MEASUREMENT AND DETAILED SIMULATION OF BEAM LOSSES CAUSED BY THIN INTERCEPTION DEVICES (WIRE SCANNERS, SCRAPERS) AT SNS

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Abstract

Conversion of Beam Loss Monitor (BLM) readings into number of lost particles is a challenging task. Any insertion device is a good means to obtain a localized loss and obtain such conversion factor with direct measurement. Such a measurement serves as a good benchmark for Monte-Carlo simulation of radiation transport. We used wire scanners and scraper-induced losses to perform analysis of BLM response to local loss. This paper also provides a technique to measure 0.1% of full beam charge being intercepted by scraper during 650kW production run extracting the useful signal from a high-noise (20 times higher than signal) environment

WIRE SCANNER AS A LOSS SOURCE

We used two loss types of detectors to reproduce wire scan: a standard ion chamber [1] and a piece of scintillating fiber wrapped around the beam-pipe. Fig. 1 shows results for these two detectors. The wire scan took place in High Energy Beam Transport (HEBT) part of the Spallation Neutron Source (SNS) linac with H- energy around 900MeV.

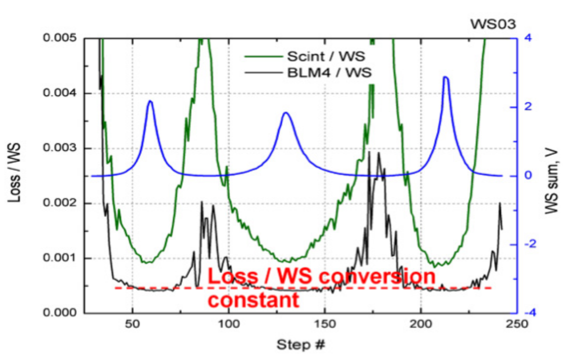

Figure 1: BLM readings normalized over WS signal.

The main goal was to see if the BLMs could deliver higher spatial resolution than the wire scanner itself. Unfortunately real improvement of existing wire scanner profiles was not achieved. This led to development of detailed simulation scenario for optimization of scintillator position. Figure 2 demonstrates the loss cone: the maximum reading is not from the closest BLM but from the downstream ones.

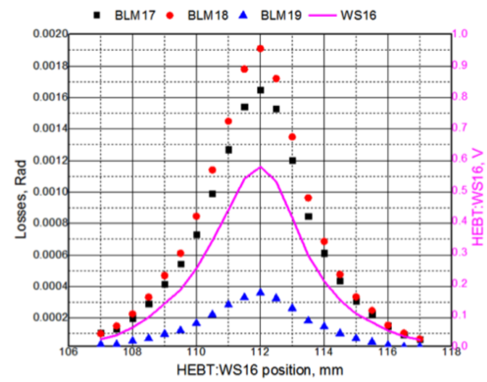

Figure 2: BLM response to wire scan.

SCRAPER CALIBRATION

Scraper is a thin (~25mg/cm2) carbon plate used to strip beam tails. When H- beam at about 1GeV hits the scraper, it loses both electrons and causes secondary electron emission from the plate. The charge collected on plate is about 5% of stripped beam. It is hard to calibrate electronics (that is measuring this charge) because only a small fraction of the beam is stripped and Beam Current Monitors (BCM), located upstream and downstream relatively to the scraper, are not accurate enough to calculate the difference. The following procedure allows calibration of the scraper signal at full power without interfering neutron production (~650kW of beam power).

- Swing the scraper back and forth so that the intercepted beam charge oscillates from 0 to 10-8C with constant period 50s (Fs=0.02Hz).
- Log scraper signals and BCM (01 is upstream and 09 is downstream) signals for several hours .
- Perform FFT of the above signals.
- Amplitude of scraper at Fs should be the same as BCM amplitude at Fs if the scraper calibration is correct.

Figure 3 plots the BCM difference (upstream minus downstream); due to BCM being not accurate enough the difference is negative and noise level is about 2E-7C. The signal measured by scraper is about 1E-8C (when scraper is inserted). Fourier transform of BCM difference clearly shows a peak at the swinging frequency as shown on Fig. 4.

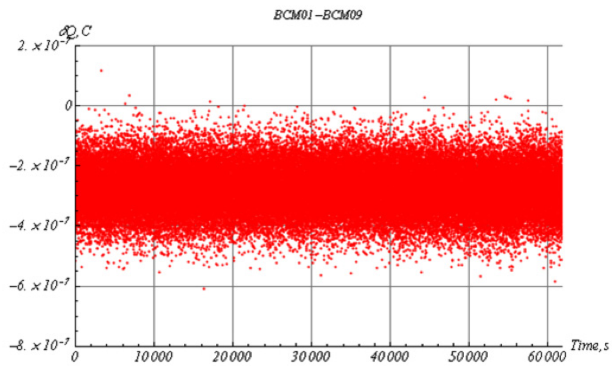

Figure 3: BCM difference.

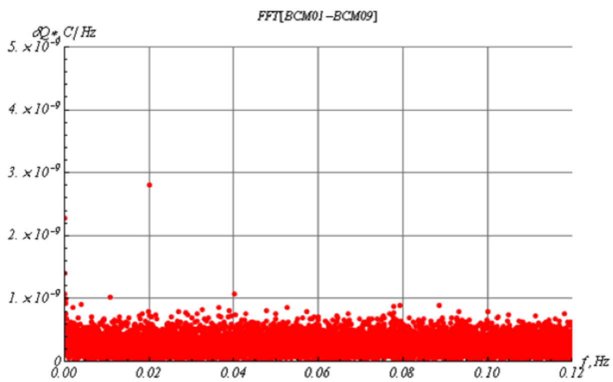

Figure 4: Fourier image of BCM difference.

The upstream BCM still has no "anomaly" at swinging frequency (the expected behaviour).

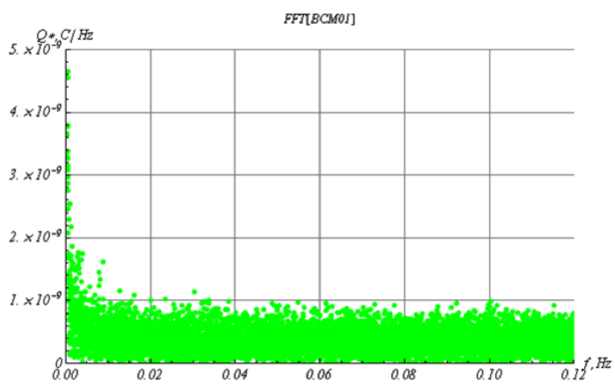

Figure 5: Fourier image of upstream BCM

Dividing BCM average amplitude around 0.02Hz by scraper amplitude at 0.02Hz (Fig, 6) conversion factor of 0.92 was obtained which tells that the scraper calibration was reasonably accurate.

It can be concluded that scraper-swinging technique is a useful method for correlation analysis. The same way one can investigate influence of scraper on losses all way downstream.

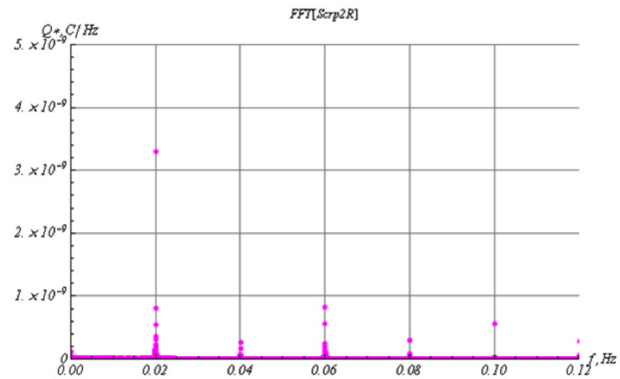

Figure 6: Fourier image of scraper signal.

LOSS SIMULATION

Any object inserted into the beam effectively becomes a point source (since the object size is usually much smaller than distance to loss monitor) and gives a good opportunity to benchmark radiation simulations. We performed several simulations in simplified scenarios [2].

In case of thin devices, the real geometry configuration plays a big role. The H- beam is stripped by a wire (or scraper) and then protons are flying further downstream. They are defocused by magnets (that are tuned for H-) and hit the bam pipe. Thus, the point source is no longer point-source and detailed configuration including field and real geometry should be considered.

We chose GEANT4[3] as main simulation tool because it is highly configurable and allows to account for all mentioned above.

We develop a special version of GEANT4 that will export SNS optics from XAL[4] and implement real SNS geometry by importing CAD-based drawings. First results should be to be available in the first half of 2010.

ACKNOWLEDGEMENTS

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