GEM Detectors - Hampton

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Report

- Overview of GEMs and electronics
- Commissioning activities since Spring 2023
- Electronics upgrade
- Tasks to be done, timeline, scenario

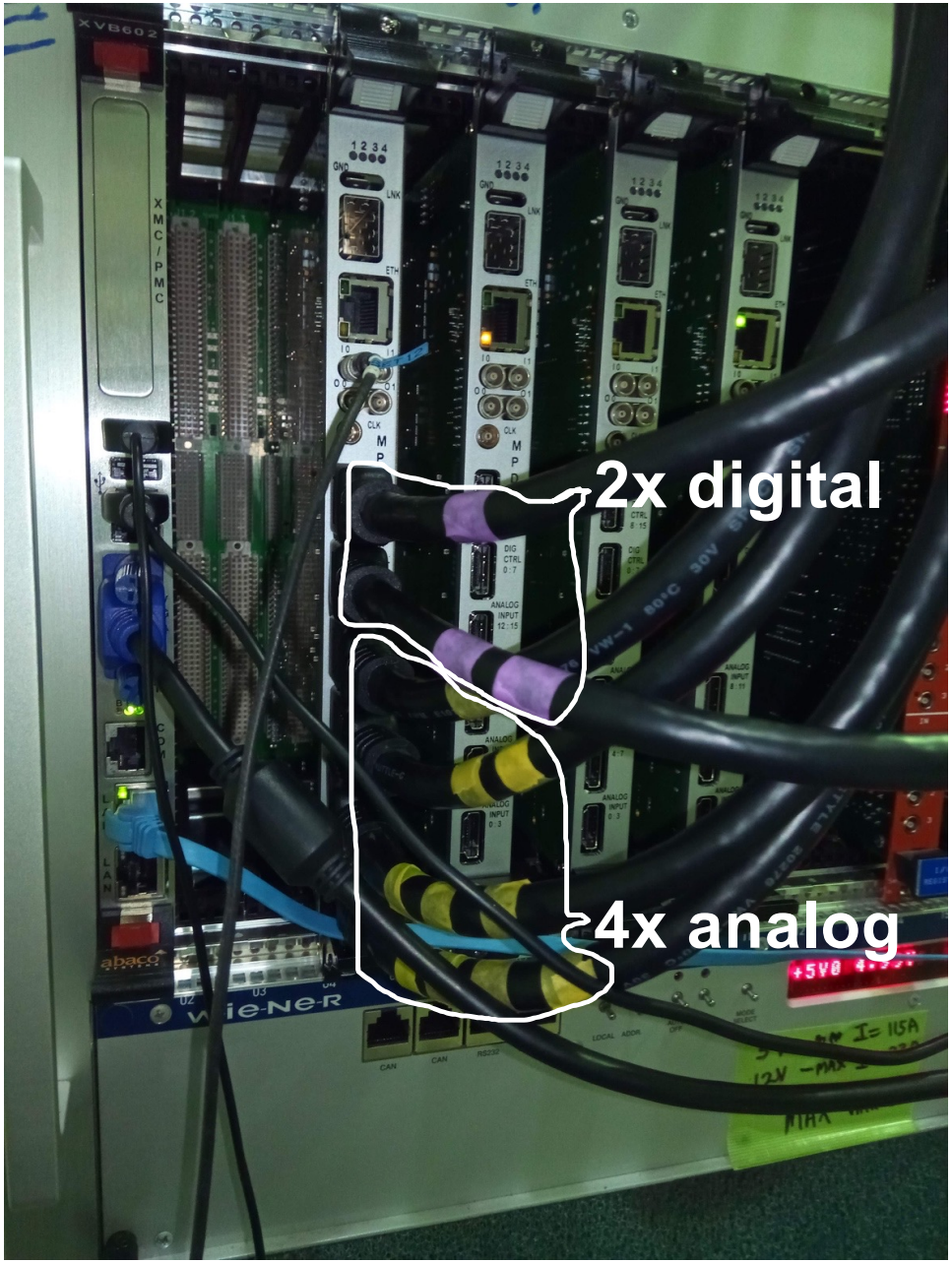
- People

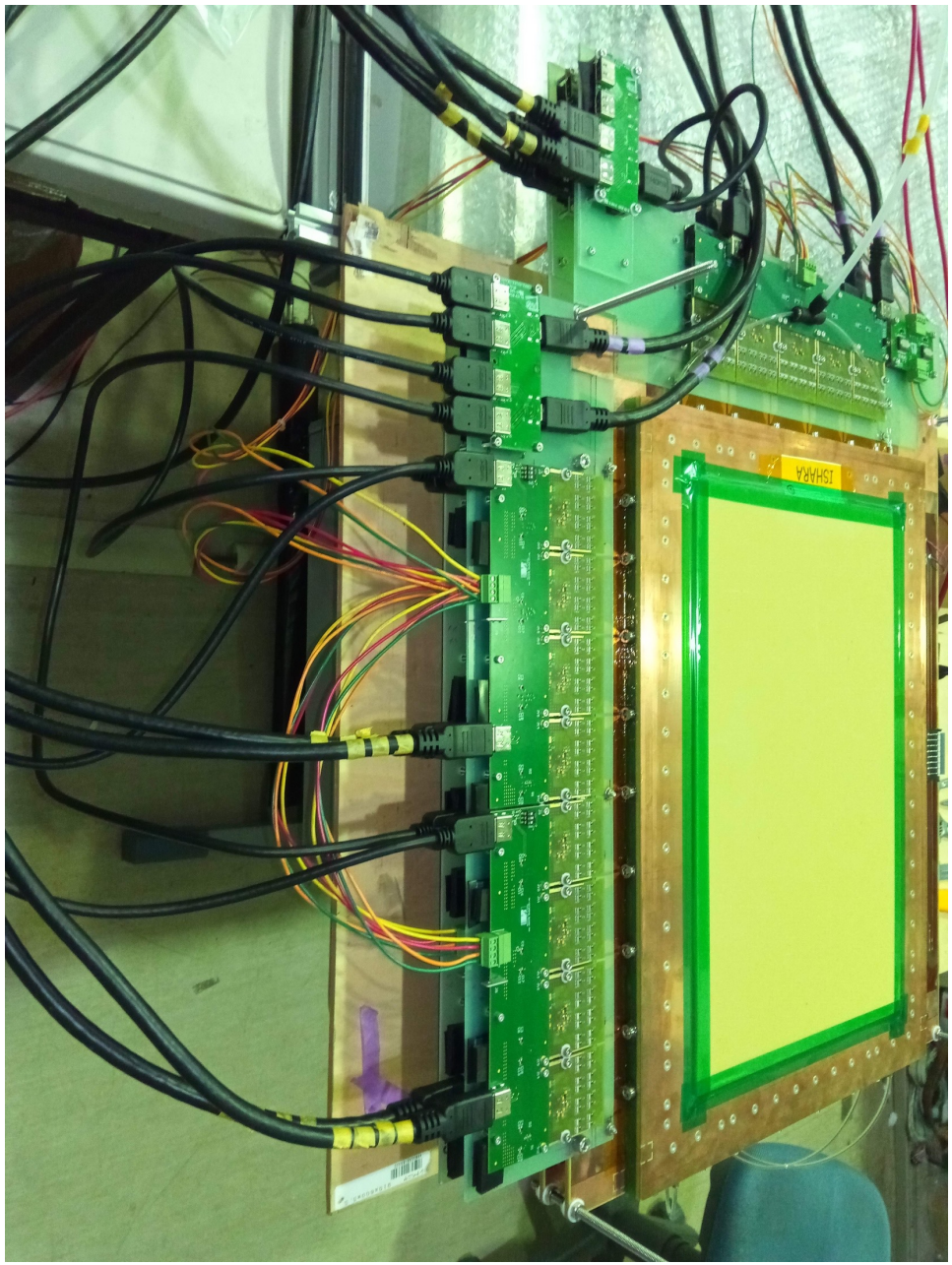
  Dr. Ryan Richards – postdoc, joined Sep 2023
  Manjukrishna Suresh – PhD student since Fall 2020, joined DL May 2023

  Tanvi Patel – PhD student on MUSE since Fall 2017, GEMs
  Sarashowati Dhital – PhD student on SBS since Spring 2021, GEM experience
  Angel Christopher – MS student on MUSE since Fall 2023, GEM analysis
  Krystal Scott – undergrad (junior), PSI Summer 2023; TRIUMF Summer 2024(?)

  Dr. Jesmin Nazeer – graduated in Aug 2023, GEMs, now former group member

Assembled GEM with electronics





APVs and MPDs

- Analog Pipeline Voltage (APV) frontend chips from CMS provide preamplification+shaping, sampling, serializing 128ch
- Analog data frames are sent on external trigger via twisted pair to Multi-Purpose Digitizer (MPD) for digitization and recording through VME system.
- One twisted pair per APV. Four (4) shielded twisted pairs per analog HDMI cable for up to 4 APVs per HDMI cable (convert 5 APVs on one HDMI from short side to 4+1 on two HDMI)
- 4 HDMI slots per MPD, 1 MPD for 4+4+4+1=13 APVs per GEM
- MPD has FPGA with firmware to communicate with APVs; using single-board VME controller (CPU) to control MPD
- Frontend APVs are not radiation hard for operation, can lose configuration. No direct exposure to particle flux.
- Inside spectrometer shielding house proven ok
  Successful operation in Hall A (Super-Bigbite)

VME and HDMI

- APV frontend cards connected to backplanes (2x 4-slot bp for 8 APVs on long side, 1x 5-slot bp for 5 APVs on short side)
- Six (6) HDMI cables between VME and GEM APV frontend (2x digital, 4x analog). One of the digital lines split to two, to serve three backplanes in total.
- Designed for 10 m, previously operated at up to 20 m length; present cables are 30’ (10 m)

- VME crate (Wiener 64x, Jlab-style) is hosting:
  1x Intel controller (Abaco XVB602) for MPD/APV configuration and VME readout of triggered event data, 1 Gbps ethernet link
  1x Multi-purpose digitizer (MPD) per GEM → 4 MPDs total
  2x CAEN V6533
- One VME system, 2 GEMs, electronics for 1 GEM delivered to TRIUMF. Problems with XVB602 and CF card.
  Provided replacement, plus 13 APVs to read out second GEM

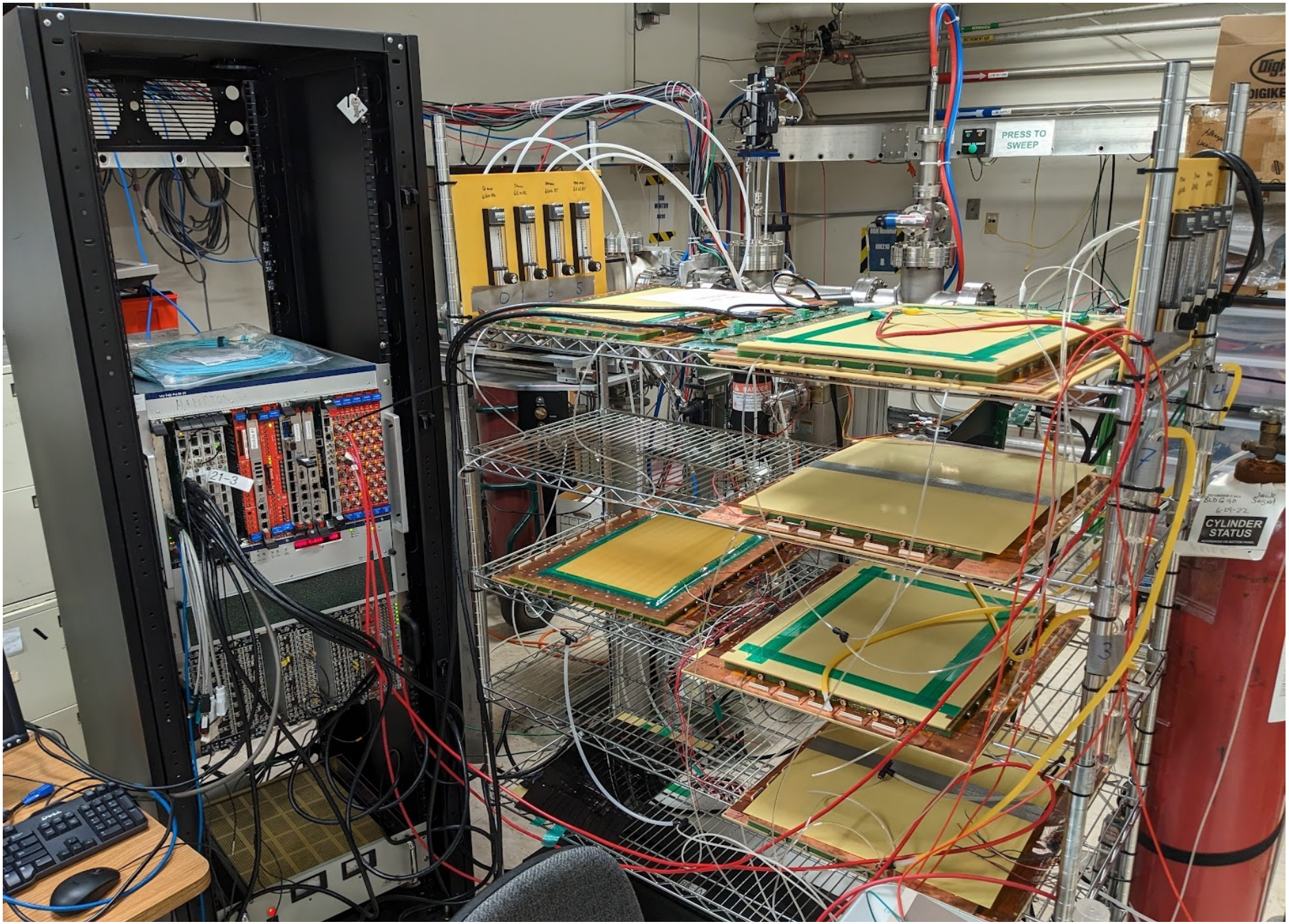
More on electronics

- Shipped 2 GEMs, 1 set of electronics (13 APVs, 2 MPDs, 1 VME crate, 1 XVB602, HDMI and LV cables), bubblers and flowmeter panel to TRIUMF in July
- 2 GEMs, 1 set of electronics hooked up, now being tested at LERF with cosmics and Sr-90; ship to TRIUMF when ready
- Obtained additional 26 APVs (2 sets) for DarkLight, returned from SBS (out of 100 lent out). All tested well in histo and triggered mode.
  In addition, 13 good cards (histogram mode-only) from stack of 20 questionable cards. Another 20 to be tested.
- MIT donated APV chips, received and inspected by P. Musico, 205 found to be good.
  EES has 346 APV chips on hand (according to database).
  UVA/JLAB ordered ~200 new APV cards, ~6 months lead time, to be used in SBS (GEn-RP, Gep-5, and MOLLER), and to return remaining 74 cards to Hampton.

Upgrade for higher readout speed

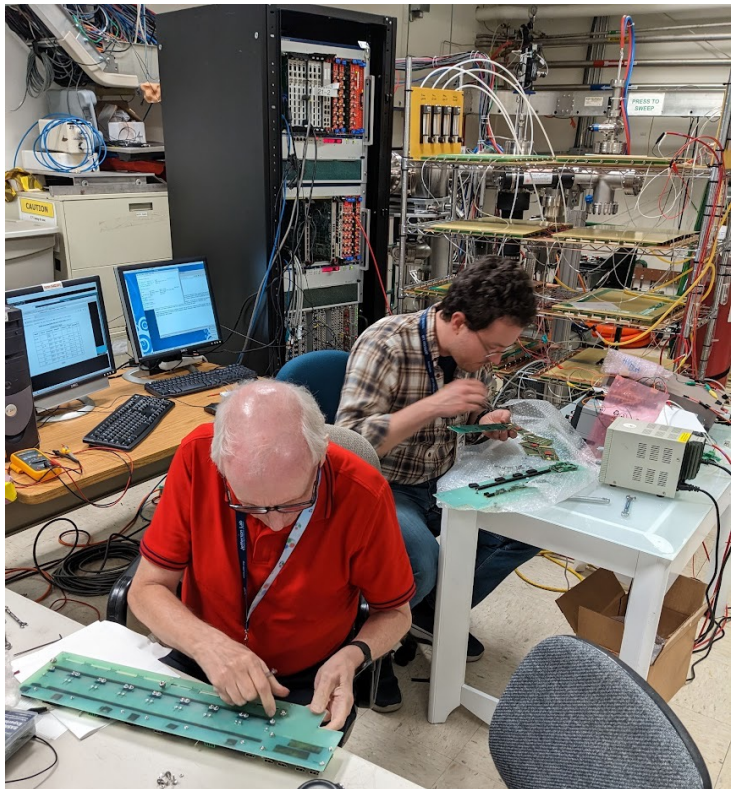
- **Upgrade path for higher readout speed (2024):**
  (VME: 1 Gbps / 100 MB/s limit)
  → Use VME only to power MPD; read out optically;
  process MPD data with VTP or SSP on VXS crate, 10 Gbps
  can run 4 MPDs / 6 samples at few kHz w/o zero-suppression
  Event size: 13*6*128*(32/2)*4 = 640 kb → 5 kHz = 3.2 Gbps
- **This is the scheme implemented at SBS**
- **Working with Jlab DAQ & Fast Electronics Group**
  (A. Camsonne, B. Moffit) to acquire VXS+VTP
- **Funding is in place to acquire two such setups**

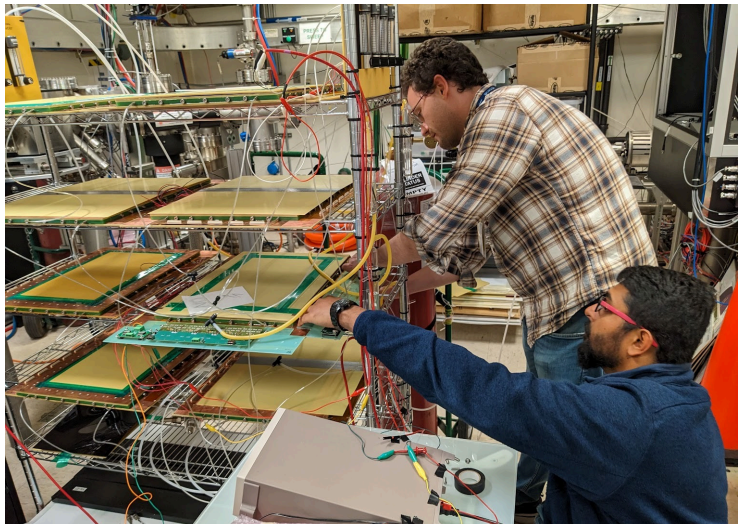
LERF User Lab 1



Work at LERF User Lab 1

- D.H and E.C. visited LERF from 4/24-5/4, to work 16-hour days
- Flushed GEMs with nitrogen
- HV tests of individual GEM foils, and with HV divider
- Tests of APV electronics
- 4 GEMs working (enough for DarkLight), 4 having issues: 3 with high dark current, one with a shorted sector
- Repairs ($0) possible by shock-ramping, by-passing protection resistors, to clear from resistive dirt and to burn off the short.
  If it fails, must replace foils.
  Costs: $20k for 4 GEMs





Naming of GEMs

GEM naming **by order of assembly**, and **predicted** evolution of quality

1 - Rui (built at CERN, masterpiece)
2 - Michael (our first one, unknown flaws?)
3 - Ishara (second, improved one)
4 - Jesmin (perfect, lots of attention)
5 - Tanvi (perfect, we really figured it out)
6 - Bishoy (becoming routine, not as perfect)
7 - Malinga (losing concentration a bit)
8 - Thir (is this the last one, finally?)

Naming scheme introduced by **Doug** and **Ethan**

GEM 0 – Michael (400 nA)
GEM 1 – Ishara (shorted)
GEM 2 – Thir (ok)
GEM 3 – Jesmin (ok)
GEM 4 – Tanvi (ok)
GEM 5 – Bishoy (1.2 muA)
GEM 6 – Rui (ok)
GEM 7 – Malinga (6 muA)

- **GEM 4 (Tanvi) cabled up at LERF, GEM 3 (Jesmin) on nitrogen**
- **GEM 2 (Thir) and 6 (Rui) at TRIUMF**

- **Ishara shorted; Michael, Bishoy, Malinga with high currents**

Software status

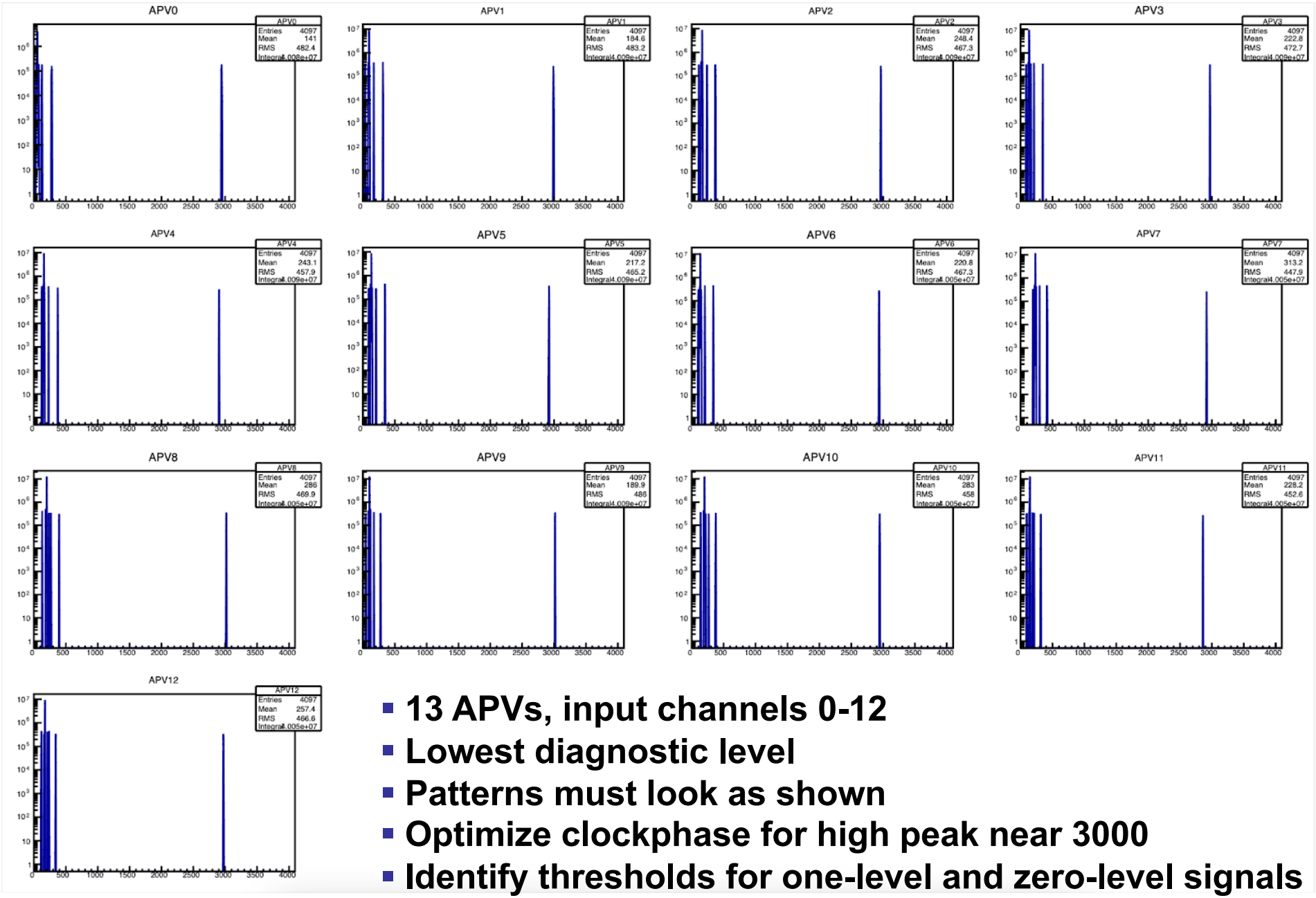
DAQ software:

- **Re-established DAQ in histogramming mode (“DAQhisto”)**
- **Re-established GEM readout with MIDAS (using DAQ server) and GEM_frontend (VME client), local area network**
- **GEM_frontend as used at ELPH in 2019**
- **Contains two banks, GEM0 and GEM1**

Analysis software:

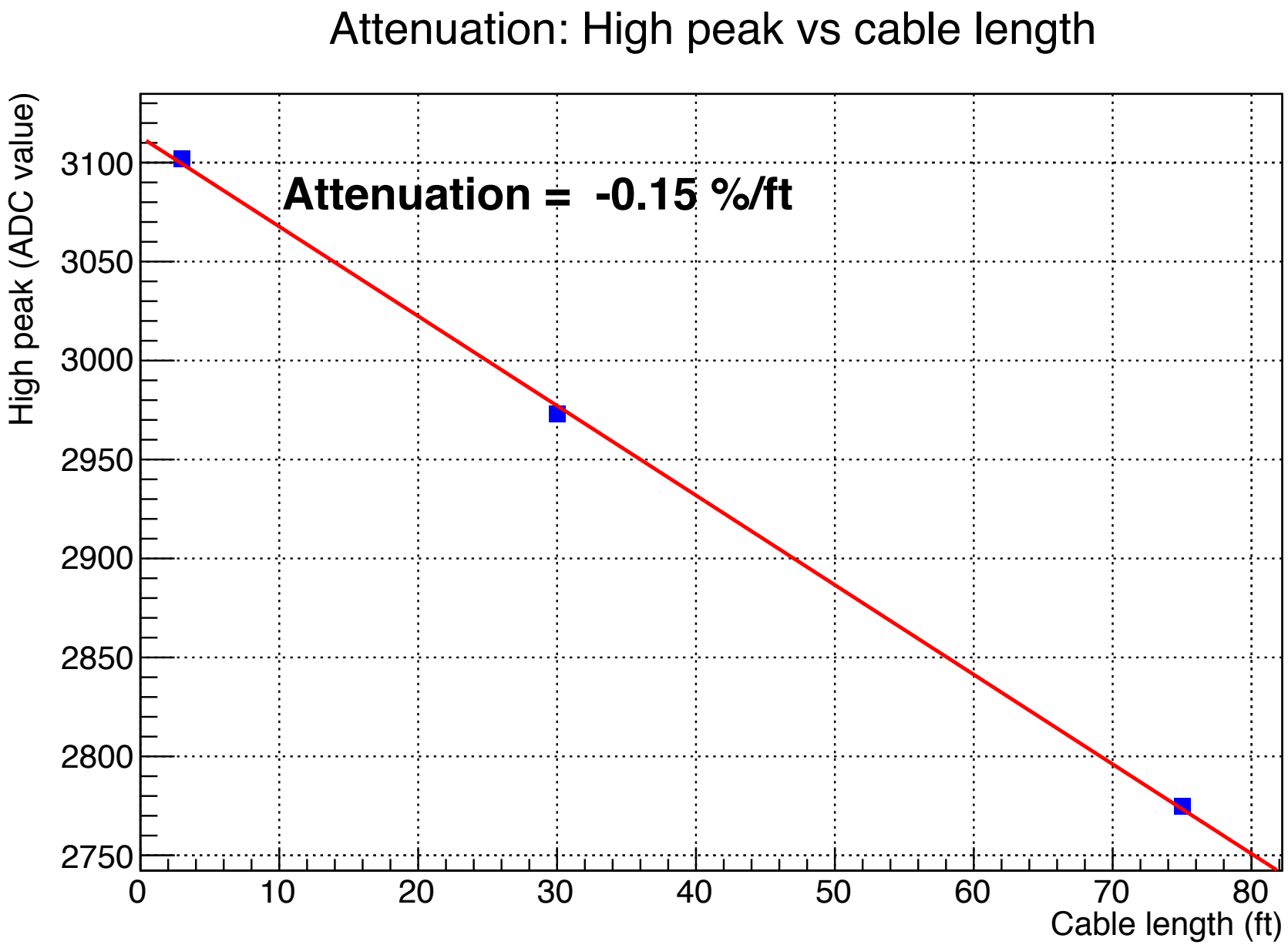
- **Re-established ulq2cooker as used at ELPH in 2019. Can analyze raw ADC spectra, and provide pedestal + common-mode subtractions**
- **Can do clustering (demonstrated with ELPH test beam data) for a single GEM. Able to re-analyze ELPH data.**

Histogramming mode



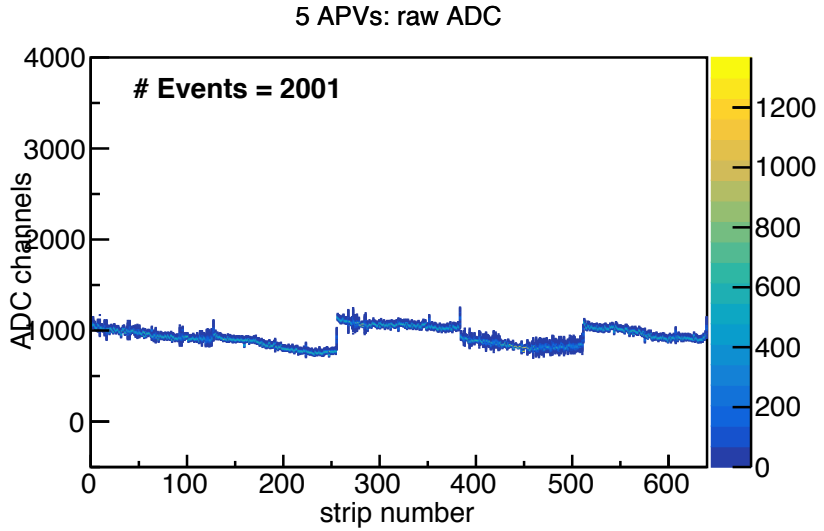
- 13 APVs, input channels 0-12
- Lowest diagnostic level
- Patterns must look as shown
- Optimize clockphase for high peak near 3000
- Identify thresholds for one-level and zero-level signals

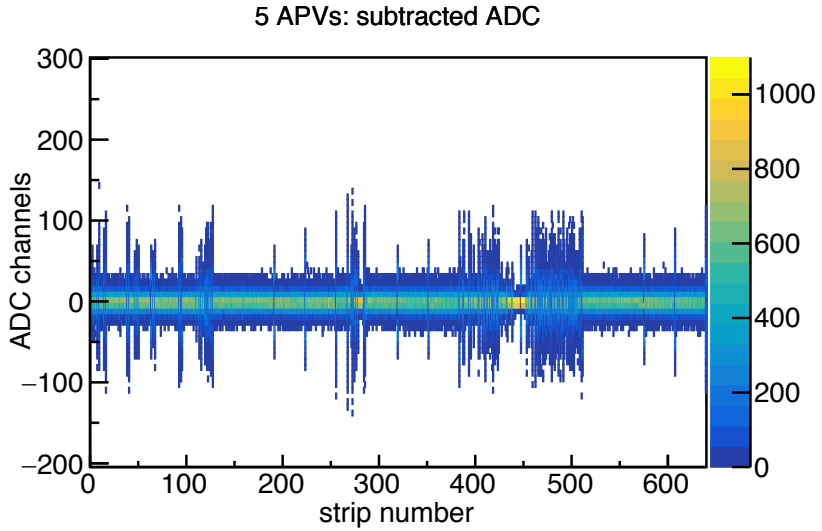
HDMI Attenuation (reported Sep 27, 2023)

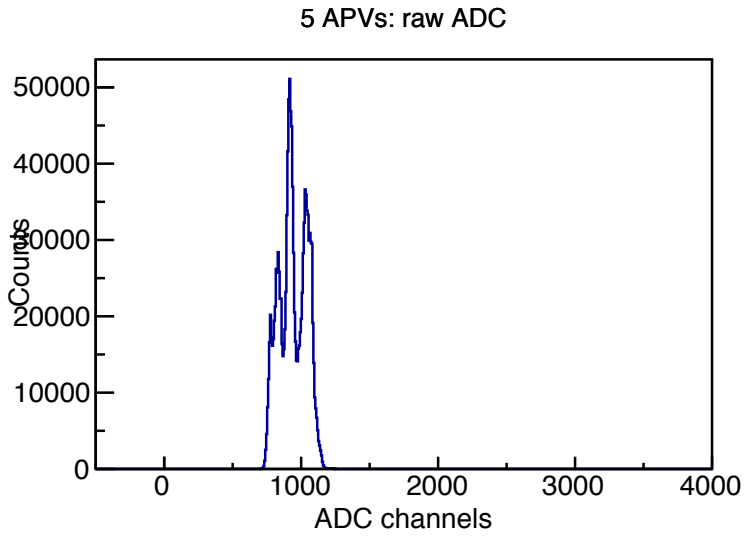


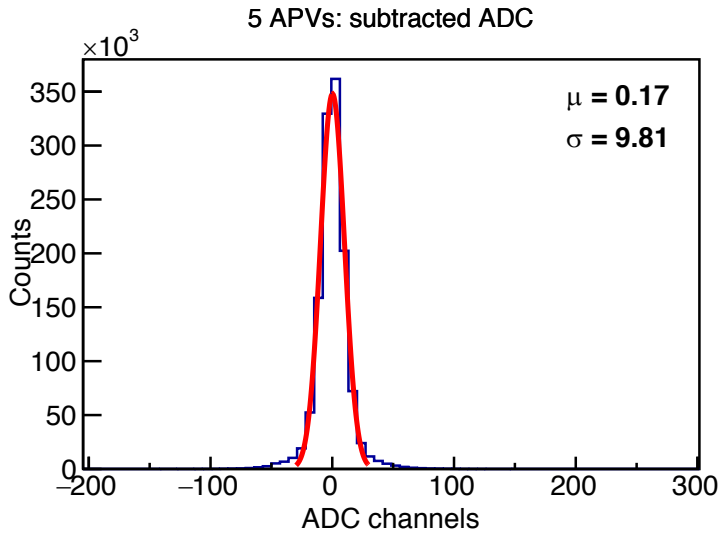
APV testing

Run 55 : APV 1-5 / BP 1





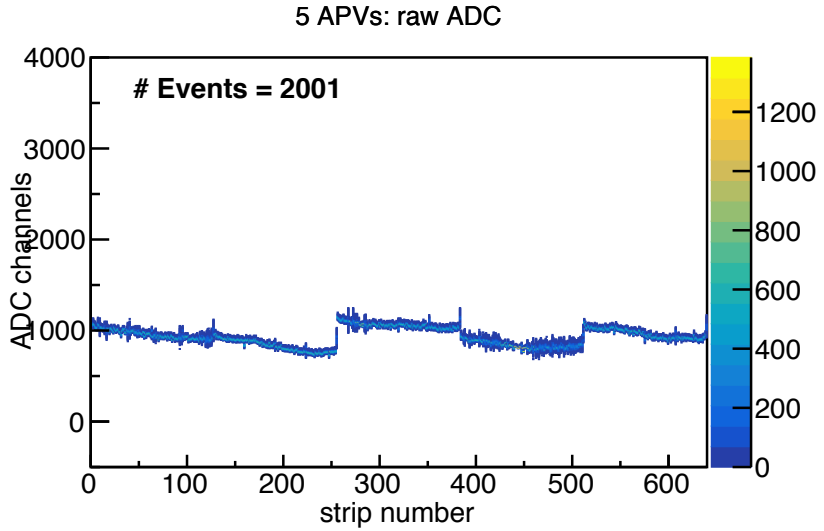


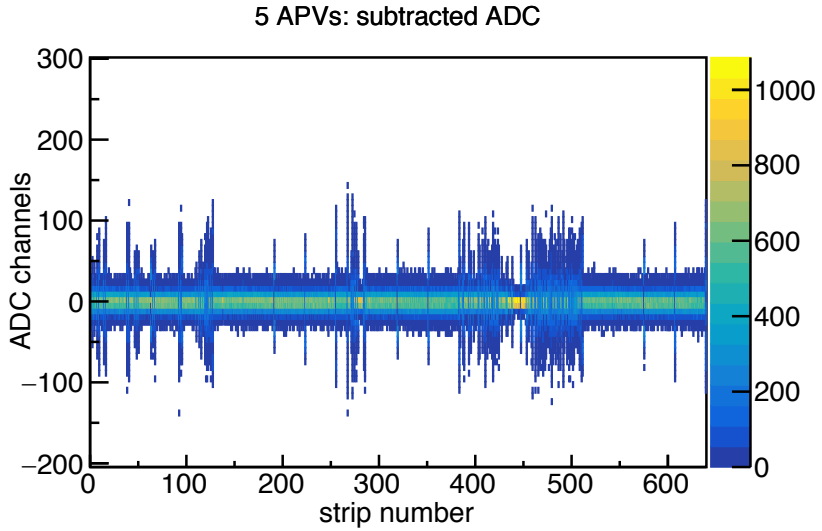


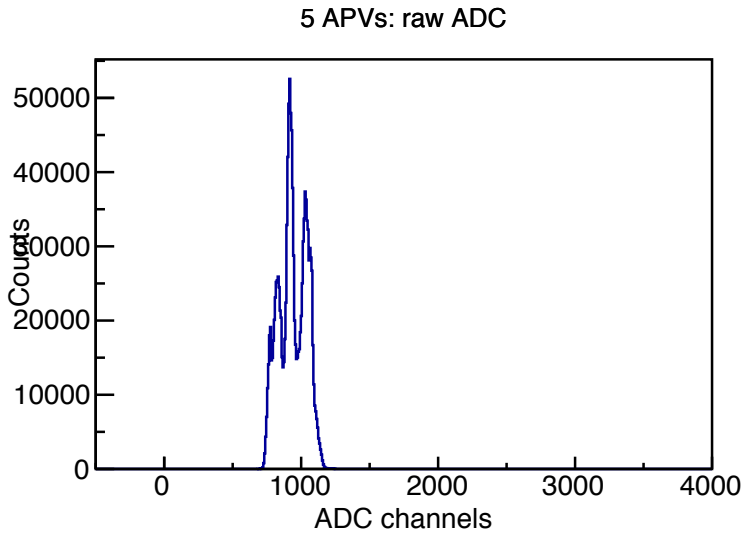
APVs detached from GEM

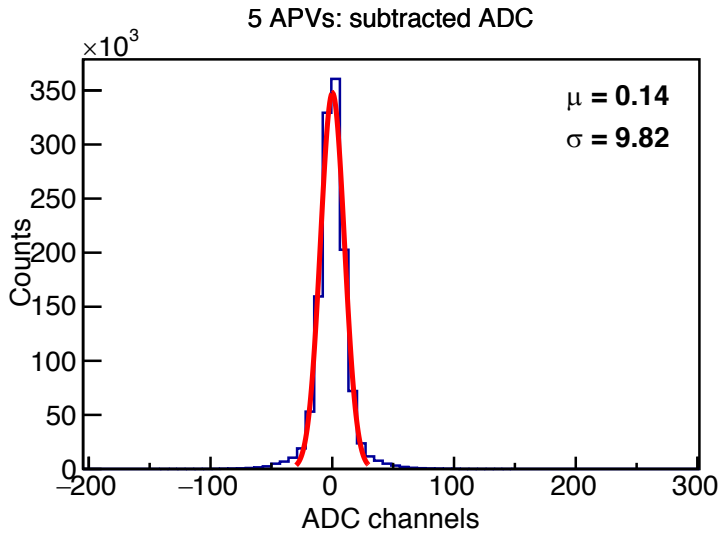
APV testing

Run 65 : APV 1-5 / BP 2





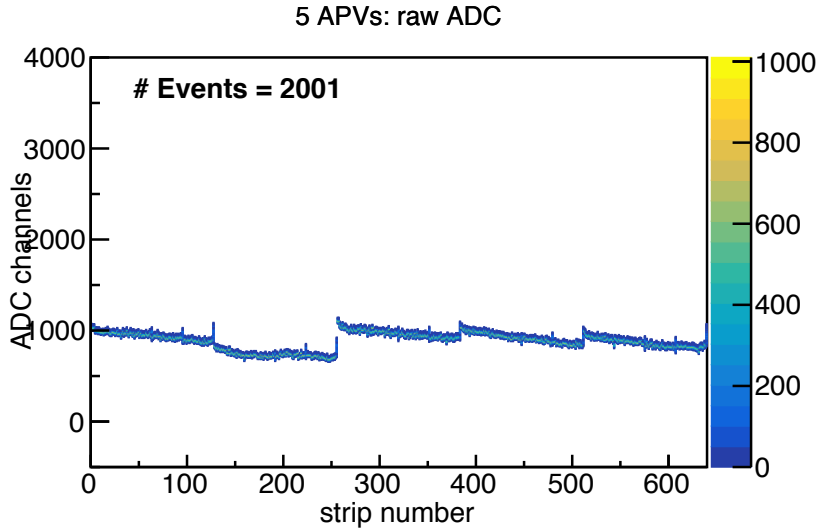


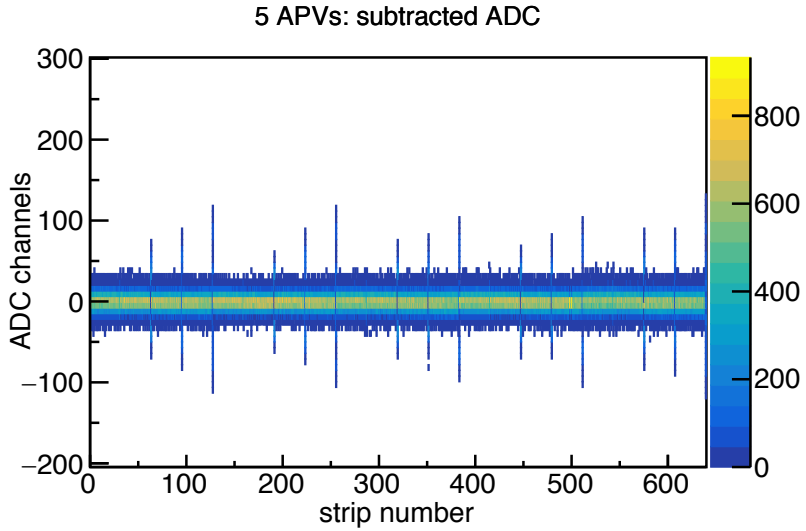


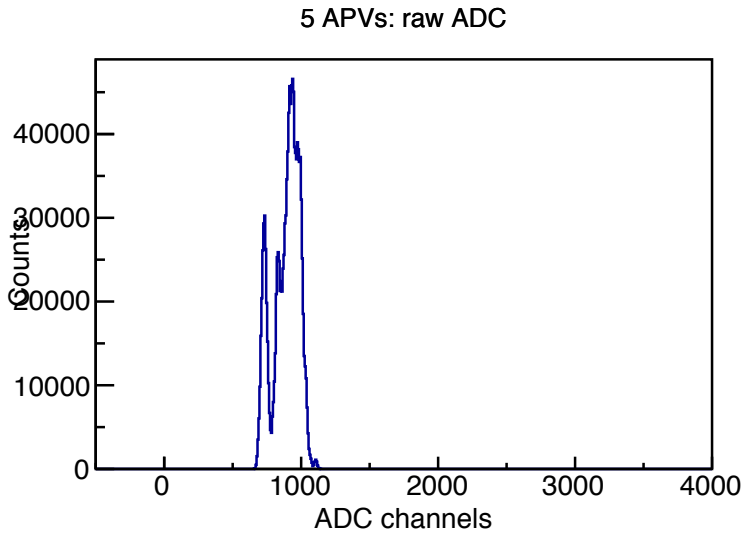
APVs detached from GEM

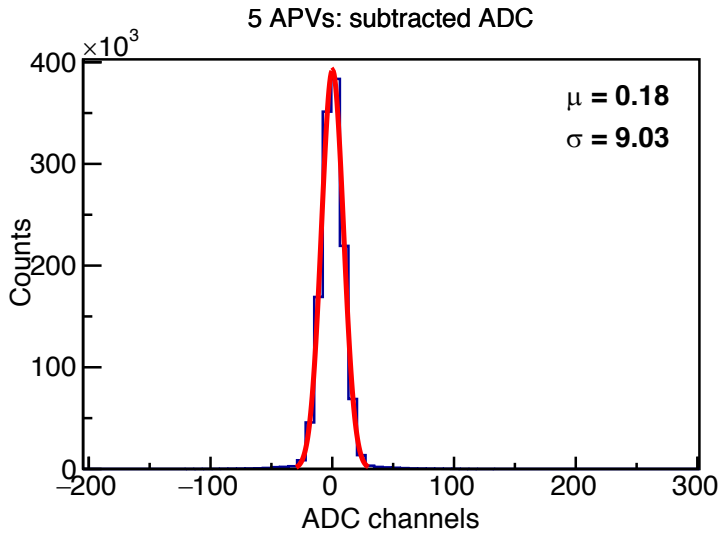
APV testing

Run 56 : APV 6-10 / BP 1





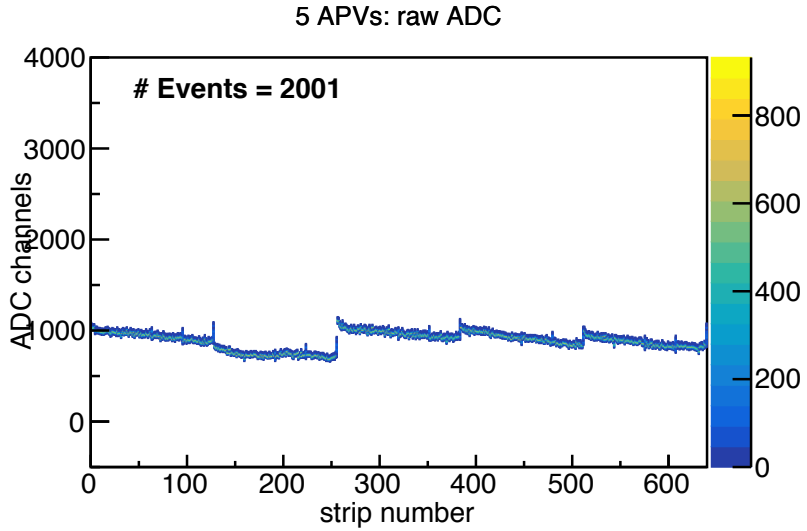


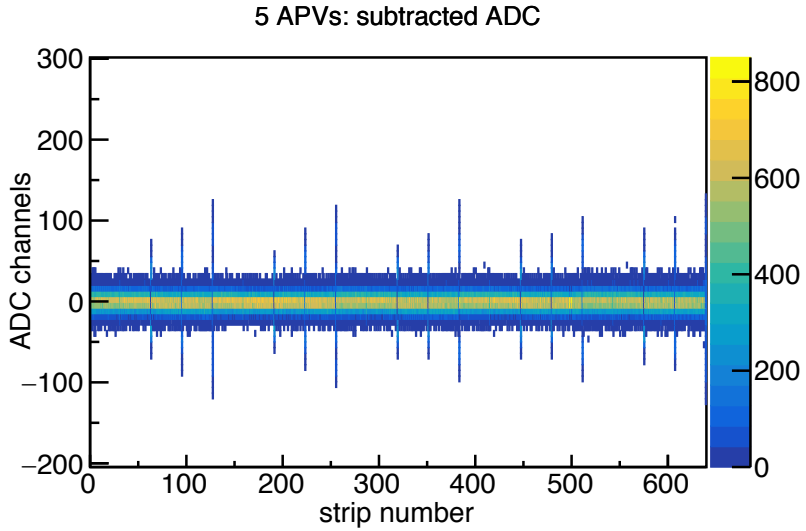


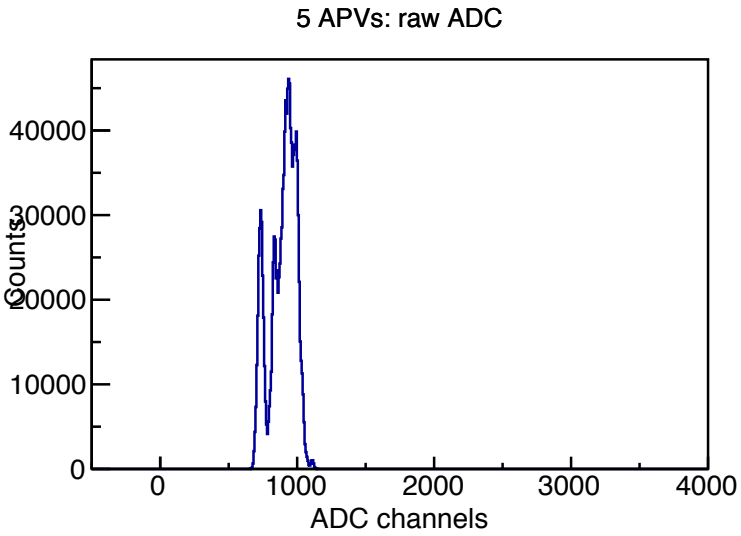
APVs detached from GEM

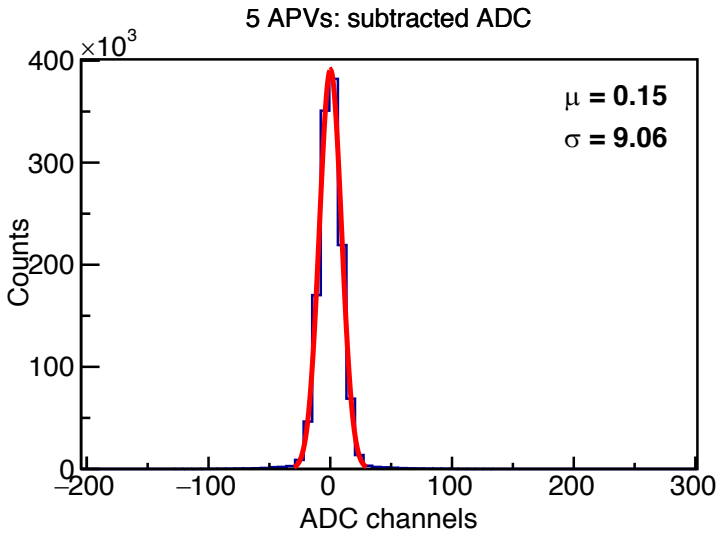
APV testing

Run 66 : APV 6-10 / BP 2





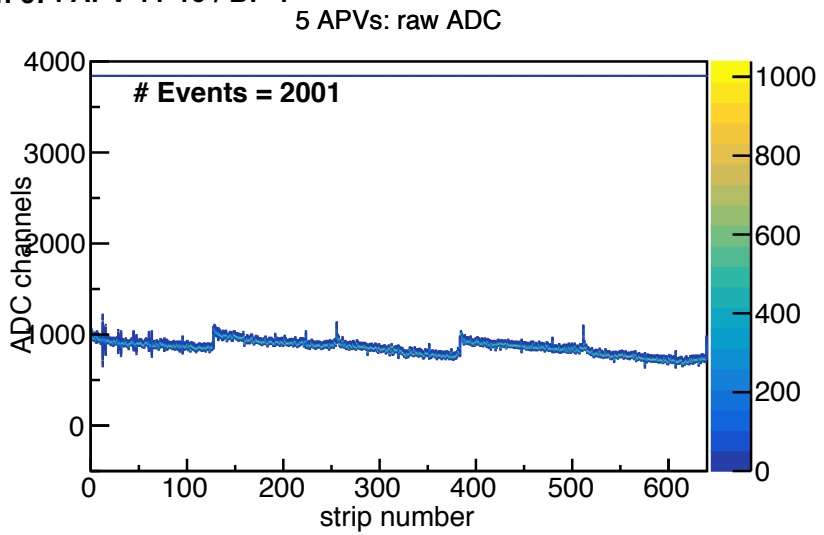


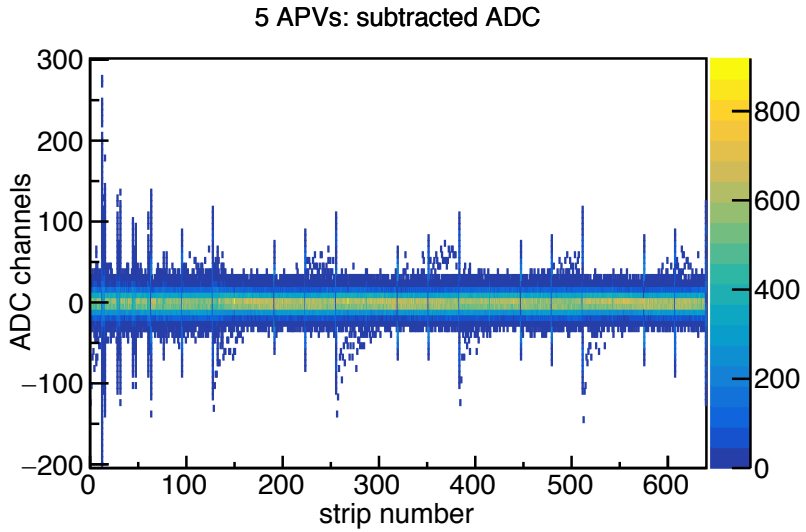


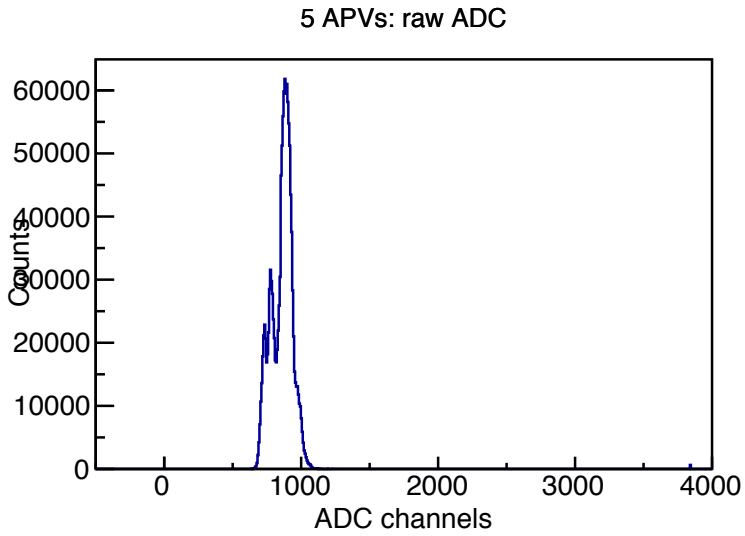
APVs detached from GEM

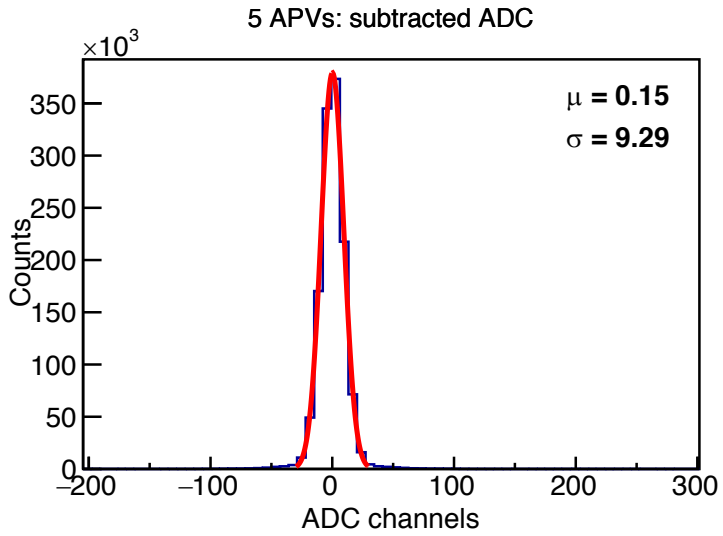
APV testing

Run 67 : APV 11-15 / BP 1





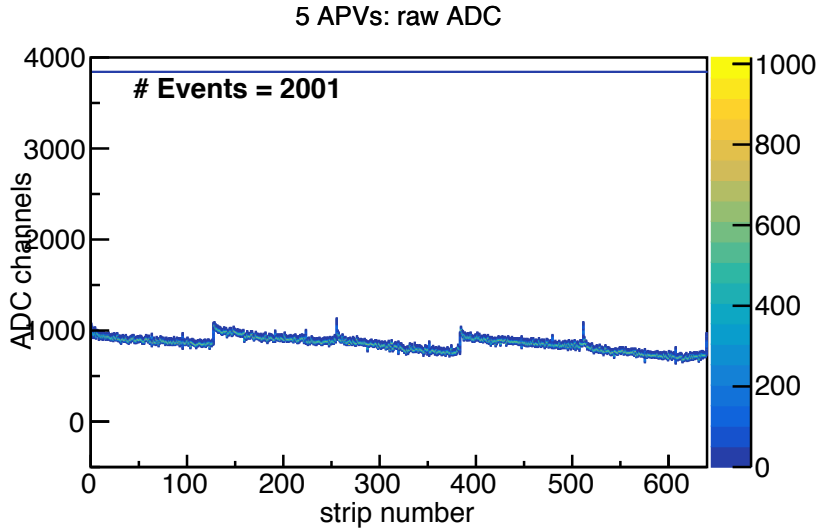


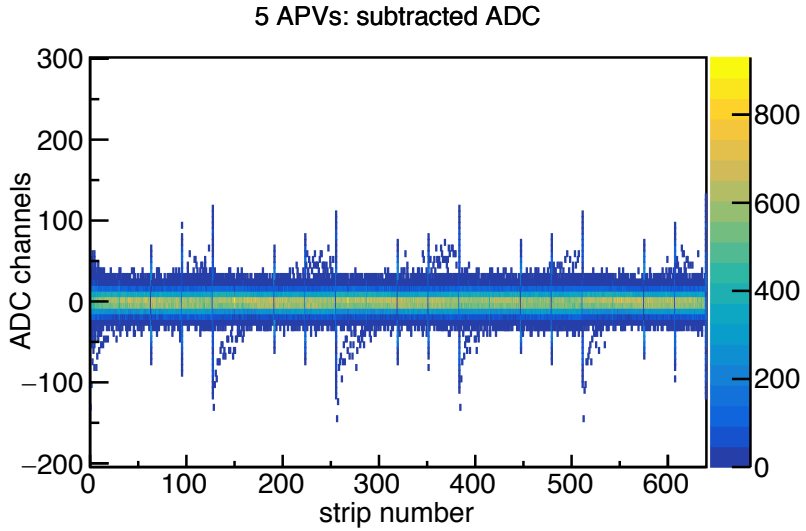


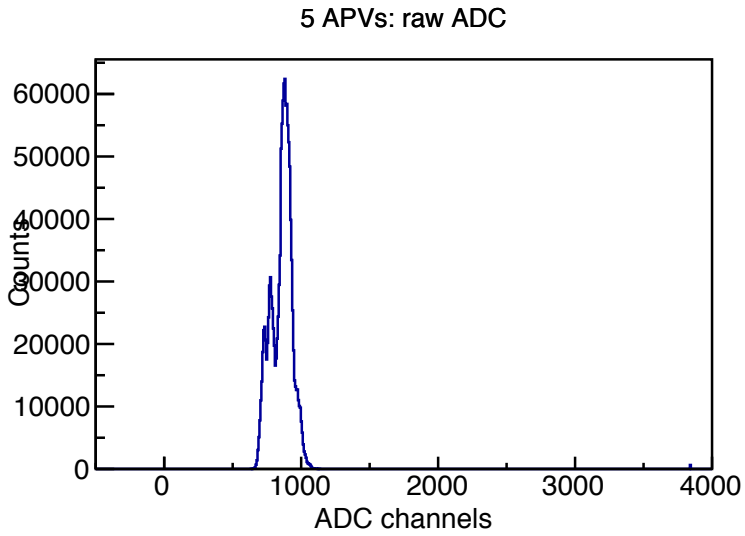
APVs detached from GEM

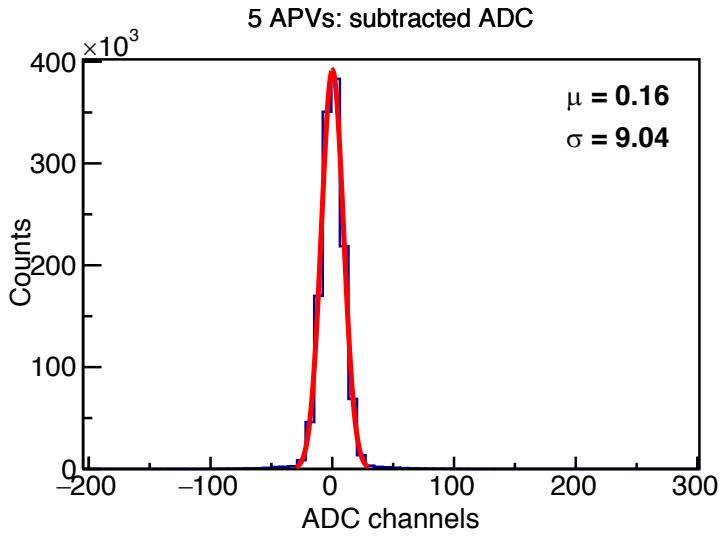
APV testing

Run 57 : APV 11-15 / BP 2





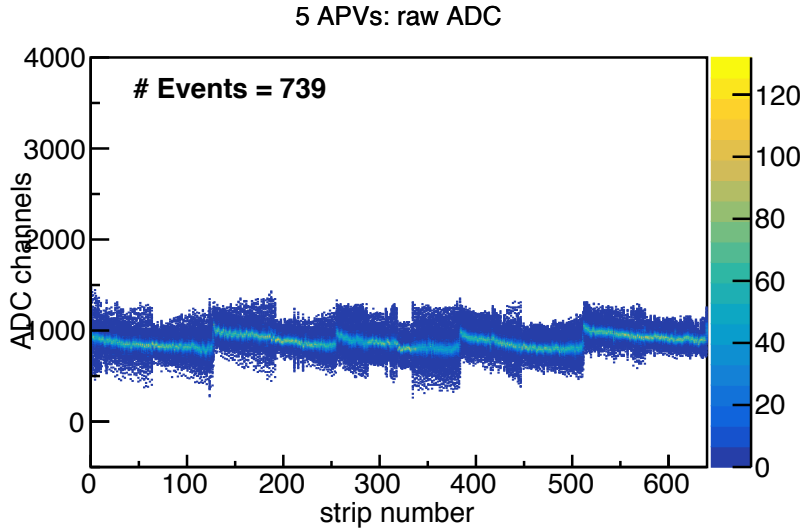


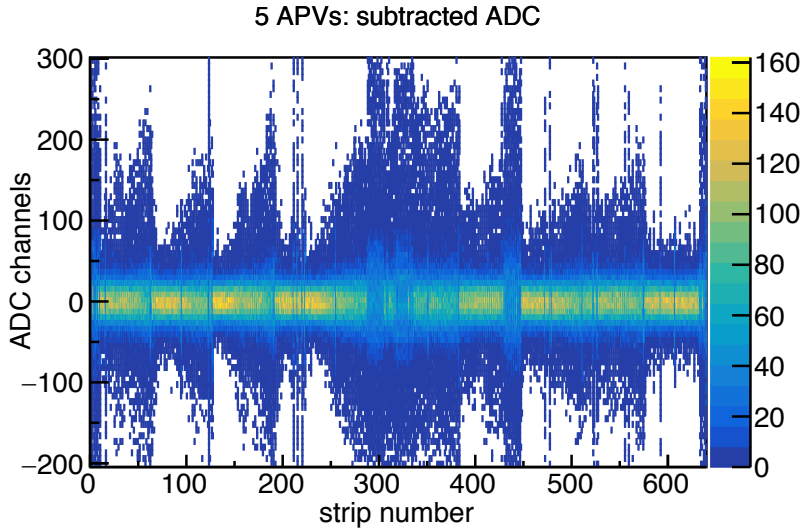


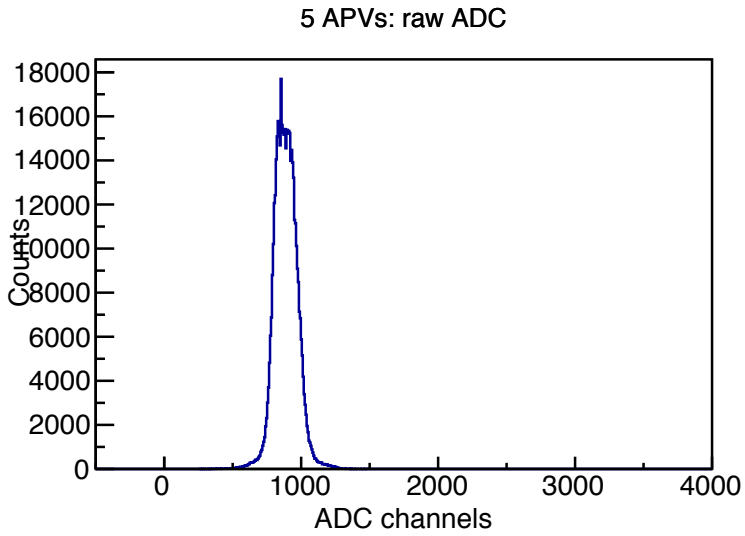
APVs detached from GEM

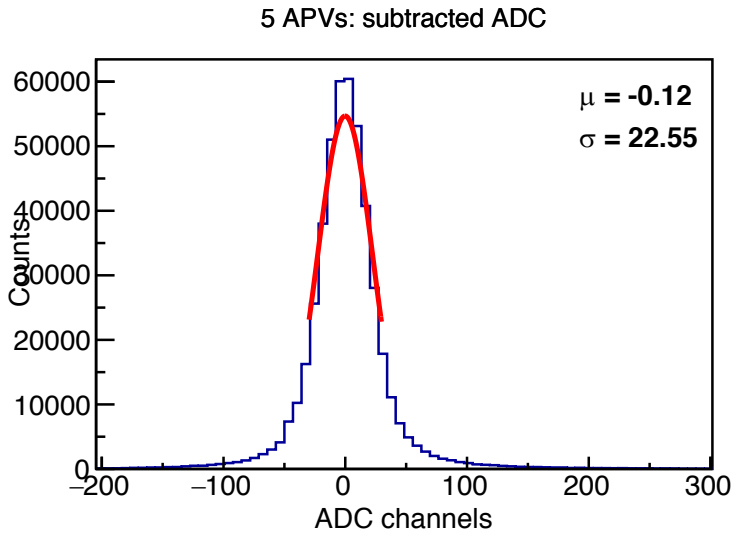
APV testing

Run 47 : "Tanvi"









APVs attached to GEM

Software tasks

DAQ software:

- **Update GEM_frontend to latest scheme implemented at PSI, update decoding / re-encoding raw GEM data structure for multi-sample modes and higher data packing density**
- **Start using DL git repo for version control of GEM_frontend. Issue of no direct ssh-out access from LERF, working with reverse tunnels**
- **Speed benchmarking (speed limited by MPD eventbuilding)**

Analysis software:

- **Update to 2023 features implemented at MUSE**
- **Port ulq2cooker to dlcooker, start using DL git repo**

Commissioning tasks

- Currently only Tanvi cabled up. Second GEM will be Jesmin. Electronics on hand. Cable up Jesmin (1 wk)
- Set up trigger latching (prevent triggers to MPD while busy) → use V262 + logic unit as in early days of MUSE (1 wk)
- Establish first signals with Tanvi. Use Sr-90 to tune latency and HV. Establish clustering analysis (1 wk)
- Use Sr-90 for mapping channels to strips/coordinates (1 wk)
- Sandwich GEM between scintillator and Sr-90 to scan efficiency vs HV, establish plateau (1 wk)
- Repeat with Jesmin (2 wks)
- Set up scintillators for cosmic ray trigger (1 wk)
- Operate single GEM for cluster map and gain uniformity (1 wk)
- Extend DAQ GEM_frontend to read out two GEMs (two MPDs)
- Operate two adjacent GEMs for efficiencies (few wks) → 3 mth

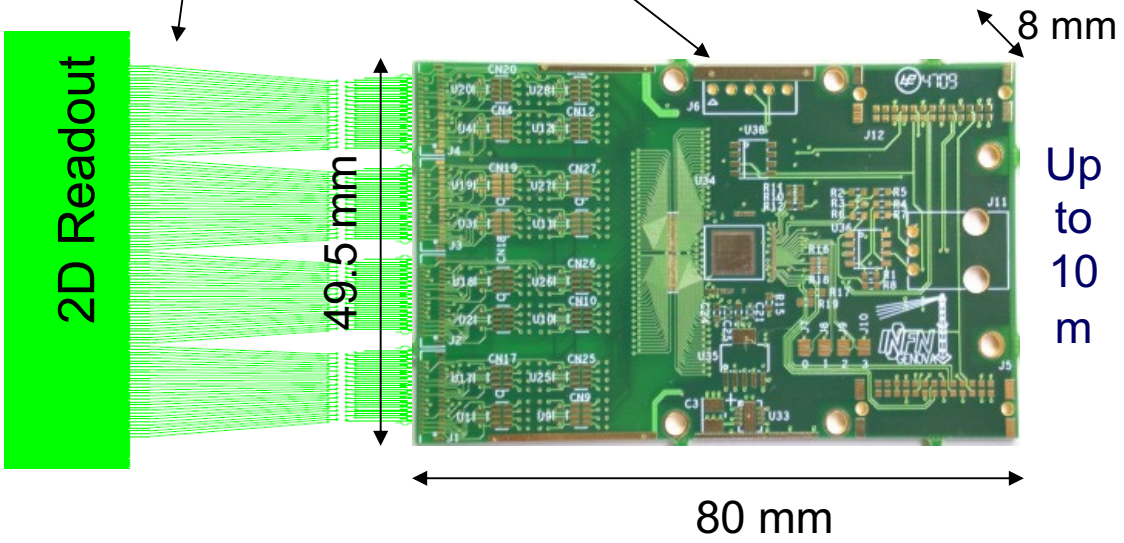
Timeline, constraints, scenarios

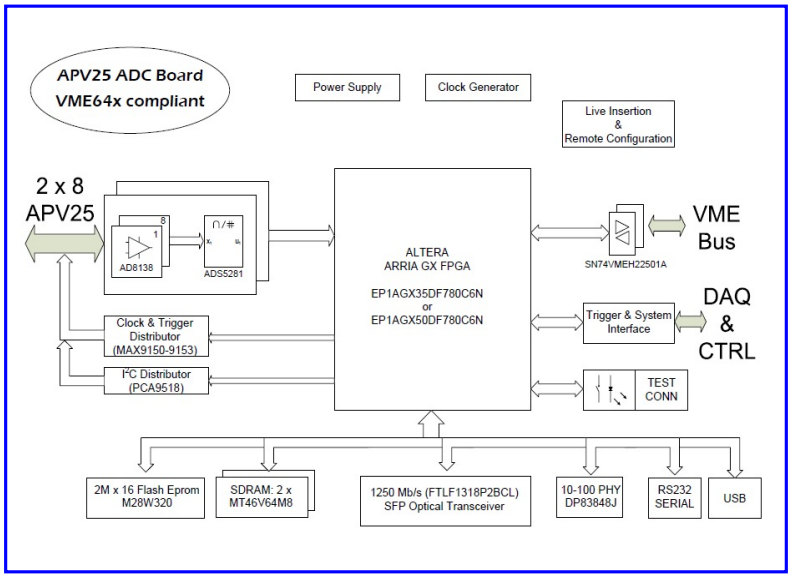
- Commissioning of Tanvi + Jesmin including DAQ and analysis will require ~3 months of focused work (Dec'23 – Feb'24)
- Ship to TRIUMF in March'24 at the soonest
- Group is also involved with MUSE and SBS
  MUSE running in Dec'23, expected to resume in April/May'24
  SBS GEn-RP to run in Apr'24 for one month, ending May 25
- Accomplish as many tasks as possible with dual systems at TRIUMF and at LERF. Keep setup at LERF also for VXS/VTP upgrade? Expect lead time of ~6 months.
- Consider initial commissioning of DL at TRIUMF with present setup at TRIUMF (only one arm), and add LERF setup later
- Manju to take PhD Qualifying exams in May'24
- M.K. loaded with teaching duties (Intro Physics, 50 students)
- Manju, Ryan, M.K. to visit TRIUMF in Summer'24 (Jun – Aug) to implement remaining setup

THANK YOU!

Readout electronics (INFN Rome)

GEM ⇒ FEC ⇒ ADC+VME Controller ⇒ DAQ





- Frontend card and controller (APV + VME) by INFN Rome, Jlab/SBS project S. Frullani, E. Cisbani, P. Musico
- APV rev. 3.0/3.1 (MUSE) and rev. 4.1 (DarkLight)
- MPD upgraded to rev. 4.0 for operation in DarkLight and MUSE

Multi-purpose digitizer (MPD)

MPD rev. 3.0

rev. 4.0

High voltage

- Up to 4,300V @ 1mA supplied to passive HV divider on GEM
- Negative HV, from Cathode layer to readout at ground level
- CAEN V6533N VME based (6 channels)
- 9W power limit → use only 2 channels per module;
  Use 2 CAEN modules for 4 GEMs
- SHV cables from VME to GEMs, 1 per GEM

Low voltage

- APV frontend cards require 2.5 V + 1.25 V operating voltages, provided by power regulator chip, one per GEM
- LV (4.5-5 V) is supplied to LV regulator board
- 1 regulator per GEM to power 13 APVs (8+5)
- 13 APVs per GEM draw <20A; total setup <100A @ 5V
- Need low-gauge LV cabling (10-12 AWG) to avoid LV drop

- Can TRIUMF provide LV power?