Control and Diagnostic System for a 10 MeV Cyclotron CYCHU-10

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Outline

- **General Introduction of CYCHU-10**

    - Main characteristics of the cyclotron and its beam

    - System composition of the compact low-energy cyclotron

- **Development of the control system**

    - Hardware Layout of General control system

    - System interlock

    - Software development

    - User Interface

- **Diagnostic system**

- **Summary**

Background

GE PET
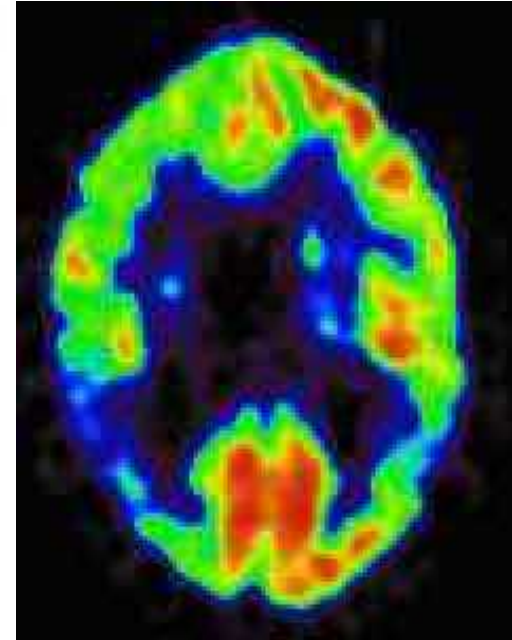
PET (Positron Emission Tomography)-- the most advanced technique of nuclear medicine in detecting of incipient tumors.
Cyclotron -- short-life isotopes production in PET system

CYCHU-10 – A 10MeV compact low-energy cyclotron

Main Parameters of CYCHU-10

Name	Design parameter
Beam species	H-
Ion source	Cold-cathode PIG source
Maximum beam energy	10 MeV
Beam current	30μA
Sector numbers	4
Sector open angle	48～53deg
Hill/valley gap size	2.4 cm / 9.6 cm
Central magnet field	1.63 T
Radio frequency	101.3MHz
Dee voltage	34 kV
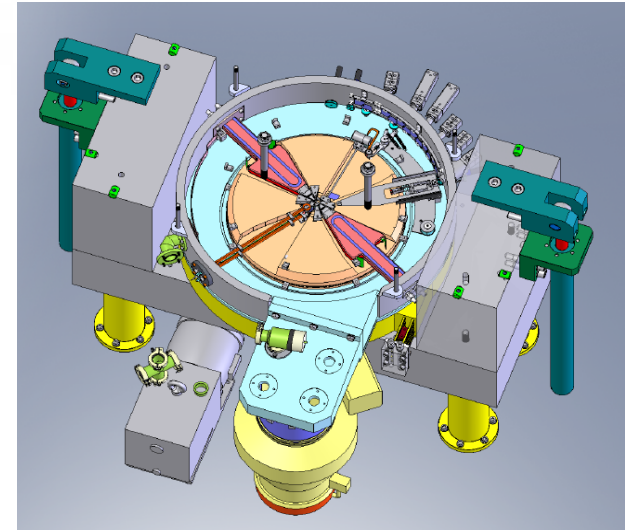
Introduction of CYCHU-10

System composition of the compact low-energy cyclotron
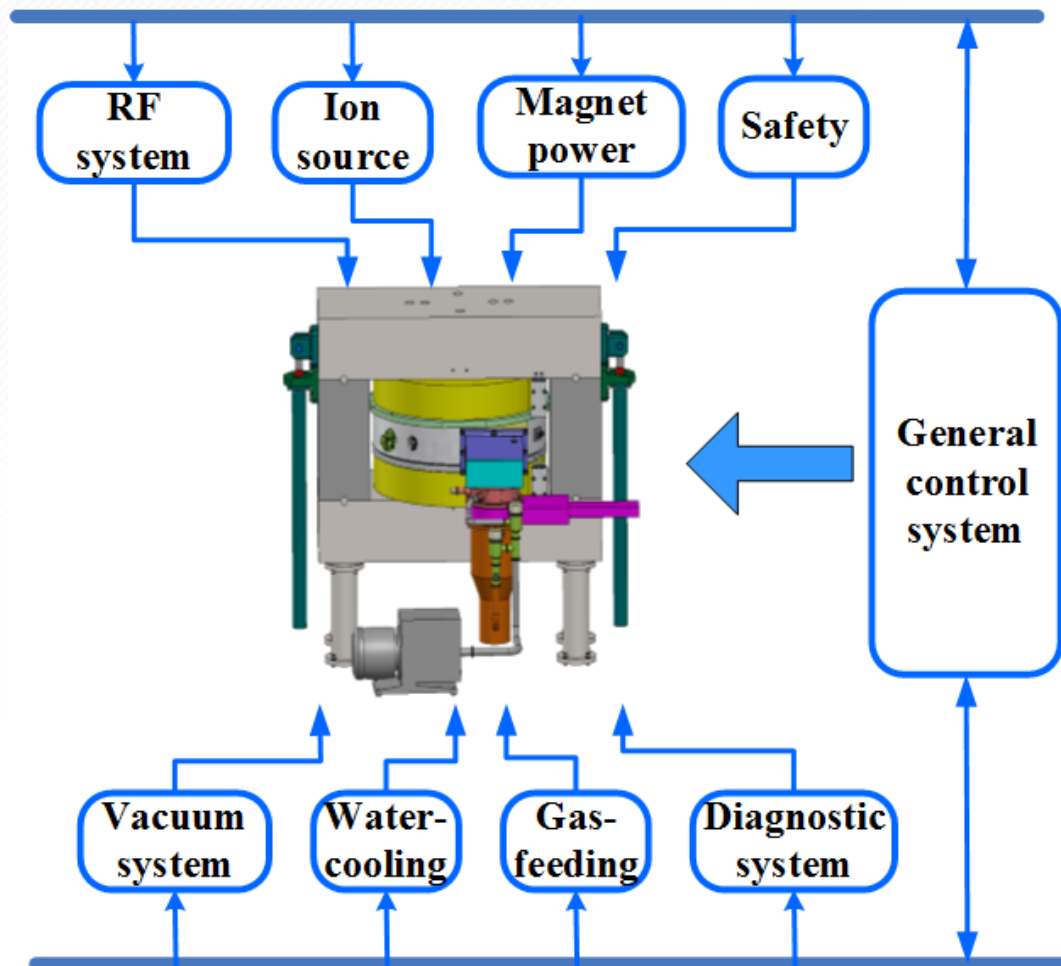
➢ RF system

Features:

➢ Triode amplifier as final stage amplifier

➢ DDS output as the RF signal source

➢ Scan and trace the resonance frequency

Parameters of the RF amplifier

Parameter	Value
Power Output	0-12kw
Dee Voltage Feedback	+10 dBm max
Frequency	100-102 MHz
Dee Voltage Monitor	0 – 2.5 VDC
Forward Power feedback	0 – 1.85 VDC
Reflected Power feedback	0 – 1.85 VDC

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Panel connections of RF controller

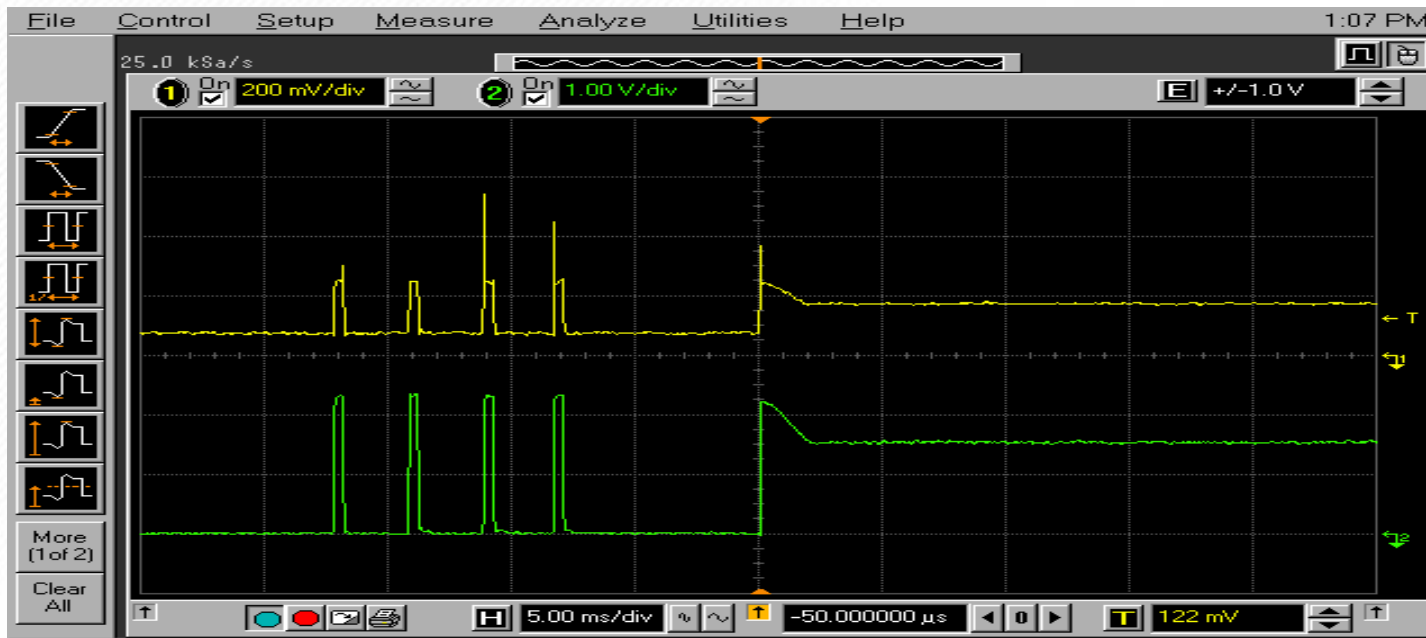## Signal:

➢ RF output-RF drive for the amplifier

➢ Dee Feedback -Less than +17dBm using an external attenuator if necessary

➢ Reflected Power Input ⌉
                          ⌐ from the amplifier 60dB directional coupler
➢ Forward Power Input ⌋

➢ RF status Output-Disable signal during resonance search

➢ RF system

Yellow-Pr

Green-Vdee

As the frequency nears resonance and SWR becomes low enough, the controller shifts into operate mode and applies drive continuously.

Dee Voltage starts higher than the requested level but is quickly brought down to the requested level by the Dee Voltage leveling loop.

Introduction of CYCHU-10

➢ RF generator operation modes

➢ **Standby Mode**

No RF drive from the controller

➢ **Course Search**

Search the configured frequency range in course search steps between upper and lower limits until an SWR measurement below the course search threshold is found.

➢ **Fine Search**

in fine search steps

➢ **Operate Mode**

Continuously seek the minimum SWR as it takes small frequency steps in order to track any drift in the cyclotron resonant frequency.

➢ **Crowbar Recovery**

Detected a level of reflected power in excess of the configured crowbar threshold.

➢ Configuration of the RF generator

Minimum Search Frequency	SWR to exit course search
Maximum Search Frequency	SWR to exit Fine search
Start Search Frequency	Maximum output level
Attenuator mode	Attenuator setting
Vdee request	Status update period
…	…

➢ The controller communicates using a message packet that carries commands to the controller and feedback regarding its status. All status packets end with a CRC for testing the integrity of the packet.

➢ Once made, the settings are stored in the controller's flash memory and are retained power down.
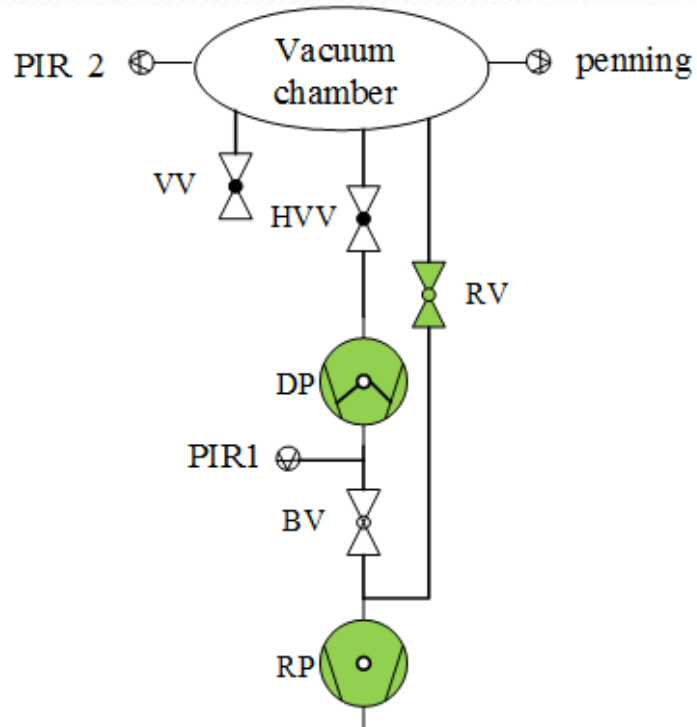
Water-cooling system

Features:

➢ Adjustable output pressure

➢ Low and high pressure protection

Parameter	Value
Refrigerating capacity	40kw
Control range	20-25℃±1℃
Water-conductivity	＜2us／cm
Max. Pump flow	8m³/h
Max. Pump pressure	1.0Mpa

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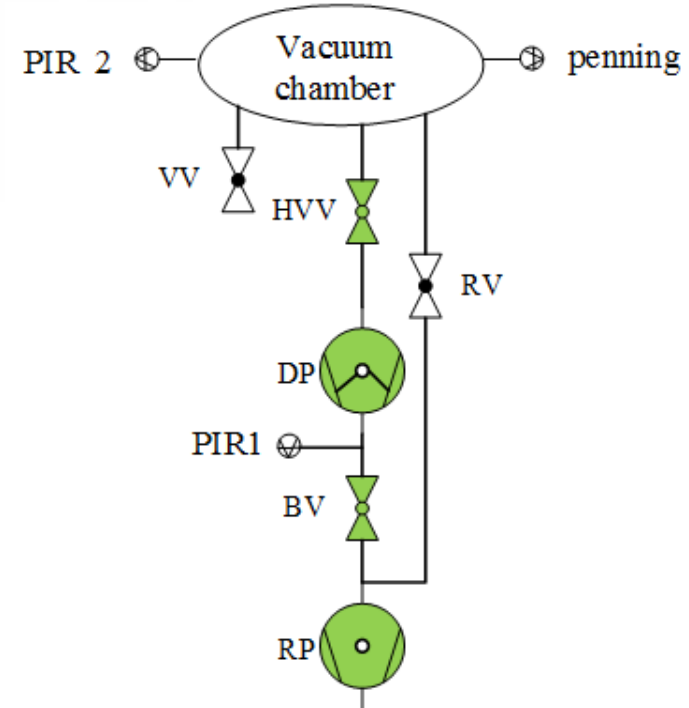
➢ Vacuum system

Vacuum without gas—7×10^{-5}Pa

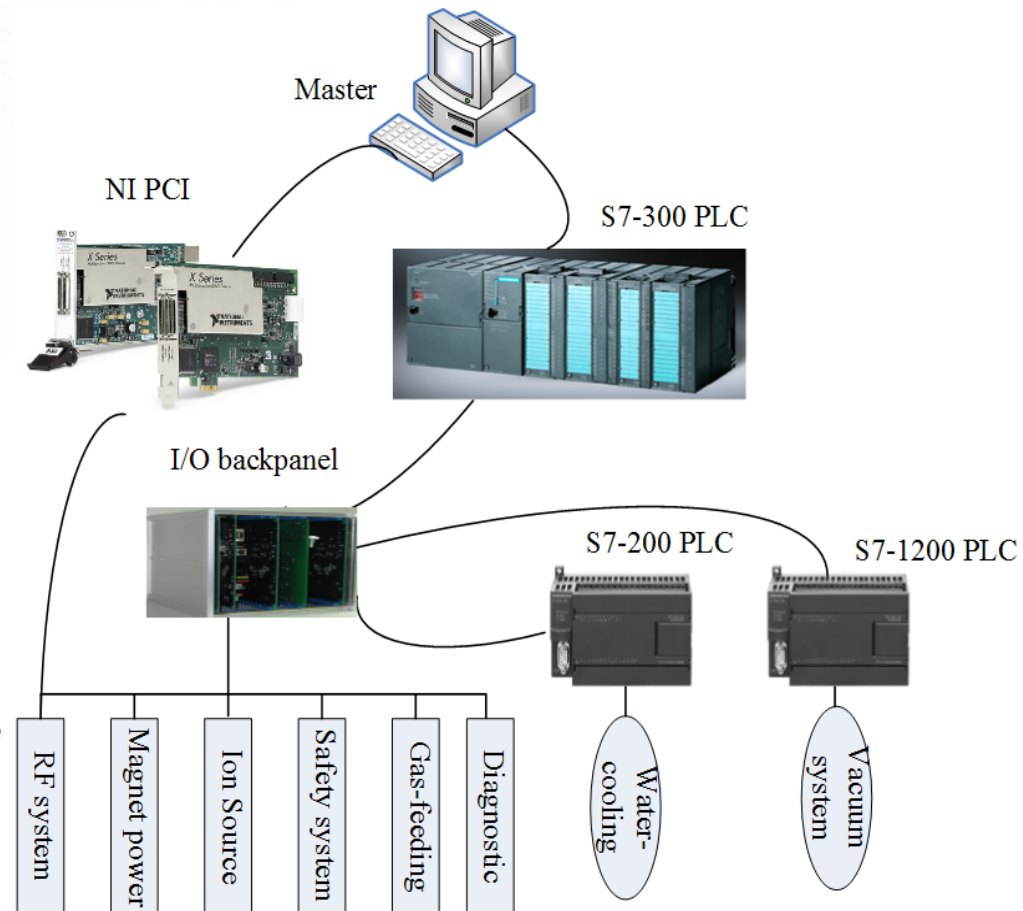Vacuum with gas —8×10^{-4}Pa

DP-Diffusion pump

RP-Rotate pump
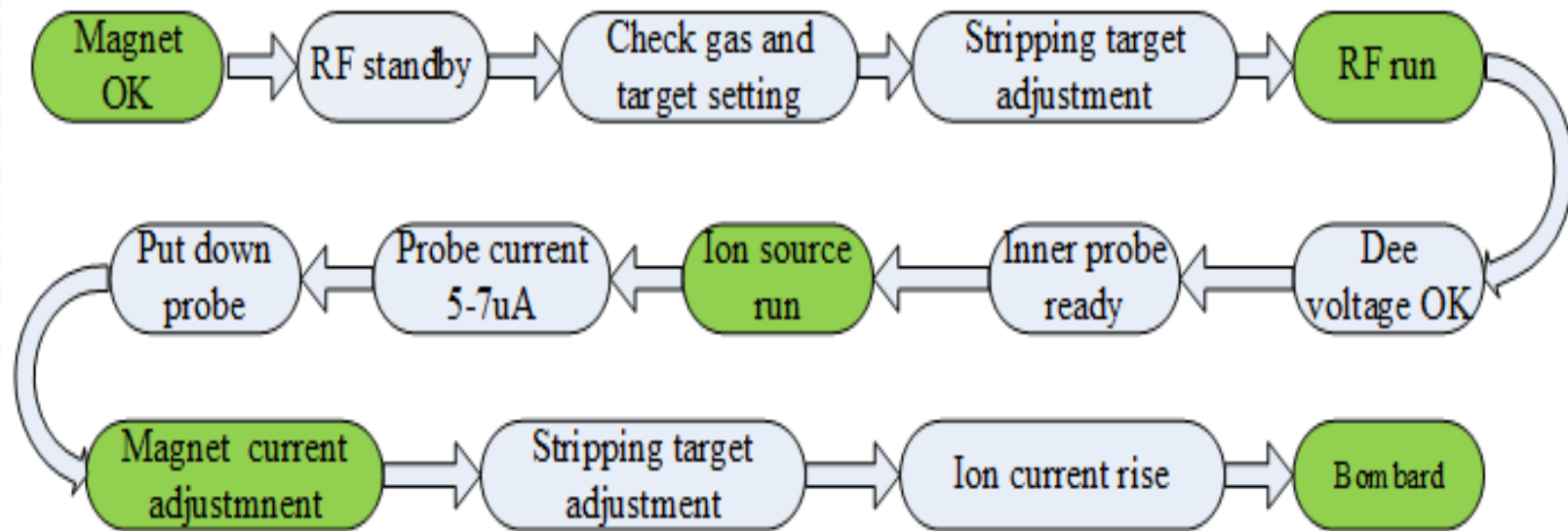
> ## Requirements

   Stable   Reliable   Safe

> ## Hardware Layout

> S7-300 PLC as General Control Unit(GCU).
> S7-200 PLC as water-cooling control unit.
> S7-1200 PLC as vacuum system control unit.
> IE communication between GCU and master .
> PCI for RF signal real-time monitoring

➢ **Flow diagram of general control program**
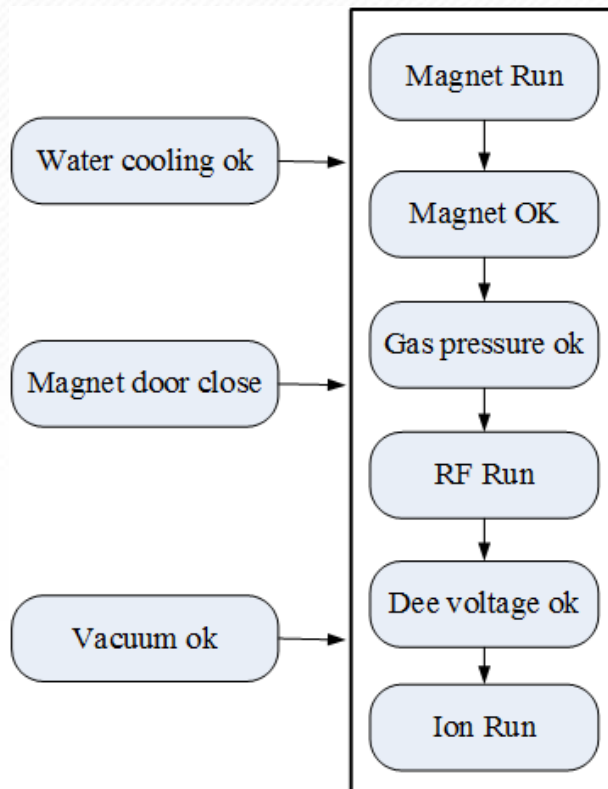
➤ **System interlock**

Software interlock

Hardware interlock
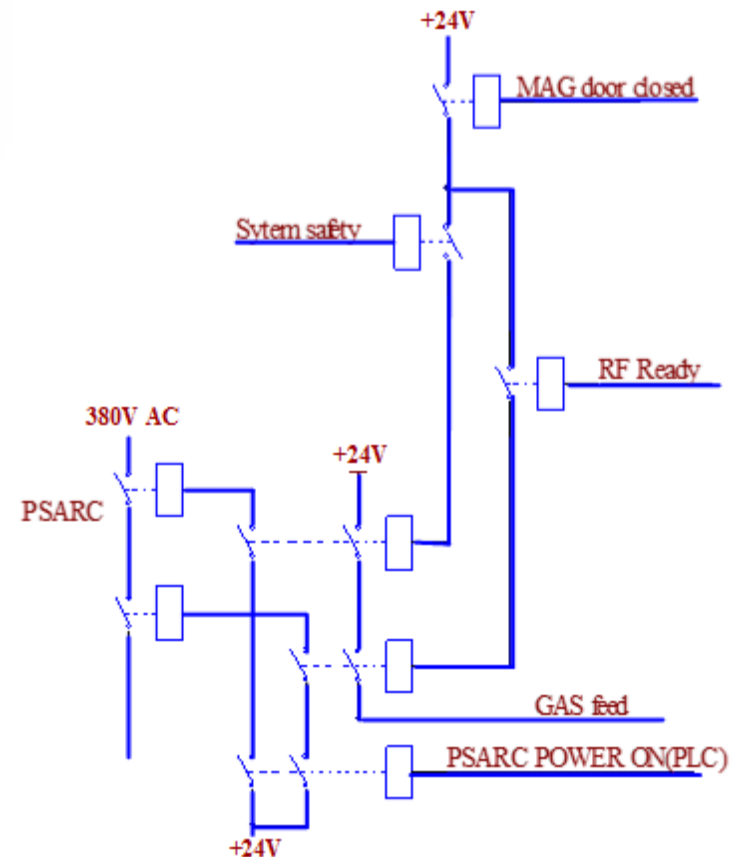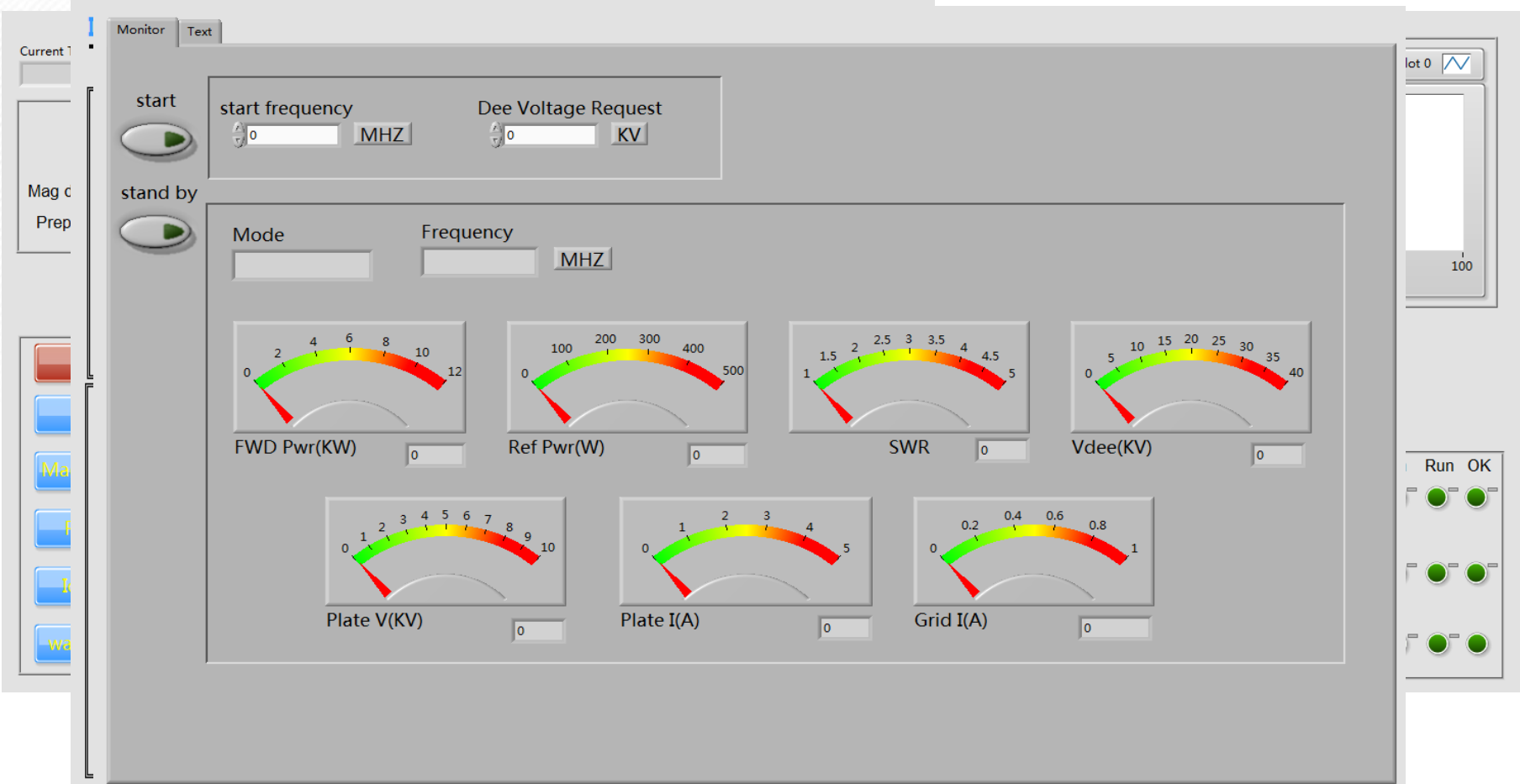
> ## User Interface

Master PC program: LabVIEW
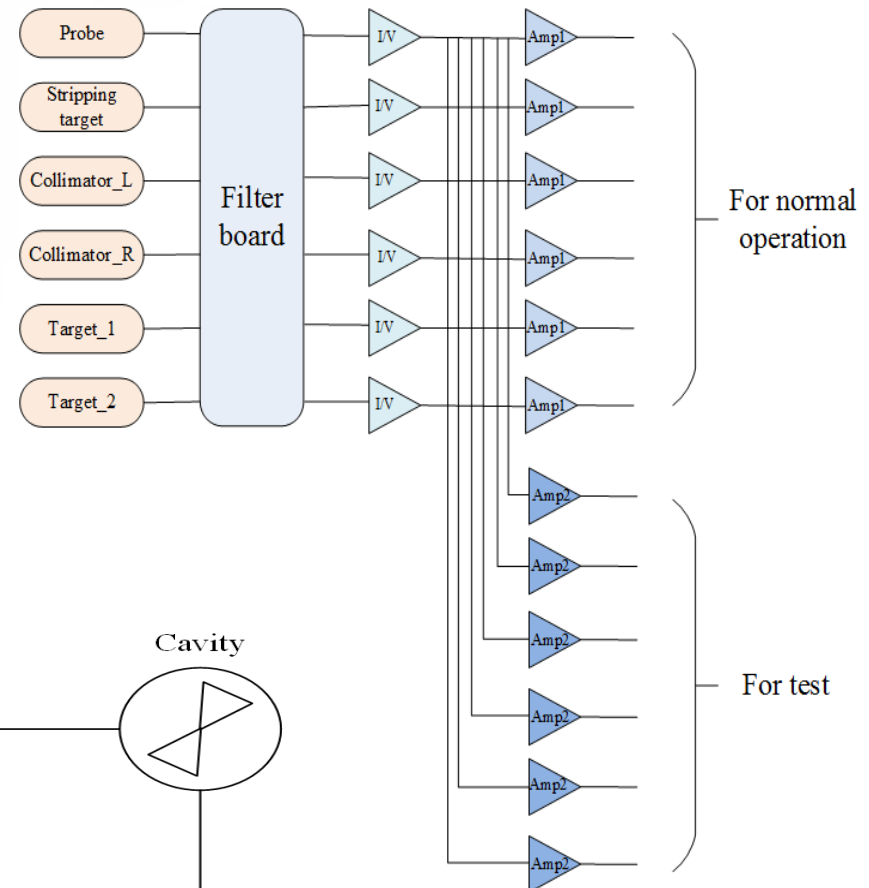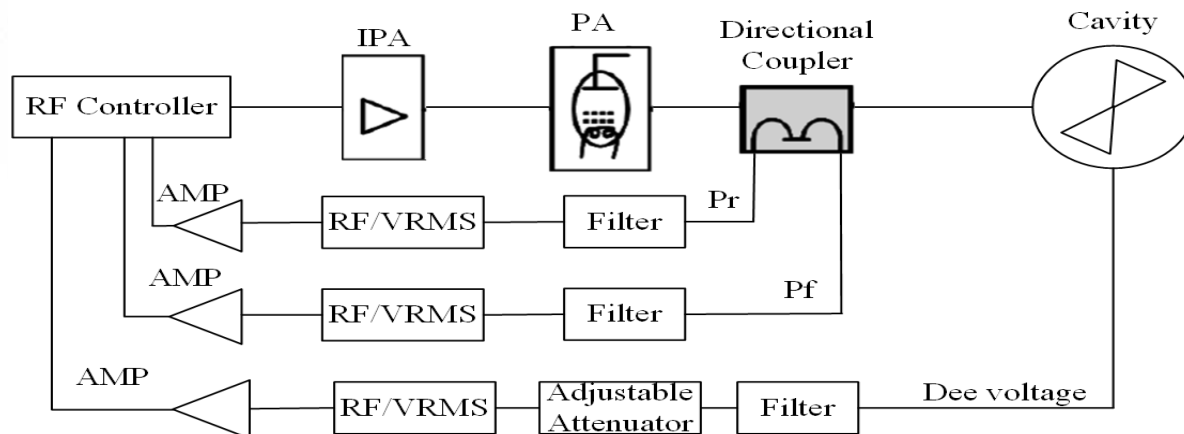Data transmission between PLC and Master PC: Open Process Control(OPC)

Beam current diagnostic
- ✓ Normal operation
- ✓ Testing

RF feedback
- ✓ Reflected power
- ✓ Forward power
- ✓ Dee voltage

Summary

- **A compact 10MeV cyclotron CYCHU-10 is under development at HUST to promote research and talent cultivation.**

- **S7-300 PLC is used as general control unit.**

- **Signals from RF generator are connected and acquired by PCI for real-time monitoring.**

- **Both of software and hardware safety interlock are deployed to ensure the security of the system .**

- **OPC architecture is used to share data between PLC control program and GUI.**

Thanks for your attention！