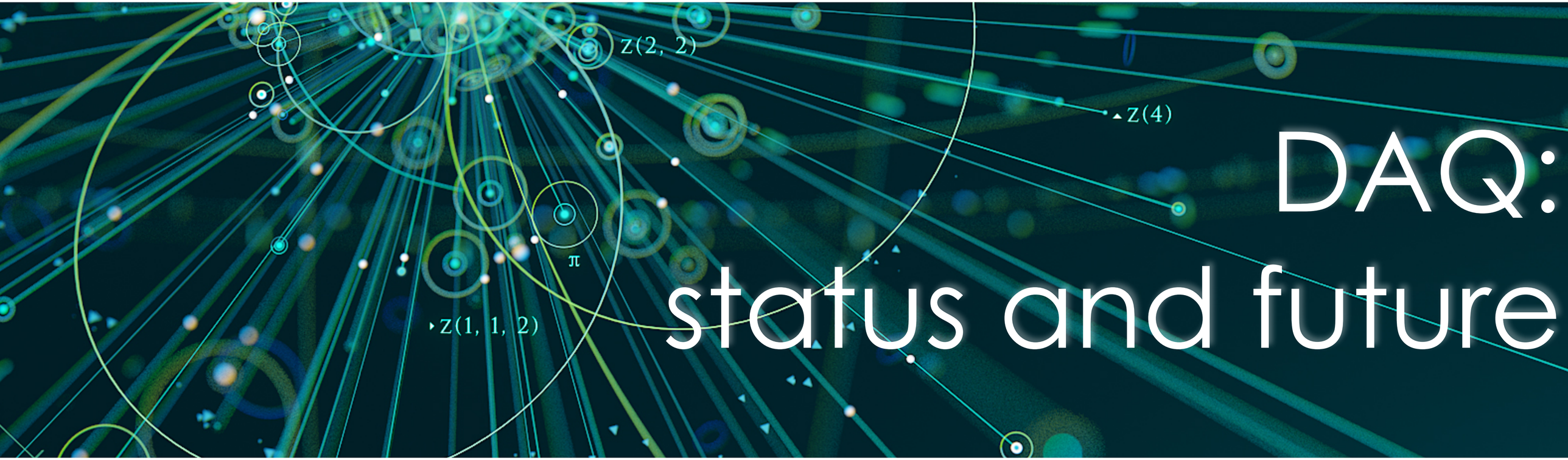


DAQ: status and future

Silvia Biondi, Mauro Villa, Riccardo Ridolfi
University & INFN of Bologna

Strike for Black lives - 10 June 2020

"**It should go without saying that Black lives matter. Yet we find ourselves again mourning and raging over state and vigilante violence against Black people.** The recent murders of Tony McDade, Breonna Taylor, Regis Korchinski-Paquet, George Floyd, and Ahmaud Arbery are just a few examples of the **violence and racism that Black people live with every day** -- and have for centuries -- in the US, Canada, and around the world. We acknowledge the ways in which the effects of anti-Black racism are compounded for people who are also, for example, **women, trans, non-binary, queer, Indigenous to the lands occupied by the United States and Canada, Latinx, Muslim, Jewish, disabled, and/or undocumented.** We demand justice, reform, and accountability now.

Therefore, as physicists, we believe an academic strike is urgently needed: **to hit pause, to give Black academics a break and to give others an opportunity to reflect on their own complicity in anti-Black racism in academia and their local and global communities.**
This **#strike4blacklives** is in dialogue with a call from colleagues in astronomy to **#shutdownSTEM** and **#shutdownacademia** for at least the day of June 10."

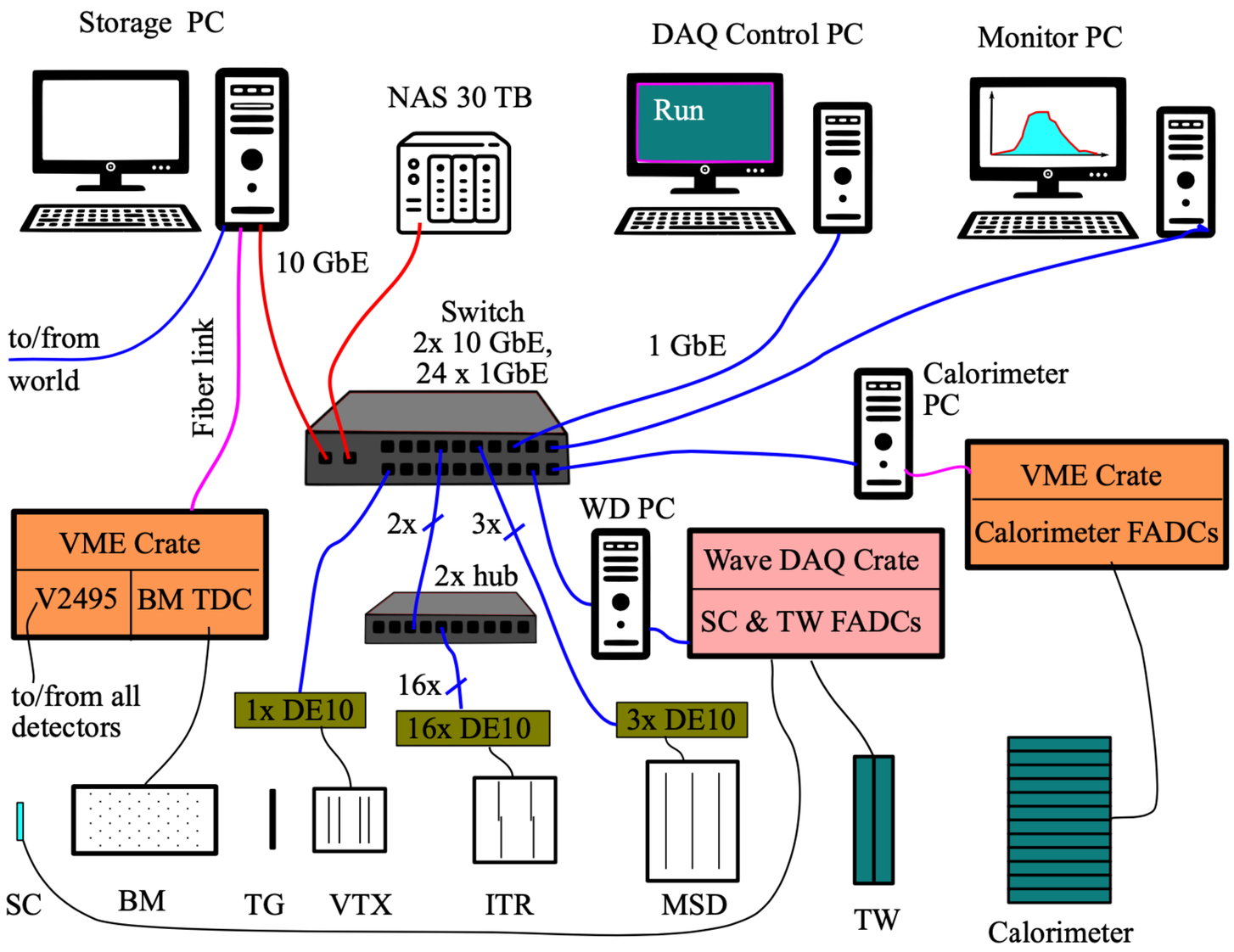
- Particles For Justice strike page
- Strike details
- Resources (books, online articles, podcasts, videos, kid-friendly resources, donations)

Outline

- The DAQ system
- Status of DAQ integration
- What we are working on now
- What is still missing
- Conclusions

New DAQ structure

- **2 VME crates:**
  - Trigger, BM and Calo boards
- **3 central DAQ PCs:**
  - for steering the whole process, storing the data and monitoring the runs both online and offline
- **detector integrated readout systems:**
  - SC, VTX, IT, MSD and TW
- for some sub-detectors we plan to have an **intermediate PC** to interface with the central DAQ:
  - Wave DAQ and Calo;
  - collect data, to store additional information which is not included into the final data format and to reduce the size of the event.



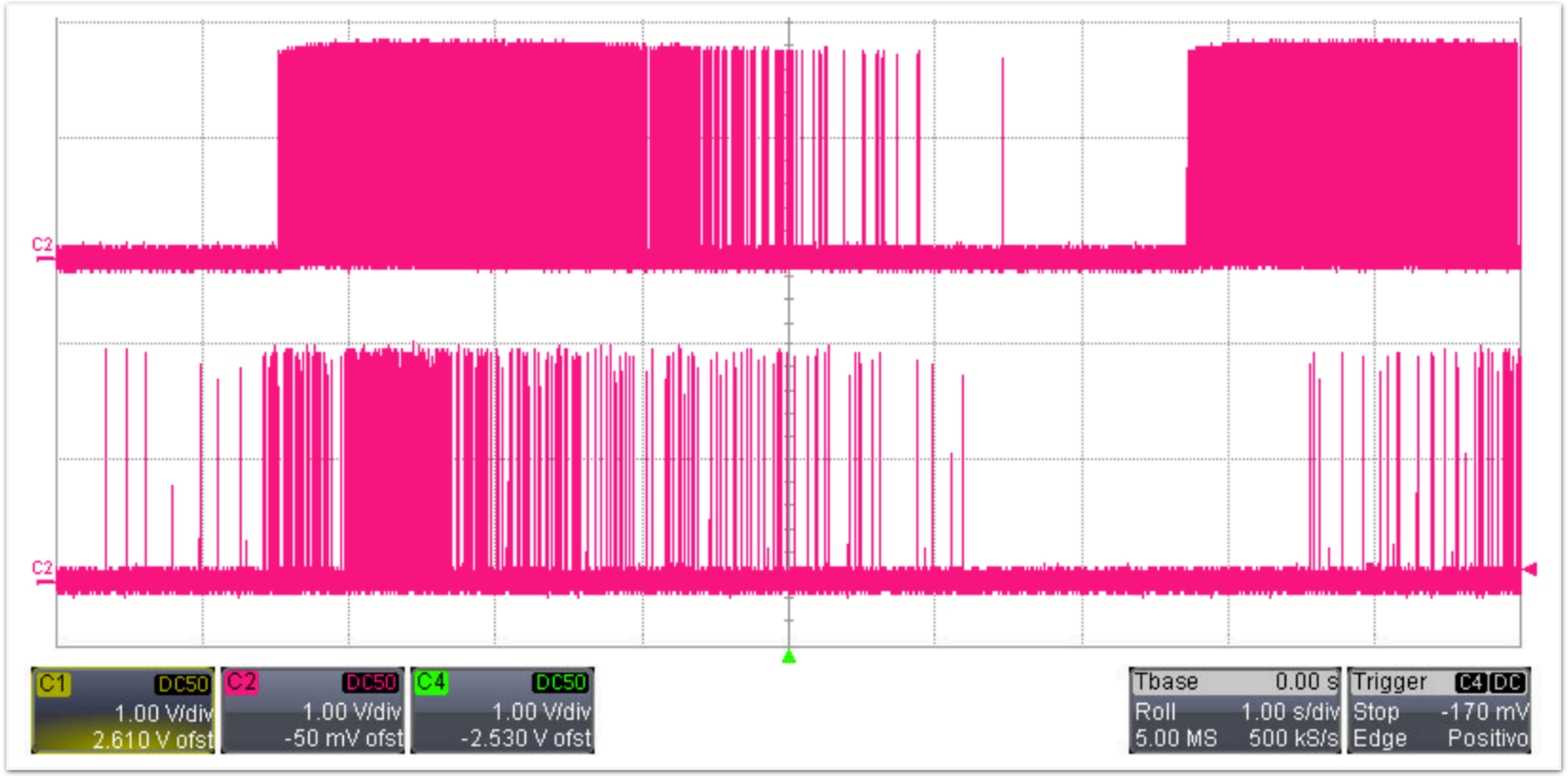
Status of DAQ integration

Sub-detector	What we will use	What we need to work on	From which institute	What we have now
Start Counter	Wave Dream	PC interface	Roma+Pisa	working system
Beam Monitor	TDC	parameters for board configuration	Milano+Roma	TDC (V1190B)
Vertex	DE10 (std)	software for TCP connection (CPU)	Frascati	DE10 (nano)
IT	DE10 (nano)	software for TCP connection (CPU)	Frascati	DE10 (nano)
Micro Strips	DE10 (nano)	software for board connection (CPU + FPGA)	Perugia	DE10 (nano)
DE/TOF	Wave Dream	PC interface	Roma+Pisa	working system
Calorimeter	FADC V17xx(?)	strongly dependent on the type of chosen readout	Torino	-

Beam simulator

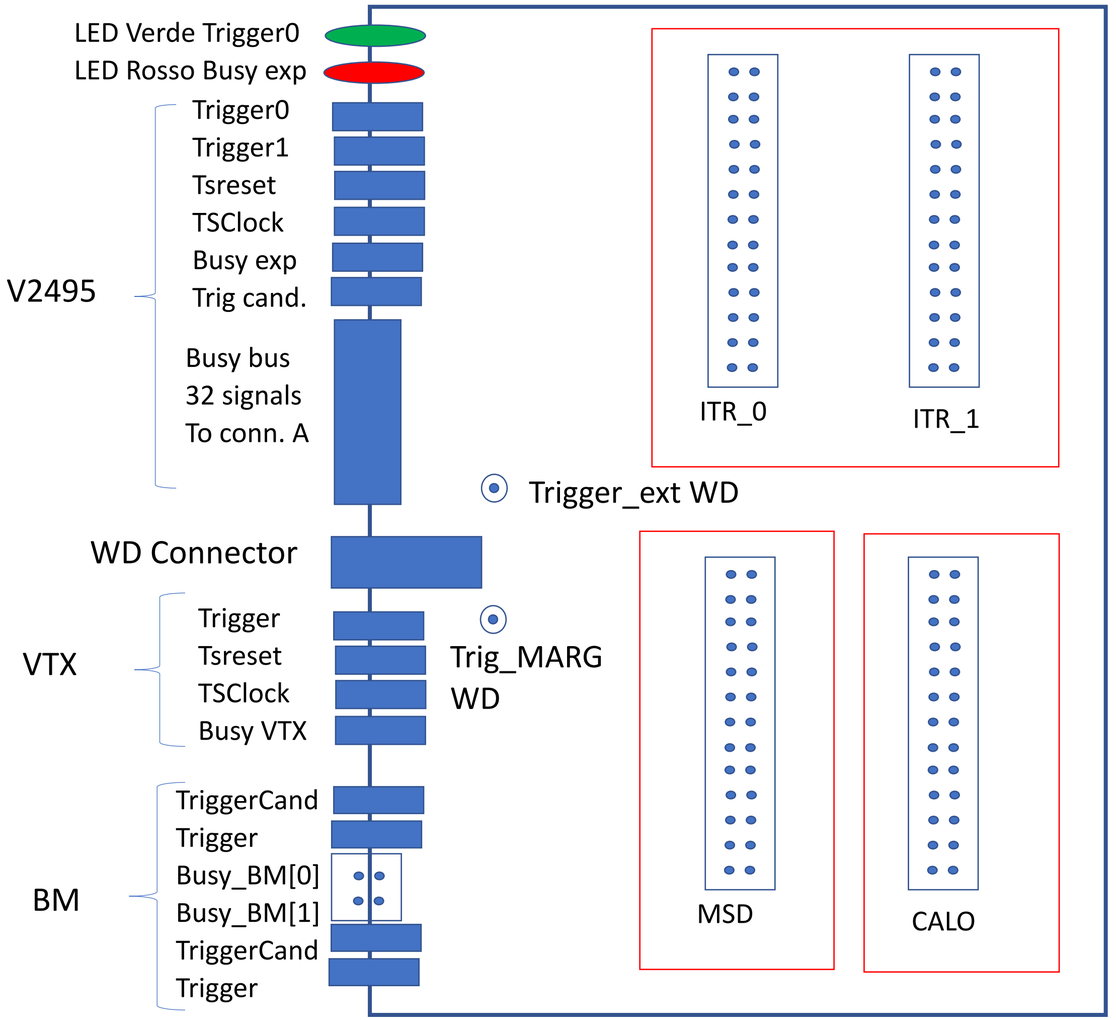
- Simulation of the beam we had at GSI;
- **more realistic environment** for debugging systems integrations;
- **simulations are not enough.**

- 6-8 s periods, varying intensity, random trigger.



Patch panel design and development

- **Reason:** distribution of trigger, timestamp and busy signals necessary to synchronise all the sub-detectors and to handle the trigger;
- **different types of signals** are designed for different sub-detectors necessities;
- designed size like a **VME 6U board**, so we can put it in the VME crate where the power can be steered by the crate itself;
- went through all the boards and readout systems of each sub-detector to finalise the **amount of signals to be received and distributed by the patch panel**.
- **ITR, MSD and Calo** are treated in the same way (with same connectors)
  - each of them will provide an **interface board to receive and send signals**.



MSD DAQ

- Working on a general FPGA+CPU framework together with detector experts;
- strong collaboration to finalise the whole setup from the sensors to the DAQ.
- **Workplan:**
  - **need to start asap a joint DAQ-MSD HW tests**
    - this is what I wrote in December, then Covid happened;
    - but planning first integration tests for September 2020.
  - in Bologna, an engineer student has done a lot of work for the DE10 firmware on MSD side;
  - hopefully we will re-start some lab activities for this part on Monday.

Work-plan for other systems

From the last FOOT Collaboration meeting, no updates have been done for these items yet

- **Beam Monitor:**
  - HV to be added in central DataBase;
  - improve online monitoring.

- **WaveDAQ:**
  - improve online monitoring;
  - test event building to check no event loss happens anymore;
  - more controls on threading;
  - starting procedure needs to be automatic!

- **VTX/IT:**
  - integration in Bologna, to be decided with interested people
  - 2-day test beam with DAQ+VTX only
  - start thinking about online monitoring

- **Calo:**
  - readout system yet to be designed (320 channels read by FADCs 17xx);
  - DAQ will be tuned on estimations from the designed setup.

Online monitoring

- **GNAM**
  - need to add all the info from different detectors;
  - possibility to check directly comparisons between different systems.

- **Online Histograms (OH)**
  - some already implemented, with very basics parameters to check;
  - for now, event size (for all the integrated modules) and time measurement and hit channels for BM.

- **Information Service (IS)**
  - widely used so far to check detector-specific parameters during the run;
  - each Readout Module can set the frequency of parameters updating.

- **DataBase (DB)**
  - used to check some interesting parameters at the end of the run;
  - for now only WaveDream readout module uses this tool.

- All this info can be **used by shifters during data taking**
  - not to overload the DAQ shifters too much (from GSI experience);
  - all detector expert should be “shifters” to check their own info.

Data flow - connection

connections going from the same client to the same server

Readout module = CLIENT

1. send **configuration** parameters to server
2. request **monitoring parameters** from server
3. tell the server **when to send data**
4. put the data in the relative **DataChannel** through parallel threads

"Slow" connection

starts when "Configure" mode and uses > 1 thread to handle different simultaneous activities

"Fast" connection

only if the system goes in "RUN" mode, stops when "stopDC" mode

Sub-detector = SERVER

1. receive **configuration** from client
2. send **monitoring parameter** to client
3. set a device parameter to "run" status and **prepare itself for the data flux**
4. **send the data** to the client

Slow control - Slow connection

connections going from the same client to the same server

Readout module = CLIENT

1. send **configuration** parameters to server
2. request **monitoring parameters** from server
3. tell the server **when to send data**
4. put the data in the relative **DataChannel** through parallel threads

"Slow" connection

starts when "Configure" mode and uses > 1 thread to handle different simultaneous activities

"Fast" connection

only if the system goes in "RUN" mode, stops when "stopDC" mode

Sub-detector = SERVER

1. receive **configuration** from client
2. send **monitoring parameter** to client
3. set a device parameter to "run" status and **prepare itself for the data flux**
4. **send the data** to the client

this is handled exclusively by the Slow connection, so it has no effect on the Fast connection for the data flow!

Online monitoring

- **Working on**
  - slow-control system for online monitoring;
  - some meetings with detector experts to define how to monitor the temperature/voltage of different sensors in the DAQ system;
  - also plan to increase the information stored in the DB, both for initial and end-of-run configuration of all the sub-detectors.

- **SC**
  - significant variations in temperature during the run not expected, no need to monitor the temperature.

- **MSD**
  - for each DE10: monitoring currents and voltages is necessary, temperature is expected to be monitored as well;
  - detector experts will check (and likely test) temperature sensors used by TW.

- **TW**
  - temperature already stored in monitoring for this sub-detector since GSI;
  - the number of needed sensors yet to be defined (max 10 sensors);
  - an intermediate board needs to be designed and placed between sensors and WD boards.

- **Calo**
  - variations in temperature expected to be not negligible;
  - proposal to have one sensor for each crystal, but yet to be defined.

Reminder: from our CDR

from CDR

Detector	Board(s)	DAQ channels	max event rate (kHz)	Event size (bytes)
Trigger	V2495	1	10	40 B
Start Counter	DreamWave	4	1	8.2 kB
Beam Monitor	TDC	36	5	0.1 kB
Vertex detector	SoC on DEx	$4 \cdot 10^6$	2	0.9 kB
Inner tracker	SoC on DEx	$28 \cdot 10^6$	2	2.1 kB
Outer tracker	Custom	$6 \cdot 10^3$	2	0.5 kB
$\Delta E/\Delta x$	DreamWave	80	1	8.4 kB
Calorimeter	QDC	400	2	1.7 kB
Total DAQ	Storage PC	-	1	22 kB

- Numbers from GSI experience
  - DAQ (trigger+BM+file structure): **530 B**
  - VTX: **650 B**
  - SC+TOFW: **29 kB**

→ **30 kB**

Conclusions

- **All the lab activities have been stoped due to the Covid situation**
  - no in-situ integrations or joint activities for sub-detectors.

- **WD system in Bologna**
  - still some work needed but in good shape.

- **VTX system still as it was at GSI**
  - planned tests with the detector experts needed to be postponed.

- **MSD detector**
  - DAQ people in Perugia in January to define the whole structure;
  - regular meetings to proceed in the integration, at least on SW side.

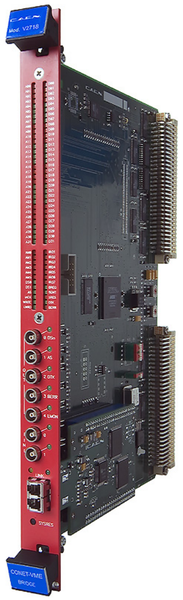
- **Other systems (IT, Calo)**
  - tests with detector experts, Calo when the readout will be defined;
  - need to define many technical points for all these systems;
  - integration will proceed as soon as they will be available (and when we are allowed to meet again):
    - we need to plan for a long integration phase well in advance ($\geq$ **5 months**) wrt a test beam.

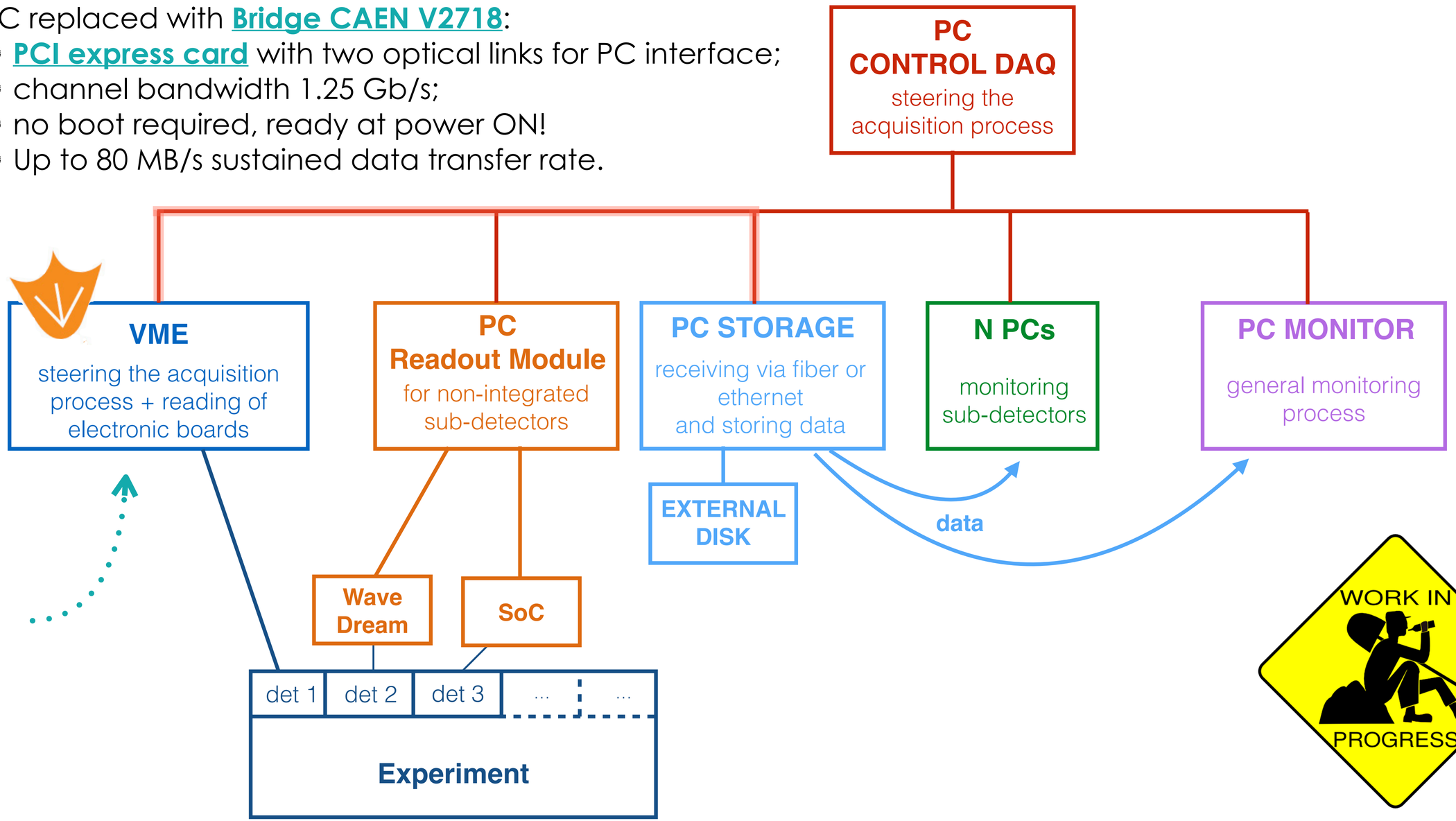
- **Works ongoing to finalise the DAQ structure (both HW and SW)**
  - online monitoring;
  - reducing levels in DAQ structure;
  - patch panel needed for the whole system.

Supporting material

New DAQ structure

- SBC replaced with **Bridge CAEN V2718**:
  - **PCI express card** with two optical links for PC interface;
  - channel bandwidth 1.25 Gb/s;
  - no boot required, ready at power ON!
  - Up to 80 MB/s sustained data transfer rate.





Calorimeter DAQ

- DAQ system yet to be designed

- **Main issue: data size**
  - plain FADC option:
    - 5/10 FPGA boards;
    - 320 channels x 1024 samples x 2 bytes = 640 kB -> 640 MB/s at 1 kHz rate;
    - exceeding the max bandwidth of VME (~80 MB/s) and writing on SSD (~200 MB/s)
  - reduction of data size and bandwidth is mandatory
    - we assume an intermediate PC for this reduction (to 2/3 kB)

- Global DAQ will be tuned on these numbers

Patch panel design and development

CAEN V2495

D connector
Input signal: Trigger_Candidate – TTL - LEMO

E connector
Output signals: TTL – LEMO
Trigger0
Trigger1
TSReset (Time Stamp reset)
TSClock (Time Stamp Clock)
Busy_Experiment

A connector
Input signals: LVDS
BusyBus (32 signals)

Wave DAQ/Wave Dream

FCI connector 8 coppie - LVDS
Output signals:
- Trigger_Candidate
- Busy_WD
- Trig_marg

Input signals:
- Trigger_ext
- TSReset
- TSClock
- Busy_Experiment

Beam Monitor, CAEN V1x90, V895

V1x90
Input signal:
- Trigger1 – LEMO - NIM

Output signal:
- Busy_BM – ECL – 110 Ohm (x2)

V895
Input signal:
- Trigger Candidate – LEMO - analog

VTX, IT, MSD - DE10 board or similar (DE10 nano)

VTX
Input signals:
- Trigger0, TSReset, TSClock – LEMO – TTL

Output signal:
- Busy_VTX – LEMO - TTL

IT, MSD → connettore 2x13
Input signals:
- Trigger0, TSReset, TSClock – LVDS

Output signals:
- Busy_ITR[0..15], Busy_MSD[0..5] - LVDS

DAQ-VTX interface problems - 1

- Integration done only at GSI – not ideal…
- Busy signal from vertex missing; decided for a fixed busy lenght (about 2-3 ms) costing us a DAQ rate of 300 Hz

- BCO not forwarded to VTX
  - - > problems in event building
  - -> Timestamp candidates:
    - framecounter (185 us period)
    - internal clock value (0.5 us period)
- VTX is missing triggers (run dependent)

DAQ-VTX interface problems - 2

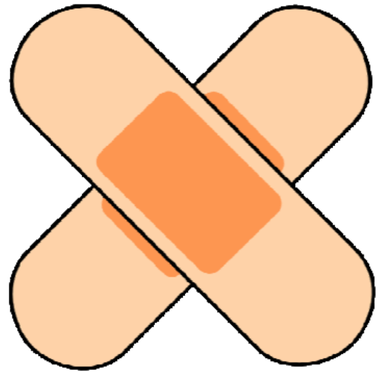
- Basically all variables that can be used for event building are NOT reliable:
  - HW triggers restarts after the first 100-200 event (approx 11 s VTX black-out)
  - Sequential events with the same frame counter value have been observed
  - Clearly wrong frame counter values
  - Out of sequence internal clock values and/or frame counters
  - Buggy HW trigger counters (rare)
  - Wrong event-internal clock value association (constantly off by 1 event)

DAQ-VTX interface problems - 3

- Observed VTX freezing:
  - About 11 s long, always after 100-250 events from the start, consistently on all runs and implying an hw trigger reset
  - Can happen also during runs and without hw trigger reset (e.g.: run 2212, VTX evts 39450-39451 matched with 40975 and 41248, 930 ms apart)
- Observed internal VTX time misalignment:
  - The 4 sensors are read out independently and shipped out via 4 UDP connections independently. The time alignment usually lasts till the first hw reset (i.e. on the first 100-250 events where most of the VTX tracks are found)
    - **Exception: run 2211 where VTX detectors keep the time alignment after the hw reset for a total of 18641 events (out of 61322 in total)**
  - Needed: internal VTX re-building for GSI runs;
    - Monitoring for next data taking!

DAQ-WD interface problems - 1

- BCO start, timestamp start
  (used for event synchronization);
  WD starts early;
  TDAQ sends two BCOResets:
  WD uses the first, trigger module uses the second
  (BTW: too few bits in the BCO#)
- Trigger start;
  - WD provides first triggers before the actual run start
    (between the first and the second BCOReset)
  - Cured with changes in the V2495 firmware



DAQ-WD interface problems - 2

- WD event losses
  - Examples from run 2212 – 116 k events for daq:
    - WD evt 0 not matchable
    - WD evt 1-12350 matched with daq 0-12349
    - From WD evt 12350-41367 one every three WD events is not written out (hw trig # jumps)
    - No more data after WD evt 41367, hw trig 51948 (daq has 64k more events)
  - Same pattern in other runs: ONE unmatchable event at the beginning, ~10k perfect, then 1 over three lost, stop recording at some point