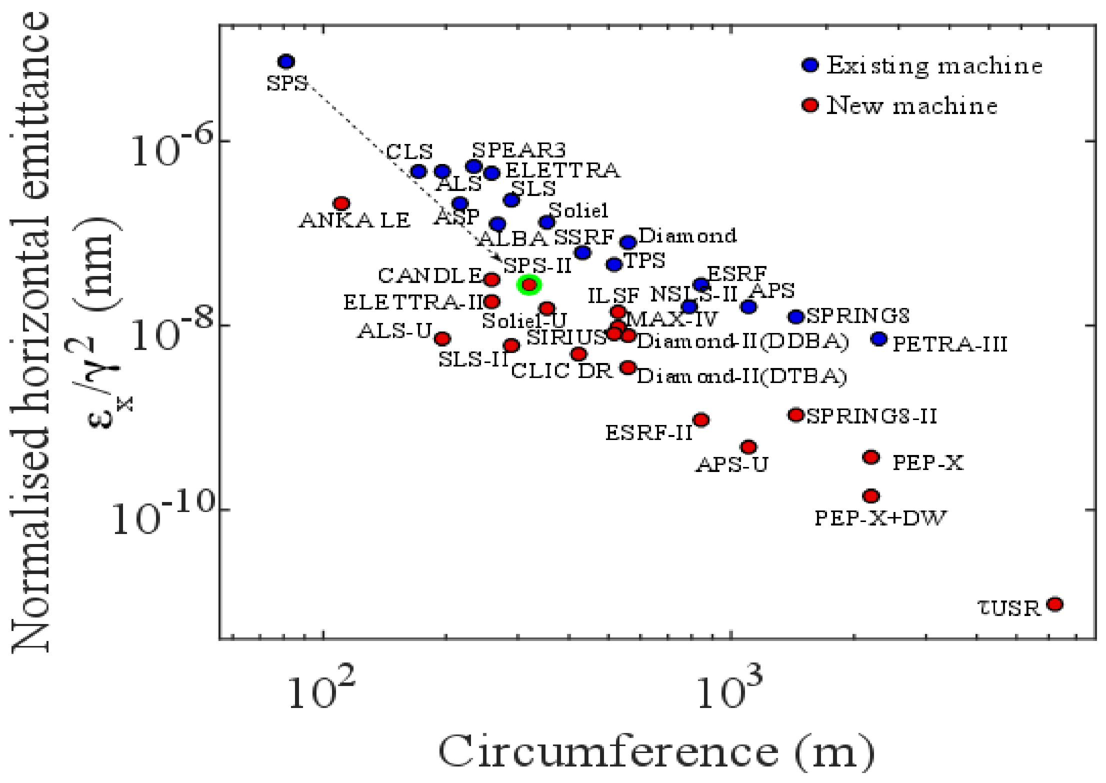
# Machine Parameters

| Parameters | SPS | SPS-II |
|---|---|---|
| **Circumference (m)** | **81.3** | **327.5** |
| **Energy (GeV)** | **1.2** | **3.0** |
| Relativistic factor γ | 2348.34 | 5870.85 |
| **Emittance $\varepsilon_{x0}$ (nm·rad)** | **41.0** | **0.96** |
| **Beam current (mA)** | **150** | **300** |
| Nat. energy spread $\sigma_E$ (%) | 0.066 | 0.077 |
| Nat. chromaticity $\xi_x/\xi_y$ | -8.7/-6.4 | -65.6/-76.7 |
| Tune $Q_x/Q_y$ | 4.75/ 2.82 | 34.24/12.31 |
| Momentum compaction $\alpha_c$ | 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

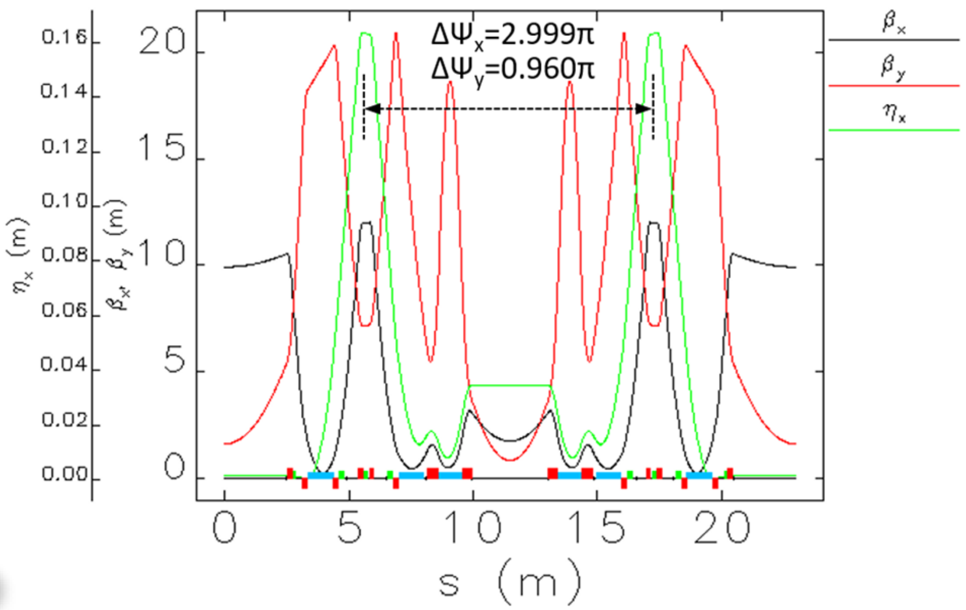


# SPS-II Storage Ring

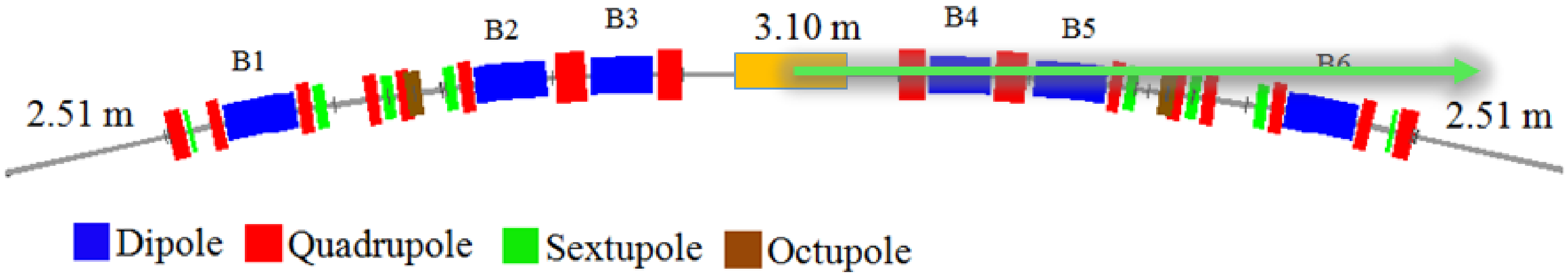
**Design concept:**

- ✓ 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**

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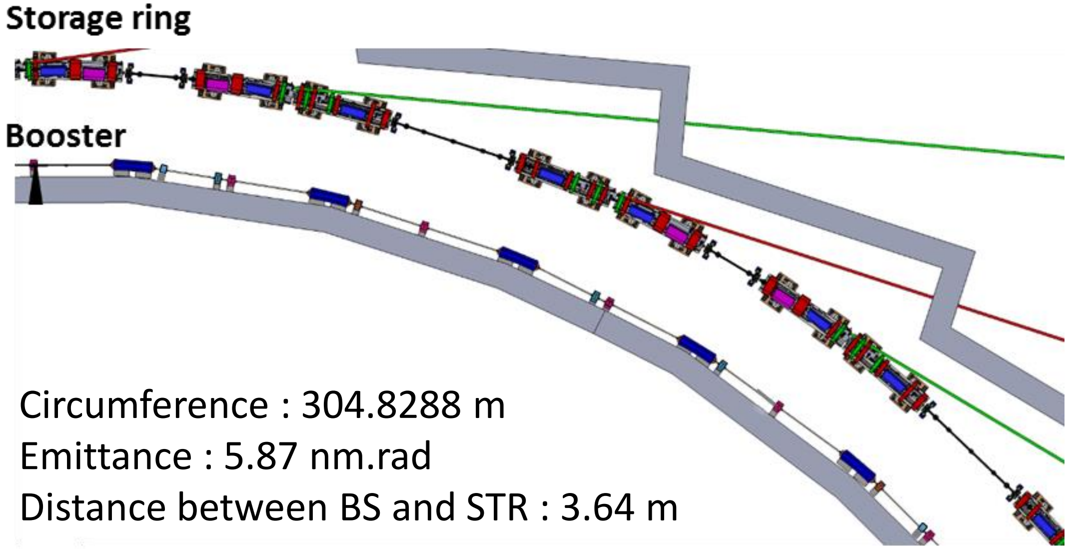
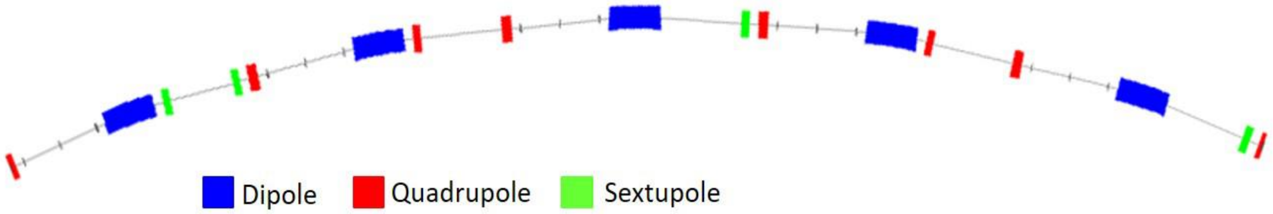
# SPS-II Booster Synchrotron




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

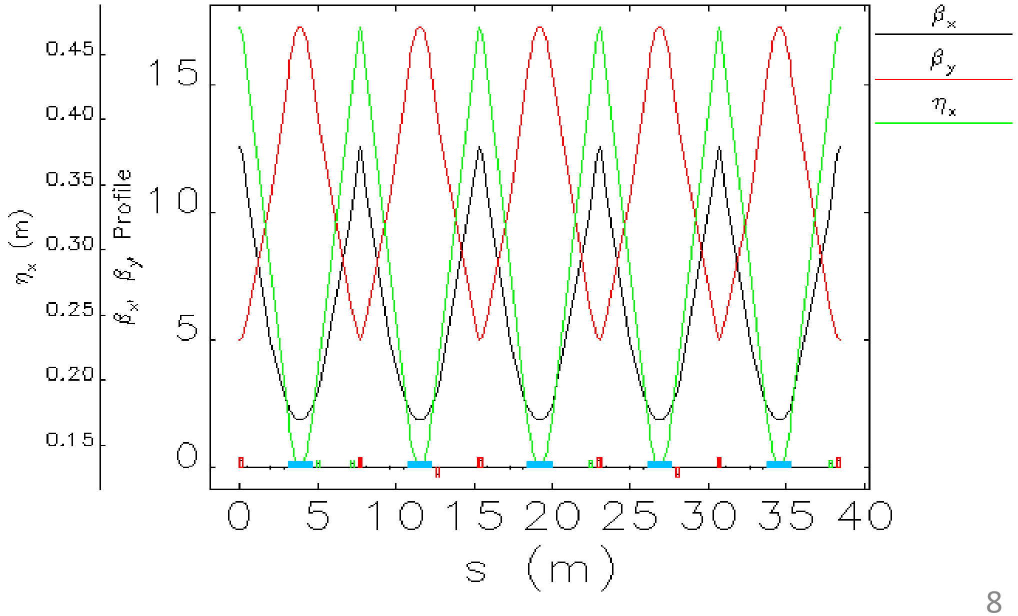
FODO with combined function magnets



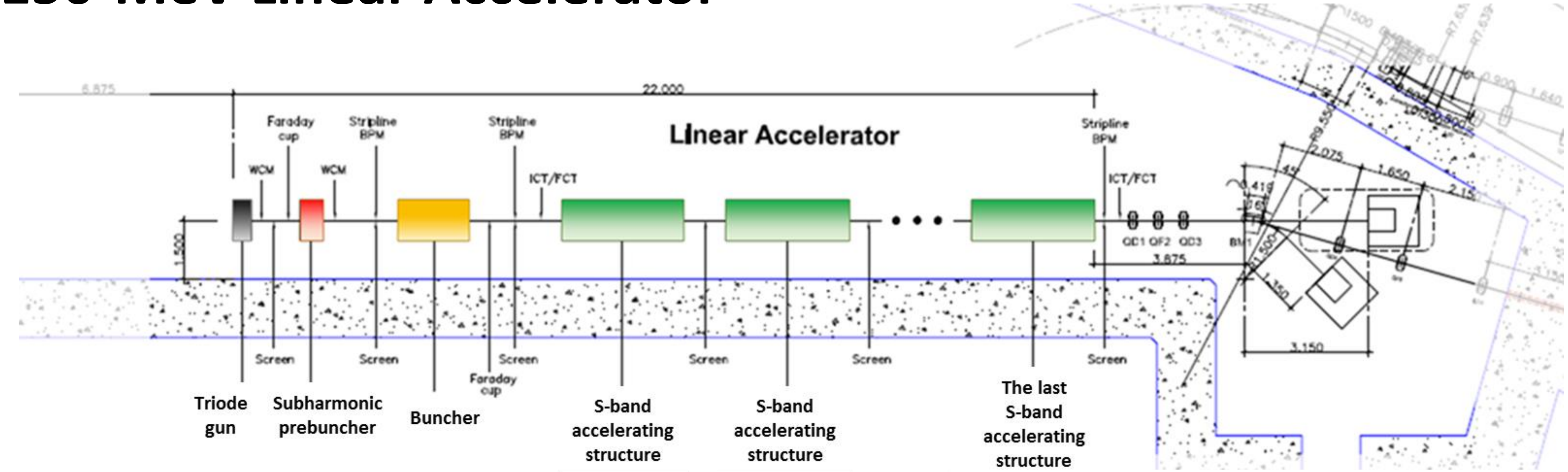

**8 Cells in total**

**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 |

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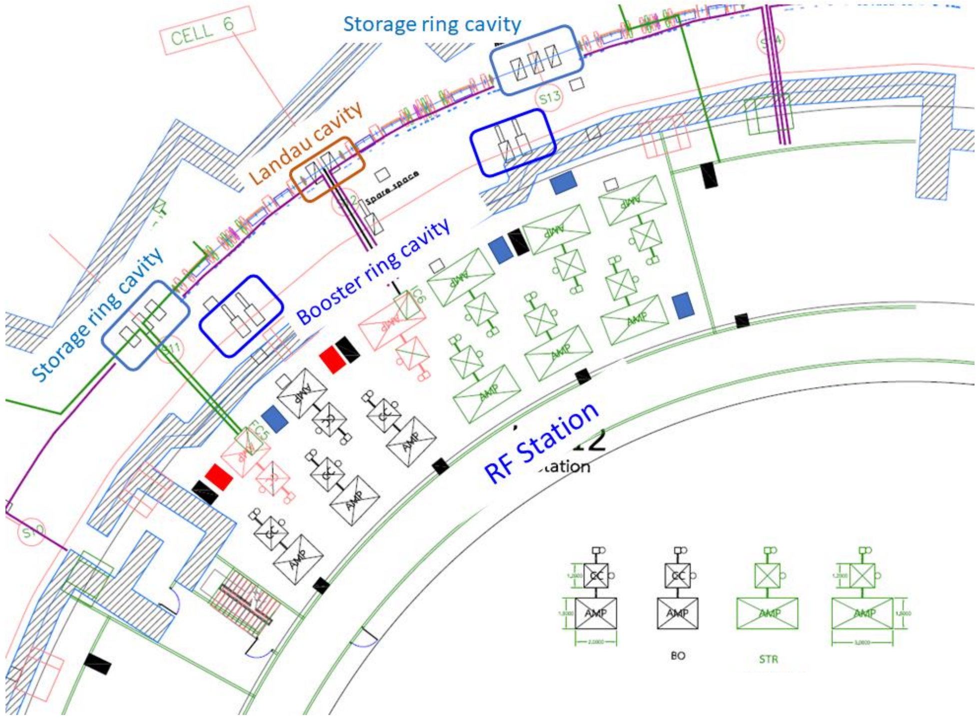
# RF System



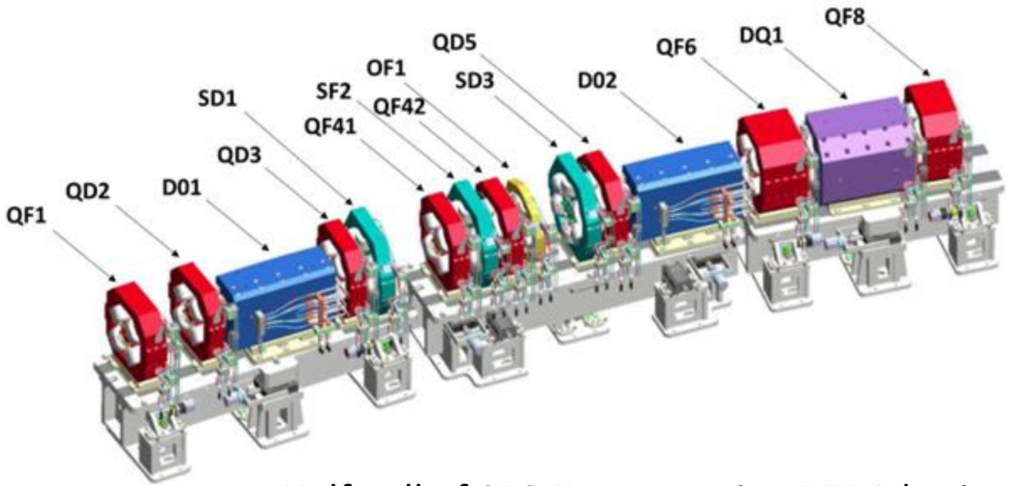

**Frequency 119 MHz**

- 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

| 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<br>1 for Landau cavity |
| - Booster ring | 1 | |

# 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 |

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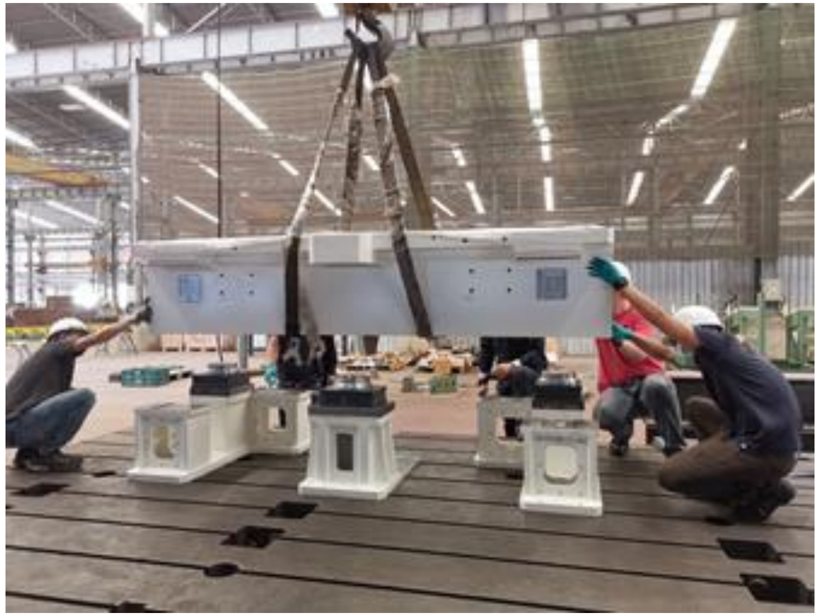
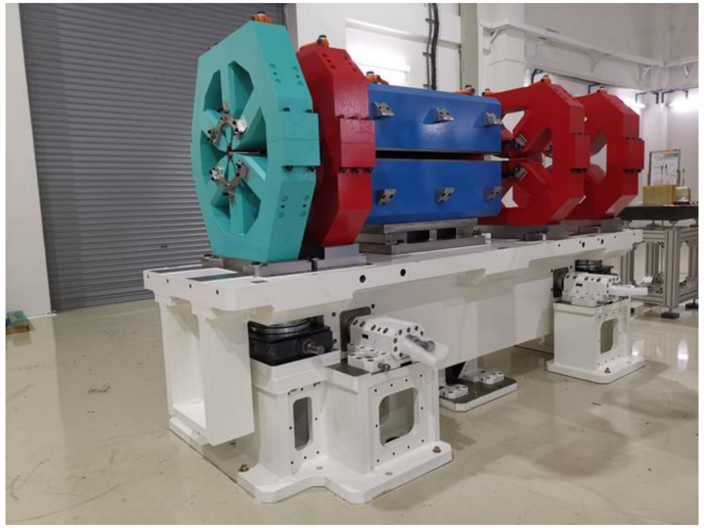
# Mechanical Positioning System

## Storage Ring Girder

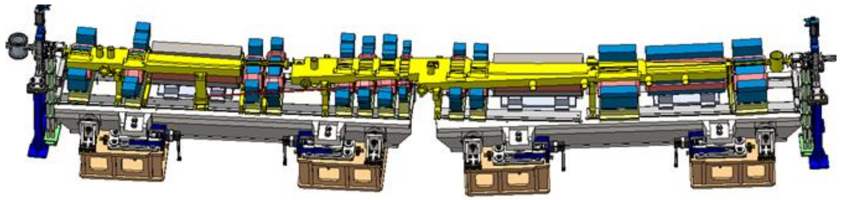


| | |
|---|---|
| Top plate size | 750 x 2,800 mm |
| Payload<br>(total magnet load) | 7 Tons |
| Levelling adjustment<br>resolution (by motor) | 0.004 mm |

## Assembly

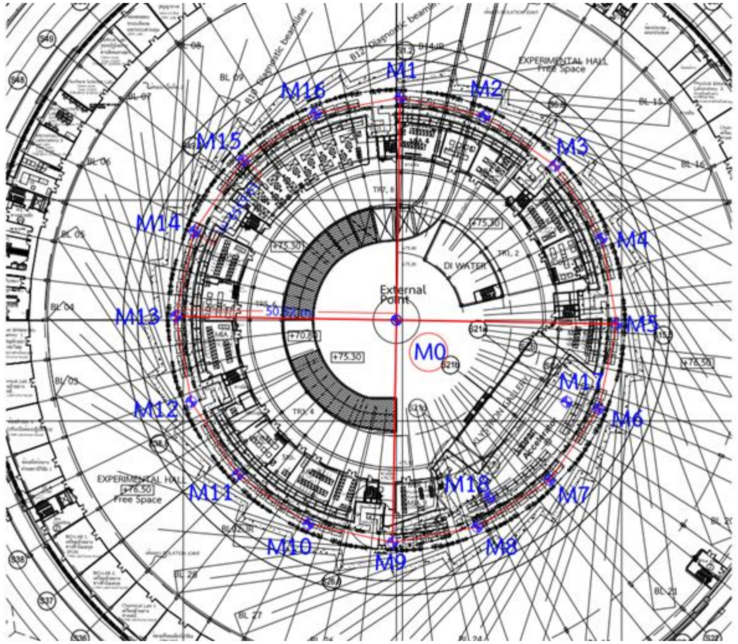


84 STR girders will be assembled and aligned with Magnets in Lab, then transport to STR tunnel for installation.



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) |

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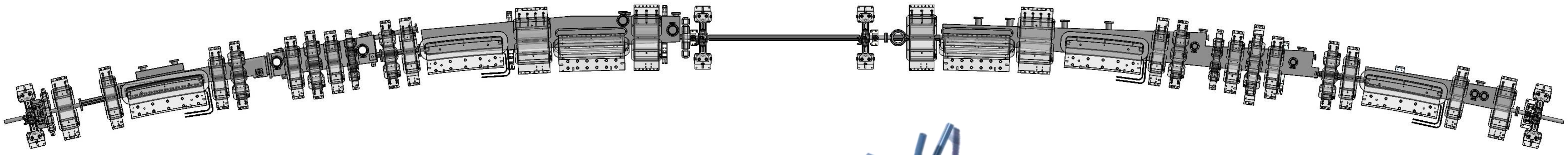
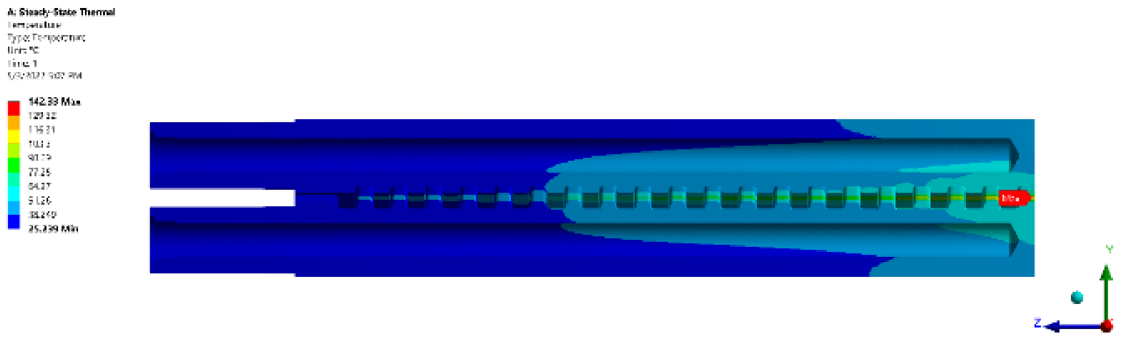
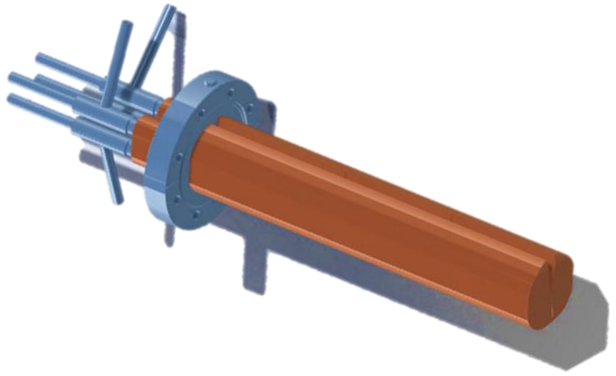
# Vacuum System

- 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 |

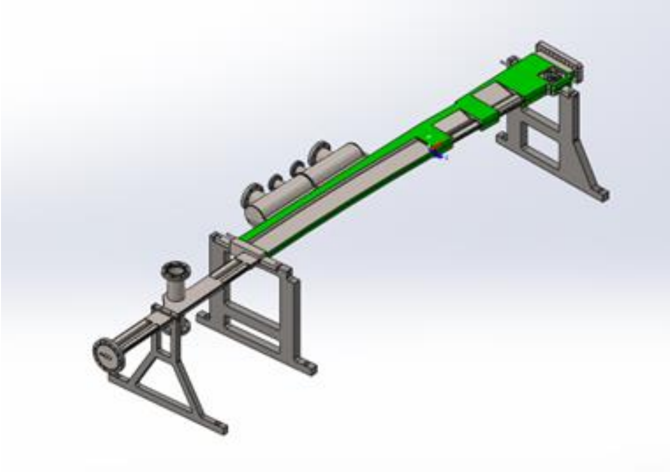




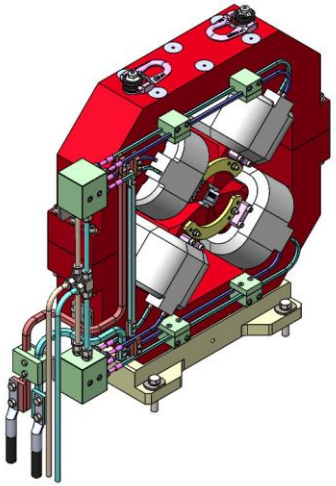



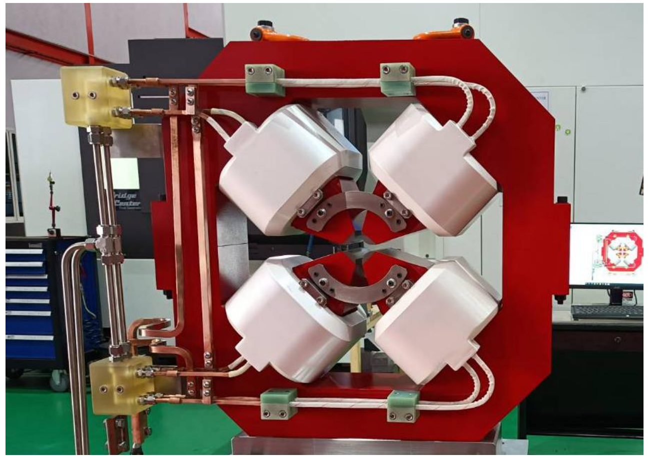
Photon absorbers have been designed to tolerate SR power with the beam current up to 500 mA + 20% margin

# Prototype Development (2021 – 2023)

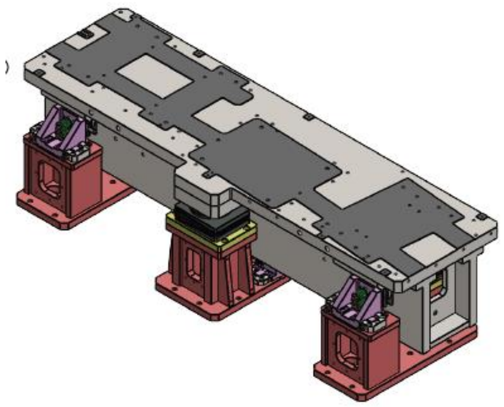


**Vacuum chambers**



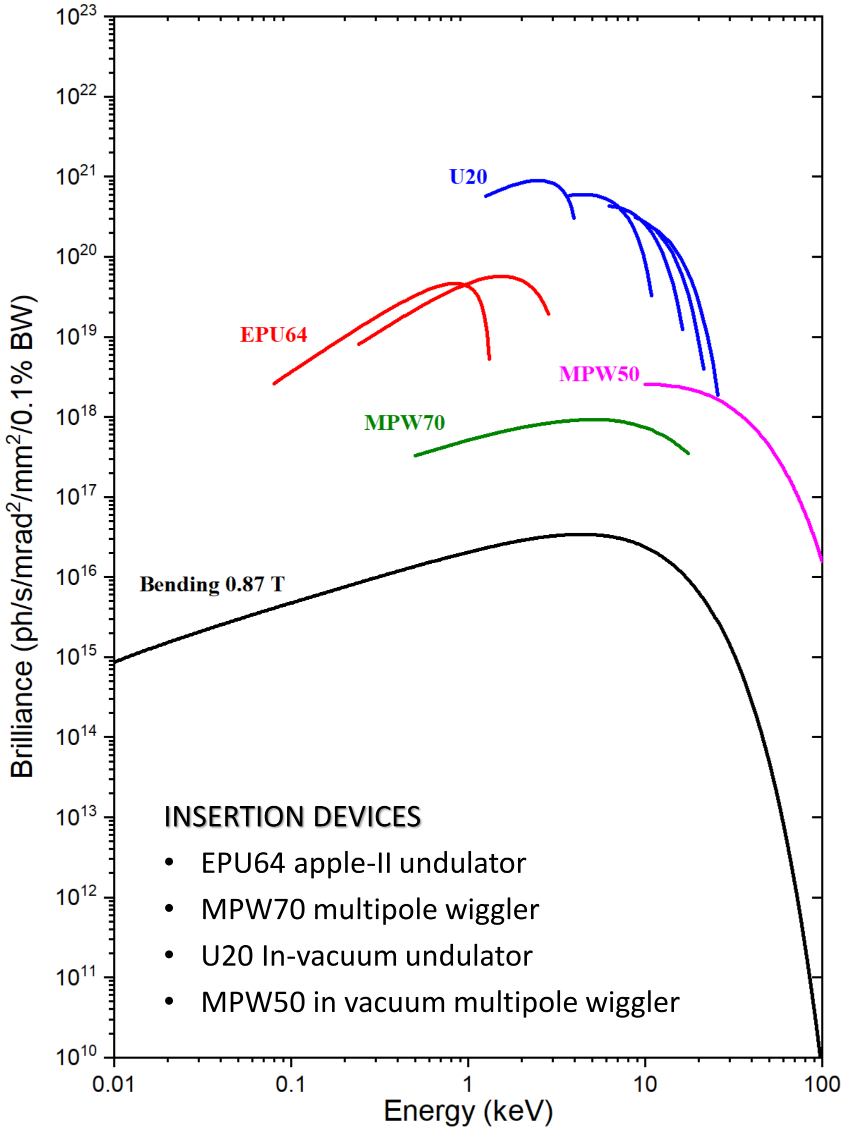


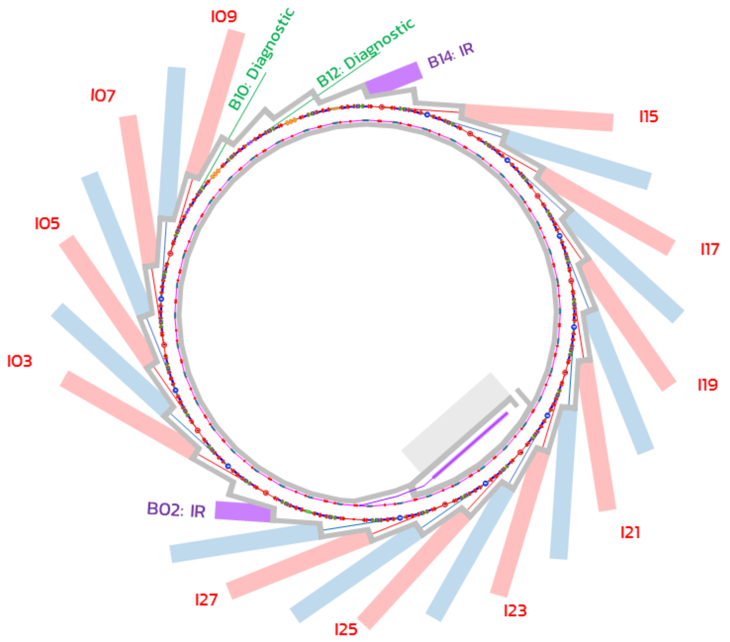
**Magnets**



**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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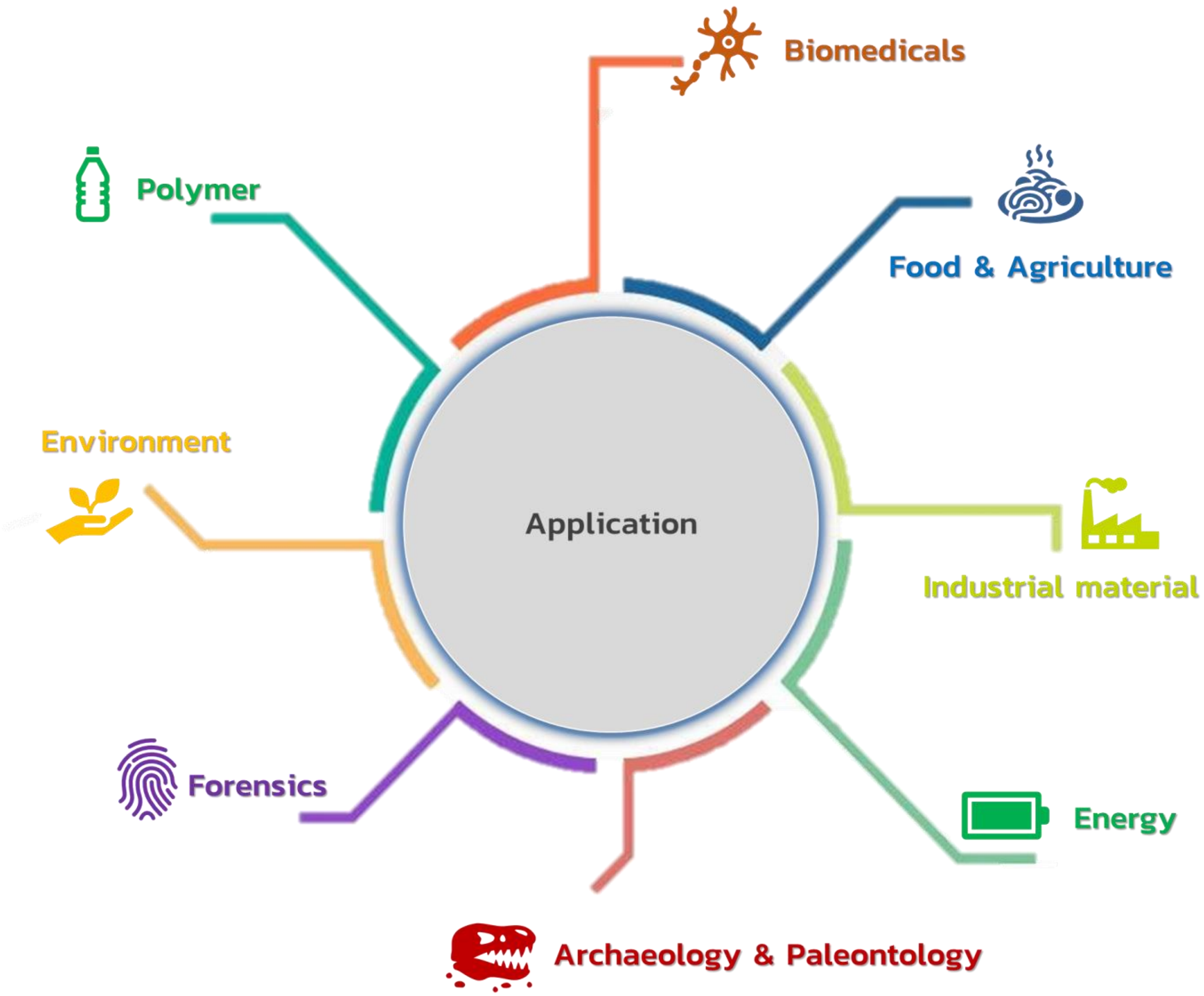
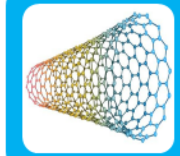
# New Opportunities for Research and Industry





Frontier sciences

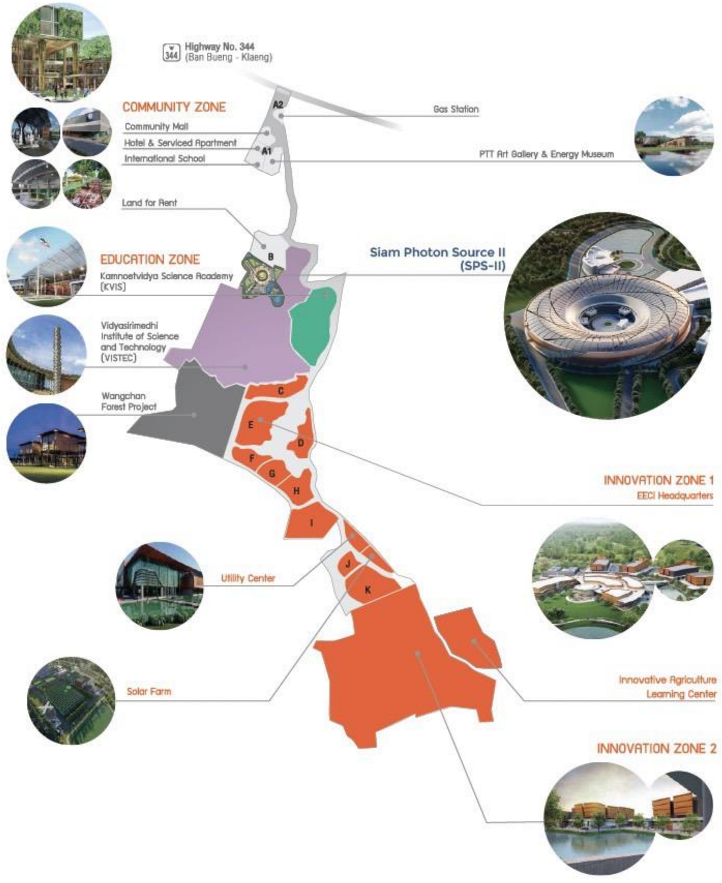

BCG researches


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) |

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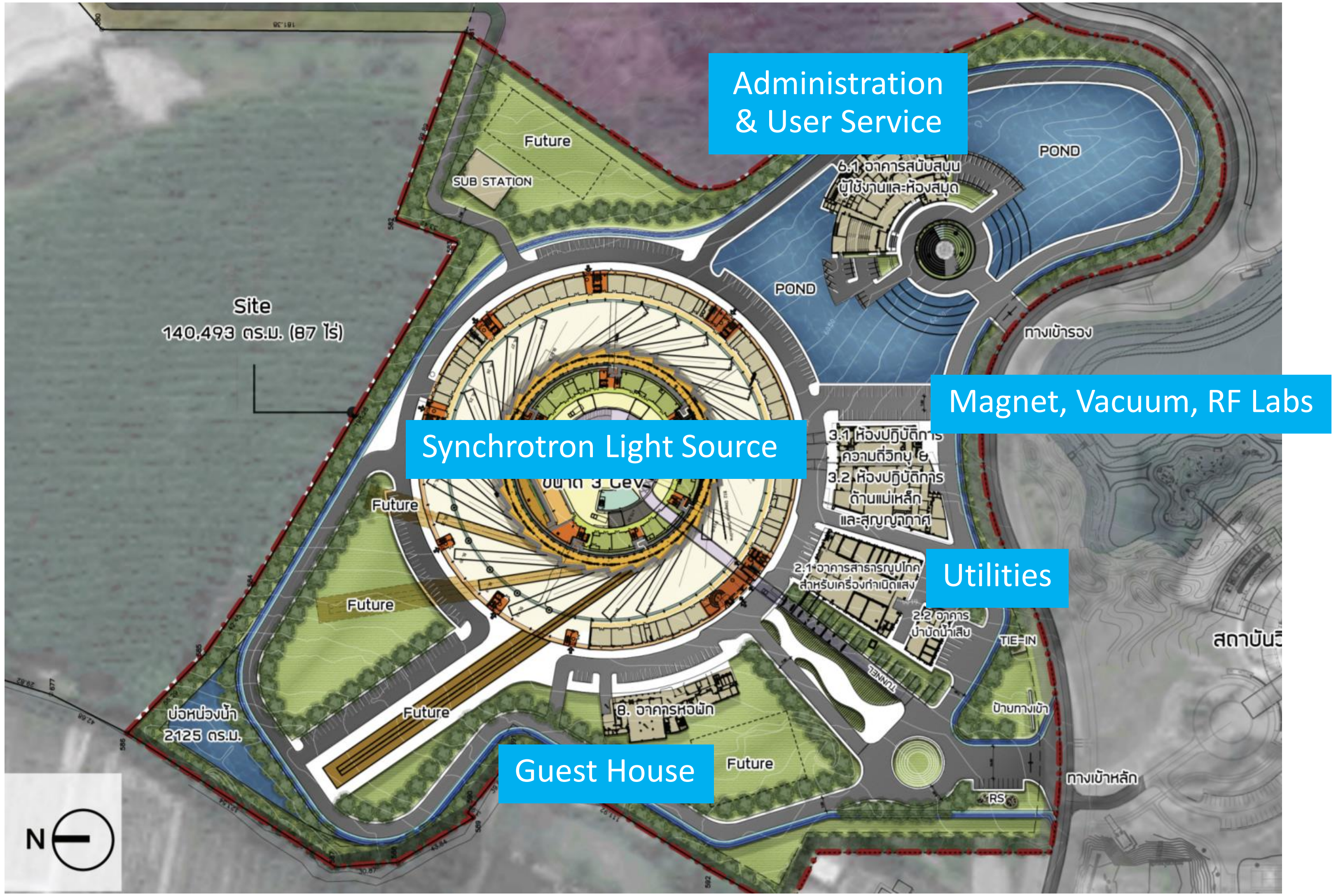
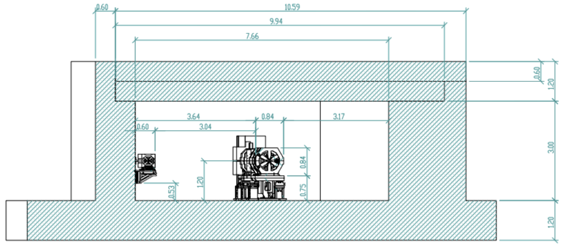
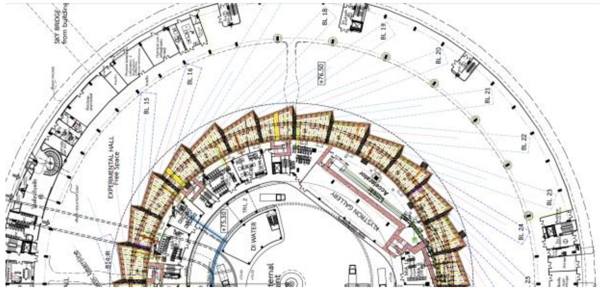
# Buildings and Facilities



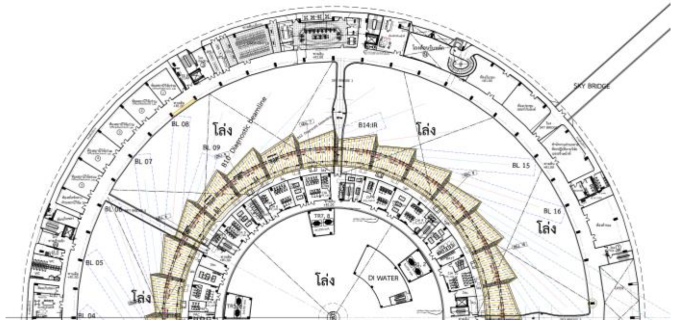



Ring Tunnel



**First floor**

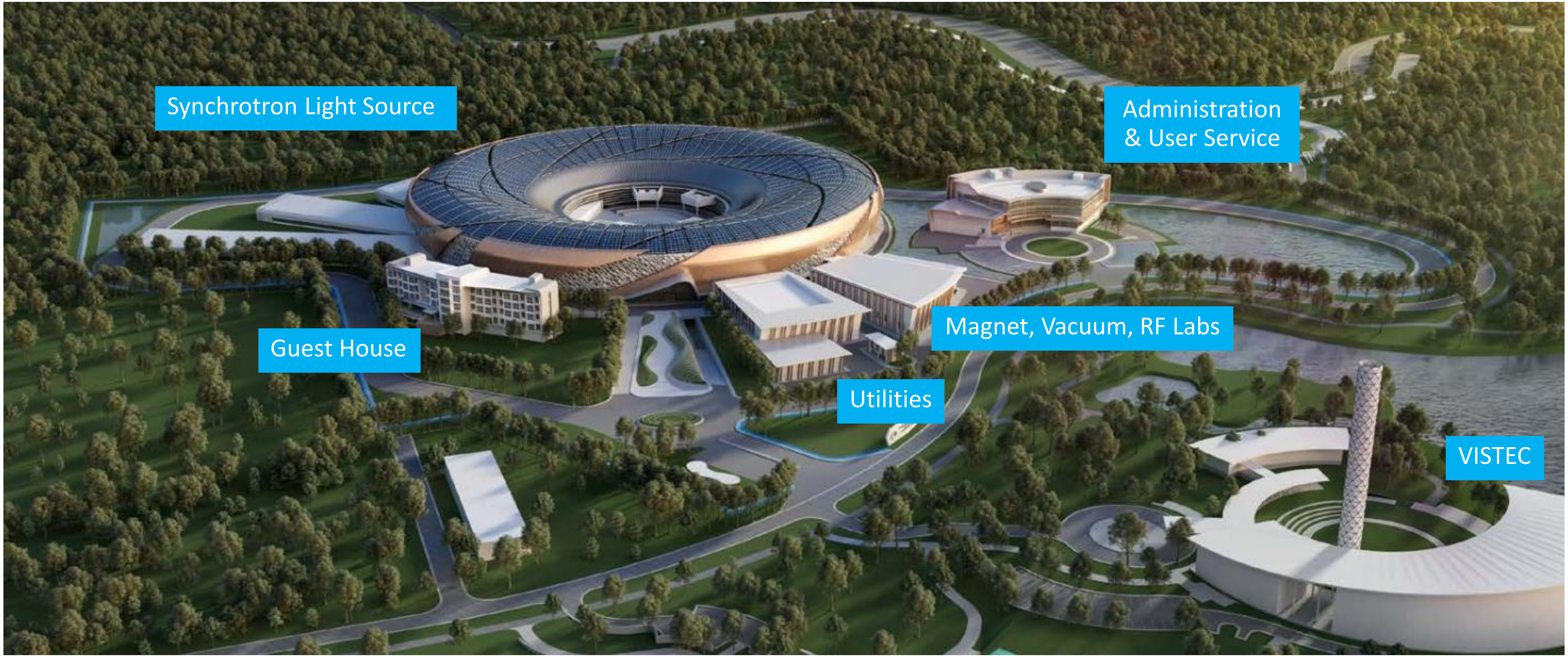
Machine Instrument Area (MIA)



**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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