HIGH RESOLUTION EMITTANCE MEASUREMENTS AT SNS FRONT END

A. Zhukov, A. Aleksandrov, ORNL, Oak Ridge, TN 37831, USA

Abstract

The Spallation Neutron Source (SNS) linac accelerates an H- beam from 2.5MeV up to 1GeV. Recently the emittance scanner in the MEBT (2.5 MeV) was upgraded. In addition to the slit - harp measurement, we now can use a slit installed on the same actuator as the harp. In combination with a faraday cup located downstream in DTL part of the linac, it represents a classical slit-slit emittance measurement device. While a slit – slit scan takes much longer, it is immune to harp related problems such as wire cross talk, and thus looks promising for accurate halo measurements. Time resolution of the new device seems to be sufficient to estimate the amount of beam in the chopper gap (the scanner is downstream of the chopper), and probably to measure its emittance. This paper describes the initial measurements with the new device and some model validation data.

BEAM TIME STRUCTURE

The SNS runs a pulsed H- beam at 60Hz. The pulse can be up to 1 mS long. It consists of a train of mini-pulses having a 945 nS period. The LEBT chopper creates such a train by periodically kicking the beam into a target to create gaps between the mini-pulses. In addition, the MEBT chopper cleans up the gap further downstream. The LEBT chopper cyclically kicks the beam in four different directions, effectively creating periodicity with a period of 4 mini-pulses. This can cause variation of emittance along the beam pulse due to mini-pulse on/off transients, improper MEBT chopper and other causes.

EMITTANCE SCANNER

The emittance scanner is a classical slit-harp device [1]. It was recently upgraded to have additional capabilities of a slit-slit scan. The harp actuator also holds a plate with a slit in it. A faraday cup located in the DTL part of accelerator is used as a collector for slit-slit scans. Table 1 shows the most important properties of the beam and emittance device.

Table 1: Scanner and Beam Parameters

Parameter	Value
Ion Energy (H^-)	2.5 MeV
β = v/c	0.073
Slit – harp distance	353 mm
Signal wires	16
Distance between wires	1 mm
HV Bias	+300 V
Macro pulse length	~ 40 uS when using scanner
Beam current	~ 30 mA
Slit	0.1 mm carbon
Wire	0.1 mm tungsten
Second slit	0.15 mm
Harp Faraday Cup distance	24.45 m

Raw Signals

In order to measure signals from harp wires we use a custom-made transimpedance amplifier with 16 independent channels. A raw signal, digitized by a GE ICS-645 (5MS/s 16 bits) ADC, is shown on figure one.

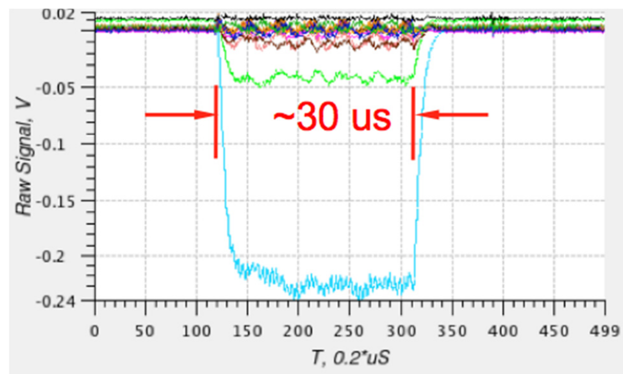

Figure 1: Raw signal from harp wires.

The time resolution of the harp signals is ~1us, and is a fundamentally limited by the current harp's design that introduces different coupling mechanisms [1].

The signal from a faraday cup is amplified by the commercially available SR445 wide-bandwidth amplifier and sampled with a 200MS/s 12 bit NI-5124 digitizer.

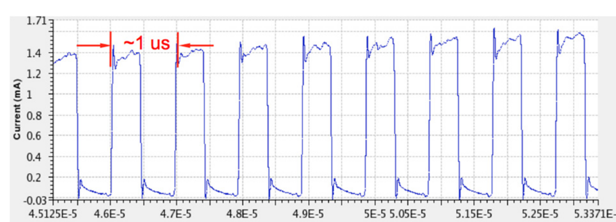

Figure 2: Raw signal from Faraday Cup.

The time resolution of the FC signal is at least 10 times better than from the harp. It clearly resolves the mini-pulse structure of SNS beam.

HIGH TIME RESOLUTION

In order to investigate the emittance variations along the beam pulse, we performed a slit-slit emittance scan and calculated emittance at different locations along the pulse. The dependence of emittance on mini-pulse number is shown in Fig.3 [2]. Blue bars represent emittance calculated around the mini-pulse's rising edge (chopper switching) and the red ones show emittance calculated in the middle, "flat", part of a mini-pulse.

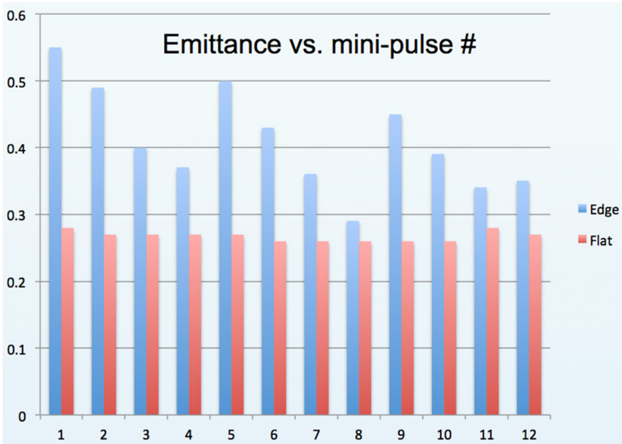

Figure 3: Emittance variation along beam pulse

It is clear that emittance calculated at the rising edge has the 4 mini-pulse periodicity.

BACKGROUND NOISE AND ARTIFACTS

Any emittance measurement contains some noise artifacts caused by electronic noise, wire coupling (in the case of harp measurements), electron coupling [1] and slit scattering. A common technique to mitigate this is the introduction of a threshold value with which signals that are lower than it are neglected. The emittance value depends on the threshold. Practically, it can be hard to select such a threshold value on a per measurement basis and consistently compare different measurements.

Figures 4-5 show a typical slit-slit scan and emittance dependence on the threshold value.

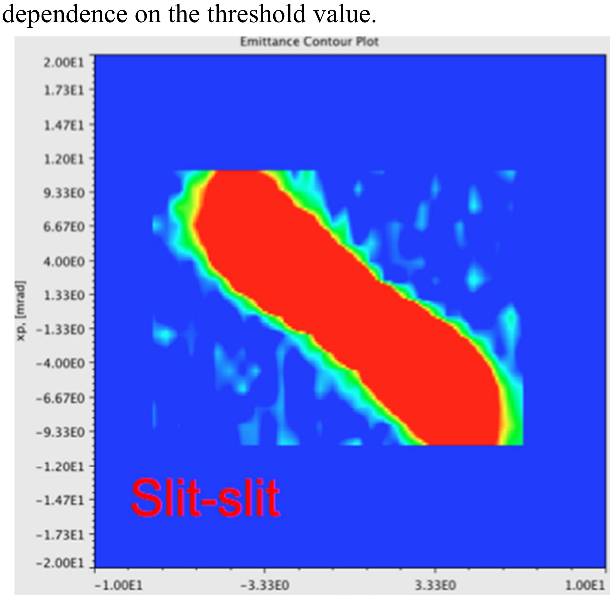

Figure 4: Horizontal emittance obtained with slit-slit scan.

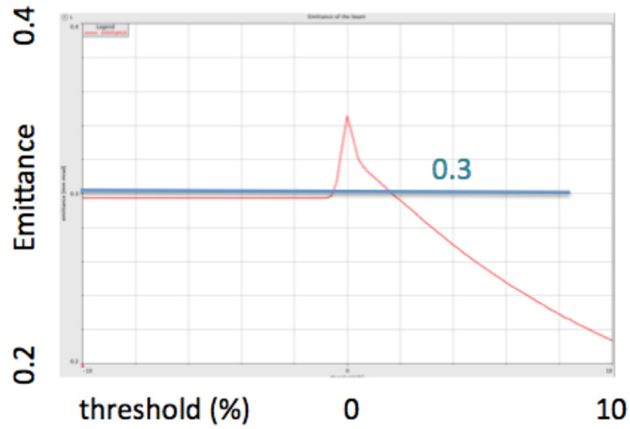

Figure 5: Emittance dependence on threshold value for slit-slit scan at Fig. 4.

The same beam was measured with slit-harp and corresponding plots are shown in Fig. 6-7. The shape of the emittance vs. threshold curve significantly differs for different types of measurements. In the case of a slit-harp measurement, there is a definite turning point where the slope of the curve changes. This change corresponds to the threshold value below which all artifacts (like the vertical stripe in Fig. 6) are neglected and only real beam is integrated. In contrast, the slit-slit scan doesn't show any artifacts, and the curve smoothly decreases while the threshold is increased.

Thus, in case of slit-slit scan, one can set the threshold to a small negative number (to account for negative noise signal being averaged with the positive noise signal). In the case of a slit-harp measurement, more analysis is needed, and it's hard to automate the process of comparing emittance values for different beam conditions.

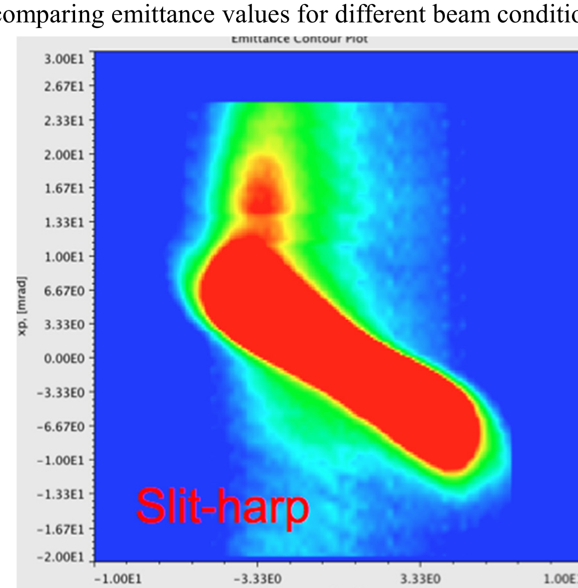

Figure 6: Horizontal emittance obtained with harp-slit scan.

ISBN 978-3-95450-122-9

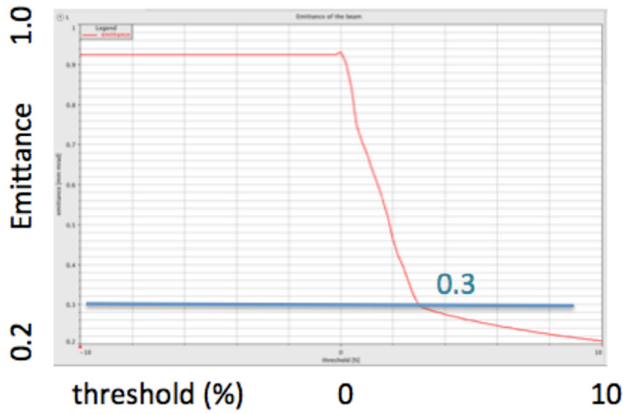

Figure 7: Emittance dependence on threshold value for slit-harp scan at Fig. 6.

WIRE IMPRINT IN PHASE SPACE

To perform a sanity check of the emittance device we inserted an upstream wire scanner into the beam. The particles intercepted by the wire form a vertical straight line in XX' space at wire scanner location. If we neglect non-linear effects, the beam line optics should transform it into a line at a different angle in the emittance slit location.

Figures 8 and 9 clearly present the wire shadow for two different wire positions.

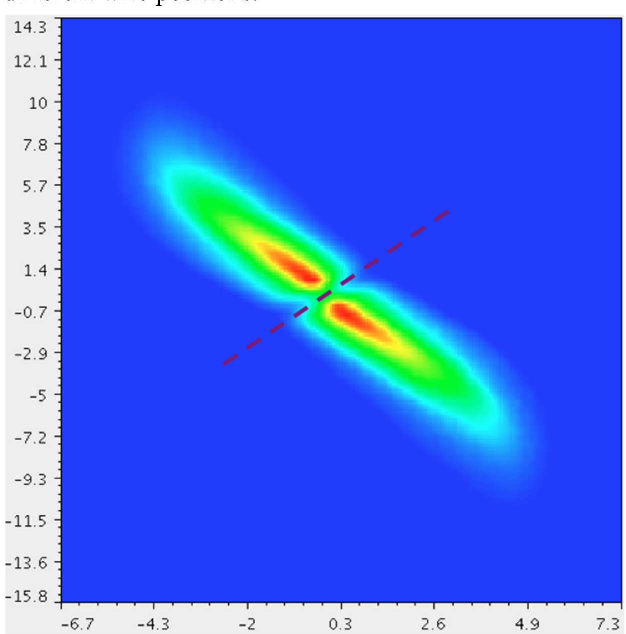

Figure 8: Emittance showing an upstream wire parked in the center of the beam.

SLIT VS. HARP COMPARISON

The MEBT emittance scanner now has two modes of operations: slit-slit and slit-harp. The slit-slit method provide fine time resolution (20nS) and has much better signal to noise ratio

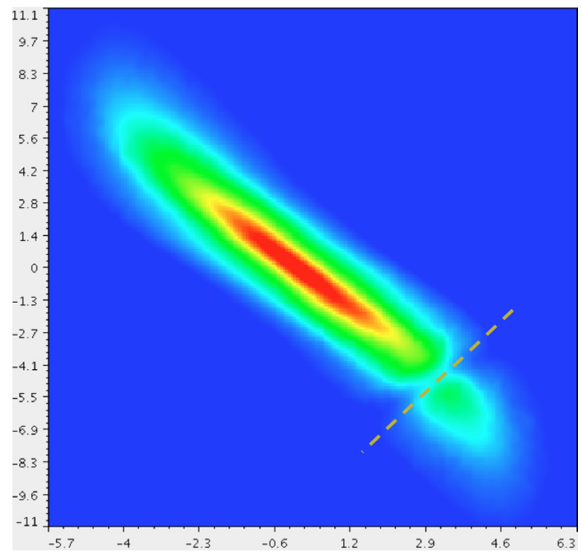

Figure 9: Emittance showing an upstream wire parked in the outer part of the beam.

The harp-harp scans can be used for fast scans when the core parameters are of main interest.

Table 2: Slit vs. Harp

Slit-Slit	Slit Harp
Time resolution ~20nS	Time resolution ~1uS
Dynamic range at least 10^4	Dynamic range ~ 10^3
One channel	16 channels (hard to calibrate)
No HV needed	Absolute values depend on HV
Cleaner scans	Artifacts and cross talk
Possibility to set threshold as a global absolute value	Threshold adjustment needed (hard to automate)
FC or loss monitor can be used as signal source	Only direct wire signal
Scan speed 30 minutes	Scan speed 4 minutes

ACKNOWLEDGMENT

ORNL/SNS is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

REFERENCES

[1] A. Zhukov et al, “Transverse Emittance Measurements in MEBT at SNS”, proceedings of LINAC2010, TUP089

[2] A. Aleksandrov et al, “Diagnostic Tools for Beam Halo Investigation at SNS Linac”, THPB013, these proceedings.