



WP13: Results from the upgraded Head-Tail Monitor for instability and crab diagnostics as input for HL specifications

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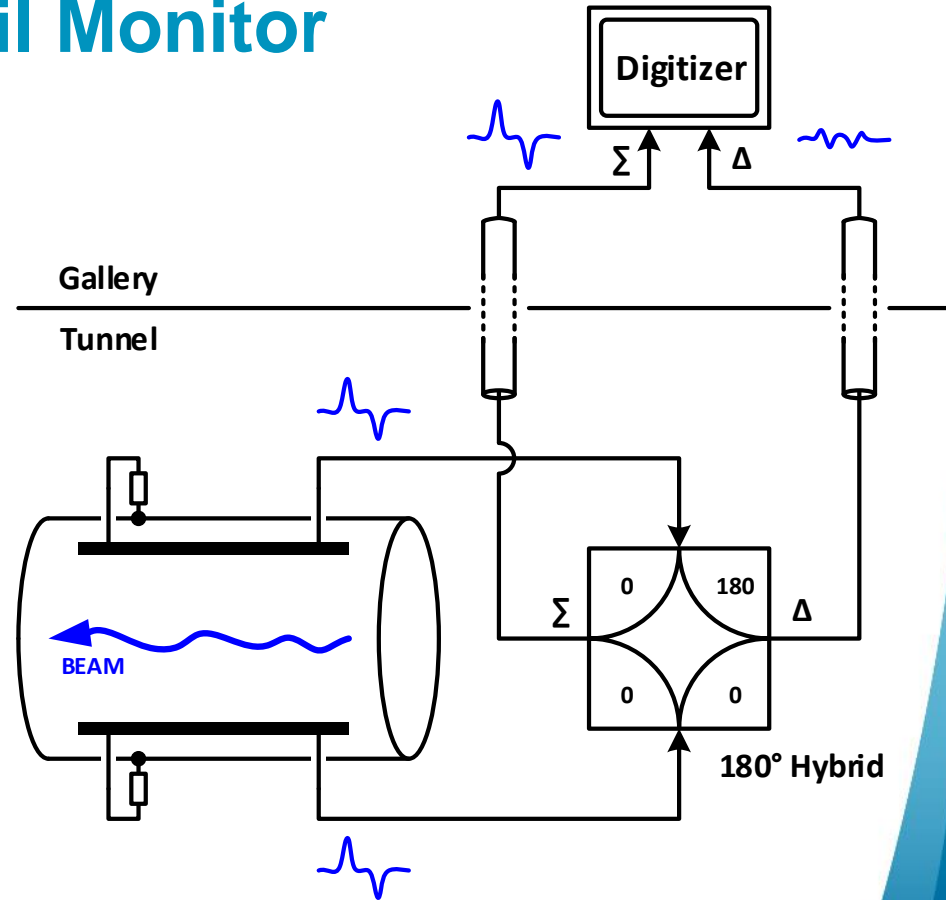
8th HL-LHC Collaboration Meeting, 15-18 October 2018, CERN

Outline

- Head-Tail Monitor introduction
- Upgrades performed during YETS17-18
- Instability monitoring
 - Usage
 - Limitations
 - Outlook for HL-LHC
- Crab cavity diagnostics
 - Results from SPS tests
 - Outlook for HL-LHC

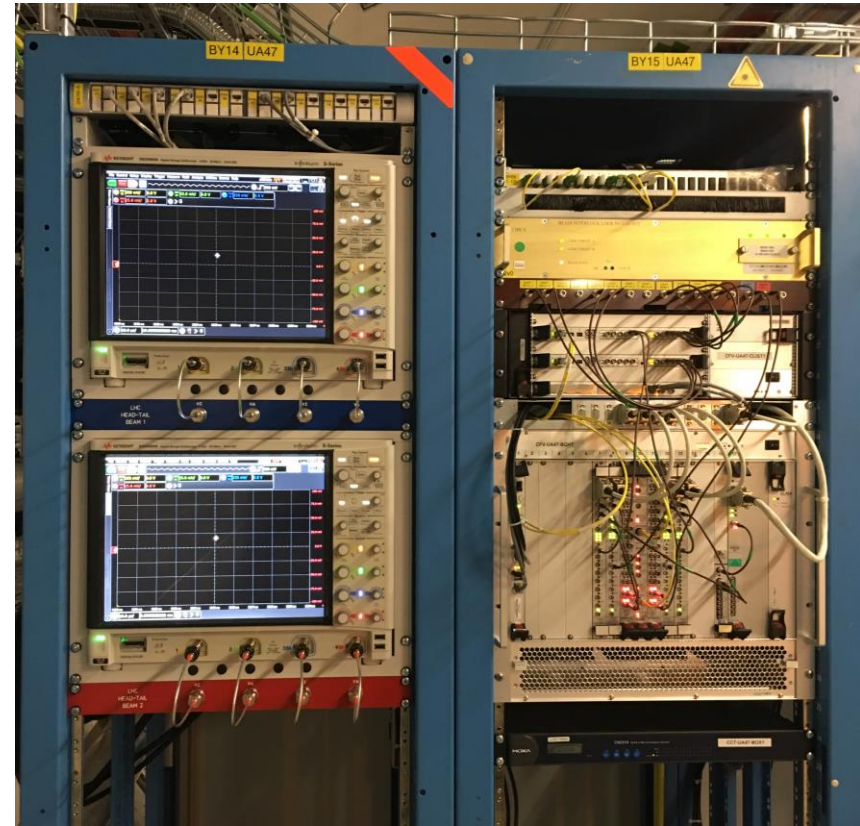
Head-Tail Monitor

- Wideband beam position monitor capable of measuring intra-bunch beam position
- 180° hybrid in tunnel calculates analogue sum and difference of long stripline BPM electrodes
- Signals acquired after short cables by high speed digitizer located in service gallery
- Originally installed in SPS/LHC for chromaticity measurements, now used primarily for instability diagnostics.



Head-Tail installations

- Single plane stripline pick-ups (BPLH/V) installed at positions optimised for high beta functions close to Q5R4/Q6R4
- Data acquisition with commercial high-speed oscilloscopes in UA47
- Readout from VME FEC via USB
- Flexible trigger system generates beam synchronous triggers
- Similar setup in SPS HCA4



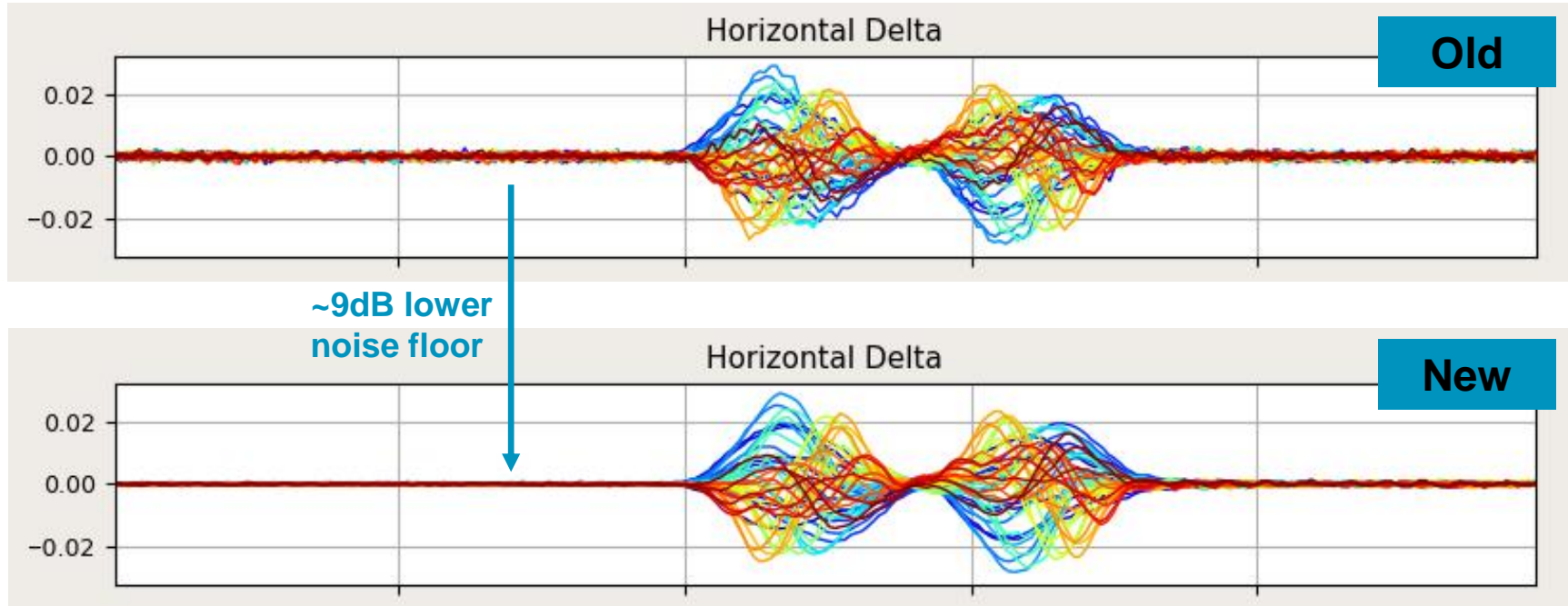
HT Monitor upgrade YETS17-18

- 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

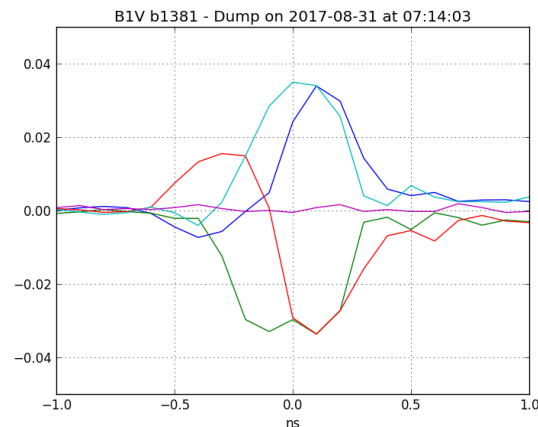
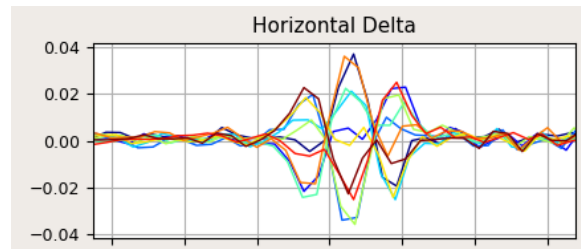
- Significant upgrade in resolution, acquisition length and readout speed compared to old models
- New dedicated 10 GbE fiber link from UA47 to dedicated storage server in CCR to avoid saturating technical network
- Pick-ups, hybrids & cabling are unchanged

HT Monitor upgrade YETS17-18



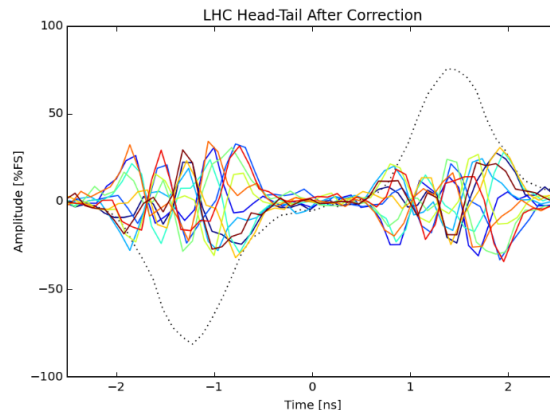
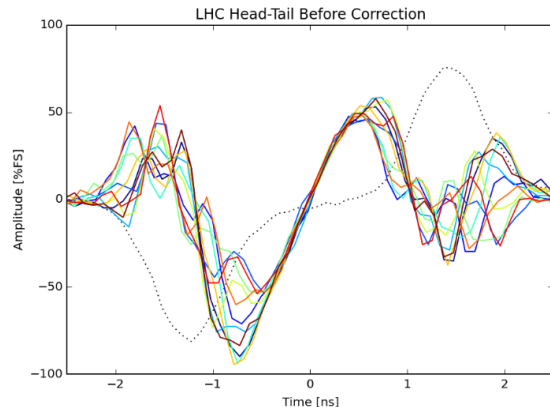
Usage for instability diagnostics

- Automatic “instability” trigger system used during operation
 - Detects growth of an instability in BBQ data
 - Sends a trigger to the HT
- Since mid-2017 last turns before a beam dump are systematically recorded
 - For 16L2 diagnostics
- Raw data stored to disk
- Data processing steps are performed offline with Python tools



Limitations of current system

- Large residual “baseline” signal due to imperfections in hybrid and orbit offset in pickups
 - Can be corrected by removing average of many turns of signal
 - Reduces dynamic range
- Current data processing is slow
 - Takes minutes on a server class PC to process ~100 turns of data
 - Large amounts of data need to be stored

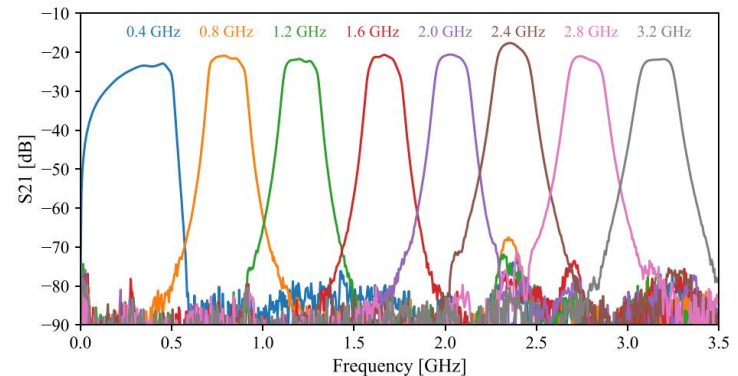
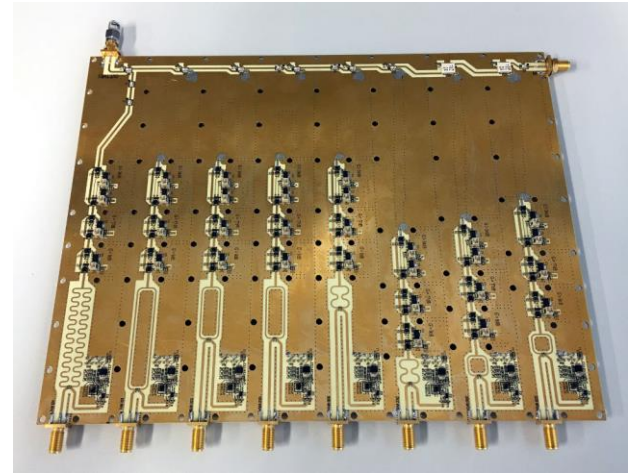


Outlook for HL-LHC

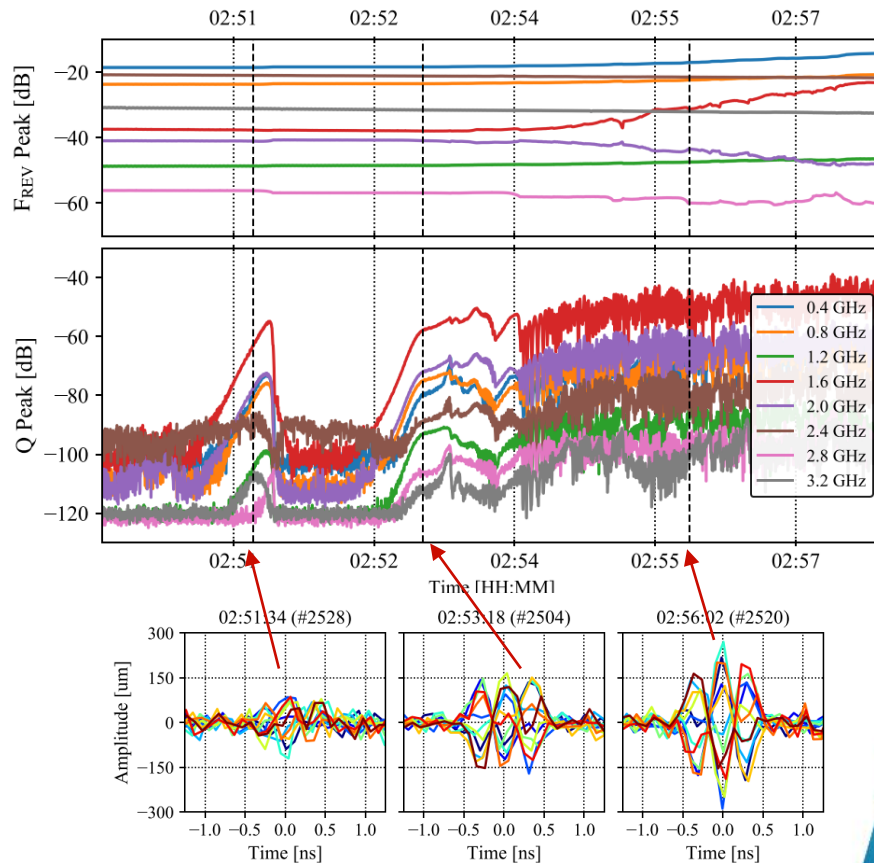
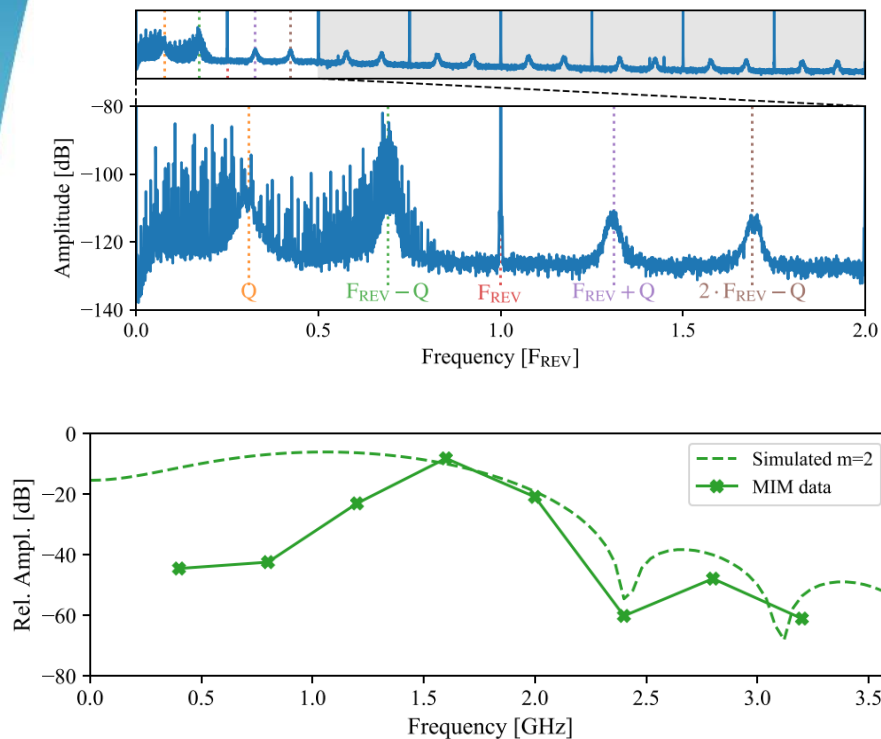
- So far the requirements for instability diagnostics for HL-LHC look to be very similar to LHC:
 - “Bunch by bunch everything all the time”
- Still many areas where improvements could be foreseen:
 - New digitizers as technologies continue to progress
 - Potential of EO-BPM for higher bandwidth and to remove limitations of hybrids
 - See next talk from Alberto
 - Improvements to data treatment and post processing
- Other techniques for online instability detection as a complement to direct digitisation being studied
 - Initial results from Multi-Band Instability Monitor presented at IBIC 2018

Multi-Band Instability Monitor

- New measurement technique to achieve higher sensitivity than Head-Tail Monitor
- Measures transverse instability using frequency domain sampling
- RF filter bank selects different components of the beam spectrum
- Each band is mixed down and sampled with high resolution diode detectors (similar to BBQ)

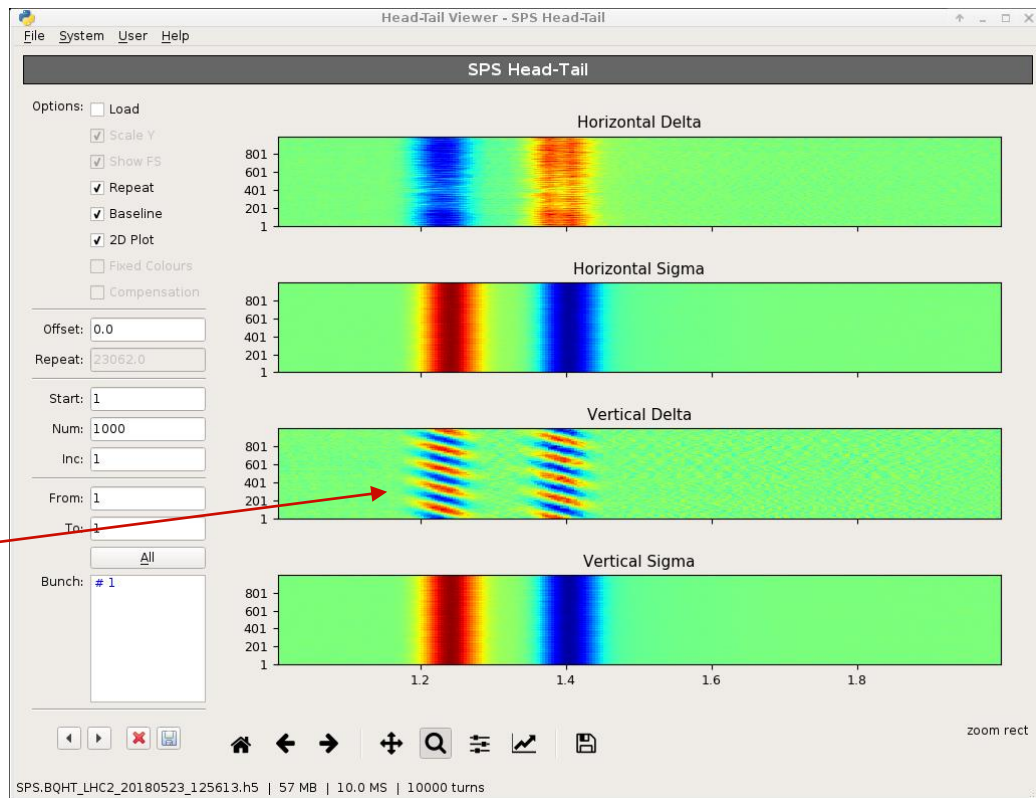


Multi-Band Instability Monitor Results



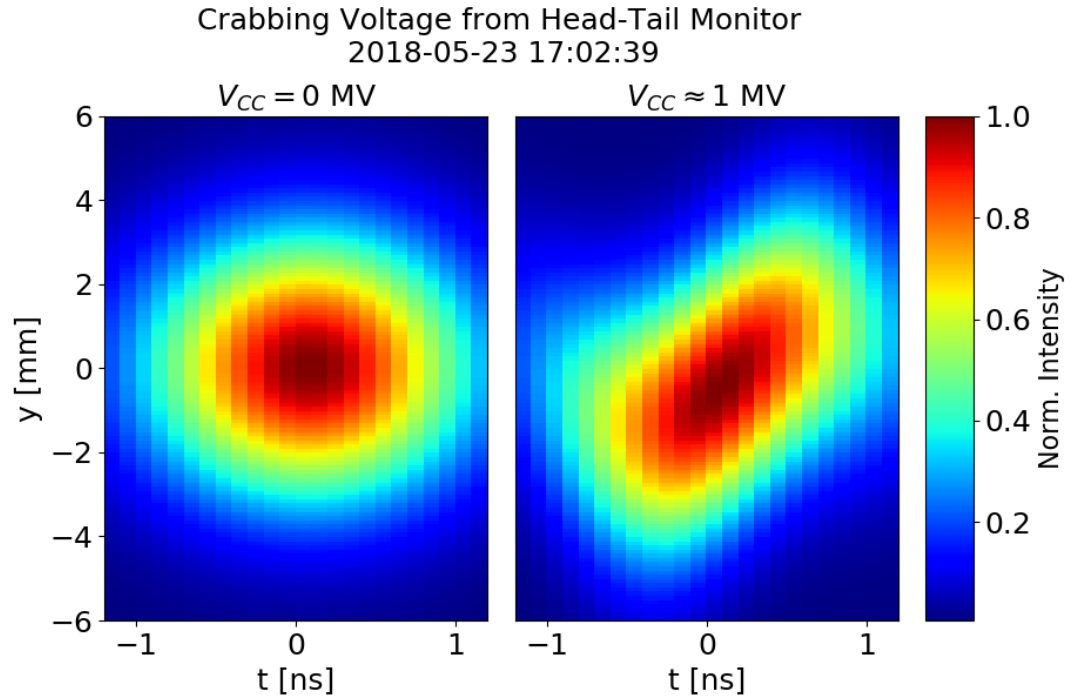
Head-Tail for CC diagnostics

- First crabbing of a proton beam observed with the SPS Head-Tail Monitor on 5th May at 12:55
 - The very first shot injected through the cavities!
- CC not phased to RF frequency resulting in clear periodic oscillation



Reconstruction of crabbing

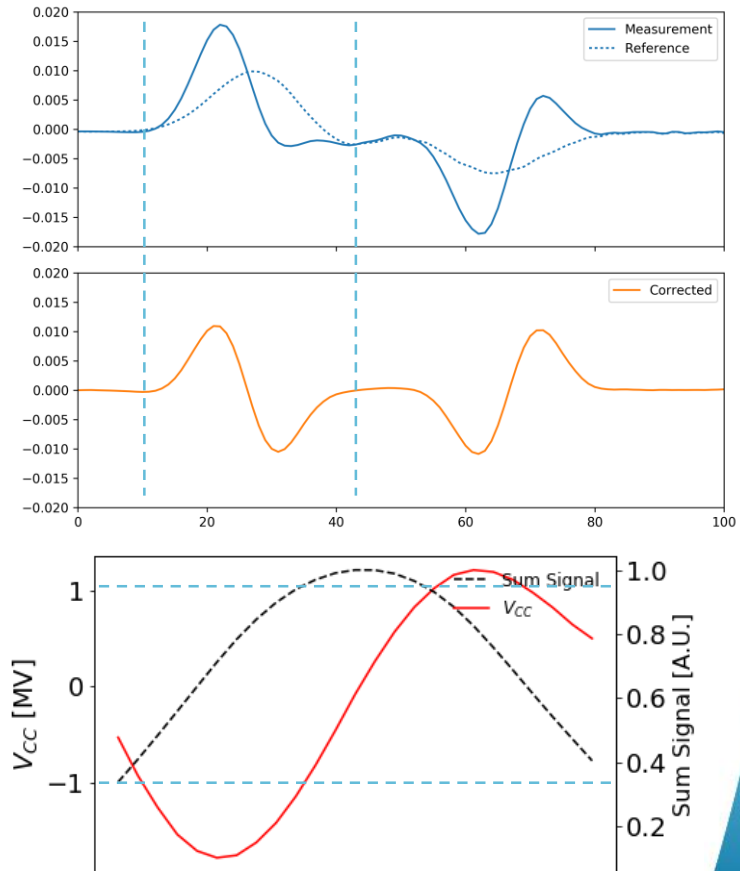
- Reconstruction of crabbing from HT monitor data
- Uses measured intra-bunch position distribution from Head-Tail Monitor
- Assumes a Gaussian transverse distribution



Courtesy L. Carver

Head-Tail correction for CC

- Well phased CC results in a static intra bunch position offset at the HT pick-up which would be removed by baseline removal
- In SPS, baseline 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...
- Further correction of asymmetry due to cable response under study



Existing LHC HT pickups

Pickup	Beta	Phase CC IP1	Phase CC IP5
BPLH.7R4.B1	482 m	136 deg	273 deg
BPLV.A6R4.B1	417 m	68 deg	187 deg
BPLH.6R4.B2	384 m	318 deg	330 deg
BPLV.7R4.B2	556 m	188 deg	170 deg

- Existing HT pick-ups generally at bad phase advances with respect to the LHC CC locations
- Will need new pick-ups for CC diagnostics
 - Space reservation: LHC-BPW-EC-0001
 - Final pickup type and locations still to be confirmed
 - Depends on final orientation of CCs in IP1 and IP5

Outlook for HL-LHC

- Crabbing measurements in HL-LHC remain challenging
- Pickups will be outside crab bump
 - Can only measure residual crabbing (% level) in operational scenarios
- Correction of baseline throughout fill non-obvious
 - Potential for improvement by replacing hybrids with an EO solution
 - May require closed orbit suppression in pickups
- Alternative processing schemes to achieve higher sensitivity are under investigation

Conclusion

- LHC and SPS Head-Tail Monitors provide intra-bunch beam position measurements
- Acquisition systems upgraded during YETS17-18 to offer increased dynamic range and longer record length
- Continues to provide valuable data for instability measurements in LHC and SPS
- Provides a direct measurement of crabbing
 - Has been a vital instrument for CC tests in SPS during 2018
- Potential upgrades for HL-LHC are under study...



Thank you

