Effects observed in electron BPM readings

Collette Pakuza, Stefano Mazzoni, BI and AWAKE teams

20th AWAKE Instrumentation Meeting, Tuesday 26 November

Contents

- Overview
- General observations with 1 Hz data
- More detailed look with 10 Hz data

Contents

Overview

BPM systems at AWAKE

ELECTRONS

Stripline:

- 7 shorted stripline BPMs in the 18 MeV electron line
- 5 in the common beam line

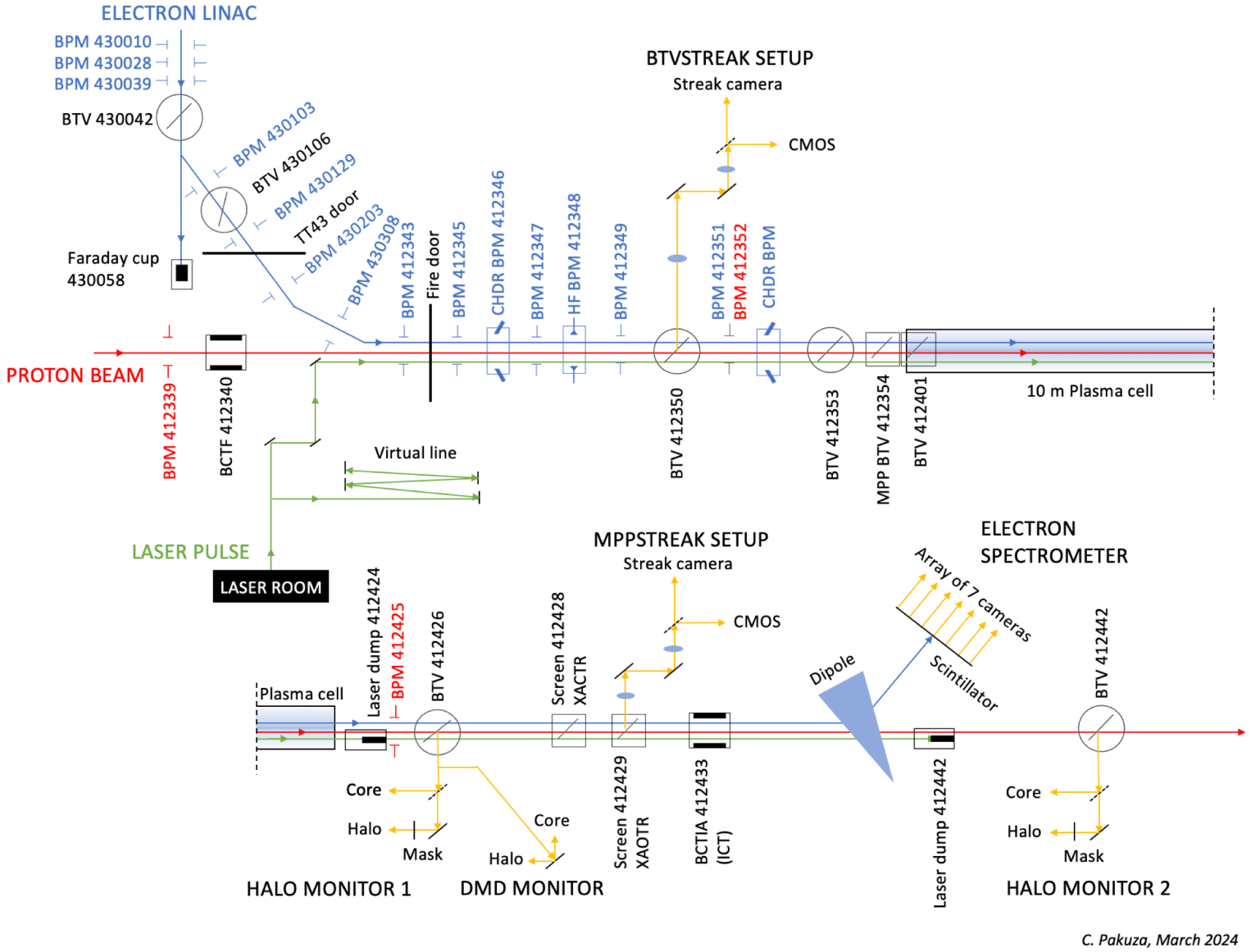
High-frequency:

- 2 ChDR BPMs in the common beam line
- 1 HF DESY inspired conical-shaped button BPM in the common line

PROTONS

- 20 button BPMs from SPS extraction to AWAKE

During the tests for the high-frequency pick-ups in 2024, effects in the BPM readings were observed when AWAKE was in the SPS cycle even when protons were not being extracted



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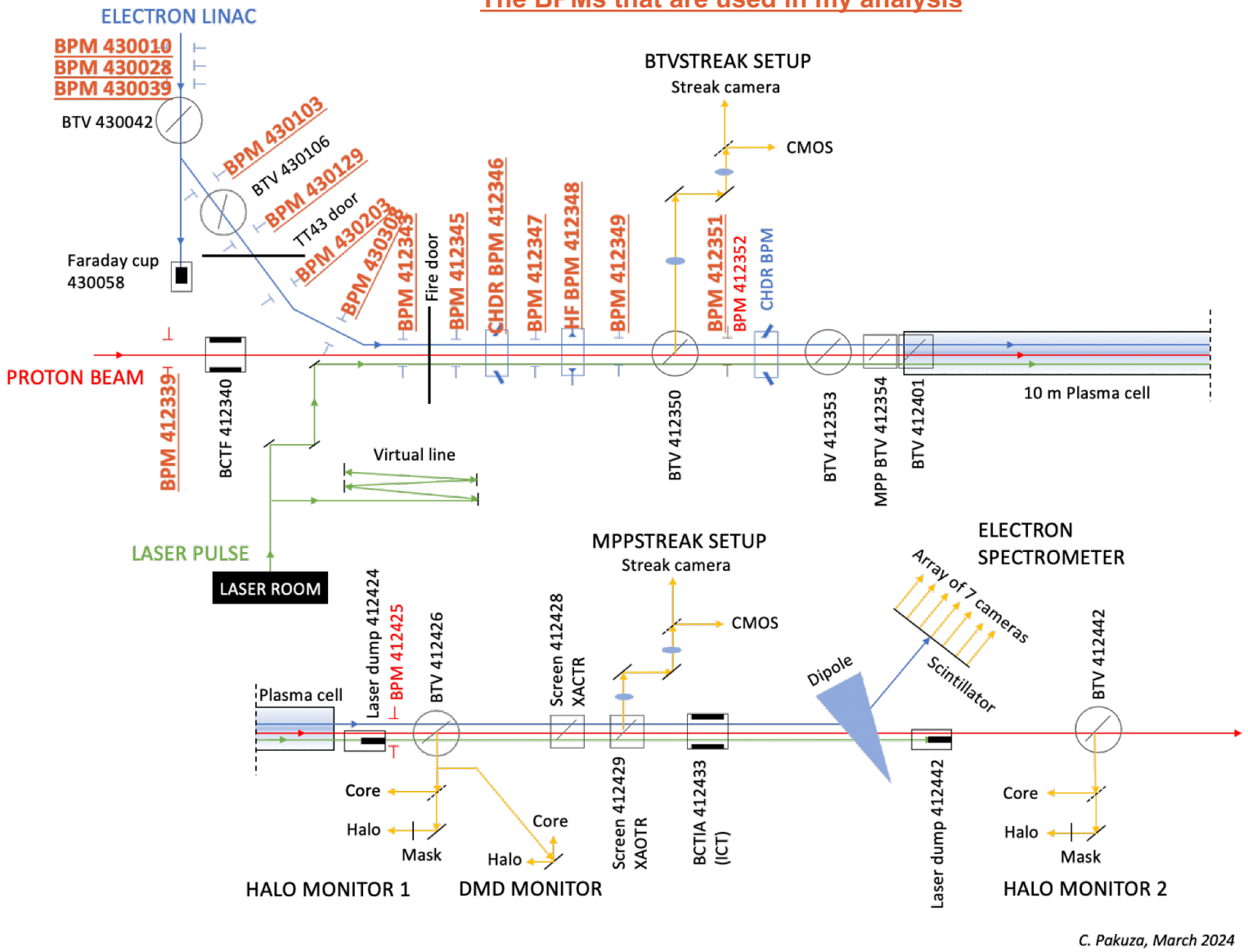
The BPMs that are used in my analysis



C. Pakuza, March 2024

Contents

Data from nxcals

Selected timeframes for the BPM position data:

28/07/2024 20:07:00 to 20:10:00 UTC – 1 x 10^{11} protons per bunch, 200 pC electron bunches (shown below)

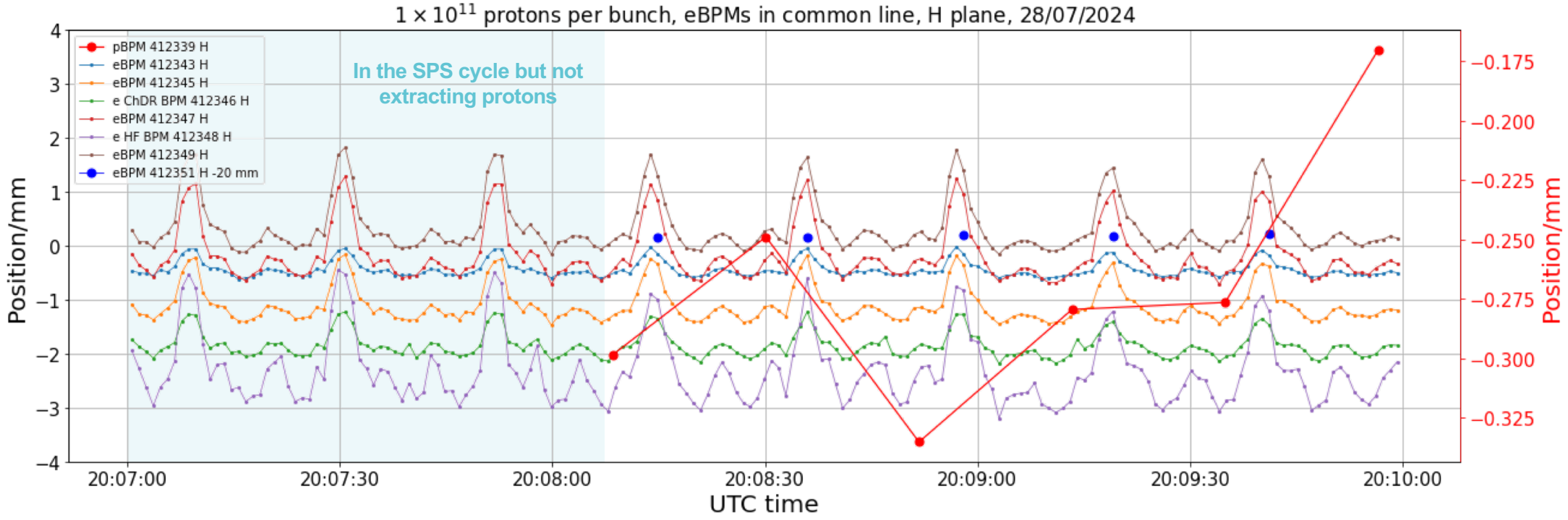
28/07/2024 20:03:00 to 20:06:00 UTC – 3 x 10^{11} protons per bunch, 200 pC electron bunches

23/07/2024 17:50:30 to 17:53:30 UTC – 3 x 10^{11} protons per bunch, 200 pC electron bunches

05/08/2024 08:47:00 to 08:50:00 UTC – 200 pC electron bunches only

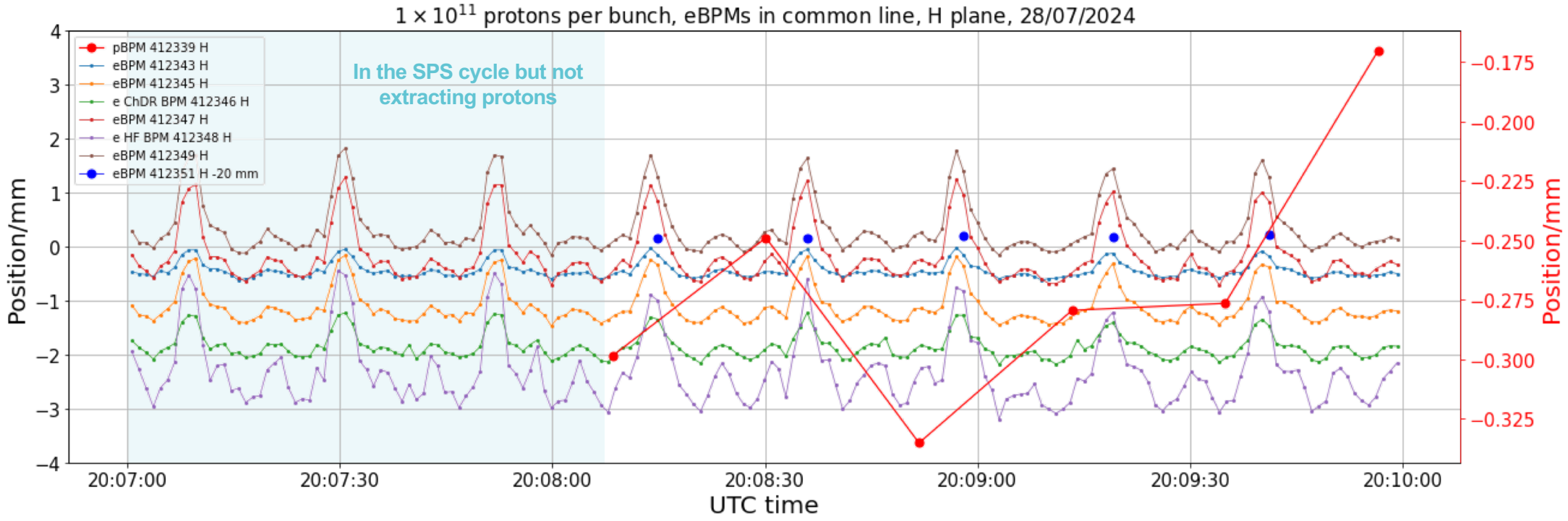
14/05/2022 12:56:00 to 12:59:00 UTC – check of 2022 data

15/10/2024 13:00:00 to 13:07:00 UTC – check of the last day of this year's run



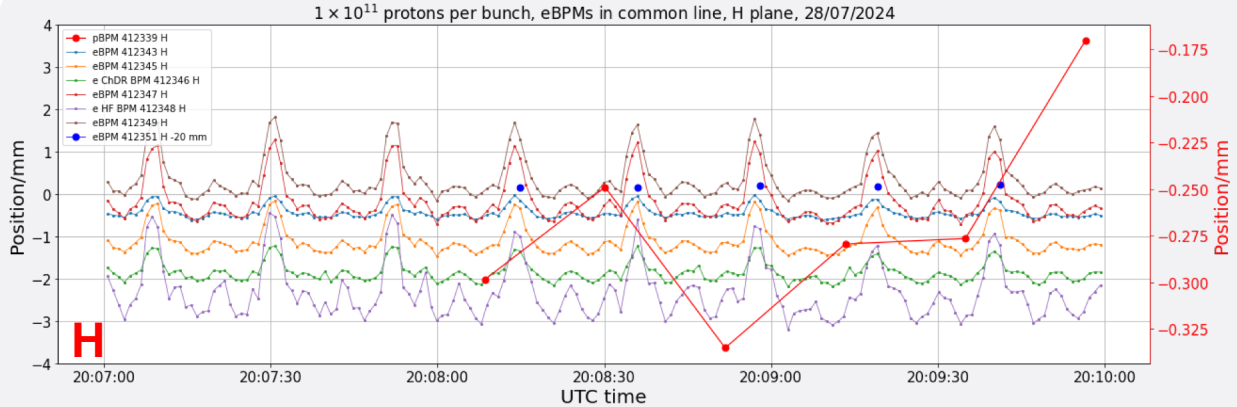
Data from nxcals

- Beam position of common line eBPMs, including the ChDR and HF BPMs, plotted and one pBPM (all horizontal plane)
- Screen in just before BPM 412351 stopping the electrons but not the protons, so BPM 412351 is reading the proton shots
- All eBPMs and pBPMs are triggered on the signal except the ChDR and HF BPMs that are triggered with 10 Hz external trigger
- The eBPM position readings publish both an average of 10 shots at 1 Hz (plotted) and a set of 10 readings at 1 Hz
- The pBPM readings are cycle bound and are published with the cycle timestamp – misaligned with timestamp of eBPM 412351 reading of the protons
- Plot shows that even when we are **in the cycle but not extracting protons, peaks are present at the rate of proton extraction**

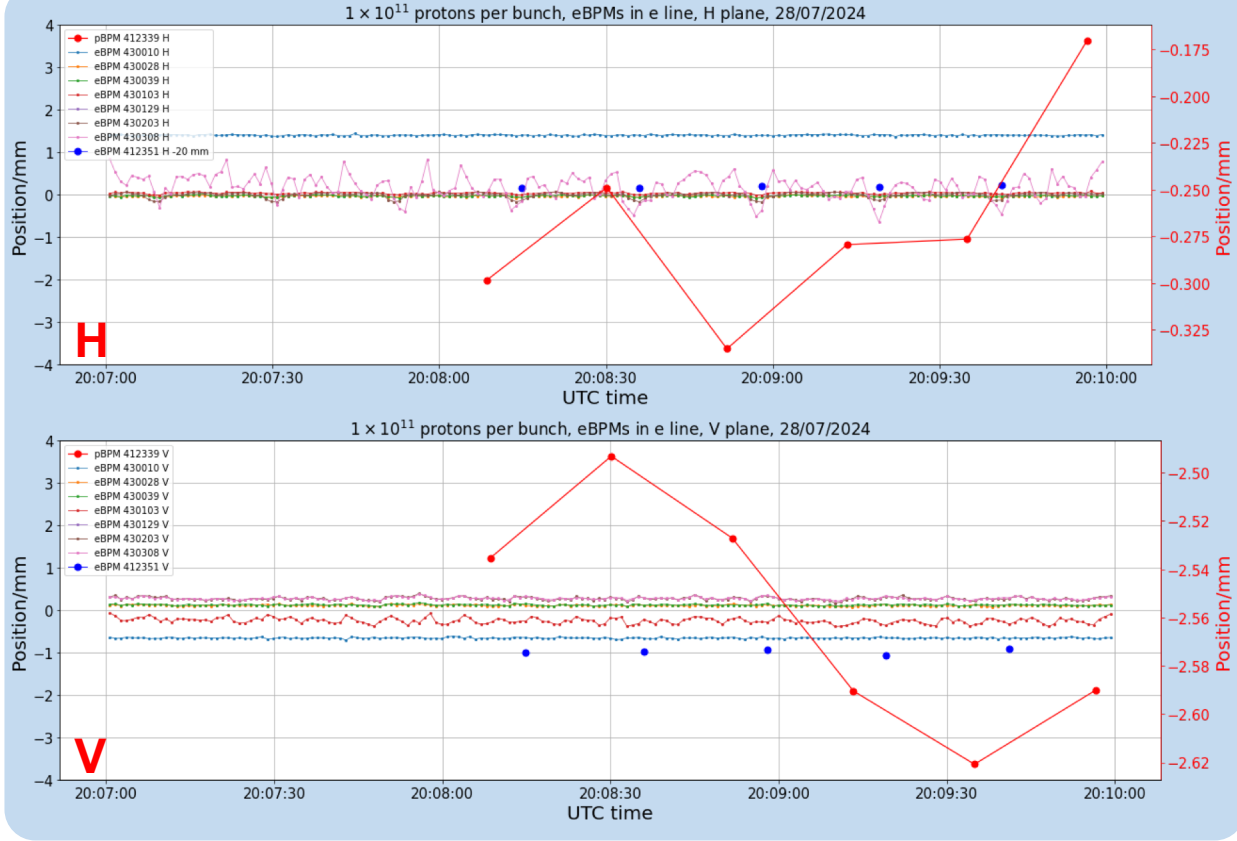


1×10^{11} protons per bunch and electrons

COMMON LINE



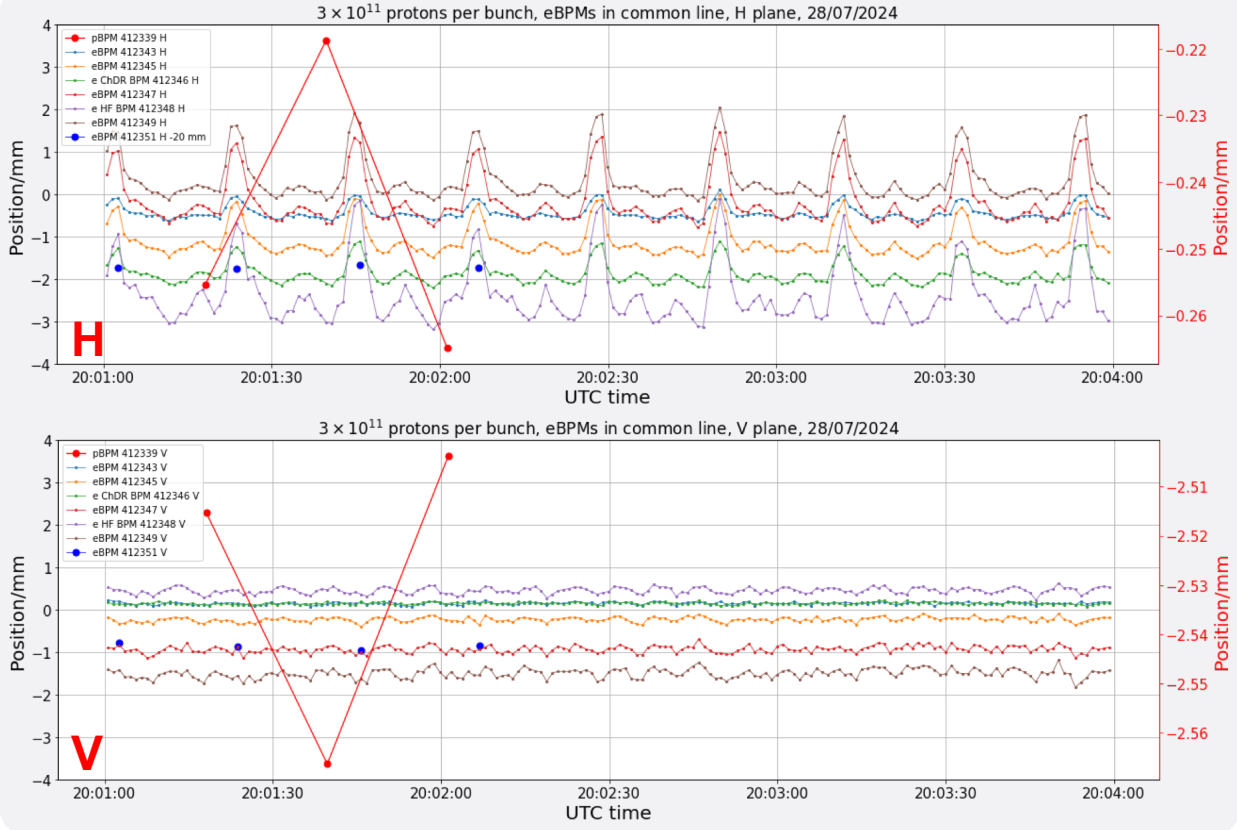
ELECTRON LINE



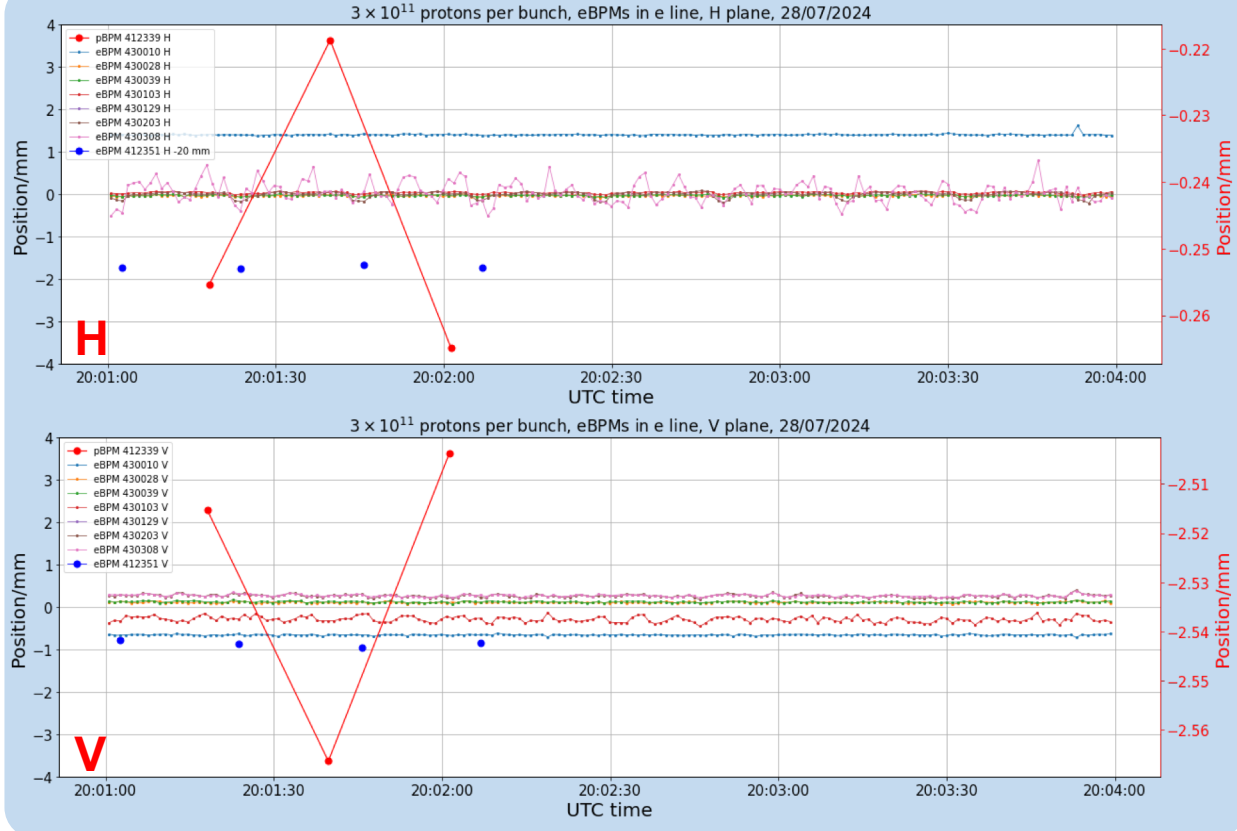
- Peaks in the H plane of common line e-BPMs
- Peaks also present in H plane of e-line BPMs but in the **opposite direction**
- No peaks or within noise in vertical plane in the common and e-line BPM readings

3×10^{11} protons per bunch and electrons

COMMON LINE



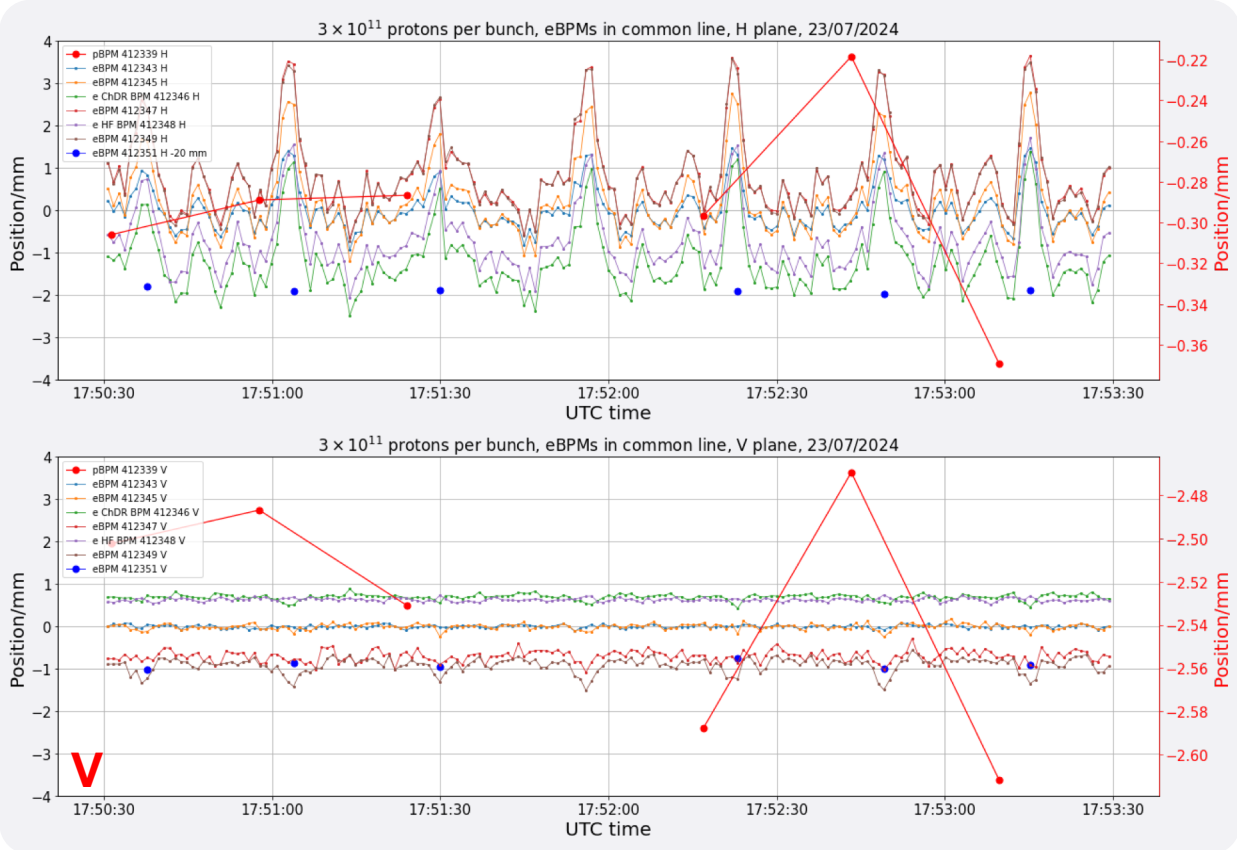
ELECTRON LINE



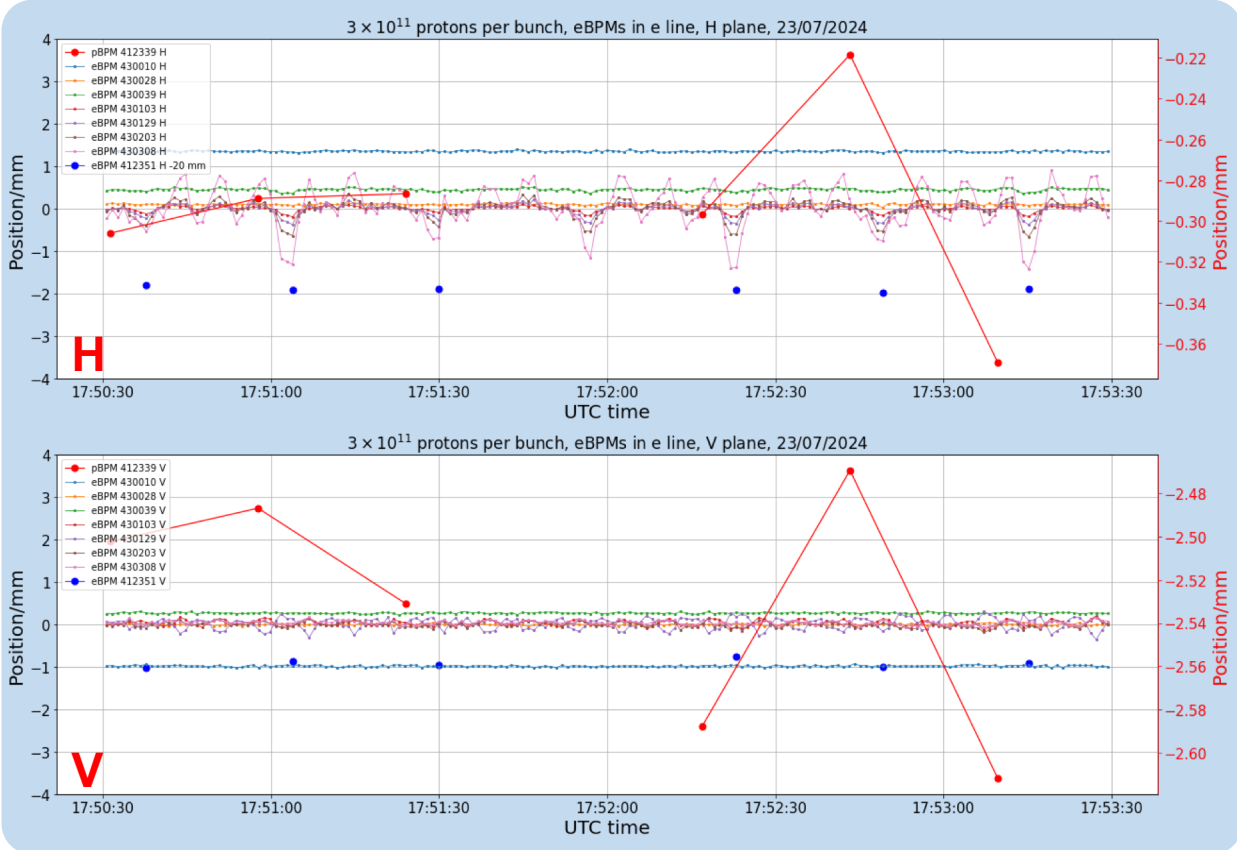
- Same day, few minutes apart, no e-beam parameters changed
- Similar situation for higher-intensity proton bunches

3×10^{11} protons per bunch and electrons

COMMON LINE



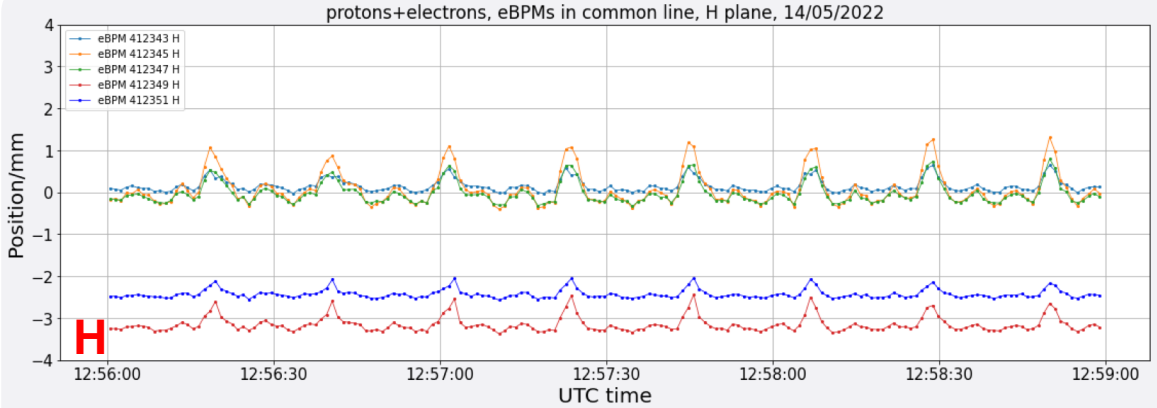
ELECTRON LINE

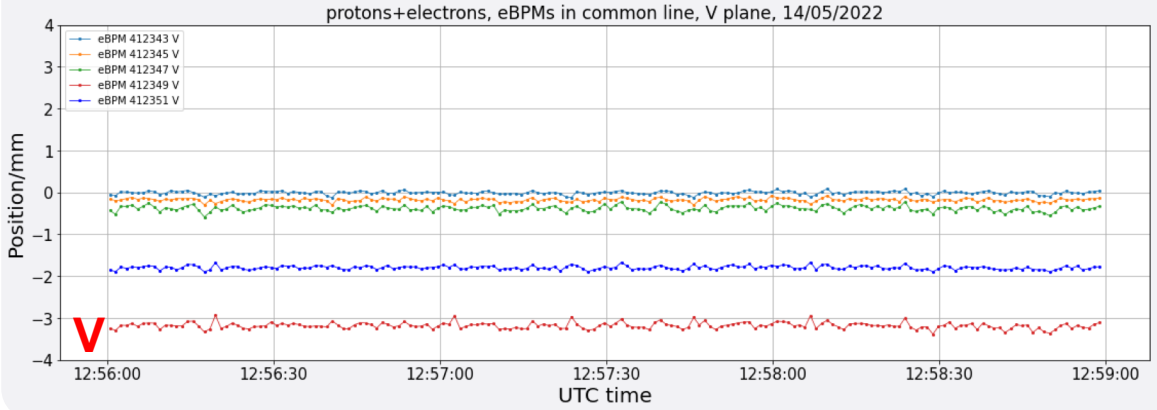


- Example from a different day, different e-beam conditions
- Peaks are more pronounced in the H plane of BPM readings in both the common and e line, where the amplitude of the peaks are increasing as you go further down the e-line
- Also some peaks can be seen in the V plane of the common line

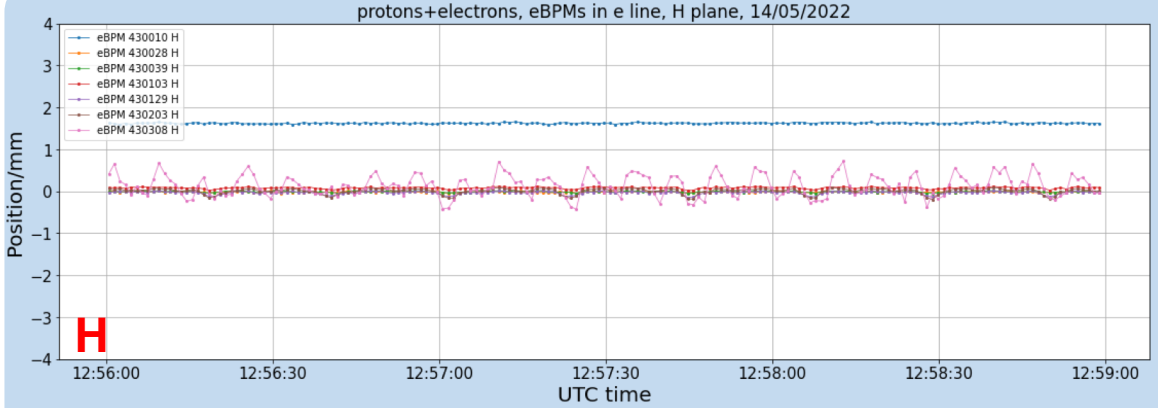
2022 data check

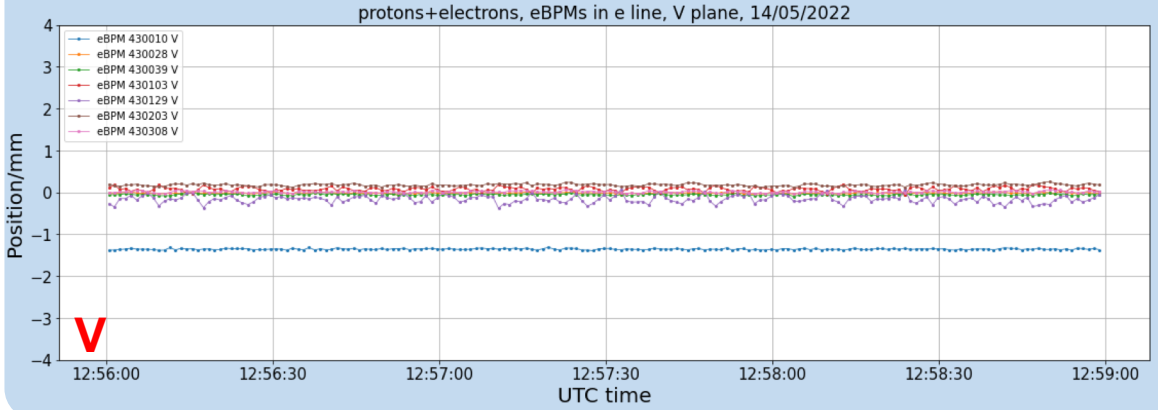
COMMON LINE





ELECTRON LINE

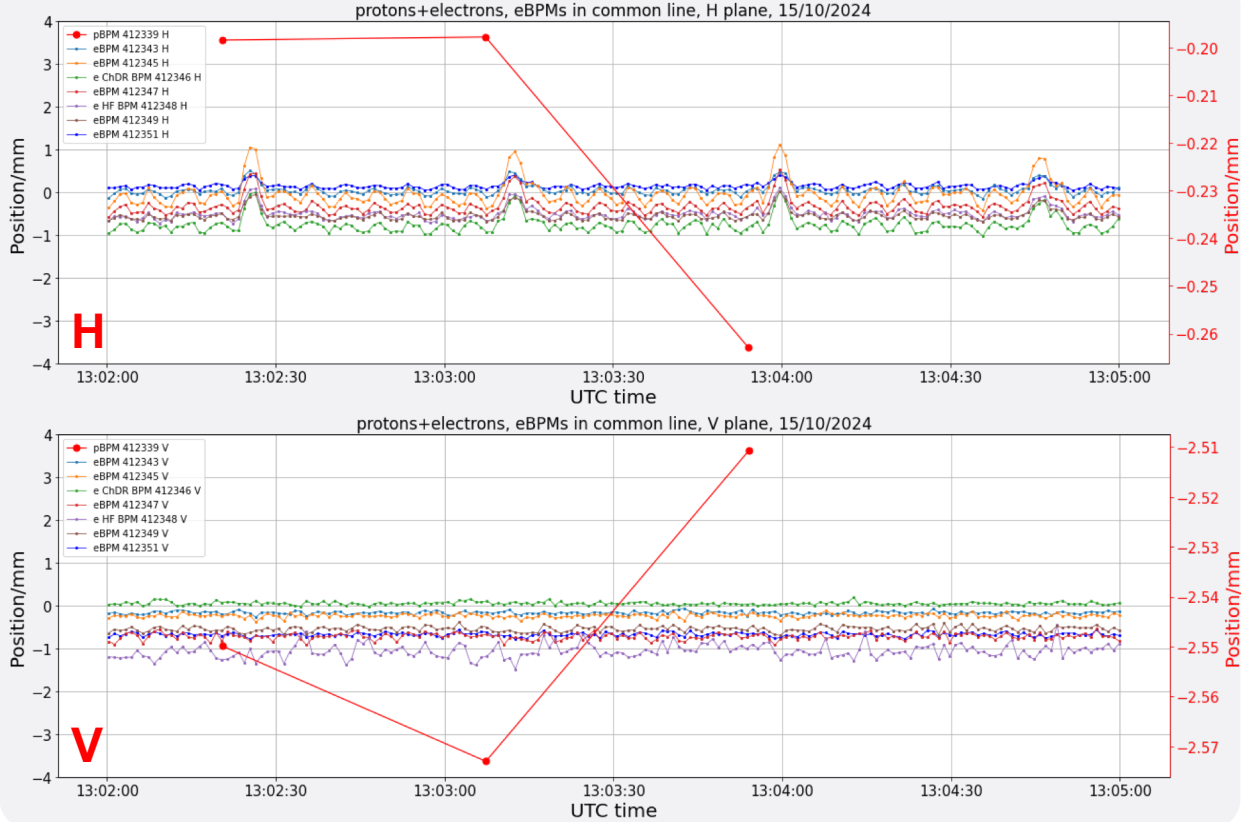




- For 1 x 10^{11} protons per bunch

Last day of 2024 Run check

COMMON LINE

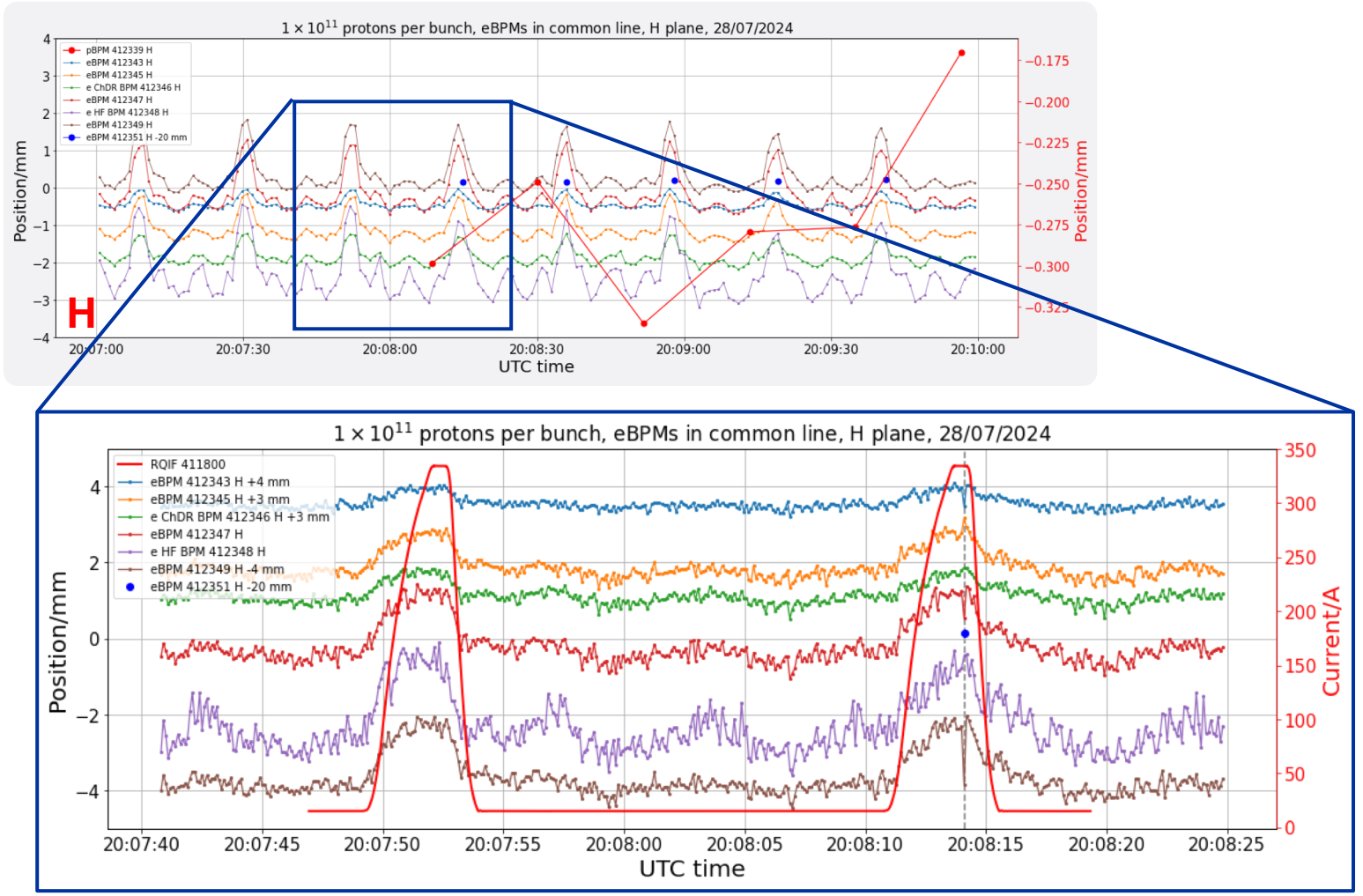


ELECTRON LINE

- Peaks still present

Contents

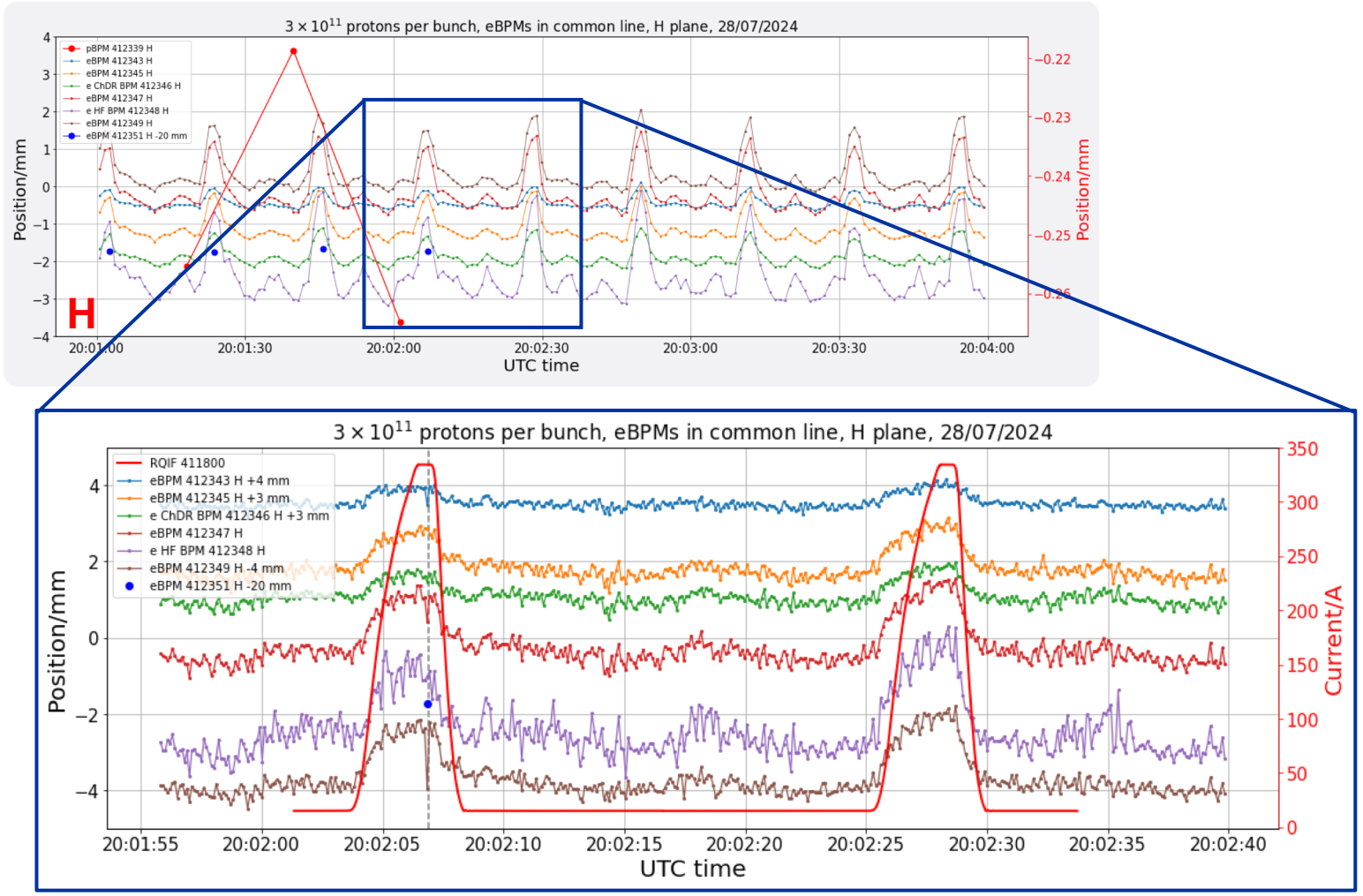
1×10^{11} protons per bunch and electrons



COMMON LINE

- Plotted is the current in a magnet in the p-line
- Correlation between the peaks in the BPM readings and this current
- Presence of the protons affects the signal in the stripline eBPMs, which we already know as they operate at 404 MHz
- Don't see much difference for the ChDR and HF BPMs
- These are better at rejecting the proton signal at 1 x 10^{11} ppb – what we already know from previous measurements without the TRIUMF detection system and simple 30 GHz detection and scope

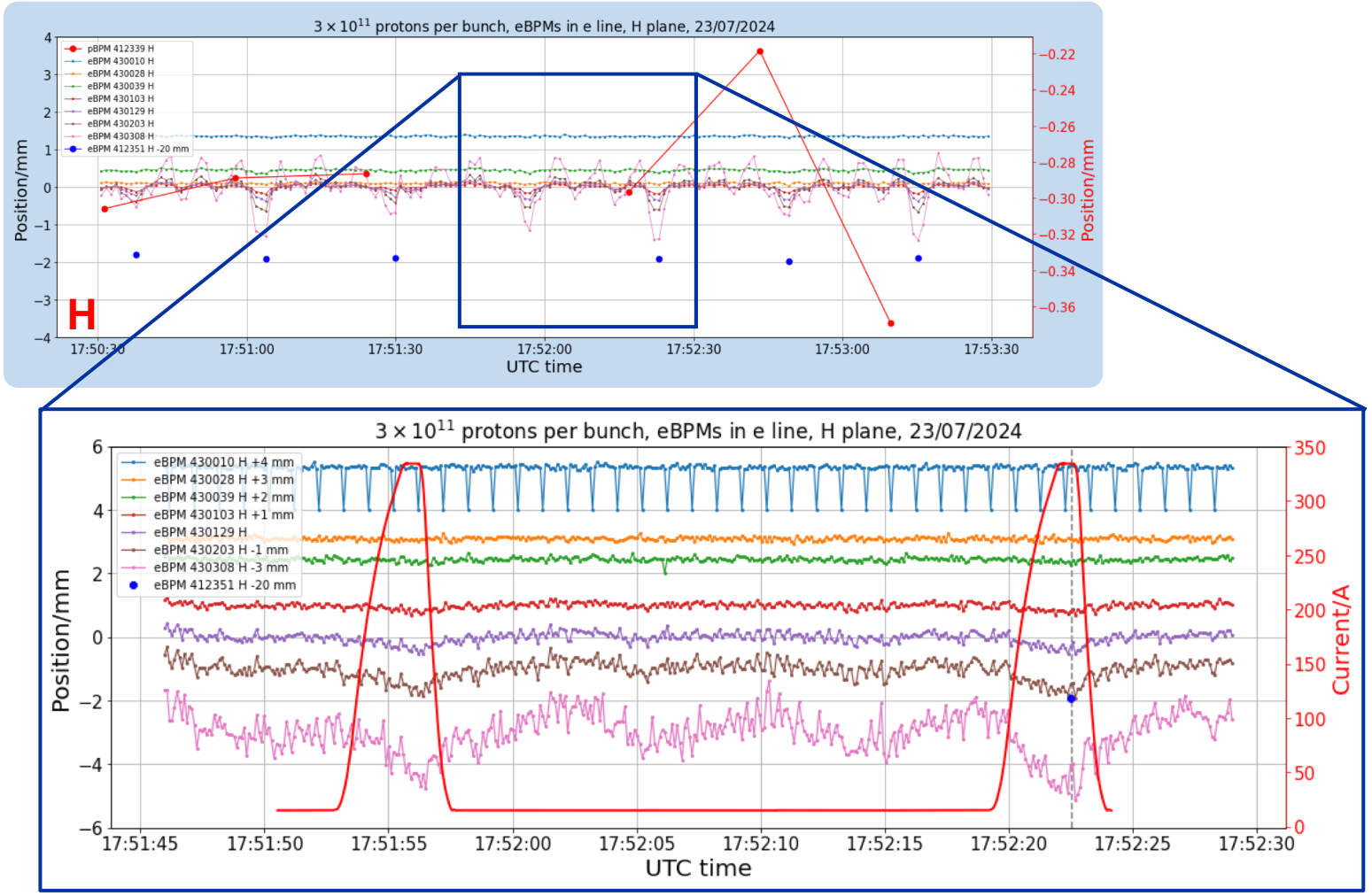
3×10^{11} protons per bunch and electrons



COMMON LINE

- Similar situation for higher-intensity protons
- Makes sense as magnet current doesn't change

3×10^{11} protons per bunch and electrons

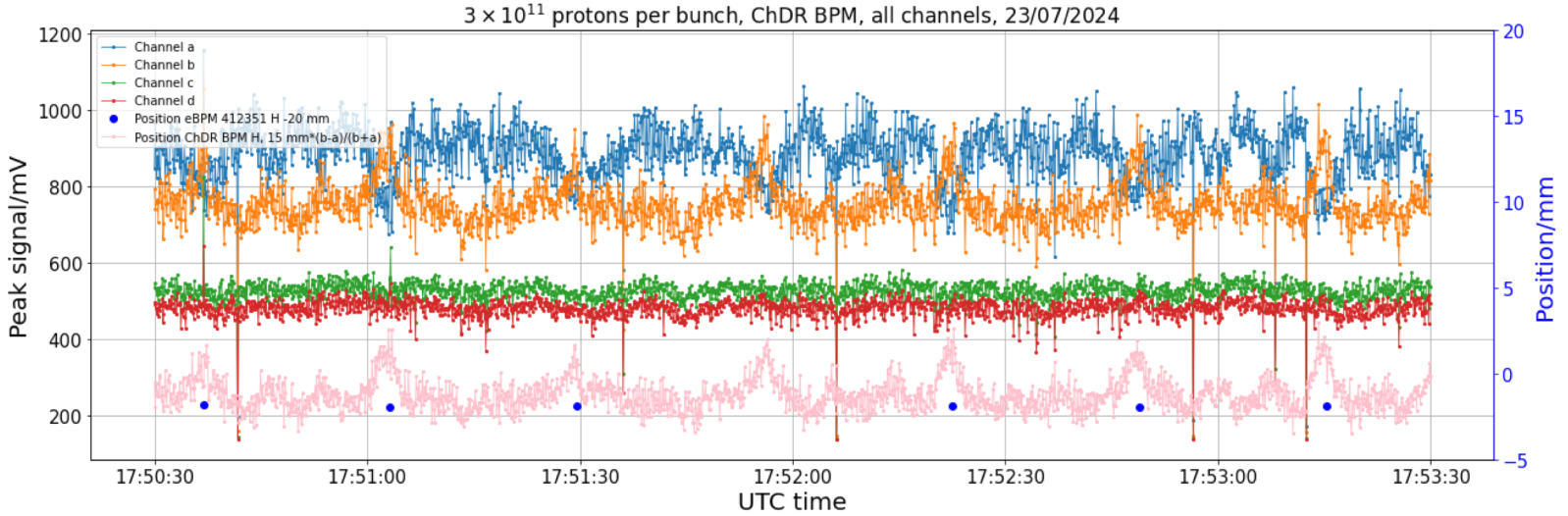


ELECTRON LINE

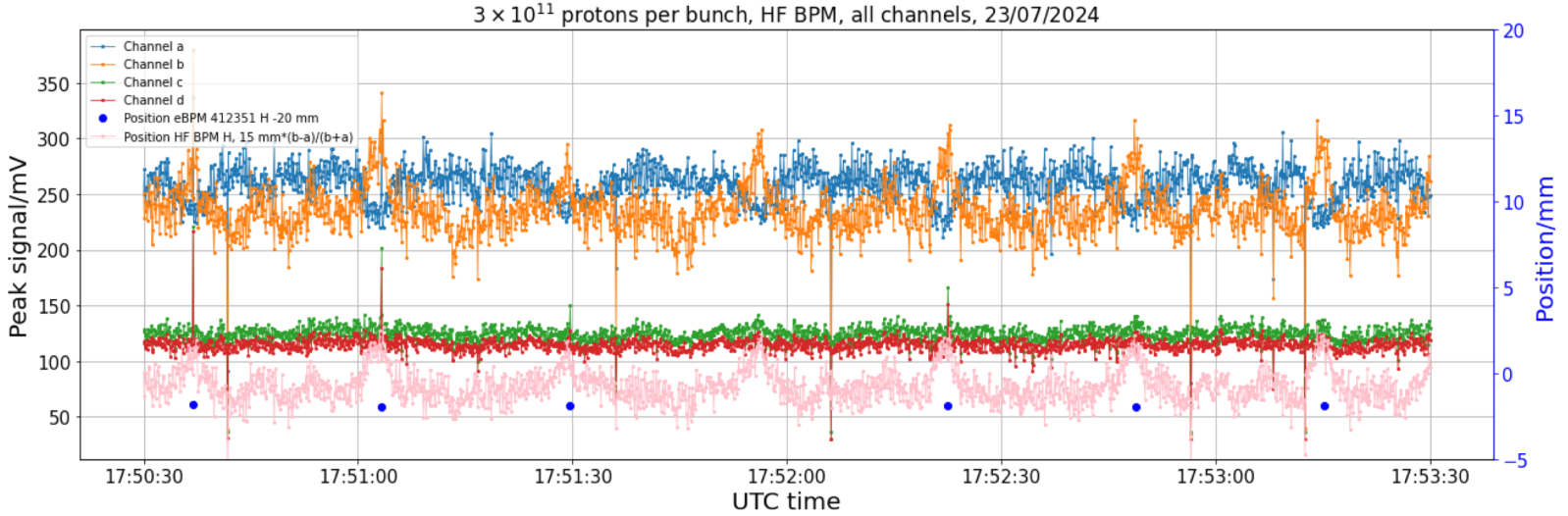
- Effect increases as you go further down the e-line

Individual channels

ChDR BPM



HF BPM



- Individual channels are logged for the ChDR and HF BPM
- Effect is seen mainly in the H-plane
- Channel a (H+ looking downstream) and b (H- looking downstream) are anticorrelated
- Little or no effect in the V-plane

Conclusions

- Peaks observed predominantly in the H plane of **all** electron BPMs in the **electron and common line** when AWAKE is **in the SPS cycle** both when protons are being extracted and not being extracted
- These peaks **correlate** with the **ramping of the magnets** in the proton line
- When the protons are present, the stripline eBPM signals are affected, which we already know
- The ChDR BPM and HF BPM operating at 30 GHz give better rejection of the proton signal (1 x 10^{11} ppb) which also agrees with observations in the past

Open questions

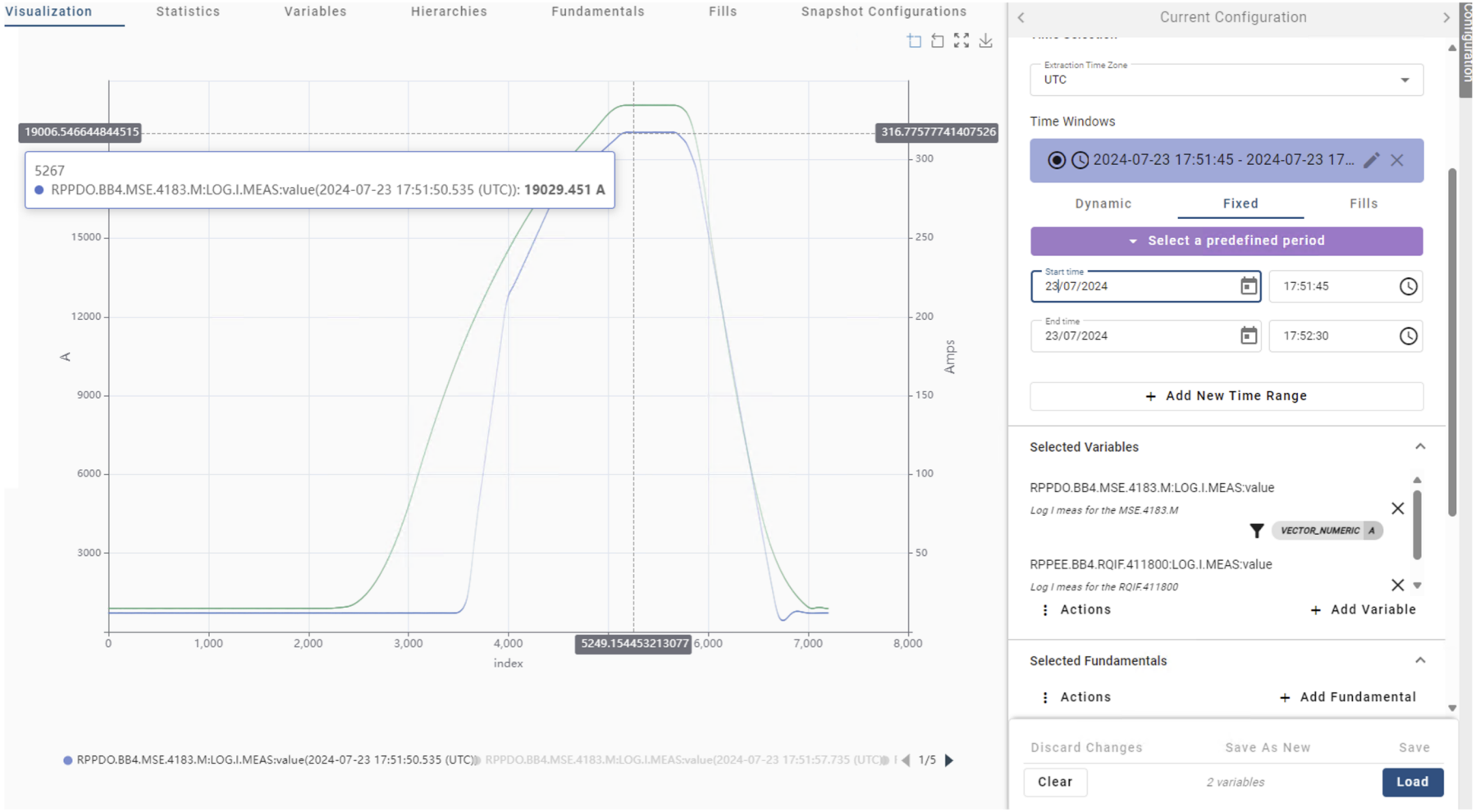
- Not yet identified the way in which the magnet currents affect the e beam
  - Is this a direct effect on the beam? Effect on other instruments causing physical movement of the beam?
  - Effect on the cables to the electronics?
  - Combination of both?
- Some further investigations needed, check all BTVs for physical movement, check cable routing (dismantling)
- Do we need cable shielding for the future?
- Do we keep the ChDR and HF BPMs for Run 2c?

Thank you for your attention!

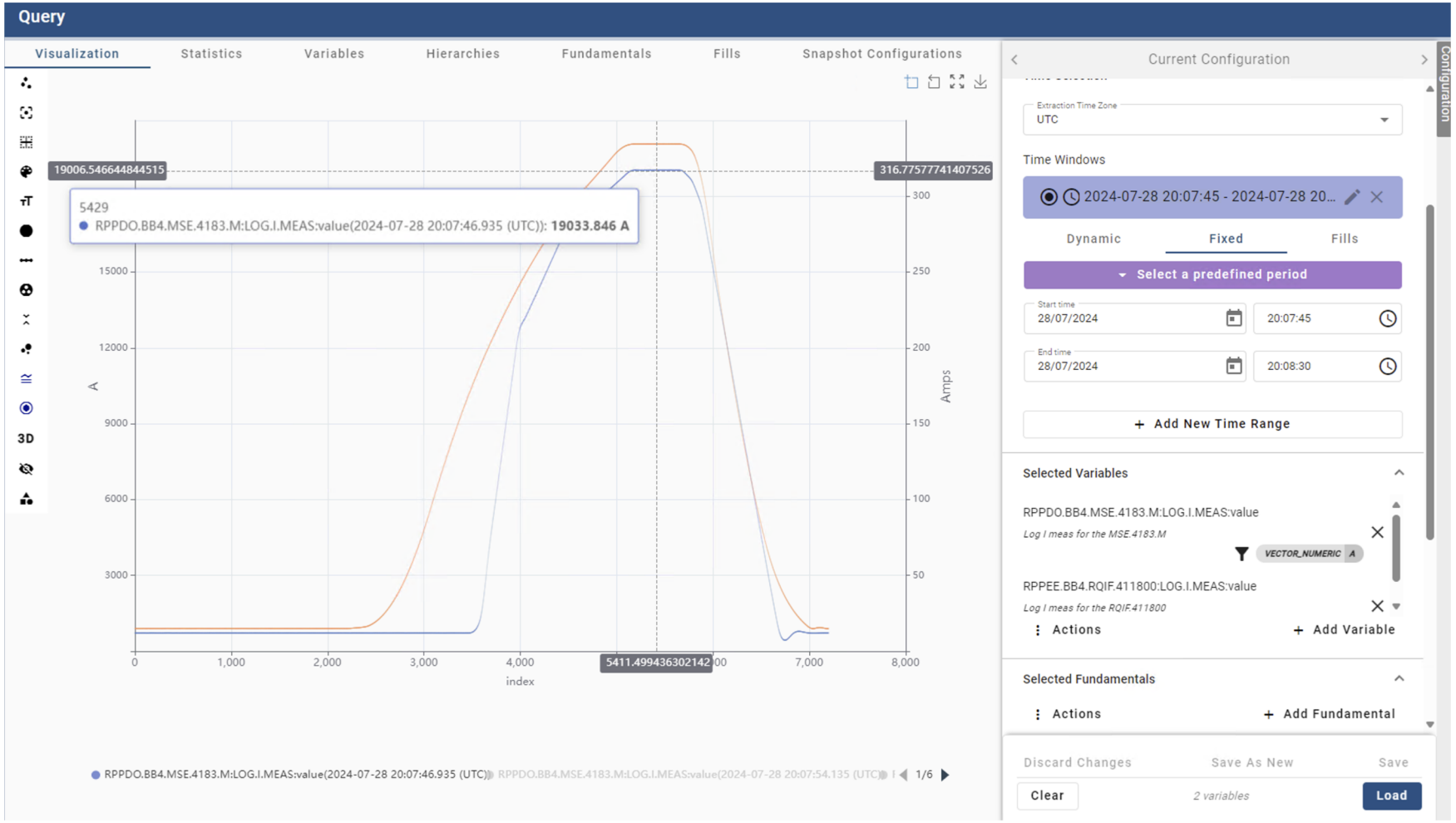
home.cern

Extra slides

Magnet current, 1×10^{11} protons per bunch



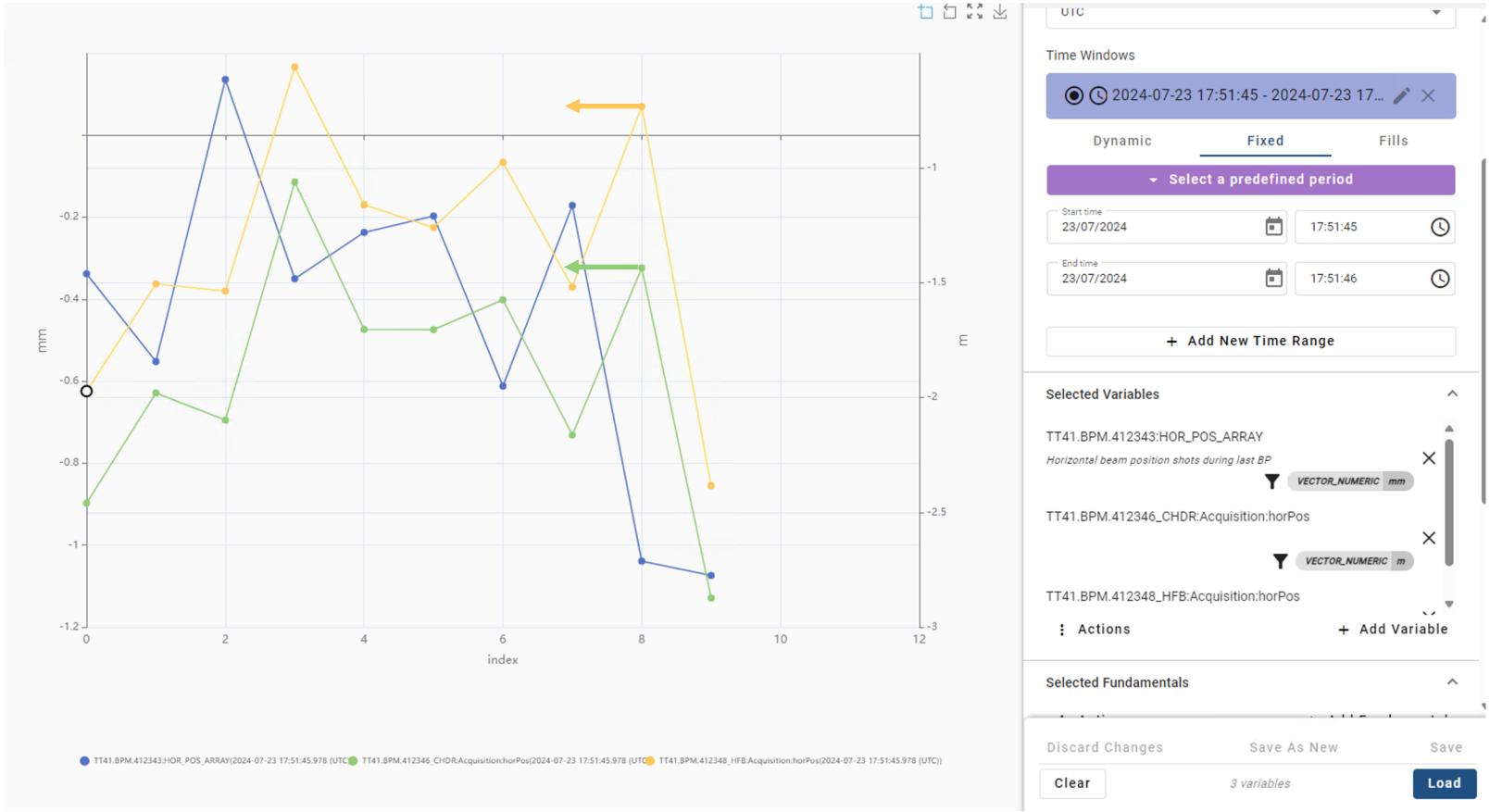
Magnet current, 3×10^{11} protons per bunch



10 Hz data alignment for the eBPMs

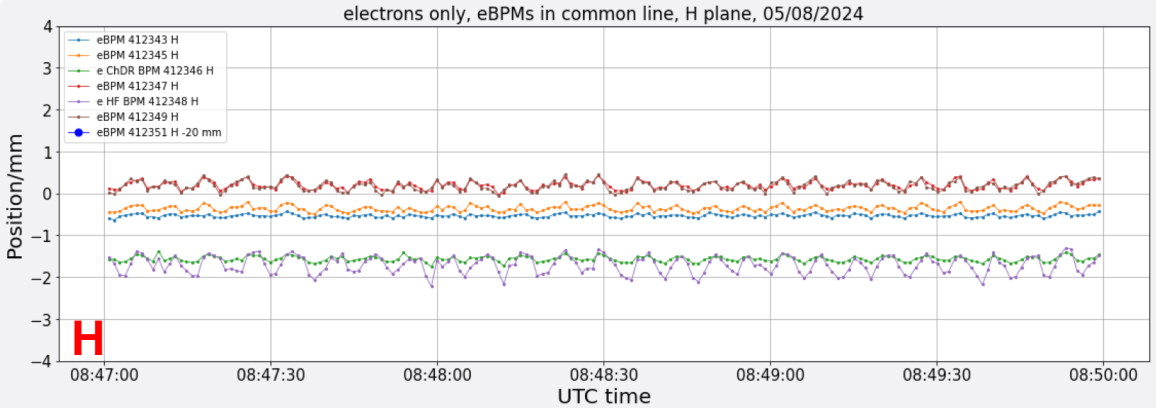
FEC publishes the 10 Hz data in sets of 10 at 1 Hz
Data looks like:
… Pos 9 | Pos 0 | Pos 1 | Pos 2 | Pos 3 | Pos 4 | Pos 5 | Pos 6 | Pos 7 | Pos 8 | Pos 9 | Pos 0 | …

- One timestamp published for all 10 data points in a set
- This timestamp is somewhere between Pos 9 and Pos 0 of the following set
- This creates some timing error
- This timestamp can either be allocated to Pos 9 or Pos 0 of the following set
- No problem if we do the same for everything but stripline BPMs are triggered on signal whilst ChDR and HFB are triggered on external 10 Hz trigger
- Therefore, need to **align the ChDR and HFB data to the stripline BPMs**
- For all the stripline BPMs, I allocated the timestamp to Pos 9 and for the ChDR and HFB, I allocate them to Pos 0 of the following set by looking at the correlation between them
- Still some error there but it is better aligned

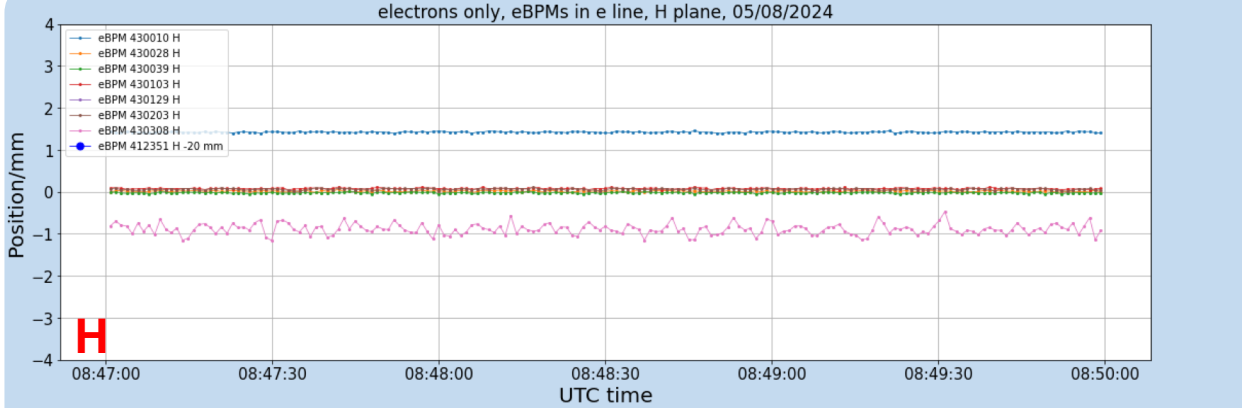


Electrons only

COMMON LINE

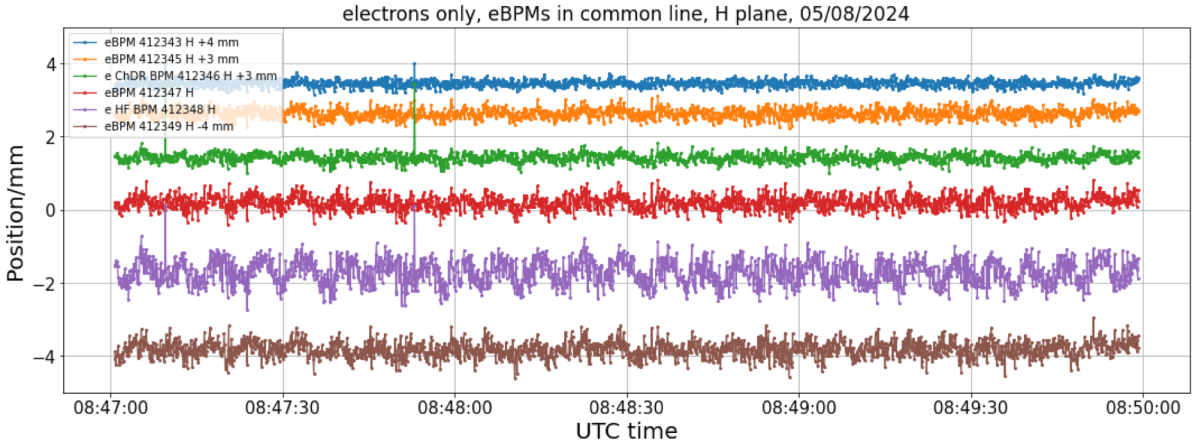


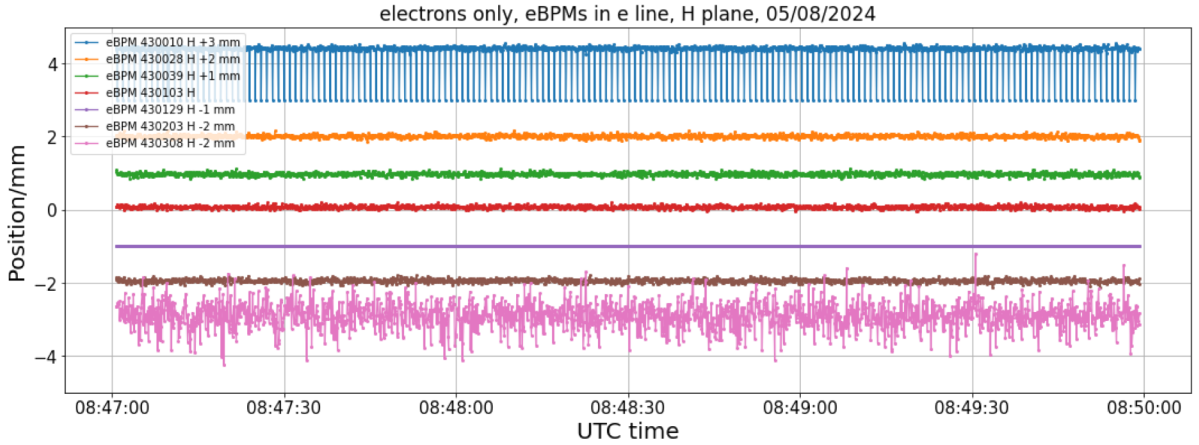
ELECTRON LINE

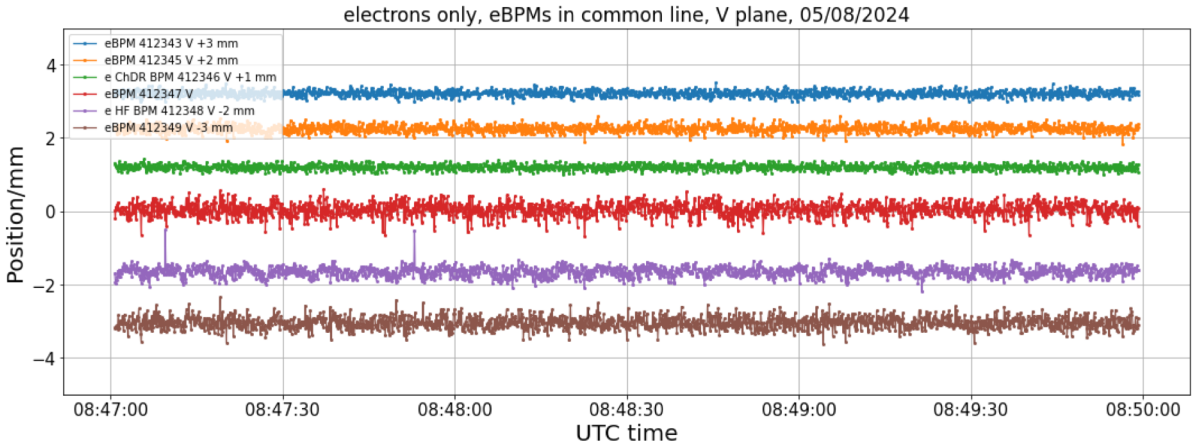


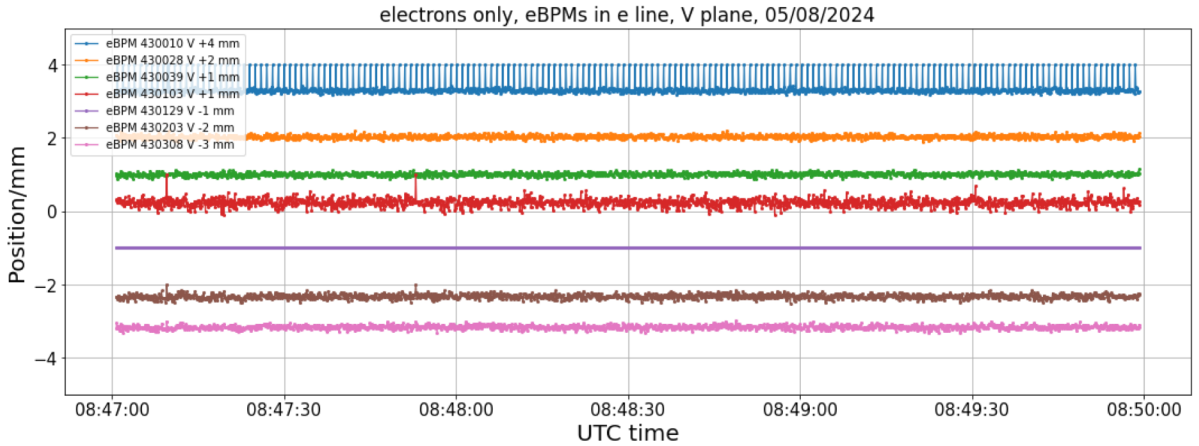
- Electrons only, not in SPS cycle, no peaks at the rate of SPS extraction

Electrons only, 10 Hz data

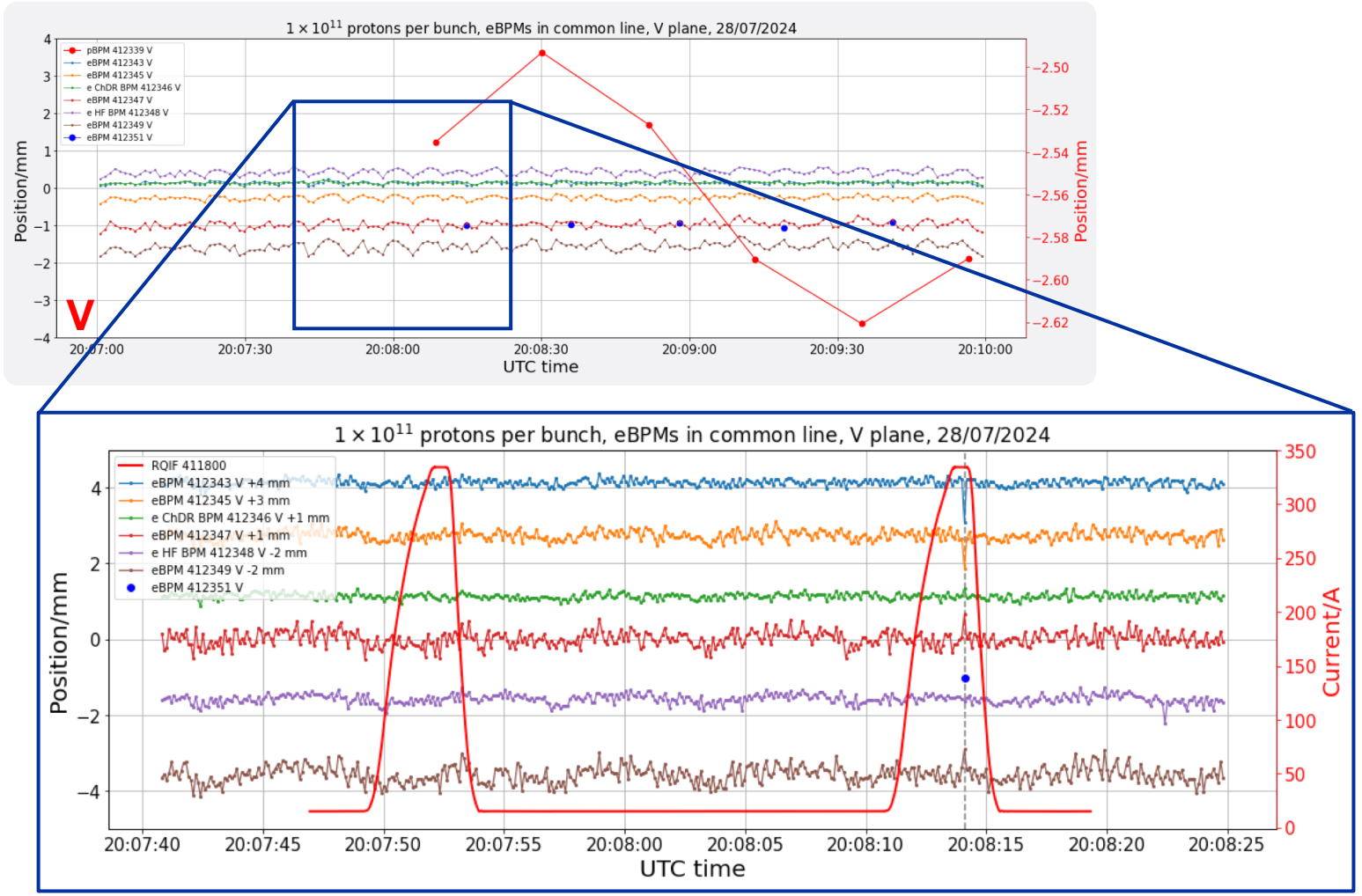








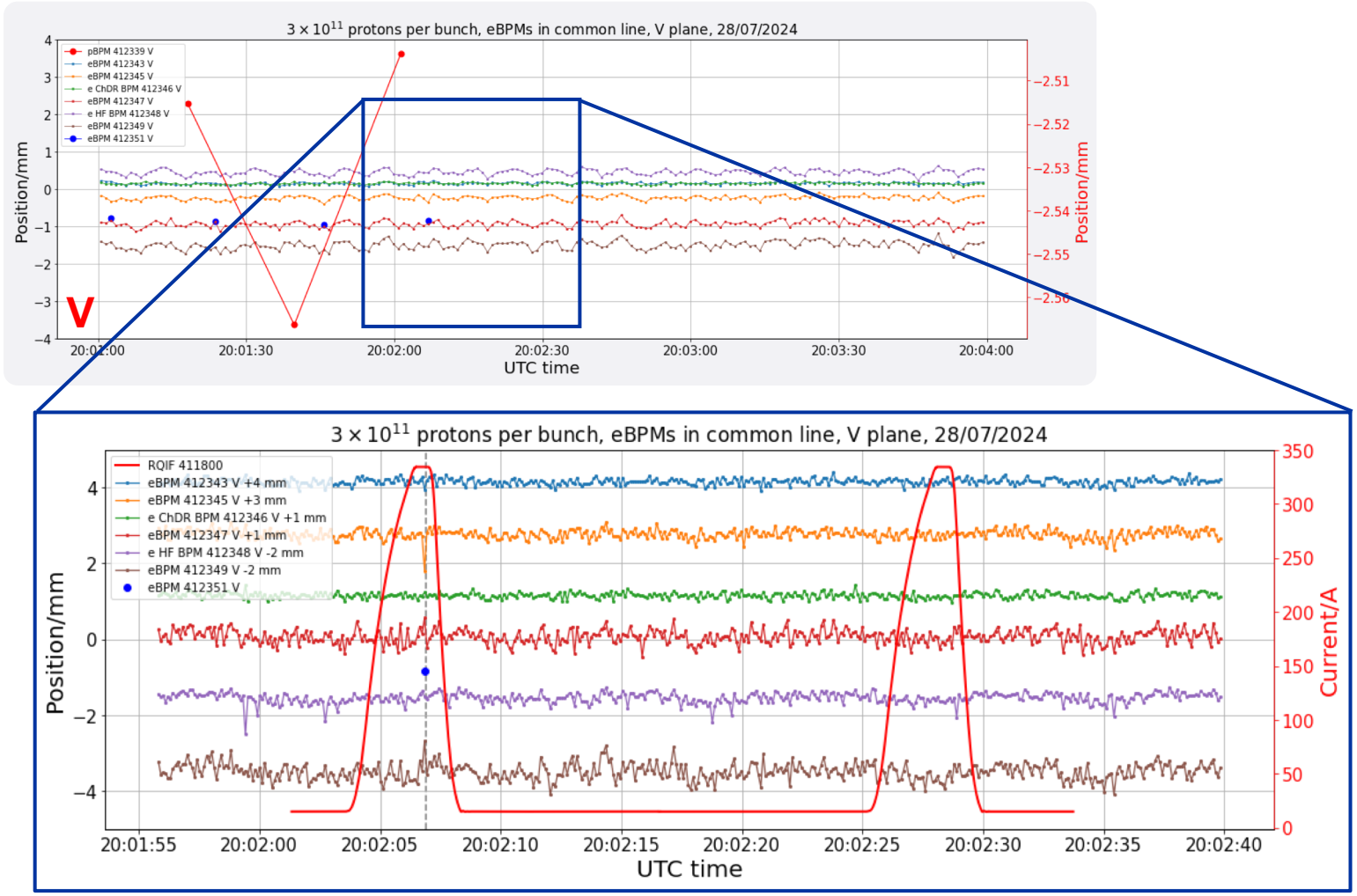
1×10^{11} protons per bunch and electrons



COMMON LINE

- Vertical plane
- Again proton signal measured in the stripline BPMs
- Can't see any dips/peaks or they are within noise

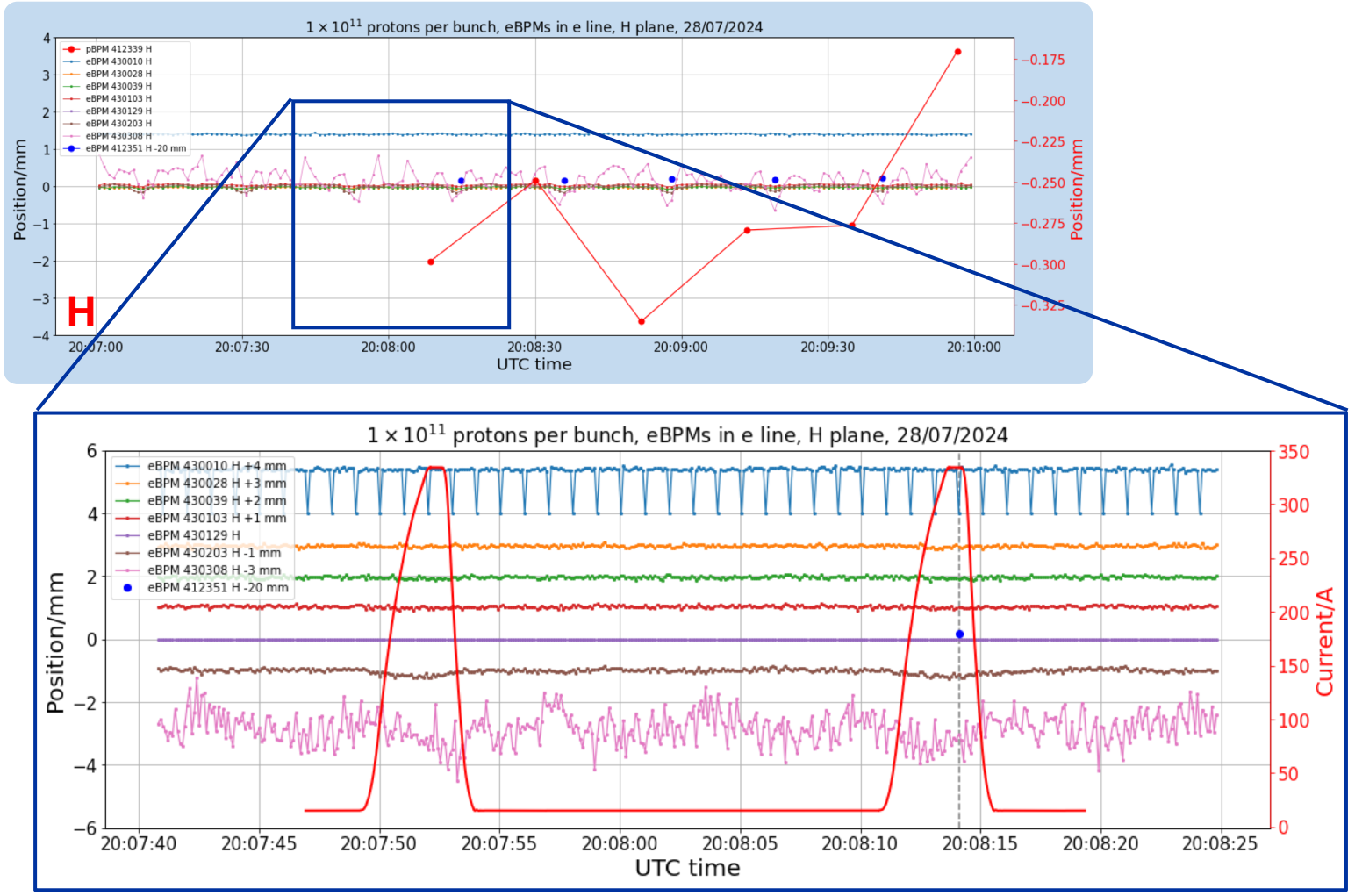
3×10^{11} protons per bunch and electrons



COMMON LINE

- Similar situation for higher-intensity protons

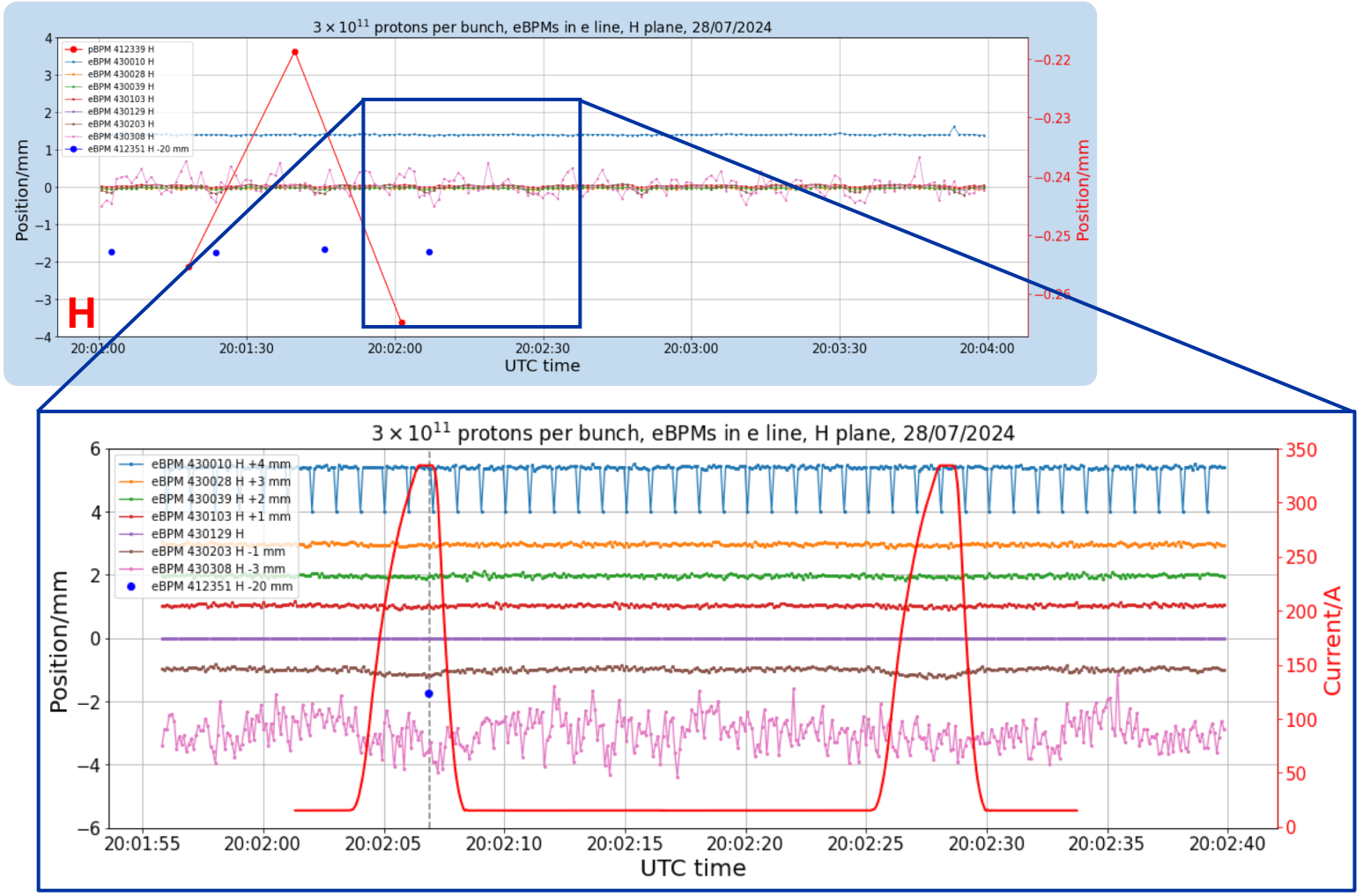
1×10^{11} protons per bunch and electrons



ELECTRON LINE

- Dips also observed in H plane readings of eBPMs but in opposite direction to the peaks in the H readings of the eBPMs in the common line
- Other dips observed in eBPM 430010 at 1 Hz – digital issue, electronics or software
- Ignore eBPM 430129 H as it was not working at this point

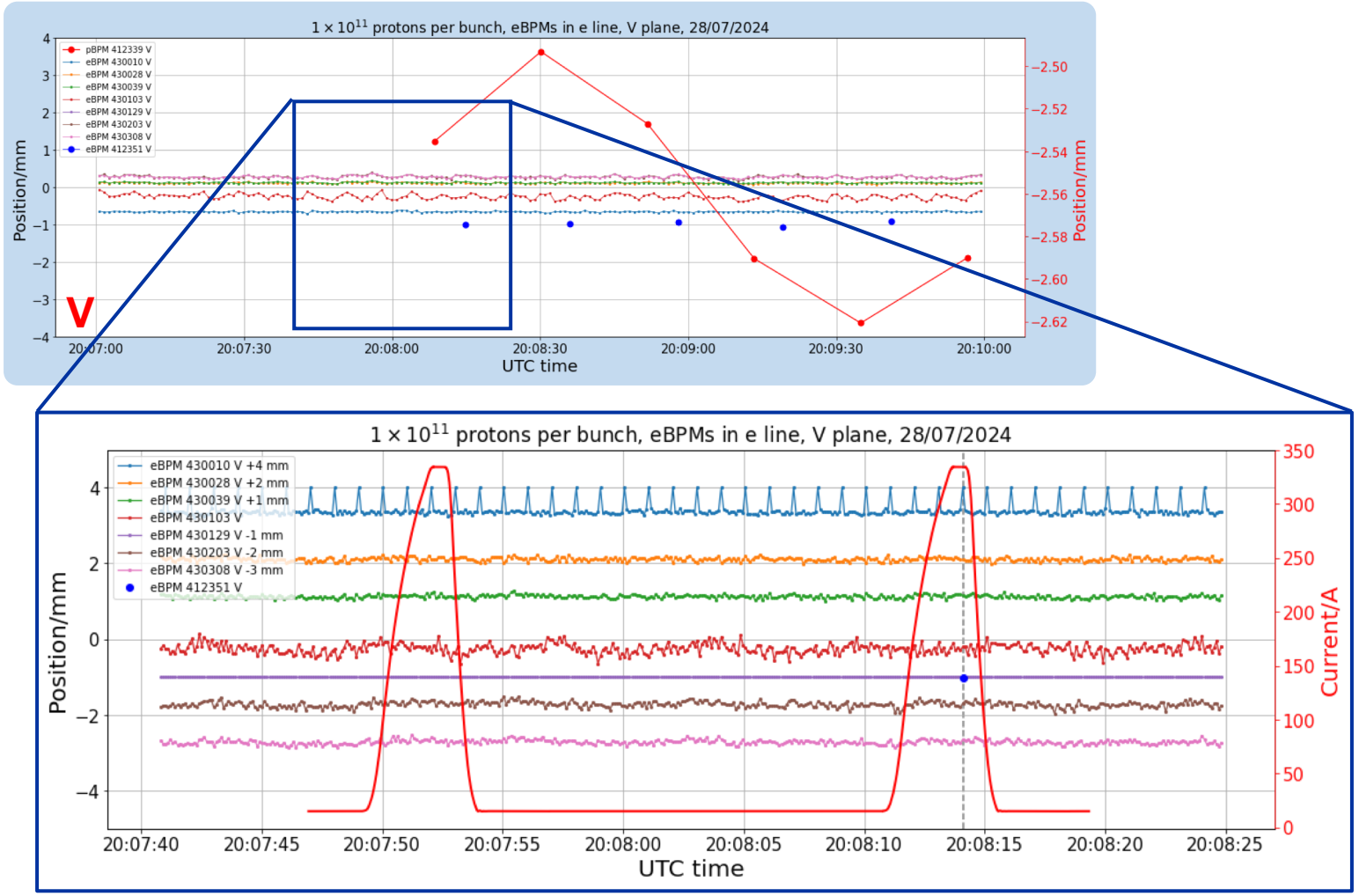
3×10^{11} protons per bunch and electrons



ELECTRON LINE

- Similar situation for higher-intensity protons

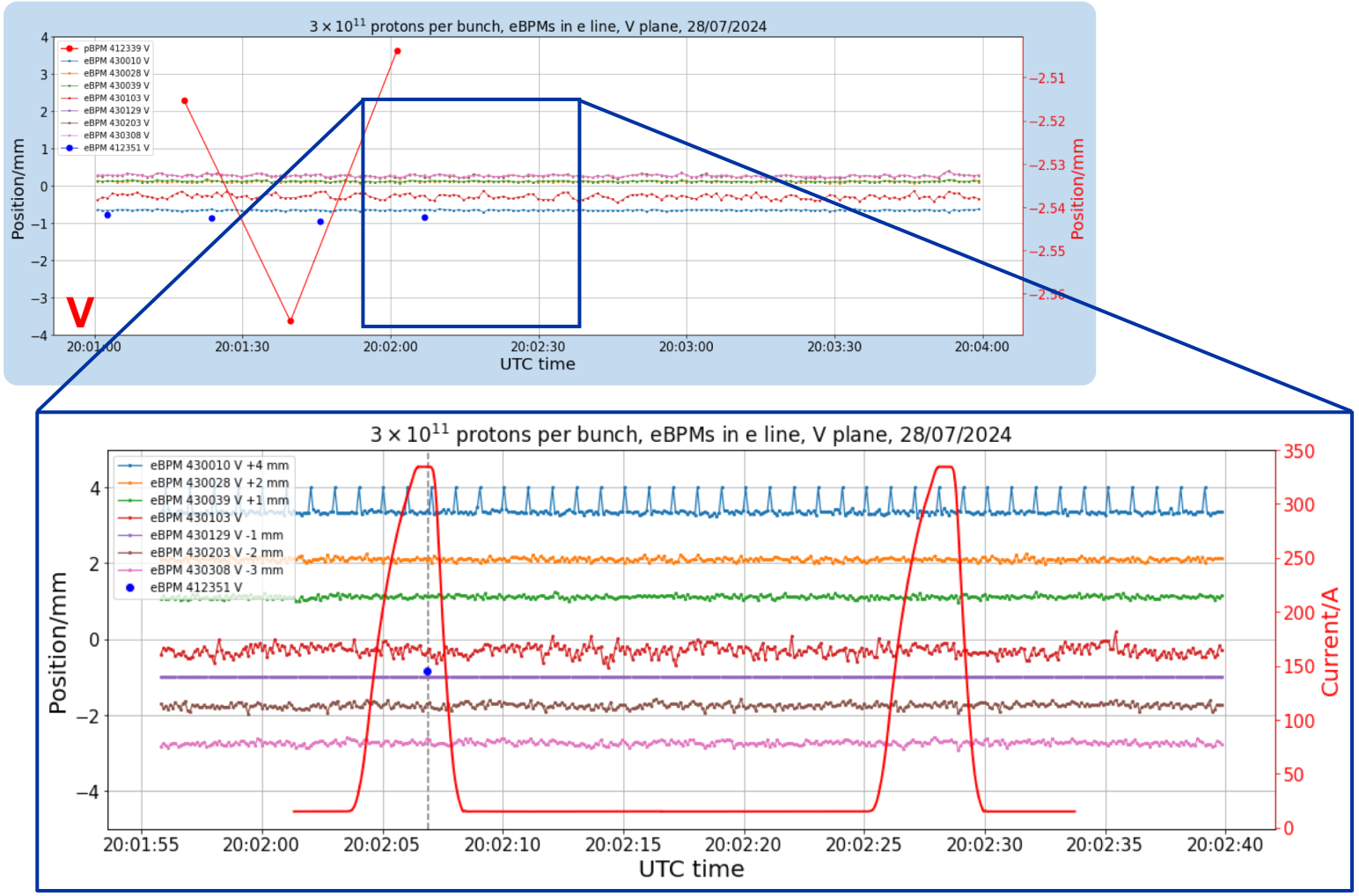
1×10^{11} protons per bunch and electrons



ELECTRON LINE

- Either no peaks or they are in the noise

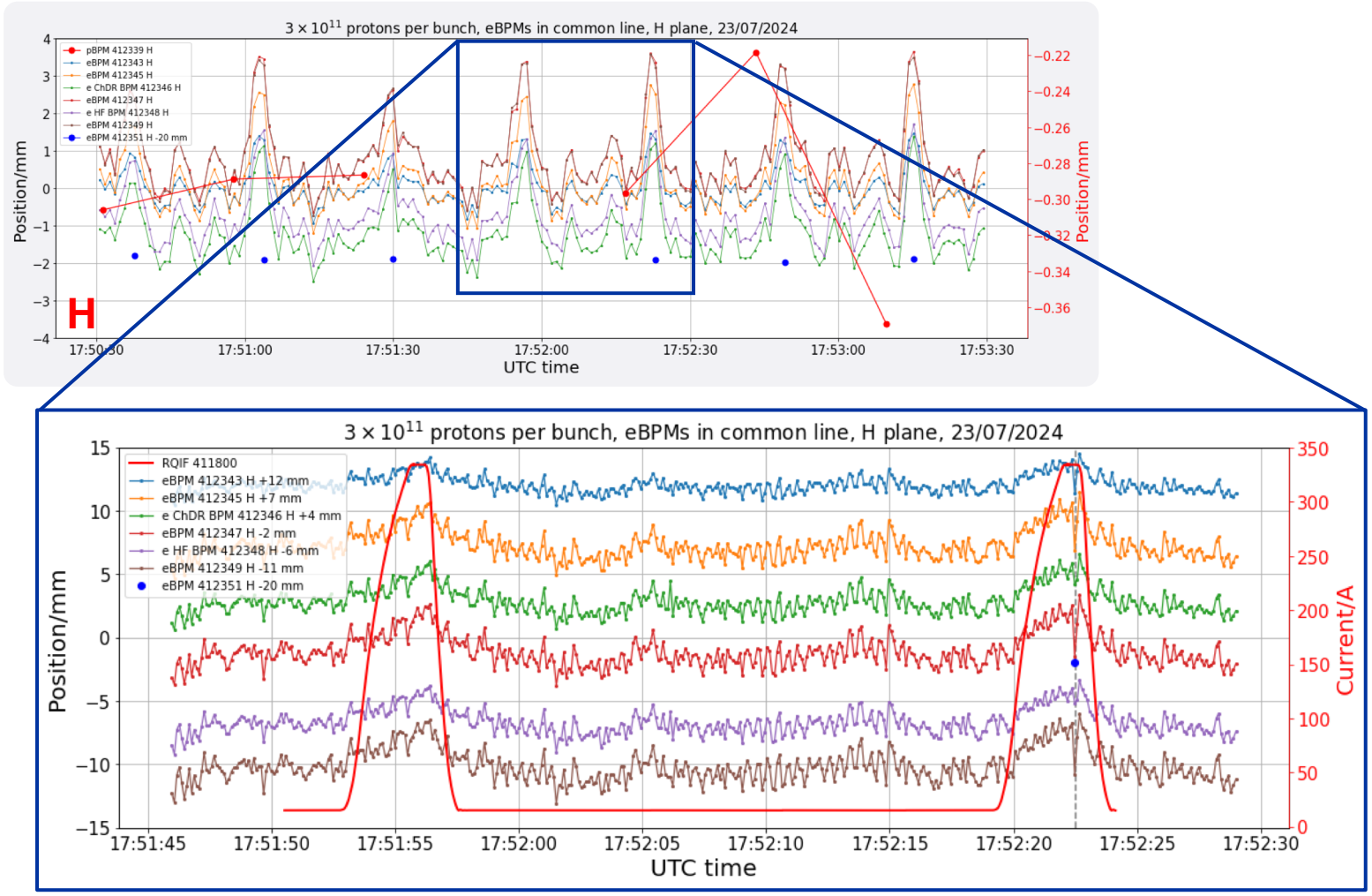
3×10^{11} protons per bunch and electrons



ELECTRON LINE

- Similar situation

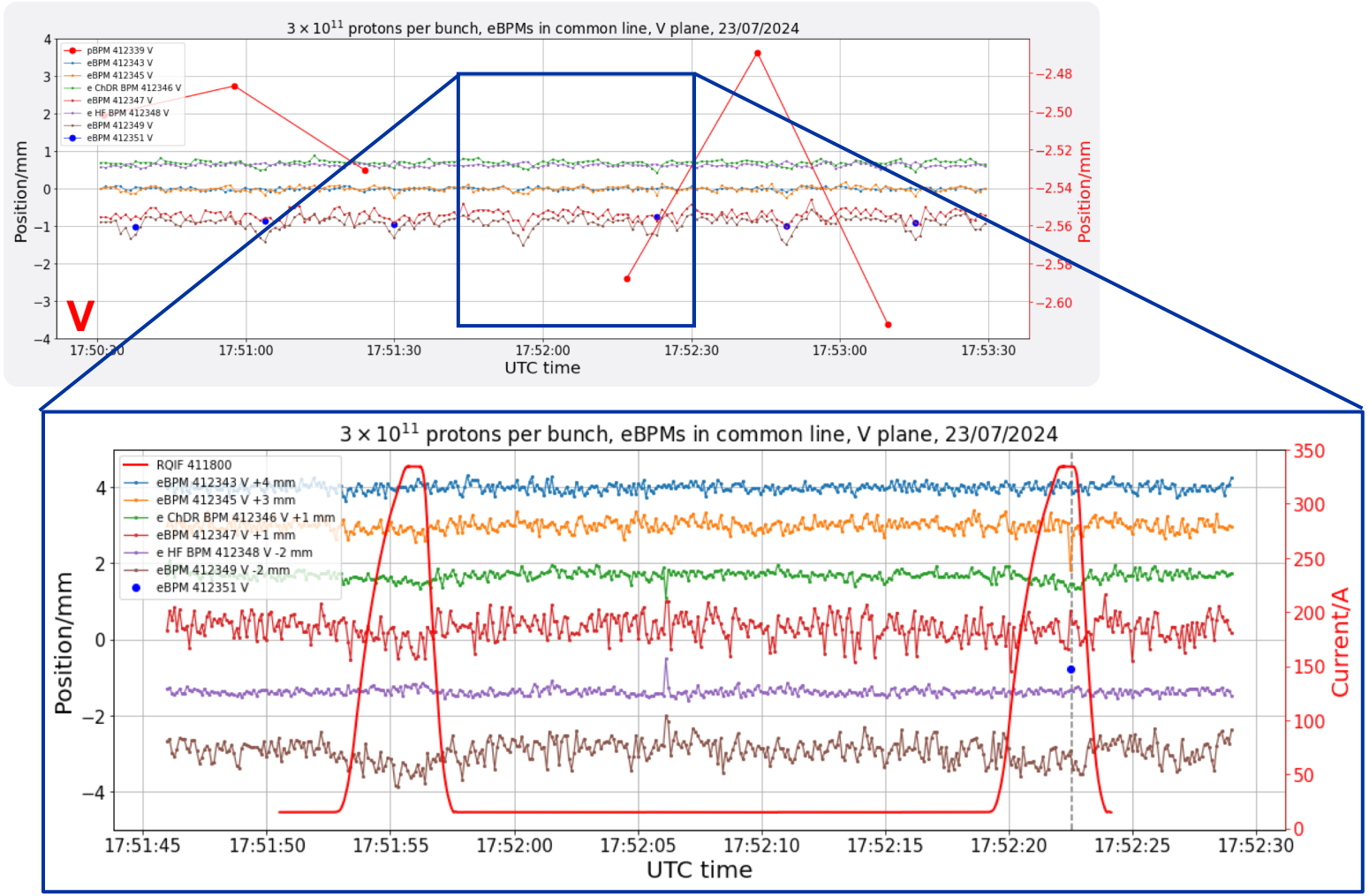
3×10^{11} protons per bunch and electrons



COMMON LINE

- Different day, different e-beam conditions

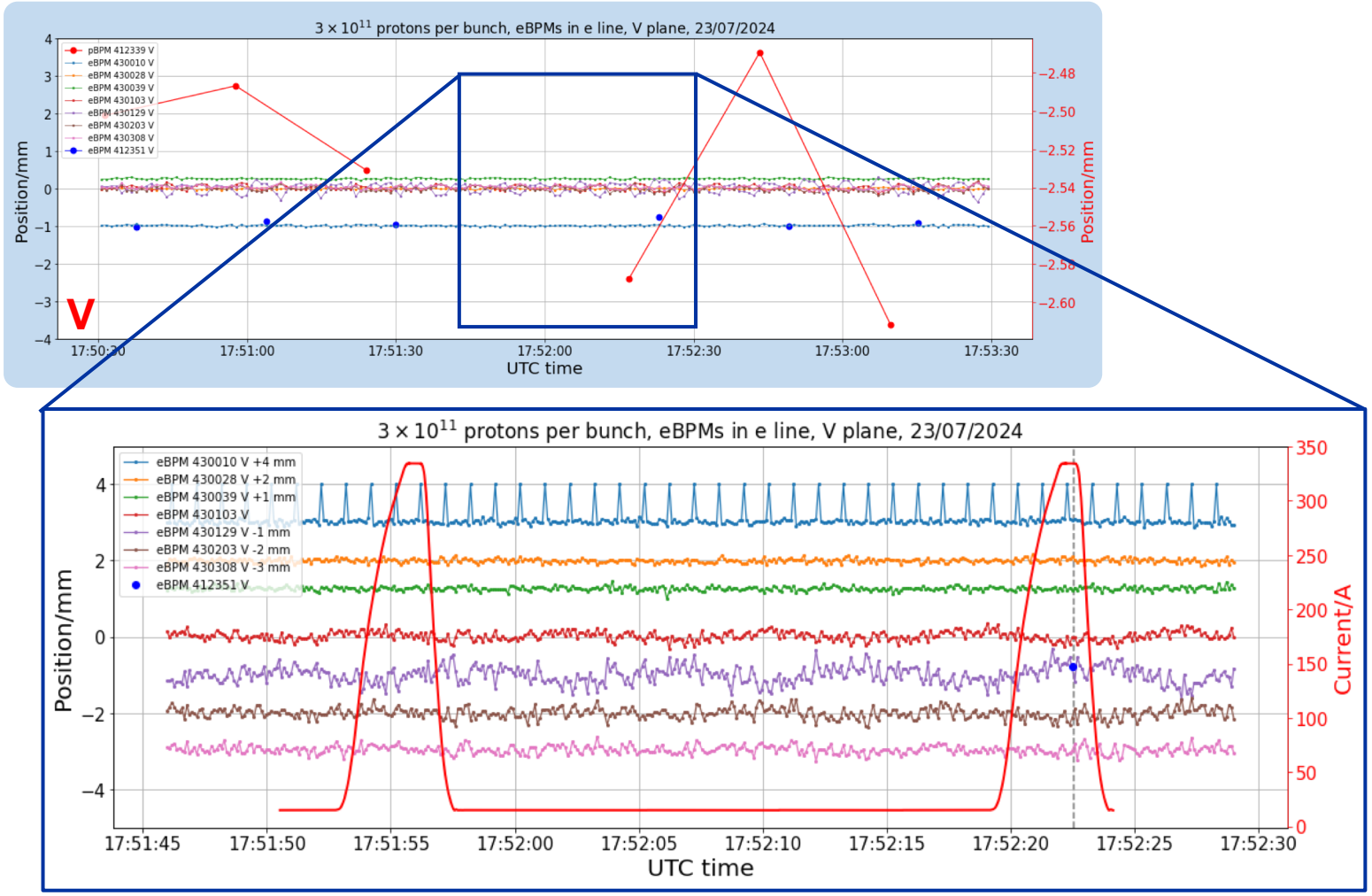
3×10^{11} protons per bunch and electrons



COMMON LINE

- Vertical plane
- Can see the dips in a couple of the stripline BPMs

3×10^{11} protons per bunch and electrons



ELECTRON LINE

Collab meeting presentation

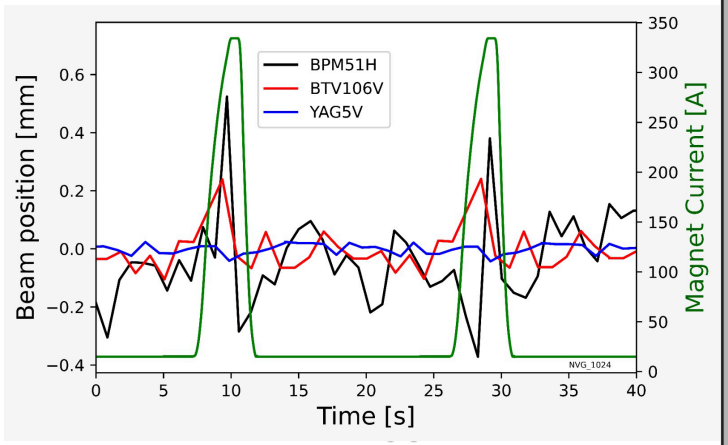
Nikita Z. van Gils, AWAKE collaboration meeting, 6-8 November 2024

Deleterious effects (II)

- The electron beam position on the BPMs showed significant "jumps" (black line), matching the SPS magnet ramping frequency (~every 20s) (green line)
- This was also observed on the beam screen after the first vertical dispersive element of the line (of lower magnitude (red line)
- At the focal point (here on the screen 5.5m into the vapour source) these jumps are within beam centroid jitters (blue line)

- Most of the time this effect was not observed at the injection location.
- If they were observed → alignment performed with extraction events only.

NB: Only vertical displacements at the site of injection are plotted since injection occurs in the horizontal plane



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