Study of event rates in undulator radiation generated by a single circulating electron in IOTA: Analysis of the AMPUR experiment of March 18, 2020

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Abstract

I. INTRODUCTION

The AMPUR experiment studies the temporal and spatial distribution of undulator radiation emitted by single electrons stored in IOTA. The experiment took preliminary data in Run 2 (February–March 2020) with a multi-anode microchannel-plate photomultiplier (MCP-PMT) in preparation for further experiments at higher resolution using Large-Area Picosecond Photodetectors (LAPPDs).

II. APPARATUS

The experiment is installed in IOTA in the M4R synchrotron-light station, downstream of the D Right straight section, where an undulator is inserted.

Undulator radiation is collected through a vacuum window, periscope mirrors and a lens onto the surface of a Photonis XPM85112 MCP-PMT. The detector was roughly aligned transversely with the radiation cone using a motorized translation stage.

The detector has a matrix of 4×4 anodes. For this experiment, the anode outputs were joined in groups of four, so that a matrix of 2×2 quadrants was used, identified as Channels 1–4. The detector was operated between −2.24 kV and −2.48 kV.

Several experiments were done in Run 2. Here we focus on the data taken on March 18, 2020. For this shift, the 4 channel outputs were connected to constant-fraction discriminators (CFDs) in the ESB building, after about 75 m of RG-58 cable. The threshold on these discriminators was −30 mV.

Following the discriminators, the NIM pulses were sent to the 4 input channels of a Picoquant HydraHarp 400 event timer. The synchronization input was provided by the 7.5-MHz IOTA revolution marker.

Time-tagged events were recorded at various beam intensities, from about 6×10^4 electrons down to 1 electron and then with no beam for background measurements. For each beam intensity, time-tagged data was taken in two main modes: (a) recording absolute times of every synchronization event (IOTA turn) for 1 s (HydraHarp ‘T2 mode’); (b) recording time differences between detector hits and revolution marker only for turns with at least one hit in the MCP-PMT, for up to 2000 s (HydraHarp ‘T3 mode’).

The logbook entry for this experiment can be found in the FAST/IOTA e-log.

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TABLE I. Event rates above threshold (-30 mV) on each of the 4 channels of the MCP-PMT, with 1 electron in IOTA.

Channel	Signal Rate [Hz]	Background Rate [Hz]
1	5.30(5)	1.19(2)
2	5.26(5)	2.48(4)
3	3.59(4)	1.37(3)
4	5.70(5)	1.88(3)

TABLE II. Rates of double coincidences with two channels of the MCP-PMT above threshold (-30 mV). Backgrounds are negligible.

Channel A	Channel B	Events	Rate [mHz]
1	2	49	24(3)
1	3	44	22(3)
1	4	2	$\sim$1
2	3	1	$\sim$0.5
2	4	59	29(4)
3	4	14	7(2)

III. RESULTS

A. Single event rates

B. Coincidence rates

C. Timing distribution of coincidences

How does the distribution of time differences change with bunch intensity?

D. Revolution marker

[1] S. Antipov et al., IOTA (Integrable Optics Test Accelerator): Facility and Experimental Beam Physics Program, JINST 12, T03002 (2017).

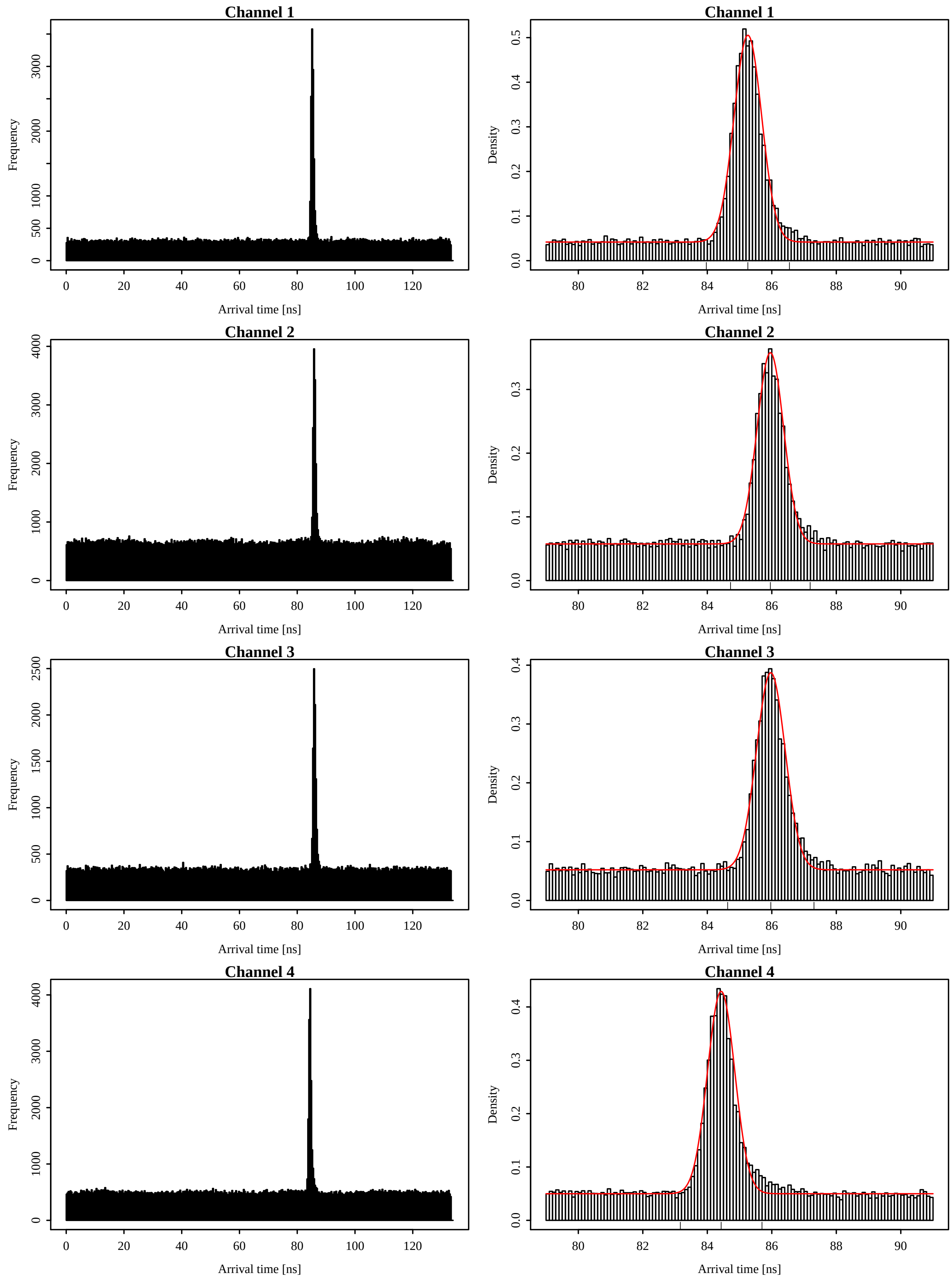

FIG. 1. Distribution of pulse arrival times with respect to the IOTA revolution marker for each of the 4 channels of the MCP-PMT with 1 electron in the machine. Data was collected for 2000 s.

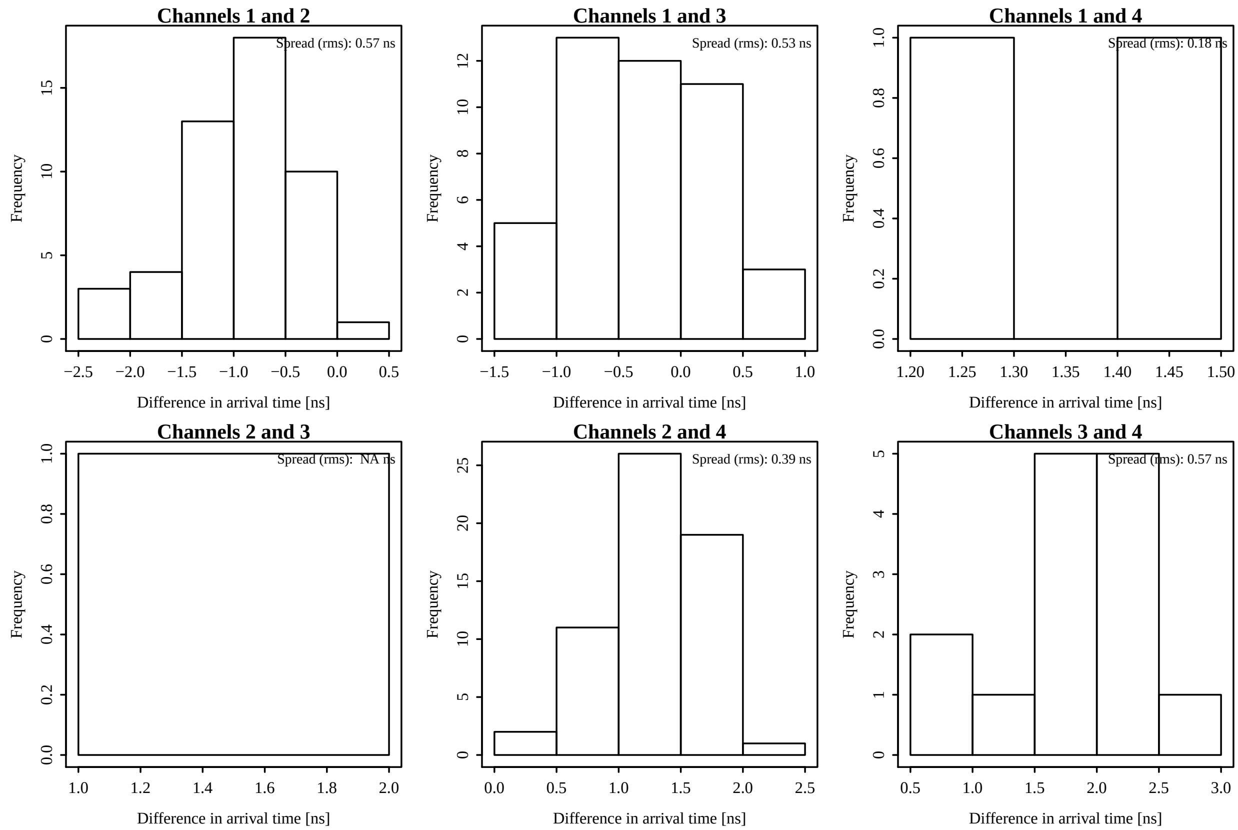

FIG. 2. Distribution of time differences of pairs of MCP-PMT channels for all double coincidence configurations. Data was collected for 2000 s with 1 electron in IOTA.

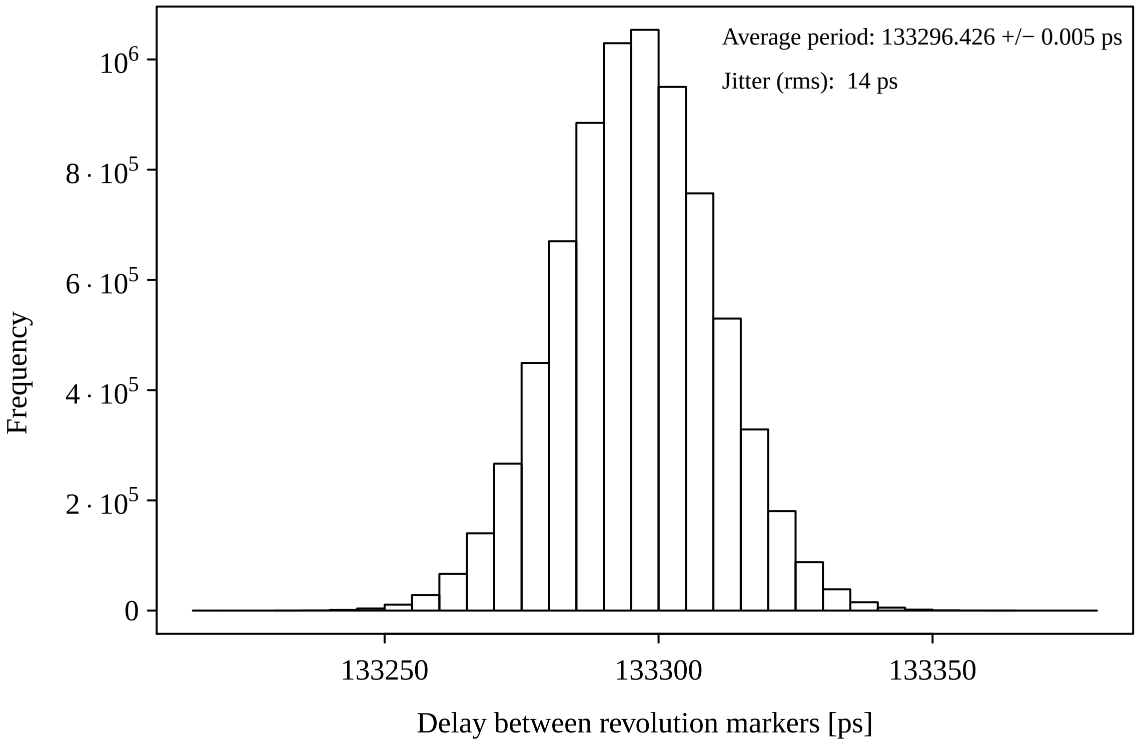

FIG. 3. Distribution of time intervals from the revolution marker (HydraHarp SYNC channel) collected over 1 s. The uncertainty on the average period only includes the statistical error on the mean.