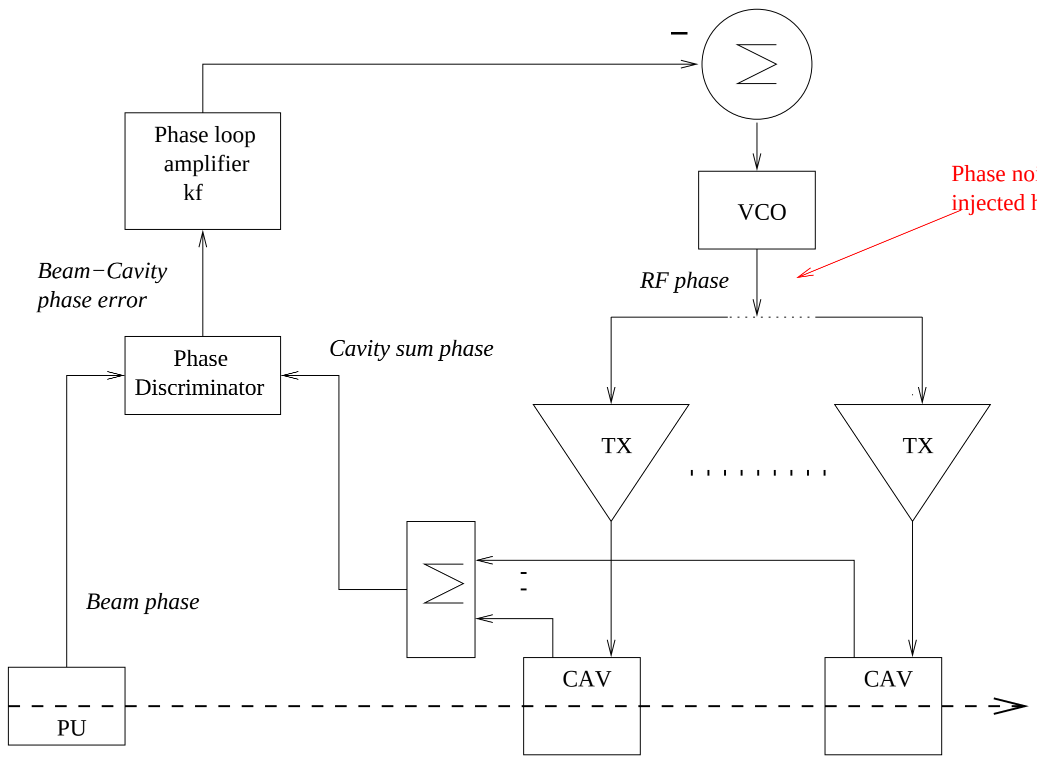
Position of the LHC luminous region

SL/HRF

reported by Philippe Baudrenghien

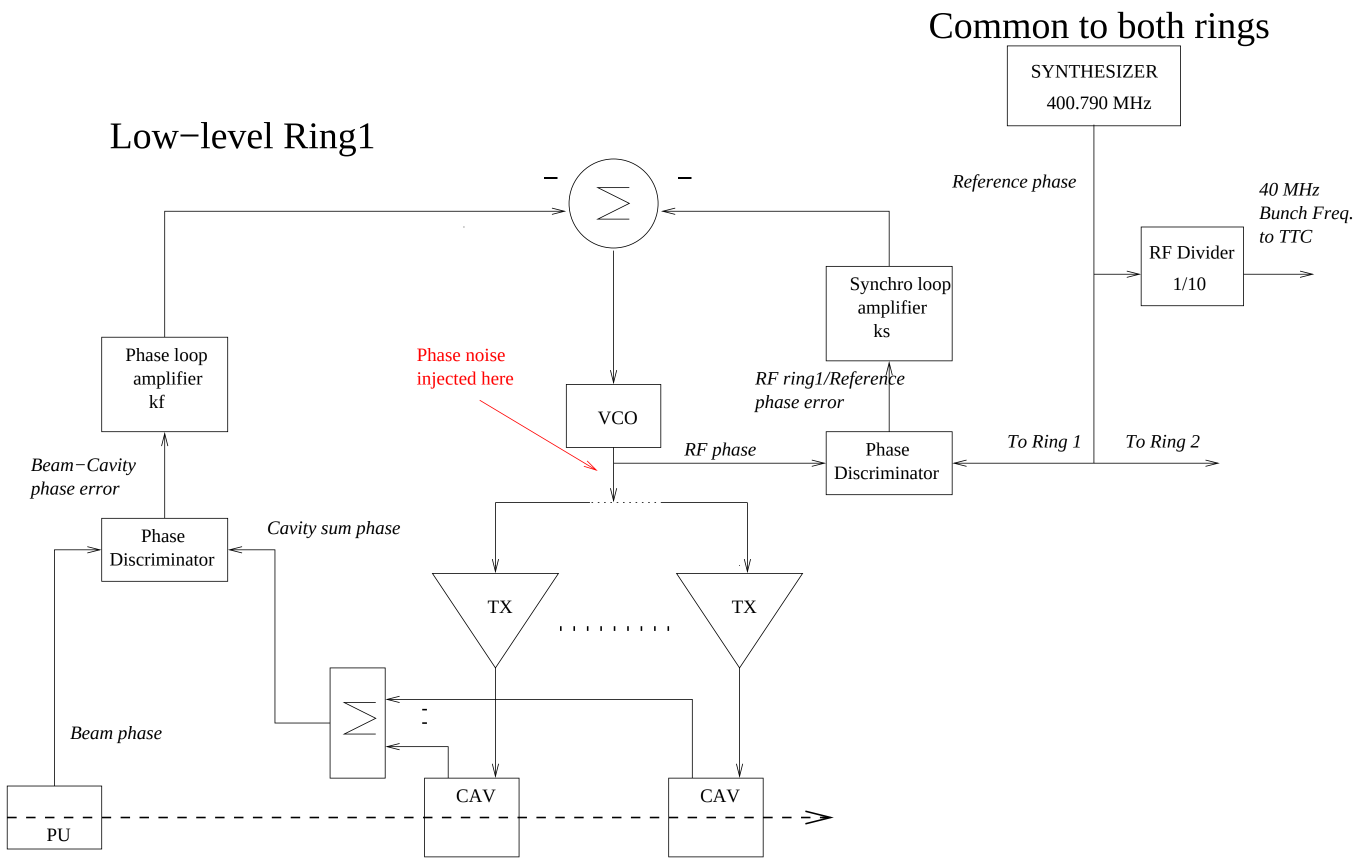
RF low-level during physics (tentative ...)

- **Good lifetime -> One phase loop per beam ....**
  - Goal : Damp the synchrotron oscillations of the bunches (f_S around 21 Hz) to preserve the longitudinal emittance and the lifetime.
  - Method: Measure the RF phase noise seen by the beam and feed-back on the VCO input to minimize it.
  - Sources of noise: VCO phase noise, RF power amplifiers (with their RF feedback and 1-T feedback), cavity microphonics and tuner noise, loop amplifiers.
  - Implementation: One loop per ring. Two independent RF systems.



*LHC low-level (**DRAFT...**).One phase loop per beam.*

- **... but we want collisions in the detectors -> Synchronization loop to lock each beam to a common reference .**
  - Goal : Keep the two beams in phase with the 7 TeV reference 400.790 MHz.
  - Method: For each ring, measure the phase difference between the RF and the reference and feed-back on the VCO input to minimize it.



*LHC low-level (**DRAFT...**).One phase loop/synchro loop per beam with a common reference.*

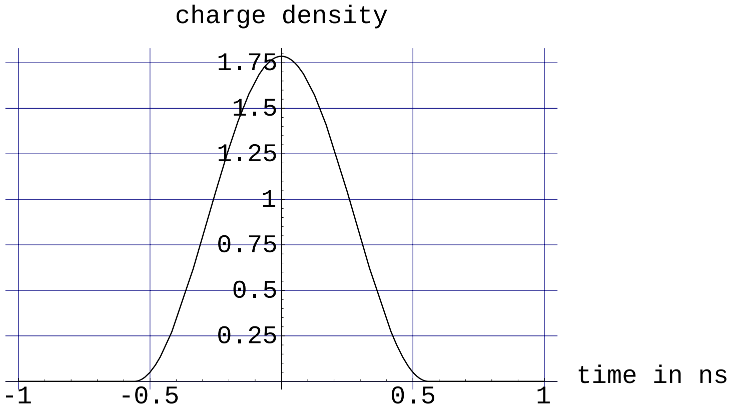
- **These two loops conflict ....**
  - Strong phase loops will drive the two beams apart (in phase) in the presence of strong independent phase noise for the two rings .
  - SOLUTION: low noise design + compromise between a phase loop with moderate gain AND a reasonably strong synchro loop.
  - FIGURES: ***For each beam we keep the phase variation between beam and reference within +- 140 ps maximum = +- B/8*** *(where B is the total length of the bunch at its base).*
  - These variations will be slow (below Frev=11 kHz) because the phase loop is only correcting low frequency effects and the possible offsets introduced by the loops will change slowly (thermal drifts, sensibility to beam intensity, ...).
  - Transient beam loading in the RF cavities induces a fast (bunch to bunch) variation of the beam/reference phase but its amplitude is at least 10 times smaller (+- 14 ps).

Effect on the collision point. Begining of coast.

- At the begining of a coast, the longitudinal bunch profile $\rho_b(t)$ can be approximated by a $\cos^2$ function

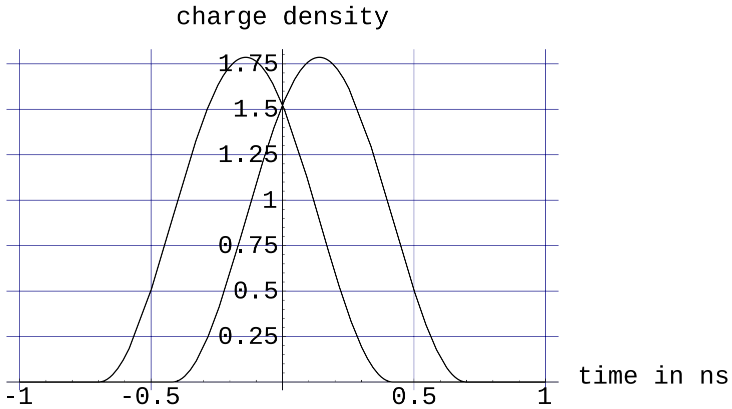
$$\rho_b(t) \cong \frac{2}{B} \cdot \left(\cos\left[\pi \cdot \frac{t}{B} \right] \right)^2$$

B=1.12 ns is the total length at the base.The half width at half heigth = B/4 = 0.28 ns (σ_{rms} = 0.202 ns).



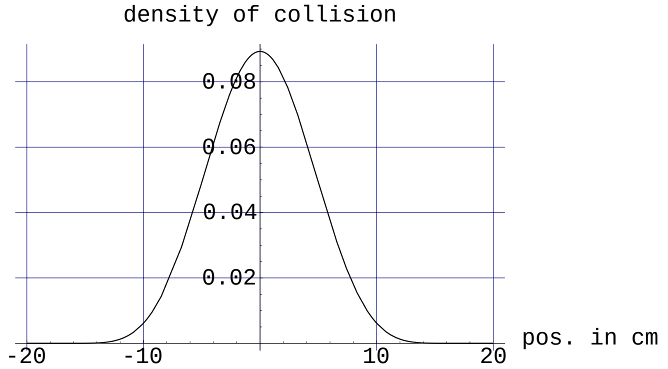
Begining of coast.
Approximative bunch profile ρ_b(t) (cosine^2) with B= 1.12 ns

- The RF phase fluctuations can displace the bunch by ε =140 ps maximum on each side (B/8 on each side).



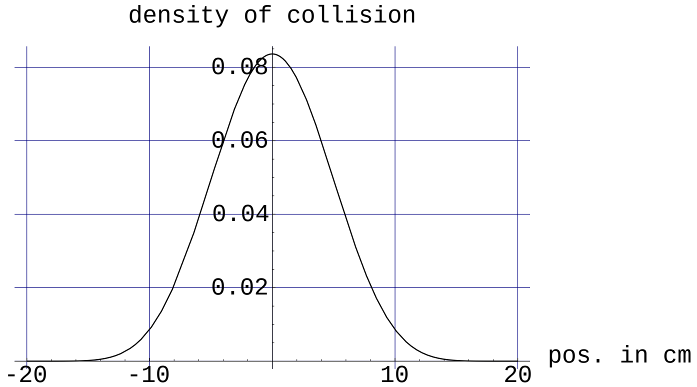
Extreme bunch profile (displaced by +- 140 ps)

- We first replace time by position in the bunch profile: B -> 33.6 cm. Two counter-rotating particles at positions x_1 and x_2 respectively will (or have) collide(d) at $x = (x_1+x_2)/2$. In the absence of the RF phase jitter, the statistical density function of collision point x is thus the convolution of the two bunch profiles: $4[\rho_b(2x) * \rho_b(2x)]$.



Convolution of 2 bunch profiles $\rho_b(x)$ with B = 33.6 cm (1.12 ns). 95 % of distribution within a width of 16.8 cm (0.56 ns).

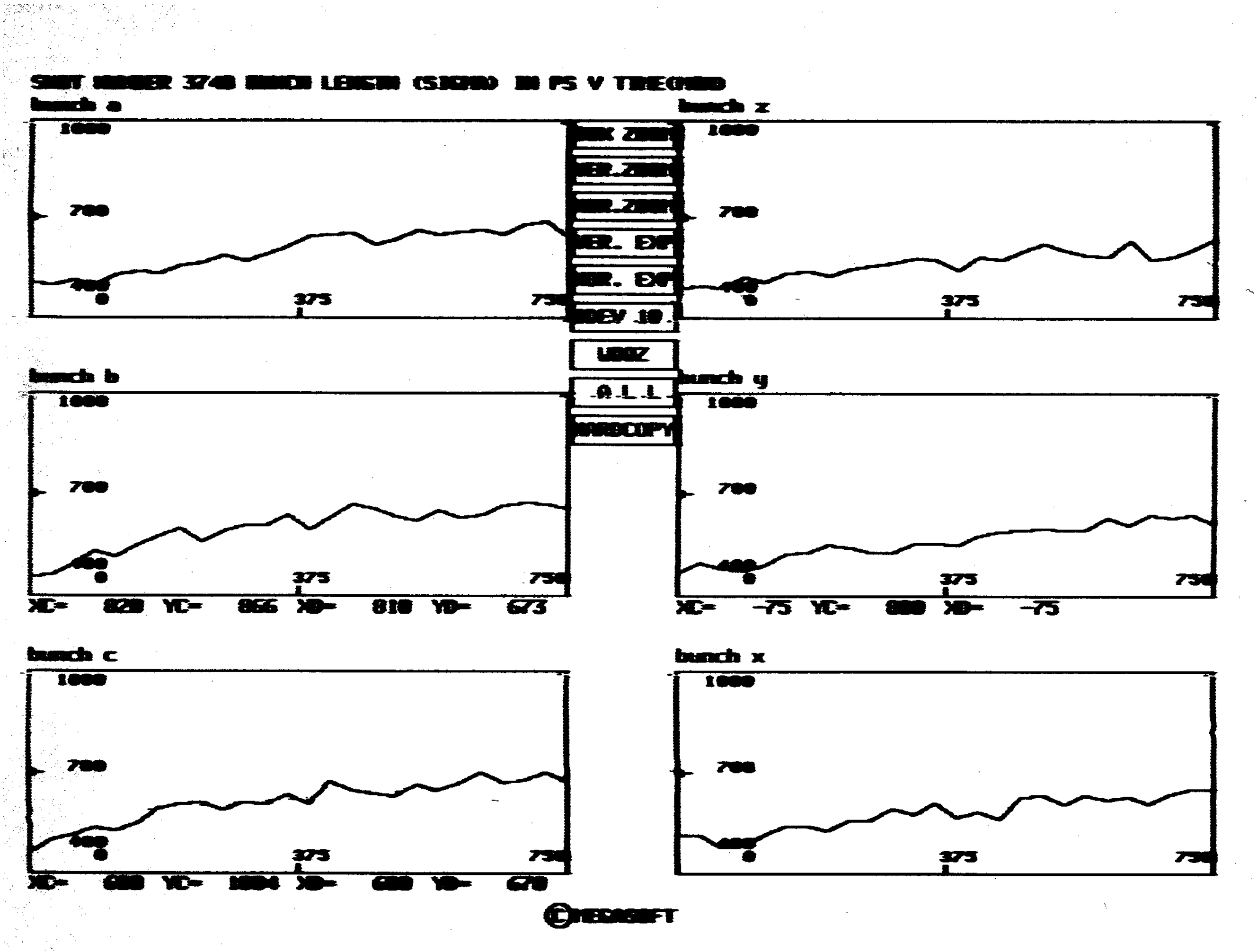
- Assuming independent uniform distributions of the RF phase jitter, we make the convolution $4[\rho_b(2x) * rect(2x/2\varepsilon) * \rho_b(2x) * rect(2x/2\varepsilon)]$ to get the density function of collision point in presence of the RF phase jitter. (This is equivallent to the convolution of the above density function with a $2\,\varepsilon = 8.4$ cm (280 ps) wide triangle function).



Effect of the RF phase jitter. 95 % of distribution within a width of 18 cm (0.60 ns).

What happens during the coast ?

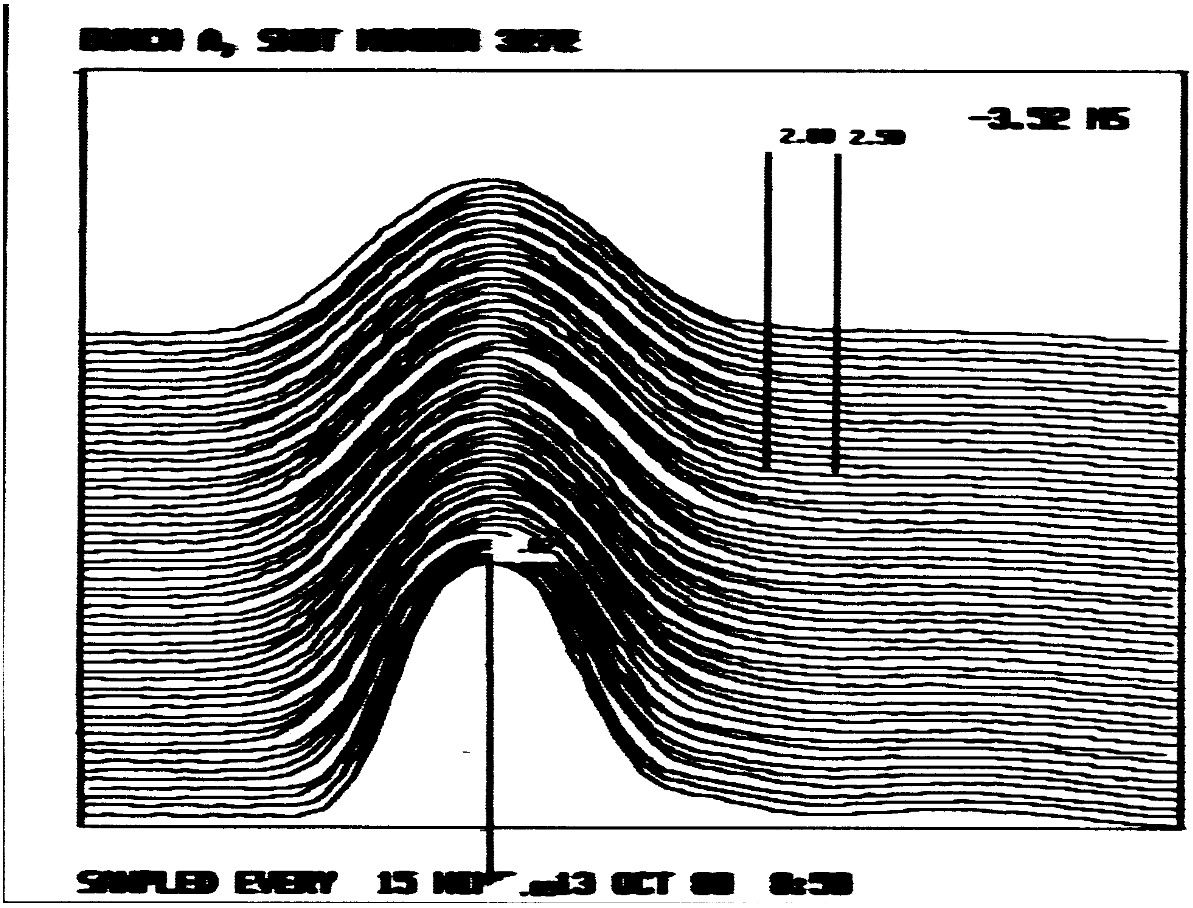
- SPS ppbar experience



Lengthening of the 3 p bunches (left) and 3 pbar bunches (right) during the 750 min (12.5 h) long coast (13 April 89). For each plot: horiz. scale spans 750 min, vert. scale plots σ (400 ps to 1000 ps). Bunch length grows from 500 ps to 700 ps (200 MHz bucket). The bunch length growth time at the begining of the coast can be estimated around 20 h. (Longitudinal emittance growth time around 10 h).

What happens during the coast ? (cont'd)

SPS ppbar experience (cont'd)



Longitudinal bunch profile of a p bunch during the 14 h long ppbar coast (13 Oct. 88). 15 min. between traces. The bottom trace (begining of coast) is well approximated by the cosine square. (The falling edge is distorted by the pick-up response). At the end of the coast (top trace) the bunch profile is gaussian (with the tails truncated by the limit of the 200 MHz bucket). The three vertical markers are at time 0 (centre of bunch), 2 ns and 2.5 ns.

What can we expect for the LHC?

- We expect the following longitudinal emittance growth time:
  - 60 h from intrabeam scattering
  - 30 h from RF noise (just a guess...)
- This gives a total of 20 h emittance growth time, i.e. 40 h bunch length growth time. After 10 hours of coast, the bunch length has increased by 30 % and the cosine square distribution has transformed into a gaussian with $\sigma = 1.3 \times 0.28 = 0.364$ ns. This is only a guess... The performance will depend on the RF noise ...

References

- LHC conceptual design, CERN/AC/95-05 (LHC), 20 Oct. 1995.
- D. Boussard, T. Linnecar, The LHC Superconducting RF System, LHC Project Report 316.
- D. Boussard, G. Dome, C. Graziani, J. Le Duff, S. Myers, F. Pedersen, RF Noise, Workshop on ppbar in the SPS, SPS-ppbar-1, 9 May 1980.