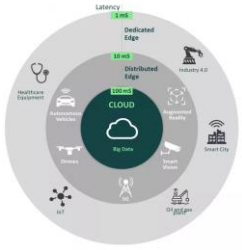
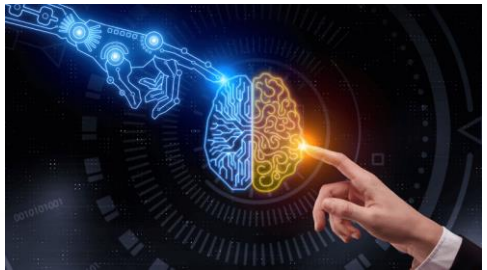
Data Acquisition System for Fundamental Physics Research

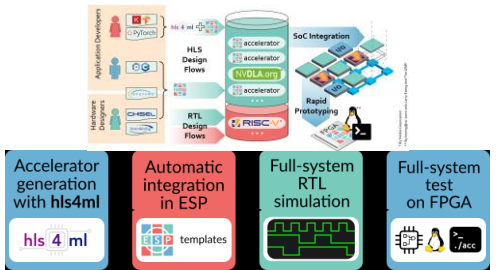
➔ *A State of the Art from an electronician's point of view*

DI2I workshop – July, 10-12th, 2023

F.Druillole – LP2I Bordeaux –







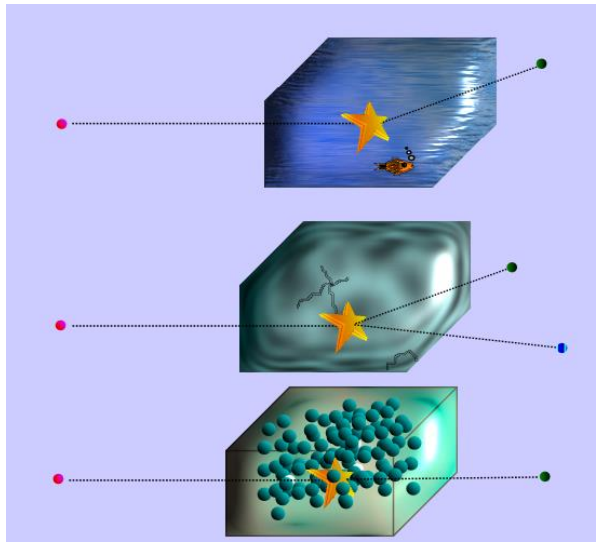
Principles

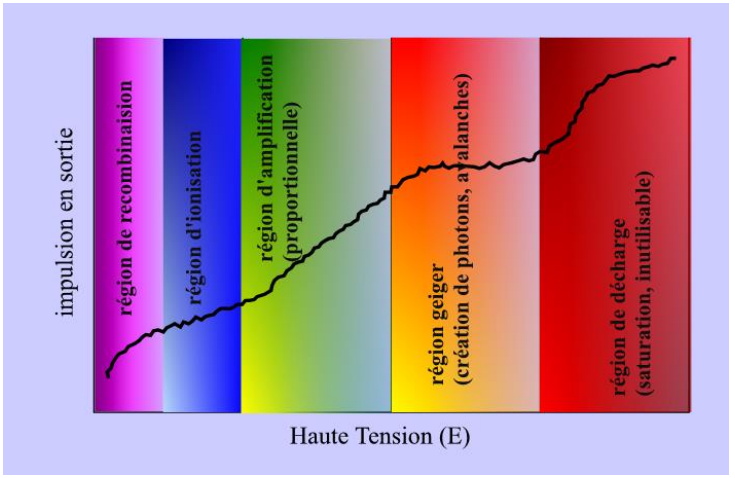
Detectors: medium sensitive to particles reaction
➔ properties change ➔ creation of a charge

→liquid

→solid

→gas





What are we looking for:

- Counting rate
- Deposited Energies
- Impulsion (quadrivector)
- Particles' beam position
- Particles' track
- Duration of interaction
- Time of flight of the particles
- mass

Multi-channel Acquisition system

What do we need to optimize:

- Minimizing background: to reject useless signals
- Perturbations : EMC
- Electronics noise

➔ From electronic's point of view, everything is Voltage and current

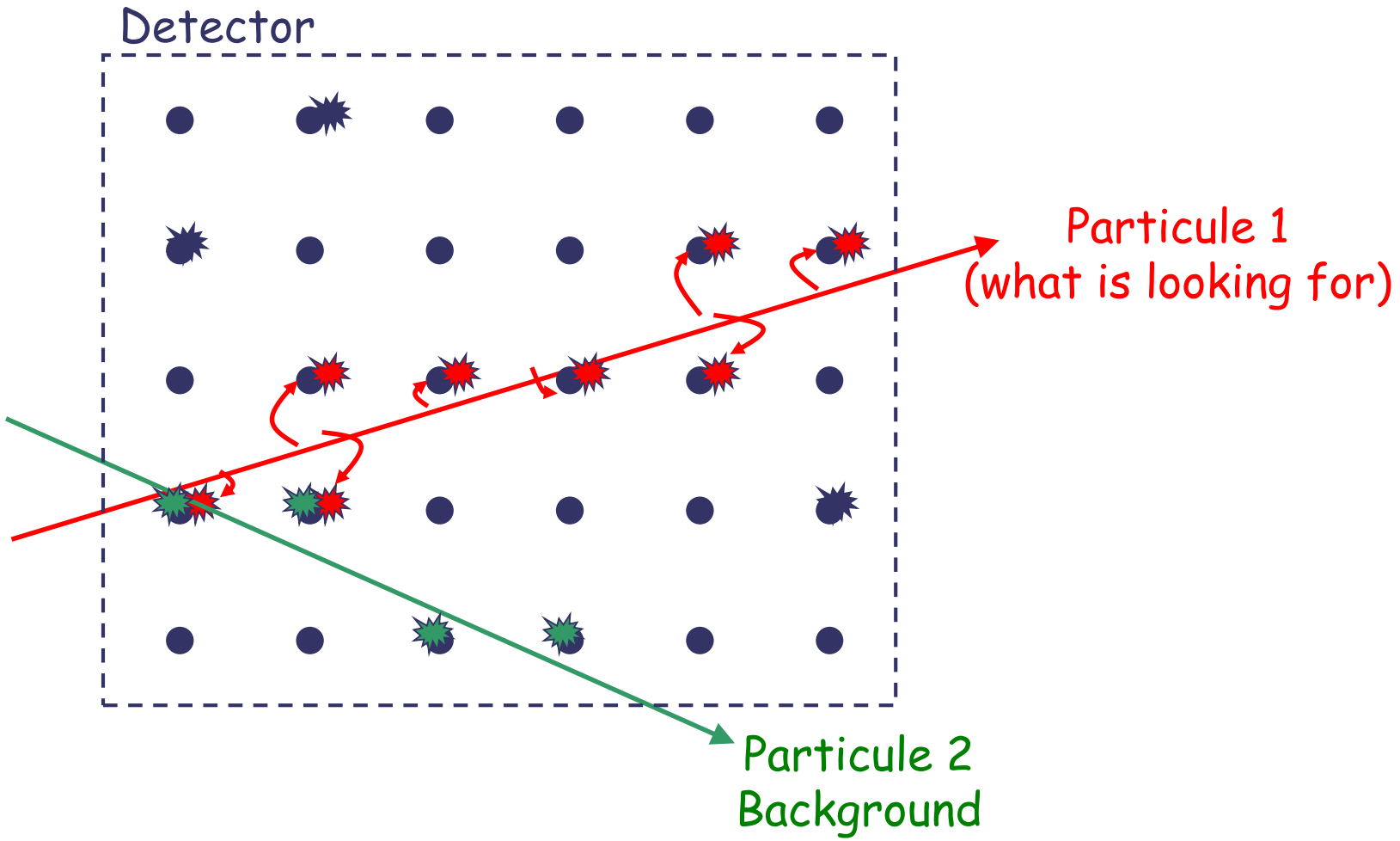
Principles – detectors of particules

- Element of detection

Hit Noise

Hit particule 1 (background)

Hit particule 2

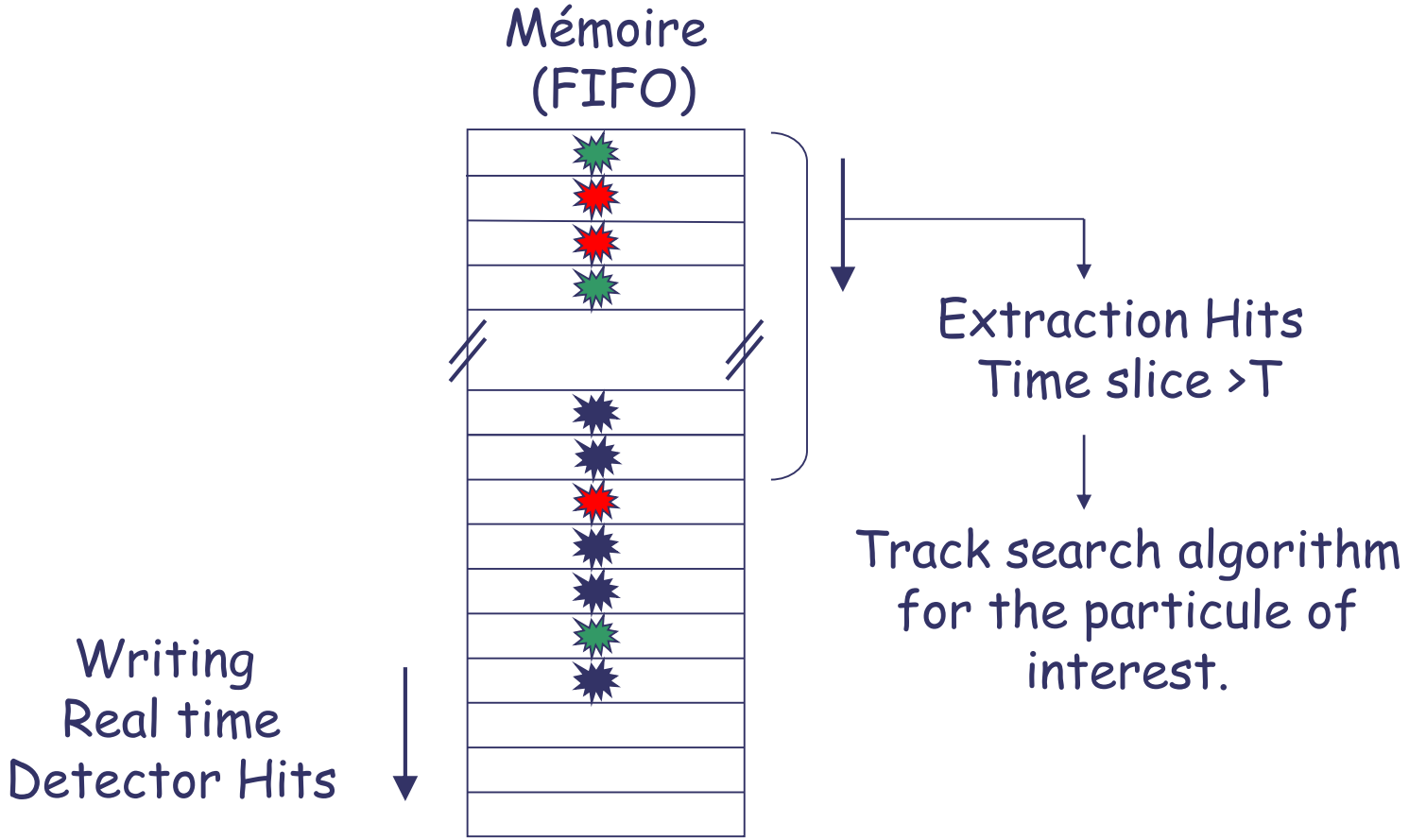


Principles – Data Analysis

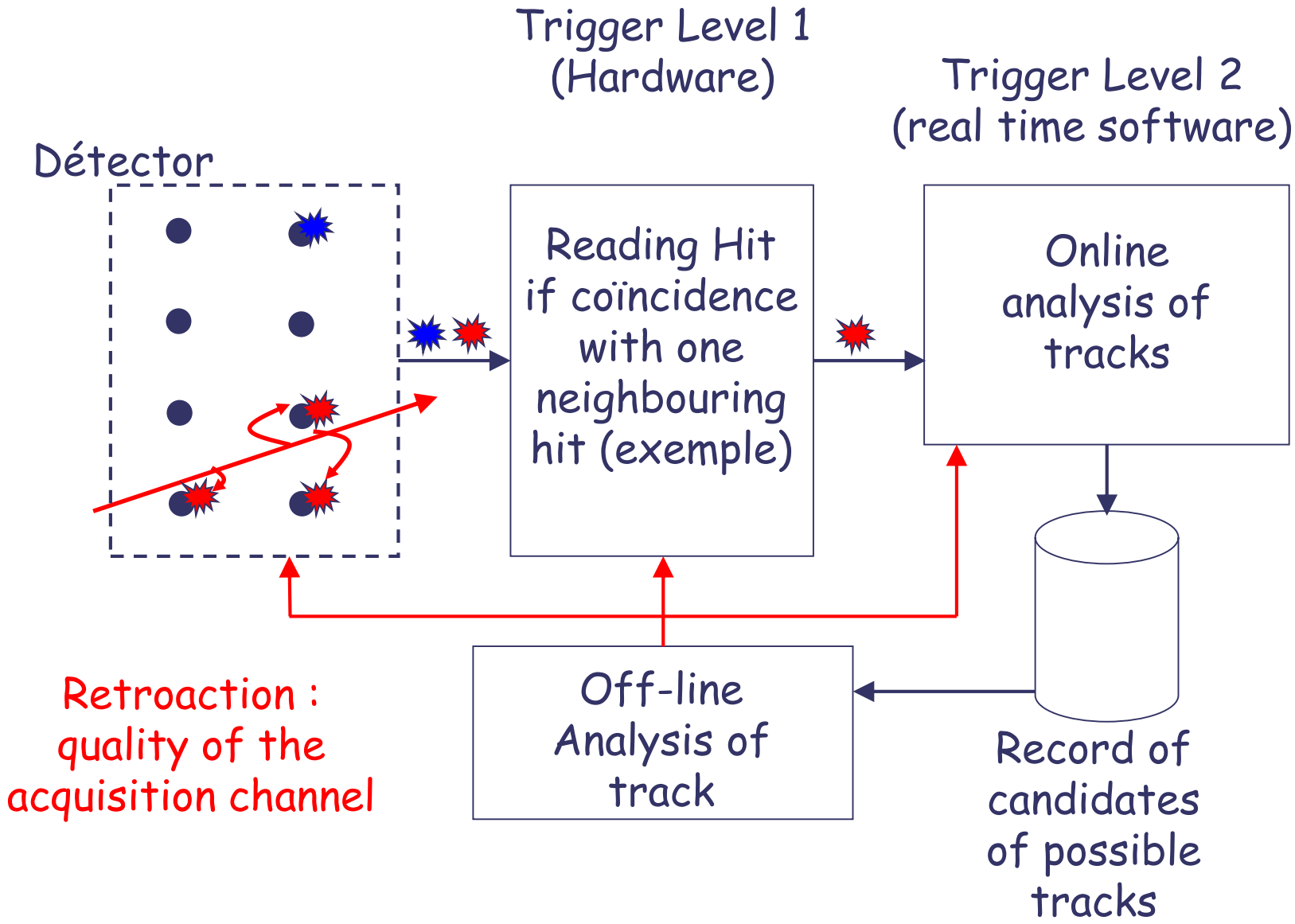
Hit = space and time information

T = life time of the particules of interest from the detector.

- Hit Noise
- Hit particule 1 (background)
- Hit particule 2 (what is looking for)



Principles – Decreasing the data stream



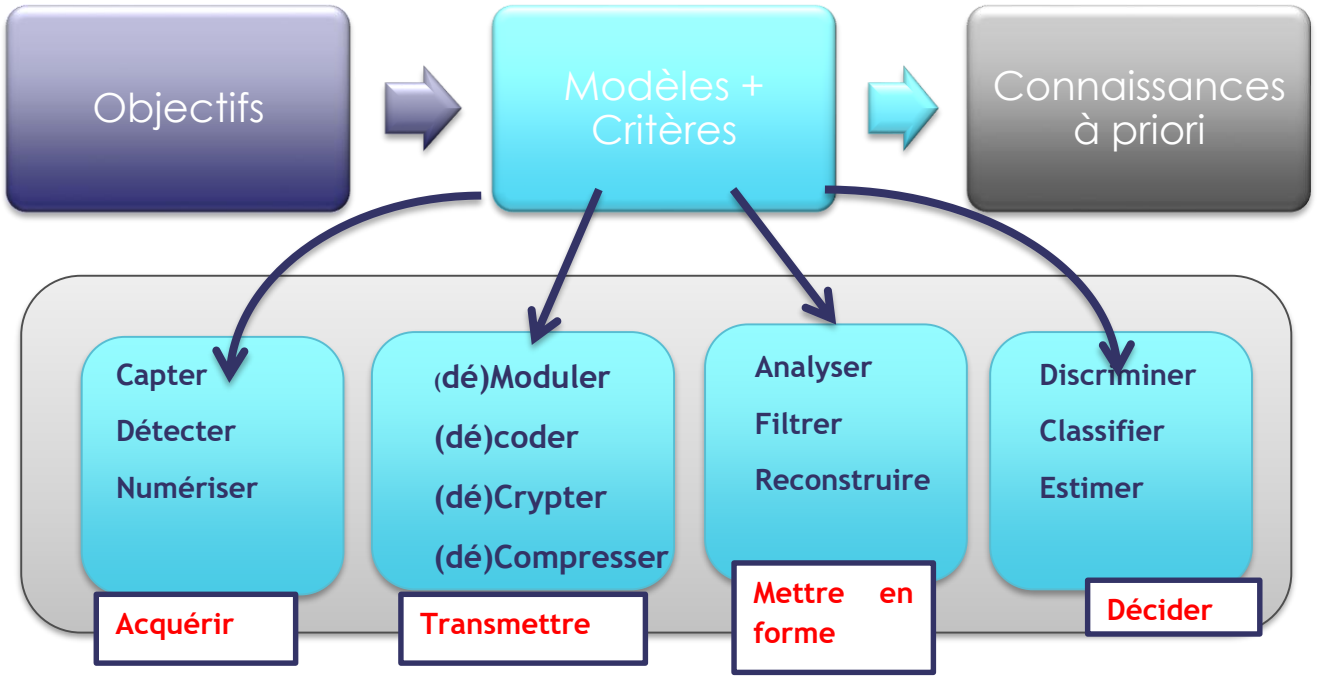
Principles – Tools and vocabulary

ASP/DSP

- Study of signals in their mathematical form and modeling a physical phenomenon
- $x(t) = a.\sin(w.t) + e(t)$

Decision theory

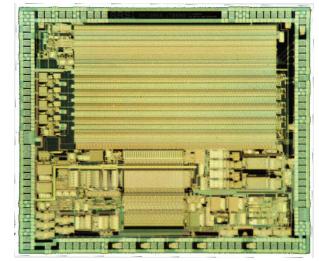
- Development of statistical models from A PRIORI knowledge in order to make an optimal choice from observations (decision-making from criteria)

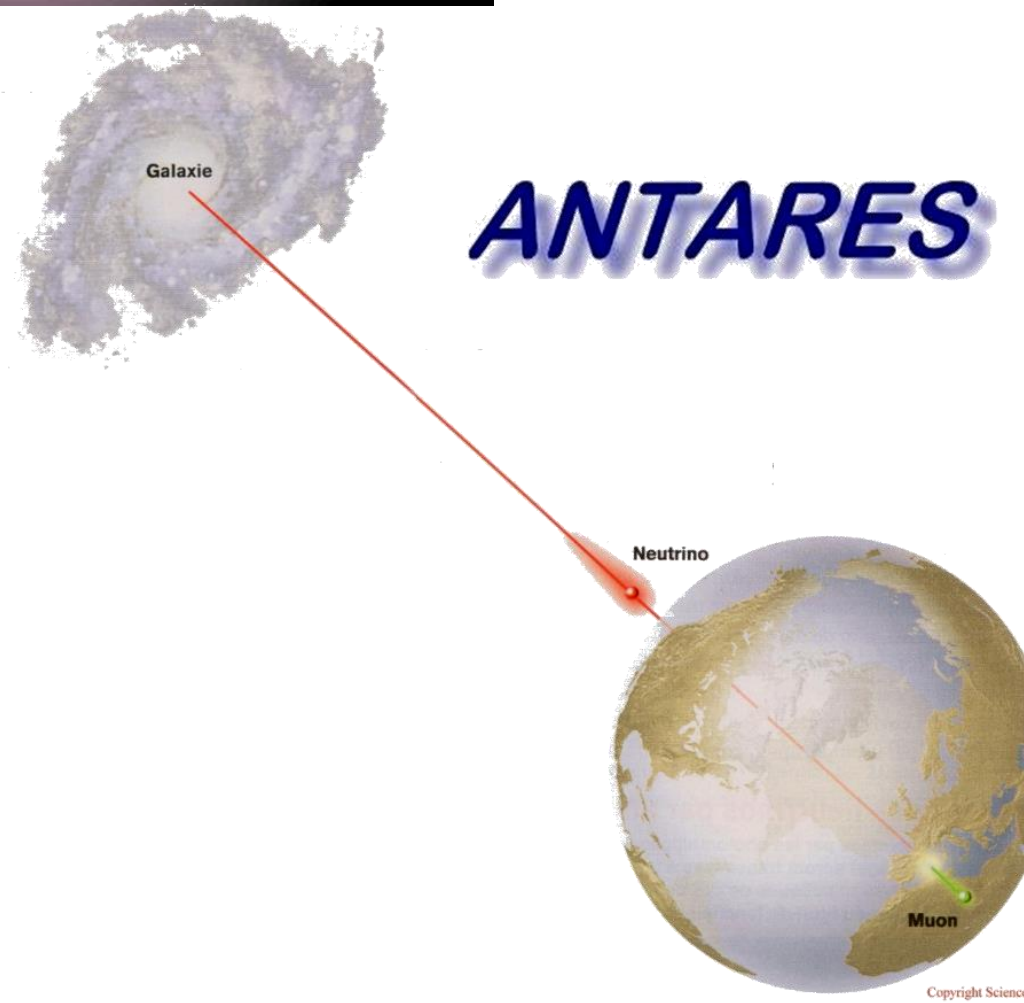


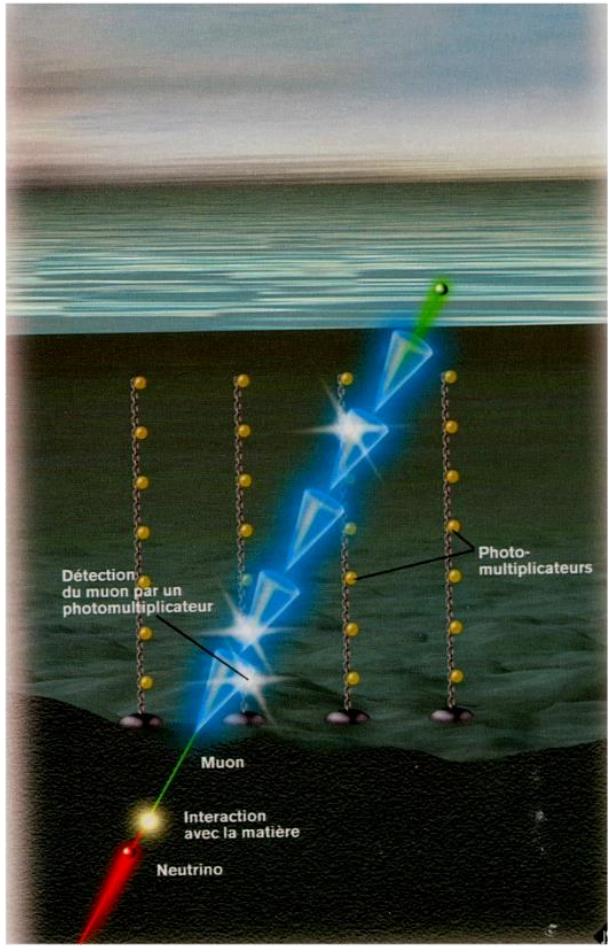
DAQ 25 years ago….

Astronomy with a Neutrino Telescope
ANTARES
and Abyss environmental RESearch

ARS1







DAQ 25 years ago….

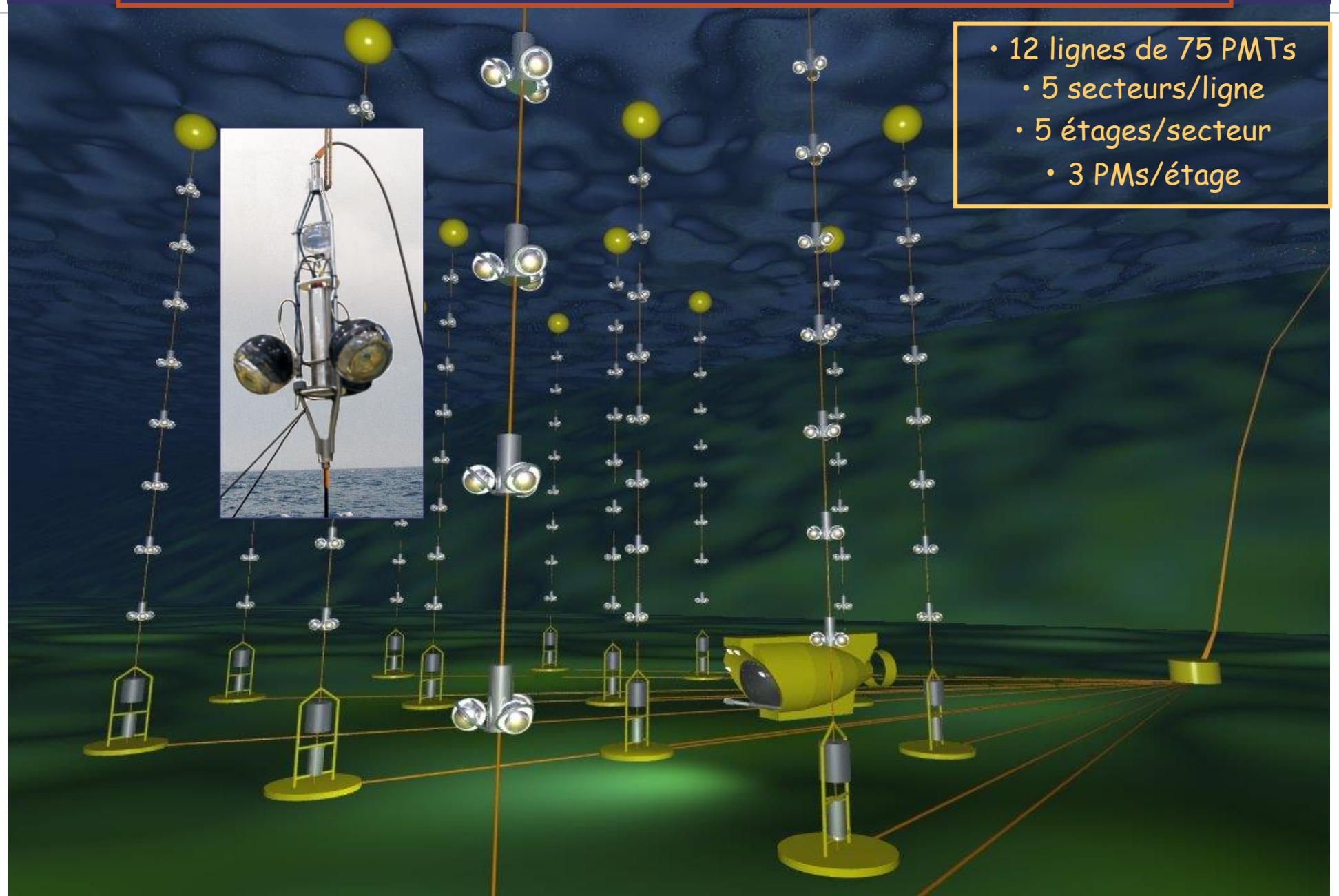
Le site de l'expérience

Station côtière
Institut Michel Pacha

Station d'alimentation

Câble sous-marin
(Fibre optique et alimentation)

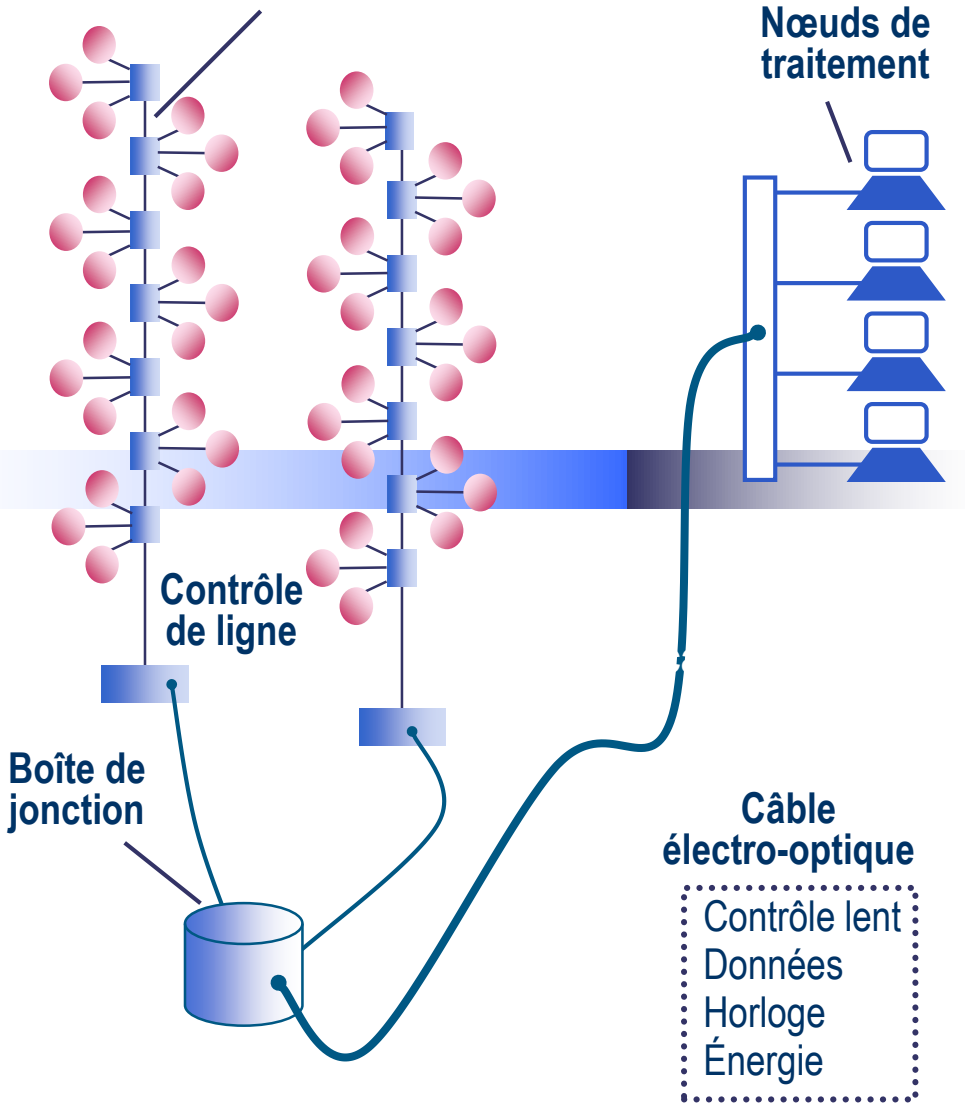
Le détecteur Antares



- 12 lignes de 75 PMTs
- 5 secteurs/ligne
- 5 étages/secteur
- 3 PMs/étage

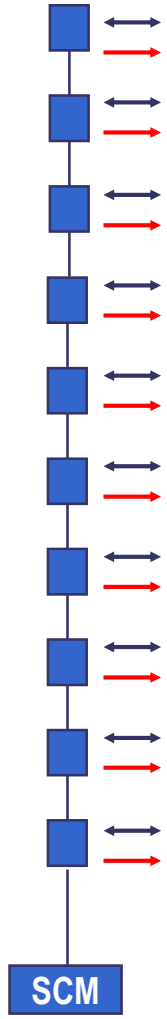
Le projet "0.1 km2"

- 12 lignes de détection (400 m)
- 300 nœuds d'acquisition (25 / ligne)
- 900 photomultiplicateurs (3 / nœud)
- 1800 sources de données à 20 Mb/s max
- Système réparti sur 30 000 000 m^3 à 2500 m sous l'eau
- Ferme de 100 nœuds de traitement

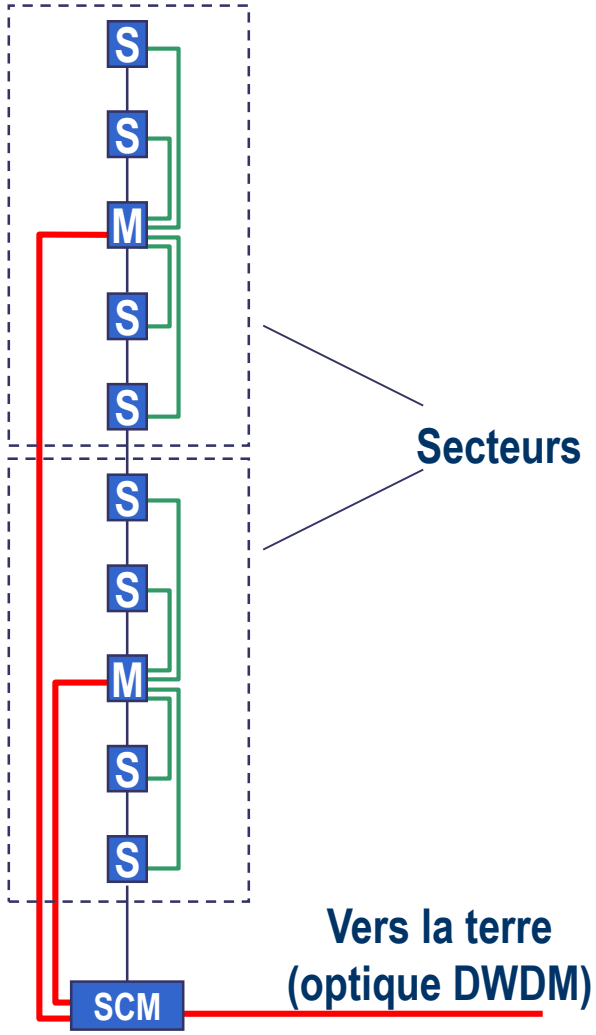


Topologie du réseau (1)

Chaque étage a son propre flot de données
(Slow Control & Données de physique)



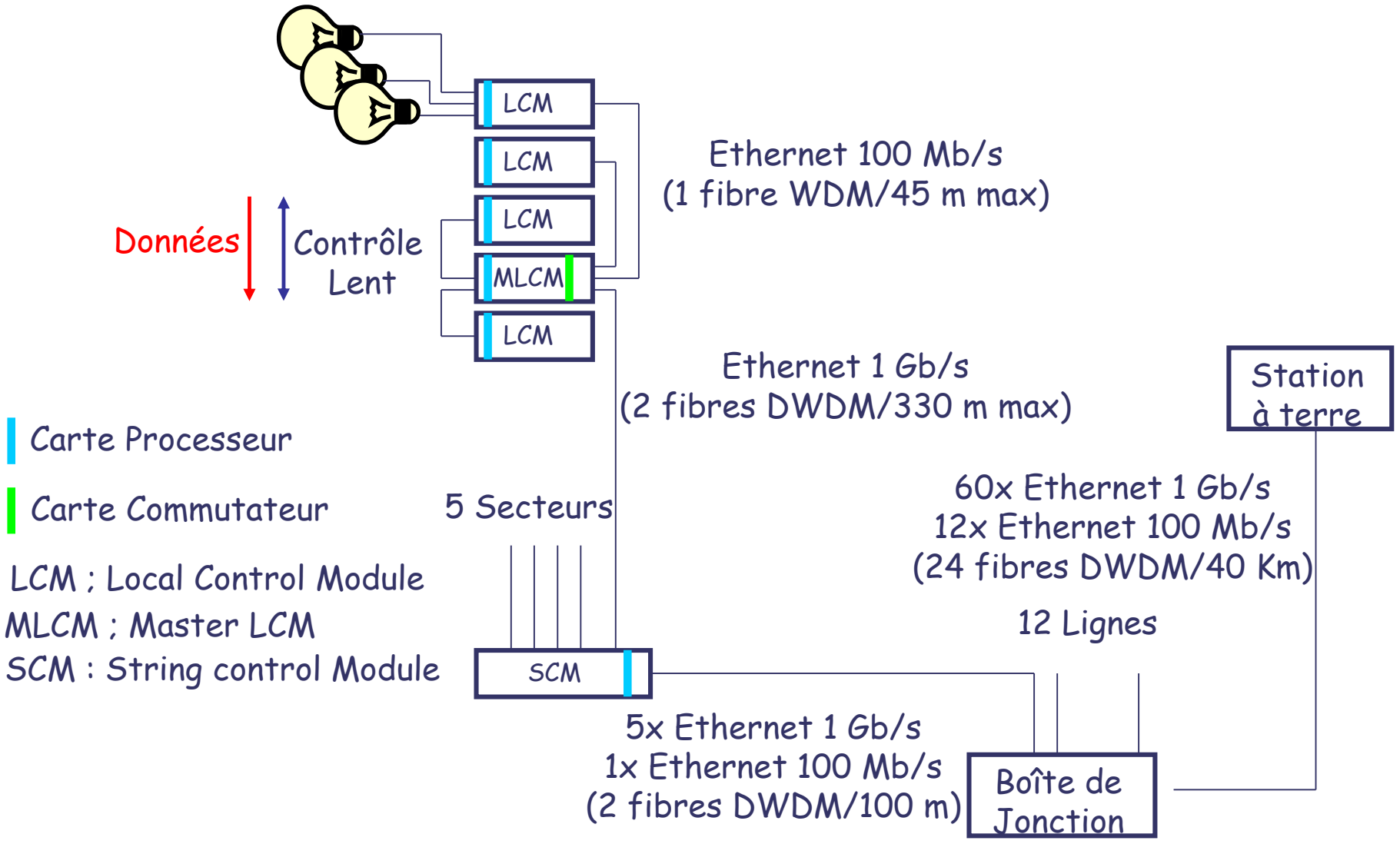
Rigidité du câble EM
Diamètre du câble
Complexité connectique



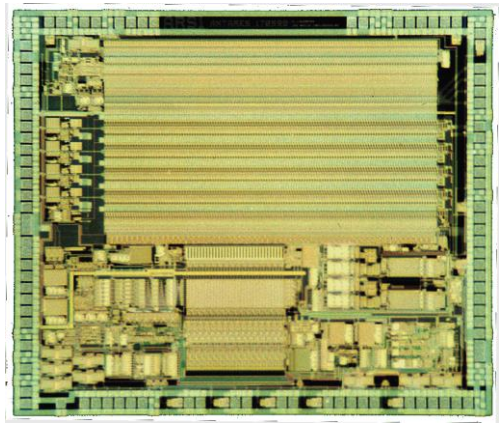
➔ Data synchronisation with the 100MHz ethernet clock.

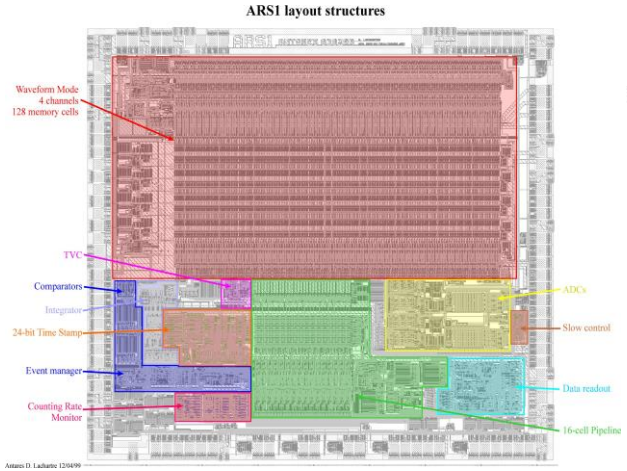
➔ Possible to start on the same edge for all connected node

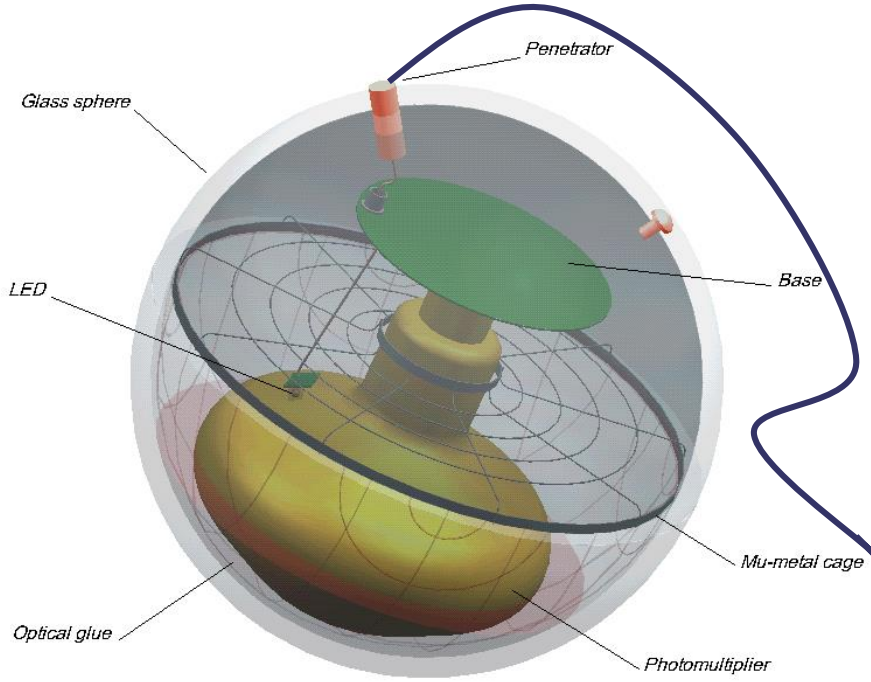
Lecture du détecteur : un réseau Ethernet



Signaux optiques

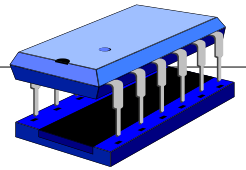


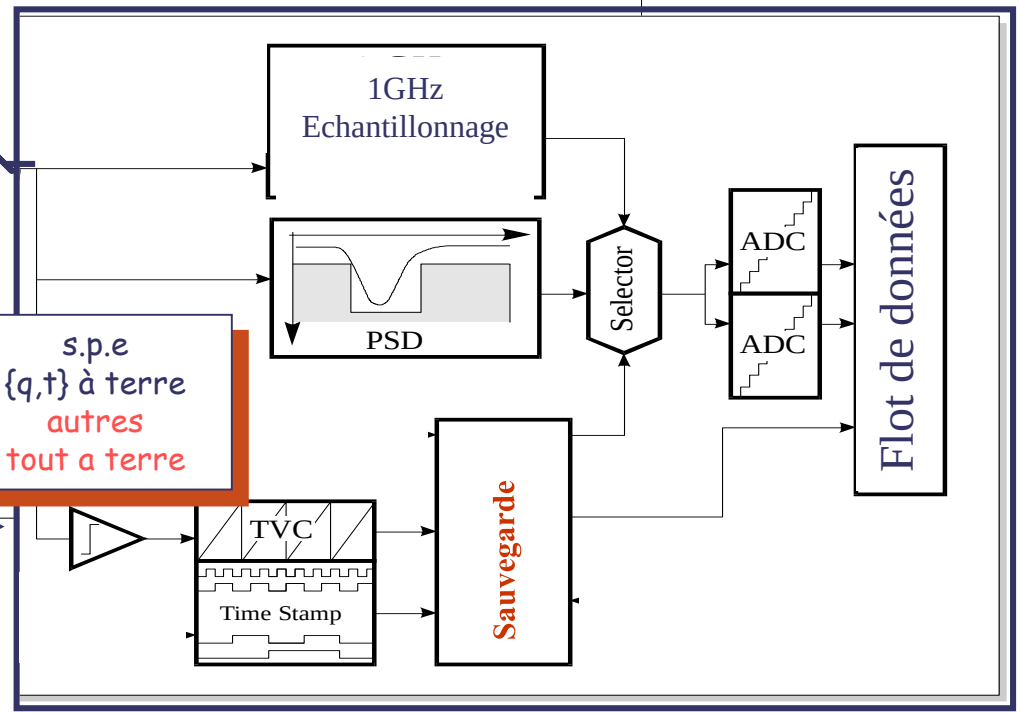




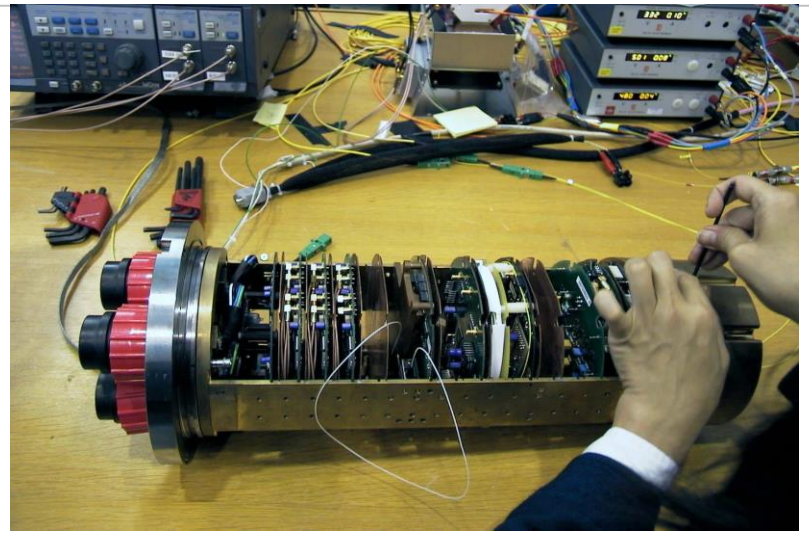
Intégration Développement à Saclay

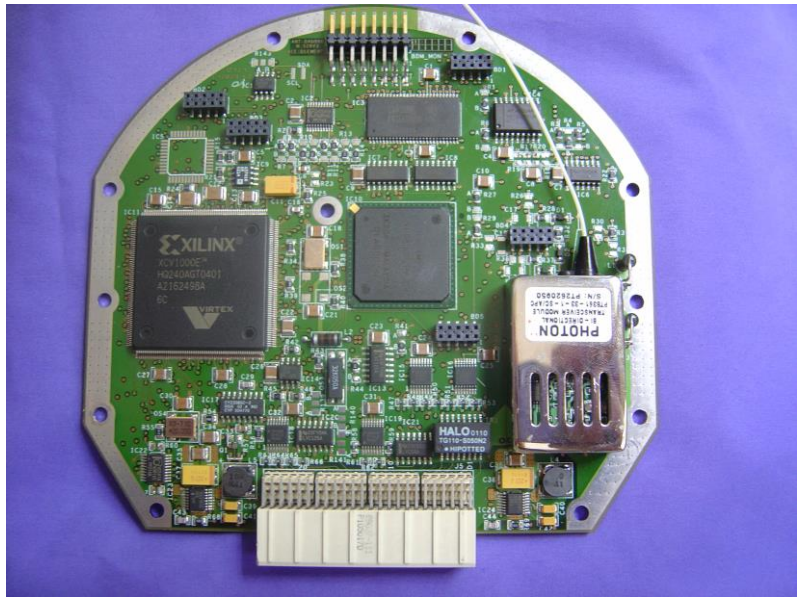
ARS
Analog Ring Sampler

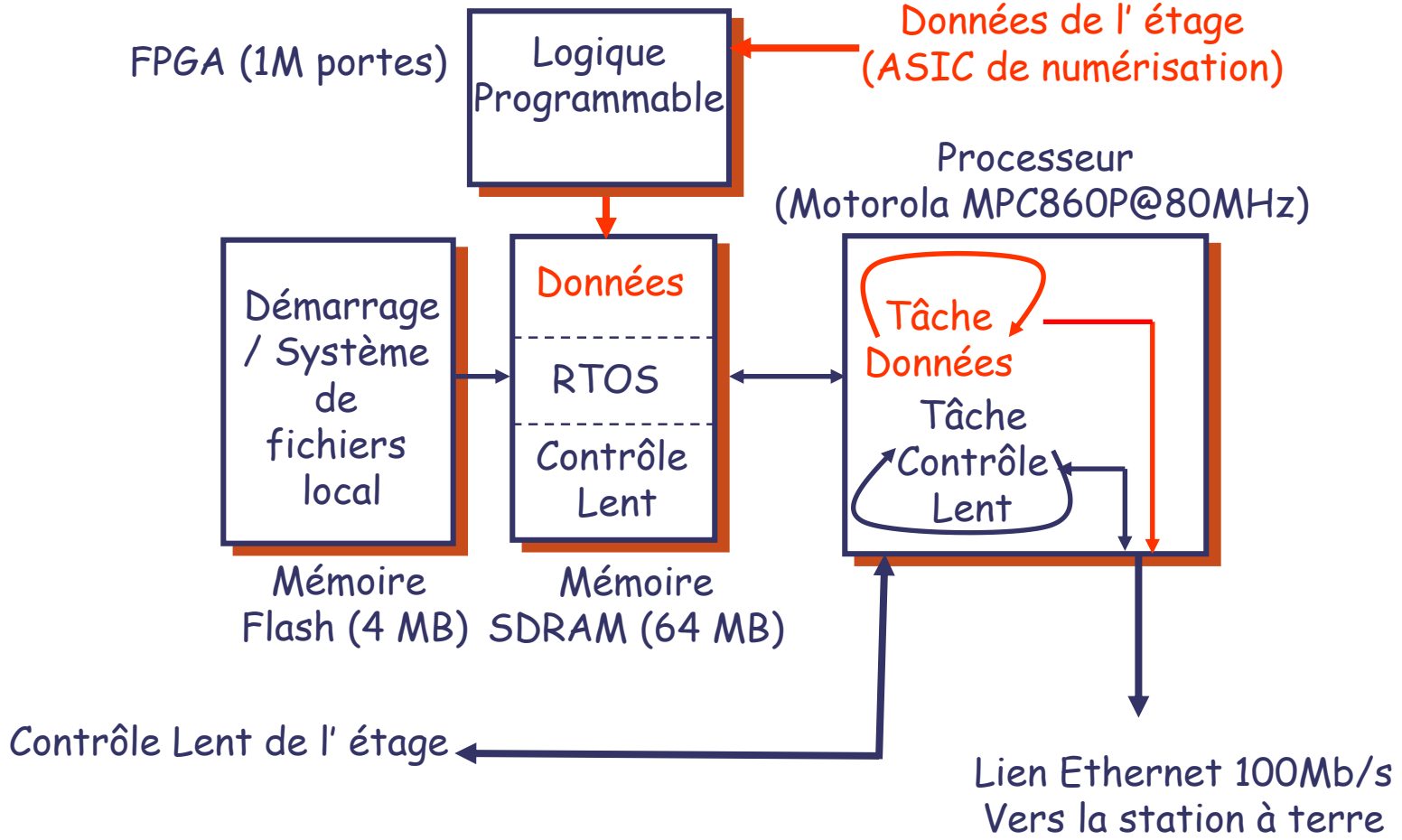




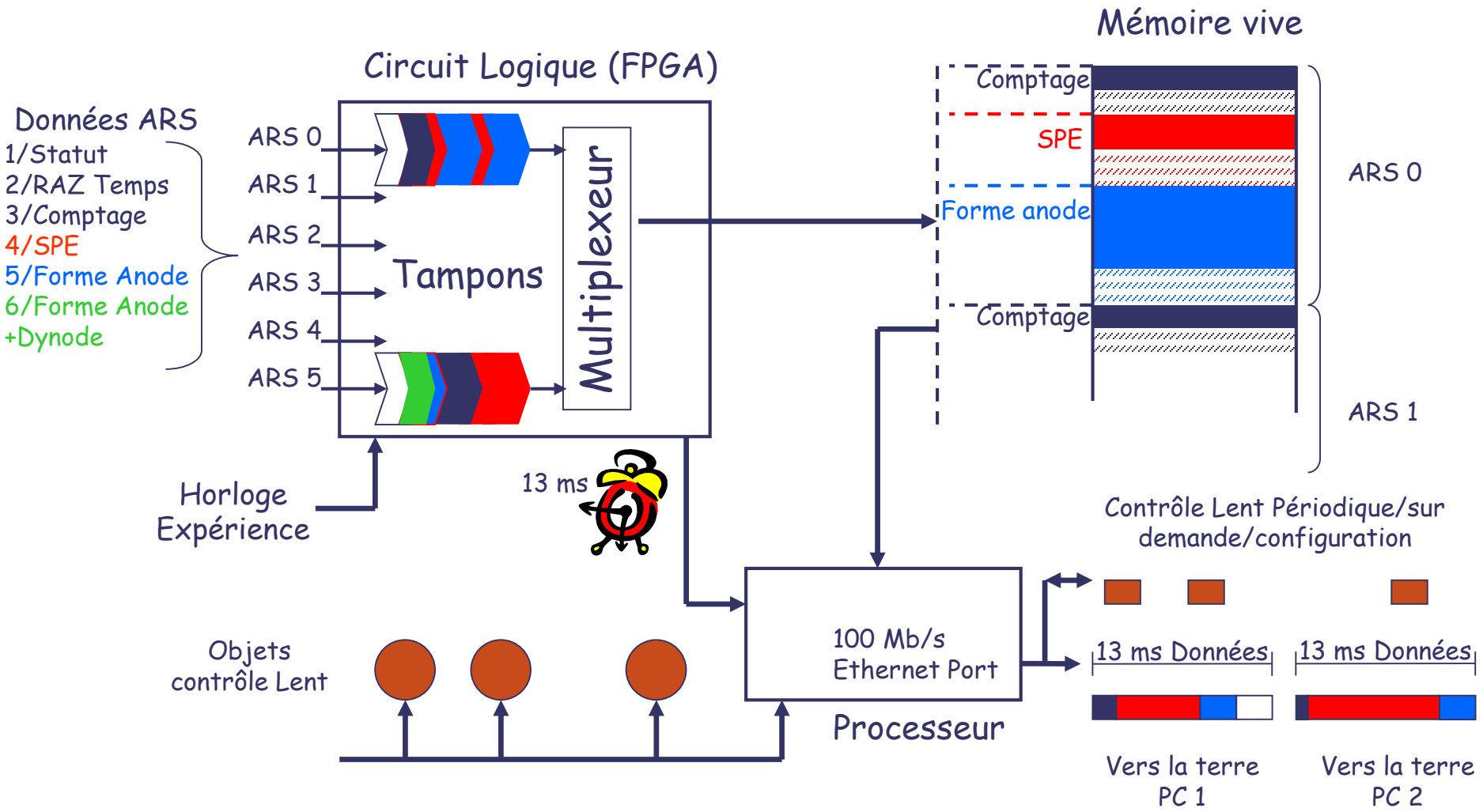
Module de Contrôle Local (LCM)



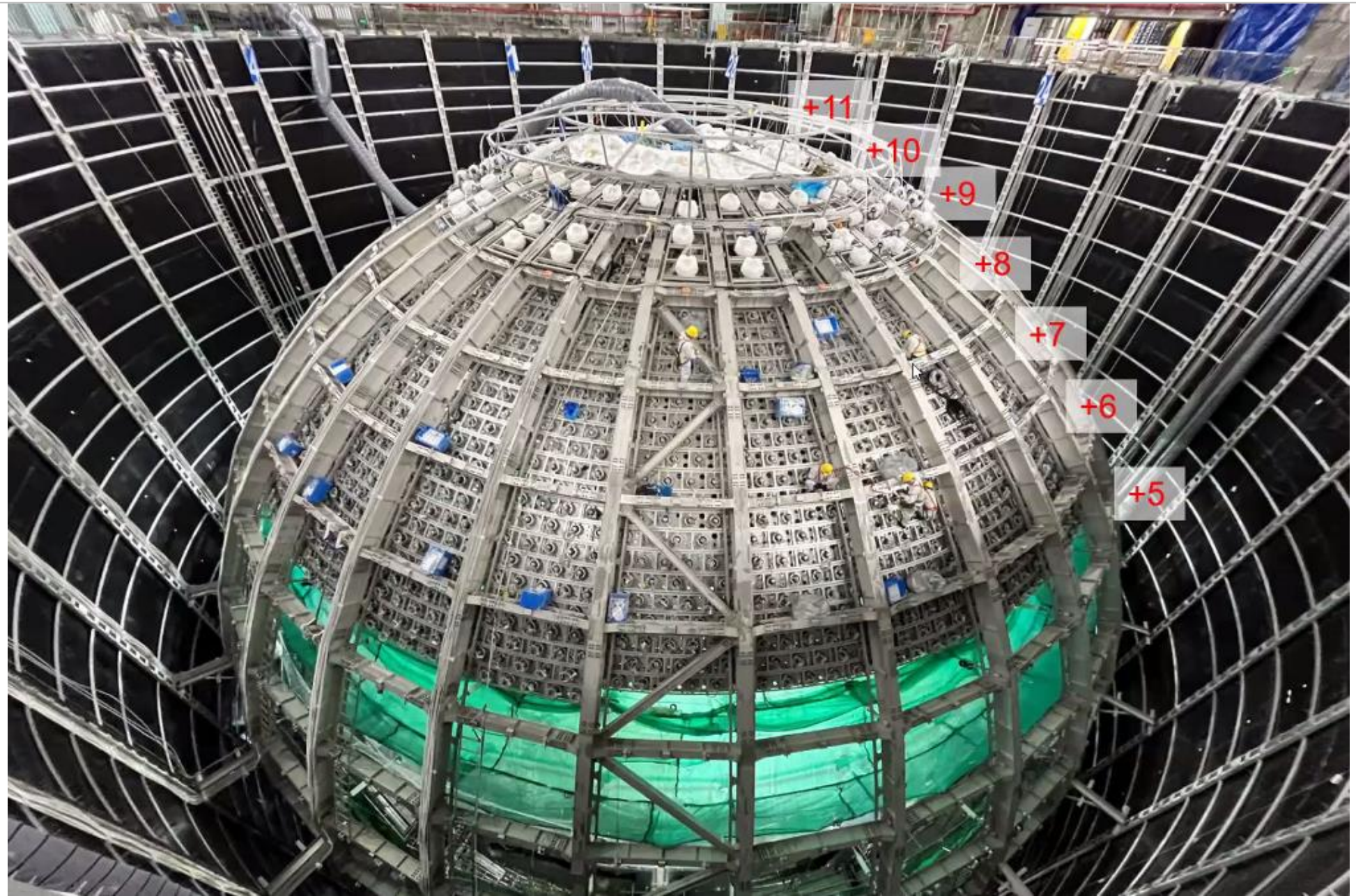




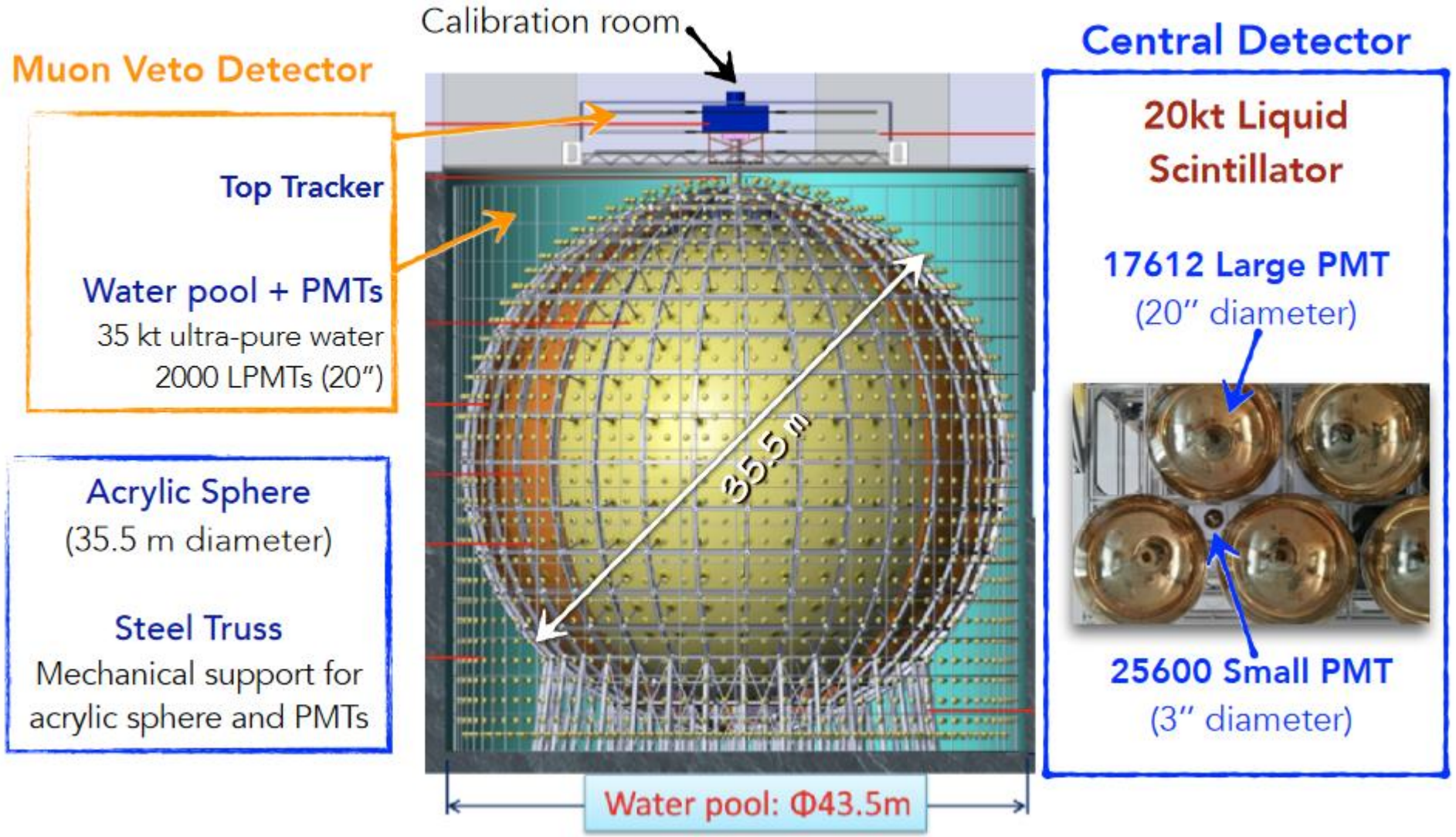
Traitement LCM des données/du Contrôle Lent



JUNO: Conception & Deploiyement (2016-2024)

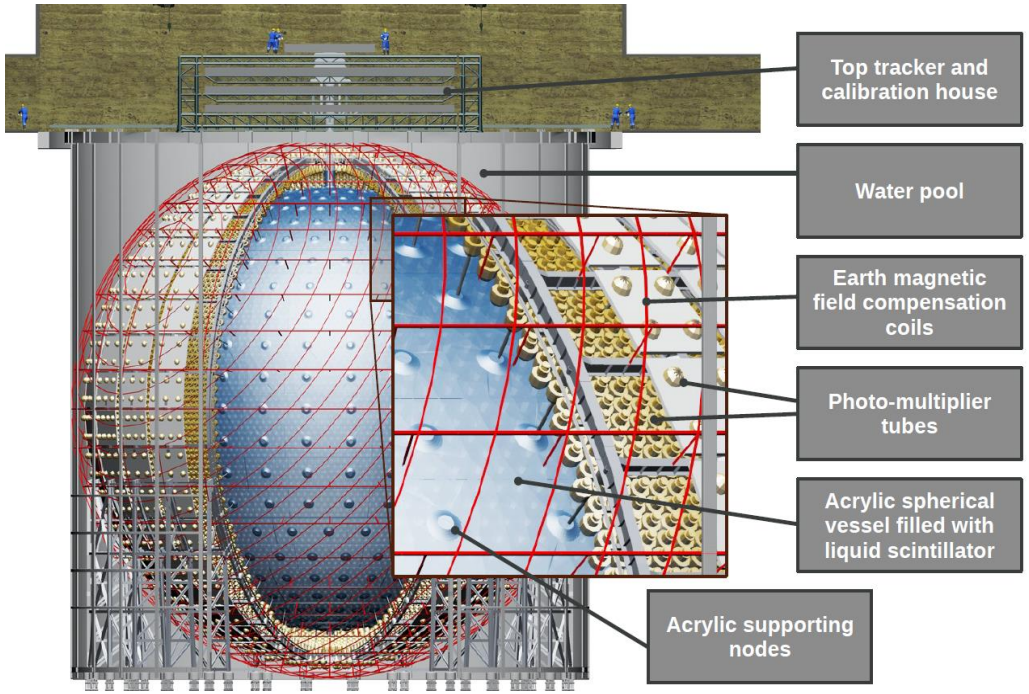


JUNO Experience : Detector

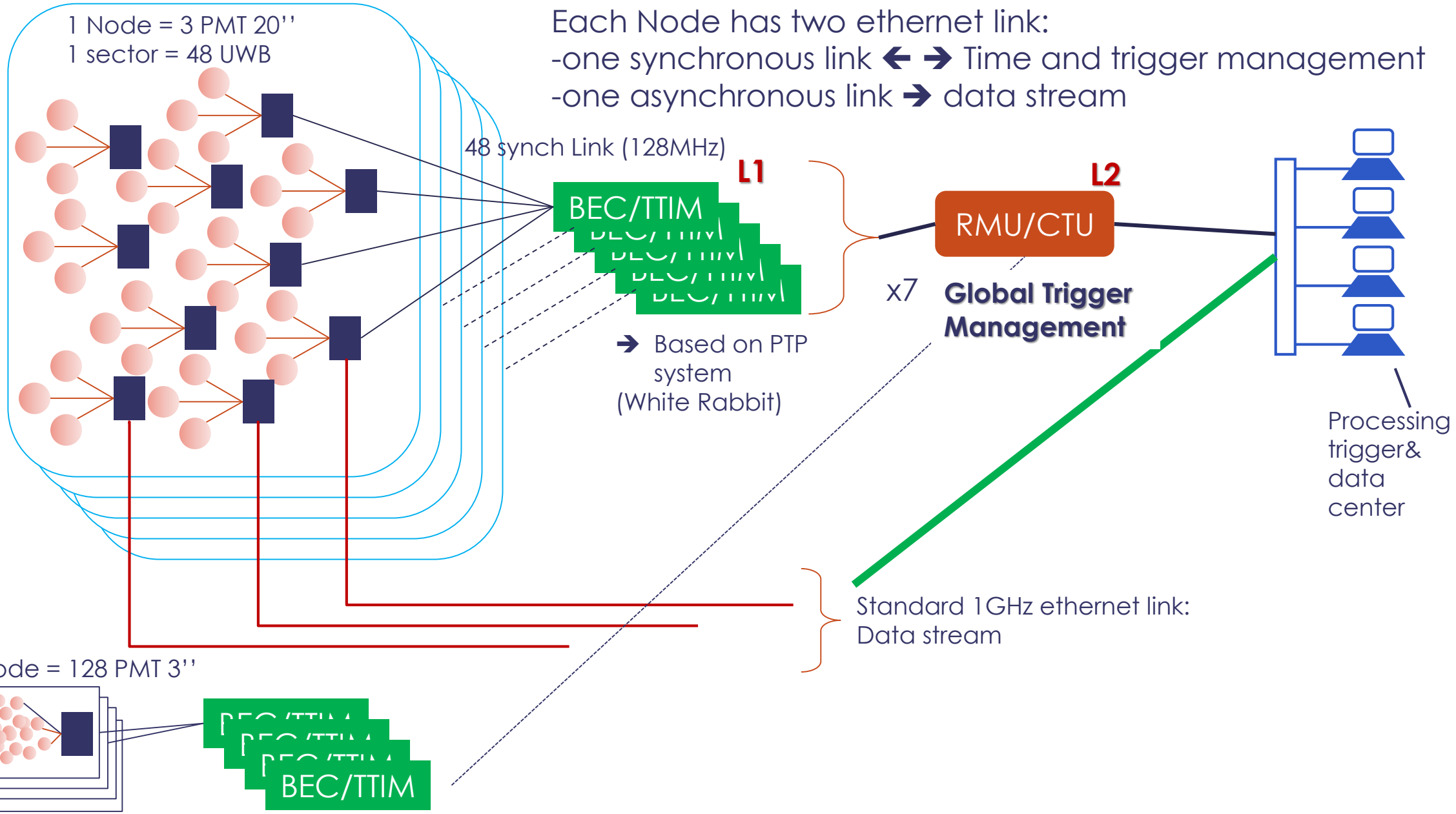


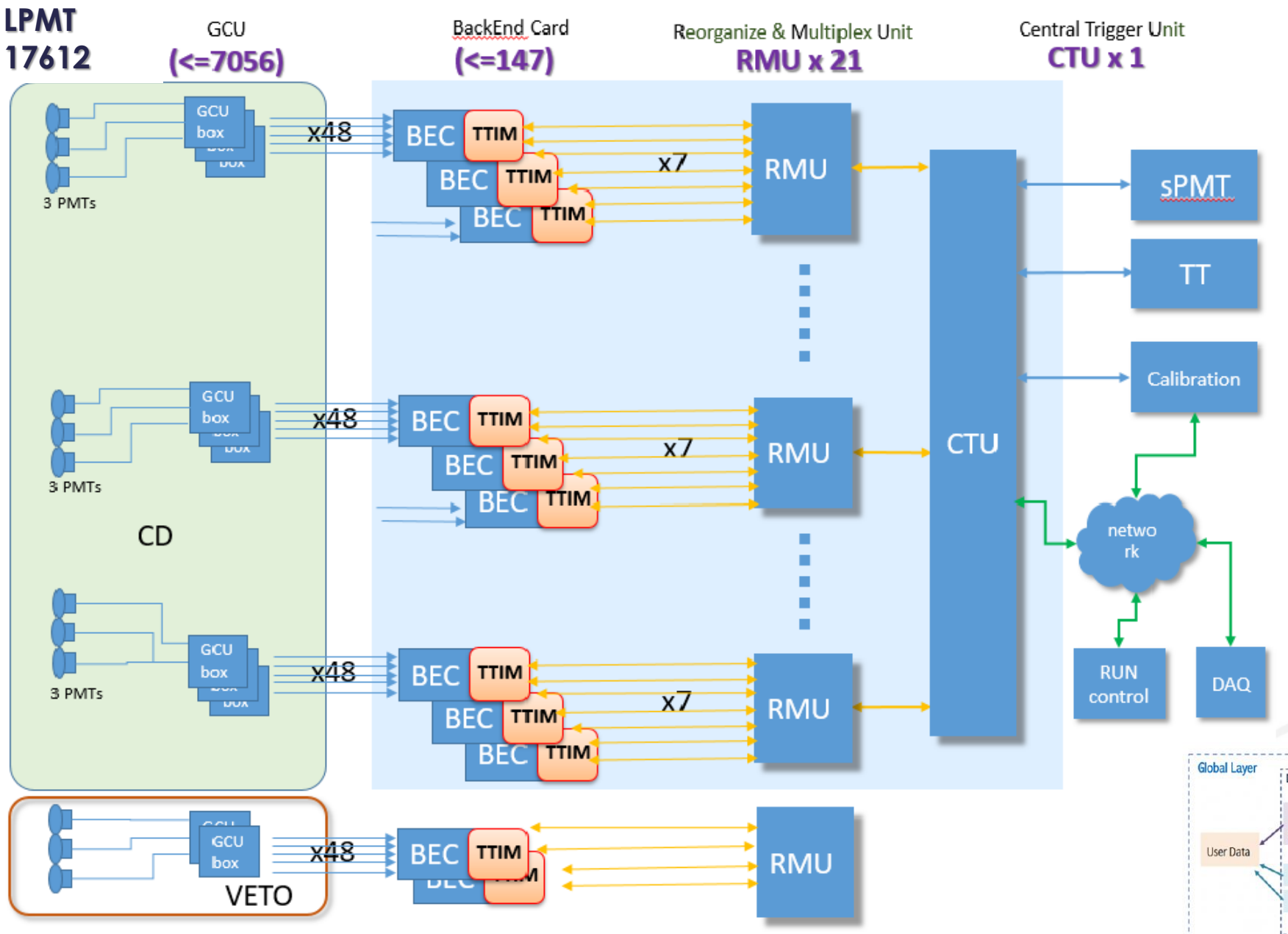
JUNO Detector Performance

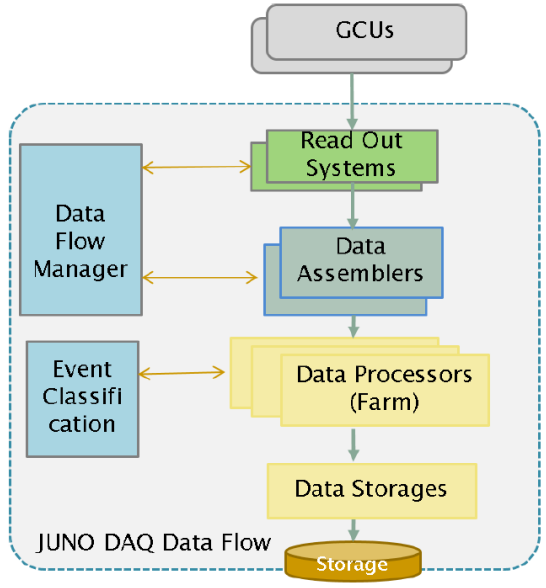
- Detect 100,000 neutrinos in 6 years of data collection → 20,000 tons of liquid Scintillator (LS) in a sphere with 35 m diameter
- Energy resolution of 3%/√E(MeV)
  → System of 18000 PM 20'' and 26000 PM 3'' (78% angular coverage) to detect ~1500 photoelectrons / MeV

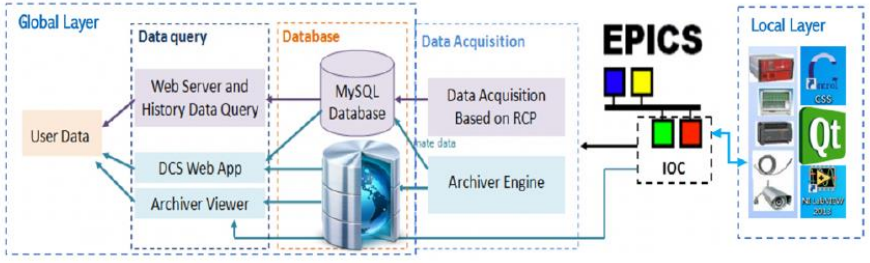


DAQ now days….


1 Node = 3 PMT 20''
1 sector = 48 UWB
Each Node has two ethernet link:
-one synchronous link ➔ ➔ Time and trigger management
-one asynchronous link ➔ data stream
48 synch Link (128MHz)
L1
BEC/TTIM
L2
RMU/CTU
x7
Global Trigger Management
➔ Based on PTP system (White Rabbit)
Processing trigger& data center
Standard 1GHz ethernet link: Data stream
1 Node = 128 PMT 3''
BEC/TTIM


LPMT
17612
GCU
(<=7056)
BackEnd Card
(<=147)
Reorganize & Multiplex Unit
RMU x 21
Central Trigger Unit
CTU x 1
GCU box
3 PMTs
x48
BEC
TTIM
x7
RMU
CTU
sPMT
TT
Calibration
netwo rk
RUN control
DAQ
CD
VETO

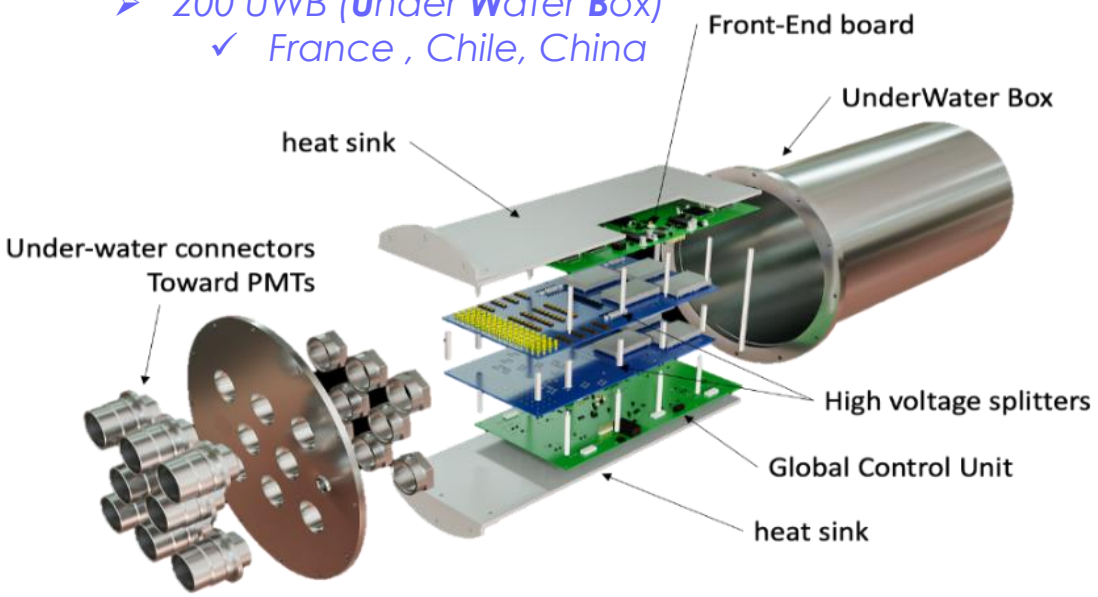

GCUs
Read Out Systems
Data Flow Manager
Data Assemblers
Event Classifi cation
Data Processors (Farm)
Data Storages
JUNO DAQ Data Flow
Storage

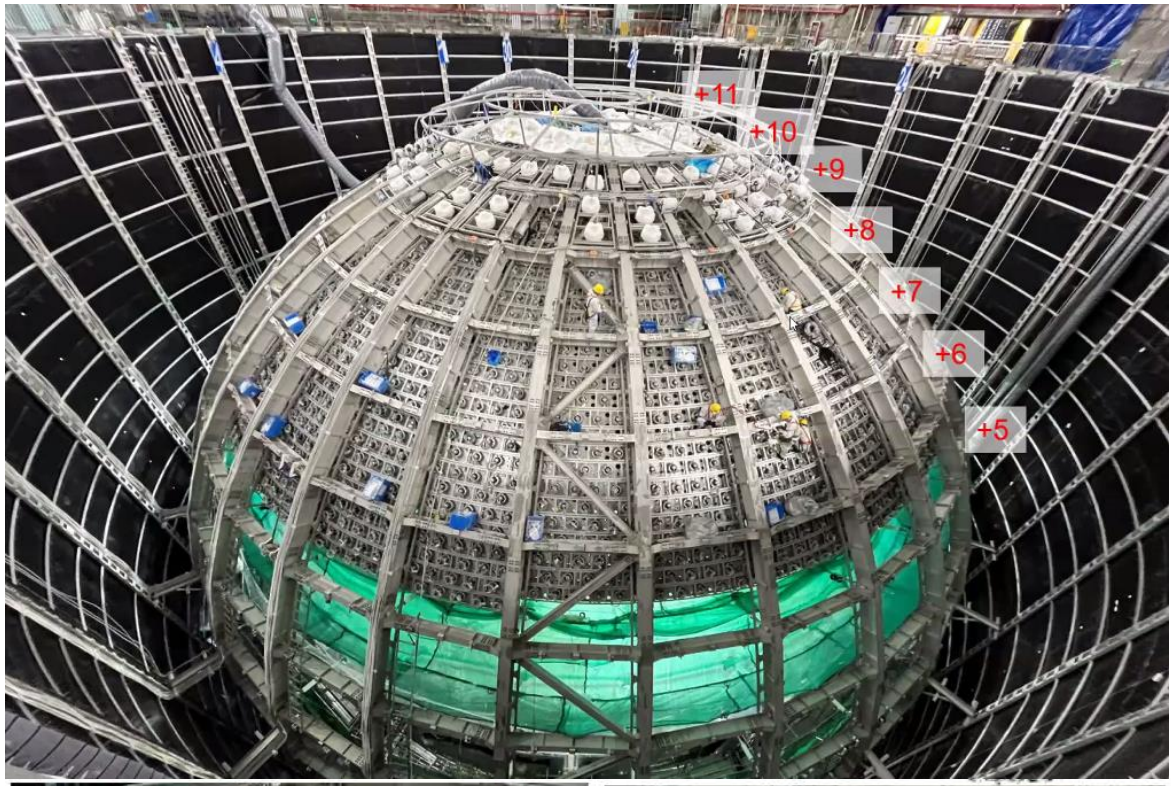

Global Layer
Data query
Database
Data Acquisition
Web Server and History Data Query
MySQL Database
Data Acquisition Based on RCP
User Data
DCS Web App
Archiver Viewer
Archiver Engine
EPICS
IOC
Local Layer

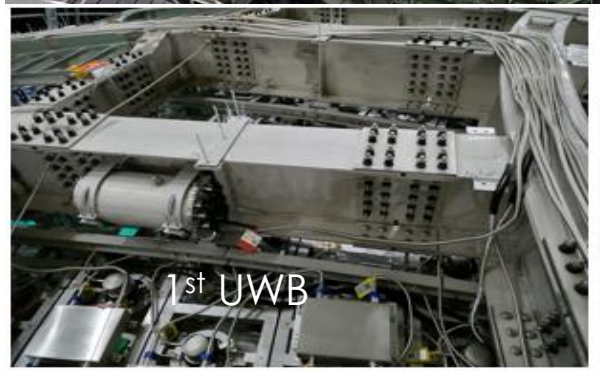
JUNO sPMT Project

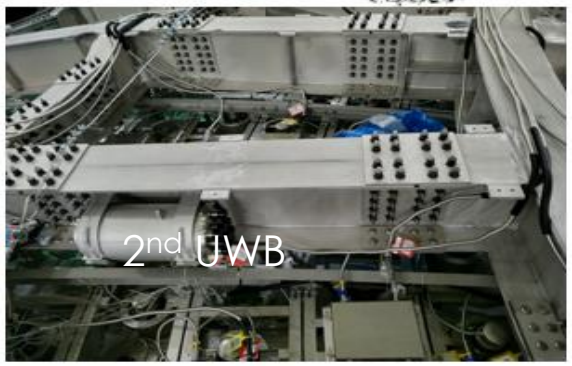
JUNO – SPMT : (FRANCE, CHINA, CHILE)

- *PMTs:*
  - *25 600 photomultipliers 3''*
    - ✓ *CHINA (HZC)*
- *Electronic*
  - ❖ *Front End Electronics for sPMTs*
    - ✓ *France: IN2P3*
  - ❖ *High Voltages Splitters*
    - ✓ *Chile*
  - ❖ *Global Control Modules*
    - ✓ *China*
- *Mechanical*
  - *200 UWB (**U**nder **W**ater **B**ox)*
    - ✓ *France , Chile, China*

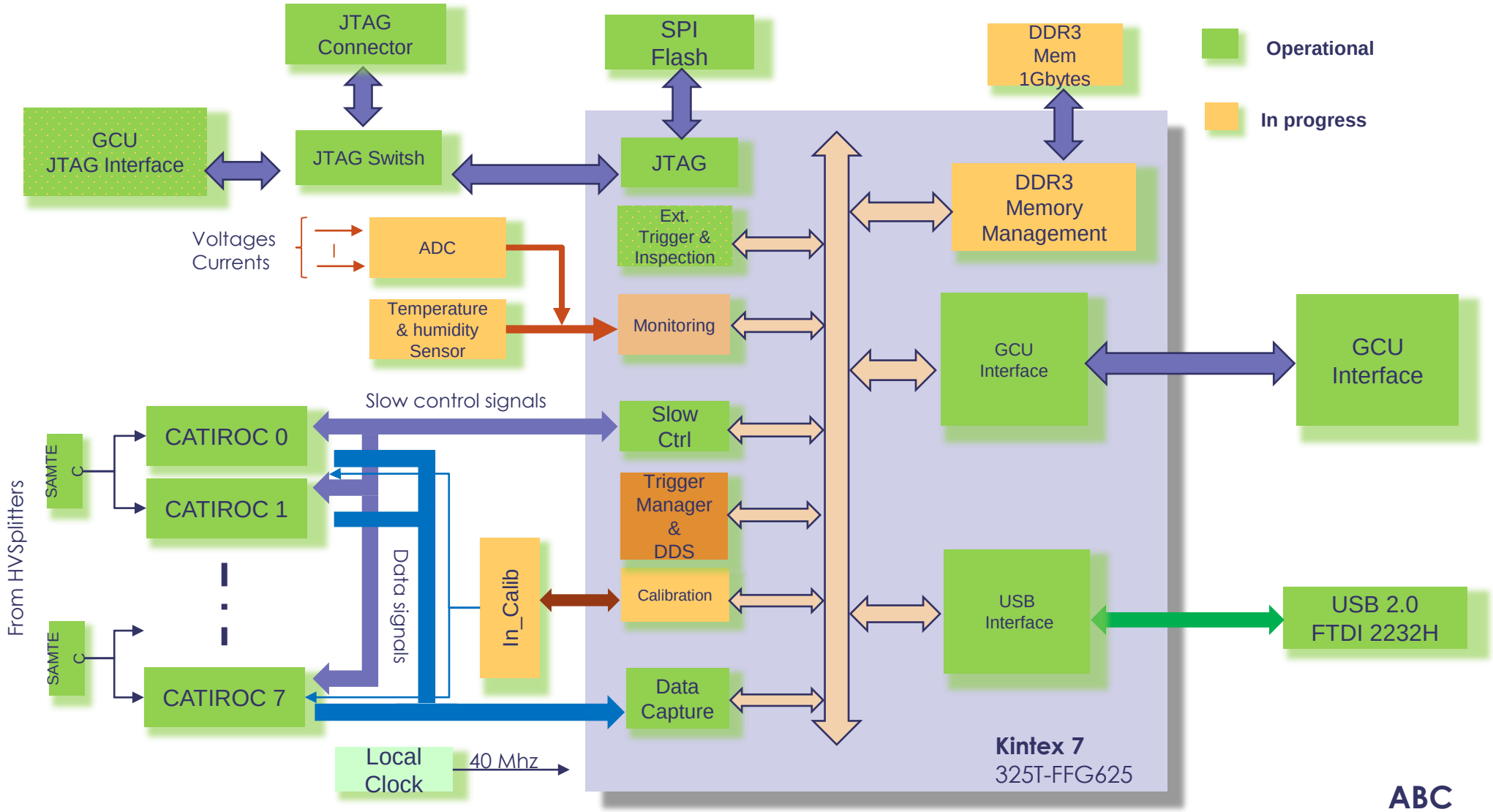




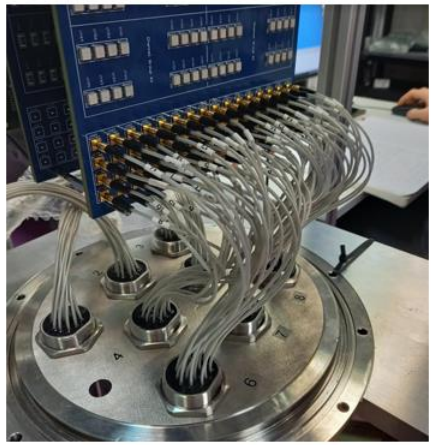




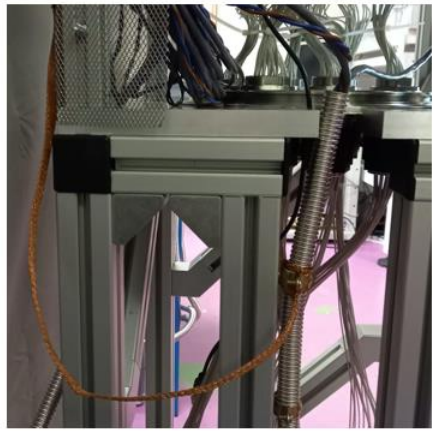
JUNO sPMT : ABC Block Diagram



LP2IB Combined test bench



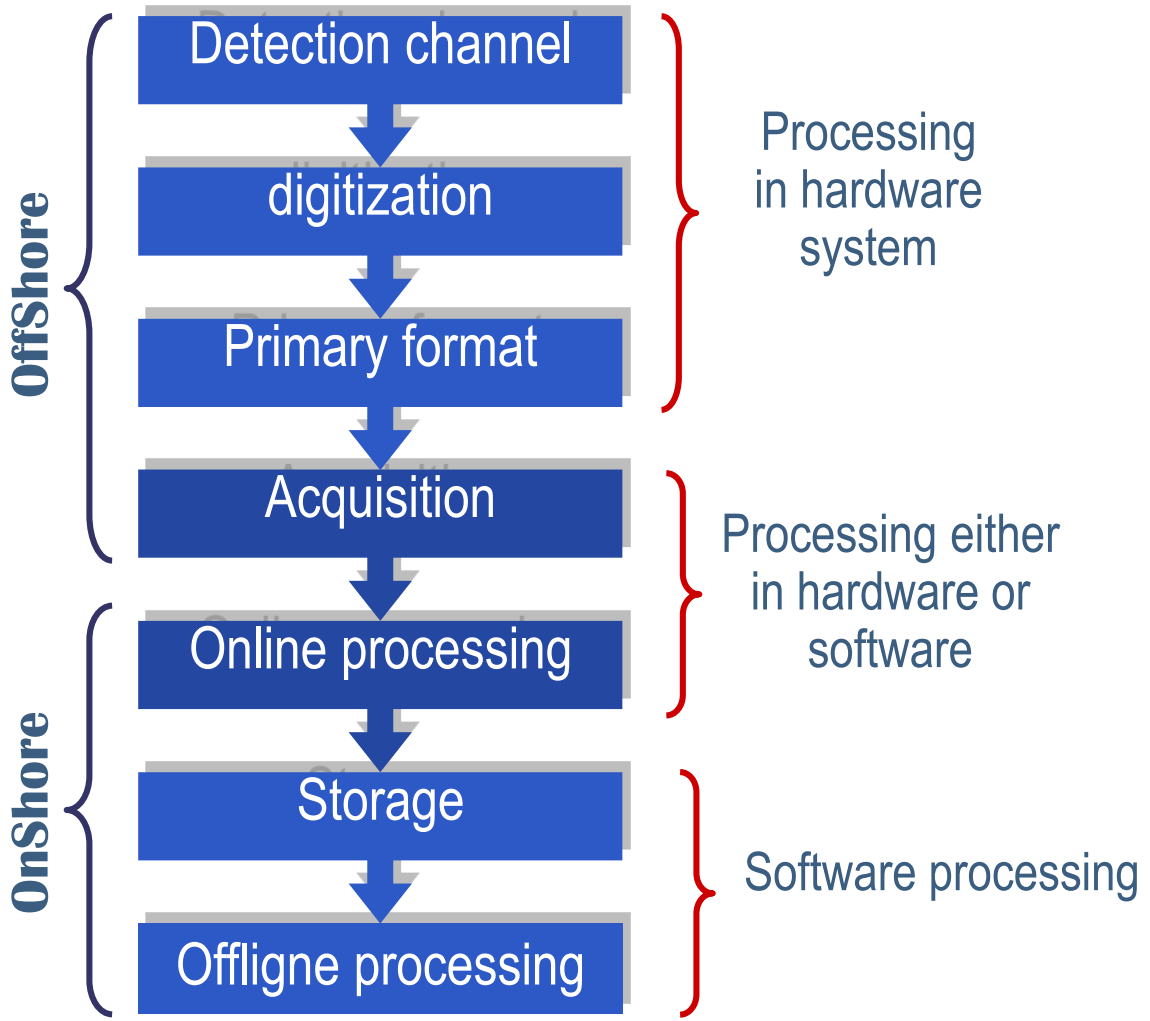
Detail of PMT connection



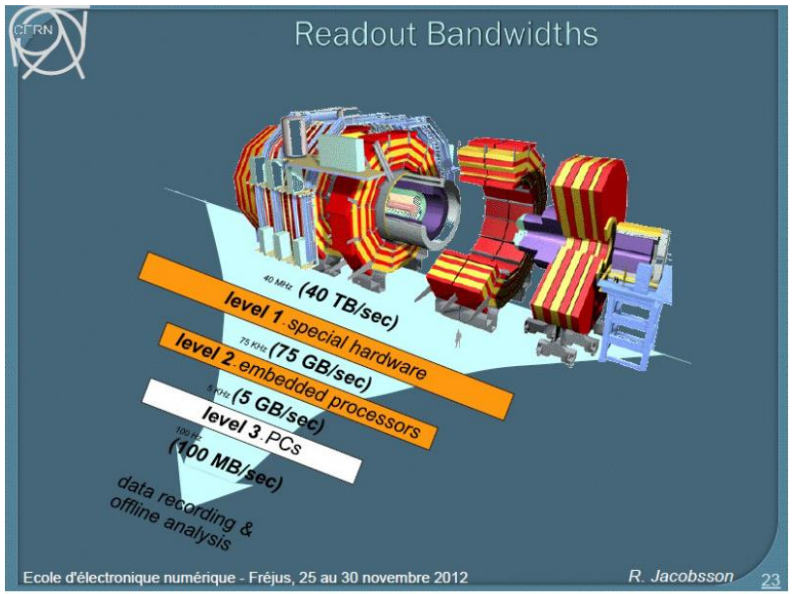
80 meter bellow connection
Detail of GND connection

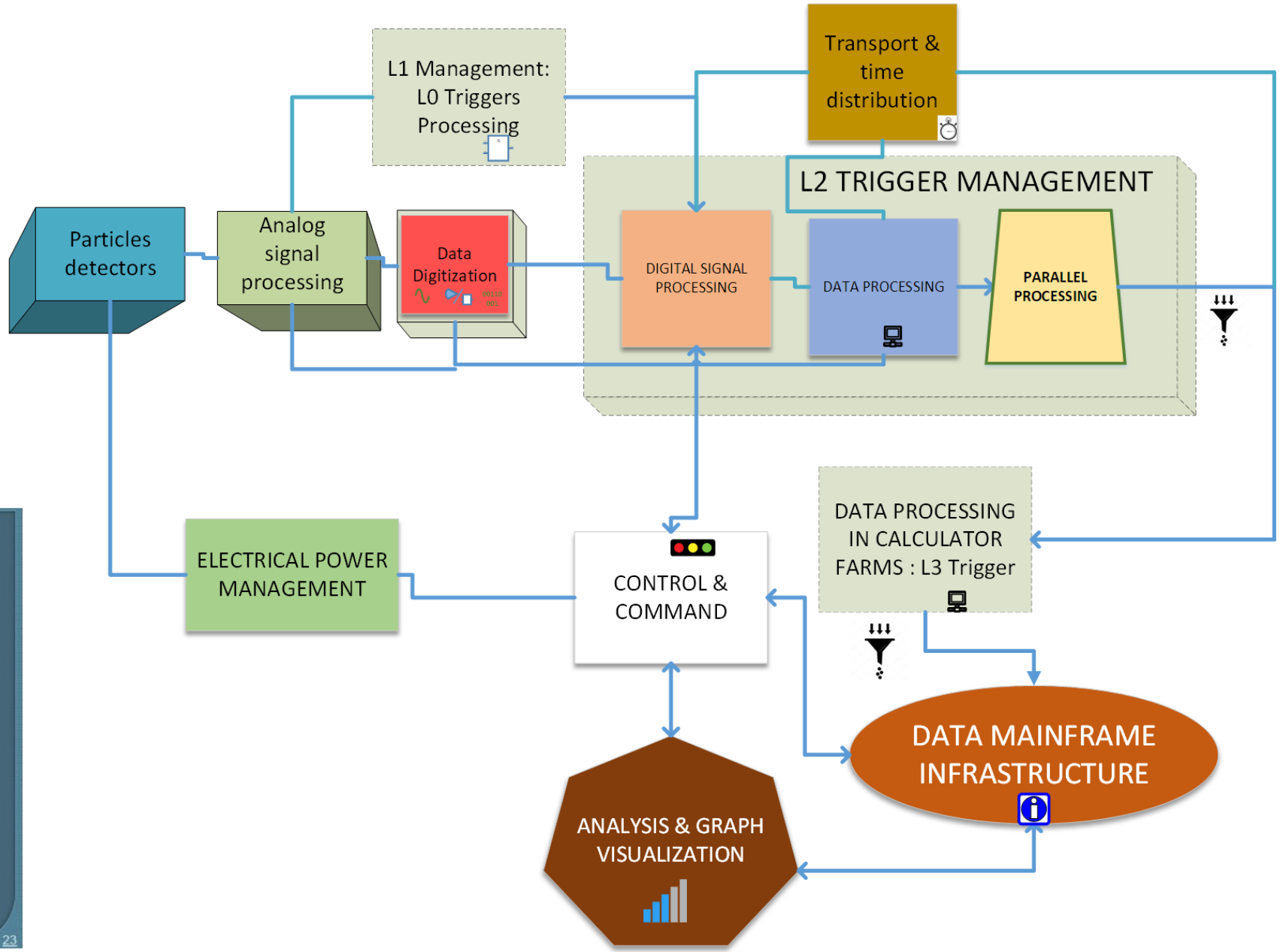
TDAQ System(Trigger & Data AcQuisition)

- Hardware and software System
- Real Time System
- Distributed System
- Heterogenous Systems
- Evolving long-term projects

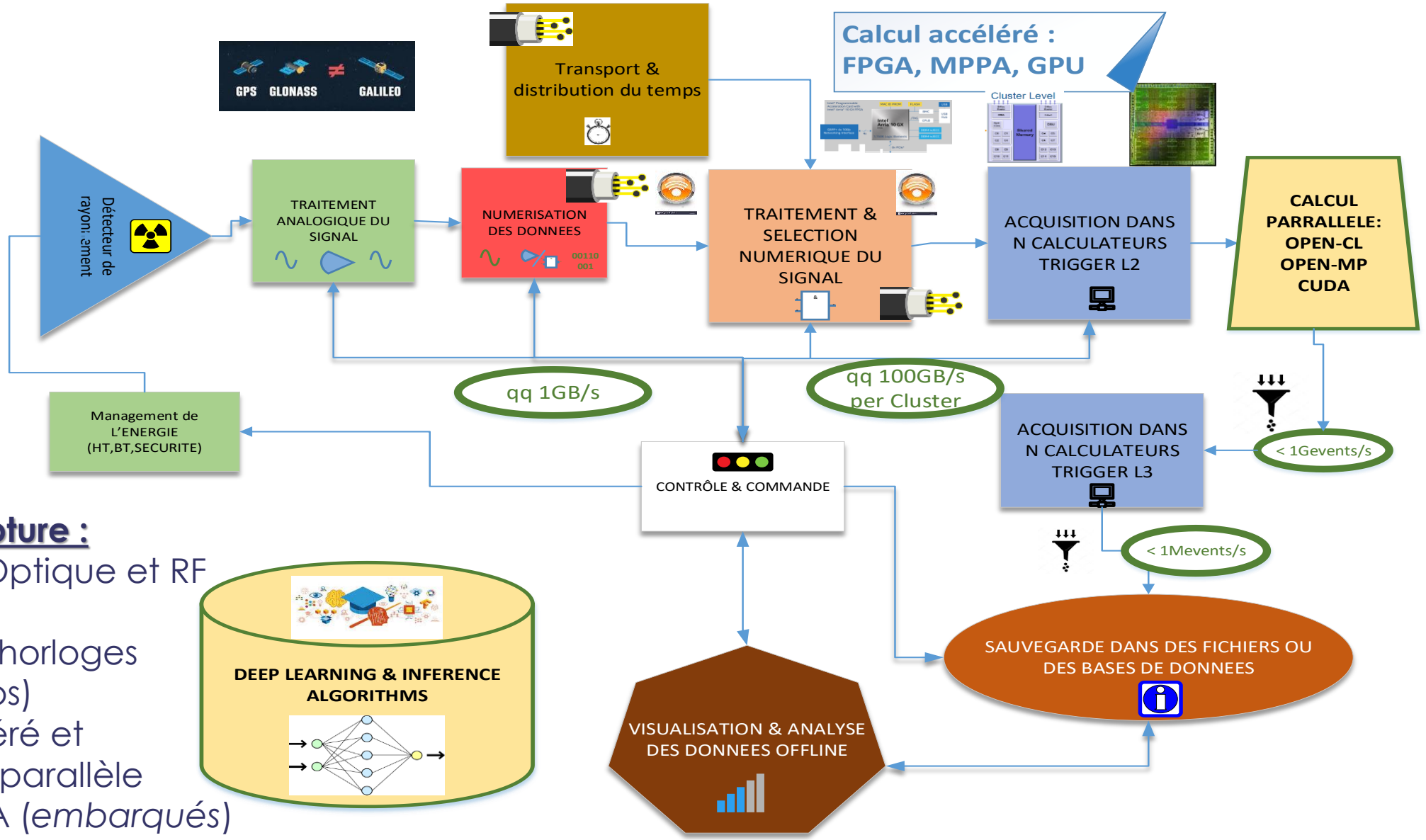


Dominant Design in Instruments for research in fundamental physics





Acceleration of emerging technologies

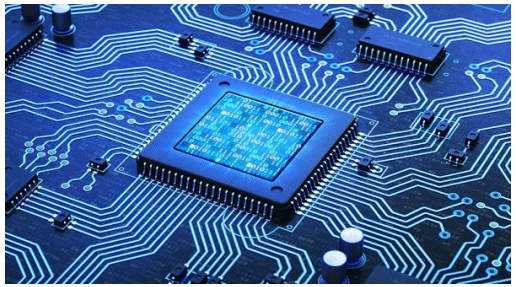


Les points de rupture :

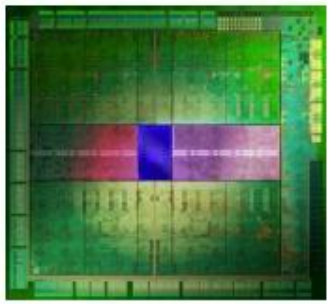
- Transmission Optique et RF des FE
- Distribution d'horloges précises (qq ps)
- Calcul accéléré et massivement parallèle
- Algorithmes IA (*embarqués*)

Technologies after digitization

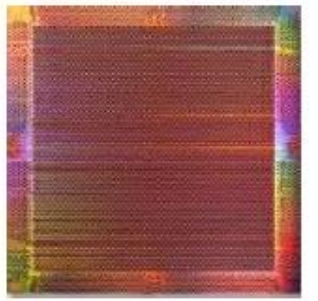
MPPA



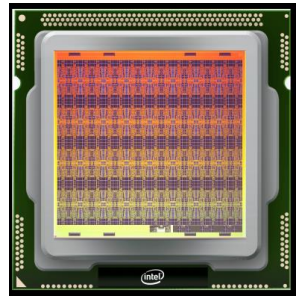
ASICs



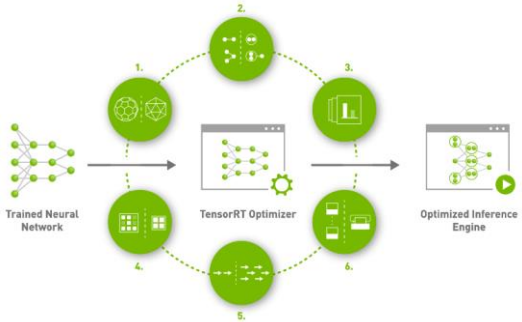
GPUs

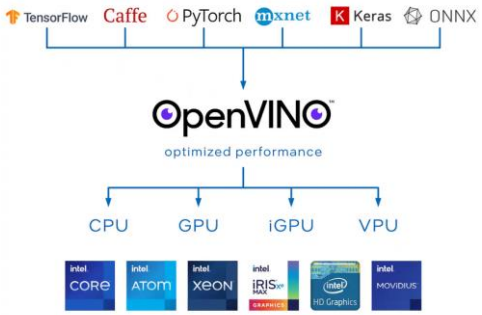


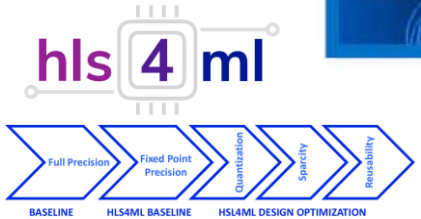
FPGAs



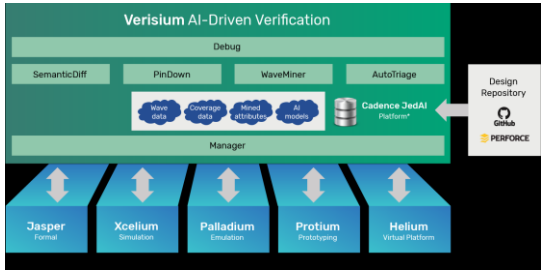
NMC

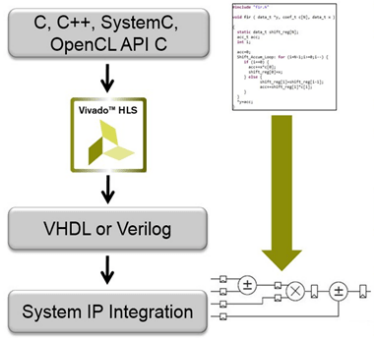


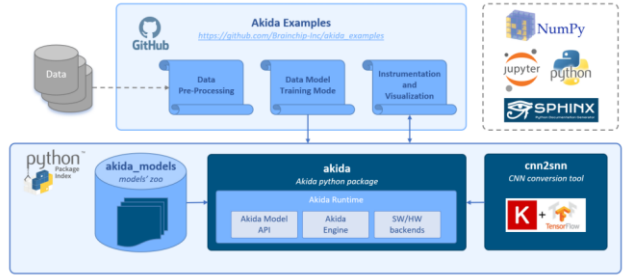




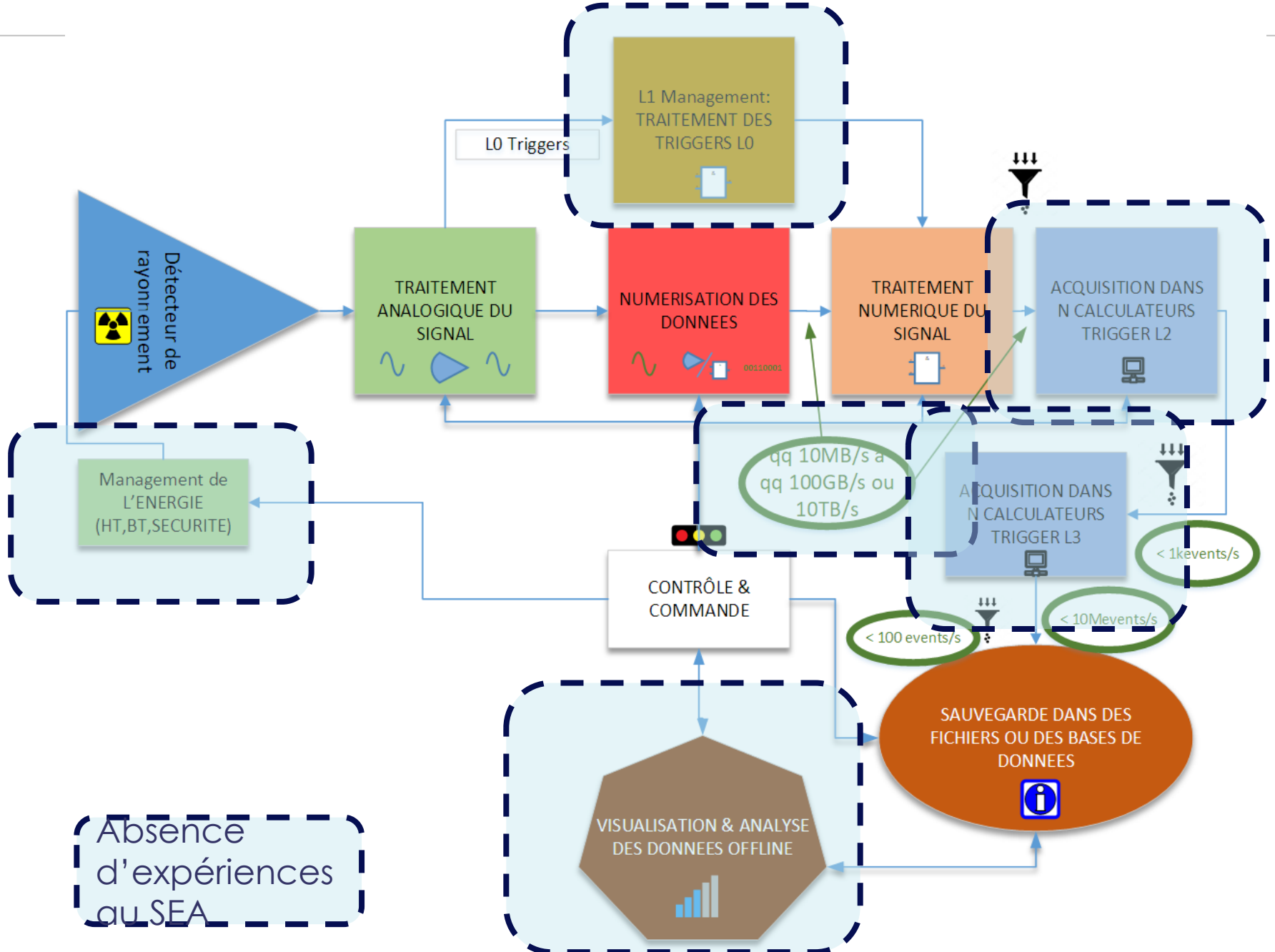
SIEMENS
Mentor Graphics





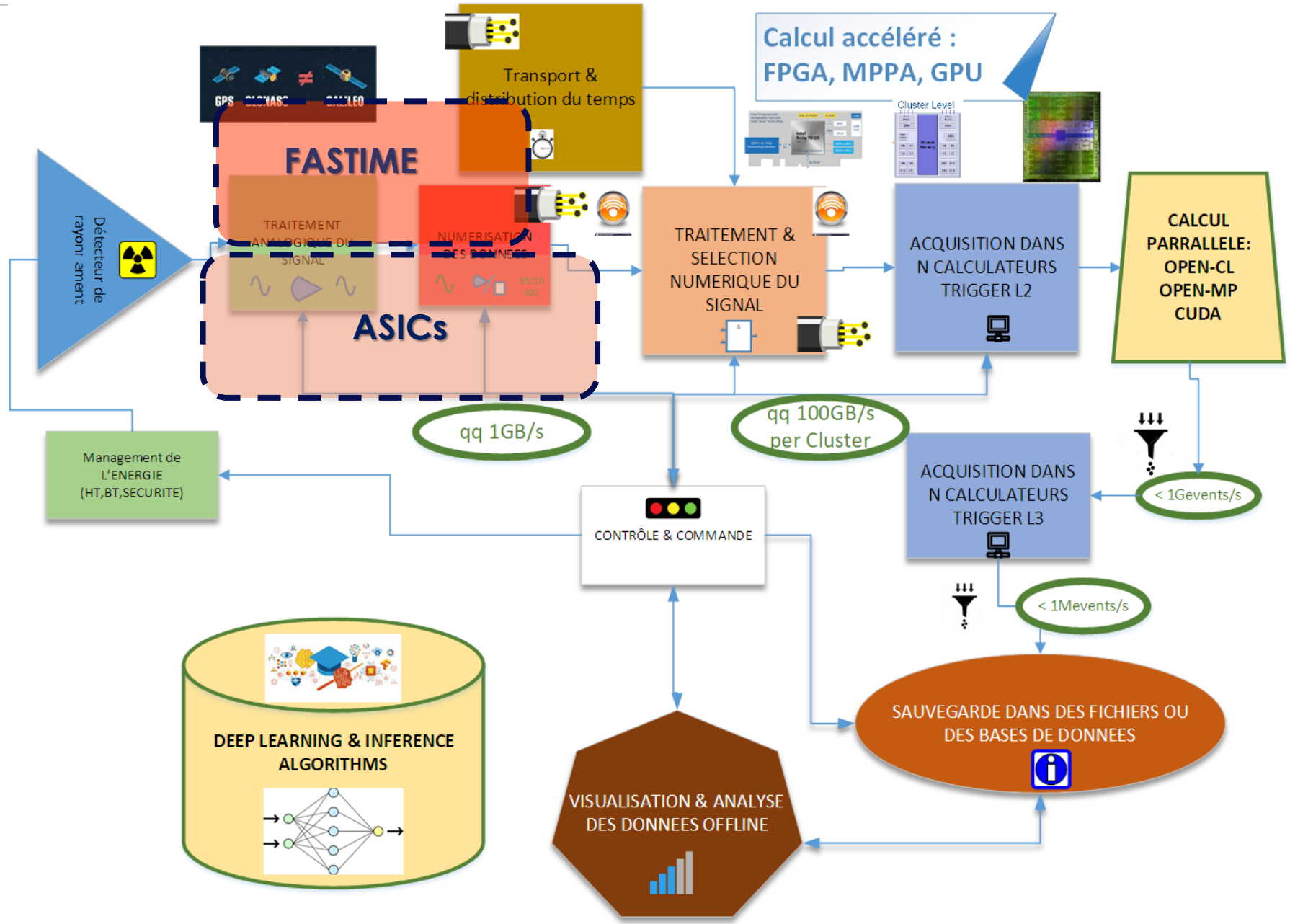


IN2P3 R&T Roadmap for the futur in Fundamental Physics

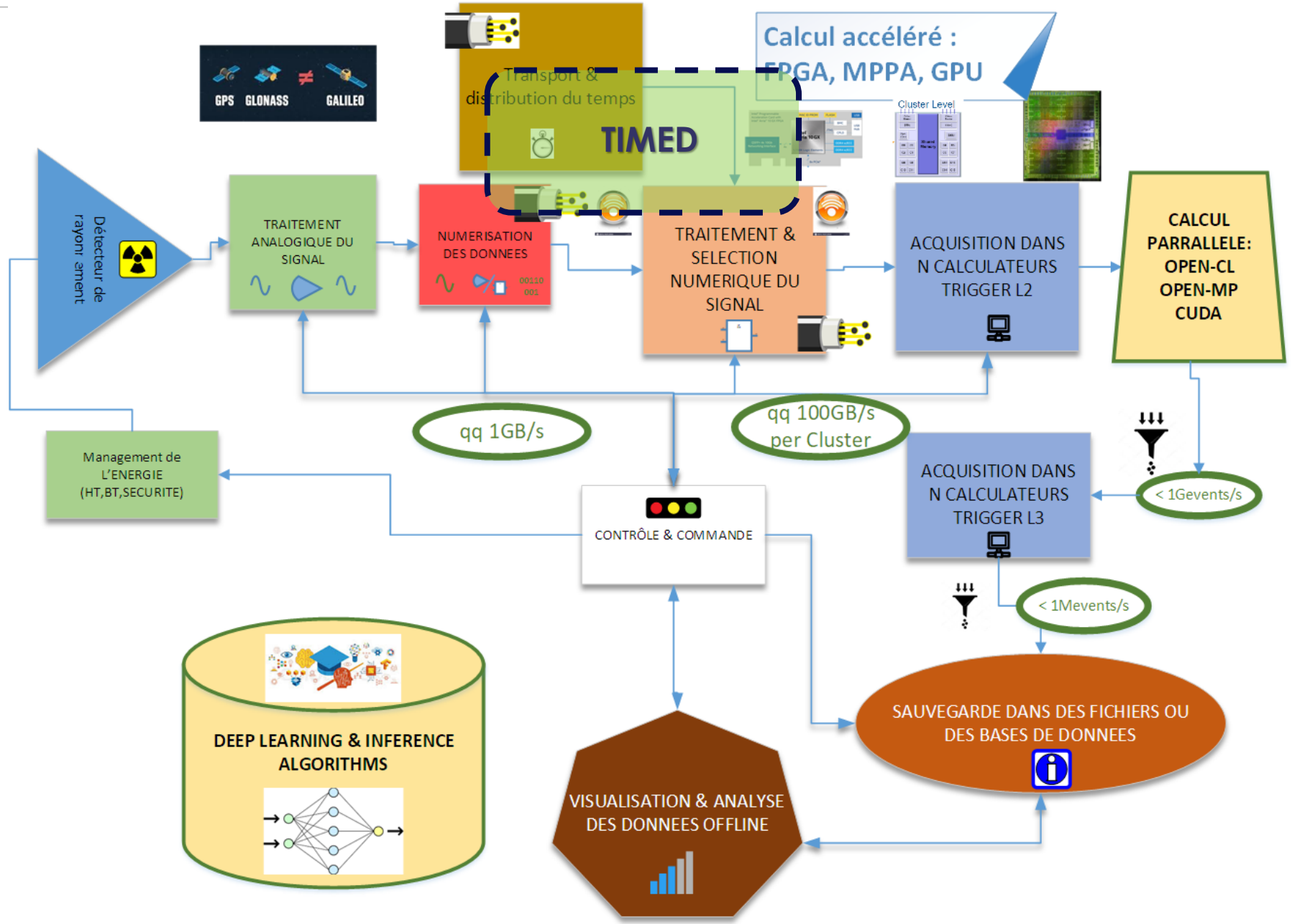


Absence d'expériences au SEA

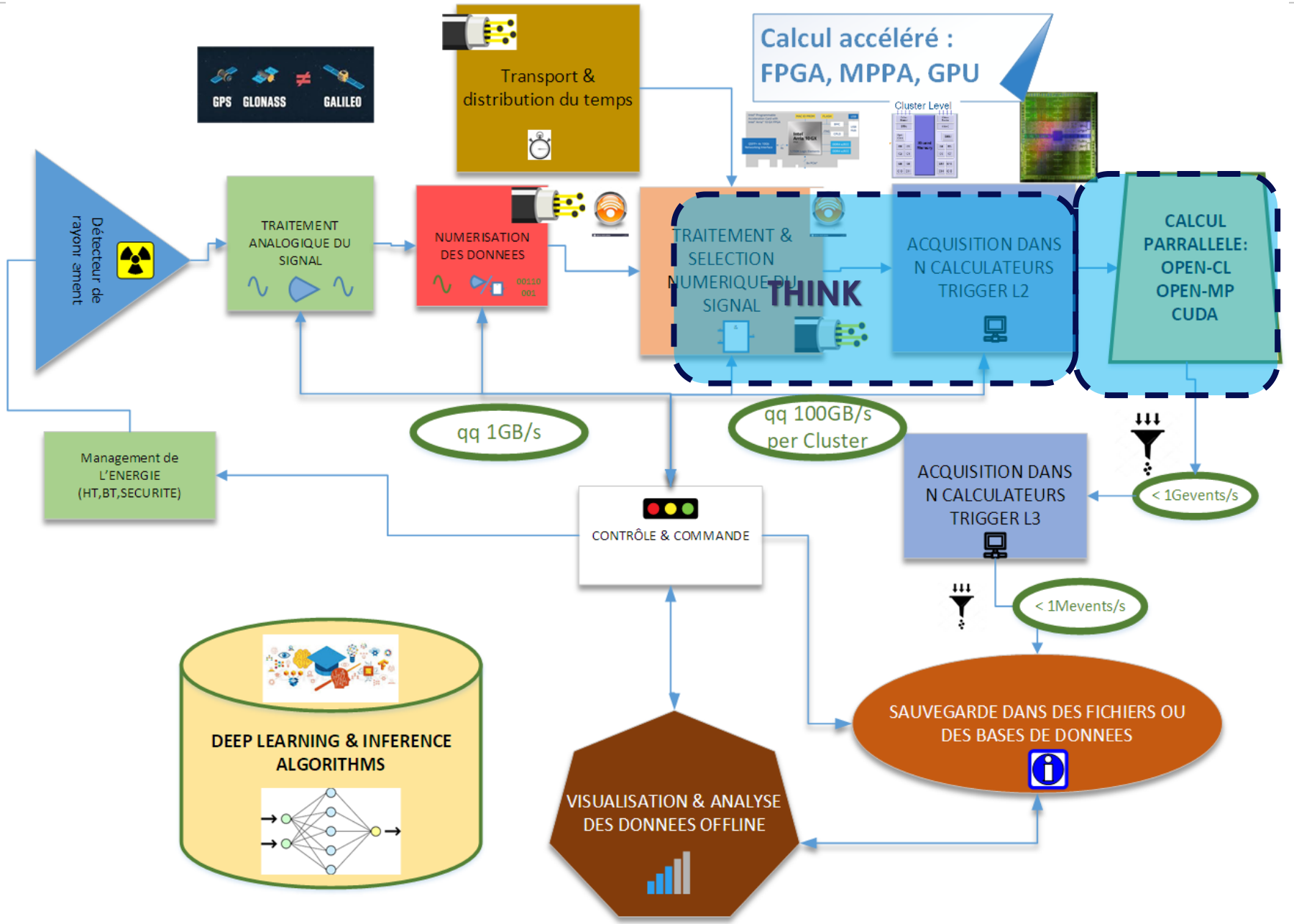
CONTEXTE DES R&T VALIDEES



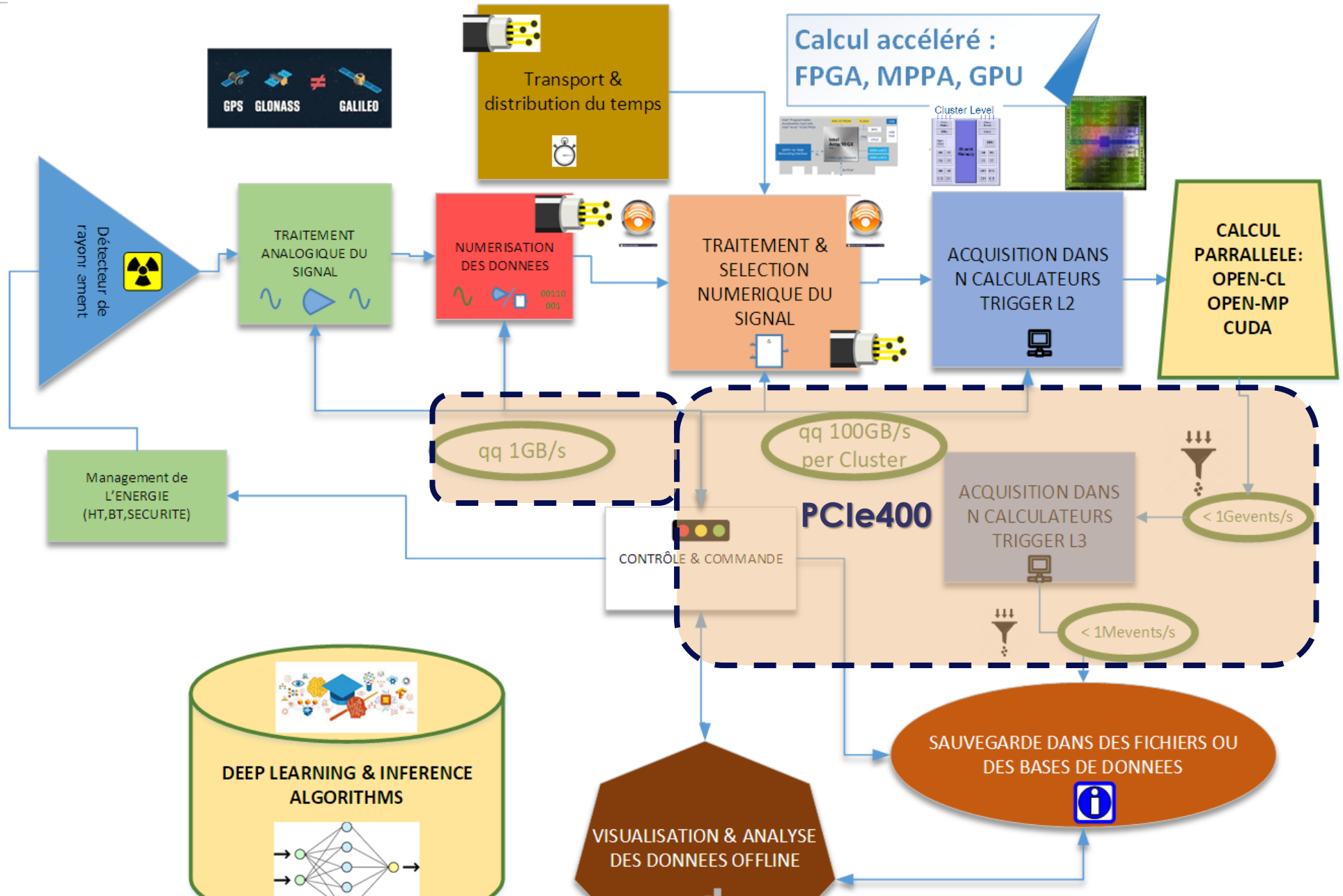
IN2P3 R&T Roadmap for the futur in Fundamental Physics



IN2P3 R&T Roadmap for the futur in Fundamental Physics



IN2P3 R&T Roadmap for the futur in Fundamental Physics



IN2P3 R&T Roadmap for the futur in Fundamental Physics