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# Beam Diagnostic at KOMAC Beam Test Stand (BTS)

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## 1. Introduction

Beam diagnostics is one of the most crucial aspects of particle accelerator operation. Through beam diagnostic data, we can infer the current state of the beam and adjust operating conditions accordingly, ultimately improving the quality of the accelerated beam. There are various types of diagnostic methods and data that can be obtained, but among them, we focus on techniques for obtaining the beam's emittance and phase space. Prior to applying beam diagnostics equipment to a 100 MeV accelerator, development and testing is being conducted at the Beam Test Stand (BTS) in KOMAC. This paper we will discuss the development of an Allison type emittance scanner and tomography-based beam diagnostic methods currently being tested at the BTS.

## 2. Beam Test Stand (BTS)

Beam Test Stand (BTS) is small accelerator which can accelerate the proton and helium up to 1 MeV/u. It was constructed to facilitate beam testing systems for accelerator equipment such as ion sources or beam diagnostic systems.

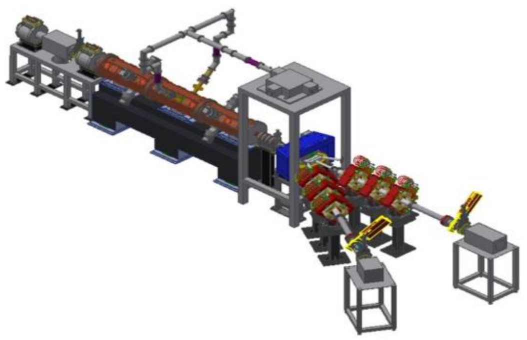

Figure 1 Layout of Beam Test Stand (BTS) at KOMAC.

Figure 1 is the layout of the Beam Test Stand (BTS). It consists of ion source, Low Energy Beam Transport (LEBT), Radio Frequency Quadrupole (RFQ), and beam transport line. The ion source extracts the beam with 25 keV/u initial energy and 10mA peak current. The RFQ accelerates the beam to 1 MeV/u and the accelerated beam transport to beam transport line. There are two beam transport line. One is straight beamline and the other is 30 degree bending beamline. At the end of beamline, wire scanners are installed so we can measure the one-dimension profile data of beam.

## 3. Allison scanner

The Allison type emittance scanner is widely used in accelerator. The Allison scanner was first suggested by Allison at 1983. It uses the deflection of charged particles in an electric field.

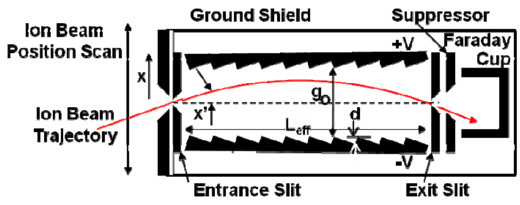


Figure 2 Schematic drawing of Allison scanner at SNS.

The Figure 2 shows the drawing of Allison type emittance scanner at Spallation Neutron Source (SNS) accelerator. It shows the general geometry of Allison type emittance scanner. The initial beam is first sliced into a single beamlet by an entrance slit. The beamlet then passes through an electrode line and receives an electric kick from the electrode. Finally, the beamlet is cut again by an exit slit, and its current is measured by a Faraday cup. The electrode's length, gap size between the electrode, and the applied potential are design parameters that define the angle of the beam at the entrance point. By sweeping the voltage at certain positions, data about current at specific positions and angles can be obtained.

### *3.1 Allison scanner at BTS*

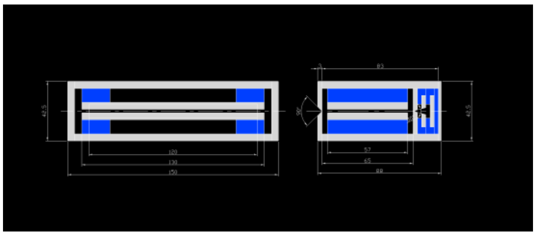

Figure 3 Drawing of Allison scanner at KOMAC BTS.

Figure 3 is the drawing of Allison scanner at KOMAC BTS. The length of electrode is 57 mm, the length between slit and electrode is 4mm, and the slit width is 0.1 mm. Therefore, the maximum analyzable angle is 68.5 mrad and the angular resolution is 1.5 mrad

The conventional data processing equation for Allison type emittance scanner ignore the thickness of slit and it assumes that the electrode is placed at the center of two slits. However, that assumption can distort the data and the distortion of data was confirmed by researchers at Facility for Rare Isotope Beams (FRIB) [1]. They suggest different equation for Allison scanner data processing which includes the influence of slit thickness and the position of electrode, so we follow their suggestion to prevent data distortion.

One of the main points of Allison scanner data processing is noisy data handling. The noise at the measurement is inevitable. However, the noise at measured data can significantly distort the final data analysis. Therefore, we adapt two kinds of noise data handling algorithm. The first algorithm is Density Based Scan (DBS) algorithm, and the second algorithm is Self-Consistent Unbiased Elliptical Exclusion (SCUBEEx) [2].

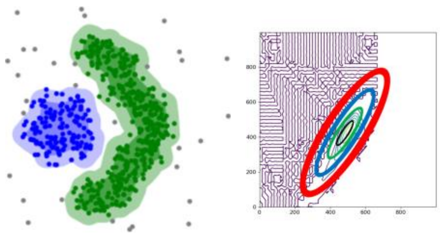

Figure 4 Concept of Density Based Scan Algorithm (Left) and Self-Consistent Unbiased Elliptical Exclusion (Right).

The DBS algorithm detect the data cluster from initial data. Usually, the shape of the phase space is ellipse, and the noise data are placed at the outlier, so the algorithm only extract the data cluster at the phase space ellipse. The SCUBEEx algorithm uses the saturation of current. The algorithm generates the first ellipse and calculate the total current with different size of the ellipse. If the total current start to saturate, it defines the final ellipse and ignore the data points which is placed outside of ellipse.

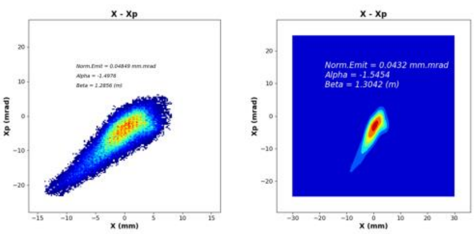


Figure 5 Noise data handling algorithm test result. Left figure is result with DBS and the right figure is result with SCUBEEx.

Figure 5 shows the algorithm test result for DBS and SCUBEEx. It shows similar calculated value for emittance and twiss alpha and beta. It confirms that those algorithms can be used for experiment data so we will use both algorithm with real beam experiment.

## 4. Phase Space Tomography

Phase space tomography began with the goal of producing high-dimensional data from low-dimensional data. Many beam diagnostic instruments measure data in zero or one dimension. This data is valuable for accelerator operation. However, obtaining high-dimensional data from beam diagnostics can enhance beam dynamics simulations and aid in understanding the beam condition.

The high-dimensional data is very valuable but usually requires special equipment, so researchers are trying to find a way to generate high-dimensional data from low-dimensional data. The one of the ways is phase space tomography method by using one dimensional profile data [3, 4]. It uses similar technique with CT at the hospital. The CT measure one-dimension data with 360 degree angle and reconstruct the two dimension image. Similarly, we measure one-dimension profile data by using wire scanner and reconstruct the phase space.

### *4.1 Phase space tomography at BTS*

There is a wire scanner at the end of BTS beamline so we measure one-dimension profile data by using wire scanner and we rotate the angle of beam by using magnetic quadrupoles.

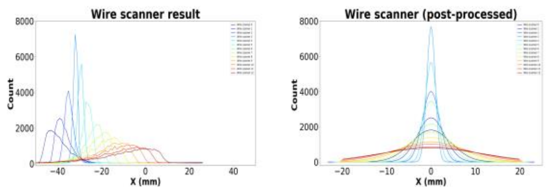


Figure 6 Measured wire scanner raw data (Left) and post-processed wire scanner data (Right).

Figure 6 is the measured wire scanner data at the straight beam line. The left figure is the raw data and the right figure is gaussian fitted data. We try to reconstruct the phase space by using the wire scanner data but the rotation angle of beam was too narrow so we can not reconstruct the proper phase space.

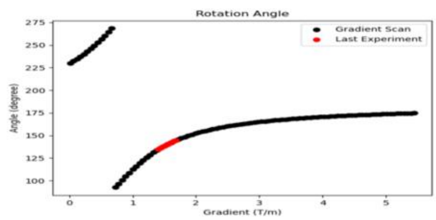

Figure 7 Rotation angle of beam at the experiment.

Figure 7 shows the rotation angle of beam. The black dot shows the rotation angle by different gradient of quadrupole and the red dot shows the experiment range. The rotation angle was around 20 degree because of large beam loss. It can be relaxed by using several magnetic quadrupoles, so we plan to use three magnetic quadrupoles for next experiment.

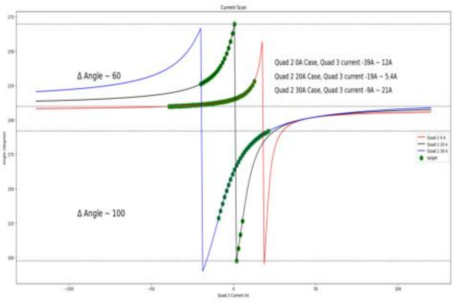


Figure 8 Tomography experiment plan with three magnetic quadrupoles.

Figure 8 is the plan for the next tomography beam experiment. We plan to use the three magnetic quadrupoles to get the profile data with large rotation angle.

## 5. Conclusions

Allison scanner and phase space tomography method are under developing and testing at KOMAC BTS. The data processing algorithm for Allison scanner is already tested and we wait for beam experiment with Allison scanner. The tomography method also starts to do the beam experiment for the confirmation of concept. Those beam diagnostic method will continuously developed and tested at BTS and then moved to 100 MeV proton main linac to improve the quality of beam service.

## ACKNOWLEGEMENTS

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