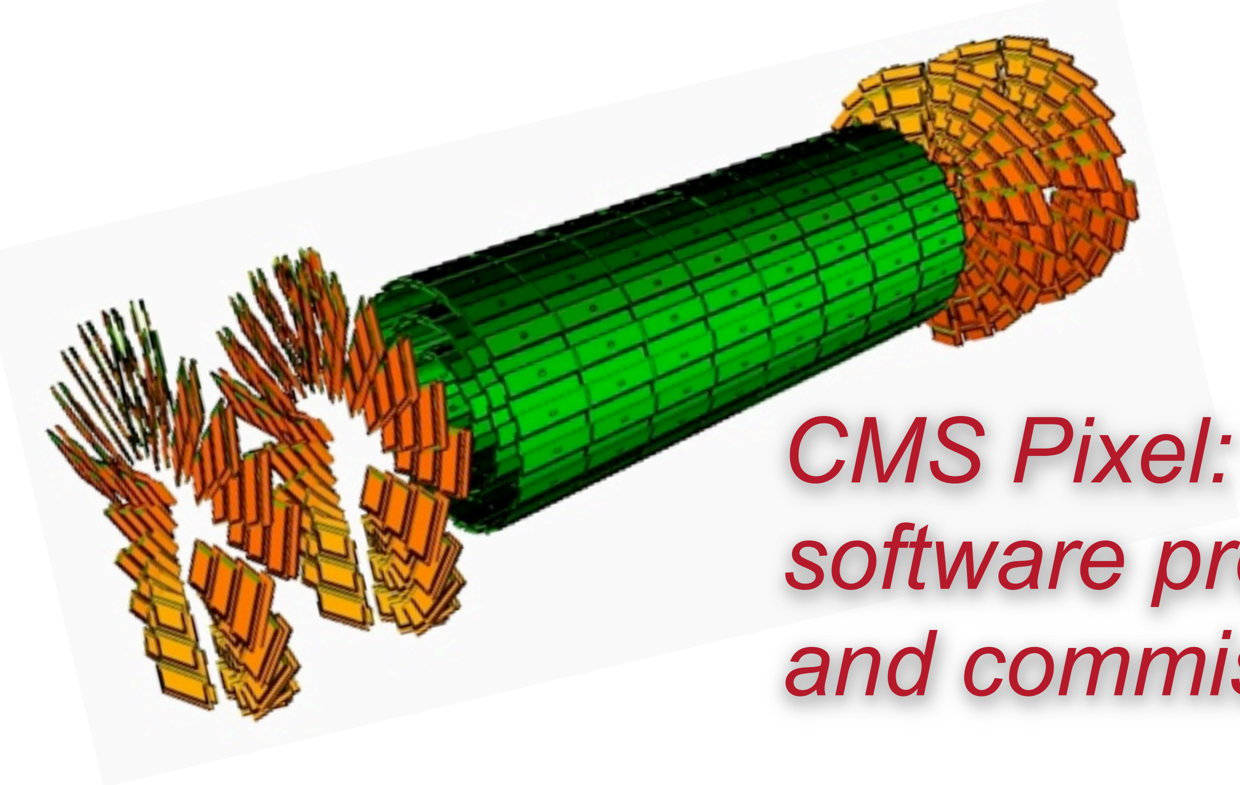

CMS Pixel: offline software preparation and commissioning

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University of Zürich

On behalf of the CMS Pixel Collaboration

17th International Workshop on Vertex Detectors

July 28-August 1, 2008 - Utö Island, Sweden

Outline

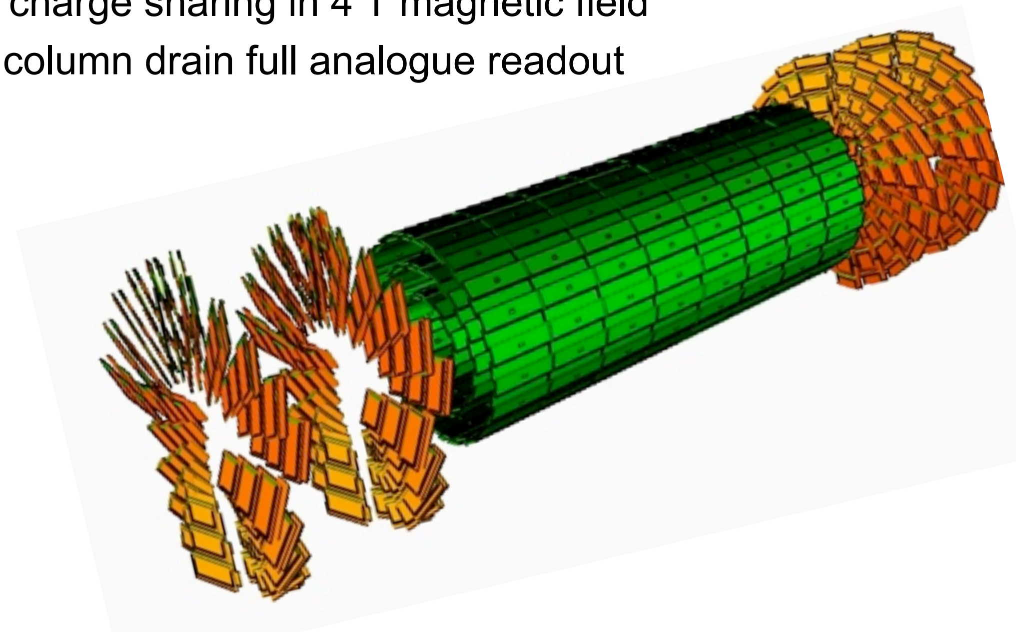
- CMS Pixel offline software
  - Detector layout
  - Simulation and hit reconstruction
- Detector calibration
  - CMS Tracker calibration workflows
  - Gain calibration and dead channels
  - Lorentz angle calibration
- Detector alignment
  - Results from CSA08 data challenge

Pixel Data Quality Monitoring:
see dedicated presentation by **P.Merkel (Friday)**
Firmware, low level calibrations and slow control:
see dedicated presentation by **A.Ryd (Tuesday)**

Detector installation

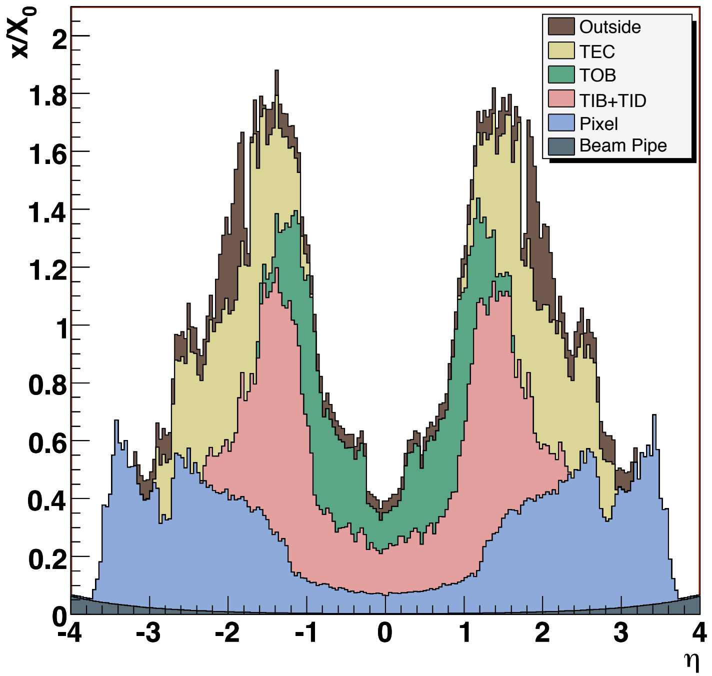
Detector layout

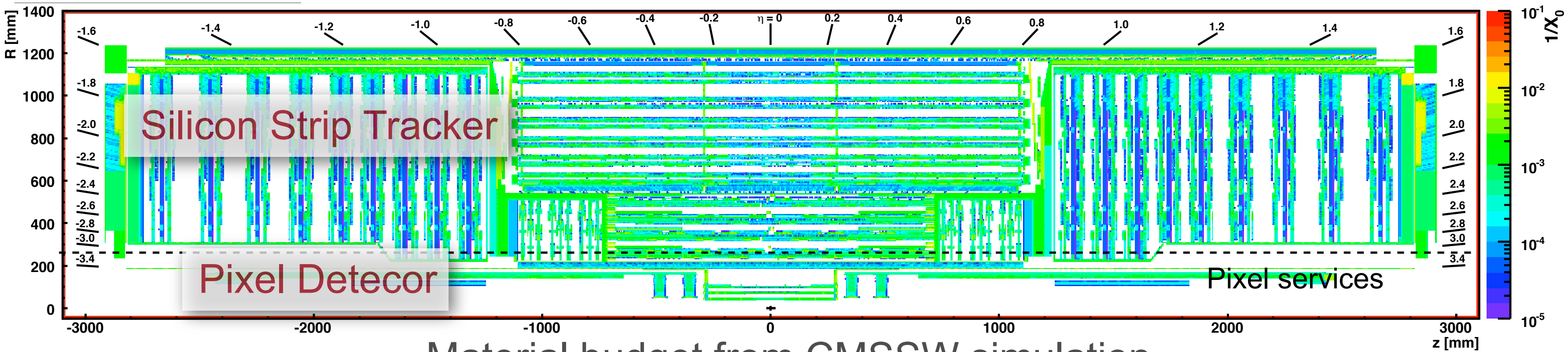
- Three barrel layers and two endcap disks at each barrel end
  - Barrel layers at 4 cm, 7 cm, and 11 cm radius
  - ~700 modules made of 16 chips in barrel region (67k channels/module)
  - Endcap disks: 24 blades made of 7 sensors (4 or 3 per side)
  - About $67x10^6$ channels in total, L~1 m, R~30 cm
- Sensors and frontend:
  - *"n-in-n"* design with p-spray (barrel) and p-stop (endcaps) isolation
  - $100(r\phi)x150(z)$ μm^2 pixel cell, charge sharing in 4 T magnetic field
  - PSI 0.25 μm CMOS chip with column drain full analogue readout



CMSSW simulation

- CMSSW simulation based on detector geometry description (XML), GEANT4 particle propagation and detector digitization code
- Pixels simulation:
  - Big effort spent in reviewing simulated material.
  - Simulated weights compared with measurements, general good agreement
  - We are finalizing the description of barrel services in the high rapidity regions



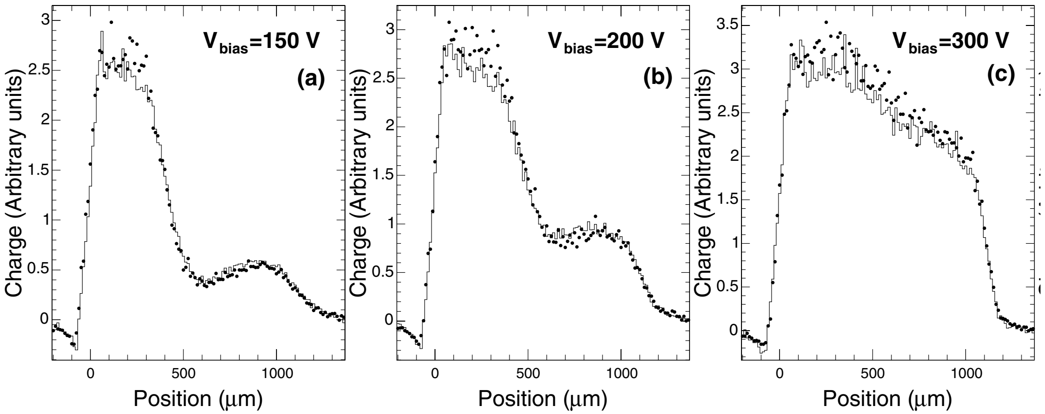


Material budget from CMSSW simulation

PIXELAV: a sensor simulation

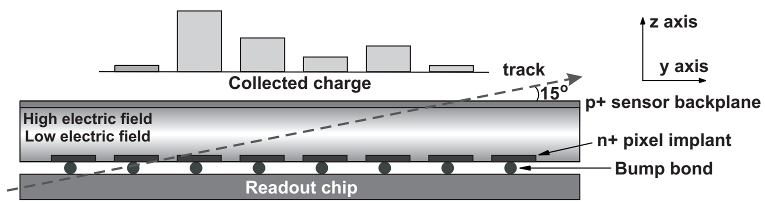
- In addition to the standard CMSSW full detector simulation a dedicated pixel sensor and front-end simulation was developed
- Electrostatic simulation based on TCAD plus charge creation, drift and signal induction based on custom program PIXELAV.
- Incorporates double-trap effective model of radiation damage. Describes cluster shapes from beam tests in a wide fluence range Φ_{eq}=(0.5-6)x10^{14} n/cm^2
- The simulation is used to extract average cluster shapes, called *templates*

Sensor irradiation: Φ=6x10^{14} n/cm^2



Full line: PIXELAV simulation
Full dots: test beam measurements

Grazing angle technique



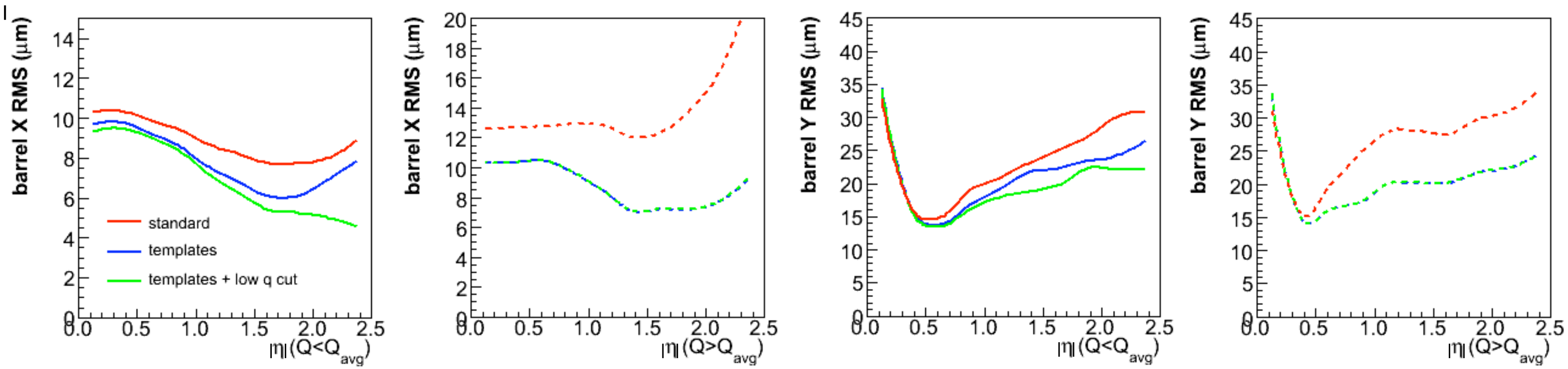
V.Chiochia, M.Swartz et al.

Nucl.Instrum.Meth.A565:212-220,2006
Nucl.Instrum.Meth.A568:51-55,2006
IEEE Trans.Nucl.Sci.52:1067-1075,2005

Hit position reconstruction

- Our pixel hit reconstruction is based on two-pass approach:
  - Standard charge interpolation method applied for track seeding and pattern recognition
    - Fast computation but not ultimate position resolution
  - “Template based” hit reconstruction used for final track fit
    - Based on interpolation between measured and expected cluster shape at a given angle
    - Slightly slower but ultimate position resolution
    - Ready to cope with irradiation effects (e.g. asymmetric clusters due to trapping)
  - Templates will be also extracted from CMS collision data

r-ϕ coordinate   z coordinate

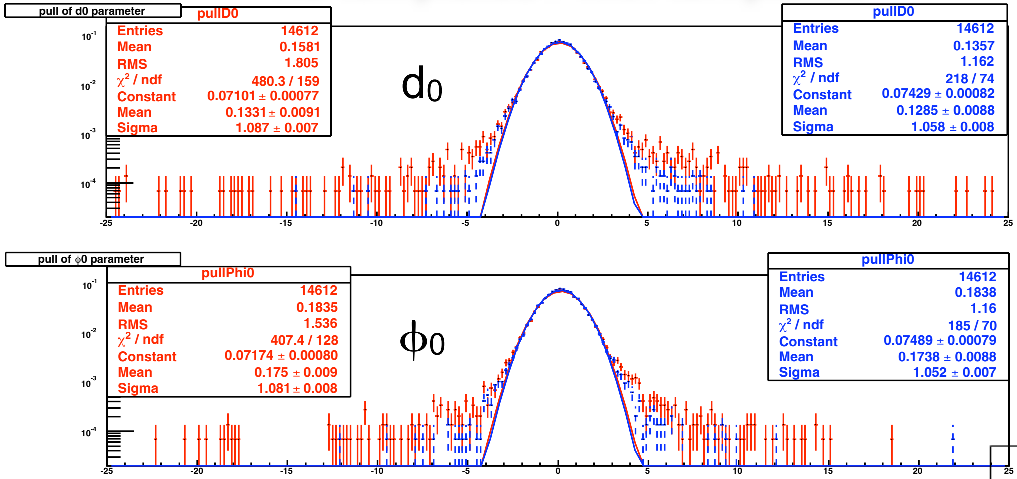


low charge bin   high charge bin

M.Swartz, D.Fehling, G,Giurgiu, P.Maksimovic, V.Chiochia
CERN-CMS-NOTE-2007-033

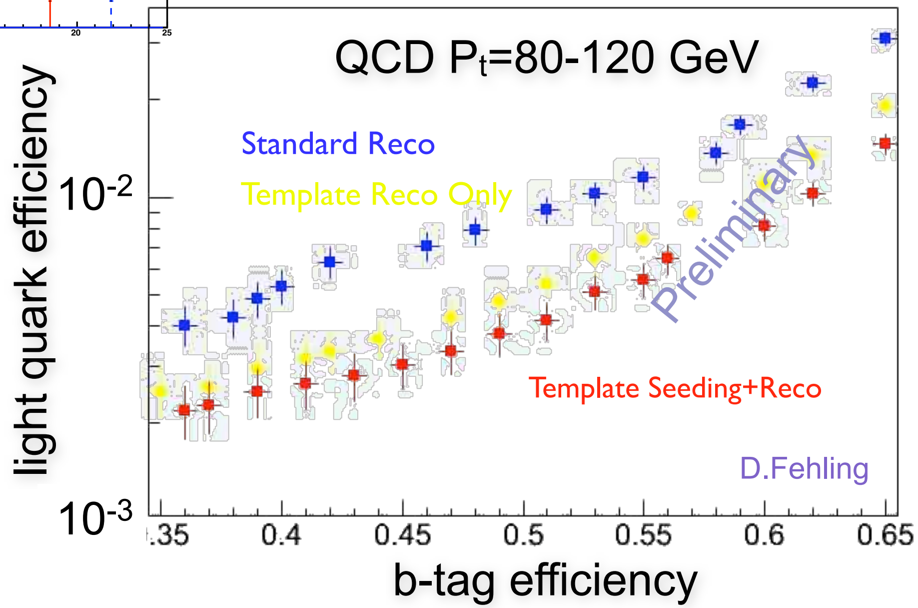
Performances in physics events

no templates / with templates

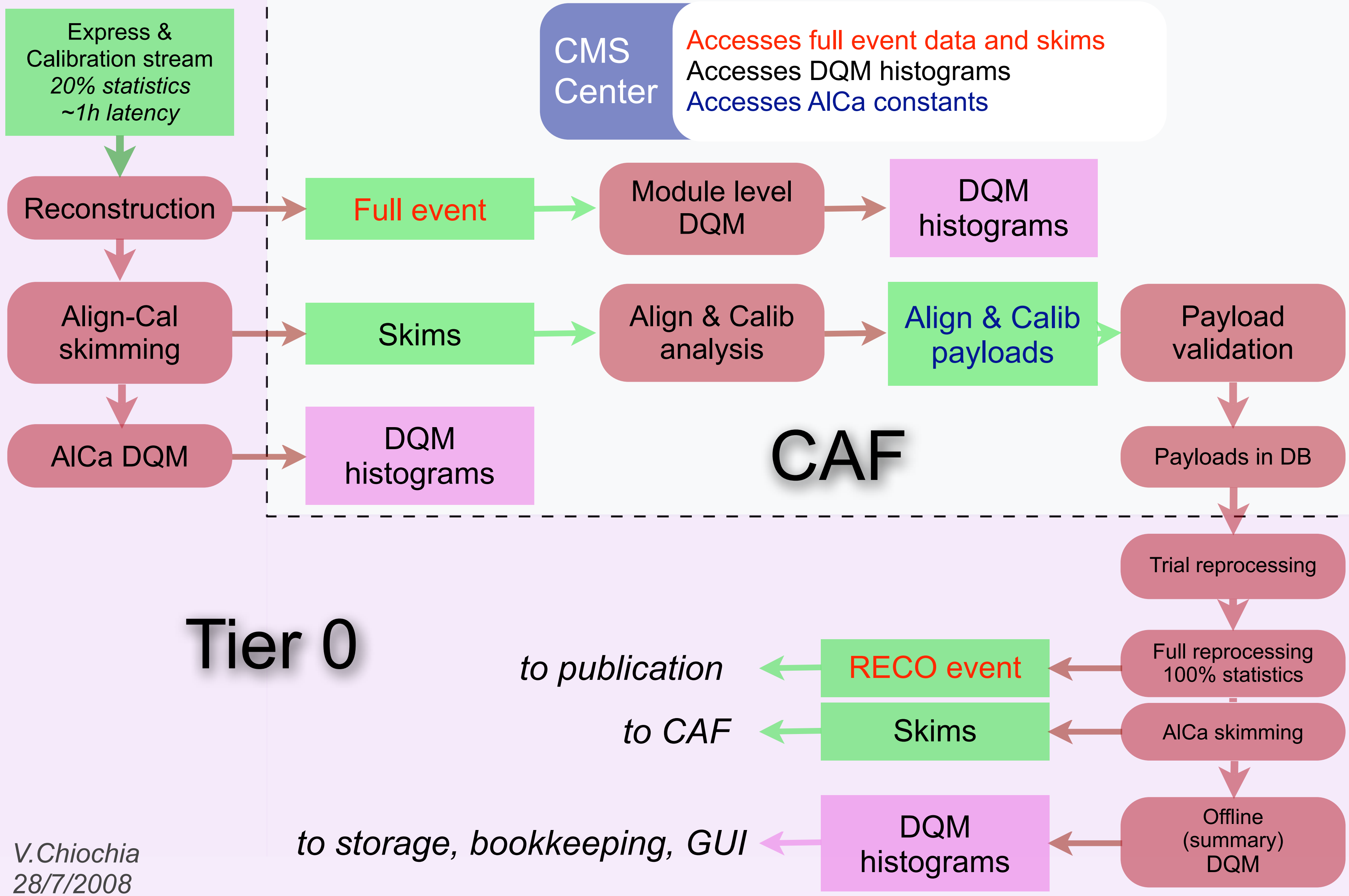


- Template-based hit reconstruction improves pulls of d_0 and ϕ_0 parameters
- Better control over distribution tails (30-50% improvement on RMS)

- Effect of template reconstruction was studied on b-jets
- In addition to hit reconstruction, templates can be used to reject track seeds incompatible with impact angle
- Observe improvement in light quark rejection factor of 2-3 w.r.t. standard hit reconstruction!

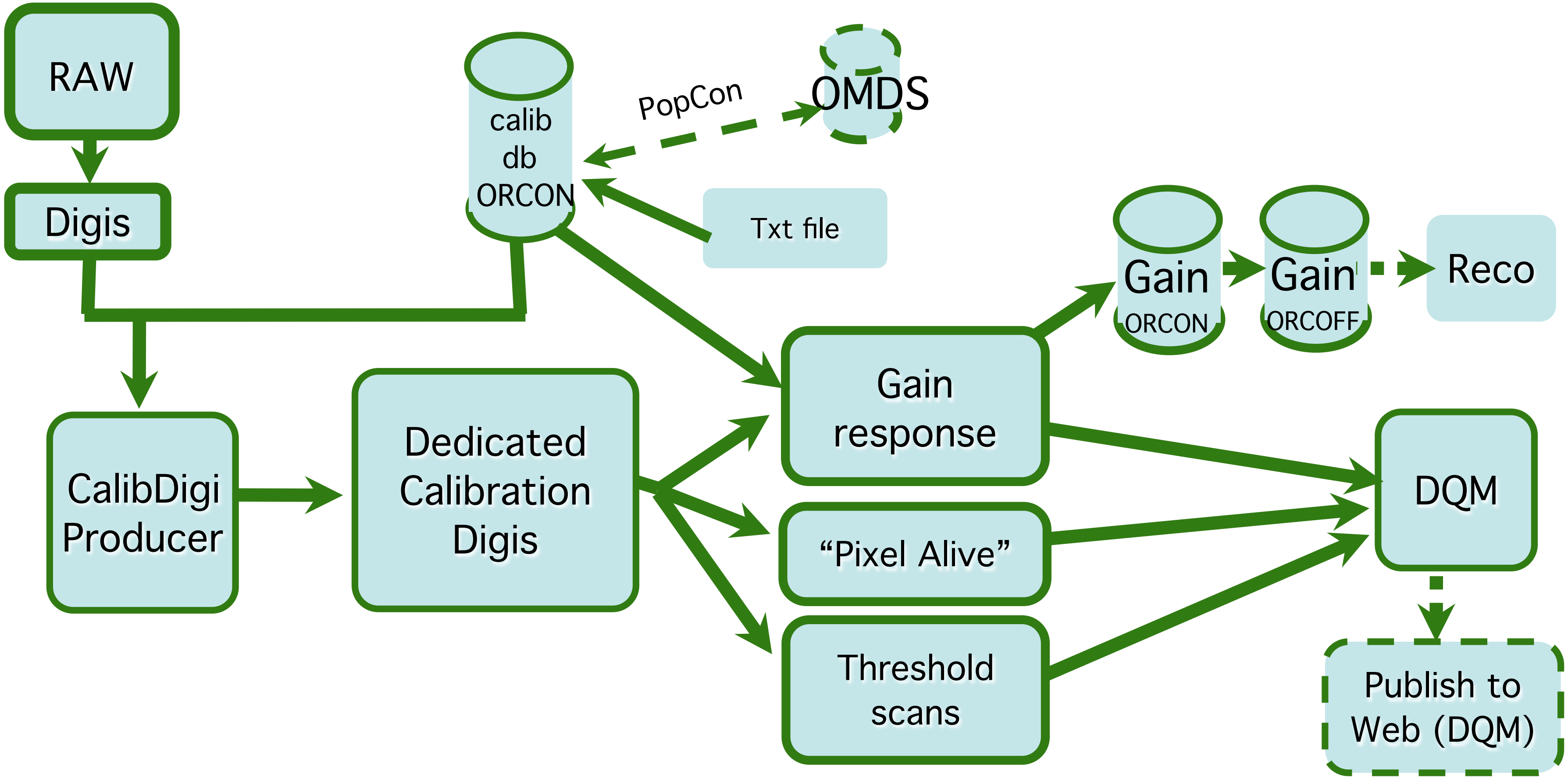


Tracker calibration and alignment



V.Chiochia
28/7/2008

Pixel calibration workflow

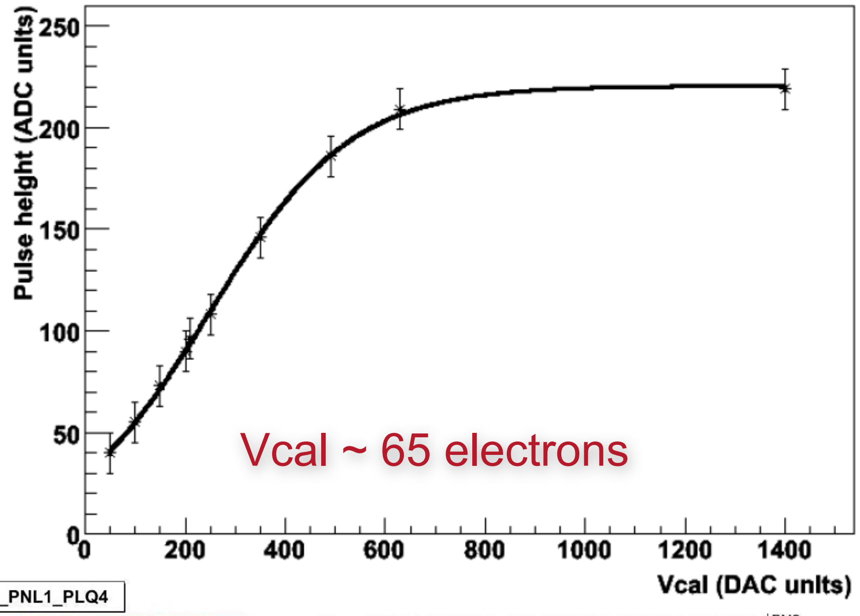


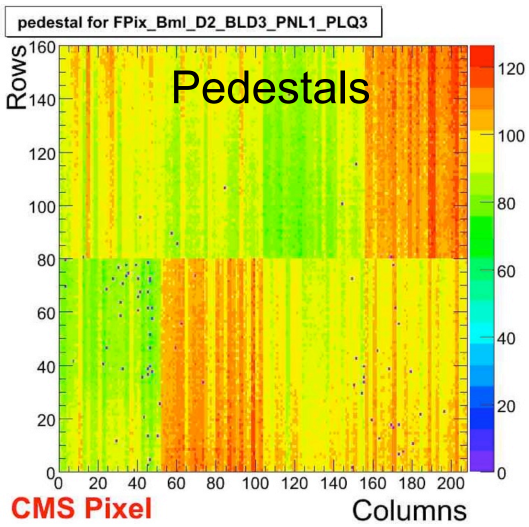
Event processing and DQM can be performed both in real time at HLT farm (parallelized) or offline at CAF

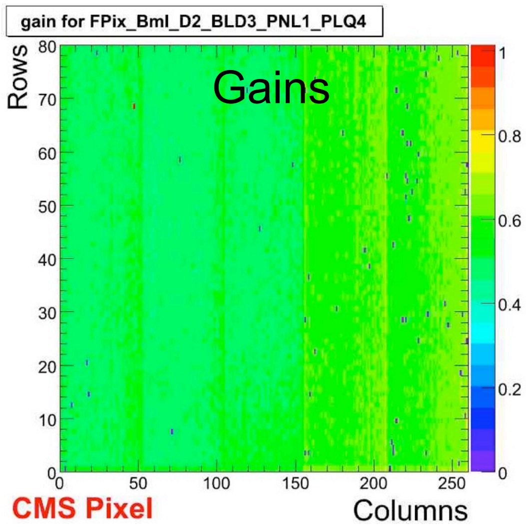
Authors: E.Friis (UC Davis), J.Keller, A.Dominguez, T.Kelly (Nebraska), F.Blekman (Cornell), V.C.

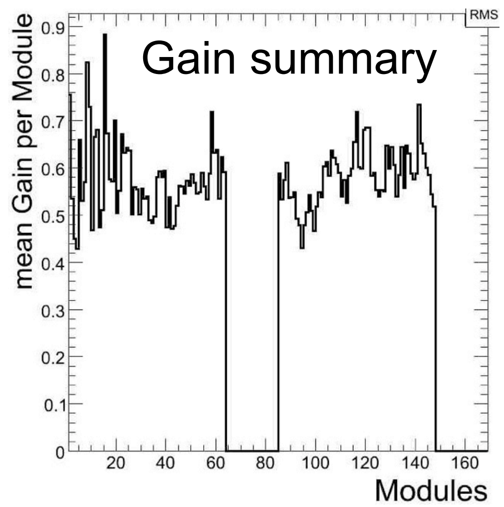
Gain calibration

- Front-end response function is almost linear at low charges and saturates at 1.5-2 mips
- Due to charge sharing only linear range is relevant for hit reconstruction
- Pedestal and gain extracted for each pixel. ADC-electron conversion applied during clusterization
- Unresponsive pixels are marked as dead



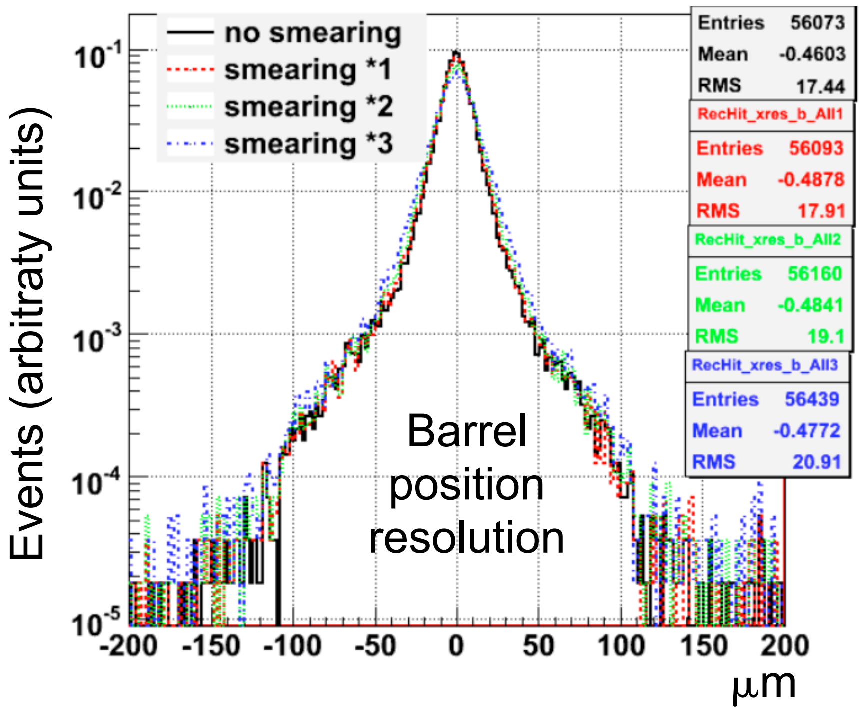


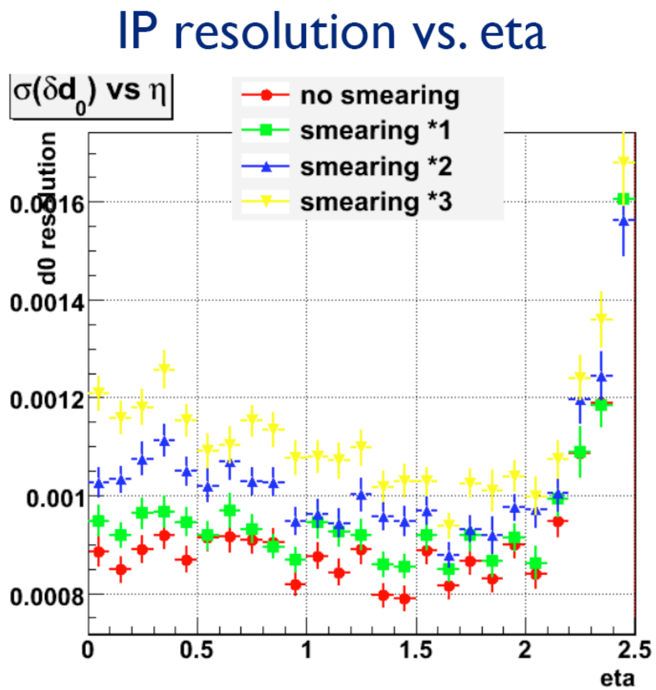




Granularity of calibrations

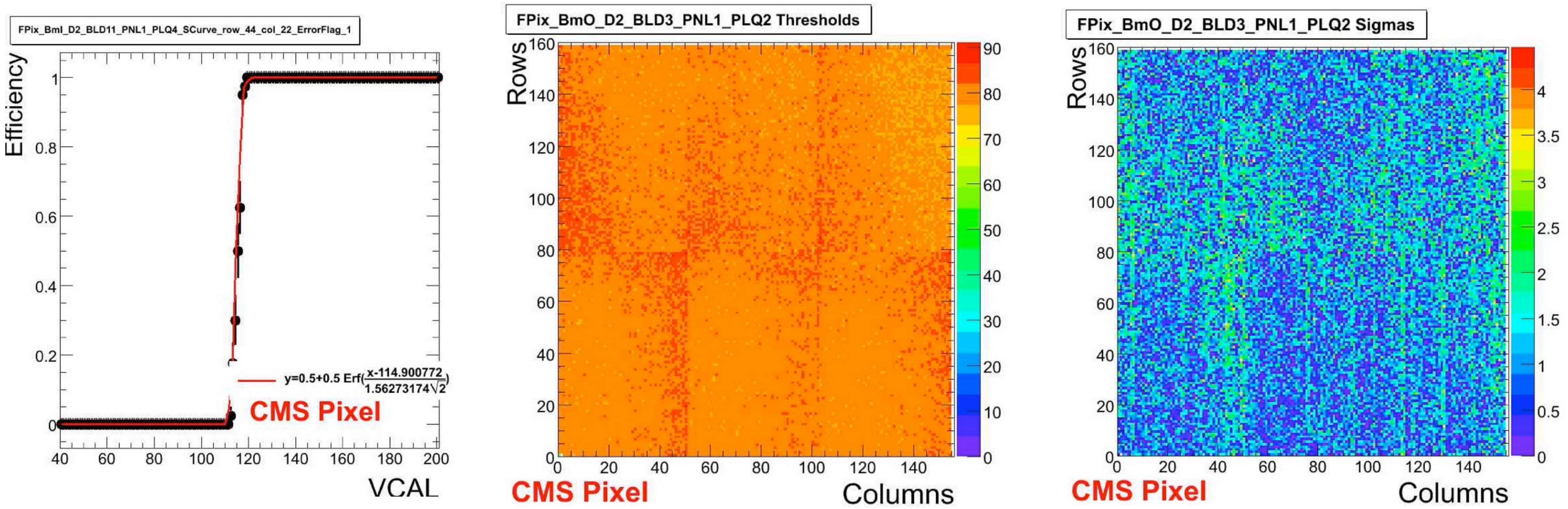
- Due to the large number of channels, the granularity of pixel detector calibrations can impact performances of HLT and reconstruction jobs
- Distribution of pedestal/gain RMS extracted from module production data and applied to physics simulation to determine best granularity
  - Constants for HLT are averaged over columns (1 MB)
  - Offline gain calibration applied with mixed pixel/column granularity (67 MB)



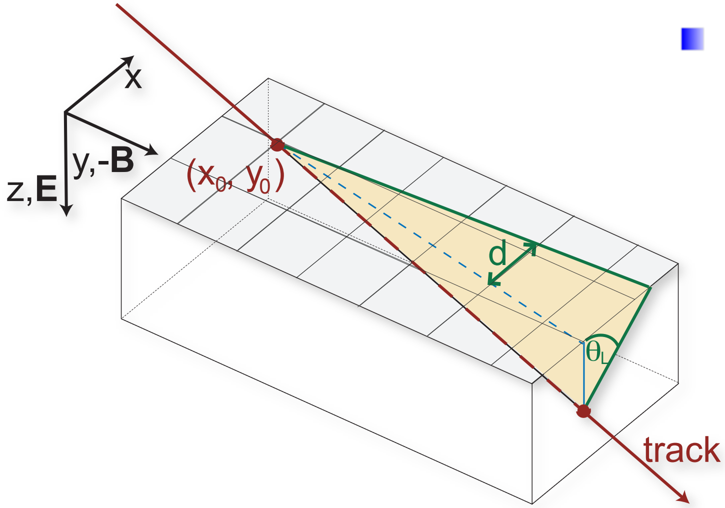


Threshold scans

- Threshold scan done performed on every pixel:
  - measures detection efficiency as function of thresholds
  - measures noise from threshold fluctuations

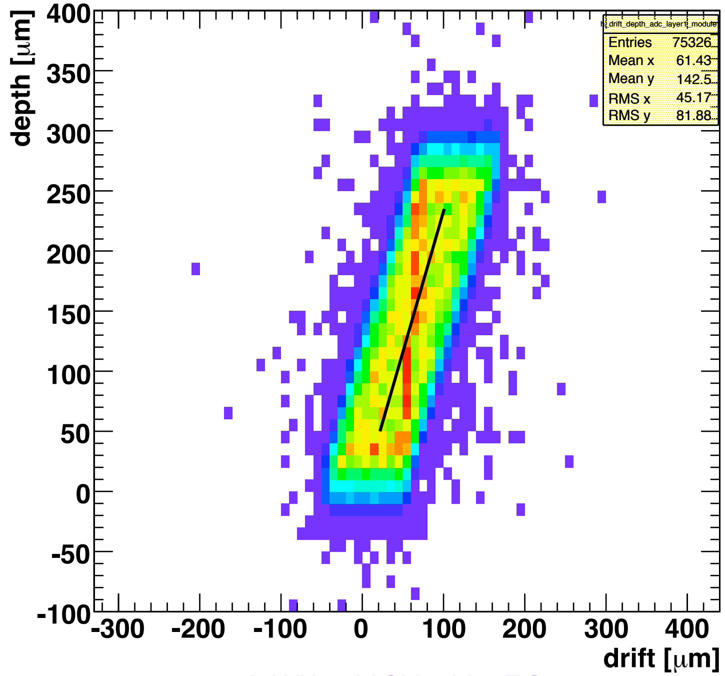


Lorentz angle calibration (1)



- Grazing angle method:
  - measure 2D cluster deflection from shallow tracks
  - Only well isolated muon tracks used with Pt>3 GeV
  - Average cluster profile extracted from extrapolated trajectory on sensor surface
  - Clusters with large charge deposit rejected to avoid anomalous shapes from delta rays

- Lorentz angle in pixel sensors:
  - ϑ_L=23° at V_{bias}=150 V from test beam measurement (~60 mm displacement)
  - Decreasing to 8° at 600 V
  - Expected radius and z-dependance due to radiation damage



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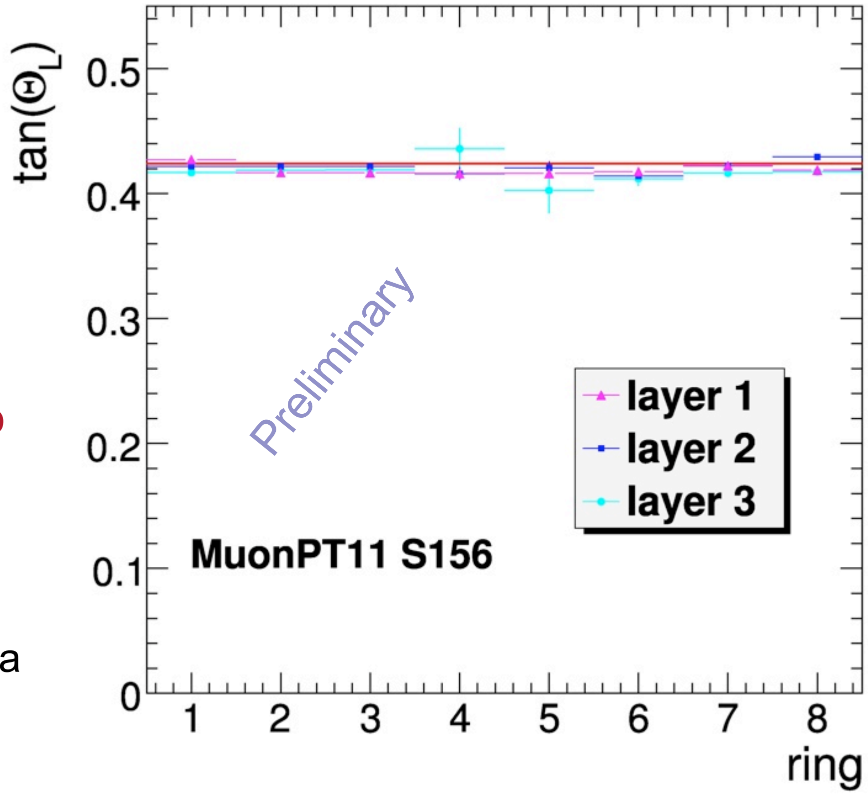
Lorentz angle calibration (2)

- Lorentz angle can be extracted for all barrel rings (ring=fixed z position)
- Precision below 1% can be achieved with less than 1k tracks per ring
  - Will be monitored in DQM
  - Correction stored in DB object and applied during reconstruction
- Technique is robust and applicable also on a partially misaligned detector
- Successfully tested during CSA08 data challenge
  - Will be tested again with cosmic ray data and magnet on before collisions

QCD jets with muon Pt>11 GeV



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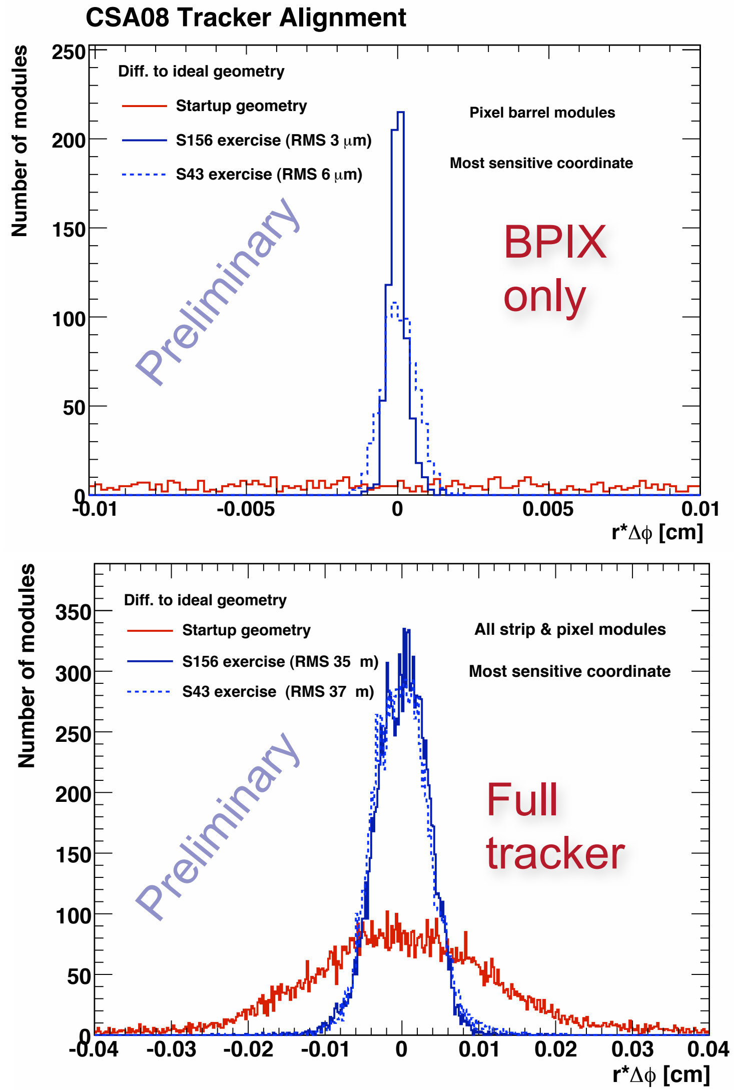
Detector alignment

- Combined Strip and Pixel alignment tested as part of CMS 2008 software and analysis data challenge
  - "S43" MC dataset: first collected pb^{-1}
  - "S156" MC dataset: first 10 pb^{-1}
  - mainly Minimum bias, J/psi, Y, Z to muons (few)
  - Initial knowledge set to survey measurements and alignment from cosmic tracks
- Summary of results:
  - Aligned coordinates:
    - 3 coordinates for single-sided strips
    - 4 coordinates for pixels and double-sided
  - CAF processing: 1.5 hours (50 parallel jobs) + minimization step of 5 hours
  - Difference between true and aligned transverse parameter ($r \cdot \Delta\phi$):
    - 3 μm for BPIX modules
    - 35 μm for the all tracker



Summary and plans

- Installation and commissioning of the CMS pixel detector is in progress
  - Current software commissioning experience based on detector integration at CERN and PSI
- Big progress made in hit reconstruction algorithms. Template based reconstruction improves position resolution, b-tagging performances and is ready to cope with radiation effects
  - Reconstruction improvement possible thanks to a detailed modeling of sensor response and irradiation effects
- Lots of efforts spent in developing a well structured and scalable calibration software framework with real time monitoring
  - Gain calibration can be performed both offline and in real time on High Level Trigger farm
- Promising results from full-scale detector alignment exercise during 2008 CMS data challenge
  - To be validated with real data: cosmic events and first collisions.
- We're looking forward to processing the first data from cosmic rays and collisions!