

ADTObsBox to Catch Instabilities

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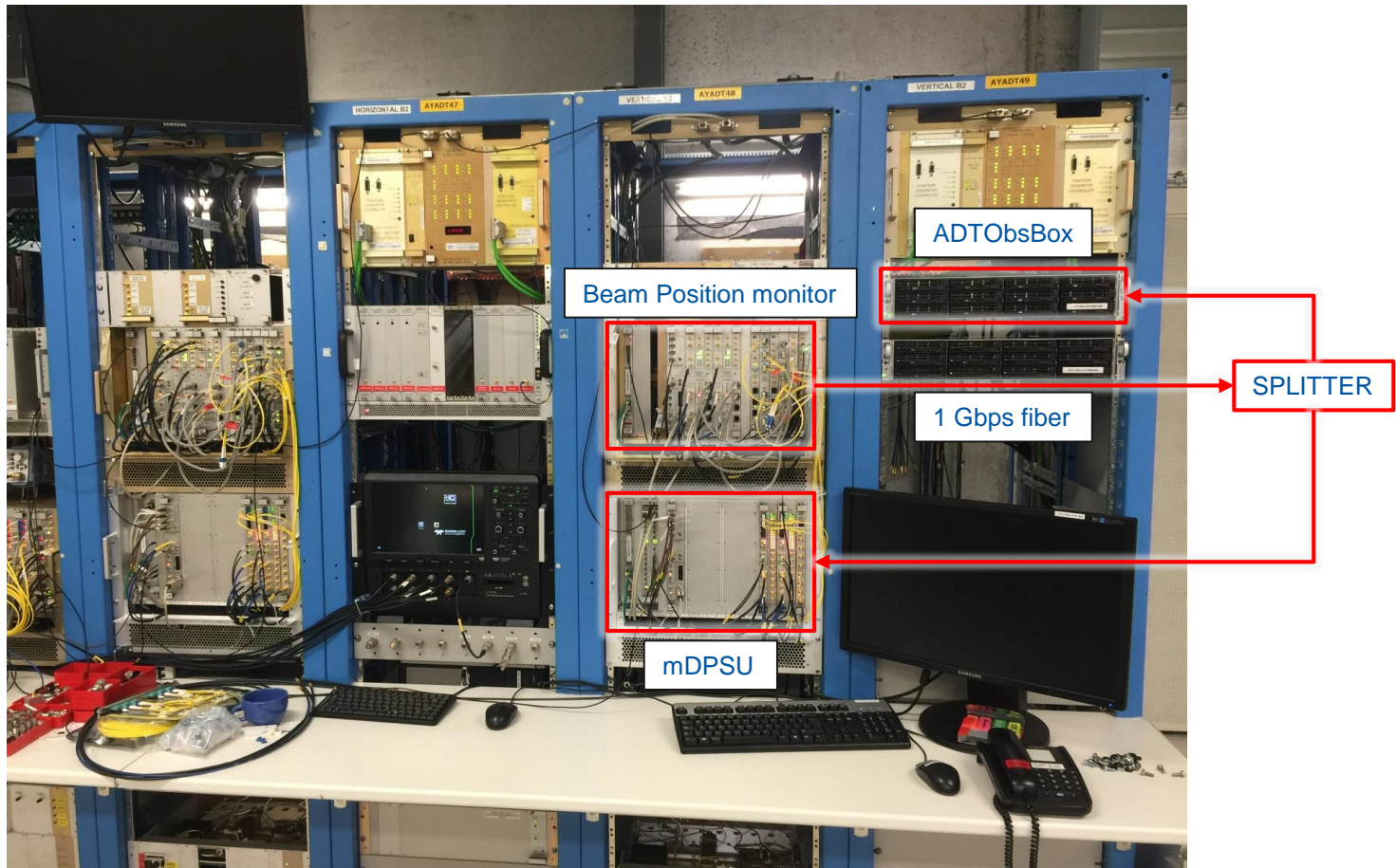
Agenda

- 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

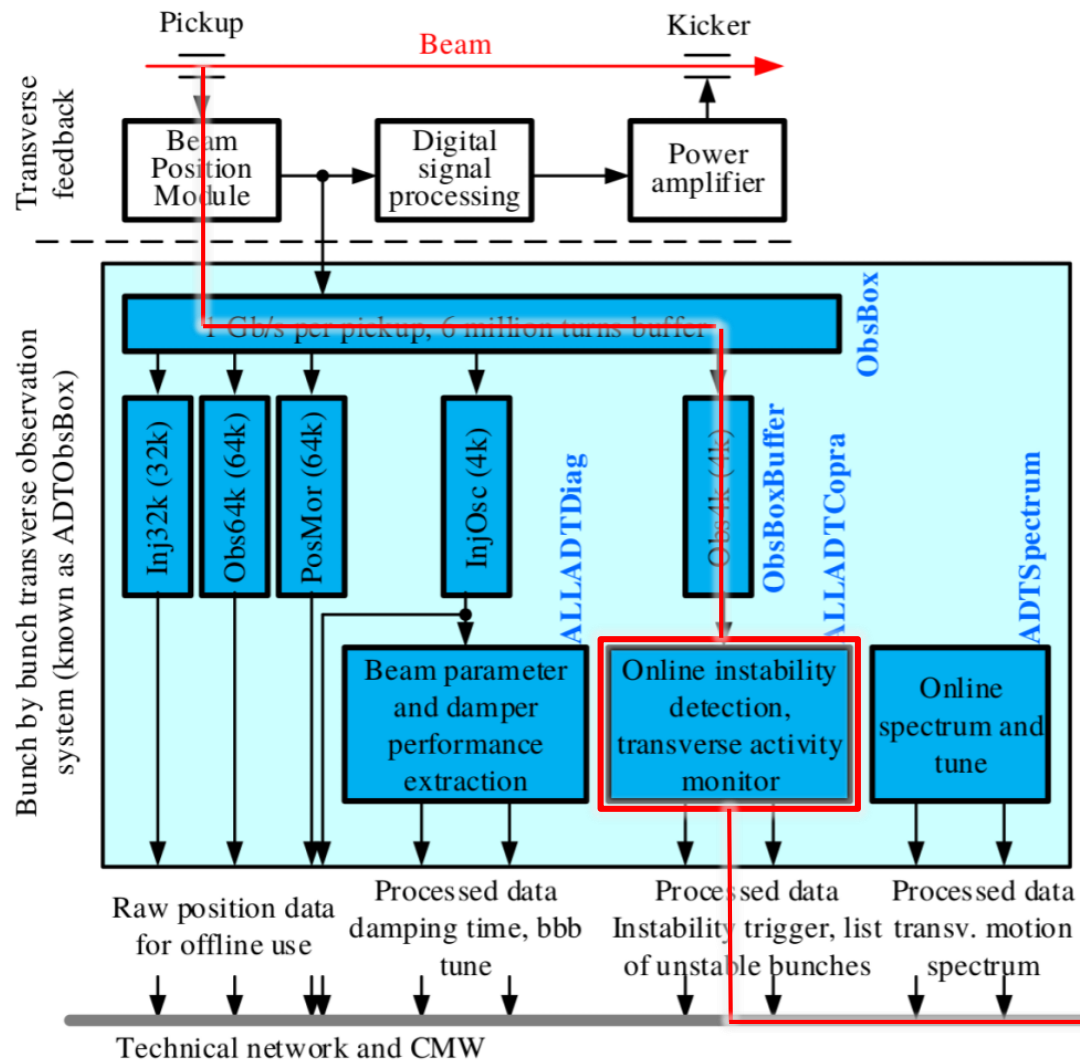
An acquisition system that takes advantage of the bunch-by-bunch turn-by-turn submicrometer transverse position data available from the transverse feedback system in the LHC and makes it available for a range of analysis tools

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

$x[n]$

Notch

$$x_n[n] = x[n] - x[n-1]$$

Hilbert transform

$$x_h[n] = -0.0906x_n[n] - 0.0198x_n[n-1] - 0.5941x_n[n-2] + 0.5941x_n[n-4] + 0.0198x_n[n-5] + 0.0906x_n[n-6]$$

Instantaneous
amplitude

$$A[n] = \sqrt{(x_h[n])^2 + (x_n[n-3])^2}$$

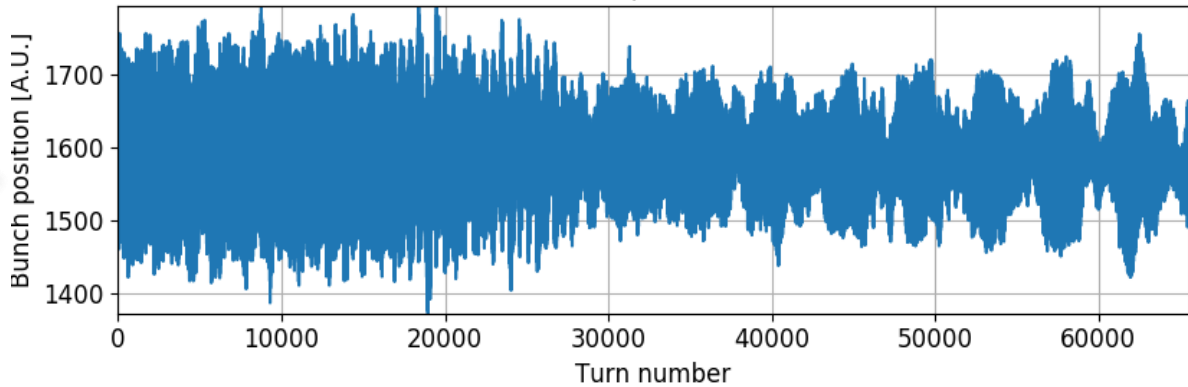
Instability
detection

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

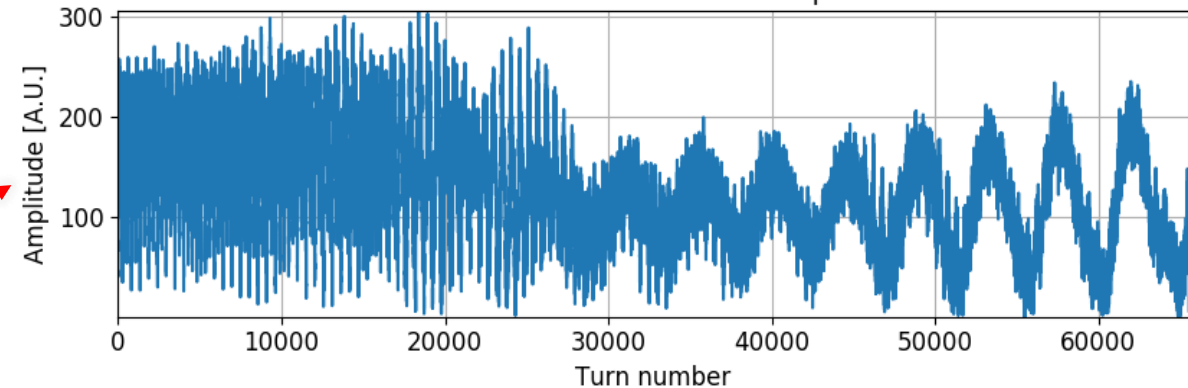
$w = \text{window size}$

LHC instabilities
trigger distribution

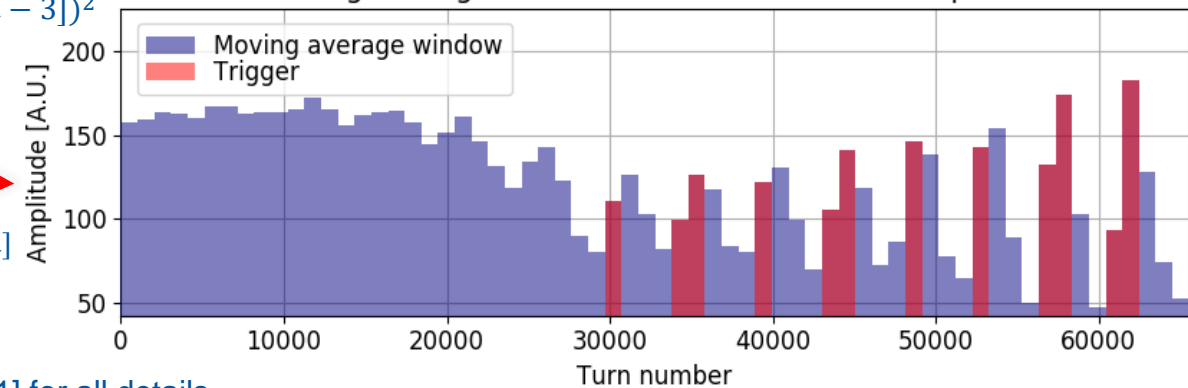
Raw bunch positional data



Instantaneous oscillation amplitude



Moving average of instantaneous oscillation amplitude

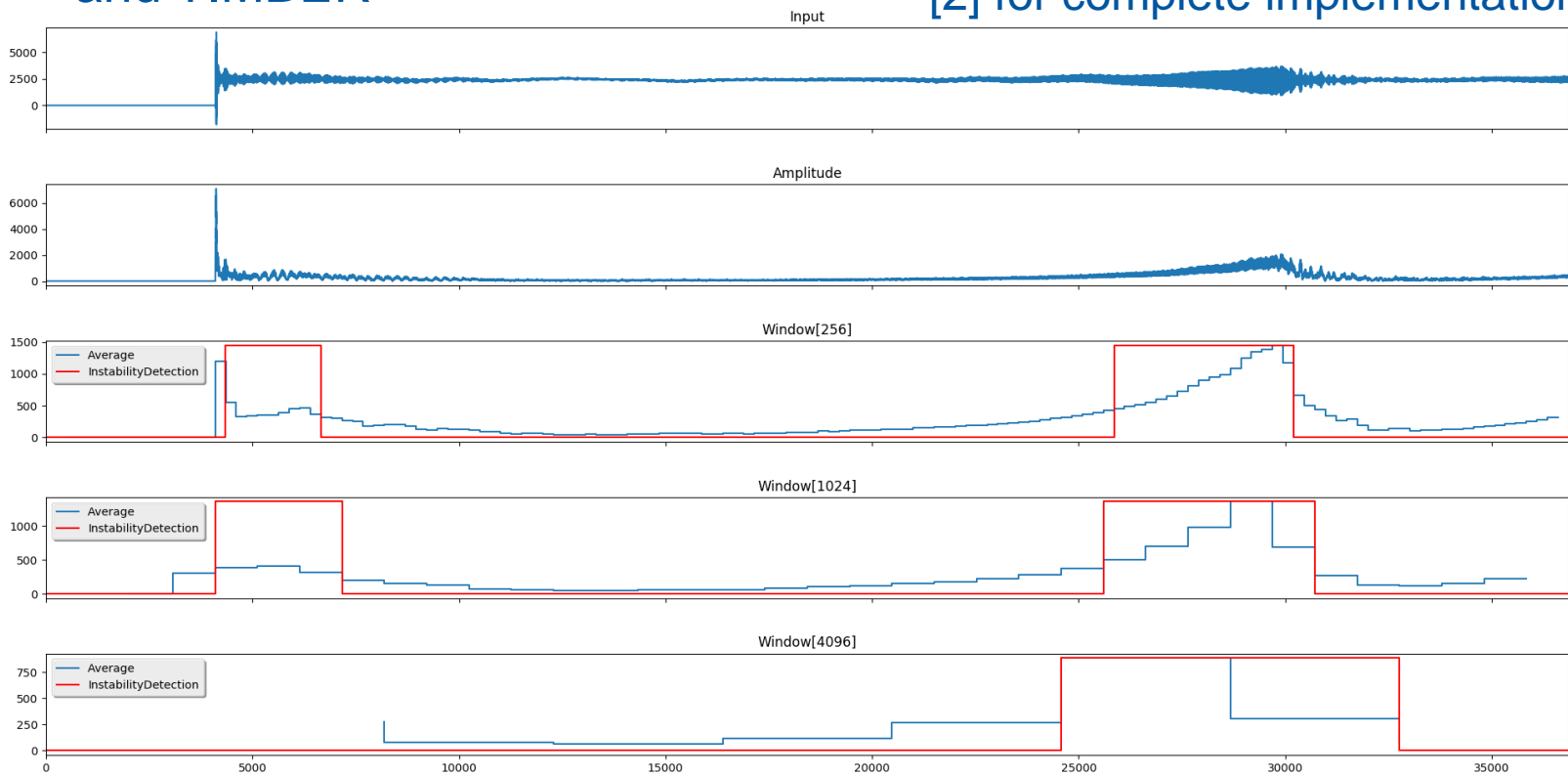


*[1] for all details

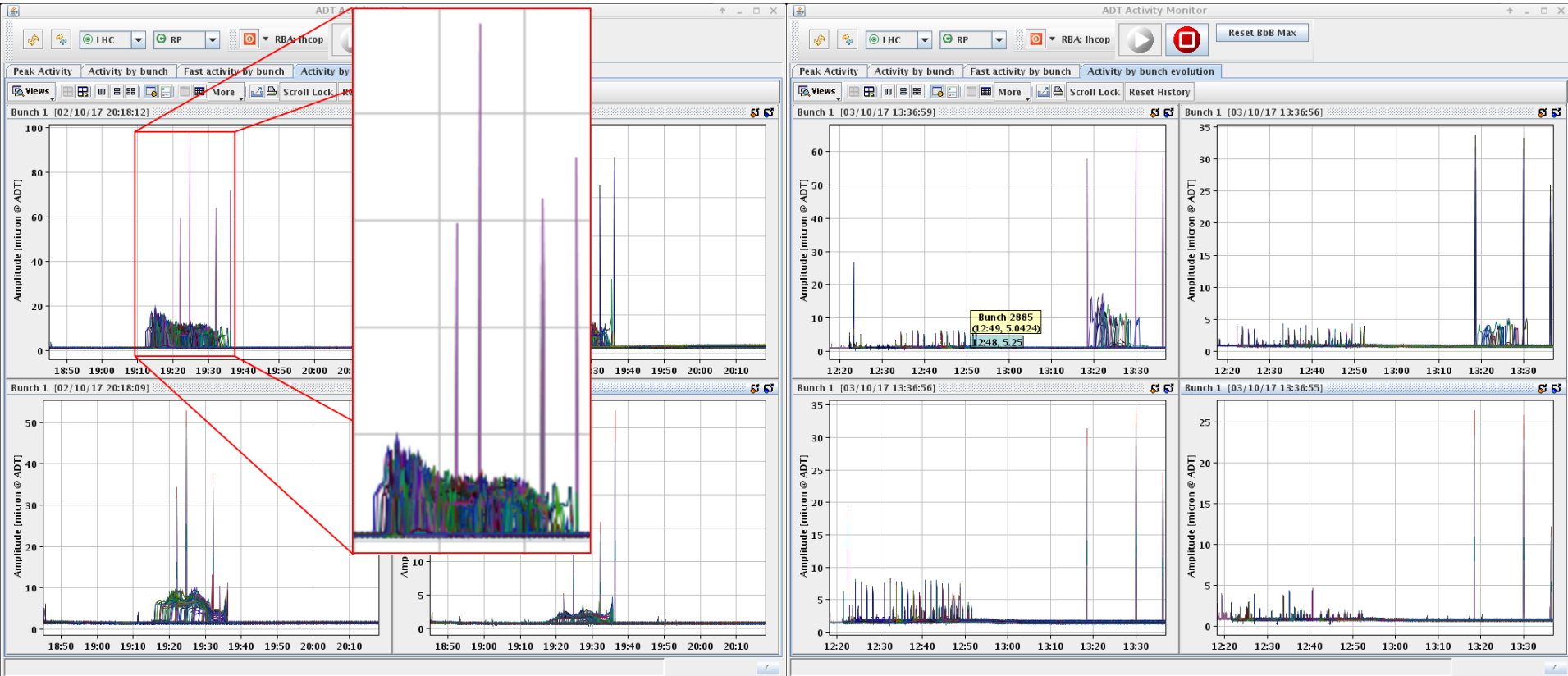
How

- 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



27/07/2017 00:41 Night LHC OP Full

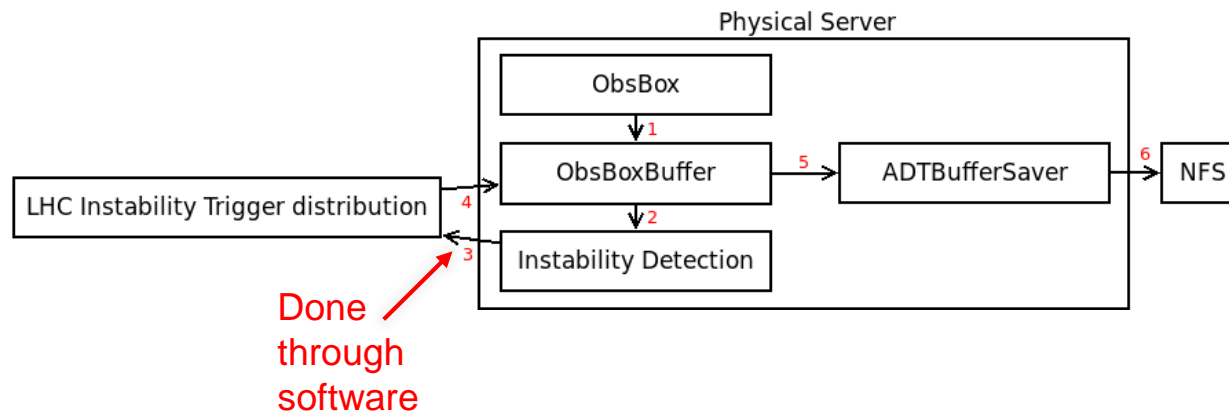
We lost quite some beam just before the ramp (while trying to get B1H in a good place).

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

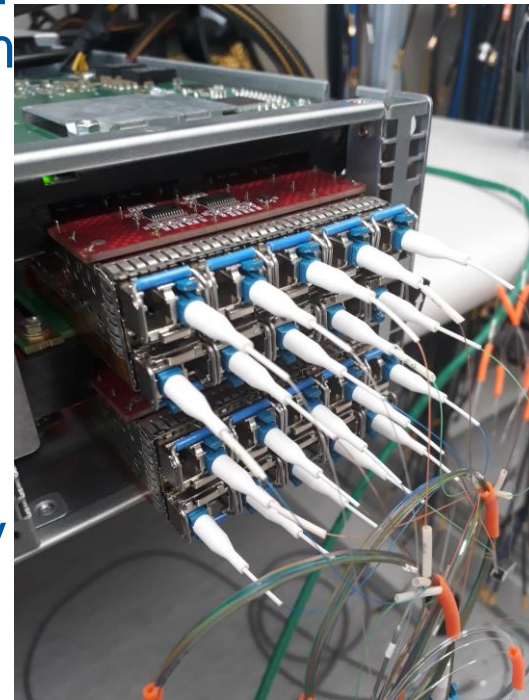
Limitations/issues

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



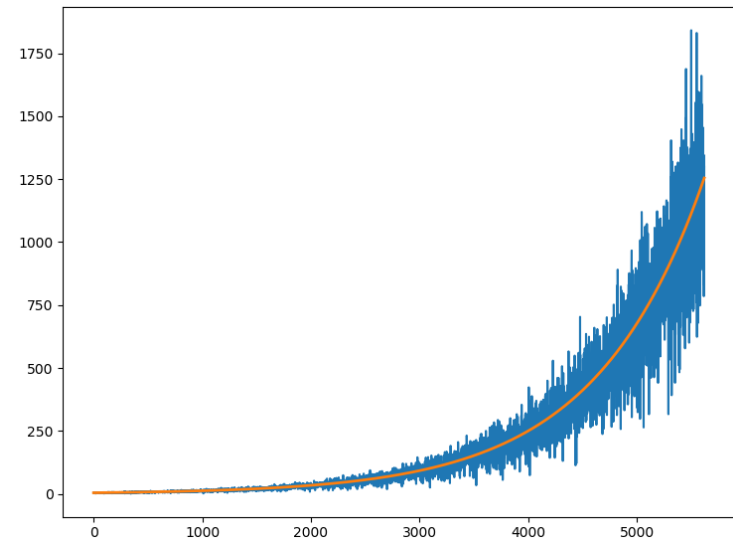
ADTObsBox in LS2

- 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

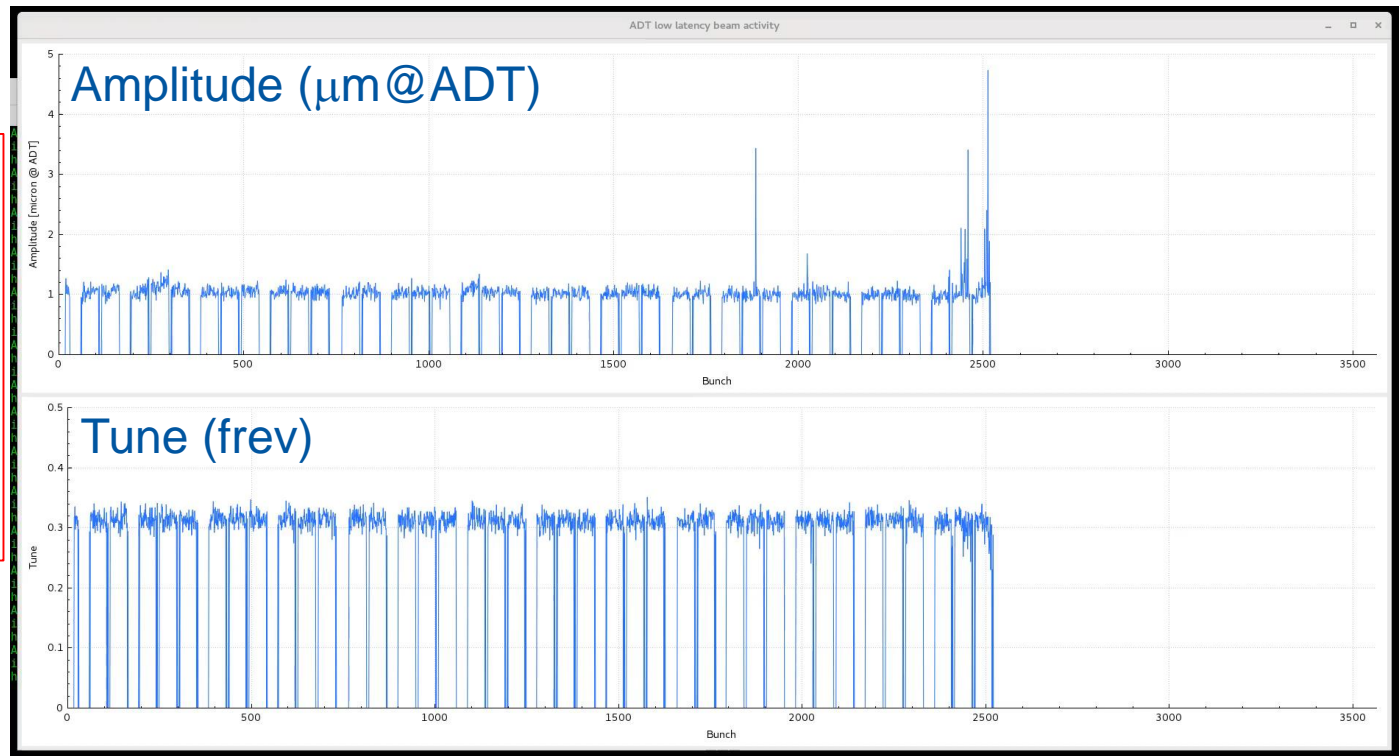
- Possible applications:
 - Finalize the real time, passive, bunch by bunch tune measurement from the ADT pickup data
 - Finalize the on demand Tune measurement system (with excitation)
 - Automated high precision tune extraction with excitation and data from all pickups (used in MDs)
 - Post mortem 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} @ 1Hz

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



$\approx 0.4 \cdot 10^{-2}$ @ 300Hz

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>

- [2] M. Soderen, “Online Transverse Beam Instability Detection in the LHC: High-Throughput Real-Time Parallel Data Analysis”, Master thesis, 2017
<https://cds.cern.ch/record/2289132>