Data acquisition system in Run0 of the J-PARC E16 experimet

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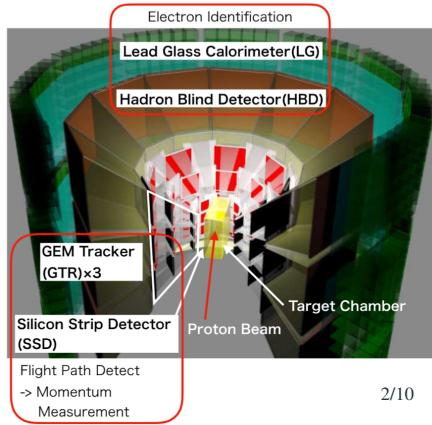
Introduction

Origin of hadron mass: Spontaneous chiral symmetry breaking

- Restoration of chiral symmetry in hot / dense medium (QGP, nuclear matter)
- Measurement of spectral change of vector mesons in nuclei
- $pA \rightarrow \rho, \omega, \phi + X$, $\rho, \omega, \boldsymbol{\phi \rightarrow e^+e^-}$

Appratus

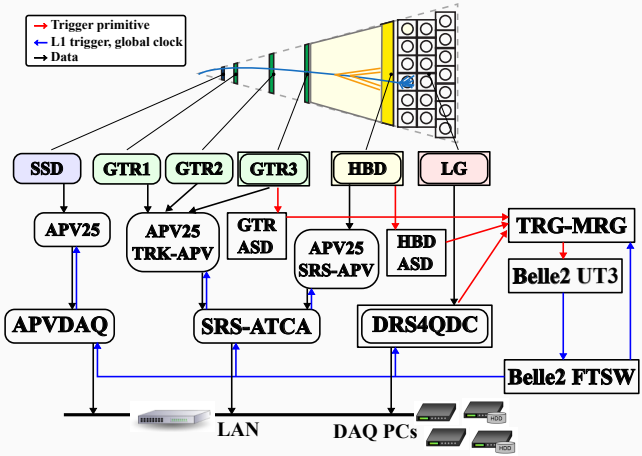
- J-PARC Hadron Experimental Facility high-momentum beam line: **30 GeV proton, 10^{10}/spill** (2 sec, 5.2 sec. cycle)
- $\boldsymbol{O}$**(10) MHz interaction rate** at thin targets
- Spectrometer with a dipole magnet
  - Tracker: **SSD** (silicon strip detector) ~**20 kch**
    GTR (GEM tracker) ~**56 kch**
  - Electron ID: **HBD** (hadron blind detector ~**40 kch**
    LG (leadglass calorimeter) ~**1 kch**



DAQ overview

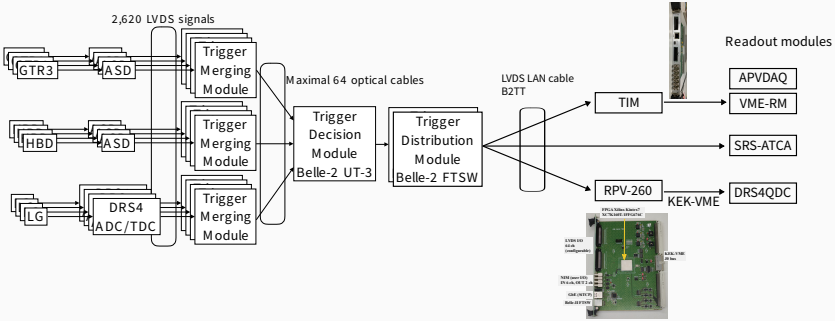
Waveform sampling by switched capacitor array chips

- **APV25 (~40 MSPS)**: SSD, GTR, HBD
- **DRS4 (1 GSPS)**: LG
- Trigger rate: 1 kHz
- Data rate: 660 MiB/spill



Trigger distribution and event synchronization

- **Trigger + tag data** distributeion and **busy** collection over B2TT (250 Mbps serial data link)
  - Trigger: L1 (physics), spill-start, spill-end, monitor of scaler
  - Tag data for event synchronization: 48-bit timestamp, 16-bit spill ID, 32-bit event ID
- **TIM (trigger intereface module)**: B2TT to NIM/LVTTL converter for APVDAQ
- **RPV-260**: B2TT to KEK-VME J0 bus



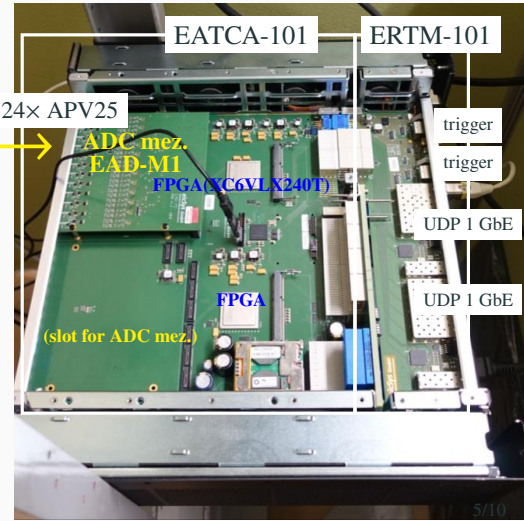
Front-end module for GTR and HBD: SRS-ATCA (ATCA variant of CERN RD51's scalable readout system)

APV25 readout in E16 DAQ

- 24 samples per event for long drift time in GTR.

Customization for E16 DAQ

- B2TT (trigger and tag receiver, busy sender)
- SEM (Soft error mitigation) for FPGA CRAM
- Multi-event buffer
- TDC (LSB = 2 ns) to measure the time difference between trigger arraival time and the sampling clock of APV25



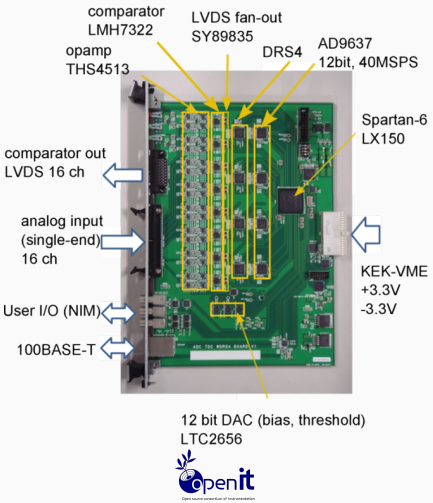
Front-end module for LG: DRS4QDC

DRS4 readout in E16 DAQ

- Cascading 2 channels for L1 latency
- 200 samples in region of interest

Firmware

- Signal processing of DRS4
  - offset correction, SCA cascading, spike filter, zero suppression, delta compression
- SEM for CRAM, ECC for the critical data
- trigger, tag and busy via KEK-VME backplane bus



Commissioning and experiments

Run-0a (commissioning)

- **Jun. 2020 (finished)**
- **6 SSD, 6 GTR, 4 HBD, 6 LG modules**

Run-0b (commissioning)

- Jan. 2021
- 6 SSD, 8 GTR, 6 HBD, 6 LG modules

Run-1 (physics run)

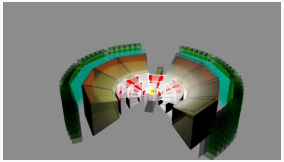
- 2022
- 8 modules in the middle part

Run-2 (physics run)

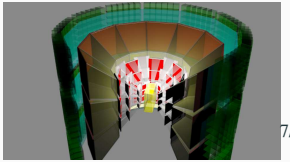
- 202X
- 26 modules: 9 (top) + 8 (middle) + 9 (bottom)

A photo of the spectrometer in **Run-0a**. Front-end modules were installed near the yoke of the dipole magnet.

RUN-1



RUN-2



Run-0a: First commissioning in beam (June 2020)

- PC setup:
  - CPU: Intel Xeon E5-2630 V4 (10 cores/20 threads) ×2
  - RAM: DDR4 256 GB in total
  - NIC: Intel X710DA4 10G ×4 (Only one 10G link was used.)
  - OS: Centos 7
- APVDAQs for SSD were handled by VME-SBCs (GE XVB-601).
- ZeroMQ(FairMQ)-based data collection software has been developed.
  - Used in the trigger DAQ. (not ready for the readout modules)
- **DAQ rate (typ.) ~300 Hz**
  - Zero suppression was not applied in the commissioning.
    Long deadtime (3 ms) of SRS-ATCA was limitting the rate.

Summanry

E16 DAQ system

- Read waveform data at 1 kHz trigger rate
  - APV25: SSD (APVDAQ), GTR and HBD (SRS-ATCA)
  - DRS4: LG (DRS4QDC)
- First commissioning in beam (Run-0a) was performed.
  - DAQ rate (typ.): ~300 Hz
  - Long deadtime of SRS-ATCA

Firther deveopments are in progress

- Parallel readout of APVDAQ by using MOCO (or modified MOCO)
- FIR filter to correct signals distorted by a long transmission line and zero suppression firmware for SRS-ATCA
- Software for online event building of the front-end modules

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