The Project of Fusion-Fission Hybrid Energy Reactor in China

Maosheng Li

Institute of Applied Physics and Computational Mathematics

P. R. China

May 16, 2011 San Francisco, USA

Contents

- The FFH project in China
- Design concepts
  - Performance analyses
  - Hybrid reactor test model
  - Other concepts
- Neutronic integral experiments
  - Depleted uranium spheral shell
  - Tritium production from LiH
  - Natural uranium
- Thermal hydraulic and nuclear fuel cycle
- Summary

The FFH Project

The fusion-fission hybrid has the potential to make a contribution to waste management, energy production, and fuel supply along a path of long-term sustainability.

The potential role of fusion-fission hybrids in China: (in priority order)

1. energy production with closed fuel cycles and little radioactive waste;
2. reduce the mass of spent fission fuel, plus modest energy production;
3. production of fissile fuel and reduce the mass of spent nuclear fuel.

The FFH Project

The conceptual design of the fusion-fission hybrid energy reactors and related verifying experiments was started in the framework of the National Magnetic Confinement Fusion Science Program in May 2010.

The project is primarily focus on the sub-critical blanket design.
The research area including:

- neutronics
- thermal hydraulic
- fuel manufacture and nuclear fuel cycle

2015 conceptual design, compare different concepts.

2020 detailed conceptual design and outlined engineering design.

2035 FFH DEMO.

The FFH Project

Participants

1. Institute of Applied Physics and Computational Mathematics
2. Institute of Nuclear Physics and Chemistry, CAEP
3. Science and Technology Information Center, CAEP
4. Institute of material and process of Sichuan
5. China Nuclear Power Engineering Co., Ltd.
6. Institute of Plasma Physics, Chinese Academy of Sciences
7. Southwestern Institute of Physics
8. Tsinghua University
9. Xi'an Jiaotong University

CAEP, Chinese Academy of Engineering Physics

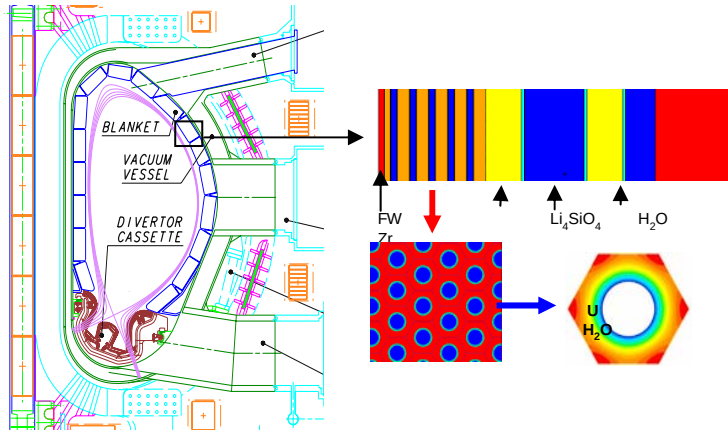
Fusion-Fission Hybrid Team

Design Concepts

Design Rules

1. Start from natural uranium, depleted uranium (thorium) or spent fuel. The initial fuel does not require enrichment.
2. Energy multiplication factor is about 10-20.
3. Using a pyroprocessing the spent fuel could be used by itself, there is no uranium enrichment nor uranium plutonium separation.

Based on the current or slightly extrapolated ITER fusion science and technology and the well developed fission technology, we put forward the concept blanket with uranium alloy as the fuel and water as the coolant. The uranium can be natural uranium, depleted uranium or the LWR spent fuel.

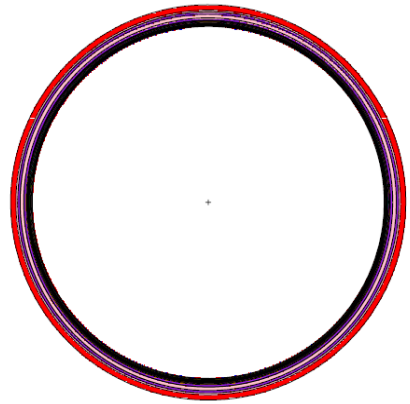


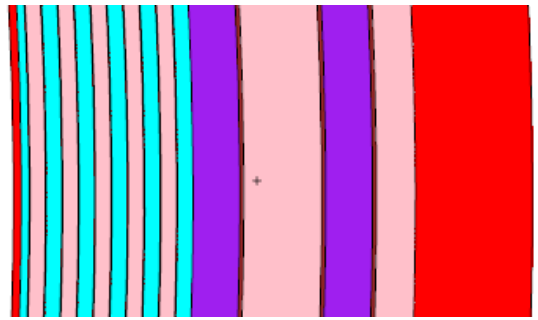
Design Concepts

IAPCM

Blanket material and size

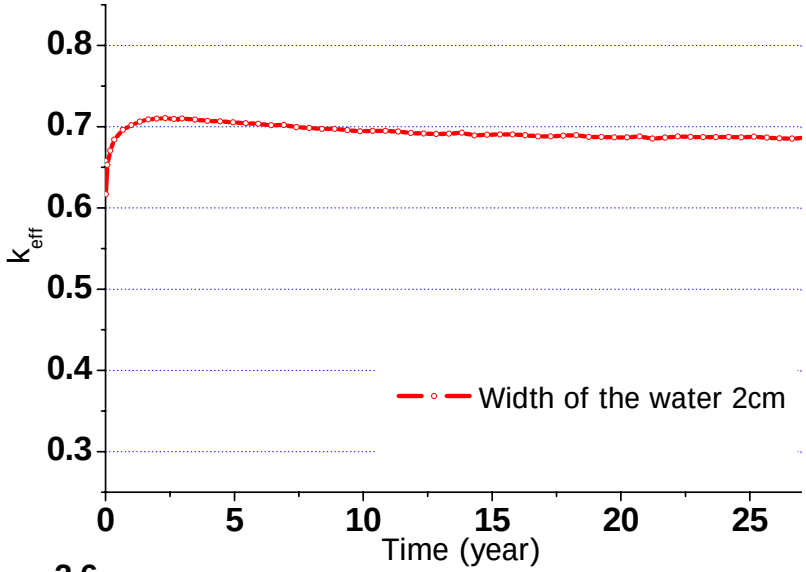
	Material	Density(g/cm^3)	Width(cm)
Plasma	DT		500
FW	Fe	7.8	1.0
FZ	U-Zr alloy	13.57	1.0
	Zr/H_2O/Zr *	6.44/0.6/6.44	0.1/**2.0**/0.1
	U-Zr alloy *	13.57	2.0
	* repeat 4 times		
TBZ	Li_4SiO_4	1.34	6.0
	Zr/H_2O / Zr	6.44/0.6/6.44	0.5/10/0.5
	Li_4SiO_4	1.34	6.0
	Zr/ H_2O	6.44/0.6	0.5/5.0
RZ	Fe	7.8	15.0

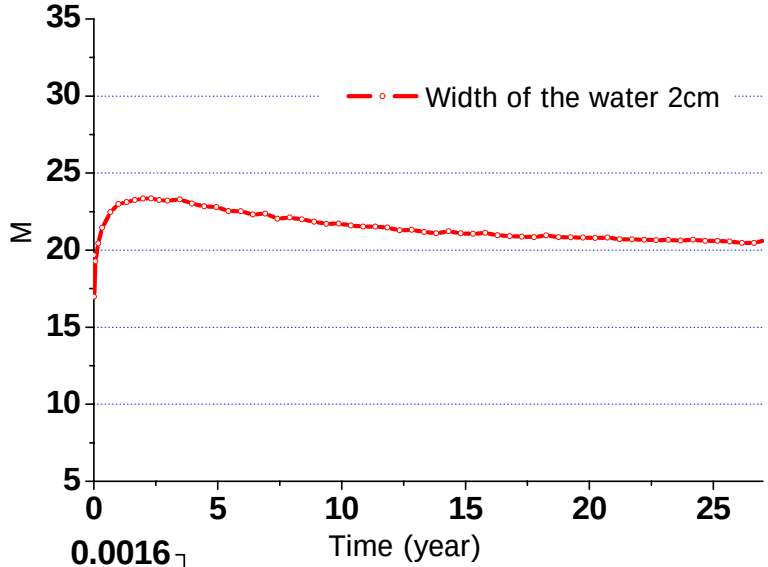


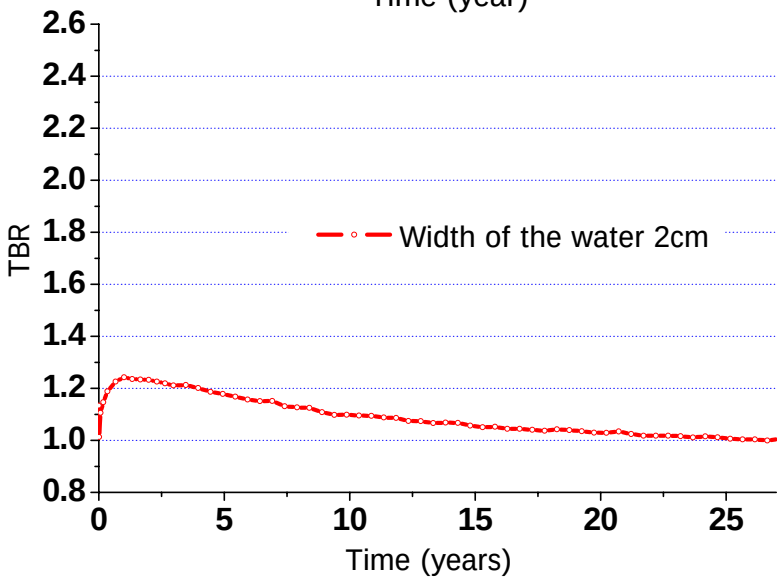


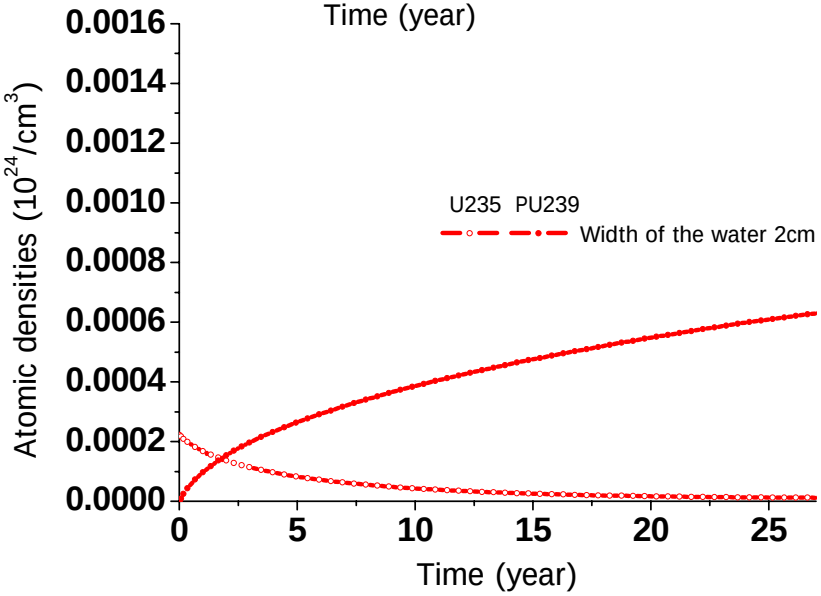
1D sphere model

Performance Analyses

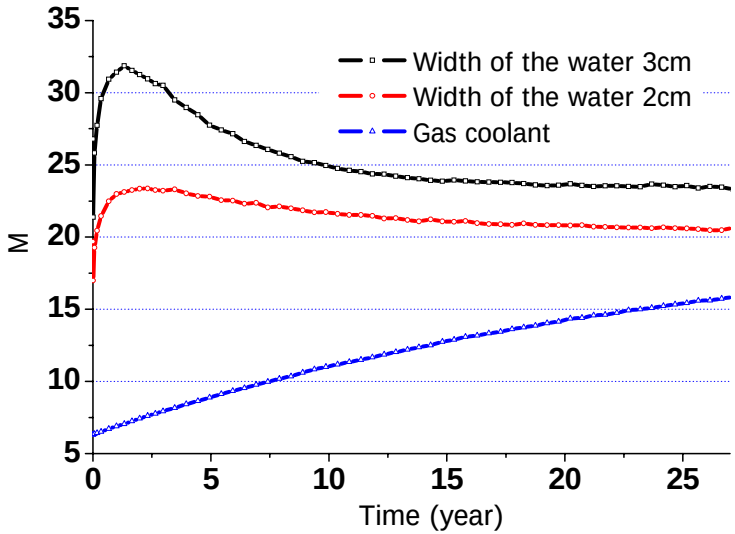


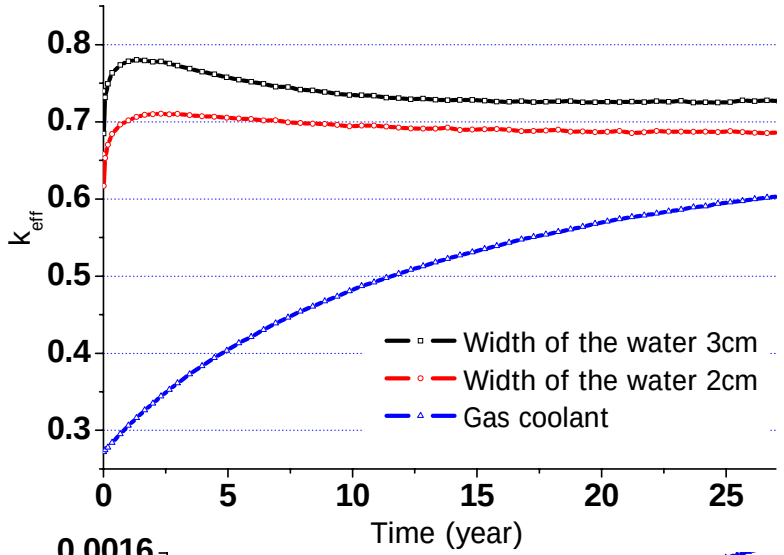


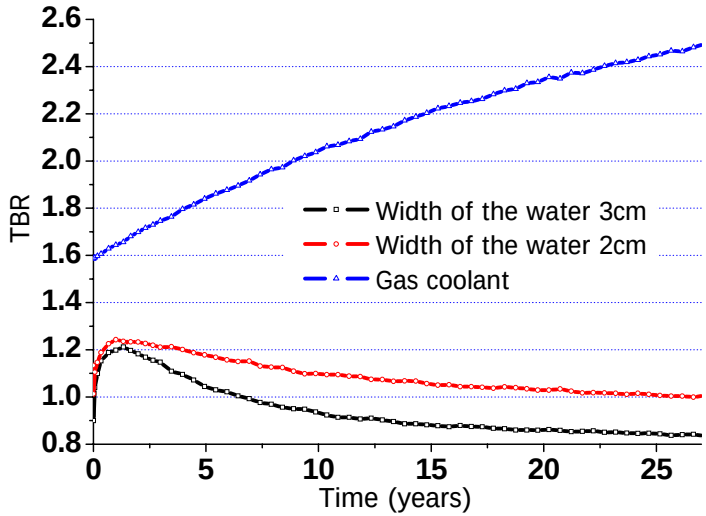


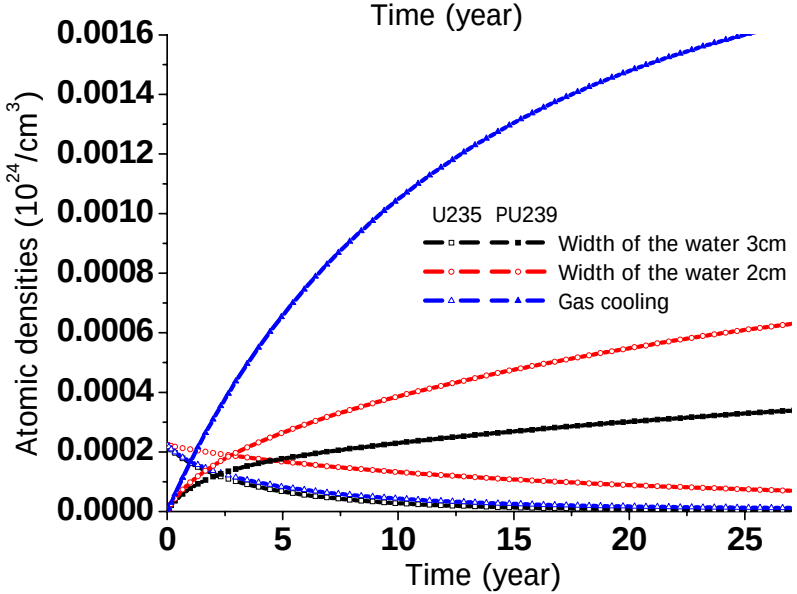


Performance Analyses





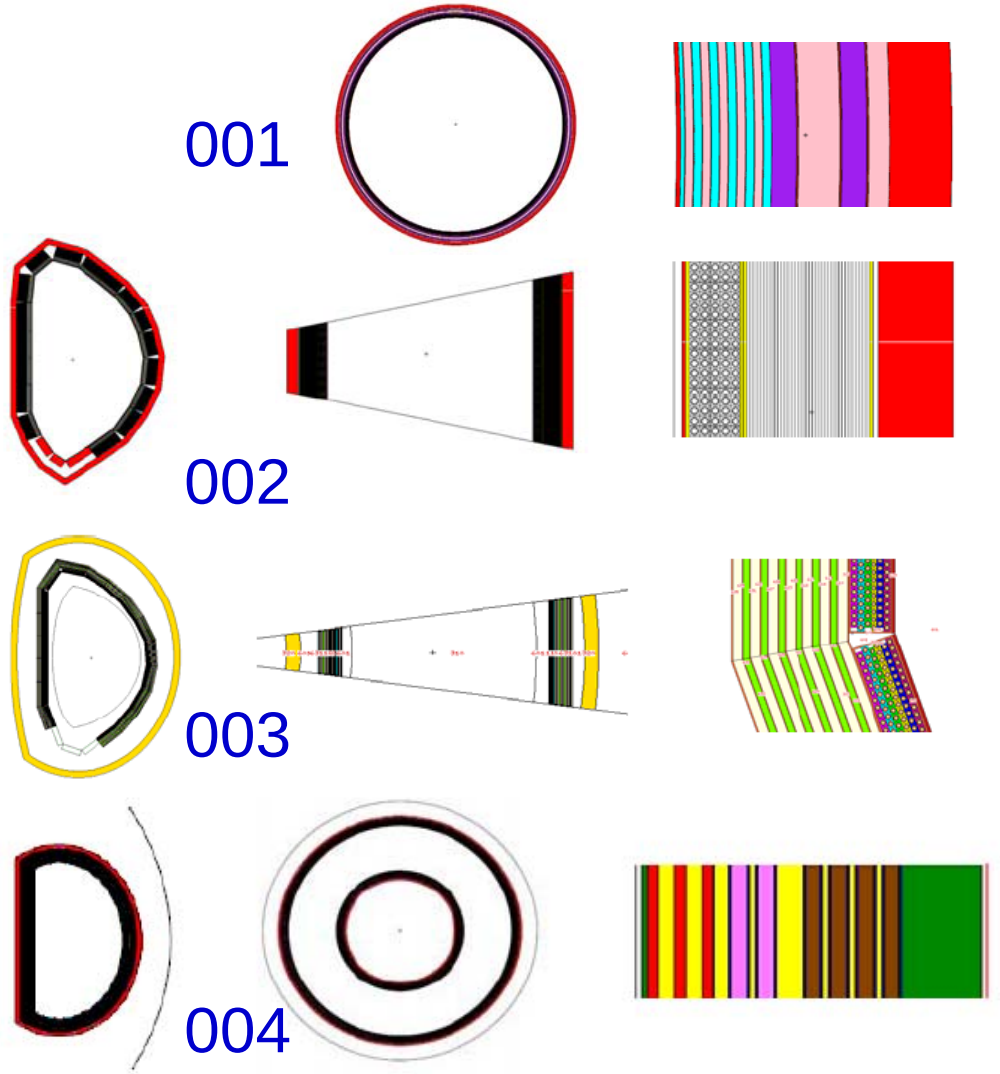




Hybrid Reactor Test Model

In Jan 2011 we released 4 hybrid reactor models to test the nuclear database and computational tools.

There are seven buenup codes in our team, there is discrepancy between each code. We will check them and complete evaluation reports this year.



First Neutronic Workshop

Other concepts

IAPCM

purpose: waste management
fuel supply

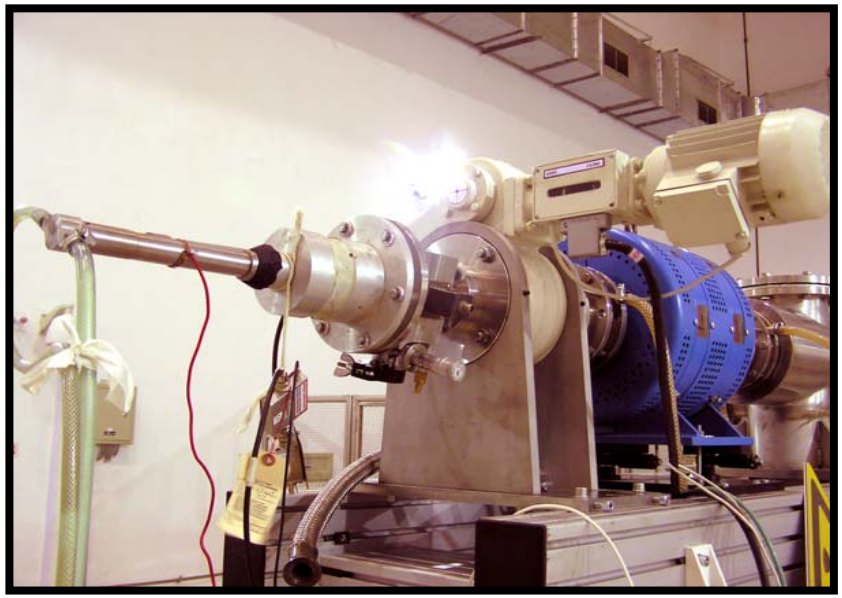
fuel: solid, liquid
thorium
metal, UZrO, UPuN, UPuC

coolant: gas
molten salts

neutron source:
laser ICF
Z-pinch ICF

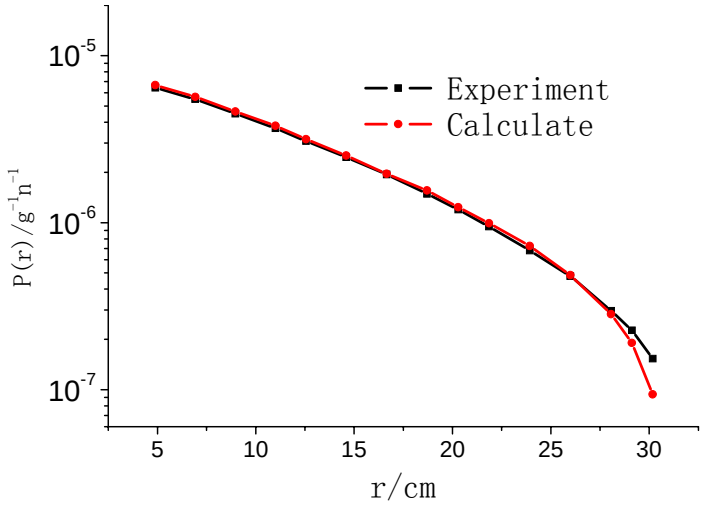
Neutronic Integral Experiments

It is essential to validate the neutron transport calculation and the nuclear database by the integral experiments, such as the measurements of plutonium production rates, fission rates, tritium production rates and neutron spectra. A series of neutronic experiments relevant to Fusion Reactor /Hybrid had been finished based on D-T neutron source in CAEP, China.

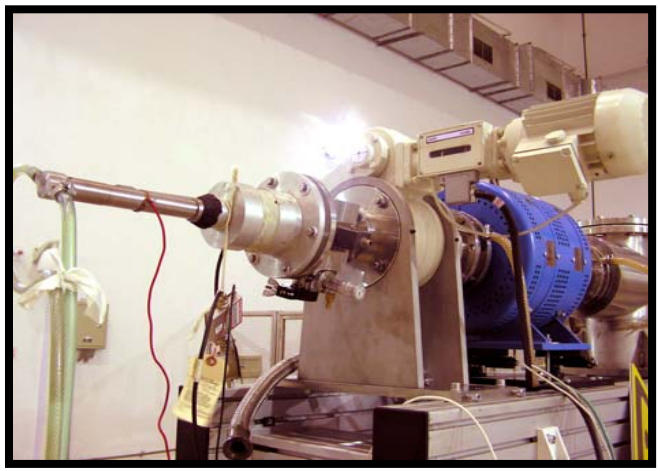


Neutronic Integral Experiments

The experiment measurements of multiplication of D-T neutron in berryllium, lead and plutonium production of 238U in depleted uranium spheral shell had been conducted in the 1980s'.



plutonium production rates



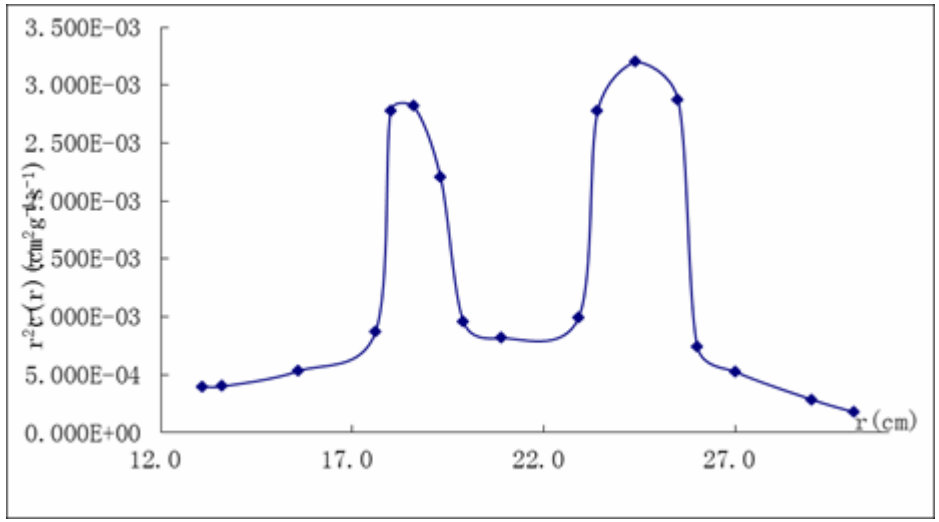
depleted uranium spheral shell

Neutronic Integral Experiments

We use the in existence depleted uranium spheral shell and polyethylene spheral shell for measurements of plutonium production rates, fission rates and neutron spectra.

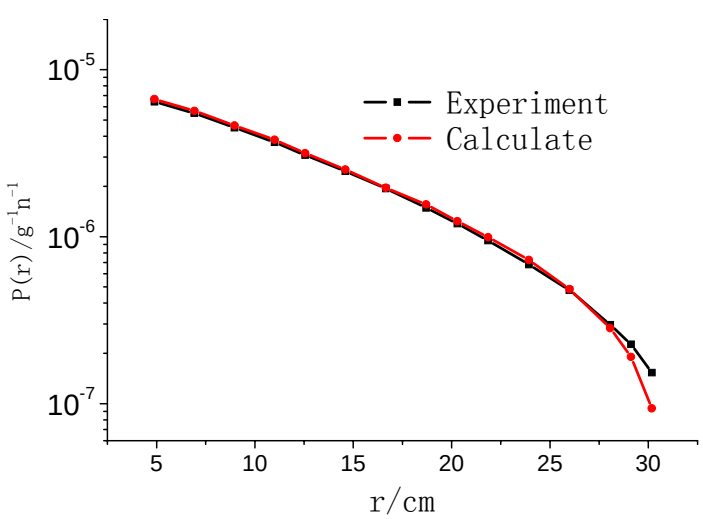
R(mm)	80-131	-181	-194	-233	-254	-300
Material	U	U	U	U	U	U
Material	U	CH_2	U	CH_2	U	U

depleted uranium and CH_2 spheral shell

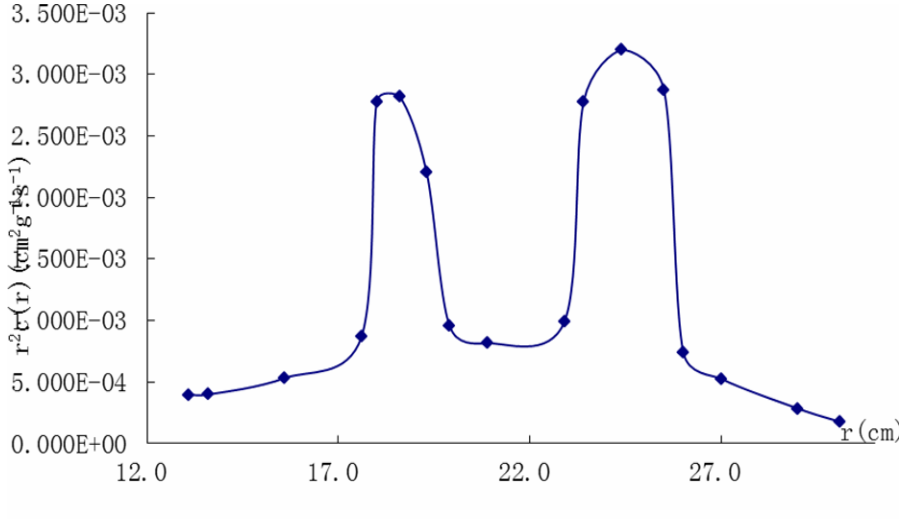


plutonium production rates $r^2C(r)$

Neutronic Integral Experiments



plutonium production rates



plutonium production rates

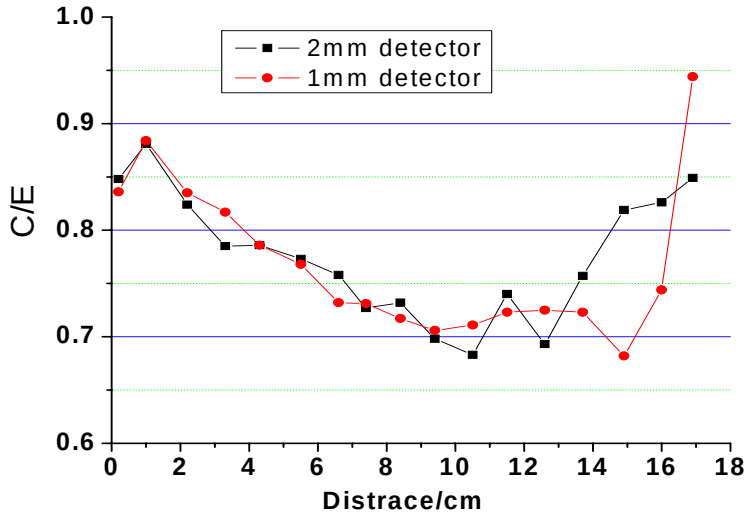
depleted uranium spheral shell

depleted uranium spheral shell

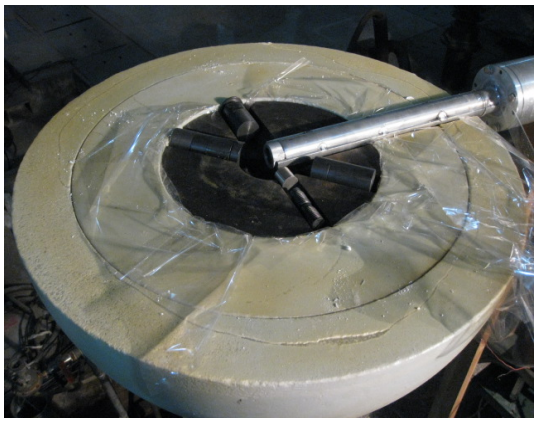
Neutronic Integral Experiments

tritium production rates

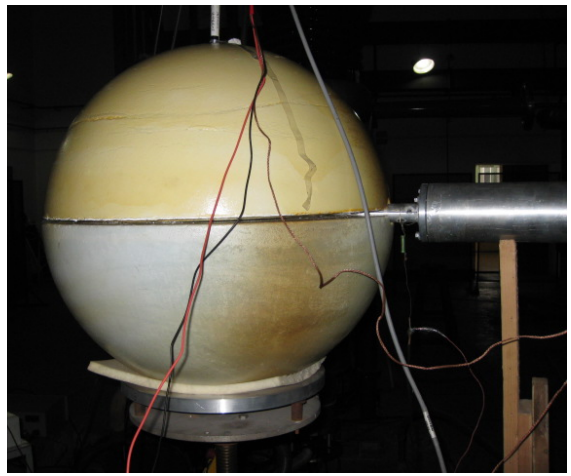
R(mm)	40-131	-300
Material		^{7}LiH
Material	U	^{7}LiH



tritium production rates

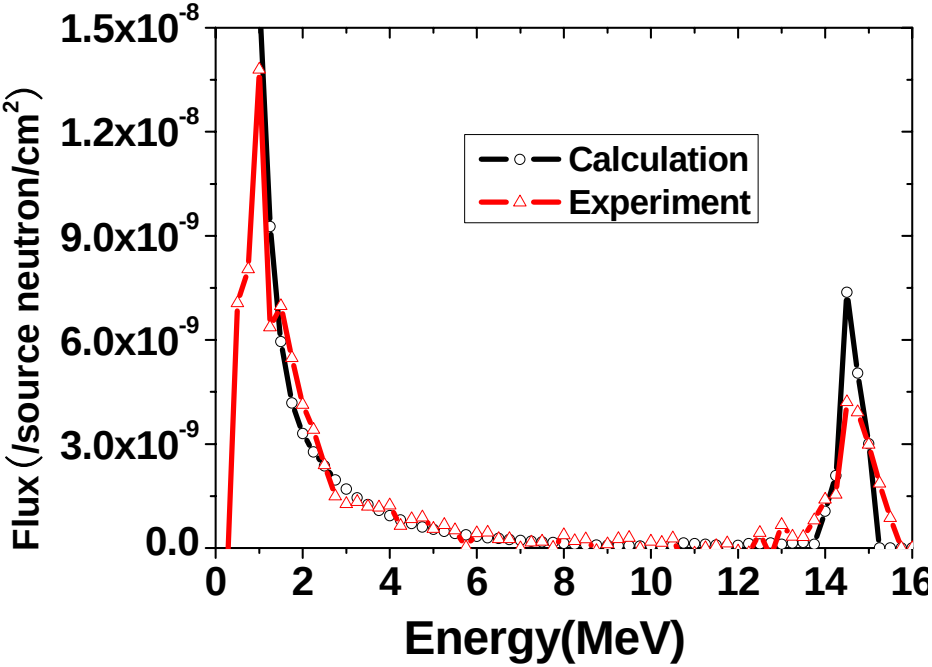


depleted uranium and ^{7}**LiH** spheral shell

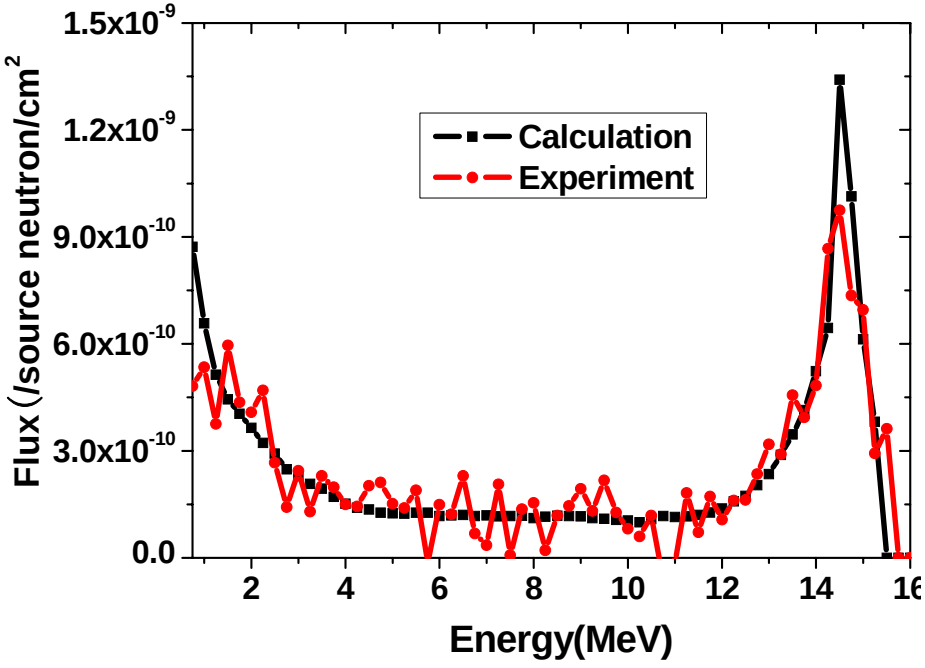


Neutronic Integral Experiments

leakage neutron spectra



depleted uranium spheral shell

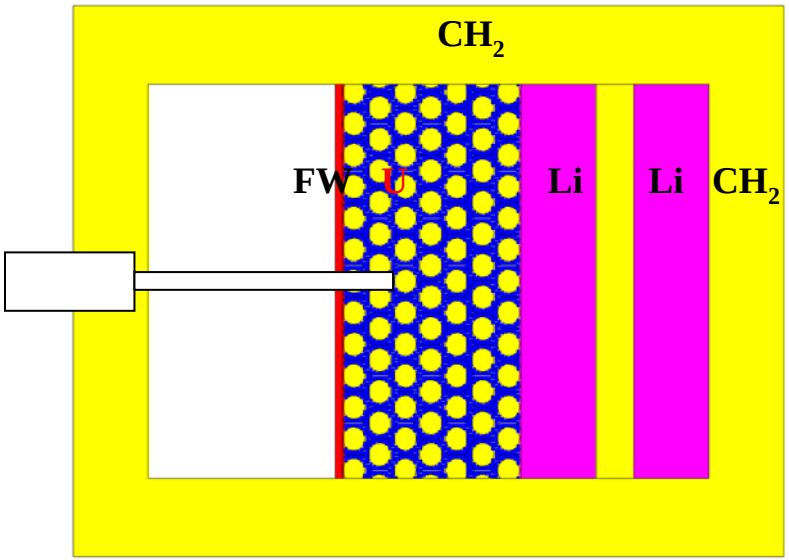


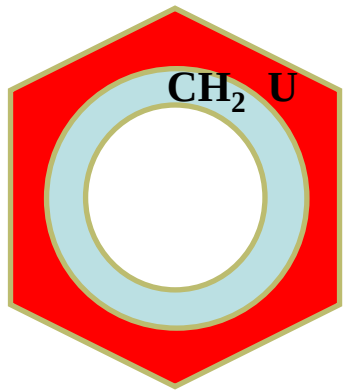
depleted uranium and ^{7}**LiH** spheral shell

Neutronic Integral Experiments

The FFH starts from natural uranium and the light water coolant is in a pressure-tube. We will do the neutronic integral experiments with polyethylene bar in natural uranium cube.

The neutronic optimization studies is doing now and will complete soon. If you are interested in the experiment and have some good ideas I'm willing to discuss with you.





Thermal hydraulic and nuclear fuel cycle

The thermal hydraulic and fuel cycle research will be started soon.

Thermal hydraulic:

The light water hybrid reactor is a pressure-tube rather than a pressure-vessel design. The complexity of the ITER geometries will make the FFH thermal hydraulic design inconvenience.

Reprocessing Technologies:

Pyroprocessing – ability to process short-cooled and specialty fuels being designed for advanced reactors. It is ideal for fast spectrum reactors and fusion-fission hybrid reactor. If oxide fuel is processed, it is converted to metal.

Summary

The conceptual design of the fusion-fission hybrid energy reactors and related verifying experiments was started in 2010.

The purpose of FFH is for energy production with closed fuel cycles.

The project is primarily focus on the sub-critical blanket design.

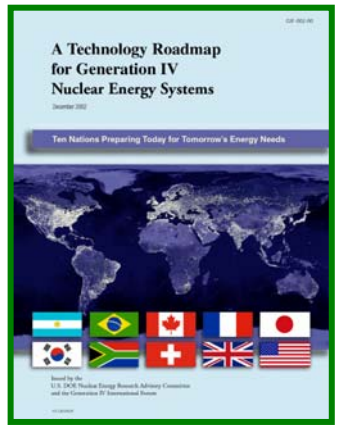
The research area including:

- neutronics,
- thermal hydraulic,
- fuel manufacture and nuclear fuel cycle

Summary

The fusion-fission hybrid is lesser developed than the alternatives for the same purpose, such as fast breeders, fast burners, accelerator-driven hybrids, and repositories of various types. The fist thing we have to do is classified the FFH with the neutron source, fuel type, coolants for the purposes and review them by certain criterions. before 2015, could we accomplish:

A Technology Roadmap for Fusion-Fission Hybrid Nuclear Energy System.



Thanks!