

BPM upgrade in the BESSY-II injector

Tackling issues from mature installation with flexible instrumentation

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Featuring
Ghosts!

Overview

Introduction to the BESSY II Injector

Ghost signals?

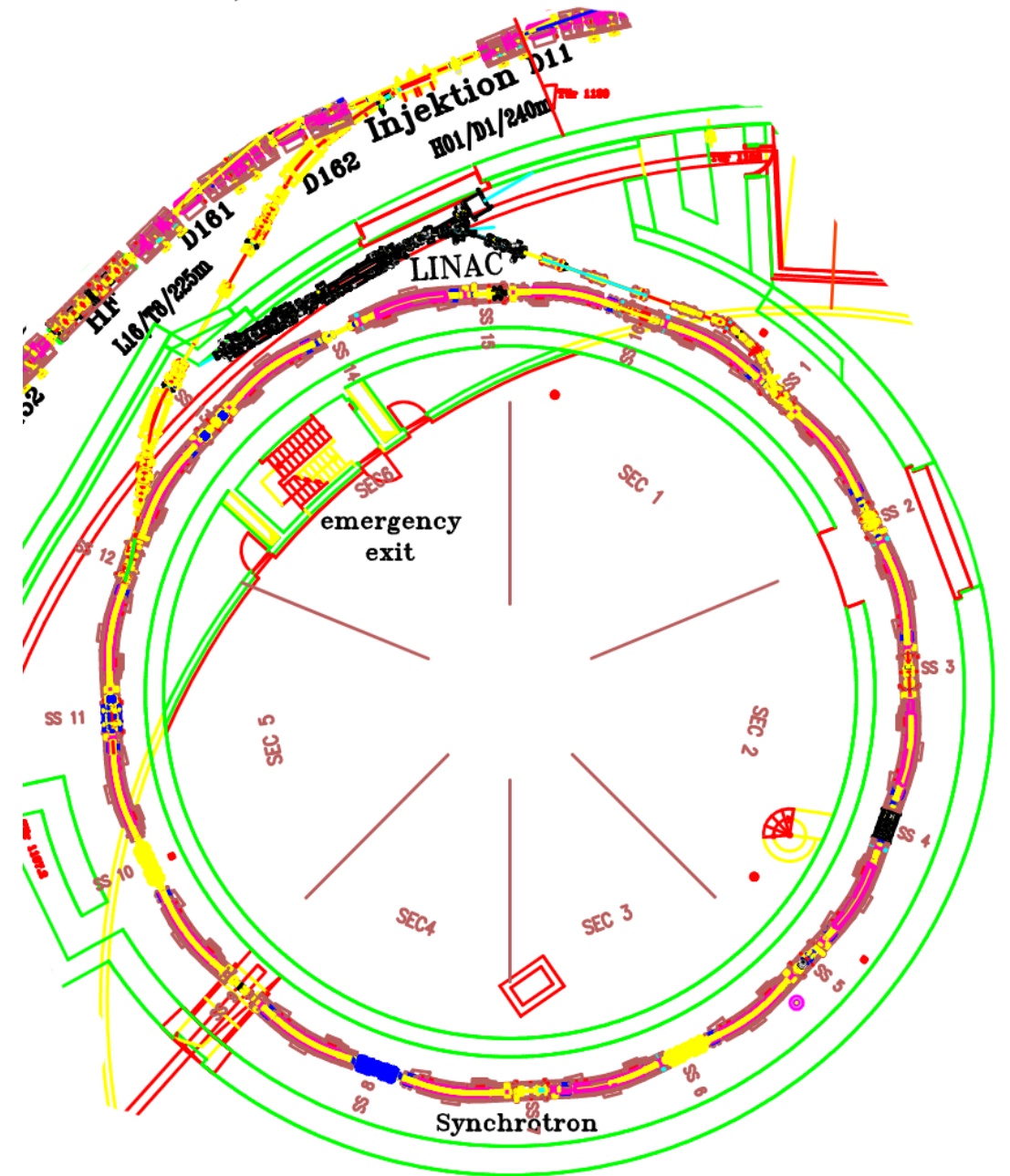
Solution by changing NCO

Installation of new BPM electronics

Conclusion

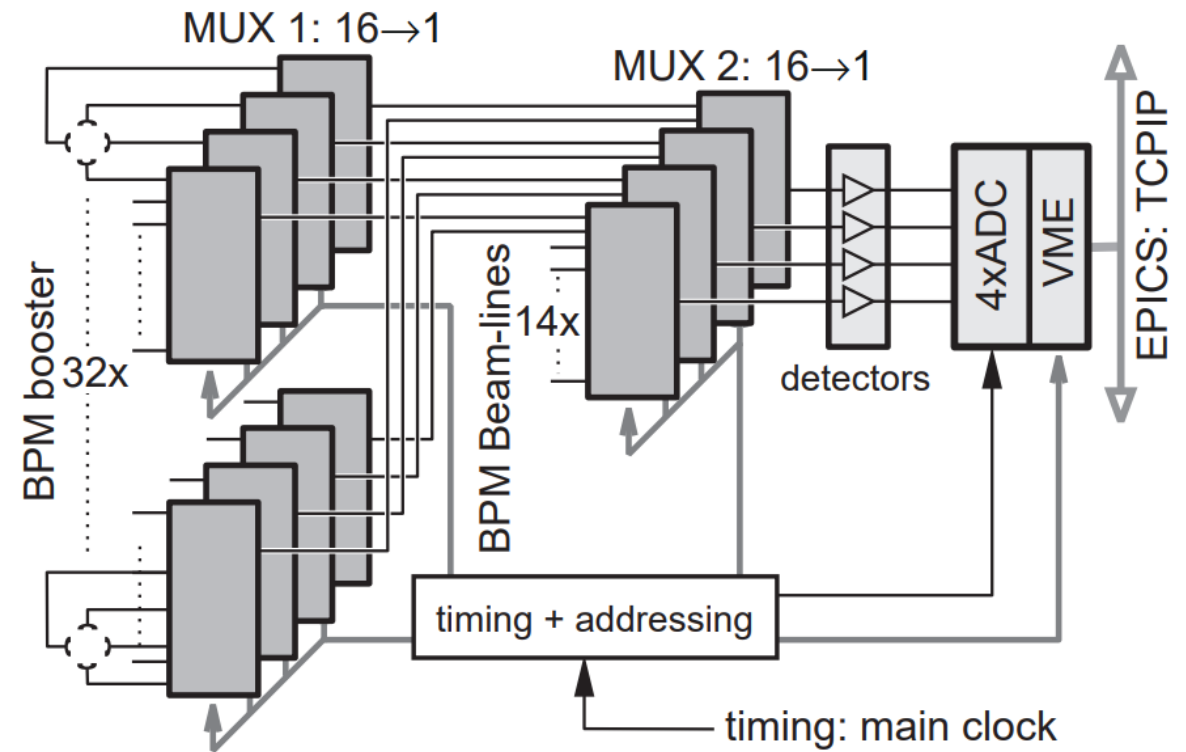
BESSY II INJECTOR AND BPMS

- In operation since April 1997
- Booster synchrotron has 16 cells, 32 BPMs
- Cycling at 10Hz, acceleration within 30ms
- Operated with 1 to 5 bunches in 160 buckets
- 1997 multiplexer of all pickups to a single set of electronics
- 2015 upgraded to multiplexer and single oscilloscope
- 2019 trials with Libera Digit 500
- 2020 trialled existing Libera Brilliance
- 2021 trialled single Libera Spark ERXR
- 2022 upgraded to 32 Libera Spark ERXR in the booster



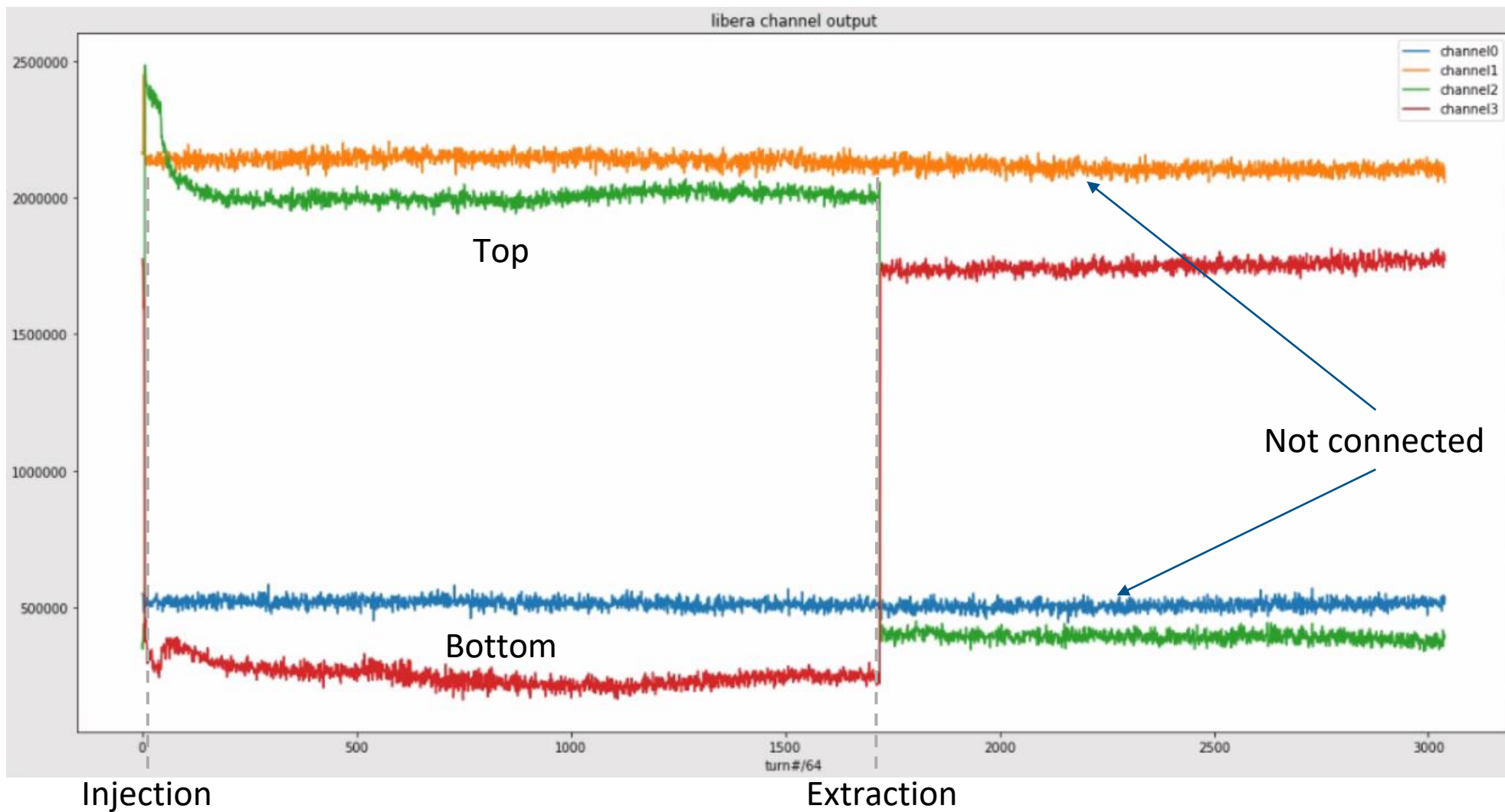
ORIGINAL BOOSTER BPM SYSTEM

- Many multiplexers, two in sequence
- Only one set of electronics with four detectors
- Four ADCs (12 bit, 10 MS/s, 512k memory), in VME
- Data delivered to EPICS
- Orbit evolution had to be recorded on successive shots
- Assumed individual shots are reproducible



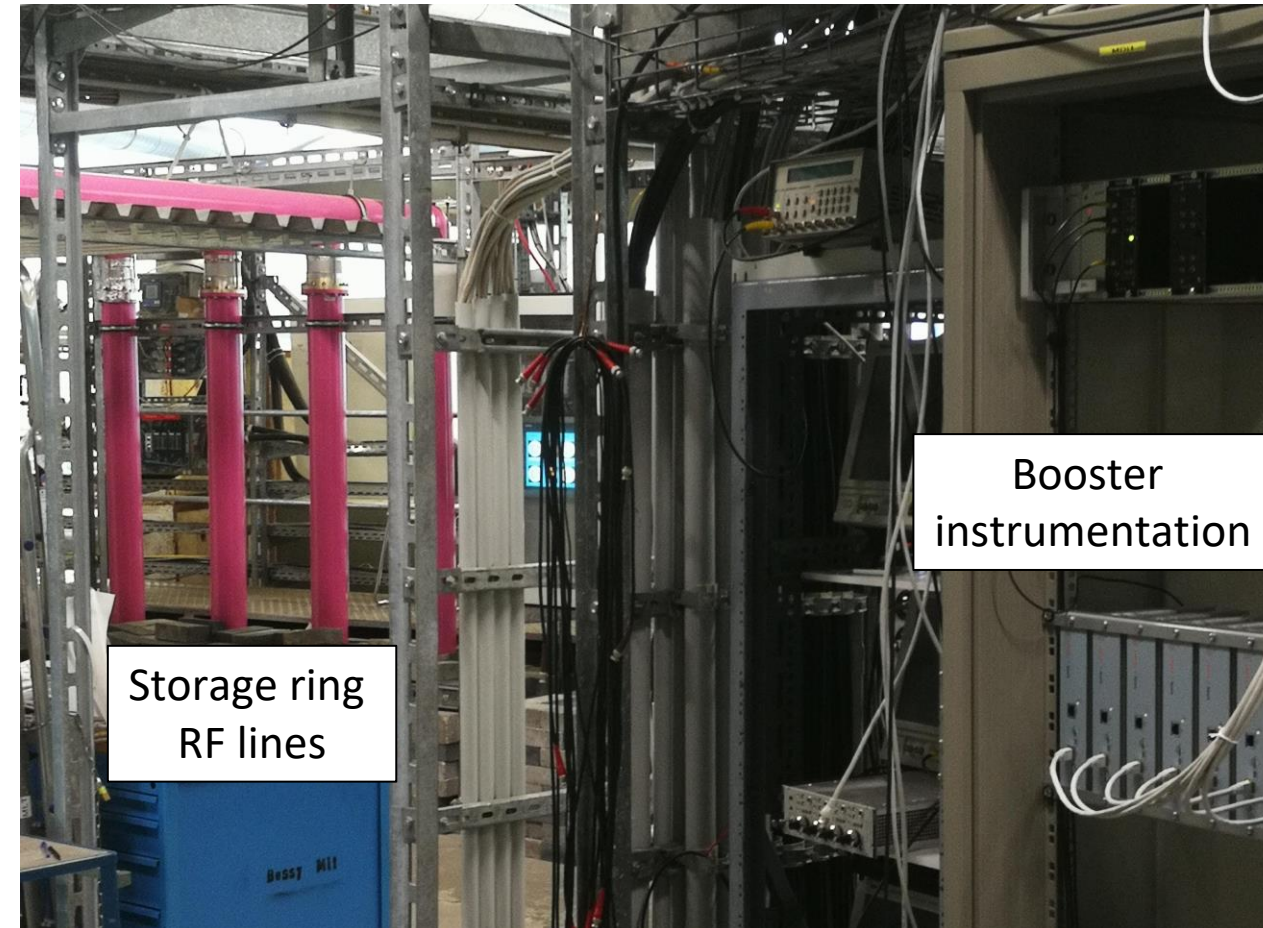
From „Fast and Flexible BPM-System: Valuable Commissioning Tool for BESSY II“, R.J. Bakker et.al., Proceedings of EPAC 1998

GHOST SIGNALS SEEN DURING FIRST TESTS WITH LIBERA



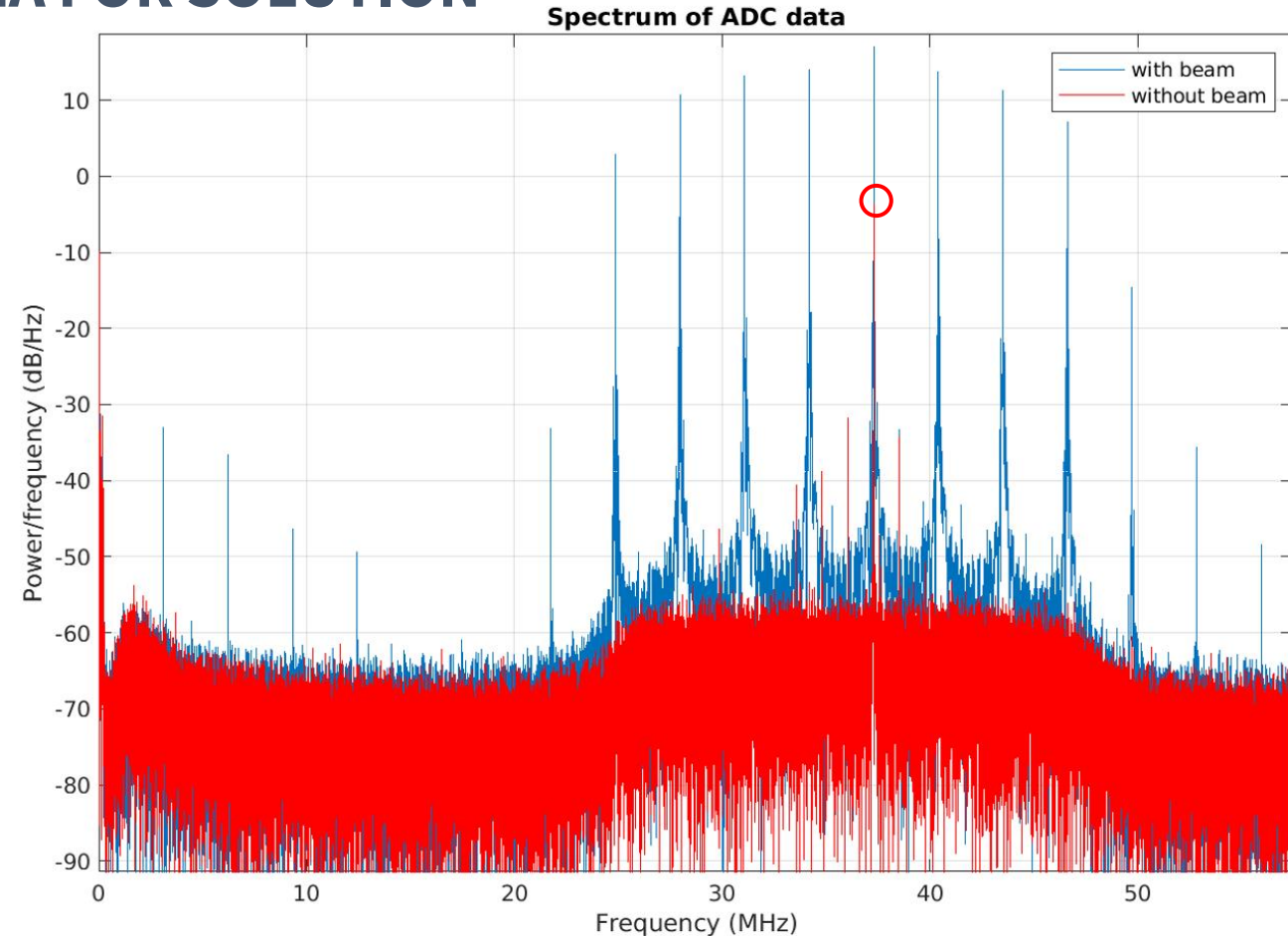
IDENTIFIED AS CROSSOVER FROM POWER RF AMPLIFIERS

- RF amplifiers for both storage ring RF and booster RF are just a few meters from the booster instrumentation racks
- Power RF uses >100m of large coax lines with ~100 bolted connections
- BPMs use flexible cabling with single sheath and weak shielding
- Signal at RF frequency is received three ways: from buttons, from main RF and from booster RF!
- Interference causes ‚ghost signals‘
- Conditions change with pickup position and time



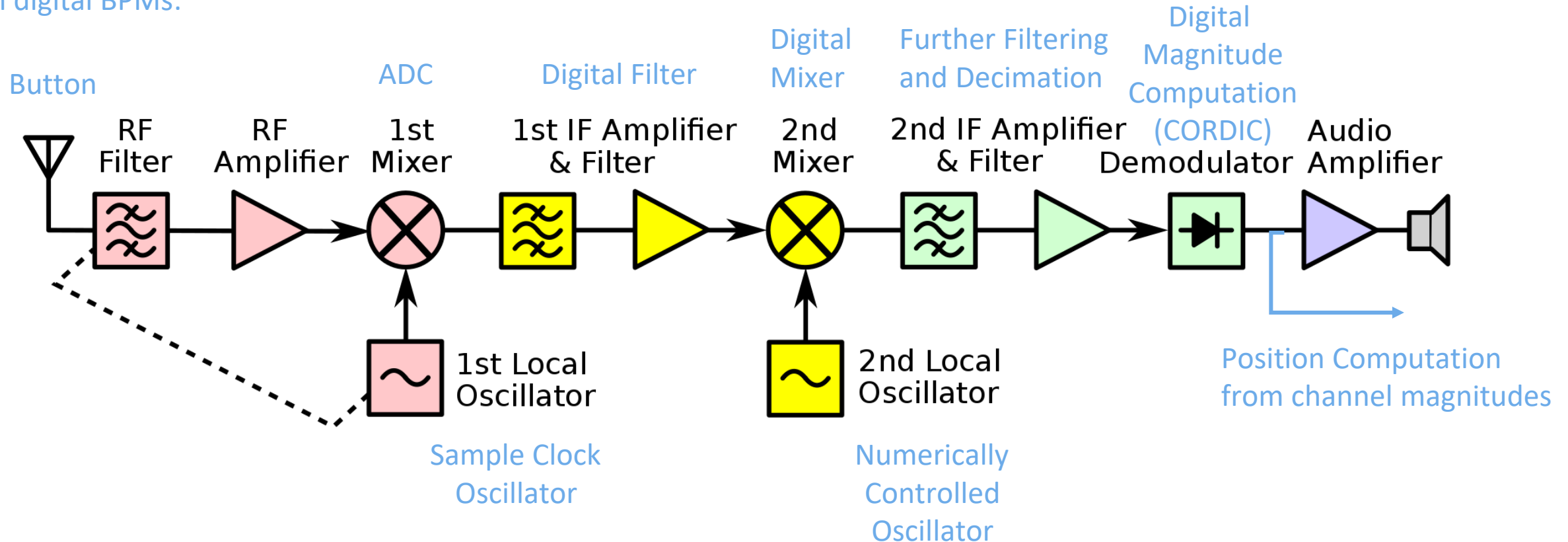
SIGNALS SEEN IN ADC SPECTRA AND IDEA FOR SOLUTION

- Large ADC rate ($\sim 117\text{MS/s}$) buffer processed through FFT
- Strong RF signal even without beam
- Beam signal repeats every 3.125 MHz = revolution frequency
- IDEA: Could the BPM receiver be tuned to a different revolution side band?
- But we want to maintain the correct TbT rate!
- NOTE: Strong sideband exist only with short fills (BESSY II booster has only 1-5 of 80 buckets filled)



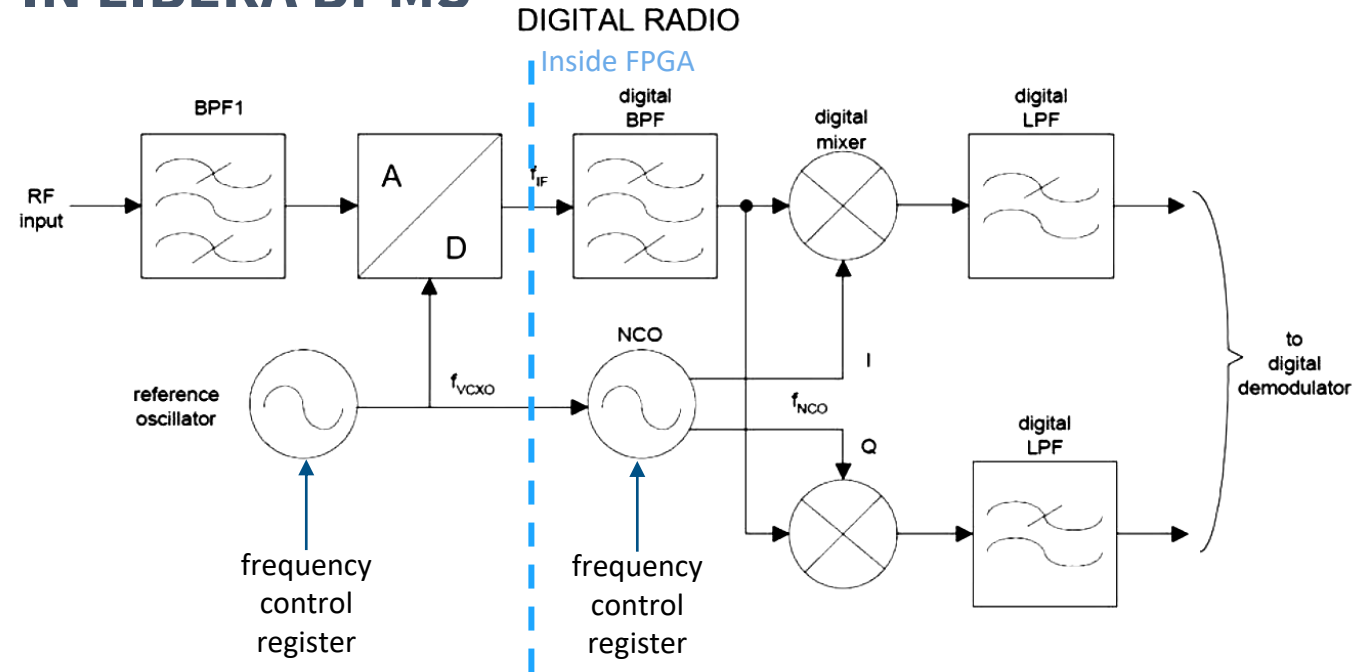
BRIEF DISCOURSE: DOUBLE SUPER-HETERODYNE RADIO RECEIVER

In digital BPMs:



CHANGING THE RECEIVER FREQUENCY IN LIBERA BPMS

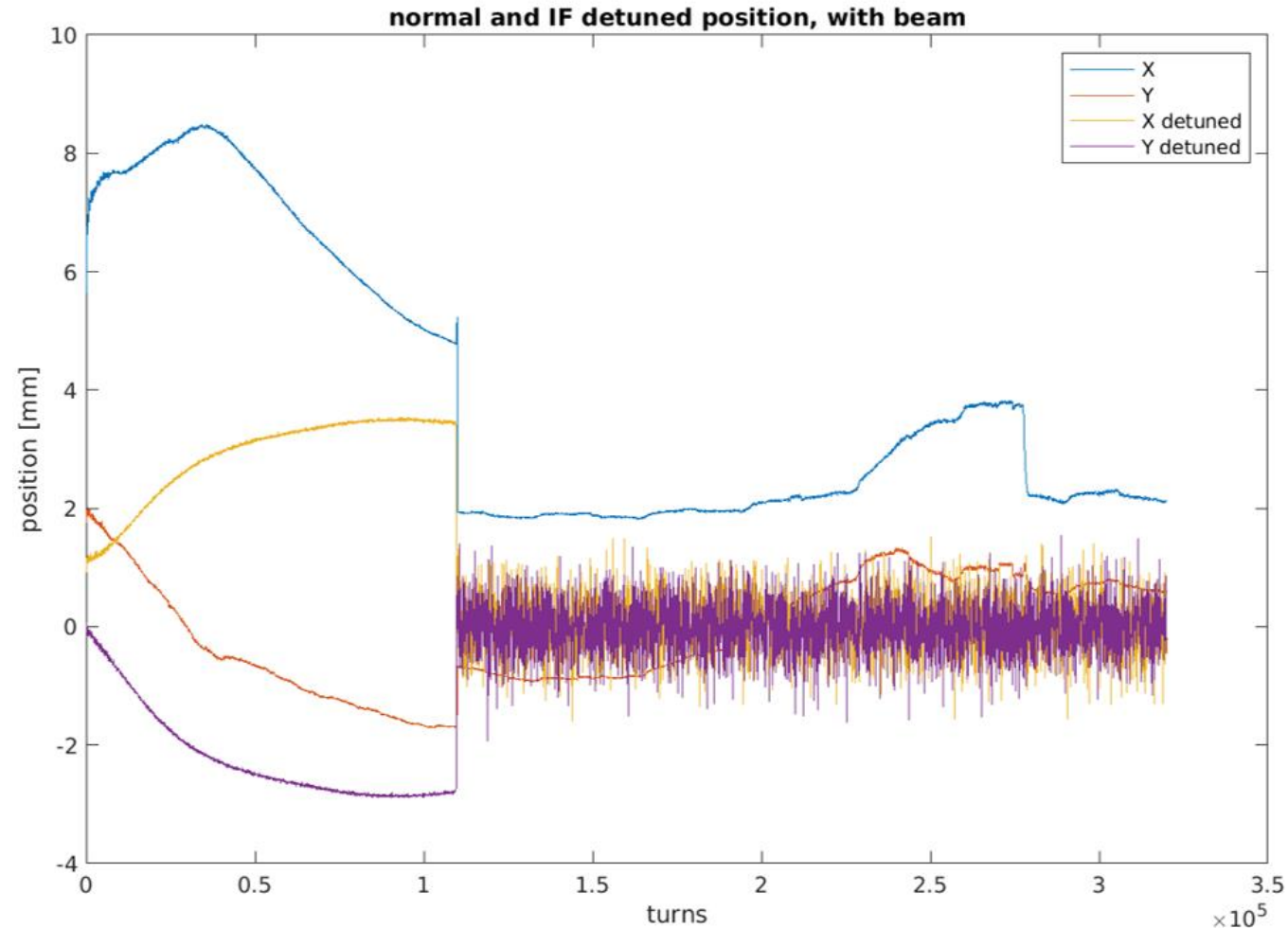
- The reference oscillator can be reprogrammed, but this will change ADC and derived TbT rate
- The Numerically Controlled Oscillator can be reprogrammed, without impact on the rate
- Access to NCO frequency control register exists on Libera Brilliance and Libera Spark
- All that is required is a single write to that register



From Libera Spark User Manual, with additions

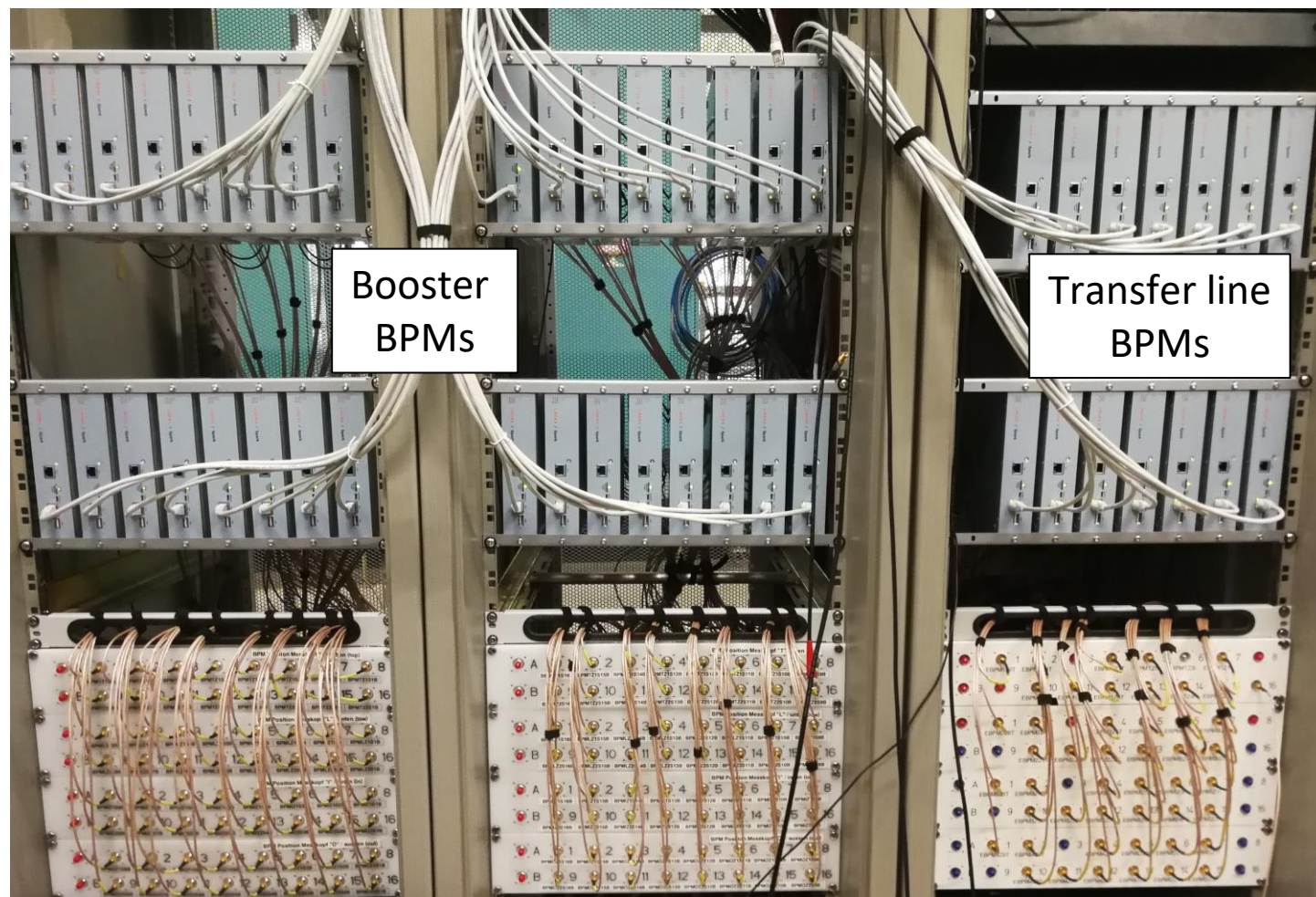
POSITION READINGS WITH CHANGED NCO FREQUENCY

- Position readings with changed NCO (IF detuned) look more like expectations
- No more ghost positions after extraction of beam
- Also much better reproducibility
- Trivial changes from the user level on Libera Brilliance and Spark
- **NOTE:** Would be nice if the digital filter could be changed in frequency as well!



UPGRADE OF ALL BOOSTER BPMS TO LIBERA SPARK ERXR

- 50 BPM systems tendered and procured in 2021
- Delivered and installed Dec 2021
- Operation from Feb 2022
- Transfer line BPMS are identical. Processing of ADC sample in external python script for positions of single passage



TRIGGERING AND CLOCKS TO MANY LIBERA SPARK ERXR

- Triggers and clocks are currently in short supply
- Timing distribution system upgrade is in process
- Triggers to each rack daisy chained to 16 BPMs
- Revolution clock to all installed 46 BPMs daisy chained
- Possible due to high impedance inputs in Libera Spark ERXR
- Have to use short T connectors, available in LEMO-00
- NOTE: Avoid RG-316 as signal cables. We plan to swap these to LMR-100.



Conclusions

- Crosstalk from RF plant (sends up to 80dBm) to BPMs (receives below -70 dBm) remains a risk in accelerators
 - Particularly, when signal power is low and RF plant is near
 - Avoid cables with low shielding effectiveness
- Changing the NCO frequency can produce quick relief
 - Show to work on Libera Brilliance and Libera Spark ERXR
 - Works only if signal has strong revolution sidebands <-> short fill pattern
- Triggers/Clocks have been successfully daisy chained between up to 46 BPMs

Thank you for your attention!

Questions?



IMPLEMENTATION DETAIL ON LIBERA SPARK ERXR

```
mdiadm@opic11c /home/controls/mdiadm
root@spark33:/opt/etc/init.d# more S99local
#!/bin/sh

echo "++ Running user init script: ${0}"

# Feel free to add custom initialization commands here.

# Special tweaks for operation in the BESSY-II booster

# Copy the stored keys including the mdiadm key to its use location
cp /opt/bessy-II/authorized_keys /root/.ssh

# Stop old ntpd, and start one with the correct peer address
/etc/init.d/S49ntpd stop
ntpd -p 192.168.212.33

# Change the NCO setting to receive not the main bunching harmonic, but
# one revolution harmonic to the side. This is required, as cavity RF is
# leaking into the button pickup cables, and lead to incorrect position
# readings and fake charge.

# NCO freq in Hz= <register>/2**32 * sampling freq in Hz
/opt/libera/bin/monitor /dev/libera.monitor 0x6040 1509042466
root@spark33:/opt/etc/init.d#
```