Beam loss and radiation in the SPS for higher intensities and injection energy

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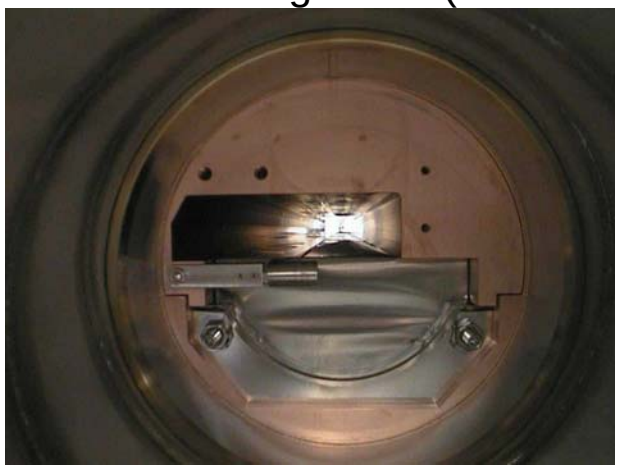
Acknowledgments: E. Shaposhnikova and all those participating to the 2004 high intensity test.

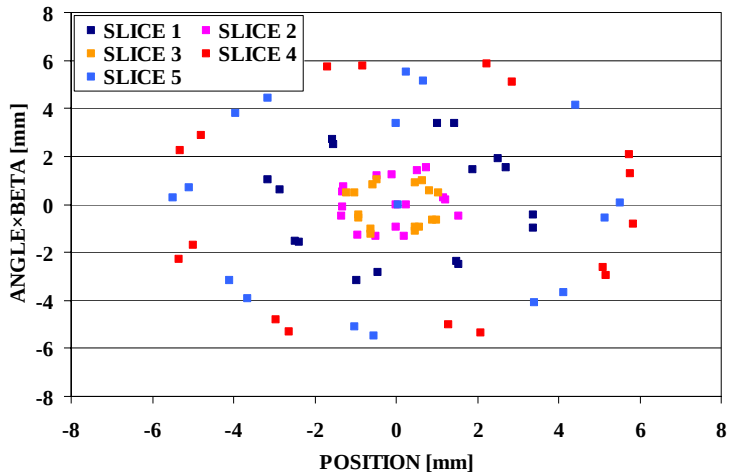
Outline

- From BLRWG study:
  - Considerations for fixed target beams
  - Considerations for LHC beams
  - Other sources of losses

Considerations for fixed-target beams

- Fixed target beams: CNGS-type and slow-extraction to North.
  - Injection losses mainly determined by V-aperture/V-beam size:
    - limitation at TIDVG ➔ removed during SD 2004-2006
    - minimization of the vertical emittance ➔ correction of the trajectories of the slices of CT (MTE) 5-turn extraction ➔ displacement of one of the Emittance Reduction Dipoles (ERD) in TT2 to achieve correction in position and angle + implementation of correction algorithm (run 2007)





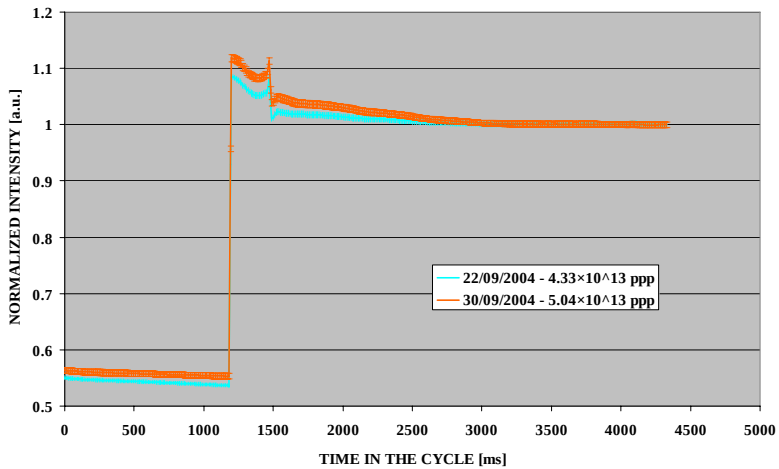
- At 26 GeV/c (for constant normalized emittance) gain by a factor ~50 in the relative losses by simple scaling rules but the gain in specific radiation (radiation/injected proton) is reduced by a factor 2 because of the higher energy.
- Need to increase strength of ERDs and to keep emittance exchange section in the injection line PS2 to SPS.

Considerations for fixed-target beams

- Capture losses:
  - No clean 200 MHz structure imposed at extraction from PS, only modulation ➔ constant capture voltage of 800 kV gives ghost bunches in the kicker gap due to recapture of particles at the beginning of acceleration. Partially improved by ”quasiadiabatic” capture of the first batch with a voltage step (0.8 MV to 2.5 MV); not possible for the second batch ➔ New beam control for separate capture of each batch.
  - True bunch-to-bucket transfer should help (but how far? given the LHC beam experience). Choice of the RF system in the PS2 and gymnastic to provide bunches that fit in 200 MHz SPS bucket is important. Single batch injection would also eliminate the need for a new beam control for separate capture of each batch.

Considerations for fixed-target beams

- Transition crossing and resulting losses:
  - Strong bunch length modulation along the batch at ~ 1.3 MHz (=minimum of 200 MHz RF feedback transfer functions) ➔ High voltage required after transition (larger kicker heating + one-turn-delay feedback during the whole ramp). It was found that increased feedback gain improved transition crossing but created problems in the front porch ➔ Variable feedback gain + increased frequency range of the feed-forward system.
  - In the last two years losses localized in 3.05 and downstream (inspected during the SD).



  - Injection above transition should solve this problem

Considerations for fixed-target beams

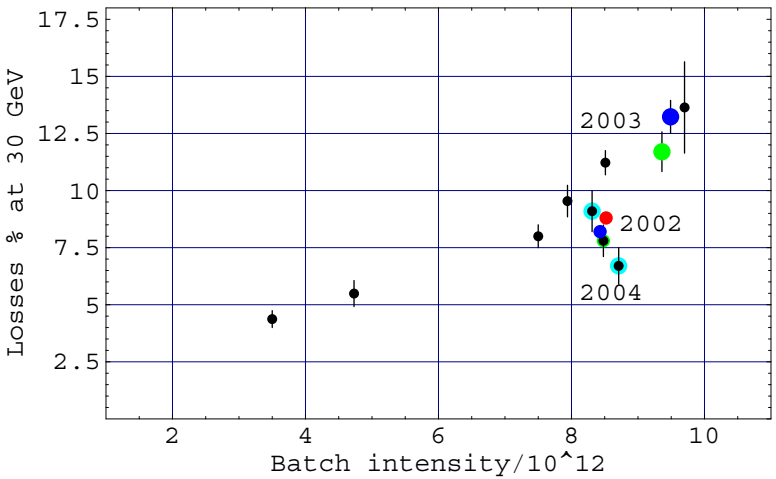
- Low-energy losses (front-porch, transition):
  - Difficult control of the working point and poor reproducibility of the ramp
  - Improved by reduction (30 ➔ 6 ms) of the time interval between consecutive vectors in the ramp (run 2007)
  - No change expected for higher injection energy

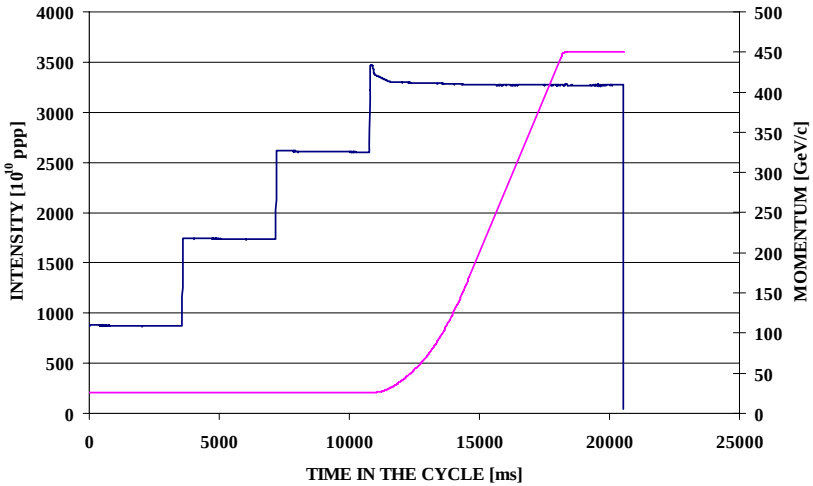
Considerations for fixed-target beams

- Slow extraction and splitter losses
  - Difficult to reduce them and therefore to increase further the intensity. Crazy idea: could of 200 MHz RF deflectors (integrated RF field ~1 MV) be used at the splitter to minimize losses at the expense of some more structure for the experiments?
- Fast extraction
  - main losses due to abort gap filling due to recapture of the un-captured beam at the beginning of the acceleration.
  - This could become worse if a scheme with 5 fast extractions is implemented ➔ Need cleaner capture: bunch to bucket transfer should help (but how far? given LHC beam experience). Choice of the RF system in the PS2 and gymnastic to provide bunches that fit in 200 MHz SPS bucket is important.
- In general going to high bunch intensity with 25 ns spacing will induce problems typical of the LHC beam ➔ see later

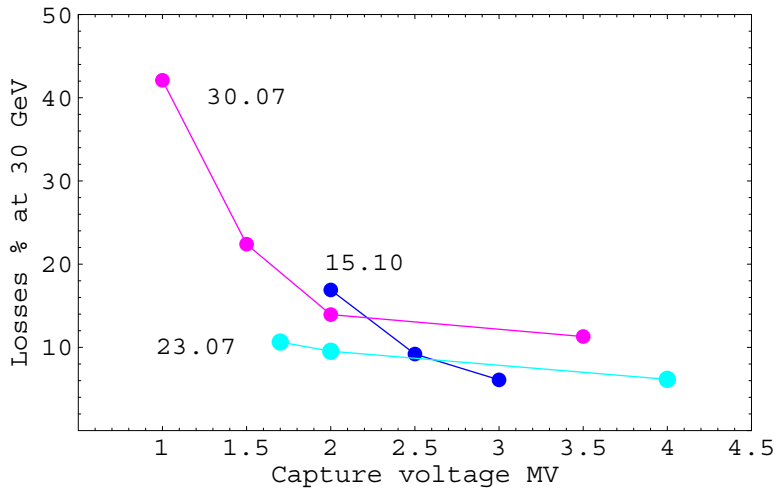
Considerations for LHC beams

- Flat-bottom/capture losses
  - Relative losses at the beginning of ramp are intensity dependent.





  - Huge losses with matched voltage (750 kV) Decreasing with voltage increase up to 2 MV. For higher voltages beam losses along the flat bottom are growing and capture loss are reducing. Best so far: injection in 2 MV and adiabatic raise to 3 MV for each injection.



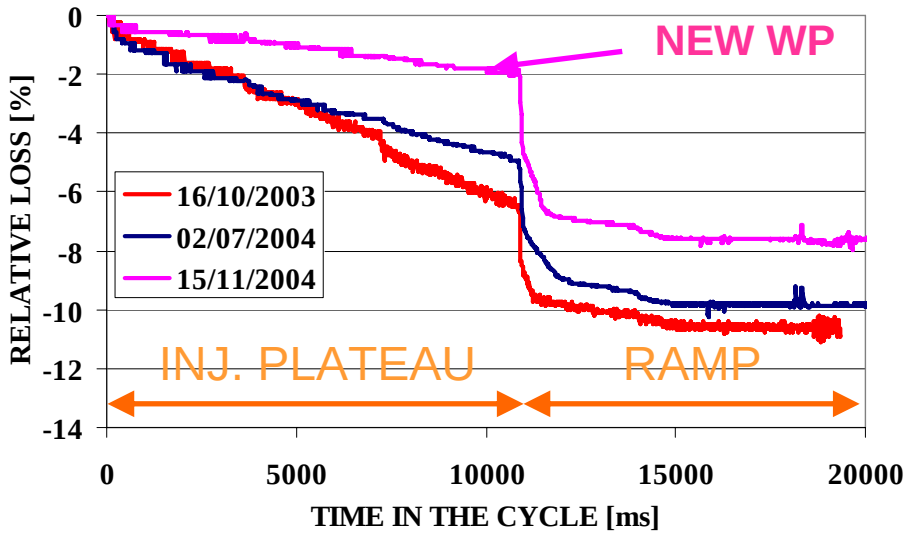
Considerations for LHC beams

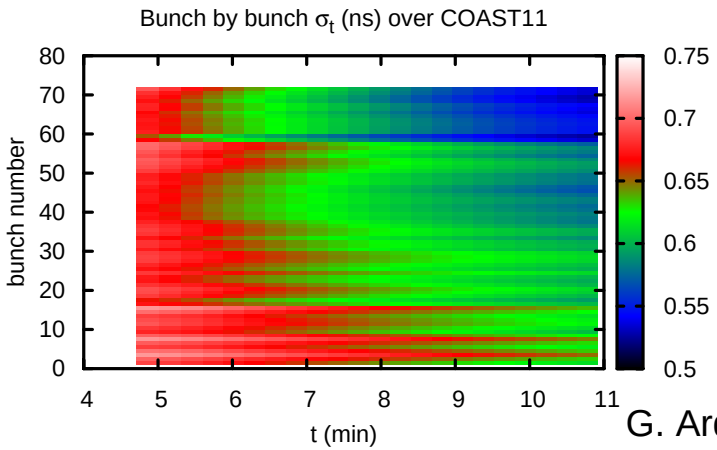
Capture and flat-bottom losses were significantly reduced by optimization of the working point.

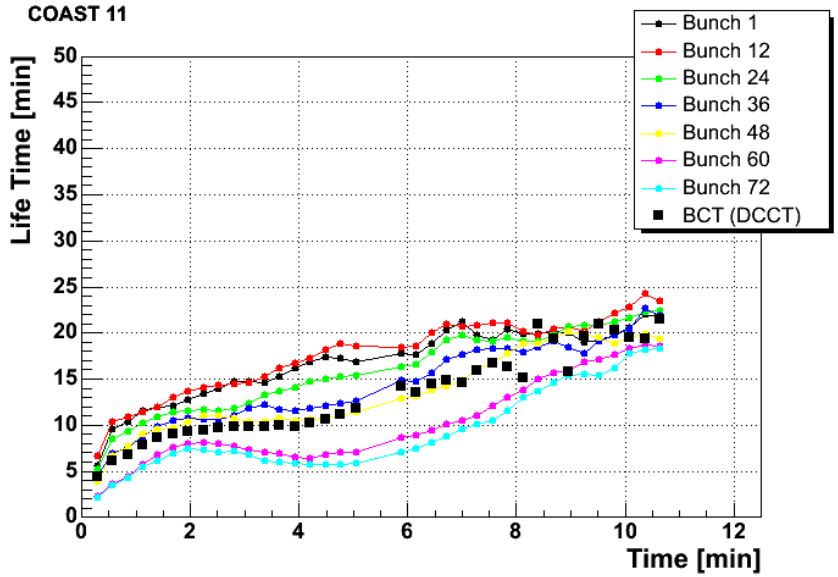
Difference in lifetime between the head and the tail of the batch

- recovers as the intensity decreases
- Bunches are getting shorter particularly at the tail of the batch

  …..while e-cloud signal disappears







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Considerations for LHC beams

- "Longitudinal" beam lifetime on the flat bottom (=decay of peak-detected signal ~500 s).
- Contribution from:
  - white RF noise (RF feedback, feedforward systems and the power amplifiers)
  - ripple on the dipole power supplies

  proven to be negligible

- Most likely explanation is:

  interplay is e-cloud density variation during the bunch passage and synchrotron motion lead to periodic tune modulation and trapping-de-trapping on resonance islands (due to strongly non-linear field of e-cloud)

  Expect deterioration from the increase intensity. FT beam from PS2 (with 25 ns spacing) will also suffer from that. Could be also a limitation for the LHC.

  Careful look at the data (large amount taken) is required ➔ then (and only then) additional studies on the basis of the results of the analysis.

Other sources of losses

- No real collimation system exist in the SPS
  - Momentum collimation (single stage) exist but it is not compatible with multi-cycling
  - No betatron collimation
  - Multi-stage collimation system might be required for high intensity high energy operation

- Synchronization of the emergency dump with the abort gap: being implemented. Vital for high intensity operation

- Losses at the beam dump absorber will be even more critical:

  at present not possible to dump cleanly between 37 and 105 GeV/c ➔ need to be revised

  Outgassing of the beam dump absorber and its impact on injection kicker operation is also an issue ➔ studies have started (ATB). Need to revise its position again?