Beam quality of the 50 ns LHC beam in the SPS MD of 2012-06-25 and operational experience

LIU SPS BD WG 2012-08-02

Contents

Introduction

MD:

- LHCMD_25ns_2011_V1 (ID: 643) (10 860 ms long flat bottom, ramp with $\dot{B}_{\max} = 0.35$ T/s) with Timing User LHCFAST3, RF MMI Target LHCMD2
- no transverse scraping during MD
- 200 MHz RF voltage dips at each injection
- 800 MHz RF voltage programme
- additional CPS blow-up (CPS BUP++)
- increased bunch intensity: initially $N_{\mathrm{Q}} = 1.5 \times 10^{11}$ at flat top then $N_{\mathrm{Q}} = 1.68 \times 10^{11}$
- additional 40 MHz cavity in CPS
- results obtained using the APWL wall current monitor and BQM data

Beam quality at injection

The beam injected during the MD was of much better quality than during LHC filling where $\sigma(\lambda)$ could be 50% larger.

- $\langle\lambda\rangle = 3.97$ ns (OP: 4.16 ns)
- $\sigma(\lambda) = 0.040$ ns (OP: 0.059 ns)
- $\langle\lambda\rangle_{\mathrm{pp}} = 0.16$ ns (OP: 0.29 ns)
- parameters stable as function of time

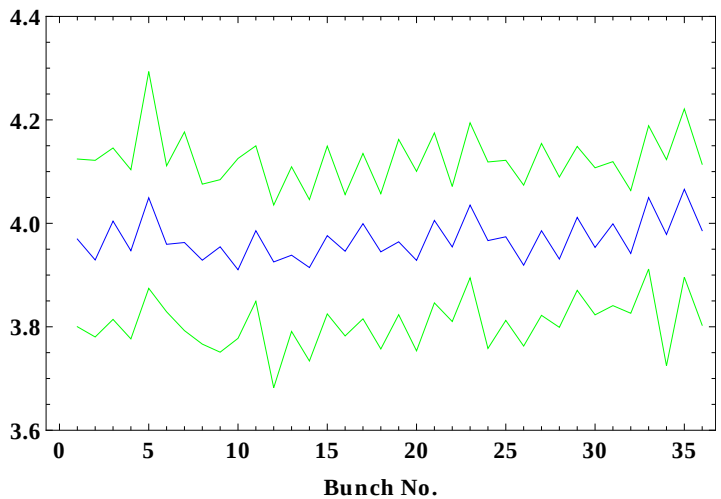


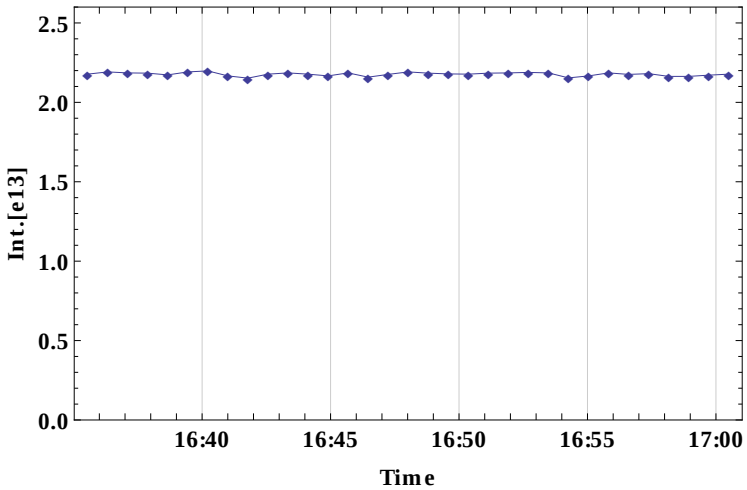
Figure : Bunch length at injection [ns] versus bunch number. 16:35 to 17:20, 2012-06-25.

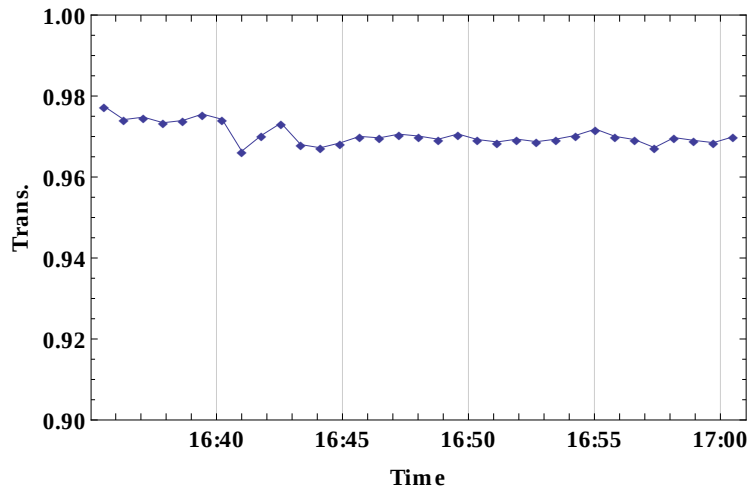
200 MHz RF voltage at flat bottom I

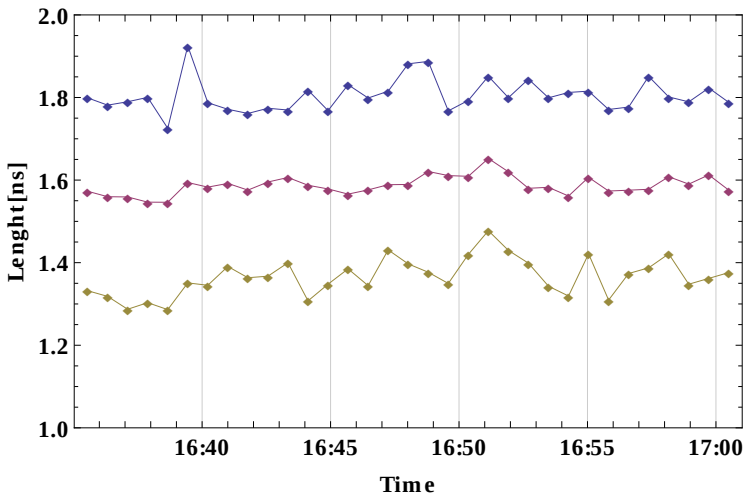
- standard 200 MHz RF voltage programme 2.2 MV/3.0 MV, dip pattern: $\{1, 1, 1, 1\}$, 7.7 MV at end of flat top
- $n_{\mathrm{B}} = 4$, change of dip pattern has equivalent effect for $n_{\mathrm{B}} = 2$

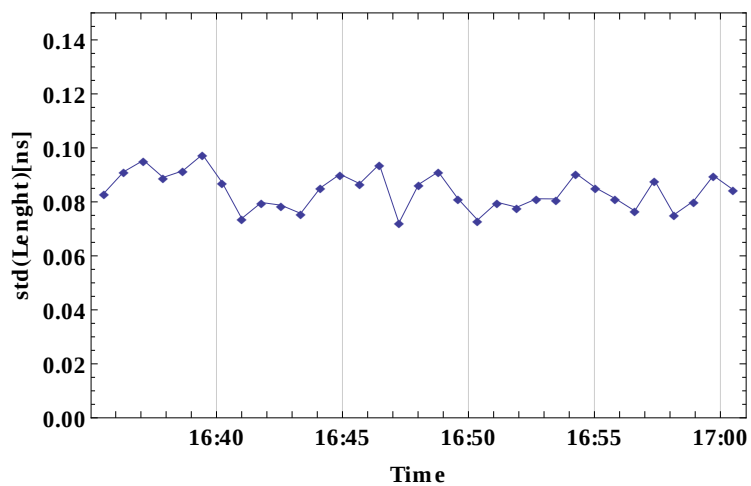
200 MHz RF voltage at flat bottom II

$\{1,1,1,0\}$, 16:37, $\{0,1,1,0\}$, 16:42, $\{0,0,0,0\}$



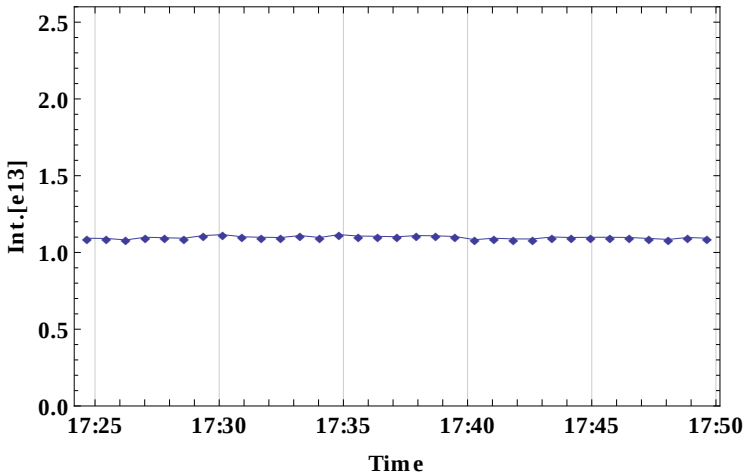


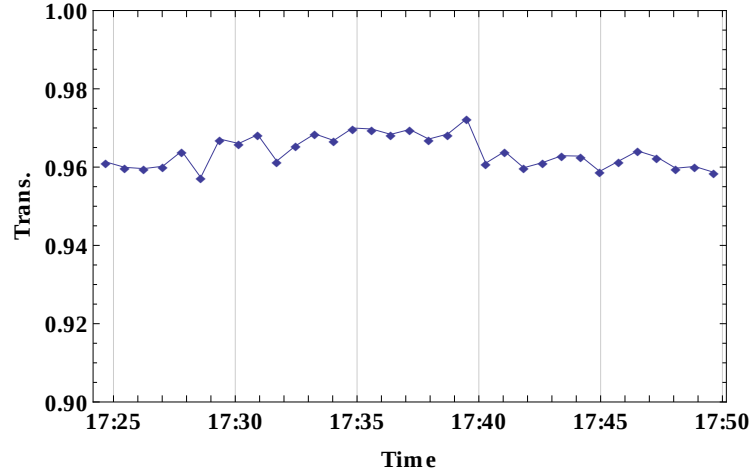


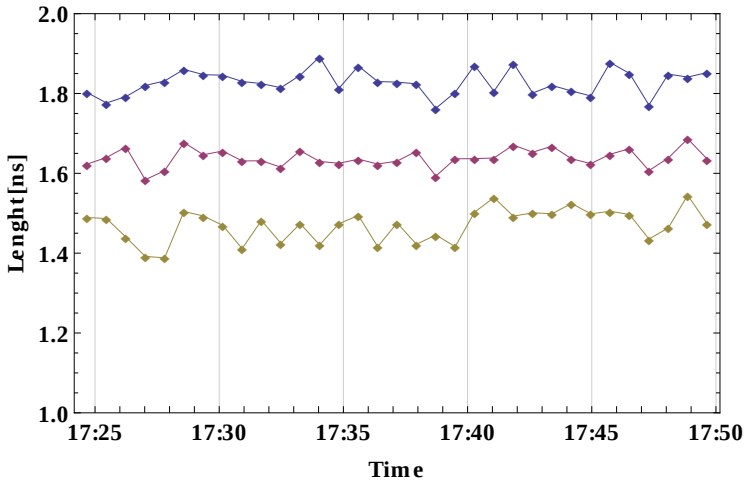


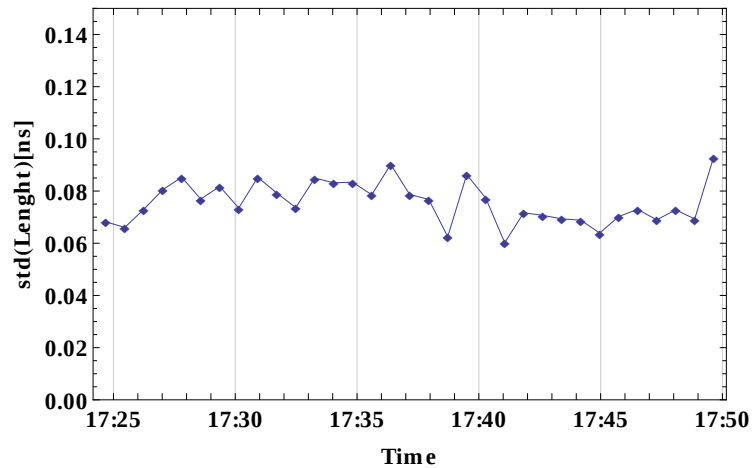
200 MHz RF voltage at flat bottom III

17:24 - $\{0, 0, 0, 0\}$ - 17:29 - $\{1, 1, 1, 1\}$ - 17:40 - $\{0, 0, 0, 0\}$









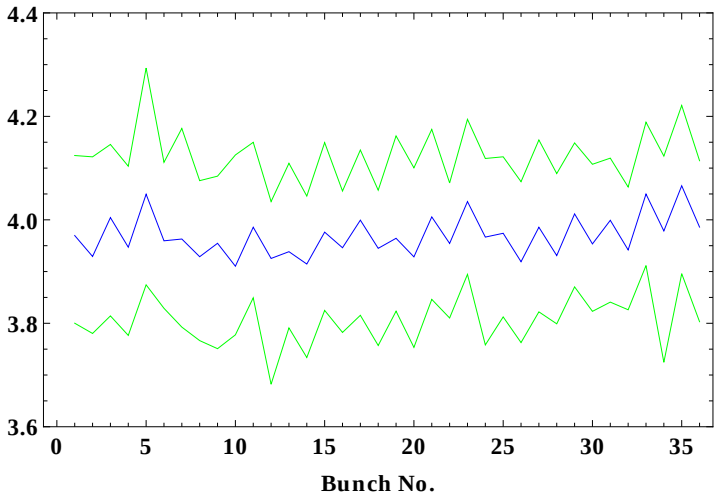
TWC 800 MHz RF voltage programme

The TWC 800 MHz RF voltage programme had been modified in several ways: increase of voltage at flat bottom in several steps and also during the rest of the cycle. No improvement of the beam quality had been observed with these modifications.

CPS BUP+ I

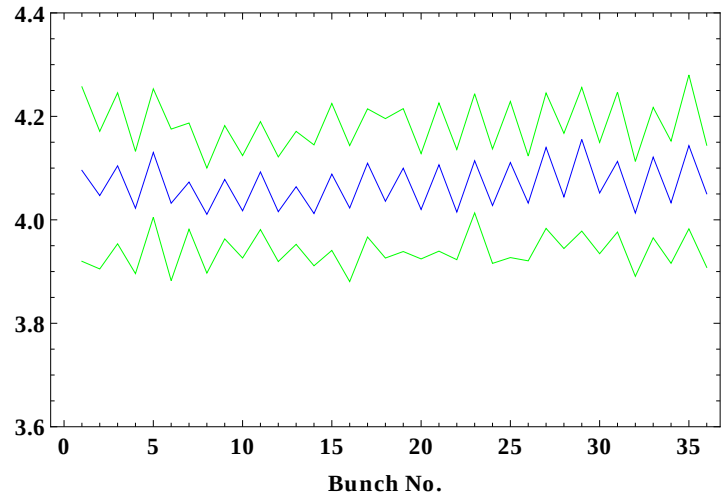
- standard CPS BUP: 3×3.5 kV
- at 17:55 CPS BUP+: 3×4.5 kV (till about 19:30)

CPS BUP



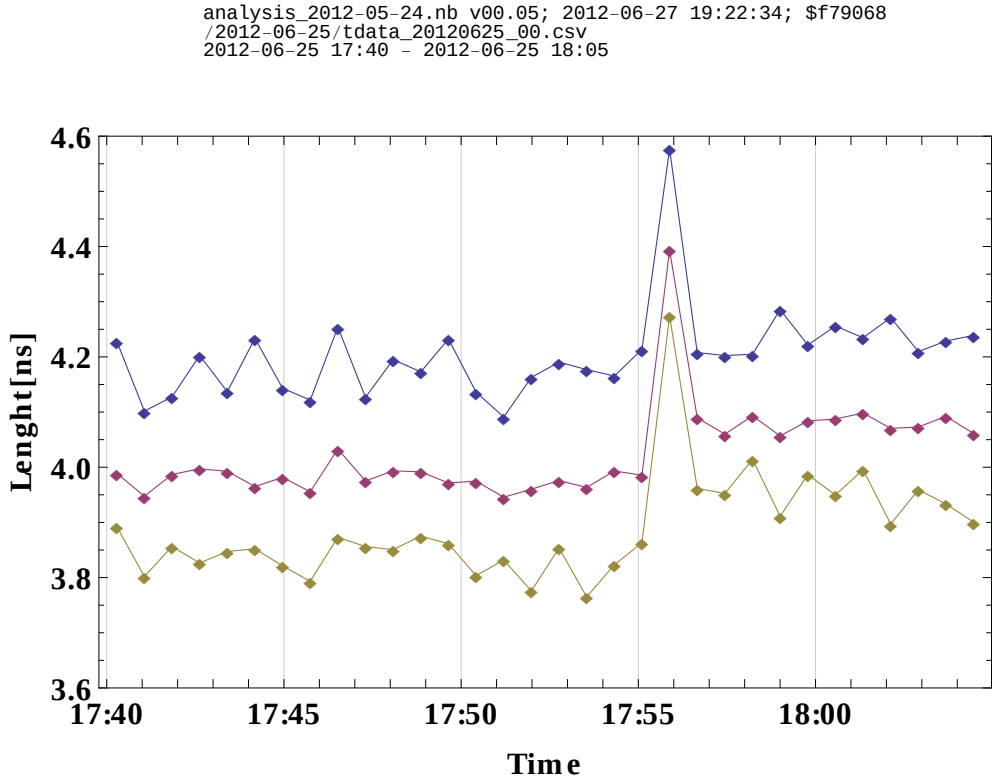
- $\langle\lambda\rangle = 3.97$ ns
- $\sigma(\lambda) = 0.040$ ns
- $\langle\lambda\rangle_{\mathrm{pp}} = 0.16$ ns

CPS BUP+



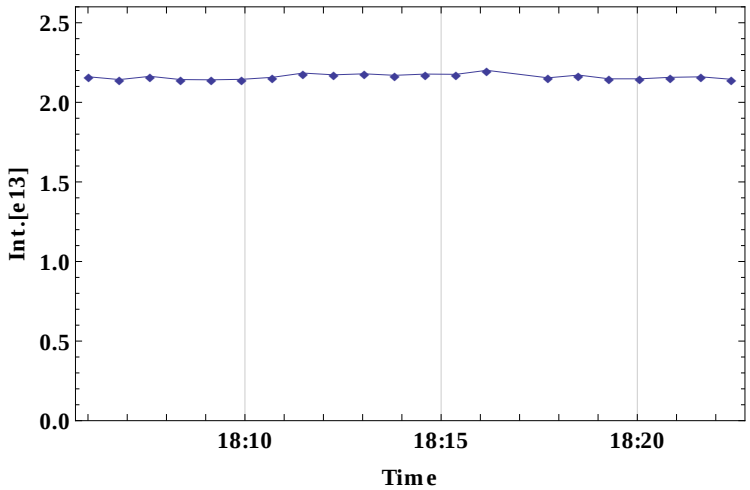
- $\langle\lambda\rangle = 4.07$ ns
- $\sigma(\lambda) = 0.045$ ns
- $\langle\lambda\rangle_{\mathrm{pp}} = 0.15$ ns

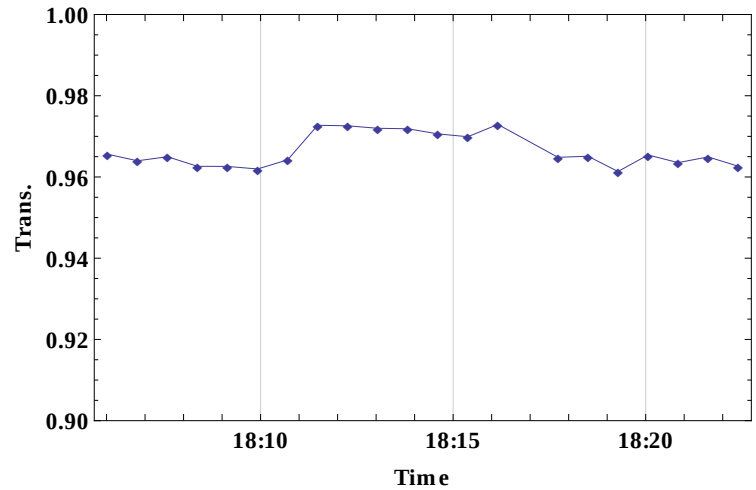
CPS BUP+ II

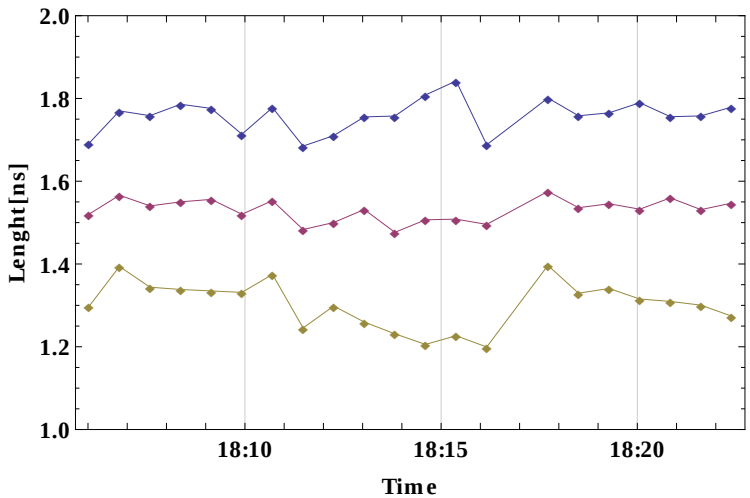

analysis_2012-05-24.nb v00.05; 2012-06-27 19:22:34; $f79068
/2012-06-25/tdata_20120625_00.csv
2012-06-25 17:40 - 2012-06-25 18:05
4.6
4.4
4.2
4.0
3.8
3.6
Lenght[ns]
17:40
17:45
17:50
17:55
18:00
Time

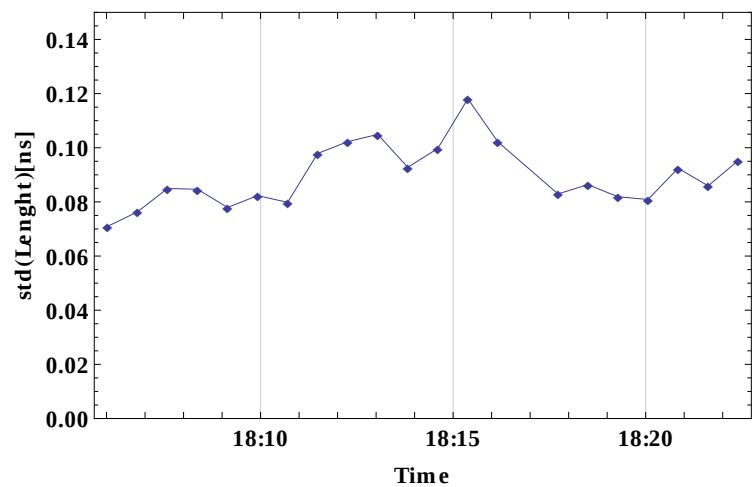
CPS BUP+ III

18:05 - $\{0, 0, 0, 0\}$ - 18:10 - $\{1, 1, 1, 1\}$ - 18:17 - $\{0, 0, 0, 0\}$



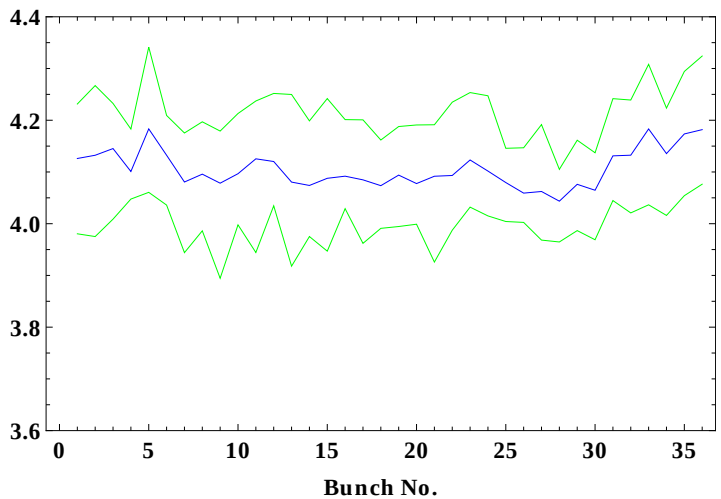






Increased intensity

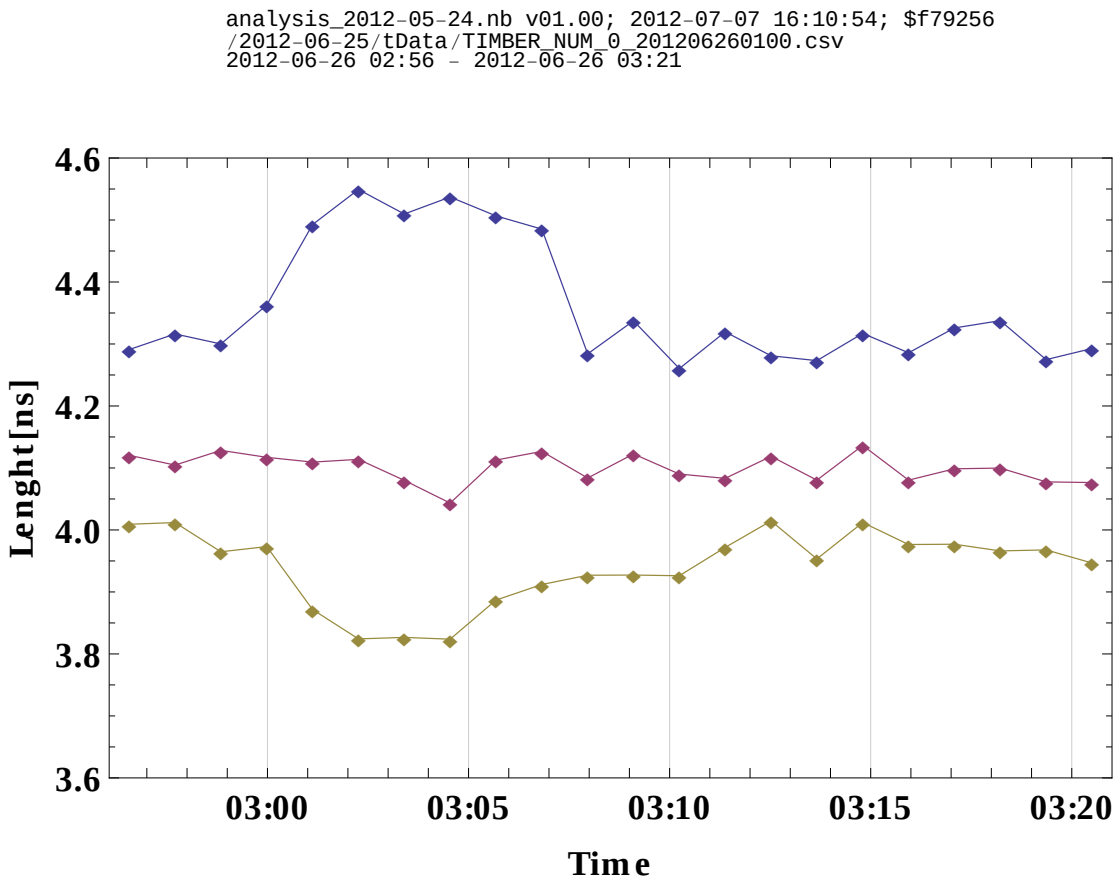
- 2012-06-26 02:15H to 03:25H: $N_{\mathrm{Q}} = 1.68 \times 10^{11}$ or about 10% higher at flat top
- CPS BUP+
- conditions at injection similar to lower intensity case
  - $\langle \lambda \rangle = 4.11$ ns (4.07 ns)
  - $\sigma(\lambda) = 0.037$ ns (0.045 ns)
  - $\langle \lambda \rangle_{\mathrm{pp}} = 0.14$ ns (0.15 ns)



Increased intensity I

CPS BUP+/CPS BUP

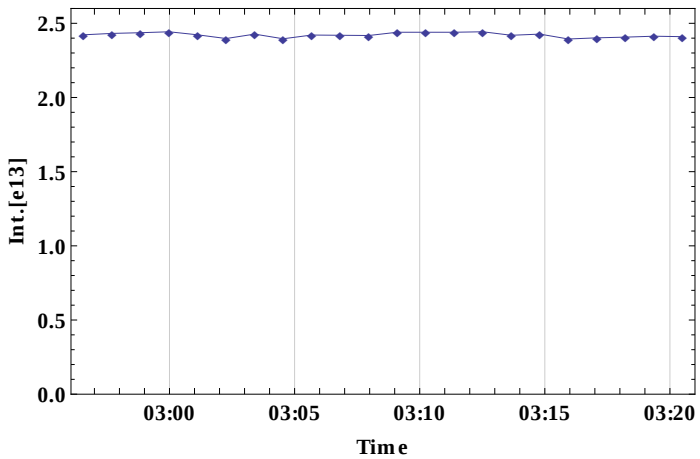
CPS BUP+ - 03:00 - CPS BUP - 03:08 - CPS BUP+

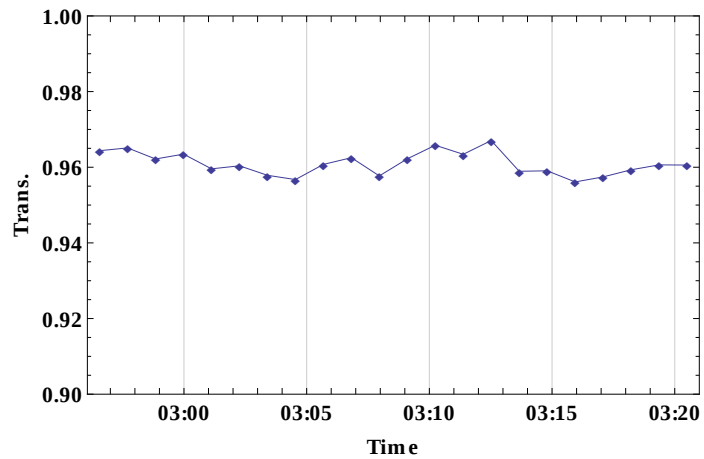


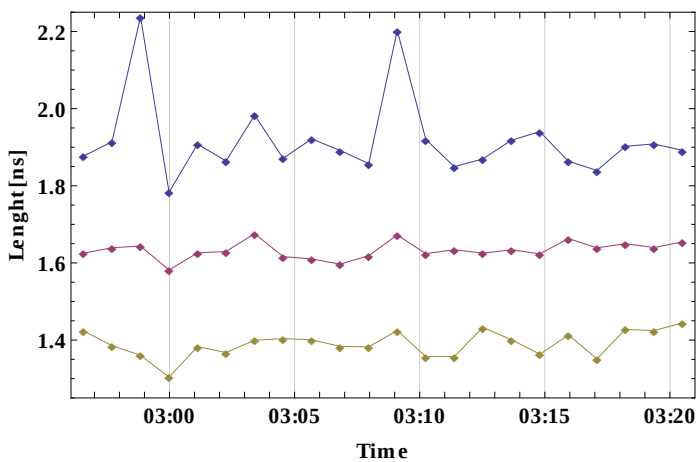
Increased intensity II

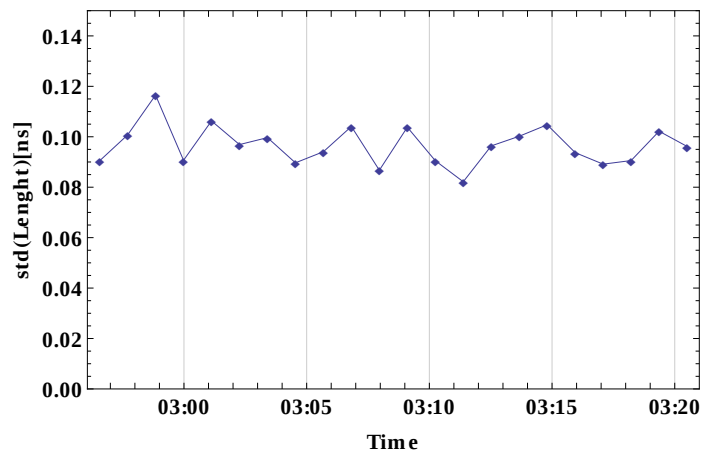
CPS BUP+/CPS BUP

CPS BUP+ - 03:00 - CPS BUP - 03:08 - CPS BUP+ $\{1, 1, 1, 0\}$ - 03:14 - $\{0, 0, 0, 0\}$





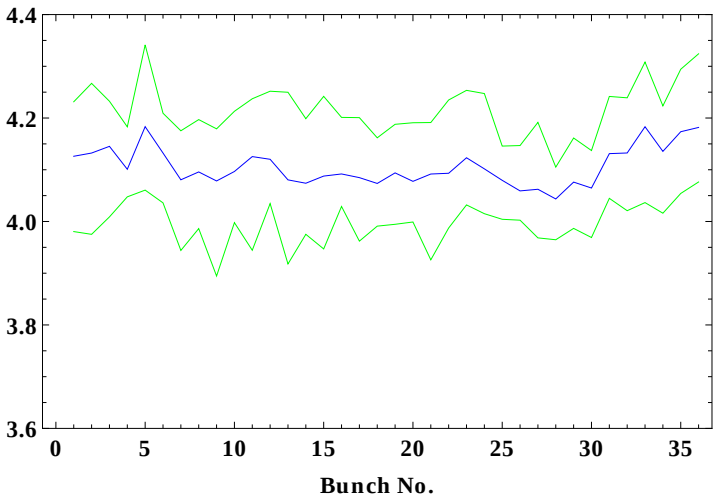




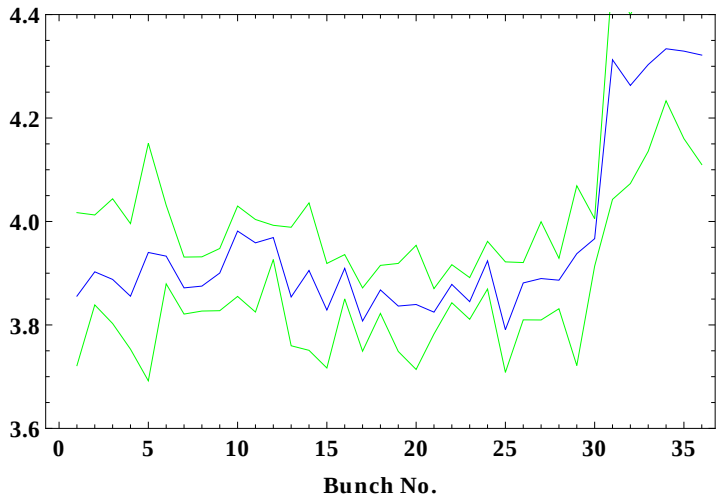
Increased intensity

Extra 40 MHz cavity in CPS

normal



extra 40 MHz



Operation after TS

- dip pattern initially $\{1, 1, 1, 0\}$ then $\{0, 0, 0, 0\}$
- LHC filling after TS with less intensity per bunch
- SPS BUP with reduced amplitude or off (LHC ok)
- overlap of BUP time and scraping time: consequences for vertical transverse emittance
- no larger than standard BUP in CPS
- injected beam quality? no issue yet

Conclusions I

- operational beam quality issues had been addressed in MD
- bunches of the first two batches were unstable at flat bottom
- SPS BUP did not increase the longitudinal emittance of the bunches of the fourth batch as expected
- bunches of the fourth batch with insufficient blow-up became unstable at the end of the acceleration ramp
- main solution to operational problems: removal of fourth dip (all dips)
- removal of dips at the expense of slightly worse transmission (typically 1% worse)
- no improvement of the beam quality had been observed with modifications of the TWC 800 MHz RF voltage programme

Conclusions II

- with additional controlled longitudinal emittance blow-up in the CPS (CPS BUP+) the bunch length modulation had a clear period of two bunches. Later during the MD, with an about 10% higher bunch intensity this effect was not visible any more. CPS BUP+ let to a slightly worse transmission (about 0.5% worse) and did not change the beam quality at flat top when using the dip pattern $\{0, 0, 0, 0\}$. The bunch profiles showed that the injected bunches were of more uniform shape with CPS BUP+.
- With $N_{\mathrm{Q}} = 1.68 \times 10^{11}$ an extra 40 MHz cavity was put into operation in the CPS. This led to a very unequal bunch length distribution at injection into the SPS and was abandoned after about 10 min.

Conclusions III

- with the higher intensity there was no effect of the CPS BUP+ on the bunch parameters at flat top nor when changing the dip pattern from $\{1, 1, 1, 0\}$ to $\{0, 0, 0, 0\}$. However, with CPS BUP+ off, the bunches must had been unstable in the CPS and the spread of bunch length observed at injection into the SPS had increased by more than a factor of two.
- operation after TS: ok with $\{0, 0, 0, 0\}$ until now but operation with $N_{\mathrm{Q}} > 1.5 \times 10^{11}$ still outstanding
- keep option of TARG_NOISE instead of VARI_NOISE?
- BQM wish: threshold improvement: n/N bunches above threshold

Acknowledgements

- MD: H. Damerau and H. Timko controlled the longitudinal emittance blow-up in the CPS, the CPS bunch rotation timing and the use of the extra 40 MHz cavity. Data of longitudinal bunch profiles using the APWL wall current monitor via the FO link, acquired by J.F. Esteban Muller and T. Argyropoulos, provided some additional details not immediately available from the BQM data during the MD. The discussions with E. Shaposhnikova during the MD were extremely fruitful.
- Operation: K. Cornelis, S. Cettour-Cave and H. Bartosik in the context of BUP and transverse emittance measurements.