

Beam and RF operation in the PS

*OP Shutdown Lectures
24/02/2023*

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ref. files, and all of you operating that incredible machine!*

Outline

- PS RF systems
 - *Overview of RF systems and their usage*
 - *Typical issues, tips and tricks*
- Construction of a cycle, RF processes
 - *Typical RF sequences in a cycle*
 - *Cavity matrix and timing trees*
 - *Overview across beams*
- Diversity of operational adjustments
 - *Based on longitudinal beam observation*
 - *A small subset to illustrate general approach*
- What's next?
 - *Future hardware changes*
 - *Future needs*

Agreements

- The focus is put on the general aspects of beam and RF operation in the PS, overview of systems, beam signals and guidelines for adjustments.
- Some aspects are not covered in details (e.g. controlled emittance blow-up, cavity feedbacks, beam control, implementation of coupled bunch feedback and principles of Landau damping...)
- The objective is to provide information relevant for PS operators, as well as PSB operators on shift in PS and curious SPS operators (willing to know why the beam is not coming).



PS RF systems

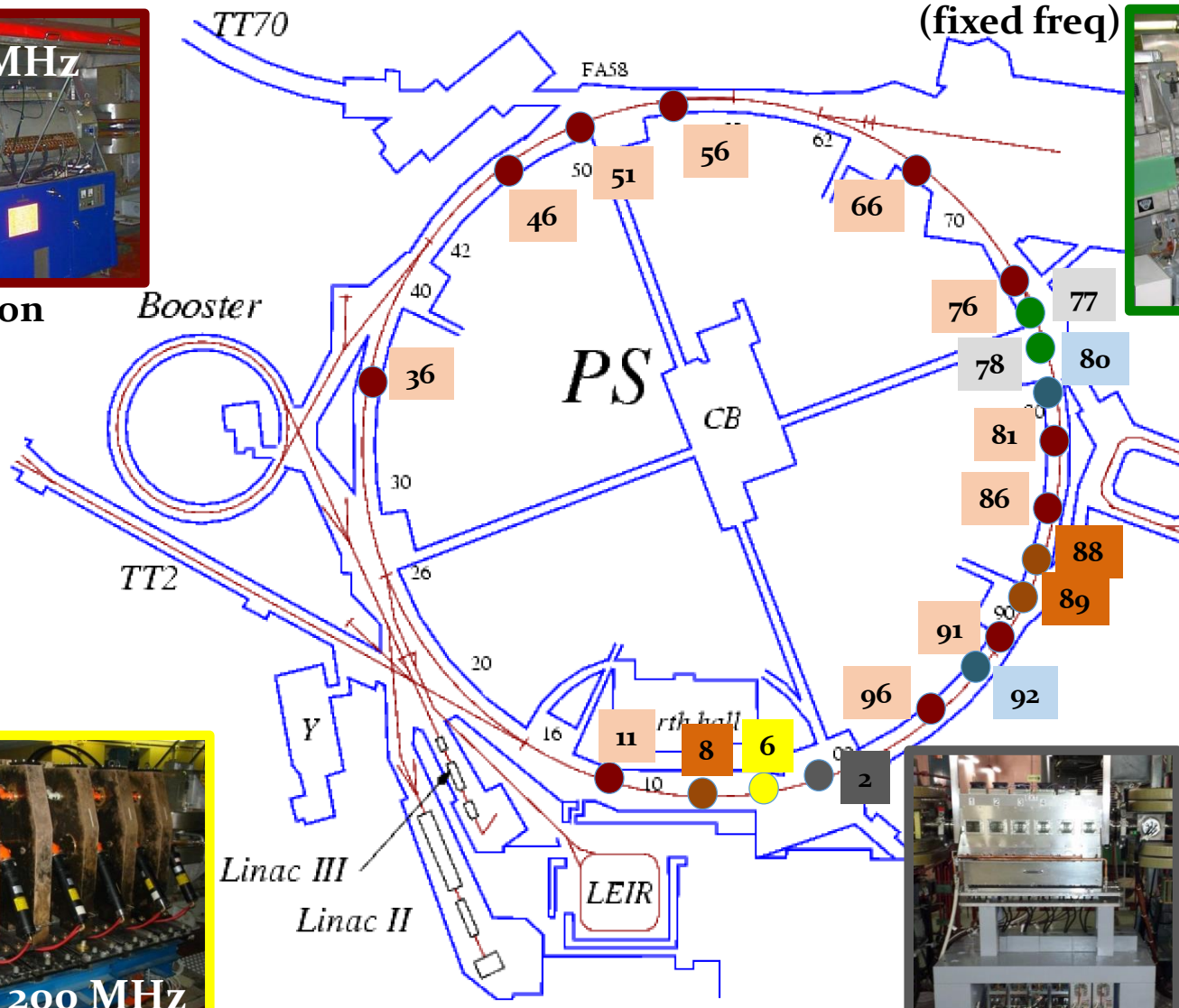
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All instruments in the orchestra...



RF systems in the PS

RF Manipulations
(fixed freq)



2.8 - 10 MHz

Acceleration
(tuning)
to SPS

40 MHz

80 MHz

200 MHz

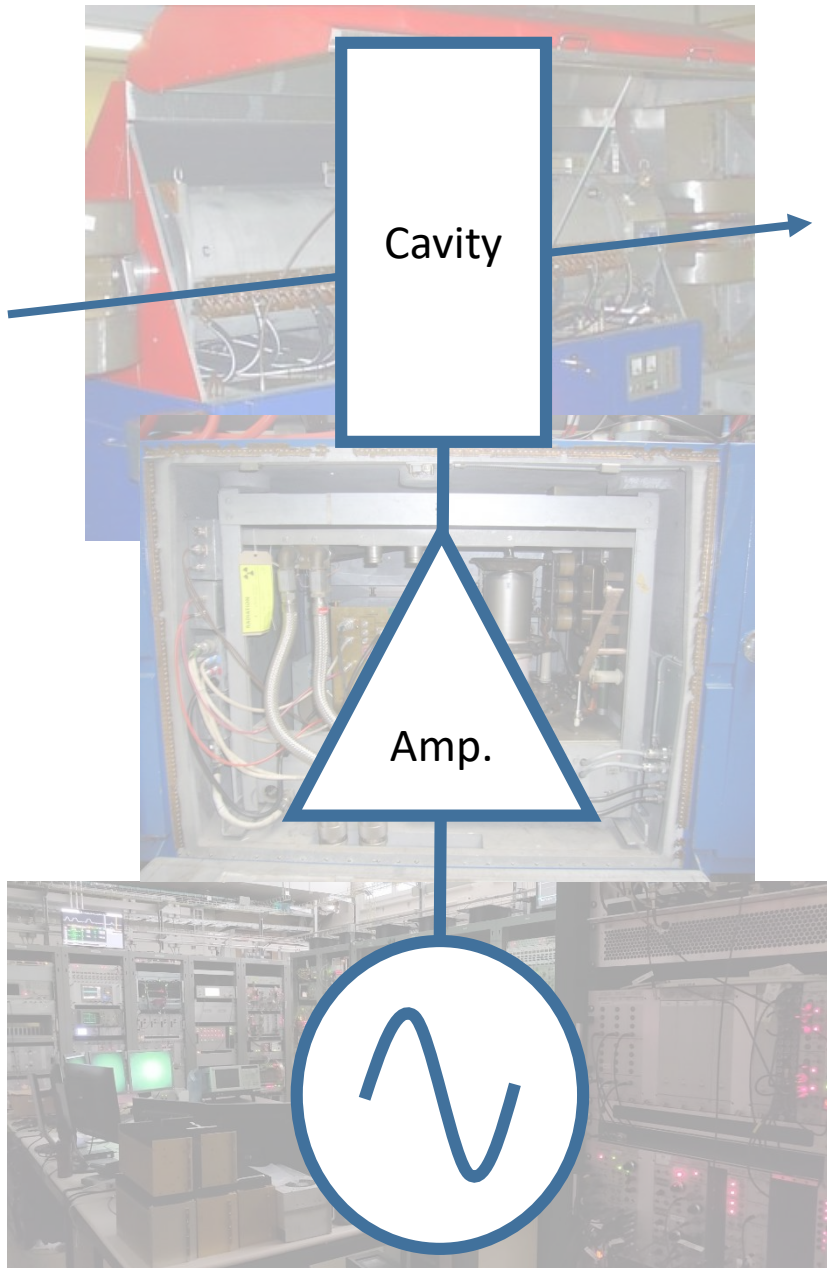
Longitudinal blow-up

Damper

0.4 - 5 MHz

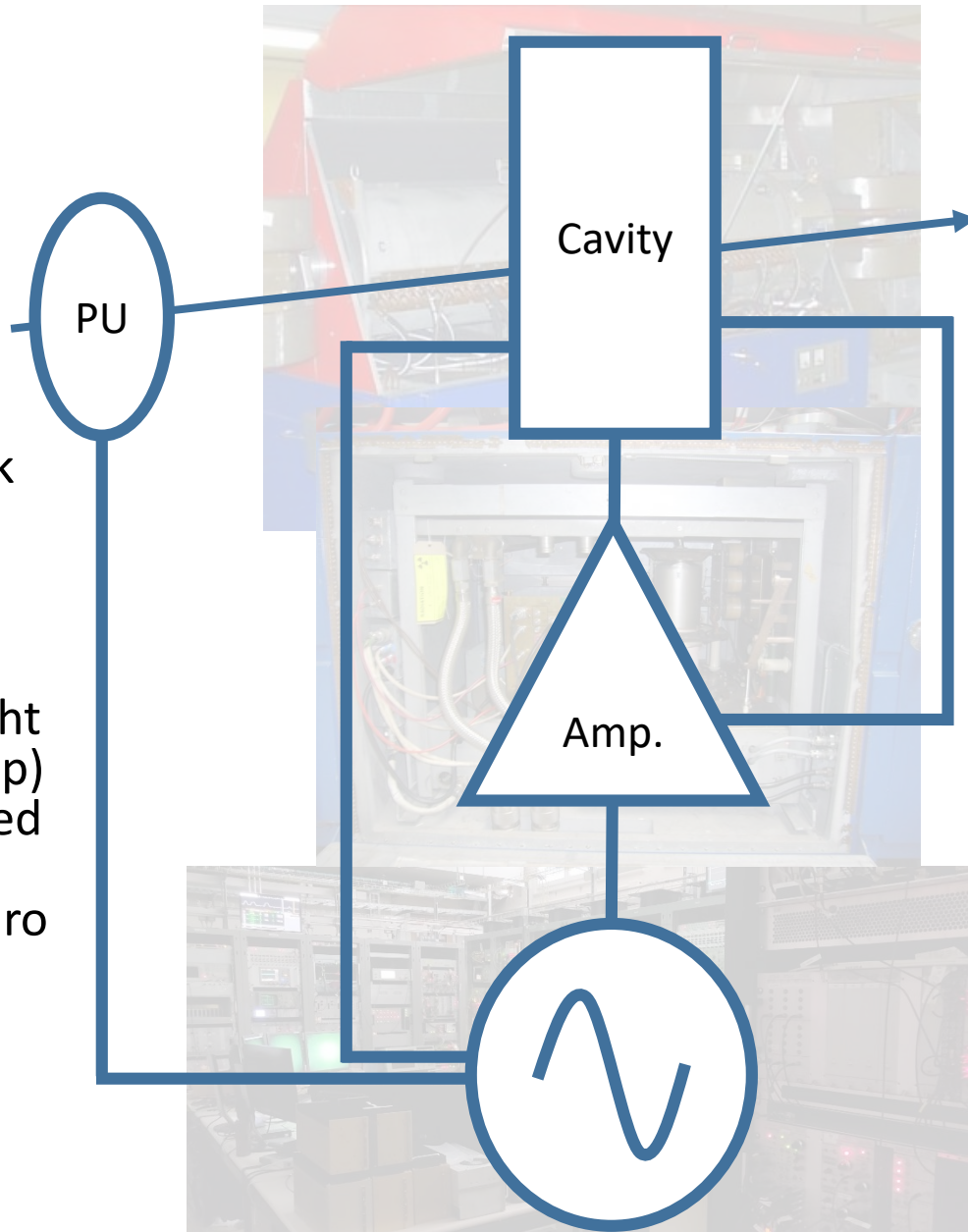
20 MHz

From low-level to high-level RF to the beam



- The power is transmitted in the RF gap where the beam passes and gets accelerated, manipulated, modulated...
- The signal is amplified to high-levels. Interlocks ensure that the amplifiers are not driven too high in power (cavity trip...).
- The low-level signals are generated from a source defining the expected waveform (RF voltage, frequency, phase).

Local and global feedback systems



Global feedback systems ensure that the beam stays in the RF bucket (phase loop), in the right orbit (radial loop) and synchronized to the next machine (synchro loop)

Local feedback systems around the cavity are used to reduce effects of beam induced voltage (e.g. one turn delay feedback 1TFB, multi harmonic feedback MHFB)

Usage of RF systems across beams

| Beam | C10 | C20 | C40 | C80 | C200 | Finemet |
|------------|-------|--------|-------|-------|--------|---------|
| TOF | Green | Red | Red | Red | Green | Red |
| EAST | Green | Red | Red | Red | Green | Red |
| AD | Green | Red | Red | Red | Green | Red |
| SFTPRO | Green | Red | Red | Red | Green | Green |
| LHC#multib | Green | Green | Green | Green | Green | Green |
| LHC#1b | Green | Red | Green | Green | Yellow | Red |
| ION#multib | Green | Yellow | Red | Green | Green | Red |
| ION#1b | Green | Red | Red | Green | Green | Red |

- RF systems have different purpose
 - C10 are used for acceleration and RF manipulations for all beams
 - C20, C40, C80 are used to shape the longitudinal beam distribution for all LHC beams (splittings, bunch shortening...)
 - The C200 are used for controlled longitudinal emittance blow-up and also 200 MHz modulation of the SPS fixed target beam
 - The Finemet cavity was originally designed for damping of coupled bunch instabilities and now for barrier bucket for transfer of the SPS fixed target beam

Beam controls

| Beam | Beam control |
|------------|---------------|
| TOF | H8H16 |
| EAST | H8H16 |
| SFTPRO | H8H16 |
| AD | HSWP |
| LHC#multib | H21, H84 |
| LHC#1b | H16LI, H84LI |
| ION#multib | H24ILHC, H169 |
| ION#1b | H16ILHC, H169 |

- The HLRF systems are controlled by different LLRF systems depending on the beam, with their own setup for phase, radial, synchronization loops (i.e. some beams share the same non-PPM loop parameters).
- LHC type beams have different beam control during the cycle (with C10 cavities), then with high frequency cavities.
- Beam controls are linked to timing trees and (most often) have corresponding WorkingSets.

Usage of RF systems, typical issues C10 ³

App counter!

| Beam | C10 |
|------------|-----|
| TOF | |
| EAST | |
| AD | |
| SFTPRO | |
| LHC#multib | |
| LHC#1b | |
| ION#multib | |
| ION#1b | |

PS 10 MHz Cavities Companion

User -> SFTPRO1

Cavity Number

| | | | | | | | | | | | |
|----------|----|----|----|----|----|----|----|----|----|----|----|
| | 11 | 36 | 46 | 51 | 56 | 66 | 76 | 81 | 86 | 91 | 96 |
| Spare | | | 1 | | | | | | | | |
| Global | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Modif. 1 | | | | | | | | 1 | | | |
| Modif. 2 | | | | | 1 | 1 | | | | | |
| Modif. 3 | 1 | 1 | 1 | | | | | | | | |
| Modif. 4 | | | | | | | | | 1 | 1 | |
| Modif. 5 | | | | | | | 1 | | | | |
| Modif. 6 | | | | 1 | | | | | | | |
| Modif. 7 | | | | | | | | | | | 1 |
| Modif. 8 | | | | | | | | | | | |

Enable1tfb Dacl True

In WorkingSet
RF-SPEC
> CPS:LL_FBC10

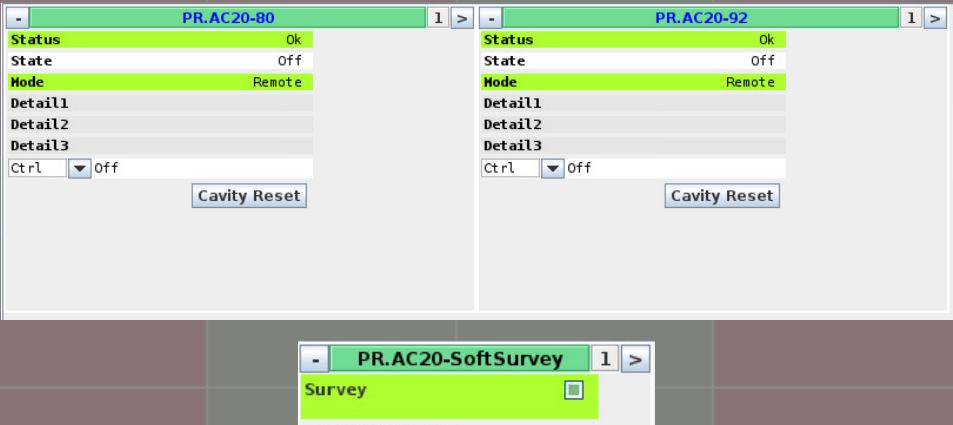
- C10 (10 + 1 spare)

- A typical issue is that one (or several...) cavity trips or doesn't follow the voltage program. This should be visible in the "PS 10 MHz Cavities Companion" app.
- A single faulty cavity can be replaced by the C11 using the "RF 10 MHz Matrix" app.
- For very high intensity beams, cavity loops can be asking for large power. Disabling the 1TFB can be attempted (+ contact the RF experts).

Usage of RF systems, typical issues C20

| Beam | C10 | C20 | C40 | C80 |
|------------|-----|-----|-----|-----|
| TOF | | | | |
| EAST | | | | |
| AD | | | | |
| SFTPRO | | | | |
| LHC#multib | | | | |
| LHC#1b | | | | |
| ION#multib | | | | |
| ION#1b | | | | |

*In WorkingSet
LONGITUDINAL
> CPS:HL_20+40+80MHz*



- C20 (1 + 1 spare)

- A typical issue is that the cavity is not ON when SPS/LHC request beam. The amplifier is switched OFF after some time when not in use to increase the equipment lifetime. Switching the cavity ON takes some time (couple of minutes).
- If C20 is off, C40 and C80 will not be pulsing on LHC multibunch beams (i.e. no splitting, beam lost entirely at SPS injection). Control is made via the WorkingSets.

Usage of RF systems, typical issues C40

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| Beam | C10 | C20 | C40 | C80 | C200 | Finemet |
|------------|-----|-----|-----|-----|------|---------|
| TOF | | | | | | |
| EAST | | | | | | |
| AD | | | | | | |
| SFTPRO | | | | | | |
| LHC#multib | | | | | | |
| LHC#1b | | | | | | |
| ION#multib | | | | | | |
| ION#1b | | | | | | |

1x40 vs. 2x40 timing selection

PA.MATNCBR 1 2

C77 PA.GSV40BR1 PA.GSV40BR2

C78 PA.GSV40BR1 PA.GSV40BR2

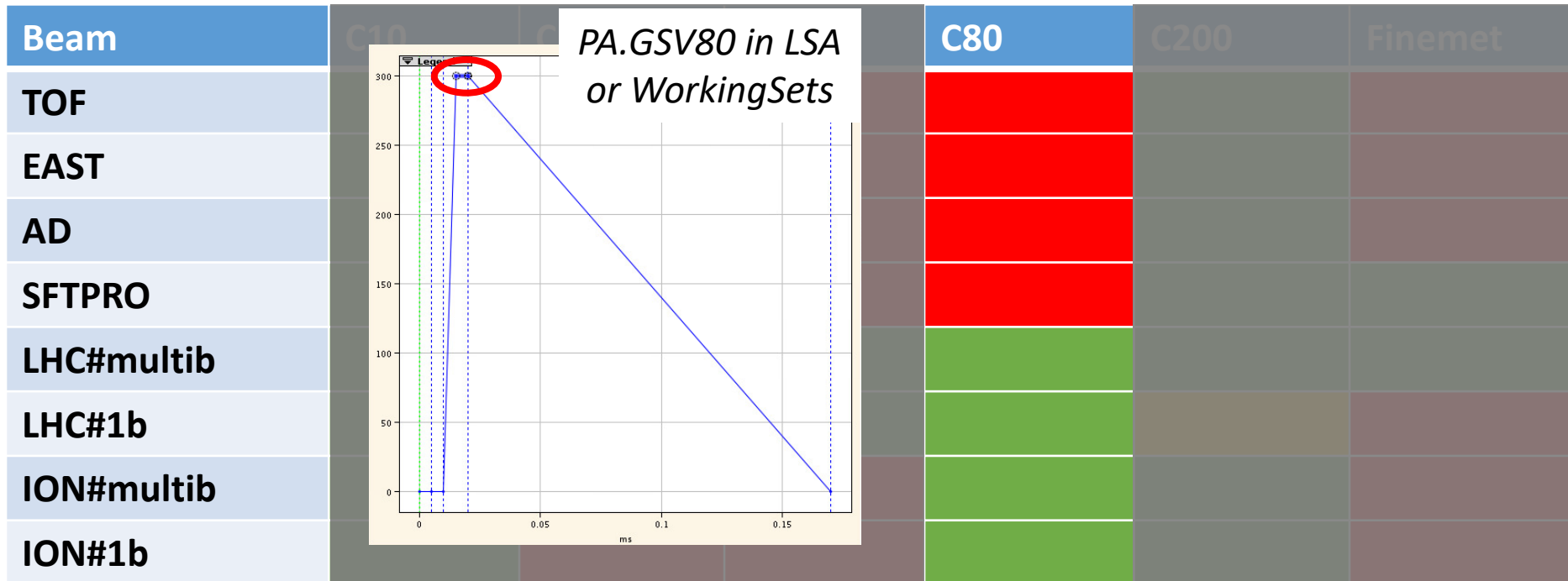
Bunch rotation only

Bunch rotation + adiabatic + splitting

- C40 (2, or 1 in degraded mode)

- A typical issue is that one cavity trips. It will manifest at PS-SPS transfer (no splitting structure, increased losses in SPS due to bunch rotation timings that should be changed).
- The cavities can be switched using the “RF 40MHz Matrix” app, and the bunch rotation settings adapted from 2x to 1x cavity (“degraded” mode).

Usage of RF systems, typical issues C80



- C80 (2 for p+, 1 for ions)
 - Used for bunch rotation in LHC p+ beams. Used for adiabatic bunch shortening for LHC ion beams.
 - A typical issue is that one cavity trips. It will manifest at PS-SPS transfer (increased losses due to bunch rotation).
 - During the run with protons only, one C80 can be used as a spare (only if tuned on the proton frequency!).
 - A last resort is to reduce slightly the RF voltage via the PA.GSV80 parameter (+ contact the RF experts).

Usage of RF systems, typical issues C200

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The screenshot displays the RF system control interface. On the left, a vertical menu lists beam types: Beam, TOF, EAST, AD, SFTPRO, LHC#multib, LHC#1b, ION#multib, and ION#1b. The main area shows a 'Cavity Number' matrix with columns C201 to C206 and rows for various functions. The 'Function' column includes Test Pulse, Blow-up 1, Blow-up 2, Blow-up 3, Blow-up 4, CT Rebunching, Spare Rebunching, and Spare Function. The 'RF Voltage' column shows values for each function. A 'C200 Matrix Switch' dialog is overlaid, showing 'From Cavity: C203' and 'To Cavity: C202' with a 'Start' button.

| Function | C201 | C202 | C203 | C204 | C205 | C206 | RF Voltage |
|------------------|------|------|------|------|------|------|-------------|
| Test Pulse | 1 | 1 | 1 | 1 | 1 | 1 | CCV 19,2 kv |
| Blow-up 1 | | | 1 | 1 | 1 | | CCV 5,4 kv |
| Blow-up 2 | | | 1 | 1 | 1 | | CCV 4,5 kv |
| Blow-up 3 | | | | | | | CCV 0,1 kv |
| Blow-up 4 | | | | | | | CCV 0,1 kv |
| CT Rebunching | 1 | | 1 | 1 | 1 | 1 | CCV 24,6 kv |
| Spare Rebunching | | | | | | | CCV 0,6 kv |
| Spare Function | | | | | | | |

- C200 (5 + 1 spare)

- A typical issue is that one cavity trips. It can be difficult to identify as the impact can be subtle (beam slightly more unstable, increased losses, reduced 200 MHz modulation...)
- The first step is to verify whether the cavities are pulsing (PA.VD200 sampler or per cavity PA.C20xVDET on OASIS)
- Slight operational adjustments of the C200 voltage can be made but only together with systematic verification of longitudinal beam parameters (and not only based on BLMs...).
- The faulty cavity can also be switched with the spare via the “RF 200MHz Matrix” applications (for a single cycle via the matrix or all users via the Inspector app).

Usage of RF systems, Finemet

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| Beam | Inspector 3.5 | Coupled-Bunch Feedback Acquisition | Finemet |
|------------|---------------|------------------------------------|---------|
| TOF | | | |
| EAST | | | |
| AD | | | |
| SFTPRO | | | |
| LHC#multib | | | |
| LHC#1b | | | |
| ION#multib | | | |
| ION#1b | | | |

- Finemet (1 cavity, 6 gaps)
 - The main aspect to check is whether the cavities are on via the “HL_ADL” inspector panel.
 - The typical impact on LHC multibunch beams is that RF phases for the triple splitting will have large changes (10s degrees).
 - The cavities are not 100% integrated in nominal operation yet. Expert apps are under development and will require time for operational integration.



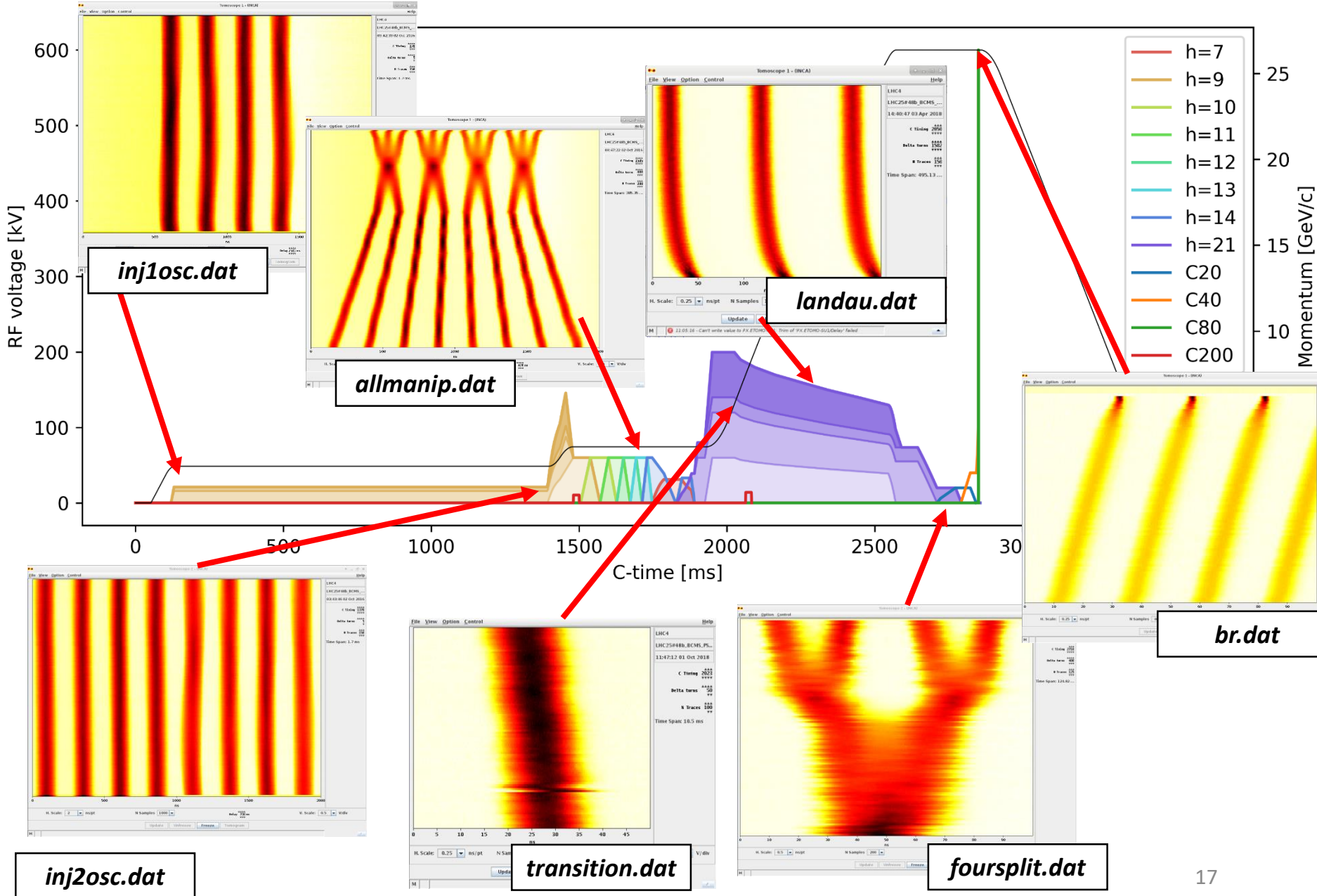
**Construction of a cycle,
RF processes**

—

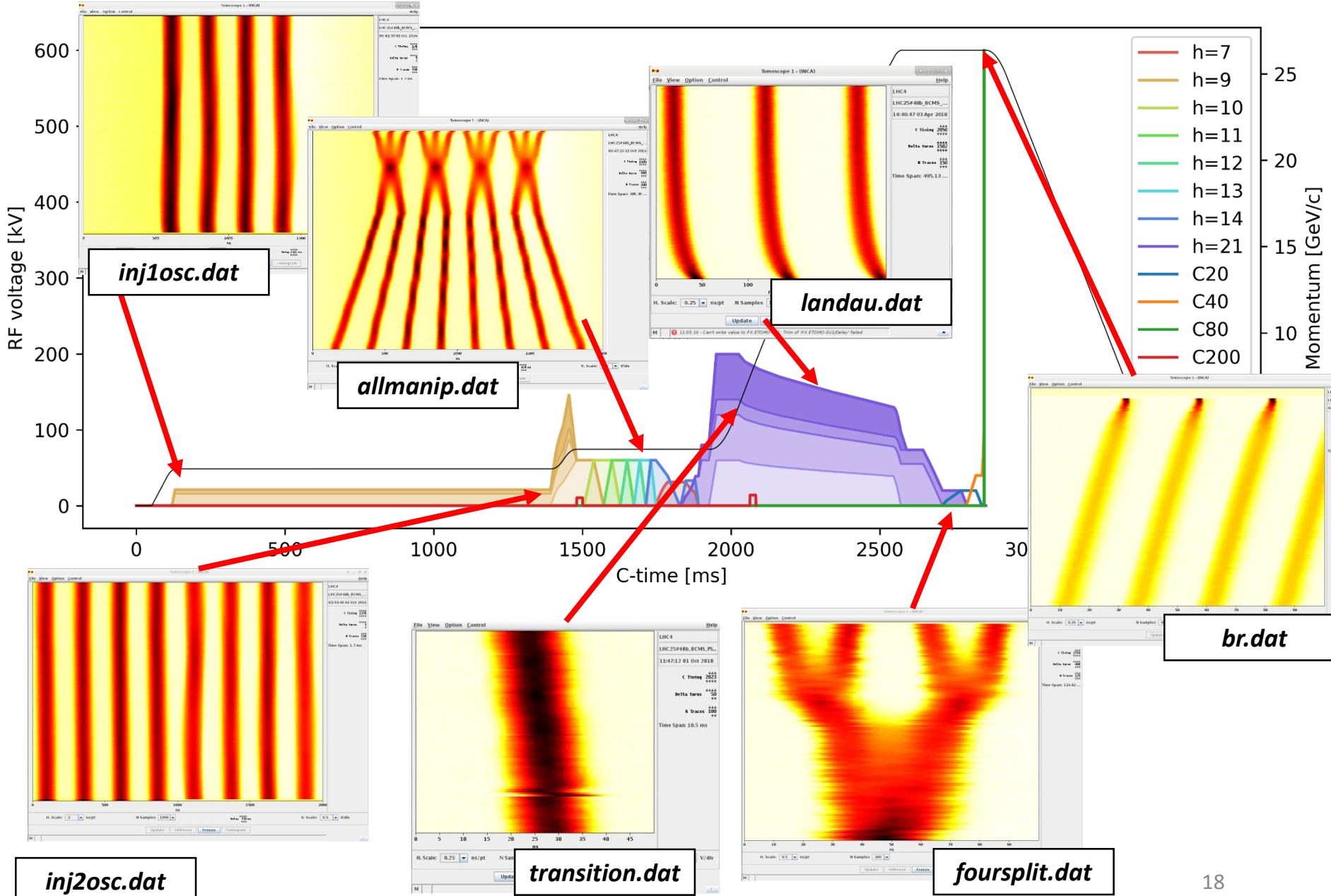
Deciphering the music sheet...



Overview of the BCMS cycle (Tomoscope ref)



Overview of the BCMS cycle (Tomoscope ref)



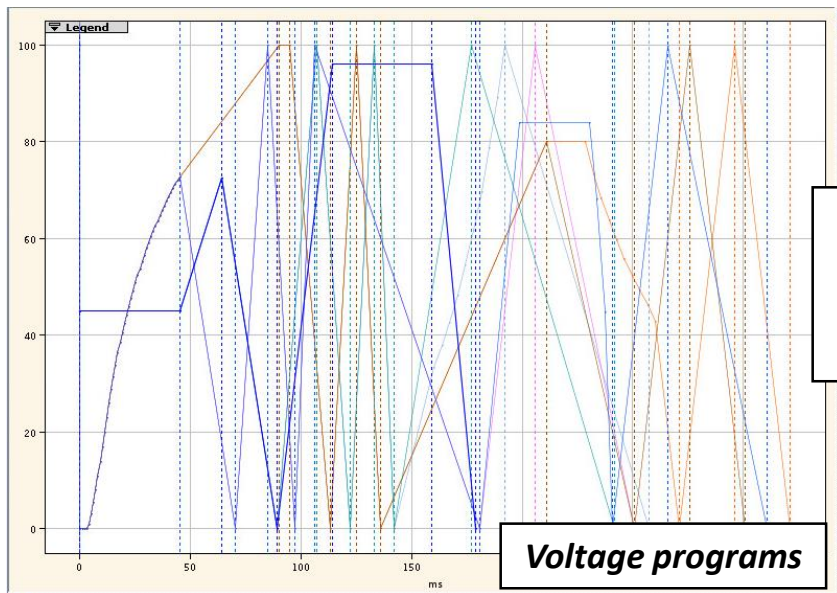
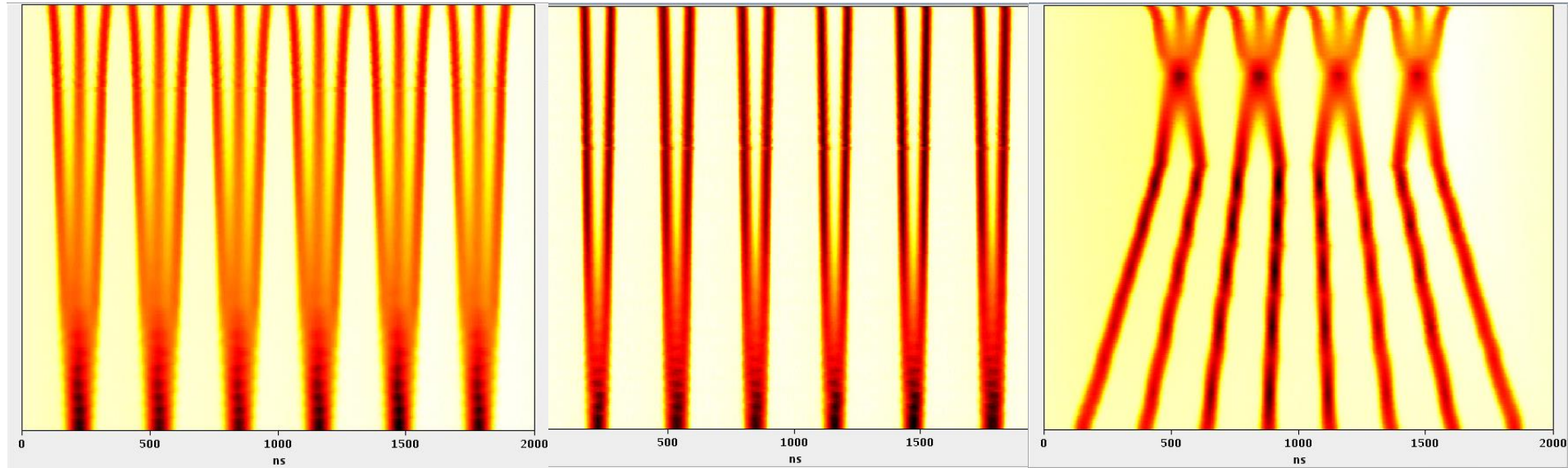
Overview of all LHC-type cycles

Construction of an LHC-type beam:

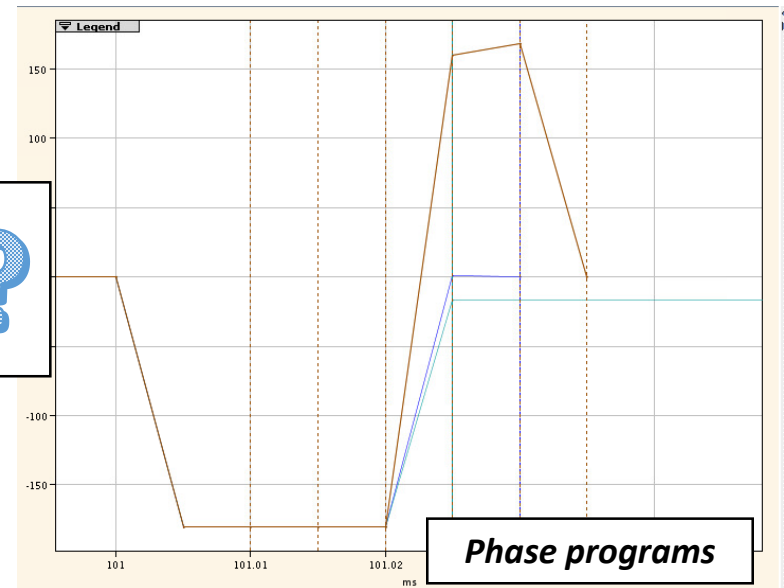
- Injection of bunches from the PSB
 - Acceleration to intermediate plateau
 - **RF manipulations to bring the beam to $h=21$ (100 ns bucket)**
 - Acceleration to flat top
 - **RF manipulations to bring the beam to $h=84$ (25 ns bucket)**
 - Bunch rotation and extraction to SPS
- **The extracted beam from PS is composed of bunches spaced by a multiple of 5 ns (the size of the SPS rf bucket), the lowest possible multiple in the PS is 25 ns ($h=84$).**



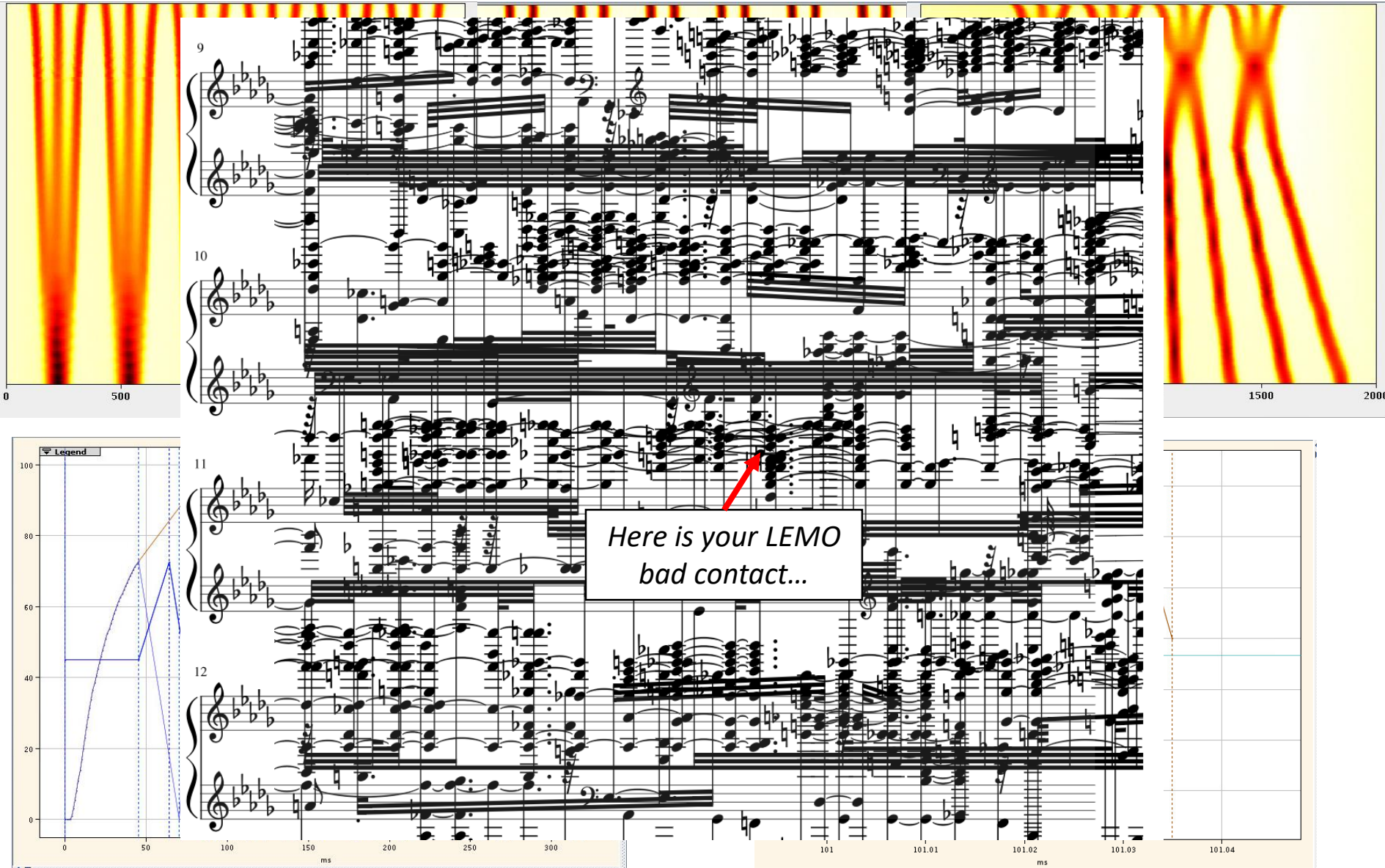
Variety of RF manipulations, variety of settings!



???



Variety of RF manipulations, variety of settings!



Grouping of “10 MHz” RF systems

3+1x harmonic groups
(tuning circuit hard wired,
up to 3x3kA tuning current!)

Cavity tuning from
2.8 MHz to 10 MHz

Up to 20 kV per cavity

8x voltage programs,
independent of the
harmonic group

C11 as spare cavity to
replace any other in case
of issue

| | HD | | | | HA | | | | HB | | | | HC | | |
|----------|---------|----|----|----|-----------|----|----|----|----|----|----|---------------|----|---|--|
| | 11 | 36 | 46 | 51 | 56 | 66 | 76 | 81 | 86 | 91 | 96 | Cavity Number | | | |
| Spare | | | 1 | | | | | | | | | | | | |
| Global | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Modif. 1 | | | | | | | | 1 | | | | | | | |
| Modif. 2 | | | | | 1 | 1 | | | | | | | | | |
| Modif. 3 | 1 | 1 | 1 | | | | | | | | | | | | |
| Modif. 4 | | | | | | | | | 1 | 1 | | | | | |
| Modif. 5 | | | | | | | 1 | | | | | | | | |
| Modif. 6 | | | | 1 | | | | | | | | | | | |
| Modif. 7 | | | | | | | | | | | | | 1 | | |
| Modif. 8 | | | | | | | | | | | | | | | |
| | Sampler | | | | Companion | | | | | | | | | | |

➤ The voltage program for a cavity is the product of settings:

$$V_{\text{cavity}} = V_{\text{global}} \times V_{\text{reduction}} \times V_{\text{modif}}$$

Timing trees (1)

Timing sequence for triple splitting nominal LHC beam

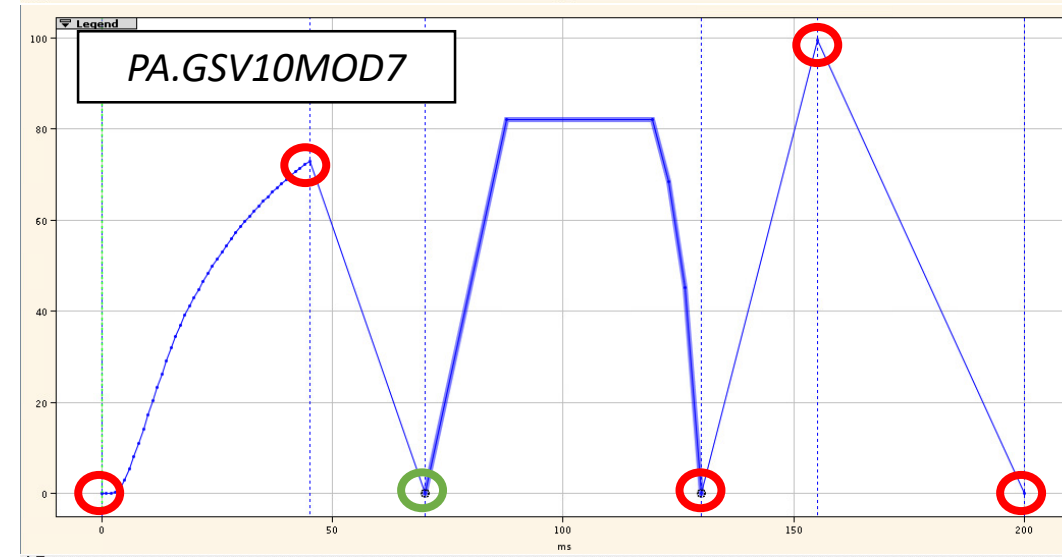
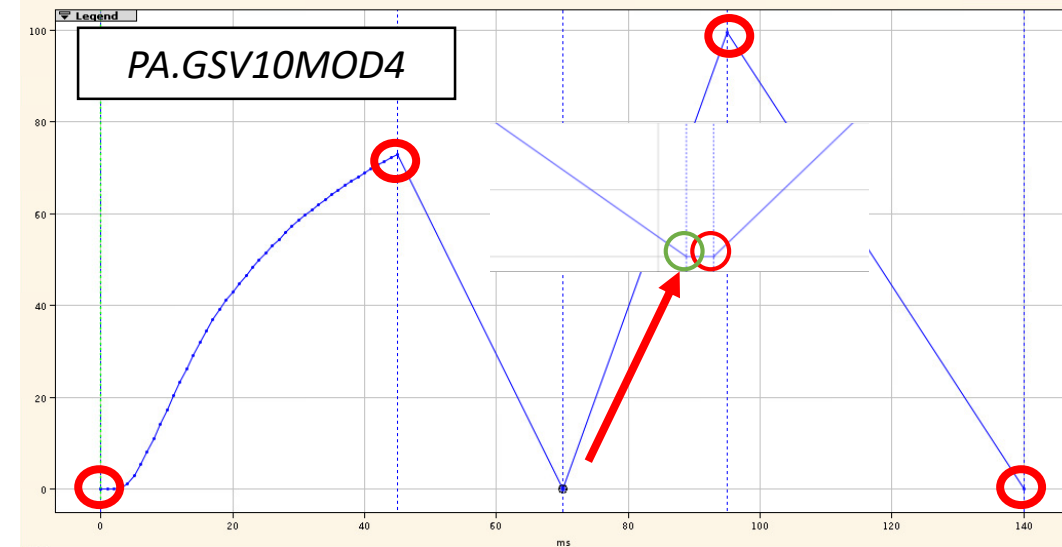
| | | | | | | | | | |
|---|--------------|---|------------|-----------|---------|-----------|-----------|---------|--|
| [-] PAX.R2VMOD3 | PAX.SH21 | 1 | 1,635.0... | 1,785.000 | -1.000 | 1,785.000 | Permitted | Enabled | Root of triple splitting. Set initial h=7 voltage. |
| [-] [-] PAX.R2VMOD6 | PAX.R2VMOD3 | 2 | 0.000 | 1,785.000 | -1.000 | 1,785.000 | Permitted | Enabled | Set initial h=7 voltage. |
| [-] [-] PAX.R2V10GLOBAL | PAX.R2VMOD3 | 2 | -35.000 | 1,750.000 | Virtual | 1,750.000 | Permitted | Enabled | Start global voltage reduction. |
| [-] [-] [-] PAX.R3VMOD3 | PAX.R2VMOD3 | 2 | 45.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=7 voltage reduction. |
| [-] [-] [-] [-] PAX.R3VMOD6 | PAX.R3VMOD3 | 3 | 0.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=7 voltage reduction. |
| [-] [-] [-] [-] [-] PAX.R3VMOD4 | PAX.R3VMOD3 | 3 | 0.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=14 voltage. |
| [-] [-] [-] [-] [-] [-] PAX.R3VMOD7 | PAX.R3VMOD4 | 4 | 0.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=14 voltage. |
| [-] [-] [-] [-] [-] [-] [-] PAX.R3VMOD2 | PAX.R3VMOD3 | 3 | 50.000 | 1,880.000 | -1.000 | 1,880.000 | Permitted | Enabled | Start h=21 voltage increase. |
| [-] [-] [-] [-] [-] [-] [-] [-] PAX.R3VMOD5 | PAX.R3VMOD2 | 4 | -50.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=21 voltage increase. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R1HPL | PAX.R3VMOD2 | 4 | 1.500 | 1,881.500 | -1.000 | 1,881.500 | Permitted | Enabled | Set phase loop offset and switch LOs to h=21. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R1H1RWHI | PAX.R1HPL | 5 | 0.000 | 1,881.500 | Virtual | 1,881.500 | Permitted | Enabled | Start h=7 radial position weight decrease. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R1H2RWHI | PAX.R1H1RWHI | 6 | 0.000 | 1,881.500 | Virtual | 1,881.500 | Permitted | Enabled | Start h=21 radial position weight increase. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.SPLH21 | PAX.R1HPL | 5 | 0.045 | 1,881.545 | -1.000 | 1,881.545 | Permitted | Enabled | Switch to real cavity return. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PX.MP1HCH-TMS | PAX.SPLH21 | 6 | 0.000 | 1,881.545 | -1.000 | 1,881.545 | Permitted | Enabled | |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R2HB | PAX.R3VMOD2 | 4 | 10.000 | 1,890.000 | -1.000 | 1,890.000 | Permitted | Enabled | Reset h=21 phase prior to acceleration. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R3HC | PAX.R2HB | 5 | 0.000 | 1,890.000 | -1.000 | 1,890.000 | Permitted | Enabled | Retune group 4 on h=21. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R2HA | PAX.R2HB | 5 | 0.000 | 1,890.000 | -1.000 | 1,890.000 | Permitted | Enabled | Retune group 3 on h=21. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R3V10GLOBAL | PAX.R2HB | 5 | 5.000 | 1,895.000 | Virtual | 1,895.000 | Permitted | Enabled | Start global voltage increase. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.S2PPROG | PAX.R3VMOD2 | 4 | 65.000 | 1,945.000 | -1.000 | 1,945.000 | Permitted | Enabled | Restart phase programme. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R3VMOD1 | PAX.R3VMOD2 | 4 | 10.000 | 1,890.000 | -1.000 | 1,890.000 | Permitted | Enabled | Start group 1 voltage. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R4VMOD3 | PAX.R3VMOD1 | 5 | 35.000 | 1,925.000 | -1.000 | 1,925.000 | Permitted | Enabled | Restart group 3 voltage. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R4VMOD6 | PAX.R4VMOD3 | 6 | 0.000 | 1,925.000 | -1.000 | 1,925.000 | Permitted | Enabled | Restart group 6 voltage. |
| [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] [-] PAX.R4VMOD4 | PAX.R3VMOD1 | 5 | 35.000 | 1,925.000 | -1.000 | 1,925.000 | Permitted | Enabled | Restart group 4 voltage. |
| [-] PAX.R4VMOD7 | PAX.R4VMOD4 | 6 | 0.000 | 1,925.000 | -1.000 | 1,925.000 | Permitted | Enabled | Restart group 7 voltage. |

- First identify the timing trees that are “in use” (corresponding to the beam control effectively in use)
- Timings are organized hierarchically and define at which moment voltage programs are started (e.g. start RF manipulation)

Timing trees (2)

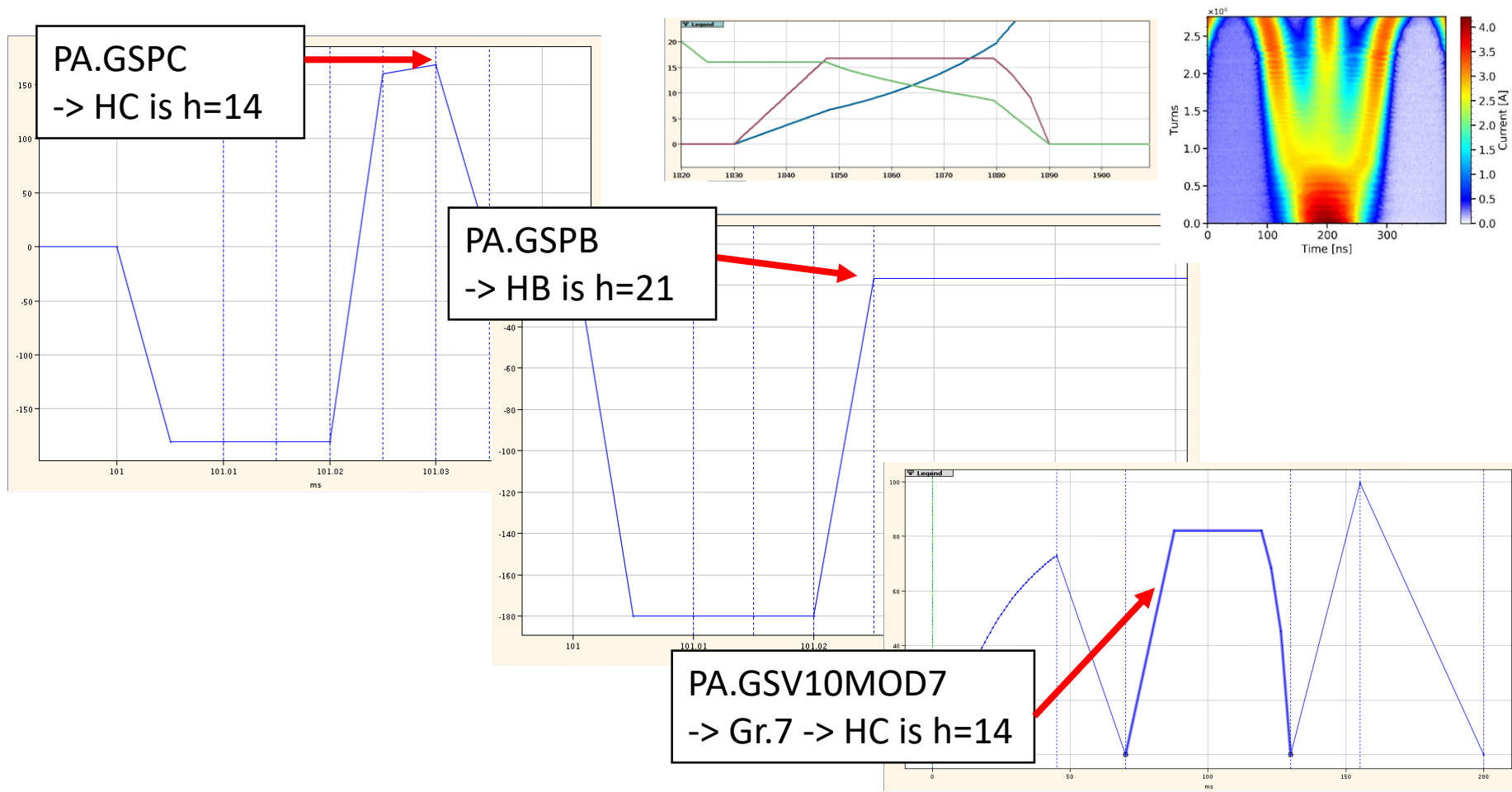
Timing sequence for triple splitting nominal LHC beam

| | | | | | | | | | |
|-------------|-------------|---|-------|-----------|--------|-----------|-----------|---------|---------------------|
| PAX.R3VMOD4 | PAX.R3VMOD3 | 3 | 0.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=14 voltage. |
| PAX.R3VMOD7 | PAX.R3VMOD4 | 4 | 0.000 | 1,830.000 | -1.000 | 1,830.000 | Permitted | Enabled | Start h=14 voltage. |



- Let's find which voltage should be adjusted for the triple splitting at h=14.
- Cavities of the voltage group 4 are going to play 0 V (these timings are kept should we need more voltage!)
- Cavities of the voltage group 7 are going to play the triple splitting voltage program (effectively a single cavity)
(NB: this function is available in the LL_MD workingset)

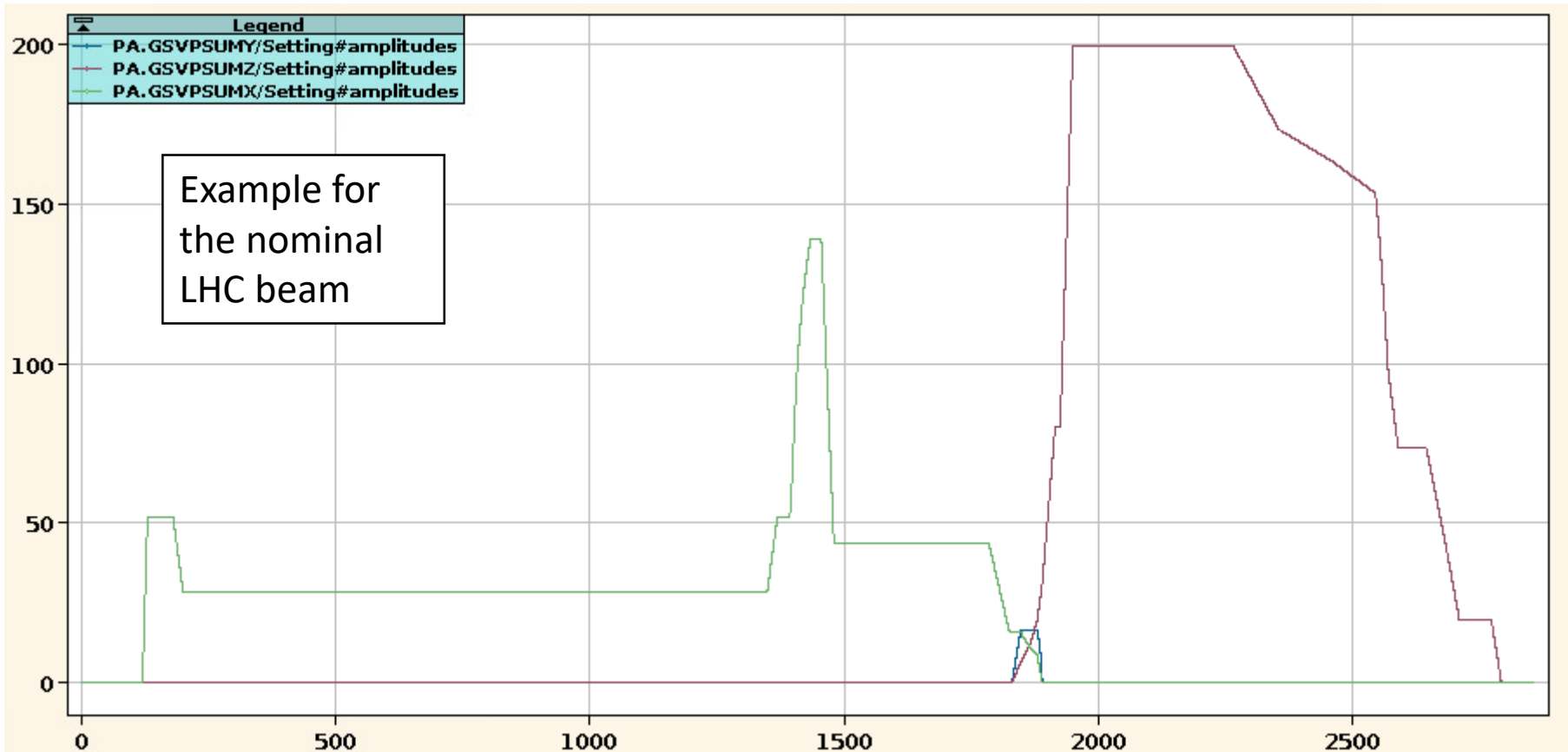
Adjusting the settings for the triple split.



- Two questions to practice until next time:
 - Where is the phase setting to adjust the merging?
 - Can you verify how we go from 36b to 48b BCMS by switching the RF phases?

Real time and per cavity functions

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- Real time functions are available noted with the “RT” suffix, as well as function per cavities (PA.GSVPCxx, PA.GSRPCxx, PA.GSHCxx...).
- Processed samplers per harmonic show the effective total voltage (in CPS:RF-TREATED-BY-H workingset).
- The final voltage program per RF harmonic is available in the PA.GSVPSUMX-Y-Z functions.

RF processes and setting up across beams

| Process | TOF | EAST | AD | SFTPRO | LHC#multib | LHC#1b | ION#multib | ION#1b |
|---|-------------------------------|-------|------------|---------------|--------------------------|--------|-------------------|----------------|
| Injection1 (inj. phase, voltage, energy matching) | -VJBR BUP | BUP | BUP | (BUP) | | | | |
| Injection2 (idem) | | | | | BUP, FSteer | | | |
| Intermediate plateau | BUP | BUP | | Split, BUP | BC, Merge, Split, BUP | (BUP) | BE, Split, BUP | RB, BUP |
| Transition crossing | Phase jump amplitude + timing | | | | | | | |
| Ramp | HD | HD | HD, BUP | HD, BUP | HD, BUP, CBFB | HD | | |
| Synchronization | | | Fine | H1H16 | Coarse Fine | Coarse | Coarse Fine | Coarse Fine |
| Top energy | | | BC | (MTE) | Split | RB | RB, (BC) | RB |
| Extraction 1 | PJBR | PJBR | PJBR | 200MOD | VJBR | VJBR | AS | AS |
| | -PJBR | -PJBR | | BB | | | | |
| Extraction 2 | PJBR | PJBR2 | | | | | | |

VJBR: (-Anti) Voltage jump bunch rotation

BUP: Long. blow-up

HD: Hereward damping

RB: Rebucketting

BB: Barrier Bucket

PJBR: (-Anti) Phase jump bunch rotation (2 osc. periods)

BC(E): Batch Compression (Expansion)

CBFB: Coupled bunch feedback

AS: Adiabatic shortening

GREEN: at least 1 ref acq.



Operational adjustments

—

Tuning violins with various tools...

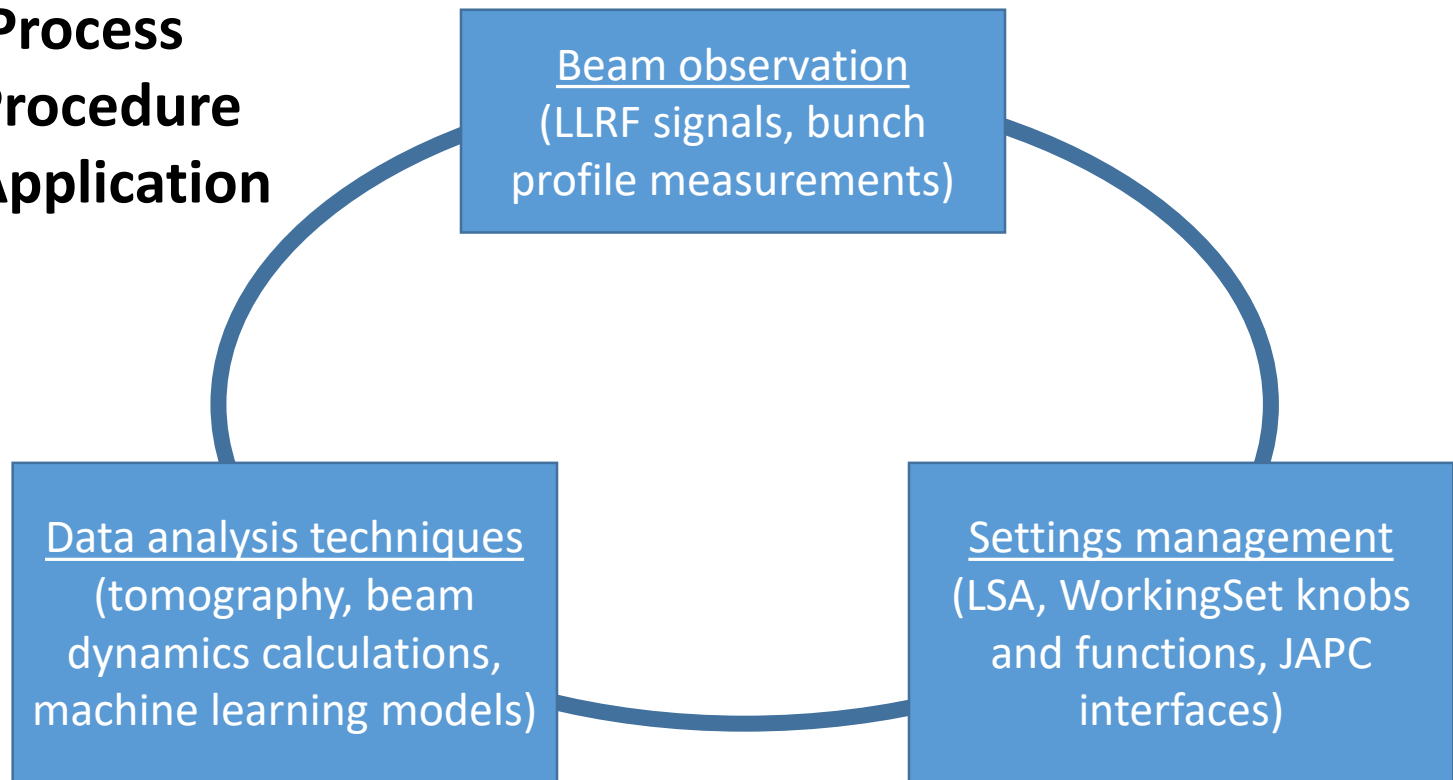


General model for settings adjustments

RF Process

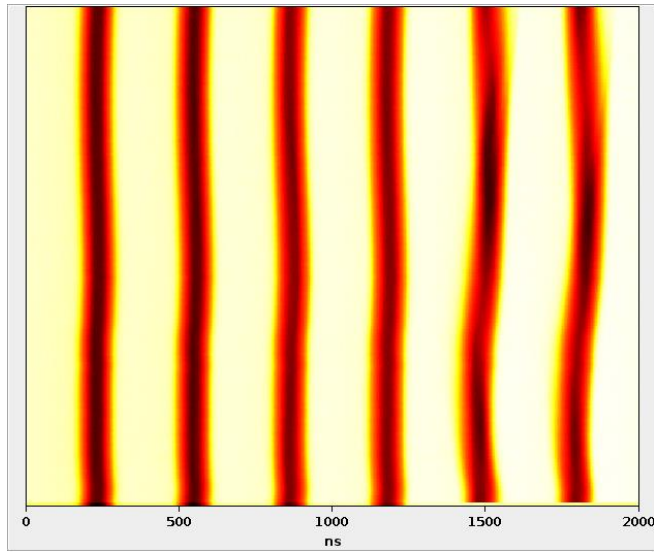
-> Procedure

-> Application



- Let's check for some cases how you would optimize
 - Injection oscillations
 - Energy matching
 - Splittings
 - Synchronization

Injection oscillations, phase oscillations



PA.GSPINJ for all bunches phase offset

PA.GSPINJ 1

Enable

Amplitude

Ref. 59.00

Init 59.00 deg

Amplitude **59.00 deg**

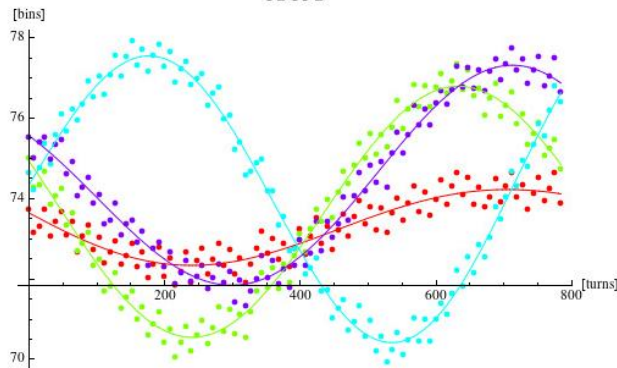
Delay

Ref. 101.000000 ms

Init 101.000000 ms

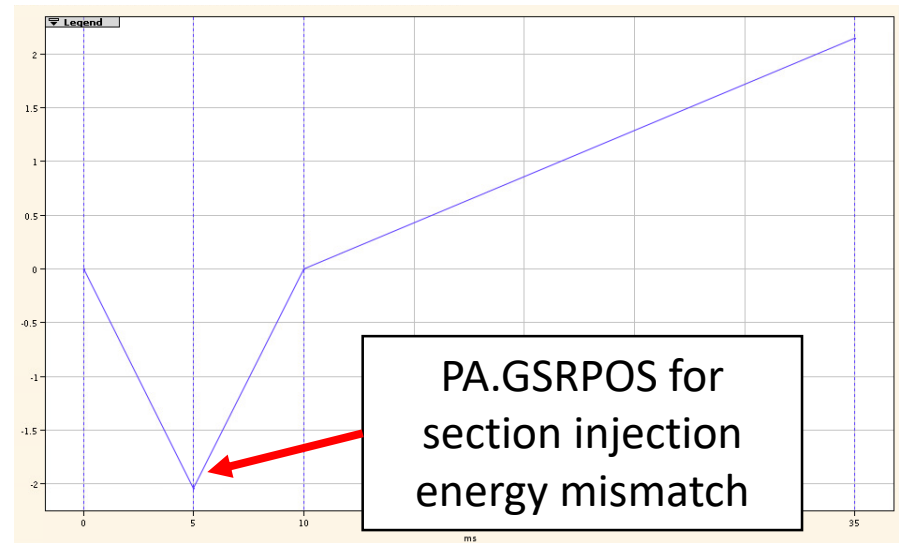
Delay **101.000000 ms**

```
fitinjosc["extensions/injosc.dat", 3492541.5, 1, 2]
TSTPS
```



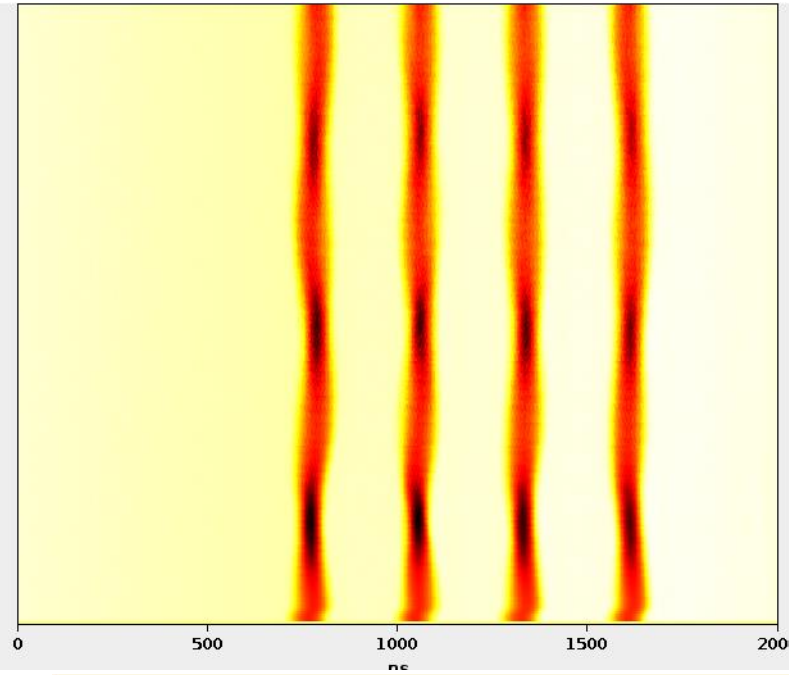
| | $\Delta\phi$ [deg] | ΔE [deg] |
|---|--------------------|------------------|
| 1 | 0.5 | 3.3 |
| 2 | 3.0 | 7.7 |
| 3 | 0.4 | -8.0 |
| 4 | 3.2 | 4.3 |

Mathematica notebook to compute expected phase



PA.GSRPOS for section injection energy mismatch

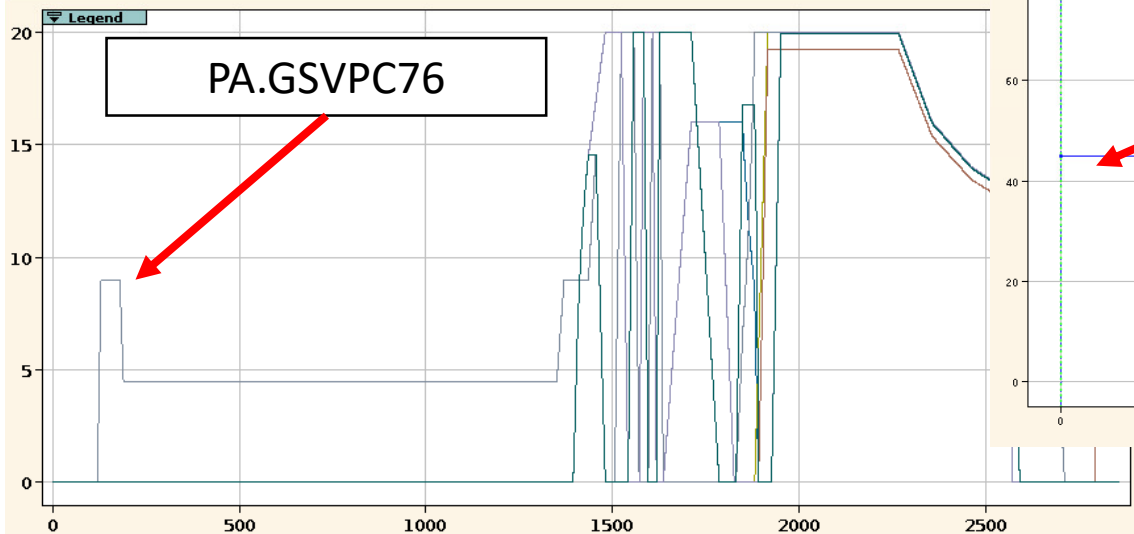
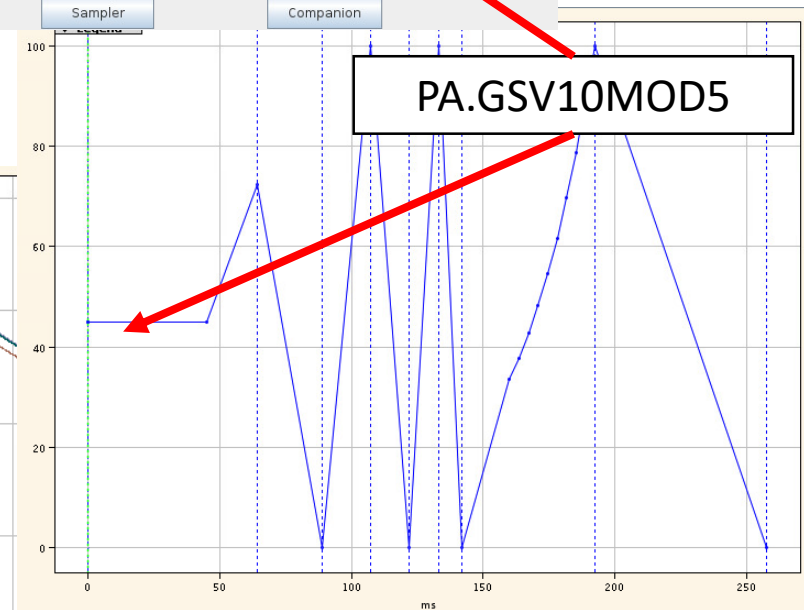
Injection oscillations, amplitude oscillations



Cavity Number

| | 11 | 36 | 46 | 51 | 56 | 66 | 76 | 81 | 86 | 91 | 96 |
|----------|----|----|----|----|----|----|----|----|----|----|----|
| Spare | | | 1 | | | | | | | | |
| Global | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Modif. 1 | | | | | | | 1 | | | | |
| Modif. 2 | | | | | 1 | 1 | | | | | |
| Modif. 3 | 1 | 1 | 1 | | | | | | | | |
| Modif. 4 | | | | | | | | 1 | 1 | | |
| Modif. 5 | | | | | | | 1 | | | | |
| Modif. 6 | | | | 1 | | | | | | | |
| Modif. 7 | | | | | | | | | | 1 | |
| Modif. 8 | | | | | | | | | | | |

Buttons: Sampler, Companion



Energy matching

How to perform energy matching?

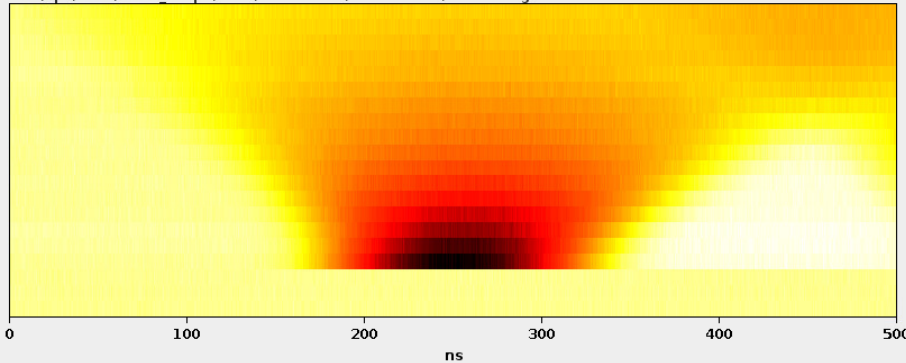
1. Open tomoscope and look at first ~100 turns after injections
2. Disable RF (manually or via the button after choosing a particle type)
3. Save tomoscope acquisition to file and load it
4. Measure offset on the MRP and set it at the bottom of the window
5. Adjust injector (PSB/LEIR) and PS settings if needed
6. Do the computation and enter the proposed values for each accelerator
7. Check with your tomoscope if it is ok
8. Repeat previous steps (from #3) if needed
9. Re enable the RF

RF Controls

Tick to control RF for ions beam **Enable RF** **Disable RF** **Open RF Knobs**

Tomoscope data

Select file...
/cps/data/tomo_scope/save/references/ILHC100#4b/ematching.dat



Machine parameters (from tomo file)

LEIR Circ. = 78.00 [m] yrel = 2.48 ytr = 2.80

▲▲▲▲▲▲ ▲▲▲
B 11500.000 G
▼▼▼▼▼▼ ▼▼▼

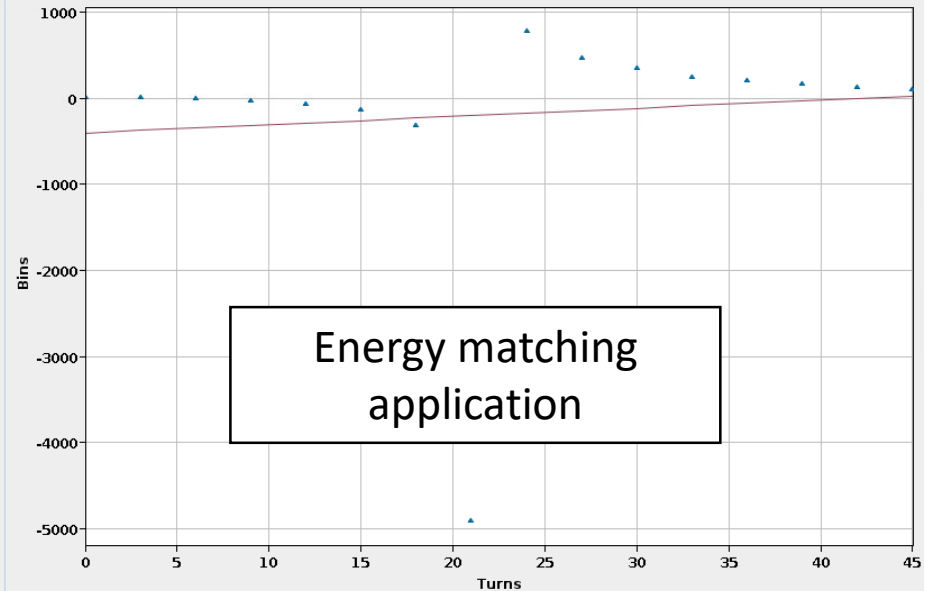
PS Circ. = 628.32 [m] yrel = 2.48 ytr = 6.12

▲▲▲▲▲▲ ▲▲▲▲▲▲ ▲▲▲ ▲▲▲
B 681.996 G # Profiles to skip 4 H 16
▼▼▼▼▼▼ ▼▼▼

▲▲▲▲▲▲▲▲▲▲ ▲▲▲ ▲▲▲▲▲▲
F. Liaison 2840000.00 Hz ΔR 0.00 mm
▼▼▼▼▼▼ ▼▼▼

Compute energy matching -->

Energy matching



Results

LEIR + PS

New B for LEIR [Gauss]: **11434.967 (-65.033)**

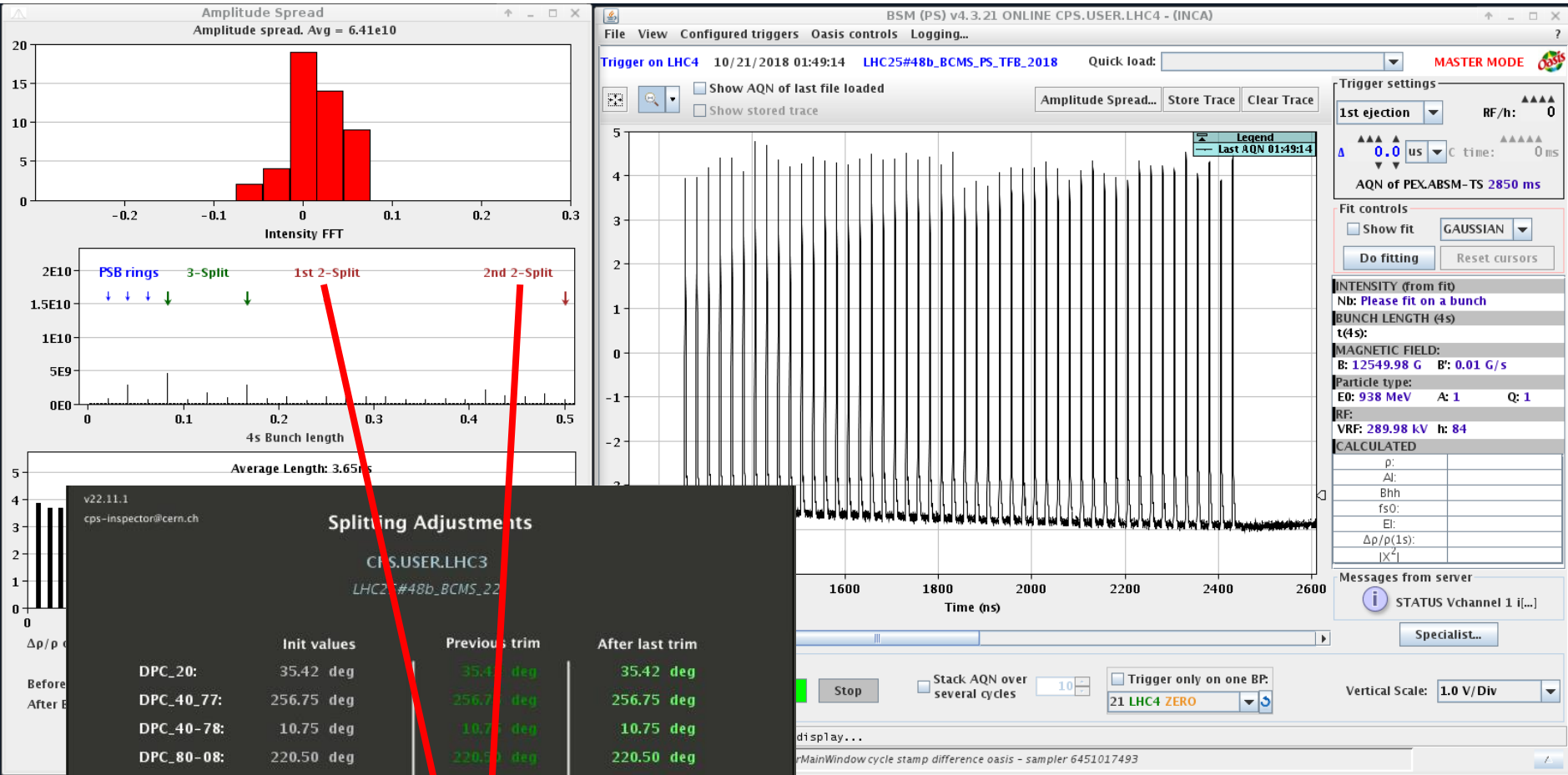
New B for PS [Gauss]: **682.666 (+0.67)**

PS Only

New B [Gauss]: **686.523 (+4.527)**

New Frequency [Hz]: **2853837.754 (+13837.754)**

Double splittings adjustments



Inspector panel to adjust double splittings

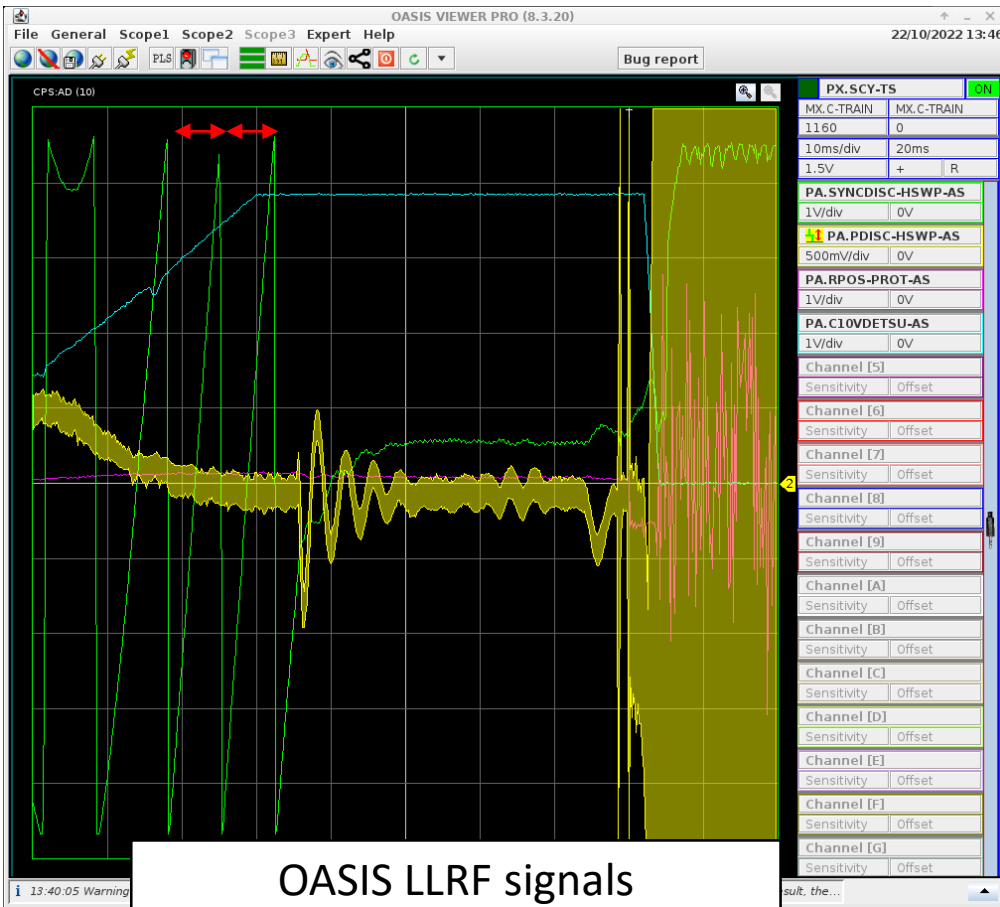
RL applied to triple splitting

16

The screenshot displays a complex software interface for a tomography experiment. The main window, titled 'Tomoscope 2 - (INCA)', shows a plot of three overlapping waveforms. The x-axis is labeled 'ns' and ranges from 0 to 350. The y-axis is labeled 'V. Scale'. Below the plot, there are controls for 'H. Scale' (set to 1 ns/pt), 'N Samples' (400), and 'DeLay' (2146 ns). A 'Phase optimisation' window is open in the foreground, showing a large empty area. To the right, a 'KnobsOpen application' window shows two knobs: PA.GSRPB and PA.GSRPC. The PA.GSRPB knob has an amplitude of -30.78 deg and a delay of 101.000000 ms. The PA.GSRPC knob has an amplitude of 162.00 deg and a delay of 101.000000 ms. The console at the bottom shows terminal output for a script execution, including commands like 'hash -r', 'unset VIRTUAL_ENV', 'export VIRTUAL_ENV', 'export PATH', 'export PS1', and 'python test_tomo_script.py stdin'.

[J. Wulff, User instructions for running Automatic Splitting Optimization scripts - CodiMD \(cern.ch\)](#)

Synchronization



OASIS LLRF signals
(PA.SYNCDISC or via global)

PA.GSRPOS 1 >

Enable

Amplitude

Ref. 0.90

Init 0.90

▲▲▲▲▲▲▲▲▲▲

Amplitude

▼▼▼▼▼▼▼▼▼▼

Delay

Ref. 0.005000

Init 0.005000

▲▲▲▲▲▲▲▲▲▲

Delay

▼▼▼▼▼▼▼▼▼▼

Changing radial placing to adjust synchro phase sweep

Present limitations for adjustments

RF Process

-> Procedure

-> Application

Beam observation
(LLRF signals, bunch
profile measurements)

- Not permanently available
- Limited availability
- Difficult to set-up

Data analysis techniques
(tomography, beam
dynamics calculations,
machine learning models)

- Expert scripts (black boxes)
- Various scripting languages (fortran, mathematica, python)

Settings management
(LSA, WorkingSet knobs
and functions, JAPC
interfaces)

- Difficult to visualize
- Difficult to identify relevant parameters
- Different entry points for adjustments
- Reference settings difficult to determine



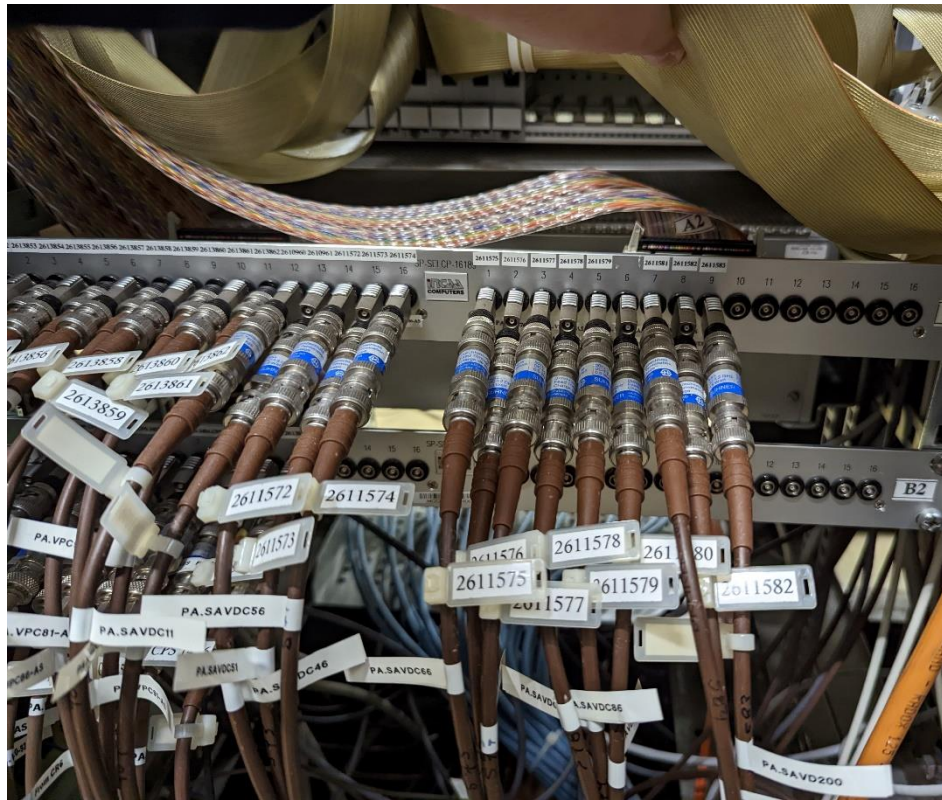
What's next?

—

*From the analog to digital
Stradivarius...*



Installation of new LLRF Samplers



| OASIS signal name | Duration | Signal source | Priority |
|-------------------|-------------|--------------------------|----------|
| PA.PDISC-H8H16-AS | Whole cycle | CR30-4/11 - CMR Buffer 5 | 1 ● |
| PA.PDISC-H16LI-AS | Whole cycle | CR30-4/10 - CMR Buffer 2 | 1 ● |
| PA.PDISC-HSWP-AS | Whole cycle | CR30-4/10 - CMR Buffer 7 | 1 ● |
| PA.PDISC-LHC-AS | Whole cycle | CR6-1/11 - CMR Buffer 2 | 1 ● |
| PA.PDISC-ION-AS | Whole cycle | CR30-4/12 - CMR Buffer 5 | 1 ● |
| PA.PDISC-H42-AS | Flat top | CR6-1/11 - CMR Buffer 3 | 2 ◆ |
| PA.PDISC-H84-AS | Flat top | CR6-1/11 - CMR Buffer 4 | 2 ◆ |
| PA.PDISC-H169-AS | Flat top | CR30-4/12 - CMR Buffer 6 | 2 ◆ |

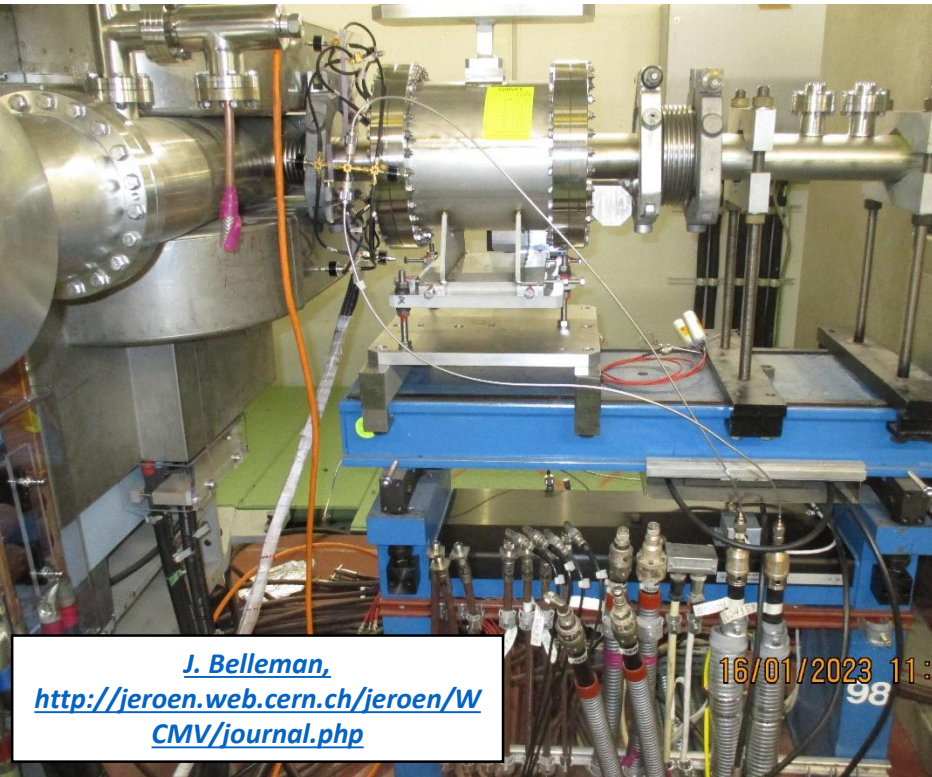
| OASIS signal name | Duration | Signal source | Priority |
|-------------------|-------------|--------------------------|----------|
| PA.RPOS-PROT-AS | Whole cycle | CR30-4/12 - CMR Buffer 1 | 1 ● |
| PA.RPOS-H16LI-AS | Whole cycle | CR30-4/11 - CMR Buffer 1 | 1 ● |

| OASIS signal name | Duration | Signal source | Priority |
|-------------------|-------------|---------------|----------|
| PA.C10VDETSU | Whole cycle | CR28-1/5 | 1 ● |

- Cavity voltage programs presently well covered by samplers.
- Low level RF signals are presently only available through OASIS which is not suited for online monitoring of signals.
- Aim at simplifying the maintenance and instructions for operational adjustments and optimization.

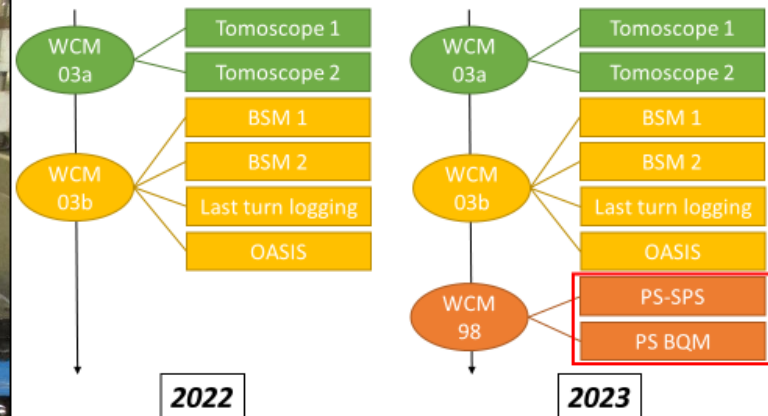
New Wall Current Monitor

???



[J. Belleman,
http://jeroen.web.cern.ch/jeroen/WCMV/journal.php](http://jeroen.web.cern.ch/jeroen/WCMV/journal.php)

Implementation - New WCM in PS



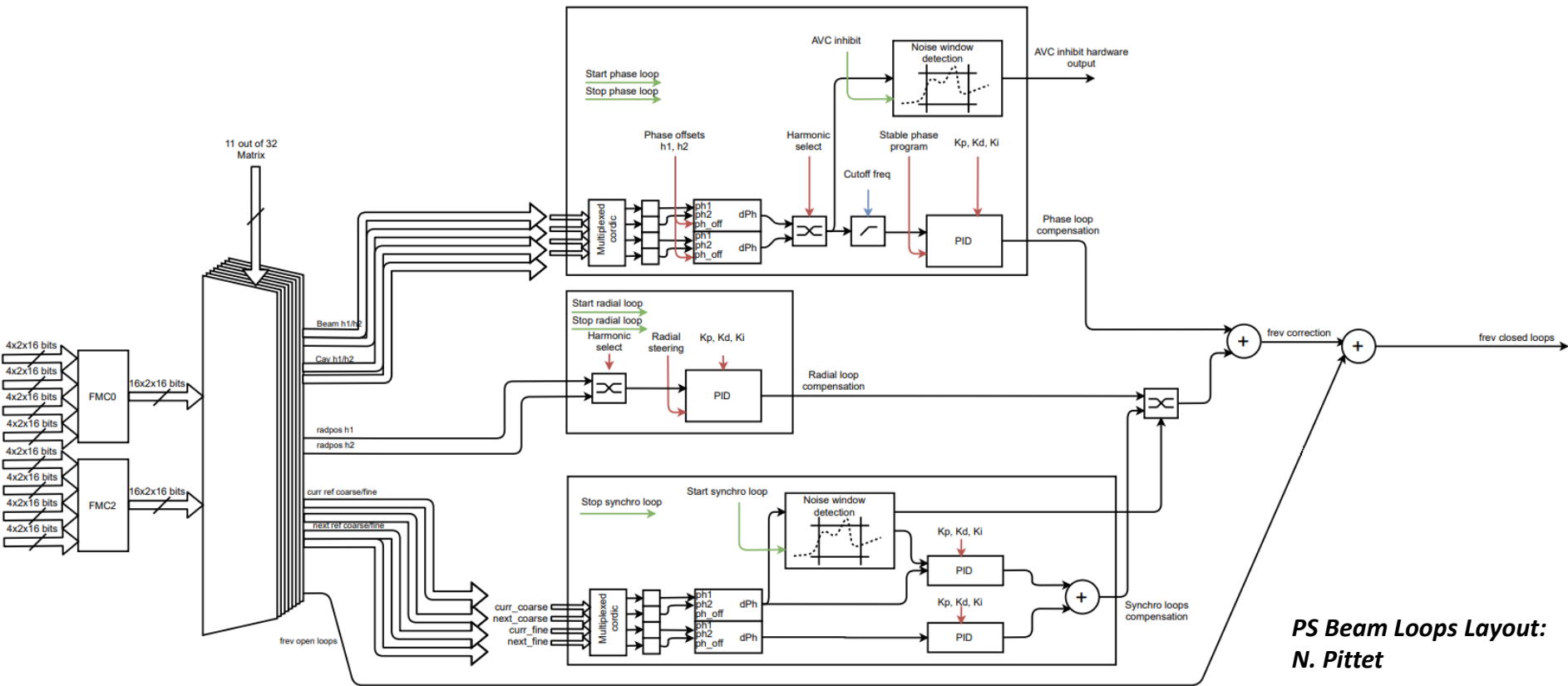
- New Wall Current Monitor approved as LIU aftermath, two more channels (NB: approved earlier, not in the context of the small project). The WCM will be installed in the PS during YETS 2022-2023.
- The lines cannot be split further without degrading the signal quality to accommodate for a PS-SPS acquisition system.

[Injectors Performance Panel: Mini workshop on KPIs \(29 April 2022\) · Indico \(cern.ch\)](#)

- New WCM install in SS98 in view of development for a PS Beam Quality Monitor.
- Together with a upgrade of all digitizer cards by BE-CEM (Tomoscope, BSM, last turn logging...), will require further developments to allow for more systematic data acquisition and analysis.

Digital beam control

???



PS Beam Loops Layout:
N. Pittet

- Digital beam control under development to be tested during the Run.
- Full operational implementation will require a whole new set of settings (controllable loop gains), procedure for operational adjustments...

New power converters for C10 tuning

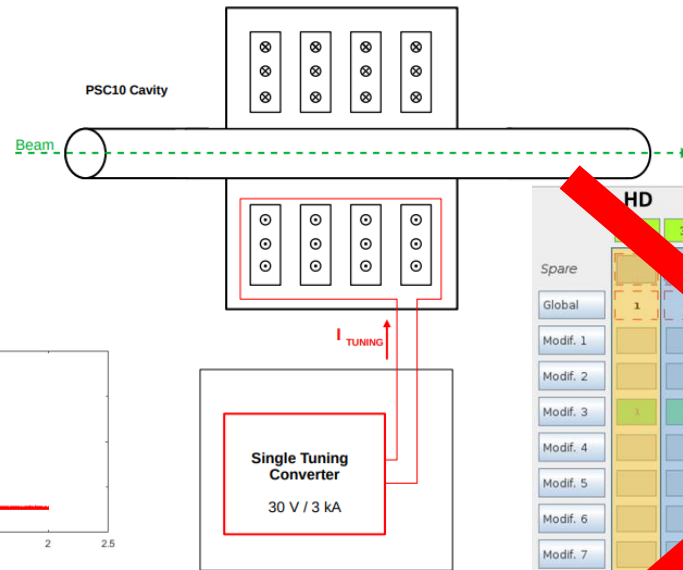
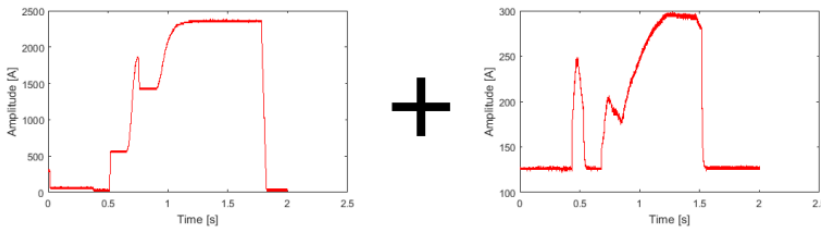
???

Single tuning power converter

L. De Mallac

- One 3 kA / 30 V per cavity.
- Independent frequency for each cavity.
- Improved flexibility for operation.
- Current reference = Coarse + Fine

Tuning current:



The screenshot shows a control interface with a grid of buttons. The columns are labeled 'HD', 'HA', 'Cavity Number', 'HB', and 'H'. The rows are labeled 'Spare', 'Global', 'Modif. 1' through 'Modif. 8'. A large red 'X' is drawn over the entire interface.

- Present power converters reaching end of life, requires consolidation and installation during LS3.
- Present proposal to have single tuning power converter will give ultimate flexibility for operation, ease of implementation of high level parameters

Final words



- The adjustment of RF parameters in the PS is a daily challenge. A full setting up and qualification of a beam requires experience, time and usage of heterogeneous environment.
- Future hardware changes will change in depth the mode of operation of RF systems in the PS. A review of the settings, observables, applications is needed in preparation for these changes.
- A review would also be necessary to address present issues and bottlenecks (update WorkingSets, missing Makerules, needs for permanent signals and online data analysis, interfacing with other machines...).
- This would also be an approach to consolidate knowledge and provide feedback on means to improve PS RF operation
An RF process a day, keeps the RF expert away...