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Status and performances of Tracker and Muon system

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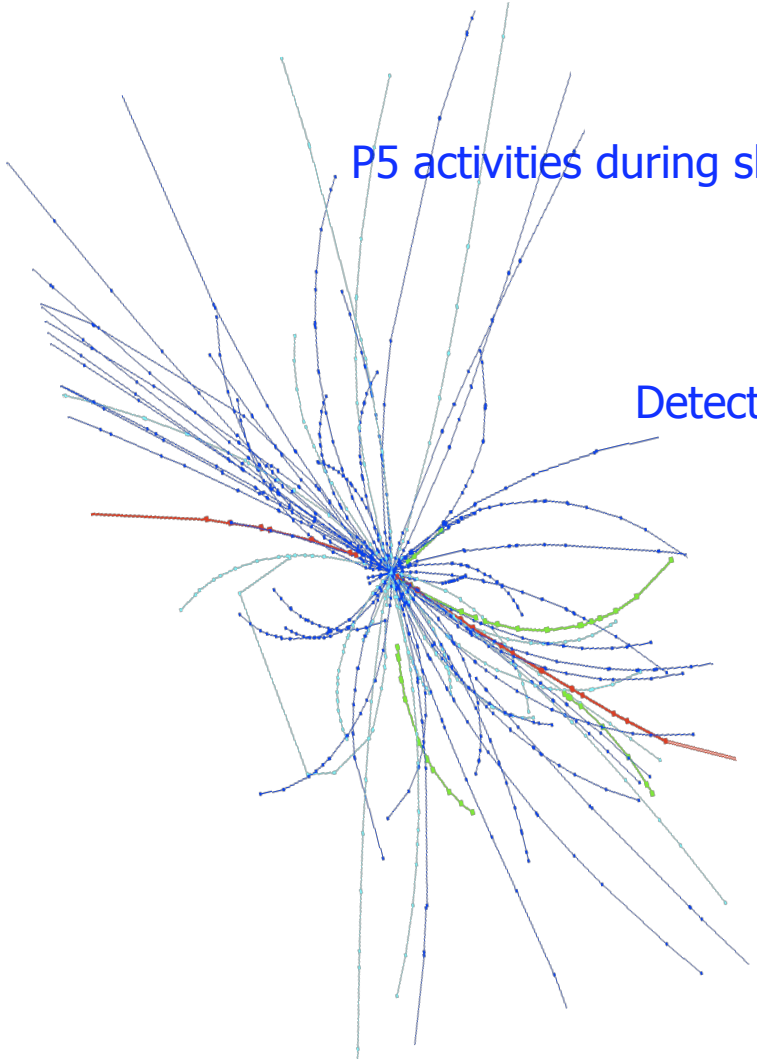
Outline



P5 activities during shutdown and commissioning 2009

DT/RPC status

Tracker operation status

Detector performance from CRAFT 2008

Muon system and L1 trigger

Tracker: Strip and Pixel calibration

Tracking

Alignment

Towards LHC

Summary

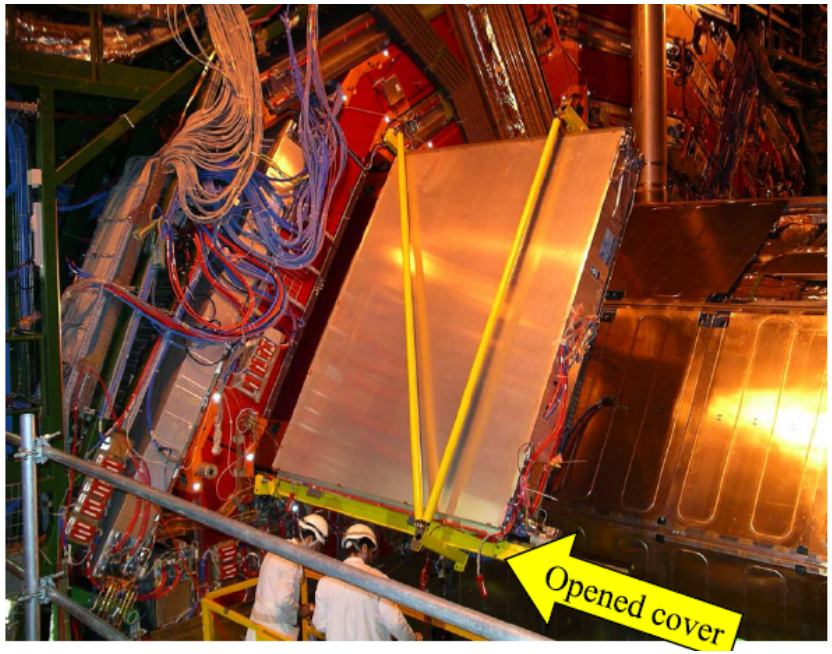
=presence of italian groups

P5 activities: commissioning and operations

Muon DT – Commissioning status

- Repair activity
  - ✓ Chambers: ~100 channels recovered
  - ✓ On-detector electronics (minicrates) problems for 1.2%: fully recovered

- HW/FW/SW upgrades
  - ✓ Improve reliability: better control and monitoring of electronics
  - ✓ Improve stability:
    - From 5 to 10 FED
    - New FW in the R/O to improve error handling)
  - ✓ DSS implemented and tested

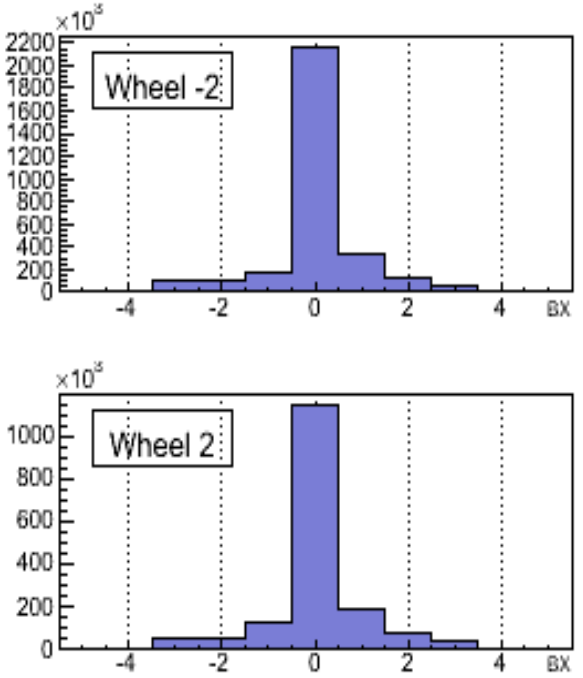


chamber extraction phase at P5

- Trigger HW
  - ✓ PHI Track Finder: 62 out of 66 needed boards working in P5 (20 being built, ready in August, but not a problem for CRAFT09)
  - ✓ ETA Track Finder: being commissioned now
- Status: STABLE during Global Runs, READY for LHC

Muon RPC – Commissioning status

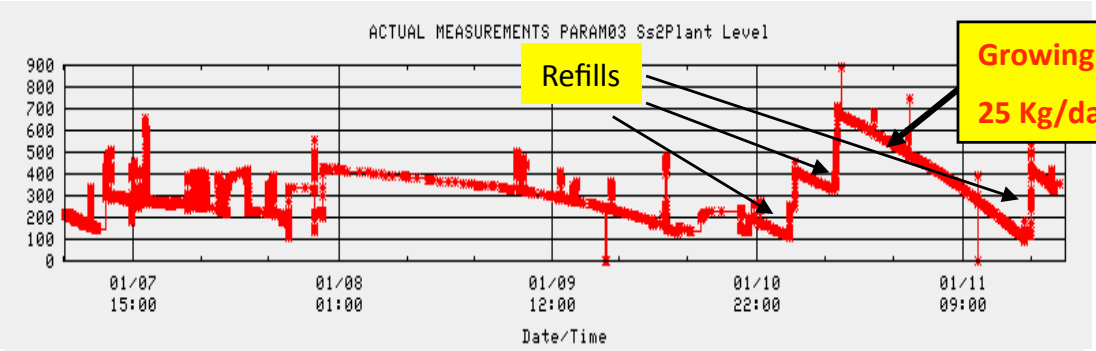
- A lot of work done on hardware:
  - ✓ Barrel and Forward ready (all Forward RPC in for the first time during MWGR_25)
- Grounding intervention:
  - ✓ Noise spikes observed with B field on during CRAFT08 (fluorescent and projector lamps)
  - ✓ Action done: Stars washers added; all shielding cables on detector shortened
- Gas system working smoothly since several months.
- Technical Trigger Unit (TTU):
  - ✓ Trigger board to select cosmic muons for calibration and alignment of other sub-detectors
  - ✓ Successfully tested for the first time during MWGR_25
  - ✓ TTU well synchronized



Silicon Tracker cooling system

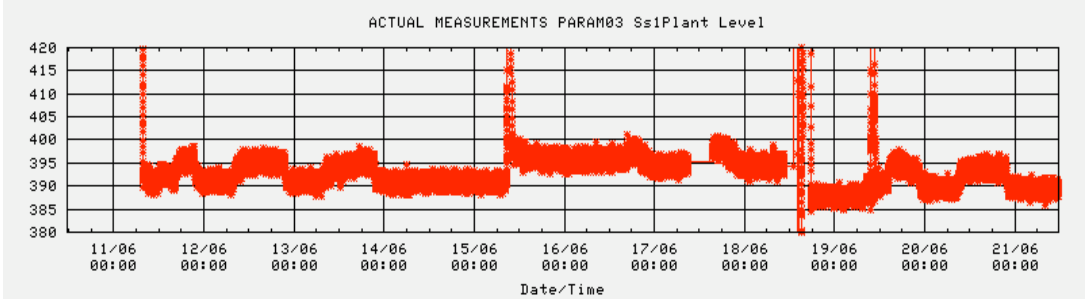
- Successful refurbishment of the Tracker Cooling plants + improved stability/monitoring
- Two SST cooling plants on the balconies were essentially rebuilt:
  - ✓ Fully assembled, tested and running C_6F_{14}
  - ✓ leak rates close to zero for Pixel and SS1
  - ✓ very low leak rate of SS2: ~250 g / 4-5 Kg per day when few lines 6 /1 over 90 are excluded

before



zoom

now



SST – Commissioning status

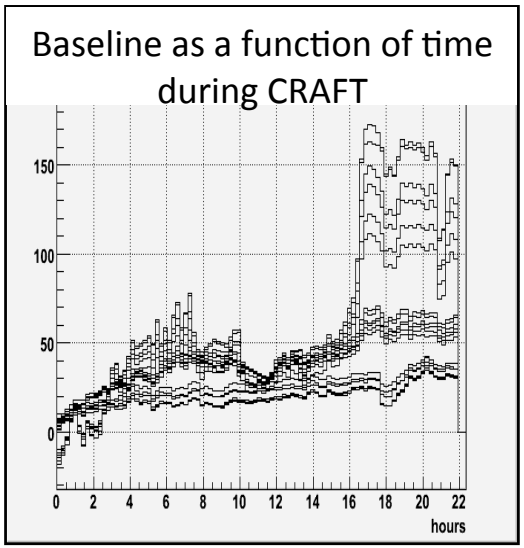
Since June 2009.

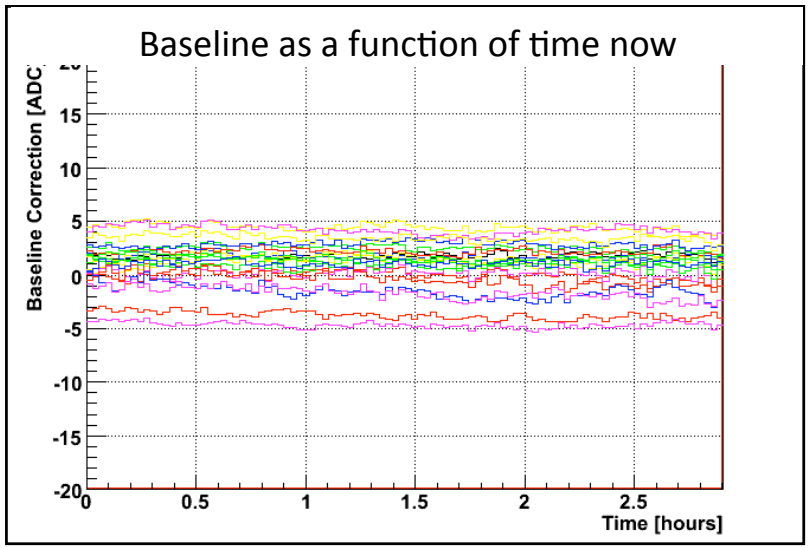
- Newly integrated TK (strips+pixel) DCS smoothly deployed
- Online DAQ deployments:
  - ✓ online diagnostic system handling DAQ error messages
  - ✓ redundancy and fast module masking improve FEC operation
  - ✓ Reduced configuration time from 240 sec (in 2008) to 100 sec
  - ✓ FED spy channel under deployment
    - monitor event raw data frames via VME readout path, in parallel with standard acquisition of the global runs
  - ✓ SST firmware under revision
    - Consolidate the SST FEDs readout
    - Include the "APV emulator" veto to filter noisy events
- Future issues: tuning of parameters to operate in *deconvolution mode*
  - ✓ readout mode for beam operation
  - ✓ fine timing adjustments needed layer by layer during cosmic running

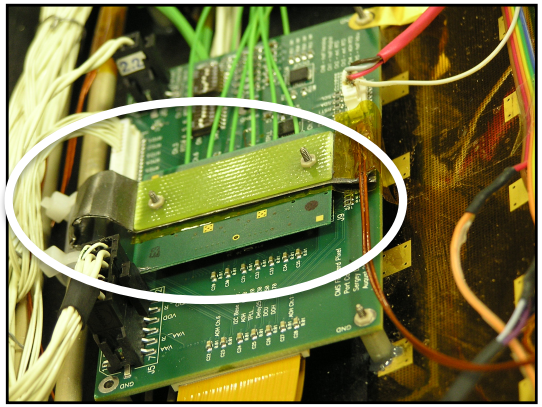
Pixels – Commissioning status

March 2009. FPIX extracted to perform maintenance

- Substitute the Silicone cooling tubes (rated up to 1.7 bar) with more robust ones (rated up to 10 bars)
- Repair the broken 6 % (but 0.5%, since it was considered too risky to be fixed; 0.5-1% lost after re-insertion). As up to now: 98.5-99% of FPIX ok; 99% of BPIX ok
- Put redundant humidity sensors for better calibration
- Improve temperature stability analog electro-optical converters (by applying a Pyrolytic Graphite "cold-finger" connected to the cooling pipes)





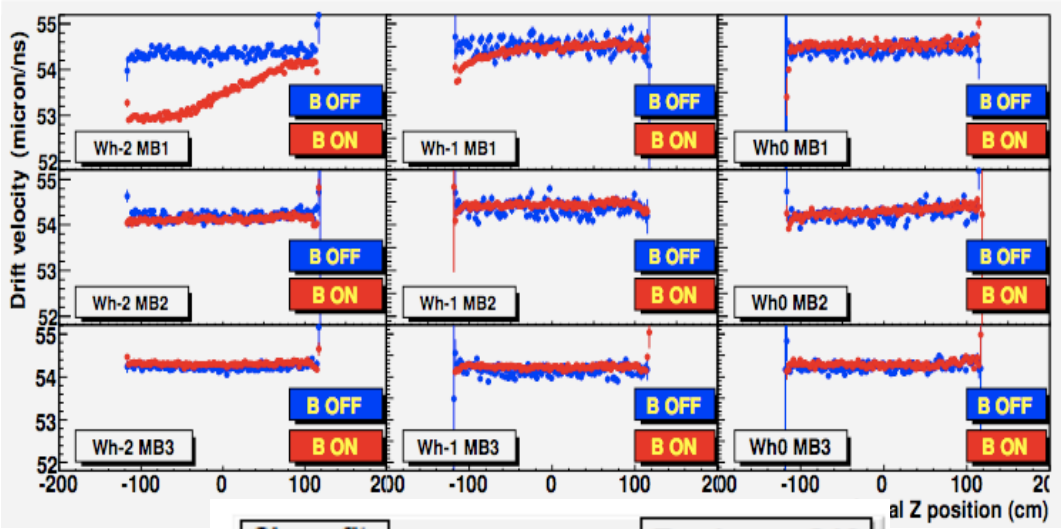


Detector performance: low level performance

Muon DT performance

Calibration of the drift velocity inside chambers:

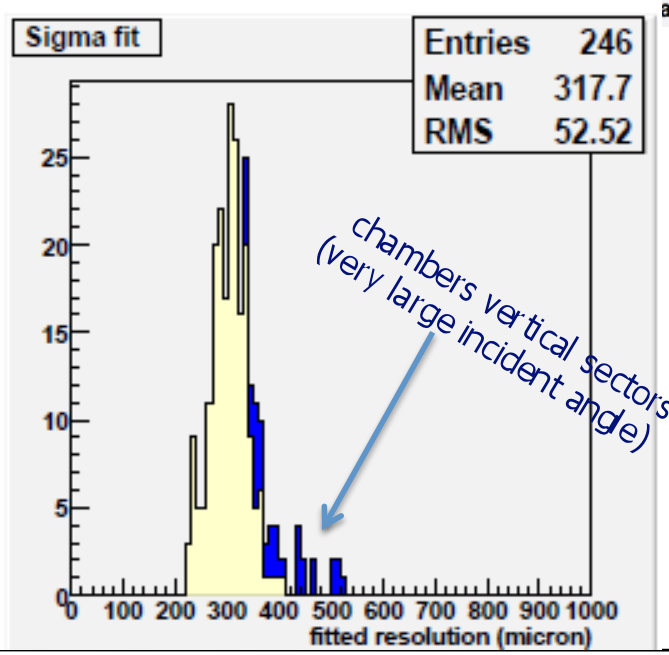
- same values for all chambers with BOFF
- Switching B field on, velocity re-calibrated doesn't change so much
- MB1: inhomogeneous magnetic field (known effect)



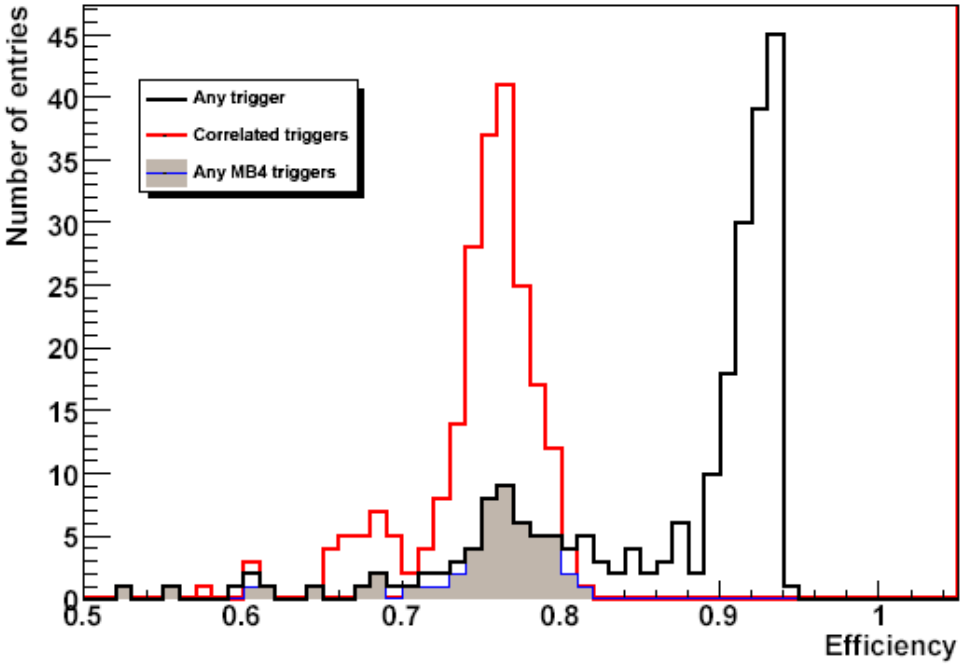
Hit residuals:

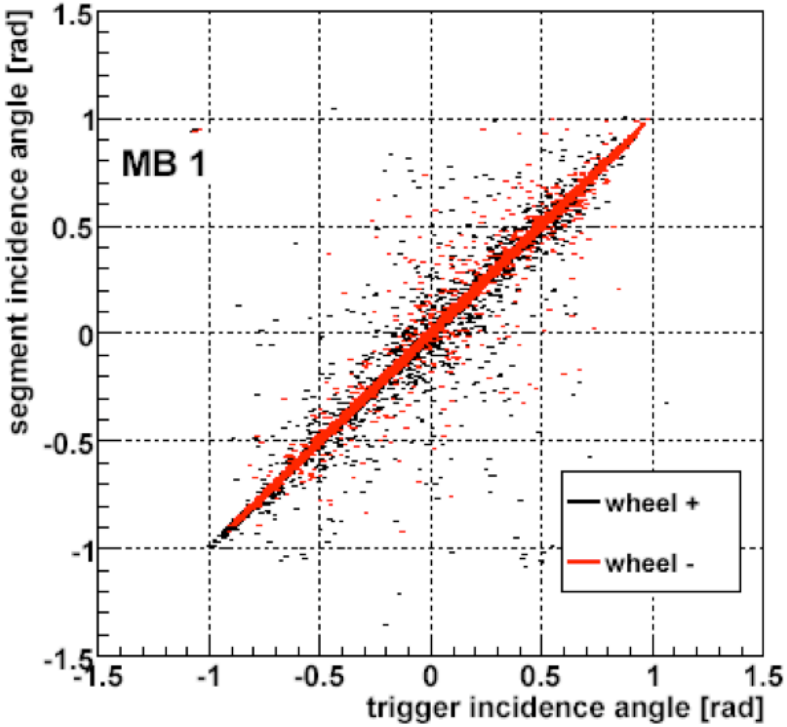
- mean centered at zero for all stations
- resolution ~320 μm

Segment reconstruction efficiency in the r-ϕ plane >99%



Muon DT – Local Trigger

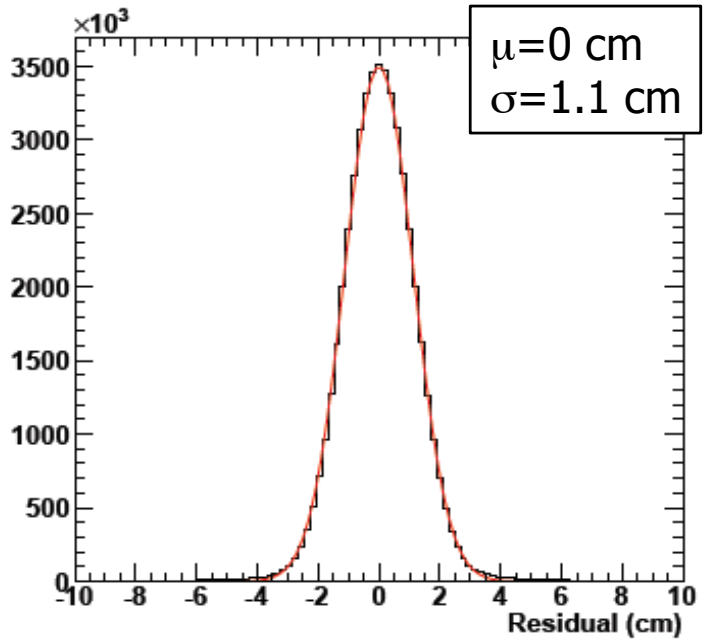


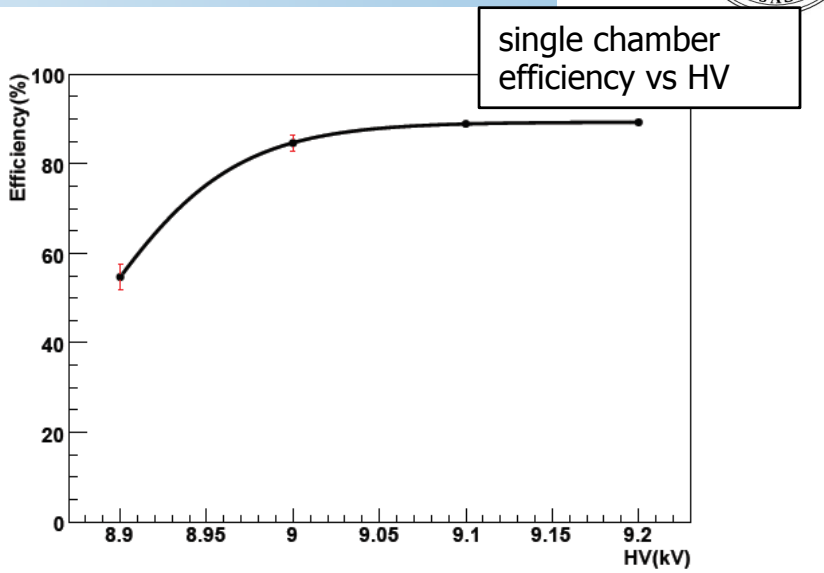


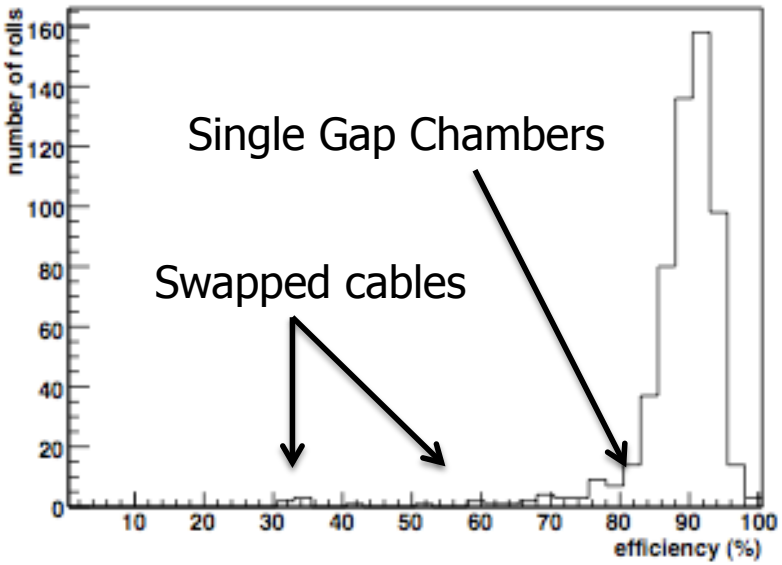
- Trigger Efficiency (one entry per chamber)
  - Black: all quality trigger
  - Red: only correlated trigger
  - Blue: any MB4 trigger (not η information)

- Reconstructed Local Track angle (from segments) vs the trigger angle primitive: good correlation

Muon RPC performances

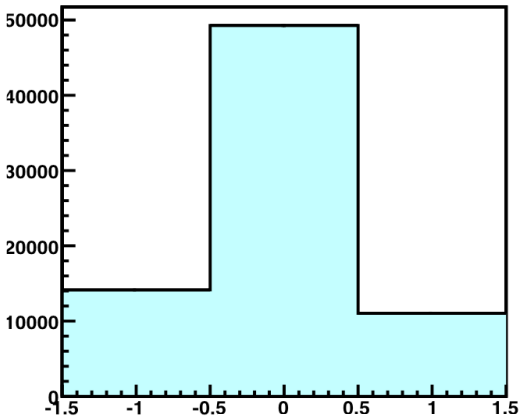




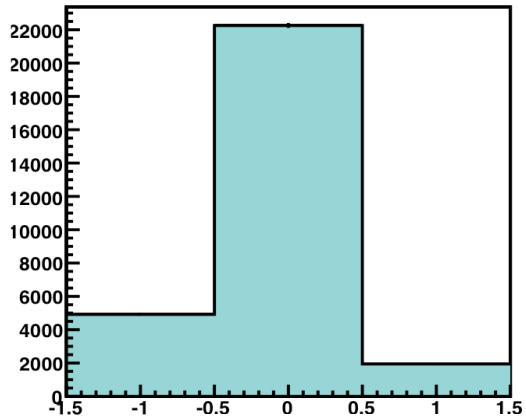


- RPC residual distribution: distance between the DT segment extrapolation and the RPC cluster center, expected RMS ~cm
- Efficiency for the Barrel region: ~90% in the working region (~ 9.1 kV)
- Low efficiencies localized in hardware problems: solved during the shut-down

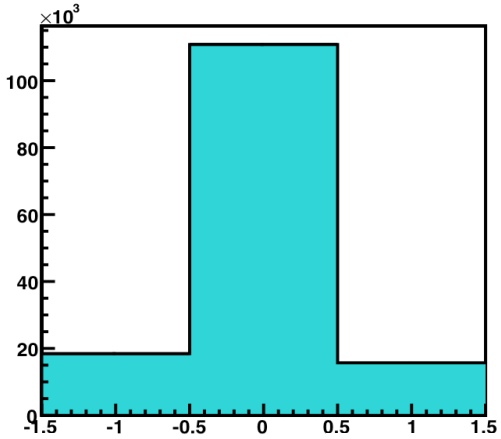
L1 Trigger synchronization



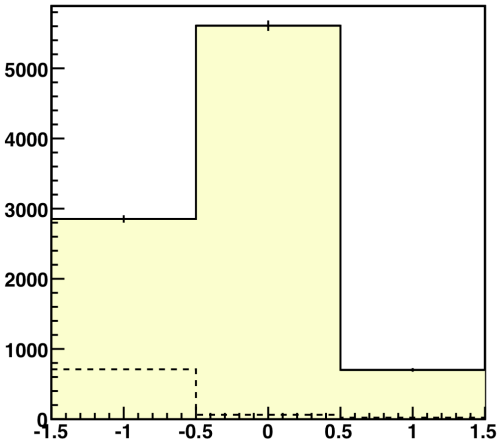
DT(Top) – DT(Bot)



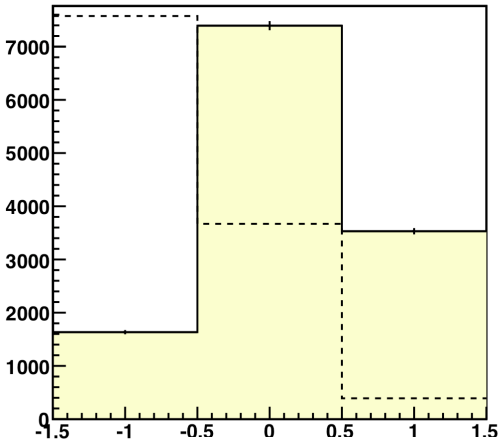
RPC(Top) – RPC(Bot)



RPC - DT



CSC(Top) – DT(Bot)



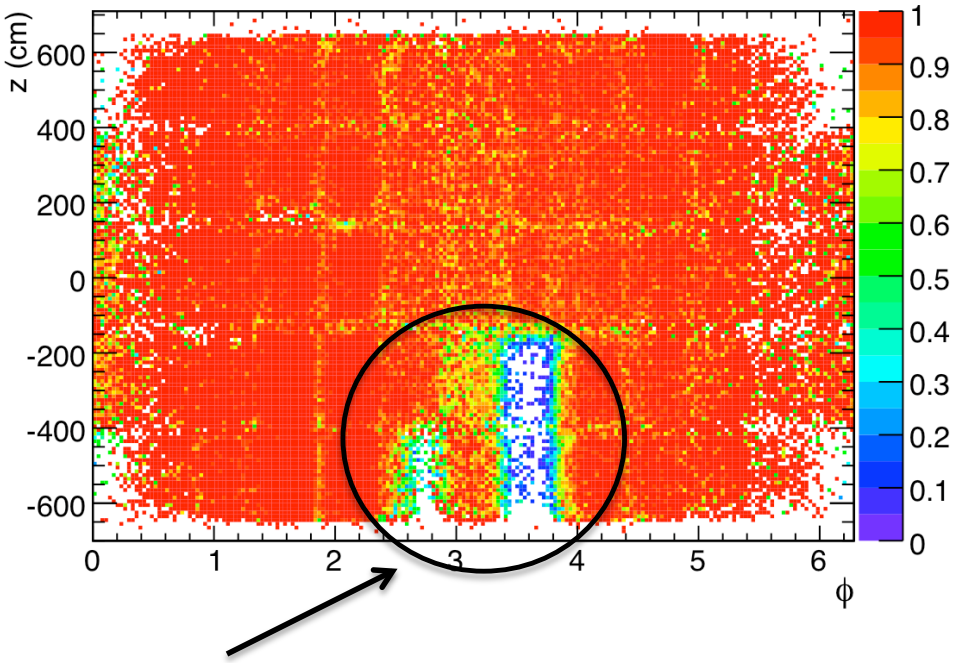
CSC(Bot) – DT(Top)

- the difference in unit of bunch crossing (expected peak at zero)
- same muon triggered by DT and RPC
- geometrical limitaiton for CSC (determination of correct time of fligth)

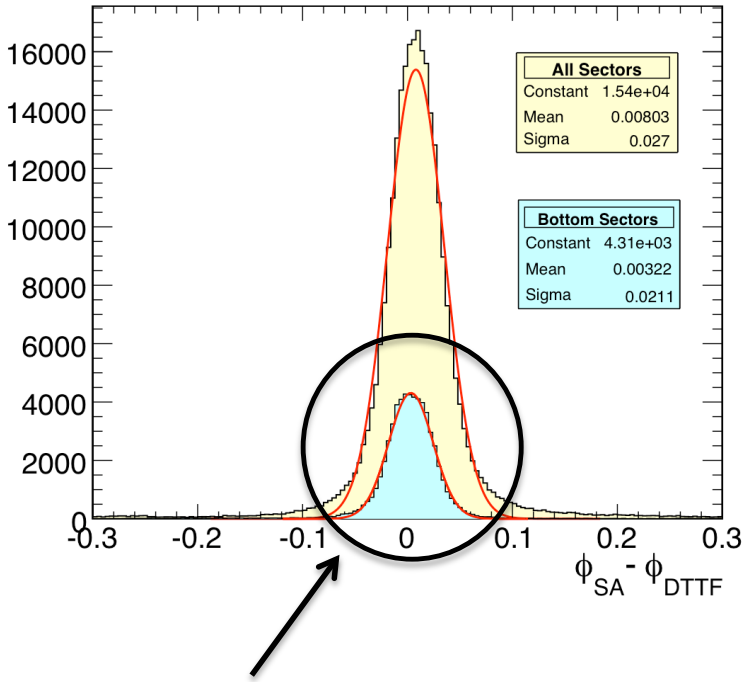
DT Track Finder performance

- DTTF efficiency overall good:
  - ✓ STA tracks used as tag
  - ✓ PHI TrackFinder tables missing

- Reconstuction of track parameters:
  - ✓ ϕ form STA tracks vs. ϕ form DTTF
  - ✓ narrower distribution using only bottom tracks



Missing Track Finder boards



Bottom sector (LHC-like)

Tracker local performance

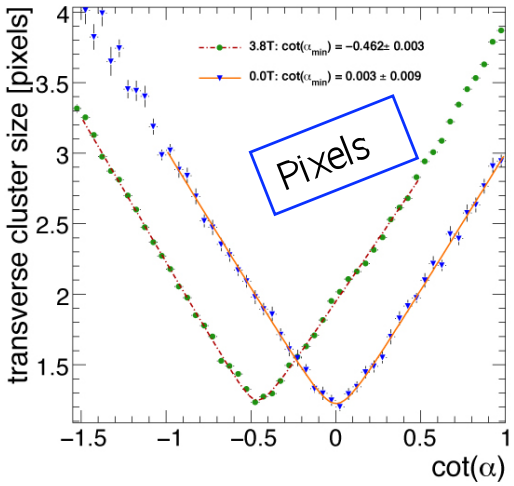
- CRAFT08 contributed to access the excellent performance of the detector:
  - ✓ High S/N: Strip ->25 (300 μm), higher than at TIF | Pixel ->25
  - ✓ Noise: low and stable during full operation period (e.g. few noisy pixels: 0.00038%)
- Calibration:

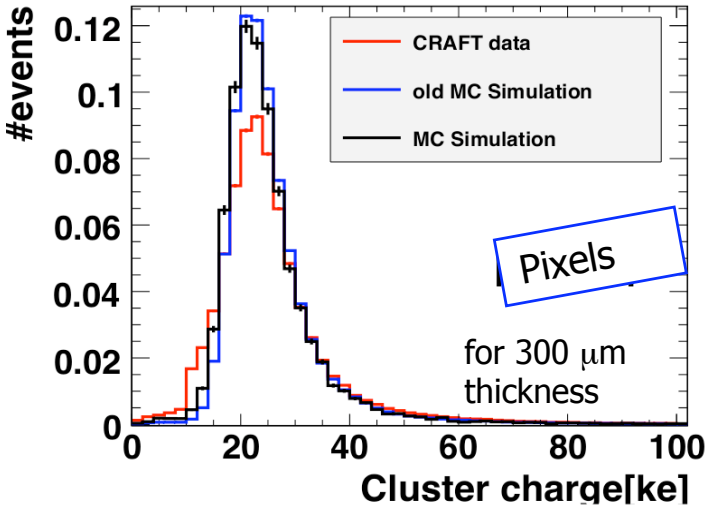
  Lorentz Angle
  - ✓ correct the drift of charge carriers due to the Lorentz force in the 3.8 T B field
  - ✓ TIB θ_L = 3.9° | TOB θ_L = 5.0°| PXB θ_L = 24.6° | PXF θ_L = 4.1°

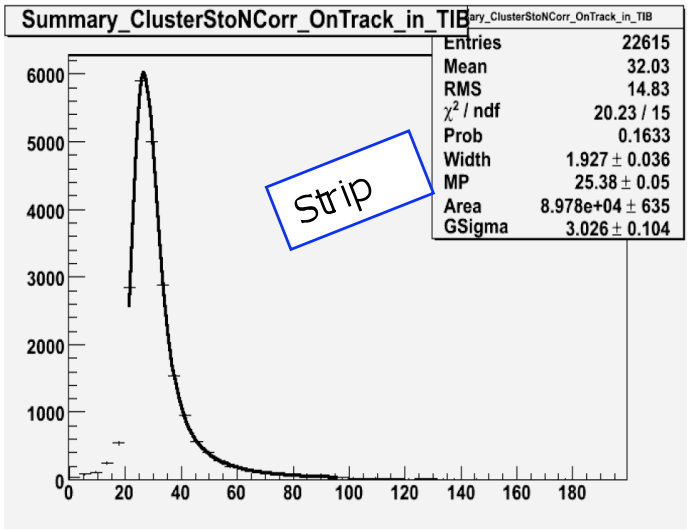
  Gain equalization of signal

  Pedestal measurement

  Bad component identification



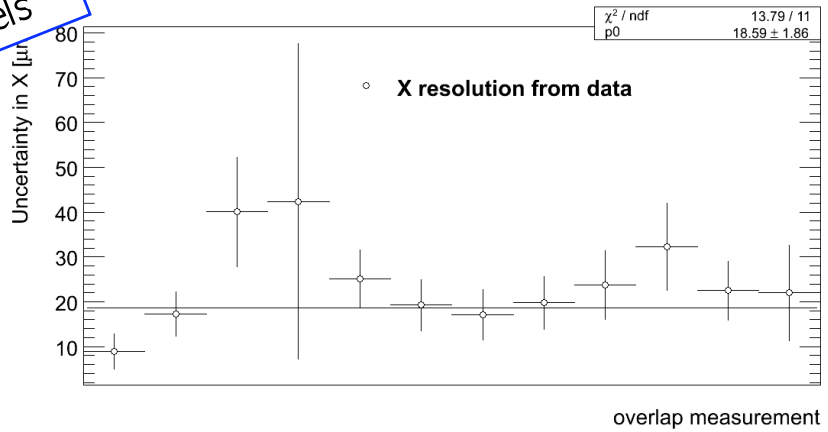




Tracker performance: resolution and efficiency

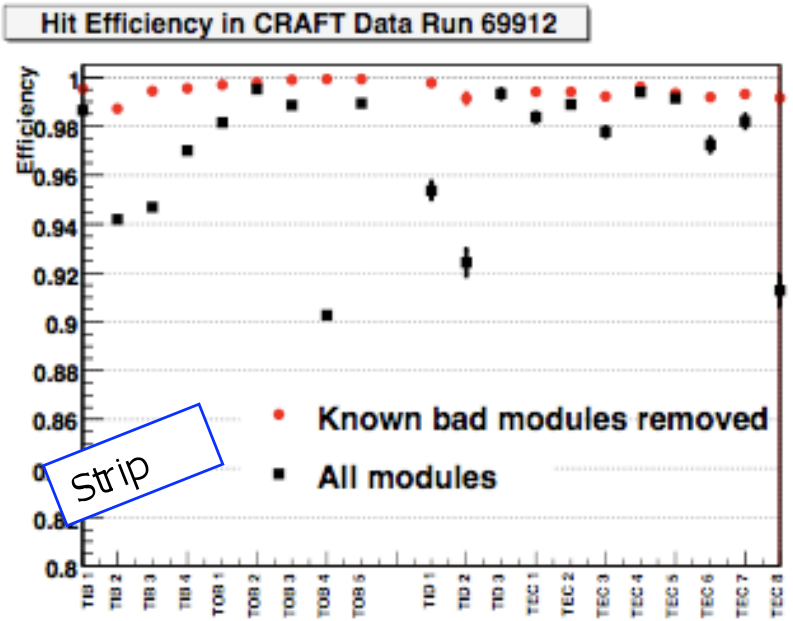
- Fully tested with CRAFT08 data
- Resolution:
  - ✓ evaluated using tracks passing through two sensors in the same layer
  - ✓ Pixel σ_x=18 +/- 2 μm| σ_y=29 +/- 3 μm
  - ✓ Strip σ_x=14 ÷ 39 +/-1 μm
  - ✓ Results in agreement with MC simulation

Pixels



overlap measurement

- Strip Layer efficiency > 99%
  - ✓ when only active modules considered (red)



Handling of faults

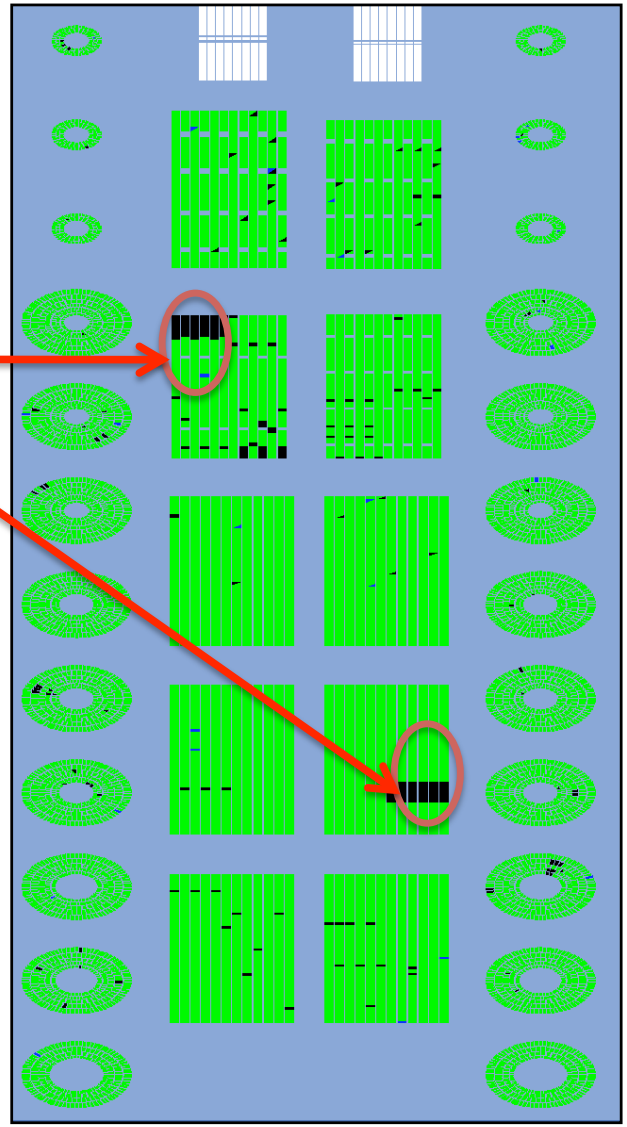
- Operational fraction considering only problems identified in commissioning:

  TIB 97.0% | TOB 98.5% | TEC+ 99.0%| TEC- 99.5%

  - ✓ Recovered control ring in TIB L2 respect to 08 operation
  - ✓ 45 modules off in TIB L3 following closure of the leaking cooling loop line
  - ✓ unstable TOB control ring maybe recoverable, with special procedures

- But…Tracker reconstruction is robust against faults in the tracker operation:
  - ✓ List of problematic components is propagated to the track reconstruction:
    - DCS (HV/LV) and FED status
    - errors in FED buffer unpacking (event by event)
    - Offline Bad Component identification

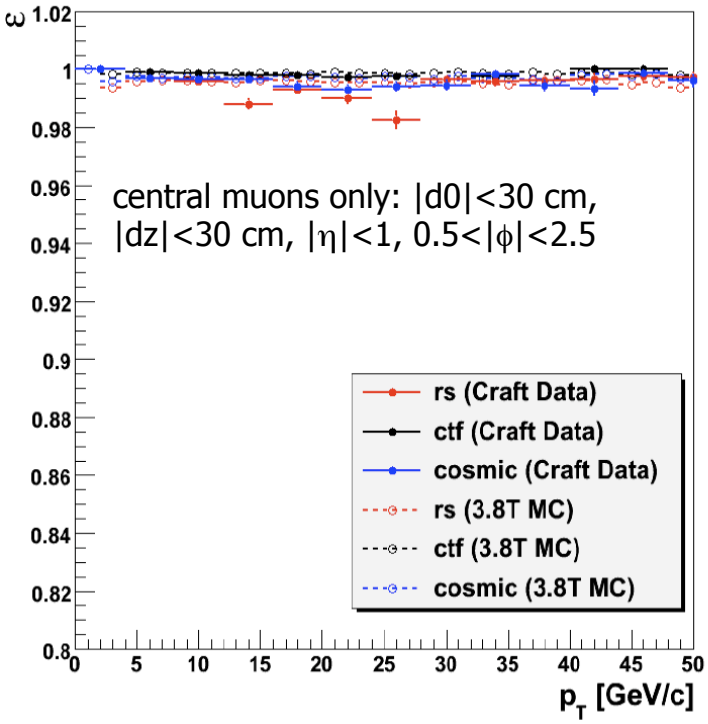
- Map of faulty modules available for MC production

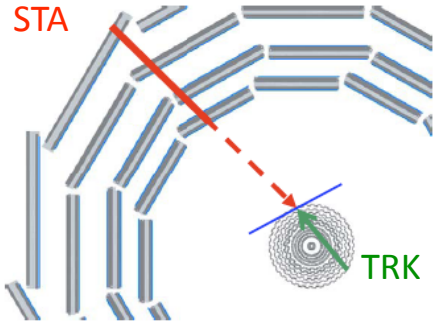


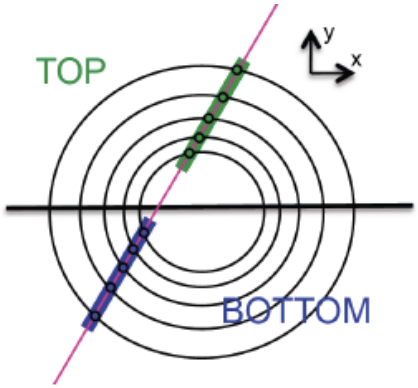
Detector performance: high level performance

Tracker tracking efficiency and resoultion

- Cosmic reconstruction widely tested on CRAFT08 data
- Track reconstruction efficiency and parameter resolution with different methods:
  - ✓ Tag&Probe method using STA muons : top leg of STA muon as tag for a reconstructed track in a Tracker cylinder
  - ✓ Tracker stand-alone method: seeding top (bottom) + full pattern recognition + bottom (top) hits removal+ final fit





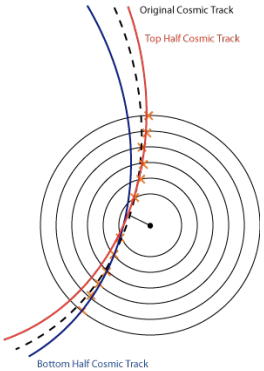


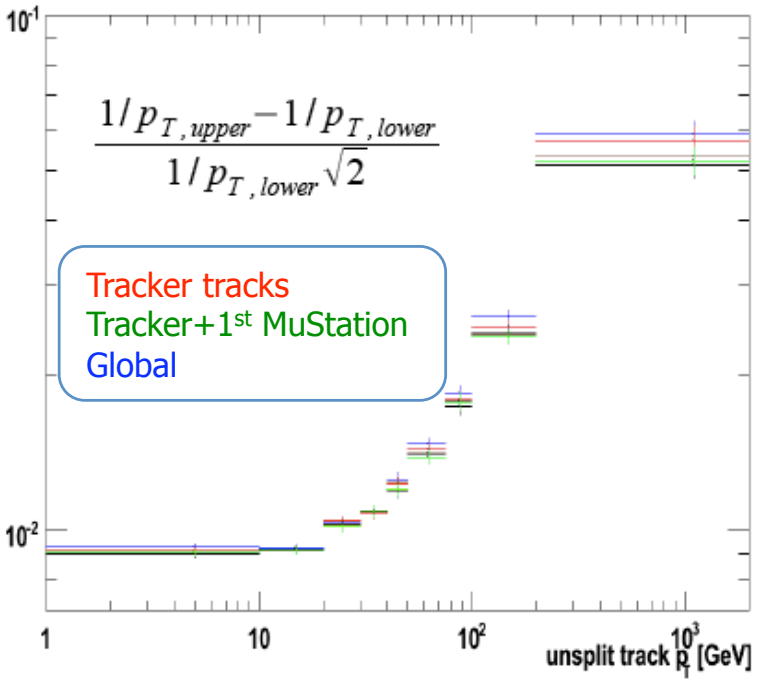
	CKF	CosmicTF
σ(dz)[μm]	76.9 ± 0.7	76.0 ± 0.8
σ(dxy)[μm]	57 ± 1	63.9 ± 0.8
σ(η)[10^{-5}]	83.6 ± 0.8	83.1 ± 0.8
σ(Φ)[10^{-5} rad]	34.8 ± 0.5	44.2 ± 0.7
$\sigma(p_T)/p_T$ [%]	1.26 ± 0.02	1.42 ± 0.02

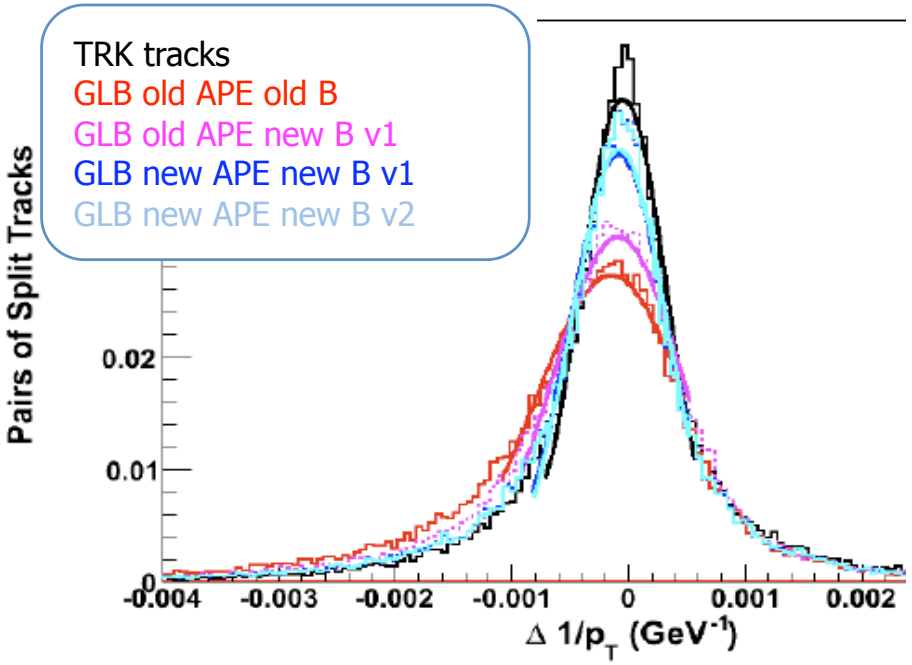
$\sigma(a)=\sigma(\delta a)/\sqrt{2}$

Global muon resolution

- Global muon resolution measured with track-splitting method:
  - ✓ expected trend (~1% for low p_T tracks)
  - ✓ Tracker tracks still better than Global at high p_T : muon alignment not as in Tracker and no *muon* APE (Alignment position Errors)
- Resolution strongly affected by Tracker APE and B-field map used in the reconstruction
  - ✓



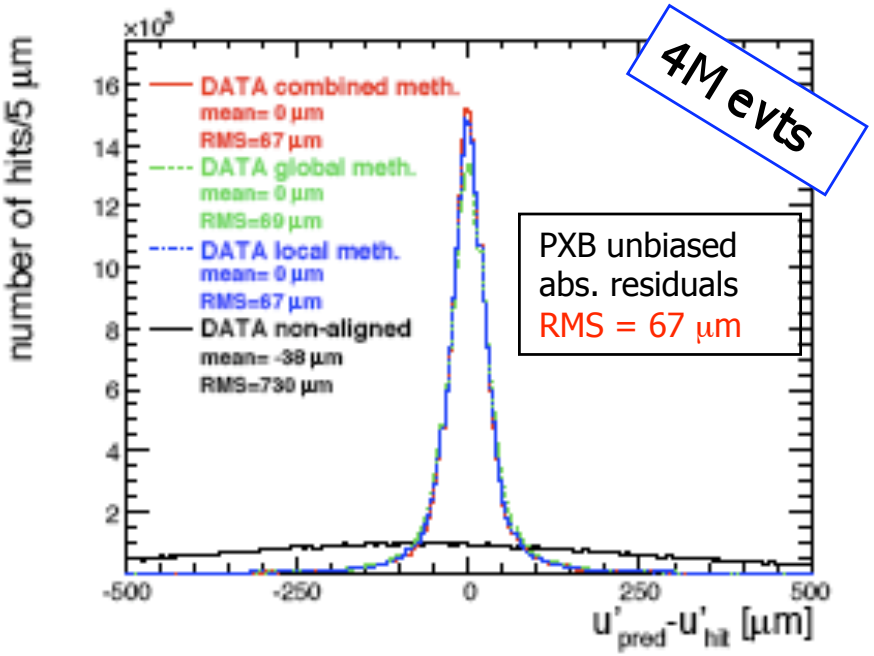




Tracker alignment

- Alignment at *module* level (stereo/rϕ in DS layers): 100% in all subdets (94% in PXF)
- Results given with *combined* method =
  global (solve global correlation) +
  local (solve locally to match the track model)
- Distribution of the Median of Residuals (DMR) as estimator of remaining misalignment

	non-aligned μm	local meth. μm	global meth. μm	combined meth. μm
PXB (u')	328.7	3.3	7.6	3.1
PXB (v')	274.1	15.0	7.1	4.3
PXE (u')	389.0	30.5	24.5	13.8
PXE (v')	385.8	37.9	20.9	14.7
TIB (u')	712.2	15.1	5.2	3.2
TOB (u')	168.6	4.1	6.2	3.2
TID (u')	295.0	8.0	7.1	3.8
TEC (u')	216.9	11.5	30.3	7.9



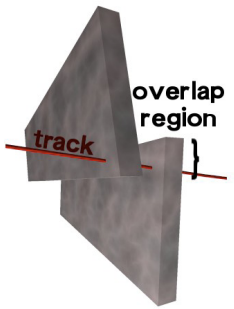
- same precision in TIB/TOB (3μm!)
- comparable precision along x/y pixel coordinates (3/4 μm)

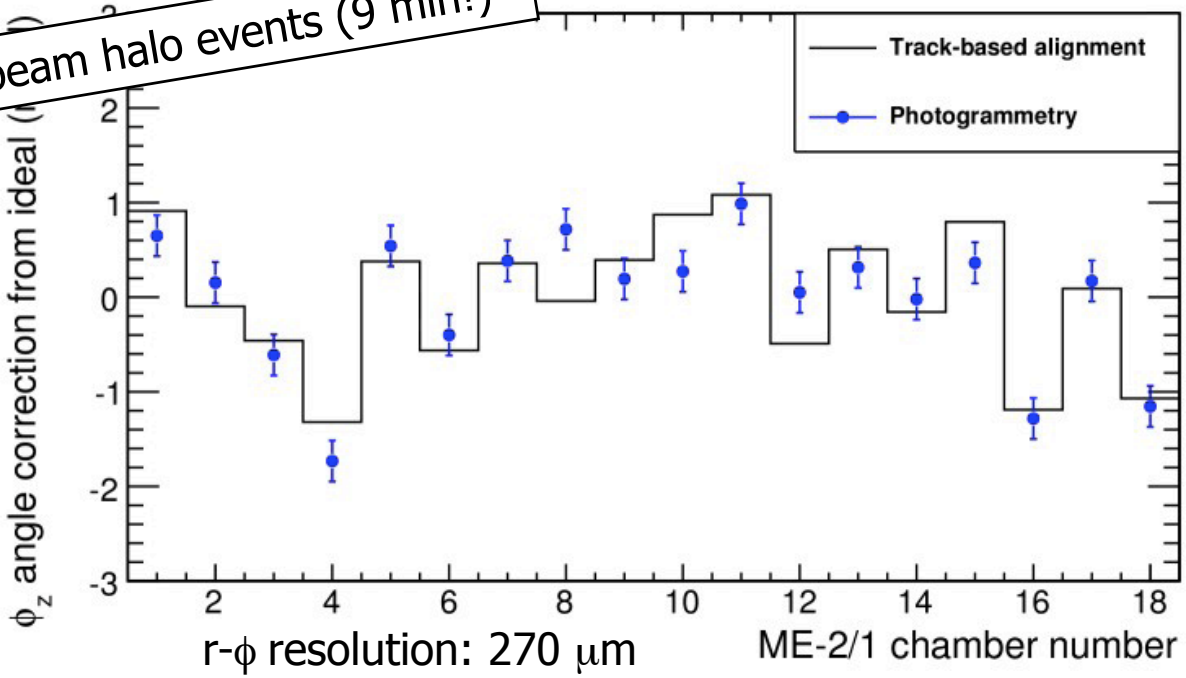
- TIB: 5 mm shift of pos/neg half-barrels along *z*, confirmed by optical survey

Muon system alignment

- Tracker geometry as a reference for aligning muon chambers
- Laser alignment in CSC and DT system (detection of 0T/3.8T movements)
  - ✓ YE+1 z displacement of ~ 12 mm towards IP
  - ✓ CSC chamber local z shifts ~ 3mm, tilted 3.5 mrad
- DT alignment good agreement with survey measurements (less than 600 μm)
- Not *everything* could be aligned precisely using cosmics: first beam halo in CSC

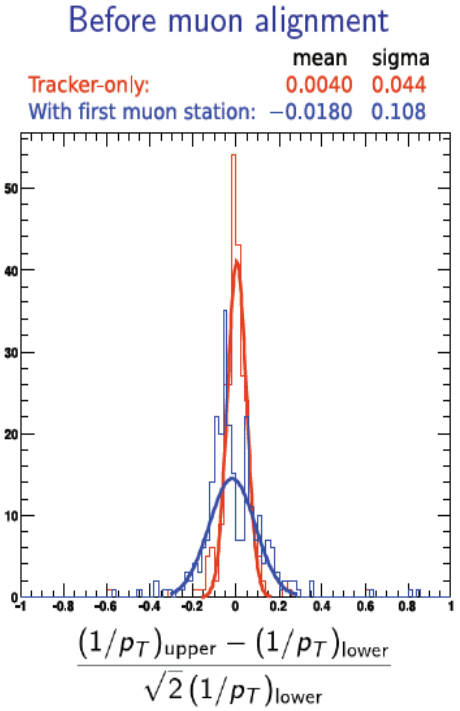
33k overlap beam halo events (9 min!)

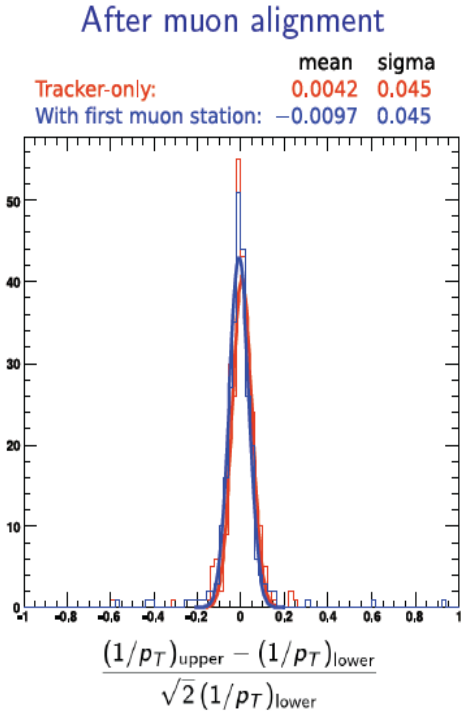


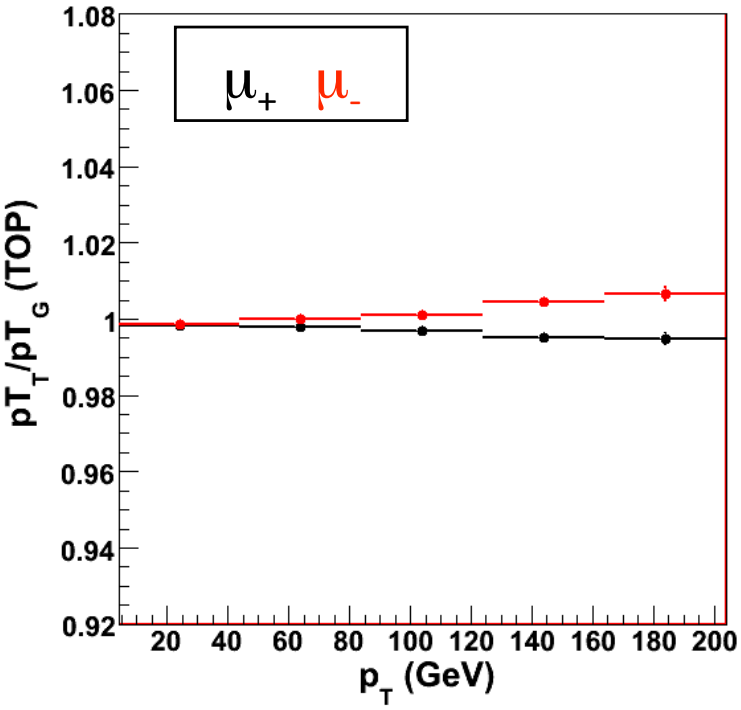


Global Tracker and Muon alignment

- Alignment affect momentum resolution
  - ✓ Method: after muon alignment Tracker tracks extrapolated to 1st muon station
- Comparison pT_{Trk} vs pT_{Glb}: global rotation of Tracker w.r.t. muon system of 350 μrad
- Hint for a leftover misalignment:
  - ✓ Not in Tracker: Curl (86 μrad) not χ^2 invariant and geometry restored after alignment
  - ✓ effect visible if $20 < p_T < 100$ GeV tracks are used for muon alignment



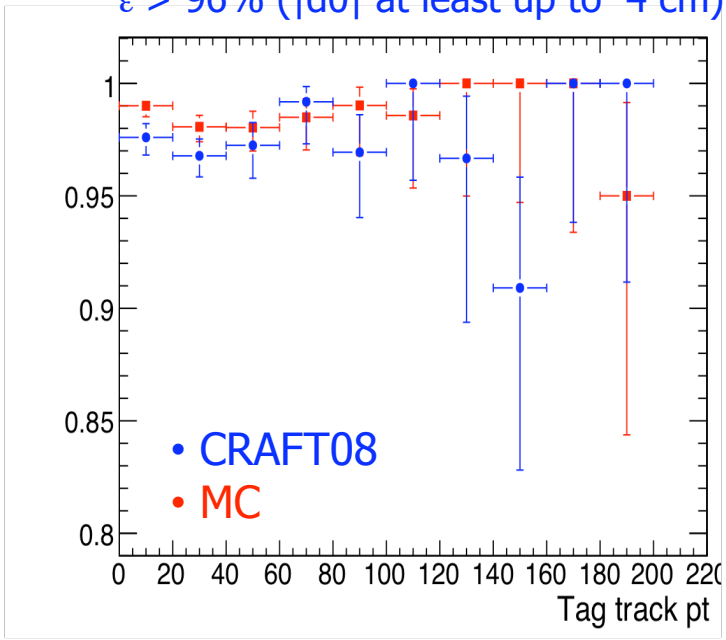


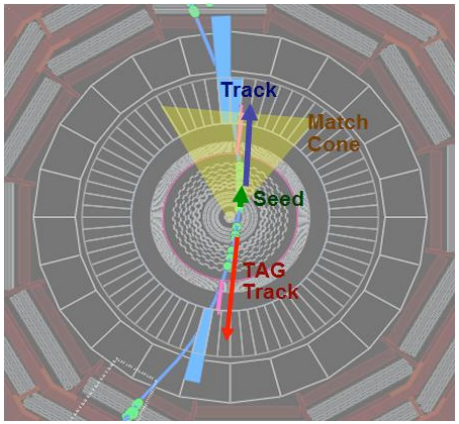


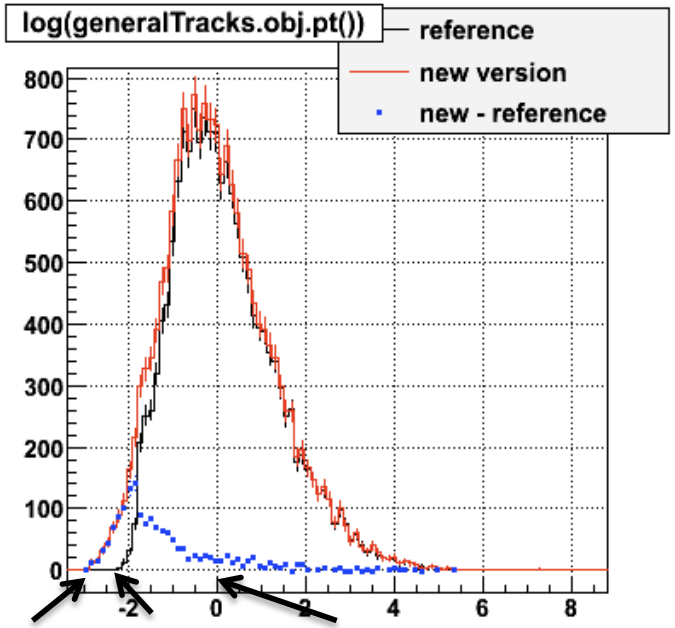
towards reconstruction in collision

- *Standard iterative tracking* tested on cosmics with a *Tag&Probe* method (one muon as tag, search for the other): ε~96% (high |d0| tracks have tighter cuts in iterative tracking)
- *K_0 and Λ reconstruction* incorporated inside default tracking software
- minimal p_T for tracks was lowered to *75 MeV*
- Activity on-going on reconstruction in *dense jets* and takle tracking with event *pile-up*

ε > 96% (|d0| at least up to 4 cm)



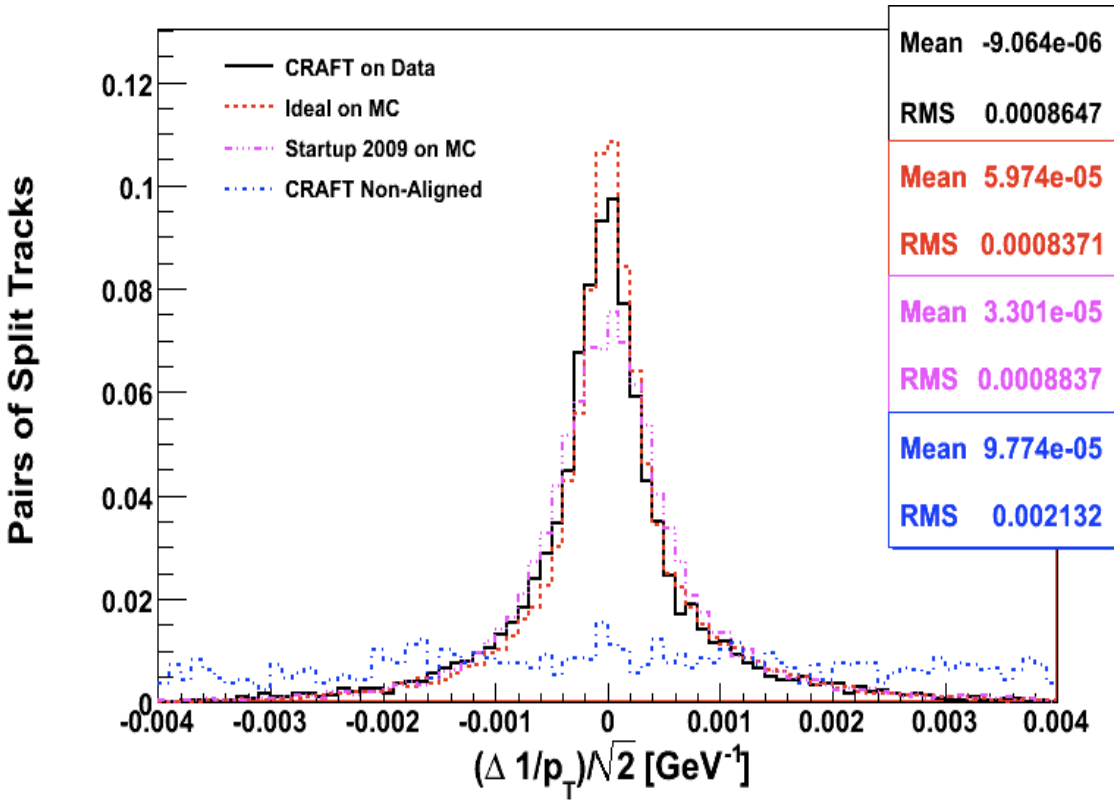




~ 90 MeV ~ 175 MeV ~ 1 GeV

- Based on the residuals and parameter resolution a misalignment scenario StartUp09 was prepared (100 pb^{-1} scenario for StripBarrel and 10 pb^{-1} scenario in Pixels/StripEndcaps):

  last CRAFT alignment do even better!



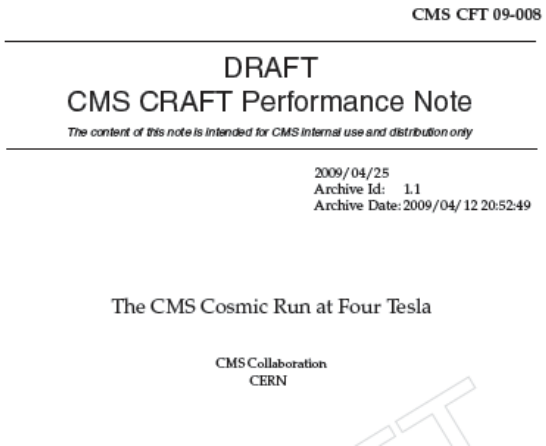
Summary

- Tracker and Muon system fully commissioned during shutdown period:
  - ✓ effort of many people provided successful results
- Performances widely tested during CRAFT08:
  - ✓ design requirments fulfilled
  - ✓ development of a good handling of faults
- Tracking: reliable and continously in development
- Alignment: precision in the Tracker close to envisaged one, matching with Muon

Tracker and Muon system are in good shape for collisions!

- And while waiting for collisions, have a nice reading….

Tracker DPG: Alignment,Pixel performance, Strip performance
Muon DPG: DTlocalReco, DTCalibration, DTLocalTrigger, RPCperformance, etc…


CMS CFT 09-008

DRAFT
CMS CRAFT Performance Note

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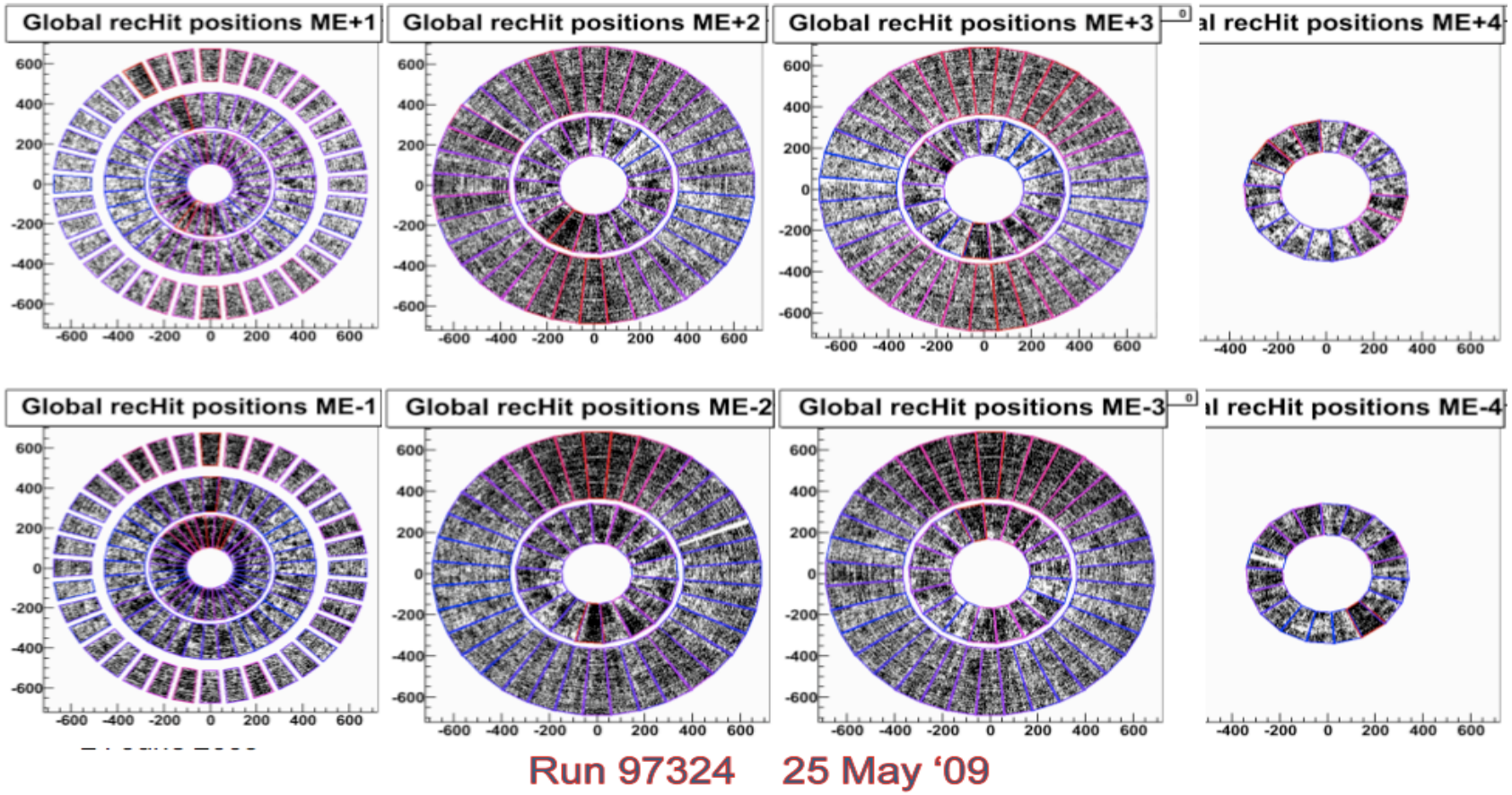
2009/04/25
Archive Id: 1.1
Archive Date: 2009/04/12 20:52:49

The CMS Cosmic Run at Four Tesla

CMS Collaboration
CERN

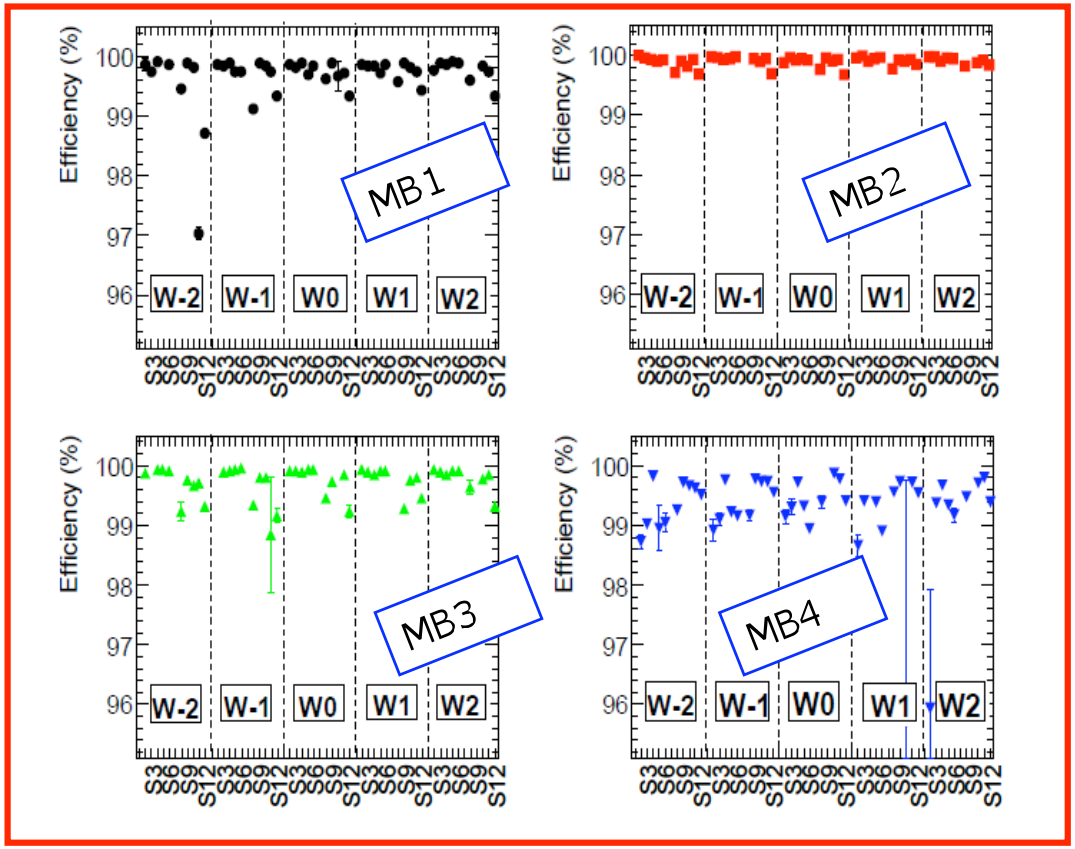
BACKUP

Muon CSC performances



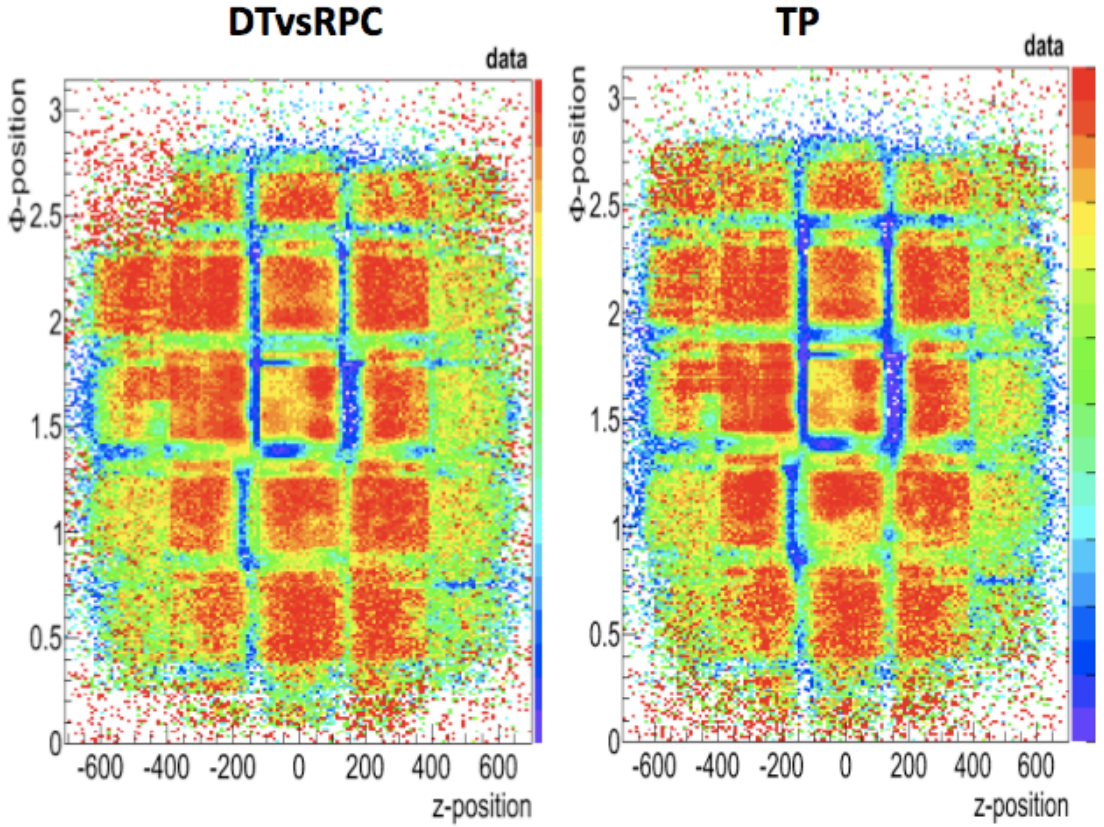
- All CSC chambers are delivering data
- No major problems observed during Global Runs.

Muon DT – Local Reconstruction



- Good segment reconstruction efficiency in the r-ϕ plane (STA muon as *tag*)

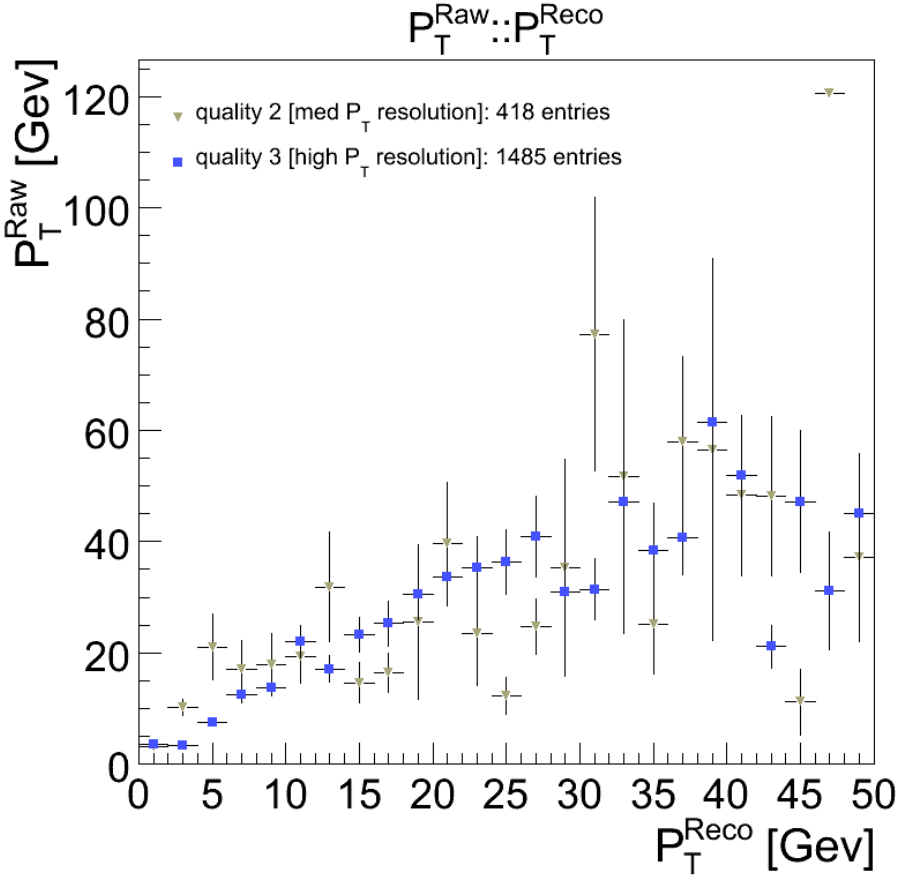
RPC Trigger performance



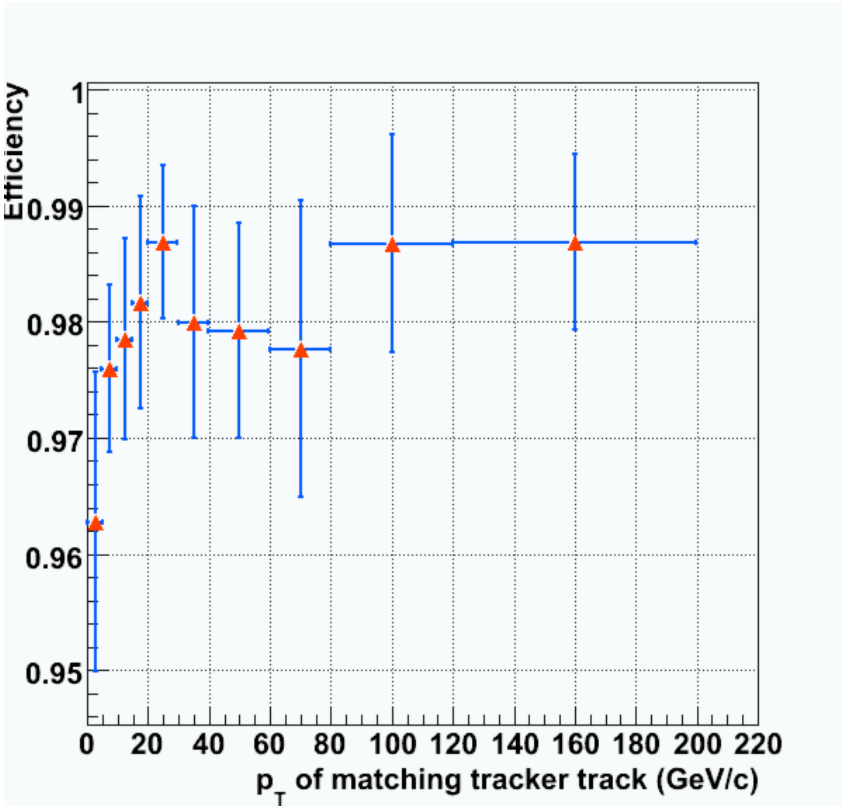
- RPC efficiency: two methods used (DT trigger and Tag&Probe) giving similar results*: good overall efficiency*

CSC Track Finder performance

CSCTF P_T vs reconstructed P_T

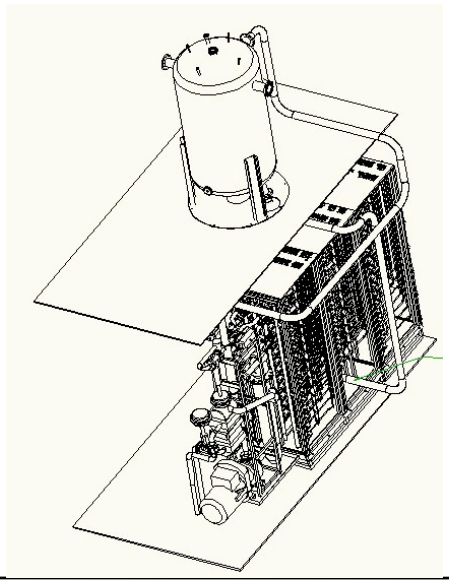


- Tracker track passing tagged in one endcap triggered by the other



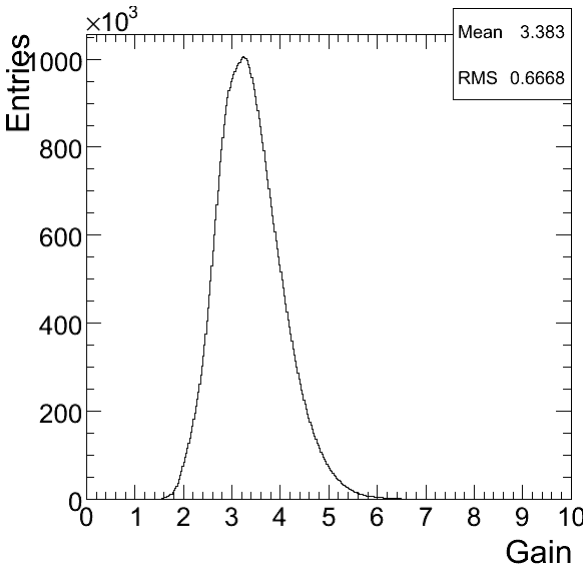
Backup: Tracker cooling plant (solution details)

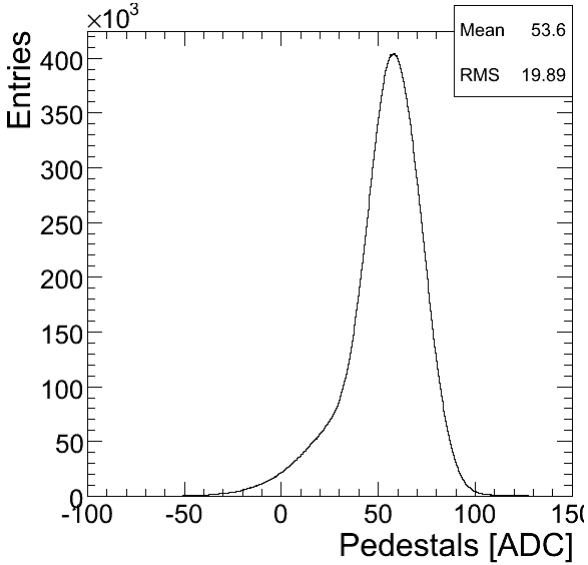
- New tanks have been designed and put one floor up wrt the plants.
- Introduced additional instrumentation
  - ✓ Monitor the components of the cooling plants.
  - ✓ Measure heat exchangers' performance.
- Redesign all the final distribution lines (90 supply and 90 returns per plant)
- In parallel a full campaign of leak search at the Tracker and its bulkhead connections was launched.

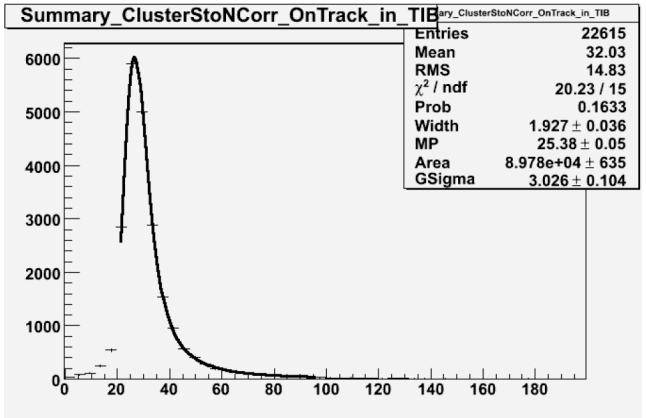


Tracker performances: Signal, noise and gain

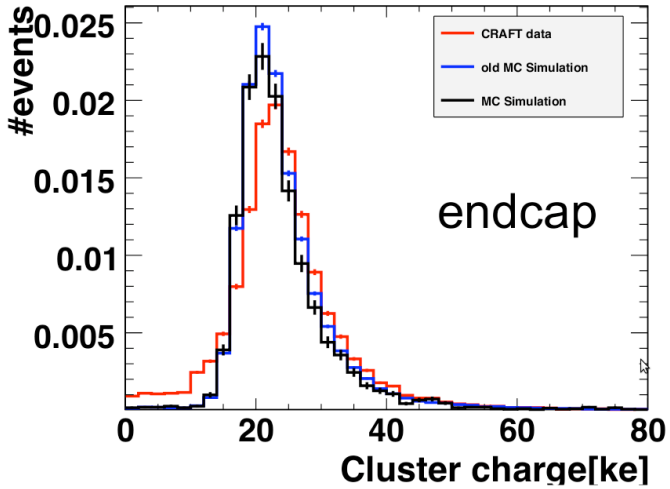
- SST: CRAFT08 data contributed to access the excellent performance, that fulfill the design requirements
  - ✓ High S/N ratio 25 (300 μm), 31 (470 μm)
  - ✓ Noise stability
- PIXEL:
  - ✓ Pedestals are stored per pixel and gains per Chip double-clmn
  - ✓ pulse heigth: released cluster charge normalized to 300 μm (MC has ideal gain calibration)







Pixels: Pulse Height and Noise



Pulse heigth

- Released cluster charge is renormalized to 300 microns
- MC has IDEAL gain calibration (no smearing of gain and pedestal values)
- Time-walk and broken clusters are not simulated in MC (and not needed for collisions)

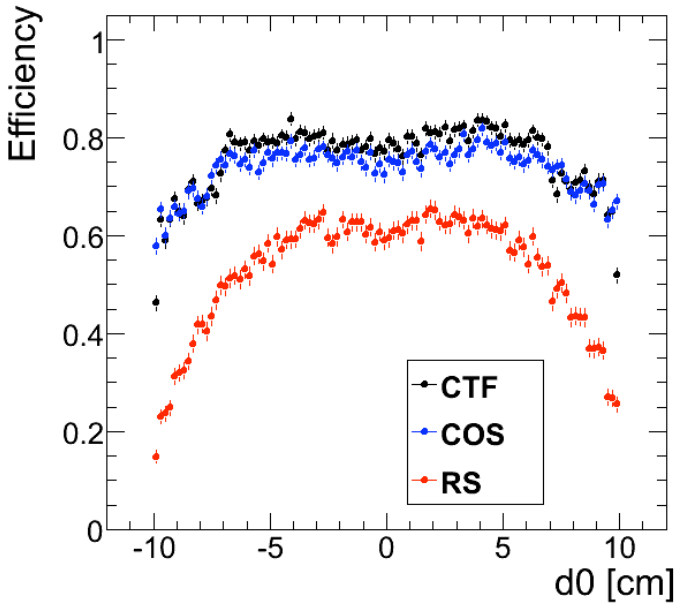
Noise			
	Glb mean	Glb RMS	ChipRMS
BPIX	85 e-	26 e-	22 e-
FPIX	141 e-	35 e-	27 e-
Threshold			
FPIX	2870 e-	200 e-	220 e-
BPIX	3690 e-	410e-	88 e-

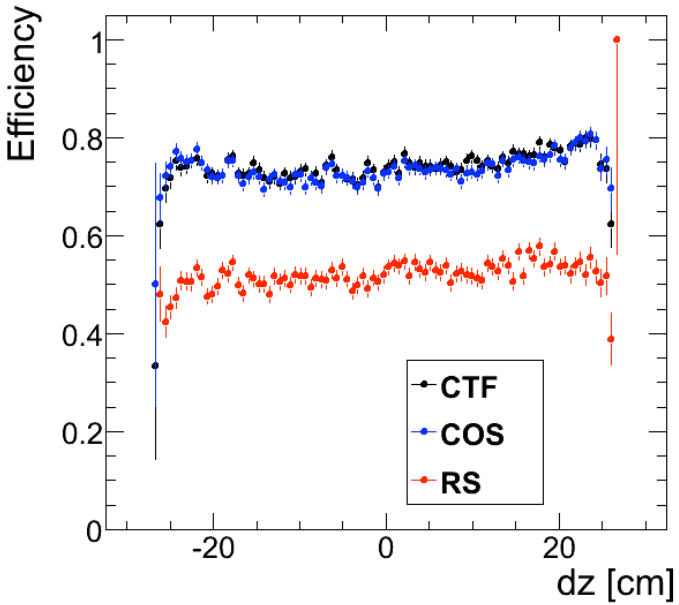
CRAFT09 analysis plans

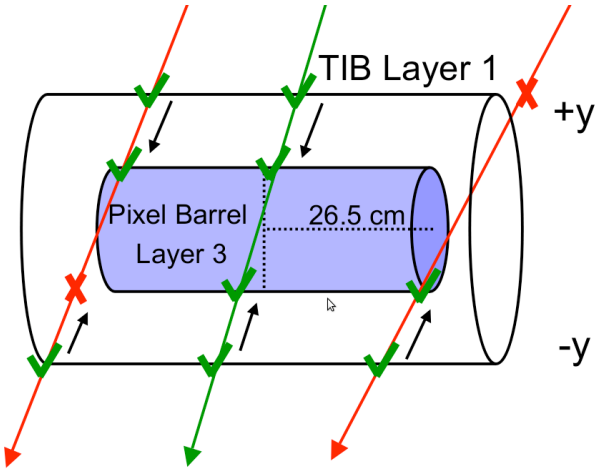
- Large analysis program
  - ✓ Validation of new offline software with cosmic data
  - ✓ Extraction of new calibration and alignment constants for first collisions
- New operating temperature at 4° and data taking in APV Deconvolution mode
  - ✓ Hardware tuning, Noise, Capacitive Couplings, Gains, Cluster Width, HIT Resolution, Lorentz Angle
- Needed Statistics
  - ✓ ~1/2M Ttracks: validation of previous measurements
  - ✓ ~4 M Ttracks: systematic effects study

CRAFT09 CMS/TK Program 09/07/13 **Tracker fully commissioned** **300Hz Trigger rate - 60% data taking efficiency** **Normalisation to Alignment Tracker Track selection (TT)** **250(1800)k TT per day(week) (1.6% of cosmic triggers)**	week 1 CRAFT09	week 2 CRAFT09	week 3 CRAFT09	week 4 CRAFT09
Validation of CRAFT09 commissioning in APV Peak (Tracker filter HLT as in CRAFT08)	1.8M TT	1.8M TT		
Calibrations with CRAFT09 in APV Deconvolution (Tracker filter HLT as in CRAFT08)			1.8M TT	1.8M TT
SST time tuning for data taking in Deconvolution mode	Driving data taking time in Peak mode			
DQM, Pixels, Strips, Alignment, Track Reconstruction Offline Software Commissioning				
Pixels Calibration/validation of new commissioning/ ~ 1.5-3% of TT (PF/PB)	>80k Tracks 7M TT ---> 200(100)k Tracks BPIX(FPIX)			
Pixels Calibration/Lorentz Angle ~ 1.5-3% of TT (PF/PB)	>80k Tracks 7M TT ---> 200(100)k Tracks BPIX(FPIX)			
Simulation tuning/sensor thickness/	Independent of APV mode >2M TT			
Simulation tuning/cross talk/	1 run Peak few hours		1 run Dec few hours	
SST gains	>250 TT Peak		>1/2M TT Dec	
SST LA	Independent of APV mode >4M TT			
SST HIT efficiency	>500k TT Peak		>2M TT Dec	
Alignment constants	Independent of APV mode >4M TT			
Laser monitoring during data taking	2000 evts Every 10'			
Special runs if enough operation time				
SST HV scan Gain-LA-Hit efficiency	3 additional days for 4 HV settings			
B field = 0/2T				
Simulation tuning/cross talk/ B=0T	1 special run per mode 2 x few hours			
SST Lorentz angle B=2T	1 additional day			
Alignment 0/2T (or 1 low B setting ?)	4 additional day per field value			
Offline Analyses				
Overlap study : Hit resolution Pt>20GeV, 6Hits, P(Chi2)>0.001 Alignment performance	Priority to Dec 3000 module pairs for 4M TT			
Track parameters Pt>4GeV, 2 hits in PB ~1% of TT	>40k Tracks 7M TT ---> 70k Tracks			
Tracking efficiency Collision like selection ~1% of TT	>40k Tracks 7M TT ---> 70k Tracks			

Pixels: Efficiency
(M.Lebourgeois, B.Mangano)





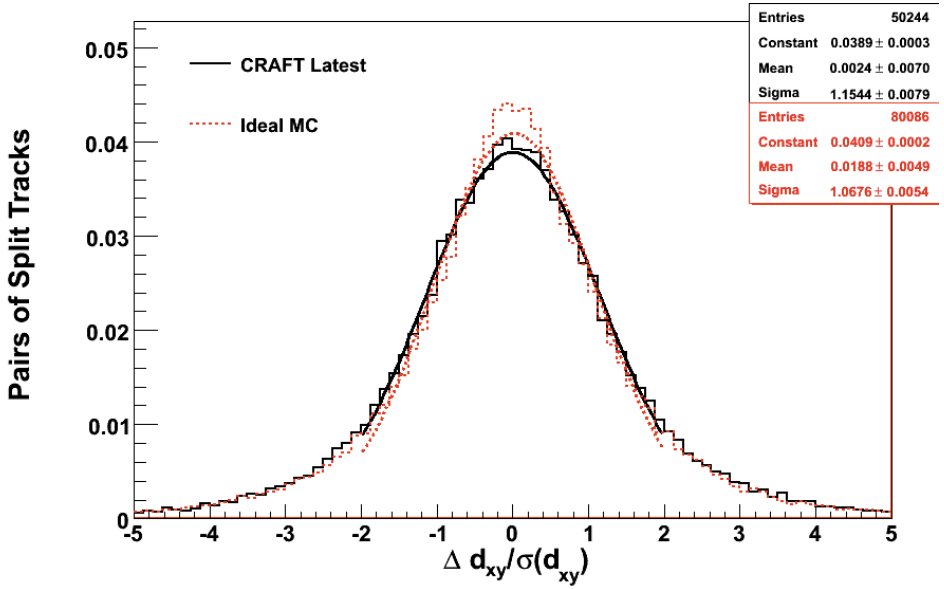


Denominator:
The track must pass through the innermost TIB layer both on the positive and negative y side
Then, the track must be capable of being forward propagated from the positive y position in the TIB to a cylinder bounded by the third layer of Bpix
Equivalently, the track must be capable of being reverse propagated from the negative y position in the TIB to the same cylinder

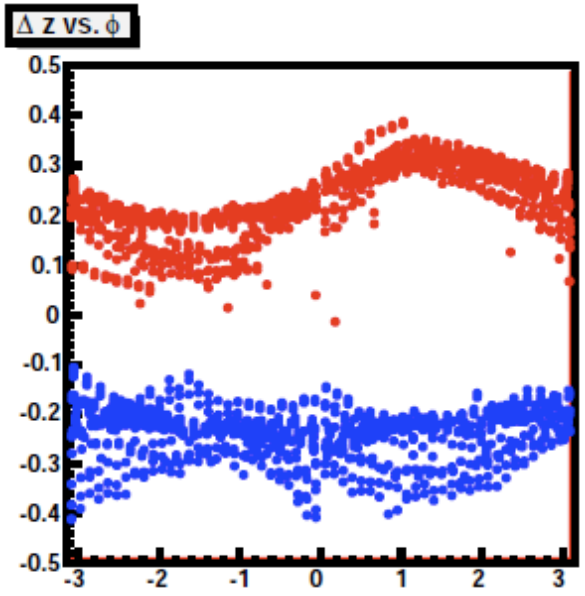
Numerator:
Subset of denominator tracks that has at least one valid Bpix hit

Comment: this is not a measurement of the sensor efficiency, but is rather a result of several factors: tracking efficiency, alignment, detector performance, timing synchronization, etc…

- Alignment Parameter Error (*APE*) properly tuned in order to have σ_{pull}~1 in the normalized residual distribution



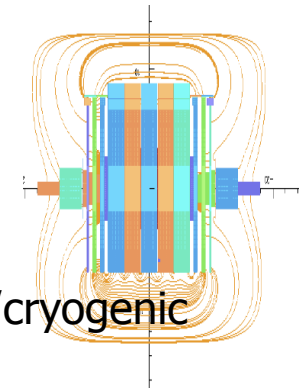
APE checked also on track parameter (d_{xy} and d_z have strong pixel dependence)

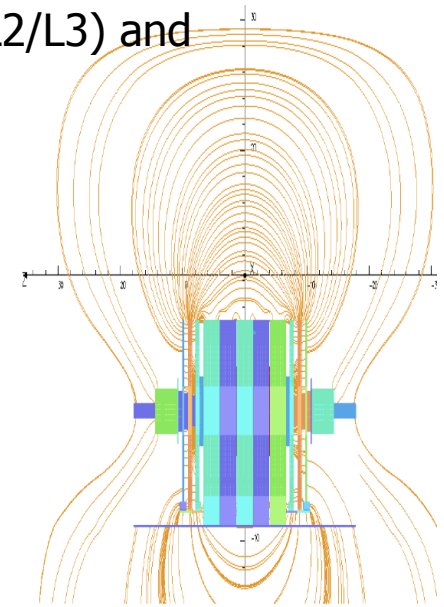


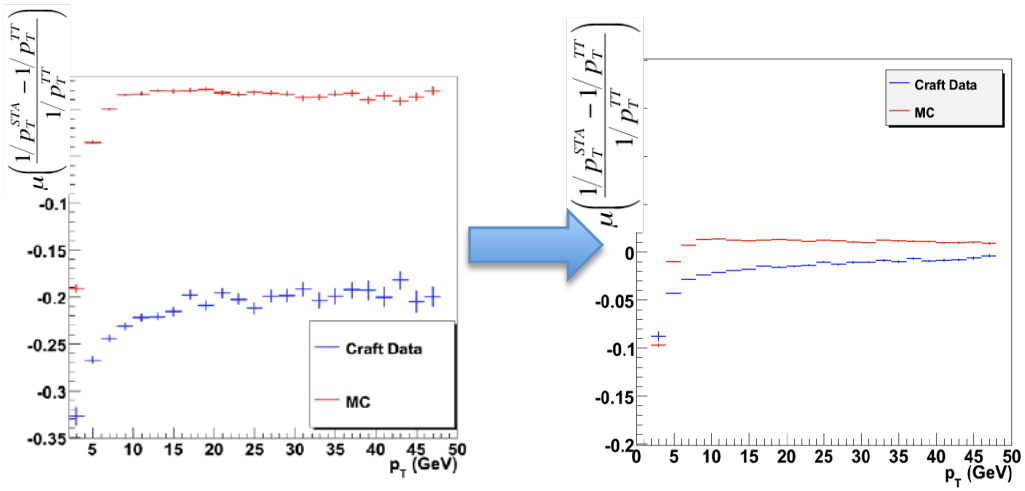
- Studies on the resulting Tracker geometry
- TIB: 5 mm shift of pos/neg half-barrels along *z*
  - ✓ Two halves shifted apart
  - ✓ confirmed by optical survey
- Investigation of remaining possible 'weak' modes

The magnetic field commissioning

- Evidence of the problem:
  - ✓ momentum scale comparison: STA vs TrackerTracks
  - ✓ measurement of muon track bending from one station to the next
- Field map in Tracker region well-known (~0.1%) thanks to MTCC probes
- Field lines squeezed in r and z: in new model boundaries are *enlarged*
- ϕ-simmetry in CMSSW map (replicated in each of 12 sectors) but electric/cryogenic chimney (S4, S3) and feet (S9, S11): *corrections inside new map*
- *Scaling factor* computed on top of ϕ-simmetric map (vaues for L1/L2/L3) and applied to different wheels: corrections inside new map
- Better agreement in momentum scale STA tracks vs. TRK tracks



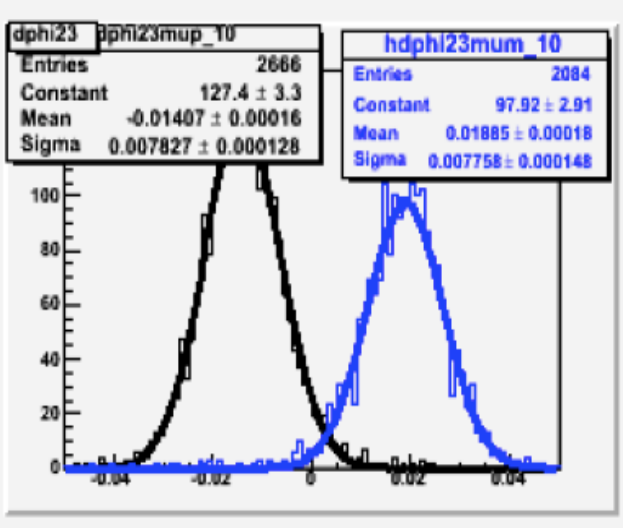




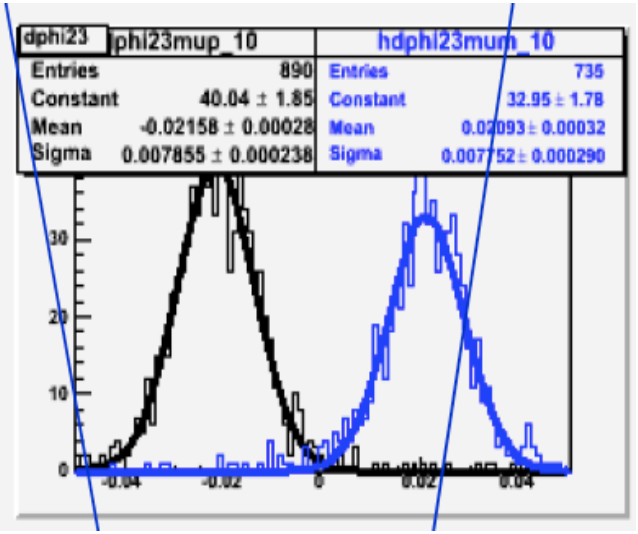
Evidence of the problem

St.2 Vs St.3

DATA 3.8 T



MC



1) measurement of muon track bending from one station to the next
   - $\Delta\phi$ between two segments of consequent chambers measured $\Delta\phi_{\mu+} - \Delta\phi_{\mu-} \propto \int B \cdot dl$
   - to first order not affected by alignment
   - significative difference between Data and MC