STATUS OF THE BEAM INSTRUMENTATION SYSTEM OF CSNS

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Abstract

The beam instrumentation system has been developed to tune and investigate the high intensity proton beam in the China Spallation Neutron Source (CSNS) project. All the physical design of the monitors has been finished and start the system set up procedure. Many kinds of beam monitors are required to measure wide dynamic range of the beam parameters, e.g. intensity, energy. Construction and application of beam monitor system are described in this paper and the first test results during the RFQ and DTL1 commissioning will be introduced also.

INTRODUCTION

The CSNS is designed to accelerate proton beam pulses to 1.6 GeV kinetic energy at 25 Hz repetition rate, striking a solid metal target to produce spallation neutrons. The accelerator provides a beam power of 100 kW on the target in the first phase. It will be upgraded to 500 kW beam power at the same repetition rate and same output energy in the second phase. A schematic layout of CSNS phase-1 complex is shown in Figure 1. In the phase one, an ion source produces a peak current of 25 mA H- beam. RFQ linac bunches and accelerates it to 3 MeV. DTL linac raises the beam energy to 80 MeV. After H- beam is converted to proton beam via a stripping foil, RCS accumulates and accelerates the proton beam to 1.6 GeV before extracting it to the target [1, 2].

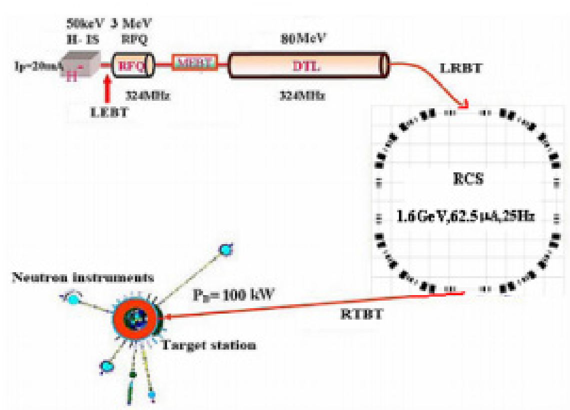

Figure 1: Schematics of the CSNS complex.

BEAM MONITORS

For the entire beam instrumentation system of CSNS, amounts of beam monitors are installed along the beam line, including beam position monitor (BPM), beam current monitor, beam profile monitor, beam loss monitor (BLM) and so on. Layout of the beam instrumentation system as shown in Figure 2.

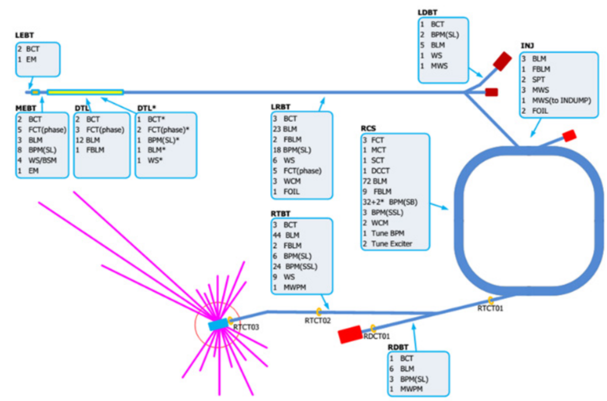

Figure 2: Layout of the beam instrumentation system of CSNS.

Beam Current Monitor

Two types of current transformers have been developed, the fast current transformer (FCT) and normal CT. FCT has a response time less than 300 ps, and used to measure the beam energy by using the TOF method, there are 5 FCT installed in the MEBT after the RFQ, and four of them were used to measure the beam energy during the RFQ commissioning, as shown in Figure 3. The measurement result is 3.1 MeV while the design energy is 3.0 MeV.

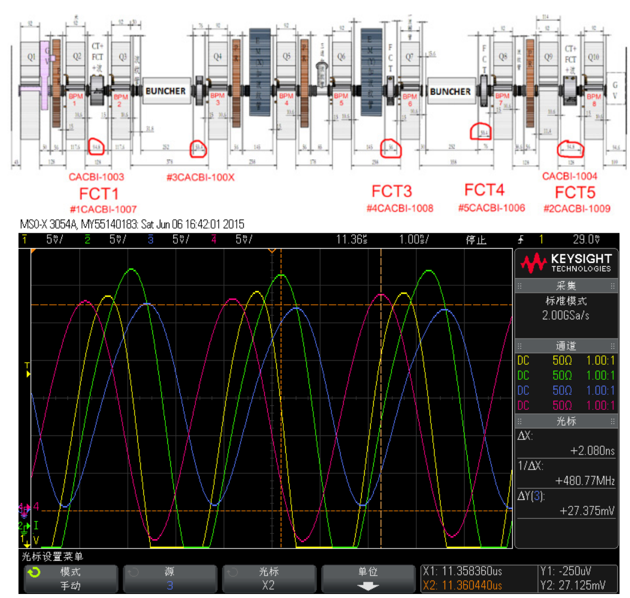

Figure 3: Layout of the MEBT, 5 FCT are labeled by red circle (up) and the beam phase measured by an oscilloscope (down).

Wall current monitor (WCM) is another way to measure the beam current. Two different design were finished based on different requirements. The WCM for LINAC as

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shown in Figure 4, the band width is 16 kHz ~ 1.5 GHz, two types of magnetic material, MN60 and C2025, have been used to improve its performance. The band width of WCM for RCS ring is reduced to 5 kHz to 100 MHz by using different magnetic materials, which are Amorphous & Nano-crystalline.

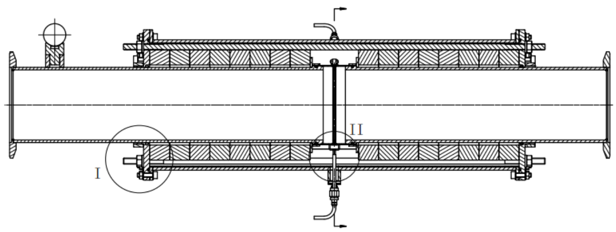

Figure 4: Schematic design of the WCM for LINAC.

Beam Position Monitor

Two type of BPM were designed for the accelerator, stripline for LINAC and shoe-box for the RCS ring and RTBT, as shown in Figure 5. 38 shoe-box BPM are installed in the RCS ring, 32 of them will be used to the orbit measurement, 3 of them will provide the beam position signal to the RF system, 1 for tune measurement, and the last 2 have lower capacitance will be used mainly during commissioning to measure lower signals.

Figure 5: Stripline BPM designed for LINAC (left) and shoe-box BPM for RTBT (right).

A BPM calibration system was designed to fit all size of monitor. One of the calibration results of stripline BPM as shown in Figure 6, the miss match between electric center and mechanical center is less than 0.15 mm.

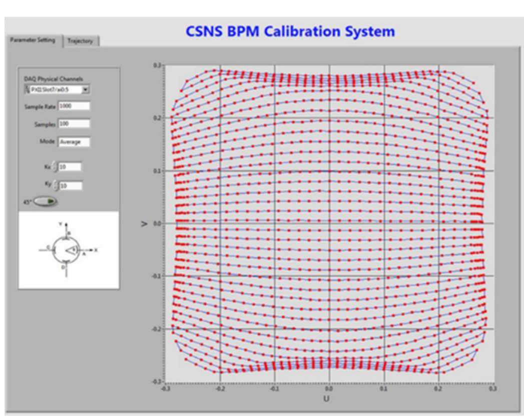

Figure 6: Calibration result of a stripline BPM.

Beam Profile Monitor

Stepper motor driven wire scanner and multi-wire scanner are the two devices chose for the beam profile measurement. Carbon wire with 50 μm diameter is used for MEBT wire scanner, as carbon wire has less energy deposition and can last longer than metal wires. Tungsten wire with 30 μm diameter is chose for the LINAC after DTL and RTBT section. The multi-wire scanner are mainly used in the injection area and in front of the beam dumps to have a faster profile measurement. The wire distribution of the wire scanners as shown in Figure 7.

Figure 7: Three wires with 45º angle separating distributed on the frame of the wire scanner, only one wire exposed in the beam pipe at the same time (left); Wires distribution of the multi-wire scanner (right).

Glowing screen beam footprint monitor was set up at the LINAC to dump beam transport line (LDBT) as another way to measure the beam profile. A tungsten mesh is put into the middle of the beam pipe, it will be heated up by the proton beam because of the energy deposition, and start glowing. The glowing can be captured by a suitable camera, and the roughly beam profile can be measured then. Figure 8 shows the mechanical design of the beam footprint monitor, 100 meshes tungsten net is chose and the maximum temperature on the net is around 500 degrees Celsius through simulation. The wave length of the glowing is mainly between 7 μm to 10 μm, which belongs to the far infrared.

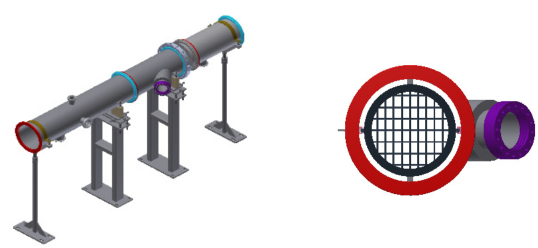

Figure 8: Mechanical design of the glowing screen beam footprint monitor, overall view (left) and the view from the beam entry side (right).

Beam Emittance Measurement System

Double slits system was set up for the low energy section beam emittance measurement, mainly for LEBT@50 keV, MEBT@3 MeV and DTL1@20 MeV. Graphite plate is welded in front of the copper plate of the first slit for the DTL1 set, in order to prevent the copper activation. The first slit of all 3 sets are with water cooling to protect the copper plate from the beam damage. One of the measurement results as shown in Figure 9, for the

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beam after RFQ ε_x=0.16π mm·mrad, ε_y=0.265π mm·mrad when the beam intensity is 15mA.

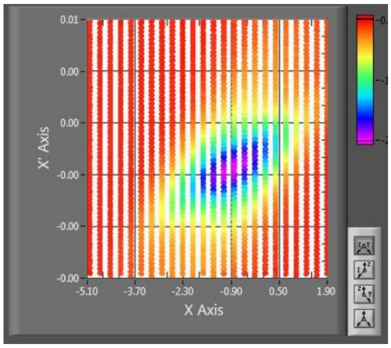

Figure 9: Emittance measurement result of the beam after RFQ (X plane).

Beam Loss Monitor

Different types of monitor were designed to measure the beam loss and to prevent the activation and heat load by intense beam loss. Ionization chamber with Ar+N2 filled, plastic scintillator together with photomultiplier and the neutron detector with BF3 filled are used to detect γ-ray and neutron induced by the lost particles. 162 ionization chambers in total distributed along the beam line as the main mean to measure the beam loss. Plastic scintillator used as the fast BLM for some key positions. The neutron detector focus on the low energy beam loss detection. Two types of BLMs were tested during the DTL1 commissioning as shown in Figure 10. Ionization chamber and Neutron detector located under the first slit of the emittance measurement system after DTL1, beam loss signal can be measured when the slit goes into the beam. The yellow line, which has 172 mV amplitude, is from ionization chamber and the green line, which has 3.31 V amplitude, is from Neutron detector.

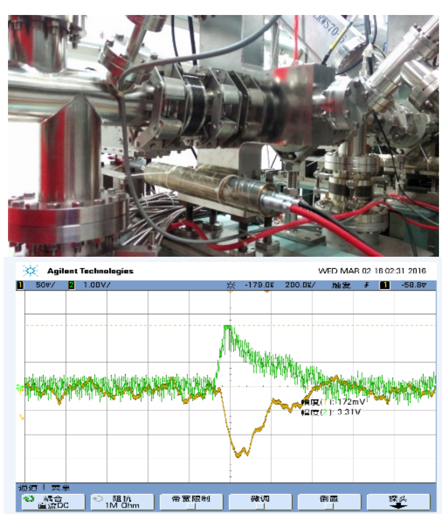

Figure 10: Ionization chamber and neutron detector were located under the first slit of the emittance measurement system of DTL1 (up); beam loss signal measured by these two BLM (down).

Mont Carlo simulation was carried out by FLUKA to validate the test result, as shown in Figure 11, which shows a kind of good agreement between simulation and experimentation. The x-coordinate shows the beam current loss measured by the CT just after the first slit, and the y-coordinate shows the beam loss signal measured by the ionization chamber and the simulated by FLUKA.

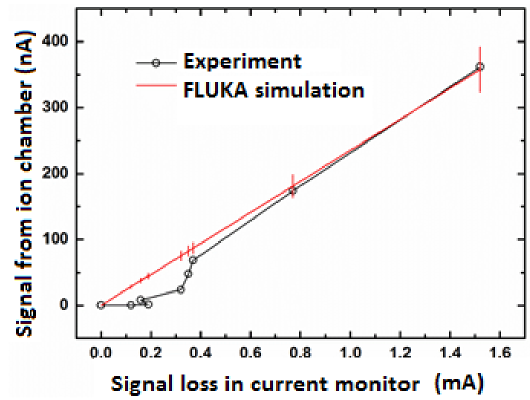

Figure 11: Simulate validation of the BLM test.

DATA ACQUISITION SYSTEM

Electronics are specific designed for all kinds of monitors, and tested during the RFQ and DTL1 commissioning. All signals are integrated into NI based system through ADC, AI or DI boards. The software for date analysis, motor control, and high voltage control are finished based on LabVIEW, and integrated into EPICS.

SUMMARY

RFQ, DTL1 commissioning have been finished March, 2016, lots of beam diagnostic elements have been tested, e.g. CT, FCT, stripline BPM, wire scanner, emittance measurement. All elements manufacturing will be finished July, 2016. LINAC commissioning will be started in September, 2016, the performance of all kinds of beam monitors will be checked this year.

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