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ADS-NWT Design and R&D Plan

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Content

- **Background**
- **ADS-NWT Conceptual Design**
- **R&D for ADS-NWT reactor**
- **Summary**

Fission Power Development and new problem

(Prediction on Future Fission at 2050, China)

Scenario	Ratio A	Ratio B	Nucl. Power	Capacity (Approximate Scale)
Low Level	10%	6%	120GW	Double in France
Mid. Level	20%	12%	240GW	Sum in US, France and RF
High Level	30%	18%	360GW	Sum all over the world

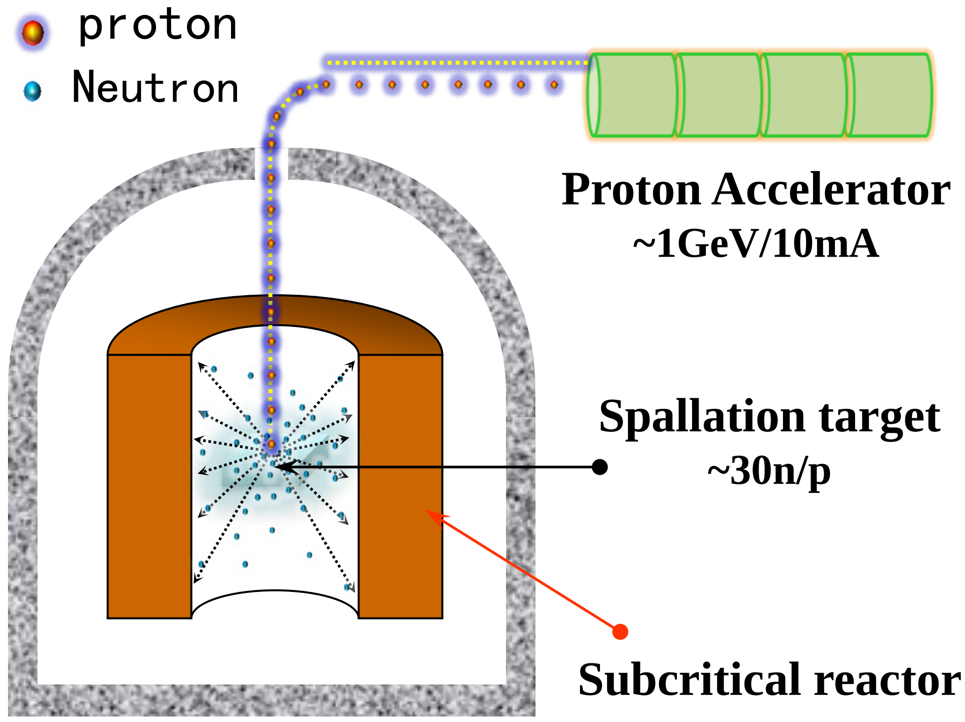
A: fraction of nucl. power in total electricity capacity

B: fraction of nucl. power in total primary energy capacity

- **Nuclear fuel supply ?**
- **Radioactive waste disposal ?**
- **Safety problem ?**

Accelerator Driven Sub-critical system (ADS)

- Accelerator supplies spallation neutrons to driven the fission reactions in subcritical reactor.
- Energy from the reactor provides electricity to the accelerator



Main function:

1. Eneygy production: n + U/Pu/MA ➔ Energy
2. Fuel breeding: n + U^{238}/Th^{232} ➔ Fissile
3. Waste transmutation: n + MA/FP ➔ less-harmful nucleus

Main Benefits of ADS

➢ Characteristics:

- Acceptable safety margin in fast spectrum
- Accelerator system control the reactor
- Can burn minor actinides
- Particularly good for closed fuel cycle
- Thorium fuel instead of uranium

➢ Benefits:

- sustainability (fuel efficiency)
- proliferation resistance
- environment
- safety

■ Chinese Academy of Sciences (CAS) has been carried out an ADS Project, and conducting an associated R&D support program.

Significant Challenges of ADS

Accelerator Performance

- achievable beam power
- reliability and required maintenance

Target station performance

- Very high heat power
- Radiation damage
- Heavy liquid metal corrosion

Subcritical reactor

- High power density and asymmetry distribution
- Heavy liquid metal corrosion

Characteristics of Liquid Lead-Bismuth Eutectic (LBE)

➢ Advantages

- Excellent neutron properties, higher neutron flux
- Good thermal conductivity, a lower operation temperature
- Low chemical activity, more safety
- Liquid metal, no radiation damage

➢ Challenges

- Compatibility of LBE with structure materials
- Flow and heat transfer characteristics of LBE

■ **Liquid Lead-Bismuth Eutectic has the good potential as the target and coolant.**

■ **LBE loops are the necessary devices for the materials technology and thermalhydraulics challenges.**

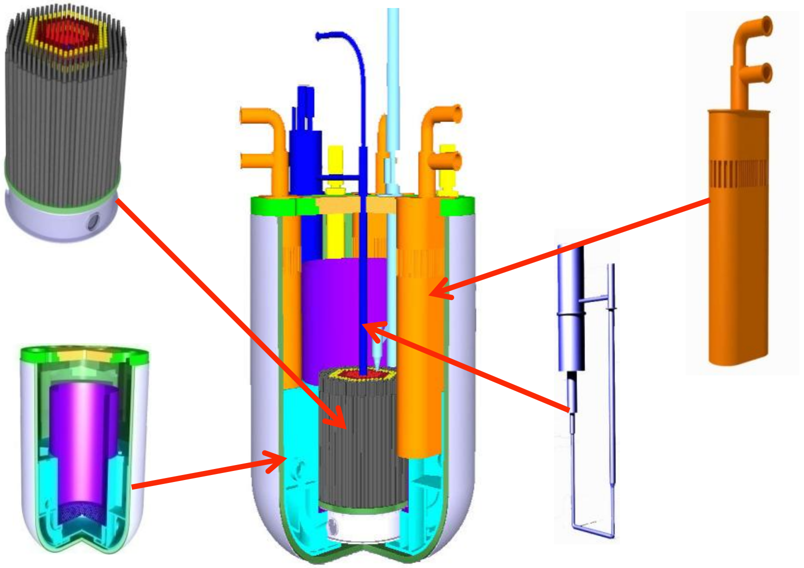
Content

- **Background**
- **ADS-NWT Conceptual Design**
  - **Design objective and principle**
  - **Blanket design**
  - **Spallation target design**
- **R&D for ADS-NWT reactor**
- **Summary**

ADS-NWT Design Objective and Principle

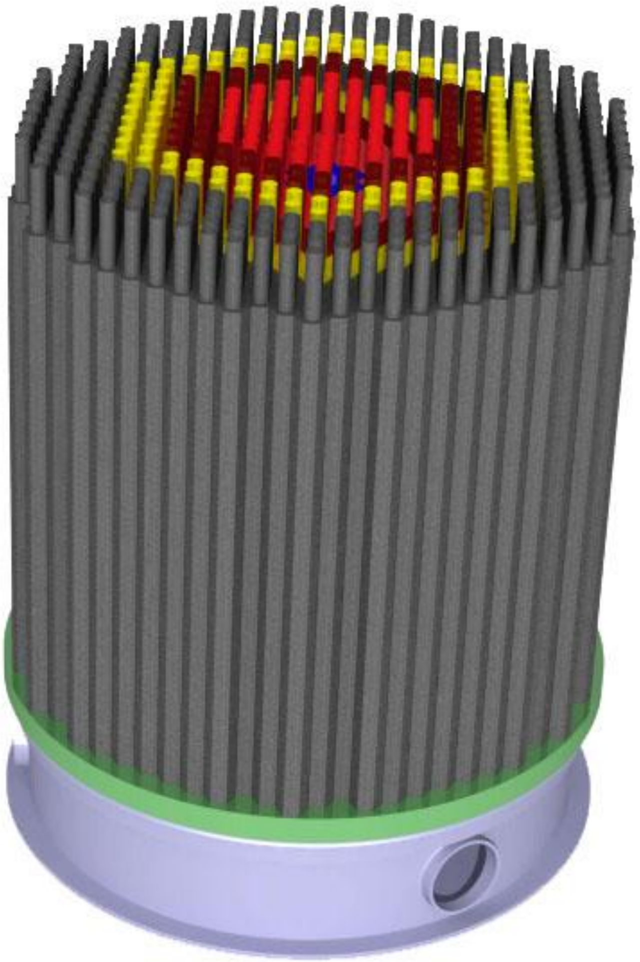
- **Design object: Demonstrate the technologies of transmutation of nuclear waste technologies of commercial ADS**

Design objective	Waste transmutation
Accelerator power	15MW(1.5GeV/10mA)
Keff	~0.98
Thermal power	~1000 MW
Spallation target	Windowless Pb-Bi Target
Fuel	TRU+Zr
Coolant	Liquid Pb-Bi



Blanket Structure Design

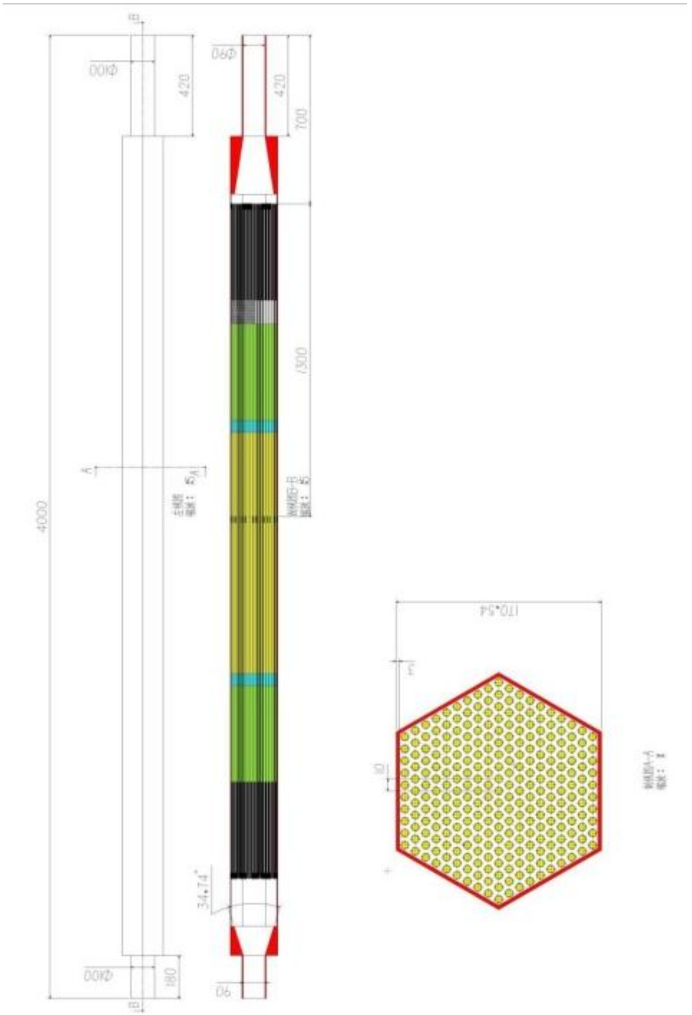
Design parameter	
Power	1000 MWth
Coolant	LBE
Inlet temperature	330℃
Outlet temperature	480 ℃
Max velocity	1.68 m/s
Core diameter	4.05 m
Core height	3.8 m
Active core height	1m
Assembly	390



Detailed design is presented in Poster 2.7.26

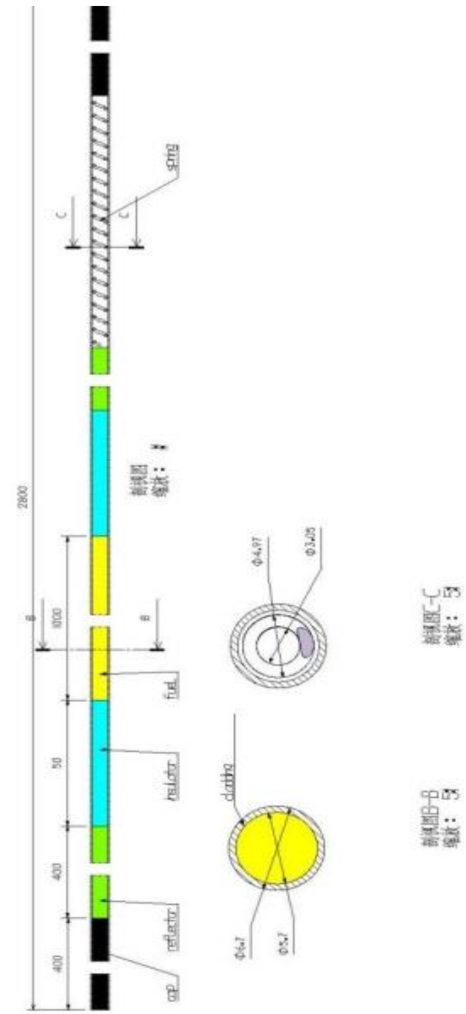
Fuel Assemblies Structure Design

Fuel assemblies design parameters	
number	210
shape	hexagon
pitch	17.45 cm
height	3.8 m
Cladding material	T91
Cladding thickness	0.50cm
Rods per assembly	271
Assembly coolant flow rate	208 kg/s
Maximum zone power density	170(w/cm^3)
Average blanket power density	26(w/cm^3)



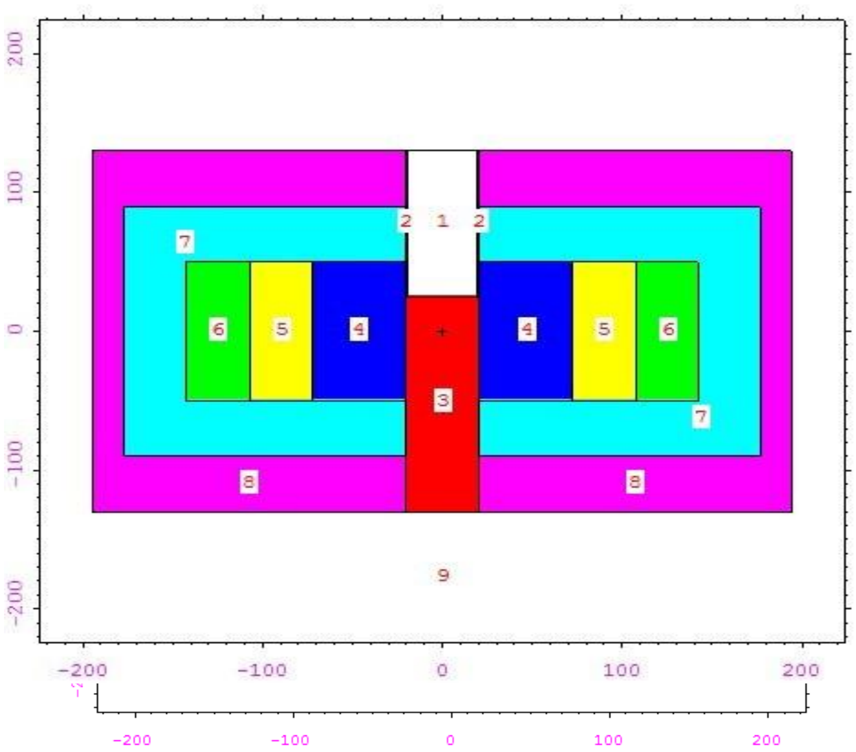
Fuel rods structure design

Fuel rods design parameters	
Number per assembly	271
Total height	1.8m
shape	cylinder
Active zone height	1m
Outer diameter	0.67cm
Pitch-to-diamter ratio	1.49
Cladding material	T91
Cladding thickness	0.10cm
Fuel form	dispersed
Fuel elements	TRU+Zr



Neutronics Model & Structure

zone	material(fraction%)	Thickness (cm)
Spallation target 3	PbBi(100)	20.150
Internal fuel zone 4	TRU(3.8)+ZR(20.53)+ PbBi(57)+T91 (16.67)	52.362
Middle fuel zone 5	TRU(4.3)+ZR(20.53)+ PbBi(57)+T91 (16.67)	34.908
External fuel zone 6	TRU(5.6)+ZR(18.73)+ PbBi(57)+T91 (16.67)	34.908
Reflector zone 7	PbBi(93.1)+T91 (6.9)	34.908
Shielding zone 8	T91(6.9)+B4C(83.1) +PbBi(10)	17.454



Neutronics Performance Parameters

Fuel zone elments	Vol（%）
T91 steel	17
LBE	57
Zr	20
TRU	5
Initial TRU loading(t)	3.84
Initial neutronics paramters	
Keff	0.98
MF=1/(1-keff)	50
Thermal power(MW)	1130
MA burnup per year(kg)	400
Power peaking factor	1.61
Maximum zone power density(w/cm^3)	170
Average blanket power density(w/cm^3)	26

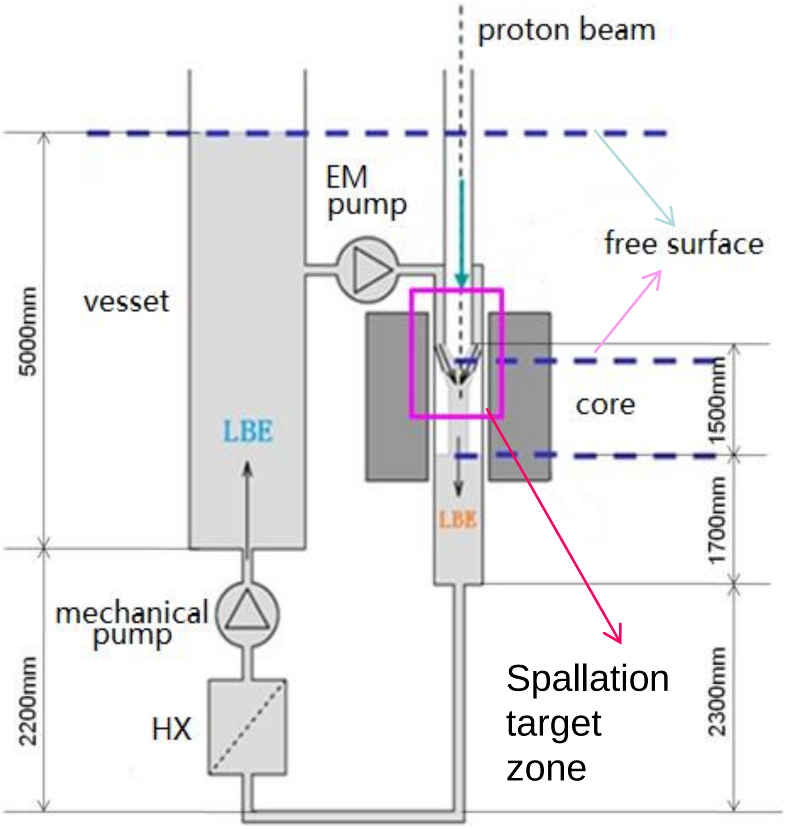
Detailed design is presented in Poster 1.7.25

Thermohydraulics Parameters

Parameter	value	unit
Coolant	LBE	
Coolant mass	~4000	ton
Coolant driven means	Forced convection	
Coolant flow height	10.7	m
Coolant pressure	1	MPa
Heat exchanger heat transfer	400X3	MW
Core inlet temperature	330	℃
Core outlet temperature	480	℃
Cladding maximum temperature	550	℃
Rod maximum surface heat flow rate	1	W/cm2
Coolant flow rate	43.7	ton/s
Coolant average velocity	1.68	m/s

Windowless Target Design

- Accelerator power: 1.5 GeV, 10 mA
- Heat deposition: ~8MW
- Structure materials: T91
- Diamater: 320mm
- Coolant flow rate: 570kg/s, velocity: 1.78m/s
- Coolant inlet temperature: 230℃
- Coolant outlet temperature: 328℃
- Driven means: mechanical pump+EM pump, forced convection



Target loop

Content

- **Background**
- **ADS-NWT Conceptual Design**
- **R&D Activities for ADS-NWT**
  - **Lead-bismuth loop development plan**
  - **Design software**
  - **China LEad-bismuth cooled Accelerator driven Reactor(CLEAR)**
  - **Planned Roadmap of ADS Development**
- **Summary**

Kylin Loops and Verification Facilities

Loop name	Type	Function	Temperature	Time
Kylin-I	TC*	Compatibility test under flowing PbBi	480-550^{O}C	Completed
Kylin-II	FC	Compatibility, flowing behavior, oxygen control unit and purification system	300~600^{O}C	2010-2012
Kylin-III	FC	thermal-hydraulics of target and reactor	300-600^{O}C	2014
Kylin-S^{T}	Static	Compatibility test in the static PbBi	200~800^{O}C	2010
Kylin-R^{T}	Flowing	Compatibility test in the rotation flowing PbBi	480~600^{O}C	2010

*TC -- Thermal Convection, FC -- Forced Convection, ST -- Static Test, RT -- Rotation Test

Series of PbBi experimental loops and verification facilities for the ADS system are going to design and built in Chinese Academy of Sciences.

Thermal Convection PbBi Loop--Kylin-I

Design Objectives:

- Thermal convection loop
- Obtain corrosion behavior of SS316L /T92 and CLAM (China low acitivation martensitic) steel

Major parameters:

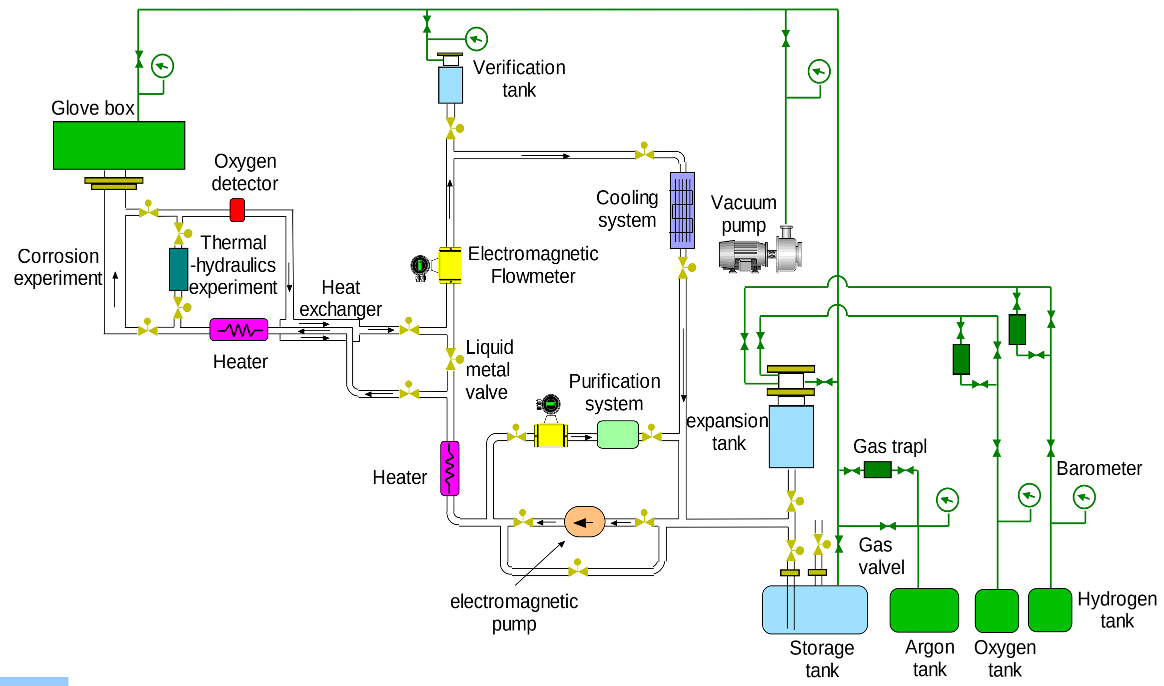
- Loop size : 0.5m×0.5m
- Structural Material : SS316L
- Inner/out-diameter : 42/32mm
- Temperature : 480 ~ 550℃

This loop has been built in May 2010 and operation time exceeds 500 hours.

Forced Convection PbBi Loop--Kylin-II

Main Parameters:

Parameter	Value
Temp. of corrosion experiment section	600°C
Velocity of corrosion experiment section	3m/s
Electromagnetic pump pressure head	0.5MPa
Temperature of low temperature section	450°C

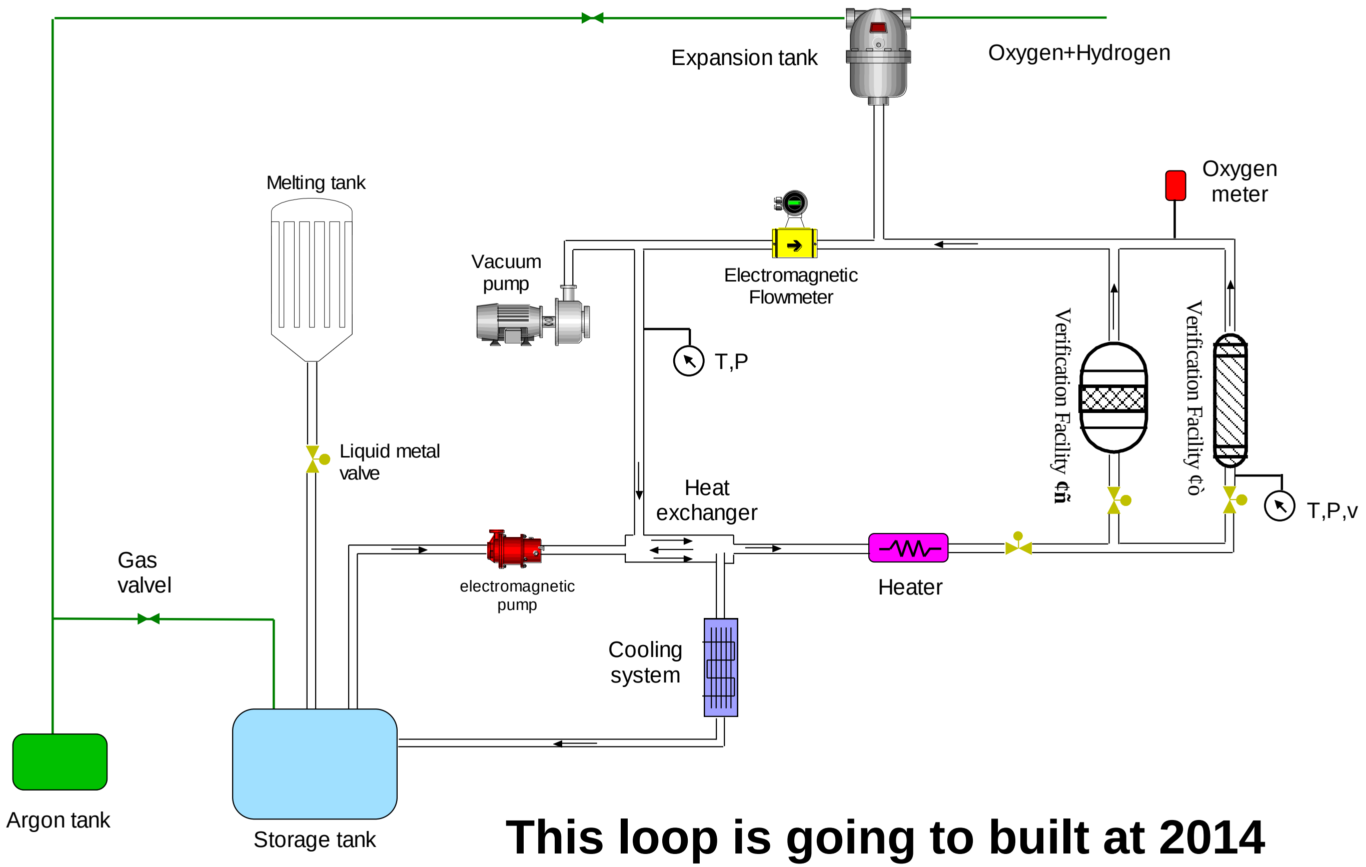


Main Components:

- **Electromagnetic/mechanical pump**
- **Oxygen concentration control system**
- **Purification system**
- **Cooling system**
- **Test sections**

This loop is going to built at the end of 2012

Large-scale PbBi Loop for Thermohydraulics Verification--Kylin-III



This loop is going to built at 2014

VisualBUS

Multi-Functional Integrated 4D Neutronics Simulation System

Main Functions

I. 4D: Coupled Calculation

- Particle Transport
- Fuel Isotope Burnup
- Material Activation & Irradiation Damage
- Radiation Dose
- Fuel cycle management

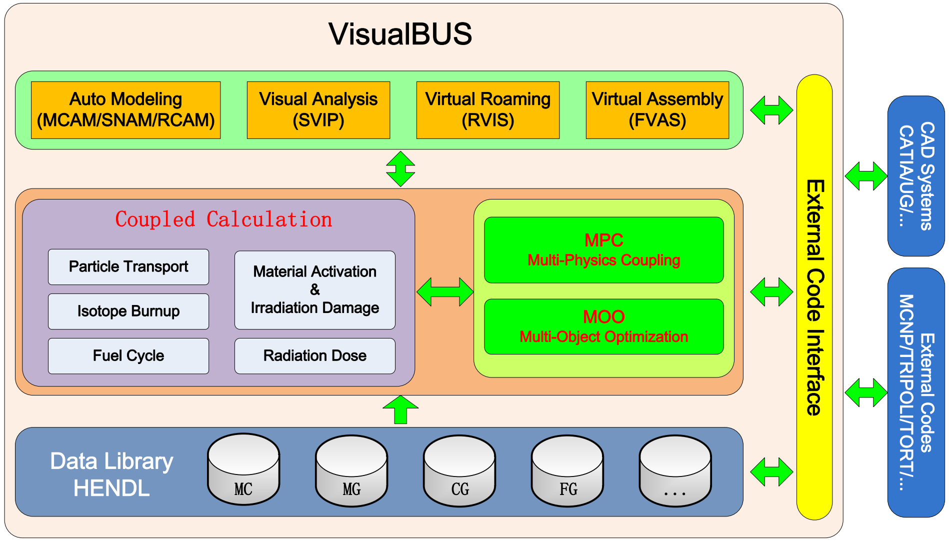
II. 4D: Automatic Modeling

- Monte Carlo (MC) geometries
- Discrete Ordinates (SN) geometries
- MC-SN coupled geometries
- Human dosimetry models reconstructed

III.4D: Visualized Analysis

- Static / dynamic physical data fields
- Virtual roaming and dosimetry assessment
- Virtual assembling of component models

- Multi-functions in One System
- Convenient Operation
- Easy-Upgrading / Integration



China LEad-bismuth cooled Accelerator driven Reactor (CLEAR)

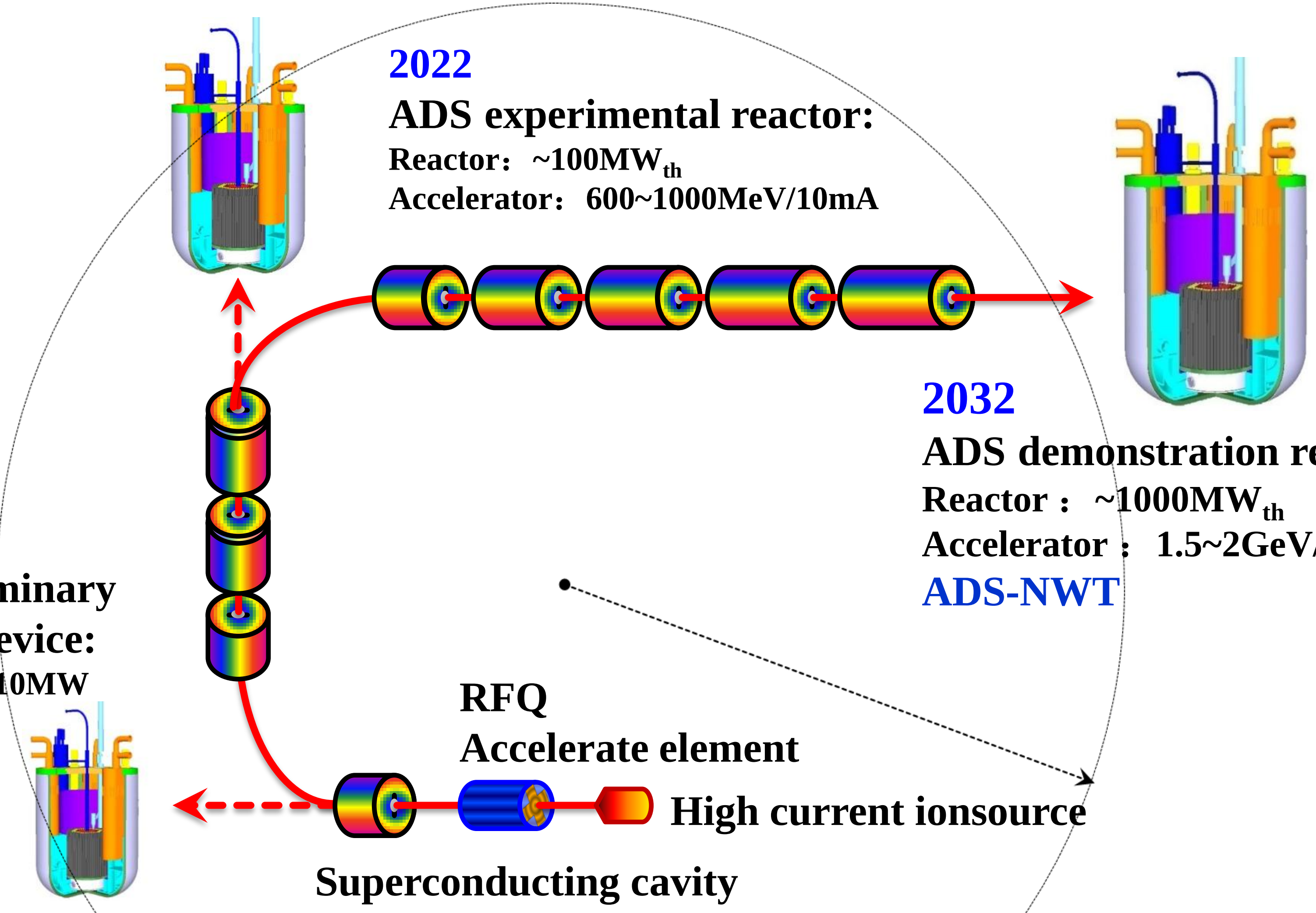
- **Project objective**

  To build a lead-bismuth cooled experimental reactor, which can be operated on critically (5-10MW_{th}) and subcritically driven by spallation neutrons in about 7 years.

- **Key testing issues for PbBi reactor**
  - Neutronics, thermohydraulics and safety characteristics;
  - Material issues and component technologies
  - Operation and control technologies
- **Conceptual design is underway**

Accelerator power	K_{eff}	Core power(MW)	Neutron spectrum	Target	coolant	Fuel
50-150MeV	~1	5-10	FR	LBE (window)	PbBi	UO2

Planned Roadmap of ADS Development



2017
ADS preliminary research device:
Reactor： 5~10MW
CLEAR

2022
ADS experimental reactor:
Reactor： ~100MW$_{th}$
Accelerator： 600~1000MeV/10mA

2032
ADS demonstration reactor
Reactor： ~1000MW$_{th}$
Accelerator： 1.5~2GeV/>10mA
ADS-NWT

Summary

- LBE-cooled subcritical ADS has a good potential for nuclear waste transmutation, which has been selected by CAS as the ADS reference design;
- FDS team now is developing the DEMO (ADS-NWT) and China LEad-bismuth cooled Accelerator driven Reactor (CLEAR) design and doing R&D work for reactor construction and operation;
- Based on the reference design, ~400kg MA will be burned up per year, and the detailed design and analysis is underway;
- CLEAR reactor will be built in the next 7 years, widely international and domestic cooperation about the reactor design and technology development is welcome.

The End

Thanks for your attention !

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