ADT Post-LS1

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From *Evian’14*: “ADT pre-LS1” …

… to *Evian’15*: “ADT Post-LS1”

Back in Business …
Recap ADT: Transverse Feedback System

The transverse damper is a feedback system: it measures the bunch-by-bunch oscillations and damps them by fast electrostatic kickers.

Closed Loop Feedback $\rightarrow$ modified Target Response $T(s)$:

$$T(s) = \frac{X(s)}{Y(s)} = \frac{OL(s)}{1+OL(s)}$$

$OL(s) = G H_S H_C H_A \ldots$ open loop transfer function

Key Parameters:
- $K$ ... Feedback loop gain
- $\phi_{PK}$ ... Feedback phase
- $T$ ... Total loop delay

Primarily designed for:
- Damping of injection oscillations
- Counteract coupled bunch instability
- Preservation of the transverse beam emittance

... plus more and more features added during run 1
Outline

- Improvements applied during LS1
- Features, present uses of the ADT in different contexts
- Issues and possible mitigation for 2016 run
- Operation with doublets
- ADT settings, operation, and experts?
- Outlook 2016
LS1: New PUs Q8/Q10 prepared (1)

- Four pick-ups per beam, per plane, located at point 4
  - Stripline PUs (constant coupling type)
  - All BPMCs existing (pick-up swap with BPF system)
  - Improvement in S/N by doubling the number PUs → Plan for 2016

### Table

<table>
<thead>
<tr>
<th>Beams</th>
<th>Layer 1</th>
<th>Layer 2</th>
<th>Layer 3</th>
<th>Layer 4</th>
<th>Layer 5</th>
<th>Layer 6</th>
<th>Layer 7</th>
<th>Layer 8</th>
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<td>Q8L</td>
<td>Q7L</td>
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LS1: New PUs Q8/Q10 prepared (2)

“Câbleur deluxe”
LS1: Cabling re-done (1)

Improvements applied during LS1:

- Replacement of PU cables to Q7/Q8/Q9/Q10 (corrugated coax vs. smooth wall)

- New cables for 8 drive signals from surface (SR4) to UX45 (better pulse for AGC) → lower losses + digitally phase compensated
LS1: Cabling re-done (2)

New cables qualified on the spot, to ensure quality of installation:
- Trace and locate defects in cables
- Identification of degradation due to installation process
- Electrical length matched to <25ps (+/-5mm for 800m cable!)

Result 1: **LS1 Re-cabling campaign was a big success** → unprecedented signal quality for beam position processing!

Result 2: We do have excellent WiFi coverage on CERN campus… Come and join us in the cable ducts!

/ ADT Post-LS1 – G. Kotzian
LS1: ADT Power System

Power amplifiers
- Maintenance (cleaning, divider calibration, re-commissioning in B.867)
- New relay plates
- New air cooling system
- New air cooling pipes
- New 200W loads
- Removal of pre-heating resistances
- New water flow meters in RB44 – RB46
- New clamp between amplifiers and kickers
- New clamp between kickers striplines and feedthroughs
- Additional vacuum gauge in RB44 (3 gauges per beams and on each sides, 12 in all)

Anode Power converters
- Cleaning
- Exchange all fans
- Adding new H.V. switches (command off/online remotely)

Status of changes with respect to run 1: increased reliability and availability
LS1: New Signal Processing Unit: \textit{mDSPU (1)}

Goals and changes from Run1 to Run 2:

- Possibility to combine \textbf{four pick-ups} → digital, currently 2 in use for Q7 & Q9
- Separate control for all features with high resolution → calls for \textbf{independent output DACs}
- Implementation of all \textbf{added features} during run 1 → more \textbf{powerful digital signal processing}
- High bandwidth \textbf{digital links} to observation box
- Complementary \textbf{data processing algorithm} to detect anti-symmetric intra-bunch motion (\textit{Todo})

Result: \textbf{New Signal Processing HW} developed during LS1, \textbf{suitable in performance} to comfortably integrate all requested features

Synergy between SPS Damper upgrade and new LHC hardware:
All tests successfully passed in the SPS in 2014 → further enhanced for LHC ADT startup in 2015
LS1: New Signal Processing Unit: \textit{mDSPU (2)}

- Independent loop gain control for
  - main loop (\textit{gain A})
  - witness bunches, used by tune feedback (\textit{gain B})
- Dedicated output for cleaning (\textit{gain C})
  - Injection gap cleaning in horizontal plane
  - Abort gap cleaning in vertical plane
  - Transverse blow-up (noise) for individual bunches (e.g., loss maps)

\textbf{RESULT: Successfully commissioned for operating LHC Run 2.}
Implementation for ADT in 2015

Links connecting BPOS VME modules to mDSPU VME processing module generating ADT drive signal

Shown: 1 beam, 1 plane $\rightarrow$ x4
**ADT Features and Use Cases (1)**

- **ADT Observation Box, a.k.a. “ObsBox”**
  - Bunch-by-bunch data available within the ADT blocks
  - Continuous, online analysis of the transverse (and longitudinal) motion, all kinds of fixed displays…
  - Storage of a full 40 MHz, bunch-by-bunch data for offline analysis
    *(see T. Levens et al: “Instability diagnostics”, these proceedings)*

Server in SR4 for ADT (1st unit)
LS1: ADT Controls

- Control software Classes supporting RDA3:
  - **ALLADTmDSPU** newly developed during LS1, replacing former DSPU
  - **ALLAbortGapClean** ported from former DSPU, readily using FESA3
  - **ALLCrateMan** migrated during 2015 (both in old and new crates)

- Former ADT LabView panels …
  - Still in use for BeamPos modules (ALLBeamPosMeas running FESA 2.10)
  - Handy to operate RF switching matrices (remote monitoring capabilities)

- New **Inspector UI panels** for setting up 8x new mDSPU cards.

However, these panels turned out to be …
New screens for ADT??

Just TOO BIG to fit on current LHCOP consoles!
New FGC RF-style function generators

New FGC RF-style function generators (8 in total), providing 88 functions:

- Cycle-dependent control of all output gain stages
  - $3 \times 8 = 24$ gain functions $\rightarrow$ commissioned
- Transition from injection tunes to collision tunes
  - $4 \times 8 = 32$ phase functions $\rightarrow$ commissioned
  - $4 \times 8 = 32$ PU mixing functions $\rightarrow$ prepared

$$\phi_{PK}$$

Controller $H_C(z)$

Sensor $H_S(s)$

Actuator $H_A(s)$

$\text{Delay}$

$\text{Gain}$

$x[n]$ $\xrightarrow{Controller}$ $y[n]$

$x(t)$ $\xrightarrow{Sensor}$ $y(t)$

Beam $G(s)$

$\phi_{PK}$
ADT Features, Performance, Use Cases (2)

- Comfortable gain margin at injection
  - Running with only 1 active module → still damped

- Loop gain saturation effects during ramp
  - Different saturation times per beam per plane → depends on frontend gain
  - Mitigation possible in digital → gain equalizer, rescaling, re-distribute loop gain
Injection damping

- Average low frequency damping times for coupled bunch modes < 10 turns
- Studies on damping times carried out (W. Hofle)
  - Single bunch → extrapolation to bunch trains
- Overdamping discovered / partly corrected (→ elogbook)

See also: “MARGINS TO INCREASE ADT GAIN AT INJECTION”, W. Hofle, LBOC 49, 6 Oct. 2015
https://indico.cern.ch/event/451051/

H-plane (beam 2)

V-plane (beam 2)
ADT Features and Use Cases (4)

• Injection cleaning, abort gap cleaning fully automated
  - Integrated into SIS
  - Linking abort gap cleaning to abort gap monitor (automatic switch-on)
  - Pulse shape is bipolar, optimization of edges to limit effect outside gap

• Blow-up device:
  - “About the correlation between Loss Map Control and Distributed Noise.”

Result 1: ADT Blow-up by injecting noise → Confirmed.

Result 2: A correlation between loss map control and distributed noise → PLAUSIBLE.

Quench test, 13 Dec 2015
Overall availability: 18 ADT Faults in 2015

Number of Faults
- UW45 cooling recovery ADT: 4
- ADT Power: 2
- ADT controls /interlocks: 4
- ADTLL/configuration: 9

Hours recorded
- Total hours: 26.02
- UW45 cooling recovery ADT: 9.27
- ADT Power: 1.02
- ADT controls /interlocks: 5.48
- ADTLL/configuration: 1.02

Three largest faults $\rightarrow$ 82 % of fault time
- UX45 interlock chassis (22.05 h), $\rightarrow$ 3 interventions
- CV water cooling UW45 recovery (9.27 h), $\rightarrow$ 2 interventions
- Gbit Link ADTLL (3.16 h), $\rightarrow$ 3 interventions
Thank you for your attention!
The ADT team works hard to be always there also during LHC run 2.
THANK YOU

Questions?
Operation with Doublets

Centre of gravity oscillation (even parity)

- Stripline pick-up output: VA (blue), VB (red)
- Hybrid output (after 650 m cable): Delta (blue), 10x, Sum (red)
- Bandpass filter: Delta (blue), 10x, Sum (red)
- Baseband Magnitude: abs(Delta) (blue), abs(Sum) (red)
- Normalized Position (in mm)

With-in bunchlet oscillation (odd parity)

- 20 MHz odd mode: no movement of COG
- Leads to cancelation

→ Odd mode invisible

LHC ADT HW working with 5 ns bunchlets, requires separate set-up (fine delays for clocks)