Digital LLRF: achievements and LS1 plans


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Outline

1. DLLRF for PSB: recap
2. 2012 run achievements (highlights)
3. Plans for LS1
4. Conclusions & outlook
DLLRF for PSB: recap

- Part of **global effort for all Meyrin synchrotrons’ LLRF**
  - Big investment for the RF group (manpower).
  - One of the two LLRF families in BE/RF: sweeping (LEIR, PSB, ELENA ...) vs. ~fixed-frequency (LHC, Linac4) machines.

- DLLRF **supports PSB HLRF R&D** (Finemet studies or upgrade of C02,C04,C16 systems).

- **Collaboration with MedAustron** (LLRF + HLRF).

- **PSB to restart with DLLRF in 04/2014** (4 rings + “ring 0”).

- **MA synchrotron** to be commissioned with DLLRF by fall 2014.
Outline

1. DLLRF for PSB: recap

2. 2012 run achievements (highlights)
   - Beam tests with prototype HW
   - Finemet R&D support + beam tests with prototype HW
   - Development & test of final HW+SW, BOR re-organisation...

3. Plans for LS1

4. Conclusions & outlook
2012 run achievements: overview

Exceptional achievements in 2012 with manpower available

project team members heavily involved in machines operation & other projects.

Three parallel paths (DLLRF in PSB ring 4):

- **Beam tests with prototype HW**
  - DSP + high level code upgrade

- **Finemet® R&D support & beam tests with prototype HW**
  - Hardware + DSP (Finemet servoloop et al.) + high level code upgrade

- **Development & tests of final HW + SW, BOR work**
  - HW, firmware, DSP, FESA, lab tests, tools, synoptics, BOR re-organisation, DLLRF installation, beam simulator …
Beam results: single batch transfer

**What:** to synchronise & extract non-equi-spaced bunches to the PS. 
*operational beam*

**How:** $h=2+1$, maintain 30% of C02 voltage after splitting. $H=2$ beam synchronised to $h=1$ reference.

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Tomogram of synchronised bunches @extraction.

Bunches @extraction. Ring 4 with DLLRF & Rings 3 with existing LLRF.

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PSB Ring 4 (DLLRF)

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Beam results: single batch transfer + rebucketing

**What:** to synchronise & extract to the PS dense and short bunches.

**MD beam**

**How:** to generate empty bucket on $h=2$ beam and to synchronise the single bunch to the $h=1$ extraction reference.

Tomogram of rebucketed & synchronised bunch @extraction.

Bunches @extraction. Ring 4 with DLLRF & Rings 3 with existing LLRF.

PSB Ring 4 (DLLRF)
Beam results: jump to unstable phase & back (*)

What: implement MedAustron slow extraction scheme; to synchronise & extract to the PS dense & short bunches. Conceptual feasibility study.

How: a controlled jump to the unstable phase, then return to the stable phase with a rotated bunch.

Tomogram of rotated bunch after return to stable phase.

(*): Many thanks to S. Hancock for his instrumental help on this topic!!
**Finemet® R&D beam results (see M. Paoluzzi’s talk)**

**What:** to accelerate high intensity beam with Finemet + C02 HLRF, both controlled by DLLRF (PSB Ring 4).  **Feasibility study.**

**How:** Finemet® phase-aligned with C02.  

Finemet®: 2 kV.  
C02: 8 kV (accel) to 1.5 kV (extr.).

500E10 protons (~6A) captured & accelerated

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Development & tests of final HW & SW

- Six types of modules: **MDDS v 2.0, ADC v3.0, DAC v 2.0, FMC-DSP-Carrier v 1.0, RTM v 2.0, VXS Switch v 2.0.**
- **VXS switch v 2.0** compatible with future B-train system distribution @PSB (many discussions with TE/MSC).
- Transferred 2-boards system to MA test stand for MA controls dev’pment

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**PSB single-ring system after LS1**

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Development & tests of final HW & SW - 2

- Firmware & DSP: many MB written & validated
  - It is text file → *lotsa* code !!
  - Co-operating developers / SW blocks
  - needed not only for exploitation but also for HW tests.

- Python scripts for interactive, automatic or overnight lab test of boards

HW tests: virtual test-bench. Picture courtesy of J. Sanchez-Quesada
SW tools for memory map management & automatic drivers generation.

- Big investment from RF group (RF/CS section), still on-going.
- To be used for all RF projects, not only DLLRF.

Memory map management tool (Cheburaska) GUI

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Other developments started

- **Beam-in-a-box** (A. Blas, M.E. Angoletta, J. Molendijk, J. Sanchez-Quesada)
  - Beam simulator (HW + SW)
  - To test DLLRF phase, radial, extraction synchro loops
  - Starting point: refinements & upgrades possible.

- **Interlock system** (A. Blas, S. Zorzetti)
  - Interfaces DLLRF, HLRF, BIS, Chopper
  - Includes also Ring 0 & Finemet cavities
  - Available in 2015, to be operational with Linac4.

*Picture courtesy of A. Blas & S. Zorzetti*
PSB BOR work

- Equipment moved in BOR to make space for 4 rings + “ring 0” HW
- All cables needed by DLLRF for operation already pulled (only rack-to-rack cabling still to be done).
- Final B-train distribution, additional Ethernet, connections, timings…
- DLLRF installed in BOR + HW, SW & controls commissioning.
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Plans for LS1

- Complete DLLRF development.
- **HW series** production for **PSB + MA**. Also PSB TFB? Decision by 05/2013.
- Install DLLRF in PSB BOR & carry out **HW commissioning**.
- Renovate existing **Oasis** analogue digitizers. Select + have installed **Oasis digitizers** for DLLRF analogue signals.
- Validate & re-commission BOR controls upgrade (ACCOR).
- Finalise **interlock system** (production & validation).
Plans for LS1 (MedAustron)

- Contribute to:
  - finalise MA LLRF design & controls interface.
  - customise SW features.
  - implement MA-specific functionalities.

- Summer-fall 2013: **MA Finemet cavity tests** (with M. Paoluzzi)
  - Tests will be carried out in MA test stand @CERN.
  - Anticipation of development to be done for PSB Finemet tests.

*Very good for CERN to gain system experience*
Conclusions & outlook

- DLLRF for PSB part of global effort for all Meyrin synchrotrons.
- Fruitful (win-win) collaboration with MedAustron.
- Exceptional achievements before LS1:
  - Beam tests (PSB LLRF + Finemet® R&D)
  - Development (HW, SW, tools…)
- Heavy planning for LS1: PSB + MA.
- MA synchrotron to be commissioned with DLLRF by fall 2014.
- After LS1:
  - PSB to restart with DLLRF in April 2014 (4 rings + “ring 0”)
  - DLLRF to support full-cavity Finemet R&D or C02,C04,C16 consolidation