Extinction measurements at PIP2IT*

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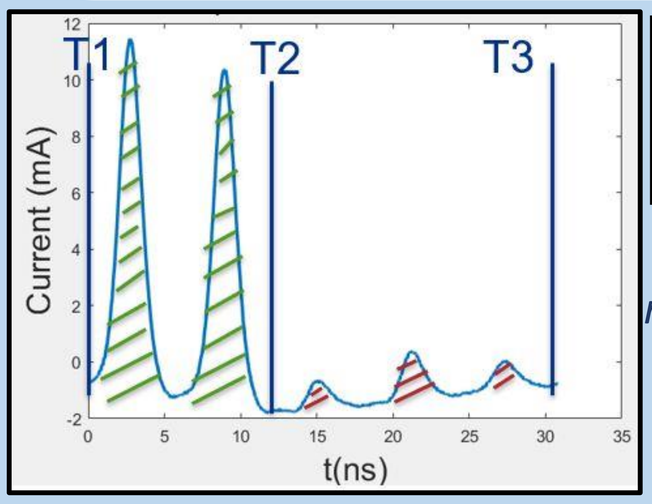
ABSTRACT

The PIP-II particle accelerator is a new upgrade to the Fermilab accelerator complex, featuring an 800-MeV H- superconducting linear accelerator that will inject the beam into the present Fermilab Booster. A test accelerator known as PIP-II Injector Test (PIP2IT) has been built to validate the concept of the front-end of such a machine. One of the paramount challenges of PIP2IT was to validate the bunch by bunch chopping system in the Medium Energy Beam Transport (MEBT). Beam measurements have been taken by two Resistive Wall Current Monitors (RWCM) and recorded by a high bandwidth oscilloscope in order to validate the complete suppression of the chopped beam. This paper aims to present the beam extinction measurements at PIP2IT and their limitations.

MEASUREMENT SCHEME

The extinction measurements aim to give an estimation of the chopping extinction in the specified PIP2IT beam configurations: 550 μs pulses, 2 mA, and most importantly the Booster pattern

Practically, we measure the charge that is left in the chopped beam by groups of successive chopped bunches that we call empty spaces. Likewise, two successive passing bunches will be analyzed together (Figure 1).



$$\text{Extinction} = \frac{\text{Nkicked}}{\text{Npassed}} \frac{\int_{T_2}^{T_3} s(t)dt}{\int_{T_1}^{T_2} s(t)dt}$$

Figure 1: Extinction measurements with 2 passed-3 chopped pattern (extinction= 8%)

WAVEFORM DISTORTIONS

Understanding the distortions of the signal (Figure 2) is essential in order to make correct estimations of extinctions. Measuring beam in the RWCM waveform implies knowing its baseline: the remaining charge is the integral of the signal above this baseline.

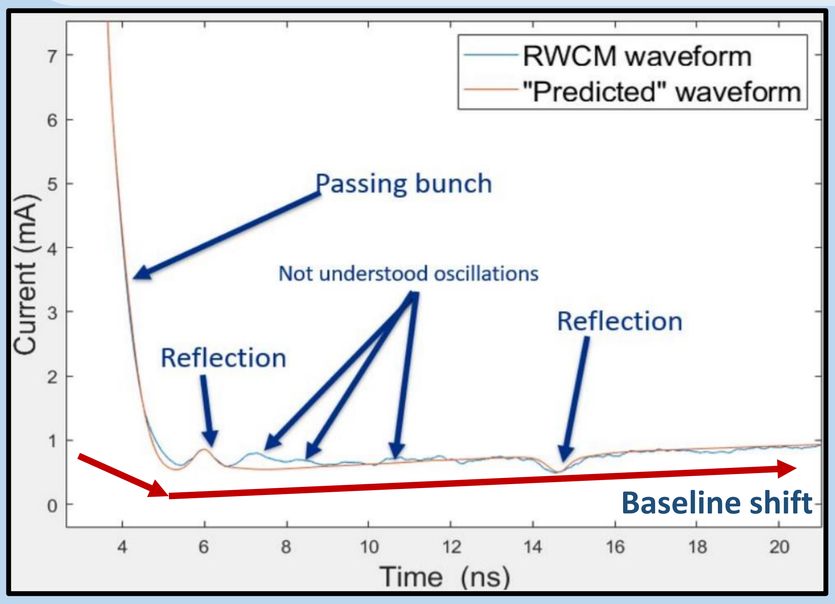


Figure 2: Different distortions in the RWCM waveform cleaned space with a 1 passed-9 chopped pattern

In Figures 1 and 2, the waveform baseline goes down during the passing bunches and goes up during the cleaned spaces. This is the consequence of the RWCM which filters the low frequencies under 7 MHz (Figure 3).

The Heliax cable (Figure 4) disperses the tails of the bunches and acts as a low pass filter with a 1.7 GHz cutoff frequency.

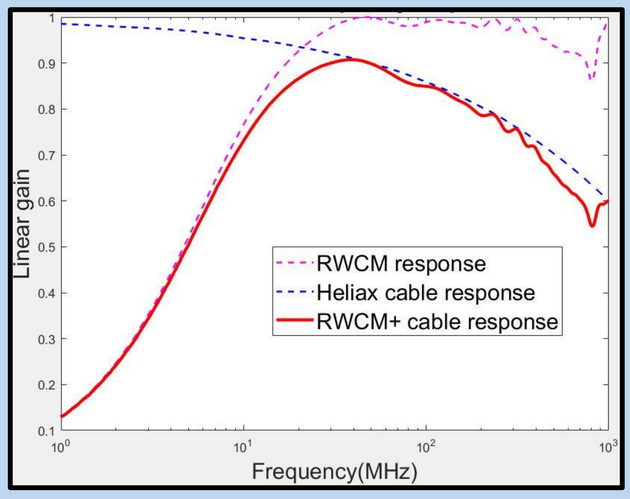


Figure 3: Heliax cable and RWCM frequency response

In addition to the distortions mentioned above, the image current created by the passing bunches is reflected and some of the reflections appear in the cleaned spaces At reflection points (Figure 4), a part of the signal power is reflected back to its origin instead of being carried all the way along the cable.

Figure 4: Cabling between the RWCM and the oscilloscope

CONCLUSION

In all cases, the measured extinction is consistent with zero, and the results differ by the value of the upper boundary of the uncertainty which depends on the quality of the analysis of the distortions. A calculation of the extinction and its uncertainty has been done in [1]. However, the estimates for the cleaned space immediately following the passing bunch have a significantly larger uncertainty. Partially it comes from after-pulse oscillations clearly not associated with the beam remnants but not properly explained (Figure 2).

REFERENCES

[1] Technical note on the extinction measurements, Mathias El Baz, PIP-II Document 5514-v1, 2021

[2] Extinction measurement in MEBT, Daniil Frolov, PIP-II Document 1567-v1, 2018

ACKNOWLEDGEMENT

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