

**The 15th Intern. Conf. on Accelerator and Large
Experimental Physics Control Systems (ICALEPCS15)**

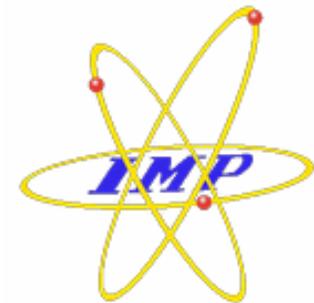
Control systems for spallation target in China ADS systems

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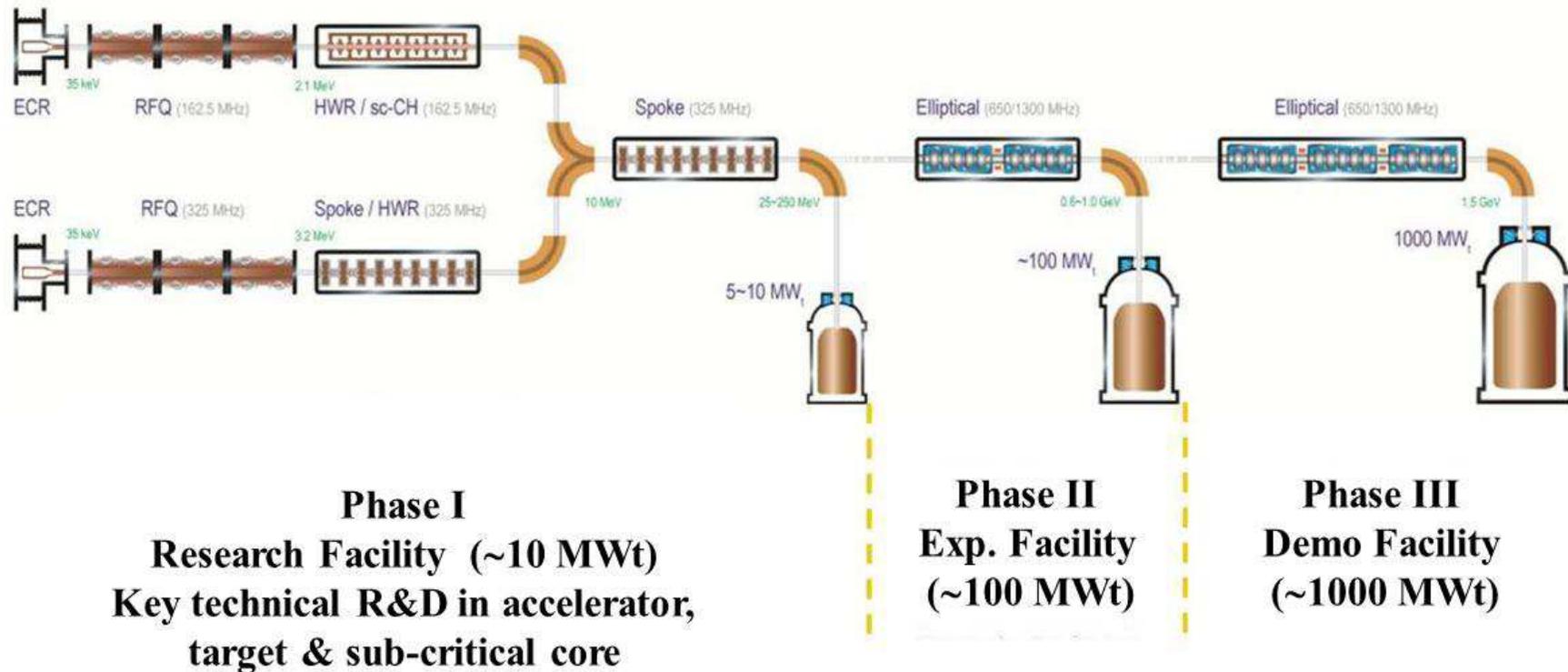
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Supported by Chinese Academy of Sciences

1. China ADS system

Accelerator driven sub-critical (ADS) System



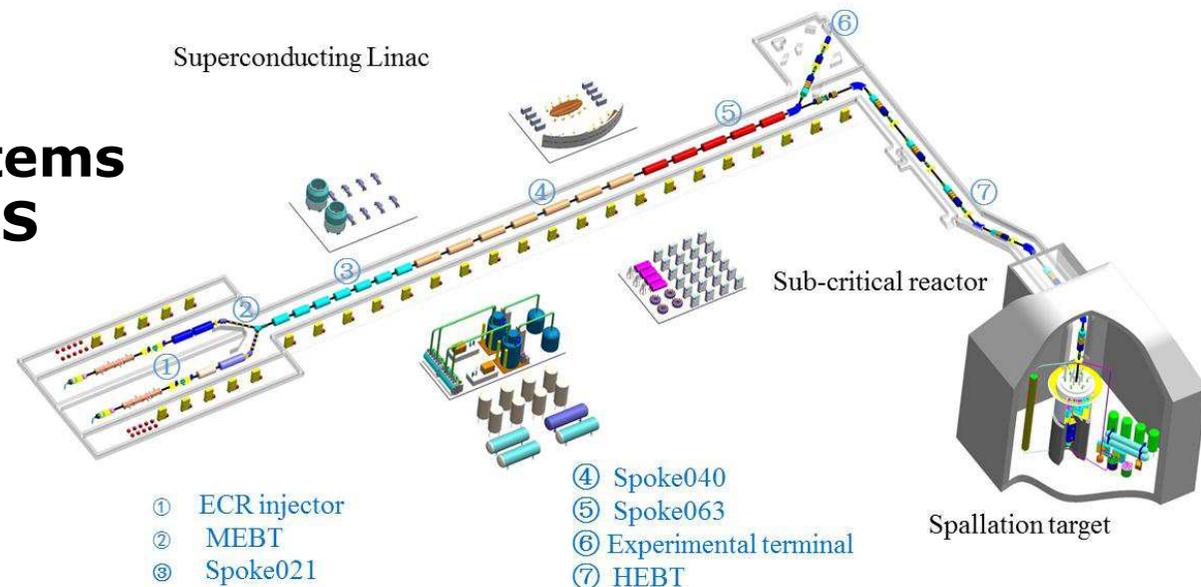
ADS Roadmap in China

1. China ADS system

Phase 1: China Initiative ADS System

- **Approved budget 1.78B RMB from 2011 to 2016 for key technology R&D:**
 - R&D for Accelerator , Target, Reactor
 - Related Research, Support system
- **Planned budget for CIADS research facility: 1.8B RMB from 2017 to 2022.**

Layout of main systems in China initiative ADS



1. China ADS system

China Initiative ADS system includes

- **A proton LINAC accelerator:**

- Beam energy: 250 MeV,
- Beam current: 10 mA.

- **A high-power spallation target:**

- Tungsten W: Granular flow target

- **A sub-critical reactor:**

- The maximum thermal power : 10 MW,
- The maximum incore neutron flux: $2 \times 10^{14} \text{ n/cm}^2/\text{s}$

2. Control system for the target

Control systems for China Initiative ADS

- **One central control system:**

for the control and operation of the overall ADS system

- **One nuclear-safety-related system:**

for the safety and protection system of the reactor

- **Several local control systems:**

To control the auxiliary subsystems for the accelerators, the target and the reactor.

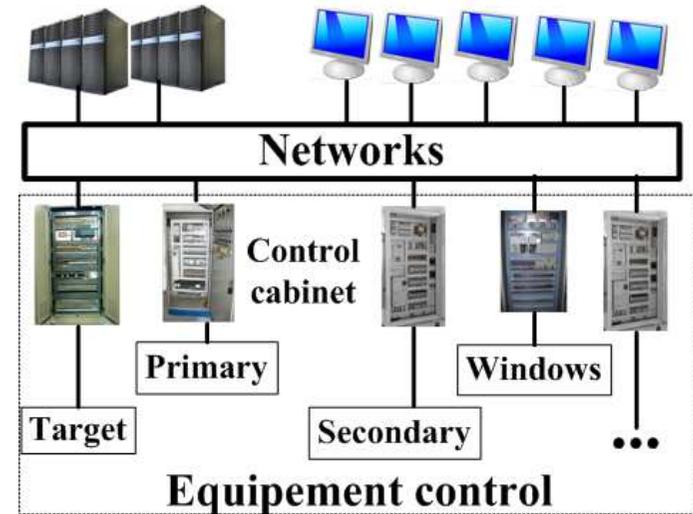
Control system for the target

- is one part of the central control system,
- is used to control various subsystems of the target.

2. Control system for the target

Three-layer architecture:

- The top **operation** layer,
- The middle **network** layer,
- The bottom **equipment** layer.



Main functions in the equipment control layer:

- **The target core subsystem:**

To monitor both neutron and temperature.

- **Primary and secondary cooling loop, target window and its cooling loop:**

To monitor and control the process parameters (temperature, pressure, flow-speed of coolants, ...).

2. Control system for the target

Networks in the middle layer

Total **six** networks for China Initiative ADS :

- an central operation network,
- a time communication network,
- a data archiving network
- three networks for
 - **reactor's** safety and protection system,
 - **accelerator's** machine protection system,
 - **personnel** protection System.
- **Three networks for the target:**
Operation, personnel protection, and data network.

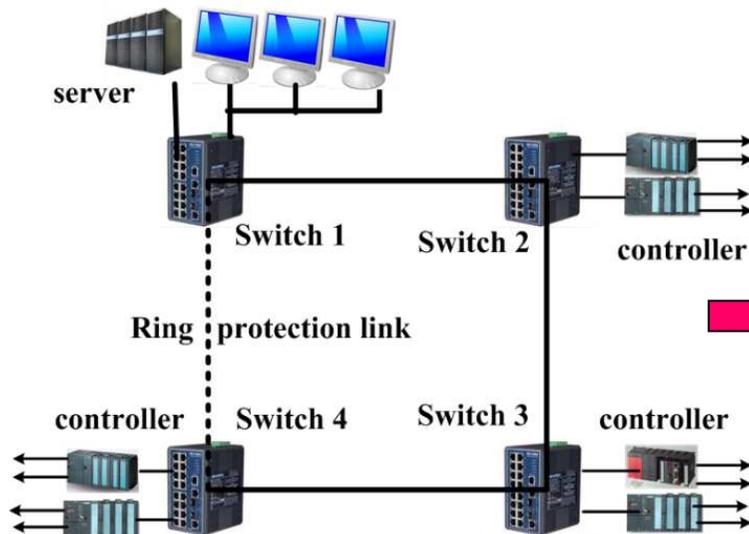
Redundancy protocols to improve the reliability

2. Control system for the target

Redundant Ethernets based on ITU-T G.8032

Ethernet ring protection (ERP) protocol in ITU-T G. 8032

- Several switches form a logical ring,
- blocking a link port, referred to as Ring Protection Link,
- Once a link fails, the RPL is unblocked.



We have built an ERP network for the target:

Four switches form one ring:

Switch EKI-7657C

from Advantech company
(<http://www.advantech.com/>)

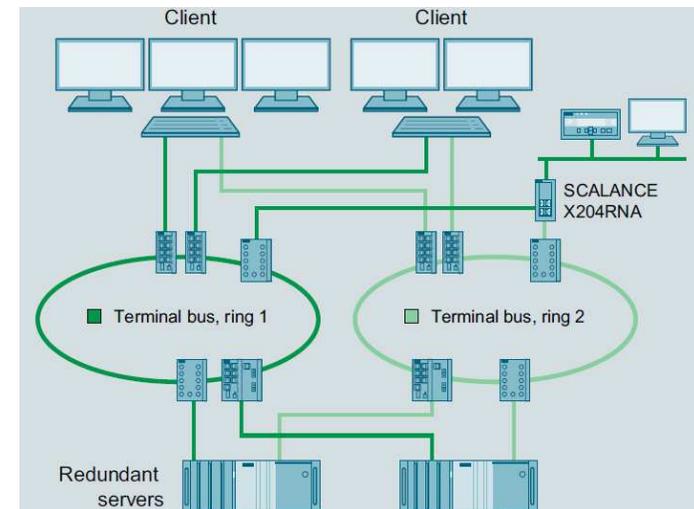
2. Control system for the target

Redundant Ethernets based on IEC 62439-3

- **Parallel Redundancy Protocol (PRP):**
To use two **independent** networks of any topology
- **High-availability Seamless redundancy (HSR)**
 - To use several switches in one ring
 - Each terminal device doubles each frame, and sends out two duplicates via the ring ports

To consider a PRP network as in Siemens SIMATIC PCS 7

- **PRP:** two fully independent Ethernet sub-networks,
- **HSR:** terminal devices with HSR functionality, such as SCALANCE X204RNA.



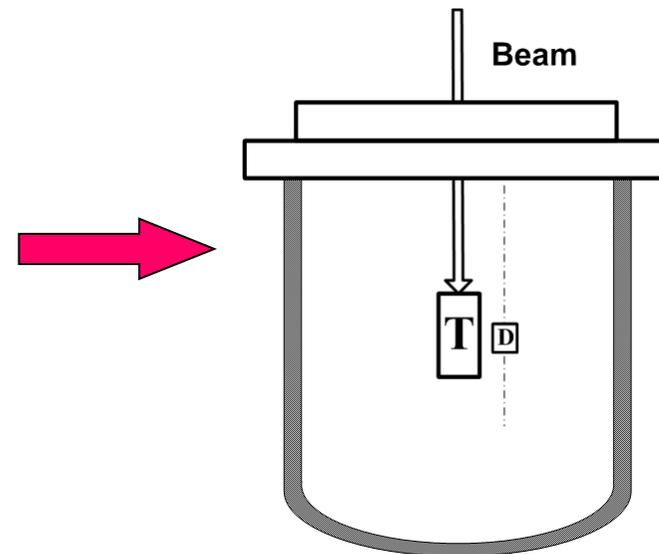
3. Equipment control

Neutron monitoring for the target

Neutron monitoring is necessary:

- for the beam **commissioning** of the accelerator,
- to better characterize the conditions within the **reactor**,
- to better investigate interrelationship among various parameters of **accelerator** and **target**.

Detector **D** must be put within the reactor core, because target **T** is located at the centre of the reactor core.



3. Equipment control

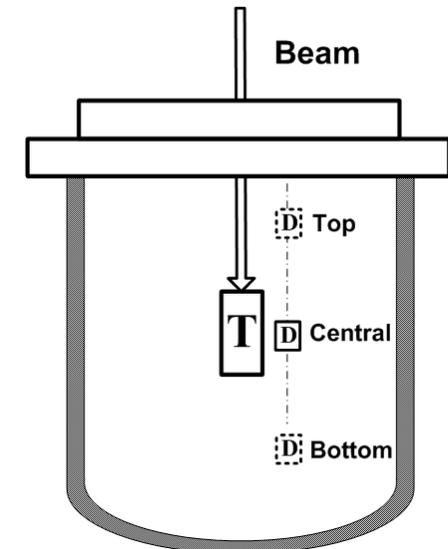
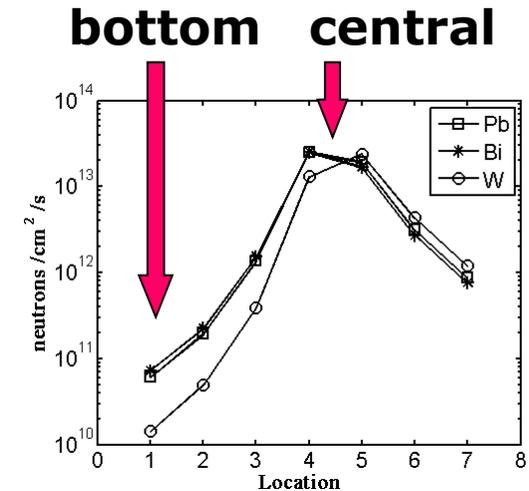
Neutron monitoring for the target

Multi-point measurement:

- to measure neutrons at the top, central, and bottom locations,
- because the central neutrons is 100 folds higher than the lower neutrons.

Motion control for neutron detector:

- It consists of drive units, limit switch assemblies, and rotary transfer devices.
- Method used in the pressurized water reactor.



3. Equipment control

Temperature monitor and control in cooling loops

Temperature control system:

- **Several temperature sensors:**

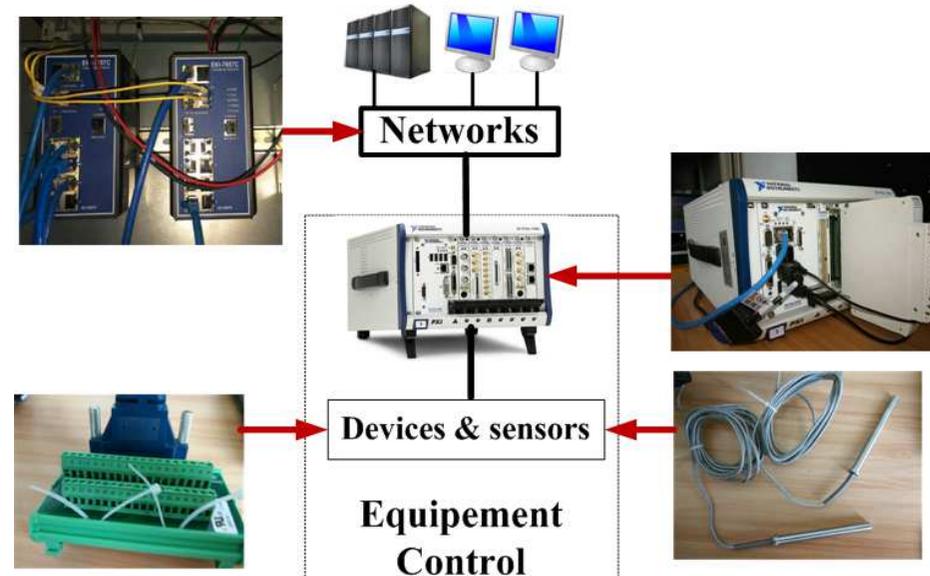
the thermocouple and the resistance temperature detectors,

- **Several temperature controllers:**

to control valves, pumps and flow speed.

N.I. products used:

- Control chassis, PXIe-1082
- thermocouple: PXIe-4353 and TB-4353.
- RTD: PXIe-4357 RTD module and TB-4357 terminal block,
- DAQ board PXI-6238.



3. Equipment control

Process control system for cooling loops

Siemens SIMATIC PCS 7:

- two redundant CPUs,
- redundant operator systems,
- redundant terminal bus
- redundant power supply modules

The automation systems of the S7-400 series :

- Standard automation systems
- Fault-tolerant automation systems
- Safety-related automation systems

Standard and fault-tolerant automation systems are being built for:

the cooling loops of the spallation target.



3. Equipment control

Process control system for cooling loops

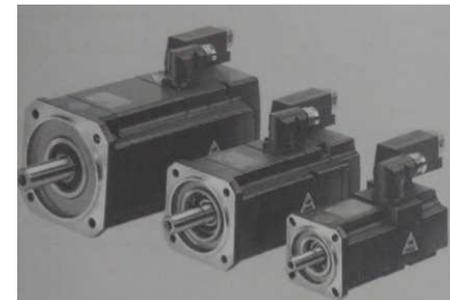
Siemens SIMATIC PCS 7:

- two redundant CPUs,
- redundant operator systems,
- redundant terminal bus
- redundant power supply modules



The automation systems of the S7-400 series :

- SIMATIC S7-400 process controller
- CPU 414-5 H PN/DP redundancy
- 8 Channels Thermocouple/RTD modules
- 16 Channels DI/DO modules
- Network adapter card: CP1623
- SIMOTION D435-2 DP/PN controller
- Synchronous servo motor



3. Equipment control

Robust electronics used in the reactor room

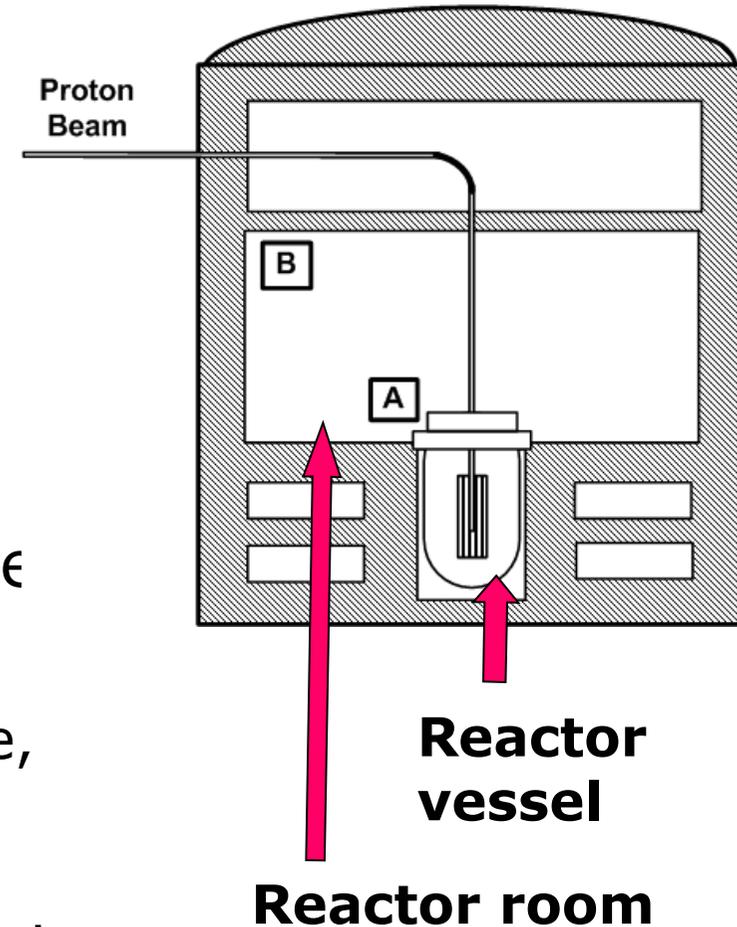
- **Neutron flux:**

- Incore: $2 \times 10^{14} \text{ n/cm}^2/\text{s}$.
- Location A: $1 \times 10^8 \text{ n/cm}^2/\text{s}$
- Location B: $1 \times 10^7 \text{ n/cm}^2/\text{s}$
(Electronics for target).

- To mitigate the neutron-induced **radiation effects** :

- Neutron shielding with polyethylene,
- the shielding thickness: 30 cm.

Simulation based on Geant4 codes.



Accelerator versus reactor

How to integrate accelerator's CS and reactor's I&C into one system

Example 1: Control software:

- EPICS has been used for accelerator and target in ADS,
- EPICS is being considered for the non-safety-related systems of the reactor.

Example 2: Naming convention:

- Accelerator: Naming convention SNS, FRIB, ITER, CEBAF, and ESS.
- Target and reactor: identification codes in power plants.
 - CCC code in England, EDF code in France,
 - EIIS code in USA, ERDS code in European,
 - KKS code in Germany.
- One or two sets for ADS?

Conculsion

- **A three-layer** control system for the target,
 - Operation, network, and equipment control layers.
- **Three networks** are required in the middle layer.
 - An operation network,
 - A personnel protection network,
 - A data archiving network.
- **Three topics** are discussed about the bottom layer.
 - I&C for neutron monitoring,
 - I&C for process control system in cooling loops,
 - Method for mitigating the neutron-induced radiation.

It is a hard work to integrate two totally different facilities, **an accelerator and a reactor**, into a system.

Thank you !