Data Acquisition and Online Monitoring

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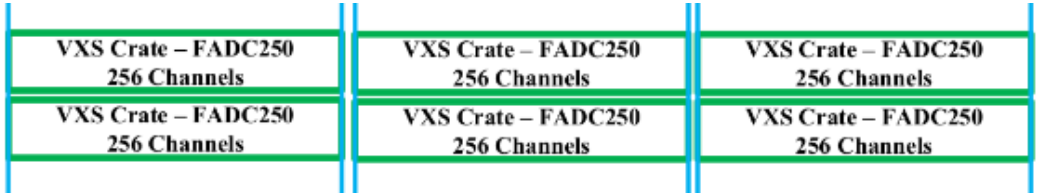
Challenges to the PRad-II DAQ System

- High rates
  - Statistics requirement from its scientific goals
  - Up to 25 kHz with reading thousands of channels
  - In PRad, the highest rates reached ~ 5 kHz
    - Data rate at 600-700 Mbytes/s, mostly from GEM

- Need for precision improvement
  - More sophisticated triggers
  - Better monitoring of the detector/data-taking status
  - Resolve some issues that were “minor” in PRad-I
    - Deal with pile-ups with waveform data

DAQ System for HyCal

- **7** Crates of FADC250
  - ROC, TI/TS
  - Up to 16 FADC per crate (**112 in total**)
  - Some spare channels for scintillators
  - Trigger formed from FADC data with pipeline data-taking
  - Test with one FADC module ongoing (Ashot's talk)

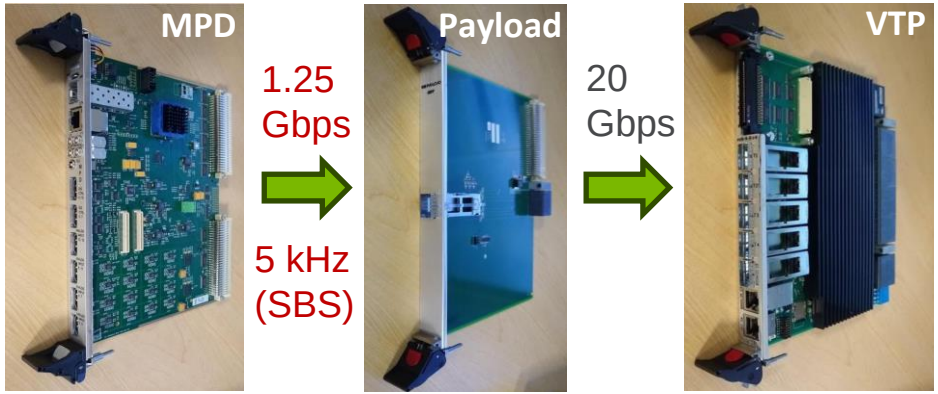


DAQ System for GEM

Credit: Xinzhan Bai

- An improved DAQ system is critical for the targeted event rates: 25 kHz
  - Bandwidth bottleneck to transfer data from thousands of GEM channels
  - Zero suppression or more MPDs (more details from Xinzhan's talk)
  - Expected start of the work for testing and integration in the 2024/12

- A factor of 5 needed for the rates
  - fewer APVs per MPD
  - Increase of the bandwidth
  - Online zero-suppression

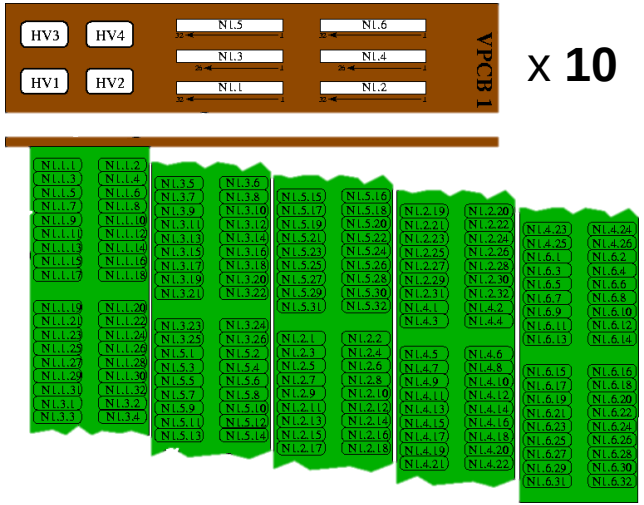


Proposed PRad-II/X17 Triggers

- Pulsar/internal triggers
  - Internal triggers
  - Random pulsar (from alpha source in the LMS system)
  - Fixed-frequency pulsar (from function generator that drives the LMS system)
- FADC triggers
  - Total energy sum
    - [x] MeV (need calibration)
  - Cluster triggers
    - Number of clusters [x]
    - Energy threshold for each cluster [y] MeV (need calibration)
    - Energy sum of the clusters [z] MeV
  - Scintillator veto

Clustering Trigger – Module Segment

- VPCB boards at HyCal back
  - 10 boards x 180 connectors each
  - Connect to 1152 + 576 = 1728 modules
- FADC modules, each has 16 channels
  - Better to have all modules of the same type
- Connections between crates
  - Needed for clustering (3x3) at trigger level
  - To communicate with adjacent crates
    - Each crate has 1 VTP with 4 optical links
    - Each optical links send/receive 32 FADC channels from other crates (128 TX/RX in total)
    - If two adjacent crates, **each boundary should have <= 64 modules**



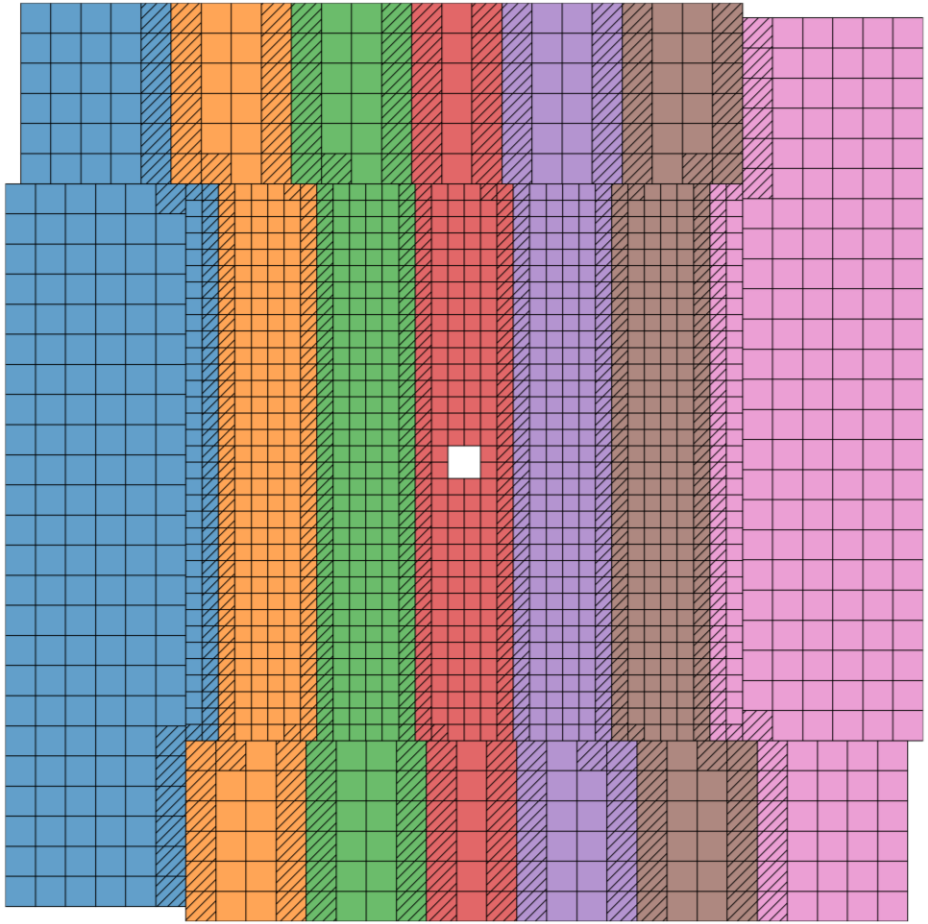
Segment of HyCal

Crate No.	No. of Ch.			No. of FADCs			Optical Links	
	All	PbWO4	LG	All	PbWO4	LG	To Left	To Right
1	242	68	174	16	5	11	0	49
2	252	204	48	16	13	3	49	49
3	252	204	48	16	13	3	47	47
4	236	200	36	16	13	3	47	47
5	252	204	48	16	13	3	47	47
6	252	204	48	16	13	3	49	49
7	242	68	174	16	5	11	49	0
Total: 7	1728	1152	576	112				

In total: **7 crates** and **112 FADC** modules

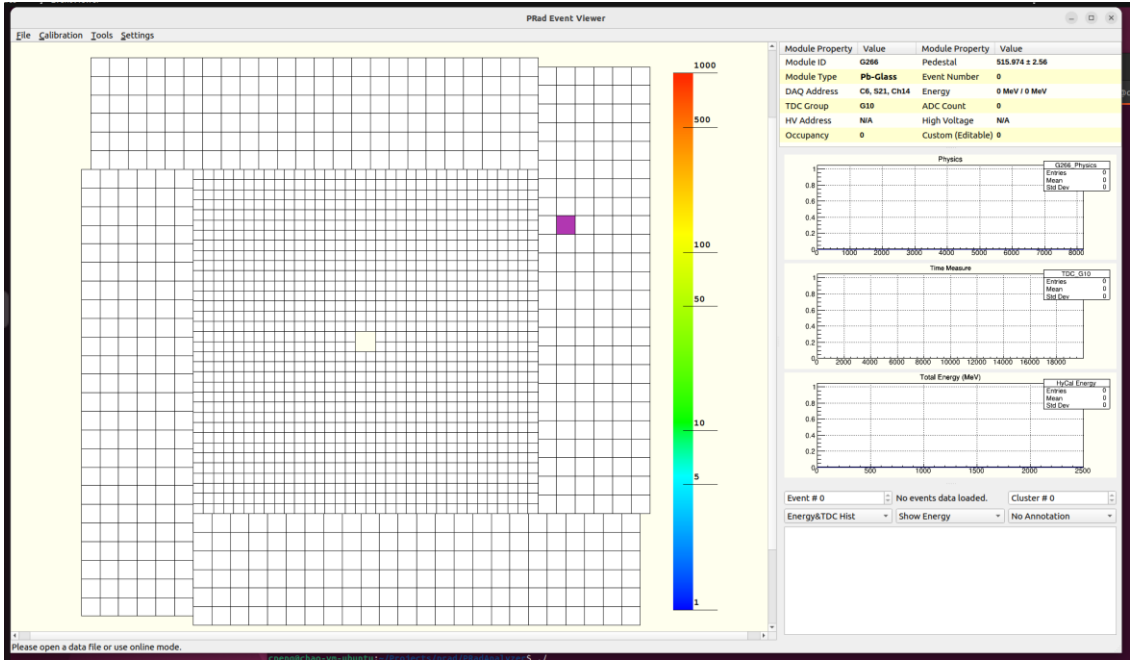
- ✓ <= 16 FADC modules per crate
- ✓ <= 16 channels per FADC module
- ✓ <= 64 channels to link between adjacent crates
- ✓ Single type of modules in each FADC

Detailed DAQ assignment (crate, slot, channel) can be found at https://github.com/JeffersonLab/prad2_daq



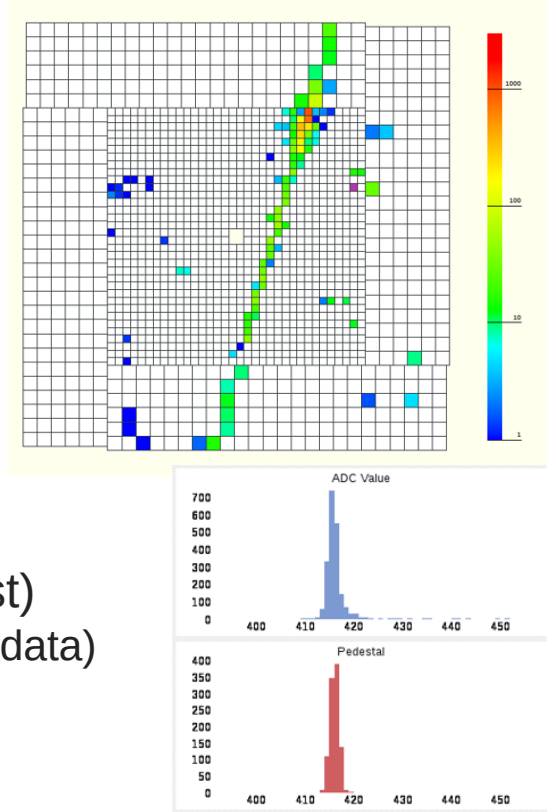
PRad Software and Online Monitoring

- PRadAnalyzer: still working
  https://github.com/JeffersonLab/PRadAnalyzer
- Event Reconstruction
  - Clustering for both HyCal and GEM
  - Non-linearity correction
  - Energy-leakage correction
  - Detector location and rotation correction
- Online monitoring
  - Read data from CODA ET
  - Read scalers info injected into the data stream
  - High-voltage control and monitoring



Online-monitoring Experimental Data

- Event visualization in the GUI
  - Energy deposit on modules
  - Occupancy of the whole HyCal
  - Pedestal mean and sigma
- Histograms
  - Energy sum spectrum (crystal, LG, and all)
  - ADC spectrum for each channel
  - TDC spectrum for each TDC group
- **Planned work** (need a fully running DAQ to test)
  - Update viewer/histograms for FADC (waveform data)
  - Add more physics-related histograms
  - May modernize the GUI



High-voltage Control

- High voltage crates are controlled via the network using CAEN library

```
# This configuration file tells the program to add CAEN high voltage crate
# The CAEN HV channel is presumed to have the same name of the connected HyCal module
# Crate name        crate ip            crate id
PRadHV_1            129.57.160.67       1
PRadHV_2            129.57.160.68       2
PRadHV_3            129.57.160.69       3
PRadHV_4            129.57.160.70       4
PRadHV_5            129.57.160.71       5
~
```

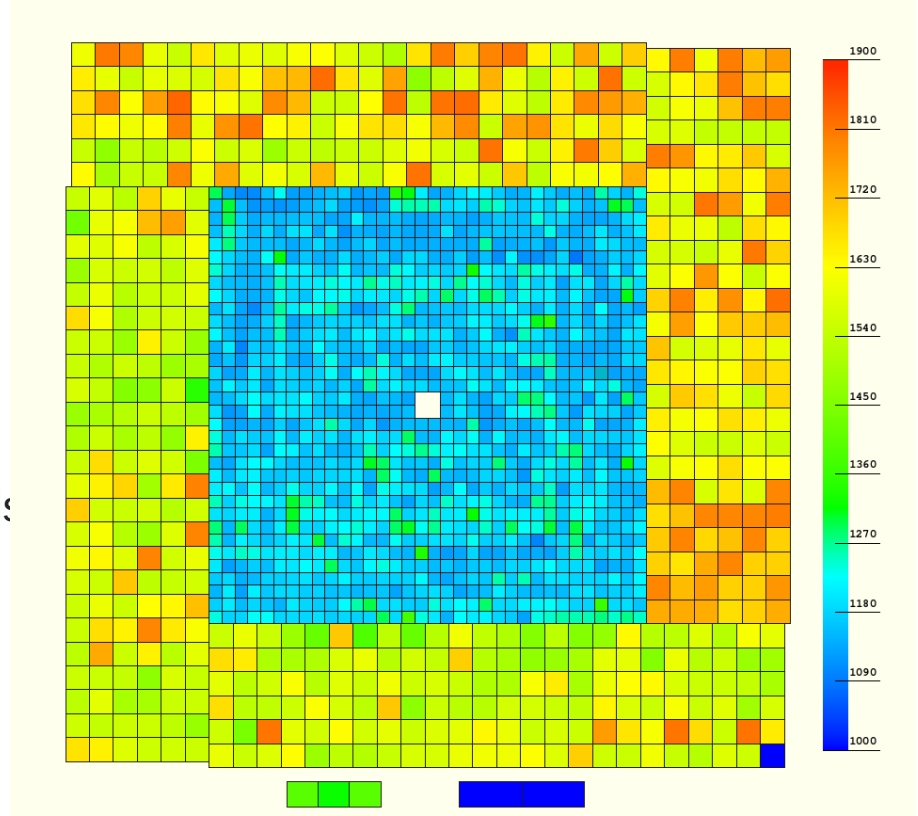
- A list of channels are pre-defined (on the crate, the software reads it)

# crate	slot	channel	name	VMon	VSet
PRadHV_1	0	0	PRIMARY1_0	1887.8	1900
PRadHV_1	0	1	G235	1657	1668.4
PRadHV_1	0	2	G118	1541.2	1552
PRadHV_1	0	3	G25	1637.4	1649
PRadHV_1	0	4	G177	1608.8	1620
PRadHV_1	0	5	G60	1676.4	1687.8
PRadHV_1	0	6	G236	1599	1610.2
PRadHV_1	0	7	G119	1541	1552
PRadHV_1	0	8	G26	1801.4	1814
PRadHV_1	0	9	G178	1676.2	1687.8
PRadHV_1	0	10	G85	1560.8	1571.4
PRadHV_1	0	11	G237	1599.2	1610.2

Online-monitoring the Detector

- Existing monitoring
  - High-voltage
  - EPICS channels values

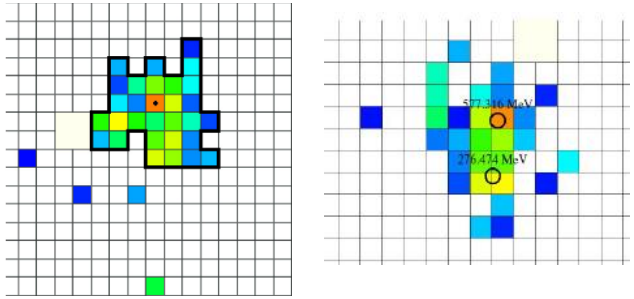
- **Need to implement**
  - HyCal temperature monitoring
  - Visualizations for EPICS channels
    - HyCal temperature
    - Target status
    - Scalers reading

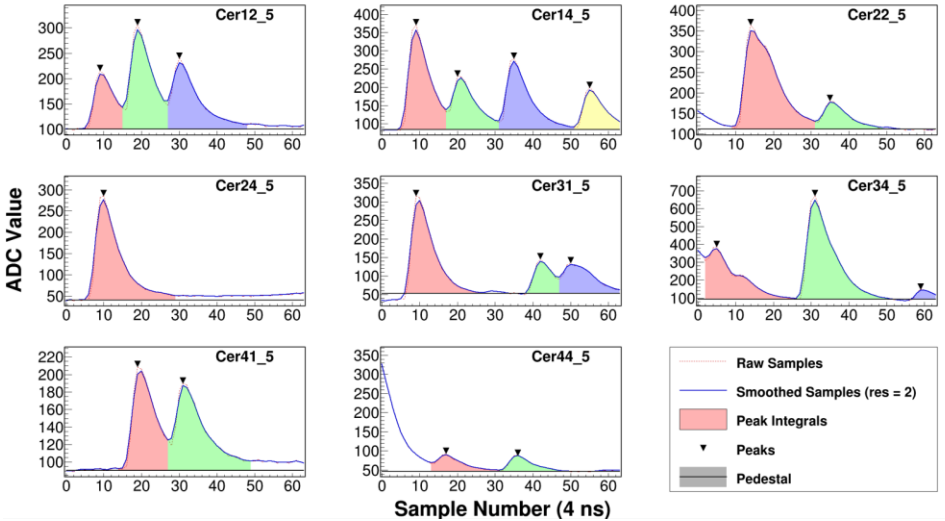


Data Analysis Framework

- PRadAnalyzer is also used for cooking data
  - Decode the evio file written by the DAQ system
  - Reconstruct raw detector outputs to hit information
  - Clustering for HyCal and GEM
  - Event matching
- **Planned updates**
  - Decoding FADC data
  - Waveform analysis
    - Pedestal fitting
    - Separate peaks
    - Timing, integral
  - Ready as standalone code
    - Need to be integrated

Clustering for HyCal





Plans and Milestones for the DAQ and Software

- ✓ Single channel DAQ
- Full HyCal DAQ
  - High-voltage, LMS
  - Connections to FADC
  - Trigger implementation
- Cosmic gain-matching
- Integration of GEM DAQ

- ➢ Decoder and waveform analysis for FADC
- Validate HV control
- Integration of GEM decoder
- Online Monitoring Updates
  - HyCal temperature
  - Scalers visualization
  - More physics histograms