THE BEAM DIAGNOSTICS OF CSNS

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Abstract

First, the beam diagnostics of CSNS is introduced. Then the progress of CSNS beam diagnostics is described. At last, the next year's plan is predicted.

INTRODUCTION OF CSNS

China Spallation Neutron Source (CSNS) will be a multi-purpose research centre. It is consisted of an 80 MeV Linac, a 3 GeV Rapid Cycling Synchrotron (RCS), two beam transport lines (LRBT, RTBT), a target and three neutron instruments. The beam power of CSNS is about 100 kW. The main beam parameters which related with beam diagnostics are listed in table 1.

Table 1: CSNS Beam Parameters

Parameter	Value
	Linac+LRBT
Particle	H^-
Beam energy (MeV)	0-80
Repetition rate (Hz)	25 (1)
Pulse current (mA)	15(5)
Macro pulse width (μs)	500(50)
Chopped pulse width (ns)	468
Chopped ratio	50%
RF frequency (MHz)	324
	RCS+RTBT
Particle	proton
Beam energy (MeV)	80-1600(80)
Repetition rate (Hz)	25(single shot)
Bunch particles	7.80E+12
Harmonic	2
Bunch length (ns)	500-100
Injection turns	225
Revolution frequency (MHz)	0.535-1.232

The number in the brackets is the value of the first step of CSNS commissioning [1].

INTRODUCTION OF CSNS BEAM DIAGNOSTICS

The CSNS beam diagnostics system is a new established system. The members in the group are all freshman. In order to finished the aim of CSNS beam diagnostics, the mature and traditional diagnostics method is firstly chosen. In China, there is not a so large scale proton accelerator. The experience on proton accelerator is absent. So the design of CSNS beam diagnostics is referred mainly from J-Parc [2] [3] and SNS [4].

The each type beam monitor according to different need from each area of CSNS accelerator is listed in table 2 and 3.

Table 2: Linac Section Beam Monitor

Type	Number		
	LEBT	MEBT	DTL
Beam Current Transformer	2	2	3
Beam Position Monitor		8	
Beam Loss Monitor		3	12
Fast Beam Loss Monitor			1
Wire Scanner		4	
Phase Detector		5	3
EMittance system	1	1	

Table 3: Ring and Beam Transport Line Beam Monitor

Type	Number		
	LRBT	RCS	RTBT
Beam Current Transformer	4	2	4
Beam Position Monitor	20	35	33
Beam Loss Monitor	28	72	50
Fast Beam Loss Monitor	3	9	2
Wire Scanner	7		8
Multi-Wire Profile Monitor	6		2
Phase Detector	5	3	
Wall Current Monitor	3	2	
DCCT		1	
Tune system		1	
Foil Video System	1		

The Introduction of Each Monitor

According to the beam structure, the monitor can be divided into two parts. The first part is BR (Before Ring) section which includes FE, DTL and LRBT. They have almost similar beam structure. The beam structure has three layers from time domain viewpoint, the top layer is the macro structure, the middle layer is chopped beam structure, and the bottom layer is the bunch structure with

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RF system frequency 324 MHz [5]. The next part is Ring section which includes RCS and RTBT, the beam structure from Linac will became two bunched beam during the injection painting procedure. The beam situation in RTBT can be thought as the situation of the last turn of RCS.

The BR Section

BCT, the ACCT is chosen as beam pulse peak current detector. It mainly monitors the beam transmission rate during commissioning and normal running. It is installed at double end of each section.

BPM, the one end shorted strip line type BPM [6] is chosen. It mainly measures the beam position. And a special one will be used, the four plate output signal is summed by a combiner, and using oscilloscope to observe the output signal. Using this method to measure the chopped beam rise time and beam bunched situation. Now, in MEBT, almost each quadrupole magnet has a BPM as its vacuum tube. In LRBT, there is a BPM near each group of the magnet.

BLM, the ion chamber filled with 70% Argon and 30% Nitrogen is chosen. Accompany with its electronics system, during the commissioning, the BLM system need detect the beam loss situation; during the operation procedure, The BLM system has a key role in Machine Protection System (MPS). When the abnormal beam loss happened, The BLM system should detect and output signal to MPS in ten micro second. In BR section, there is a BLM at every three meters. If the distance between two devices is larger than three meters, the BLM will be installed near the device.

FBLM, the plastic scintillator and PMT type is chosen because of its easy operation. The FBLM is too sensitive, the cosmic ray can produce larger signal than beam loss signal. So it is hard to use it as MPS input signal. Now the FBLM system is planned to observe beam loss during the commissioning. So several FBLM are installed in BR section.

WS, three scanned wire structure is chosen. In MEBT area, the carbon fibre is chosen as the material of signal wire because it can be survived during 50 micro second, 1 Hz, 3 MeV H^- beam bombarded. But the mechanical property of carbon wire is not so better than metal wire. In LRBT, because the beam can pass through the wire, the tungsten wire can be used. The four WS system is used to get beam emittance and to supply the beam size for beam transvers dynamic tuning.

Phase detector, the Bergoz's [7] 20 turn FCT is chosen as phase detector. The composite of electronics is similar with LANL design [8]. The signal from FCT is down convert to IF signal, and an ADC using four times IF frequency sample the IF signal. In FPGA, the sampling data is calibrated and calculated to get the amplitude and phase of FCT signal. Three FCTs are used to measure the bunch velocity (energy) by TOF method [9]. Those data can help the physicist to tune the amplitude and phase set point of the RF cavity. If the space is enough, each RF cavity has three FCTs. The distance of FCT1 and FCT2 is short, and the distance of FCT1 and FCT3 is long. The reason of using this layout is to improve the measurement accuracy of beam energy.

EM, the scanning double-slit system is adopted to measure the beam emittance on LEBT and MEBT. The LEBT EM should give the first beam emittance of whole accelerator. And it will supply to physicist as the initial condition of beam dynamic simulation. The MEBT EM will give a cross check beam emittance with multi-WS system. At initial commissioning, if the software of calculated emittance from WS data is not so perfect, the EM data will be the candidate of emittance measurement.

MWPM, as the beam passes the monitor just one times, the beam profile is gotten. The measured speed is very quickly by MWPM compared with WS. It is suited for RCS single shot tuning mode. Those monitor are installed at injection area, and in front of the each dump. According to J-Parc experience, the beam current in the injection dump line is very small, so it is better to enlarge the signal wire to strip.

WCM, because the bunch length of LRBT is very small, the Fermi type [10] WCM is chosen for LRBT. The design frequency bandwidth is about 3GHz. The LRBT debuncher will be tuned through the bunch length changed measured by WCM.

The Ring Section

BCT, DCCT, those detector mainly monitor the bunch charge. So referred from J-Parc RCS design, the output signal from CT will be divided by revolution frequency. And DCCT, it is planned to buy from Bergoz Company. AS for RTBT, we have not decided which type between Bergoz's ICT and WCM to measure the bunch charge.

BPM, the linear cut box type BPM is chosen. The BPM has two structures. One has the four plates to supply two directions beam position data. The other just supplies one direction data. There are three BPM which serves as RCS LLRF radial feedback detector in those 35 BPMs. The electronics of BPM is planned developing by our colleges. It includes two modes, the average mode and turn by turn (TBT) mode. In average mode, from injection to extraction, the system can output 20 averaged beam position data. In TBT mode, first, the system can store the TBT position data in local memory; second, it can supply real position data in fixed period. In TBT mode, if the control system gave a trigger signal, it should stop refreshing beam position data. All the position data in electronics local memory will be downloaded in offline mode.

Tune, it is composed of two beam exciters and one special BPM monitor [11]. For BPM signal processing, two methods are planed using. The first is using real time spectrum to deal with the BPM signal. The second is that developing the special processing module. It needs a 20 MHz ADC according to our frequency range, and the algorithm can be developed in FPGA or DSP.

MWPM, on RTBT, the two MWPMs are installed near extraction dump and proton beam window. According to international experience, the MWPM near beam window

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is adopted online mode. The life time of MWPM is long enough for beam window. The electronics method is used to get the beam distribution on beam window.

THE PROGRESS OF CSNS BEAM DIAGNOSTICS

We have a 3.5 MeV and 352.2 MHz RFQ. Base on it, a beam dynamic experiment is carried on. A series beam monitor is developed. Those monitors can be thought as the prototype of the CSNS BR section monitor except MWPM and FVS. Most of those monitor are tested with RFQ 20mA proton beam. The EM system is tested with prototype of CSNS ion source beam.

BPM, the Bergoz LR-BPM module is used, and the readout system based on VME structure using EPICS [12] is built. The Hytec [13] ADC 8411 is chosen. During the measurement, RF noise can be measure by BPM system. From Fig. 1, the top part of blue line means zero position. But, the bottom part of measured data is the affection from RF noise. Although the amplitude of the RF noise is about 1% of the BPM plate signal, we plan to improve the connector reliability and the system shielding.

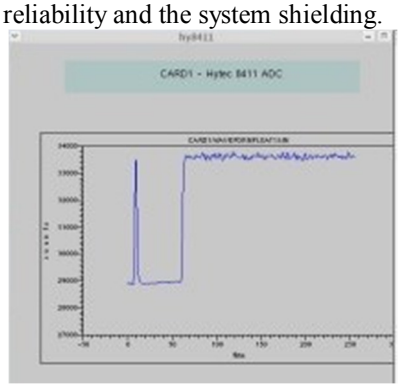

Figure 1: The signal of BPM.

WS and EM, the SNS WS circuit is referred [14] as for WS and EM signal processing circuit. Also the readout system of them are developed which include motor control, ADC, serial communication and so on. Now the synApps [15] SSCAN is used to get the scanned raw data. The data is transforms to text file and draw the beam profile (Fig. 2) in other software.

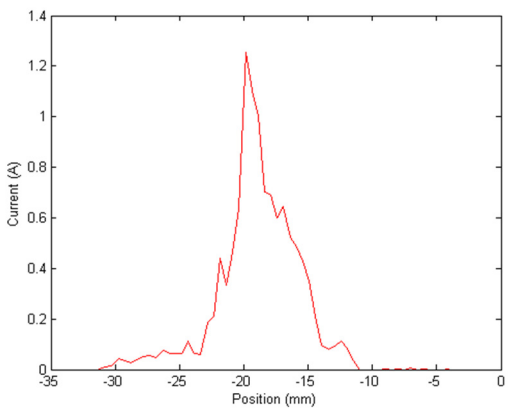

Figure 2: The measured beam profile.

During the test, if more than four motors are powered on, the brake current of motor will become the noise of other system. So we improve the motor power supplied method. And the ADC 8411 100 kHz sampling rate is not enough, a 1MHz Hytec ADC will be bought for WS system.

THE NEXT YEAR'S PLAN

According to the CSNS CPM plan, at mid of the next year, the commissioning of CSNS FE will be started. All beam monitors in this area should be finished manufacturing, purchasing, assembling and pre-commissioning.

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