

# PLC Based Vacuum Control and Interlock System of the CYCIAE-230 Superconducting Cyclotron Beam Line

Mingzhi Hu,Xiaofeng Zhu,Jingyuan Liu,Hongru Cai,Zhiguo Yin,Tianjue Zhang,Yang Wang,Bohan Zhao,Shangmeng Jiang,Aolai He,Qiqi Song,Fangdi Yang,Tianyi Jiang,Ping Liu,Rui Xiong

**China Institute of Atomic Energy, P.O. Box 275(3), Beijing 102413**

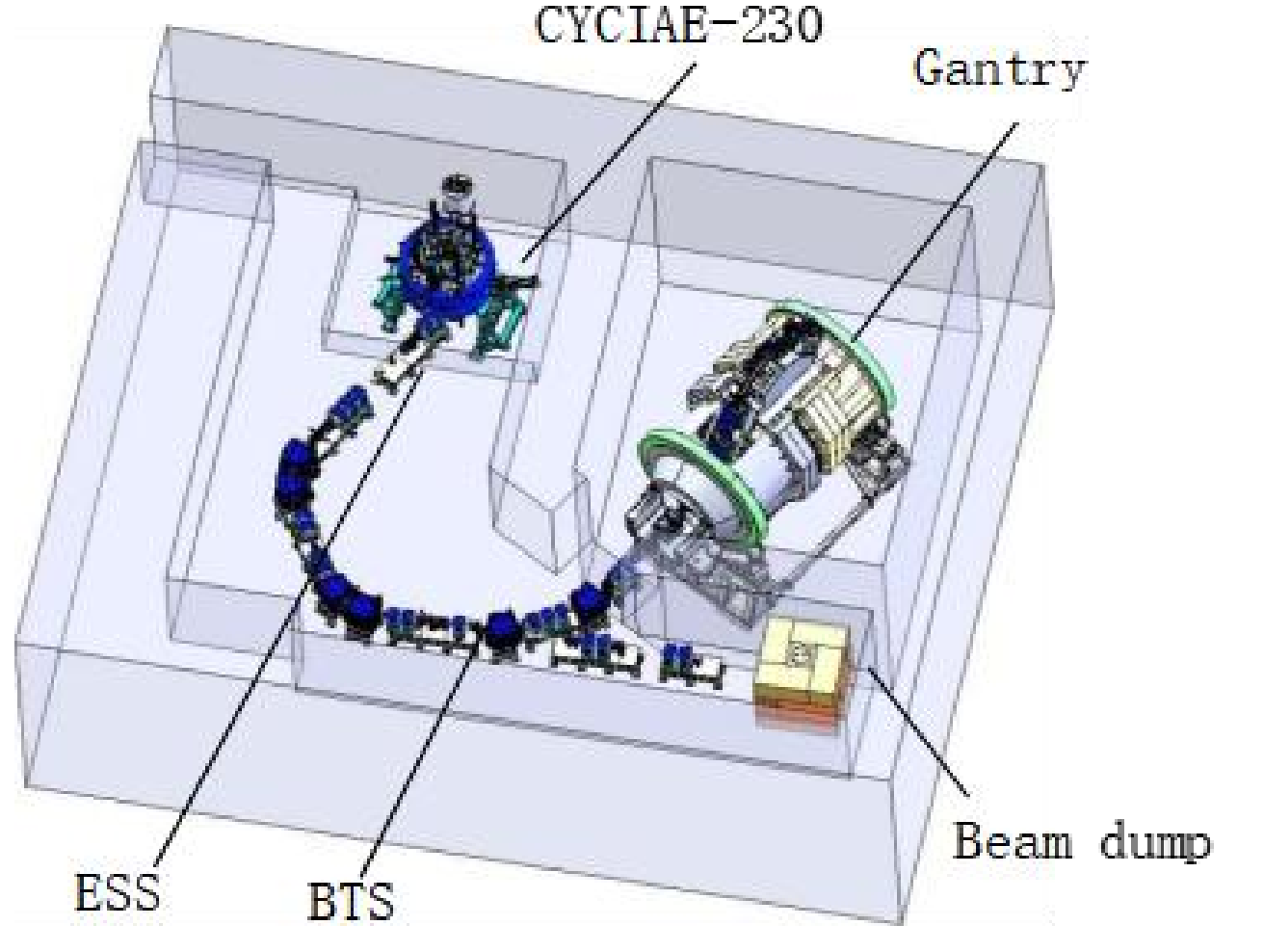
## Abstract

In the CYCIAE-230 superconducting cyclotron beam line, a vacuum system capable of providing a pressure of about  $5\text{e-}4$  Pa is required for particle beam transport. In order to provide enough interlocking to protect the vacuum environment and ensure the normal transmission of particles in the beam line, a vacuum control system based on programmable logic controller (PLC) has been developed and integrated into the accelerator monitoring system. The PLC not only interfaces with the fast acting relay based on interlocking signal, but also interfaces with the equipment based on Profibus communication to monitor and control various parameters in the vacuum system, such as pump speed, vacuum pressure reading, valve status, water cooling status, etc. This work presents the structure and interface logic necessary for communication with a series of valves, vacuum gauges and molecular pump controllers. In addition, the interface strategy between the vacuum control and the rest of the accelerator control system is also presented.

## Layout of CYCIAE-230 and Beam Lines

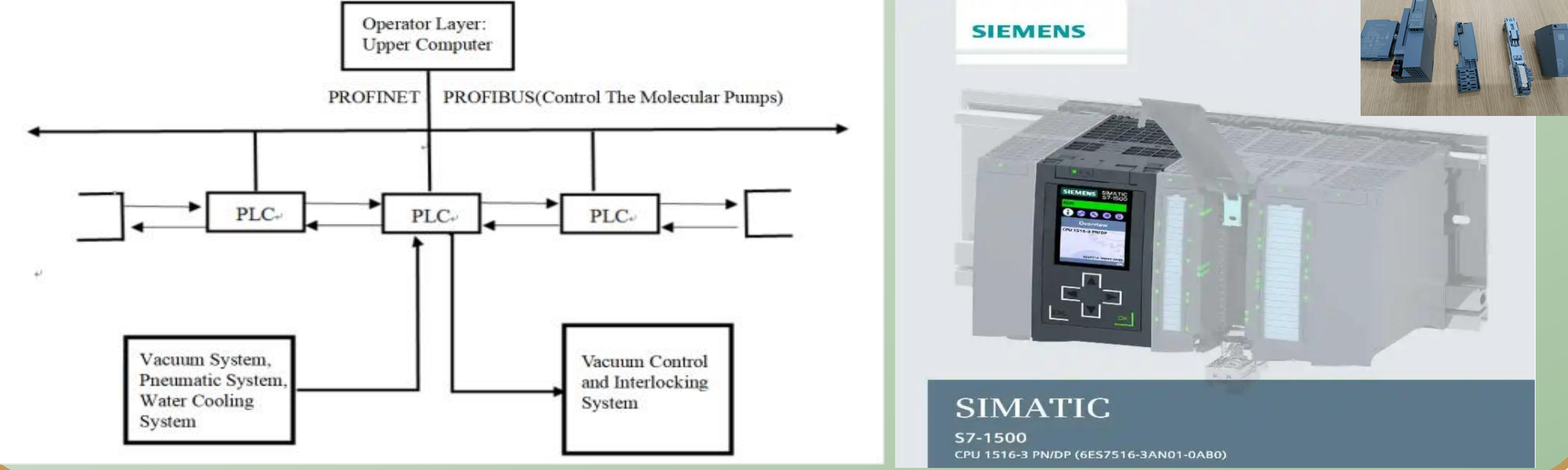
The CYCIAE-230 superconducting cyclotron leads out a proton beam with high energy and low current intensity, which is transmitted to the irradiation terminal through the beam line system. **This equipment includes:**  
**a superconducting proton cyclotron,**  
**a beam transport line,**  
**a 360-degree Gantry,**  
**and other therapeutic equipment.**

**In this beam line control system, vacuum control and interlocking system is again essential.**



## Control System Strategy

The vacuum control and interlocking system of beam line is developed based on PLC. Programmable logic controller (PLC) is chosen because it is more suitable for this task, especially because it can provide simple and economical solutions for logic control, process automation and condition monitoring. At the same time, the familiar Siemens PLC is preferred for control. In addition, its standardized hardware and program parts make it easy to assemble and program.



## Control of Mechanical and Molecular Pumps

### Mechanical pump control:

The main controller keeps the output of 24V, drives the contactor wire package to close, and controls the remote control of the mechanical pump to open. The main controller outputs 0V, drives the contactor to disconnect the wire package, and controls the mechanical pump to turn off.

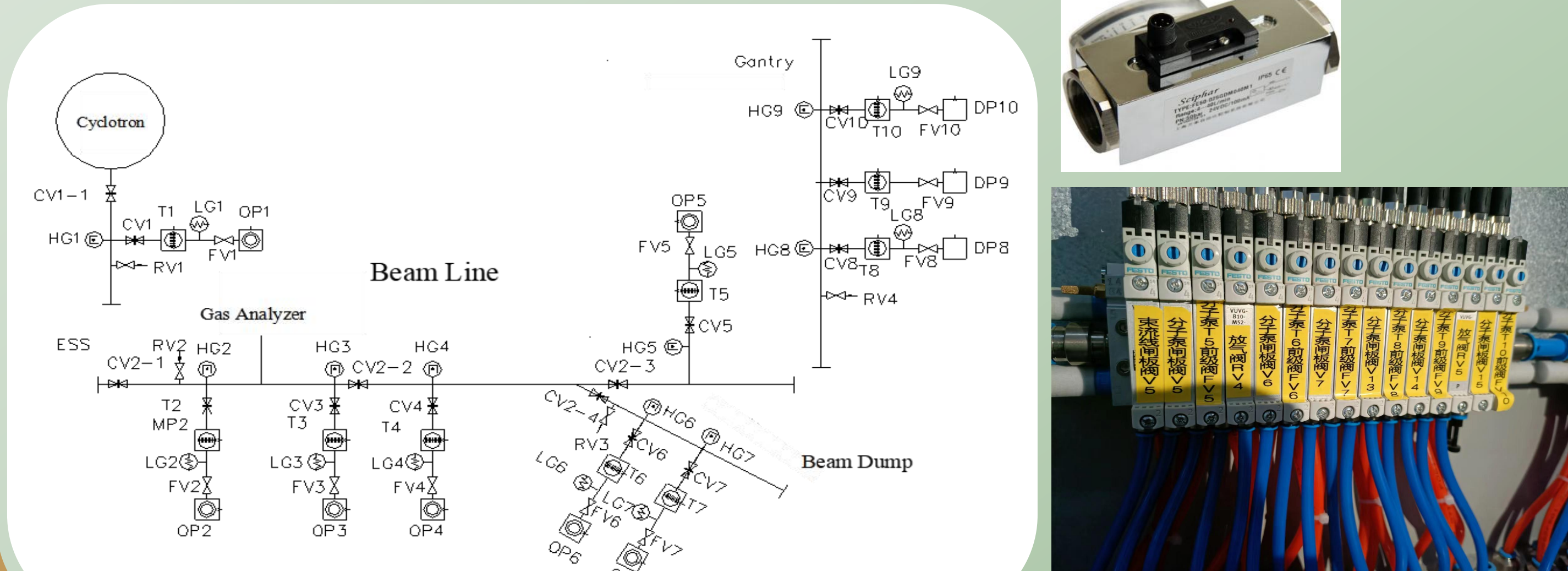
### Molecular pump control:

TC353 molecular pump controller is used in this beam line. Connect with PLC by PROFIBUS interface, generate corresponding GSD file and import it into Snep7 for configuration. The address of the corresponding molecular pump can be set through the dip switch of TC353. Then the molecular pump is remotely controlled by TIA.



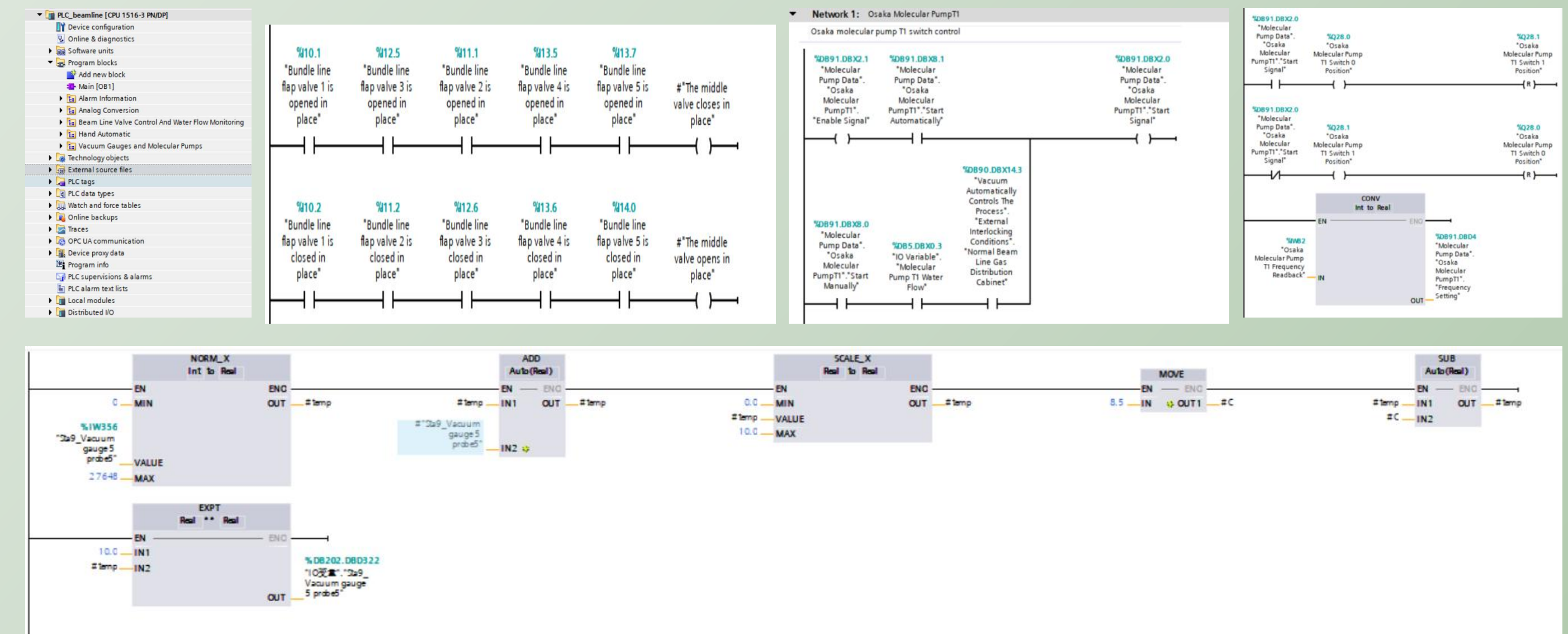
## System Requirement

The pneumatic system can control the opening and closing of the valve, and correspondingly assist the realization of the vacuum environment of the beam line. The water cooling system mainly ensures that the equipment including molecular pumps, magnets, etc. work normally at a suitable temperature. In order to ensure the normal transmission of particles in the beam line, the vacuum system needs to provide a vacuum environment with a pressure of about  $5\text{e-}4$  Pa.



## Implementation and Results of Control Scheme

In our controller, Siemens series 1516 CPU is used, which is mainly used to realize the interlocking of equipment and the control of running sequence. Other modules used are Siemens series distributed IO slave station IM155-6, analog input module, digital input and output module. The analog input module can select the input range of 0 V~10 V voltage and 0~20 mA current through TIA system settings.



Realization of Human Machine Interface (HMI) is based on producer/consumer design pattern and it is also made for control program of CYCIAE-230 beam line .

**The right figure shows the Human Machine Interface (HMI) of the vacuum control and interlocking system of the beam line based on PLC.**



## Conclusions

The vacuum control and interlocking system of beam line based on PLC has been successfully applied to the beam line of CYCIAE-230 superconducting cyclotron, and has been tested. The system can successfully operate valves, mechanical pumps and molecular pumps, and monitor the status of related equipment. Some vacuum interlocking operations are also being verified. At present, the beam line control system based on PLC is being further developed, which will make the beam line related functions including the beam diagnosis control system more perfect, and which can better adjust the proton beam from the accelerator to the treatment end.