HCAL Commissioning/Operations and Plans

CMS Run & DPG Coordination Workshop

January 25th, 2016

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Outline

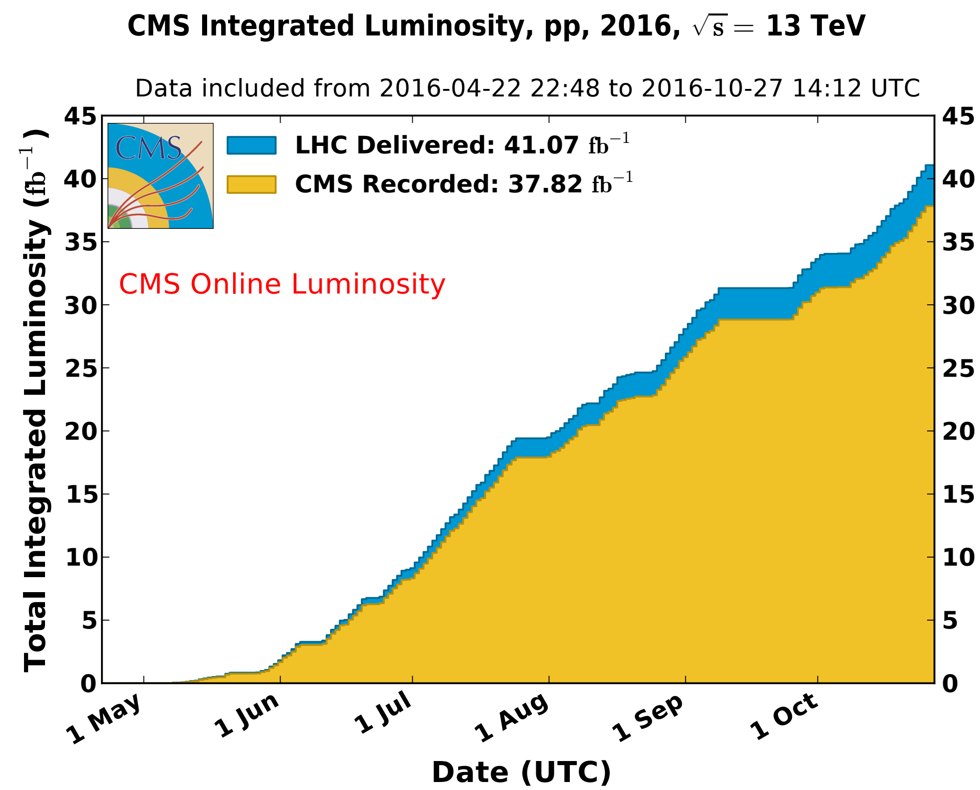
- Brief review of 2016:
  - performance
  - lessons learned and improvements for 2017

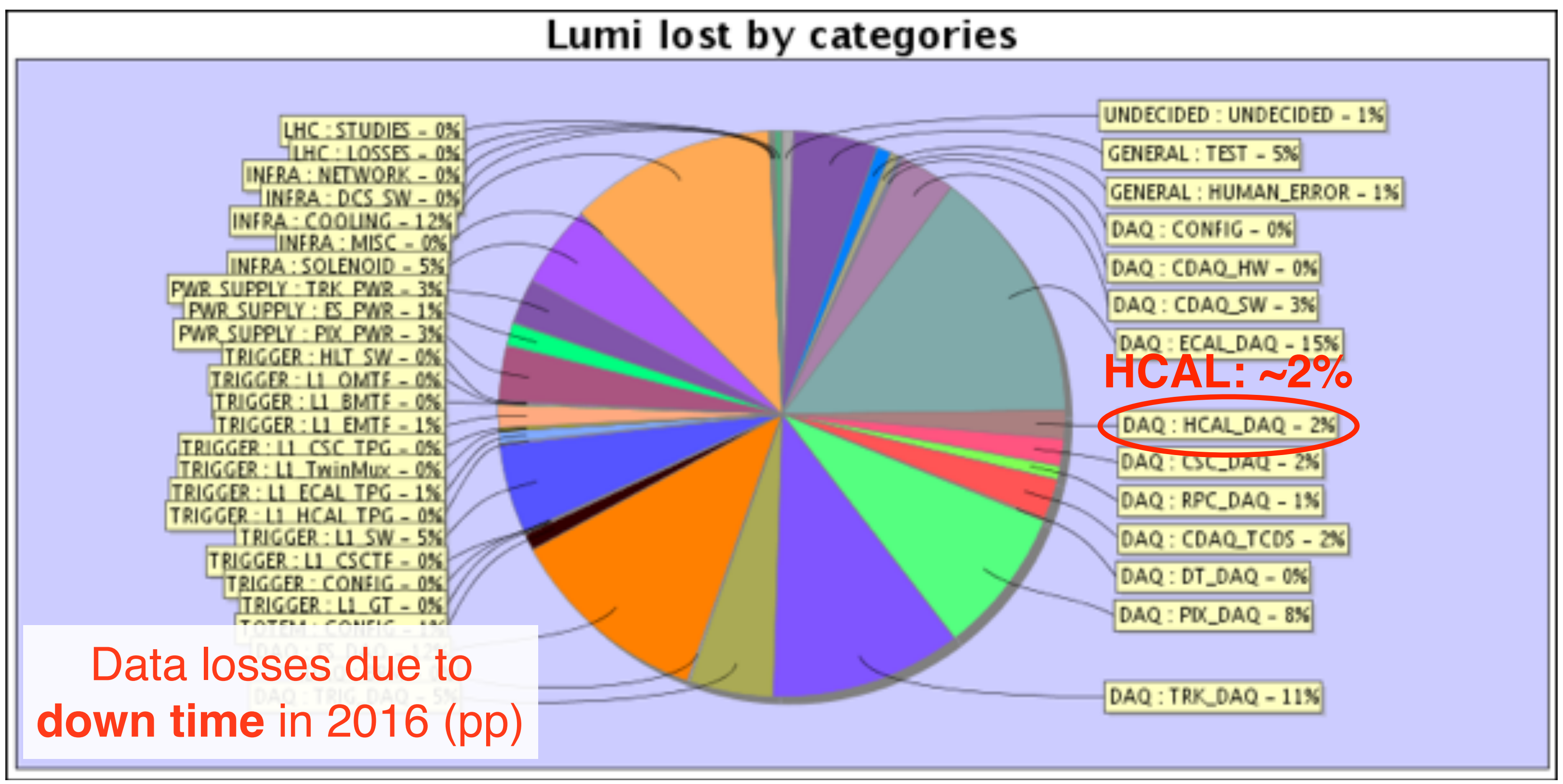
- Plans for commissioning and 2017 data taking:
  - HF PhaseI upgrade
  - HE PhaseI upgrade

2016: performance and lessons learned

HCAL taking data efficiently in 2016…

- Global **CMS** data taking efficiency in 2016 was ~92% in pp and ~96% in pPb
  - data loss at downtime is ~1.6 fb^{-1} for pp collisions (~4% of the total delivered luminosity)
  - data loss at downtime is ~3.6 nb^{-1} for pPb collisions (~1.9% of the total delivered luminosity)



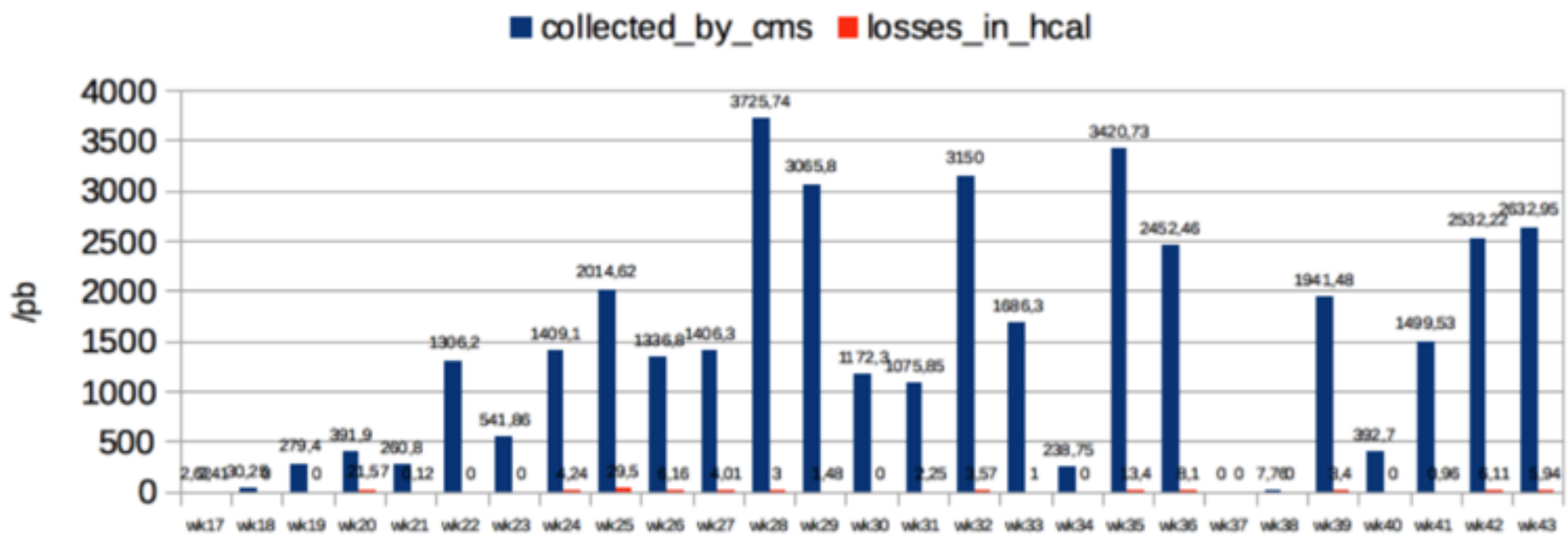


- **HCAL** has generally behaved **very stably** during data taking in 2016
  - responsible for only **~2% of the total lumi loss** at downtime (~27 pb^{-1}) in **pp**
  - **no lumi loss** at downtime because of HCAL during **pPb**

- Downtime losses mainly due to a **few isolated incidents**, no broad recurring issues

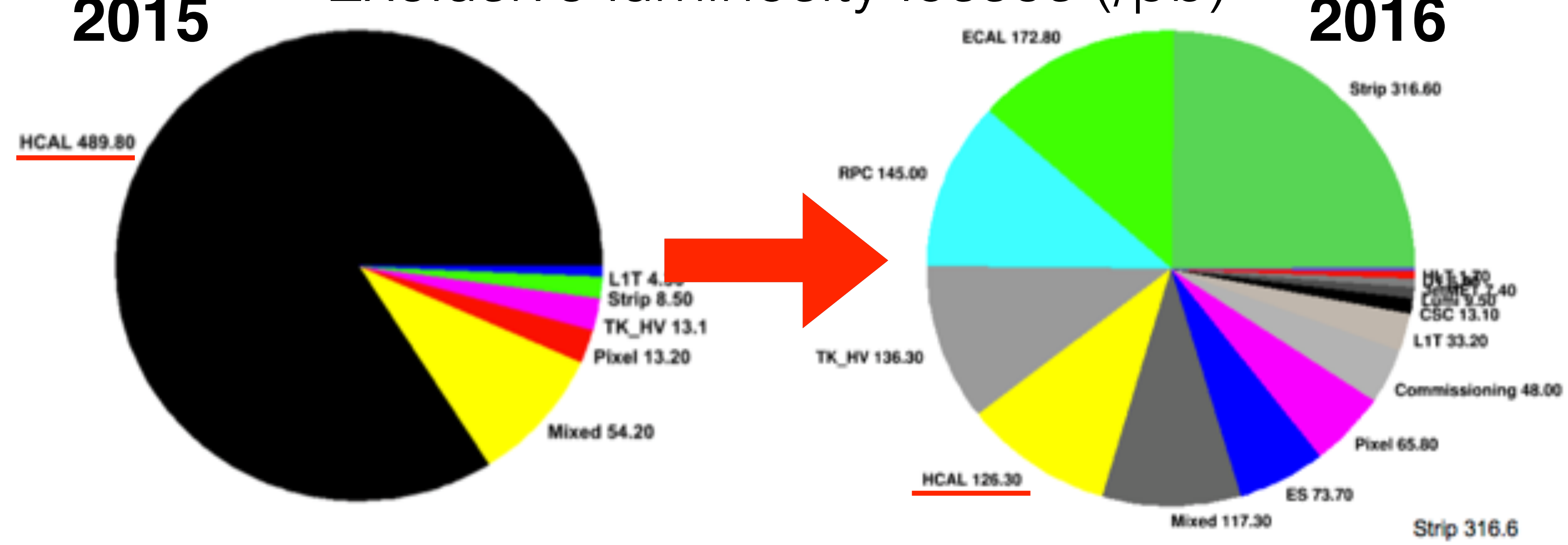
… and delivering good quality data too

- HCAL has performed very well in terms of data certification:
  - only ~126 pb^{-1} out of 37.4 fb^{-1} certified are marked bad because of HCAL (~0.3%) for pp
  - only ~0.1 nb^{-1} out of 90.3 nb^{-1} certified are marked bad because of HCAL (~0.1%) for pPb



- Much better figures compared to last year!

Exclusive luminosity losses (/pb)



Detailed breakdown of downtime / bad data

- HCAL inputs relevant for the Studies of failures scenarios

DOWNTIME ANALYSIS

- Total **CMS downtime** (pp run): **1.68 fb^{-1}**
- **HCAL downtime** (pp run): **~27 pb^{-1}** (1.6% of total down time)

– bad μHTR configuration incident: 11.8 pb^{-1} (44%)

– remaining ~15 pb^{-1} due to either offending μHTR (replaced) or bad transitions (e.g. stop-start, fixed).

– **from August onwards, no more downtime caused by HCAL**

- Total **CMS downtime** (pPb run): **3.62 nb^{-1}**
- **HCAL downtime** (pPb run): **0**

CERTIFICATION

- **CMS recorded data** (pp run): **37.82 fb^{-1}**
- **HCAL bad data** (pp run): **~126 pb^{-1}** (3.9% of total bad data)

– bad μHTR configuration incident: 24.3 pb^{-1} (19%)

– HF rack turbine fault: 21.6 pb^{-1} (17%)

– HF LV SEUs: ~50 pb^{-1} (40%)

– HV trips: ~10 pb^{-1} (8%)

– single LSs with random noise: ~20 pb^{-1} (16%)

- **CMS recorded data** (pPb run): **193.84 nb^{-1}**
- **HCAL bad data** (pPb run): **~0.1 nb^{-1}** (1% of total bad data)

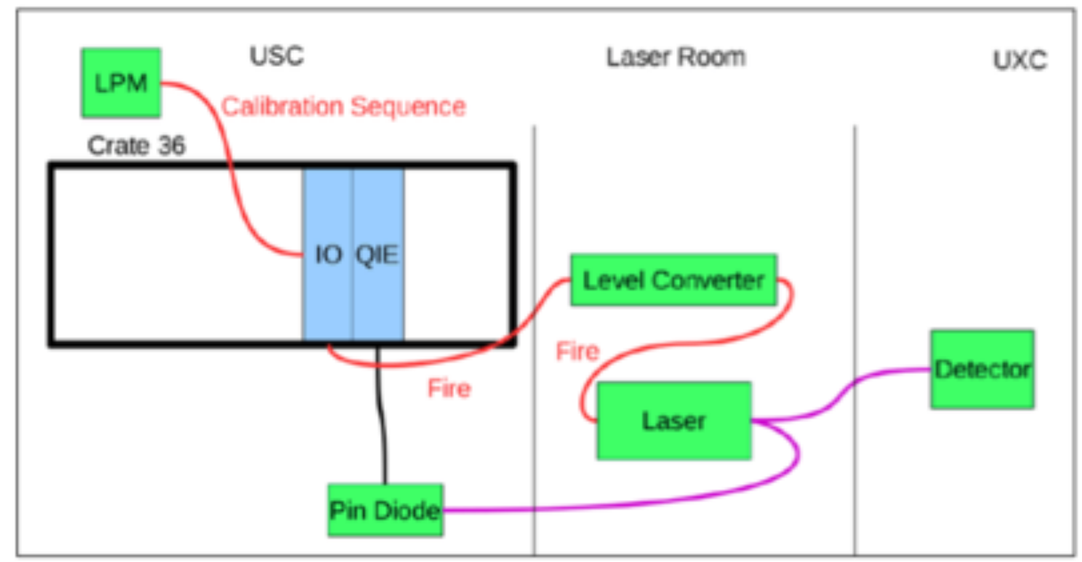
Main achievements in 2016

- **μTCA backend** commissioning:
  - after some initial difficulty, consistent and stable all year long, thanks to strong effort between F/W, μTCA and DAQ experts
- **Trigger Primitives**:
  - managed to achieve a ~perfect agreement between HB/HE TPs as delivered by μTCA and VME
- **Online software** improvements: exceptional job from a very dedicated team
  - fixed a number of bugs that caused issues in various transitions
  - configuration time greatly improved
  - support of upgrade system
- **Monitoring and alarming**:
  - alarmer improved with full μTCA backend monitoring
  - RunningDegraded mode implemented
  - DQM completely rewritten

Strong dedication by all shifters — essential for smooth operations
Many thanks to **HCAL DOC, DAQ on call** (online) and **ROC** (remote) shifters and to the **PFG** team

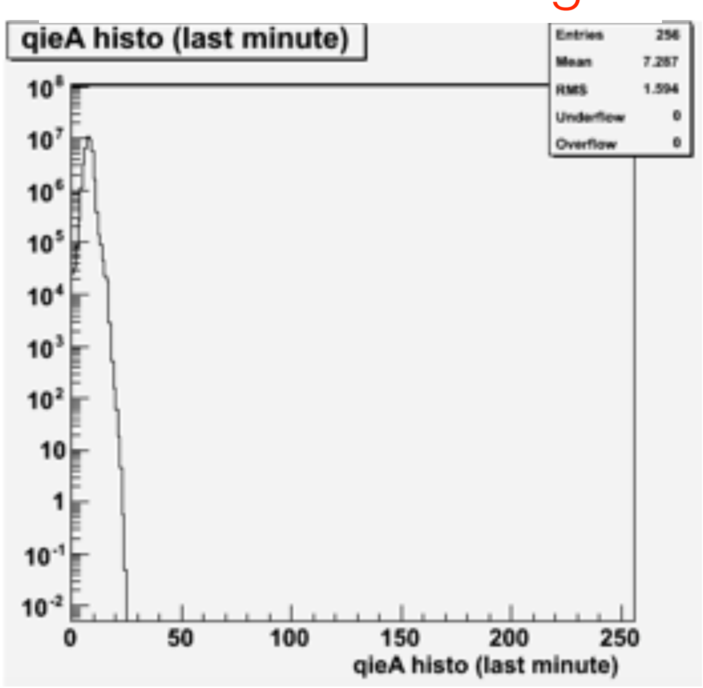
Recommissioning of laser orbit gap operations in 2016

- We restored **laser calibrations in the orbit gap**, with a new laser and µTCA-based boards for laser control (uMN-IO) and monitoring (uMN-QIE)
- A lot of effort from many people
  - laser installation, uMN* boards commissioning, online software, monitoring and alarming, DQM

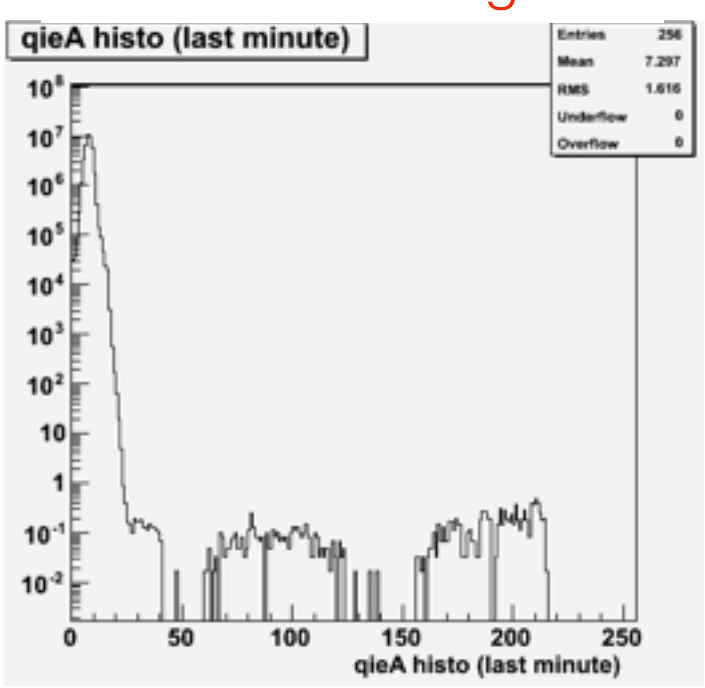


- The laser is continuously **monitored through 2 pin diodes**. Alarms and RunningDegraded mode if the laser fires outside the orbit gap in physics
- We enabled the laser on Aug. 5 and it has been running until mid Nov. with ~no issues
  - only a couple of single event misfires throughout the year (not in stable beam), due to auto reboot of laser PC (disabled now)

pin diode when the laser is NOT firing



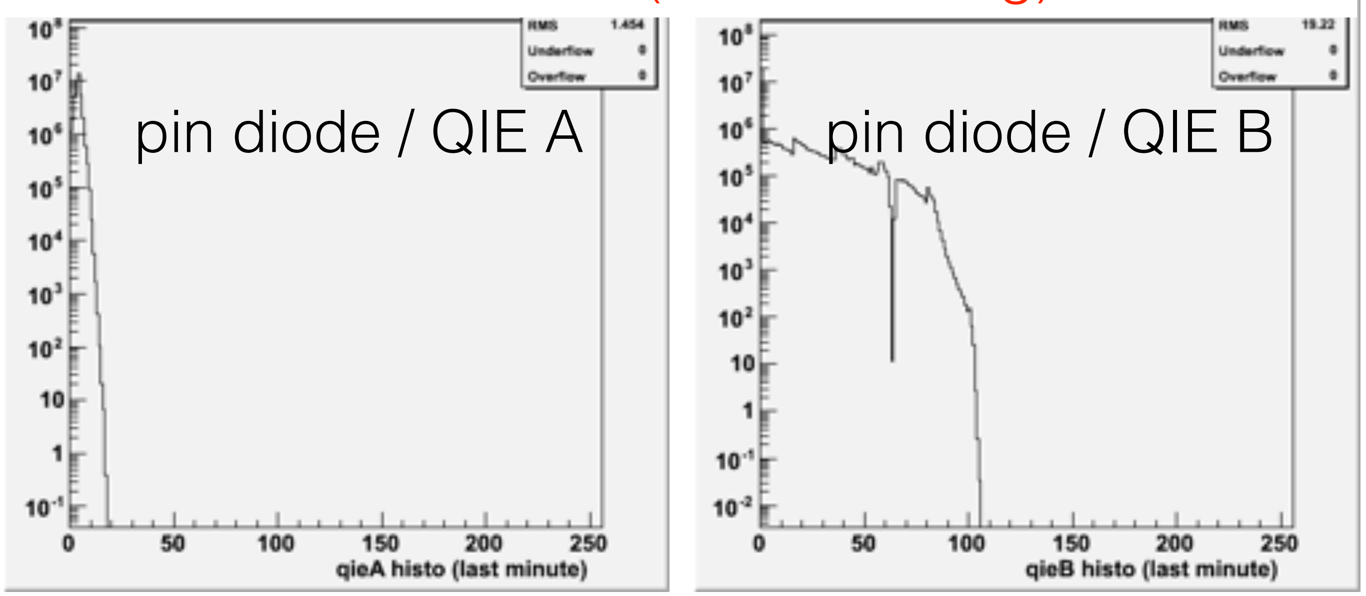
pin diode when the laser is firing



Laser work for 2017

- From mid Nov. 2016 on, we experienced some troubles operating the laser:
  - laser firings with **random delays**, can fall **outside the orbit gap**
    - » laser was parked until the end of 2016 run
    - » first suspect: **level converter** in the laser room (receives uMNIO signal on copper cable and generates trigger the laser)
    - » for 2017: send out the **signal from uMNIO optically through the SFP** and **bypass the level converter** (NIM module already being produced at MN)

PEDESTALS (laser not firing)

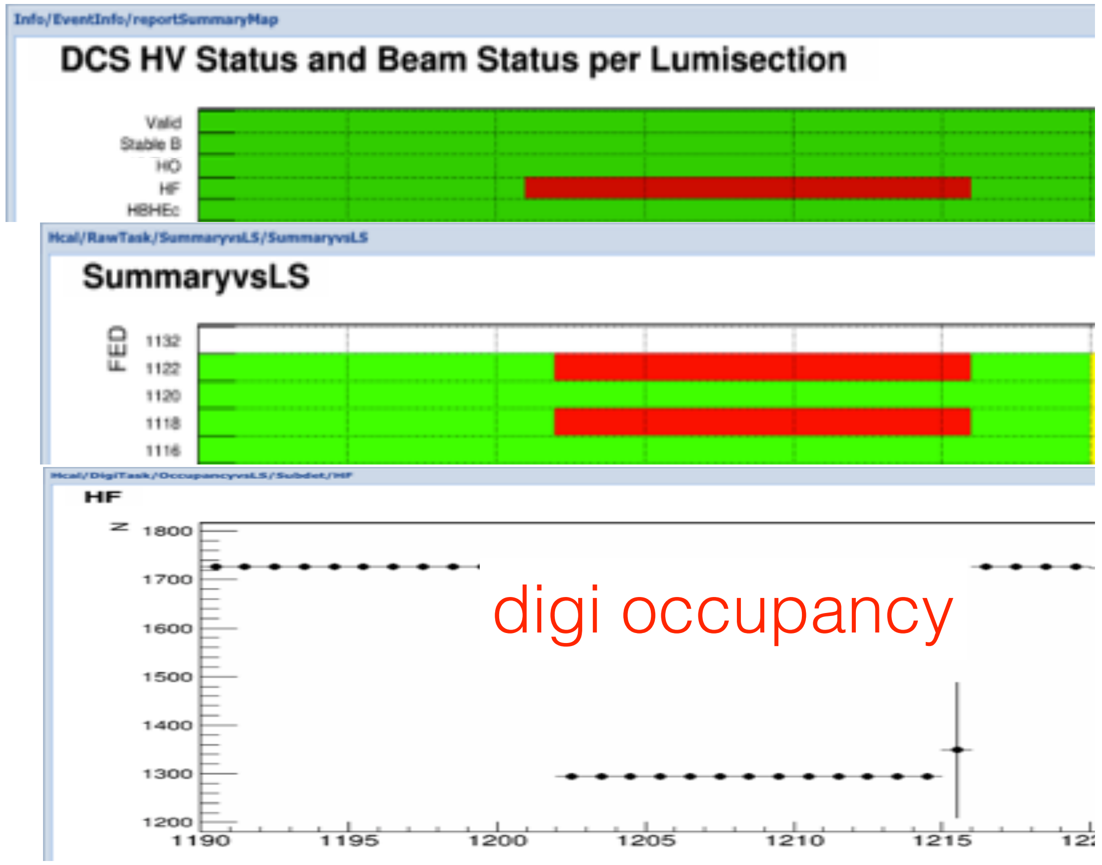


- **broadening of the QIE B pedestal**. Possible solutions:
  - » check F/W, QIE configuration
  - » check spare boards
  - » use a standard QIE10 card

- For 2017, **extend DQM summary** maps with data from laser calibration events: assess HCAL overall health from laser events
  - spot new dead channels, readout synchronization issues from laser pulse timing, etc.

Recurring issue: HF LV errors

- We experienced few HF LV communication errors in 2016 (14 instances during pp)
  - interpreted as **SEUs in the CAEN A3100 modules**, causing them to loose communication
    - » only seen when beam is in the machine
    - » only seen in HF+
  - the LV may or may not stay on
- We get notified by SMS. Problem also visible on DQM and DCS. To fix it:
  - try a **recovery procedure** (implemented Sep. 2016) to regain communication with the faulty module; **turn the LV on**, in case it went off
    - » only worked once in 2016
  - if it doesn't work, **power cycle the AC/DC**



- Recovery is typically quick (<~ 20 LS):
  - depends on alarm notification / DCS shifter and prompt reaction by the DOC
  - studying the possibility of a fully automatic recovery procedure

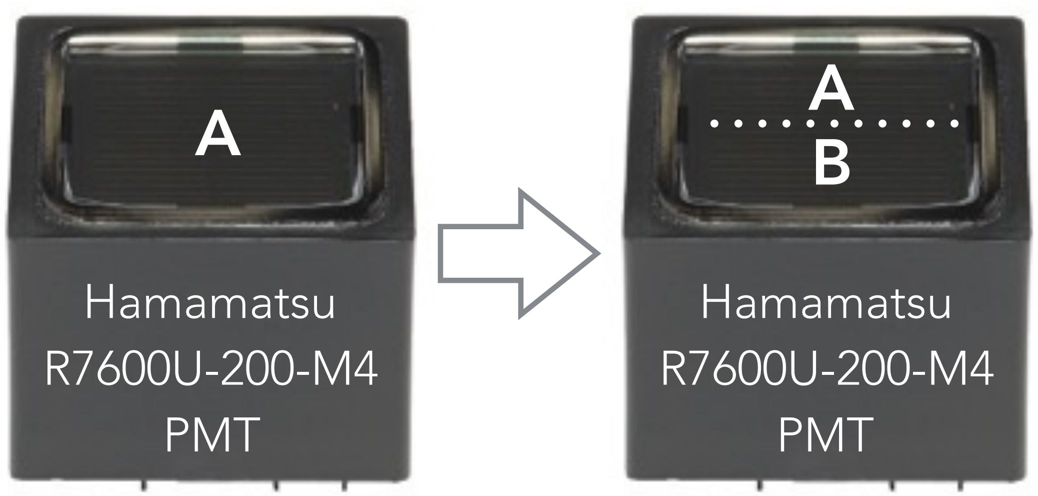
Recurring annoyance

- **µHTRs** are fragile in case of power cycles / shutdowns:
  - ~1–2% probability of a card resulting in an unhealthy state after a power cycle (we have 144 µHTRs)
  - Can manifest in many ways:
    - » F/W corruption — need to reprogram it
    - » cannot communicate with the card — DAQ errors on configure
    - » bad data from the card — spotted in DQM
    - » bad TPs sent to L1 — only visible in L1 DQM
  - A few hours time is needed to put the system back in a healthy state after a major intervention
  - Hope to perform more tests with µTCA and F/W experts — for now, have to be vigilant on case of F/W reload and/or power cycles
- Lockup in the communication to the **Acromag crate**:
  - needs power cycling to recover (couple of minutes' time)
  - **doesn't lead to data loss** even if it happens in stable beams (unless FE needs to be reconfigured at that very moment)

2017: PhaseI upgrade and re-commissioning strategy

HF PhaseI upgrade

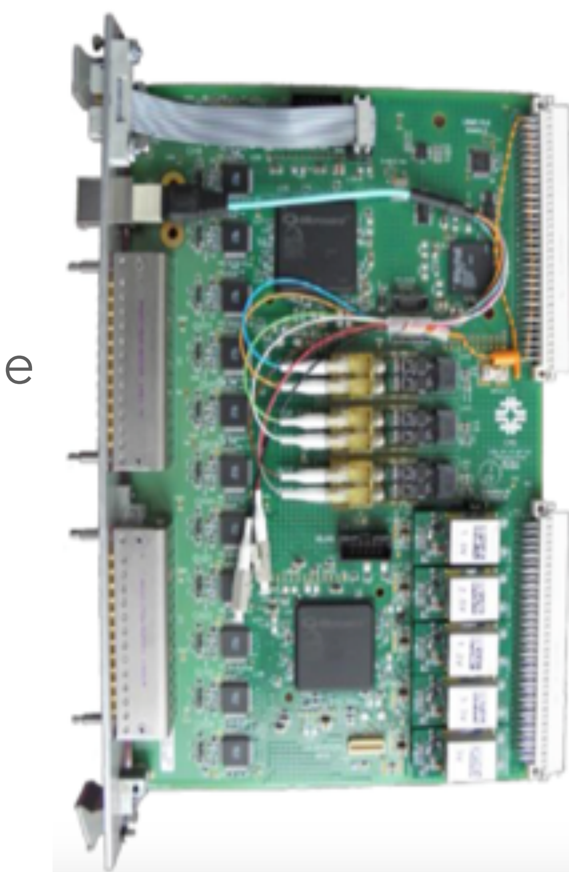
- The **HF upgrade at a glance**: new photodetectors to reduce anomalous hits from particles hitting the PMT. During LS1:
  - new, **thin-window multi-anode PMTs** installed
  - new HV system + LV recabled to allow scaling for new FE
  - new FE cables + UXC-USC readout fibers installed
  - backend upgraded to μTCA



- **Dual-anode readout** as it adds further discrimination power for spurious signals affecting one anode, with the ability to recover energy measurement from the other anode

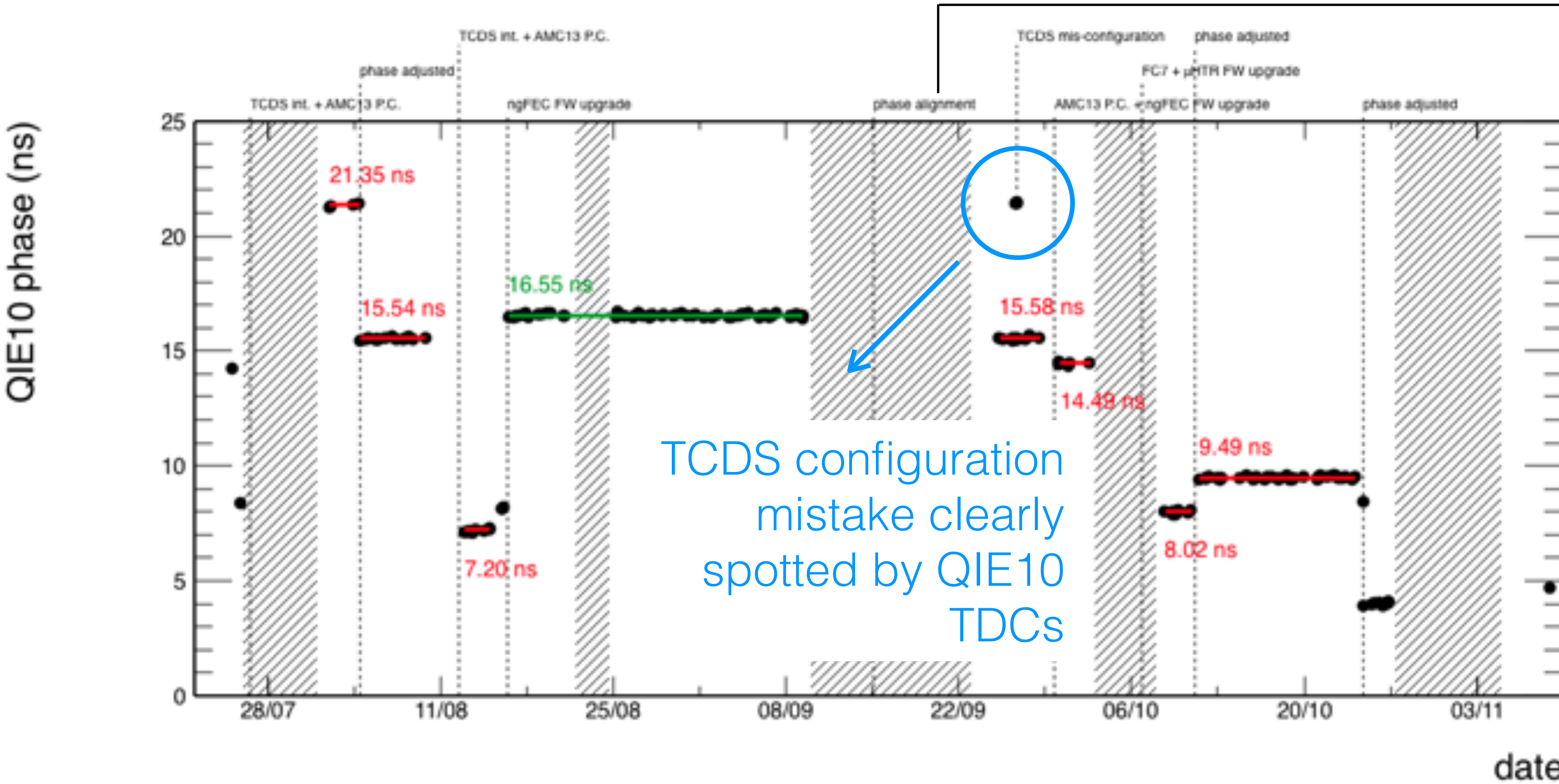
- New **front-end electronics** to support increased number of channels and new photosensors — QIE8 (7bit ADC) → QIE10 (8bit ADC)
- FE with **embedded TDC** to discriminate from physics signals (spurious signals arise 2-7 ns earlier)

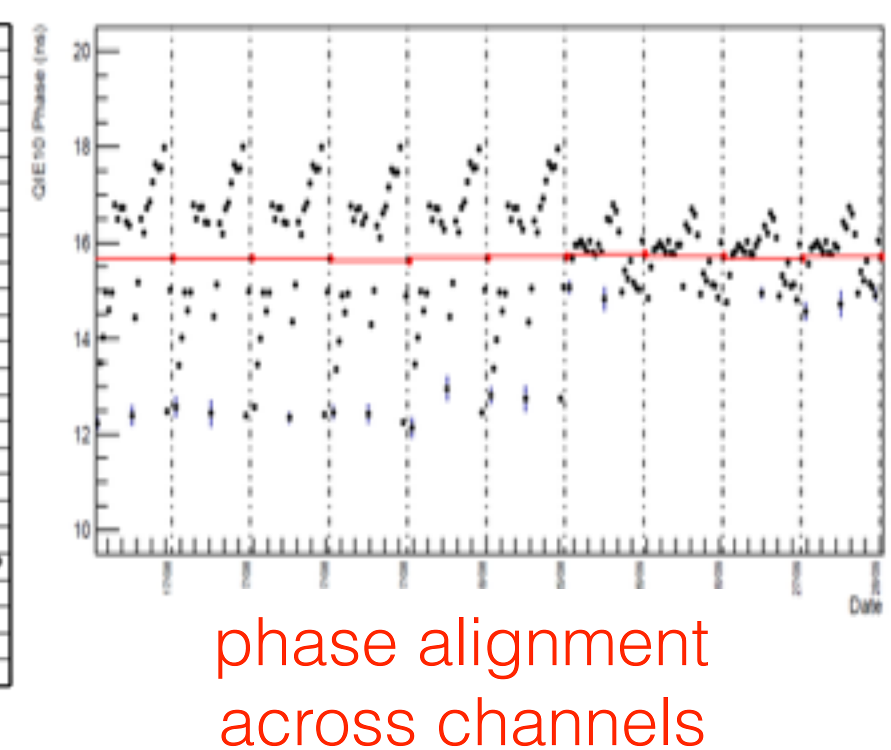
← in 2017 ↑



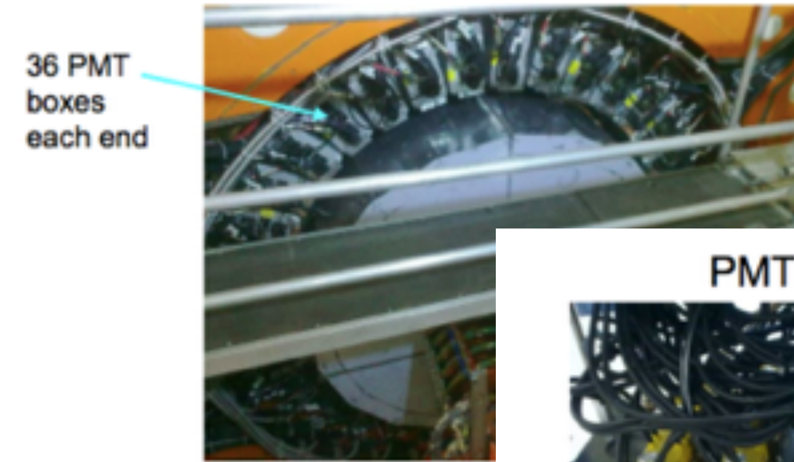
HF PhaseI upgrade — the 2016 pilot system

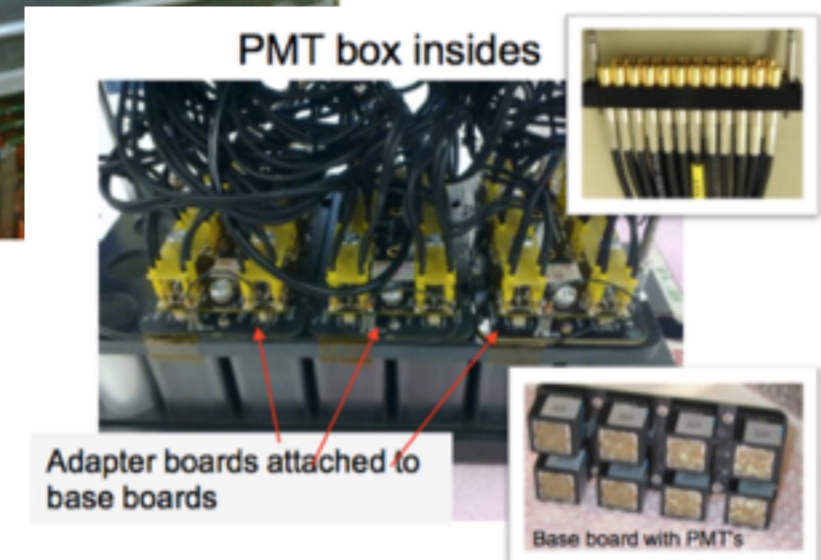
- We installed a dual-anode PMT readout box in HF+ to commission the new QIE10 front-ends in parallel with normal data readout with QIE8
  - 22 channels have their light output split 50%/50% between the QIE8 and the QIE10
  - we sacrificed 2 HF channels reading out both anodes with QIE10s
  - QIE10 readout monitored in DQM for each run
    - » TDC timing is monitored in online DQM and mostly stable, unless major external interventions
    - » the phases of all channels were fine tuned to align to physics in September, resulting in a narrower peak in a DQM plot
    - » average phase adjusted several times to find the optimal working points for Physics in 2017





HF Phasel upgrade — installation





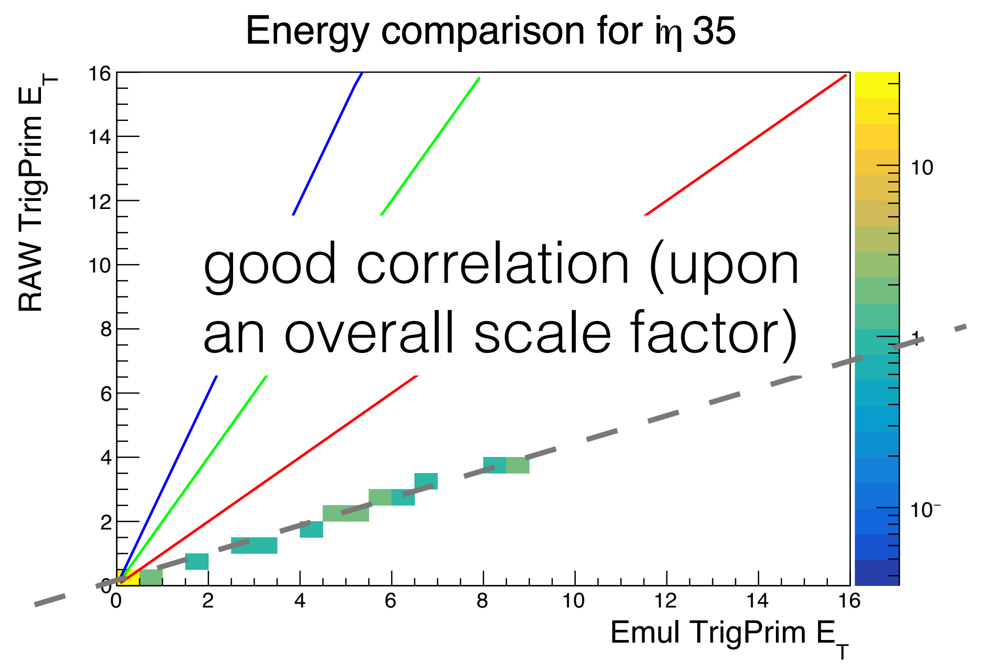
- Refurbishment of 72 PMT boxes in SX5:
  - rework 1 quadrant (9 PMT boxes) per week; **finish by March 3** according to schedule
  - progressing well, **ahead of schedule** (already 39 boxes reworked, 35 fully tested)
  - scaffolding built in HF+ / HF- to access upper boxes
- HF LV system reconfiguration — ongoing:
  - additional CAEN power supplies inserted into existing EASY crates for HF- Q3,4
  - integrate new power supplies into DCS
- New FE racks installation and recabling in UXC — driving the schedule:
  - each quadrant will take ~2 weeks (allowing more time for the first quadrant)
  - this week in HF- Q3 and Q4:
    - » new QIE10 crates inserted and powered up
    - » TTC fibers connected to ngCCM. Establish ngCCM - ngFEC communication
  - by end of the week:
    - » install PMT boxes, connect FE cables, first quadrant checkout
  - complete **HF installation by mid. March** — try and parallelize work of HF+ and HF- as much as possible

HF PhaseI upgrade - commissioning

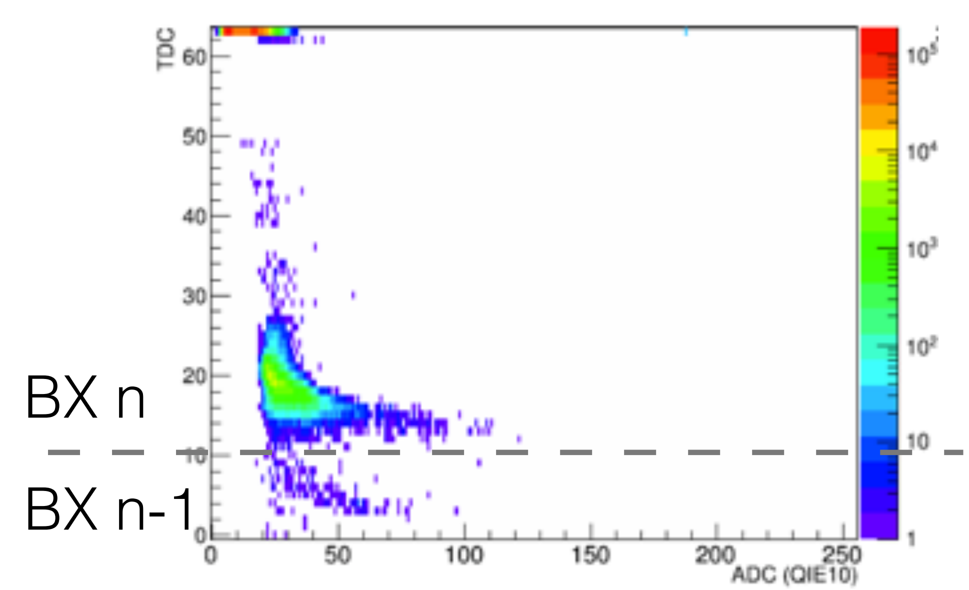
- **HF quadrant** sign off in **local**. Multi-step approach:
  - establish BE-FE communication (ngFEC-ngCCM) through ngCCMServer and talk to all slots
  - connect data fibers, communicate through μHTRtool and establish good μHTR links
  - take local runs (pedestal / charge injection)
  - sign off FE crate
  - install PMT boxes and Winchester (PMT-FE) cables
  - take LED runs to check connection with PMT
  - sign off quadrant
- **sourcing** (one week per HF side):
  - jargon for measurements of the response using a radioactive source (^{60}Co) inserted in stainless steel tubes along the z-axis of the detector
  - crucial to check the mapping and cabling of the new detector
  - will allow first intercalibration of the two anodes
  - no need to wait for a full HF side to be signed off, can source HF "Dee" as soon as they're signed off
- According to schedule, **commissioning done by end of March** (2 weeks contingency)
  - should be ready to participate to CRUZET/CRAFT as they start
  - tests in global possible / valuable even before that with a sub portion of HF

HF PhaseI upgrade - trigger commissioning

- **Latency of ngHF** cfr. legacy system being measured with dedicated setup at b904:
  - single LED pulse illuminates both ngHF (QIE11/igloo2 @4.8Gbps) and legacy HF (QIE8 @1.6Gbps)
  - carry data on identical fibers to μHTRs and compute full TPs
  - send results to RJ45's on μHTR front-panels and probe with scope
  - same measurement done for ngHE shows 2-3BX more latency for the ng system (compliant with L1 requirements)
  - HF expected to be the same / faster
- Pilot QIE10 system in 2016 allowed for a first **emulator vs. data comparison** of **TPs**: →
  - F/W, LUT database interface and offline software fully implemented
  - first results encouraging
  - emulator validation with local / global laser & LED runs

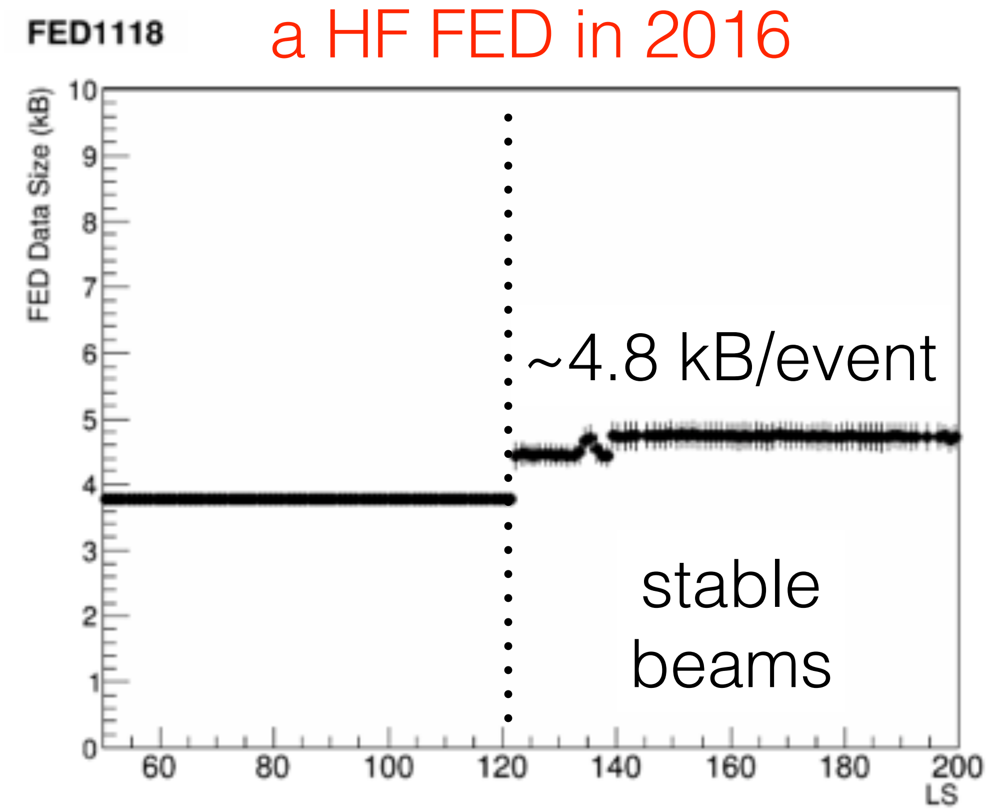


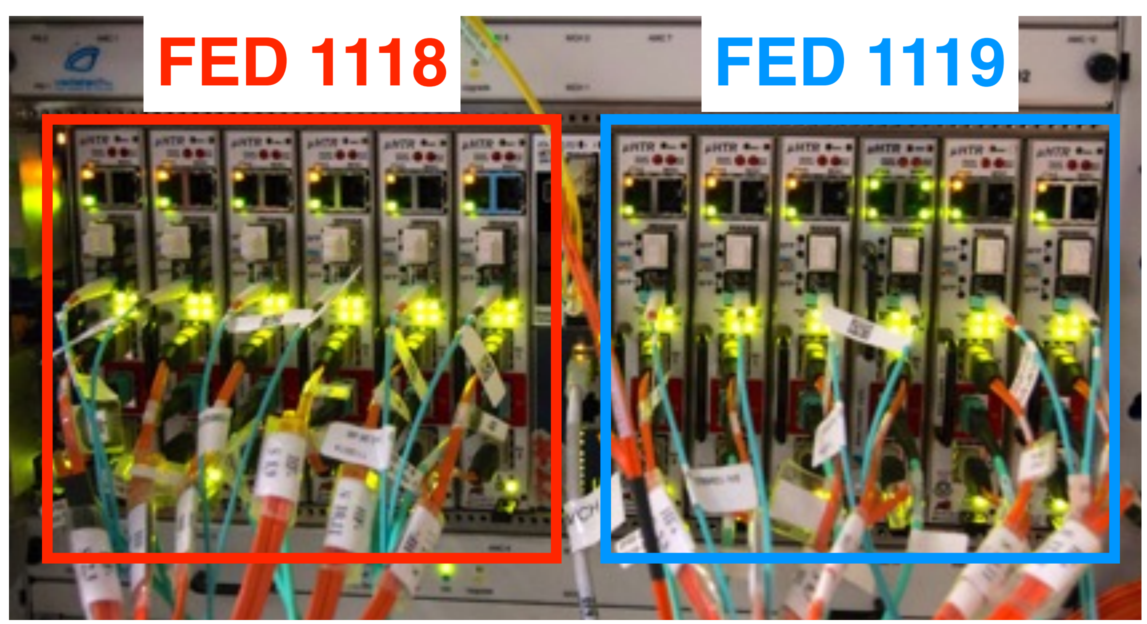
- Final commissioning only possible with **collisions in LHC**:
  - QIE10 TDC phase needs to be adjusted such that direct PMT hits fall in the previous BX
    - » TP algorithm will suppress late hits (timing incompatible with good signal)
    - » no need for a dedicated phase scan run — use embedded TDC



HF PhaseI upgrade: dual DAQ links

- After PhaseI upgrades installation, event size is expected to increase:
  - by ~4× in HF — dual anode readout + TDC information per each channel from QIE10 FE card
- AMC13 links can carry 10 Gbits/s → **limit of ~10 kB/event/FED @ 100 kHz**
- We need at least a factor of 2 in data throughput → 2 DAQ links from each AMC13
- **Dual DAQ links installed during TS3** in HF
  - working as expected

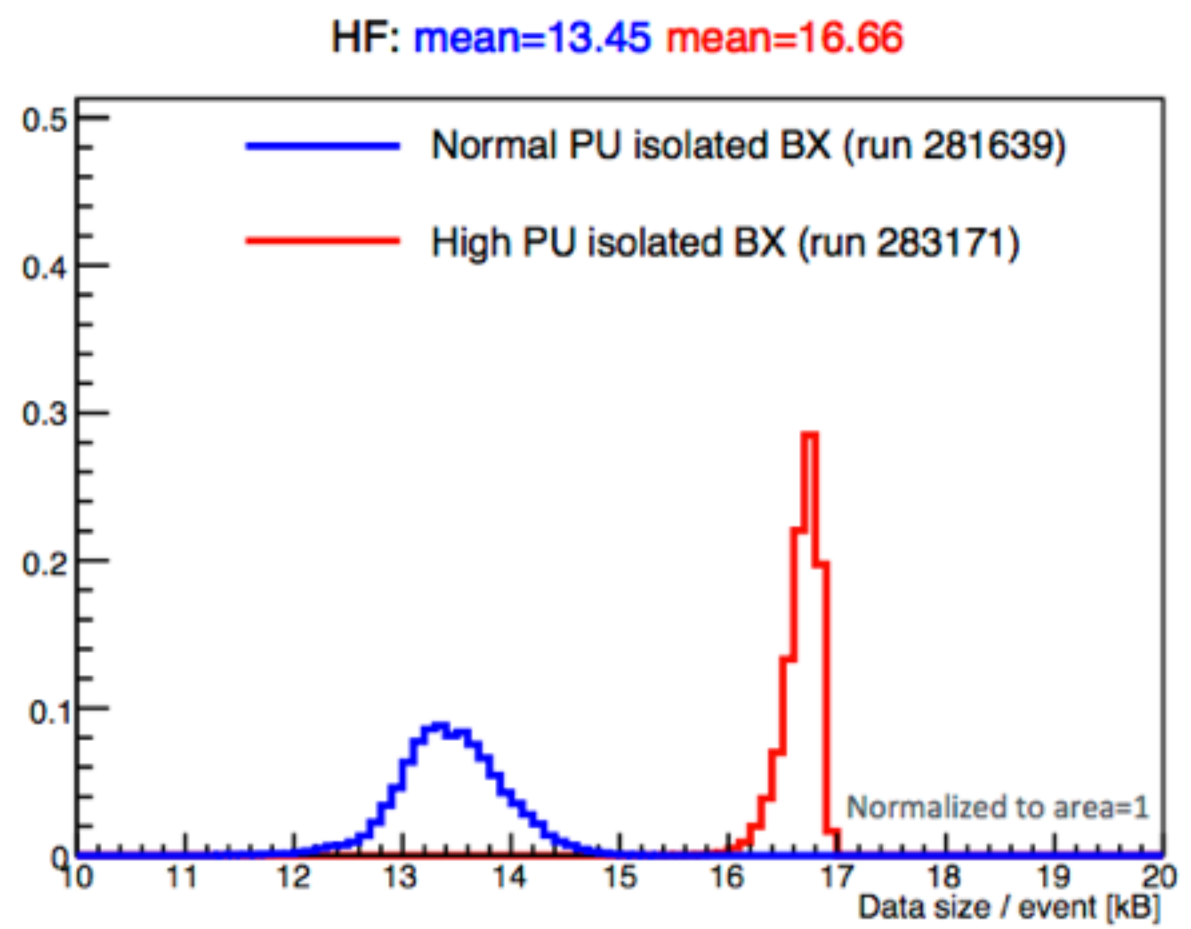




HE/HF PhaseI upgrades: high pileup

- HF readout in 2016:
  - **full readout, no zero suppression** of QIE data applied (as requested by jet/met)
    - » no instantaneous luminosity dependence of the data payload (at first order)
  - **non-zero TPs are saved** to the data too → mild instantaneous luminosity dependence

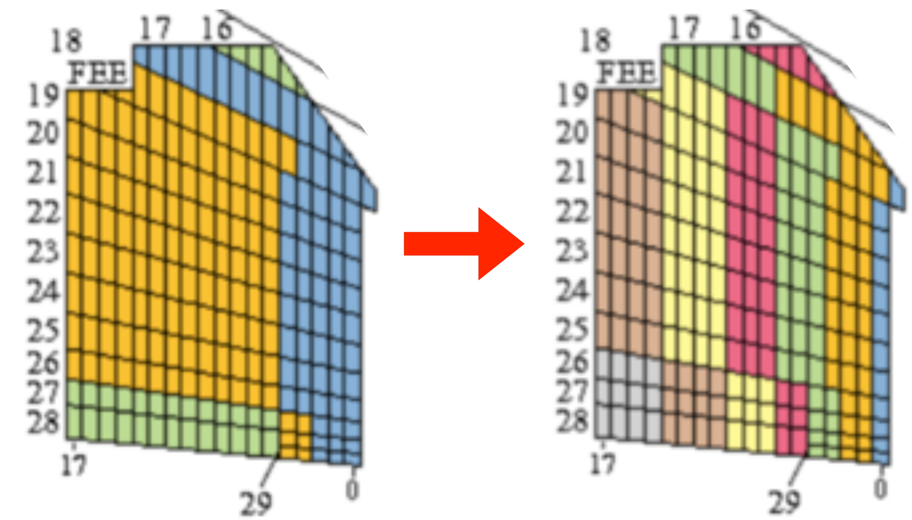
- Results of high pileup run:
  - at high PU, **saturation of TPs observed**
  - FED payload size slightly above the allowed limit of 5 kB/event/FED
  - payload size can be easily reduced
    - » applying a higher threshold for TPs copied in data
    - » sensible ZS of QIE data could be studied too
  - **not a concern for ngHF in 2017**



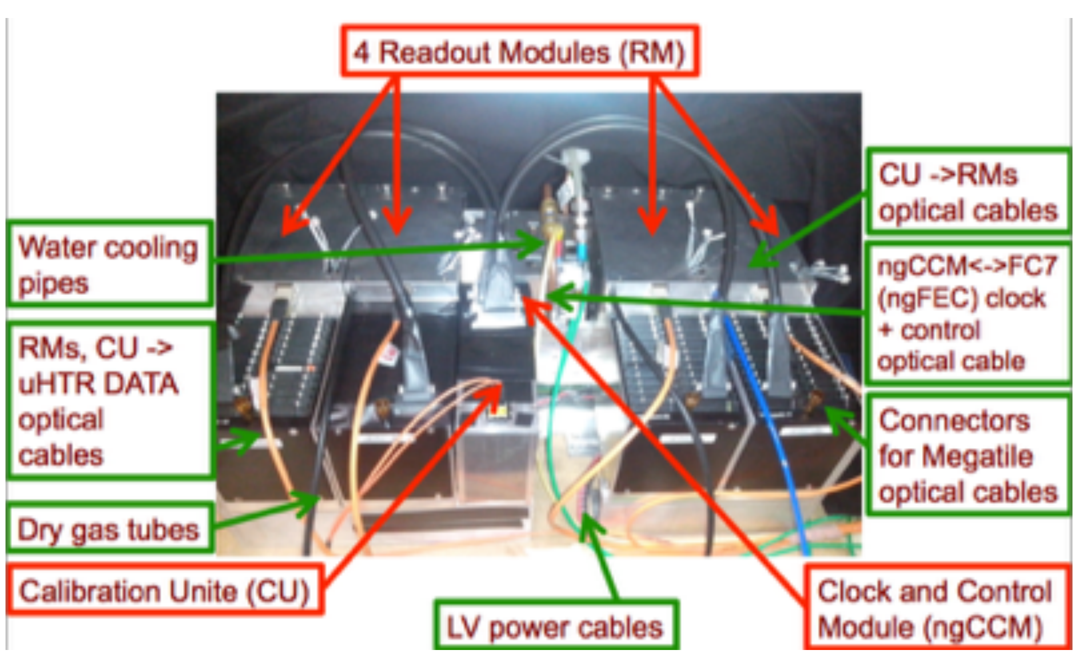
saturation at ~17 kB (5.6 kB/event/FED)

HE PhaseI upgrade

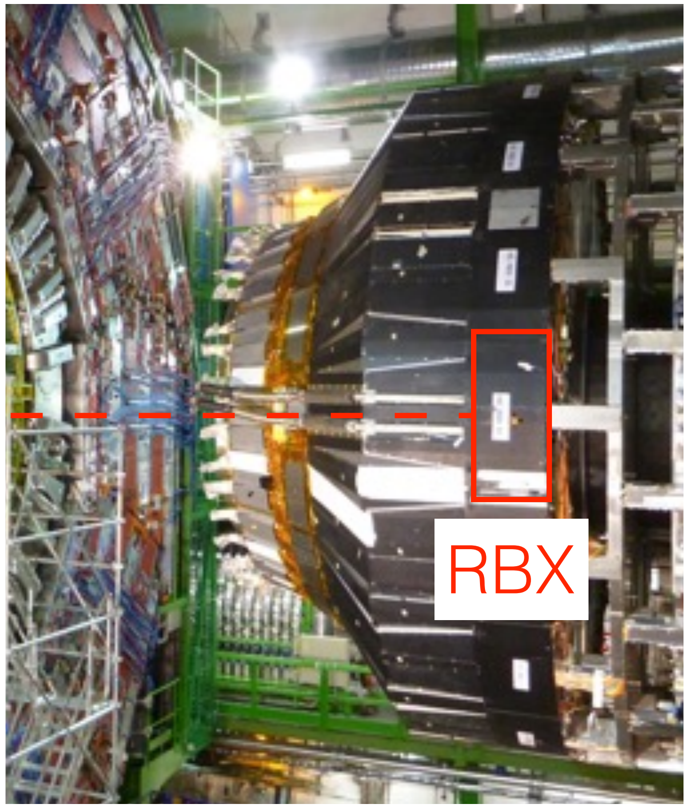
- The **HE upgrade at a glance**: FE readout upgrade with SiPM+QIE11 to mitigate signal loss due to radiation damage (and reduce noise)
  - the radiation damage to HE scintillators has a strong gradient across detector volume
  - new SiPM+QIE11 readout supports up to 7 depth segmentation, allowing fine-grained calibration corrections vs. depth, alleviating worsening of jet energy resolution
- Need replace 36 RBXs:
  - each covers a 20° sector in HE



HCAL ENDCAP



ngRBX



HE PhaseI upgrade

- Considering risks versus physics benefits at this point in time, HCAL PM has recommended to **postpone the full replacement of 36 RBXs**

- In view of full potential installation next year, **two other essential steps** will happen during this EYETS:
  - install **MM optical fibers** from USC (ngFEC) to UXC (patch panel) and from patch panel to RBX for **redundant ngCCM communication**
    - » fiber length measured
    - » 1 order already placed, 2nd to be placed by end of this week
  - **full sourcing of HE** to thoroughly exercise the procedure, given time constraints of next YETS and obtain a reference calibration set for QIE8

- **Installation of 1 ngRBX** would be **highly beneficial** in view of future full installation, especially if done during a short YETS (a.k.a. **Plan1**)

- **We could roll back** to legacy HPDs+QIE8 if problems arise before CMS closure
  - a proper assessment of the risks of dismounting and restoring the legacy RBX is ongoing

HE PhaseI upgrade - 1 RBX commissioning

- Our **tentative schedule** for Plan1 installation (still to be approved):
  - HEM14 is the candidate for replacement;
    get approval for removal next week
  - *Saturday Feb. 11th — 12th*: **sourcing of legacy** HEM14
    - can't happen before: scaffolding installation interferes with muon work;
      need to finalize the sourcing procedure
  - *Monday Feb. 13th:* **remove** HEM14/QIE8
  - *Feb 14th — 17th*: **install** HEM14/QIE11
    - first sanity checks (ngFEC—ngCCM communication, QIE cards, etc.)
  - *Feb. 18th — 19th*: **sourcing of PhaseI** HEM14/QIE11
  - *Feb. 20th — Mar. 3rd*: **commission and exercise** the new RBX to gain confidence
    - local pedestal / LED runs
    - global runs, especially for TPG commissioning
  - *Mar. 3rd*: **CMS decision** whether to keep the new RBX or revert to HPD+QIE8

Conclusions

- HCAL in a good shape after the Christmas sleep:
  - turned on LV in HB / HE+ / HO last week
  - first local runs taken
  - HB / HE (?) / HO ready to join MWGR, as soon as they start
- HF undergoing major upgrades
  - everything is moving on schedule
- HE full upgrade postponed, installation of 1RBX under evaluation
- Still, a whole lot to do:
  - full sourcing of the legacy detector
  - be ready for installation / commissioning of 1 RBX

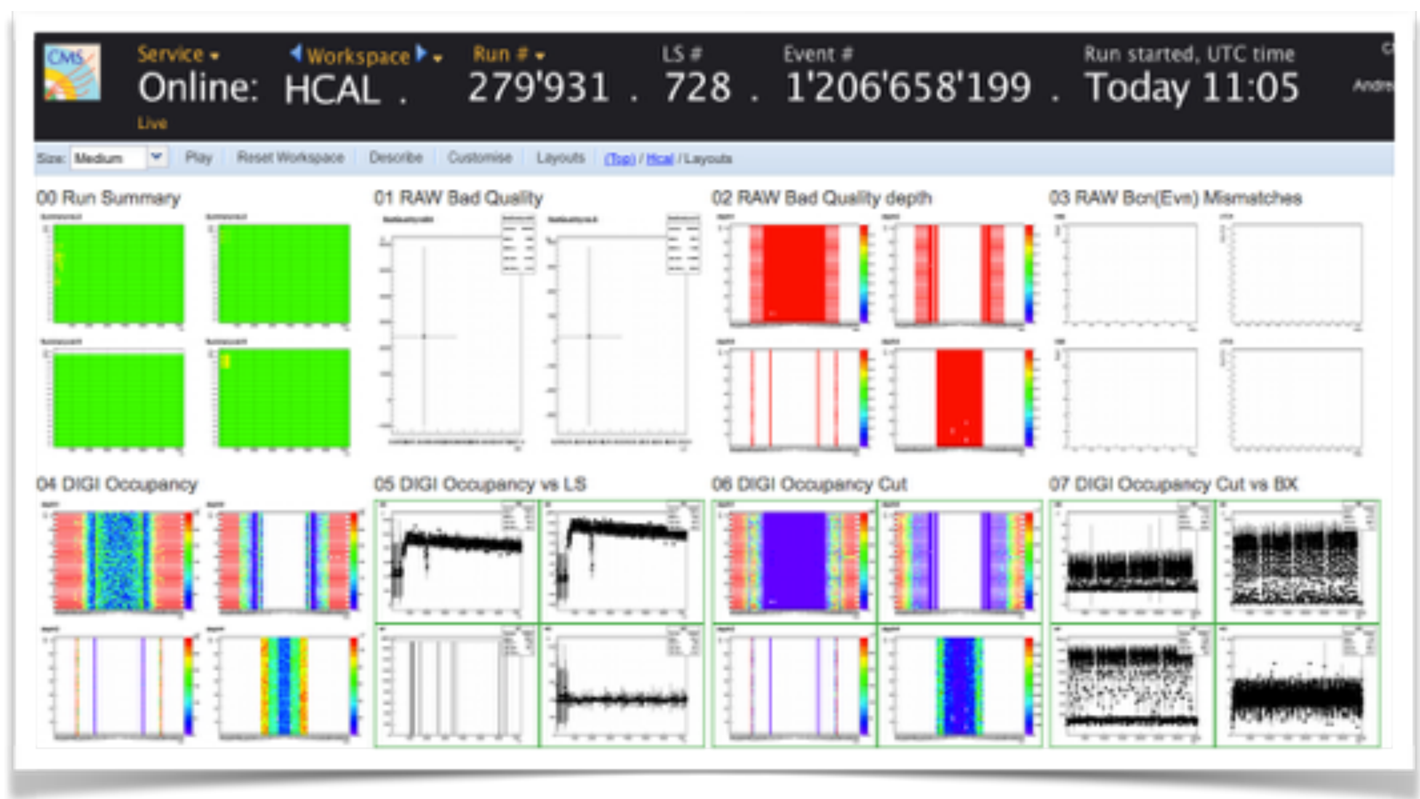
Backup

Key ingredients: online monitoring and DQM

Alarm Rule	Active	FATAL	ERROR	WARN	Masked
UHTR-ORBIT_RATE	43	0	43	0	12
DCC-spigot-trunc-data	1	0	0	1	0
UHTR-POWER	0	0	0	0	128
UHTR-BAD_ALIGN	0	0	0	0	12
RBX-CCMServer-Error	0	0	0	0	4
HTR-Fiber-Idle	0	0	0	0	2
DCC-L1A-BCN-Mismatch	0	0	0	0	1
DCC-L1A-EVN-Mismatch	0	0	0	0	1
DCC-Spigot-Empty-Event	0	0	0	0	1
DCC-Spigot-UncorrectedError					1
DCC-Spigot-Skipped-Event					1

- HCAL Alarmer: our primary tool for detecting hardware issues
  - monitor the status of RBXs, FE-to-BE links, BE (μHTRs+AMC13s), laser, etc.
  - trigger a prompt reaction in case of problems (mail, SMS, RunningDegraded)

- HCAL DQM rewritten from scratch during 2015, new version put in production in 2016
  - lumi-section-based status computation to better catch transient problems
  - monitoring of global and local runs
  - continues to expand to meet our needs (e.g. upgrade pilot systems)



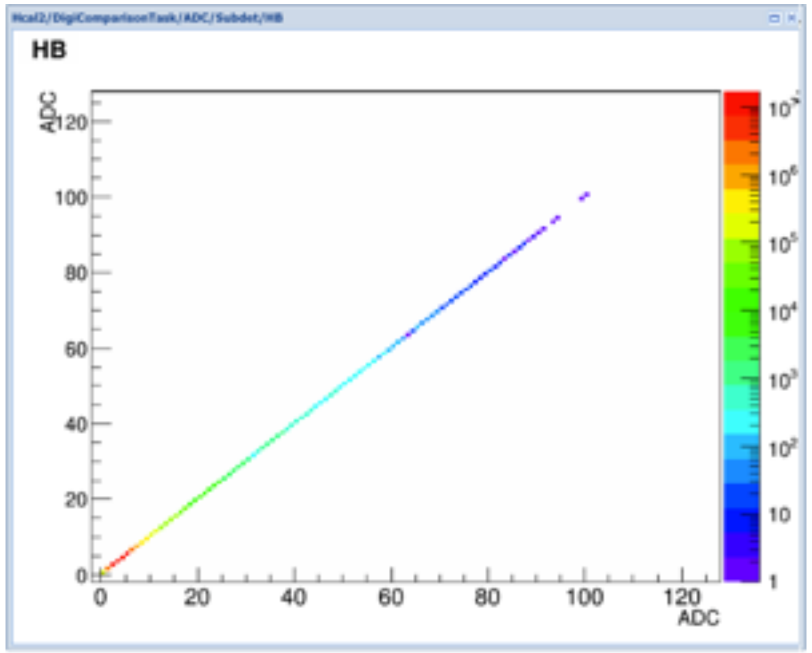
- All the (few) problems we have had were caught by DQM

Upgrade to new µTCA backends for HB/HE

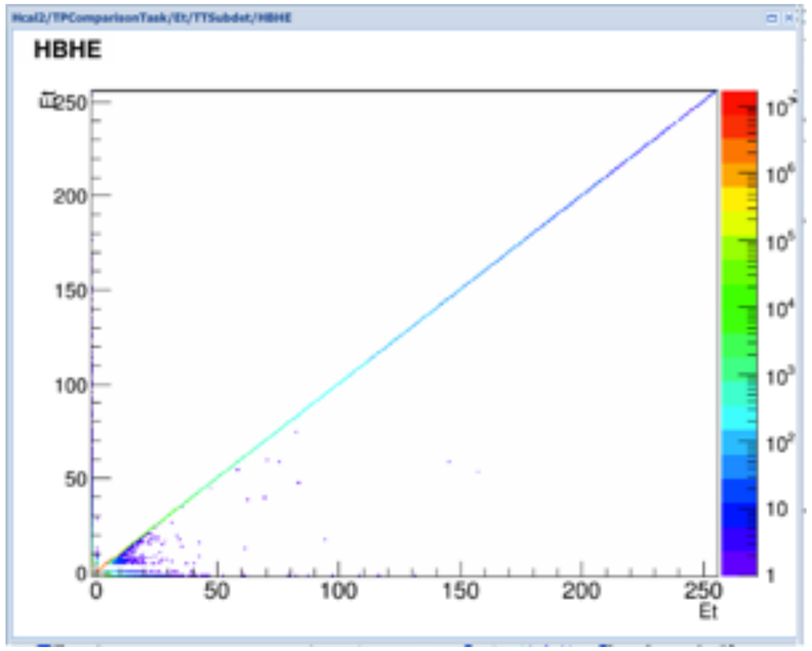
- Since the beginning of the year, HCAL has run with completely new µTCA- based backends in HB/HE
  - VME backends readout in parallel to cross-check until Sep.
  - fundamental prerequisite for PhaseI upgrades
- Some difficulty at the beginning of the year, solved by a strong interaction between DAQ, µTCA and F/W experts

- Perfect matching of VME and µTCA data obtained, and VME decommissioned during TS2
  - µTCA revealed issues in VME we were not aware of

µTCA vs VME digis



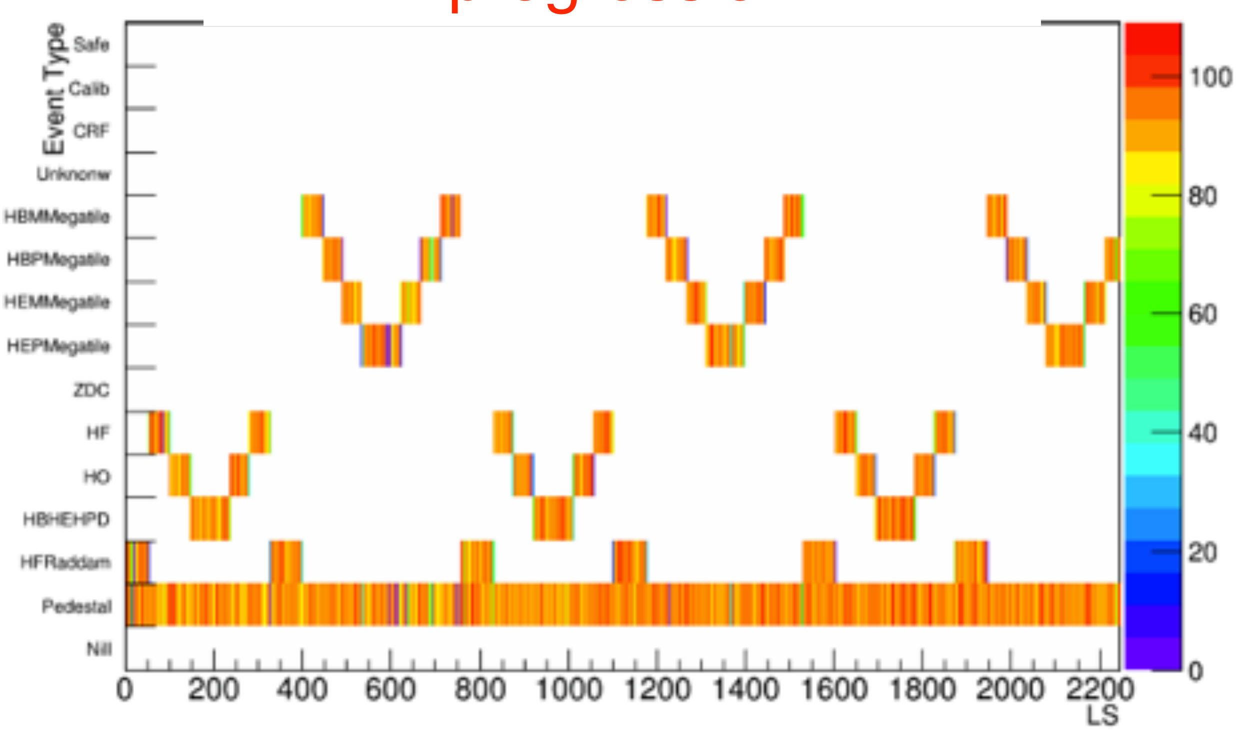
µTCA vs VME TPs



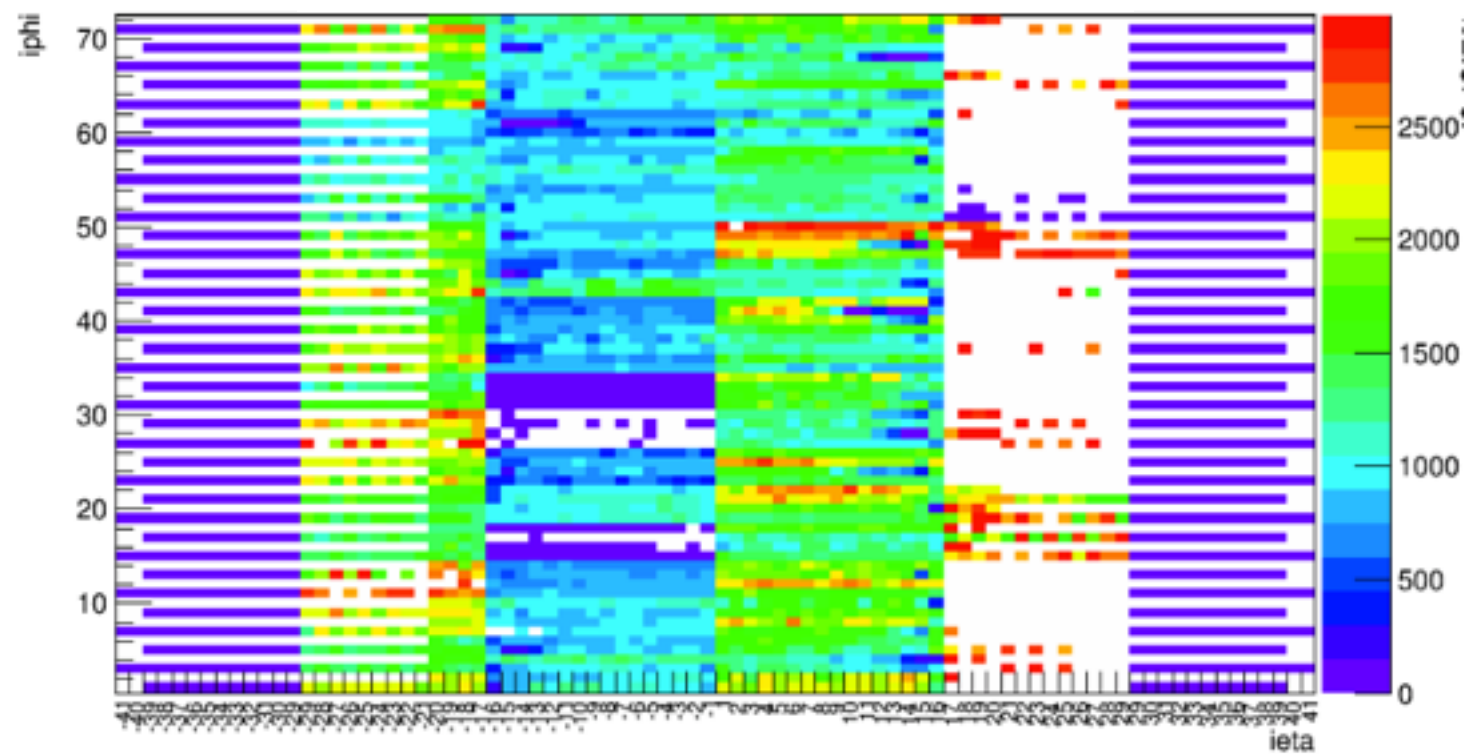
Laser sequence

- Calibration sequence in the orbit gap monitored through DQM
  - the laser fiber selector moves continuously during a run, so that the whole detector is scanned in ~ 2 hours
  - laser events interleaved with pedestal events

orbit gap sequence progression



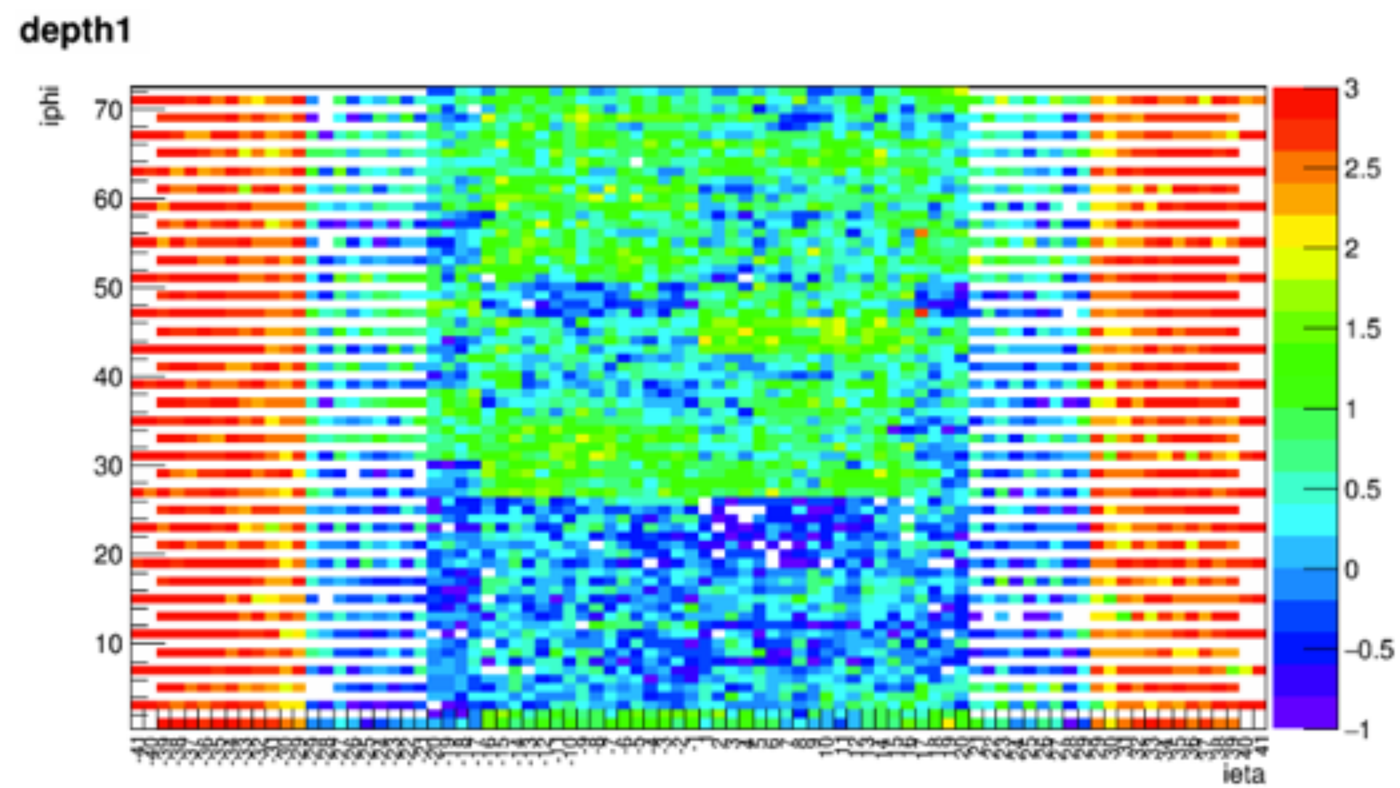
average laser amplitude across the whole detector



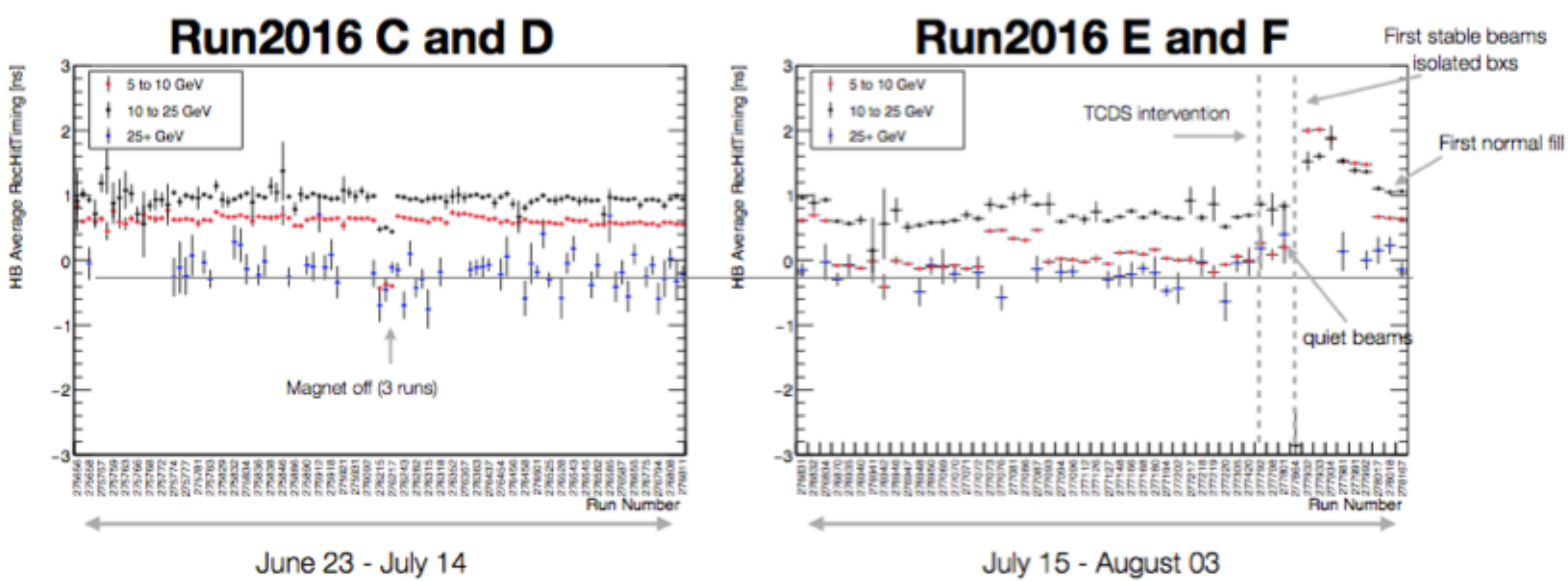
- Working towards a map in DQM which summarizes HCAL overall health, as extracted from laser events
  - spot new dead channels, readout synchronization issues from laser pulse timing, etc.

HCAL recHit timing

- Uniformity of HB/HE/HF timing checked with recent data and monitored in DQM
  - recHit timed in within ~2 ns
- RecHit timing evolution measured through the charge sharing between time slices (HBHE) or with specific "50/50" channels (HF)

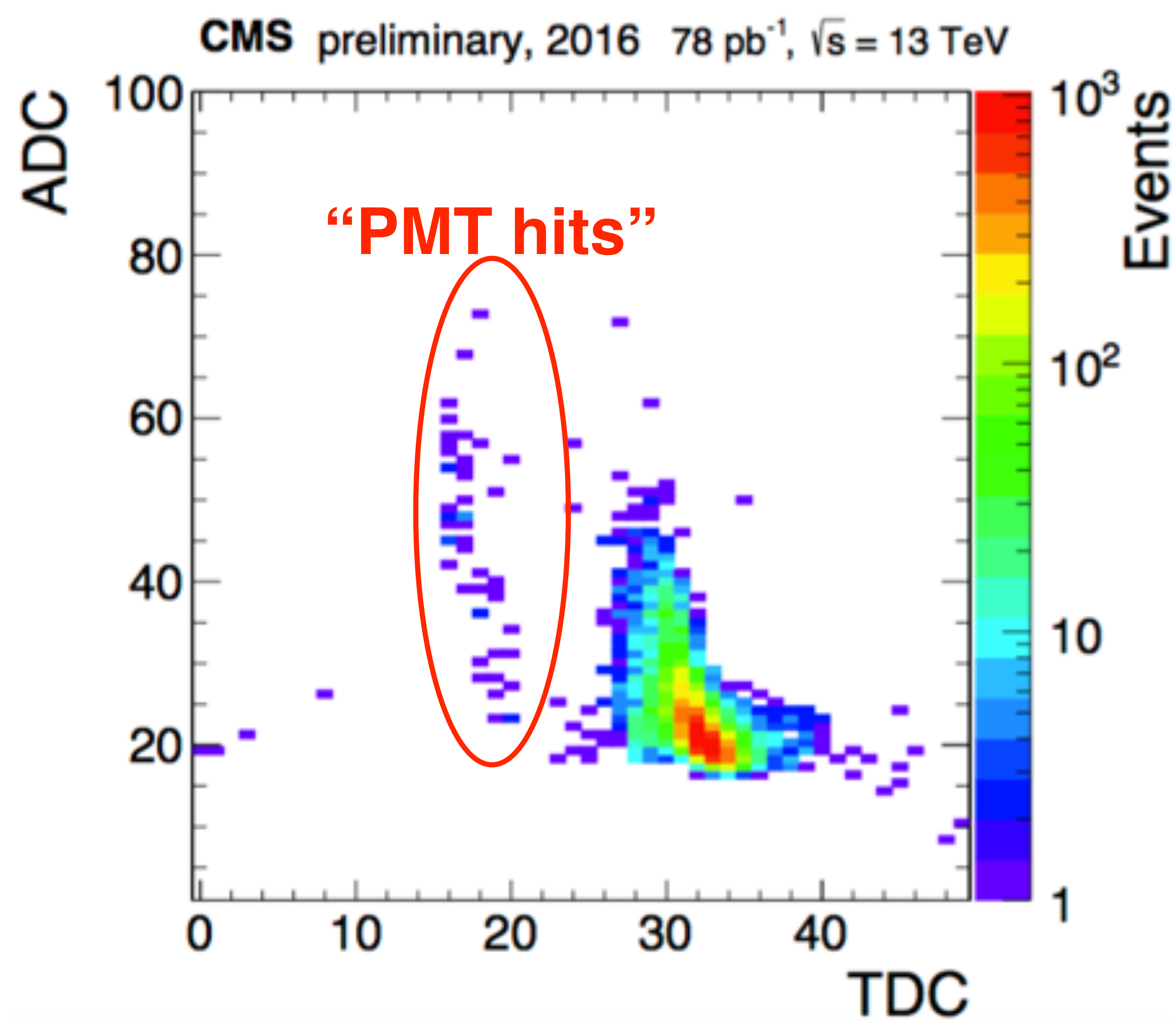


timing generally stable during 2016



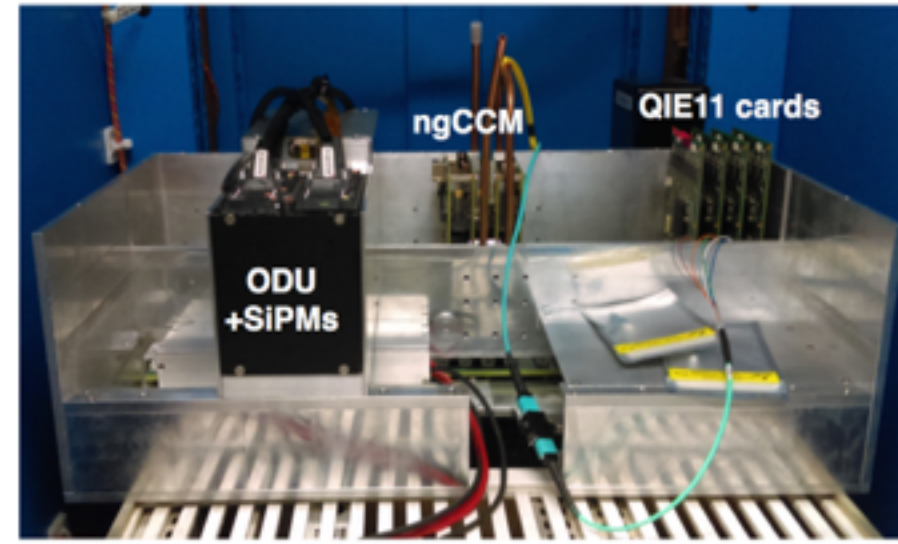
HF PhaseI upgrades: QIE10 commissioning

- We installed a dual-anode PMT readout box in HFP+ to commission the new QIE10 front-ends in parallel with normal data readout with QIE8
  - 22 channels have their light output split 50%/50% between the QIE8 and the QIE10
  - we sacrificed 2 HF channels reading out both anodes with QIE10s
  - QIE10 readout is monitored in DQM for each run
- Analysis of ADC vs. TDC for a QIE10 channel shows the physics signal (at ~15 ns in the picture) plus early counts (at ~9 ns)
  - 1 TDC = 0.5 ns
  - early signal consistent with noise from particles incident on PMT quartz window
- Correlation between time and energy expected for the constant-current-threshold TDC used in digitization



HE PhaseI upgrades: QIE11 commissioning

- CastorRadiationFacility installed on the CASTOR table during TS2
  - a set of scintillators/WLS fibers connected to HCAL laser injection system, read out by HE PhaseI FE (SiPM+QIE11) feeding to μHTR in USC.
  - the new HE front-end is working well in both local and global runs
  - FE-BE links stable, signals timed in (both physics and laser in orbit gap), full HE PhaseI readout chain works in P5



- Very high occupancy given location close to beam pipe, TDC info may already be providing new information