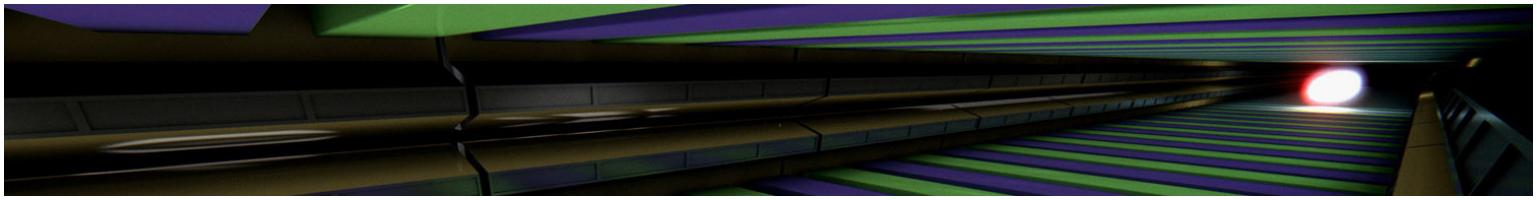


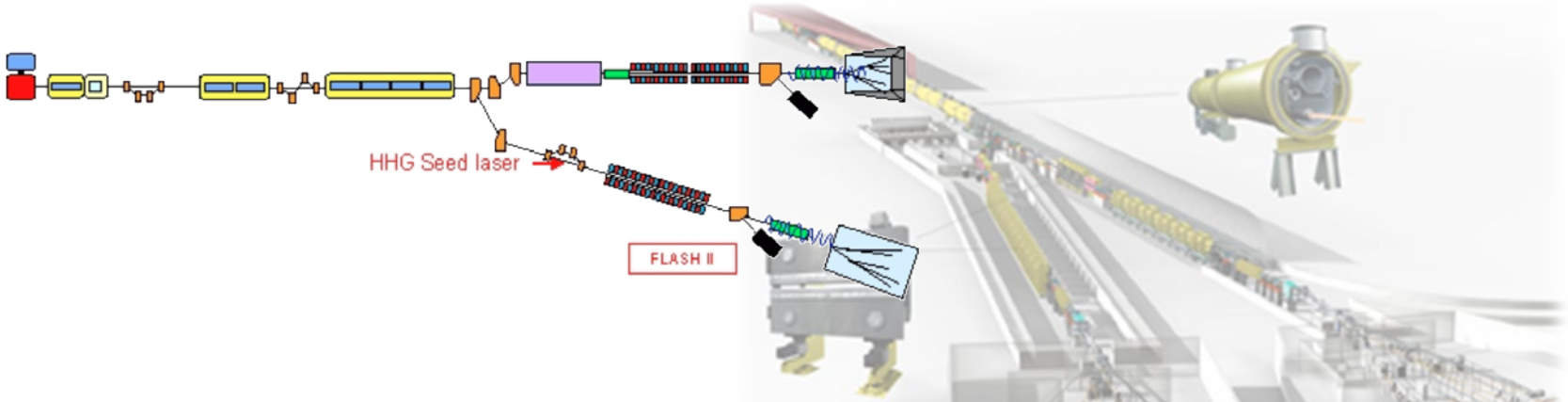
XFEL-MPS

XFEL Machine Protection System (MPS) based on uTCA

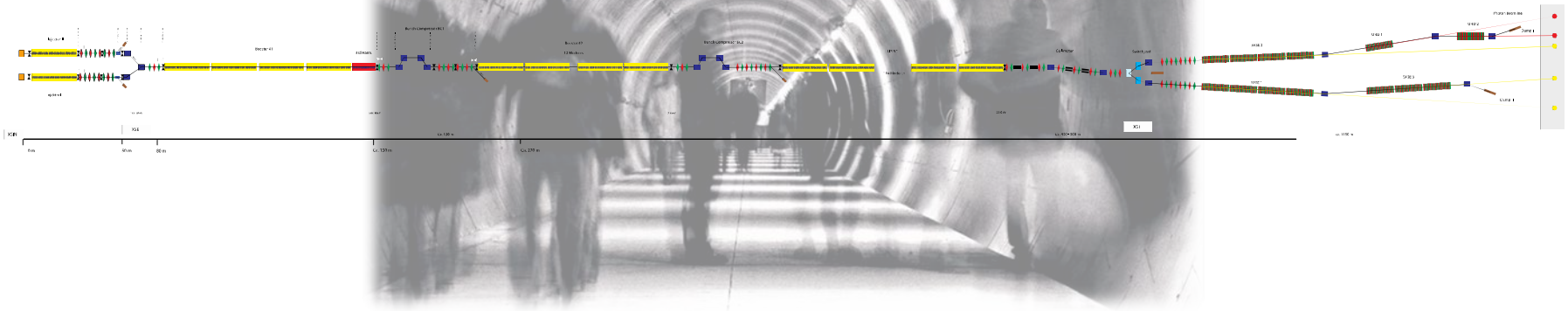
Sven Karstensen, DESY

European XFEL

FLASH 2 and XFEL

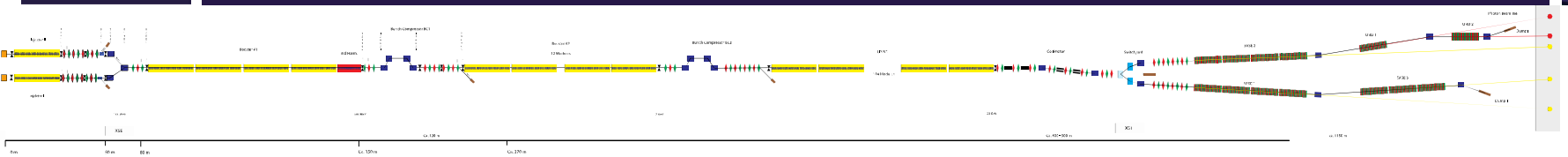


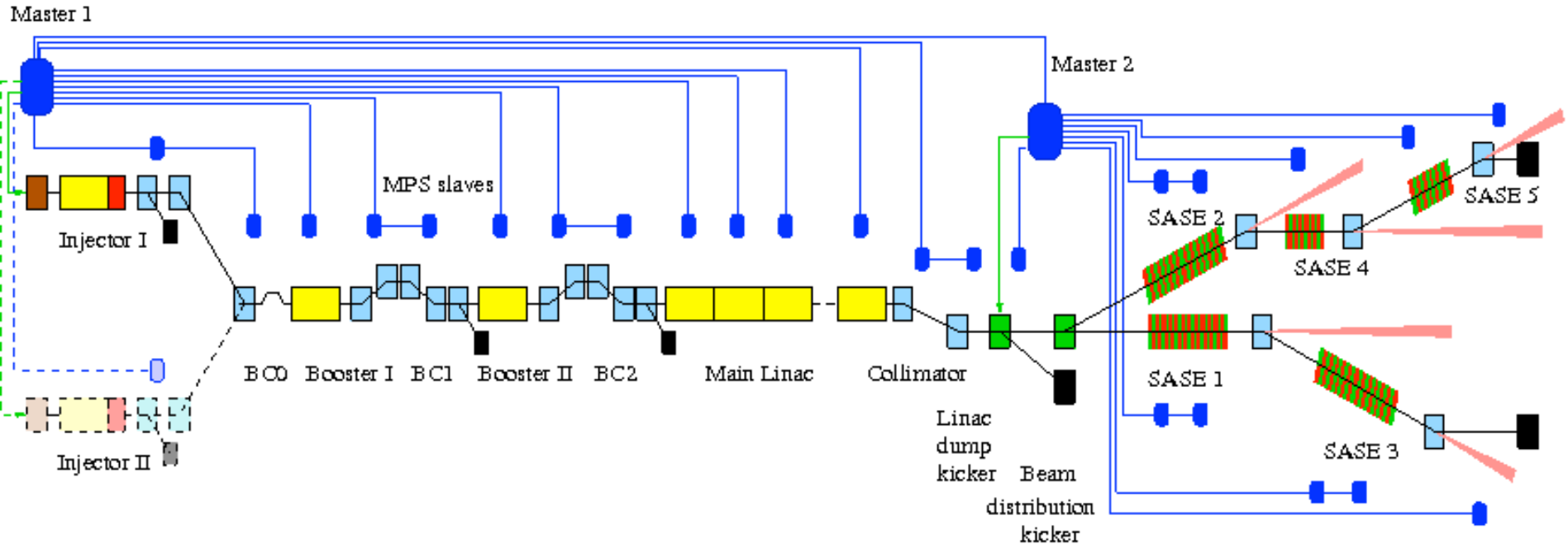
Overall length
FLASH: 500m
XFEL: 5.4 km



European XFEL

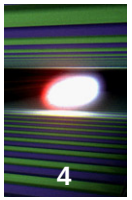
MPS architecture in XFEL





2 Masters, >120 Slaves

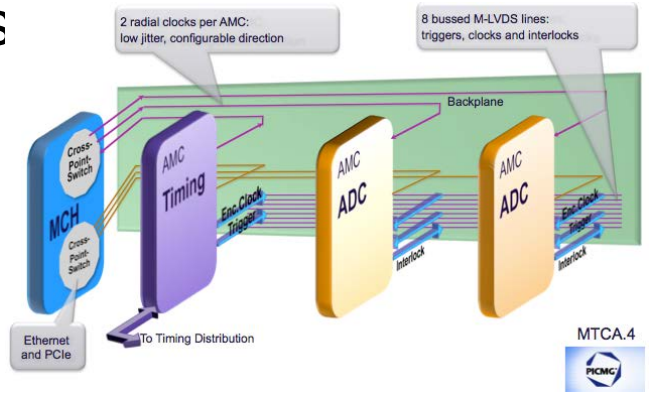
The Problems

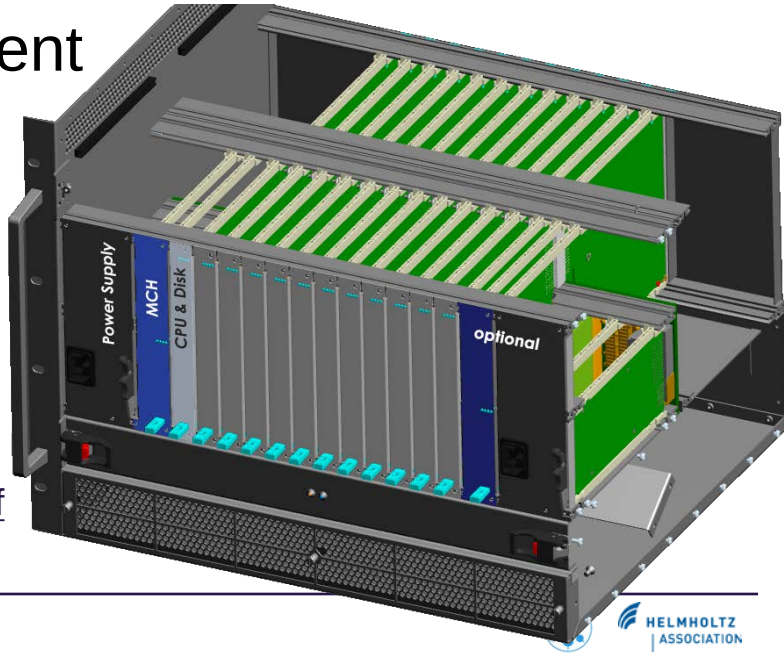


- Latency of signals
- Reliability of components
- Maintenance without shutdown the accelerator

MTCA.4 in general

- IPMI Management for 12 AMC modules
- Management for up to 4 Power Modules
- Fabric Switching for up to 60 Ports
  - 12 GbE minimum
  - 12 x 4 lanes XAUI, PCI-E or SRIO
- Management for up to 2 Cooling Units
- Optionally provides Shelf Management
- Front Panel Alarms
- Clock Distribution system
- Fabric Channel Uplink
- HOT SWAPable





Source: http://www.picmg.org/pdf/introduction_to_microtca.pdf
and Kay Rehlich, DESY

European XFEL

MTCA.4 @ XFEL

- **Modular + modern architecture**
  - Reusability + PCIe + Ethernet
- **High availability (.999 to .99999)**
  - Redundant power and fan optional
  - IPMI management

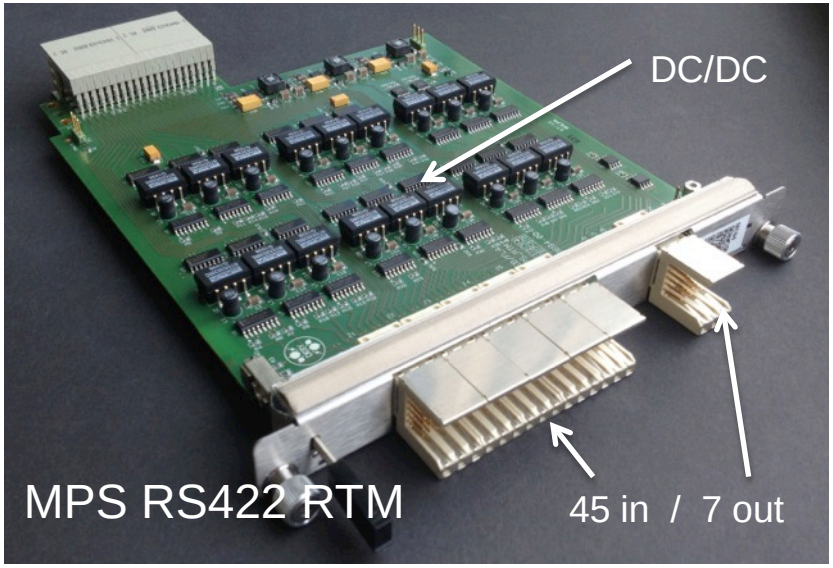
$$A = \frac{E[\text{Uptime}]}{E[\text{Uptime}] + E[\text{Downtime}]}$$

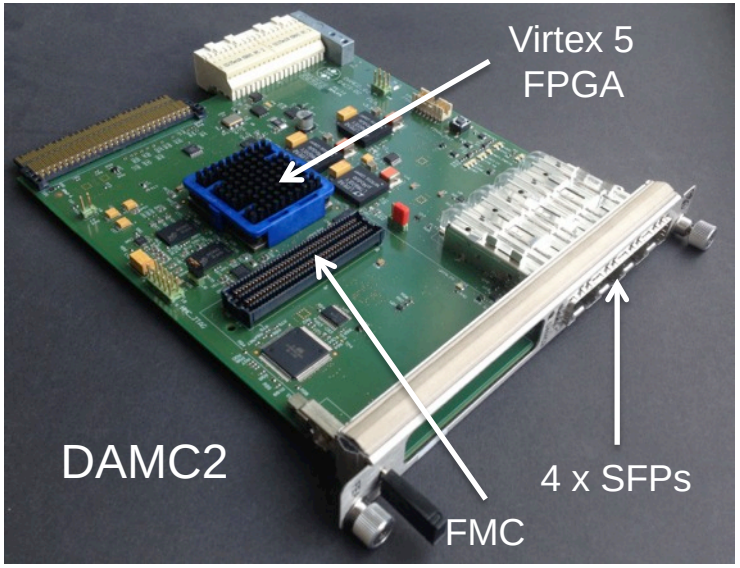
- **High performance**:
  - Very low analog distortions
  - 4 lanes PCIe: 400 MB/s ... 3.2 GB/s
- XFEL fast electronics will be based on **MTCA.4**: > 200 Crates

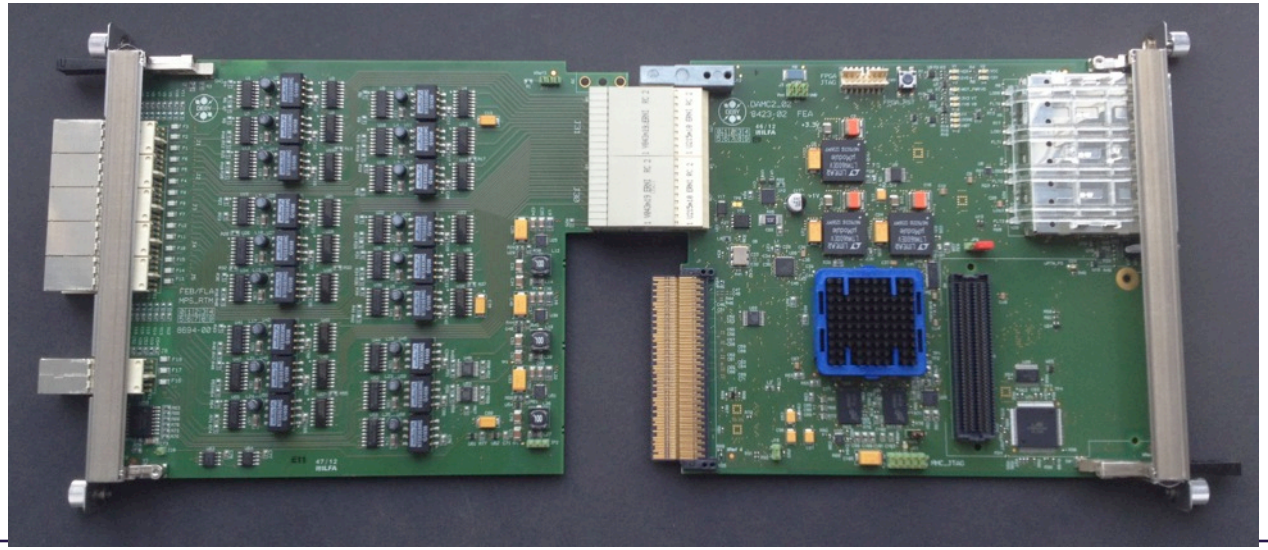
Courtesy to Kay Rehlich, DESY

European XFEL

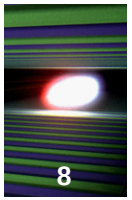
MPS MTCA components, DESY design





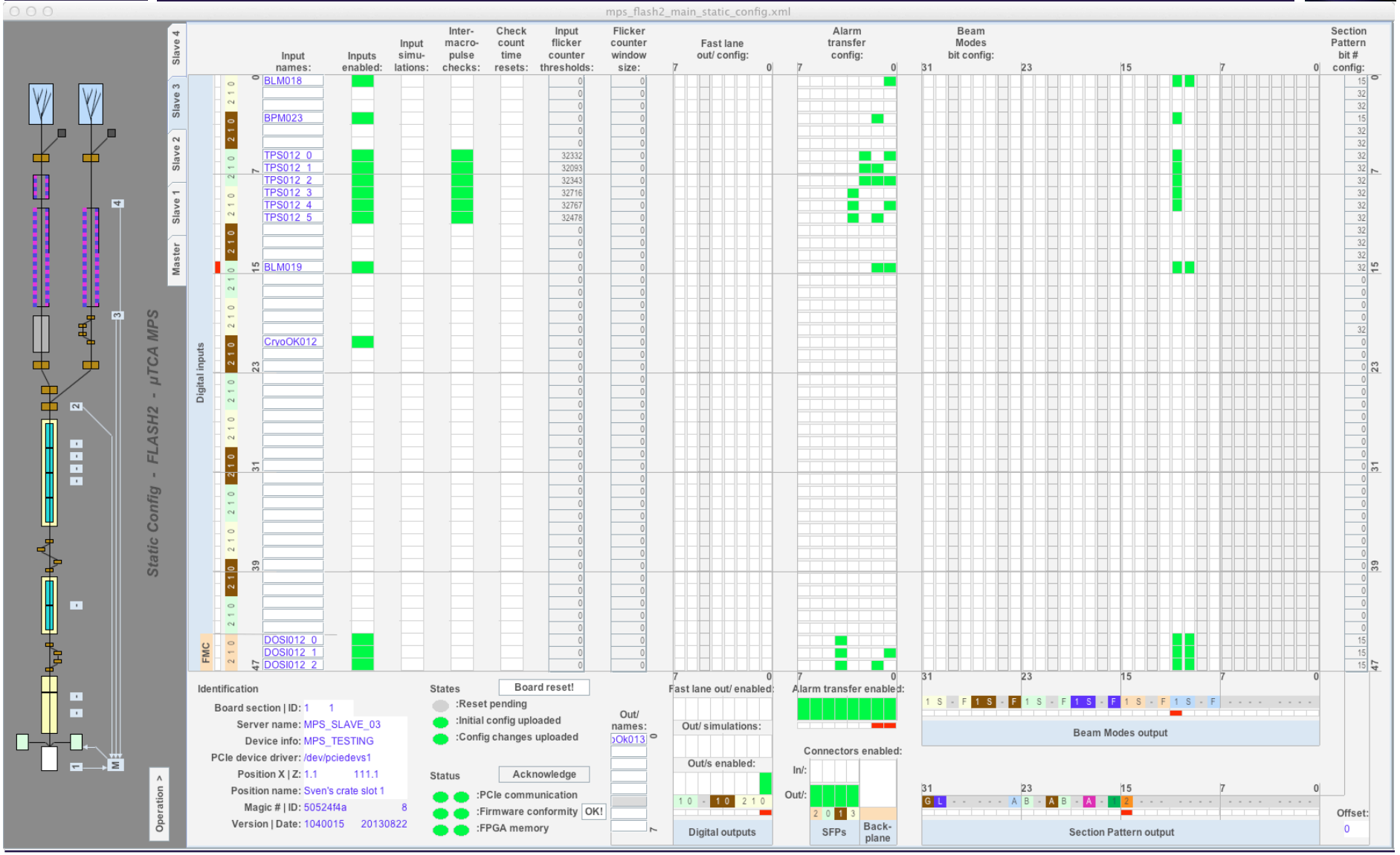


Overall MPS features

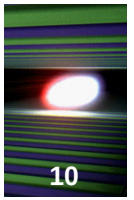


- Scalability
- same firmware in every DAMC2
- Every DAMC2 slave holds all information of all prior connected slaves (debugging)
- Every slave can be connected to the timing system
- Every slave can be hold one I2C driven FMC Dosimetry board
- Configurable – NOT programmable

Configuration Panel

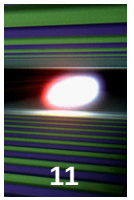


General MPS features for every DAMC2



- 45 RS422 external input channels
- 3 internal input channels for FMC
- 7 RS422 output channels, 1 Backplane Output
- I^2C support to FMC
- 4 SFP I/O fiber optic lines (0-4 Inputs, 0-4 outputs)
- Addressable up to 64 Sections, each equipped with 64 DAMC2 MPS modules
- Indirect redundancy
- Fast internal RS422 link from in- to outputs
- Debug Register
- LED status indicator (heart beat, server connection, initialization)

IN- and OUTPUT channel features

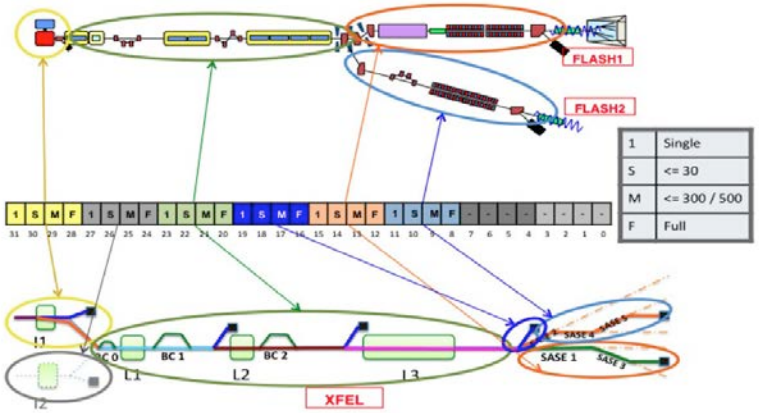


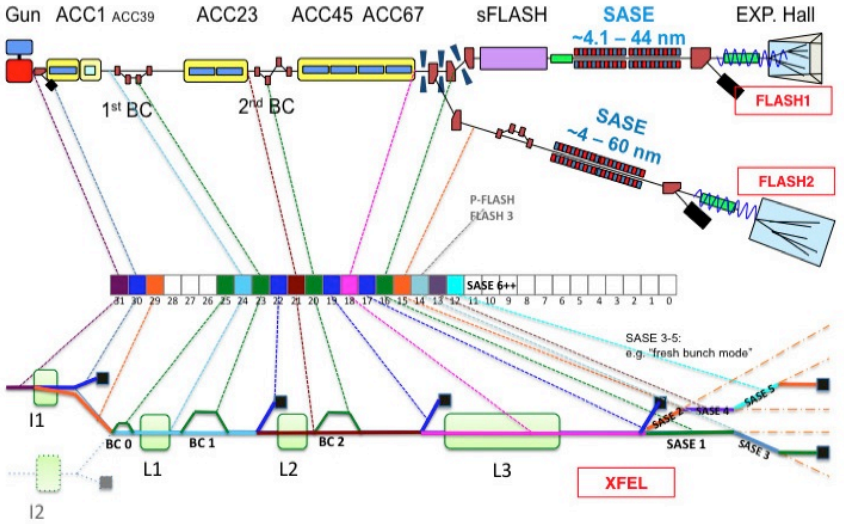
- Options for each INput channel (48):
  - Enable / disable Inputs ; Test input; Check functionality of connected systems between Macro Pulses; Pulse counter within a given time, both configurable; Beam Mode generation; Section Pattern generation; Alarm Type generation; Save each Alarm into DOOCS history

- Options for each OUTput channel (8):
  - Enable / disable Outputs ;Test output; Fast output line; Save each action into DOOCS history; Fast Output configuration on same DAMC2 board

The Protocol

Information structures, protocol priority, pre-processing





Beam Modes

63-52						
Sec 63-58	Addr 57-52	51	50-48	47-40	39-32	31-0
FFF 12 (6+6)		P 1	CNT 3	spare 8 bit	ALARM Type 8 bit	BEAM Modes 32 bit

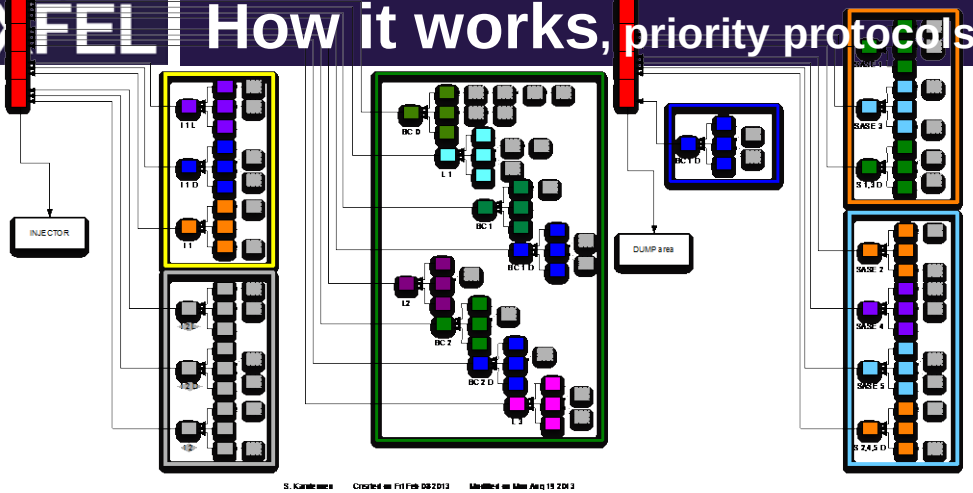
Section Pattern

63-52						
63-58	57-52	51	50-48	47-40	39-32	31-0
FFE 12 (6+6)		P 1	CNT 3	spare 8 bit	spare 8 bit	SECTION PATTERN 32 bit

Slave Info

63-52				
63-58	57-52	51	50-48	47-0
000 - FFD 12 (6+6)		P 1	CNT 3	single SLAVE information 48 bit

How it works, priority protocols



timing

Slave 2

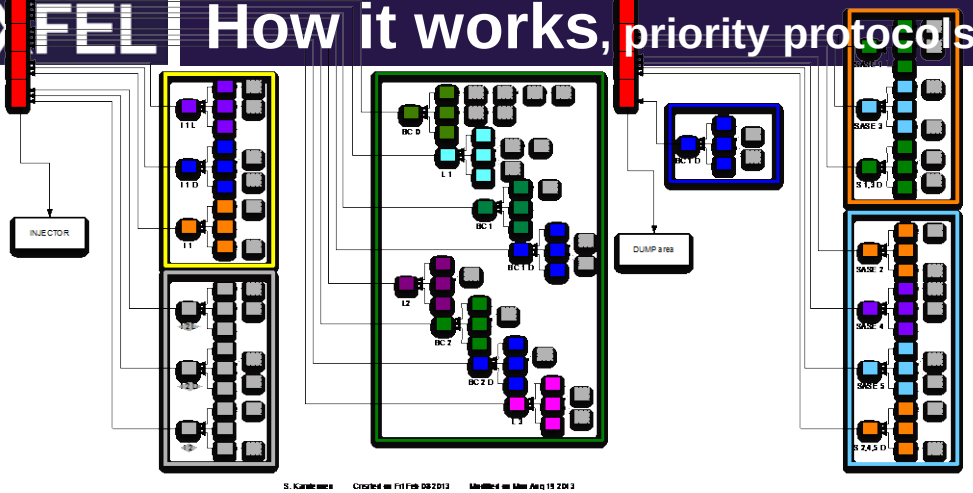
Slave 1

Master

Slave 3

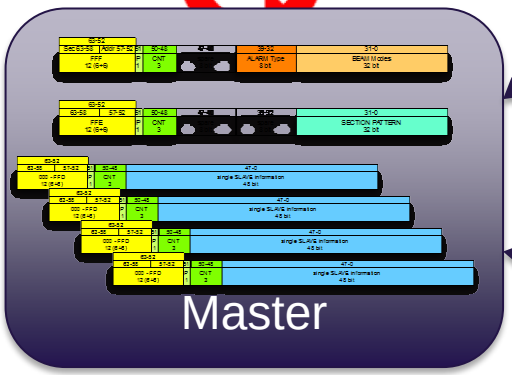
ALARM out

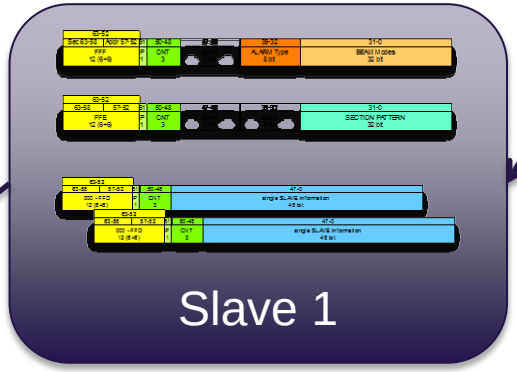
How it works, priority protocols

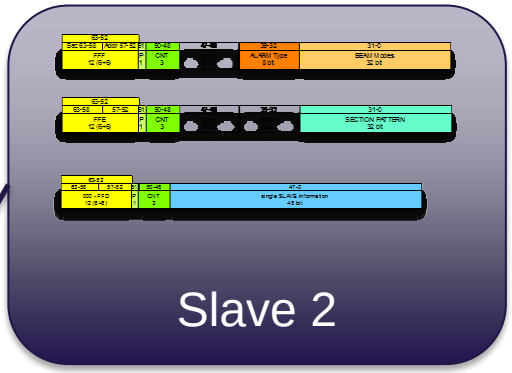


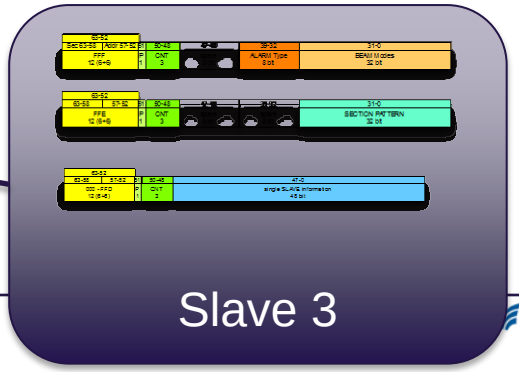
1.) Beam Modes **very high**

timing



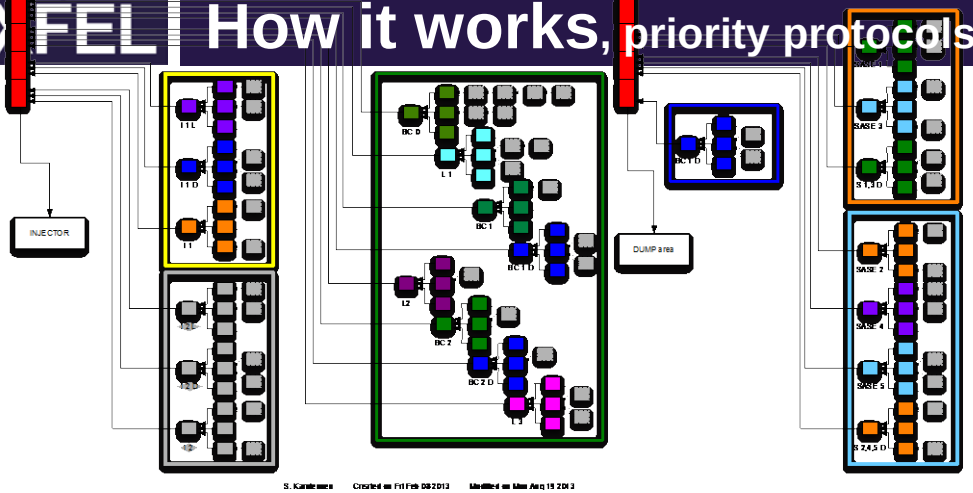






ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

Alarm

timing

Master

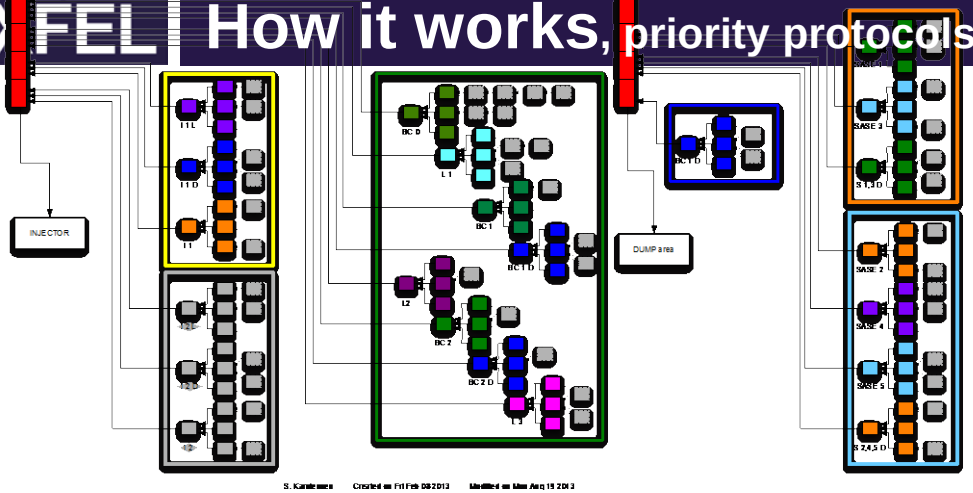
Slave 1

Slave 2

Slave 3

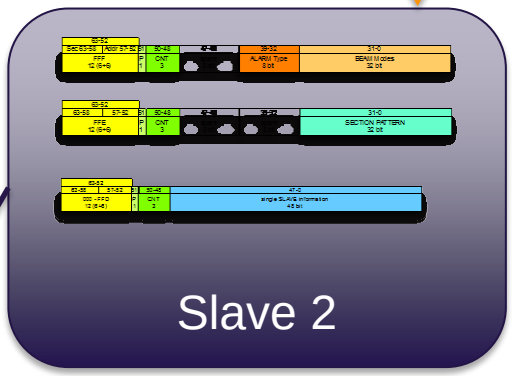
ALARM out

How it works, priority protocols

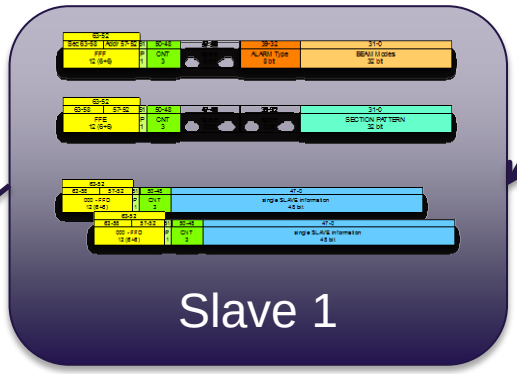


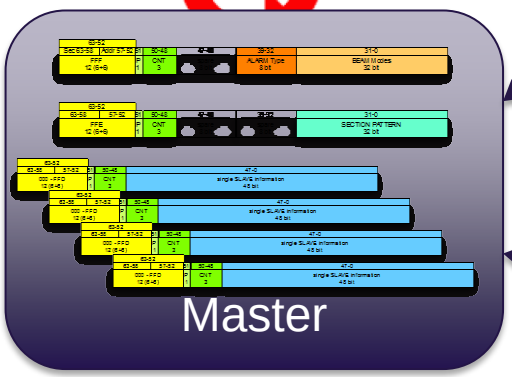
1.) Beam Modes **very high**

Alarm

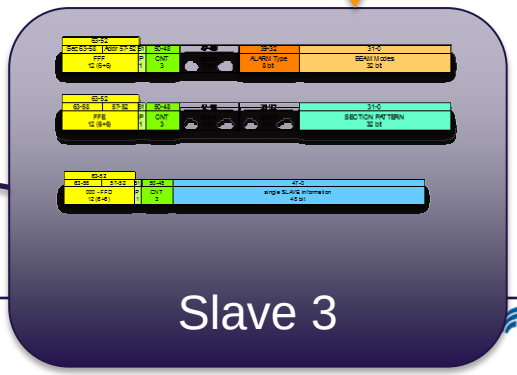


timing



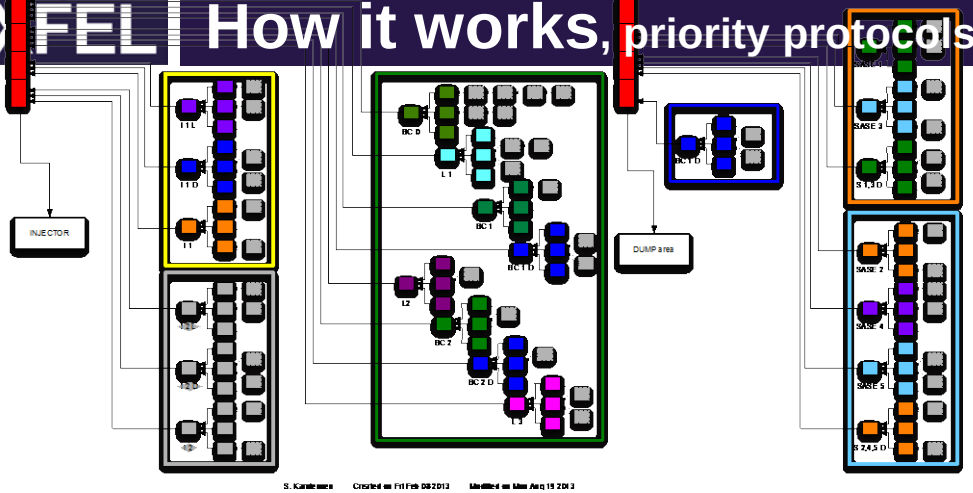


Alarm



ALARM out

How it works, priority protocols



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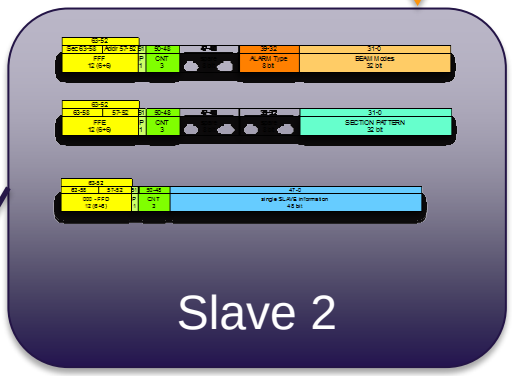
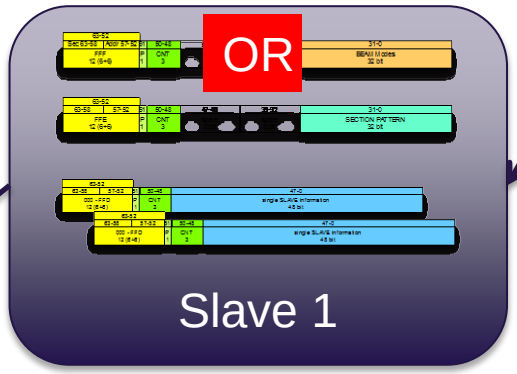
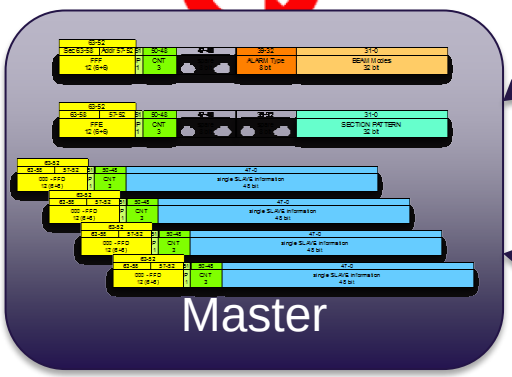
Alarm

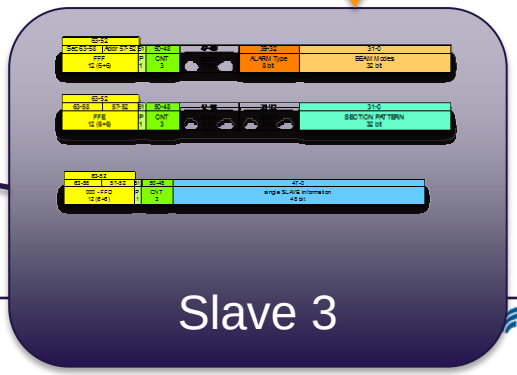




timing

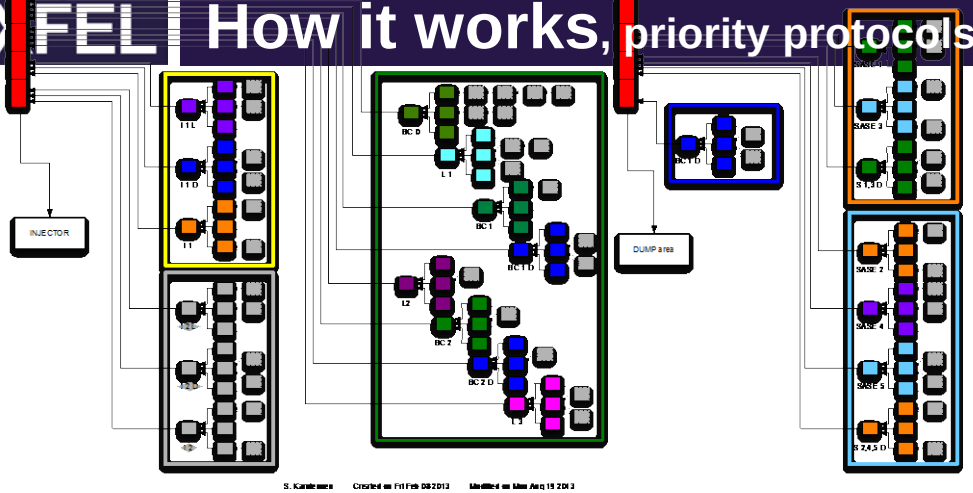


Alarm



ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

Alarm

Slave 2

OR

Slave 1

timing

OR

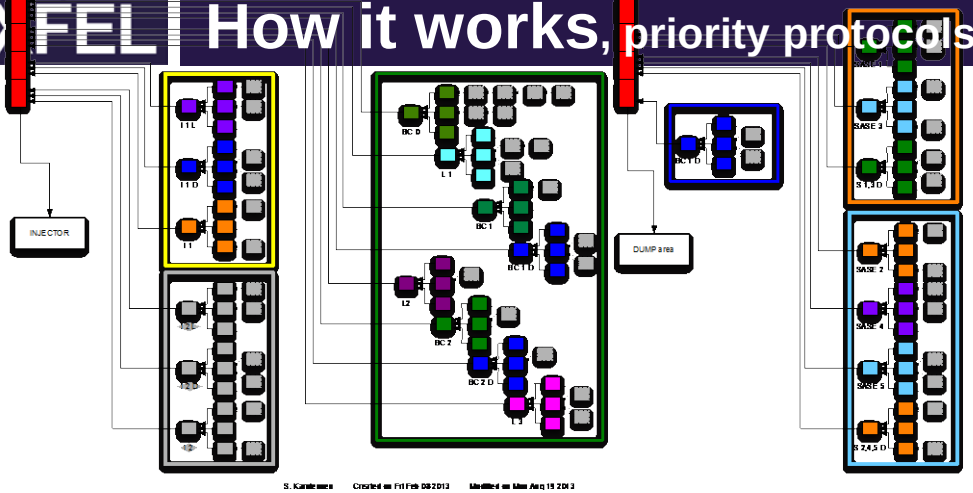
Master

Alarm

Slave 3

ALARM out

How it works, priority protocols



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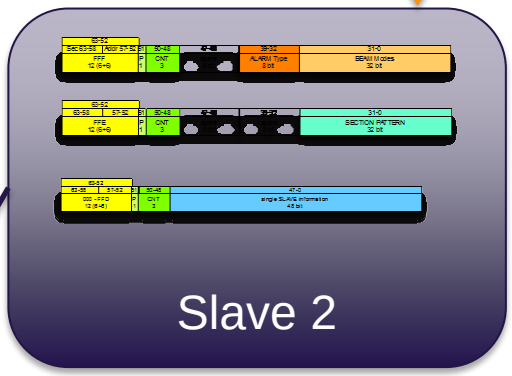
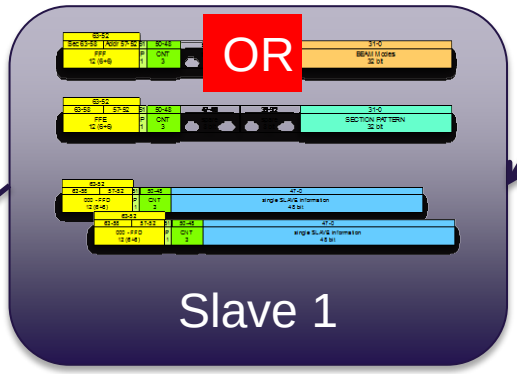
Alarm

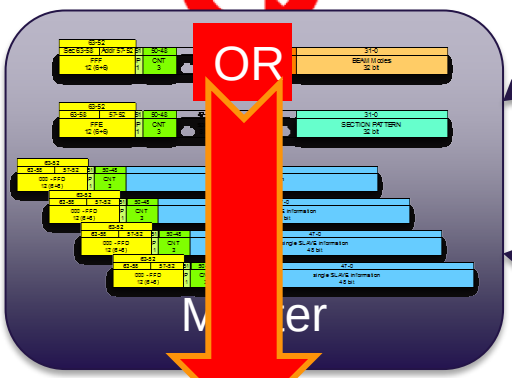


Slave 2



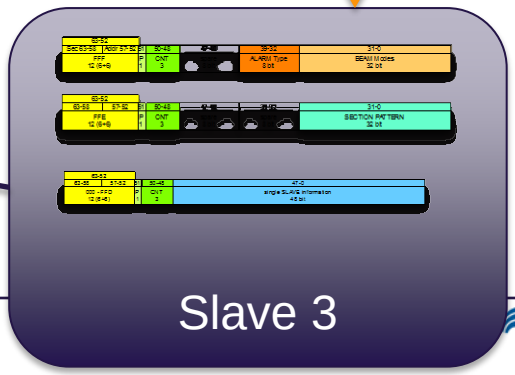
Slave 1

timing



M ter

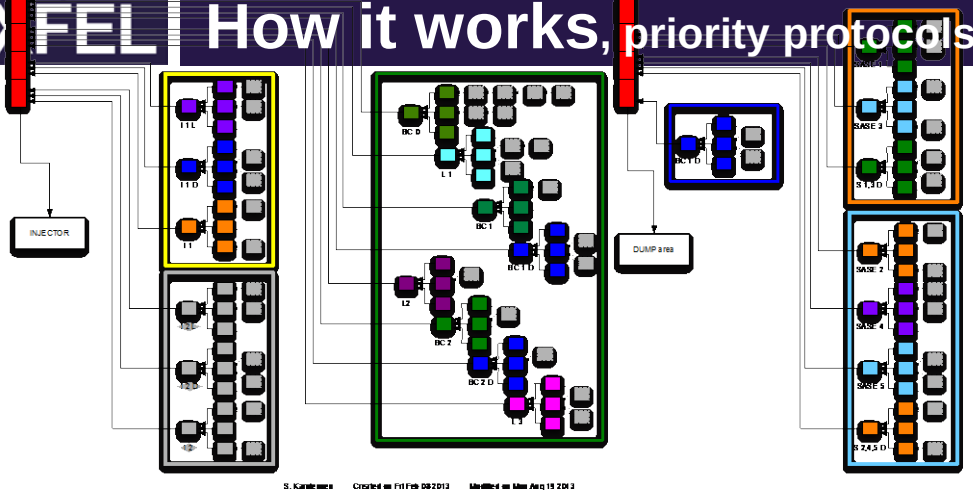
Alarm



Slave 3

ALARM out

How it works, priority protocols



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Alarm

Slave 2

OR

Slave 1

timing

OR

Master

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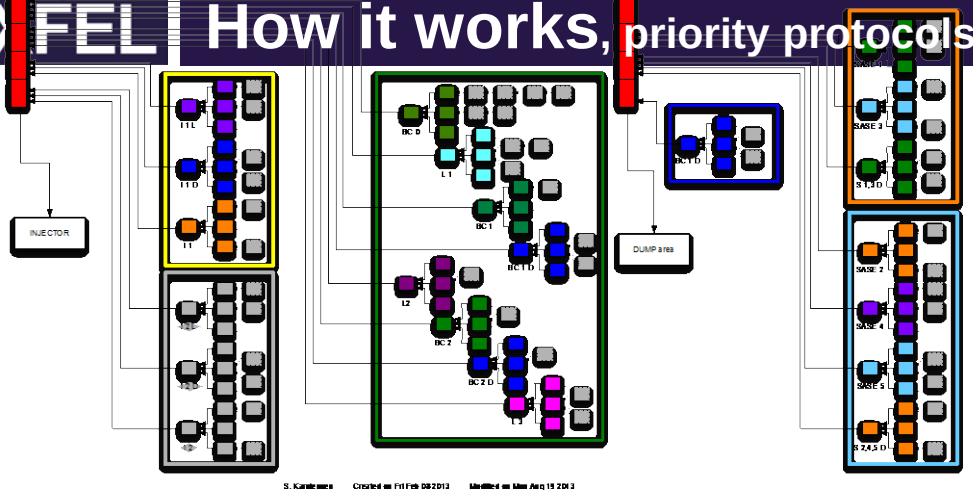
Slave 3

ALARM out

How it works, priority protocols



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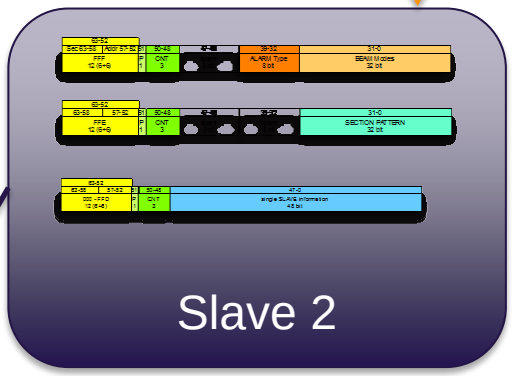
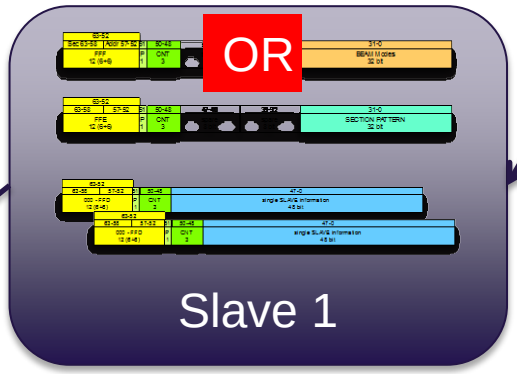
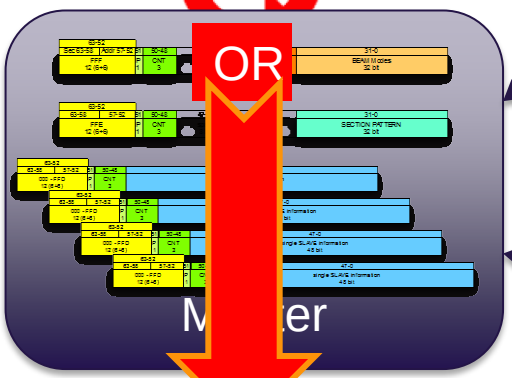
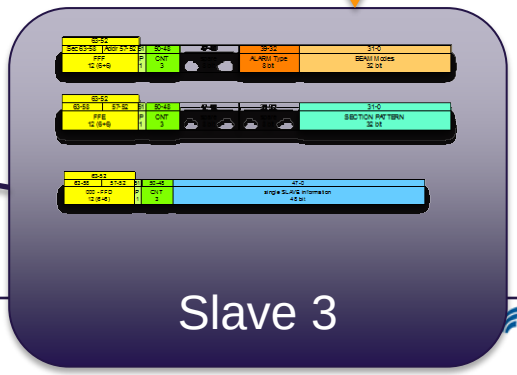




timing

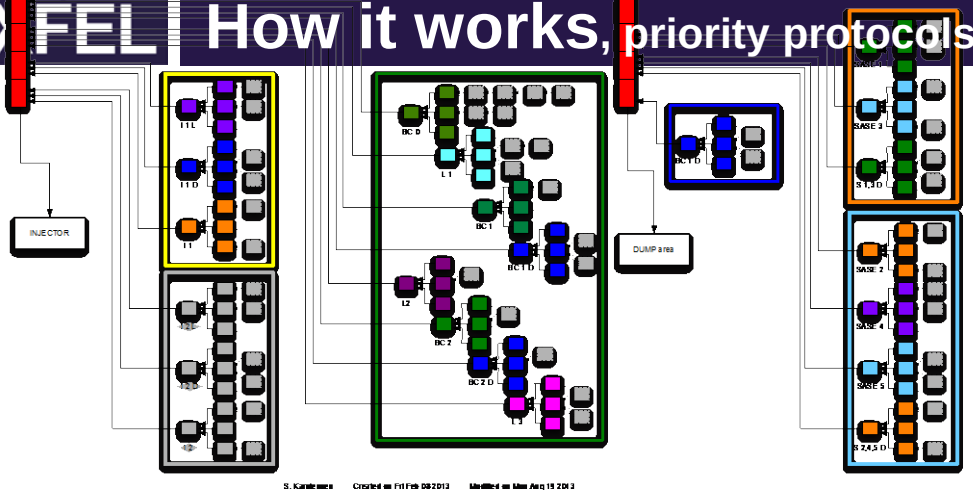


Alarm



ALARM out

How it works, priority protocols



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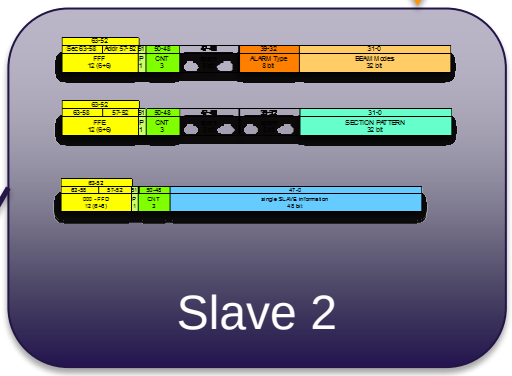
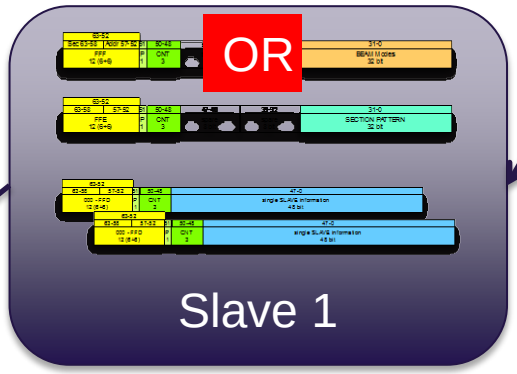
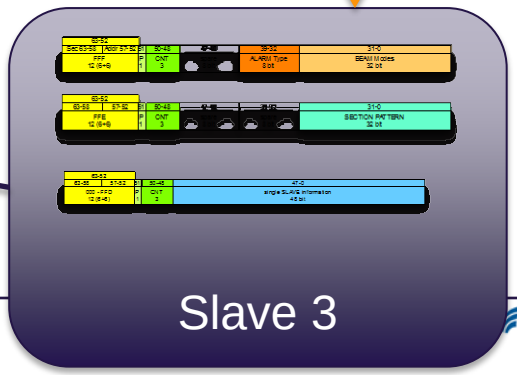
Alarm



timing

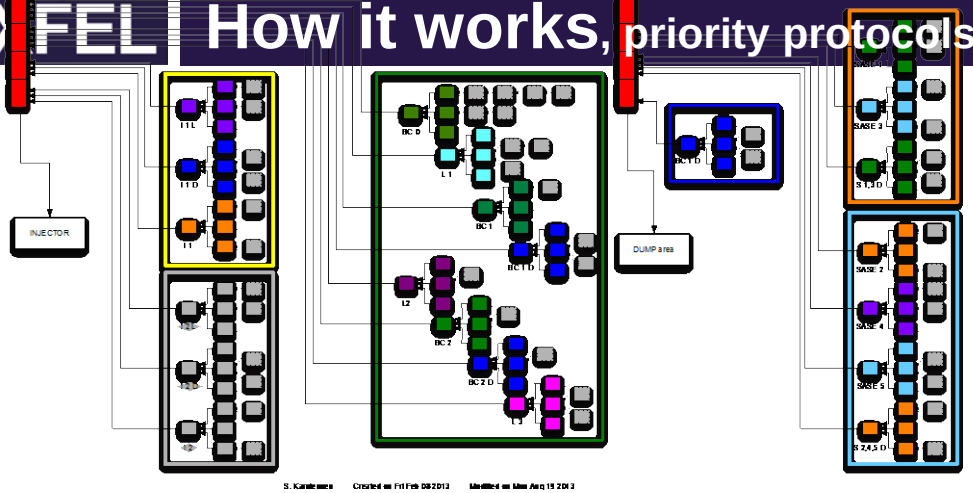


Alarm



ALARM out

How it works, priority protocols



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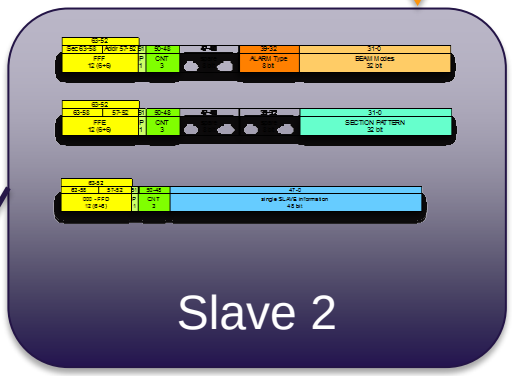
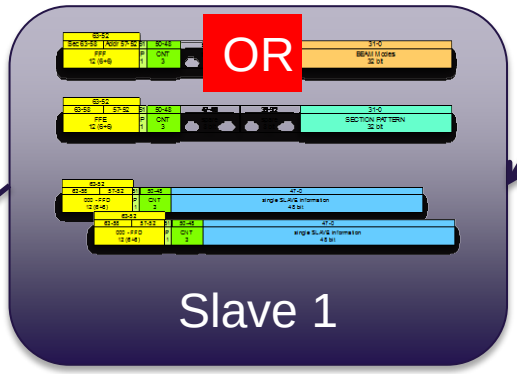
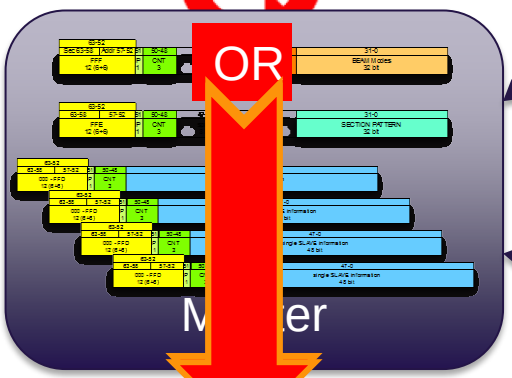
Alarm

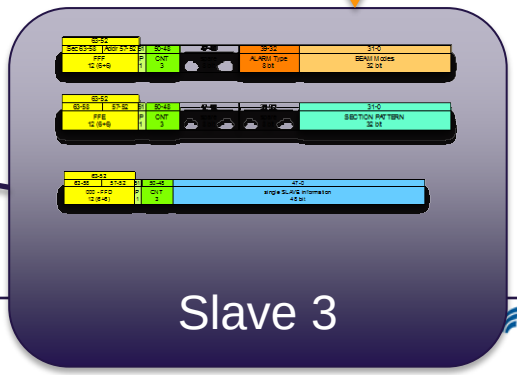




timing

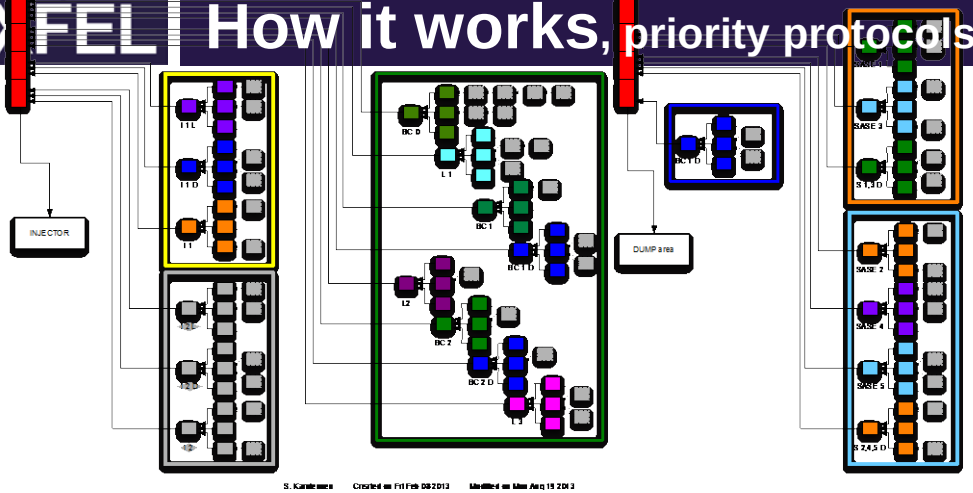


Alarm



ALARM out

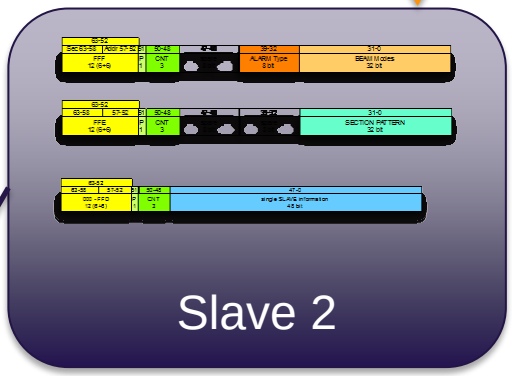
How it works, priority protocols

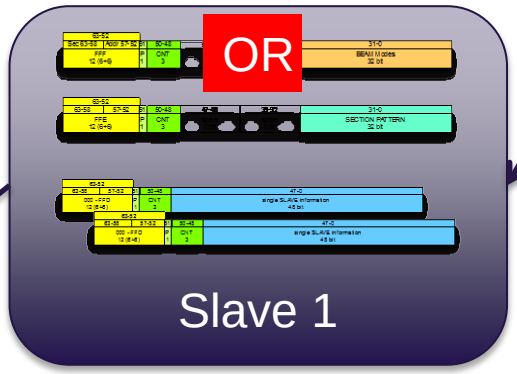


1.) Beam Modes **very high**

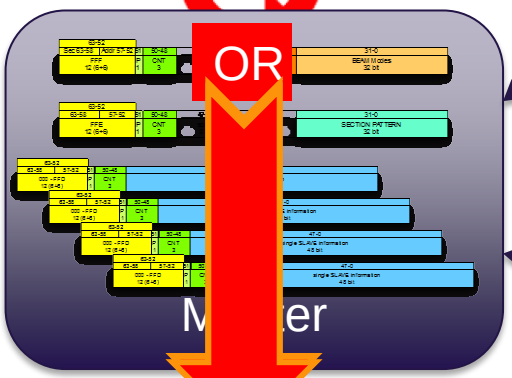
2.) Section Pattern **high**

Alarm



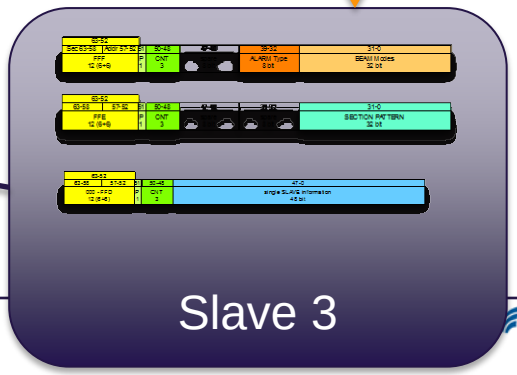


timing

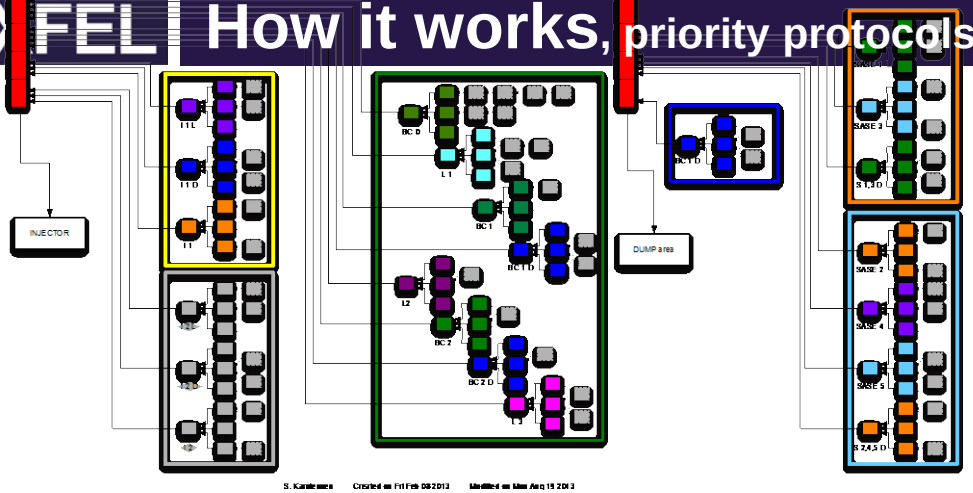


ALARM out

Alarm



How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

Alarm

timing

OR

Slave 2

OR

Slave 1

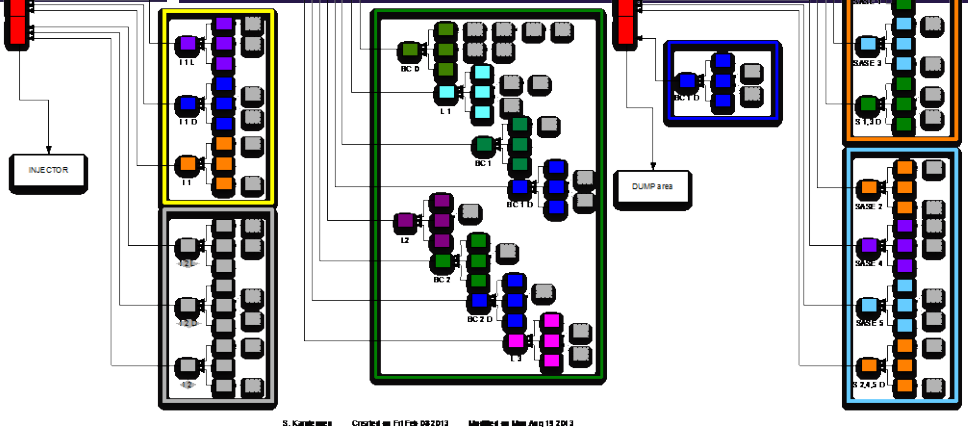
Alarm

Master

Slave 3

ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

Alarm

timing

OR

OR

OR

Slave 1

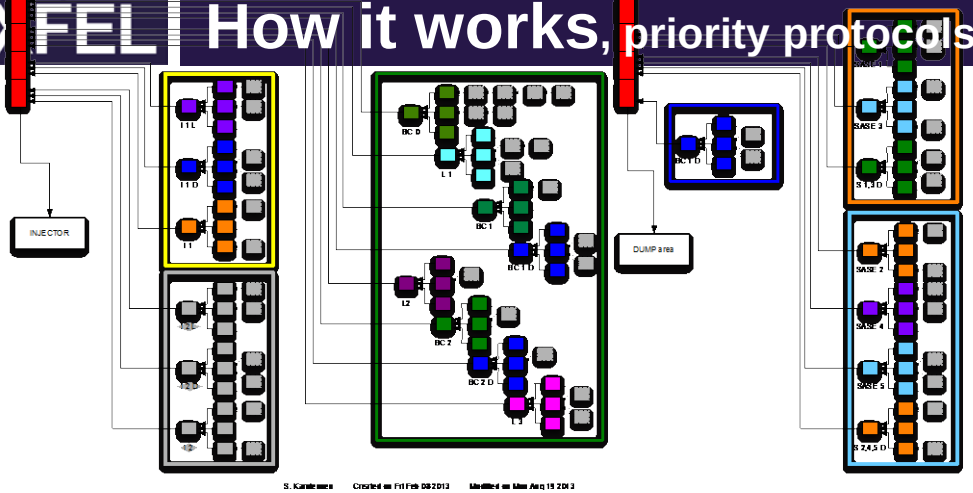
Slave 2

Alarm

Slave 3

ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

Alarm

timing

OR

OR

OR

Slave 1

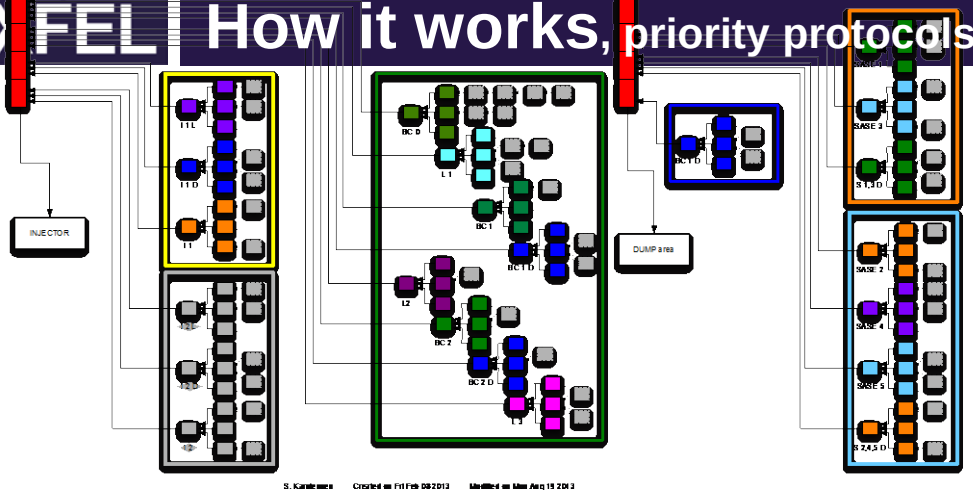
Slave 2

Slave 3

Alarm

ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

Alarm

timing

OR

OR

OR

Slave 1

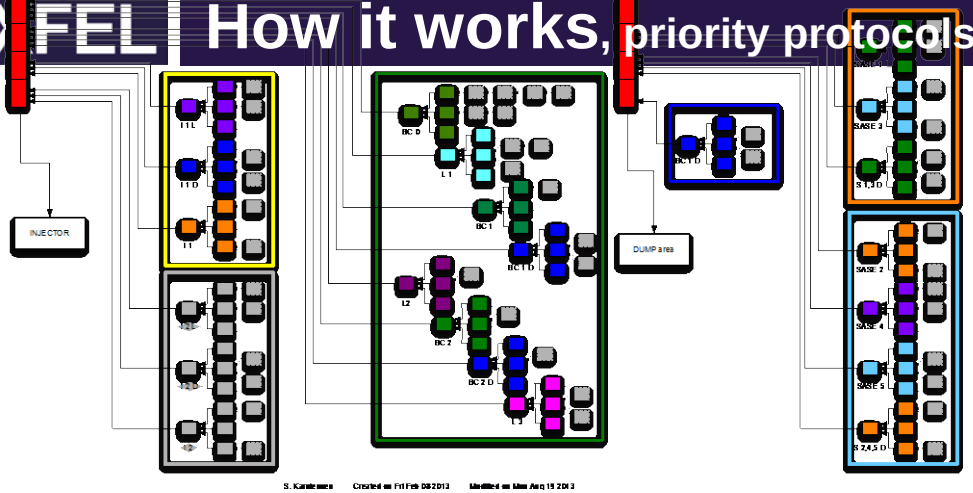
Slave 2

Alarm

Slave 3

ALARM out

How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

Alarm

timing

OR

OR

OR

Slave 1

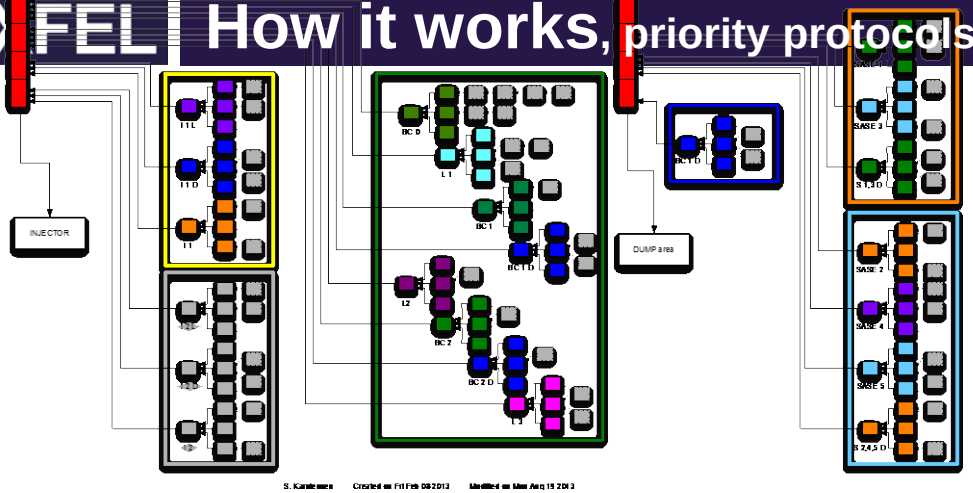
Slave 2

Slave 3

Alarm

ALARM out

How it works, priority protocols

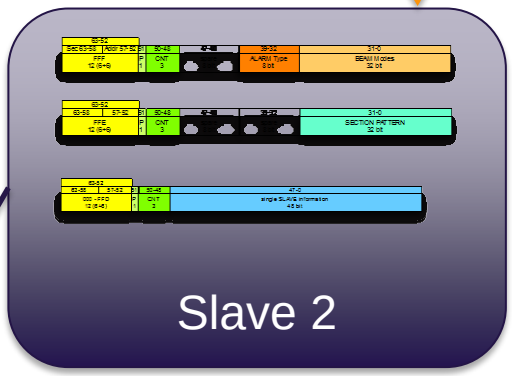


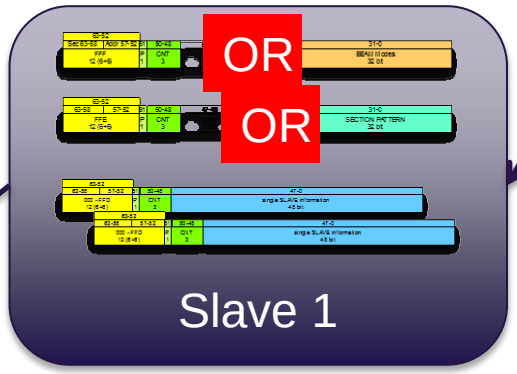
1.) Beam Modes **very high**

2.) Section Pattern **high**

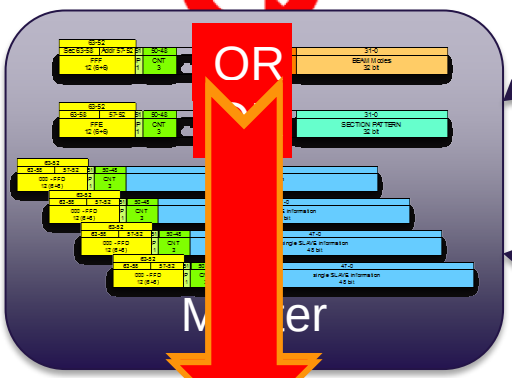
3.) Slave info **low**

Alarm



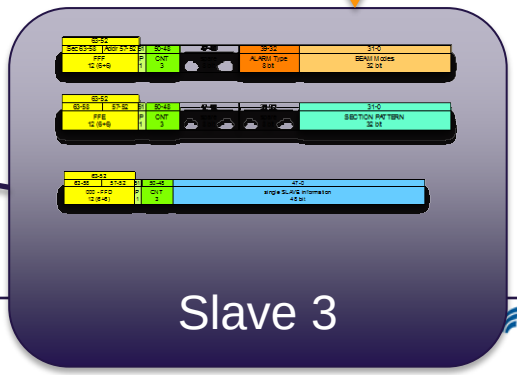


timing

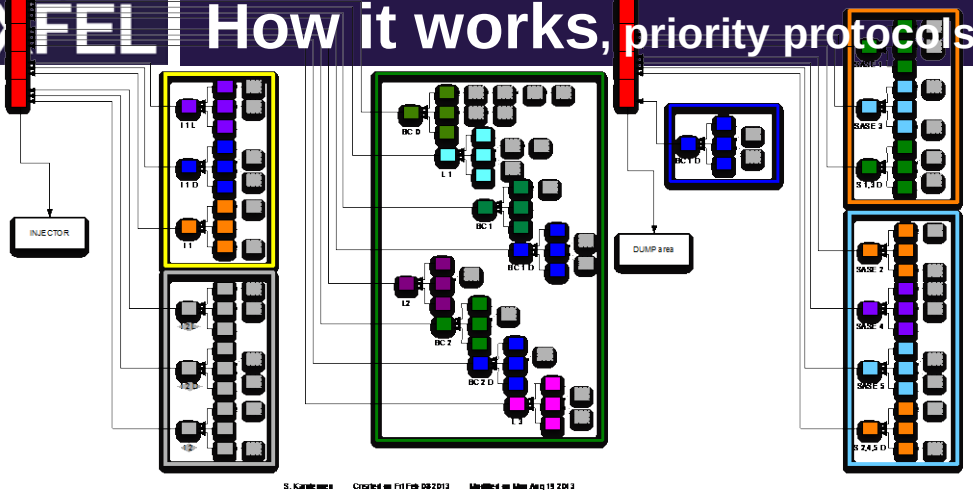


ALARM out

Alarm



How it works, priority protocols



1.) Beam Modes **very high**

2.) Section Pattern **high**

3.) Slave info **low**

Alarm

timing

OR

OR

OR

Slave 1

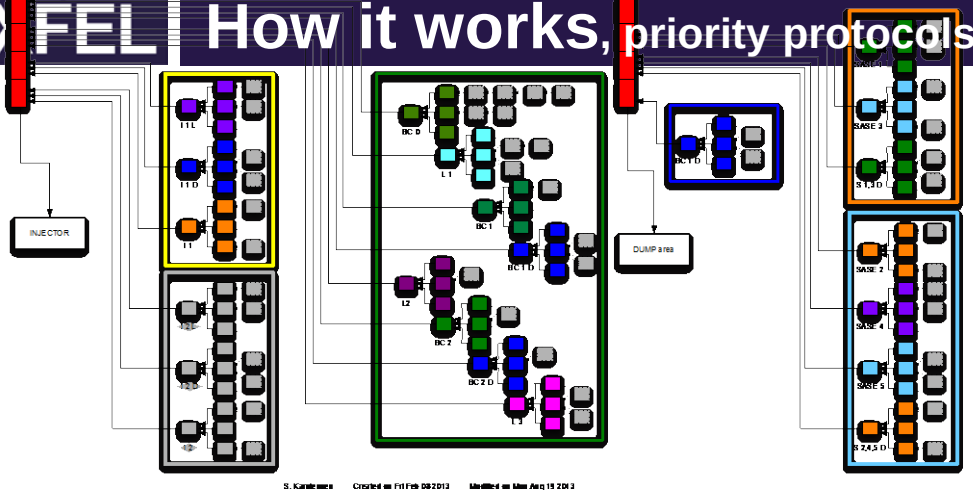
Slave 2

Slave 3

Alarm

ALARM out

How it works, priority protocols

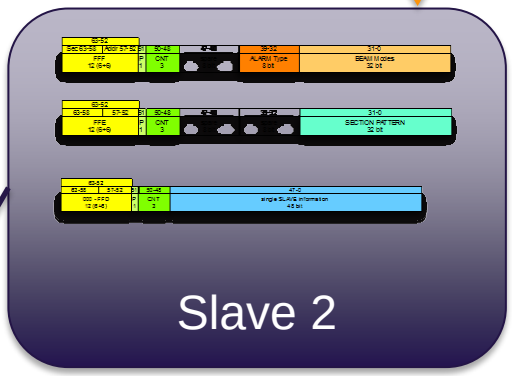


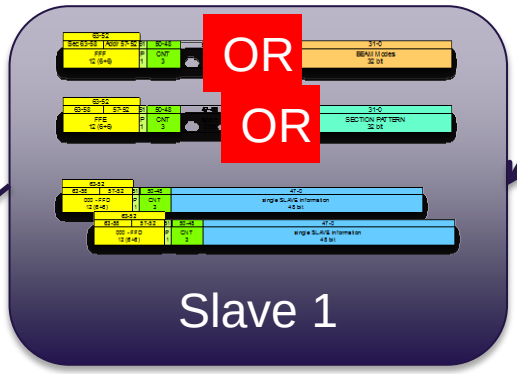
1.) Beam Modes **very high**

2.) Section Pattern **high**

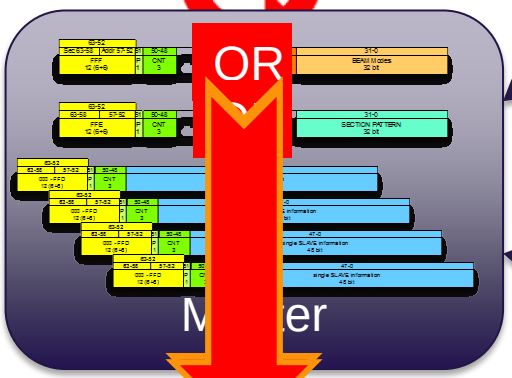
3.) Slave info **low**

Alarm

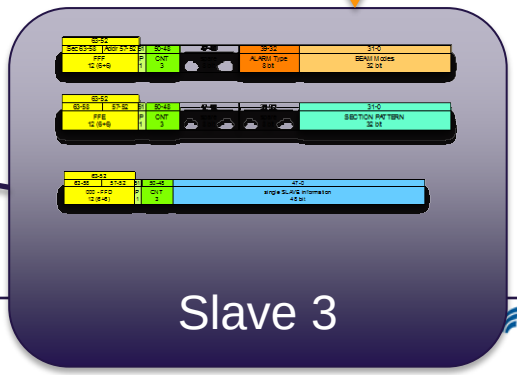




timing



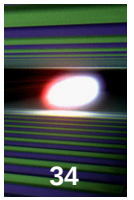
Alarm



ALARM out

European XFEL

Reaction Times in XFEL



Beam loss location	Distance from injector	Distance from dump	# of lost bunches
Injector	0 m	-1970 m	0
BC1	160 m	-1810 m	7
BC2	360 m	-1640 m	15
Linac center	1040 m	-930 m	44
Linac end	1650 m	-320 m	69
Beam distribution	2010 m	40 m	2
Last undulator	3010 m	1040 m	44

- ~ 50 bunches are inside accelerator
- Signal transport from dump to injector 20 µs (2000 m)
- ~ 50 bunches generated before laser is blocked
- Using beam dump kicker reduces the number of lost bunches inside SASE Undulator sections.

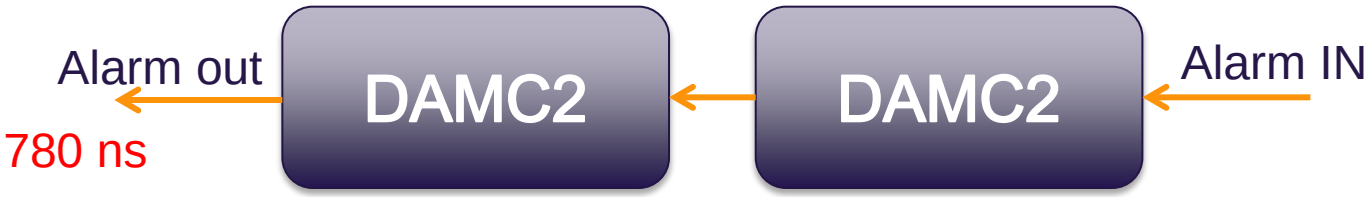
What does all information of the slides before now mean for our largest problem:

the Latency?

Latency MPS-DAMC2 boards (August 2013)

Fiber optics: unattended (5ns / m)
Speed: 1.25 GBps

Latency between DAMCs will be improved.
Factor 3 is aspired.



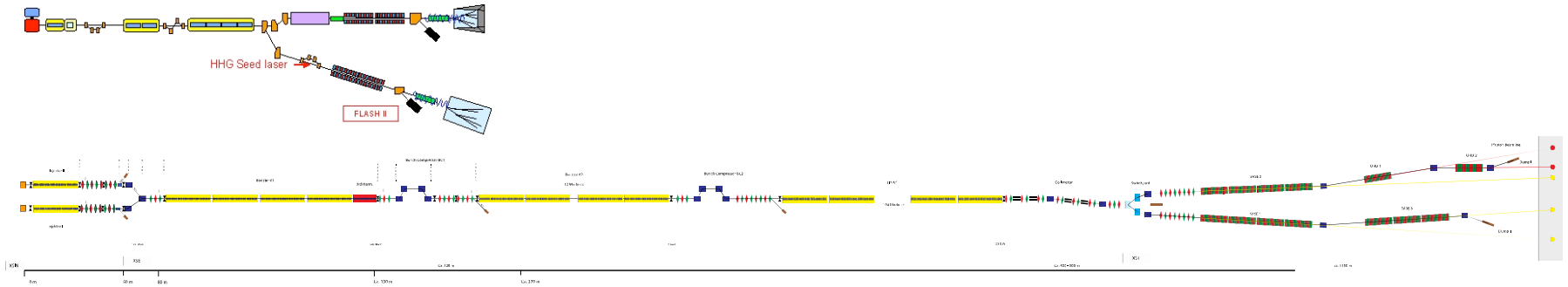
XFEL needs 20 µsec, we peak: 1400 ns + 2000 m * 5 ns/m = 11,4 µsec

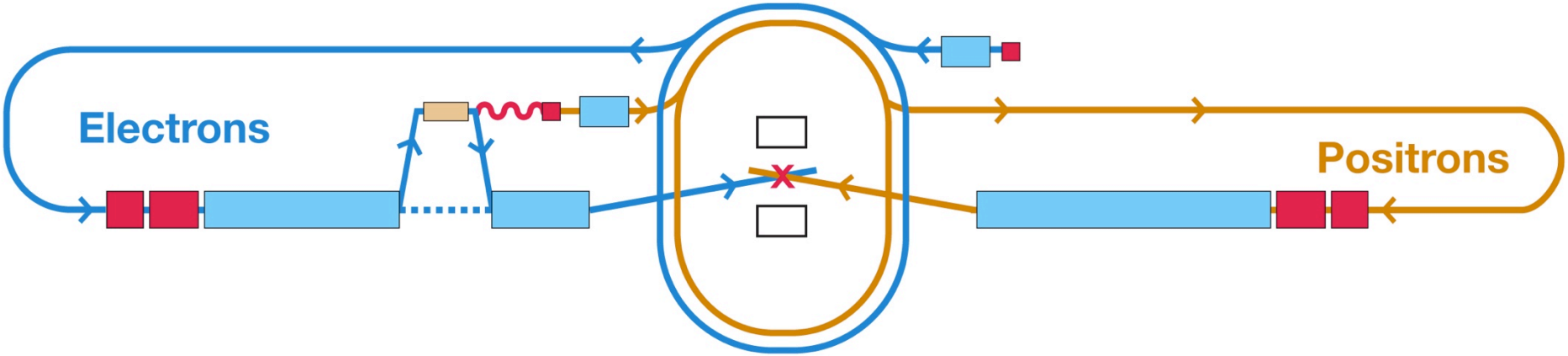
Thank You

European XFEL

FLASH II, XFEL, ILC

- scalability

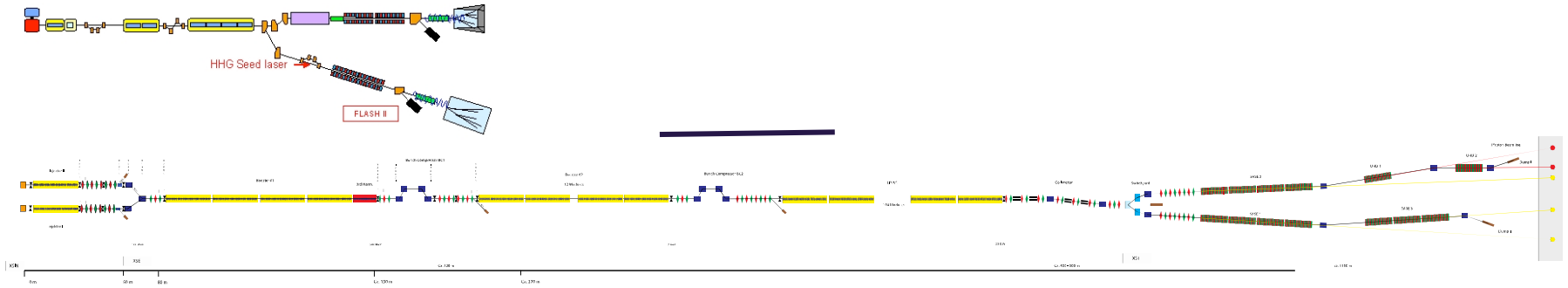


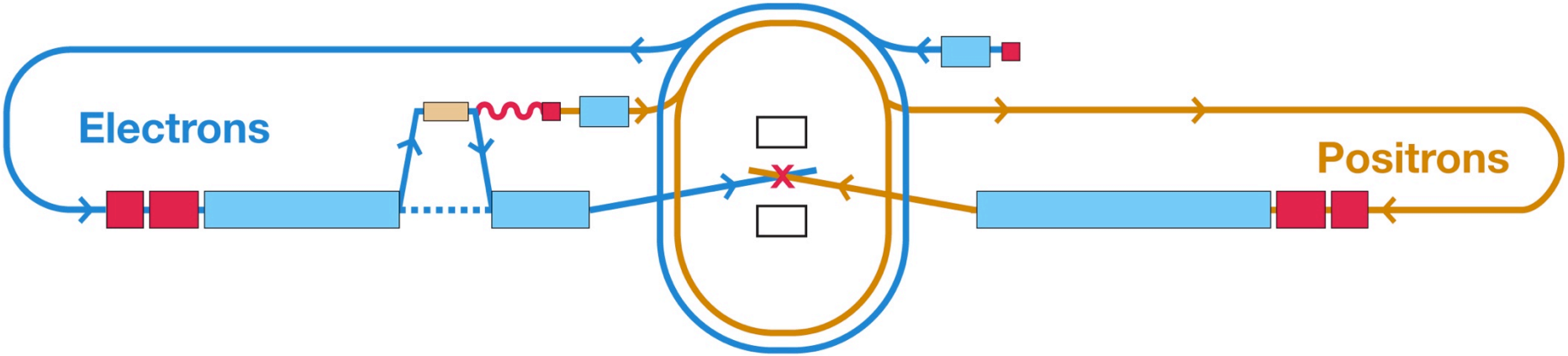


European XFEL

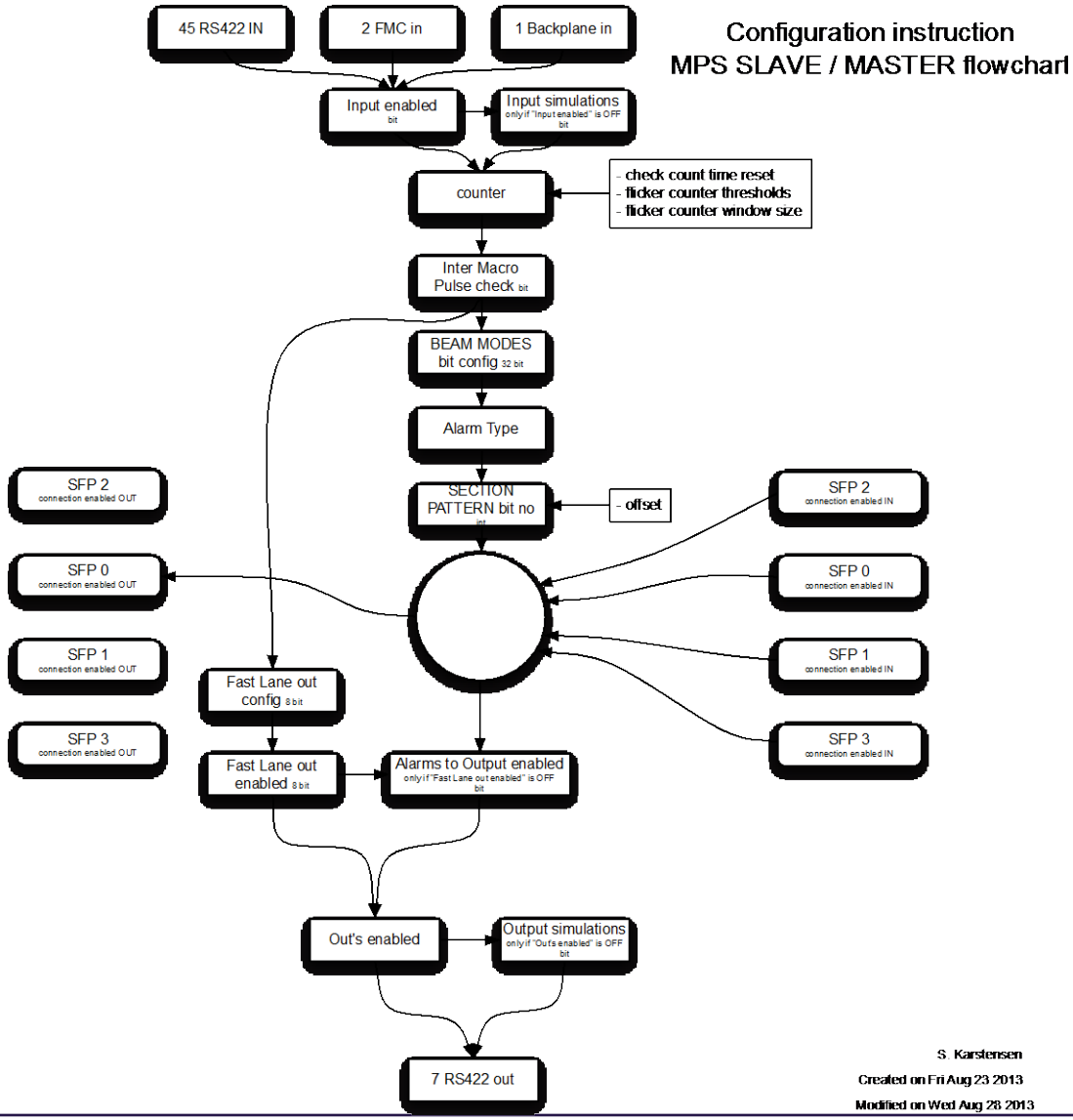
FLASH II, XFEL, ILC

- scalability



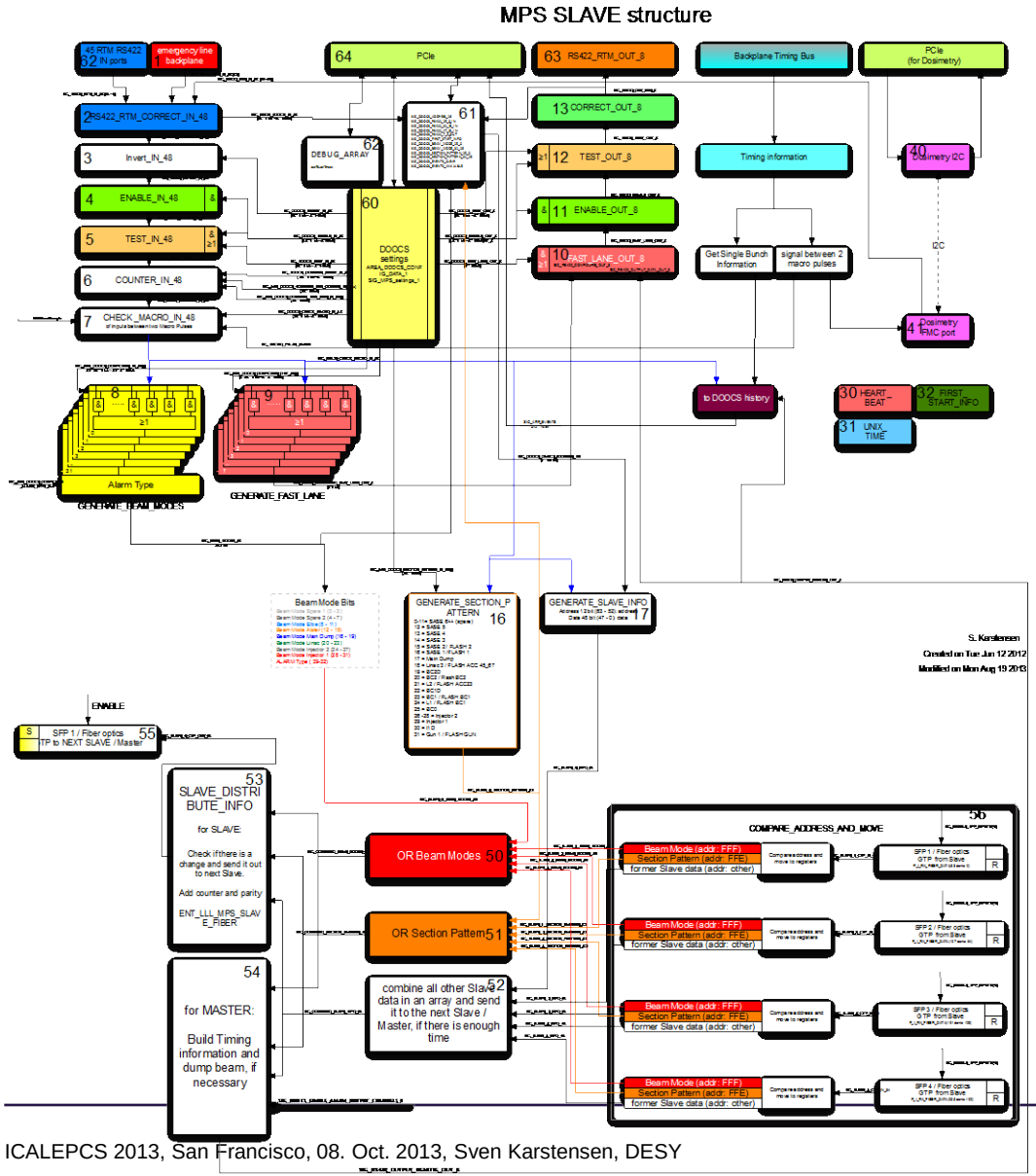


Configuration Instruction



European XFEL

MPS architecture in XFEL



- Numbers in drawing corresponding to numbers in FPGA code
- Excel Sheet includes all addresses