Standardized Data Infrastructure for Tokamak:

Implementation in VEST (Versatile Experiment spherical tokamak)

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2025 KPS Spring Meeting

1. Introduction

- A **Tokamak** is a torus-shaped device that uses magnetic fields to confine plasma for fusion research.
- Especially, **Spherical Tokamaks (STs)** are low aspect-ratio tokamaks, enabling higher plasma pressure (β) relative to magnetic field strength, and offering an attractive path for compact fusion reactors.

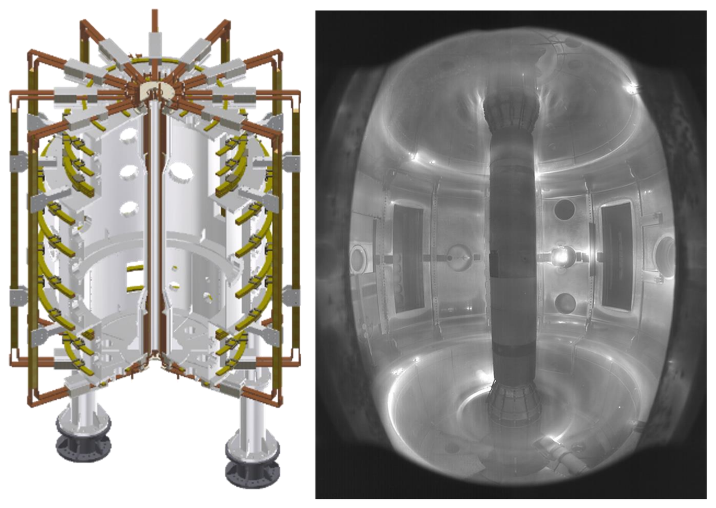
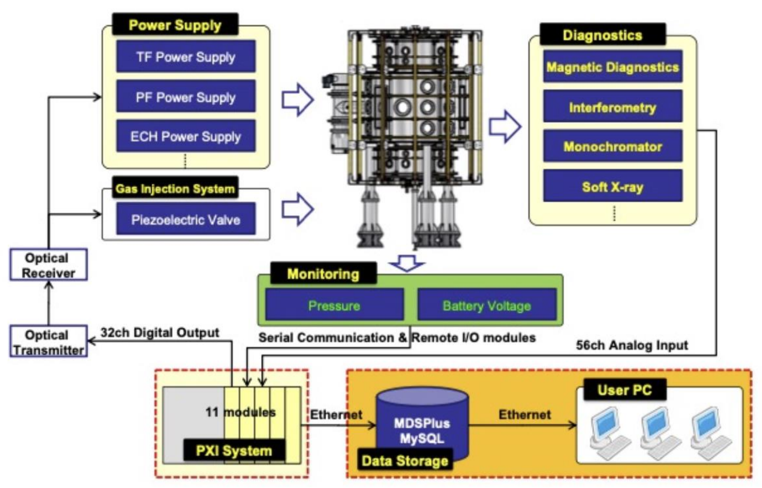


Figure 1. VEST tokamak

- **VEST (Versatile Experiment Spherical Torus)** is Korea's only spherical tokamak, located at Seoul National University.
- Due to the lack of a unified framework, it wasn't possible to access all relevant data in one place, which posed a significant bottleneck for physics analysis and interpretation.

Figure 2. Current database system of VEST.



- Need centralized controllable database system and compatible analysis tool to construct integrated workflow

➢ ***Develop unified and IMAS-compatible database***

➢ ***Implement analysis module VAFT***

2. VEST database & VAFT Library

- Developed a centralized, IMAS-compatible database system based on ODS/IDS schema and POSIX&HSDS backend.
- Enables automated integration of diagnostic data, equilibrium reconstruction, and profile fitting into a structured database.
- Provides simulation-ready inputs for stability analysis and transport analysis through a streamlined workflow.
- Recent shots are actively integrated into the system, with multiple analysis workflows under development to broaden its capabilities.

➢ **Create a feasible workflow from experimental data to simulation code (Stability, Transport)**

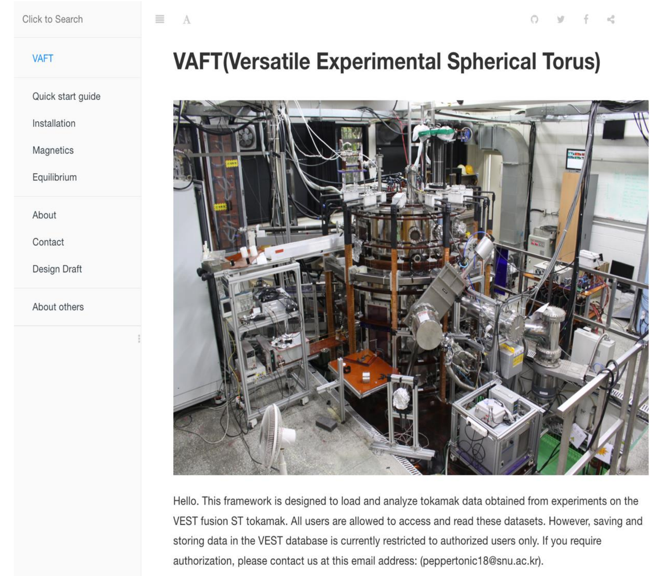


Figure 4. *User manual of VAFT library*

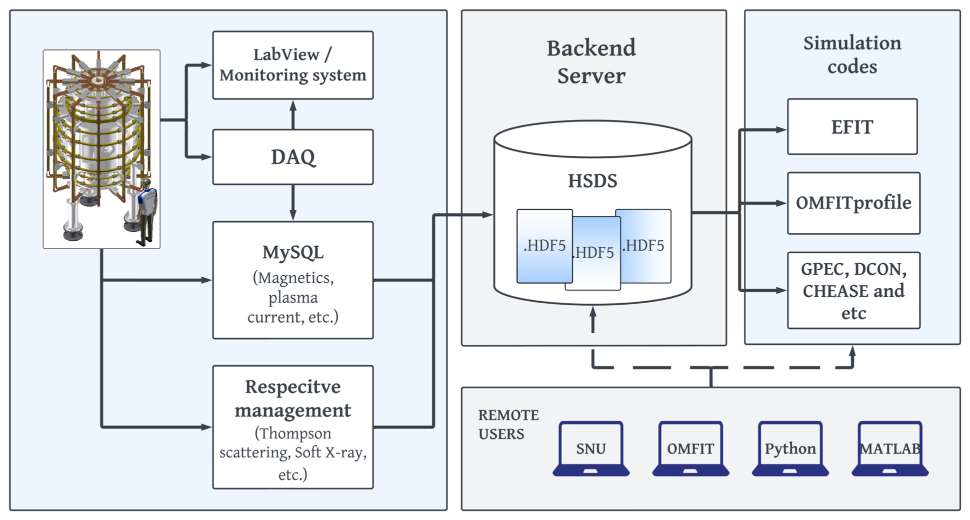
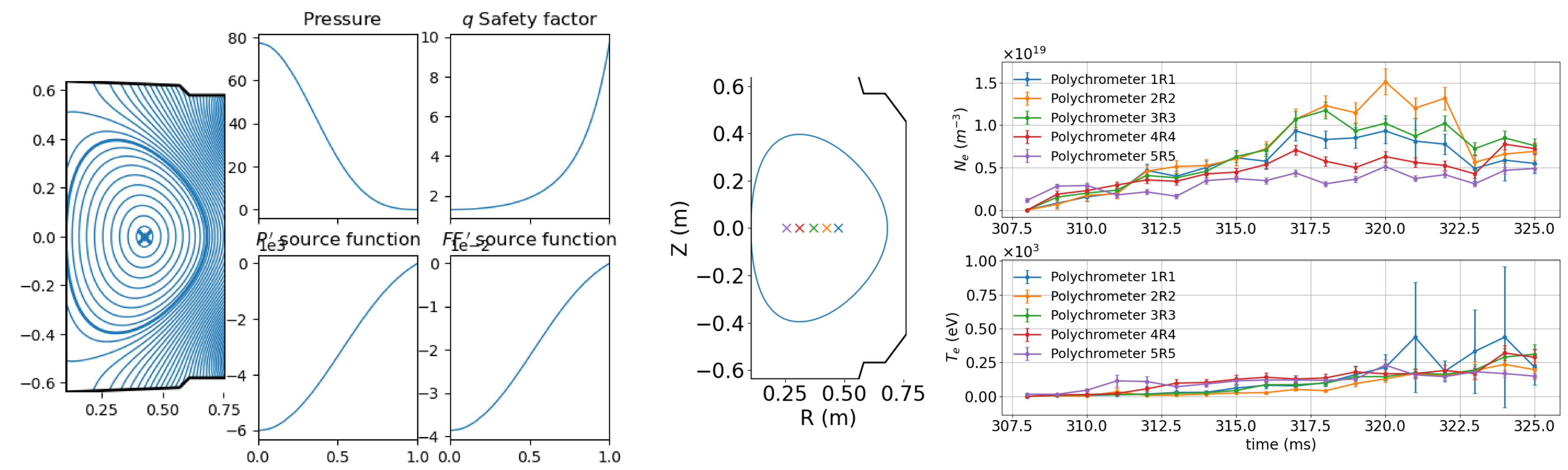


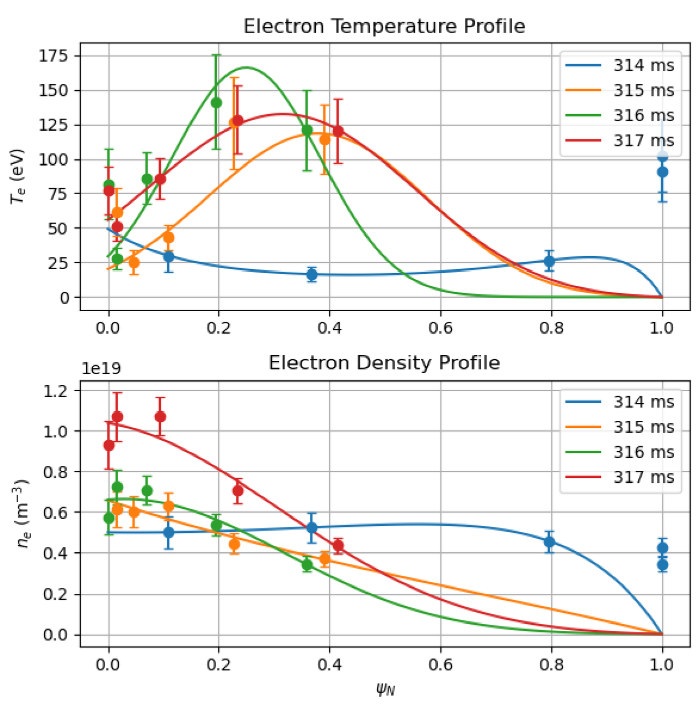
Figure 3. *Overall workflow of improved VEST database system.*

- **VAFT (Versatile Analytical Framework for Tokamak)**
- **VAFT** provides a unified interface to experimental data, enabling modular analysis pipelines and supporting integration with simulation tools.
- Open to collaborative use across Korean universities for accessing and analyzing VEST experimental data

4. Applied scenarios

1. Automated Core Profile Fitting with Kinetic Diagnostics





- At present, basic kinetic profiles for electrons are provided to support transport analysis, while ion-related quantities will be incorporated in future development
- An exponential fitting model is currently applied in an automated routine, where updated Thomson and magnetic diagnostics trigger equilibrium reconstruction via EFIT and mapping to flux coordinates, followed by profile fitting and database storage
- Additional fitting models are planned to enhance flexibility and accuracy

Figure 6. *Mapping and fitting of Thomson Scattering data onto EFIT equilibrium in ψ_N coordinates, enabling kinetic simulation initialization.*

2. MHD Stability Analysis Workflow Using EFIT, CHEASE, DCON

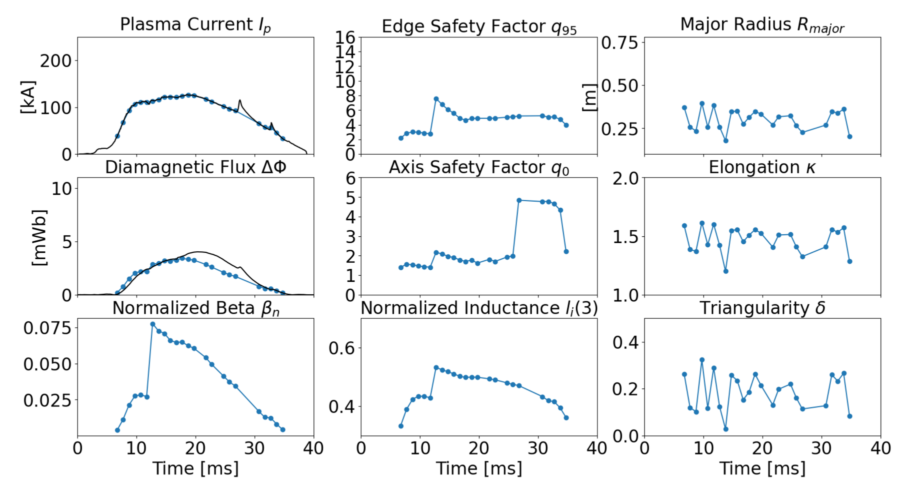


Figure 7. *0D Temporal profile*

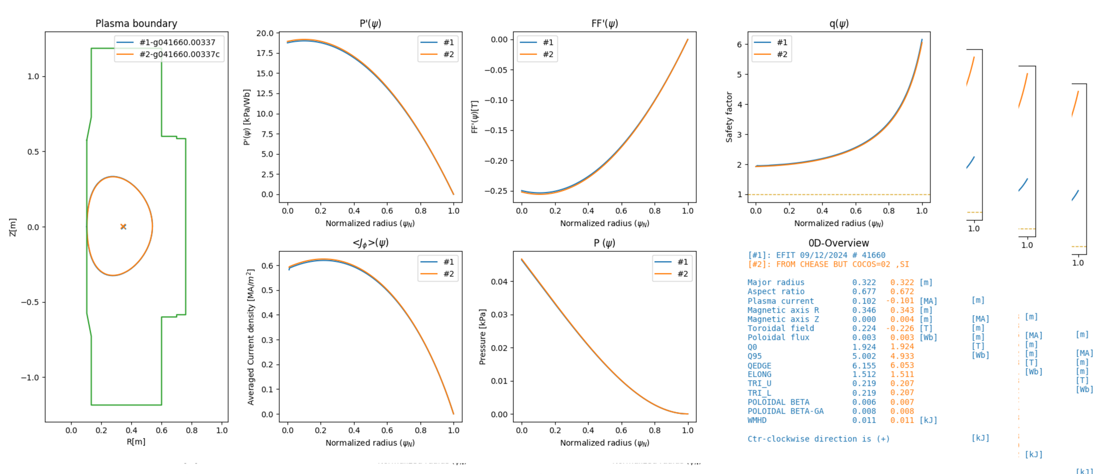


Figure 8. *Refined poloidal equilibrium using CHEASE based on the initial EFIT reconstruction*

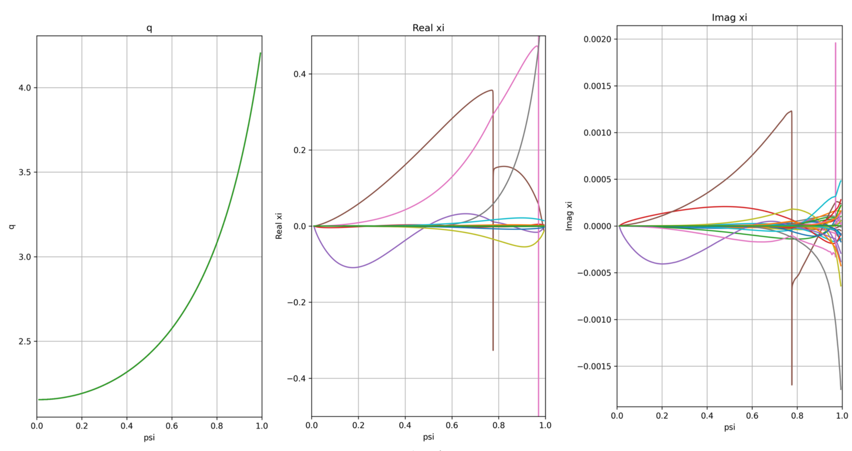


Figure 9. *|ξ · ∇ψ| profiles for n=1 modes obtained from DCON, comparing multiple m_{out} values across the normalized poloidal flux ψ*

- This workflow has been applied to ~7,000 shots (#38,000–#45,000) from 2023 to 2025.

- Magnetic equilibrium is initially reconstructed using **EFIT** by solving the Grad–Shafranov equation to obtain the poloidal flux function

$$\Delta^{*}\psi \;=\; -\mu_0 R^2 \frac{dp}{d\psi} - \frac{1}{2}\frac{dF^2}{d\psi}$$

- **CHEASE** refines equilibrium by solving the inverse Grad-Shafranov equation with fixed boundary conditions from EFIT
- **DCON** determines ideal MHD stability for each toroidal mode number by solving Euler-Lagrange equation and perturbed potential energy(δW), based on energy principle.

$$\delta W \;=\frac{1}{2\mu_0}\int_a^b d\psi\,[\Xi'^{\dagger}F\Xi' + \Xi'^{\dagger}K\Xi + \Xi^{\dagger}K^{\dagger}\Xi' + \Xi^{\dagger}G\Xi]$$

5. Conclusion & Future work

Conclusion

- Constructed an IMAS-based database on VEST to enable standardized and collaborative use of tokamak data
- Implemented an accessible Python library (VAFT) to enable remote data processing and analysis.
- Provide an optimized framework and workflow to bridge the gap between simulation and experimental data

Future works

- Incorporate tools such as OMFITprofiles and Bayesian inference to quantify uncertainties, enforce physical constraints, and automate the reconstruction of high-fidelity kinetic equilibria.
- Mapping the data no implemented in current ODS format
- Connection to other simulation tools such as TRASSIC, TRANSP and etc.

References

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This research was supported by the National R & D Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (2021M3F7A1084418).