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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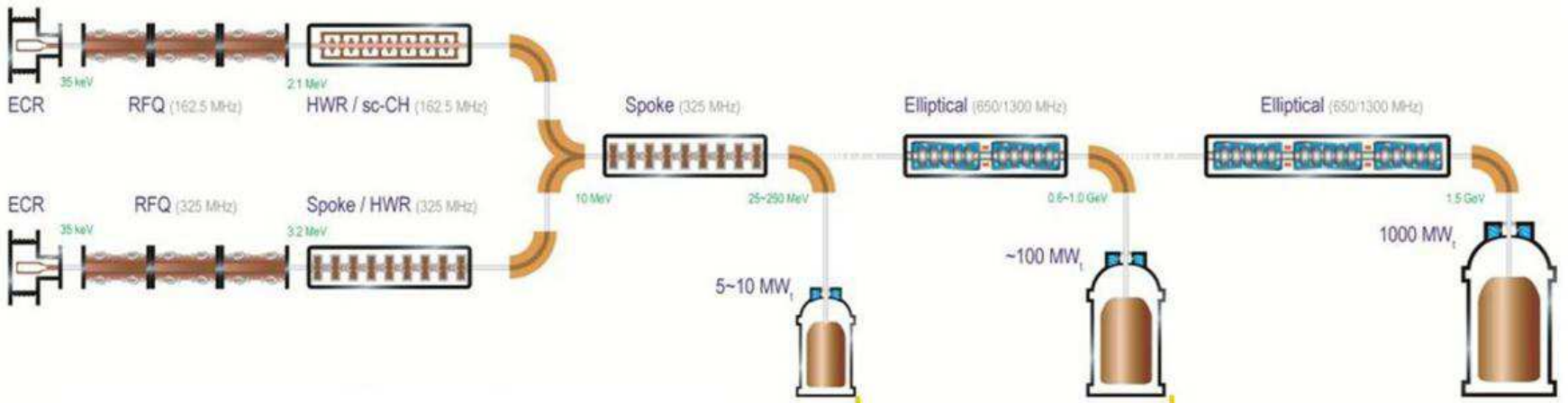
# 1. China ADS system

## Accelerator driven sub-critical (ADS) System




**Phase I**
**Research Facility (~10 MWt)**
**Key technical R&D in accelerator, target & sub-critical core**

**Phase II**
**Exp. Facility**
**(~100 MWt)**

**Phase III**
**Demo Facility**
**(~1000 MWt)**

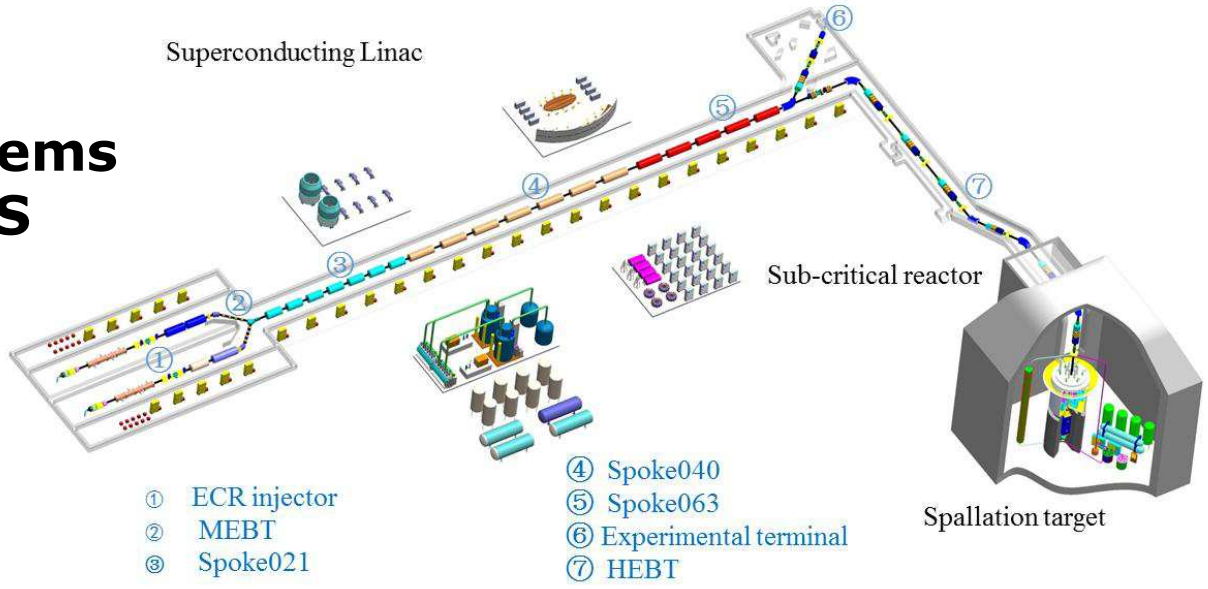
## ADS Roadmap in China

# 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: $2\times10^{14}$ $n/cm^2/s$

# 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.

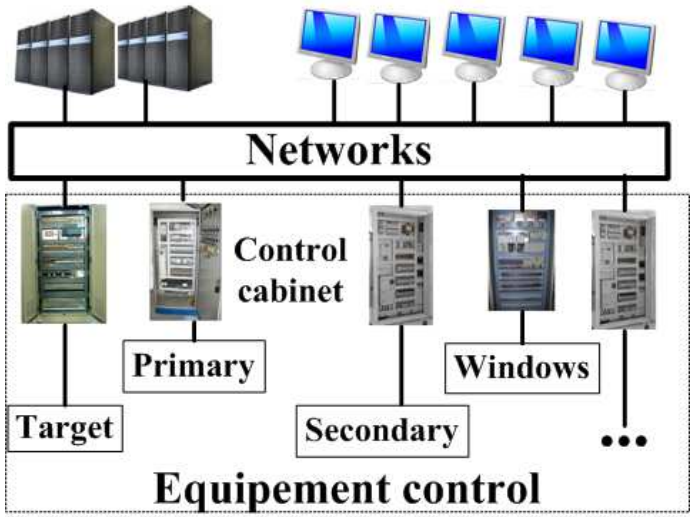
## Control system for the target

- 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.

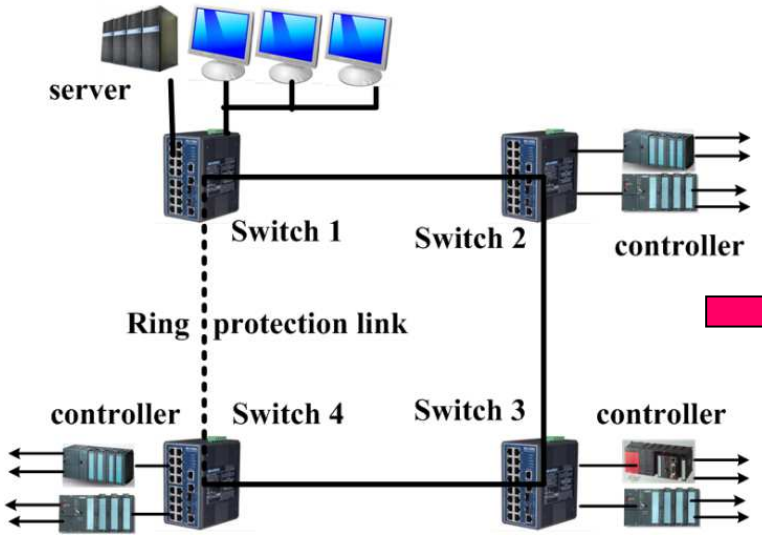
**Redundancy protocols to improve the reliability**

# 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/)

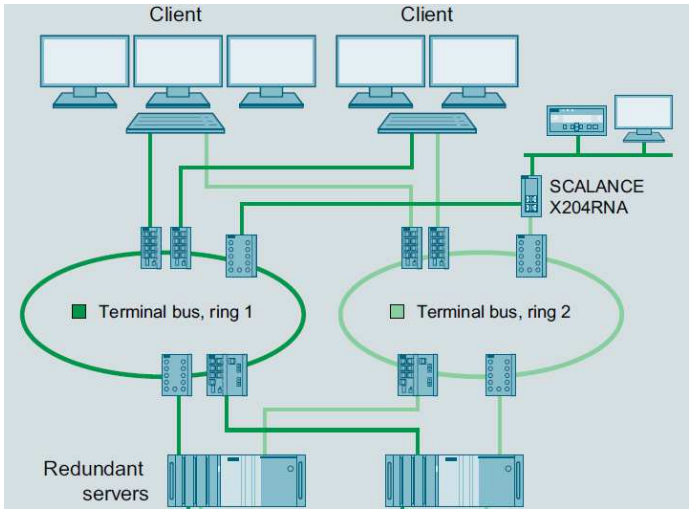
# 2. Control system for the target

## 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

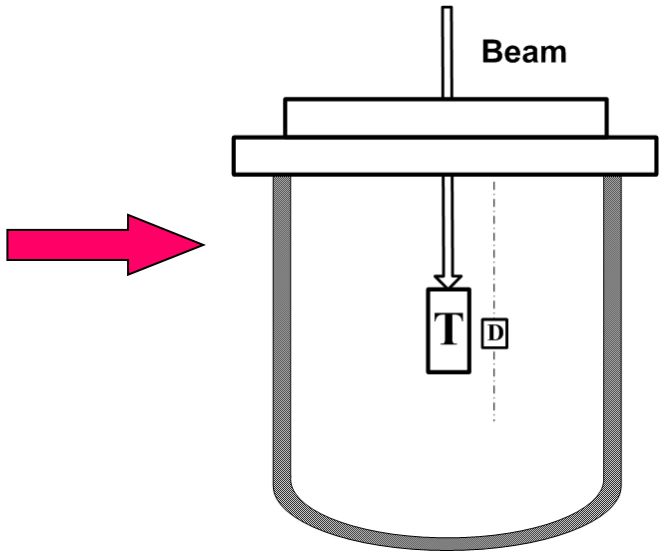
## Neutron monitoring for the target

### 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.

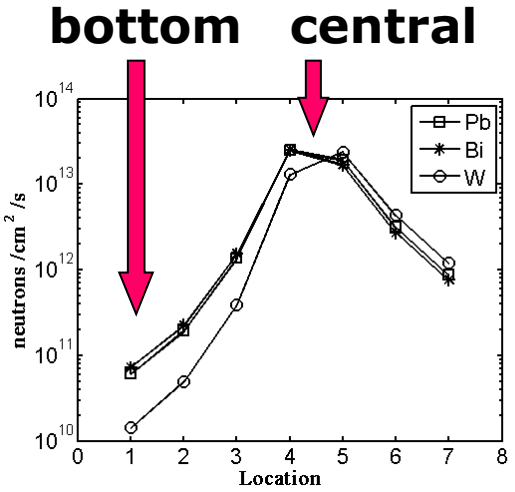


# 3. Equipment control

## Neutron monitoring for the target

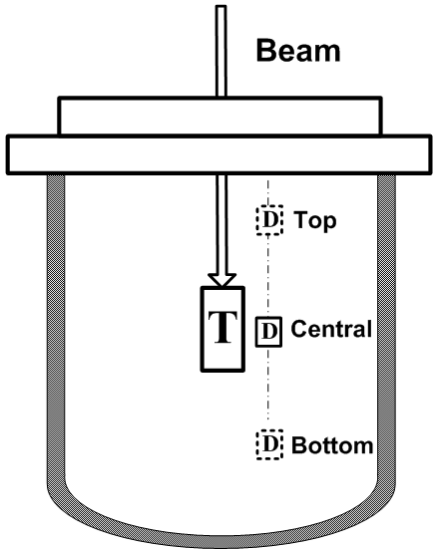
### Multi-point measurement:

- 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

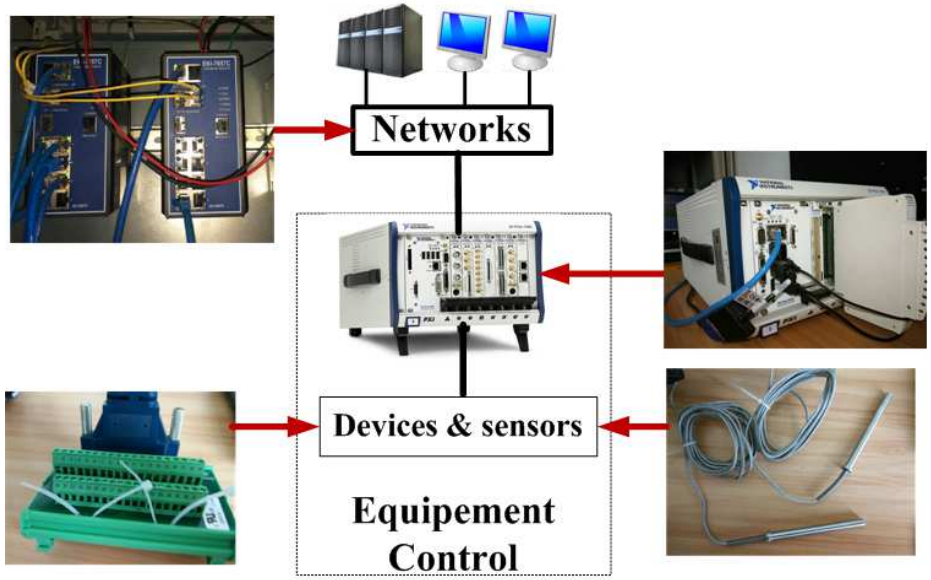
## Temperature monitor and control in cooling loops

### 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

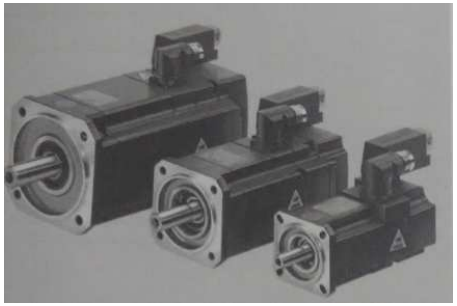
## Process control system for cooling loops

### 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

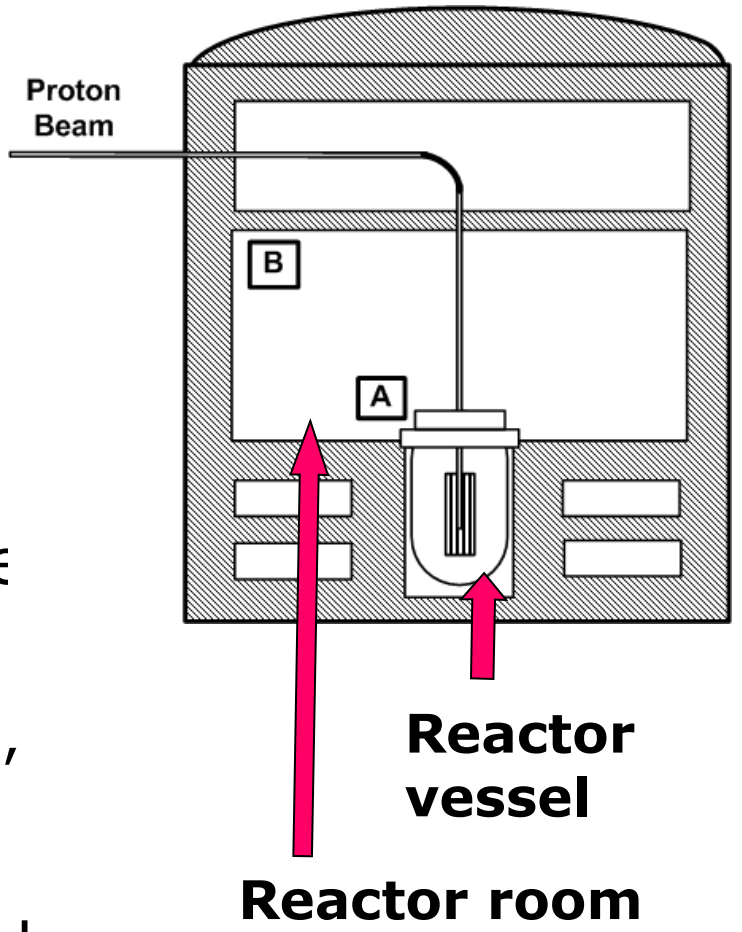
## Robust electronics used in the reactor room

- **Neutron flux:**
  - Incore: $2\times10^{14}$ $n/cm^2/s$.
  - Location A: $1\times10^{8}$ $n/cm^2/s$
  - Location B: $1\times10^{7}$ $n/cm^2/s$

    (Electronics for target).

- To mitigate the neutron-induce **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 !**