Status of the Strip hit inefficiency (HIP) studies

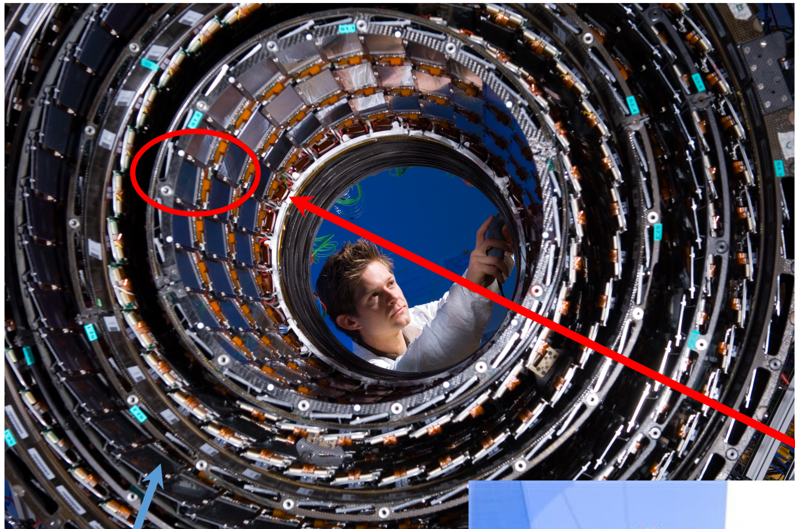
Gaëlle Boudoul
CMS Weekly General Meeting
4 August 2016

Outline

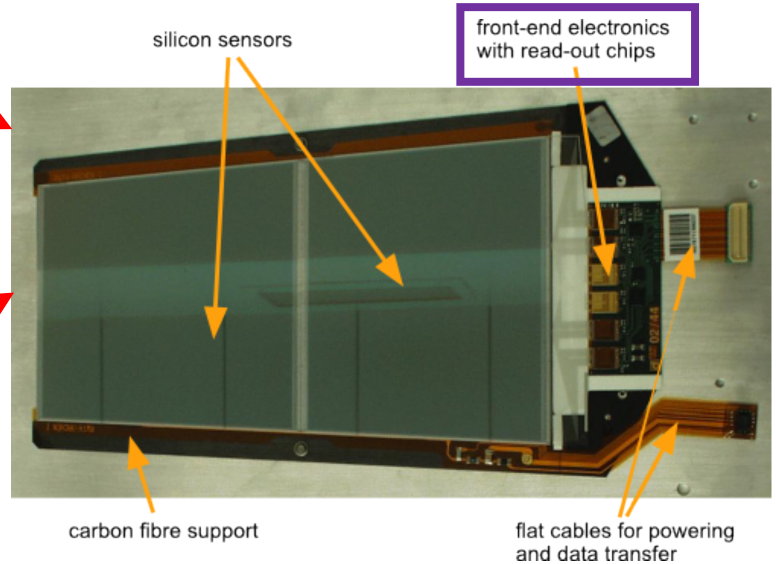
- Brief Introduction : The Silicon Strip Tracker and Readout Chips
- What is a HIP and what we do observe
- Mitigations and Plans
- HIP Task Force

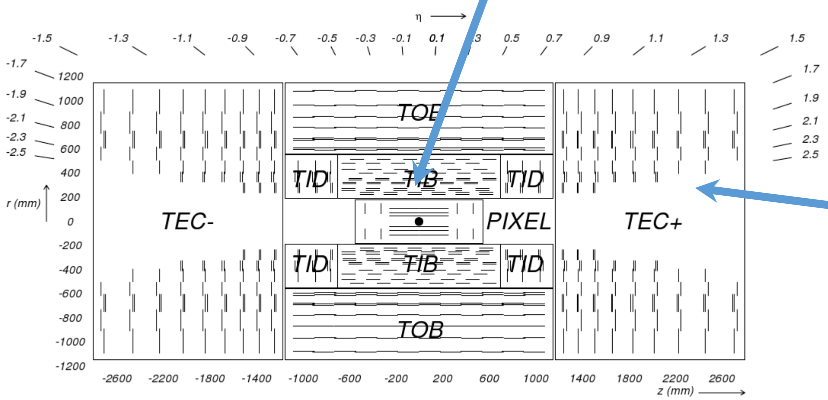
The Silicon Strip Tracker in a nutshell

Layers of TIB
(Construction)

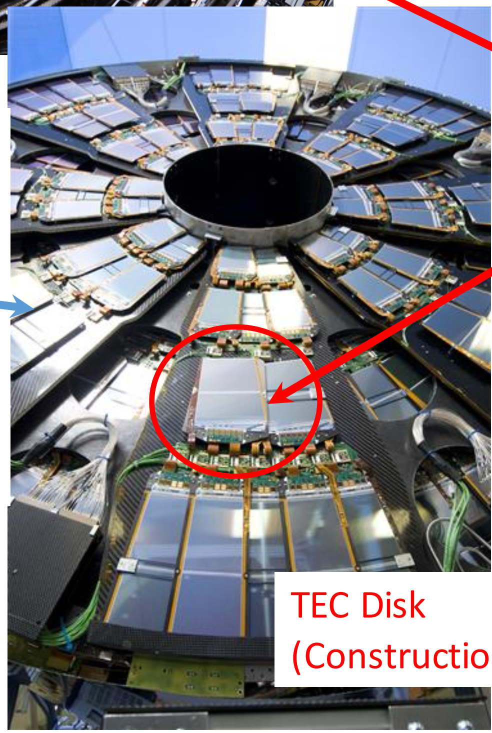


Layers and disks are composed of
Modules (with different shapes, thickness…)
~15000 Modules in total





Full Tracker

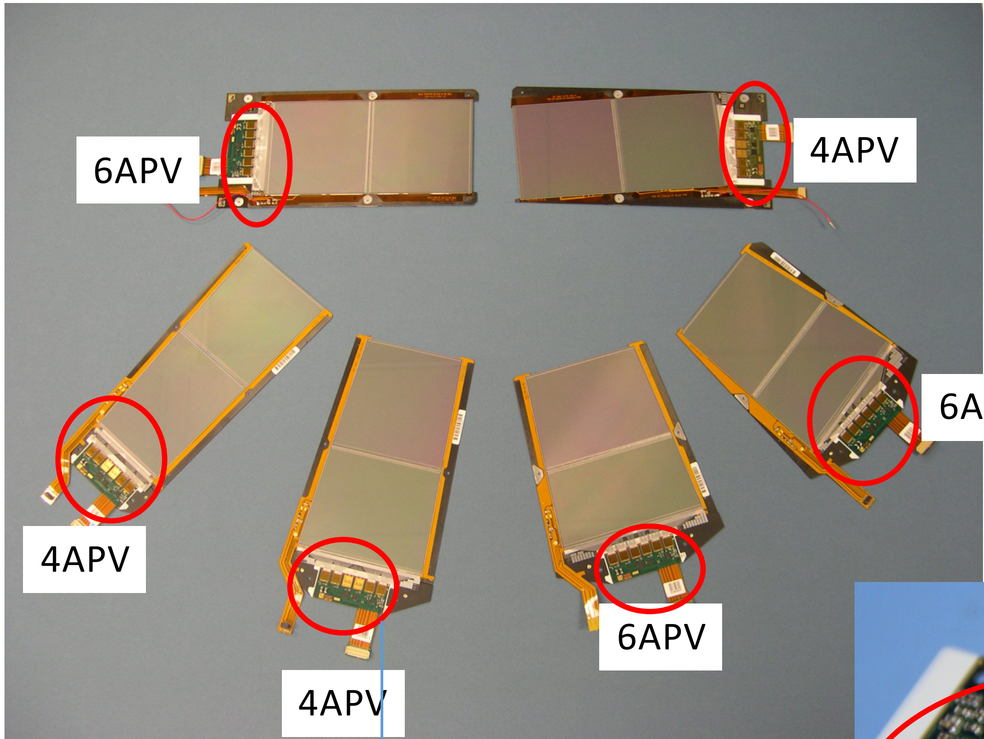


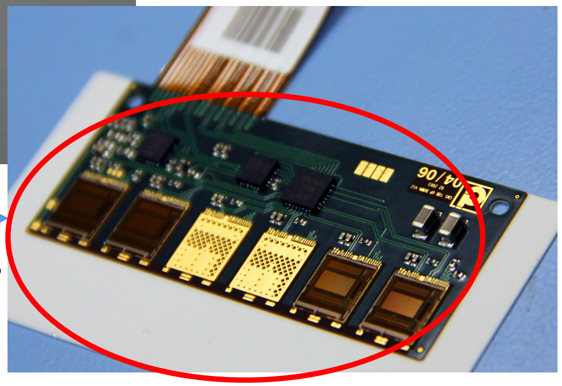
TEC Disk
(Construction)

75000 Read Out Chips (APVs)
→10 million read-out channels
covering about 200 m2 total area

[Ref: The CMS tracker system project : Technical Design Report]()

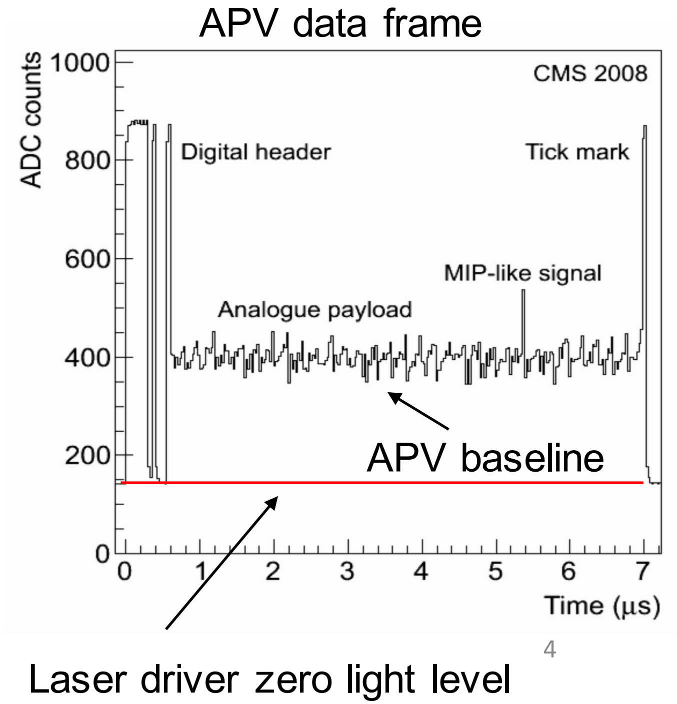
The APV25 chip




Zoom on the APVs

[REF: The CMS Tracker APV25 0.25 µm CMOS Readout Chip]()

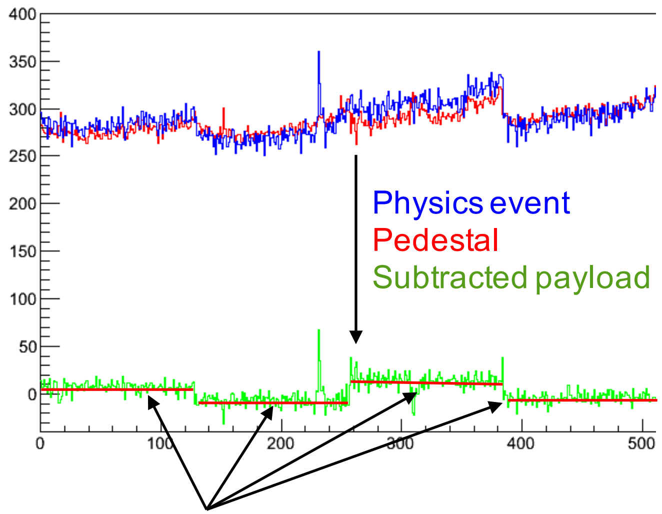
- Readout chip for the silicon strip tracker modules
  - 4 or 6 APVs per module
  - 128 strips per APV
- The APV sends out data in so-called frames
- **Baseline (median of all strips)** of the APV is adjusted to a certain height within this frame to optimize dynamic range



Some Basics

- Each strip has a certain signal height in the absence of a particle hit → pedestal
  - Fluctuation of this signal level around the pedestal = noise
- Pedestal and noise are used in zero-suppression to identify strips with signal
- After pedestal subtraction the median value of all chips of the APV will (typically) be different from 0 = common mode

Module with 4APVs :

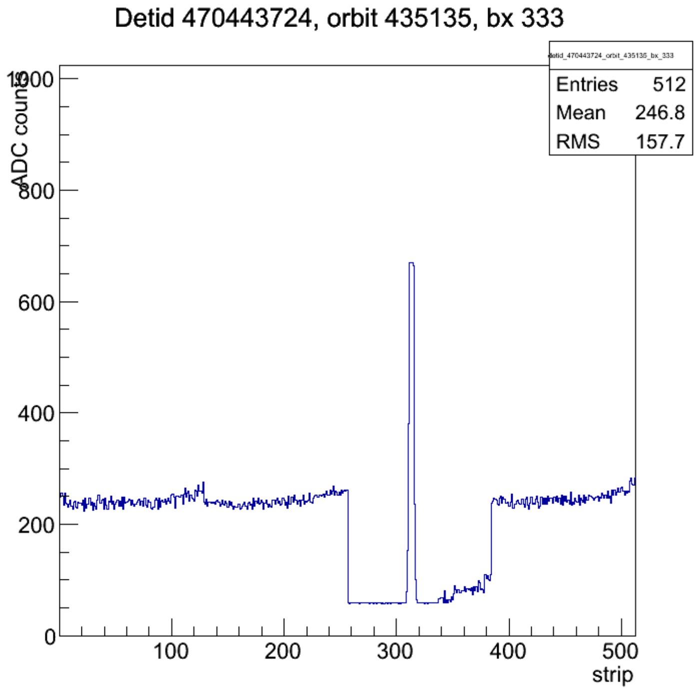


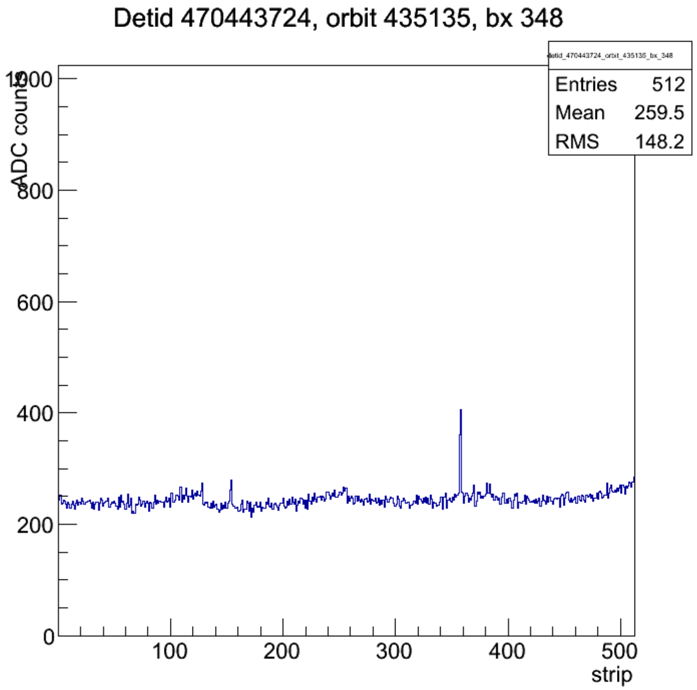
Common mode values

Preliminary question … what means HIP, what is it ?

- HIP = Highly Ionizing Particle (maybe someone should update the CMS glossary ? https://twiki.cern.ch/twiki/bin/view/CMSPublic/WorkBookGlossary ☺)
- Inelastic nuclear collisions of hadrons incident on silicon sensors generate secondary Highly Ionizing Particles (HIPs)
- Can deposit as much energy within the sensor bulk as several hundred Minimum Ionising Particles (MIPs)
- HIP events were first observed to saturate the entire APV front-end chip and introduce deadtime into the readout system during a beam test at the CERN X5 beamline (2002) See : **The Effect of Highly Ionising Events on the APV25 Readout Chip**

What happens when a HIP occured?



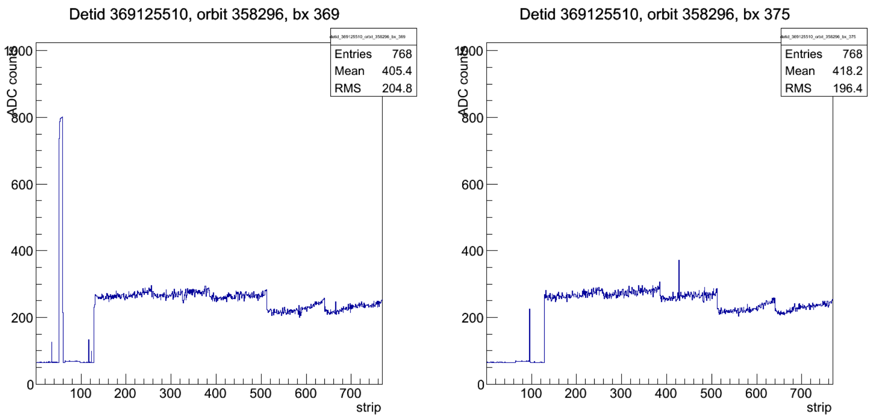


- HIP Event : Huge charge causing the drop of the baseline of the affected APV
- ’Normal’ (MIP) Event

What do we see with LHC data

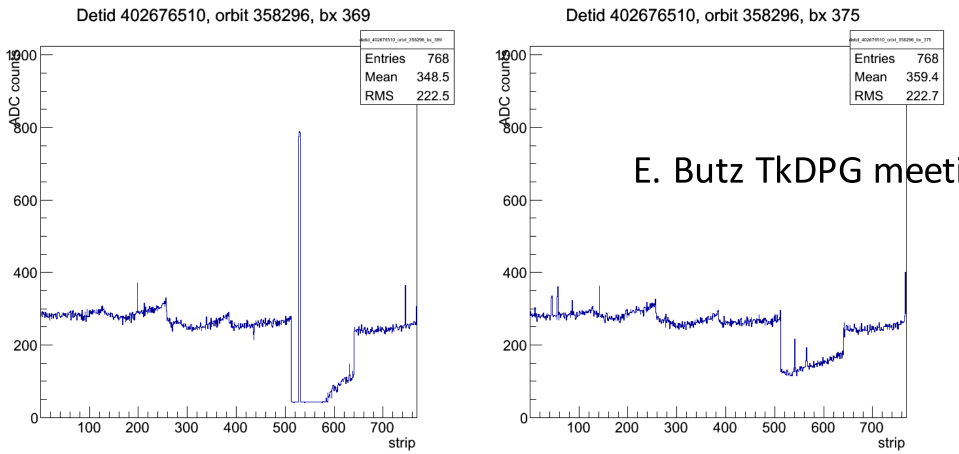
- Thanks to run taken in vigin raw mode (no zero suppression) one can visualize HIP events and see what is happening after..
- Examples :

Two events with 6 bx separation



Baseline suppressed but hits visible after HIP 6bx earlier

Two events with 6 bx separation

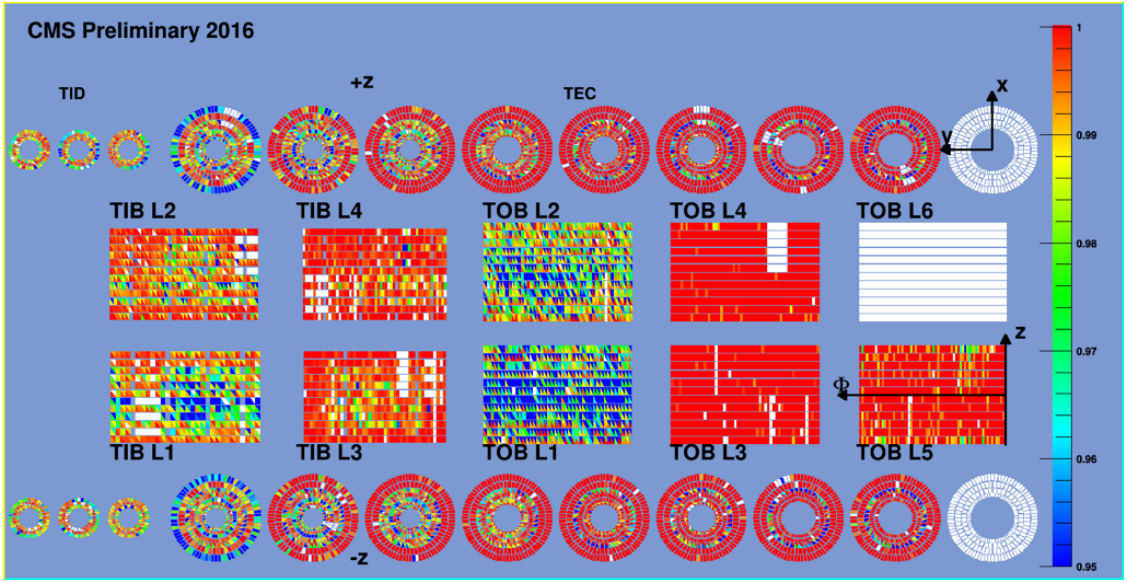


E. Butz TkDPG meeting May16

“Non-flat HIP” and non-flat recovery

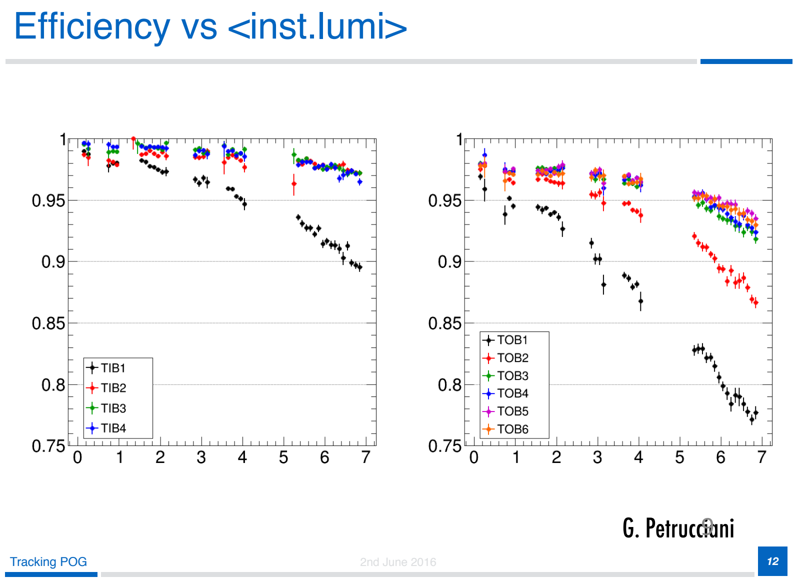
Affected APV25 chips are experincing deadtime after a HIP event, as the APV25 data frames contain baselines shifted to the lower limit of the available dynamic range and no signal in any of the 128 channels.

Consequence on the Hit efficiency



Caveat : please don't pay (nor draw) conclusions of the fine structures of the map , hit efficiency and possible biases of the method are under evaluation

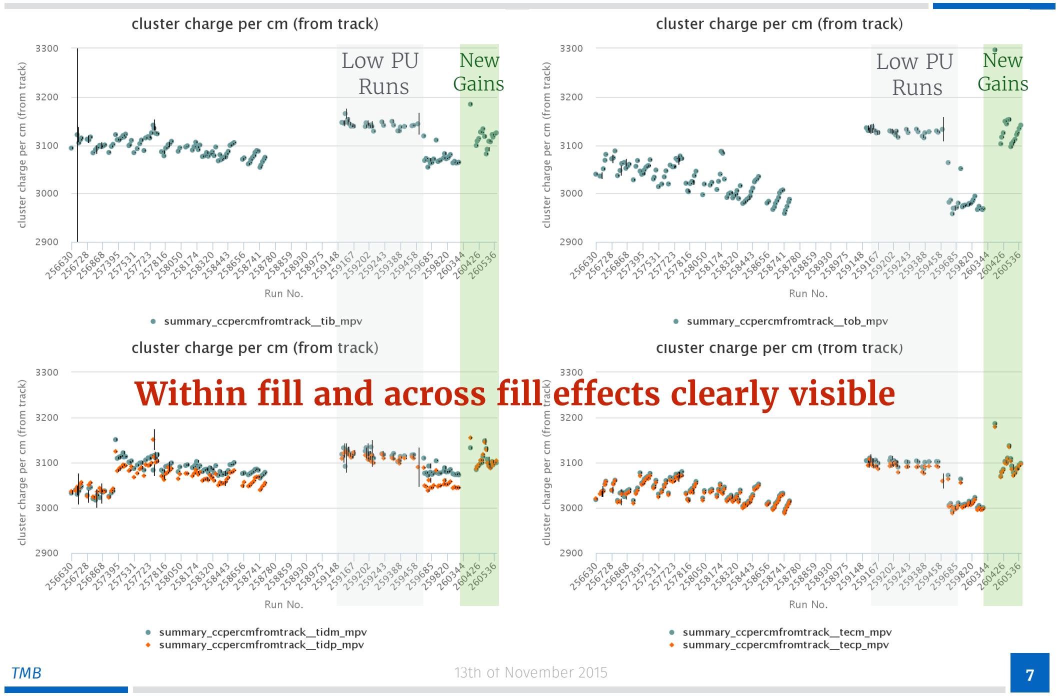
- Hit inefficiencies are observed due to the HIP events and the time for the APVs to recovers.
- On this map , one can see that the most affected are inner layers of TIB/TOB and inner rings of TEC
  - Main hypothesis : Balance between occupancy (inner parts) and sensor volume (length/thickness)
  - This hypothesis is currently quantified and tested
- Also confirmed by Tracking measurements



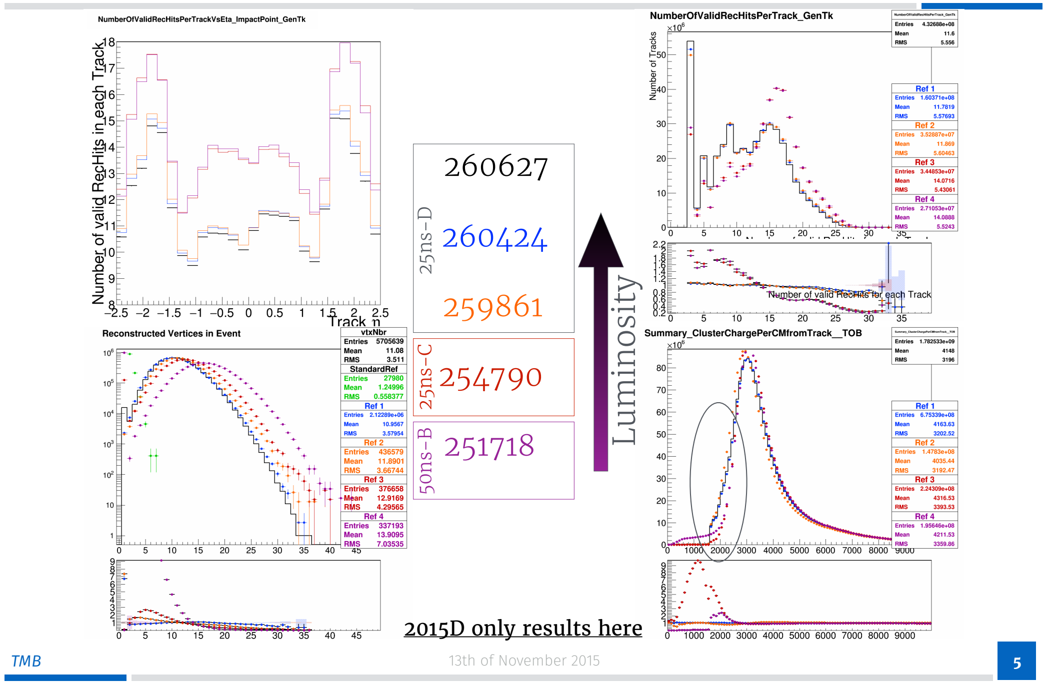
Observation from 2015

- Performance measured in 2015
  - Tracker- Tracking performance affected with a clear dependency with luminosity

“Charge Stability” in Run2015D



Track/vertex/hit Properties- Full2015

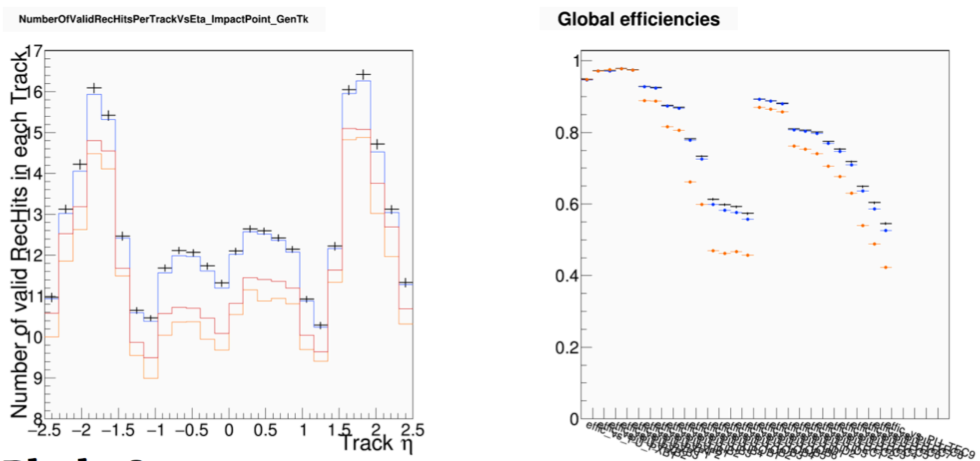


M. Rovere, V. Innocente et al.

First Mitigation From Tracking POG

Mitigation in 800

CCC RETUNING IN PR12718 - DATA "VALIDATION"



Black: 800pre4

Orange: IB/ before 800pre4

Ignore Blue

Red: Prompt-Reco (full statistics)

XPOG 2nd February 2015 11

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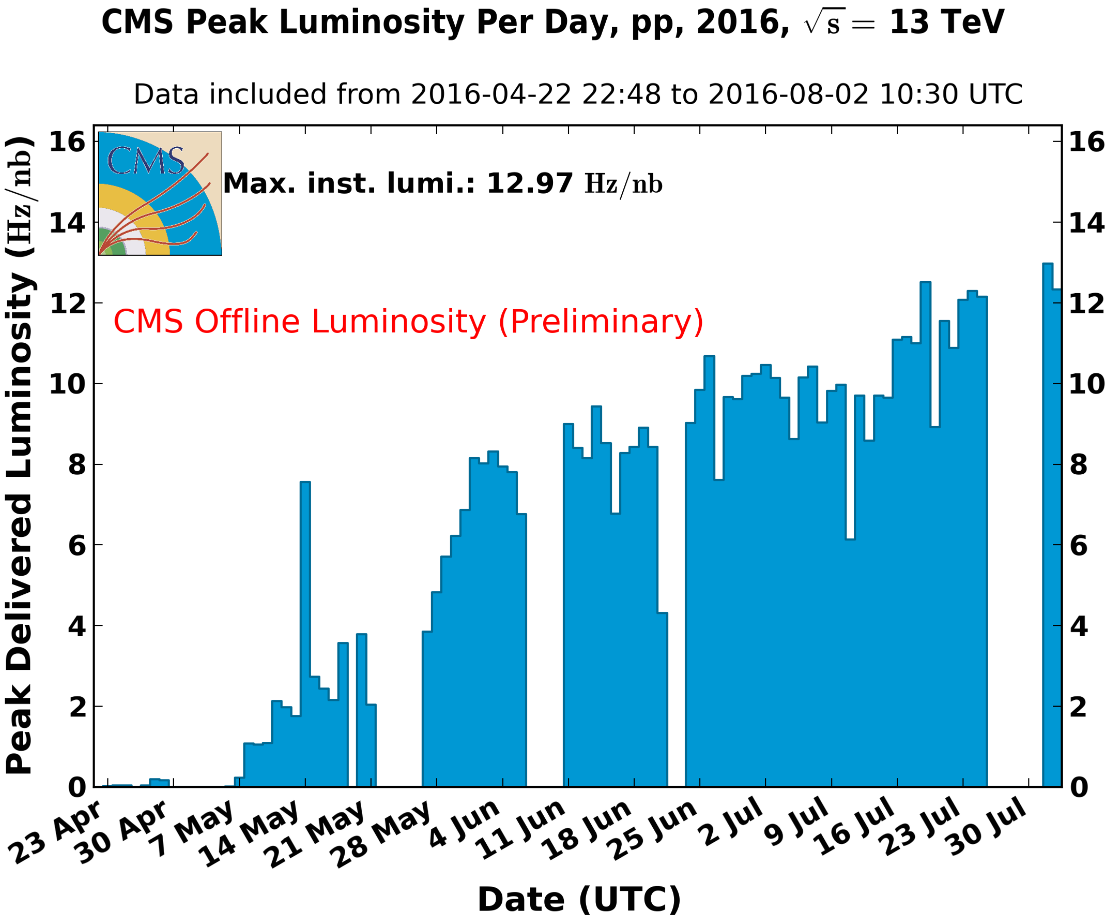
- Cluster Charge Cut retuning
- This mitigation is already in place since ~beginning of January 2016
    - Recovering a large fraction of the losses observed in 2015

M. Rovere, V. Innocente

2016 : LHC is performing extremely well

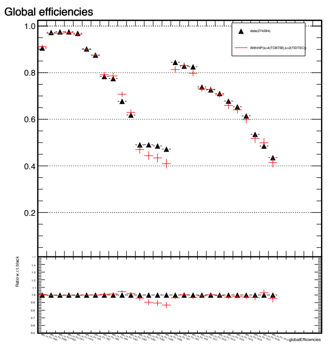


More actions are needed to mitigate the increase of the luminosity

Need of a realistic simulation

- In order to assess performance of any software mitigation, a realistic simulation is needed
  - Simulating at the digis level the loss of signal due to the probability of being affected by a HIP
- This simulation is in place et samples have been made available for data-MC comparison in order to support the software mitigation effort
  - The simulation looks reasonnable but can certainly still be improved

Basic data/MC comparisons: run 274284 (IL∼6e33)

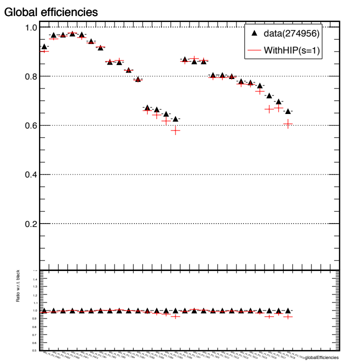


Adjust two internal scaling factor for the map creation: one for TIB TOB (7), and one for TID/TEC (5).

July 29, 2016 9 / 11

data/MC comparisons: run 274956 (IL∼2.2e33)

Using the previously created map: adjust one single scaling factor to account for inst. lumi change.

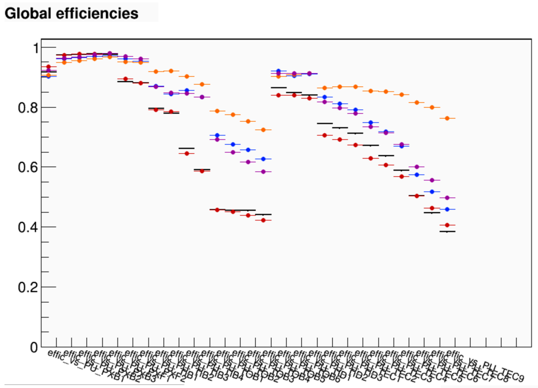


July 29, 2016 10 / 11

S. De Visscher
Simulation Meeting
2016, Jul 29

Tracking Mitigation

- A new mitigation from Tracking POG has been proposed : Details in last CMS week TRK report

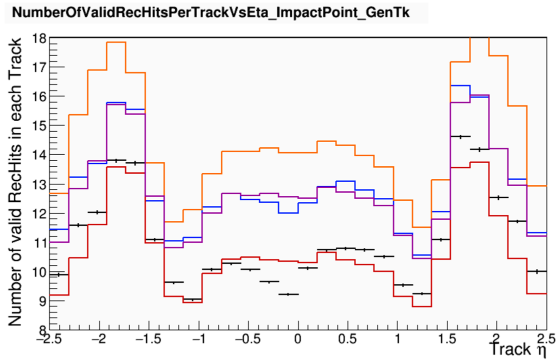


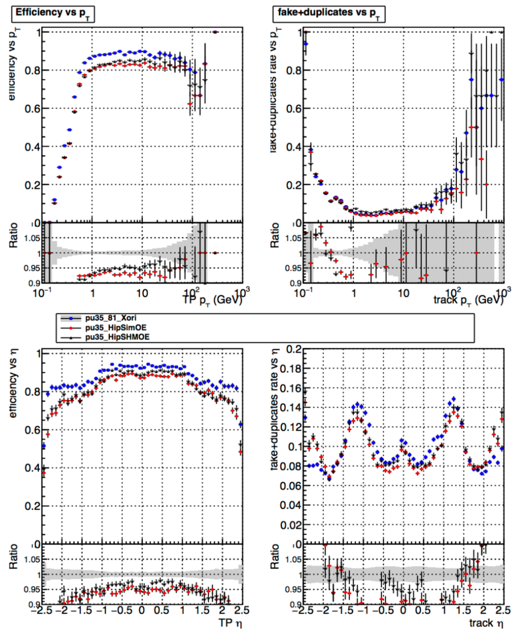
Run 274314 standard reco
Run 274314 with HIP mitigation

MC (TTBAR 35PU) original
MC with HIP simulation
MC with HIP Sim and mitigation

REMINDER:
plots p_t > 1GeV

Asymmetry in data most probably due to greater effect of BPIX2 inactive octant





High purity general tracks
Standard
HIP simulation
Mitigation (pt>900MeV)

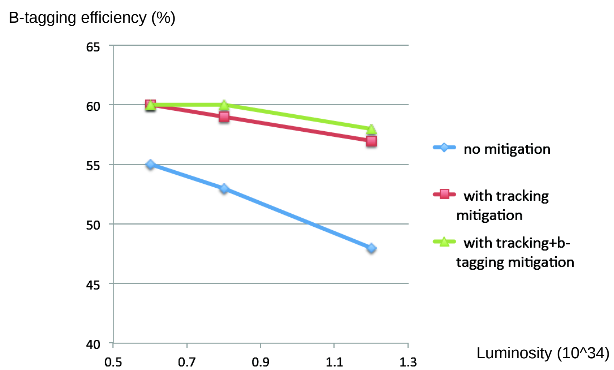
M. Rovere,
V. Innocente,
M. Kortelainen

VALIDATION also presented in the PPD meeting
Just before the general meeting

Btagging Mitigation

- Relaxing the cut on the number of hits is improving btagging efficiency
- Fresh results presented at the last Btagging Meeting (Aug 1srt)

Impact HIP vs luminosity – 1% mistag



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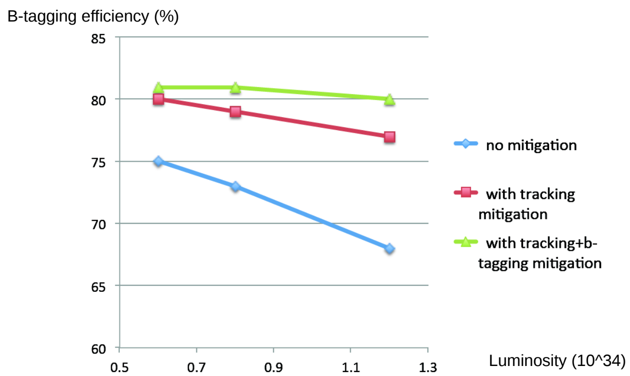
Impact HIP vs luminosity – 10% mistag



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Jarne Theo De Clercq, Petra Van Mulders

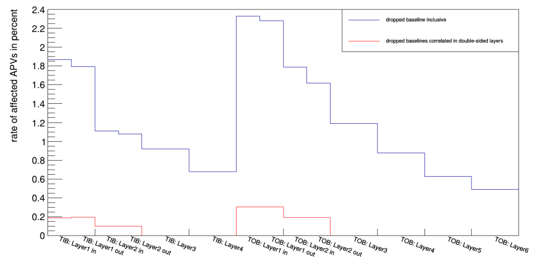
Tracker Detector Possible mitigation ?

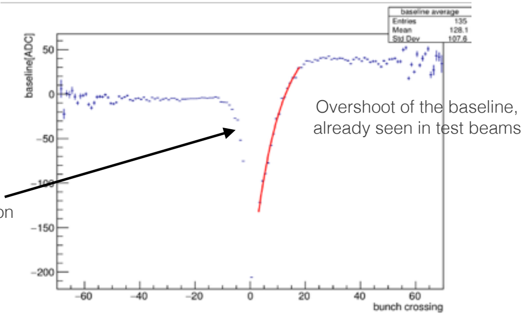
- The current Strip Tracker will take data till LS3
  - Only the inner Pixel will be exchanged in 2017
- Several fronts under investigation in order to try to mitigate this effect
  - **But to be clear the only short-term solution is a software (offline) mitigation**.
- The very first step is to understand deeply the issue
  - We had the opportunity to take two virgin raw runs which are extensively analysed
  - The main points still in progress are:
    - HIP Rates
    - Recovery time :
      - Measurements are indicating something between ~250ns up to ~ µs - Still under investigations
- Most likely more virgin raw runs will be needed

VIRGIN RAW DATA ANALYSIS

- **Rate of HIP events**
  - Selection of APVs based on the baseline drop
  - Higher rate on inner layers
  - Detailed study of double layers on-going. For now see an higher rate on the modules closest to IP.
- **Following recovery of the performances**
  - Selection of APVs based on the baseline drop. Investigations for adding other criteria.
  - Define the time of these events to be 0
  - Look for evolution of:
    - Baseline: recovery found to ~10-15 bx.
    - Hit multiplicity
    - Cluster charge
  - On-going work. Needing refined selections.
- **More studies planned**

rate of affected APVs per layer





Baseline recovery for events with a saturated baseline.

E. Chabert, M. Jansova, JL Agram et al.

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Mitigation from the FED?

- Can the FEDs identify properly the affected APV and propagate the information to Offline Reconstruction ?
  - First assuming this is possible : assessing the impact of the knowledge on physics (tracking) performance is going to be performed thanks to simulation.
  - Then virgin raw data can be used to see whether affected APVs can be easily identified (easily means with respect to what can be done in a fed), using the Common Mode for example.
- If success of the two points above when we can think whether this is really feasible at the level of the Fed and in which timescale

Virgin Raw Data & Zero Suppression algorithm

- Virgin raw (VR) data are also used to assess performance of different (possible) zero suppression algorithms
  - Raw Data Processed to test different ZS algorithms: median, HI, baseline follower, median on a small strip range, shifted pedestals etc…

- The VR is also important to classify where the hits are lost: detector, ZS, clusterizer, cluster Charge Cut etc…

To Do List

- *The To-Do list preapred to undertand and eventually mitigate as much as possible the HIP impact is huge and evolving – Selection of items…*

- Collect VR data with pixel and reconstruct them
  - To be used to understand where the hits are lost: detector, ZS, clusterizer, CCC, outliers rejection,…
  - To be used to test different ZS algorithms: median, HI, baseline follower, median on a small strip range, shifted pedestals,…
    - Be sure about compatibility between FED ZS and offline ZS (aka "Strasbourg puzzle")
  - To check if we can add some information in the FED payload to tag inefficient APVs
  - Spy channel??
- Understand if 50ns and 25ns are qualitatively different or not
- Understand if 2012 and 2015+2016 are qualitatively different or not
- Understand if the shifted pedestals have really NO effect
- Investigate the modules in TOB L1 with large S/N also at large luminosity!!
- Study variations of common mode, correlation with wide clusters, correlation with inefficiencies. The aim is to be able to tag possibly inefficient APVs event by event
  - We may need a map of the common offsets for each APV
  - Compare common mode in cosmics (high rate?) runs and in collision runs
- Enable common mode monitoring in DQM with the existing code
- Hit efficiency "a la Strip DPG" with tight search window
  - As a function of luminosity, BX, pileup, layers,…
  - With different conditions on the probing tracks: one hit up- and one hit downstream, with no missing hits except for the probed one, only hit upstream,…

- Investigate non-linearity of TOB L1 cluster multiplicity as a function of luminosity
  - Correlation with pixel hit multiplicity, number of vertices, luminosity from BRIL,…
  - To try to measure the hit efficiency independently from track reconstruction
- Measure hit efficiency in different part of the modules
  - To check for material effects
- Determine an unbiased cluster charge distribution of hits from good tracks
  - From the Strip DPG hit efficiency
  - From muon tag&probe analysis
- Classify the hit losses in double sided modules
- Recompute the effective layer efficiency from the muon analysis using the track reconstruction with mitigation
- Correlate any efficiency measurement with the hit occupancy with the aim of measuring an inefficiency "cross section"
  - Rescale layer efficiency results with the occupancy
- Prepare simulation code and configuration for CMS
  - Add the simulation of the distorted cluster charge
  - It can/has to be an iterative process: we should not aim for perfection at the first try otherwise we will never "try"
- Estimate impact of HIP at higher luminosities
- Estimate impact of HIP with phase 1 pixel detector
- Retuning of b-tagging track selection

HIP Task Force

- In order to go through the to-do list , prioritize and follow up the various fronts, a HIP task force is now in place
- Kick Off meeting organized yesterday :
  - https://indico.cern.ch/event/560058/
- The main mailing list/e-group is cms-trk-HIP@cern.ch
- Weekly Meetings are scheduled Wednesday morning 10.00 – 12.00 https://indico.cern.ch/category/8442/
- We are trying to keep track on activities and Results in this twiki page : https://twiki.cern.ch/twiki/bin/view/CMS/SiStripHitEffLoss