Fluxgates debugging
Magnetic Field Mapping

Magnetic shielding meeting

25/07/2019

Takashi Higuchi

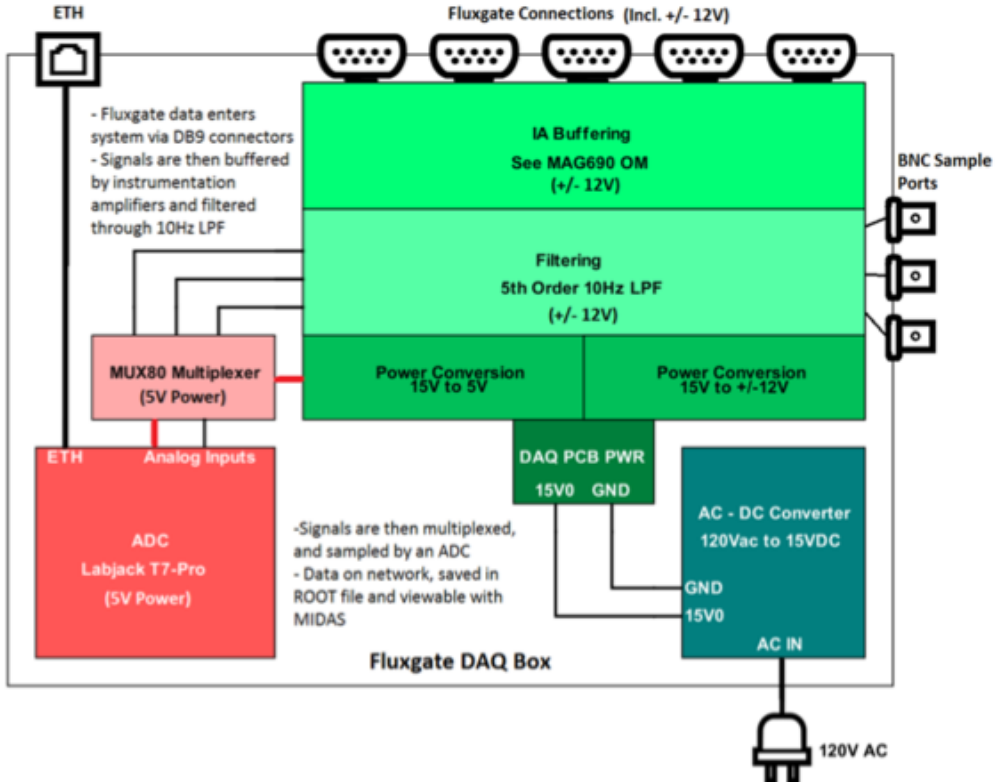
Xander Naumenko

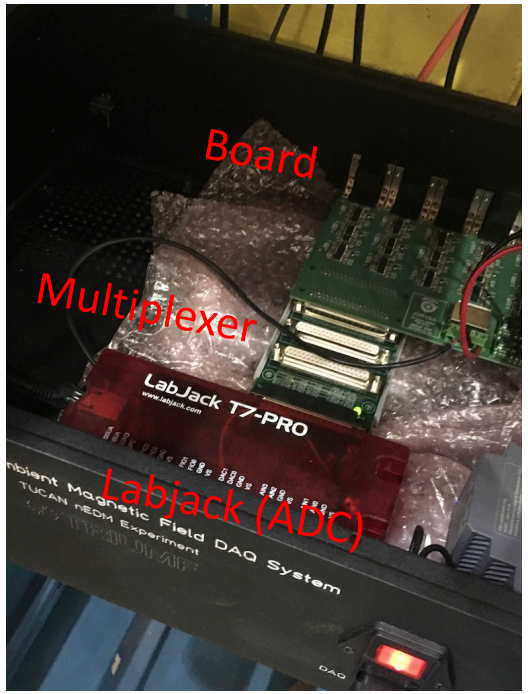
Contents

- Current DAQ system: debugging
- Preparation for the first field mapping

Overview of the current DAQ system

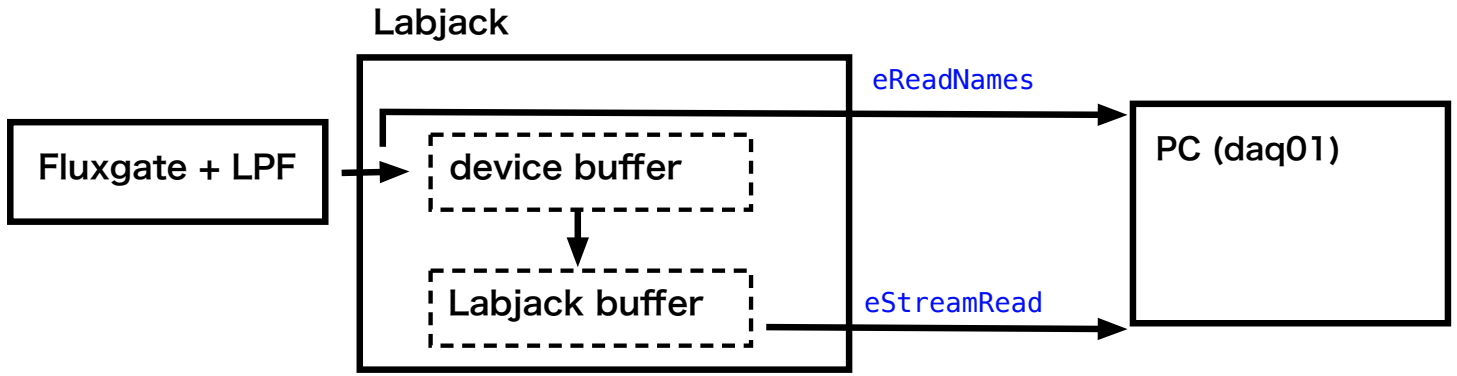
- 5 fluxgates Bartington Mag03-xx (total 15 channels)
- The DAQ board (LP filter + amplifiers) built by Elspeth Cudmore (link)
- ADC: a microcontroller Labjack T7-Pro with two multiplexer to increase # of inputs, connected to daq01.ucn.triumf.ca
- C code on daq01 to control Labjack: developed by a series of students





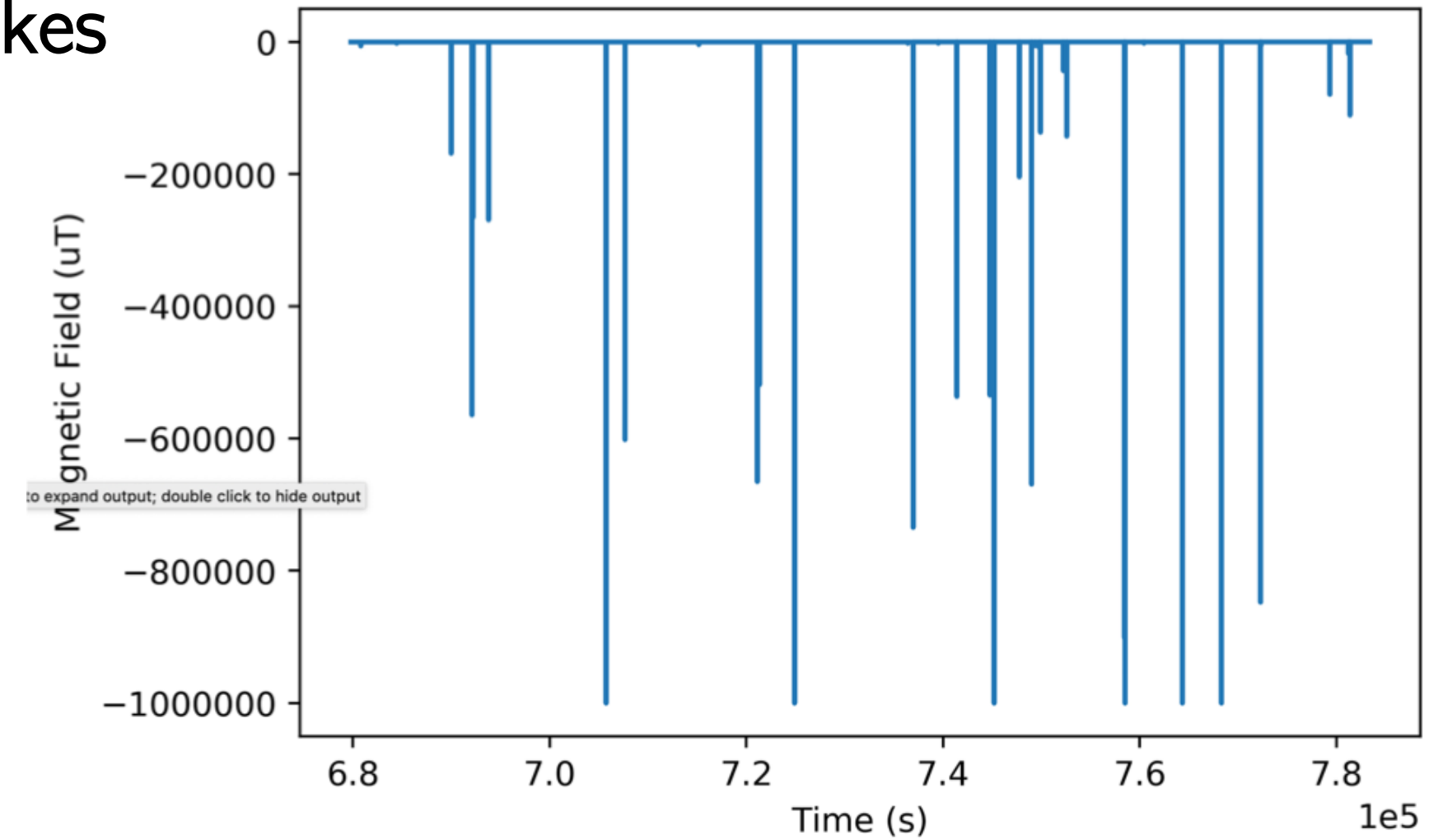
Overview of the current DAQ system

- The labjack has two kinds of buffer, what a PC accesses to is Labjack buffer
- Two ways to get data to a PC: eReadNames (no buffering) / eStreamRead (through buffer, higher data sampling rate)
- The online C code :
  - Data acquisition rate on Labjack is set to 500/s
  - Loop in 1s interval in which
    - Acquire data by eStreamRead, average them to get one value per channel, timestamped
    - Upload data to MIDAS



Data transfer from device buffer to Labjack buffer is almost instant
the # of data points in each buffer before execution of eStreamRead can be recorded

Problem: spikes

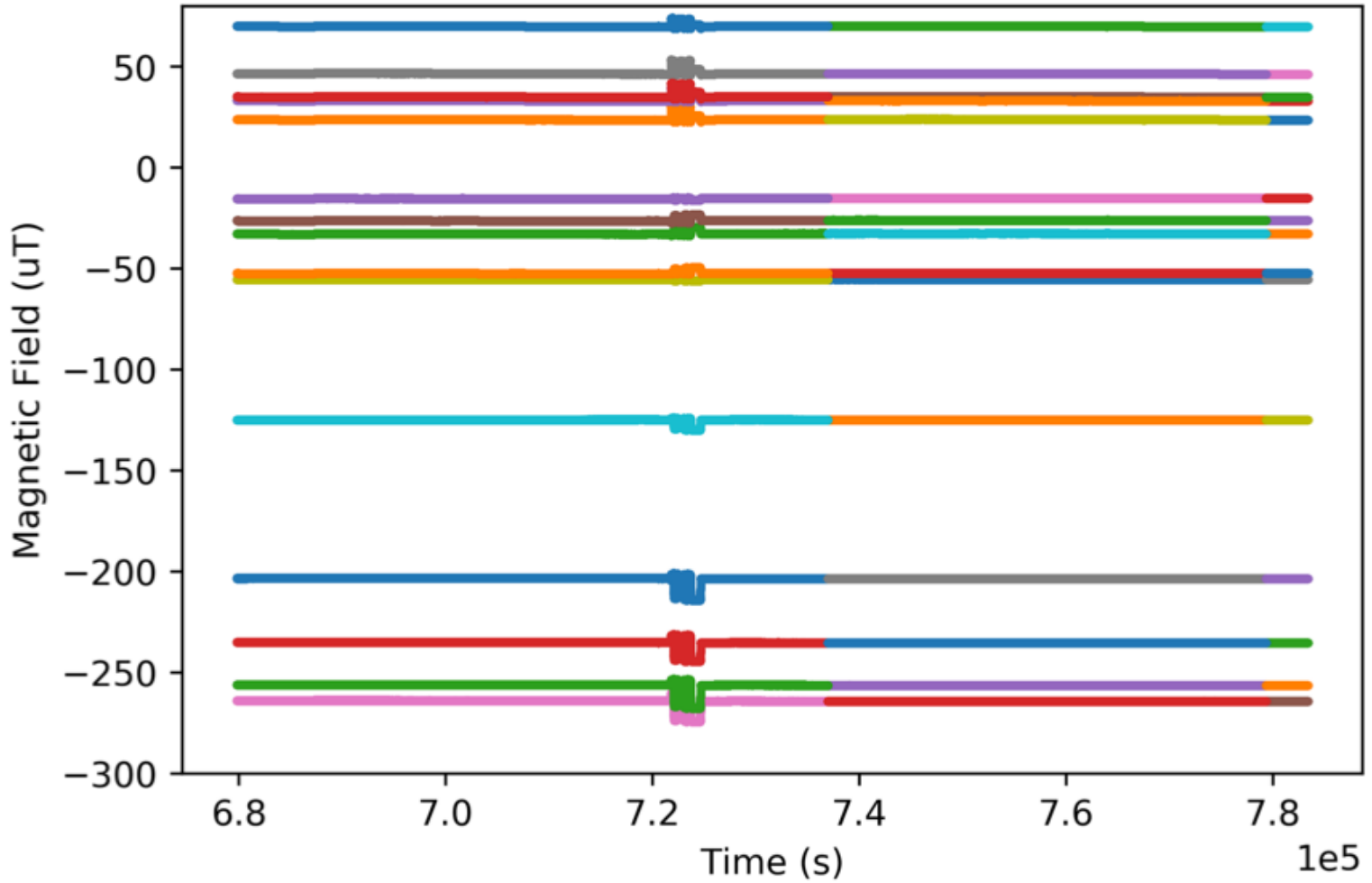


- Invalid values mixed in the read out, according to the manual, invalid value of -9999 is returned
- According to the manual, it is related to overflowing of buffer

From the manual of T7 series

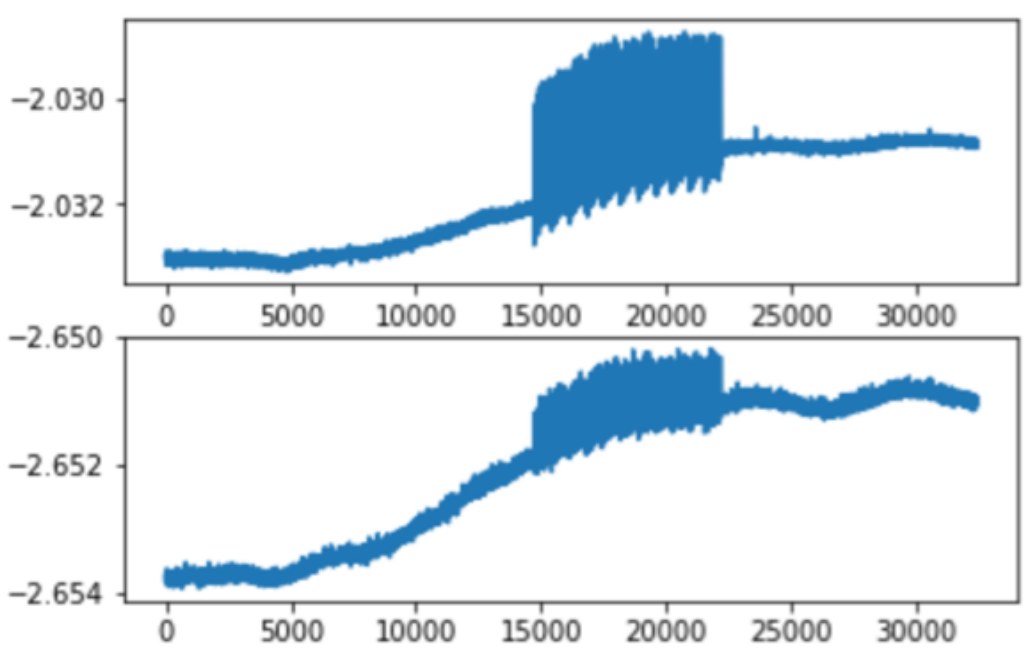
- Found here: https://ucn.triumf.ca/edm/magnetic-shielding/fluxgates-and-daq
- A few things of our interest:
  - 3.2 Stream Mode:
    - Stream mode is the way you get the highest input rate
    - *The T7 uses a feature called auto-recovery. If the buffer overflows, the T7 will continue streaming but discard data until the buffer is emptied, and then data will be stored in the buffer again. The T7 keeps track of how many scans are discarded and reports that value. Based on the number of scans discarded, the LJM driver adds the proper number of dummy samples (**-9999.0**) such that the correct timing is maintained. Auto-recover will only work if the first channel in the scan is an analog channel.*
    - # Another place where this number is found is 14.0 AIN about **AIN_ALL_RANGE**
      A read will return the correct setting if all channels are set the same, but otherwise will return -9999.
- Maximum data rate depends on the STREAM_RESOLUTION_INDEX (we use 0) and also on the # of channels used (15 chs not even in the table): see next page

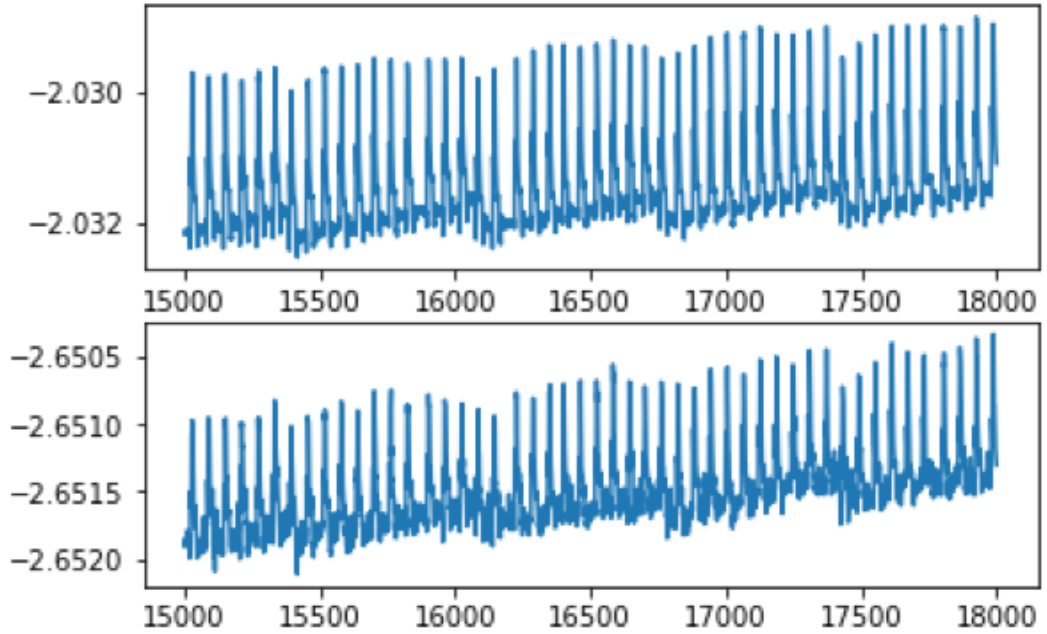
Problem: Swaps of channels



- Not sure what is causing this phenomenon. Observed ~once in 10 days
- Suspicious: Labjack code / multiplexer

Problem: Artificial noise?





- Acquired by a loop of eReadName
- Perhaps the board is creating noise which is not present in the real magnetic field?

Software debugging

- Xander is testing the system with a Labjack code without MIDAS connection
- Investigation especially on timing issues
- Systematic studies:
  - Sampling speed limitations on eReadNames
  - Sampling speed limitations on eStreamRead

Systematic: eReadName sampling speed

- In a simple loop with one eReadName every cycle, change the ScanRate (thus delay time) to check the limit of the rate

```
int scanRate = 1000/msDelay;
```

- Details:
  - Tested with 15 channels
  - RESOLUTION_INDEX was 1 (<-> 316 uV (32 nT) resolution)

- Result:
  - Tested with 15 channesl
  - About 60 ms (17 Hz) is the limit
    -> Consistent with the manual, because 15 x 0.04 ms = 60 ms
  - If a faster rate is set, Labjack returns an interval longer than the commanded one (e.g. 80 ms for commanded 40 ms, 60 ms for commanded 20 ms)

Table A.3.1.1. Effective resolution and sampling times for various gains and resolution index settings. Resolution index settings 9-12 apply to the T7-Pro only.

Resolution Index	Effective Resolution [bits]	Effective Resolution [µV]	AIN Sample Time [ms/sample]
Gain/Range: 1/±10V			
1	16.0	316	0.04
2	16.5	223	0.04
3	17.0	158	0.06
4	17.5	112	0.09
5	17.9	85	0.16
6	18.3	64	0.29
7	18.8	45	0.56
8	19.1	37	1.09
9	19.6	26	3.50
10	20.5	14	13.4
11	21.4	7.5	66.2
12	21.8	5.7	159
Gain/Range:10/±1V			
1	15.4	48	0.23
2	16.0	32	0.23

Systematic: eStreamRead sampling speed

- Key constants:
  - msDelay: defined by us to control ScanPerRead
  - ScanRate: how many datapoints the Labjack acquires in a second in its device buffer
  - ScansPerRead : defines how many of datapoints in buffer the PC reads from Labjack buffer

```
int msDelay = 1000;
double INIT_SCAN_RATE = 2000;
int SCANS_PER_READ = (INIT_SCAN_RATE * msDelay) / 1000;
Stream(handle, NUM_CHANNELS, CHANNEL_NAMES, INIT_SCAN_RATE,
SCANS_PER_READ, NUM_READS); // start eStreamRead
```

- Example on online code:

```
msDelay = 1000;
ScanRate = 500;
→ ScansPerRead = 500
```

- Xander's test:

  For a certain ScanRate, sweep msDelay (thus ScansPerRead) and compare the stability of the sampling interval

Systematic: eStreamRead sampling speed

- Results:
  - For ScanRate = 250 and RESOLUTION_INDEX = 5, the optimum was **50 ms ≦ msDelay ≦ 100 ms**
  - For > 100 ms, we saw remaining buffer data in the LJK backlog
  - The lower limit 50 ms (20Hz)
  - The manual

Programmed delay (ms)	Standard Deviation of Measured Delay(s)
1000	0.07421812814186443
500	0.0761626485954064
200	0.08034751238586482
100	0.008393065174905158
50	0.0075171051770485916
20	0.0438590258011826

Resolution Index = 5	1 : ±10V	5.5k	2.2k	990	630	4.4k
	10 : ±1V	5.5k	630	23	N.S.	1.3k
	100 : ±0.1V	N.S.	N.S.	N.S.	N.S.	N.S.
	1000 : ±0.01V	N.S.	N.S.	N.S.	N.S.	N.S.
Resolution Index = 6	1 : ±10V	2.5k	1.3k	630	315	2.6k
	10 : ±1V	2.5k	320	N.S.	N.S.	640
	100 : ±0.1V	N.S.	N.S.	N.S.	N.S.	N.S.
	1000 : ±0.01V	N.S.	N.S.	N.S.	N.S.	N.S.
Resolution Index = 7	1 : ±10V	1.2k	650	315	N.S.	1.3k
	10 : ±1V	1.2k	220	N.S.	N.S.	440
	100 : ±0.1V	N.S.	N.S.	N.S.	N.S.	N.S.
	1000 : ±0.01V	N.S.	N.S.	N.S.	N.S.	N.S.
Resolution Index = 8	1 : ±10V	600	315	N.S.	N.S.	630
	10 : ±1V	600	200	N.S.	N.S.	400
	100 : ±0.1V	N.S.	N.S.	N.S.	N.S.	N.S.
	1000 : ±0.01V	N.S.	N.S.	N.S.	N.S.	N.S.

*N.S. indicates settings not supported in stream mode.

- But occasionally, the stable setting above gets outlying intervals. Under investigation.

Testing the online code with MIDAS

- We found that that the default timing parameters of the online code is not optimum. The buffer tends to overflow, as the PC cannot digest the buffer (in our test run, it stopped with an error “Buffer Overflow”. Before it was returning invalid output -9999, not sure why the behaviors are different)
- We basically need two loops
  - The loop on MIDAS (should not be too fast in order not to put too much local space)
  - Fast enough access to Labjack
    (in case we want to acquire data from Labjack at a level of ~100 Hz)
- We will consult Thomas

New setup in the meson hall

- The pole used by Paul Sarte and Edgard is installed
- Mag03MC1000 read by three commercial multimeters
- Currently acquiring data with the triaxial fluxgate next to FG-04 (“1” in the code)
- The height which can be scanned by this setup
  - The height of the platform floor : 1.75 m
  - The height of the pole : 2.1 m

  → 1.8 ~ 3.8 m from the floor can be scanned

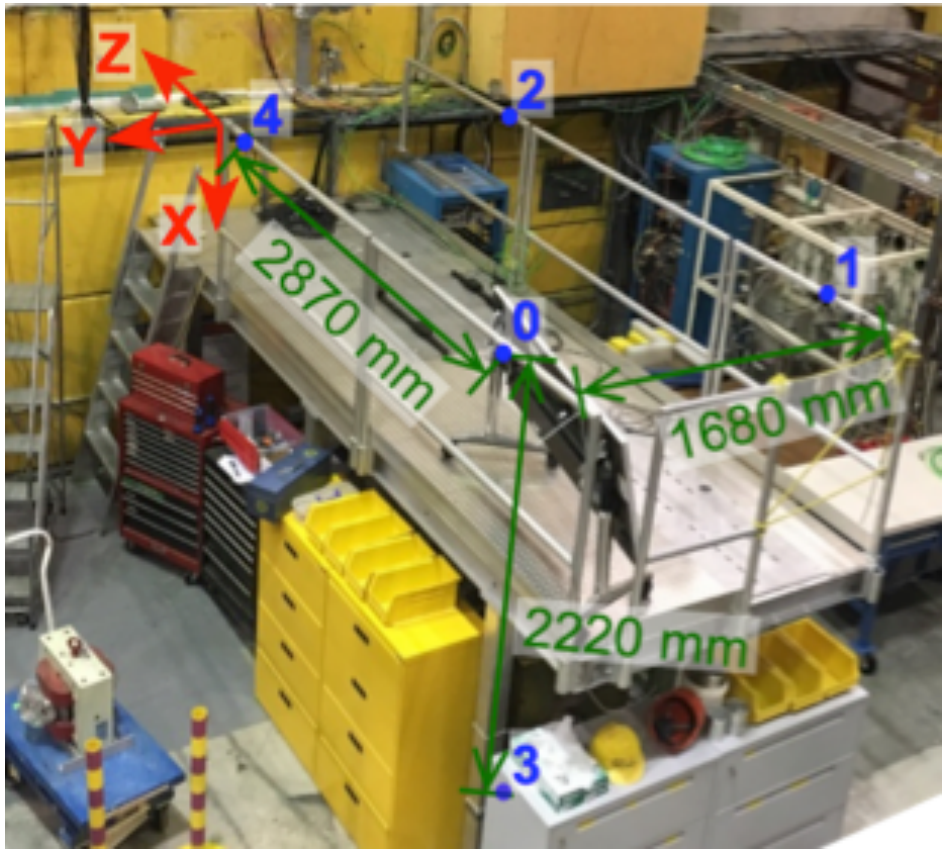
- Once we find a solution to ensure mechanical (rubber sheets?), will do a preliminary scan (next week?)

New setup in the meson hall

- The pole used by Paul Sarte and Edgard is installed
- Mag03MC1000 read by three commercial multimeters
- Currently acquiring data with the triaxial fluxgate next to FG-04 (“1” in the code)
- The height which can be scanned by this setup
  - The height of the platform floor : 1.75 m
  - The height of the pole : 2.1 m

  → 1.8 ~ 3.8 m from the floor can be scanned

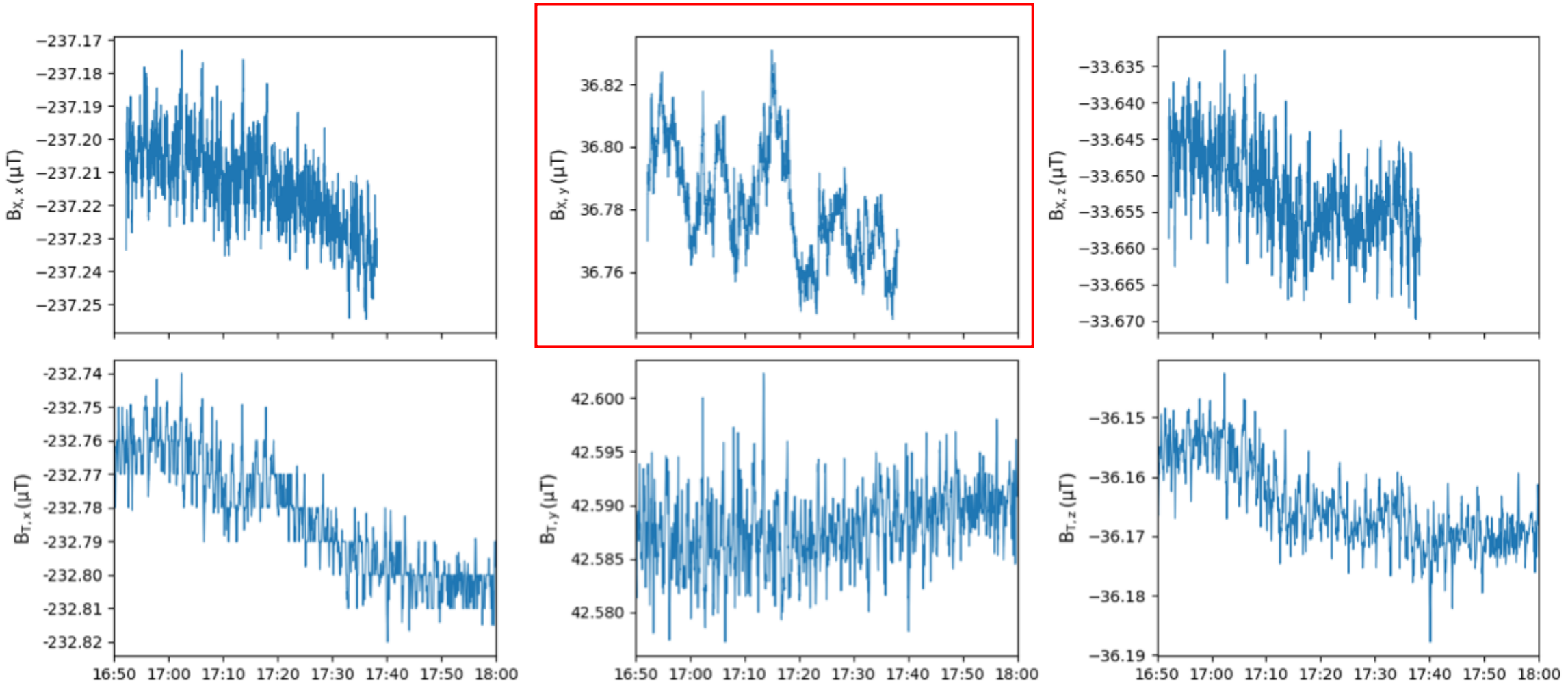
- Once we find a solution to ensure mechanical (rubber sheets?), will do a preliminary scan (next week?)



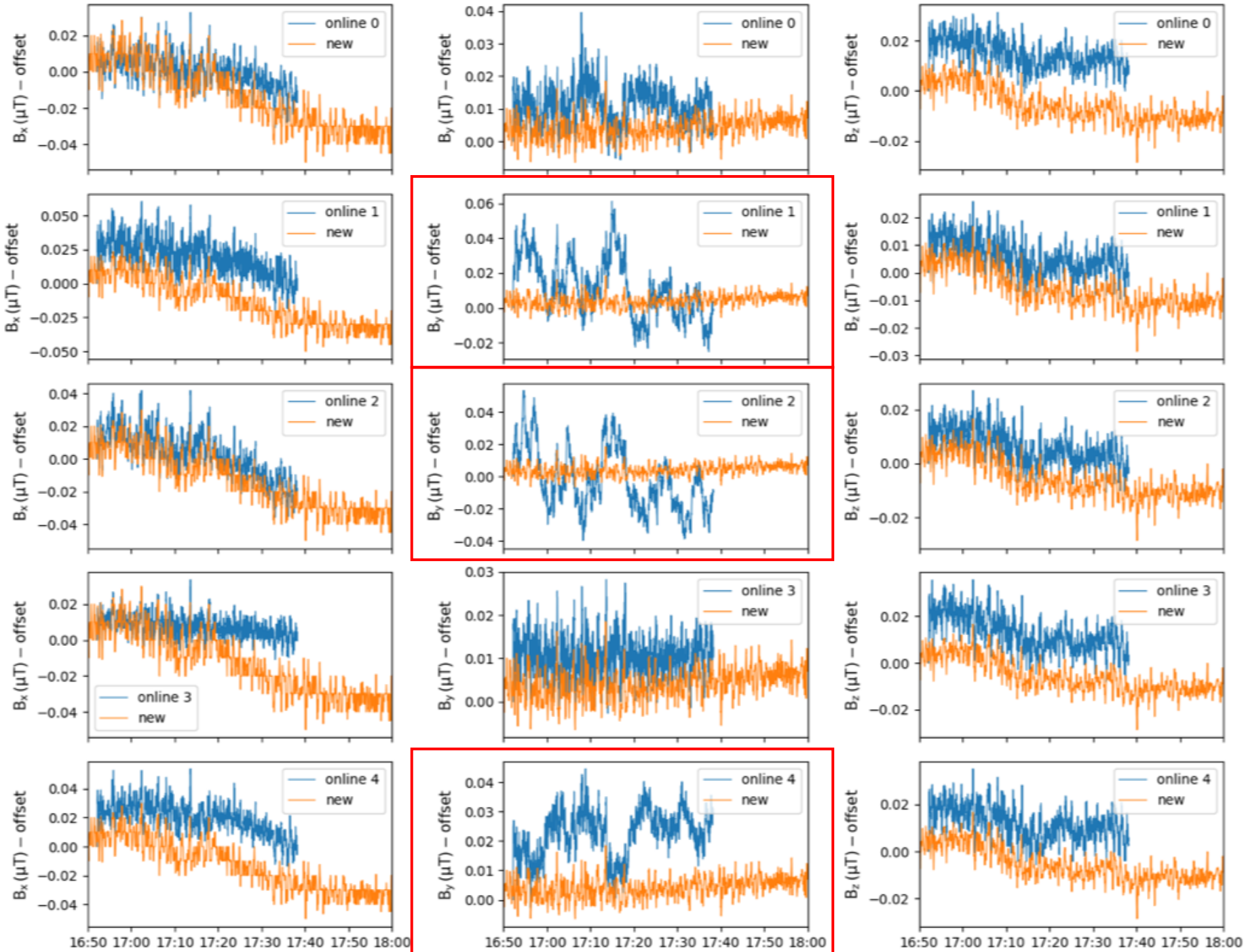
Comparison of data between the two systems (23.07)

Online

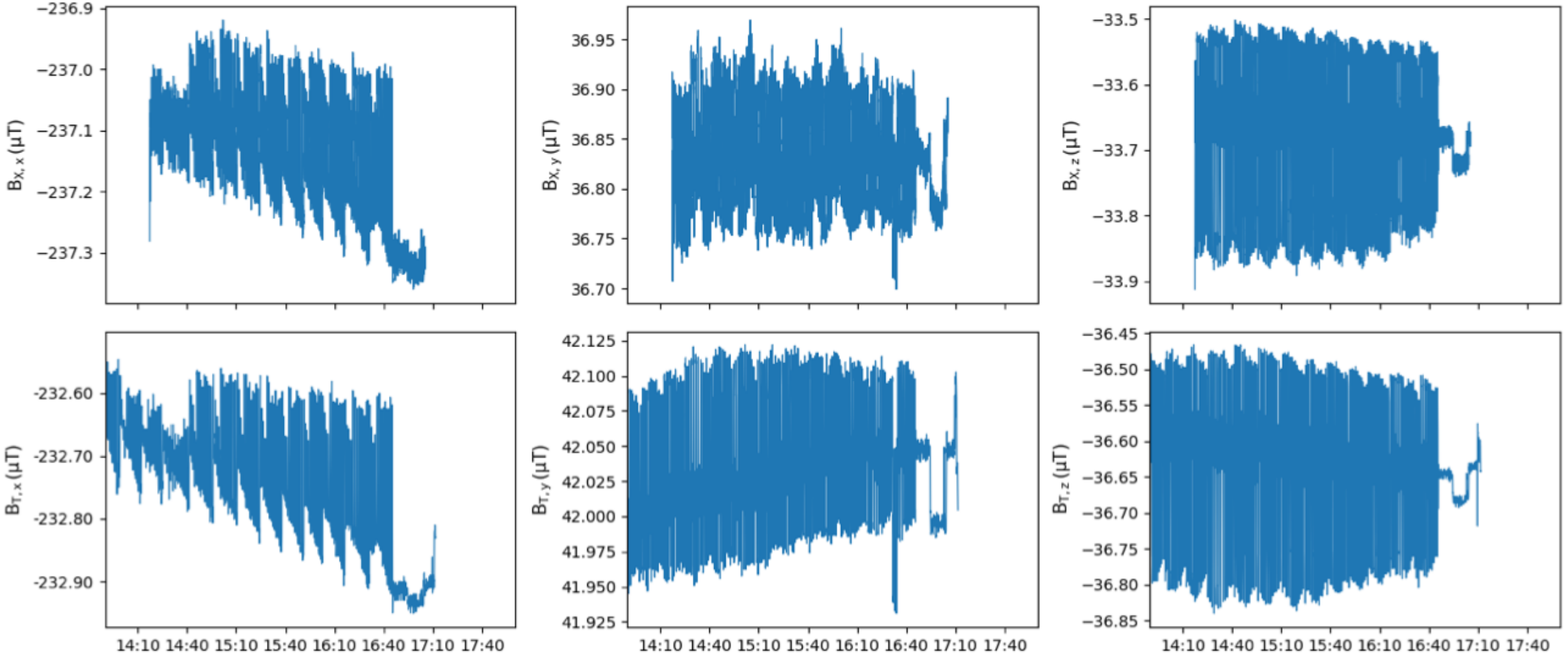
New



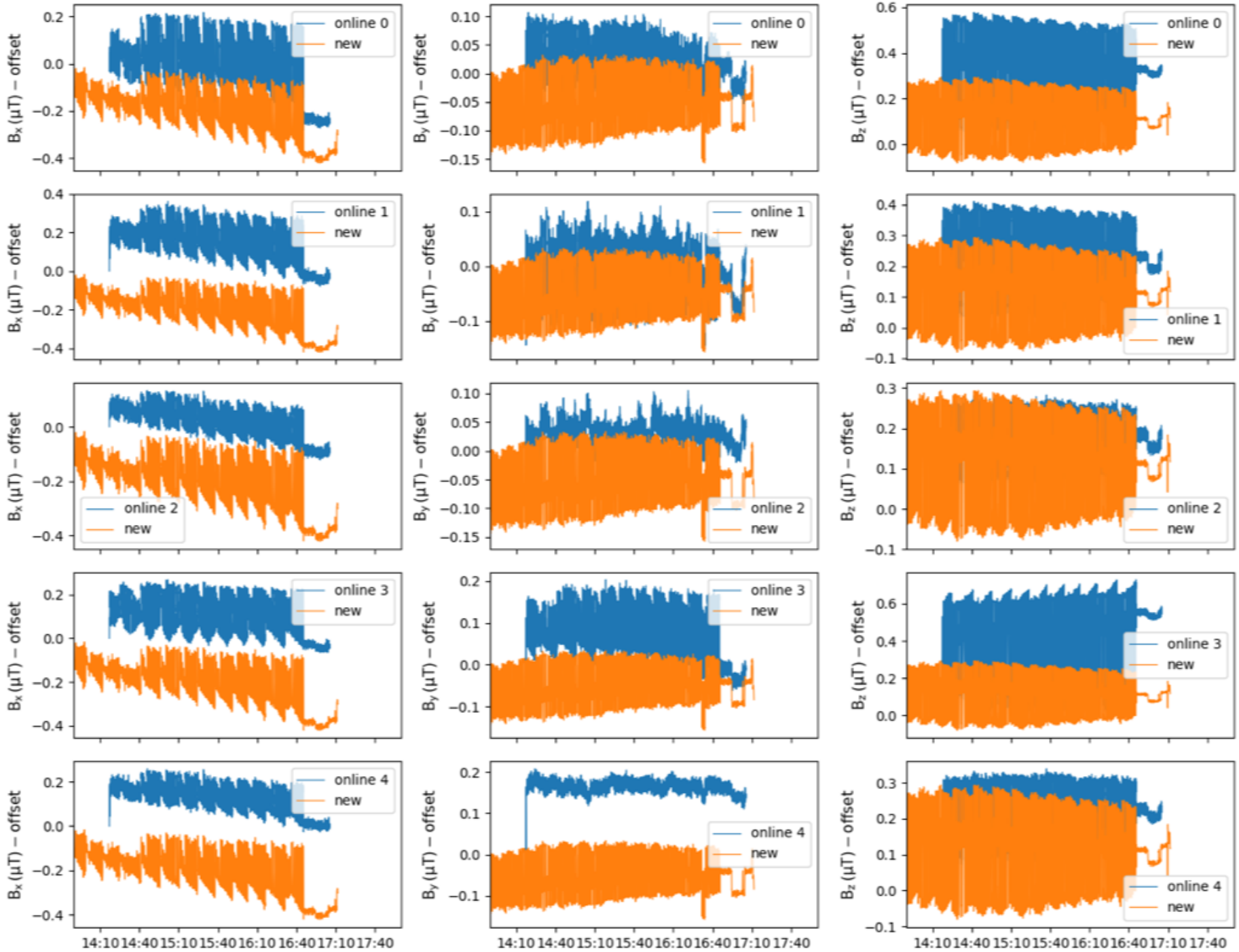
- The channel Y seems to have a hardware issue…


online 0
new
online 1
new
online 2
new
online 3
new
online 4
new
B_x (μT) − offset
B_y (μT) − offset
B_z (μT) − offset
16:50 17:00 17:10 17:20 17:30 17:40 17:50 18:00

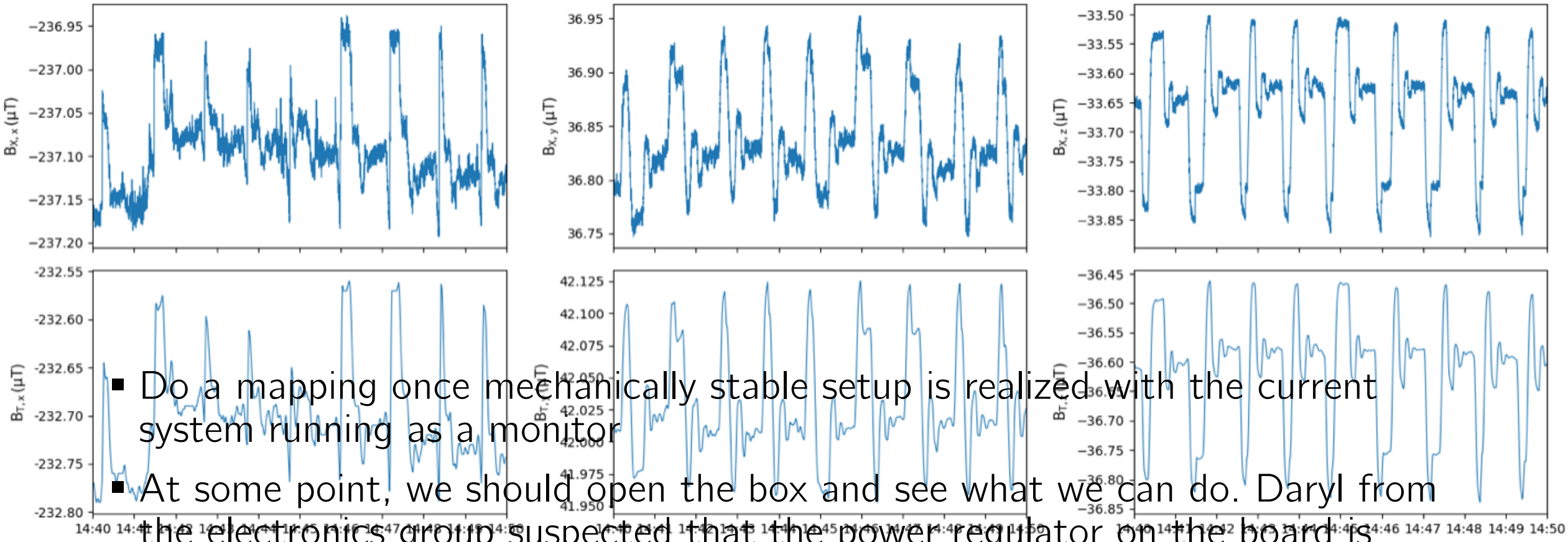
Comparison on 24/07 afternoon



- The regular ramps we saw previously were real. Stopped at around 16:40


online 0
new
online 1
new
online 2
new
online 3
new
online 4
new
B_x (μT) − offset
B_y (μT) − offset
B_z (μT) − offset
14:10 14:40 15:10 15:40 16:10 16:40 17:10 17:40

Zoomed-in



- Do a mapping once mechanically stable setup is realized with the current system running as a monitor
- At some point, we should open the box and see what we can do. Daryl from the electronics group suspected that the power regulator on the board is coupled to signal lines and causing noise. He said it is not easy to replace the power supply unit from the board.
- The software debugging can be continued in parallel to the hardware check

Next

- Mapping on the platform
  - once mechanically stable setup is realized
  - with the current system running as a monitor
- At some point, we should open the box and see what we can do. Daryl from the electronics group suspected that the power regulator on the board is coupled to signal lines and causing noise. He said it is not easy to replace the power supply unit from the board.
- The software debugging can be continued in parallel to the hardware check by another Labjack of the same series (T7).

Previous mapping campaigns by Paul & Edgard

- Links: report, presentation
- Mapping campaigns in M13 (current TUCAN) and M11, M20
- Issues of alignment for M13 measurement, made a pole for M11 & M20 ones
- Observed commonly: |B| ≲ 300uT, stronger near the floor
  → apparently we saw a different tendency. Local fields?