

# Timing System & Bunch Pattern Server

Or: What you never wanted to know about the timing system but were forced to find out.

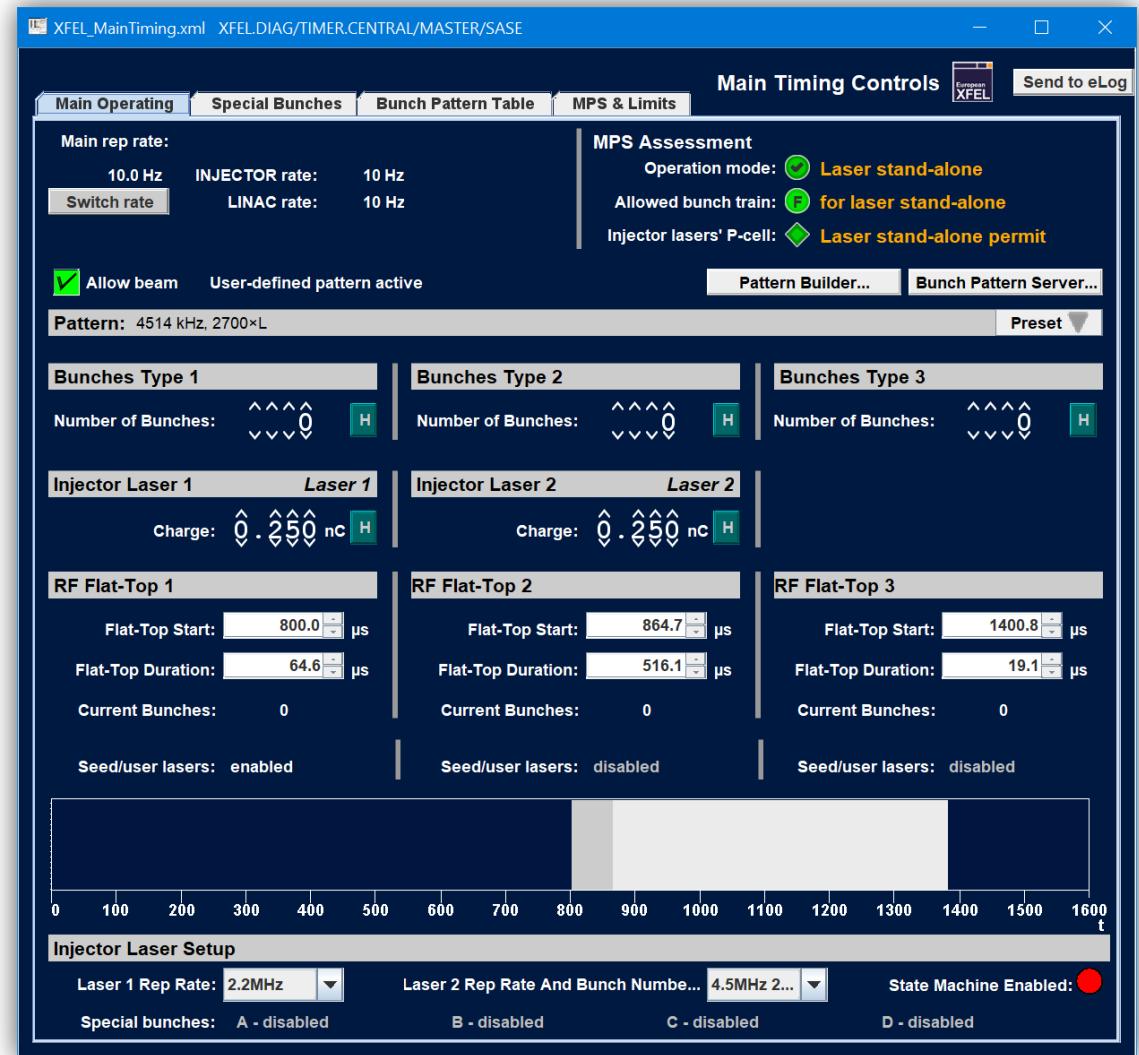
- x2timer & Bunch Pattern
- Beam Distribution at the XFEL
- Virtual XFEL Demo

# x2timer & Bunch Pattern

# The x2timer Timing Board

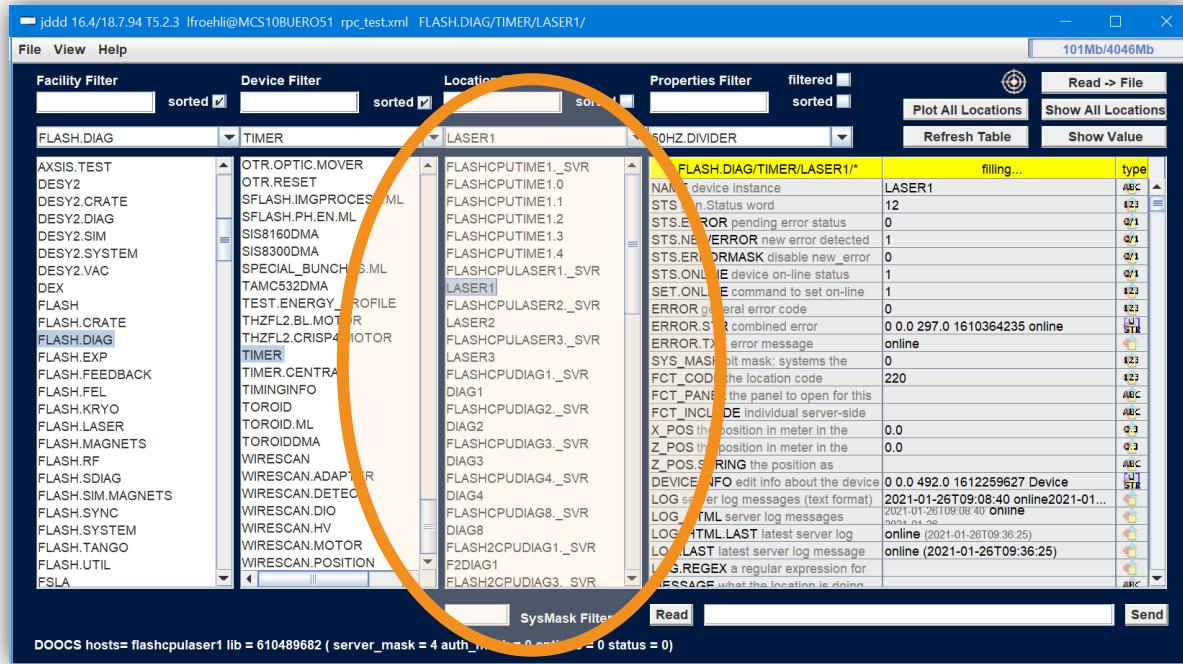
Generating the heartbeat for our facilities

- Generates precision clocks and triggers
- Can be transmitter or receiver (multi-star topology) or stand-alone
- Present in most MTCA crates
- Main DOOCS interface: x2timer server (Arthur Aghababyan, Olaf Hensler)



# x2timer Servers in the DOOCS Namespace

## Where to find x2timers in DOOCS



x2timer servers are ubiquitous:

SINBAD.DIAG/TIMER

SINBAD.DIAG/TIMER.CENTRAL

FLASH.DIAG/TIMER

FLASH.DIAG/TIMER.CENTRAL

XFEL.DIAG/TIMER

XFEL.DIAG/TIMER.CENTRAL

XFEL\_SIM.DIAG/TIMER

XFEL\_SIM.DIAG/TIMER.CENTRAL

KALDERA.DIAG/TIMER

TEST.DIAG/TIMER

TEST.XFEL/TIMER

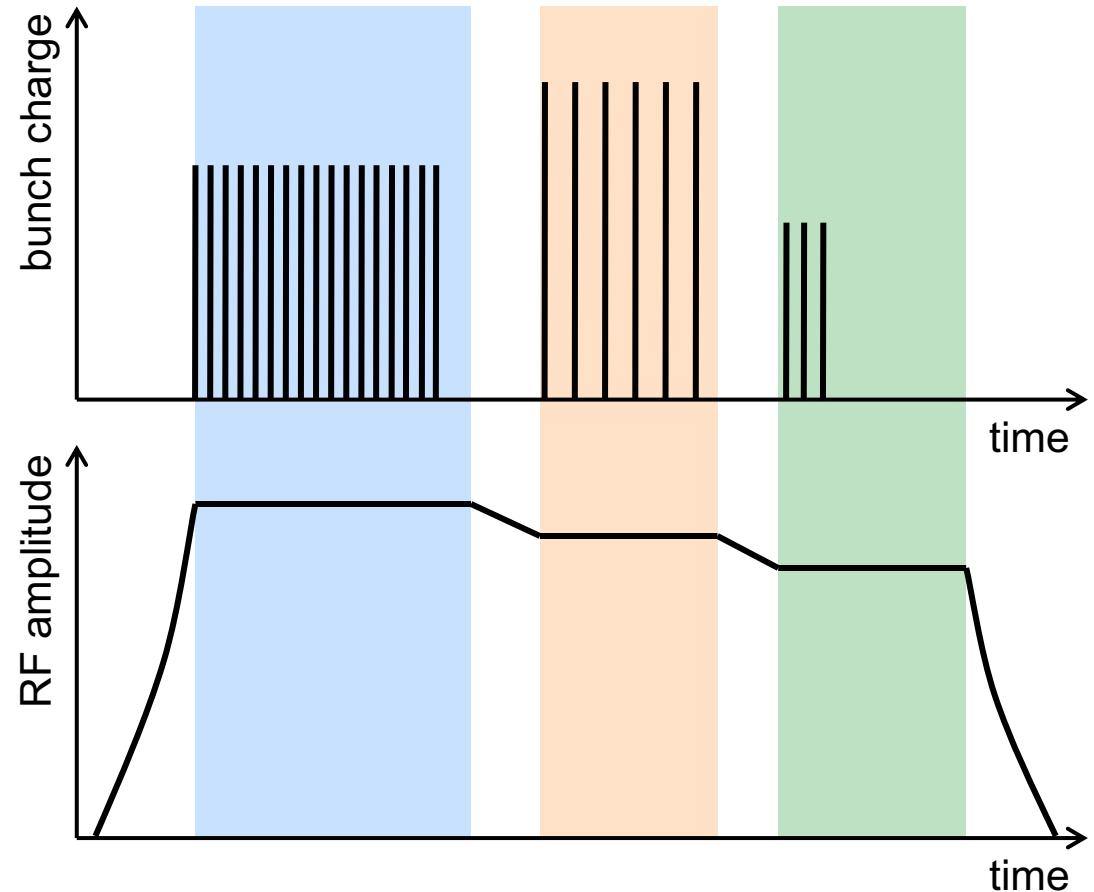
LAB.\*/TIMER

...

# x2timer Legacy Mode

## Up to three beam regions

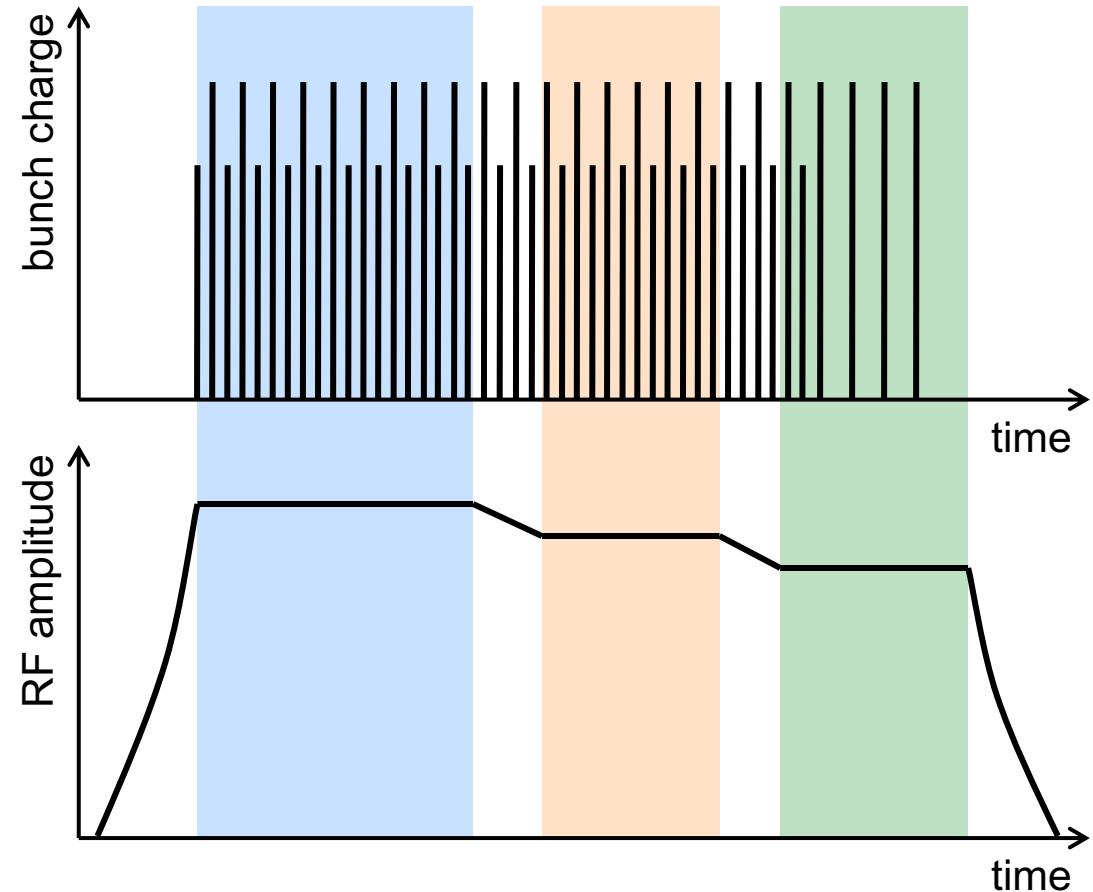
- Up to three beam regions (“flat-tops”)
- Between the beam regions, the LLRF may change amplitude & phase freely
- Bunches are only possible inside the beam regions
- Only one type of bunch per beam region (same injector laser, destination, charge, ...)
- Simple → Can be used directly from x2timer server
- No longer supported



# x2timer User-Defined Mode

## Maximum flexibility

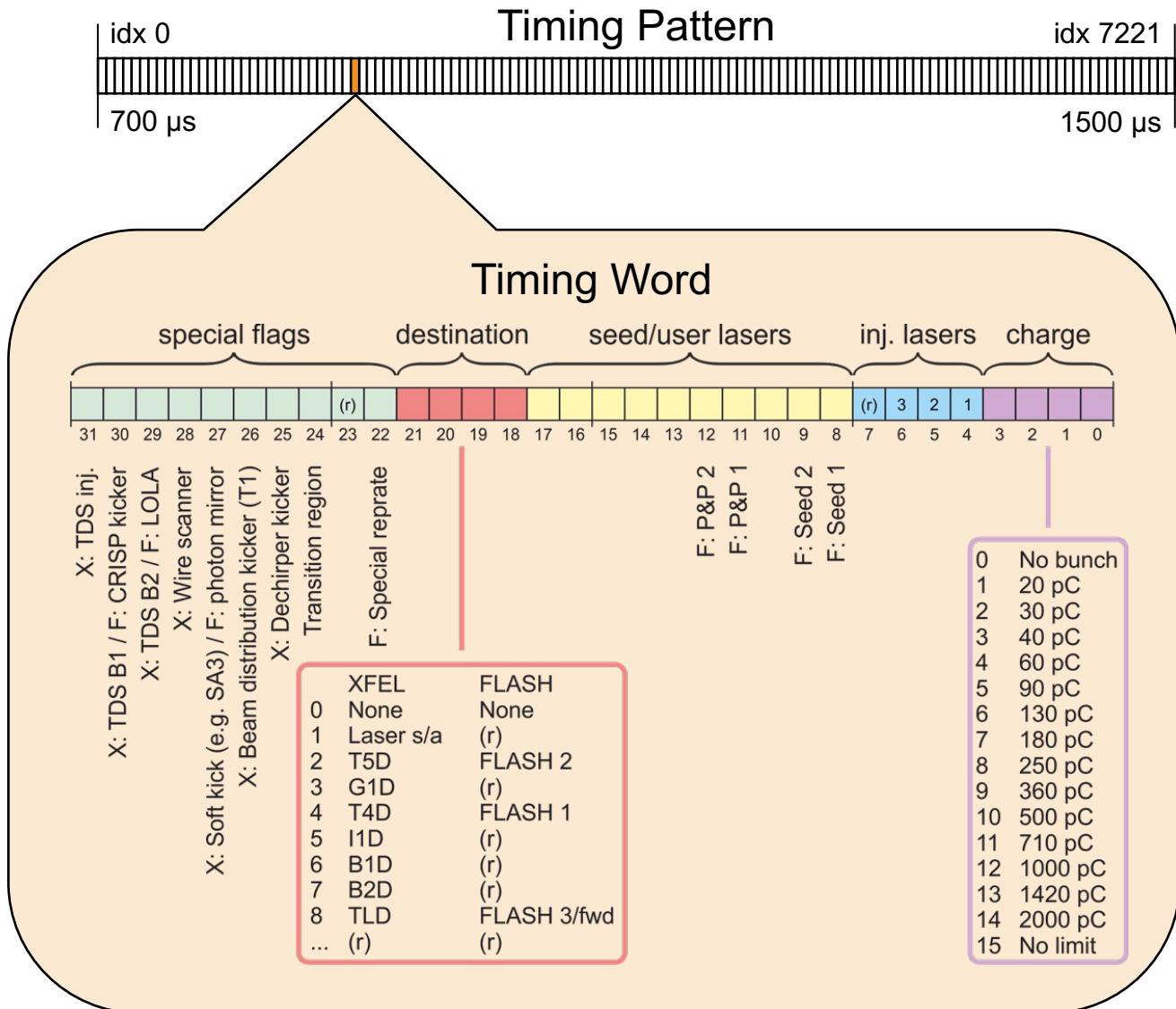
- (Almost) arbitrary number of beam regions
- Bunch types, lasers, destinations, and beam regions are decoupled
- Programmed via a huge pattern table
- New pattern tables are sent to the x2timer at 10 Hz by the bunch pattern server
- Used at FLASH, XFEL, PITZ, KALDERA, ...



# The Timing Pattern in Detail

An array of 7222 “timing words”.

- The timing pattern is an information block that is distributed by the timing system before each macropulse.
- Timing boards generate triggers from it.
- Hard- and software uses it to classify bunches/pulses.
- Table with 7222 [8192] entries
- 9.028 MHz raster (110.8 ns step)
- Covers a time span of 800  $\mu$ s [910  $\mu$ s]
- Each entry is described by a 32-bit integer (“timing word”)



# Beam Distribution at the XFEL

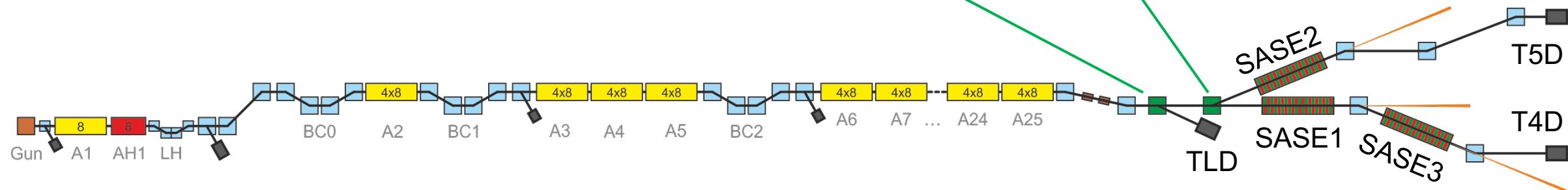
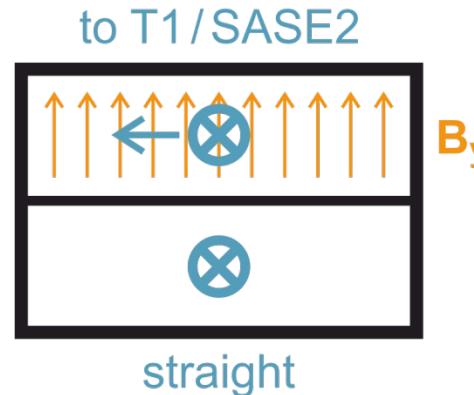
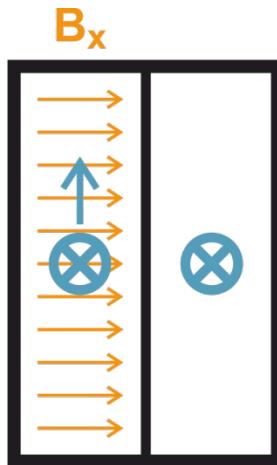
# Beam Distribution Scheme

## TLD Kicker

- Fast (4.5 MHz)
- Horizontal kick (left)

## Lambertson Septum

- Vertical deflection (up)



## Beam Distribution Kicker

- Slow (tens of  $\mu$ s)
- Vertical kick (up)

## Lambertson Septum

- Horizontal deflection (left)

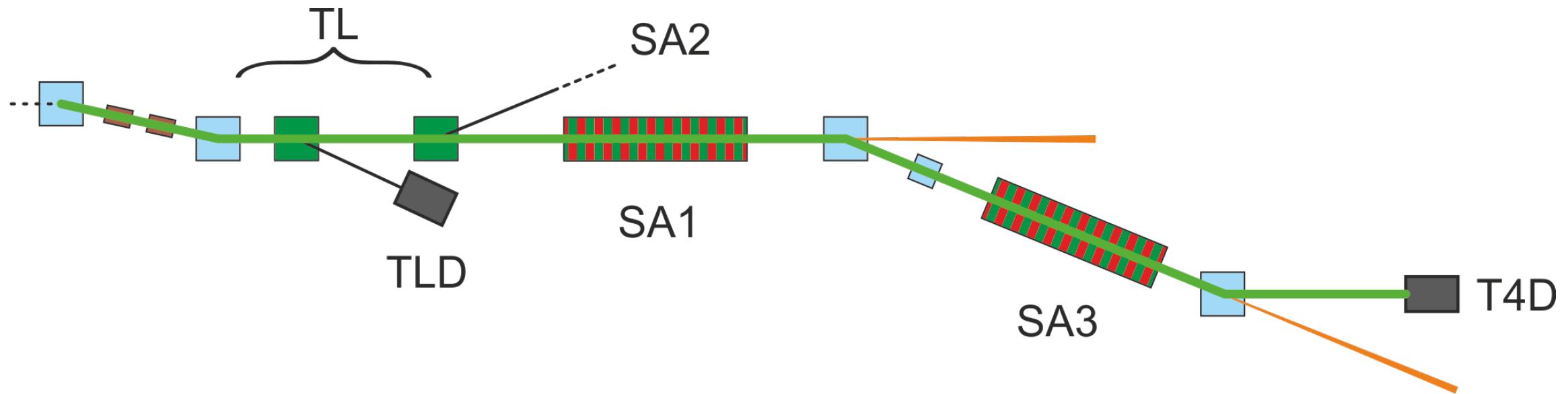
# Fresh Bunch Mode: Implementation

Lasing in SA1 induces energy spread => less or no lasing in SA3

Lasing can be suppressed

■ on individual bunches

■ by exciting a trajectory oscillation with a fast kicker (*soft kick*).



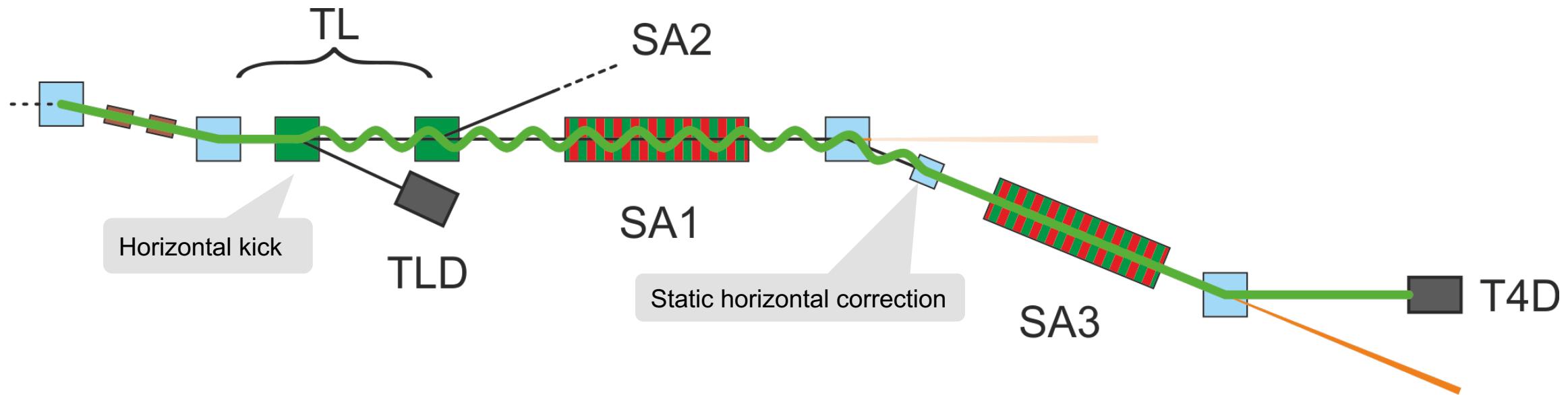
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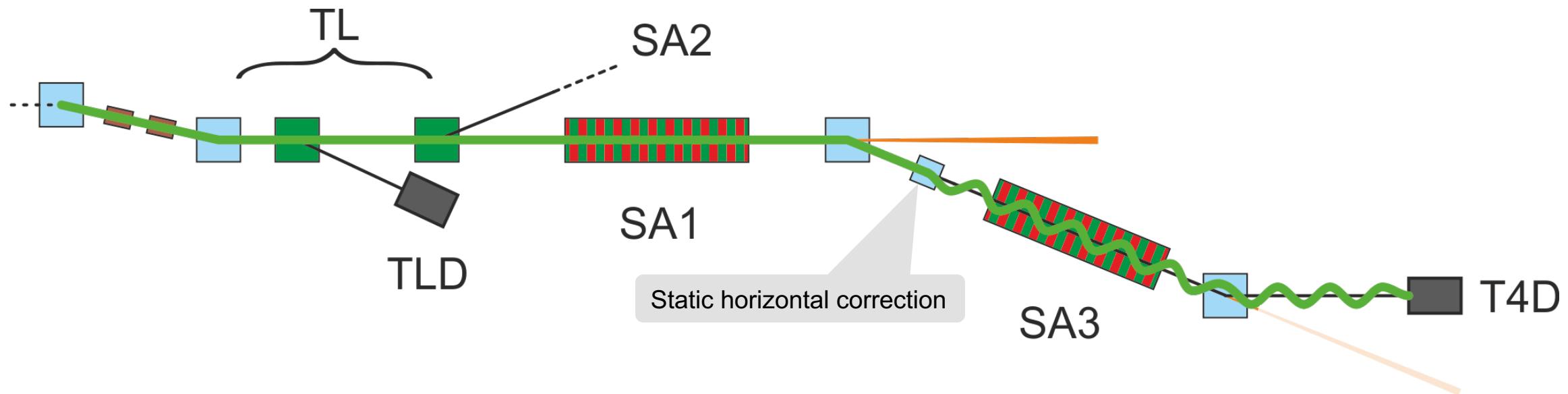
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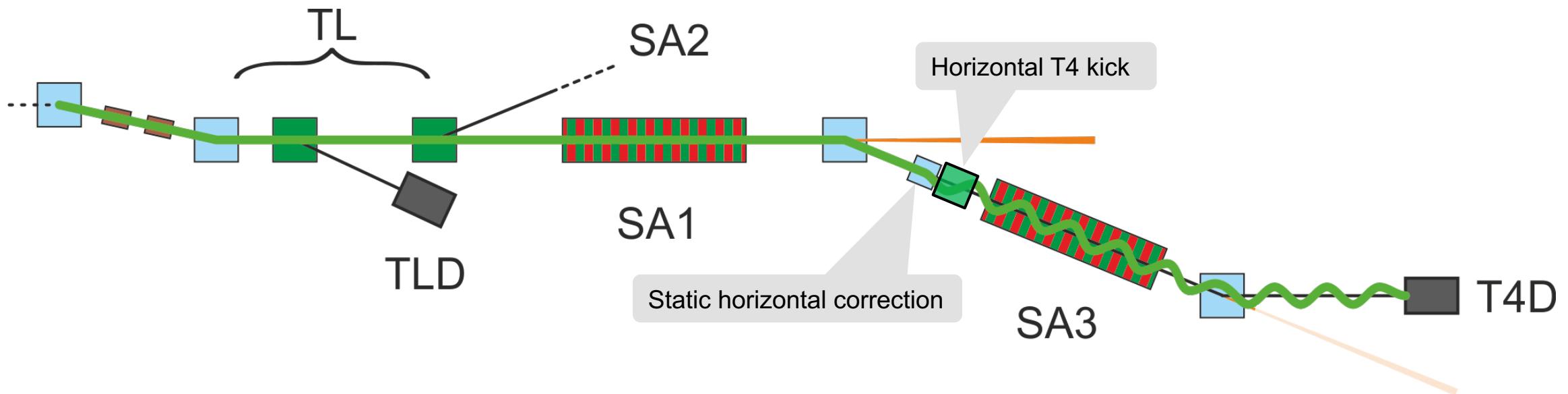
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# Fresh Bunch Mode: Additional Kick in T4

There is a “TLD-type” kicker in the T4 section, in front of SA3.

It is fired for SA1 bunches to increase the oscillation amplitude in SA3.



# Beam Distribution: Get Your Kicks

## (All four of them)

Four types of kicks can be triggered by the timing system:

■ Kick to TLD (fast)

**Destination: TLD**

■ Kick to south branch/SASE2 (slow)

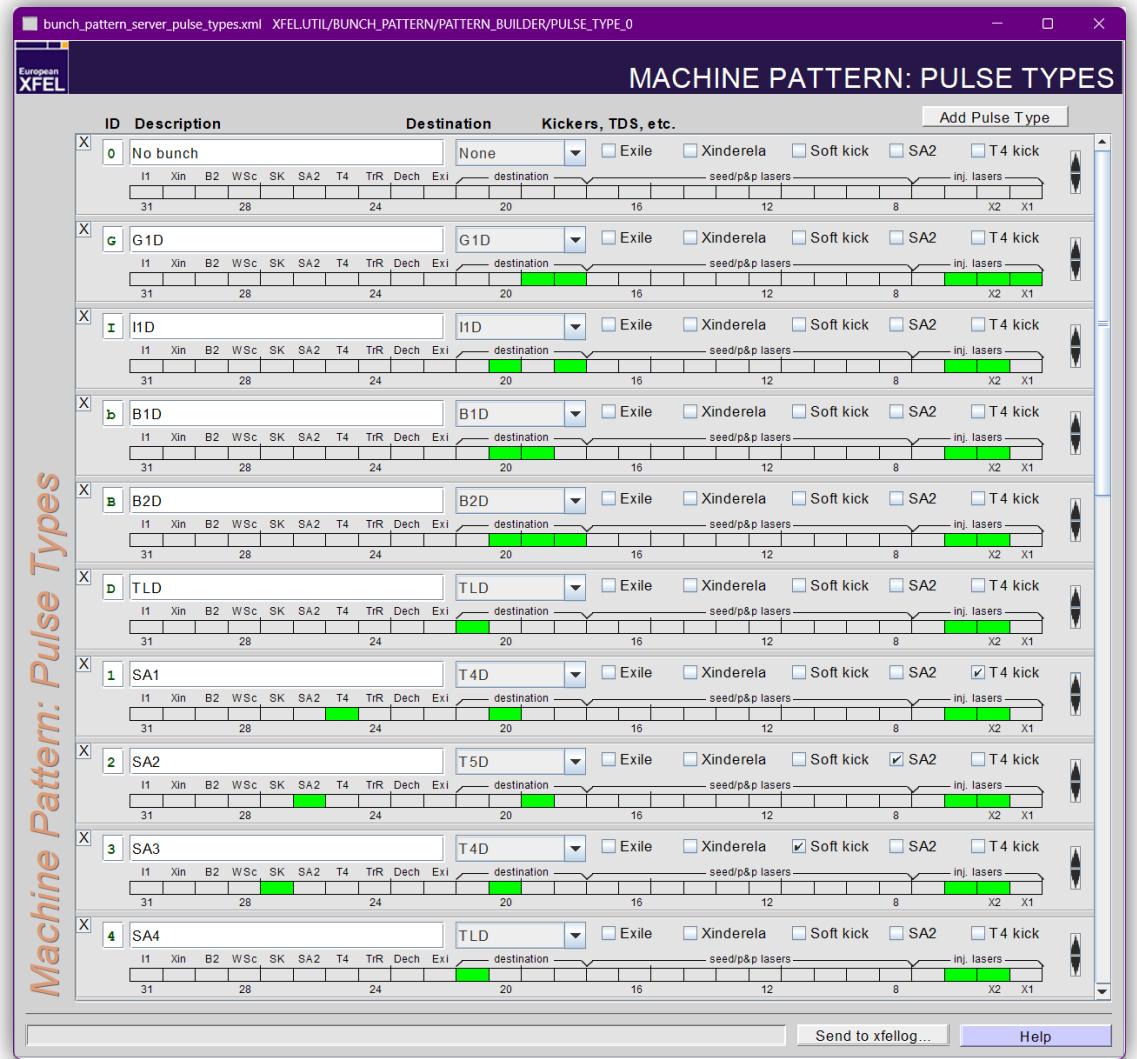
**Destination: T5D or Bit: "SA2"**

■ Soft kick (fast, one of the TLD kickers)

**Bit: "SK" (Soft Kick)**

■ T4 kick in front of SASE3 (fast)

**Bit: "T4"**



# Live from the Virtual XFEL

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**BUNCH PATTERN SERVER: PATTERN BUILDER (MACHINE PATTERN)**

**Virtual FLASH**

**1. Pulse Types**

0: No Bunch • 1: FLASH1 • 2: FLASH2 • F: FLASHForward • G: Gun Nepal 1 • g: Gun Nepal 2 • L: Laser standalone • T: Test For Laser

**2. Pulse Patterns**

**[A]**

Base Frequency: 1003 kHz

Start Time	Description	Sub-Pattern	# Ticks	# Repetitions
700.0 <input type="button" value="μs"/>	FLASH 1	1	^ ^ ^ ^	110
809.7 <input type="button" value="μs"/>	Gap	0	^ ^ ^ ^	110.00
919.3 <input type="button" value="μs"/>	FLASH 2	2	^ ^ ^ ^	30
949.2 <input type="button" value="μs"/>	0		^ ^ ^ ^	0.00

**3. Charge / Intensity Profiles**

Profile #1 (Bunch charge): +200 pC for pulse type 2 • +110 pC for pulse type 1

**4. Bunch Counters**

BUNCH\_COUNTER\_1 Pulse IDs generating these bunches: FLASH1 Excess bunches at the end of the train are replaced by: 1 2

BUNCH\_COUNTER\_2 Pulse IDs generating these bunches: FLASH2 Excess bunches at the end of the train are replaced by: 2 4

BUNCH\_COUNTER\_3 Pulse IDs generating these bunches: FLASHFwd Excess bunches at the end of the train are replaced by: F 0

BUNCH\_COUNTER\_4 Pulse IDs generating these bunches: Diagn Excess bunches at the end of the train are replaced by: X 0

**5. Tail Clean-Up**

Remove the following pulse types from the end of the pattern: ...but leave this many tail pulses untouched: 2

**6. Pattern Sequence**

Sequence: [A] → [A]

**7. Review Pattern**

Show Machine Tag [A] [A]

700 800 900 1000 1100 1200 1300 1400 1500 1600 [μs]

View Pattern... Open the Pattern Viewer in a separate window.

**8. Apply, Save & Load**

1003 kHz, 110×1, 110×0, 30×2, 0×0

**Apply & Switch** Send this pattern to the timing system and switch it to user mode.

**BUNCH PATTERN SERVER**

**Virtual FLASH** Operation mode: FLASH1 FLASH2 off FLF

**Main** **Charge/Lasers** **Special Functions** **Expert** **Log**

Beam allowed:   H Pattern sequence: [A]

User-defined pattern active:  Pattern: 1003 kHz, 110×1, 110×0, 30×2, 0×0

Auto-adjust RF flat-tops:

	Bunch Type 1	Bunch Type 2	Bunch Type 3	Bunch Type 4
Requested number of bunches:	FLASH1 12	FLASH2 24	FLASHFwd 0	Diagn 0
Current number of bunches:	12	24	0	0
User control allowed:	<input type="checkbox"/> H	<input type="checkbox"/> H	<input type="checkbox"/> H	<input type="checkbox"/> H

Total: 36

Beam limits: 0

ok

Clear All Limits

Clear Limit #

# ^ ^ ^ ^  
v v v v v

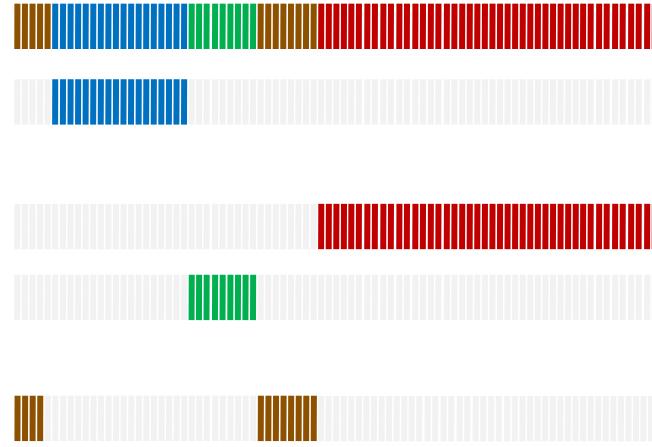
Pattern Builder... Pattern Viewer... Send to ttfflog... Help

# Subtrains – Reflecting the Pattern in the Control System

A subtrain is the set of all bunches in a macropulse that share some common feature. Seven of them are defined at FLASH.

They appear mainly in property names:

X.**FLASH2**.TRAIN.MEAN\_PKPK  
the mean value and peak-to-peak variation over all bunches of subtrain **FLASH2**



**ALL** contains all bunches.

**FLASH1** contains all bunches with destination FLASH1

**FLASH2** contains all bunches with destination FLASH2.

**FLASH3** contains all bunches with destination FLASHfwd.

**LASER1** contains all bunches produced by the first injector laser

**LASER2** contains all bunches produced by the second injector laser

**LASER3** contains all bunches produced by the third injector laser