JUNO sPMT ABC Front-End Board

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On behalf of SPMT group
LP2IB, University of Bordeaux/ IN2P3

JUNO Experiment: International cooperation

Country	Institute	Country	Institute	Country	Institute
Armenia	Yerevan Physics Institute	China	Tsinghua U.	Germany	U. Tuebingen
Belgium	Universite libre de Bruxelles	China	UCAS	Italy	INFN Catania
Brazil	PUC	China	USTC	Italy	INFN di Frascati
Brazil	UEL	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	IECS
China	CIAE	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 Jyvaskyla	Slovakia	FMPICU
China	Jilin U.	France	IJCLab Orsay	Taiwan-China	National Chiao-Tung U.
China	Jinan U.	France	LP2i Bordeaux	Taiwan-China	National Taiwan U.
China	Nanjing U.	France	CPPM Marseille	Taiwan-China	National United U.
China	Nankai U.	France	IPHC 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 physicists mainly from China and Europe, 77 institutes including 5 at IN2P3

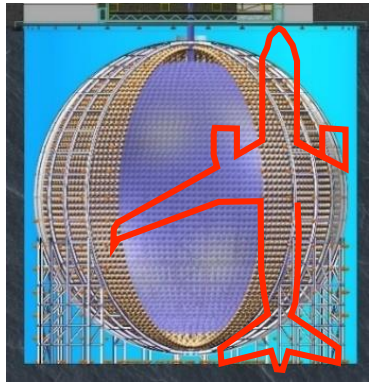
JUNO Experience : Goal

- Determine the order of neutrino masses using electron antineutrinos emitted from two nuclear power plants in China

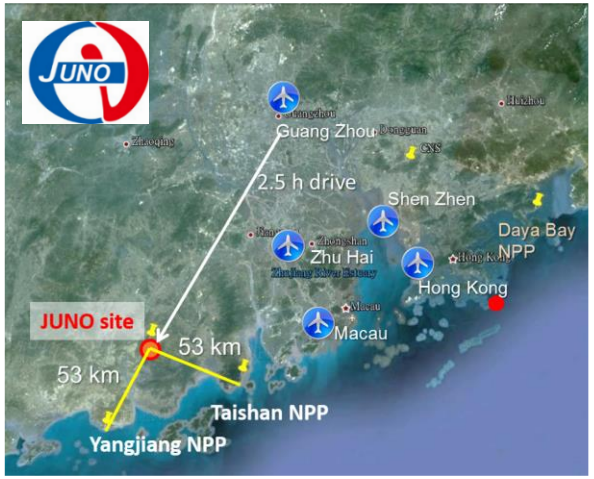
Réacteurs nucléaires
(~10^{21} ν/s/GW)

Oscillation des neutrinos

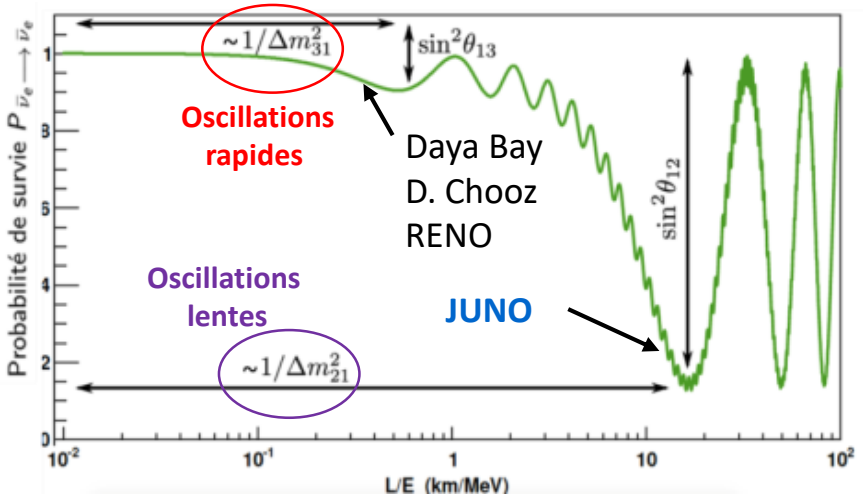
Base de vol ~53 km



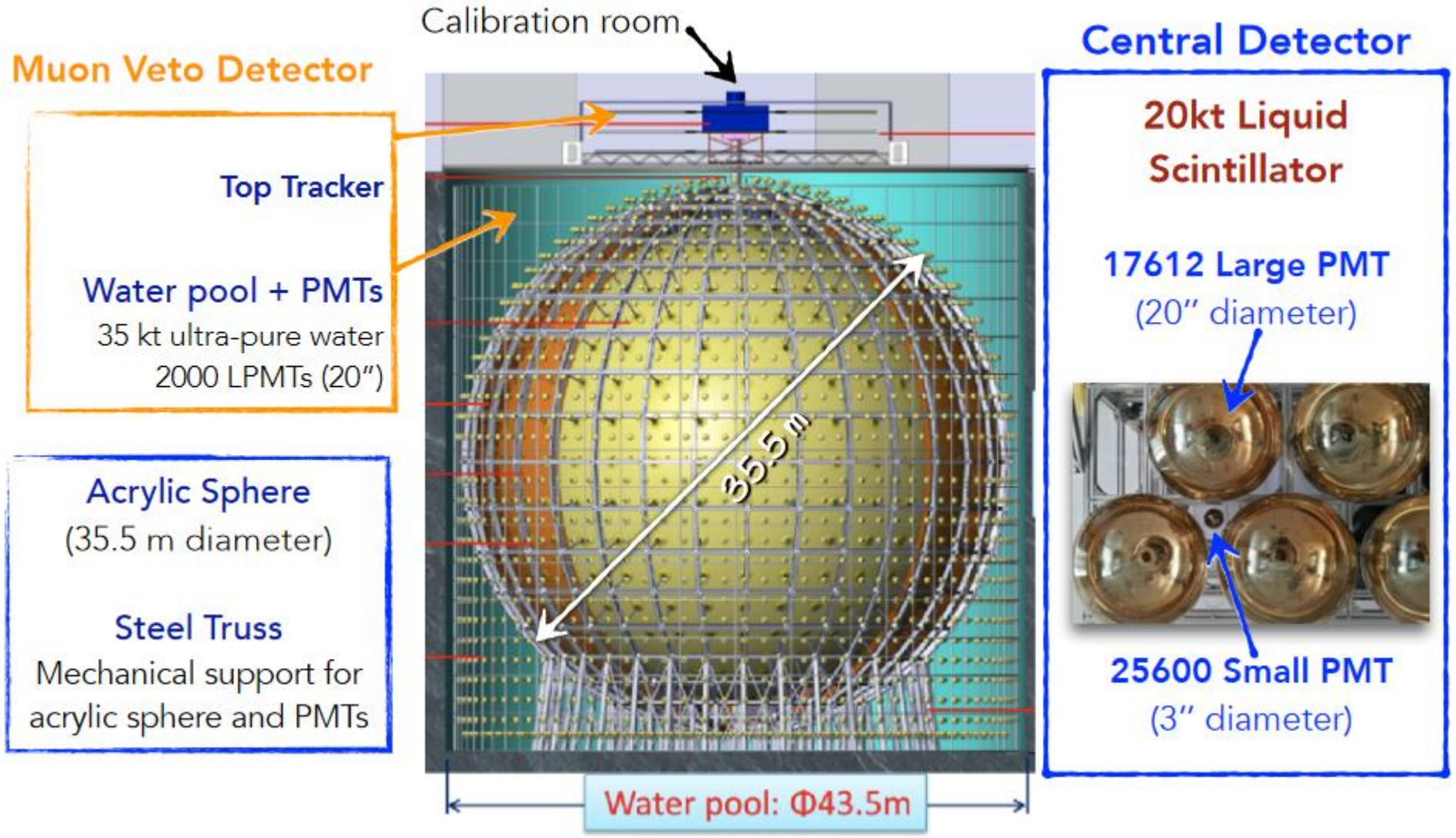
Détecteur JUNO



- Precision measurement (<1%) of 3 neutrino oscillation parameters
- Measurement of solar neutrinos, Supernova neutrinos , geo neutrinos, …



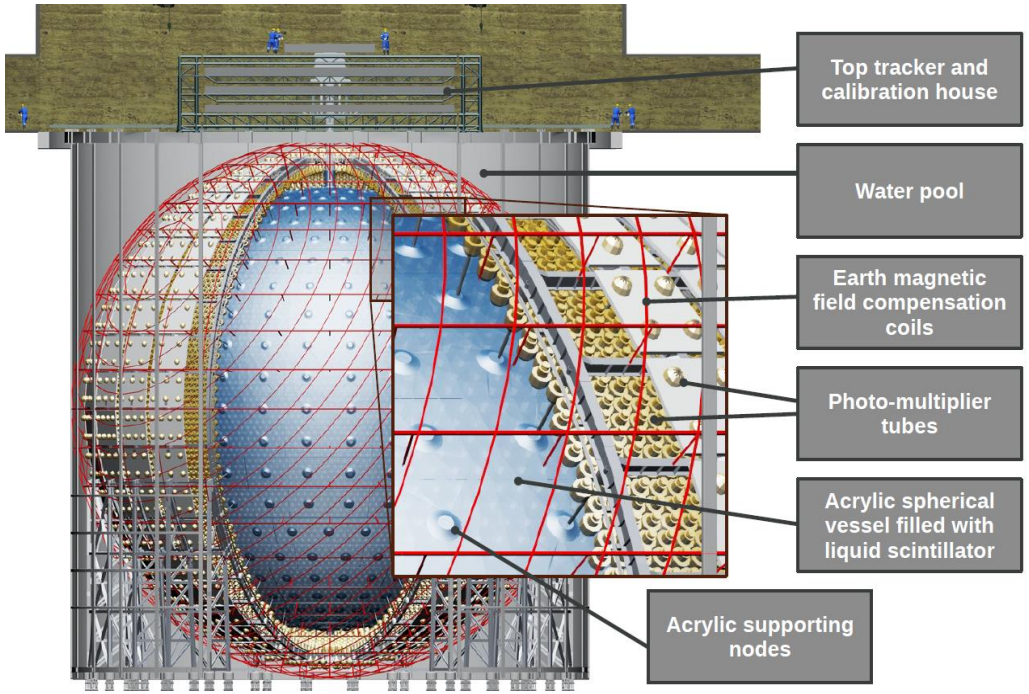
JUNO Experience : Detector



JUNO Detector Performance

- Detect 100,000 neutrinos in 6 years of data collection → 20,000 tons of liquid Scintillator (LS) in a sphere with 35 m diameter
- Energy resolution of 3%/√E(MeV)

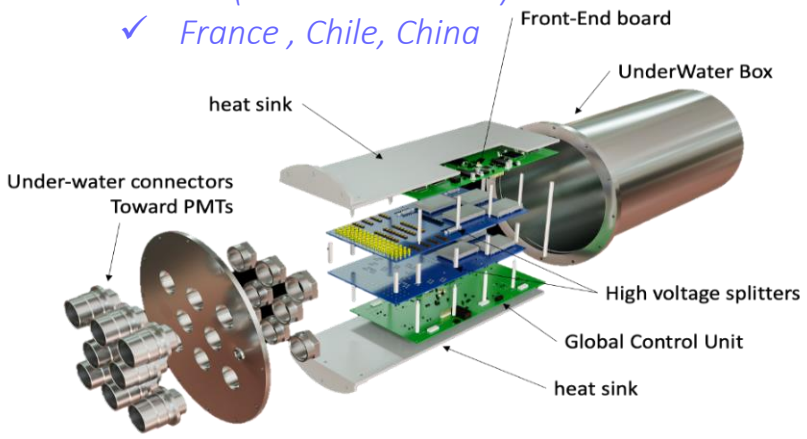
  → System of 18000 PM 20'' and 26000 PM 3'' (78% angular coverage) to detect ~1500 photoelectrons / MeV

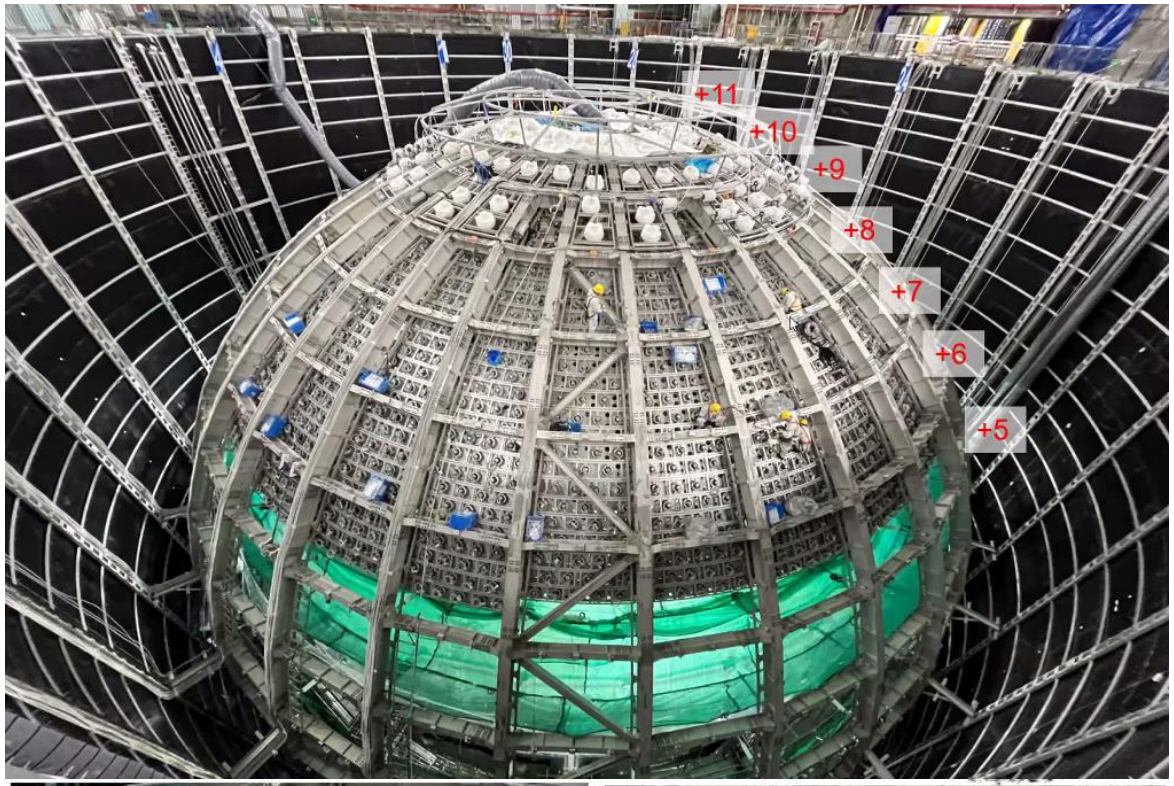


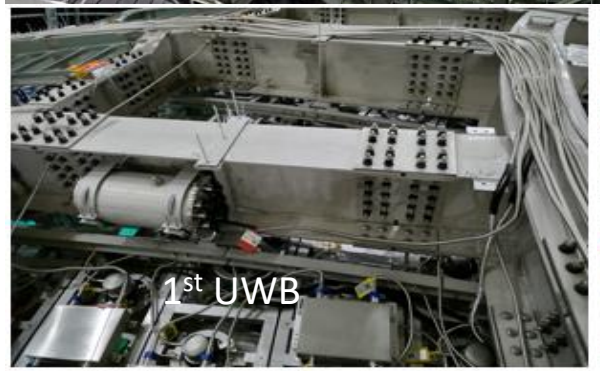
JUNO sPMT Project

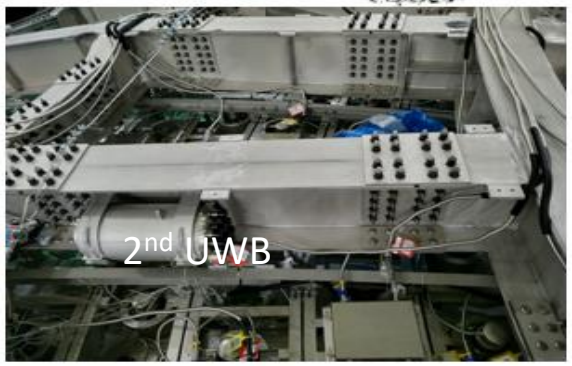
JUNO – SPMT : (FRANCE, CHINA, CHILE)

- *PMTs:*
  - *25 600 photomultipliers 3''*
    - ✓ *CHINA (HZC)*
- *Electronic*
  - ❖ *Front End Electronics for sPMTs*
    - ✓ *France: IN2P3*
  - ❖ *High Voltages Splitters*
    - ✓ *Chile*
  - ❖ *Global Control Modules*
    - ✓ *China*
- *Mechanical*
  - *200 UWB (Under Water Box)*
    - ✓ *France , Chile, China*

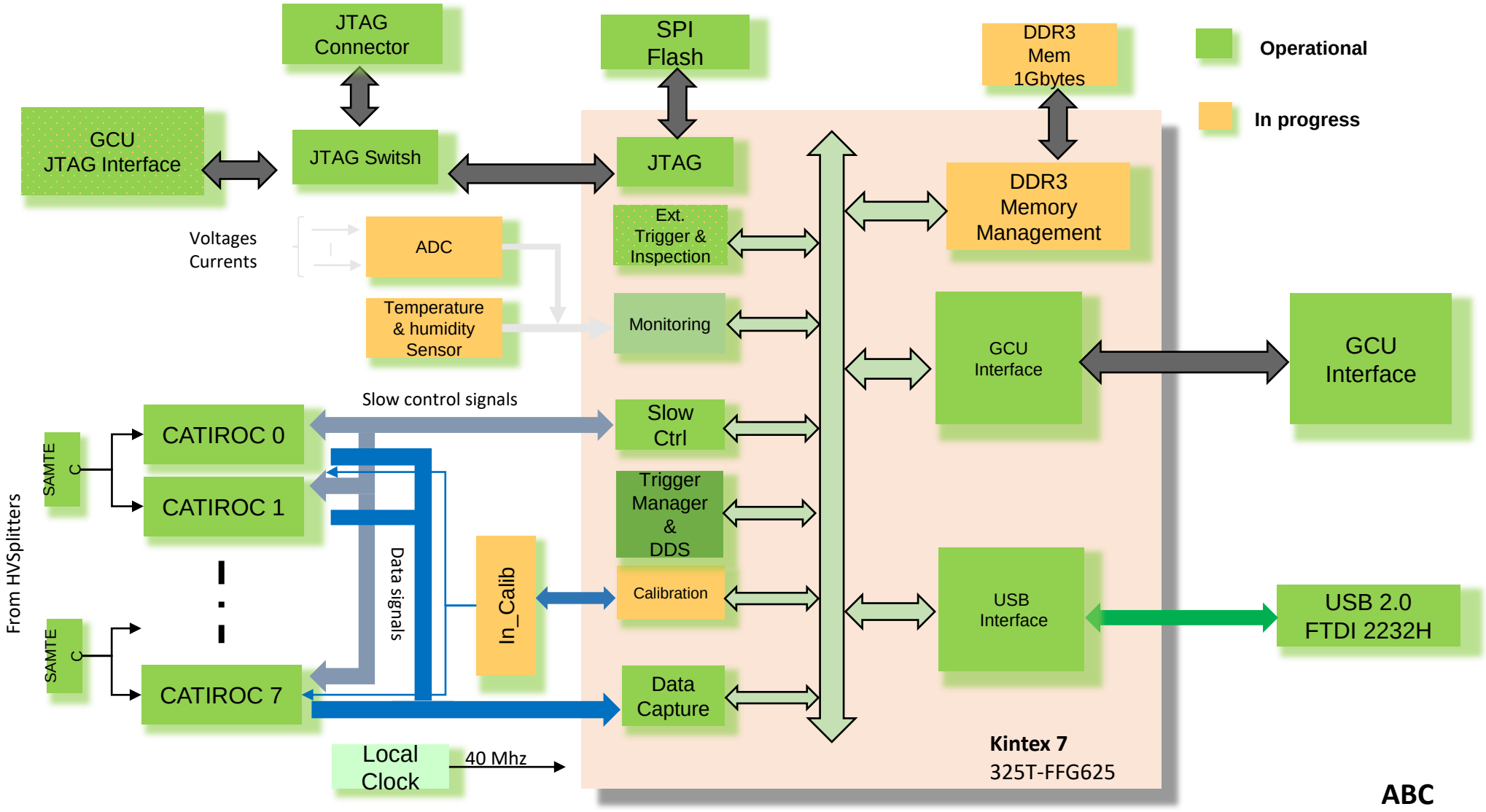




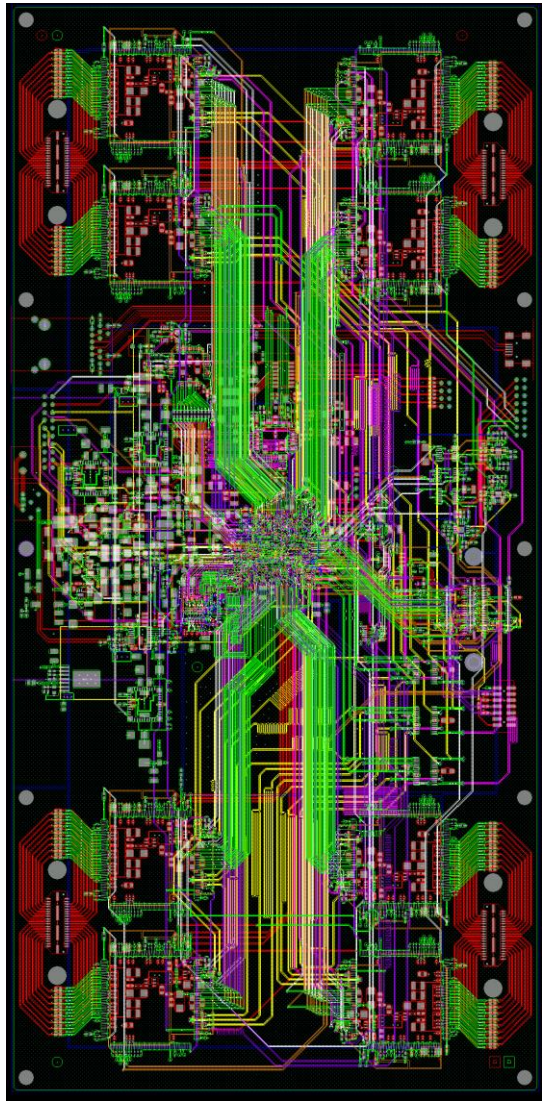




JUNO sPMT : ABC Block Diagram

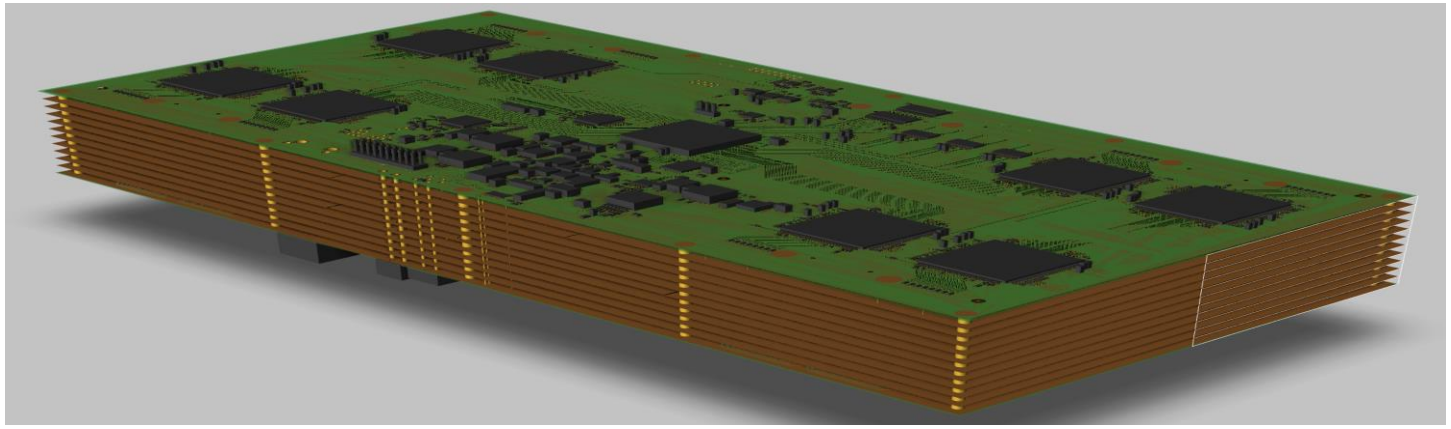


JUNO-SPMT : ABC PCB Overview

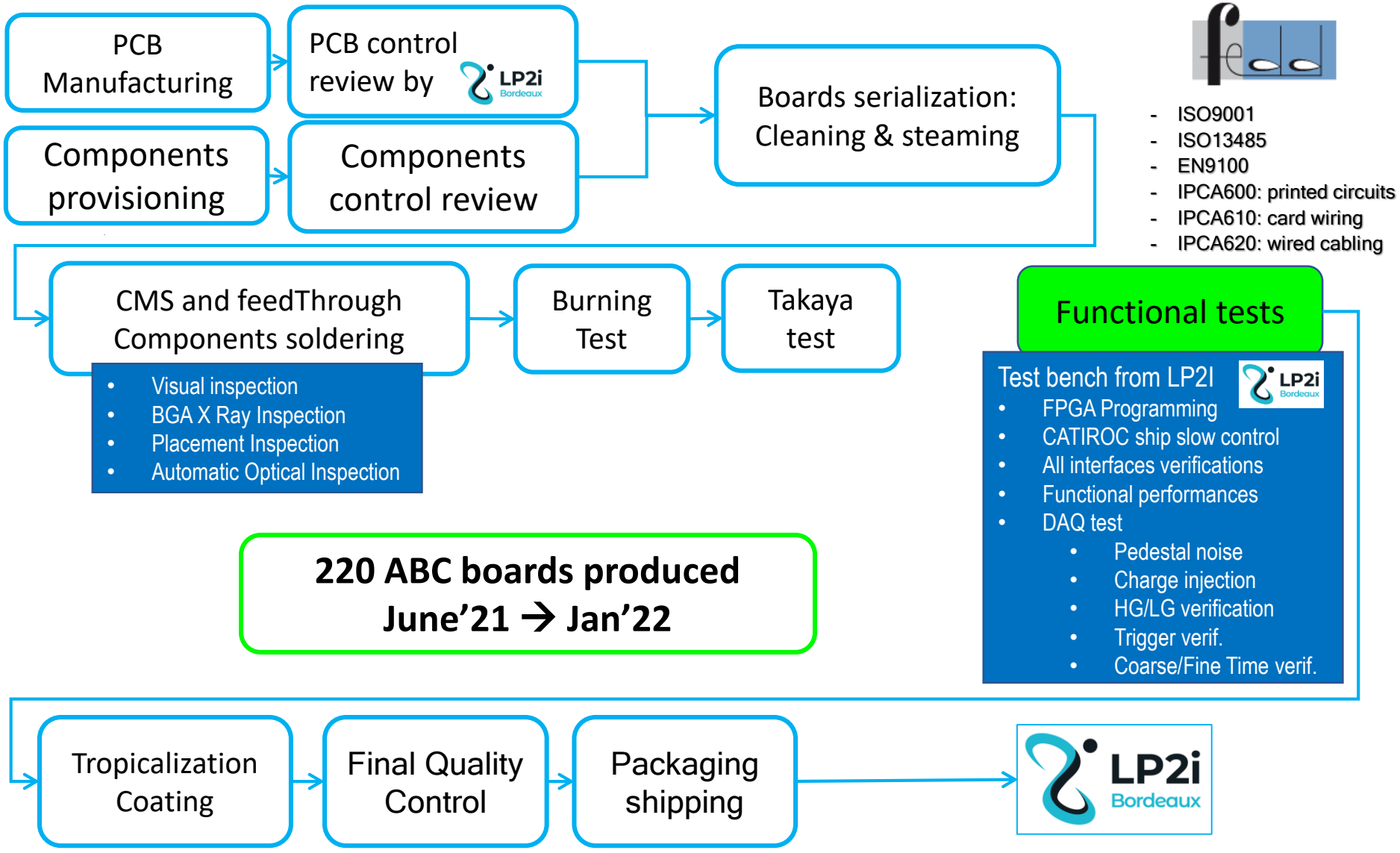


- 12 Layers
  - 5 Powers plans
- compatible with IPC standards
  - IPC 7351, IPC 2222, IPC 2221
  - IPC 4101
- 1902 Components
  - CMS technology
- 45 differential pairs

Layer	Thickness (µm)	Single impedance	Differential impedance
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	

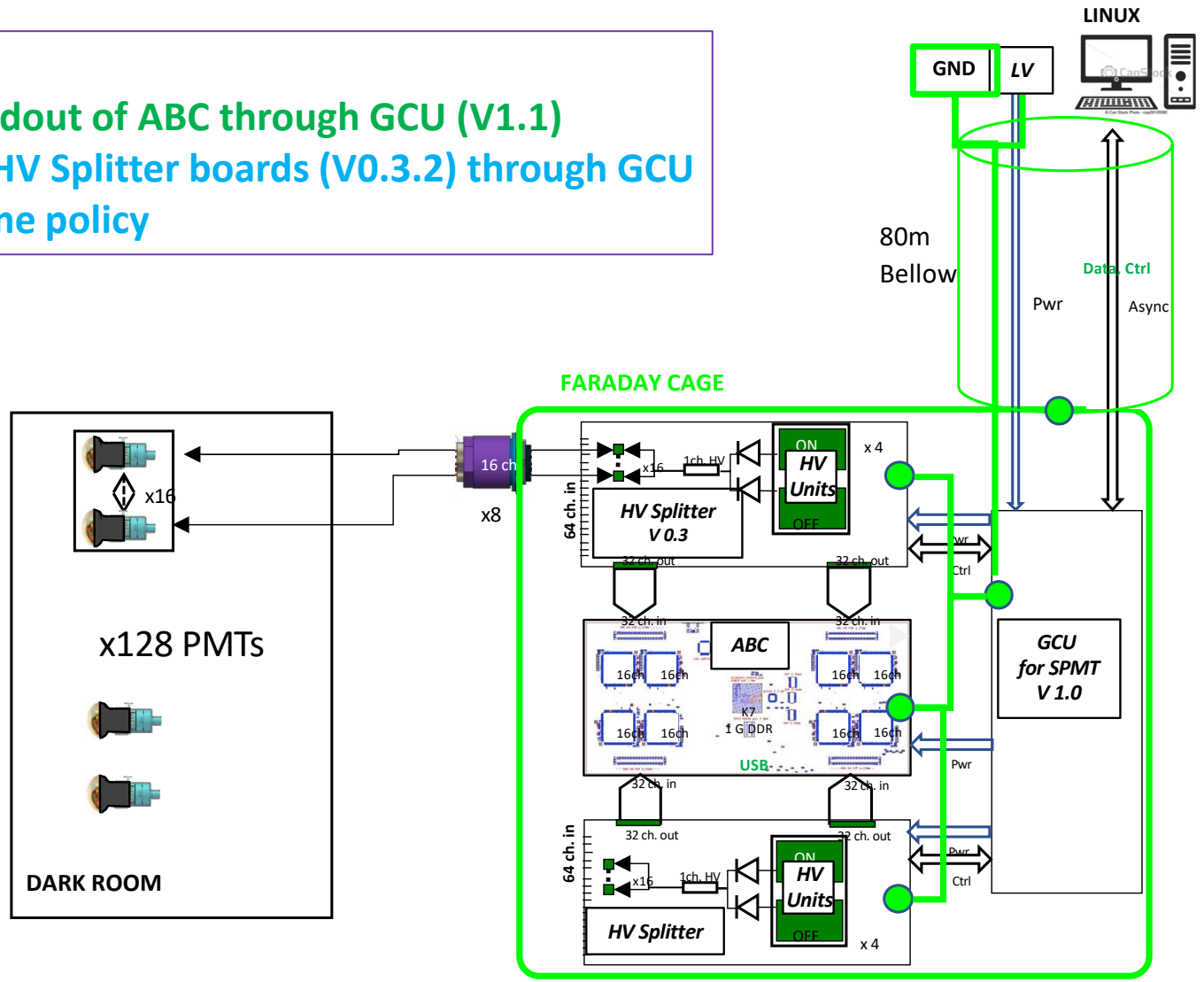


ABC Production and Tests at FEDD company

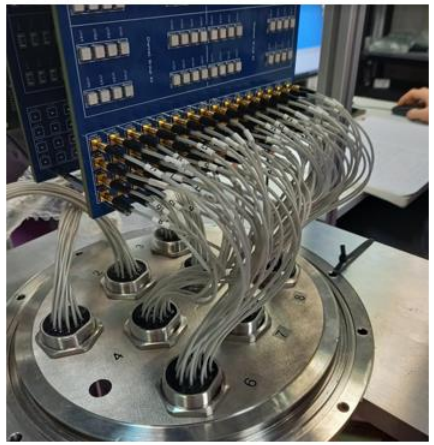


LP2IB Combined test bench

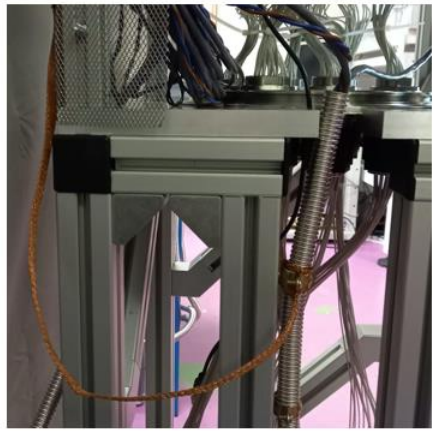
128 3'' JUNO PMTs
Control Power and readout of ABC through GCU (V1.1)
Control and power of HV Splitter boards (V0.3.2) through GCU
JUNO grounding scheme policy



LP2IB Combined test bench



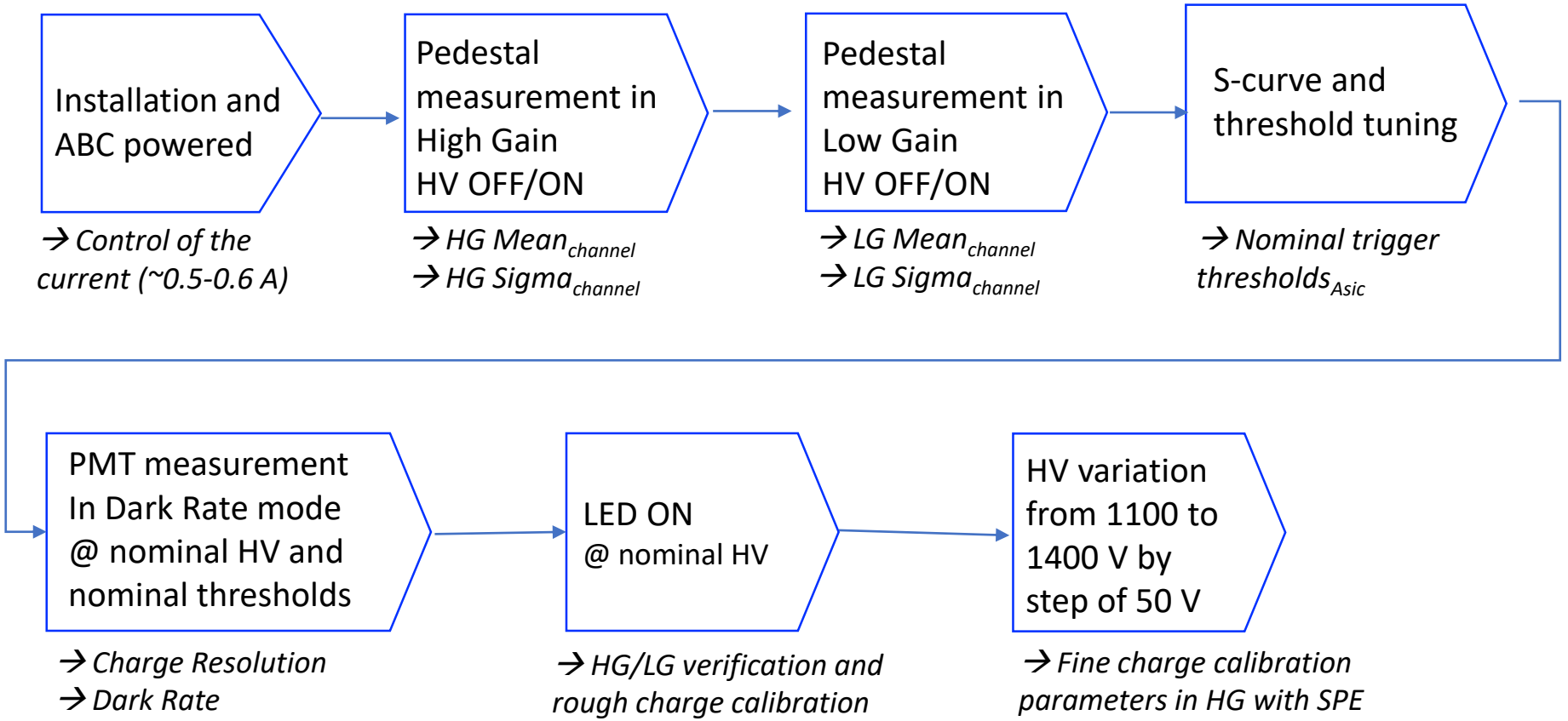
Detail of PMT connection



80 meter bellow connection
Detail of GND connection

Acceptance and calibration test sequence

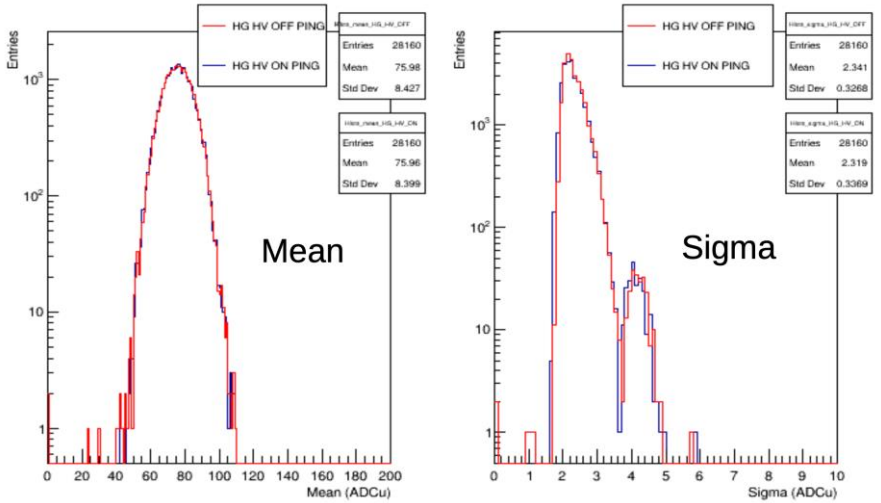
Sequence step by step and deliverable



➢ **All the sequence lasted ~25' and was fully automatized**

ABC readout front-end board performances from production

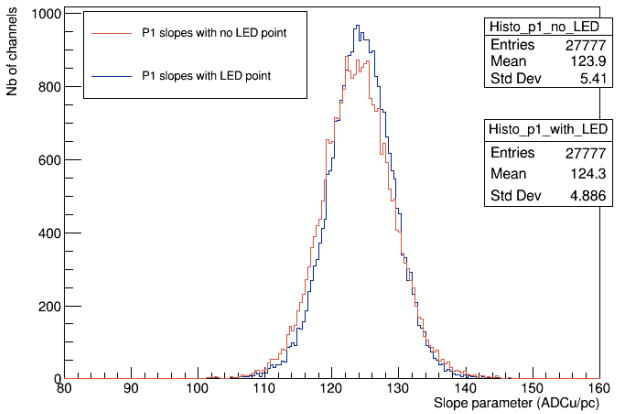
Mean and sigma pedestal distributions



- Low noise achieved
  ~4% PE / <1% PMT resolution

- Front-End boards parameters delivered for integration

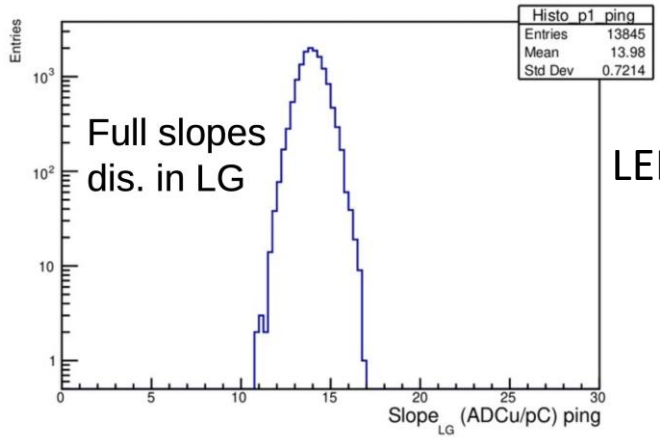
Calibration parameters in High Gain



SPE + LED

- High Gain range [1/3 - 10] PE @Gain 20

Calibration slope in Low Gain

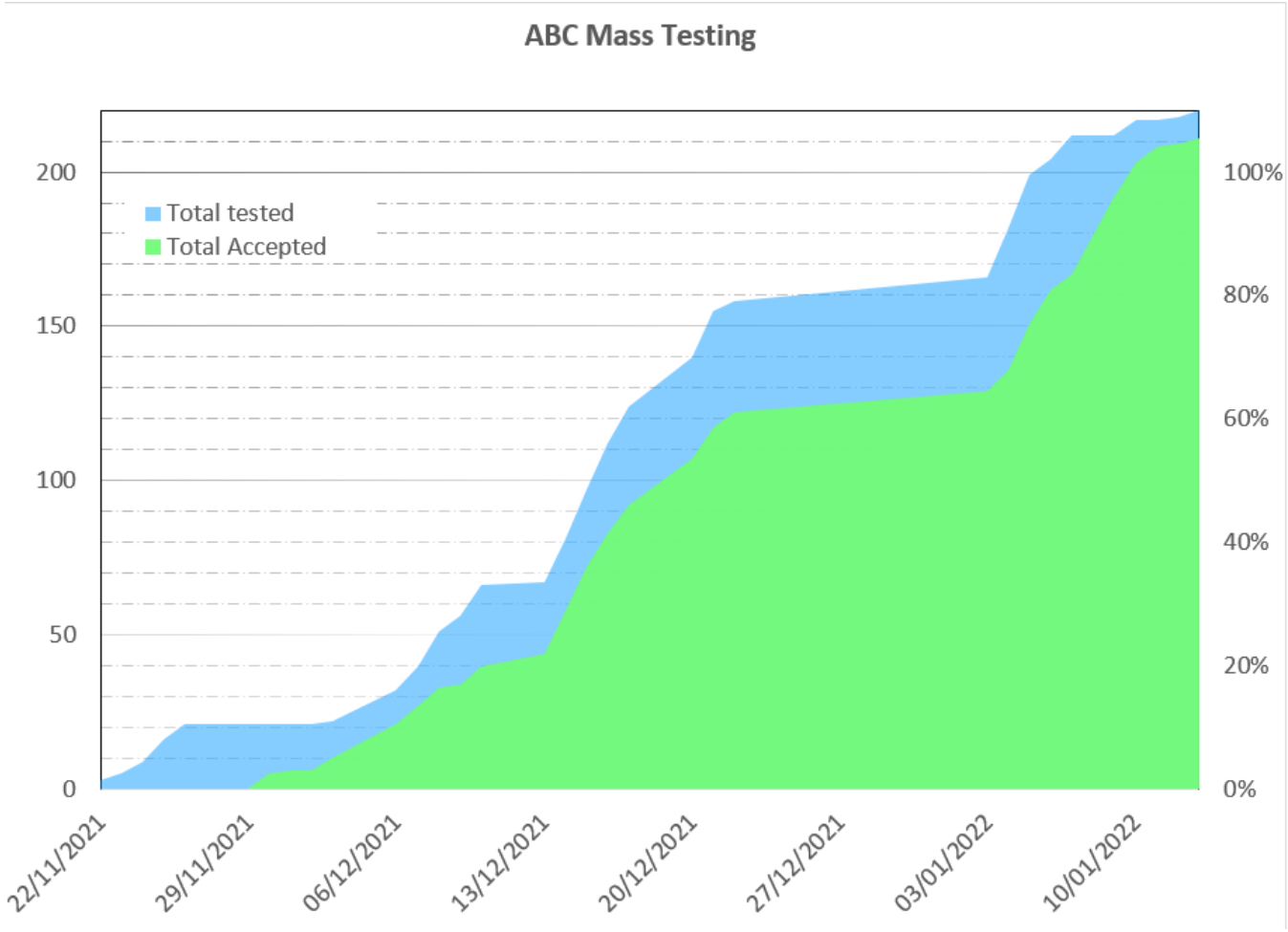


LED only

- Low Gain range [10 - 150] PE @Gain 20

ABC mass testing: summary

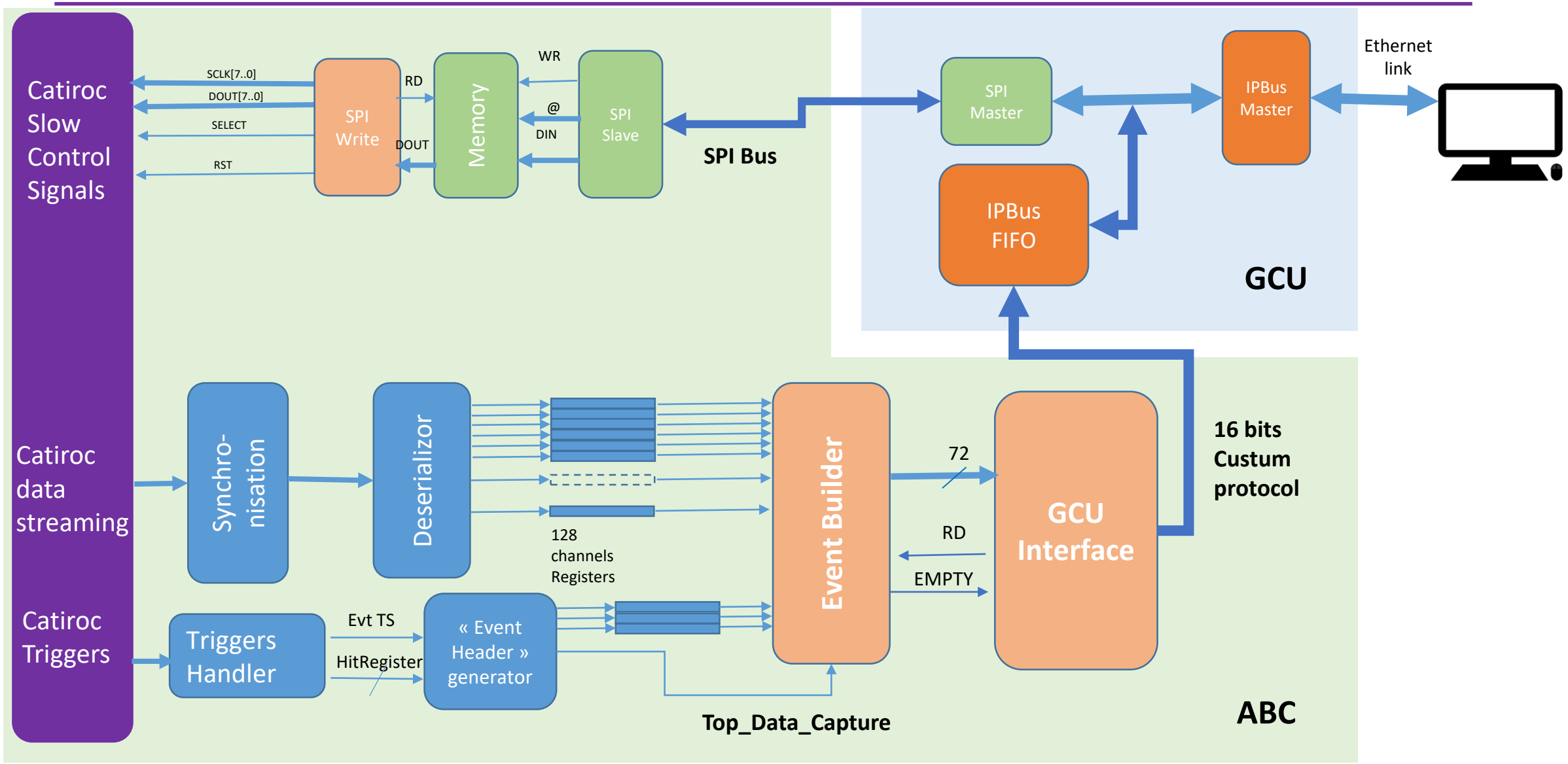
220 ABC front-end boards have been produced, delivered and tested
212 have been accepted for the SPMT system (96.4%)



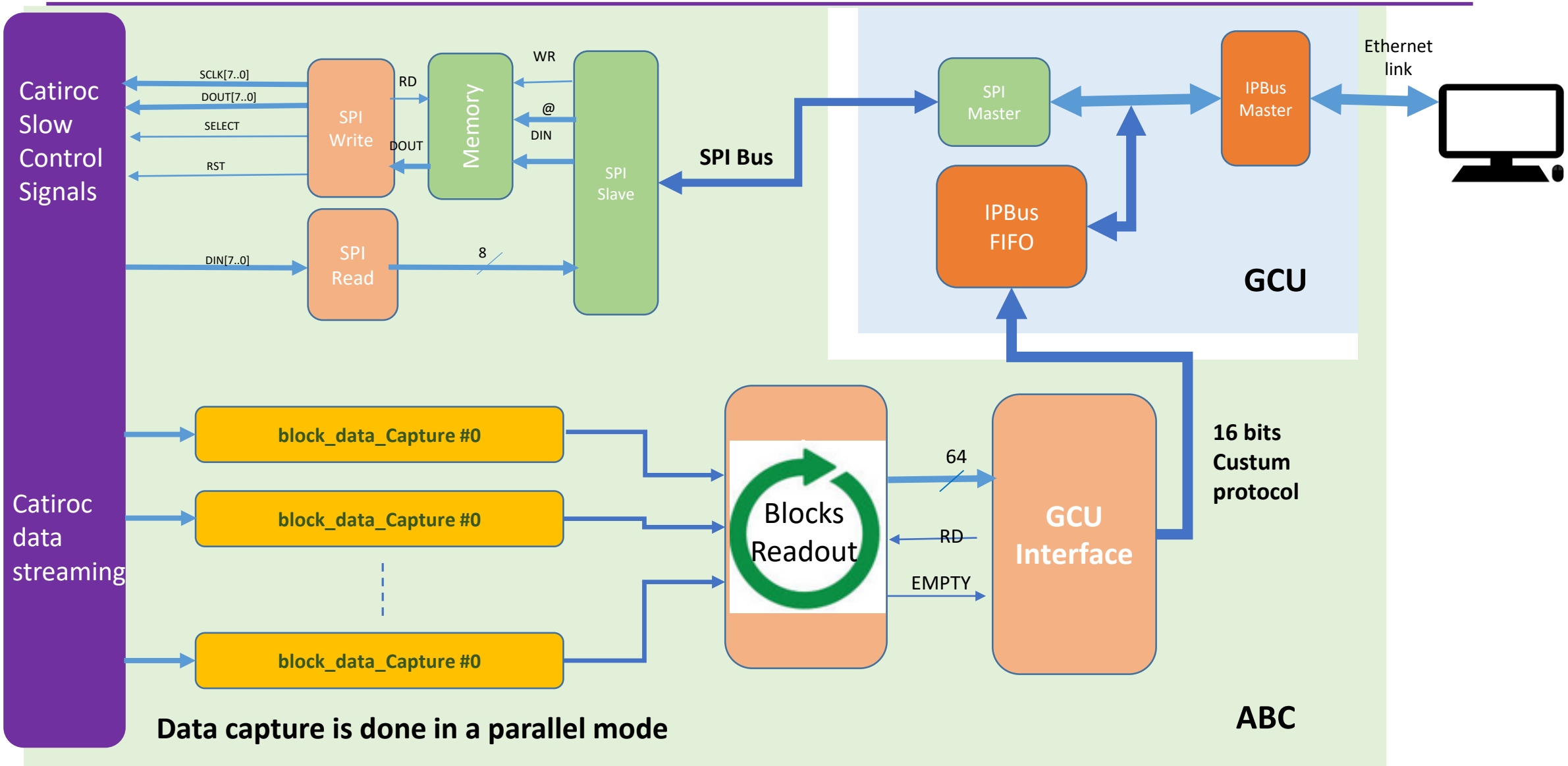
JUNO-SPMT ABC Firmware Progress

- ABC Firmware 1.0 (2021-2022): deployed for PMT testing and UWB integration
- ABC Firmware 2.0: Q/T data stream
  - ✓ perfectly fits CATIROC performances
- ABC Firmware 3.0: Q/T + Discriminator Data Stream (DDS)
  - ✓ Trigger width gives information on the charge
  - ✓ (allows to recover charge of hits triggered during
  - ✓ charge integrator dead-time)
  - ✓ First measurement: DDS principle is working !
  - ✓ To be finalised and delivered in 2023

ABC Firmware 1.0

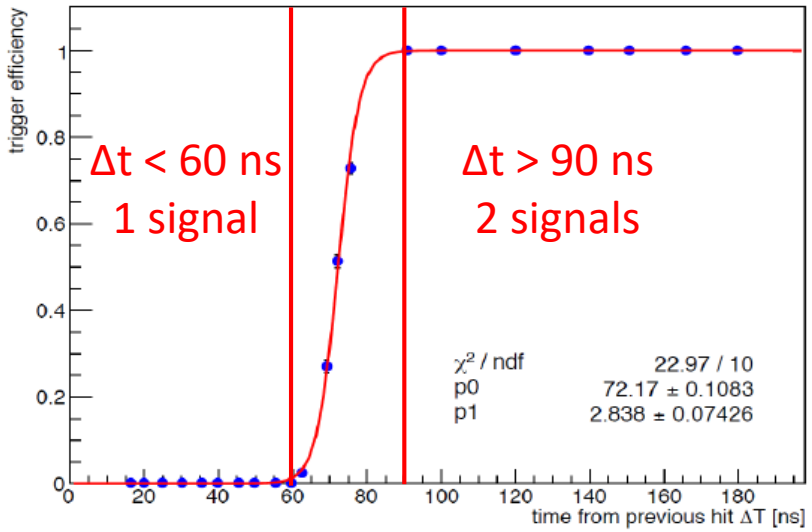


ABC Firmware 2.x



Catiroc trig. deadtime vs Firmware 2.x deadtime

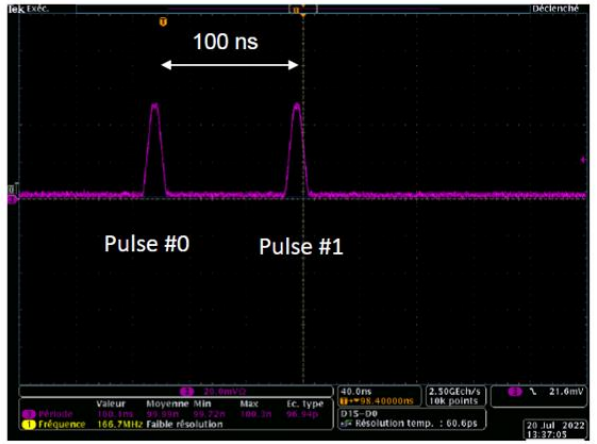
- Catiroc trigger deadtime : due to trigger processing in analog part of circuit

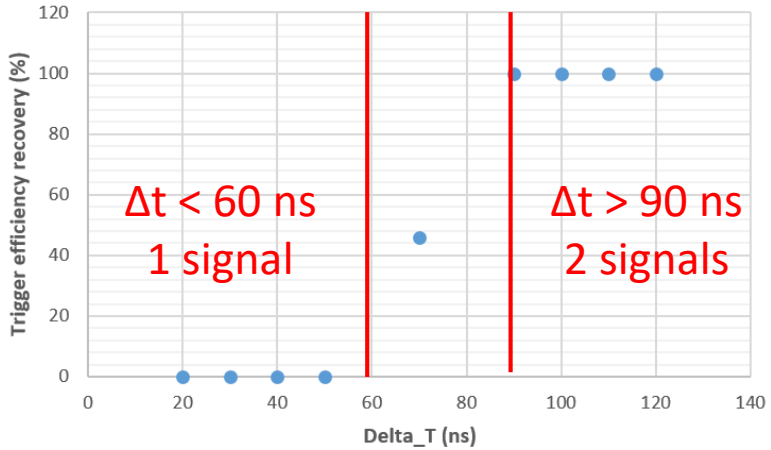


→ the curve of the trigger efficiency is not affected by the Firmware 2.0

→ No additionnal deadtime added by the firmware 2.0

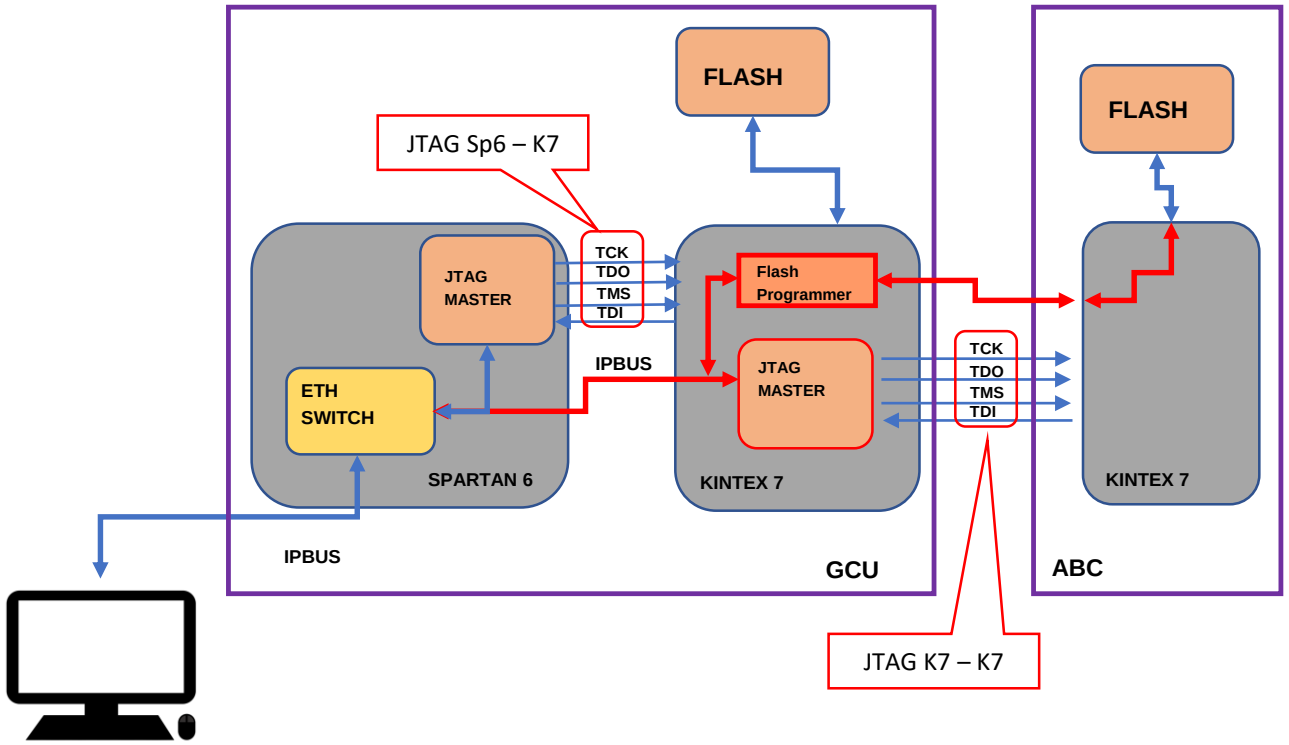
- Using ABC board and firmware 2.0 with pulse generator in burst mode in the same channel





JUNO-SPMT ABC Remote Programming

FIRMWARE STRUCTURE



1. Install Master JTAG ON GCU Kintex7
   - ➢ Dedicated firmware on GCU

2. Configure ABC Kintex7 as Gateway for Flash programmer
   - ➢ Dedicated firmware on ABC

3. Install ABC Flash Programmer on GCU Kintex
   - ➢ Dedicated firmware on GCU

4. Download a Bitstream to ABC Flash
   - ➢ FPGA_Prog Software

❑ The whole procedure is automated with Shell scripts, and can be applied to the 200 ABC boards of the experiment

The End