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

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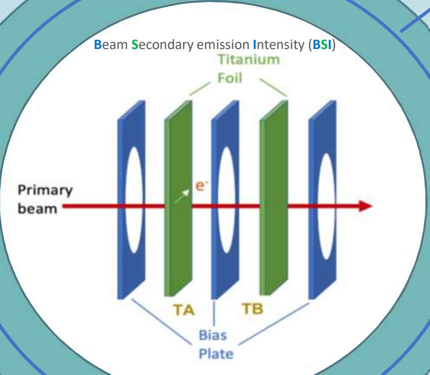
Abstract

The CERN fixed target experimental areas have recently acquired new importance thanks to newly proposed experiments, such as those linked to Physics Beyond Colliders (PBC) activities. Secondary Emission Monitors (SEMs) are the instruments currently used for measuring beam current, position and size in these areas. Guaranteeing their reliability, resistance to radiation and measurement precision is challenging. This paper presents the studies being conducted to understand ageing effects on SEM devices, to calibrate and optimise the SEM design for future use in these beamlines. These include feasibility studies for the application of machine learning techniques, with the objective of expanding the range of tools available for data analysis.

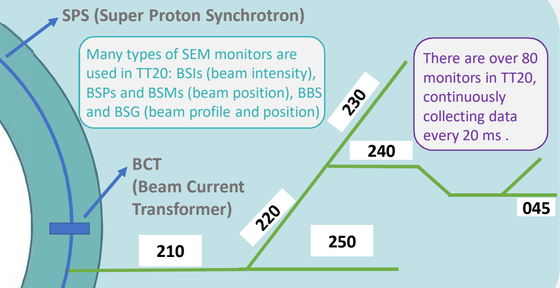
SEM Operating Principle

- Protons hit metal foils/bands transferring energy to the material
- Energy transfer liberates electrons, generating a current, that can be measured
- The number of electrons emitted per incident proton is known as the Secondary Emission Yield (SEY)
- Changes to the material over time, affect the SEY
- The number of ADC counts in the device is related to the number of protons via a calibration factor:

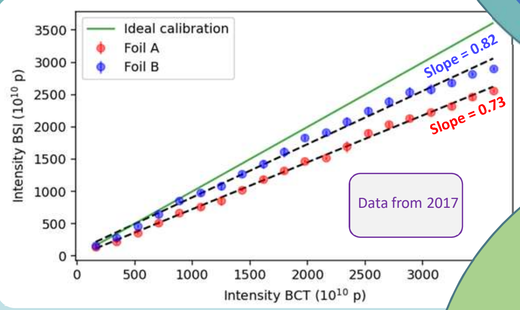
$$C_f = \frac{N_p}{N_{ADC}}$$



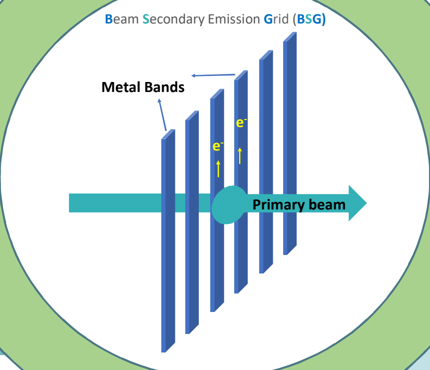
The TT20 Beam Line



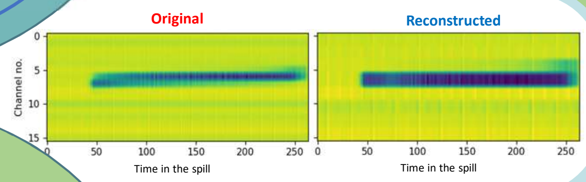
Beam Intensity Studies

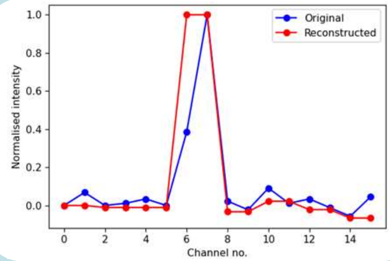


- Non linearity possible causes:
  - SEY drift in time
  - DAQ dependence on signal level
  - Variation of losses with beam intensity.
- Slope deviation possible causes:
  - Systematic errors in the BSI calibration (e.g. SEY and DAQ gain)
  - Absolute extraction losses
- Calibration:
  - Slow extracted beam -> calibration with BCT not possible
  - Calibration to be performed via activation method

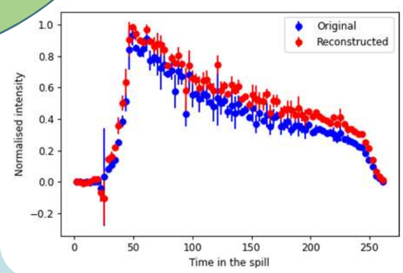


Beam Profile and Position Studies





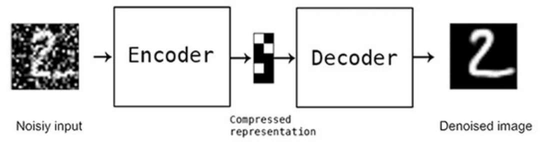
Noise is reduced at the tails, but the peak becomes broader



Smaller spread in the data, evidenced by smaller error bars, suggests noise reduction

Using Auto Encoders for Noise reduction

- An auto encoder is a deep neural network commonly used for image processing with 2 main parts:
  - **Encoder** compresses the original image into a lower dimensional representation, via a series of layers.
  - **Decoder** mirrors the encoder, taking the compressed representation and reconstructing the original image.
- Some resolution can be lost in this process, this can be exploited to reduce the noise in an image



Acknowledgements

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