

Design and Implementation of 3 Dimensional Data Visualization in Virtual Tokamak

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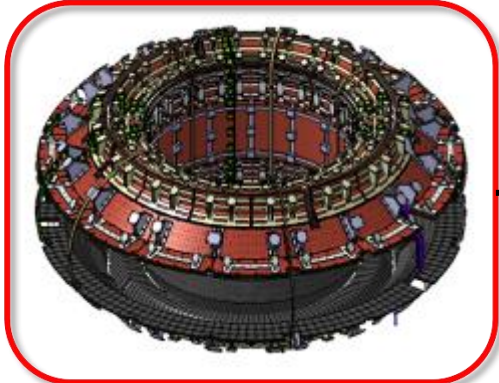
²Center of Hefei physical science and technology, University of Science and Technology of China, Hefei, China.

OUTLINE

- **Motivation**
 - Integration the visualization of data with EAST model
 - The procedure for the visualization of EAST
 - The previous work about virtual EAST
- **Virtual Tokamak System**
 - Platform architecture
 - Underlying framework
- **Data Visualization in Virtual Tokamak**
 - Magnetic field visualization
 - 2D magnetic field
 - Poincare plot of 3D magnetic field perturbations
- **Summary**

Integration the visualization of data with EAST model

EAST design and engineering models

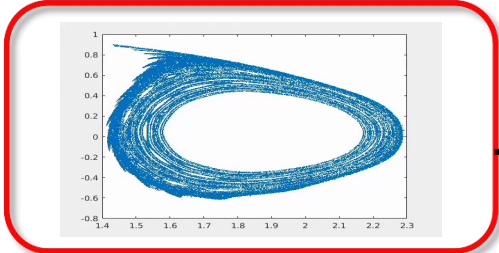


Detailed diagnosis information

PCS	DAQ	NS m ²	Z/m	R/m	Theta/Deg	Phi/Deg
pcbpv1t	HBPH1T	0.218520105	-0.663111056	1.301052894	89.955826	158.6890401
pcbpv2t	HBPH2T	0.22380322	-0.503128672	1.30076039	90.170041	158.6908021
pcbpv3t	HBPH3T	0.221671392	-0.343081251	1.300881921	90.217829	158.6916262
pcbpv4t	HBPH4T	0.221677542	-0.18317099	1.300690223	90.129856	158.6917548
pcbpv5t	HBPH5T	0.213311123	-0.022601478	1.300586795	89.917558	158.7279693
pcbpv6t	HBPH6T	0.227872467	0.136922328	1.300488716	90.032225	158.6837605
pcbpv7t	HBPH7T	0.223831952	0.296805322	1.300297705	89.975222	158.6955076
pcbpv8t	HBPH8T	0.225069428	0.456827833	1.30017813	90.410885	158.6992575
pcbpv9t	HBPH9T	0.160543808	0.760310462	1.296304769	90.013191	157.437
pcbpv10t	HBPH10T	0.164222998	0.860511611	1.296038692	90.344189	157.4395
pcbpv11t	HBPH11T	0.119068602	0.919480501	1.335927252	108.32613	157.445
pcbpv12t	HBPH12T	0.161326435	1.147106895	1.550318799	24.277837	157.7855
pcbpv13t	HBPH13T	0.162299715	1.194947643	1.707522093	-0.874606	157.75
pcbpv14t	HBPH14T	0.118872254	1.088806847	1.810709394	-76.91265	157.4505
pcbpv15t	HBPH15T	0.16073985	0.987898452	1.864832802	-30.02306	157.464
pcbpv16t	HBPH16T	0.162299715	0.937062823	1.952134838	-30.55919	157.442
pcbpv17t	HBPH17T	0.217306295	0.833294638	2.324609769	-47.46367	156.943365
pcbpv18t	HBPH18T	0.221409112	0.686583576	2.436369218	-55.50972	156.9271396
pcbpv19t	HBPH19T	0.222810539	0.528187682	2.528096513	-63.93729	156.8751177
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pcbpv21t	HBPH21T	0.224596677	0.181555478	2.634105276	-81.40461	156.8491022

Detailed magnetic measurement information

Simulation and analysis results



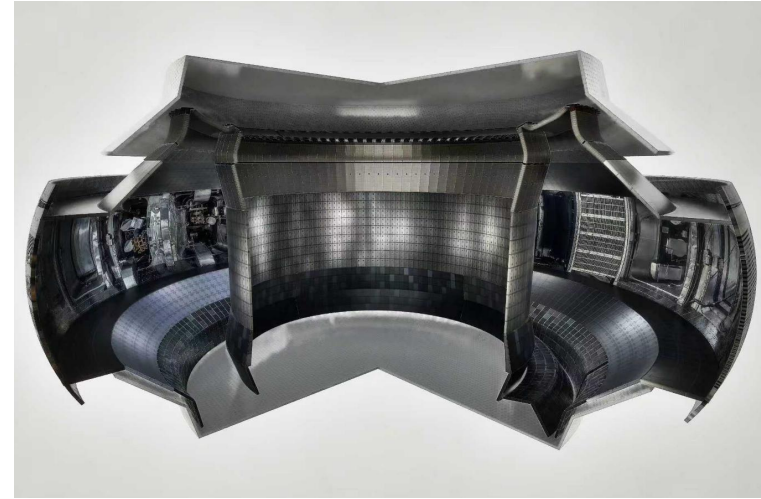
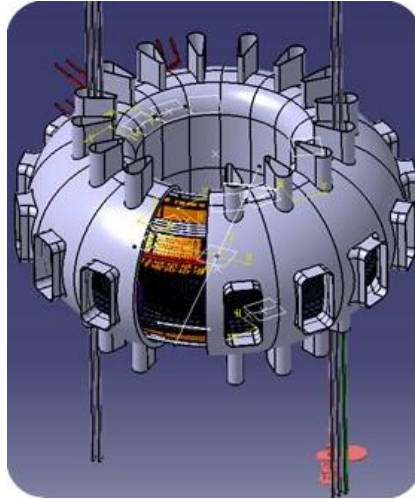
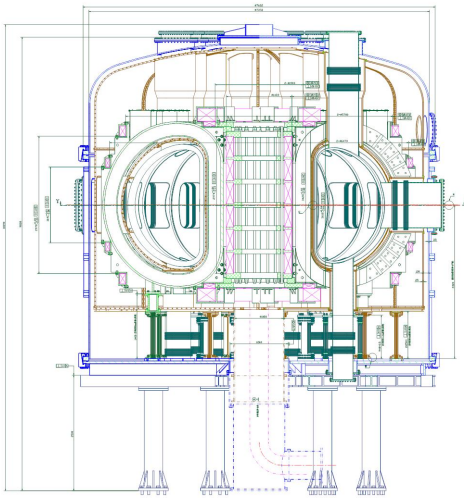
Virtual Tokamak



- In order to realize fusion energy, we need to resolve many scientific and engineering challenges.
- The operation and maintenance of fusion device in the limited space are also a critical subject.

EAST model visualization
Data visualization
Database
MySQL
MDSplus
Rendering time<5s
Framerate>40FPS

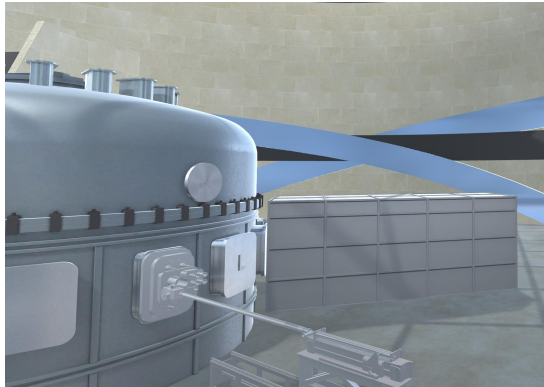
The procedure for the visualization of EAST



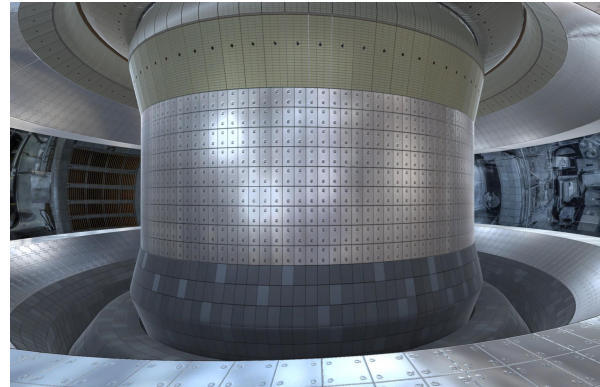
Original CAD Data ➡ **fbx Format** ➡ **Retopology** ➡ **Rendering**

- The EAST tokamak is chosen as the target device in this development.
- EAST consists of numerous components. It is upgraded every few years.
- Catia is used to design and create the EAST model. The sizes of the catia data are about 3GB.
- Unreal Engine 5 is chosen as the main development tool to render the EAST model and visualize the relevant data.
- The detailed Catia data is not suitable for the game engine. It is essential to convert the highmesh data into low polymesh forms.
- 3dsMax is used to simplify and optimize the model.

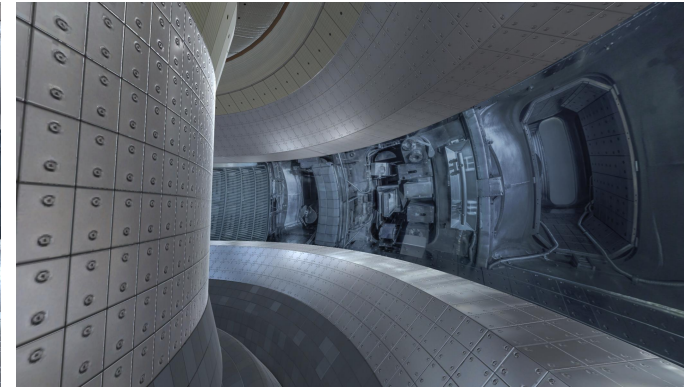
The previous work about virtual EAST



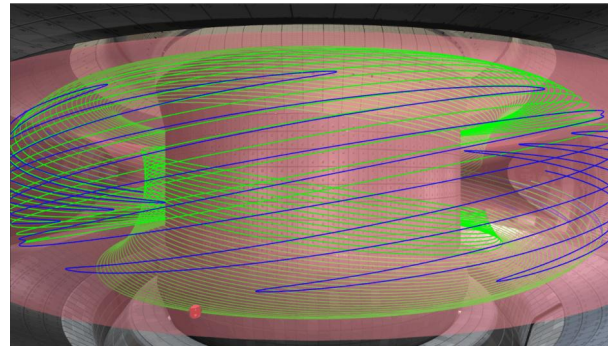
EAST host model



EAST vacuum model reconstruction



Window map



Data visualization



Magnetic probe virtual installation



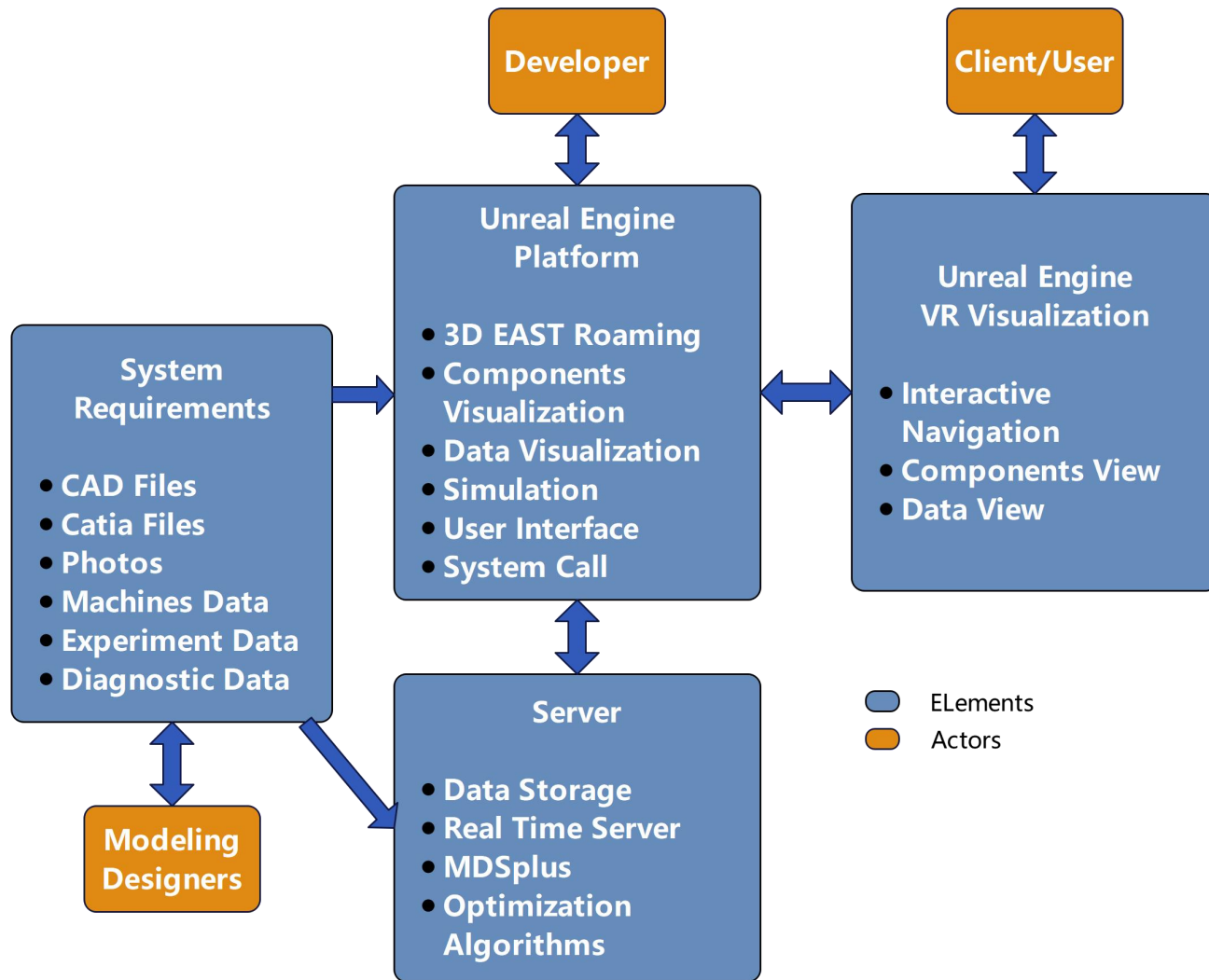
Installation in realistic scene

- In the previous work, EAST model visualization has been realized for diagnosis components virtual installation. Particle trajectory data has been realized in the EAST.
- EAST divertor has been upgraded in recent years. The performance of virtual EAST has been improved. More comprehensive data visualization has also been attempted to be incorporated into the system.

OUTLINE

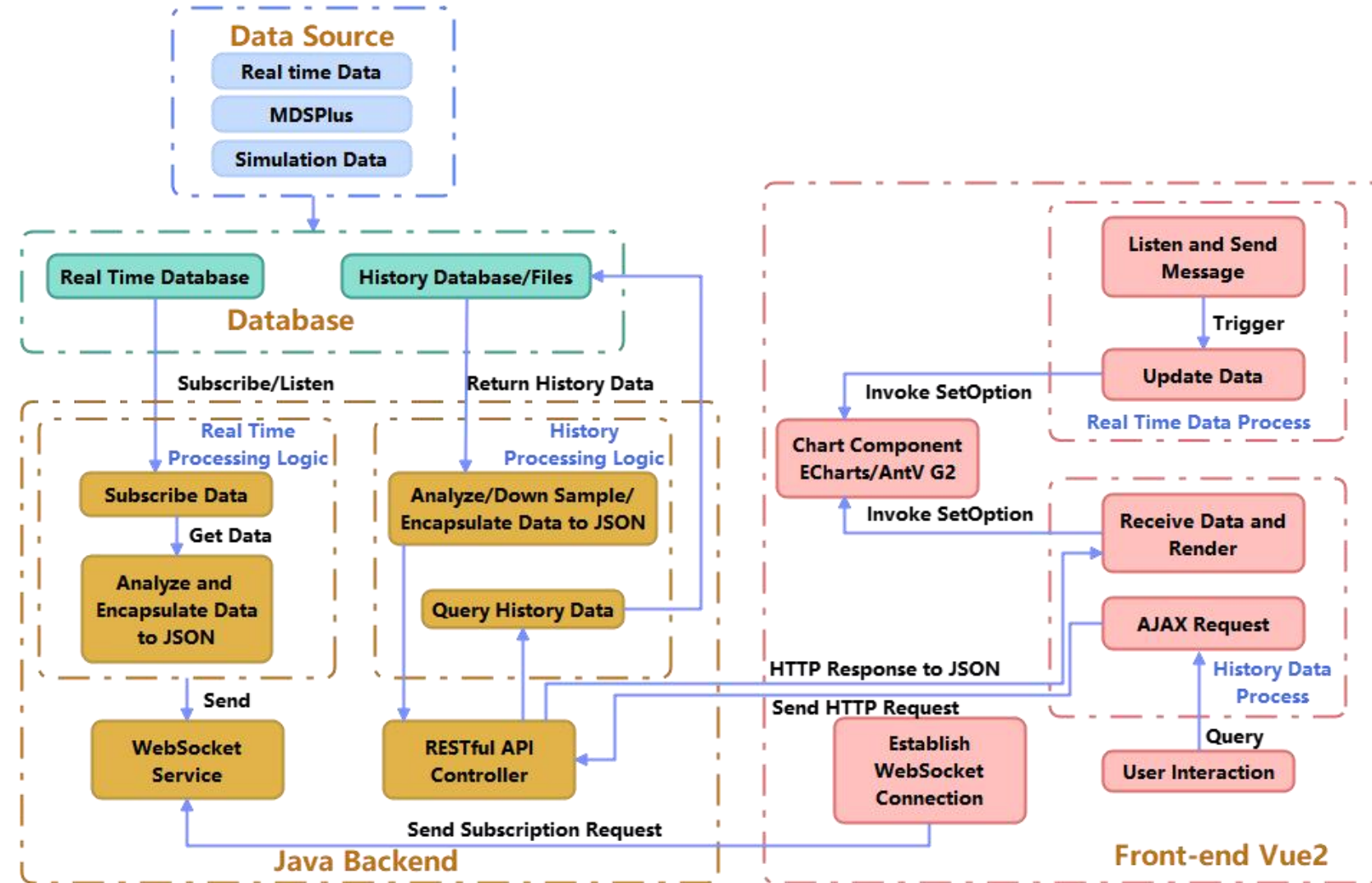
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Platform architecture



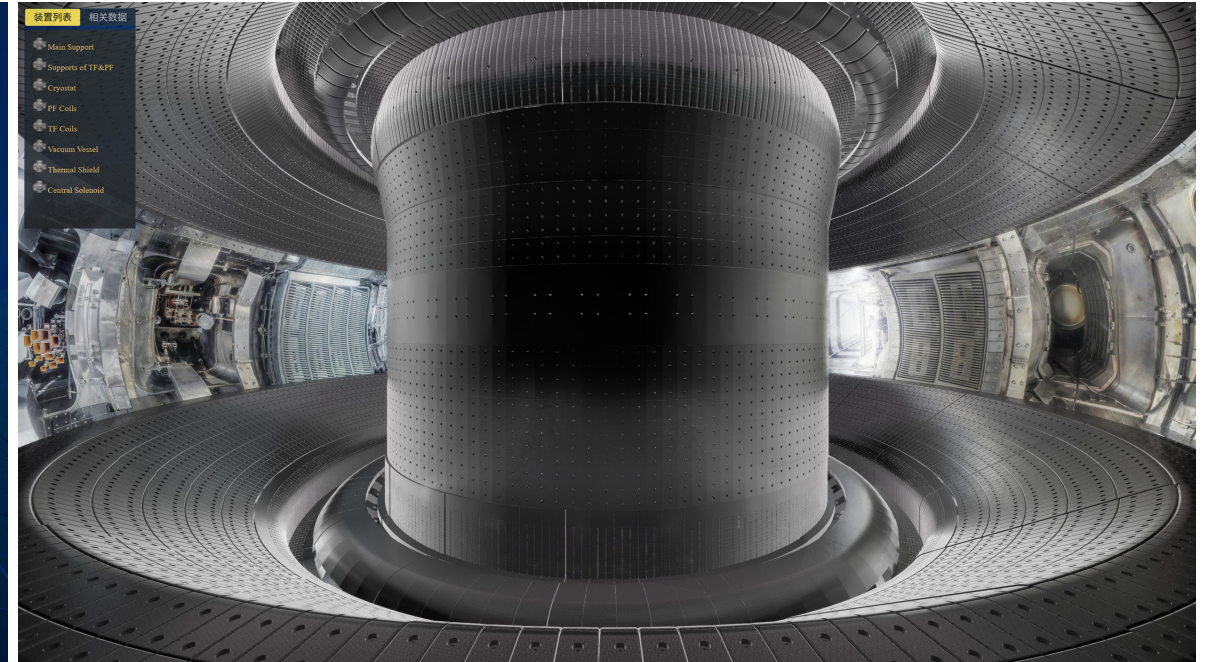
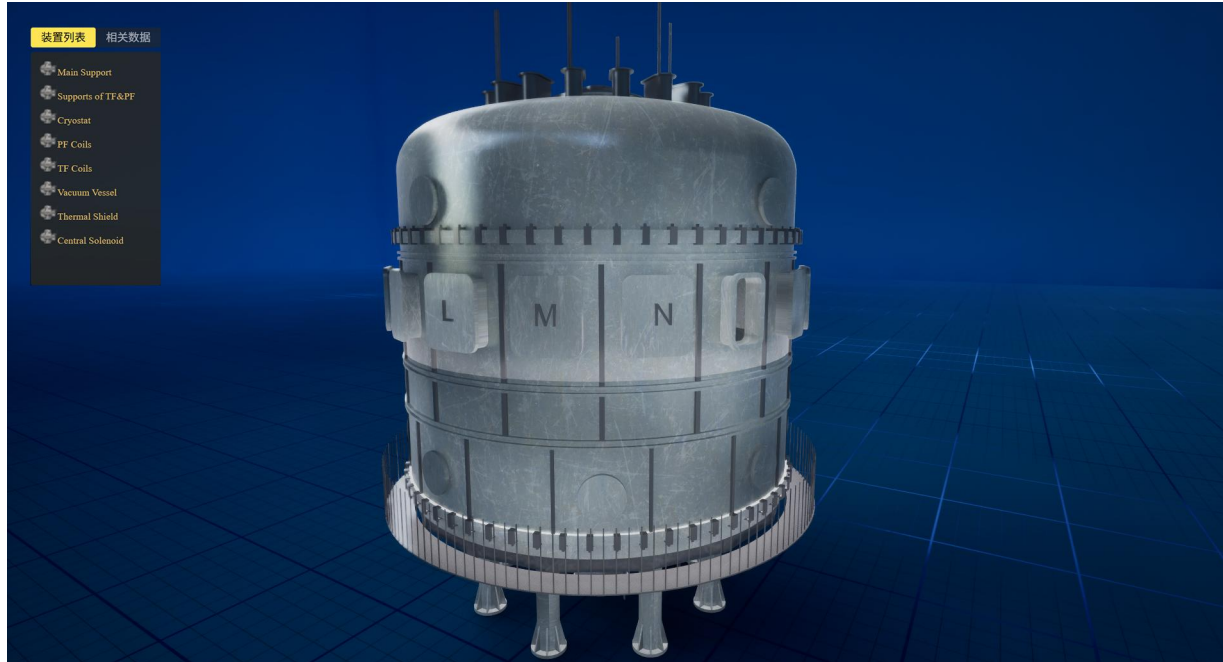
- According to system requirements, some model files like CAD or Catia files and EAST photos are collected.
- In order to visualize 3D data, Machines data, experiment data and diagnostic data are read or exported from database.
- Unreal Engine 5 is chosen to realize the system. In the system, 3D EAST roaming and components visualization are implemented.
- Three kinds of data are visualized.
- In the Server, Data storage and optimization are realized. Data can be read from MDSplus.
- In the Client, components can be chosen to display or hide in the tree list.

Underlying framework



- Real time and history database are deployed to store relevant data.
- In Java backend, real time data is subscribed and then analyzed and encapsulated to JSON.
- WebSocket service is established to send subscription request.
- In history processing logic, we can analyze or down sample or encapsulate data to json, query history data from history database.
- In front-end VUE, component echarts are rendered from realtime data process and history data process.

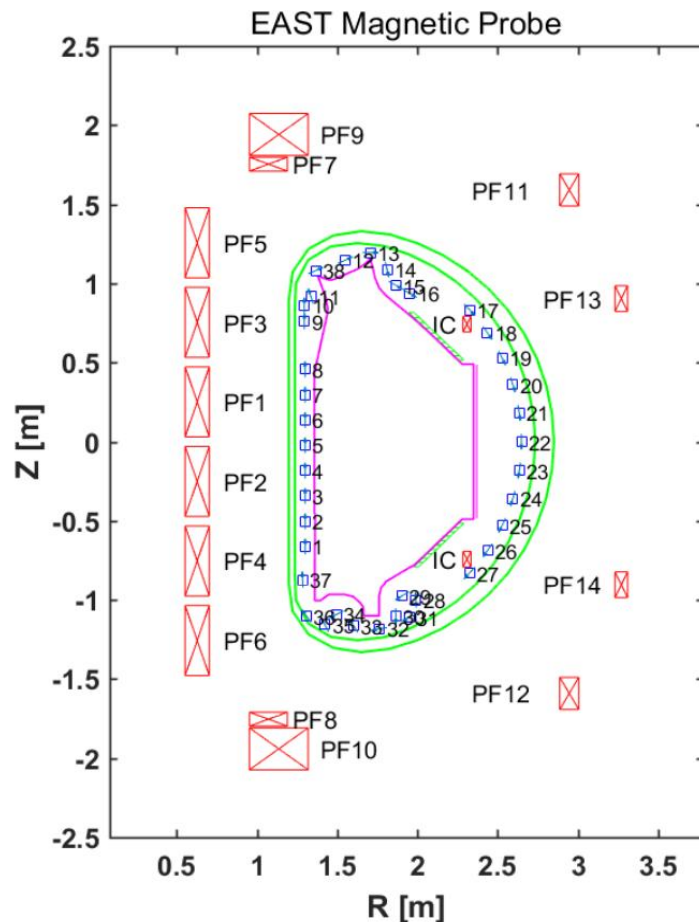
Virtual EAST



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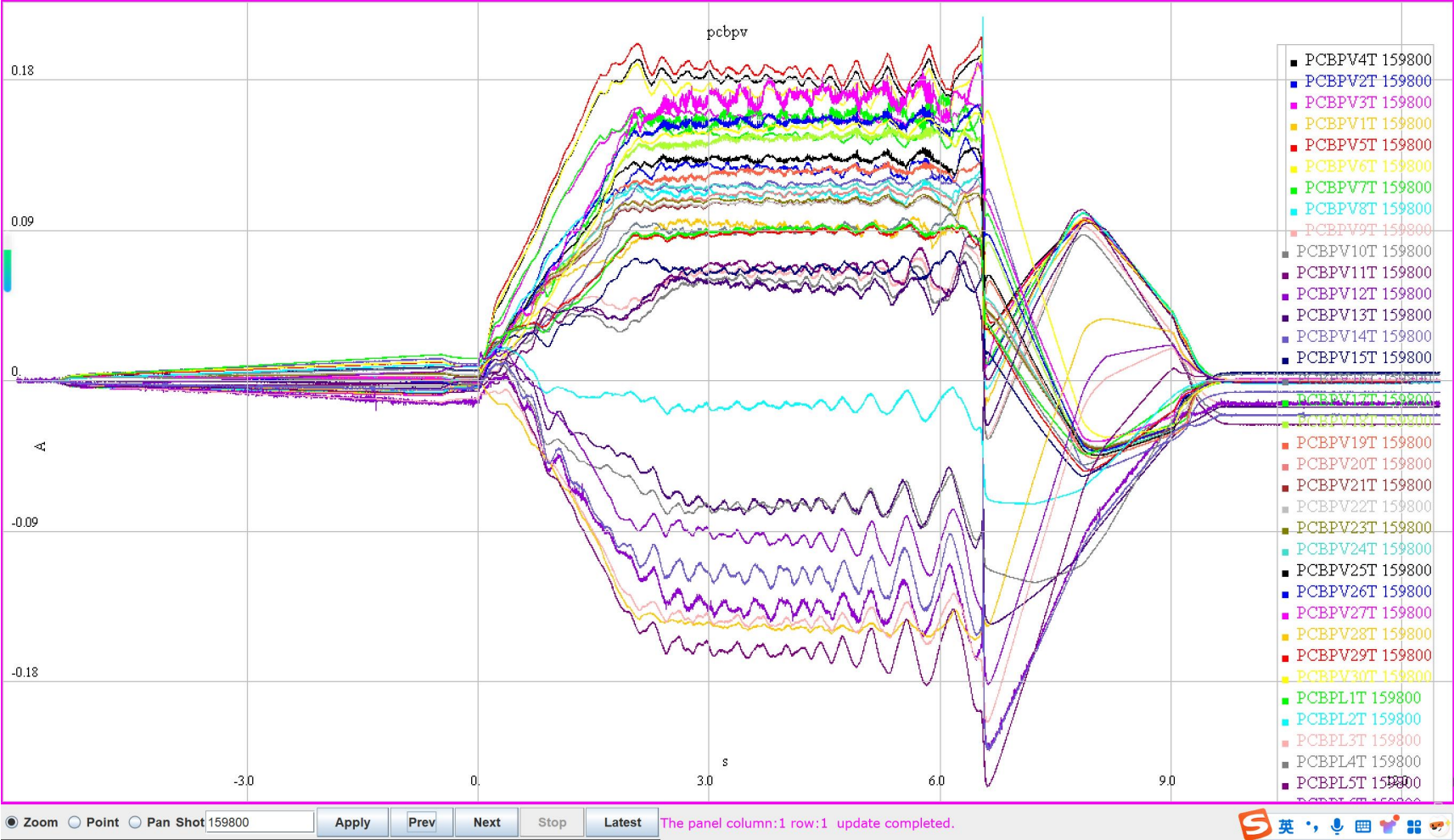
Magnetic Field Visualization



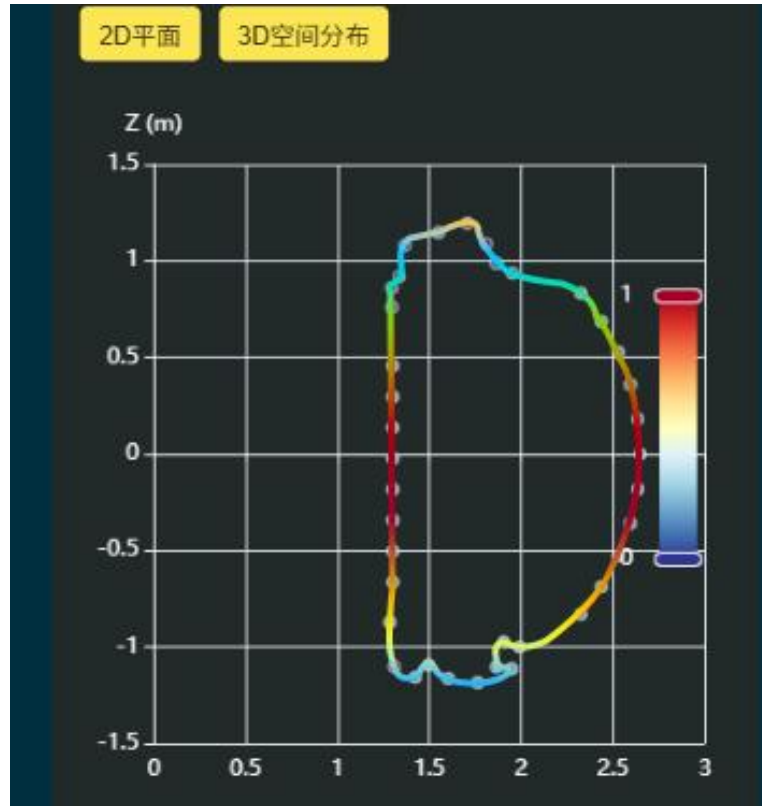
- The toroidal magnetic probe (two-dimensional structure, 38 sets in the toroidal direction) is used to measure the internal magnetic field of the vacuum vessel, primarily for plasma shape inversion and equilibrium control.
- 38 magnetic probes correspond to 38 signal names, and each signal can measure the magnetic field value at a certain moment.

PCS	DAQ	NS m ²	Z/m	R/m	Theta/Deg	Phi/Deg
pcbpv1t	HBPH1T	0.218520105	-0.663111056	1.301052894	89.9558261	158.6890401
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pcbpv7t	HBPH7T	0.223831952	0.296805322	1.300297705	89.975222	158.6955076
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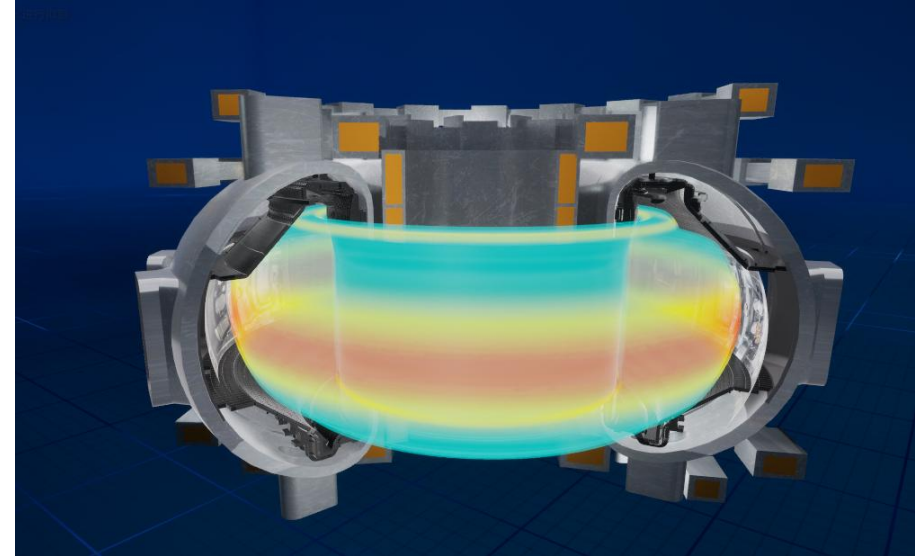
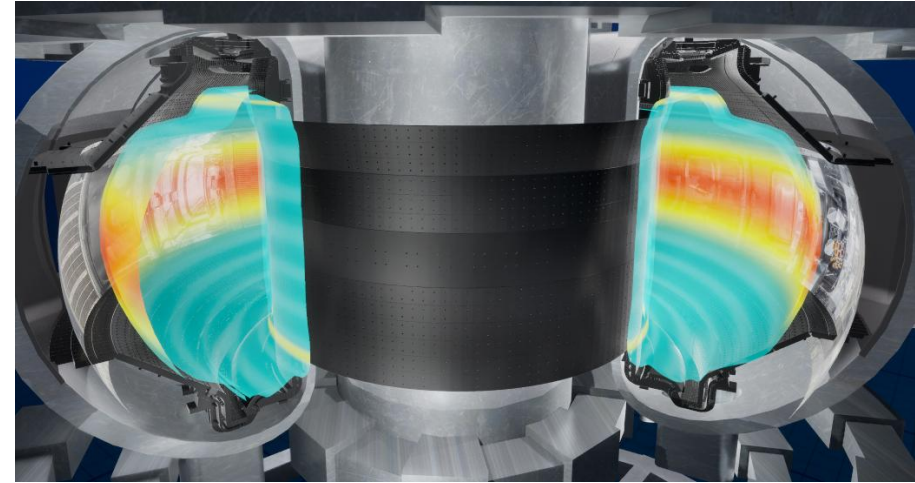
View the magnetic field in Webscope.



3D magnetic field visualization



In 2D space, 38 values are set to the 38 points. Rotate the contour to render 3D magnetic field visualization.



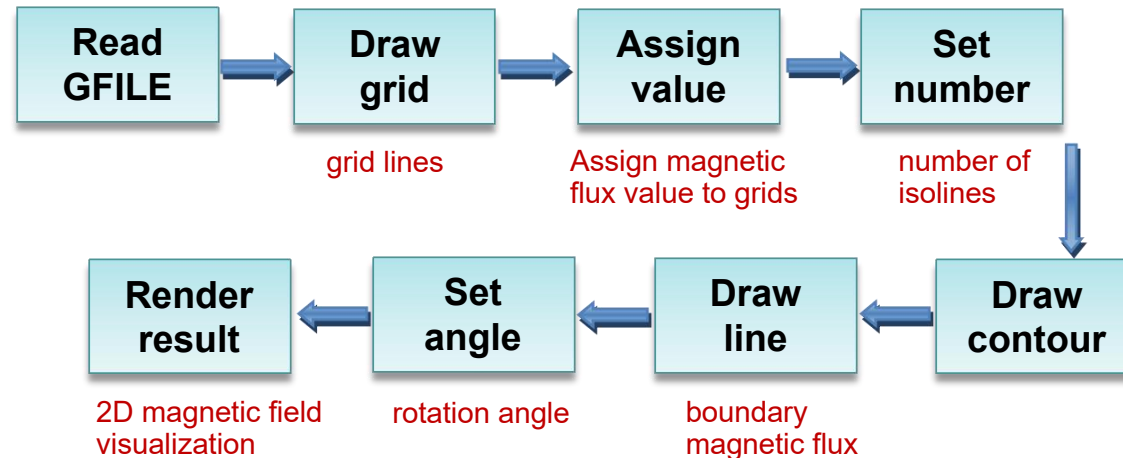
2D Magnetic Field

EFIT

- Solves the problems of plasma two-dimensional balance in tokamak

GFILE

- Standard output file of the EFIT program
- Standard input file format of some other programs
- The number of grid points, flux value of calculation grid, plasma boundary location, plasma profile information



```
EFITD 08/02/2006 #103519 4200 3 129 129
0.140000000E+01 0.240000000E+01 0.185000002E+01 0.120000000E+01
0.000000000E+00
0.188344642E+01 -0.320778996E-01 -0.338785269E+00 -0.184932242E+00
0.242084000E+01
0.447586668E+06 -0.338785269E+00 0.000000000E+00 0.188344642E+01
0.000000000E+00
-0.320778996E-01 0.000000000E+00 -0.184932242E+00 0.000000000E+00
0.000000000E+00
0.450404637E+01 0.450366219E+01 0.450328072E+01 0.450290196E+01
0.450252593E+01
0.450215262E+01 0.450178204E+01 0.450141420E+01 0.450104910E+01
0.450068674E+01
0.450032714E+01 0.449997029E+01 0.449961620E+01 0.449926487E+01
0.449891632E+01
0.449857054E+01 0.449822754E+01 0.449788732E+01 0.449754990E+01
0.449721526E+01
0.449688343E+01 0.449655441E+01 0.449622819E+01 0.449590478E+01
0.449558420E+01
0.449526644E+01 0.449495151E+01 0.449463941E+01 0.449433015E+01
0.449401785E+01
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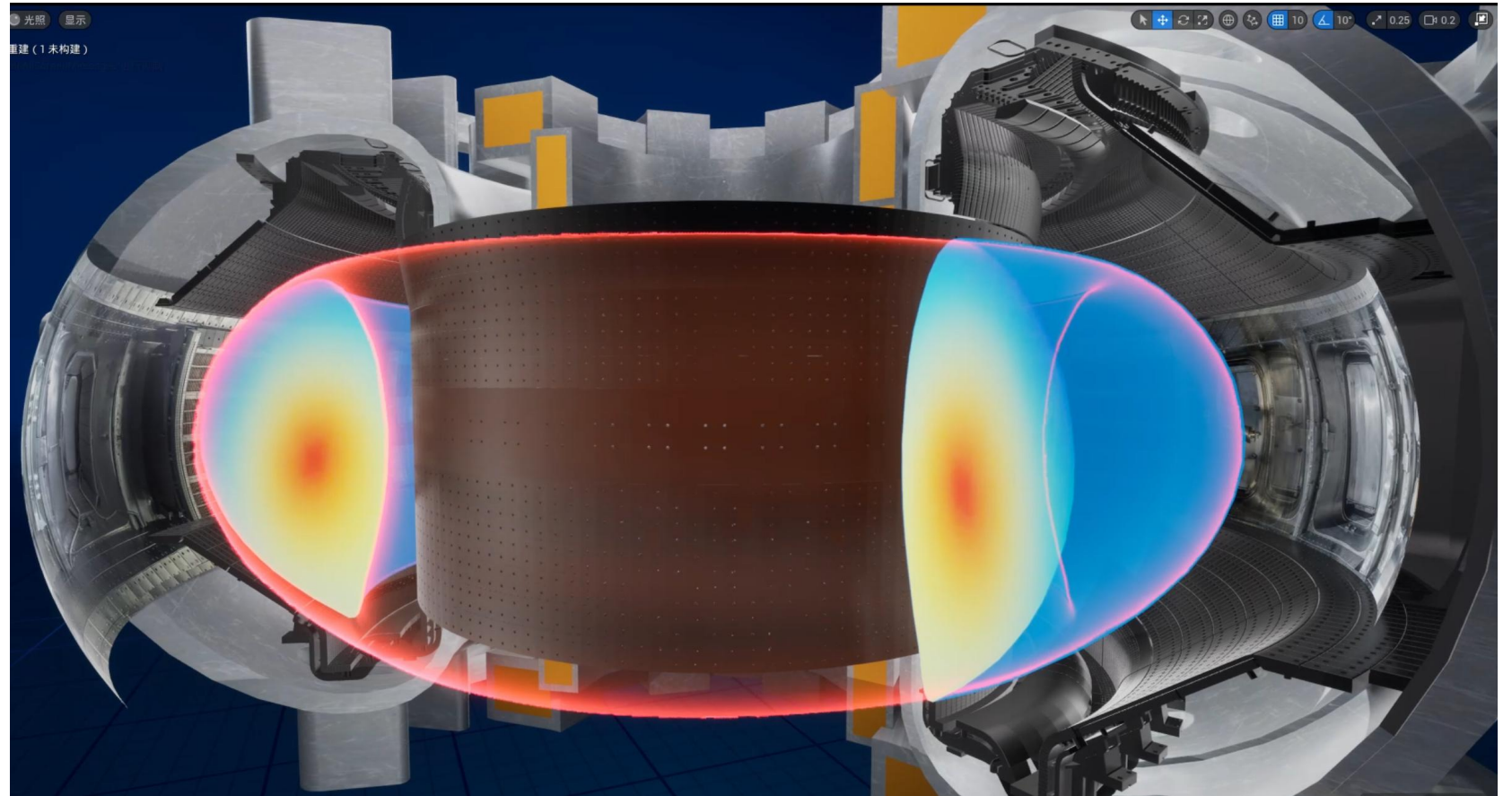
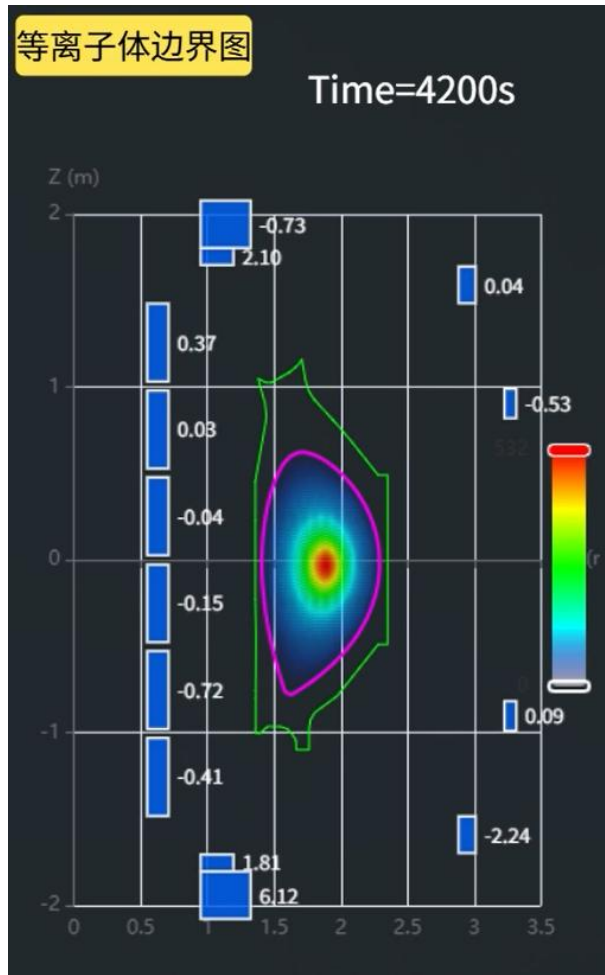
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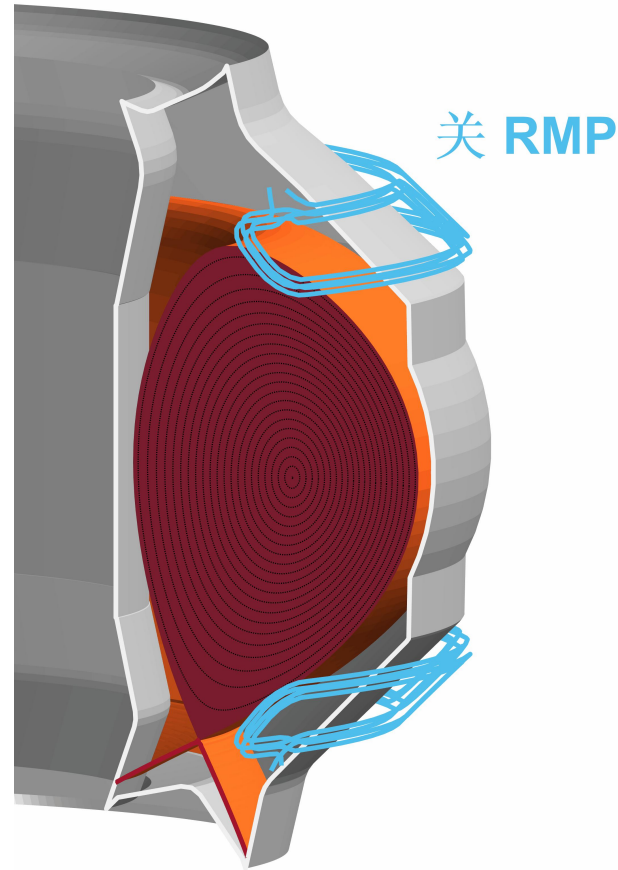
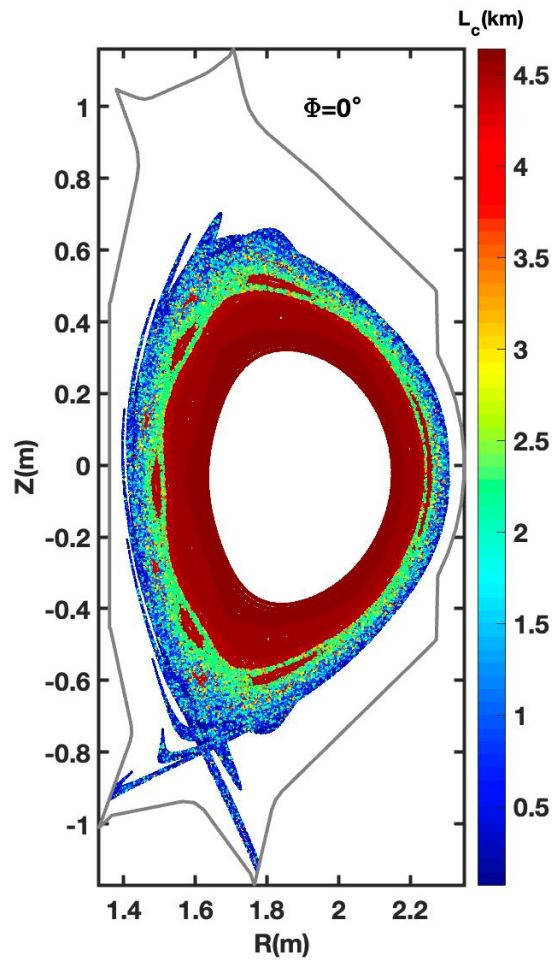
2D Magnetic Field

Contour of Magnetic Flux

Data Visualization in Virtual EAST



Poincare plot of 3D magnetic field perturbations

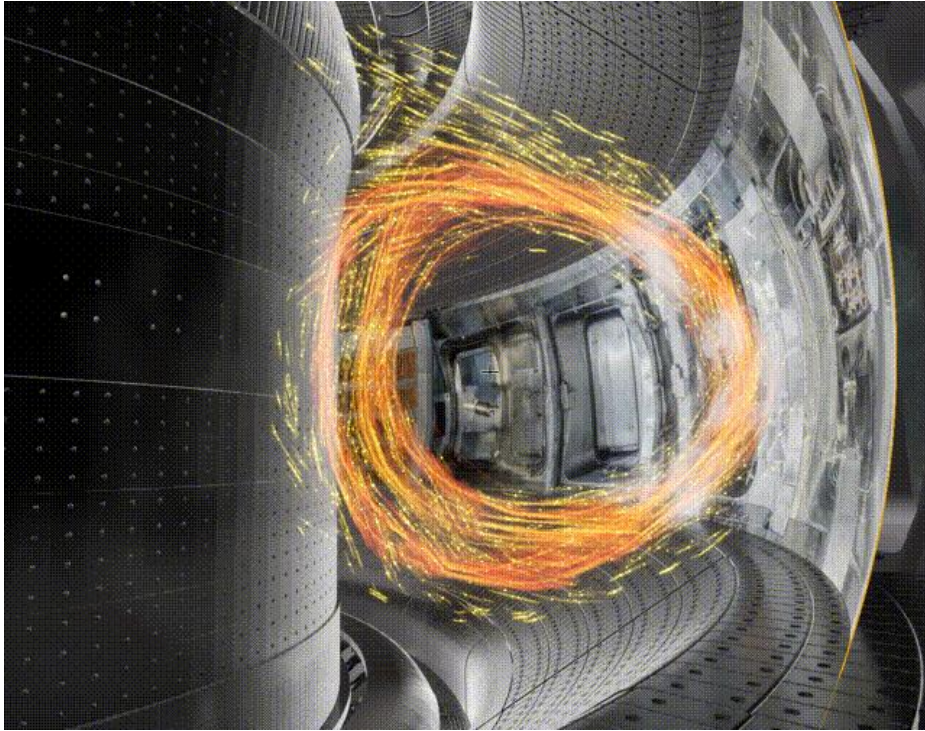


- Under ideal condition, the magnetic flux surface in tokamak is nested torus and toroidal axisymmetric.
- With the resonant magnetic perturbation (RMP) application, the 3D magnetic topology is changed and the magnetic field became toroidal asymmetry.
 - 1) The radial perturbed fields broke the rational surfaces to create island chains;
 - 2) the overlapped island chains in the edge create a stochastic layer;
 - 3) the perturbed invariant manifolds of the separatrix create homoclinic tangels around the X-point.

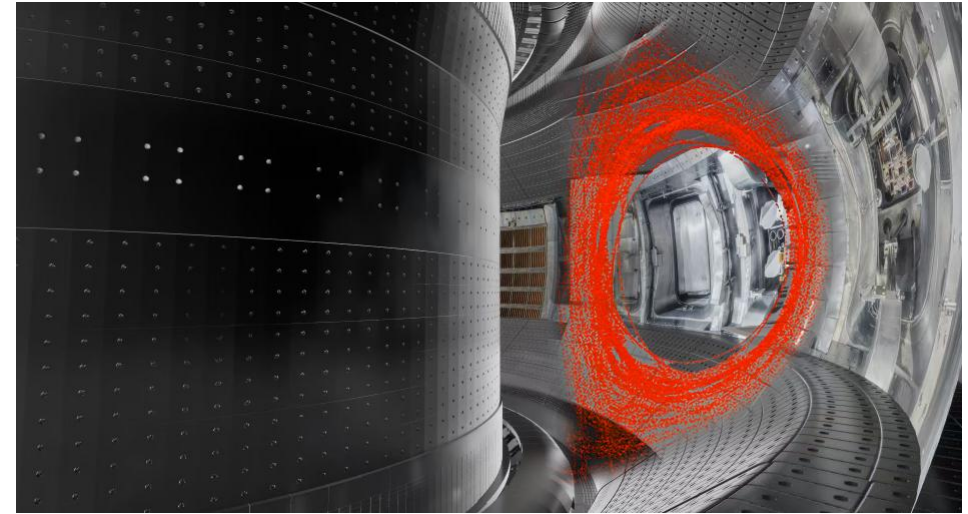
【M. Jia et al 2018 Nucl. Fusion 58 046015】

【M. Jia et al 2016 Plasma Phys. Control. Fusion, 58 055010】

Poincare plot of 3D magnetic field perturbations



- The figure shows an example of combined geometry of the machine and the 3D magnetic topology, represented by a Poincare Plot on one toroidal position of the resonant magnetic perturbation application in EAST.



- The visualization of the 3D magnetic topology in the machine provide an intuitive background which can help researchers analyse other experimental observations.

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Summary

- Data visualization of Magnetic field visualization, 2D Magnetic field and Poincare plot of 3D magnetic field perturbations was completed and integrated into virtual tokamak system.
- Detailed data processing procedure and visualization steps were specified.
- Additional data visualization will be realized and added to the virtual environment.
- Experiment data will be fetched from the database and rendered in real-time.