Operational Issues in the Low-level Beam Controls of the PS

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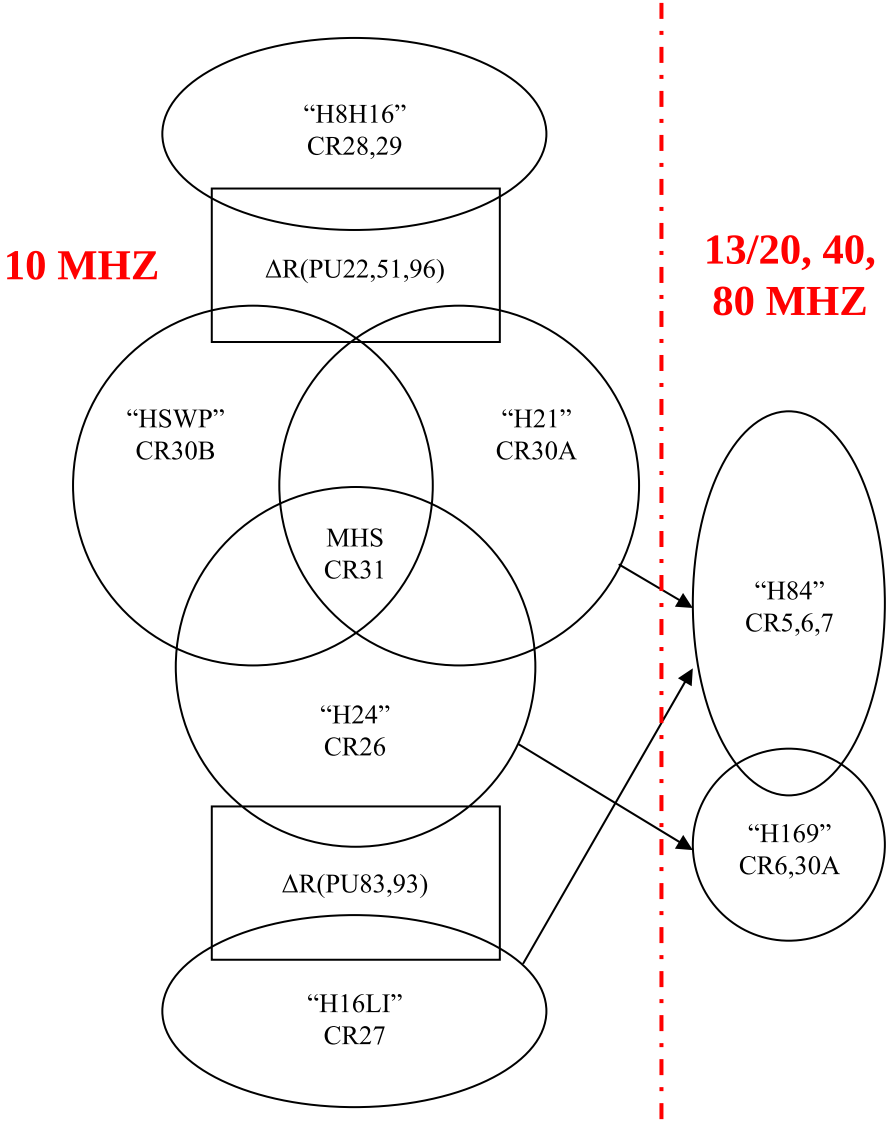
Abstract
The remarkable versatility of the PS machine comes at the price of the complexity of its rf beam controls, which never cease to evolve. Historically, these systems have not only been maintained, but, to a large extent, have also been operated by the specialists who put them together. How can we ensure their operational reliability when such expertise is becoming thin on the ground?

PS Beam Controls for Non-experts



<u>Excluding</u> all controls modules (GFAs and their DACs, TG8s and their pulse repeaters, etc.), all purely diagnostic equipment and pick-up amplifiers, and anything even vaguely high-level, the bottom line is:

Total = 540 modules

=>

~1 tonne of NIM
~500 test points*

*Cf., 76 Oasis channels.

Case in Point: LHC-type Beams

Year	Process
<1999	40 + 80MHz cavity commissioning. Debunching-rebunching. Ejection bump compensation.
1999	Triple splitting.
2000	20MHz cavity commissioning. 2 × double splitting. Double batch injection (3+3). 50ns spacing (half nominal intensity).
2001	New closed-loop generation of h=21 ("local"), h=42, h=84. Train distribution at ejection. Re-establish 2 × double splitting. Pseudo-radial loop. h=7 –> 21 compensation. Advance ejection synchro ahead of all high-energy gymnastics. Re-establish double batch injection (2+4). 50ns spacing (nominal intensity). Short single bunch within the new low-level architecture. Ultimate intensity. Longitudinal instability analysis and cure (h=21). … Fine synchro.

Year	Process
2002	"Smooth" start of the pseudo-radial loop. Double batch injection (4+2). h=7 –> 14 splitting and acceleration steps for 75ns spacing. Longitudinal instability analysis and cure (h=14).
2003	13MHz cavity commissioning. h=14 –> 28 splitting and h=84 rebucketing for 75ns spacing. Double batch injection (4+2) for 75ns spacing. Nominal pilot beam. High-density pilot beam.
2004	New DDS for h=21 ("local"), h=28, h=42, h=84. Second 13MHz cavity commissioning. Totem beam(s). Coupled-bunch instability feedback.
2005 + 2006	Addition of ILHC beam control. New modules for remote control of phase for all splittings (including ions) and of CBI feedback harmonics. 13/20MHz phase correction function. Improved fine synchro (h=84, superheterodyne).

Reproducibility Issues

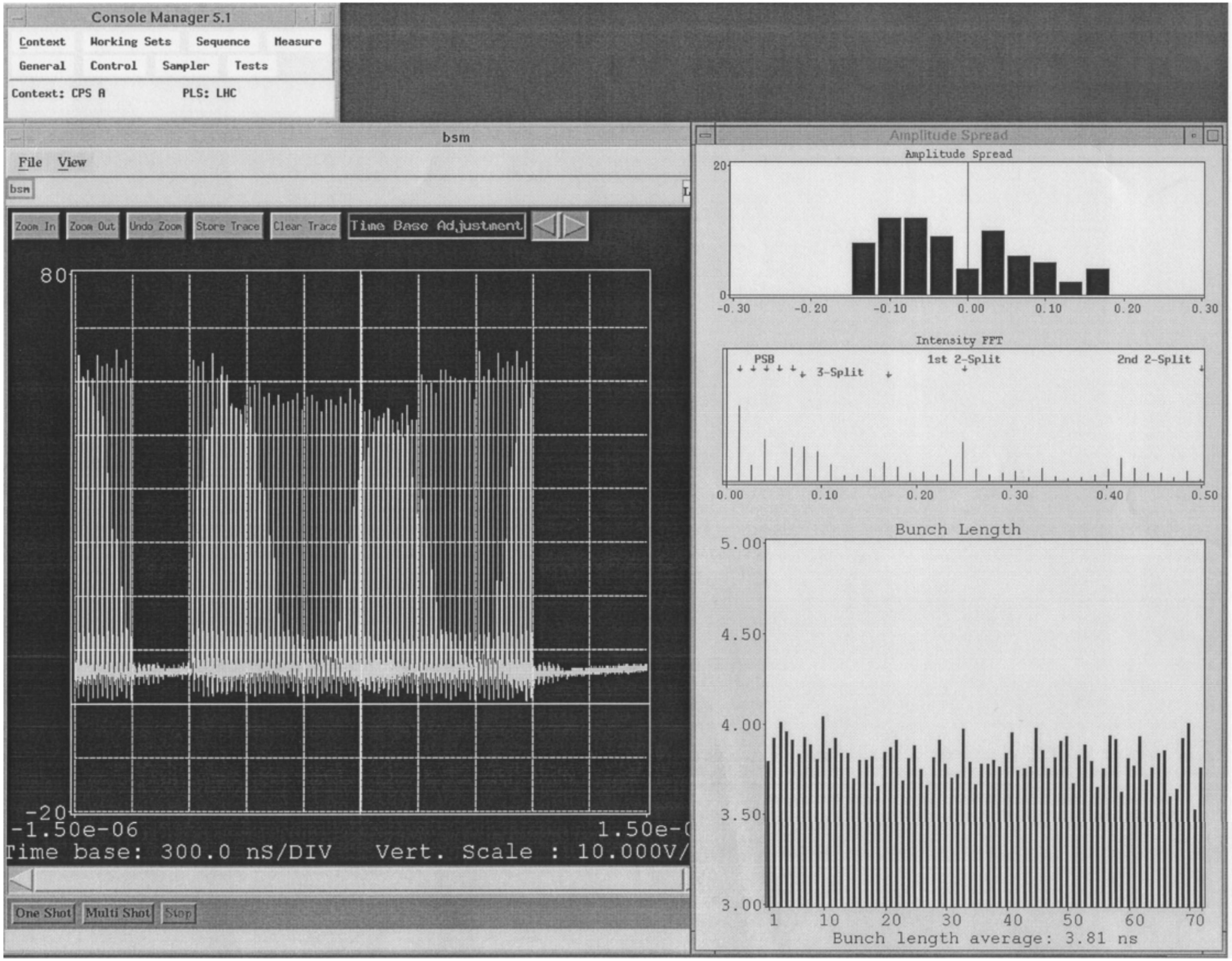
- LHC-type beams require up to 5 distinct rf systems in the same cycle.
- ~8 phases must be controlled at or near the 1º level (only half of these are remotely controllable).
- There are a similar number of hardware delays – some of them critical at the 1ns level (and none of them are remote).
- All these parameters are inter-related.
- There are 3 cascaded synchronization steps to lock onto the SPS – each of them entails up to five parameters (none of which are remote).
- The non-reproducibility of the PS magnetic field on the long injection plateau of the double-batch variants (and, we suspect, at the arrival on the flat-top of all LHC-type cycles) leads to shot-to-shot and day-to-day variations.
- We observe variations in cavity response and beam control effects according to the intensity per bunch and the number of bunches in the machine.
- Even without counting all the different intensity options, each with different numbers of PSB bunches, there are at least 7 variants of LHC-type beams – and that's just for protons.

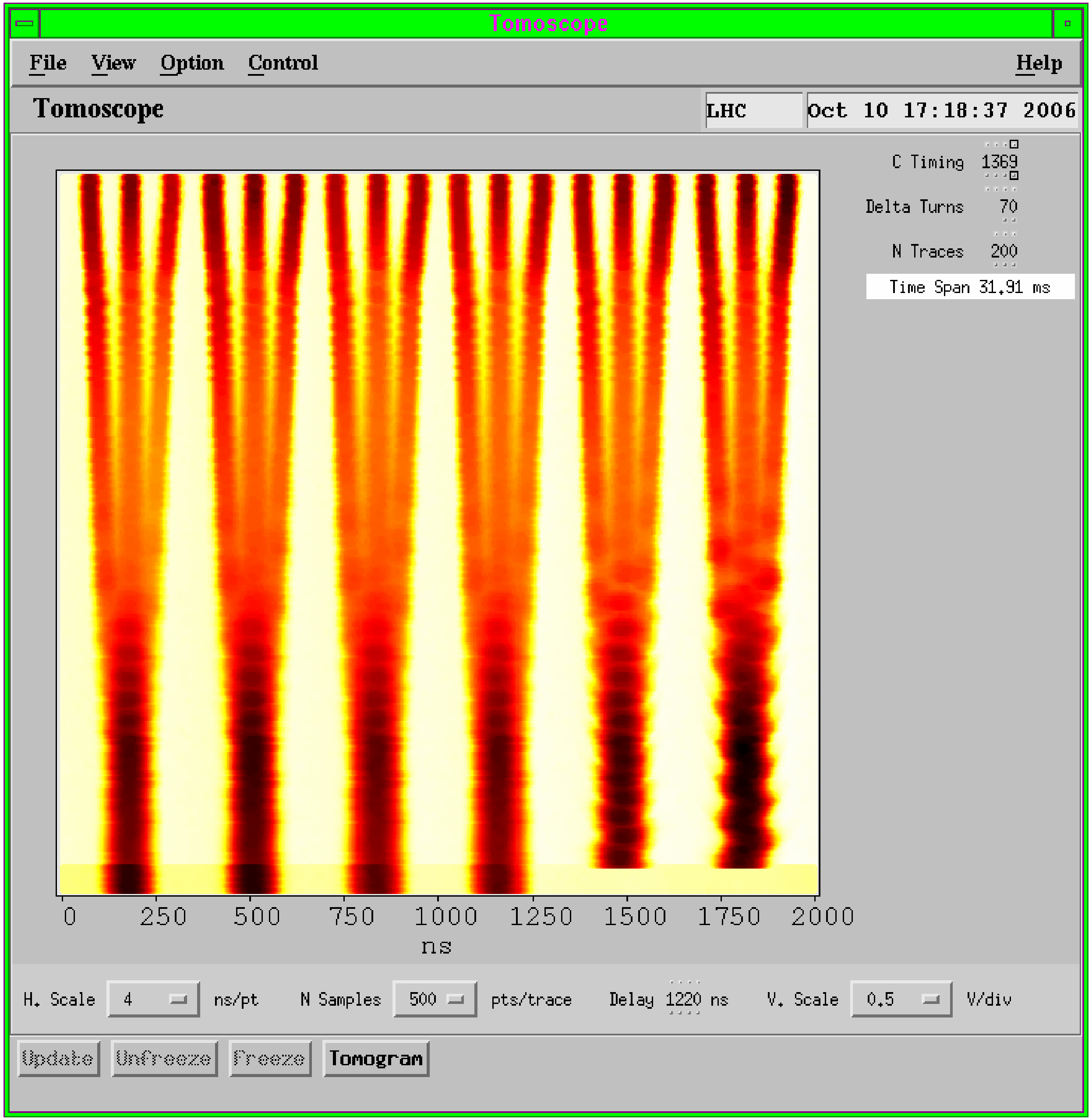
Technical Issues

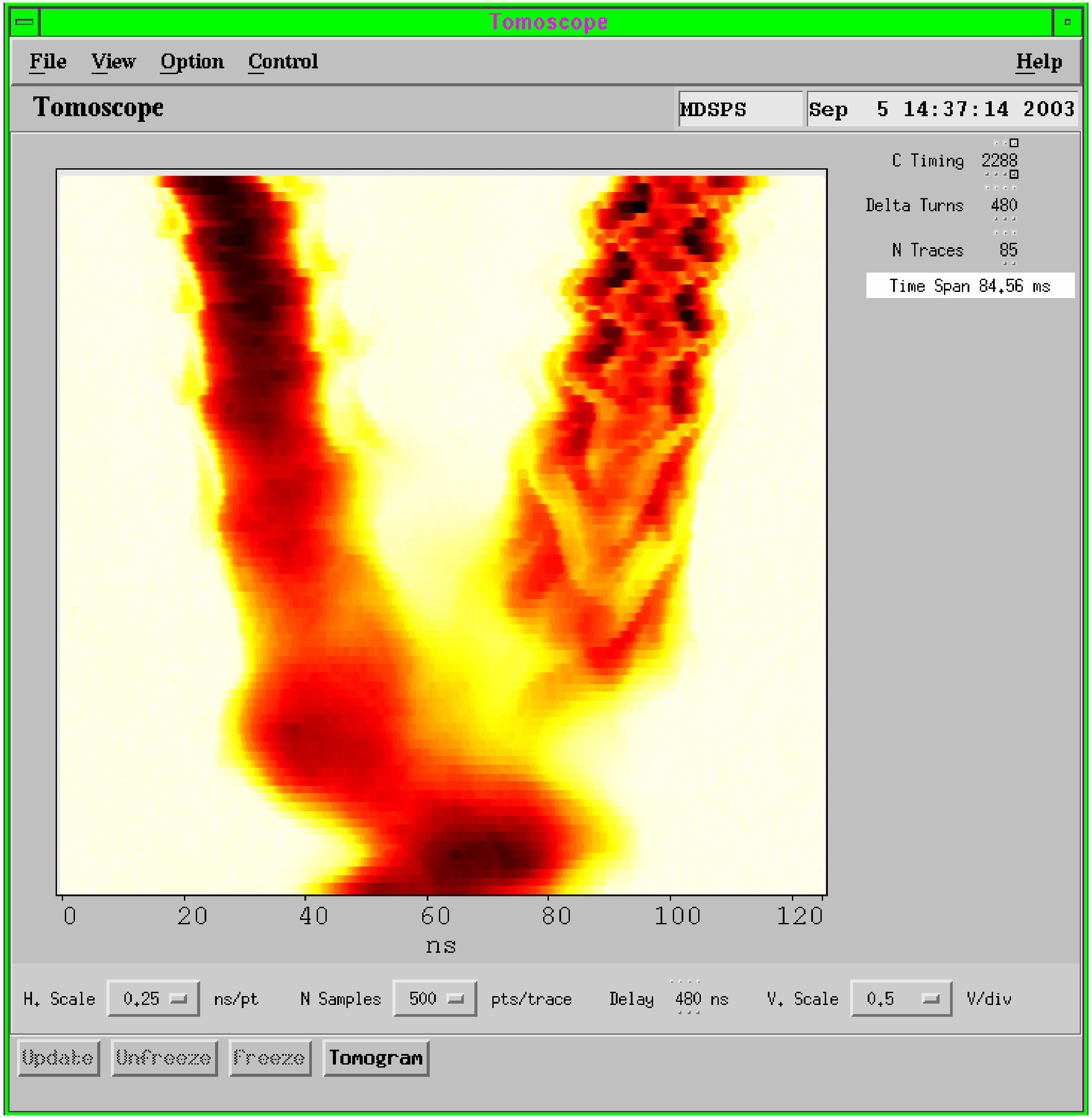
- MHS technology was developed for the antiproton production beam and provides an individual source capable of arbitrary harmonics for each 10MHz cavity. All MHS sources receive a common clock that is tagged at the revolution frequency. The servo loop acts back on the phase of the clock by comparing the beam phase with one such drive. Since the feedback is not generated with respect to the cavity returns, this requires the 10MHz cavities to be well-behaved under all conditions of rf frequency and beam loading. They are not.
- A consequence of the common clock is that there is no relative phase control of the harmonic components during triple splitting, ion gymnastics and batch compression. A new tagging scheme is being considered to overcome this.
- High-frequency cavity phase is a function of voltage. This was first identified at 13MHz. Correction hardware has been implemented, but there were no 75ns beams in 2006. Cf., 40MHz?
- Not only are the manual synchro controls intrinsically non-ppm, the performance of the existing module is dependent upon the initial conditions. A more robust synchro could be implemented in the PS and Booster without waiting for a full-blown all-digital beam control to be rolled out (with significant additional benefits for the rms power dissipation of the PFWs).

Longer-term Issues

- PS2.
- All-digital beam control.
- DSP measurement of cavity phase (AB-Note-2006-050 RF).
- Operator training versus expert intervention: self-fulfilling prophecy.
- The so-called “piquet” will never be better than a first-line service.


Console Manager 5.1
Context
Working Sets
Sequence
Measure
General
Control
Sampler
Tests
Context: CPS A
PLS: LHC
bsm
File
View
Zoom In
Zoom Out
Undo Zoom
Store Trace
Clear Trace
Time Base Adjustment
80
-20
-1.50e-06
Time base: 300.0 nS/DIV
Vert. Scale : 10.000V/
One Shot
Multi Shot
Stop
Amplitude Spread
Amplitude Spread
Intensity FFT
PSB
3-Split
1st 2-Split
2nd 2-Split
Bunch Length
Bunch length average: 3.81 ns


Tomoscope
File View Option Control Help
Tomoscope
LHC
Oct 10 17:18:37 2006
C Timing 1369
Delta Turns 70
N Traces 200
Time Span 31.91 ms
0 250 500 750 1000 1250 1500 1750 2000
ns
H. Scale 4 ns/pt
N Samples 500 pts/trace
Delay 1220 ns
V. Scale 0.5 V/div
Update Unfreeze Freeze Tomogram



Tomoscope
File
View
Option
Control
Help
Tomoscope
MDSPS
Sep 5 14:37:14 2003
C Timing 2288
Delta Turns 480
N Traces 85
Time Span 84.56 ms
0
20
40
60
80
100
120
ns
H. Scale
0.25
ns/pt
N Samples
500
pts/trace
Delay
480 ns
V. Scale
0.5
V/div
Update
Unfreeze
Freeze
Tomogram

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