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THE INSTALLATION AND APPLICATION OF MULTI-WIRE PROFILE MONITOR FOR PBW IN CSNS *

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Abstract

To monitor the size and position of 1.6 Gev proton beam in front of proton beam window(PBW) of China spallation neutron source (CSNS), one multi-wire profile monitor (MWPM) is designed and installed with PBW. It can bear the heat caused by beam and generate signal to electronic in local station. We can monitor the situation of beam and protect PBW using MWPM.

INTRODUCTION

In the CSNS, proton is accelerated to 1.6 Gev after drawn from Rapid Cycling Synchrotron(RCS), then transported to target which is behind PBW by Ring to Target Beam Transport(RTBT). The target in CSNS is flat package made of tungsten and covered by tantalum, to protect target and PBW, we need to monitor the position and shape of beam, to make sure the offset of beam center and convergence situation is safe. One MWPM is designed and installed to achieve this.

DESIGN OF MWPM

Scheme Selection

The main beam parameter of CSNS is shown in Table 1, there are two stage of CSNS with different beam power 100 kW and 500 kW, while at the beginning for engineering acceptance the power is 20 kW, so the scheme should cover all low and high range

Table 1: Main Parameter of CSNS

Phase	I	II
Beam power on target [kW]	100	500
Beam energy on target [GeV]	1.6	1.6
Ave. beam current [uA]	62.5	315
Pulse repetition rate [Hz]	25	25
Protons per pulse [10^{13}]	1.56	7.8

The two most used scheme is tungsten wire and thermocouple, as in Jparc, SNS, and VMOS which using reflected light path with camera, as in PSI, but the VMOS method need the temperature rise over 1000 °C, at last we decide to use tungsten wire method.

Simulation and Design

As for calculate temperature of tungsten wire, we consider highest beam power and beam current as Table 2.

Table 2: Beam Parameter for Simulation

	MWPM
3 time sigma	L*W=84 * 21mm
current	15.6A
Pulse time	80ns
power	1.6Gev
Repetition frequency	25Hz

We consider that there are two bunches in one period and the distance between is 160 ns, then choose two type of wire, 50 um and 100 um. Using SRIM tool [1], we can get the deposition energy of proton on wire at 1.6 Gev with reference of formula 1,

$$-\frac{dE}{dx} = \frac{4\pi k_0^2 z^2 e^4 n}{mc^2\beta^2}\left[L_n \frac{2mc^2\beta^2}{I(1-\beta^2)} - \beta^2\right] \quad (1)$$

then with beam current 15.6 A we can get final heat generation rate and double it to 5.4E14 W/m3 because of the uncertainty we cannot cover during calculation.

At last we get the maximum temperature of wire as 1020 K in Fig. 1, according to the temperature 2000 K tungsten need to generate visible spectrum, it is not suitable for VMOS method, if we consider 20 kW beam power, the temperature would be even much lower. From the result we think the wire is safe under normal situation. If the beam moves to boundary of MWPM, it may destroy the PBW, so we install some little copper sheet on boundary and using thermocouple to monitor temperature, it is also used for machine protect. The highest temperature would be 687 K.

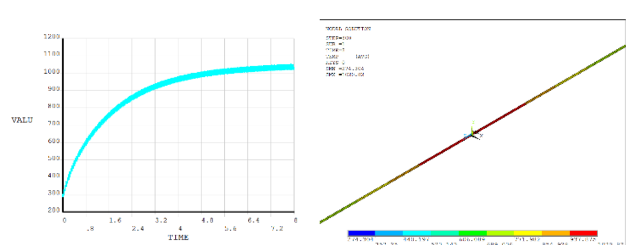

Figure 1: Temperature of wire.

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We also rebuild beam size with different wire number on simulated data in Fig. 2, first we generate 2D Gaussian distributed data, then use different size of wire to get integral value, fitting to get sigma and FWHM, then compare it to theoretical value, according to result, the wire number which act with beam should over 13 then precision is better than 1%. But in mechanical structure, we bore a hole on ceramic plate and install device to hold wire, under this limitation, the range between wire can only be 7 mm, so x direction will meet requirement while the precision of y direction would be lower.

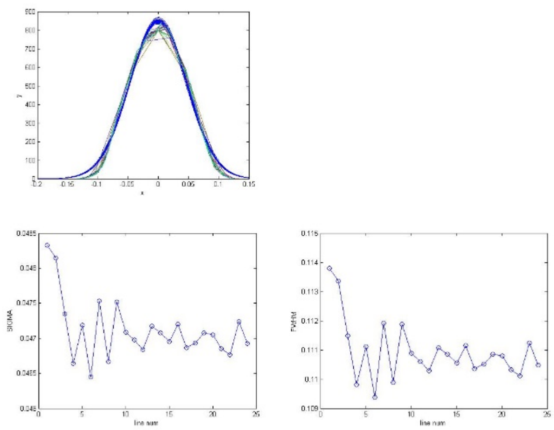

Figure 2: Simulation of FWHM and Sigma of beam.

Mechanical Design

We use two ceramic plate for beam size measurement [2], one is 100 um wire and the other is 50 um. Each plate has two layers of wire, as in Fig. 3, one is x direction with 29 wires, the other is y direction with 15 wires, the distance between wire is 7 mm. The 50 um plate is used as backup of system. In the design of electronic, each layer of wire can be given high voltage [3], this can reduce cross-talk between different layer and shielding interference from outside.

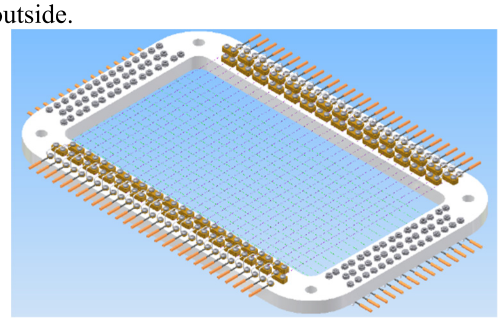

Figure 3: Model of wire plate.

The third layer is for copper sheet and thermocouple in Fig. 4, copper sheet is assembled at the edge of plate to act with beam when patron position shifts too much, there are 16 thermocouple around the plate.

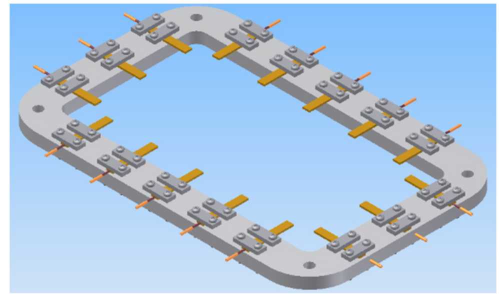

Figure 4: Model of thermocouple plate.

There are 5 hole left on the PBW, in Fig. 5 each is designed for 41 pins feedthrough, we want all the wire used as double-ended, so the wire need total 176 pins of output, while the thermocouple need 32 pins, and the PBW itself need 4 pins of thermocouple for protect, the total number is not enough, so we set 7 wires on the edge to single-ended, the structure is shown below.

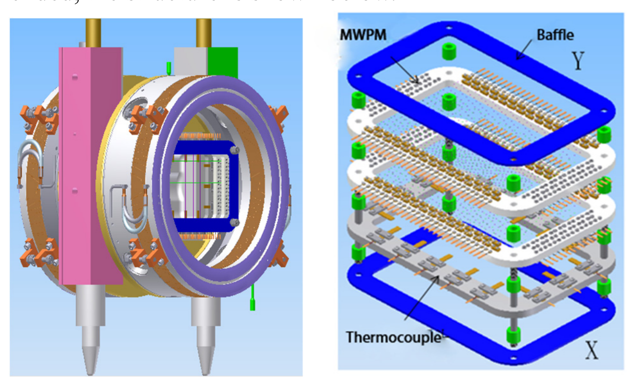

Figure 5: Model of MWPM in PBW.

The thermocouple is flexible fiberglass insulation N type thermocouple made by OMEGA, for limitation of situation in PBW, we install the temperature transmitterTXDIN1620 in local station, not near the PBW. And the 41 pins cable from MWPM to local station is custom made, each pin is covered by Polyimide film to make it bear the strong irradiation after targeting.

Installation and Experiment

After all the wire and thermocouple is mounted and tested, the MWPM is installed to the PBW and connected to feedthrough on it. The whole structure is shown in Fig. 6.

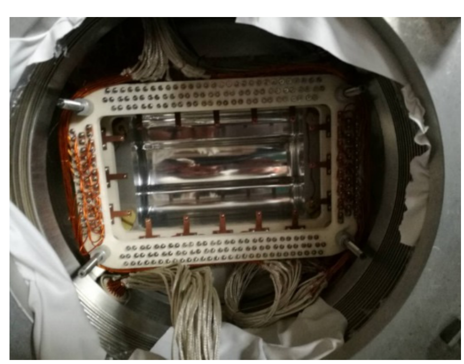

Figure 6: MWPM installed in PBW.

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The signal on the wire is deal with electronic, the transmitted to acquisition System, which is made mainly by PXIe-6358 and PXI-6713 card from NI instruments, the control software is made by LabVIEW. At last it will give the profile of beam.

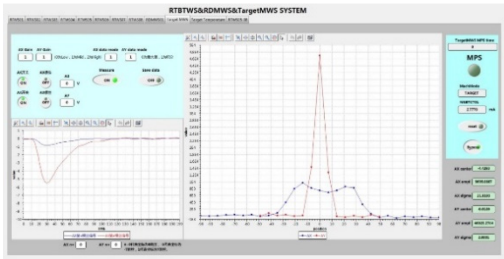

Figure 7: Profile of beam by MWPM.

In targeting experiment, MWPM system work well and give the profile of beam as in Fig. 7. After fitting of measurement data, we can get beam 2D distribution of X,Y plane as shown in Fig. 8, from the fitting result, the y sigma 2.8 mm is close to its theoretical value, while the x shape is nearly rectangle as wanted.

The MWPM is very important in targeting experiment, some of output is used for machine protect, it can run for long time, while optical scheme has very obvious attenuation now. It has happened that the x center shifts a lot for some time in experiment, this may cause serious problem and need monitor immediately.

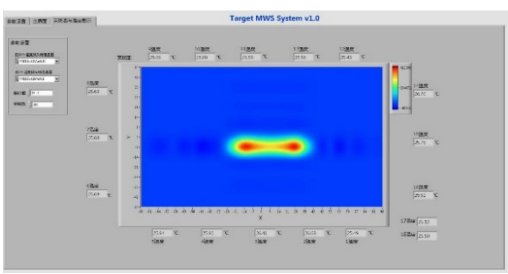

Figure 8: Synthetic beam 2D distribution

CONCLUSION

In this paper, we describe the design and simulation of MWPM, after machining and installed, it worked well in beam targeting experiment and give profile result for monitoring, it plays an important role in machine running. The resolution of y direction is not high as x direction because of space limitation, we need to find to improve it.

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