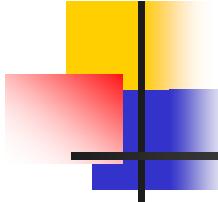


# **Current Status on ADS Basic Study in Research Reactor Institute, Kyoto University**

**Cheolho Pyeon**

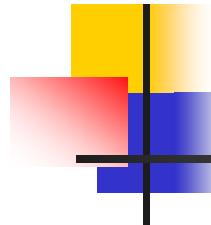
**Research Reactor Institute, Kyoto University, Japan**

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- Composition of ADS in Kyoto Univ.
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(IAEA ADS CW from 2015)
- Summary



# Background and Purpose

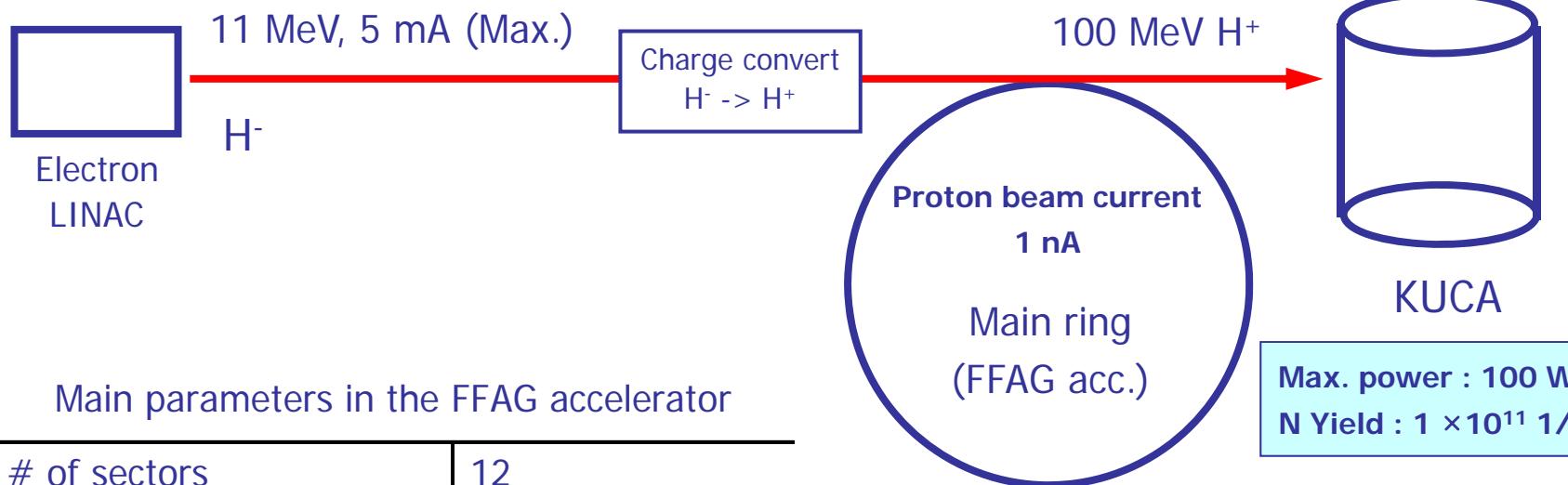
## Background

- An original concept of ADS for producing energy and transmuting MA and LLFP
- $^{235}\text{U}$ -loaded ADS experiments with 14 MeV neutrons
- $^{235}\text{U}$ - and  $^{232}\text{Th}$ -loaded ADS experiments with the variation of
  - Core spectrum: Fuel -> HEU, Thorium (Th), NU
  - Moderator -> Polyethylene (PE), Graphite (C), Beryllium (Be)
  - External source: 14 MeV neutrons
  - 100 MeV protons (with heavy metal target; W, Pb-Bi...)

## Purpose

- Conduct feasibility study on ADS through the experiments at KUCA
- Investigate neutron characteristics of ADS through the experimental and the numerical (MCNPX) analyses

# FFAG accelerator (100 MeV protons)



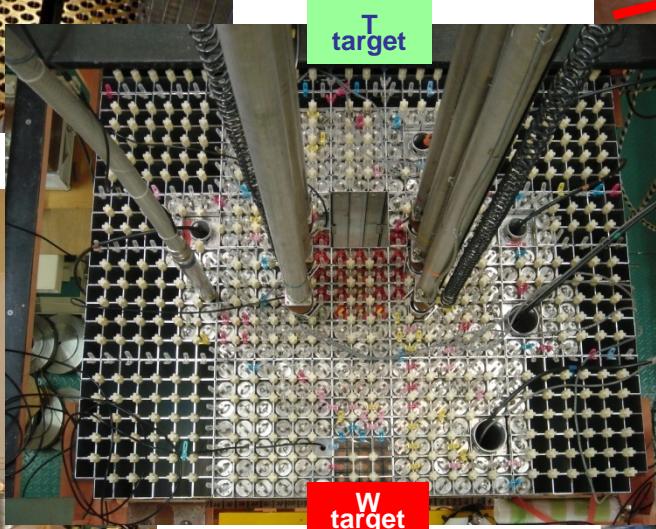
# of sectors	12
Energy	2.5 – 150 MeV
Repetition rate	120 Hz
Average beam current	1 nA
Rf frequency	1.5 - 4.6 MHz
Field index	7.5
Closed orbit radius	4.4 - 5.3 m



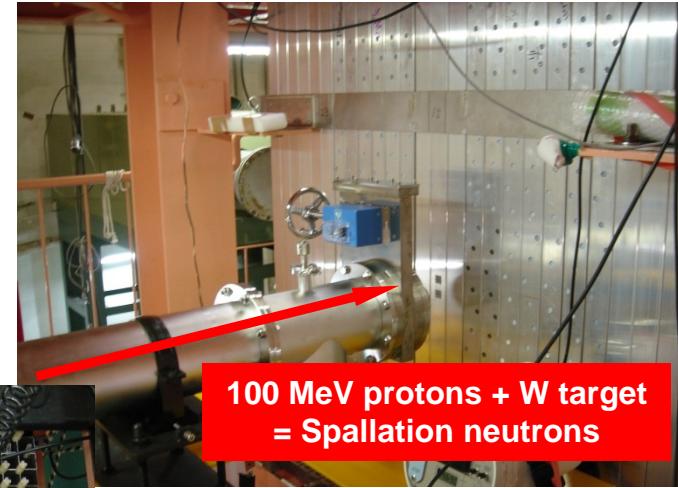
# ADS composition at KUCA



Beam line of D



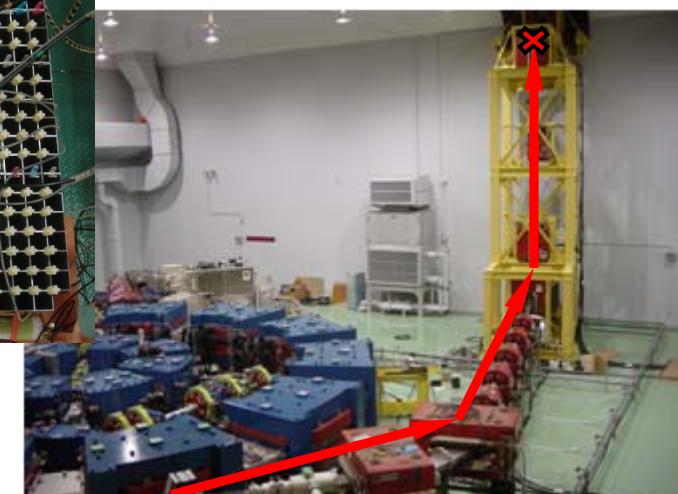
KUCA core



Beam line of protons



Pulsed neutron generator



FFAG accelerator  
C. H. Pyeon, Kyoto Univ. 5

# KUCA core (Solid-moderated core)

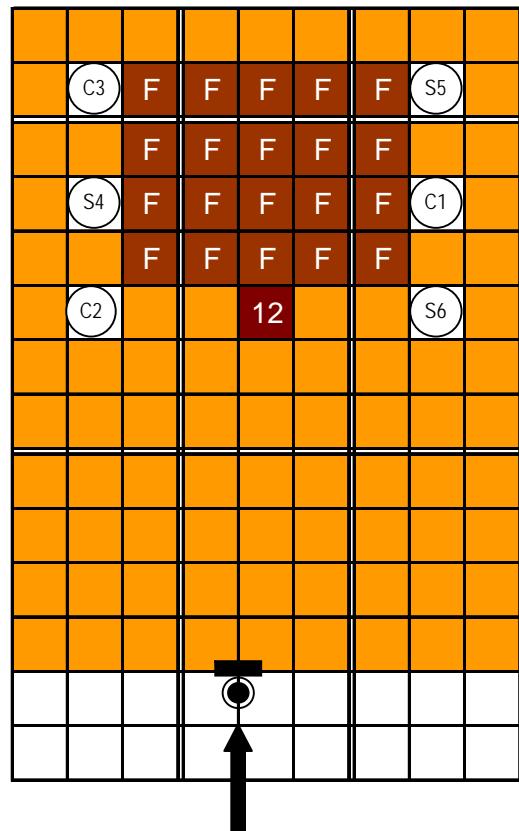


Fig. KUCA core

- KUCA core -  
A solid-moderated and -reflected core

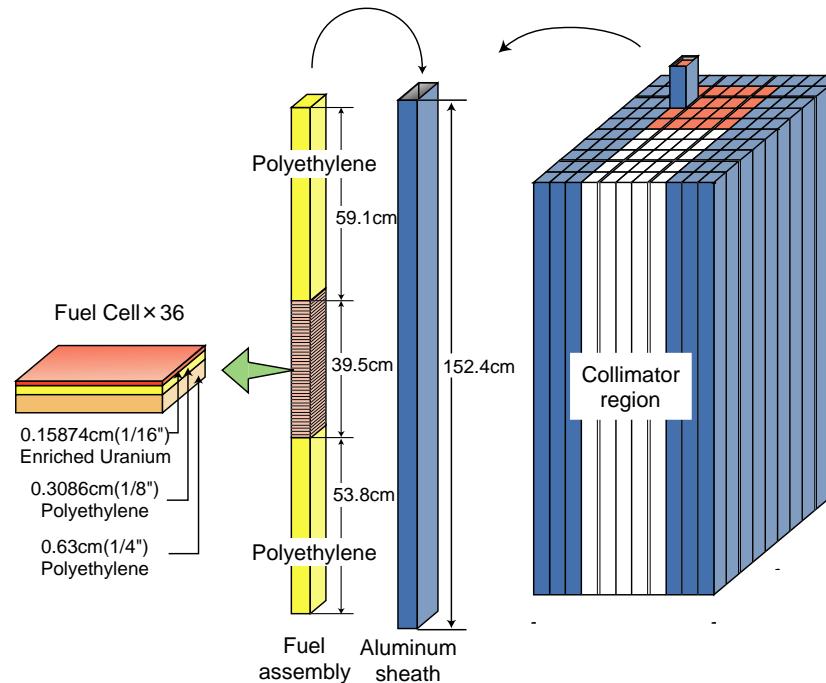
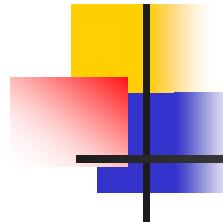


Fig. Image of KUCA core and fuel assembly loaded

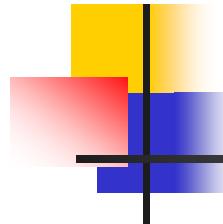


# ADS experiments with 14 MeV neutrons

## Experiment benchmarks (IAEA ADS CRP in 2007 to 2011)

- Subcriticality measurements
- Neutron spectrum (Activation foils)
- Reaction rates (M and k-source)

- C. H. Pyeon, *et al.*, *J. Nucl. Sci. Technol.*, **44**, 1368 (2007).  
C. H. Pyeon, *et al.*, *J. Nucl. Sci. Technol.*, **45**, 1171 (2008).  
C. H. Pyeon, *et al.*, *J. Nucl. Sci. Technol.*, **46**, 965 (2009).  
H. Shahbunder, *et al.*, *Ann. Nucl. Energy*, **37**, 592 (2010).  
H. Taninaka, *et al.*, *J. Nucl. Sci. Technol.*, **47**, 376 (2010).  
H. Shahbunder, *et al.*, *Ann. Nucl. Energy*, **37**, 1214 (2010).  
H. Taninaka, *et al.*, *J. Nucl. Sci. Technol.*, **48**, 873 (2011).  
H. Taninaka, *et al.*, *J. Nucl. Sci. Technol.*, **48**, 1272 (2011).  
C. H. Pyeon, *et al.*, *Ann. Nucl. Energy*, **40**, 229 (2012).



## **$^{232}\text{Th}$ -loaded ADS experiments**

### **Comparative study on $^{232}\text{Th}$ -ADS (IAEA ADS CW in 2013 and 2014)**

- Neutron spectrum (core)**
- Subcriticality (core)**
- External neutron source  
(14 MeV neutrons vs. 100 MeV protons)**

C. H. Pyeon, *et al.*, *Ann. Nucl. Energy*, **38**, 2298 (2011).

C. H. Pyeon, *et al.*, *Nucl. Sci. Eng.*, **177**, 156 (2014).

M. Yamanaka, *et al.*, PHYSOR 2014, (2014).

## $^{232}\text{Th}$ -ADS: Profile of thermal neutrons

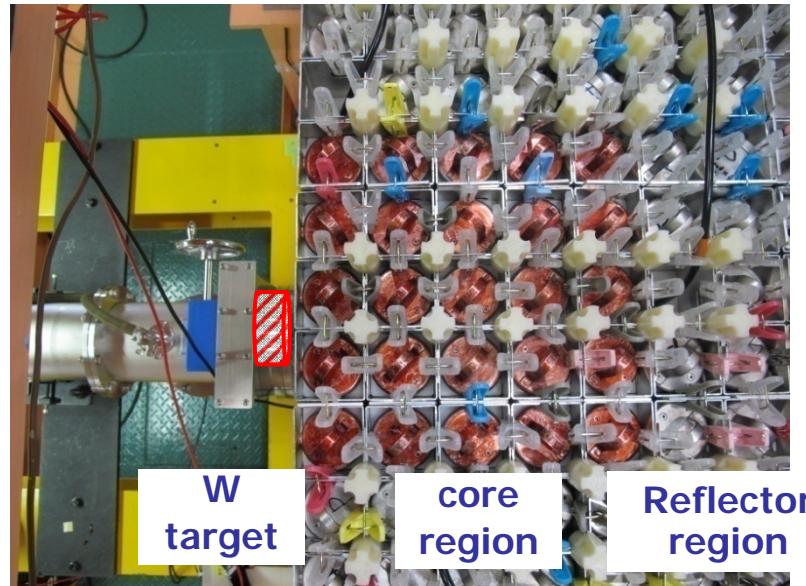


Fig. Core configuration of  $^{232}\text{Th}$ -loaded core

### Effects

- 1) Neutron spectrum in core
- 2) External neutron source at target  
(14 MeV neutrons vs. 100 MeV protons)

Note: Protons; 100 MeV, 50 mm dia., 0.1 nA

Target; W, 50 mm dia., 9 mm thick

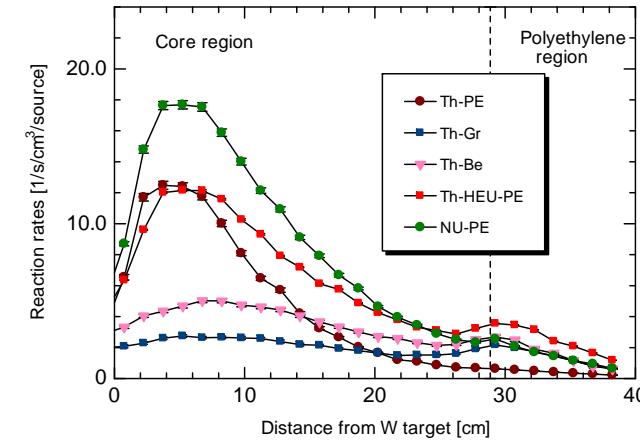


Fig. Measured  $^{115}\text{In}(\text{n}, \gamma)^{116\text{m}}\text{In}$  reaction rates ([100 MeV protons](#))

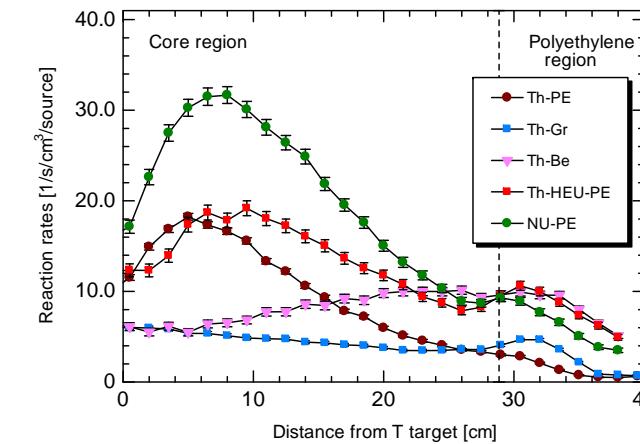


Fig. Measured  $^{115}\text{In}(\text{n}, \gamma)^{116\text{m}}\text{In}$  reaction rates ([14 MeV neutrons](#))

## 232Th-ADS: Kinetic parameters

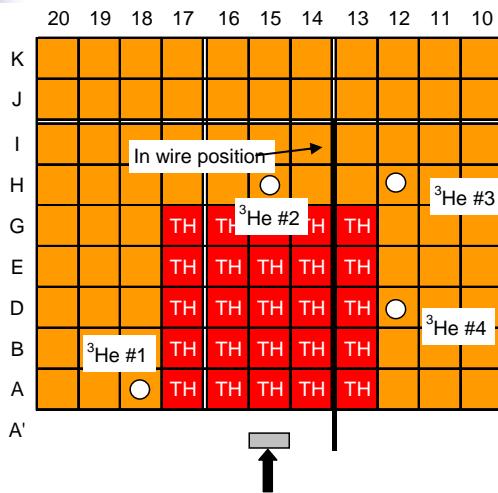


Fig. Core configuration of  $^{232}\text{Th}$ -PE core  
(100 MeV protons)

Table Results in  $k_{\text{eff}}$  ( $^3\text{He} \#3$ ; Area ratio method)

	Cal.	Exp.	
Core	MCNPX	100 MeV Protons	14 MeV Neutrons
Th-HEU-PE	<b>0.5876</b>	<b>0.7346</b>	<b>0.6577</b>

$\beta_{\text{eff}} = 8.491\text{E-}03$ ; SRAC-CITATION 107-G, 3-D

$\alpha = 5065 \pm 28$  (100 MeV Protons)

$5288 \pm 13$  (14 MeV Neutrons)

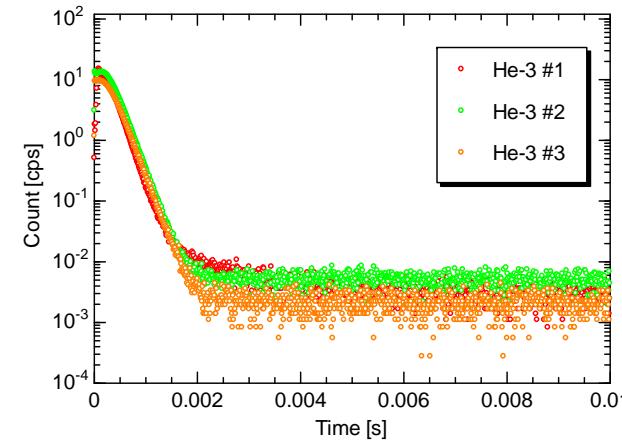


Fig. Results in Th-HEU-PE with 100 MeV protons

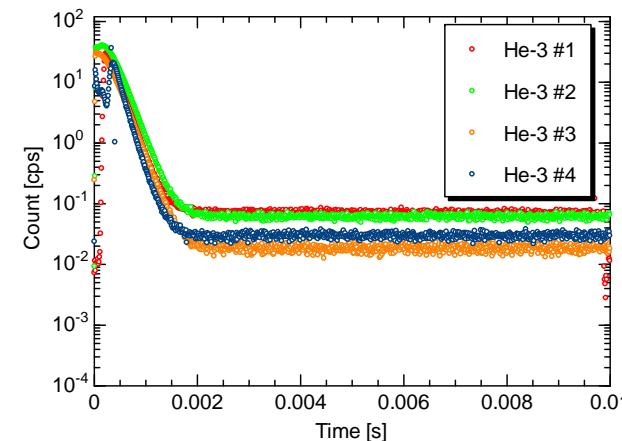
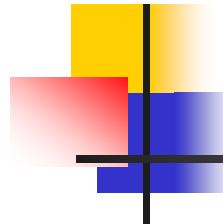


Fig. Results in Th-HEU-PE with 14 MeV neutrons



## ADS experiments with 100 MeV protons

### 235U-loaded ADS experiments with 100 MeV protons (IAEA ADS CW from 2015)

- Target (W, W-Be, Pb-Bi) study
- Subcriticality monitoring
- Neutron spectrum
- Reaction rates (M and k-source)

J. Y. Lim, *et al.*, *Sci. Technol. Nucl. Install.*, **2012**, ID: 395878, 9 pages, (2012).

C. H. Pyeon, *et al.*, *Nucl. Eng. Technol.*, **45**, 81 (2013).

A. Sakon, *et al.*, *J. Nucl. Sci. Technol.*, **50**, 481 (2013).

A. Sakon, *et al.*, *J. Nucl. Sci. Technol.*, **51**, 116 (2014).

C. H. Pyeon, *et al.*, PHYSOR 2014, (2014).

C. H. Pyeon, *et al.*, *Prog. Nucl. Energy*, (2014). [in print]

# Target study (Static analyses)

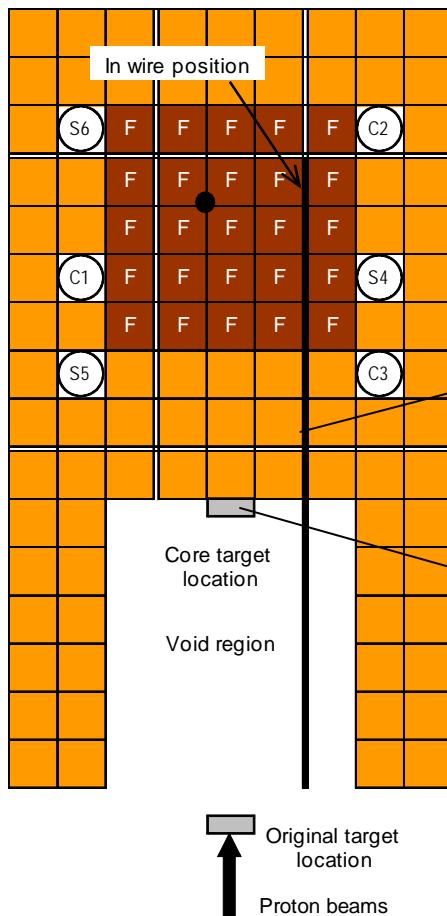


Fig. Core configuration of  $^{235}\text{U}$ -PE core  
(100 MeV protons)

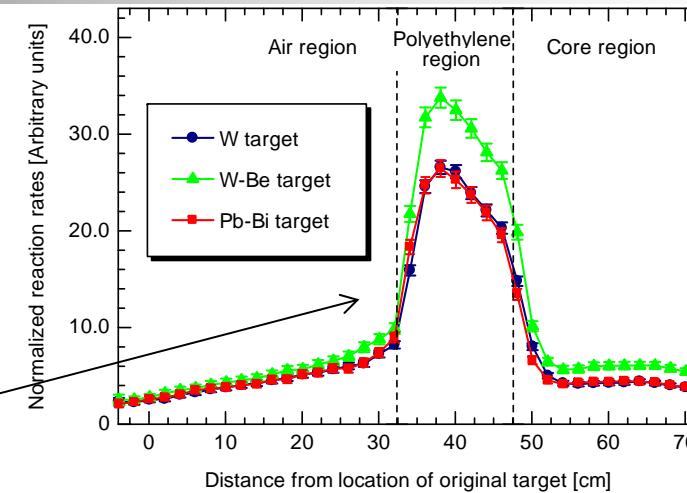


Fig. Measured reaction rate distribution (M and k-source study)

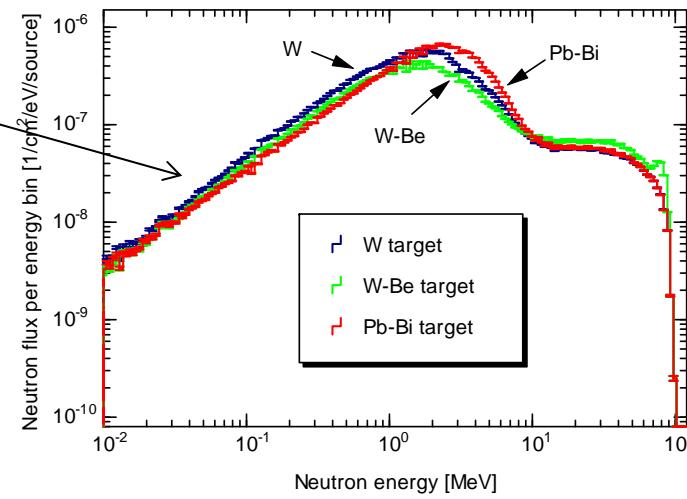
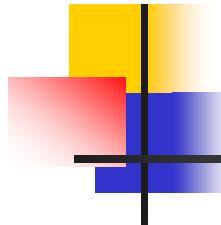
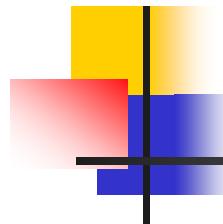


Fig. Neutron spectrum with the variation of target (MCNPX)



# **Solid Pb-Bi study on nuclear transmutation (collaboration with KUCA and JAEA)**



# Uncertainties of Pb-Bi x-sec

## ➤ Motivation

- Discrepancy between JENDL-3.3 and JENDL-4.0 of Pb-Bi x-sec.  
through numerical simulations of JAEA ADS model (Pb-Bi coolant model)

## ➤ Experiments at KUCA (critical state)

- Sample worth (reactivity) of Pb and Pb-Bi plates in the critical state

## Upcoming experiments (Successive investigation)

- Sample worth of Bi plates in the critical state (finished in Pb and Pb-Bi)

Table C/E values of sample reactivity by Pb plates

Reactivity (pcm)	JENDL-3.3	JENDL-4.0	ENDF/B-VII.0
89	$1.62 \pm 0.14$	$1.17 \pm 0.11$	$1.05 \pm 0.11$
105	$1.57 \pm 0.11$	$1.09 \pm 0.09$	$0.97 \pm 0.09$
140	$1.52 \pm 0.08$	$1.04 \pm 0.07$	$1.02 \pm 0.06$
151	$1.66 \pm 0.08$	$1.17 \pm 0.07$	$1.13 \pm 0.07$

## $^{235}\text{U}$ -fueled and Pb-Bi-zoned core

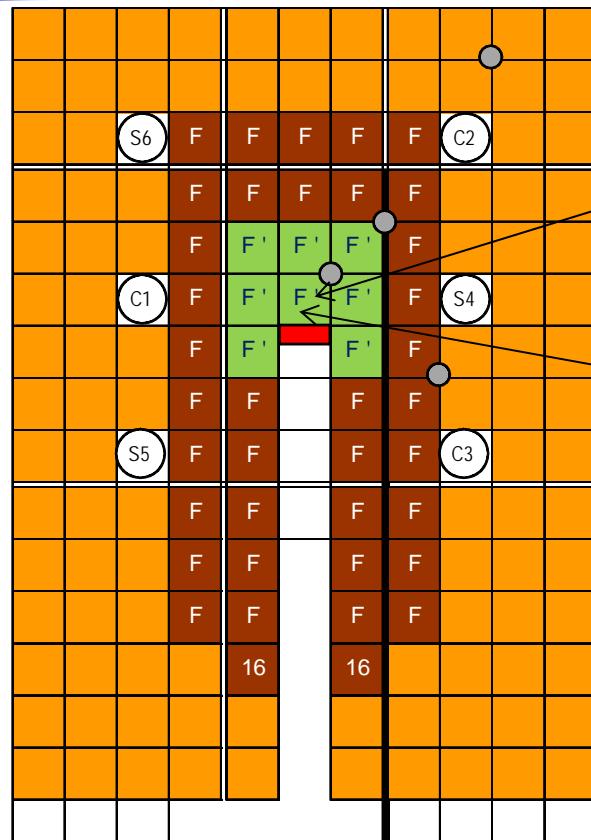


Fig. Core configuration of  $^{235}\text{U}$  and Pb-Bi zoned core

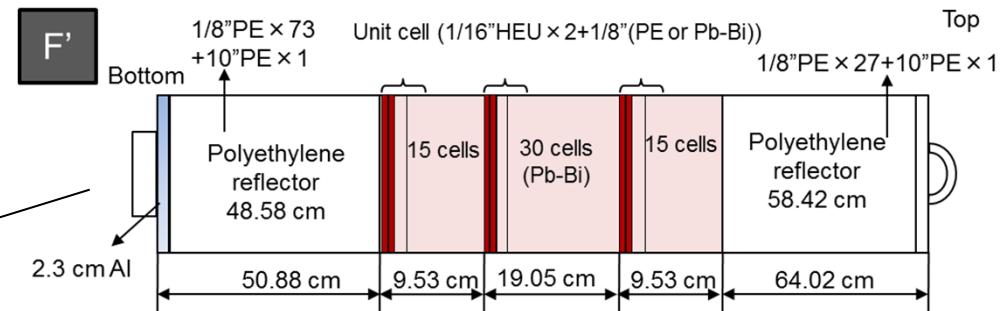


Fig. Fuel assembly of  $^{235}\text{U}$ -PE and Pb-Bi

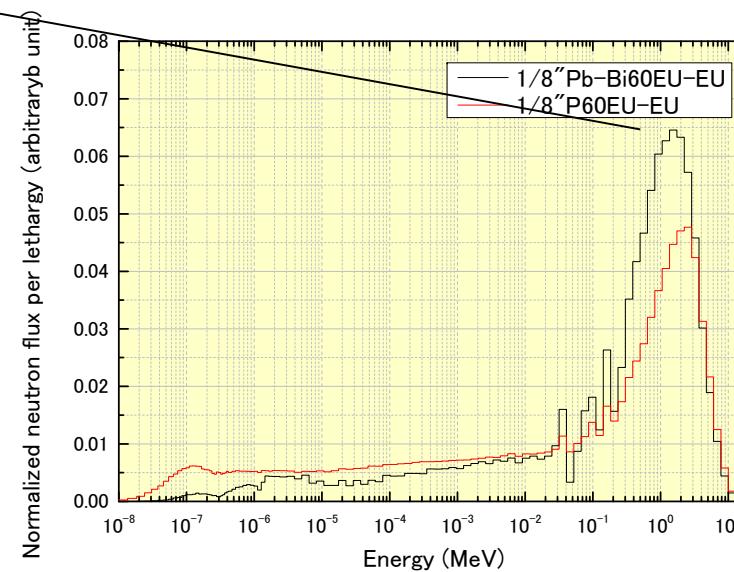
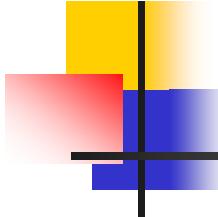


Fig. Neutron spectrum of core center in F' at 100 MeV proton injection onto Pb-Bi target



# Summary

## ■ Campaign of ADS experiments in Kyoto Univ.

- KUCA core with 14 MeV neutrons and 100 MeV protons

## ■ $^{235}\text{U}$ - and $^{232}\text{Th}$ -loaded ADS experiments

- Study on static and kinetic parameters with the variation of Core spectrum, Subcriticality and Source spectrum

## ■ New ADS experiments with 100 MeV protons

- Pb-Bi target study
- Subcriticality monitoring
- Neutron characteristics on  $^{235}\text{U}$  and Pb-Bi zoned core
- Uncertainty of Pb-Bi cross sections

## ■ Future works

- Evaluation of uncertainty of Pb-Bi cross sections
- Feasibility of nuclear transmutation of Minor Actinides (MAs;  $^{237}\text{Np}$  and  $^{241}\text{Am}$ ) by ADS