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Wir schaffen Wissen – heute für morgen

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Timing system of the SLS and the SwissFEL

- Agenda:
- Some history
- The SLS timing (recap)
- What we done with it (applications)
- The SwissFEL and its timing requirements
- Our plans
-
- Note: majority of what is done in the timing area (applications) nowadays is done by my colleague Babak Kalantari. Although we are discuss the issues almost daily, for more details please ask him.

A short history of how the timing business with Micro-Research got started (about 12 years ago)

- my first job at PSI (the Swiss Light Source project) was to figure out a solution for the machine timing
  - Had a couple of APS event cards
  - Policy: No hardware development in the controls
  - Find a manufacturer to produce cards
  - Best offer came from Micro-Research
    - Asked if redesigning the cards were OK. Yes!
  - Contract in 1999; first application (booster commissioning) mid-2000
- Added RF-synchronization, lots of other features
- Diamond got interested
- Other institutes followed...

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Because others followed...

- The BIG advantage: the new cards are backwards compatible (except cabling, but that's ok)
- Otherwise, we would have a big obsolescence problem
  - No possibility to upgrade
    - Would mean unhappy users
- Now we can replace old components with new gradually
  - New users (or users with new requirements) get a new card
- Lesson: keeping systems continuously up-to-date is a great value
  - One may appreciate it fully only when the time comes...

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The SLS timing in short

Injection system based on event system (first MRF design – everybody else is more modern now…)

- Special cards in Linac local timing (KEK design)
- 3.125 Hz injection cycle
- Use records inherited from APS (eg, egevent, er, erevent)
  - Saved time to get started
  - I soon came to dislike these records but they did their job (for us - others have had to tweak)
  - now they have been refactored to simple records by Michael Davidsaver at BNL – good!
- Injection control, diagnostics, power supply control, beamline timing,etc. Is provided by event system.

Experiences from the first 12 years

Reliability is important: first system to start, always on

- We have had very little hardware problems
- Most problems from cabling, especially from patch panel connections
  - transceiver failures may be on the increase (too early to say)
    - The earlier ones are not pluggable

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Where we still may have a few specialities: the applications on top of the timing system

Top-up with filling pattern control (aka FPF)

- SLS machine was designed for top-up. We started regular top-up operation few months after machine start
- top-up has a huge impact on machine stability
- Our application can do any filling pattern (that the machine tolerates) and keep the pattern
- Please look at my filling pattern monitor talk from the previous EPICS meeting
- Good filling pattern control helps to reduce many unstabilities:
  - BPM filling pattern dependency, RF instabilities
  - Our (microfocus) beamlines saw these before

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Other applications: Operating modes (part of injection control):

- Use (or non-use) of the injector when top-up is not active
  - In the beginning just switched the linac trigger
- Mode 1: Powersave
  - Do not trigger booster ramps, kickers
  - But: they need to be warmed up before injection works well
  - Do some empty cycles before sending beam from linac
  - Huge saving in electricity
  - Increase lifetime of thyratrons (of pulsed magnets)
    - We did not get to keep the saved money…

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Other applications (continued)

- Mode 2+ (has a couple of variations): top-up+experiments
  - To allow the use of the linac for experimenting when it is idle (development, PhD students,...)
    - Many measurements can be done interleaving the operation. e.g., use screen monitors but drive them out when injection needed – and back again when injection done
  - Use linac only, or linac and booster for experimenting
  - Has made several measurements and graduate theses possible...

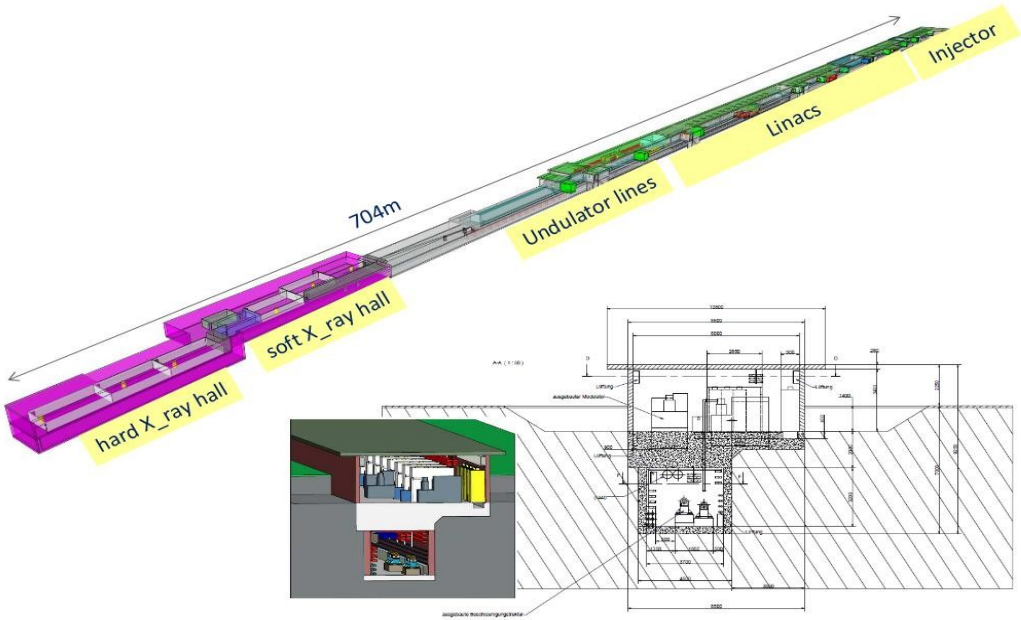
New issues:

- More and more beamline requests for timing support
  - Time-resolved experiments
  - Hybrid fill – single bunch
  - 500 MHz data acquisition (see the talk at BNL)
    - (magnetic domains, low photon intensity)
  - Detector synchronization
    - Many detectors triggered in complicated patterns
- Exotic fills
  - Multi-camshaft
  - „comb“
- Low-alpha mode

  the special fills do not need any extr work from us

The SwissFEL Machine

Recap before going to the timing details:
The accelerator will be a “compact” X-ray FEL (many similarities to SACLA at Spring-8)



- C-band RF
- 100 Hz repetition rate
- (plan) two bunches in each cycle, separate bunches with a fast kicker
- the machine will be underground, technical gallery right above (place constraints)

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The SwissFEL Timing and synchronization

- Event system (Micro-Research) for operation sequencing, optical system for reference generation and distribution
- We need beam synchronous data collection and actions (is already under development)
  - Collect a number of PV:s so that they are guaranteed to be from the same pulse
    - Bpm readings, RF pulse parameters, camera images,..etc.
    - Can be nicely synchronized with events
    - Diverse hardware platforms
      - » Developed Linux diver for (PMC) EVR
      - » Contact Babak if you are interested
      - » First version but seems to be stable

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Beam synchronous data acquisition

- The first user requirements for BS DAQ were very „creative“
- We were already thinking about a dedicated data network (for timing and data)
- But put that on hold and work with easier to implement stuff (SLAC implementation with some enhancements) to get experience until we get a better idea of the real requirements
- We may have to revisit the TDN idea soon (in a year or so)

Enhancements that we would like to have:

- 142.8 MHz frame rate
- This is the frequency of our master oscillator
  We have a complicated mixture of cavity and other components´ frequencies – running at the master RF rate would make things easier
  - Avoid complication with „superperiods“ - subharmonics to satisfy different subsystem needs (laser, LLRF,...
- On-EVG sequencer (offload CPU)
  - Lots of sequence programming (master pattern generator)
  - Idea:load patterns to EVG, EVG runs autonomously

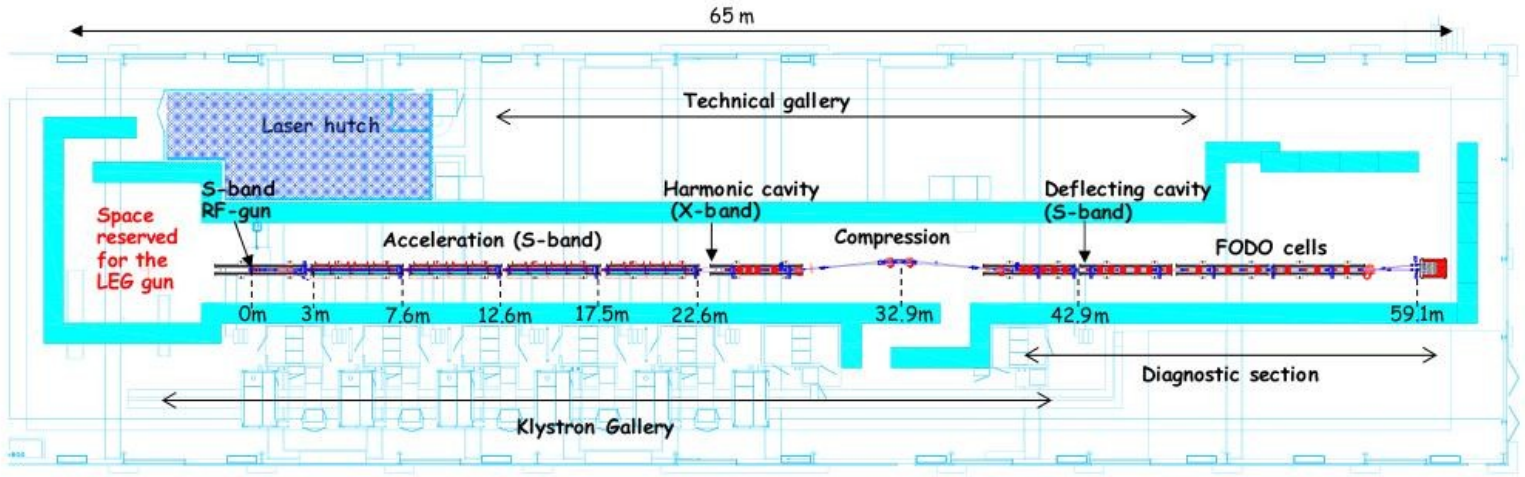
Enhancements that we would like to have (cont.):

- Use of upstream link, from EVRs to EVG
  - Discussion about tighter machine-beamline communication (beam trigger fine-tuning)
    - The idea is not fully developed yet...
  - The uplink feature is in fact there, but we have not yet used it.
- Monitoring of the fanout/concentrators
  - Transceiver temperature, power level,...
  - Is already been/being implemented?

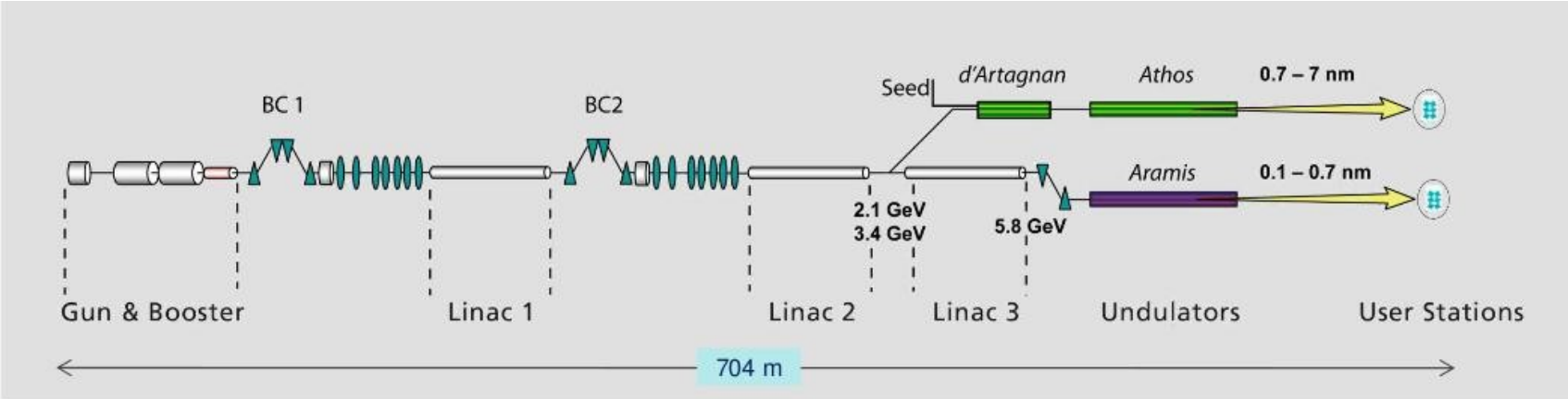
Acknowledgements

Jukka Pietarinen for his great work, all the users of the event system and of course Babak Kalantari.

Test Machine: 250 MeV Injector



The SwissFEL Machine



Two beamline branches:

•Aramis: Hard X-ray SASE FEL. Wavelength tuning mainly by electron beam energy (2.2 – 5.8 GeV) with some tunability by the gap of the undulator modules.

•Athos: Soft X-ray SASE FEL with APPLE II type undulator modules. Wavelength tuning by undulator gap with two injection energies of the electron beam (2.1 and 3.4 GeV).

D'Artagnan: FEL for wavelengths above Athos, seeded with an HHG source.