Development and Future of MNSR

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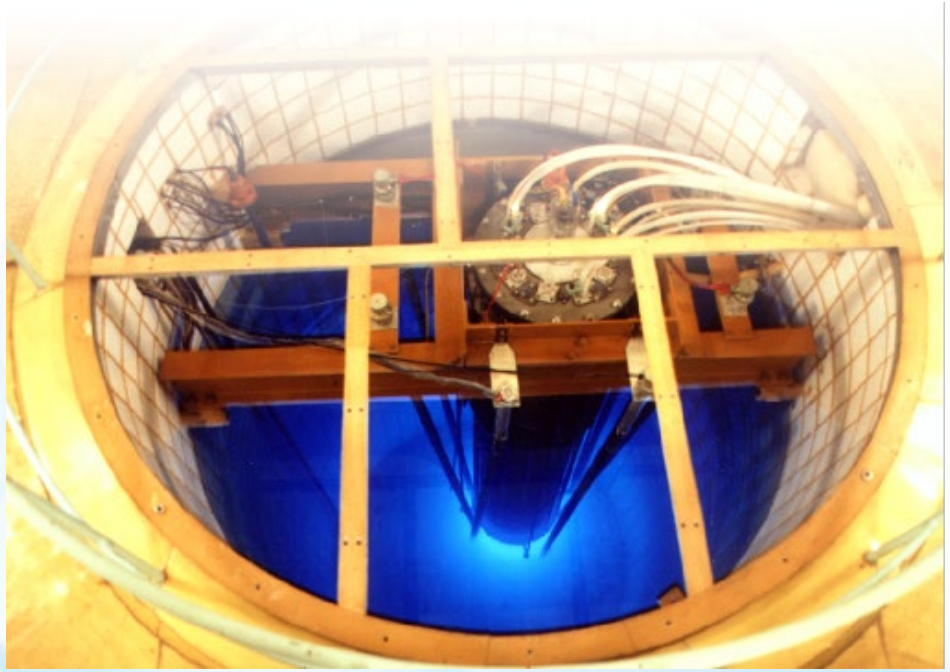
Contents

- Introduction of MNSR
  - History,Structure,Feature,MNSRs in the world.
- Application of MNSR
  - E&T,NAA,probe testing, etc.
- Development and future of MNSR
  - LEU conversion, BNCT, Decommission,etc
- RRs in CIAE

Part I. Introduction

Introduction

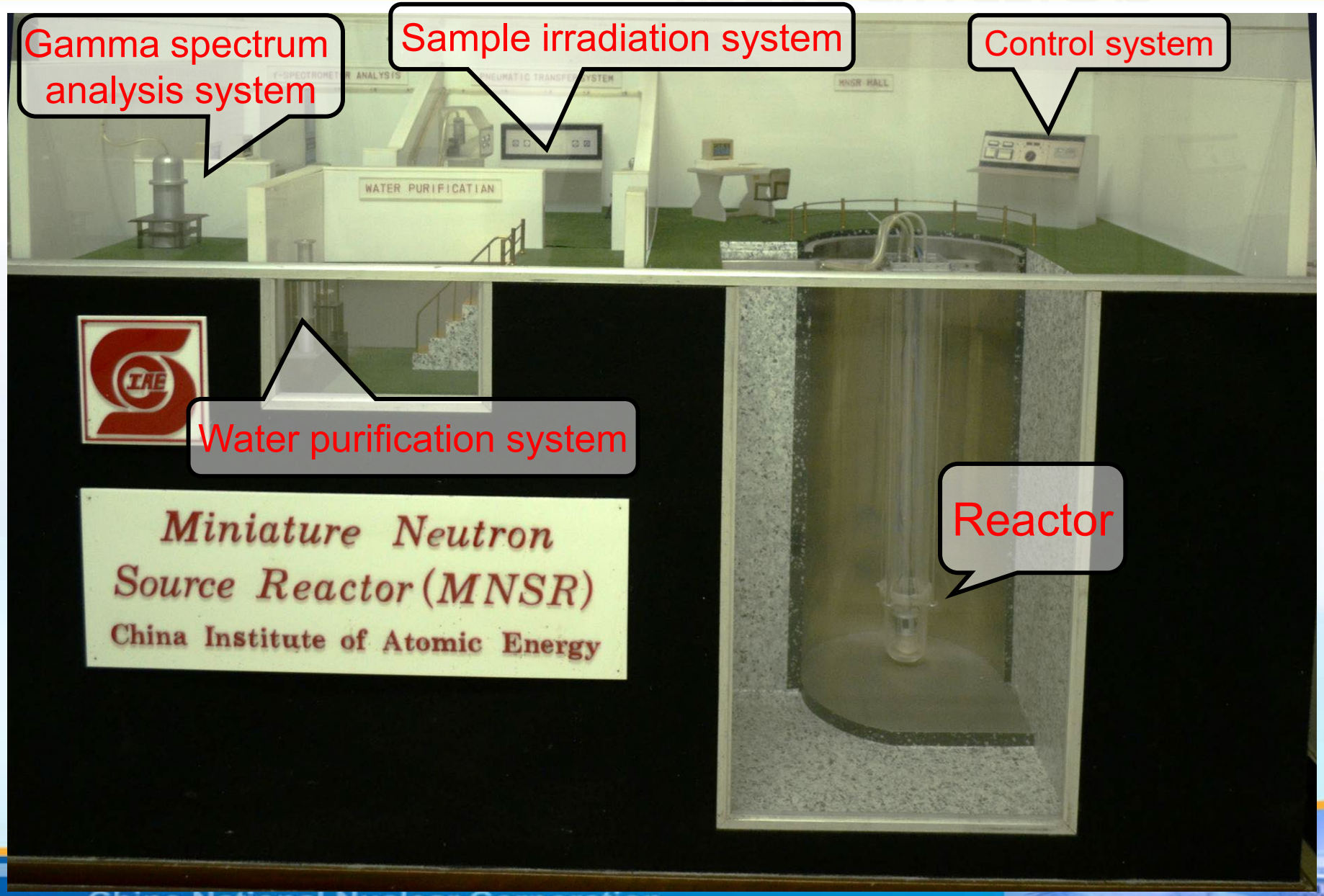
- History
  - CIAE began to develop MNSR in 1970s :
    Core desgin;
    Zero power experiment;
    Commissioning.
  - 1984.3 Prototype MSNR reached full power 27kW
  - Shutdown in 2015 for conversion
  - 2015.9 HEU core unloading
  - 2016.3 LEU core loading



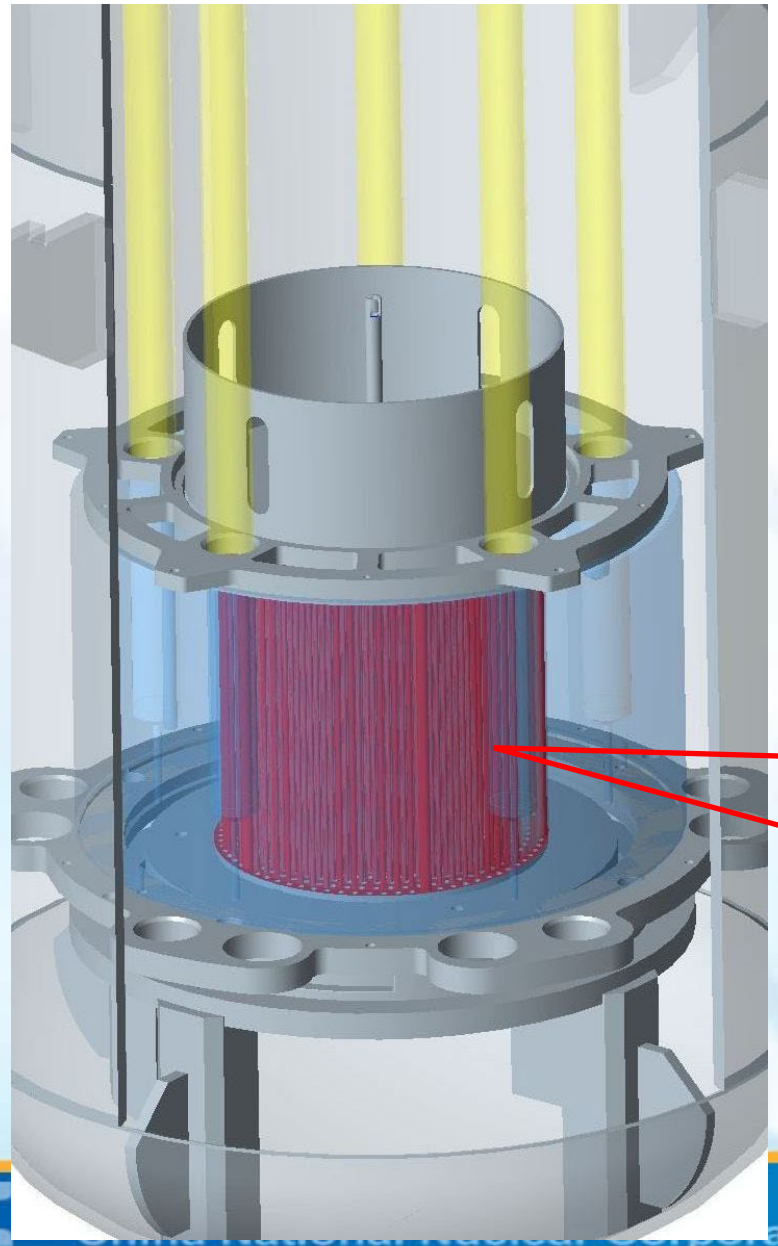
Introduction

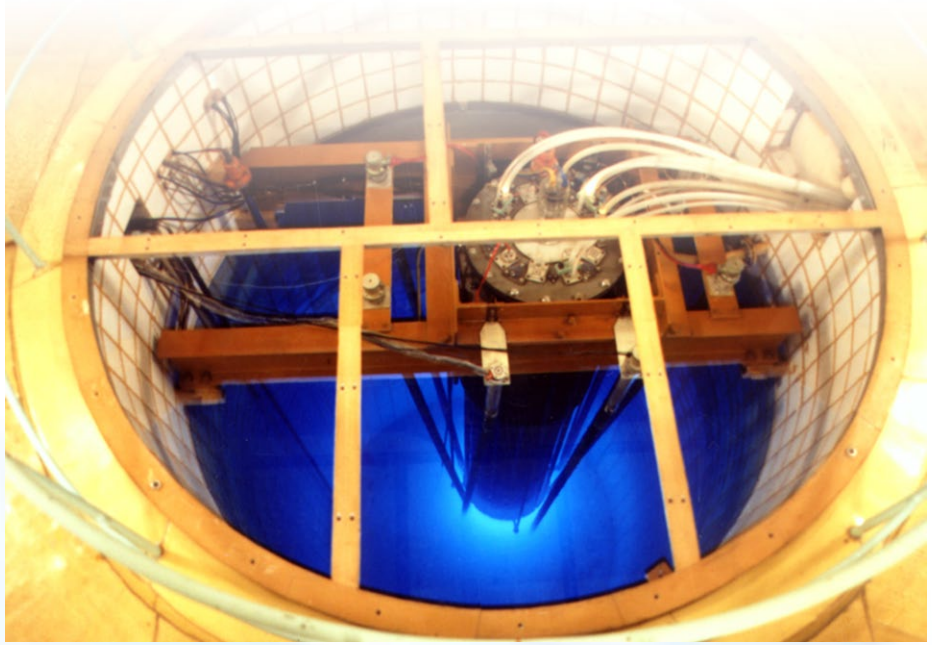
- Main Description
  - Power:30kW (for MNSR-IAE, it is 27kW)
  - Beryllium metal as reflector
  - Light water as both moderator and coolant
  - Natural convection as cooling method
  - HEU(~90%U-Al), AL cladding, or
  - LEU(~13%UO_2), Zr-4 cladding

Introduction



Introduction



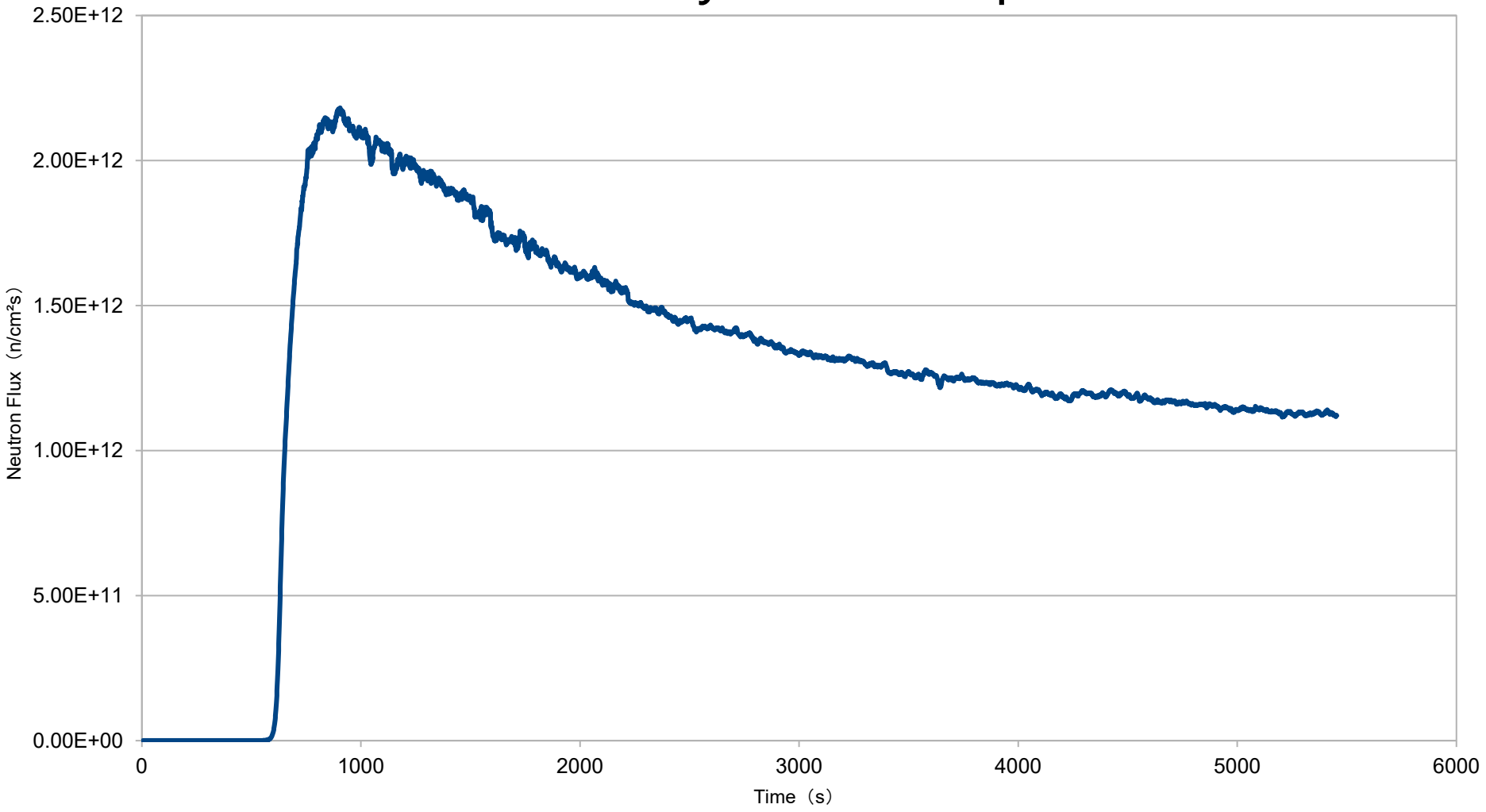


Introduction

- Safty
  - Inherent safety feature: no nuclear accident will occur at any time
  - Environmental friendly: radiation level outside reactor building is almost the background level
- Economy
  - The loading of U-235 is only about 1.2kg;
  - No need to refuel after more than 20 years of operation;
  - The reactor building is a civil building;
  - Reactor does not need safety grade equipment.
- Easy to operate
  - Only 1 operator was needed to operate the reactor;
  - It only takes 200-300 seconds from shutdown to full power.

Introduction

Total Excess reacivity release experiment



Introduction

Beijing, MNSR-IAE	• Built in Mar.1984 • LEU Conversion at 2016
Shenzhen University MNSR-SZ	• Built in May 1988
Shandong, MNSR-SD	• Built in May 1989 • Decommission in 2012
Pakistan, PARR-2	• Built in Nov. 1989
Shanghai, MNSR-SH	• Built in Dec. 1992 • Decommission in 2008
Iran, ENTC MNSR	• Built in Mar. 1994
Ghana, GHARR-1	• Built in Nov. 1995
Syria, SRR-1	• Built in Mar. 1996
Nigeria, NIRR-1	• Built in May 2004 • LEU Conversion at 2018
Beijing, IHNI	• Built in 2009
Thailand, SUT-RR	• Planning

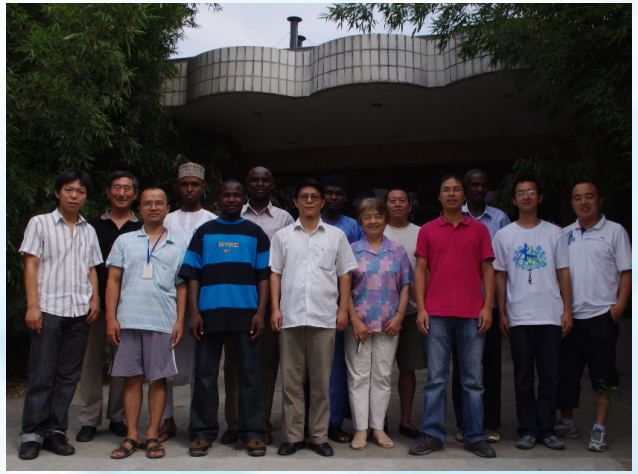
Part II. Applications

Applications

- E&T
- NAA & PGNAA
- Probe testing
- RI production(Lab. use only)
- Neutron Imaging
- BNCT

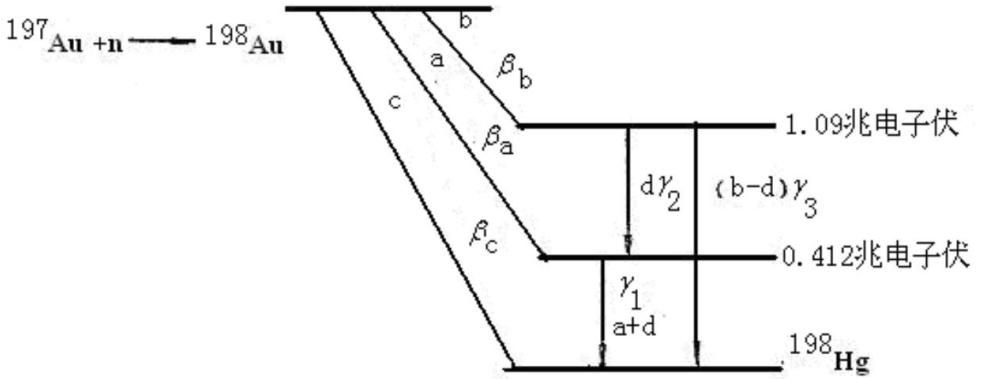
Applications

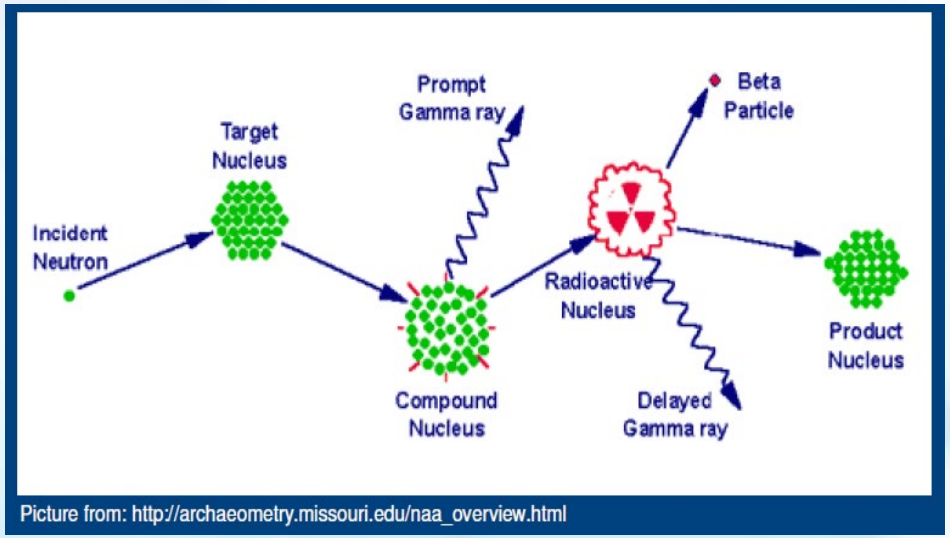
- E&T
  - Any facility can be used for E&T, but MNSR is particularly suitable for E&T.

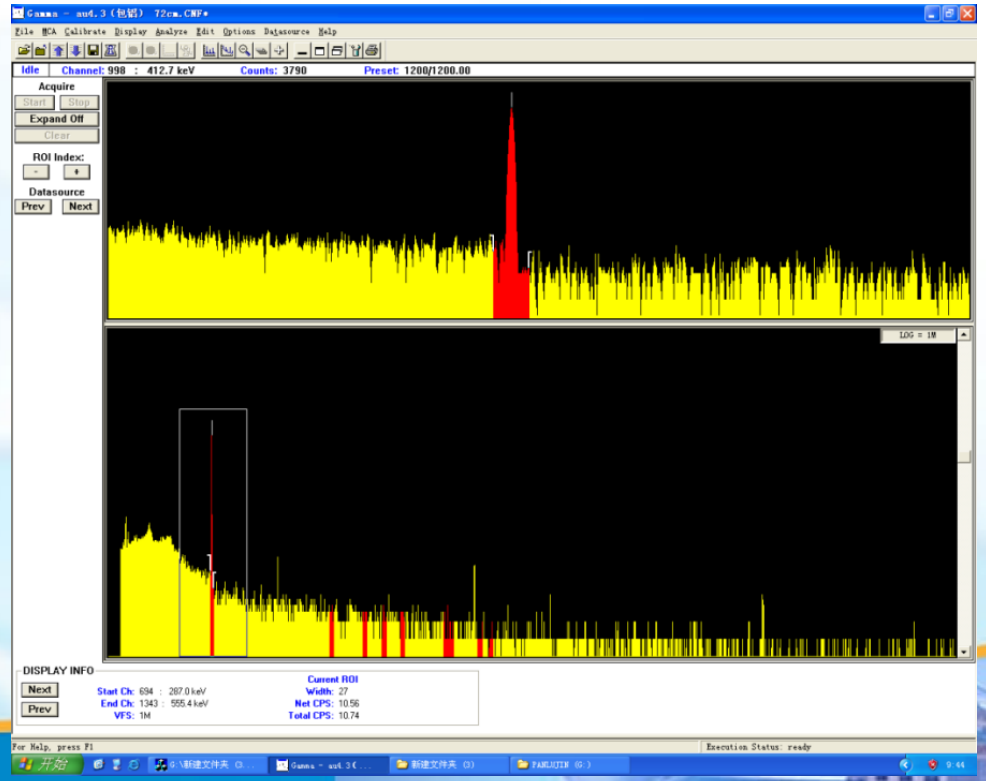


Applications

- NAA
  - The typical use of NAA is to analyze nuclides in samples. For example, mineral ore.







Applications

- NAA
  - Sometimes，NAA can be also used in criminal investigation.

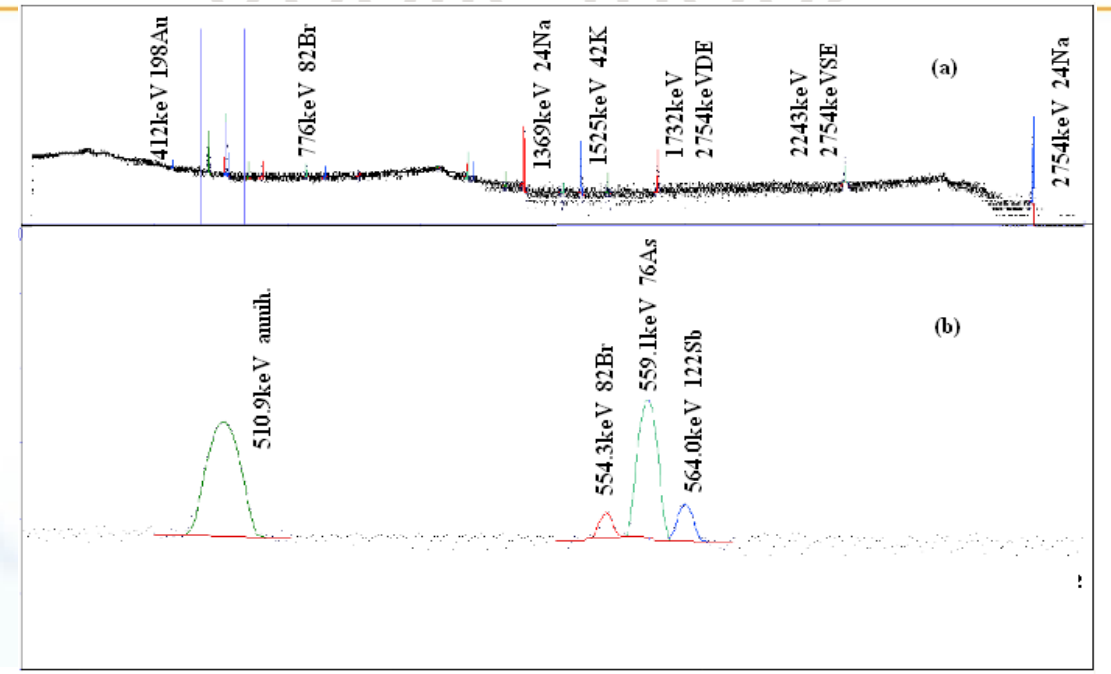
Here is an example:

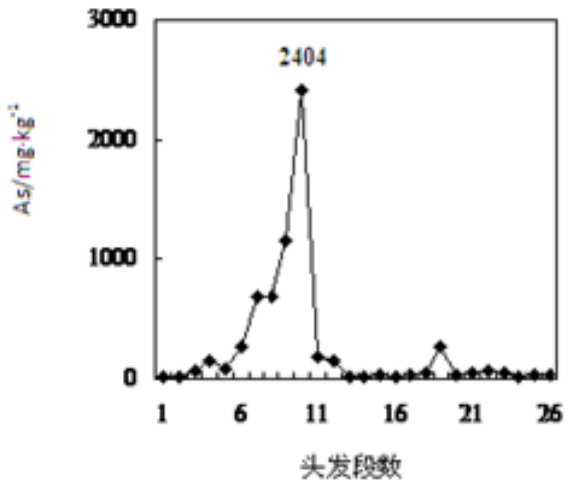
- “The Mystery of Emperor Guangxu's Death”

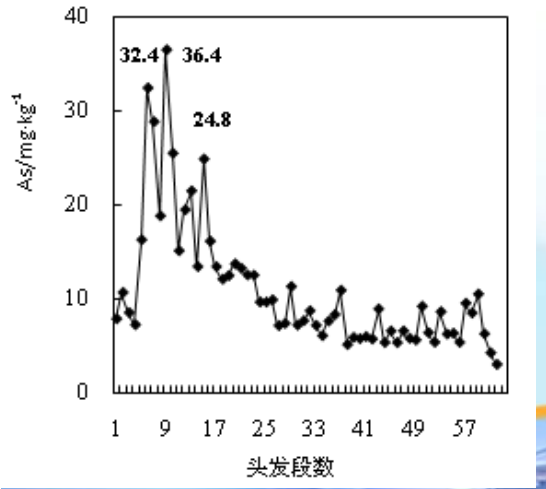
[1]王珂,张永保,邹淑芸,等.清光绪帝死因研究[J]. 2009.

Applications

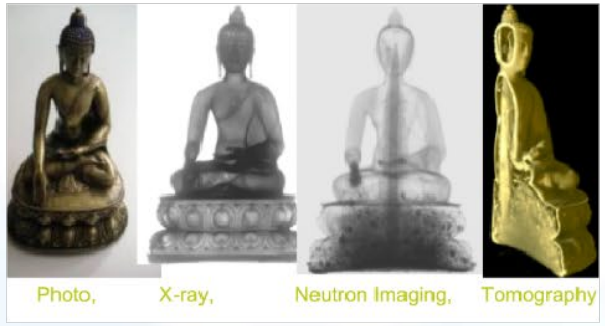
- NAA
  - The arsenic content in hair, body, bone, and the solid in the tomb were analyzed by NAA method in MNSR Lab.



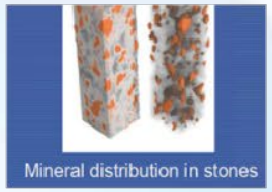




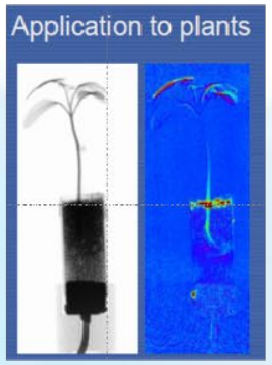
Applications



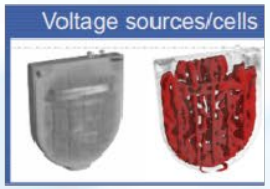
Utilization of Neutron Imaging



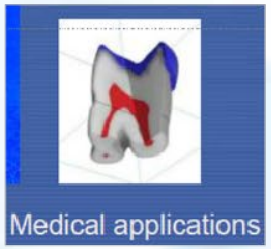
Mining



Agriculture



Industry



Medical

Part III.Development and Future

Development and Future

- LEU conversion
- BNCT
- Decommission and Technical reserve

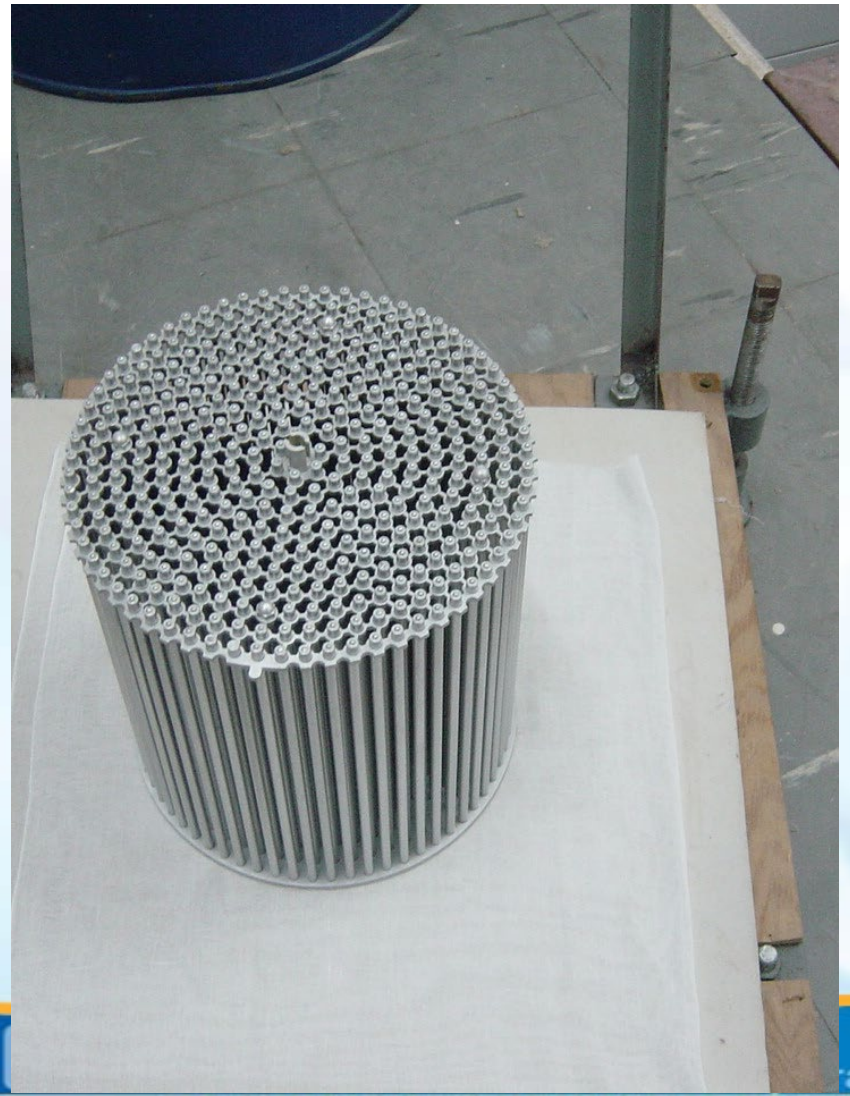
3.1 LEU convesion

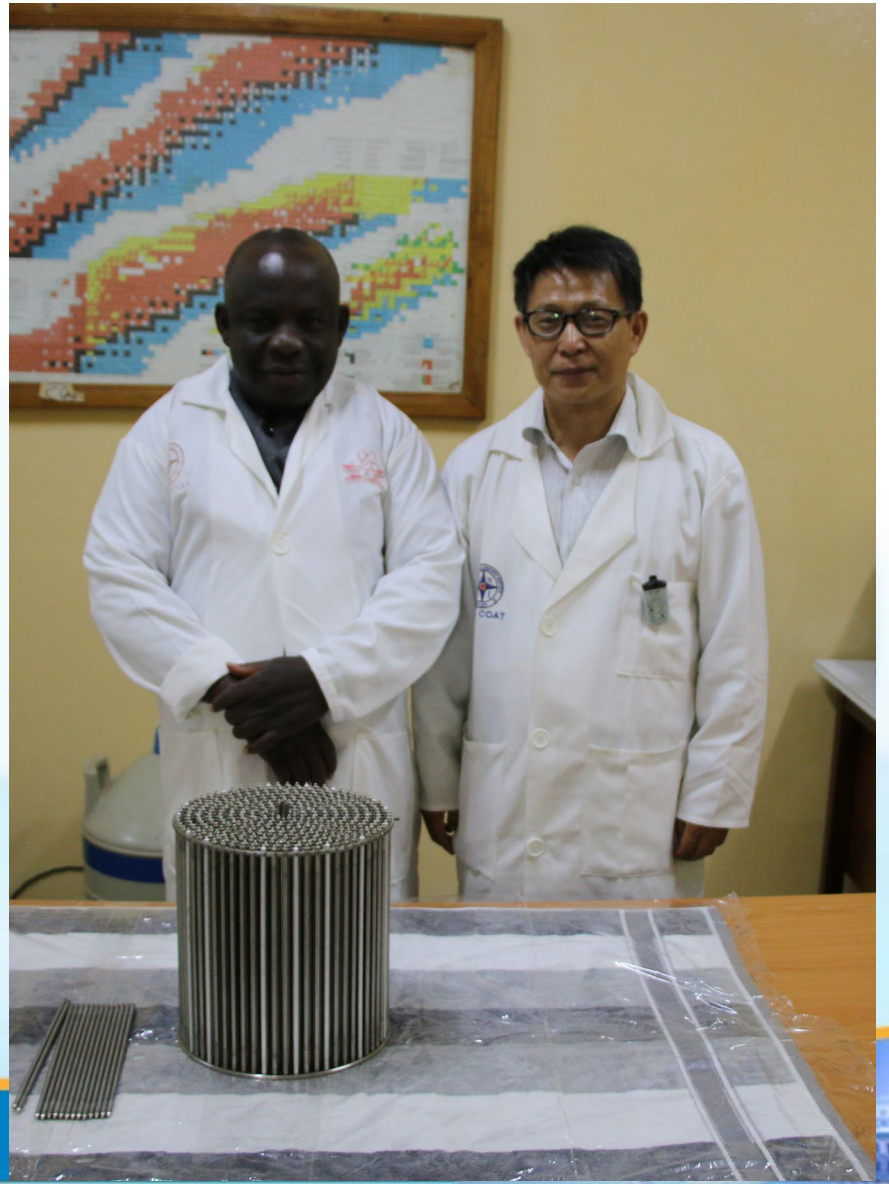
LEU Conversion of MNSR

- LEU conversion completed MNSRs
  - Protype MNSR, Ghana MNSR and Nigeria MNSR
- "Ghana model"
- Promoting LEU conversion on the rest MNSRs

LEU Conversion of MNSR

Use a LEU Core replace the HEU one.





LEU Conversion of MNSR

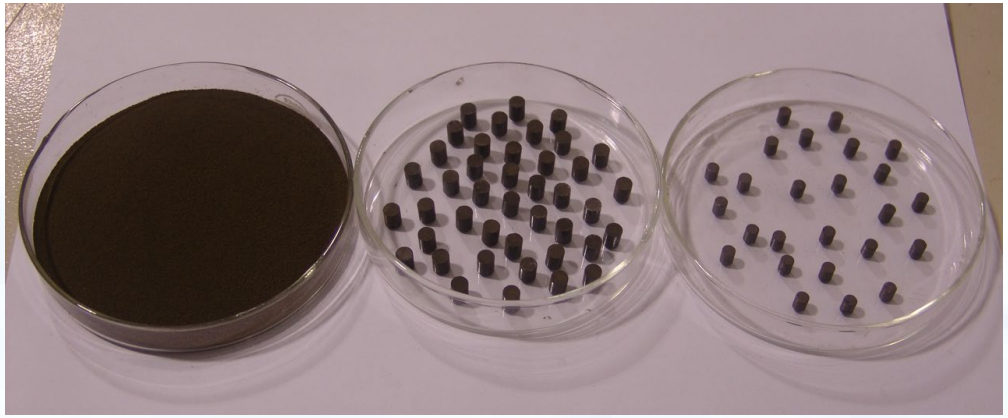
Diffirence between LEU core and HEU core

		LEU	HEU
Fuel Meat	Size	Φ4.3mm×230mm	
	Material	UO_2	U-Al alloy
	Enrichment ot U-235	~90%	~13%
Cladding	Material	Zr-4	Al alloy
Fuel pin	Size	Φ5.5mm×248mm	
Fuel assembly	Size	Φ230mm×258mm	
	Fuel pin Loading	335 fuel pins+15 dummy	344 fuel pins+2 dummy
	U-235 Loading	~1.2kg	~0.98kg

Ghana Model

- LEU fuel design and manufacture
- Zero Power Test of new fuel
- LEU fuel International Transportation
- HEU burnt fuel unloading
- LEU fuel loading and Reactor Commissioning
- HEU burnt fuel International transportation
- HEU burnt fuel storage and disposal

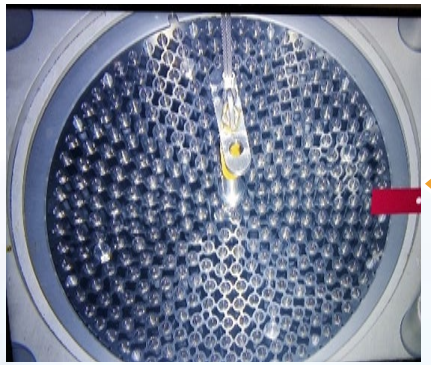
LEU fuel manufacture



Zero Power Test

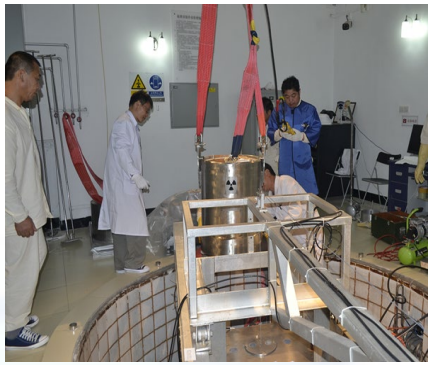
LEU fuel transportation

HEU unloading



Removing the core

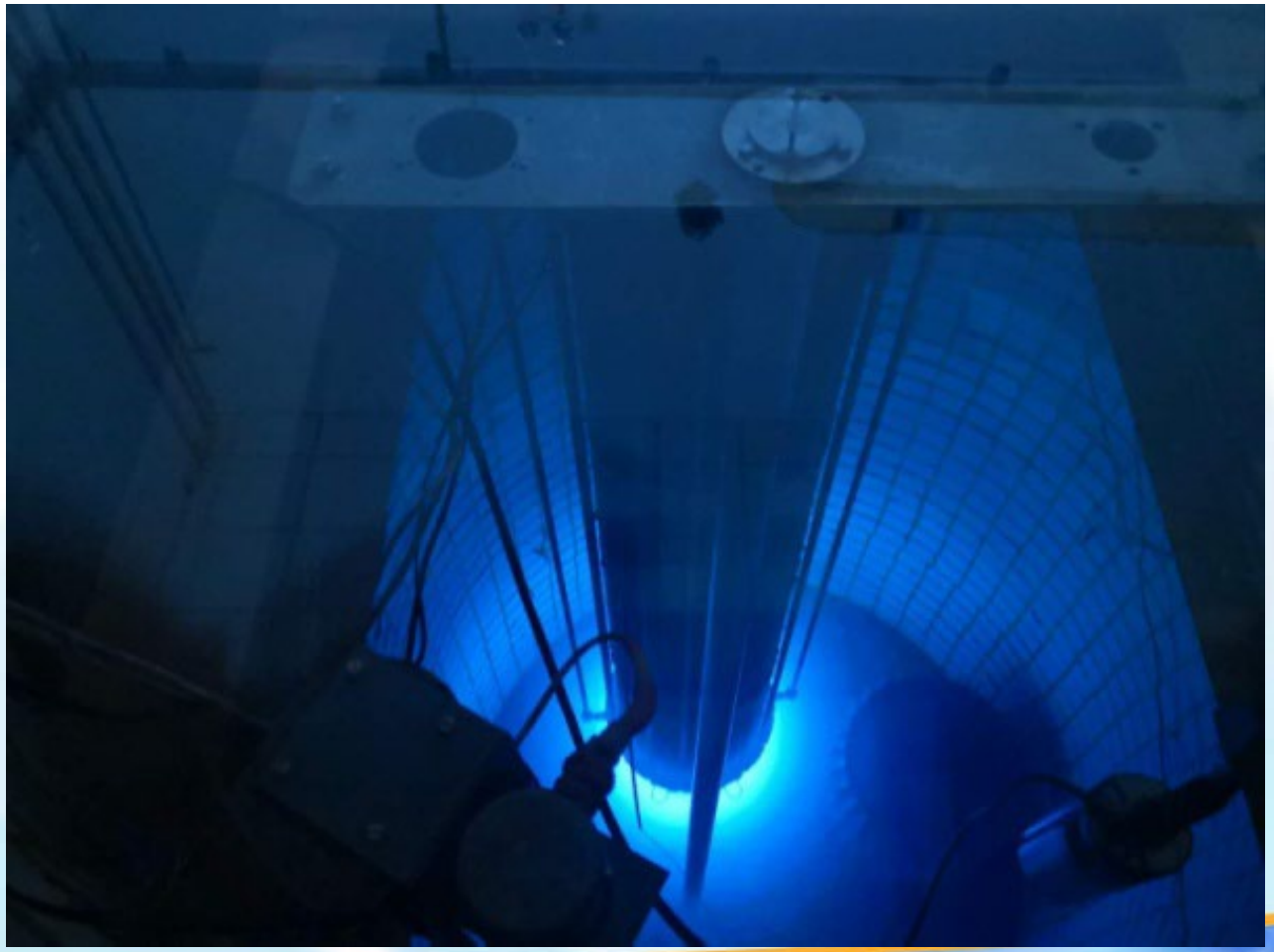
Spent fuel transportation



LEU fuel Loading

Commissioning

- Full Power Operating



HEU burnt fuel return

HEU burnt fuel return

HEU burnt fuel return

3.2 BNCT

BNCT

- Basic Principles

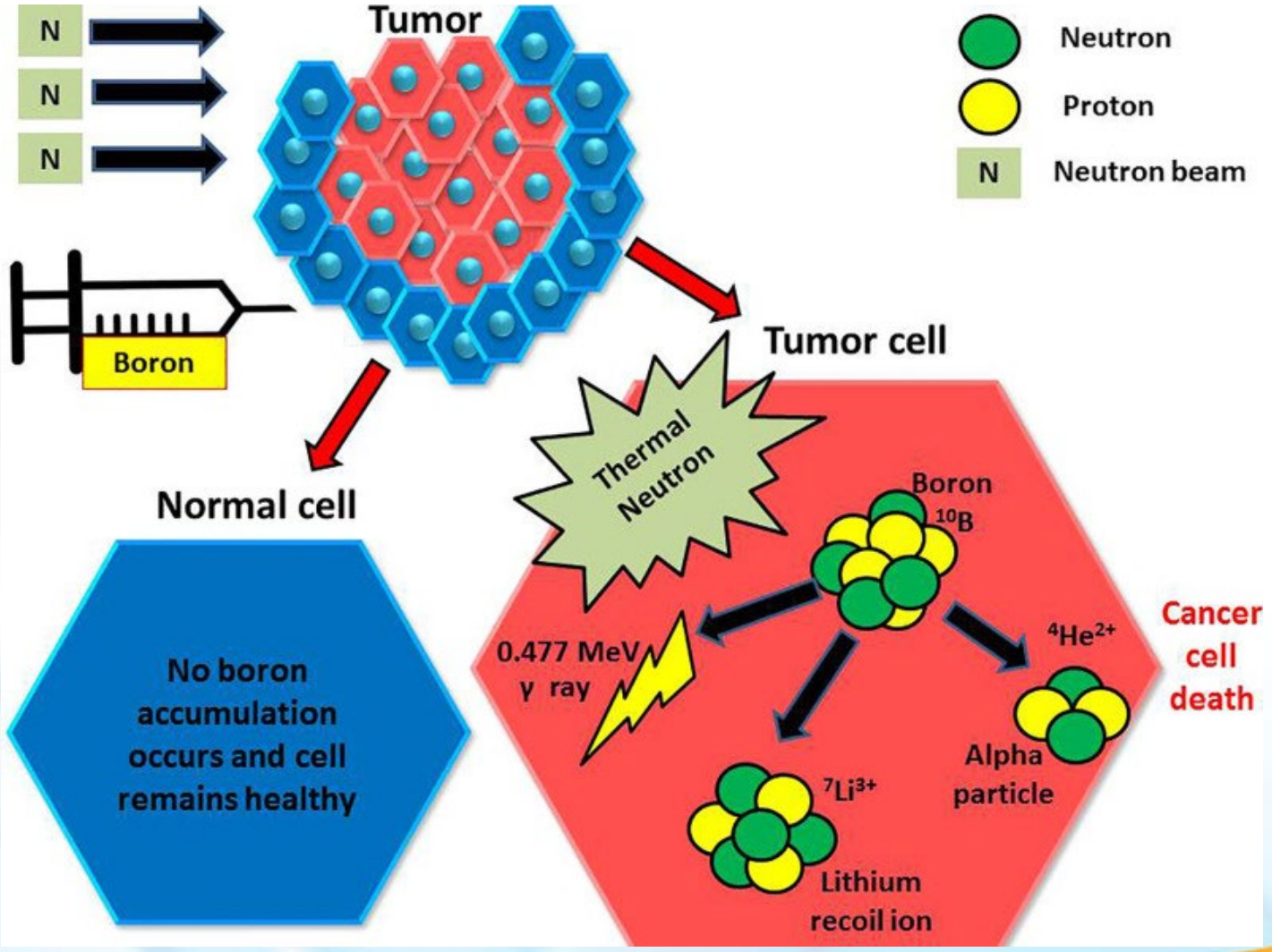
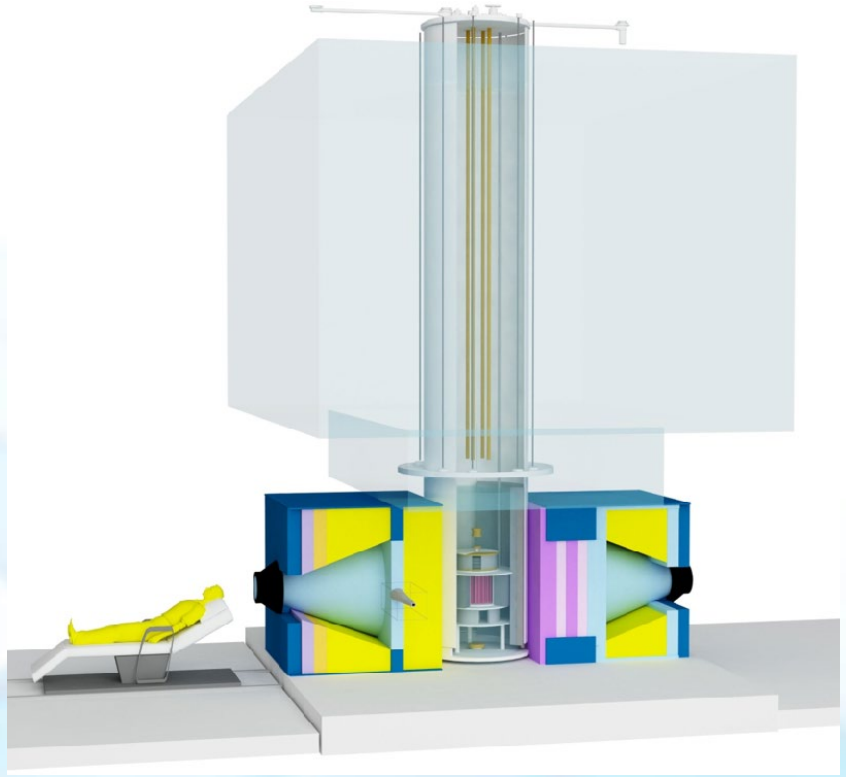


Fig from: Malouff, T. D. , et al. "Boron Neutron Capture Therapy: A Review of Clinical Applications." Frontiers in oncology 11:601820.

BNCT

- IHNI
  - In-Hospital Neutron Irradiator
  - Based on MNSR, power:30kW
  - Built in 2009
  - The 1st RR dedicated to BNCT
    - 1 thermal neutron beam, neutron flux over $1\times10^{9}n\cdot cm^{-2}s^{-1}$
    - 1 epithermal neutron beam, neutron flux near $5\times10^{8}n\cdot cm^{-2}s^{-1}$



BNCT

- Preclinical animal experiments have been conducted

BNCT

- Several clinical trials have been conducted for the treatment of melanoma.

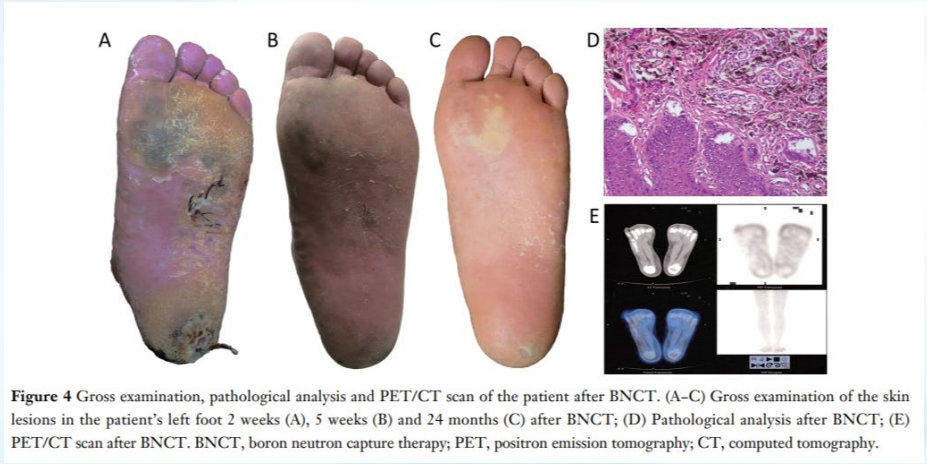


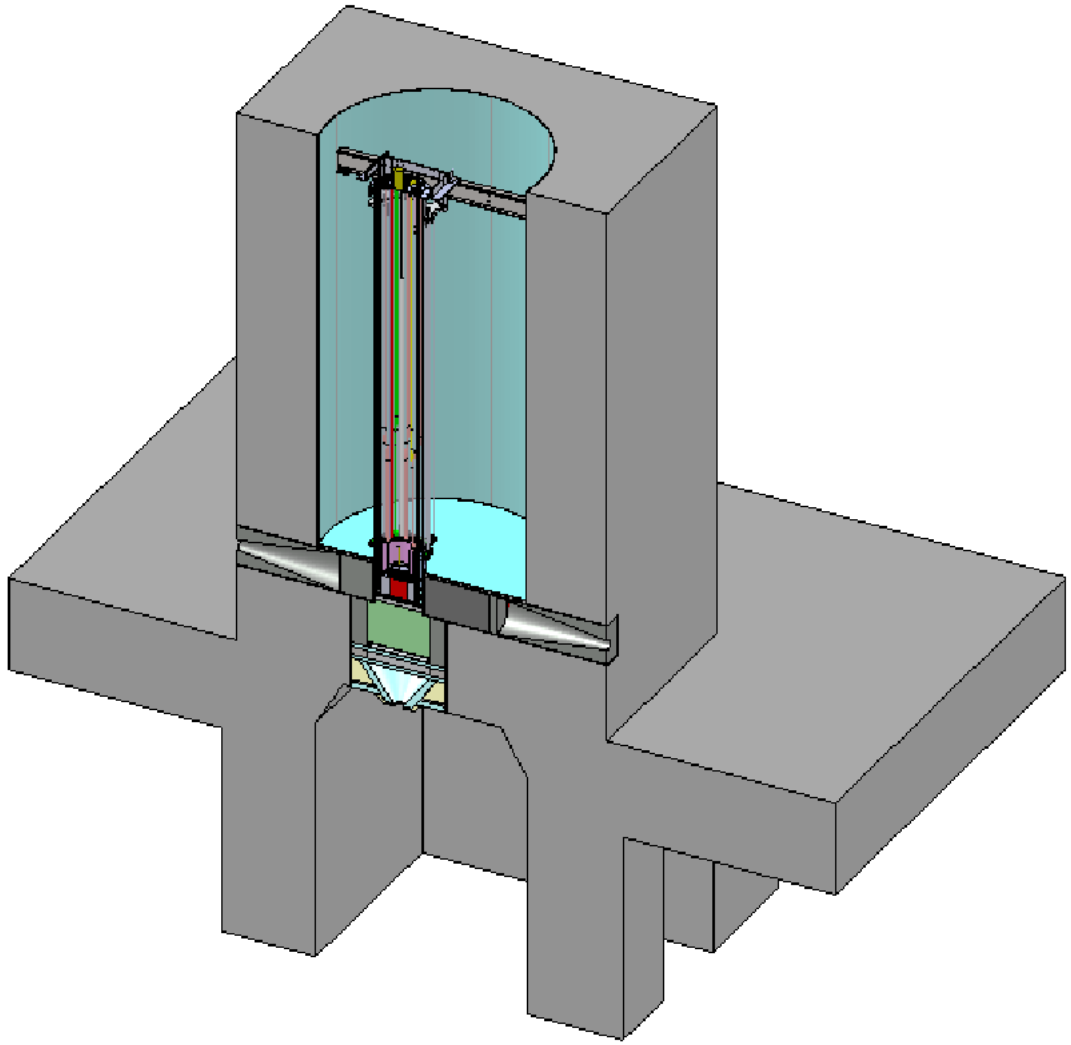
Figure 4 Gross examination, pathological analysis and PET/CT scan of the patient after BNCT. (A–C) Gross examination of the skin lesions in the patient's left foot 2 weeks (A), 5 weeks (B) and 24 months (C) after BNCT; (D) Pathological analysis after BNCT; (E) PET/CT scan after BNCT. BNCT, boron neutron capture therapy; PET, positron emission tomography; CT, computed tomography.

Figure 3 The patient was repositioned in the irradiation room and then received neutron irradiation in the thermal irradiation room of the IHNI. IHNI, in-hospital neutron irradiator.

Yong Z , Song Z , Zhou Y ,et al.Boron neutron capture therapy for malignant melanoma: first clinical case report in China[J].

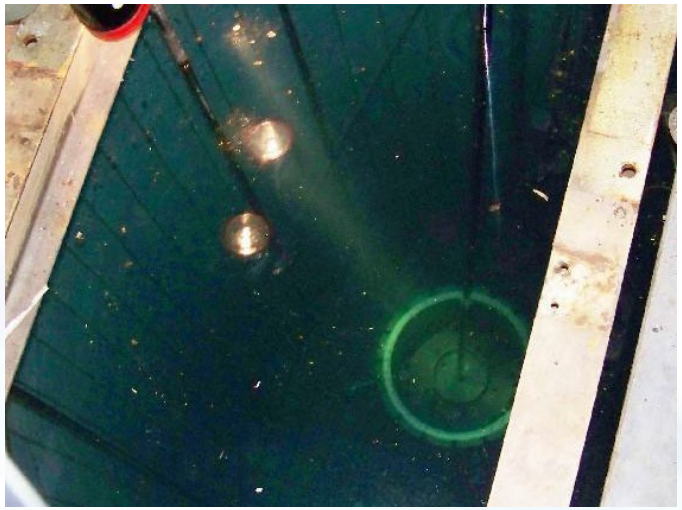
BNCT

- A new design of MNSR for BNCT is under construction in Thailand.
  - It will have 1 vertical neutron beam for BNCT and several horizonal beams for research.
  - Epithermal neutron flux at the beam exit over $1\times10^{9}n\cdot cm^{-2}s^{-1}$



3.3 Decommission and technical reserve

Decommission



Decommission

Part IV. RRs in CIAE

RESEARCH REACTORS IN CIAE

中核集团 CNNC 中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

Heavy Water Research Reactor(HWRR)

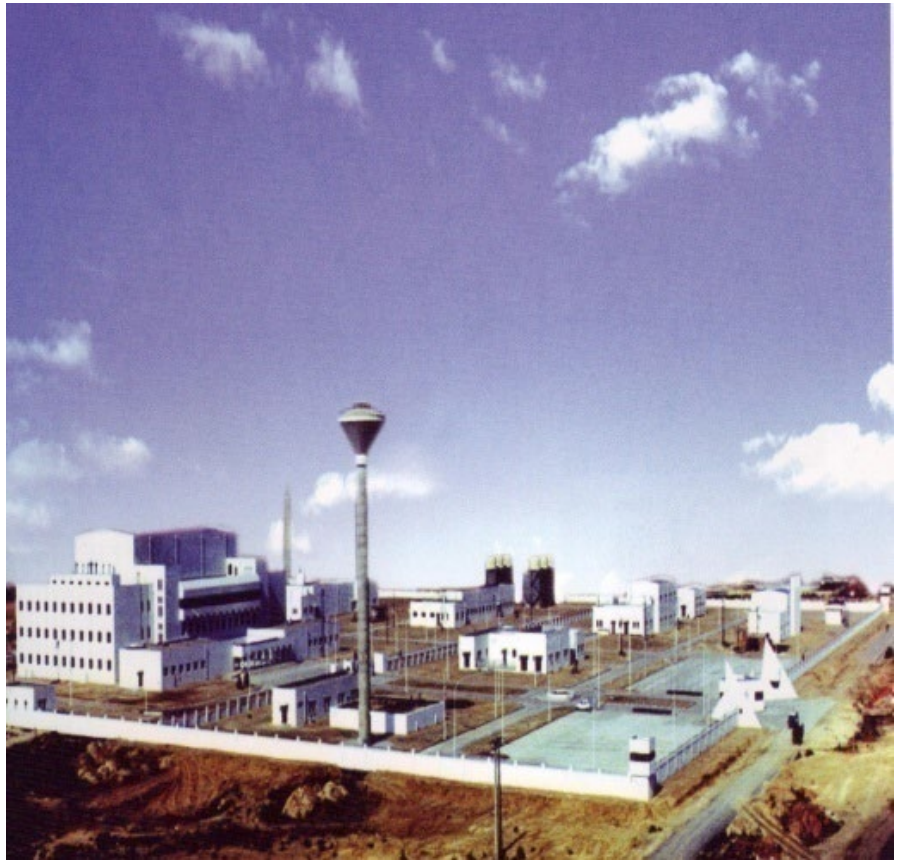
core type	water tank
power	10~15MW
coolant	D_2O
max thermal flux	$2.6\times10^{14}n/cm^2s^{-1}$
horizontal channel	7
vertical channel	33

- The HWRR was operated from 1958 to 2007, and made a great contribution to the nuclear industry development of China.
- Now, it has been shutdown and under decommissioning.

RESEARCH REACTORS IN CIAE

中核集团 CNNC 中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

Export of HWRR



Algeria Birine Nuclear Centre

- HWRR was exported to Algeria in the year of 1987;
- High Temperature High pressure experimental loop and Low Temperature Low pressure loop was built in the year of 1991;
- From 2015 to 2019, reactor was upgraded and became a modernized reactor;
- In the near future, more facilities will be built to meet the demand of radioisotope production.

——This project was hailed as "a model of south–south cooperation" by IAEA

RESEARCH REACTORS IN CIAE

中核集团 CNNC 中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

Swimming Pool Reactor(SPR)

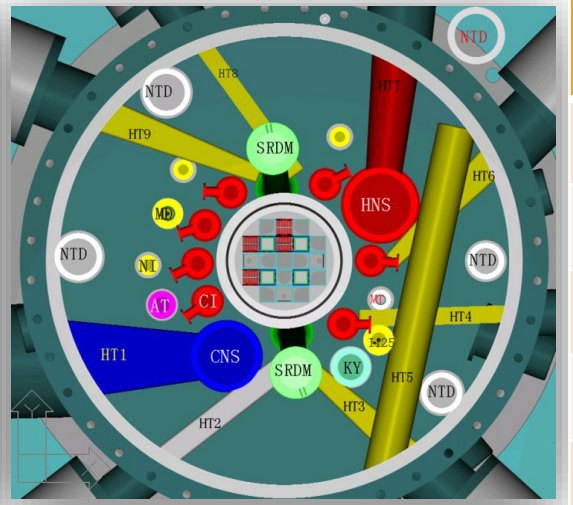
core type	pool tank
power	3.5MW
coolant	H_2O
max thermal flux	$5.2\times10^{13}n/cm^2s^{-1}$
horizontal channel	5
vertical channel	20

- It is the first reactor designed and constructed by China independently.
- It reached first criticality on 20 Dec 1964.
- Till now, it has been operated safely for 58 years

RESEARCH REACTORS IN CIAE

中国原子能科学研究院
CHINA INSTITUTE OF ATOMIC ENERGY
中核集团 CNNC

China Advanced Research Reactor(CARR)



core type	Pool— tank
power	20~60MW
coolant	H_2O
reflector	D_2O
max thermal flux	$2.5\sim8\times10^{14}n/cm^2s^{-1}$
horizontal channel	9
vertical channel	25

- CARR is multi-purposed and high-performance research reactor.
- It reached first criticality on 2010.
- its available thermal neutron flux is the highest in Asia.
- it can undertake almost all the reactor application requirements.

RESEARCH REACTORS IN CIAE

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China Experimental Fast Reactor(CEFR)

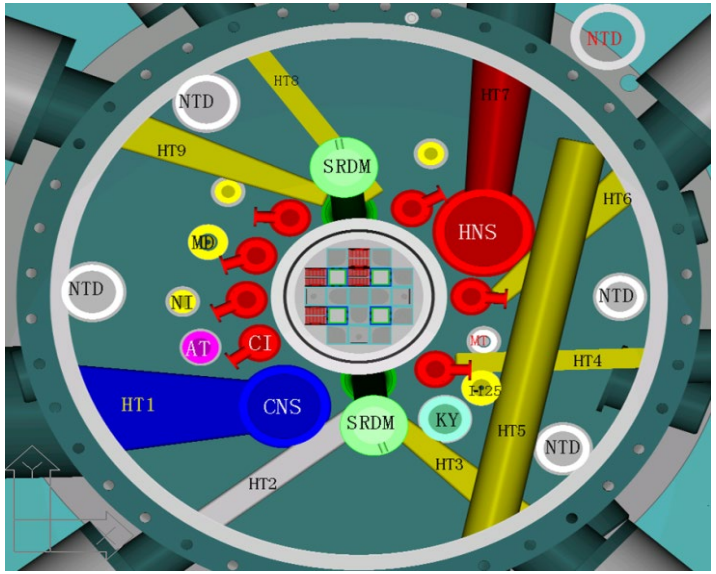
core type	Pool
thermal power	65MW
electric power	20MW
coolant	Liquid Na
fuel	UO_2

- CEFR is the prototype reactor for commercial fast reactor.
- It reached first criticality on 2010.
- a passive residual heat removal system was established for the first time.

APPLICATION OF RESEARCH REACTOR

中国原子能科学研究院
中核集团 CNNC CHINA INSTITUTE OF ATOMIC ENERGY

- Research reactors Use neutrons or γ-rays released by fission to do irradiation test research and radioactive isotopes production.
- Research reactors are the basis for establishing nuclear industry system.



APPLICATION OF RESEARCH REACTOR

中核集团 CNNC 中国原子能科学研究院 CHINA INSTITUTE OF ATOMIC ENERGY

Nuclear power technology R&D and technical support

- New type fuel R&D
- Material irradiation performance research
- Nuclear power personnel training

Neutron physics research

- Neutron scattering
- Neutron activation analysis
- Neutron radiography
- Etc.

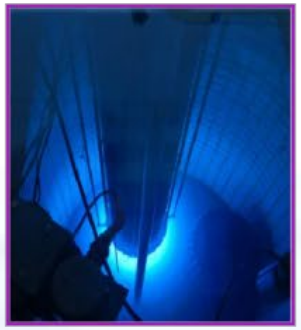
Technical reserve on RRs

RR life cycle

- Siting & Site Evaluation
- Design
- Construction

- Commission

- Operations



- Decommission

- Release

Thank You!