Beam Diagnostic Tools for Crab-Cavity Tests in the SPS

T. Mastoridis[1]

[1]California Polytechnic State University, San Luis Obispo, CA

November 20^{th} 2014

Acknowledgement:
This talk would not be possible without the material and help from H. Bartosik, R. Calaga, J. Fox, W. Hofle, T. Levens, G. Papotti, R. Steinhagen, M. Tobiyama

Why do we need advanced diagnostic tools?

SPS tests

- Achieve sub-nanosecond resolution to setup, operate, evaluate crab cavities
  - Evaluate head-tail motion
  - Measure orbit, tune, tune-shift along the bunch, bunch emittance.
  - Turn-by-turn data for optics measurements and crab dispersion
- Pickups and advanced processing of associated beam signals are necessary.
  - This talk focuses on the available processing instrumentation.
  - The question of the pickups is important as well though: how many? What kind of technology (strip lines, tapered strip lines, etc.)?

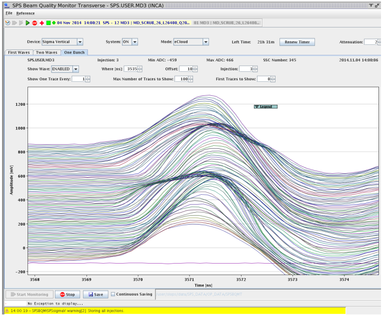
Instruments of Interest

SPS tests

- Four instruments of interest:
  - Head Tail Monitor from BI group at CERN
  - Transverse BQM
  - Multiband Instability Monitor (MIM)
  - Transverse Wideband Feedback
- Other options
  - Install a streak camera and look at synchrotron light at 450 GeV.
  - Adjust collimation with and w/o crabbing and check beam losses with tilted bunches.
  - Another implementation to consider: Intra-bunch Feedback System at J-PARC.

Transverse BQM: Description

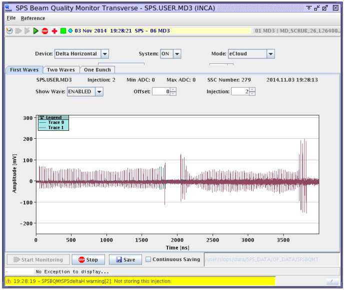
- 10 bit resolution, 8 GSPS sampling rate
- Uses an exponentially tapered stripline
- $\approx$ 32 megasamples usable memory. Maximum 4k turns
- Reconfigurable for any SPS cycle sequence with separate settings for the individual cycles.



Courtesy H. Bartosik

Transverse BQM: Pros and Cons

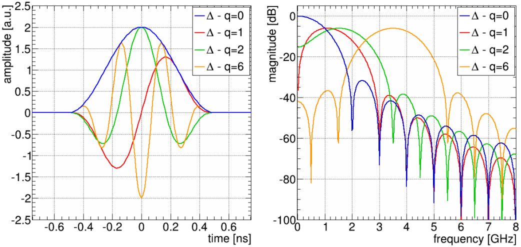
- Pros:
  - Already developed and used. GUI and logging application in operation (developed by F. Follin), FESA support completed (G. Papotti).
  - The acquisitions recently helped determine that the PS extraction kicked was not perfectly timed.
- Cons:
  - Issues with data logging since too much data is being generated $\rightarrow$ limited functionality.



Courtesy H. Bartosik

Multiband Instability Monitor: Description

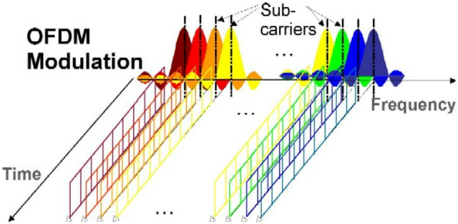
- Multiband-Instability-Monitor (MIM) provides an alternative nm-level and wide-bandwidth ($>$ 6 (12 GHz)) transverse and longitudinal instability diagnostic.
- The beam signal is passed through an RF filter bank, and each output downconverted to baseband and sampled with a high resolution ADC (similar to BBQ).
- Initial version will have 8 frequency bands from 0.4 to 3.2 GHz and will only acquire turn-by-turn. Future upgrade would have full bunch-by-bunch acquisition (in parallel).
- The goal is to have a development system in the SPS for testing.
- The residual modes from the crab cavities should be visible
- Utilizes long stripline pickup



Courtesy R. Steinhagen

Multiband Instability Monitor: Pros and Cons

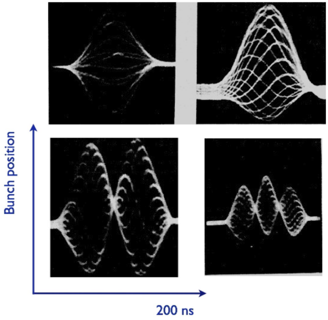
- Pros:
  - Could have bunch-by-bunch resolution, for >10k turns and a bandwidth of 6 GHz
  - Can run continuously (no data limitation), looking at each mode and provide a warning if over a threshold → useful for post mortem analysis
  - More sensitive than any other direct time-domain detection
- Cons:
  - In development.
  - Looses some of its sensitivity in bunch-by-bunch mode.



Courtesy R. Steinhagen

Head Tail Monitor: Description

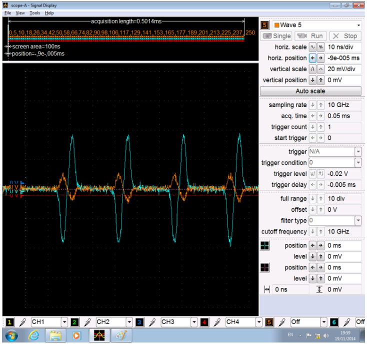
- 8-bit Guzik digitizers installed in the SPS (http://www.guzik.com). They replace the scope. Embedding custom firmware in them is not straightforward.
- 20 GSPS (single plane) or 10 GSPS (both planes).
- Maximum 64GS of data (i.e. 16GS/channel = 1.6 seconds)
- Utilizes same long stripline pickup as MIM.



Courtesy T. Levens

Head Tail Monitor: Pros and Cons

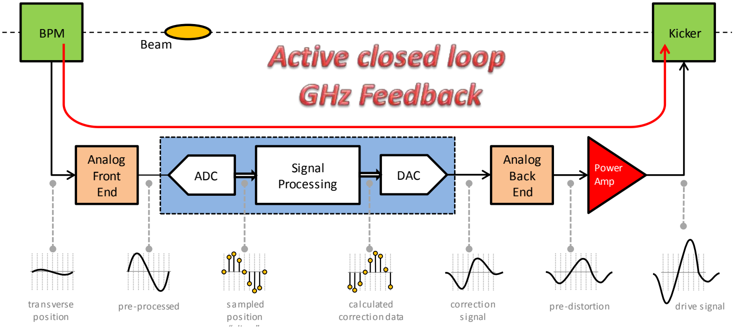
- Pros:
  - High sampling rate.
  - Upgrade of existing system.
- Cons:
  - Huge amount of data to process and store.



Courtesy T. Levens

Wideband Transverse Feedback: Description

- 4 GSPS (8 GSPS to be developed), 8 bits.
- Closed loop test were performed in the SPS in 2012 (proof of principle)
- Reconfigurable processing
- Software available to fit data to models → characterize beam dynamics and evaluate different feedback algorithms.



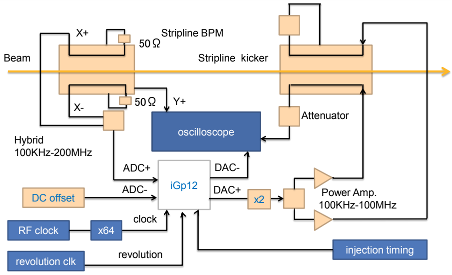
Courtesy J. Fox

Wideband Transverse Feedback: Pros and Cons

- Pros:
  - As this system's primary purpose is active feedback, it offers a lot of additional advantages beyond diagnostics.
  - Full control of FPGA (Headtail monitor possible, but harder than expected) → Could select data to store, remove majority of useless zeros, and thus record longer sequences of data.
  - Synchronized to RF clock
  - Data processing and analysis software ready.
  - Can do active experiments, measurements of beam transfer function (useful for instabilities, not necessarily crab cavities)
  - Could possibly act on RF Amplitude Noise effects (SPS+LHC)!
  - Similarly to MIM, it can provide post mortem recording.
  - And of course has applications past diagnostics: damp TMCI, e-cloud driven instabilities. Applicable to SPS, LHC scrubbing run, future LHC?
- Cons:
  - Demonstrated for a single bunch only
  - Low sampling rate currently (4 GSPS)

J-PARC Intra-Bunch Feedback System: Description

- 64 slices in 200 ns long bunch (limited resolution for SPS applications?)
- Successful in suppressing instabilities at J-PARC.
- Online analysis of instability data.
- Utilizes Dimtel's iGp12 www.dimtel.com/products/igp12



Courtesy M. Tobiyama

Contacts

- Transverse BQM: H. Bartosik, G. Papotti (CERN).
- Multiband-Instability-Monitor: T. Levens, T. Lefevre (CERN).
- Head-Tail Monitor: T. Levens, T. Lefevre (CERN).
- Transverse Wideband Feedback: J. Fox (SLAC), W. Hofle (CERN).
- J-PARC Intra-bunch Feedback System: M. Tobiyama (KEK).

Conclusions

- Each system has advantages, disadvantages.
- It might be reasonable to set specifications/requirements before full evaluation, allocation of resources?
- Promising and exciting technologies.
- Decision should be made on associated pickup technology as well.

LHC applicability

- SPS excellent test-bed for LHC applications
- LHC diagnostics for crab cavity operation
- Probe proximity to instabilities through Beam Transfer Function measurements. In the case of the Wideband Feedback, potentially even act on these instabilities.

Many thanks to H. Bartosik, J. Fox, W. Hofle, T. Levens, G. Papotti, R. Steinhagen, M. Tobiyama.

Thank you for your attention!