# Improvement of dynamics calculation code DSE for Accelerator Driven System

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# Table of contents

# I. Introduction

- **Development of Accelerator Driven System (ADS)**
  - An ADS has been developed to transmute high level waste which includes such as MA (Minor Actinide) and LLFP (Long-Lived Fission Products)
  - The ADS has following characters;
    - High transmutation efficiency than Critical reactor
    - High inherent safety and flexibility of core loading on designing etc.

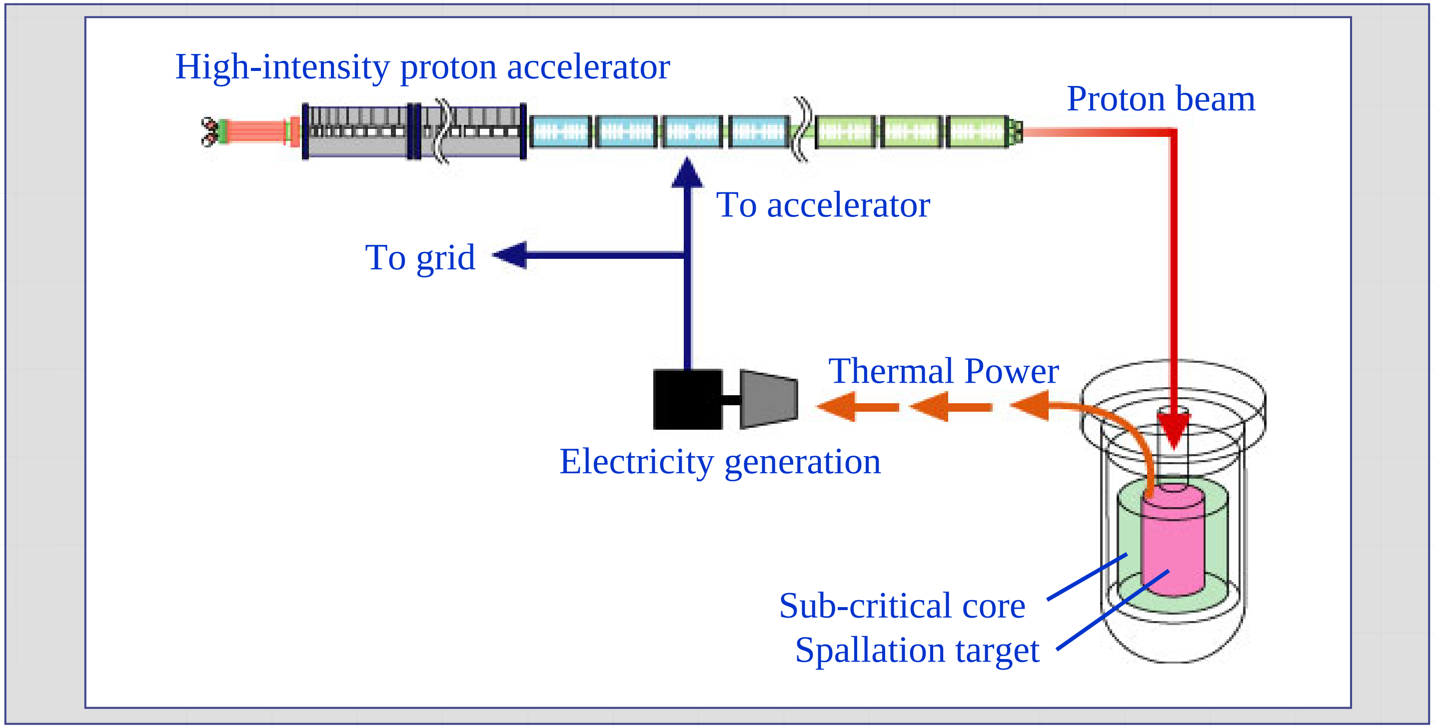



Fig. Concept of Accelerator Drive System

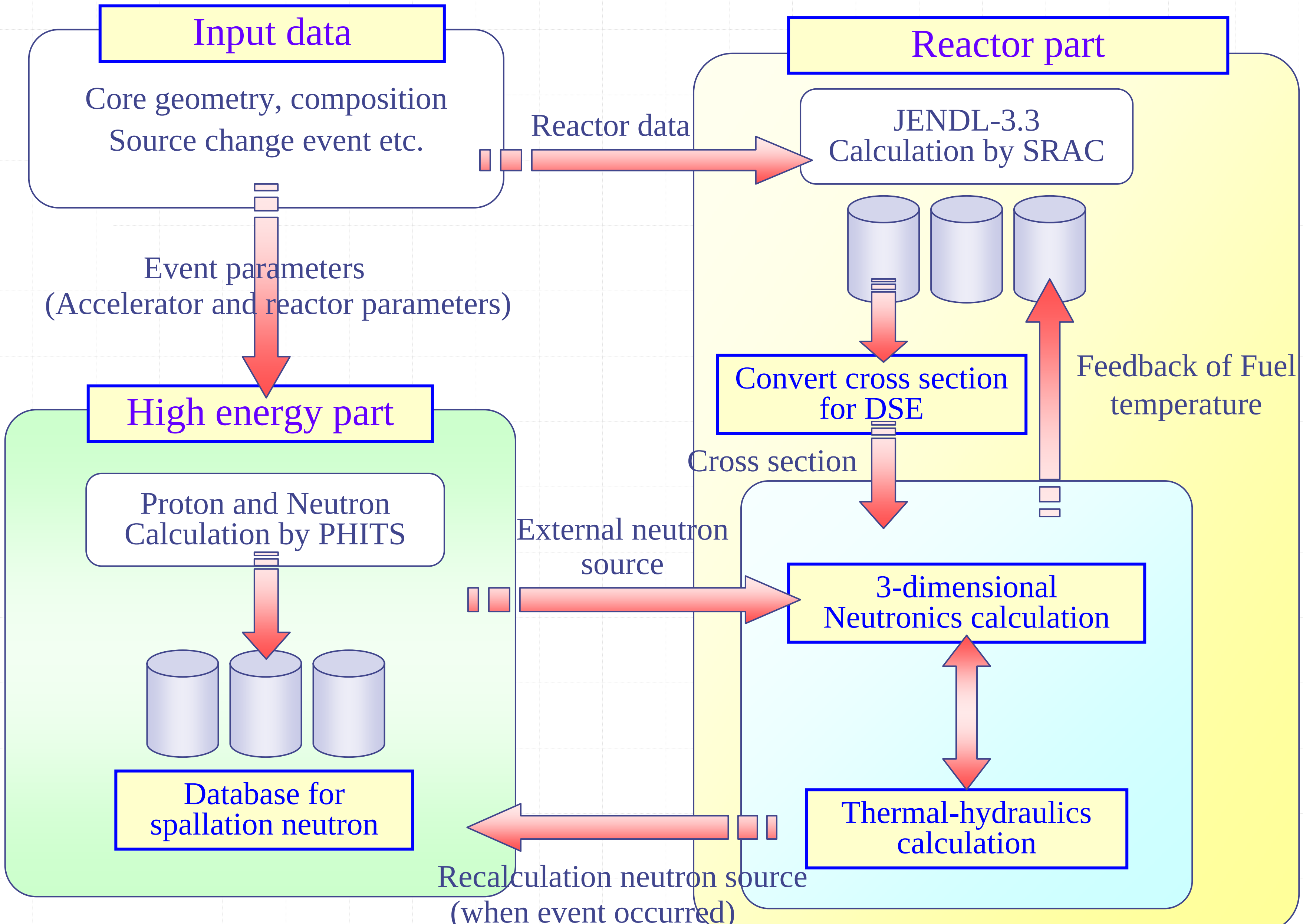
# II. DSE code system

- To study ADS dynamics, DSE code system has been developed

**DSE (**Dynamics calculation code system for Sub-critical system for External neutron source**)**

- DSE can treat both changes of
  - the accelerator parameters
    - (beam intensity, energy, diameter, injection position etc.) and
  - the reactor parameters
    - (coolant flow, reactor power, temperature, density etc.)
- This code can calculate both static and dynamics calculations for neutronics and thermal-hydraulics
- DSE calculates
  - the neutron flux, the adjoint flux, the dynamics parameter, the external neutron source and
  - the thermal power, the coolant temperature and the fuel temperature etc.

# Concept of DSE code system



# DSE code system

- DSE has three function for neutronics calculation
  - DSE-C : Diffusion code (CITATION)
    - Low change of neutron flux events (startup, shutdown and restart etc.)
  - DSE-T : Transport code (THREEDANT)
    - wide range dynamics events
  - DSE-M : Monte Carlo code
    - reference calculation with high accuracy

Development of DSE-M and its application

- DSE has been verified for
  - The static neutronics calculation by comparing with other codes
  - The dynamic neutronics calculation by comparing with theoretical value and other codes
  - The thermal-hydraulics calculation by comparing with the benchmark problem

# Development of DSE-M

- DSE-M has adopted the GMVP code
    - General Purpose Monte Carlo Code for Neutron and Photon Transport Calculations based on Multigroup Methods developed by JAEA
  - DSE-M can solve
    - the exact treatments of neutron transport, angular dependence and geometry description
    - the adjoint calculation function, the calculation of the dynamics parameters
  - The effect of the calculation error by the Monte Carlo calculation is examined
    - In the static calculation, the maximum error is about 1.4% in neutron flux
    - The error of dynamics calculation is about 1.0% in core power (if the history is enough)
    - The calculation error of the Monte Carlo to the dynamics calculation is a little
  - DSE-M has a problem for calculation time
    - The static calculation of 5 million histories spends about 20 hours
    - The dynamics case of 40sec event spends about 3 days
- We consider that DSE-M is effective for the reference calculation

# III. Application of DSE-M

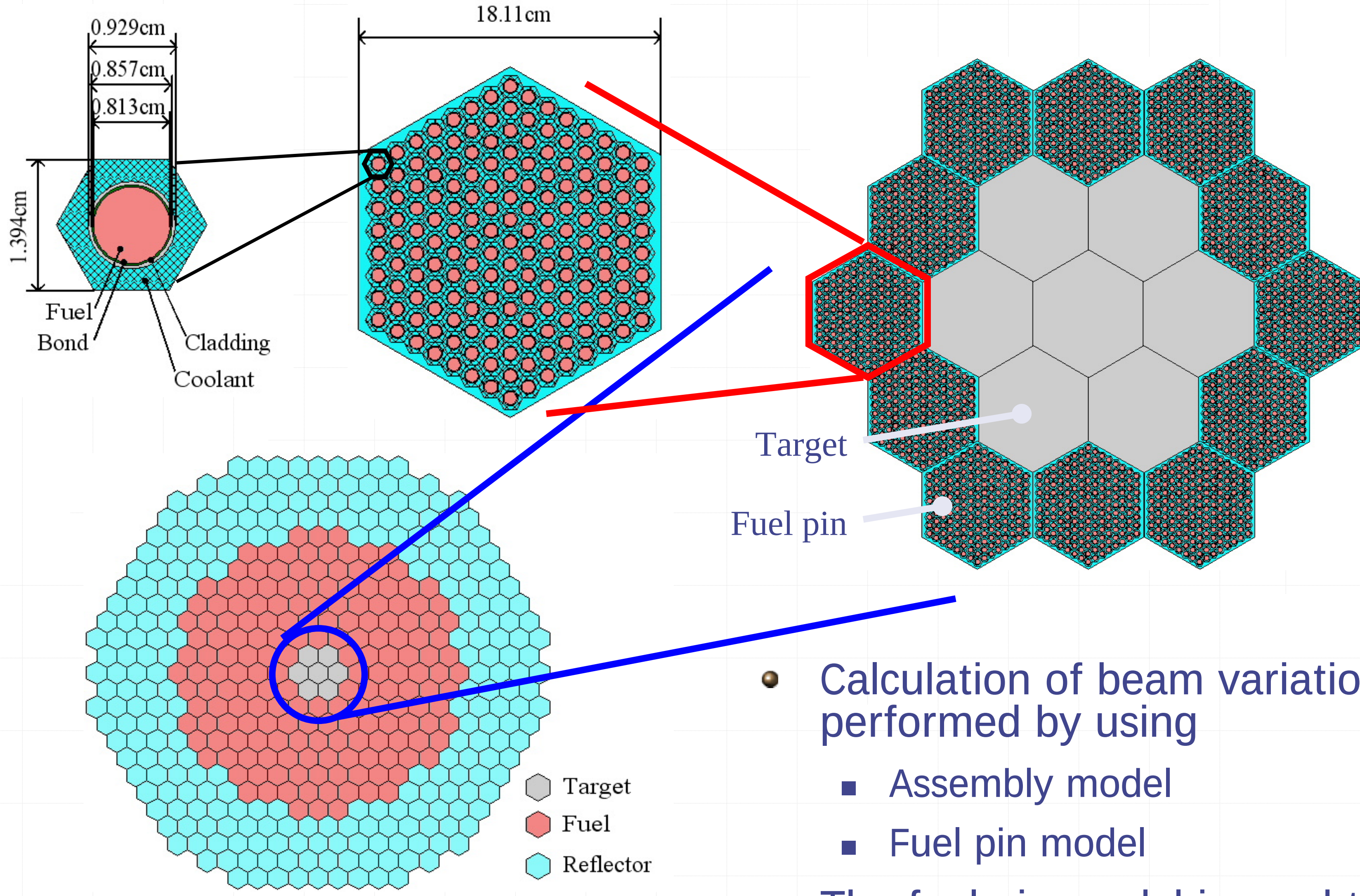



Fig. fine geometry model

- Calculation of beam variation is performed by using
  - Assembly model
  - Fuel pin model
- The fuel pin model is used to define the fuel pin in the assembly

# III. Application of DSE-M

- Beam variation events
  - Reference case
    - The proton beam is injected the center of the core with the diameter of 1cm
  - Beam diameter case
    - The beam diameter is changed from 1 to 40cm
  - Beam shape case
    - The beam diameter of y-axis is changed from 1 to 13cm, while the diameter of x-axis is fixed to 26cm
  - Beam injection position case
    - The beam injection position is changed from 0 to 24cm, i.e. the beam moves from the center to the peripheral of the target

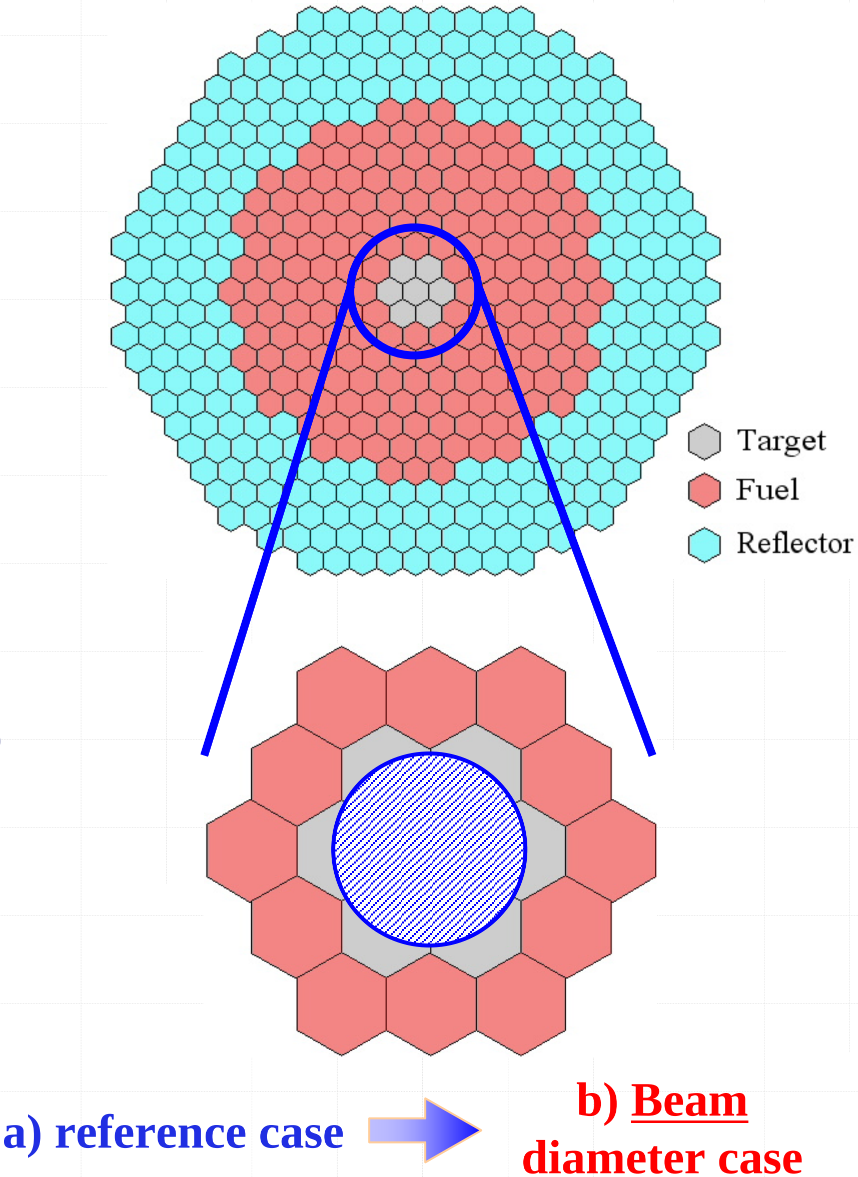



Fig. Conceptual for beam variation events

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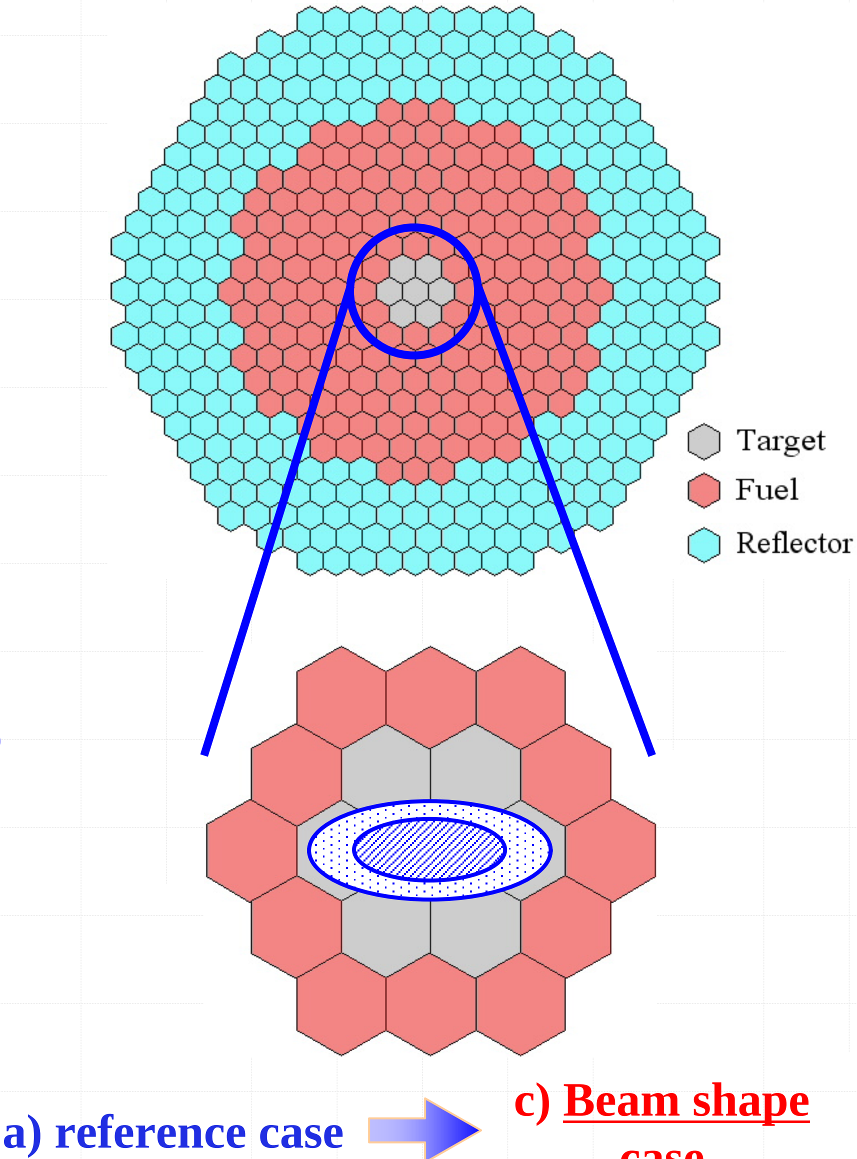


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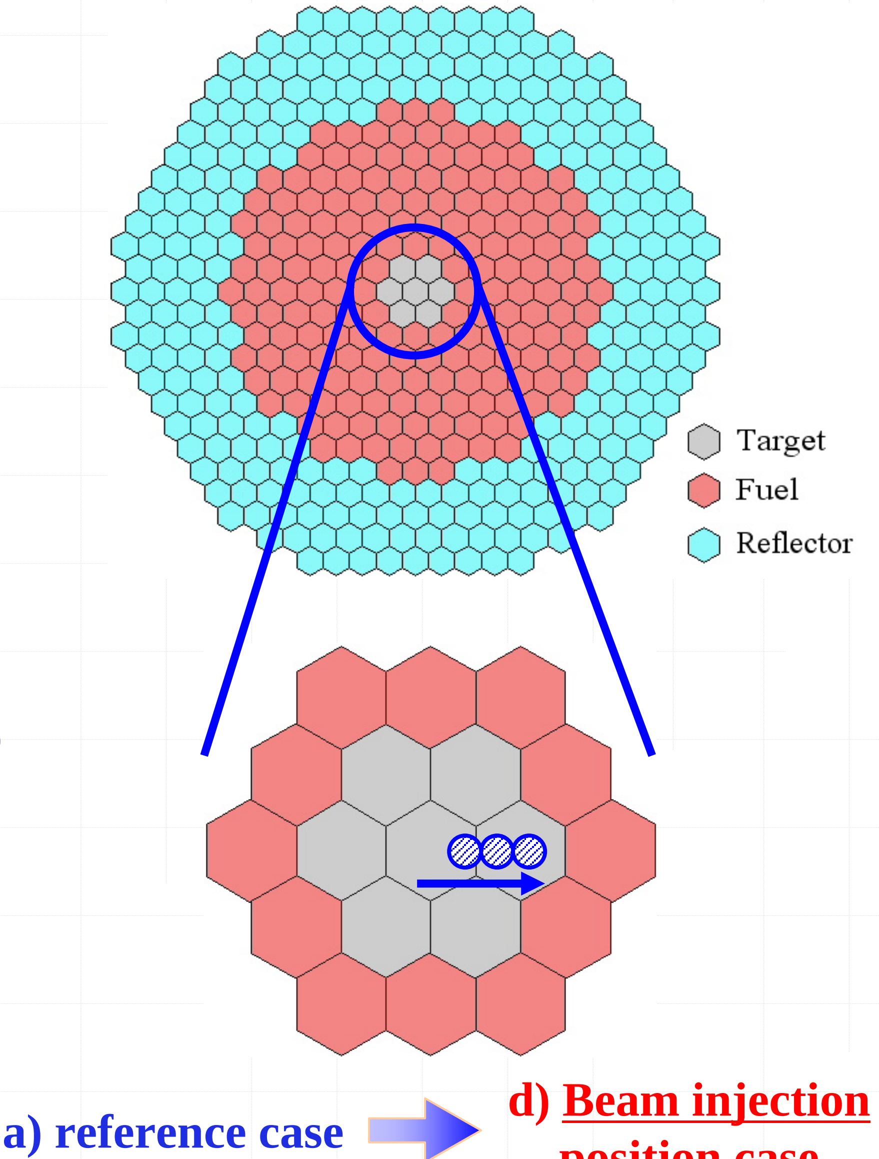


Fig. Conceptual for beam variation events

# Adopted ADS model in this study

Table. Main parameter of reference ADS

| | |
|---|---|
| Thermal power | 800 [MWt] |
| Multiplication factor | 0.95 |
| Core height/diameter | 1.00 / 2.50 [m] |
| Target height/diameter | 1.50 / 0.5 [m] |
| Core fuel element | (MAs+Pu)+ZrN |
| Target and Coolant material | Liquid Pb-Bi |
| Coolant temperature (in/out) | 603 / 703 [K] |
| Coolant flow rate | $1.98*10^8$ [kg/h] |
| Transmutation efficiency | 250 [kgMA/year] |
| Proton beam energy | 2.0 [GeV] |

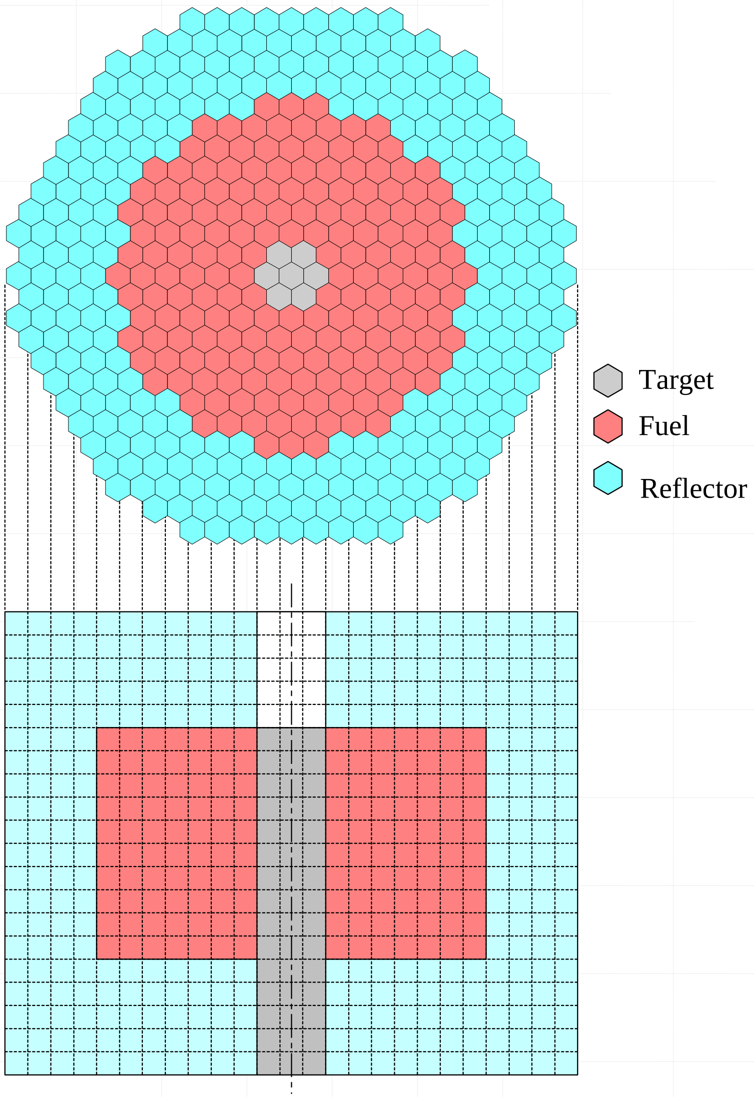


Fig. ADS core design and calculation mesh

# Calculation for the variation of position (1)

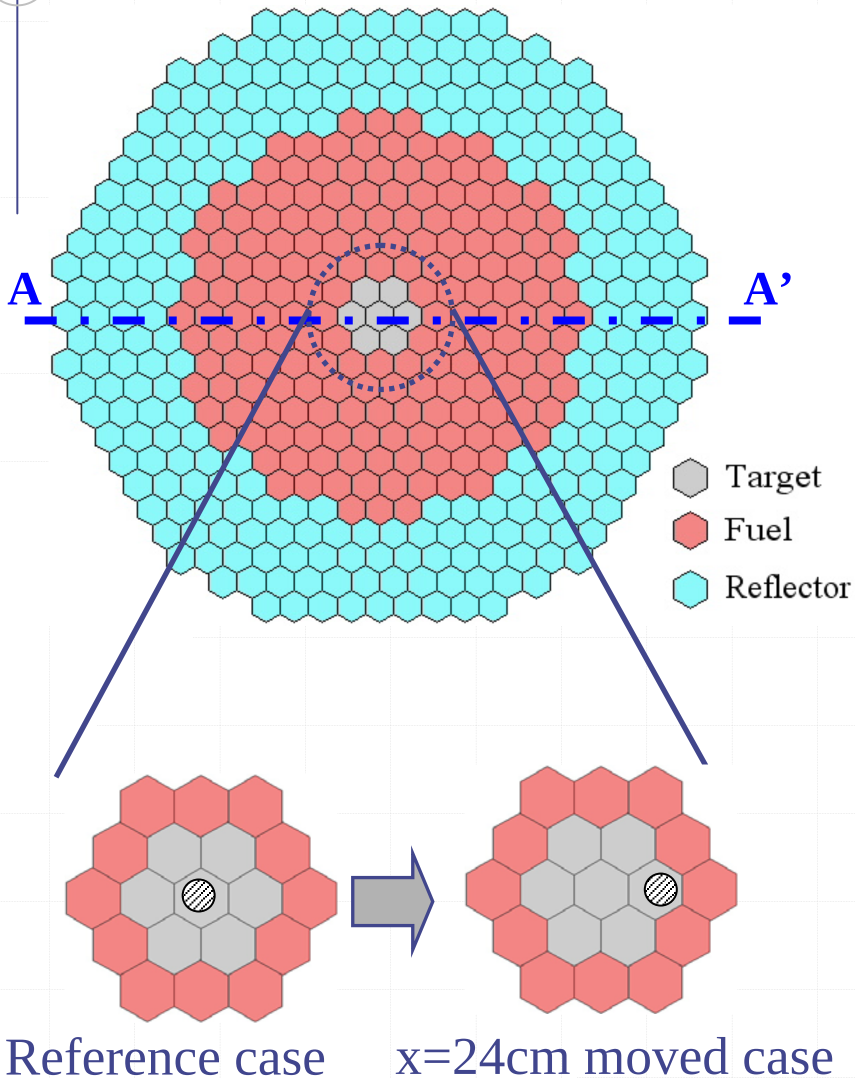


Fig. ADS calculation model

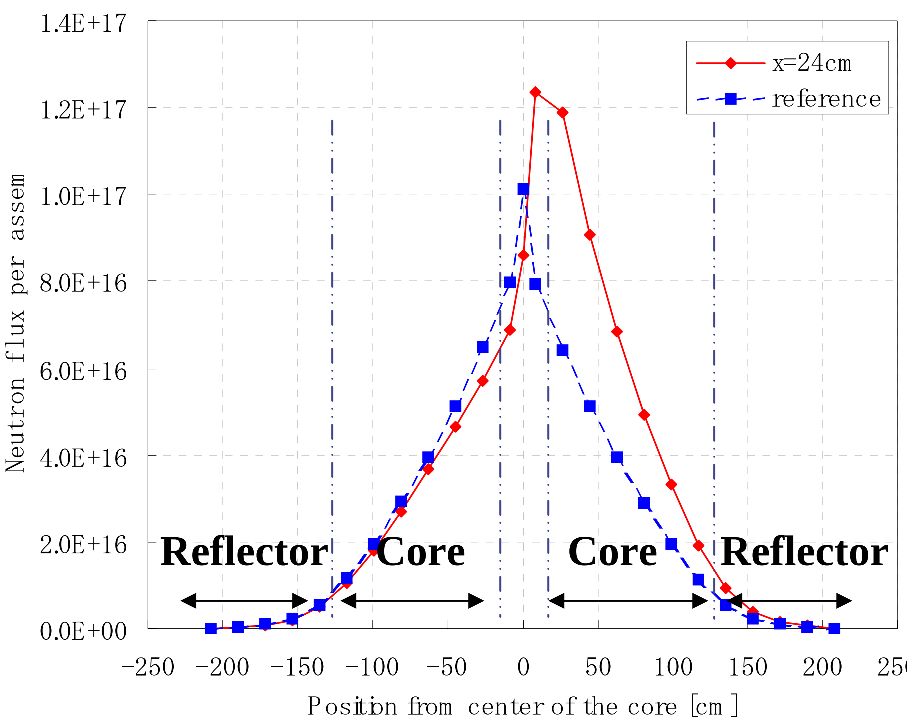


Fig. Neutron flux distribution (assembly model)

- It is confirmed that the peak of the neutron flux significantly increases at the position of core center

# Calculation for the variation of position (2)

- The maximum peaking factor (MPF) is examined

$$MPF = \frac{\text{maximum neutron flux at peak location}}{\text{average neutron flux of the core}}$$

- When the beam injection position move from 0cm to 24cm, the MPF increases about 1.6 times larger

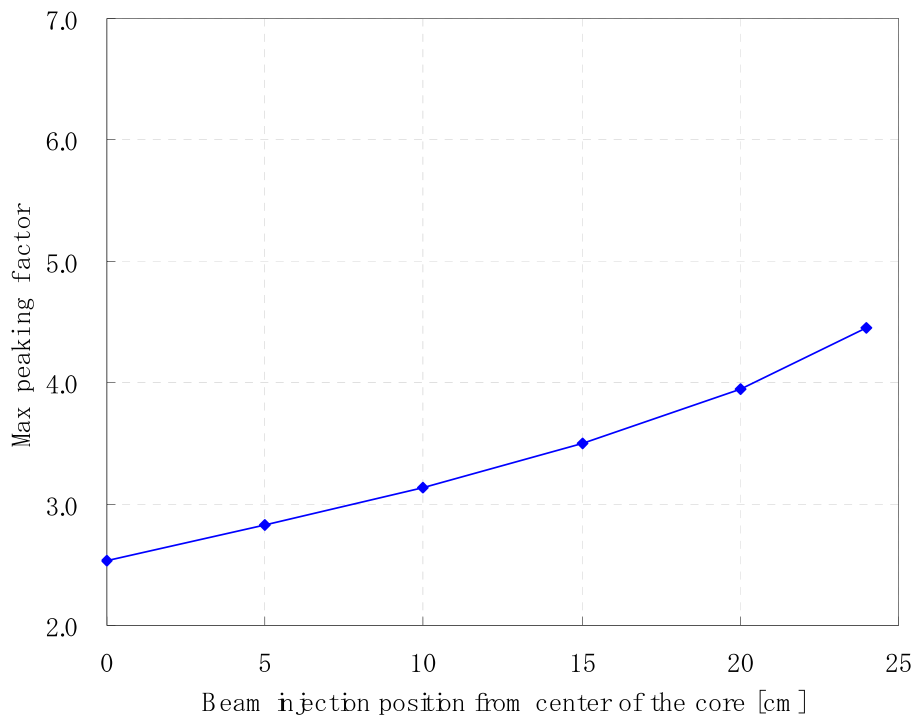


Fig. Calculation results for maximum peaking factor in assembly model

# Calculation for the variation of position (3)

- The fuel pin model is applied
  - The MPF for the pin cell model is 6.7, while the MPF by the assembly model is 4.5
- The MPF by fuel pin model increases about 1.6 times larger than that by assembly model
- Neutron flux distribution is varied significantly with the change of beam injection position

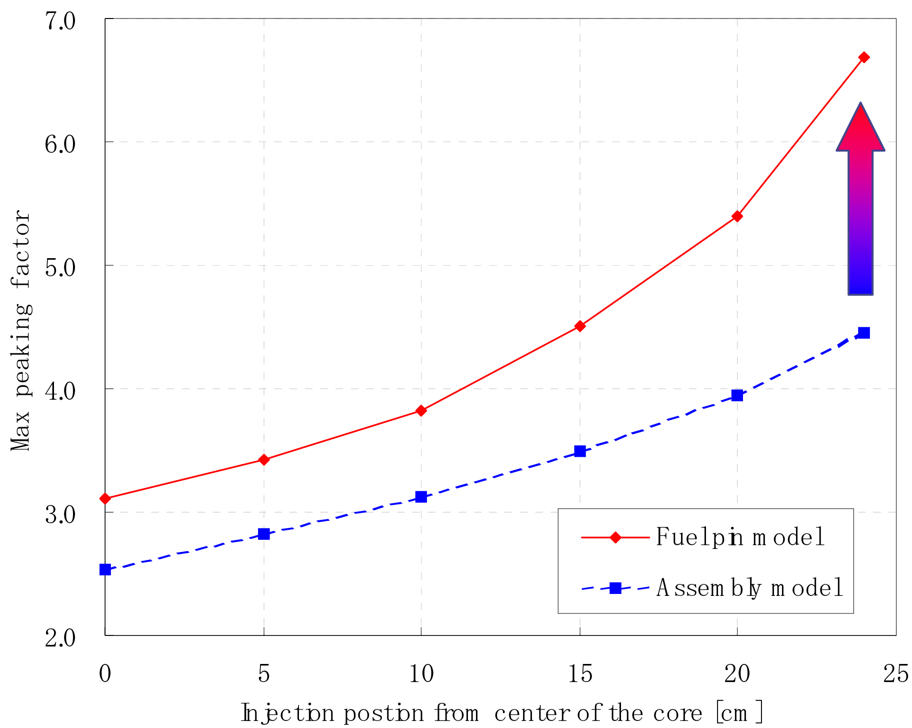


Fig. Calculation results for maximum peaking factor in fuel pin model

# For the variation of the core power

- The dynamics calculation is examined by using DSE-M (by the assembly case)
- When the beam injection position moves from 0cm to 24cm at 20sec,
  - The thermal power quickly increased from 800 to 900MWt
  - The fuel temperature increase was about 1800K after 20sec
- The variation of the beam position has significant effect to thermal power and fuel temperature

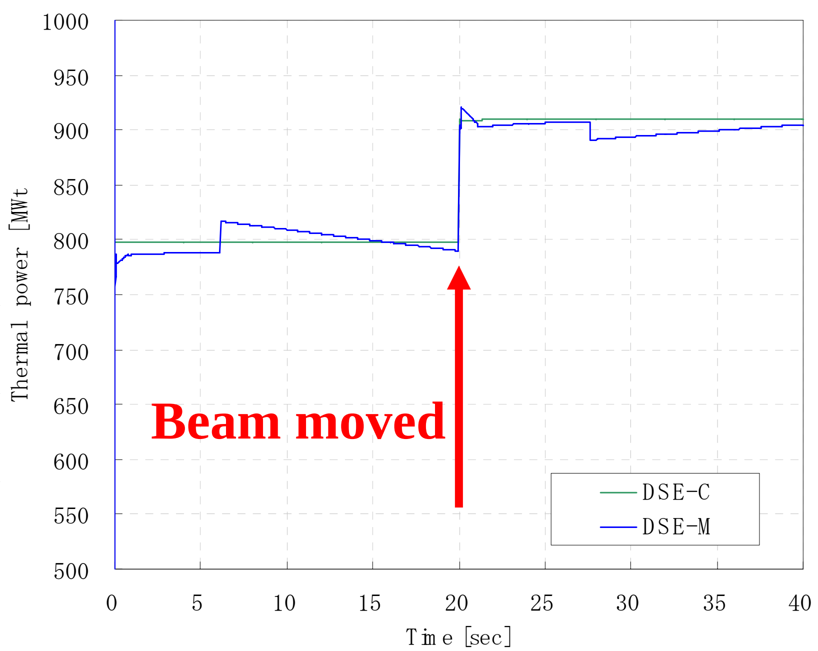


Fig. Variation of thermal power

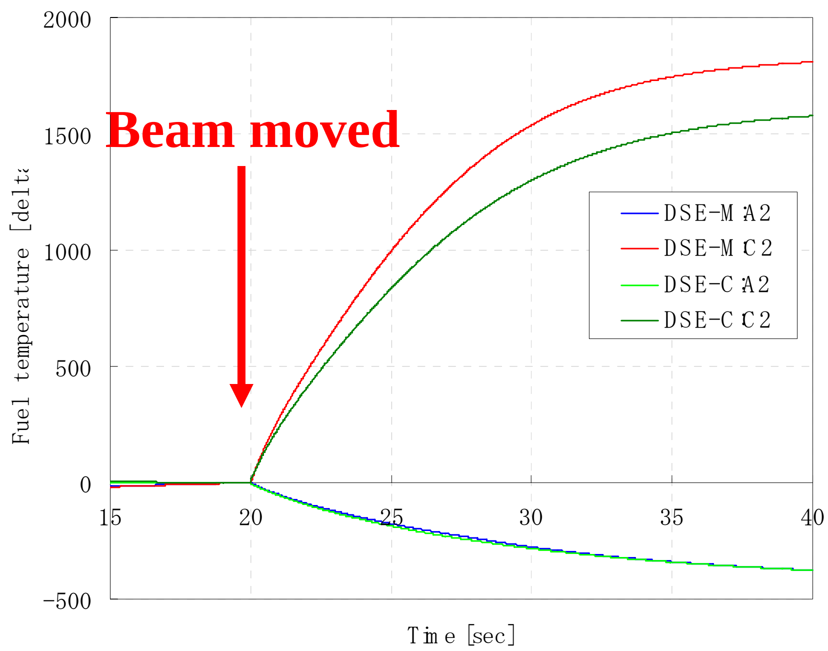


Fig. Variation of fuel temperature increase

# IV. Summary and future works

- DSE code system have been developed
  - We developed the code which has three method of neutronics calculations
  - DSE-M can solve the exact treatments of neutron transport, angular dependence and geometry description, the adjoint calculation function, the calculation of the dynamics parameters
  - In the static and dynamics calculation, the effect of the calculation error of the Monte Carlo is a little
- By using DSE-M, the calculation of the beam variation events was performed
  - The diameter case and the shape case have a little effect
  - The Beam injection position case has significant effect to neutron flux, core power, fuel temperature
    - When the beam injection position moves from 0cm to 24cm,
      - The MPF for the pin cell model is 6.7
      - The thermal power quickly increased from 800 to 900MWt in the dynamics
      - The fuel temperature increase was about 1800K after 20sec in the dynamics

# IV. Summary and future works

- The verification of DSE should be performed with the experiment data
- We are searching the dynamics experiment data
- Experiment conditions is required
  - Sub-critical core
  - Experiment of variation of neutron source
    - Insertion or withdrawal of fixed neutron source
    - Variation of Beam intensity by accelerator
  - Experiment of reactivity insertion
    - Insertion or withdrawal of the control rod
    - Control rod drop
  - Neutron counting by neutron detector
    - Several locations in core
    - Time dependent measurement