

FEL-I Endstations Overview: First Experiment Planning and Readiness

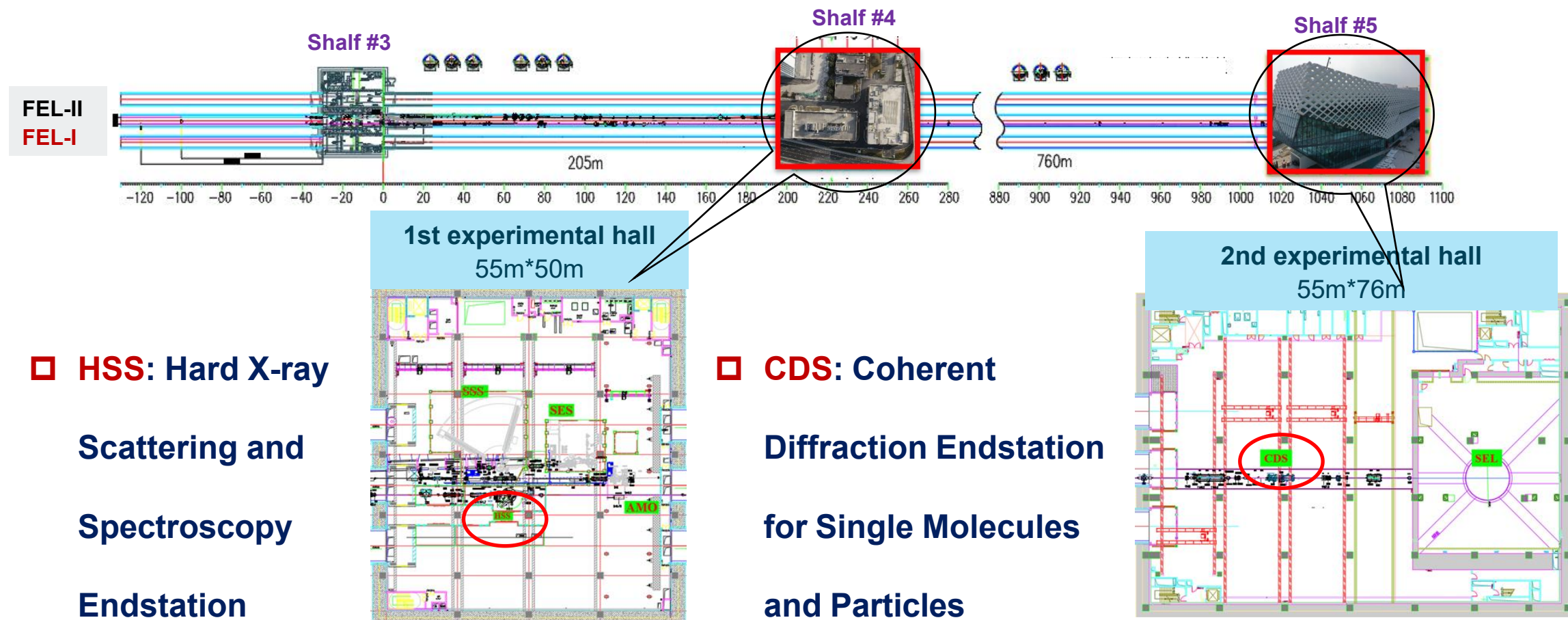
Huaidong Jiang

On behalf of FEL-I Department

Oct. 20, 2026

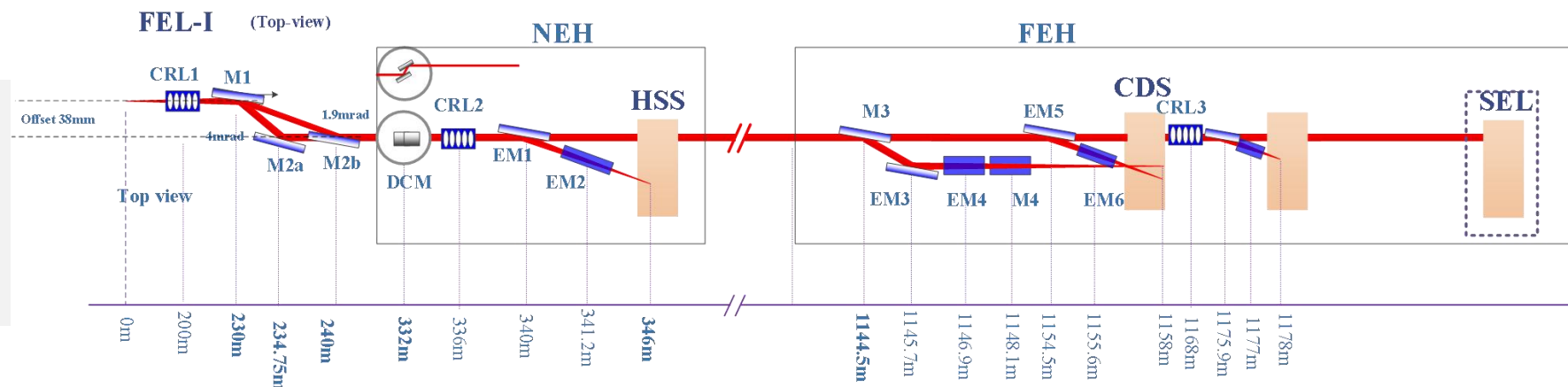
FEL-I Beamline and Endstations

SHINE Overall Layout of Beamlines and Endstations



Progress of FEL-I Beamline

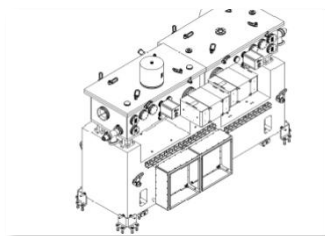
FEL-I:
3~15keV;
up to 100nm focus



- The installation of FEL-I beamline began in May 2026.
- The FEL-I beamline will be ready for receiving FEL radiation in **Mar.** 2027.



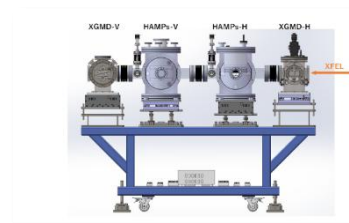
Monopulse spectrometer



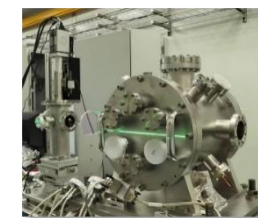
HSS KB



BLM



Hamps

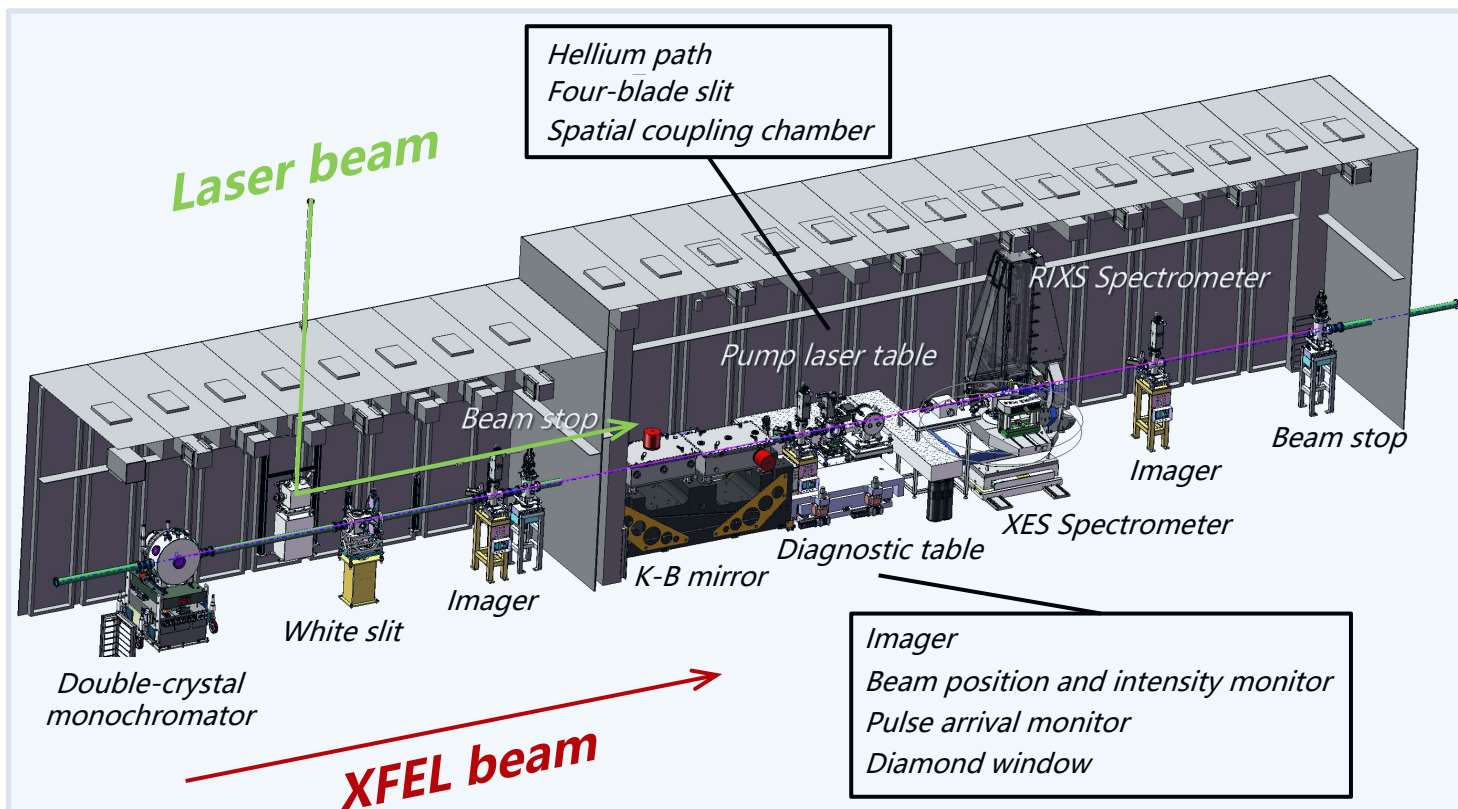


FEL-I Wavefront Sensor

HSS: Hard X-ray Scattering and Spectroscopy

Update: Installation in progress

Elementary excitations & electronic dynamics



Parameters	Values
Energy range	3~15 keV
Pulse energy @8GeV/100pC	170 μJ @7keV 80 μJ @12.4keV
Monochromator Energy resolution	Si(111): $2\text{E}-4$ @3-15keV Si(311): $5\text{E}-5$ @5.6-15keV
Type of focusing	K-B & (CRL in the future)
Focal spot size at sample (H×V, FWHM)	$6\mu\text{m}\sim 200\mu\text{m}$
$\Delta E/E$	$4\text{E}-5$
ΔT	~ 100 fs

2026.Q1

2026.Q2

2026.Q3

2026.Q4

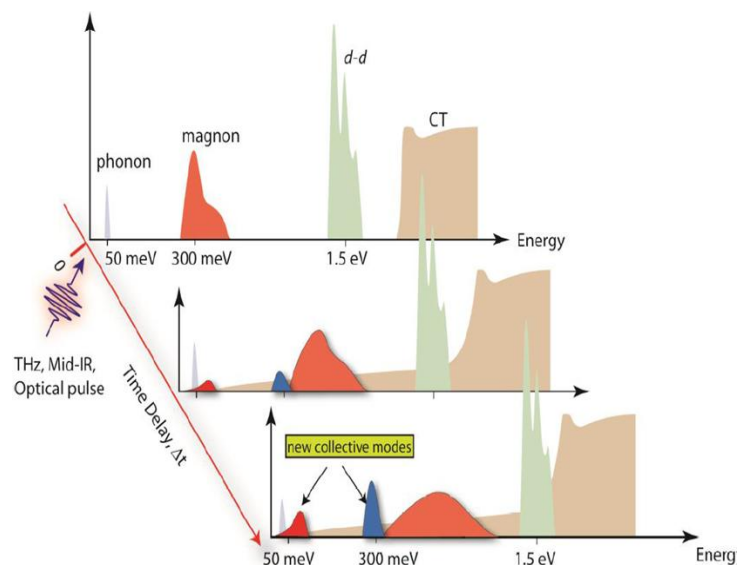
Start installation

RIXS spectrometer

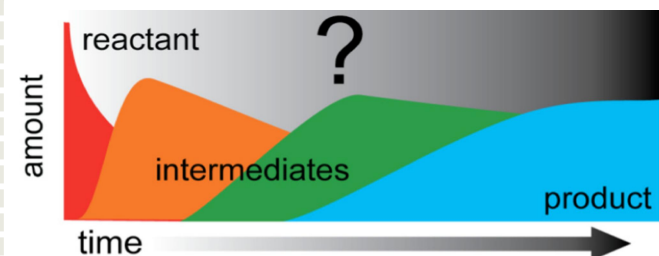
Finish installation

Scientific Objectives & Methods

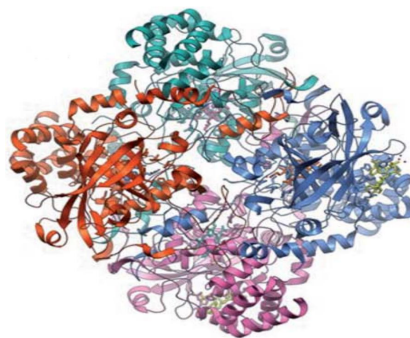
- **Elementary excitation** in correlated quantum materials. (tr-RIXS)
- **Electronic structure** and **spin dynamics changes** in chemical, biological, energy materials. (tr-RXES, XES, HERFD-XAS)
- **Structural evolution** phenomena such as phase transitions and solvation. (tr-XRD, XSS)



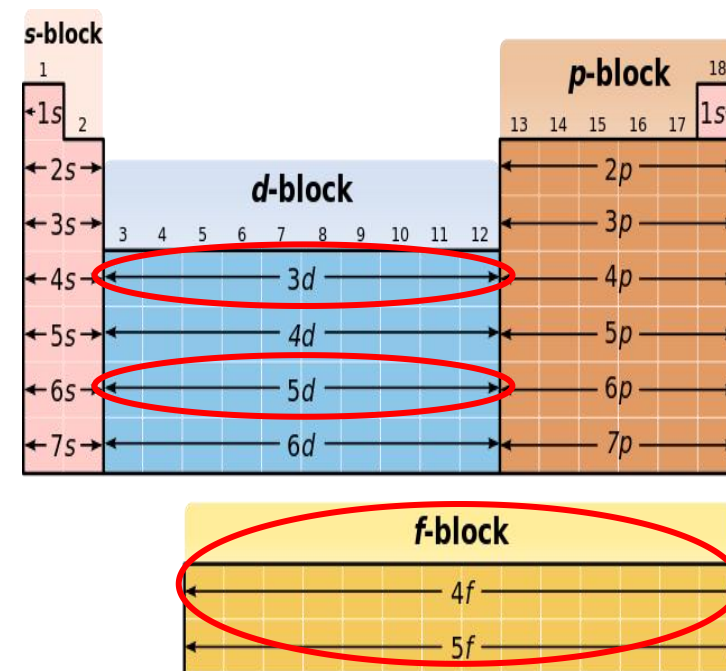
Elementary excitations in strong correlated quantum materials. No. SLAC-R-1053 (2015)



Chemical reaction dynamic process

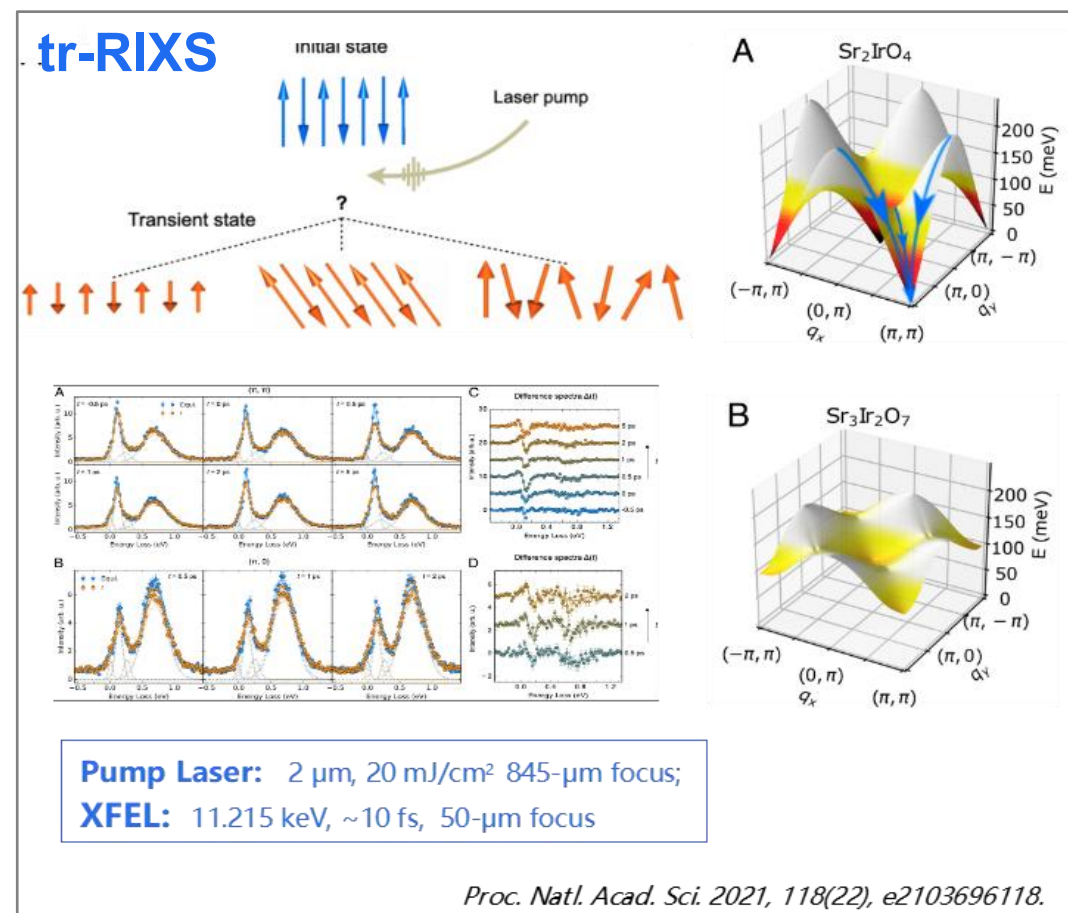
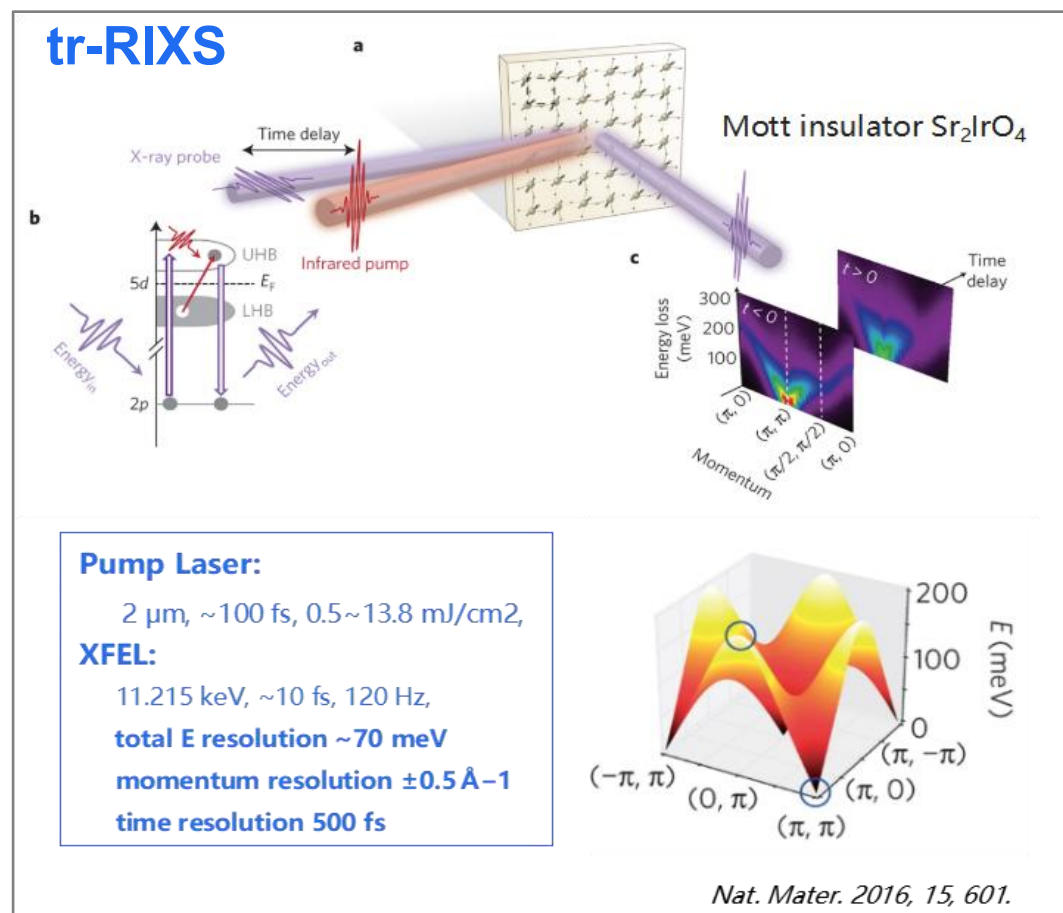


Fe^{2+} and Fe^{3+} in hemoglobin



Experiment Planning: Science cases

- ◆ **Time-resolved magnetic RIXS at the iridium L_3 edge (11.215 keV)**
 Samples: correlated transition-metal oxide (Sr_2IrO_4)
 Reveal how magnetic correlations and electronic structure evolve after excitation

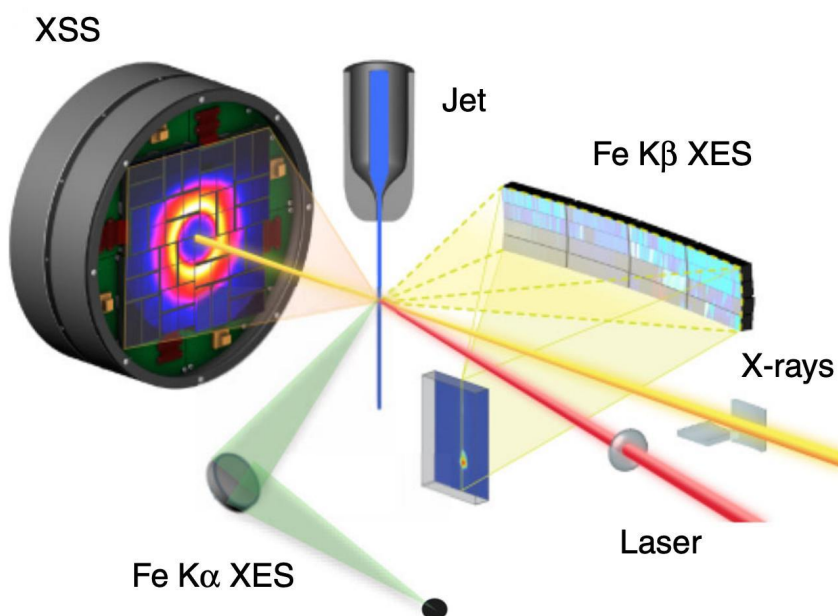


Experiment Planning: Science cases

◆ Time-resolved Fe K_α & K_β XES and X-ray solution scattering (XSS)

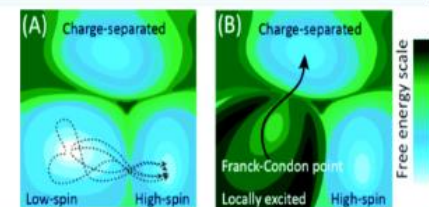
Correlated tracking of **electronic** and **structural** dynamics

Samples: $[\text{Fe}(\text{bpy})_3]^{2+}$ as a benchmark



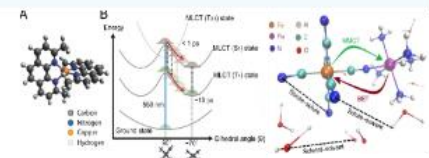
Physics

- Spin crossover
- Nuclear wavepacket motion
- Electron-phonon coupling
- Liquid-liquid phase transition



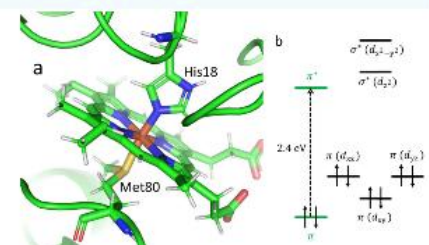
Chemistry

- Molecular dissociation and rearrangement
- Ultrafast solvation
- Multi-channel relaxation



Biology

- Photodissociation mechanism of cytochrome c
- Axial structural distortion
- Energy transfer and biological functions



Nat. Chem. (2021)

Nat. Commun. (2021)

Nat. Commun. (2020)

Chem. Sci. (2019)

J. Phys. Chem. B (2016)

ACS Nano (2024)

Nat. Commun. (2023)

Chem. Sci. (2023)

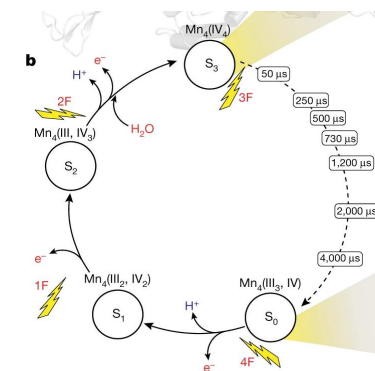
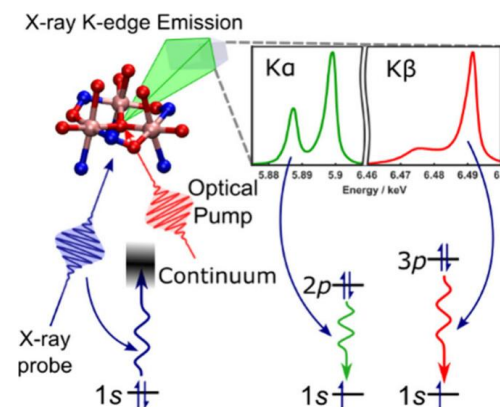
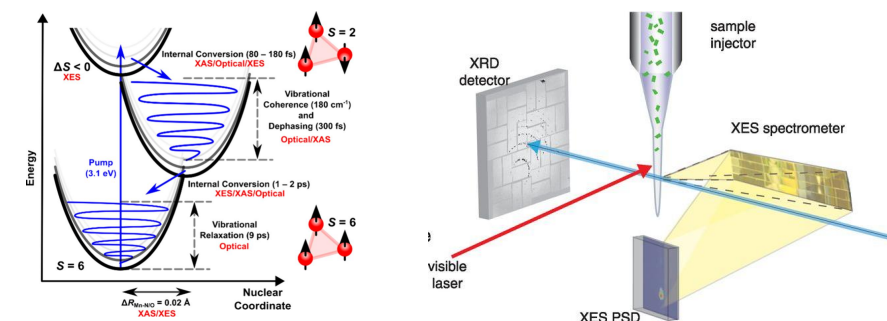
Nature Commun. (2015)

HSS Endstation: Pilot Experiment and Readiness

- Pilot Experiments:**
(tr-XES + tr-XSS)
- ◆ Photochemical Dynamics of Photoinduced Spin Crossover in $[\text{Fe}(\text{bpy})_3]^{2+}$
 - ◆ Photoinduced Jahn–Teller Distortion in $\text{Mn}(\text{acac})_3$
 - ◆ Oxidation Dynamics of the Kok Cycle in Photosystem II (PSII) Mn_4CaO_5

Experimental parameters based on the current situation

Sample	20~50 mM $[\text{Fe}(\text{bpy})_3]^{2+}$ / $\text{Mn}(\text{acac})_3$ / Mn_4CaO_5 50-300 μm Liquid jet, Helium flow	ready
XFEL photon	$\text{Fe} \geq 7112 \text{ eV}$, $\text{Mn} \geq 6539 \text{ eV}$, 100 μJ , 30 fs	
Monochromator	DCM Si(311) or Si(111)	
Spot size on sample	10-50 μm (V) x 200 μm (H)	
Repetition rate	10 Hz - 1 kHz	
Pump laser	400-600 nm, 10-15 $\mu\text{J}/\text{pulse}$, 0.5 kHz	
Time window	-1~5 ps fine scan, 5~20 ps medium scan	
Spectrometer	XES spectrometer	ready
Detectors	Jungfrau 0.5M and 4M, 1 kHz	ready
Total time resolution	$\leq 100 \text{ fs}$	

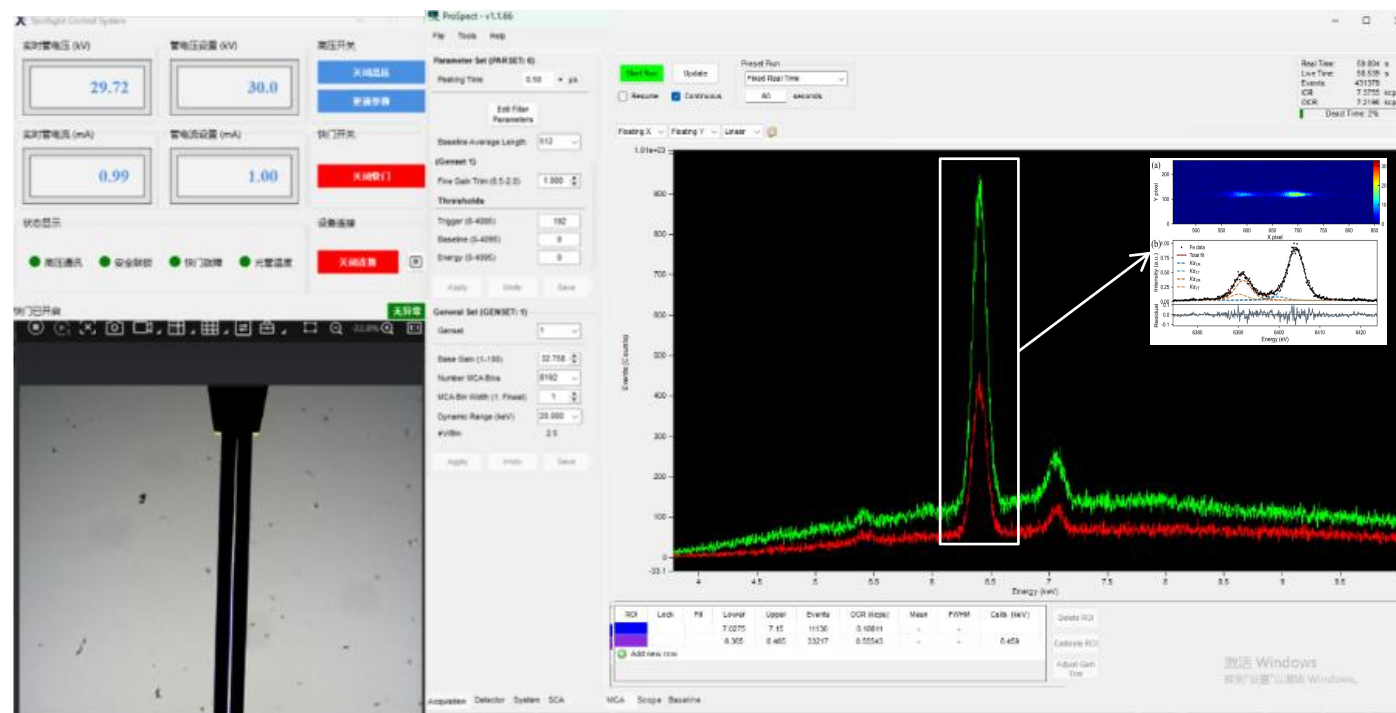


HSS Endstation: Pilot Experiment and Readiness

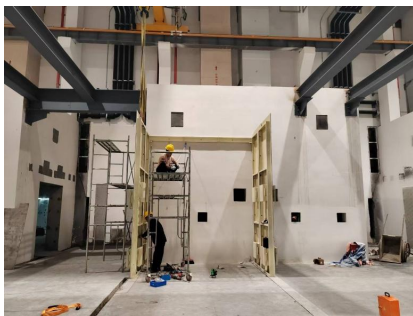
- Pre-experiments for Fe emission spectroscopy, especially for **sample system testing**.
- **Fe K_{α} and K_{β} has been collected successfully**, and will be detected with spectrometer in high energy resolution mode by the end of this year (Fe and Mn $K_{\alpha_{1,2}}$ and $K_{\beta_{1,3}}$ and $K_{\beta_{2,5}}$).
- DAQ and control system has been developed for the offline testing.

X-ray focal spot: 170 μm

Sample: 30 mM $[\text{Fe}(\text{bpy})_3]\text{Cl}_2$ aqueous
200 μm liquid jet



Current Status of HSS Endstation



2024.10.31



2025.6.20



Optical Hutch



K-B mirror



RIXS spectrometer



- 2020-2024 CDR & TDR
- 2025.10.22 TAC meeting, 90% Contract signing
- 2026.04.21 TAC meeting, Preparing for online installation
- 2026.07 Starting online installation
- 2026.08 White slit, Imager, Beam stop, K-B mirror installed
- 2026.09 Beam stop, RIXS spectrometer installed
- 2026.10.19 TAC meeting, Helium path, Sample system, RXES spectrometer offline integrated and under testing
- 2026.11 Complete online installation
- 2027.03 Complete joint debugging
- 2027.04 Complete all ready for XFEL
- 2027.10 Commissioning

7/16 equipments has been installed

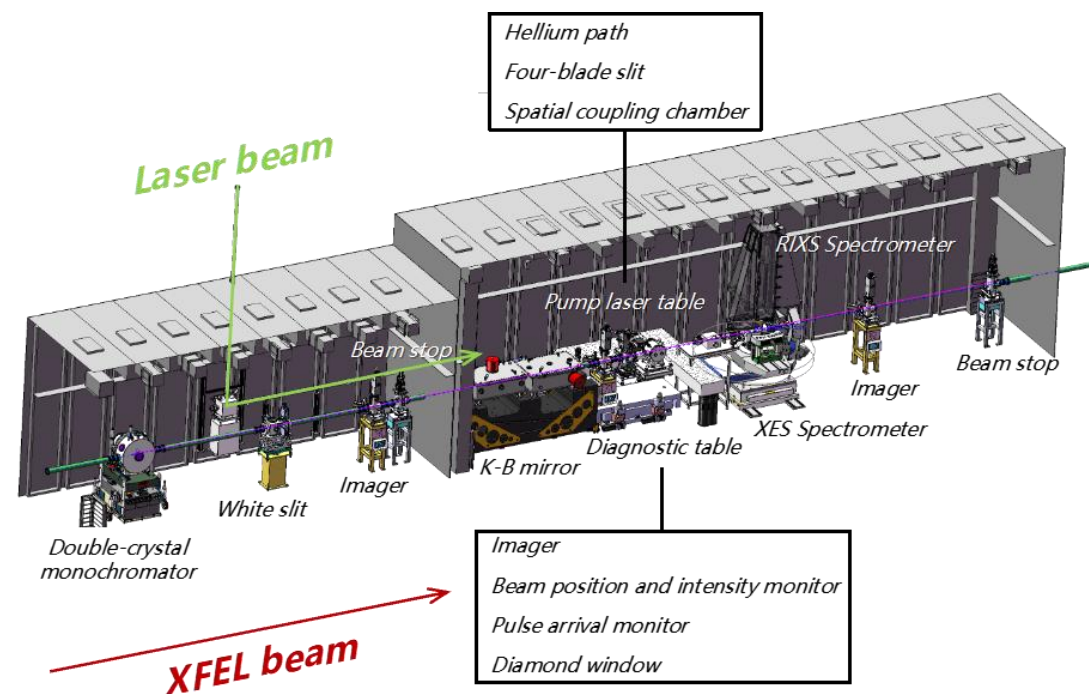
Commissioning Plan

	2027											
	Q1			Q2			Q3			Q4		
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Functional Tests - Spectrometers Movement & Scanning - Liquid Sample System - Helium Path Transport - Spatial & Temporal Coupling - Beamline Instruments Test				<i>First Lasing of FEL-I</i>								
Controls, DAQ, Trigger & Timing - Synchrotron and related systems - In coordination with General Experimental Technology Department (GET)												
Beamline Commissioning With XFEL - Beam Transport With DCM & K-B Mirror - Energy Bandwidth & Focal Spot - Slits, Imager, BPIM, PAM												
Spectroscopy & Scattering Acceptance - Time & Energy Resolution - Pump-probe demonstration										 <i>Commissioning</i>		

Problems and Challenges

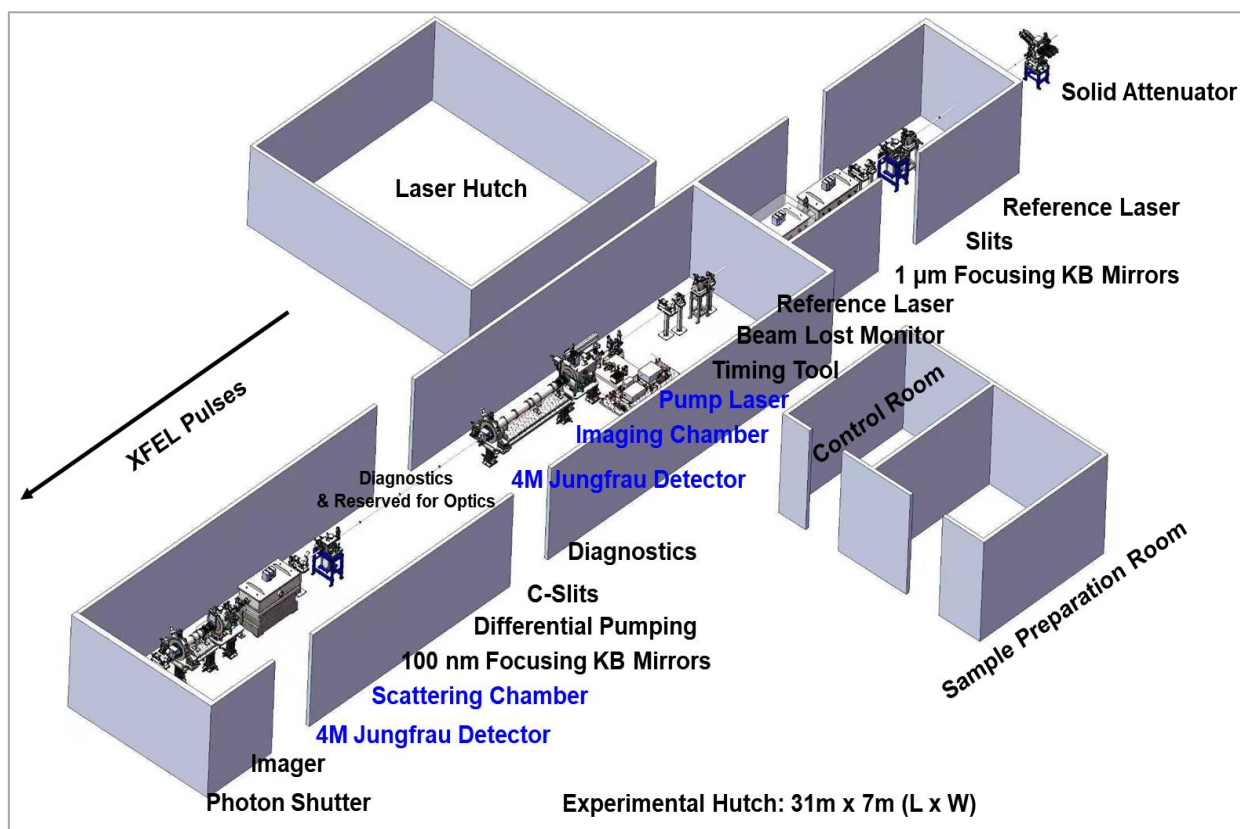
The very tight installation and commissioning window before the FEL-I first lasing.

Beamline	1. K-B mirror performance verification
	2. Double-crystal monochromator delivery time (Mar. 2027) needs to be guaranteed
Diagnosis	1. Alignment laser system, Pulse arrival monitor, Spatial coupling chamber contracts have not been signed
Pump laser	1. Laser table delivery time (Jan. 2027) needs to be guaranteed
	2. Optical path design and setup should be done as early as possible
Endstation	1. The very constrained space of EH
	2. The remaining contracts for acceptance and pilot experiments



CDS: Coherent Diffraction Endstation for Single Molecules and Particles

Update: Installation in progress



Main Photon Parameters (2027)

Items	Parameters
Photon Energy	5–10 keV
Average Pulse Energy	$\geq 100 \mu\text{J}$ (Source Point)
Beam Stability	$\leq 10\%$
Repetition Rate	$\leq 2 \text{ kHz}$
Bandwidth	$\leq 0.1\%$
Pulse Length	$\leq 100 \text{ fs}$
Focusing Capability	1.0 μm & 100 nm (Two IPs)
Sample Environment	High Vacuum: Helium: Atmosphere
Sample Delivery	Aerosol Injector (SPI); GDVN & LCP (SFX)
Detectors	Jungfrau 4M (4 mm Central Hole)
Pump Lasers	1030 nm, $\leq 40 \text{ fs}$ @ 100 kHz;

2026.Q1

2026.Q2

2026.Q3

2026.Q4

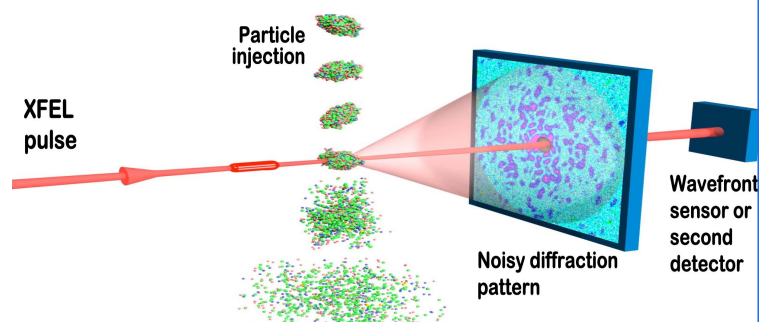
Start installation

Finish installation

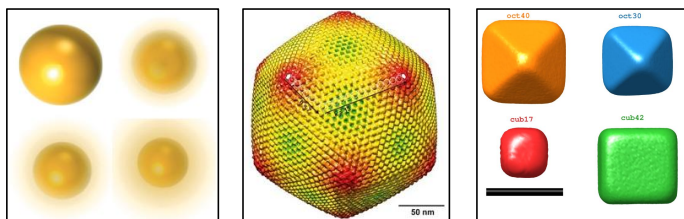
Scientific Objectives & Methods

Ultrafast X-ray Imaging

Structure of Individual Particles



(Time-resolved-) Single Particle Imaging

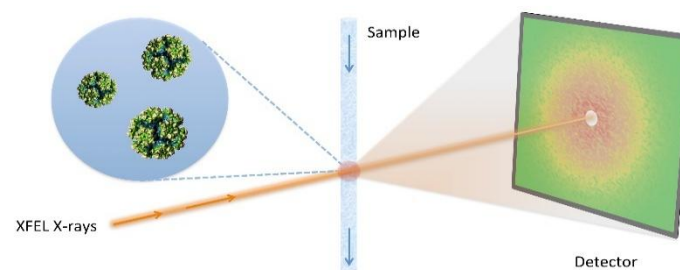


Nanoparticles, Virus, Aerosols, Clusters, etc.

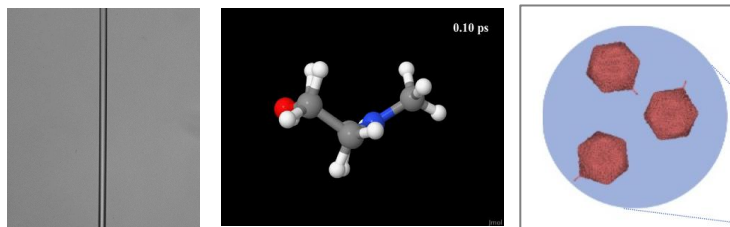
Science **316**, 1444 (2007); *Nature Phys* **2**, 839 (2006);
Phys. Rev. Lett. **114**, 098102(2015); *Optica* **8**, 5 (2021).

Ultrafast X-ray Scattering

Time-resolved Structure Dynamics



(Tr-) Forward Scattering (SAXS, FXS, USS, etc)

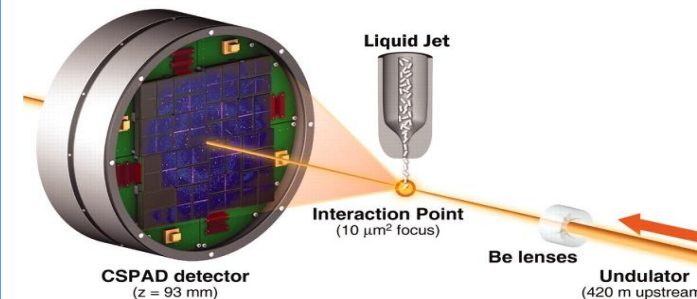


Liquid, Gas, Multi-particles, etc.

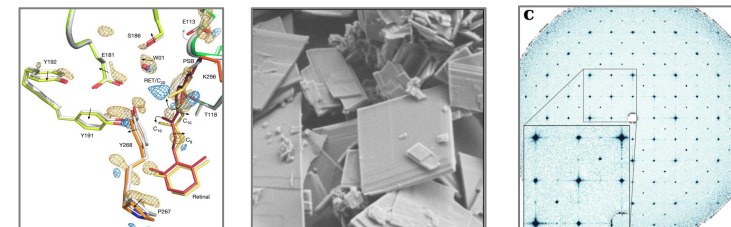
Proc Natl Acad Sci USA **115**, 11772 (2018); *Nat. Chem.* **11**, 716 (2019);
Nature Phys **12**, 966 (2016).

Ultrafast X-ray Crystallography

Atomic Structure of Microcrystals



(Tr-) Serial Femtosecond Crystallography



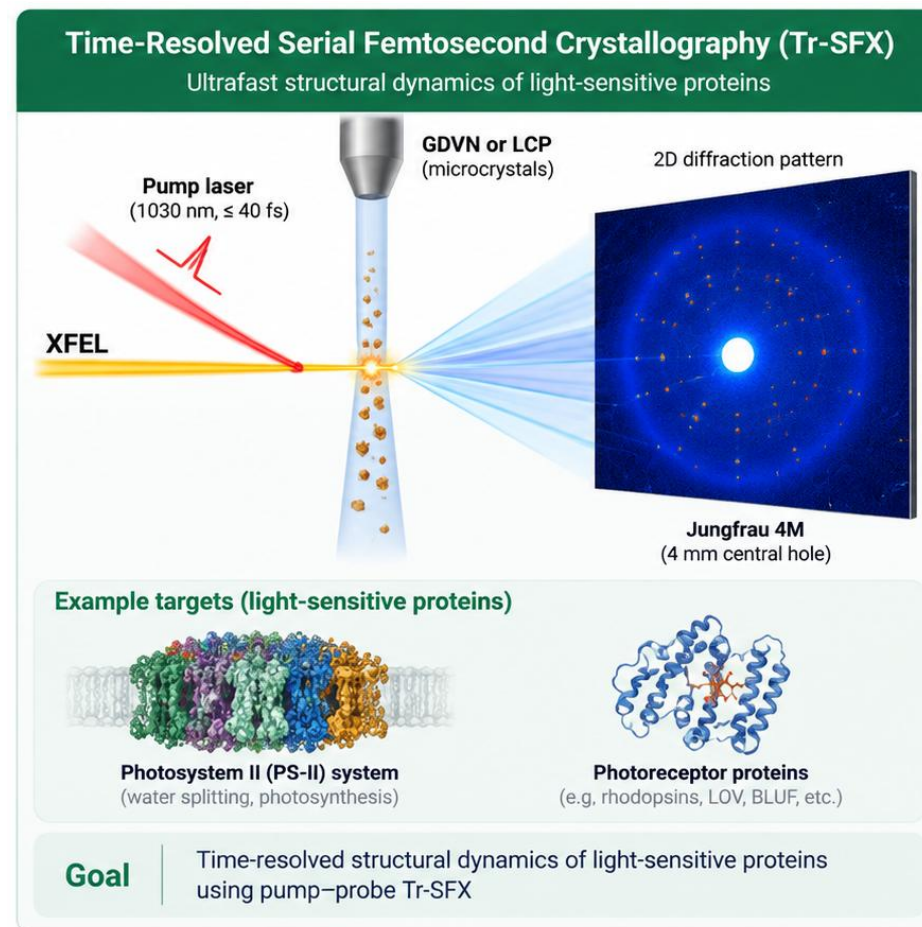
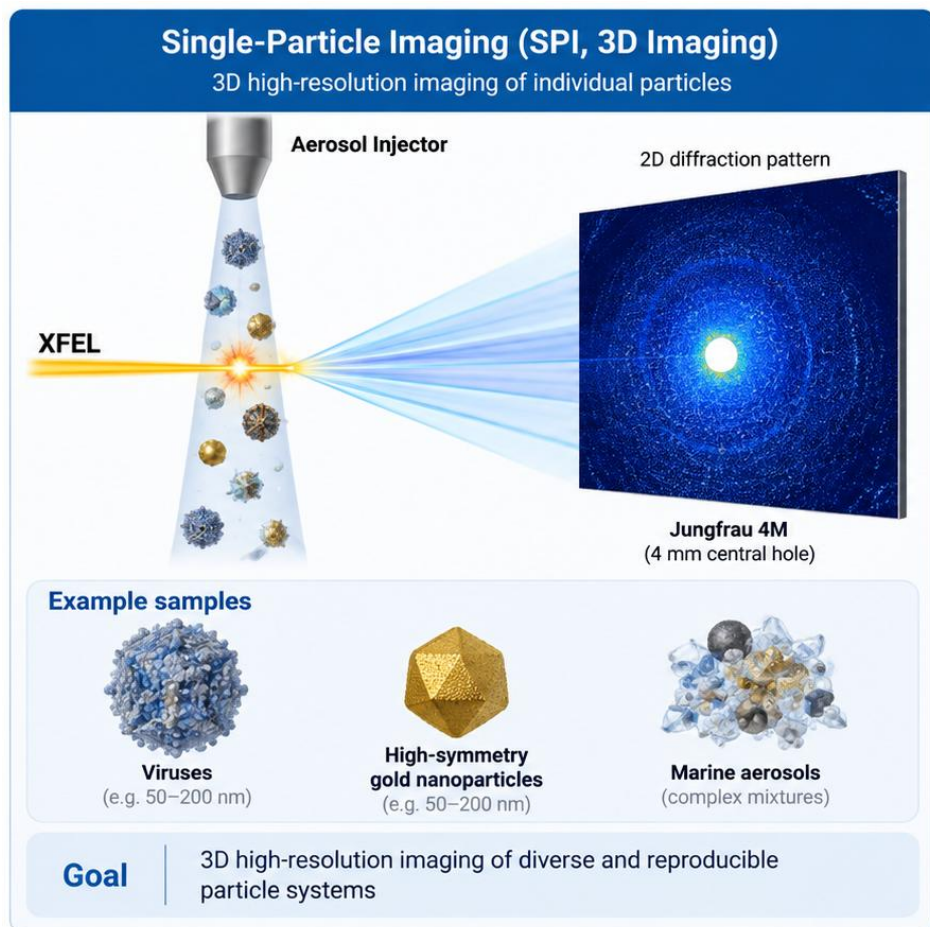
Protein Crystals, Tiny Crystals, Quantum Dots, etc.

Nature **615**, 939 (2023); *Nature* **601**, 360 (2022);
ACS Nano **19**, 28372 (2025).

Capturing Atomic Structures and Ultrafast Dynamics

Experiment Planning: Science cases

- ◆ Atomic structure of crystalline proteins with Tr-SFX method;
- ◆ Single protein particle imaging for non-crystalline proteins with Tr-SPI



CDS Endstation: Pilot Experiments and readiness

Pilot Experiment - SPI:

High-throughput Imaging of Biological Particles and Nanocrystals with Aerosol Injector.

X-ray Photon Parameters:

5 keV, 30 fs, > 100 uJ, 100-1000 Hz

Pump Lasers: No

Sample Injections:

ESI and Atomizer & Uppsala AFL-100

Samples:

Melbourne Virus, Gold NPs, NaCl Aerosols.

Detector: 4M JF with 4mm Hole.

Online Data Analysis:

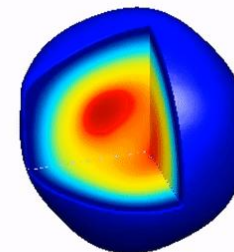
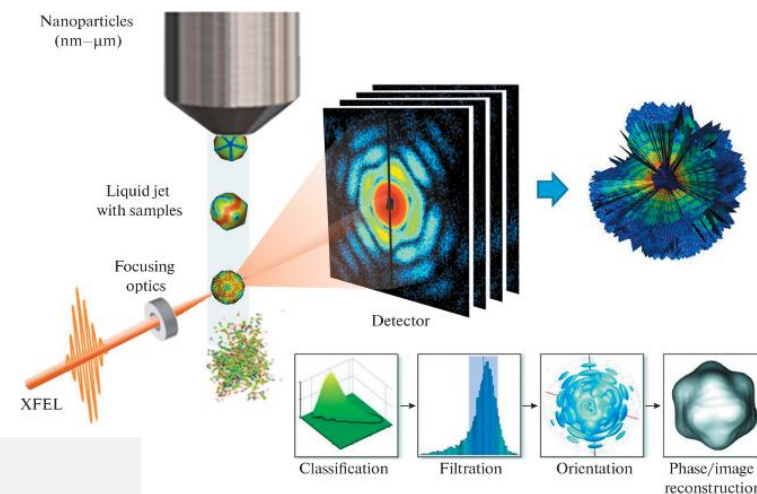
Ready

Control Panel and PyDM:

Ready

Collaborations:

Prof. Zihe Rao (STU),
Prof. Quan Wang (STU),
Prof. Changyong Song (POSTECH),
Prof. Christoph Bostedt (EPFL, PSI),
Prof. Filip Maia (Uppsala U.), *etc.*



CDS Endstation: Pilot Experiments and readiness

Pilot Experiment Tr-SFX:

Dynamic Structure Change of photoreceptor proteins with Pump Lasers.

X-ray Photon Parameters:

9.5 keV, 30 fs, > 100 μ J, 100 Hz

Pump Lasers:

518-800 nm, 100 μ m, 40 fs, < 50 μ J

100 Hz, Delay: -10 ps to 100 ps

Sample Injections:

GDVN with MPI Anti-Settler

Samples:

UVR8, PhyA, PhyB.

Detector: 4M JF with 4mm Hole.

Online Data Analysis:

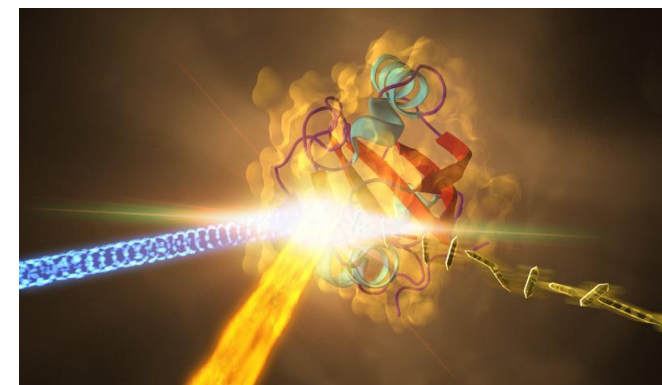
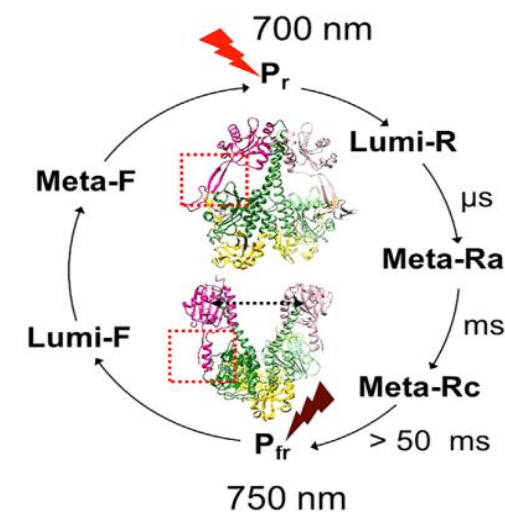
Ready

Control Panel and PyDM:

Ready

Collaborations:

Prof. Jiangyun Wang (IBP, CAS),
Prof. Ilme Schlichting (MPIImF),
Prof. Wenkai Zhang (BNU),
Prof. Hongjie Li (STU),
Prof. Bei Ding (SJTU),
Prof. Lijin Tian (IB, CAS), *etc.*



Progress of CDS Endstation



Experimental Hutch



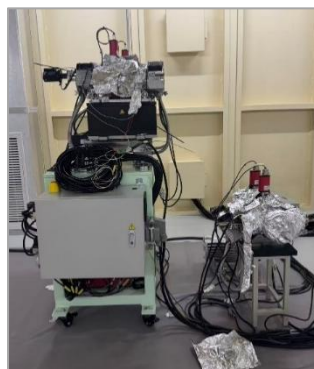
Pump Laser Hutch



Solid Attenuator



Ref. Laser



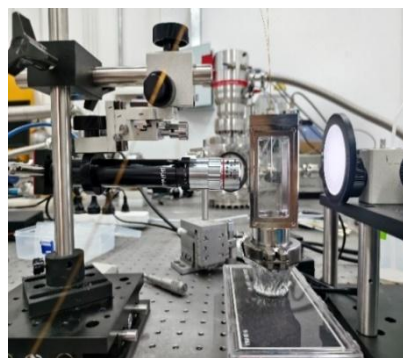
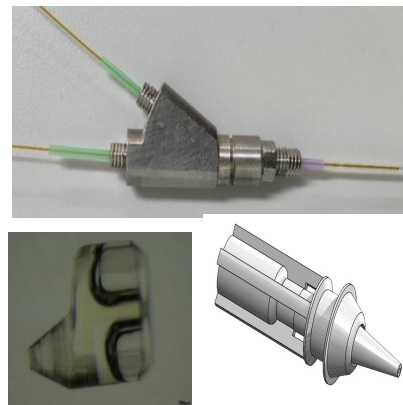
Differential Pump

Status of Functional Modules

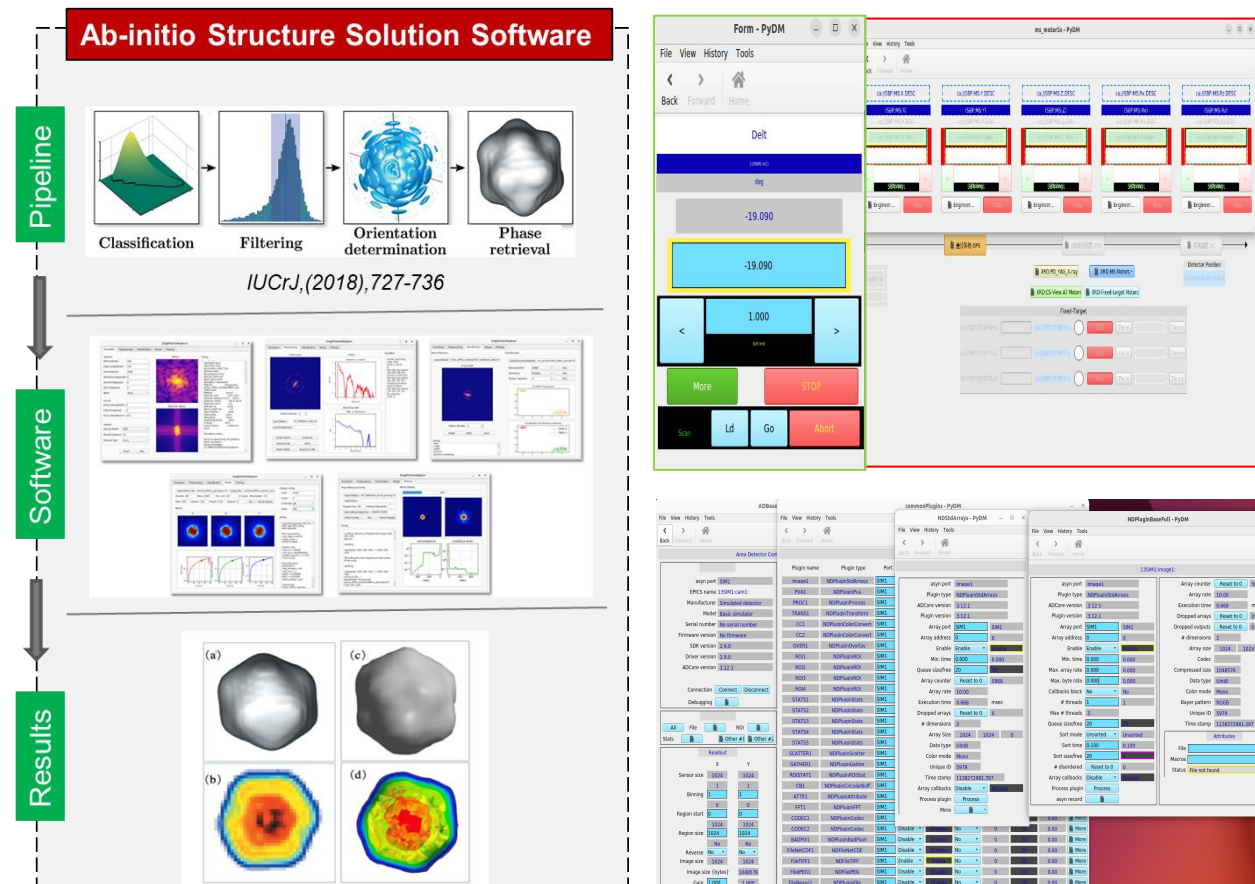
- May 2026: Factory Manufactory and FAT
- Jun. 2026: Installation for FEE Instrument
- Sep. 2026: Offline Integration for Core Instrument
- Oct. 2026: Core Instrument Installation
- Nov. 2026: Differential Pump & Detector Installation
- Dec. 2026: Complete of Diagnostics Installation
- Jan. 2027: Complete of Supporting System
- Mar. 2027: Offline Commissioning
- Dec. 2027: Acceptance test

Readiness of CDS Endstation

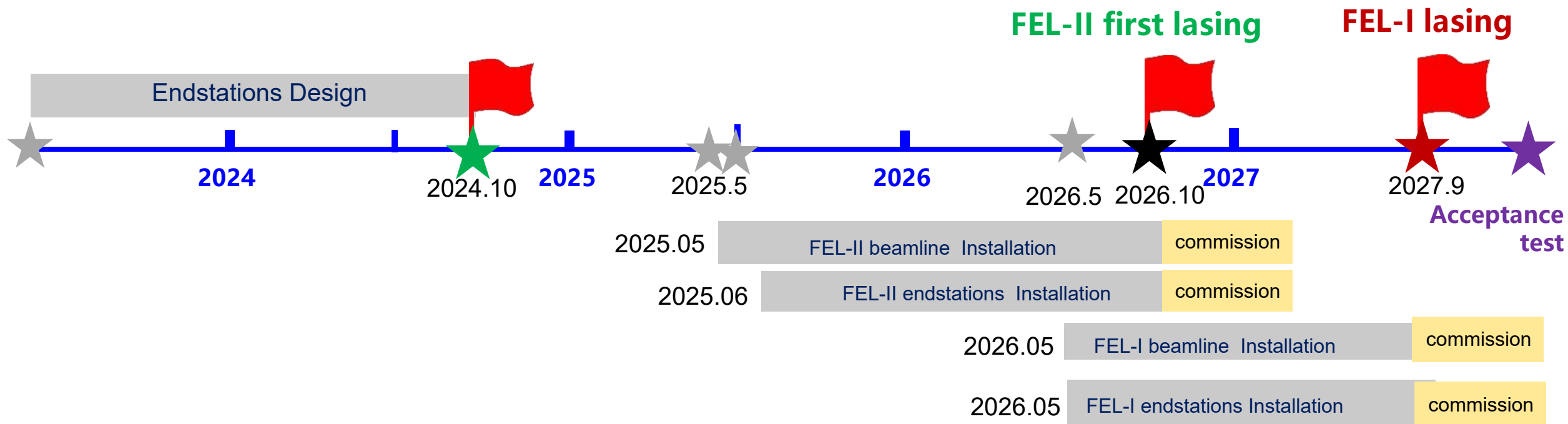
Sample Delivery



Data Analysis and Control GUI



Schedule of FEL-I Beamline and Endstations



- ◆ **Mar. 2027:** FEL-I beamline ready for laser
- ◆ **Sep. 2027:** FEL-I first lasing
- ◆ **Nov. -Dec. 2027:** The FEL-I beamline, endstation commissioning.

Commissioning plan

FUNCTIONAL MODULE / SCOPE		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
01	Vacuum, Interlock & Differential Pumping Pumps, gauges, valves and interlock	APR–JUL								
02	Controls, DAQ, Trigger & Timing Synchrotron and related systems In coordination with General Experimental Technology Department (GET)	APR–JUL								
03	Beamline Optics & Photon Diagnostics at IP Offset mirrors and beam transport GMD, GATT, SATT, imagers and reference lasers					AUG–NOV				
04	Beam Profile & Focus at IP 100 nm focus characterization Knife-edge scan, ptychography and wavefront sensing							OCT–NOV		
05	Diffraction: Fixed Targets, Atomizer & ADL 100 nm focus; fixed metallic nanoparticles on Si3N4 membranes; aerosol injector at 100 Hz								NOV–DEC	

Emphasized by TAC

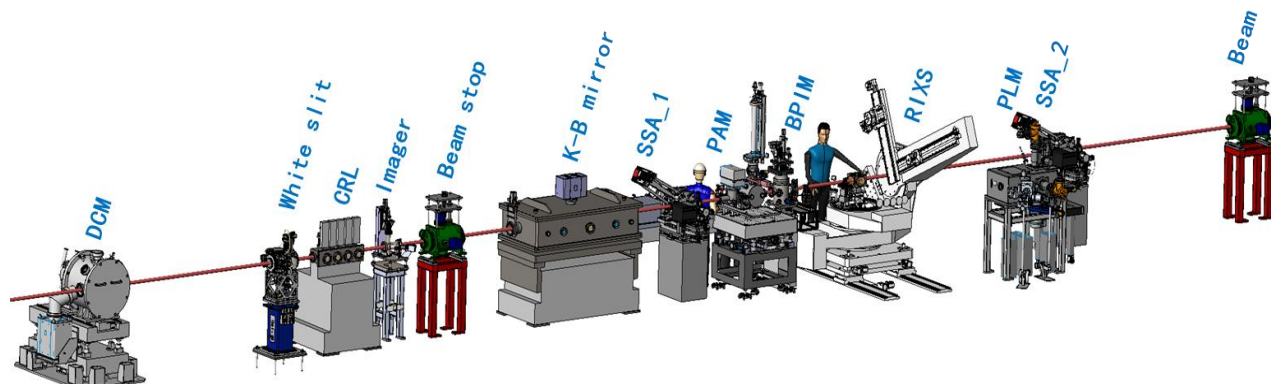
Suggested by TAC

Suggested by TAC

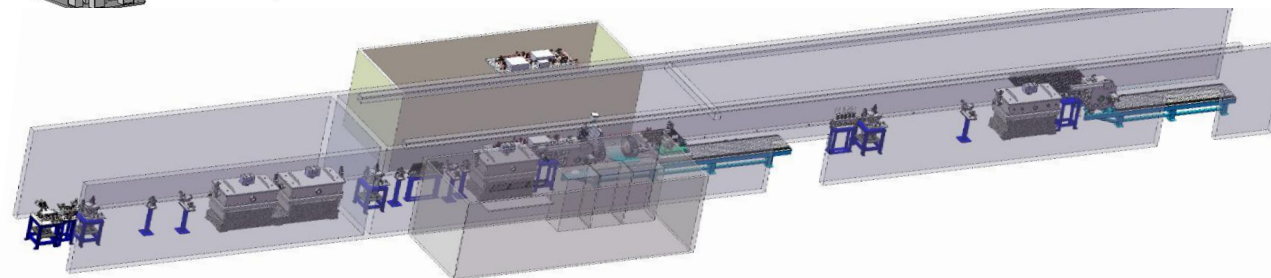
Summary

- The installation of FEL-I endstations began in June 2026.
- The HSS and CDS endstations will complete online installation in Nov and Dec 2026.
- Both endstations are expected to be ready for commissioning in Oct. 2027.

HSS Endstation



CDS Endstation





Thank you for your attention!

