Update/Status for NPS HV, Electronics, DAQ

Brad Sawatzky

NPS Collaboration Meeting

Feb 1, 2021

DAQ Hardware for NPS

- **NPS: 1080 $PbWO_4$ blocks**
  - → Readout consists of JLab F250 FADCs
    - » Full waveform for crystals of interest
    - » < 1ns timing res. is provided by F250s
  - → NPS trigger generated by JLab VTP modules in NPS F250 VXS crates
- **Hardware needed for NPS** **(All hardware in-hand except where noted)**
  - → 68x FADCs (Note: 52 modules to be provided by Physics Div / FE group pool)
  - → 5x VXS crates
  - → 5x SD + TI + Linux SBC / ROC
  - → 5x VTP modules (Order placed with FE group May 2020)
  - → HV supplies (2x SY4527 crates + 64 HV modules: 1152 HV channels)
- **Firmware development**
  - → VTP firmware
    - » provide required summing trigger, and 'sparsification mask' to F250s
  - → F250 FADC firmware updated to emit waveform data based on channel mask from VTP
  - → TI/TM firmware must support full complement of 5 NPS crates + 3 HMS crates
- **LED System Driver boards**
  - → Each NPS block has a UV LED attached; can be run in two modes
    - » Bleaching (extended UV exposure used to 'heal' accumulated radiation damage)
    - » Pulse mode (used to test trigger and individual block responses)
  - → FE Group board design nearly complete

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Potential contention with SBS?

- **Firmware development**
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VTP / F250 / TM Firmware / Trigger

- VTP (5+1 modules ordered May 2020)
  - → Cluster trigger based on 3x3 groups, with 1 row shared between crates
  - → Logic signals emitted by each VTP will be OR'd in NIM to form NPS trigger
    - » CODA trig: HMS .AND. (.OR. of NPS)
    - » Timing latency on VTP triggers deterministic to <12ns
  - → Define/update VTP data payload
    - » cluster charge, timing?
    - » cluster crystal list to be used to sparsify F250 waveform readout
- F250 FADC (51 modules from FE/PD pool)
  - → Hi-res timing required (< 1ns)
    - » Preserve multi-hit/ch output
  - → QDC data, Scaler data
  - → Full waveforms (25 samples)
    - » Compressed?
  - → VTP info used to sparsify F250 readout channels to those in a 5x5 cluster(s) centered on the 3x3 'trigger' cluster(s)

- TI/TM modifications (if needed?)
  - → must support 5 NPS crates + 3 HMS crates
  - → maintain six L1 trigger inputs on primary TM
- CODA / HMS trigger assumptions
  - → 'Standard HMS' NIM triggers will be available
    - » ¾, EL_{real}, EL_{clean}, ...
  - → NPS + HMS trigger made in NIM
    - » NPS + HMS {¾, EL_{foo}}
    - » NPS VTP latency is NOT a problem
- NPS detector assembly and full DAQ chain readout tests to be done in TestLab highbay space starting 2021

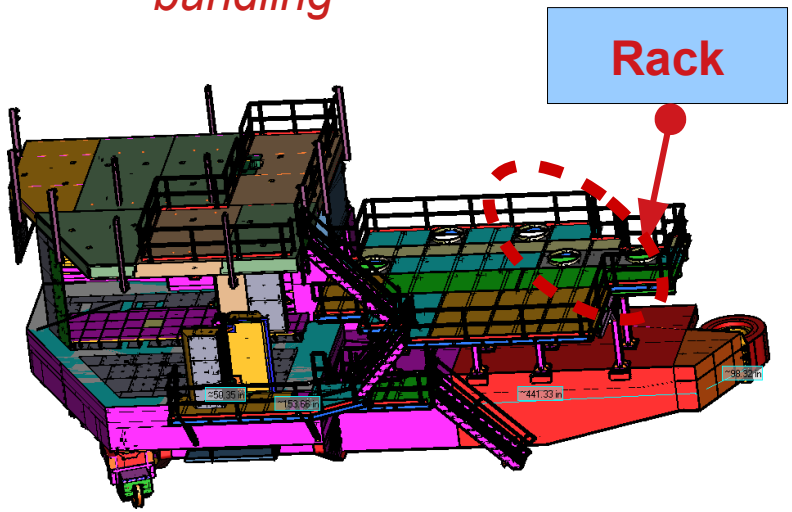
FE/DAQ group actively working on firmware

NPS DAQ Challenges

- Most work driven by requirement to handle high-rate kinematics + waveform output
  - → 13 kHz HMS (DIS) triggers (+ background)
    - » need NPS trigger (→ VTP firmware)
    - » need 'Event-Blocking' enabled
  - → 'high' multiplicity in NPS (75+ crystals)
  - → waveform output for participating crystals is a 'Must' (~25 samples/ch)
- Pending issues
  - → VTP firmware development
    - » 3x3 crystal cluster triggers
    - » Emit logic-out for NIM trigger with HMS
    - » 'sparsify' F250 readout (only store waveforms from 5x5 clusters centered on 3x3 'trigger' cluster)
  - → Analyzer support for VTP payload
  - → Analyzer support for Event-Blocking mode
    - » 'Unblock' in secondary ROL?
      - – may be simplest? no analyzer changes needed [Moffit?]
    - » 'Unblock' at analyzer? [Bob M]
- Firmware questions *wrt* VTP/F250s
  - → Hall B firmware has compression, but removes features to achieve this
    - » need to ensure necessary timing, QDC, scaler(?) data still present
  - → May require upgrading HMS F250 firmware as well
    - » need to address knock-on changes to CRLs and analyzer assumptions for HMS
  - → *Or* lossless compression in 2nd stage ROL + libCoda mod?
    - » no F250 firmware change, no decoder changes
- Firmware / DAQ questions have been discussed with FE Group
  - → No "show-stoppers" but requires development resources be allocated to this project
- Updates to Hall C analyzer software
  - → Non-trivial work here!

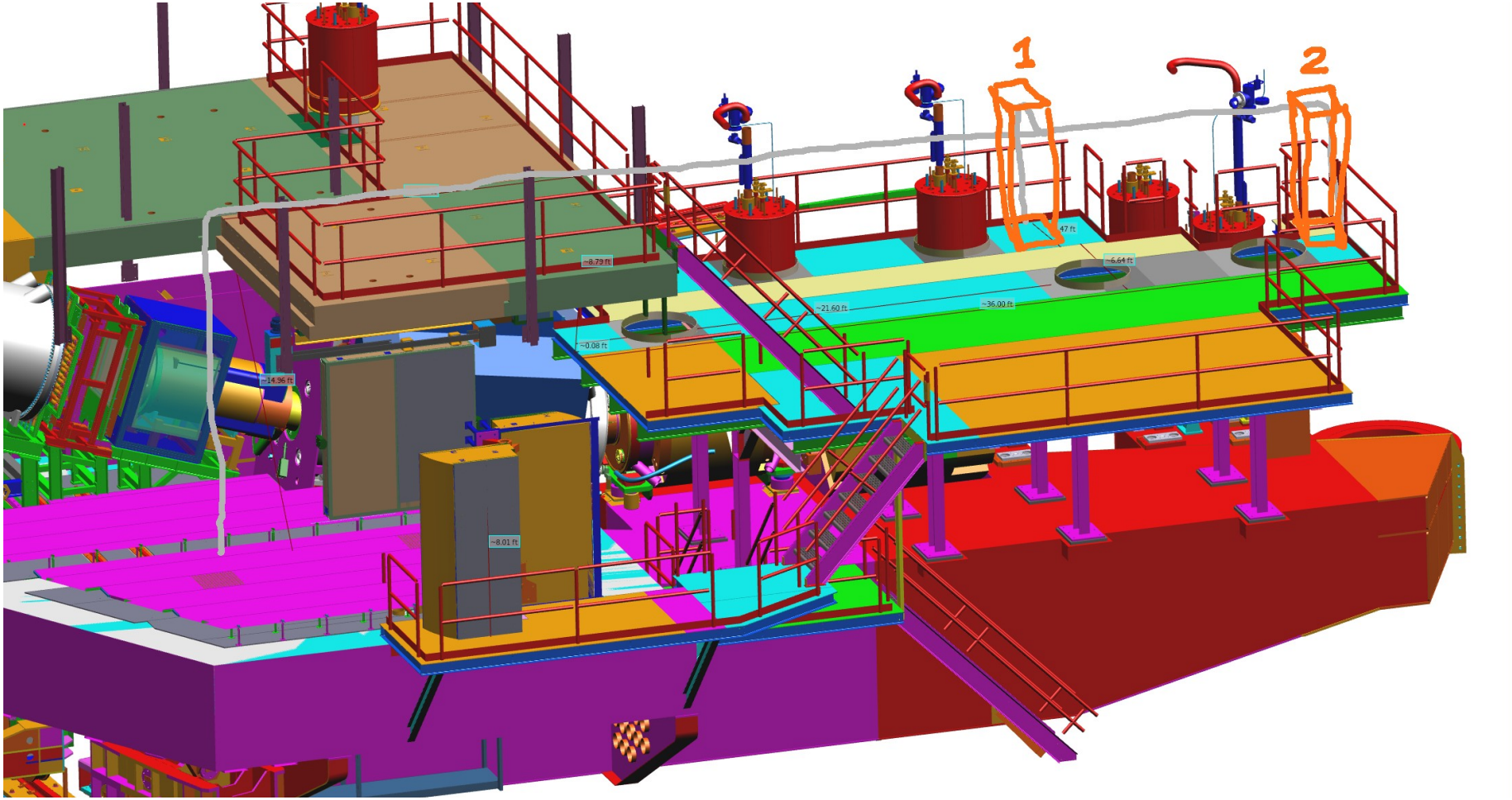
Signal/HV/LED Cable Runs

- Plan is for a single 84” tall, 19” standard width rack to be placed near the pivot
  - → Planned to go on the upper, power supply deck
- The rack at the pivot will provide a BNC:BNC patch for 1080+20 RG-58 cables *only*
  - → *Cables in-hand; needs bundling*



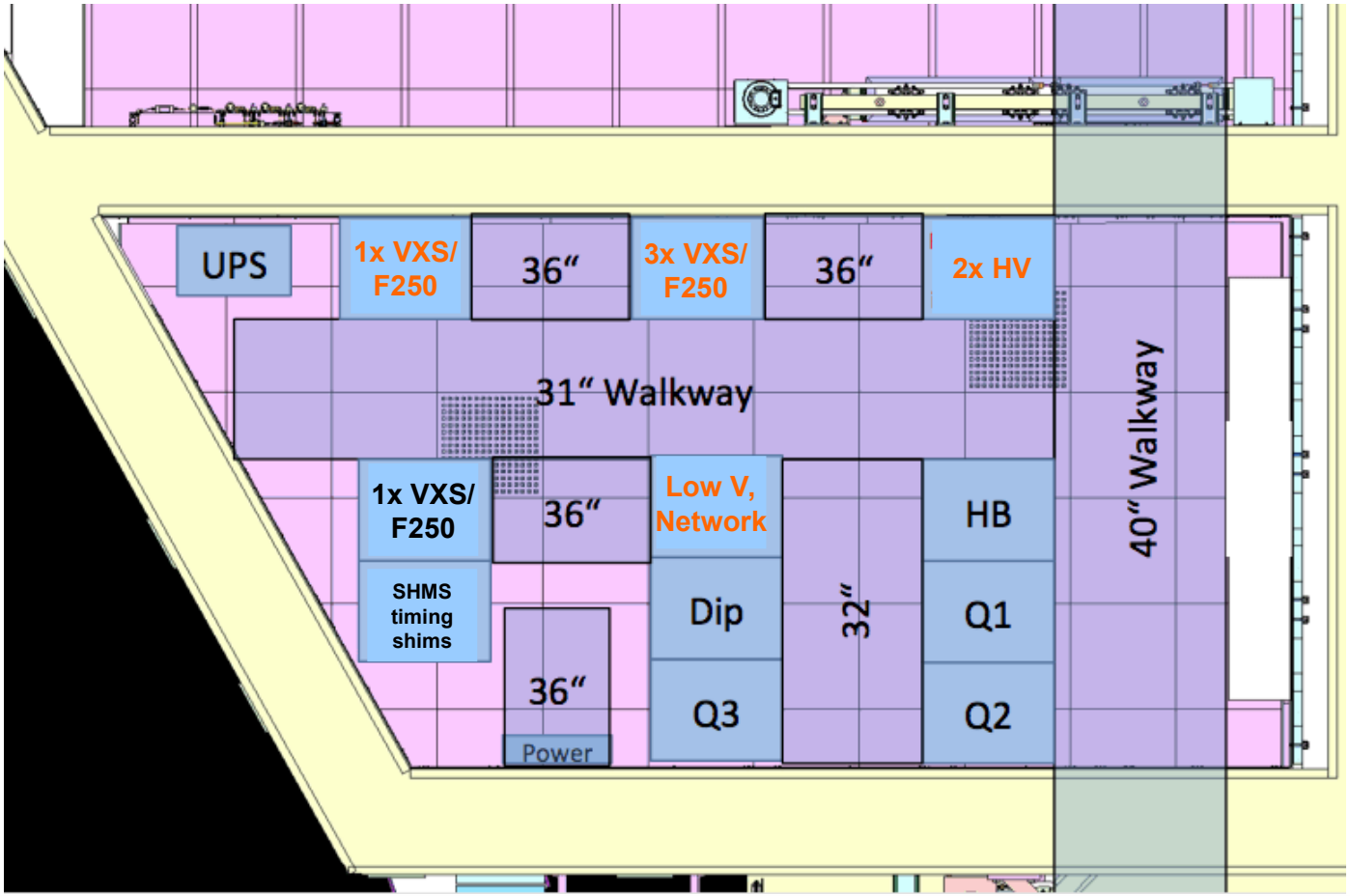
- Other cables will follow the same path past the rack to the NPS, but with no patch panel:
  - → 30+2 multi-conductor HV
    - » Assembly in progress (DSG)
  - → 60+2 80-wire ribbon cables for LED system
    - » *New* : need to buy/assemble when LED board final (soon)
  - → Heavy-gauge detector grounding cable(s)
    - » Isolation pads for NPS
    - » Need to establish/ensure clean detector ground
    - » *Purchase, or have?*

Crude cable path from SHMS to Rack Location (2 options)



Rackspace in SHMS hut

- 4+1 VXS crates + 2 High Voltage crates (red indicate new crates)
  - → It's pretty snug, but it'll fit…
  - → Cables flow into crates via cable trays running above racks



Cable Bundle Summary

- This covers cables run between SHMS detector hut to NPS detector
  - → Signal, HV, LED cables
  - → All cables follow same run
    - » Cables are ~150' long
    - » Patch panel rack for signal cables is intended to be roughly half way
- Cable bundle cross section and weight estimate (above cables)
  - → ~120 in^2 (cross section area)
  - → ~50 kg/m; ~33 lbs/ft

- *NOT* considered in this document:
  - →Thermal monitoring readout or Temperature control systems
    - » Heat exchanger plumbing, control lines, etc

Paulo / Designers working on cable path (Jan 2021)

NPS Detector Slow Controls

- NPS detector will need additional instrumentation for **Thermal Monitoring/Control** and **LED system**

- Thermal Monitoring/Control
  - → Model after Primex/HyCal/ComCal
  - → Only local control needed
    - » Remote monitoring is straight forward
  - → Brad will be JLab point of contact for integration / EPICS
    - » DSG support in place
      - – See Aaron's Talk
- Existing EPICS Archiver and Alarm Handler software used for automatic signal logging/ monitoring

- Thermal Monitoring/Control Notes
  - → Rough Channel/Function List:
    - » Readbacks for chiller/air-handler at minimum
      - – Status, in/outflow temps, etc
  - → Internal air temp readback(s)
  - → Multiple detector temp readbacks (few dozen ch)
    - » Several locations in crystal mount / HV divider region

- LED controls (JLab FE Group)
  - → Controller/driver design in progress...
    - » Custom control board
    - » Design near-final (William Gu)
      - – Procurement TBD
  - → See Chris' Talk

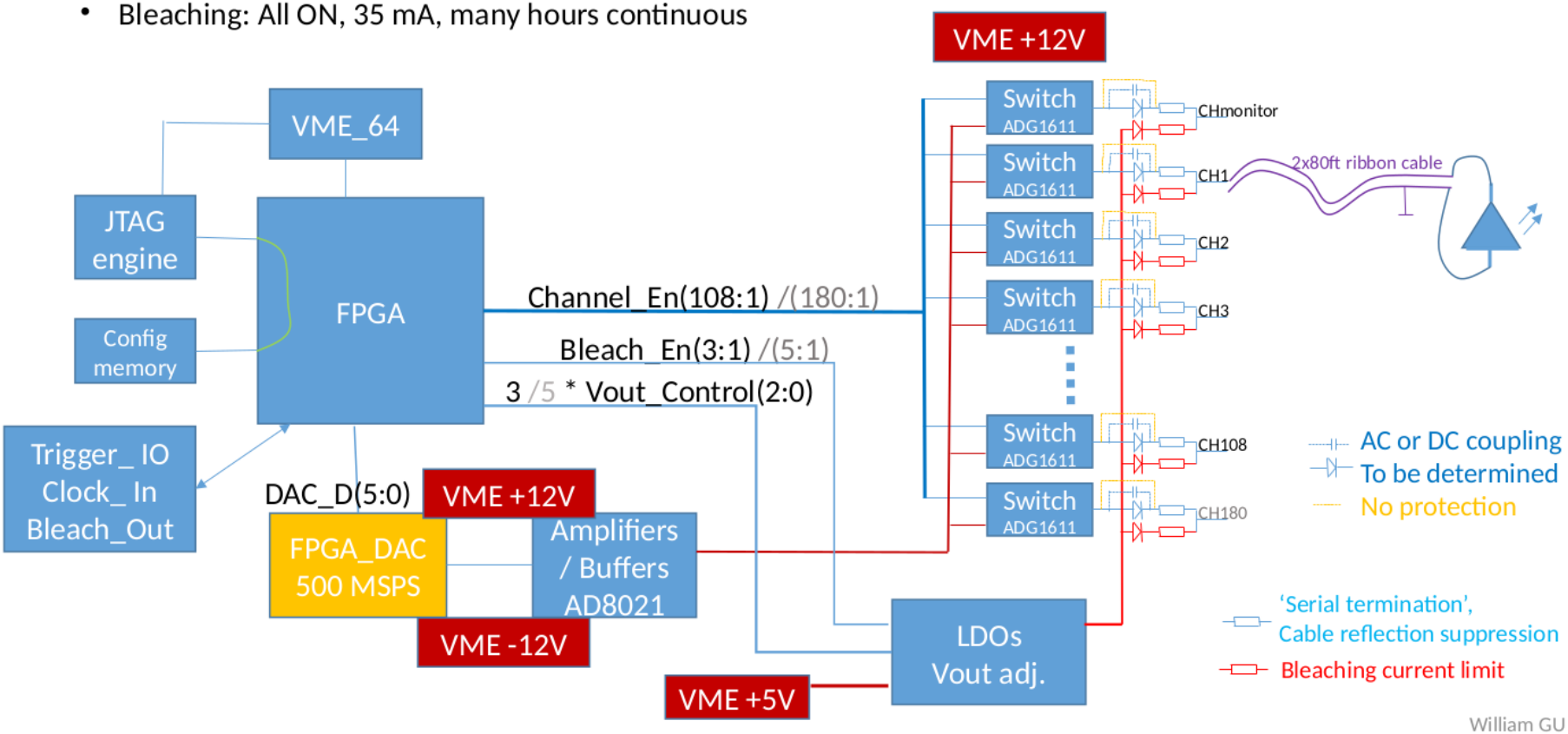
LED Driver Board

VME LED Driver (VLD) design

1080 (30x36) LEDs, through 160ft long ribbon cables (100 Ohm impedance).

- Calibration: individually enabled, up to 110 mA , ~ns pulses
- Bleaching: All ON, 35 mA, many hours continuous

Design is Ready,
PCB is ready to order



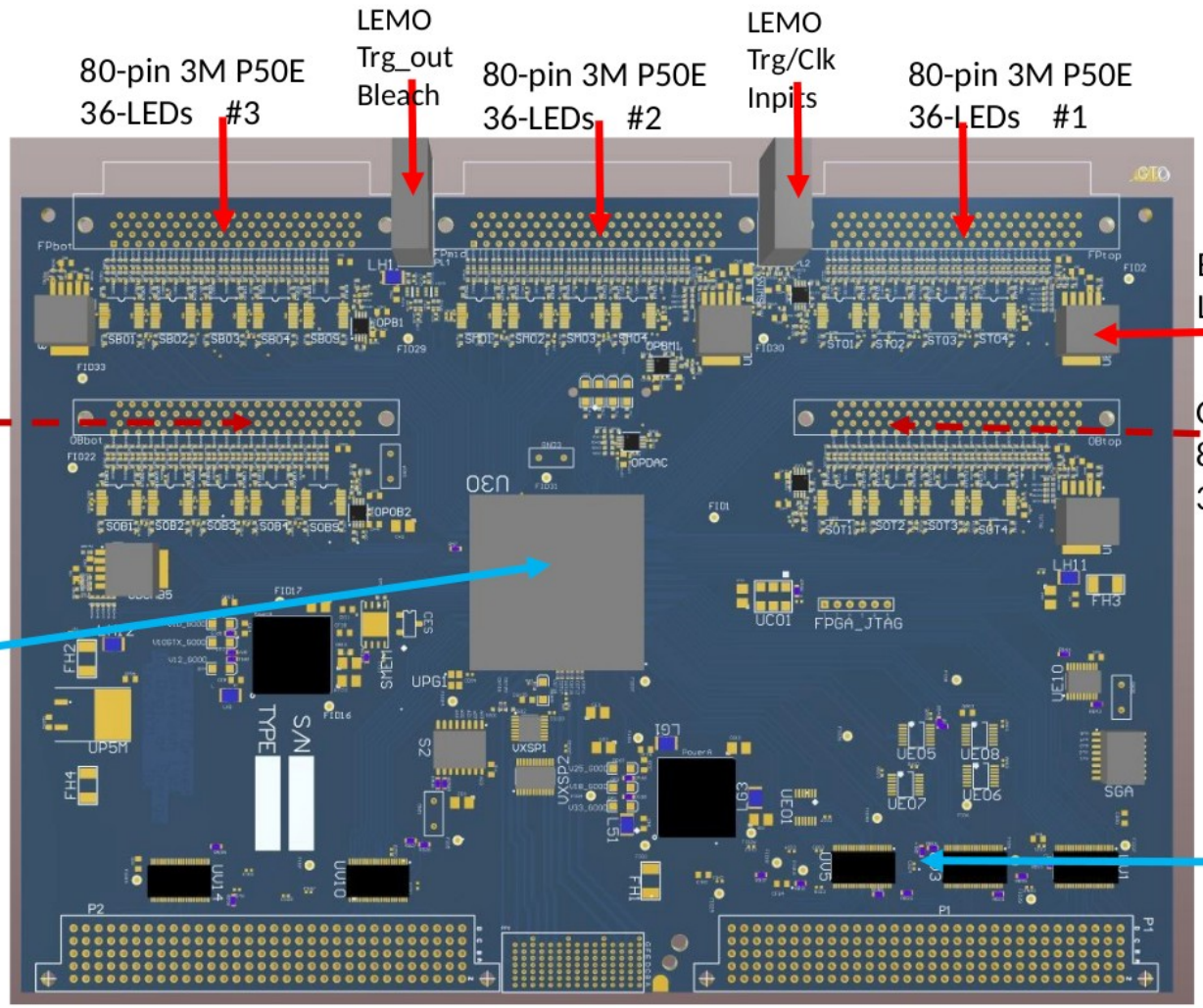
LED Driver Board

VLD PCB

1080 channels:

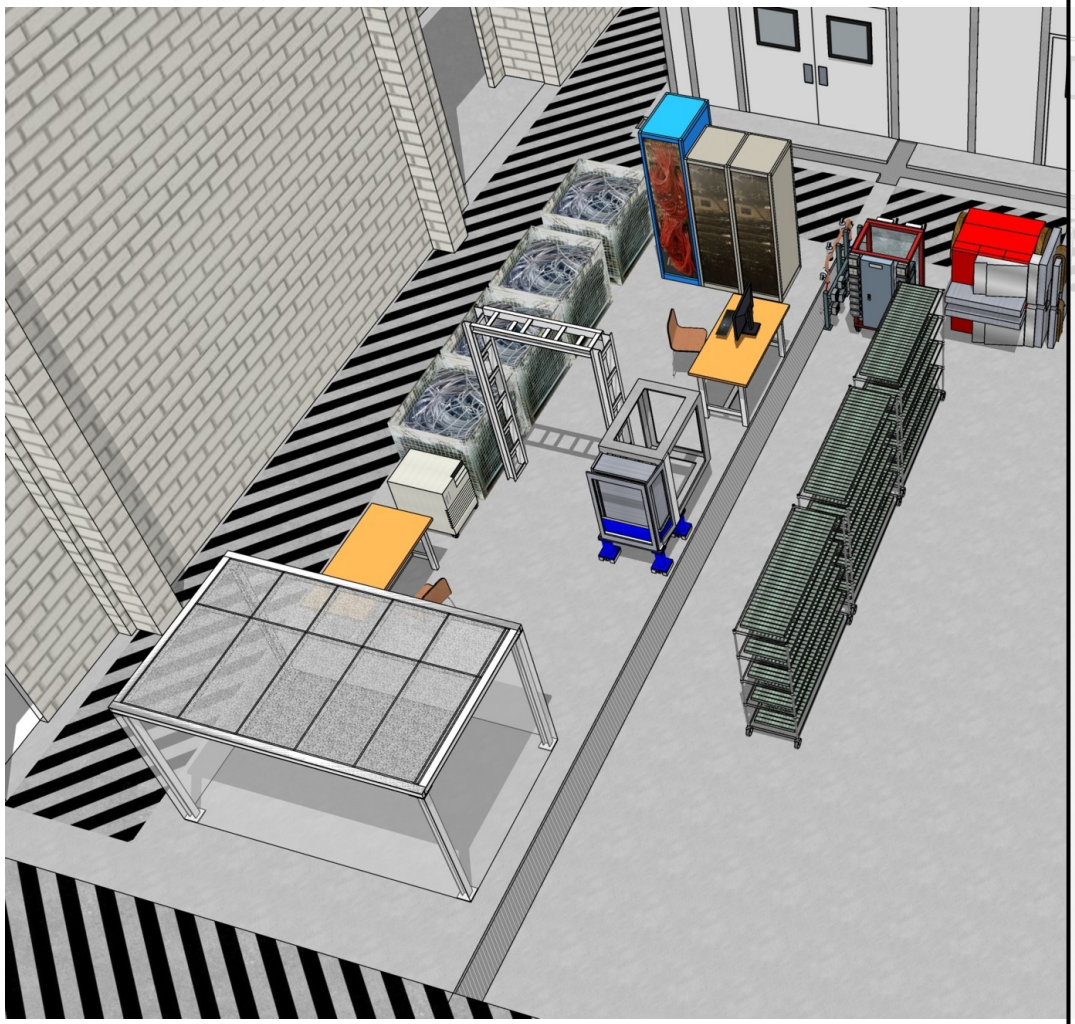
- 10 VLDs:

the front panel connector only



William GU

NPS Detector Layout in TestLab



- "To do" list
  - →Need to design/build cable bridge
  - →Unbox and bundle signal cables
  - →NPS detector assembly timeline / personnel
    - » *Discussions throughout today/ tomorrow*

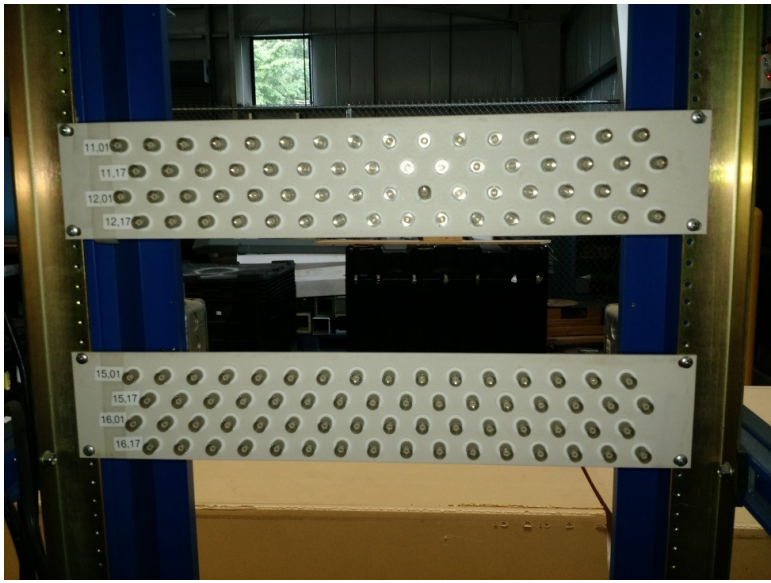
DAQ/HV/Cable Status Summary

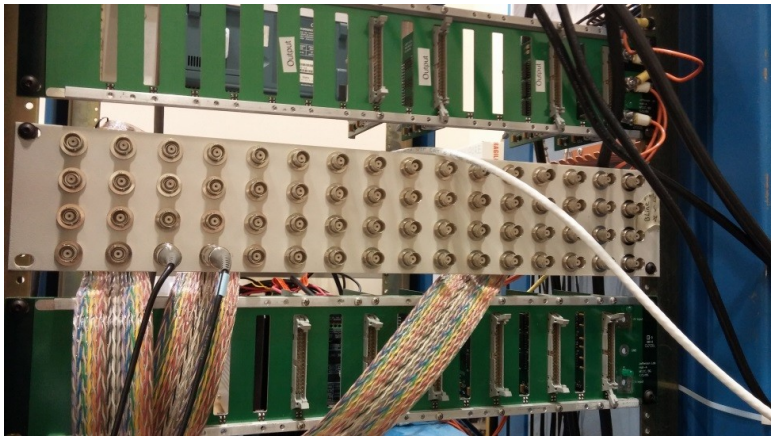
- Support hardware proc./staging (Brad)
  - → Patch panel, NPS→DAQ cabling
    - » *2200 signal cables in-hand but need bundling*
    - » *Patch panel rack needs assembly*
      - – *Parts should be in-hand? (Segal, Beaufait)*
  - → HV Crates (Brad + DSG)
    - » Procurement complete; QA issues with CAEN are being addressed
- Slow Controls
  - → LED Control (*DSG + FE Group*)
    - » Driver board design (near) complete; fabrication needed
    - » Control GUI?
    - » Need 60x new ribbon cables
  - → "Integrated" NPS controls (*DSG*)
    - » Confirmed with DSG Fall/2020
      - – *Timeline?*
- DAQ HW Procurement (Brad)
  - → VTP boards (5+1)
    - » Ordered 2020; awaiting delivery
  - → F250s available but *must*
    - » Reserve when dates known!
- DAQ Firmware/SW Devel. (FE Group)
  - → VTP, F250 modifications
  - → 3.5 person-months
    - » *Timeline?*
- Analyzer (Hall C) mods (Steve?)
  - → *Integrate existing DVCS software into hcana*
  - → *Decoder updates for VTP, F250 mods*
  - → *Solve and Implement "Data Unblocking" issue*
  - → *Merge multi-threaded podd with hcana?*
- Full DAQ integration and Testing (Brad)
  - → *Establish plan/timeline/people*

Backup Slides

BNC Patch Notes

- BNC patch panels must be 'high-density'
  - → Pre-existing layouts shown on right
  - → 64 isolated BNC feedthroughs per 3.5” tall panel
- 1100 RG-58 cables run from patch to five F250 VME/VXS crates in SHMS electronics hut
  - → BNC on patch panel
  - → LEMO in electronics hut
- Volume estimate for 1100 RG-58
  - → Penetration area
    - » 72 in^2 (min) + overhead
  - → Cable tray
    - » nominal 24” wide, 4–6” tall





Cable Bundle Weights / Sizes [p. 1/2]

- RG-58 bundle size/weight
  - » ~1100 cables
  - » OD: 0.2”
  - » 37 g/m each

  → Rough cross section for 1100 cable bundle
  - » 44 in^2 (simple pack)
  - » 80 in^2 (with overhead)

  → 41 kg/meter = 28 lbs/ft

- HV multi-conductor cables
  - » 32 cables
  - » OD: 0.4”
  - » 50 g/m each

  →Rough cross section for 32 cable bundle
  - » 5 in^2 (simple pack)
  - » 10 in^2 (w/ overhead)

  → 1.6 kg/m = 1.1 lb/ft

Cable bundle packing / weight estimate are rough

Cable Bundle Weights / Sizes [p. 2/2]

- Ribbon cable (LEDs)
  - » 62x 80-wire ribbon
  - » 0.1” thick; 4” wide
  - » 100 g/m each

  → Rough cross section for 62 cable bundle
  - » 25 in^2 (simple stack)

  → 6.2 kg/meter = 4.1 lbs/ft

- Detector ground cable(s)?

  →Supplement / ensure clean ground between NPS and DAQ

  →Heavy gauge ground cable(s)
  - » very low resistance

  → Not sure of details, won't dominate the cable load though...

Cable bundle packing / weight estimate are rough

NPS High Voltage Supply

- High Voltage Requirements
  - → 1100 channels
  - → -1.6kV @ < 1 mA base draw
- Supplied by 2 CAEN SY4527 HV Chasses w/ Booster
  - →16x CAEN 7030TN Cards each
    - » Each card: 36ch, 1mA max/ch (matches 36 crystal columns)
  - →576 ch/crate; 1152 ch total
- HV procurement complete
  - →2 Crates + 34 cards on-site
  - →DSG working with CAEN on firmware issues since Fall '19

Radiall HV Connector

HIGH VOLTAGE MULTIPIN CONNECTORS

- ❑ High voltage connectors (breakdown voltage 12,5 kVdc).
- ❑ High density rectangular connectors for 23 or 52 high voltage contacts.
- ❑ Braid to braid electrical continuity achieved once plug & receptacle are mated.
- ❑ Rear release, rear removable size 23 crimp contacts.
- ❑ Interlock contacts.

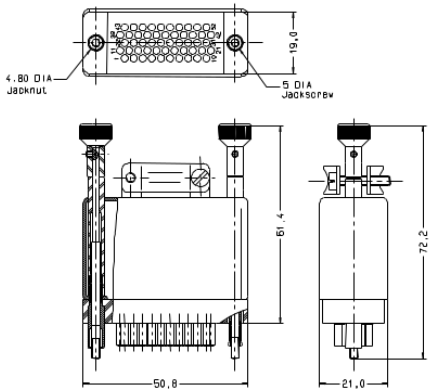
These connectors have been designed for high voltage applications on four CERN experiments (ATLAS, CMS, ALICE, LHC-B) of the LHC (Large Hadron Collider) particle accelerator. For connectors with 23 or 52 contacts (size 23 crimp), there are five configurations available (see table on reverse side). The connectors can be fitted with two interlock pin contacts that switch off the power supply before unmating the standard contacts . Both interlock and standard contacts are rear release rear removable crimp contacts. The electrical continuity between the plug and the receptacle is provided by the connector pin guides.

TECHNICAL CHARACTERISTICS :

● Material insulator :	Thermoplastic UL94V0 - halogen free - tensile strenght reduction does not exceed 6% after a cumulative exposition to 5 10^{7}Gy at a rate of 1 to 2 Gy / h.
● Backshell & shroud :	Aluminium alloy nickel plated.
● Locking device :	Stainless steel and nickel plated copper alloy.
● Contacts :	Copper alloy gold over nickel plated.
● Breakdown voltage :	12,5 kV dc.

ISO 9001 APPROVED

DIMENSIONS :
The drawing below shows the dimensions (mm) of the plug for cable and for 52 socket contacts.



CERN / RADIALL CROSS REFERENCES :

CERN P/N	RADIALL P/N	Designation
09.41.34.700.2	691802002	Plug for cable and for 52 socket contacts
09.41.34.720.8	691802004	Plug for cable and for 52 pin contacts
09.41.34.705.7	691803002	Receptacle for cable and for 52 pin contacts
09.41.34.710.0	691803004	Receptacle for front panel and for 52 pin contacts
09.41.34.730.6	691803006	Receptacle for front panel and for 52 socket contacts
09.41.34.500.8	691802003	Plug for cable and for 23 socket contacts
09.41.34.520.4	691802005	Plug for cable and for 23 pin contacts
09.41.34.505.3	691803003	Receptacle for cable and for 23 pin contacts
09.41.34.510.6	691803005	Receptacle for front panel and for 23 pin contacts
09.41.34.530.2	691803007	Receptacle for front panel and for 23 socket contacts
09.41.33.840.5	691804200	Size 23 pin contact for 0,12mm² cross section cable
09.41.33.820.9	691804201	Size 23 pin contact for 0,02mm² cross section cable
09.41.33.830.7	691804300	Size 23 socket contact for 0,12mm² cross section cable
09.41.33.810.1	691804301	Size 23 socket contact for 0,02mm² cross section cable
09.41.33.890.5	691804230	Size 23 interlock pin contact for 0,12mm² cross section cable
09.41.33.880.7	691804231	Size 23 interlock pin contact for 0,02mm² cross section cable
T.B.D	282281	Crimping tool
T.B.D	282585001	Positioner
T.B.D	282549024	Insertion / extraction tool

For further information please contact your nearest Radiall representative :

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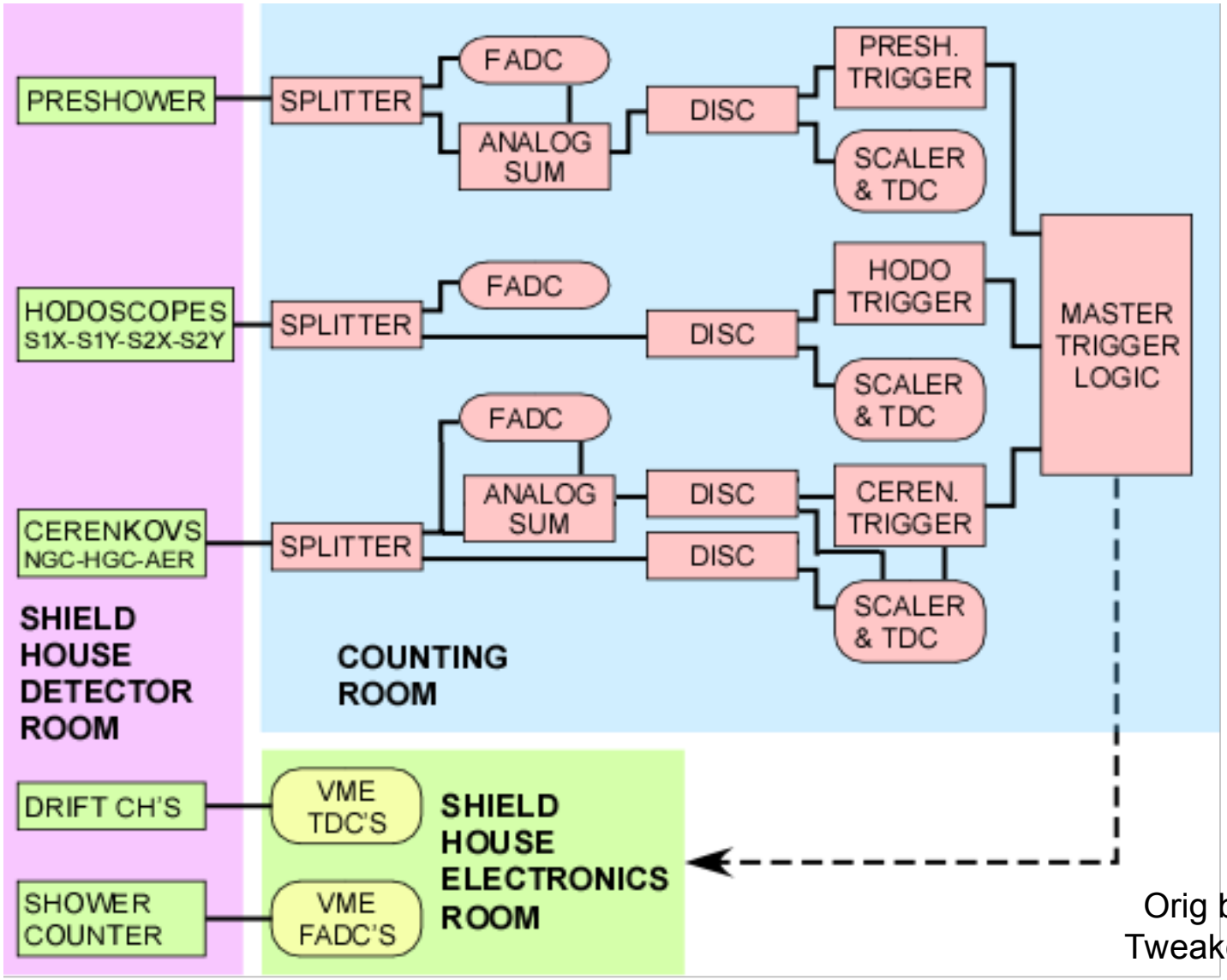
https://www.datasheets360.com/pdf/8778225758601965736
https://www.caen.it/products/a996/

Existing SHMS + HMS Standard DAQ Triggers and Hardware

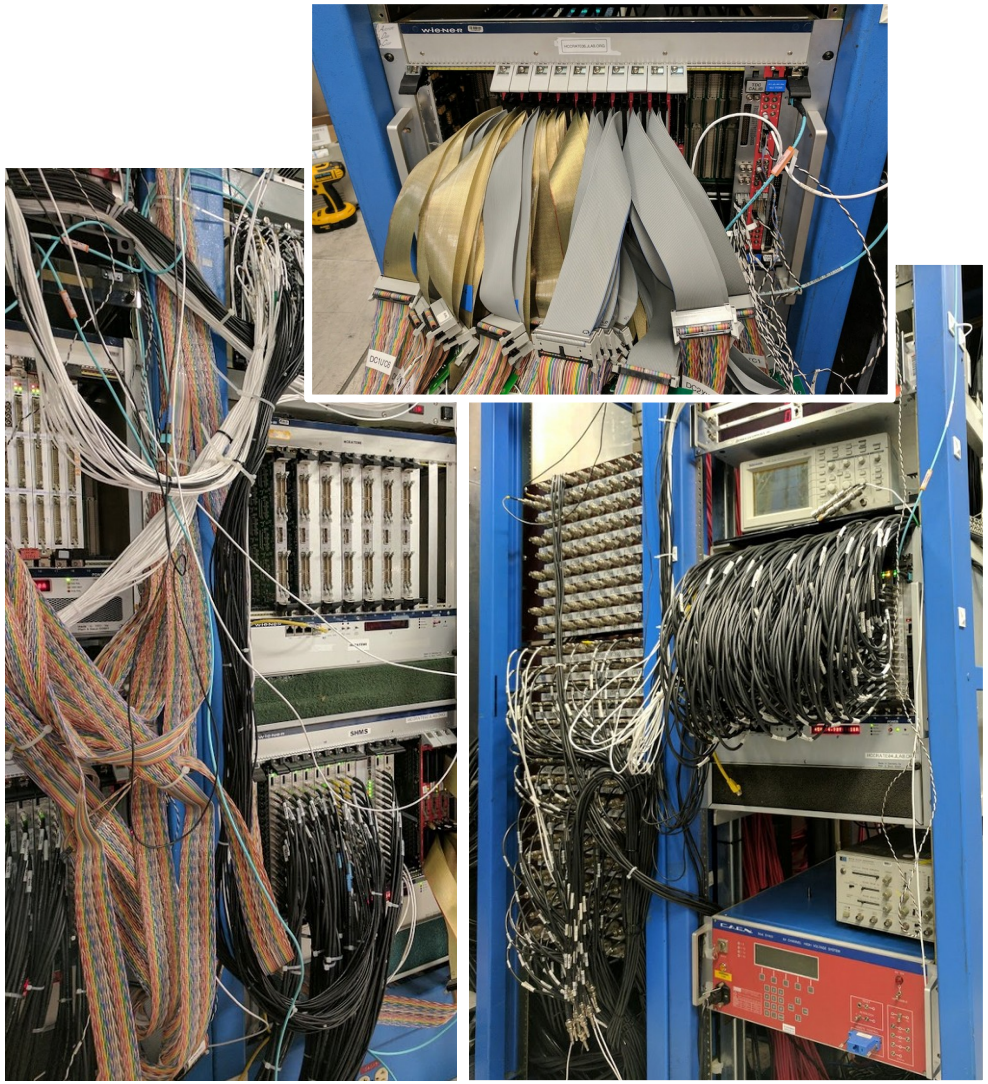
SHMS/HMS Trigger/Electronics



Orig by H. Fenker
Tweaked by Brad S.

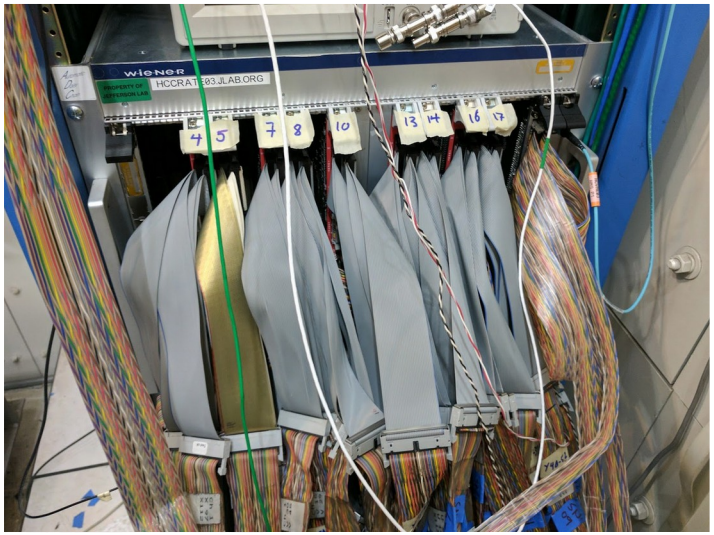
SHMS Instrumentation

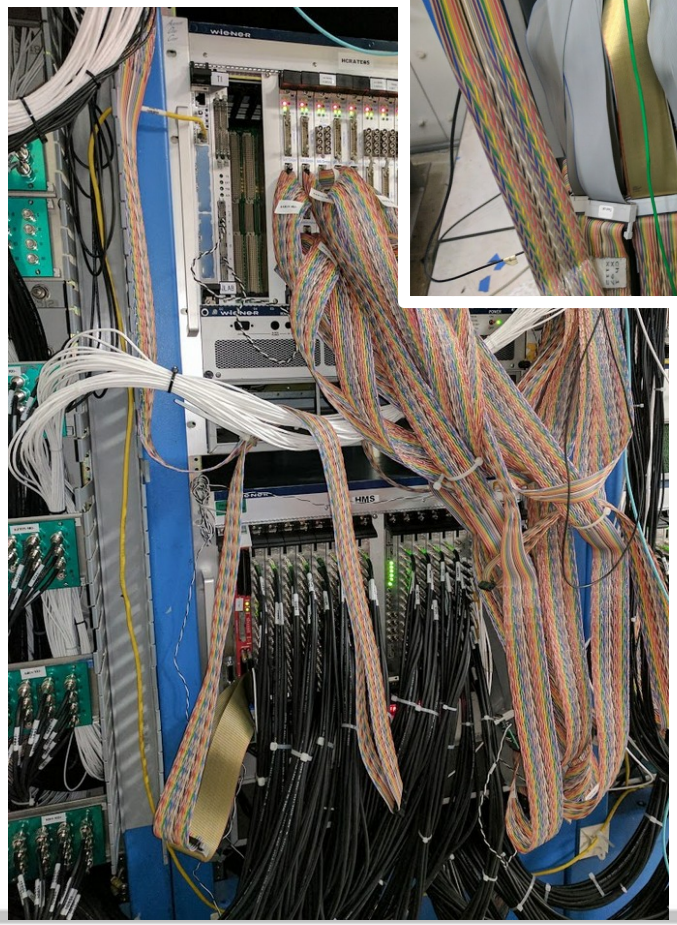
- **SHMS**
  - → ROC2: CH
    - » Hodoscopes, Cerenk.
      - – FADC + 1190s
    - » Misc. Signals
      - – *ie*. Triggers, Hel
  - → ROC4: SHMS hut
    - » Shower + Preshower
      - – FADCs
  - → ROC6: SHMS hut
    - » Drift chambers
      - – 1190 TDCs
  - → ROC8: CH
    - » Hardware scalers
    - » BCMs, Helicity gated scalers



HMS Instrumentation

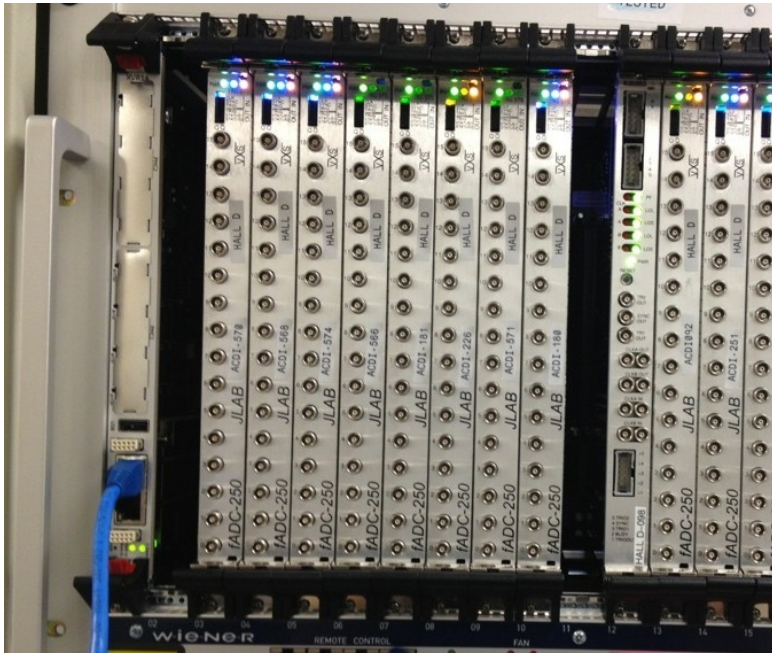
- **HMS**
  - → ROC1: CH
    - » Calor, Hodoscopes, Cerenk.
      - – FADC + 1190s
    - » Misc. Signals
      - – *ie*. Triggers, Hel
  - → ROC3: HMS hut
    - » Drift chambers
      - – 1190 TDCs
  - → ROC5: CH
    - » Hardware scalers
    - » BCMs, Helicity gated scalers





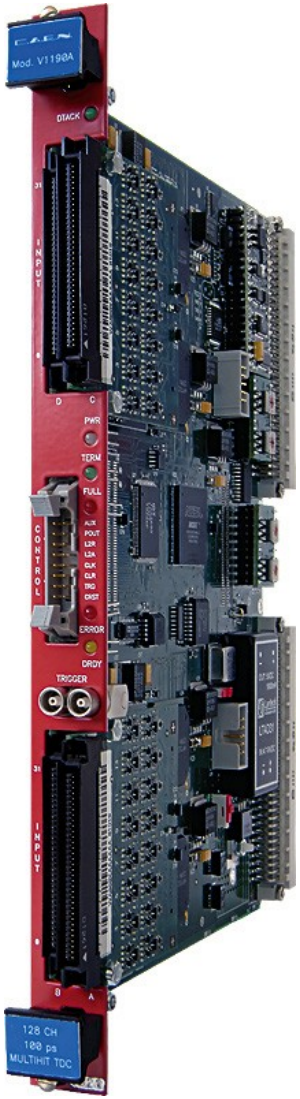
JLab F250 FADCs

- JLab FADCs
  - → Constantly digitizing input voltage every 4ns
  - → Multi-hit 'ADC'!
    - » Can readout anything within an ~8 usec ring buffer
  - → Each 'Hit' contains
    - » Integrated charge
    - » Peak Amplitude
    - » Timing (~ 1 ns)
    - » Pedestal meas.
    - » Pulse profile / 'Scope trace' (*)
  - → Scaler data too
  - → Pipeline capable, deep buffer, etc..
- Differences from older QDCs
  - → Multi-hit!
    - » Must identify the 'good' hit using, for example, a timing cut



CAEN 1190 TDCs

- CAEN 1190
  - → Multi-hit TDC
  - → 128 channels/module
  - → ~100 ps resolution
  - → Pipeline capable, deep buffer, etc...
- Differences from older TDCs:
  - →Module's “Common Stop” is not a good timing reference!
    - » Primary function is to initiate a “Read” in the module.
  - →Requires a “reference time” to measured in one of the 128 inputs



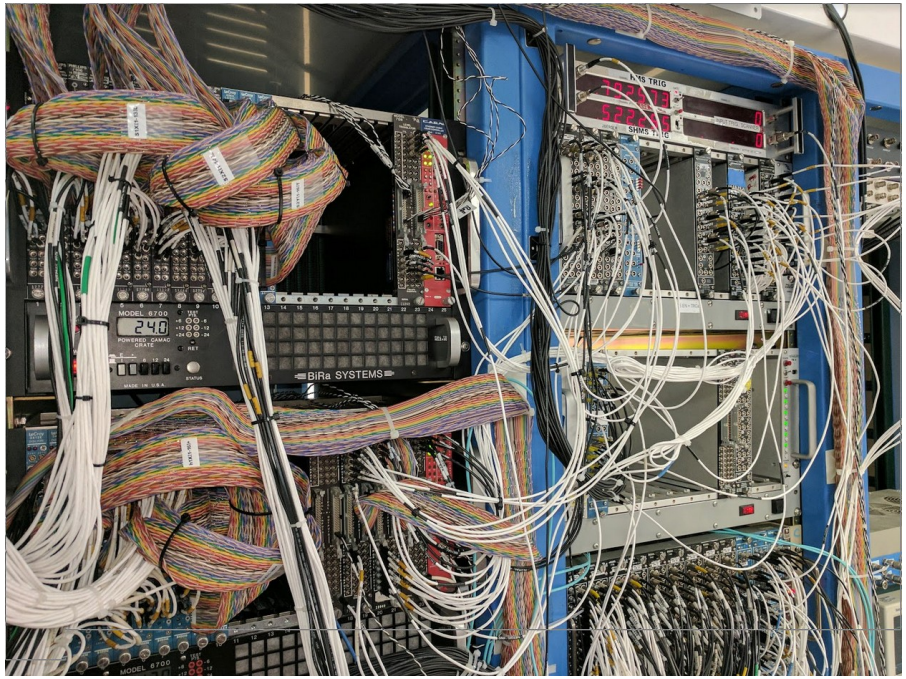
Available SHMS / HMS Pre-Triggers

- Scintillator Planes: S1x, S1y, S2x, S2y
- SCIN = 3/4 { S1x, S1y, S2x, S2y }
- CER = Cerenkov Sum
- ~~STOF = [S1x.OR.S1y] .and. [S2x .OR. S2y]~~

- PSh_Hi = Preshower sum, 'high-threshold'
- PSh_Lo = Preshower sum, 'low-threshold'

- EL-Hi = SCIN .and. PSh_Hi
- EL-Lo = 2/3{SCIN, ~~STOF~~,PSh_Lo} .and. CER

- EL-Real = EL-Hi .or. EL-Lo
- EL-Clean = EL-Hi .and. EL-Lo



- Pulser/Random trigger
  - → EDTM injection for deadtime monitoring, trigger setup, etc
  - → EDTM should always be ON and set to nominal 10 Hz
- Each arm has its own Trigger Master (behaves like a TS)
  - → Maximum of 6 trigger inputs on Trigger Master modules
  - → Both coincidence and independent/parallel-arm operation available
- We use TM module for trigger prescaling
- NOTE: There is *no* Calorimeter Sum for SHMS trigger
  - → SHMS Pre-Shower sum *does* exist

Coincidence Mode Triggers

- SHMS Trigger Master controls all SHMS + HMS crates in 'Coin. Mode'
  - → Still a single TM, so still maximum of 6 triggers for SHMS_singles + HMS_singles + and Coin. triggers
  - → For example, these are the current triggers:
    - » T1: SHMS 3/4
    - » T2: SHMS EL_real
    - » T3: HMS EL_real
    - » T4: HMS 3/4
    - » T5: (COIN) SHMS 3/4 .AND. HMS EL_real
    - » T6: (COIN) SHMS 3/4 .AND. HMS 3/4