Secondary emission monitor simulation, measurements and machine learning application studies for CERN fixed target beamlines

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Abstract

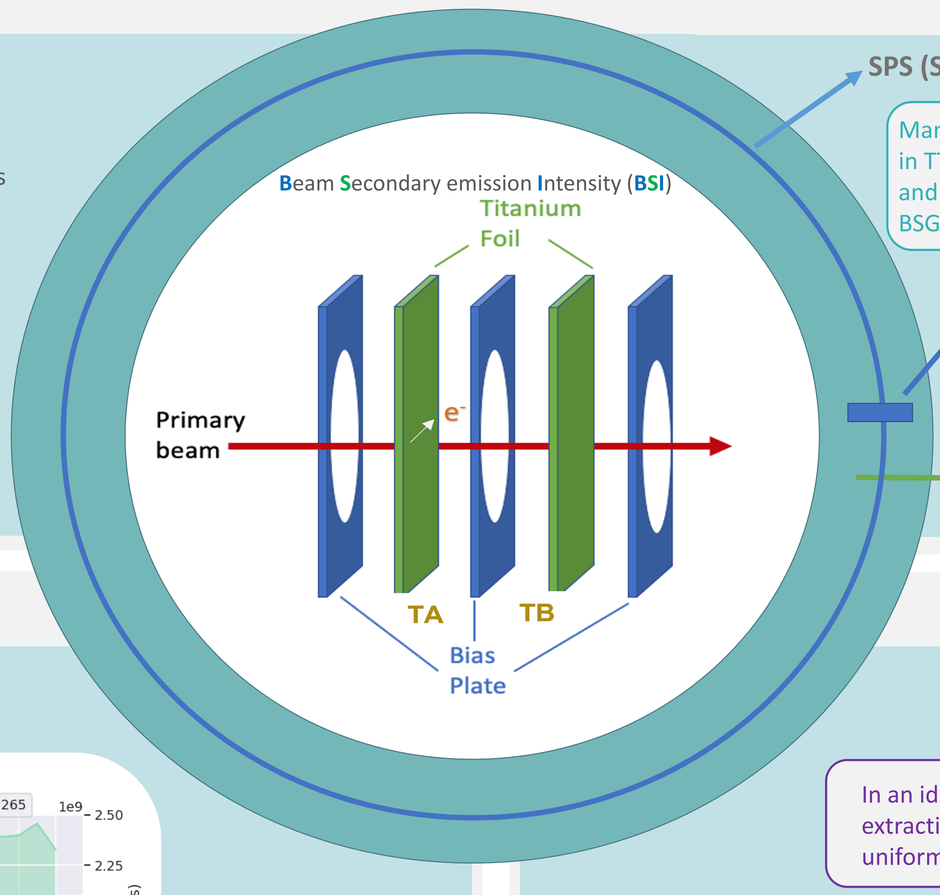
Secondary Emission Monitors (SEMs) are currently used for measuring beam current, position and size in fixed target beamlines at CERN. Ongoing and newly proposed experiments, have generated a renewed interest in these areas and highlighted the need for upgrading ageing instrumentation still in use. Assessing the current performance of accelerator and beamline instrumentation is crucial for smooth operation. Finding solutions that are stable over long time frames, resistant to radiation and deliver the precision needed by users is challenging.

This contribution presents an overview of the ongoing work necessary to calibrate and optimise SEM design for future use in these beamlines. This includes status and plans for numerical simulations and beam-based experiments. Finally, feasibility studies for the application of machine learning techniques are discussed to expand the range of tools available for SEM data analysis.

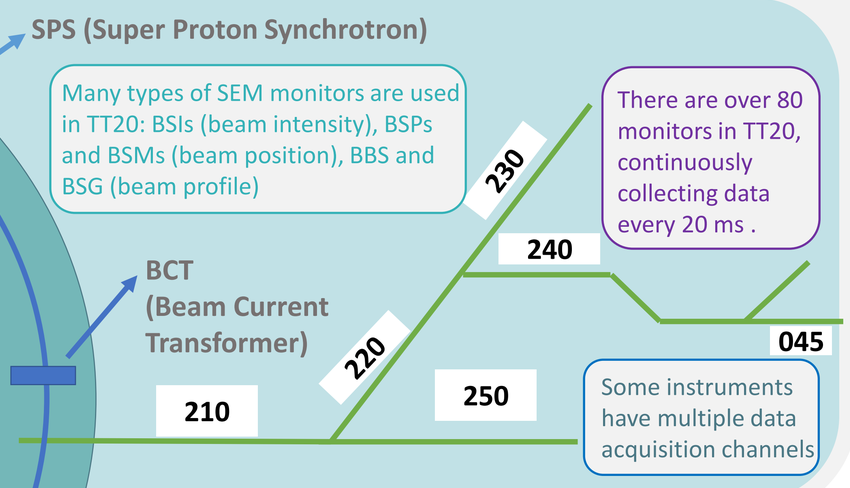
BSI Operating Principle

- Protons hit metal foils generating secondary particles
- Current of secondary particles measured from metal foils
- Bias foil prevents particles from be recounted
- Number of protons can be related to the current via the Secondary Emission Yield (SEY)

$$Signal_{SEM} = G_{electronics} \cdot n_{protons} \cdot SEY$$

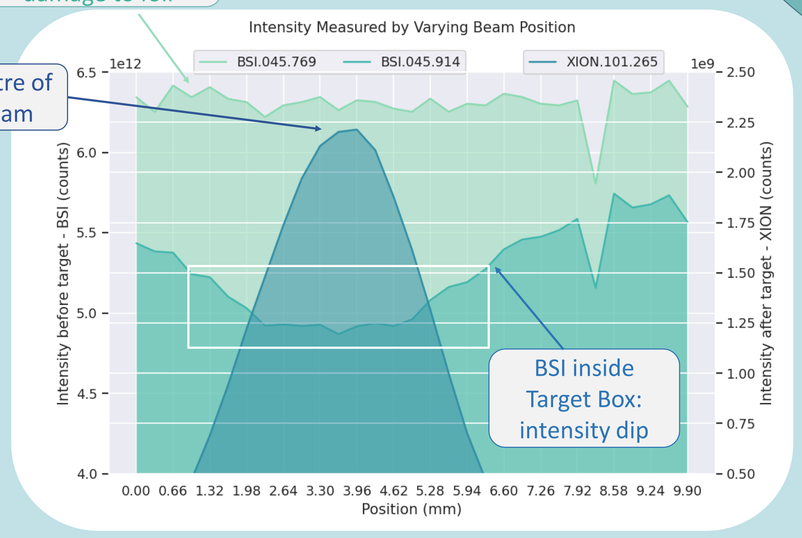


The TT20 Beam Line



BSI Ageing Measurement

Upstream of Target box, minimal damage to foil

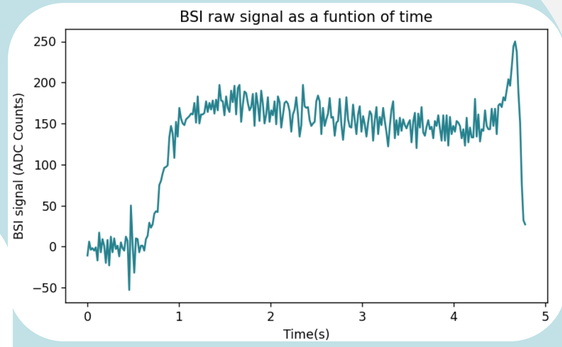


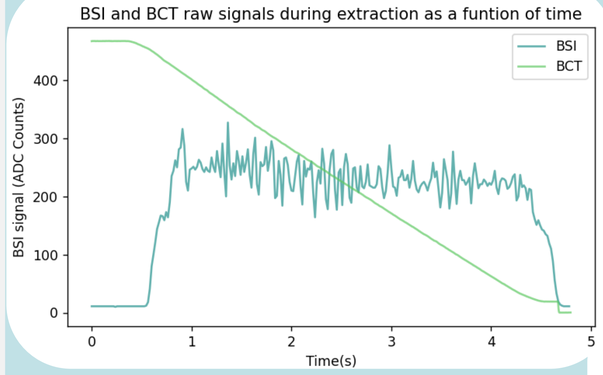
Method

- Position of the beam varied
- Intensity measured with 2 BSIs before target
- Intensity after target measured with separate instrument

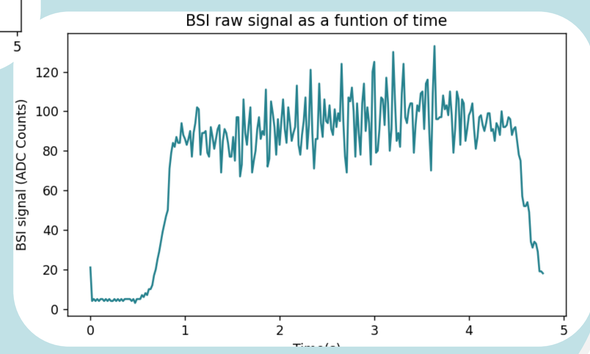
Problems with the raw signal data

In an ideal case the extraction should be uniform and flat





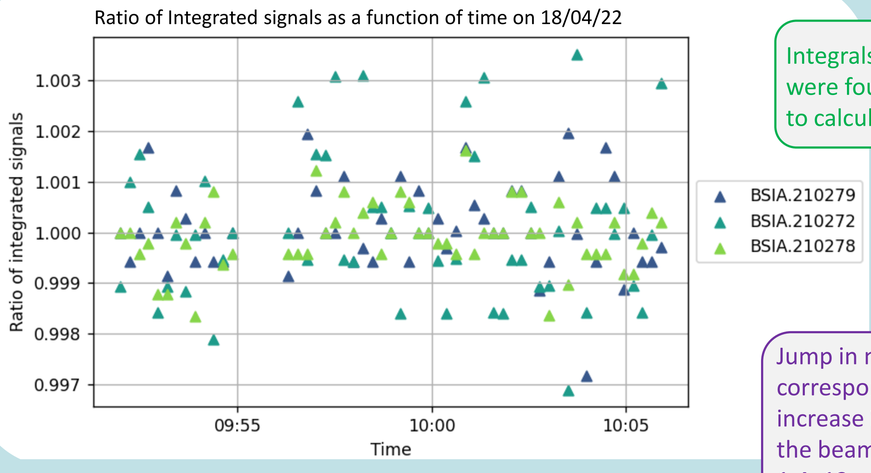
Signal in BCT reduces during extraction, whilst signal in BSI increases



Some signals appear to be cut off too early

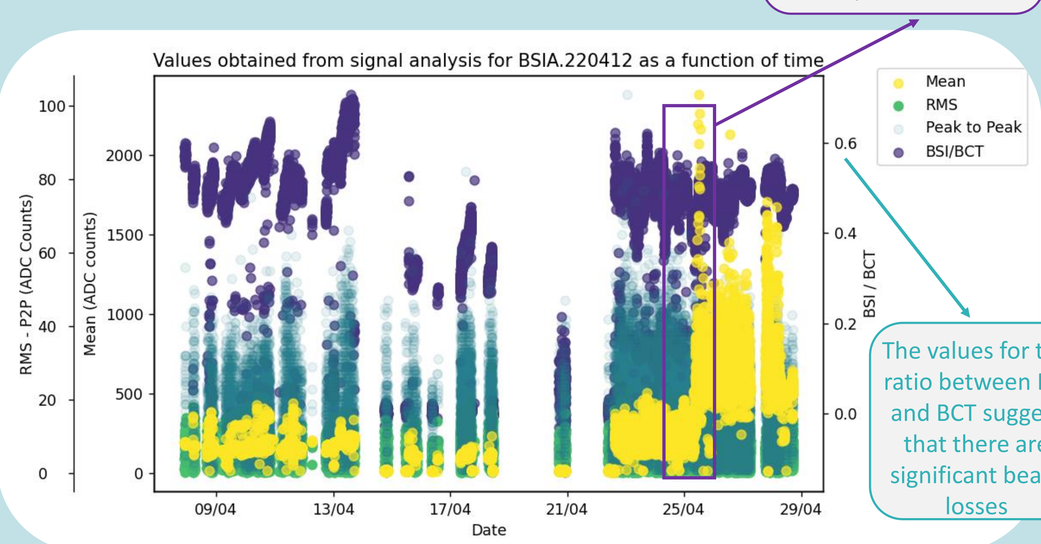
variation in signal makes it hard to separate noise background and signal

BSI Signal analyisys



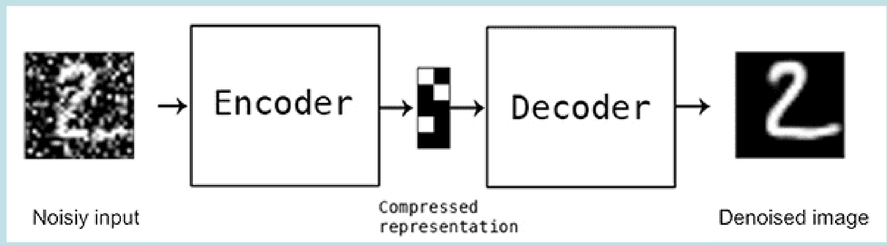
Integrals Published online were found to be similar to calculated integrals

Jump in mean current corresponds to an increase in intensity of the beam from 4.5e12 to 1.4e13 particles



The values for the ratio between BSI and BCT suggest that there are significant beam losses

Using Auto Encoders for Noise reduction



- An auto encoder is a deep neural network commonly used for image processing
- It can be trained to learn patterns, create a representation, from which it can reconstruct an output similar to the data on which it was trained.
- This can be exploited to reduce the amount of noise in an image
- Work is now underway to apply this to reduce signal noise in BSI data and other SEM detectors in transfer lines at CERN

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