GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

INFN
Istituto Nazionale di Fisica Nucleare

Trigger and DAQ for CYGNO-04: *hardware-wise*

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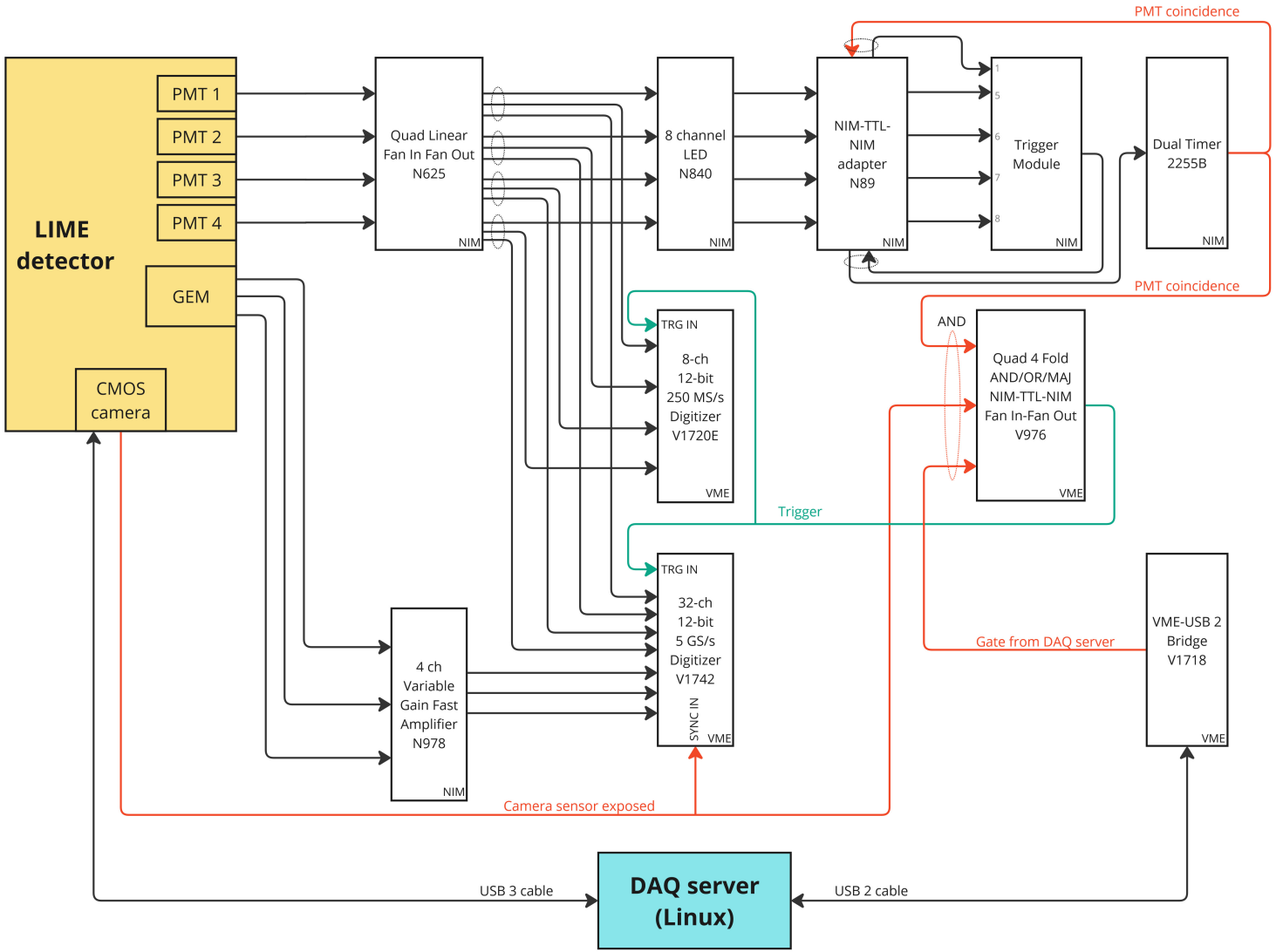
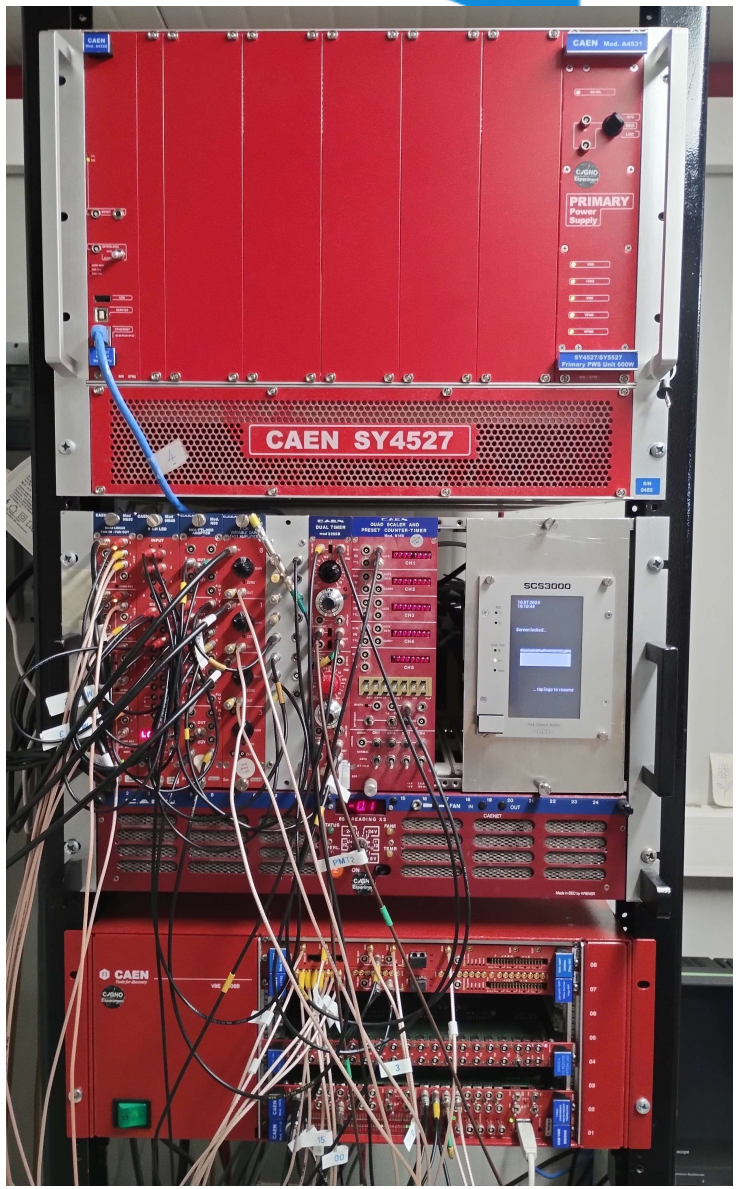
Topics

- **LIME DAQ** (our current DAQ)
- **CYGNO-04 DAQ:**
  - ✓ **Plans: 1 year ago → Now**
  - ✓ **Hardware overview**
  - ✓ **Trigger modes**
  - ✓ **DAQ Synchronization and Event Builder**
  - ✓ **List of Material**
  - ✓ **Trigger Module v2**

LIME DAQ





Herman Lima - GSSI - 18/09/2024

** HV system not shown*

CYGNO-04 DAQ plans: 1 Year Ago

Trigger and DAQ for CYGNO_04

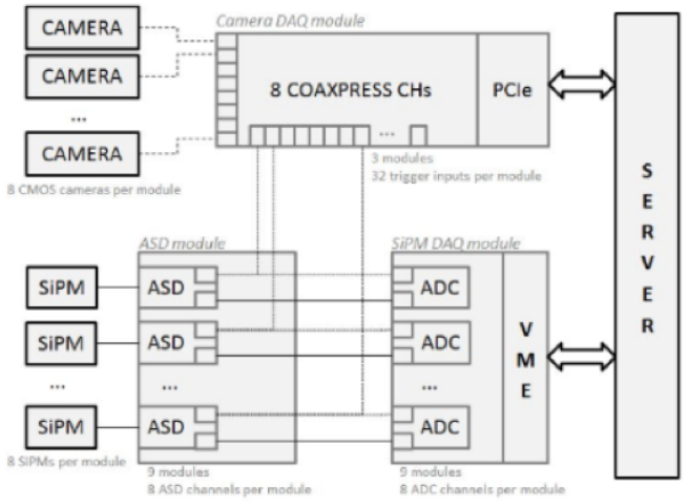
Two readout path:

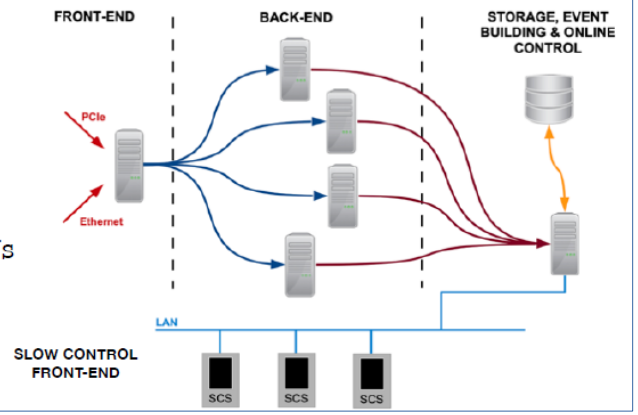
- **camera (4 Hamamatsu Orca-Quest):**
  - exposure 0.3 s/pic/cam @ 18 MB/pic/cam → 60 MB/s/cam → 240 MB/s with 4 cameras → SSD local storage
  - CameraLink PCIe frame grabber @ 2.5 GB/s
- **photodetector (8 channels per side):**
  - Assuming a trigger rate of 10 Hz, a 12-bit digitization @ 750 MS/s, $\lesssim$ 1 us, $\sim$ 0.2 MB/s
  - Assuming a trigger rate of 10 Hz, a 12-bit digitization @ 250 MS/s, $\lesssim$ 10 us, $\sim$ 0.6 MB/s

Two possible trigger levels:

- **HW trigger:** photodetector with minimal logic (e.g. majority)
- **Software trigger:** reconstruction of images and waveforms on a farm of CPUs/GPUs and based on interesting features (eg. clusters)

MIDAS used for Readout, Trigger and slow control





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presented by S. Piacentini in the Collab. Meeting 2023, 06/12/2023

CYGNO-04 DAQ plans: Now

a few updates

Trigger and DAQ for CYGNO_04

Two readout path:

- **camera** ~~**(4 Hamamatsu Orca-Quest):**~~ → 6 Orca-Quest
  - exposure 0.3 s/pic/cam @ 18 MB/pic/cam → 60 MB/s/cam → ~~240 MB/s with 4 cameras~~ → SSD local storage
    360 MB/s with 6 cameras
  - ~~CameraLink PCIe frame grabber @ 2.5 GB/s~~ → 0.6 GB/s
- **photodetector (8 channels per side):**
  - Assuming a trigger rate of 10 Hz, a 12-bit digitization @ 750 MS/s, $\lesssim$ 1 us, $\sim$ 0.2 MB/s
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- **HW trigger:** photodetector with minimal logic (e.g. majority)
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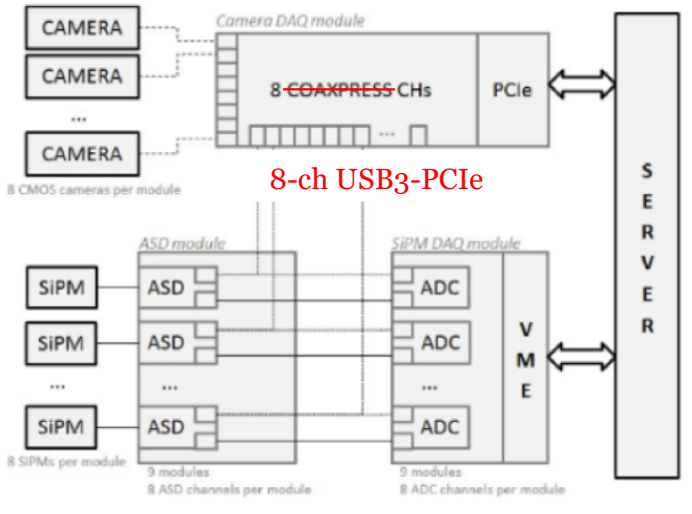
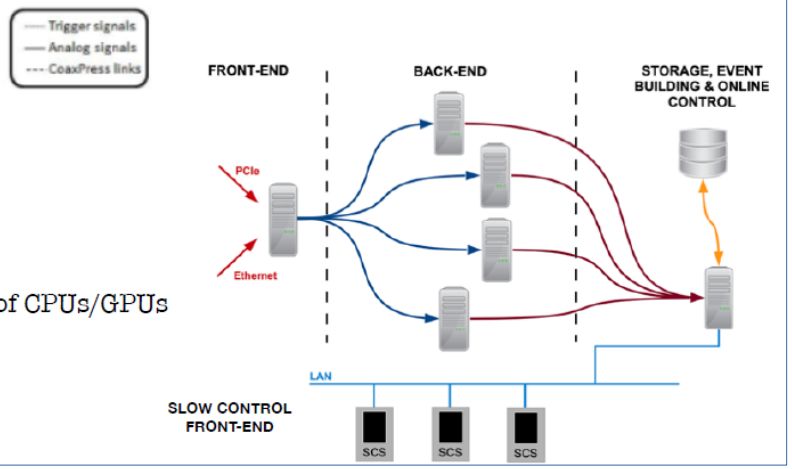
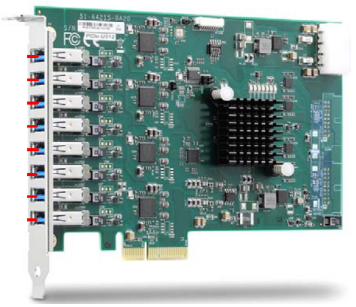


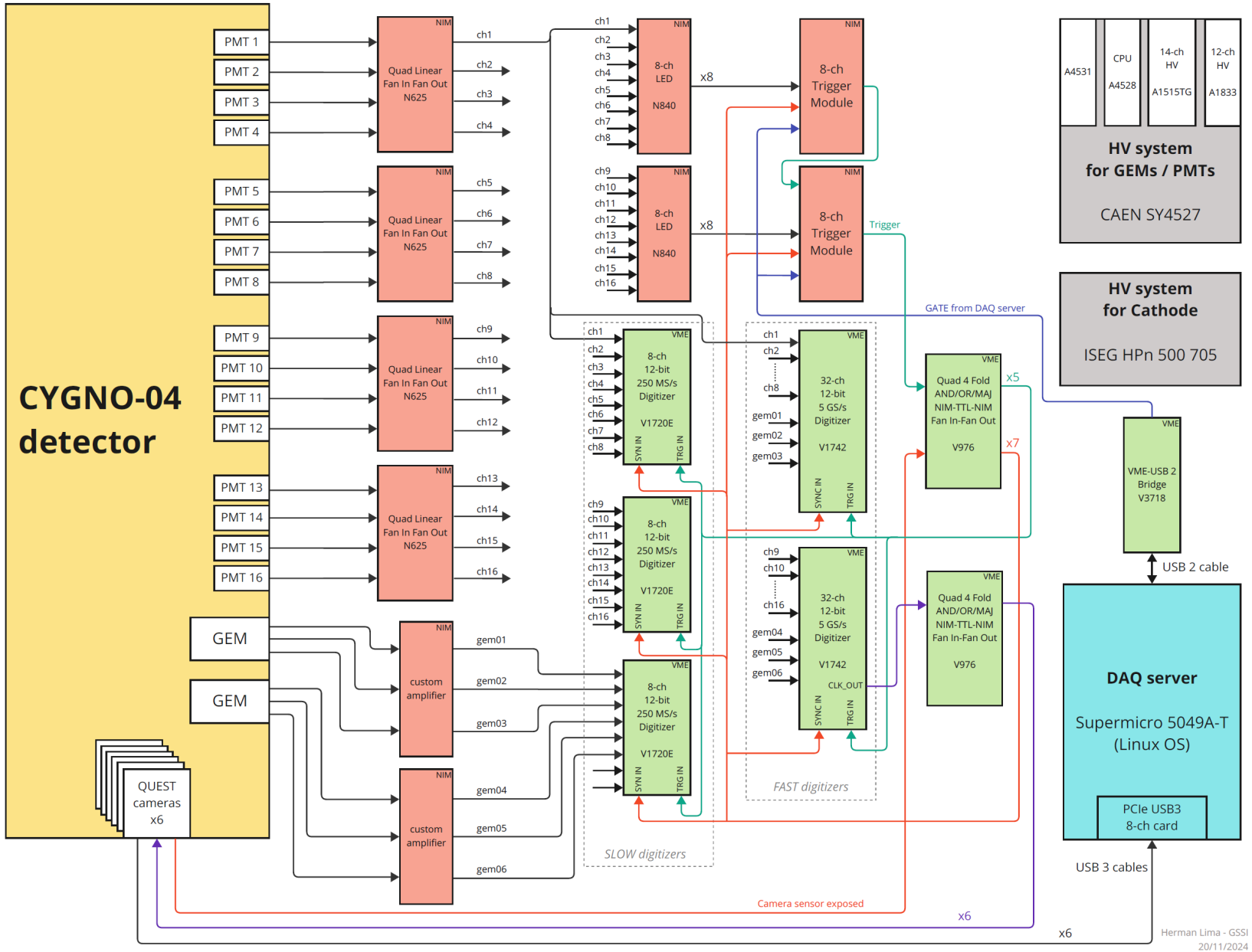




PCIe-U308 (Adlink)
- 8 ch frame grabber
- delivery: mid-Dec
- tests after Run 5

presented by S. Piacentini in the Collab. Meeting 2023, 06/12/2023

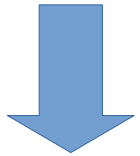
CYGNO-04 DAQ: Hardware overview



- Since CYGNO-04 is a dual TPC detector, the idea is to design two independent data acquisition (DAQ) paths (discr-trigger-digitizers) that can also run in a ‘combined mode’.
- This solution allows to acquire events from a single TPC (8 PMTs, 3 cameras) or the whole detector.
- A possibility under discussion is to read (digitize) the output of the third-layer GEM.

CYGNO-04 DAQ: Trigger modes

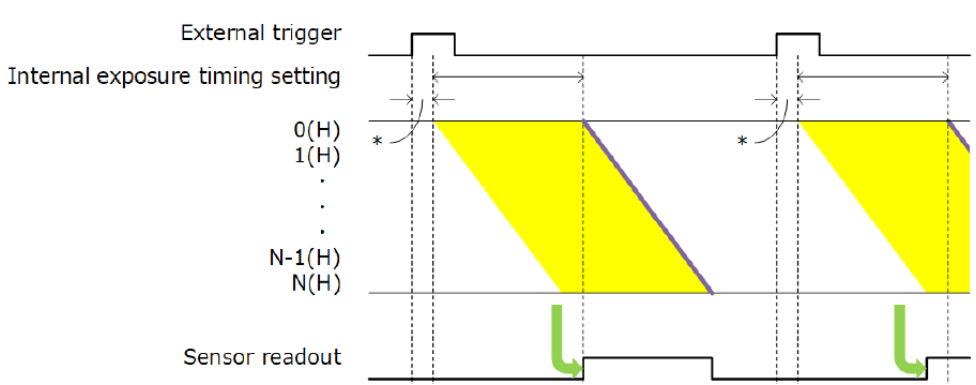
- A DAQ architecture that can read each TPC alone (*single mode*), or both TPCs (*combined mode*), allows the possibility to run CYGNO-04 in different **Trigger modes** (scenarios):
  - PHYSICS: DM search mode, no need to run in ‘combined mode’
  - COSMICS: could be useful to run in ‘combined mode’
  - PEDESTAL: run each TPC independently (‘single mode’)
  - CALIBRATION: iterations between ‘single’ and ‘combined’ modes

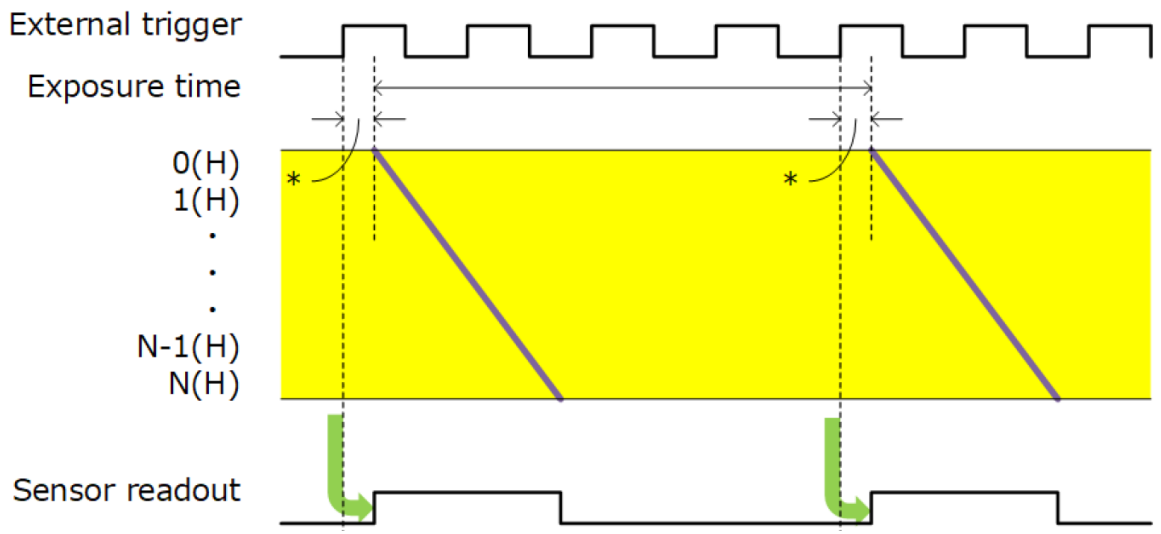


TO BE DISCUSSED

CYGNO-04 DAQ: Synchronization

- The major feature not optimized in LIME data acquisition is the long **deadtime** between two consecutive images. The camera is triggered by software through the DAQ server.
- Proposed solution: change the camera operation mode from ‘software trigger’ to **External Trigger mode (Trigger times)** figure below right**.**
- One of the digitizers is the Master, sending a reference *ext_trigger* to the six cameras.
- The exposure time of the cameras is defined as the number of *ext_trigger* periods (1 to 10k).
- Both the exposure and readout of the camera are made by the external trigger, reducing the deadtime.

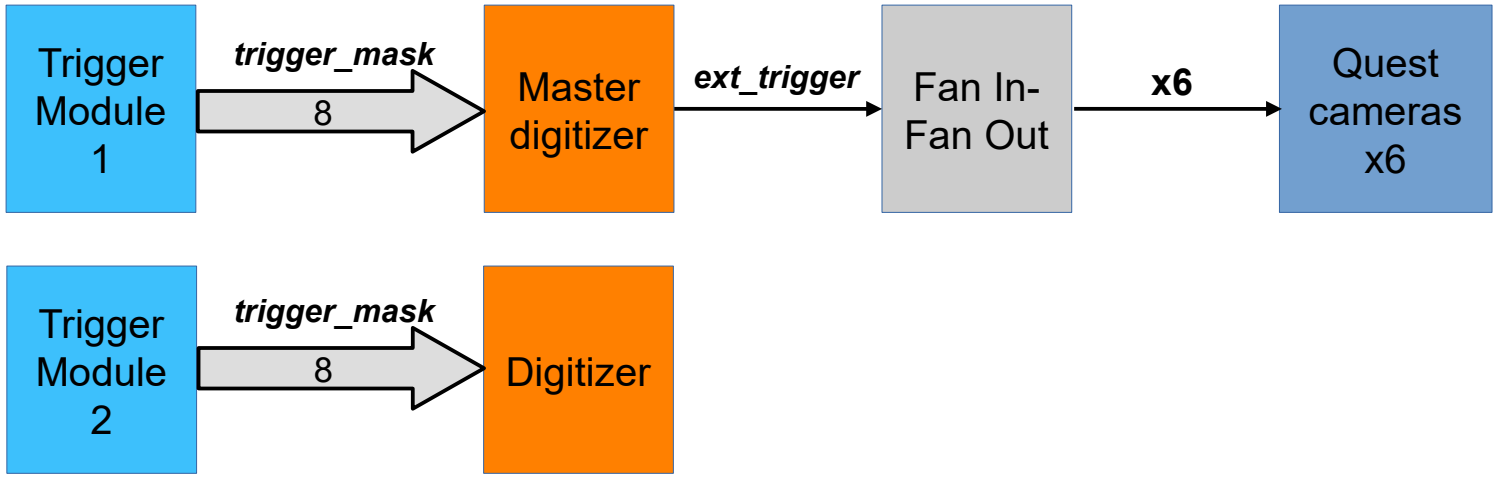




Page 45 of ‘C15550-20UP/C15550-20UP01 Instruction Manual’.

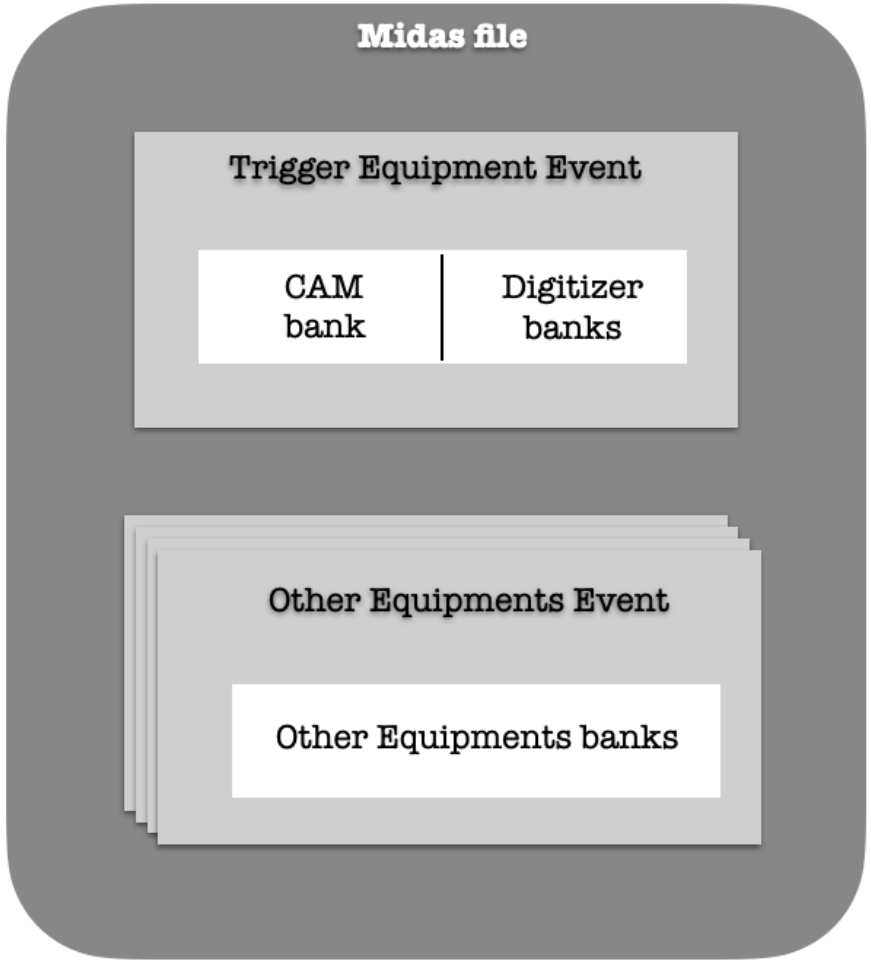
CYGNO-04 DAQ: Synchronization

- The acquisition of the camera is realized by opening a Gate with the DAQ server.
- A *Trigger Time Tag* (TTT), in each digitizer, is reset at the start of the exposure (beginning of a Run).
  TTT is provided by a 60 bits (V1742, Fast Digitizer), and 48 bits (V1720, Slow Digitizer), scaler embedded in the read data packet.
- Each Trigger-Module provides for one of the digitizers an 8-bits mask (*trigger_mask*) with the PMTs fired for the corresponding Trigger pulse.
  The *trigger_mask* is embedded in the data packet, so that it's possible to recover from the data which detector caused the trigger.
- With all these information, the *Event Builder* is able to fully reconstruct the events for both detectors.

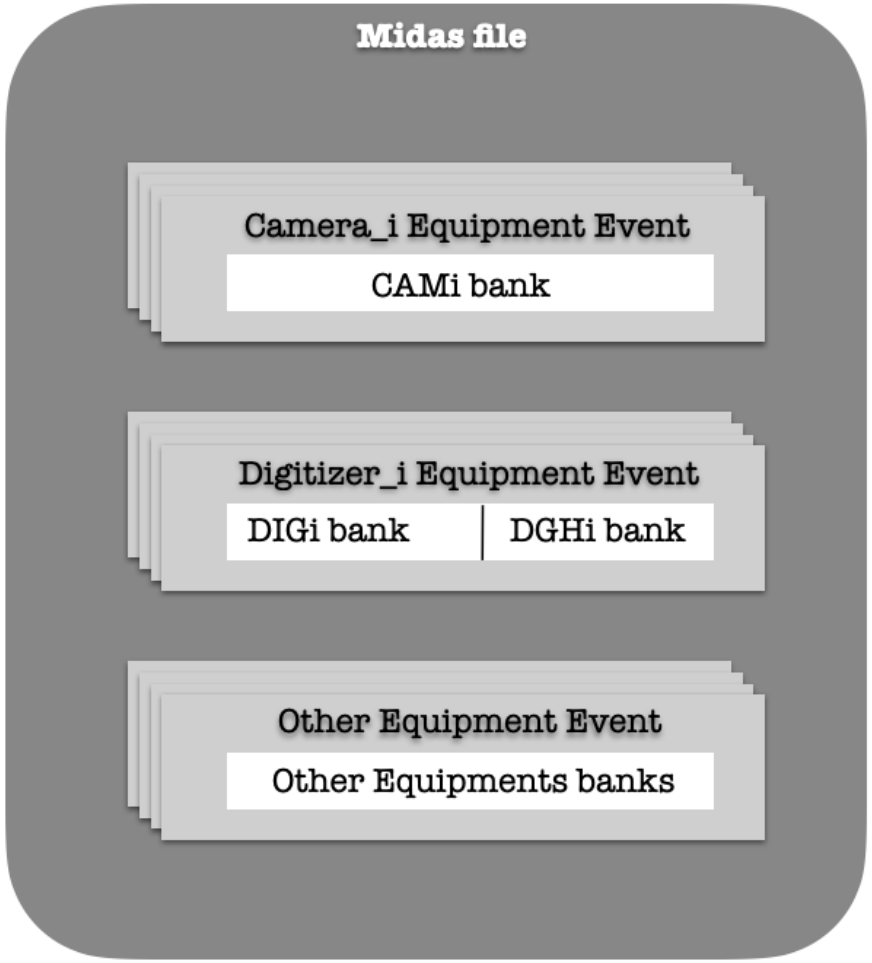


CYGNO-04 DAQ: Event Builder

Current LIME datafile structure



Proposed CYGNO-04 datafile structure



** S. Piacentini*

CYGNO-04 DAQ: List of Material

	GROUP	DESCRIPTION	Model	Manufact.	Need	Available	TO ORDER	Notes
1	NIM module	Quad Linear Fan In Fan Out	N625	CAEN	4	4	0	1 available at LNF and 2 ordered
2	NIM module	8-ch Discriminator	N840	CAEN	2	2	0	1 available at LNF
3	~~NIM module~~	~~4-ch Fast Amplifier~~	~~N978~~	~~CAEN~~	~~2~~	~~4~~	~~4~~	D. Pinci said there is a custom amplifier design going on and this module won't be used in CYGNO04 (21/10/24).
4	NIM module	8-ch Trigger Module	TM v2	GSSI	2	1	1	under development / estimated delivery of new comps. mid Dec
5	NIM crate	12-slots standard NIM crate		CAEN	1	3	-2	1 available at LNF and 1 at LNGS
6	VME module	8-ch, 250MSPS Digitizer	V1720E	CAEN	3	3	0	2 available, need 1 more because of the GEMs (28/10/24)
7	VME module	32-ch, 5GSPS Digitizer	V1742	CAEN	1	3	-2	1 available at LNF and 1 at LNGS
8	VME module	Quad 4 fold Logic, NIM-TTL-NIM	V976	CAEN	2	1	1	1 fanout of the Trigger signal and 1 Clock to cameras
9	VME module	VME-USB2 Bridge	V3718	CAEN	1	1	0	1 available at LNF (accord. to Francesco Renga)
10	VME crate	4U, 8 slots, VME64 std crate	VME8008B	CAEN	1	1	0	8 slots used / I said to D. Pinci that it is safer to replace by a 21-slot standard crate (21/10/24). Ex: CAEN VME8100
11	HV module	12-ch for the PMTs	A1833	CAEN	1	1	0	
12	HV module	14-ch HV for Triple-GEMs	A1515BTG	CAEN	1	1	0	
13	HV crate	Universal Multichannel Power Supply System	SY4527	CAEN	1	1	0	
14	HV system	AC/DC High-Voltage Power Supply	HPn 500 705	ISEG	1	1	0	
15	Computing	8-ch, USB3-PCIe interface card	PCIe-U308	ADLINK	1	0	1	1 unit ordered by GSSI / estimated delivery mid December
16	Computing	Graphics Processing Unit (GPU)	???	???	1	1	0	according to D. Pinci (21/10/24) one (maybe 2) GPU is already installed in LIME DAQ Server.
17	Computing	USB 2 cable (Type-A to Type-C connectors)			1	0	1	check if available at LNF
18	Computing	USB 3 long cable			6	0	6	
19	Computing	Xeon processor workstation (DAQ server - Linux)	5049A-T	Supermicro	1	1	0	
20	Computing	Computer (Windows OS)			1	1	0	
21	Sensor	Orca Quest qCMOS camera	C15550-20UP	Hamamatsu	6	1	5	5 new cameras ordered by GSSI (nov/24)
22	Sensor	Photomultiplier Tube (PMT)	R7378	Hamamatsu	16	4	12	ordered?
	** Minimum Requirements.*							

CYGNO-04 DAQ: Trigger Module v2

REMEMBERING:

- The **Trigger Module** is a custom module (NIM format) designed for LIME/CYGNO, based on two small cards: an FPGA board and a Raspberry Pi.
- Perform three logic functions (remotely selectable): AND, OR, Majority
- Accessible through Ethernet connection (SSH) for remote configuration of seven internal registers.
- The FPGA firmware can also be remotely updated, using a local computer connected via USB.

IMPROVEMENTS in version 2:

- 16 IO's → **22 IO's**
- Only TTL/LVTTL inputs → **8 NIM inputs** (using a new custom conversion board)
- NIM rear connector included for power supply
- New processing capabilities are planned for the inputs 'Camera Exposed', Gate, Trigger In, GEM.

CYGNO-04 DAQ: Trigger Module v2

22 IOs in Trigger Module v2

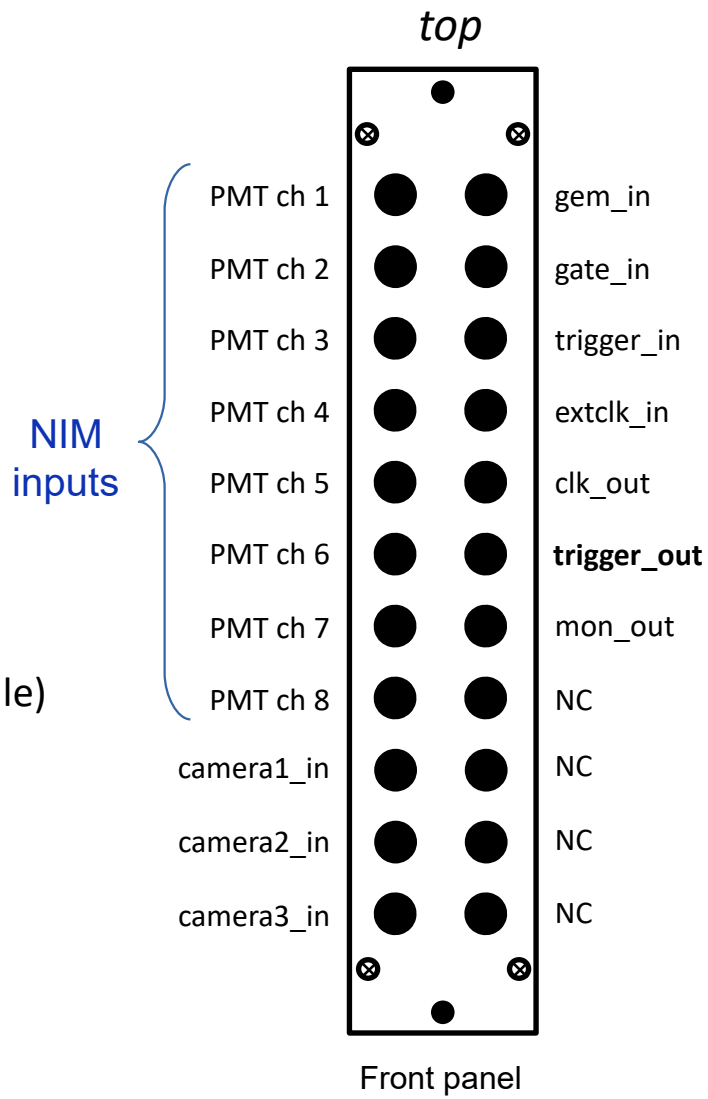
INPUTS (15):

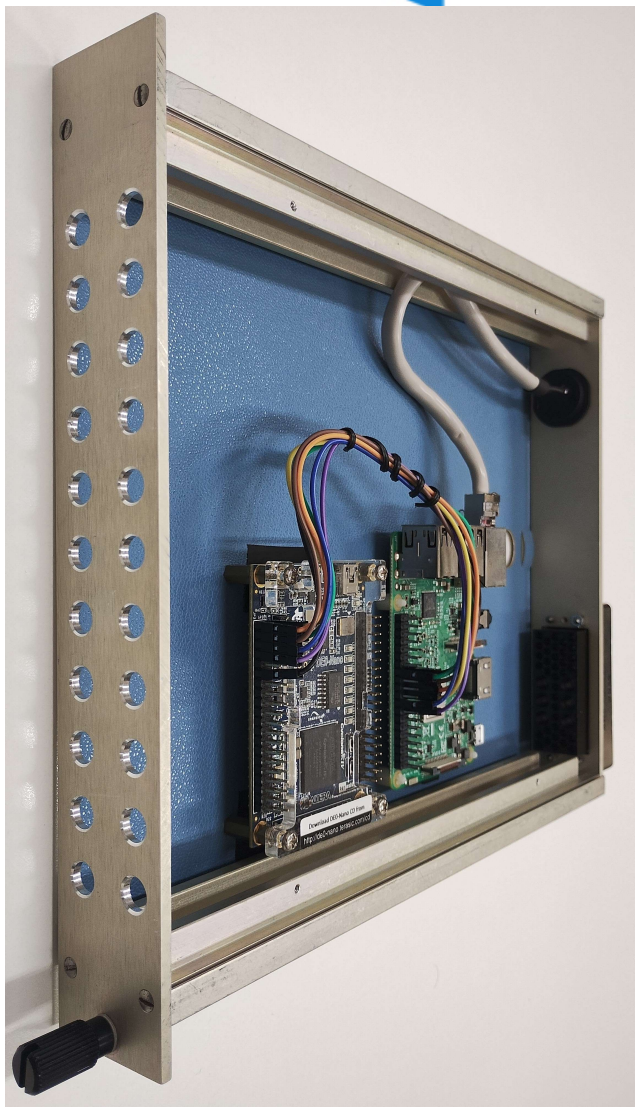
- 8 PMT input channels (*'PMT ch X'*)
- 3 for the 'sensor exposed' output of the cameras
- 1 for a GEM logic ('trigger') signal
- 1 for the GATE signal from the DAQ server
- 1 for an external trigger signal
- 1 for an external clock signal

OUTPUTS (3):

- 1 clock
- 1 trigger output (to be distributed by a V976 module)
- 1 monitoring output (for debugging)

- 4 Not Connected (now)





Trigger Module v2 under development.

Thank you for your attention.