Multiple Laser Tracker Synchronization for Vibration Analysis

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Field Mapping System (FMS)

A custom-built device to map the magnetic field of the Mu2e Detector Solenoid. It consists of a propeller assembly that travels on rails down the length of the solenoid, with a pair of rotating propellers which hold magnetic field sensors, thus allowing measurement of the entire interior volume of the solenoid. The propellers also carry geodetic prisms for establishing the position of all components.

We characterize the rigidity of the mechanical coupling between components of the propeller assembly, as well as the vibrations introduced into the system by moving down its rails and then stopping.

Field Mapping System Assembly, showing the Big Propeller (Green), Small Propeller (at the end of the red shaft), base (tan), geodetic prisms (brown knobs), and magnetic Hall sensors (grey triangles). Image credit: DFSM Design Group, ANL

Rigid Coupling Hypothesis

Measurements were taken to (dis)prove the hypothesis that components of the assembly are rigidly coupled. The rigid coupling would manifested as phase coherence in vibrations while dynamic (rattly) coupling would appear as phase drift.

Equipment and Measurements

Three API LTs were used for measurements. SA with User Datagram Protocol (UDP) utility were used for collecting data and operating the instruments.
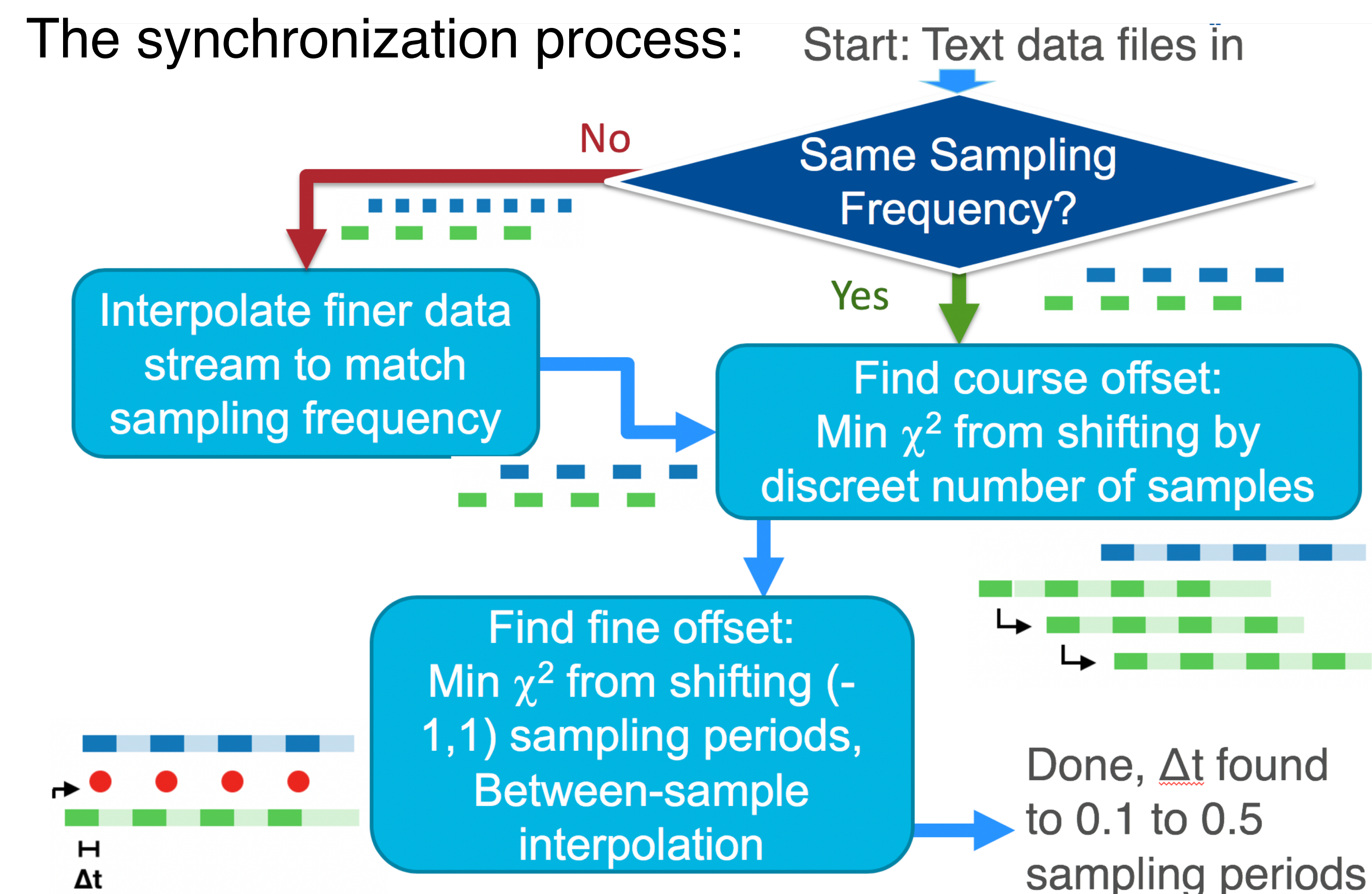
UDP allows collection of accurate high frequency timestamps of laser tracker measurements.

*Measurement setup at Argonne National Laboratory.*

Data Processing

Data streams with relative time stamps (each starting at 0s) need to be synchronized. A custom python program is used to find the time shift between streams, using common features of the data.

The synchronization process:

Start: Text data files in

Same Sampling Frequency?

No — Interpolate finer data stream to match sampling frequency

Yes — Find course offset: Min χ^2 from shifting by discreet number of samples

Find fine offset: Min χ^2 from shifting (-1,1) sampling periods, Between-sample interpolation

Done, Δt found to 0.1 to 0.5 sampling periods

Results and Conclusion

Comparison of the synchronized position sequences shows tight phase coherent vibration between all 3 streams. This confirms rigid connection between segments of the FMS.
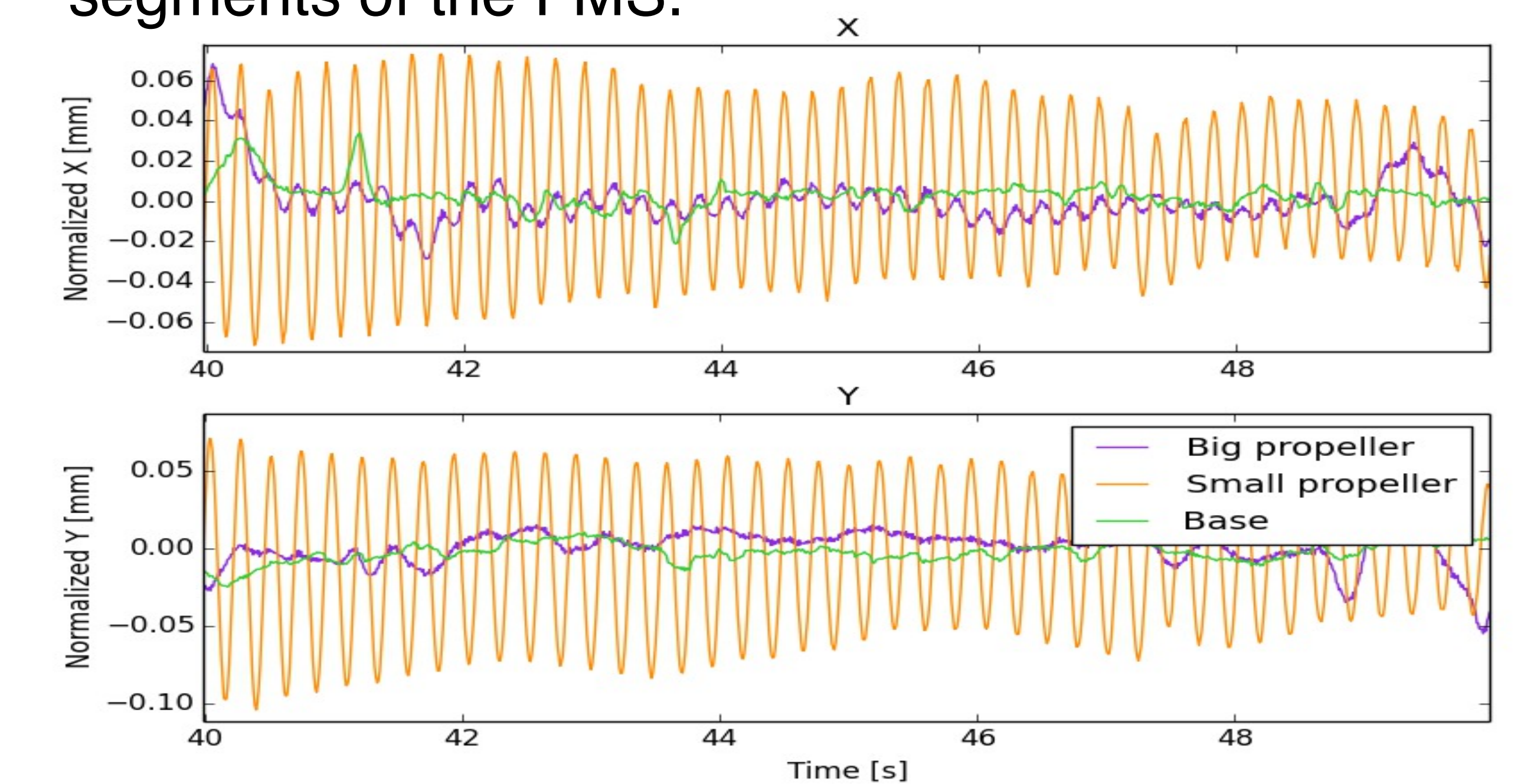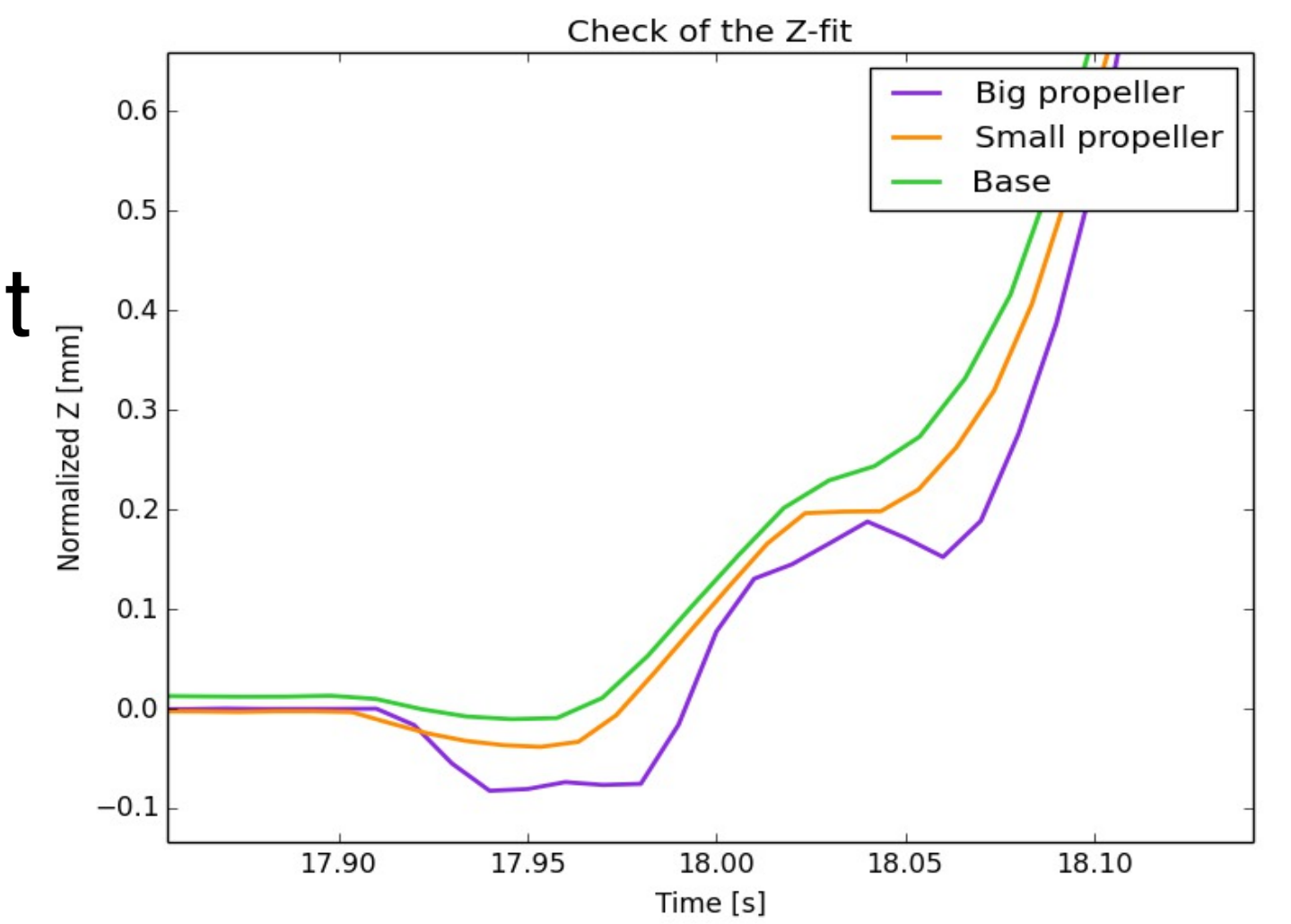
Closeup of the system vibrations in X and Y axes (right-left and up-down)

Fourier analysis of the streams further reveals the influence of individual sources of vibration.

This method enables general non-contact vibration measurements of large structures.
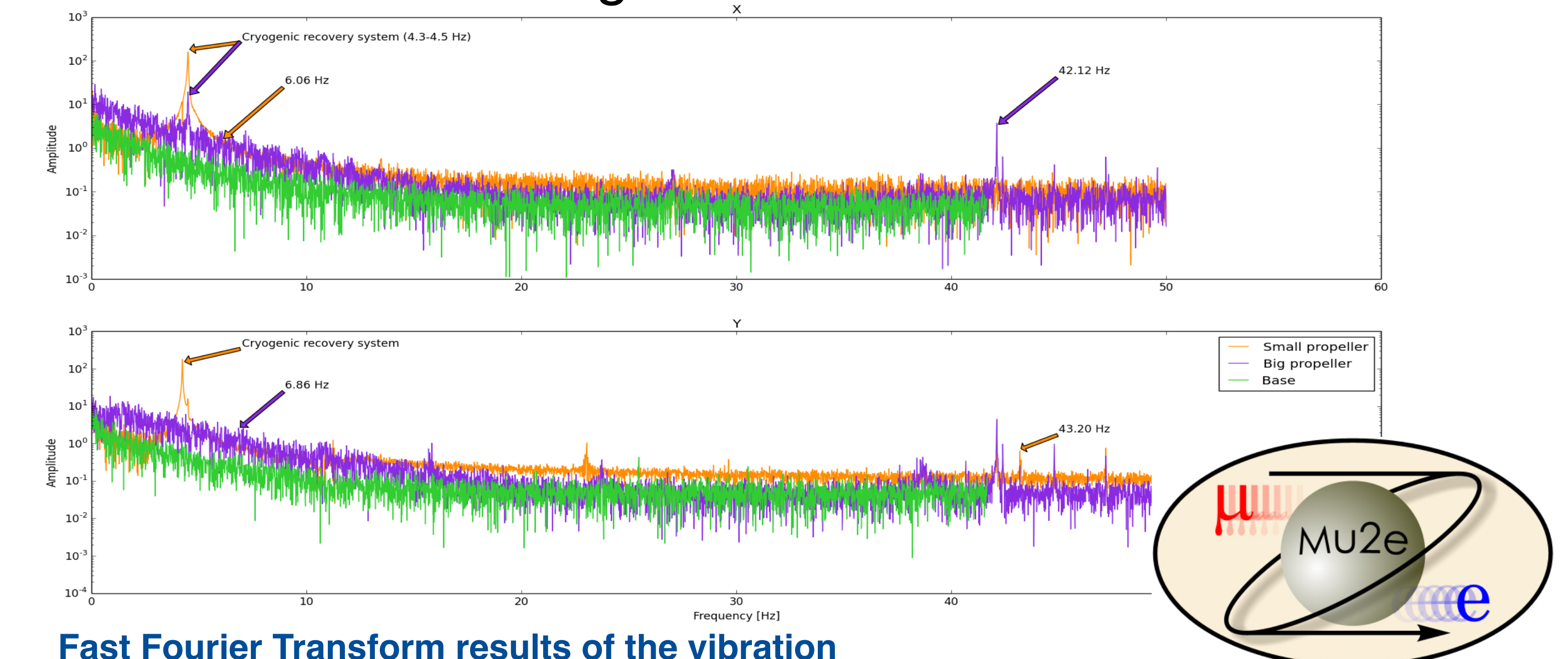
Fast Fourier Transform results of the vibration