Progress of Fusion Nuclear Technology, Material and Safety Studies at FDS

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Contributed by FDS Team
Institute of Nuclear Energy Safety Technology (INEST)
International Academy of Neutron Science (IANS)

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FDS: The Consortium for Nuclear Technology Innovation

International Academy of Neutron Science (IANS)
(Headquarter located in Qingdao)
President: Academician Prof. Yican WU
Personnel in Qingdao: ~300 researchers

Qingdao Base

Institute of Nuclear Energy Safety Technology Co., Ltd. (INEST)
(Legal entity invested jointly by CAS and IANS)
Honorary Director General: Yican Wu
Director General: Prof. Yong SONG
Personnel in Hefei: ~200 researchers

Hefei Base

Institute of Radiation Medicine Technology Co., Ltd. (IRMT)
(Legal entity invested jointly by CAS and IANS)
Director General: Prof. Liqin HU
Personnel in Nanjing : ~150 researchers

Nanjing Base

Other bases under construction (Shanghai, Beijing, Hangzhou, Shanxi)

- In response to the latest requirements of the reform of national science & technology system, FDS has been upgraded to a new organizational form, becoming a large institution of science and technology group
- Thanks to its very competitive technologies and brilliant talent team, FDS is highly valued and strongly supported by national & local governments, as well as social groups.
- The scale of FDS is rapidly expanding, with a series of new bases under construction.

International Academy of Neutron Science (IANS)

Qingdao

Institute of Nuclear Energy Safety Technology Co., Ltd. (INEST)

Hefei

Institute of SuperAccuracy Radiation Technology Co., Ltd. (ISART)

Nanjing

Orientation of Fusion Studies at FDS

Innovative Concepts

FDS-MFX
FDS-I/-SFB, C-DEMO
FDS-II, FDS-III, FDS-ST
…

D-T Tokamak

+

GDT mirror
…

Alternative concepts

Common Technologies

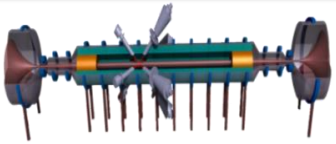
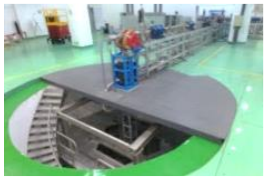
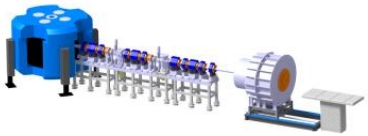
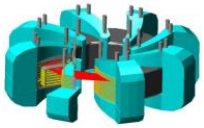
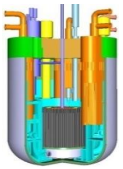
Fusion Nuclear Technology, Materials and Safety

1. Neutronics & Nuclear Technology
2. Materials & Blanket Technology
3. Fuel Cycle & Tritium Technology
4. Safety, Environment & Socio-economics

Develop technologies shared among various fusion concepts

Snapshot of High Intensity Neutron Sources by FDS

Mini → High

HINEG-M	HINEG-I	HINEG-II	HINEG-III
10^{8-11} n/s	10^{12-13} n/s	10^{13-15} n/s	10^{17-18} n/s
 (a) Mini neutron generator (ø25/43mm,10^8 n/s)	 (a) D-T neutron Generator	 (a) Ultra-high D-T neutron source	 (a) GDT-based V-FNS
 (b) Mobile neutron source ($10^{9\sim11}$ n/s)	 (b) China Lead-based Zero-Power Reactor CLEAR-0	 (b) Cyclotron neutron source (30MeV,~1mA)  (c) China Lead-based Experimental Reactor CLEAR-A10 (~10MWt)	 (b) High Flux SNS (900MeV, 1~10mA)  (c) China Lead-based Demo Reactor CLEAR-A100 (~100MWt)

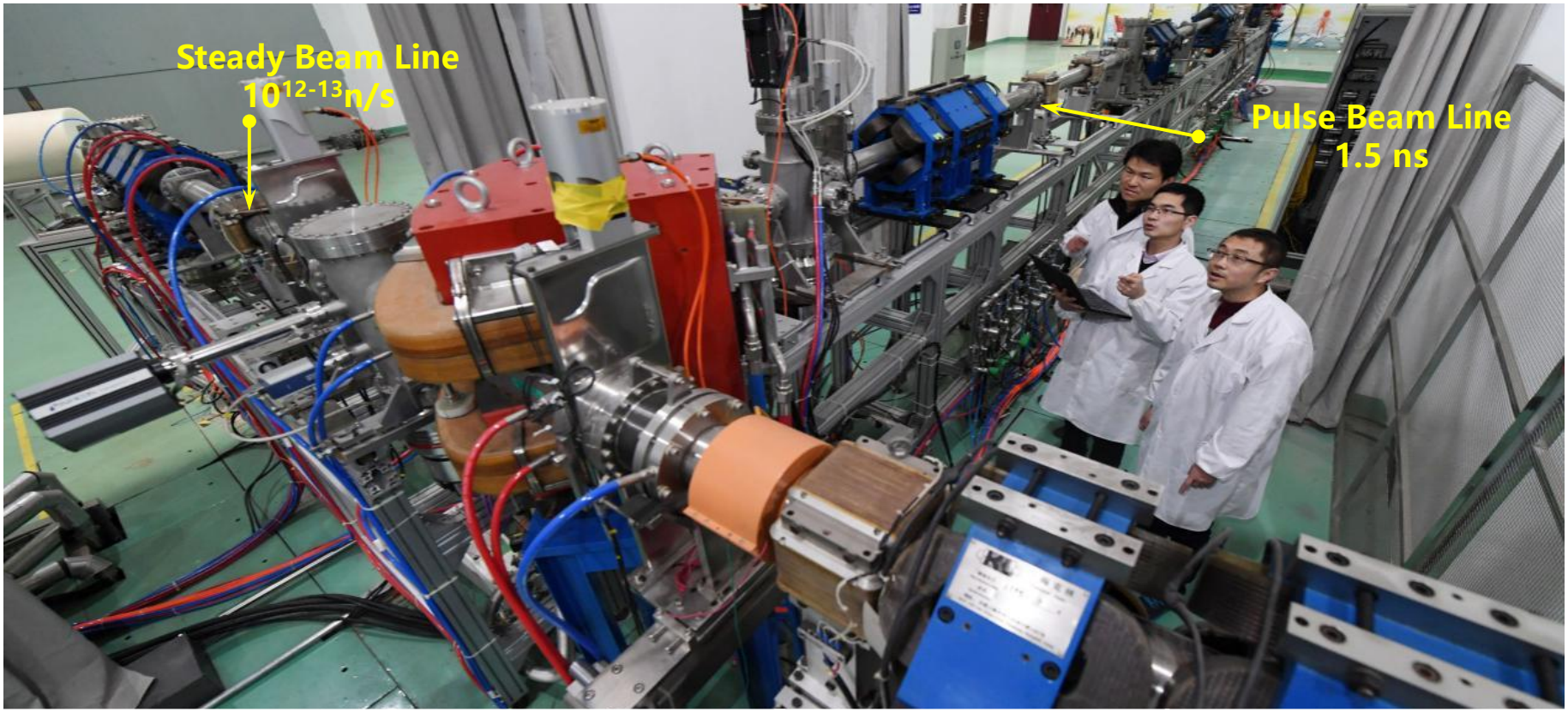
Fusion: Neutronics Design Validation → Material Irradiation Test → Components Performances Test

Fission (LFR / Subcritical System…): Core Physics & Shielding Design Validation → Lead-based Mini-Reactor(~10 MWt) → Nuclear Fuel Breeding & Transmutation

Extended Nuclear Technology Applications: Neutron Radiography , Radiotherpy, Logging, Security Inspection, Isotope Production etc.

HINEG-I: D-T Fusion Neutron Generator (Ready)

Neutrons yield: 6.4×10^{12} n/s, coupling with Lead-based zero power reactor CLEAR-0



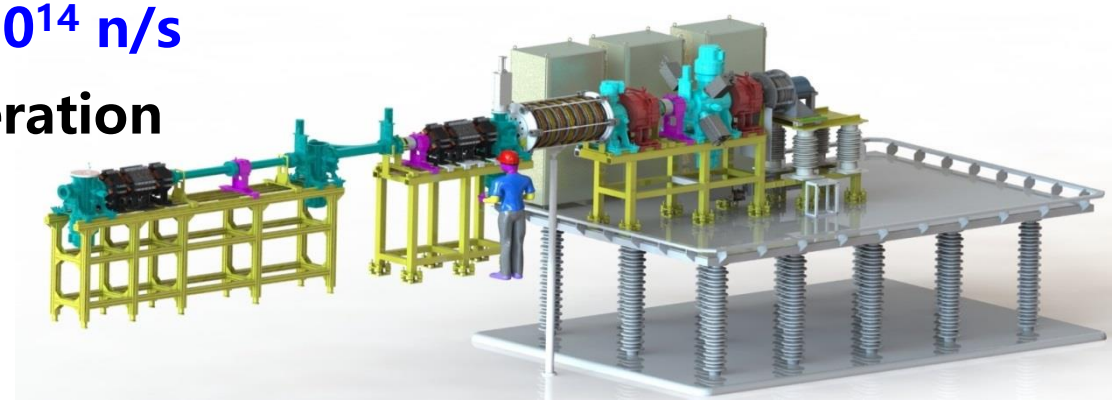
HINEG-IIa: Ultra-high intensity D-T Neutron Source
(Under Construction)

Application Goals

- Radiation damage mechanism of materials under fusion neutron irradiation environment
- Validation and calibration of materials irradiation data obtained with other ion/neutron source (e.g. reactor, spallation)
- Extended nuclear technology applications including radiography, neutron therapy, etc.

Main parameters

- Neutron yield: 10^{13}-10^{14} n/s
- D-D and D-T dual operation mode

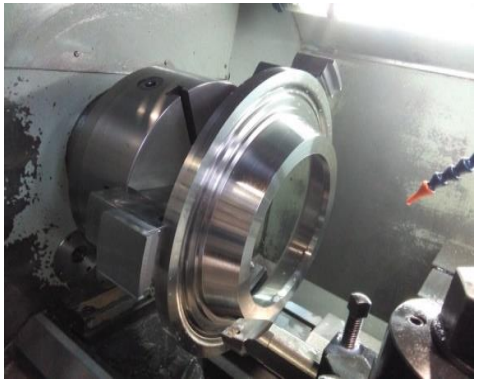


Construction are on going

Progress of HINEG-IIa

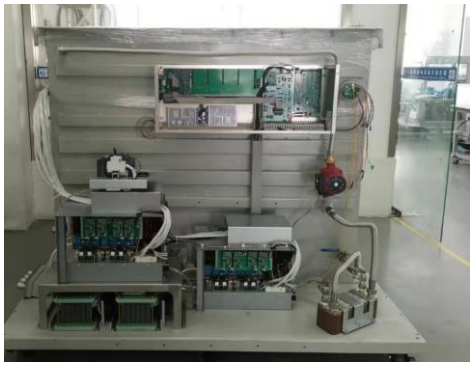
Ion Source

Extraction system



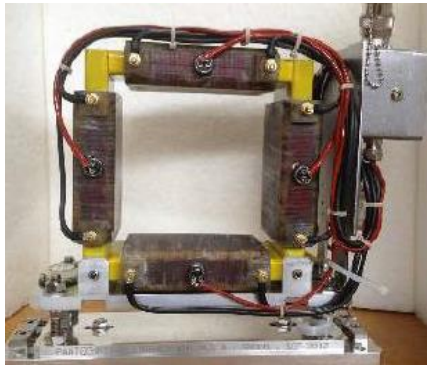
Vacuum Vessel

Insulating Transformer



HV Power Supply

Chiller



Steerer

C&C Cabinet

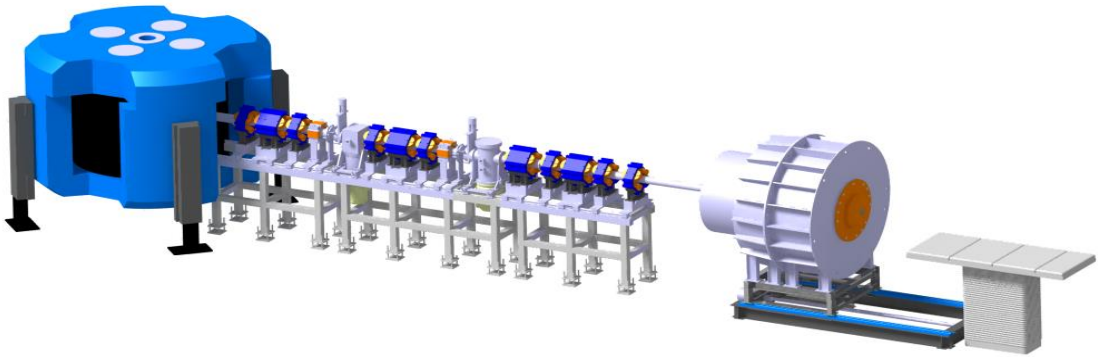
Engineering design has been finished, components manufacture and assembly are under going

Application Goals

- Neutron source for **boron neutron capture therapy**
- Validation of **isotope production** technology based accelerator
- **Validation of accelerator & target technologies for subcritical system**
- **Fundamental science and neutron irradiation research platform**

Main parameters

- **Neutron yield: >10^{14} n/s**
- **Accelerator: proton, 30 MeV/1 mA**
- **Target material:** Be
- **CW operation**



Progress of HINEG-IIb

Cyclotron

RF Syetem

Ion Source

HV Power Supply

Components manufacture are under going
Assembly will start at early 2022

Buildings for HINEG-II Facilities

Shielding room and supporting laboratories almost ready in Qingdao Base

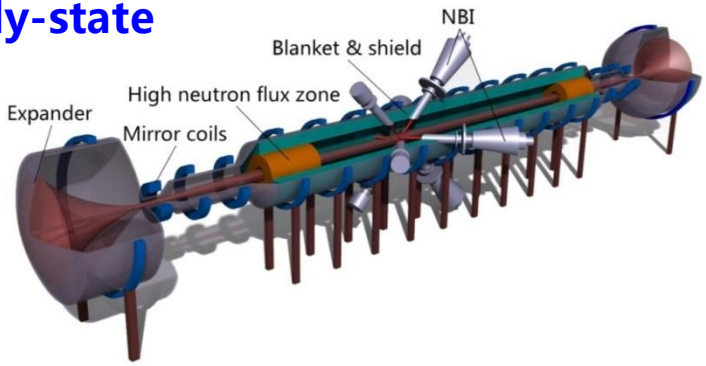
HINEG-IIIa: High Flux GDT based VFNS (Planning)

Application Goals

- Full lifetime irradiation test of fusion materials (≥20 dpa/FPY)
- Component test of blanket and divertor
- Reliability data of nuclear components
- Validation of radioactive waste transmutation

Main Parameters

- **Neutron yield: ≥10^{18} n/s, volumetric, steady-state**
- Tritium consumption rate: <200 g/FPY
- Neutron flux and test volume:
  - ≥ 2 MW/m^2 (~35 L)
  - ≥ 1 MW/m^2 (~100 L)
  - ≥ 0.5 MW/m^2 (~1 m^3)



- **Linear, simple and compact structures**
- **Relative low demand of technologies**

Based on HINEG-IIIa, an international mega-science project proposal titled

"Axisymmetric LInear Advanced Neutron sourCE (ALIANCE) "

was jointly initiated by FDS & BINP in 2018

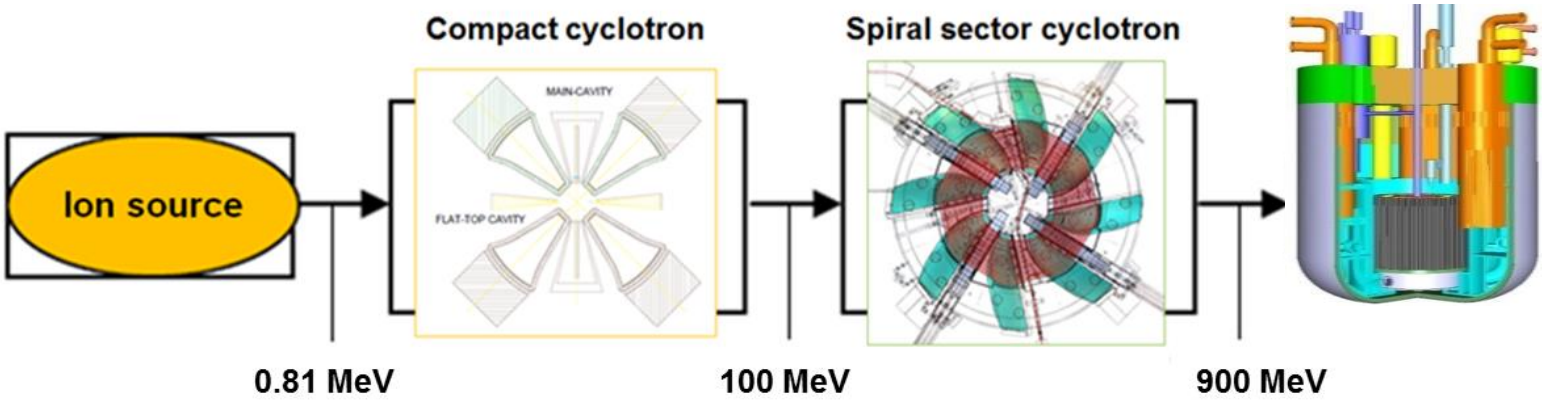
HINEG-IIIb: High Flux Spallation Neutron Source (Planning)

Application Goals

- Driver of a multi-purpose subcritical nuclear system (**China Lead-based Demo Reactor CLEAR-A100**).
- Multi-purpose and flexible fast neutron irradiation platform

Main Parameters

- **Neutron yield: $10^{17\text{-}18}$ n/s**
- **Accelerator:** 900MeV/1-10mA proton beam
- **Spallation Target:** Pb



Conceptual design of HINEG-IIIb are on going

Structural Materials and Test Blanket Modular

I. CLAM: China Low Activation Martensitic steel

- 3×6-ton Ingots & Components
- Breakthrough in 3D printing of blanket first wall

National RAFM steel standard is published (GB/T 38820-2020)

II. ODS-CLAM: Oxide Dispersion-Strengthened CLAM

- Nanoparticles: <10 nm, >10^{24} m-3
- Yield strength at 700 ºC: >500 MPa
- Creep life at 120 MPa/650ºC: >10,000 hr
- Swelling after 200 dpa ion irradiation: <0.1%

Supported by National Key Technology R&D Project of China

III. China TBM Program

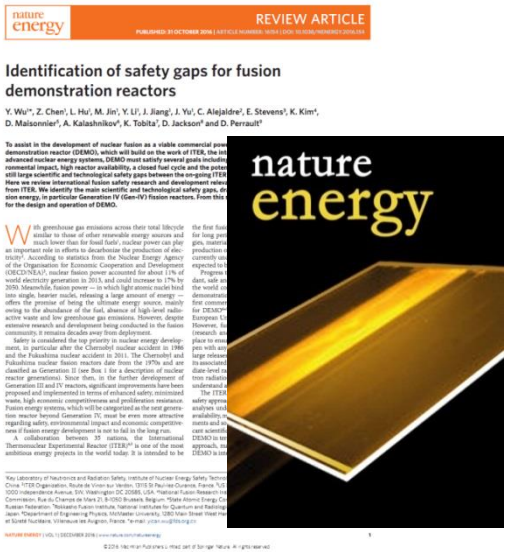
- Fabrication of 1/3 scaled DFLL-TBM by welding technologies

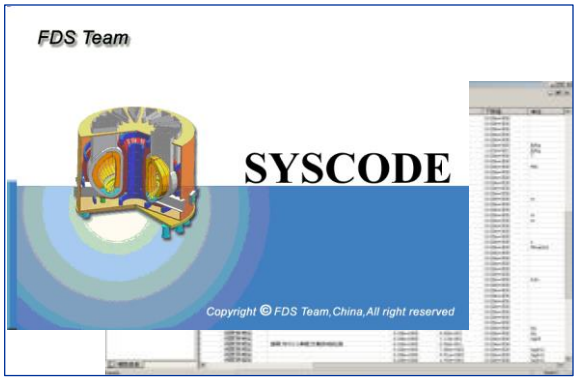
Study of Safety, Environment and Socio-economics

1. Identification of Safety Gaps analysis for Fusion DEMO Reactors and published in Journal of Nature Energy.

2. Organized and hosted two international workshops on ESEFP to promote research on fusion safety assessment and regulatory, such as safety approach, safety design, licensing, et al.

3. Fusion System Analysis and Economical Assessment Program(SYSCODE) was developed. SYSCODE was selected as the highlight of 2015 by IEA.





Summary

1. In response to the latest requirements of the reform of national science & technology system, FDS has been upgraded to a new organizational & institutional form.

2. The scale of FDS is rapidly expanding which supported by national & local governments, as well as social groups, and three major new bases are under construction, we welcome international collaboration & communication in Qingdao, Hefei, Nanjing and other places.

3. Common fusion technologies of neutron sources, materials, and safety have been developed continuously, especially the several new neutron source facilities under construction recently.

Thanks for Your Attention!

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E-mail: contact@fds.org.cn