



Recent progress of PES for Spectral diagnostics of FEL-II beamline

Photoelectron Spectrometer (PES)

Junqin Li
Beamline and Diagnostics Technology

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Introduction & Design

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Online commissioning

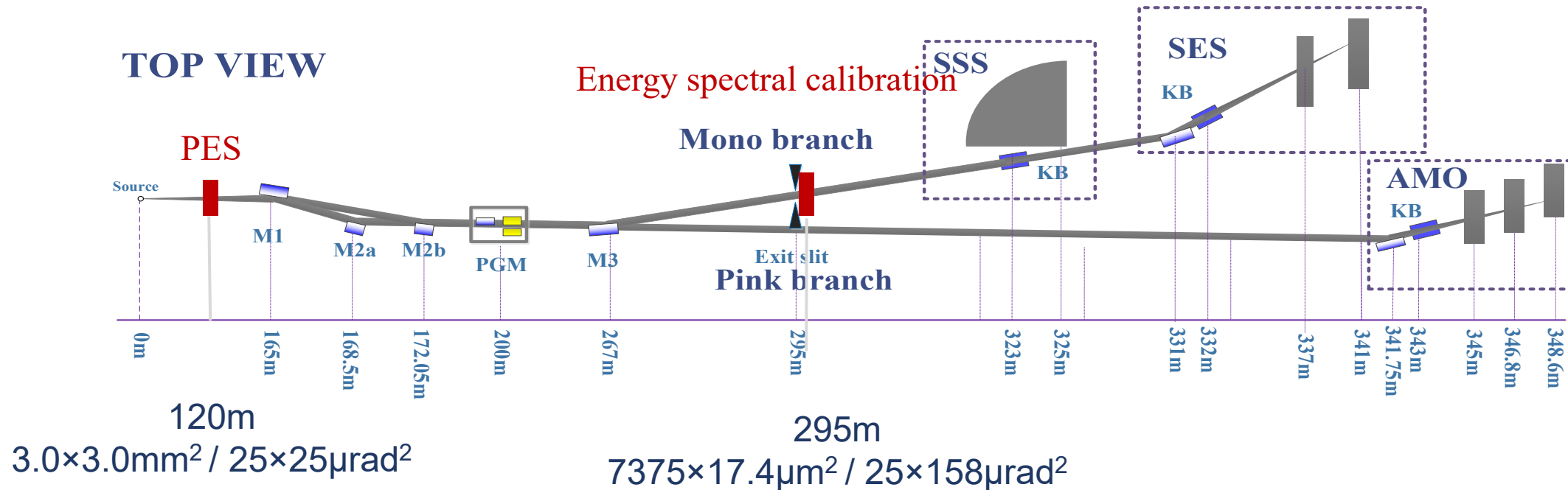
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Installation & Checking

Installation @ SHINE
Checking and testing

Introduction

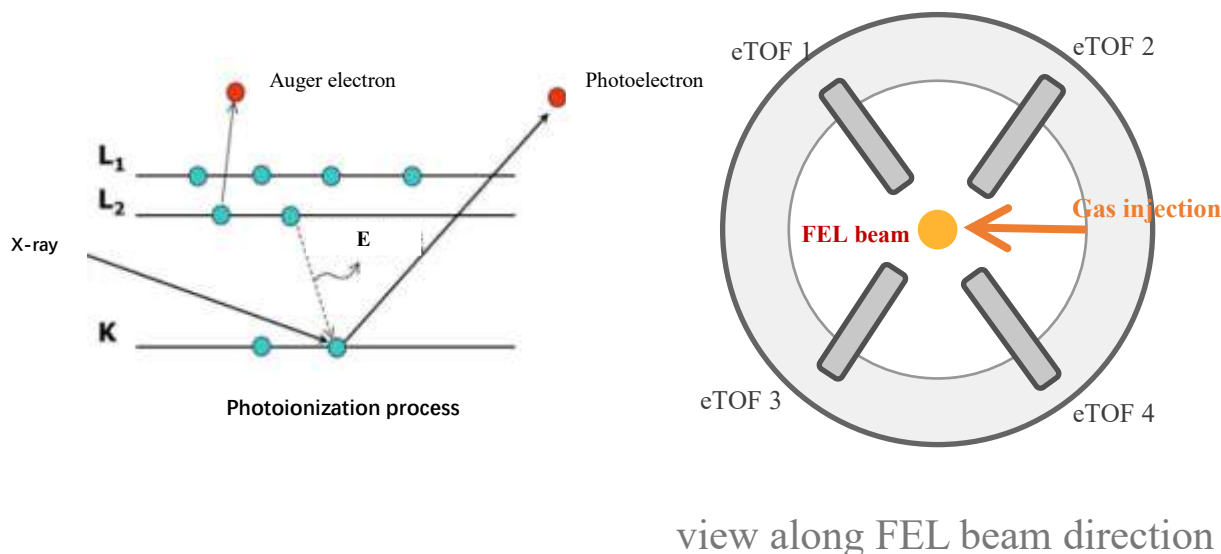
Function: To measure the FEL photon spectrum (single-shot / multi-pulse averaged)



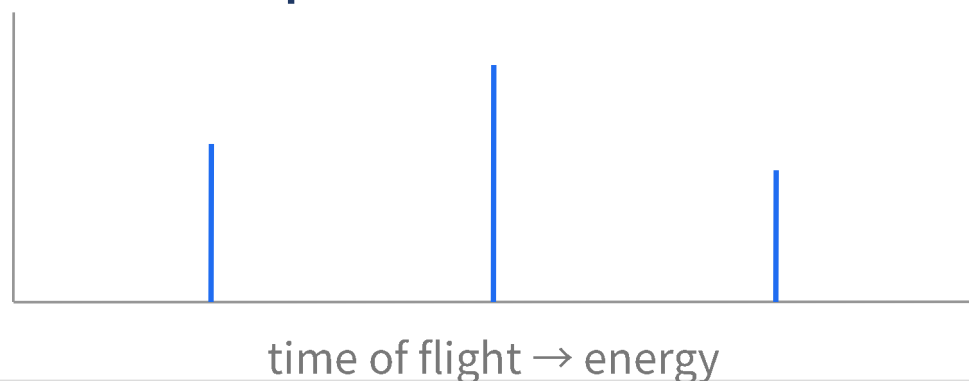
- ❑ Located as upstream as possible (120 m) for a small beam spot (4–10 mm) to improve energy resolution.
- ❑ A YAG imager installed downstream of the exit slit (295 m) is used for energy-spectral calibration.

Working Principle of PES

It is based on the photoionization, eTOF is used to measure the kinetic energy of photoelectrons to derive the spectrum.



Measured TOF spectrum



1. Ionization: FEL photons ionize gas at the center; photoelectrons emitted in all directions.

2. Detection: eTOF collects and guides electrons → MCP detector at the end.

Photoelectric Effect

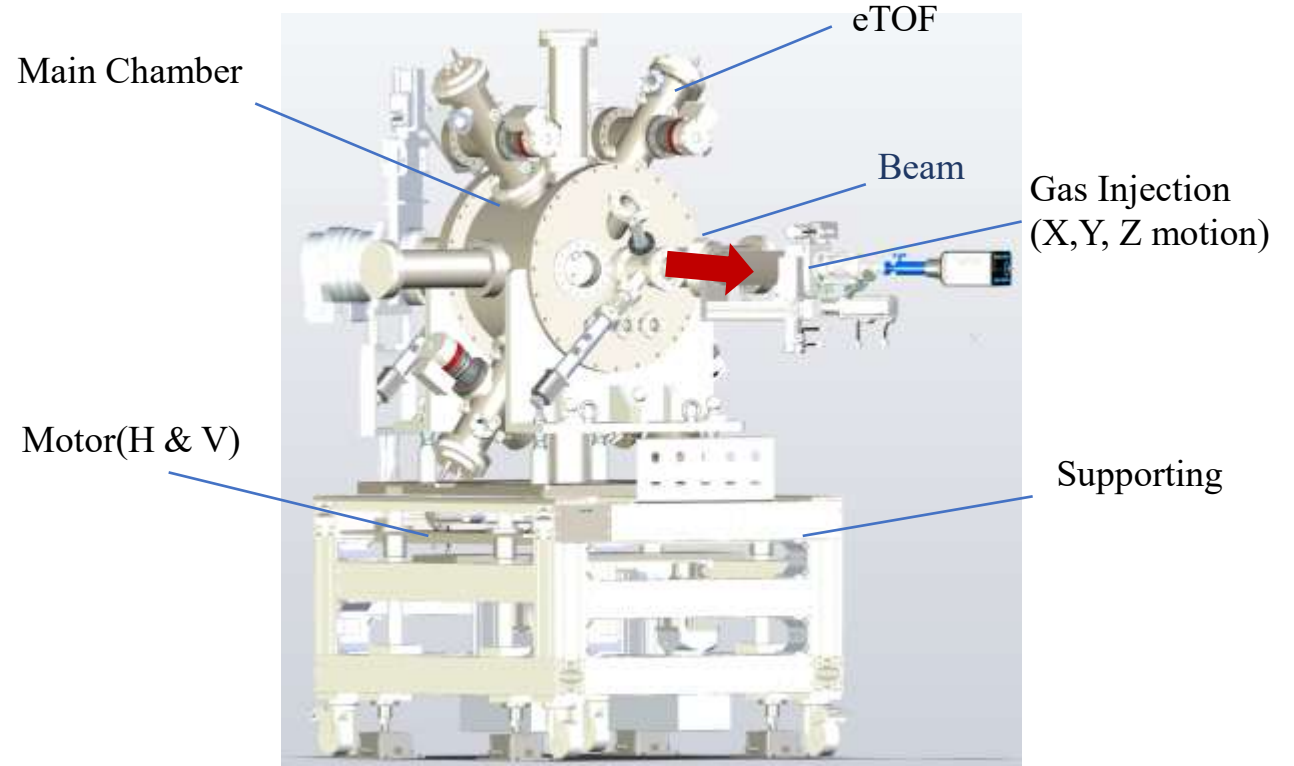
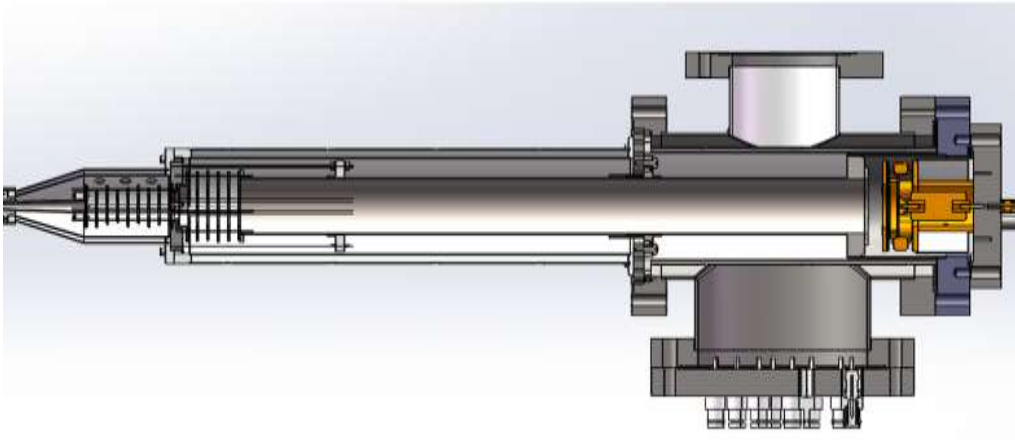
$$E_k = h\nu - E_b$$

3. Derive $h\nu$: E_b known → $h\nu = E_k + E_b$ for each detected electron.

4. Spectrum: $h\nu$ distribution = FEL photon energy spectrum (single-shot or averaged).

The Mechanical Design of PES

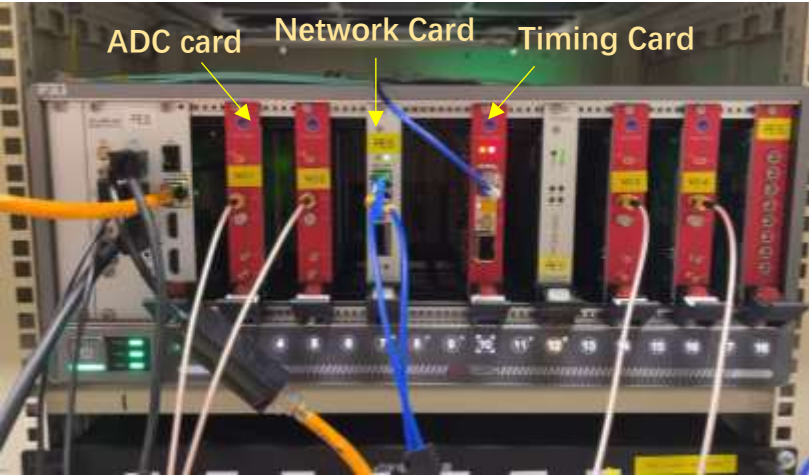
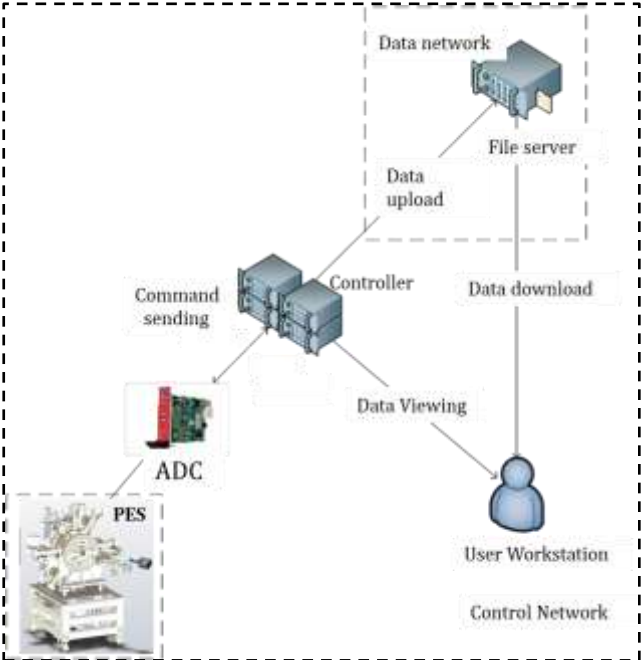
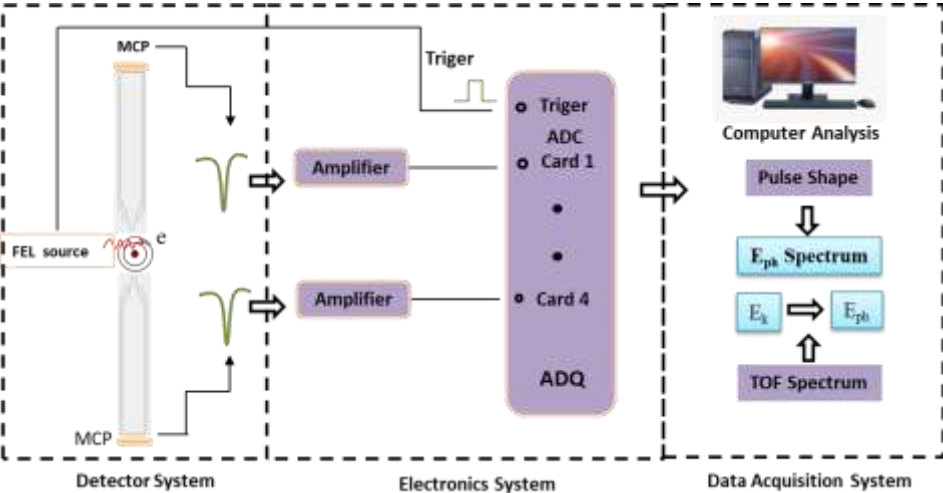
- ❑ The design accommodates 8 eTOFs in total.
- ❑ Four eTOFs are installed in phase I.
- ❑ Each eTOF consists of: nose + electrostatic lens + drift tube.
- ❑ The beam passes through the center of the eTOF plane;
- ❑ Gas is injected at 45° to the beamline.



Markus Braune, et al, J. Synchrotron Rad. (2016). 23, 10–20
Peter Walter, et al, J. Synchrotron Rad. (2021). 28, 1364–1376
Alberto De Fanis, et al, J. Synchrotron Rad. (2022). 29, 755–764
J. Laksman et al., Appl. Sci. 14 (22), 10152 (2024)

Detectable electron energy range	100–3000 eV (electron)
Energy resolution	0.5 eV @ 400 eV (photon)

Data Acquisition System

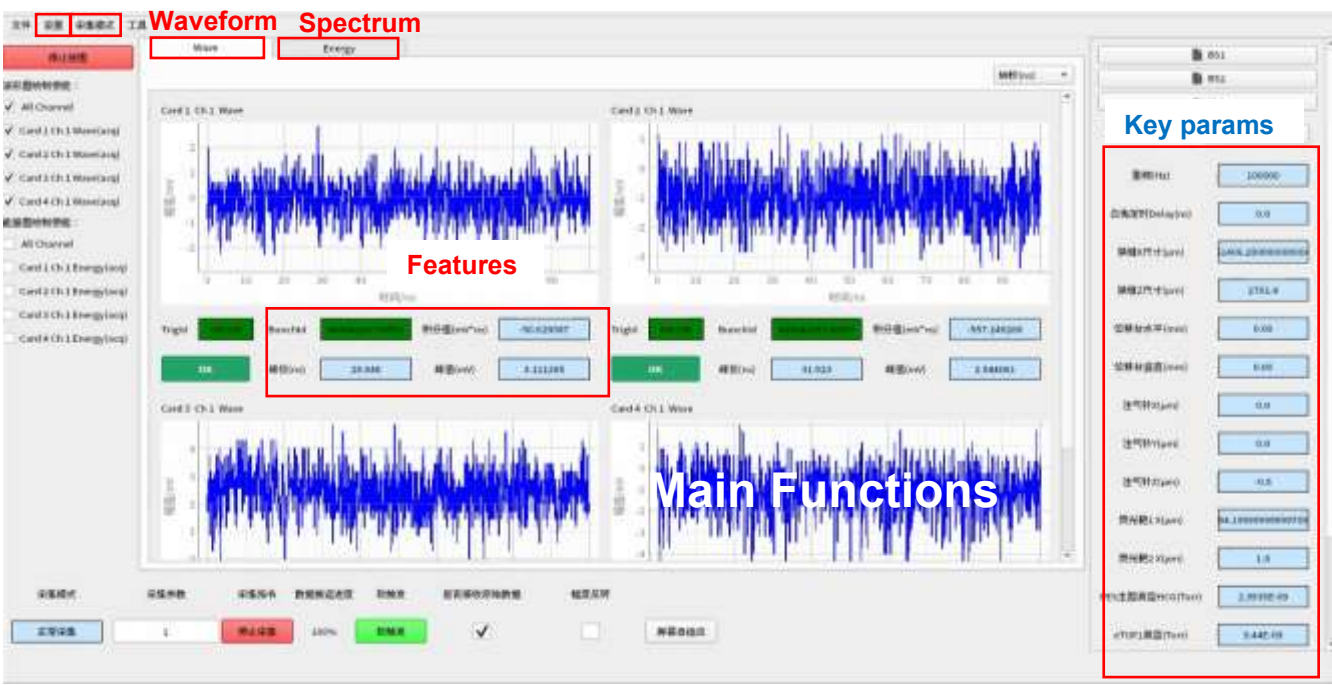


Parameters of the Data Acquisition System

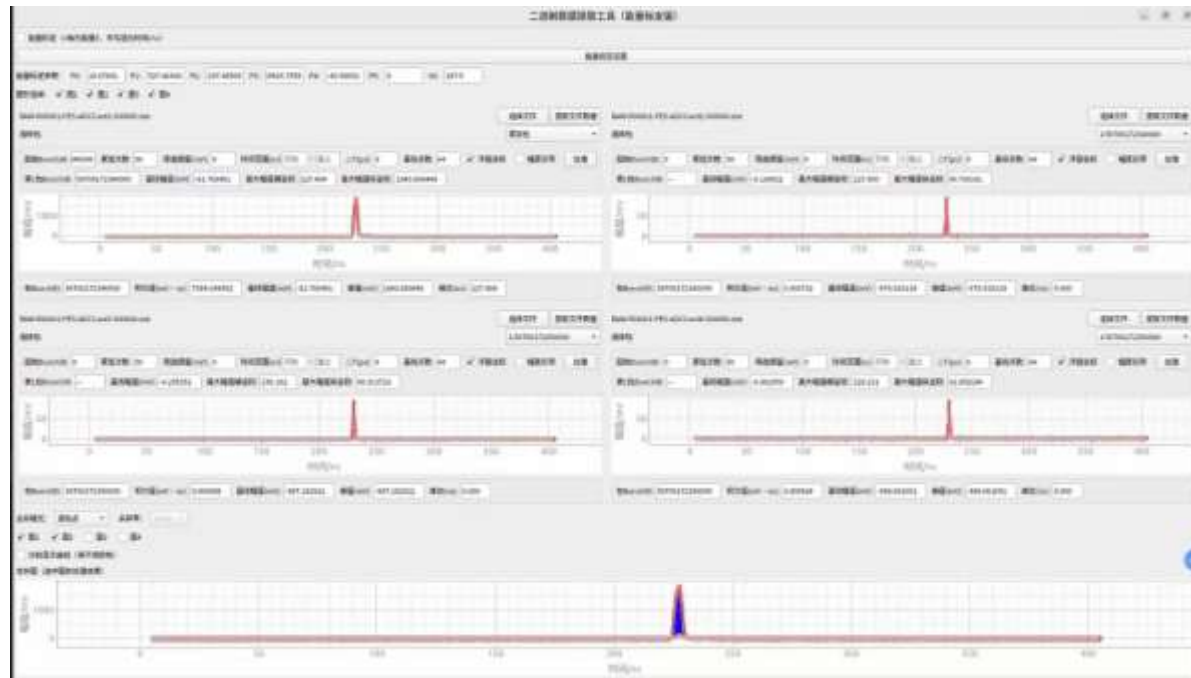
ADC acquisition cards	4 cards
Sampling rate	10 GSPS
Bandwidth	3 GHz
Data transfer rate	up to 4 GB/s
Data storage	4 TB local SSD + remote server

Data Acquisition Software:

Data Acquisition Interface



Post-processing Interface



Main Functions

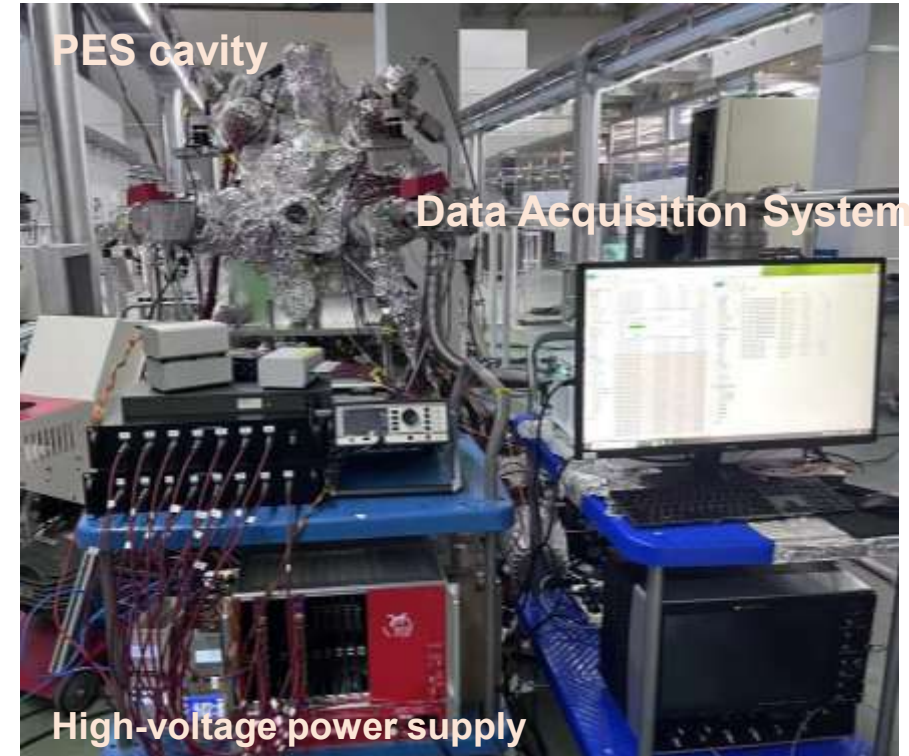
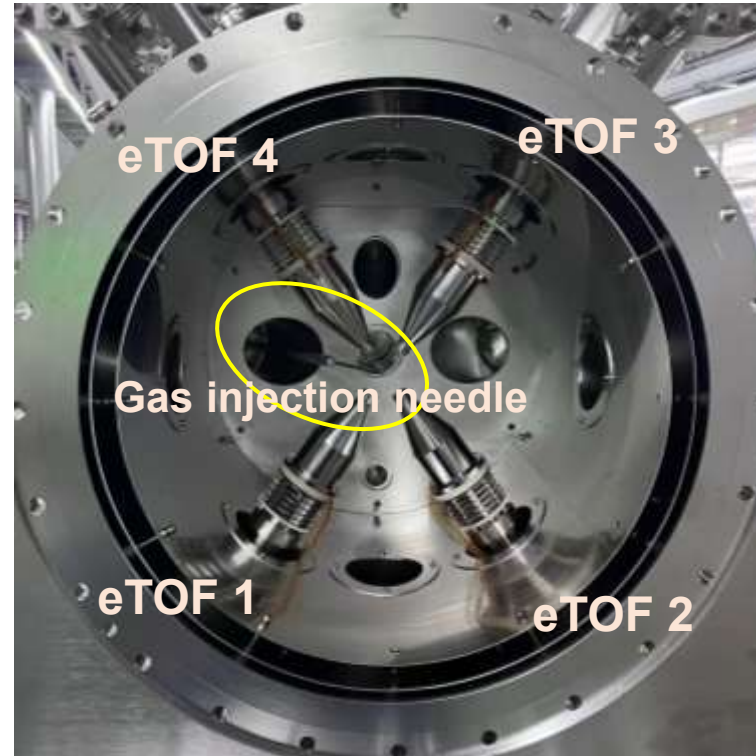
- 1. 4-channel ADC synchronous acquisition: both the waveforms and energy spectra; feature values bound with Bunch ID; recording of key parameters.
- 2. ADC card parameter can be configured: trigger source, threshold, sampling rate, acquisition length.
- 3. Multiple acquisition modes: continuous, single-shot, multi-pulse accumulation.
- 4. Local & remote data storage; 100 kHz repetition rate, 180 ns acquisition length per shot.

Post-processing Capabilities: Data replay

- 1. Load and plot 4-channel raw waveform data;
- 2. Fit and calculate feature values (peak position, amplitude, area);
- 3. Cumulative averaging of four-channel waveforms;
- 4. Time–energy fitting and energy-spectrum visualization.

Online Test & Commissioning @SXFEL

- ▣ The PES has been installed at SXFEL.
- ▣ Online test was done in November 2025, ~ 24 hours.



The eTOFs are angled at 54.7° from horizontal..
Gas injection needle is horizontal, at 45° to the beam.

Experimental conditions

Photon energy: ~ 577 eV

Repetition rate: 10 Hz

Target gas: Ar @ 1×10^{-6} Torr

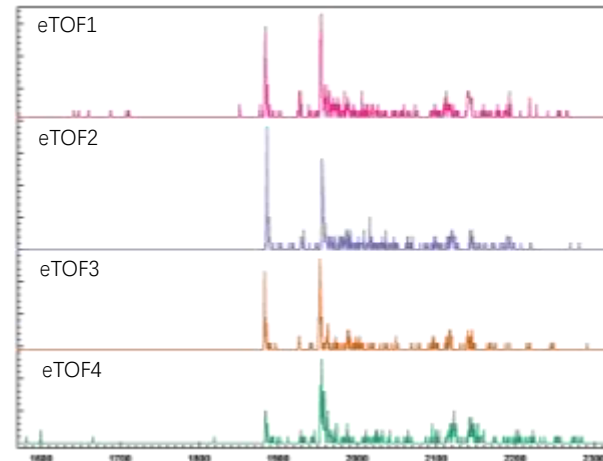
eTOF retardation: 197 V

Cumulative Counting Mode: ~ 1 hour

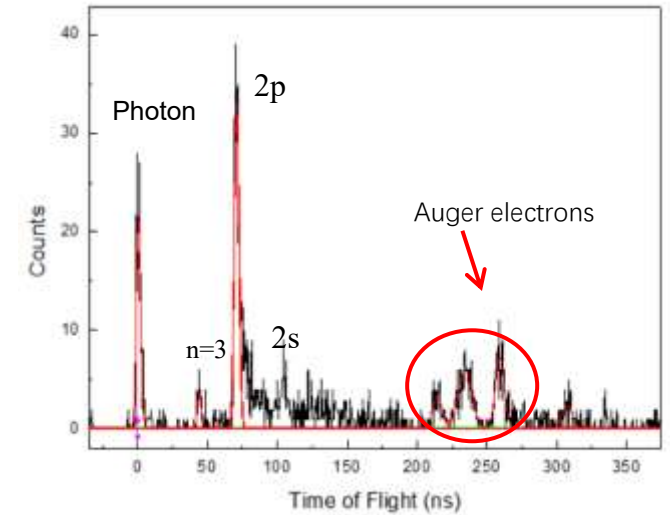
Operation regime

- Pulse energy ≥ 1 mJ (or 100 μ J): single-pulse diagnostics.
- Pulse energy ≈ 10 μ J: accumulate several pulses.

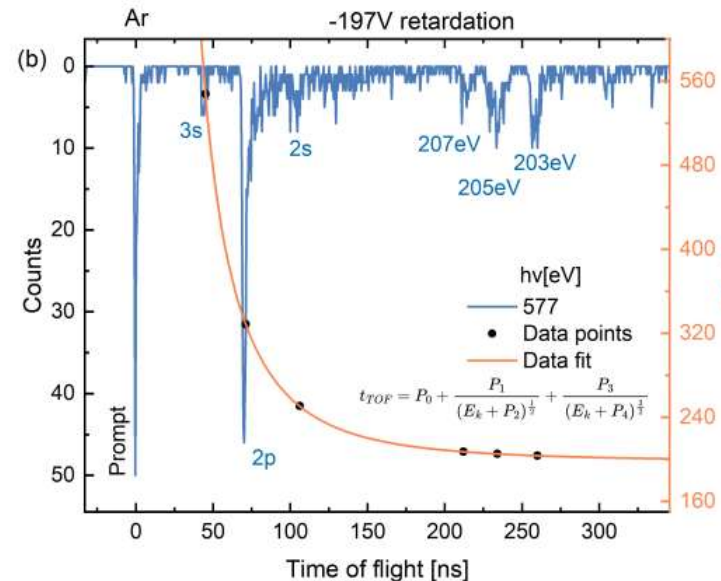
① Time-of-flight spectra (4 eTOFs)



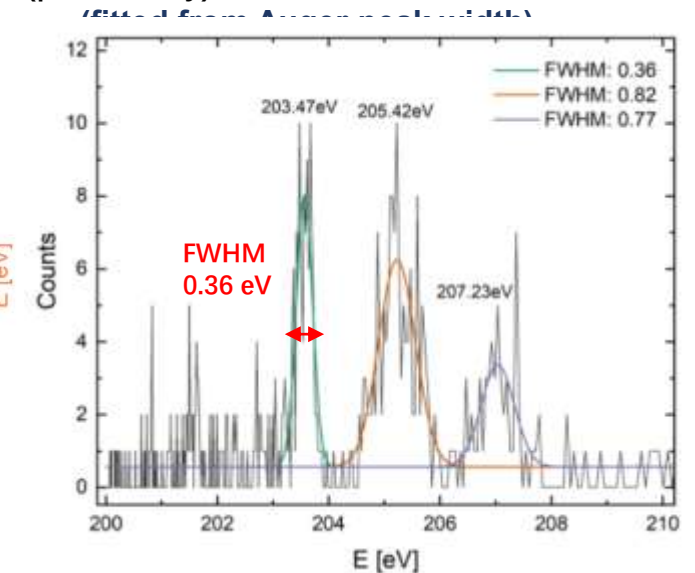
② Sum of 4 eTOFs



③ Energy calibration



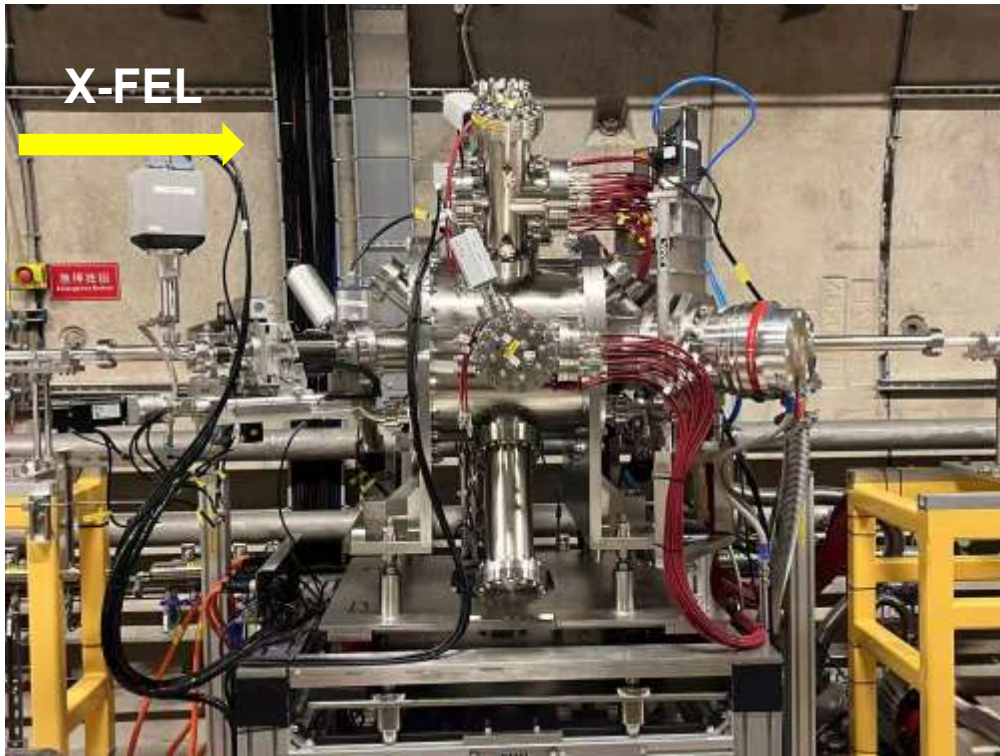
④ Energy resolving power: 0.36 eV (preliminary)



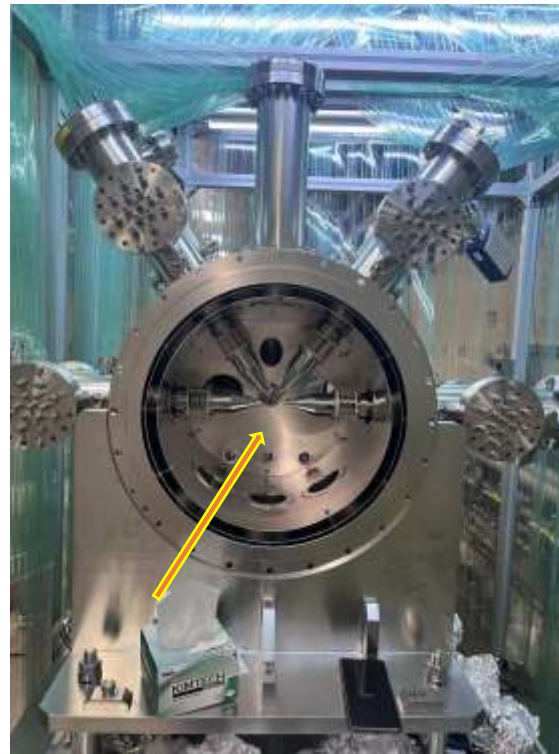
PES: Installation @SHINE

Two eTOFs are installed horizontally.

The other two form a 54.7° angle with the horizontal pair.



Chamber System



4 sets of eTOF



Data Acquisition and
Control Cabinet

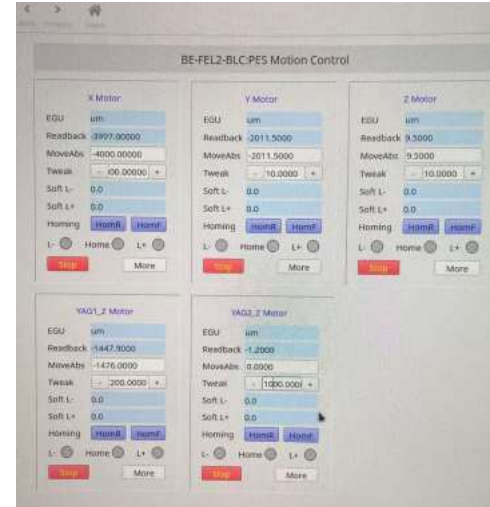
Checking and testing of PES on FEL II

Test items

1. Checking and testing of the motors.
2. Checking of YAG screen.
3. Controlling of gas injection.
4. Remote controlling of eTOFs and high voltage for detectors.
5. Data acquisition for PES.

The testing has been completed and can fulfill the requirements of on-line testing (Sep. 16, 2026).

Motor controlling



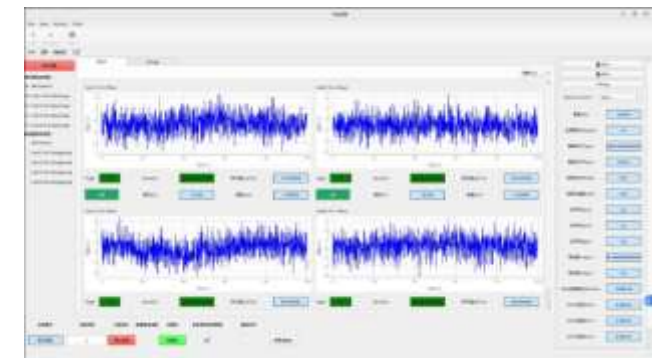
YAG screen



High voltage controlling

Custom	Name	IOSet	V0Set	Blow	VHart	Par
01.000	CHANNEL00	50.0 uA	0.0 V	-0.9 uA	-0.2 V	On
01.001	CHANNEL01	50.0 uA	-23.0 V	-0.5 uA	-22.6 V	On
01.002	CHANNEL02	50.0 uA	-40.0 V	-1.1 uA	-39.8 V	On
01.003	CHANNEL03	50.0 uA	-66.0 V	-0.7 uA	-65.6 V	On
01.004	CHANNEL04	50.0 uA	-91.0 V	-1.0 uA	-90.7 V	On
01.005	CHANNEL05	50.0 uA	-116.0 V	-0.8 uA	-116.2 V	On
01.006	CHANNEL06	50.0 uA	-112.0 V	-1.0 uA	-111.8 V	On
01.007	CHANNEL07	50.0 uA	-117.0 V	-0.8 uA	-116.8 V	On
04.000	CHANNEL08	50.0 uA	-124.0 V	-0.8 uA	-124.1 V	On
04.001	CHANNEL09	50.0 uA	-124.0 V	-1.3 uA	-124.0 V	On
04.002	CHANNEL02	50.0 uA	-130.0 V	-1.3 uA	-130.2 V	On
04.003	CHANNEL03	50.0 uA	-134.0 V	-0.8 uA	-133.7 V	On
04.004	CHANNEL04	50.0 uA	-114.0 V	-0.9 uA	-113.8 V	On
04.005	CHANNEL05	50.0 uA	-143.0 V	-0.7 uA	-140.7 V	On
04.006	CHANNEL06	50.0 uA	-141.0 V	-41.8 uA	-140.7 V	On
04.007	CHANNEL07	500.0 uA	0.0 V	-0.6 uA	0.1 V	On

Data acquisition of PES



Summary

- We have designed a PES instrument equipped with four eTOF spectrometers.
- Data-acquisition hardware (4× ADC, 10 GSPS) and software are fully operational.
- Online test @ SXFEL — energy resolving power of 0.36 eV (preliminary).
- The same PES design has been installed at SHINE.



Thank you for your attention!

