INTENSE
First Annual Workshop - 2-3/Feb/2022

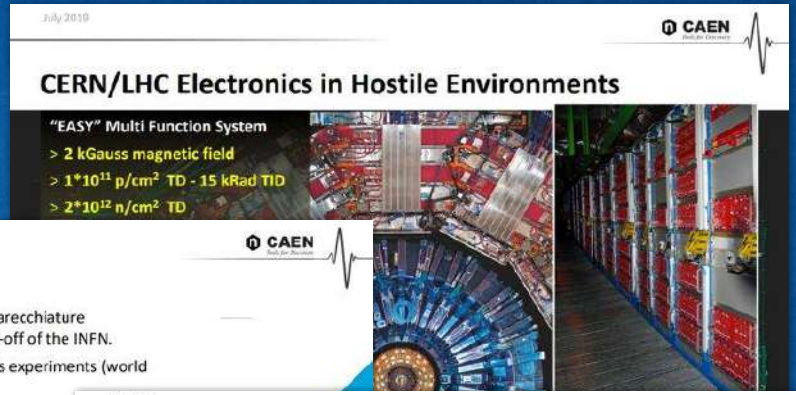
DAQ systems in particle physics

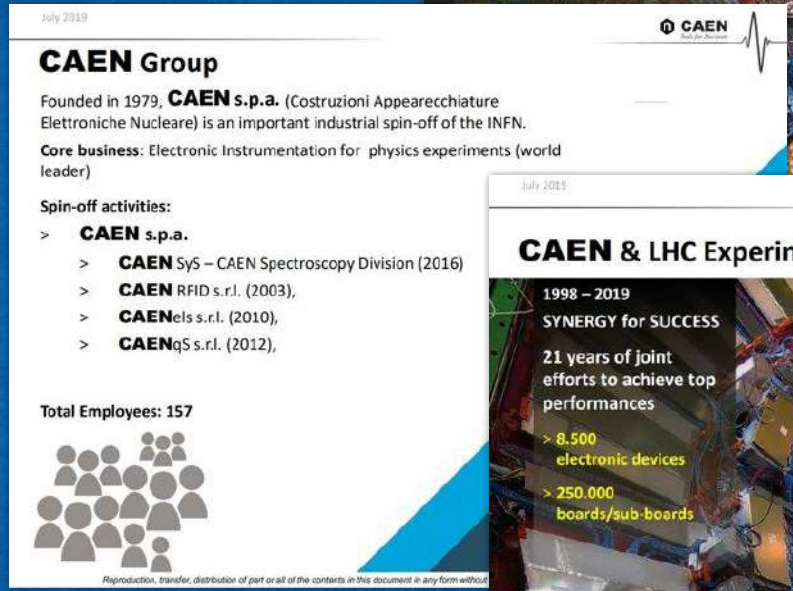
Matías ***Simonetto***

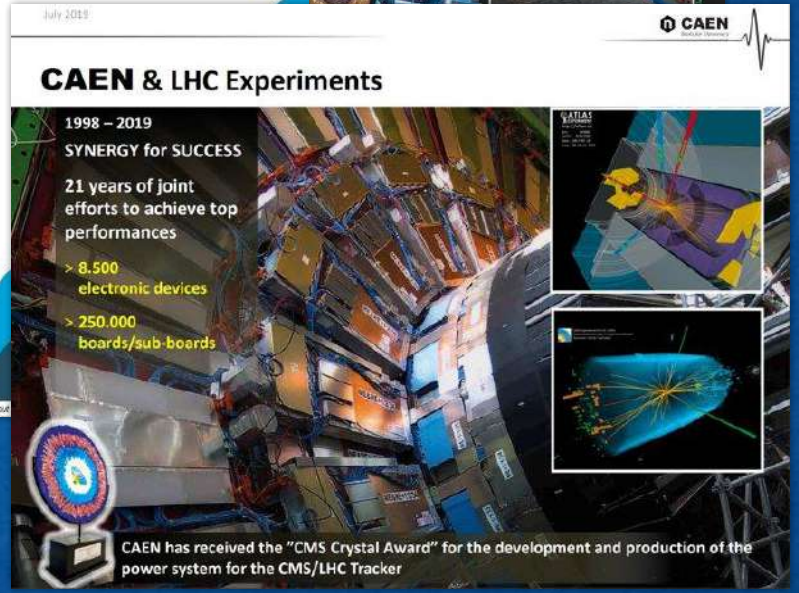
CAEN Tools for Discovery
European Commission
Intense
H2020 MSCA ITN
G.A. 858199

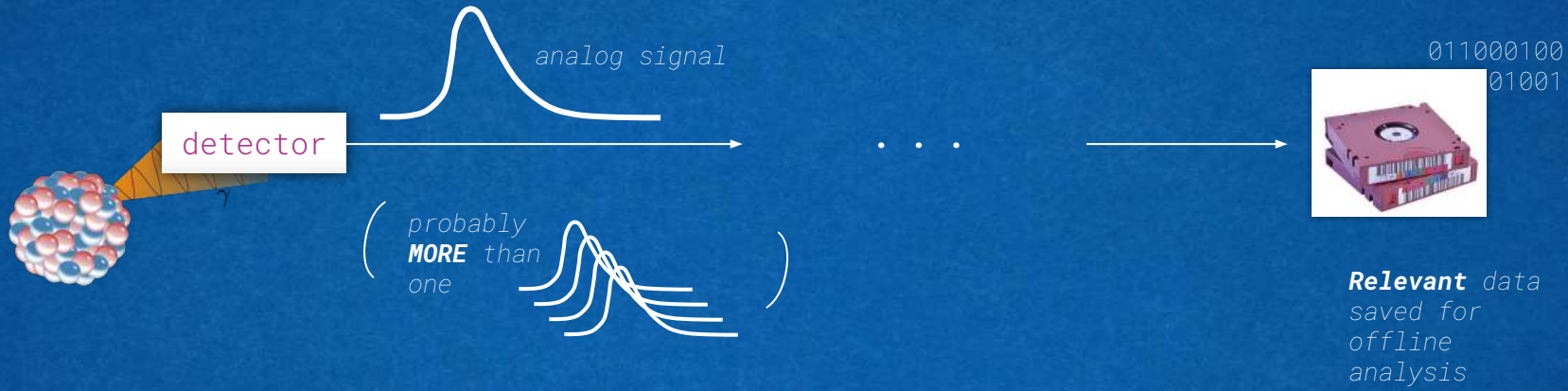
Objective as ESR in CAEN

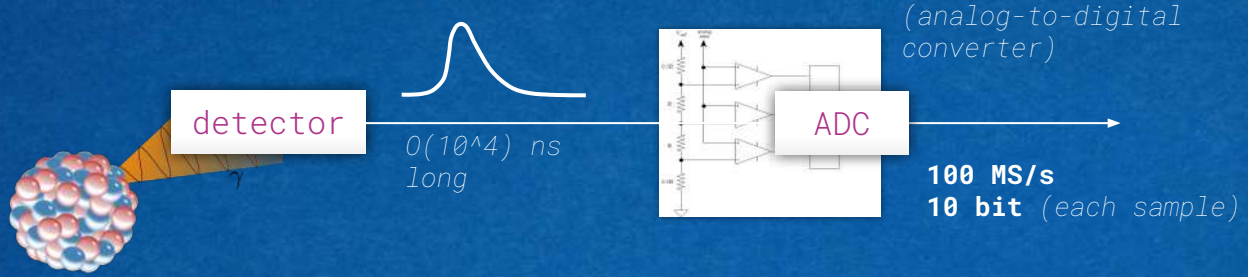
design and develop software control systems for DAQ for LAr-TPC detectors





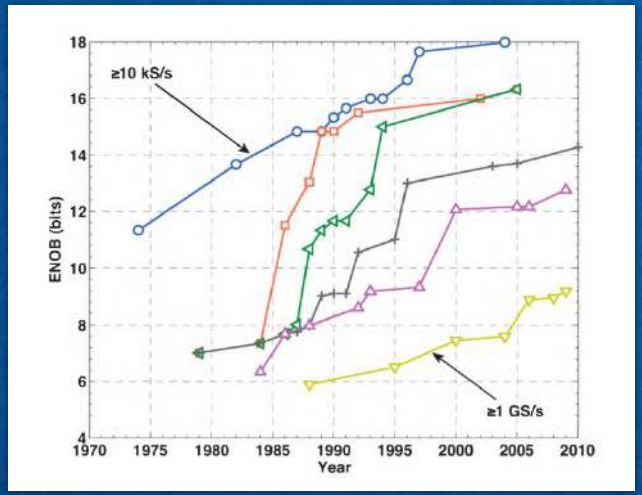


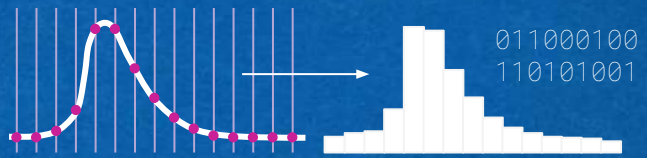

analog signal
detector
γ
probably
MORE than
one
. . .
011000100
01001
Relevant data
saved for
offline
analysis

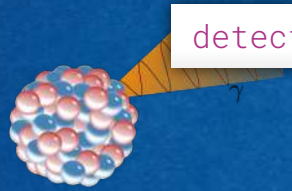


1 Gbit/s !

~ like watching 40 videos in 4k at the same time



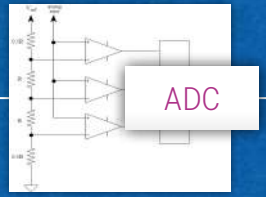




detector

O(10^4) ns long

1 kHz



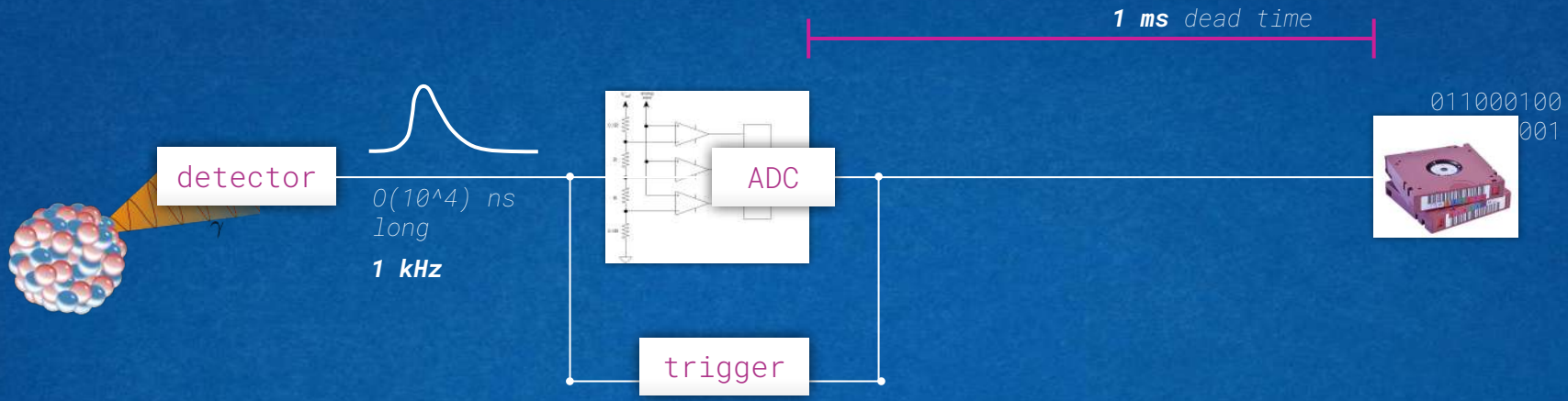
ADC

trigger

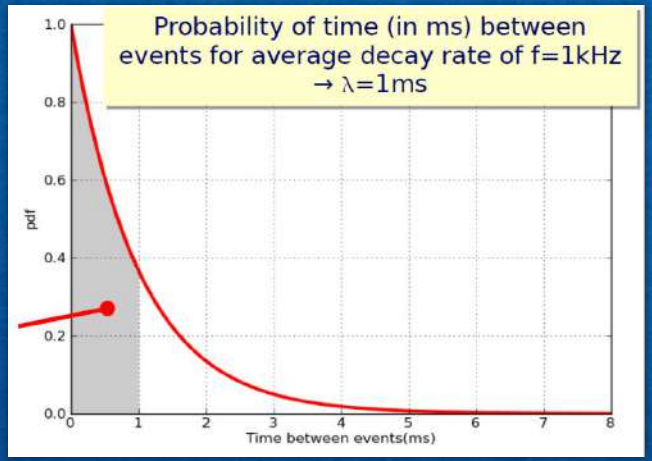
"events" of
10 bit (ADC) x 100 (samples in the window)
*= **1000 bits***

1000 bits x 1 kHz =
1000 kbits/s

~ like watching one video in HD (1080p)



What if a trigger is created when the system is ***busy****?*



average input rate ***f = 1kHz***
average output rate ***v = ?***
dead time ***τ = 1 ms***

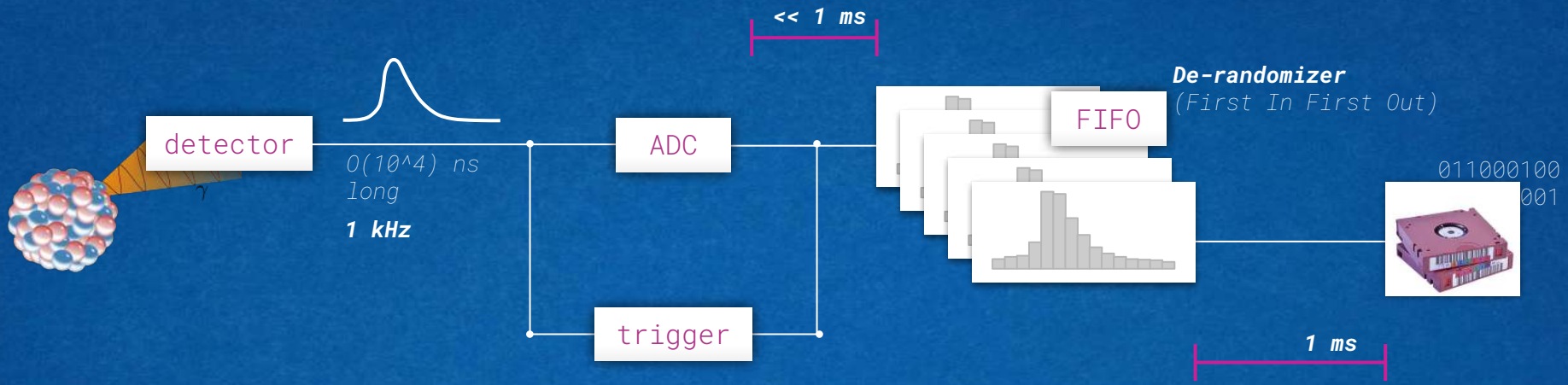
probability "BUSY" ***P(BUSY) = v.τ ⇒ P(~BUSY) = 1 - v.τ***

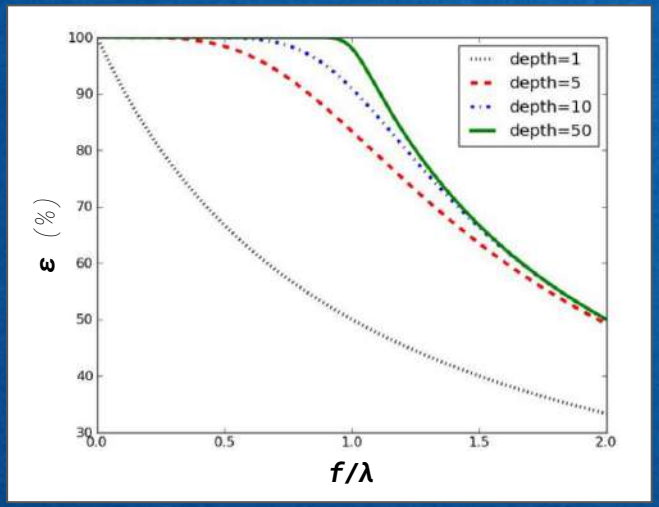
v = f.P(~BUSY) ⇒ ***v = f / (1 + f.τ)***

efficiency ***ε = v / f = 50%***

to get ***ε ~ 99%*** *(@ f = 1 kHz)* → ***τ < 0.01 ms***

OVERDESIGN X100

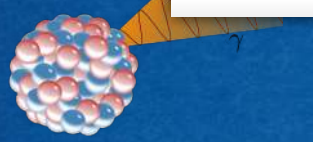




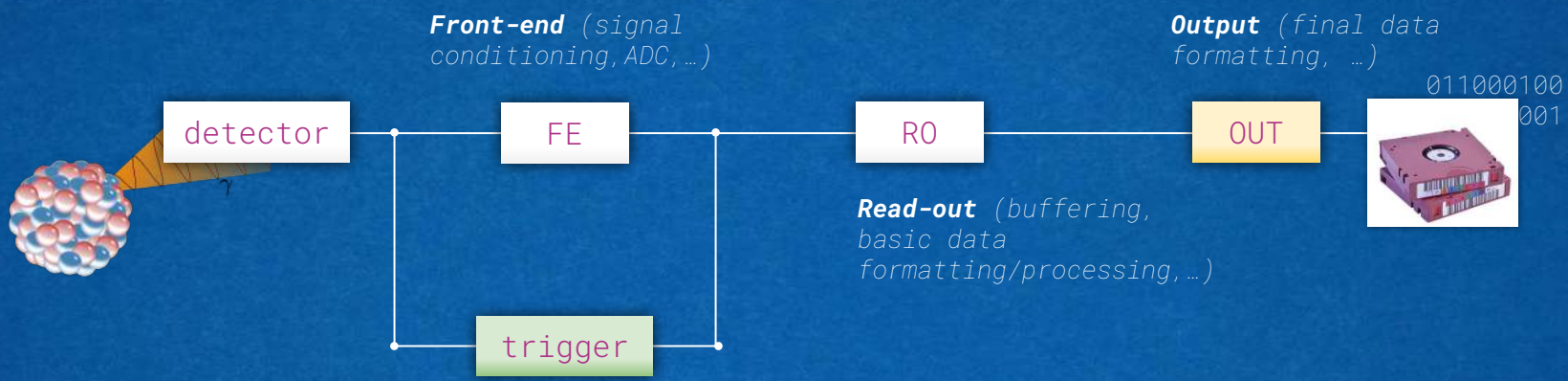
DAQ capability
λ = 1/τ

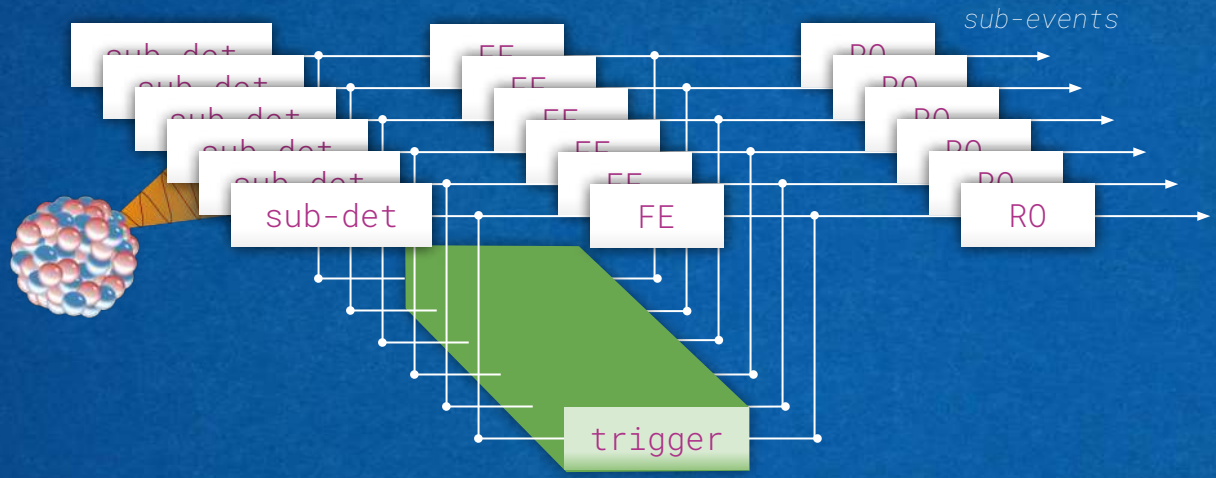
in this case
λ = 1/1ms = 1kHz

Still ***1000 kbits/s*** *…*
do we need to save all that data?

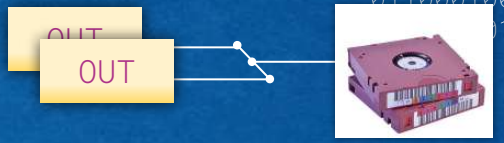


- ***Online processing*** *using Digital Pulse Processing (DPP) algorithms:*
  - *Pulse* ***triggering and filtering***
  - *Pulse* ***Height Analysis*** *(PHA)*
  - *Pulse* ***Shape Discrimination*** *(PSD)*
  - *High Resolution* ***Timing*** *(HRT)*
- ***Customizable***

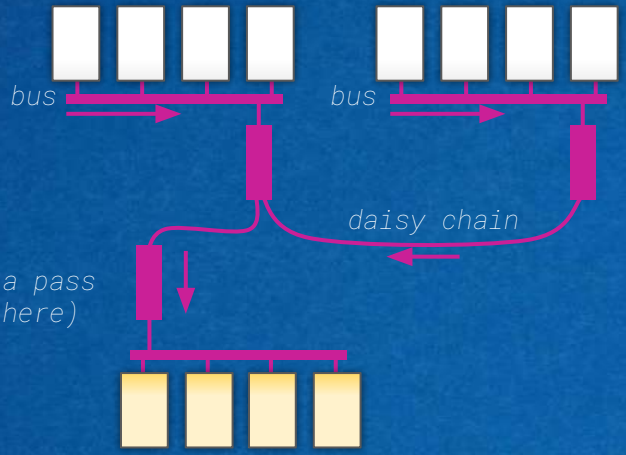

Front-end (signal conditioning, ADC, …)
Output (final data formatting, …)
011000100
001
detector
FE
RO
OUT
Read-out (buffering, basic data formatting/processing, …)
trigger


sub-events
sub-det
FE
RO
trigger

?


OUT
011000100

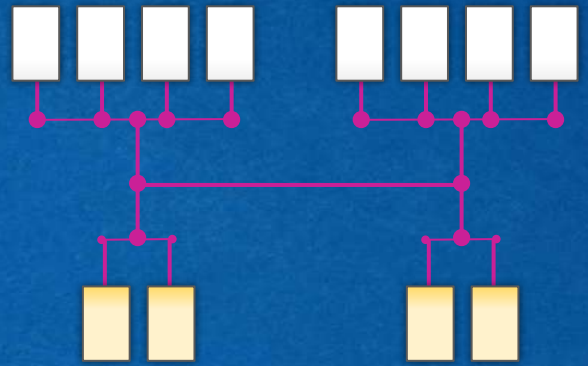
BUS BASED



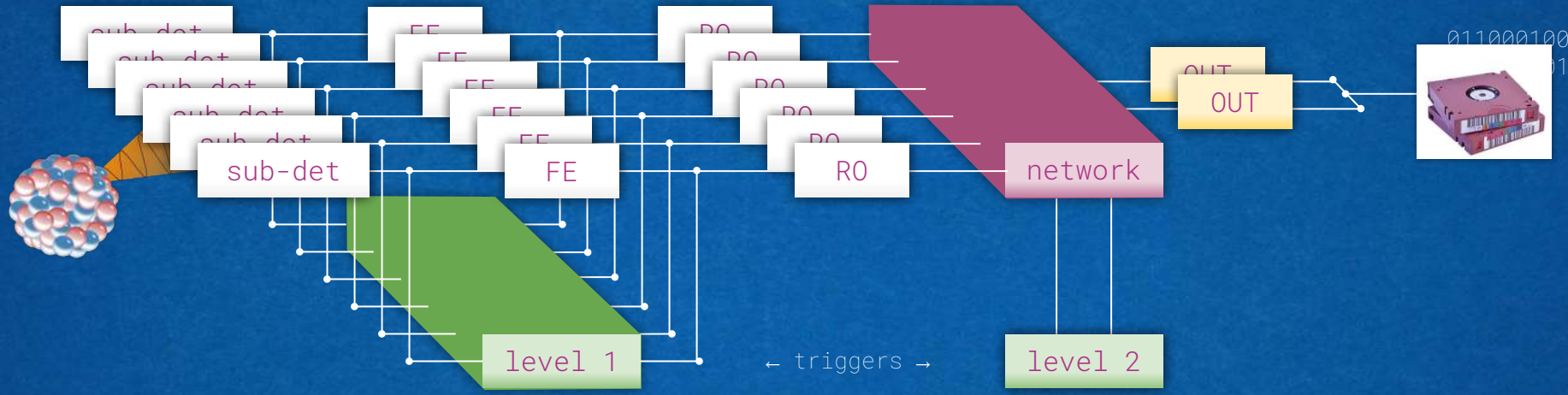
VME crate

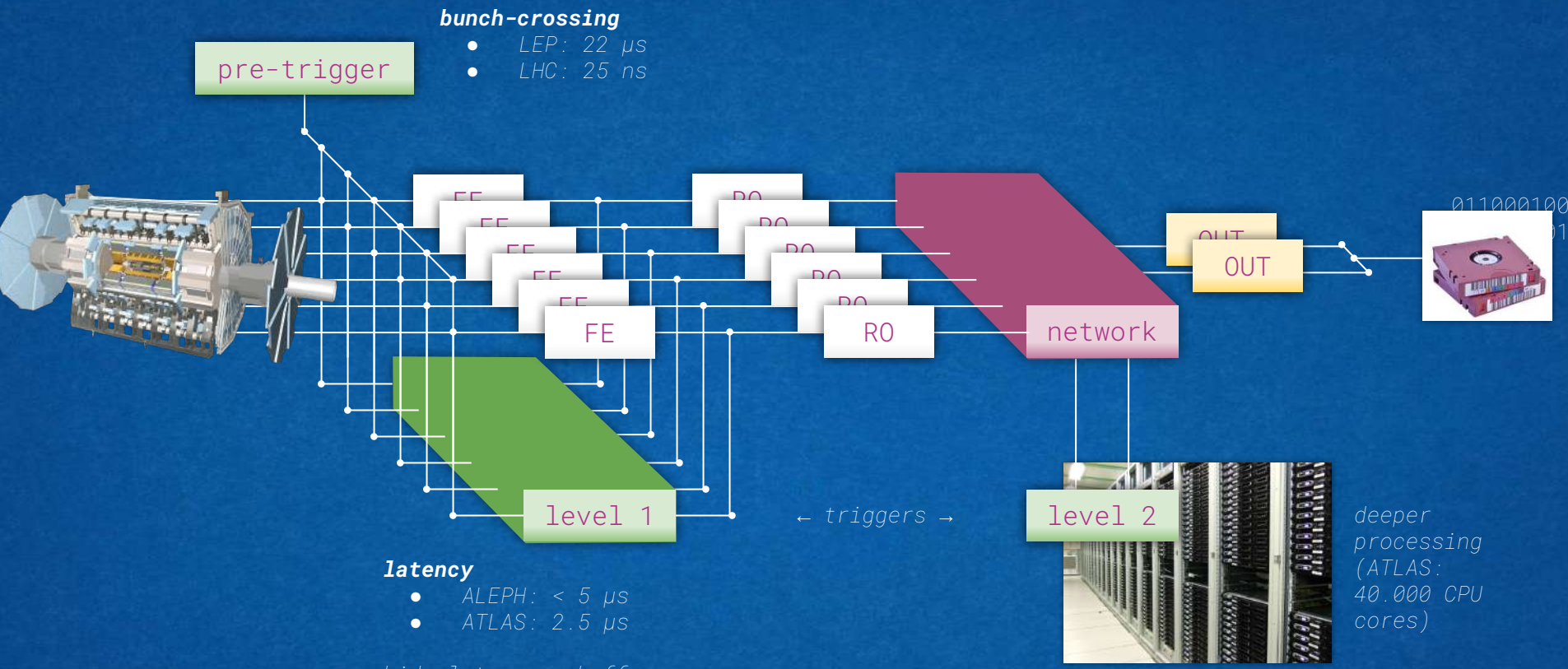
- *Limited number of devices in the same bus*
- *Limited distance between devices*
- *Architecture "masters"/"slaves"*
- *< 1Gbit/s (VMEBus max.~ 400 Mbit/s) (bandwidth is shared)*

NETWORK BASED



- *Devices are equal ("peers").*
- *Multiple and "popular" technologies (Ethernet (Fast, Gigabit, 10. Gigabit), InfiniBand,…)*


sub-det
FE
RO
network
OUT
level 1
← triggers →
level 2


bunch-crossing
LEP: 22 μs
LHC: 25 ns
pre-trigger
FE
RO
network
OUT
level 1
level 2
← triggers →
latency
ALEPH: < 5 μs
ATLAS: 2.5 μs
hide latency → buffers
deeper processing (ATLAS: 40.000 CPU cores)
triggers are complicated: TDAQ

end

Data Acquisition in Particle Physics Experiments
Ing. Giuseppe De Robertis – INFN Sez. Di Bari
https://agenda.infn.it/event/15138/contributions/28606/attachments/20405/23148/DAQ.pdf

Front-end Electronics and Data Acquisition in Particle Physics
Igor Konorov - Institute for Hadronic Structure and Fundamental Symmetries
http://indico.ictp.it/event/8680/session/28/contribution/104/material/slides/0.pdf

Trigger and Data Acquisition (DAQ)
Manfred Jeitler - Institute of High Energy Physics (HEPHY) of the Austrian Academy of Sciences
https://www.niser.ac.in/sercehep2017/notes/TDAQ_ManfredJeitler_A.pdf

Introduction to Data Acquisition
Monika Wielers - Rutherford Appleton Laboratory
https://indico.cern.ch/event/354290/contributions/833024/attachments/702126/963973/daq_ral_lecture_041214.pdf