

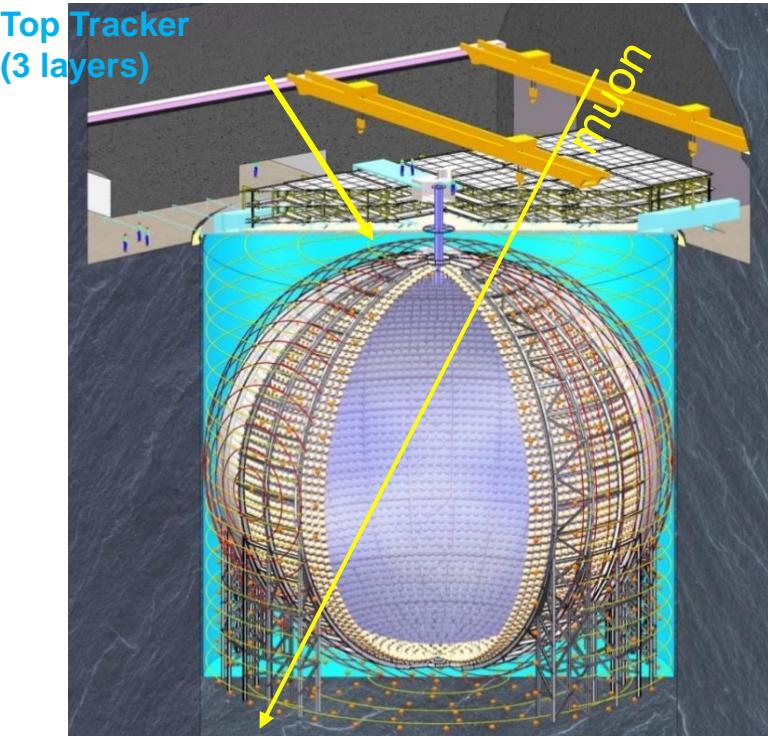
Global Trigger Board System

GTB Design Review passed 2022-01-24

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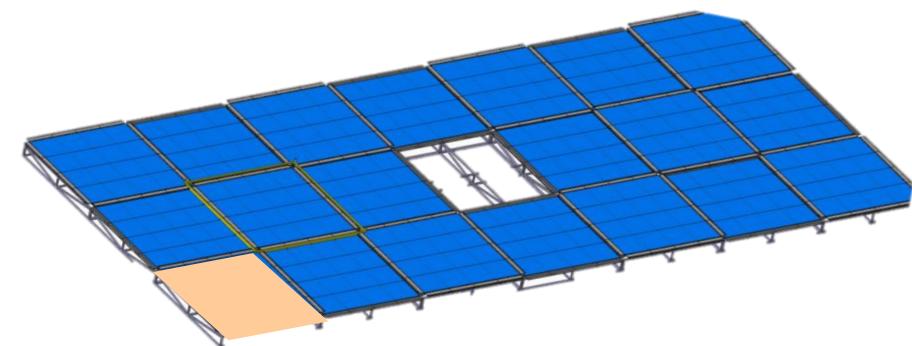
JUNO Top Tracker



- 63 walls (496 modules)
- 32 k scintillator strips (2.6 cm)
- 6.8x6.8 m² sensitive area/wall
- 64 k channels in total
- 1000 Front End Boards to be installed



1 of 3 layers composed of 20 walls

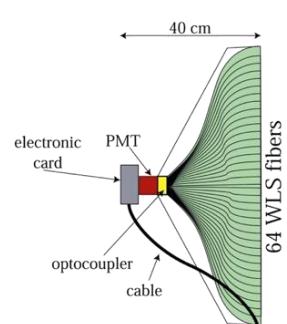


TT wall with readout electronics

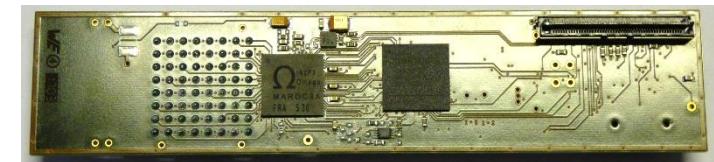
Concentrator Board



Split-power



Front End Board



Basic numbers for a single wall:

- ◆ Square of 7*7m
- ◆ 64*16 Channels
- ◆ ~50KHz/PMT dark & radioactive noise

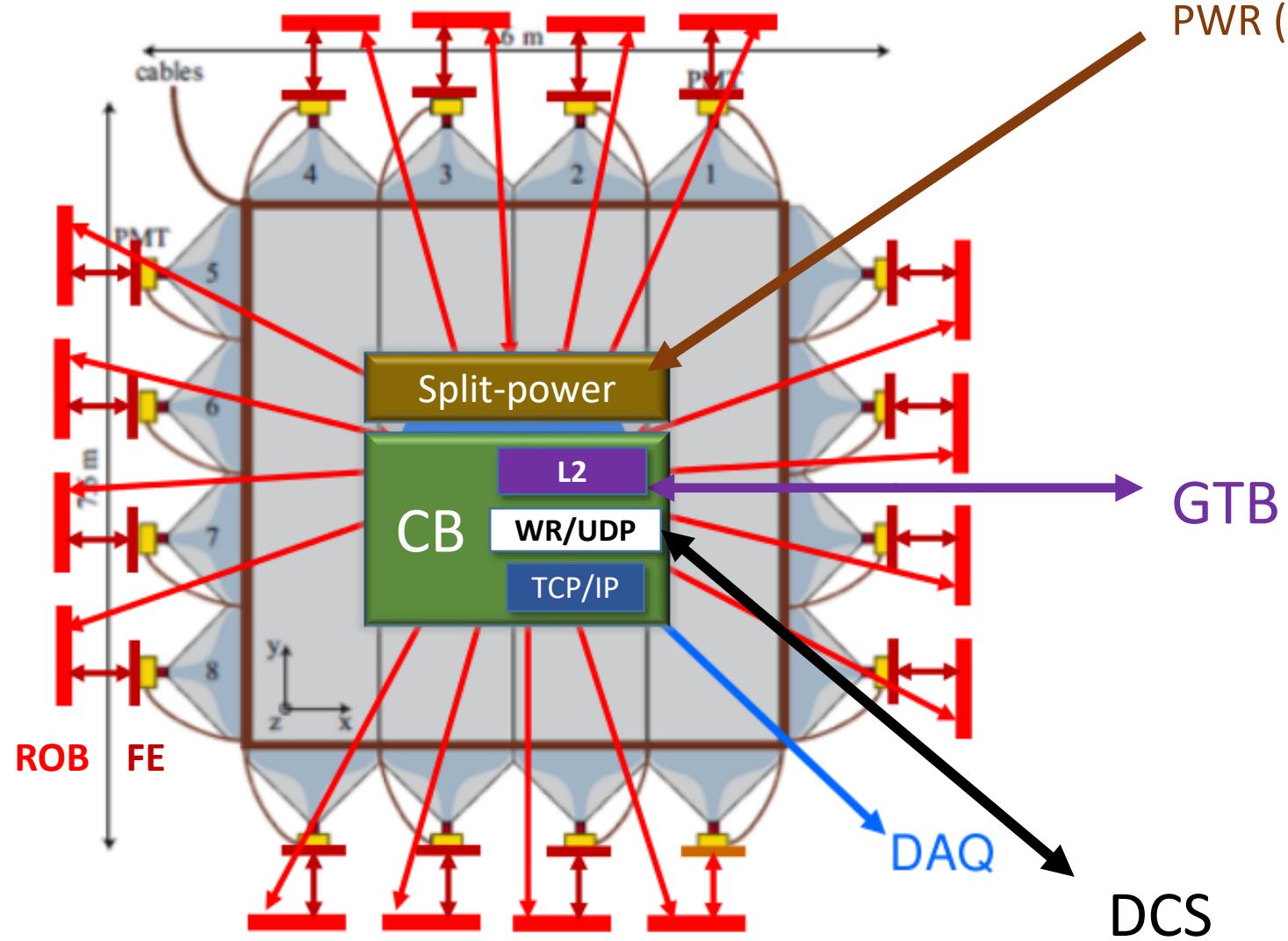
L2 Trigger (GTB)



Read Out & Front End Boards
installed in the End Cap



Single TT wall readout electronics



Electronic components of a TT-wall:

- 16 PMTs
- 16 FE
- 16 ROB
- 1 Concentrator
- 1 split-power

Copper cables for local data connections

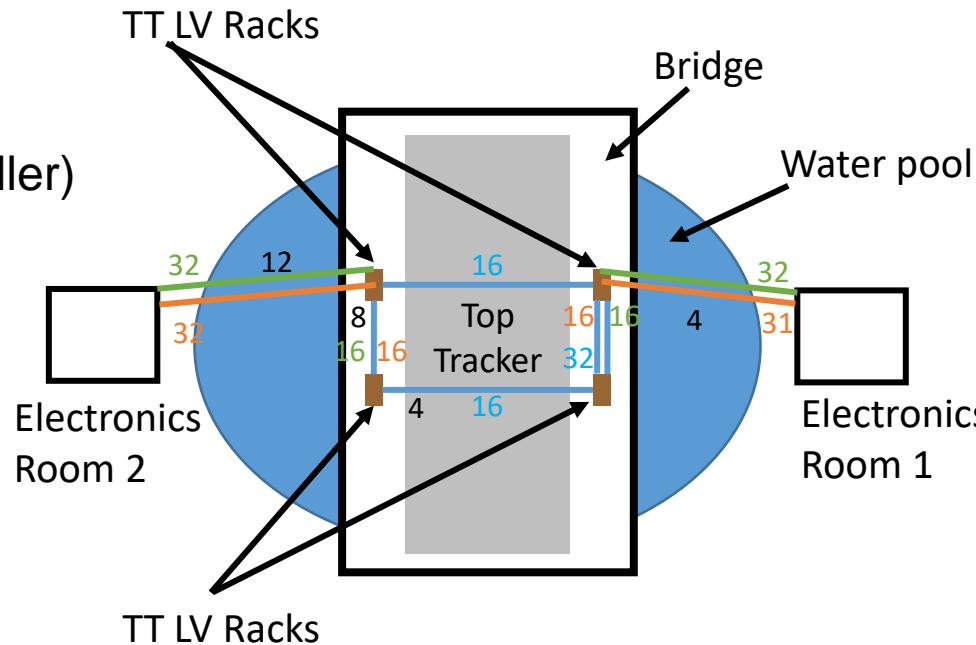
- ROB-CB
- CB-split-power

Optical cables for distant data connections

- DCS
- DAQ
- L2

Cabling

We need 2 racks in each electronic room (DAQ/DCS and Ethernet controller)



- DAQ TCP/IP
- SC/WR UDP
- L2 H protocol
- Wiener TCP/IP

		PS1			Power Supply		
		PS1			PS2		
		CABLE TYPE 3	CABLE TYPE 2	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 2
PS1		CABLE TYPE 3	CABLE TYPE 2	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 2
		CABLE TYPE 4	CABLE TYPE 3	CABLE TYPE 2		CABLE TYPE 2	CABLE TYPE 3
		CABLE TYPE 3	CABLE TYPE 2	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 1	CABLE TYPE 3
		PS3			PS4		

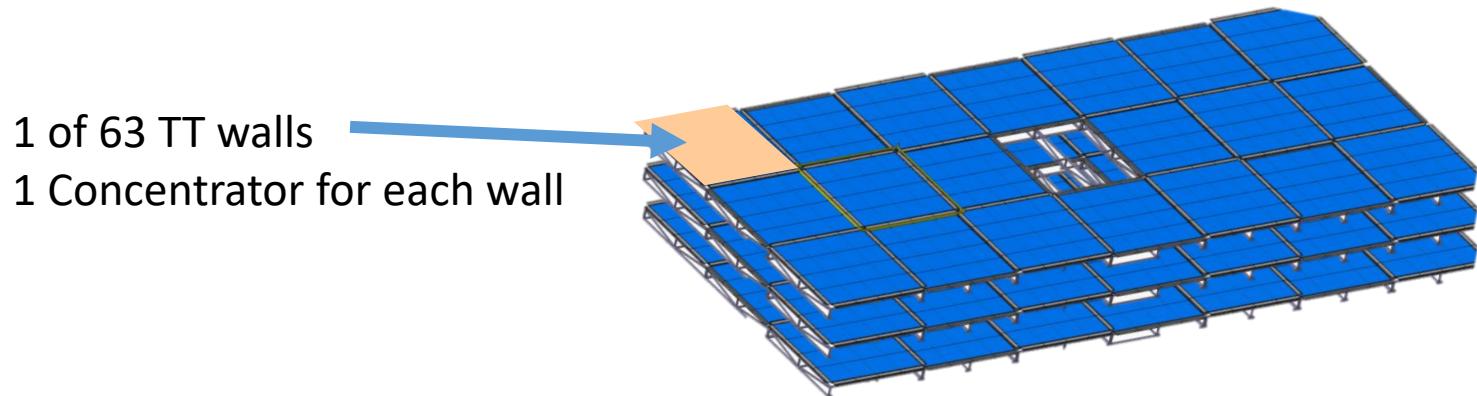
Power supplies + passive fiber connections

Type 1 10m	(6x3=18)
Type 2 20m	(6x3=18)
Type 3 25m	(6x3=18)
Type 4 35m	(2x3=6)

Concentrator

Juno Top Tracker

Concentrator in the TT readout

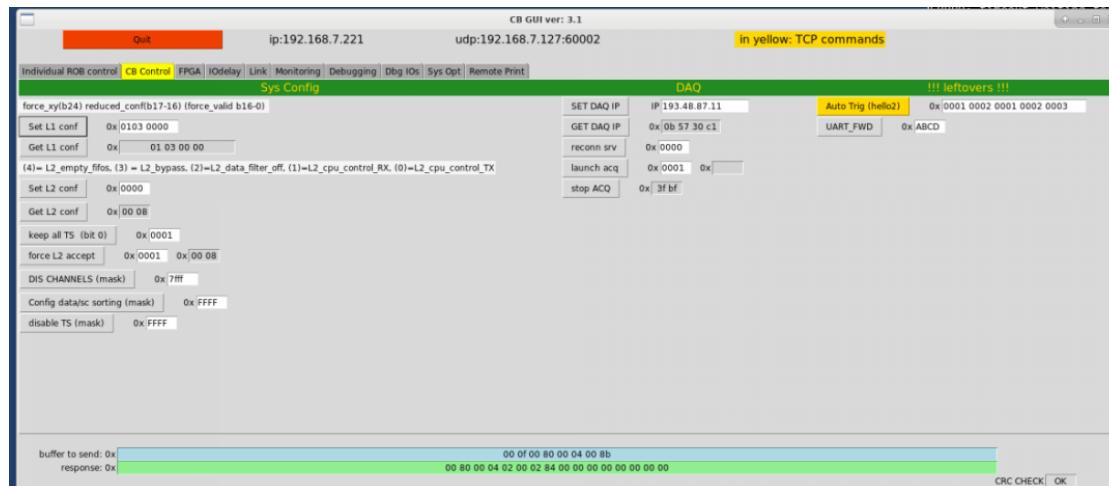


Data rate & dead-time reduction

Reduces data rate from ~40 kHz @ each ROB to ~50 kHz @ CB
 => Effectively dividing the trigger rate by **16**

Goals	Functionality
Reduce data rate to DAQ	Perform Level 1 (L1) trigger veto
Allow for further data rate reduction via L2 veto	Communicate with a unique TT-L2 card
Avoid unnecessary charge measurements	Reset MAROC readout in the FEB
Correlate events at the TT and JUNO levels	Time stamp ROB data
Reduce the # of signal links in the detector	Control 16 ROBs and MUX data streams

Concentrator firmware

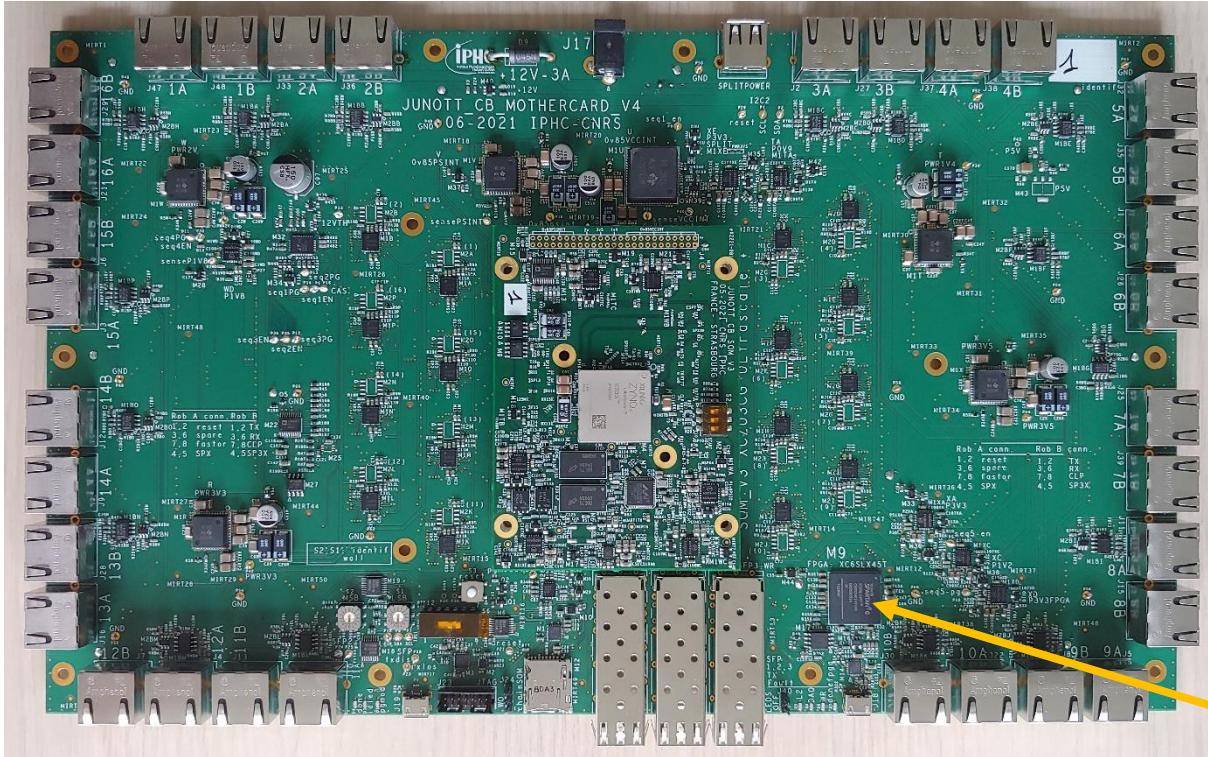


Latest problem seen in the ROB communication

FUNCTIONALITY AFFECTED	PROBLEM
EVENT COUNTER register (@ 0x0104)	IN THE CASE OF TRT : The register counts hits but it should count events. IN OTHER CASE : reset not tested
HVSET and HVUPDATE commands (0x10 and 0x60)	The high voltage is update with the HVSET command, and not only with HVUPDATE
CNSTAT register (@ 0x0001)	Some status writes don't work (for example to change acquisition mode)

- Actual CBs tests interface. Need to be updated, we are waiting for the final GUI from Russians
- Interface improvements :
 - better organization of commands
 - values in decimal and directly in the physical quantity
 - more natural display of states
 - easier debugging
- Also improve the firmware of the CB :
 - Include GTB communication
 - Verification of the time stamp
 - Optimization of the command

Concentrator Test bench



- Flashing the 2 FPGA
- Test of TCP and UDP communications
- ROB links loopback test
- Test of voltage monitoring and measurement of the power supply
- Test of the L2 link

- Test of each individual boards (SOM + Mothercard)



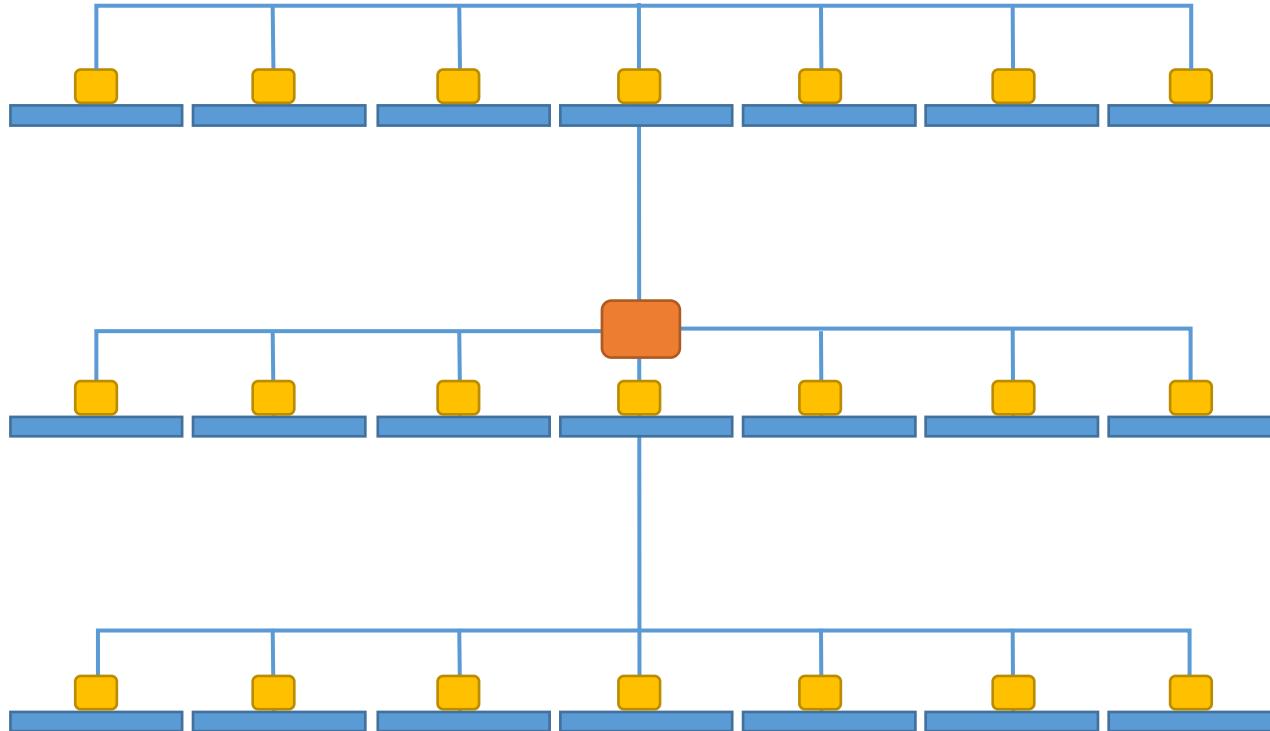
Spartan 6 FPGA

Global trigger board

Juno Top Tracker

GTB Implementation

Main goal of the GTB : send to the concentrator reset/validation signal



The GTB is connected to every concentrator by optical link :

- 64 optical links to this board (63 concentrators + 1 Ethernet)
- 1 link dedicated for external trigger coming from global DAQ (disable local reset and keep all data)

Requirements for GTB

- Accept interesting events (muon tracking)

- Alignment of L1 coincidences inside a time window

- Veto of background noise

- PMT dark noise coincidence
 - Radioactivity

- Misc. requirements (optional)

- Periodic/random trigger for Detector study
 - Scale/throttle in case of extreme situation
 - Commissioning study

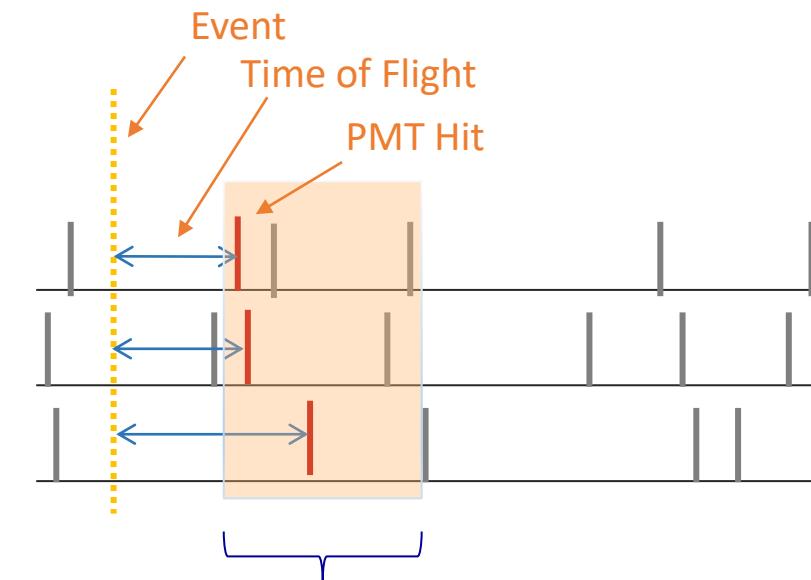
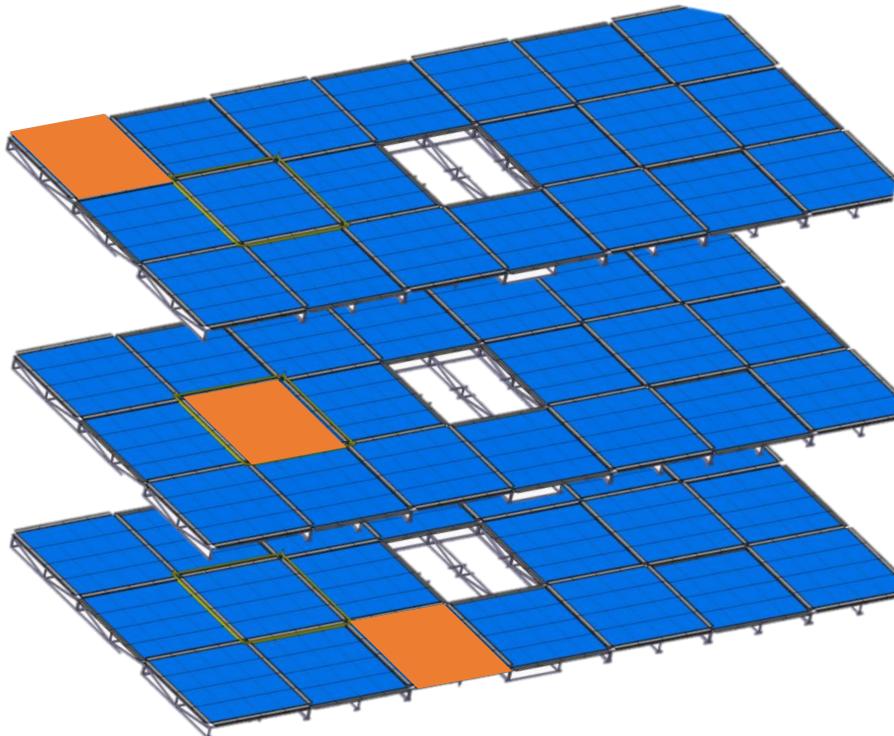
- Information available from L1

- X-Y coincidence time

- Several algorithms under study

- 3 different walls have L1 triggers
 - 3 aligned walls have L1 triggers

L1 Triggers Alignment

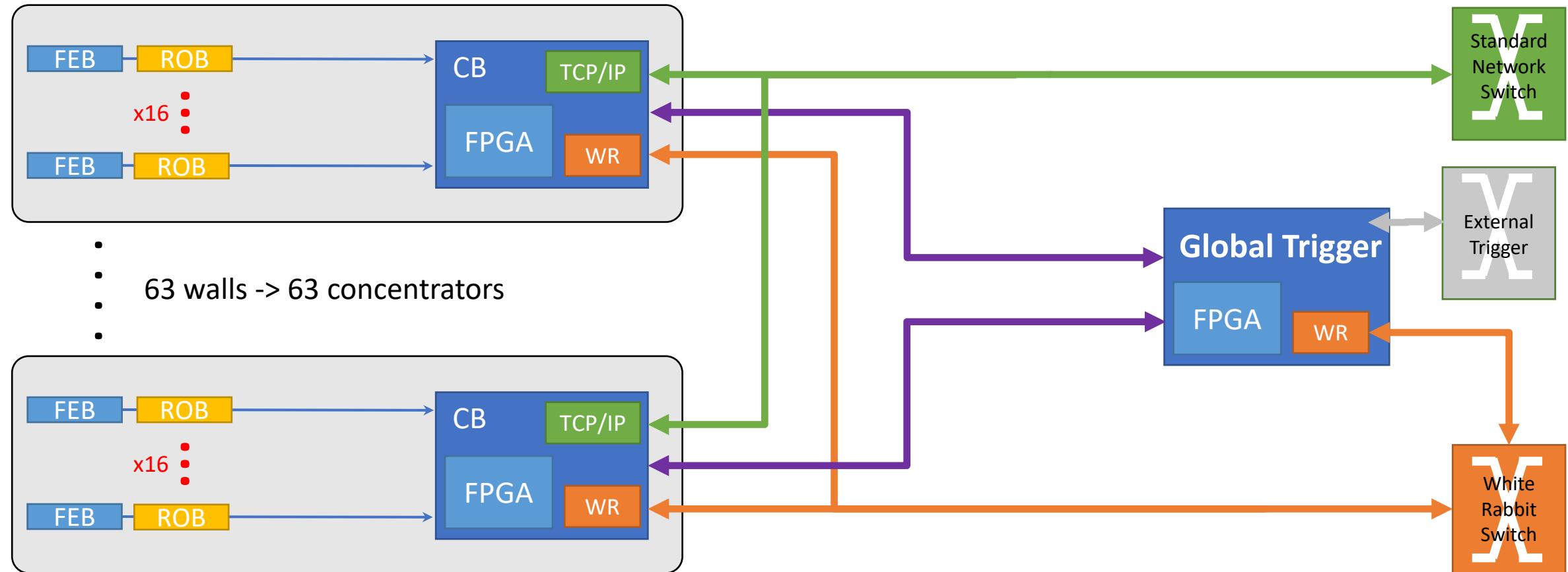


Trigger L2 decision window ~200ns

Basic numbers:

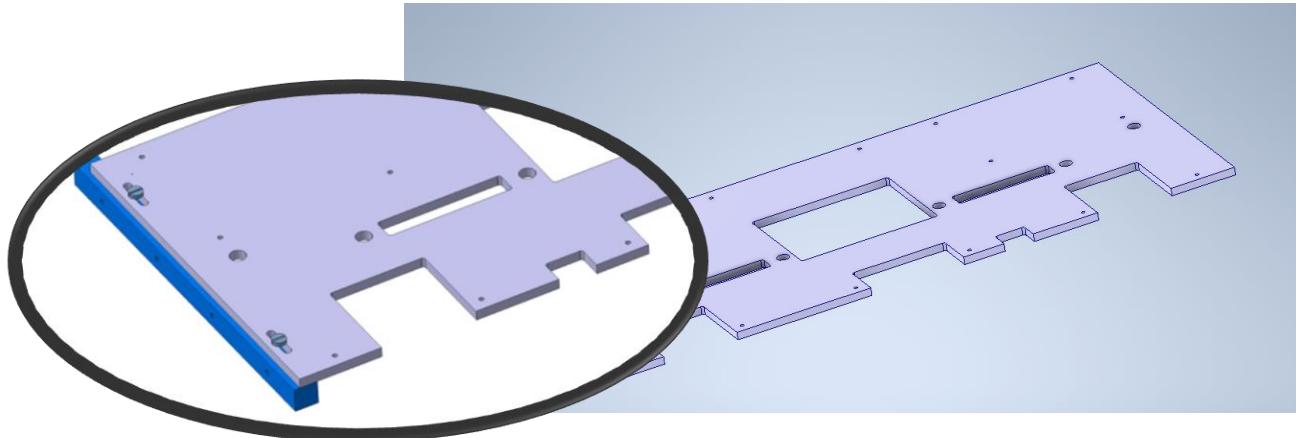
- 49 m length bridge 21 m wide
- ~64 000 Channels
- 50K dark noise (radioactivity)

Global Trigger Board Synoptic



- The optical link between concentrator and GTB will propagate WR timestamp measurement of fastOR
- The GTB is synchronized with the WR by the slow control optical link
- External Trigger should be given by the trigger of juno via SFP optical link (to be defined)

GTB mechanical drawings & constraints

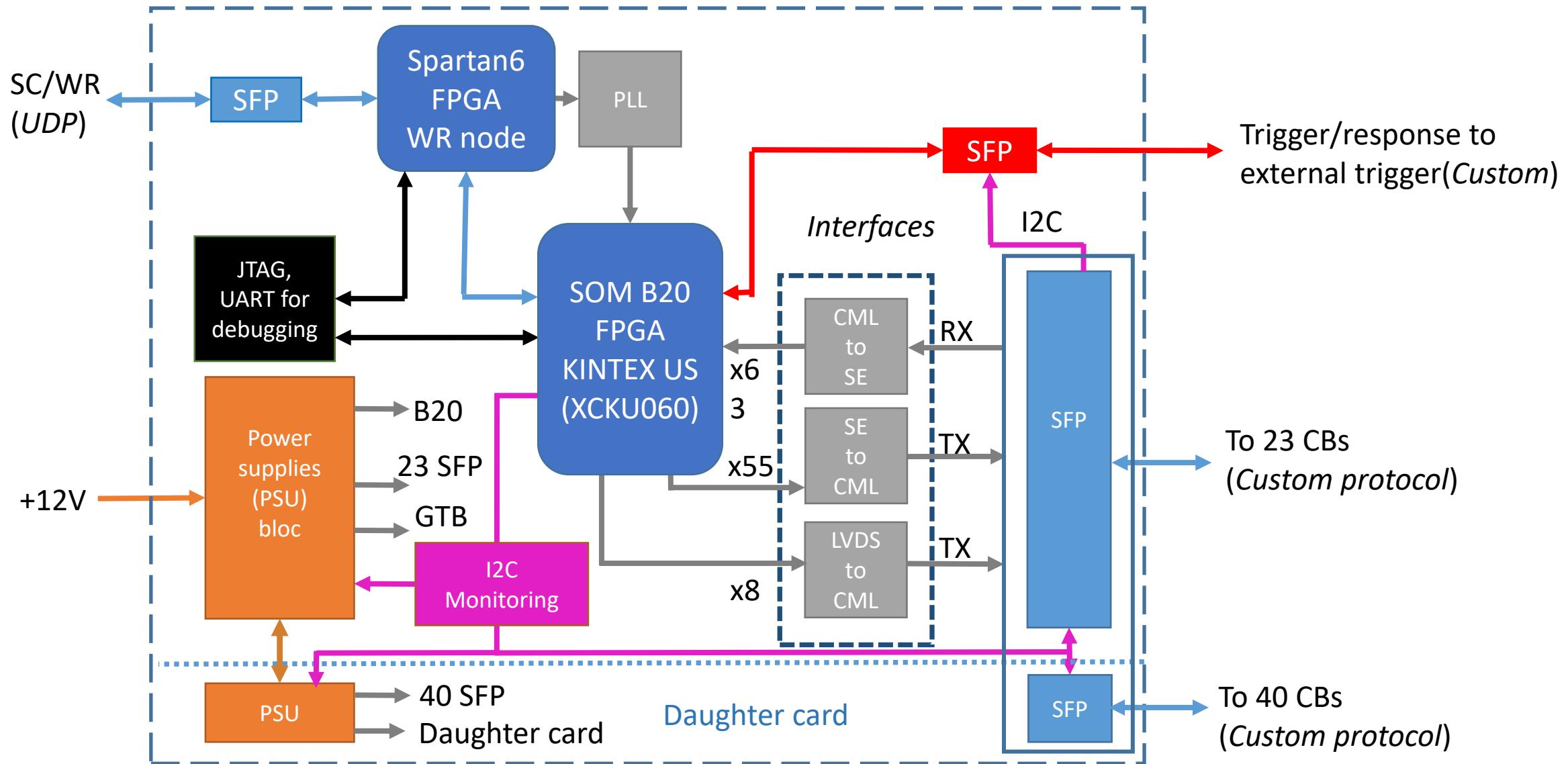


- Use of a commercial crate with some mechanical modifications
 - Ventilation
 - Front/back plate
 - Fixation
 - Strong fixation plate added

Temperature below 29 degrees with cooling

Without cooling more than 60 degrees

GTB block diagram

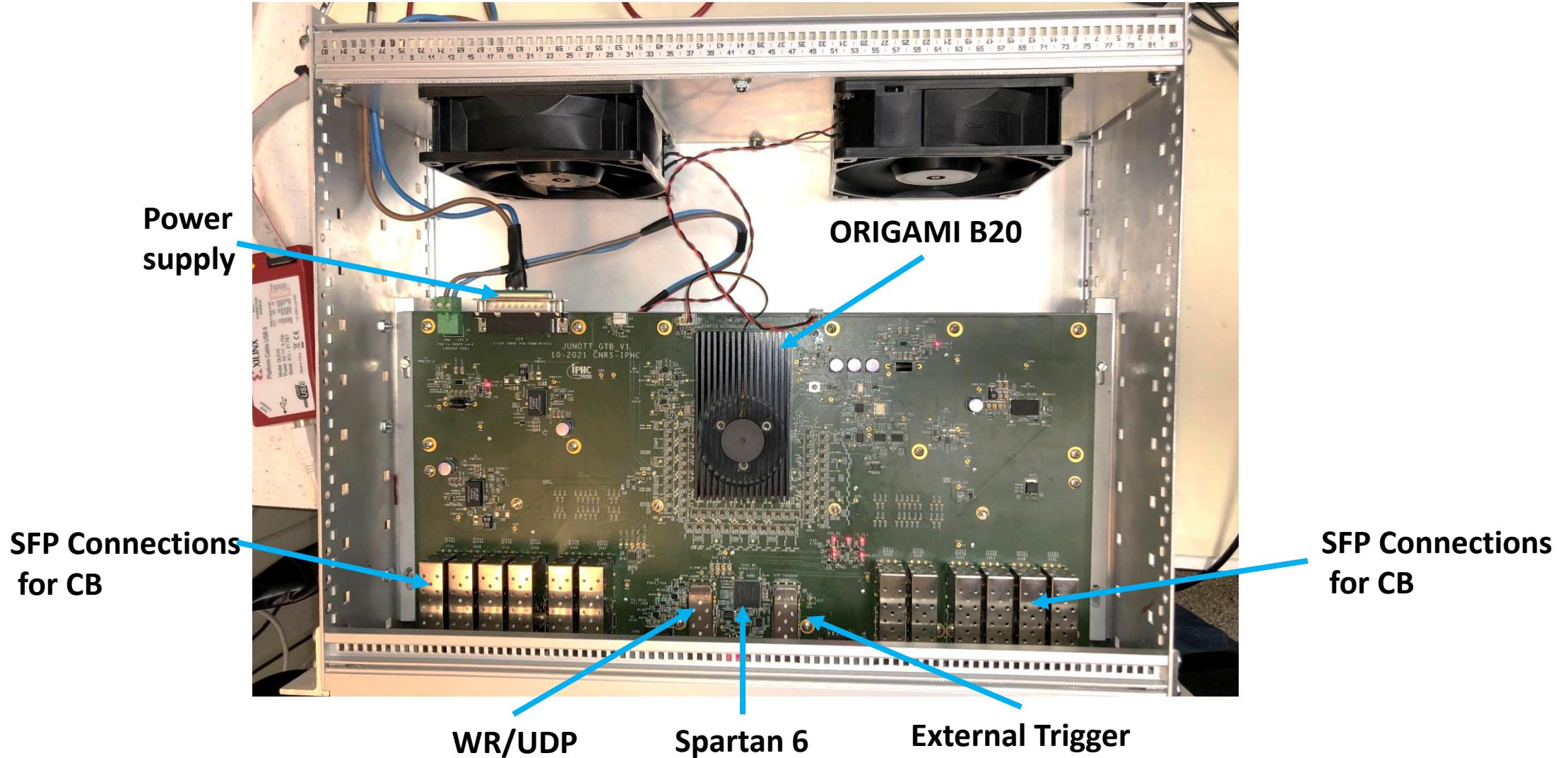


Global Trigger Board

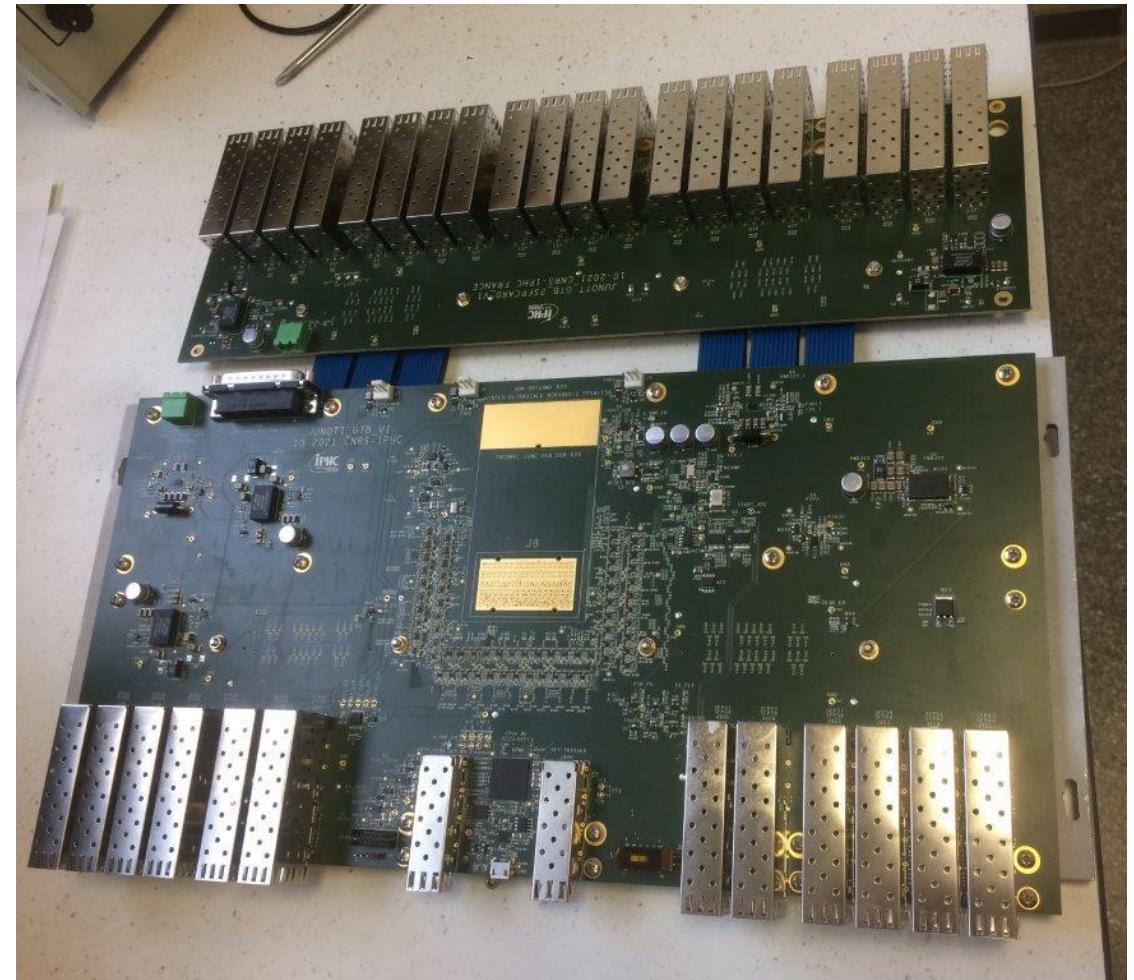
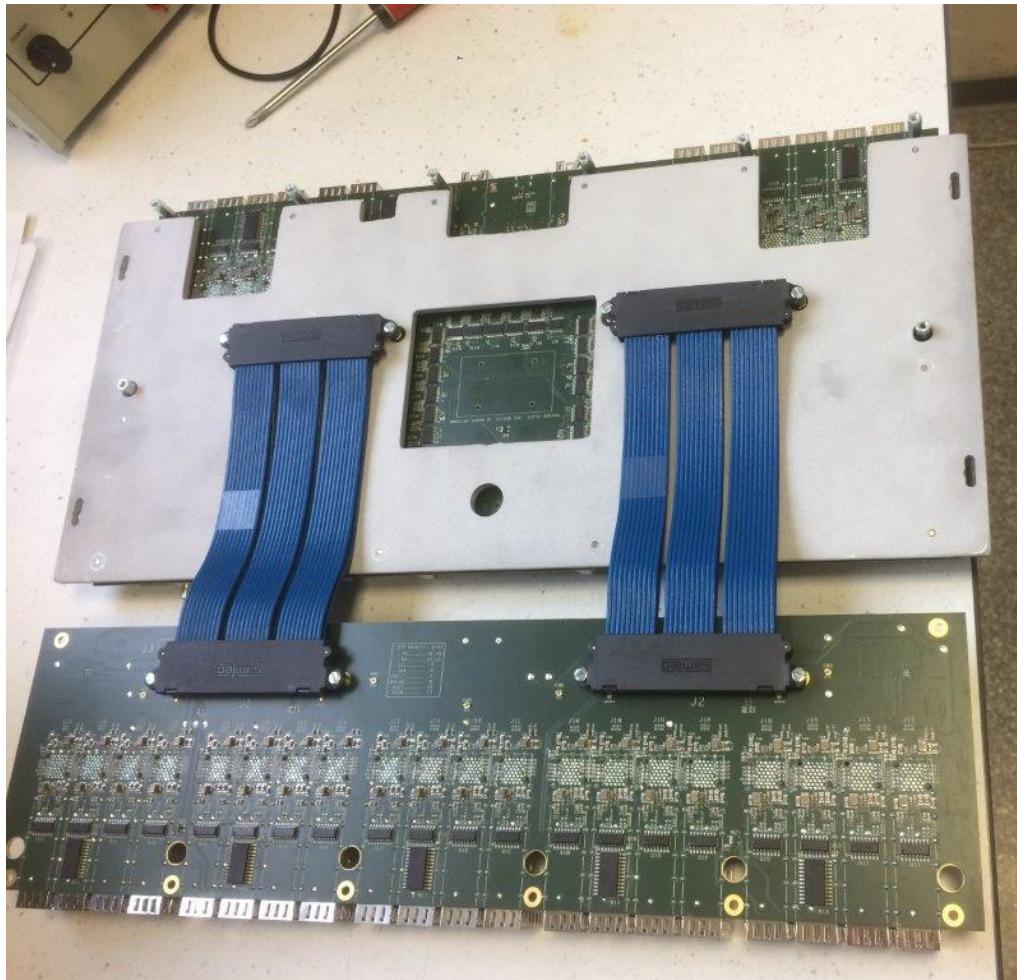
- GTB
 - Improved Power-Good monitoring circuits
 - Added ADCs for power supply monitoring (SOM and CB)
 - Modifications to better comply with IPC standards
 - Changed a few components for improved availability (CLK fanout, FLASH mem)
 - Firmware implementation of Gb Ethernet connection for Slow control/ WR
 - UDP based as in the concentrator
 - Check of all the links in loopback mode
 - CB-GTB link developed & tested

- ✓ First GTB board has been assembled at IPHC (1st week of January 2022)
- ✓ Electrical and individual blocs tests done
- ✓ Porting of the CB Spartan firmware on the GTB platform
- Writing first prototype of the main FW

Picture of the board



GTB Debug mode



WR synchronisation

```
WR PTP Core Sync Monitor wrpc-v4.2-18-g88b9712-dirty
Esc = exit

TAI Time: Fri, Jan 14, 2022, 16:31:06

Link status:
wr1: Link up (RX: 1271, TX: 288) IPv4: 192.168.7.12 (static assignment)
Mode: WR Slave Locked Calibrated ←

PTP status: slave

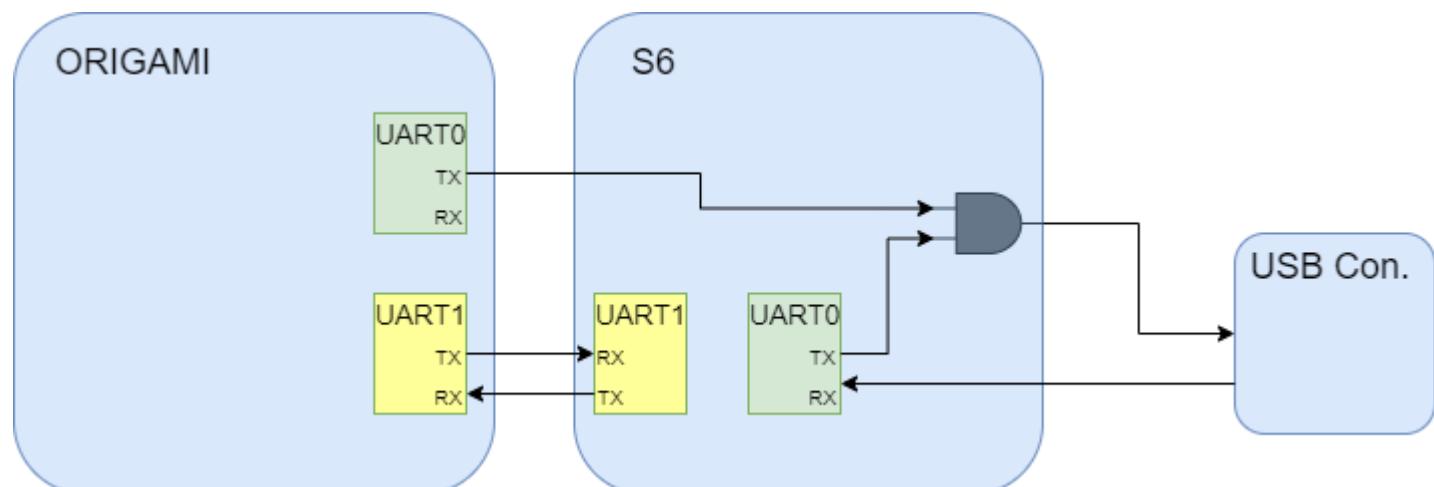
Synchronization status:
Servo state: TRACK_PHRSE
Phase tracking: ON
Aux clock 0 status: enabled

Timing parameters:
Round-trip time (μs): 896109 ps
Master-slave delay: 446751 ps
Master PHY delays: TX: 225645 ps, RX: 234707 ps
Slave PHY delays: TX: 0 ps, RX: 6400 ps
Total link asymmetry: 2607 ps
Cable rtt delay: 429357 ps
Clock offset: 2 ps
Phase setpoint: 4249 ps
Skew: 4 ps
Update counter: 103
```

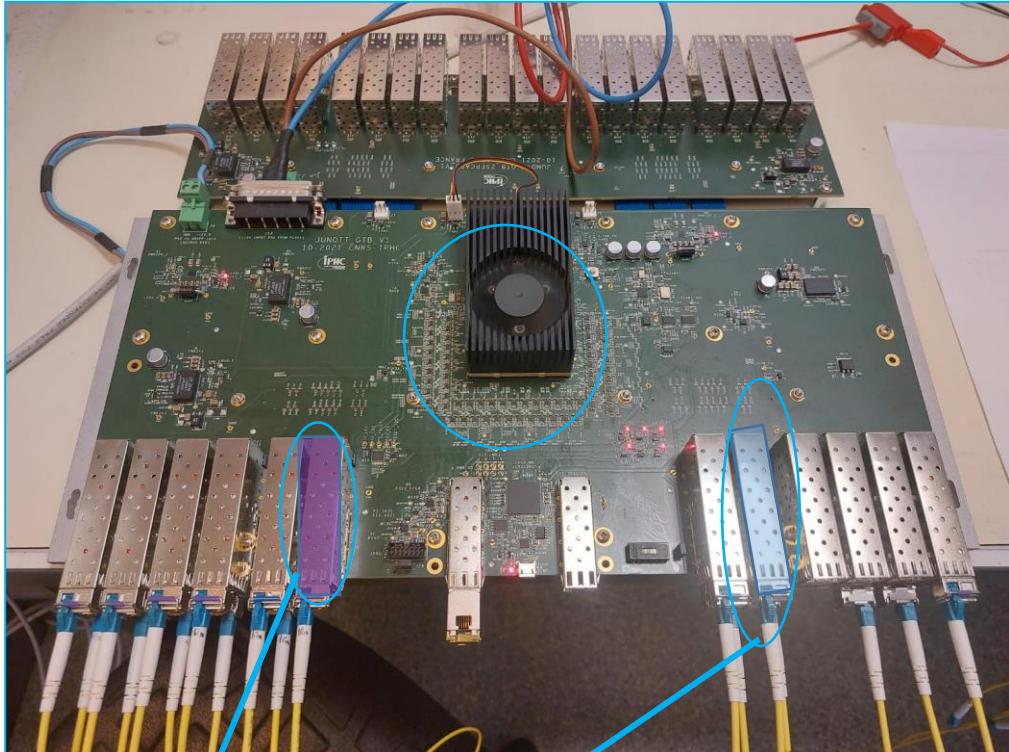
The board is synchronized to the WR switch

UDP Communication

- The only link to the external world is given by S6
- We have 2 UART links
 - Send command between FPGAs(UART1)
 - Debug messages (UART0)



Tests @450 Mbps with ORIGAMI board



Connection via 10m Fiber

All the lines are checked and working in loopback mode @450 Mbps inside the FPGA without error using 8b10b balancing.



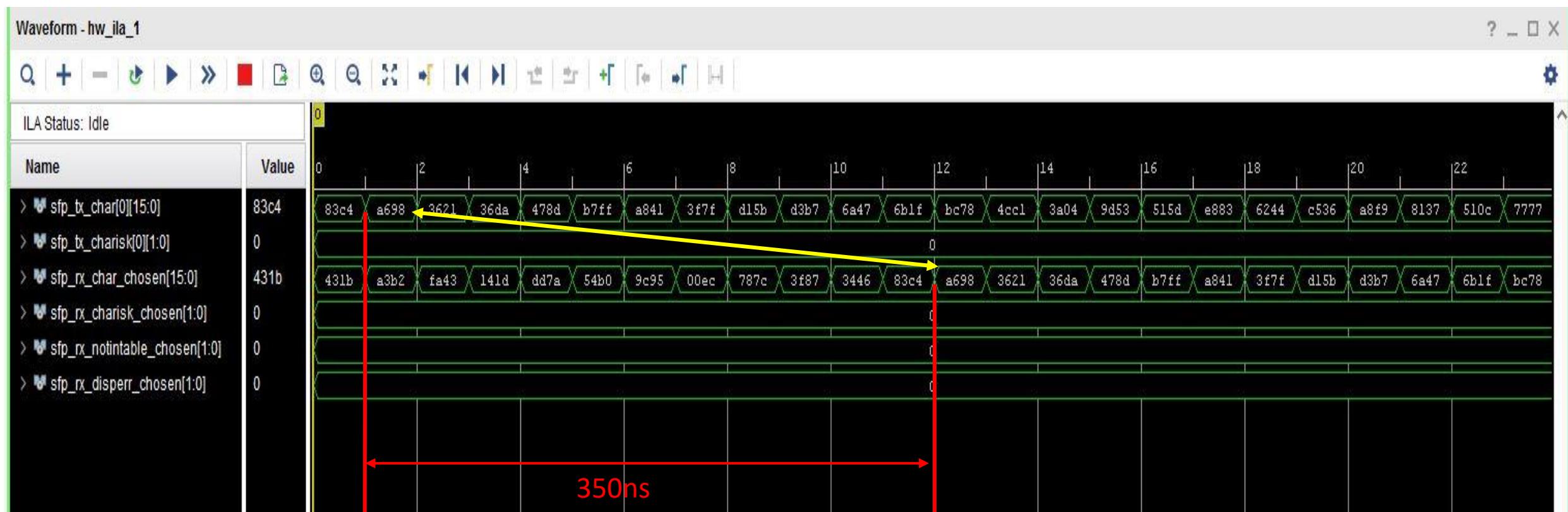
all the lines are working @450Mbps

Tests @450 Mbps with ORIGAMI board

Sending on line 51 and receiving on RX9 @ 450Mb/s with 10m of fiber

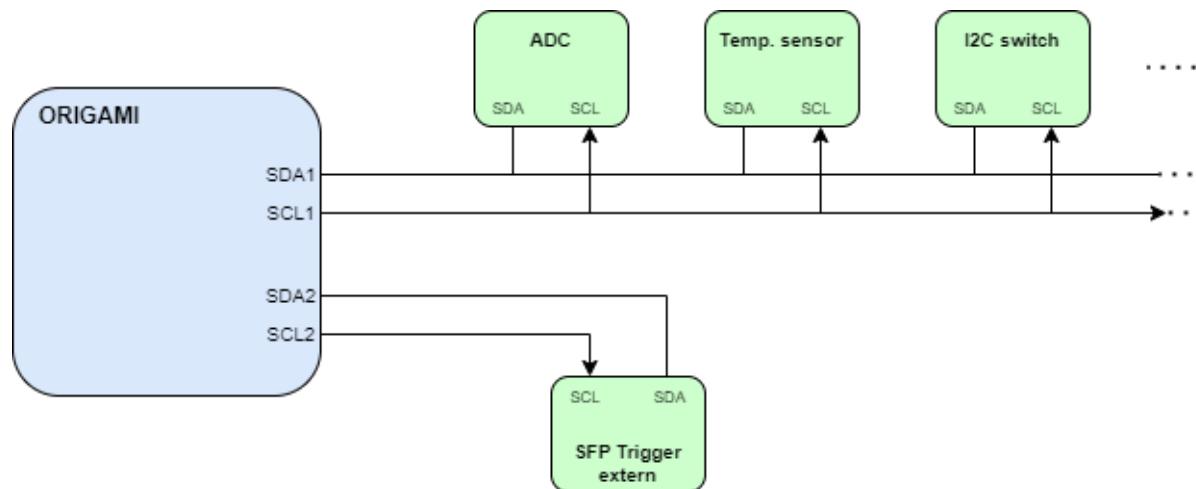
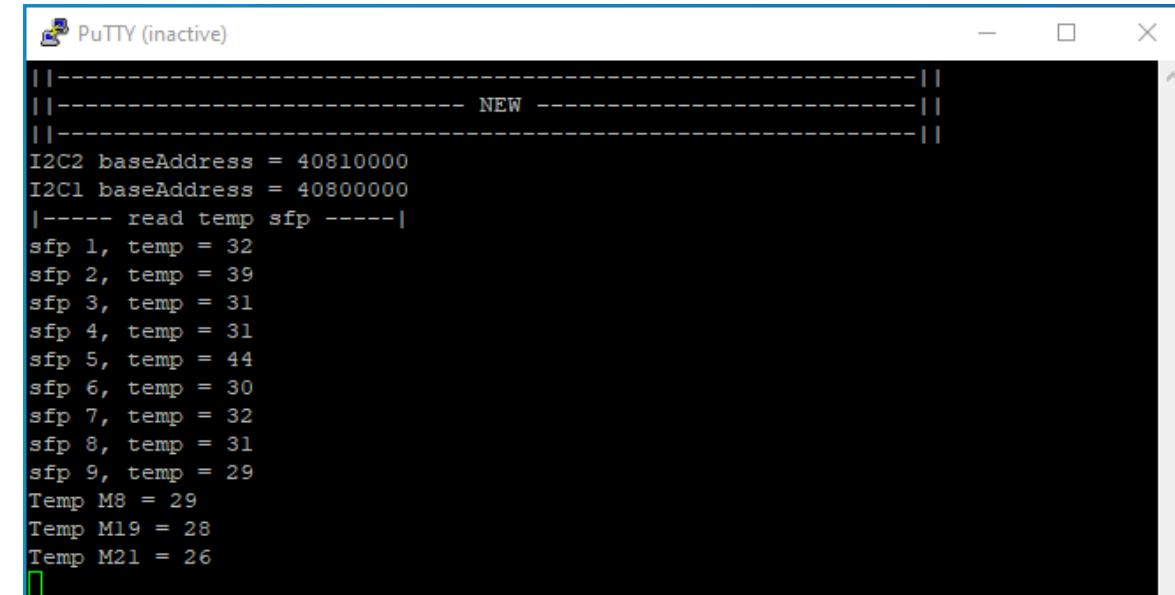
Delay between sending and receiving around 350ns

With 40m (longest fiber) around 600ns



Slow control via I2C

- We have two I2C links
- All I2C module have been tested
 - SFP modules, temp. Sensor, ADC...

```

PuTTY (inactive)
----- NEW -----
I2C2 baseAddress = 40810000
I2C1 baseAddress = 40800000
|---- read temp sfp ----|
sfp 1, temp = 32
sfp 2, temp = 39
sfp 3, temp = 31
sfp 4, temp = 31
sfp 5, temp = 44
sfp 6, temp = 30
sfp 7, temp = 32
sfp 8, temp = 31
sfp 9, temp = 29
Temp M8 = 29
Temp M19 = 28
Temp M21 = 26

```

GTB-CB Data Protocol

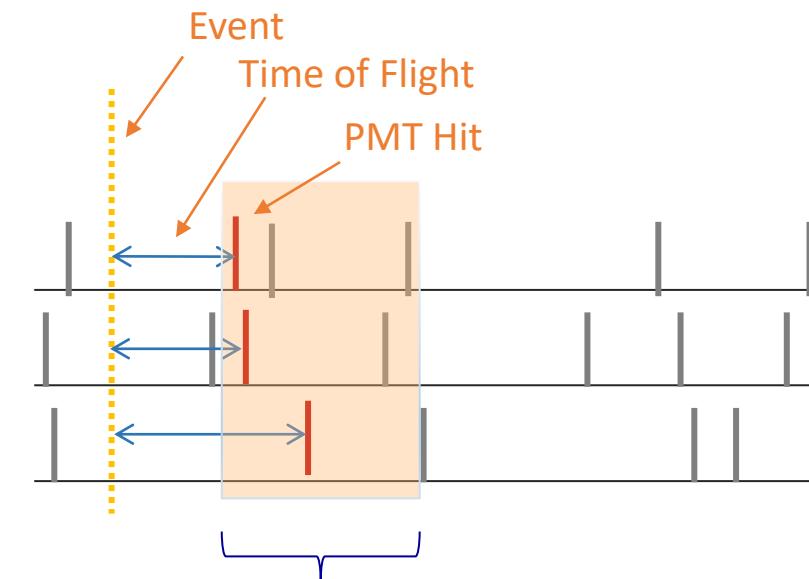
On each trigger CB will send to GTB the Timestamp in 15 bits + 1 padding bit means something around 32 μ s

If the timestamp **trigger is not correlated**

- with other valid timestamps
- the GTB send back the timestamp to CB
- with an additional bit invalidating the trigger (16 bits).
- the CB will reset the charge acquisition
- in the same way as for L1 trigger

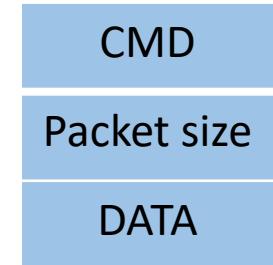
If the timestamp **trigger is correlated**

- with other valid timestamps
- the GTB send back the timestamp to CB
- with an additional bit validating the trigger (16 bits).
- the CB will keep the charge acquisition.



Trigger L2 decision window ~200ns

Some extra commands could be send to the concentrators in case of external triggers or special configurations with extra configurations bits



Communication packet

- In case of communication problem with CBs, we can communicate with them though the GTB with some extra commands

- For example :
 - Synchro. all channel
 - Synchro. one channel
 - Trigger extern
 - Transfer to CB
 - Dummy word test
 - Get version
 - I2C command
 - Counter for test CB<->L2
 - Config trigger
 - Setting time window
 - Flash FPGA
 - Get TRT (nb trigger/sec)
 - TRT ΔT
 - Disactivate CB
 - Validate CB
 - Configuration mas delay cable

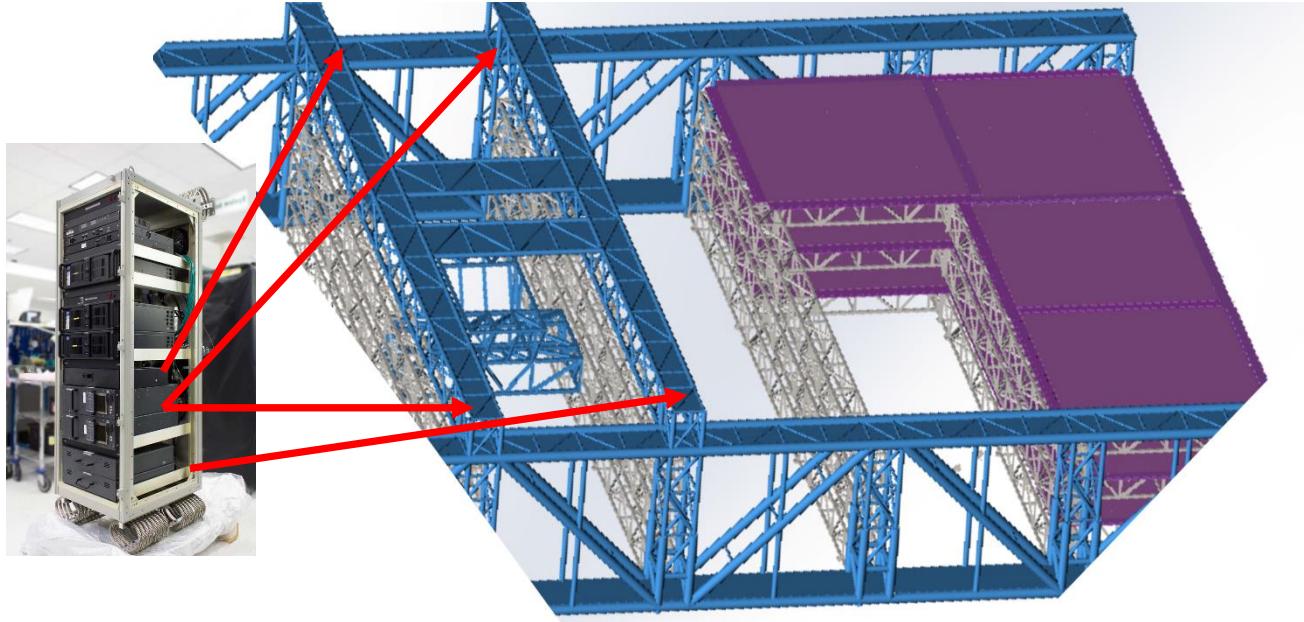
Outlook and production plans

- Combined CB-GTB tests has been done and the GTB design is validated
- The 64 links have been tested and are working@450MHz
- Writing of the first draft of communication protocol between GTB and DAQ
- Realization of the GTB FW should be working at the end of the year

The end

Thank you for your attention

GTB mechanical drawings & constraints



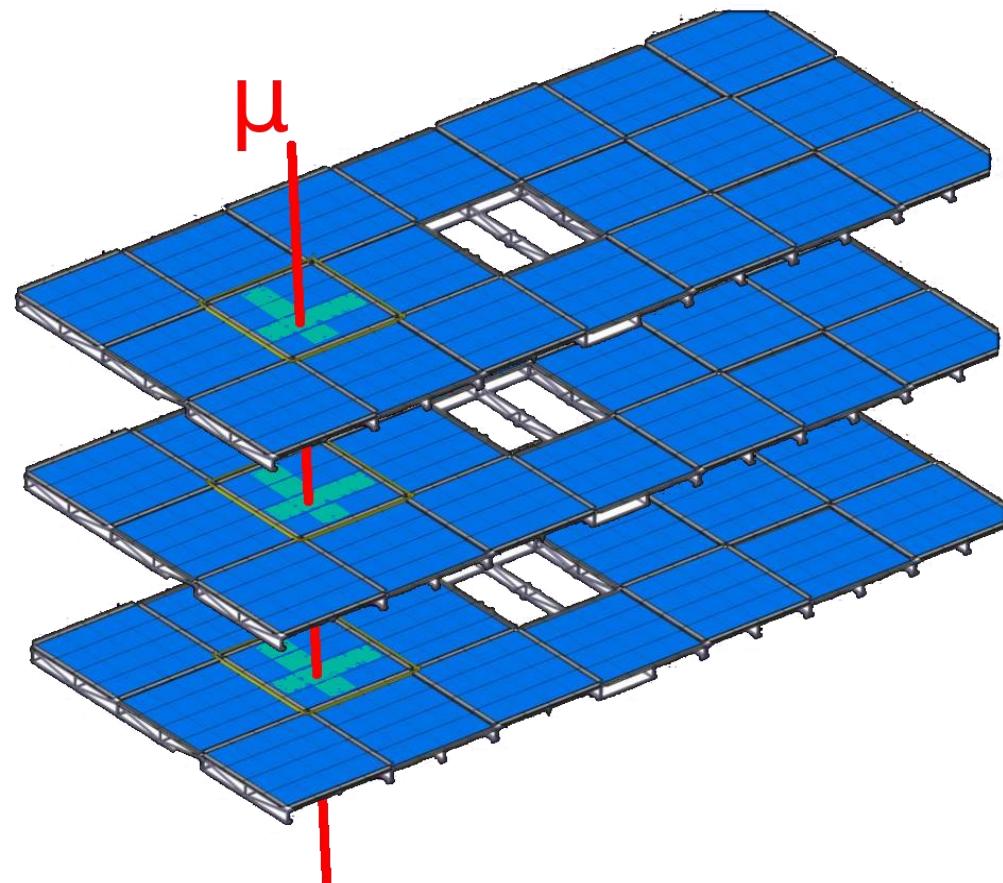
- 4 Rack on the top of the bridge
- for LV power, fibers and.....GTB

The Board must fit in a 19" rack
We have decided to have 2 boards (Mother & Daughter) for all 63 SFP connections to the concentrator

Temperature test

VENTIL1 (gauche)	VENTIL2 (B20)	VENTIL3 (droite)	Face Av	Face Ar	SFP modules			TC74 (M8-M19-M21)			Caméra IR	
Modules SFP					GTB		2SFPCARD	GTB	2SFPCARD		GTB	
					41-52	53-64	1-12	centre	1-12	30-40	1-12	30-40
Températures en °c												
ON	ON	ON	30.1	43.2	40	39	-	29	23	25	39.5	-
OFF	ON	ON	-	-	47	44	-	30	24	26	40.9	-
OFF	ON	OFF	36	38.6	63	59	-	39	36	37	46.4	-
ON	ON	ON	30.1	-	40	-	38	28	25	24	36	-
OFF	ON	ON	30.1	-	43	-	42	28	27	25	36	-
OFF	ON	OFF	49	-	66	-	70	39	49	36	50	-

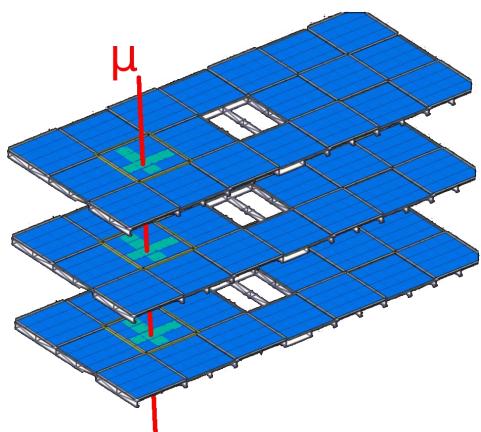
GTB Algorithm



- **Cannot rely on only 2 layers to detect muon**
 - Too high radioactive background
 - Any two background points correlated in time form a line...
- **Information available:**
 - Which wall sent the L1 trigger
 - Time of the trigger
- **Require time coincidence using sliding time window**
 - Window size almost optimized
- **Accepted L1 configurations:**
 - 3 L1 from aligned walls in different layers
 - 3 walls (fallback option)

GTB logic (sliding window)

Valid events = 3 L1 from aligned walls in different layers

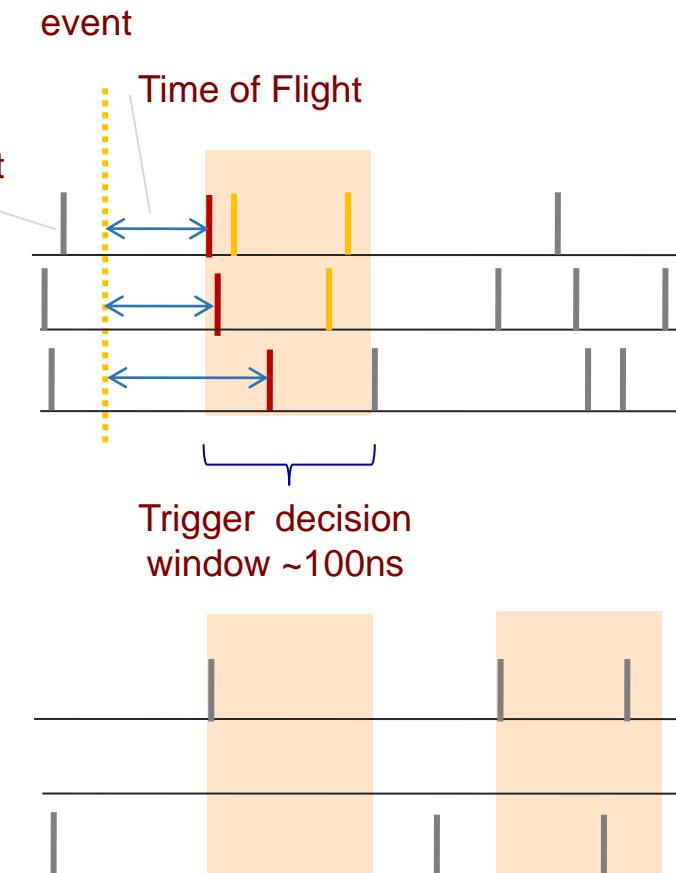


Valid trigger

Top Layer
Middle Layer
Bottom Layer

Invalid trigger

Top Layer
Middle Layer
Bottom Layer



L1 trigger from Top Layer requires L1 triggers from middle and bottom layer to be valid

No L1 trigger from at least one layer.

(Not in figure) Validation signals from a 3 unaligned wall (line from first 2 L1s)