Pixel Phase1: status and plans for the 2017 commissioning

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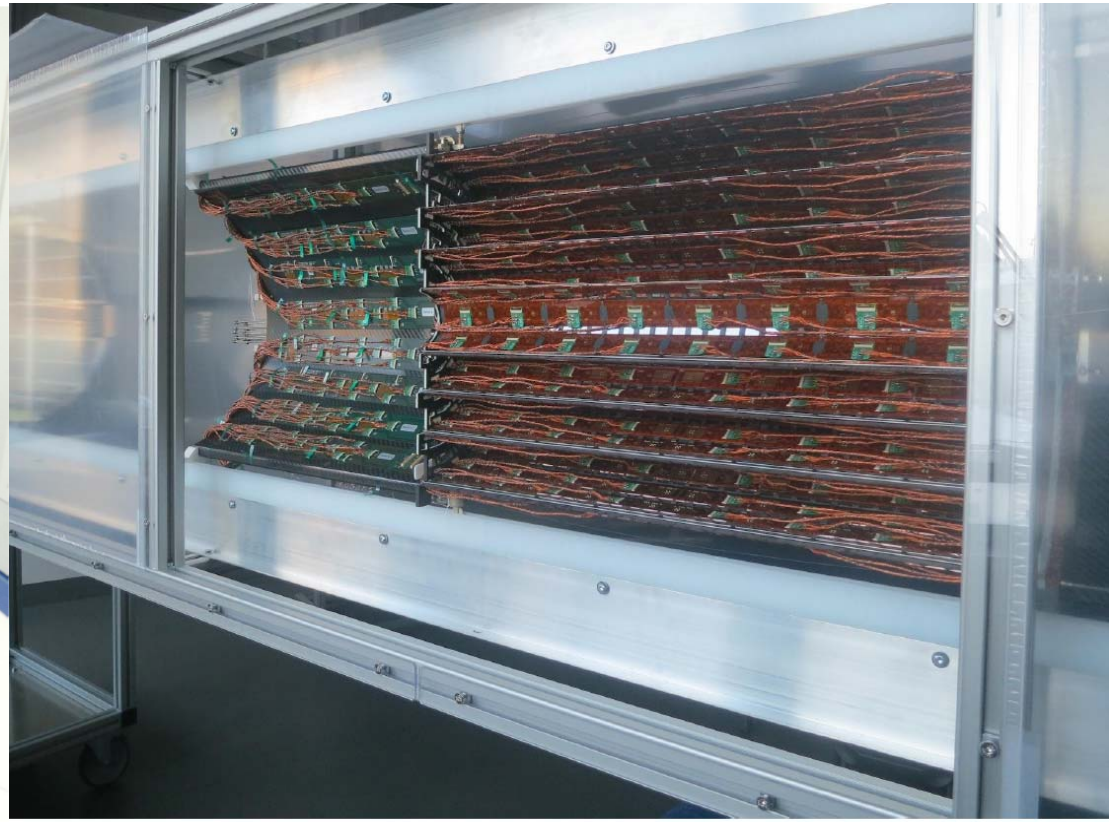
The new Phase 1 pixel detector

- The Phase I detector has an additional Layer and Disk → Better tracking, vertex reconstruction and b-tagging efficiency
- Digital readout with increased buffer sizes (can expect nearly 100% efficiency)
- Very similar sensor, with slightly better resolution (Smaller pixel thresholds)



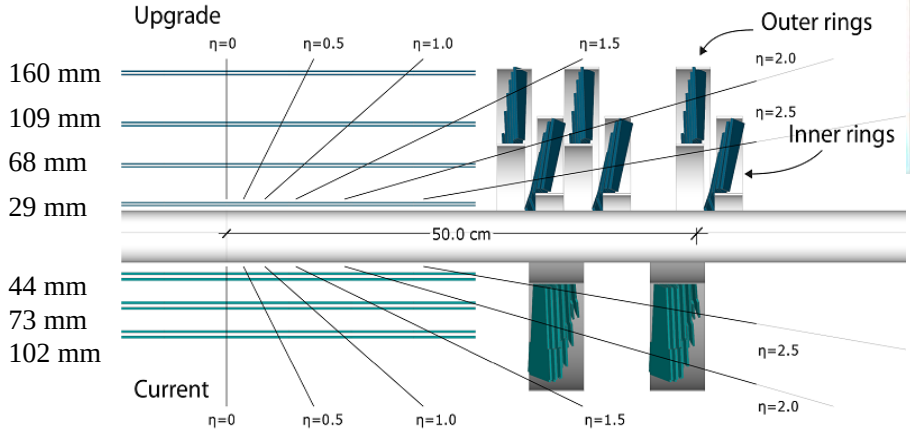
Pixel Simulation: geometry

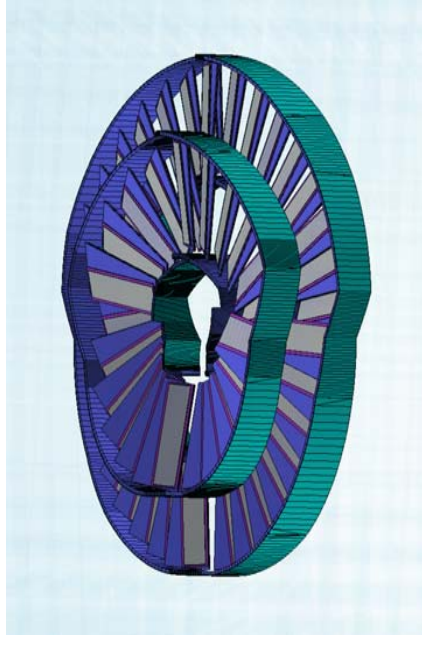
- Geometry description was nearly finalized in 810
  - **Received more information on components masses in BPix**
  - **Have the fully assembled system at hand for overall comparison**
  - **Last modification this week...**

- Simulation experts reviewed our latest description in context of the whole CMS description
  - **Found very similar number of objects**, physical/logical volumes, minor decrease in memory size at initialization
  - **Some CPU penalty (several %)** is observed in QCD – **Pixel is a suspect**
    - possible improvements seem to be in the domain of the simulation group
  - Our own investigations (Marcel) showed 6% more CPU time – **only about half is due to the new support ring**

- **Barrel** Pixel – **volume descriptions** (positions, size) expected to be **OK**

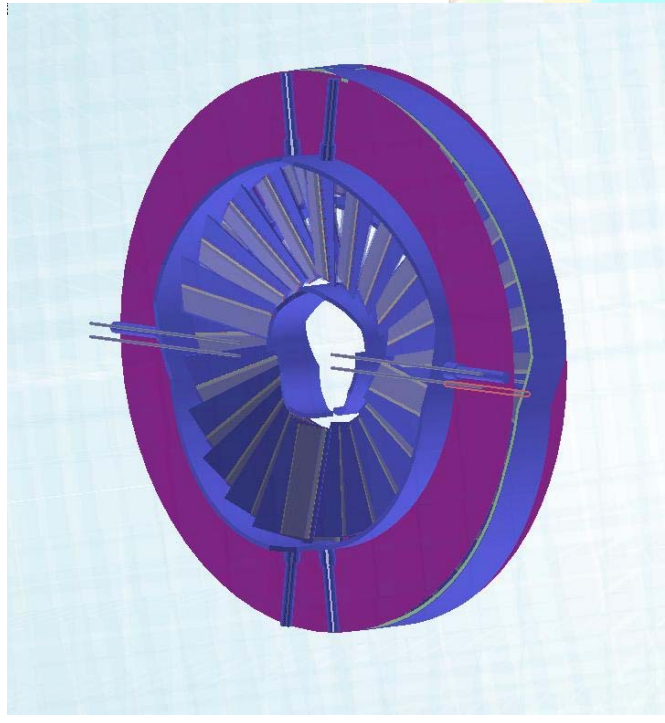
- **Forward** Pixel
  - Found **small overlaps** between Flex Cable Disk and Support Rings at **~100 microns (pre3)**
  - **Small corrections to the sensor thickness 300 um → 290 um (pre3)**
  - Polycone in support arms should be replaced by simple cylinders for speed optimization (TO DO)





Pixel Simulation: material budget

- Material compositions mostly follow engineering design
  - Densities of volumes are adjusted to match total mass weighted in the lab at various steps of the detector construction
  - Whenever new measurement results arrive, we readjust description
- Small differences from real detector possible
  - Simplifications in modeling: **objects reshaped/cut** in order to produce **simpler description** or **avoid overlaps**
  - Module-by-module variations in manufacturing
- Barrel Pixel – recent fixes to material budget
  - More information on the weights of facets:
    - 10-25% more than in simulation, while error in manufacturing is ~10%
    - fix by adjusting just the CFK density **(pre3)**
  - Composition of Layer 4 flange (replacing Airex with CFK): 140 g → 520 g **(pre3)**
  - Total weight: 1621 g → 2232 g, while measurement shows 2281 g
  - Supply tube Sectors C+D+A (large eta) a ~13% deficit in total mass (**pre3**)
- Forward Pixel
  - Lab measurements show variations in mass of ~**5% among sensor modules**
  - About **12% difference** in the mass of the **support** structure in the **inner and outer rings**, but **agreement** in total for the **whole disk**
  - At **very large eta inside the Tracker volume**, **uncertainty** in the service cylinder mass below **5%**
- Material will be measured as soon as possible after collisions
  - A proposal for a **tracking based direct measurement of radiation length**
  - **NI measurement group** has expressed commitment to do the 2017 measurements



Pixel Simulation / Local reconstruction

- Detector **simulation** and reconstruction in good shape **for initial physics object studies – Needs to be finalized by March**

- Initial settings for the simulation / reconstruction are nearly complete
  - **Bad components** after detector construction finished – defined in Database
  - Pixel losses due to **dynamics inefficiency** initially considered negligible (99.8%) – defined in Database
  - **Lorentz-angle** induced charge drift, finalized when HV setting is decided – in software / Database
  - **Gain settings**: front-end response (gain curve), and the thresholds have been adjusted – in software / Database
  - FED cabling map is final (will be cross-checked at detector commissioning) – defined in Database

- **In 810 test, a bias in hit position (Simhit vs CPE position) observed, not fully understood**
  - Large pixels in ROC edges are not configured (remains of the TDR settings) – reenabling does not remove bias
  - Sensor thickness is being verified in simulation and reconstruction

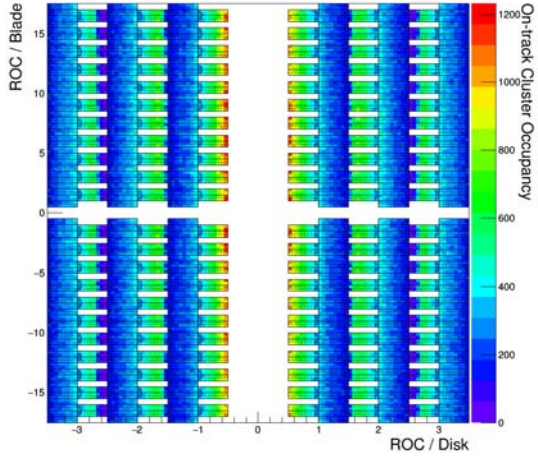
- CPE
  - GenericReco performs well, nevertheless (alignment sees no problems with it) – default setting in Tracking at the moment
  - Templates – large position bias, also seen by alignment
    - Due to significantly different geometry
    - **Template object has been modified in a way that should handle the new FPix, compatible with the old FPix (should be in pre4)**
    - Needs testing, but new test objects are being generated

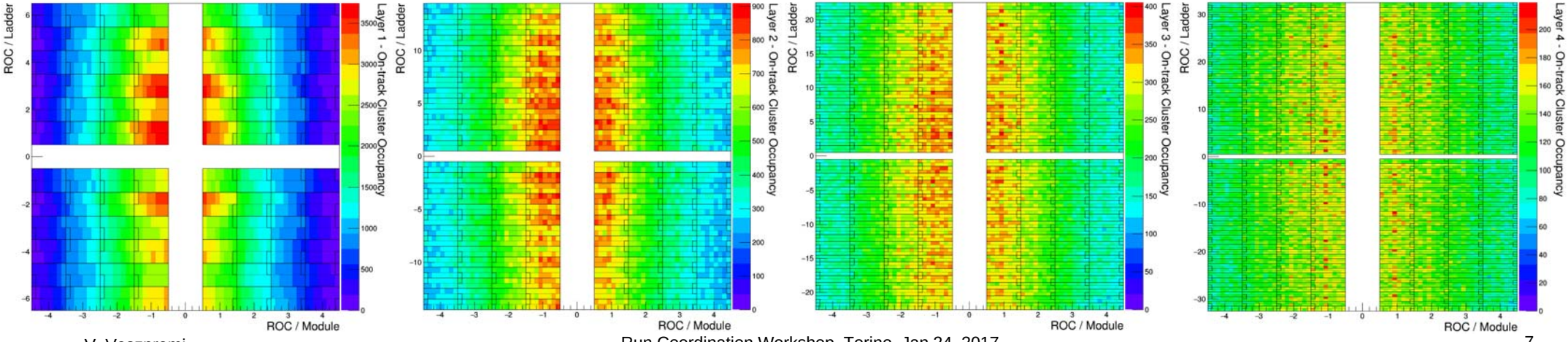
Pixel offline Monitoring and Calibration tools

- **Database and detector monitoring** tools are almost fully **up to date**
  - Most of the developments require stable geometry, centrally produced samples (esp. PU-weighted)
  - Started already when 810_pre16 was available
- **Gain** calibration tool:
  - Requires some scripting changes due to the different FED numbering
- **Lorentz Angle** measurement is being updated
  - No major changes needed, as measurement is local in nature
  - Some adjustment in the sqlite producer once the HV settings are agreed on
- **Resolution** measurement
  - Will be very similar: we refit tracks using triplets
  - The extra layer allows us to measure better resolution on Layer 2+3 and Disk 1+2
- **Hit efficiency** measurement is progressing:
  - Layer 1 hit propagation needs to be added
  - Selection cuts (fiducial selection, removing overlaps, etc...) to be updated
- SiPixelCoordinates:
  - New tool developed for better Geometry handling/plotting

Pixel offline Monitoring and Calibration tools

- Occupancy plots for offline analyses were updated for the new geometry
  - 66 M pixels → 126 M
- New class SiPixelCoordinates
  - Allows the plotting at various ganularities: individual pixels / ROCs / etc..
  - Eg. These plots have a Readout chip granularity
  - Phase 0: 2304 (L1) + 3840 (L2) + 5376 (L3) + 4x 1080 (FPix) = 15840 ROC
  - Phase 1: 1536 (L1) + 3584 (L2) + 5632 (L3) + 8704 (L4) + 6x 1792 (FPix) = 30208 ROC
- New ROC granularity plots are also provided by DQM





Pixel offline plan for 2017 running

- Before first collisions:
  - Provide **calibrations** based on the **best knowledge** of the detector (Lorentz Angle, Templates etc.)
  - Gain calibration is the last step of online calibrations

- In the beginning of data taking in ~June, we plan to:
  - **Fine tune the timing** of the detector using the first collisions:
    - **Coarse** time alignment with **DQM**
    - At the same time, **validate timing offline** based on offline analysis (Efficiency and Cluster charge/size)
    - **High Voltage Bias scan** to validate Voltage settings (expect fully efficient detector on nominal voltages)
  - **Measure the Lorentz Angle** and update the **Templates, GenErrors** based on measurements from data
  - Measure and **validate** that the **resolution** is as good as expected (similar or better than the current detector)

- Monitoring during the year:
  - In the beginning of **each data-taking period**, we **measure LA, hit efficiency, resolution**, and check if performance is as expected → update certain payloads if needed
  - **Check** the performance of the **simulation** against data and tune it if needed
  - **Inefficiencies will be added when needed** (although detector is designed to easily handle 2e34 instantaneous luminosities)

- Later during the year:
  - Occasional HV Scans → after around 20-40 fb-1, voltages will need to be raised (similar to the beginning of Run II)
  - Raising the voltage may only happen in 2018 if the integrated luminosity is not too great

Pixel offline Documentation and manpower

- Pixel offline Twiki:
  - https://twiki.cern.ch/twiki/bin/view/CMS/PixelOfflineSoftware
- 2017 Task list:
  - https://twiki.cern.ch/twiki/bin/view/CMS/PixelOfflineSoftwareResponsibilities#2017_Pixel_Offline_Tasks
  - Tasks are well covered: all of the most important tasks have a person
  - Please respond if interested in a certain task (Some large EPR tasks are sometimes shared within people)
  - Detailed task descriptions:
    - https://twiki.cern.ch/twiki/bin/view/CMS/PixelOfflineSoftwareResponsibilities#Detailed_Task_Descriptions
- Main Pixel tools software repository:
  - https://github.com/cms-analysis/DPGAnalysis-SiPixelTools

Tracker alignment stategy

- **Derived a two-step strategy** to align the new pixel detector
  - Step 1: Align all degrees of freedom of the pixel high-level structures
    - BPIX half-barrels + FPIX half-cylinders
    - PCL configuration
  - Step 2: Align all pixel module degrees of freedom except for FPIX-z
    - Topology of collision tracks cannot constrain z-position of forward modules
    - Cosmics + zmumu events (w/ zmumu constraint) would help

- This is **assuming the strip detector remains well aligned** (which was the case during the 2015/16 break)
  - Might **consider** aligning the **strip high-level structures in another step** (Probably a second order effect)
  - If we want **to align** also the **strips at module-level** we absolutely **need cosmics** or zmumu data to protect from weak modes

- Derived strategy w/ phase-0 detector and confirmed w/ phase-1 detector

- Feel rather confident to get first alignment results after 1-2 days
  - Details to be confirmed (see next slide)

Tracker alignment – thoughts on start-up strategy

- **Keep PCL workflow** (SiPixelAli) running, but writing to a test tag
  - **Step 1** of our strategy is **automatically done**
  - We could fetch the results from the test tag
  - Possibly **cross check with ``manual'' alignment**

- **Would like** to be able to **flexibly update conditions in EXPRESS w/o central validation**
  - Possibly better reconstructed tracks w/o delay from validation
  - If internal validation shows improved performance, we might already inject step 1 result to cure high-level structure misalignment
  - We can align on EXPRESS -> Alignment could be in time for PROMPT

- **Potential problems if track reconstruction efficiency is really low**
  - As long as it is not zero (no alignment possible) it means a delay until enough tracks have been collected
  - Currently **studying the lowest possible APE** given our misalignment scenario
  - **Next step: Study what PU is tolerable** for alignment and in terms of tracking efficiency/fake-rate

Tracker alignment – Requirements @ start-up

- **ZeroBias events would be fine** for us, but **slightly too soft pT-spectrum** for alignment purposes
- **MinBias from HLTPhysics dataset might be better** because the tracks have higher pT
  - HLTPhysics is just an L1 pass-through, i.e. no tracking involved and (possibly not-working) online tracking is not an issue for us
  - Reduced rate wrt. ZeroBias would be fine if the tracks are of better quality
  - We are in contact with HLT people to check if tracking is an issue in general with the initial misalignments
  - Prepared payloads for alignment and errors (in PROD DB)
    - TrackerAlignment_Phase1Startup_Misalignment_v0
    - TrackerAlignment_Phase1Realignment_Step1_v0
    - TrackerAlignment_Phase1Realignment_Step2_v0
    - TrackerAlignmentExtendedErrors_Phase1Startup_PIXEL100_STRIP20
    - TrackerAlignmentExtendedErrors_Phase1Startup_PIXEL200_STRIP20
    - TrackerAlignmentExtendedErrors_Phase1Startup_PIXEL300_STRIP20
    - TrackerAlignmentExtendedErrors_Phase1Startup_PIXEL400_STRIP20
    - TrackerAlignmentExtendedErrors_Phase1Startup_PIXEL500_STRIP20
- **Unprescaled triggers** would speed up the alignment process
- Evaluating options to **maximize EXPRESS and HLTPhysics rate** to have faster turn-around for alignment updates
- **Instead of private ReReco ask for flexibility to insert frequently into EXPRESS** → automatic “ReReco”

Tracker alignment – CRAFT scenario

- Need to be **ready for unscheduled CRAFT** data prior to collision data-taking (very successful in 2016)
- We will **use basically the same strategy** as for collisions, **but FPIX-z would be aligned**
- Depending on # cosmics the granularity of the "module-level" alignment will be adjusted
- **Exact number** of cosmics useful for aligning FPIX-z needs to be determined **for phase-1 detector**
  - **Currently not enough phase-1 cosmics MC available**
  - **CRAFT15: 3 M events** → 1.8 M tracks
    - Event rate: 4Hz
    - Track rate w/ BPIX hit: 0.1Hz
  - **CRAFT16: 590k events**
- **CRAFT** would allow **early alignment of strip detector**
  - Otherwise, need to wait for enough zmumu or interfill/CDC cosmics to be able to control weak modes
- **DECO mode in CRAFT is preferred** to avoid compatibility problems between PEAK and DECO
- **CDC rate was 0.06Hz in 2016**
  - Currently investigating micro-GT muon triggers instead of parasitical use of NoBPTX

Tracker alignment – Expected quality during data-taking

- For the **case of no-cosmics alignment** the expected quality has been estimated at TkAl meeting 11-Jan-2017 (**50 – 100 um alignment precision**, only in **FPIX-z** we have **approx. 240 um**)

- **Need to study performance if cosmics are available**
  - Requires phase-1 cosmics samples
  - Only with cosmics FPIX-z can be aligned

- Performed a **study of alignment quality vs. number of used tracks** with phase-0
  - Presentation at TkAl meeting 12-Oct-2016 shows **minor improvement w/ more than 5 M MinBias tracks**
  - **To be confirmed** with phase-1 detector

- Can expect significant improvement if enough cosmics and zmumu data available

- To fully align strip detector we need all types of tracks
  - Get (interfill/CDC) cosmics as soon as possible

Tracker alignment – Software commissioning

- **Basic commissioning of the tools is done**

- **Final** commissioning **depends on the availability of**
  - Various kinds of **phase-1 samples**
  - Especially cosmics and zmumu datasets
  - People still returning from vacation

- Have not yet used CMSSW_8_1_0 MinBias samples
  - Produced private samples with pre16 release and validation wrt. official pre16 showed no discrepancy

Tracker alignment – Dedicated alignment hardware

- **During the legacy alignment campaign we experienced problems with the dedicated machines for tracker alignment**
  - Still need to find a dedicated person/group responsible for these machines
  - Need to find a working long-term solution
  - **Existing machines are partly already out of warranty** and might break
  - Need to replace them and **possibly enlarge the number of nodes**
    - Currently only two high-memory machines
    - Latest alignment was running 1.5 days and consumed 150 GB w/o using all data and w/o including all calibrations (could not use CRAFT and CRUZET in parallel)
    - New machines should have UMA architecture, as demonstrated by Claus Kleinwort

Pixel Phase 1 DQM Software status

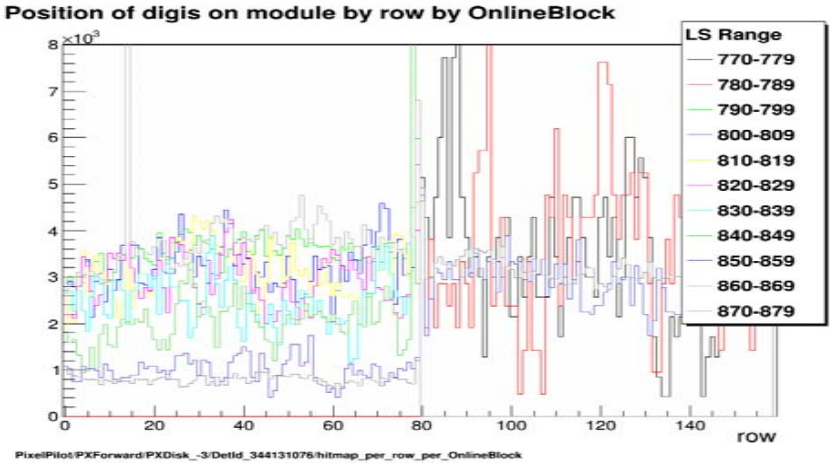
- Well advanced an **integrated in 90X**
  - a lot of improvement will come in 9_0_0_pre3

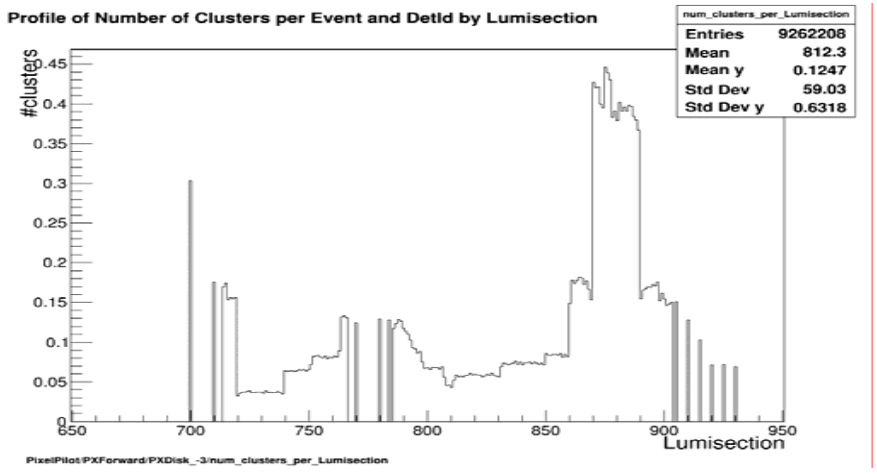
- A **fairly complete** and clear **documentation** is available:
  - https://twiki.cern.ch/twiki/bin/viewauth/CMS/PixelDQMPhaseI
  - An hands-on tutorial session will be held next Thursday dedicated to future developers

- A dedicated set up **to support timing scans online** needs to be created, and run by the core DQM team
  - https://twiki.cern.ch/twiki/bin/view/CMS/Phase1TimingScan
  - Successfully **tested on Pilot Blade** data in 2016
  - Will need adapting to 2017 (CMSSW releases, config files etc.)

- Soon will circulate a detailed review of the structure and content of the new framework

DQM: Plots on Pilot Blade

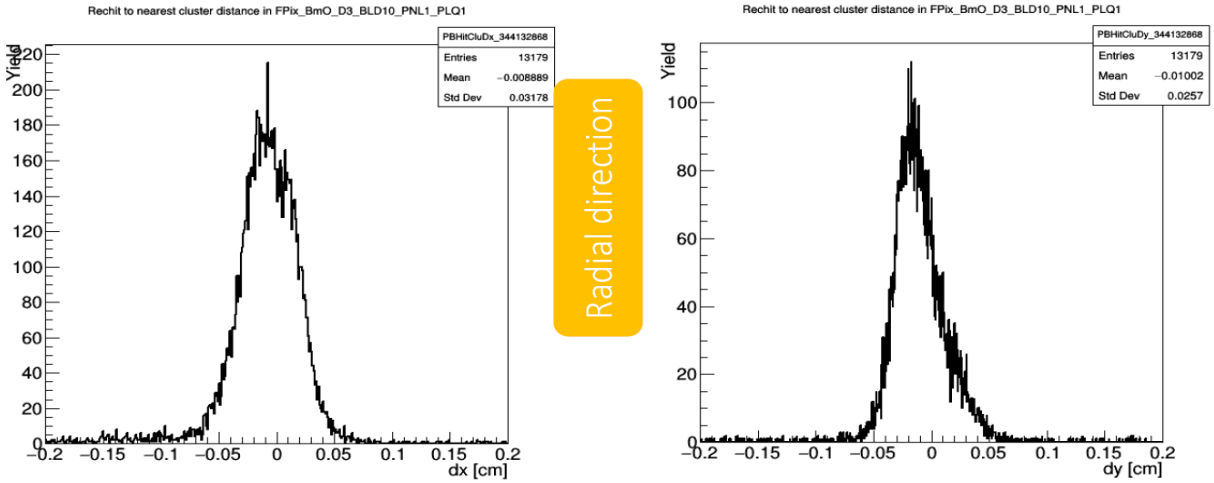


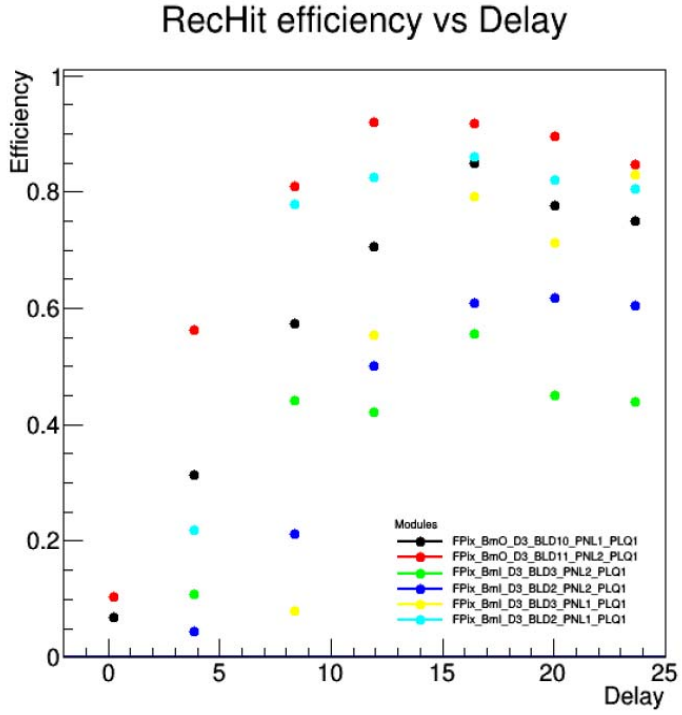


- **DQM plots quantities integrated over LS ranges**
- Experiments on which plots can be useful:
  - **Superimposed 1D** histograms for different LS ranges (top)
  - **Trend profiles** for the relevant detector partitions (bottom)
- Ran a private online **DQM for Pilot Blade timing scans during pPb running**
  - Needed to change online settings (timig) in sync
  - **Enhancements in number of clusters** when **at right timing** is clearly visible

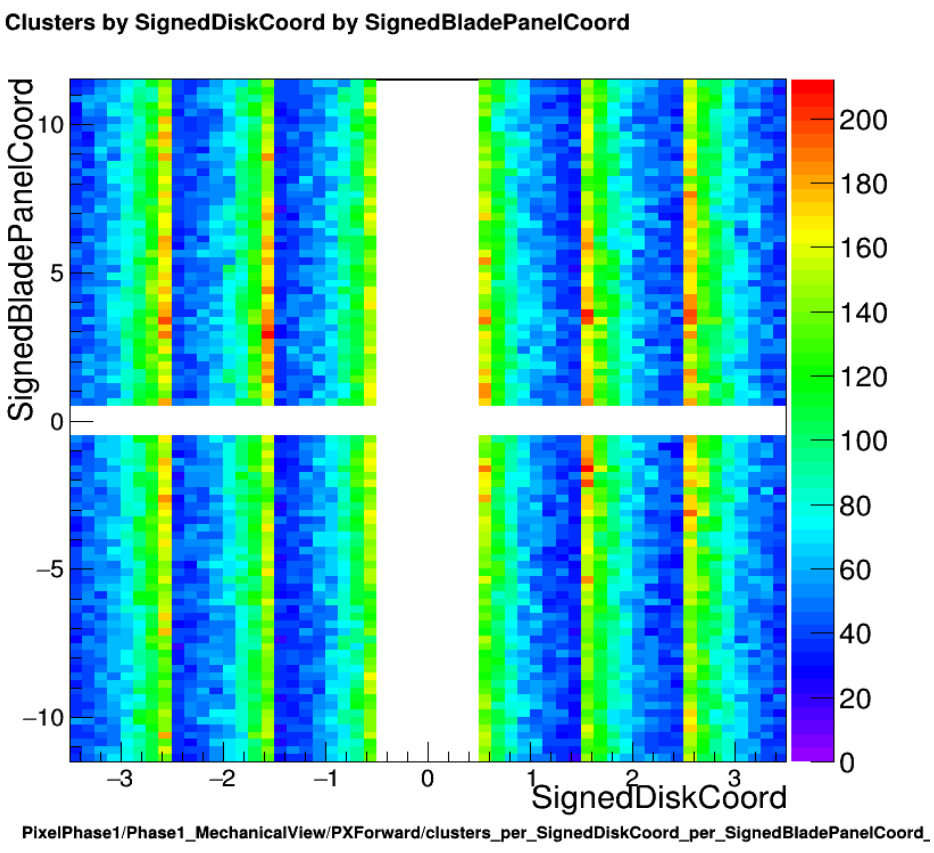
Pilot Blade timing – from last LHC (HI) fill...

- **Timing scan evaluated offline**, demonstrates reading out the right event with the Pilot blade
- Very **hard to measure** intrinsic detector **resolution and efficiency**
  - Simplified regional tracking for faster re-reco
  - In the fringe of tracking coverage
- **Clear evidence of optimal timing** setting

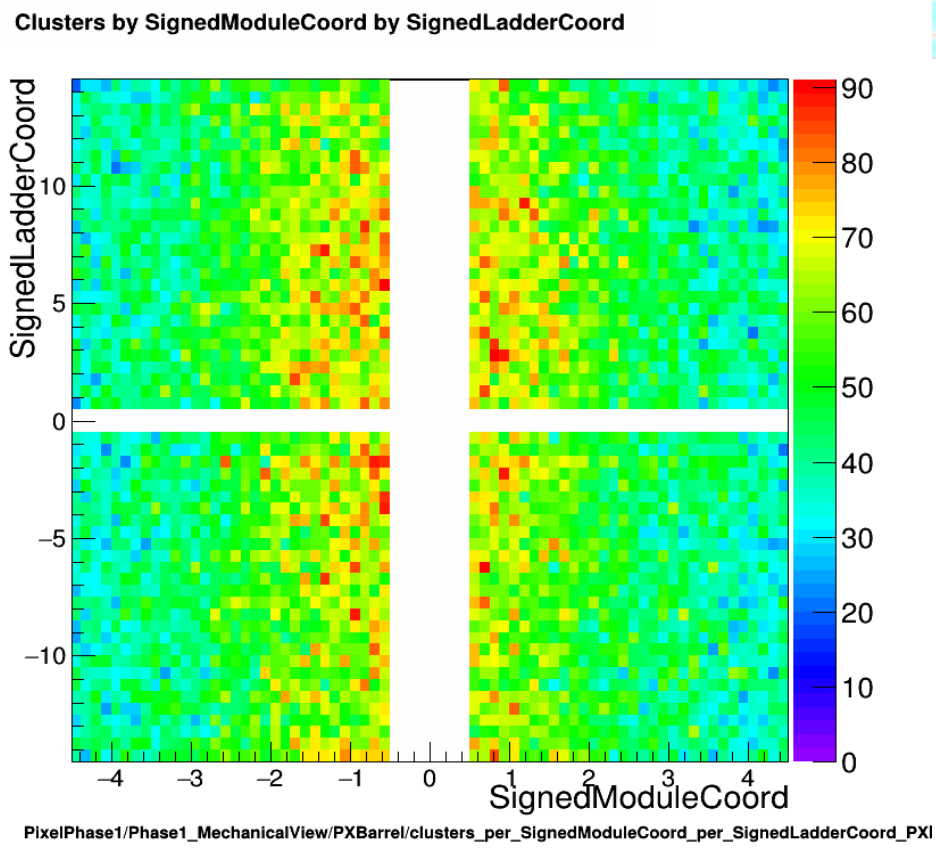




DQM: Pixel Maps



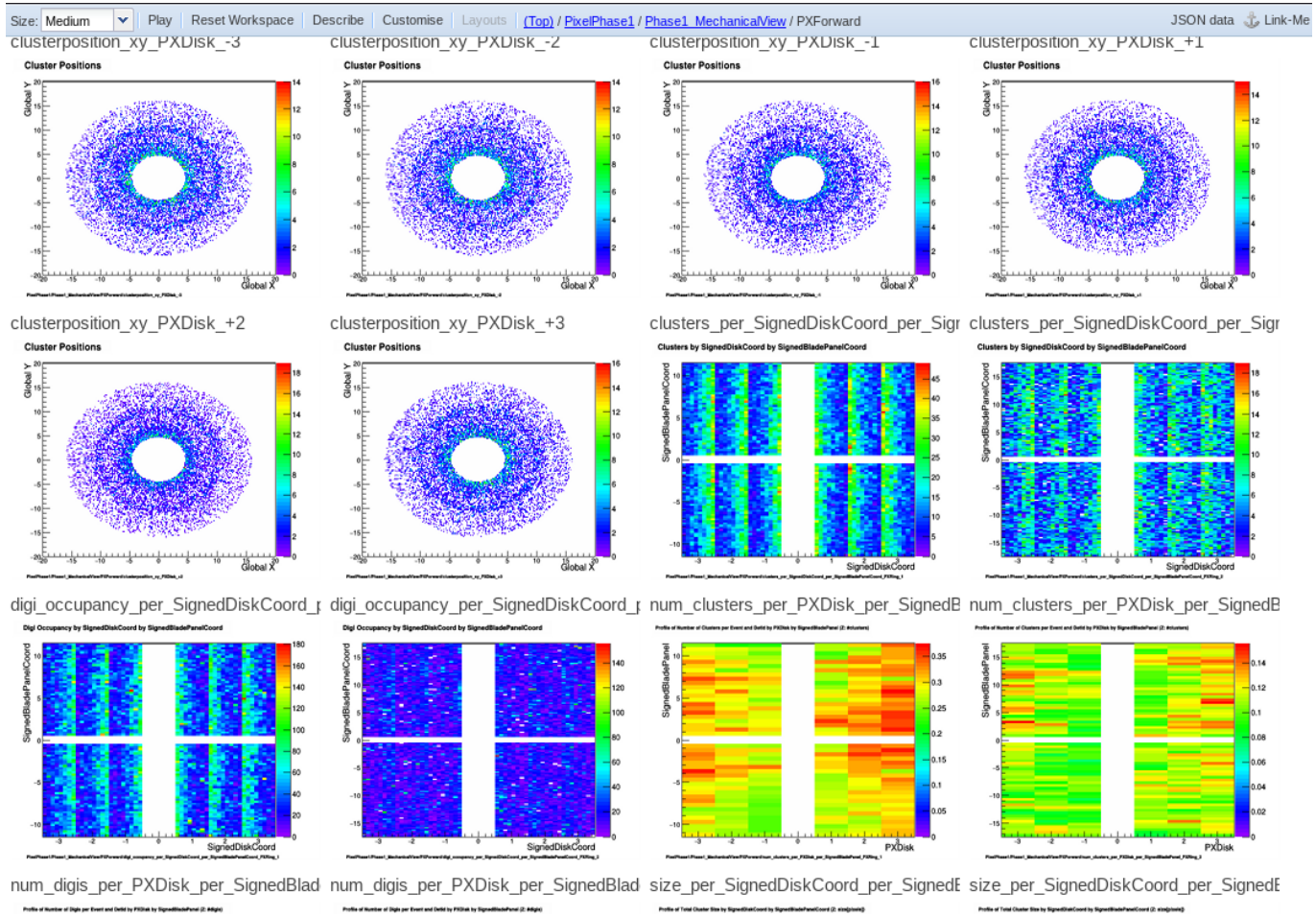
FPix : One per Ring(inner,outer)



BPix: one per Layer

DQM: Pixel Maps Zoology

Global Position Maps



ROC level Maps (count)

Module level 2D profiles

Special Online Setup for Phase1 calibration

- Normal online DQM should run as usual for production

- Have a **dedicated online DQM** client to produce special plots **for time alignment**
  - Should run in the **production system** as a **separate process** (private online DQM as for the Pilot Blade is error-prone).
  - **Small** and specific **selection of plots** allows faster feedback (more events can be processed in limited time)

- Potentially have even more processes e.g. for experimental changes or higher statistics on specific quantities (digis, clusters, tracking in online etc.)

- Tune Summary plots with real data

Plans for the beginning of data taking

- DQM shift operation 2017
  - DQM on-call experts for pixel and strips
  - Prompt Feedback Group
    - 2 shifters (Cern + FNAL) + SL (at Cern) + 2 **experts** on-call
  - 2 weekly reports from the SL
    - the DQM and DPG meetings (Tue and Fri)
    - plus 2 daily reports on data quality (ELOG)
  - DQM expert **at P5** to assist Phase 1 calibration
    - on top of the on call experts
- Shift coverage
  - Tracker Offline shifts
    - Shifter slots are 100% covered
    - Missing only 3 weeks of SL
    - About 50% of remote SL in the second part of the year
  - DQM on-call
    - A team has been formed last year
    - Will be involved deeply in the first period of data taking

Preparation for start-up – discussions with RC

- Triggers:
  - Heavy software commissioning: **ZeroBias, Random** – if ZeroBias rate reduced +a **Tracker independent trigger** (HLT_Physics)
  - Normal operation: **ZeroBias, Random, NoBPTX, SingleMuon**

- ALCARECO
  - Alignment group:
    - TkAlMinBias – mix of various physics triggers, includes ZeroBias
    - TkAlMuonIsolated – single muon
  - Strip group:
    - CalibProdSiStripGains
    - CalibProdAfterAbortGap
    - PromptCalibProdSiStripGains
    - PromptCalibProdAfterAbortGap
    - PromptCalibProdSiStrip
  - Pixel group **uses no ALCARECO**

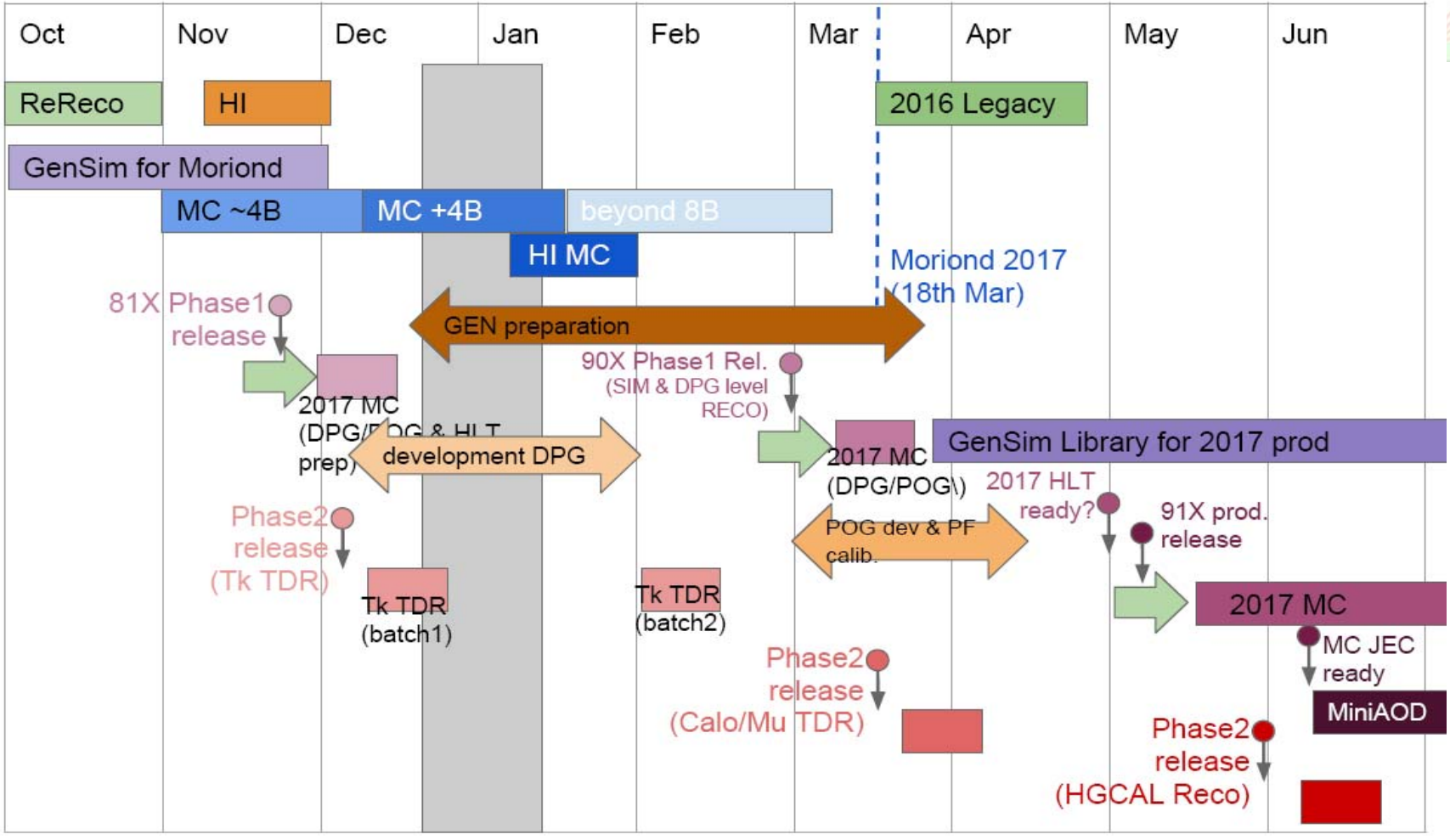
- RAW data
  - For the triggers mentioned earlier
  - **Easily available for the whole year**

- Express data
  - FEVT is desired in the first month
  - **Should always be available for ~a month**
  - During heavy commissioning:
    - ZeroBias trigger should be unprescaled (more precisely, maximum whatever HLT takes)
  - Normal operation
    - Prescale of ZeroBias can go back to normal when tracking at HLT is good enough

- RECO
  - For the triggers mentioned earlier
  - **At least, ~2 months after production**
  - **For the full year:** RECO or AOD (**anything with tracks**) is ok **as long as RAW is easily available**

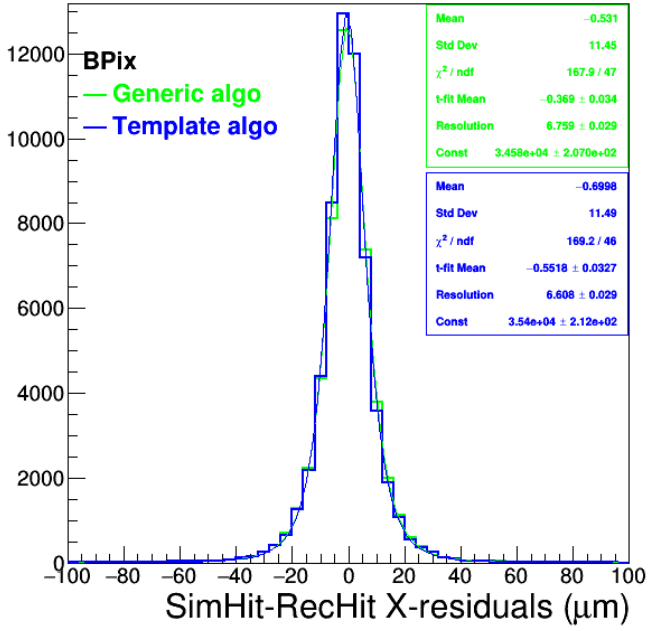
Backup

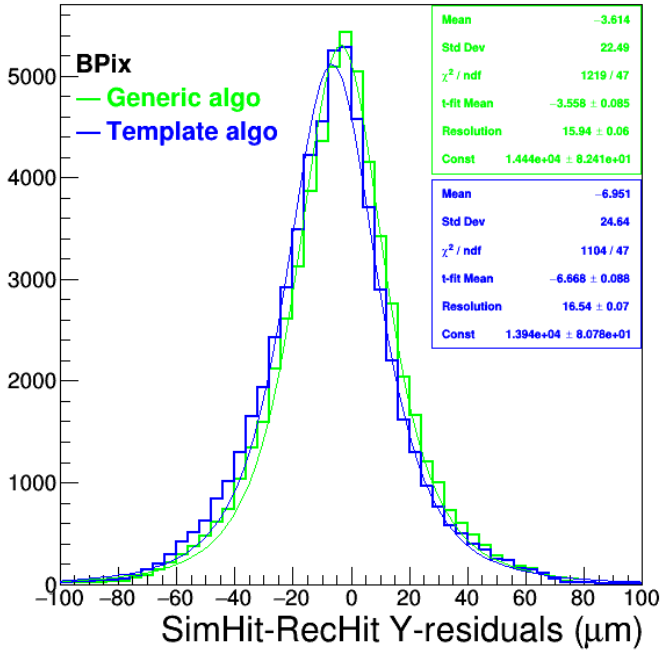
Production schedule (under development)



Local reconstruction - simulation

- Example validation of Barrel Pixel geometry and local reconstruction





- Simhit – Rechit residual along local x (global phi) and local y (global z)
- Good resolution for both Generic and Templates cluster position estimate with the present DB content
  - Position bias with Templates will be corrected by March

Misalignment at start-up

Structure	Δx [μm]	Δy [μm]	Δz [μm]
TPBBarrels	500 (uniform)	500 (uniform)	1000 (uniform)
TPBHalfBarrels	100 (uniform)	100 (uniform)	100 (uniform)
TPBLadder	500 (uniform)	500 (uniform)	500 (uniform)
TPBModule	100 (gaussian)	100 (gaussian)	100 (gaussian)
TPEHalfCylinders (+z)	250 (fixed)	250 (fixed)	-680 (fixed)
	250 (fixed)	-250 (fixed)	-720 (fixed)
TPEHalfCylinders (-z)	250 (fixed)	250 (fixed)	3940 (fixed)
	-250 (fixed)	250 (fixed)	4020 (fixed)
TPEHalfDisks	250 (uniform)	500 (uniform)	100 (uniform)
TPEBlade	300 (gaussian)	300 (gaussian)	200 (gaussian)
TPEModule	200 (gaussian)	200 (gaussian)	50 (gaussian)
StripModule	20 (gaussian)	20 (gaussian)	20 (gaussian)