

JUNO sPMT ABC Board

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LP2I Bordeaux, University of Bordeaux/ IN2P3

Expérience JUNO: Collaboration internationale

Country	Institute	Country	Institute	Country	Institute
Armenia	Yerevan Physics Institute	China	Tsinghua U.	Germany	U. Tuebingen
Belgium	Université libre de Bruxelles	China	UCAS	Italy	INFN Catania
Brazil	PUC	China	USTC	Italy	INFN di Frascati
Brazil	UFEL	China	U. of South China	Italy	INFN-Ferrara
Chile	PCUC	China	Wu Yi U.	Italy	INFN-Milano
Chile	SAPHIR	China	Wuhan U.	Italy	INFN-Milano Bicocca
China	BISEE	China	Xi'an JT U.	Italy	INFN-Padova
China	Beijing Normal U.	China	Xiamen University	Italy	INFN-Perugia
China	CAGS	China	Zhengzhou U.	Italy	INFN-Roma 3
China	ChongQing University	China	NUDT	Latvia	IFCS
China	CTAF	China	CUG-Beijing	Pakistan	PINSTECH (PAEC)
China	DGUT	China	ECUT-Nanchang City	Russia	INR Moscow
China	Guangxi U.	Croatia	PDZ/RBI	Russia	JINR
China	Harbin Institute of Technology	Czech	Charles U.	Russia	MSU
China	IHEP	Finland	University of Jyväskylä	Slovakia	FMPICU
China	Jilin U.	France	IJCLab Orsay	Taiwan-China	National Chiao-Tung U.
China	Jinan U.	France	IP2i Bordeaux	Taiwan-China	National Taiwan U.
China	Nanjing U.	France	CPPM Marseille	Taiwan-China	National United U.
China	Nankai U.	France	IPIIC Strasbourg	Thailand	NARIT
China	NCEPU	France	Subatech Nantes	Thailand	PPRLCU
China	Pekin U.	Germany	RWTH Aachen U.	Thailand	SUT
China	Shandong U.	Germany	TUM	U.K.	U. Warwick
China	Shanghai JT U.	Germany	U. Hamburg	USA	UMD-G
China	IGG-Beijing	Germany	FZJ-IKP	USA	UC Irvine
China	SYSU	Germany	U. Mainz		

694 physiciens de Chine et d'Europe principalement, 77 instituts dont 5 à l'IN2P3.

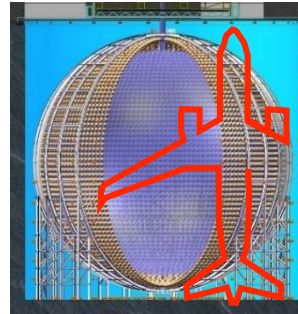
Expérience JUNO: objectif

- Déterminer l'ordre des masses des neutrinos en utilisant des antineutrinos électroniques émis par des réacteurs en Chine (expérience complémentaire de KM3Net, DUNE, HyperKamiokande)



Réacteurs nucléaires
($\sim 10^{21}$ ν /s/GW)

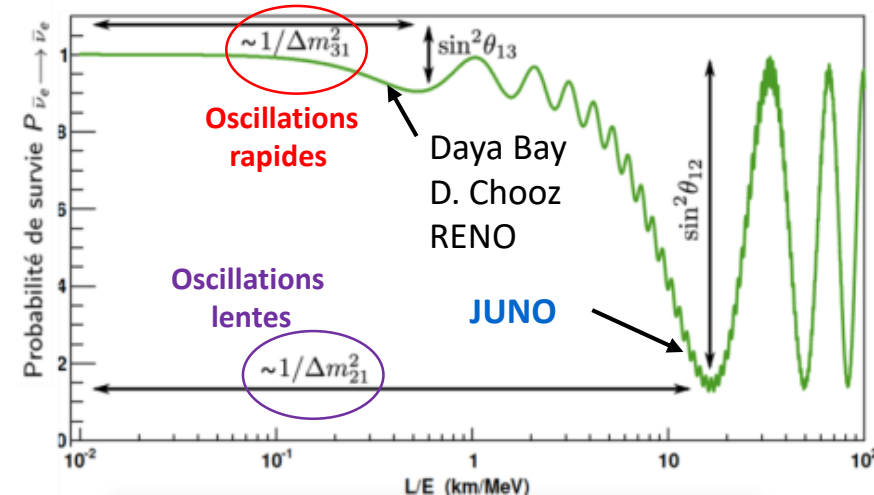
Oscillation des neutrinos
→
Base de vol ~ 53 km



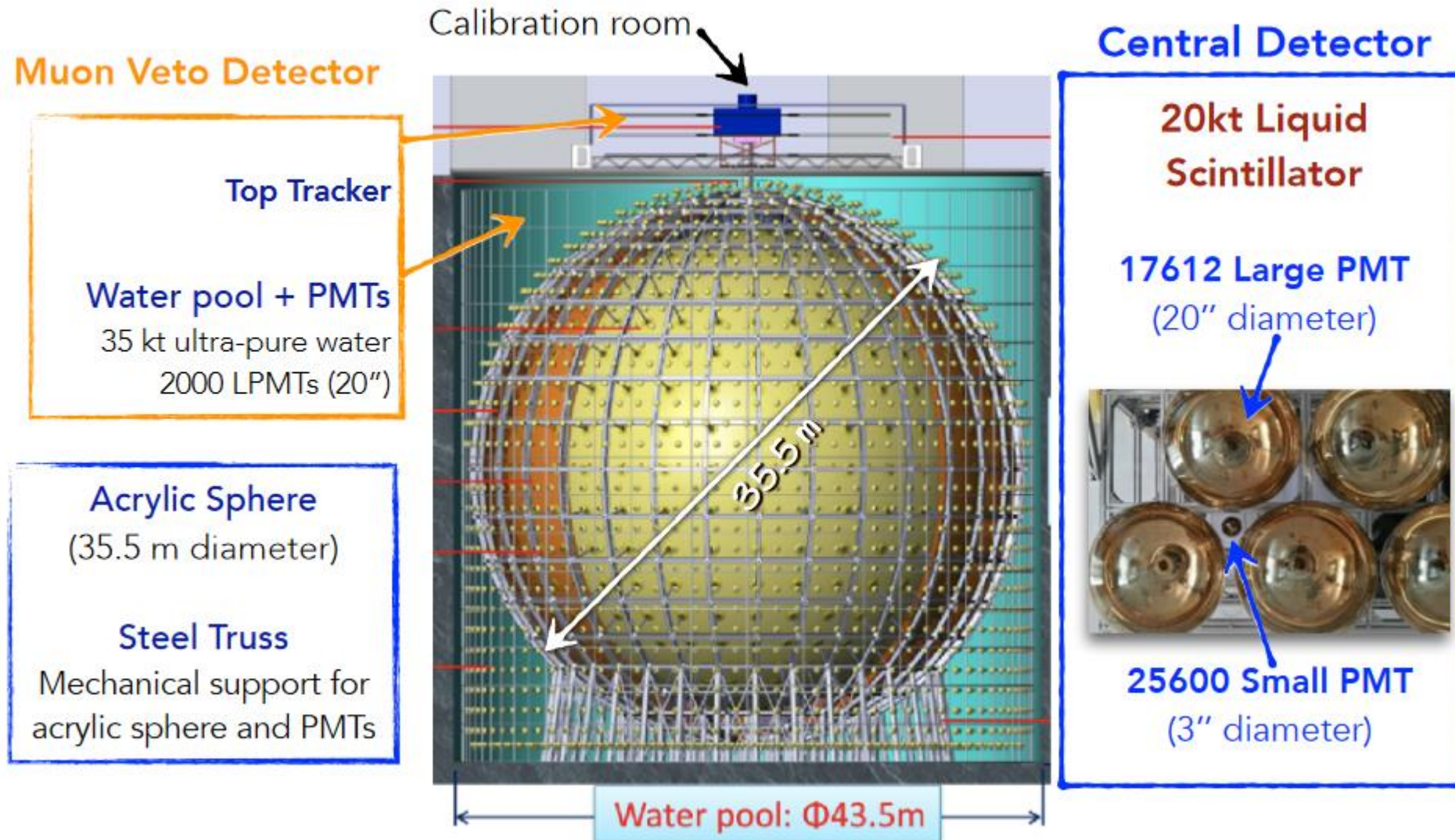
Détecteur JUNO



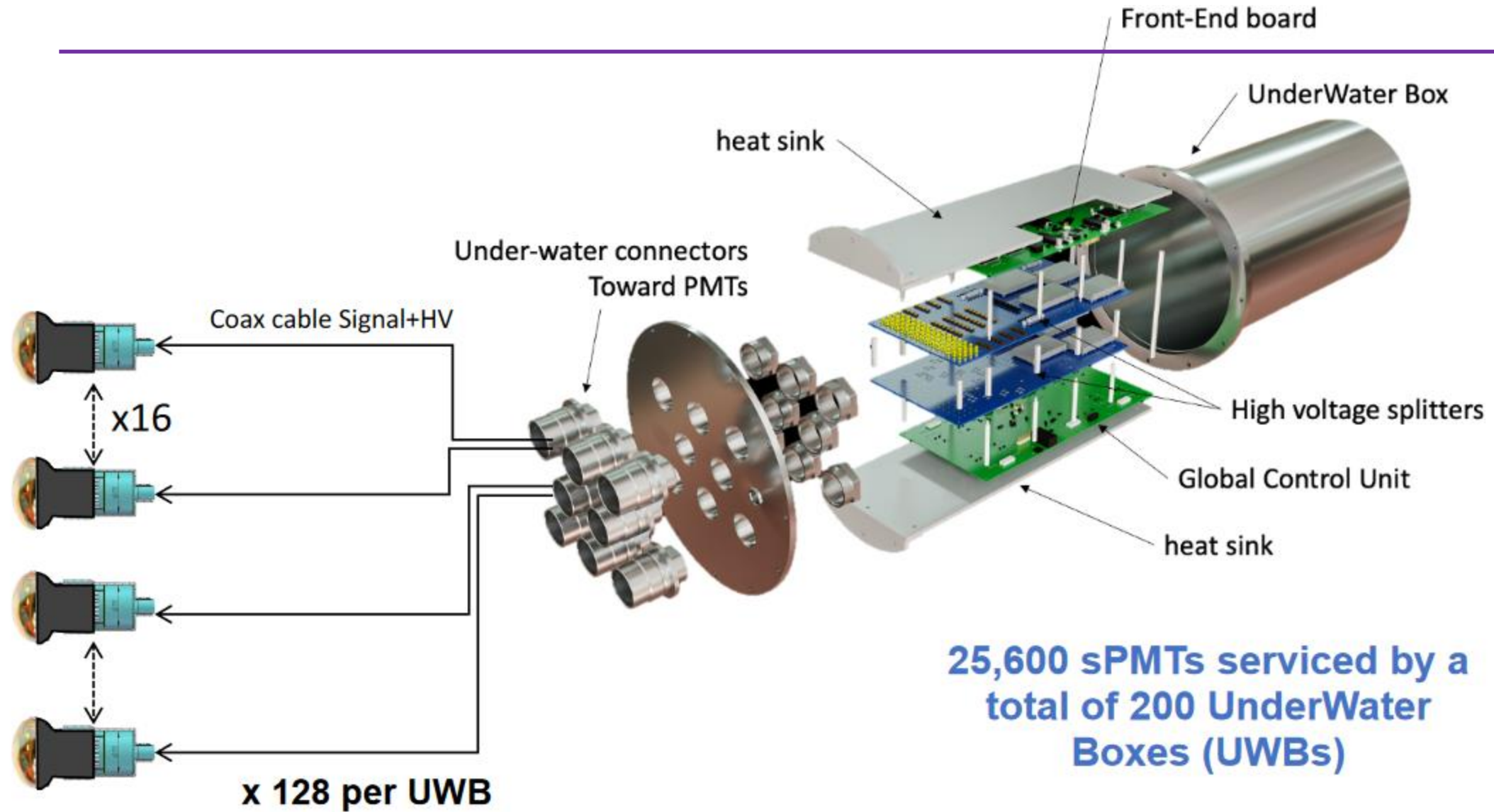
- Mesure de précision ($<1\%$) de 3 paramètres d'oscillation des neutrinos
- Mesure des neutrinos solaires, de Supernova, des géoneutrinos, ...



Expérience JUNO : le détecteur



Le projet JUNO sPMT



Asics Battery Card : Front End Board

- 8 CATIROC (Charge And Time Integrated Read Out Chip):

- 128 channels inputs
 - time and charge
 - self triggering

- In_Calib : One per CATIROC

- External Trigger: One signal for the 8 CATIROCs

- FPGA KINTEX 7 :

- Slow Control
 - Data Readout.
 - Monitoring

- Memory: RAM type DDR3

- Size of 1 Giga Byte.

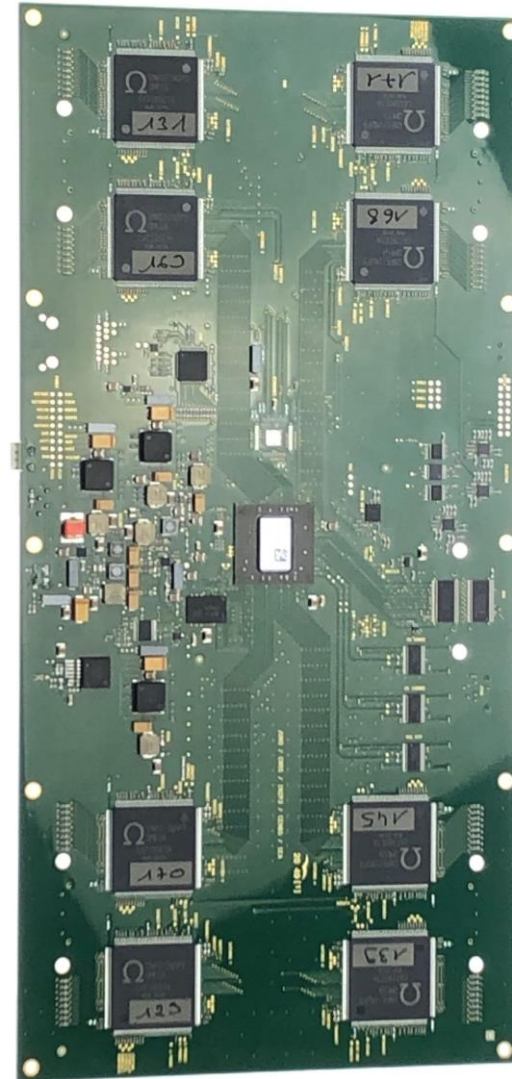
- SAMTEC QTE type connector :

- interface with the GCU.
 - Interfaces with HVSplitters

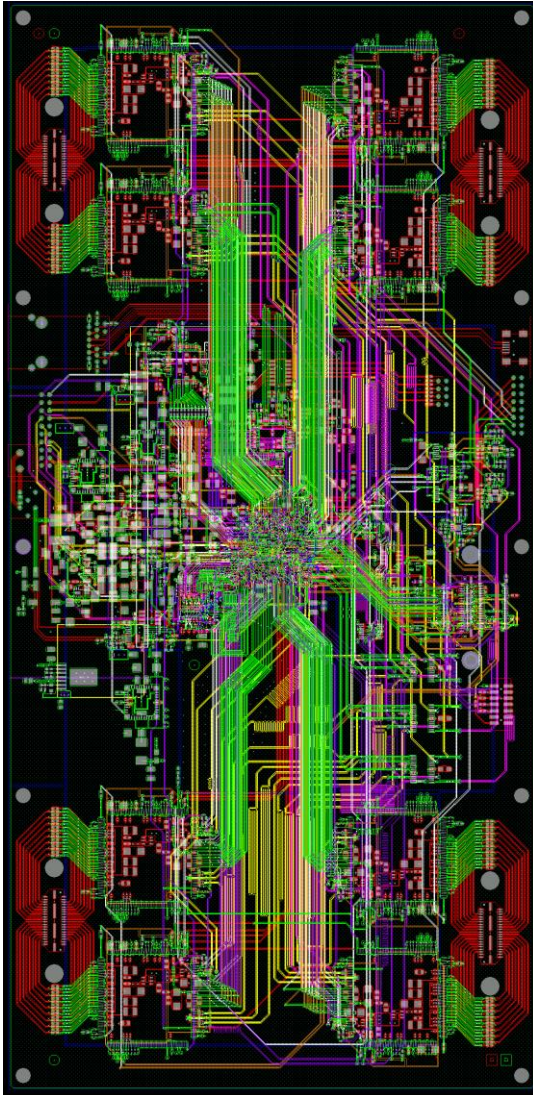
- USB 2.0 : Computer interface for Testing

- Ethernet :

- Option

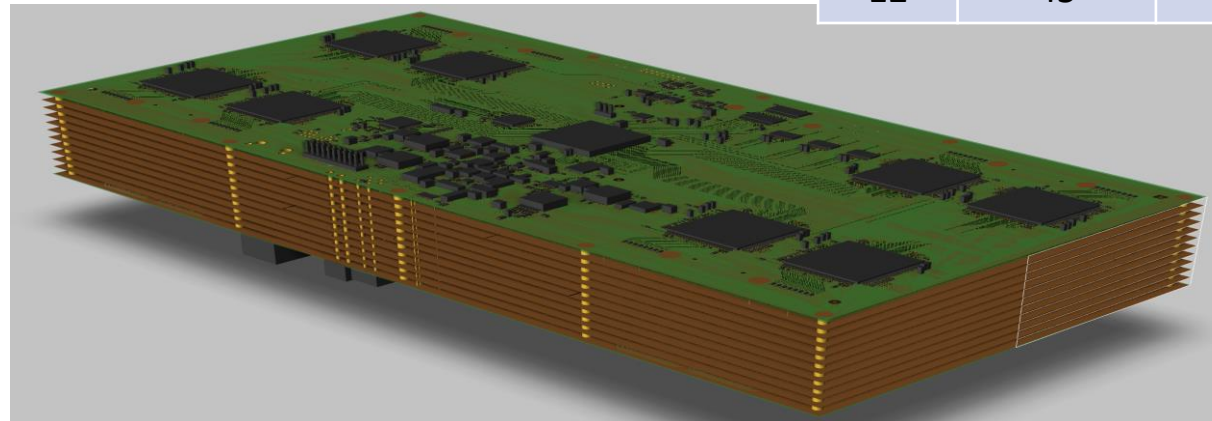


ABC V1.2 : PCB

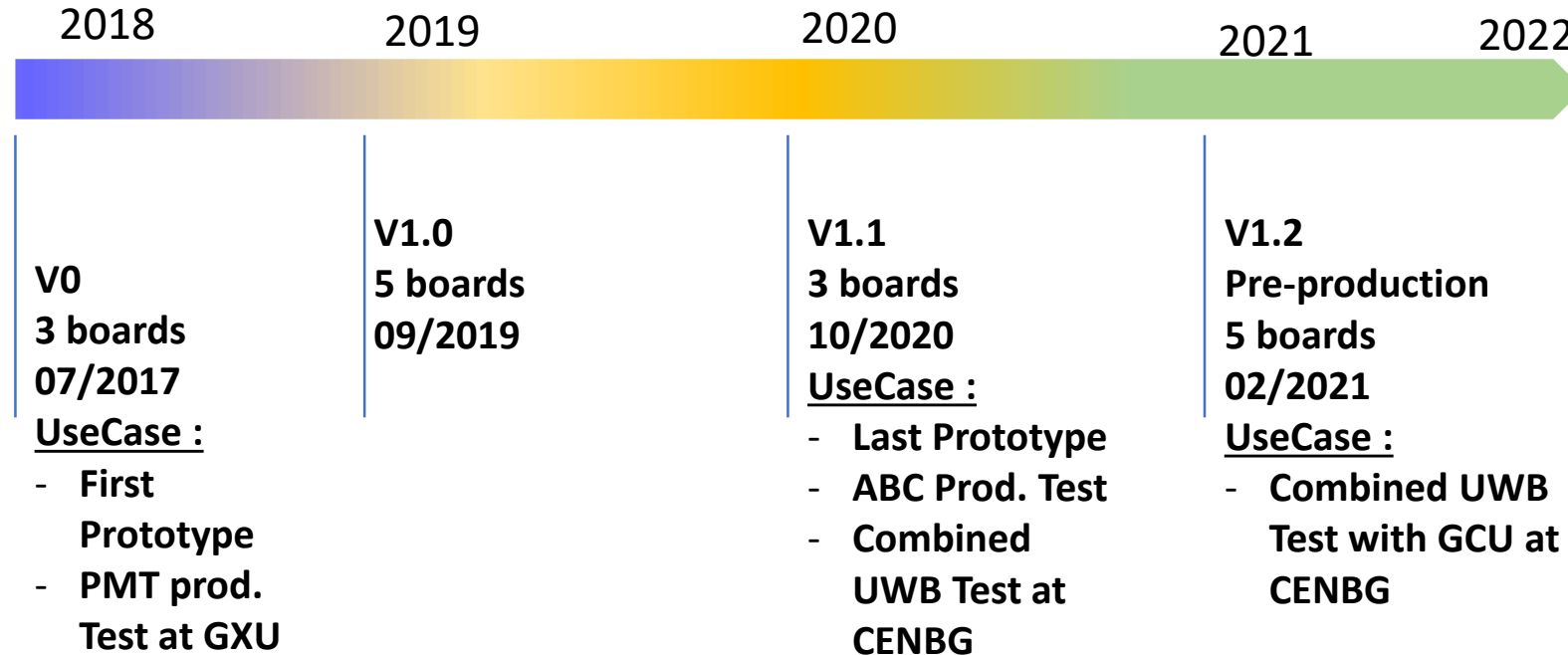


- 12 Layers
 - 5 Powers plans
- compatible with IPC standards
 - IPC 7351, IPC 2222, IPC 2221
 - IPC 4101
- 1902 Components
 - CMS technology
- 45 differential pairs

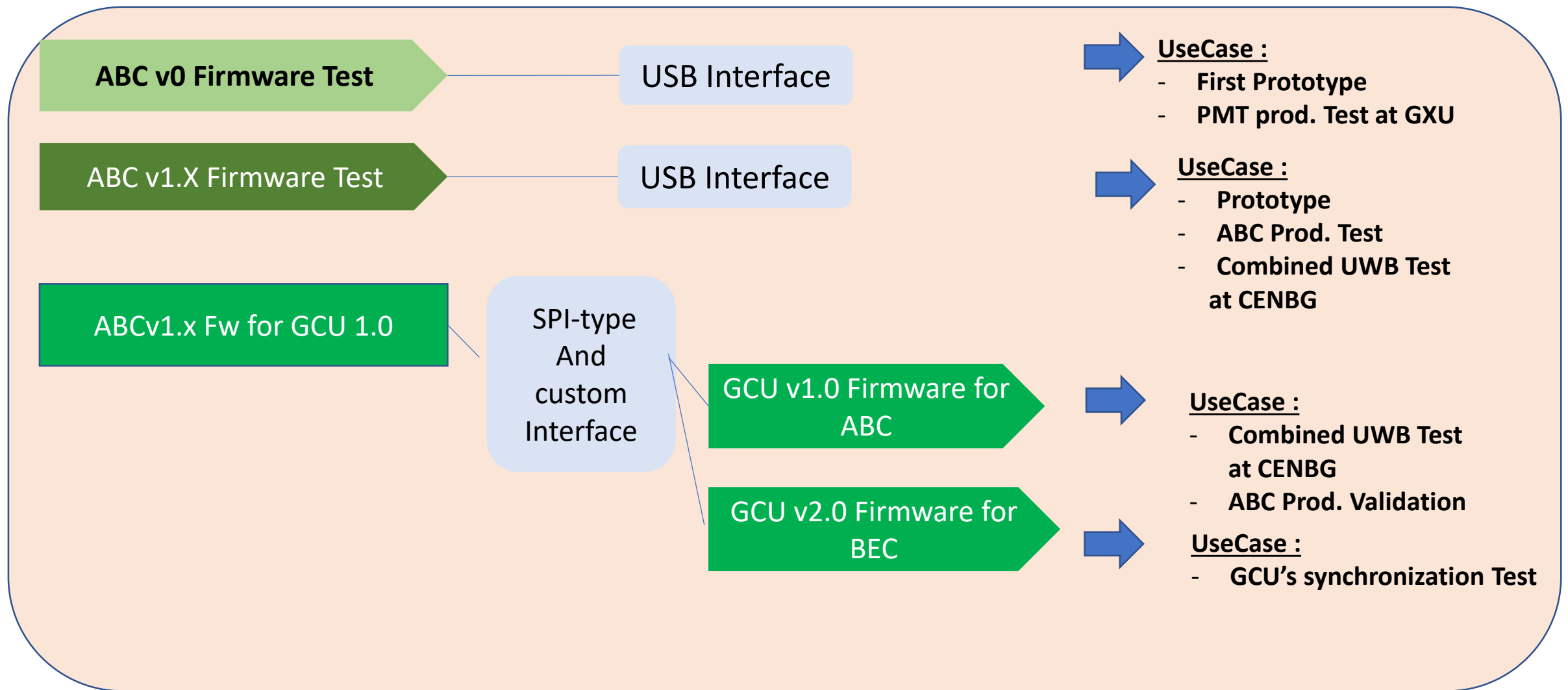
Layer	Thicknes s (μ m)	Single impedanc e	Differenti al impedanc e
1	45	50	100
3	18	40,50	
4	18	40,50	
6	18	40,50	
8	18	40,50	80,100
10	18	40,50	80,100
12	45	40,50	



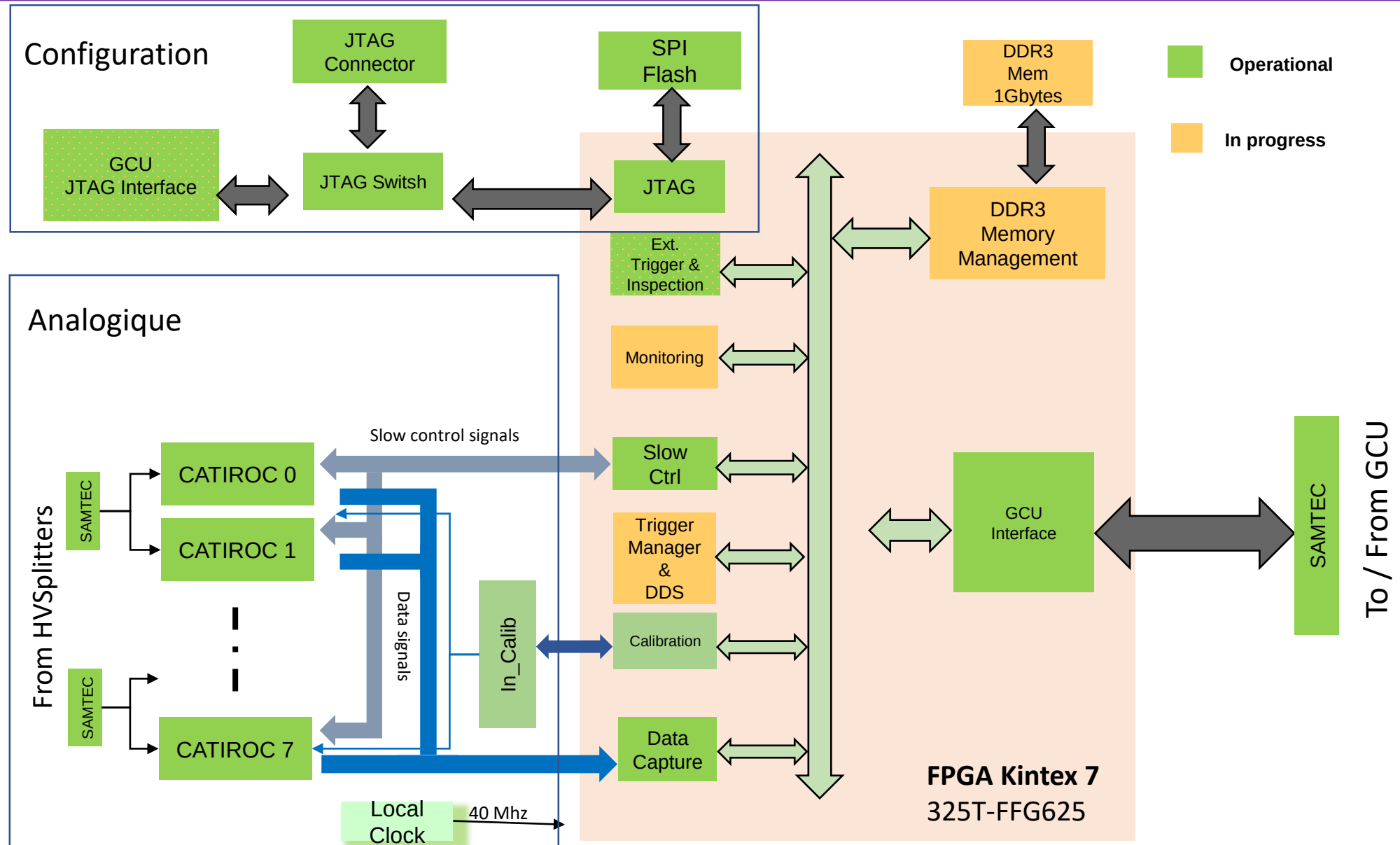
SPMT ABC Hardware versionning



SPMT GCU-ABC Firmware versionning

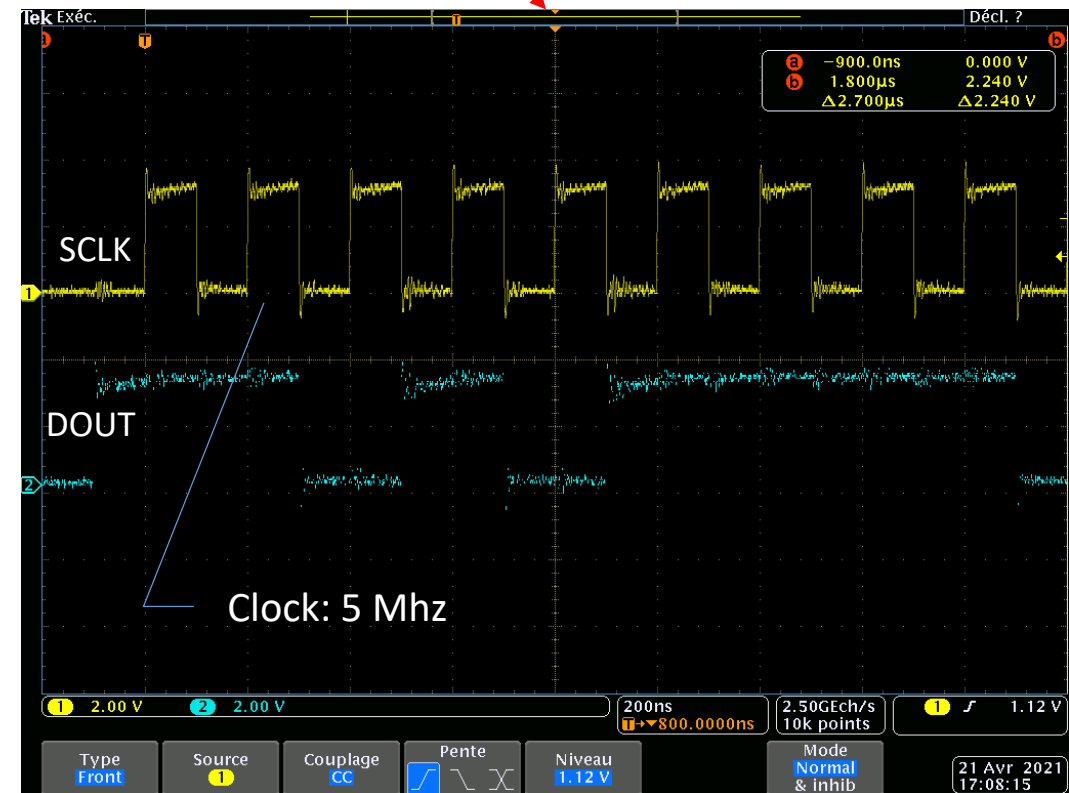
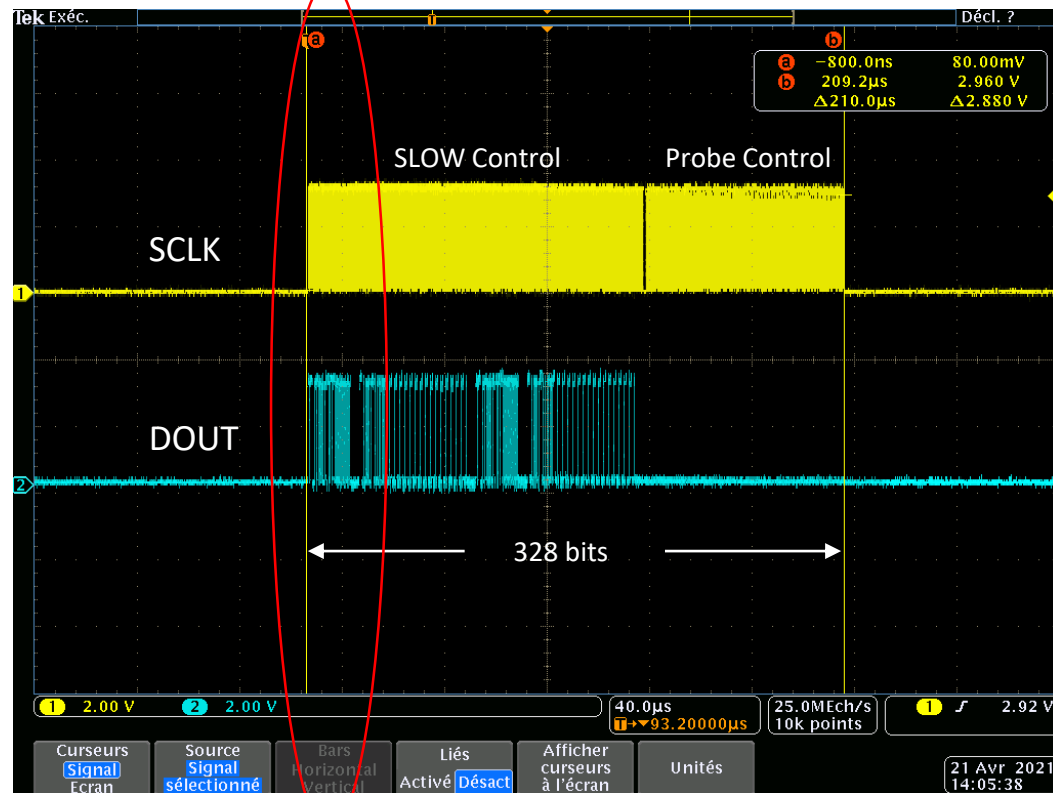


SPMT ABC : Block Diagram



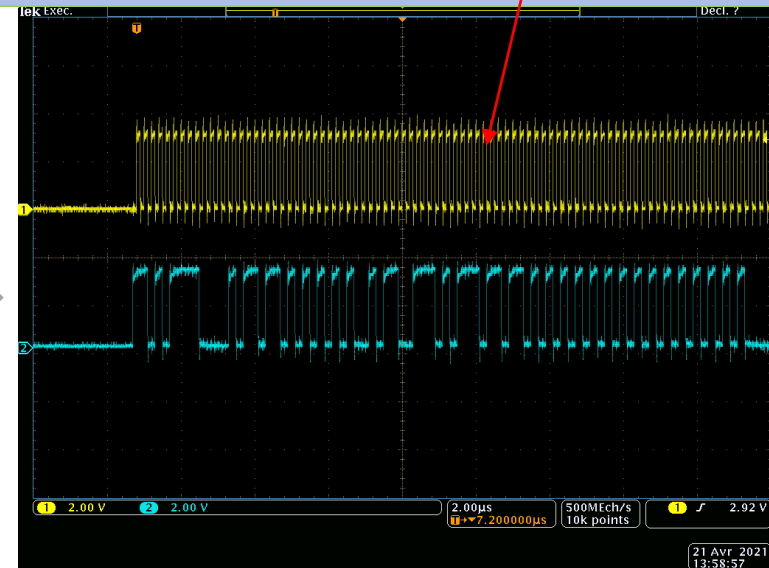
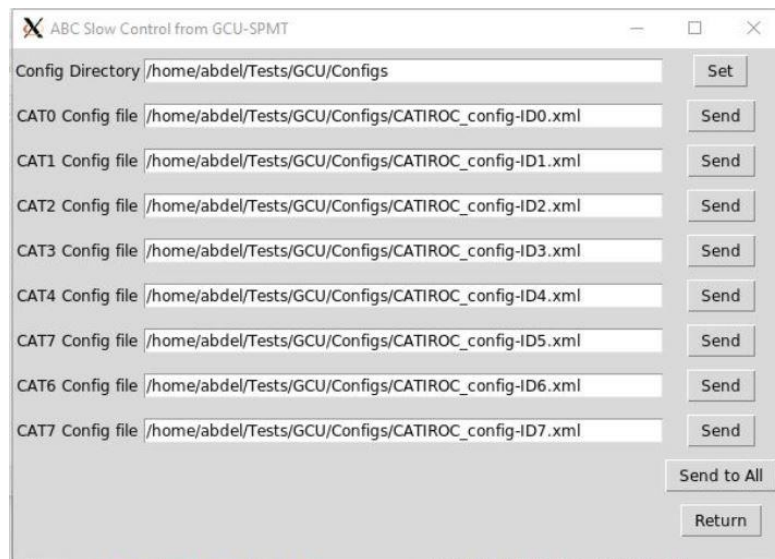
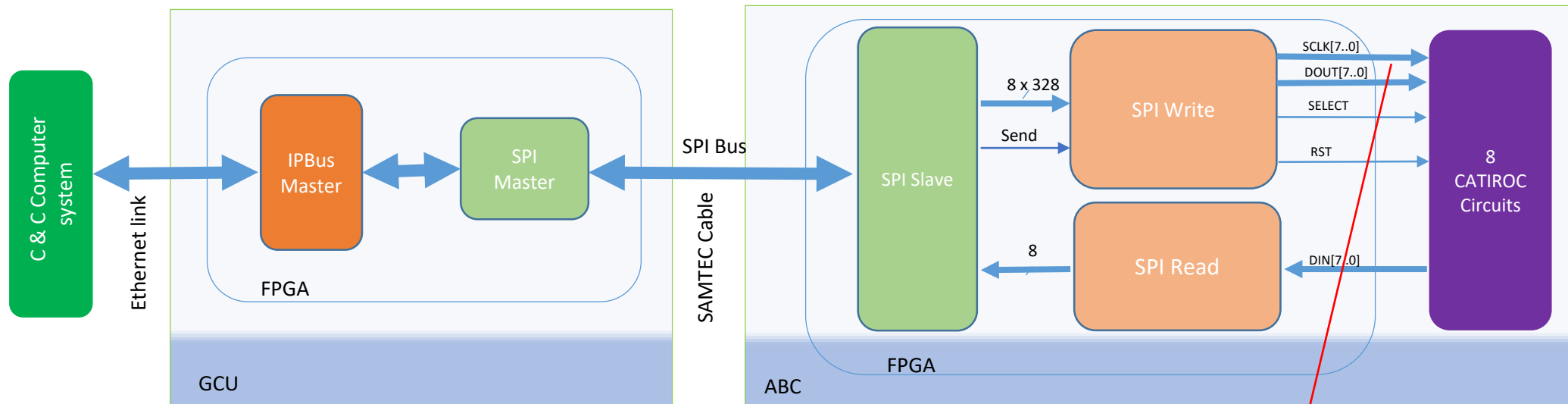
ABC Firmware: CATIROC Slow Control

❑ For each CATIROC

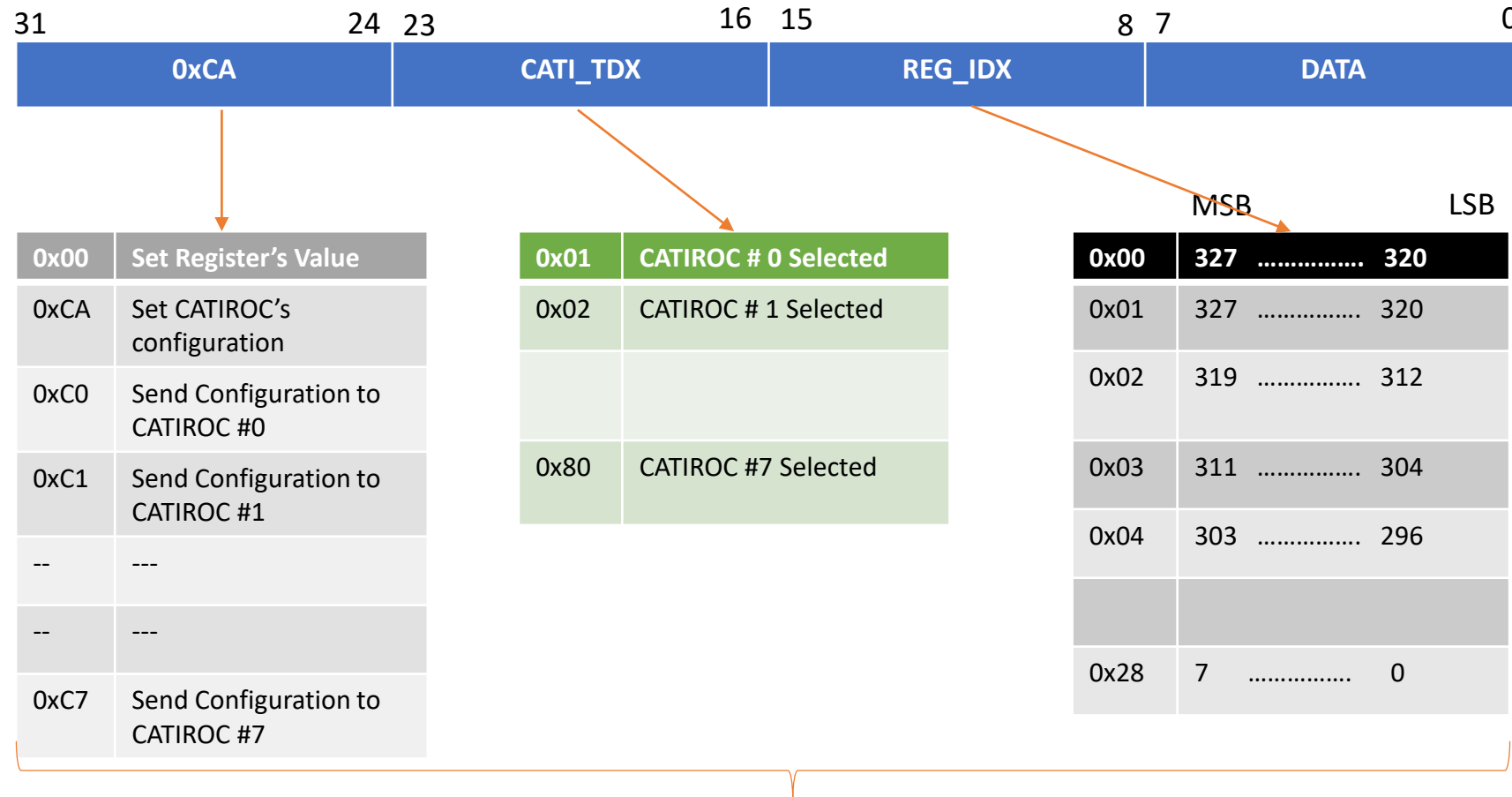


- ❑ The control timing of CATIROC is scrupulously respected
- ❑ The transmission frequency is 5 MHz, which guarantees a transfer reliability

ABC GCU Firmware : CATIROC Slow Control



ABC Firmware: CATIROC Slow Control



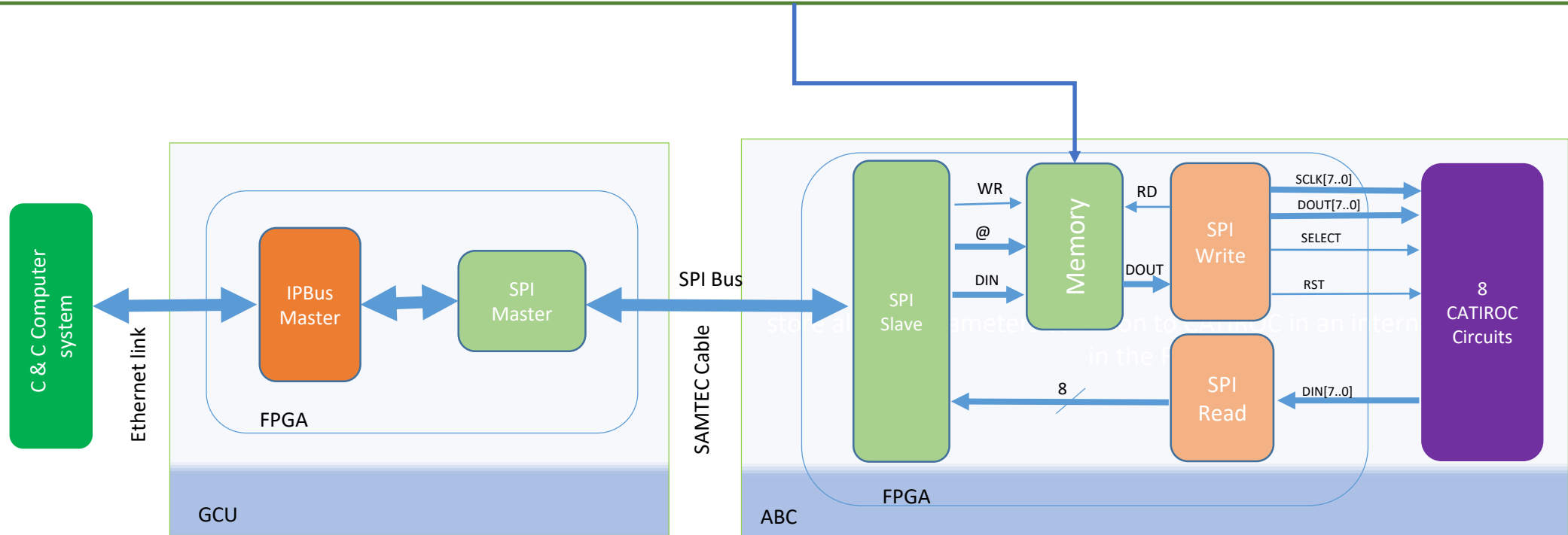
❑ 41 Bytes (328 bits) to set and send to each CATIROC

❑ 328 Bytes per ABC → **OK for Testing mode** → But takes a long time ...

ABC Firmware: CATIROC Slow Control

► Solution for new version

- ❑ store all the parameters common to CATIROC in an internal memory in the FPGA
- ❑ Possibility for the user to modify the rest of the parameters
 - ❑ Gain per channel
 - ❑ The discriminator threshold
 - ❑ The HG / LG switchover threshold



ABC Firmware : CATIROC Slow Control

SPMT Electronic Control V2.0 : GCU # 1

HV Control | **Slow Control** | Pedestal Readout | PM Readout | Scurve | Inspection

Config Directory:

Load Configs files

SC Status

CAT0 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 0	
CAT1 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 1	
CAT2 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 2	
CAT3 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 3	
CAT4 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 4	
CAT7 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 5	
CAT6 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 6	
CAT7 Config file	/home/abdel/00_Projets/JUNO/01_Software	100	520	Send -> CAT 7	

☐ Common Threshold

ABC Number:

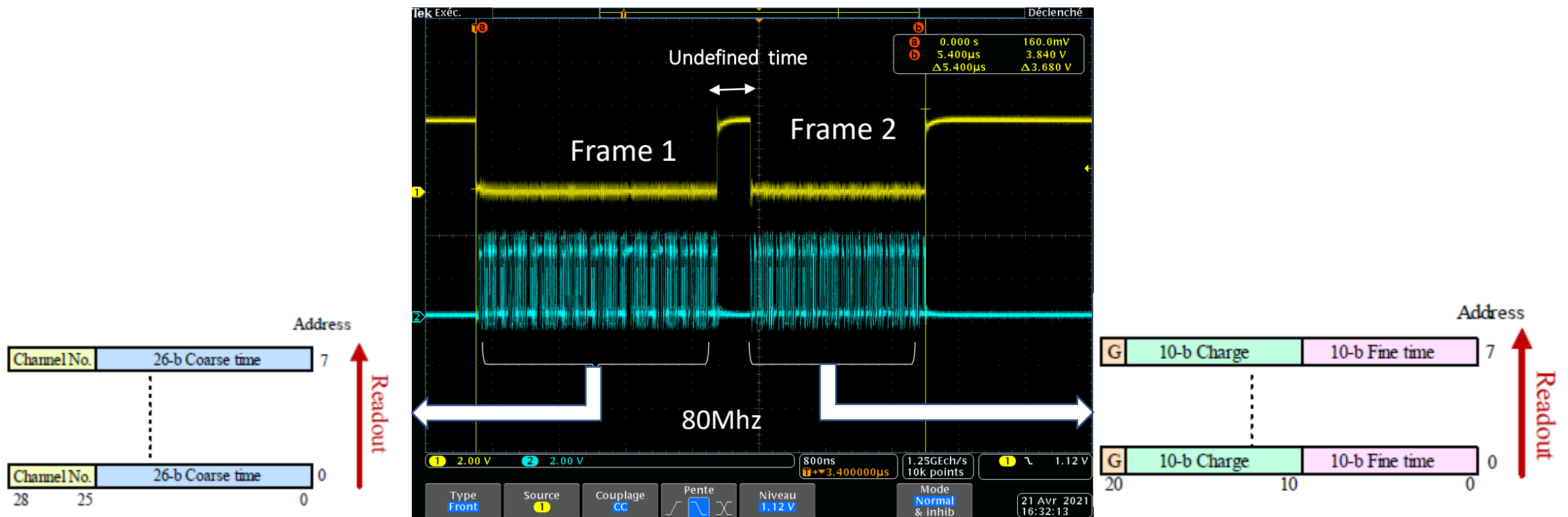
Threshold:

HG/LG Thresh.:

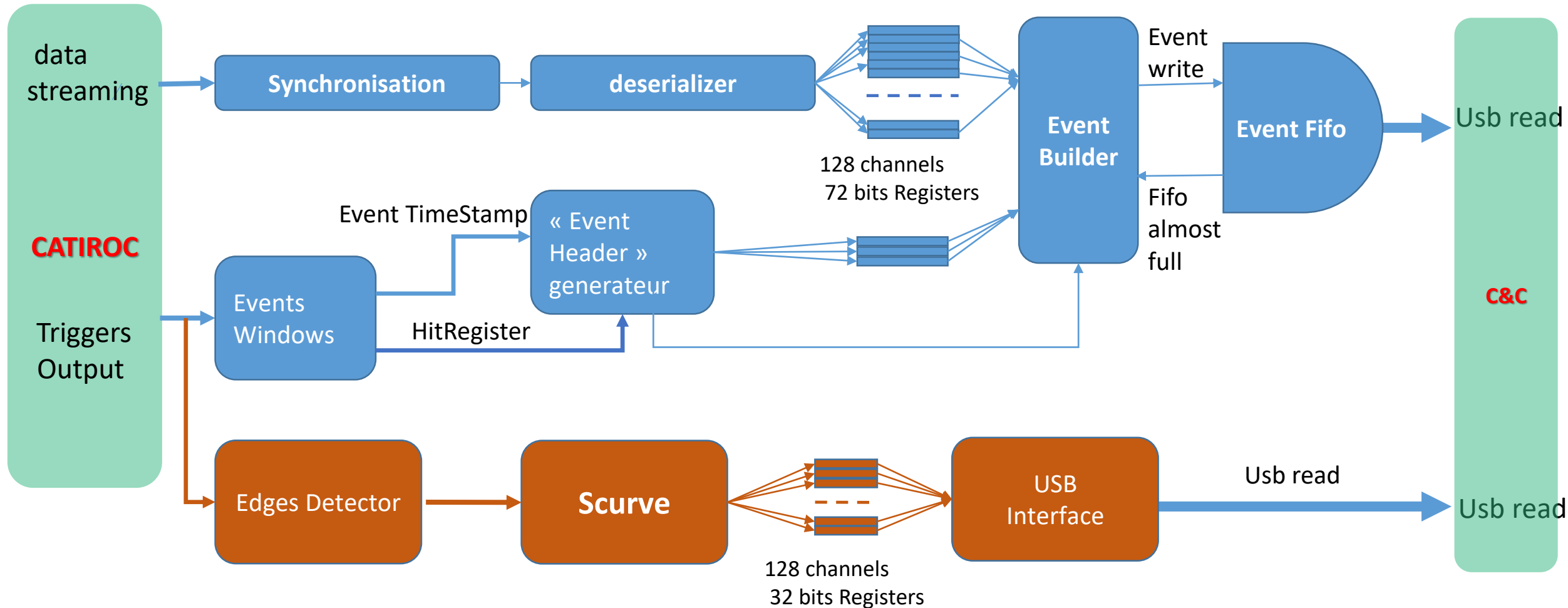
The Slow Control Status reflects the comparison of the 328 bits written and reading To/From the 8 CATIROC

ABC Firmware: CATIROC Data Capture

CATIROC Digital Readout

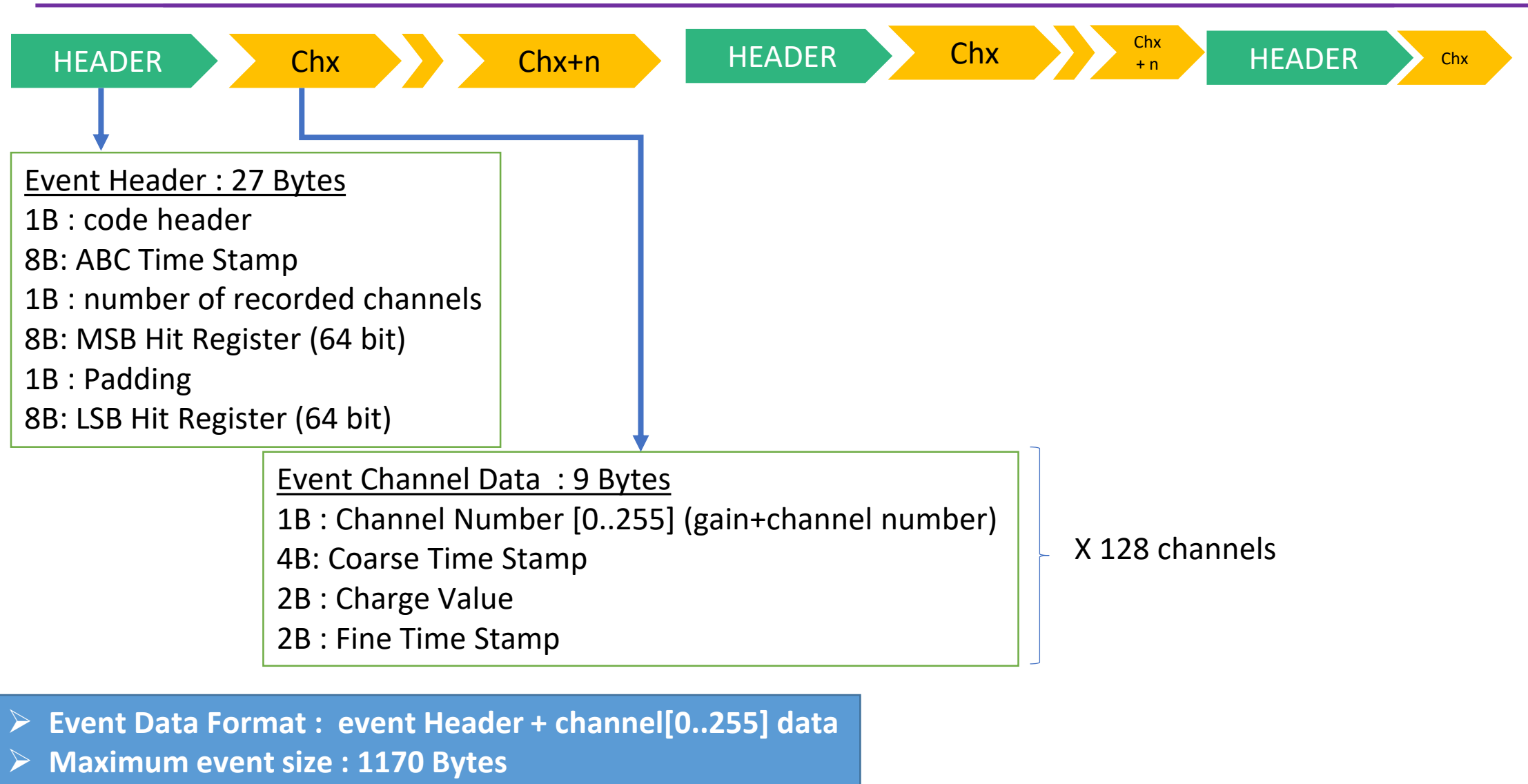


ABC TEST Firmware: Data Capture

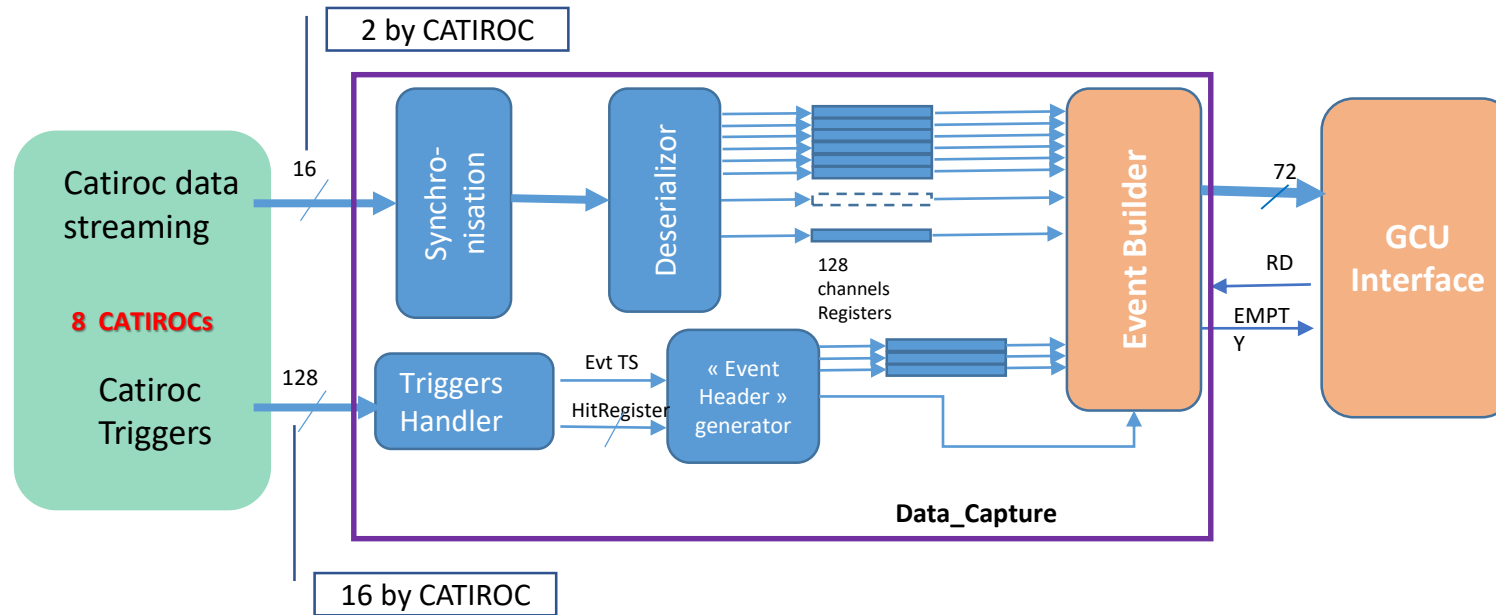


Reference clock : 160 MHz
CATIROC : 40 MHz

ABC USB Firmware : Data format



ABC Test Firmware : Limitations



■ The ABC Test firmware used for the mass tests of the ABC board, is based on the parallel readout of the 8 Catirocs (16 signals).

■ This readout is triggered by the first CATIRO and stopped by the last one.

■ No data corruption

■ we lose some data during the firmware dead time

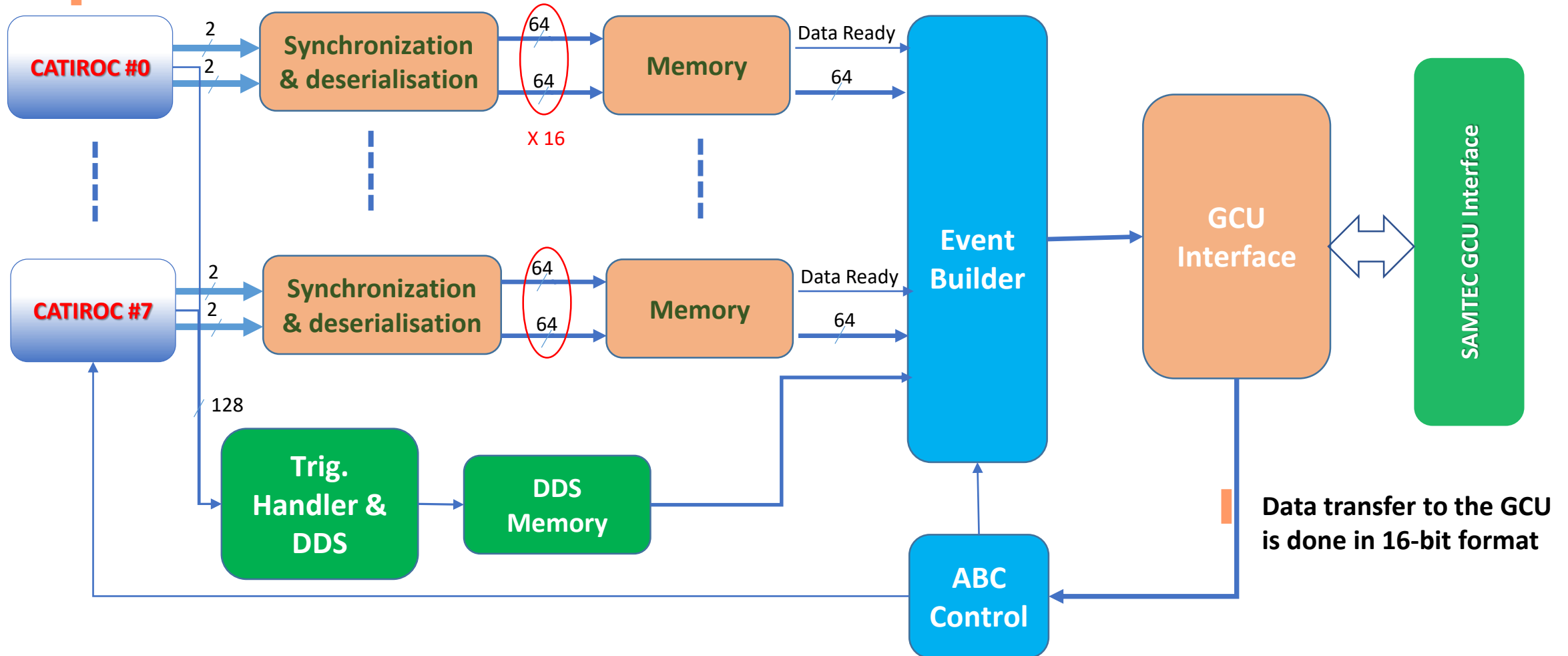
■ ping pong data confusion

ABC New Firmware : Data Capture

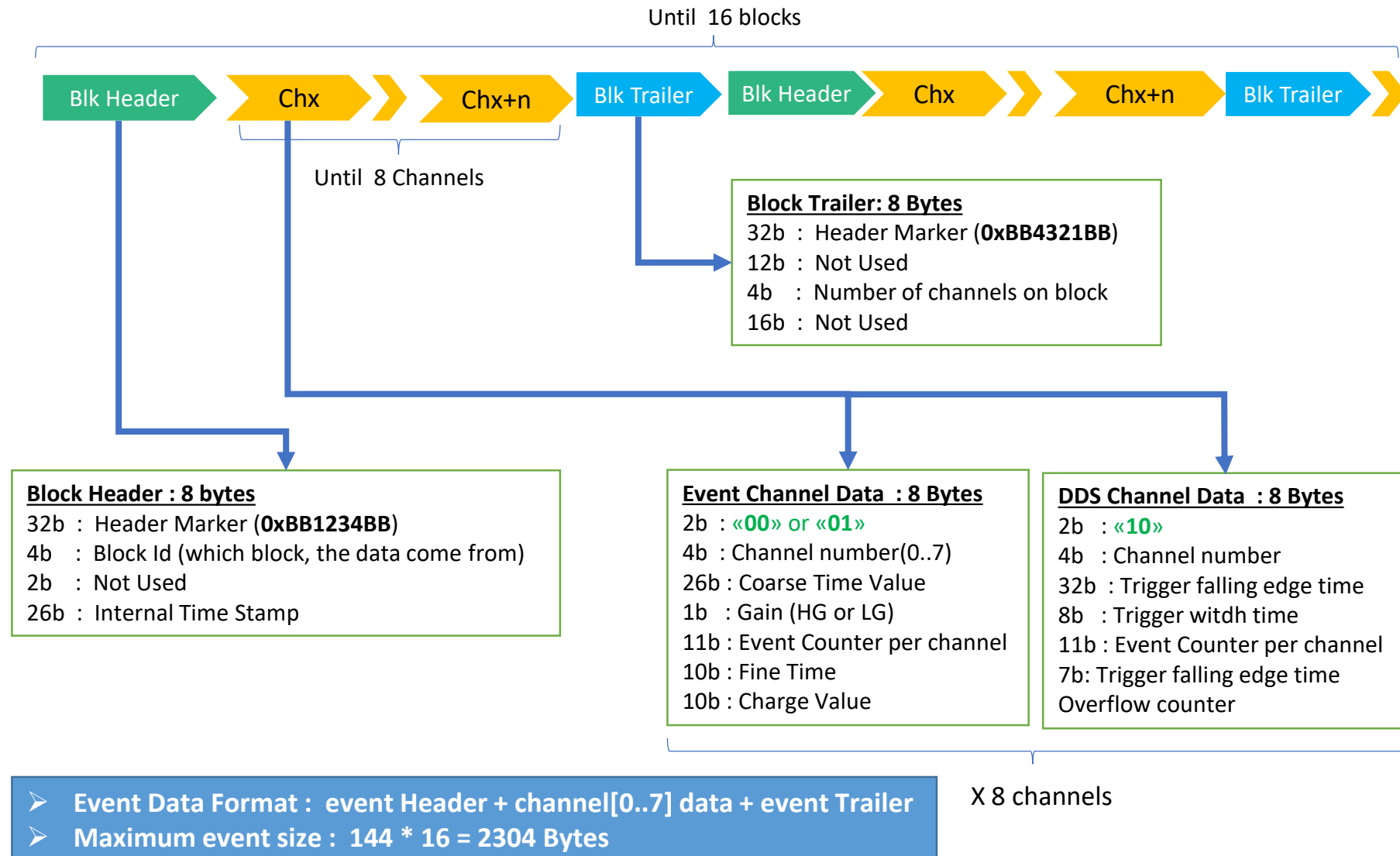
Data capture is done in a parallel mode (by block)

Each capture manages the data of one ½ CATIROC (block)

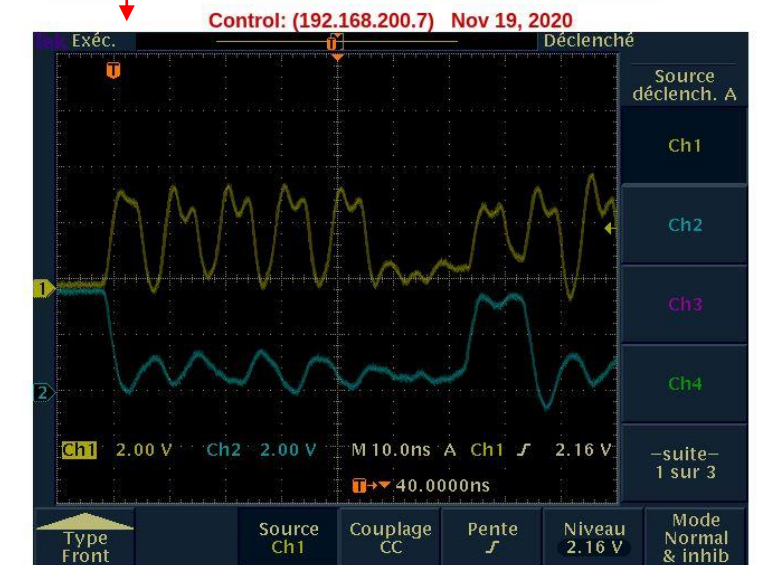
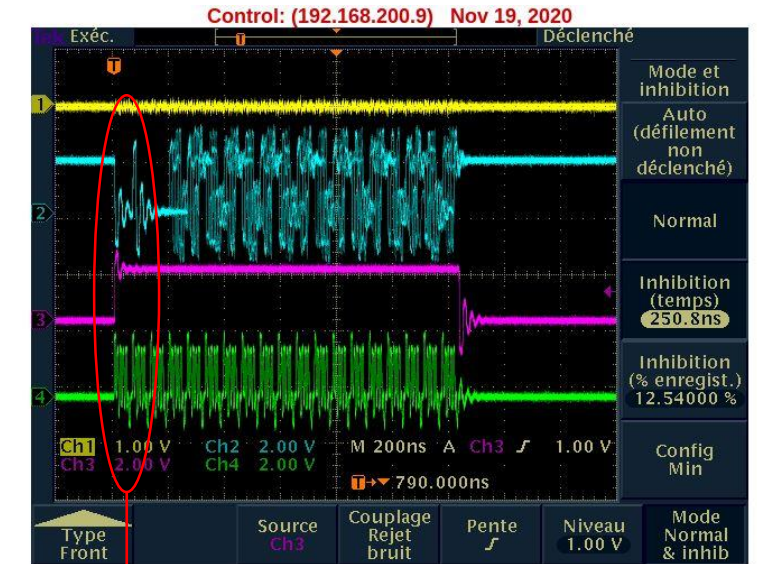
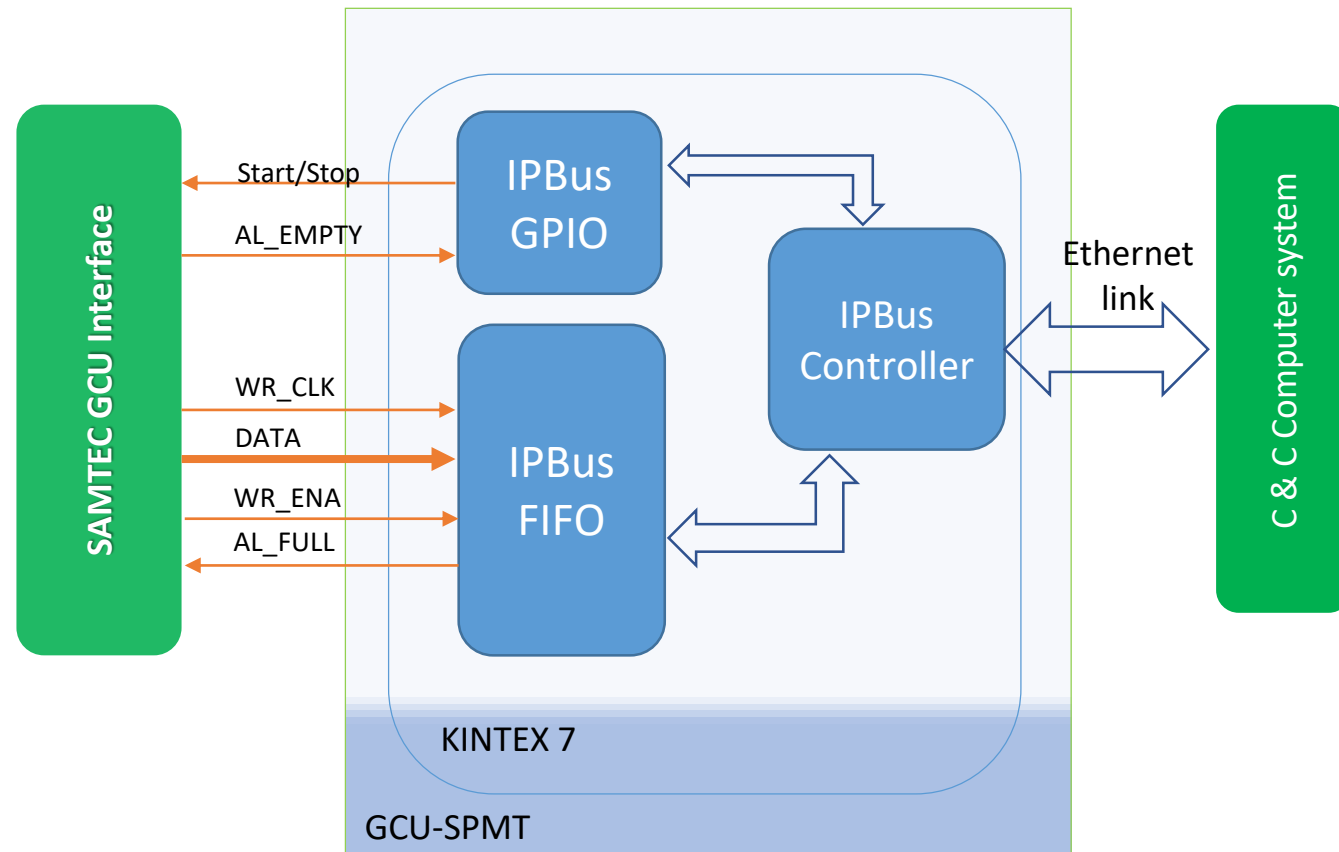
Each block handle 8 channels



ABC New Firmware : New Data Format



Data Capture with GCU : GCU Side

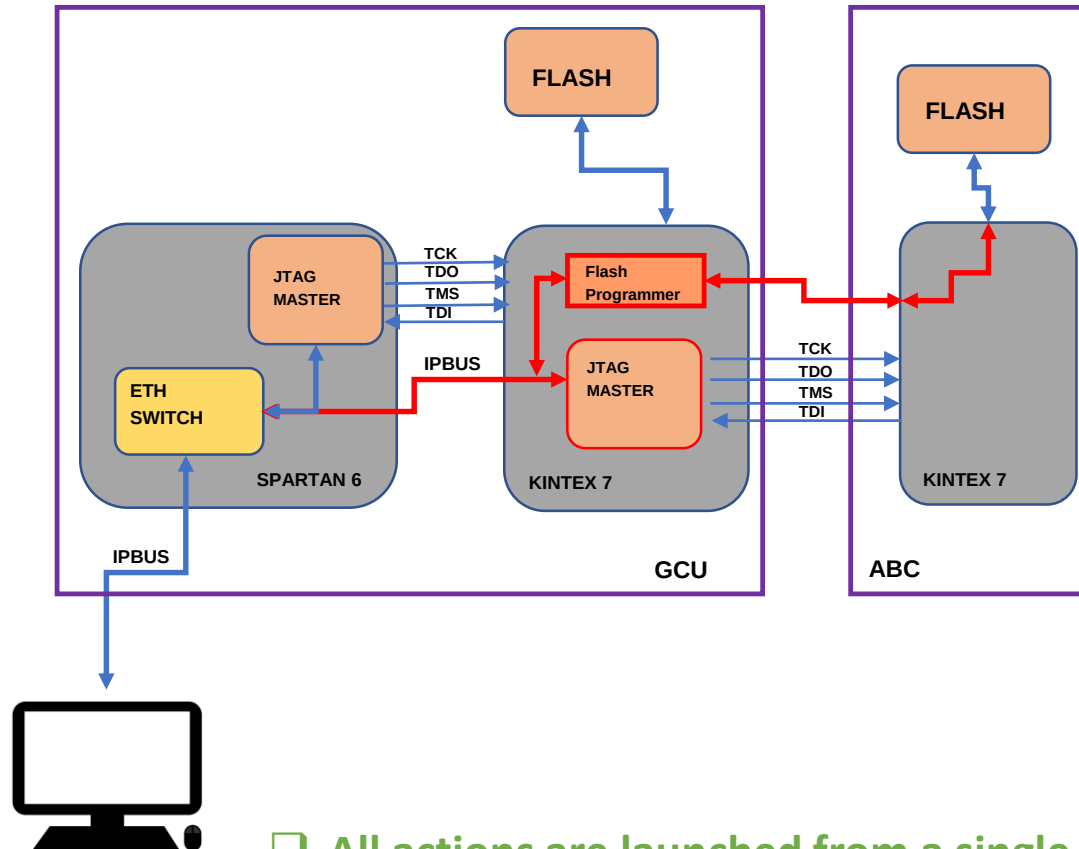


Conclusion :

Data Transfer Rate : 200 MBytes /s (1.6 Gbits/s)

ABC Remote Programming

FIRMWARE STRUCTURE



1. Install Master JTAG ON GCU Kintex7

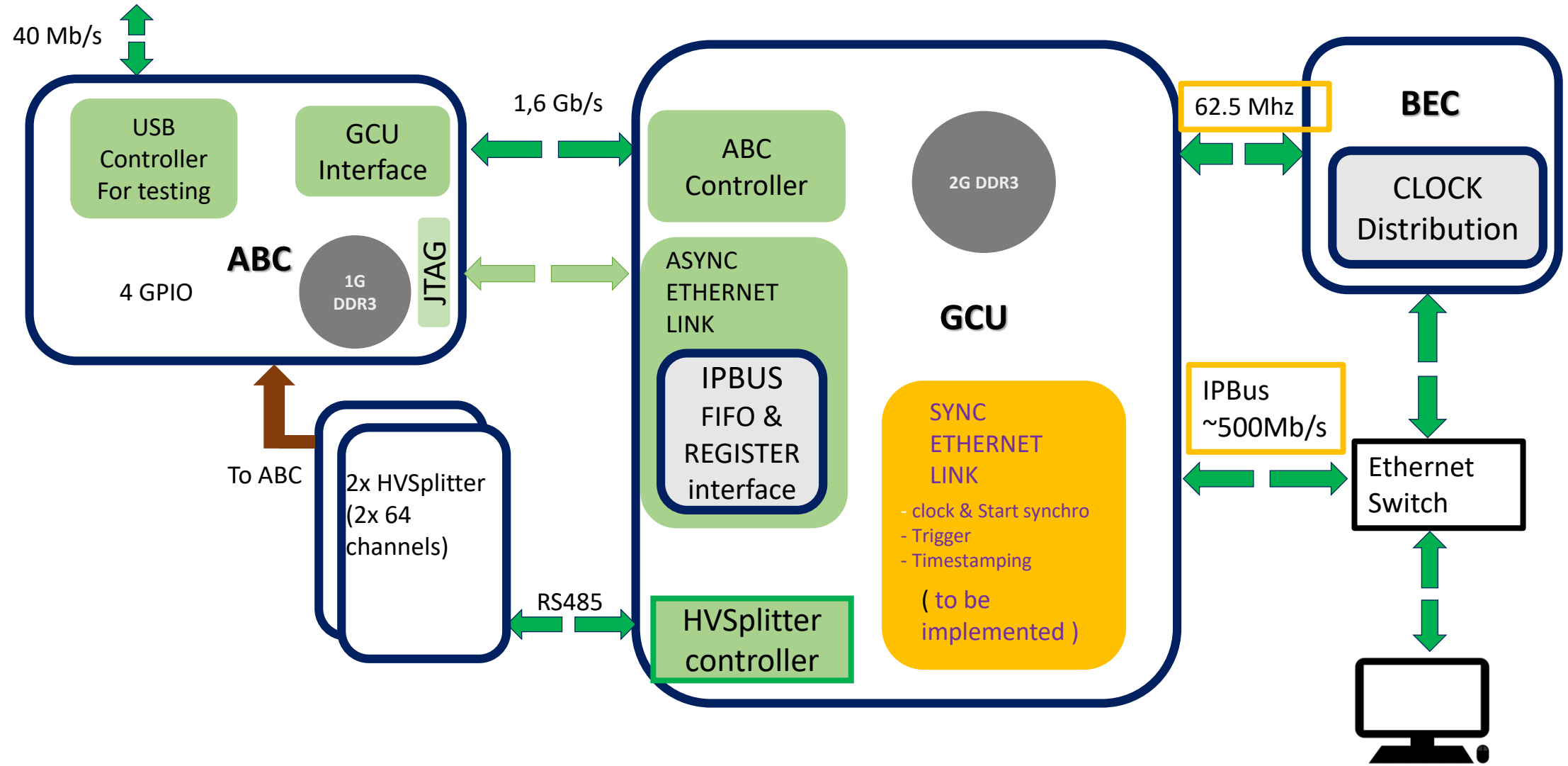
2. Configure ABC Kintex7 as Gateway for Flash programmer

3. Install ABC Flash Programmer on GCU Kintex

4. Download a Bitstream to ABC Flash

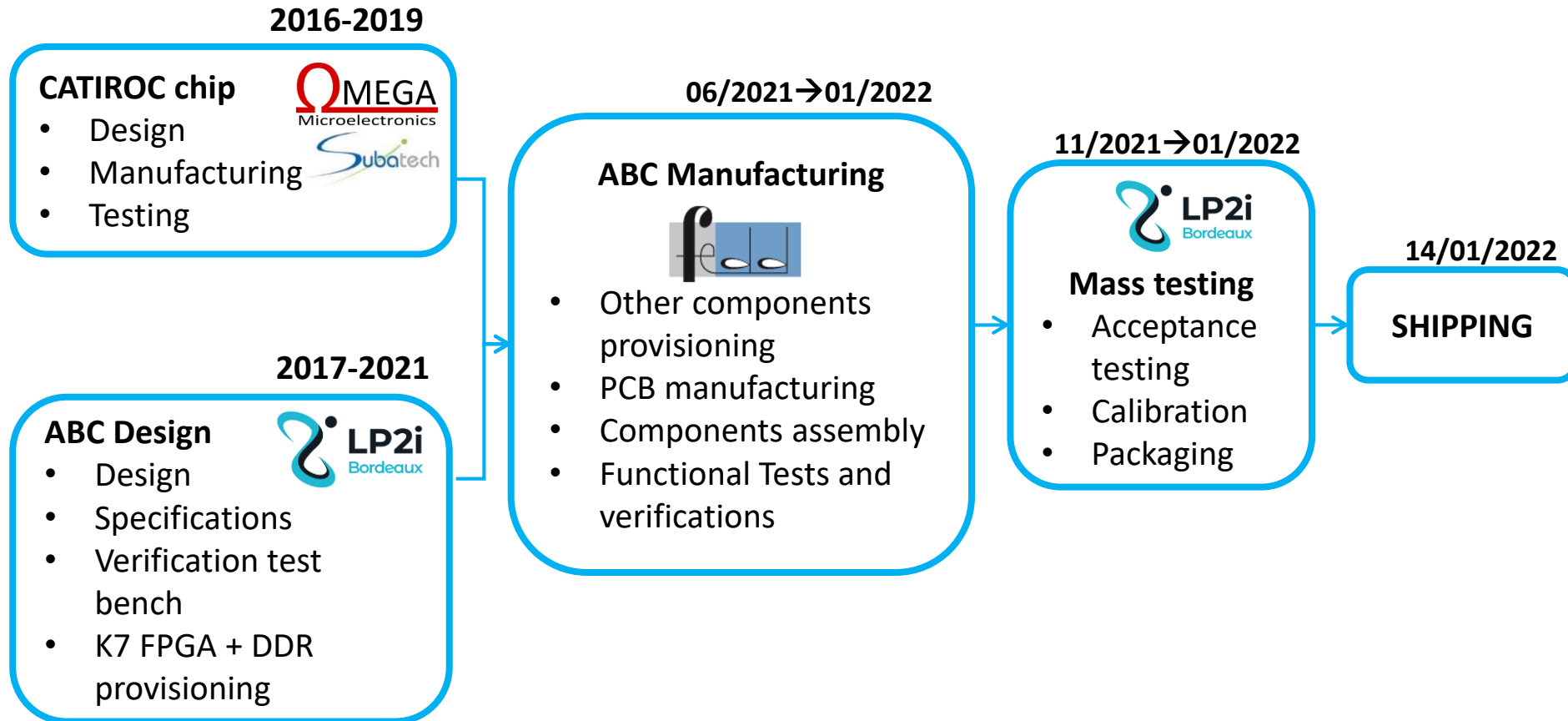
❑ All actions are launched from a single shell script.

ABC External interface

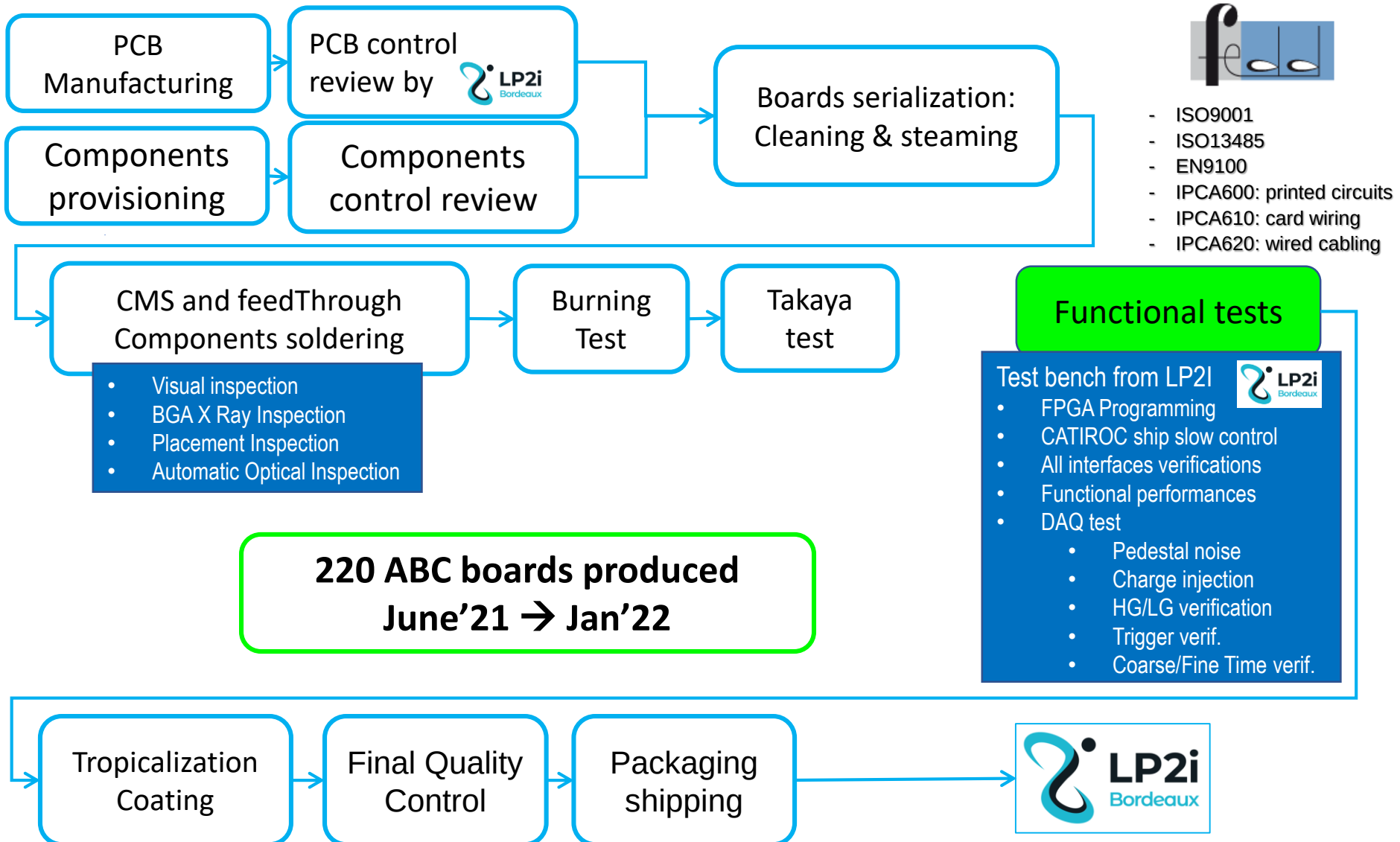


ABC mass testing and calibration performances for SPMT system

Reminder



Production and Tests at FEDD company

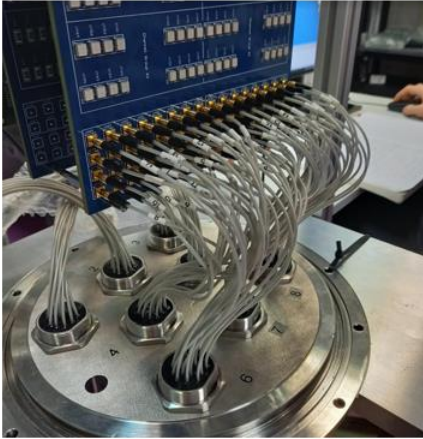


Production and Tests at FEDD company

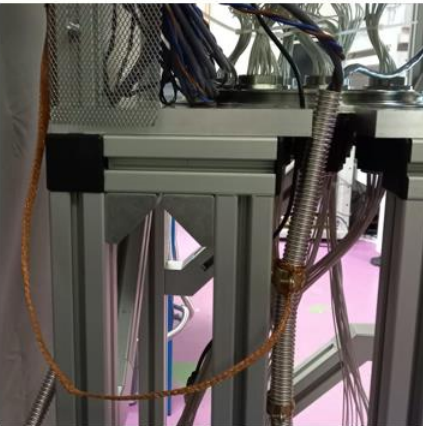
- PCB control review at FEDD company



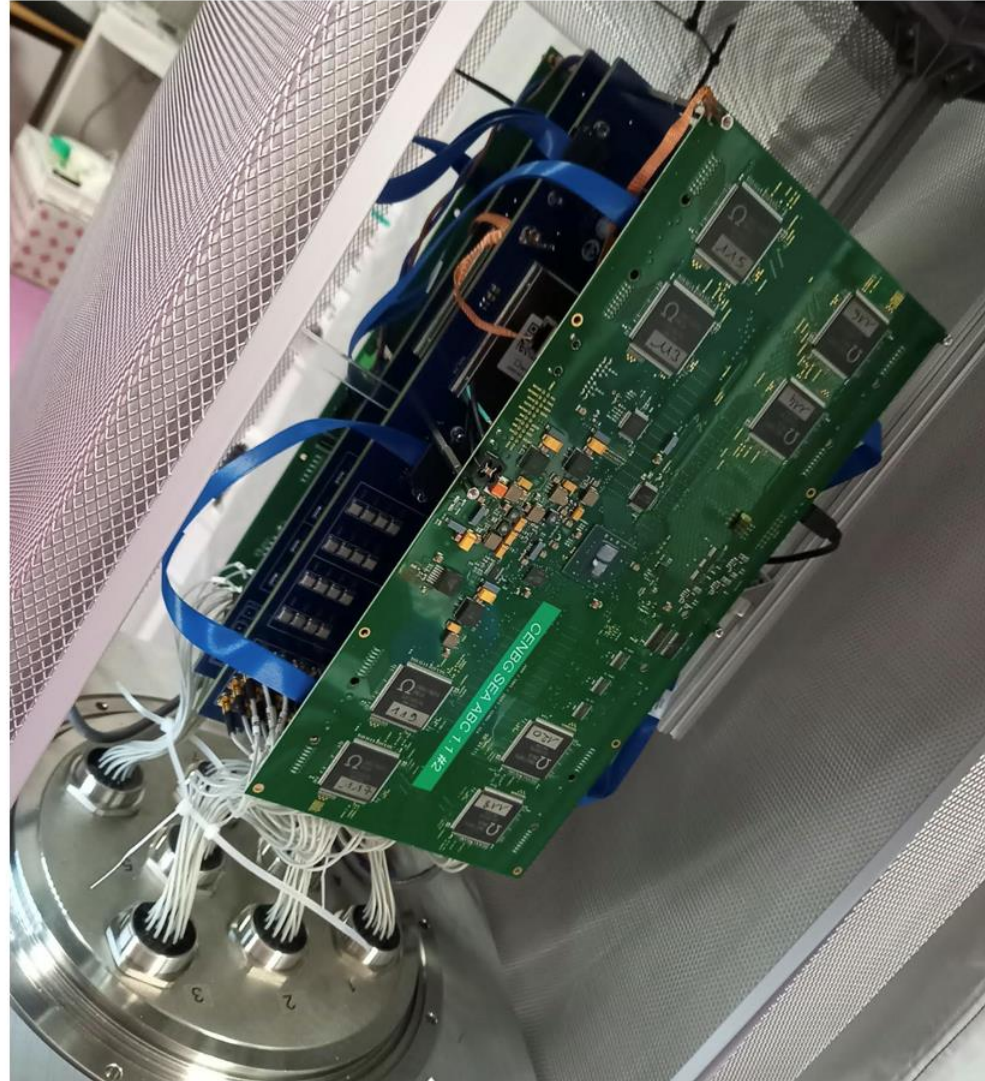
Combined test bench at LP2IB



Detail of PMT connection



80 meter bellow connection
Detail of GND connection



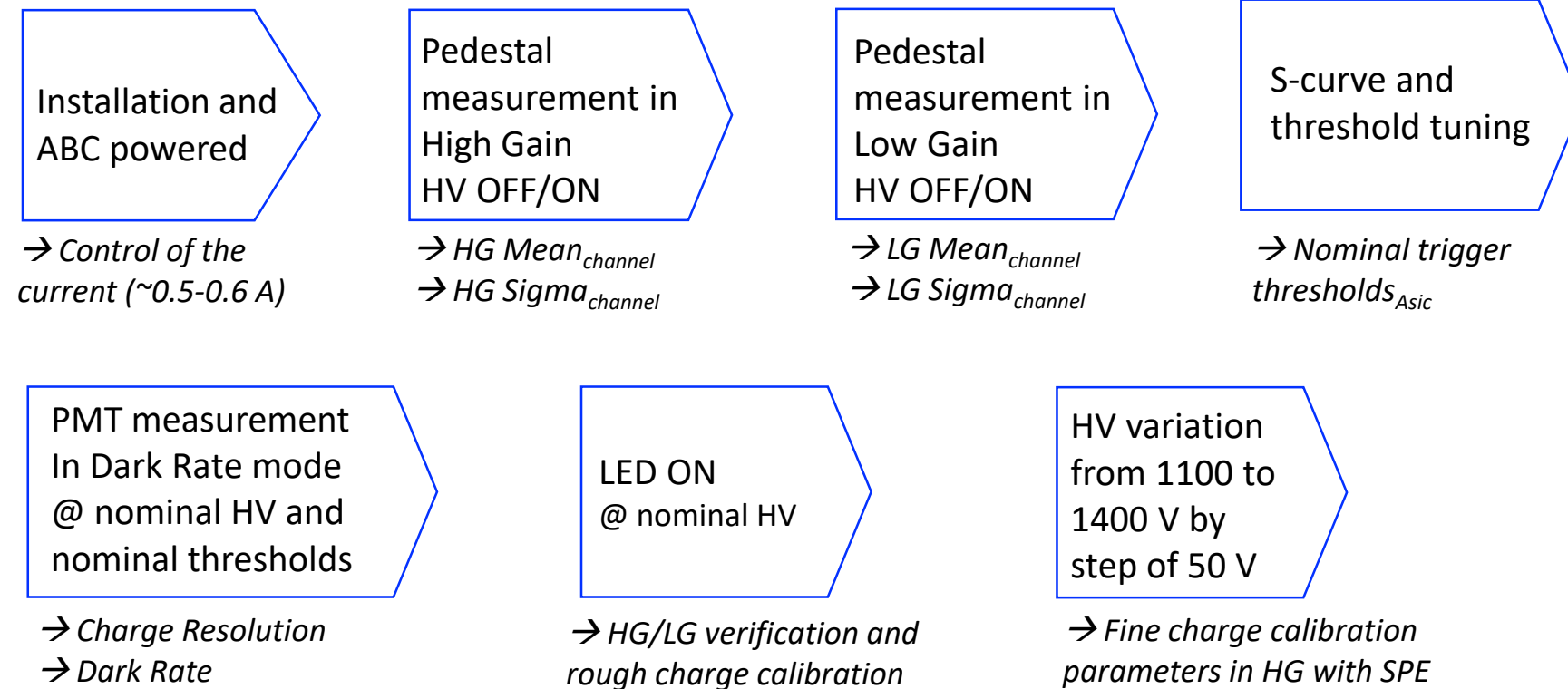
Combined test bench at LP2IB

- 128 JUNO 3'' PMTs in a dark room



Acceptance and calibration test sequence

- Sequence step by step and deliverable



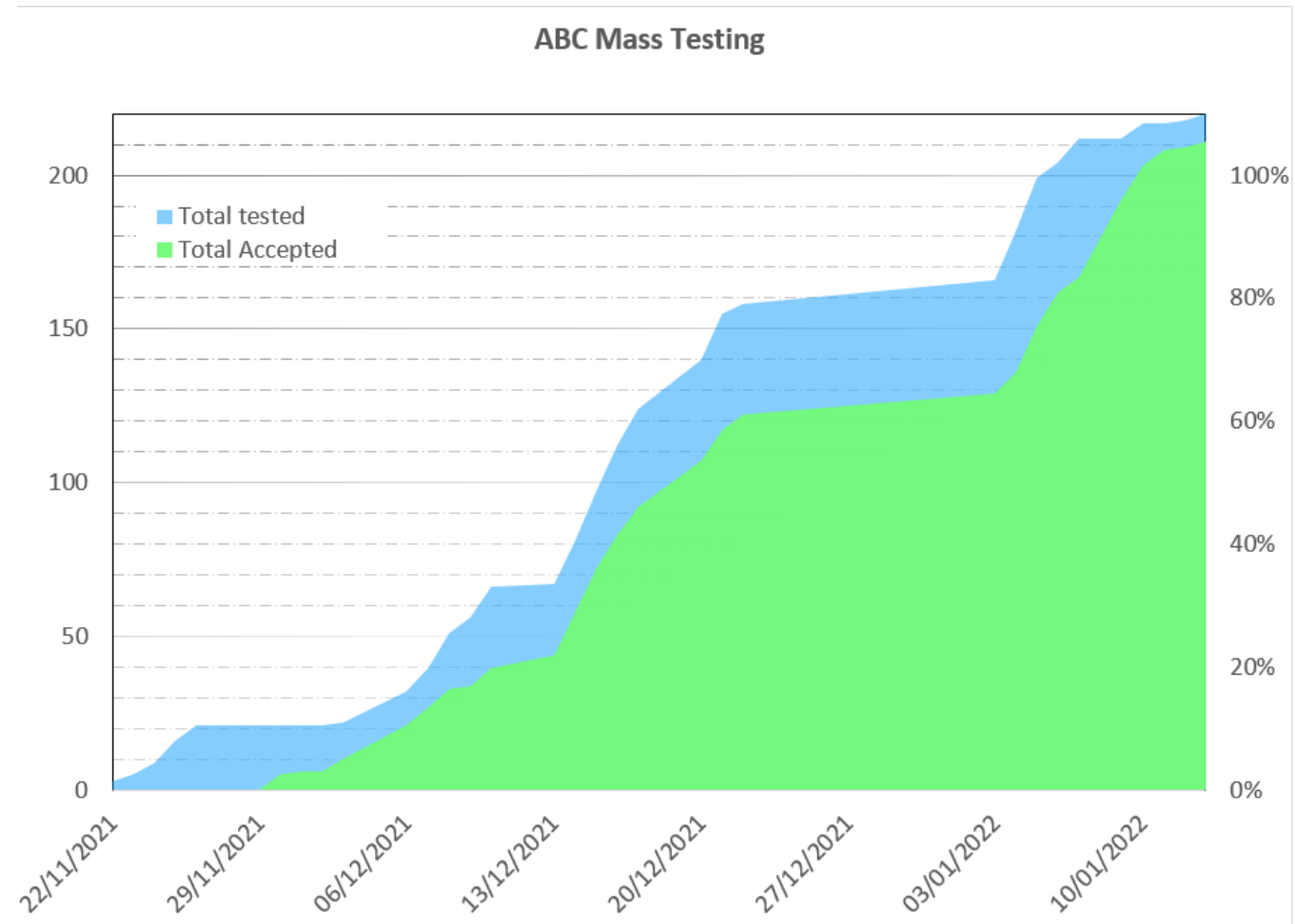
→ all the sequence lasted $\sim 25'$ and was fully automatized

Acceptance and calibration test sequence



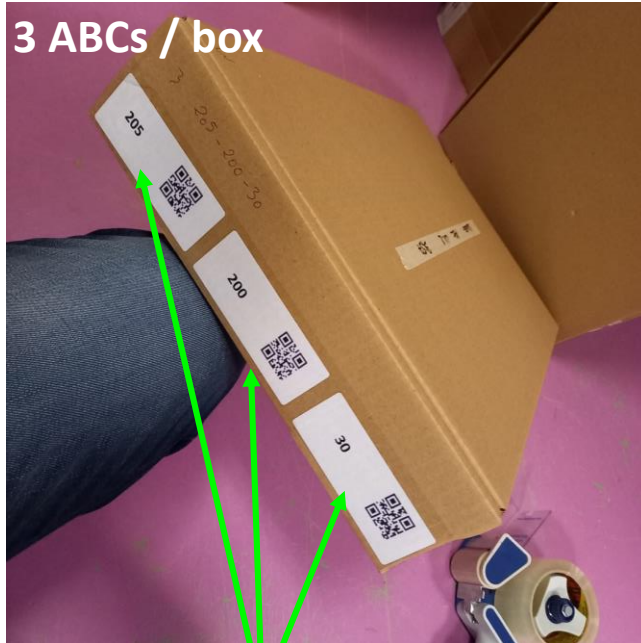
ABC mass testing: summary

- 220 ABC front-end boards have been produced, delivered and tested
- 212 have been accepted for the SPMT system (96.4%)



Shipping

Carboard Boxes
3 ABCs / box



ABCs ID + QR code



Shipping

- 5 ABC sent to IHEP on Dec 21
- 209 ABC sent JUNO Site on January 14, 2022



TOTAL: 214 ABCs shipped

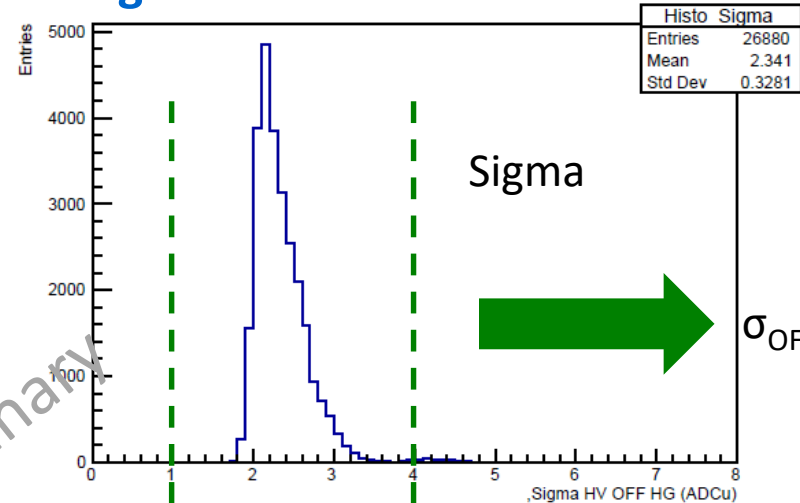
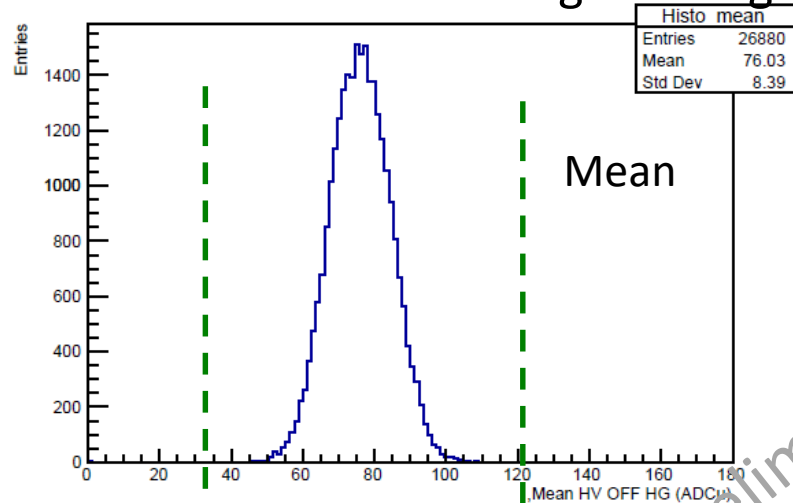
- 200+10 spares for JUNO-SPMT
- 3+1 spare for JUNO-TAO

Summary

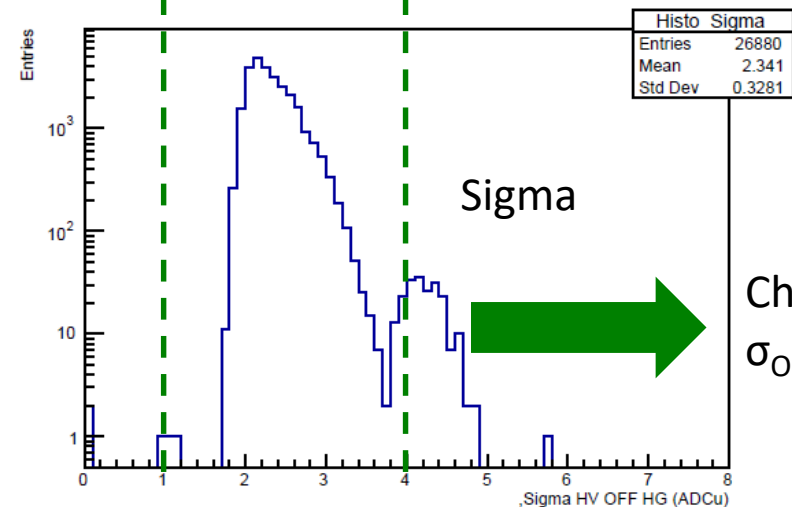
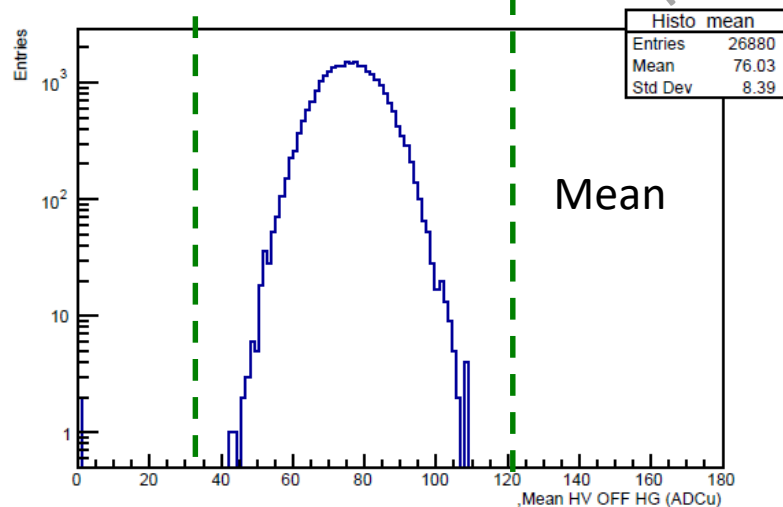
- Production and Functional Tests successfully performed at FEDD company
- Acceptance and calibration tests successfully performed with 128 PMTs at LP2I Bordeaux
- Preliminary results of the mass testing exhibit good performances of the ABC boards → final analysis in progress
- Some ABC boards temporary rejected by the tests with identified issues. Other issues to be investigated
- 214 validated ABC boards sent to China on January 14th 2022: 210 for JUNO-SPMT system and 4 for JUNO-TAO veto
- Next major step: development of the final firmware for the SPMT system

ABC mass testing: pedestal results

- Pedestal mean charge and sigma in **High Gain mode with HV OFF**



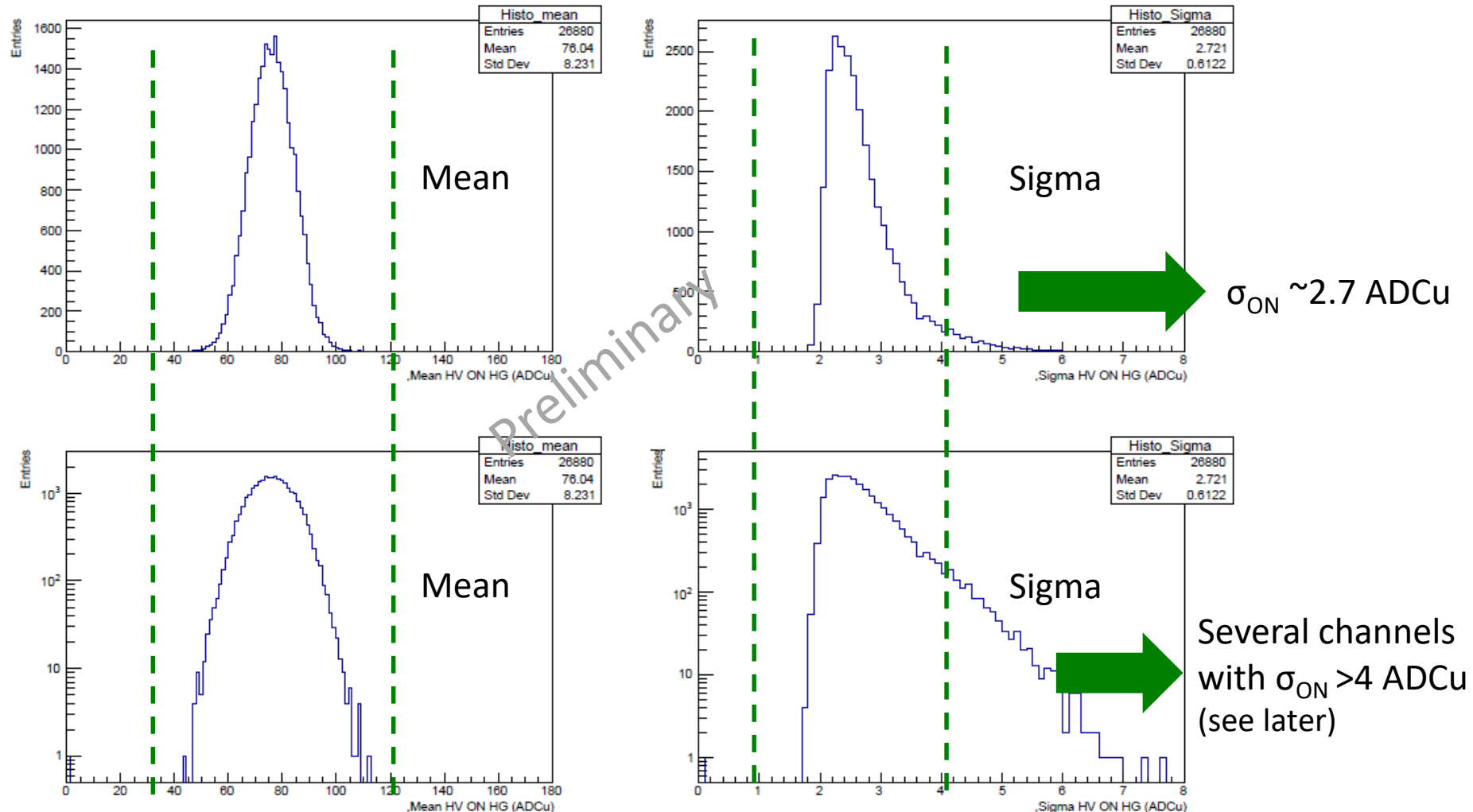
$\sigma_{\text{OFF}} \sim 2.3 \text{ ADCu}$



Ch80 with
 $\sigma_{\text{OFF}} > 4 \text{ ADCu}$

ABC mass testing: pedestal results

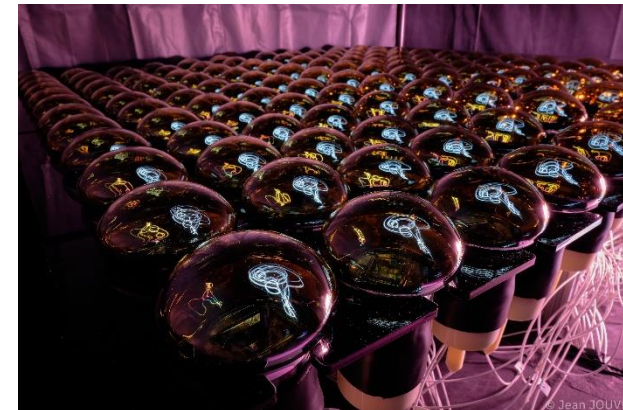
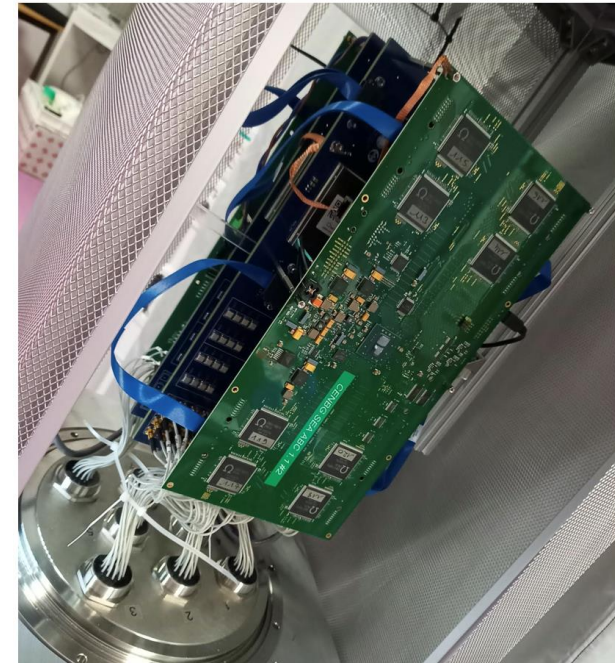
- Pedestal mean charge and sigma in **High Gain mode with HV ON**



Validation of the new firmware for ABC with PMT data.

Experimental setup

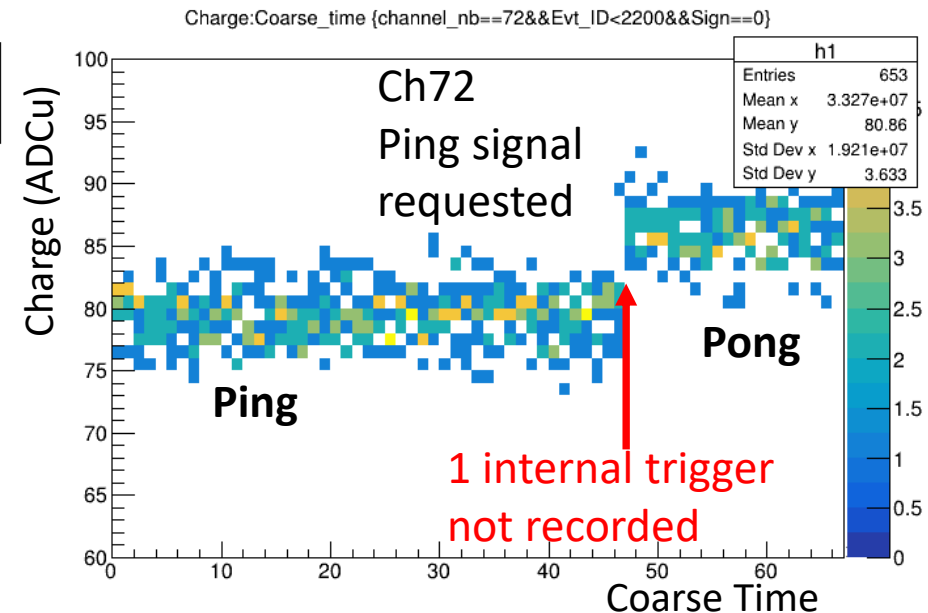
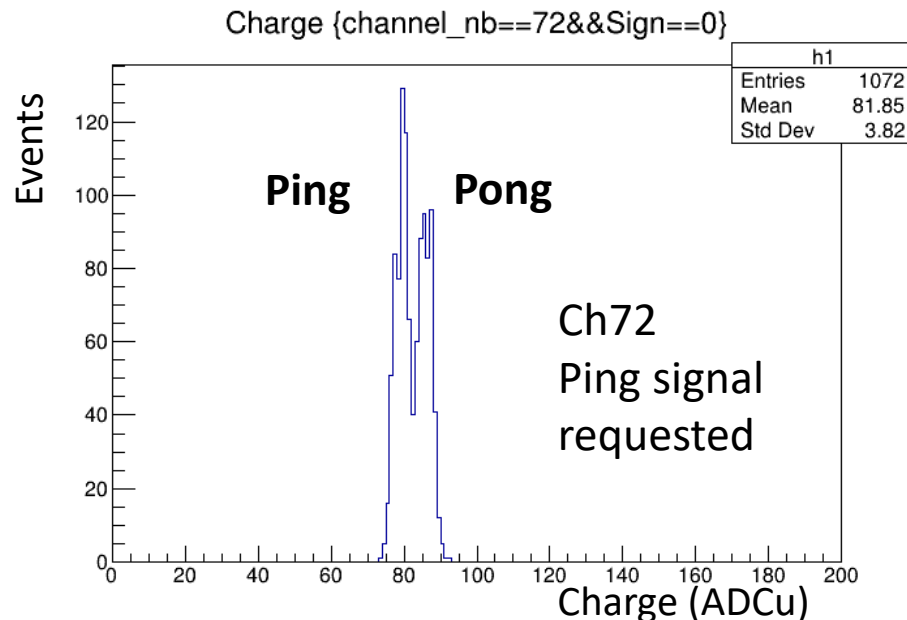
- **New firmware** tested with the 128 3-inch PMT test bench at LP2i Bordeaux with ABC#58
- **Main Asic parameters:**
 - Slow Shaper RC value: $RC=50$
 - Preamplifier Gain: 20
 - Slow Shaper peak time: 30 ns
 - HG/LG threshold @520 DACu
 - Force trigger with $f=1.3$ kHz
 - Trigger threshold depending on the measurements (Pedestal or physics)



Pedestal runs

Reminder: Pedestal with Test Firmware

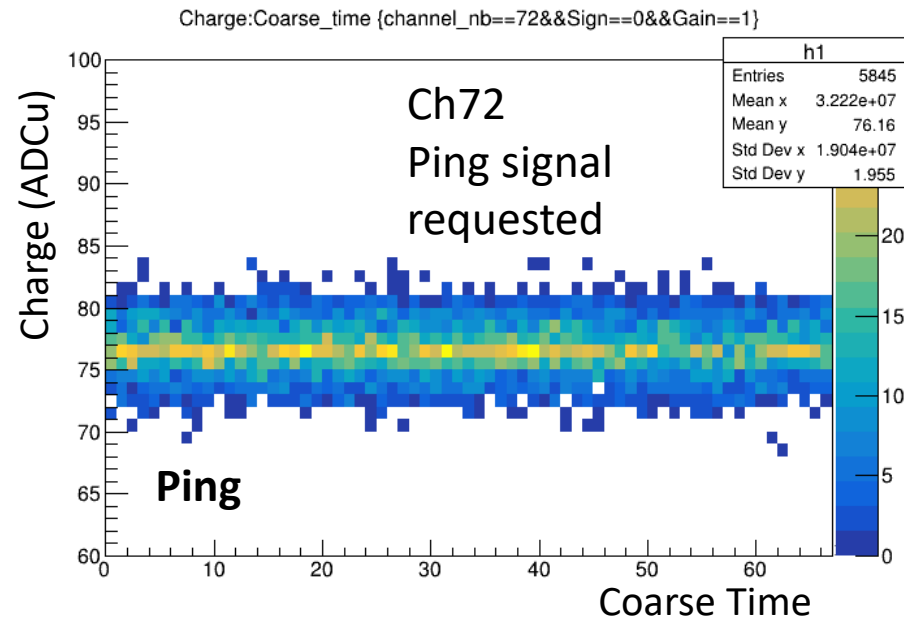
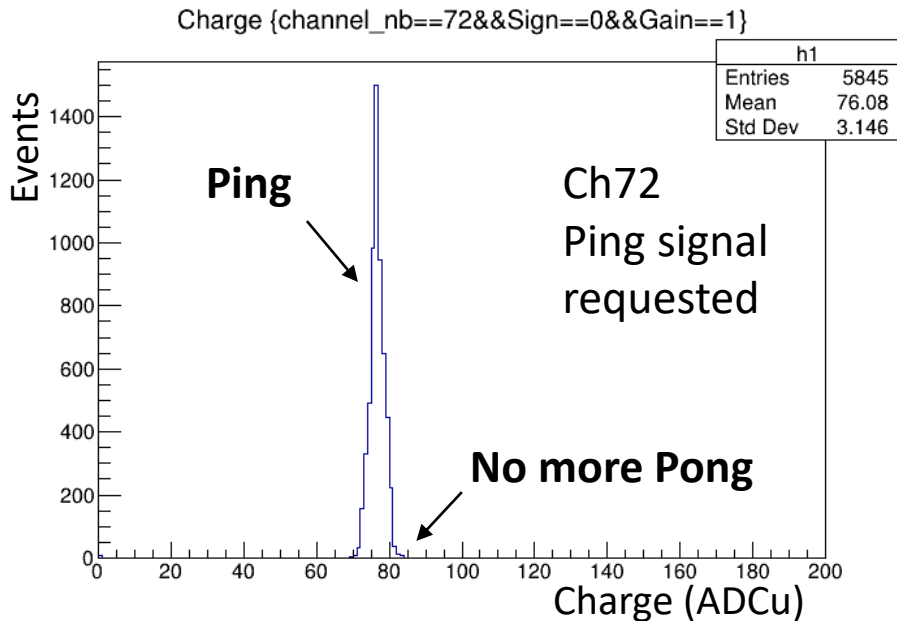
- During ABC Pedestal mass testing with the [Test Firmware](#), observation of some mismatch between Ping/Pong channels with HV ON (*see DocDB-7795*)
- If one internal trigger coming from DN rate is not recorded by the Test Firmware, Pong signal is taken as Ping signal
- Example for [ch72 in ABC#58](#)



→ May come from the Test firmware due to the $\sim 6\text{-}8\ \mu\text{s}$ deadtime between 2 events in the same Block (1 Block = 8 channels = $\frac{1}{2}$ Asic)

Pedestal @100 DACu with new firmware

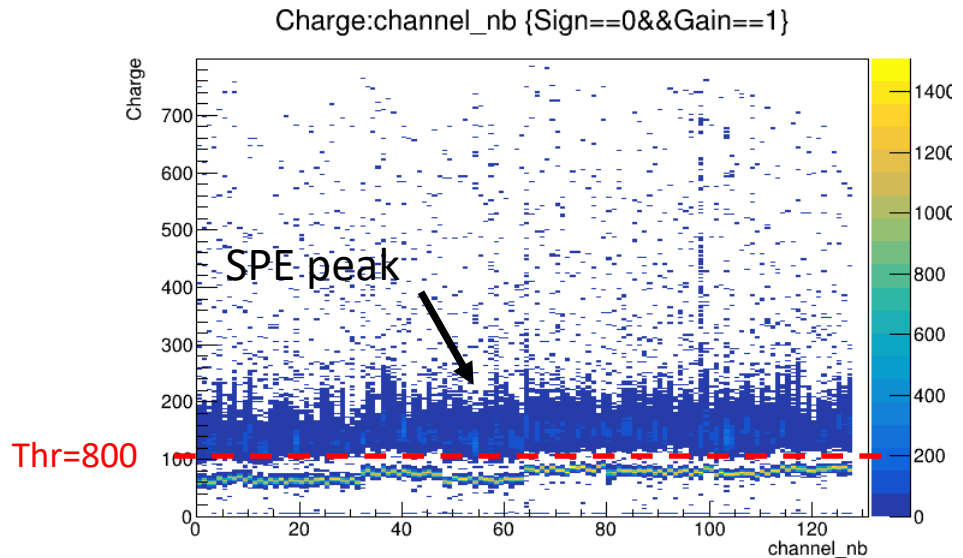
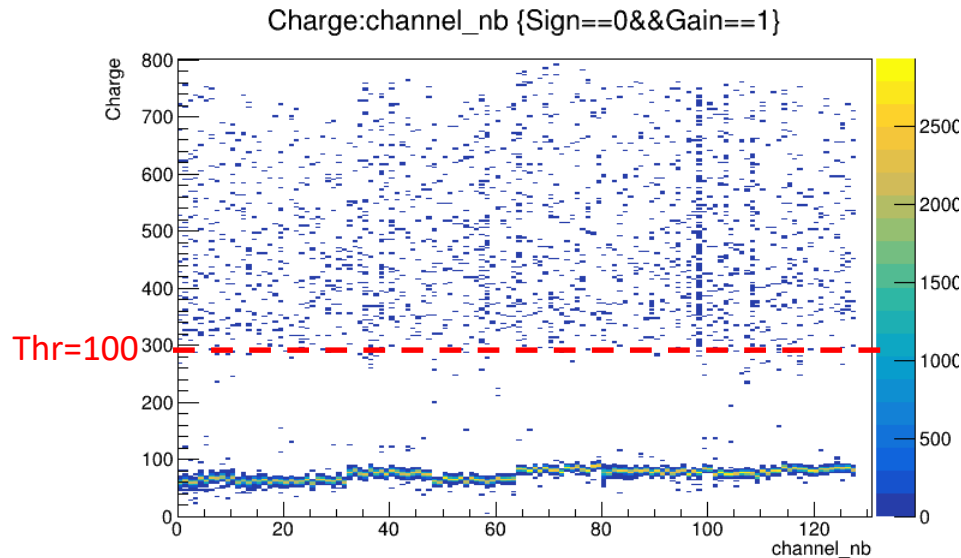
- Performed with the [New Firmware](#) on July 2022 on same ABC#58, ch72 with the same trigger threshold at 100 DACu



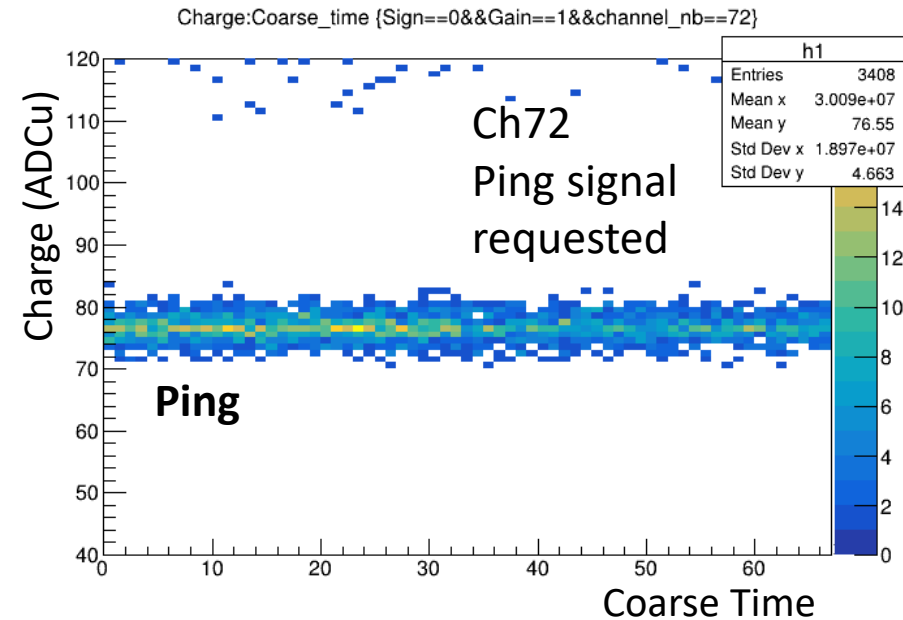
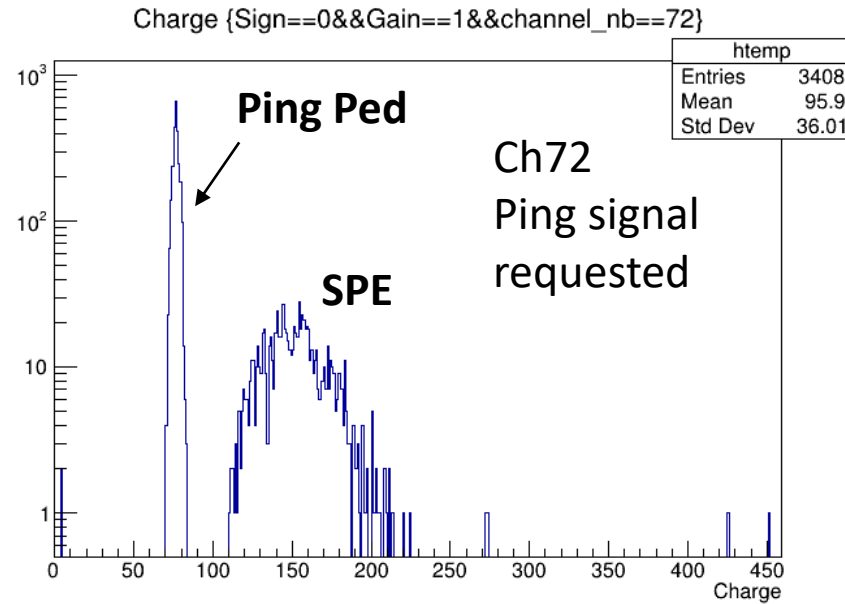
→ With the new firmware, no more mismatch between Ping and Pong signals in Pedestal runs with a trigger threshold @100 DACu

Pedestal @800-870 DACu new firmware

- Performed with the [New Firmware](#) on July 2022 on same ABC#58, ch72 with the [lower trigger threshold at 800 and 870 DACu](#)
- **Goal:** to check if there is no lost event with a higher rate of internal trigger (SPE evts)

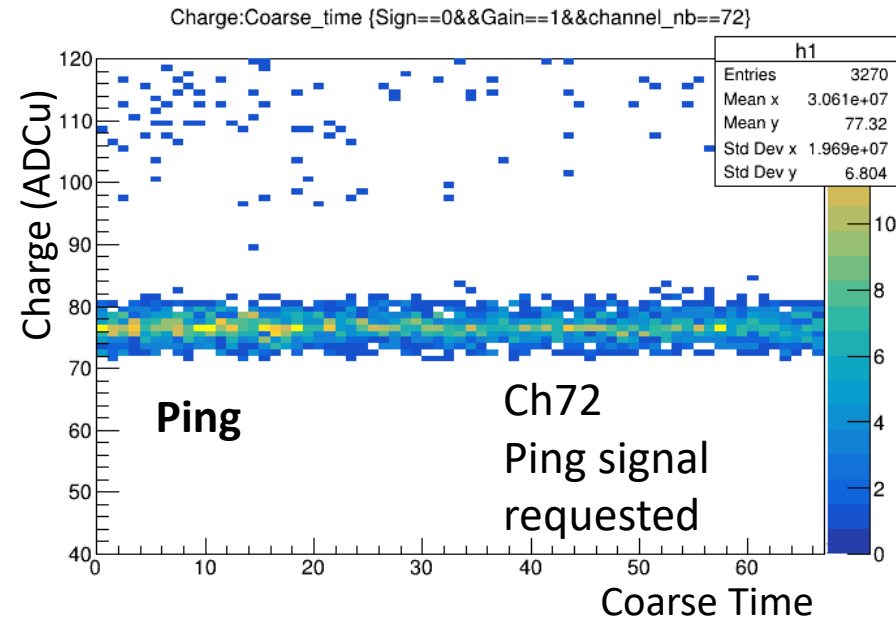
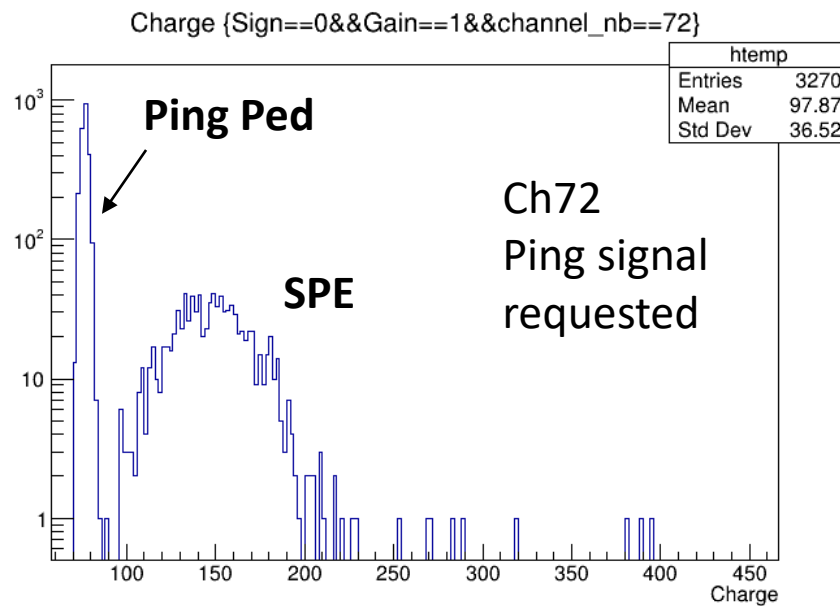


Pedestal @800 DACu with new firmware



→ With the new firmware, no mismatch between Ping/Pong signals in Pedestal runs with a trigger threshold **@800 DACu**

Pedestal @870 DACu with new firmware

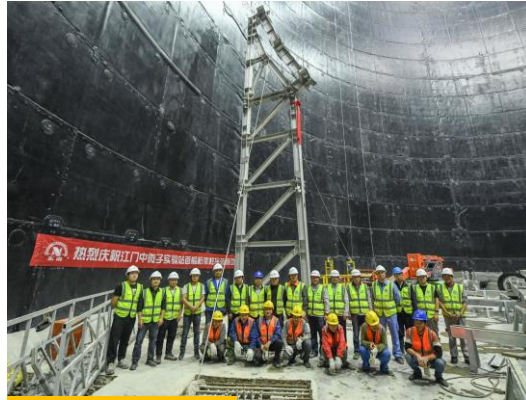


→ With the new firmware, **at the level of the dark noise rate**, no mismatch between Ping/Pong signals in Pedestal runs with a thres. **@870 DACu**

Comments

- The **New Firmware is more efficient** to handle both force trigger (Pedestal mode) and internal trigger (Physics mode) even at very low thresholds
→ Lower threshold (~870 ADCu) may be used during JUNO data taking to still measure physics events during a Pedestal run in order to minimize loss of physical events (deadtime)
- Anyway, it seems obvious that, time to time, **ping and pong channels will be mixed in case of very high rate (ping-pong-ping scenario within 6 μ s)**
 - Not a problem for most of the channels for which pedestal mean charge are close (less than 3 ADCu)
 - For channels exceeding 5-10 ADCu charge difference between Ping and Pong, it may affect slightly the charge measurement → to investigate the possible impact
→ final mitigation using the DDS when it will be available

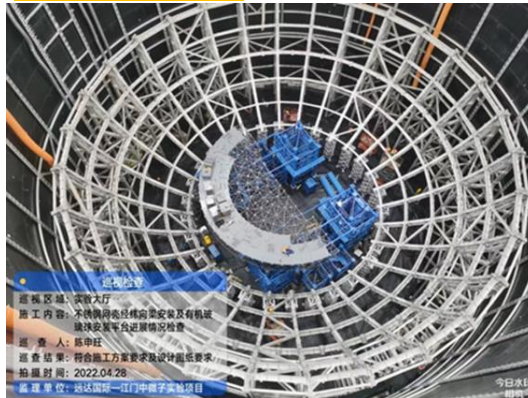
JUNO Project Status



Jan. 21st



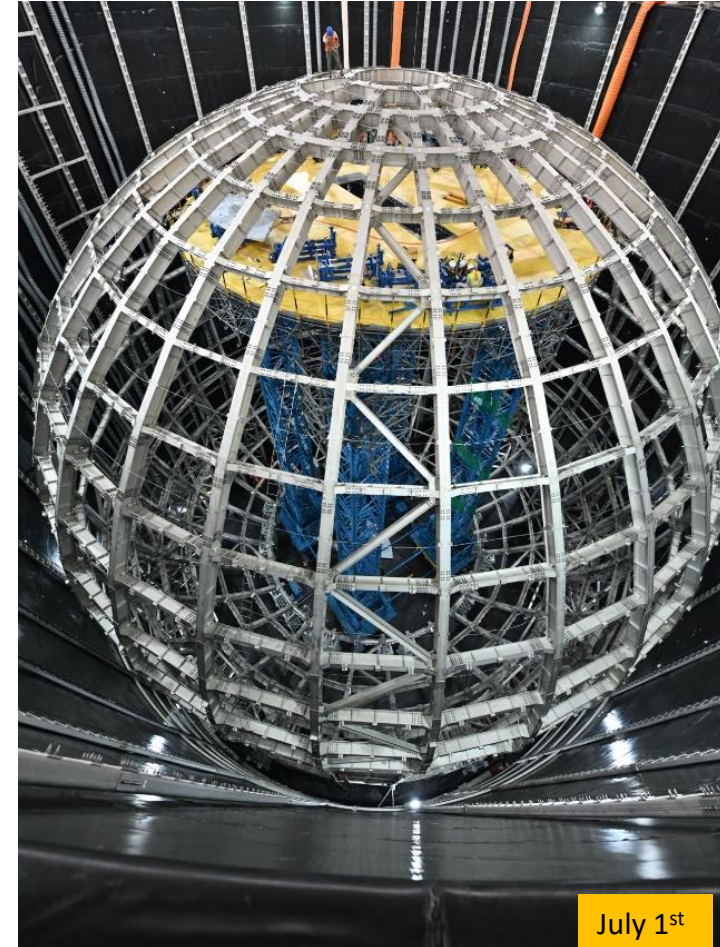
Mar. 8th



April 28th

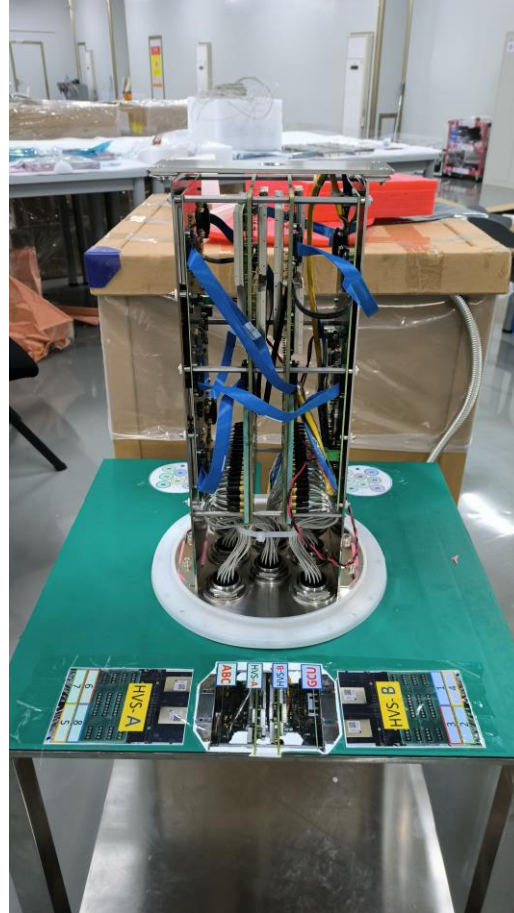


May 27th



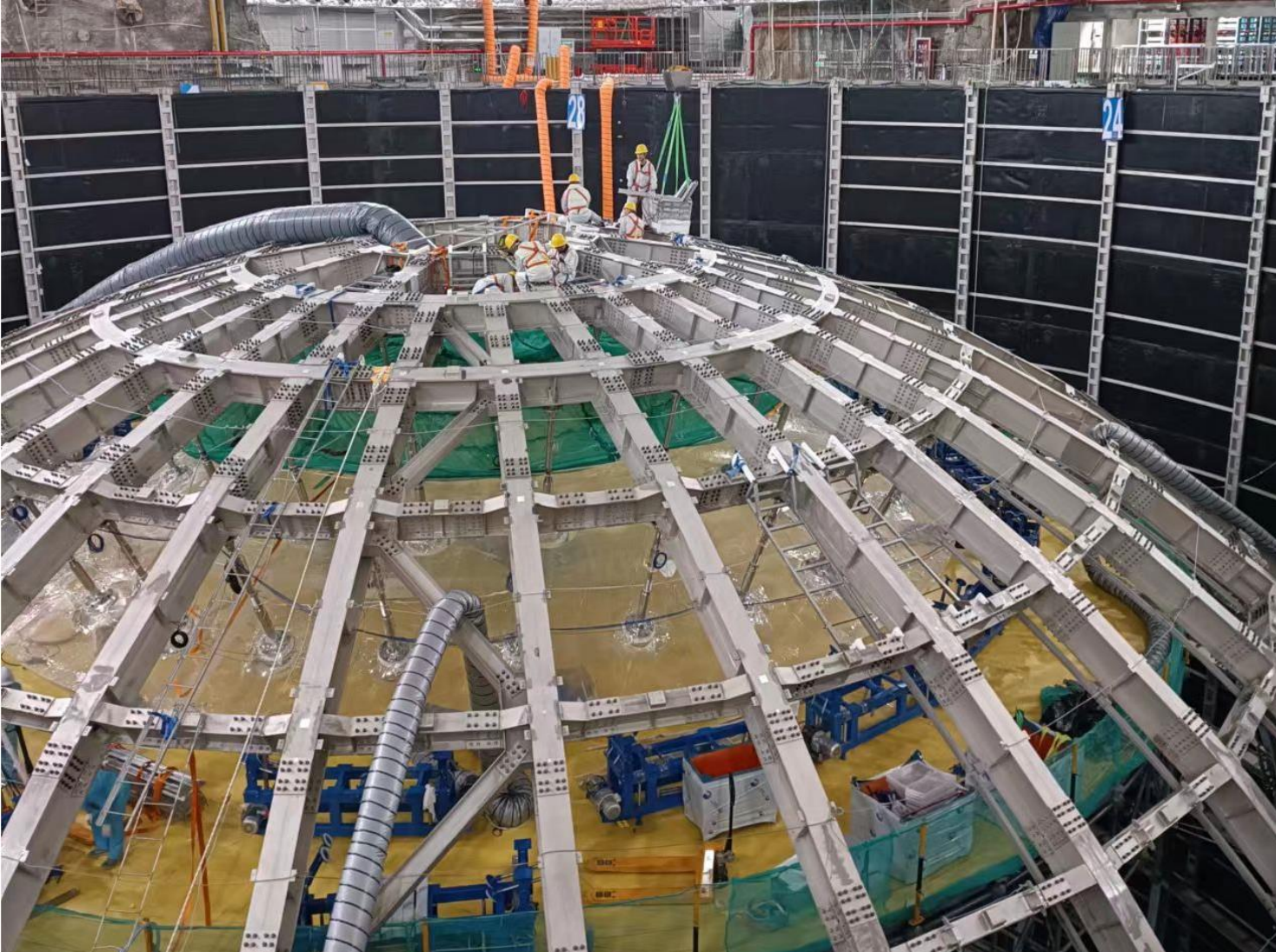
July 1st

sPMT JUNO Project Status



► Since the End of August More than 10 UWB are mounted and fully tested ...

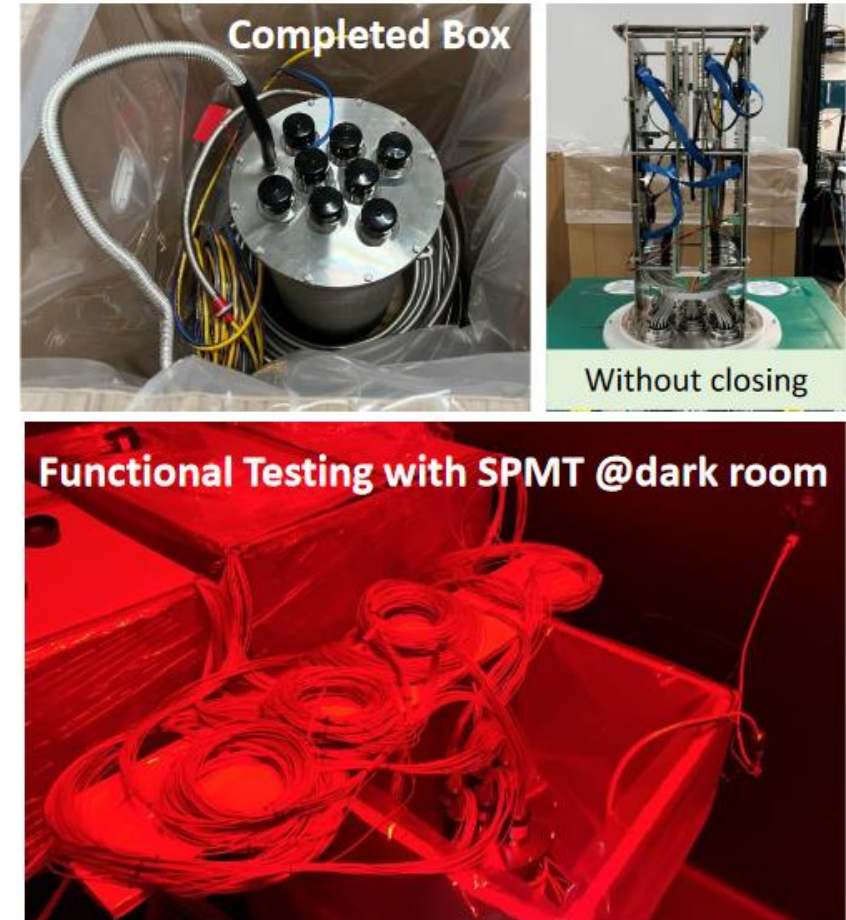
Underground installation



Status @ 05/12/2022

- UWB integration is in progress: 3 pcs per day
- Productivity: ~60% (107/210)
- Testing processures works well
 - Functional testing: 3 pcs per day
 - Leakage testing: 3~4 pcs per day

Processures	Detail status	Num.
Intergation	Completed box	126
	Waiting for closing box	0
Testing	Passed functional testing	125
	Passed leakage testing * 5 remaining need to test	121
	Failure	1
Packaged		96





Merci à la « Dream Team »