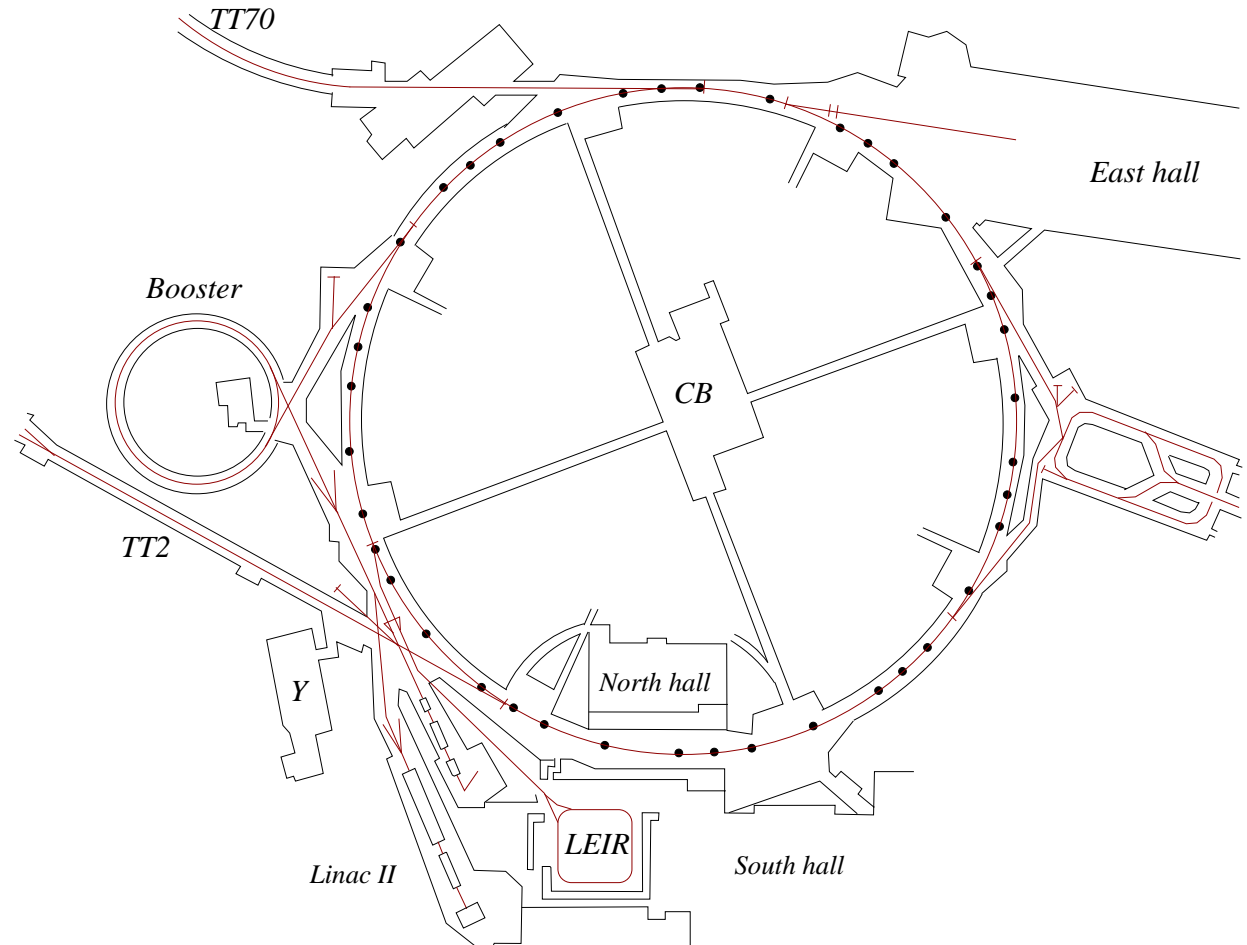




Measuring particle beam trajectories

The CERN PS complex

- Radius: 100 m
- Energy: 26 GeV
- RF harmonic: 8 to 420
- Bunches: 1 to 420
- Charge/bunch:
 $1 \cdot 10^9$ to $8 \cdot 10^{12} Q_0$
- Pick-Ups: 40
- PU type : Electrostatic

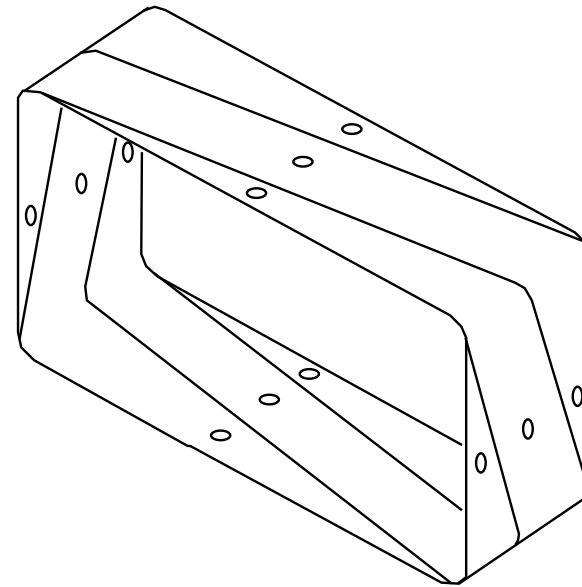




Measuring particle beam trajectories

Pick-Up electrodes

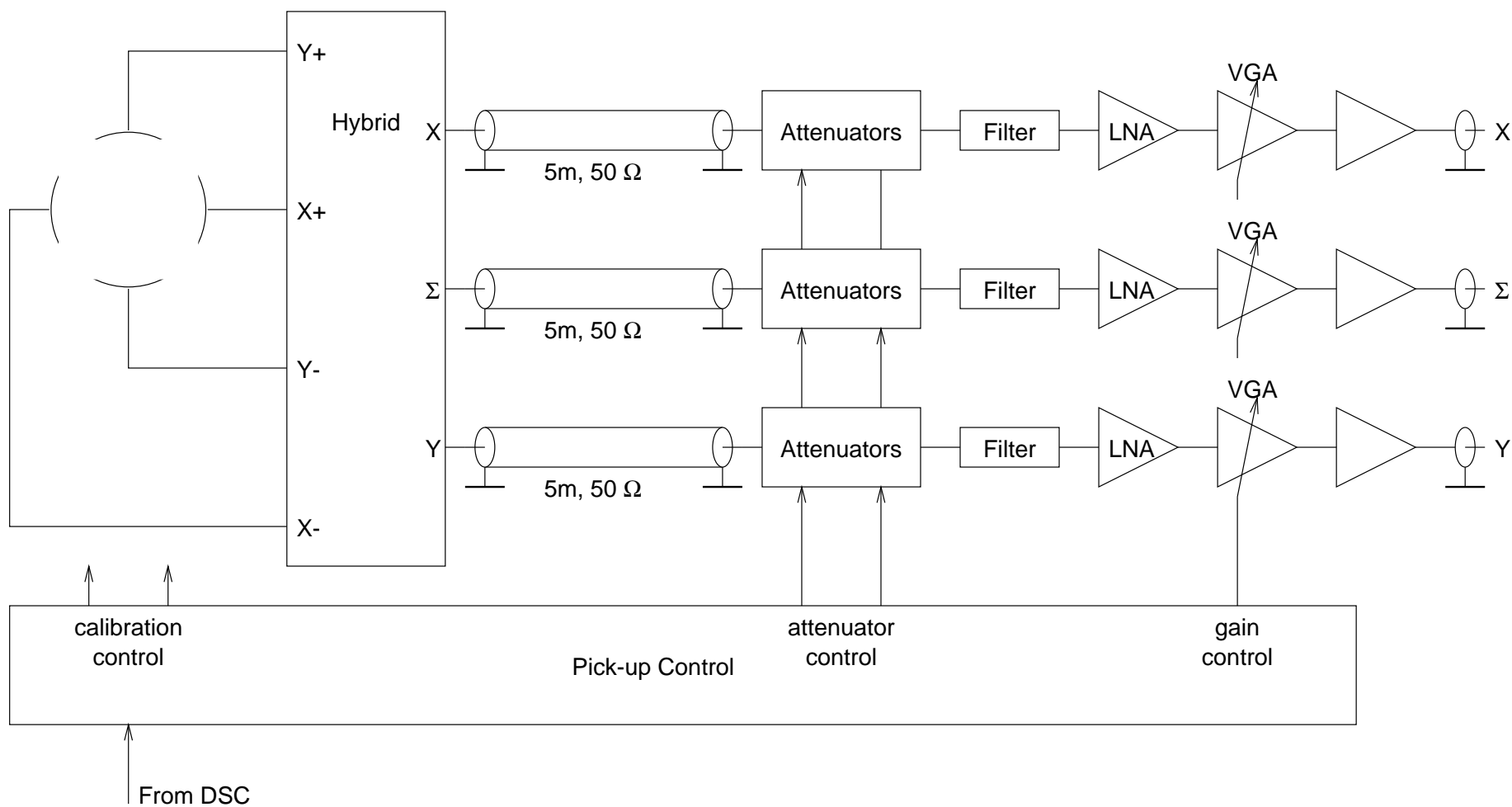
- Length: 62 mm
- Aperture: 166x80 mm
- Capacitance: 100pF
- R_t : 0.52 Ω
- S_x : 174 mm
- S_y : 82 mm





Measuring particle beam trajectories

Analogue signal processing



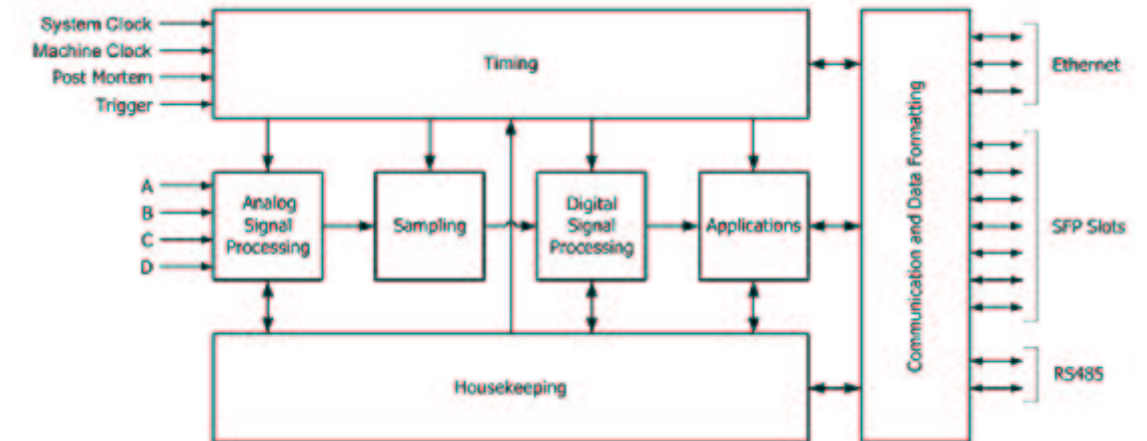


Measuring particle beam trajectories

Acquisition

Digitizing hardware: Libera

- Four 125MSPS, 12 bit ADCs
- Large SDRAM
- Xilinx Virtex II FPGA





Measuring particle beam trajectories

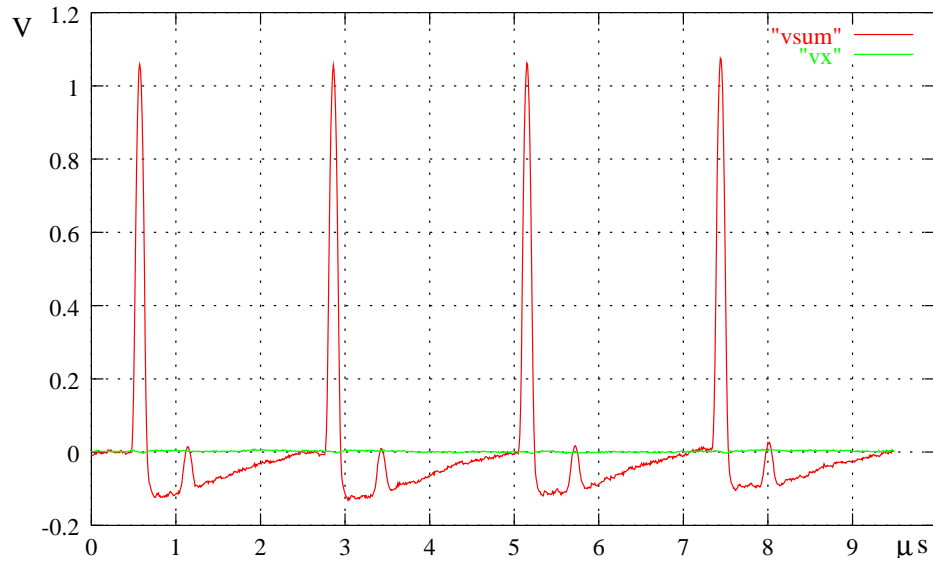
What needs to be measured:

- Trajectory of each bunch up to $h=21$
- Orbits of individual bunches up to $h=21$
- Tune?

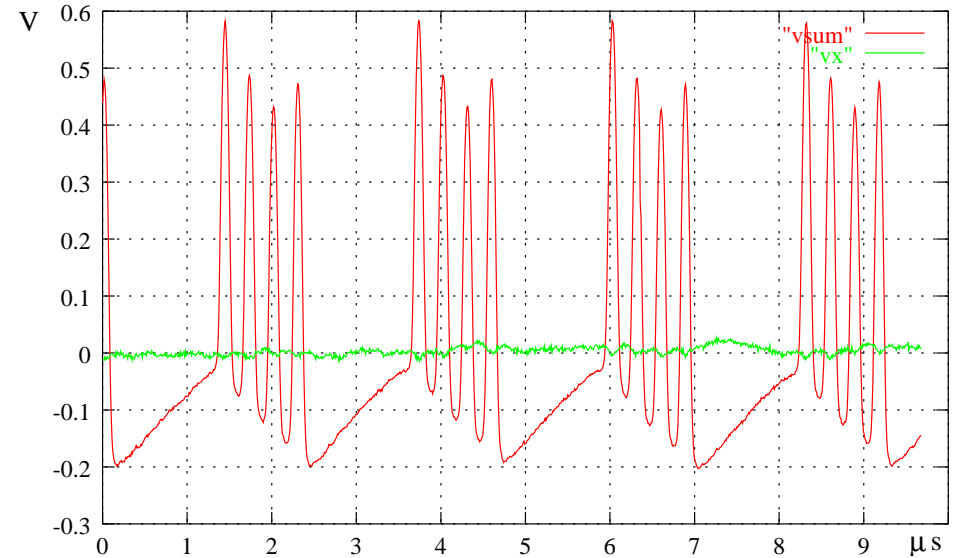


Measuring particle beam trajectories

Sample signals



EASTC, $3.6 \cdot 10^{12} p^+ / b + 3 \cdot 10^{11} p^+ / b$

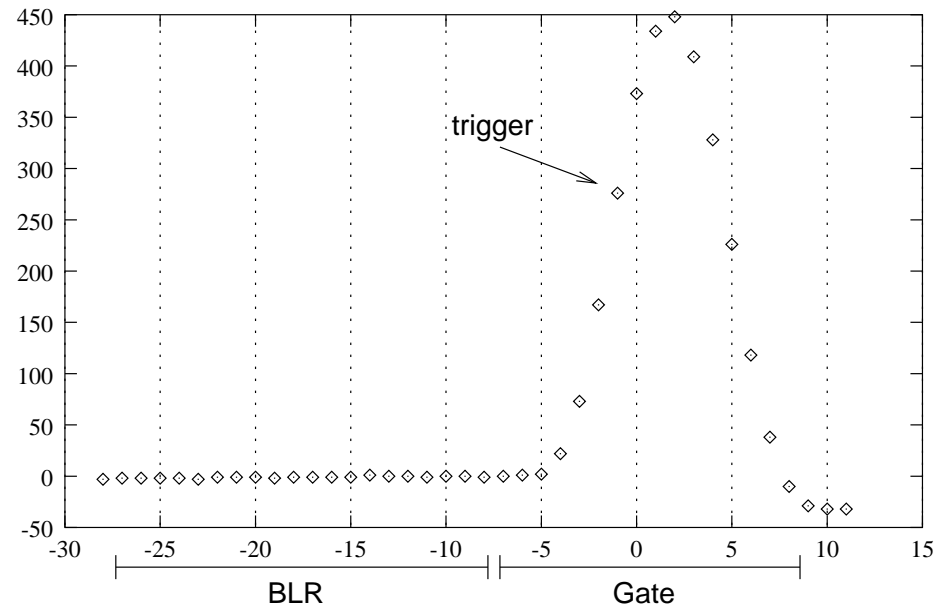


AD, $3.7 \cdot 10^{12} p^+ / b$



Measuring particle beam trajectories

Integration algorithm



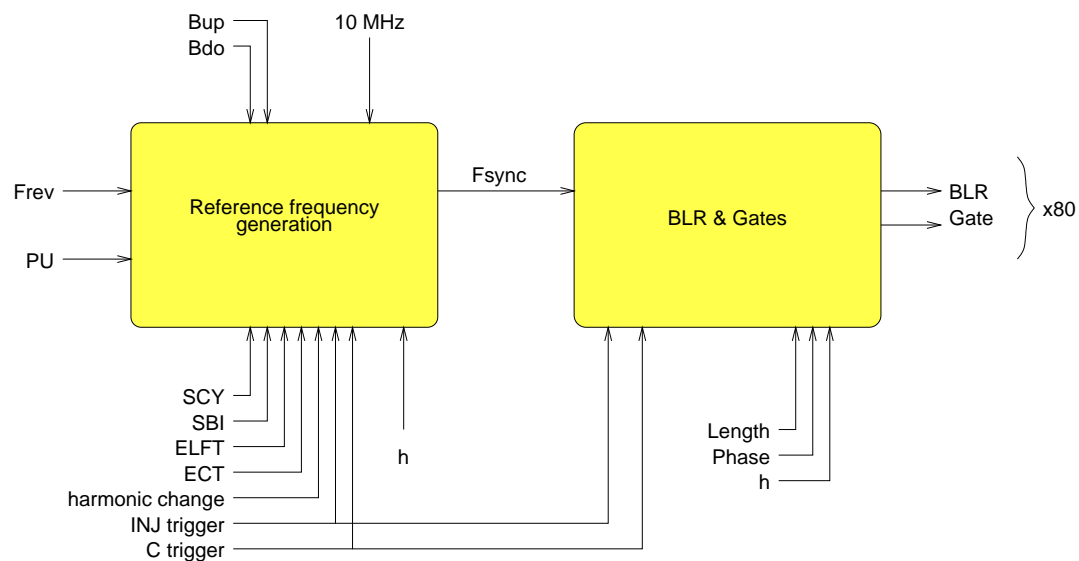
- Base line sampled and low-pass filtered just prior to bunch
- Integration is simple addition of baseline-corrected samples
(This leaves a lot of room for refinements)



Measuring particle beam trajectories

Synchronization

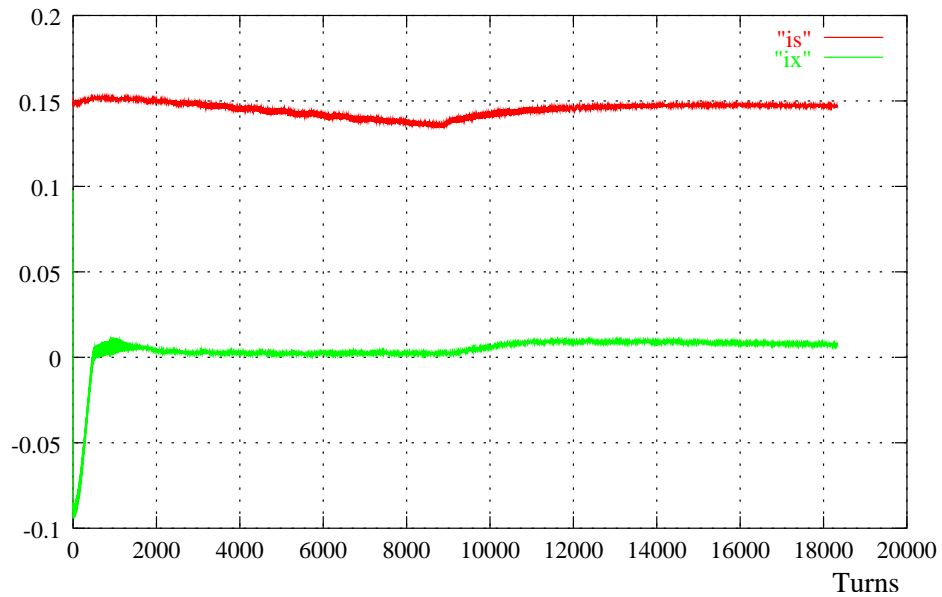
- Edge detection doesn't work
 - Different-intensity bunches in the same cycle
 - Variable number of buckets filled
 - Bunch splitting changes number of bunches on the fly
 - Multiple ejections
- Synchronization is necessarily complex and it must be flexible too



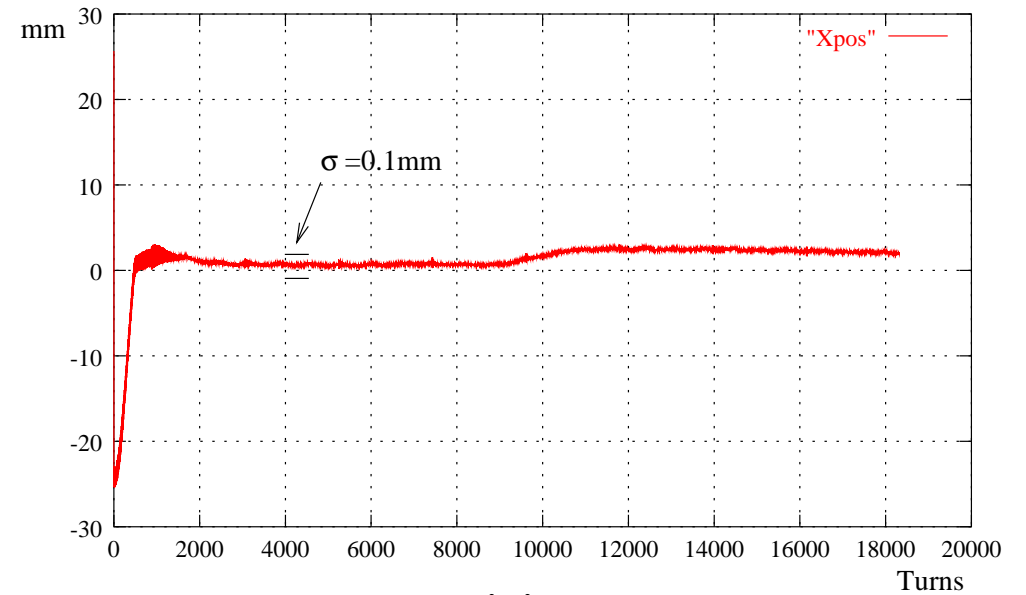


Measuring particle beam trajectories

Finding the position



Integrals



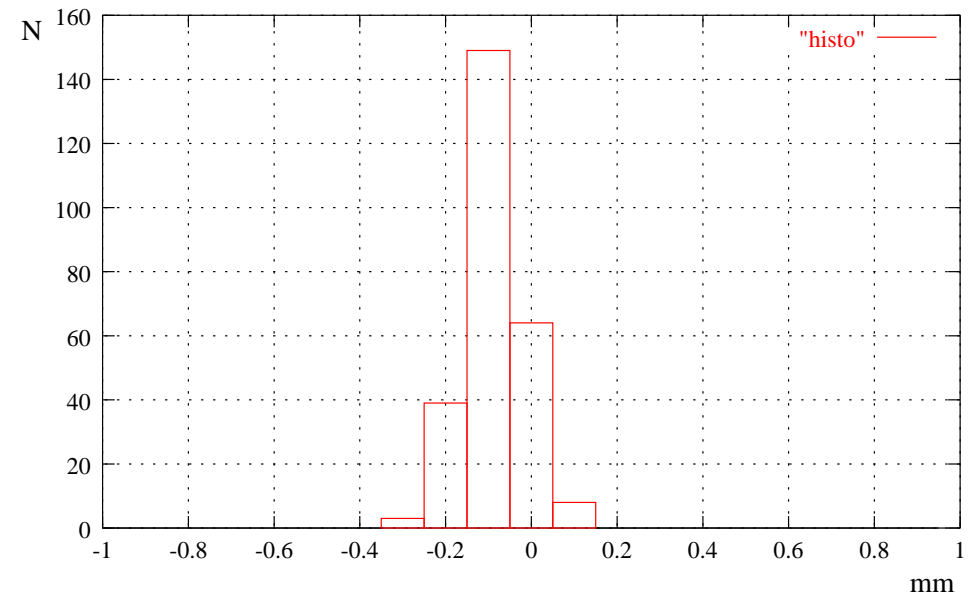
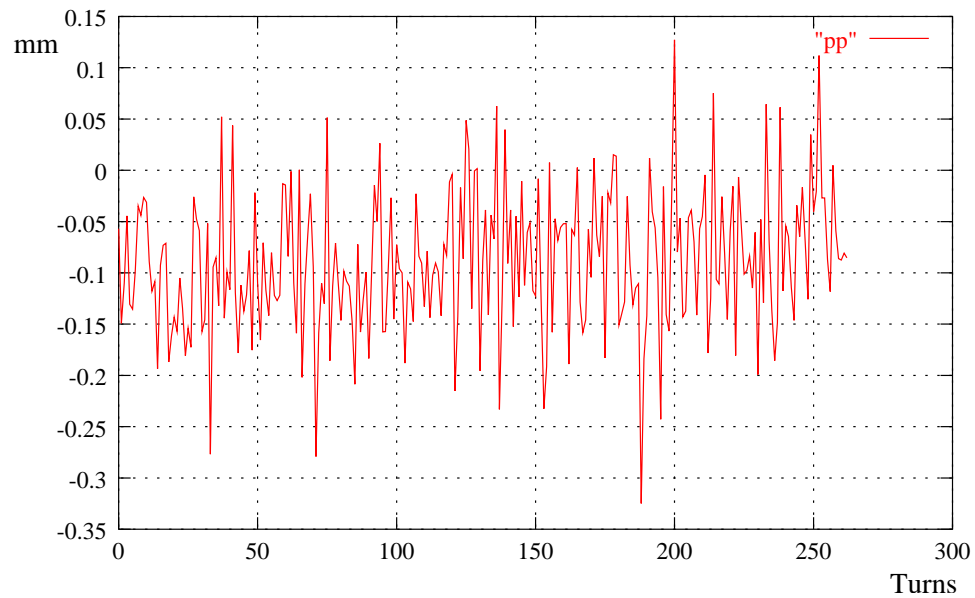
Positions

$$x = S_x \frac{\Delta_x}{\Sigma}$$



Measuring particle beam trajectories

On resolution



$$\sigma_{X/\Sigma} = S_x \frac{\bar{X}}{\bar{\Sigma}} \sqrt{\frac{\sigma_X^2}{\bar{X}^2} + \frac{\sigma_\Sigma^2}{\bar{\Sigma}^2}}$$

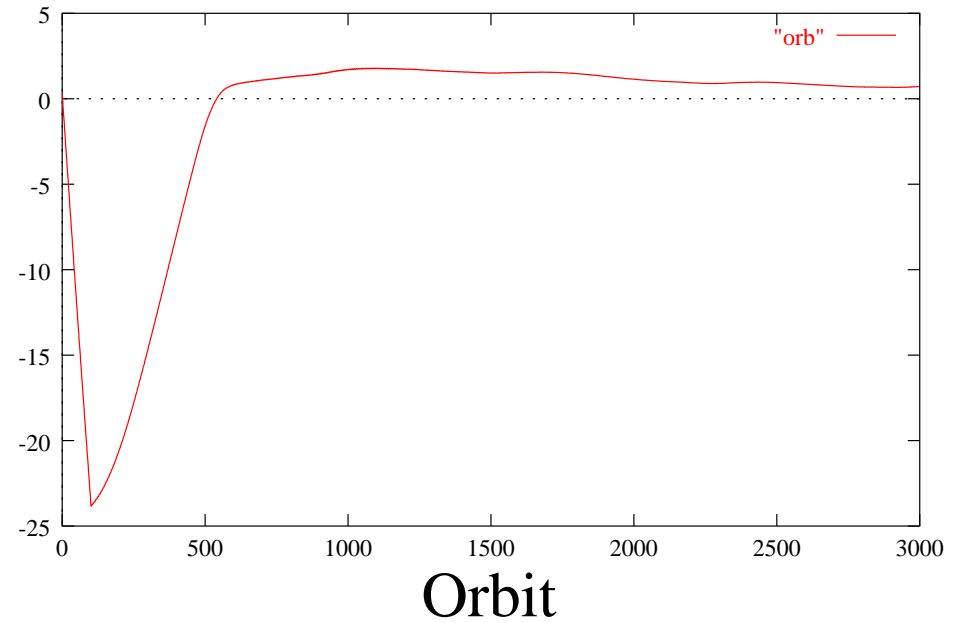
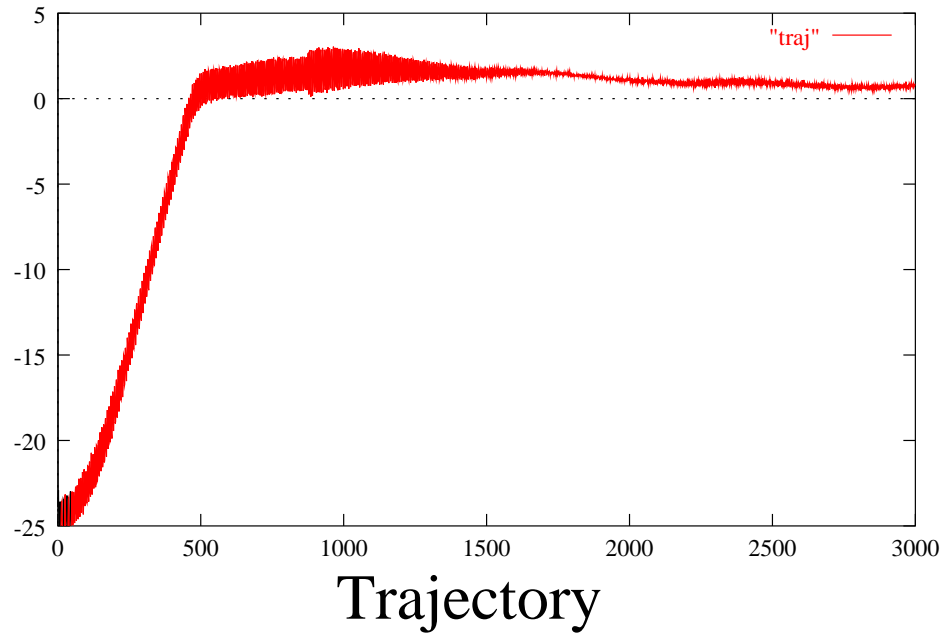
$$\mu : -0.09\text{mm}$$

$$\sigma : 0.07\text{mm}$$



Measuring particle beam trajectories

Orbits

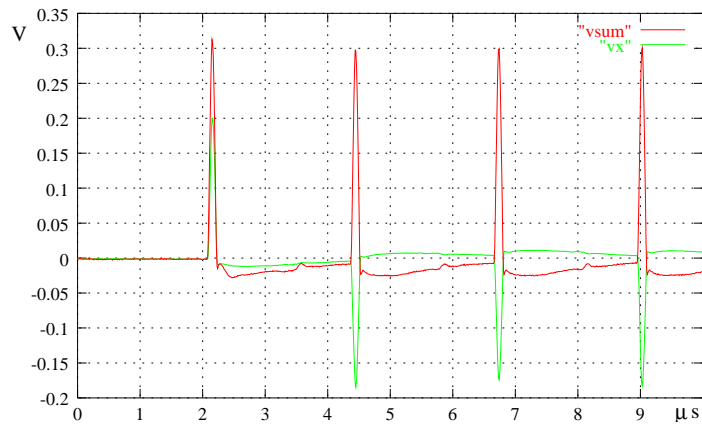


- Average N trajectories ($N \sim 100$)
- Gain 10 times in resolution

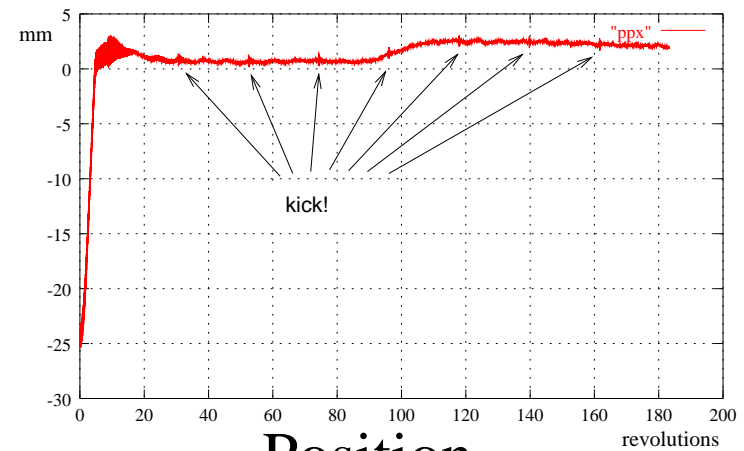


Measuring particle beam trajectories

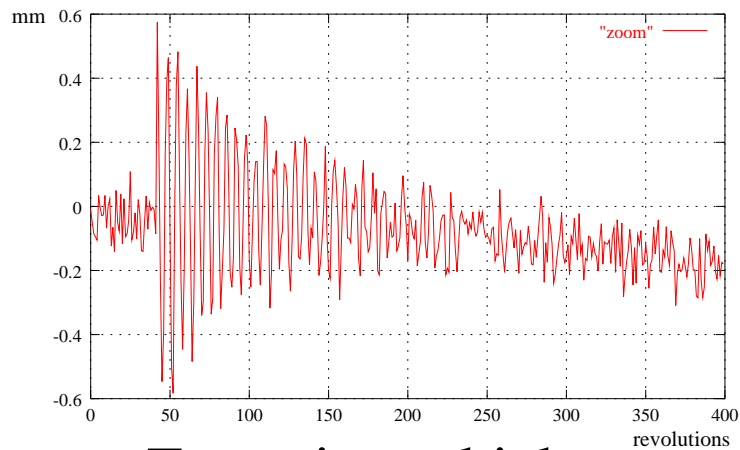
Tune measurement



Raw data

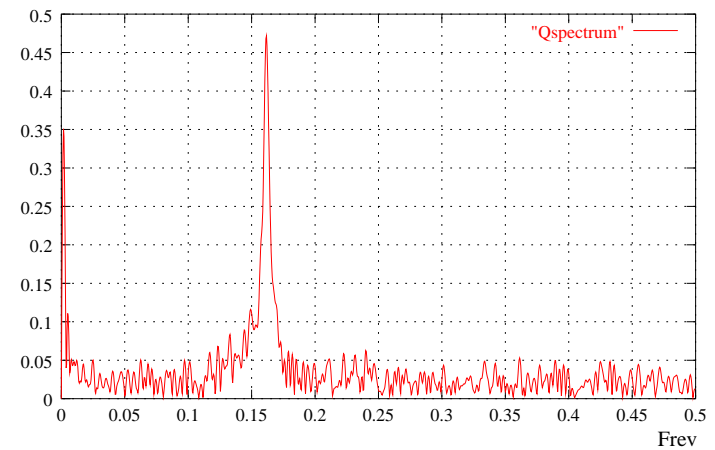


Position



Zoom in on kick

Fourier →



$q=0.1615$



Measuring particle beam trajectories

Conclusions

- A prototype Libera has been used to acquire PU signals at the CERN PS.
- Data processing has been done off-line, so far.
- Measuring trajectories all bunches every turn with 0.1mm resolution is possible.
- Resolution is limited by analogue signal, not by digitizers.
- The synchronization problems persists.



Measuring particle beam trajectories

References:

- J.M. Belleman, "Using a Libera signal processor for acquiring position data from the PS orbit pick-ups", CERN AB-Note-2004-059 BDI,
<http://documents.cern.ch/archive/electronic/cern/others/ab/ab-note-2004-059.pdf>
- The transparencies on PU data treatment:
<http://cern.ch/jeroen/slides/Darmstadt2004/algorithms.pdf>
- The transparencies on the PU pre-amplifier electronics:
<http://cern.ch/jeroen/slides/Darmstadt2004/electronics.pdf>