PXD in Phase 3
–
Highlights and Issues From the operation point of view

B. Spruck

(For more details: see talk from last B2GM)

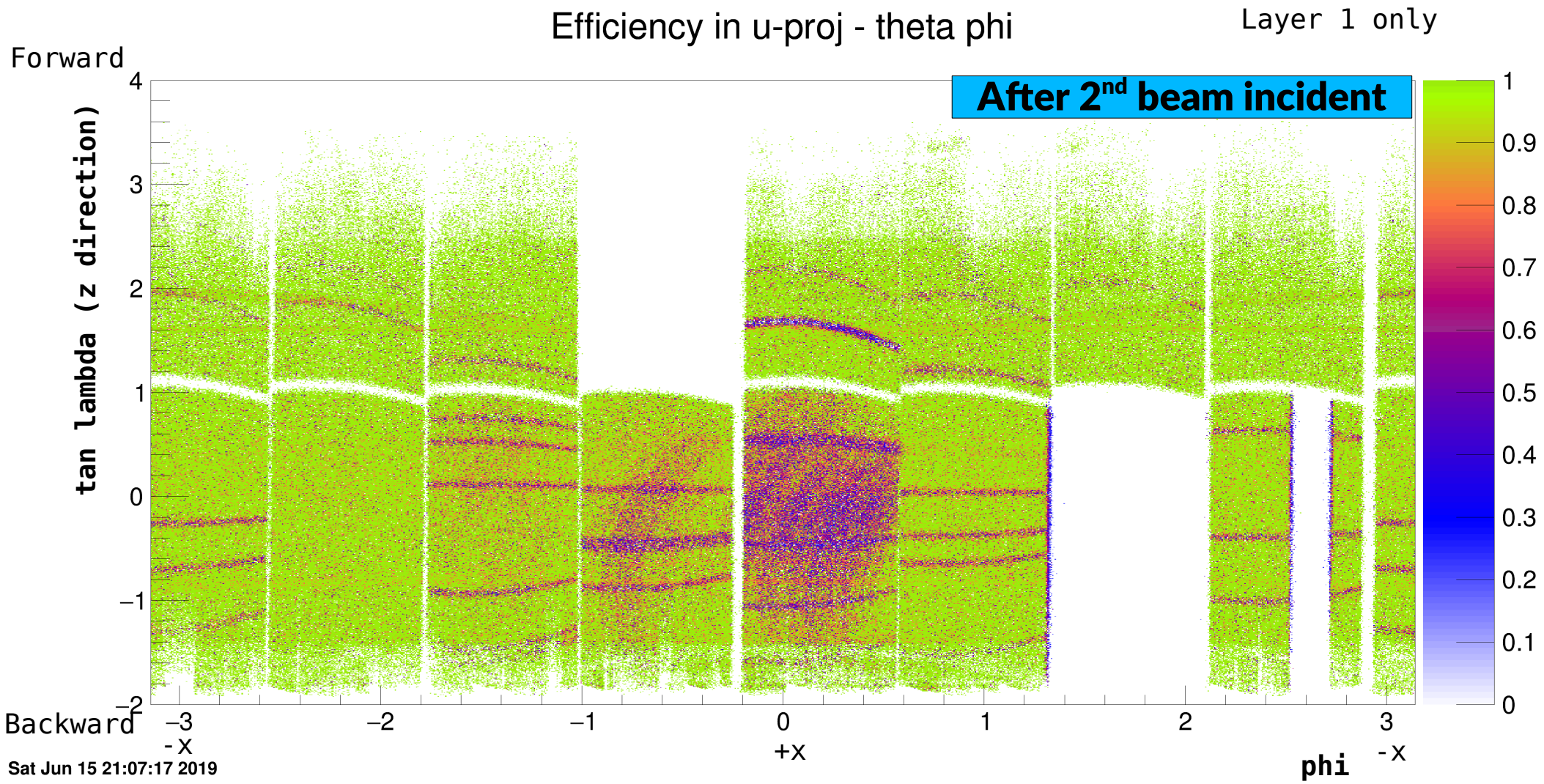
PXD Status

- 20 modules installed end of 2018
- Taking data for large fraction of the time without **major** issues
- Overlapping trigger firmware deployed
  - >5kHz trigger rate with data
- Continuous injection in both rings (w/o gated mode)
- Event selection used regularly
- ROI selection proved (for ½ of modules, DHE order)
- No serious problems in Run Control, HV Control Interface
- DAQ interface (EB and ROI) problems fixed (outside PXD)

Incidents

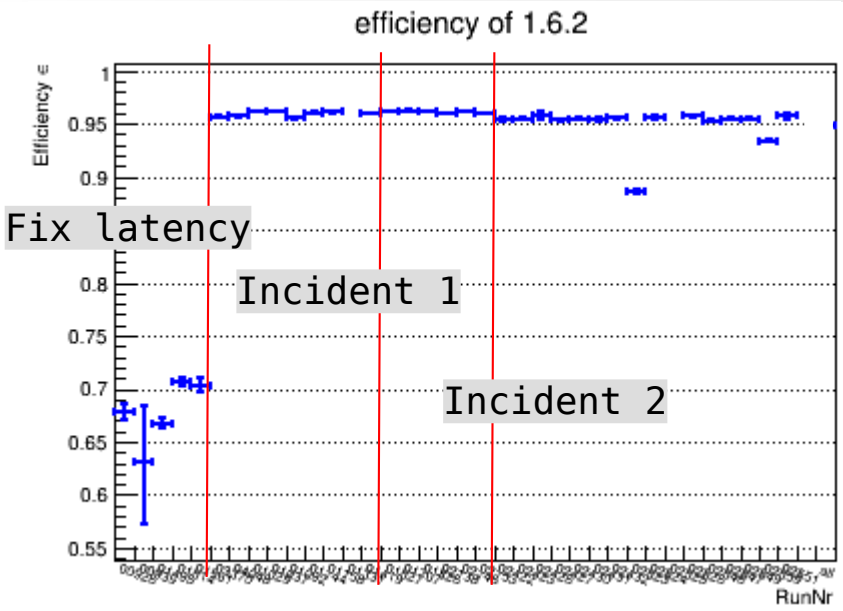
- Over voltage triggered several times
  - DHH (DHI?) firmware issue; PSU issue (replaced)
- Beam incidents (QCS quench, magnet PSU failure, …)
  - One module broken, (one module recovered), damaged gates on others
  - Unclear reason
- One DHP link lost, light power decreased on others?
  - Transceiver broken
- Running with DHP temperature measurement off for days
- 25% data loss by wrong DHP trigger delay (April/May)
- DHP last gate issue → wrong “work-around” use for few runs (days)
- Dangerous: Masking/HV on ↔ Injection

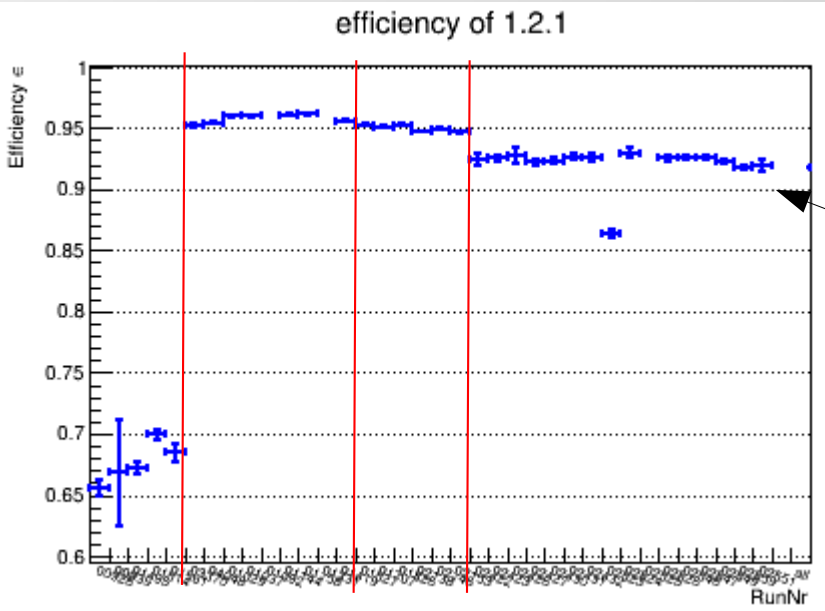
Efficiency Plot 2D

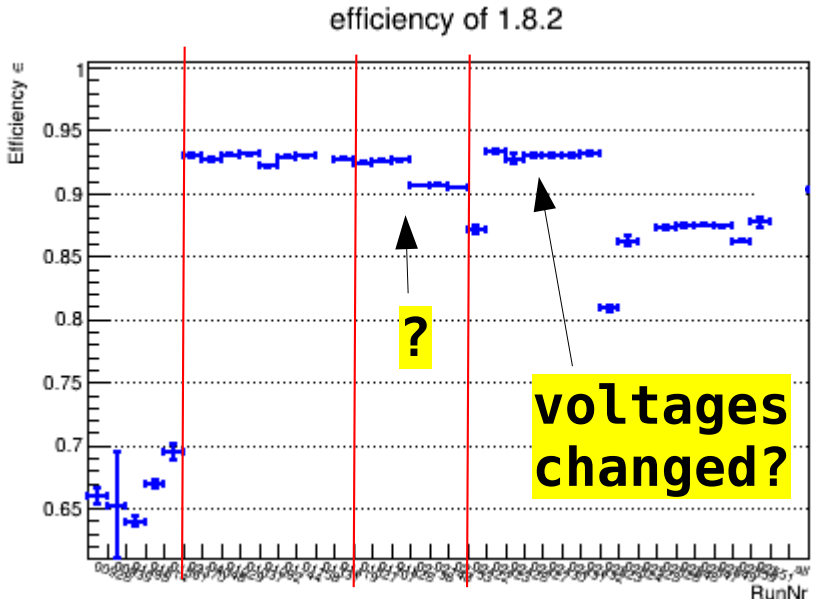


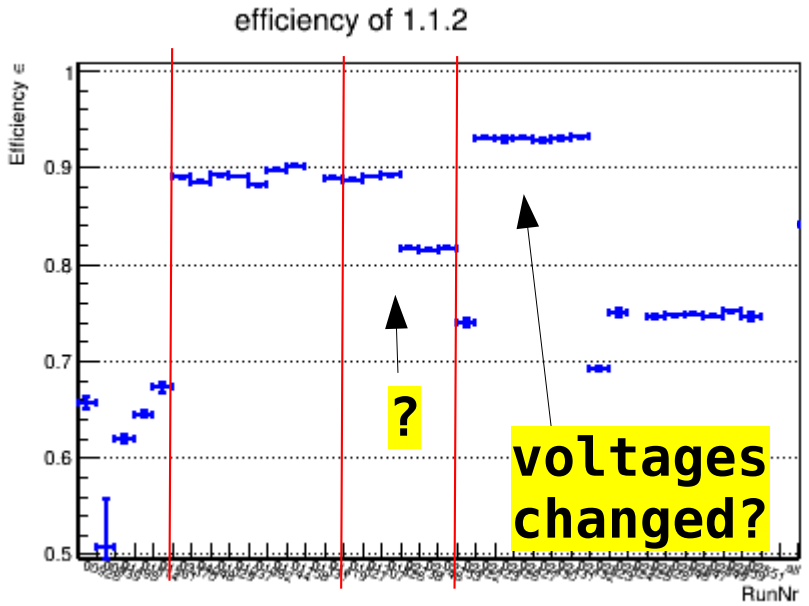
- Efficiency holes, ring structures, (gains?)
- Dead gates (increased with the two incidents from ~16 to ~80)
- Can be seen in plain hit maps already

Phase 3 Efficiency – Time Development









- Efficiencies ↔ Working point
- Compensation?

Firmware Problems

- Different versions of DHE, DHC, DHI firmware
  - Several updates during phase 3
  - Unclear what update was responsible for (rare) problems
  - KEK system used for debugging → mandatory to test at DESY!
- "HLT before DHH" (misleading name, as part of DHH stopped sending data (in most cases))
  - Firmware and/or DHP ASIC issue
- DHH firmware was updated/changed several times
  - PXD Busy and data corrupting happen with some versions
  - Different reasons → fixed with latest versions used
- **Most problems finally fixed**
- **Missing features rolled out over summer break**

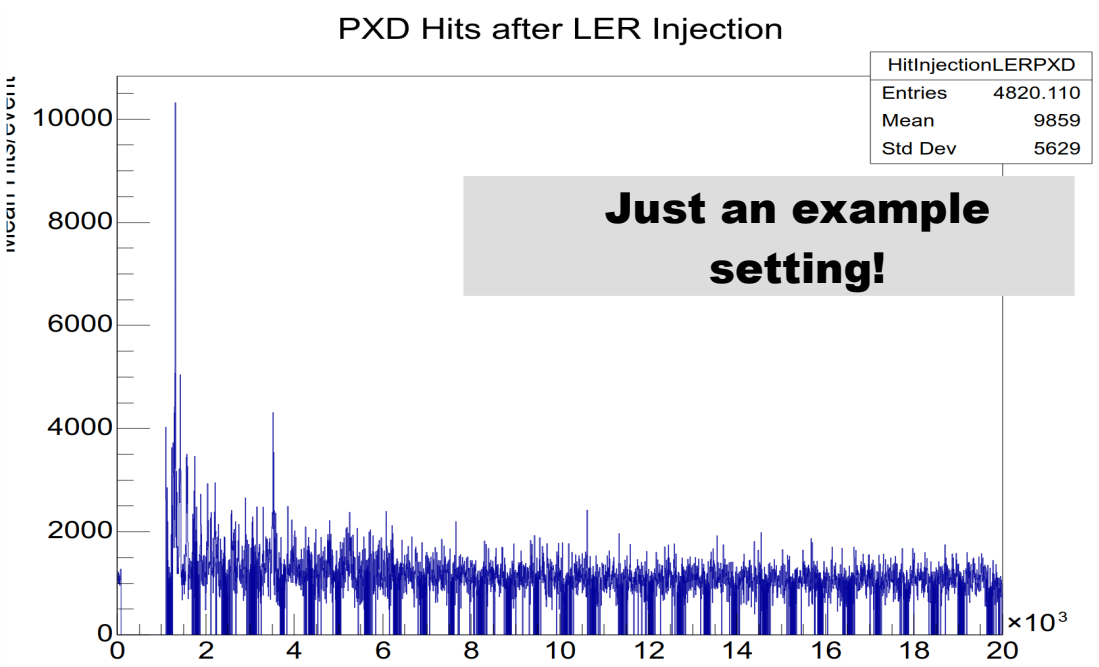
Software, Firmware, Calibration

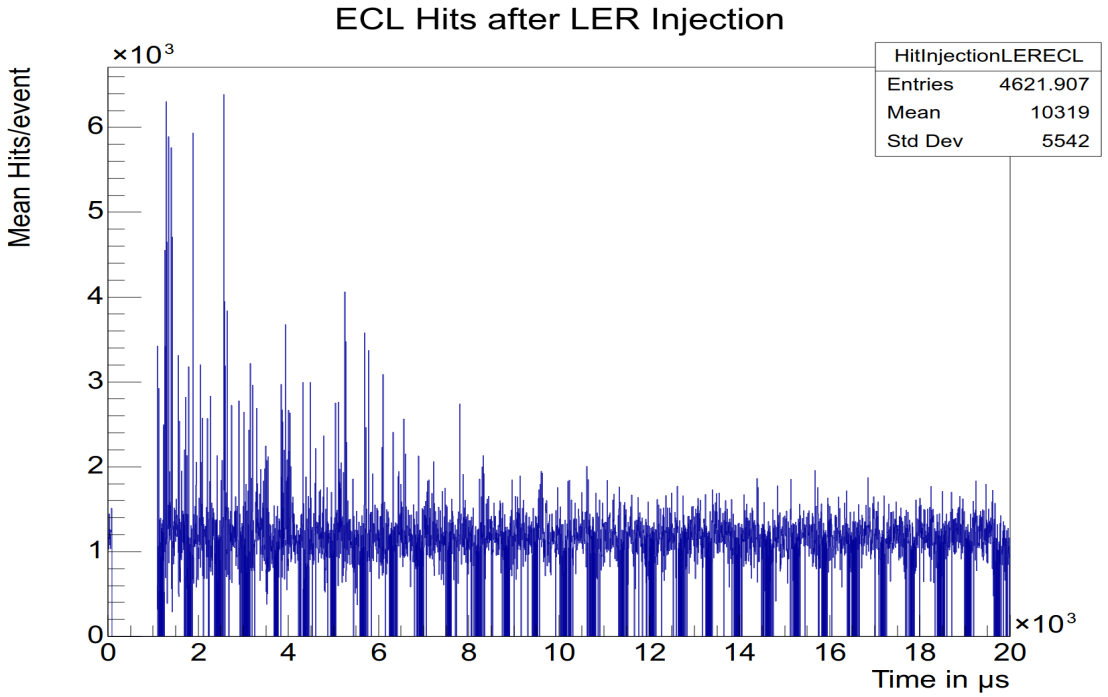
- Problems coming together
- Local vs FTSW triggering, desync of modules → calibration/pedestals failed
- Upload of pedestals/JTAG problems
- Logging message flood
- High CPU / parallel ramping
- …
- Hard to disentangle the reason sometimes

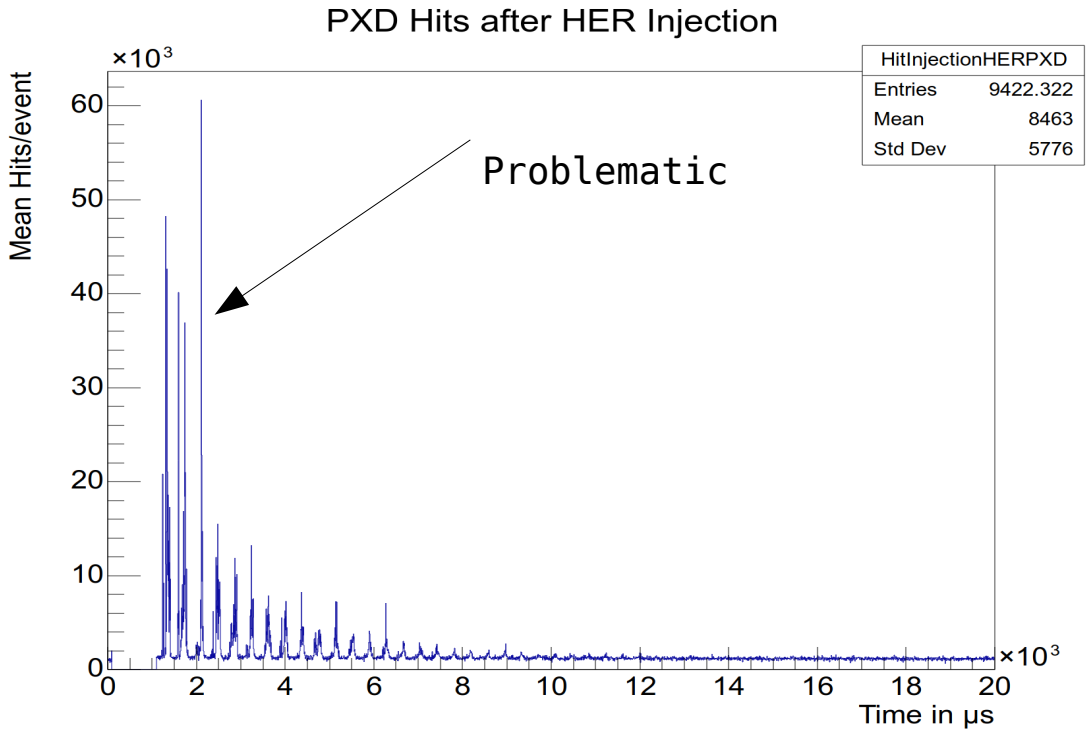
Continuous Injection, Trigger Veto

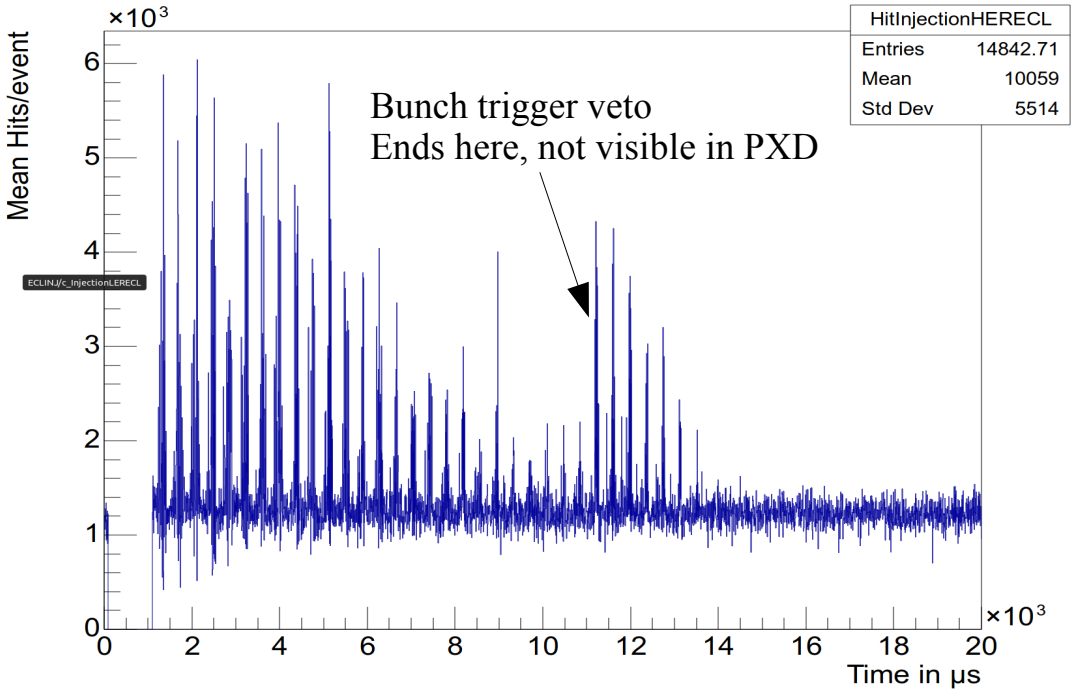
- Continuous injection in both rings
  - ‘Acceptable’ backgrounds in PXD during injection
  - Only Belle 2 trigger veto, no gated mode (yet)
    - Spikes after injection killed DHP/DHE sync
    - Workaround: longer overall veto

Occupancy after Injection





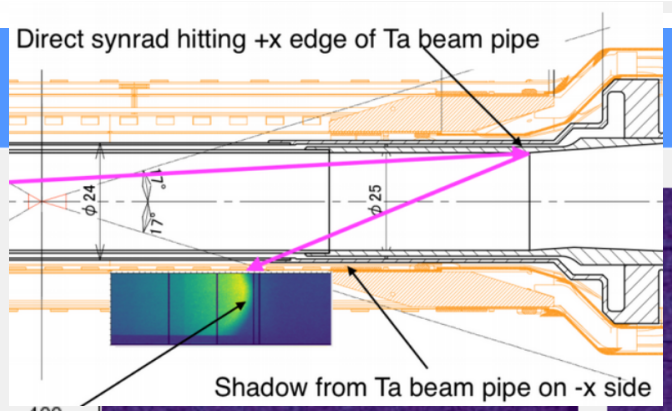




Problems – High Occupancy During Injection

- High occupancies together with triggers following shortly after each other → "link dropped" (actually the link is still there, but no data is coming for the current event)
  - DHP fifo full (CM=63)
  - Mainly during HER injection, 'dirty bunch'
- This won't stop the DAQ → manual SALS
- DHP ASIC limit
- Workarounds
  - 1: Increase the trigger veto length thus we should not get triggers when we have highest occupancy
  - 2: Gated Mode (todo)
  - 3: Reset DHP during injection veto time thus the dropped links would be limited to a time span between two injections.

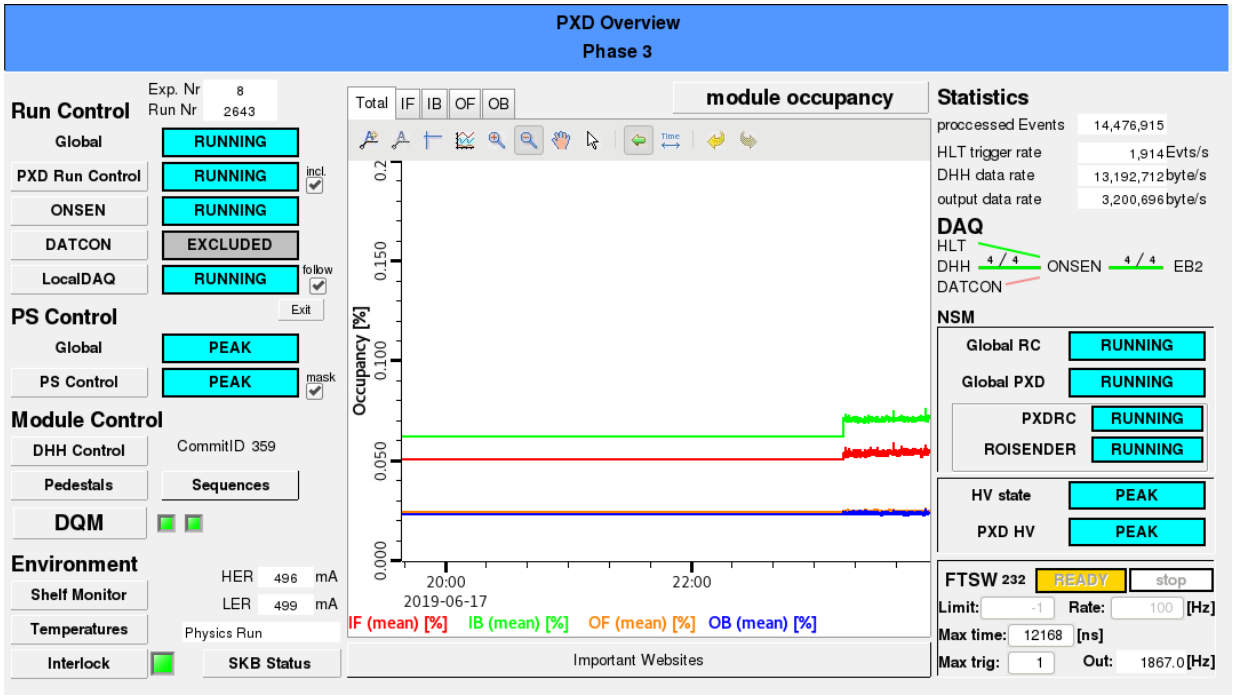
"Synchrotron" Radiation Problem



Problem: Cannot correct for non-uniform rad damage!
We get the damage even if we DO NOT see it because HV is off!!

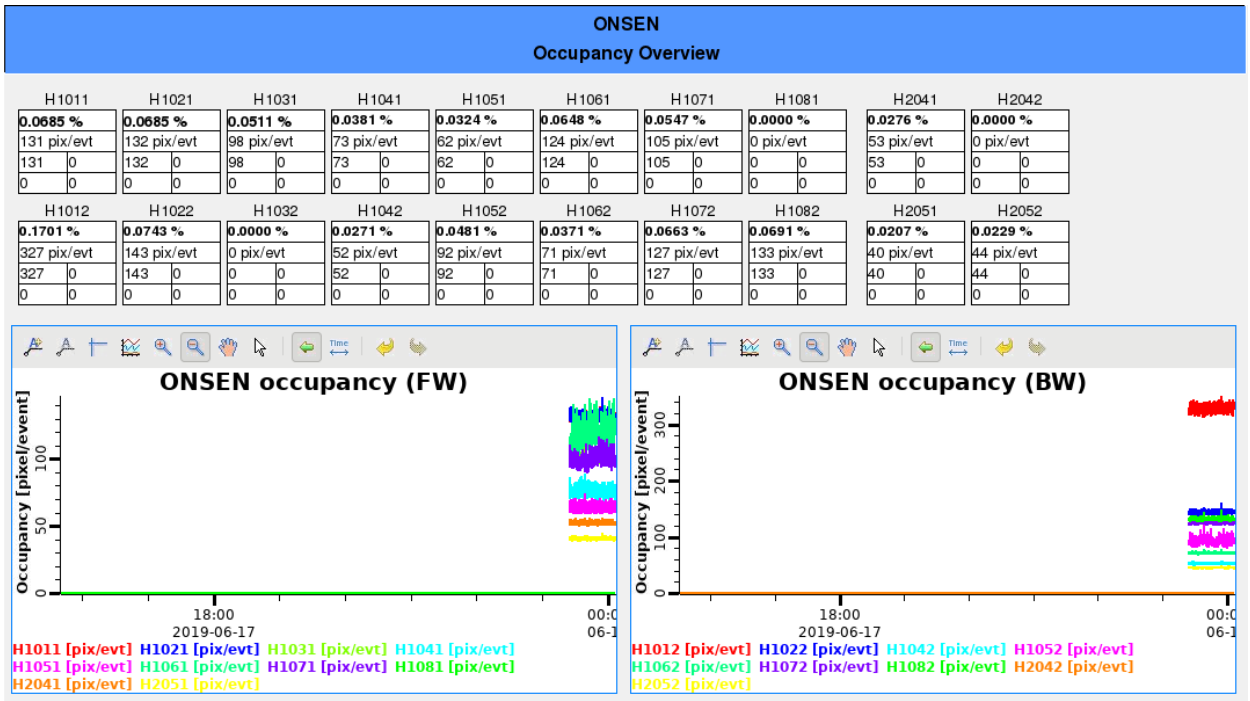
On-line monitoring and feedback to BCG/Accelerator
→ Florian

PXD Shifter CSS, BCG/Accelerator feedback



Continuous update and progress on GUIs.
→ still changing!
Please check before your shift!

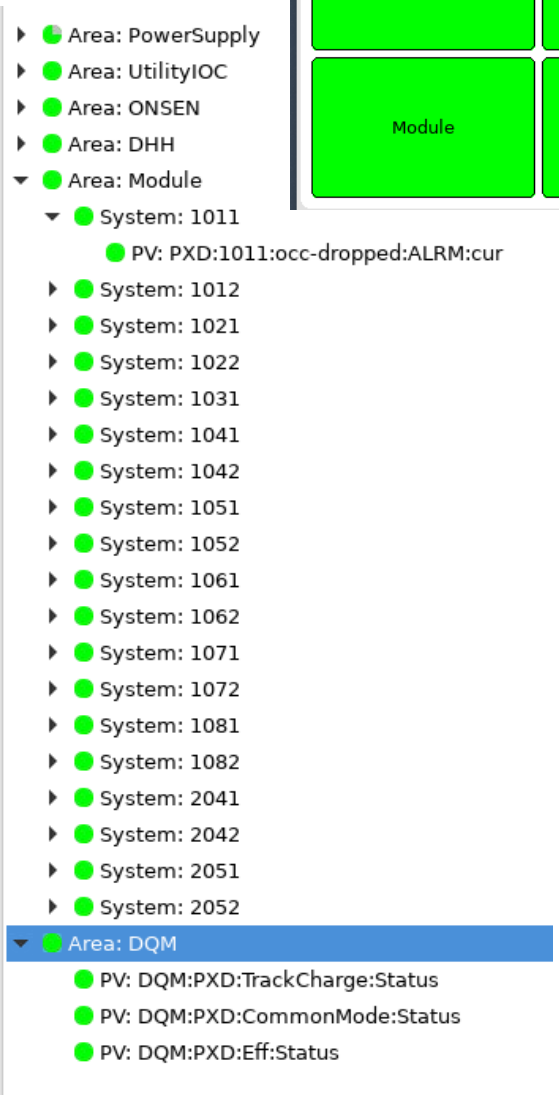
Recommended list of OPI, layout etc for shifter? → discussion

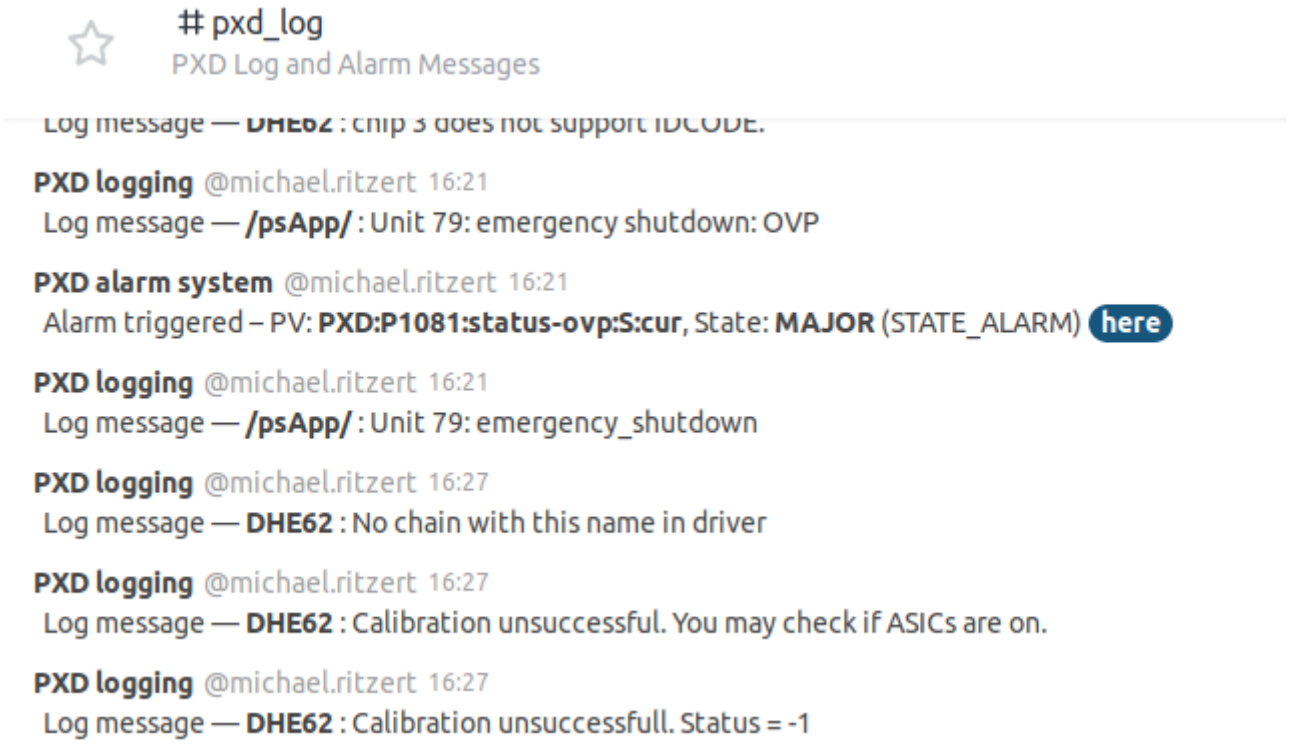


<u>BCG feedback:</u>
"Occupancy" (data rate) calculation removed from DHH firmware.
Now: Real pixel based occupancies counted on ONSEN. (no data rate fudge factors anymore)

Slow Control & PXD Alarm System

- PXD SC: no major issues, hardware was upgraded
  - IOCs, GW, archiver, monitoring…
- Alarms system & alarm tree
  - DHP temp measurement, occ. Drops, links …
  - New: Interface to RocketChat
  - (independent development from the one which is now used for DAQ/Zabbix)



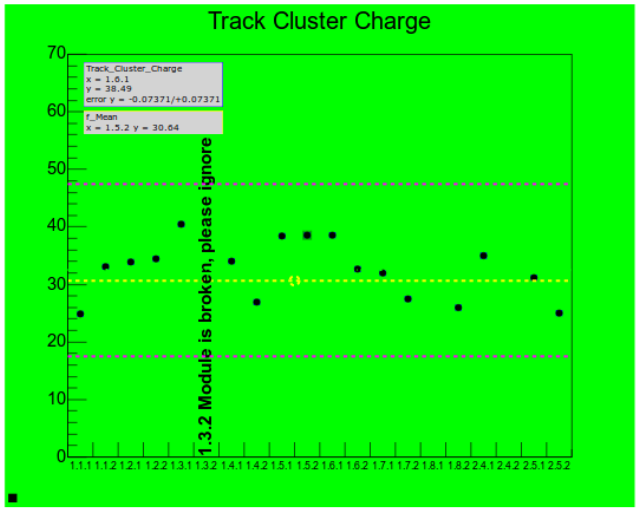


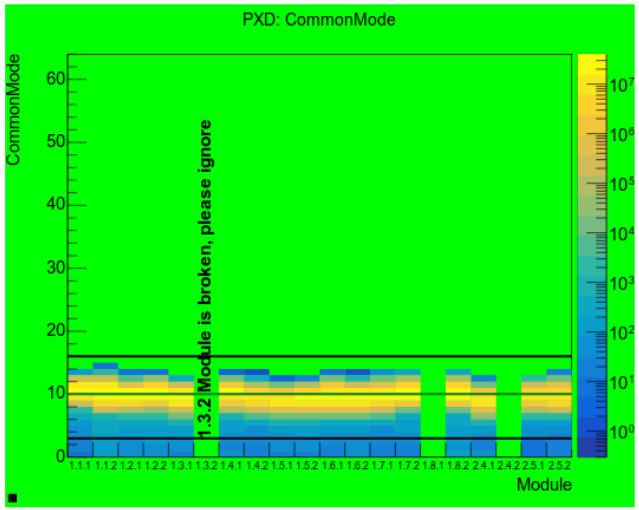
Overview of Other Issues

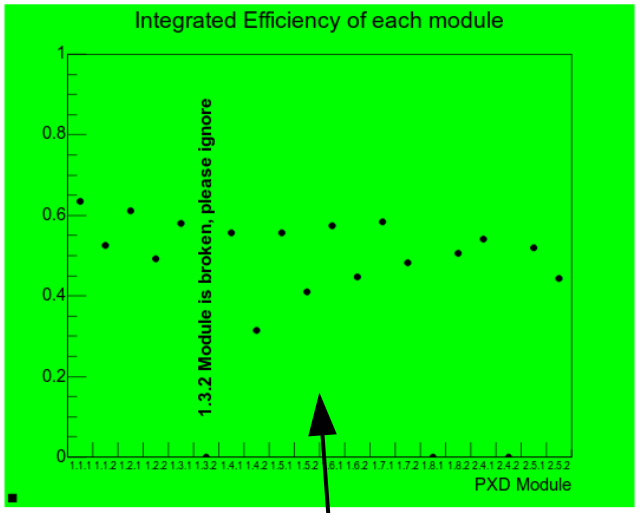
- Long HLT startup time, long buffering and processing times for some events (up to 2 minutes!), challenge for ONSEN buffering → full → trigger busy at each run start
- HLT does not clear buffers and/or worker nodes crash → for some events we never get triggers → still in memory at run stop
- NSM timeout EB/HLT → PXD seen as excluded by HLT or Event Builder 2 (seems to be solved)
- Not all problem come from PXD even if PXD notices an error

NOT PXD ISSUES

DQM "flags" in Alarm System







Histogram Status exported to EPICS & archived

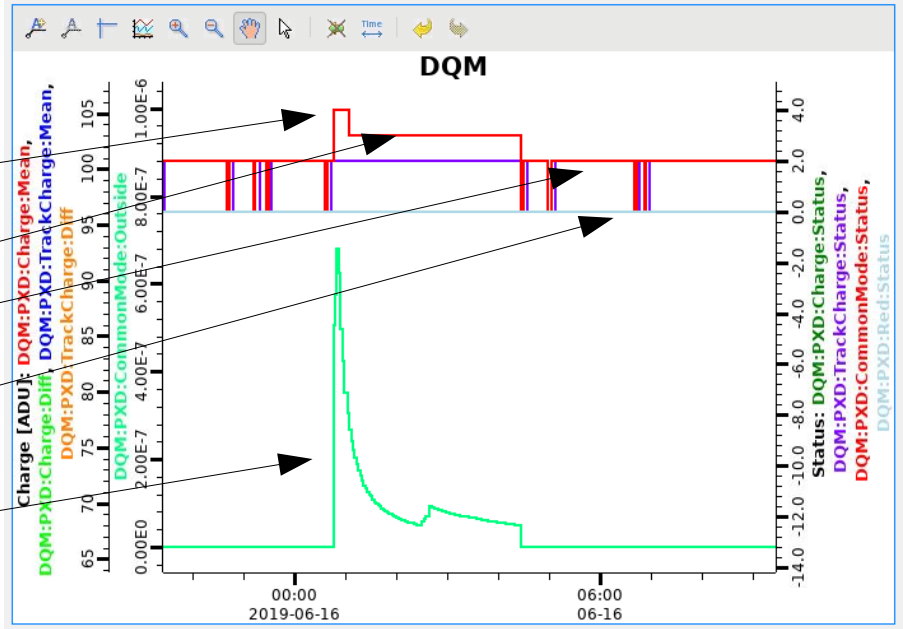
RED = CHECK!!!

YELLOW = check

GREEN = OK

GREY = empty

Value the decision is taken from



50% puzzle solved,
Checked on in and outgoing leg of track
→ algorithm needs change

More/other/better DQM tools will be added/available soon!
→ Monitoring Task Force

DHH Load Balancing

- Load balancing was missing, only ¼ of buffer capabilities on ONSEN and ¼ of bandwitdh to DAQ Event Builder
  - → Busy during HLT start up time & limits on DAQ tests
- Needed for full bandwidth!
  - Scheme on DHH, ONSEN and Event Builder need to be configured identical
- Changes
  - 1 → 4 outputs per DHC
  - 4 → 16 ONSEN selectors used
  - 4 → 16 EB inputs used
    - Each 4th event goes to one EB input
- (still ½ of the full system)
- ONSEN and EB scheme prepared and tested already in 2018
  - Worked out of the box, no surprises
- Recently tested without modules and w/o ROI selection

- Important: CR Shifter can only change between STANDBY and PEAK
  - Recovery need PXD experts
- Working as designed, but maybe not what is wanted
  - Injection inhibited while HV is in error (after over voltage protection shutdown) turning on/off or interlocked (cooling)
  - Removed TURN ON/OFF from state machine response (this is not what is intended…)
  - Automatic transition from ERROR to OFF
- Ongoing discussion …

- Observed several OVP in phase 3. → PXD shifter need to intervene as error state is blocking injections. Not clear yet how we can fit some (partly) automatic recovery in the current HVC scheme.

Backups / Details

Over Voltage Protection (OVP) Emergency Off

→ See Talk by M. Ritzert

- Triggered OVP in Nov 2018:
  current limits for clear-off to close => increased current limits
- Triggered OVP in April 2019:
  frequently: 1072, unit 80, but also other ones less frequent
  After update of DHI firmware / JTAG libraries
  reason still unclear
  => switched back to old version
- Still under investigation? (DESY long term test)
  https://agira.desy.de/browse/BIIPXDH-289
- How to handle PS when OVP happens:
  bring it into a save state, ramp up (recover)
  https://agira.desy.de/browse/BIIPXDH-259
- Retuning of gate-on voltages
  - Actual currents as current limit (1 week)

2019-04-26 22:53:55, H1012 ovp
2019-04-24 23:13:11, H1082 ovp
2019-04-26 18:10:33, H1082 ovp
2019-04-29 18:47:30, H1082 ovp
2019-03-29 04:31:56, H1032 ovp
2019-04-08 10:01:30, H1062 ovp
2019-04-24 11:13:48, H1072 ovp
2019-04-24 16:45:01, H1072 ovp
2019-04-27 17:37:56, H1072 ovp
2019-04-28 22:25:31, H1072 ovp
2019-04-29 09:38:33, H1072 ovp
2019-04-29 22:06:42, H1072 ovp
2019-04-30 17:58:45, H1072 ovp

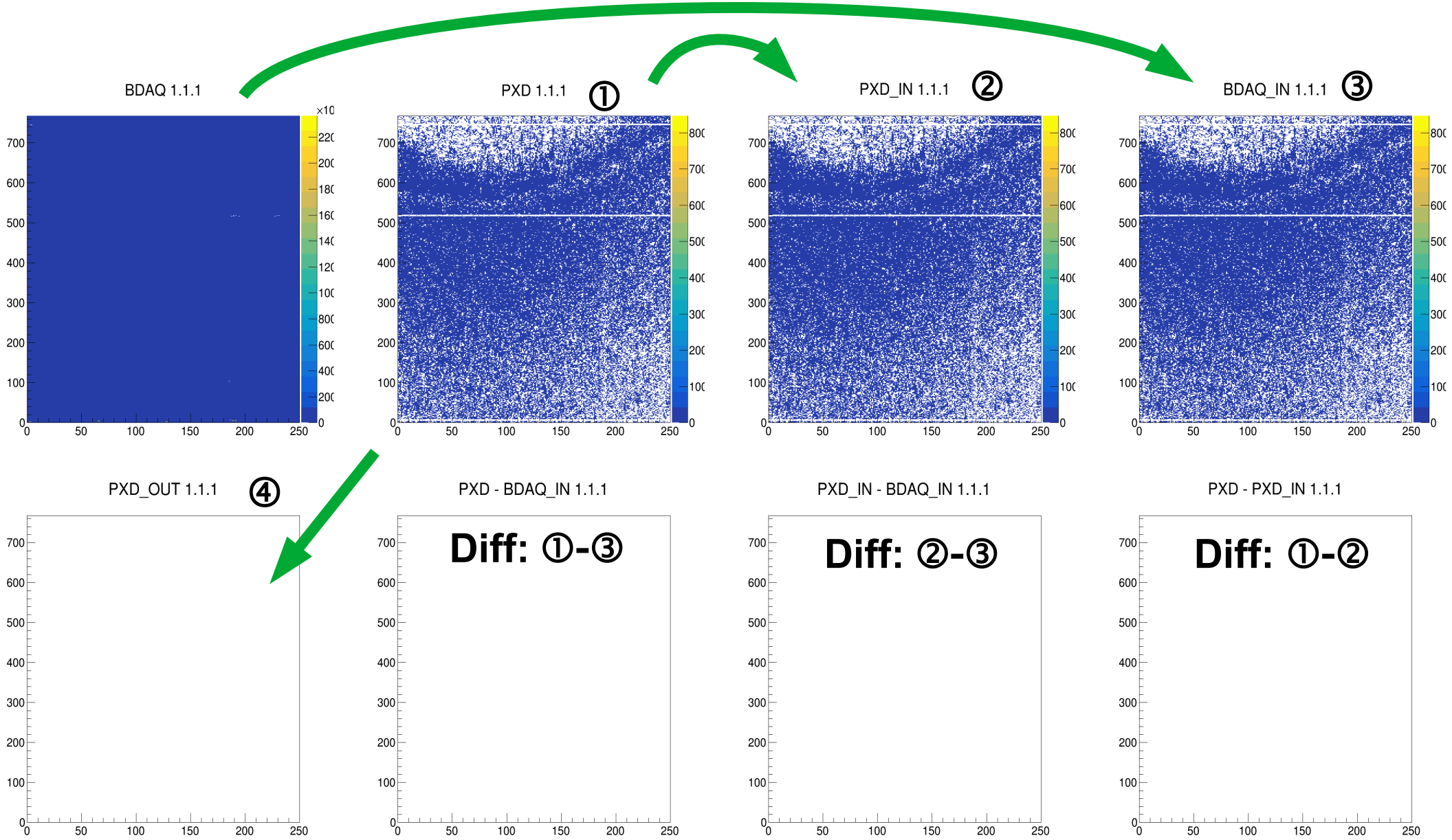
- Module emergency shutdown w/o reason due to OVP
  - Not observed for quiet some time (solved?), Reason not completely understood
- Re-evalute logic now because we want a faster emergency off

New!

- … and so for all other modules (see backup slides)
- No hits OUTSIDE of ROIs
- No extra hits inside ROIs
- No hit is missing inside ROI
- → <u>everything is selected/rejected as it should</u>
- **New! Full run 8/1092 has been analysed**
  - Basf2: post-release 4 (master)
  - From 5 file → 150 files = ~300 GB
  - From 91244 → 2.656.799 events
    - 2.248.818 could be used (84%)
    - In 407.981 events (15%) BonnDAQ data was incomplete (thus for these we see a difference!)

Emulate ROI Selection & Cross-Check

→ software emulation of ROI selection (on BonnDAQ and basf2 selected data)

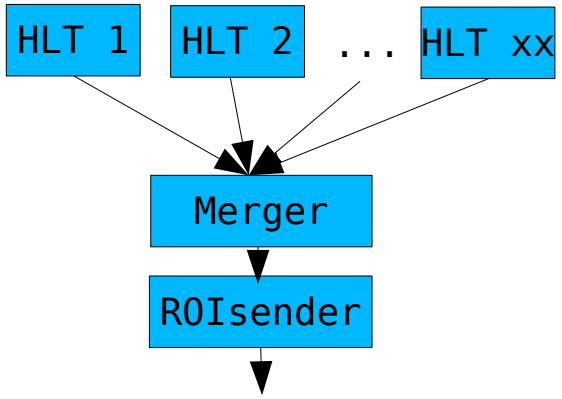


①②③ should be identical, ④ and all the differences should be empty

PXD-EB Interface

- Stable
- Few unexplained crashes on EB side
- Changes for ½ PXD and Load Balancing, different distributions schemes
  - Number of links from PXD to EB
  - Order in which events are distributed on the links
  - → configurable, tested and implemented from 2018 on (Simon, Yamagata, BS)
  - Verified again this summer
- NSM timeout issue (“PXD not included”)
- If some events are not coming from HLT→ ROISENDER → ONSEN, we will run out of sync at EB immediately.

HLT → PXD Interface



- "ROISENDER" and "MERGER"
- Stable
  - Lot of bug fixes and improvements before phase 3
  - Changes ahead: get away from mqueue
- NSM timeout issue ("PXD not included")
- If some events are not coming from HLT→ ROISENDER → ONSEN, we will run out of sync at EB immediately.

- HLT:
  - Events still got lost (not only dying workers)
  - Events still take too much time (>2min!)
  - Main impact: high trigger rate tests
  - Stale events from last run → now: better buffer flush before HLT STOP
    - (more a problem for EB, not so much for ONSEN)

(Trigger) Rate Tests

- Without DHH → 40kHz and more have been tested (already last year)
- Two explicit tests June 21st and June 25-26th
- Occupancy (0.052%=112 pixels); not saturate the link to EB (4*100MB/s max)
- Without event selection and ROI selection, the data rate at the output to EB is factor 30-50 higher than realistic case.
- run in global: null, poisson, HLT: passthrough & beam_reco
- 2us holdoff, 10kHz, 20kHz, 30kHz, 50kHz input trigger rate

(Trigger) Rate Test

- Main problem: Missing (trigger) events from HLT, memory is filling up by “forgottten” events
- Summary (after some fix was applied on HLT)
  - 30 kHz worked fine for DHH and ONSEN. HLT script passthrough (no processing at all)
  - 50 kHz is limited by DHH (most likely) to 35 kHz at 0.052% occupancy

  This run was performed with beam_reco_filter. Since HLT threads die and sometimes take > 200s for processing, PXD data in ONSEN memory get stuck. I think, 50 kHz and passthrough was not performed. But since we observe different causes of limiting factor, it's clear that this works as well up to 35 kHz. Hopefully HLT processes will not die such frequently after switch HLT handling to ZMQ. While running with PXD only, HLT load was quite low and not limiting factor of performance.

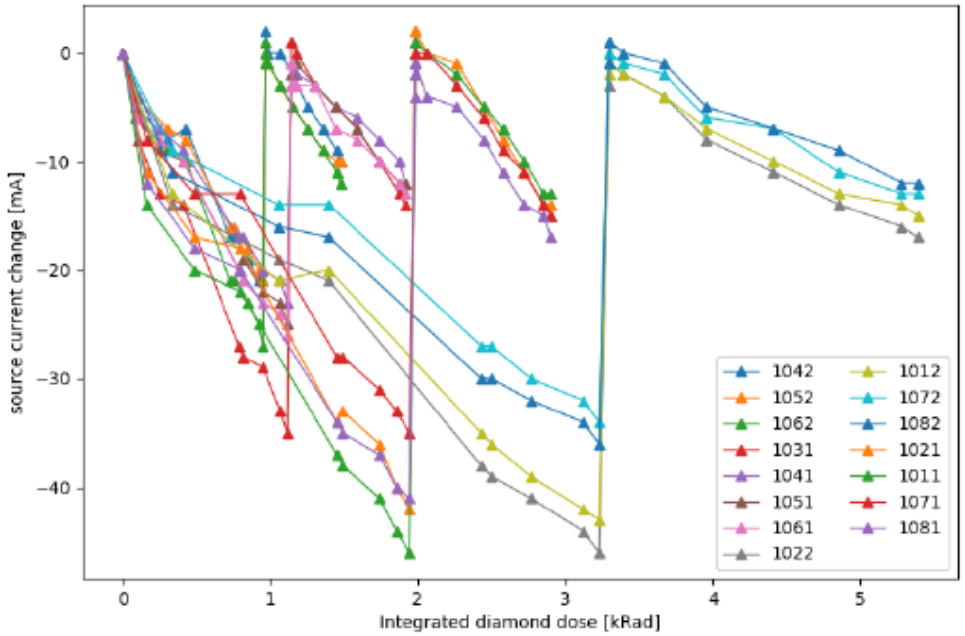
- Remember: the selected the occupancy depending on what you want to test → if we are dominated by back pressure from EB, we cannot go to higher rates. Realistic test would need load balancing and data reduction by 1/5 event and 1/10 ROI selection

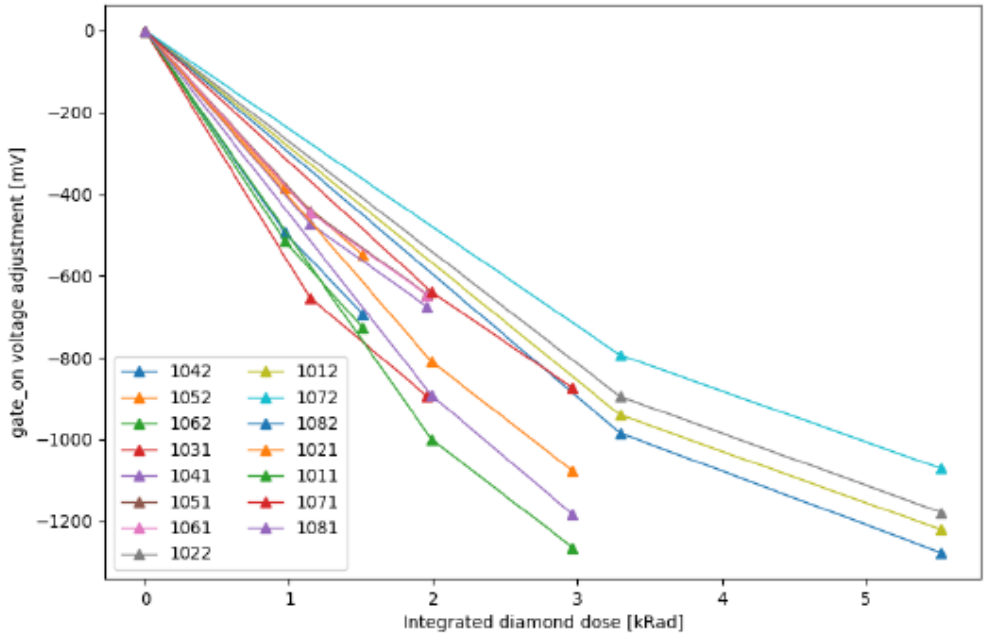
Radiation Dose

- Retuning of gate-on voltages
  - 08.04.2019, 09.05.2019, 20.05.2019
  - No defined strategy – when to do re-calibration

Source currents

[P1011] = 90	[P1012] = 75
[P1021] = 102	[P1022] = 110
[P1031] = 99	
[P1041] = 96	[P1042] = 98
[P1051] = 107	[P1052] = 101
[P1061] = 109	[P1062] = 112
[P1071] = 102	[P1072] = 85
[P1081] = 90	[P1082] = 68
[P2041] = 80	[P2042] = 73
[P2051] = 85	[P2052] = 55





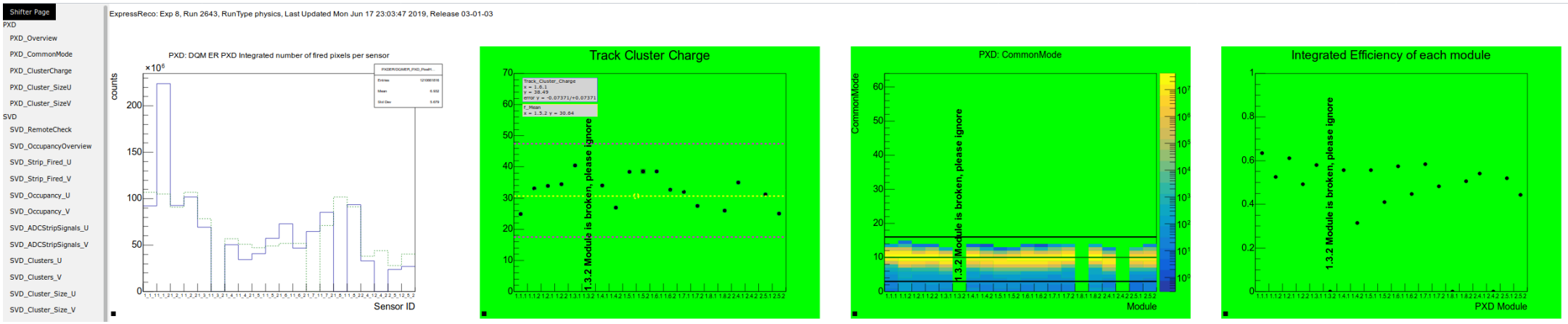
Solved Problems

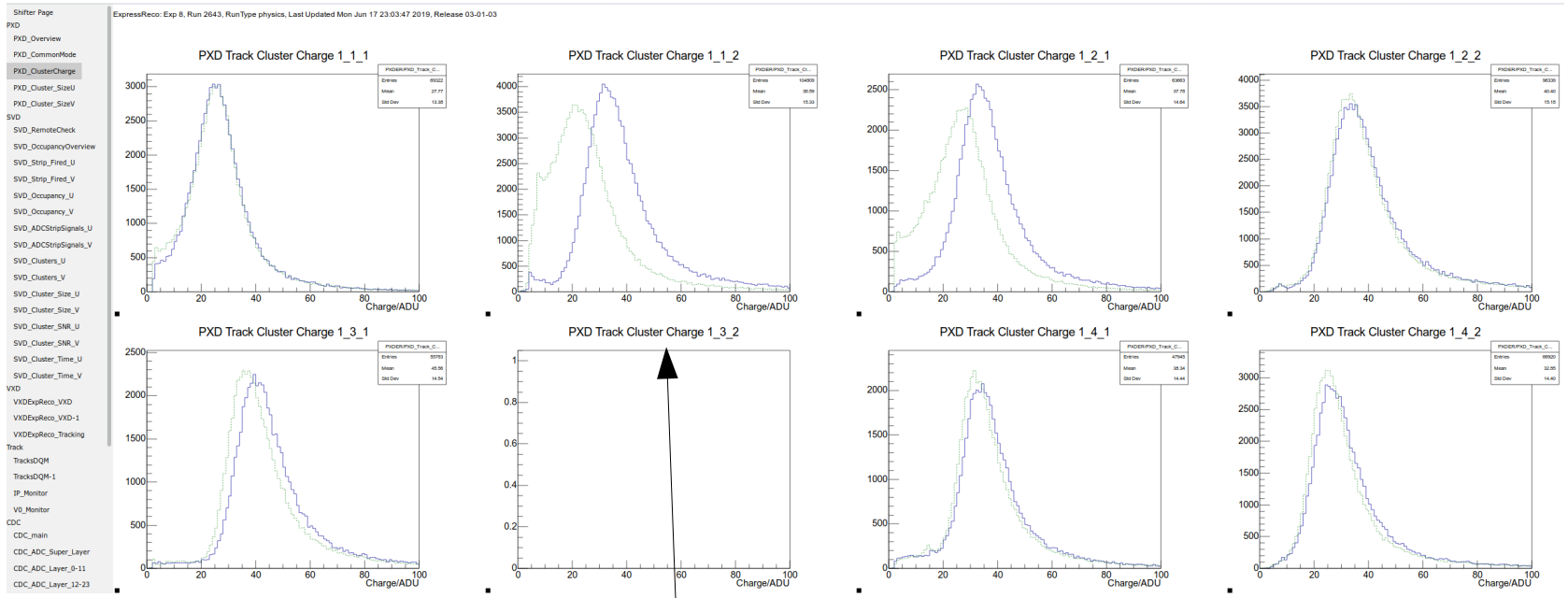
- Trigger delay, DHP latency
  - **We lost 25% efficiency in early phase 3**
  - need physics trigger and knowledge of first gate
- Occupancy calculation (was data rate on DHH → now real pixels on ONSEN)
- Parallel ramp-up (CPU limited, Log message flood)
- JTAG, pedestal upload & verify
- Workaround for “DHP last gate bug” (was done wrongly for some time)
  - Now fire 2 pixels permanent in second last row in each DHP
- Lot of H1051 (DHI50) data drop fixed by FW update on DHI

“Occupancy Drops”

- No data is received from (at least) one DHP anymore, thus occupancy for the module shows a sudden drop.
- DHP link is still there, no data arriving or data arrives with wrong frame ID and therefore no taken into account for “event building” on DHE.
- Reason:
  - Not completely clear. DHP issue, DHP-DHE de-sync?
- Triggered by:
  - Large occupancy events within a short time intervall, DHP fifo full (CM=63)
  - HER injection, ‘dirty bunch’
- Workaround:
  - Extend trigger veto after injection, thus we do not read out DHP memory
- Long term:
  - Reset DHP during each injection?
  - Gated Mode

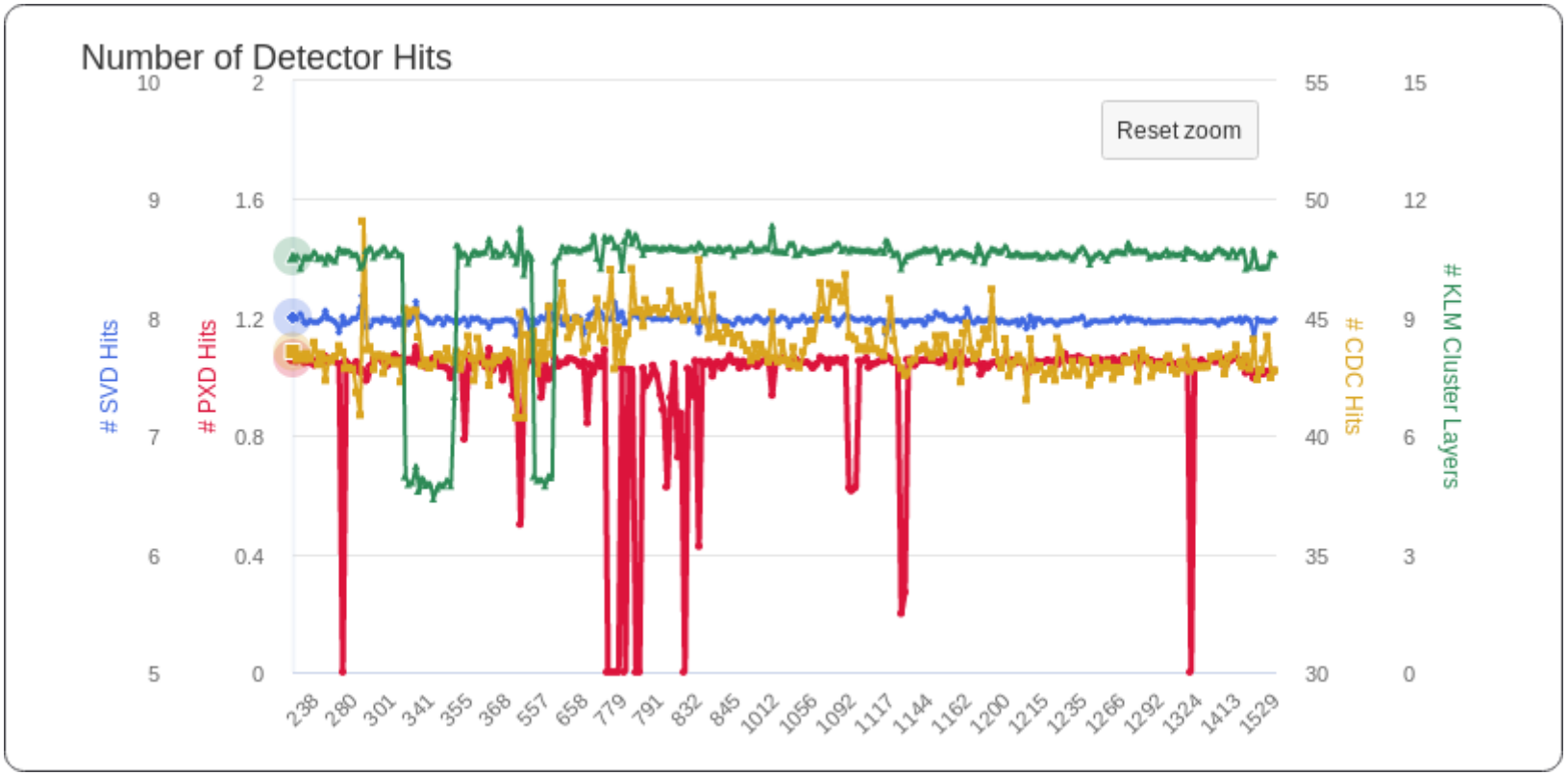
Online DQM Plots & Flags





Optimized since ref was taken

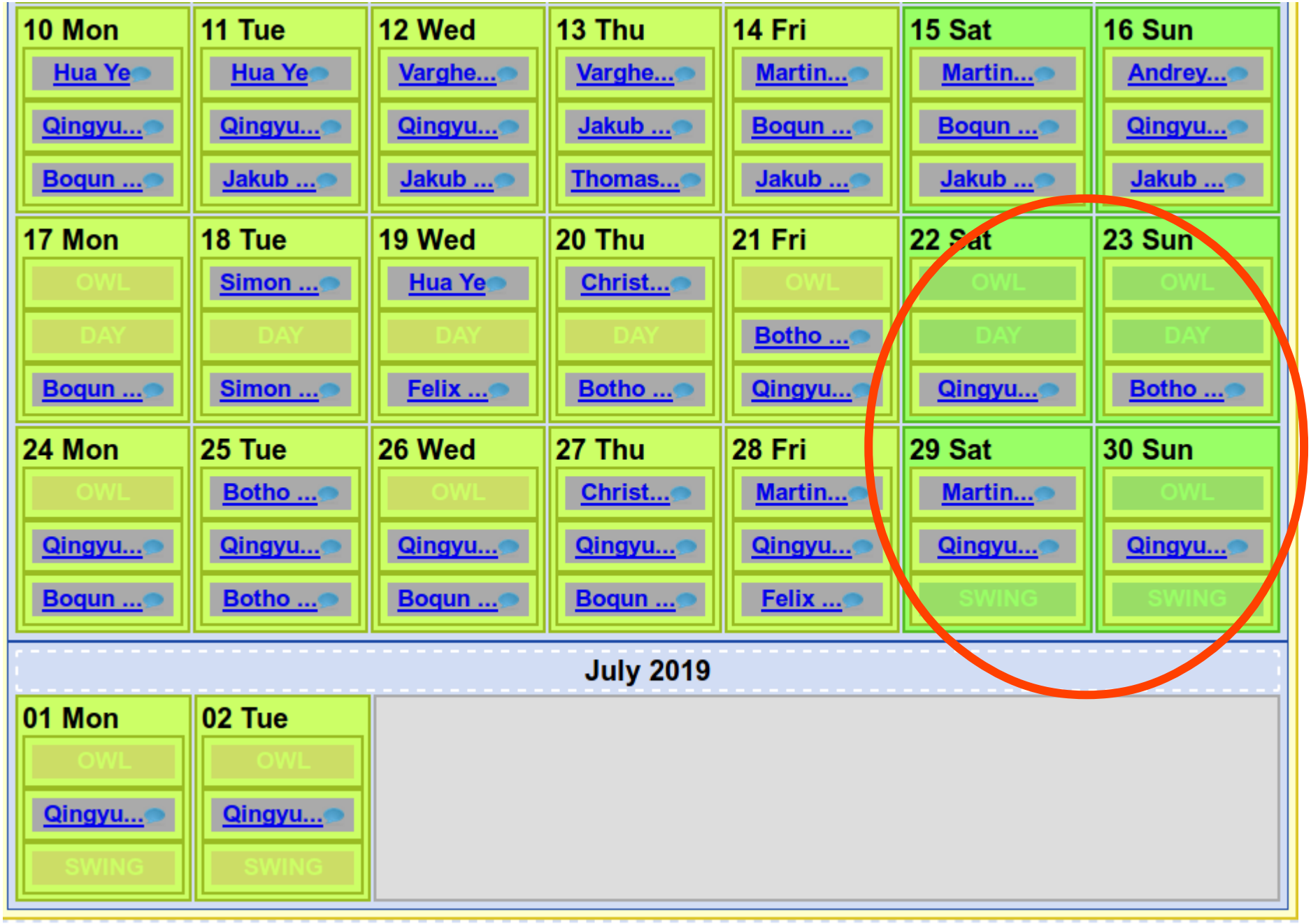
- Limits for turning Green, Yellow, Red to be discussed and adjusted.
- Not so clear if we really can conclude sensor and data quality


Number of Detector Hits
Reset zoom
SVD Hits
PXD Hits
CDC Hits
KLM Cluster Layers
10
9
8
7
6
5
2
1.6
1.2
0.8
0.4
0
55
50
45
40
35
30
15
12
9
6
3
0
238
280
301
341
355
368
557
658
779
791
832
845
1012
1056
1092
1117
1144
1162
1200
1215
1235
1266
1292
1324
1413
1529

Shifter, CSS

- Shifting with similar issues as in Phase 2
  - Most shifts taken by “local” experts, weekend and owl shifts lack coverage
  - Backup expert is needed for real trouble!
- Reachability! (telephone or voip mandatory)
- GUIs mostly stable, some minor improvements (FW changes, IOC changes, new features improvements)
- Manual: Hard to keep up to date with new developments/issues
- Procedures for calibration (pedestal taking) not clear
  - (covered by technical issues)
- Elog, shift reports, jira, iterations, now improved
- Shifter should qualify each run on Confluence (→ request from mgmt)

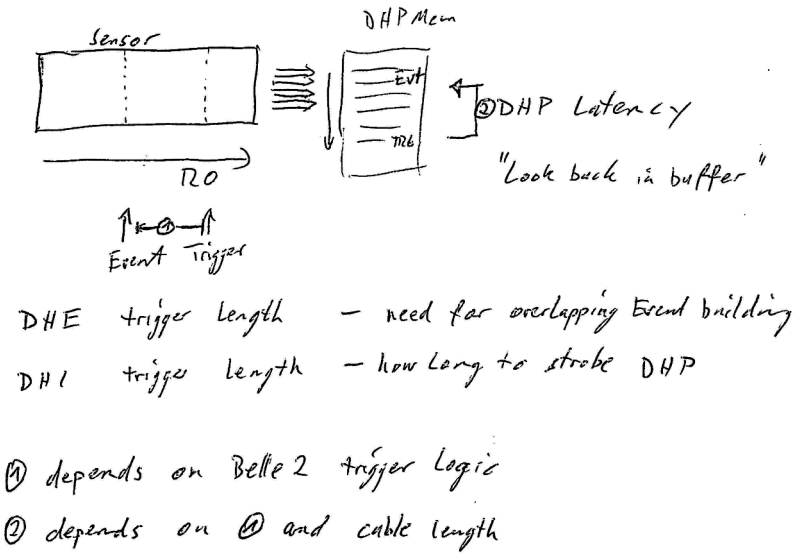
Shift Coverage – Insufficient



- Module optimization (tuning of HV, bulk, clear off), “voltage sweep”, hard during data taking
  - Even if we automate this, we need to find a better way in the future
- DHC load balancing → summer shutdown (we need the buffer memory on ONSEN!)
- Gated Mode → this week?
- Reorder Input to DHC for ROI processing (FW or opt. Switch)
- DATCON (included for few runs for testing)
- HV Control (in case of OVP etc)
  - Move to save state which does not block injection → jira tickets
  - → recovery of single modules
  - Is HV control scheme sufficient to map PXD states for physics ready and injection blocking? → discussion with SC group

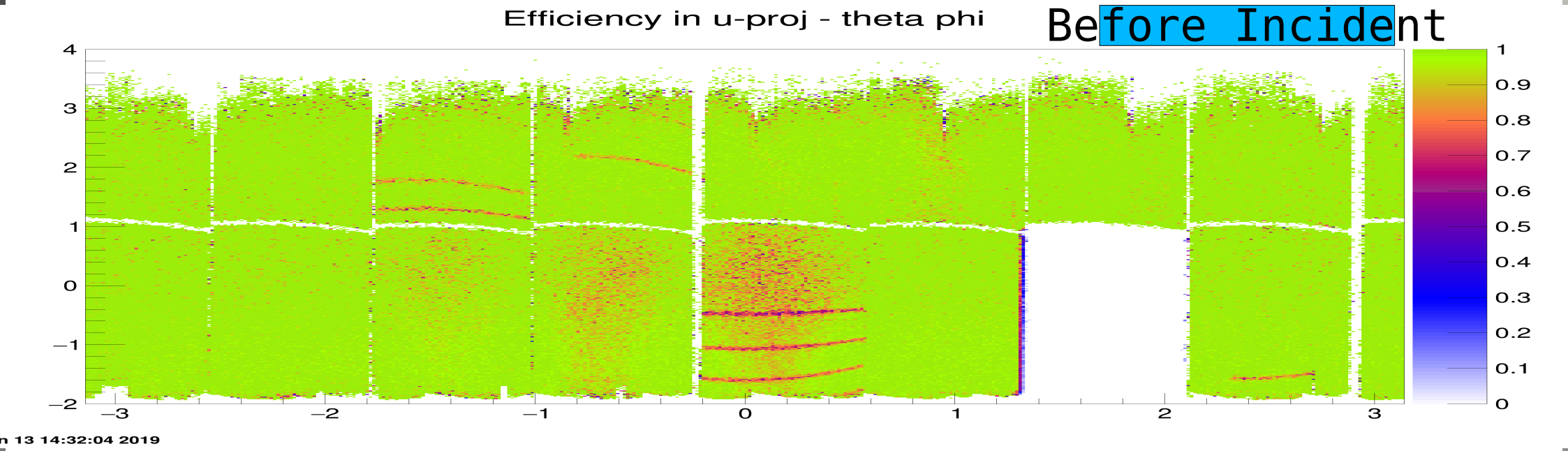
PXD Trigger "delay"

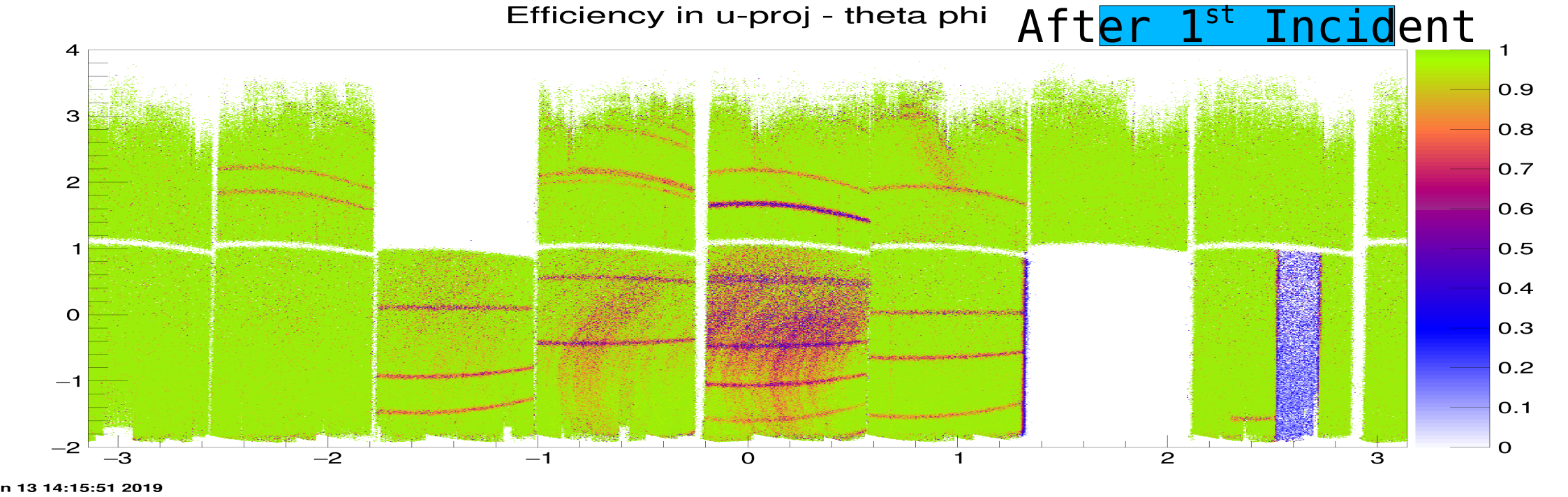
- PXD trigger consists mainly on one parameter:
  - DHP latency (look back in time in DHP memory)
  - 1 gate ≙ ~100ns
- Readout length depends on two parameters
  - DHI trigger length (strobe length to DHP)
  - DHE trigger length (used by the FW to build event)
- Latency depends on the trigger latency and timing of Belle2
  - DHP latency was ~50 in Phase2
  - Was set to 5 in early Phase3?
    - 45 gates off → ~23% (=45/192) loss of efficiency!
- Finding correct timing only possible with "real" physic triggers (but low stat with cosmics)
  - Need correct trigger gate (timing pixels) → can tune "Start Gate emulator" on DHE, x-check
  - Need to know the readout frame the pixel is firing in (timing pixels), determine when next readout frame starts (per DHP!). Information is lost in overlapping firmware due to event building



- PXD stopped run for two main reasons:
  - DHH did not send data anymore (finally BUSY)
  - DHH send too many corrupted data
  - HLT did not send Triggers* (anymore)
  - HLT did not send Triggers for too many events at the beginning of a run (overwrite)
    - → memory occupancy at end of run
  - Misconfiguration or -operation (after pedestal taking, ioc crash, operator error)
- * this could happened if the HLT did not notice that PXD was included into run (NSM SC timeout!)
  - NSM timeout of EB (have observed that before…)
- EB2 crash → link to ONSEN drop → PXD ERROR

Comparison


Efficiency in u-proj - theta phi
Before Incident
n 13 14:32:04 2019


Efficiency in u-proj - theta phi
After 1st Incident
n 13 14:15:51 2019