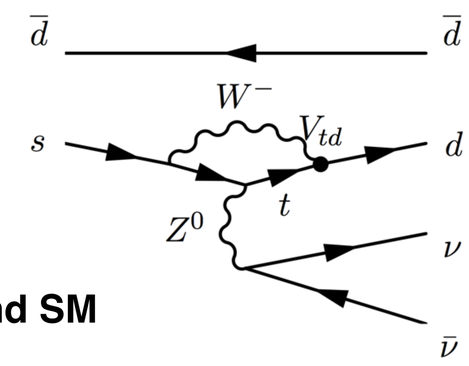
Upgrades of the Data Acquisition System for the KOTO Experiment

Stephanie Su, University of Michigan, U.S.A.
for the KOTO Collaboration

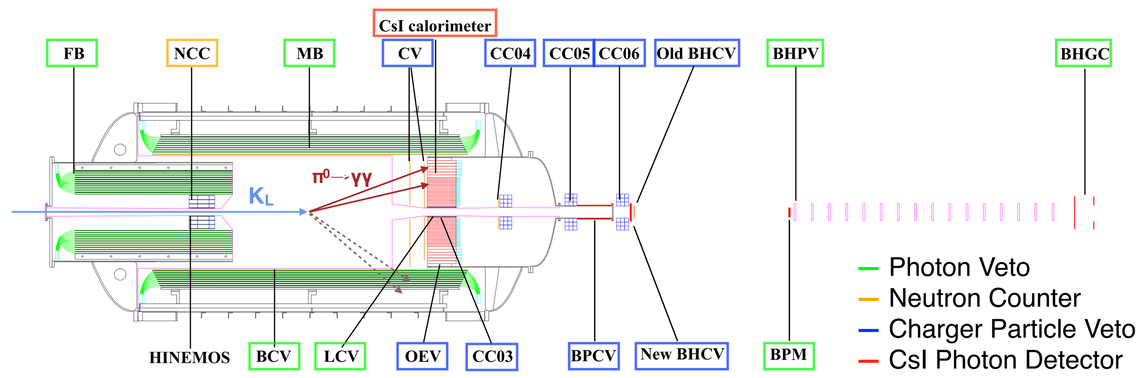
KOTO Experiment at J-PARC

Goal: Search for $K_L \longrightarrow \pi^0\nu\bar{\nu}$

- Rare decay: SM BR ~ 3 x 10^{-11}
- Small theoretical uncertainty: 1~2%
  → **Sensitive to the SM**
- 2nd order FCNC
  → **Sensitive to new physics beyond SM**



Detect: 2γ on the CsI calorimeter + nothing else



Data Acquisition System

ADC

- Shape waveform signals using 10-pole Bessel Filter
- Digitize detector waveforms using 125 MHz and 500 MHz 14-bit ADC
- **Compress data using lossless compression algorithm**
- Store waveform information in the pipeline and wait for L1 trigger decision

L2 Trigger System

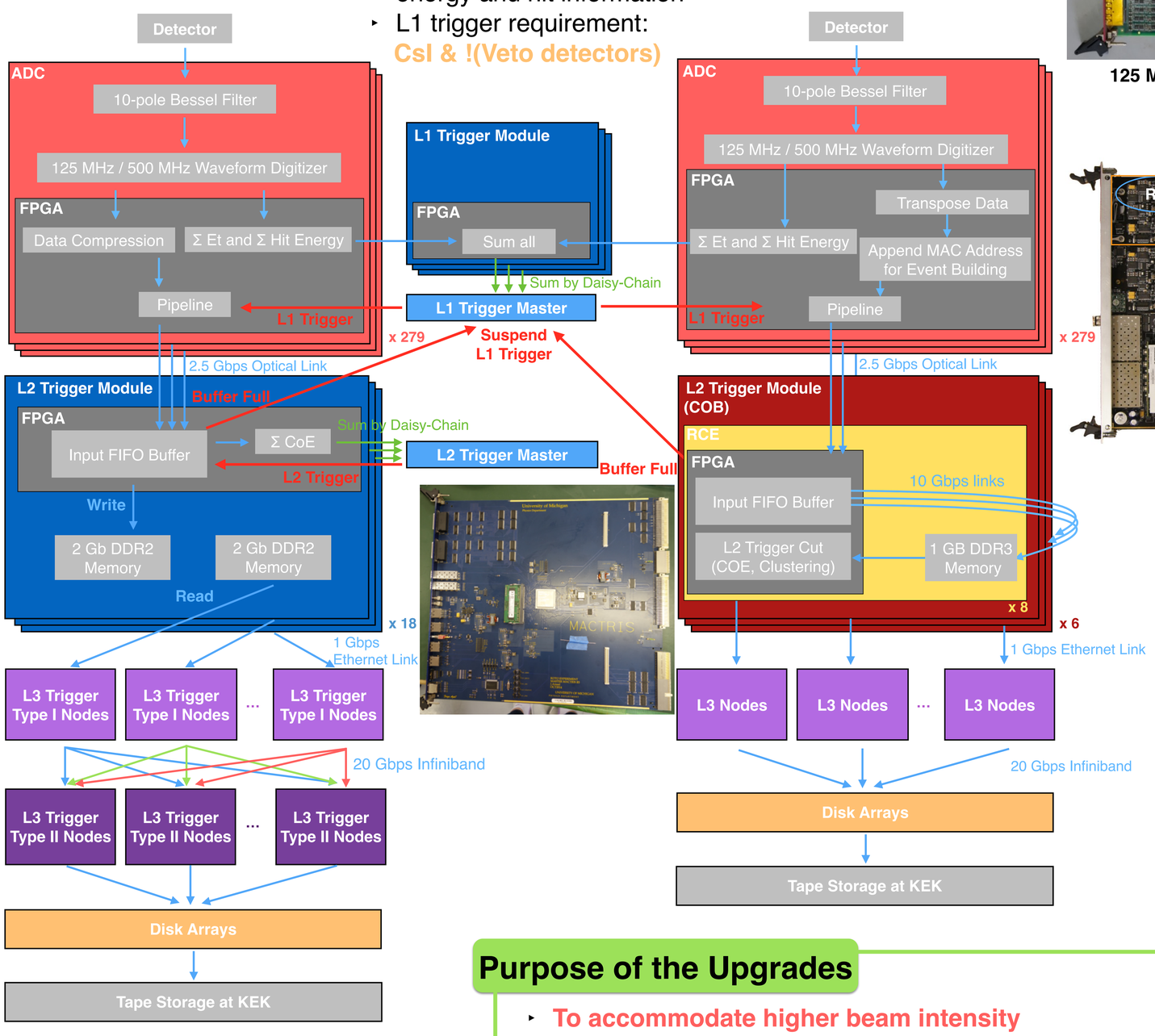
- Make L2 trigger decision using **Center of Energy (CoE)** on the CsI calorimeter
- During a spill:
  - Store entire spill of data onto 2 Gbit onboard memory
  - Read out data from the other 2 Gbit onboard memory to L3 trigger system

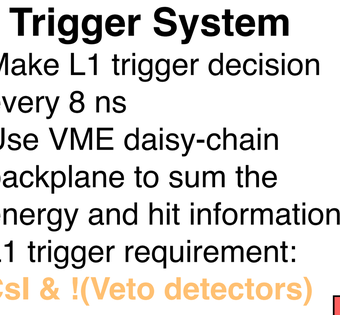
L3 Trigger System

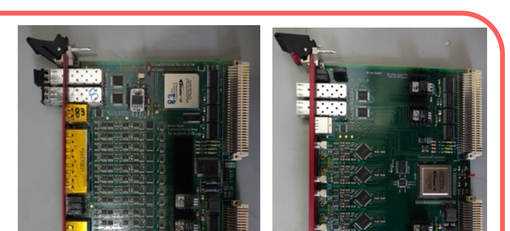
- **Build events using Infiniband**
- Each Type I Node:
  - Receives event fragments from each L2 trigger module
  - Sends event fragments to Type II nodes via Infiniband (event ID & spill ID)
- Each Type II Node:
  - Builds a complete event
  - Decompresses and transposes the data to analyzable format
  - Recompresses events for storage
- Transfer files from each computer node to disk arrays, then permanent storage at KEK

L1 Trigger System

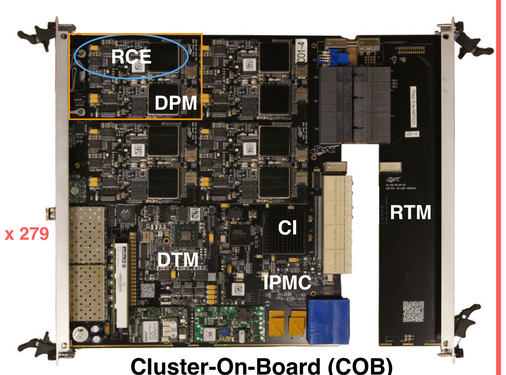
- Make L1 trigger decision every 8 ns
- Use VME daisy-chain backplane to sum the energy and hit information
- L1 trigger requirement:
  CsI & !(Veto detectors)





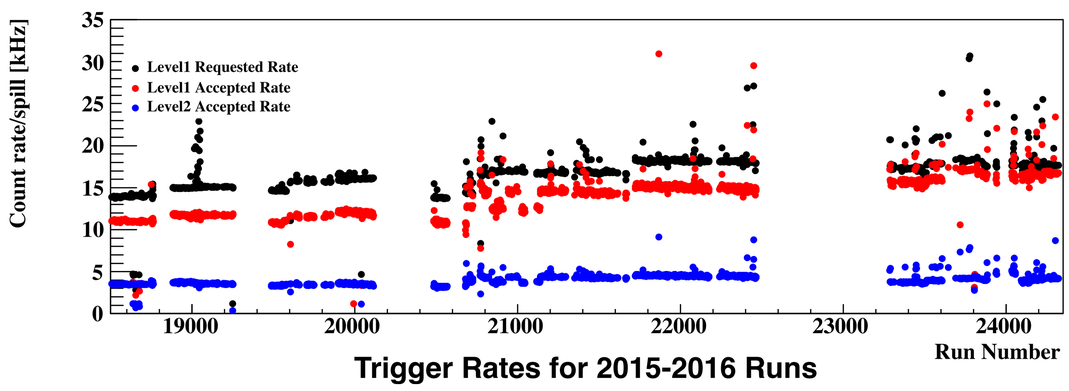


125 MHz ADC | 500 MHz ADC

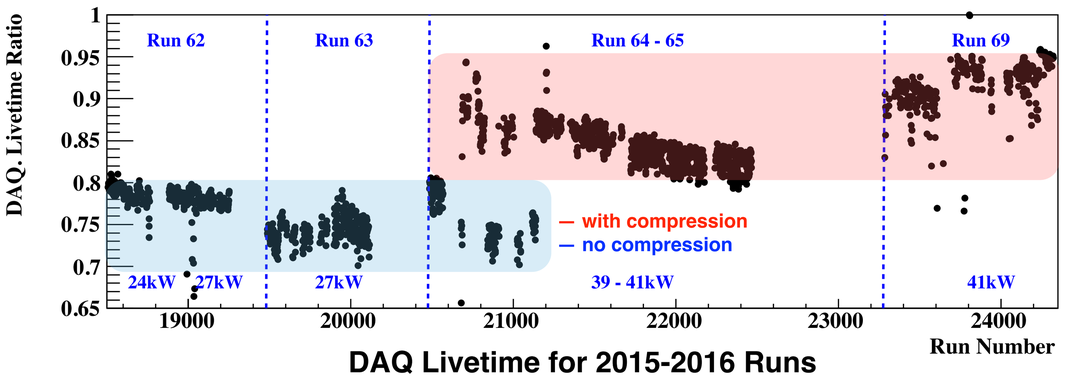


Cluster-On-Board (COB) developed by SLAC

L3 Trigger System



Trigger Rates for 2015-2016 Runs



DAQ Livetime for 2015-2016 Runs

Purpose of the Upgrades

- **To accommodate higher beam intensity**
  - Current bottleneck: 50 kW
- To enhance DAQ performance and lifetime

Changes on the ADC

- **Secure data quality**
  - Bit checking using checksum

Upgrades of the L2 Trigger System

- **Event Building on L2 trigger system**
  - Full backplane connectivity
- High performance Cluster-on-Board (COB)
  - Reconfigurable Clustering Element (RCE)
    - FPGA (Zynq 7030, Zynq 7045) with ARM processors
    - 1 GByte DDR3 memory
    - On-board Linux and RTEMS Operating Systems
- High-speed 10 Gbps links between components
- New L2 trigger cut (ex. CoE, Cluster counting)

Upgrades of the L3 Trigger System

- **Event categorization using trigger tag information from MACTRIS**
- Developing analysis technique for L3 trigger cut

Conclusion

The current KOTO DAQ system successfully collected compressed and uncompressed ADC data since 2015, at beam powers of 24 kW to 42 kW. Upgrades of the hardware is in progress in order to improve DAQ performance with anticipation of increasing beam power.