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THE DESIGN OF SCANNING CONTROL SYSTEM FOR PROTON THERAPY AT CIAE*

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Abstract

A novel proton therapy facility is designed and constructed at China Institute of Atomic Energy (CIAE) in Beijing, which includes a superconducting cyclotron CYCIAE-230 to provide 230 MeV proton beams for cancer therapy. As a part of therapy control system, the scanning control is designed to scan the beam for the access of required tumour volume field. Two set of dipole magnet is driven for changing the beam path. Meanwhile, interfaces between scanning system and other systems will be built for beam control and safe considering. In order to acquire high precise feedback control, the beam position and dose monitor ionization chambers will be constructed in the nozzle. Detailed description will be presented in this paper.

INTRODUCTION

Proton therapy has proven to be an effective cancer treatment with minimal side effects. Due to the progress of superconducting devices, very compact cyclotrons, suitable for hospital installations, can be manufactured with lower cost. In order to promote the development of proton therapy in China, CIAE (China Institute of Atomic Energy) has designed a superconducting cyclotron, which would produce a 230 MeV, 300 nA proton beam [1].

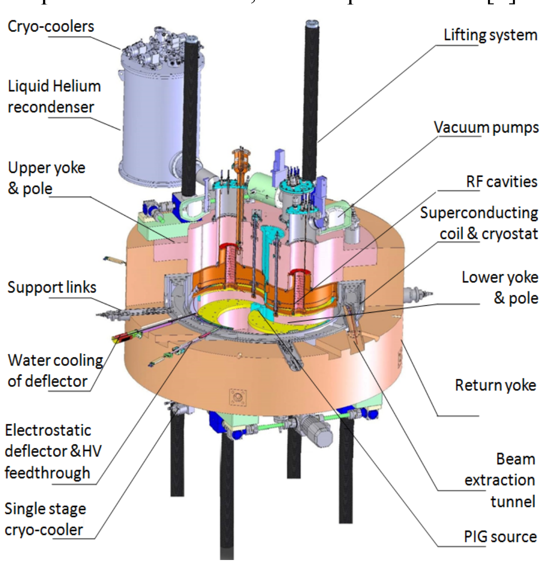

Figure 1: Layout of CYCIAE230 Cyclotron.

As the essential Part of Proton therapy, CYCIAE230 are in commissioning phase, including the cryogenic system and RF system as shown in Fig. 1. Meanwhile, the beamline and gantry are in construction. The specification of cyclotron is shown in Table1. The treatment control system is needed for whole treatment. Scanning control system belongs to the treatment control system and is the core part to do the main process. So, a dedicated scanning control system is designed for the proton therapy facility. Detailed system design will be presented below.

Table 1: Cyclotron Specifications

Parameter	Value
Extraction energy	>230MeV
Extraction current	>500nA
Injection/Extraction field	2.35 T / 2.95 T
RF frequency	~71.3 MHz
RF voltage	70 kV/110 kV

SCANNING CONTROL SYSTEM

In the whole control system of proton therapy, scannning control take a important role. Whatever any scanning mode was used. Also there are complex interfaces with other subsystems. Scanning control system require the the therapy data table to direct the scanning to target volume and the field feedback data to verify the scan process. Figure 2 shows the positon of scanning control system in the whole control system, which is essensial for proton therapy system. The device layer is mainly comprises of needed hardware for convetional process, which accept the control of relatively target front end. The lower layer is safe related function that protects the patient against over dose radiation. The central interlock system will act as a protector for treatment. The last layer is control layer. In this layer, scanning control system is the coordinator to arrange other subsystem to work together smoothly under the defined process. The interface to cyclotron is through the data exchange to cyclotron control system.

Functionalities

Fast dynamic scanning functional specification is as follows:

Interface with accelerator control system to adjust the vertical deflector to stabilize the beam current. The repetition rate is about 1kHz, and the beam off time is lower than 50usec, intensity stability is lower than 5%.

Scanning mode: step & shoot, continue scanning 'TV' or contours scanning, the two sweeper magnets should control the beam position up to 2cm/Ms.

Scanning delivery function comes out that scanning control system dynamically operate the actuators according to the feedback data which involves the position and beam intensity.

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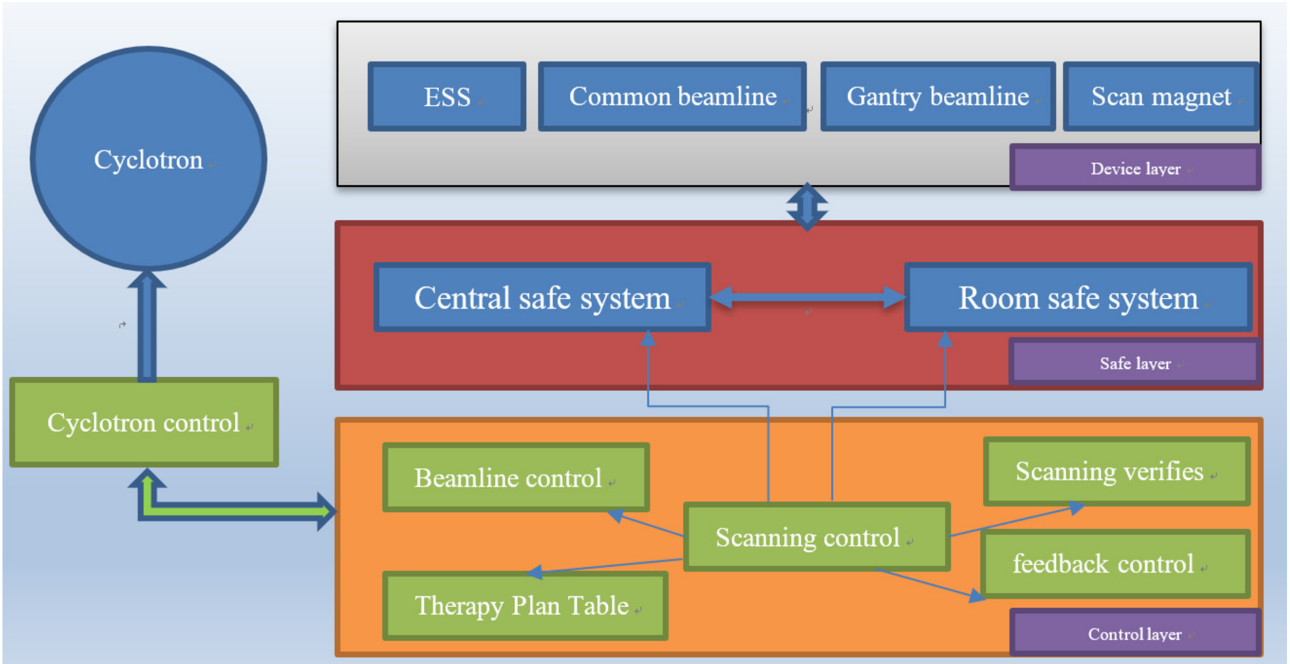

Figure 2: Scanning control system interfaces with other subsystems.

Scanning verifying function facilities a fast data acquiring board to pick up data periodically around 10us. The board is connected to field hall probe to verify the sweeper magnet, and to ionization chambers to verify beam current.

Fast control function is based on FPGA technology to validate measured data or interrupt beam in case of coincidence.

Hardware Design

The scanning system is composed of three different parts. The digital compute board is the master component. Another part is ADC/DAC part, which is in charge of signal convert rapidly to magnet controller or from field sensors. Through the therapy plan data achieved from treatment control system, master computer gives the final output signal instantly according the designed algorithm. The final part is the ionization chamber for beam position and dose value feedback. The final scanning control cabinet is shown in Fig. 3.

Connections between main compute board and ions chamber eletronics are via fibre optics to ensure stable and robust transmision against radiation damage and single event upset to electronics.

Figure 3: Layout design of scanning control cabinet.

The next stage of design is the ionization chamber to monitor the position of beam and verify the dose rate. The sensitive area of ionization chamber is 41mm diameter and the readout pixel for position monitoring is 180. In order to protect beam quality, extra thin film window and electrodes is designed so as to negligible beam scattering. The energy range is from 30 MeV to 250 MeV for proton. The integral linearity is better than 30 um maximum deviation relative over sensitive area. Depend on signal to noise ratio, the best position resolution is about 10um.

Software Design

The scanning control software is comprised of four modules, and the modules interfaced internally with fast bus. These main modules are as following corresbording the hardware. Core compute module (CCM): This module is mainly responsible for actually current value output and directing the feedback flow. This is the master module which operates the whole scanning system and handles beam stable situations throughout the feedback loop. It communicates with other subsystems over a fast TCP/IP network connection. User Interface Module (UIM): It provides device screens to operators which display live scanning information [2,3]. Covert Management Module (CMM): This module is designed to produce the interpolation values result from the delivery table. Safe Interlock Module (SIM) : This is the import module because the beam safe operation is depent on the fast respond to cut off. With the safe policy, a proper action should be carried out as soon as possible. Above the four modules, critical algthrim is developed to implement the system requirment best. For example, during the beam delivery session, any illegal action is not allowed. There are also some interface modules to related systems for data information.

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Safety Interlock System

The scanning control system is directly connected to safety interlock system that consists of a fast interlock system that cuts off RF sources switch to the RF amplifier. It is built on the cyclone series FPGA platform. It supports 32 fast digital inputs (100 ns response time), 32 slower (response within 10μs) and 16 analogue channels (100 kHz).

In addition, there is a slow interlock system based on a Siemens S7-400 PLC system. The current system support about 1000 i/o channels but enough memory space is ready for expansion if safety needed. The data is collected by a server which broadcast the readout over Ethernet to be easily picked up by the EPICS channel access client. The radiation protection area is protected by a door interlock. A unique procedure is required before closing the door. This is implemented in the slow interlock safety PLC.

Other Demand

The scanning control system is sensitively to beam stable capability. So, there is strictly requirement for accelerator with stable beam position and continuous and stable beam. Also, requirement for ESS for fast adjustable beam intensity and fast adjustable beam energy. In emergency condition, the fastest beam cut-off is to shut down the RF source.

Due to the open loop control of magnet power supply, over-shot will occur, and the delay feedback of ionization chamber also have a side effect for high accuracy dose delivery. A new method for fast dose feedback needs to be developed for high accuracy protection.

CONCLUSION

CIAE has designed a scanning control system for proton therapy that integrates all the different subsystems necessary for treatment process. The fast feedback system is based on FPGA technology with state-of-art algorithm. The use of EPICS simplifies the extensible feature for coming requirement of other subsystems.

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