Design of gas jet based high energy proton beam diagnostic instruments

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Introduction

Bhabha Atomic Research Centre (BARC) is designing and developing linear high power high intensity proton accelerators for Accelerator Driven Subcritical Reactor System (ADS) and other nuclear applications [1]. Power of proton accelerators around the world is compared in table 1 [2]. Since the accelerator power requirement for ADS is greater than 10 MW, it is required to develop custom instruments for this accelerator that can handle the high power.

Beam diagnostics instruments play a key role in feedback control of the particle beam for reliably maintaining the quality of the beam, reduction of beam losses and safe operation.

Invasive monitors such as scintillation based monitors or wire scanners used for lower intensity beams may get damaged by the high intensity beams. Hence minimally invasive techniques have to be explored to operate at higher power.

Laser based beam diagnostic instruments suitable for H- cannot be utilized for proton beam as these utilize the property of neutralization of the negative H- particle by the laser.

Also, synchrotron based monitors used for electron accelerators require bending magnets to be introduced in the beam path making it complex for the linear proton accelerators.

Currently techniques being explored for non invasive beam profile measurement of proton beams are Residual gas monitor, Gas jet monitor, electron gun scanner based monitor and electro-optic systems. Of these the gas jet monitors show promise for the energy ranges relevant to the ADS application [3]. Also it has the capability to provide 2D profile of the beam. It is also being explored as a useful tool for other additional diagnostics of the beam such as intensity [3], and halo measurement [4]. Gas jet devices are used in different nuclear physics experiments also.

Currently this technique has been tested on lower energy electron beams using Ionization Profile Monitors at other labs. At BARC similar setup is being developed to be tested in the beam line of Low Energy High Intensity Proton Accelerator (LEHIPA) which is the front end of ADS. Its layout is shown in Figure 1. Currently beam diagnostics developed and tested at BARC for LEHIPA includes water cooled Wire scanners, faraday cups and fast faraday cups, DCCT and button pickups.

Gas Jet Design

Gas jets have number of applications such as Laser machining, aeronautics, molecular spectroscopy, nuclear fusion and atomic physics.

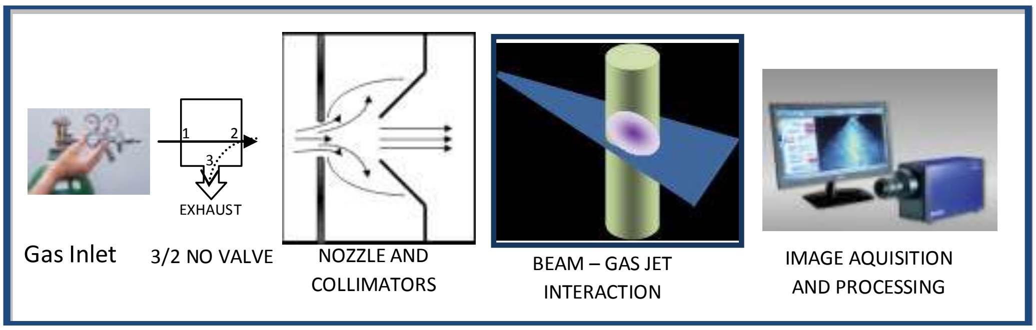

Fig 1 Layout of the System

The gas jet design in [3] is felt to be suitable for current design. 2D Numerical simulations of orifice nozzle for different pressure ratios and nozzle dimensions are being carried out. Result of one such simulation has been shown below.

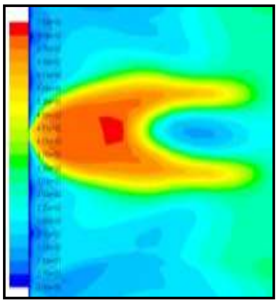

Fig 2 Screenshot of gas jet simulation

Fast Valve Control System

Block diagram of a simple fast controller designed for the inlet valve is shown in figure 2.

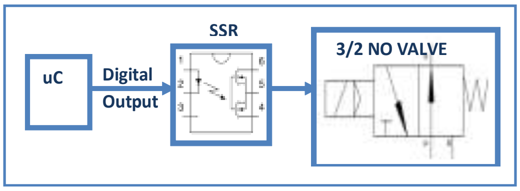

Fig 3 Fast 3/2 Valve Control System

Image capturing

Ionization profile monitors (IPM) are the generally preferred method of profile capturing in similar beam profile setups due to the higher efficiency. However, Beam induce fluorescence (BIF) would be used at least initially in this setup as the studies will be carried out for high intensity beams. Sensitive camera with high speed digital interface and triggering features along with optics would be used.

Image processing

Electronics for high speed readout followed by processing to remove background noise due to radiation or interference is also being developed. Along with beam parameters such as position, intensity, 2-D transverse profile, transverse emittance with the help of solenoids, and halo measurement that are being explored at other foreign labs, diagnostic of longitudinal beam parameters with the help of RF deflectors and fast image capturing electronics would also be explored using the current setup at LEHIPA.

Conclusion

Based on literature survey and experiences obtained during the accelerator development the requirement of advanced beam diagnostic systems for high power proton accelerators has been understood. A suitable technique based on supersonic gas jets has been identified and its scheme has been detailed. This scheme is useful for observing number of beam parameters at large range of intensity and energy. Thus it would be a significant tool in realizing reliable, safe and efficient operation of accelerator system for ADS and other nuclear physics applications.

Table 1: High Power Operational Proton Accelerators

Facility	Power (kW)	Energy (GeV)	Time Structure	Accelerator Type
TRIUMF	100	0.52	CW, 23 MHz	cyclotron
LANSCE area A	80-120	0.8	120 Hz	linac
ISIS Present	200	0.8	40 Hz to TS-1 10 Hz to TS-2	70 MeV H^- linac + RCS
J-PARC MR (FX)	240	30	0.4 Hz x 5 us	3 GeV into RCS
J-PARC RCS	300	3	25 Hz x 1 us	181 MeV linac + RCS
FNAL MI	400	120	9.4 us every 2.2 s	Linac + RCS
CERN SPS	470	400	4.4 s cycle length	linac + 2 stage RCS
SNS	1,000	0.94	60 Hz	linac + accumulator
PSI	1,300	0.59	CW, 50MHz	2 stage cyclotron

References

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