ADTObsBox to Catch Instabilities

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Agenda

• What is the ADTObsBox
• How the ADTObsBox has been used to catch instabilities
• LS2 upgrades to increase its hunting capabilities
• How the ADTObsBox will be used to catch instabilities
What is ADTObsBox

An acquisition system that takes advantage of the bunch-by-bunch turn-by-turn submicrometer transverse position data available from the transverse feedback system in the LHC and makes it available for a range of analysis tools.
What is ADTObsBox

One system per plane per beam so four in total
Four pickups per system so 16 in total
What is ADTObsBox

- **Automatic logging:**
  - processed performance data (damping time, tune)
  - instability signatures
  - processed spectra

- **CCC fixed displays:**
  - damping time, tune
  - transverse activity
  - transverse instability

- **Users semi-online analysis in while still in CCC:**
  - MDs
  - activity after injection
  - scrubbing
  - tune shift observation
  - coupling correction
  - collimator impedance

- **Offline analysis, download in CCC, analyze later:**
  - MDs
  - long time inj. osc. storage
  - drift observation

- **Subscribers outside CCC:**
  - RF, BI
Data

- 4.6 TB of data stored since late 2017 in our nfs-server
  - 336 GB/221368 files: Every injection, all bunches, 4k turns
    - Triggered by BeamIN
  - 474 GB/9754 files: Post mortem data, all bunches, 64k turns
    - Triggered by BeamOut
  - 3700 GB/179793 files: Instability data, all bunches, 64k turns
    - Triggered by internal beam instability detection
  - 72 GB/41269 files: Other data (e.g. dedicated MDs)

- Since fill 6030, stored to a dedicated server (unlimited storage time) with backup to CASTOR. Owned by us and maintained by CO.

- ADTObsBox™ data used for: Injection drift observation, Post-mortem analysis, Instability cause analysis, MDs, Generating cool animated plots for meetings and papers
- ABP has automatic scripts that goes through the data after every fill to search for interesting event
How

Real-time action/ serialization/ float conversion

$\mathbf{x} \left[ n \right]$

Notch

$\mathbf{x}_n \left[ n \right] = \mathbf{x} \left[ n \right] - \mathbf{x} \left[ n - 1 \right]$

Hilbert transform

Instantaneous amplitude

$\mathbf{A} \left[ n \right] = \sqrt{\left( \mathbf{x}_h \left[ n \right] \right)^2 + \left( \mathbf{x}_n \left[ n - 3 \right] \right)^2}$

Instability detection

LHC instabilities trigger distribution

$\sum_{n=\left(m+1\right)W}^{(m+2)W} \mathbf{A} \left[ n \right] \gg \sum_{n=mW}^{(m+1)W} \mathbf{A} \left[ n \right]$

$w = \text{window size}$

*1 for all details
How

- Three windows of length 256, 1024 and 4096 turns
- The maximum instantaneous amplitude for every 4096 turns and the output from the longest window is sent to the ADT activity monitor and TIMBER

*[2] for complete implementation details
As a bonus: ADT activity monitor

We lost quite some beam just before the ramp (while trying to get B1H in a good place).

It looks like some of the bunches lost from the moment they were injected, both in B1 and B2 - before starting the ramp.

The pattern of the bunches losing looks random... bunches losing were detected by the ADT instability monitoring in B1.
Limitations/issues

- Long delay from fiber to trigger (~1s)
- Limited computational resources when it was implemented
- False triggers caused by glitches in the data-stream, complex to detect

Done through software
ADTObsBox in LS2

- Substantial amount of work is put into the upgrade of the system
- Substantial investment for the upgrade of the system (105000 CHF from RF budget)
- New acquisition cards and drivers have been developed that allows for one-turn delay from fiber to analysis (was 4096 turns)
- Each new server will receive all 16 channels which will allow for cross-plane cross-beam analysis
- Computational resources required just to receive data is reduced by a factor ~100
- Multi-threaded driver. Many readers, not only FESA class
ADTObsBox in LS2

- Introduction of a 24h buffer for data from all 16 pickups
  - Uses 144TB of local hard-drives
- 4 triggers limit removed to synchronize acquisition with more instruments
- Possible to implement more sophisticated instability analysis with new servers
- Receive triggers from LHC instability trigger distribution

Exponential curve-fitting using least-square method
ADTObsBox in LS2

- Three new servers
- One new server has the same performance as all four of the old ones
- Real-time server:
  - GPUs for ?
  - Instability analysis
  - Passive tune extraction
  - ..... 
- Buffer server:
  - Same functionality as current system
  - 144TB local storage (24h full machine buffer)
- Development server:
  - Possibility to run unorthodox experiments
ADTObsBox features in RUN 3

- Possible applications:
  - Finalize the real time, passive, bunch by bunch tune measurement from the ADT pickup data
  - Finalize the on demand Tune measurement system (with excitation)
  - Automated high precision tune extraction with excitation and data from all pickups (used in MDs)
  - Post mortem data analysis immediately after dump?
  - Saving certain internal signals from the Digital signal processing (expert use)
  - Excitation feedback control
    - Send signals from ADTObsBox to mDSPU such as increase gain or stop excitation
ADTObsBox features in RUN 3

Request from ABP and OP to implement a passive, bunch by bunch tune measurement using the ADT pickup data. The goal is $10^{-4} \ @ \ 1\text{Hz}$.

Combining data from all 4 pickups using a NUDFT-III on a GPU is being tested.

Testing passive tune extraction with data from one pickup during one of the last fills of run 2.

Approximately $0.4 \times 10^{-2} \ @ \ 300\text{Hz}$.
Scenarios for ADTObsBox in RUN 3

- "We want it to detect instabilities automatically and reliable”
  - Can be done but we have limited resources. Input and help from ABP would be appreciated
- "We saw something interesting a few hours ago”
  - Download the data from the 24h buffer
- "We want to test [x] and analyse all the data in real-time”
  - Can be done on the development machine in your favourite programming language
- "We want to save all the data for one MD”
  - 100 bunches for 8h \(\approx\) 1TB(compressed)
- "We want to freeze all the buffers every s and save it to your nfs server”
  - The new dedicated fibers should allow for this

TODO: replace with 10km cables
Thank you for your attention
References

[1] G. Kotzian, “Transverse feedback parameter extraction from excitation data”, presented at IPAC’17, Copenhagen, Denmark, May 2017
https://cds.cern.ch/record/2631483

https://cds.cern.ch/record/2289132