Front End Electronics for NectarCAM

ASICs

FEB

CDMR

Quality monitoring of the FEB production

Issues

Production and time schedule

F. Toussenel (LPNHE)

On behalf of the NectarCAM FEE team

NectarCAM F2F Meeting, Bordeaux, October 10-12 2022

cherenkov telescope array

NectarCAM

What happened during the last 3 years – Short summary

Barcelona meeting - Dec. 17-18 2019

Bordeaux meeting - Oct. 10-12 2022

2020 | 2021 | 2022

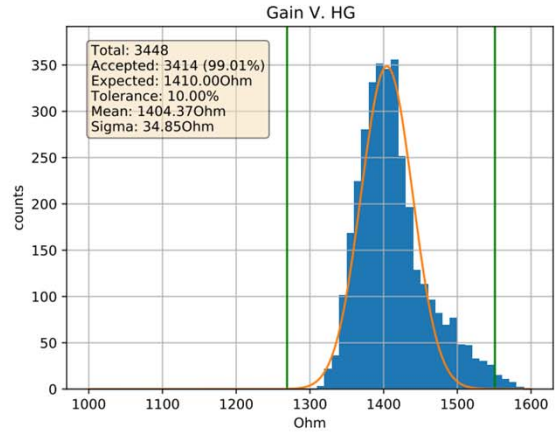
ASICs Production	IMEC :ACTA, PACTA, TL0, TL1 For 15 cameras -Dec 2019			Final delivery by IMEC After almost 3 years QC ongoing in Barcelona
NCAM CDMR	CDMR preparation	CDMR	HP RIX closed for FEE March 18 2022	
Nectar & ACTA	Nectar + new ACTA Large production		2k ACTA delivered	Packaging issue → Nectar delivery for Preserial may 2022
FEB version 6	FEB2 V6 protos	FEB2 V6 intensive test Perfs as expected	FEB2 V6 bidding process Order for preserial (25) sept.	FEB2 V6 test& validation LPNHE + IRFU; Order for 1,4k FEBs :Sept. 2022
Intel FPGA	FPGA procurement issue, 11 in stock, no more available in the world		FPGA bidding	FPGA start of deliveries
QM	QM modules Assembly with FEB V5	QM ready for testing	Plenty of runs with 265 modules in Saclay : ped., Calib., various trig	
FW, SW & test	During the whole period : firmware, software and test bench sw improvements and new features added. Lot of tests in Saclay with IRFU team			

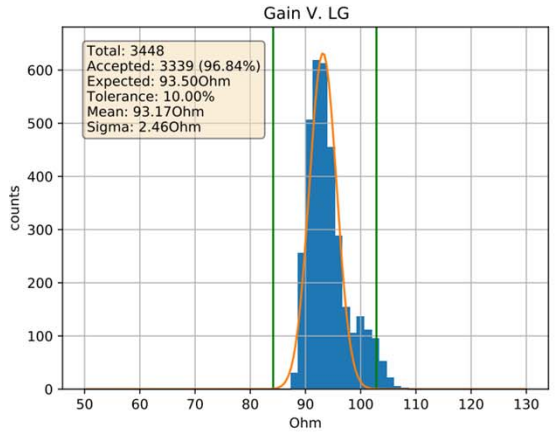
CPPM LPNHE PARIS LUPM LABORATOIRE MONTPELLIER UNIVERS & PARTICULES DESY Irfu CEA Saclay Institut de recherche sur les lois fondamentales de l'Univers irap LAL IFAE Universitat de Barcelona Ciemat LAPP GAE IPAG IPN ORSAY CENBG

ASICs status: last news from ICCUB on PACTA, ACTA & TL0

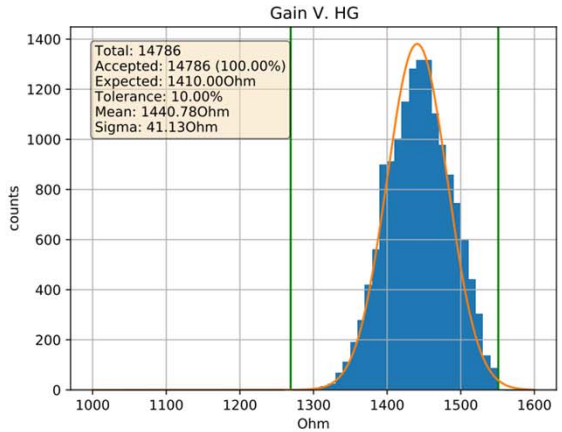
PACTA

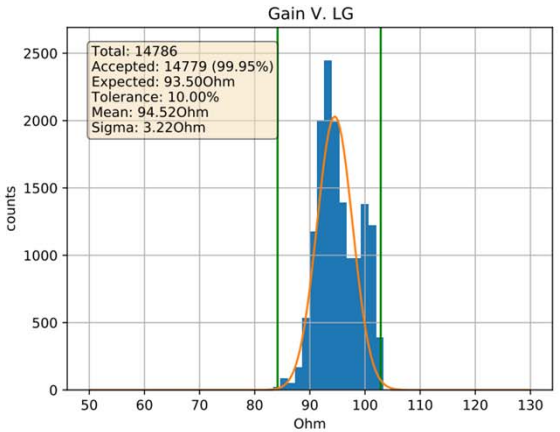
- October 2021 we received about 21k units
  - More than 20k units validated
  - No big differences with the 2017 production
- September 2022 we received about 11k units
  - More than 500 units validated. The remaining ones, pending to be validated
  - No big differences expected with the 2017 production





2017



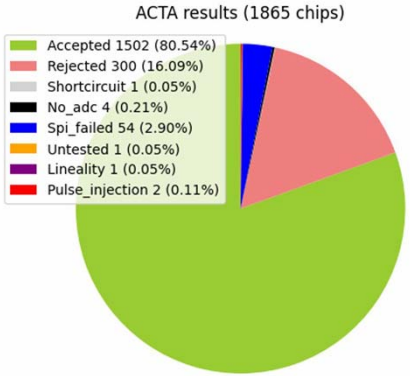


2021

ASICs status: last news from ICCUB on PACTA, ACTA & TL0

ACTA

- ACTAf2ChF version
  - More than 12k units validated
  - About 5k units pending to validate (in principle they are no needed)
  - No big differences with the 2017 production
- ACTAf2ChFiP (with pulser)
  - More than 1,6k units validated (we received 1965 units at beginning 2022)
    - 100 units already delivered to LPNHE to validate this new design (March 2022)
  - About 440 units pending to receive during October 2022
    - Other 880 pending to be ordered
  - Full production already launched (September 2022), no date for the delivery
  - No big differences with the ACTAf2ChF



ACTAf2ChFiP QC summary

TL0

- November 2021 we received about 9k units
  - QC is ongoing right now at Barcelona

ASICs status: last news from NECTAR

From NECTAR2 to NECTAR3

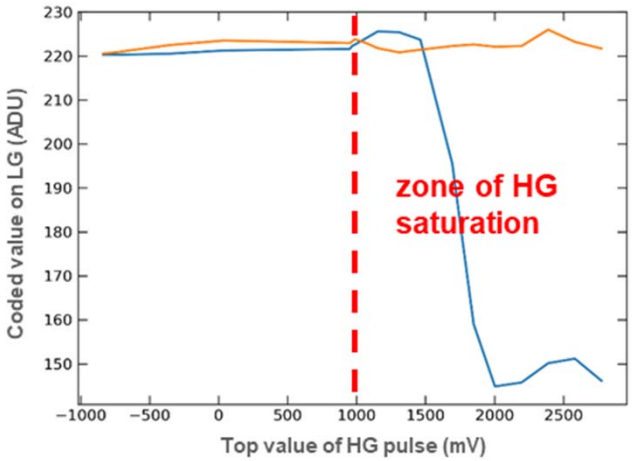
- NECTAR2 was the first version allowing ping-pong (PP) mode (to lower the dead-time) and packaged in QFN100 package (obsolescence of the previous package).
  - Produced in MPW (few samples)
  - Was used on very first prototypes of FEBs V6
  - Few “unwanted features” detected during FEBV6 + Camera tests in 2021

- NECTAR3 is the “production” version with corrections of the “features”, all validated in the test bench:

  - Data damage when a trigger occurs during the readout of the previous event
  - Parasitic coupling between the analogue input signal and the data being read
    => both effects (specific to « pingpong events ») are now negligible in NECTAR3
    see F. Brun’s talk tomorrow
  - LG distortion when HG saturates (damage LG linearity), already there in NECTAR1 used for HESS-upgrade. Programmable clipping introduced in NECTAR3

8ns-long pulse injected on HG (C1) for various input amplitudes exploring both the normal and overload zones of NECTAR. LG (C2) input is set at the BL value. Amplitude measured on LG (C2)
NECTAR2 (blue): large variation when the ADC saturates
NECTAR3 (orange): very strong improvement

=> To be confirmed by bi-gain linearity measured on FEB V6



NECTAR 3 Packaging and production

- Engineering run of 12 wafers delivered in July 2021 (~1000 NECTAR + 500 ACTA / wafer)
- **Serious issues** for NECTAR plastic packaging (by APTASIC subcontracting the operation in Korea):
  - Jan 2022, after 6 months of failures, the Korean packager decided to throw the towel

  They still delivered few packaged chips considered as bad or almost-bad…but the fortunately, most of them were actually tested as good on our test bench. This allowed :
    - To qualify the NECTAR 3 chip → green light for production of 50 wafers
    - To equip 10 FEB V6
  - Q1 2022: Investigations to qualify a new packager, 2 solutions studied in parallel :
    - New Taiwanese sub-contractor of APTASIC
    - Chinese packager (direct access) as a backup
- **Good (recent) news:**
  - Both packagers delivered recently respectively 2000 and 1000 more NECTAR3 chips.
  - All are working well with **test Yield of >85%**

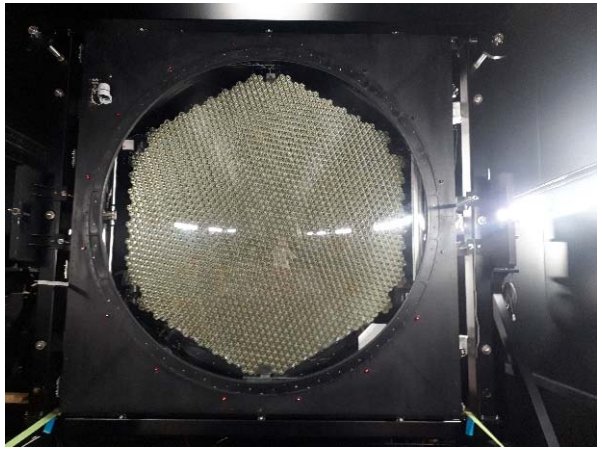
    ➔ > 2100 tested NECTAR3 available for FEBV6
  - Production of 50 wafers delivered (Aug + Sept)
- 31 wafers already sent for packaging to APTASIC. At this time, no firm delivery schedule available
- From China, we expect : 500 ACTA in ~2weeks and 2000 NECTAR3 + 1000 ACTA next month

  ➔ Enough for a second camera

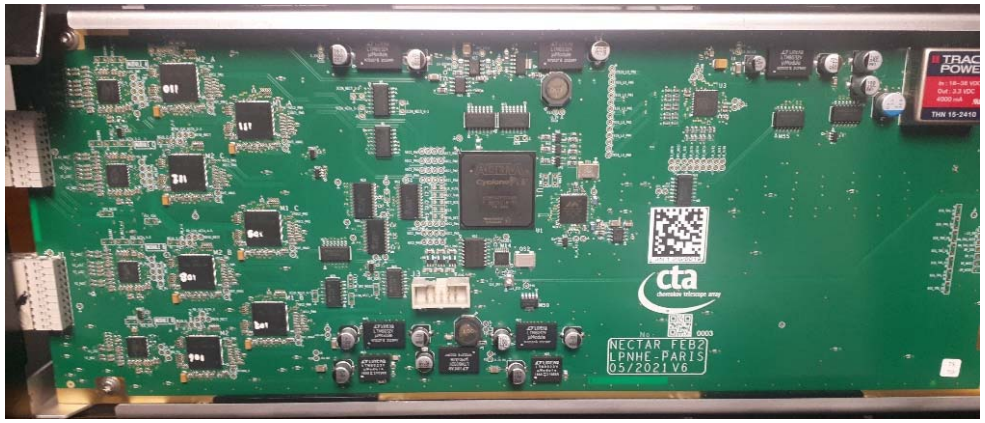
Front End Board Version 5.1

313 boards available and operated in the QM at Saclay since > 1 year

Might be replaced by FEB2 V6 in the QM before shipment to La Palma



Front End Board version 6




Reminder => main changes

- New Nectar chip with reduced dead time (ping pong mode) => /10
  - Reduced memory depth in pp mode=> /2 => 512 cells => 512 ns @ 1 GS/s
- New Nectar Package : QFN 100 instead of QFP 128
  - New FEB layout, single version of the Nectar chip (top)
  - Simplified layout with all 7 Nectar chips on the top side of the PCB (cheaper)
- New clock system => Select remotely between internal and external 66,66 MHz clock

Current status

- FEB2 V6 prototypes delivered in July 2020 and successfully tested
- Bidding process launch in April 2021
  - Company selected in September 2021 and order for preserial boards (x25) placed
- **Preserial delivered in June 2022 (x11) and successfully tested in Saclay => green light for production**
- Tests still ongoing at LPNHE and at IRFU
- Order for 1400 boards placed in September.

Front End Board version 6 verification & validation

Tests performed on production site

Some improvements done for FEB V6

- *Gain adjustment (ICF) now performed before baseline adjustment (DACL)*
- *Optimisation of the test duration (plots performed independently of the data taking (in //))*

New tests
In pulser test being implemented to check that the function is operational on all the produced boards.

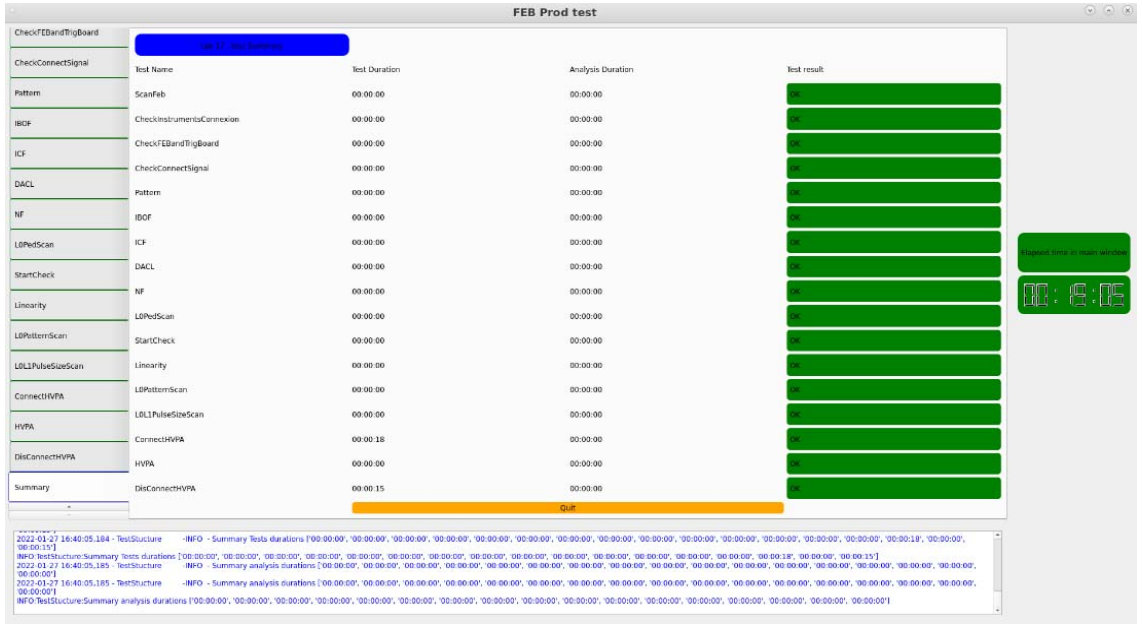
Requirements verification in Saclay

On prototypes, see :

- MST-CAM-TN-0580-IRFU for Dead time
- MST-CAM-TN-0581-IRFU for linearity
- MST-CAM-TN-0340-IRFU for timing

On preserial (10 boards installed in the QM)

Data taken in July
Results presented soon (science session)



CDMR documents updated for FEB2 V6

- *High priority RIX closed in March 2022*
- Perfs verification MST-CAM-JF-0551-LPNHE :
- *Design report :* MST-CAM-TN-0315-LPNHE
- User's manual : MST-CAM-UM-0567-LPNHE

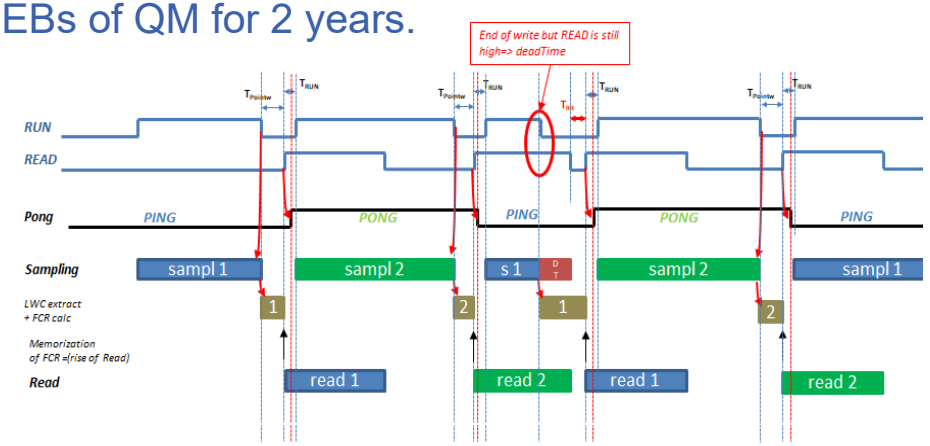
…

FEB firmware

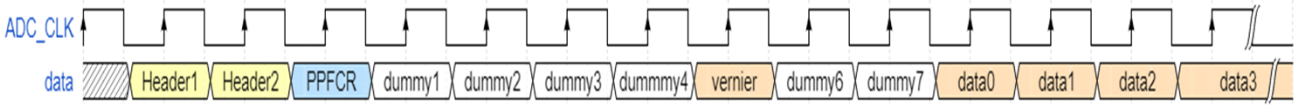
NECTARCAM V5 : Design for FEBV5.1

- Release NECTARCAM_V5.6 has been implemented on all FEBs of QM for 2 years.

NECTARCAM V6 : Design for FEBV6

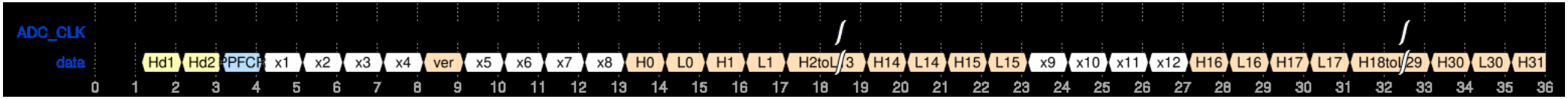


- Release NECTARCAM_V6.1: Test @ IRFU on 10 Boards
  - Nectar2 : Mode PingPong and new serial readout frame
    - New readout process for controlling Nectar in both mode: Normal and PingPong (pp)
    - In pp mode, due to code error on 16 first samples of each channel, the firmware reject them before saving DATA.
    - New synchronization of each channel with header1 and header2 of serial readout frame.



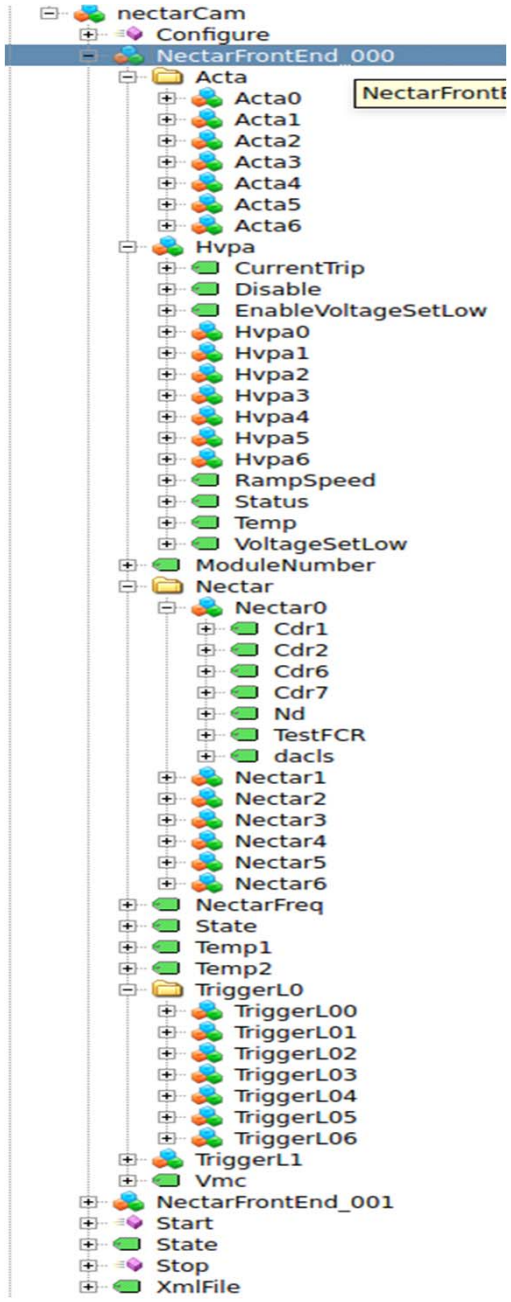
  - GEDEK has been updated. It includes a new process for programming new FEB EEPROM
  - Distributed clock: A new process to control the clock switch has been added for DTBP fw upload while using Dist. clock

- Release NECTARCAM_V6.2:
  - ACTA Pulser : Control of Pulser in 3 modes : Periodic (until 35kHz), Single pulse and standalone (Periodic @ 800Hz)
  - Nectar3: longseq serial frame for fixing code error in PingPong mode. (Test ongoing)
    - New mode longseq has been implemented without modifying UDP DATA
    - Vernier and PPFCR can be put in place of 2 first markers (HG & LG) of each channel in UDP DATA.



IN PREPARATION: transfer of firmware source files from SVN to GIT

FEB software - NMC & qnectarCAM



- ***New features :***
  - Integration of the new nectar chip
  - Management of the new clock system
  - Method to update the new Flash Memory Chip for FPGA on the FEB,
    - the upload is considerably faster
  - ACTA2f2ChFiP integration
  - ACTA2f2ChFiP pulser management
  - Remote update of the Interface Board Firmware
  - New Interface Board registers

Note : firmware upload duration
- FEB : 4 mn
- DTBP : 1mn30
- IB : 4mn30 (subject to change)

- ***Bugs Corrections :***
  - Improvements of stability
  - Smaller and lighter process

- ***Ongoing works :***
  - Code Quality Policy
  - Documentation needs to be updated

CDMR status

FEE RIXes

High priority Rix => Closed in March 2022

#	TRACKER	STATUT	PRIORITÉ	SUJET	ASSIGNÉ À	MIS-À-JOUR	CATÉGORIE
42596	Duty	Closed	High	Unclear document application	Toussenel Francois	18/03/2022 15:28	Front End Electronics

Remaining Rixes

- 42768, 42561 => FEBV6 user's manual
  - **Description** =Section 11.3 Incomplete?
  - **Answer :** yes, it is incomplete, work in progress, to be finalized (same answer as for Task 42661: RIX 42561)
  - Status : open => This RIX can be revisited and closed once the version with the additional information is presented.
  - **Plan : prepare and submit an update of the document by the end of this year.**

- 42767: => FEBV6 user's manual
  - **Description :** Section 9: At the beginning of this section, it would be very useful for the reader of this document, to incorporate additional information such as: step by step instructions to setup the connection, required cabling, screenshoots/diagrams, etc.
  - **Answer** : The instructions for setup board are in paragraph "3.7.Power up of FEB"., Some additional informations will be added for a better understanding., Document will be revised.
  - Status : open : Thanks for the feedback, RIX can be revisited and closed once the version that includes the changes mentioned previously is presented
  - **Plan : same as previous.**

CDMR status

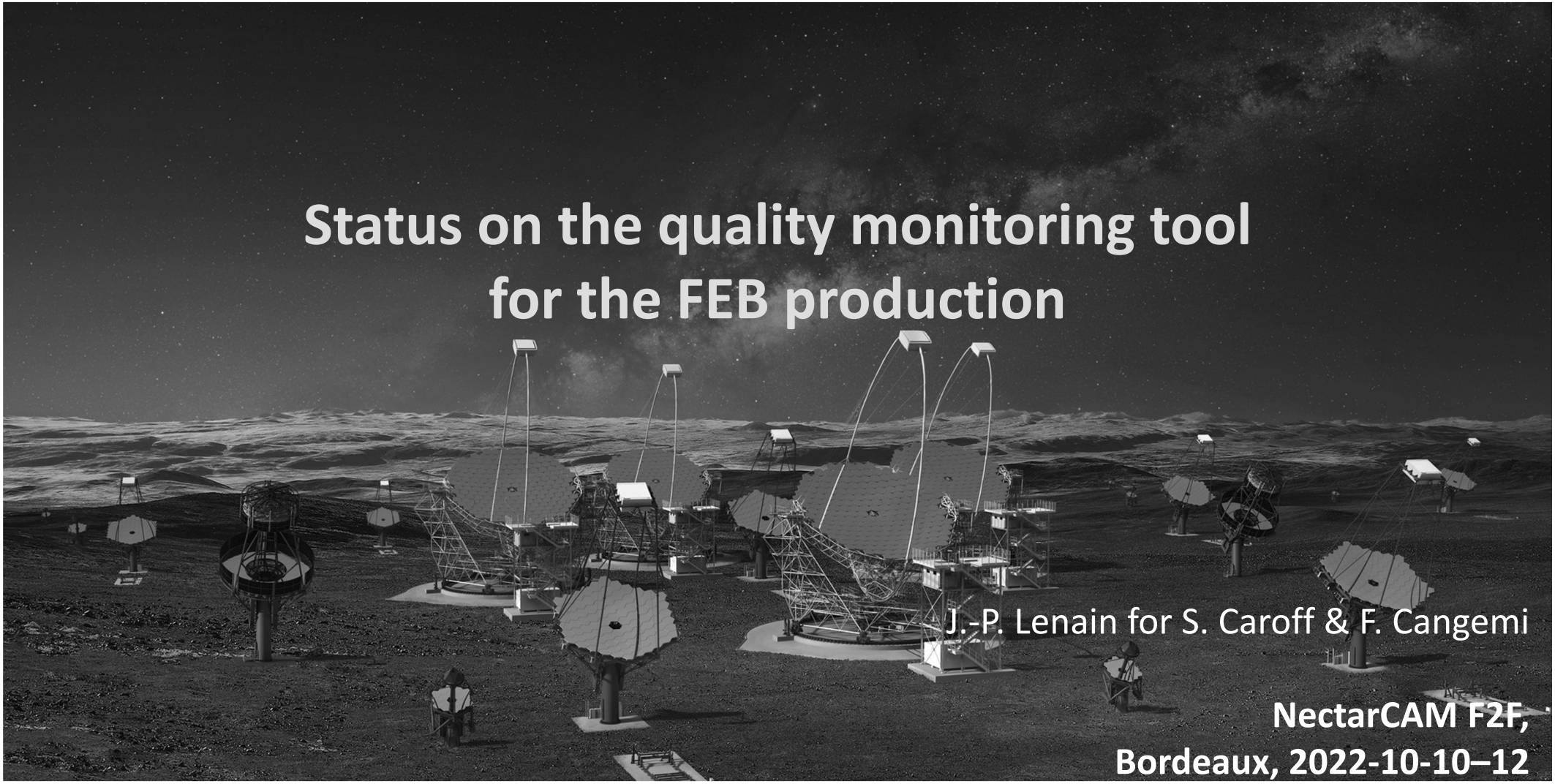
- 42763 => FEBV6 user's manual
  - **Description** = Missing acronyms: PACTA, PPS, EPCS. Does the board have any test points or LED indicators?
  - **Answer :** - Missing acronyms: PACTA, PPS, EPCS: they will be added in the table of acronyms.
  - -Yes, severals tests points are included on the board (differential and unipolar). A list will be included in annex. No LED indicators on the board.
  - **Status** : **updated document provided**
  - **Still open =>** Thanks for including the additional information.
    It would be valuable to include a couple of extra features in the table in Annex 3, such as, range (for the user to know, for example, which is "normal" voltage range for P1V1) and the type of signal (pulse, sine wave, etc). This is mainly to guide the user of this manual, if and when he/she needs to perform any type of measurement using one or more of the tests points listed, he/she knows what to expect - which also serves as a troubleshooting indicator..
  - **Plan : not obvious : ? Rix should be closed but after answering, a new request came out ☺?**
  - **Might be that it will never end …**

- 42606: #42606 => ICD with BP => François => transferred to Julie

- 42454: #42454 => NMC user's manual
  - **Description** : 1. No applicable documents are reported.
  - 2. Section 3.1, parameter -c. An XML configuration file is reported. Please provide a reference where this configuration file is described. This file seems an important part of the software because it allows configuring the FEBs parameters.
  - **Answer :** - Yes, Applicable documents will be added in the table, namely FEB users manual, NMC ICD Issue 2. Indeed, it is important, detailed informations will be provided and document revised.
  - **Status** : open : Accepted with the following remarks: The RIX will be considered closed when a new version of the document containing the agreed modification/improvement will be provided.
  - **Plan : prepare and submit an updated document before the end of the year**

CDMR status

- 42399: #42399 => NMC ICD
  - **Description** : Issue: It is not easy to evaluate the content of the ICD for the follwoing resons:
    - The Annex is not accessible.
    - Applicable and Reference documentation is missing (e.g. Architecture, Use Cases, Requirements)
    - The scope of the document is very generic and a proper description of the context of the ICD and the systems involved is missing (Introduction)
    - Requirement Specification for the interface is missing
    - Title of section 1.2 is not coherent wit the content (OPC UA CODE- list of errors)
    - Content of section 2 is not introduced as well as the content of the tables.
    - There is no space between different sub-sections of section 2 and text and tables
  - Suggestion: Please revise the document accordingly1. No applicable documents are reported..
  - **Answer :** - - Annex: login and passwd to be added in the document
    - Requirements : to be able to configure and monitor FEB. All functionalities are detailed in the FEB users manual and the NMC ICD. In addition The NMC users manual is available for final user.
      Use case : see above, same documents.
    - Introduction: Yes, work in progress, the document will be updated with a proper introduction.
    - Requirements : Based on FEB users manual and FEE requirements. no specific document so far.
    - Title of section 1.2 : OK, it will be corrected.
    - Content of Section 2 : Ok, the document will be updated accordingly.
    - Suggestion : yes, we will follow the suggestion, work in progress, the document will be revised
  - **Status** : open : Accepted with this Remark: The RIX will be considered closed when the new version of the ICD containing the modification listed will be presented.
  - **Plan : prepare and submit an updated document before the end of the year**
    - **Not an easy job regarding architecture, Use cases & requirements …**
    - **Development effectively based on the FEB user's manual to properly interface all functionalities …**



Status on the quality monitoring tool for the FEB production

J.-P. Lenain for S. Caroff & F. Cangemi

NectarCAM F2F,
Bordeaux, 2022-10-10–12

NectarBase

- Data from functional tests ingested during FEB production for each received bunch, fed into a ZODB data base.
- Bokeh server runing inside a Docker container, frontend accessible at: http://lpnhe-cta.in2p3.fr/BokehNectarBase_readonly
- NectarBase software developed by Sami Caroff and Floriane Cangemi during their post-doctoral positions at LPNHE.
- Following the code structure of the test bench software developed by Sonia Karkar and Claire Juramy:

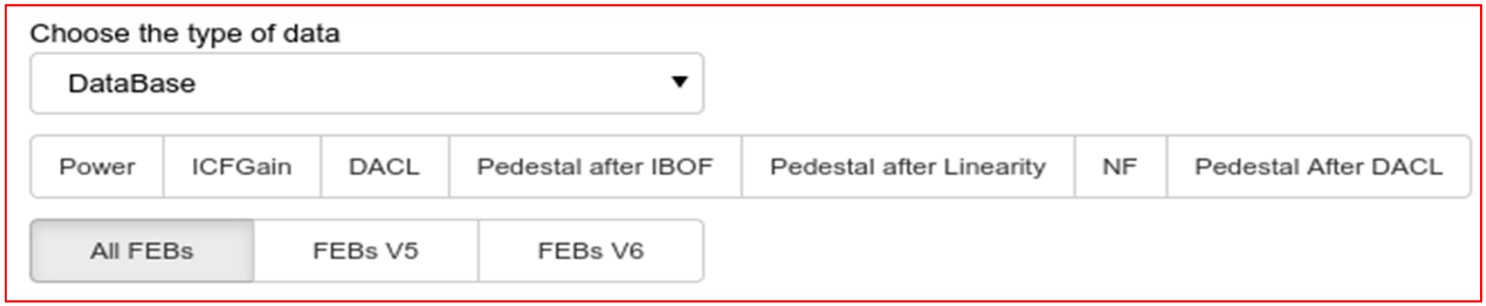
```
svn.in2p3.fr/cta/MST/NectarCAM/FebTest
svn.in2p3.fr/cta/MST/NectarCAM/CameraTestPlottingTools
svn.in2p3.fr/cta/MST/NectarCAM/NectarPlot
svn.in2p3.fr/cta/MST/NectarCAM/FebDockers
```

- Test bench data stored at LPNHE and copied on the grid

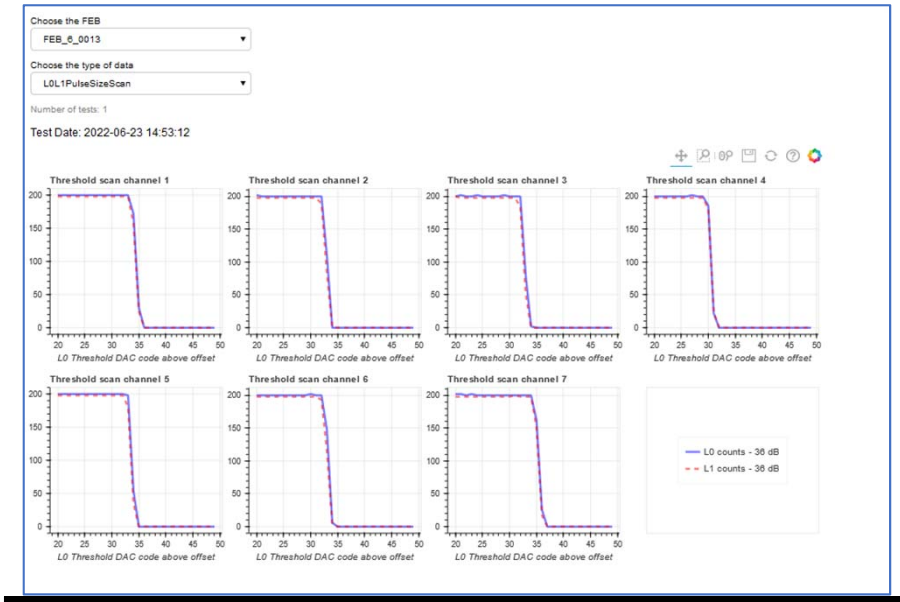
NectarBase

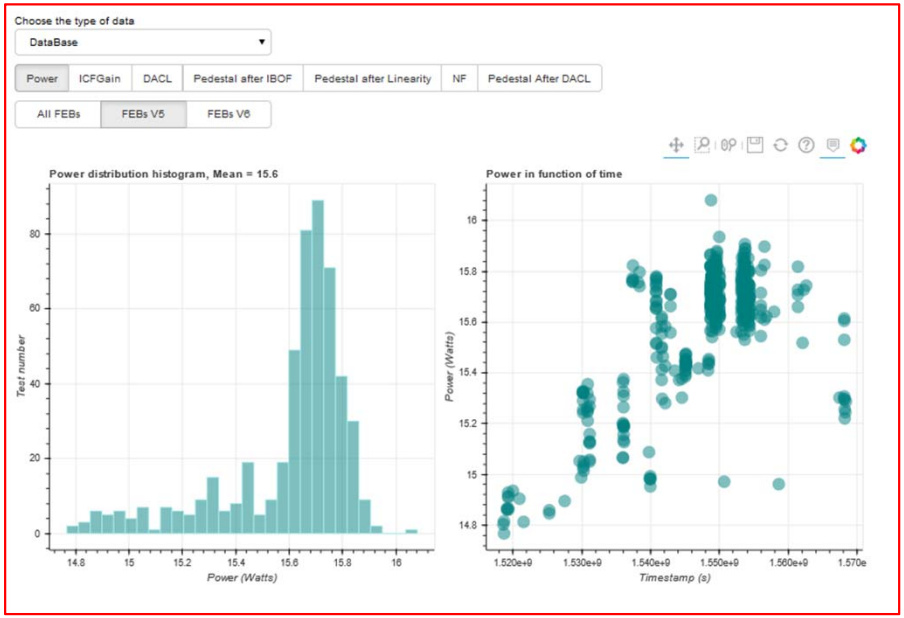
You can

Select a parameter and display the results for all FEBs



Select a FEB number,
display the result for each single test





Remaining developments

- Status: ready to ingest new test data from FEB v6 production !
- TODO: Integrate visualization of pulser functional test once implemented in the test bench software.

FEB issues

Technical

- 1 failure ***:***
  - FEB 1.2/5/0247 connection lost in the QM => oscillator replaced => back to operation

- Dead time of the readout :
  - slightly higher than the requirement with feb V5 and nectar1
  - Fixed with nectar2 chip using ping pong (pp) mode.

- Nectar2 : minor issue with ADC non linearity and with pp mode when an event occurred during readout
  - Fixed with nectar3 chip => to be used for production

- Use of distributed clock (not a requirement)
  - Still to be validated, pending on teams availability (not highest priority)

- NF peaks observed during the prod test => not seen during the tests at IRFU but still being investigated

FEB issues

Procurement => Worlwide issue with ASIC production and packaging

- Difficulty to procure Intel FPGA => took quite some time to find a solution with Intel, arrow, Ouestronic.
  - Tender associated to the FEB tender by Ouestronic
  - Deliveries started, orders placed for 7 cameras ,
  - last order to be placed in Q1 2023 => hopefully fixed but …
  - Cost increase : 20% in 2021, what's next ? => important to finish procurement asap.
  - Current status
    - **875 FPGA and 1440 EEPROM delivered (~3 cameras)**
    - Still 1105 to be delivered (already ordered)
    - Final order ~600 FPGA and 1100 EEPROM to be placed asap

- Difficulties with ASICs packaging
  - Fixed for ICCUB ASICs with IMEC => **all ASICs delivered now** => cost stable.
  - Almost fixed for Nectar and new ACTA chips => deliveries started

- Cost increase
  - FEB production costs revised according to inflation + $/€ change => + ~ 3%
  - So far , cost still under control compare to the estimates => important to launch production asap.

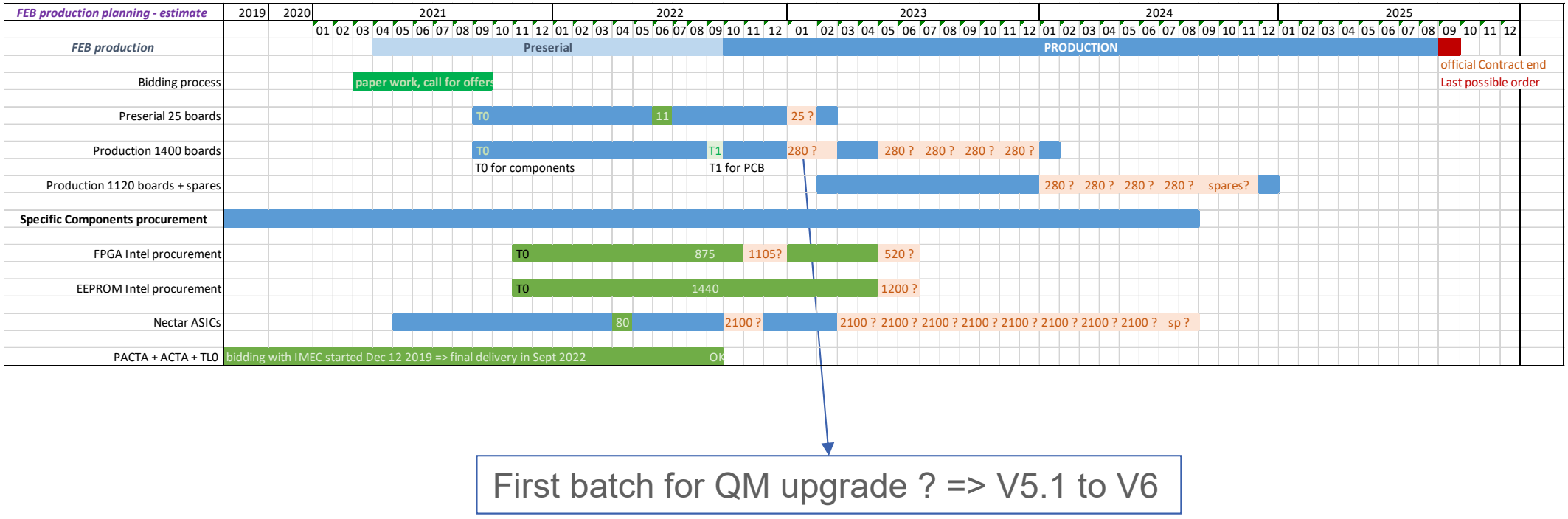
- Procurement delays
  - Prototypes delayed due to the first confinement
  - Preserial delayed due to difficulties with nectar packaging

FEB tentative production schedule

Current estimate following our visit to Ouestronic on Oct 5th 2022 (subject to change …)

- *Pcb procurement could be quick : situation improving*
- *Components available for 5 cameras*

Specific ASICS available and tested for 1 camera by the end of 2022 => to be confirmed



First batch for QM upgrade ? => V5.1 to V6