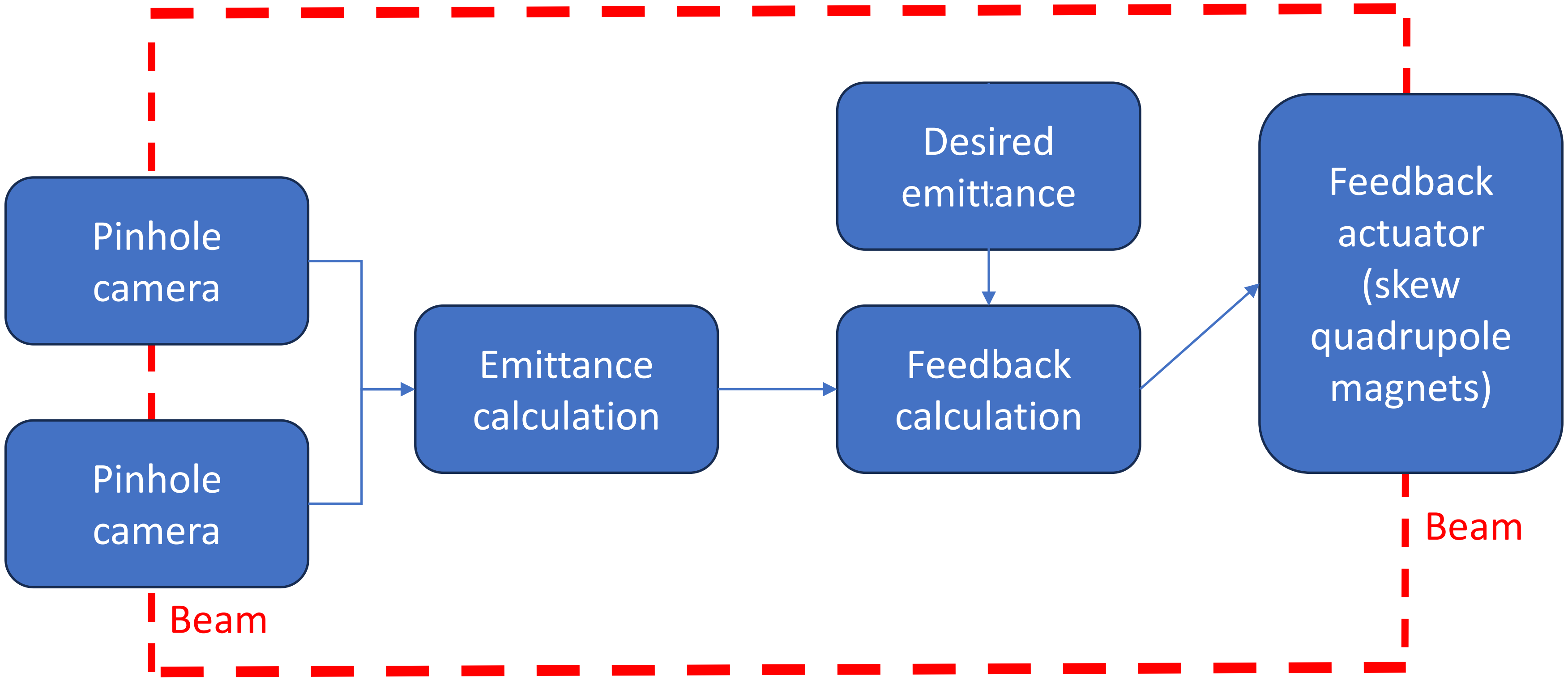
The journey to multi bunch emittance control

More than just feedback

Alun Morgan, Dmitrii Rabusov

What do we do now

- Feedback loop using pinhole cameras as detector and skew quadrupole magnets as actuators



Why not just keep doing that?

Limitations of existing system

- It cannot stabilise horizontal and vertical emittance simultaneously as it is coupling control based.
- Small reduction in dynamic aperture
- Suffers from hysteresis
    - performance degrades over time
- Feedback loop limited to a few Hz due to pinhole camera update rate.

Additional Diamond-II considerations

- We will not have the flexibility to use the skew quadrupole magnets due to the impact on off axis injection
- Operating modes in Diamond-II may require per bunch size manipulation. (e.g. hybrid bunch)

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Why use side band excitation with the MBF?

Sideband excitation

It has less impact on lifetime and injection efficiency compared to the existing skew quadrupole approach

Additional MBF bonuses

- No new hardware required in the storage ring.
- This allows the emittance control to be applied to all or a subset of bunches as operations require.

- There are some differences in behaviour which need to be accounted for before it can be used in operation.

Emittance Control for Diamond-II
Ian Martin, Alun Morgan, Shaun Preston
9th Low Emittance Rings Workshop
CERN, 13th-16th February 2024

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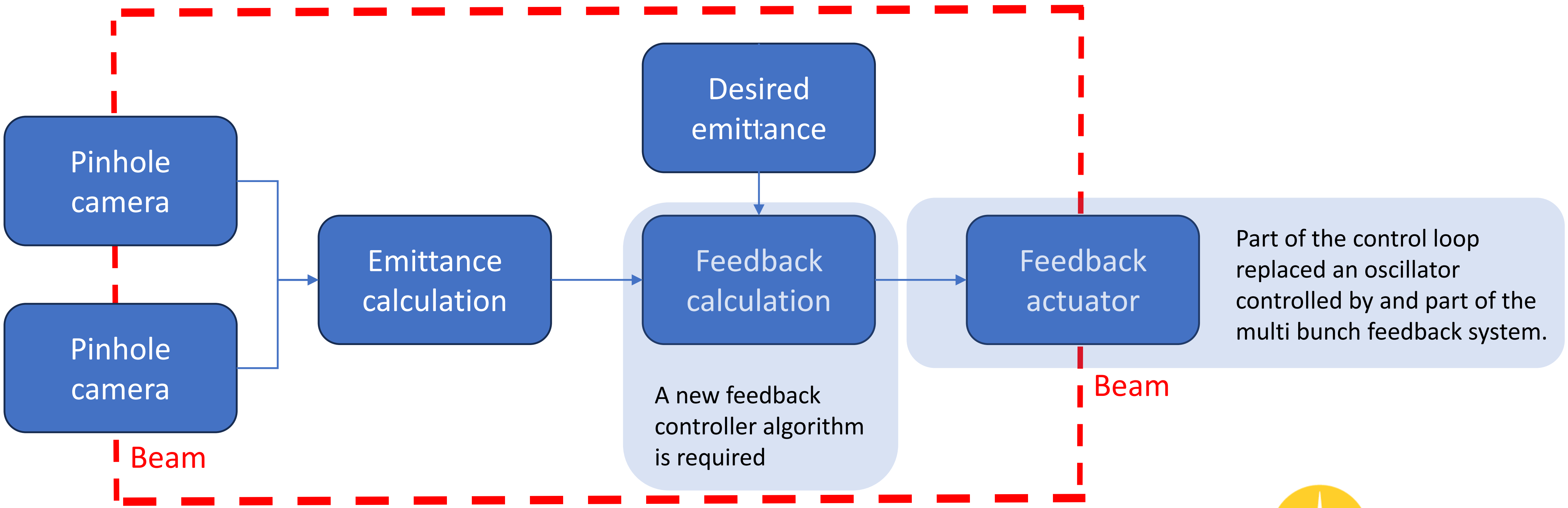
What is the new approach?

- Keep the existing emittance monitoring but replace the actuator of the feedback.



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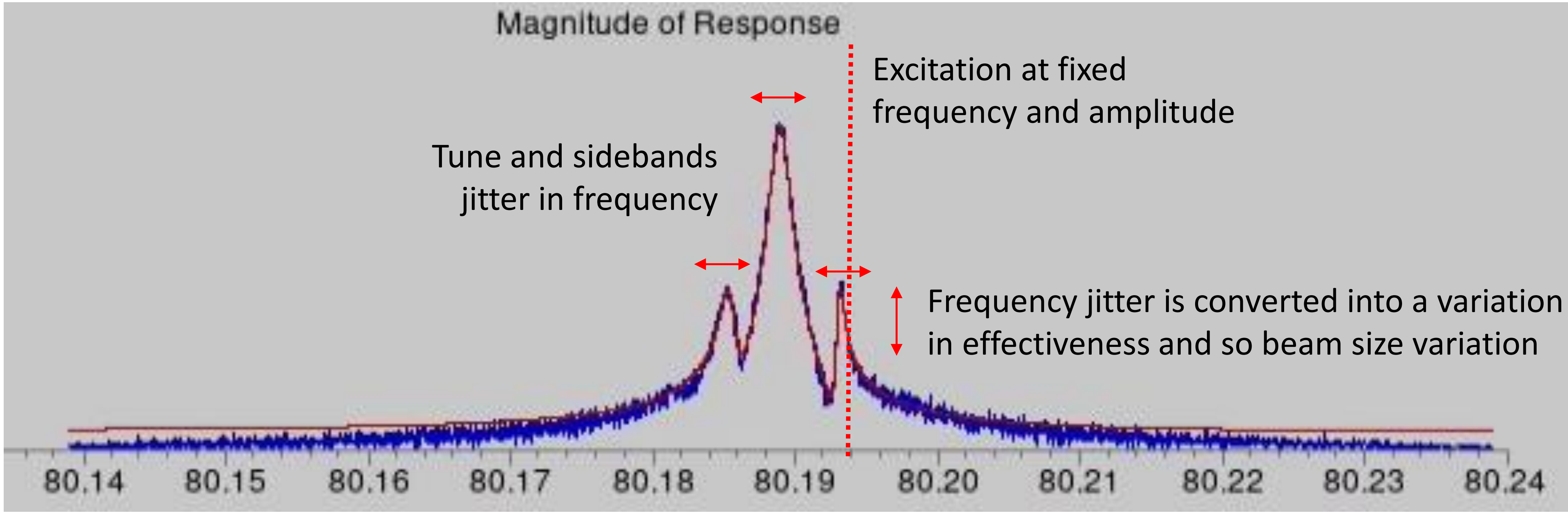
Tune tracking

- In Diamond we need to use tune tracking to make sideband excitation practical



We may not need this in Diamond-II due to the 3rd harmonic cavity.

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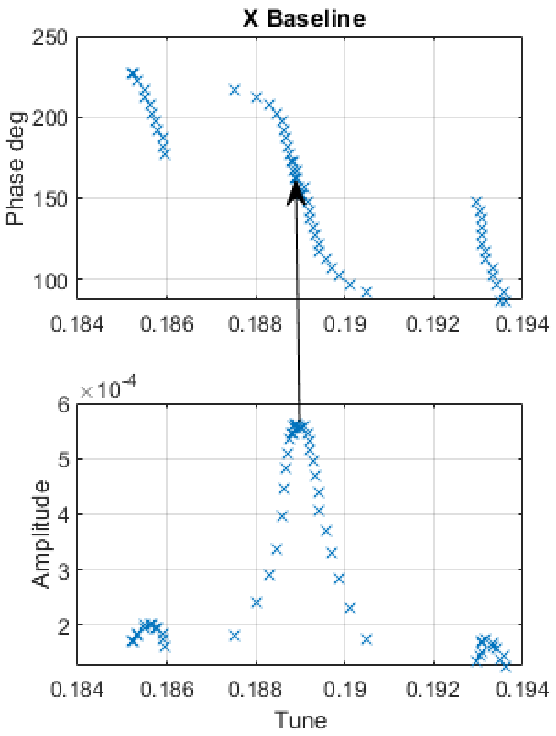
Tune tracking limitations

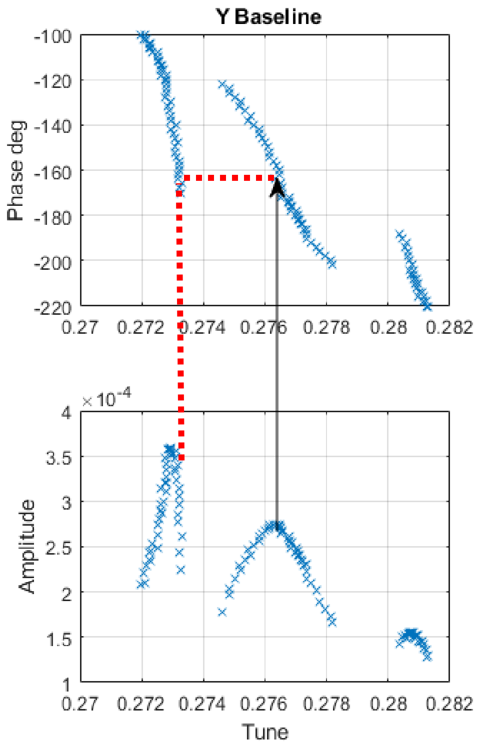
Machine change has broken the tune tracking twice since 2020

- Unable to identify the causes

The past

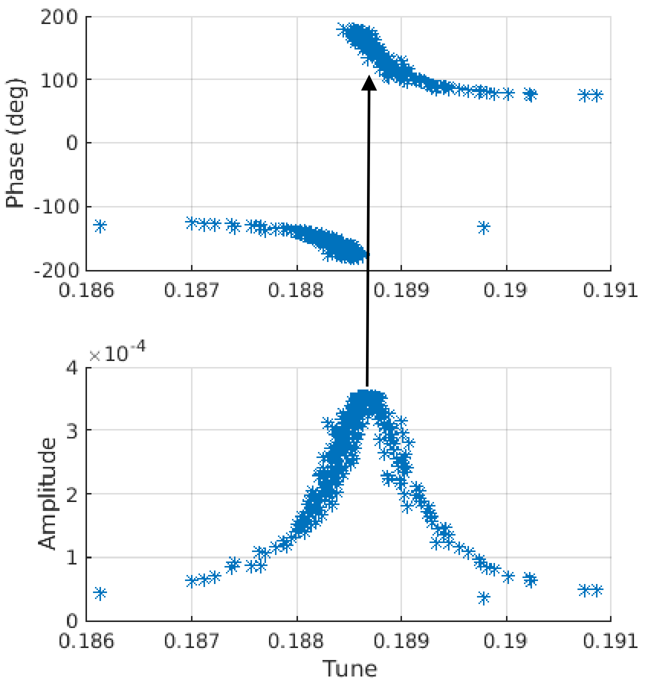


2020 multivalued solutions



Developed improved locking scheme

2023 unexpected phase shift



Retuned the entire system

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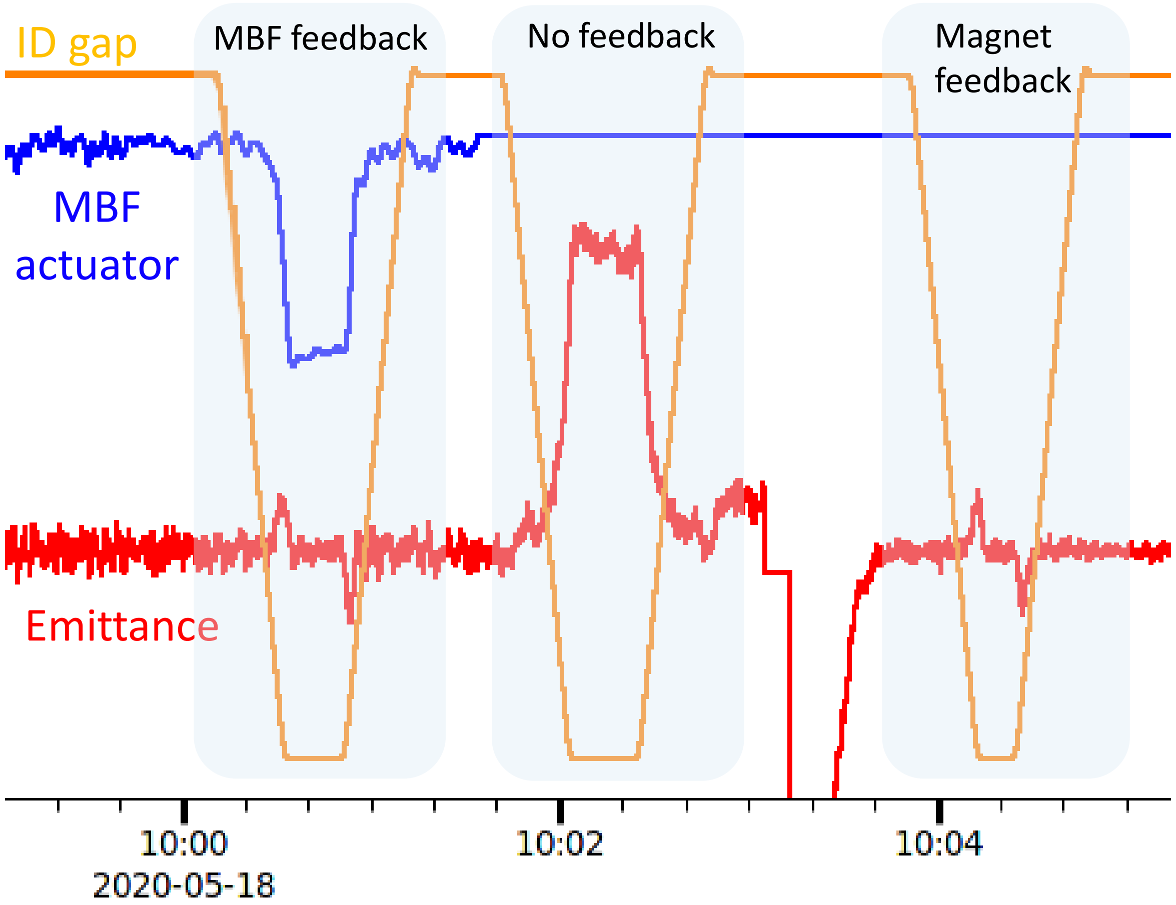
MBF emittance feedback development

Initial proof of concept done in 2020 by Guenther



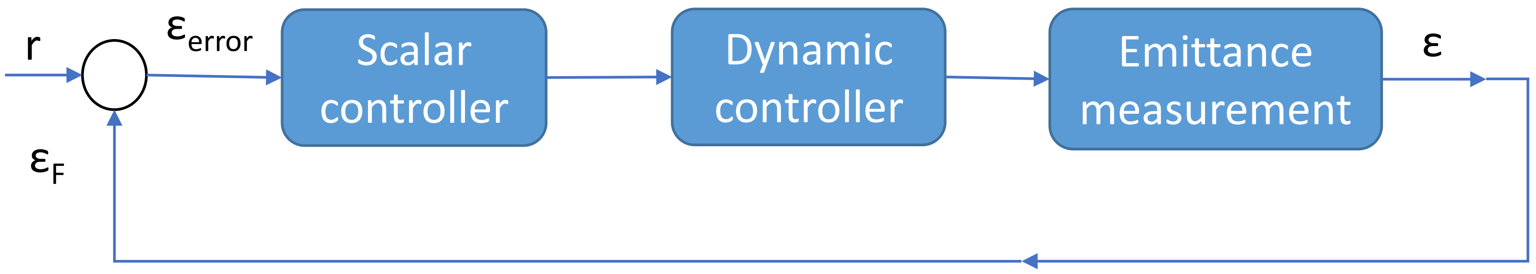
Largely manual but looked promising.
Various issues identified in operating alongside standard operation, for example:

- Making sure the target bunch is filled
- The need to turn off the feedback on the few bunches either side of the tracking bunch

Basically, it allowed us to define the problem much more clearly.

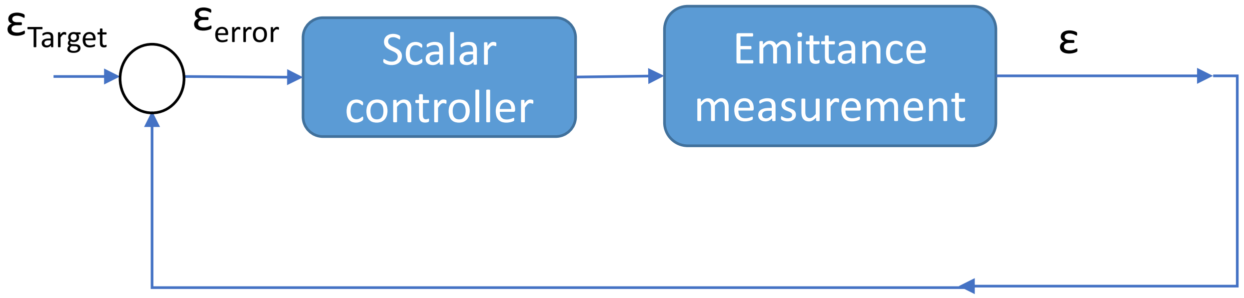
Development of a new MBF vertical emittance feedback algorithm

Existing skew quadrupole base algorithm



Much of the controller is related to the magnet dynamics and so needs to be redeveloped to use the MBF system instead

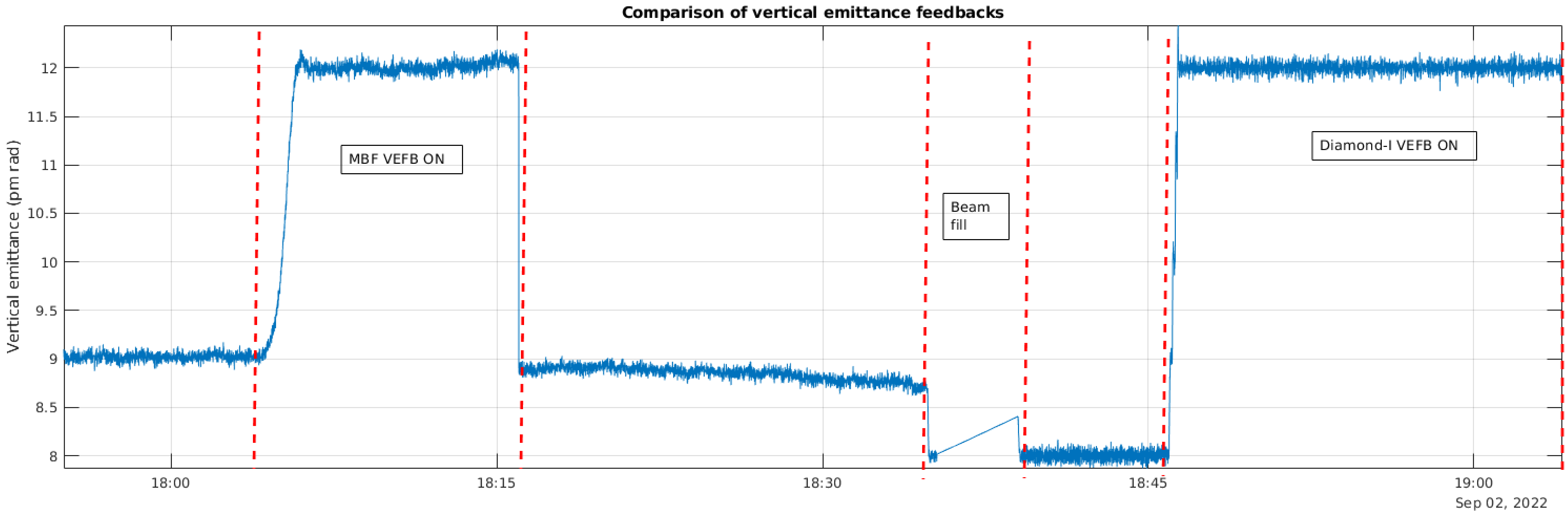
MBF based algorithm (tested September 2022)



Operational proof of concept

No dynamic adjustment of parameters so currently it takes too long to stabilise after ID changes.

Testing the simple emittance control



Response rate when changes occur:

Magnet based system	8 s / pm rad
MBF system	29 s / pm rad

Standard deviation over a few mins in the **stable state**:

No feedback	0.030pm rad
Magnet based system	0.037pm rad
MBF system	0.060pm rad

Next step is to use proper systems analysis to develop a full feedback model

Broader considerations

The MBF system will become machine critical in more ways.

MBF focussed

- Assessing and developing new operational uses of the MBF system.
  - PPRE
  - Bunch cleaning
  - Emittance feedback
- Integrating all the different operating modes to work together in various combinations.

Accelerator focussed

- Improving our assessment of the working point stability.
- Identifying the impact of various machine settings.
- Improving our understanding of the impact of MBF setting changes.

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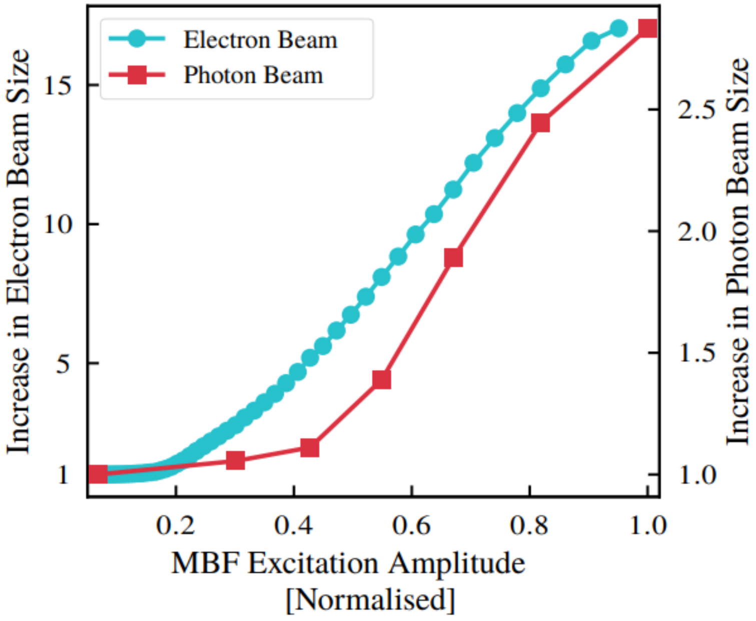
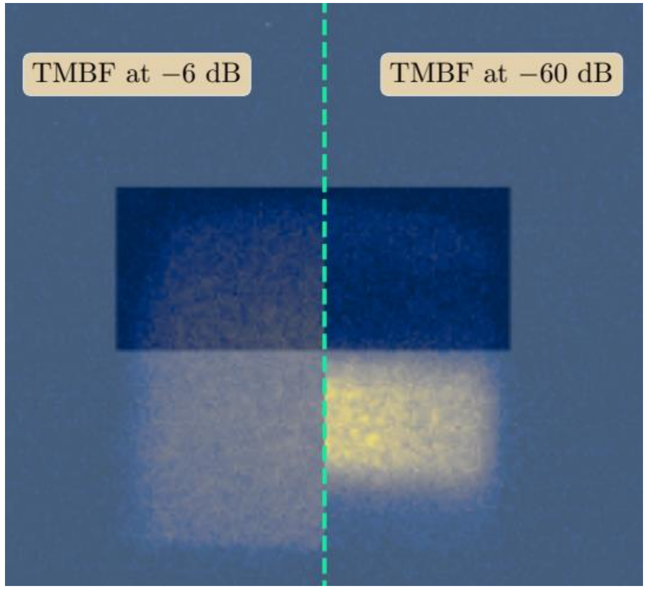
Broader studies – Pulse Picking by Resonant Excitation for use with 'timing users'

- An alternative to hybrid fill.
  - Feasibility study in collaboration with one of our beam lines



Machine measurement



Beamline measurement

Lifetime without Compromise

doi: 10.18429/JACoW-IPAC2023-MOPM036
- S. Wilkes

Investigations into operating Pulse Picking by Resonant Excitation (PPRE) in the vertical plane

doi: 10.18429/JACoW-IPAC2023-MOPM037
- S. Wilkes, A. Morgan, G. Karras, I. Martin, M. Warren

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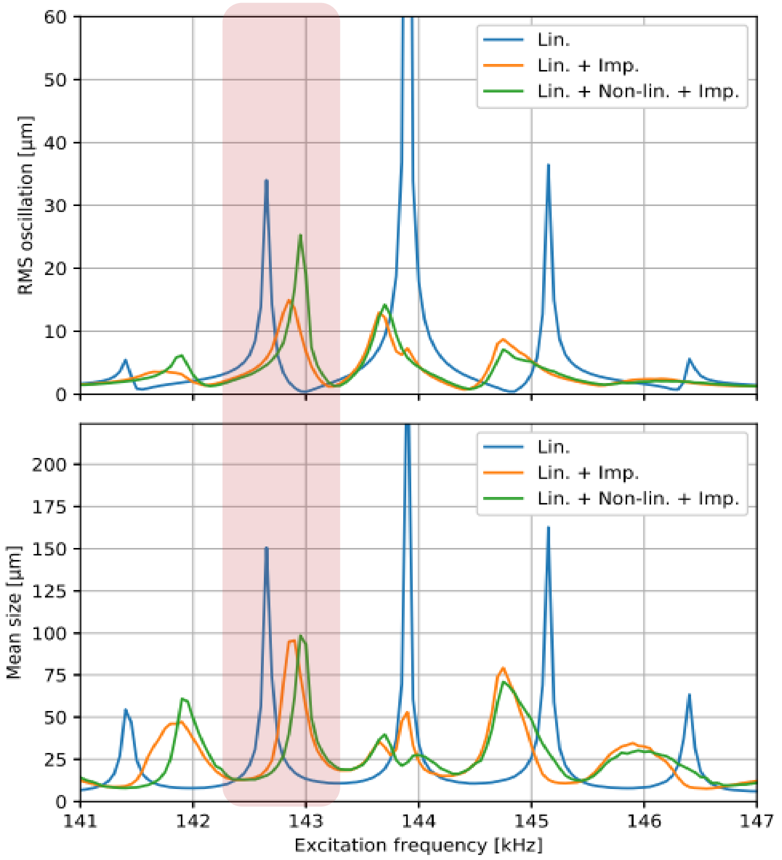
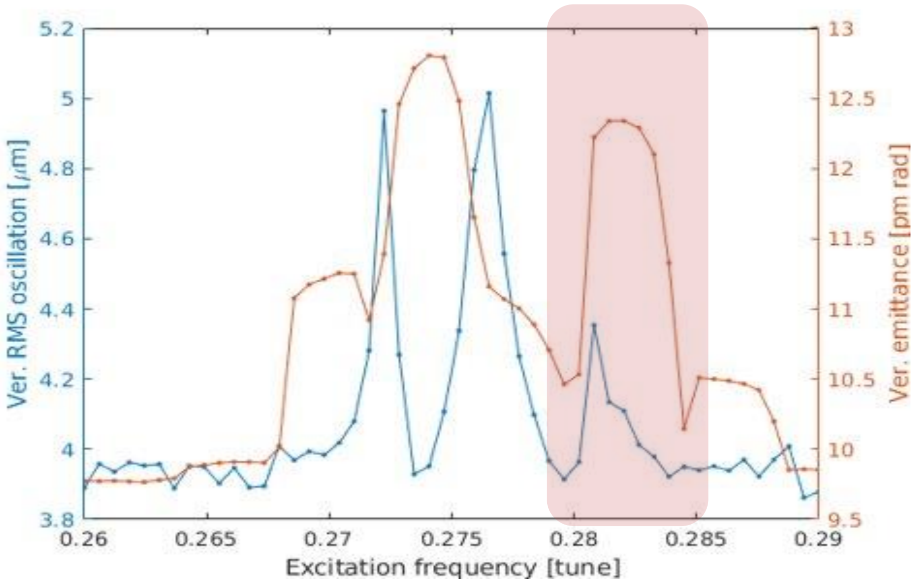
Broader studies – settings optimisation

Simulation



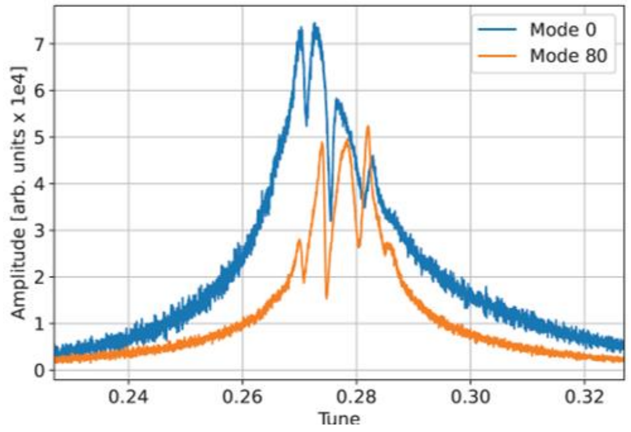
Including the impedance causes a broadening and shifting of the sidebands as well as showing the asymmetry similar to the measured data.

Measurement



Measured impact of chromaticity and bunch charge

The Asymmetry of the peaks and the sensitivity with excitation harmonic indicates that **long-range wakefields have a significant impact.**



Emittance feedback for the Diamond-II storage ring using resonant excitation
doi:10.18429/JACoW- IPAC2022 - TUPOMS035
S. T. Preston∗ , T. Olsson, B. Singh

Measurements for emittance feedback based on resonant excitation at Daimond light source
doi:10.18429/JACoW-IBIC2022-WEP37
S. T. Preston∗ , T. Olsson, A. Morgan† , L. Bobb

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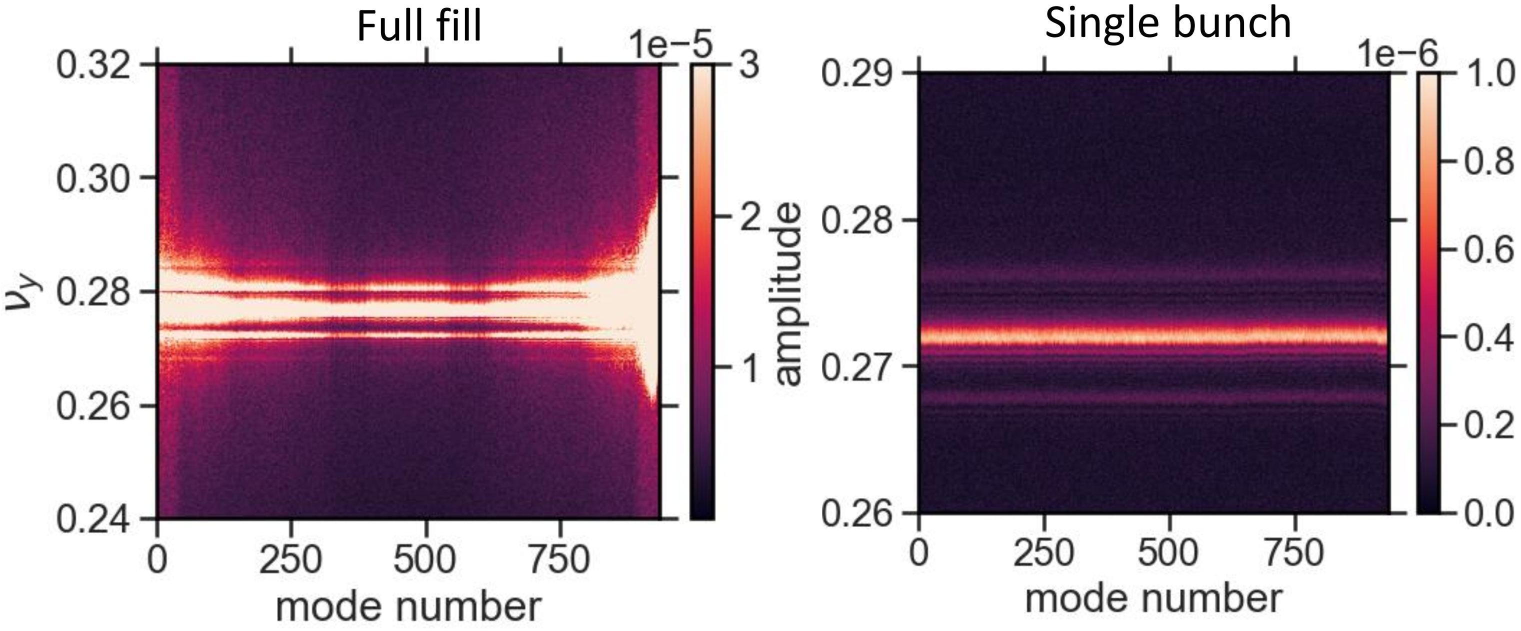
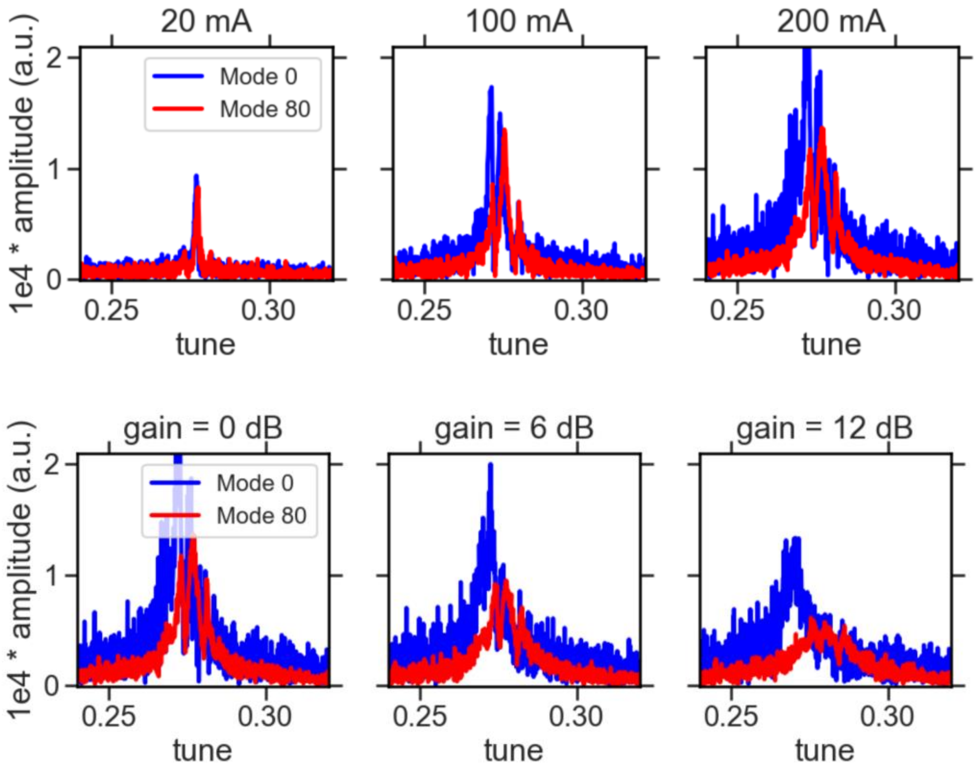
Broader studies – further investigation of excitation harmonic modes

Dependencies investigated so far
Fill pattern
Excitation amplitude
Beam current

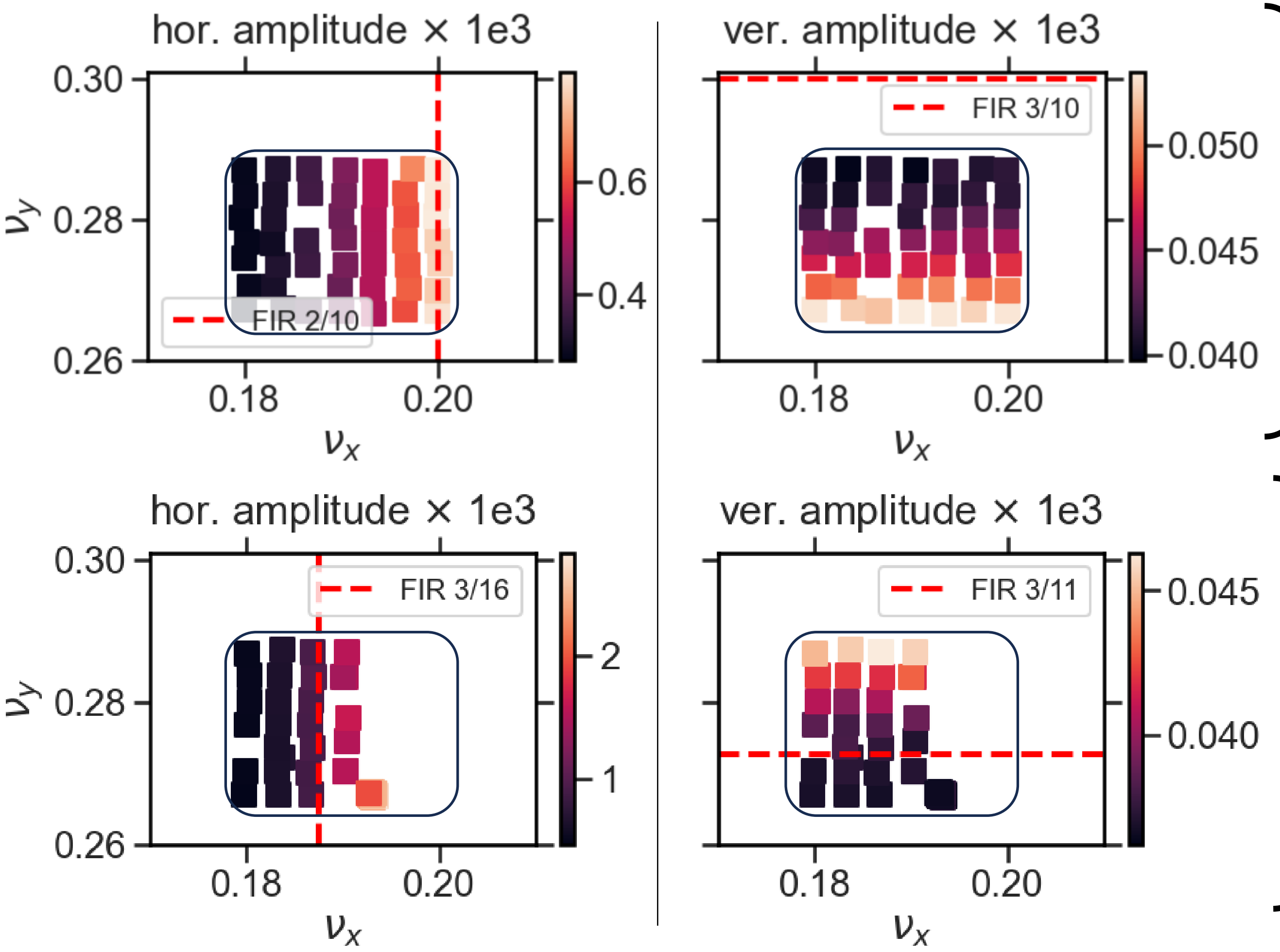
Tune excitation with equivalent charge per bunch.





Signal integrated over the beam depends on excitation mode

Broader studies – Measuring the effects of MBF bandwidth on feedback robustness



Shorter filter
Wider
bandwidth

Longer filter
Narrower
bandwidth

- **tune scans at I = 150 mA around the current working point**

Future work and questions

- **Develop an improved feedback algorithm**

Measurement studies

- **Single bunch operation** - To better separate the effect of long and short range wakefields.
- Find a more **optimal accelerator setup** with minimal sideband driven centroid motion
- Can this residual centroid motion be mitigated by the multi-bunch feedback ?

Simulation

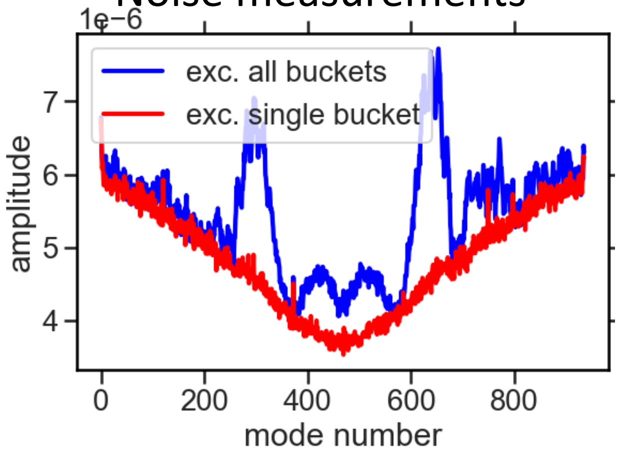
- Understand the effects of a 3rd harmonic cavity
- Include both short and long range wakefields

Questions

Experience with 3rd harmonic cavity
Experience with ramped / booster operation
Experience with Amplifiers

Where does the noise floor variation with excitation mode come from?

Noise measurements



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