

# 50 ns LHC BEAM THROUGH THE INJECTOR CHAIN IN 2008

E. Métral (for the injector chain)

- ◆ **This was a request from the LHCCWG (held on 13/02/2008)  
⇒ MDs were planned in 2008**
  - PSB
  - PS
  - SPS
- ◆ **Conclusion**
- ◆ **Appendix: LHCINDIV + LHCPILOT (at the same time) in the SPS**

## 2 REQUESTS FROM THE LHCCWG (held on 13/02/2008)

- ◆ **(a) 1<sup>st</sup> priority:** Check what happens in the SPS if we inject 2 bunches, 1 with high intensity (LHCINDIV in the PS) and 1 with low (LHCPILOT in the PS)
  - **Contact person: E. Métral**
- ◆ **(b) 2<sup>nd</sup> priority:** Check that we can still produce the 50 ns beam in the PS and see what happens in the SPS
  - **Motivation: This 50 ns option is interesting again to try and satisfy the need of low luminosity in IP2**

Discussion with W. Herr (14/02/08): With the 50 ns beam (without changing anything) the luminosity is reduced by a factor 2 (2 times less bunches) and the long range effects are also reduced by a factor 2. If in addition, the transverse emittances are 10-15% smaller then one can almost completely forget about long-range beam-beam effects!

6/25

# 50 ns BEAM IN THE PSB (1/3)

*Courtesy K. Hanke  
(APC, 26/09/08)*

## LHC50 Specifications (PSB)

I sent info from R. Garoby's talk at Chamonix2003: [http://ab-div.web.cern.ch/ab-div/Conferences/Chamonix/2003/transpar/1\\_1\\_Garoby.pdf](http://ab-div.web.cern.ch/ab-div/Conferences/Chamonix/2003/transpar/1_1_Garoby.pdf)

identical with 25ns beam but with half the intensity (priv.com. 17/07/08)  
are other intensities than this one required? – specs must be clarified/confirmed

### 25ns beam:

- 4+2 rings (2 users!) @ h=1
- 150-160E10 protons/bunch
- $e_x=e_y=2.5 \pi$  mm mrad
- $e_l=1.3$  eVs, bunch length 180 ns / all @ PSB extraction

well established, operational beam with 2 dedicated users

try to reduce the intensity per bunch to 75-80E10 protons/bunch while leaving the other parameters as much as possible unchanged;

in particular the longitudinal parameters need to be unchanged for splitting in the PS – use transverse shaving and compromise transverse emittance

# 50 ns BEAM IN THE PSB (2/3)

*Courtesy K. Hanke  
(APC, 26/09/08)*

## Production Strategy

starting point are the nominal LHC25A+B

- reduce the injection efficiency
- use vertical shaver to obtain the desired intensity
- use more C16 to blow up longitudinal emittance and preserve the longitudinal parameters (bunch length and emittance); can be adjusted according to PS-RF requirements
- the transverse emittances are those naturally produced with this production scheme, i.e. smaller emittances to be blown up in the SPS
- due to the lack of users, different intensity LHC beams including the 50ns beam must be stored in archives of the operational LHC25A+B; archives are created for a set of intensities ranging from 1/10 to 2/3 of the nominal LHC beam intensity (**0.1-0.2-0.33-0.5-0.66**)
- the half intensity LHC25 is referred to as the “nominal” LHC50 in the PSB

# 50 ns BEAM IN THE PSB (3/3)

Courtesy K. Hanke  
(APC, 26/09/08)



OPERATION DISPLAY

File View Option Help

opdisp LHC25A 6 Aug 14 11:51:55 2008

Beam State	PSB User	PS User	Particule	Harmonique	Destination	Energy
NORMAL	LHC25A		PROTON	H1	BDUMP	1400

Unit : 1e+10	1	2	3	4	Sum
LTB.TRA55	323	349	340	338	1349
BI.TRA10	321 100%	350 100%	338 99%	338 100%	1346 100%
BI.TRA20	259 81%	296 85%	277 82%	273 81%	1105 82%
INJECTION	162 63%	175 59%	164 59%	162 60%	664 60%
CAPTURE	151 93%	148 84%	149 91%	148 91%	596 90%
ACCELERATION	78 52%	81 55%	81 54%	80 54%	320 54%
BT.TRAS	85 109%	161 199%	81 100%	156 195%	342 107%
BTP.TRA					-1 -0%
BTY.TRA112					-12
BTM.TRA					278
Increment	Nb turns	Nb turns	Nb turns	Nb turns	All rings
0.0	1.7	2.1	2.0	1.9	-1.0

LINACII	INJ_RING_1	INJ_RING_4	BTP_LINE
LINAC->PSB	INJ_RING_2	RF_Cavities	SHAVERS
INJ_COMMON	INJ_RING_3	Magnetic	

One Shot Unfreeze Freeze

No message

◆ Measured transverse emittances:  
~ 1  $\mu\text{m}$  in both planes

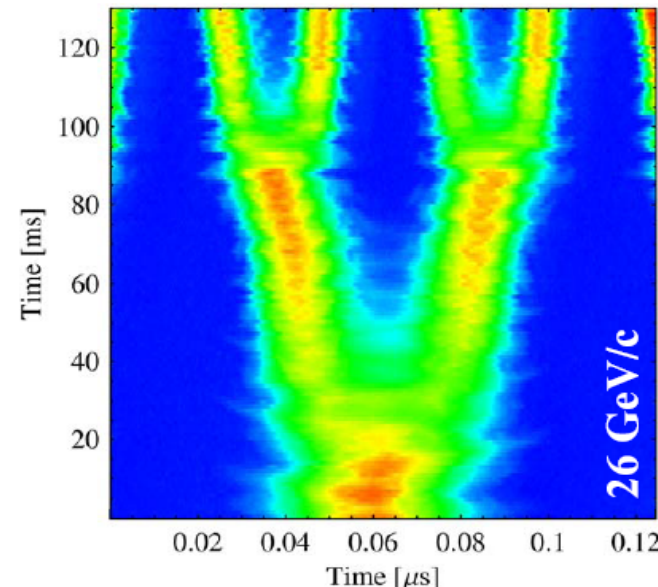
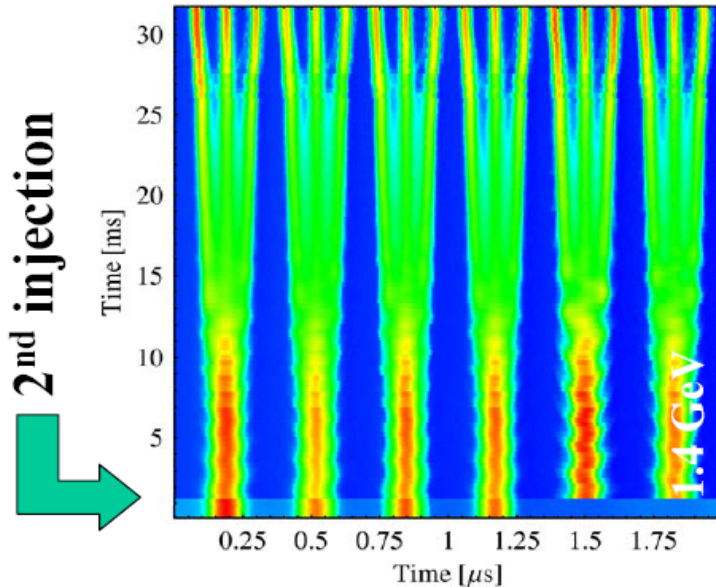
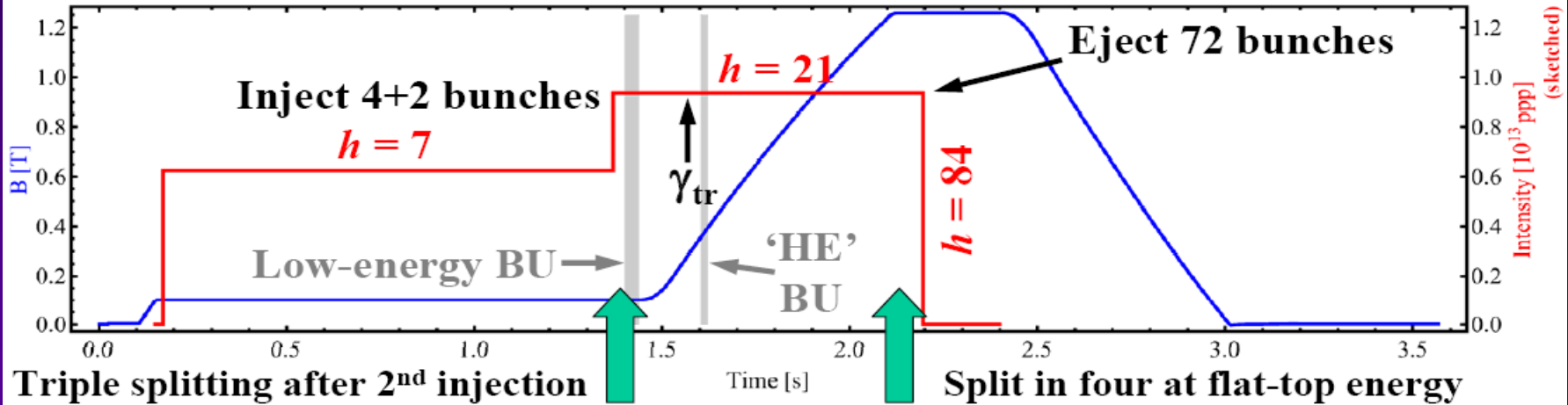
⇒ If one can rely on the SPS to blow up the transverse emittances, then the beam is ready in the PSB

Vertical shaving

# 50 ns BEAM IN THE PS (1/3)

## The LHC25 (ns) cycle in the PS

4



Courtesy H. Damerou  
(APC, 26/09/08)

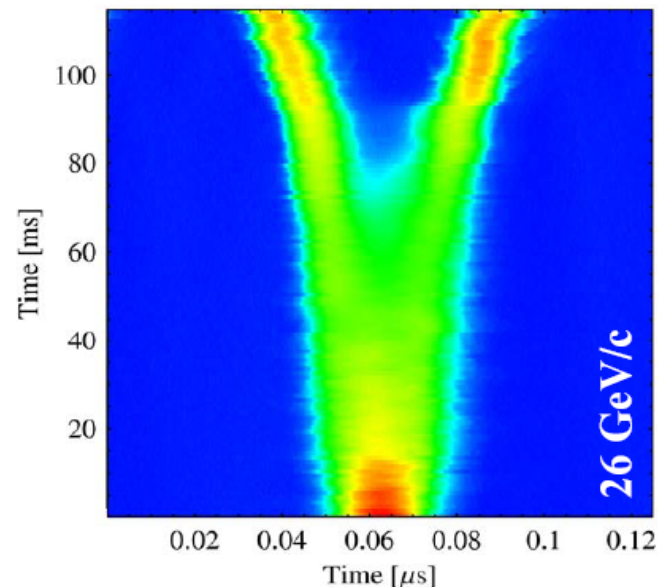
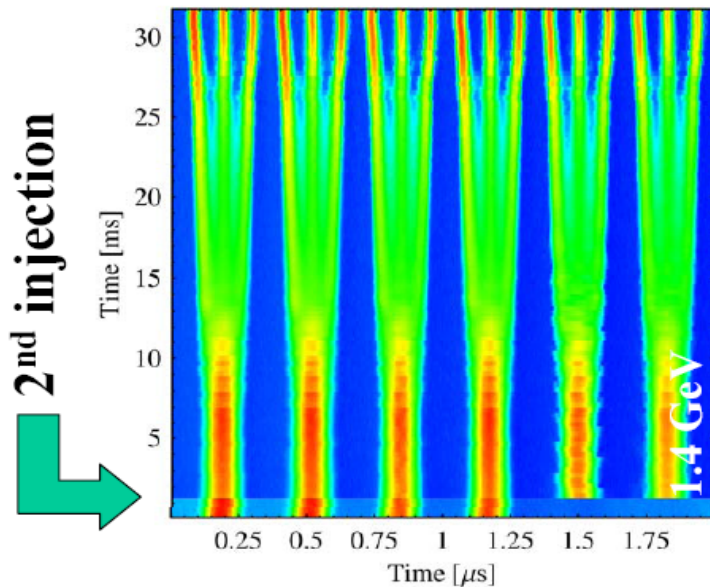
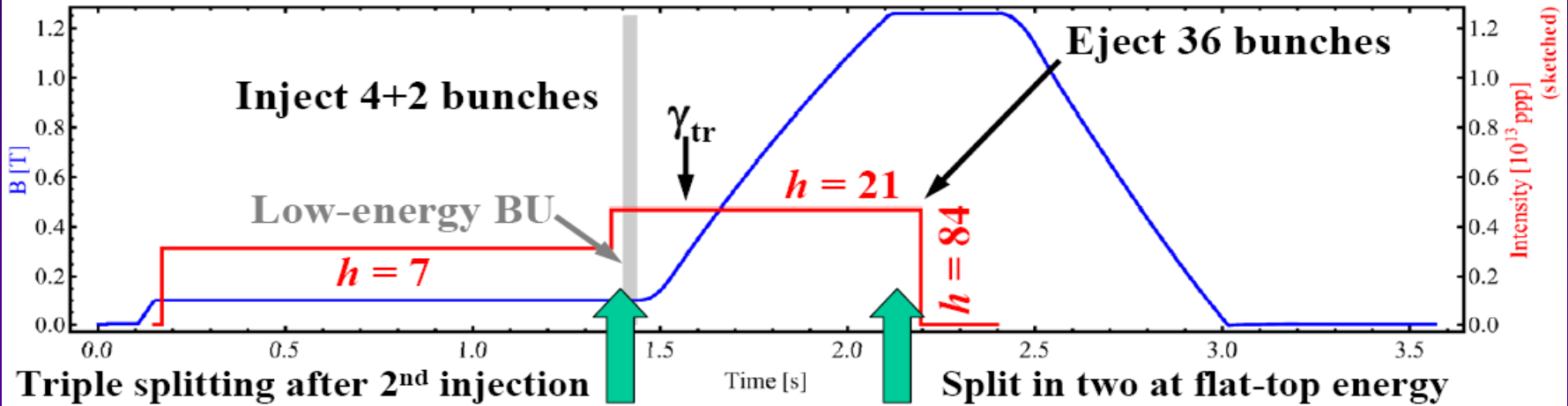
→ Each bunch from the Booster divided by **12** →  $6 \times 3 \times 2 \times 2 = 72$



# 50 ns BEAM IN THE PS (2/3)

## The LHC50 (ns) cycle in the PS

5



Courtesy H. Damerou  
(APC, 26/09/08)

→ Each bunch from the Booster divided by 6 →  $6 \times 3 \times 2 = 36$

# 50 ns BEAM IN THE PS (3/3)

## ◆ Delicate issues

- The longitudinal emittance during acceleration is very small ( $\sim 0.65$  eVs)  $\Rightarrow$  Coupled-bunch oscillations
  - Well damped with the present feedback adjusted for 25 ns
  - No systematic adjustment for 50 ns (not ppm for 25/50 ns)
- Bunch splitting at flat-top
  - Twice lower longitudinal emittance
  - Equal splitting sensitive to RF phases  $\Rightarrow$  Prone to drift
- Fine synchronization before extraction
  - It works but is fragile



# 50 ns BEAM IN THE SPS (1/10)

◆ 2 Long Injector MDs  $\Rightarrow$  Weeks 33 (August) and 41 (October)

◆ Week 33

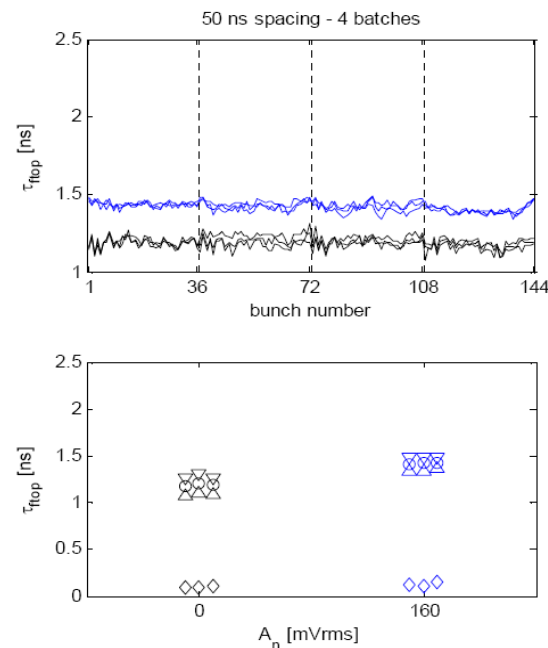
■ Beam parameters OK (see below, for RF)

■ ... But, interlocks with MKDV1 and ZS ion traps

$\Rightarrow$  Decided to make additional measurements in week 41

## 50 ns beam: $\tau$ at flat top

- usual techniques
  - 2 RF systems + controlled emittance blow up
    - see previous APCs
- with and without blow up
  - not needed for stability
    - $\tau = 1.3$  ns, or  $\varepsilon = 0.4$  eVs
  - quite uniform  $\tau$ , and stable
    - $\tau = 1.5$  ns, or  $\varepsilon = 0.5$  eVs
- ion traps interlocks and pressure spikes
  - few measurements

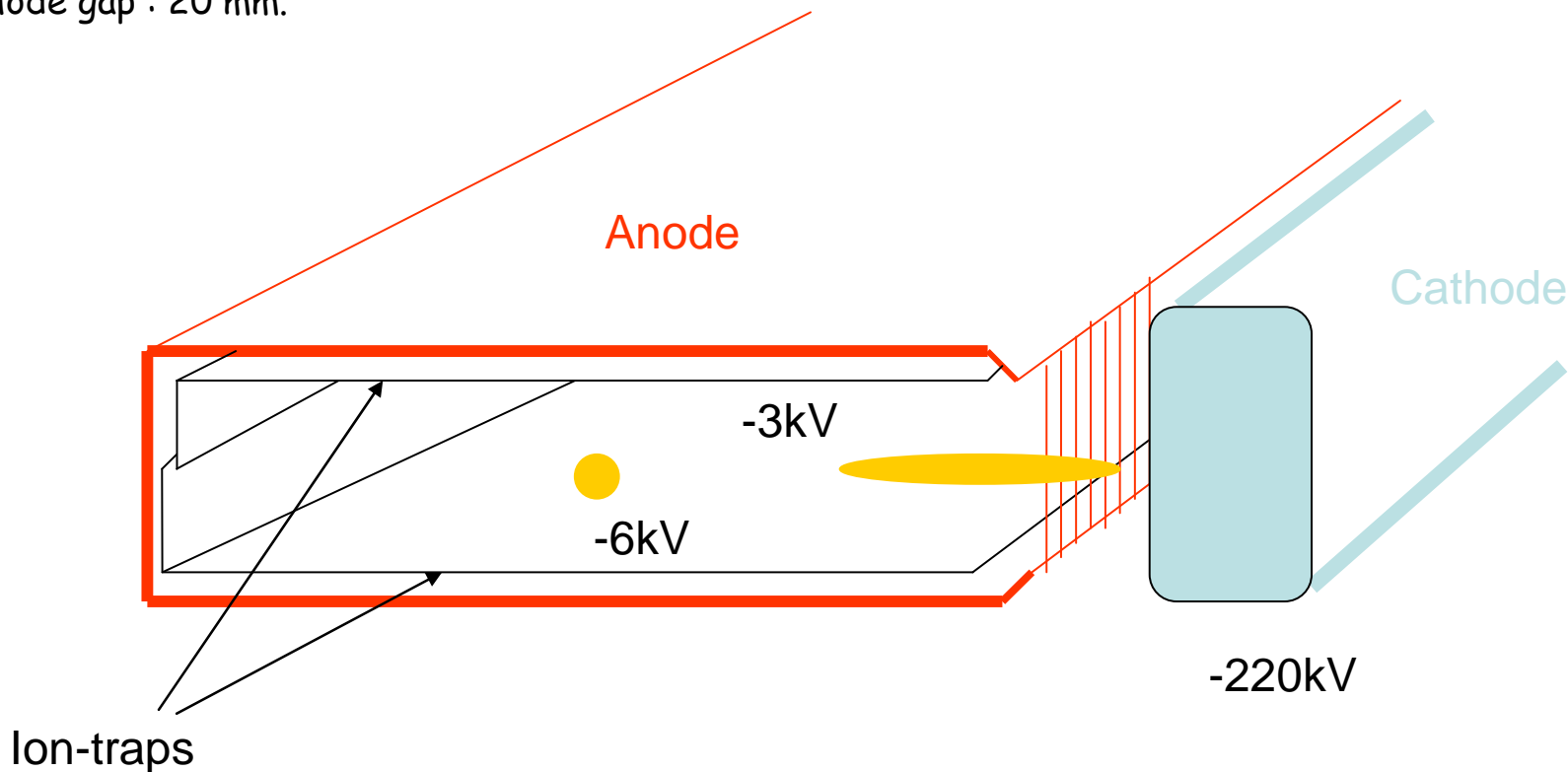


ZS

## 50 ns BEAM IN THE SPS (2/10)

- Active length  $\sim 3$  m (per septum).
- Anode (grounded) :
  - Equipped with 2000  $W_{.75}Re_{.25}$  septum wires.
  - Wire diameter  $50 \mu\text{m}$  (first ZS) to  $100 \mu\text{m}$ .
  - Wire spacing  $1.5$  mm.
- Cathode at a voltage of  $-220$  kV ( $110$  kV/cm).
- Anode-cathode gap :  $20$  mm.

- Ion traps (circulating beam side):
  - Voltage of  $-3$  to  $-6.5$  kV
  - $\sim 2-3$  kV diff. top/bottom
  - Sum of all voltage difference should be  $\sim 0$  to avoid orbit distortions at low energy. Critical for leptons, usefulness less evident now...

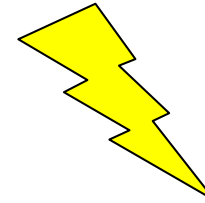


Courtesy J. Wenninger

# 50 ns BEAM IN THE SPS (3/10)



Sparky !!!



- Electrostatic devices like the ZS's are **prone to spark !!**
- Sparks are neither good for the beam, nor for the ZS's themselves.
- A fixed display with the spark rate is available. To be surveyed...
  - We could interlock this with the new SW interlock system. To be seen...
- The **ZS's are very sensitive to electron clouds induced by high intensity LHC beams** - can lead to very high spark rates !! For that reason, during LHC beam MDs :
  - The girders are retracted.
  - The ZS voltage is set to 0.
  - The ion traps are left on to clean ions produced by the e-clouds.

Courtesy J. Wenninger

# 50 ns BEAM IN THE SPS (4/10)



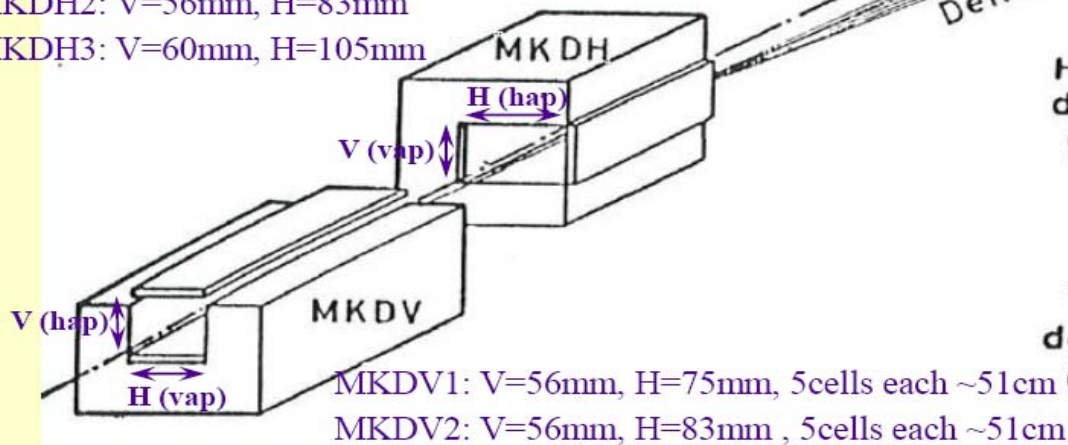
## Principle of Beam Dumping

- ◆ When the beam cannot be extracted: dumping of the beam using the MKD beam dump system (MD, emergencies...)
- ◆ Function of the kicker magnets:
  - ◆ Sweep the beam to distribute the beam energy over a large volume of the absorbed block.

MKDH1: V=56mm, H=96mm

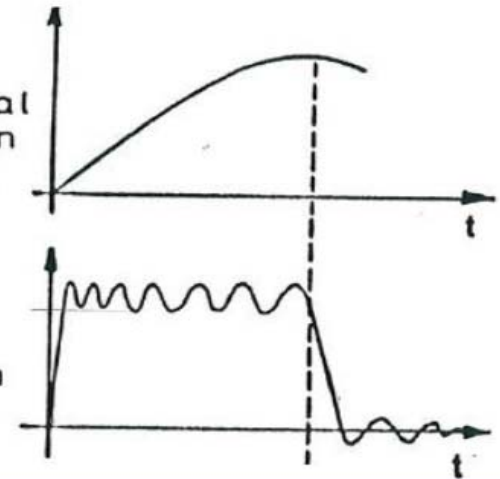
MKDH2: V=56mm, H=83mm

MKDH3: V=60mm, H=105mm



Horizontal deflection (MKDH)

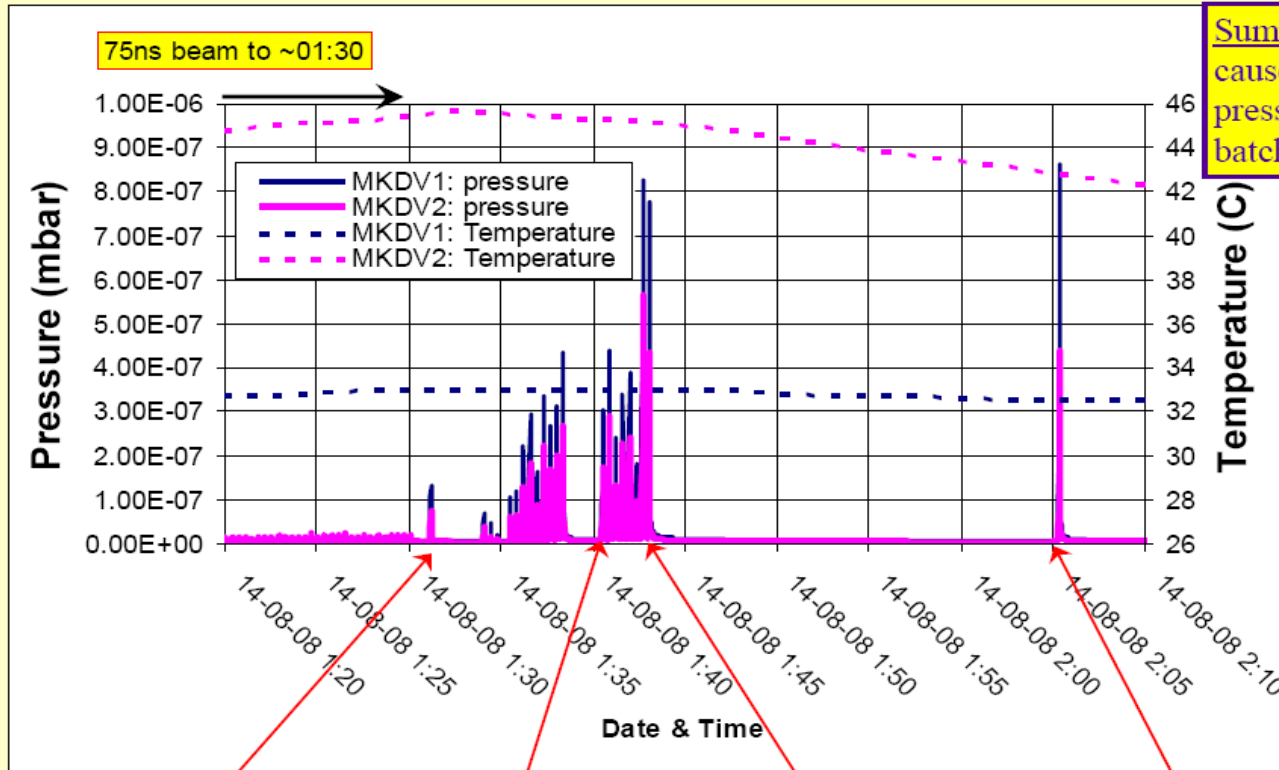
Vertical deflection (MKDV)



# 50 ns BEAM IN THE SPS (5/10)



## MKDV Pressure on 14/08/2008, between 01:20hrs & 02:10hrs.



**Summary:** 50ns beam causes pressure rise; high pressure with 3 or 4 batches per shot.

Information from: **Giulia Papotti:**

Started 1 batch 50ns beam at 1:32hrs, continuously.

One shot of 2 batches of 50ns beam at 1:42hrs.

One shot of 3 batches of 50ns beam at 1:43hrs: interlock.

Single shot of 4 batches of 50ns beam at 2:05hrs: interlock.

Mike Barnes, AB/BT

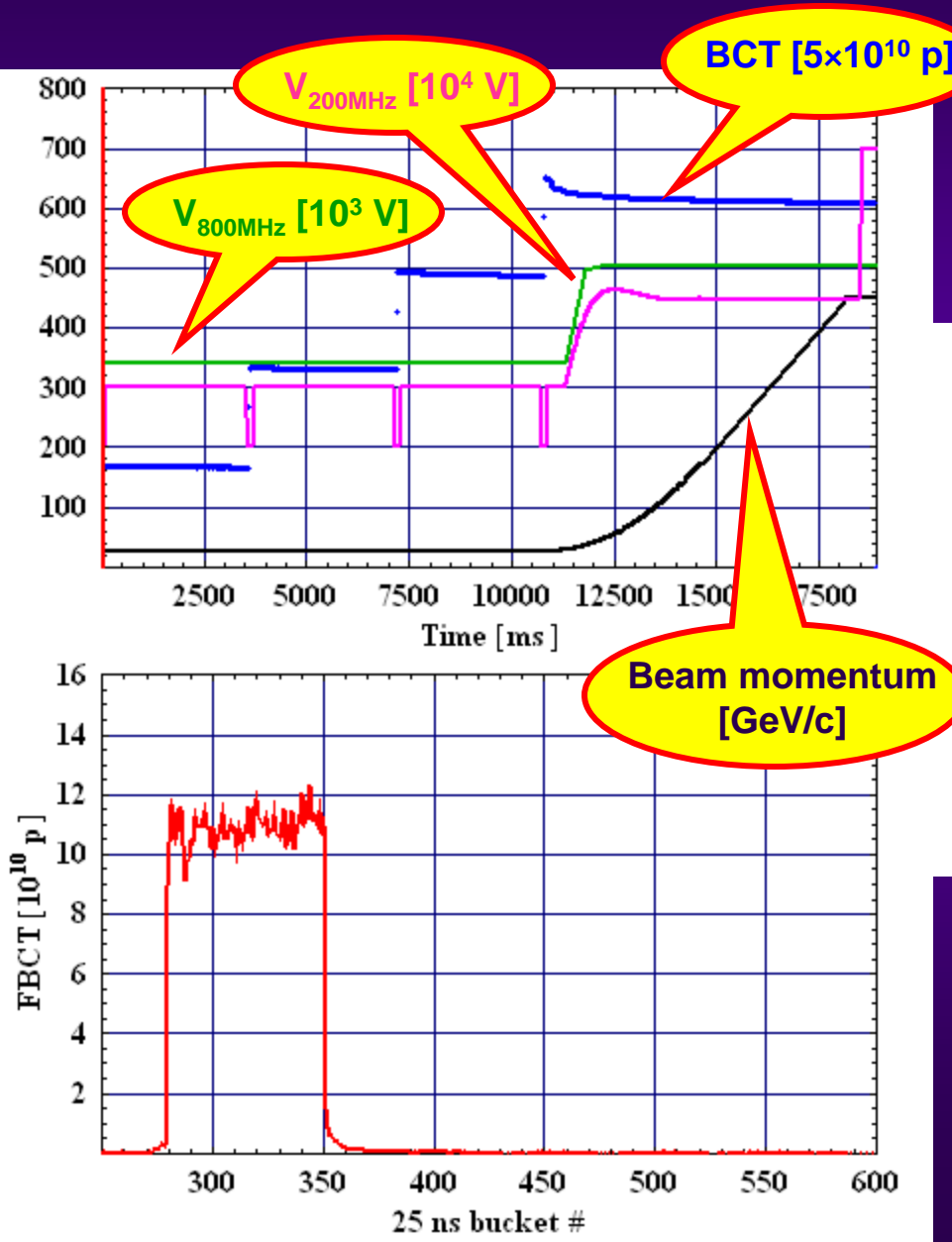
APC: September 26, 2008

## 50 ns BEAM IN THE SPS (6/10)

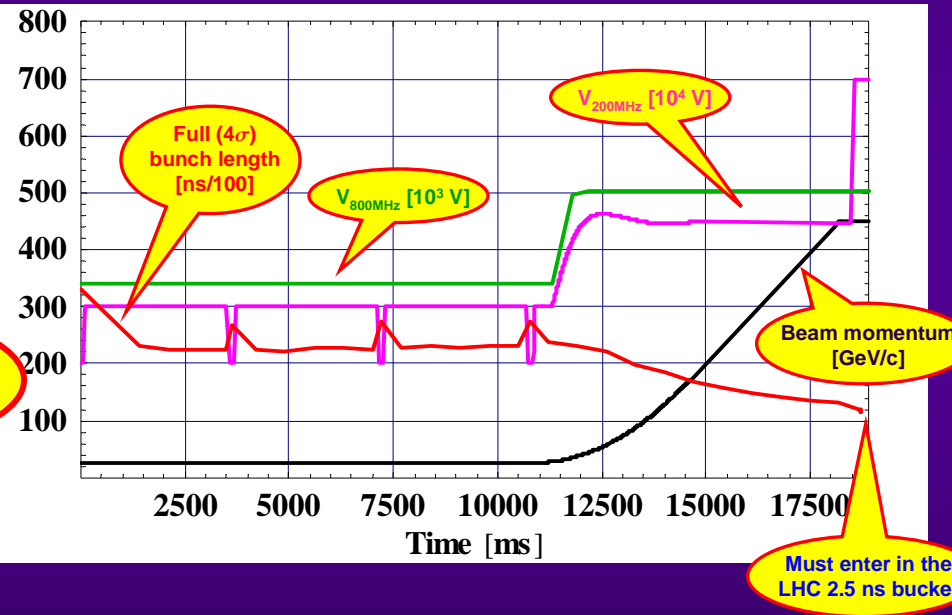
- ◆ Giovanni presented studies yesterday (17/11/08) at the LIS meeting to try and see if one can explain this huge and fast pressure rise by electron cloud
- ◆ However, in each cases the 25 ns should be more critical, which was not observed during the MD (confirmed also in week 41)!  $\Rightarrow$  This is still at puzzle!
- ◆ Note that a problem of outgassing on this MKDV1 was also the reason why we could not accelerate the nominal 25 ns LHC beam to top energy in 2007!
- ◆ During MDs in 2007, the last voltage step (which reduces the bunch length at the very end before going to the LHC) was removed to allow the beam to go to 450 GeV/c otherwise it would not have been possible
- ◆ We were told last year that the ferrite was not baked out on this kicker (during SD 06/07) and that it will not be done for 2008  $\Rightarrow$  In fact next year we will have a new magnet with ferrite baked out!

# 50 ns BEAM IN THE SPS (7/10)

## ◆ Reminder on the nominal 25 ns beam



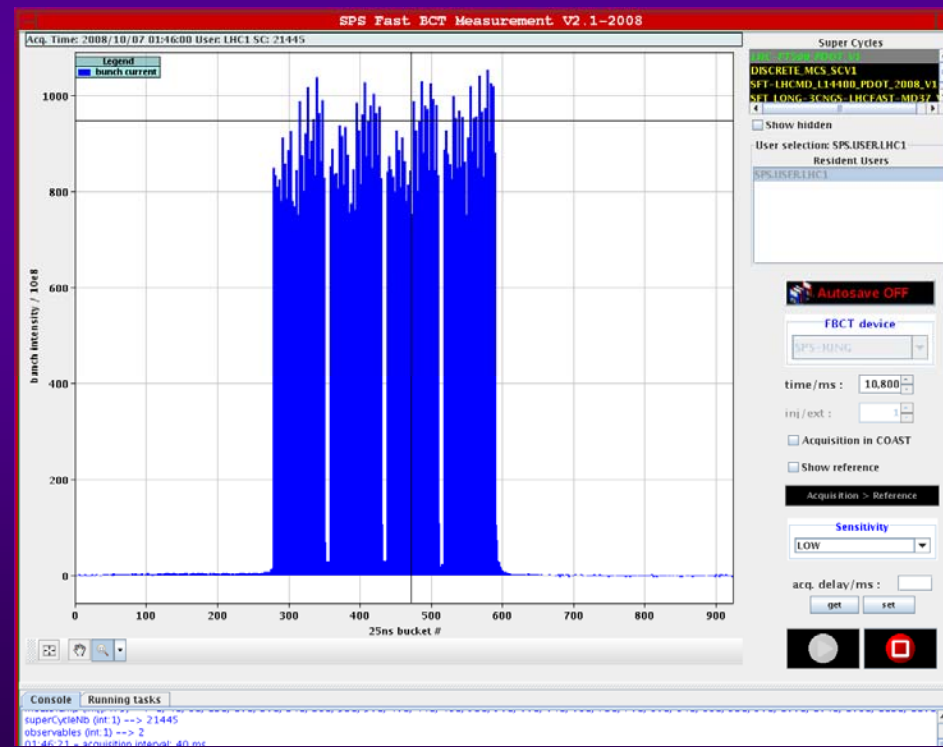
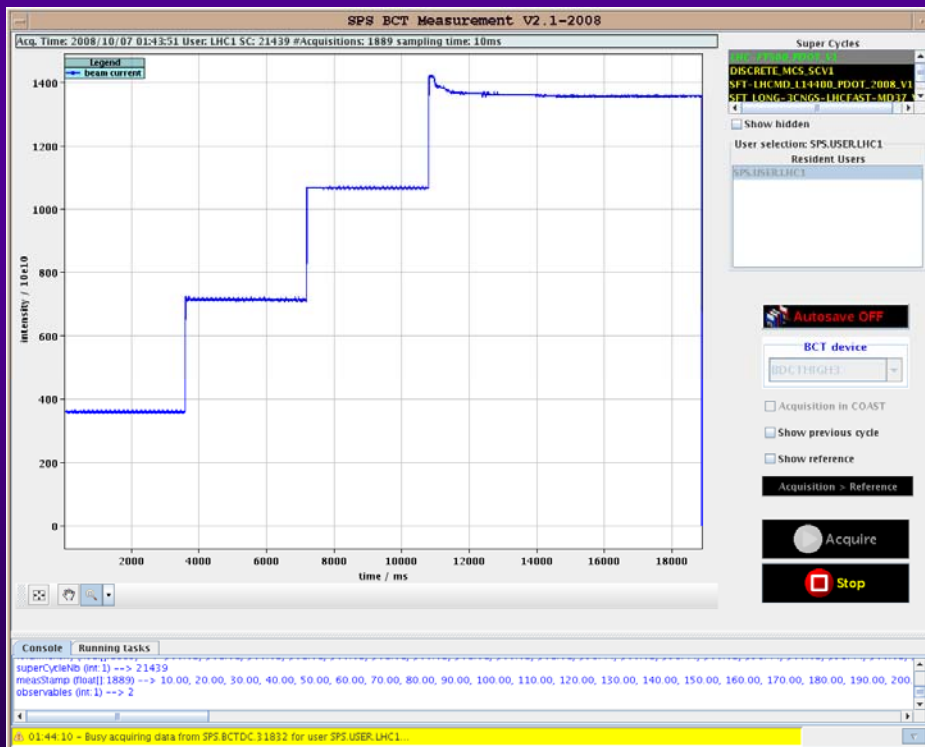
## ◆ Example of bunch length with nominal (4x72 bunches) beam but lower intensity ( $\sim 2.5\text{E}13 \text{ p}$ )





# 50 ns BEAM IN THE SPS (8/10)

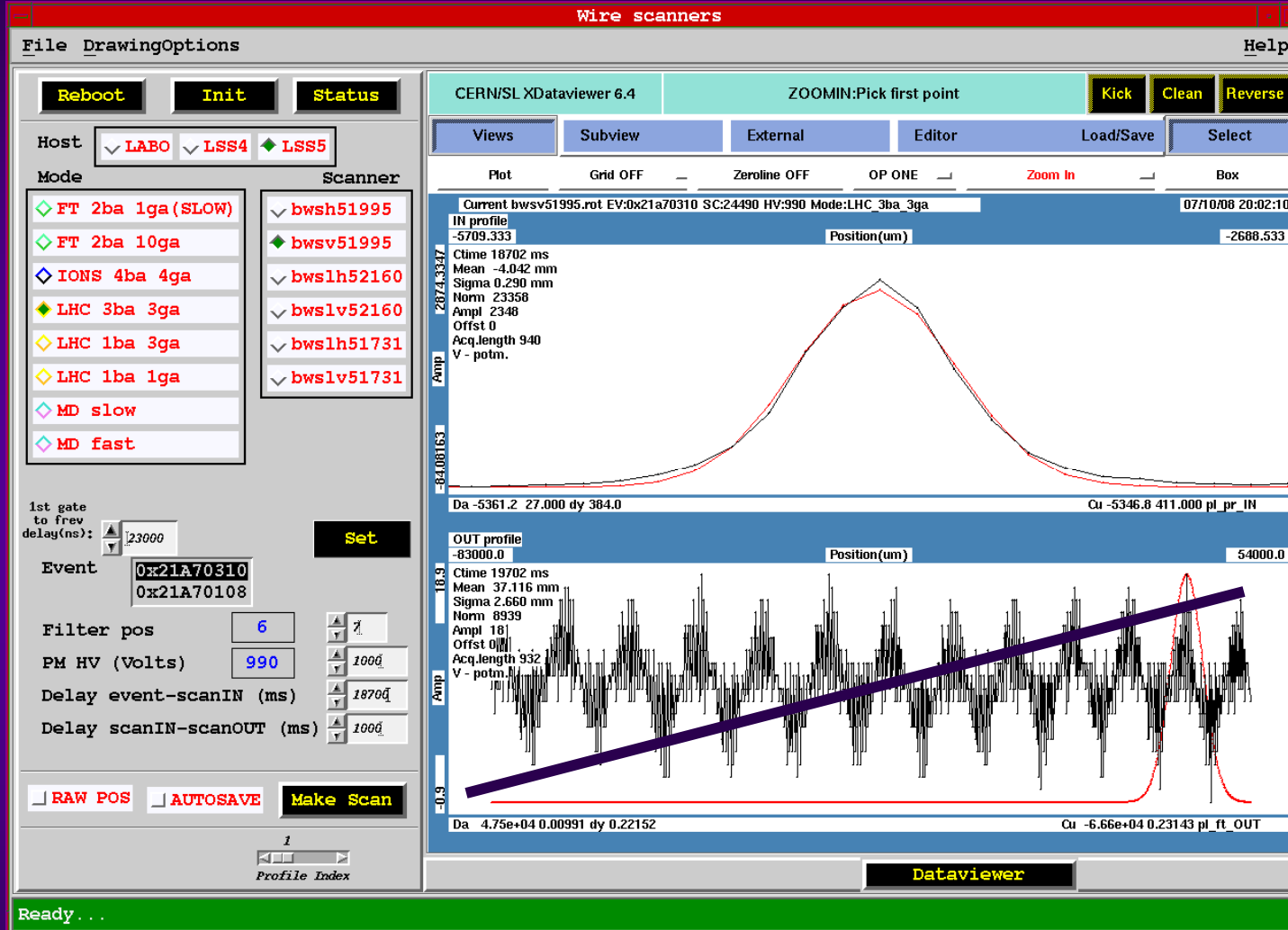
- ◆ **Reminder:** The batch spacing for 50 ns beam should be 9 (25 ns) empty buckets, i.e. 250 ns (instead of 225 ns for the 25 ns and 75 ns beam)
- ◆ **On week 41, TU 07/10/08**
  - Again ZS ion trap interlock with nominal intensity
  - $\Rightarrow$  ~ 80% of nominal intensity



# 50 ns BEAM IN THE SPS (9/10)

◆ Total intensity increased to ~  $1650E10$  p (~ nom. int.) at 19:59 on TU 07/10/08 :

■  $\sigma_y = 0.29$  mm  
 $\Rightarrow \epsilon_y = 1.4$   $\mu$ m



# 50 ns BEAM IN THE SPS (10/10)

The screenshot displays the 'Wire scanners' control interface. On the left, there are control panels for 'Host' (LABO, LSS4, LSS5), 'Mode' (FT 2ba 1ga (SLOW), FT 2ba 10ga, IONS 4ba 4ga, LHC 3ba 3ga, LHC 1ba 3ga, LHC 1ba 1ga, MD slow, MD fast), and 'Scanner' (bwsH51995, bwsv51995, bws1h52160, bws1v52160, bws1h51731, bws1v51731). Below these are settings for '1st gate to prev delay(ns): 23000', 'Event' (0x21A70310, 0x21A70108), 'Filter pos: 6', 'PM HV (Volts): 990', 'Delay event-scanIN (ms): 18700', and 'Delay scanIN-scanOUT (ms): 1000'. A 'Make Scan' button is visible at the bottom of this panel.

The right side shows the 'CERN/SL XDataviewer 6.4' window with two plots:

- IN profile:** Shows a peak at Position (um) 4261.8182. Statistics: Time 18704 ms, Mean -0.274 mm, Sigma 0.428 mm, Norm 16538, Ampl 971, Offst 75, Acq.length 910, H - potm.
- OUT profile:** Shows a noisy signal with a purple linear fit line. Statistics: Time 19704 ms, Mean -70.768 mm, Sigma 3.429 mm, Norm 7795, Ampl 17, Offst 79, Acq.length 903, H - potm.

At the bottom of the interface, a yellow bar displays the status: 'Scan in progress... please wait... 30'...'.

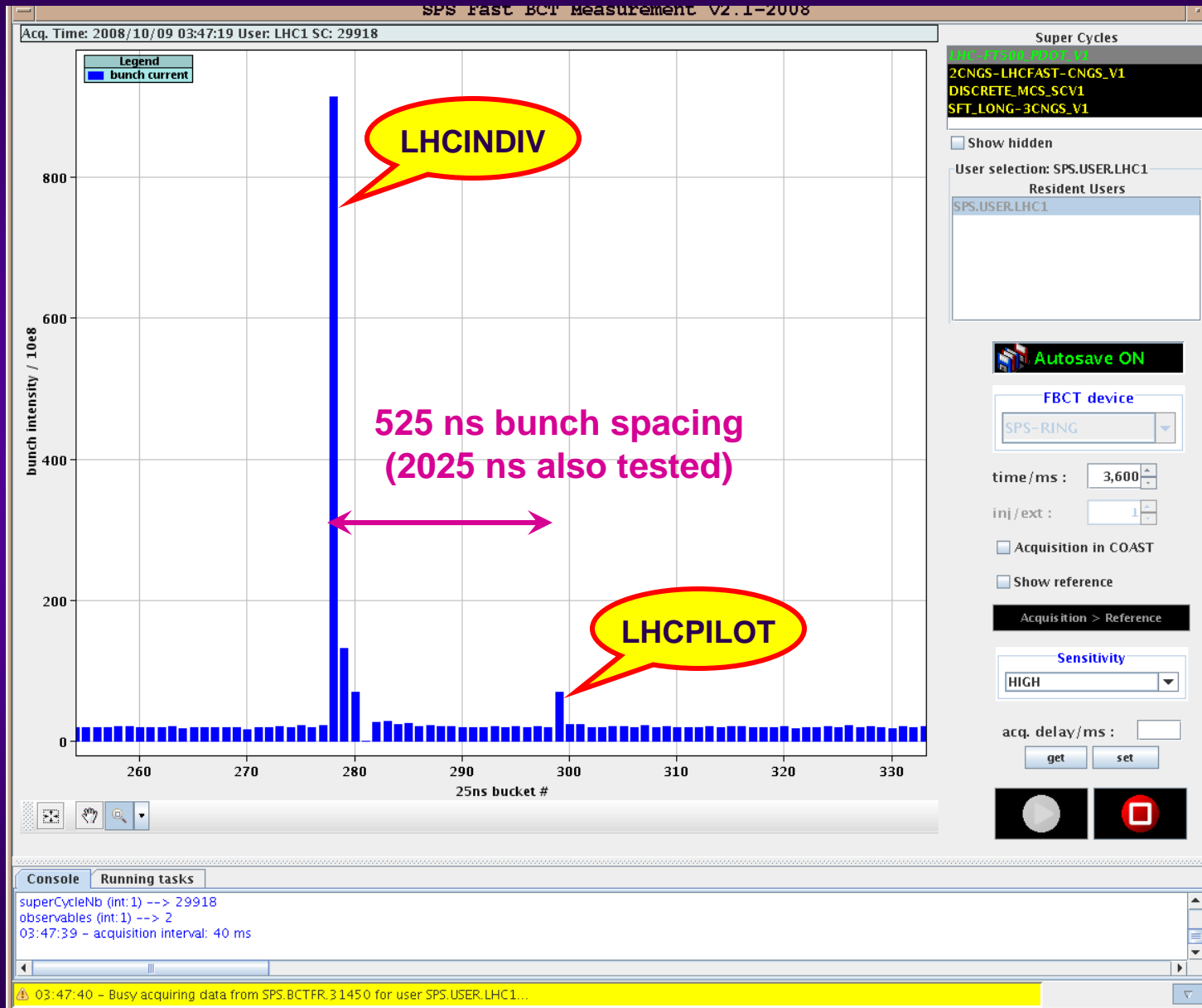
■  $\sigma_x = 0.43 \text{ mm}$

⇒  $\epsilon_x = 1.1 \text{ } \mu\text{m}$

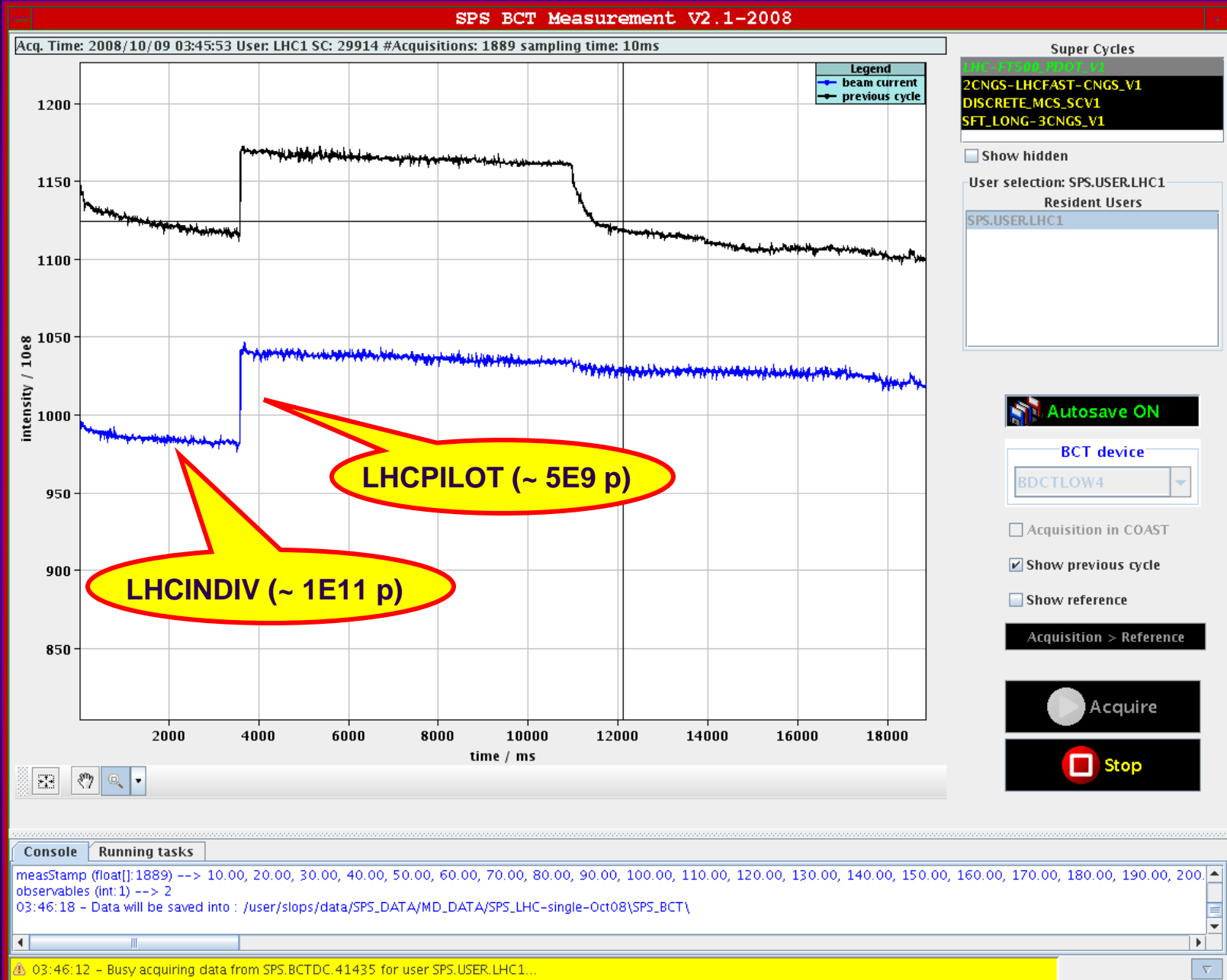
# CONCLUSION

- ◆ **The nominal 50 ns LHC beam was produced through the whole injector chain**
- ◆ **The beam parameters are OK  $\implies$  The transverse emittances are much smaller than nominal ( $\sim 1\text{-}1.5 \mu\text{m}$  instead of  $3.5 \mu\text{m}$ )**
- ◆ **IF NEEDED, controlled transverse emittance blow up is available in the SPS to blow up the beam from  $\sim 1 \mu\text{m}$  to  $\sim 3.5 \mu\text{m}$  (see APC, 14/11/08: <https://ab-div.web.cern.ch/ab-div/Meetings/APC/2008/apc081114/EM-APC-14-11-2008.pdf>)**
- ◆ **Issues with SPS interlocks (outgassing)**
  - ZS ion trap
  - MKDV1

# APPENDIX: LHCINDIV + LHCPILLOT IN THE SPS (1/3)



# APPENDIX: LHCINDIV + LHCPILLOT IN THE SPS (2/3)



# APPENDIX: LHCINDIV + LHCPILOT IN THE SPS (3/3)

- ◆ **Bunch length measurements just before extraction (T. Bohl)**
  - LHCINDIV  $\Rightarrow$  1.2 ns ( $4\sigma$ )
  - LHCPILOT  $\Rightarrow$  0.8 ns ( $4\sigma$ )
  
- ◆ **Measured transverse emittances:  $\sim 2.5\ \mu\text{m}$**