Head-Tail Monitor for CC Diagnostics

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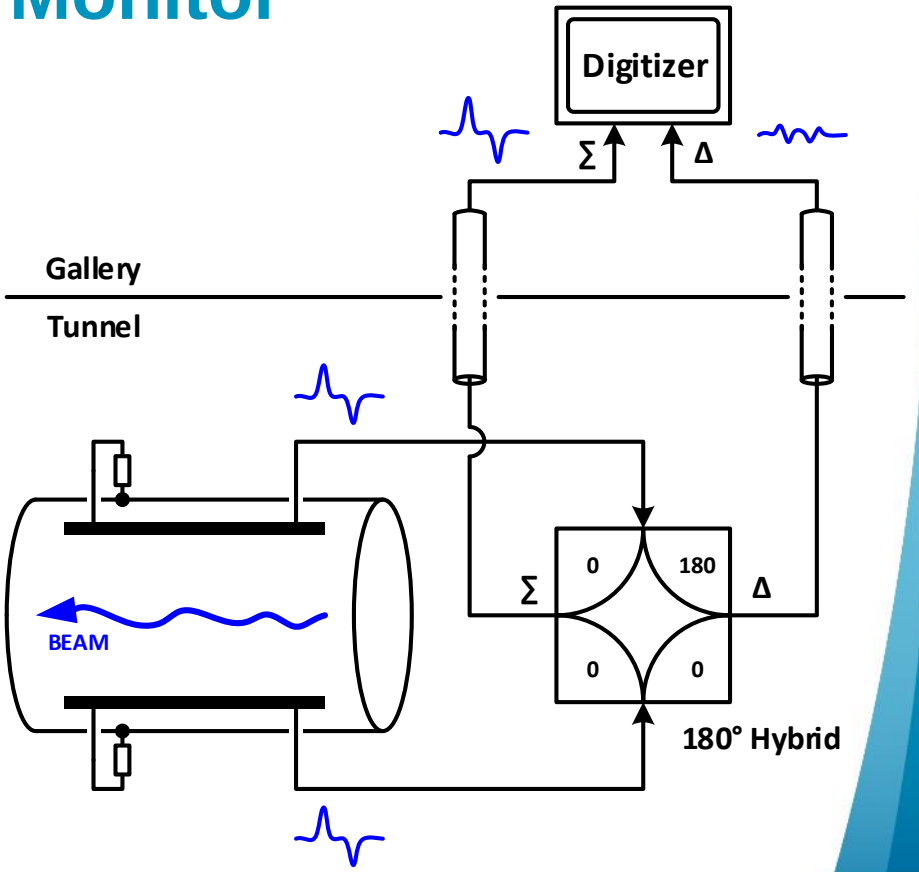
Head-Tail Monitor

LHC Head-Tail Monitor is a wide-band beam position monitor capable of measuring intra-bunch beam position.

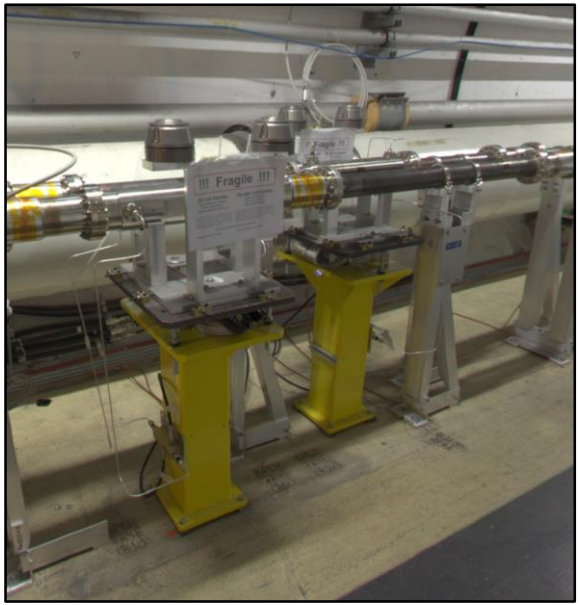
- Long strip-line BPM
- 180º analogue hybrid calculates sum (Σ) and difference (Δ)
- Signals acquired by high speed digitizer in service gallery

Originally installed in SPS/LHC for chromaticity measurements, now used primarily for instability diagnostics.

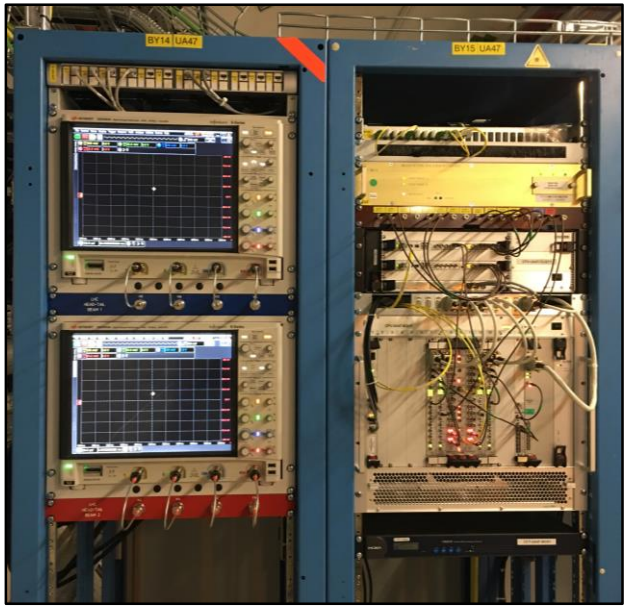


LHC Head-Tail installations

Four single plane 40cm strip-line pick-ups (BPLH/V) installed close to Q5R4/Q6R4 (locations optimised for high β)

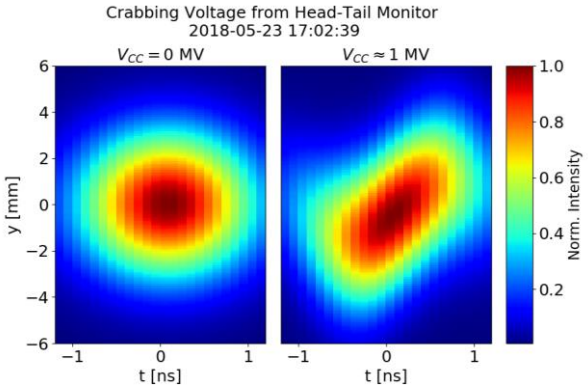


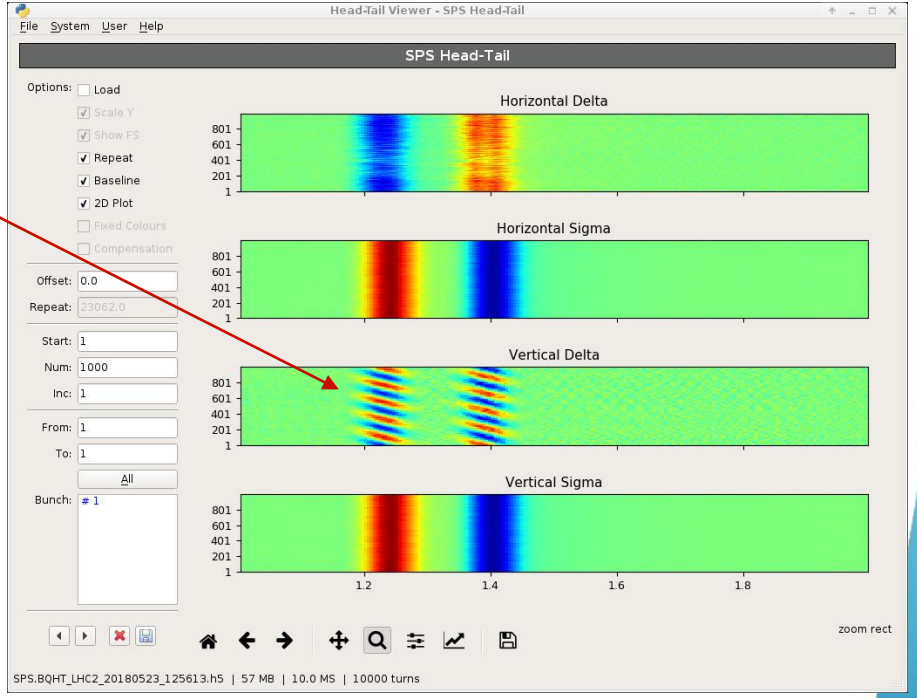
Data acquisition with commercial high-speed (10 GSPS, 10 bit) oscilloscopes in UA47



Head-Tail for CC diagnostics

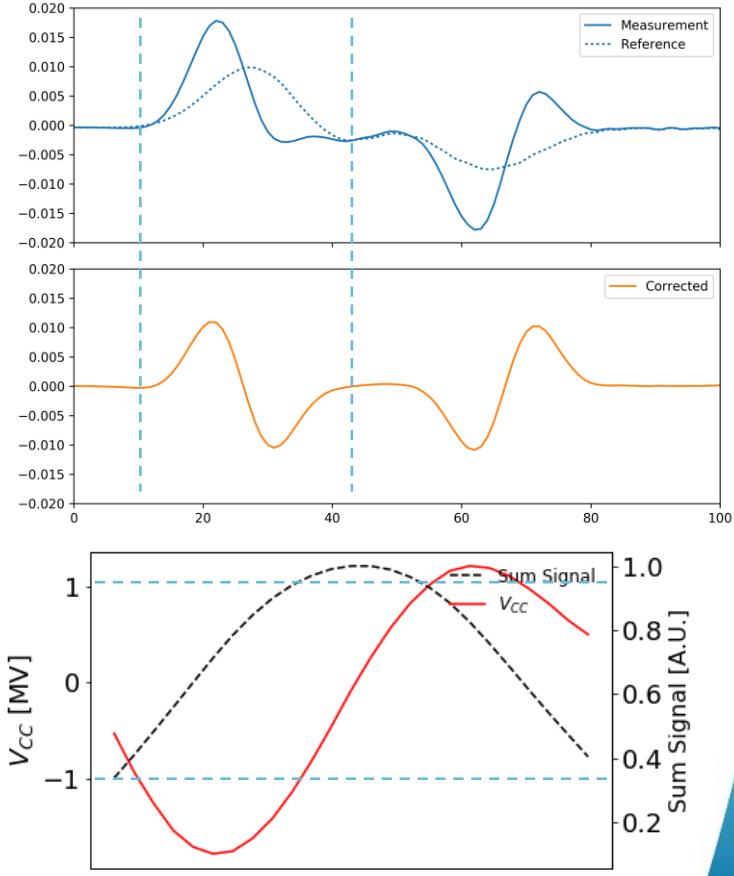
- First crabbing of a proton beam observed with the SPS HT in 2018
  - CC not phased to the RF frequency resulting in a periodic oscillation
- Reconstruction of crabbing made using measured intra-bunch position
  - Assuming a Gaussian transverse distribution





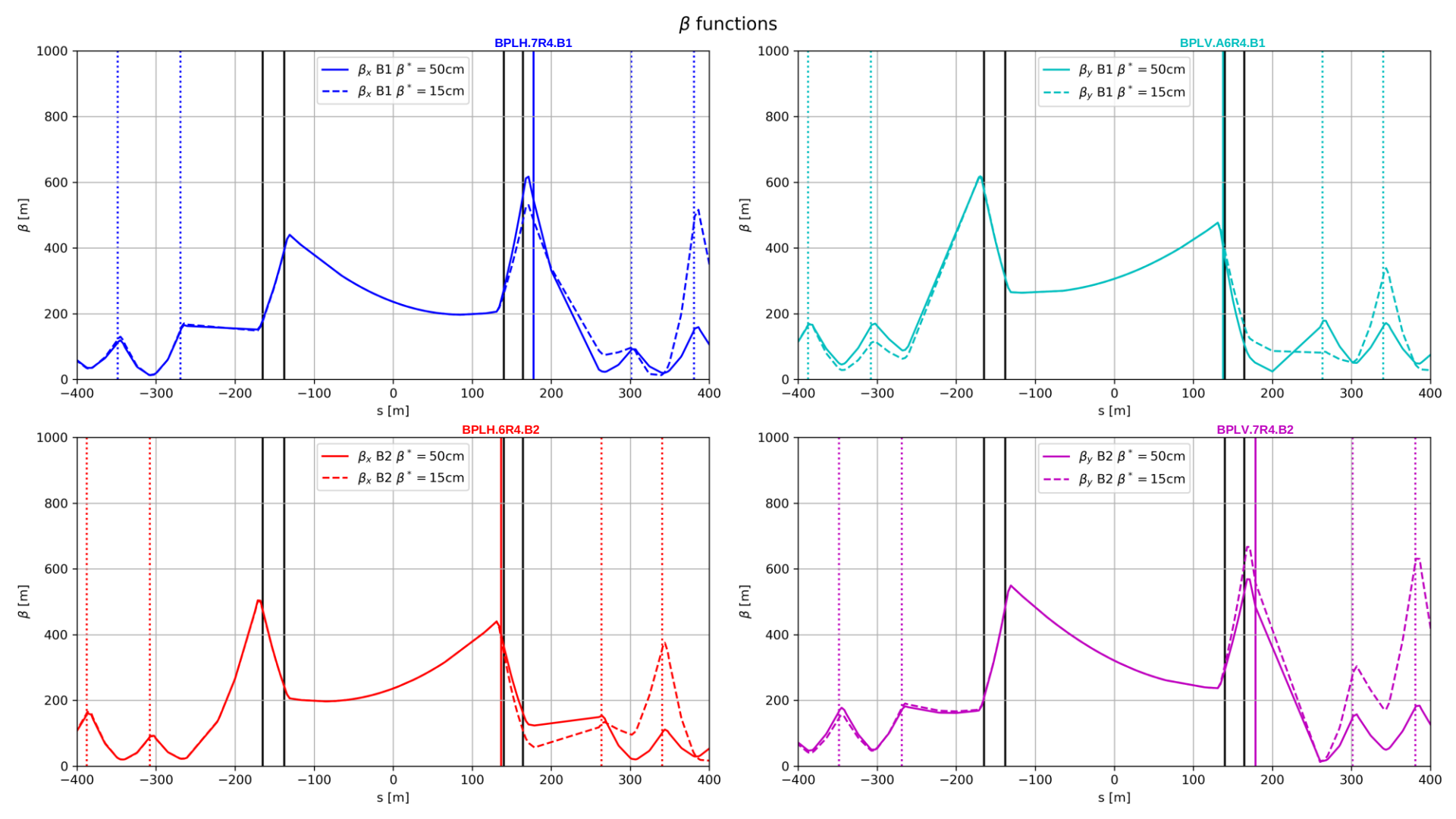
Head-Tail correction for CC

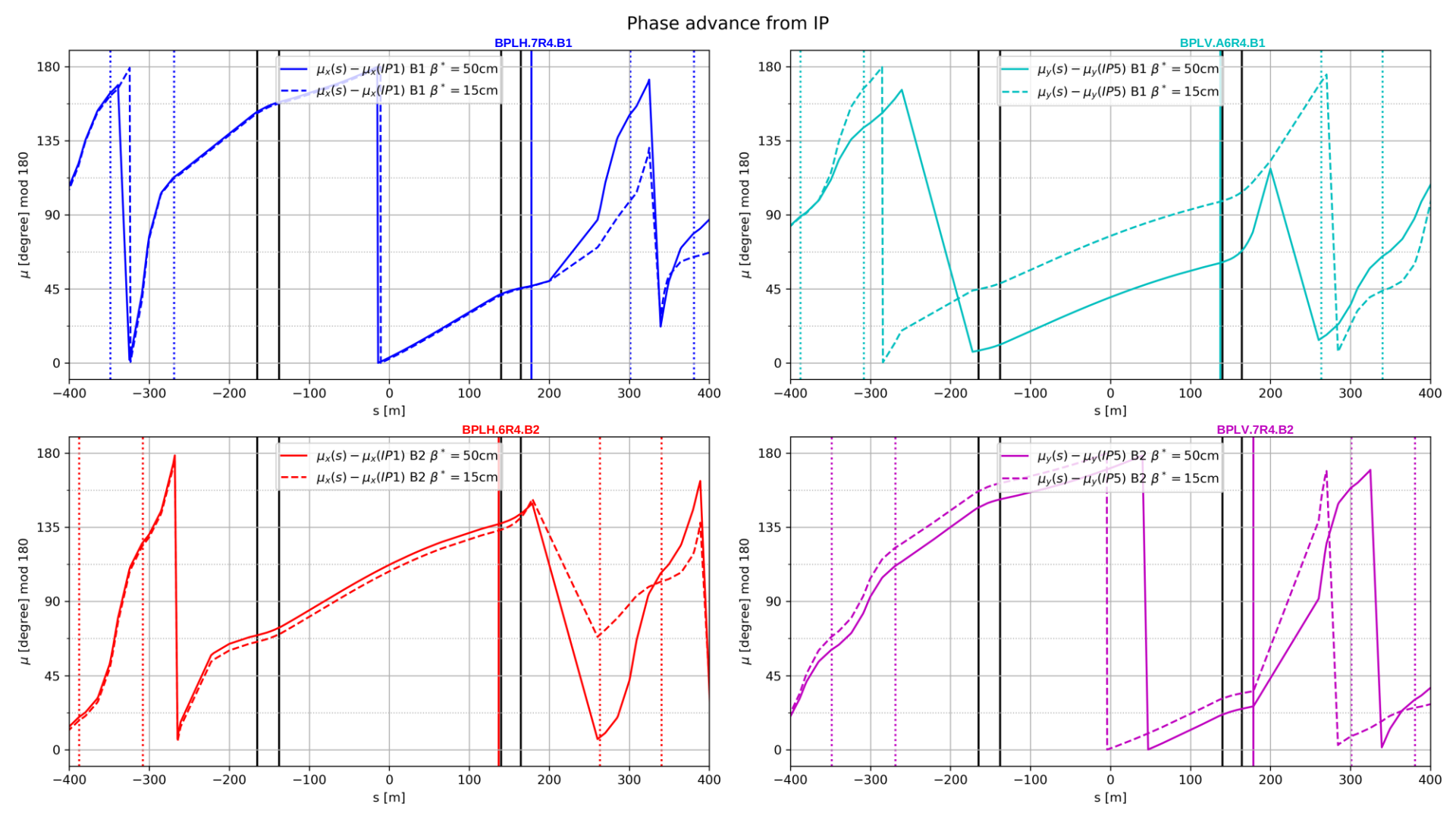
- Well phased CC results in a static intra-bunch position offset at the HT pick-up
- HT monitor measurement has a “baseline” which is superimposed on the signal
  - Orbit offset, imperfections in PU/hybrid, …
  - Reduces available dynamic range
- In SPS correction has been performed by taking a reference measurement in each cycle with the cavities un-phased or off
  - Works well, but not a technique that is applicable to long fills in HL-LHC…
- Correction of asymmetry due to PU & cable response also needed

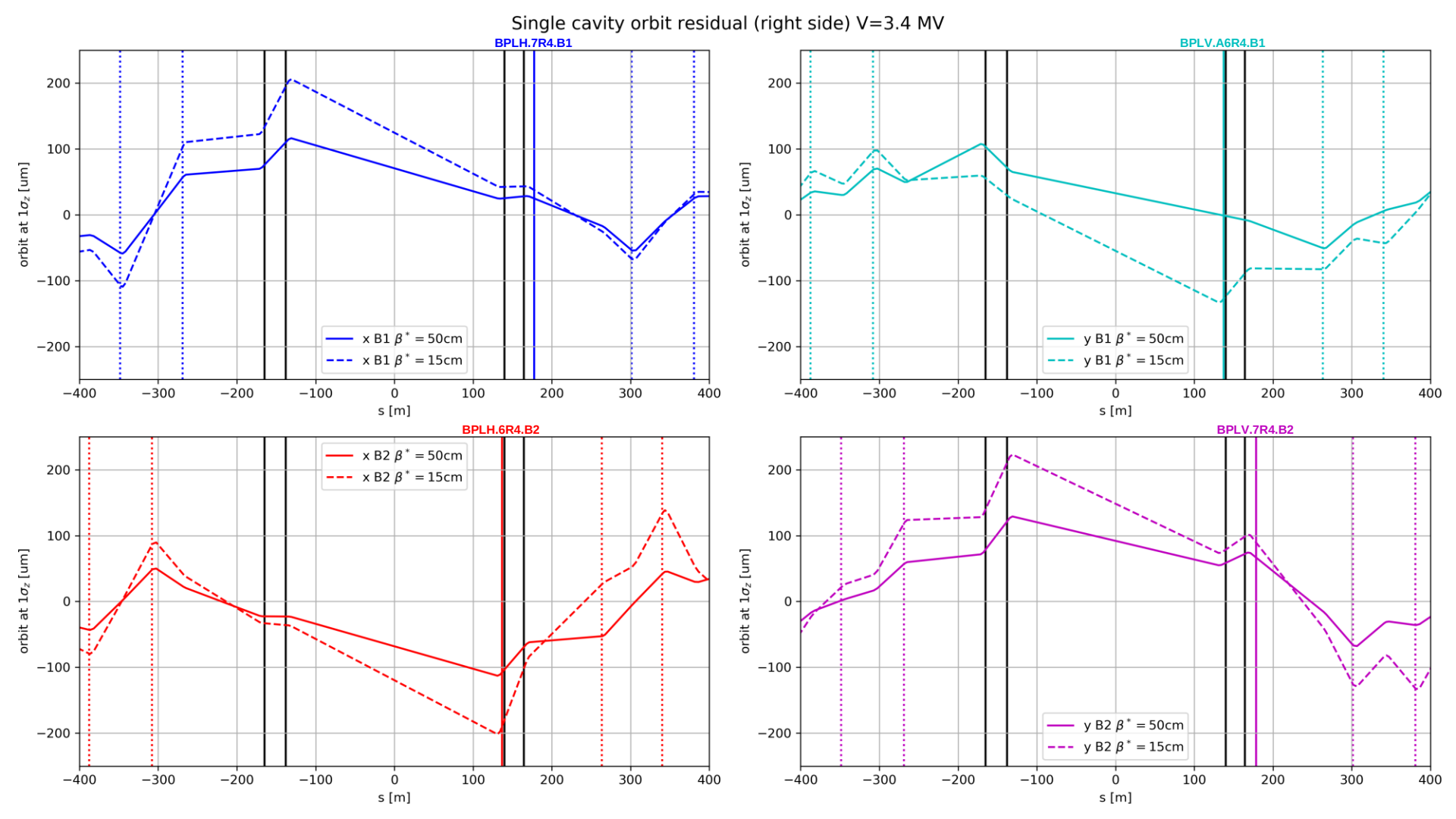


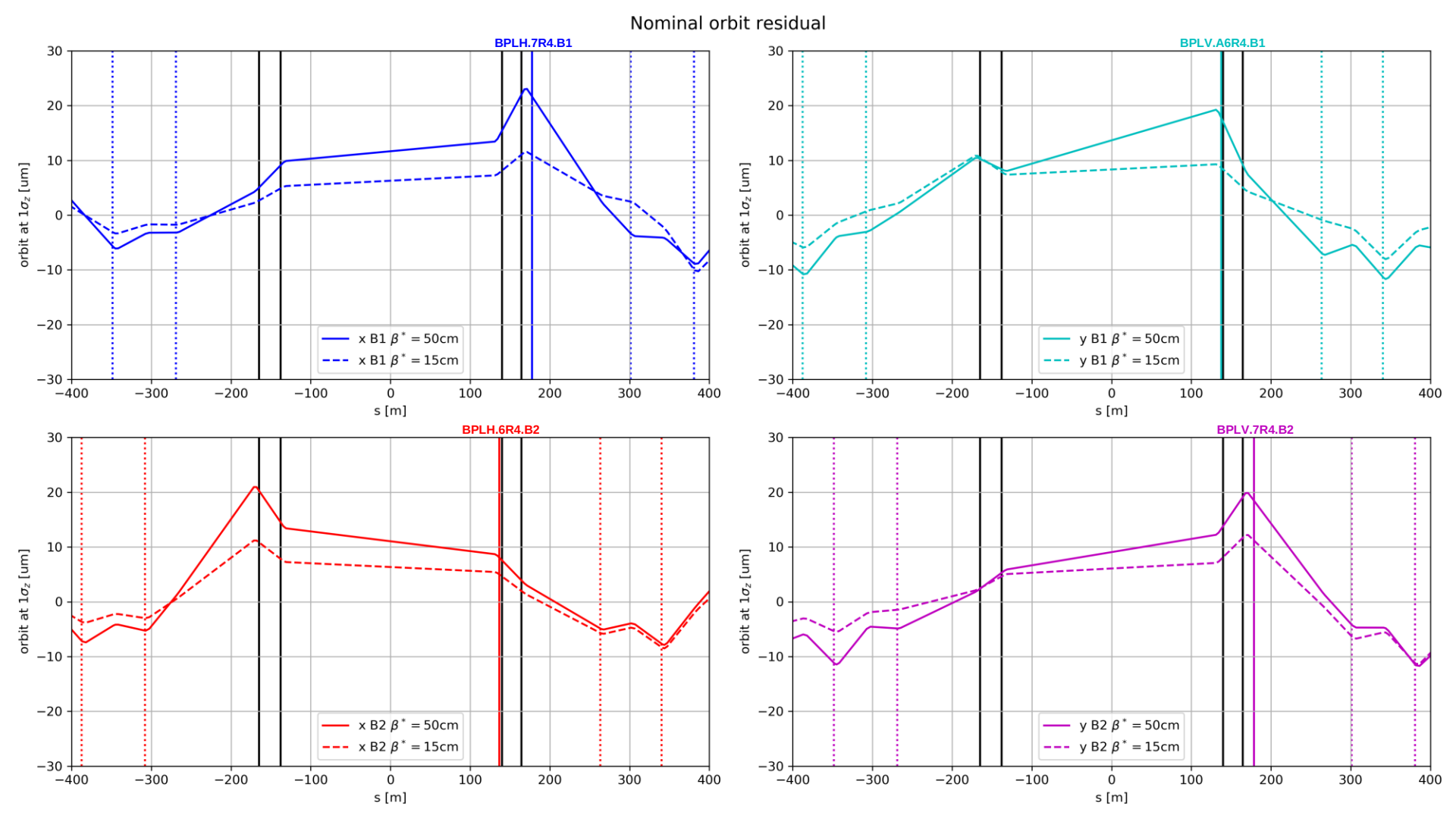
HT in HL-LHC

- Existing HT monitor locations optimised for high β
  - BPLH.7R4.B1 & BPLV.A6R4.B1
  - BPLH.6R4.B2 & BPLV.7R4.B2
- These locations do not necessarily have good phase advance with respect to the CC in IP1[H] and IP5[V]
- ~1m of space reserved between Q5 and Q6 on both left and right of P4 (location of existing BQK) for new pick-ups
  - LHC-BPW-EC-0001
- Pick-up type (EO vs. standard, etc) not yet decided
  - Baseline is 1 BPM per beam/plane


β functions
BPLH.7R4.B1
β_x B1 $\beta^* = 50$cm
β_x B1 $\beta^* = 15$cm
BPLV.A6R4.B1
β_y B1 $\beta^* = 50$cm
β_y B1 $\beta^* = 15$cm
BPLH.6R4.B2
β_x B2 $\beta^* = 50$cm
β_x B2 $\beta^* = 15$cm
BPLV.7R4.B2
β_y B2 $\beta^* = 50$cm
β_y B2 $\beta^* = 15$cm
β [m]
s [m]


Phase advance from IP
BPLH.7R4.B1
$\mu_x(s) - \mu_x(IP1)$ B1 $\beta^* = 50$cm
$\mu_x(s) - \mu_x(IP1)$ B1 $\beta^* = 15$cm
BPLV.A6R4.B1
$\mu_y(s) - \mu_y(IP5)$ B1 $\beta^* = 50$cm
$\mu_y(s) - \mu_y(IP5)$ B1 $\beta^* = 15$cm
BPLH.6R4.B2
$\mu_x(s) - \mu_x(IP1)$ B2 $\beta^* = 50$cm
$\mu_x(s) - \mu_x(IP1)$ B2 $\beta^* = 15$cm
BPLV.7R4.B2
$\mu_y(s) - \mu_y(IP5)$ B2 $\beta^* = 50$cm
$\mu_y(s) - \mu_y(IP5)$ B2 $\beta^* = 15$cm
μ [degree] mod 180
s [m]


Single cavity orbit residual (right side) V=3.4 MV
BPLH.7R4.B1
BPLV.A6R4.B1
BPLH.6R4.B2
BPLV.7R4.B2
orbit at $1\sigma_z$ [um]
s [m]
x B1 β^* = 50cm
x B1 β^* = 15cm
y B1 β^* = 50cm
y B1 β^* = 15cm
x B2 β^* = 50cm
x B2 β^* = 15cm
y B2 β^* = 50cm
y B2 β^* = 15cm


Nominal orbit residual
BPLH.7R4.B1
BPLV.A6R4.B1
BPLH.6R4.B2
BPLV.7R4.B2
orbit at $1\sigma_z$ [um]
s [m]
x B1 β^* = 50cm
x B1 β^* = 15cm
y B1 β^* = 50cm
y B1 β^* = 15cm
x B2 β^* = 50cm
x B2 β^* = 15cm
y B2 β^* = 50cm
y B2 β^* = 15cm

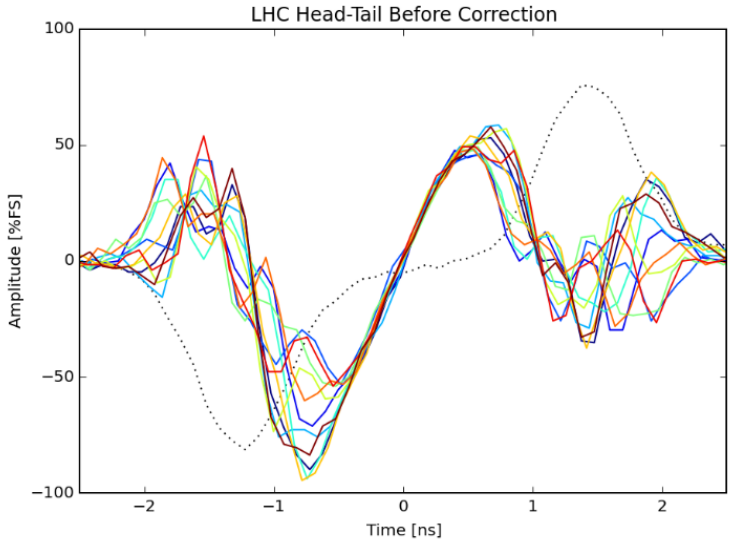
(Preliminary) Conclusion

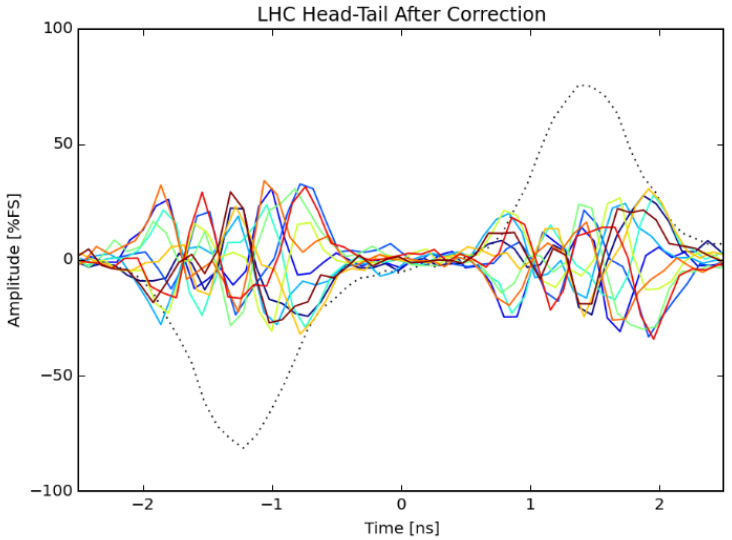
- Based on the latest optics, although the phase advances are not optimal, the crabbing *should* be visible at the current HT pick-ups (with averaging)
  - Order of 10µm residual for both cavities on (at the limit)
  - Order of 100µm for single cavity at 3.4 MV
- Some possibility for optimisation by moving pick-ups
  - Note: optimum for single cavity is not the same as for the residual
- Space of existing BQK has been reserved for new pick-ups
  - Exact technology choice (EO vs. standard) not yet decided
- Still some open questions for the signal processing to be investigated
  - Baseline evolution with bunch parameters
  - How to do baseline correction during a long fill
  - Cable transfer function deconvolution

Thank you

Correction for instability diagnostics

- Baseline corrected by subtracting average of many turns of signal
- Removes baseline, preserves varying signal





HT Monitor upgrade YETS17-18

- During YETS17-18 new oscilloscopes have been installed for LHC & SPS HT monitors:

Model	Samp.	Res.	Turns	Readout	File Size
Old	10 GSPS	8-bit	11	3 MB/s	40 MB
New	10 GSPS	10-bit	451	170 MB/s	3.2 GB

- Significant upgrade in resolution, acquisition length and readout speed compared to old models
- New dedicated 10 GbE fiber link from UA47 to dedicated storage server in CCR to avoid saturating technical network
- Pick-ups, hybrids & cabling are unchanged

HT Monitor upgrade YETS17-18