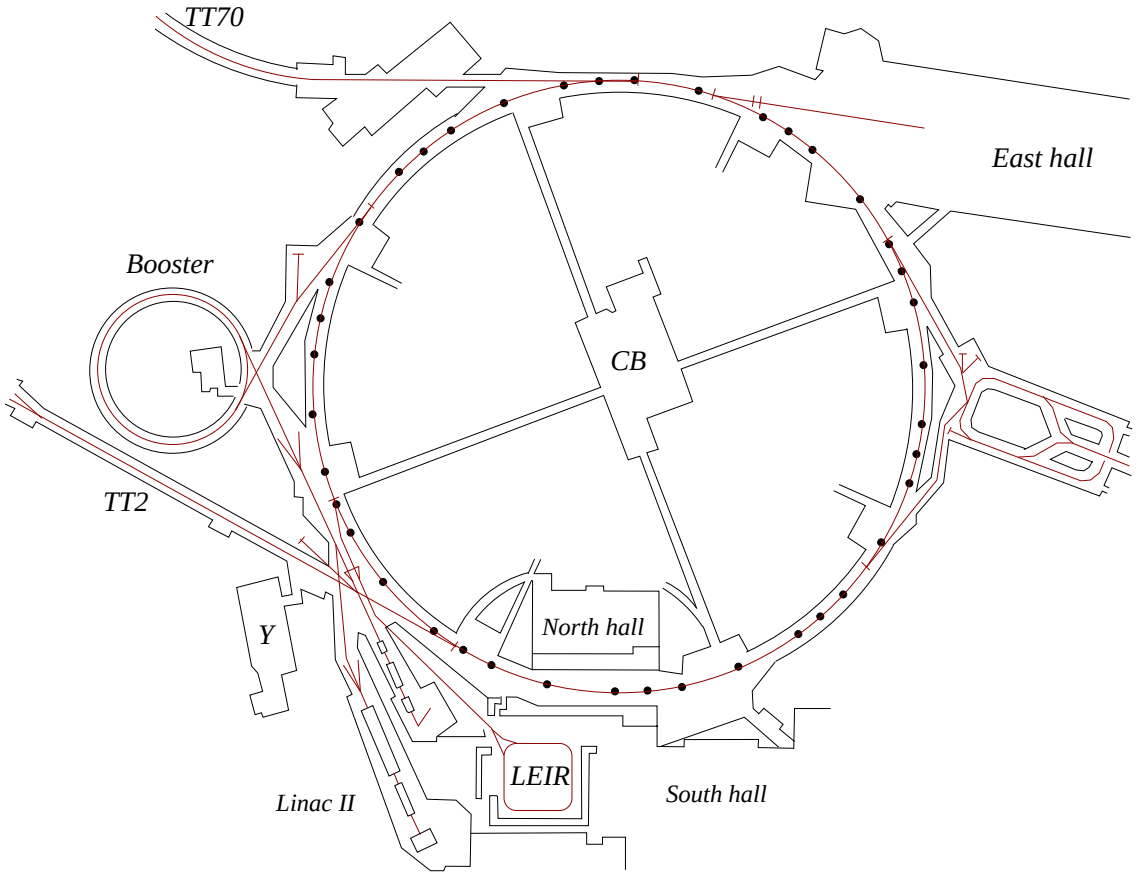
Digital BPM Systems for Hadron Accelerators

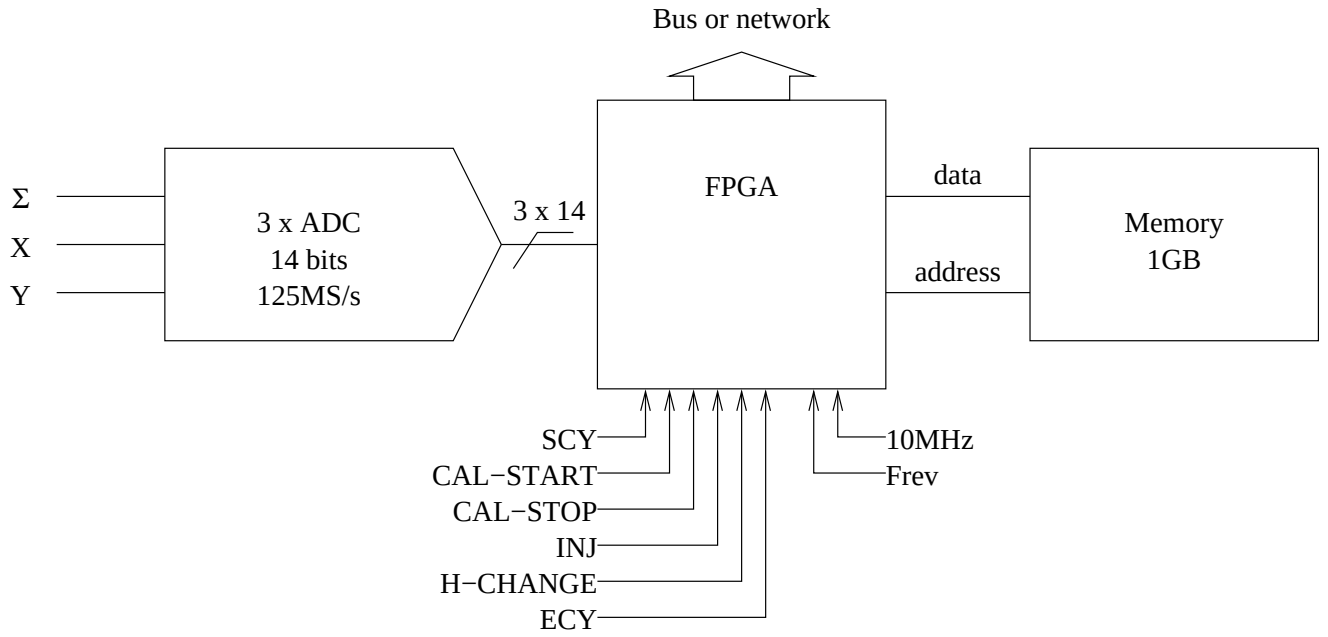
Proton Synchrotron
26 GeV
200 m diameter
40 ES BPMs
Built in 1959



Trajectory measurement:
- System architecture
- Inputs
- Principles of operation
- Measurement examples

System architecture

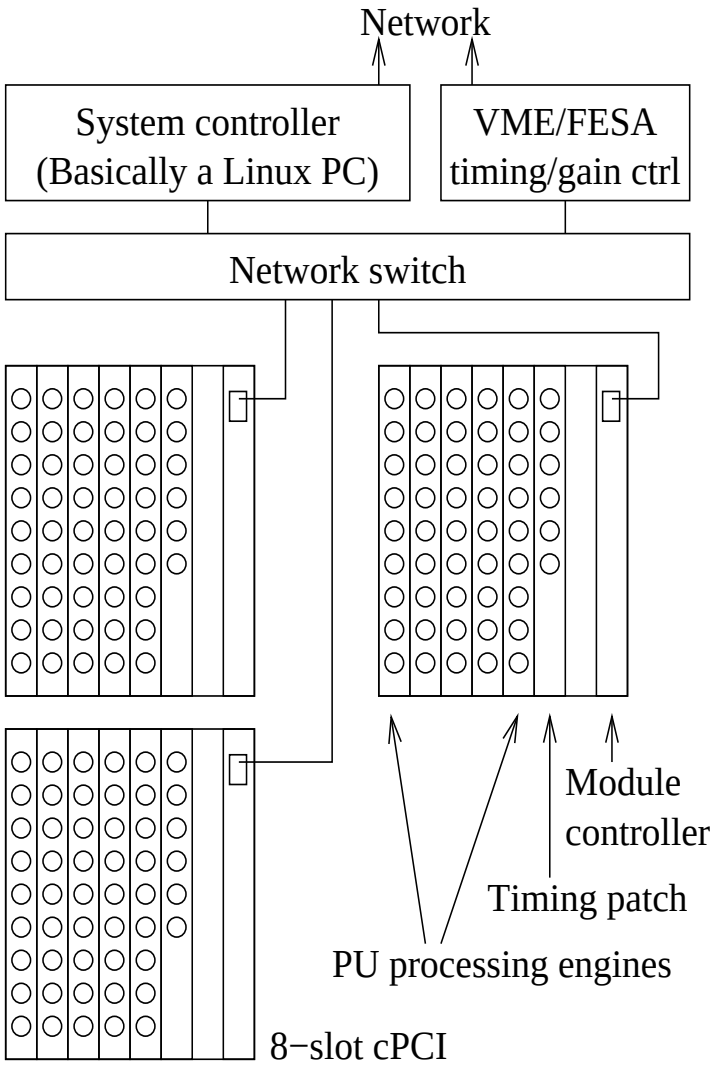
For one PU station:



ADCs: LTC2255, 14 bit, 125MS/s
FPGA: Xilinx Virtex-4
Memory: 256MB/PU

Data is streamed into a circular buffer.
Persistence: A few seconds

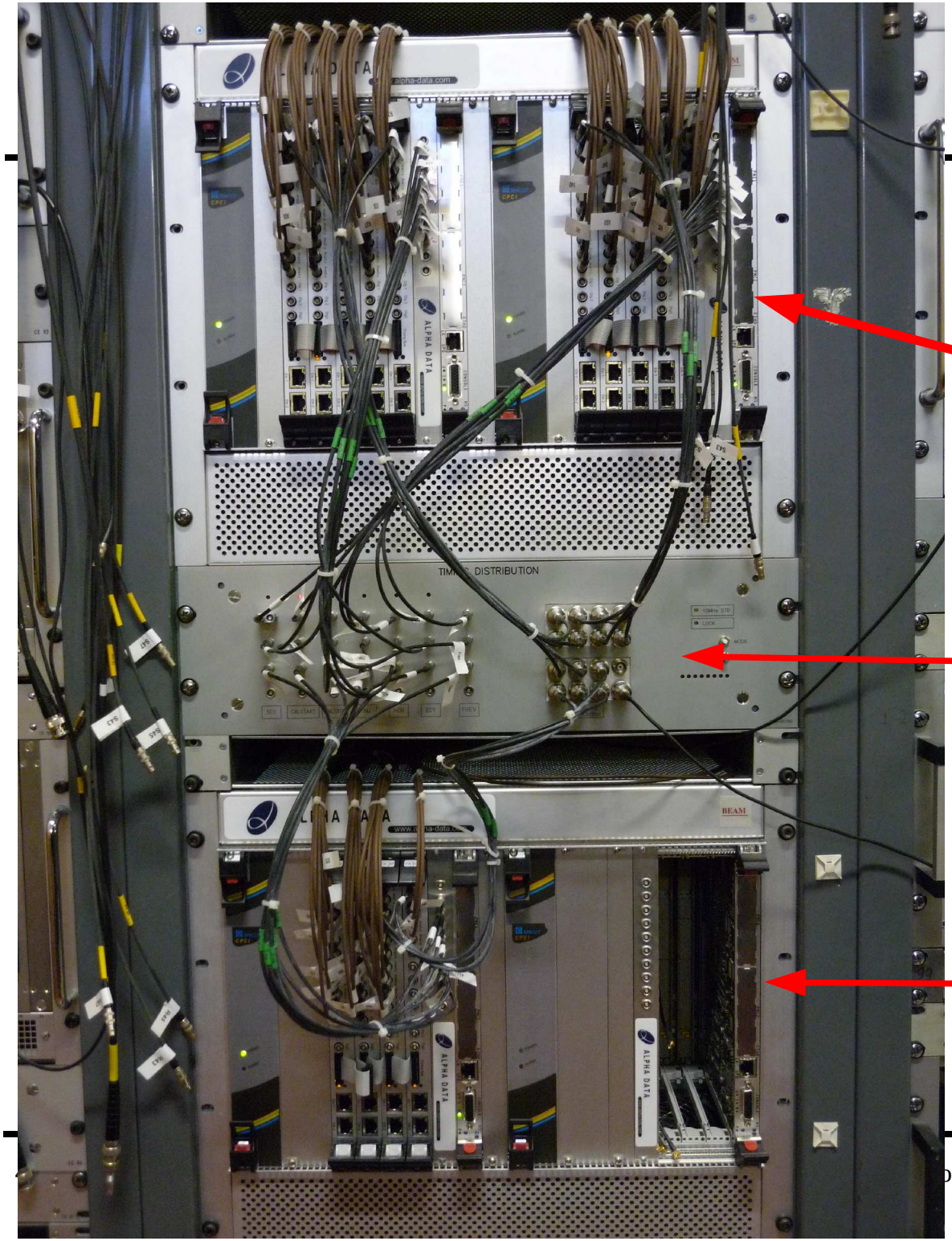
System architecture



- 14 PU Processing Engines
- Treating 3 PUs each
- 3 half-width cPCI crates
- One system controller

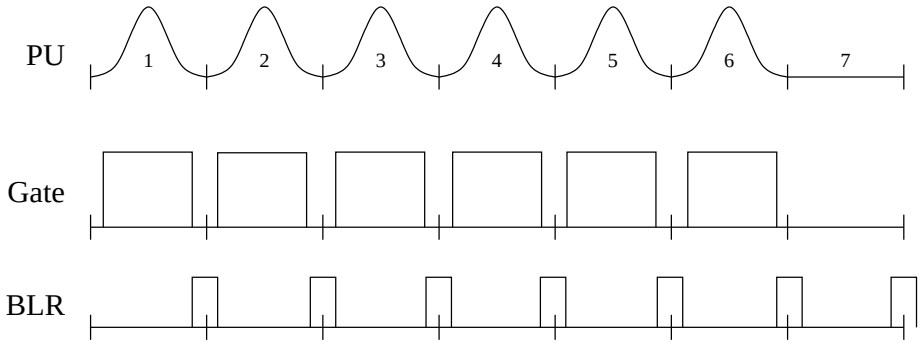
The cPCI crate processors are connected to the system controller using Gigabit Ethernet.
The system controller connects to the accelerator network using a 2nd network interface.
A VME crate for timing, pre-amp control and a FESA server

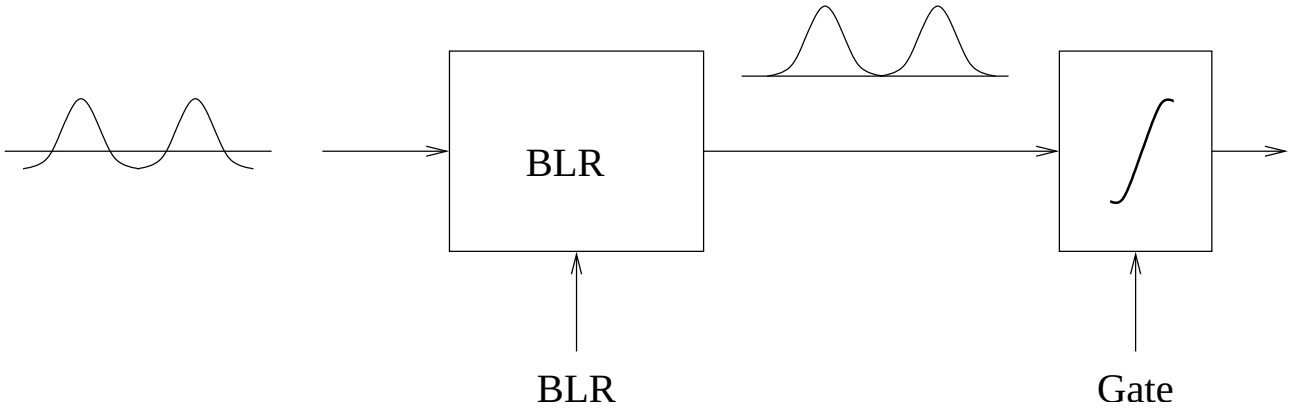
TMS photo



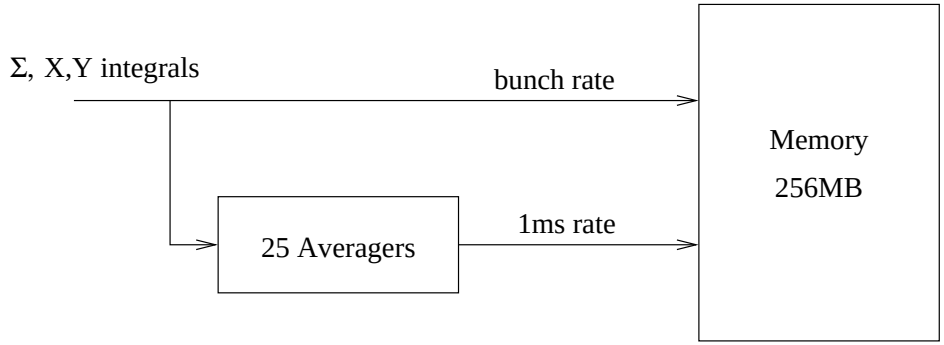
Position measurement principle

Position of each bunch is measured individually
Integration over the length of one bunch
Base Line Restoration is needed because the
BPMs have no DC response





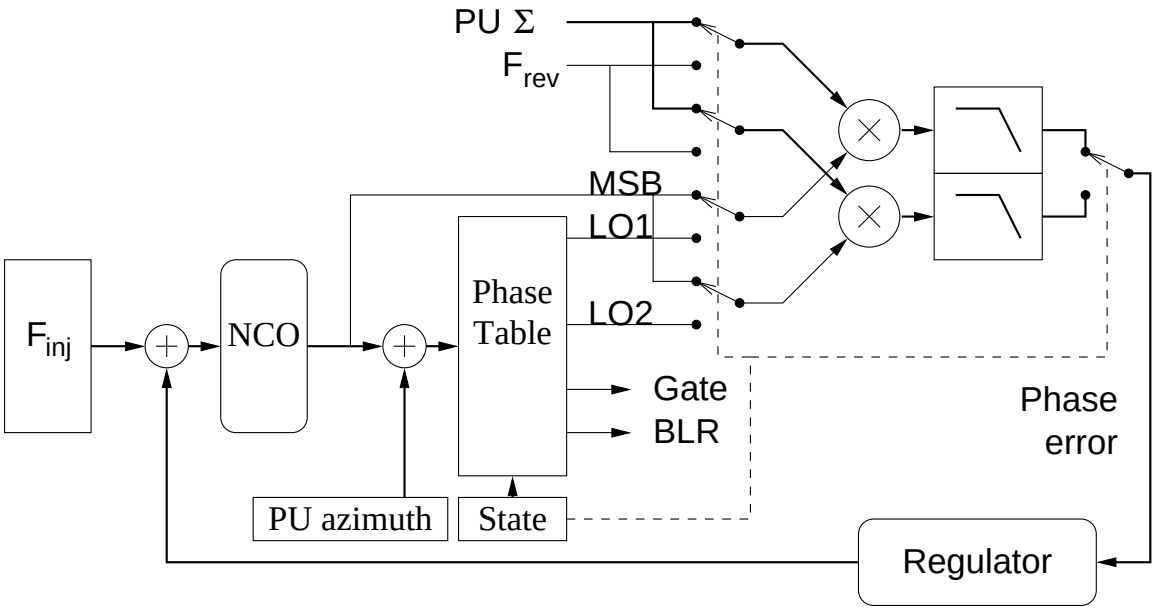
Data paths

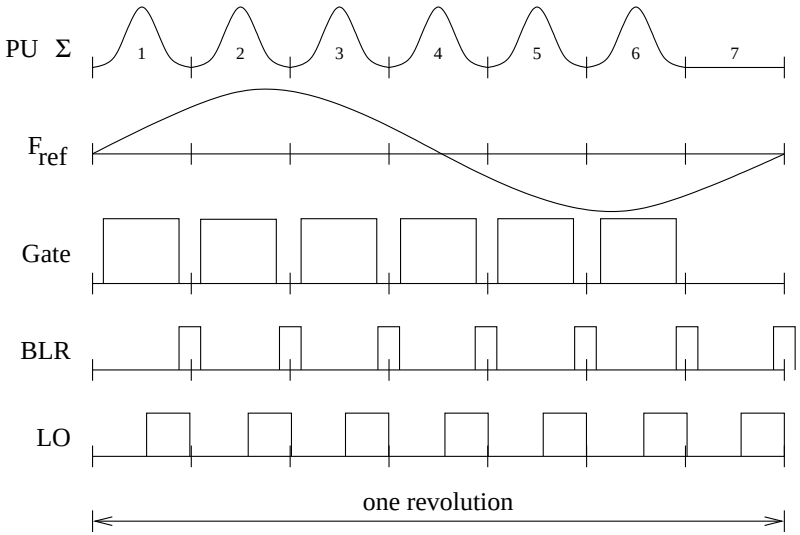


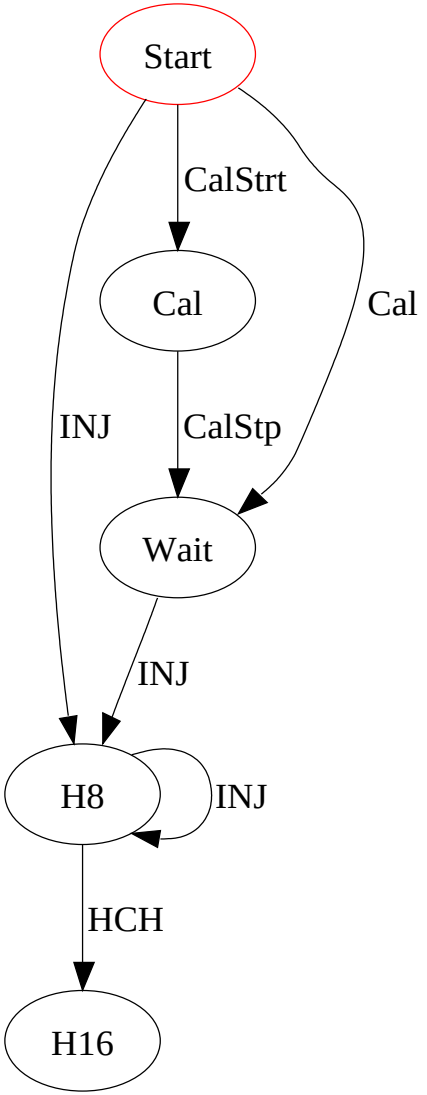
- Trajectories are the main object of the system
- Orbits are recorded by accumulating averages at 1ms intervals
- There is an averager for each bunch
- One channel averages over all bunches
- MRP requires additional post-processing

Most of the memory is used for trajectory data (0xfe00000 bytes). Averaging tables are of size 4096.

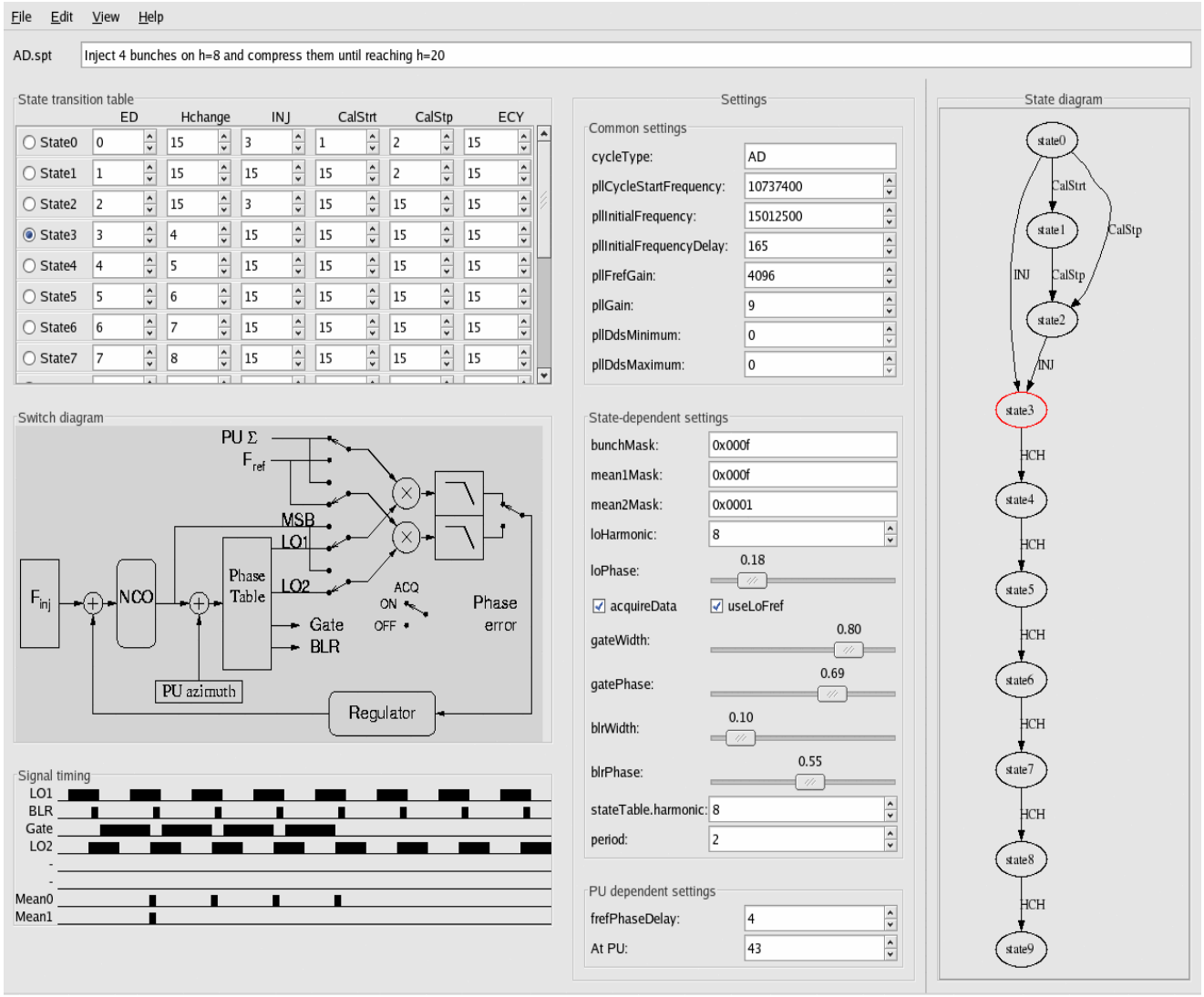
Synchronization







Phase Table Editor



Purpose:

Define state sequence
Define harmonic values
Generate Gate, BLR and LO

There is a state table file for each beam type

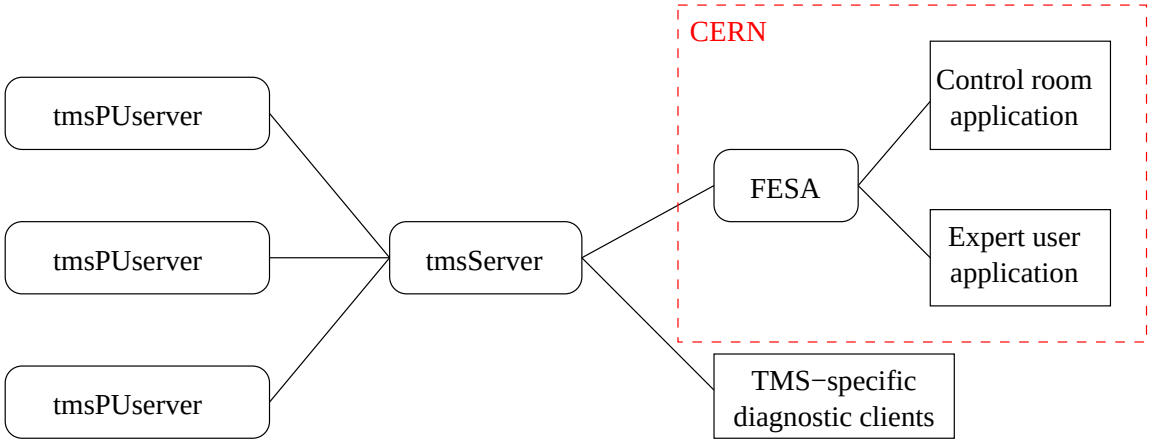
The system loads the right one according to the PLS telegram just before each cycle start

Some considerations...

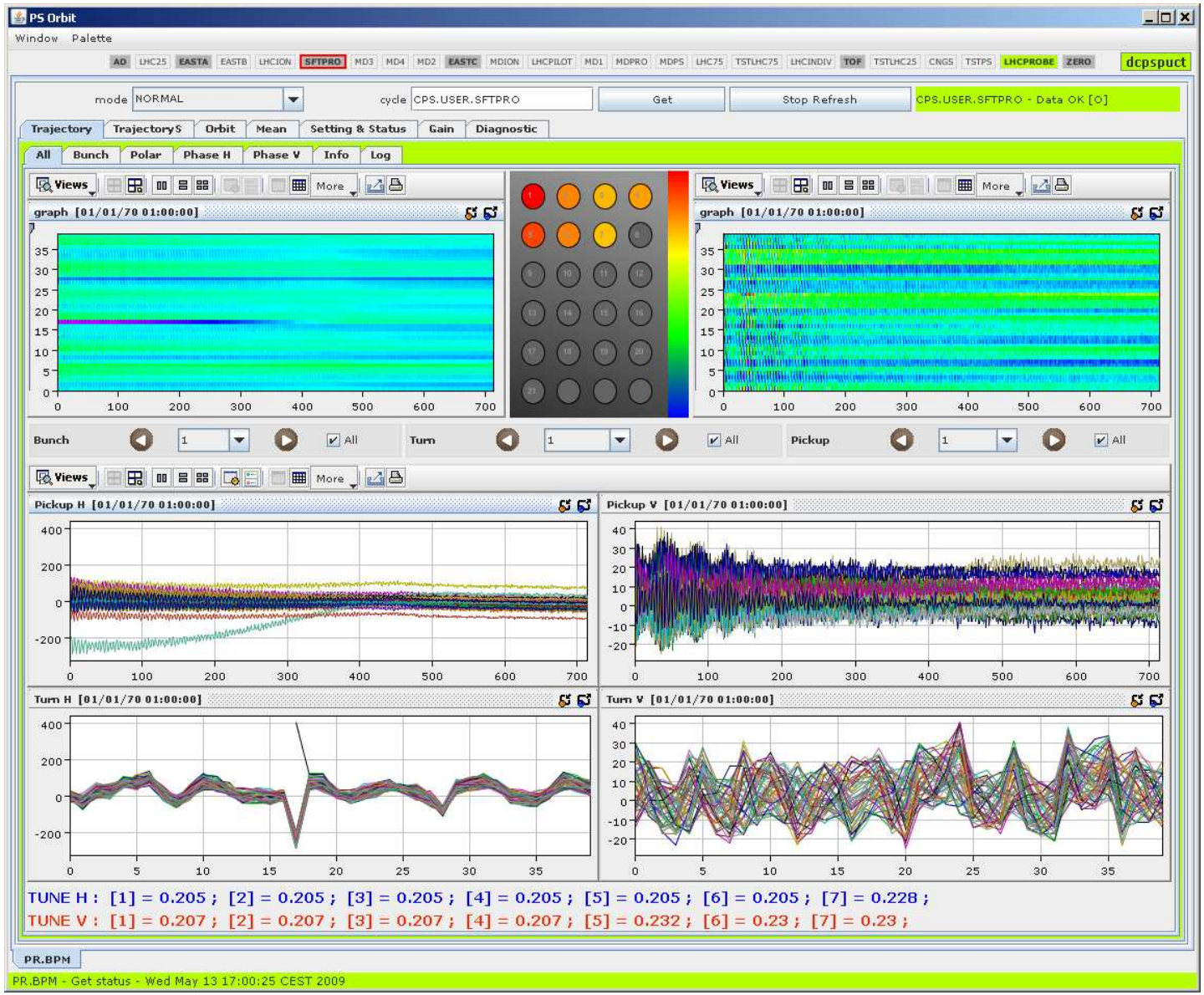
The aggregate front-end data rate is 30 GB/s (120 channels x 125MS/s x 2 bytes). After data reduction: 3GB/s (40 BPMs x 20 bunches x 8 bytes x 477 kHz).

- The system acquires more data than you can hope to get out of it.
- The TMS can serve multiple simultaneous independent clients.
- It can deliver up to about 500k points/cycle.
- That's about 25ms of trajectory, or instantaneous positions at a given PU over a full acceleration cycle of 1.2s.
- Intervening software layers and network bottlenecks may well prevent you from exploiting that.

Software architecture

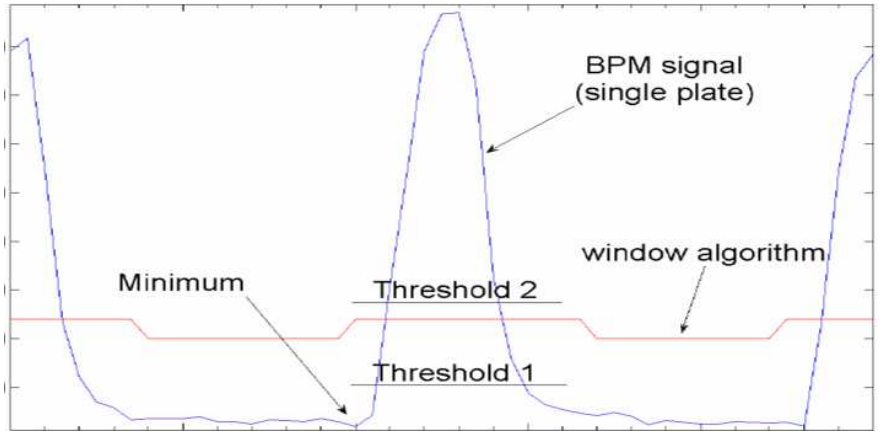


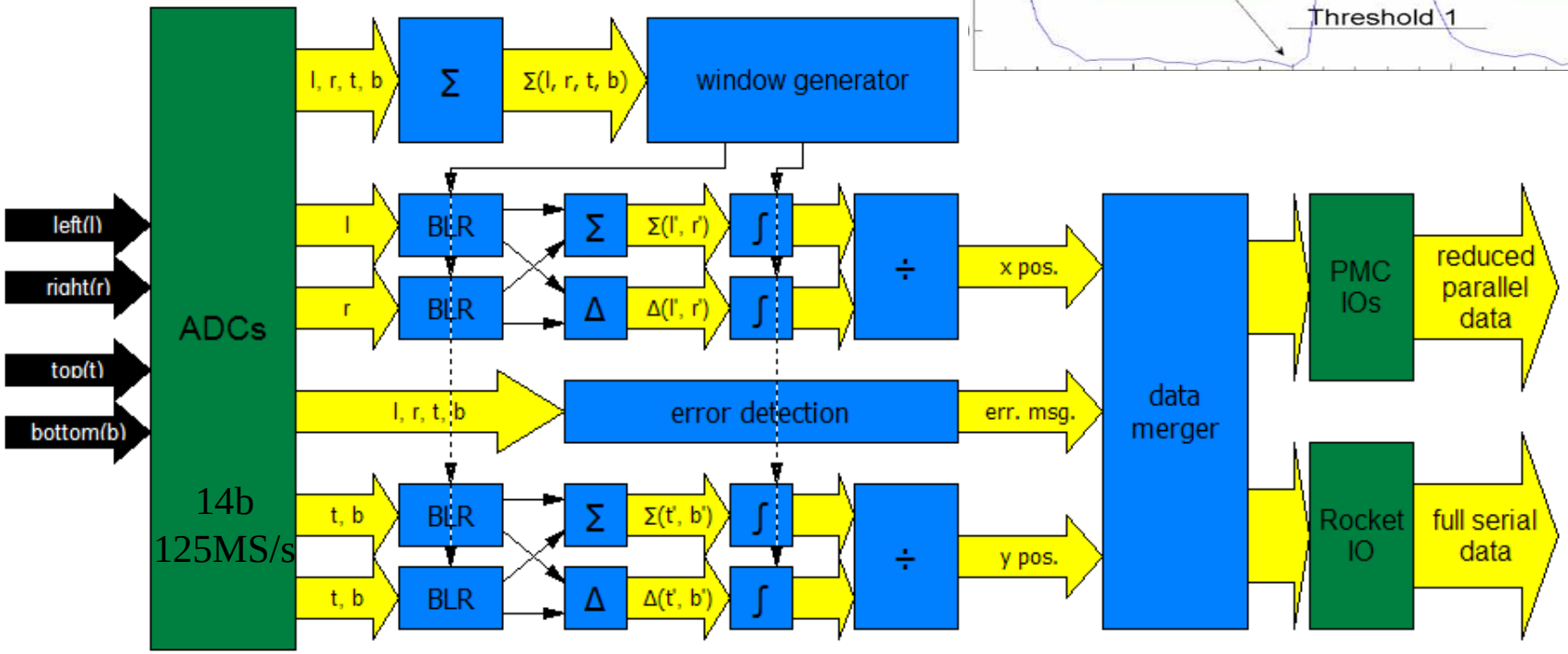
Expert interface using FESA



Work at GSI, for SIS18

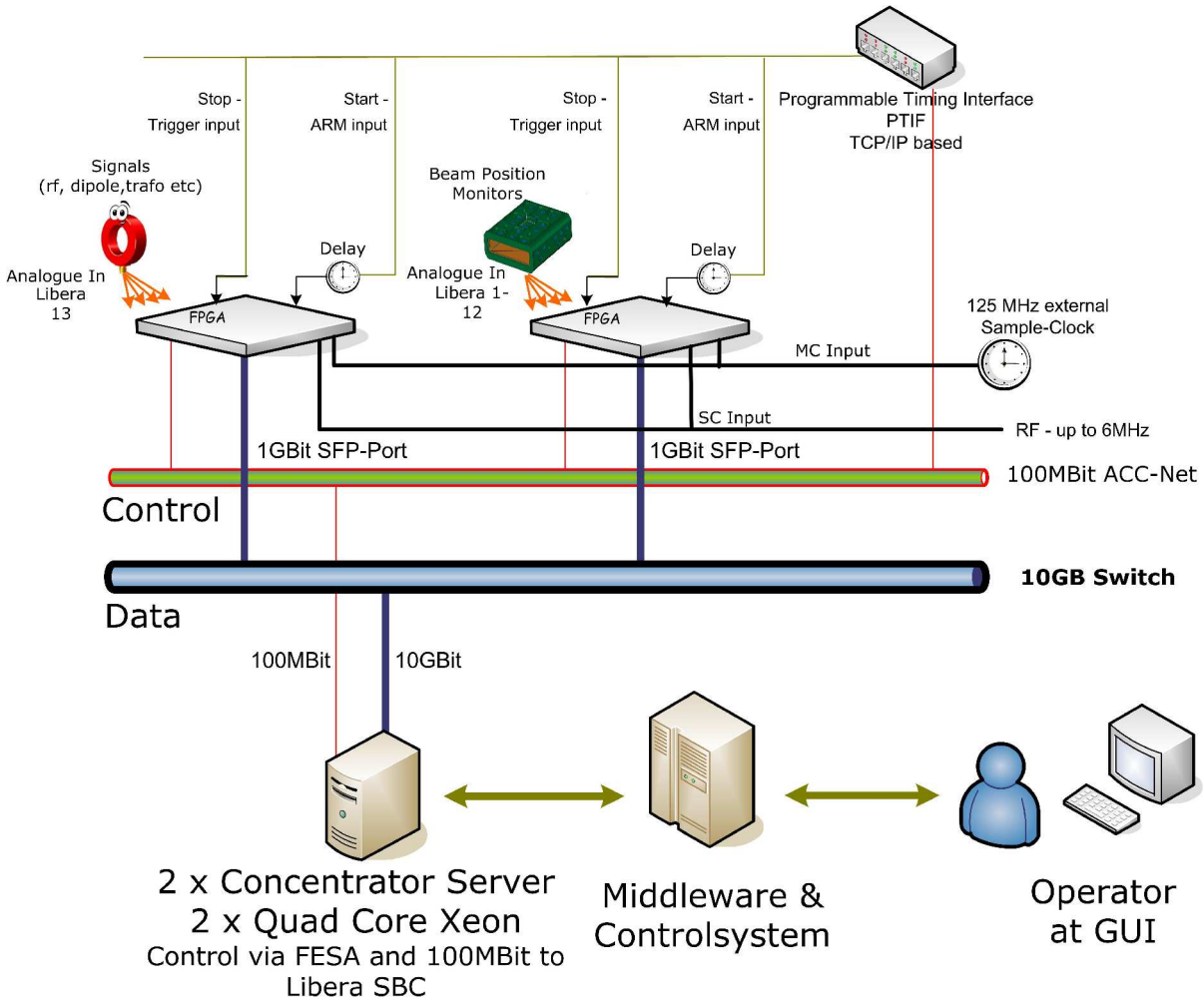
Hardware platform: I-tech's Libera
Digitizes individual plate signals.
Beam-synchronous timing via threshold crossing detection.





Data Acquisition and Analysis for SIS18 BPM

The position of *each individual* bunch is transferred to the server
The readout via FESA (CERN), developed in cooperation with COSYLAB



Status:

Nearly finished incl. GUI

First test in Feb. 09

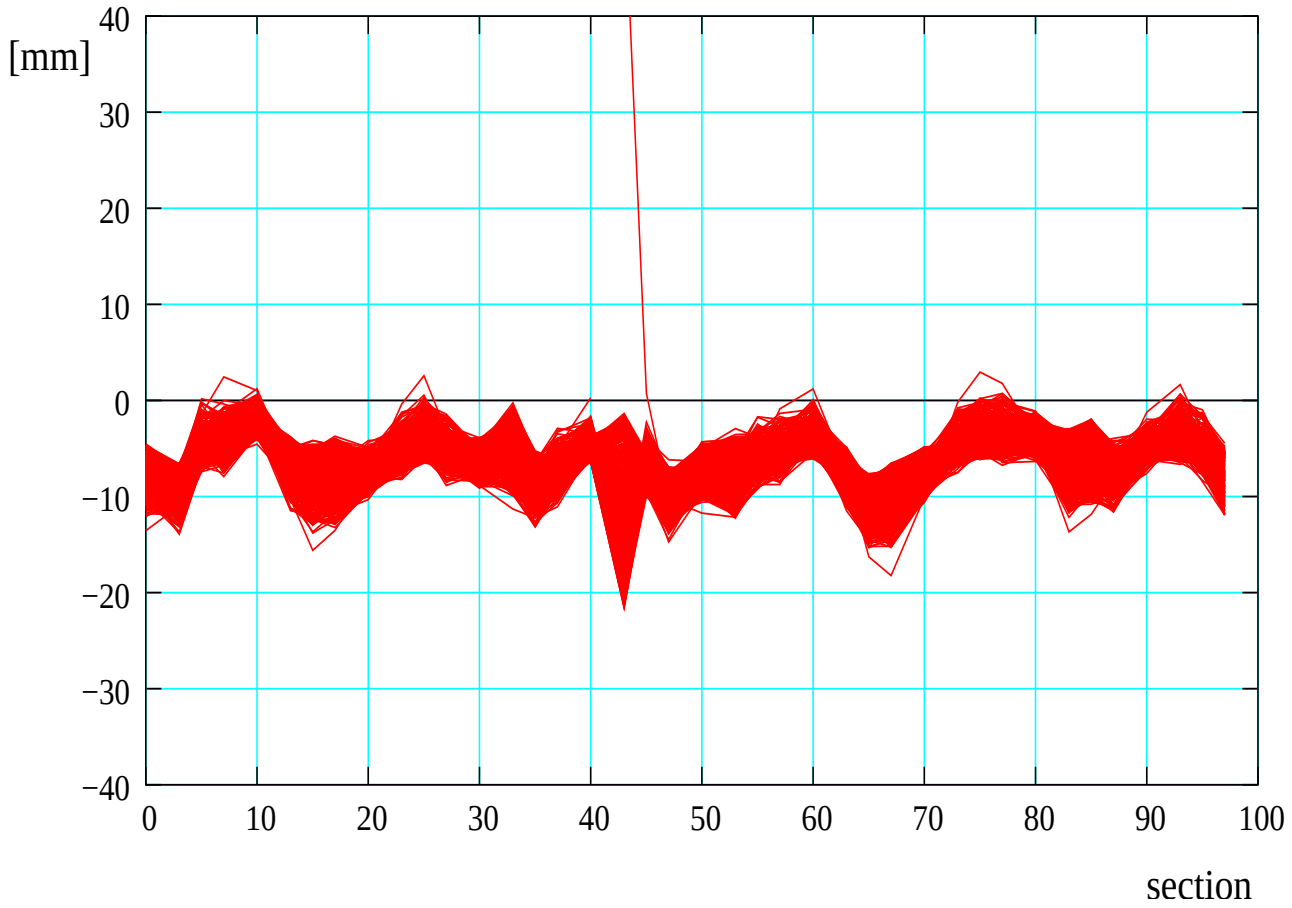
Features:

Data rate: up to 600 MB/s (50MB/s per BPM)

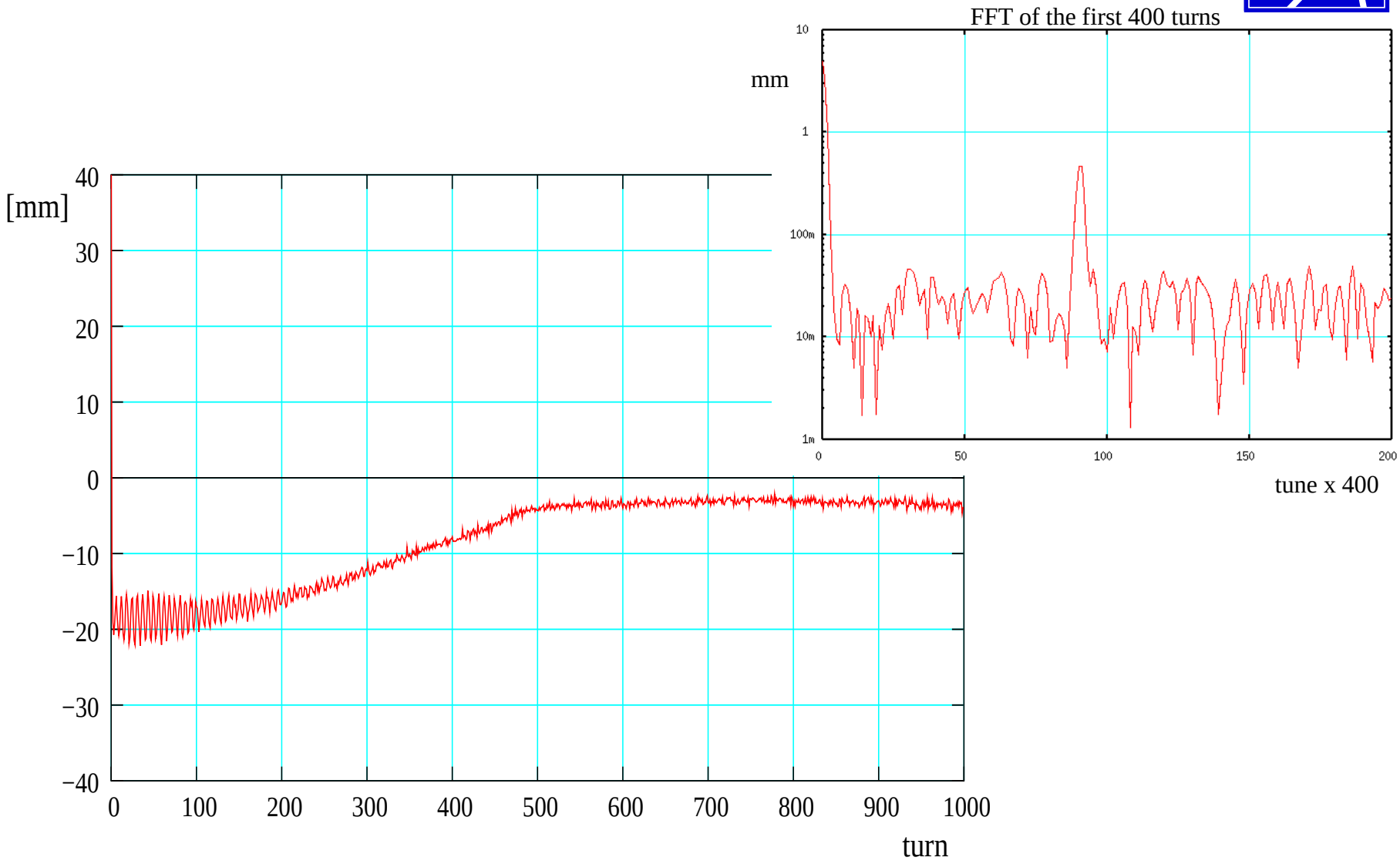
On-the-fly calculations

Evaluation tools for tune (see poster), closed orbit, trajectories

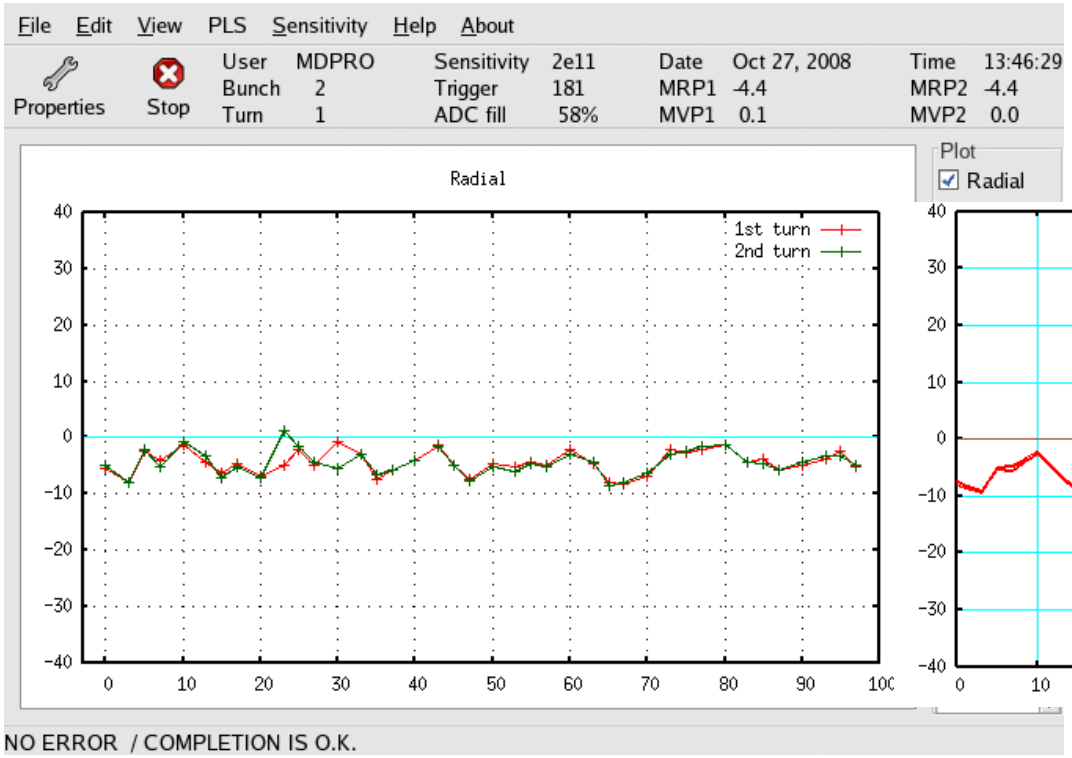
P+ beam, injection + 1000 turns

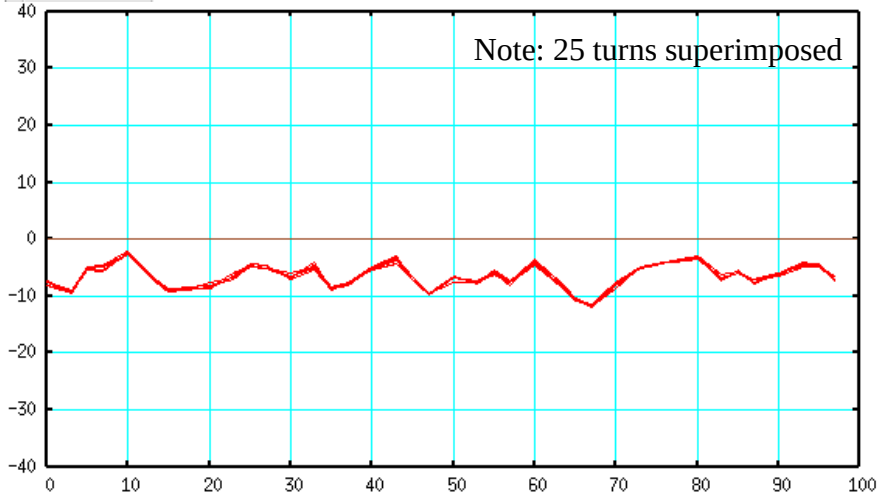


P^+, injection oscillations & injection bump collapse



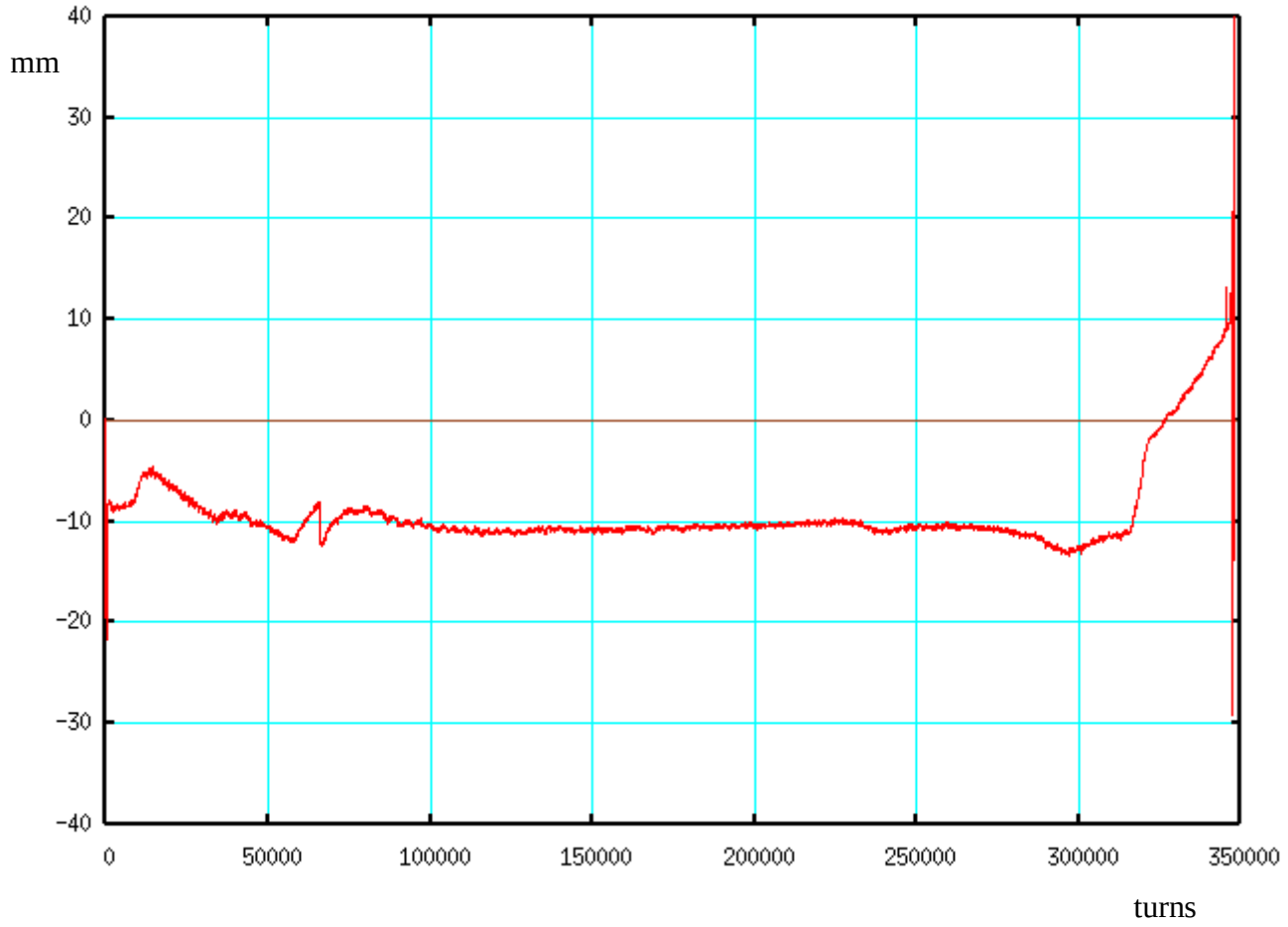
Side-by-side comparison of CODD and TMS



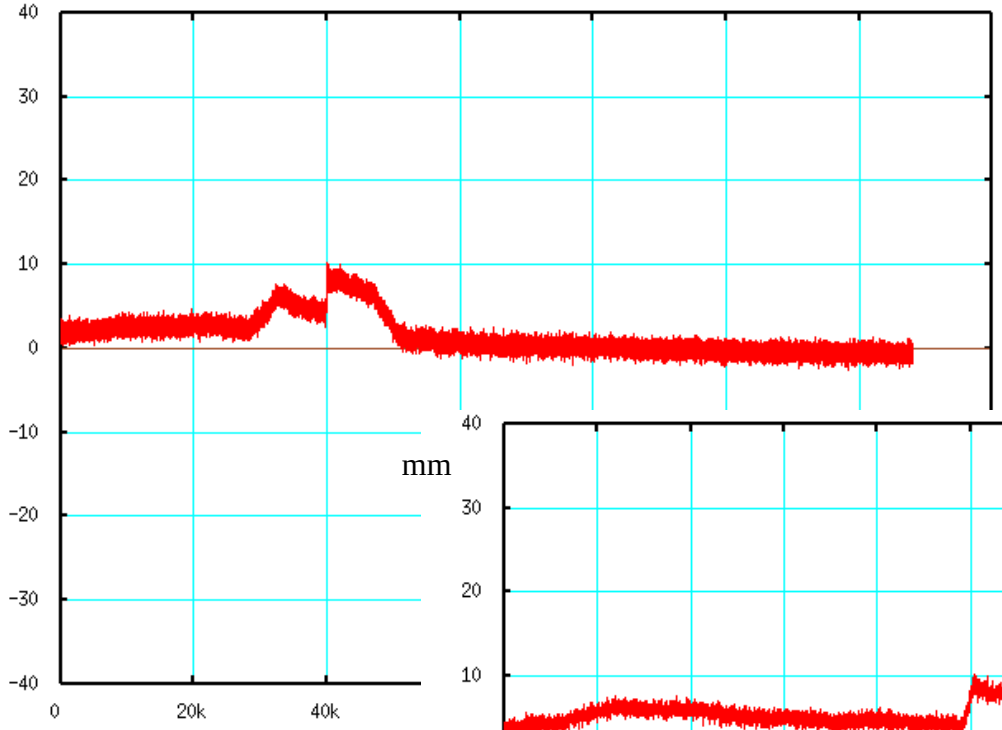


One of two 5e12ppb P^+ bunches, 11ms after injection

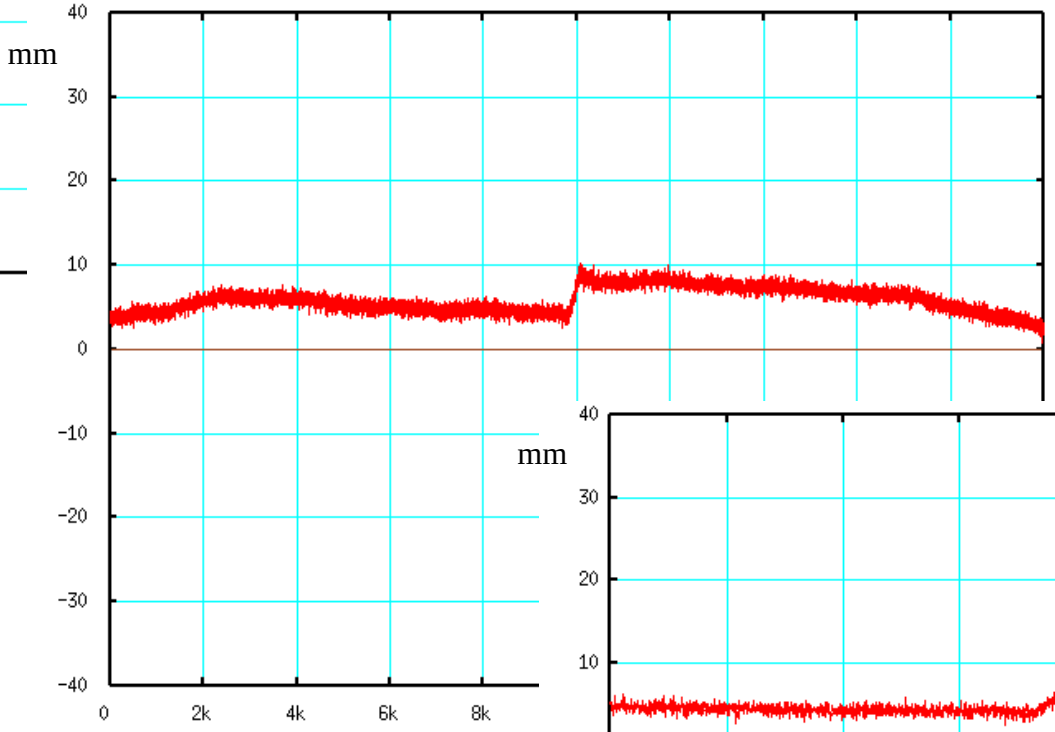
P^+, position at PU43, full cycle



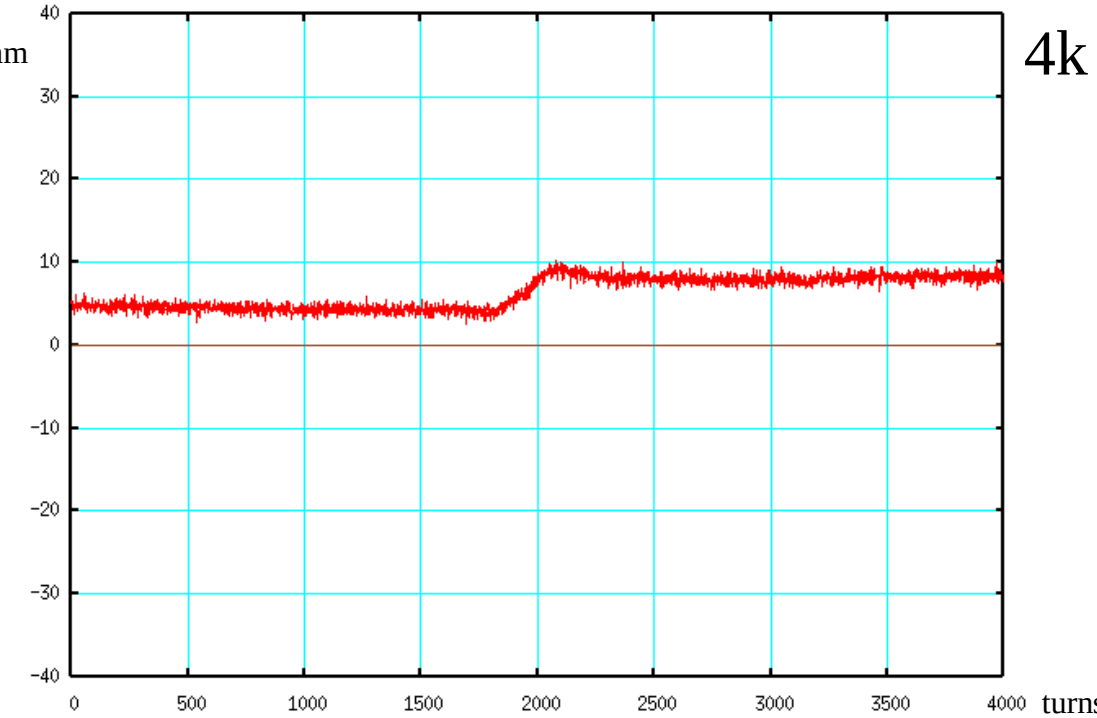
(These data are low_pass filtered to reduce noise)



128k revolutions



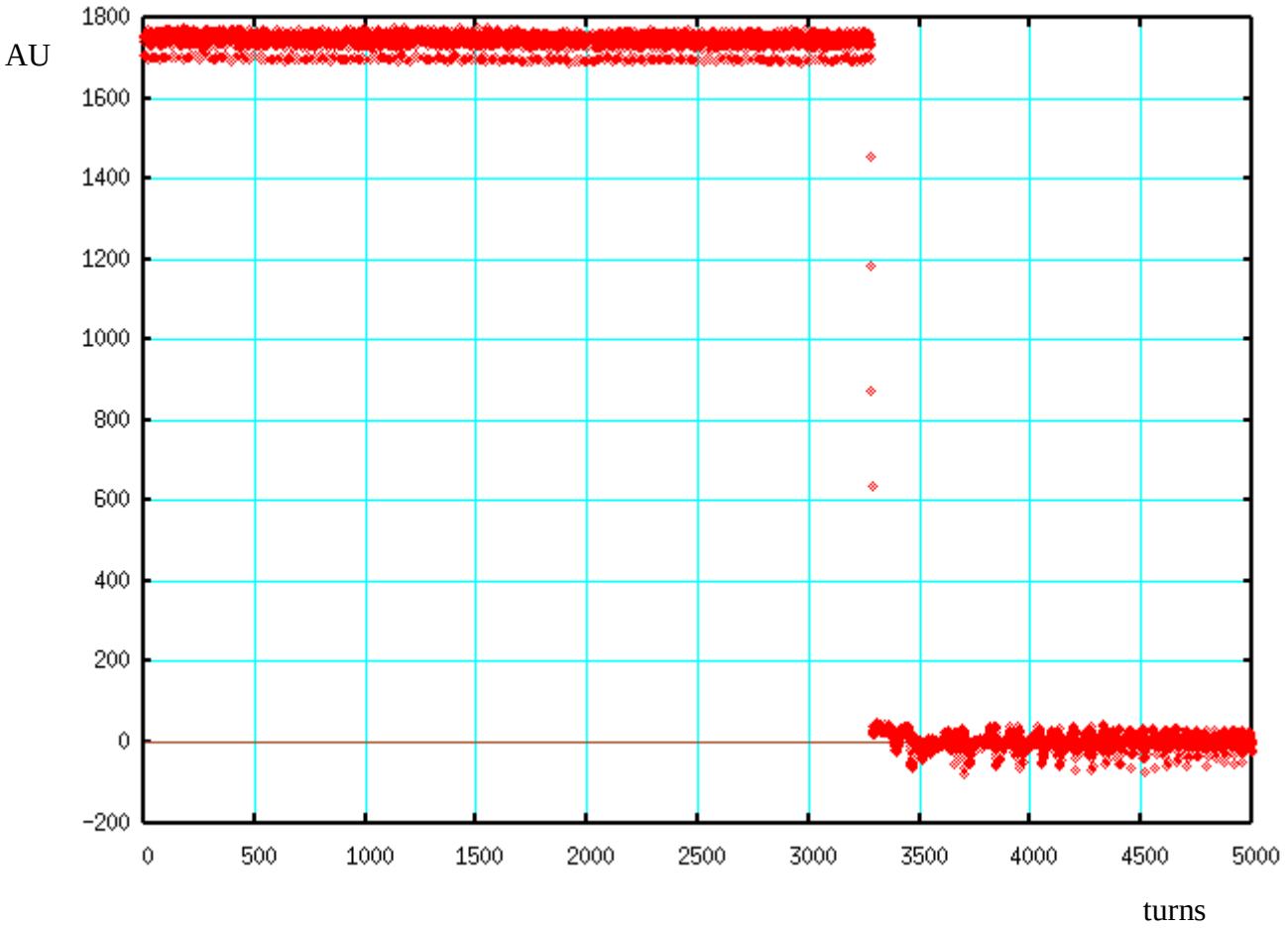
20k



4k

SFTPRO γ-Transition crossing seen at PU33

Ejection: Sum signal on PU15 starting at 838ms



Note: Extraction over 5-turns

Conclusions

The old PS trajectory system (CODD):

- Two-turn trajectories only
- On one selected bunch
- 5ms dead time

The new PS trajectory measurement system (TMS):

- Thousands-of-turns trajectories
- Orbits (trades time resolution for position resolution)
- Multi-bunch acquisitions

For both systems:

- Raw resolution: 0.3mm

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