TriDAS for EIC

A proposal for a Trigger-less Data Acquisition System

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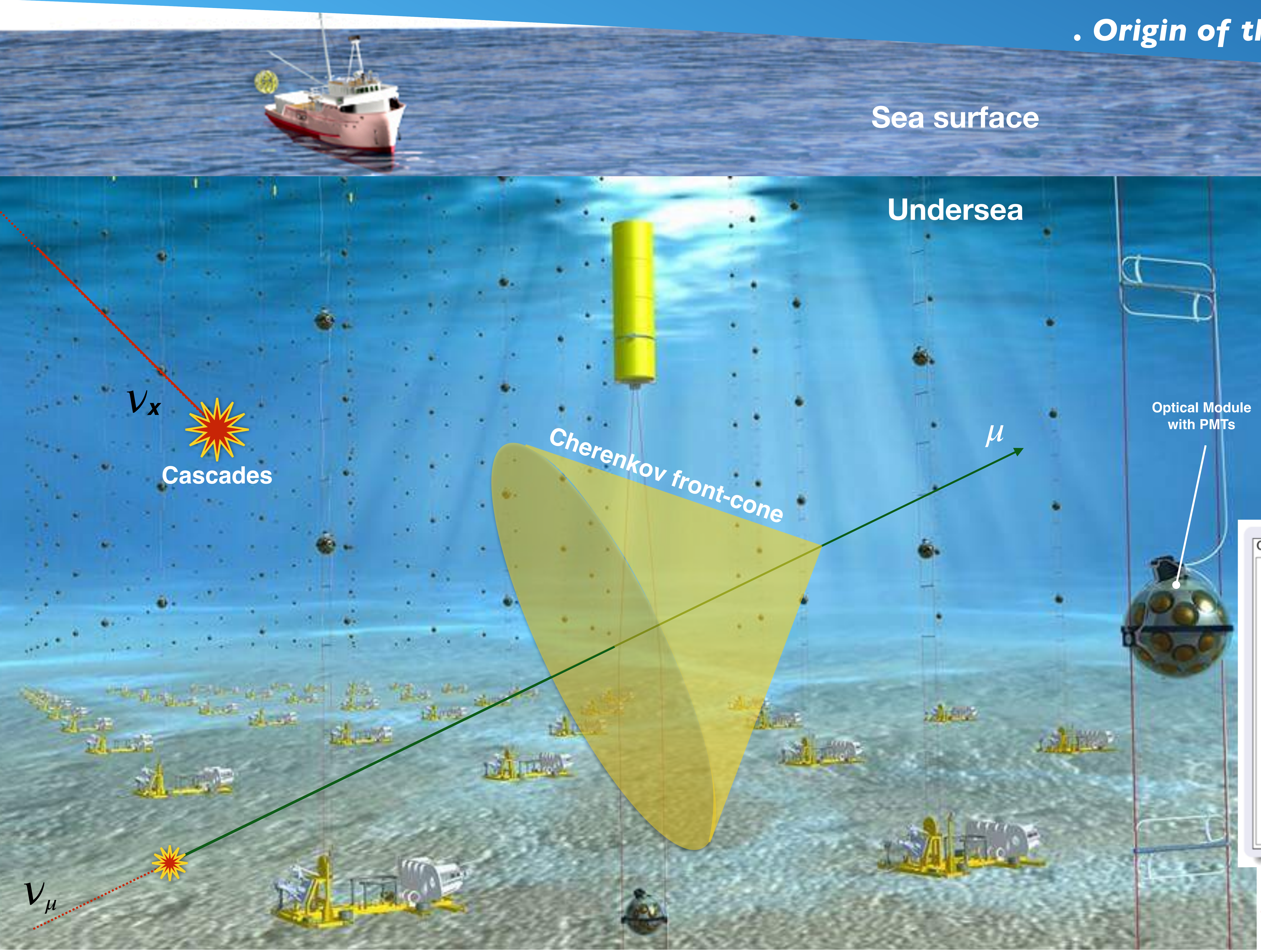
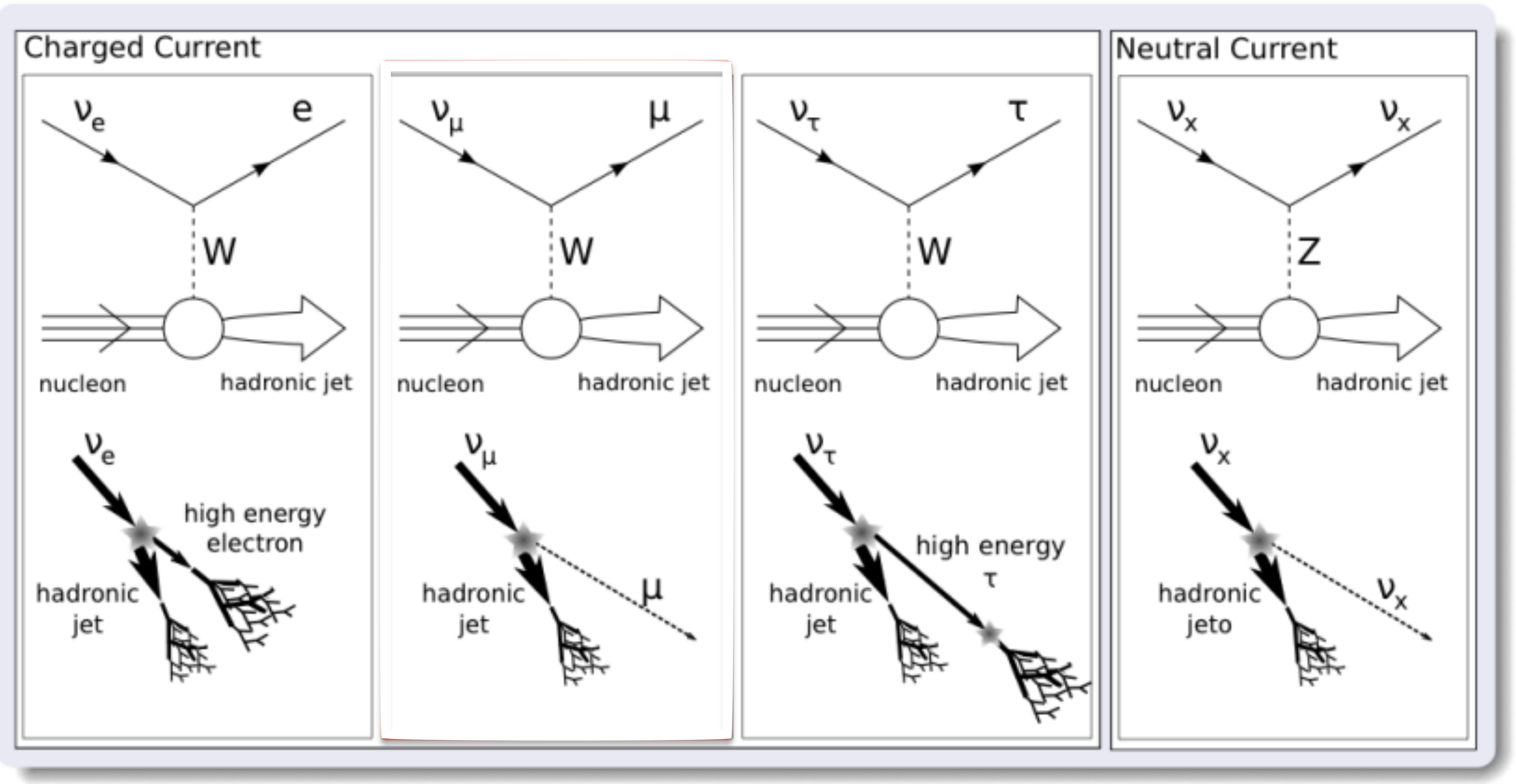
Farnesina
Ministero degli Affari Esteri e della Cooperazione Internazionale

- The origin of this idea
- A trigger-less proposal
- Implementations for BDX



M. Markov:
"We propose to install detectors deep in a lake or in the sea and to determine the direction of the charged particles with the help of Cherenkov radiation"
1960, Rochester Conference



Best channel for Energy estimation

Golden channel for Astronomy (good angular res.)

"Double bang" resolved @ E>1PeV (τ range >50 m) rare events

Partial energy information

Seabed depth: -2500 / -3500 m, Instrumented volumes: > 1 km^3 , vertical structures >500 m

. Underwater/ice Neutrino Telescopes on Earth .

Very small neutrino cross-sections

$$\sigma_{\nu N} \sim 7.8 \times 10^{-36} \left(\frac{E}{GeV}\right)^{0.36} [cm^2] \quad \text{for } E_\nu > 1 \text{ TeV}$$

Very small expected fluxes

W.B. bound:

$$\frac{dN_\nu}{dE} \sim 9 \times 10^{-9} \left(\frac{E}{GeV}\right)^{-2} \left[GeV^{-1}\ cm^{-2}\ sr^{-1}\ s^{-1}\right]$$

⇒

- **O(km³) volume size detector**
- **many detector elements**
- **many years uptime**

Astrophysical source searches
with angular resolution < 1 deg over a km³ scale

⇒

-Time resolution of O(1ns)
- Positioning resolution O(10 cm)

No bunch-crossing time info

Abyssal sites

Undersea only: ^{40}K and bioluminescence
e.g.: > 50 kHz @ 10'' PMT (0.3 p.e. threshold)
Signal (atm. μ) to noise ratio $<10^{-4}$

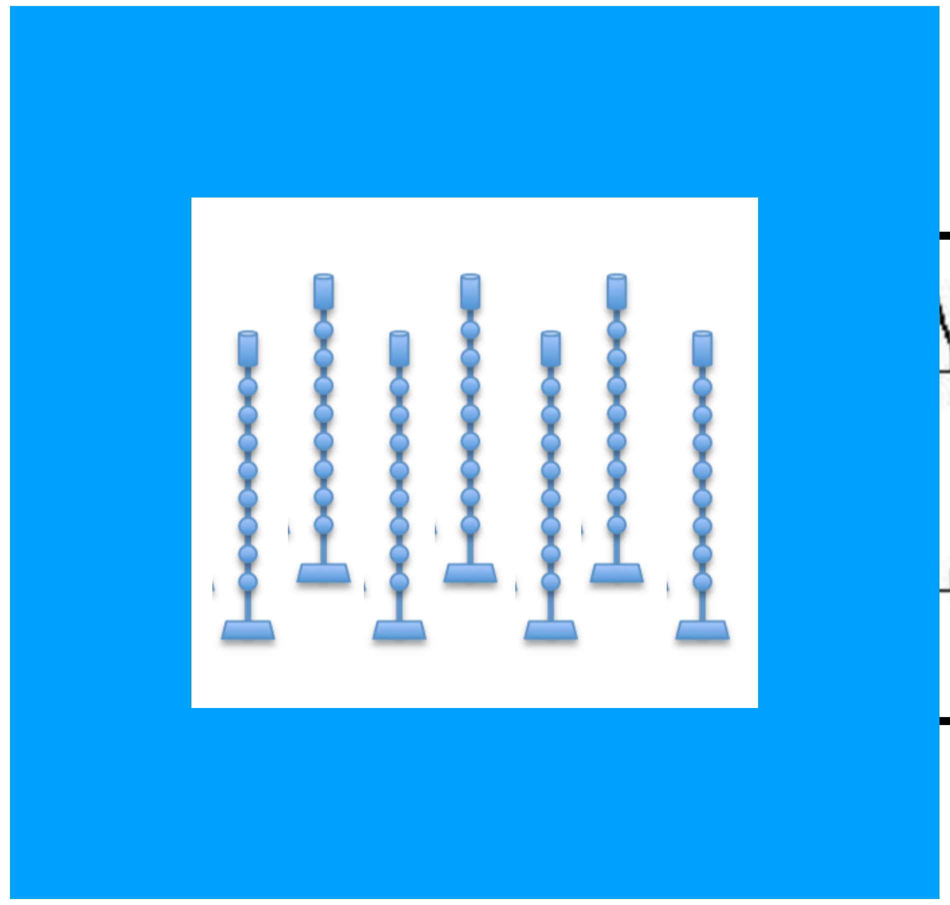
⇒

- **Simple detector off-shore**
- **On-line Trigger on-shore**
- **Continuous data taking**

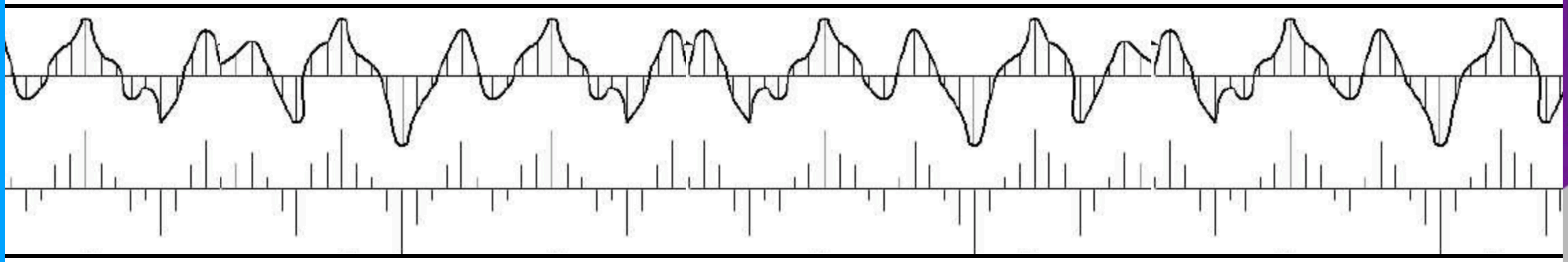
⇒

- ***All data to shore***
- **high throughput handling**
- **fast and effective background rejection**

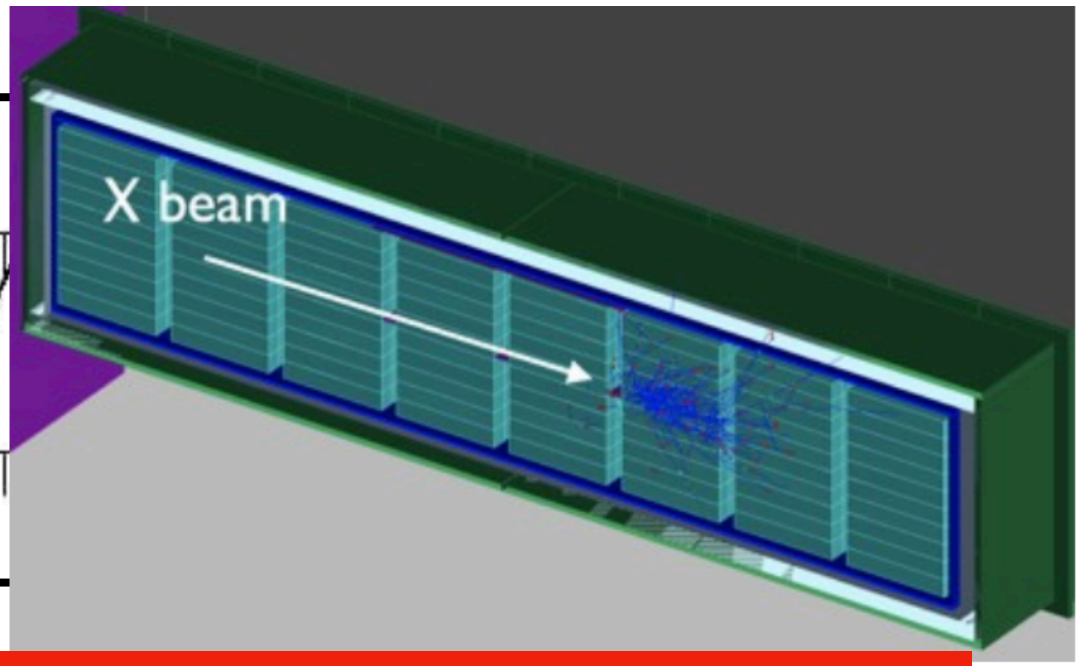
Neutrino Telescopes
PMTs inside the "*scintillator*"



Continuous signal sampling (e.g. one PMT/SiPM channel)



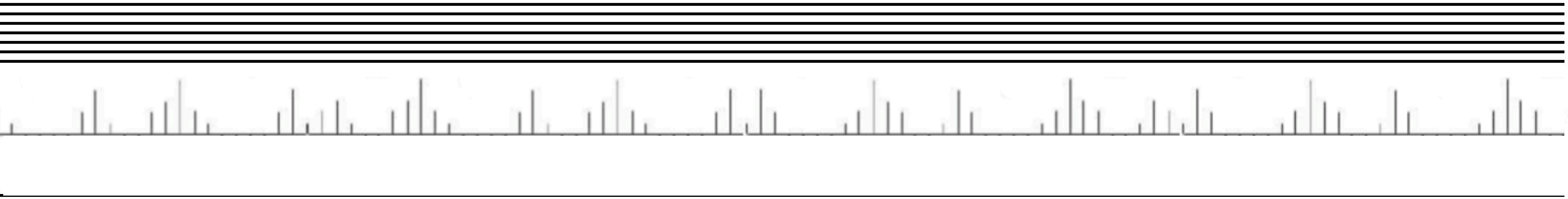
BDX
SiPMs around scintillators



Refer to Luca Marsicano's yesterday talk

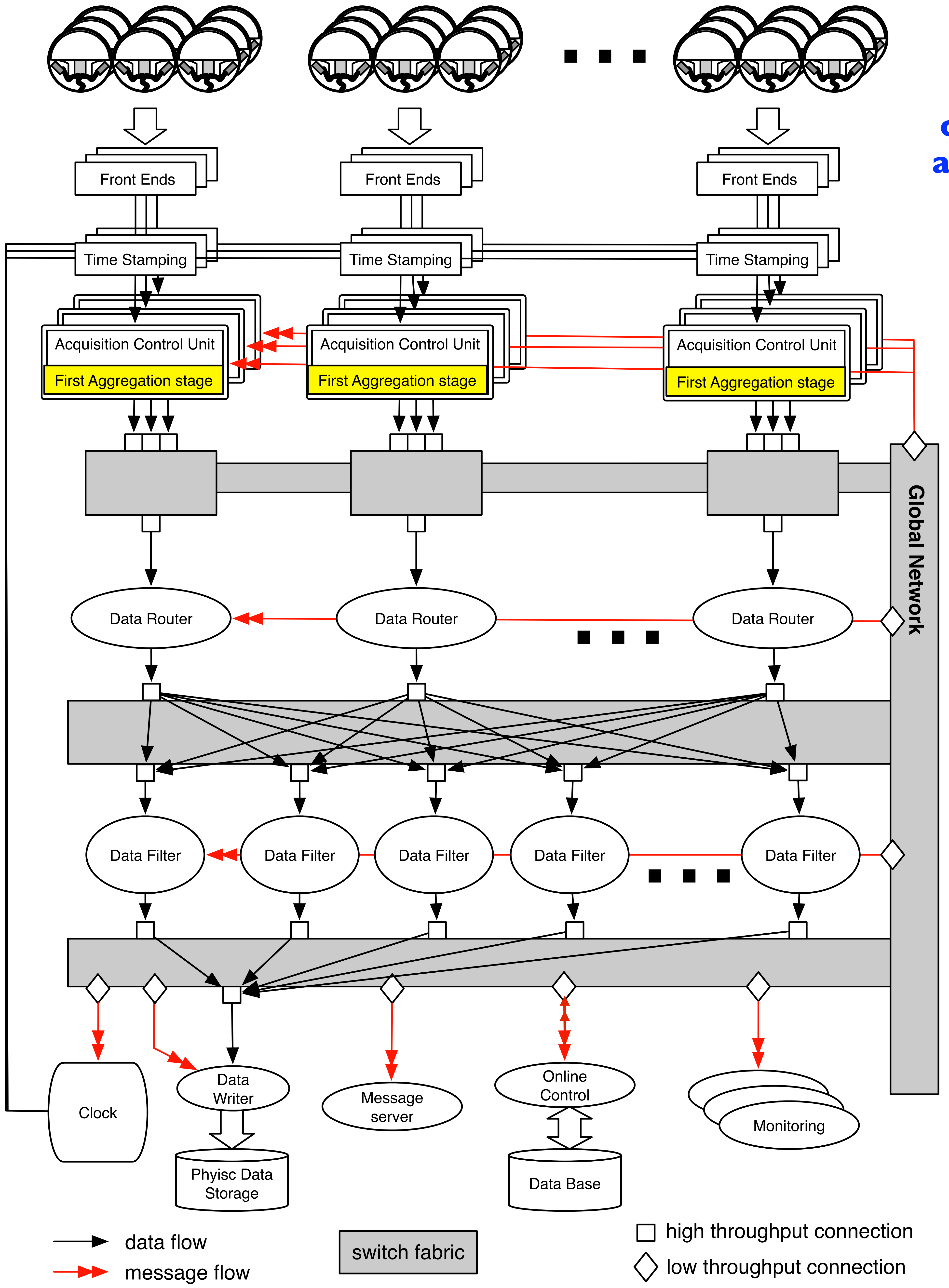
- **continuous,**
- **asynchronous**

channels streaming out of over-threshold (L0-skipping) samplings



The data are streamed out to the *Trigger-less Data Acquisition System* - ***TriDAS***, implemented on the computing resources


time
Time-slice i-1
Time-slice i
Time-slice i+1
all channels
Scan full TS - all channels
for Level 1 triggers events
Event 1
Event 2
Event n-k
Event n
...
...
Event by event check for Level 2 triggers
at least
one L2 ?
No
Drop
Yes
Storage



off-shore acquisition

aggregation and routing

filtering

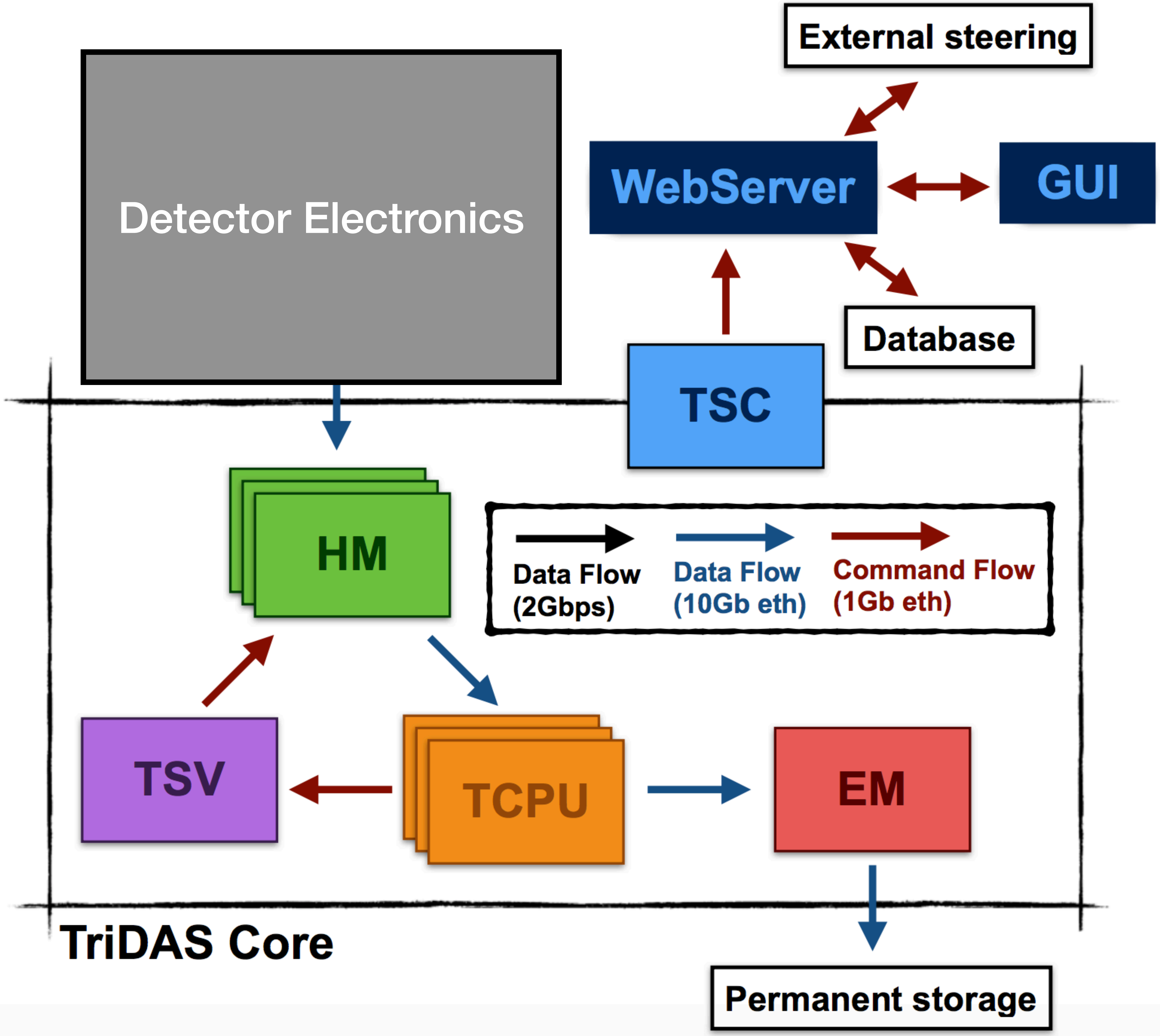
storage & control

A similar DAQ model is applied to both ANTARES and KM3NeT.

a) It ***exploits fixed latency electronics*** for clock distribution (different implementations)

b) The recorded type and number of information per each hit may be different.

c) It can be generalised for other applications, with the due dimensioning of resources.

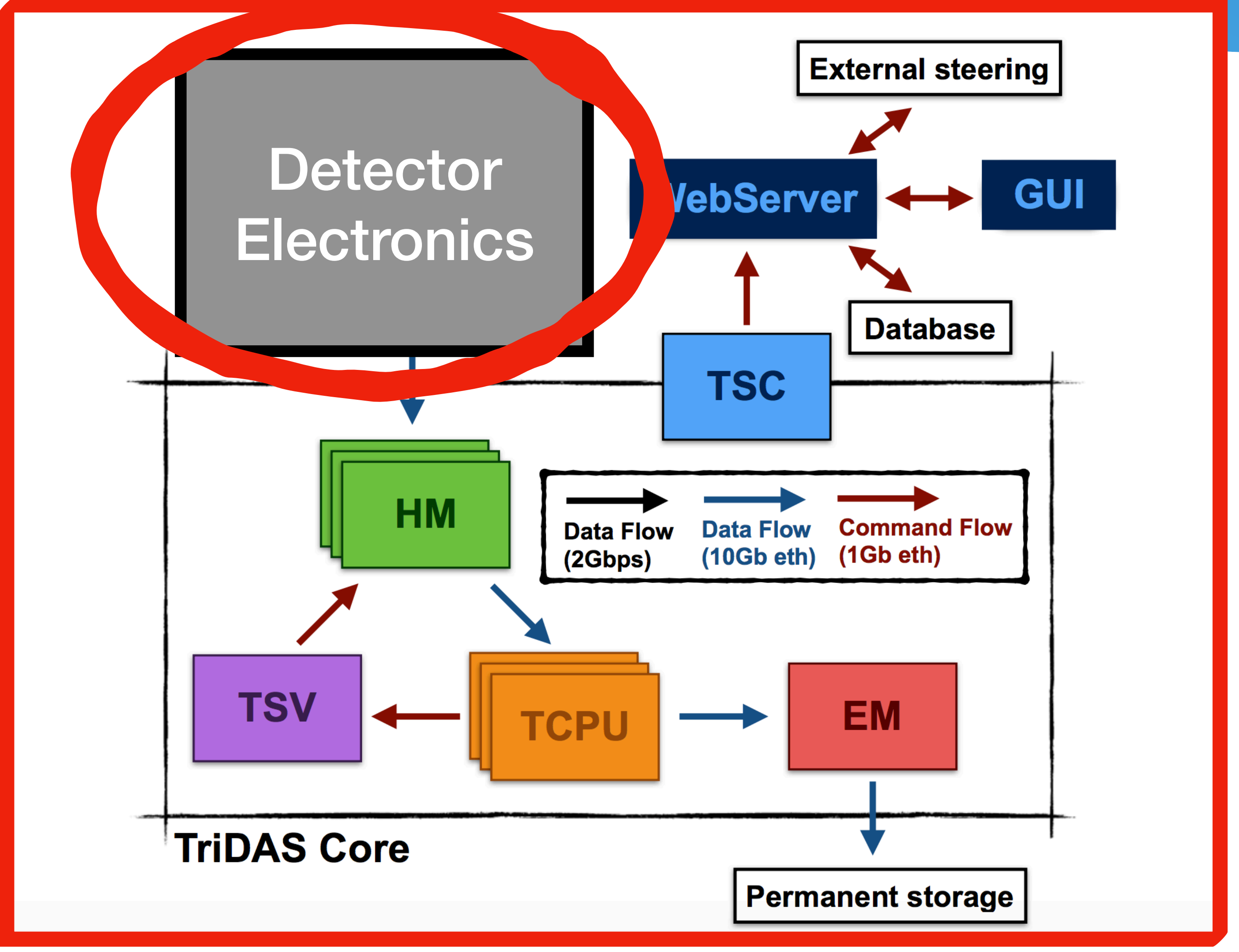


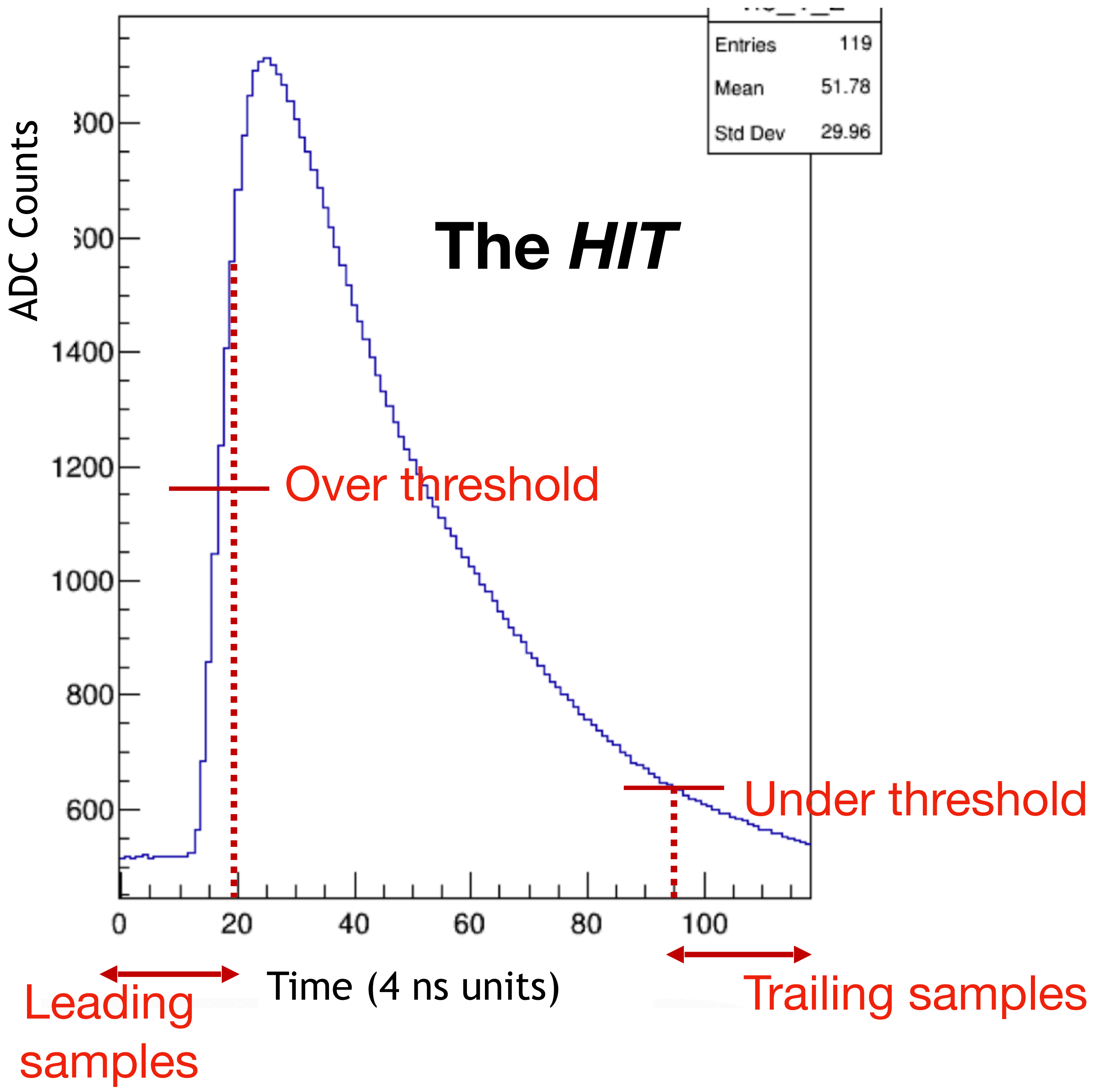
TriDAS core written in C++ 11

Auxiliary technologies

boost C++ LIBRARIES, Jenkins, git, ANGULARJS, Crossbar.io

Atlassian Bitbucket, CMake, ØMQ



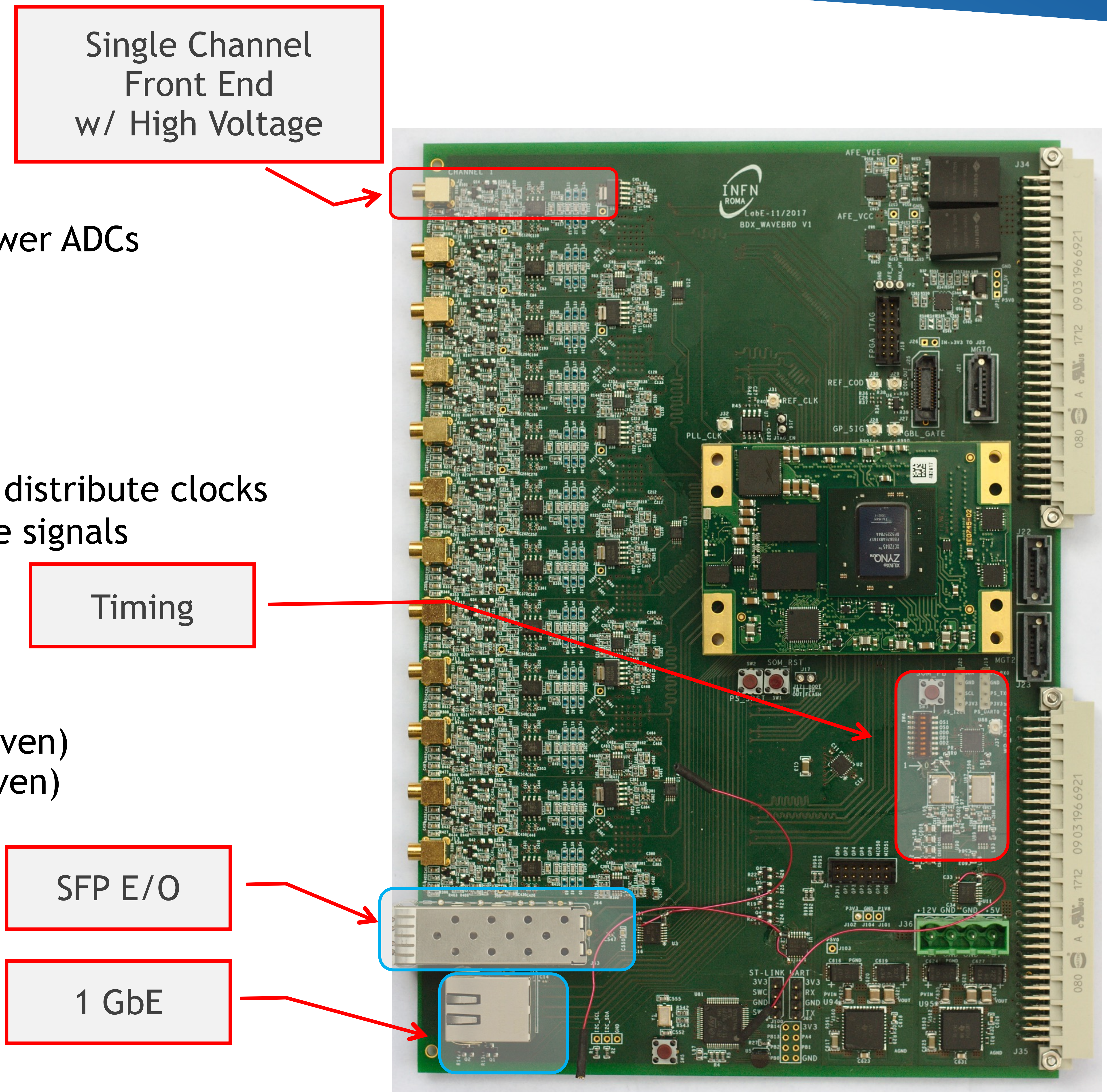


From Fabrizio Ameli's yesterday talk

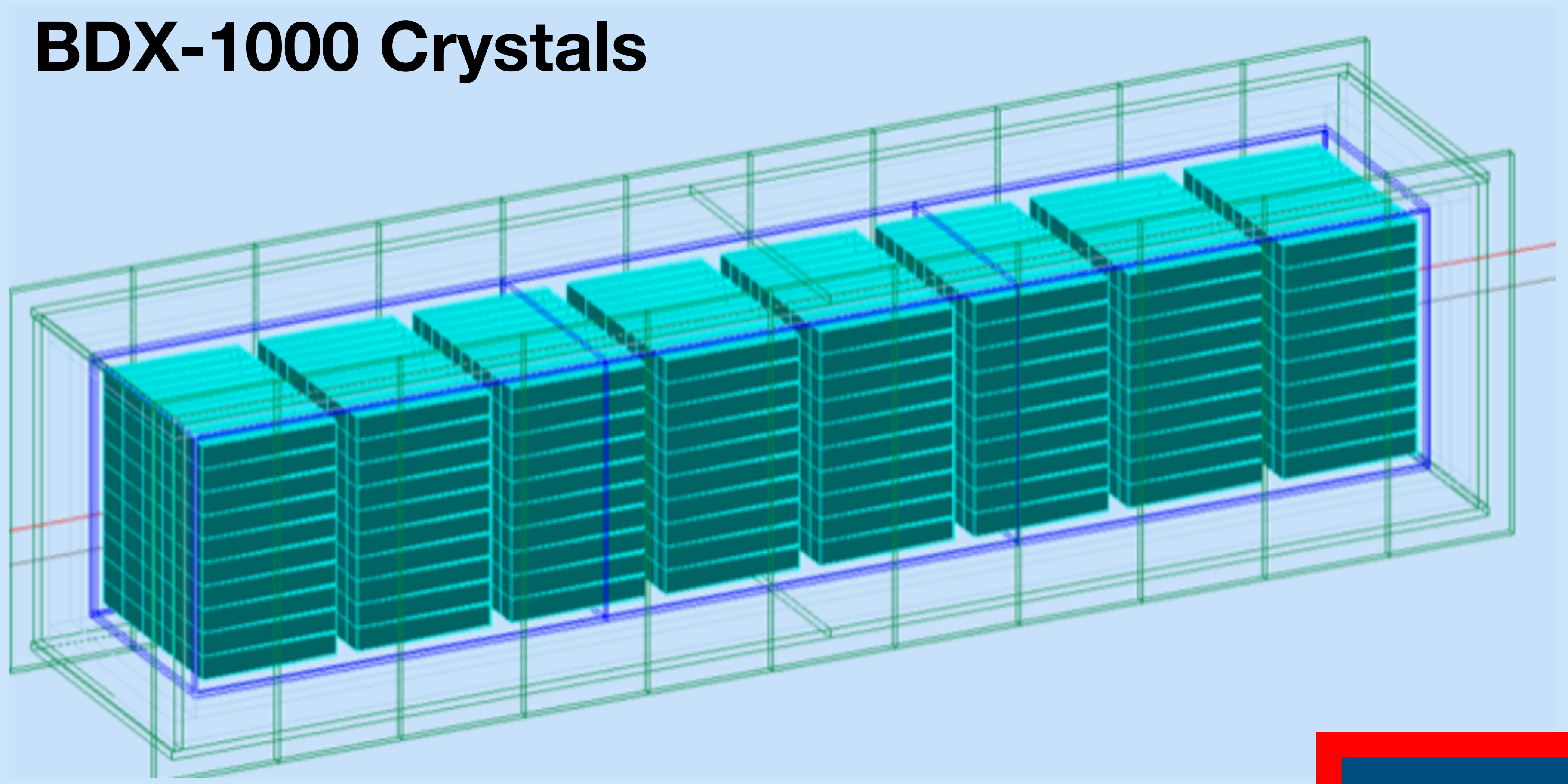
Signal channels:
- 6 dual-channel ultra low-power ADCs (12/14 bit up to 250MHz)

Timing:
- Timing interfaces:
- PLL to clean, generate, and distribute clocks
- External clock and reference signals
- White Rabbit enabled board

High Speed interfaces:
- 1 x GbE connector (PS driven)
- 1 x SFP connector (PL driven)

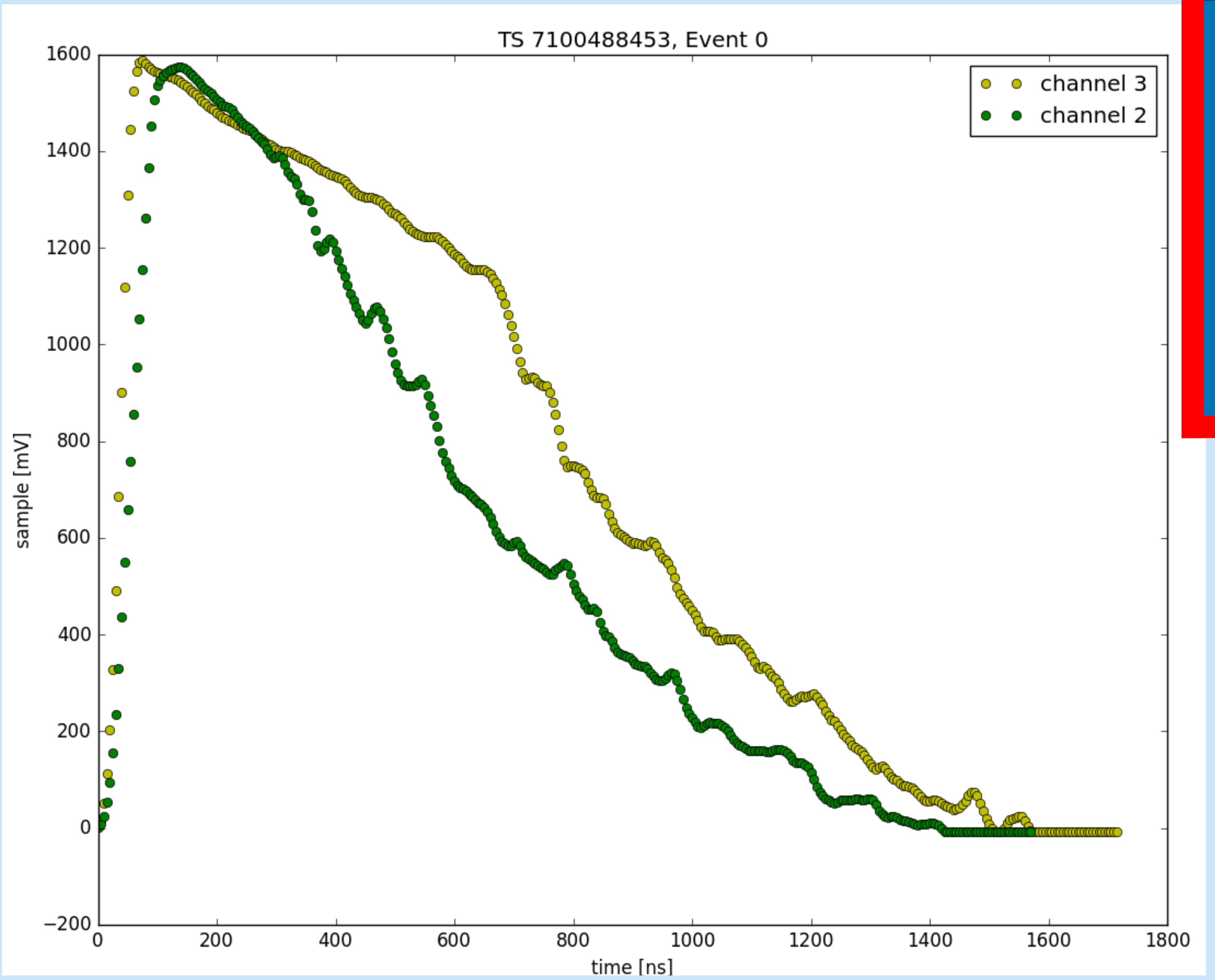


BDX-1000 Crystals

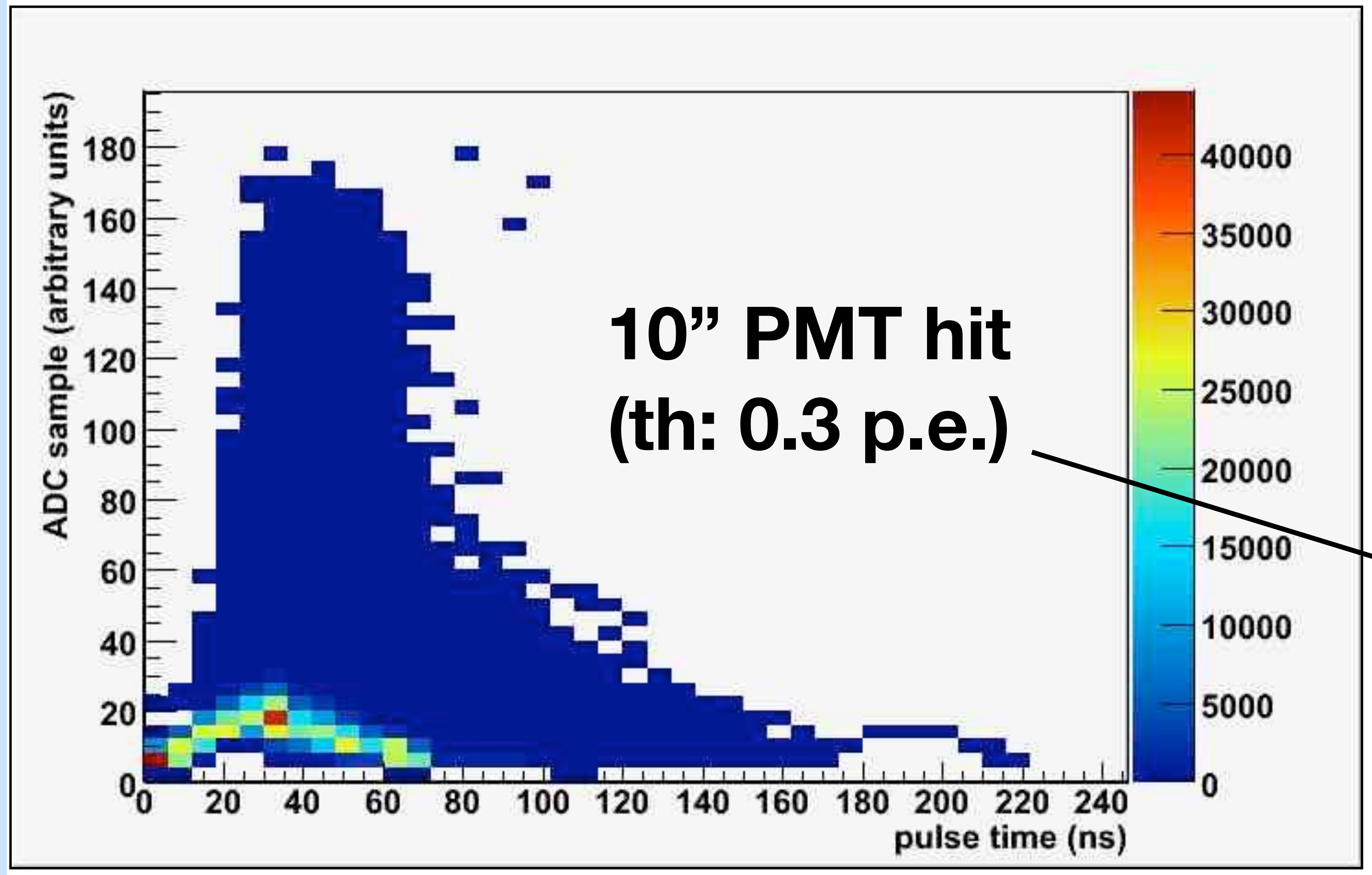


A sketch of a KM3NeT-Italy tower

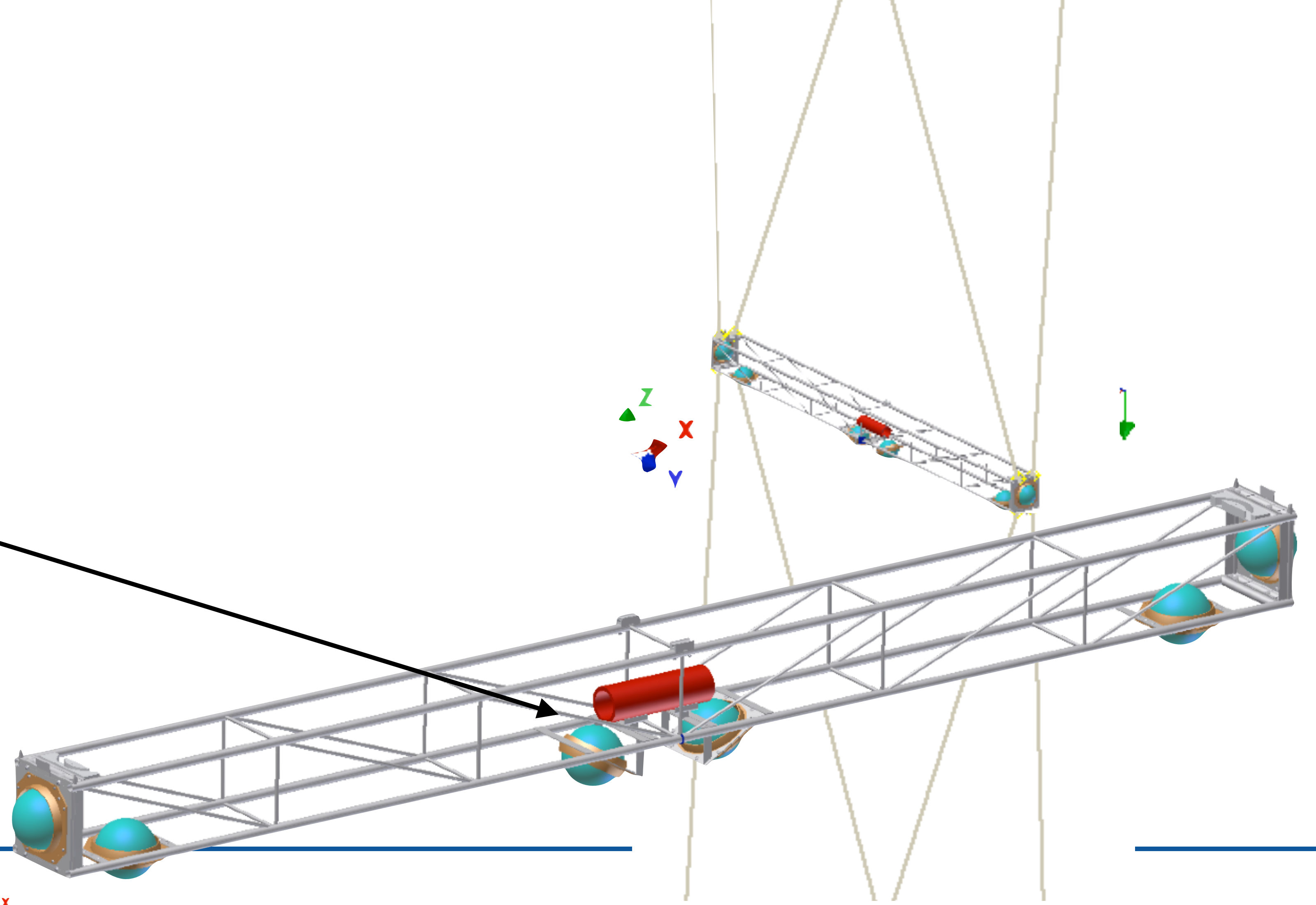
	BDX	KM3NeT (Towers)
N. Channels	**1000** (only crystals considered)	**672** (6 PMTs x 14 floors x 8towers)
Single rate/channel (Hz)	5	50×10^3
Hit size (B)	3×10^3	46
Global Throughput (Mbps)	**120**	$\mathbf{12 \times 10^3}$

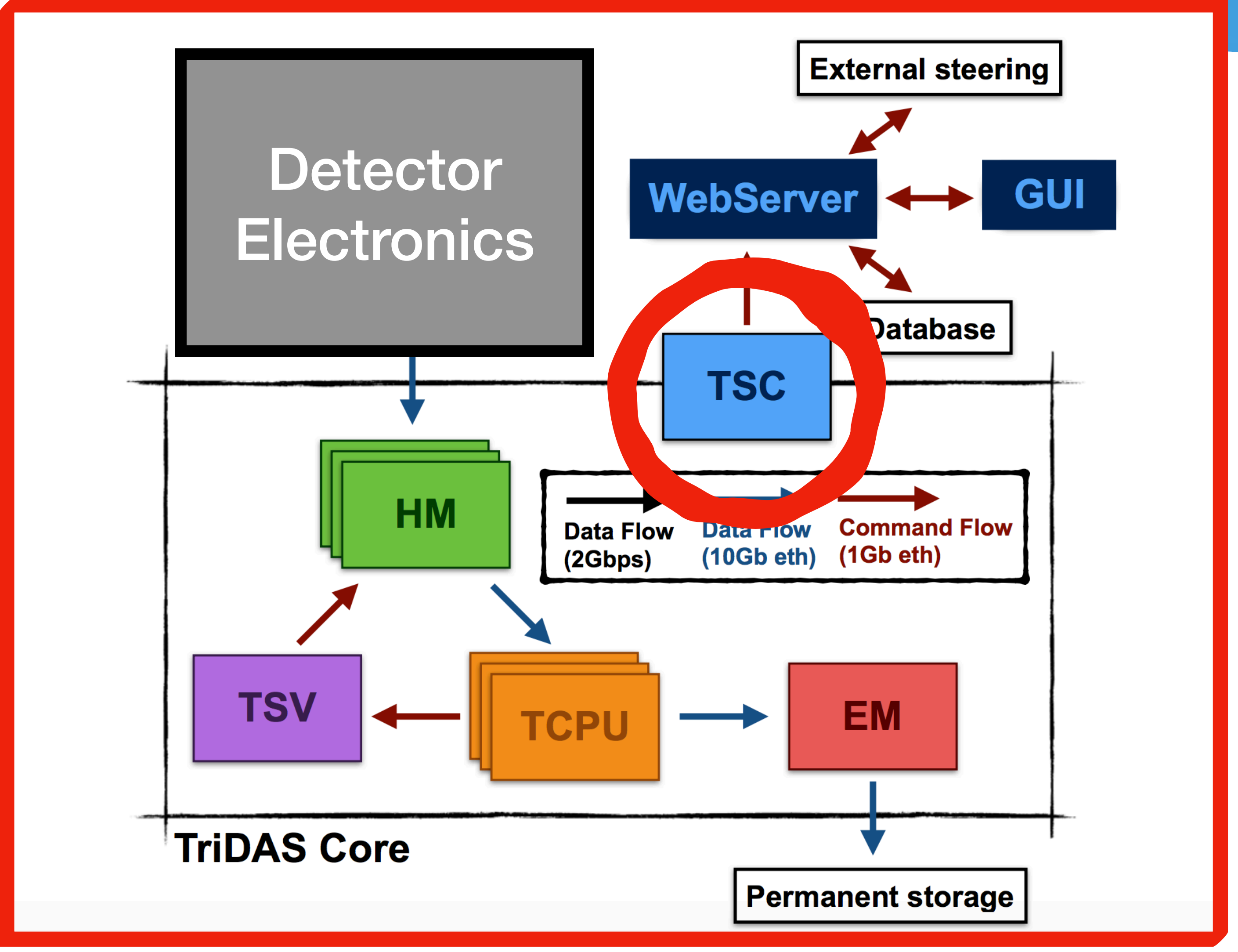


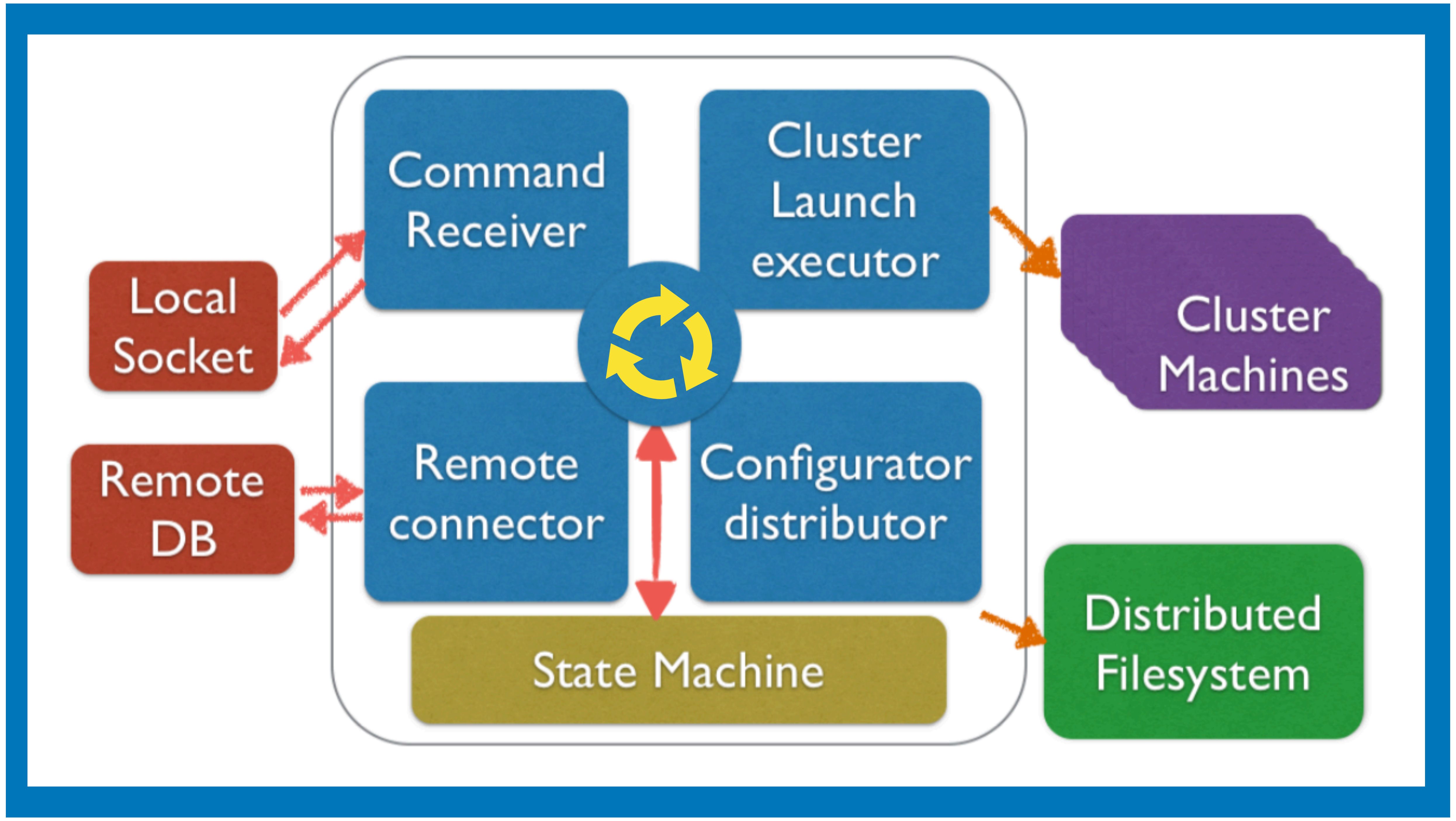
SiPM-CsI(Tl) chrystals hit (th: 0.5 p.e.)



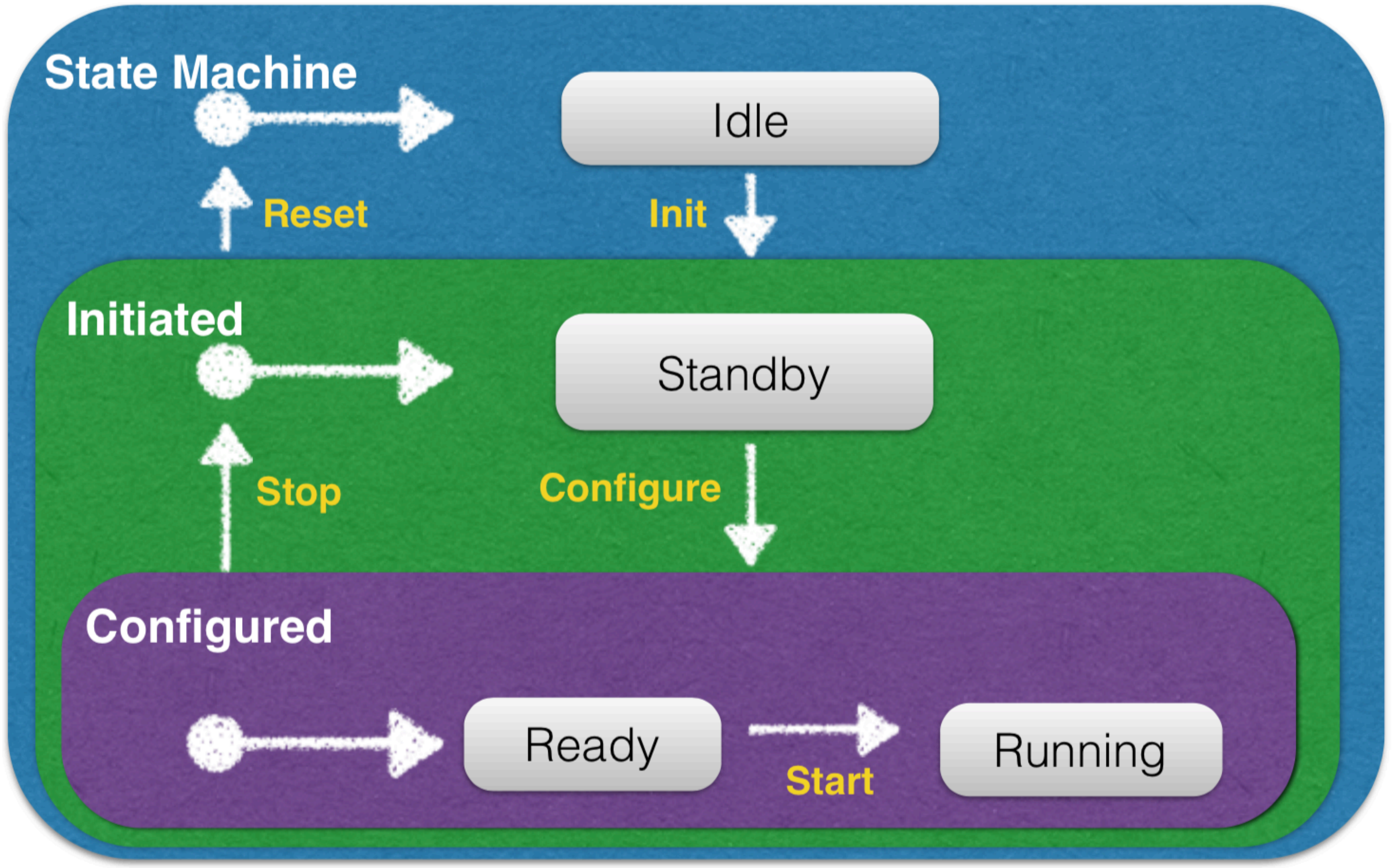
10" PMT hit (th: 0.3 p.e.)

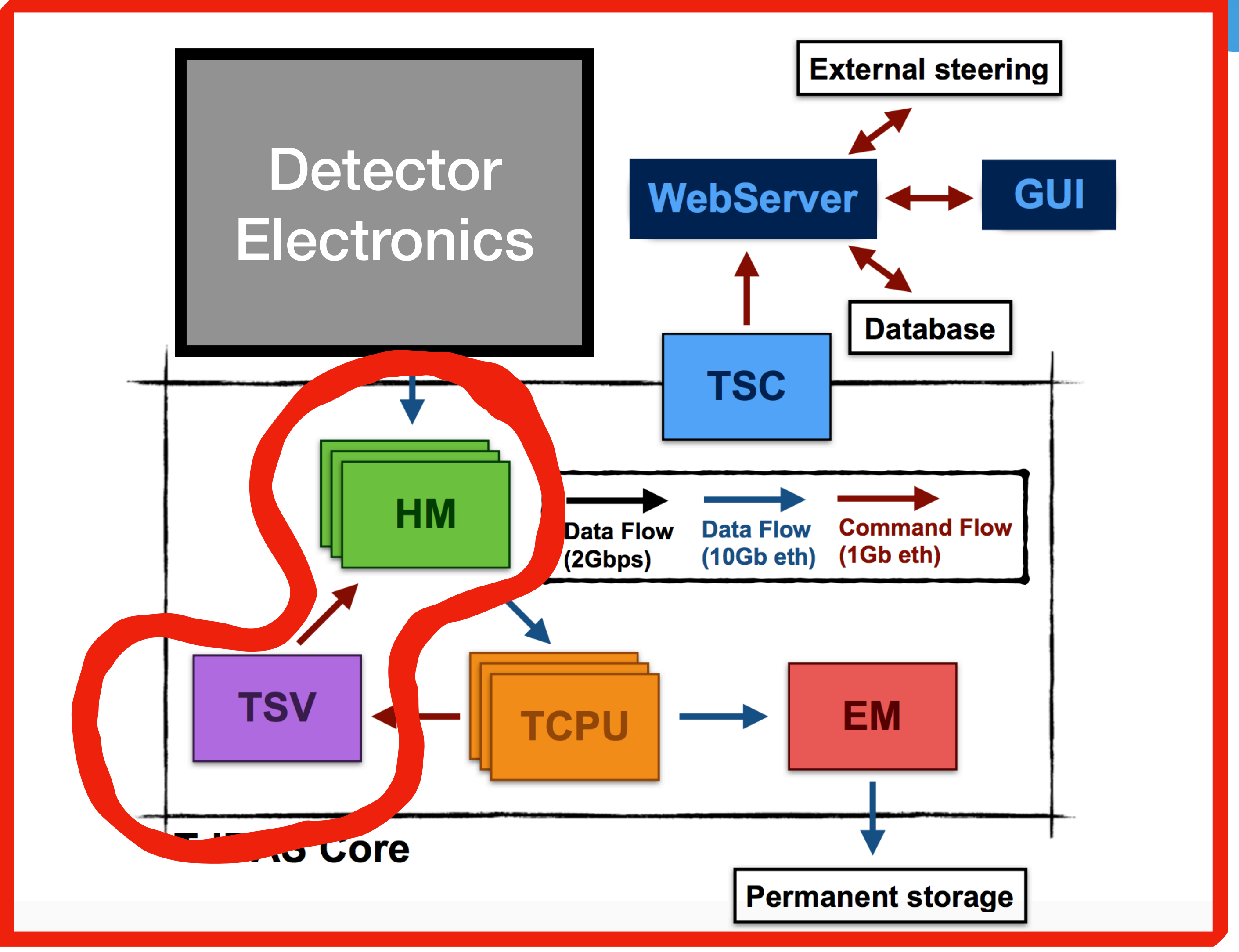


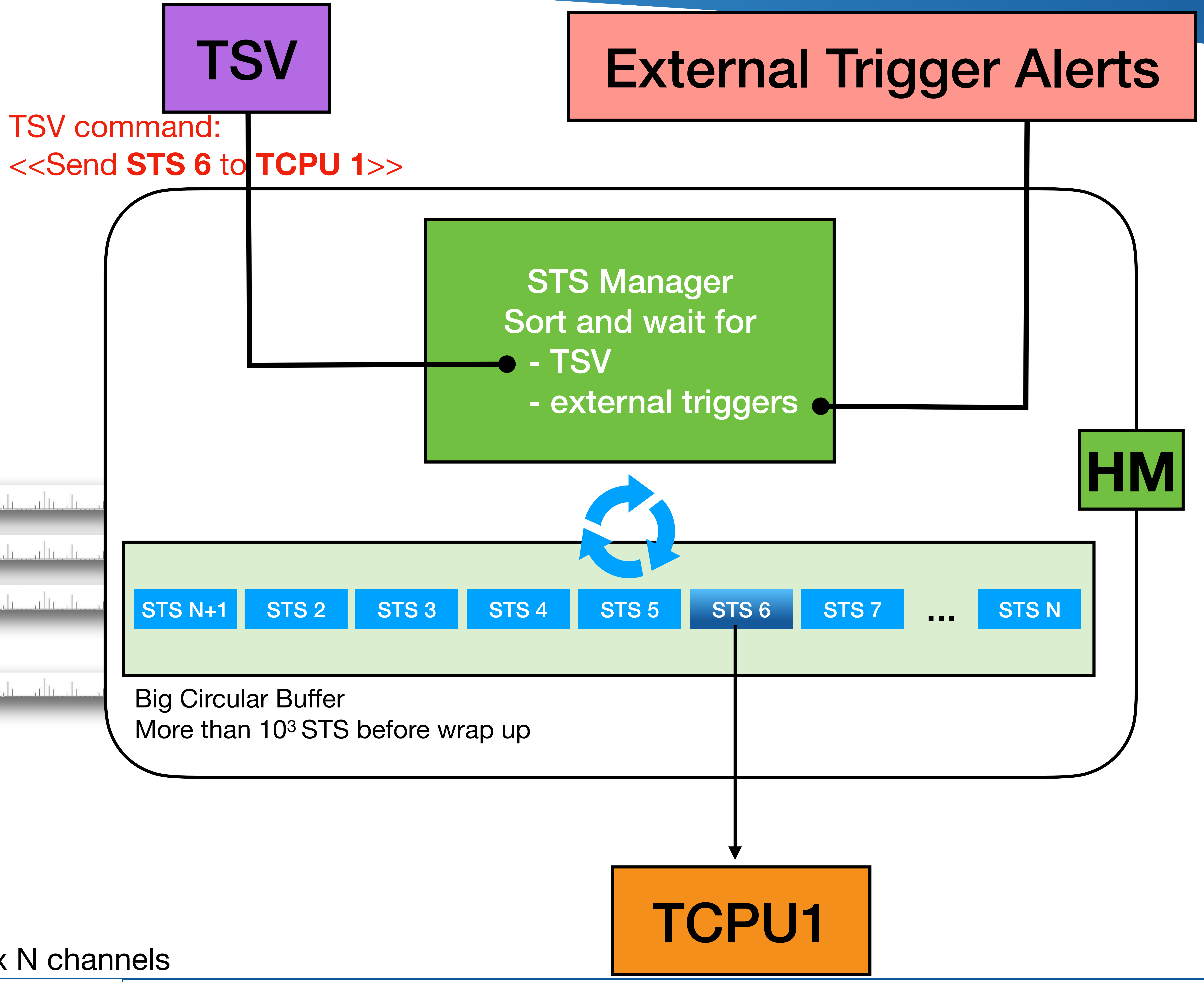


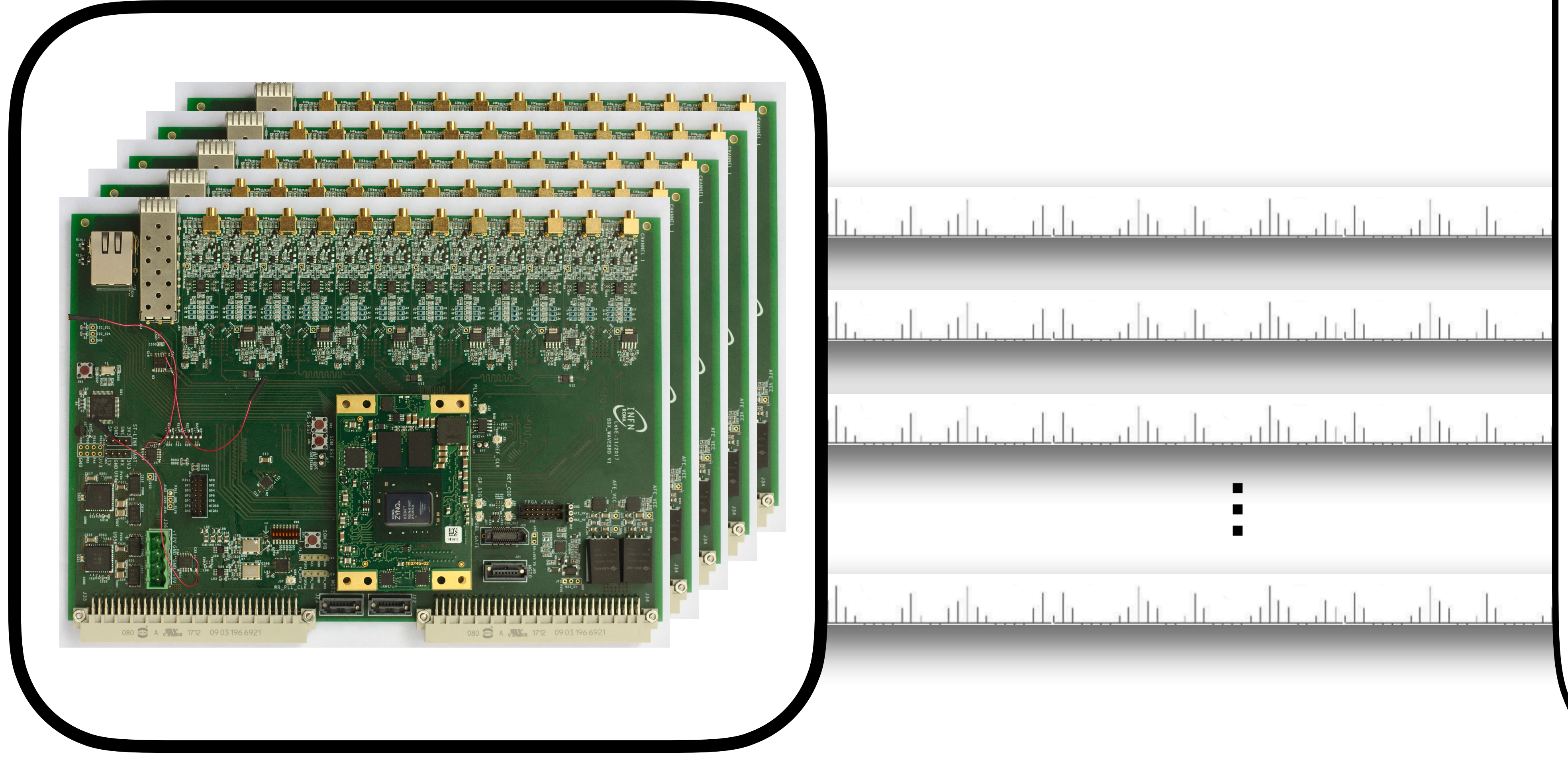


TriDAS
Hierarchical State Machine



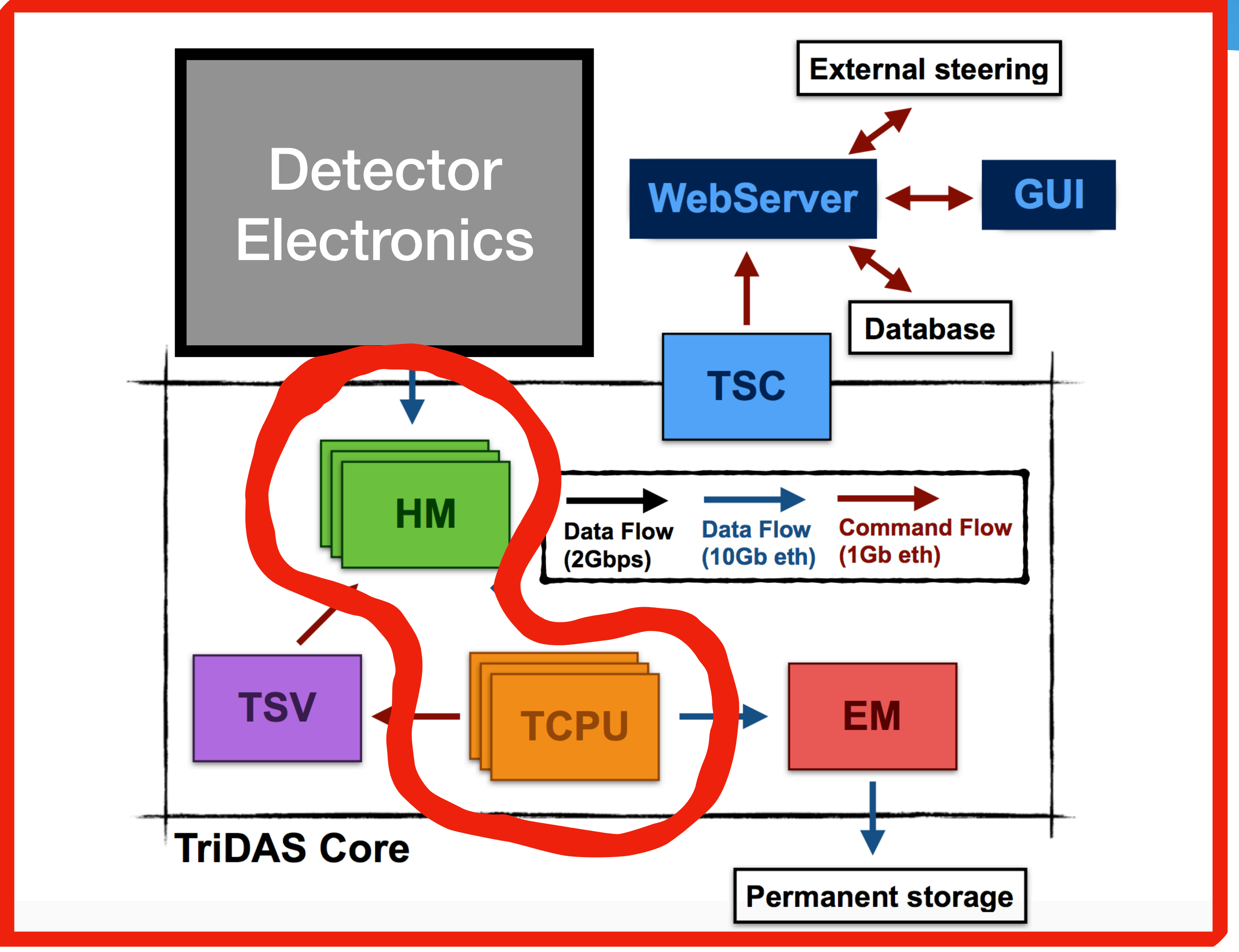




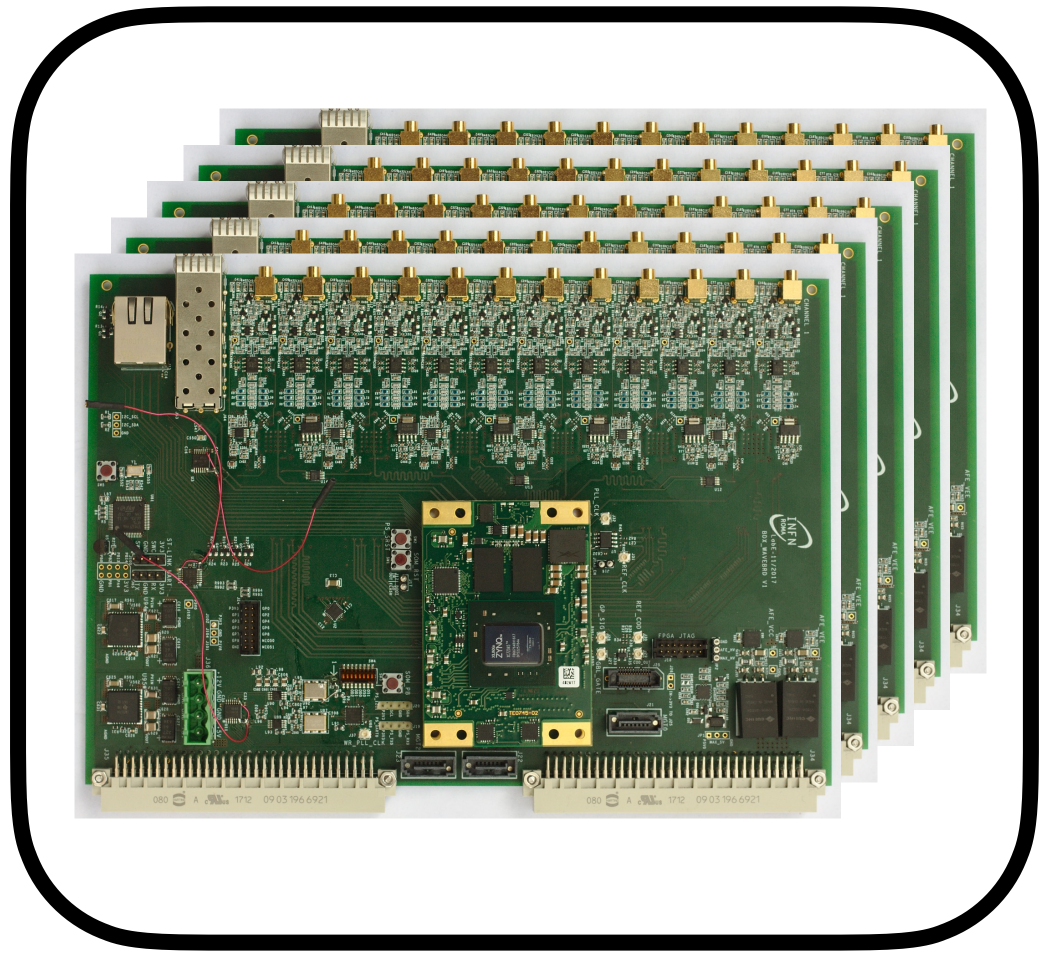


1 Sector
N Wave-Boards = *12 x N* channels

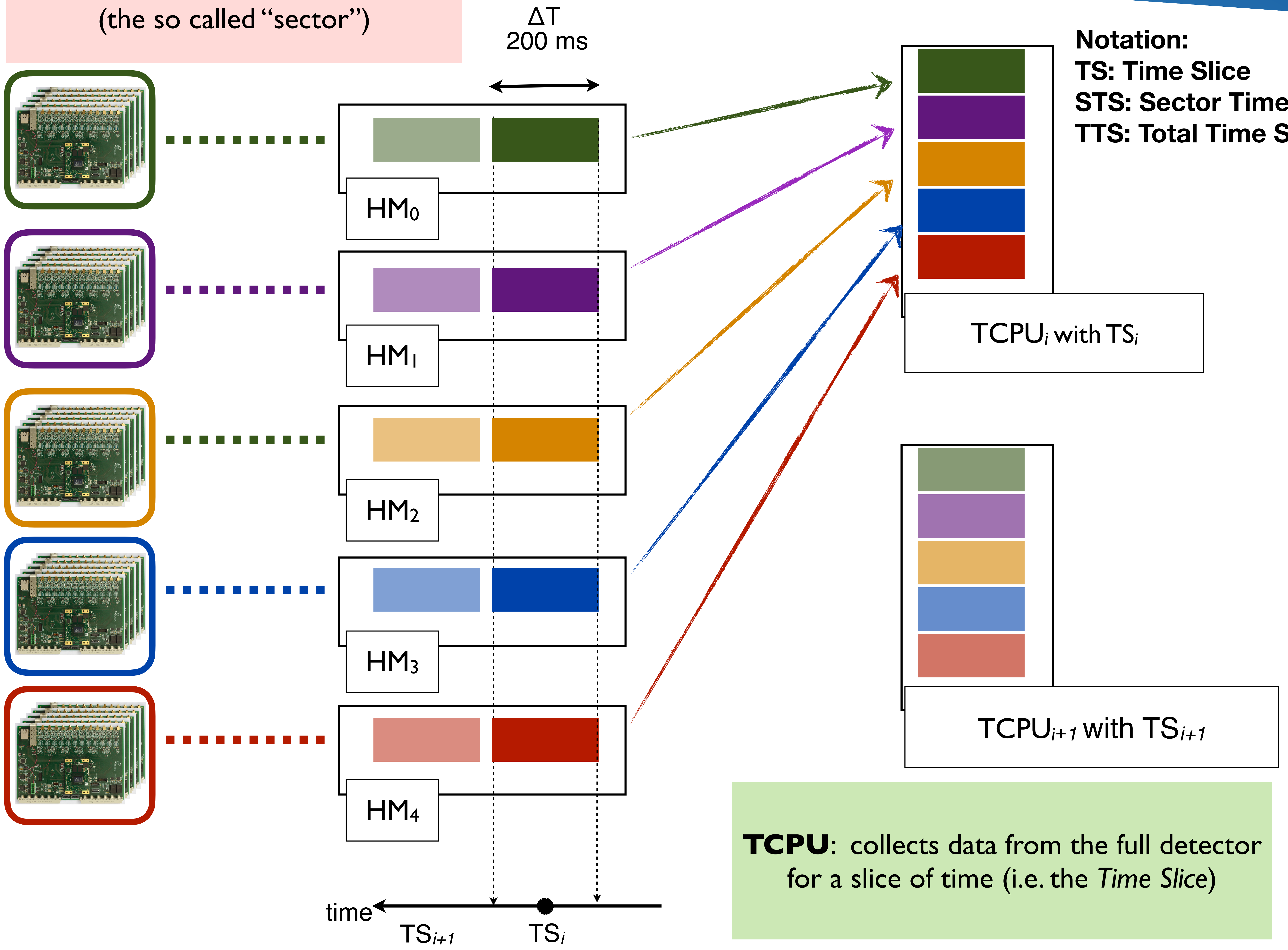
Notation:
TS: Time Slice
STS: Sector Time Slice, containing data from 12 x N channels



HM: receives subsequent data from a fraction of the detector (the so called "sector")

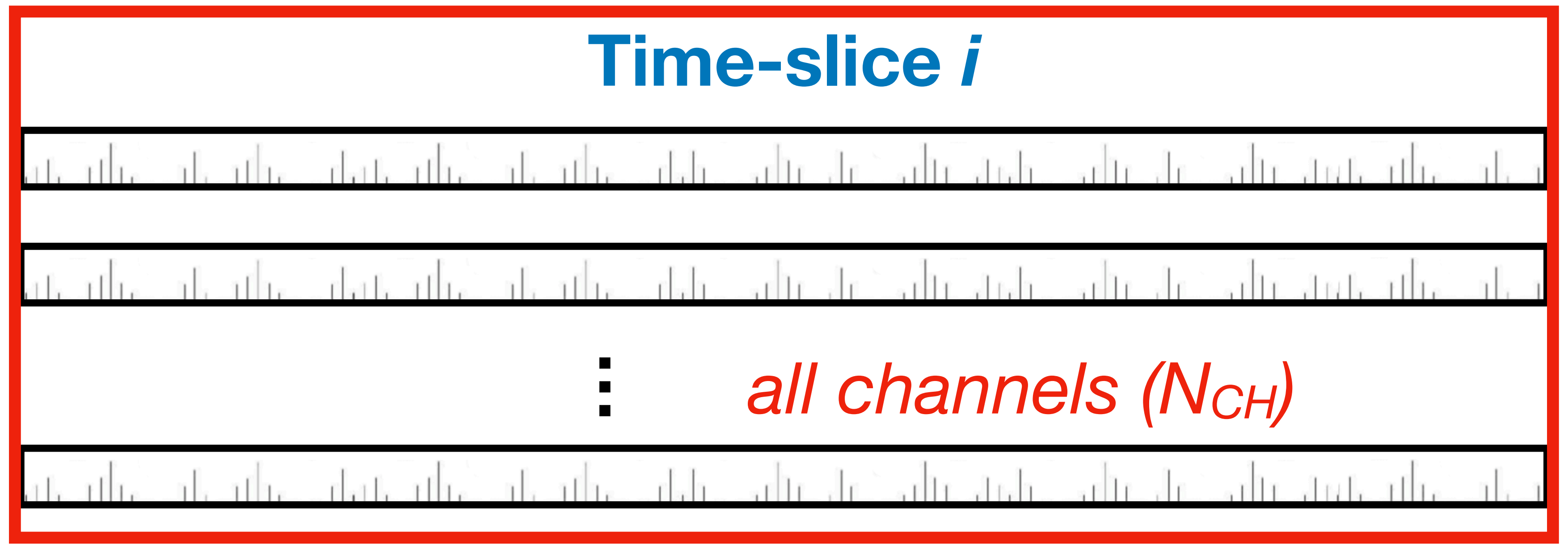


1 Sector
N Wave-Boards = *12 x N* channels



Notation:
TS: Time Slice
STS: Sector Time Slice
TTS: Total Time Slice

TCPU: collects data from the full detector for a slice of time (i.e. the *Time Slice*)

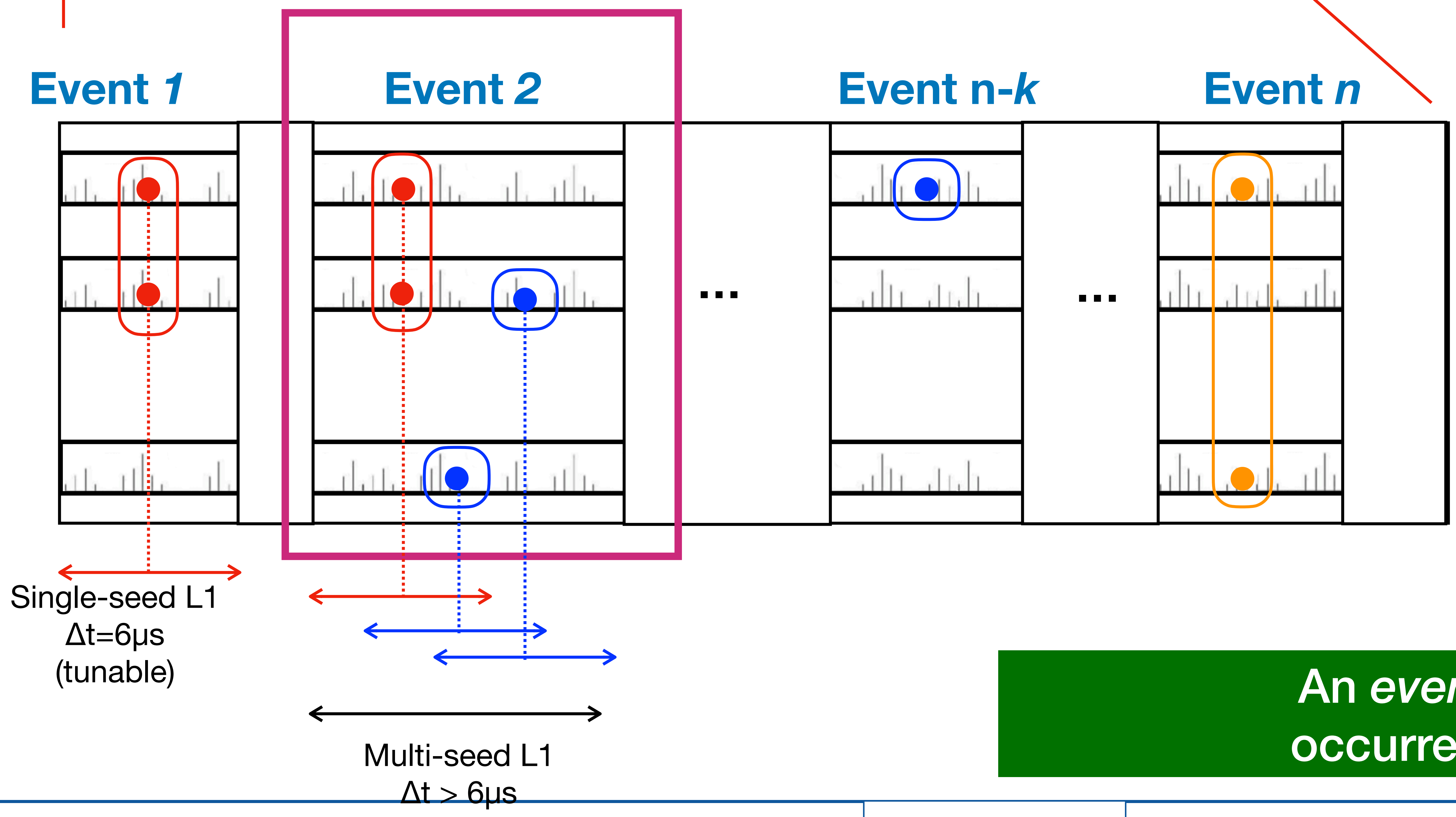


$$N_{CH} = 12 \times N_S \times N_{WBS}$$

N_{WBS} = number of WaveBoard per sector

N_S = number of sectors

All the hits occurred within a given TS, from all the channels of the detector are calibrated and then time-sorted. Finally *Level 1 triggers* seeds are searched for.



L1 seeds

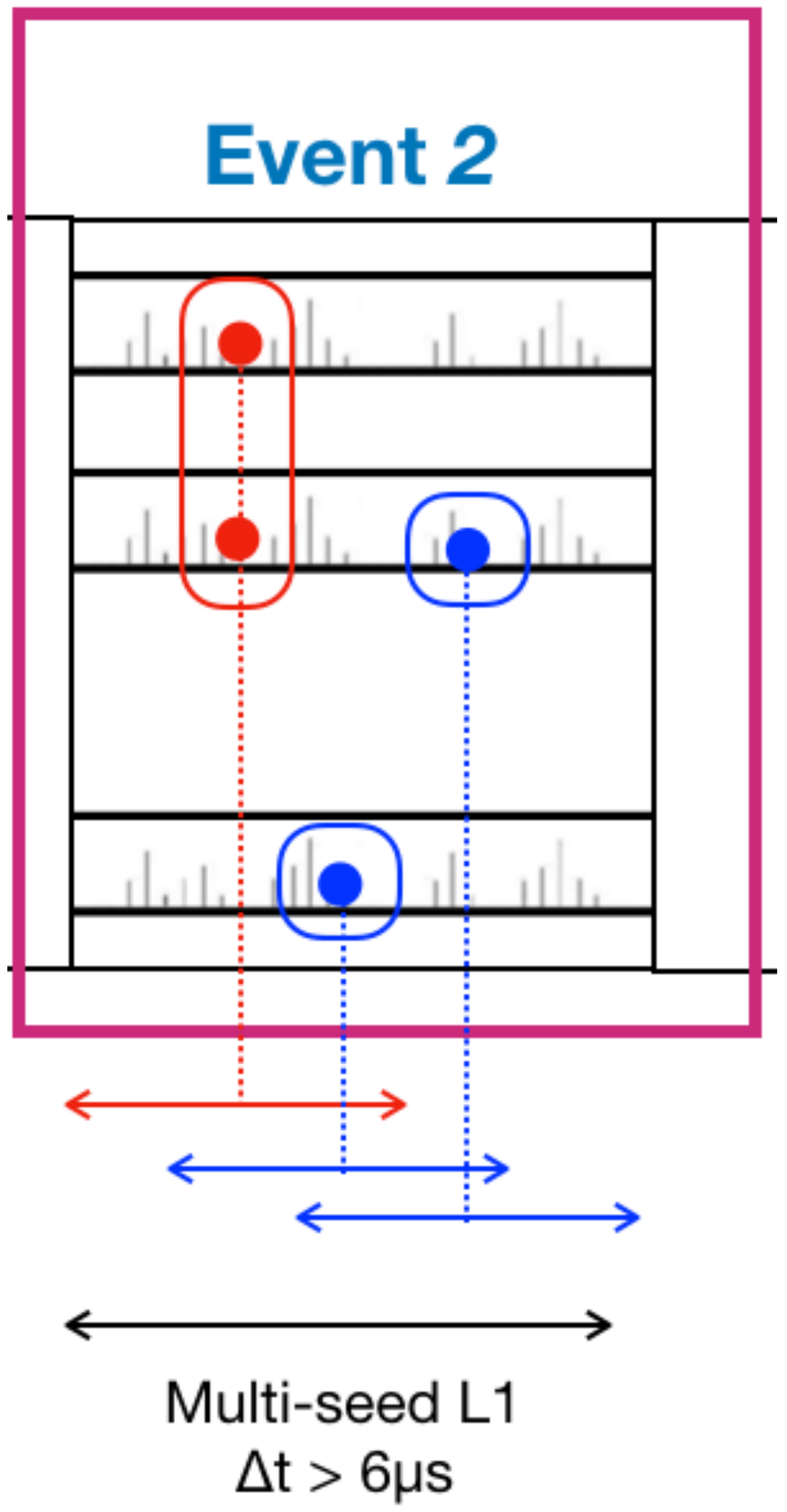
Charge over threshold
($Q \geq Q_{th}$ in ADC)

Coincidence seed 1
(e.g. subsequent scintillators, $\Delta t \leq 10$ ns)

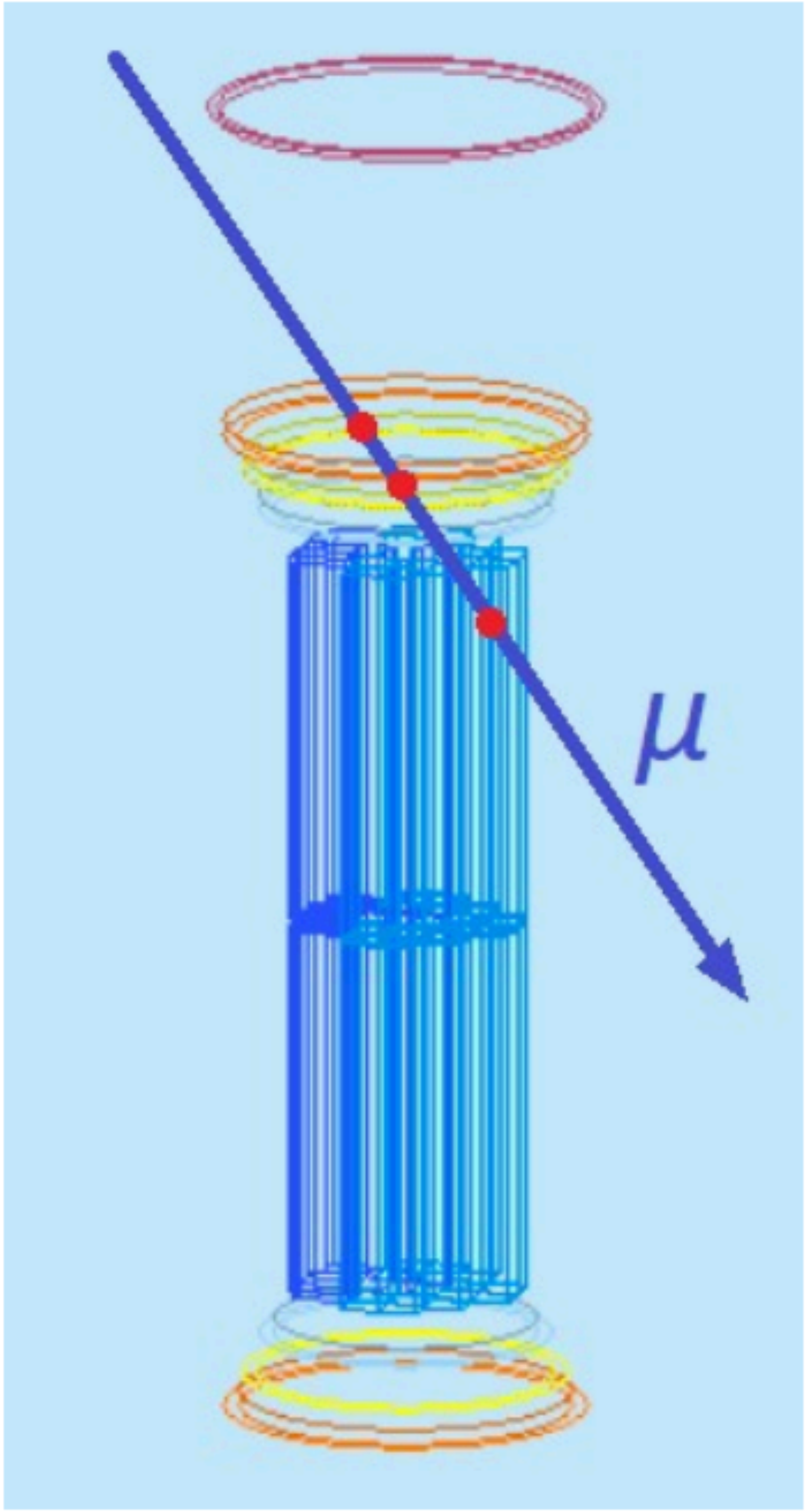
Coincidence seed 2
(e.g. distant scintillators, $\Delta t \leq 100$ ns)

Additional **charge pre-requisite** before testing time-coincidences

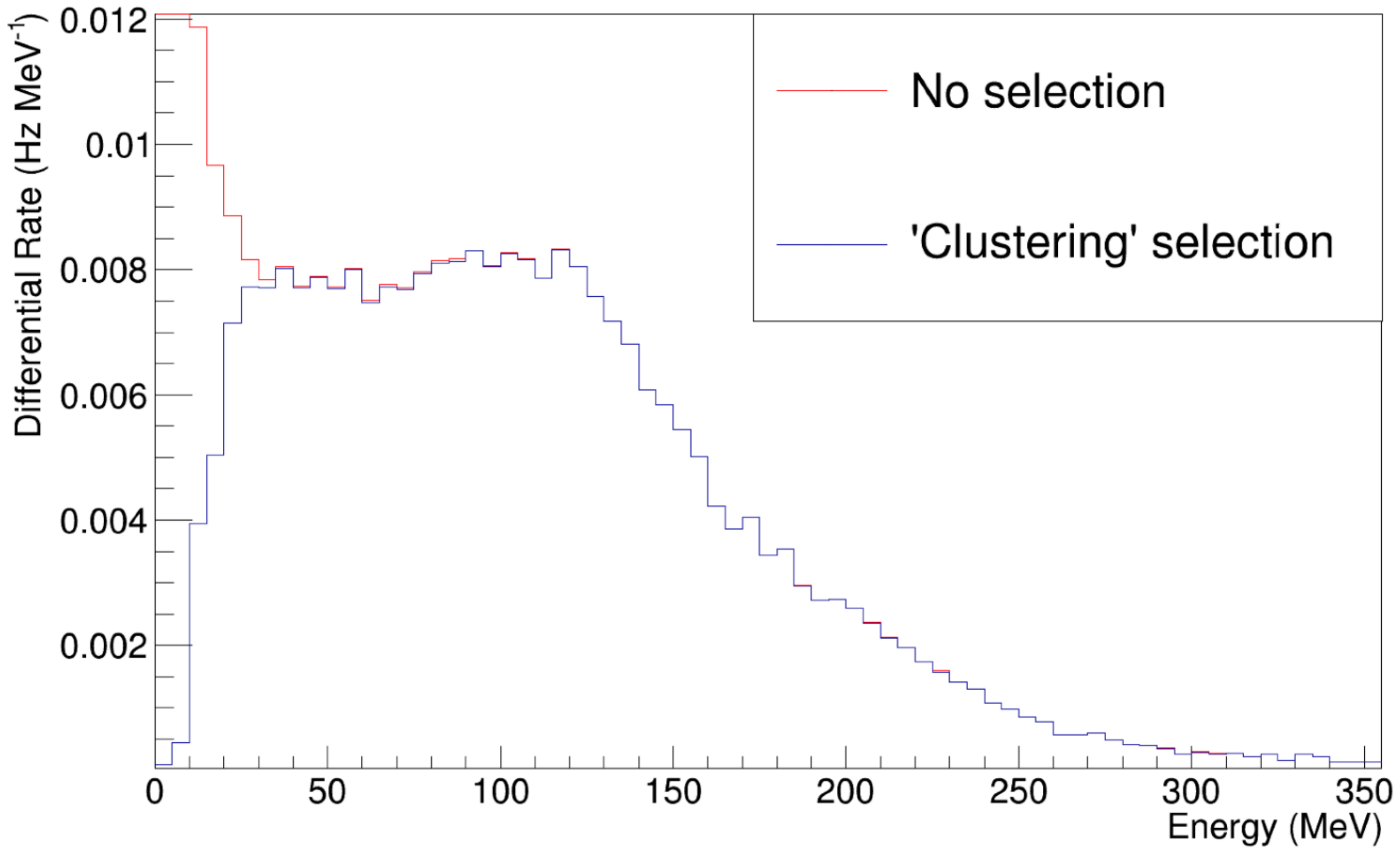
An *event* is a selection of hits from all the detector occurred around the time of one or more L1 seeds



A L2 trigger condition is obtained by combining the hits according to Higher level space-time relation:

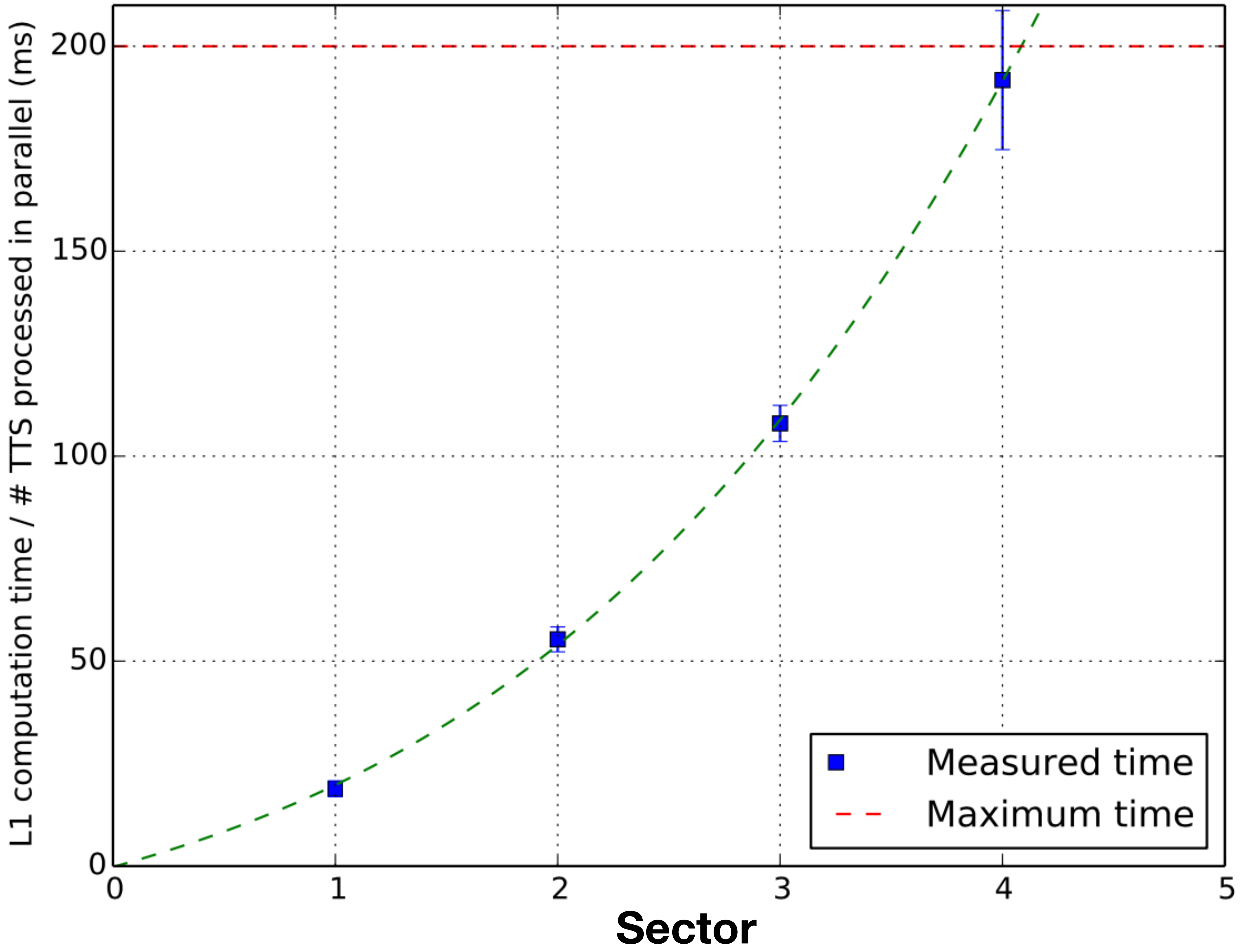


- Simple topological correspondence, such as a veto-condition
- Sequential seeds along a specific direction
- Charge-clustering
- Charge vs. time
- Scalers



For a detailed report of a recent validation of TriDAS with BDX-mini see Luca Marsicano's yesterday talk

- Simulated Poissonian single rate per cahnnel: ***100 kHz***
- N. of TCPUs: 4 nodes (**32 cores** Intel(R) Xeon(R) CPU E5-2640 v2 @ 2.00GHz)
- Concurrent TimeSlice processing: **20 TS in parallel/node**
- Time Slice duration : **200 ms**
- L1 event length: **6 μs**
- 1 Sector = **7 WaveBoards** (84 channels)



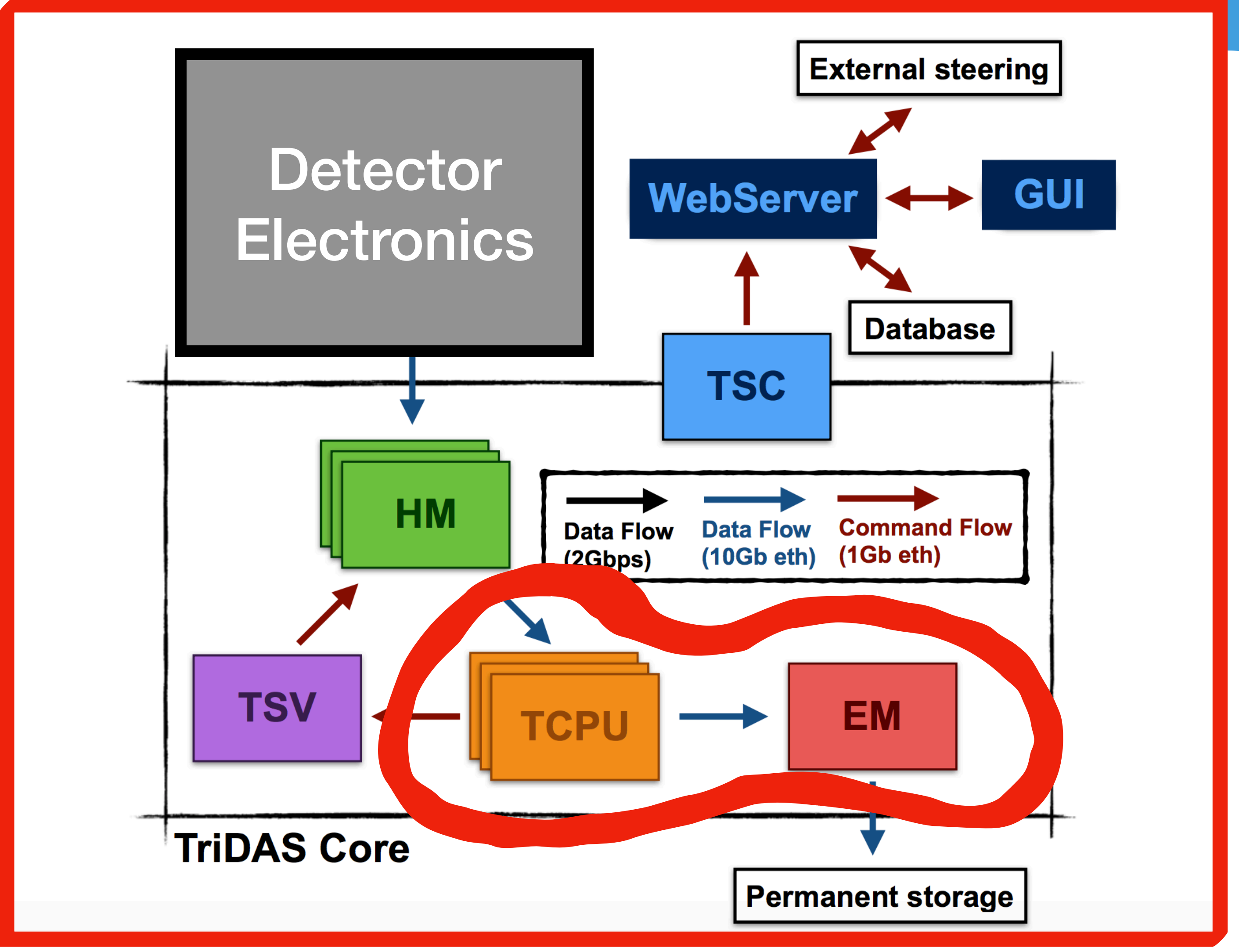
It means that for N>4 Sectors (336 channels at 100 kHz single rate!) additional TCPU nodes are needed (or more trigger threads, if allowed by the computing resources).

Granny's recipe:

add TCPU as much as it suffices !!

…without affecting the DAQ design.

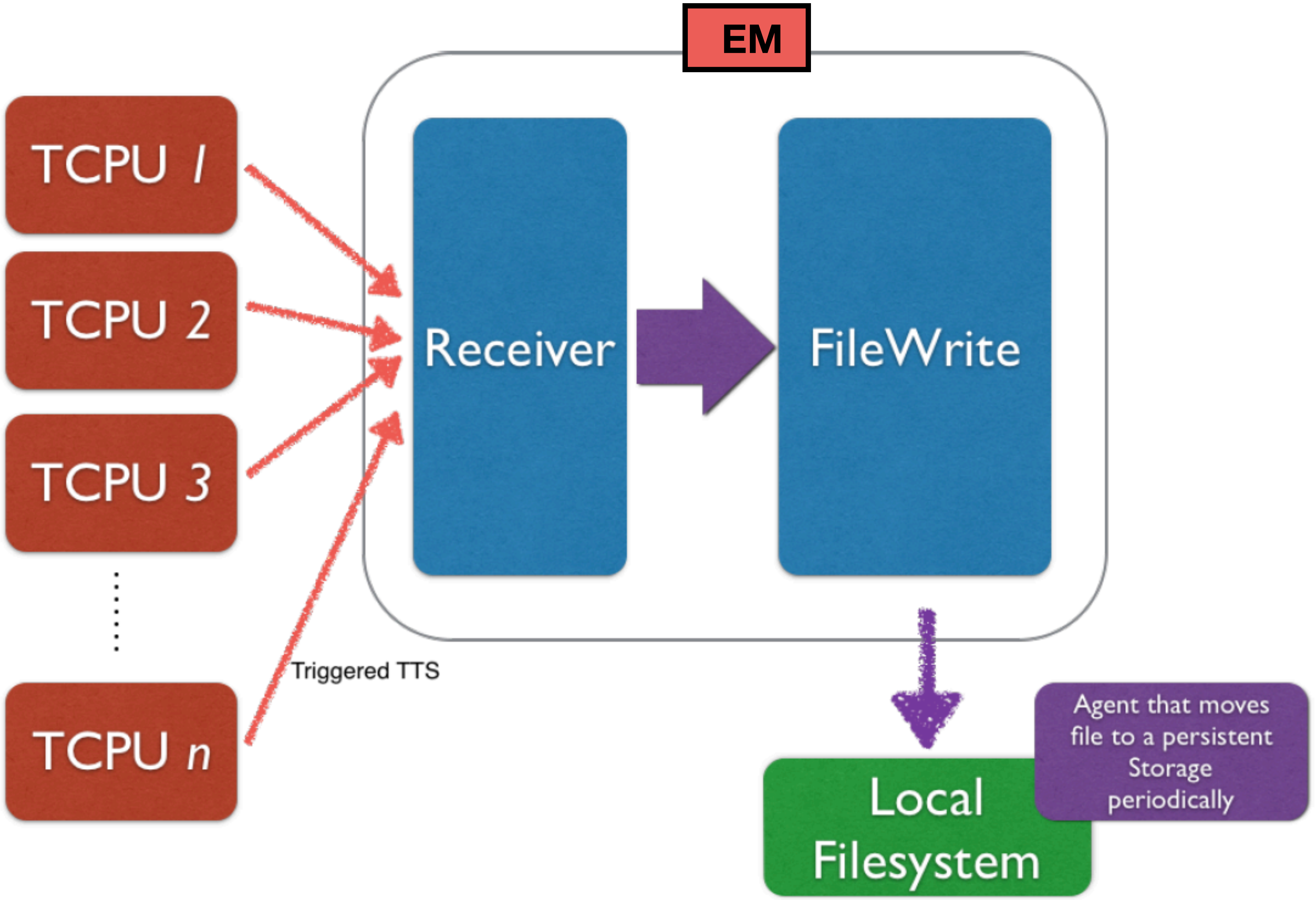
Scalability is granted!



One **event is the collection of hits** which is supposed to describe the passage of neutrino induced muon or shower.

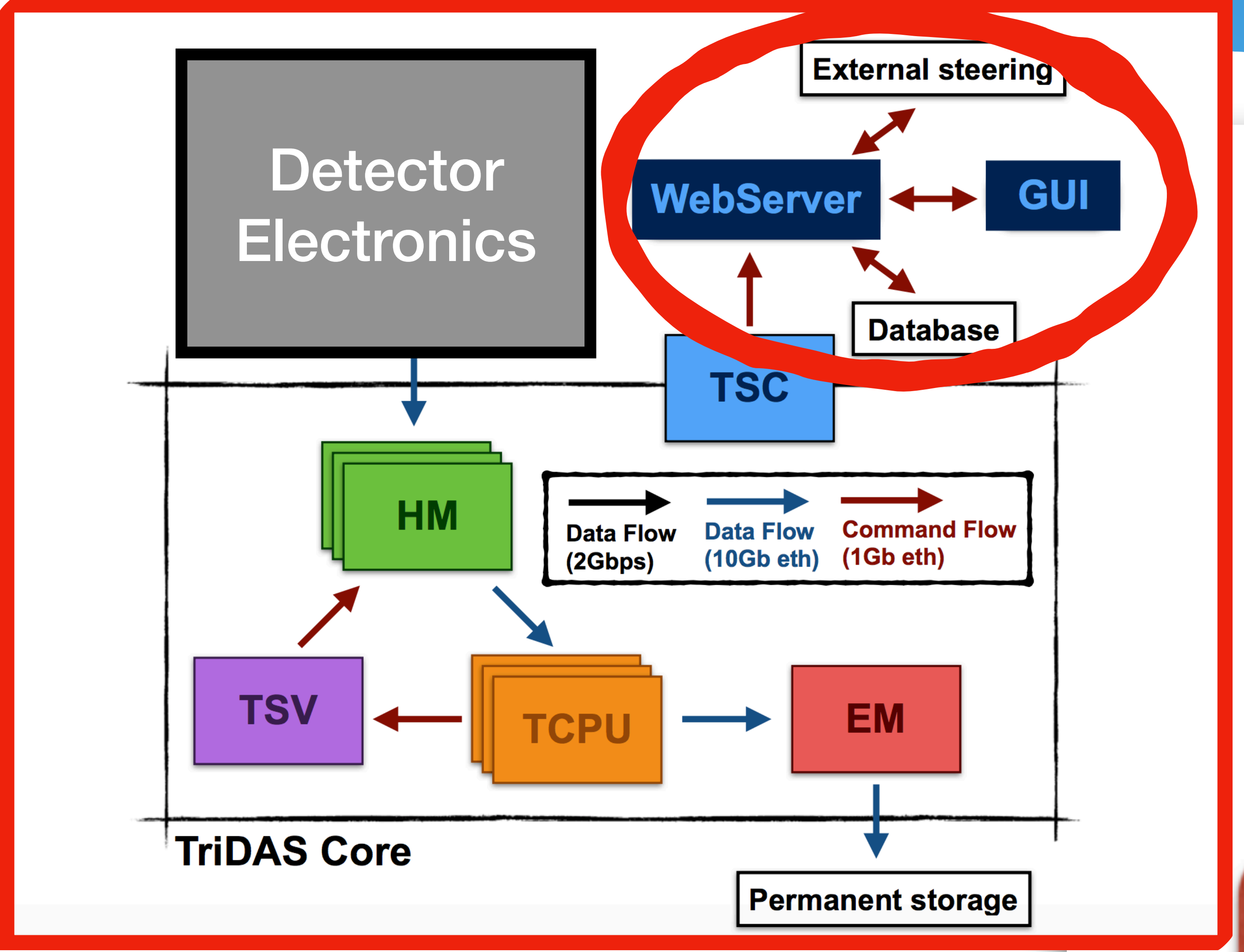
TCPUs **asynchronously process** independent Time Slices. The events are collected, but not time ordered, by the EM into a file.

High-level readout classes are prepared to parse the recorded file.

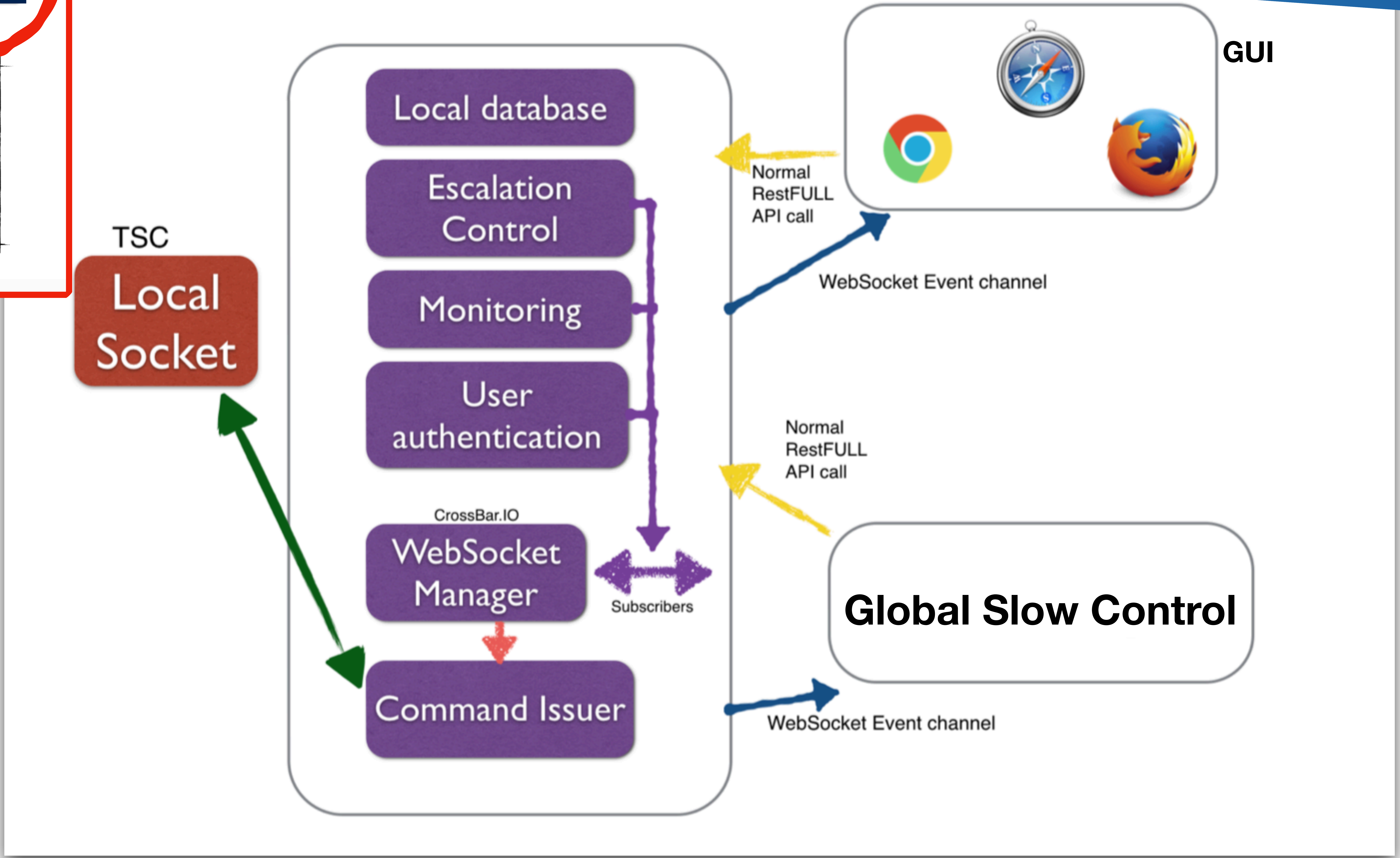


Binary post-trigger file

PTHeaderInfo
Runsetup info (JSON)
TS Header
TriggeredEventHeaderInfo #1
Hit #1
Hit #2
...
Hit #N
...
TriggeredEventHeaderInfo #M
Hit #1
Hit #2
...
Hit #N



Detector Electronics
External steering
WebServer
GUI
Database
TSC
HM
Data Flow (2Gbps)
Data Flow (10Gb eth)
Command Flow (1Gb eth)
TSV
TCPU
EM
TriDAS Core
Permanent storage



TSC
Local Socket
Local database
Escalation Control
Monitoring
User authentication
CrossBar.IO
WebSocket Manager
Subscribers
Command Issuer
GUI
Normal RestFULL API call
WebSocket Event channel
Normal RestFULL API call
Global Slow Control
WebSocket Event channel

The Trigger-less Data Acquisition System, ***TriDAS**,* is a modular and scalable framework for data taking.

Developed in modern C++ , it takes advantage of many world-wide consumed technologies for inter-process communications and data handling algorithms.

With minimal changes and/or parameter-tuning, it is promisingly applicable in different contexts: from large throughput experiments, such as the undersea neutrino telescopes, to beam-dump experiments.

The recent (January 2019) preliminary tests at JLAB with BDX-mini represented an important on-site milestone.
It paved the way to larger setups and long-duration tests, waiting for the final approval of the BDX experiment.

Yet to be done:

- Development of a functional abstract layer, for a virtual topological mapping of the channels. This will enhance the versatility when matching the hardware setup to possible L1 and L2 trigger conditions.

- Realisation of a global Slow-Control framework to steer coherently both the detector and TriDAS

Thank you!

Further readings

T. Chiarusi, M. Spurio, High-energy astrophysics with neutrino telescopes, DOI: 10.1140/epjc/s10052-009- 1230-9, The European Physical Journal C (2010).

C. Pellegrino, et al., The trigger and data acquisition for the NEMO-Phase 2 tower, DOI 10.1063/1.4902796, AIP Conference Proceedings (2014).

M. Pellegriti et al., Long-term optical background measurements in the Capo Passero deep-sea site, DOI: 10.1063/1.4902780, AIP Conference Proceedings (2014).

TriDAS web site: https://bitbucket.org/chiarusi/tridas.

C. Pellegrino, T. Chiarusi , The TriDAS for KM3NeT neutrino telescope, DOI 10.1051/epjconf/201611605005, VLVNT 2015 Conference Proceedings (2015).

R. Ammendola et al., NaNet3: The on-shore readout and slow-control board for the KM3NeT-Italia underwater neutrino telescope, EPJ Web of Conferences 116, 05008 (2016).

M. Favaro, et al., The Trigger and Data Acquisition System for the KM3NeT-Italia towers EPJ Web of Conferences 116, 05009 (2016)

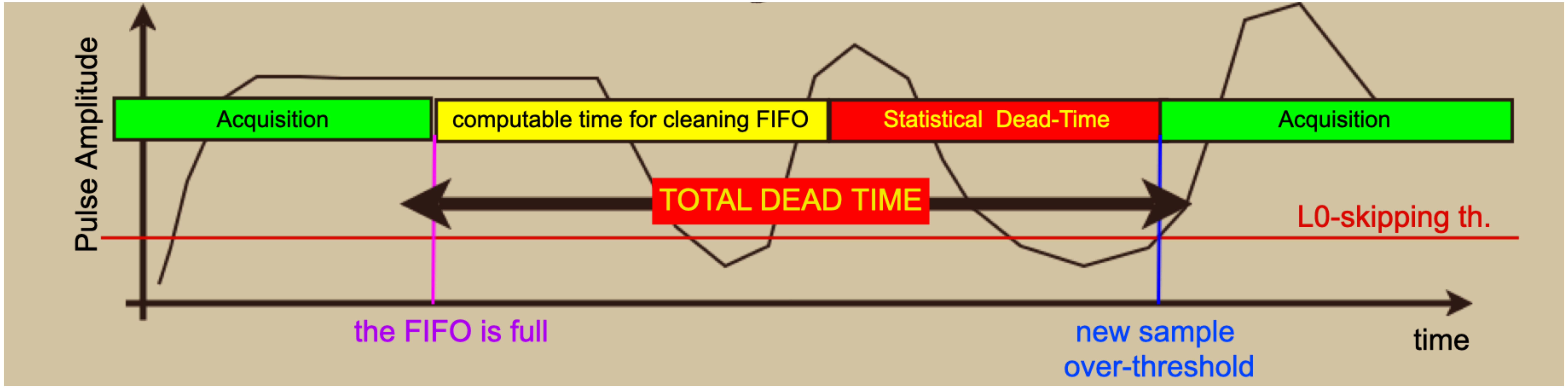
M. Manzali, et al., The Trigger and Data Acquisition System for the KM3NeT-Italy neutrino telescope , Proceedings of CHEP 2016

BDX proposal: https://arxiv.org/abs/1607.01390

Aggingere qualcosa sul sistema di rete

Spare slides

- The overall trigger rate will be $R_{trg} = 5\ Hz/\text{crystal} \cdot 1000$ crystals $= 5$ kHz.
- The data size of each crystal signal is: $D_{crs} = 2048$ samples $\cdot 12$ bit/sample $= 3$ kB. The total data rate from crystals is: $DR_{crs} = D_{crs} \cdot R_{trg} = 14$ MB/s.
- The data size of a FADC-integrated pulse is $D_{veto} \simeq 12$B. Assuming (conservatively) that $N_{veto}/10$ veto counters report a pulse for each trigger, the total data rate from these is: $DR_{veto} = N_{veto} \cdot D_{veto} \cdot R_{trg} = 1$ MB/s.
- The total event rate is: $DR_{tot} \simeq 1.1 \cdot (DR_{crs} + DR_{veto}) = 16$ MB/s. A 10% overhead has been assumed for event-related information (event time, indexes of channels, ...)



An estimation of the statistical dead-time can be done only via MC, using information about the PDF of the hit rates from the real data