PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

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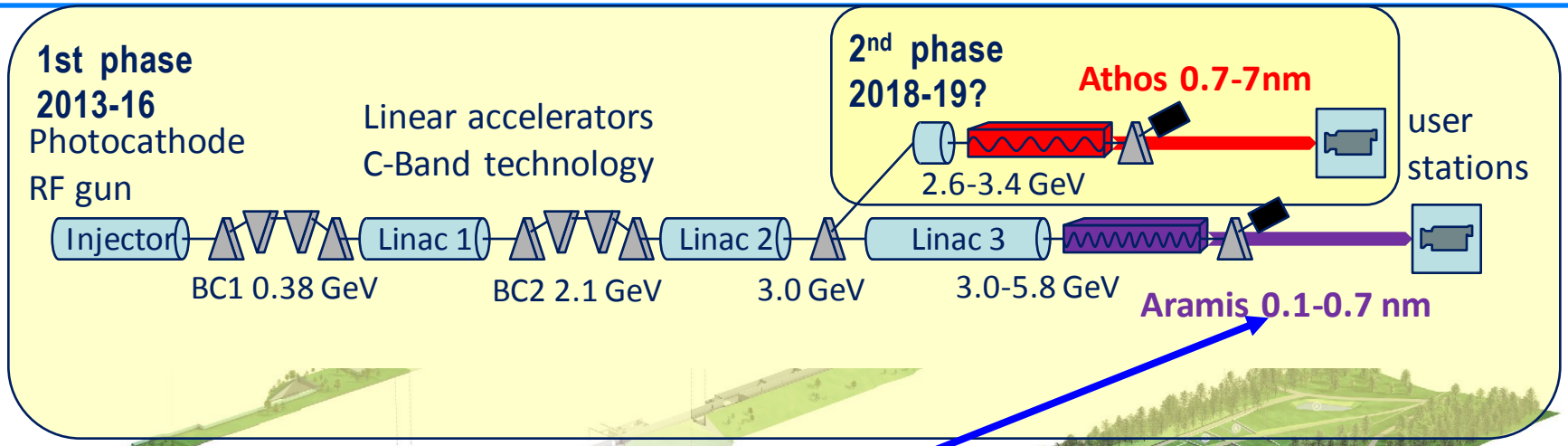
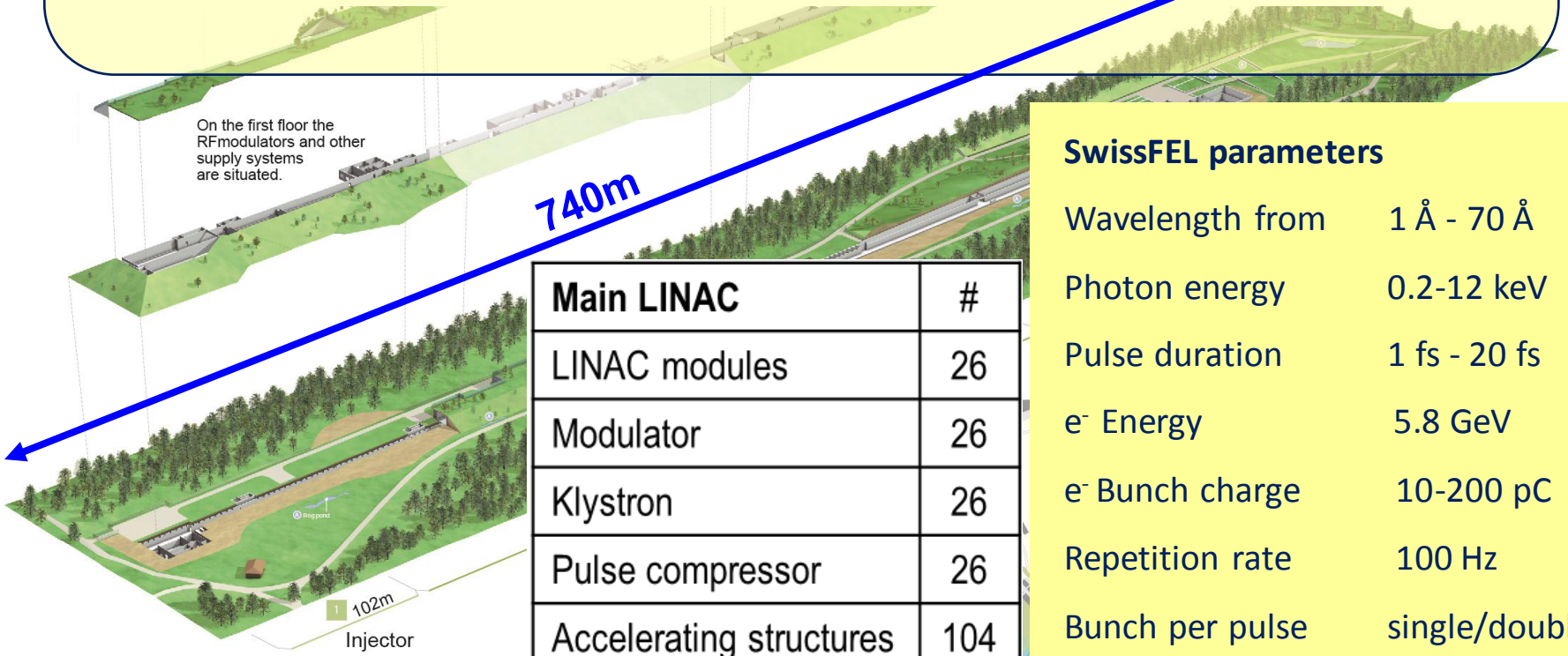
SwissFEL Timing System

SwissFEL Machine





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

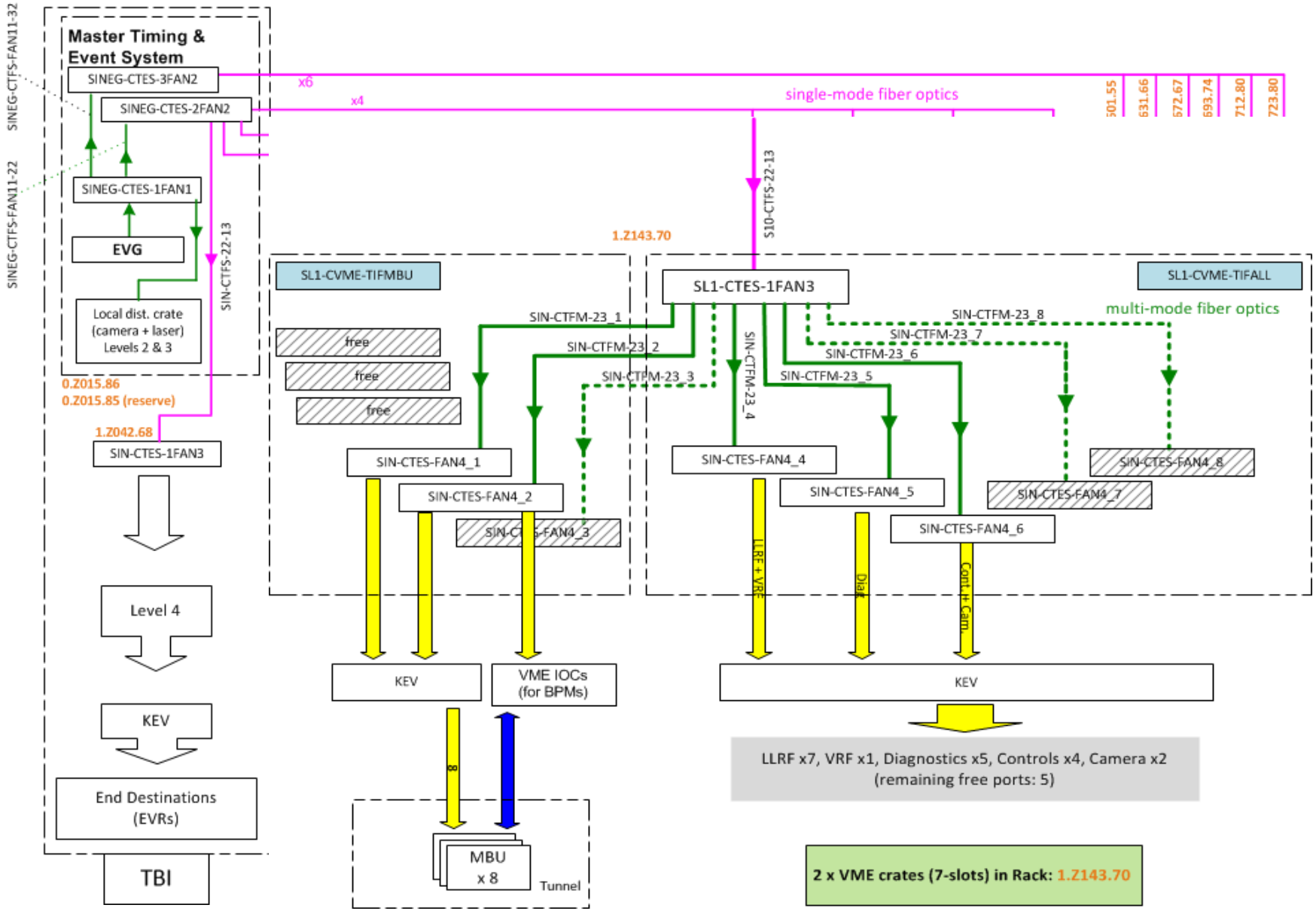
SwissFEL parameters

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

(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 emmitance 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)

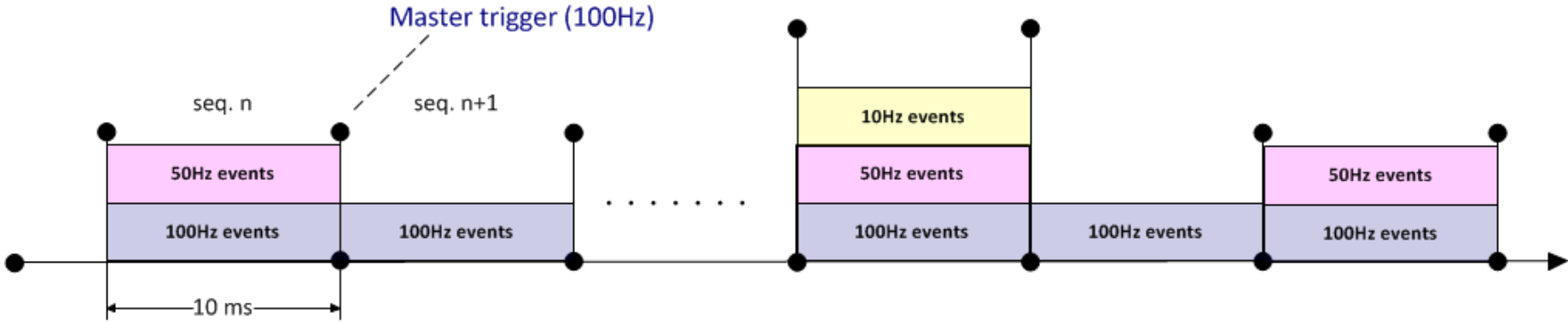
1 EVG (VME)			
70 Fan-out/concentrator, full-duplex1-to-8, (VME)			
150 EVR (VME)	90 EVR (PCIe)	20 EVR (PMC/XMC)	100 embedded EVR (Direct event stream)
VME-based systems: RF, LLRF, Laser, diagnostics, etc.	Camera servers, detectors systems, motion control systems	Compact VME systems; plugged on CPU board 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 ≤ 100Hz, e.g., 25Hz, …)

  due to lack of performance, available power, radiation budget, etc.
- **Laser rate triggers** (variable ≤ 100Hz, e.g., 10Hz, …)

  pulses with expected beam; controlled reduced rate for machine protection or development, can include diagnostics systems

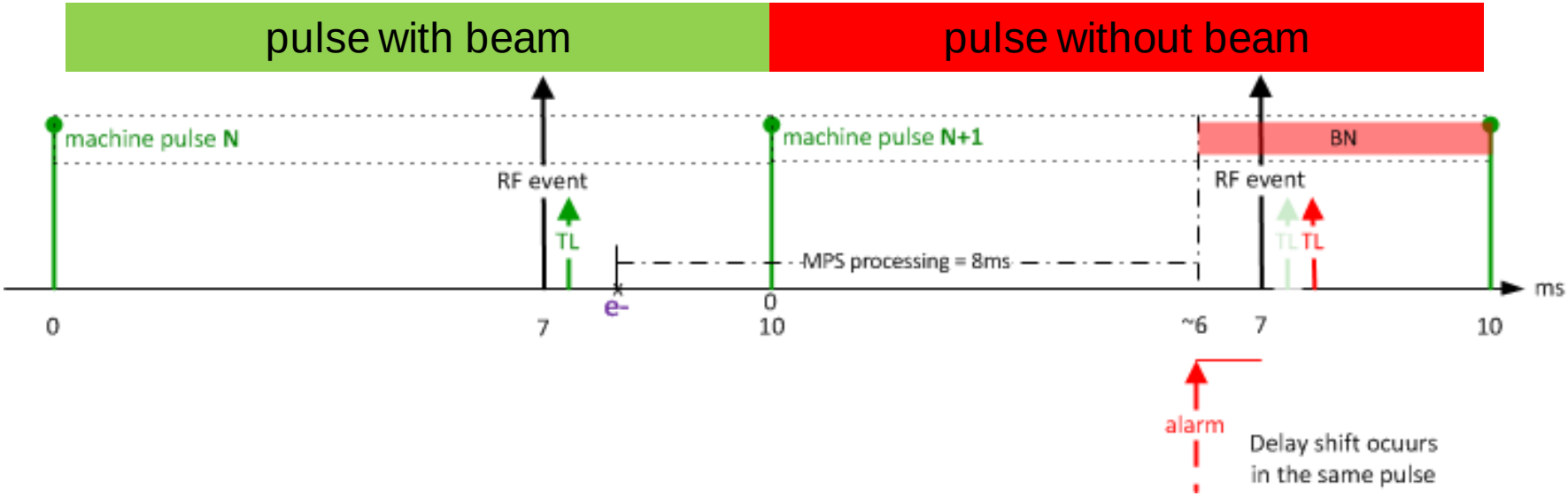


➢ **Every sequence has different event pattern with respect to previous**

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:
  - (1) Delay shift occurs immediately for selected triggers
  - (2) 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**