Preliminary results of the E-Cloud Instability MDs at the SPS

G. Rumolo, in ABP-LIS Section meeting (02/07/2007)
MDs with: G. Arduini, T. Bohl, R. Calaga, E. Métral, G. Papotti, S. Redaelli, B. Salvant, E. Shaposhnikova, R. Tomás
For data handling big thanks to: F. Roncarolo, B. Salvant

- Motivation and aim of the measurements
- Brief summary of 2006 experimental attempt to study the scaling law of the ECI at the SPS
- 2007 MDs:
  - 08.06.2007 before the scrubbing run
  - 26-28.06.2007 after the scrubbing run

→ Evidence:

⇒ **E-cloud instability** is one of the main single bunch intensity limitations in the SPS for the LHC beam.

⇒ It is cured with **high positive chromaticity**

→ How would the electron cloud instability threshold change if the injection energy into the SPS was raised to 50-70 GeV/c ?

→ Answer to this question is not straightforward:

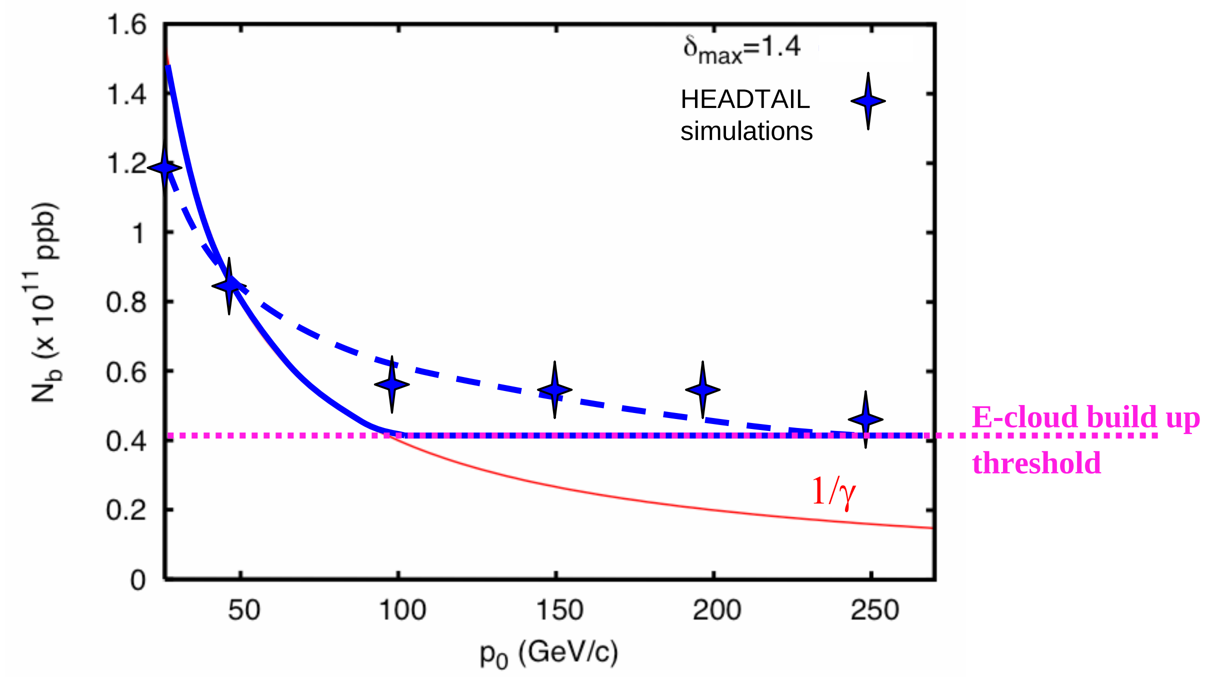
⇒ Higher energy means more rigid, therefore **more stable**, beam

⇒ At higher energy the beam gets **transversely smaller**, which enhances the pinch of the electrons as the bunch goes through them

⇒ The matched voltage is lower at higher energy, which translates into a **lower synchrotron tune** (destabilizing)

⊗ We carried out HEADTAIL simulations to answer the question !

HEADTAIL prediction using model with self-consistent e-cloud



For δ_{max}=1.4 the instability threshold decreases with γ up to ~100 GeV/c, then it levels off at the value of the build up threshold

→ Conservation of longitudinal emittance, bunch length and normalized transverse emittances.

→ Bunch always matched to the bucket !

2006: Experiment at the SPS trying to prove the scaling law of e-cloud instability with energy…

• On the 24.10.2006 we used a 20.4 s long LHC cycle with 5 batches with 48 bunches injected in 10.8 s and then ramped to 450 GeV/c

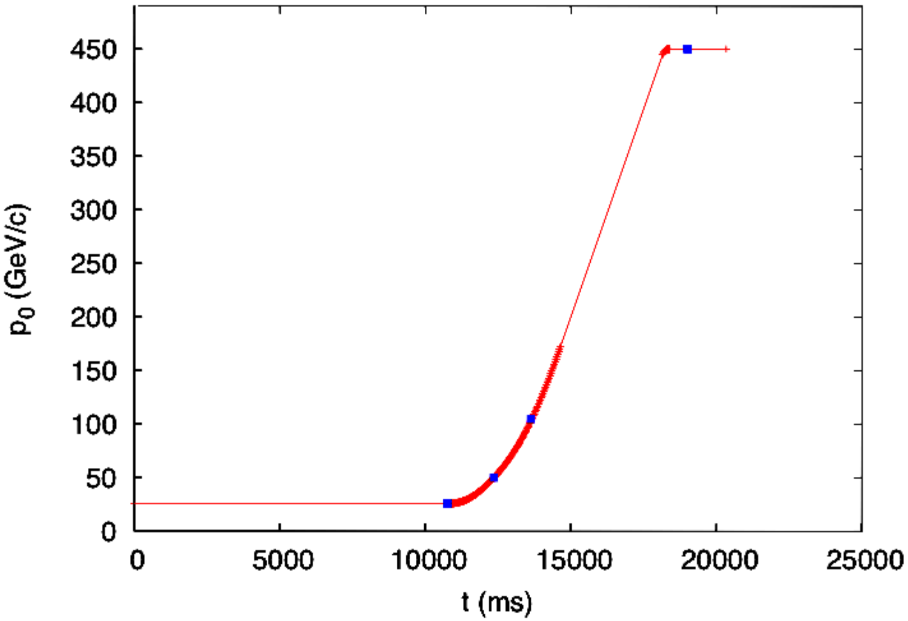
• Measurement points are:

→ 26 GeV/c, 10770 ms,
  beam dump @ 10850 ms

→ 50.2 GeV/c, 12360 ms,
  beam dump @ ?

→ 105 GeV/c, 13630 ms,
  beam dump @ 13670 ms

→ 450 GeV/c, 19000 ms,
  beam dump @ 19060 ms



The only clear sign of vertical instability was observed at 26 GeV/c

→ Losses observed
→ Seems to affect bunches from the tail of the third batch (LHC-BPM application)

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Dekompressor „H.264“
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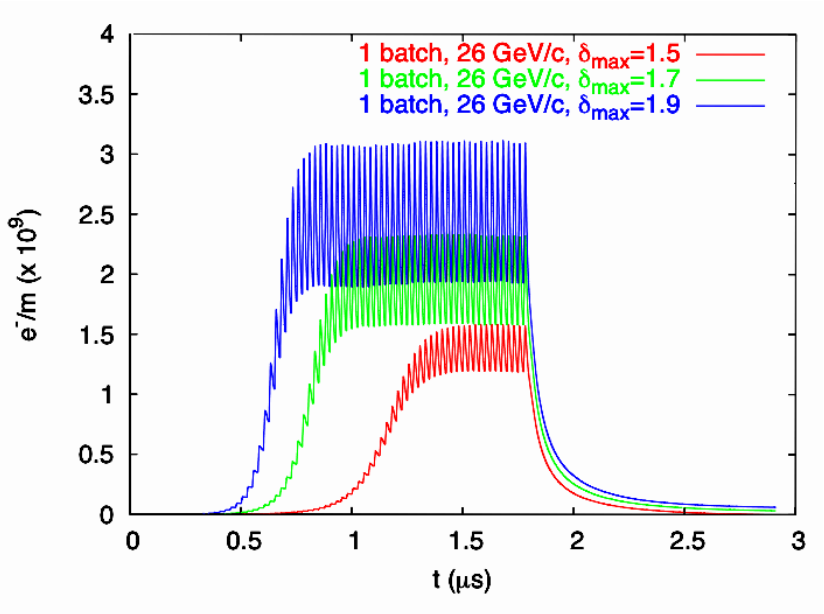
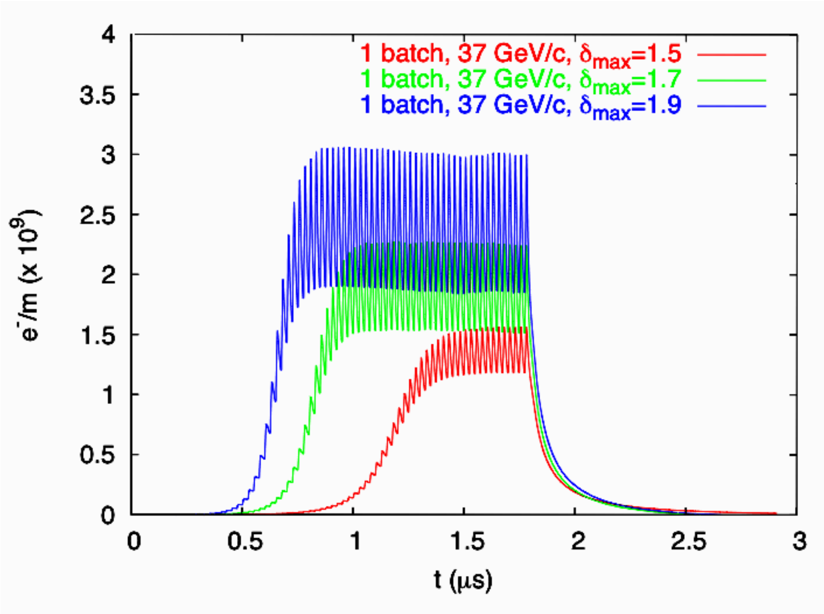
2007 MDs at 26 and 37 GeV/c





Measurements at a 37 GeV/c flat top with one batch (72 bunches) in W23 and W26

→ Simulations predict that the electron cloud build up is about the same at both energies, but the instability should be slightly worse at 37 GeV/c

→ Before the scrubbing run the δ_{max} should be significantly higher,

→ There should be a difference with the measurements after the scrubbing run

2007 MDs at 26 and 37 GeV/c in W23

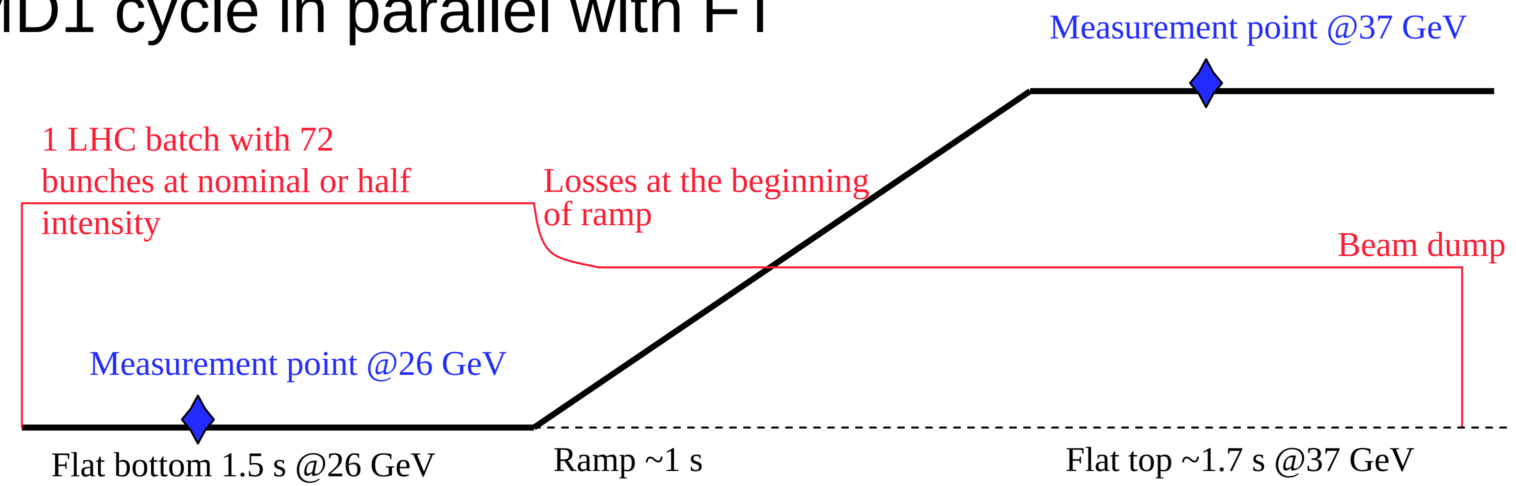
• Vertical chromaticity was lowered at the measurement points, till the beam becomes unstable. Look for *Q'* threshold for instability

→ *Q'=-0.19* at 26 GeV/c (setting value)

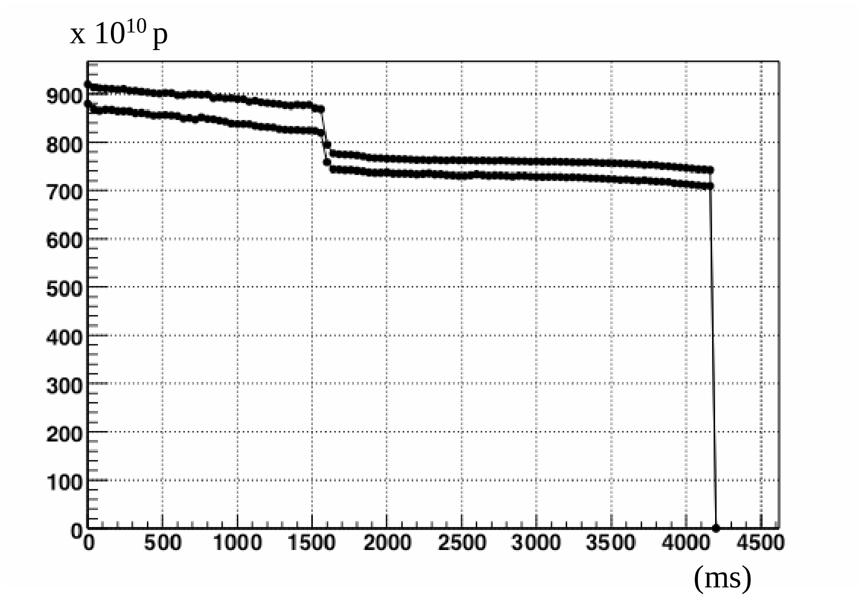
→ *Q'=0* at 37 GeV/c (setting value)

• The damper gain was kept to nominal value all along the cycle

MD1 cycle in parallel with FT

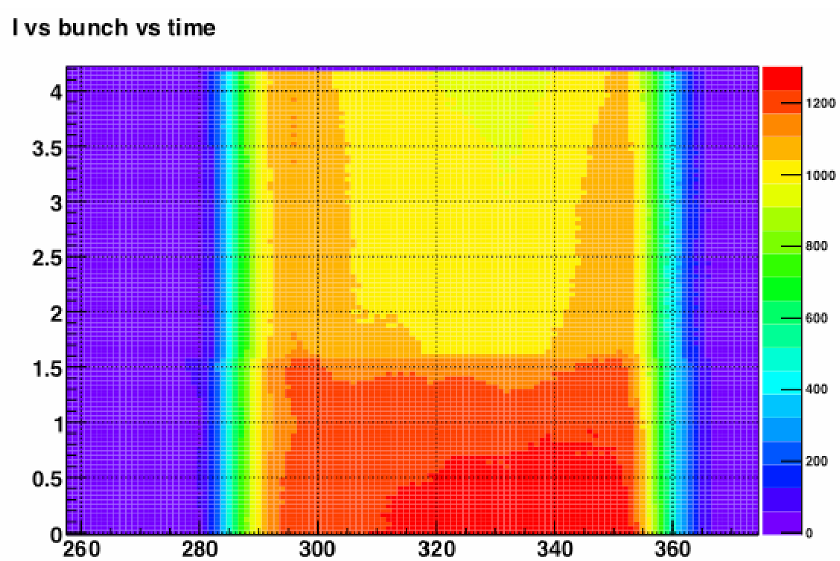


Stable case



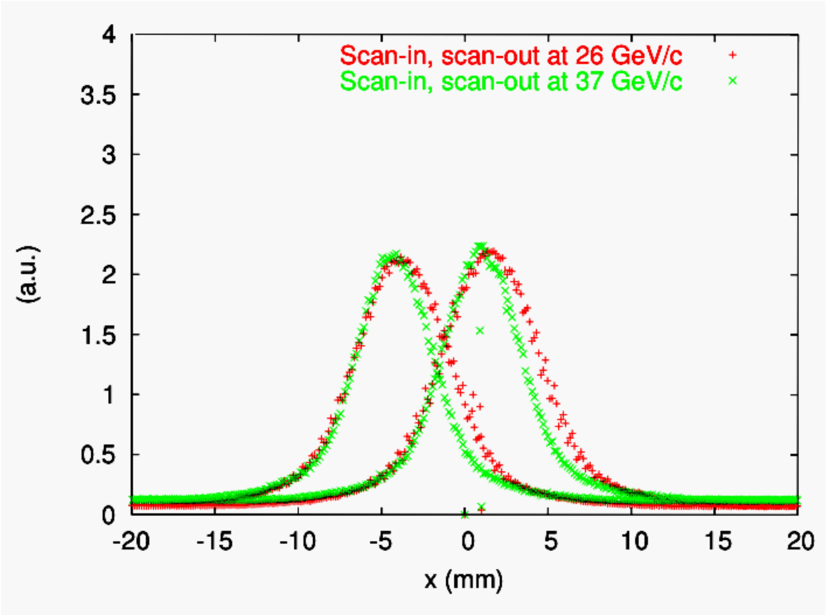
The BCT shows quite bad lifetime at flat bottom (~3% losses over 1.5 s) and 10 to 20% loss at the begining of the ramp, depending on the shot

The Fast BCT shows that most of the losses at the beginning of the ramp happen in the middle of the batch



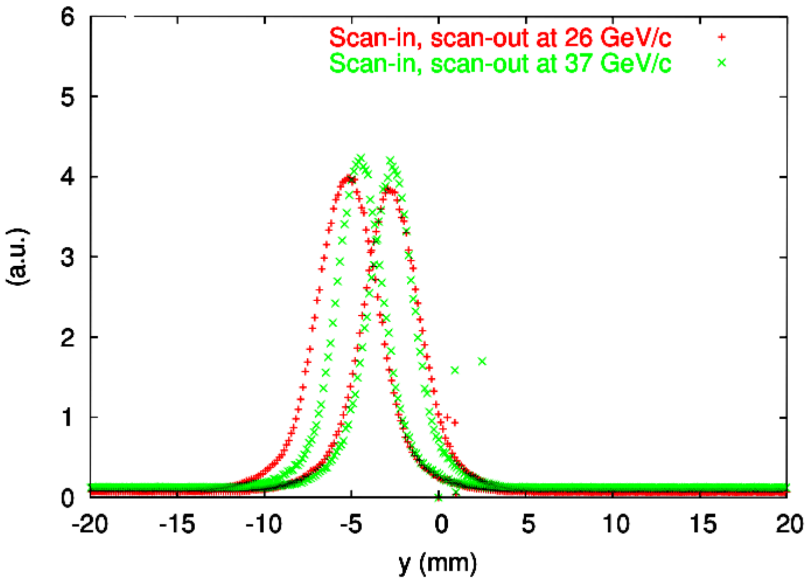
Stable case

σ_y measurement compatible with ε_{yN}=3.1 μm



Measurements with the SPS-WS51995 give:

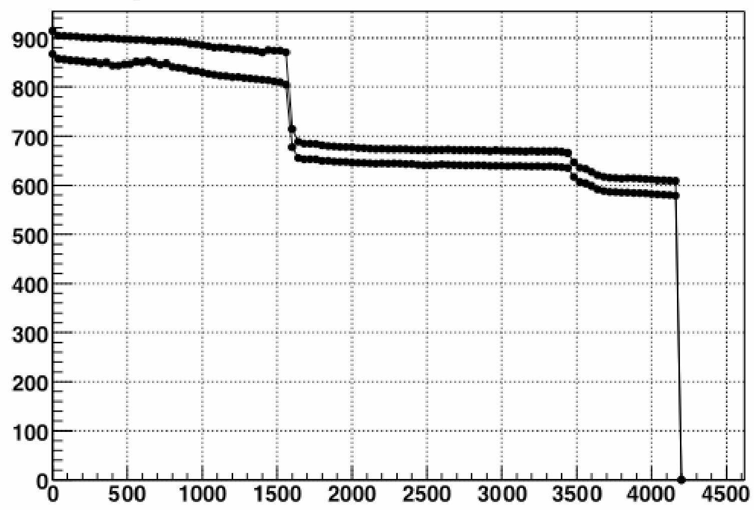
σ_x=2.9 mm @26 GeV/c and
σ_x=2.47 mm @37 GeV/c



Measurements with the SPS-WS51995 give:

σ_y=1.67 mm @26 GeV/c and
σ_y=1.36 mm @37 GeV/c

20h29 ⇒ instability@37 GeV

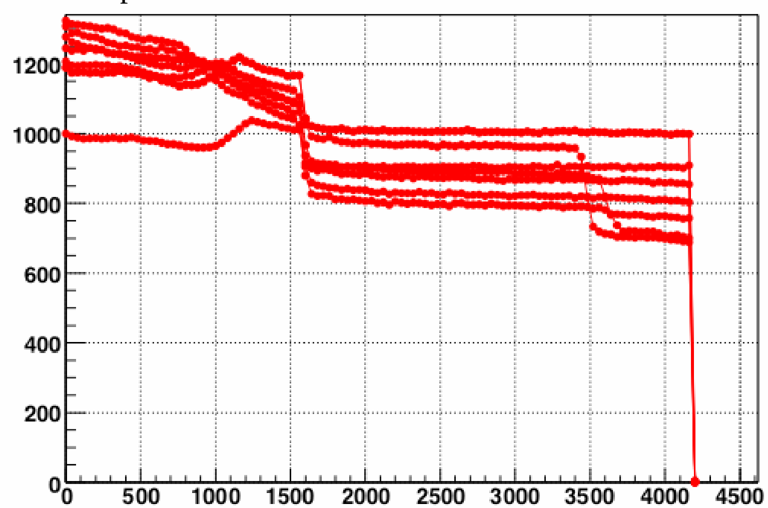


Here Q'_V was trimmed to 0 at 3500 ms.

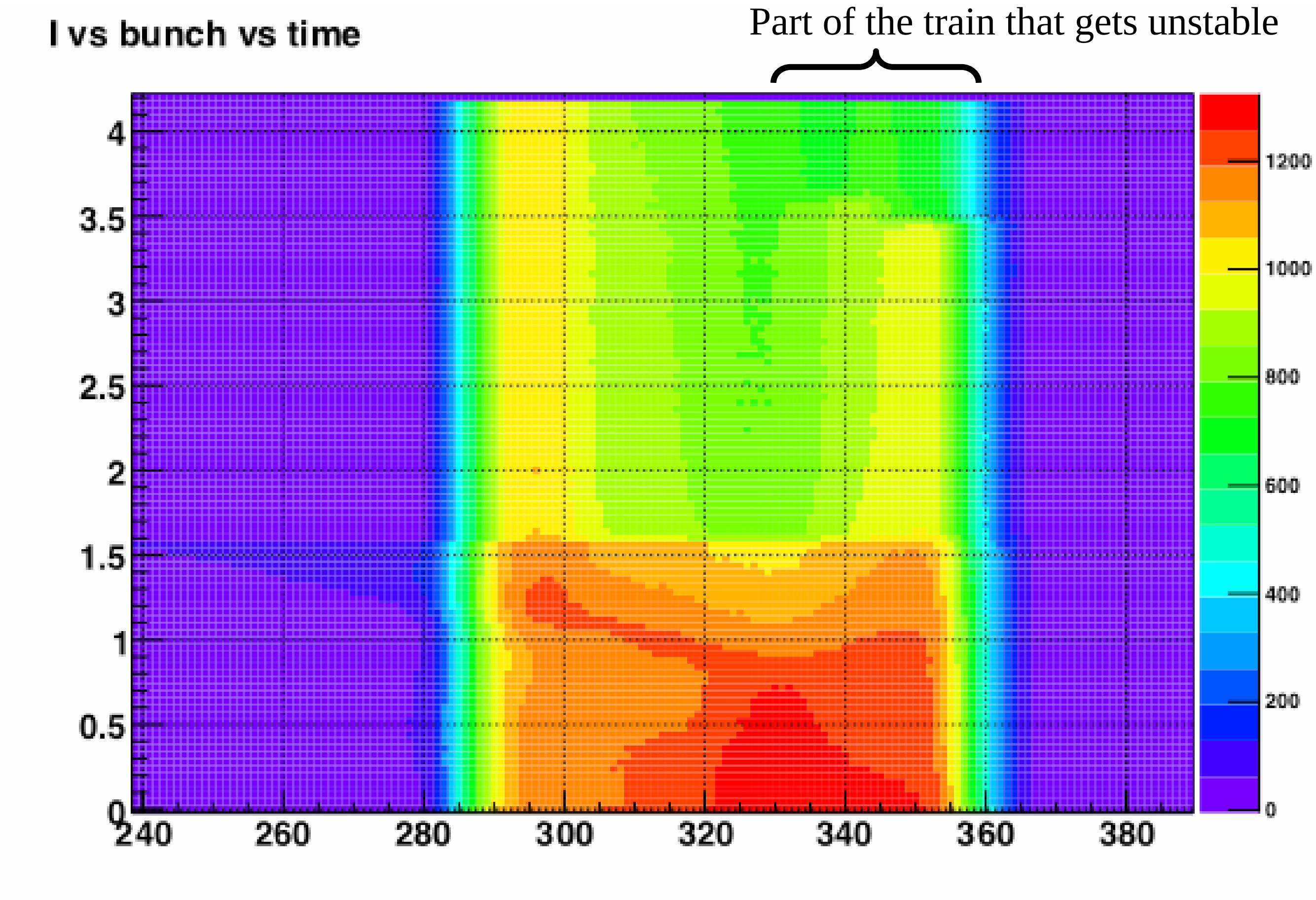
Losses occur due to an instability

The Fast BCT shows the time evolution of 7 bunches along the batch (1,11,21,31,41,51,61,71).

Losses affect the bunches in the tail of the train



20h29 ⇒ instability@37 GeV



20h29 ⇒ instability@37 GeV

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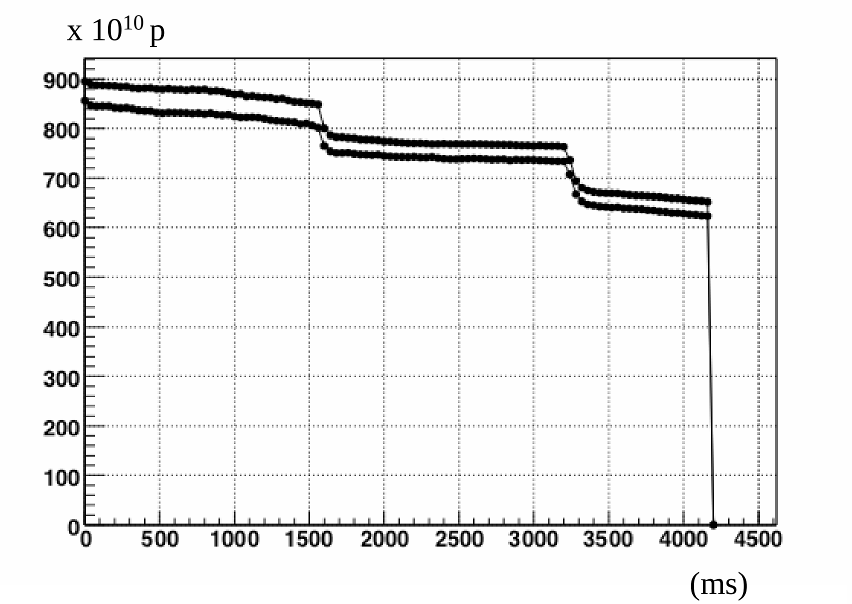
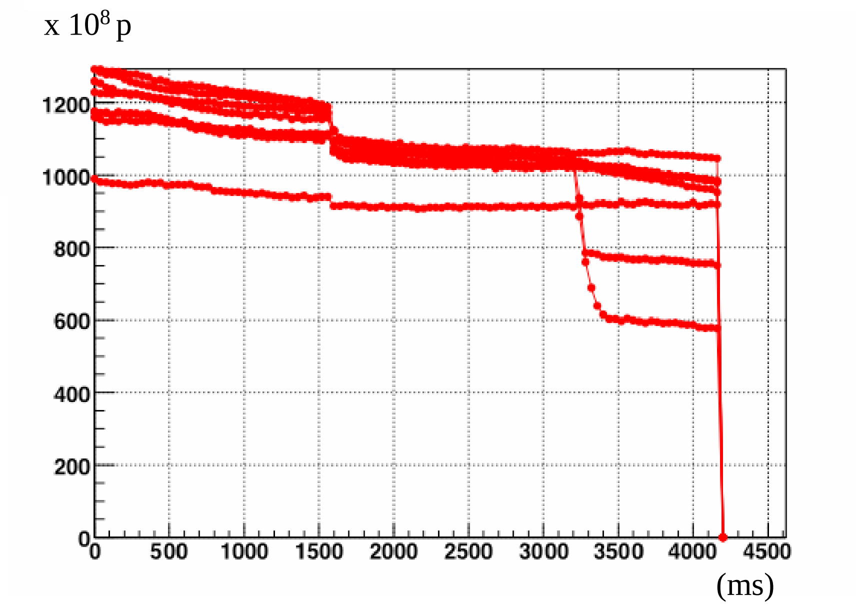
20h37 ⇒ instability@37 GeV

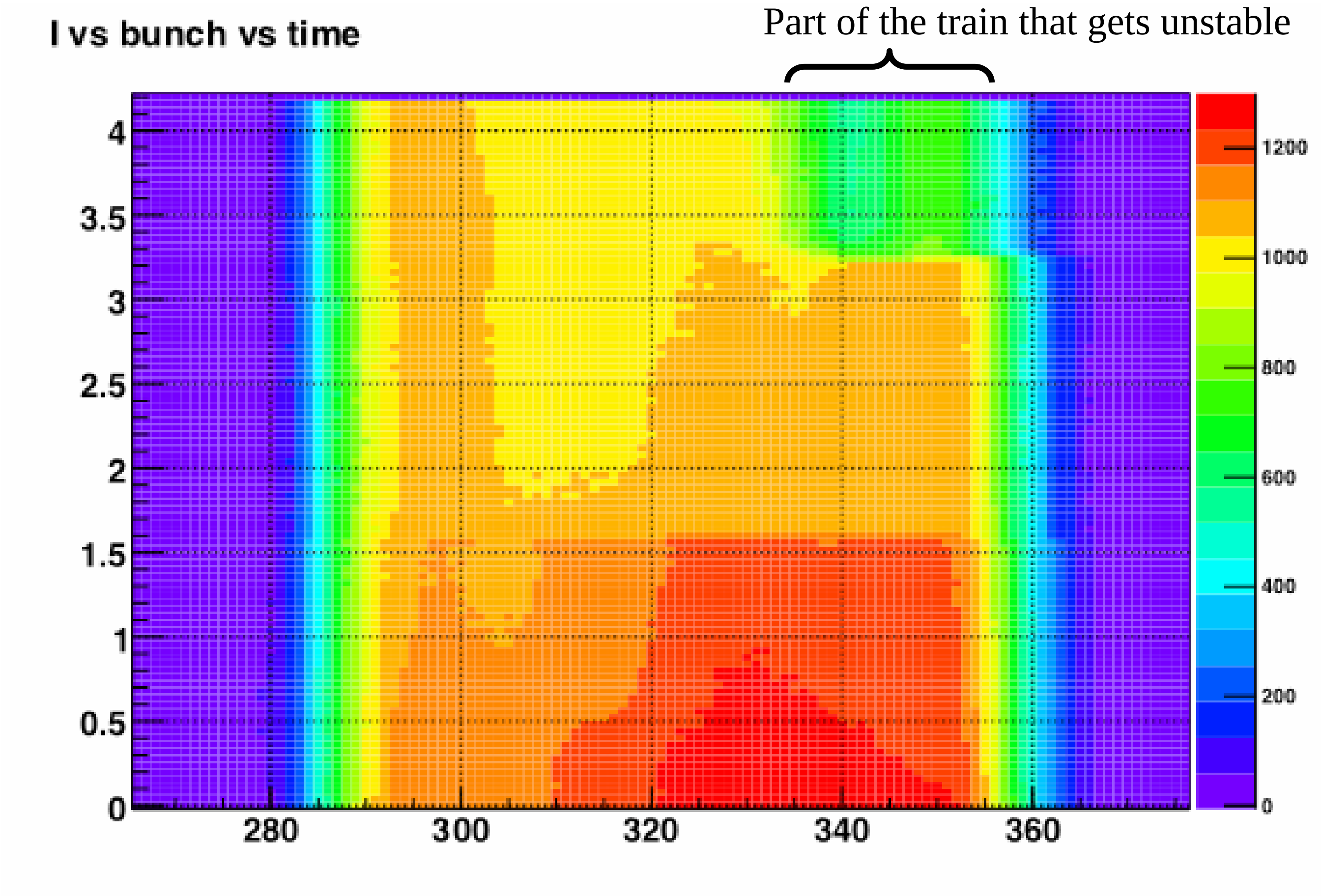


Same as before: Q'_V was trimmed to 0 at 3500 ms.

Losses occur due to an instability



20h37 ⇒ instability@37 GeV



20h37 $\Rightarrow$ instability@37 GeV

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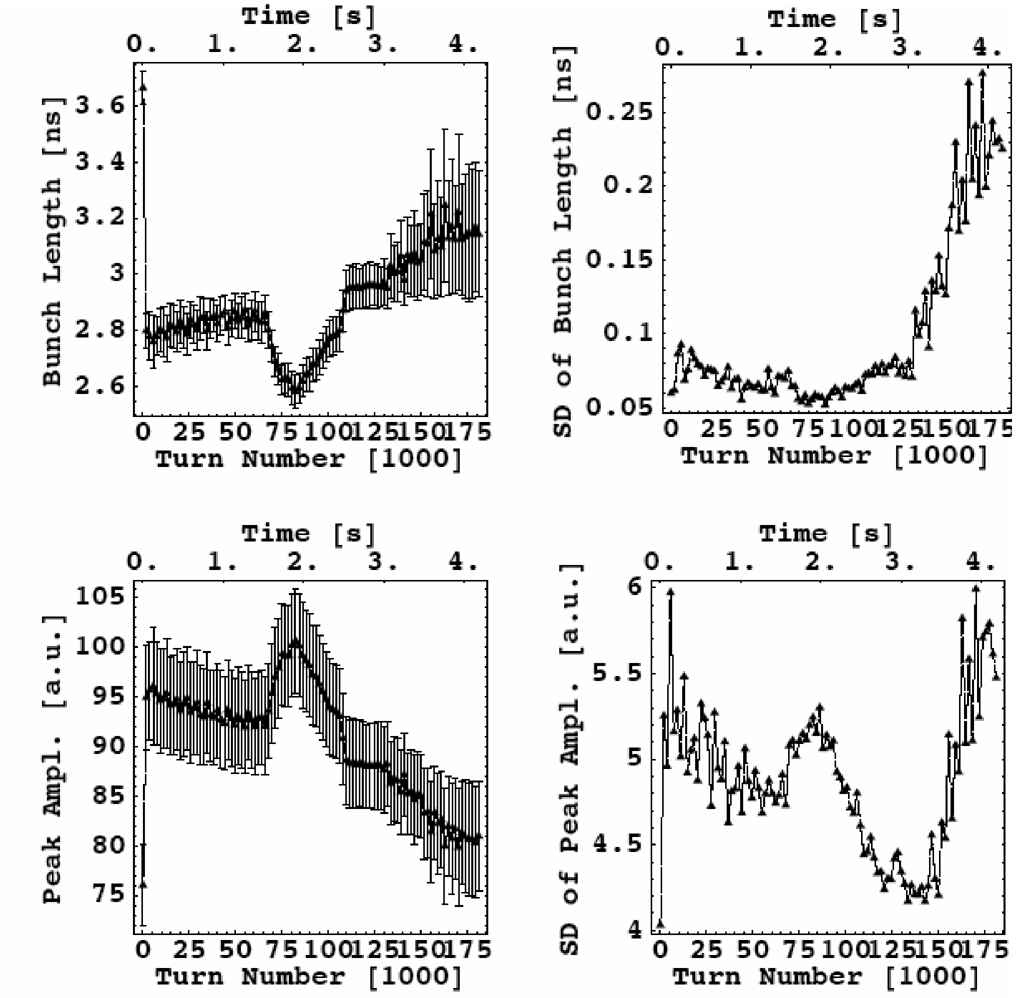
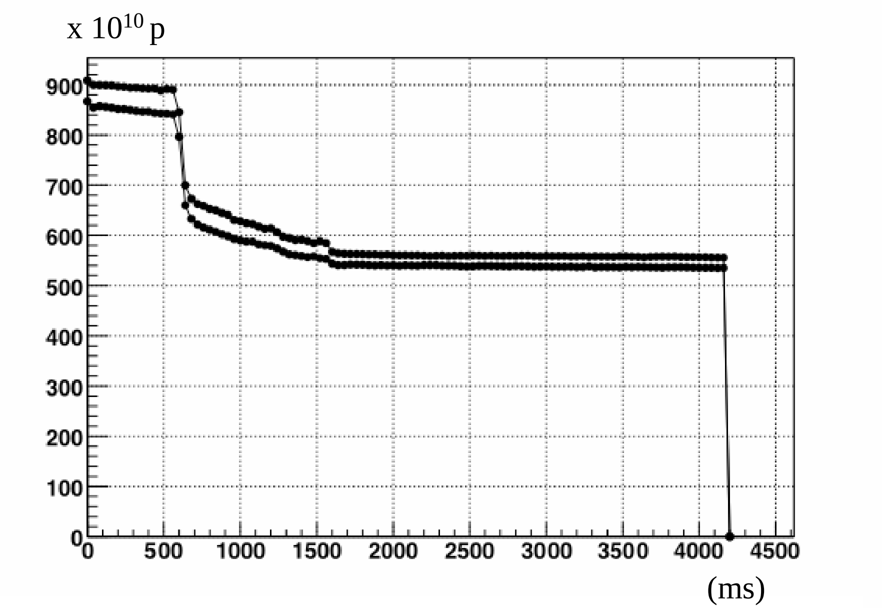
Instability@37 GeV, the longitudinal plane

In the longitudinal plane, there is bunch lengthening at the time of the instability

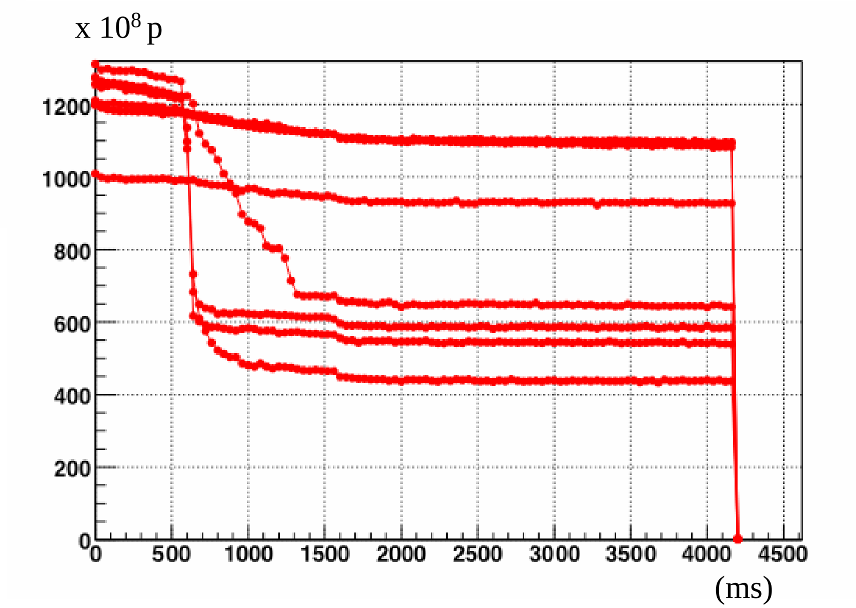


20h52 ⇒ instability@26 GeV

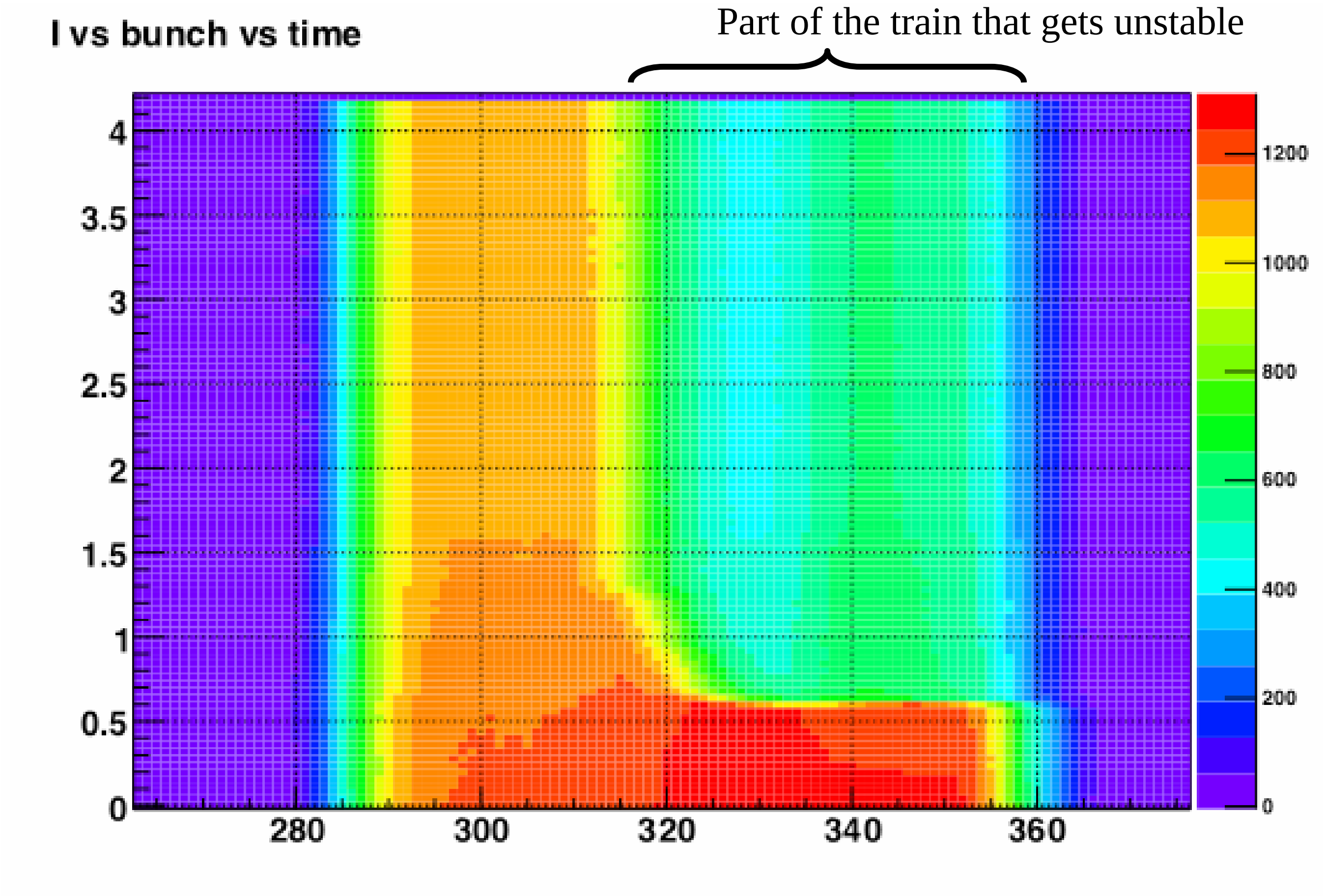


Here Q'_V was trimmed to -0.19 at 550 ms.

Losses occur due to an instability



20h52 ⇒ instability@26 GeV



20h52 ⇒ instability@26 GeV

Zur Anzeige wird der QuickTime™
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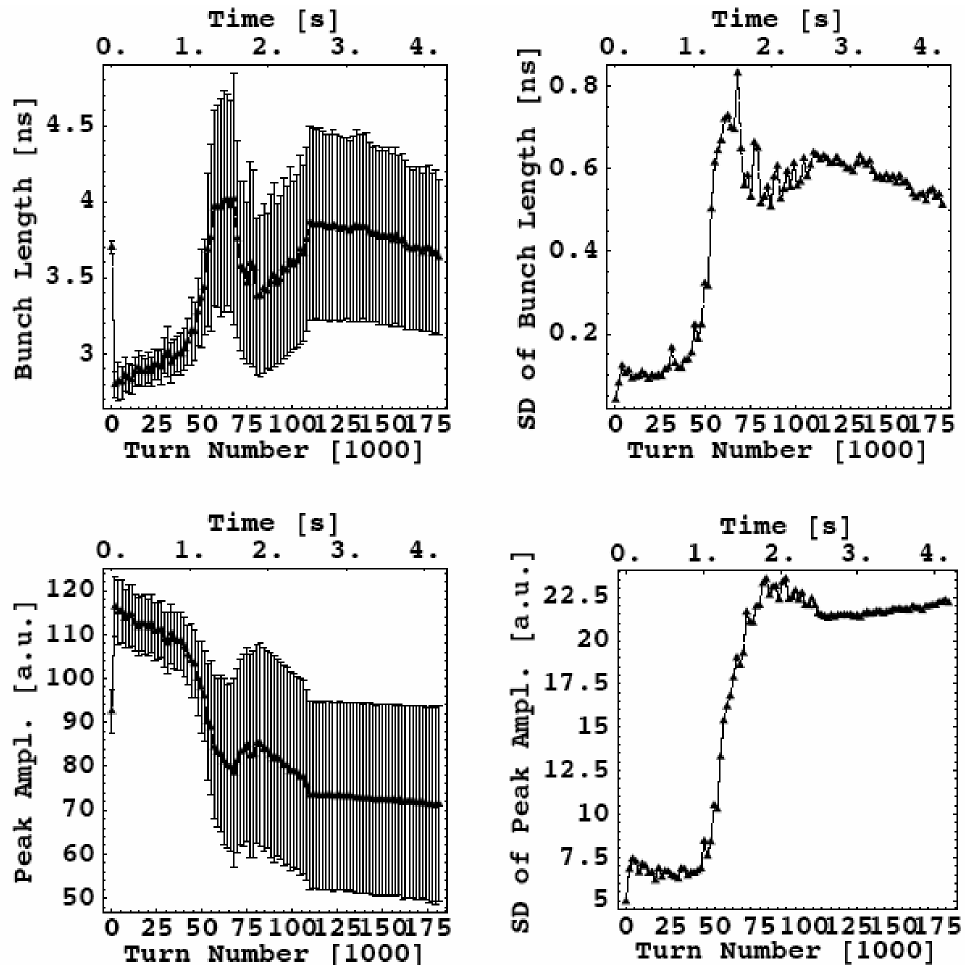
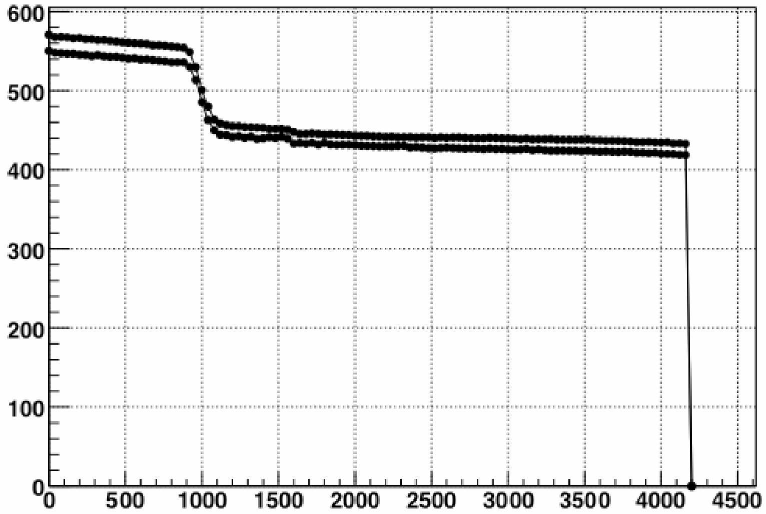
Instability@26 GeV, the longitudinal plane

Similarly to what observed at 37 GeV, in the longitudinal plane, there is bunch lengthening at the time of the instability

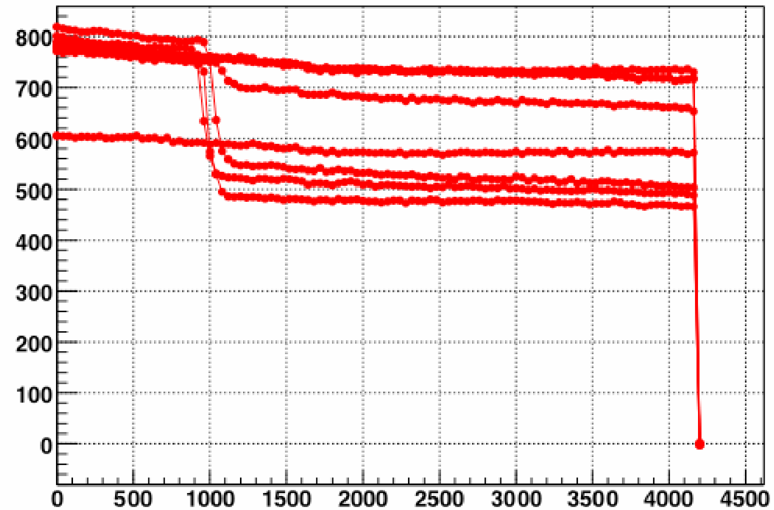


21h21 ⇒ instability@26GeV



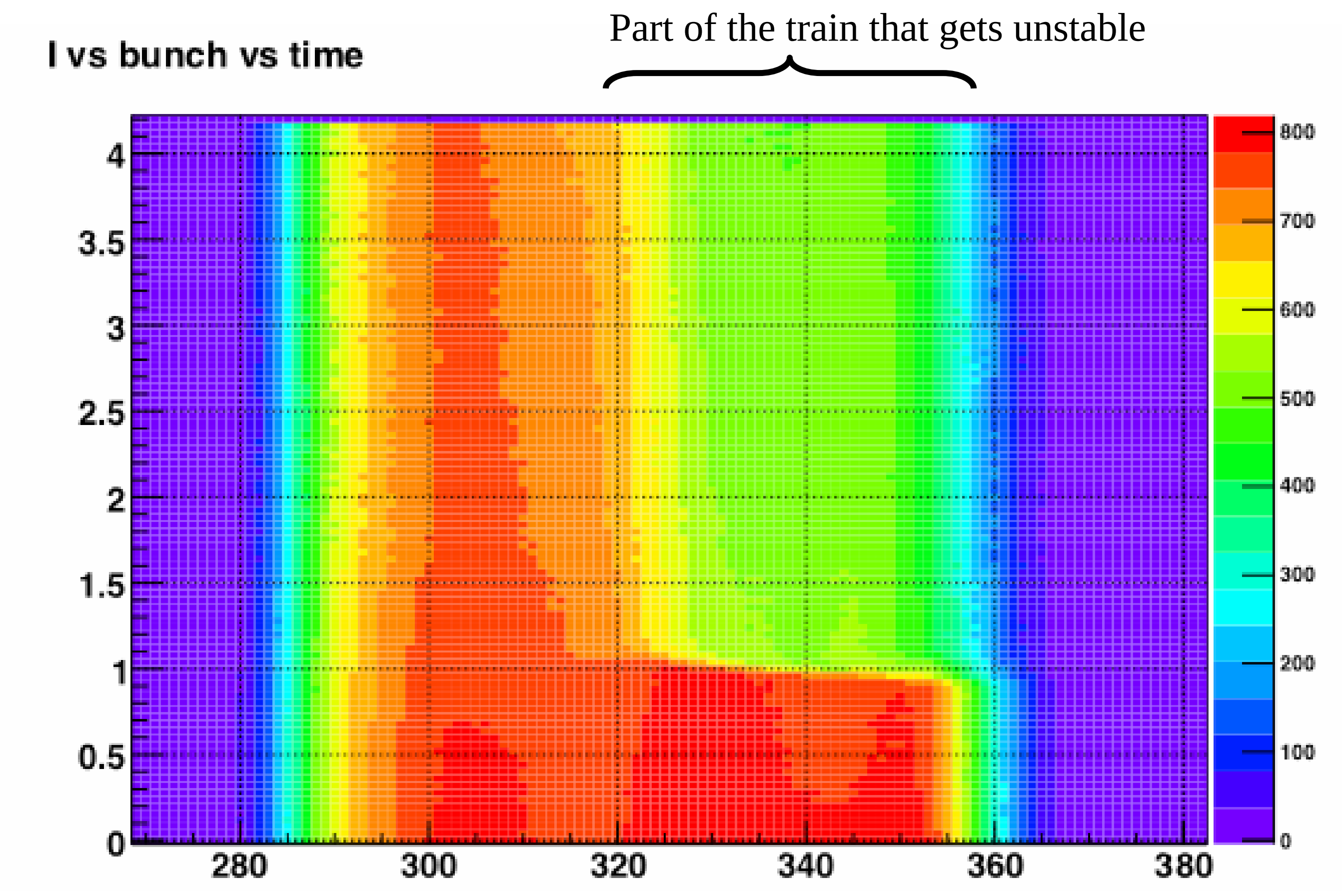
Chromaticity trimming as before but having injected half the intensity

Losses occur due to an instability



The instability is slower, the losses manifest themselves farther away from the point where chromaticity is changed (550 ms)

21h21 ⇒ instability@26GeV



21h21 $\Rightarrow$ instability@26GeV

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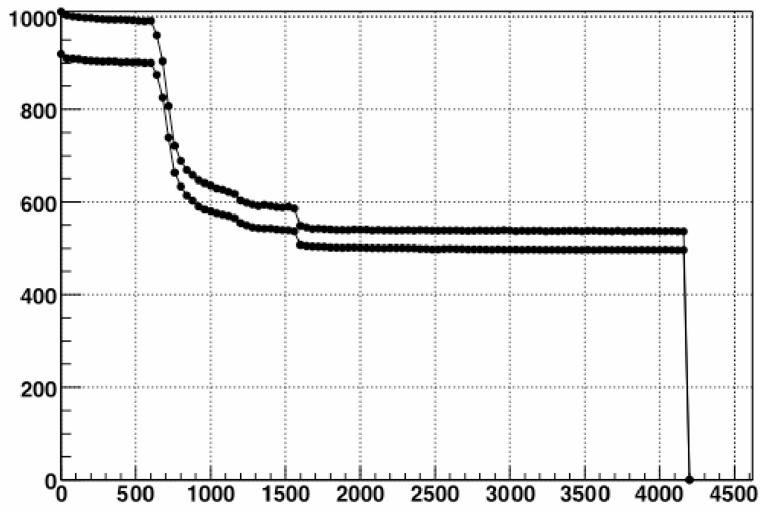
26.06 More MDs

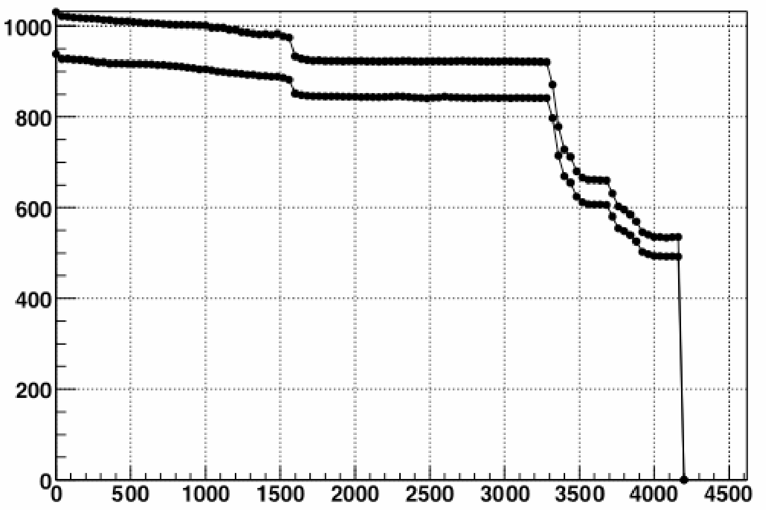
⇒ Less loss on the ramp

⇒ Instability@26GeV and 37GeV at full and half current

⇒ About the same Q‘ thresholds as on 08.06

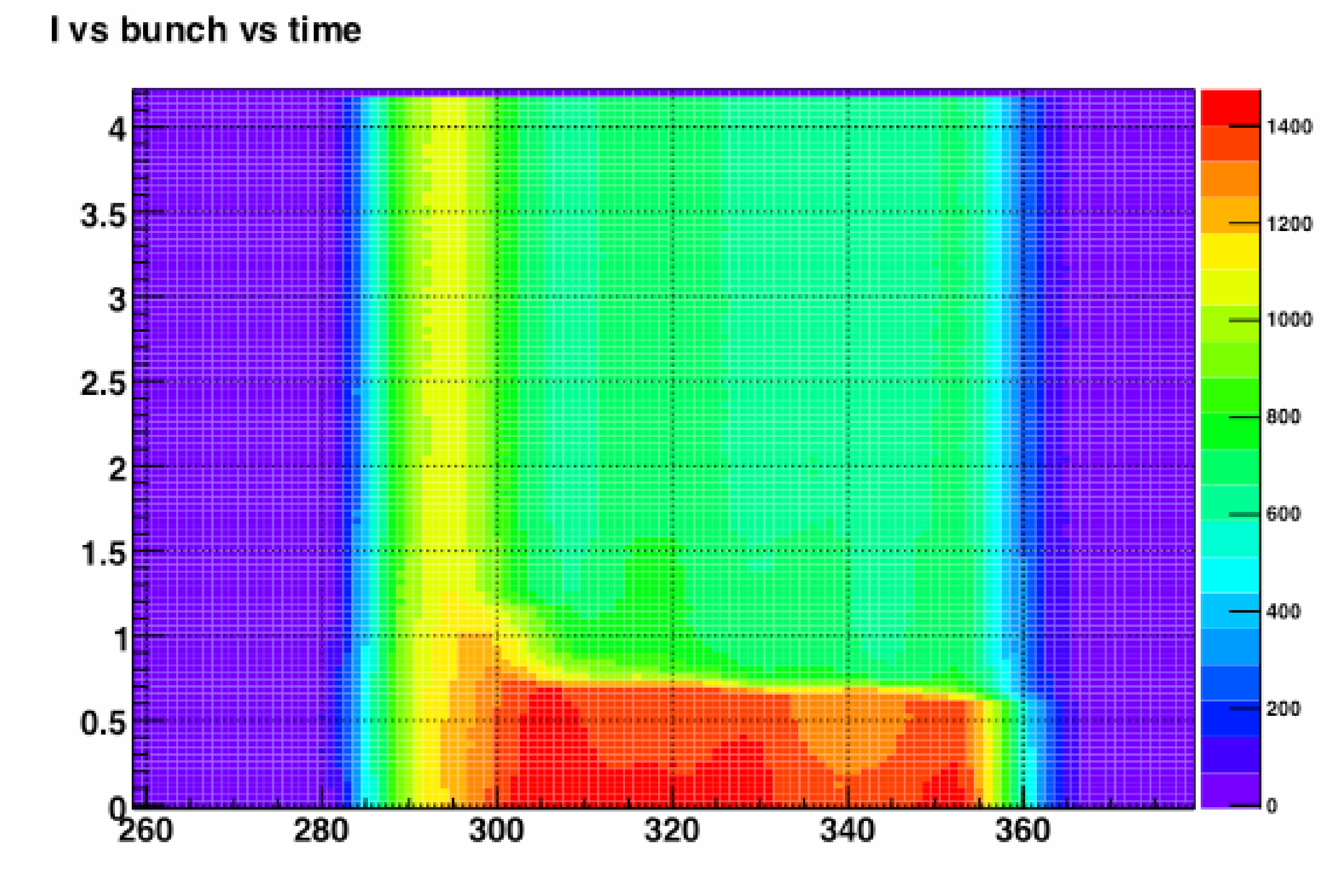


Q‘ switched to -0.19 at 550 ms

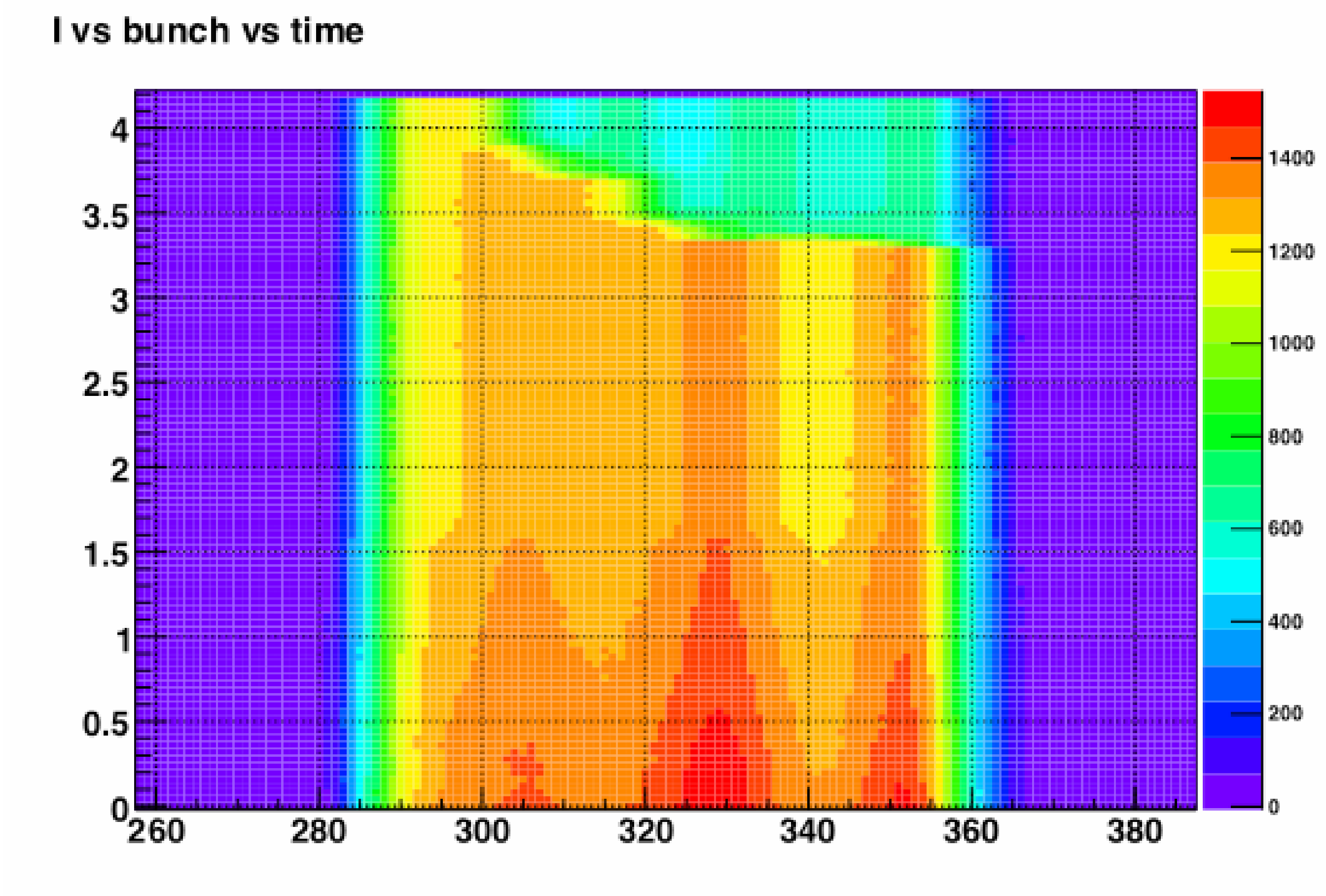


Q‘ switched to -0.01 at 3000 ms

26.06 MDs
⇒ Strong instability at 26 GeV/c



26.06 MDs
$\Rightarrow$ Strong instability at 37 GeV/c



26.06 MDs
⇒ Strong instability at 26 GeV/c

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26.06 MDs

⇒ Strong instability at 37 GeV/c

Zur Anzeige wird der QuickTime™
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benötigt.

Summary of the observations

- 1 batch of LHC beam **vertically unstable** at
  - **26 GeV/c** for **Q'_V setting below -0.19**
  - **37 GeV/c** for **Q'_V setting below 0**
- Chromaticity calibration carried out on the 28.06.2007 shows
  - Setting -0.19 @26 GeV/c $\Rightarrow$ ***$Q'_V = 2.2 \pm 0.2$***
  - Setting 0 @37 GeV/c $\Rightarrow$ ***$Q'_V = 3.3 \pm 0.2$***
- Beam is unstable with same thresholds in Q'_V both at full and half current, but the instability rise time is longer at lower intensity.
- Only the tail of the bunch train is affected by the instability.
- Pattern of the instability along the bunch train seems to clearly point to a coupled bunch instability at 26 GeV/c. A 37 GeV/c it is not evident.

$\Rightarrow$ Is the observed instability due to electron cloud ?....

What is still planned for 2007 MDs

Measurements at an intermediate flat top at 55 GeV/c in W34

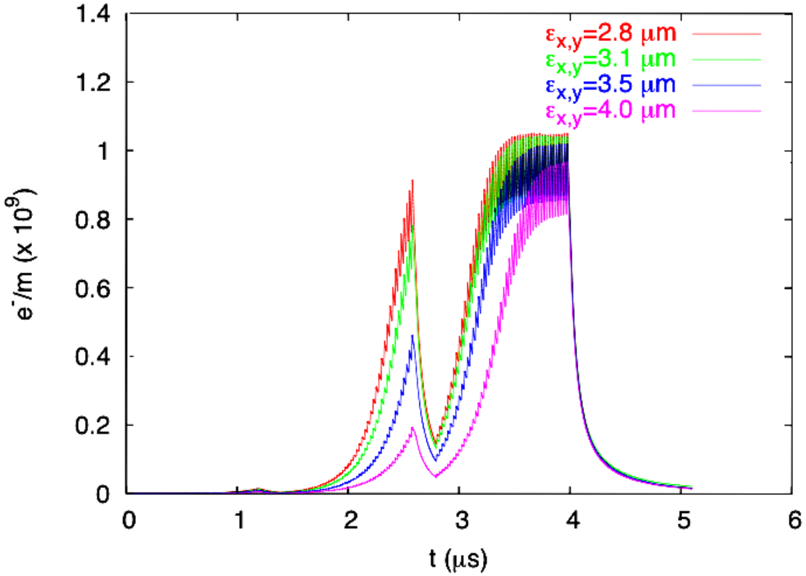
→ Expected ~50% difference in the intensity thresholds for the e-cloud instability

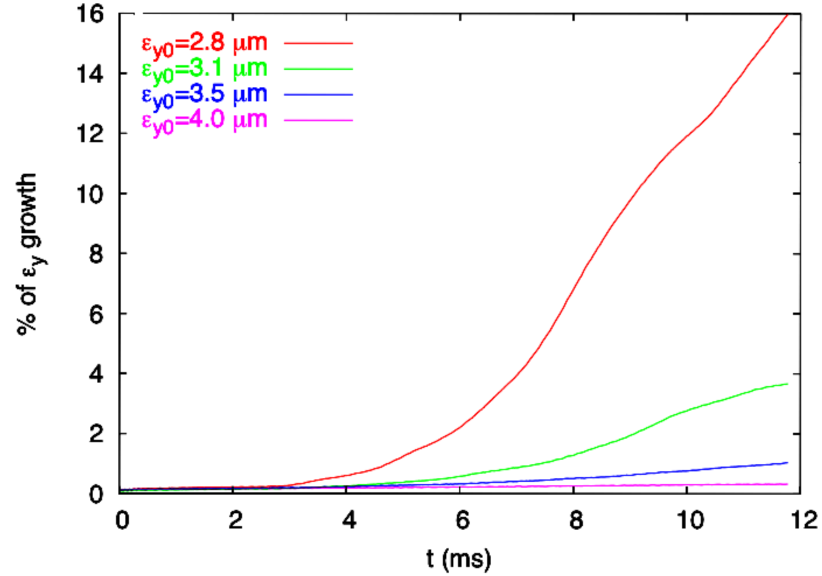
→ Measurement with 4 LHC batches

→ The voltage at 4.5 MV should be very close to the matched value

⇒ Whatever the result of the experiment, we will be able to test the electron cloud instability in the range of the future injection energy with the PS2

What is planned for 2007 MDs (III)





Measurements at flat bottom (26 GeV/c) with different transverse beam sizes

→ From the scaling law of the e-cloud instability with energy, a key role seems to be played by the decreasing transverse beam size with energy

→ Maybe inject transversely larger beams and have less blow up due to the e-cloud instability ?

What is planned for 2007 MDs (IV)

Instrumentation needed

Systematic acquisition is needed with:

→ LHC-BPM for turn by turn and bunch by bunch acquisition of the Δ signal

→ BCT and Fast BCT to check for losses when the instability appears

→ WS to check the transverse beam size at the measured energies

→ Bunch length measurements at the measured energies

⇒ Last year there were some issues with the timing between different applications. E.g., when dumping the beam at 10850 ms

- o HT-monitor would see beam up to 10853 ms + 87 turns
- o LHC-BPM would see beam up to 10887 ms + 240 turns

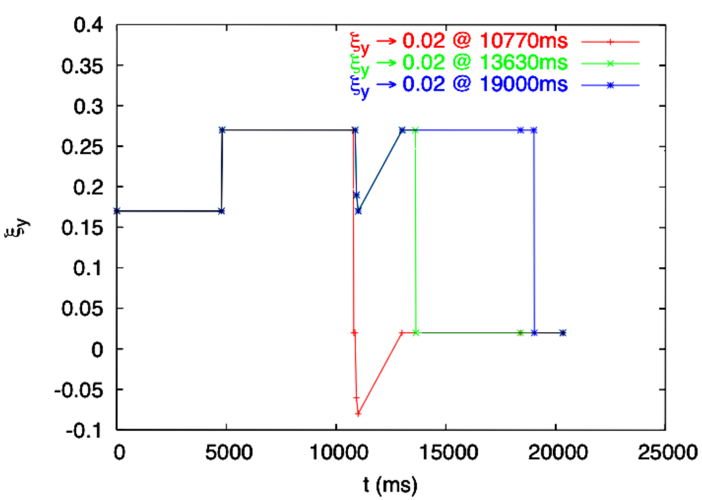
2006: Experiment at the SPS trying to prove the scaling law of e-cloud instability with energy...

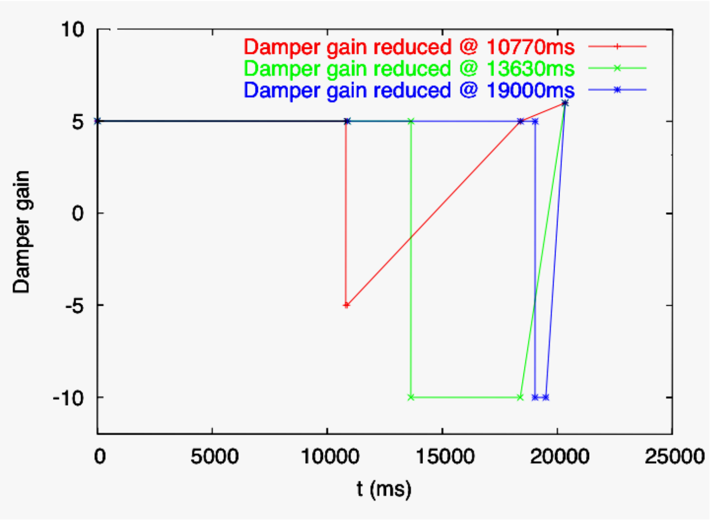
- Vertical chromaticity was corrected at the measurement points

  → *Q'=0.05* at 26, 105, 450 GeV/c

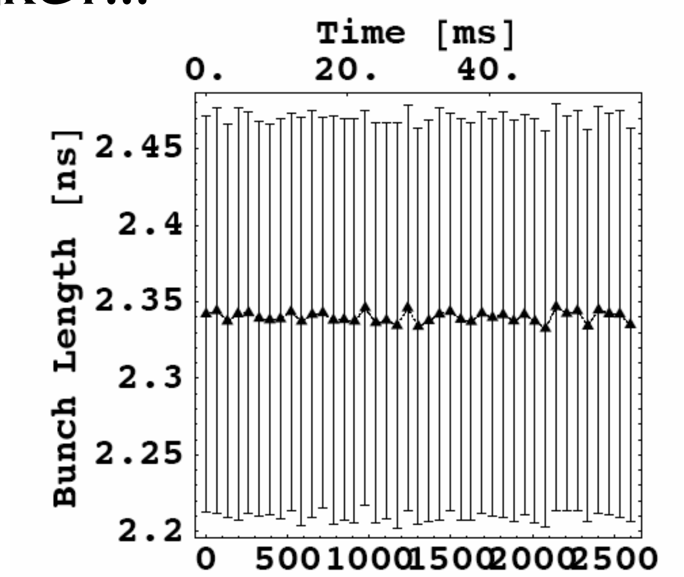
  → *Q'=0.2* at 50.2 GeV/c (? from handwritten logbook)

- The damper gain was reduced at the measurement points





2006: Experiment at the SPS trying to prove the scaling law of e-cloud instability with energy…



- 200 MHz rf-voltage was set to:
  - → 3.3 MV at 26 GeV/c
  - → 4.5 MV at 50.2, 105 GeV/c
  - → 4.5 MV at 450 GeV/c
    then ramped down to 500 kV over 19 ms from 19000 ms

- The 800 MHz cavity was on all the time, except for the very last measurement, which was performed at flat top with the 200 MHz voltage ramped down as described above.

- Bunch length measurements @26 GeV/c show bunches with 4σ ~(2.35 ± 0.12) ns, all corrections included (thanks to T. Bohl)