

# ELECTRON CLOUD BUILD-UP AND RELATED INSTABILITY IN THE CERN PS

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- ◆ **Introduction**
- ◆ **Electron cloud build-up in 2000 and 2001**
  - Emittance measurement problems with SEMwires
  - Baseline drifts in electrostatic pick-ups
  - Effect of a solenoidal field
  - Effect of gaps in the bunch train
- ◆ **Single-bunch radial instability in 2001**
- ◆ **Conclusion**

# INTRODUCTION

## Nominal LHC beam at the exit of the PS

- A train of 72 bunches
- Number of protons per bunch :  $1.1 \times 10^{11}$
- Bunch spacing : 25 ns
- Momentum : 26 GeV/c
- Longitudinal emittance ( $2\sigma$ ) : 0.35 eVs
- Transverse emittances ( $1\sigma$ , normalised) :  $2.5 \mu\text{m}$
- Total bunch length ( $4\sigma$ ) : 4 ns

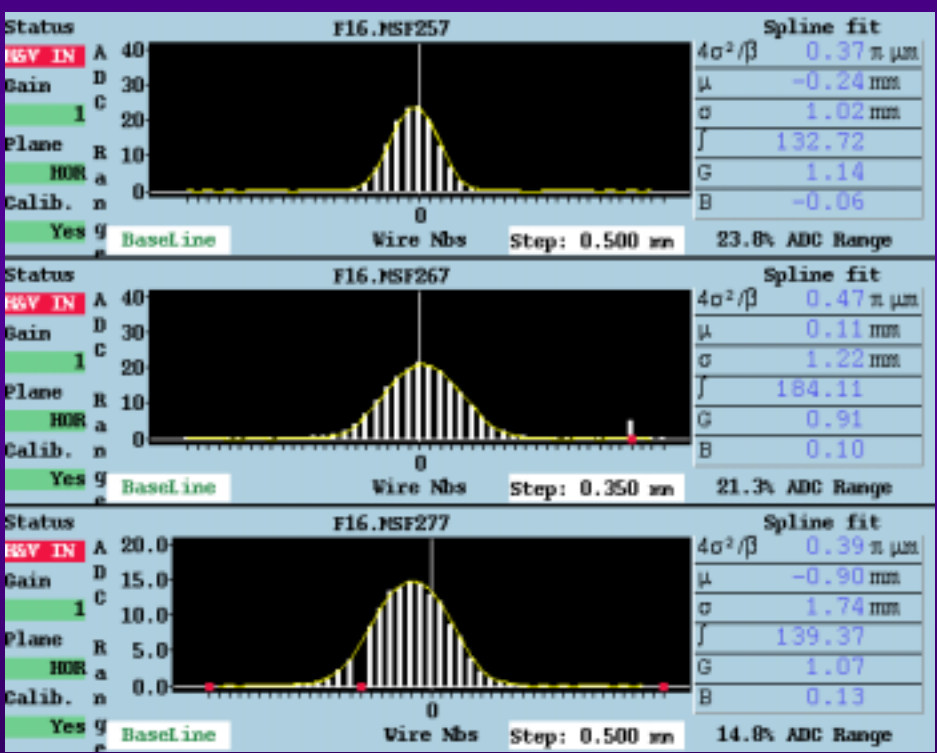
Just before extraction, the bunches are compressed from  $\sim 16$  to  $\sim 4$  ns by bunch rotation in a mismatched bucket, within  $\sim 200 \mu\text{s}$  ( $\sim 100$  turns). The electron cloud build-up is observed during this bunch compression

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (1/8)

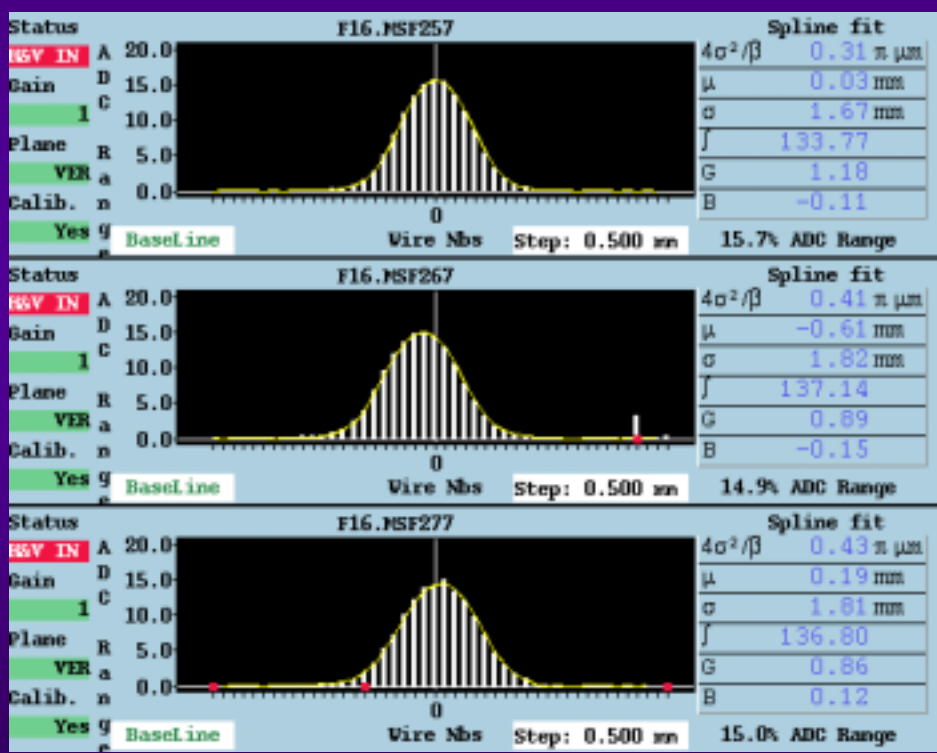
Transfer line between PS and SPS

## (i) Emittance measurement problems with SEMwires

Emittance measurements using the SEMwires in TT2  
**WITHOUT** bunch rotation



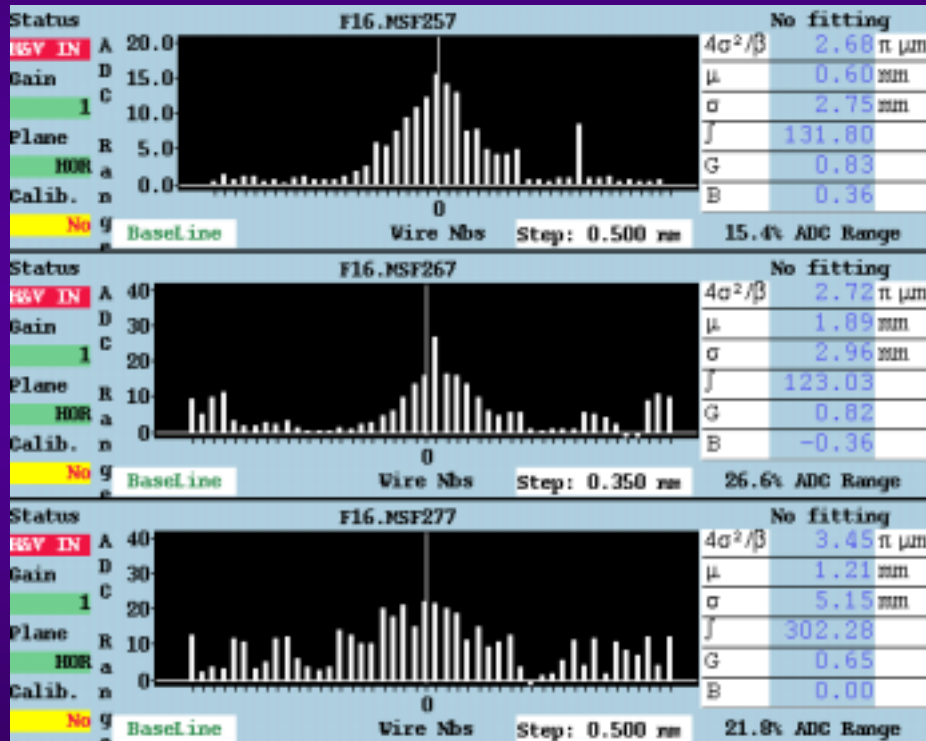
H - plane



V - plane

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (2/8)

Emittance measurements using the SEMwires in TT2  
**WITH bunch rotation**



⇒ Electrons are created ...

**H - plane**

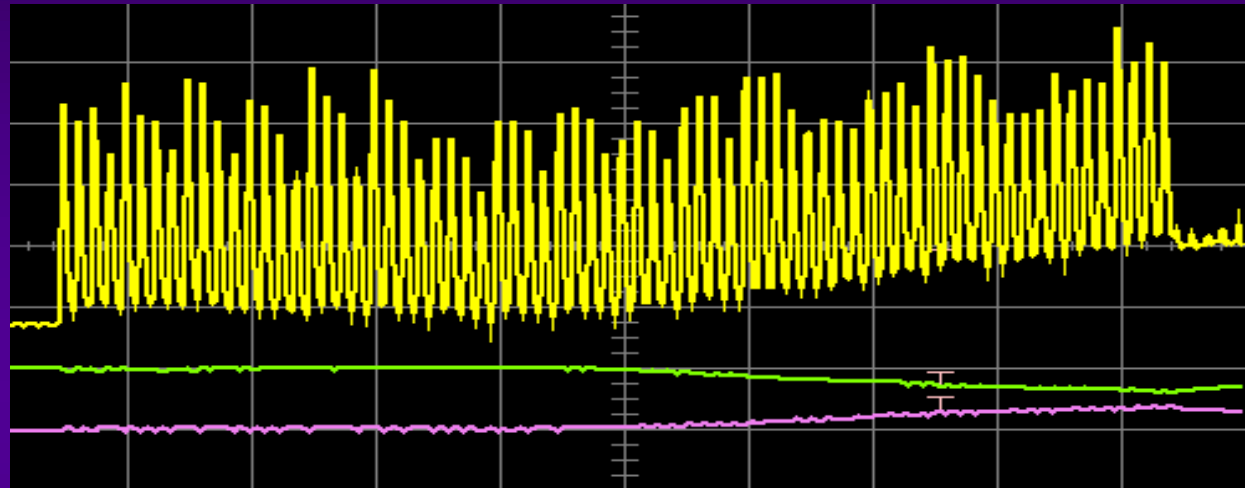
# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (3/8)

## (ii) Baseline drifts in electrostatic pick-ups

Nominal beam seen on a pick-up in TT2

Time scale :  
200 ns/div

PU located in a  
field-free region.  
Bandwidth :  
0.006-400 MHz



$\Sigma$

$\Delta x$

$\Delta y$

$$V \approx 300 \text{ mV}$$

$$C = 500 \text{ pF}$$

$\Rightarrow$

$$n_e = \frac{CV}{e} \approx 10^9$$

$\Rightarrow$

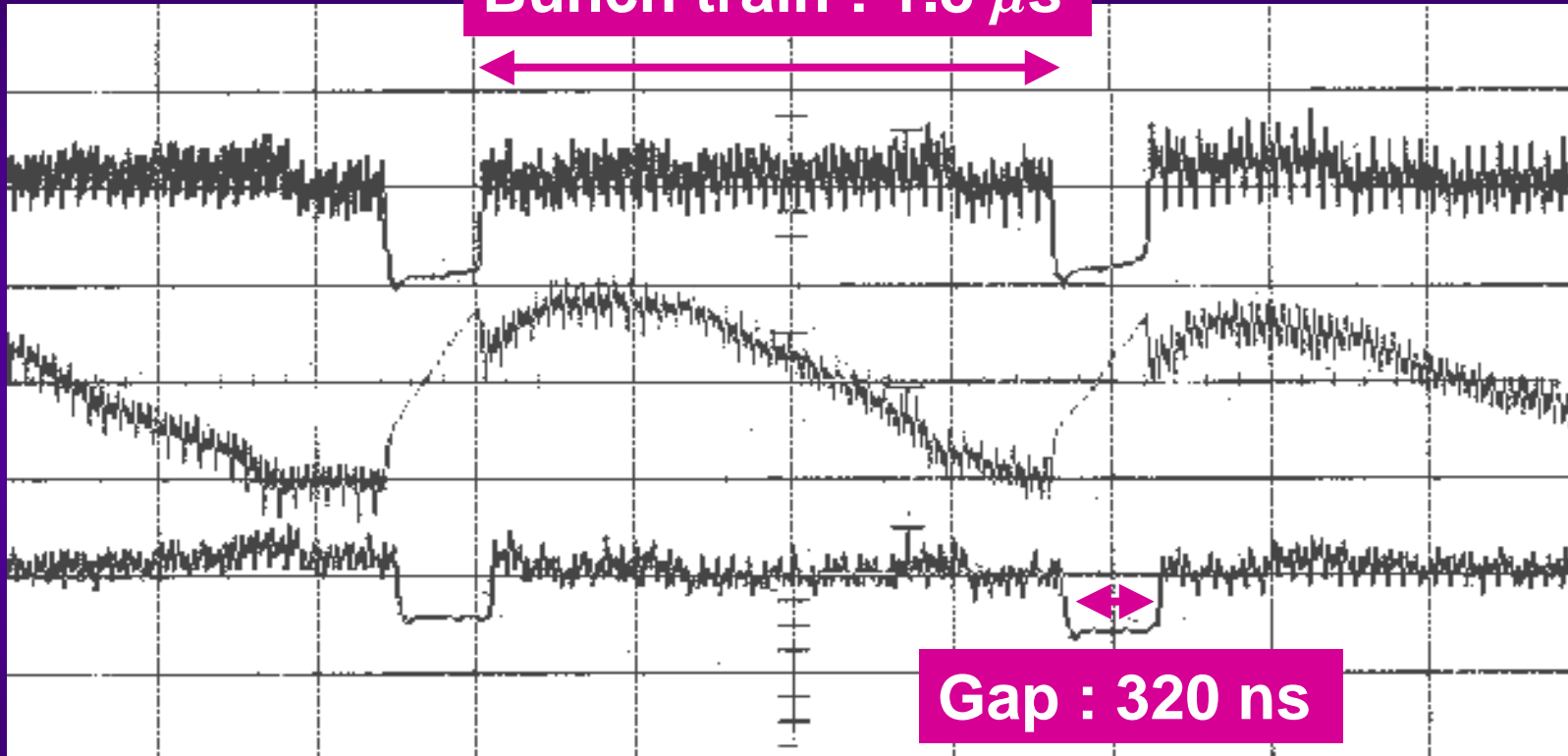
$$\text{vol}_{\text{PU}} = 0.12^3 \approx 0.0017 \text{ m}^3$$

$$\rho_e = \frac{n_e}{\text{vol}_{\text{PU}}} \approx 6 \times 10^{11} \text{ m}^{-3}$$

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (4/8)

Nominal beam seen on a pick-up in PS

Bunch train :  $1.8 \mu\text{s}$



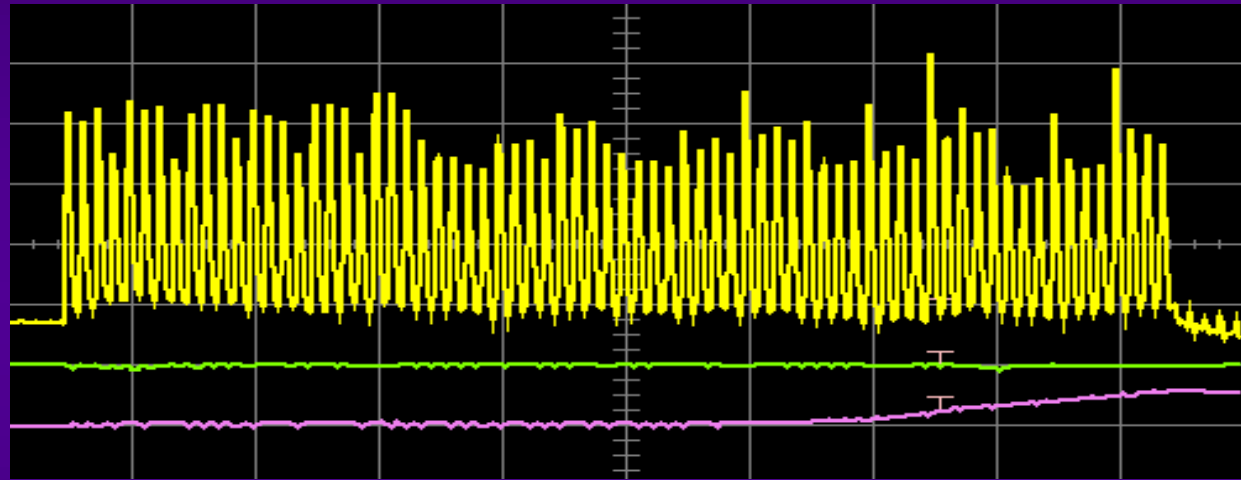
Time scale :  
500 ns/div

PU located in a vertical dipole field region  
(combined-function magnets are used in the PS).  
Bandwidth : 0.2-30 MHz

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (5/8)

## (iii) Effect of a solenoidal field

Nominal beam seen on a pick-up in TT2

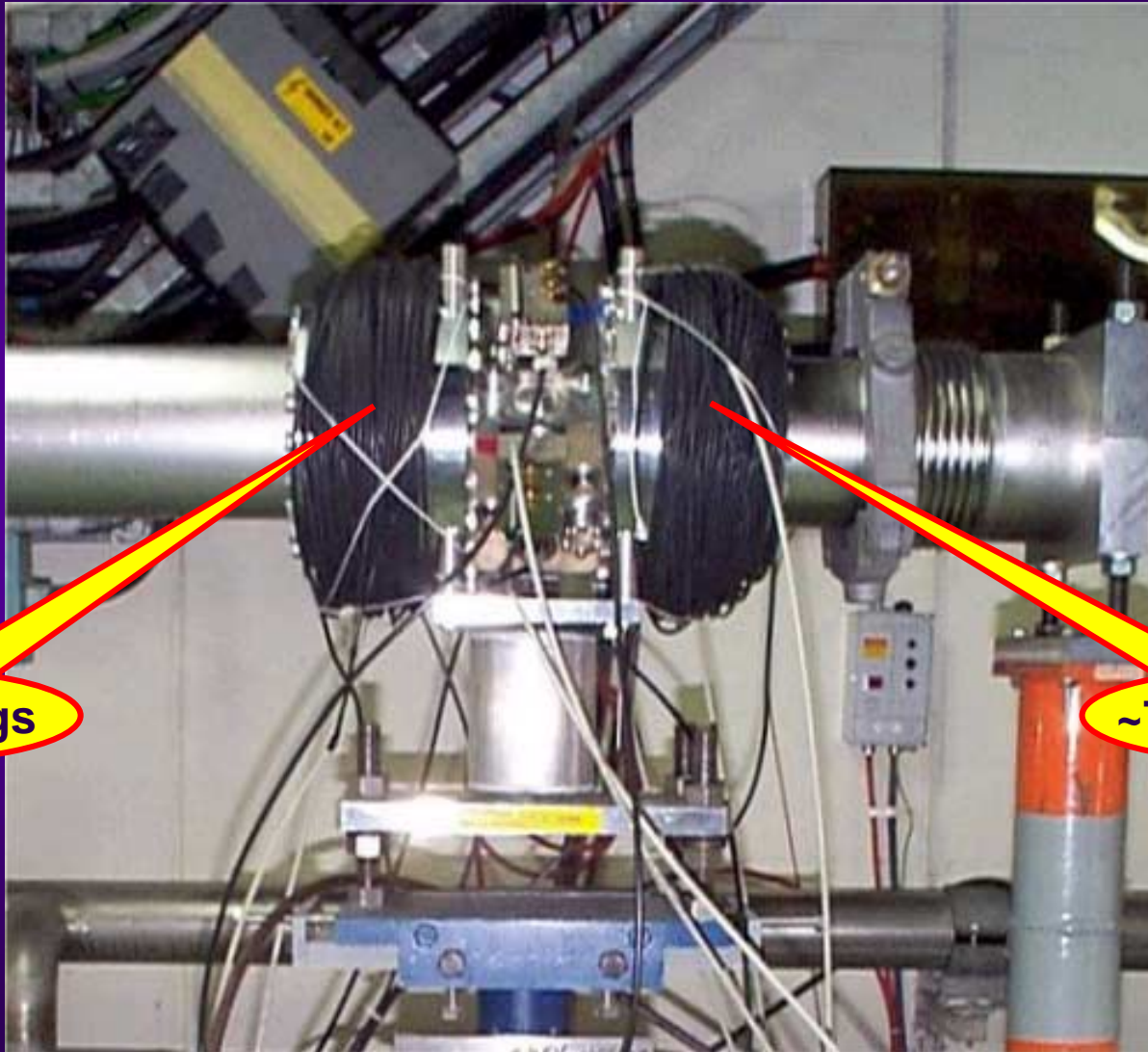


Time scale :  
200 ns/div

With solenoid : ~ 50-100 G  
(~70 windings before and after the 25 cm long PU device)

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (6/8)

Solenoid around the pick-up in TT2



~70 windings

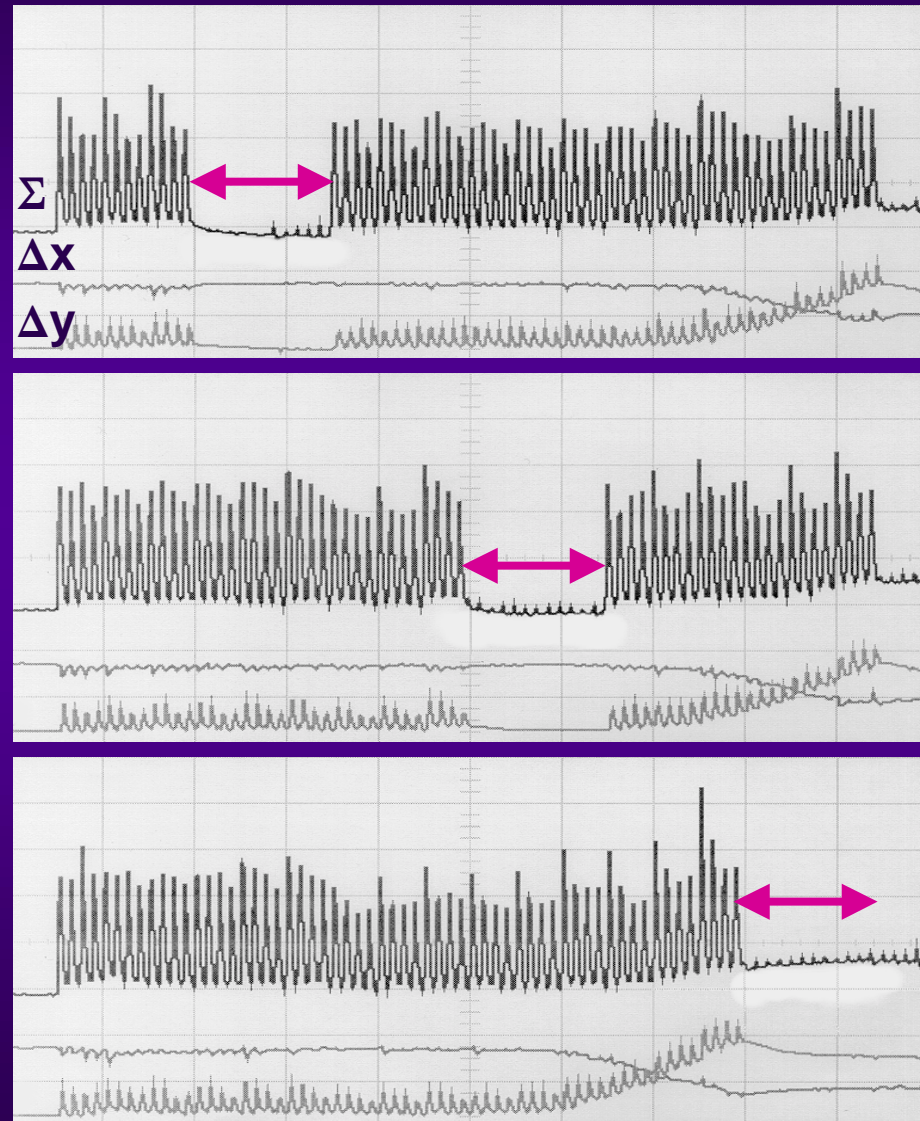
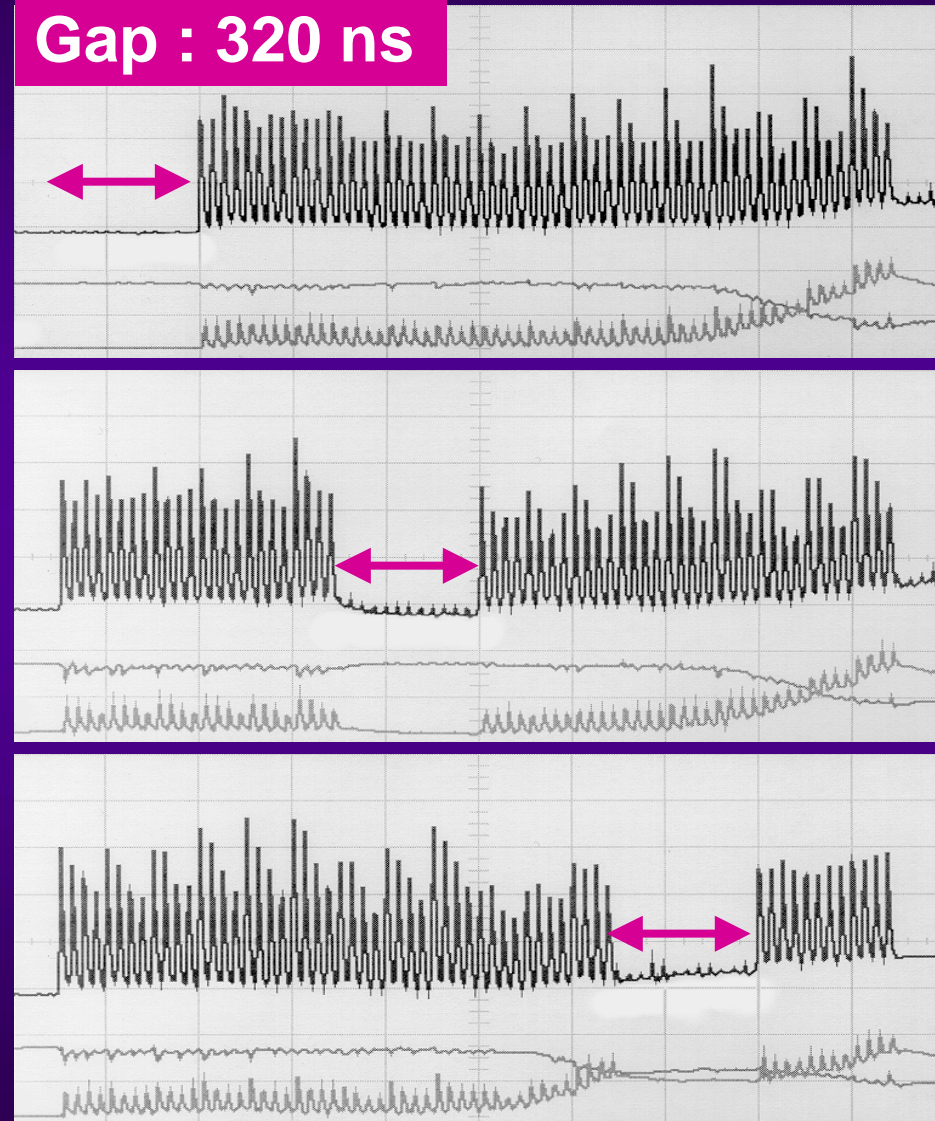
~70 windings

# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (7/8)

(iv) Effect of gaps in the bunch train

Gap : 320 ns

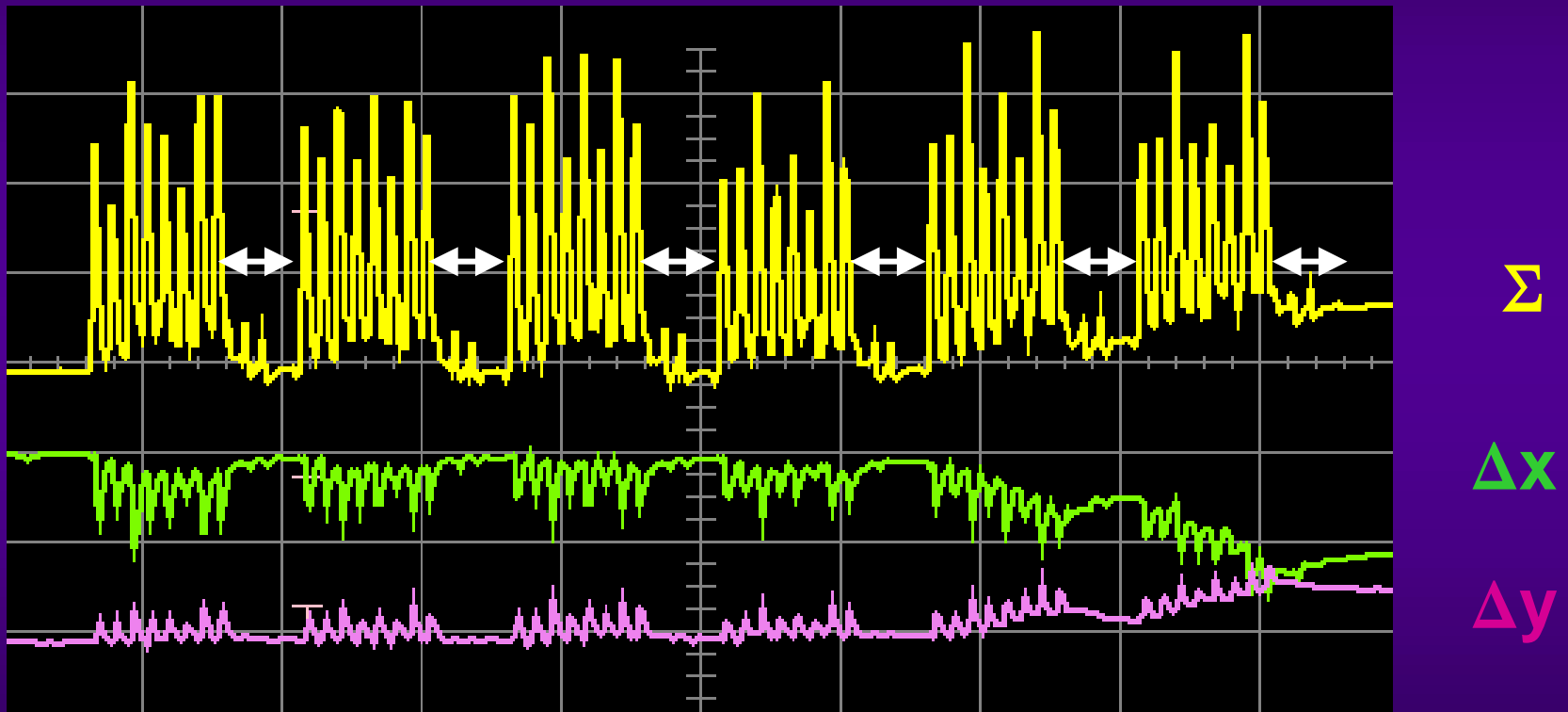
Nominal beam on a pick-up in TT2



# ELECTRON CLOUD BUILD-UP IN 2000 AND 2001 (8/8)

Nominal beam on a pick-up in TT2

6 Gaps : 120 ns each



Time scale : 200 ns/div

# SINGLE-BUNCH RADIAL INSTABILITY IN 2001 (1/5)

- ◆ **Electron cloud effects on the nominal PS beam for LHC**
  - **Generate only beam diagnostics problems**
  - **No time to develop an instability**
- ◆ **Electron cloud effects on a modified PS beam for LHC**
  - **Beam used : nominal one, but kept with a bunch length of ~10 ns during ~100 ms before extraction**
  - **The electron cloud build-up is observed**
  - **The beam is unstable**

- **Single-bunch radial instability**
- **No beam loss**
- **Beam size blow-up :  $\times$  ~10-20 in H and ~2 in V**

# SINGLE-BUNCH RADIAL INSTABILITY IN 2001 (2/5)

**Spectrum Analyzer  
(zero frequency span)**

**Center 357 kHz**

**10 dB/div**

**200 ms**

**Extraction**

$\tau \approx 18 \text{ ms}$

$N_b \approx 4.2 \times 10^{10} \text{ p/b}$

$N_b \approx 4.6 \times 10^{10} \text{ p/b}$

$\tau \approx 4 \text{ ms}$

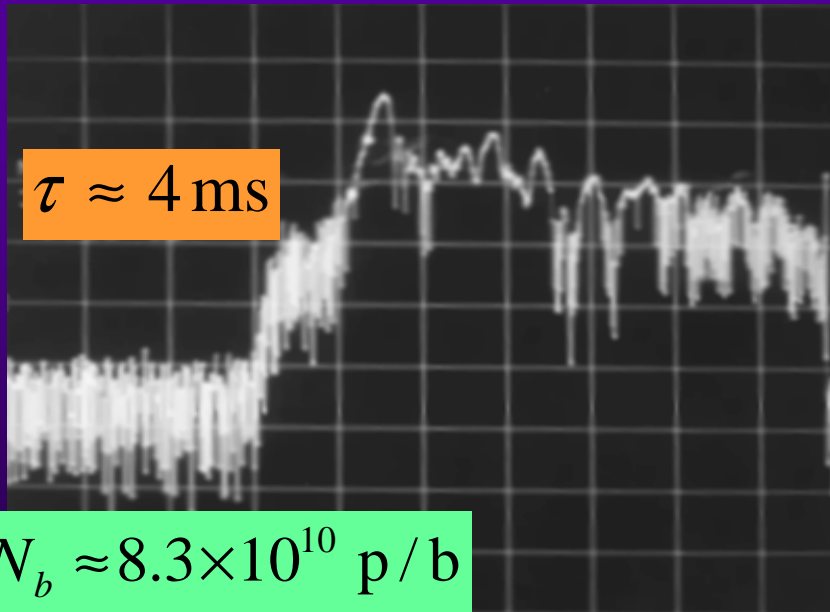
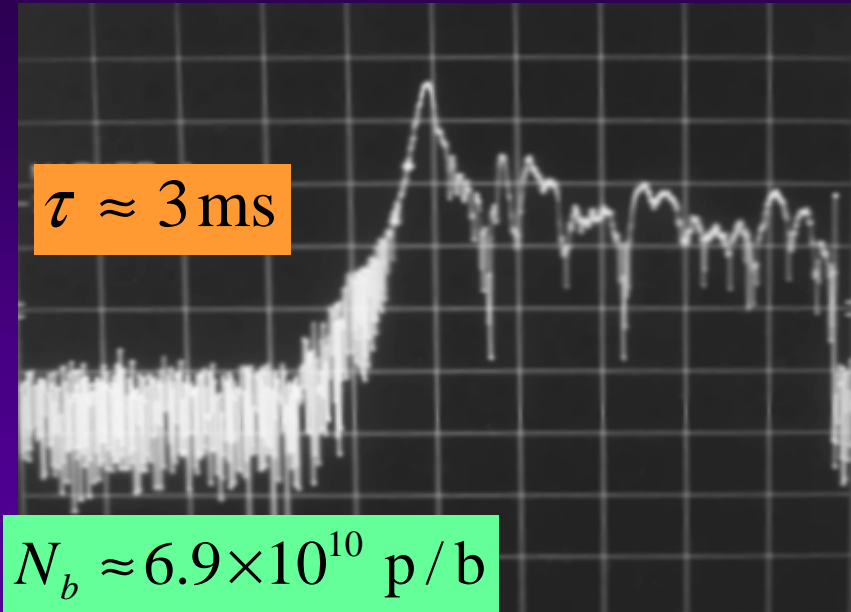
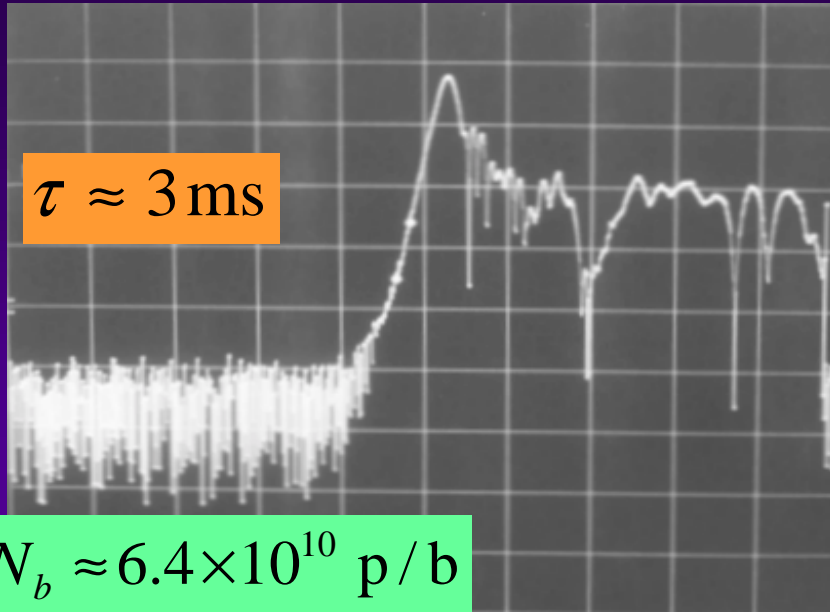
**Spectrum Analyzer  
(0  $\Rightarrow$  10 MHz)**

$N_b \approx 5.5 \times 10^{10} \text{ p/b}$

$N_b \approx 5.5 \times 10^{10} \text{ p/b}$

SWEEP TIME  
20.0 msec

# SINGLE-BUNCH RADIAL INSTABILITY IN 2001 (3/5)

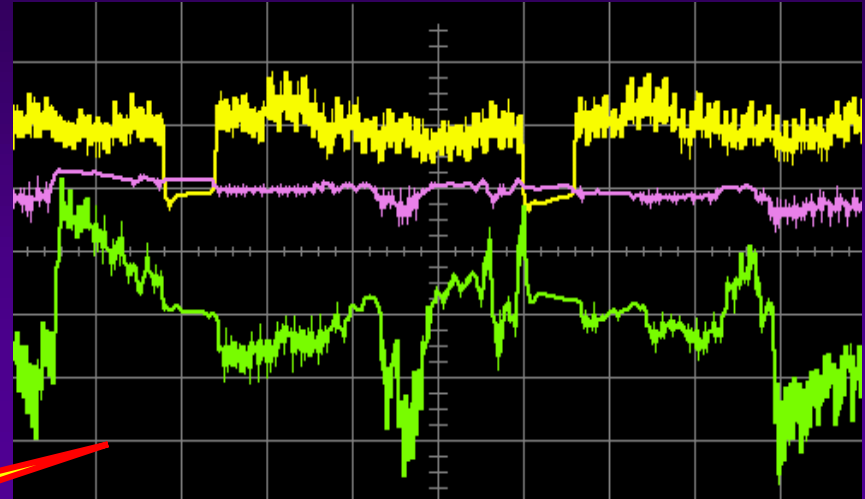
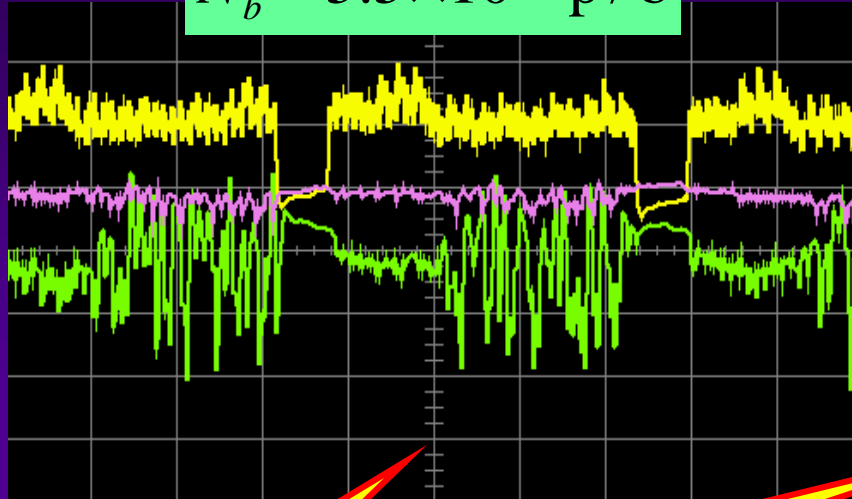


# SINGLE-BUNCH RADIAL INSTABILITY IN 2001 (4/5)

$$N_b \approx 5.5 \times 10^{10} \text{ p/b}$$

In PS

Time scale : 500 ns/div



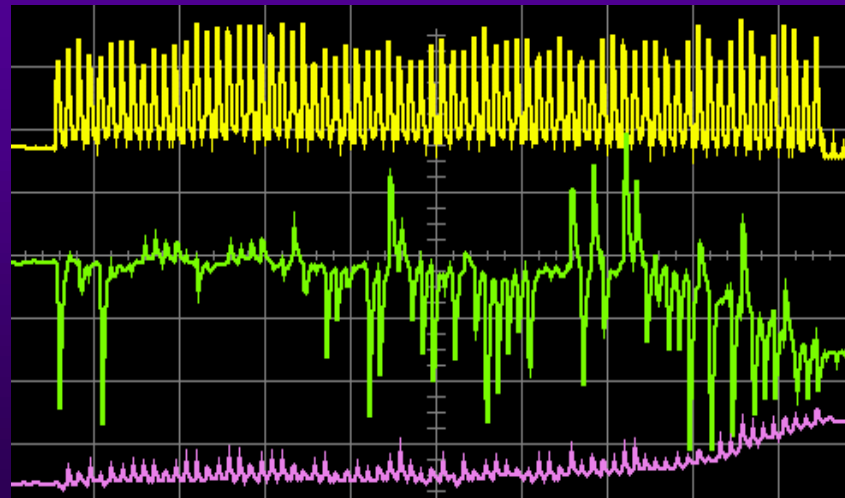
$\Sigma$

$\Delta y$

$\Delta x$

In TT2

Time scale : 200 ns/div



2 pictures in the same conditions

# SINGLE-BUNCH RADIAL INSTABILITY IN 2001 (5/5)

## Cures tried

- ◆ **Chromaticity** ⇒ **No effect**
- ◆ **Octupoles** ⇒ **Some improvements with very high current values (>200 A)**

# CONCLUSION

- ◆ **Electron cloud effects on the nominal PS beam for LHC**
  - Generate only beam diagnostics problems (in the PS ring and TT2 transfer line)
  - No time to develop an instability (since it appears in the very last turns of the PS during bunch compression)
- ◆ **Electron cloud effects on a modified PS beam for LHC (bunch length of ~10 ns during ~100 ms before extraction)**
  - The electron cloud build-up is observed
  - The beam is unstable
    - Single-bunch radial instability with no beam loss
    - Beam size blow-up :  $\times \sim 10-20$  in H and  $\sim 2$  in V
    - Rise-times of few ms (several synchrotron periods)
    - Chromaticity  $\Rightarrow$  No effect
    - Octupoles  $\Rightarrow$  Some improvements with very high current values ( $>200$  A)

$$T_s = 1.4 \text{ ms}$$