ATF2 Tuning with 2-train Mode

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ATF2 Collaboration Meeting

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2-Bunch Operation Requirements

- Eventually, need to move to continuous operations in "2-bunch" mode
  - Essential for goal 2 to stabilize IP @ nm-level with high-bandwidth feedback
  - May also be essential for max IPBSM operation if final doublet jitter beyond tolerance
- Operating principal:
  - Bunch #2 should have same tuning requirements as current 1-bunch operations to achieve small IP spot size (<40nm)
  - Then use bunch 1 as input to stabilize bunch 2 to high precision
   - *requires large bunch1:bunch2 correlation*

Requirements for Tuned Bunch2

- Beam condition observed to be highly dependent on orbit
- To deliver bunch2 with same tuning as in 1-bunch operations:
  - Need to ensure delivered orbit identical for bunch1 as tuning done in 1-bunch mode
  - May not be possible due to bunch-bunch dynamics in DR and/or non-linear variability of extraction kick based on timing.
- Therefore, may need operation of beam diagnostics in EXT & FFS as in 1-bunch mode
  - IPBPM
  - **Stripline BPMs**   Will need anyway for 2-bunch mode for orbit
  - **C-band cavity BPMs**   feedback
  - **Profile monitors**
  - Wire-scanners
  - IPBSM
  - ICT's
- Simplest way for many devices may be to set up 2-bunch mode, then "switch off" bunch 1 when required by preparing special timing mode for source laser?
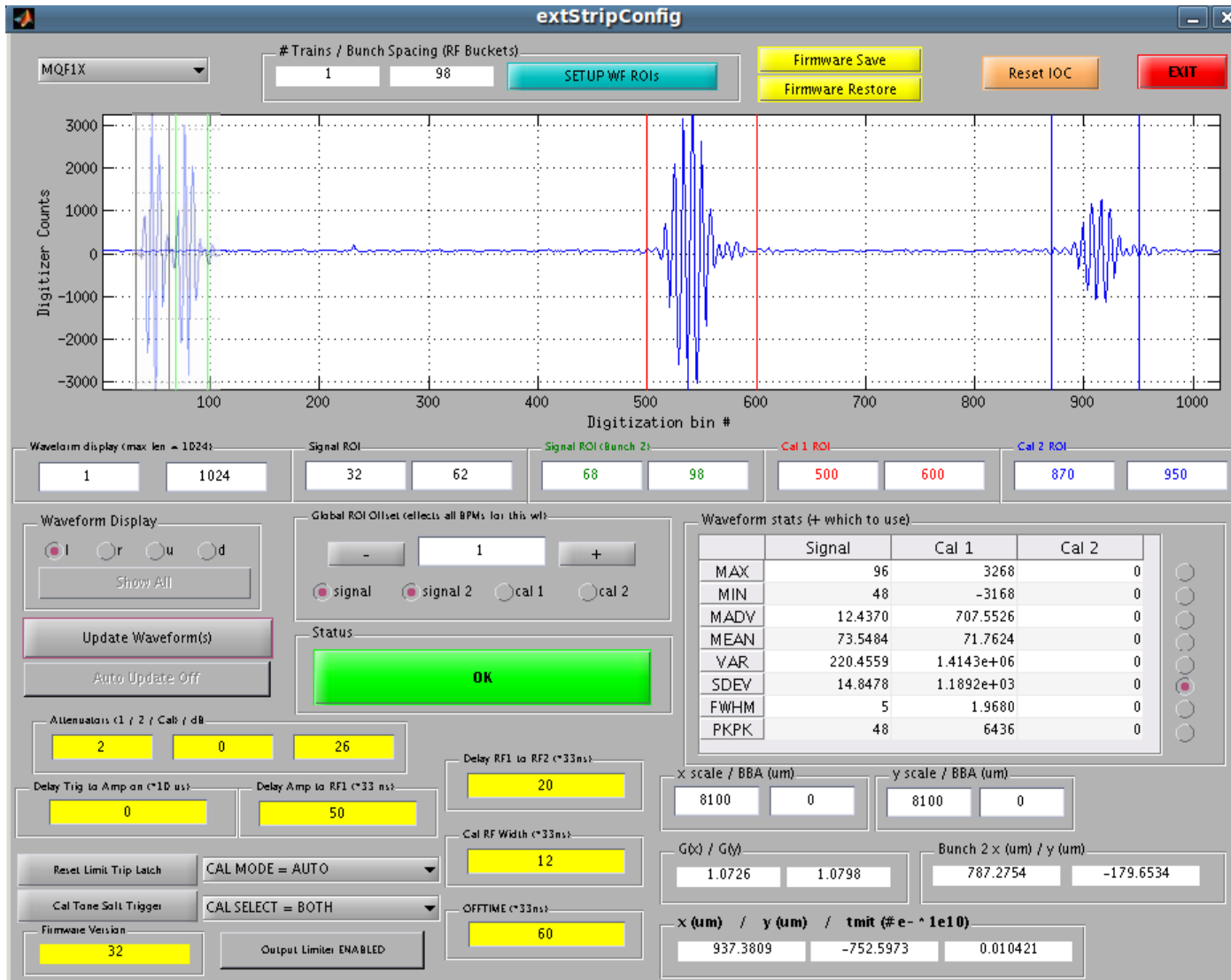
Stripline BPMs

- Example strip response with stripline BPM down-mix electronics for 2 different bunch spacing's.
- Clear separation of bunches with ~100 s-band bucket spacing without need for complex signal processing
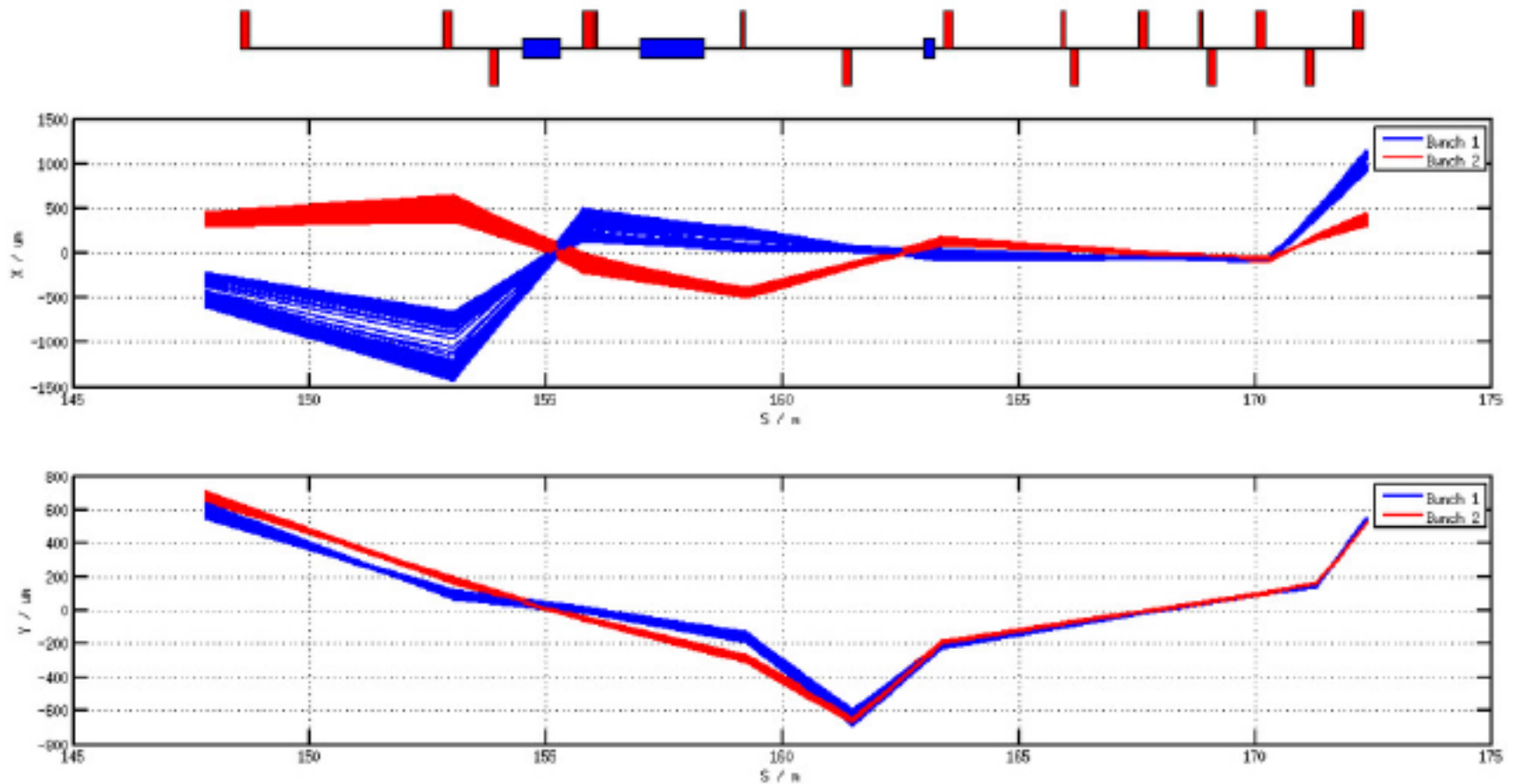 - Suggestion to standardise 2-bunch delivery based on this?
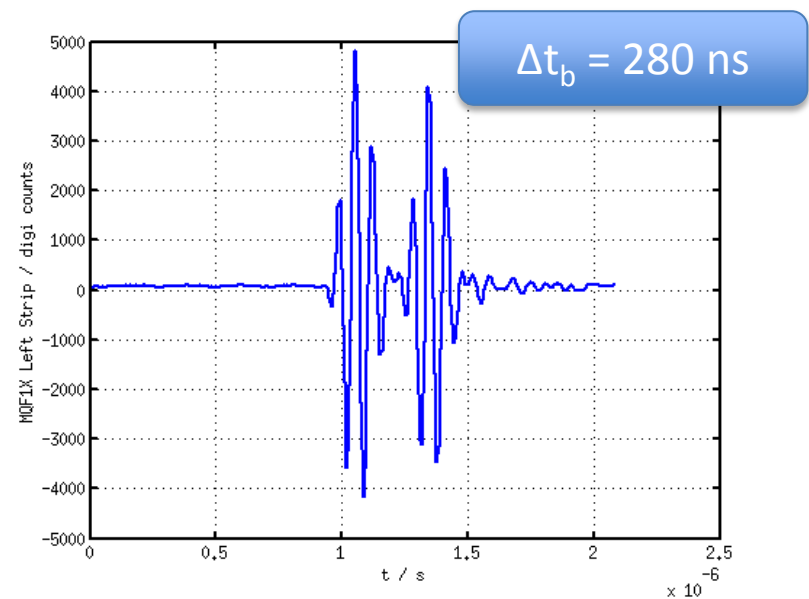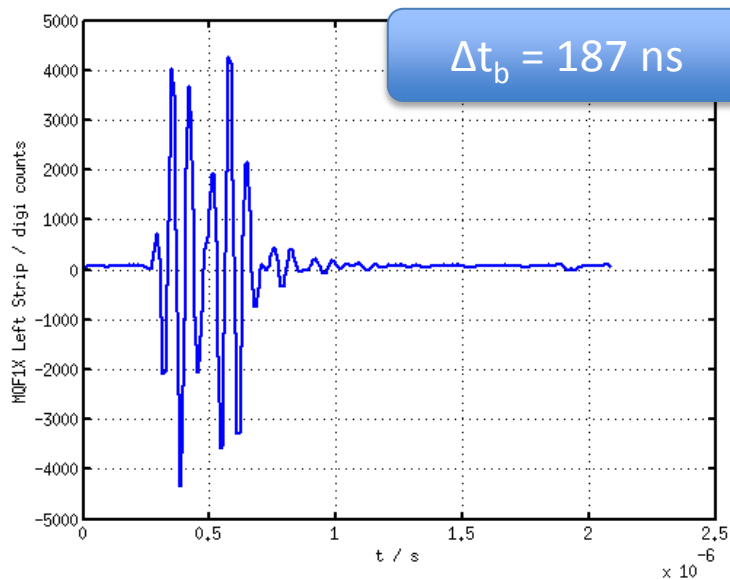
2-Bunch Stripline BPM Setup

- Addition to standard BPM setup software to include ROI's for bunch2

- Timing changes between 1 and 2 train mode require different setup configs for each mode.

- New PV's available for 2nd bunch
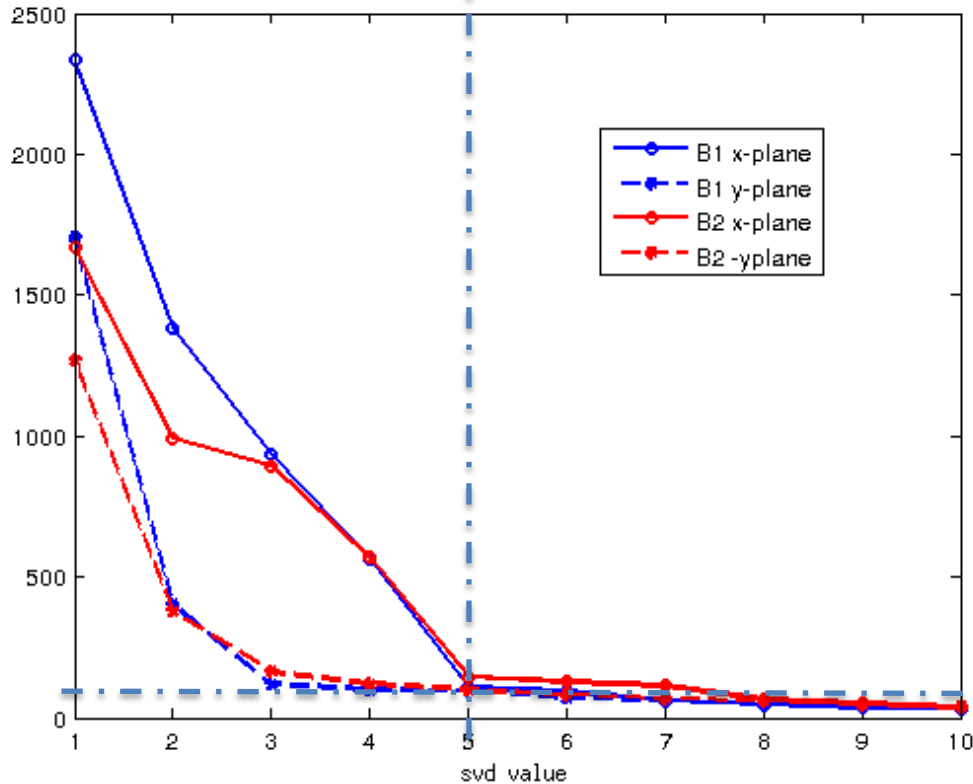 - "MQF1X:X2" "MQF1X:Y2" etc…
  - Also added to archiver

2-Bunch Orbit

Stripline Resolution in 2-bunch mode

BPM	X Res. / um [b1 , b2]	Y Res. / um [b1 , b2]
MQF1X	2.2, 2.6	2.3, 2.4
MQD2X	2.4, 6.2	2.9. 3.1
MQF3X	2.3, 3.1	2.8, 2.9
MQF4X	2.5, 3.3	3.5, 3.2
MQD5X	3.5, 5.1	3.5, 3.5
MQF6X	2.7, 3.2	2.6, 2.6
MQF7X	3.6, 5.0	3.9, 6.3
MQD8X	2.1, 5.3	2.8, 3.2
MQF9X	2.5, 2.1	1.8, 2.5
MQF13X	2.1, 2.9	2.4, 2.3
MQF14X	1.8, 1.8	5.0, 4.6
MQF15X	3.3, 1.9	2.0, 2.4

• Estimate BPM resolution for bunch 1 and 2 separately using SVD analysis from stripline BPM orbit.
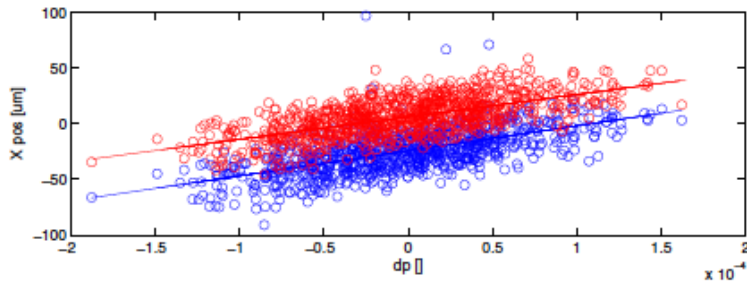
2-Bunch Orbit Analysis

Jitter reconstruction at entrance of EXT line

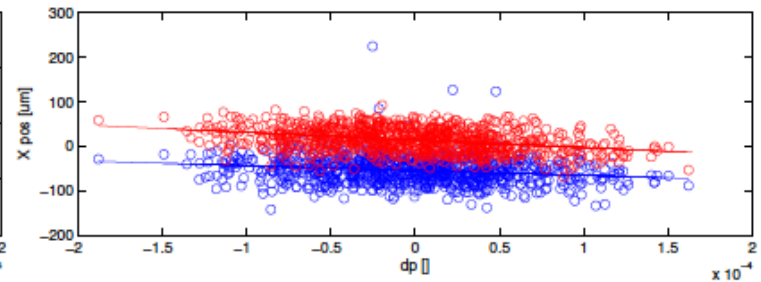|	σ_x	σ_{p_x}	σ_y	σ_{p_y}	σ_E
Bunch-1	1.2051e-05 m	5.0581e-06	2.2627e-06 m	1.9783e-06	5.4553e-05
Bunch-2	1.2475e-05 m	4.5697e-06	2.2127e-06 m	1.9924e-06	5.5235e-05
Correlation	0.99	0.99	0.99	0.99	0.99

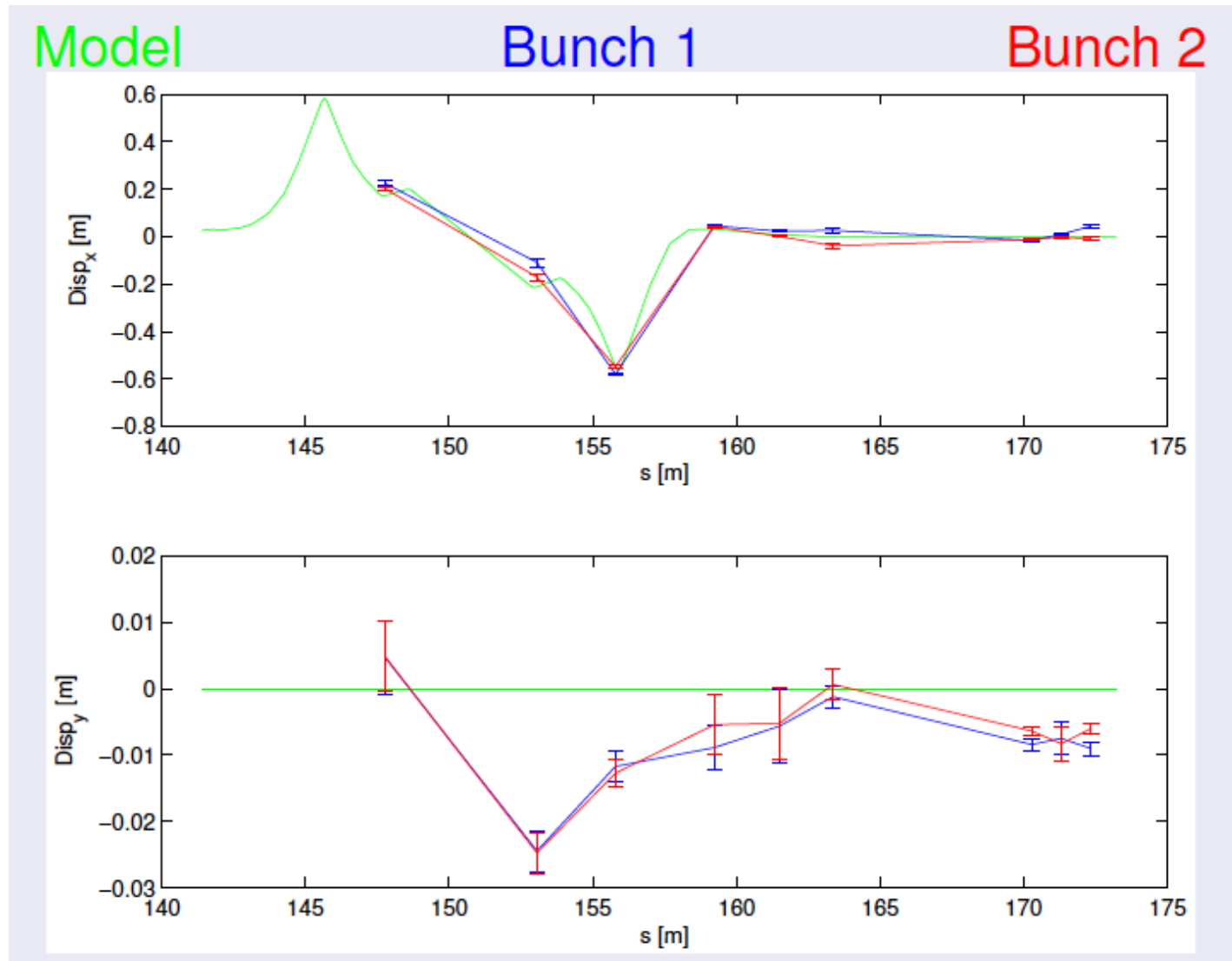Dispersion reconstruction (Bunch 1 Bunch 2)

MQD2X   MQF4X
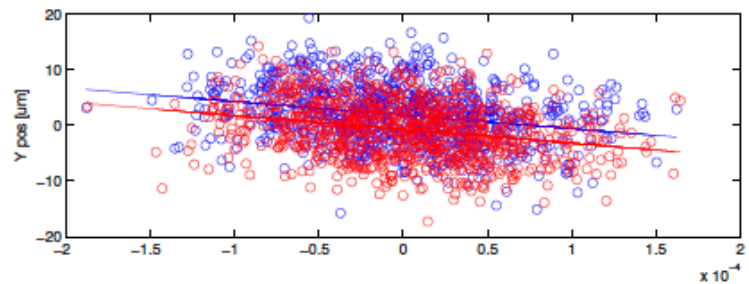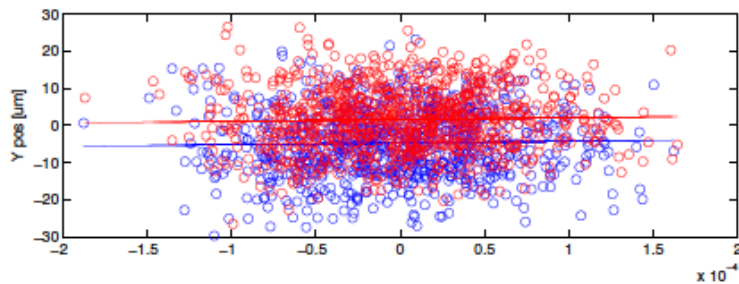
# Dispersion Reconstruction from 2-Bunch Orbit

2 Bunch OTR Operation?

- Joint multi-bunch shift with FONT to study possibility of using OTRs with 2-bunches.

- Can use high-bandwidth FONT kicker to identify/move bunches.

- Unfortunately, orbit difference between bunches significant enough that one bunch always hits the target frame for 2 of the OTRs leading to unacceptable background conditions
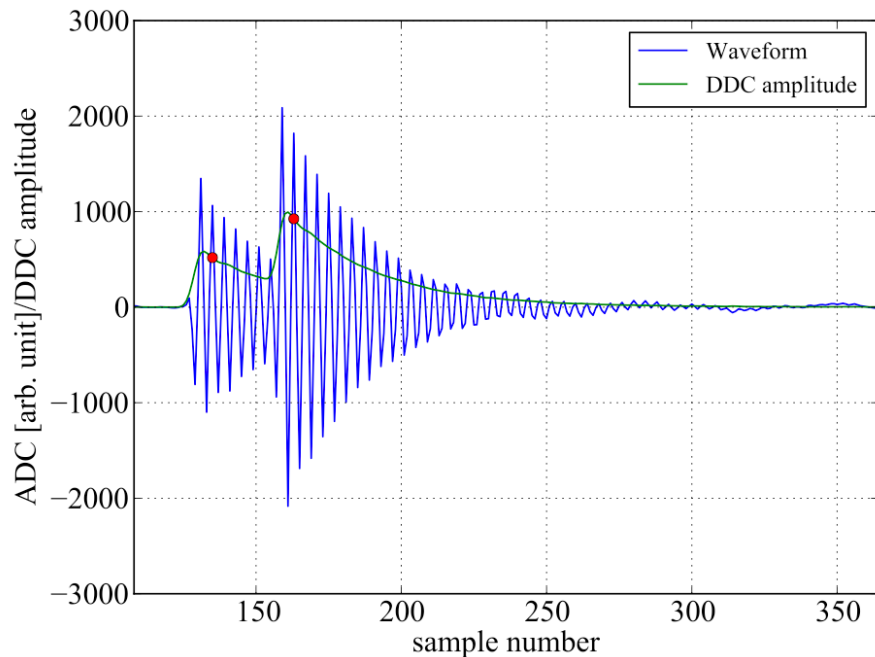 - Will need "Switch off Bunch 1" capability to use OTRs
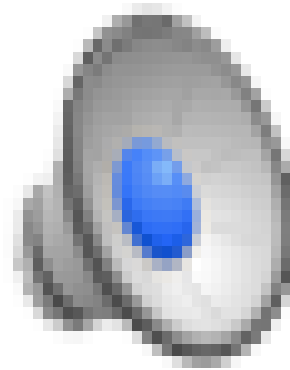
2-Bunch Coupling Differences

- Clearly different coupling conditions observed between b1 and b2.

- Due to orbit difference in extraction or inflector system?
  - Further study may shed light on coupling source

- Highlights need to fully tune in 2-bunch mode.
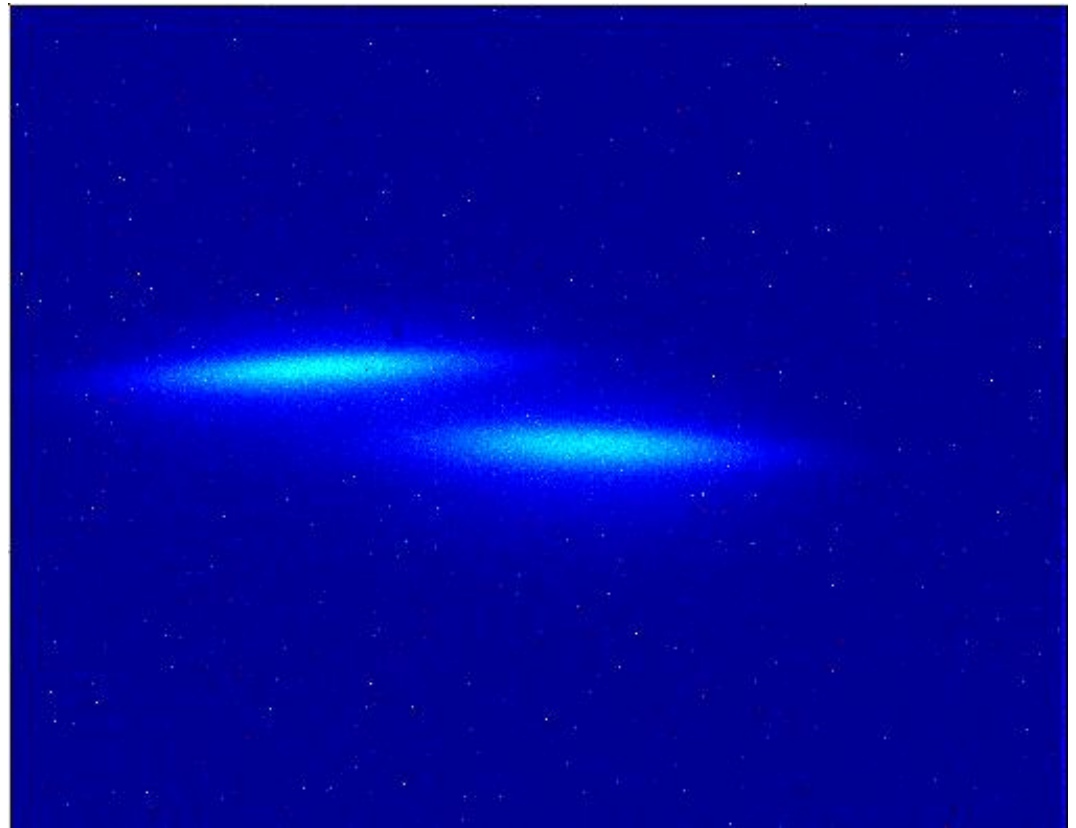
C-Band Cavity BPM 2-Bunch Operation?

- Past studies by YoungIm, Nirav, Stewart suggest 2-bunch operation of c-band system possible by subtracting extrapolated bunch 1 signal from bunch 2.

- Also experience with similar analysis style by Frisch et. al. @ FLASH using cavity HOM signals in multi-bunch operations.

How to Configure Cavity BPM system for 2-bunch operation

- Configuration procedure follows proceeding steps (for dipole and monopole cavities):
  - ***Switch OFF B2***
  - Usual CAL for B1 (I-Q rotation angle, signal decay time, gain for dipole cavities)
  - ***Switch OFF B1, ON B2***
  - Usual CAL for B2
  - Both bunches ON
- Independent bunch readout by:
  - Sample B1 DDC in-phase DDC amplitude in usual way for B1 position determination
  - Using B2 I-Q rotation, extrapolate B2 I and subtract from B2 waveform and sample for B2 position determination
- **Needs independent bunch timing control capability**
- **Need to supplement existing BPM processing software with this capability and populate new EPICS PVs.**

Summary

- Requirement to upgrade EXT/FFS beam diagnositics to work in 2-bunch mode to perform tuning/feedback etc
  - Bunch 2 has obviously different properties to bunch 1
- Stripline BPM 2-bunch mode operational.
- Clear route to get operational c-band BPM system
  - Needs software work
- Further studies to investigate source of 2 bunch differences desirable
  - From intra-bunch DR dynamics or from injection/extraction system inhomogeneities?
- Required control-system modifications
  - Independent bunch on/off control
  - Fire main EXT hardware trigger only when beam present will also greatly simplify many things…