Preliminary results of SPS MD week 22

E. Shaposhnikova
for SPS SG and RF team,
thanks to OP team

SPSU SG, 24.06.2010

SPS beams

Beam parameters		SPS at 450 GeV/c (maximum injected minus losses)					LHC ultim./+
		LHC	LHC	LHC	FT	LHC	LHC
bunch spacing	ns	25	50	75	5	indiv	25
bunch intensity	10^{11}	1.2	1.2	1.2	0.13	**1.8**	1.9(2.3)
number of bunches		4x72	4x36	4x24	4200	1	288
total intensity	10^{13}	**3.5**	1.7	1.2	**5.3**	0.02	5.5(6.6)
long. emittance	eVs	0.7	0.4	0.4	0.8	0.3	<1.0
norm. h/v emittance	µm	**3.6**	2.0* 1.1/1.4	2.0*	8/5	0.3	**3.5**

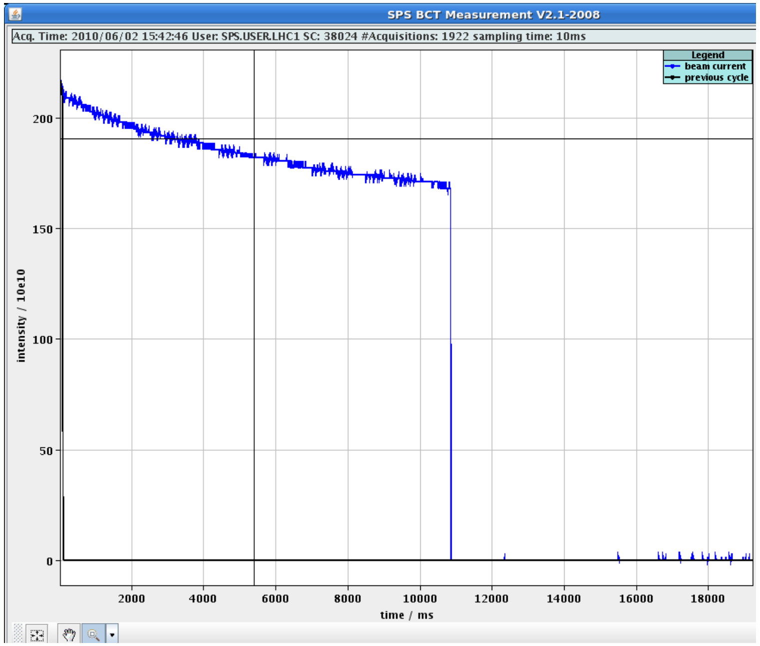
* single batch injection in PS

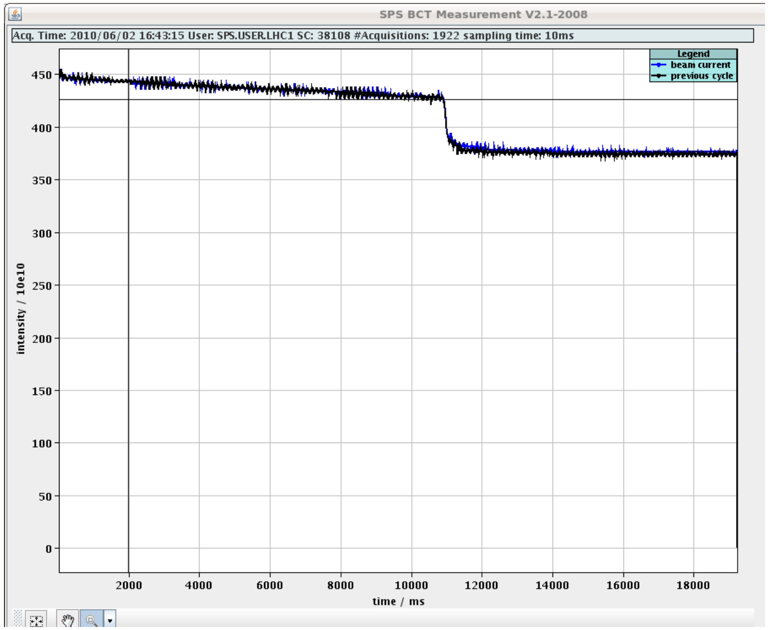
MD on June 2-3

- Large efforts in whole injector chain, in the PSB and PS in particular (thanks!) to prepare ultimate intensity LHC beam in advance
- From 12:00 on 2.06 till 20:00 on 3.06 (too long for the same people involved) – stopped due to MKE heating to 70 deg
- Up to 1.9×10^{11}/bunch injected, longitudinal emittance 0.38–0.4 eVs, transverse emittances 5 μm
- 12, 24, 48, 72 bunches, then 1,2,3,4 batches
  - limitation from MKE → from 2 to 1 batch (first night, at 1:00)
- Nothing broken but issues with
  - MOPOS (only in BA3, BA4 and BA6 – the rest was deduced) – injection oscillations
  - FBCT – saturated at 1.4×10^{11}

Beam intensity and losses

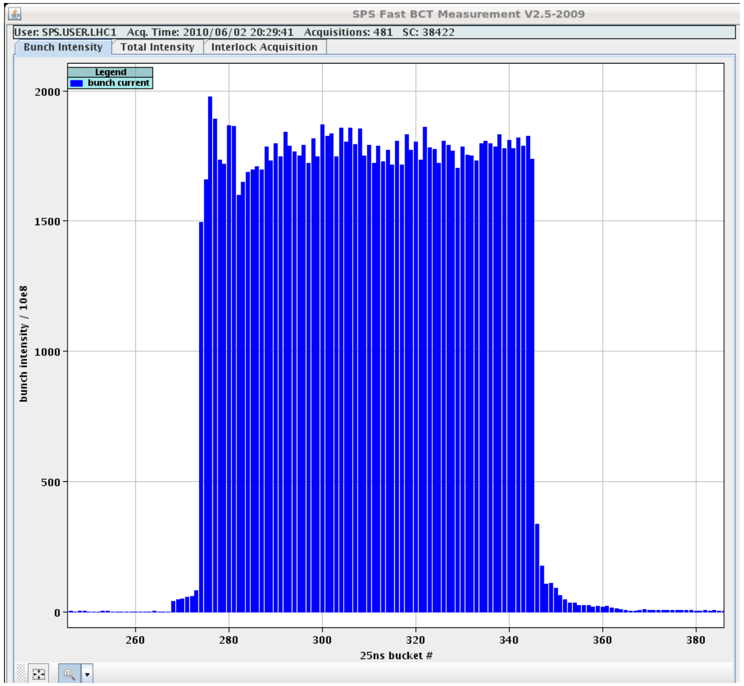
12 bunches of 1.88×10^{11} and 24 bunches

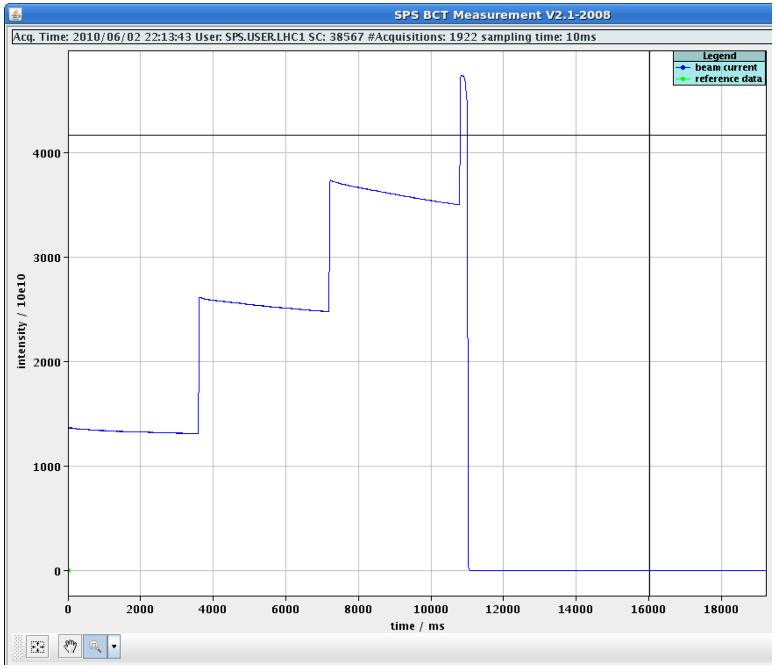




Main observations
Beam intensity and losses

1 batch 72 bunches of $1.8x10^{11}$ and 4 batches…





Main observations
Beam intensity and losses

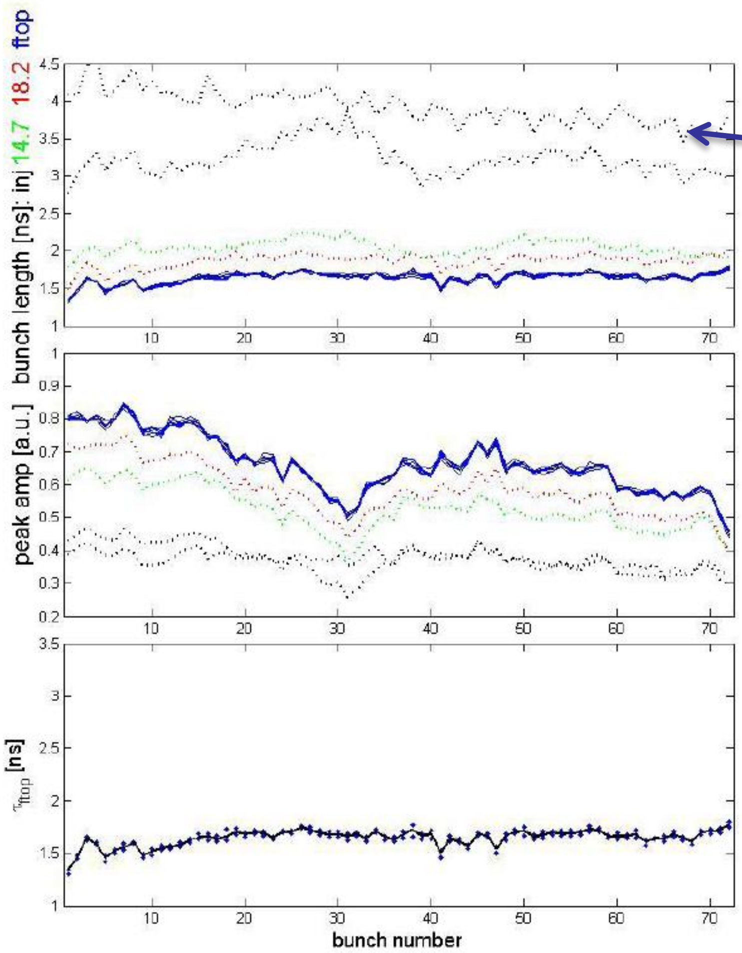
- Maximum intensity achieved at 450 GeV is 1.6×10^{11} /bunch in one batch
- Increasing number of batches led to decrease of bunch intensity on FT (more detailed analysis is pending) with
  - 1.52×10^{11} /bunch for 2 batches,
  - 1.48×10^{11} /bunch for 3 batches,
  - 1.4×10^{11} /bunch for 4 batches
- Capture losses were reduced after modification of the 200 MHz (and 800 MHz) voltage program through the cycle: from 0.65 eVs constant bucket area to 0.75 eVs, then V=5.5 MV constant (V_{800}=0.5 MV)
- Most of the time voltage on FT was 5.5 MV (nominal and max 7 MV) – to reduce effects of heating and outgassing

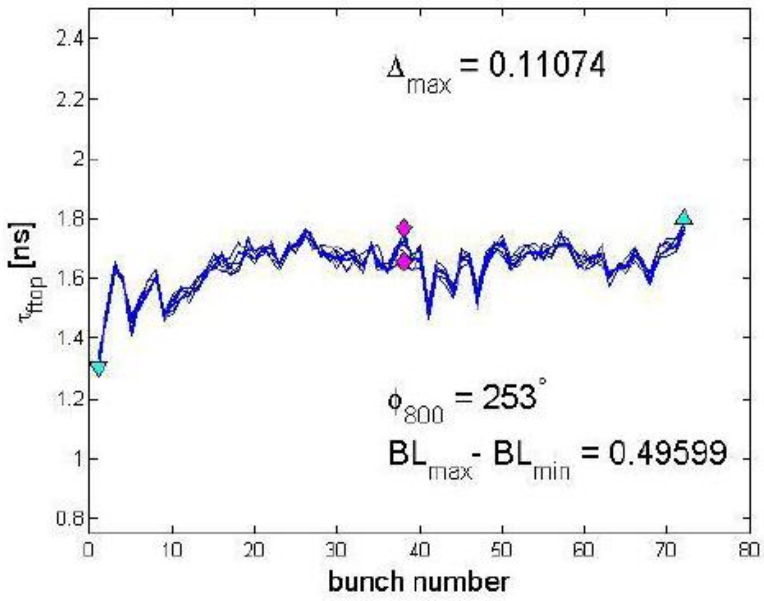
Main observations

- Very large beam losses: injection, along the flat bottom and at the beginning of ramp (capture)
  - 30 % at the beginning of MD
  - 20 % at the end
- Chromaticity was first reduced (W. Hofle for transverse damper operation) to $\xi = 0.1$, then increased again to $\xi_H=0.2$ and $\xi_V=0.3$
- Transv. emittance blow-up during the ramp: $5 \rightarrow 10\ \mu m$

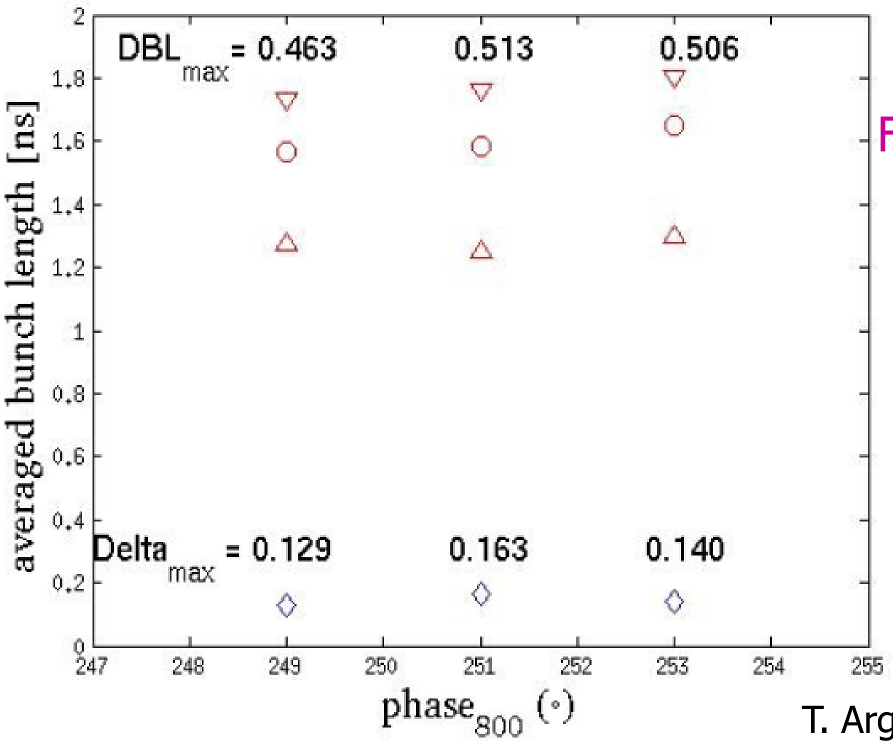
  (horizontal blow-up larger, also increased for more batches)
- Beam was very unstable longitudinally on flat bottom (already with 12 bunches in the ring), variation of the 800 MHz voltage on FB (and switching off) did not help
- No direct e-cloud observation (ECM) due to absence of the StSt reference liner

Bunch length during cycle and on FT: 1 batch, V_{200}=7 MV, V_{800}=0.64 MV, noise blow-up





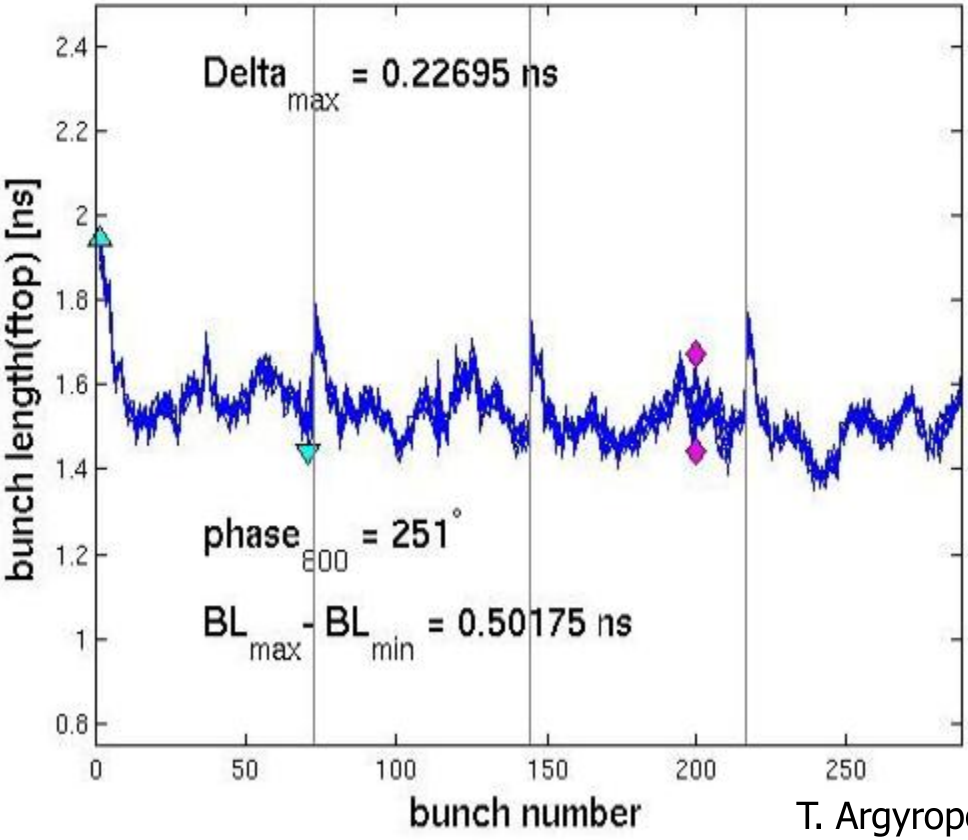
Beam stability in a double RF system:
1 batch, V_{200}=7 MV, V_{800}=0.64 MV, noise blow-up



FT: 1.5 10^{11}/bunch

T. Argyropoulos et al.

Beam stability in a double RF system: 4 batches, V_{200}=5.5 MV, V_{800}=0.5 MV, blow-up



FT: 1.4 10^{11}/bunch

T. Argyropoulos et al.

Future MD studies for SPS upgrade

- a-C coating: e-cloud suppression, ageing, outgassing:
  - nominal and higher intensity LHC beam, ions
- limitations with "above nominal" intensity beams

  (beam losses, e-cloud scaling with intensity, beam quality,…)
  - multi-bunch: increase intensity in steps (more work in injectors, but…)
  - single bunch with highest possible intensity
- TMCI threshold with nominal LHC emittances (FB specification):
  - single bunch of ultimate intensity
- stability and emittance blow-up in double RF system
  - nominal and above nominal intensity LHC beam, single bunch
- impedance identification and follow-up (reference measurements)
  - nominal and lower intensity LHC beam with 25 ns, 50 ns, 75 ns and 150 ns spacing
  - single bunch with constant longitudinal parameters and variable intensity

Intensity limitations
(LHC beam with 25 ns bunch spacing)

intensity /bunch	Origin	Leads to	Present/**future** cures/measures
$0.2x10^{11}$	longitudinal coupled bunch instability due to longitudinal impedance	- beam loss during ramp - bunch variation on FT	(FB, FF, long. damper) - 800 MHz RF system - emit. blow-up → RF
$0.3x10^{11}$	e-cloud due to the StSt vacuum chamber (δ_{SEY}=2.5, 1.3 is critical for SPS)	- dynamic pressure rise - transv. (V) emit. blow-up - instabilities - losses (via high chrom.)	- scrubbing run (δ→1.6) - high chrom. (0.2/0.4) - transv. damper (H) - (50/75 ns spacing) - a-C coating (δ→1.0)
$0.5x10^{11}$	Not known exactly e-cloud + impedance (?)	- flat bottom/capture beam loss (10-15 %)	- (lower chromaticity) - WP, RF gymnastics - collimation
$1.5x10^{11}$	Beam loading in 200 MHz RF system	- voltage reduction on FT - bunch phase modulation	- Feed-back & FF - RF cavities shortening
$1.6x10^{11}$ (?)	TMCI (transverse mode coupling instability) due to transverse impedance	- beam losses - emittance blow-up	- higher chromaticity - high voltage - transverse high bw FB

SPS limitations: impedance

- Search for unknown impedances:
  - transverse (broad-band and narrow-band): only 60% known → TMCI
  - longitudinal (narrow-band - HOMs) → coupled-bunch instability

- Follow up with beam measurements reduction of known impedances
  - MKE: serigraphy – 3 done, 5 more in 3 years (2013)
  - MKDV, MKDH: complete transition pieces between magnet and tank
  - 800 MHz TW cavities: active damping with new FB and FF (2011)
  - 200 MHz TW cavities: 20% reduction due to modifications (2015)

→ MDs with nominal and lower intensity LHC beam and single bunch

Beam loss

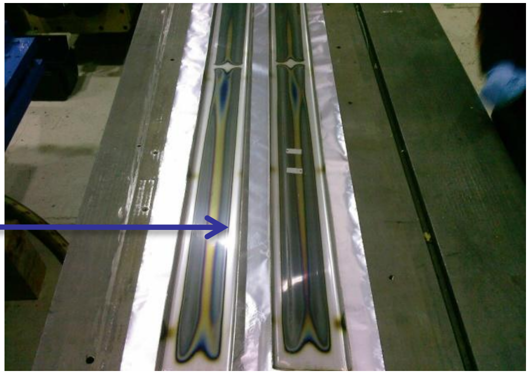
- Relative beam loss (flat bottom + capture) are increasing with intensity for 25 ns spaced LHC beam

  → The origin of beam loss
  → e-cloud mitigation (coating)
  → Impedance reduction (after identification)
  → Beam collimation:
  - loss control and localization
  - clean LHC beam scrapping
  - machine protection (with fast BLMs)

→ Studies with high intensity (above nominal) LHC beam

e-cloud mitigation: a-C coating

- Experimental set-up in the SPS (4 e-cloud monitors)
  - no ageing after venting and beam exposure for lab coatings
- 3 MBBs coated using their dipole field were in the SPS from 2009 (2 now)
  - no e-cloud signal (mw transmission)
  - outgassing, small reduction in pressure rise
  - some ageing (SEY→1.3), 2 are still in the ring
  - insufficient quality of coating (1 MBB cut-open)
- Exchangeable sample with lab (good) coating:
  - ageing (SEY→1.5) after venting and e-cloud



→ Two options:

(1) Improvements to coating system inside the magnet (and diagnostics) → studies

(2) Coating of vacuum chamber in lab → magnet dismantling (2 MBB in W35)

If a-C coating should be implemented from 2011/2012 SD – little time for studies…