The DAQ for the KOTO Experiment and RPT Upgrade

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On behalf of
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Overview

- KOTO Experiment
- The DAQ System
- DAQ Performance
- Upgrades
- Summary

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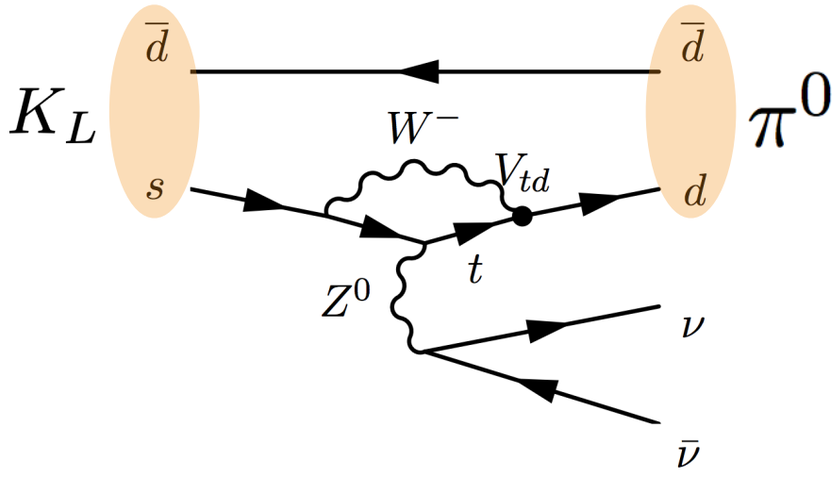
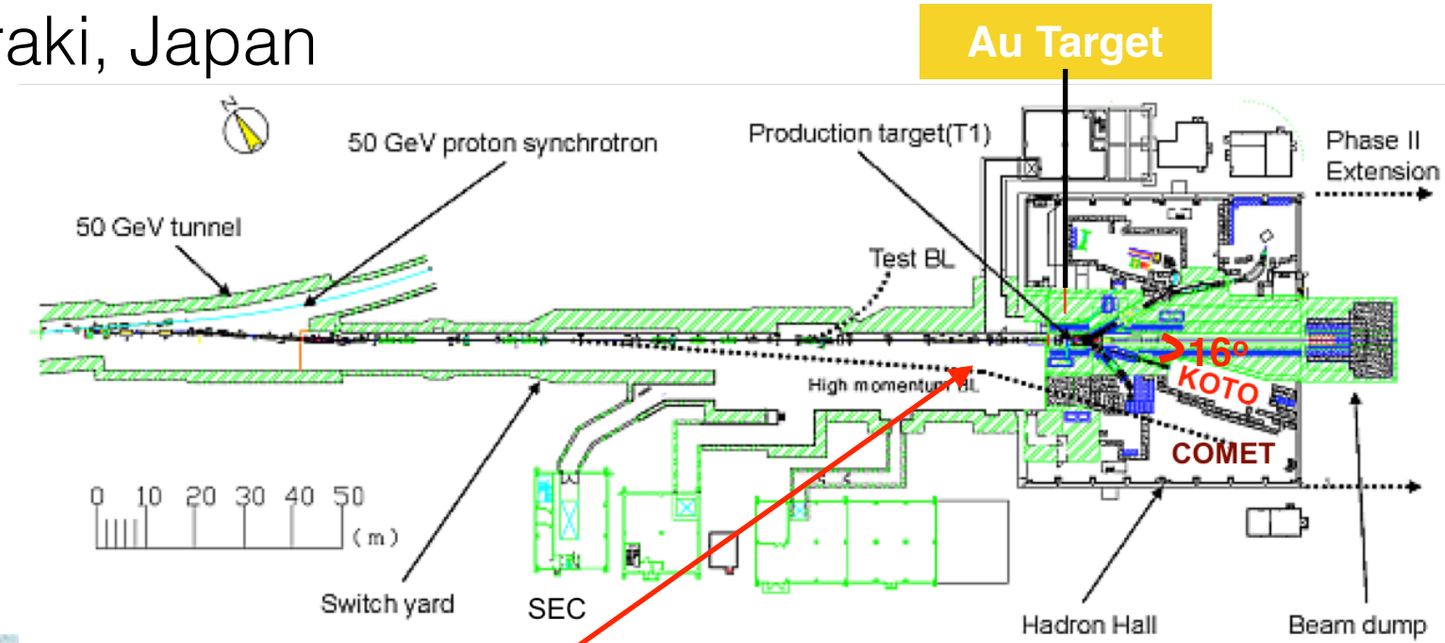
KOTO Experiment at J-PARC

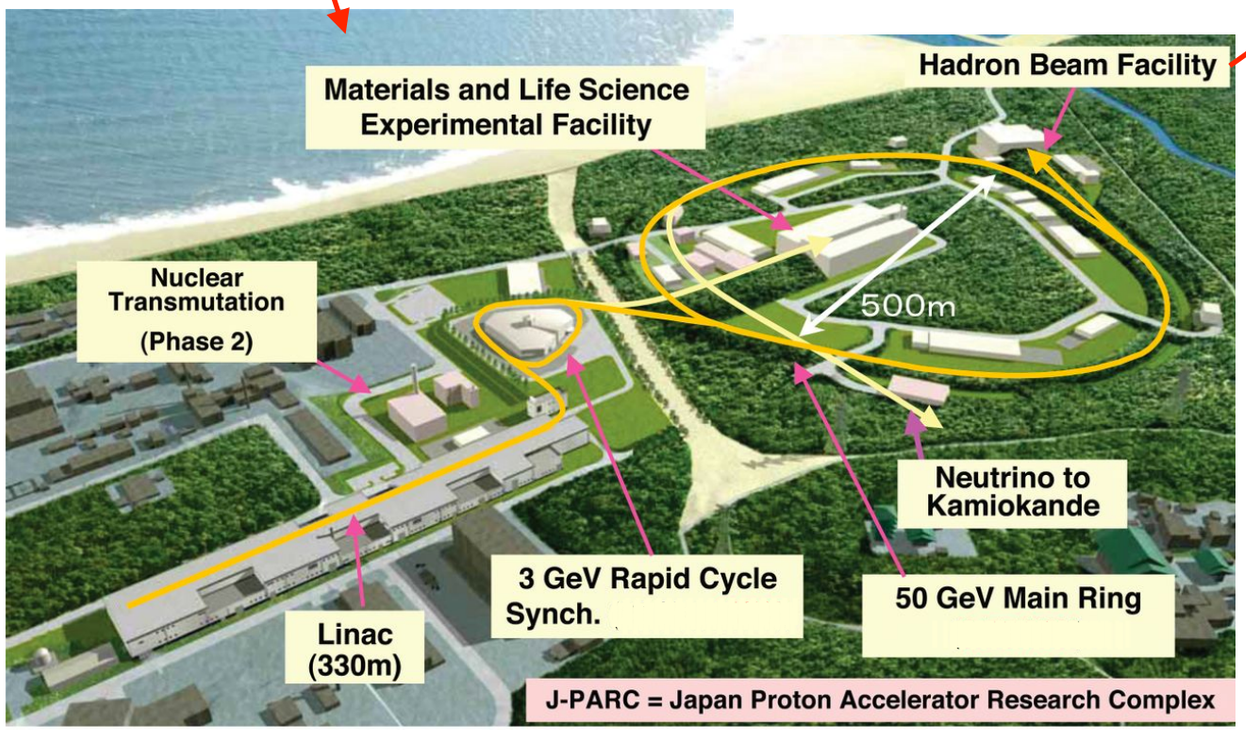
- Study $K_L \rightarrow \pi^0 \nu\bar{\nu}$ decay
- Branching ratio (SM): 2.4 x 10^{-11}
  - see one event in ~250 billion events
  - 2013: 24 kW
    2015: 24 kW ~ 42 kW
    2016: 42 kW
    2017: 42 kW ~ 100 kW



KOTO Experiment at J-PARC

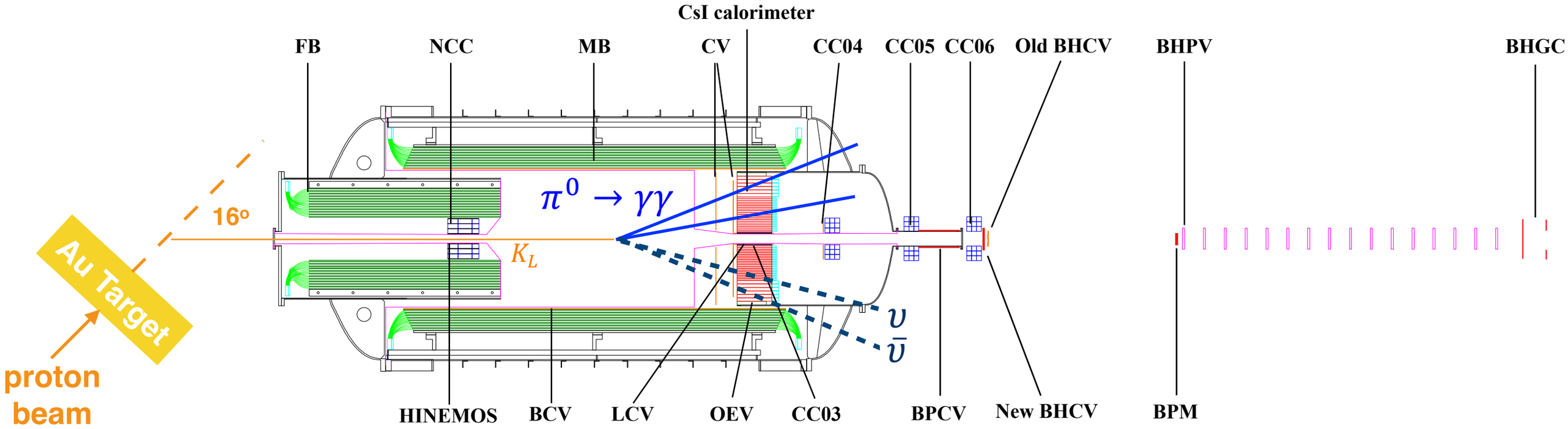
- Located at Tokai, Ibaraki, Japan





KOTO Detectors

- Final signal: two photons on the CsI calorimeter



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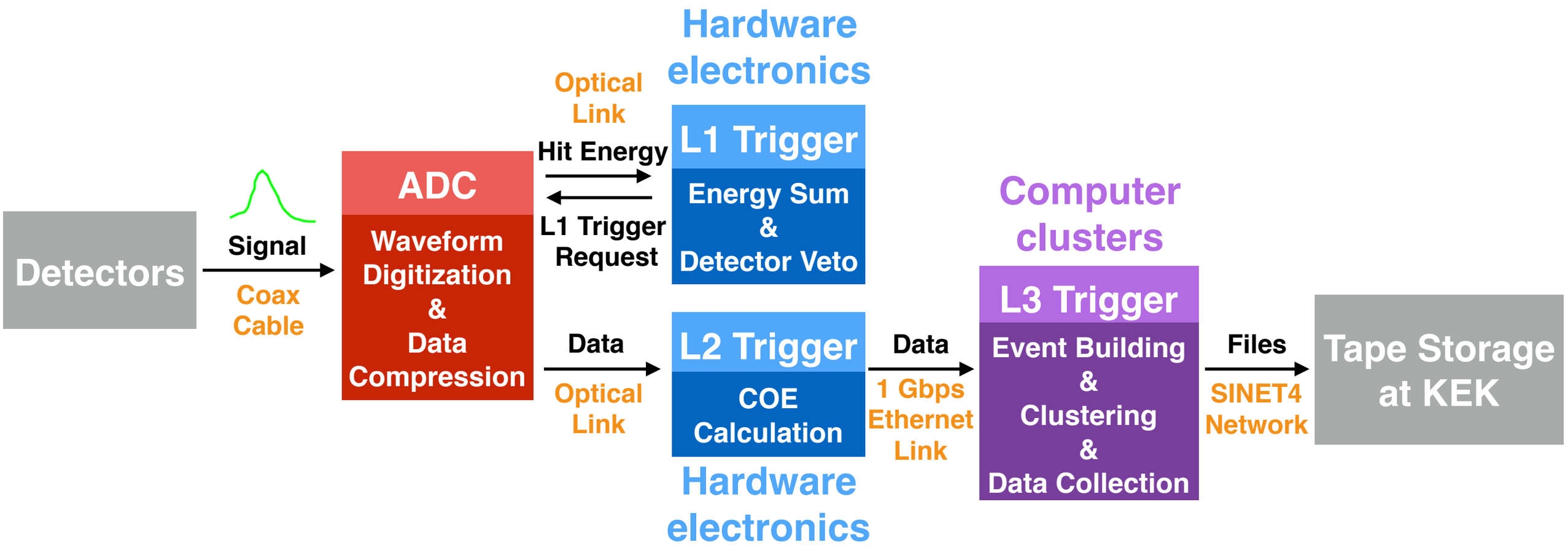
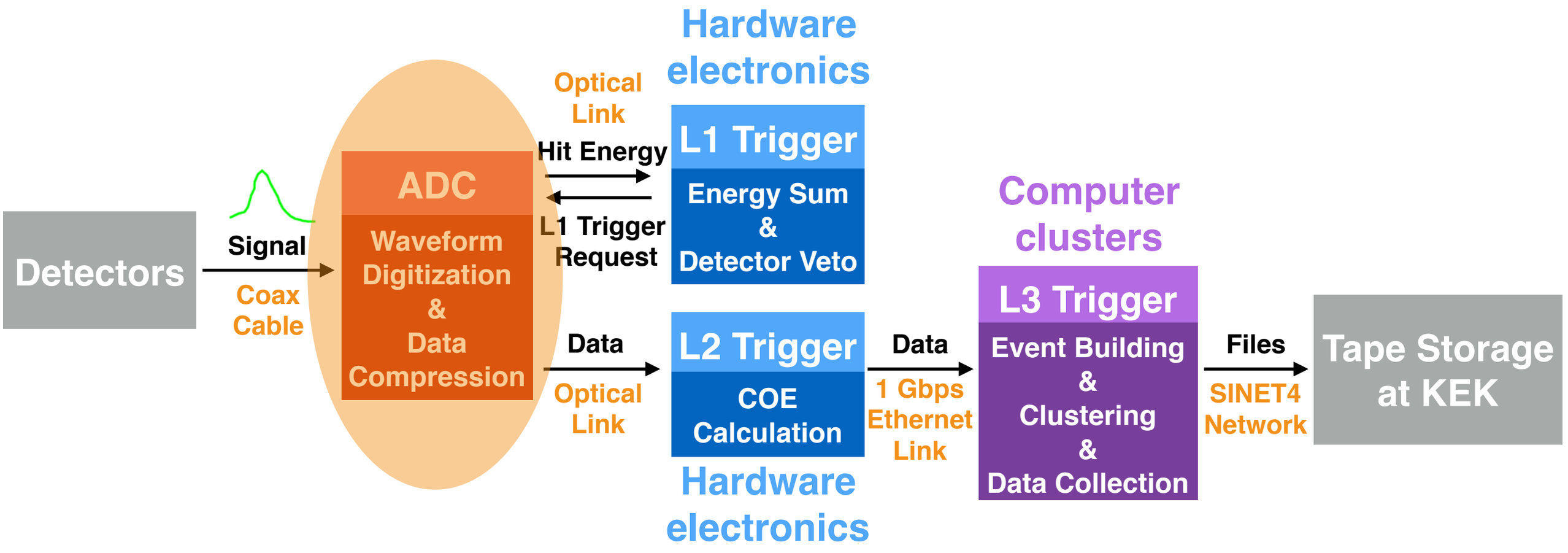
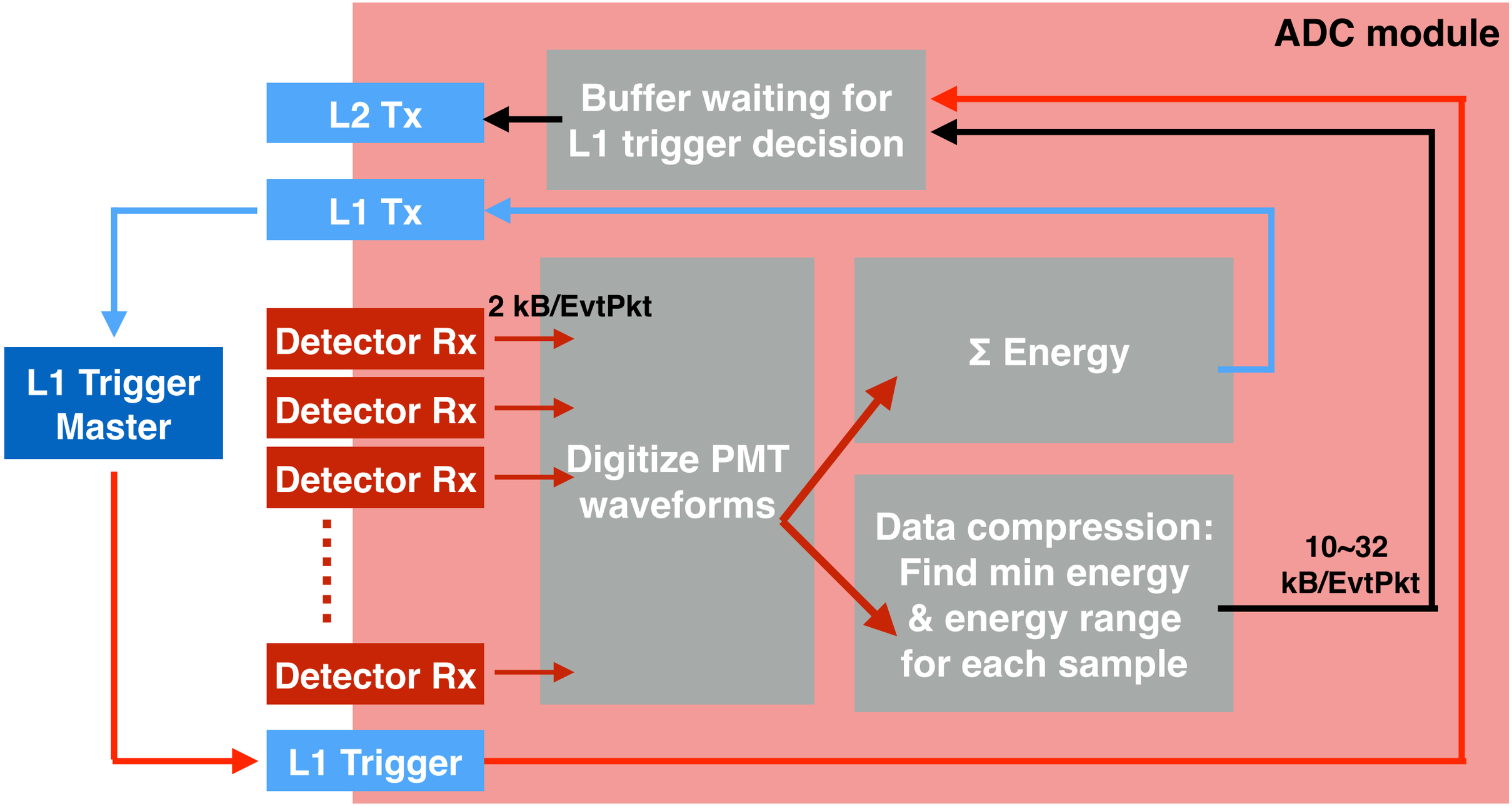
KOTO DAQ System



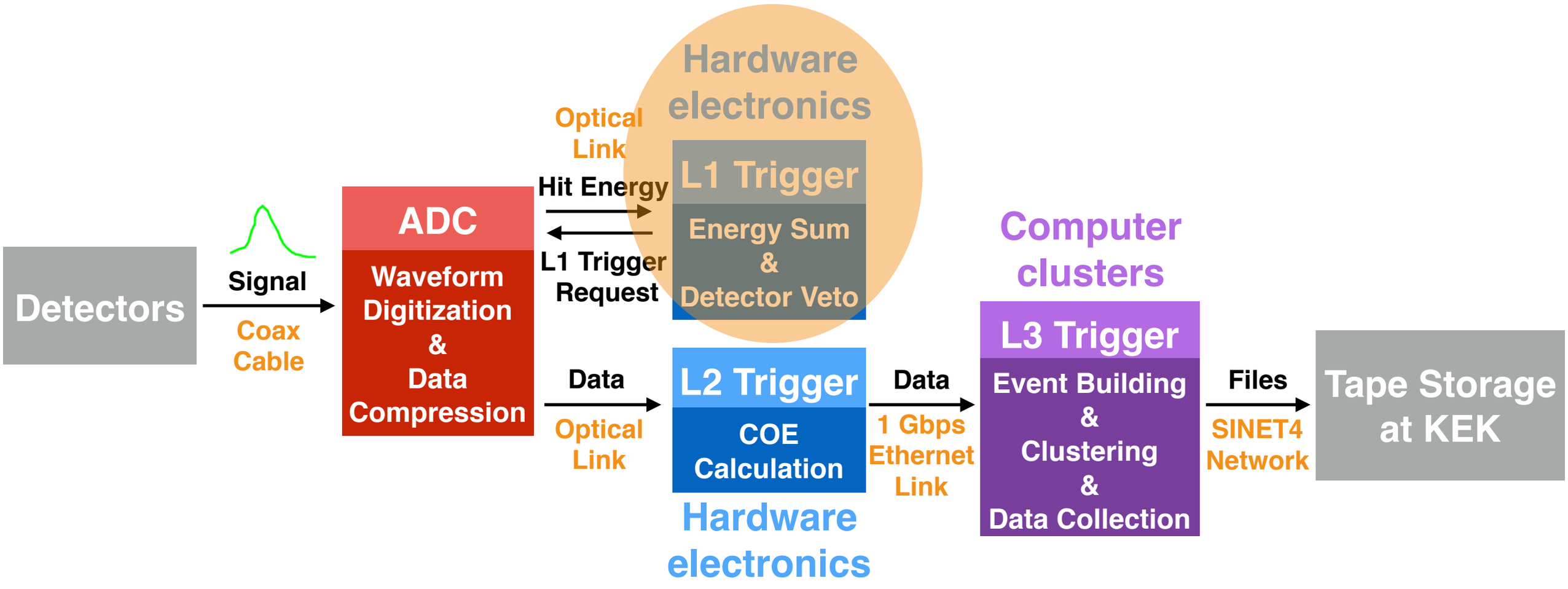
KOTO DAQ System



ADC Module


ADC module
L2 Tx
Buffer waiting for
L1 trigger decision
L1 Tx
L1 Trigger
Master
2 kB/EvtPkt
Detector Rx
Detector Rx
Detector Rx
Detector Rx
Digitize PMT
waveforms
Σ Energy
Data compression:
Find min energy
& energy range
for each sample
10~32
kB/EvtPkt
L1 Trigger

KOTO DAQ System



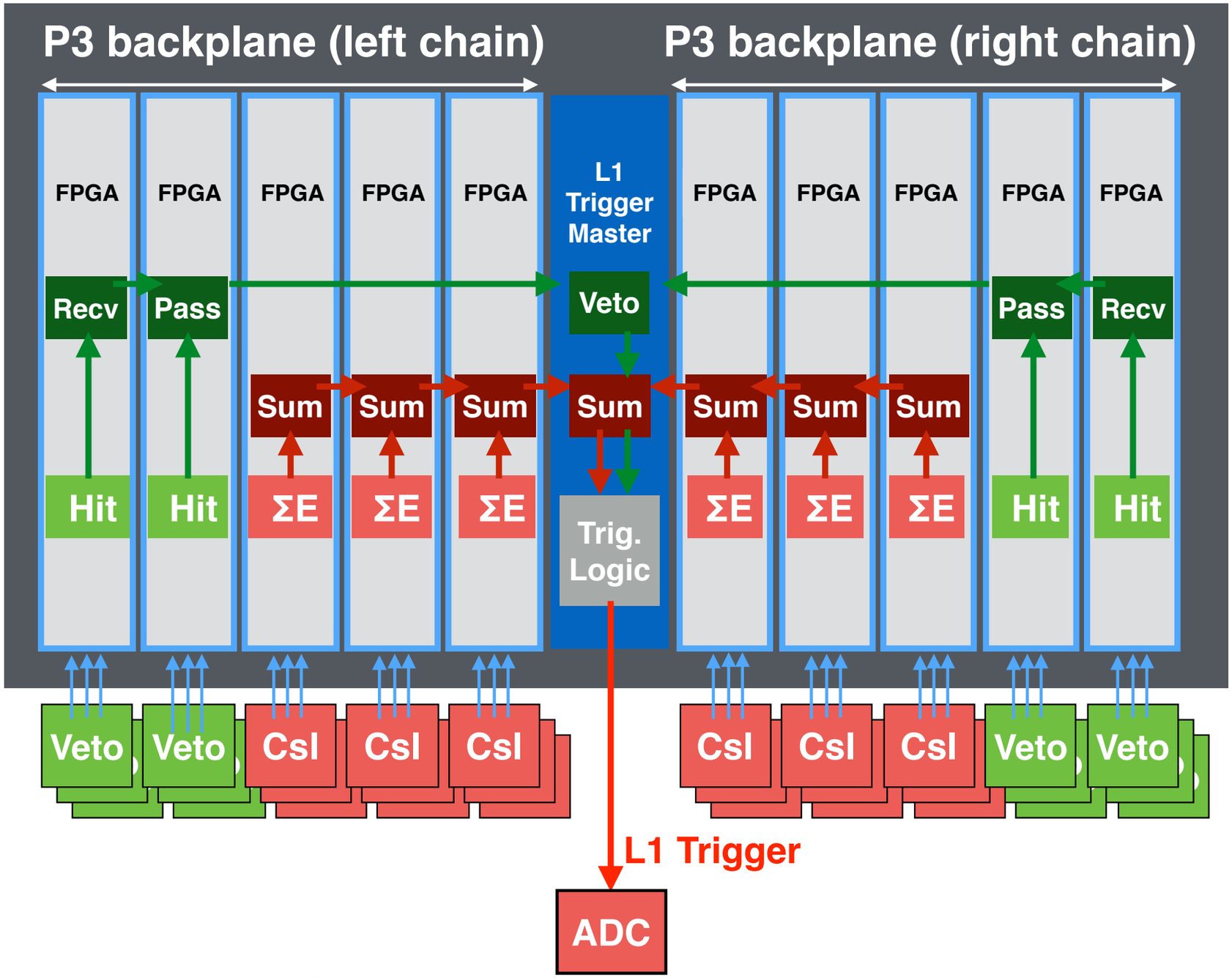
L1 Trigger System

- Σ Energy
- Detector veto
- Master L1 trigger
  - makes trigger decision
  - sends decision to ADC

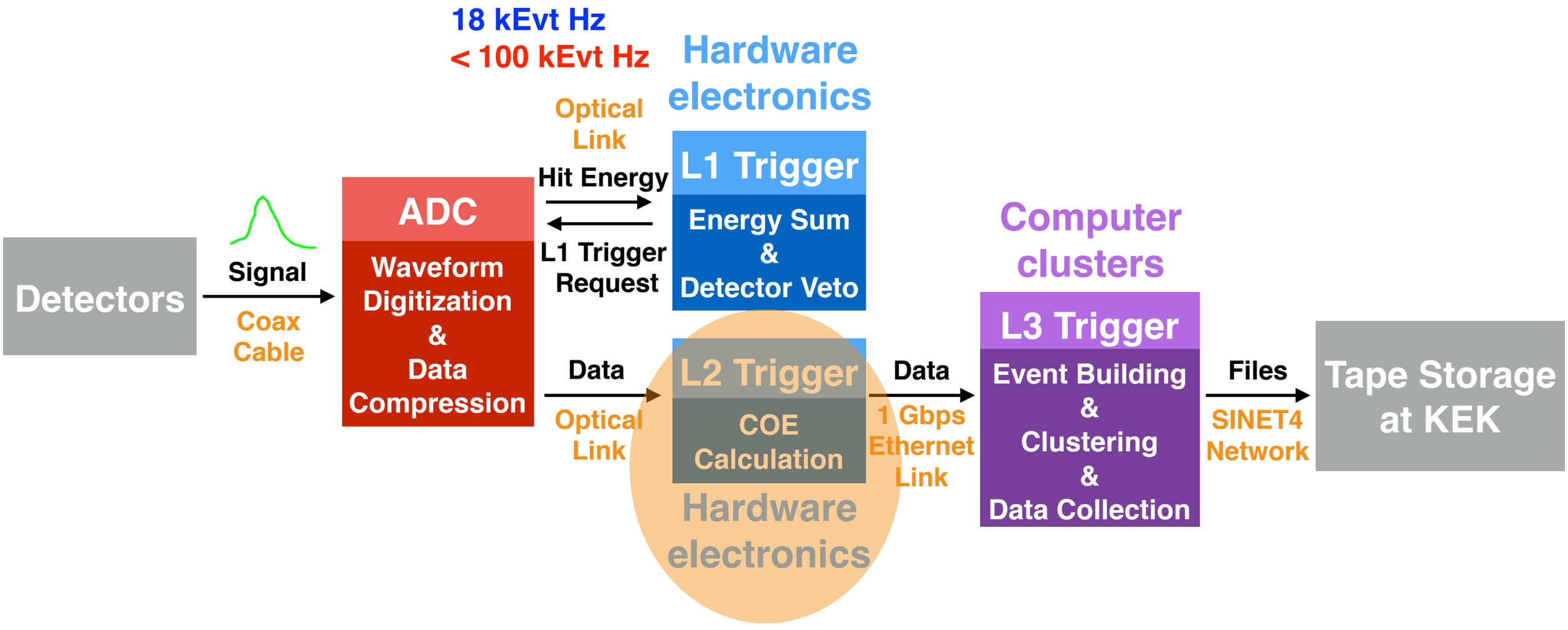
L1 Trigger Modules

2.5 Gbps Optical link

ADC



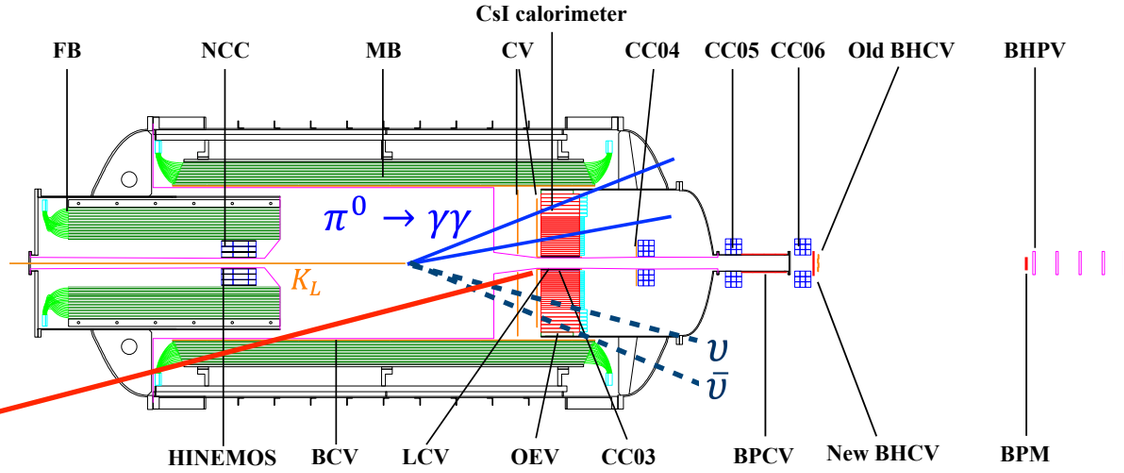
KOTO DAQ System

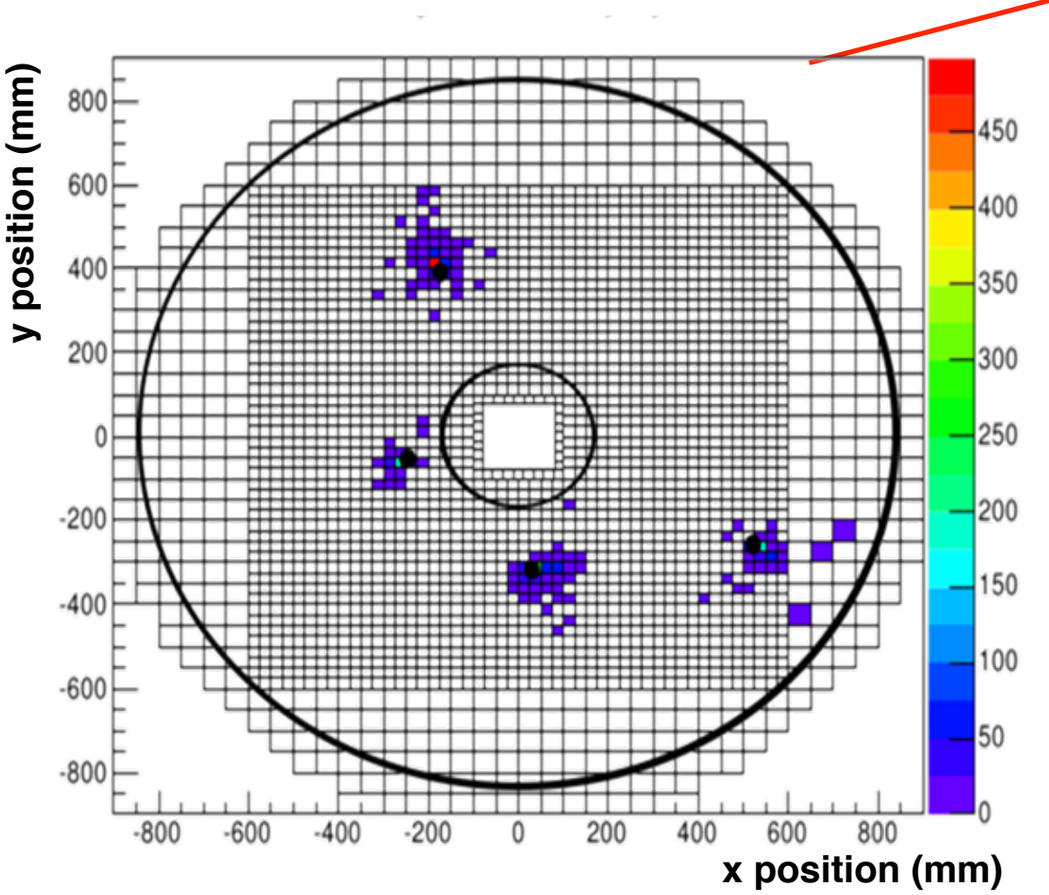


L2 Trigger System

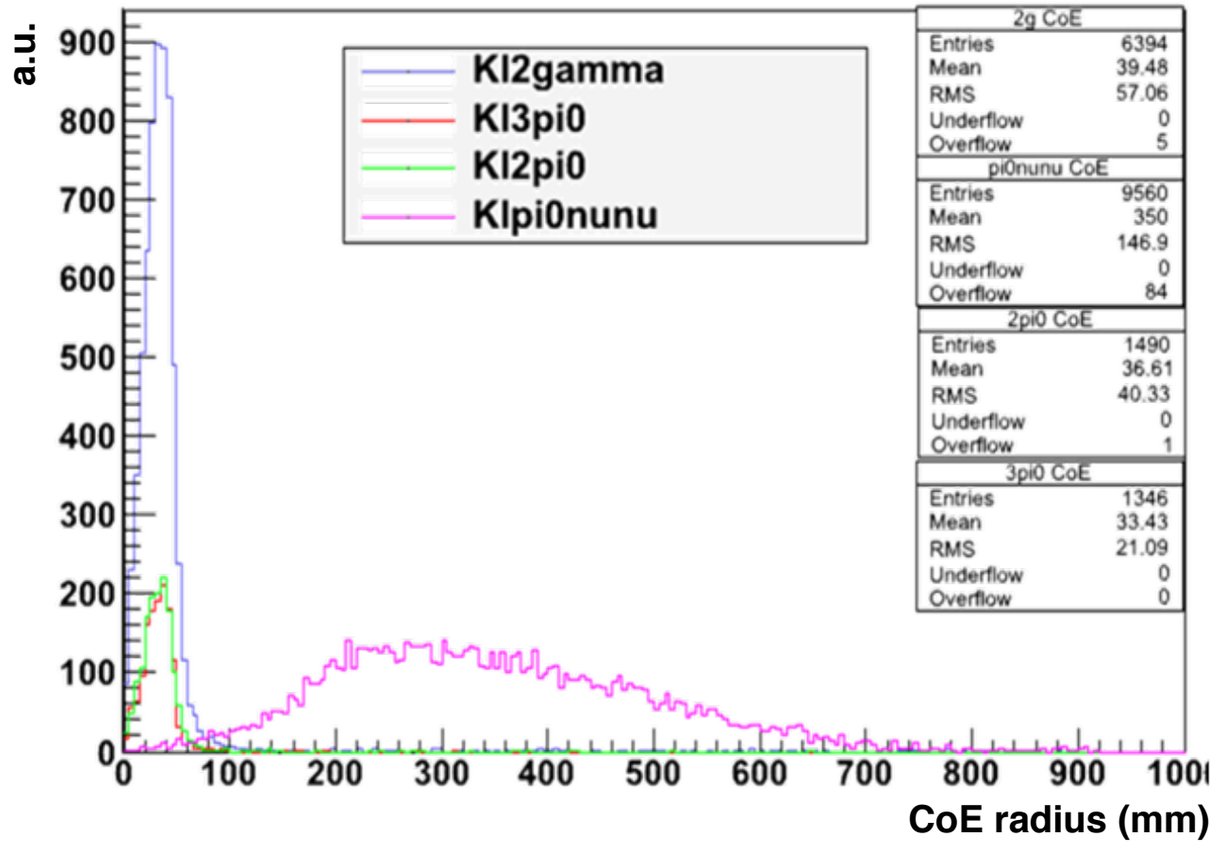
- Center of Energy (CoE) event selection
  - remove sensitive events decays (CoE < 165 mm)

$$\text{CoE radius} = \frac{\sqrt{\left(\sum_i E_i x_i\right)^2 + \left(\sum_i E_i y_i\right)^2}}{\sum_i E_i}$$



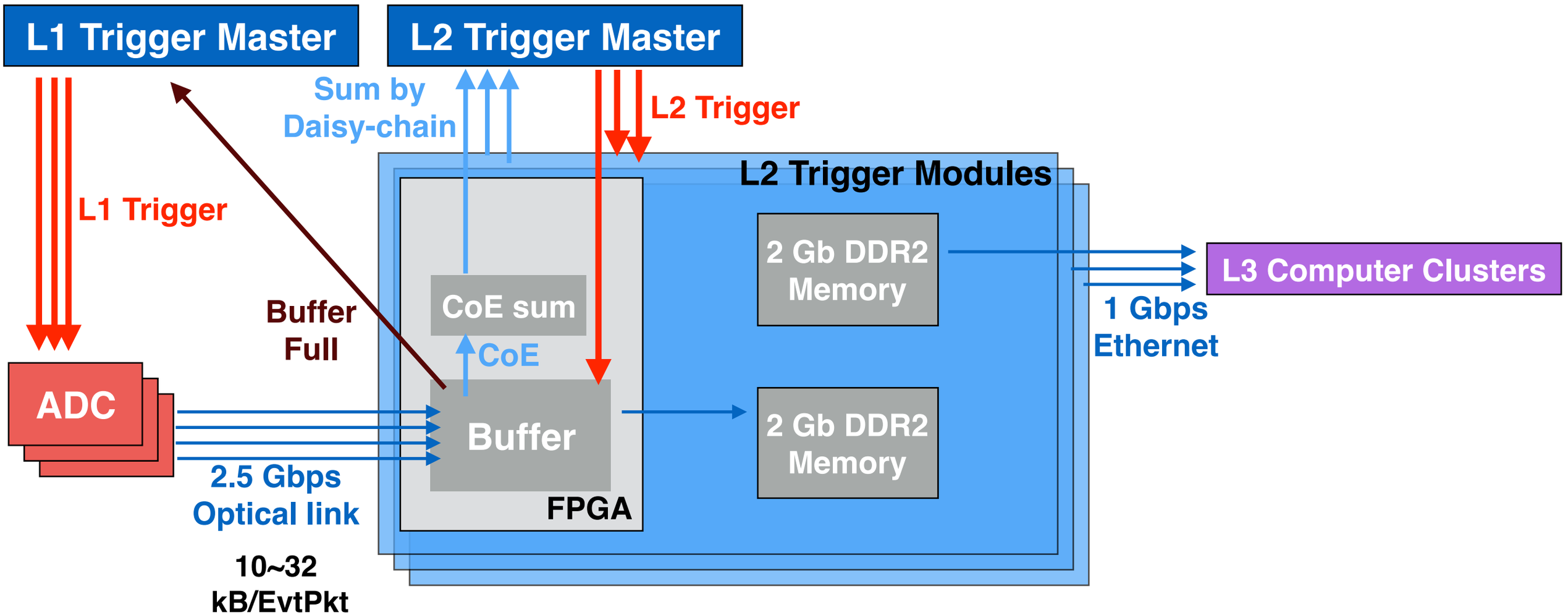


CsI calorimeter cluster display

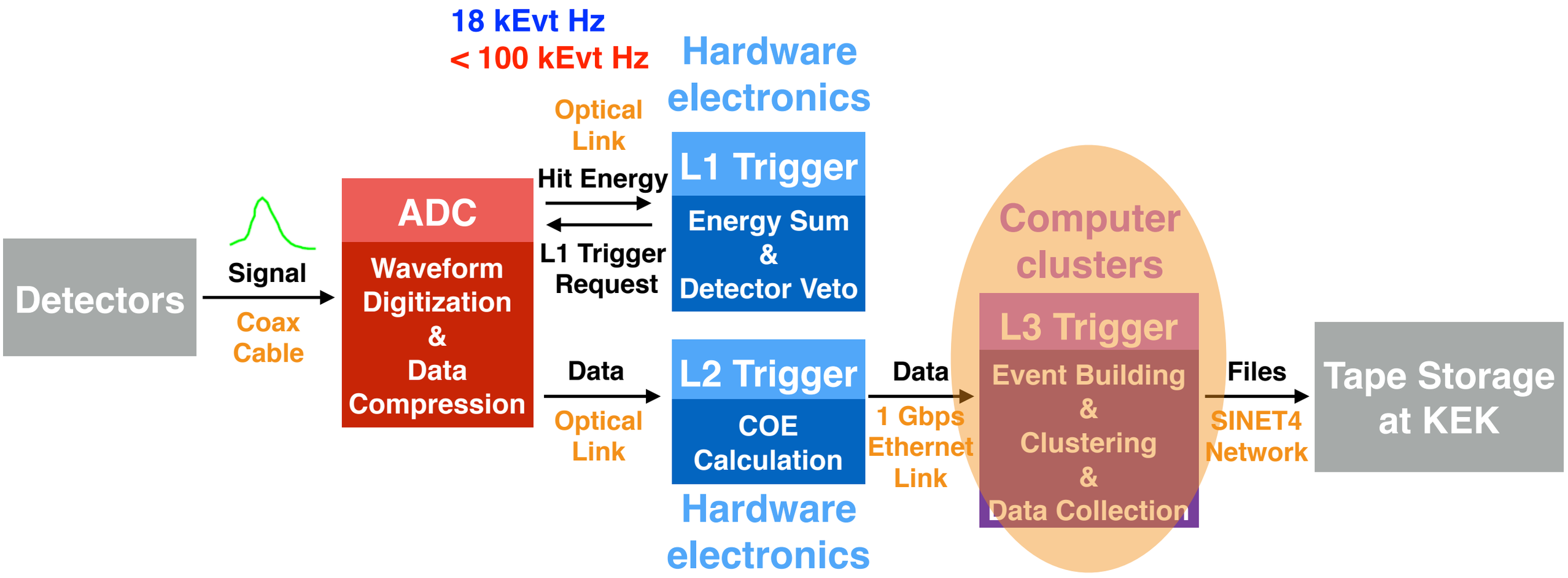


CoE distribution for various neutral K_L decays

L2 Trigger System



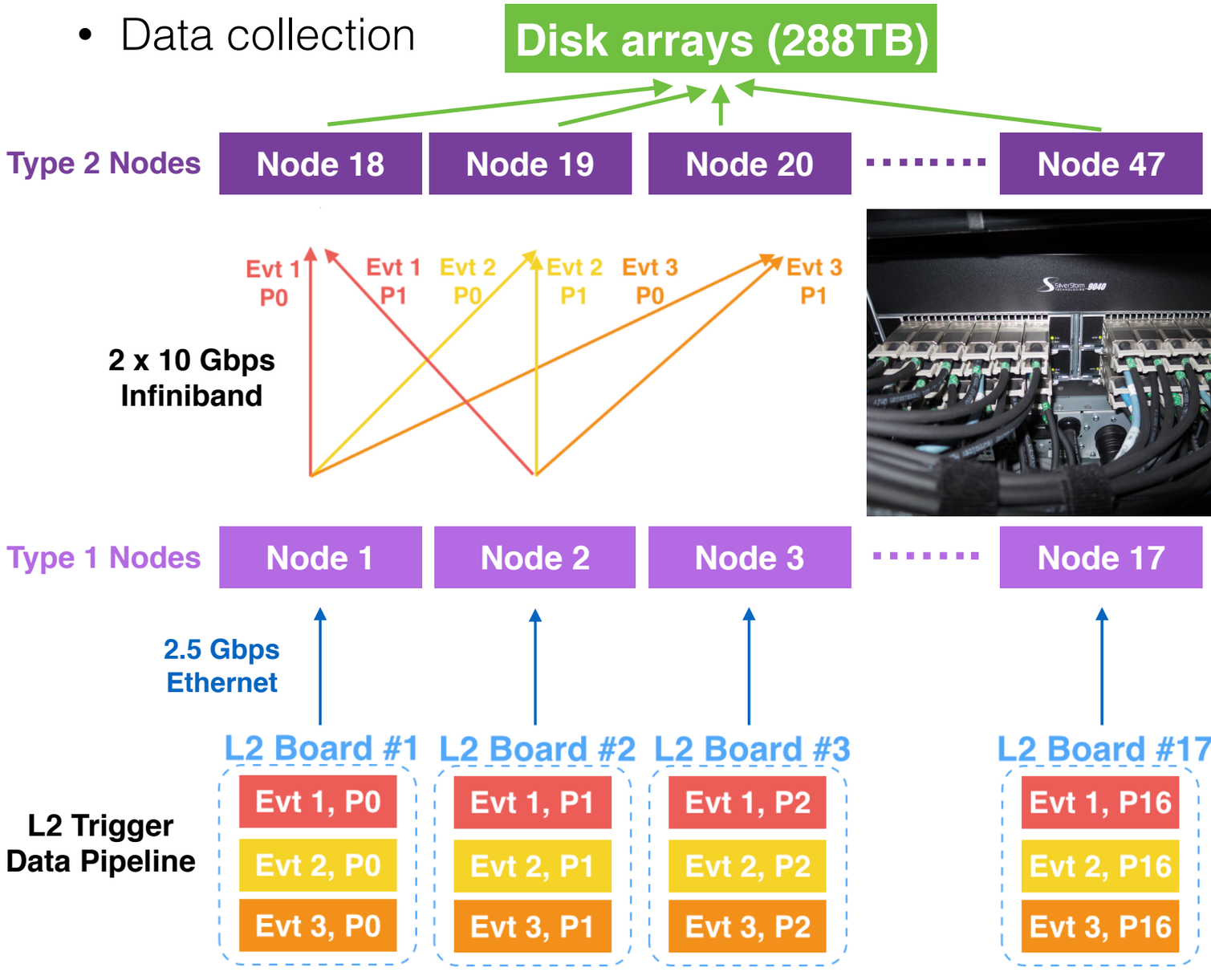
KOTO DAQ System



Data Rate	11 kEvt Hz	3.5 kEvt Hz
Output Limit		< 4 kEvt Hz

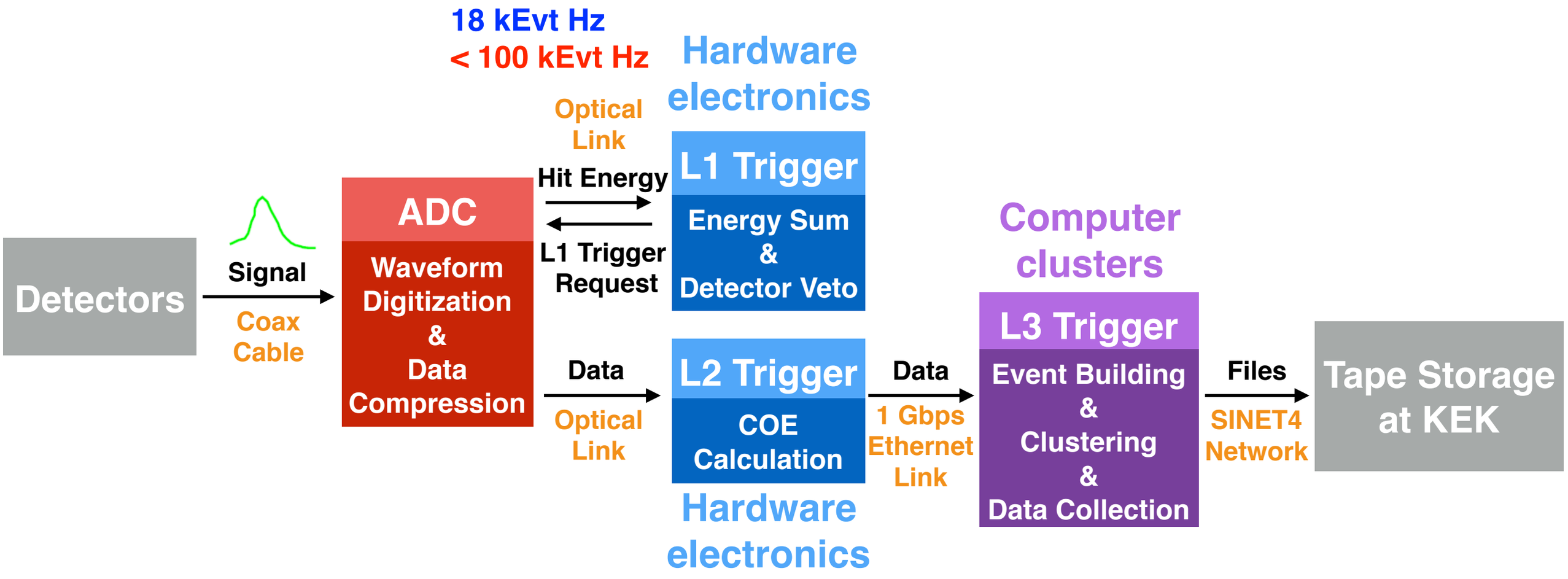
L3 Computer Clusters

- Event building
- Clustering
- Data collection



L3 computer cluster

KOTO DAQ System



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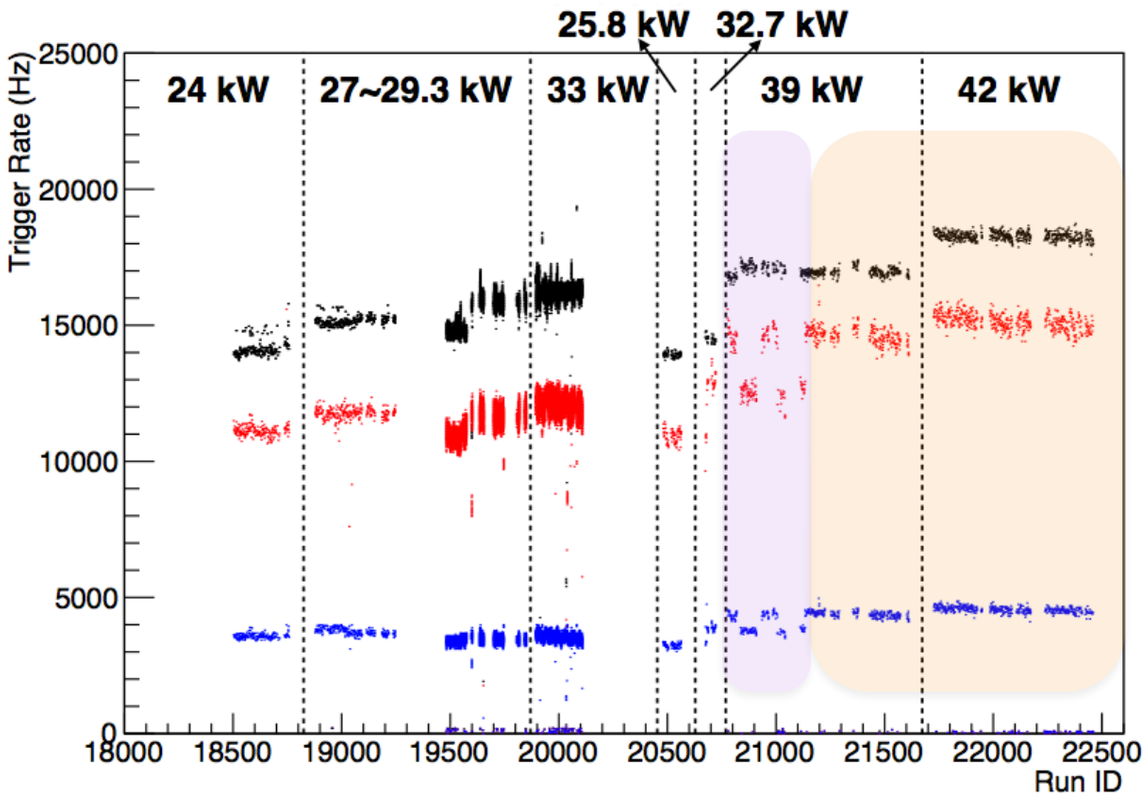
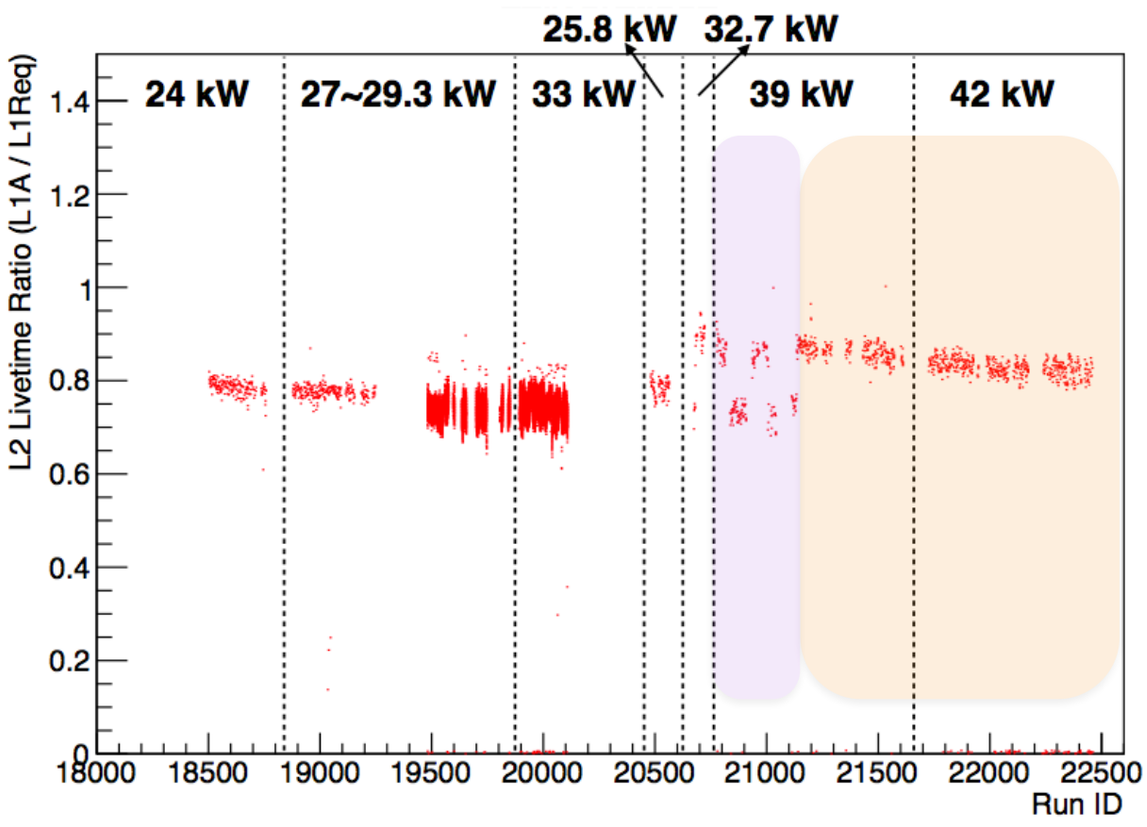
KOTO DAQ Performance (2015)

- ADC lossless data compression improved the L2 livetime ratio



Trigger Rate for all 2015 physics runs



L2 livetime ratio

L1 Req: # of events generated by L1 trigger
L1A: # of events considered for the L2 trigger decision
L2A: # of events passed the L2 trigger decision
ADC data compression test
ADC data compression implementation

$$\text{L2 livetime ratio} = \frac{\text{L1A}}{\text{L1Req}}$$

Summary for Current DAQ

- The current KOTO DAQ system performance improved from 2013 to 2015 with beam power increased from 24 kW to 42 kW

- Beam power will increase up to 100 kW
  - DAQ upgrade

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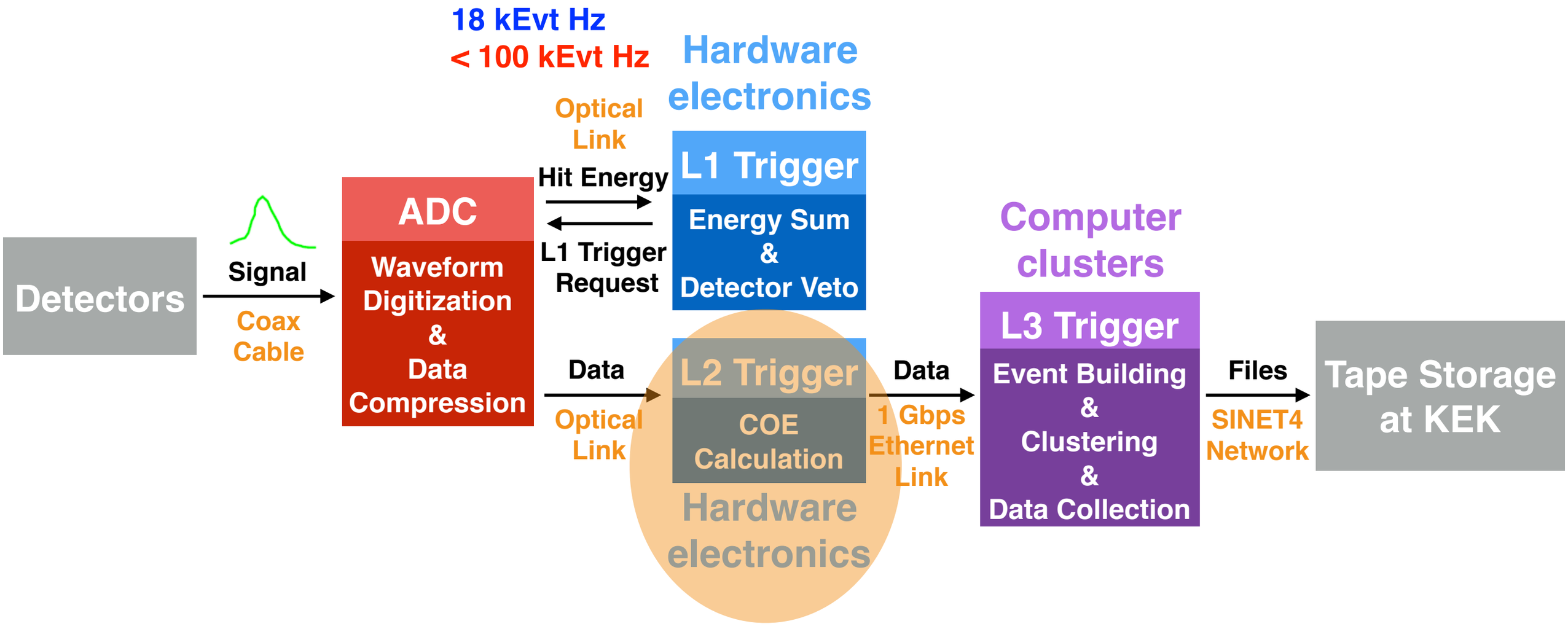
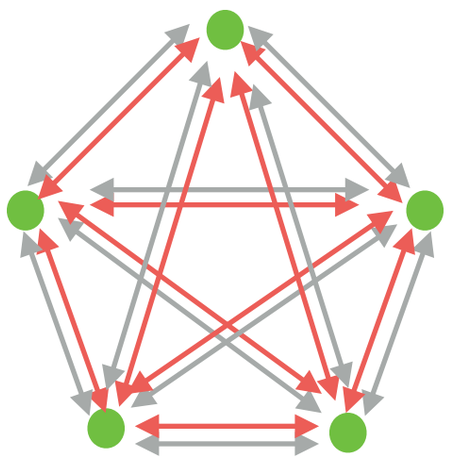
L2 Trigger —> RPT

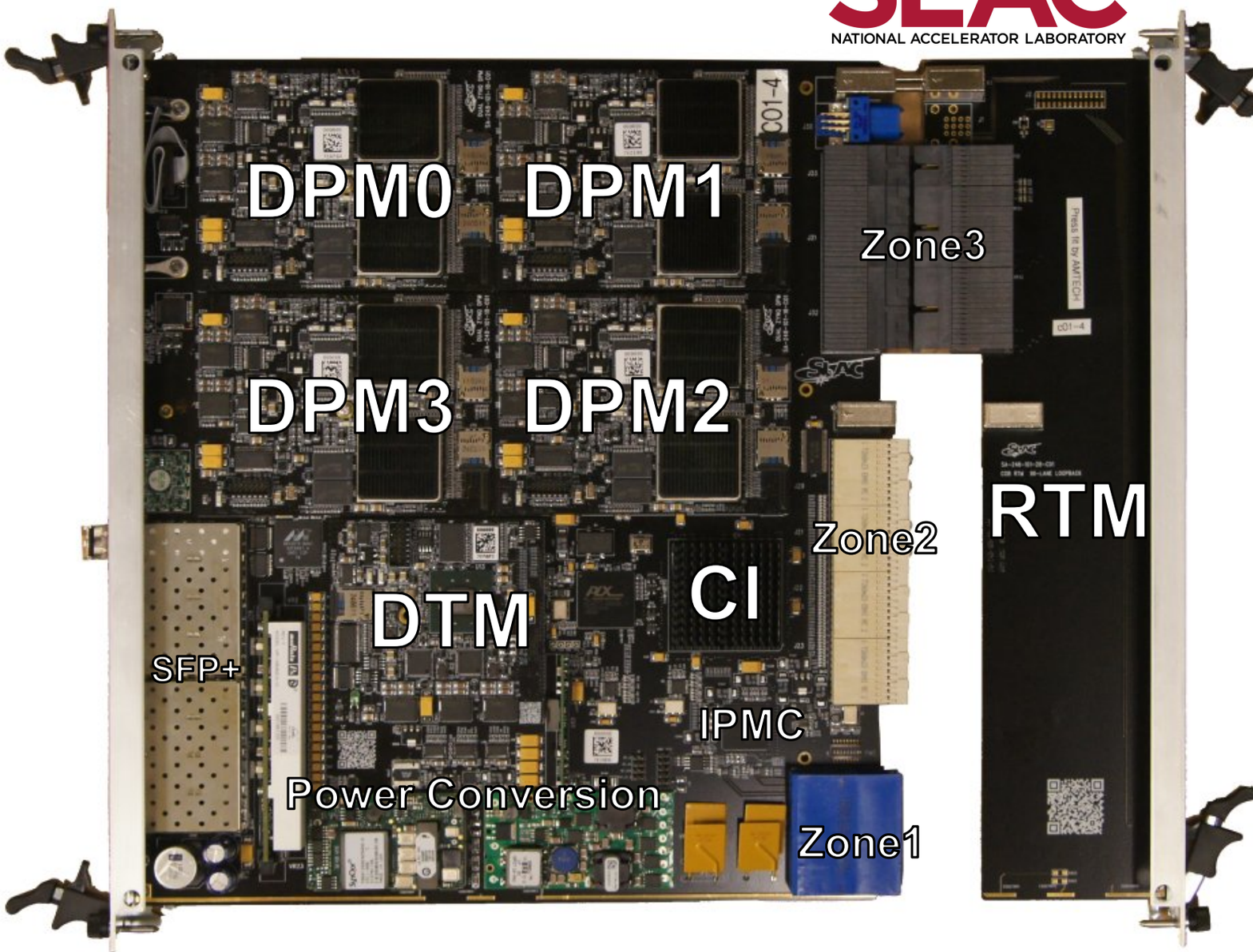


RCE Platform Technology (RPT) Upgrade

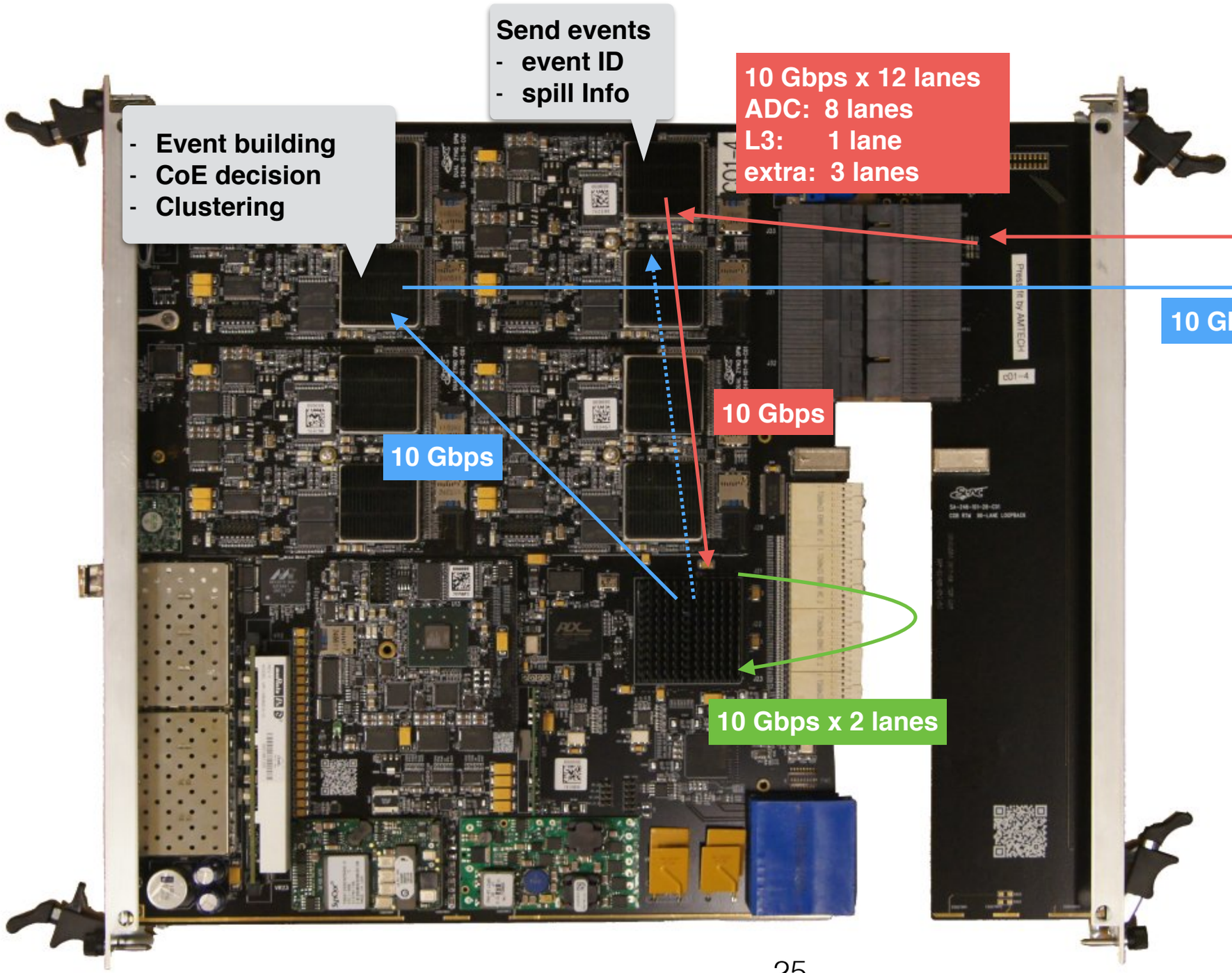
- Cluster-on-Board (COB)
  - Reconfigurable Clustering Element (RCE, Zynq-7000)
- Rear Transition Module (RTM)
- Replicated-mesh ATCA crate



Replicated-mesh netwrok



Cluster-On-Board Data Transport



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- The current KOTO DAQ system functions well up to 42 kW

- New upgrades on the L2 trigger system is required to maintain the DAQ livetime for increasing beam power up to 100 kW
  - We anticipate the PRT upgrade will allow us to handle up to ~283 kW beam power