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A 2-IN-1 EMITTANCE SCANNER

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Abstract: A new Allison type emittance scanner has been designed as a combination to measure both horizontal vertical planes in one assembly. This is accomplished by having two identical emittance scanners oriented at right angles to each other, and the whole assembly driven along an axis 45 degrees from vertical.

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1 Introduction

Allisson type emittance scanners [1] are widely used at TRIUMF and other accelerator laboratories to measure the transverse phase-space density of charged particle beams. It is a simple diagnostics device consisting of a Faraday cup, a pair of high-voltage electrodes like an electrostatic steerer with a pair of slits, one at the entrance and the other at the exit at a grounded potential. The beam emittance is measured by moving the scanner across the beam along the horizontal or the vertical planes. Often, it is required to measure the beam emittance in both horizontal and vertical planes in facilities such as ISIS-I1, ISAC [2], ARIEL at TRIUMF. At a given location, there are two independent emittance scanners that have been installed to measure the emittance in both planes. In this note, a feasible 2-in-1 emittance scanner design has been shown using an Allison type emittance scanner. The emittance scanners are arranged in such a way that they measure both horizontal and vertical emittances with a single motion across the beam. Major advantages are the overall reduction in the cost, ease of operation and maintenance by using a single actuator, common power supplies and control system.

2 Scanner design

The maximum measurable angle by an Allison type scanner for a given geometry is

$$x'_m = \frac{2g}{D + 2\delta} \tag{1}$$

corresponding to a maximum applied potential difference between the electrodes is

$$V_m = \frac{8g^2\phi}{D^2 - 4\delta^2} \tag{2}$$

Parameter	$e\phi = 30$ keV	$e\phi = 300$ keV
Slit aperture width (s)	0.05 mm	0.05 mm
Electrodes length (L)	72 mm	72 mm
Electrodes separation gap (g)	5 mm	2.5 mm
Electrodes to slit gap (δ)	1.4 mm	1.4 mm
Angular resolution ($\Delta\theta$)	$\pm$0.7 mrad	$\pm$0.7 mrad
Maximum measurable angle (x'_m)	$\pm$128.9 mrad	$\pm$64.4 mrad
Maximum applied voltage (V_m)	$\pm$1074 V	$\pm$2685 V

Table 1: Design parameters of the proposed emittance scanner for the injection beamline with a beam energy ($e\phi$) of 30 keV an 300 keV.

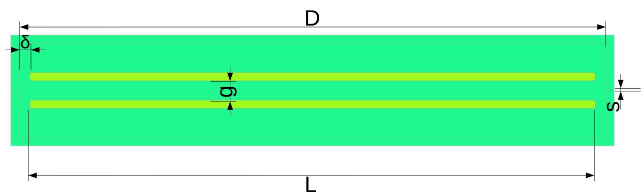

Figure 1: A cross sectional view (1/2 view of the full geometry) of the emittance scanner with its scanner parameters.

The calculated scanner design parameters, which are compatible for measuring phase-space density in the new horizontal injection beamline [3, 4] of TRIUMF's 500 MeV main cyclotron, are shown in table 1. It has been proposed to measure the beam emittances in the periodic section of the injection beamline. Here, the beam acceptance is about 120 μm through an aperture radius of 25 mm, which leads to a maximum angular divergence of about 18 mrad in both horizontal and vertical planes. This divergence angle is within the maximum measurable angle by the emittance scanner provided in table 1.

Figure 1 shows a cross section view of the emittance scanner excluding the beam current measuring devices such as the Faraday cup, electron multiplier, etc. Thermal calculations for a high power beam are not included in this design. Figure 2 shows the geometrical view of the emittance scanner from the OPERA electrostatic model and Fig. 3 shows the calculated electric field (E_y) along the axis of the emittance scanner with an applied potential difference of 2 kV between the electrodes. It should be noted that the difference between the geometrical length ($L = 72$ mm) of the electrode and the calculated effective length ($L_{eff} = 72.8$ mm) is about 0.8 mm. In this case error in the measured divergence angle will be within the angular resolution ($\Delta\theta = 0.7$ mrad). The calculated ion trajectory through the emittance scanner with an initial divergence of 48.5 mrad at the center of the entrance slit in the emittance scanner is shown in Fig. 4

In order to measure the phase-space density in both horizontal and vertical planes, two identical emittance scanners with the parameters provided in table 1 are proposed to be assembled and installed as shown in Fig. 5. The positional movement of the two scanners is 45° with respect to the x or y planes, rather than the conventional movement along the x or y planes. In this method, the position of the horizontal (x) or vertical (y) emittance scanner's slit is simply correlated with the scanner movement position (d) by factor of $\sqrt{2}$, i.e.,

$$x = y = \frac{d}{\sqrt{2}} \tag{3}$$

and the measured angle at this position is

$$x' = y' = \frac{VL}{4g\phi} \tag{4}$$

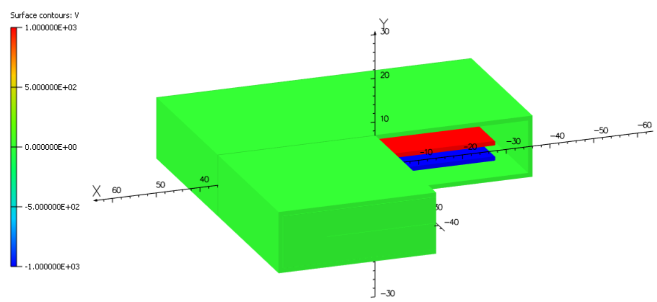

Figure 2: A geometrical view (3/4 view of the full geometry) of the emittance scanner.

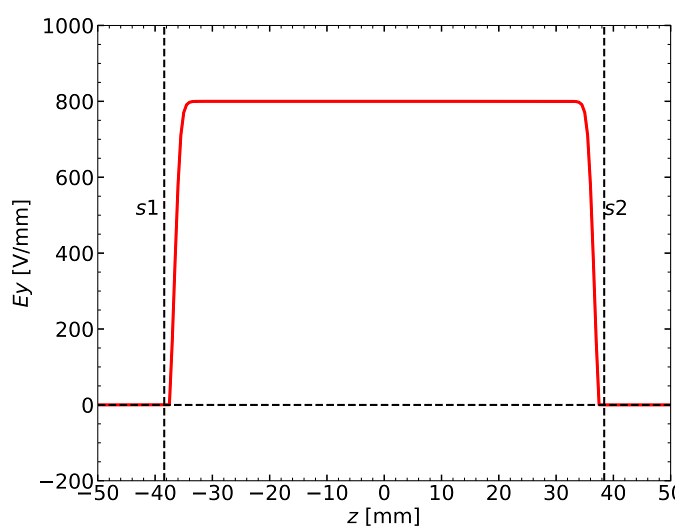

Figure 3: The calculated electric field (E_y) along the axis of the emittance scanner with an applied potential difference between the electrodes is 2 kV.

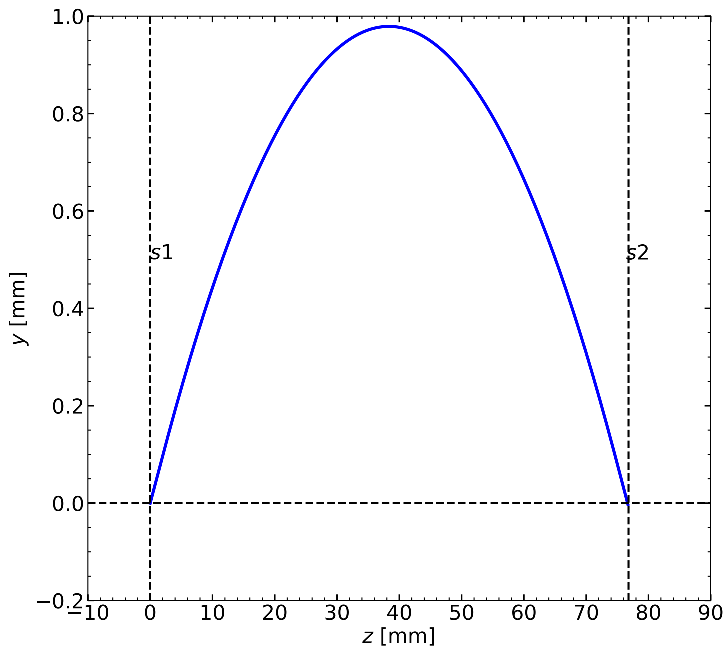

Figure 4: The calculated 300 keV H^-ion trajectory for a given initial divergence of 48.5 mrad through the emittance scanner with an applied potential difference between the electrodes at 2 kV.

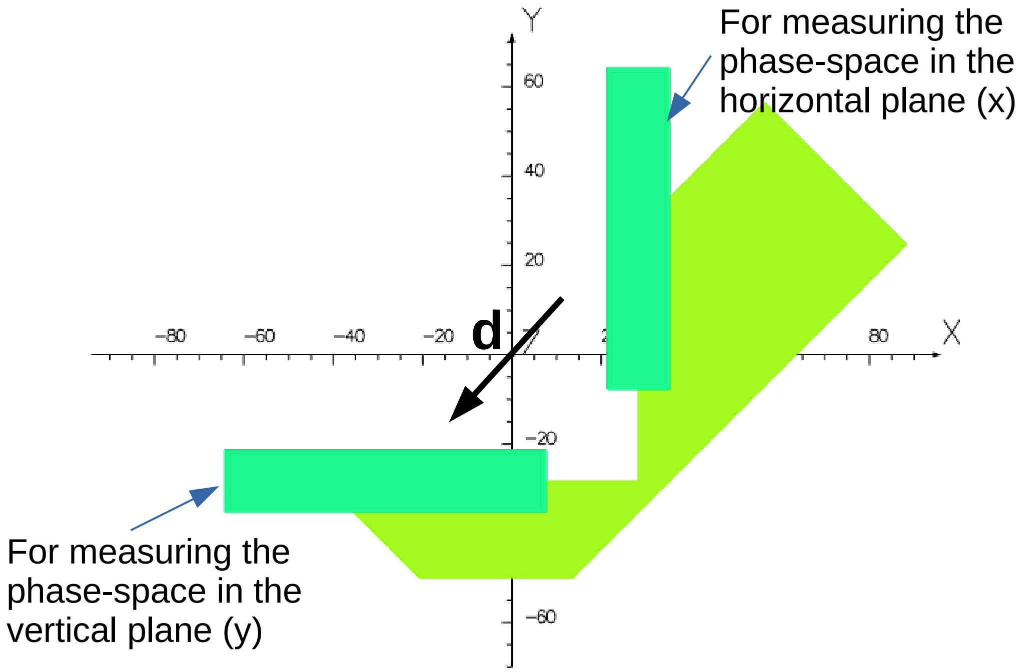

Figure 5: The proposed orientation of installation and movement of the emittance scanners in order to measure the phase-space density of the ion beams for both horizontal and vertical planes. The angle of mechanical actuator orientation is 45° with respect to the horizontal or vertical planes.

3 Summary and outlook

An example of the Allison type emittance scanner design and installation method has been presented to measure the phase-space density in both horizontal and vertical planes. The scanner design parameters are compatible with the transported beam through the new horizontal injection beamline. A similar design could be implemented and tested in the near future.

References

[1] Allison, Paul W., Joseph D. Sherman and David B. Holtkamp. "An Emittance Scanner for Intense Low-Energy Ion Beams." IEEE Transactions on Nuclear Science 30 (1983): 2204-2206.

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[3] M. Marchetto, S. Saminathan, *Replacement of the ISIS horizontal injection beamline*, Document-218327, TRI-DN-22-05, Internal report, TRIUMF, 2022.

[4] S. Saminathan, *Optics design of the ion source injection terminal I2*, Document-213184, TRI-DN-21-16, Internal report, TRIUMF, 2022.