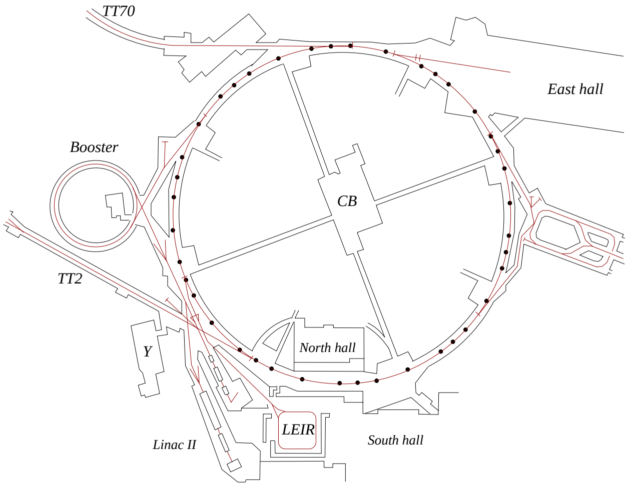
## Digital BPM Systems for Hadron Accelerators

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



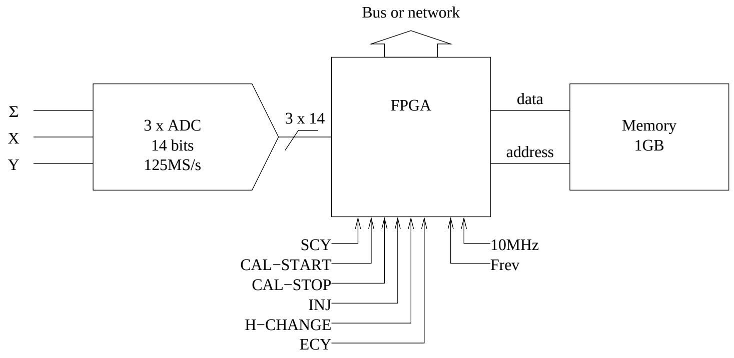

Trajectory measurement:

- System architecture
- Inputs
- Principles of operation
- Measurement examples



## System architecture

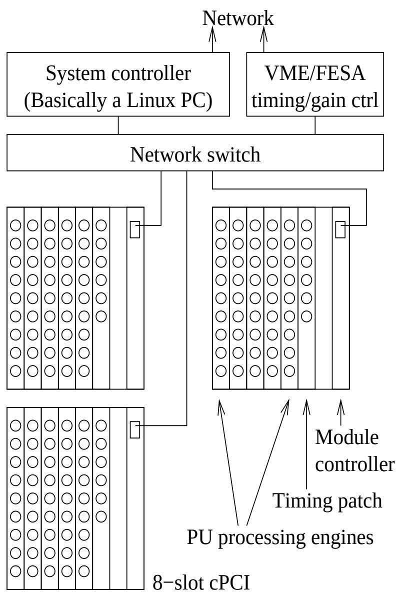
For one PU station:




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

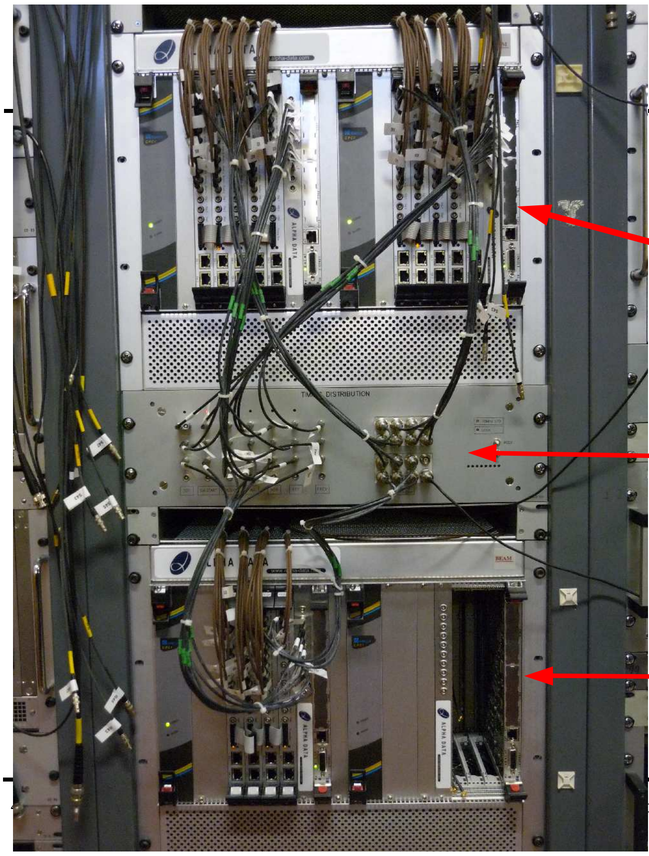



- 14 PU Processing Engines
- Treating 3 PUs each
- 3 half-width cPCI crates
- One system controller

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



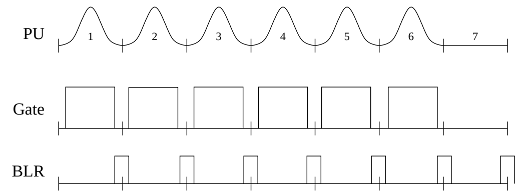
cPCI crates

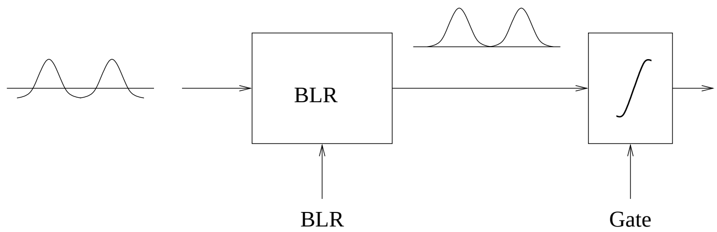
Timing

cPCI crates

## Position measurement principle

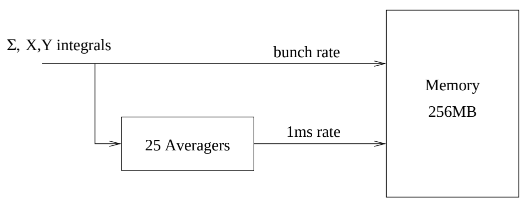
Position of each bunch is measured individually
Integration over the length of one bunch
Base Line Restoration is needed because the
BPMs have no DC response





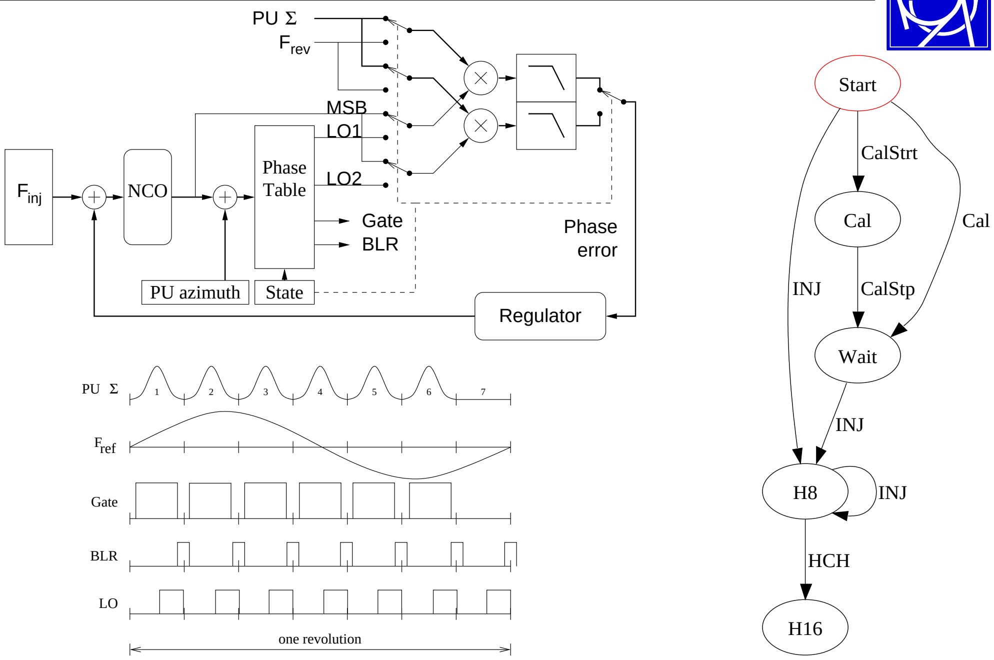

## Data paths




- 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

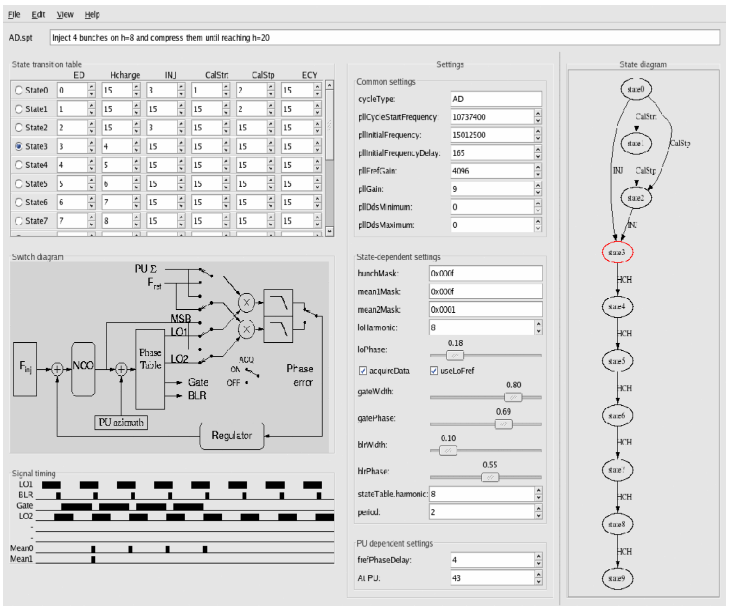
Most of the memory is used for trajectory data (0xfe00000 bytes). Averaging tables are of size 4096.

# 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

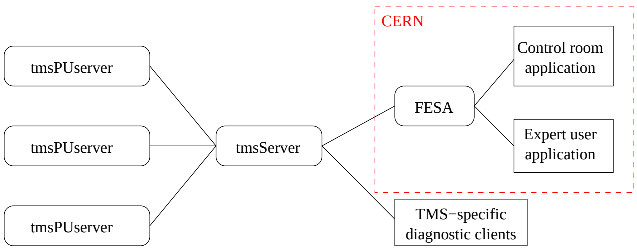
## Some considerations...

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).

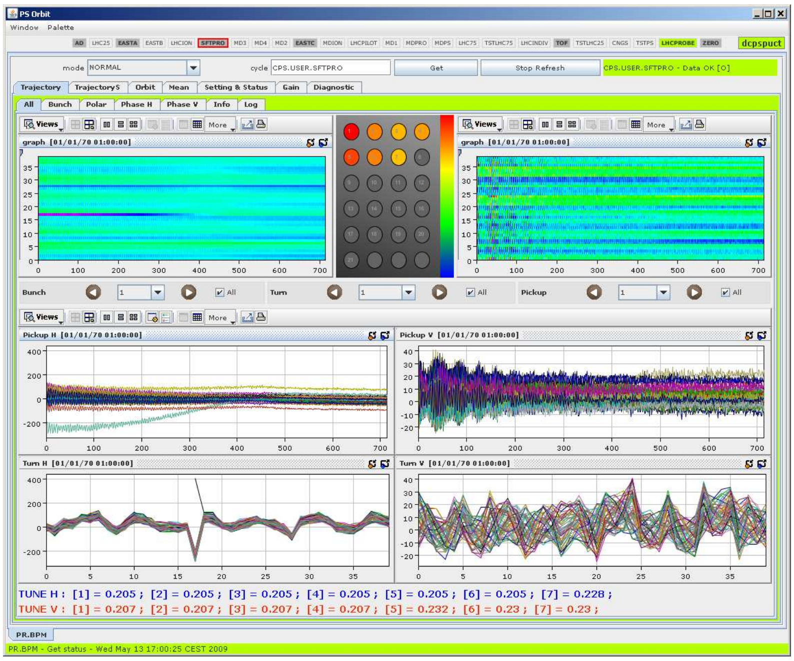
- The system acquires more data than you can hope to get out of it.
- The TMS can serve multiple simultaneous independent clients.
- It can deliver up to about 500k points/cycle.
- That's about 25ms of trajectory, or instantaneous positions at a given PU over a full acceleration cycle of 1.2s.
- Intervening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



## Software architecture



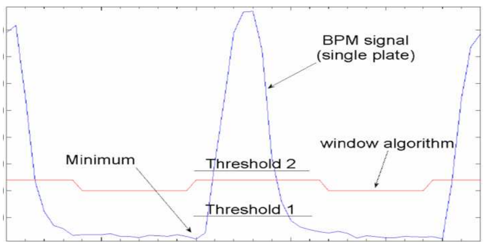
## Expert interface using FESA

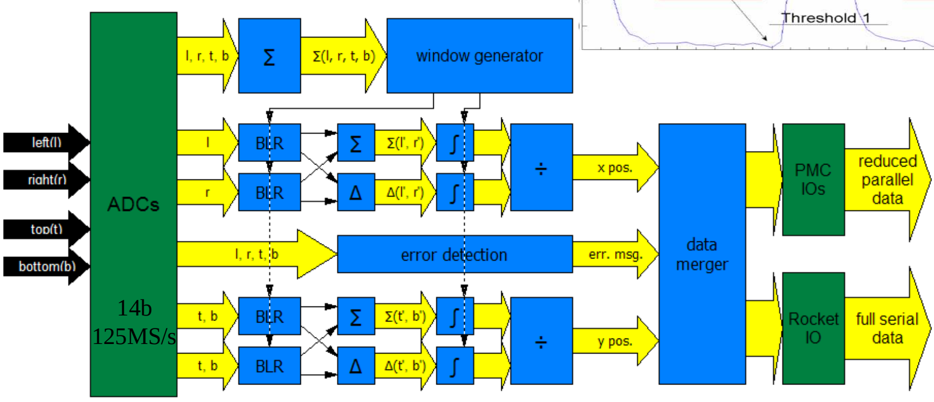





## Work at GSI, for SIS18

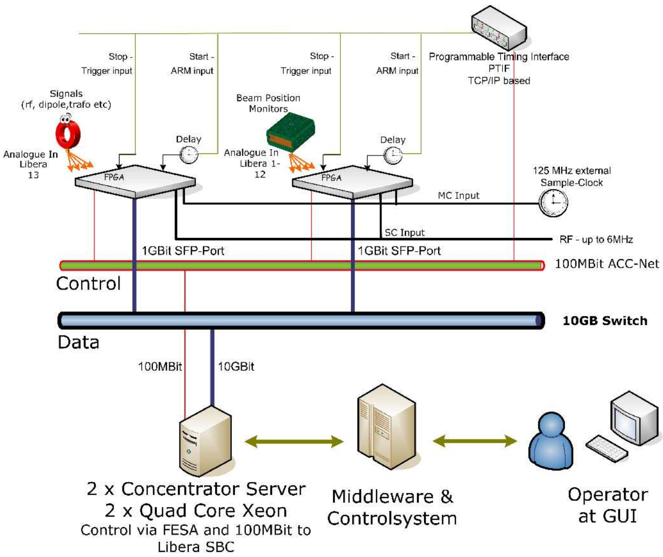
Hardware platform: I-tech's Libera
Digitizes individual plate signals.
Beam-synchronous timing via
threshold crossing detection.



## 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:**

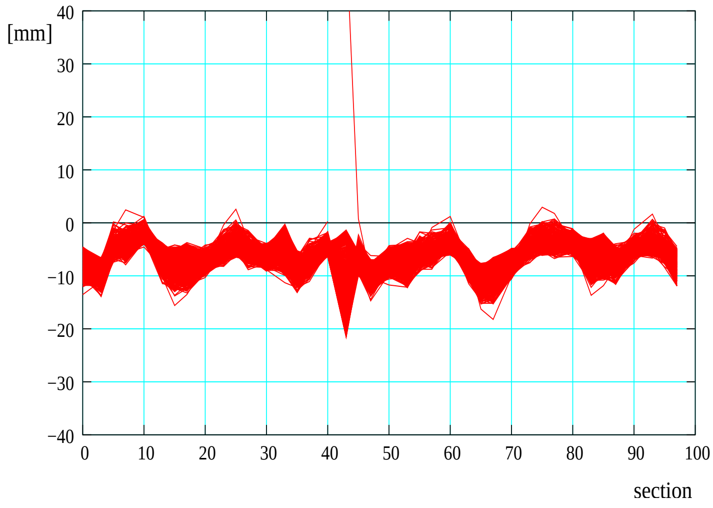
Data rate: up to 600 MB/s (50MB/s per BPM)

On-the-fly calculations

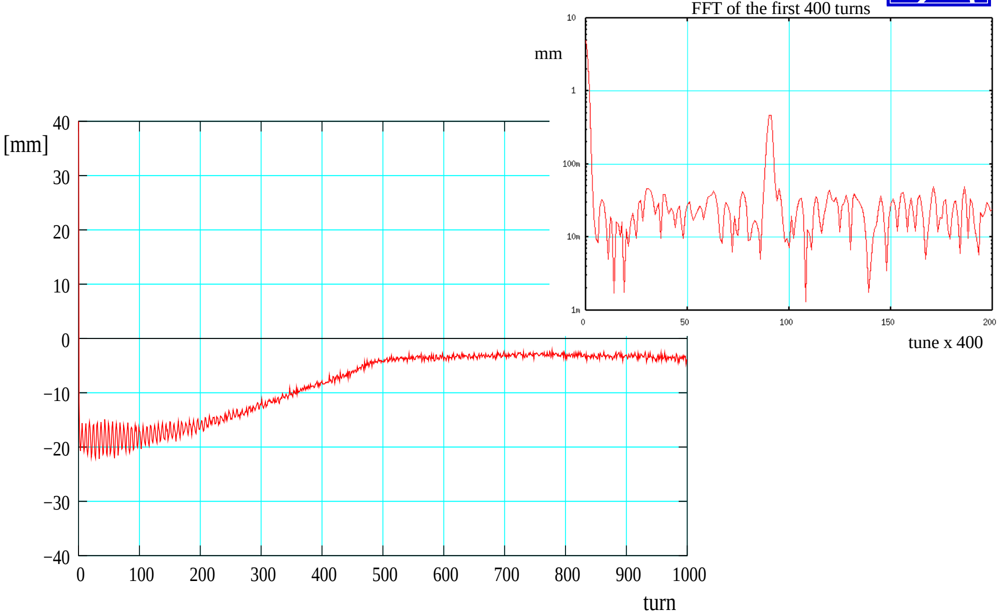
Evaluation tools for tune (see poster), closed orbit, trajectories



## P+ beam, injection + 1000 turns

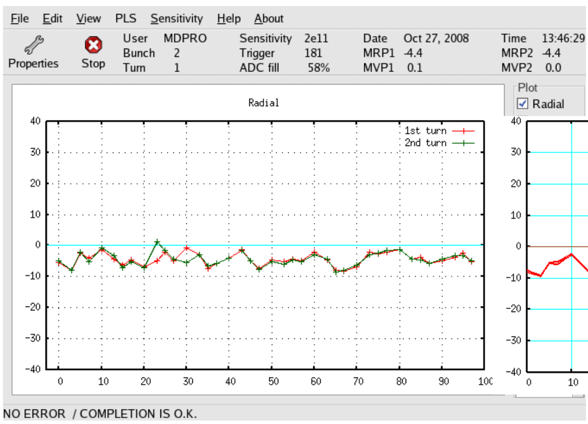


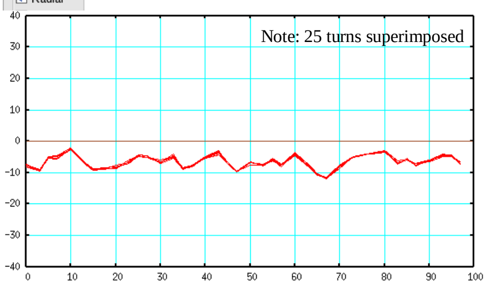
# $P^+$, injection oscillations & injection bump collapse





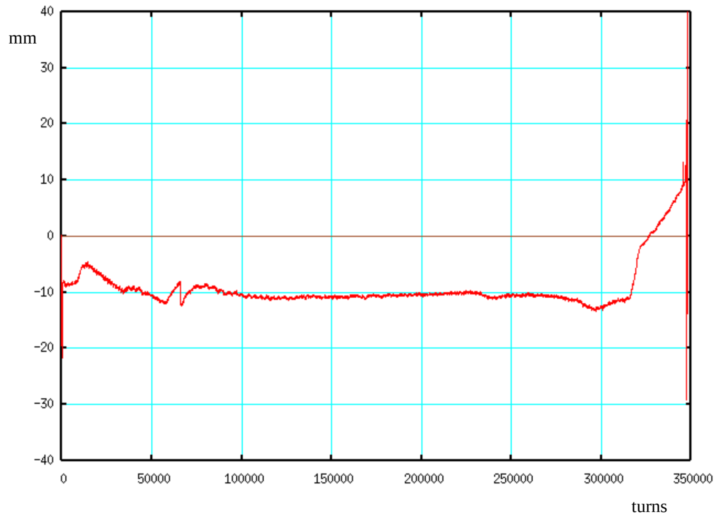

# Side-by-side comparison of CODD and TMS




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

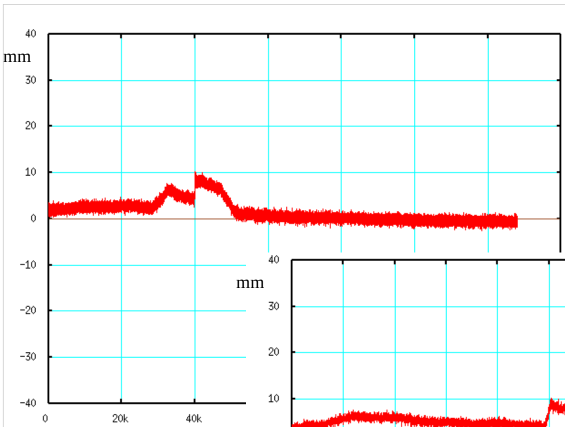
# P⁺, position at PU43, full cycle



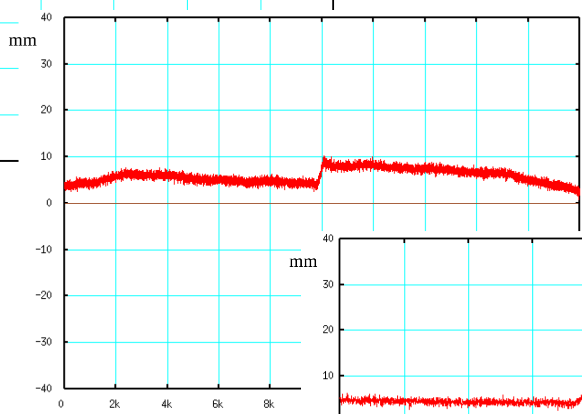

(These data are low_pass filtered to reduce noise)



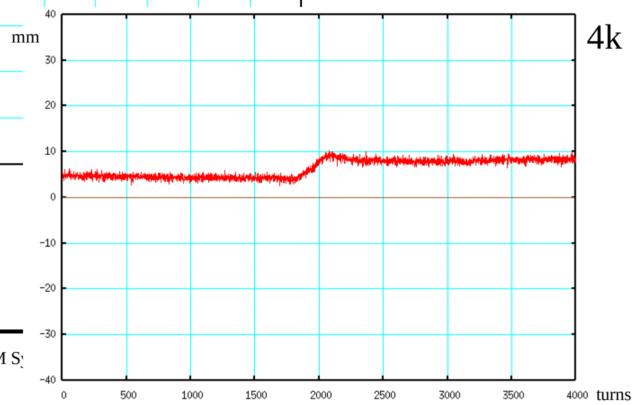
# 128k revolutions




20k

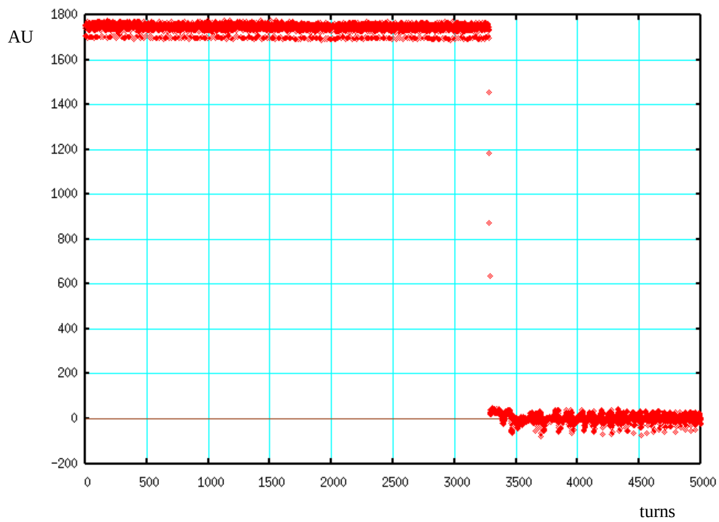



4k




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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