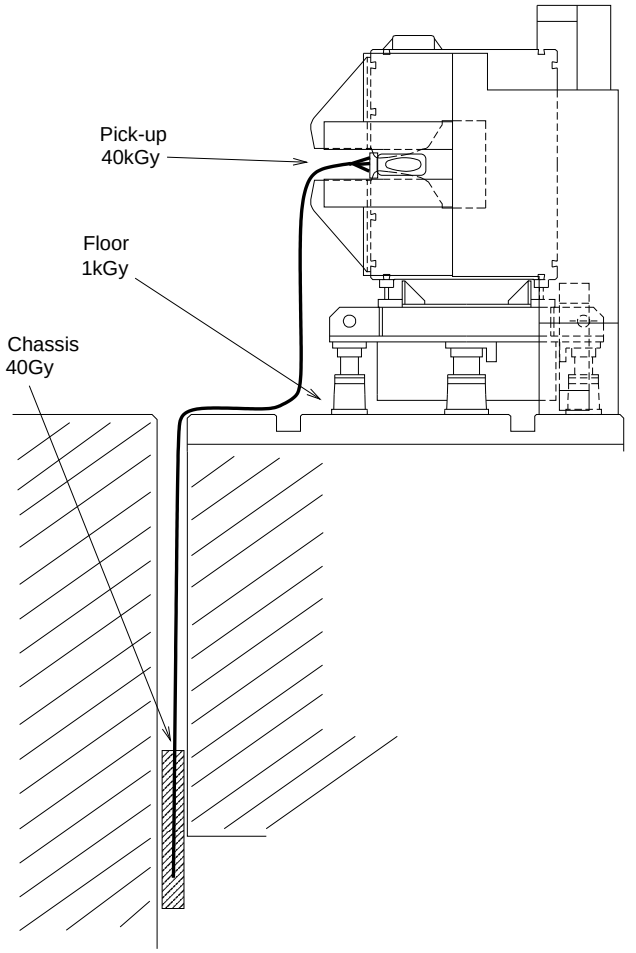
Trajectory measurement for the CERN PS

- Alternating Gradient
- Strong Focusing
- Proton Synchrotron
- 26 GeV (p^+)
- Accelerates p^+, Pb^{53+}
- Radius: 100 m
- 100 Combined Function Bending Magnets

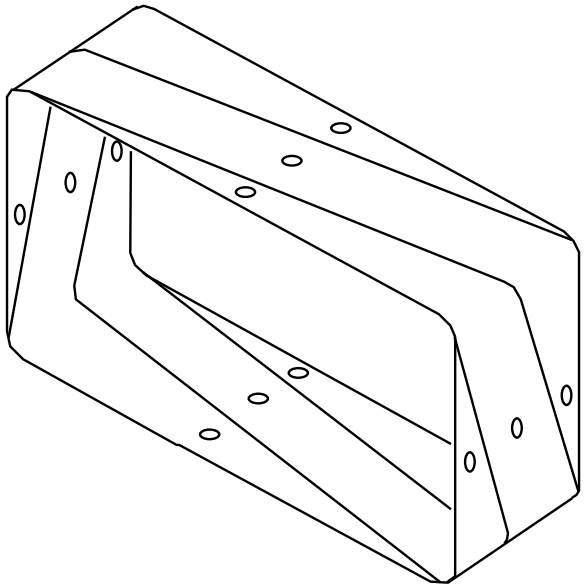
Trajectory measurement for the CERN PS

- Forty electrostatic pick−ups around the ring
- Pick−ups installed in vacuum manifold
- PU Radiation dose ~40kGy/yr
- Electronics installed under concrete beam

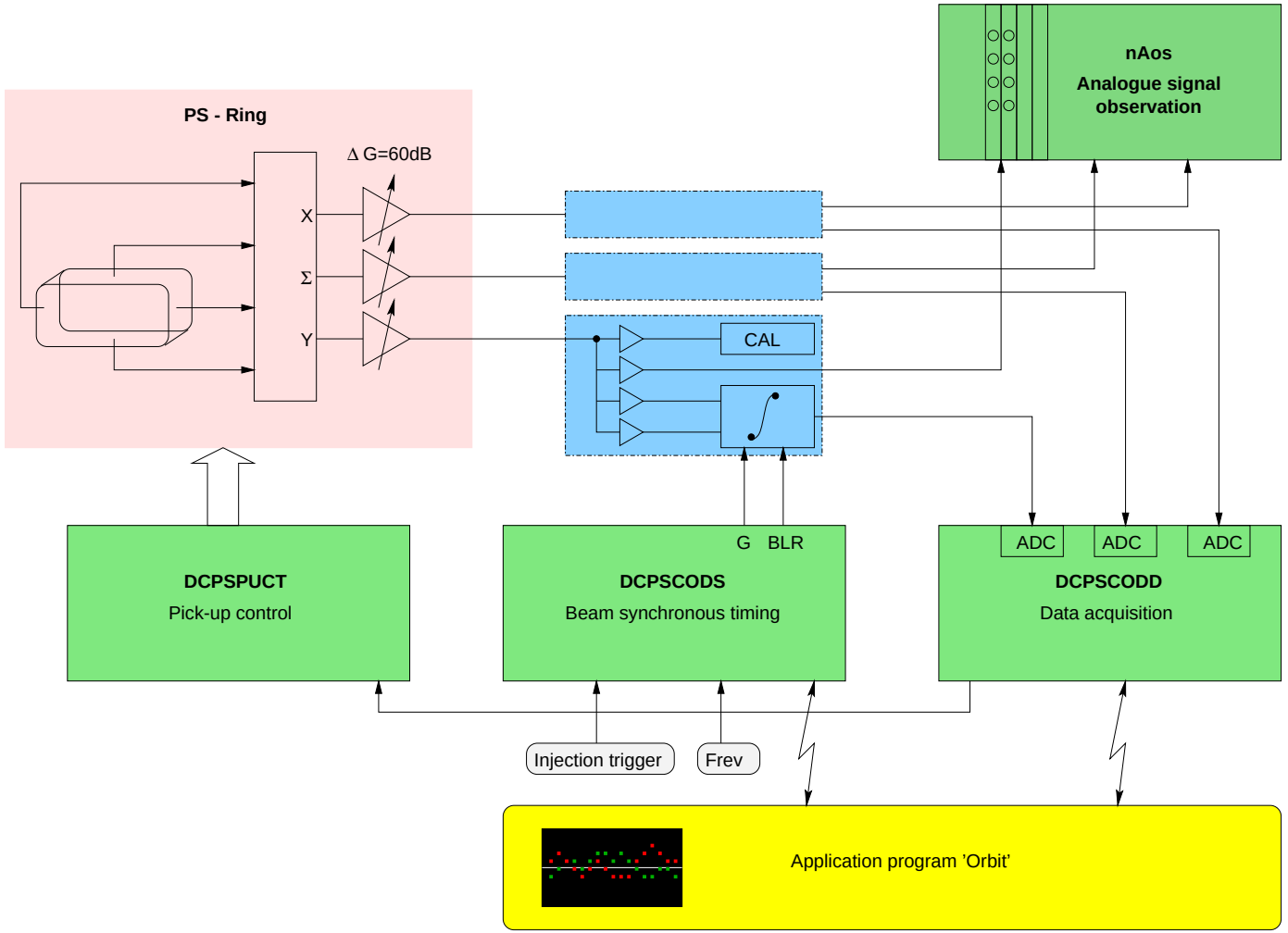


Pick−Up electrodes

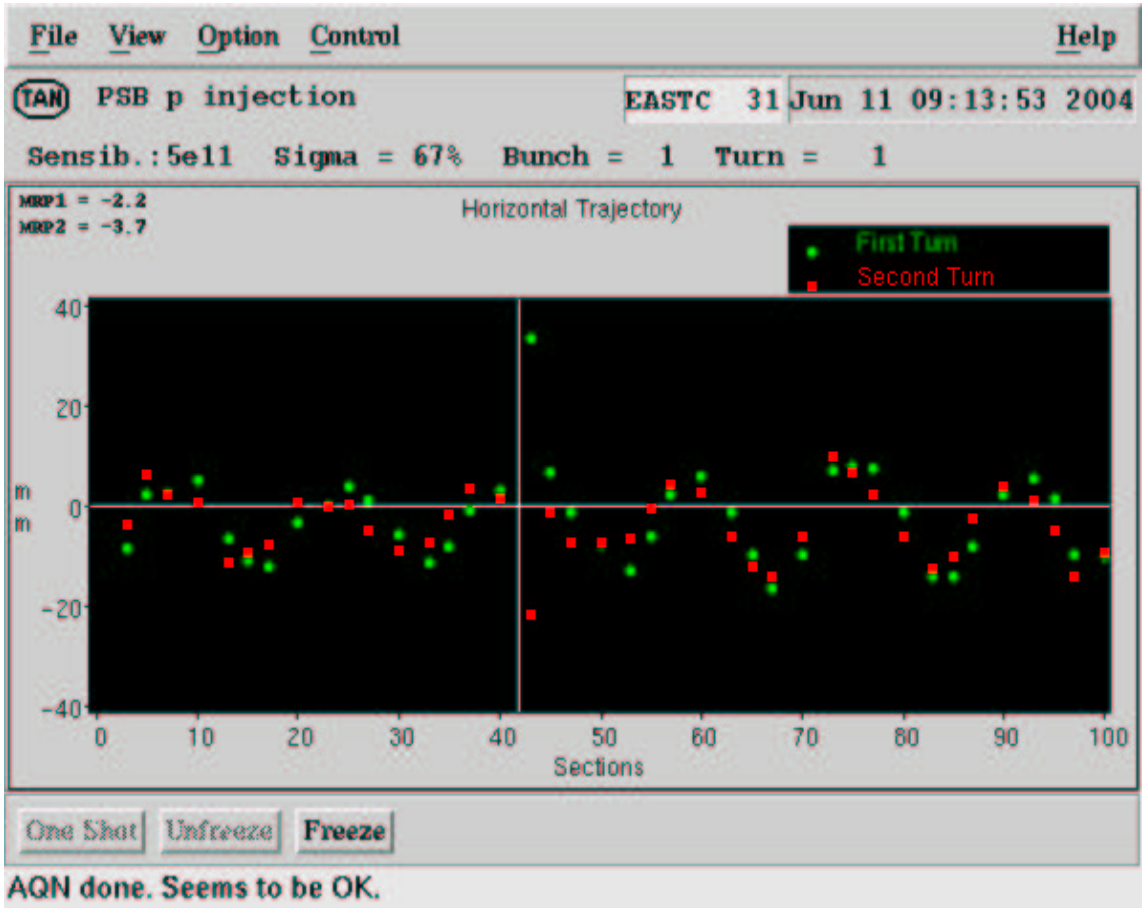
- Length: 62 mm
- Aperture: 166x80 mm
- Capacitance: 100pF
- R_t: 0.52Ω
- S_x: 174 mm
- S_y: 82 mm



Analogue signal processing



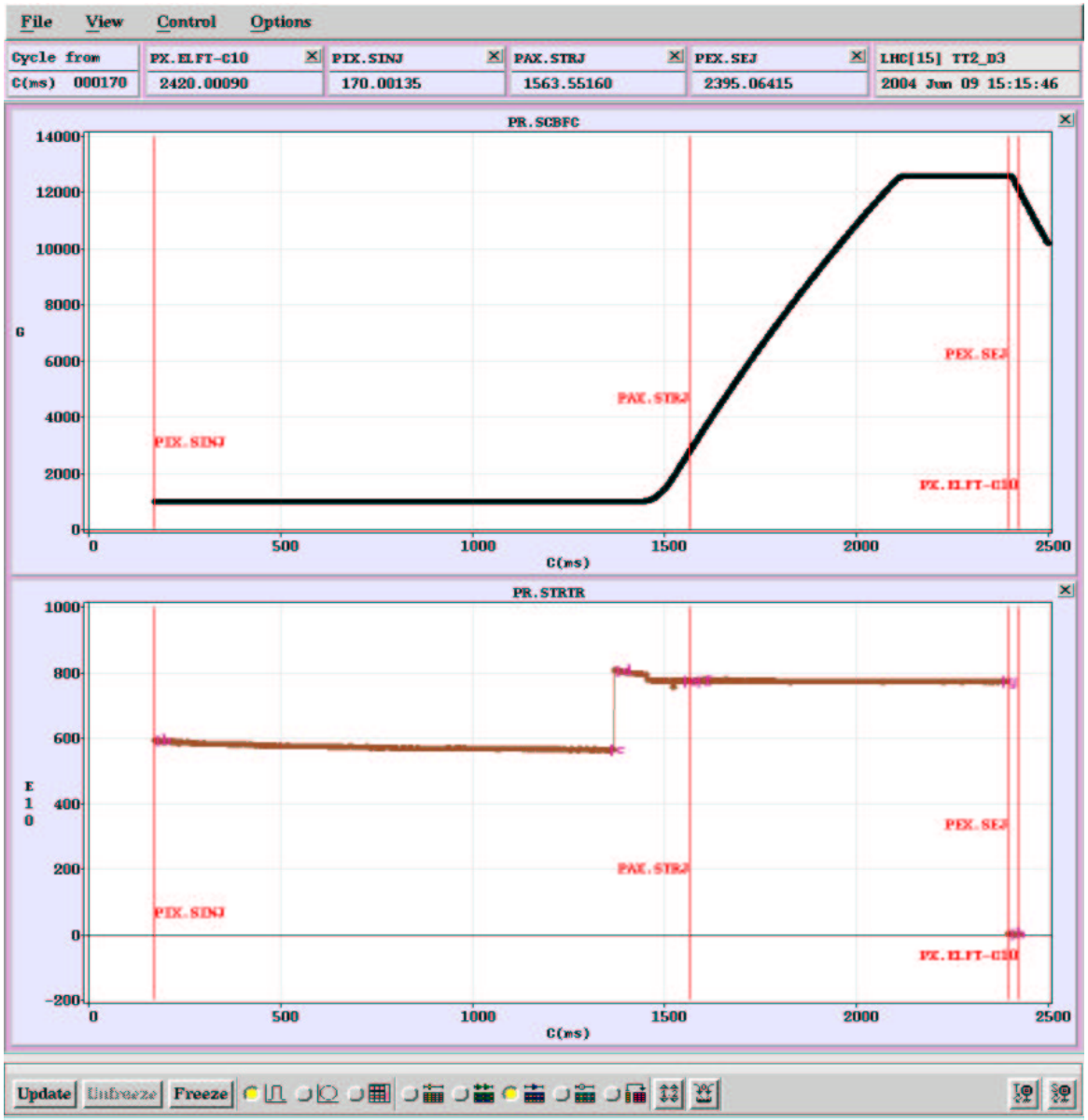
Trajectory measurement for the CERN PS



Trajectory measurement for the CERN PS

Magnetic Cycles

- Peak B=1.26T
- $\frac{dB}{dt}$ = 2.3T/s
- Injection field B=0.1T
- Injection at C170
- Injection E=1.4 GeV (p^+)

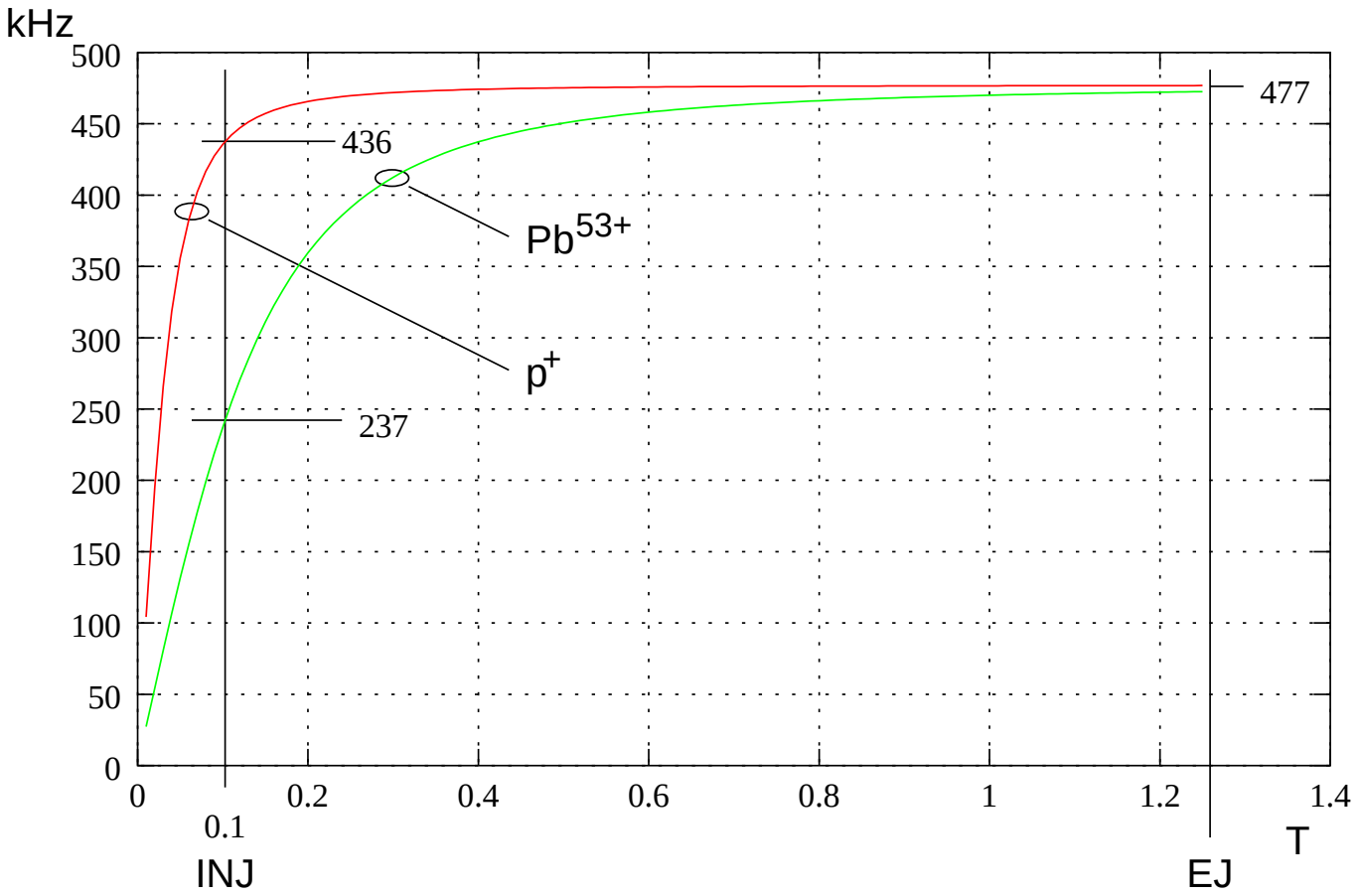


Trajectory measurement for the CERN PS

Revolution Frequency vs. B field

$$f = \frac{R_m Q h B}{2\pi R_0 m \sqrt{1+\left(\frac{R_m Q B}{m c}\right)^2}}$$

R_m = 70.0789 m
R_0 =100 m
Q = [C]
m = [kg]
B = [T]



Timing

- TG8 VMEbus modules
- Receive PLS telegrams
- Produce C−train (1 kHz)
- Eight user−defined timing outputs
- Interrupts
- Timing events can be defined as Cxxx + n periods of one of three local clock sources. (One internal 10MHz and two inputs.)

Trajectory measurement for the CERN PS

How does the accelerator know what to do?

- Accelerating cycles every (multiple of) 1.2 s
- ’PLS telegram’ distributed to front−end computers (DSC)

• USER line	ex: SFTPRO, EASTC, LHC, etc.
• Particle type	ex: PROTON, PB53
• Destination	ex: FTARGET, EAST_T7, etc.
• Harmonic number	ex: H8, H8H16, HSWP, etc.
• etc, etc,	

Some beam properties

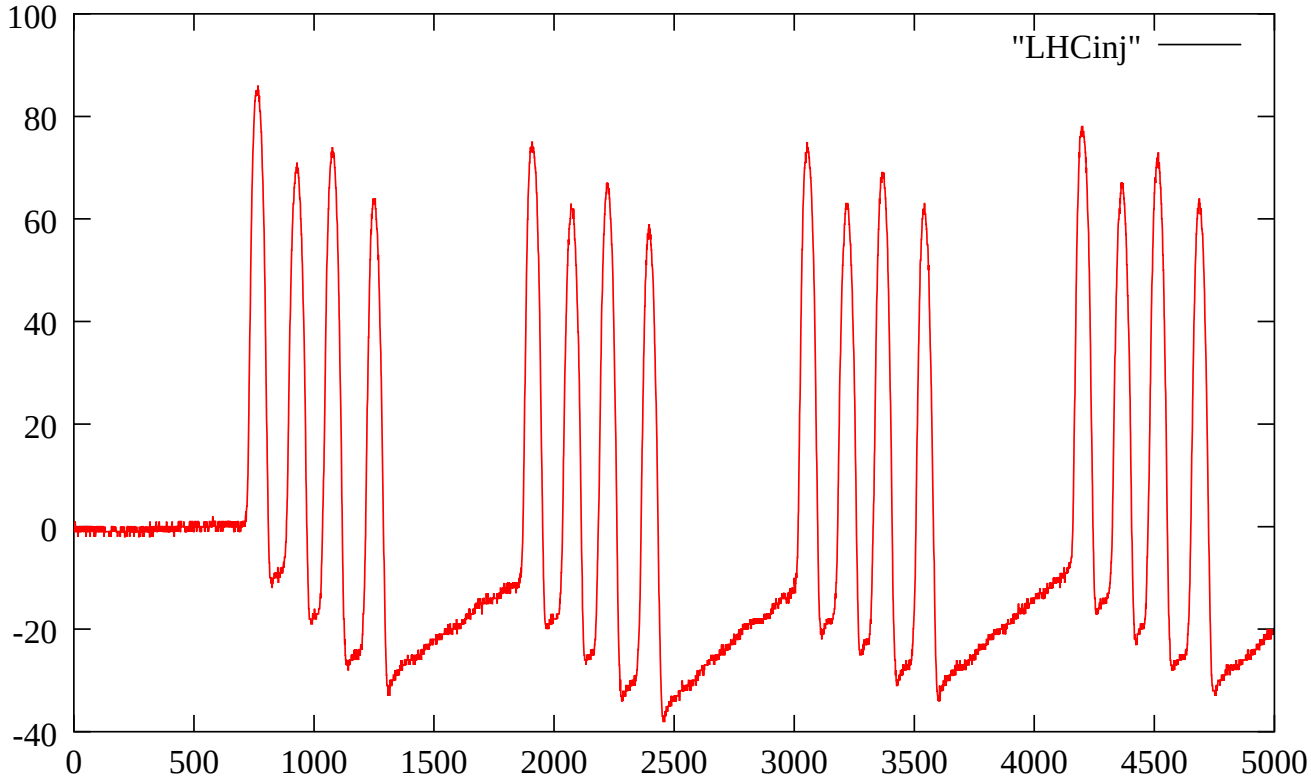
- Beam intensity can be from 1e9 to 7e12 q_0/b
- Bunch length can vary from 4 to 200 ns
  (But the PU electronics' bandwidth limits the minimum bunch length to 30ns)
- Number of bunches can go from 1 to 420
  (But we need not measure beyond 21)
- Bucket frequency varies from 3.4 to 10.5 MHz

Trajectory measurement for the CERN PS

An LHC beam at injection.

Four bunches are injected on h=7. After 1.2 seconds, two more bunches are added into the empty buckets. All bunches are then split into three before being accelerated.

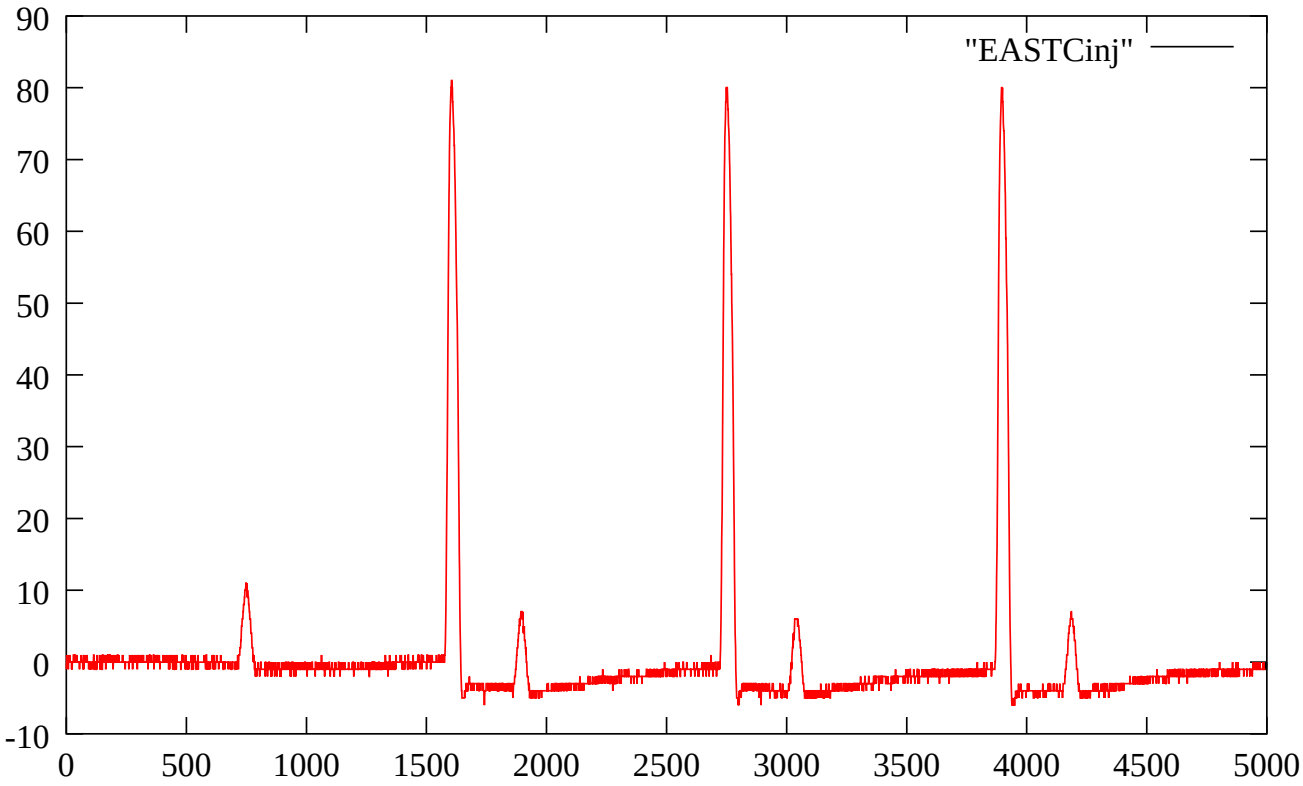
The beam intensity is about 2e12ppb.



Trajectory measurement for the CERN PS

On EASTC, two bunches of widely different intensities can be injected. Both are accelerated together and then the big one is ejected.

The small one is accelerated a bit more before being ejected also, to another destination.



RF gymnastics

- Some beams are split on the fly. For example:

  SFTPRO is injected on h=8, and then split into two to become h=16, followed by debunching and rebunching at h=420

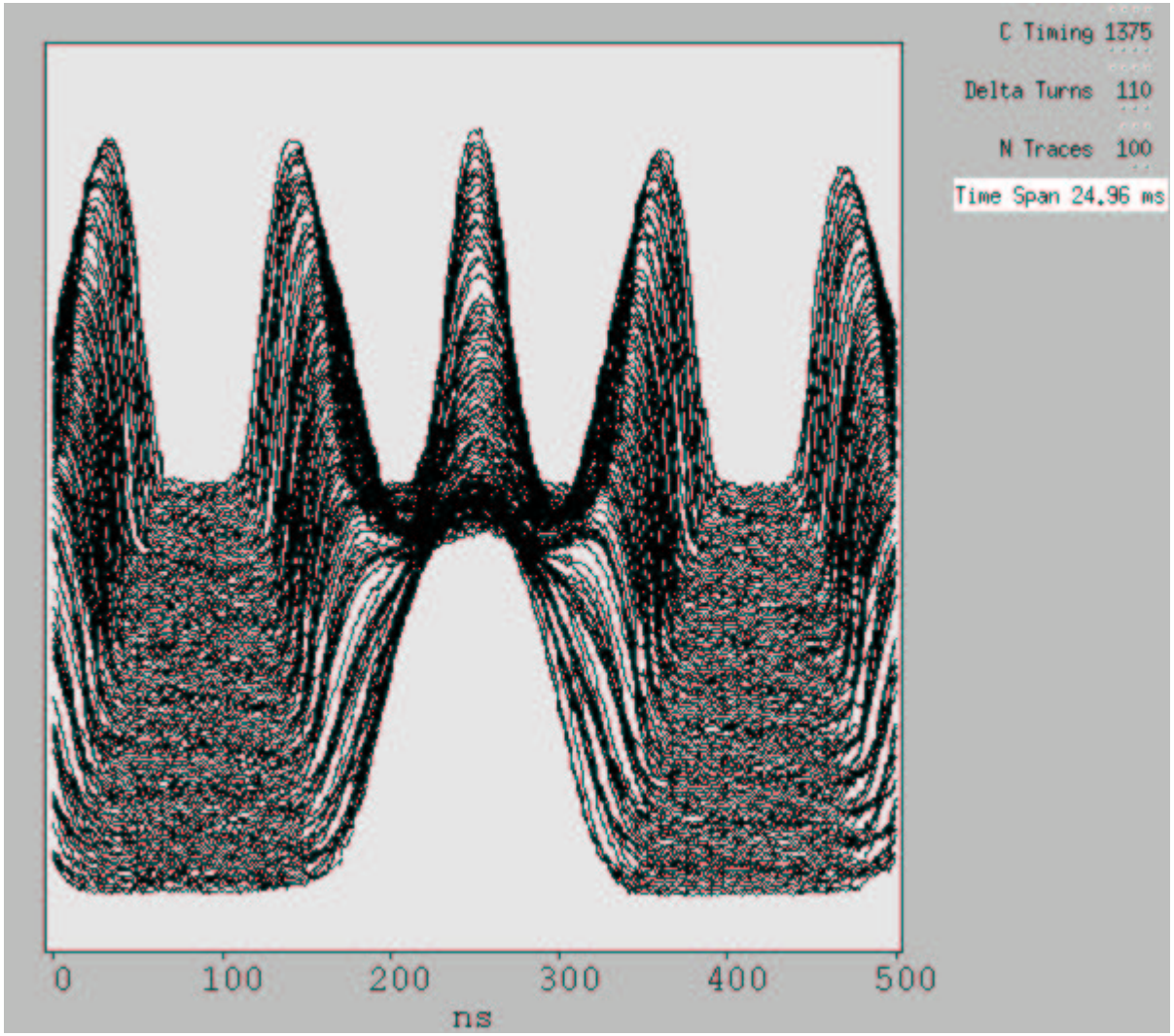
  LHC is injected on h=7, gets split into 3 to become h=21 followed by two more successive splits into two, ending up at h=84.

Trajectory measurement for the CERN PS

RF gymnastics

During LHC cycles, each bunch is split into three equal bunchlets in about 25ms.

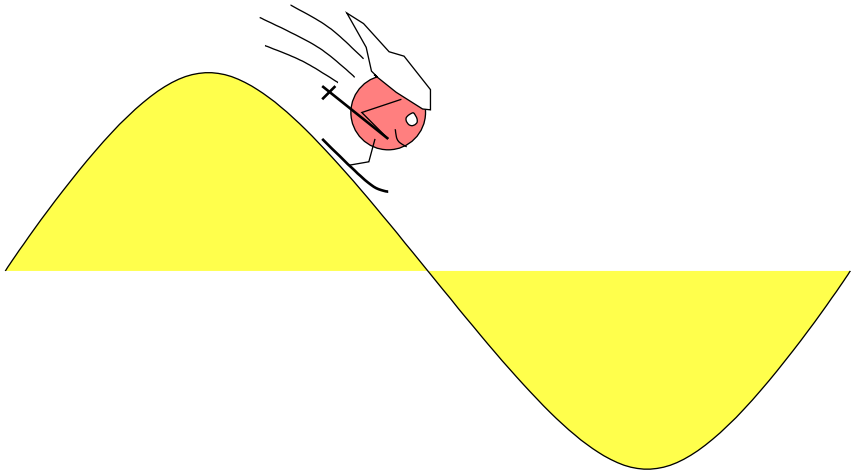
This is done on the injection plateau at 1.4GeV, by gradually increasing the RF at h=21, while at the same time reducing the RF at h=7.



Beam synchronous timing

Why we can't use cavity RF as a reference:

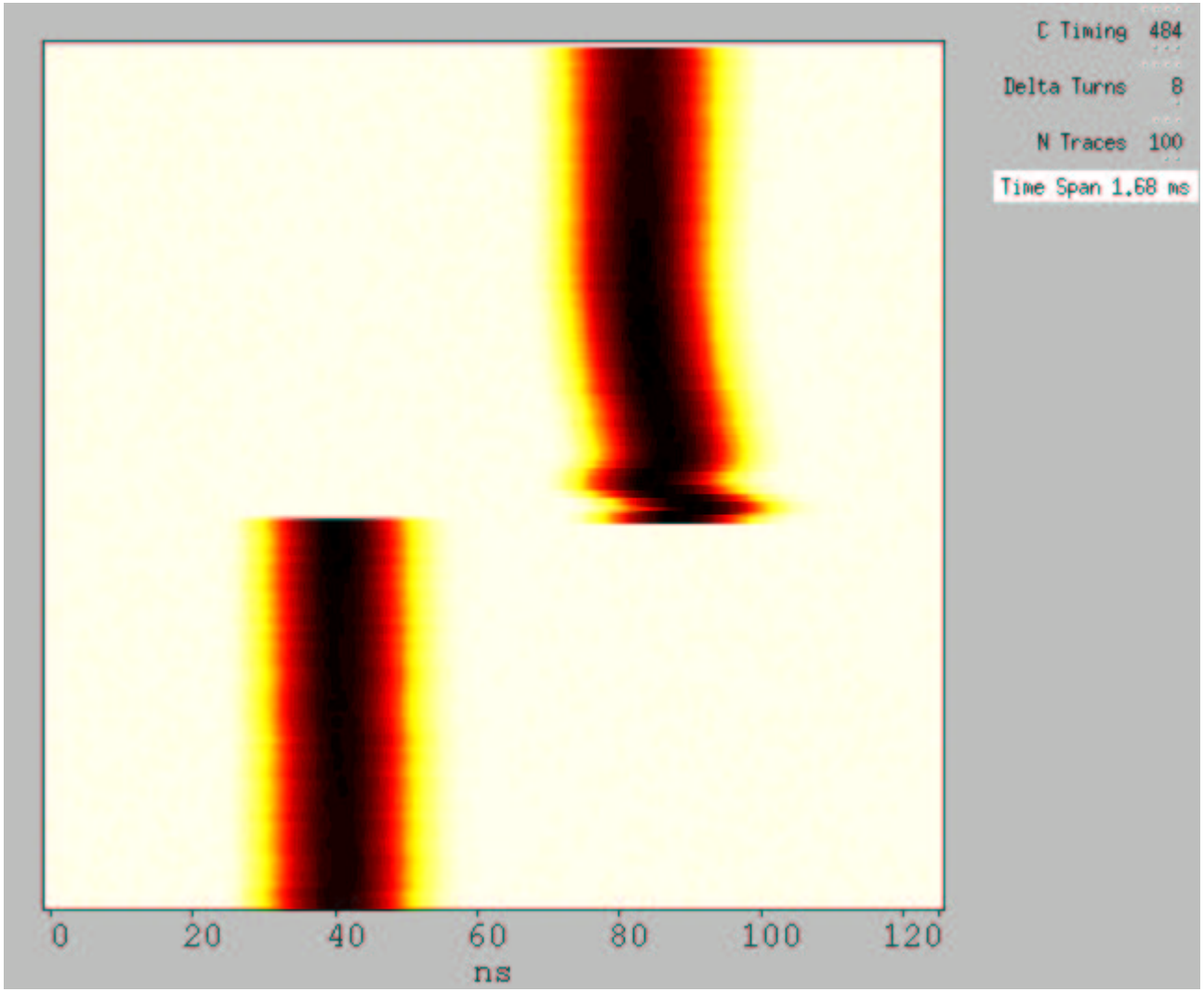
Cavity RF changes phase depending on whether the beam is coasting or being accelerated (~π/6), before or after transition (~2π/3).



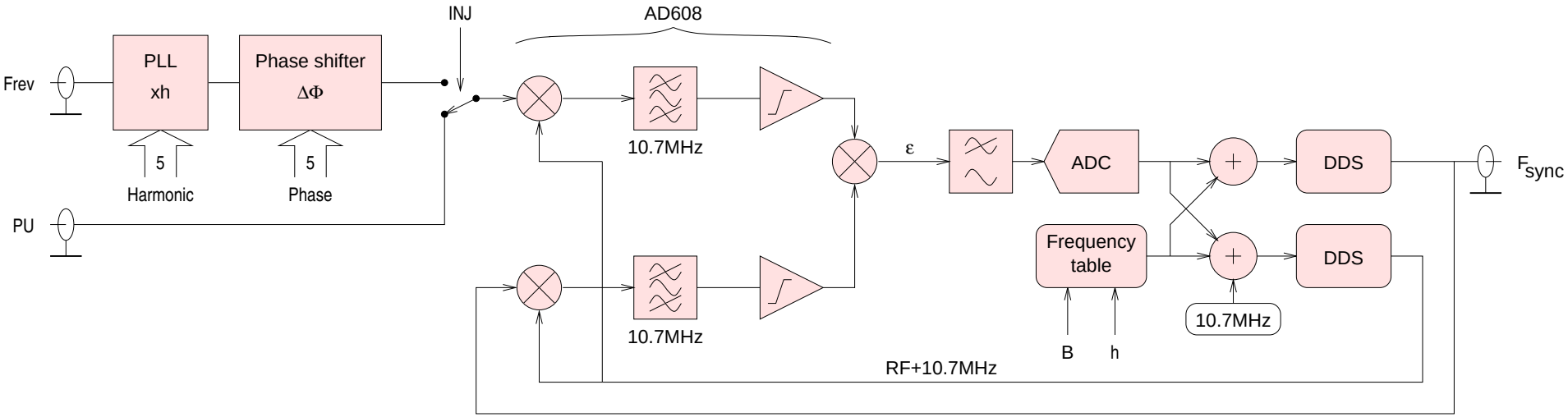
Trajectory measurement for the CERN PS

In the PS, a p^+ beam goes through transition at a kinetic energy of 4.8 GeV (γ_{tr}=6.08). The phase of the cavity RF is changed abruptly to maintain longitudinal stability.

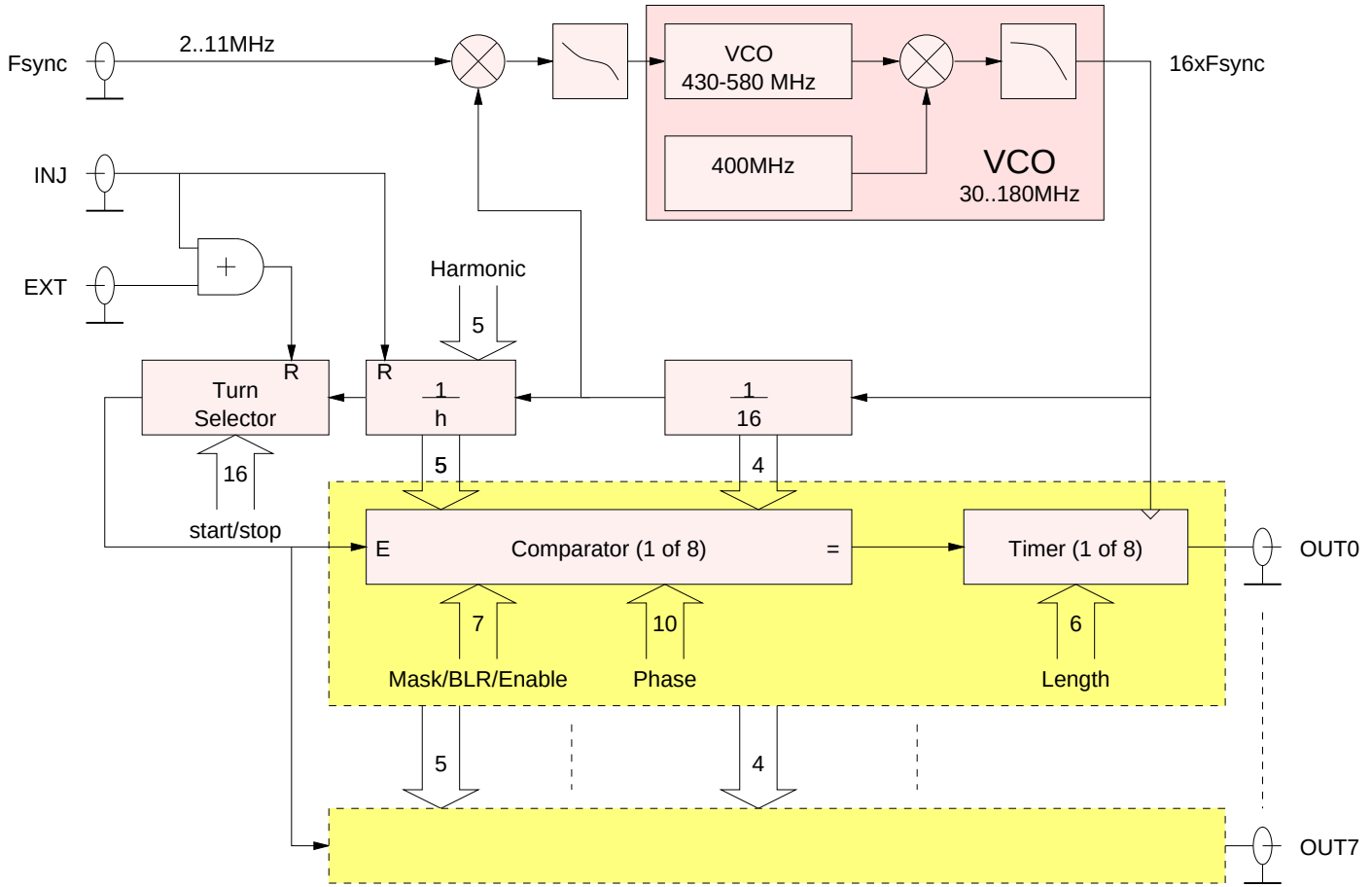
This picture has been taken on a SFTPRO cycle. The phase change due to $\gamma-$ transition is about 120°.



Beam synchronous timing I



Beam synchronous timing II



Trajectory measurement for the CERN PS

Requirements: What do we need?

- Trajectory at injection(s), ejection(s)
- Orbit of a selected bunch everywhere else
- Mean radial position
- Single bunch, multi−turn position
- Tune?

E. Bravin et al, "Specification of the beam position measurement in the PS machine", AB−note−2004−001(ABP)