# LHC Tune and Chromaticity Diagnostic and Feedback Control Systems

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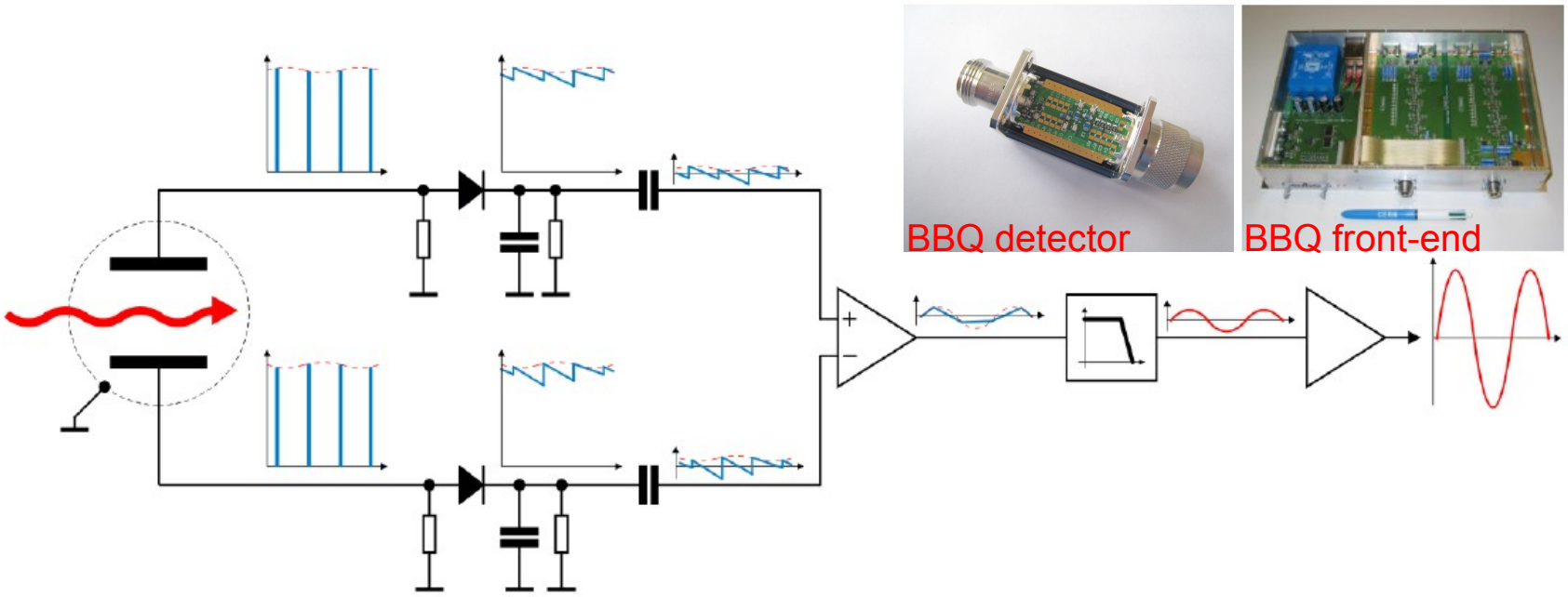
# Outline

- Please, also have a look on recent Q/Q' CARE workshop, in particular the following presentations:
  - BI-SW LIDS:
    - FFT: click here or here (non-LHC systems)
    - PLL: click here
    - Radio LHC: http://cs-ccr-samba1.cern.ch:8001/
  - Base-Band-Tune (BBQ) principle:
    http://adweb.desy.de/mdi/CARE/chamonix/071212_chamonix_bbq.ppt
  - LHC PLL principle:
    http://adweb.desy.de/mdi/CARE/chamonix/LHC_PLL.ppsx
  - LHC Tune/Chromaticity (FB) Control:
    http://adweb.desy.de/mdi/CARE/chamonix/2007-12-12_Qp_workshop_Chamonix_FB_Architecture.pdf

... Feedback Diagnostic Tutorial will come at a later stage

# LHC Q Base-Line Q Instrumentation
# Back-bone: Base-Band-Q Principle on a Slide

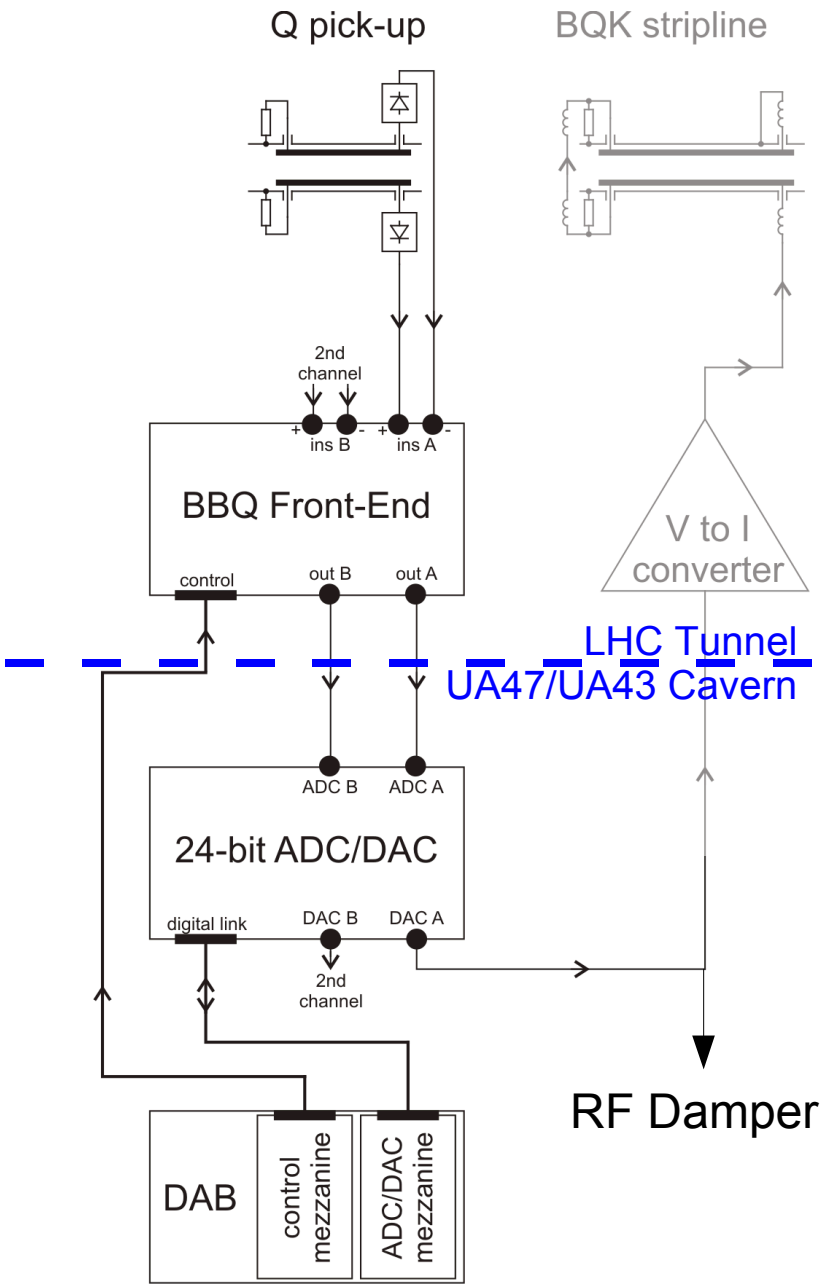



- Basic principle: AC-coupled peak detector
  - no saturation, self-triggered, no gain changes between pilot and nominal
  - intrinsically down samples spectra: ... 6 GHz → 1kHz ... $f_{rev}$
    - Base-band operation: very high sensitivity/resolution ADC available
    - Measured resolution estimate: < 10 nm → ε blow-up is a non-issue
- One of the few turn-key systems in the LHC
  - easy/very fast commissioning – done in parallel with RF capture

# LHC Q Base-Line Q Instrumentation
## BBQ System Overview

- Back-bone: Base-Band-Q Meter[1] (BBQ)
  - well tested and proven solution:
    SPS, LEIR, PSB, RHIC, Tevatron, ...
- Pick-ups: 40 cm strip-lines
- Shakers: 1 m strip-lines
  - magnetic deflectors driven ± 3 A max.
  - working bandwidth: 1 - 6 kHz
  - maximum kick angle: 0.1nrad@7TeV
    → 23 nm@β = 180m per turn
- RF Transverse Damper (W. Höfle)
  - 2 modules beam/plane
  - timing (MTG) for on/off
  - Monitoring via "RadioLHC"
- 3 x 2 (nearly) identical installation (tunnel
  (2 development/hot-spare systems on the surface)
- ... some redundancy:
  8 systems available vs. 2 needed

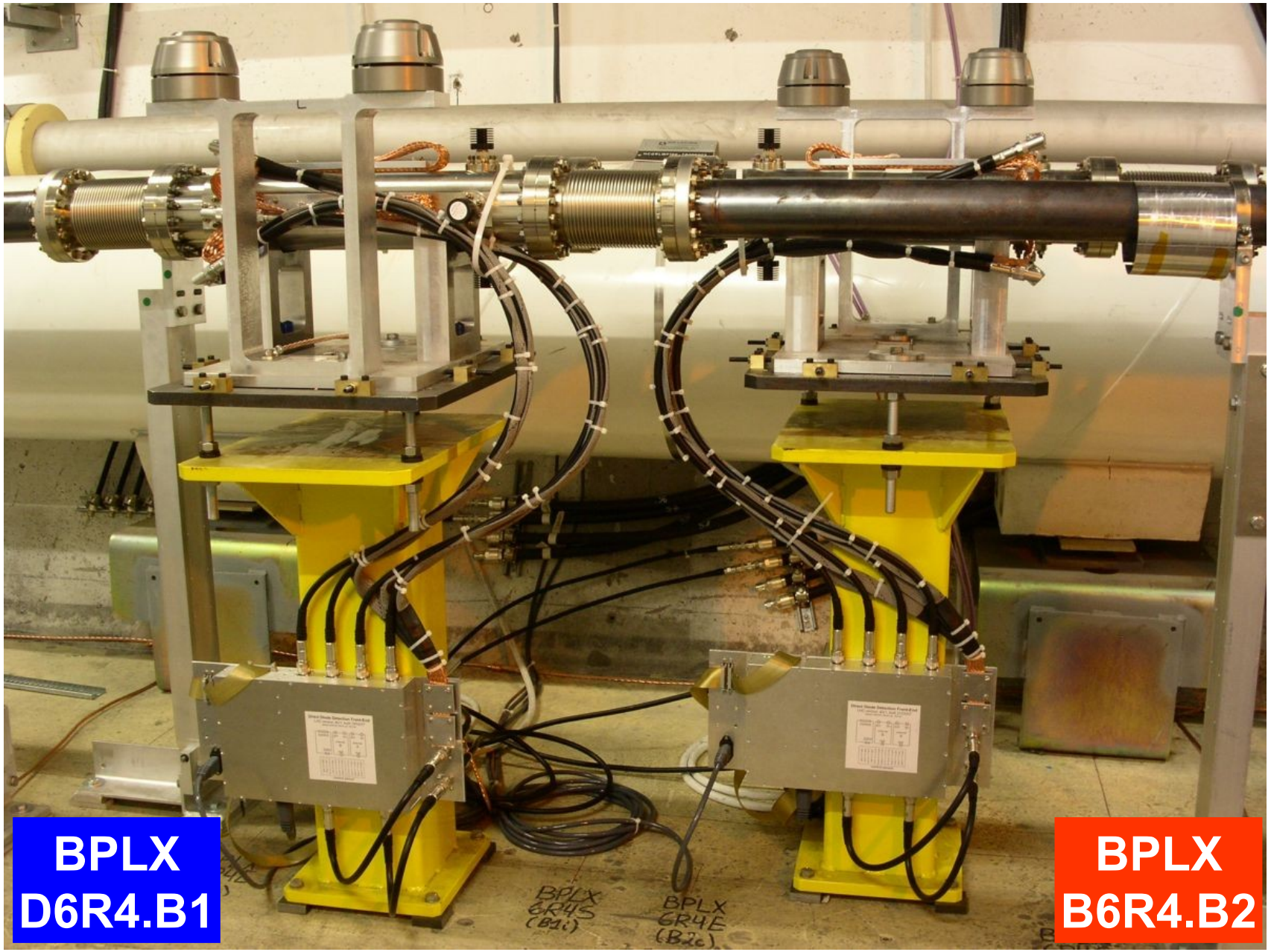
[1]M. Gasior: LHC-Project-Report-853



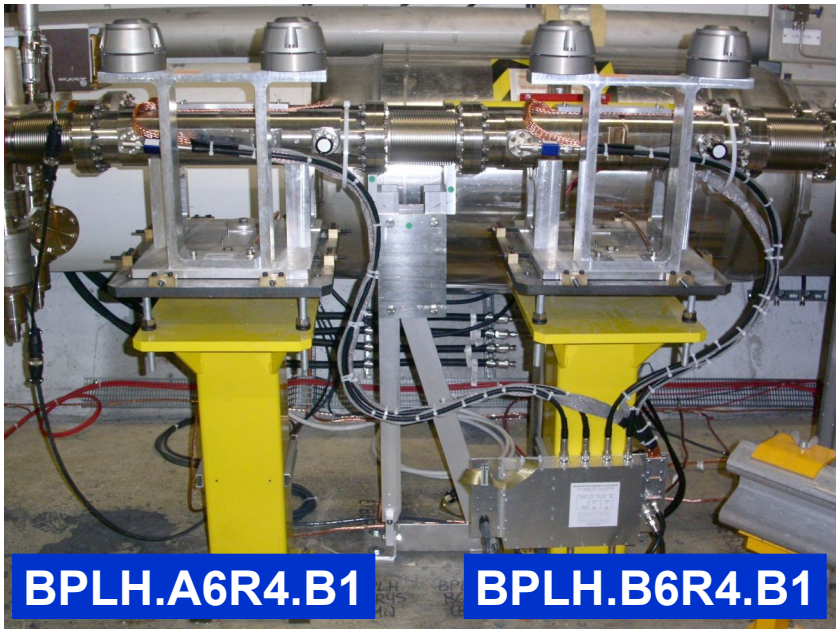
# LHC Base-Line Q/Q' Diagnostics Overview – Q/C⁻ BBQ Use-Cases Abstraction

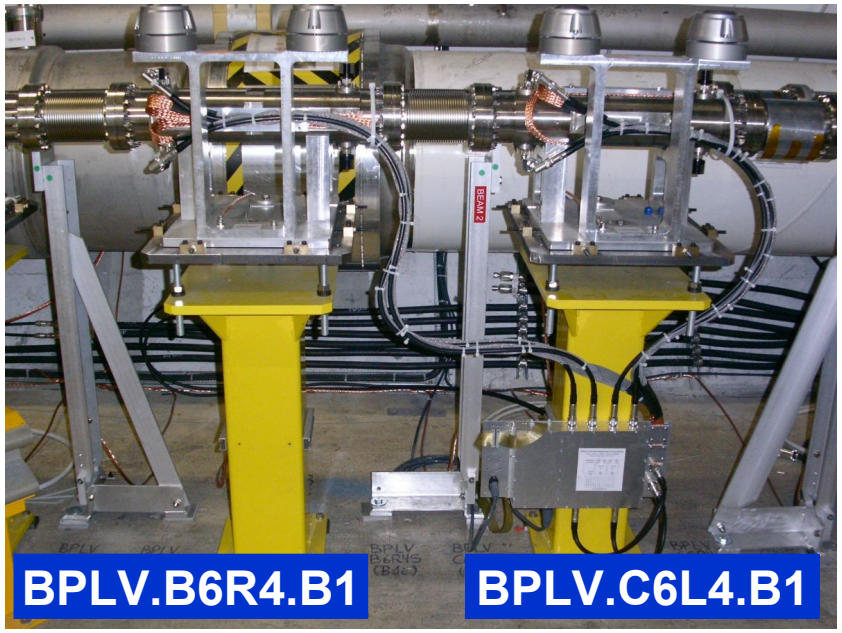
- Three independent BBQ Tune/Coupling diagnostic chains available per beam:
  - PLL based acquisition of Q, Q'... - commissioning pending!
    - one measurement at high/reduced acquisition frequency, targets:
      - 100 Hz for feedbacks (driven by need to reduce feedback latencies)
      - 1 Hz for general purpose logging
    - expert: high frequency data that is event synchronised and buffered (post-mortem, PLL setup), typical length: 5 min ↔ < 1 MB of data
    - main use: monitoring/logging, feedbacks, fill-to-fill studies, ...
  - FFT based acquisition of Q,Q'... – 'periodic' – B2 fully commissioned
    - one measurement every 1 second starting from first-injection
    - intended use: monitoring/logging, (feedbacks), fill-to-fill studies, ...
  - FFT based acquisition of Q,Q'... – 'on demand' – B2 fully commissioned
    - n-measurements synchronised to an external event (BPM, BQ, ...)
    - intended use: expert diagnostics, detailed studies, ...

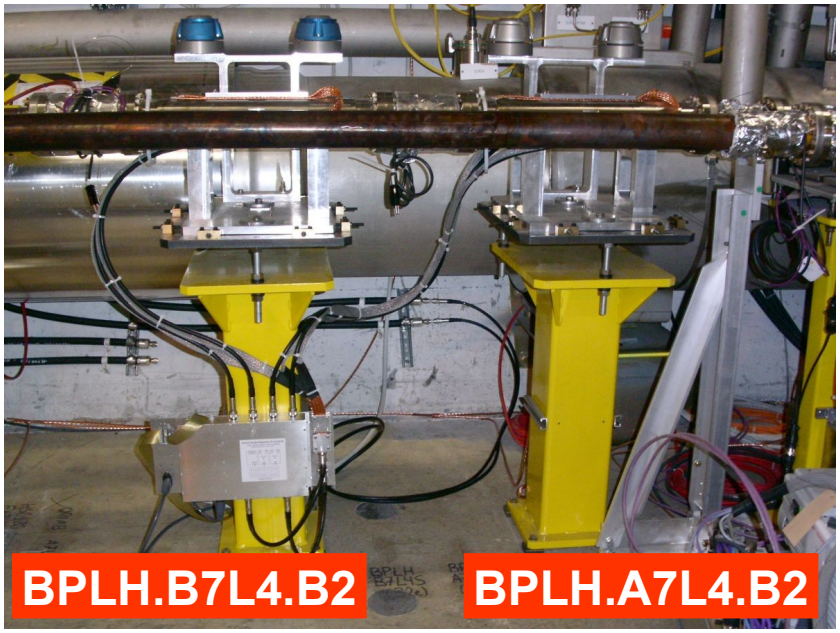
# LHC On-Demand B1 & B2 Systems

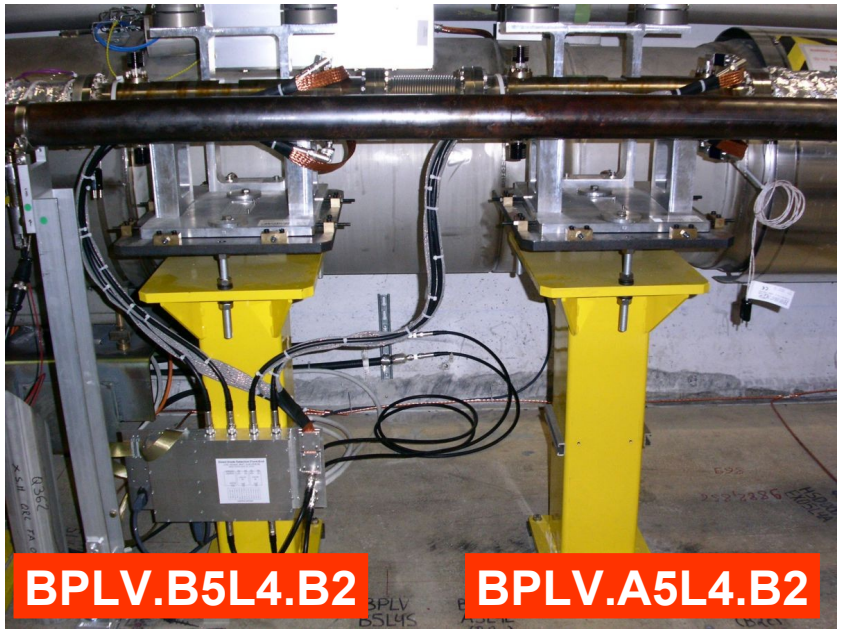


# LHC Continuous and Development B1 & B2 Systems

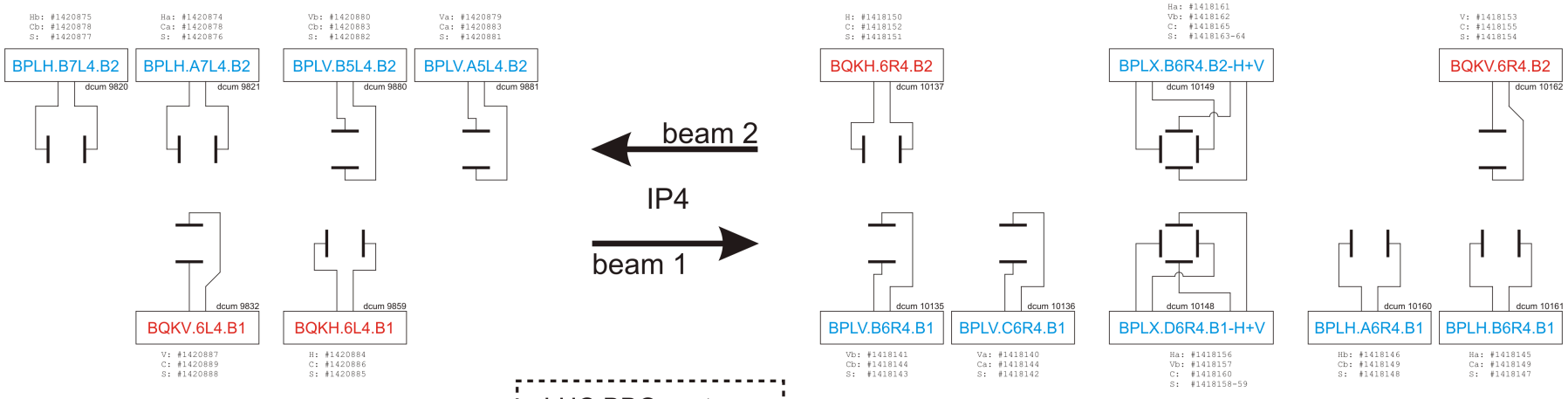


# BBQ-Front-End/FESA Layout




## LHC BBQ systems

Diagram v. 7/07/08, M. Gasior, AB-BI-QP

Legend:

| | |
|---|---|
| 2c | - 2 Coaxial cables |
| m48 | - 48-wire multiwire cable |
| H (V) | - Horizontal (Vertical) signal |
| Ha (Hb) | - Horizontal signal on digitizer channel A (B) |
| C | - Control |
| S | - Spare |

### BY09.UA43

BQKH.6L4.B1 (2c+m26)
H: #1420884
C: #1420886
S: #1420885

BQKV.6L4.B1 (2c+m26)
V: #1420887
C: #1420889
S: #1420888

BY11.SX4 (2c+m48)
- not used
S: #1420959-60
C: #1420961

damper tunnel UX45 (2c)
- not used
AYADT24.UX45: #1420952
AYADT19.UX45: #1420953

### BY10.UA43

BPLH.A7L4.B2 (2c+m26)
BPLH.B7L4.B2 (2c)
Ha: #1420874
Hb: #1420875
C: #1420878
S: #1420876-77

BPLV.A5L4.B2 (2c+m26)
BPLV.B5L4.B2 (2c)
Va: #1420879
Vb: #1420880
C: #1420883
S: #1420881-82

BY11.SX4 (4c+m48)
- AFE chBs (direct)
BPLH.B7L4.B2 #1420954
BPLV.B5L4.B2 #1420955
- copies of chAs (buffer amp)
BPLH.A7L4.B2 #1420956
BPLV.B5L4.B2 #1420957
- control of chBs (slave)
pin 1-26/48 of #1420958

BY06.UA47 (4c+m48)
- PLL DACs/tickler signals
B1-H: #1420892 (R->L)
B1-V: #1420893 (R->L)
B2-H: #1420894 (L->R)
B2-V: #1420895 (L->R)
- not used
C: #1420896

FFT1.B2 ("continuous")
slot #15, codec slave, AFE control

PLL.B2 ("PLL system")
slot #17, codec master, BQK control

CFV-UA43-BQPLL

### BY10.SX4

BY12.UA47 (4c+m48)
- copies (buffer amp)
B1-H: #1418187
B1-V: #1418188
B2-H: #1418189
B2-V: #1418190
- control m48
not used #1418191

damper surface SR4 (8c)
- not used
S: AYADT44.SR4: #1418204-11

DEV.B1 ("development")
slot #4, codec master, gain control

DEV.B2 ("development")
slot #15, codec master, gain control

CFV-SX4-BQ

### BY11.SX4

BY09.UA43 (4c+m48)
- AFE chBs (direct)
BPLH.B7L4.B2 #1420954
BPLV.B5L4.B2 #1420955
- copies of chAs (buffer amp)
BPLH.A7L4.B2 #1420956
BPLV.B5L4.B2 #1420957
- control of chBs (slave)
pin 1-26/48 of #1420958

BY07.UA47 (4c+m48)
- AFE chBs (direct)
BPLH.A6R4.B1 #1418182
BPLV.B6R4.B1 #1418183
- copies of chAs (buffer amp)
BPLH.B6R4.B1 #1418184
BPLV.C6R4.B1 #1418185
- control of chBs (slave)
pin 1-26/48 of #1418186

BY10.UA43 (2c+m48)
- not used
S: #1420959-60
C: #1420961

BY06.UA47 (2c+m48)
- not used
S: #1418192-93
C: #1418194

### BY06.UA47

BQKH.6R4.B2 (2c+m26)
H: #1418150
C: #1418152
S: #1418151

BQKV.6R4.B2 (2c+m26)
V: #1418153
C: #1418155
S: #1418154

BY11.SX4 (2c+m48)
- not used
S: #1418192-93
C: #1418194

BY10.UA43 (4c+m48)
- PLL DACs/tickler signals
B1-H: #1420892 (R->L)
B1-V: #1420893 (R->L)
B2-H: #1420894 (L->R)
B2-V: #1420895 (L->R)
- not used
C: #1420896

### BY07.UA47

BPLH.A6R4.B1 (2c+m26)
BPLH.B6R4.B1 (2c)
Hb: #1418146
Ha: #1418145
C: #1418149
S: #1418147-48

BPLV.B6R4.B1 (2c+m26)
BPLV.C6R4.B1 (2c)
Vb: #1418141
Va: #1418140
C: #1418144
S: #1418142-43

BY11.SX4 (4c+m48)
- AFE chBs (direct)
BPLH.A6R4.B1 #1418182
BPLV.B6R4.B1 #1418183
- copies of chAs (buffer amp)
BPLH.B6R4.B1 #1418184
BPLV.C6R4.B1 #1418185
- control of chBs (slave)
pin 1-26/48 of #1418186

damper tunnel UX45 (2c)
- not used
AYADT02.UX45: #1418176
AYADT08.UX45: #1418177

FFT1.B1 ("continuous")
slot #4, codec slave, AFE control

PLL.B1 ("PLL system")
slot #6, codec master, BQK control

CFV-UA47-BQPLL

### BY12.UA47

BPLX.D6R4.B1-H (2c+m26)
BPLX.D6R4.B1-V (2c)
Ha: #1418156
Vb: #1418157
C: #1418160
S: #1418158-59

BPLX.B6R4.B2-H (2c+m26)
BPLX.B6R4.B2-V (2c)
Ha: #1418156
Vb: #1418157
C: #1418160
S: #1418158-59

BY10.SX4 (4c+m48)
- copies (buffer amp)
B1-H: #1418187
B1-V: #1418188
B2-H: #1418189
B2-V: #1418190
- control m48
not used #1418191

damper tunnel UX45 (4c)
- DAC outputs to the damper
B1-H: #1418178 (AYADT02.UX45)
B1-V: #1418179 (AYADT08.UX45)
B2-H: #1418180 (AYADT25.UX45)
B2-V: #1418181 (AYADT19.UX45)

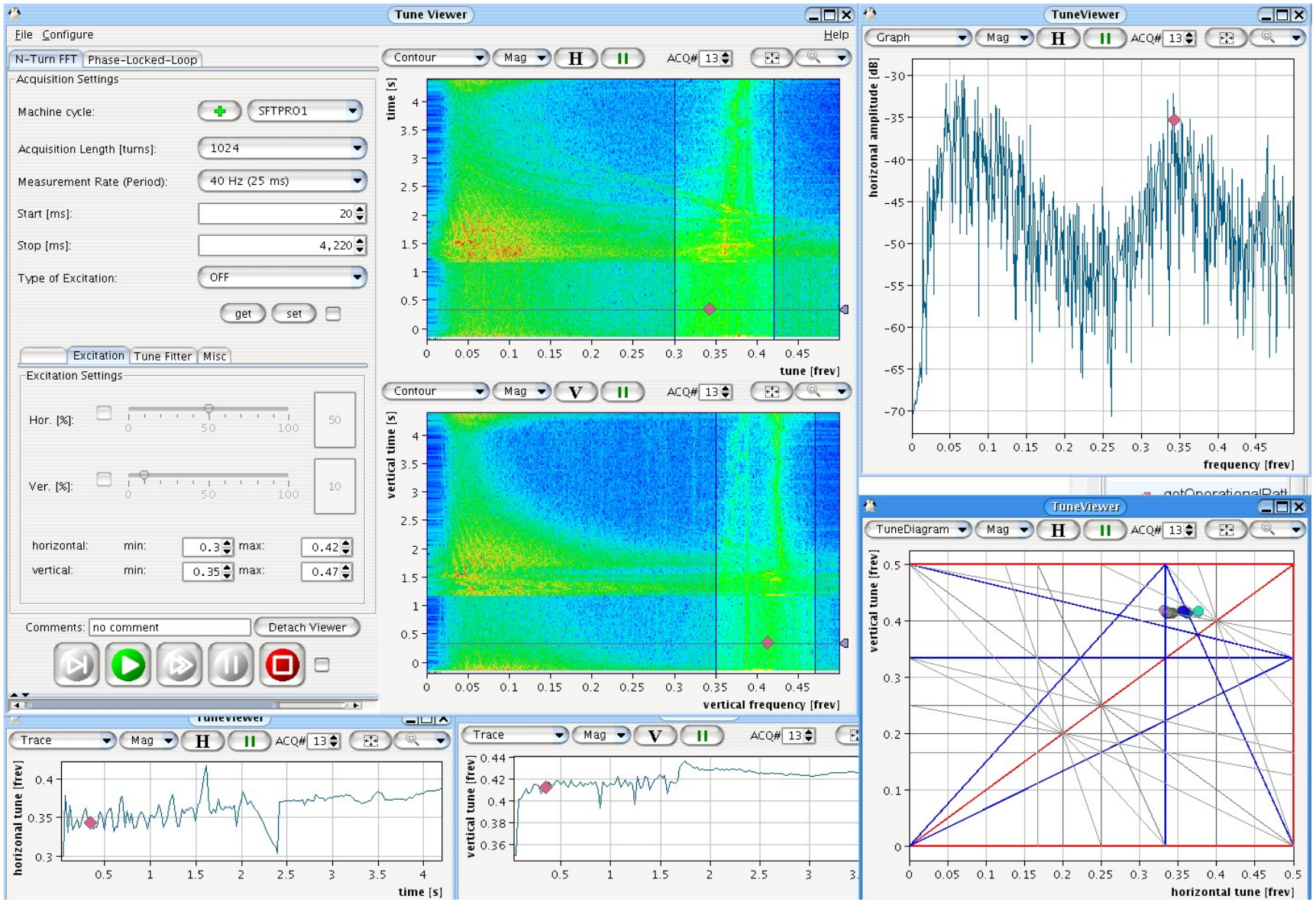
FFT2.B1 ("on demand")
slot #4, codec master, gain control

FFT2.B1 ("on demand")
slot #15, codec master, gain control

CFV-UA47-BQ

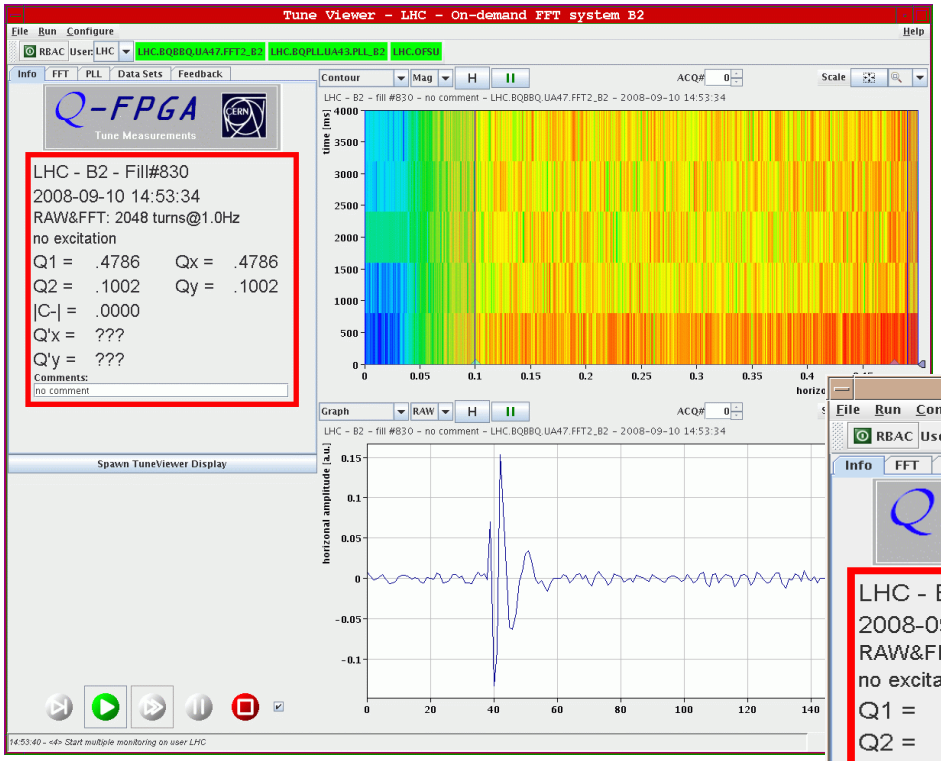
# Hands on .....
# TuneViewer – Functional Overview

- http://slwww.cern.ch/~pcrops/releaseinfo/pcropsdist/accsoft/tuneviewer/PRO/TuneViewer-LHC.jnlp



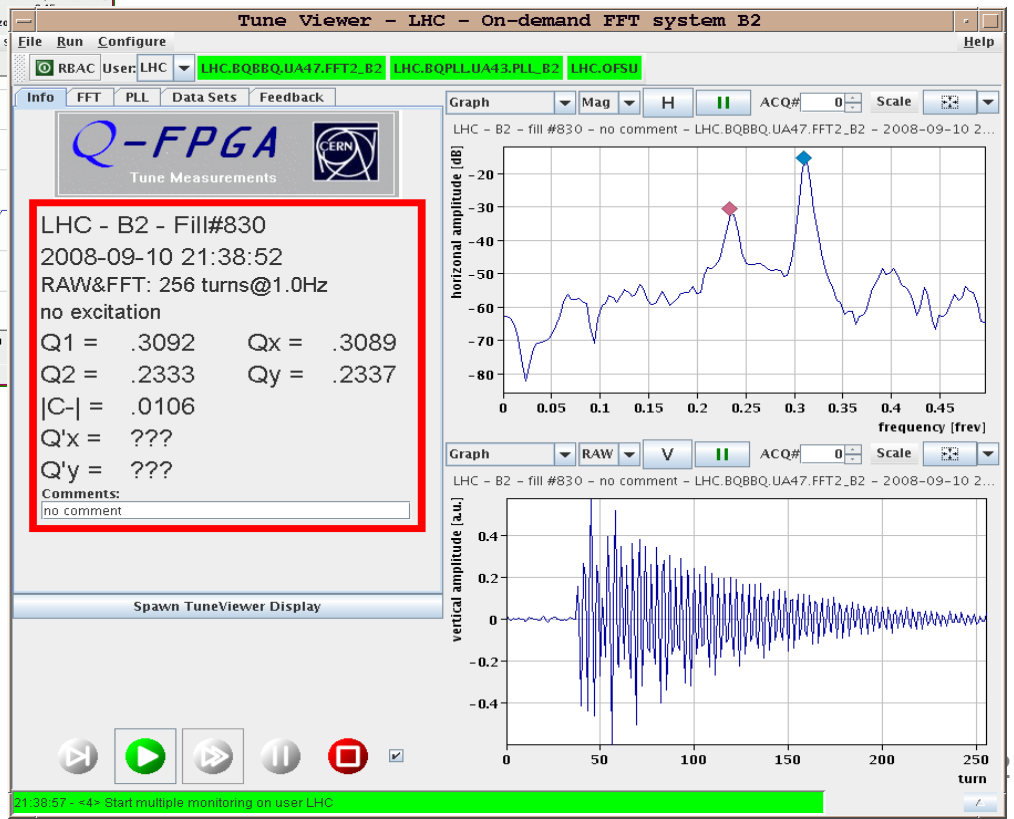
# Present Commissioning State

- BBQ systems for B2 include excitation and correction fully commissioned!



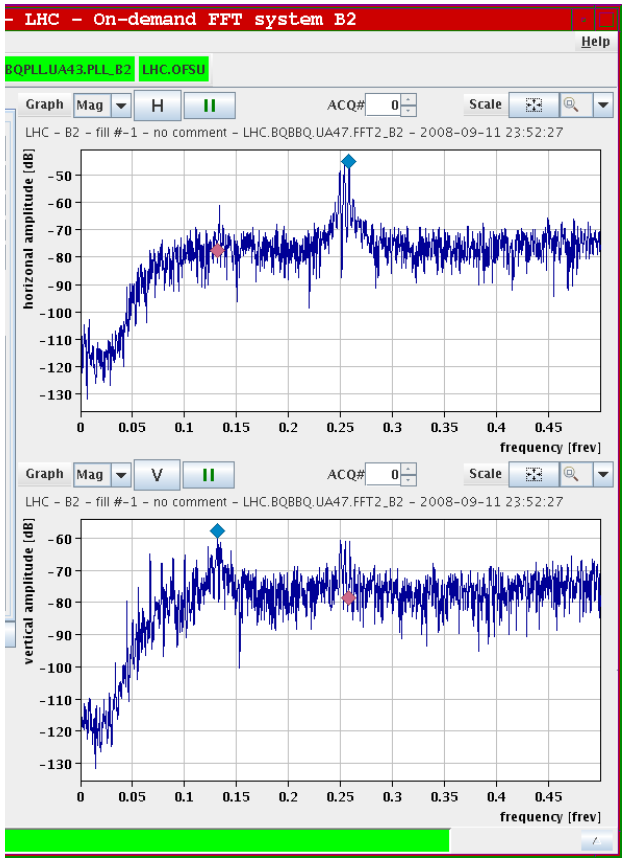

Very first turn!

first circulating beam...

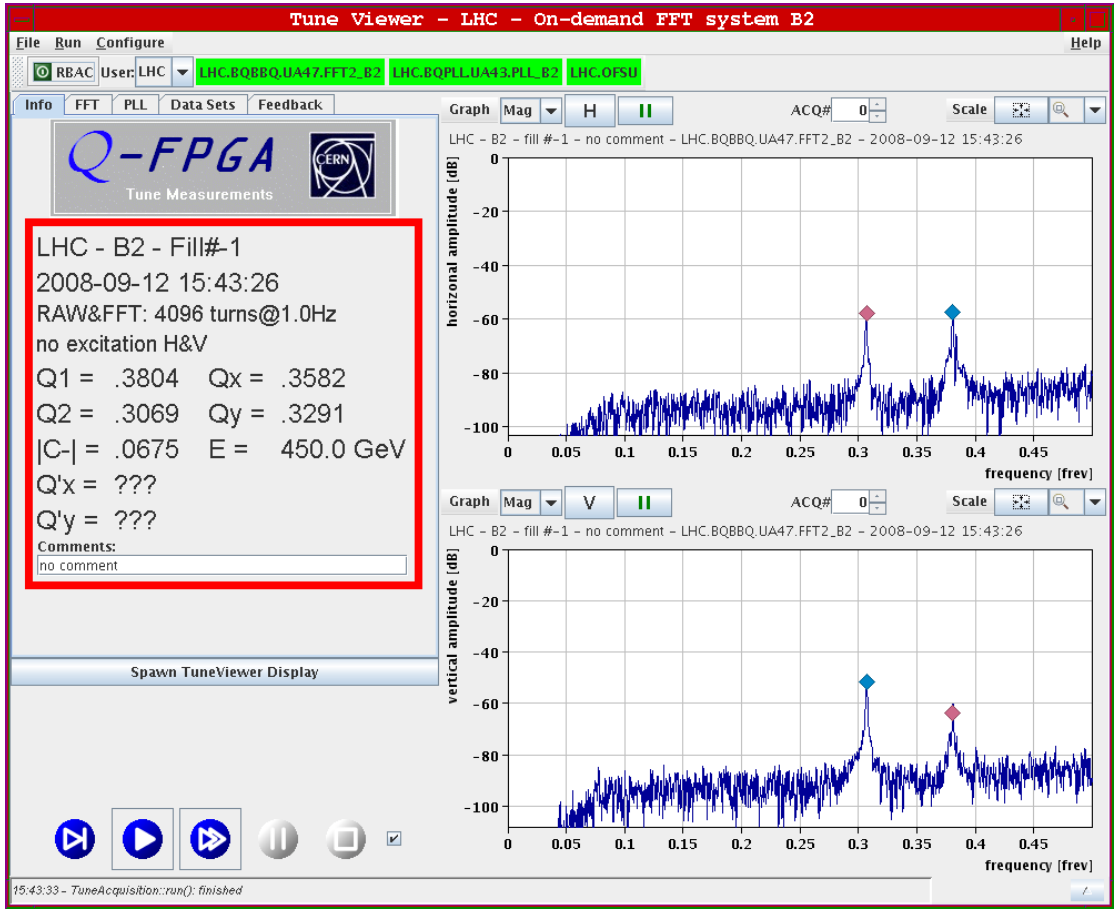


# Present Commissioning State
# ... lots of first

## ... chirp excitation



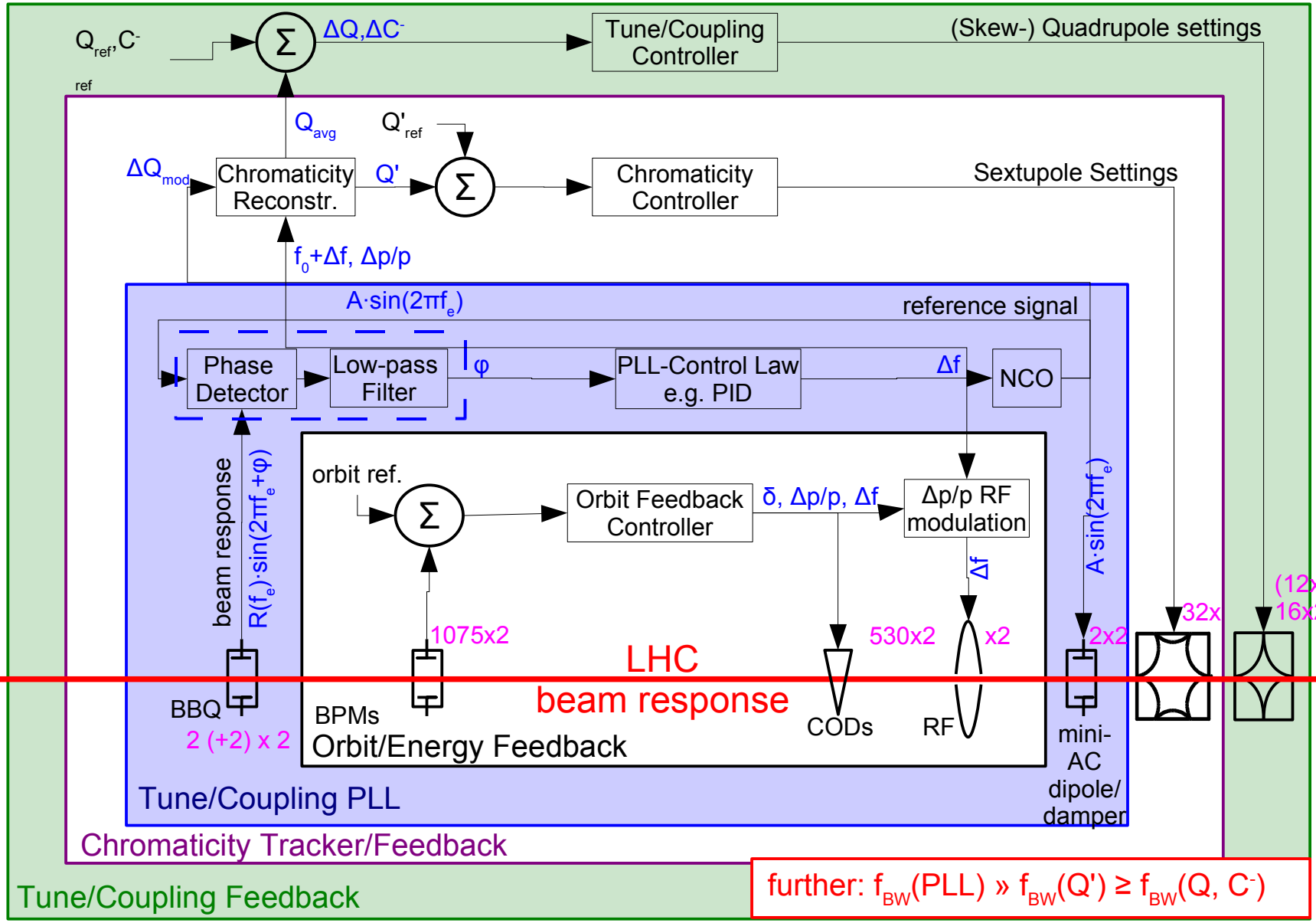

## ... coupling measurement



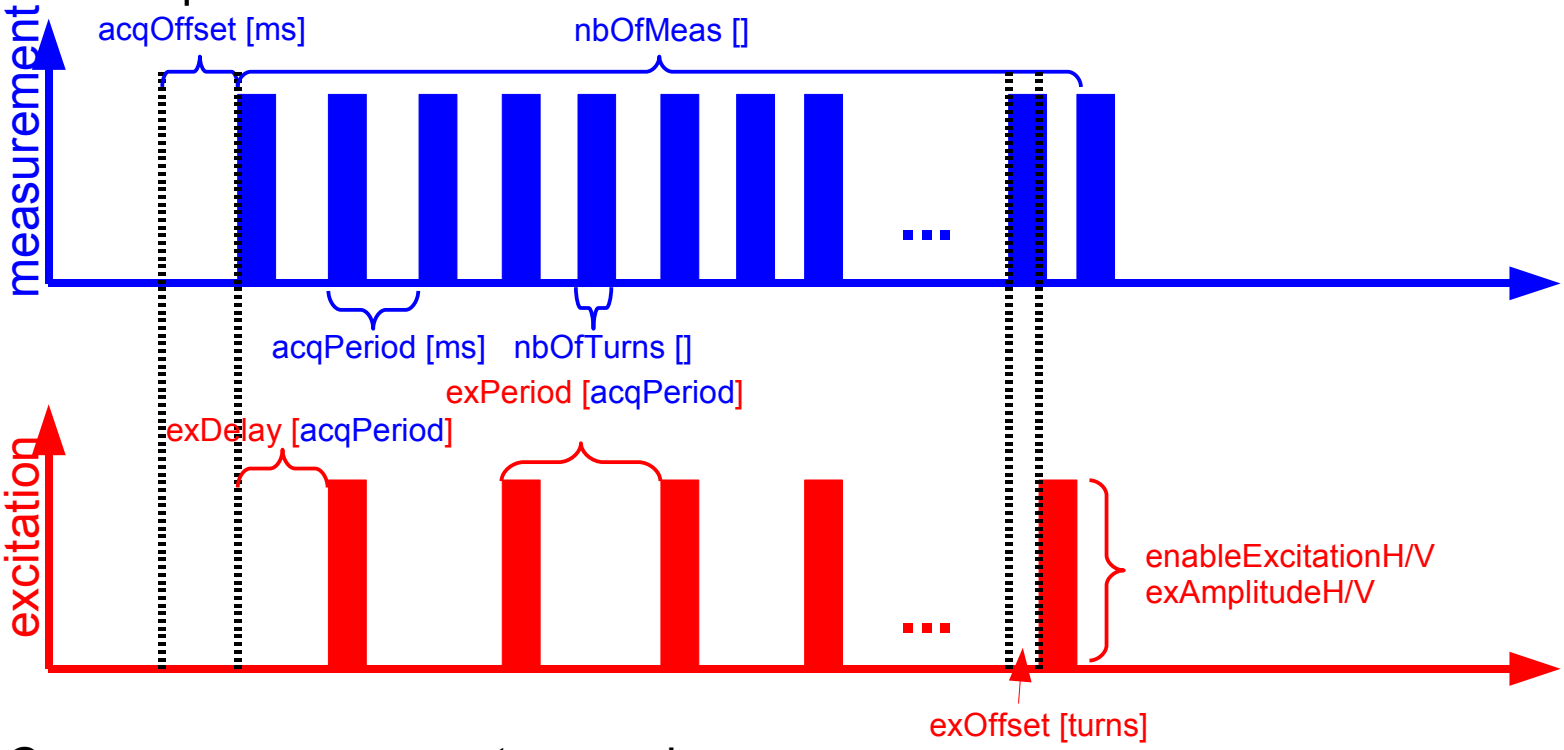
# Conclusions

- Things done:
  - Base-line fully commissioned for B2 → can be given to OP
    - Checked: FFT1, FFT2 BBQ Systems, polarities, gains, timing, RF Damper, Q and Q' correction schemes (via LSA), MKQ kicker response (synchro delay timing pending → V.Kain/BPMs), ...
- Things to be (re-) done:
  - Full commissioning of B1 FFT1 & FFT2 BBQ systems
    - first turn works (all detectors alive), plane pending
    - B1 RF damper system (amplitudes/plane)
  - Full commissioning of B1 and B2 BBQ PLL (pre-requisite for first ramp)
  - Quadrupole & sextupole circuit mapping/polarity checks
  - Automated Q' & $C^-$ measurement and correction procedure
  - Feedback on/off, cross-talk with LSA, ...
  - Training of LHC operators/EIC's
    (ongoing, many have never seen/measured/corrected Q/Q' and even less C-)
- Your comments/suggestions .....

# ...Conquer:
# Cascading between individual Feedbacks



# FFT Based Q Acquisition – 'On Demand'
# FESA 'Settings' Property




- Common measurement scenario:
  - measure (acqState=on) from injection (acqOffset=0) every 10 ms (acqPeriod=10) till 900 ms (nbOfMeas=floor(900/acqPeriod)) while kicking the beam every measurement (exDelay=0) in the vertical plane (exMode=KICK, enableExcitationH = true, enableExcitationV = false)

# FFT Based Q Acquisition – 'On Demand'
# Example: Tests at the SPS - Real-Beam Data