



Wir schaffen Wissen – heute für morgen

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SwissFEL Timing System

SwissFEL Machine

1st phase

2013-16

Photocathode

RF gun

Linear accelerators

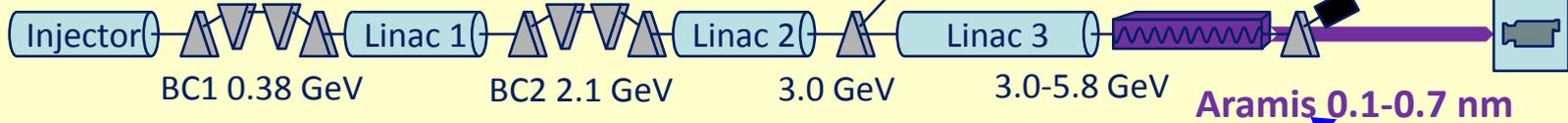
C-Band technology

2nd phase

2018-19?

Athos 0.7-7nm

user stations



On the first floor the RF modulators and other supply systems are situated.

740m

102m
Injector

SwissFEL parameters

Wavelength from 1 Å - 70 Å

Photon energy 0.2-12 keV

Pulse duration 1 fs - 20 fs

e⁻ Energy 5.8 GeV

e⁻ Bunch charge 10-200 pC

Repetition rate 100 Hz

Bunch per pulse single/double

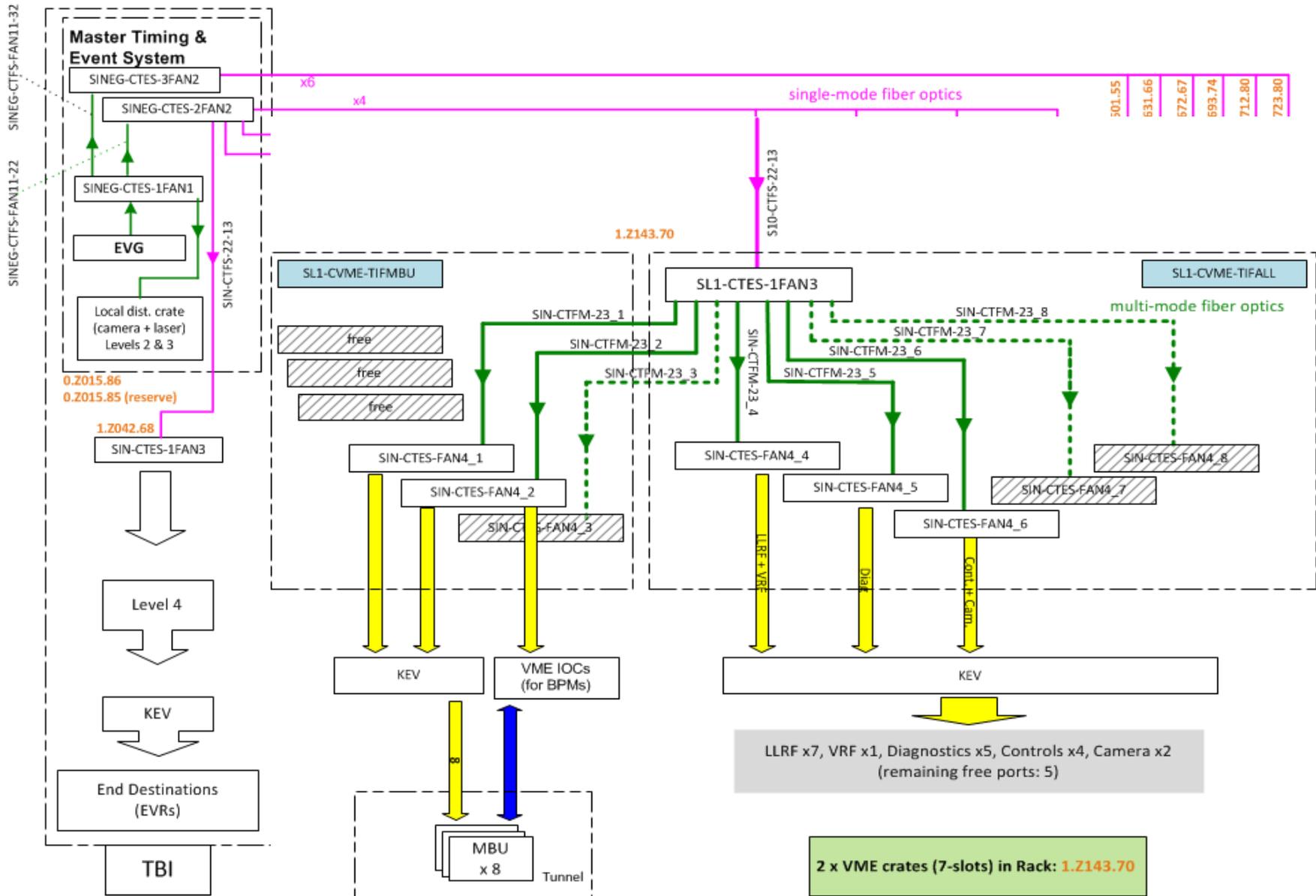
Bunch spacing 28ns

Main LINAC	#
LINAC modules	26
Modulator	26
Klystron	26
Pulse compressor	26
Accelerating structures	104
Waveguide splitter	78

(Swiss)FEL Timing homework

1. **Check/Specify H/W requirement:** event clock, jitter budget, drifts, functions/features, etc.
2. **Specify control system (bus) interfaces/form factors:** VME, PCIe, direct event stream, etc.
3. **Specify AC mains synchronization issues:** phase and/or cycle selection for beam
4. **Design/implement timing network:** distribution layers, network monitoring, latency issues
5. **Specify interface to special system:** e.g. Machine Protection System (**MPS**)
6. **Rep rate handling:** several event groups with controlled independent rep rates
7. **Beam rate handling:** control beam rate without manipulating rep rate (fixed trigger rate)
8. **Pulse-synchronous acquisition & controls**
 - **Synchronous read:** pulse ID tagging, time stamping, coordinate parallel acquisition instances (multi-user), local/remote buffering, synchronous archiving
 - **Synchronous write:** synchronous machine scans, e.g. fast emittance measurements involves synchronous magnet setting and beam profile reading

Timing Distribution Network



SwissFEL Event System

- Event clock **142.8 MHz**, **7ns**, (specifies **delay** and event **positioning** resolution)
- Event sequence (re)programming at **100 Hz**
- New features: conditional sequence events (EVG), double delay pulsers (EVR)

1 EVG (VME)

70 Fan-out/concentrator, full-duplex1-to-8, (VME)

150 EVR (VME)

90 EVR (PCIe)

20 EVR (PMC/XMC)

100 embedded EVR
(Direct event stream)

VME-based systems:
RF, LLRF, Laser,
diagnostics, etc.

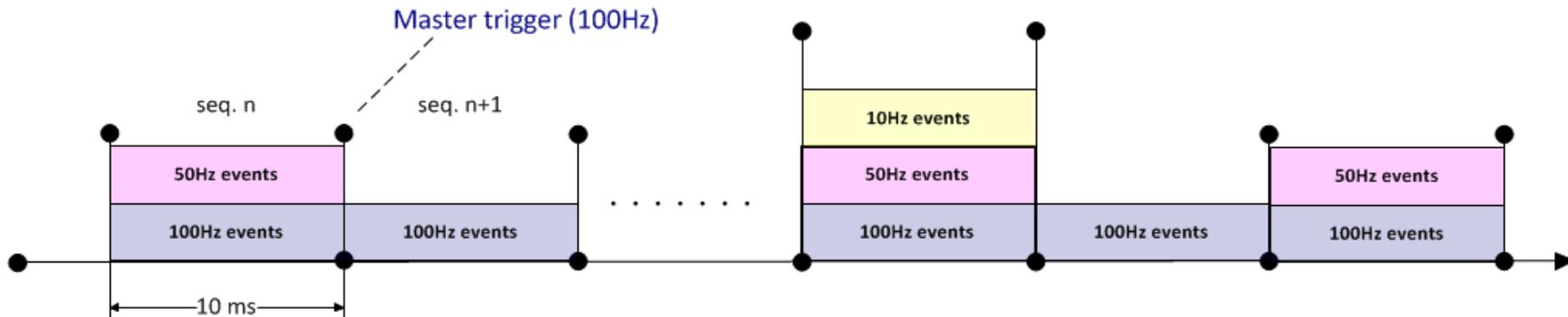
Camera servers,
detectors systems,
motion control
systems

Compact VME
systems; plugged on
CPU board or
intelligent FPGA
carrier (aka IFC)

decode event stream
in custom FPGA:
BPMs, diag. front-end
electronics, e.g.
BLMs, etc.

Rep rate controls

- **some systems require trigger at every pulse** (fixed 100Hz)
- **RF rate triggers** (variable $\leq 100\text{Hz}$, e.g., 25Hz, ...)
due to lack of performance, available power, radiation budget, etc.
- **Laser rate triggers** (variable $\leq 100\text{Hz}$, e.g., 10Hz, ...)
pulses with expected beam; controlled reduced rate for machine protection or development, can include diagnostics systems

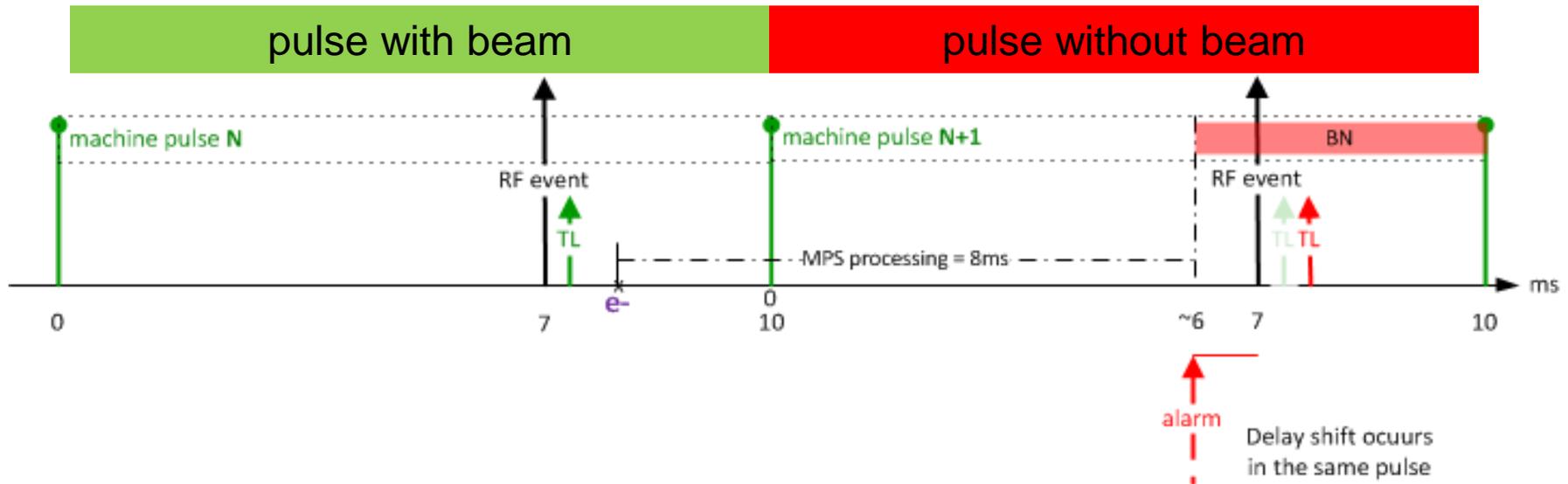


➤ Every sequence has different event pattern with respect to previous

Works well with good book-keeping of event patterns (i.e. soft sequences) and running of H/W sequencers in Ping-Pong (parallel play/program)

Machine Protection System (MPS) interface

- Delay shift mechanism to generate beam **blackout**



- TL in **green** is the trigger with normal delay; leads to beam generation (**Beam Ok**)
- TL in **red** is the trigger with shifted delay; leads to beam blackout (**Beam Not ok**)
- shift of ~ 10 us to Gun RF; why delay shift? continues triggers maintain machine **stability**
- Required actions:
 - Delay shift occurs immediately for selected triggers
 - Beam status has to be reliably distributed (Beam (Not) Ok)

Machine timing operation modes

- General timing question for every system at each (100Hz) pulse:
 - a) Should this system be triggered? determined by **(event) rep rate**
 - b) Should the trigger delay be shifted? determined by **MPS** or user's **demand**
 - **on-demand Gun RF delay shift?** machine conditioning without beam, e.g., startup
 - **on-demand Laser delay shift?** dark current measurement (without shutter control)
 - c) What is **beam status**? whether or not beam will be produced

MPS alarm	shift Laser delay	shift Gun RF delay	Beam status
No	No	No	Ok
Yes	-	-	Not ok
No	Yes	No	Not ok
No	No	Yes	Not ok

Conclusion

- **New requirements pushes towards new generation of the event system**
- **Extracting operational requirements requires effort and patience**
- **FEL timing involves many interesting challenges**

Thanks!

Machine timing modes, cont'd

Some consequence:

- It must be possible to force on-demand shifted delay locally & individually per system
- MPS alarm must override local demand of shifted delay
- Beam status (signal/info) is a global machine status to be distributed reliably:
 - Known ahead of time if caused by on-demand shifted delay (**easy**)
 - Otherwise, unknown until MPS processing time is finished (**difficult**)

Additional feature:

- Emulation of MPS alarm internally in timing system (e.g., test or simulation purposes)

Even more:

- For the next N pulses (don't) produce beam using shifted delay only

Short list of requirements

Incomplete list; suggests some implementation ideas too

- 1. Event clock 142.8 MHz**
- 2. Continuous drift compensation; long term drift < 0.7ns peak-peak**
- 3. Delay shift mechanism (controlled by DBUS / events / both ??); must allow enable/disable and local/manual control**
- 4. Sequence event masking (in/out) controlled int./ext.**
- 5. Data buffer transmit upon int./ext. H/W trigger (in addition to S/W trigger)**
- 6. Distribution (fan-out) monitoring (VME bus interface)**
- 7. Upstream data (and event) broadcasting by EVG without S/W intervention**
- 8. Stimulate delay shift mechanism at EVG internally in addition to external MPS alarm**