Introduction to Radiation Safety Works for CiADS Research Facility

Peng Luo

On behalf of the ADS Research Team

Institute of Modern Physics （IMP), CAS

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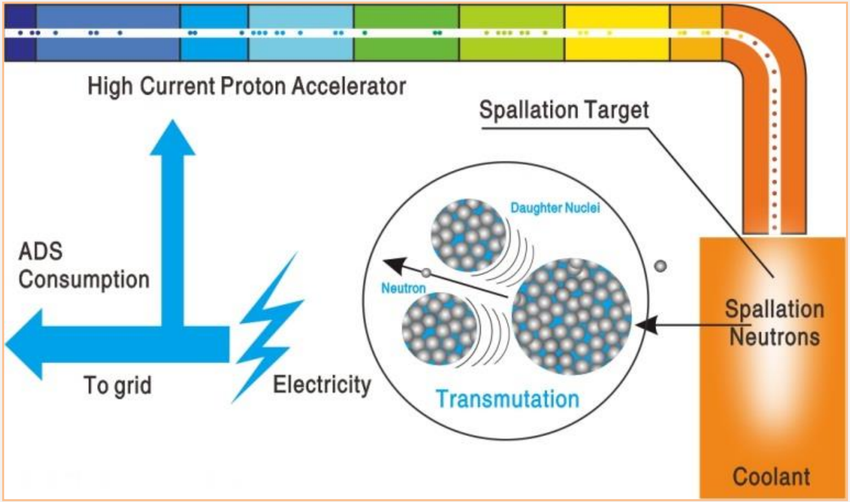
Outlines

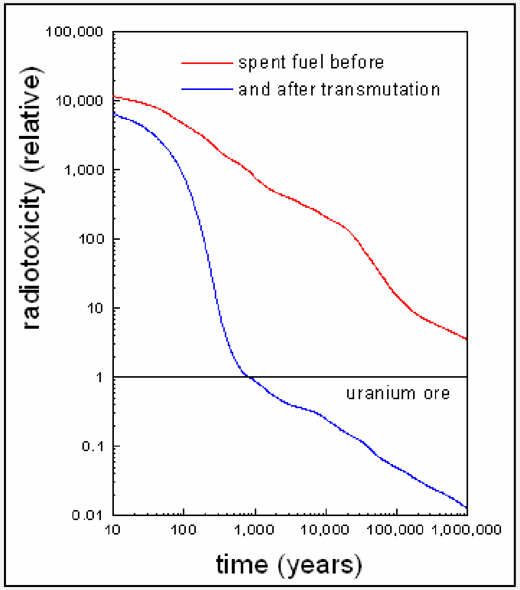
- Introduction to China ADS program
- Methodology for Radiation Safety Study
- Simulation Study and Results
- Questions for discussion

Accelerator Driven Systems (ADS)

- ADS was proposed for nuclear waste transmutation and nuclear power generation since late 1980s - early 1990’s;
- ADS consists of a high power proton accelerator, a spallation target, and a sub-critical core, which produces intensive, hard spallation neutrons by bombarding high energy protons on target to drive the sub-critical core;
- Minor actinides are burned by fission reaction with fast neutrons, long-lived fission products are removed by thermal neutron capture.

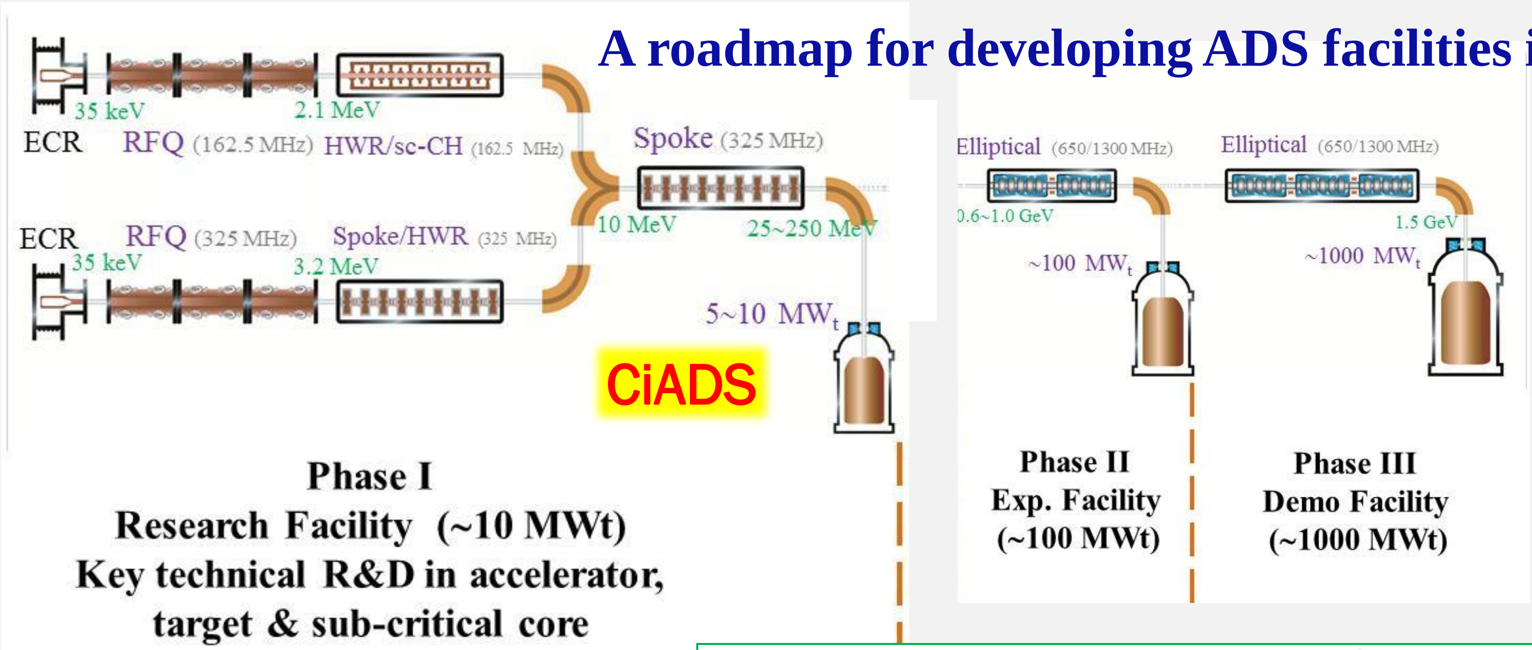


Schematic diagram of ADS

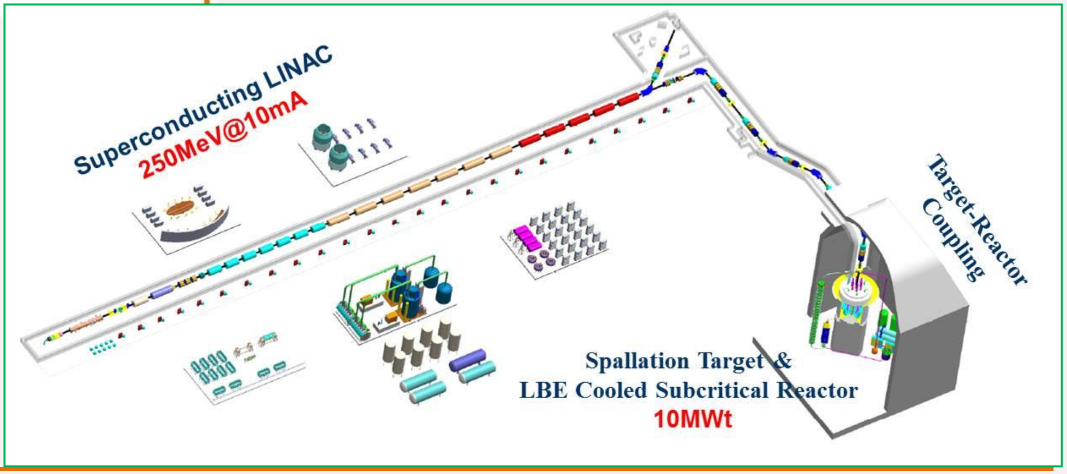


China ADS Program

A roadmap for developing ADS facilities in China



- 2011-2016: ¥1.7 Billion from CAS for key technical R&Ds ;
- Chinese Initiative ADS (CiADS) are designed, and approved by the National Development and Reform Commission with ¥1. 8 Billion.



Radiation Safety Issues for CiADS

- Residue production and distribution in spallation target;
- Radiation exposure caused by residues;
- Neutron activation of spallation target tube, beam tube, and other components;
- Radiation exposure caused by neutron activations;
- Target materials adhering to tubes and its safety problems;
- Environmental impacts caused by CiADS;
- Shielding considerations for the system

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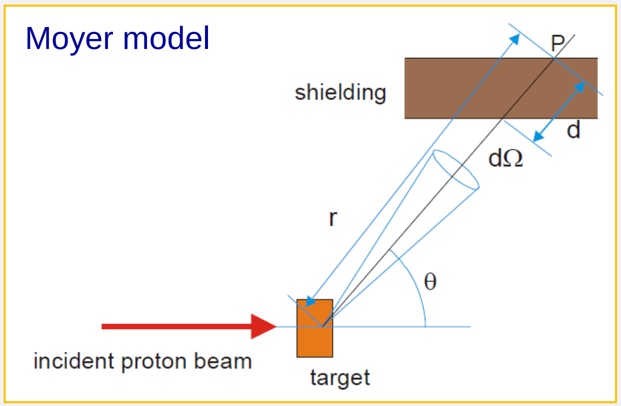
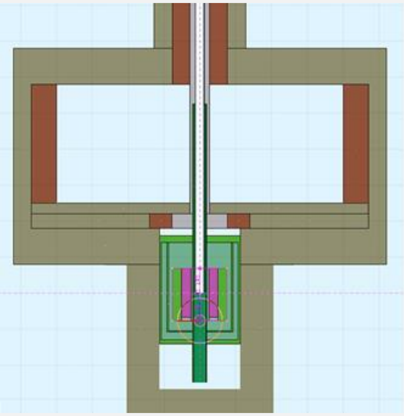
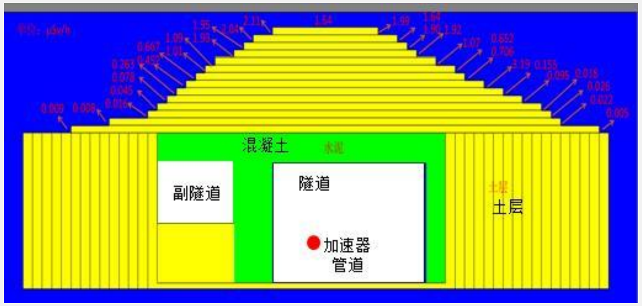
Methodology

Calculation based on Moyer model + Monte Carlo Simulation

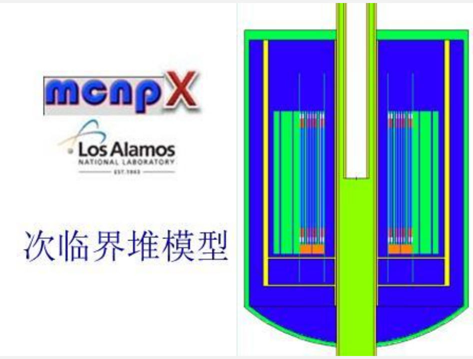




Target-reactor coupling

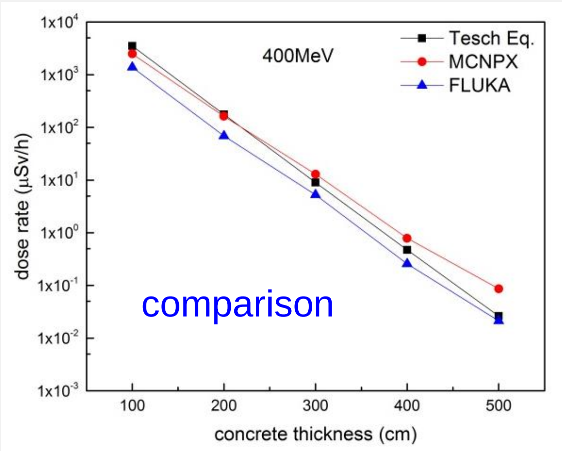


Accelerator tunnel



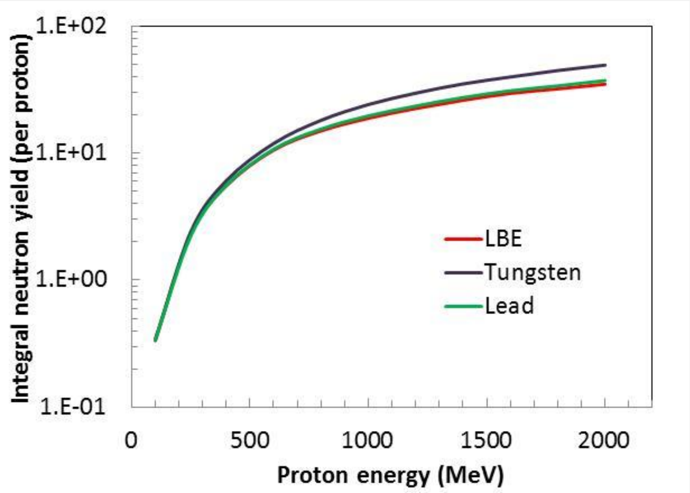
Sub-critical Reactor

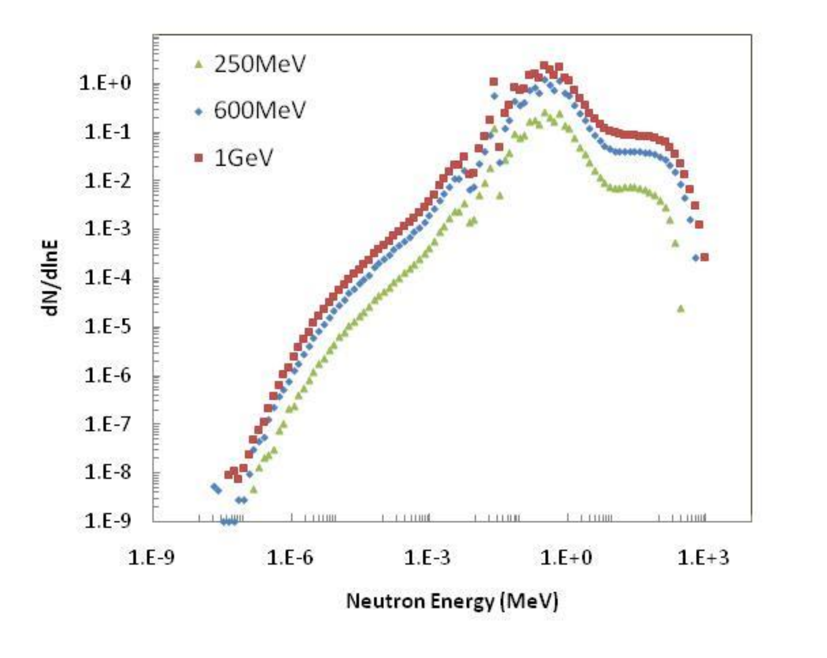
Spallation target

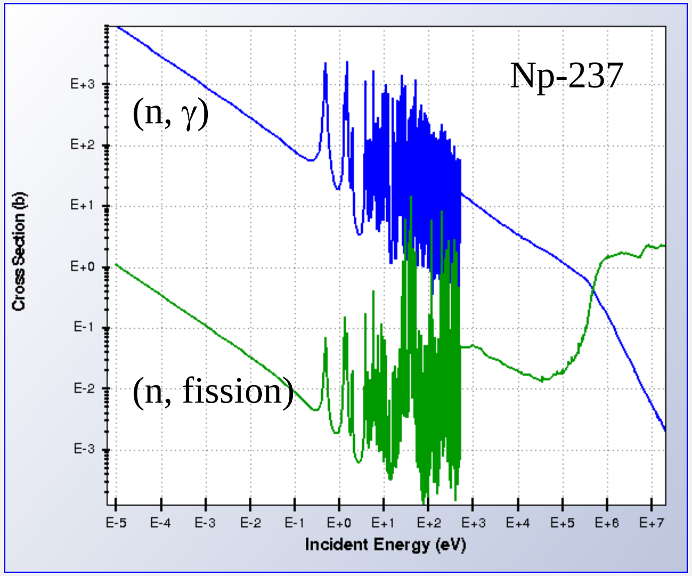


Neutron Yields

- Neutron yield for different targets vs. proton energy;
- With higher proton energy, the higher neutron yield for tungsten target;
- More than 80% neutrons with E_n>100 keV.







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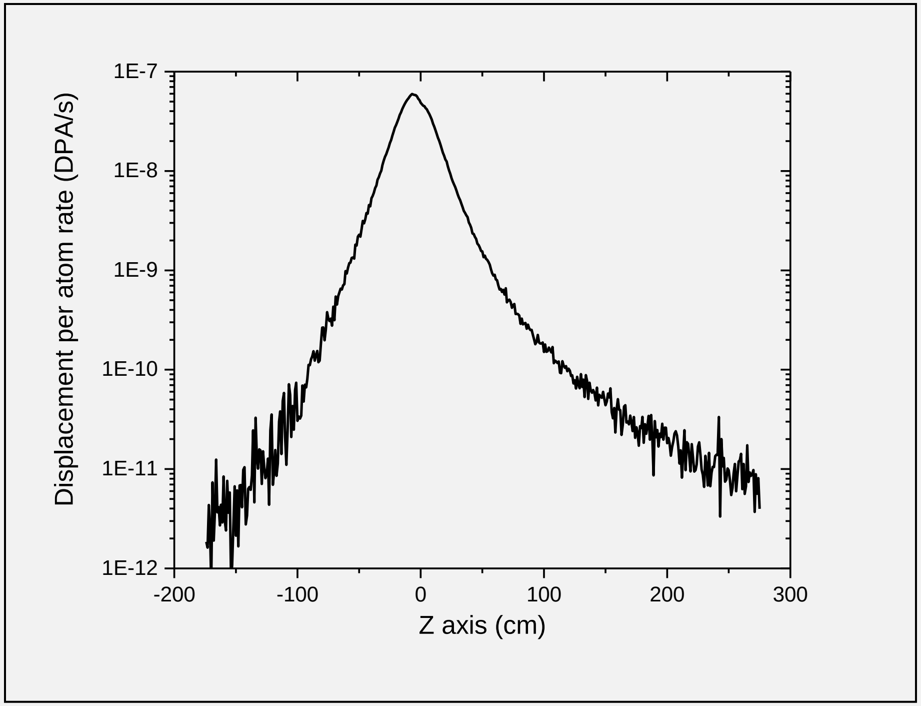
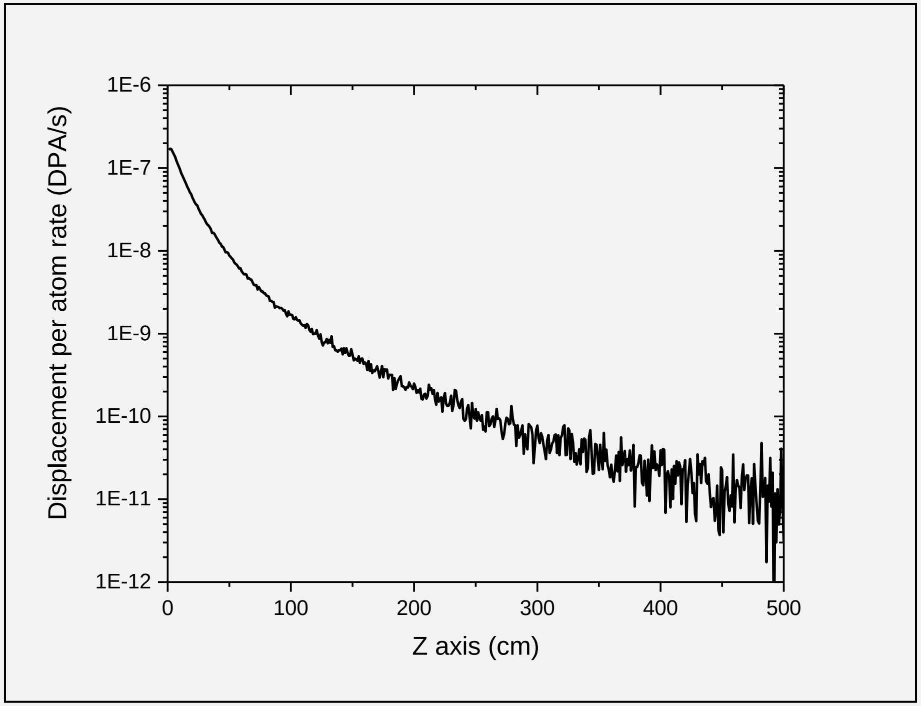
Radiation Damage in Beam/Target Tube

- Radiation damage in materials causes deterioration of material properties and limits its lifetime in nuclear facilities;
- The designed operation time is 3 months/year, and totally ～3years in 10 year lifetime;
- The maximum radiation damage to target tube is to be 0.5DPA/90 days, and 1.3DPA/90 days for beam tube.



Radiation damage in target tube



Radiation damage in beam tube

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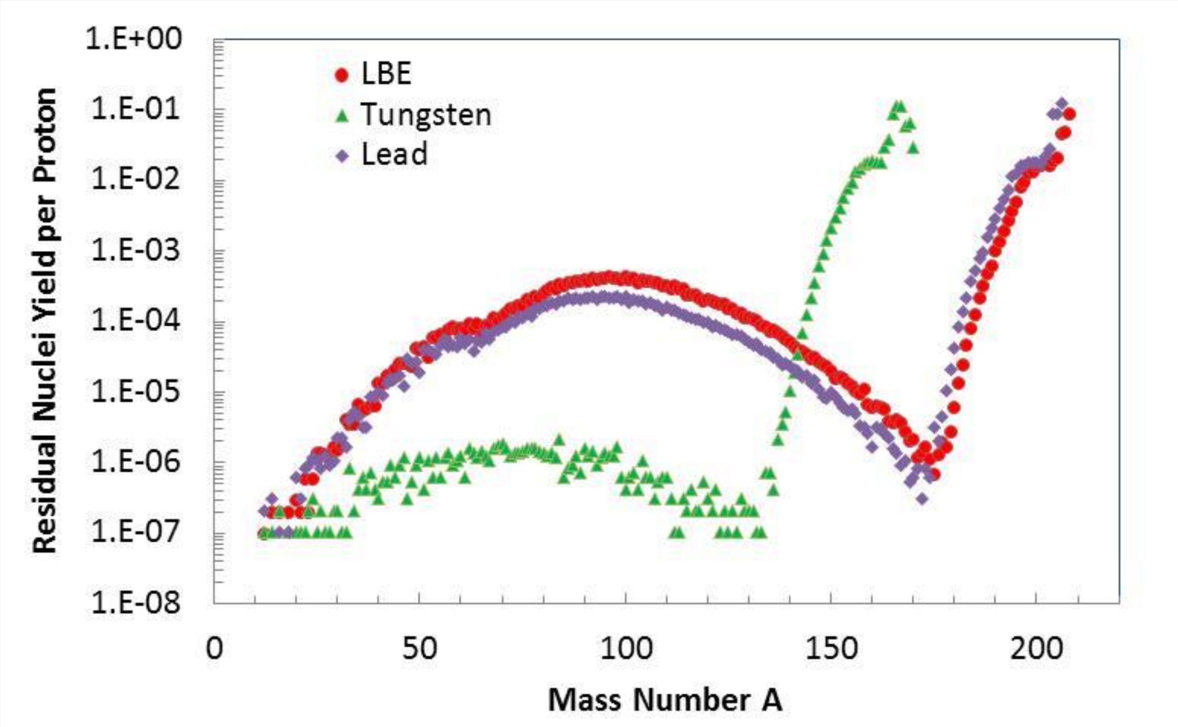
Residual Yield Distribution

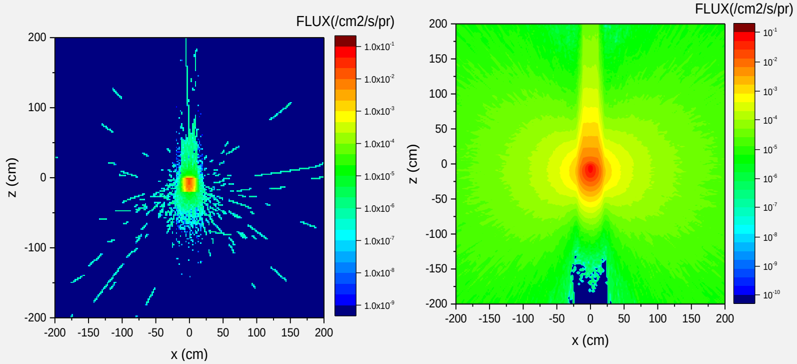
- Residual products spread over two major regions;
- Residues produced in tungsten target are 2-3 orders lower than those for lead and LBE targets；
- Most of residual products are short-lived.



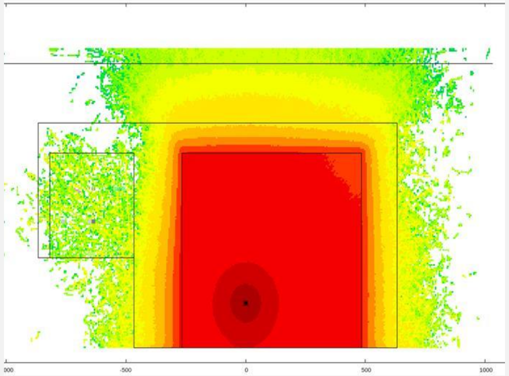
Statistics of Residues' Half-lives

$T_{1/2}$	Number of Nuclides
< 1 s	36
1-60 s	82
1-5 min.	61
5-10 min.	27
10-30 min.	43
30-60 min.	23
1-24 hr	94
1-30 d	61
30-365 d	36
1-5 yr	9
5-30 yr	3
30-100 yr	1
>100 yr	19
stable	147
total	642

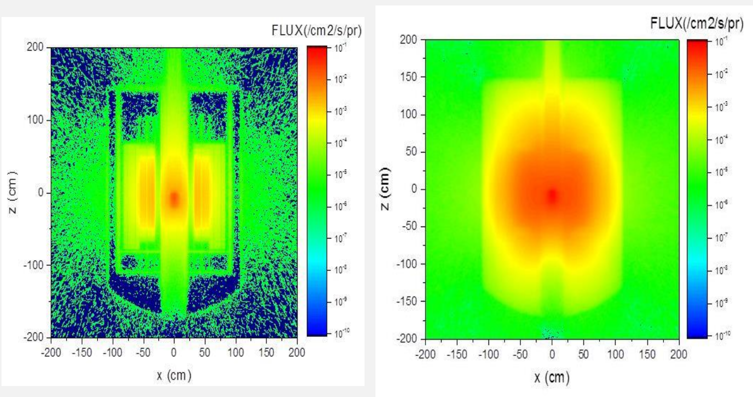
Radiation Distribution



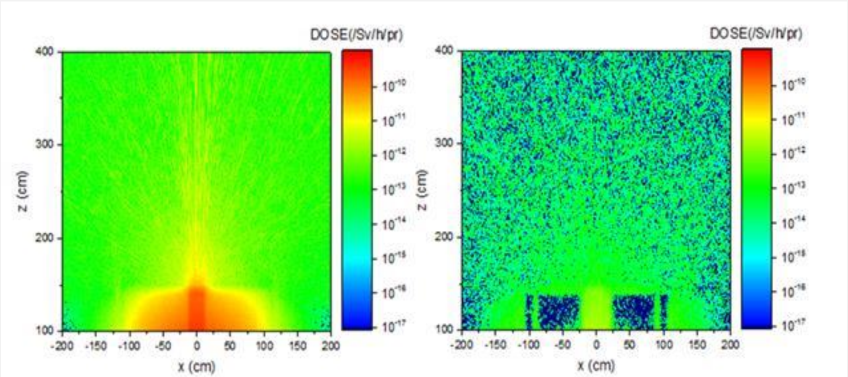
Distributions in target for proton and neutron



Radiation distribution in accelerator tunnel



Distributions in reactor for photon and neutron



Radiation distributions at the top of the reactor

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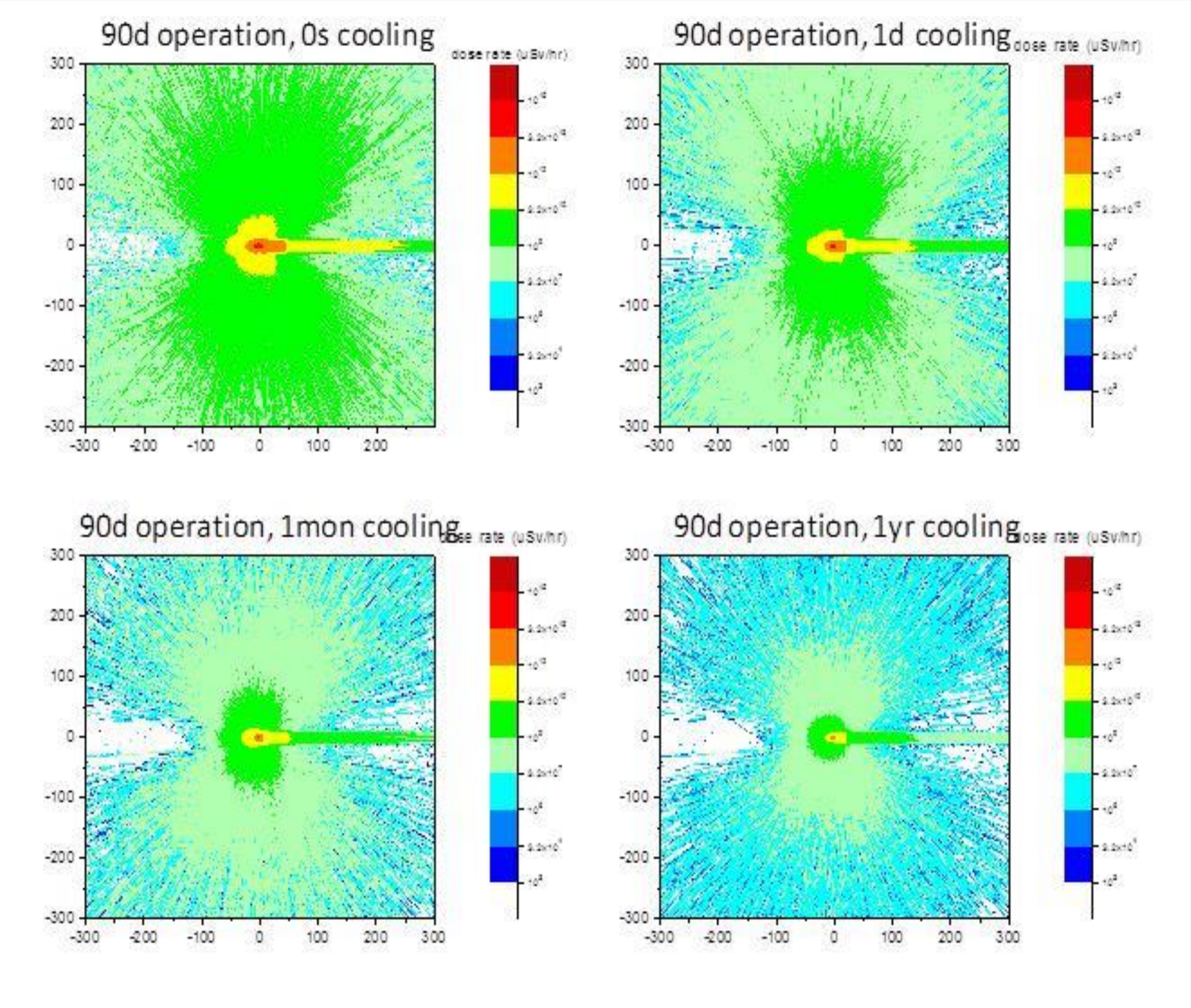
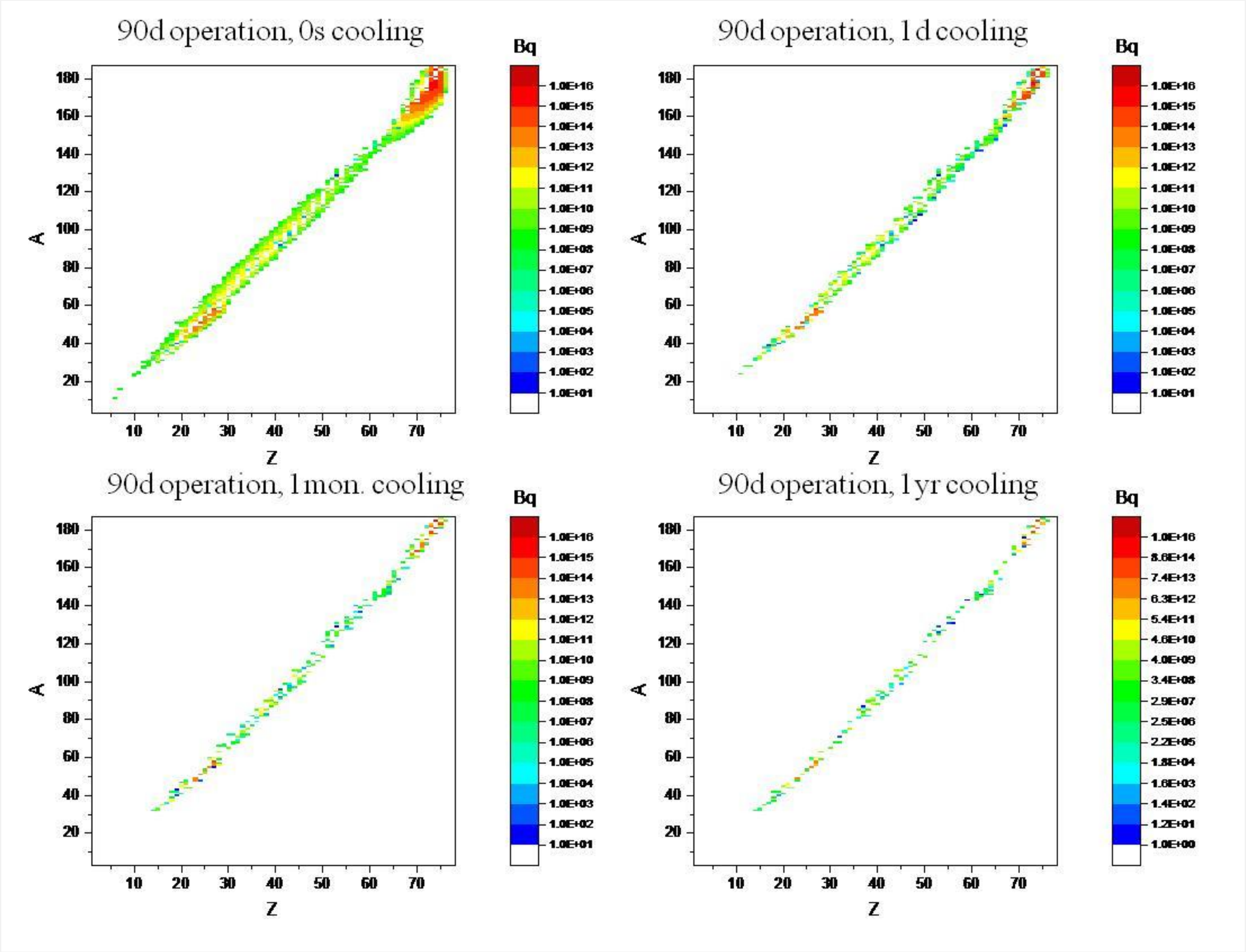
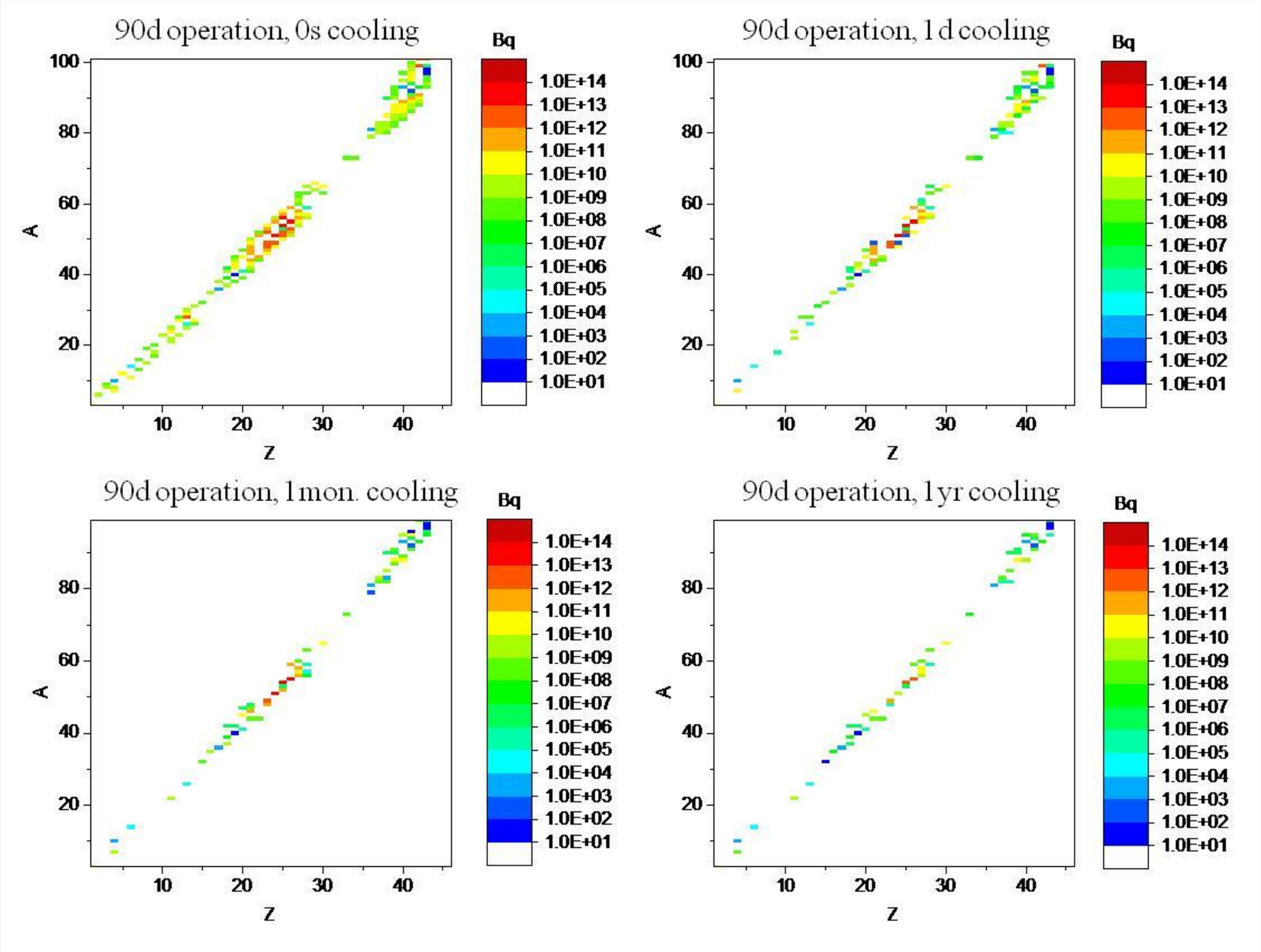
Radiation Dose around Target System



Residual Activity in Target



Induced Activity in Target Tube



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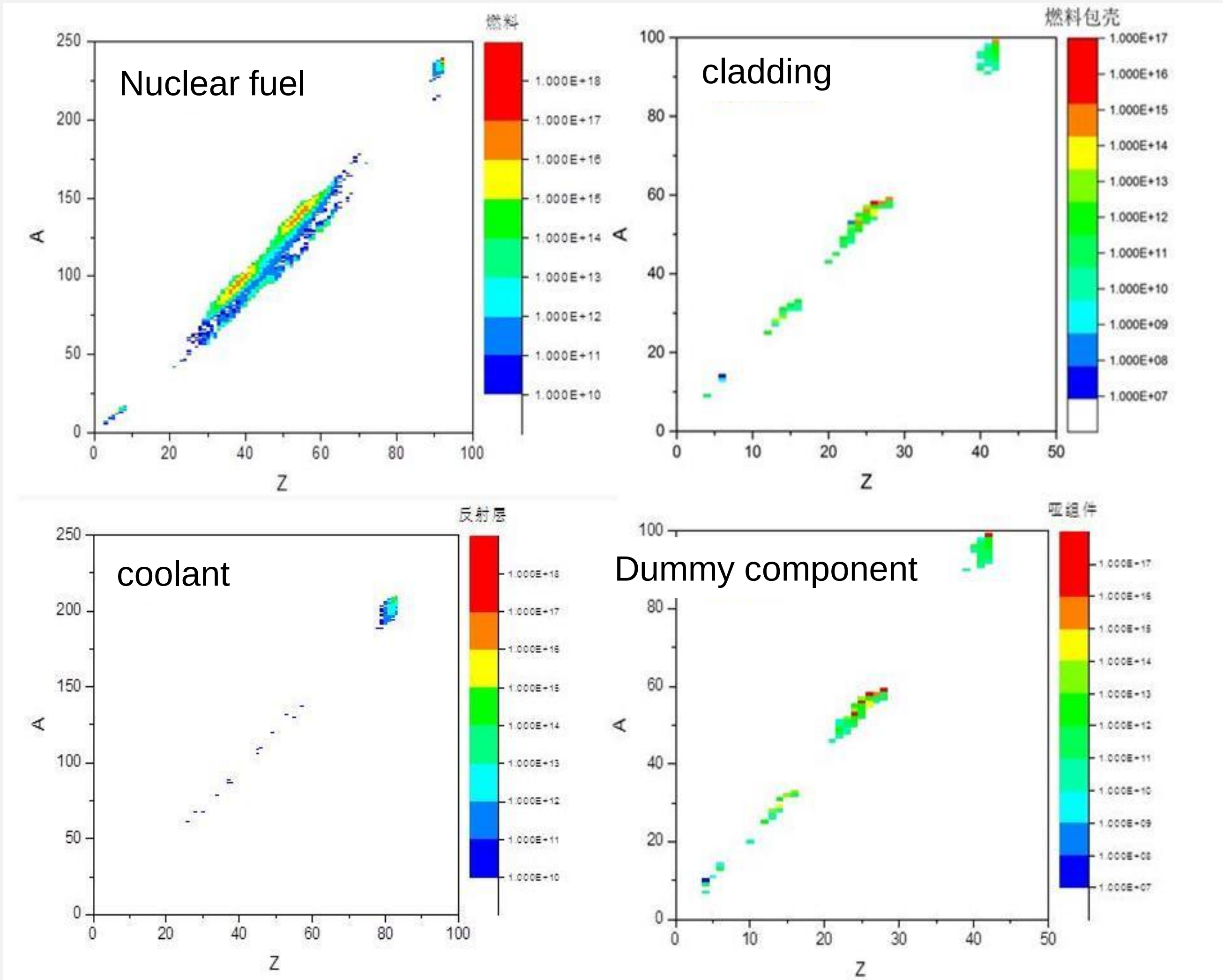
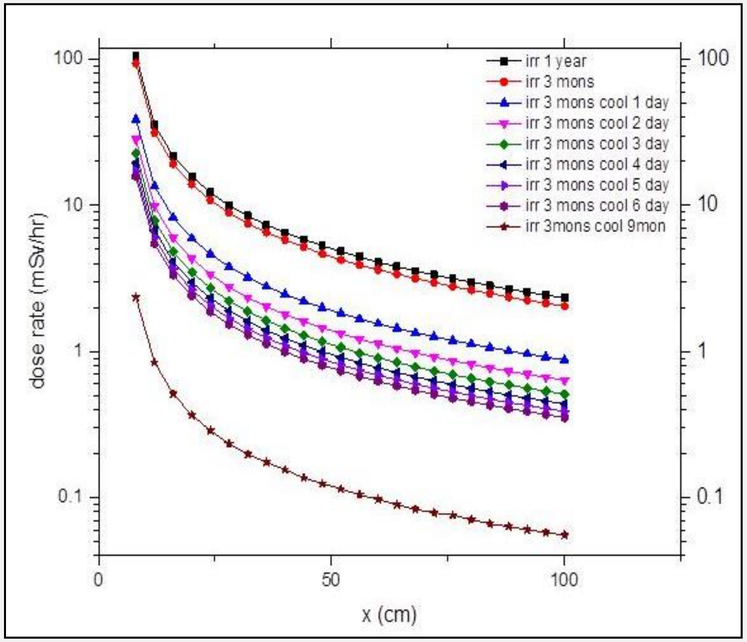
Induced Activity in Reactor



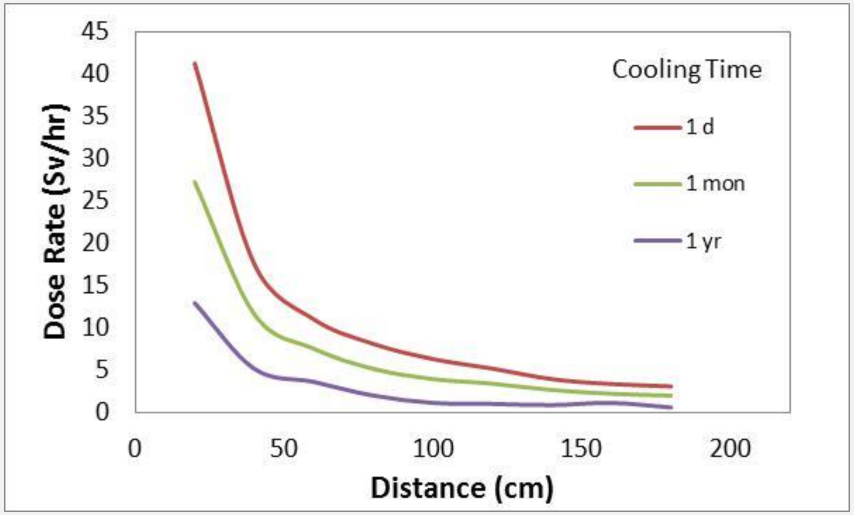
Radiation Dose from Target System

- The radiation dose rate from residual products and induced radionuclides could be hundreds Sv/hr;
- After one year cooling, the dose rate could be reduced more than two orders;
- After long time operation, target tube and other components become highly radioactive and bring safety problems for maintenance staff.

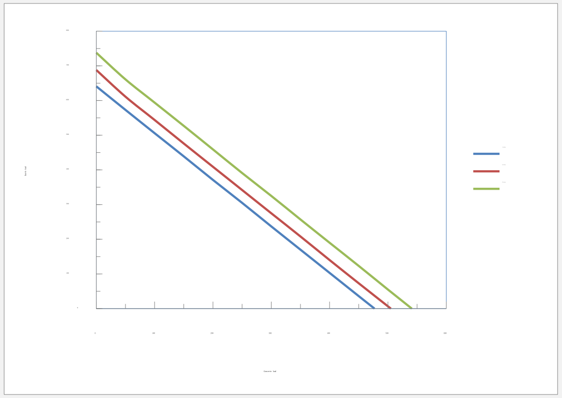
Radiation dose from the target system



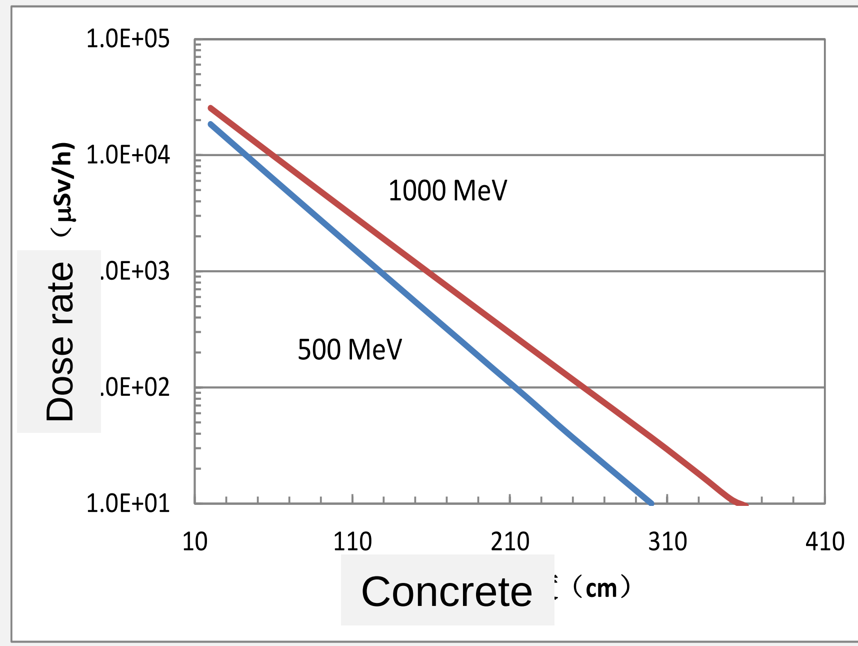
Radiation dose from irradiated target tube



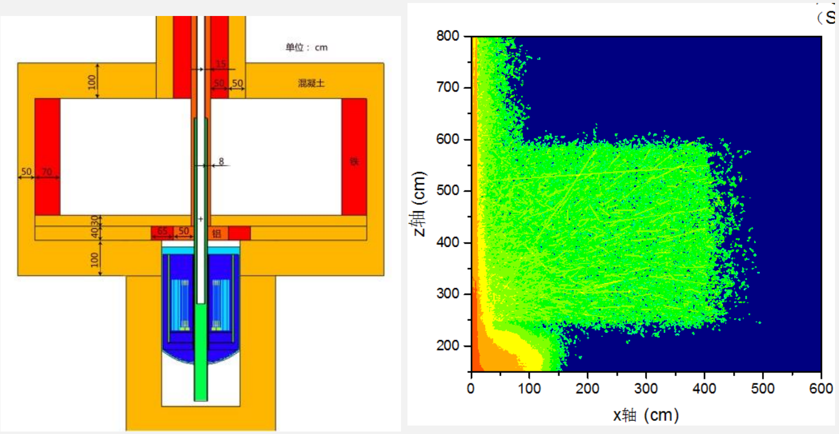
Shielding calculation



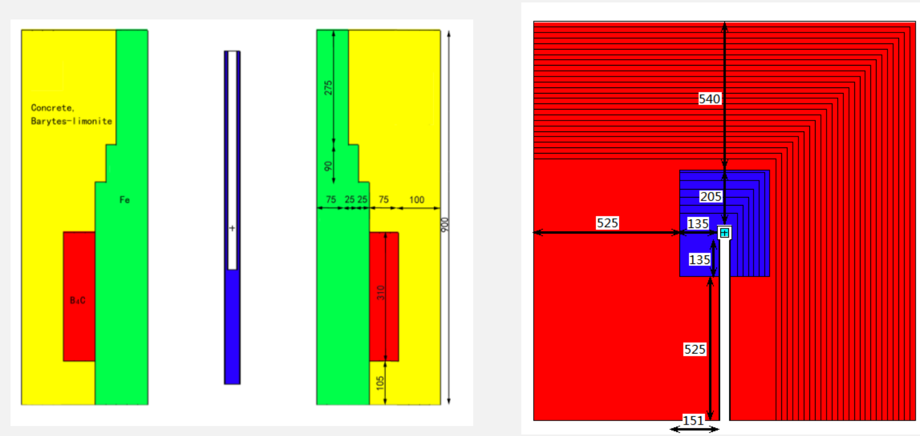
Shielding design for accelerator tunnel



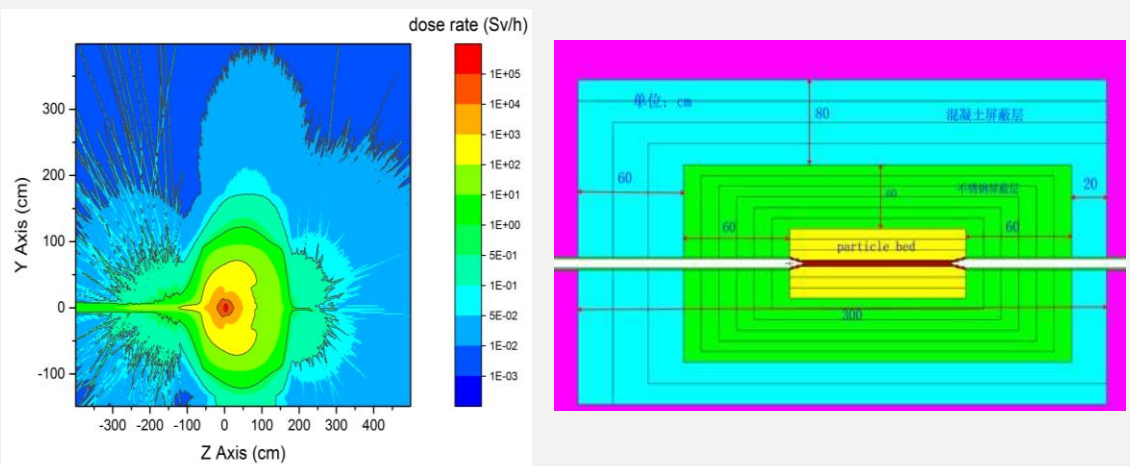
Shielding calculation



Shielding design for reactor



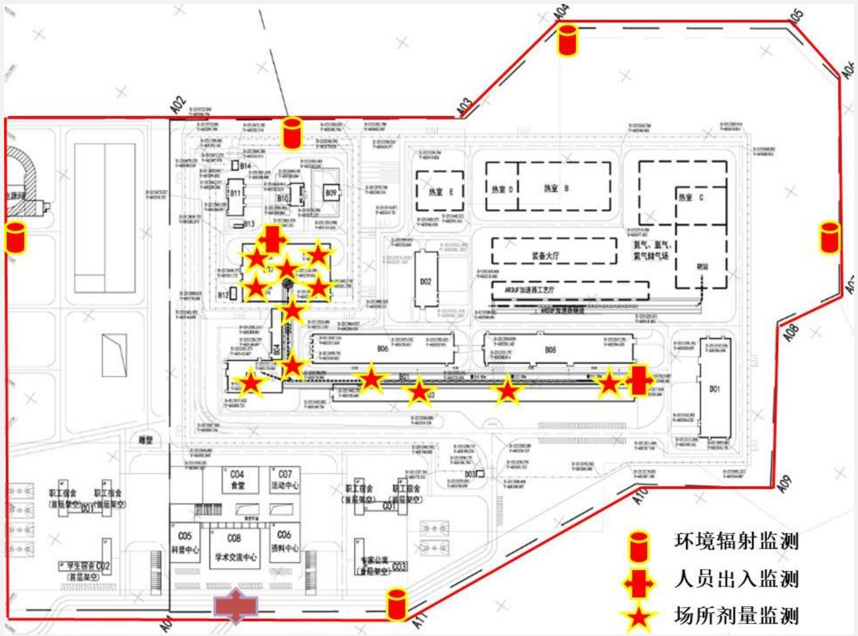
Shielding design for experimental terminal



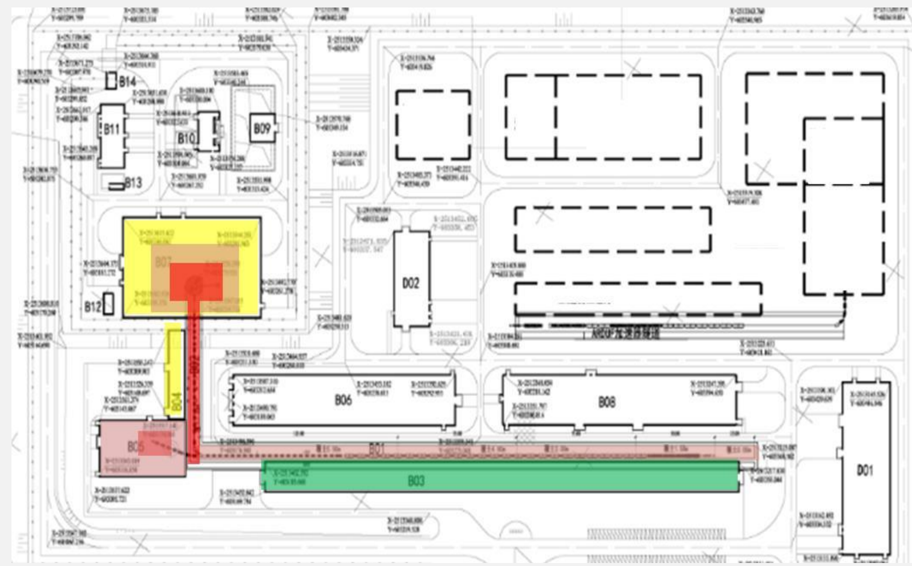
Shielding design for collimators

Design for radiation monitoring and zooning

Layout of radiation monitoring



Radiation zooning areas



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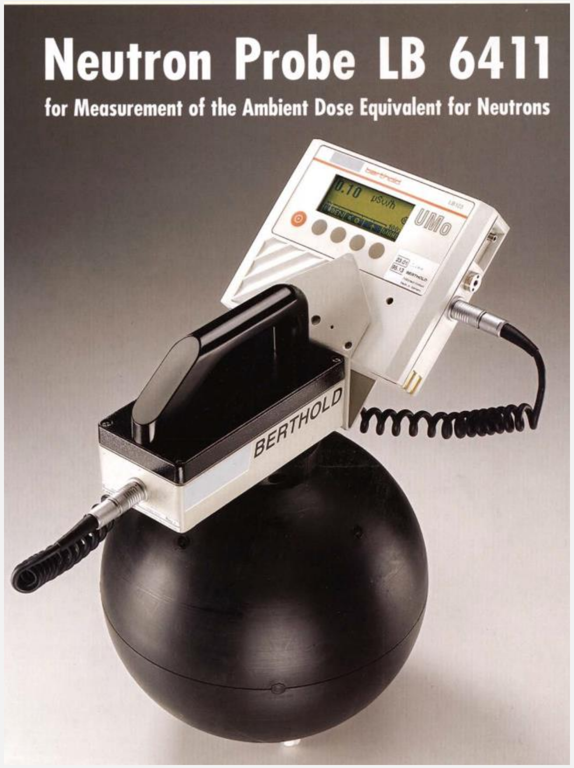
Instrumentation for radiation protection

Big part of the instruments for radiation safety would be imported;
Some of them will come from domestic manufacturers.

FHT 762

FHT 192

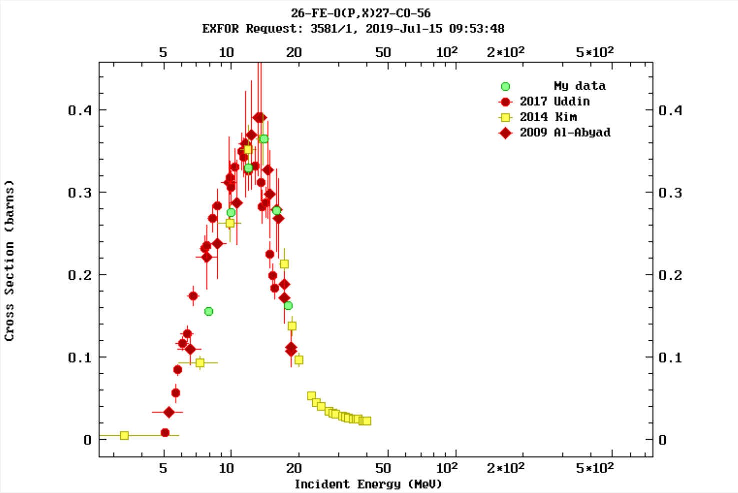
FHT 6020

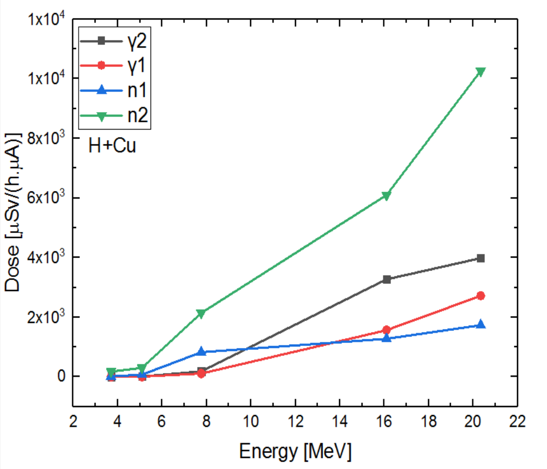


Experiments at 25MeV Demo Accelerator

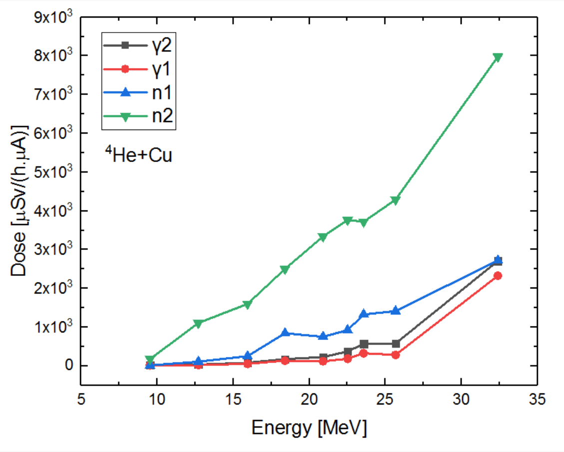
Experiment Settings

Residue Analysis





Response of instruments for radiation dose monitoring



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Questions for discussion

- Software and methods for radiation safety analyses and shielding design;
- Remote handling systems for radiation safety;
- Considerations for the design of radioactive waste management;
- Radiation measurement and monitoring systems for high dose areas;
- 1w/m beam loss for shielding design is more conservative?
- The effective method to calculate the decay of induced nuclides over the time;
- Experiments at ESS?

  - On-site study of radiation safety works?
  - Remote handling system design for management of radioactive materials.

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Thank you!