Stato della preparazione per il Run 2017: Pixel e Strip tracker

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Outline

- Introduction: challenges to the Tracker in 2017
- New pixel detector
  - Current status of the phase-1 pixel detector
  - Checkout procedure and calibrations
  - Calibration with beams
  - Status of the offline software
  - Interesting tasks / projects within phase-1 pixel detector
- Strip detector
  - Operations
  - Hit efficiency and resolution
  - Calibration
  - Simulation plans
- Alignment in 2017
- Operations in 2017
- Conclusions

The challenges ahead to the Tracker

2016 data taking: record instantaneous luminosity and very large integrated luminosity:

- peak inst. lumi. ~1.5×10^{34} $cm^{-2}s^{-1}$, peak PU ~48;
- 40 fb^{-1} collected in 2016, exceeds the Run1 + 2015 integrated luminosity;
  - Increase of the pixel ROC analog current;
  - sensor ageing: change of sensor depletion voltage and increase of leakage current;
  - loss of gain of the analog opto-hybrid lasers;
- big detector occupancy: up to 10^{-3} in Pixel, ~3.5% in TIB, ~2.5% in TOB at PU ~40-50;
  - Pixel detector links and FED bandwidth limit: PU~52 at 100kHz L1 rate
    - FRL clock frequency change helped to avoid a lower limit in 2016
  - no bandwidth limit from Strip readout,
  - observed lumi-dependent dynamic inefficiencies in pixel (expected) and in strip (unexpected but eventually fixed):

2017 data taking: expected the same integrated luminosity to be collected;

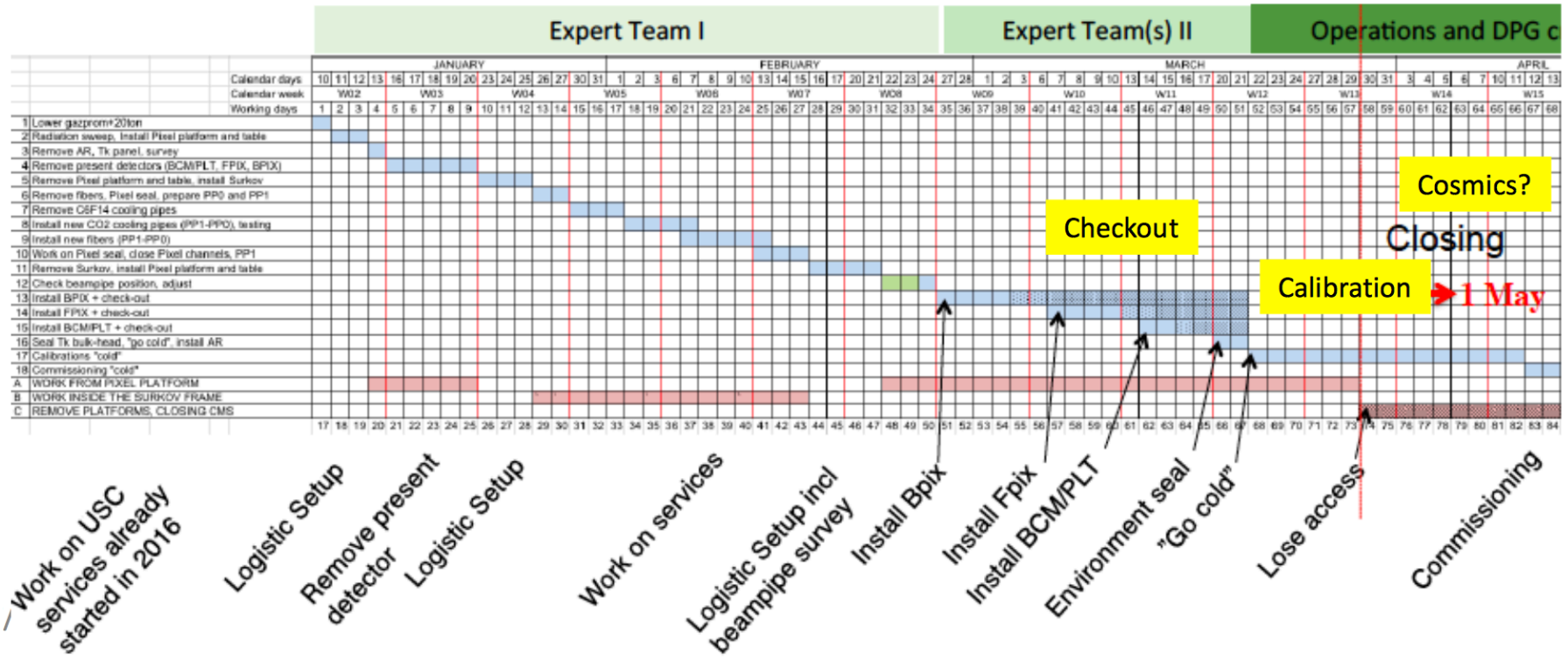
- peak values higher than those in 2016: inst. lumi. ~1.9×10^{34} $cm^{-2}s^{-1}$, peak PU ~55;
- strip detector will get the same amount of dose of 2016, almost doubling the total collected dose;

2017 run: new pixel detector

New pixel detector designed to cope with $2*10^{34}$ cm^{-2} s^{-1} and PU~100 with safety margin

- dynamic inefficiency below 2% in all the layers
- detector to FED links ok up to PU~120 at 100 kHz
- FED data rate ~4-5 Gbps at PU~130: 10 Gbps links are foreseen

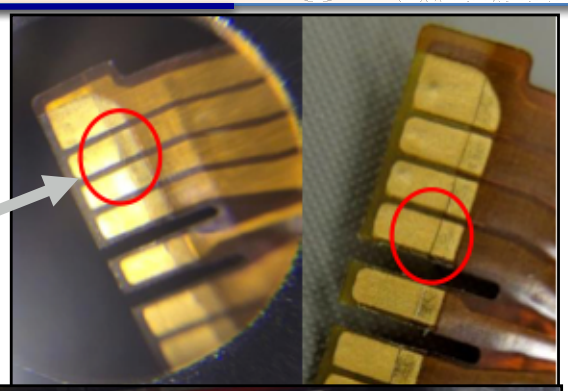
- INFN contributed to the construction with 180 modules of layer 3 and will provide a small team of people to work on the detector calibration

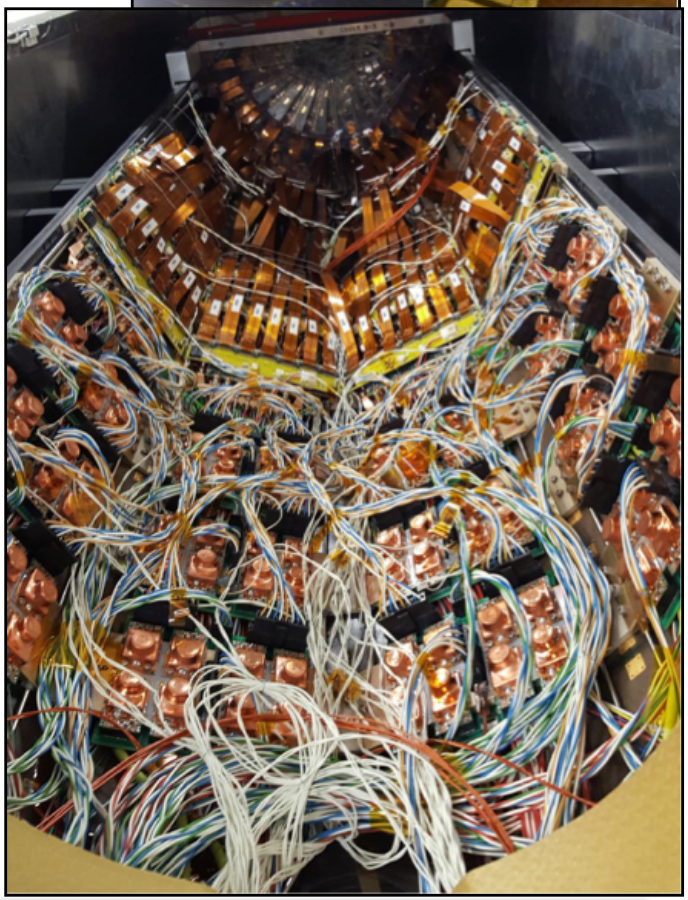


Current status of the phase-1 pixel detector

FPix

- FPiX is entirely at CERN
- Cable cracking issue to be addressed
  - Develop where the Kapton cover ends, near the connector pads
  - Requires significant force and bending to crack gold plating / aluminum
  - Loose signal / power transmission
  - Root cause of the cable cracking unclear (insertion, connection, Kapton protection, bad cable batch, combination of … ?)
  - Working on a test to identify these cables electrically
  - We have sufficient time / spares for repairs





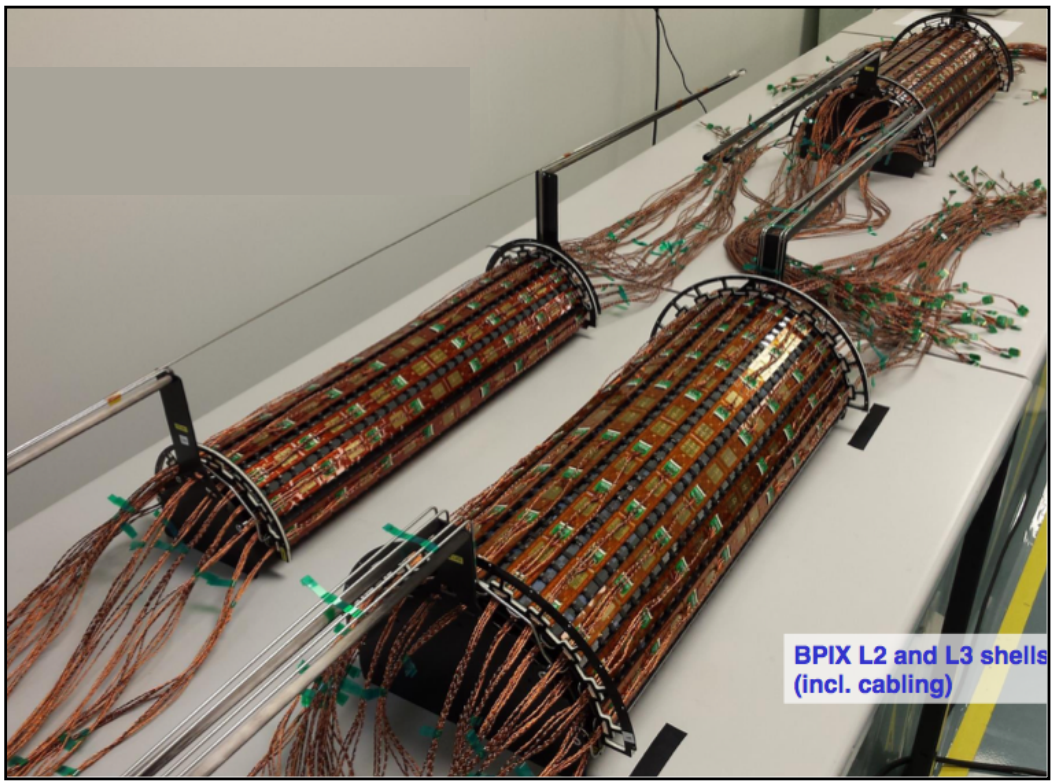
Half Cylinder fully assembled

Current status of the phase-1 pixel detector

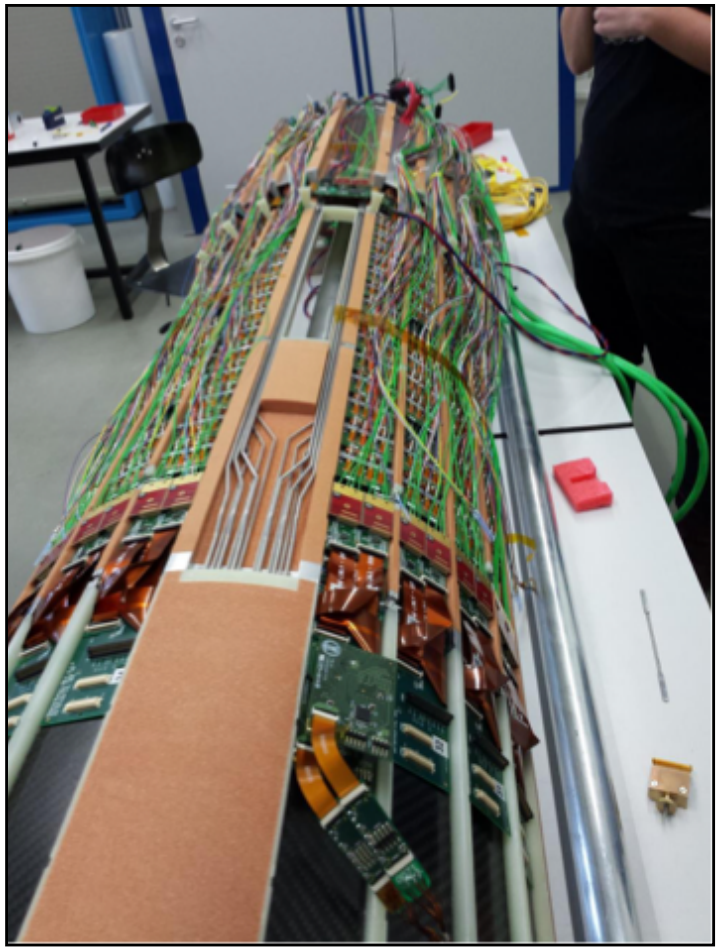
BPix

- All BPIX Half Shells are fully assembled and tested
- Merging of L4 + L3 + L2 + L1 shells ongoing / done
- Merging BPix with Service Tube end in wk5 / 2107 (February)
- Transport to P5 in wk 6 / 2017 (mid February)

L2 and L3 Half Shells fully assembled



Service Tube



Current status of the phase-1 pixel detector

DAQ

- Coming along, vey useful pilot blade for development / commissioning
- Heavily in use in test set-ups (FPix@CERN and BPix@Univ. Zurich)
- Now concentrating on commissioning aspects (speed)
- Continuing FED commissioning & rate testing using 8 FEDs in a crate at P5 connected to CMS central DAQ
- Hardware (crate installation, network connection, TCDS and C-DAQ cables, install and dress / connect fibres from PP1 to PP2 and from PP2 to FEDs and FECs, check optical connections) will occur in February / March

Pixel DAQ underwent to major changes with respect to phase-0. It will require debugging, development, experts taking care of the changes and upgrades

P5 Installation and Services

- CO_2 plant inclusive transfer lines in place and commissioned
- Dry Gas system in place
- Power system - all components in hand - exchange early 2017
- Installation procedure clear and has been rehearsed several times
- Only simple tests will be performed, no advanced calibrations ➜ see next slides

Checkout before insertion in CMS

BPix quick check at P5 before insertion (only simple tests will be performed, no advanced calibrations):

- Connect cooling ➜ check integrity
- Connect Power Supply ➜ observe consumption
- Connect DAQ ➜ verify can talk to all detector components, *i.e.* modules, POH, DOH, DELAY25, PLL, CCU
  - Run DELAY25 ➜ check operability of DELAY25, PLL, DOHs, TBMs
  - Run TBMPLL ➜ checks operability of POHs and TBMs
  - If a lot of time is available we can run PixelAlive

Checkout carried on by a small crew of experts

Same procedure, both for BPix and FPix, will be used during the "fast checkout", right after insertion in CMS (before giving "ok" to CMS for closing up)

Checkout after insertion in CMS

Wait for target temperature stabilisation (-20° C)

Sequence of calibrations:

- **Delay25:** test / ensure proper data trasmission
- **POH bias:** measure / tune light yield from each POH and look at the channel mapping
- Adjust **TBM-phases** (TBM PLL) for the 400 MHz digital readout
- **CalDel:** see if basic settings are ok (e.g. WBC)
- **VcThr vs CalDel:** gives a good working point / check for thresholds, double check WBC
- **PixelAlive:** we can see the state of every pixel on each Read Out Chip (ROC)
- **SCurves:** we measure the threshold of every pixel of each ROC (tests trim settings)
- **BumpBonding tests:** we see the state of the connections of the ROC to the sensor

More extensive calibrations:

- **Iana read-back:** verify analog current consumption
- **Pulse height optimisation:** take advantage of all our bits
- **Gain calibration**
- **Threshold minimisation**
- More extensive TBM phases (*i.e.* include **ROC delays**)

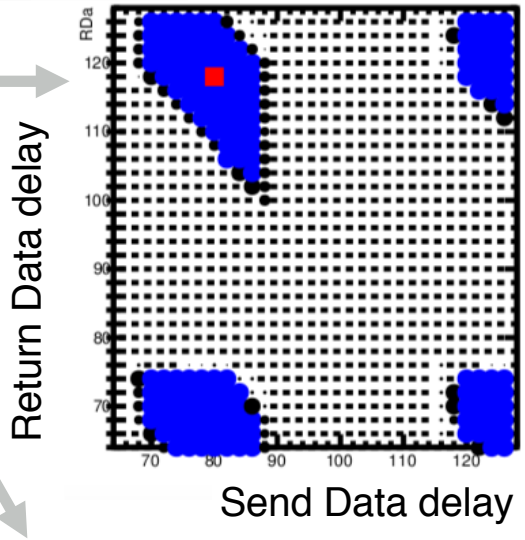
Checkout carried on by experts

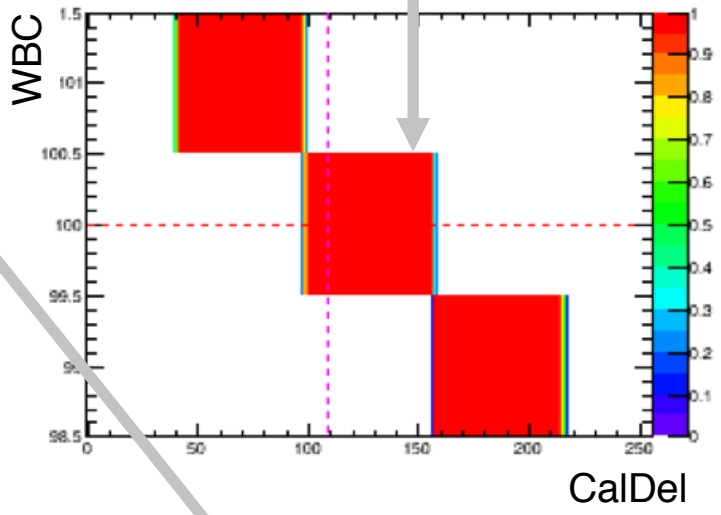
We do not plan shift work, but we will establish a system where 1-2 people start calibrations very early in the morning (6:00-7:00) and another 1-2 people stay until late at night (23:00-24:00)
Foreseen 11 days in total

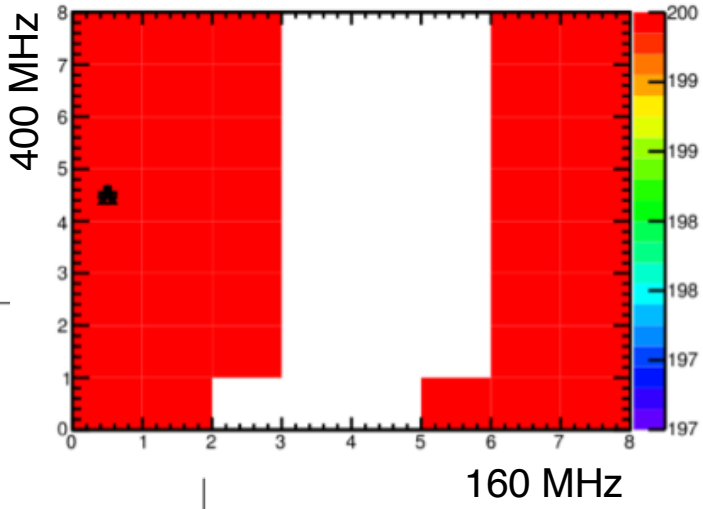
Checkout after insertion in CMS

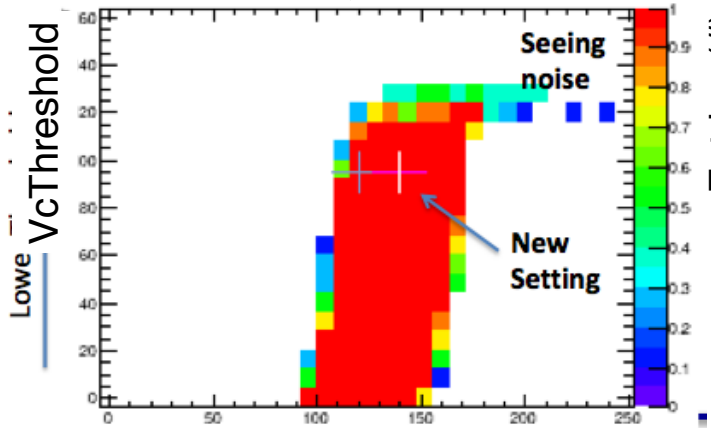
Sequence of calibrations:

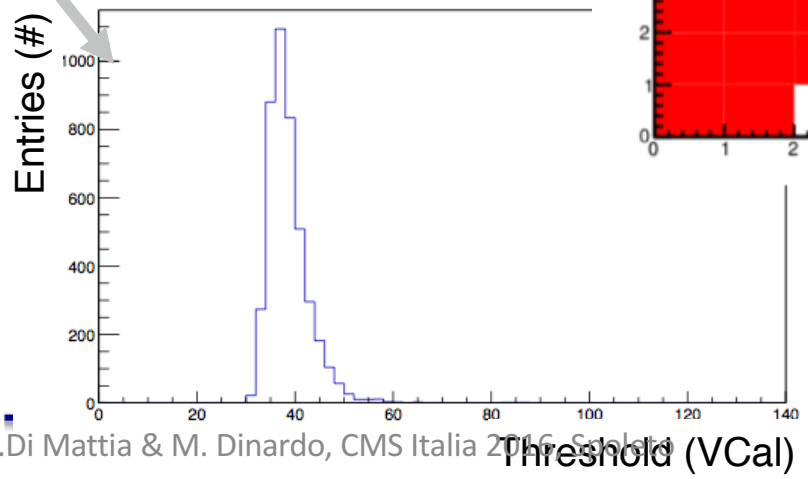
- **Delay25:** test / ensure proper data trasmission
- Adjust **TBM-phases** (TBM PLL) for the 400 MHz digital readout
- **CalDel:** see if basic settings are ok (e.g. WBC)
- **VcThr vs CalDel:** gives a good working point / check for thresholds
- **Threshold minimisation**







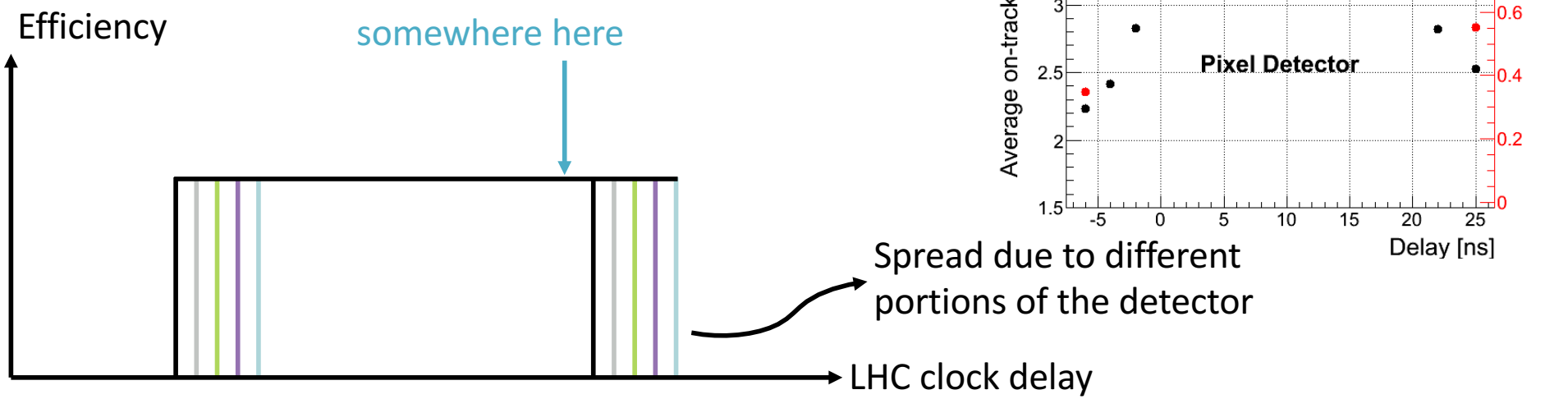




Calibration with beam

- **Clock phase scan:** optimise efficiency for low and high pulse height
- **Lorentz-angle and Template (hit reconstruction) calibration:** not critical. We will start we new, un-irradiated, sensors, so in principle we know what parameters to use, however we will be working at a new temperature, some small adjustments might be needed

cosmic data may help here!

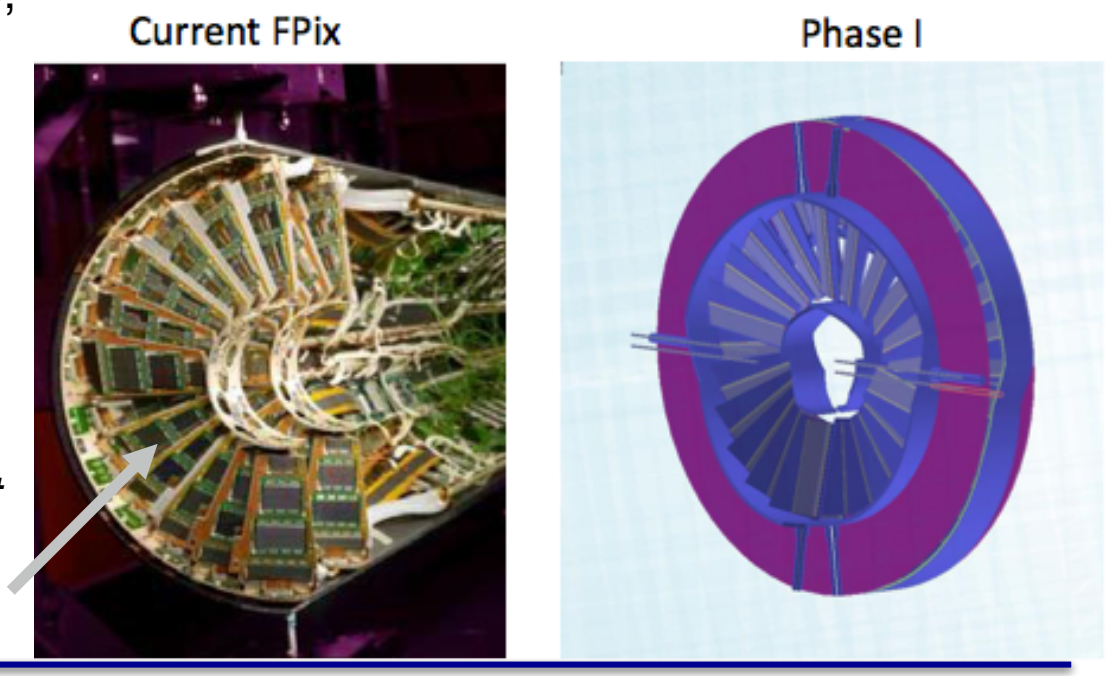


Status of the offline software

Hit Efficiency, Resolution, Lorentz Angle, Gain Calibrations, etc…:

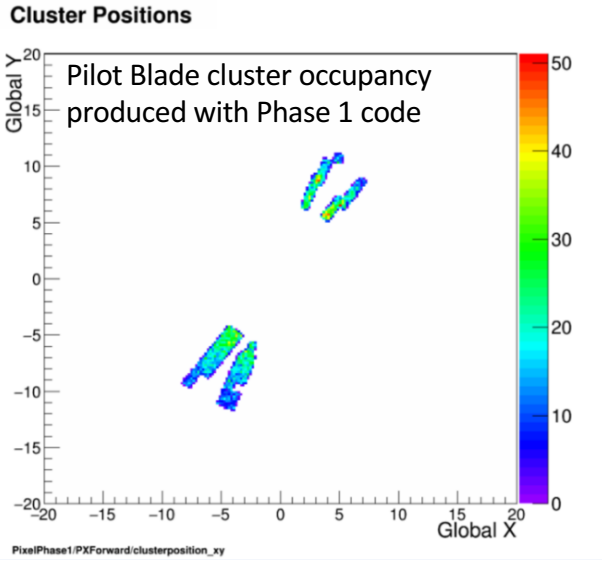
- **BPix:** geometry is very similar, only have one additional layer, code is up-to-date;
- **FPix:** geometry is very different, it requires some modifications in some (Non-CMSSW) code;
- **DB tools:** Loaders/Readers are in excellent shape for Phase-1;
- **Analysis tools (Hit Efficiency/Resolution/Lorentz Angle):** in general there is good progress and we aimed to move to geometry independent code;
- **RecHit to SimHit comparison tool:** up to date and used to compare the generic/template reco performance;
- **Gain Calibration tool:** the code will require some minor changes (mostly scripting) mainly due to different FED numbering

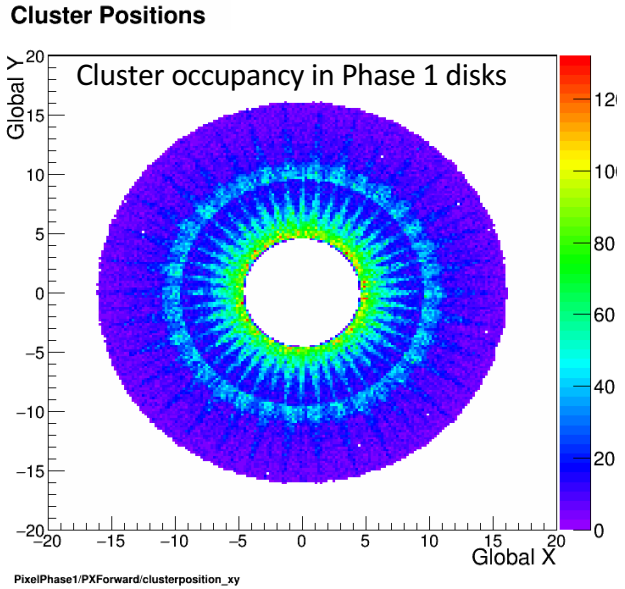
Geometry difference between current (phase-0) and phase-1 FPix



Pixel Phase 1 DQM: status and plans

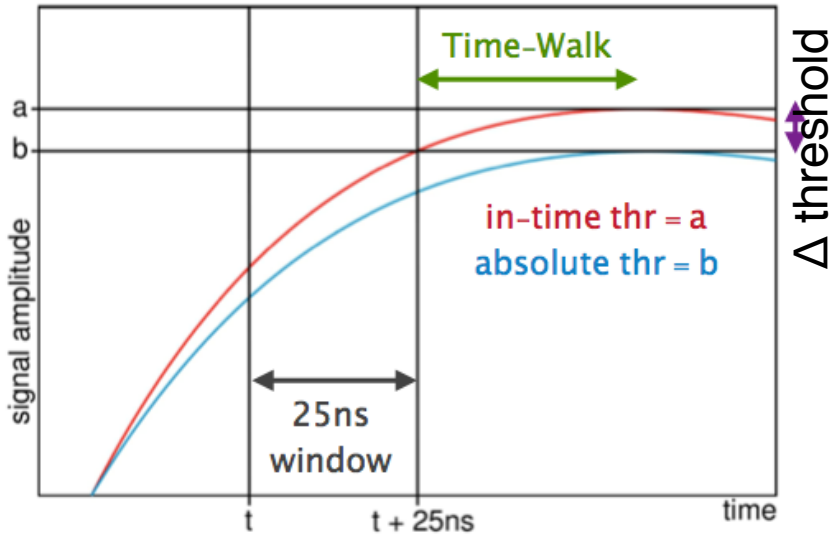
- The project is in a well advanced state, fully integrated in 8_1_X and 9_0_X cycles
  - Most of the nedded plots are available and the code has been extensively tested on MC and real data
    - **used successfully for Pilot Blade timing!**
  - for more details see:
    https://indico.cern.ch/event/573683/contributions/2327526/
    https://indico.cern.ch/event/536892/contributions/2391244/
- Problem: **"active" contributors are only a few**
  - We need manpower and documentation to facilitate newcomers
- To do (before March 2017):
  - Introduce Quality Test monitoring and "Summary Plots"
  - Adapt FED error monitoring to the new digital read-out
  - Introduce in a "standard" Workspace in the GUI and define the layout for the shifters

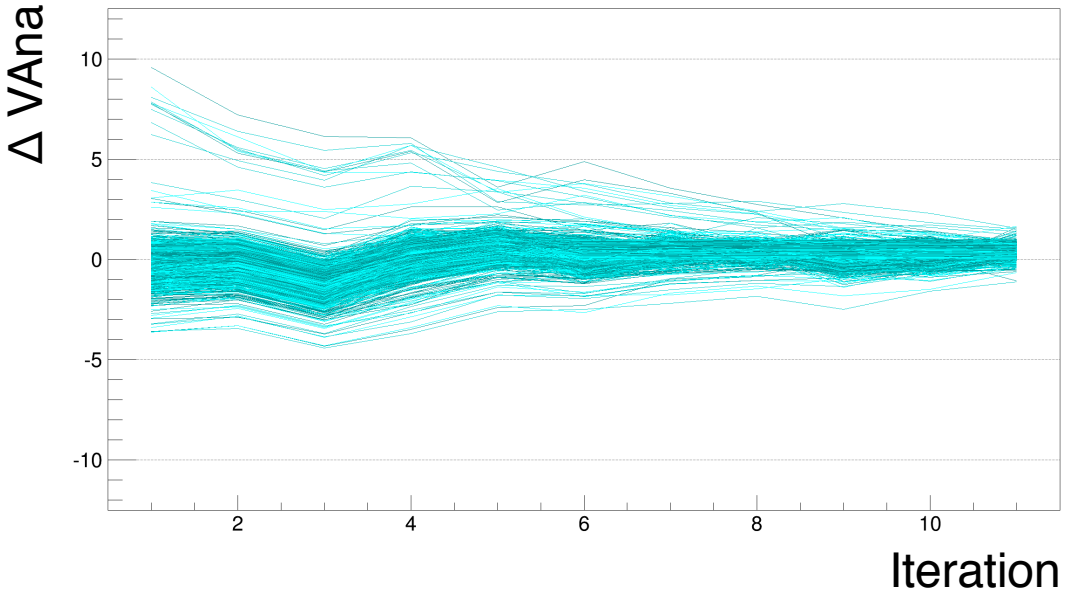




Interesting tasks / projects within phase-1 pixel detector

- Ameliorate / upgrade and maybe rethink the scripts for the analog current optimisation and for the threshold minimisation (they have been inherited from phase-0 but they need amelioration, make them more robust and for what concern the analog current optimisation we might need to rethink at the procedure)





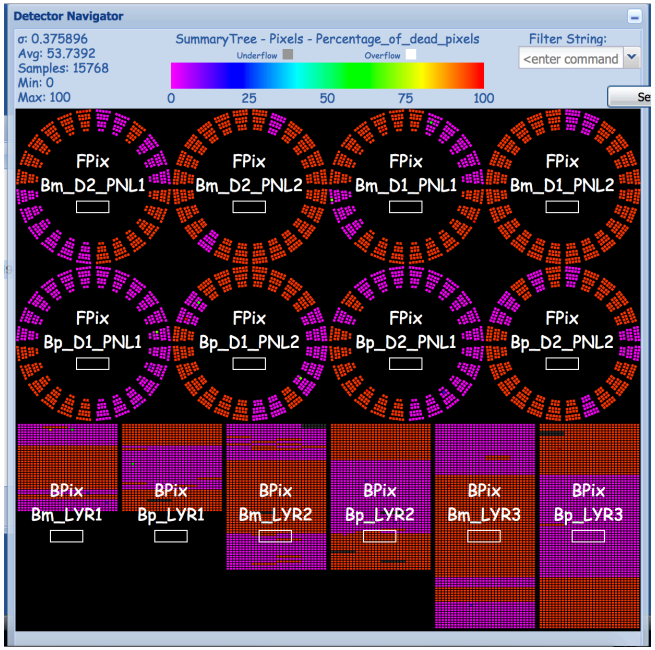
- Develop a FED supervisor for to detect ROC SEUs by spying the data. Right now ROCs are reprogrammed every ~2 pb^{-1}, it would be better (also to reduce the pixel dead time) to detect the ROC SEUs in a mode direct way

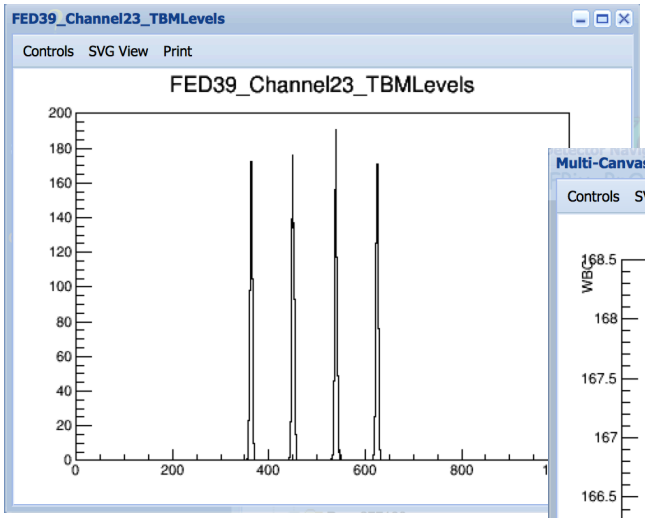
- Thanks to the fact that FEDs and FECs sit in the same crate, we could implement a system for the reprogramming of the pixel detector in a selective way, i.e. reprogram only the portion of the detector that needs it (to reduce the pixel dead time)

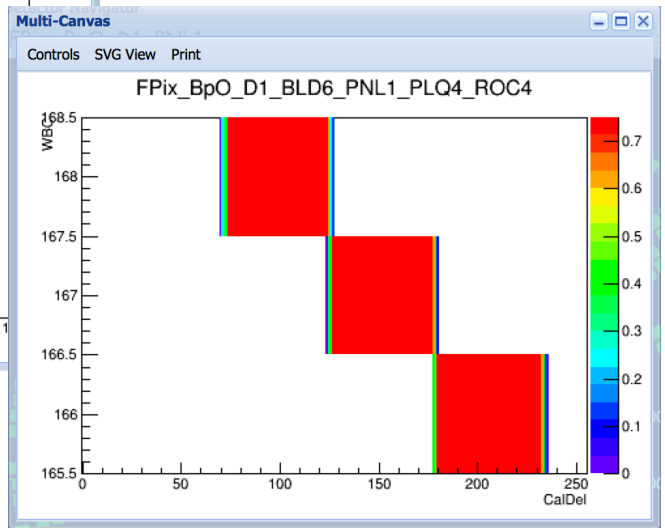
Interesting tasks / projects within phase-1 pixel detector

- Develop calibration readout through the same readout path used for data taking. Right now the readout of the calibrations is performed throughout the VME bus (or u-TCA bus), which is much slower than the data readout. This would speed up the calibrations by a lot (think of calibrations like PixelAlive or SCurves that takes hours (worst is GainCalibration with ~8 hours))

- Ameliorate the application called **HistoViewer** which is meant to visualise on a nice web interface the output of the calibrations







- We need to develop the save/read-back of the configuration from database !

Strip operations

Data losses due to Strip detector in 2016: ~536 pb^{-1} (~2% of the luminosity)

- strip data-taking inefficiencies: ~220 pb^{-1}
- useless data due to Strip detector not included in global run while fixing problems:316 pb^{-1}
- but NO evidence of systematic problems;

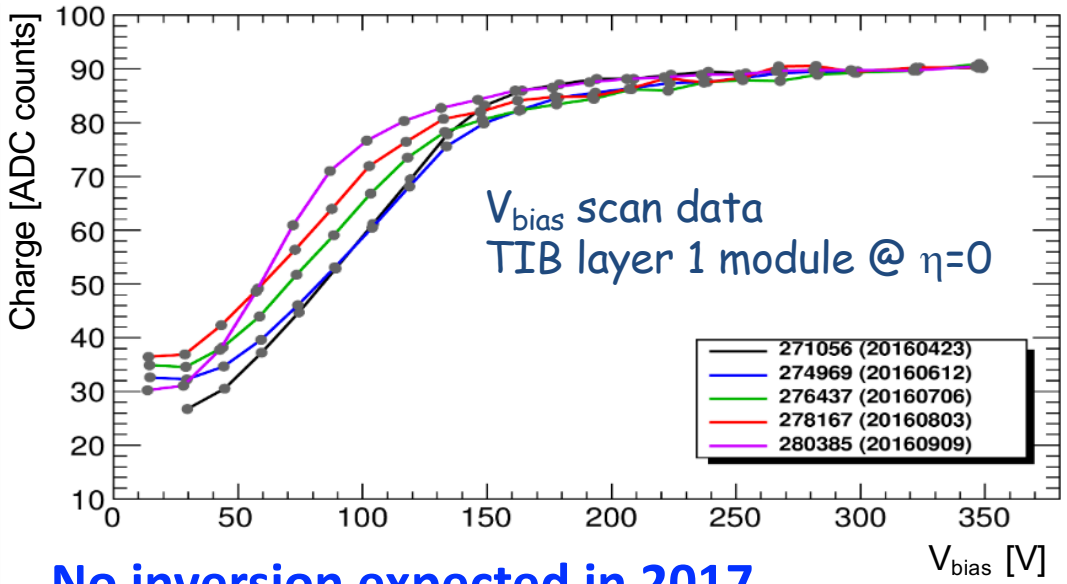
Very well established operation procedures and experts team

- Several people involved in the daily activities
  - Strip DOC + on-call DAQ , DCS, DQM, Offline shifters (x3)
  - Operation and DPG managers, pixel and strip crews for detector tuning
- Daily detector monitoring
  - Power supply parameters, detector temperatures, humidity, cooling and dry air plant parameters;
- Periodic detector retuning
  - Strip tracker pedestal and noise for zero suppression (4 times) and AOH parameters (3 times)

Lesson learned from 2016 and issues to be fixed for 2017

- understanding the noise in inner rings of TID/TEC during cosmic runs;
- systematic monitor the instability of control ring where a CCU is skipped;
- better use of the offline DPG analyses / expertise to reduce the workload:
  - early detection of problematic channels, avoid to upload wrong noise measurement

Monitoring the strip sensor ageing



April 2016 → September 2016

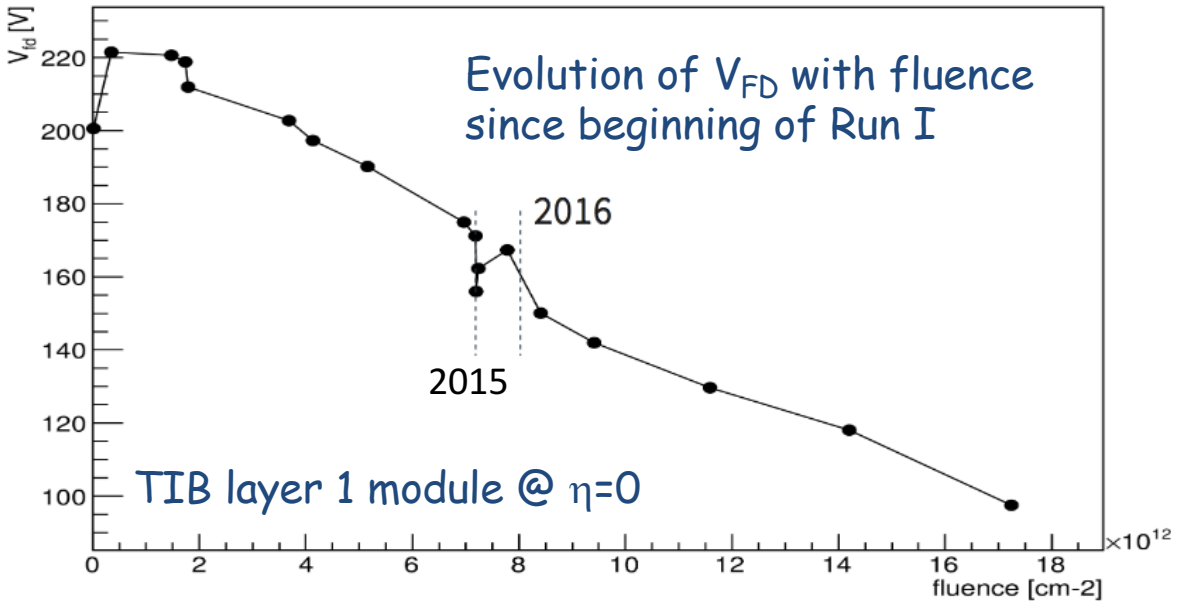
- Small (on few PU) bias scan performed monthly, complete scan done twice per data taking year;
- Ageing process proceed at a regular pace; no inversion seen in 2016
  - V_{FD} decreased by 60 V after 40 fb^{-1};

No inversion expected in 2017, apart few outliers.

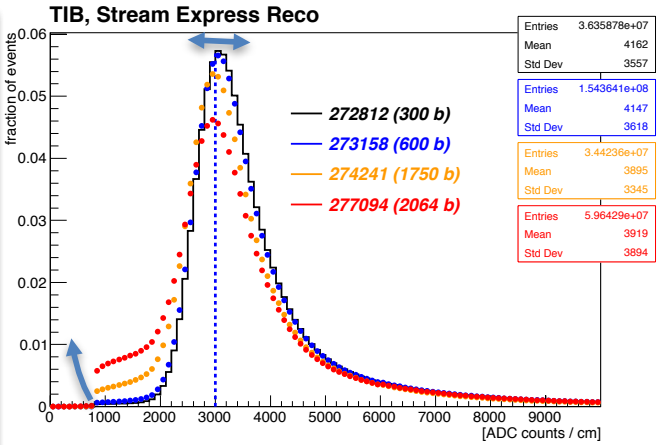
To do:

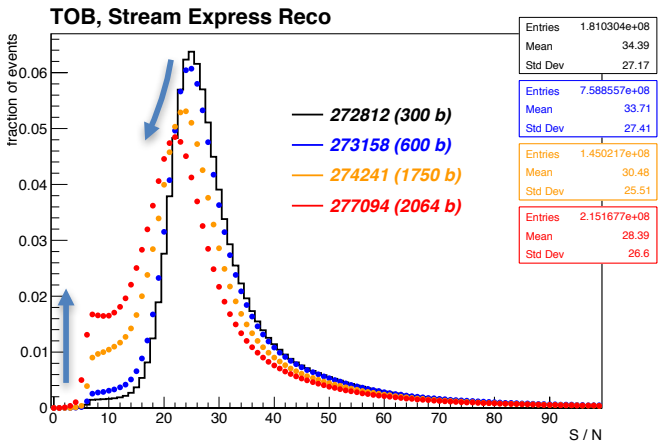
- compare bias scan results with the tool for predicting the sensor evolution;
- more systematic studies foreseen (TOB layers);
- use of DCU info to correct for leakage current;
- test correlation with hit efficiency;

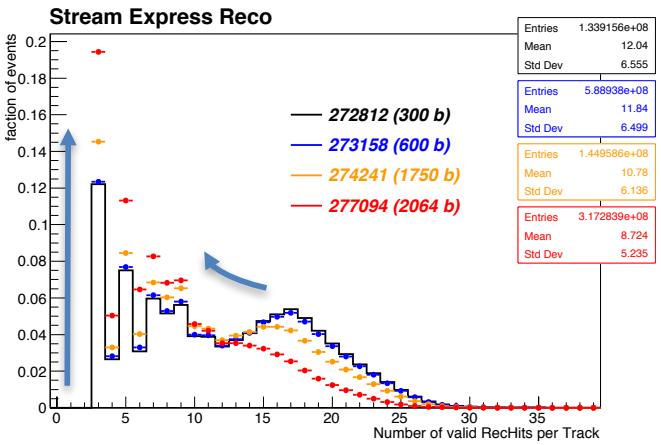
May need manpower here!



Strip hit inefficiency

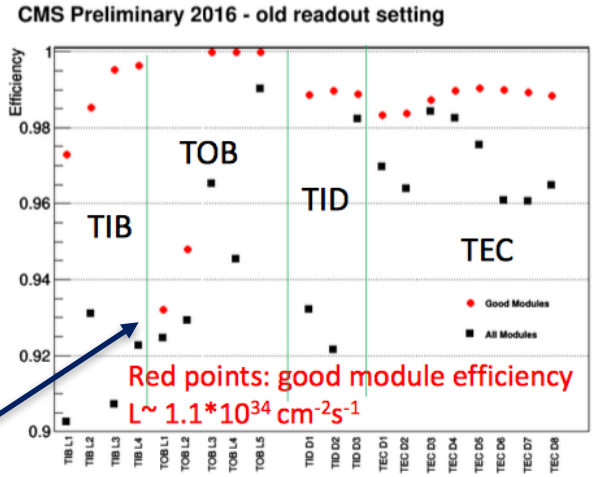


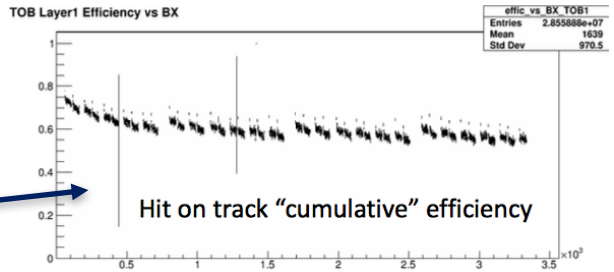




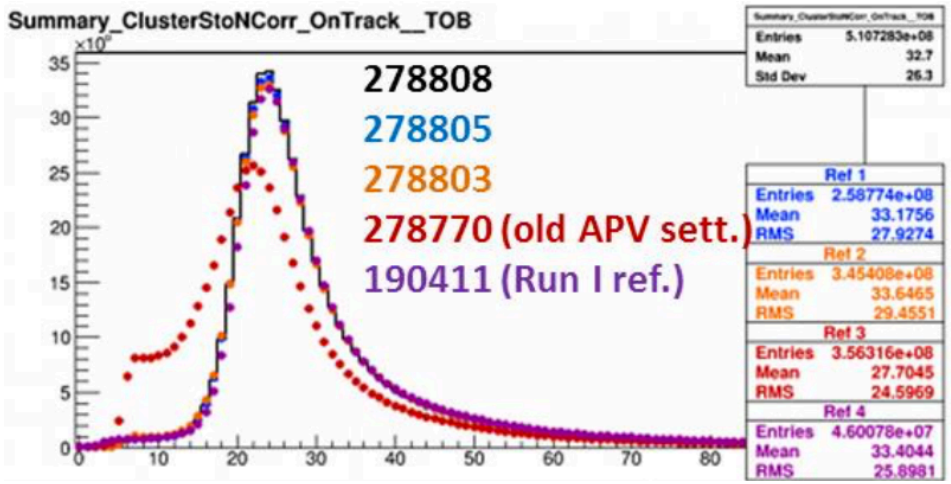
In 2015 and 2016 higher and higher inefficiency was observed in the strip tracker

- Too low hit signal
  - hits are either not reconstructed or not used in reconstruction;
- Number of hits on track reduced
  - not good for B-tagging
- Tracking efficiency affected
- Main features:
  - effect increase with luminosity
  - TOB layer 1 and 2 are the most hit by this
  - dependence on the position of the LHC orbit





Efficiency after APV VFP fix



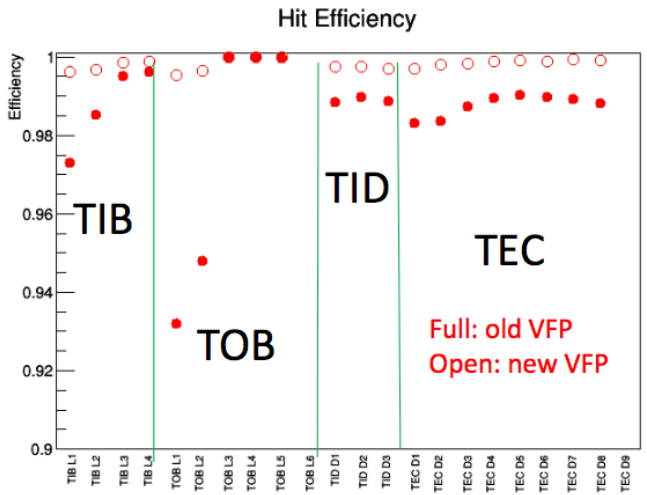
APV pre-amp saturation was the culprit of the strip dynamic inefficiency.

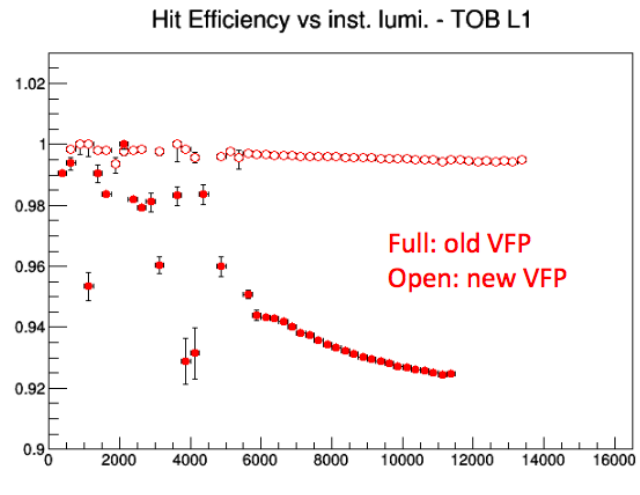
- Fixed from 2016H era, with a different setting of the pre-amp VFP;
- Hit signal and efficiency restored;
- Tracking efficiency restored

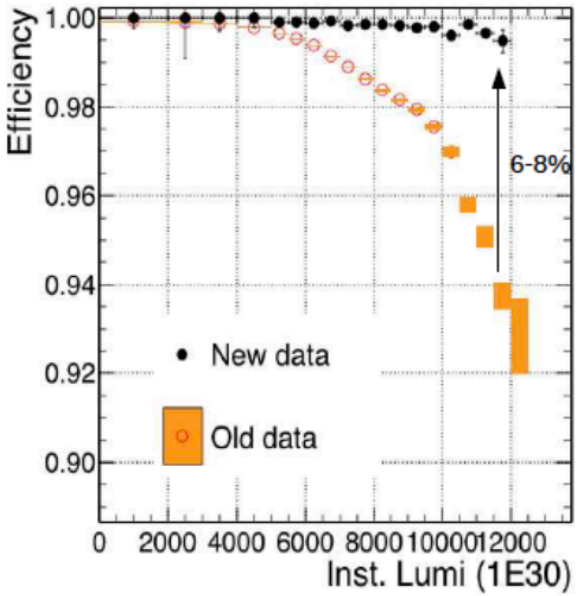
Not expected in 2017: APV is far from saturation with the new setting
https://indico.cern.ch/event/586706/contributions/2363782/

Hit efficiency study in 2017: improve existing tool, compare result with independent methods.

Plans: https://indico.cern.ch/event/536862/contributions/2401846/attachments/1386418/



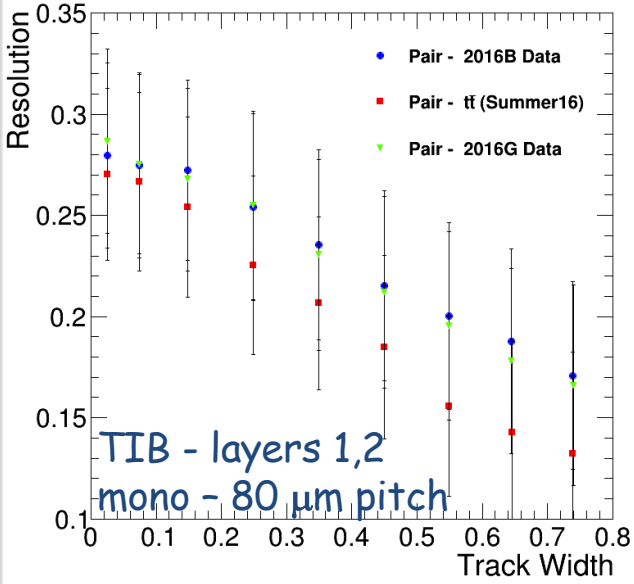


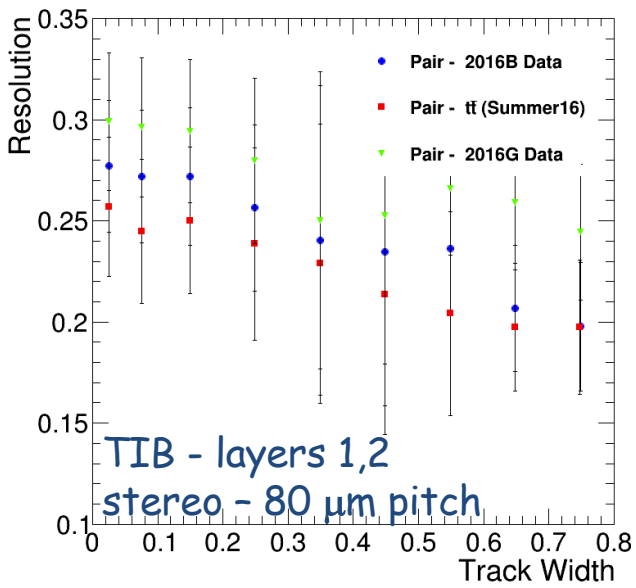


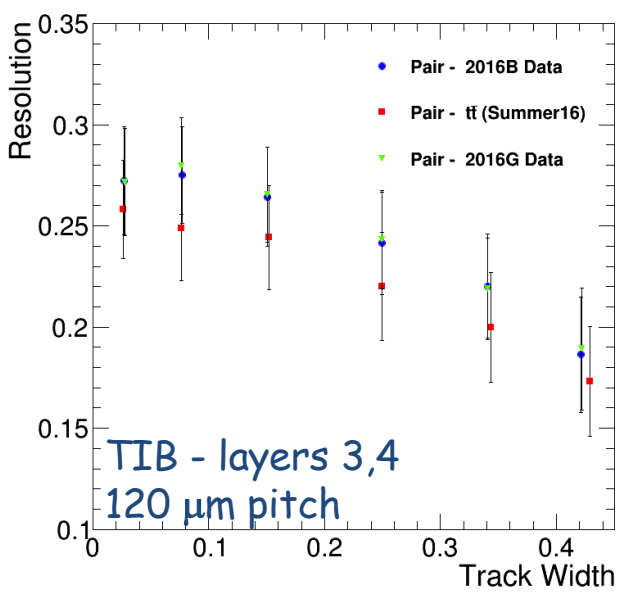
Strip hit resolution

In 2016 the analysis of strip hit resolution has been resurrected

- results on TIB and TOB subdetector available (units in fraction of pitch values);
  - congruency with performance on 2015 data successfully cross checked;
- same performance before and after APV VFP change;
  - resolution of TIB stereo layers slightly different: to be checked.







Goal for 2017: reduce the latency time to produce updated results. Explore several options: exploit the ALCARECO data, include monitoring histograms in DQM, create an ad hoc Primary Dataset from PromptReco.

Manpower needed!

Strip calibration: bad components

Running smoothly @ PCL for every run

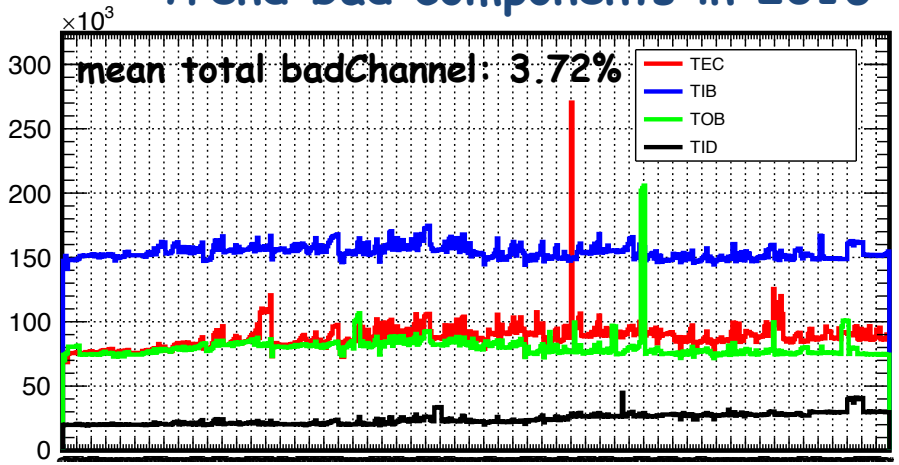
- percentage of bad strip constant before and after APV setting change
- few system failures independent from the bad components algorithm / analysis; calibration provided with had hoc computation

For 2017 the algorithm needs reinforcement to cope with few cases where the Bad Channel detection did not work properly:

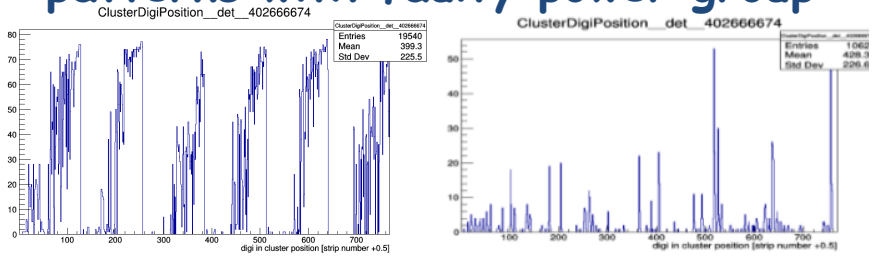
- Issue with power group
  - Same module behave differently in different runs:
  - Explore use of DCS information at module level;

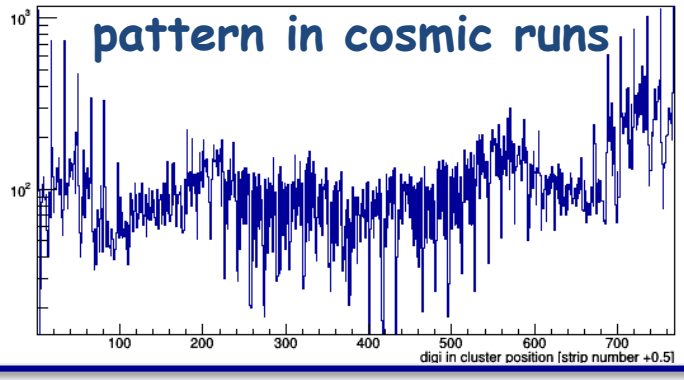
- Large occupancy in TID/TEC inner discs in cosmic runs after high lumi collision runs;
  - pattern of the occupancy very different;
  - algorithm detects the issue but not very efficiently;

Trend bad components in 2016

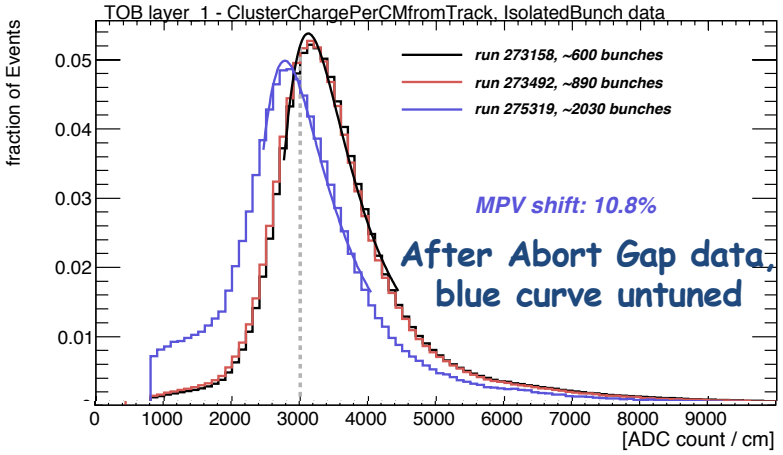


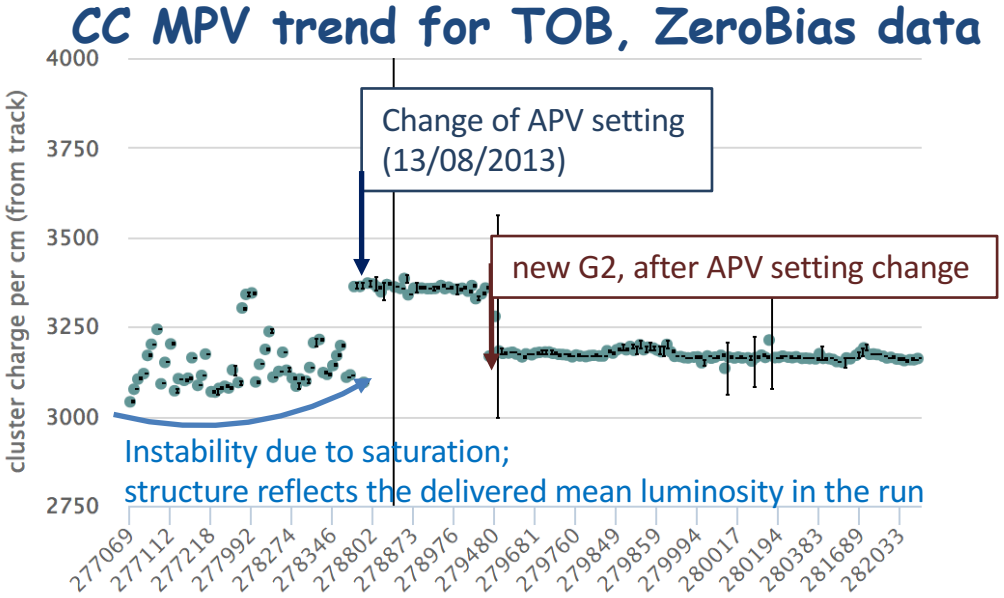
patterns with faulty power group



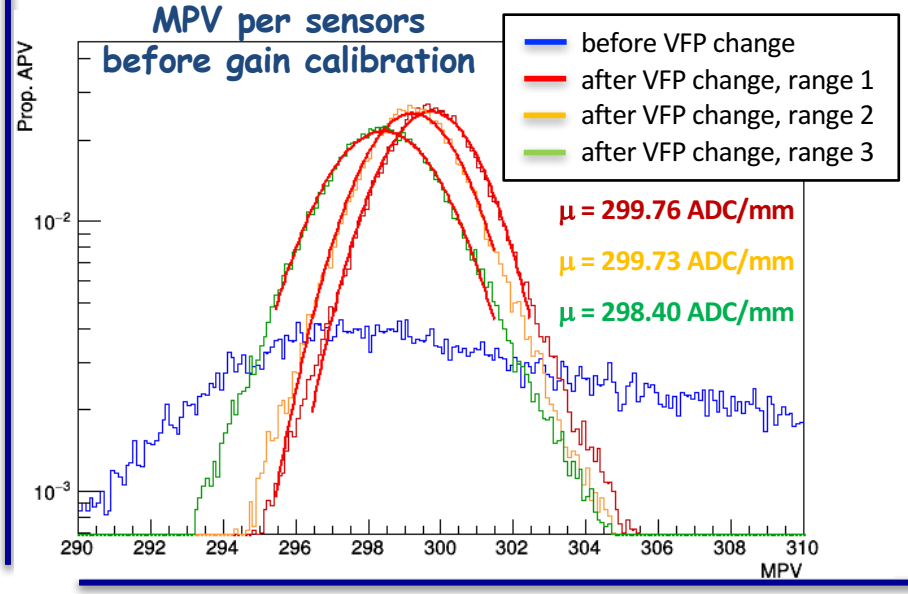


Strip gain: tuning with particle data (G2)





Cluster charge stability spoiled by saturation even on After Abort Gap data: (mean) tuning achieved with frequent gain updates



Statistic collected @ PCL but assembled manually

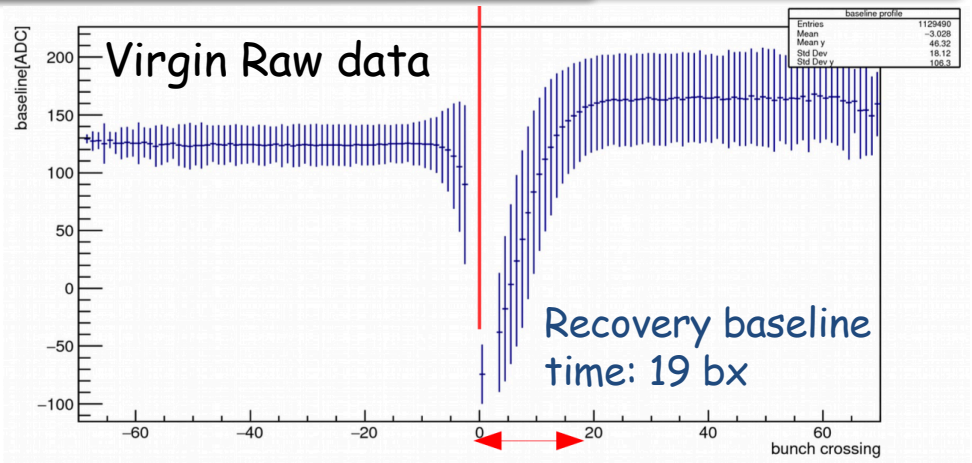
- few failure of the system which have been handled manually;
- it was virtually impossible to have a stable tuning for the cluster charge before the VFP change;

In 2017 the time lag due to the gain payload validation will be removed by exploiting the harvesting procedure @ PCL.

Plans: https://indico.cern.ch/event/536862/contributions/2401846/attachments/1386418/

Plan for simulation

- **Maintain and update the simulation for the HIP (from Simon de Visscher)**
  - developed in 81X and never backported in 80X
  - being used by the lumi group;
  - ongoing work:
    - update the “HIP” effect propagation through bunches to the actual baseline recovery time;
    - checking that the results are still consistent



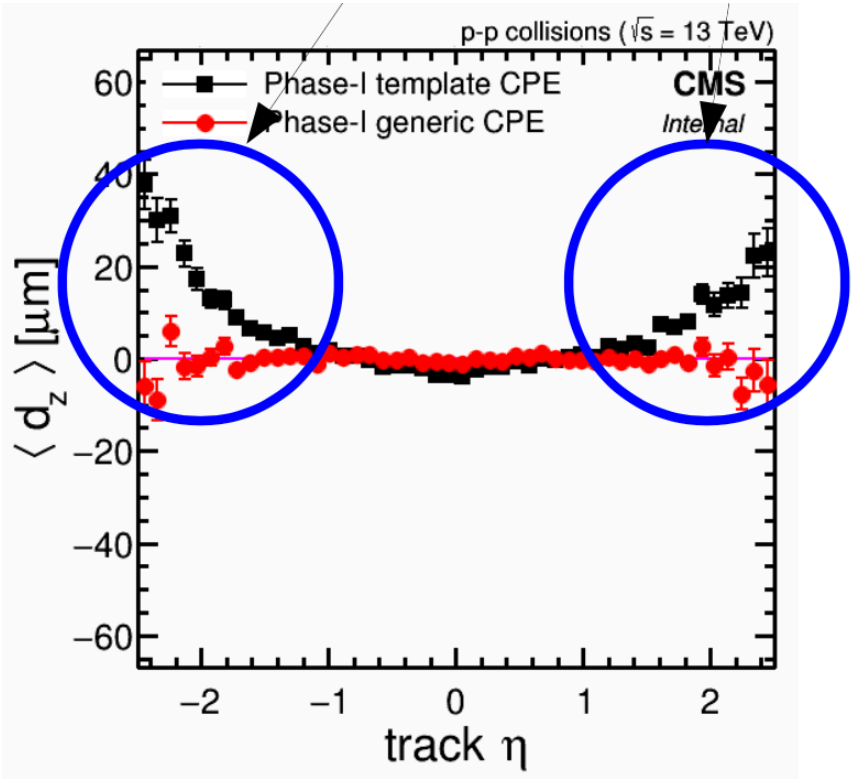
- **Develop the simulation for the APV saturation**

https://indico.cern.ch/event/536858/contributions/2335946/attachments/1354964/2047233/Hall_DPG_1016.pdf

  - Feed with latest estimate of occupancies measured at 1.5E34
  - Extrapolate occupancies to 2E34
  - Check how shifted pulse at pre-amp output and single strip level can be correlated to MPV shift + increase in tail in cluster S/N
  - study impact on the performance with different APV settings (as a function of the lumi);

Alignment with the new Pixel detector

- Most of the important tools run on MC and produces sensible results
  - base classes have been made geometry independent (lot of framework changes) but algorithms and tools left unchanged;
- Realignment studies are presently done with the MC for Phase 1 geometry (closure tests)
  - P-p collision + cosmic MC sample produced;
  - two scenarios defined – available in GT-s payloads
    1. Realistic strip + ideal Phase 1 pixel alignment
    2. Pseudo-asymptotic: realistic strips + misaligned Phase 1 pixel
- Studies on alignment "mis-calibration" scenarios ongoing to test the sensitivity to template and LA calibration:
  - biases due to non perfect template knowledge: cosmic alignment needed before startup!
- More details here: https://indico.cern.ch/event/536861/contributions/2381182/



To do

- Fix PCL framework;
- Full commissioning of alignment and validation tools;
- Refinement of re-alignment strategy;
- Converging on detailed plan for first 1-2 weeks of data- taking and beyond

2017 Tracker PFG teams, DQM and operations: ongoing to-do list

- **No change foreseen in the team compositions**
  - Operations: 2 DOCS + 3 on-call experts
  - PFG: 3 offline shifters (~50% remote) + 2 on-call experts
- **Improve the effectiveness of the "Prompt Feedback Group" (a.k.a shift crew)**
  - Improve training procedure and documentation
  - Improve offline tools for shifters
    - HDQM, TkCommissioner
  - More frequent feedback on data quality
- **DQM code development and maintenance**
  - Strip and Tracking DQM code
    - introduce TH2Poly maps, introduce monitoring of DAQ partitions ("ControlView")
- **Reviewing the list of key roles**
  - replacement for the coordination of the material budget team;
  - DCS need a person;
- **Larger ops team for pixel ?**
  - the (operation) experts for the present detector are also phase 1 experts: no “transition team” is needed!!

Conclusions

- **Though Bpix integration delay, the new pixel detector is on time to be installed end of February;**

- **Clear e detailed plan for commissioning the new pixel detector**
  - checkout being carried on by the experts team;
  - manpower needed for other tasks;
  - offline software and alignment read on MC data, need final validation with data

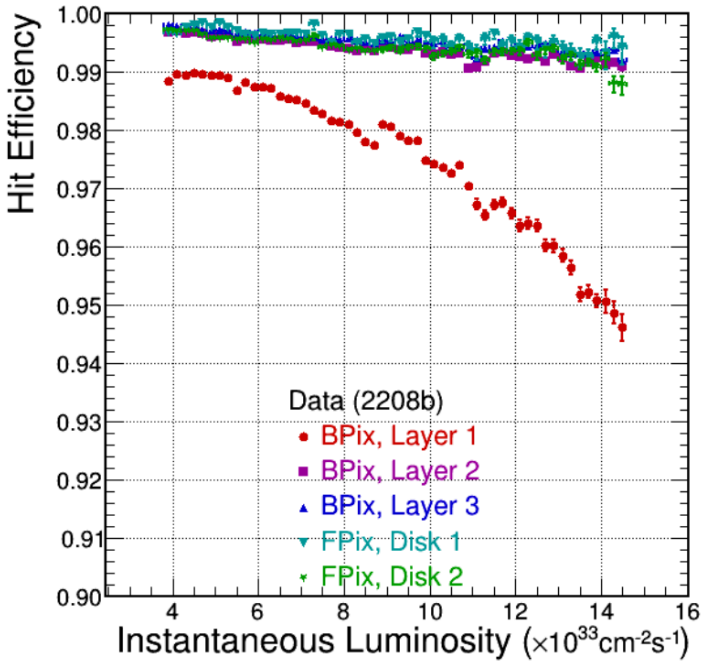
- **Strip detector hardware in good shape**
  - No systematic/recurring problem during 2016 operations;
  - Strip hit efficiency crisis has been solved nicely, not expected to come back;

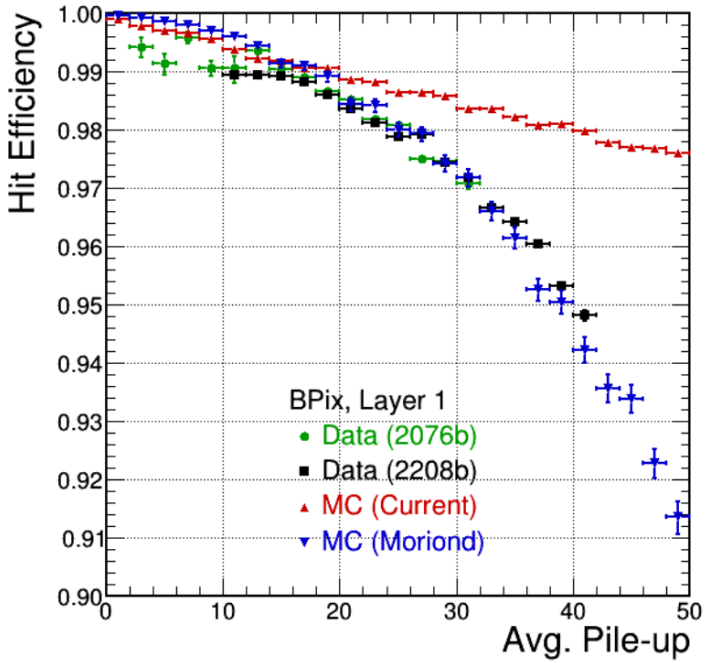
- **Plans to improve in many areas (Routine tuning, Performance monitoring, calibration, simulation) being defined now and finalized in January;**
  - few issue to understand and fix;
  - manpower needed for some tasks.

Backup

Pixel hit efficiency in 2016

- High luminosity/occupancy and trigger rate cause dynamic inefficiency because of buffer overflows and dead time during double column readout
  - Non-negligible effect in BPIX layer 1 when luminosity exceed $10^{34}\,cm^{-2}s^{-1}$
- Measured in data and tuned in simulation
  - Final MC tuning used only for the Moriond production

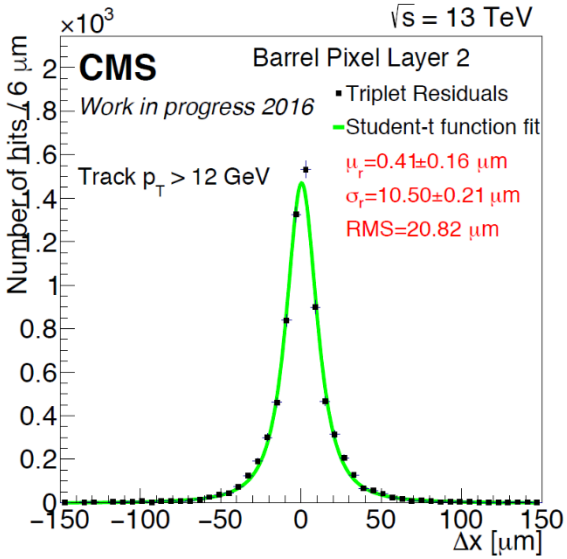


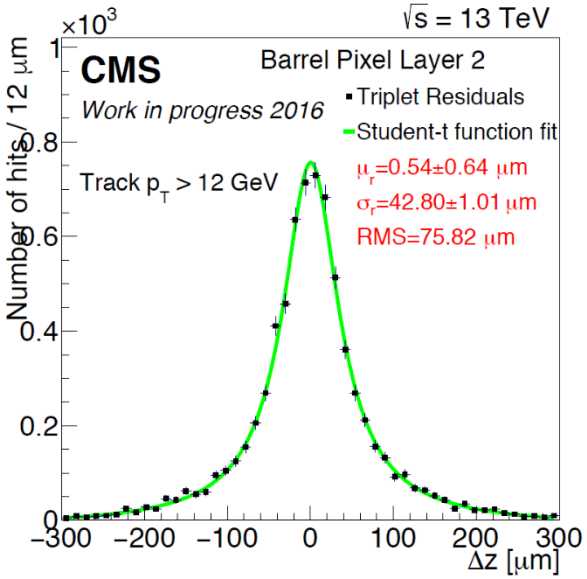


Pixel hit resolution in 2016

Hit resolution (μm)									
Run/time	2015 beg	2015 end	273725	275886	277087	280251	280385	281797	283040
Lumi	**0.0**	**4.2**	**5.1**	**12.4**	**21.7**	**34.6**	**35.5**	**36.8**	**39.3**
Bpix-X	8.6	8.6	8.4	7.8	10.2	12.1	10.4	10.5	8.6
BPix-Y	22.5	23.0	24.1	28.0	26.1	31.7	31.5	27.3	35.1
Fpix-X	15.5	18.7	19.7	25.3	20.5	21.2	25.2		33.1

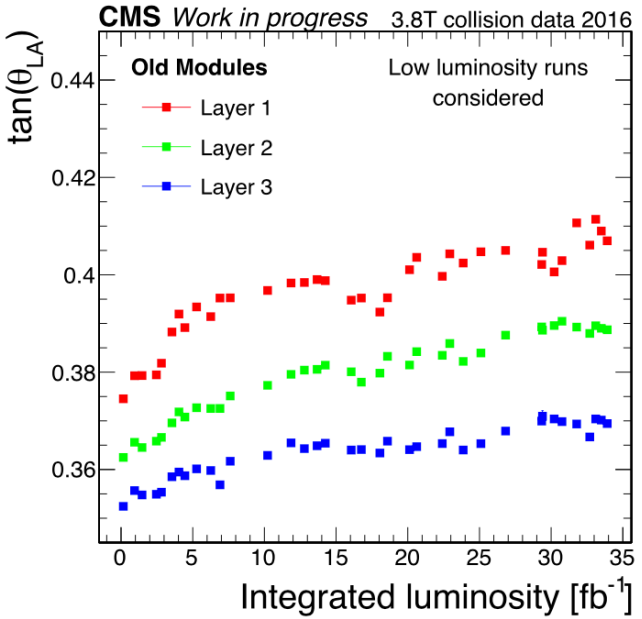
- Measured from mid-point residuals in pixel triplets
  - Sensitive to alignment: ultimate results after rereco
- 2016 values slightly larger than 2015
  - Non-final alignment, non-final templates, slightly higher threshold (?)

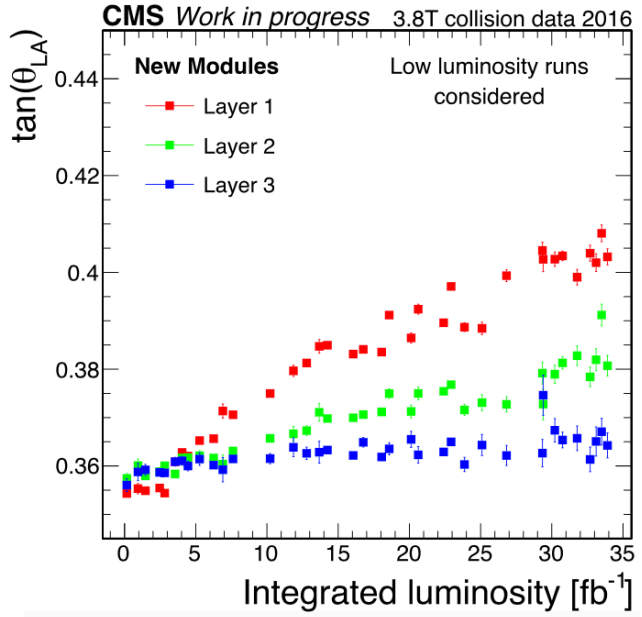




Pixel calibration in 2016

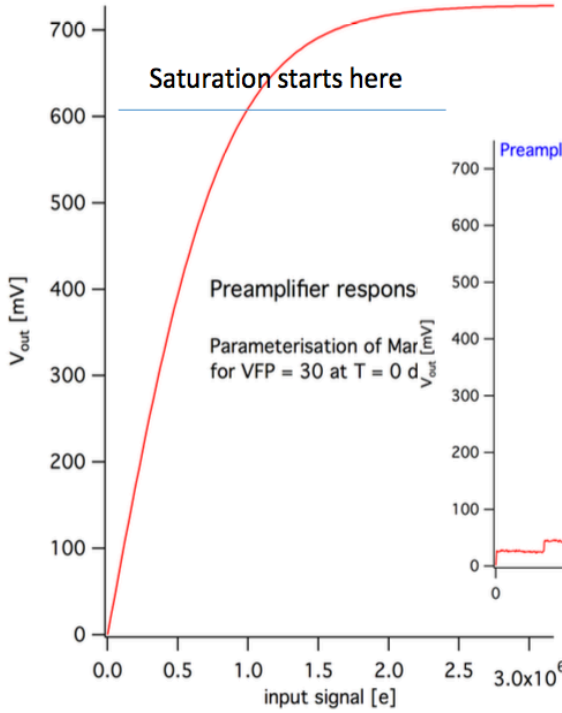
- Pixel calibrations to avoid resolution degradation
  - Pixel Lorentz Angle and Templates
    - Radiation changes E-field and mobility: Lorentz drift and cluster properties change with time
    - Two updates in 2016 so far
      - Four updates for legacy rereco
  - Pixel gain calibration
    - Updated once in 2016
      - Last calibration results not uploaded: charge injection circuit to be recalibrated

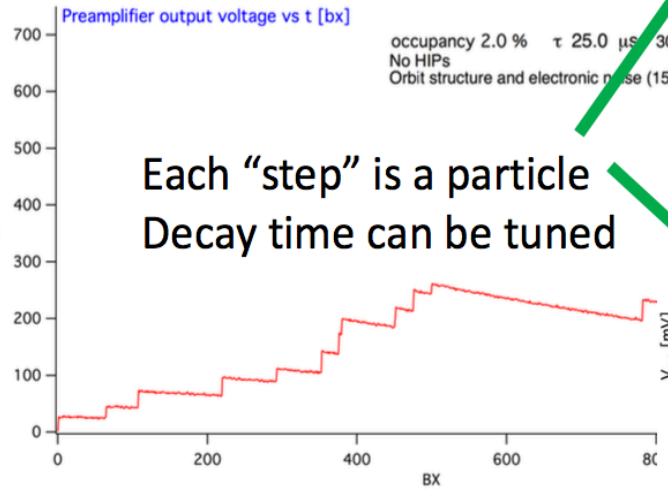




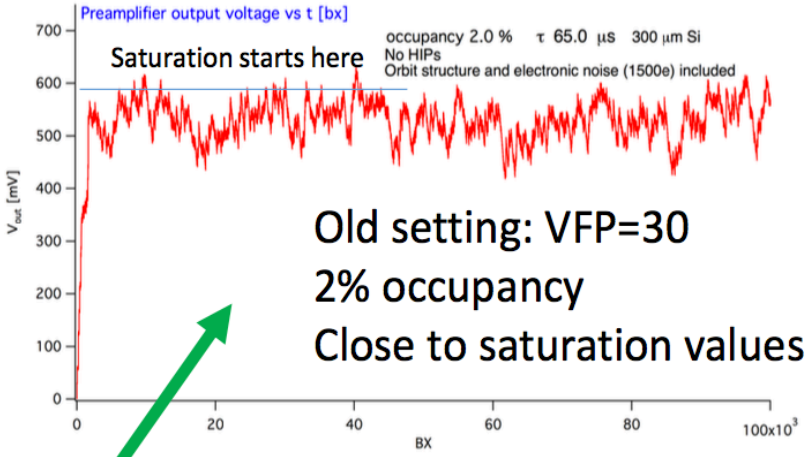
Strip inefficiency: investigation and solution

- Starting hypothesis: Highly Ionizing Particles
  - Unexpected with this rate
- Final explanation: APV pre-amp saturation due to high occupancy and too slow discharge time
  - Thanks to Erik Butz and Mark Raymond!
- Solution: change discharge time setting (aka VFP from 30 to 0)

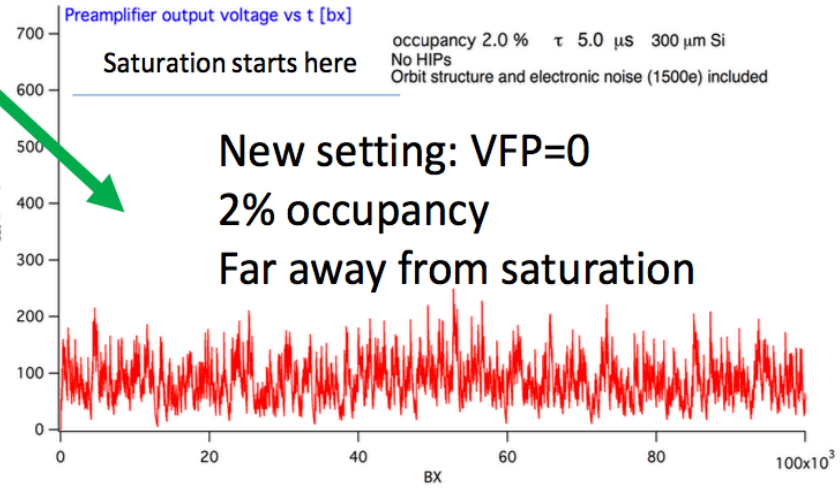




Each "step" is a particle
Decay time can be tuned



Old setting: VFP=30
2% occupancy
Close to saturation values



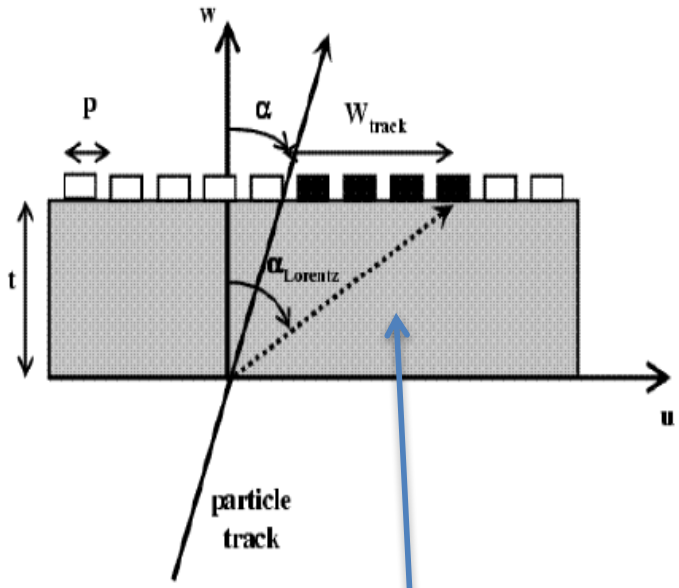
New setting: VFP=0
2% occupancy
Far away from saturation

Strip hit resolution: definition

Hit position: is the cluster baricenter corrected with the shift due to the Lorentz drift.

Hit position resolution:

- in the measurement frame is set to be **1/√12** in both 2D coordinates for each hit (uniform distribution)
- in the local frame the error is **pitch/√12** for the precise coordinate and **(strip length)/√12** for the coarse coordinate.

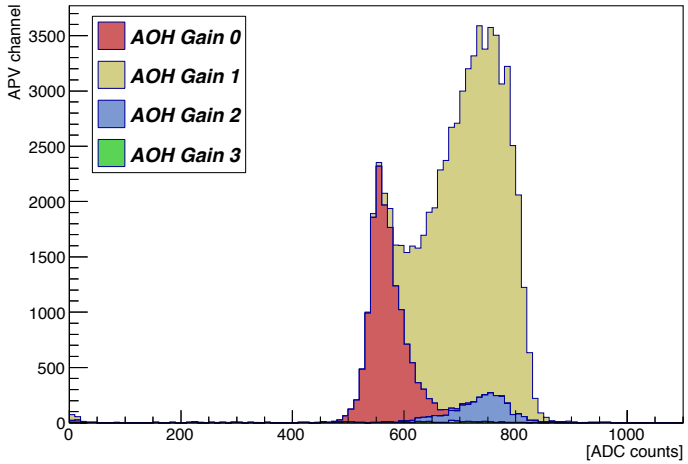


- It has been measured using MC truth and is parameterized as a function of the reconstructed cluster width (actual size of the cluster, in number of strips) and the expected cluster width.

- The expected cluster width / track width is the track projection on the precise coordinate in the measurement frame corrected with the Lorentz shift, in units of the strips.

Strip gain: factorizing the optical gain (G1)

Tickmark height, run H era

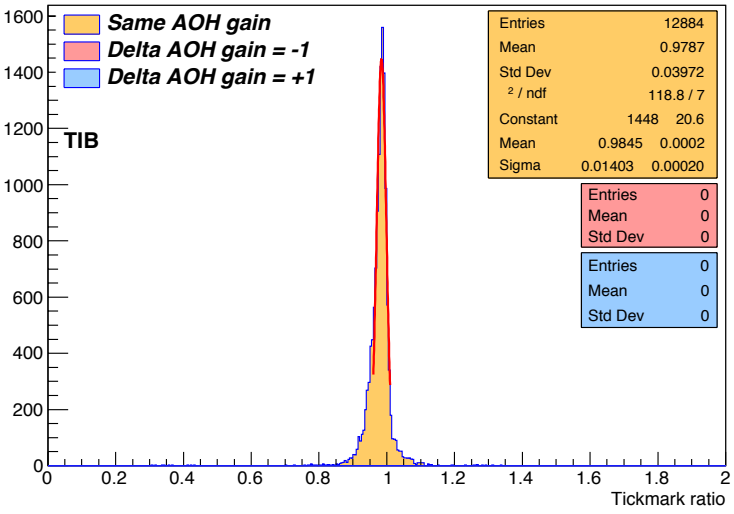


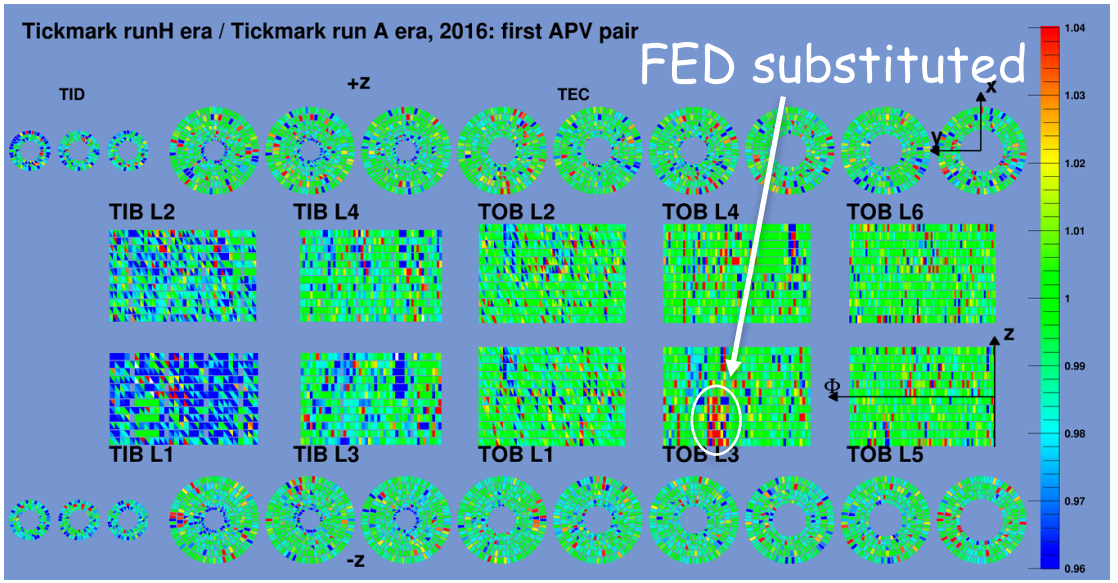
Derived from the online timing runs

- five updates delivered in 2016:
  - follow drop of optical gain: 3.5% drop after 30 fb^{-1};
  - account for changes due to FED substitution;
- some lag due to validation;
- one failed upload due to miscommunications;

In 2017 we aim to have the G1 factor in production immediately after the timing run are validated by the online crew, because the time lag increases the work overhead for the particle calibration.

Tickmark run H era / Tickmark run A era, 2016

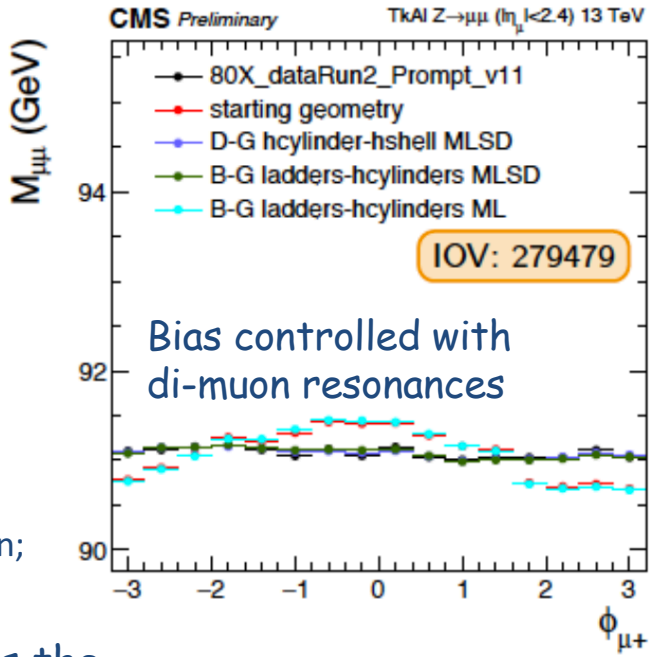


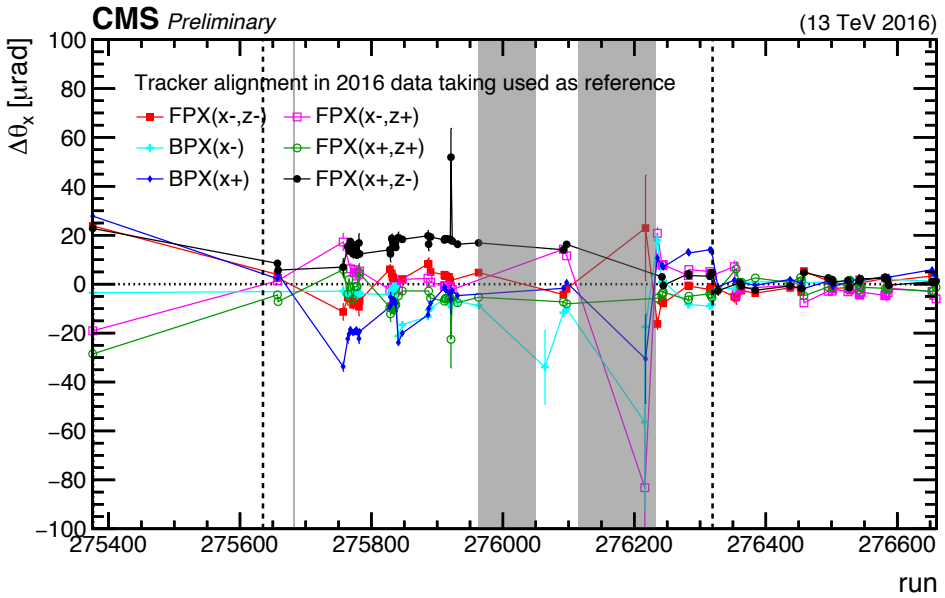


Alignment, status and performances

Alignment status

- Two algorithms (Millepede and HipPy) + validation tools (cosmic track splitting, DMR, primary vertex validation);
- Tracker modules aligned with collision and cosmic tracks:
  - cosmic tracks are mandatory to align TID and TEC; at least 106 cosmic tracks needed;
  - Looking at cosmic in collisions: 0.06 Hz. Not yet competitive, trigger to be improved
- Several alignment campaigns;
- Pixel large structure position is monitored @ PCL:
  - alignment parameter updated if movements larger than a few tens of micron;
  - O(100) updates in 2016.





BPix residual is the most sensitive