The offline Data Quality Monitoring system of the ATLAS Muon Spectrometer

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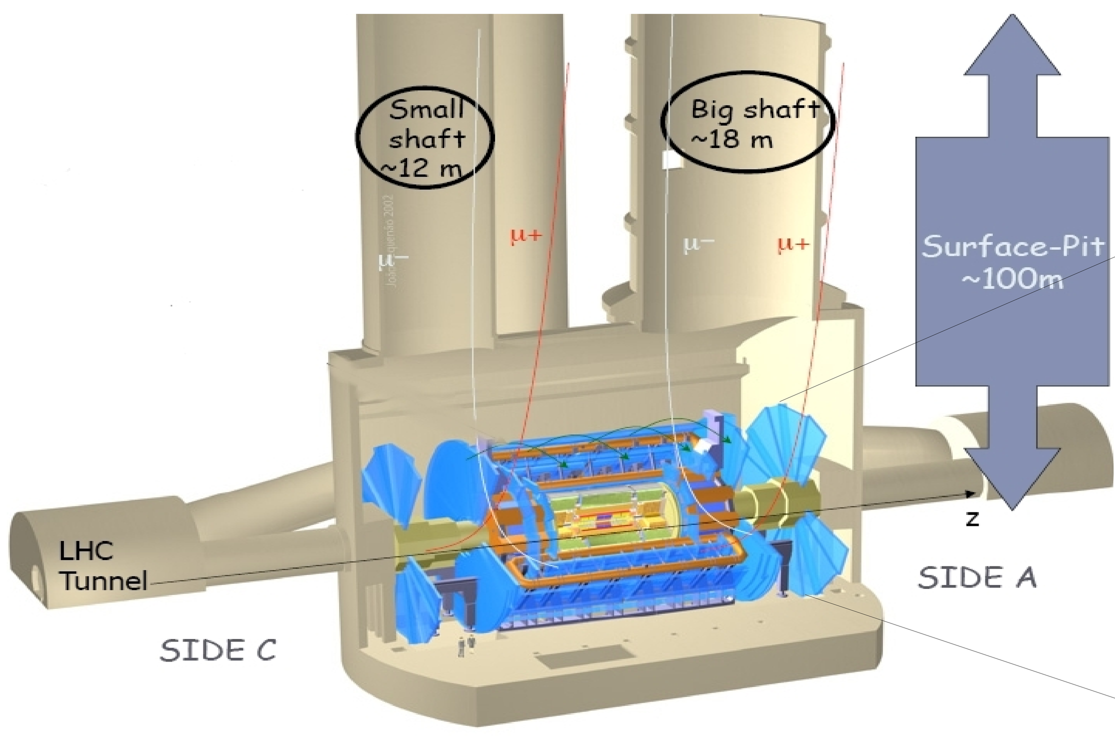
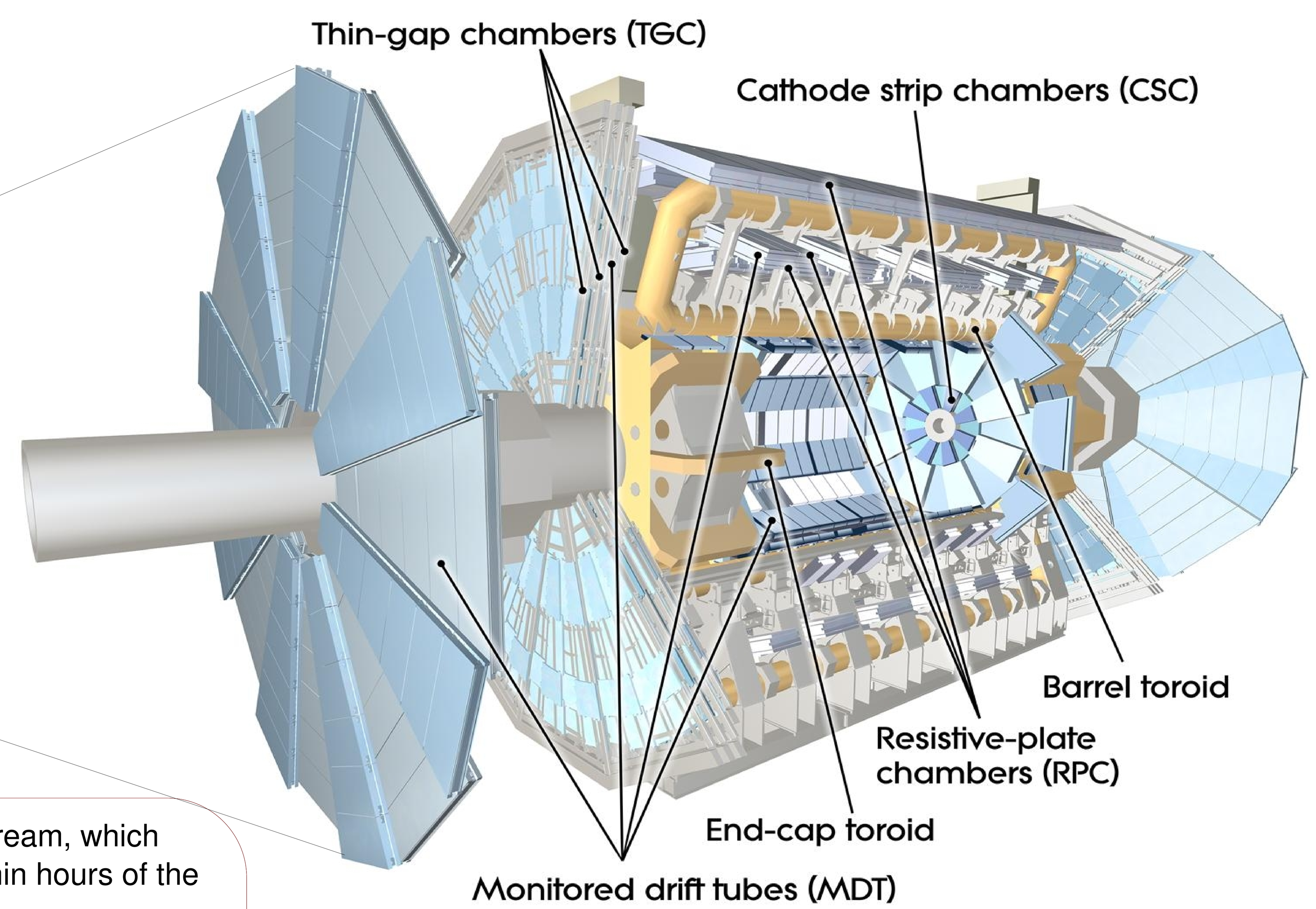
The ATLAS detector has been designed to exploit the full discovery potential of the LHC proton-proton collider at CERN, at the center-of-mass energy of 14 TeV. Its Muon Spectrometer (MS) has been optimized to measure final state muons from those interactions with good momentum resolution (3-10% for momentum of 100GeV/c-1TeV/c). In order to ensure that the hardware, DAQ and reconstruction software of the ATLAS MS is functioning properly, Data Quality Monitoring (DQM) tools have been developed both for the online and the offline environment. The offline DQM is performed on histograms of interesting quantities, which are filled in the ATLAS software framework "ATHENA" during data processing at CERN Tier0 facility. Then those histograms can be displayed and browsed by shifters and experts. They are also given as input to the Data Quality Monitoring Framework (DQMF) application, which sets a status flag for each of them, to be propagated to a global status and saved in a database. A web display of DQMF results is also available.

The offline muon DQM structure and content, as well as the corresponding tools developed using cosmic ray data from the MS commissioning phase, are presented, with examples from the Barrel.

The ATLAS detector in the pit:



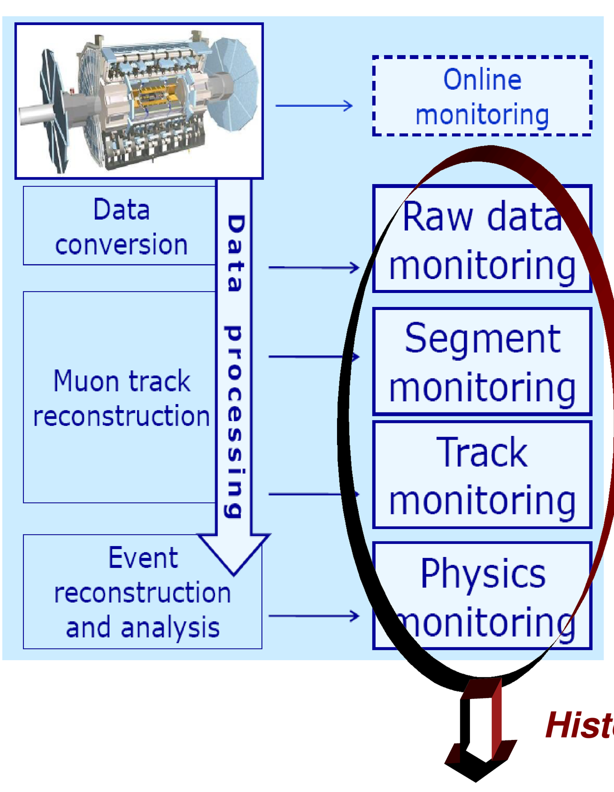


The ATLAS Muon Spectrometer

... comprises chambers of 4 different technologies:
- RPCs and TGCs for trigger, in the Barrel and EndCap regions respectively
- MDTs and CSCs for precision track measurement in the $|\eta|<2.5$ and $2.5<|\eta|<2.7$ regions respectively

The flow of the Offline Data Quality Monitoring

The offline DQM is run at the same time with the full reconstruction on the Express stream, which contains ~10% of the data. This fast processing is done at CERN-Tier0 machines within hours of the run, and signals the quality of the run for full processing.



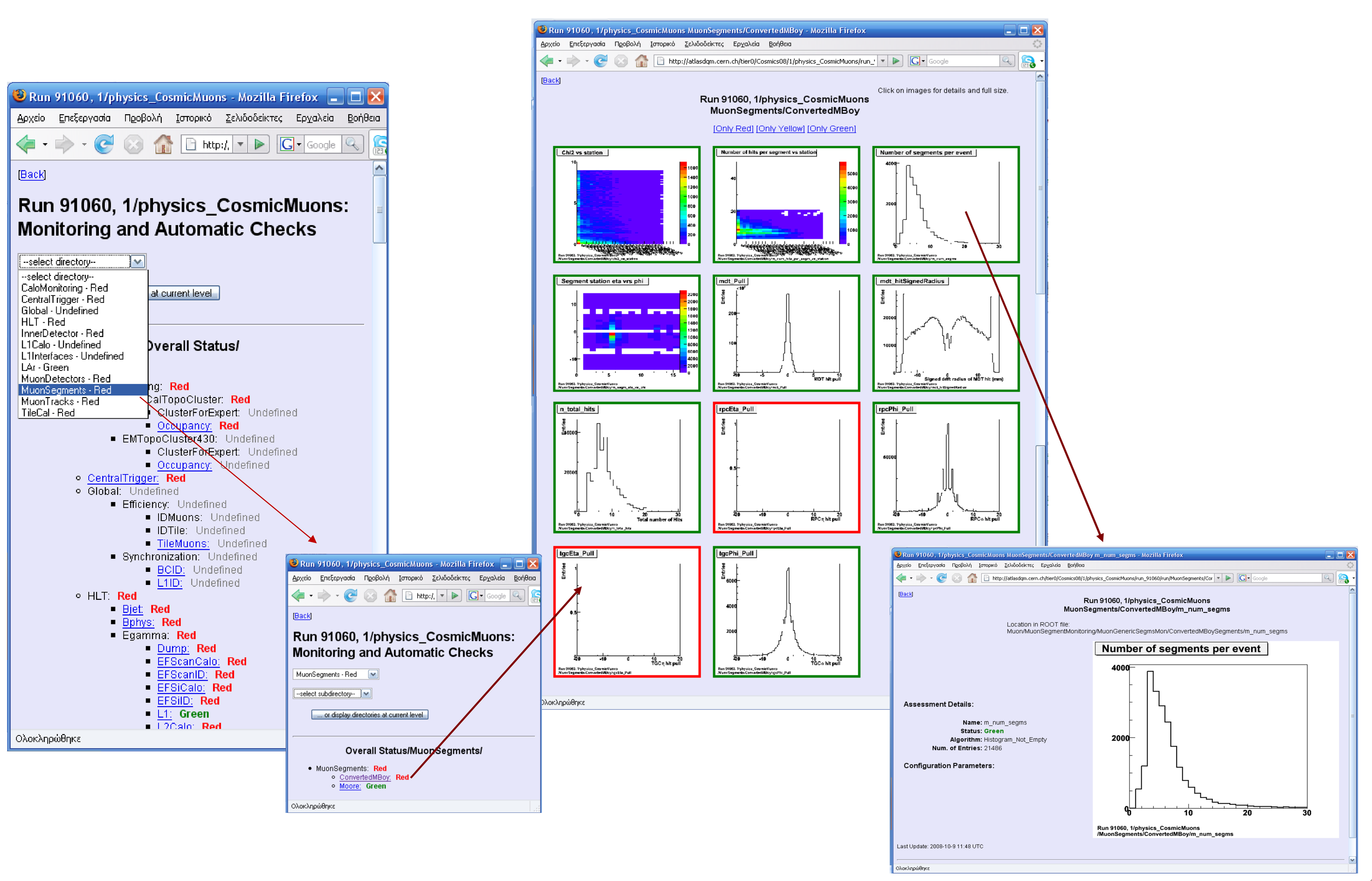
The monitoring follows the flow of the reconstruction chain:

- Raw byte stream data are converted to hit information (Low level)
- Track segments are reconstructed from trigger and precision hits, using pattern finding algorithms.
- Muon tracks are reconstructed in the whole MS (Mid level)
- Physics objects are formed using combined information from different subdetectors (High level)

Histogram output is then fed into the...

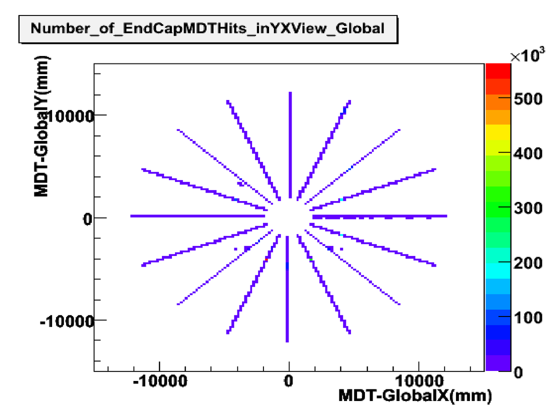
Data Quality Monitoring Framework

DQMF is an application designed to check histograms in an automated way and report results and summaries, both in the online and the offline environment. Its functions are
- ***Navigation*** through the histogram tree and ***plotting*** in a user-friendly way.
- Automatic ***web display***
- Performance of various ***checks*** on the histograms, using simple (eg. mean and RMS) or more sophisticated algorithms (eg. comparison with ***reference histograms***). Those checks use ***thresholds*** to set ***alarm levels*** (GREEN, YELLOW or RED) on the quality of the data, and ***propagate*** these quality flags to more global levels (eg. chamber->sector->Barrel side A/C->whole MS->detector)
- ***Storage*** of data quality flags and other quantities of interest in a ***database*** for later use by analyses

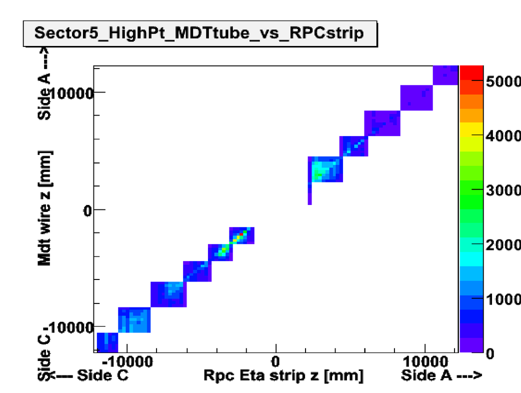


Raw Data Monitoring

At this level, hit related quantities are monitored, in order to check the condition of chambers, verify it against the online Monitoring results, and test the readout and decoding chain from online to offline. Such quantities are
- Hit multiplicities and noise levels, noisy and dead channels
- Spacial and time correlations of the trigger and precision chambers
- Charge (ADC) and time (TDC) spectra, and especially t_0 and t_{max} stability

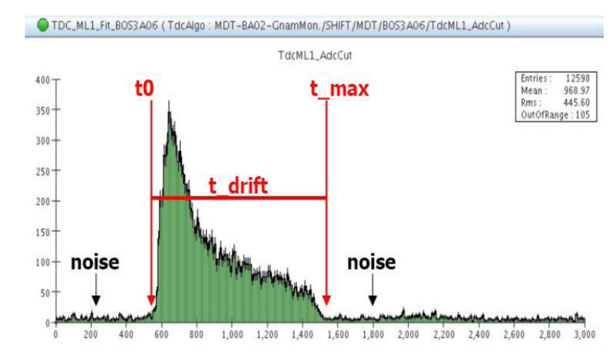


XY map of EndCap MDT occupancy (number of hits), reflecting the geometry of the MS



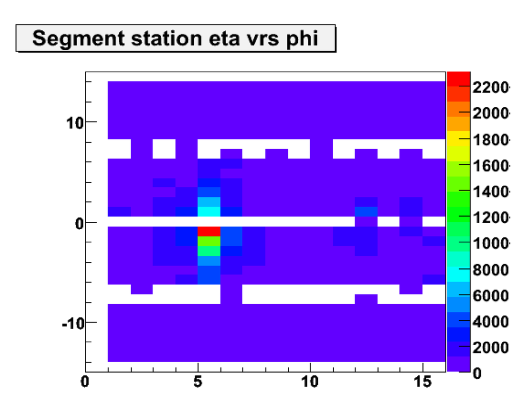
Hit correlation for a given Barrel sector: MDT wire vs RPC strip z position

Typical MDT TDC spectrum. The t_0 and t_{max} are defined from fits of the leading and trailing edge of the spectrum, and depend on the trigger timing and gas conditions respectively.

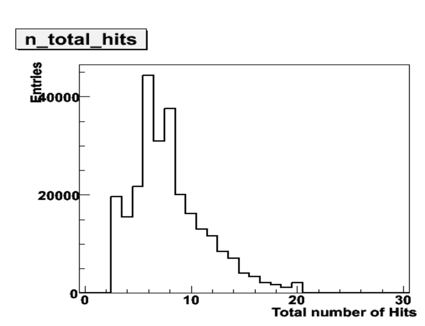


Segment and Track Monitoring

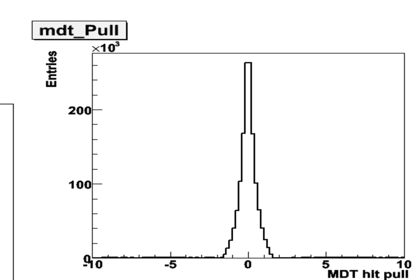
At this "mid level" monitoring, there is access to reconstructed quantities, which are checked in order to test the reconstruction chain for the two algorithms used. The segments are confined to one station, therefore they are used to monitor the reconstruction efficiency per chamber and verify the calibration. The tracks, spanning the whole MS, are also used for verification of the alignment and magnetic field mapping. Such quantities monitored are
- Segment and track multiplicity, hit on segment/track multiplicity
- Fit quality and parameters
- Hit residuals, pulls, local spacial distributions
- Chamber and tube efficiencies
- Track p_T and charge ratio



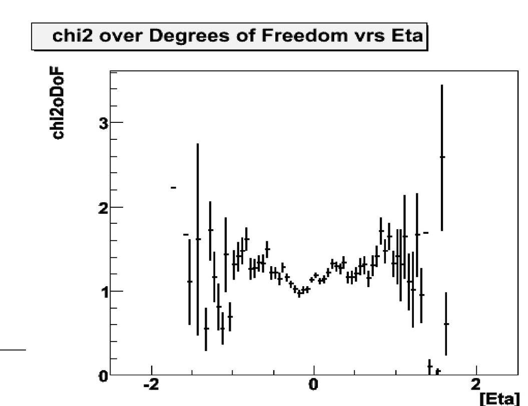
ηφ map of reconstructed segments. The concentration of segments on the top of the detector is characteristic of cosmics.



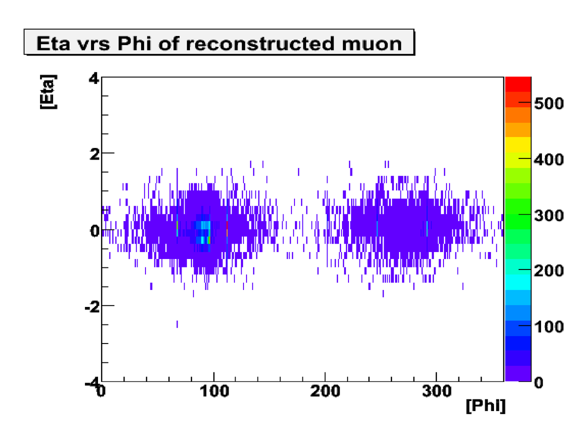
Number of hits per segment, with peaks reflecting the number of MDT layers (6 or 8)



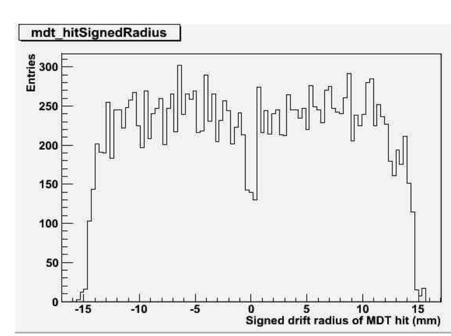
MDT hit-on-segment pull



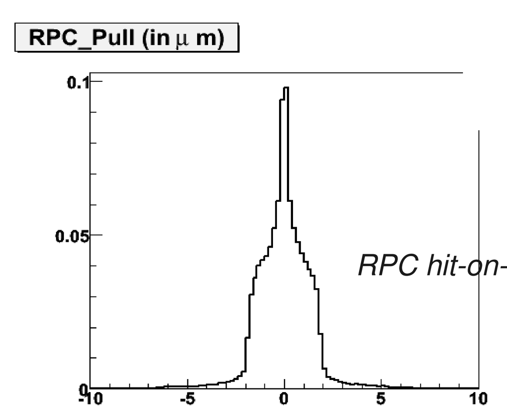
χ^2/d.o.f. of the track vs η station



ηφ map of reconstructed tracks. The two concentrations of tracks correspond to cosmic muons transversing the detector.



MDT hit-on-segment drift radius. The flatness of this distribution is a test of the quality of the calibration.

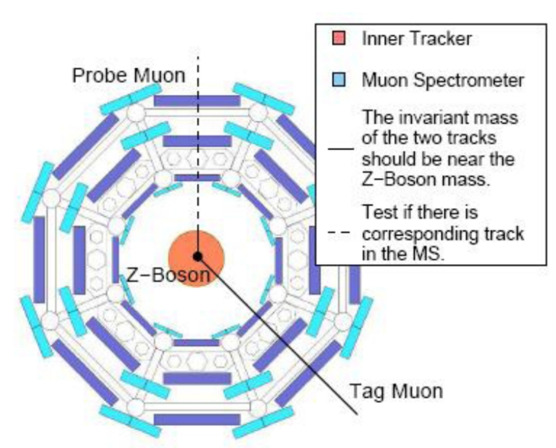


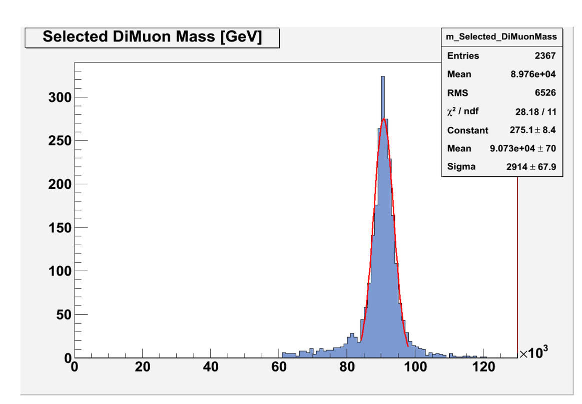
RPC hit-on-track pull

Physics Monitoring

At this "high level" monitoring, physics quantities are checked in order to test the overall MS and detector performance, software chain and long-term stability, as well as the robustness of the calibration, alignment and magnetic field mapping. Such quantities are
- Reconstructed particle mass peaks, for the momentum scale and resolution
- p_T and charge asymmetry distributions
- Well-known particle production cross-sections
- Muon trigger and reconstruction efficiencies.

The efficiencies are measured with the "Tag-and-probe" method: A "tag" muon is selected with strict quality requirements. Then a loose "probe" muon is chosen (usually just an Inner Detector track), according to the requirement that it gives the Z boson mass together with the tag muon. Finally the probe muon is matched with a MS track or an object that passes the trigger whose efficiency is being meaured.





Invariant di-muon mass in simulated data, where the Z boson mass peak is obvious.

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