Characterization of the PS Kickers for Improved Fast Extraction

F. Klose*, P. Arrutia, M. A. Fraser
SY-ABT-BTP

Motivation

Fast extraction describes several techniques for extracting proton beams from a synchrotron. In CERN's Proton Synchrotron (PS), single-turn and multi-burst extraction are used for safely dumping the beam, filling the Super Proton Synchrotron (SPS) or providing beam to fixed-target experiments. For fast extraction, the extraction magnet, made up of separate modules, needs to be able to reach full power during the abort-gap, which is a gap between the bunches. The aim of this project is to develop a method for measuring and optimizing the synchronicity of the kicker magnet modules which will improve beam loss at extraction and how tightly the accelerator can be packed. This method is currently being applied to the kicker KFA71 in the PS to study the rising edges of its modules.

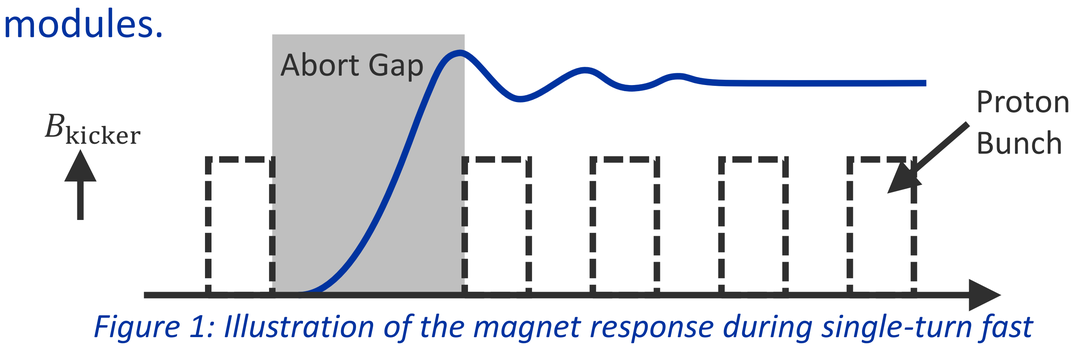


Figure 1: Illustration of the magnet response during single-turn fast extraction. The beam has a gap between the bunches that is large enough to allow the magnet to come to full strength.

Method

Betatron Oscillations:

Betatron oscillations are oscillations of the protons around the design orbit of the accelerator. They arise from the alternating focusing and defocusing forces used to confine particles in accelerators and oscillate at a specific frequency called the *tune*.

Measuring kick response for a single module:

1. Inject a low intensity beam containing a single bunch.
2. 'Excite' the beam using a small kick produced by the module.
3. Measure the induced *betatron oscillations* and their ringdown using beam position monitors (BPM) situated around the PS.
4. Remove DC offset and apply a narrow band pass filter centered on the *tune* to remove noise.
5. Compute amplitude of the oscillations after the kick, keeping the largest.
6. Extract the beam and repeat with a different kick delay/module.

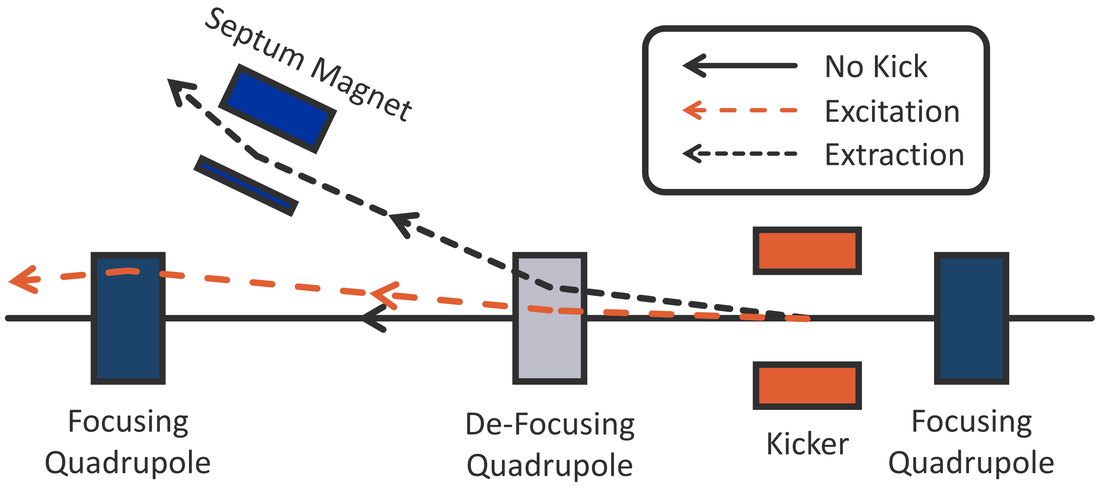
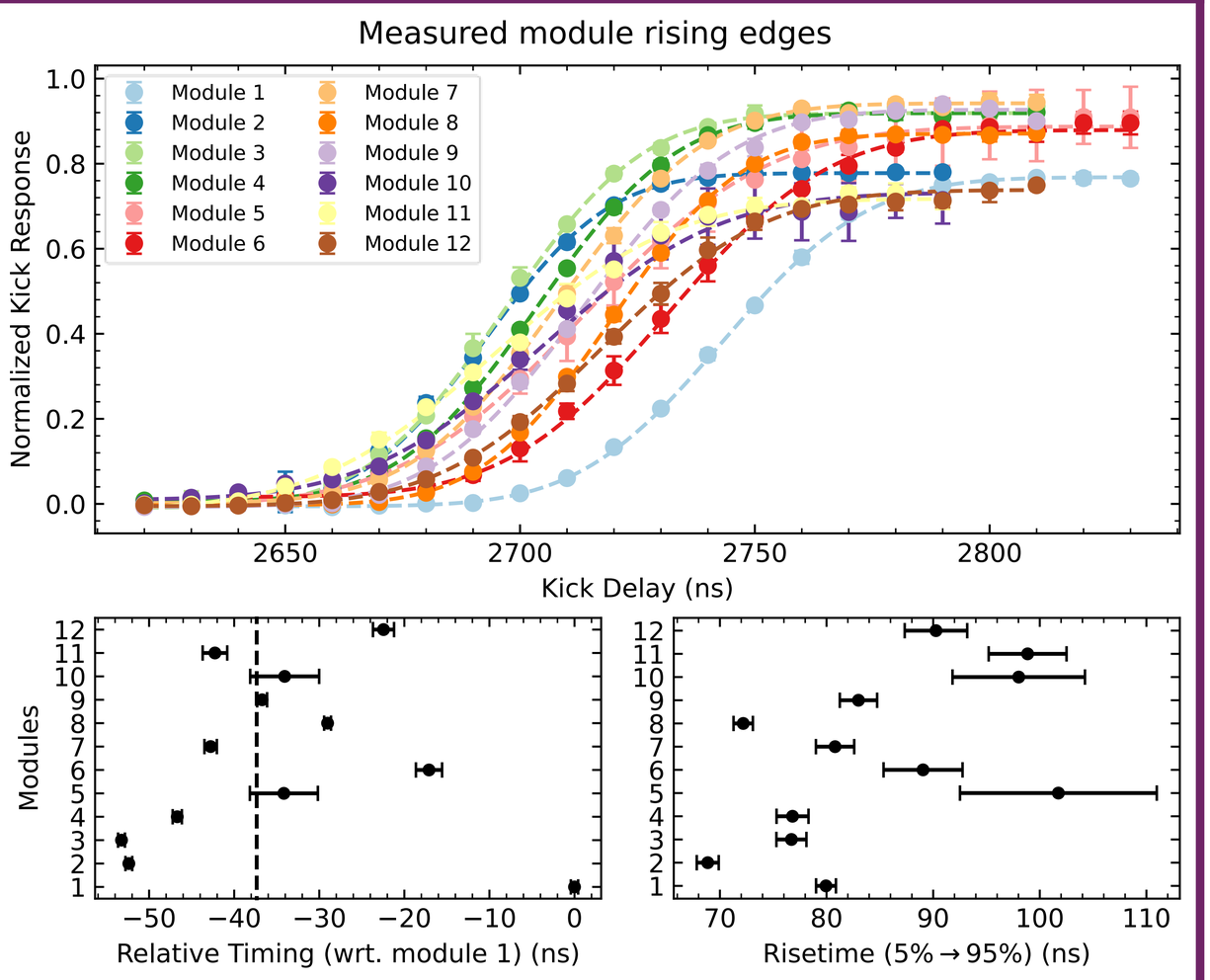


Figure 2: Illustration of a simplified beam extraction scheme showing the differences in beam path for no kick, a small excitation kick as used in this method and an extraction kick at full strength.

Extracting Performance Parameters:

1. Shift and normalize the waveform using the minimum and maximum measured amplitudes, respectively.
2. Fit the curves obtained from the kick response measurement using a simple model: $f(t) = a \times \text{erf}\left(\frac{t - t_0}{w}\right) + c$.
3. Measure the relative timing by determining at what time the normalized kick response reaches a value of 0.5.
4. The risetime is obtained by scaling w ($t_{\text{rise},5\%\rightarrow95\%} = 2.33 \times w$).

Results



The measured waveforms (symbols with error bars) and their fits (dashed lines of same color) are shown in the figure above (top plot). While the zero response of all the modules converges to roughly the same value, at full strength there is up to a 20% difference in the strength. Currently there is no explanation for this difference. The relative timings compared to module 1 are shown in the bottom left with the mean timing difference (dashed line) of -32 ± 0.7 ns. The risetimes of each module are shown in the bottom right. The risetimes are between 70 to 100 ns with most modules situated around 80 ns or so.

Conclusions & Future Work

Having characterized the rising edges of KFA71, the next step is to adjust the hardware timings of the modules and remeasure to confirm that the technique works. The spread in the maximum response will also need to be investigated further. Further refinement of the technique is needed to make it robust enough to be added to the toolset of the PS operators. It would also be interesting to use this approach to measure further performance characteristics of the kicker, such as the ripple in the waveform.

References:

1. Steinhagen, R. J. (2009). Tune and chromaticity diagnostics. https://doi.org/10.5170/CERN-2009-005.317
2. Fraser, M. A. *Single and Multi-turn Fast Extraction*. *CERN Accelerator School*. Erice; Italy. Retrieved July 2023, from https://cas.web.cern.ch/sites/default/files/lectures/erice-2017/fraser.pdf.

CERN Summer Student Poster Session 2023

*Contact: fklose@cern.ch