Muon Calibration

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OUTLINE

1. Detectors calibration
   - MDT Calibration strategy for first collisions
   - Ongoing activities involving italian groups:
     1. MDT *[Roma 1, Roma 3]*
     2. RPC/L1 *[Lecce, Napoli, Roma 1, Roma 2]*
2. Muon momentum calibration *[Frascati, Roma 3]*

Calibration of precision chambers (MDT)

Calibration tasks:

- Syncronization of the drift-time measurements (t0 determination).
- Determination of the *r(t)* relationship (*r-t*)
- Determination of the single-tube resolution *s(r)*.

MDT drift properties are very sensitive to environmental conditions.
The *r-t* calibration should be performed:

- per chamber to avoid large corrections (mainly temperature effects)
- frequently (each day) to ensure the required precision.

r-t accuracy:

- Ultimate goal: 20 μm.
- Contributions to the *r-t accuracy:*

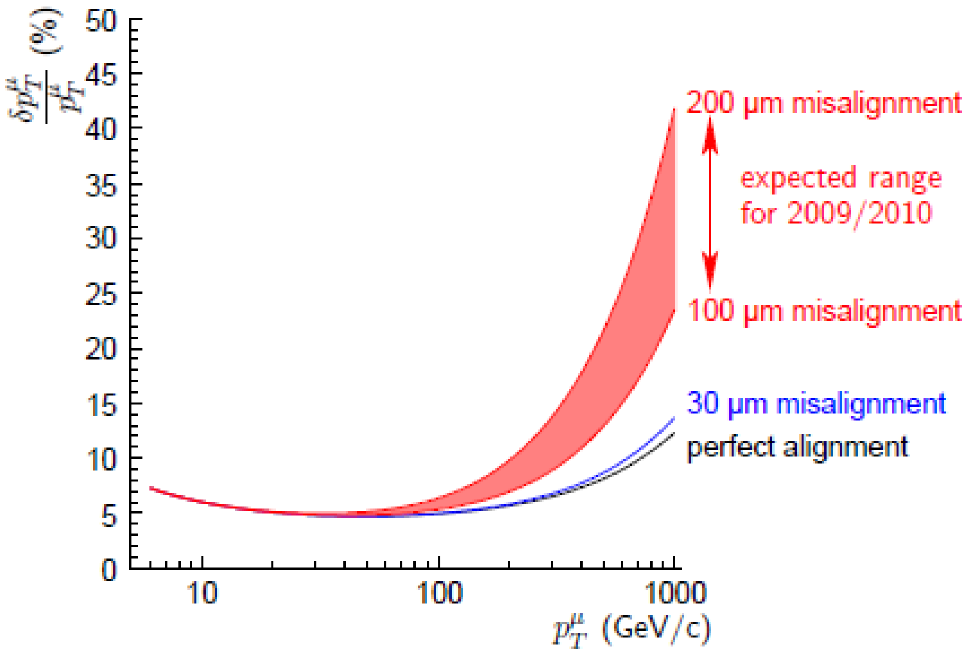
$$\delta r(t) = \sqrt{\underbrace{\left(\frac{dr}{dt}\right)^2 \cdot (\delta t_0)^2}_{impact\ of\ t_0\ precision} + \underbrace{\epsilon^2(t)}_{error\ on\ r(t)}}$$

$\Rightarrow\ \delta t_0 \lesssim 1$ ns, $\epsilon(t) \lesssim 20\ \mu$m required.

ATLAS and LHC operation in 2009/2010

- Expected alignment accuracy of the spectrometer:
  <100 μm in the end caps, 100-200 μm in the barrel.

Expected stand-alone muon momentum resolution:

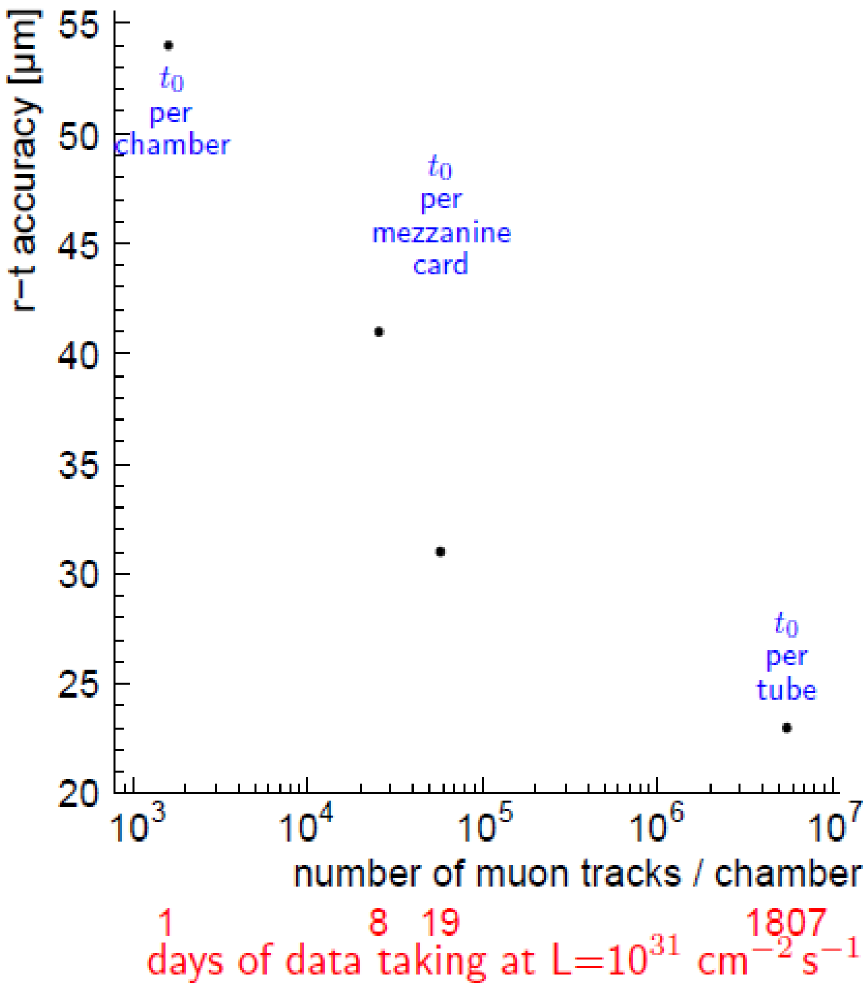


Almost no performance degradation for p_t<100 GeV

Goal for 2009/2010: Keep the contribution of the r-t accuracy to the resolution degradation almost negligible compared to the alignment error:
Required r-t accuracy <60 μm

r-t accuracy with first data

r-t accuracy after time synchronization and autocalibration



Assumptions:

- L=10^{31} cm^{-2} s^{-1}
- Calibration stream at a rate of 100 Hz, i.e. 0.25 Hz/chamber.

Conclusions:

- Desired initial r-t accuracy already after 1 day of data taking.
- 30 μm r-t accuracy close to TDR requirement after 1 week of data taking!
- TDR requirement of 20 μm unreachable due to missing statistics for a tube-by-tube synchronization; relative t_0s needed.

Calibration Strategy for 2009/2010

Very low luminosity period ($L \sim 10^{29}$ $cm^{-2}s^{-1}$)

- Very low muon rate: <0.0025 Hz/chamber (<200 muons/chamber/day).
- Initial *r-t* from gas monitor chamber (*) plus corrections.
- t_0s determined with t_0 refit (as a free parameter in the track fit).

Modest luminosity period ($L > 10^{30}$ $cm^{-2}s^{-1}$)

- Sufficient statistics for *r-t* calibration and t_0 fits per chamber.
- Run standard calibration algorithms on muon data of individual chambers.

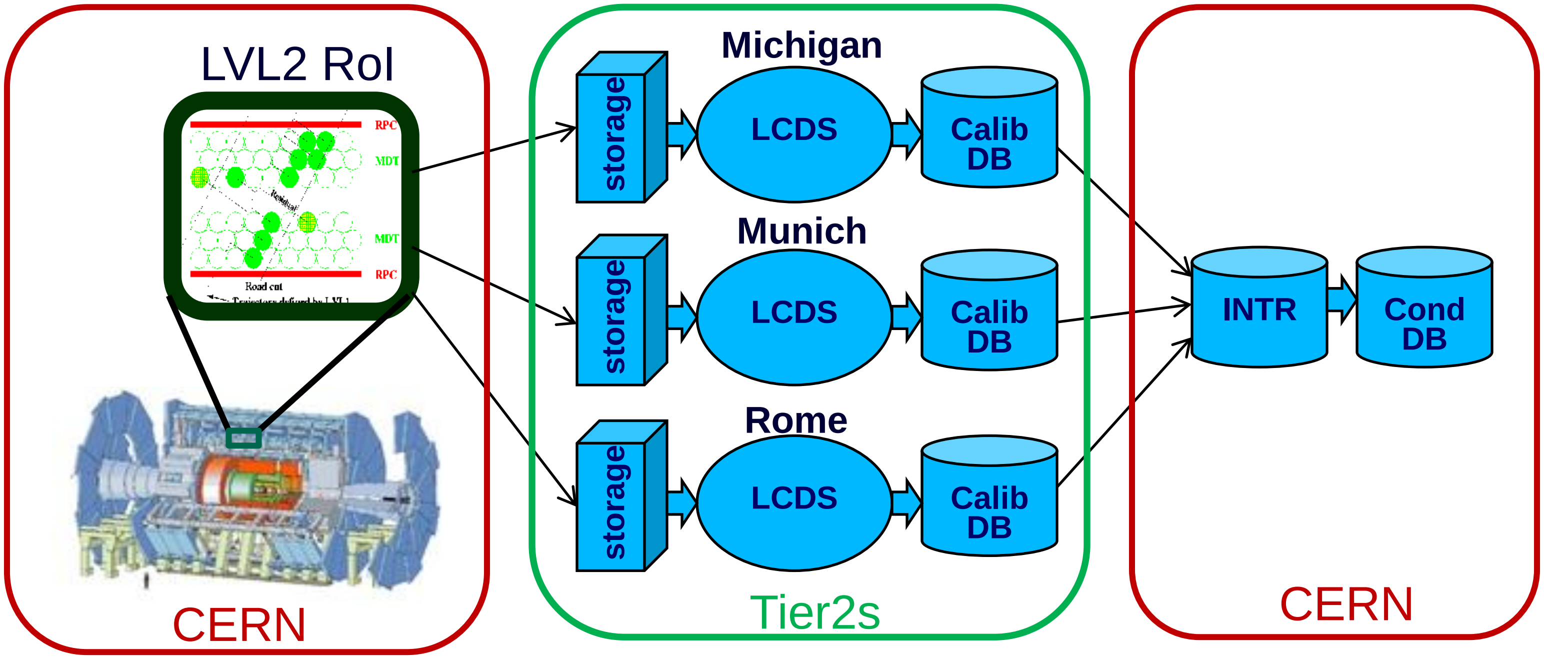
Preparatory work

- Use commissioning data to understand the use of gas-monitor r-t relation in combination with corrections.
- Try to get relative chamber t_0s with cosmics to reduce the required statistics with pp data.

(*) A single chamber operated with cosmic rays sharing the in&out gas lines with the spectrometer.

MDT Calibration procedure

- Muon calibration stream is extracted from the LVL2 processing units.
- Stream data are collected at CERN and automatically sent to the calibration centers (Michigan, Munich, Rome, Naples).



The Local Calibration Data Splitter (LCDS):

1. Automatically produces ntuple (in ATHENA) for each incoming stream dataset;
2. Runs the MDT DQA for DQ regions (BarrelA/C, EndcapA/C);
3. Runs the MDT calibration, processing separately each calibration region;
4. Stores the results in the local db (replicated via ORACLE streams to CERN INTR db).
5. Calibration constants are eventually copied into the Conditions db.

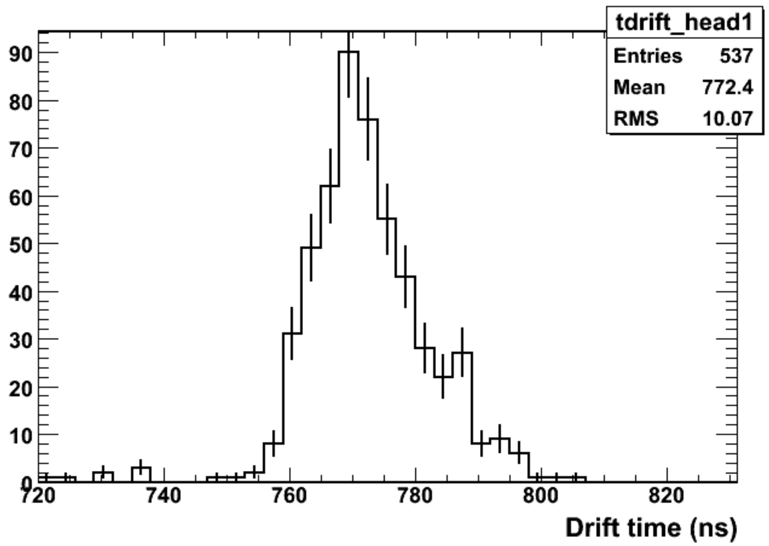
MDT Calibration

The MDT calibration chain is fully operational (from stream extraction to constants writing in the DB).

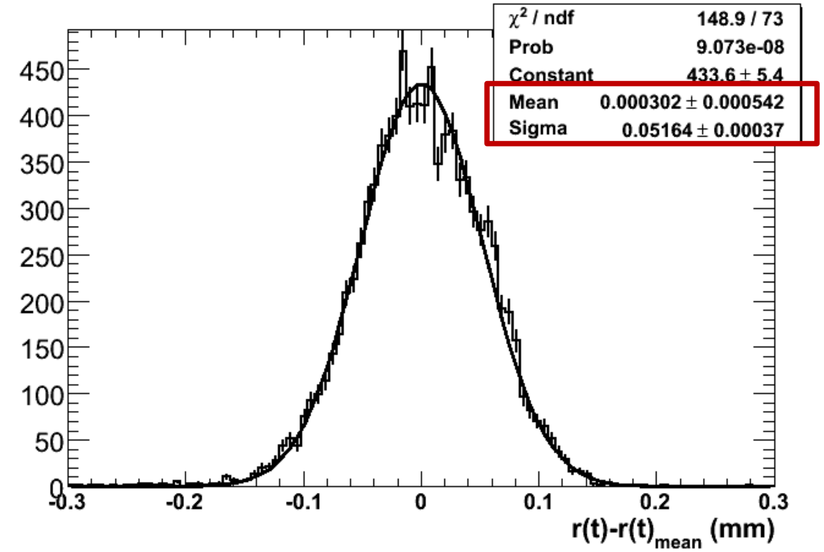
- To do: test and apply the *r-t* corrections (B-field, wire sag, time slewing, …)

- Regular shifts were taken during the last data taking period at the Rome Calibration Center.

Calibrations in the last data taking period



Chamber total drift time distribution for all the chambers.



Dispersion of the r-t points around the mean r-t value.
Only BM chambers are used to properly exploit RPC timing

MDT Data Quality Assessment with the calib stream

- MDT Data Quality Assessment exploits the "**offline DQMF**" package
- DQMF analyzes histograms produced from ntuples and assigns quality flags.
- Results and summaries are
  - **published on WEB,**
  - **stored in MDT DQA COOL database.**

- The DQ assessment at the calibration centers was performed on the whole spectrometer using the Offline DQMF.
- used for MDT DQA by shifters at the last cosmic data taking (Apr/May 2009).

NEXT STEPS
Optimize the analysis and the algs for the MDT DQA.

WEB display: example of an overview histogram

MDT multilayers illumination

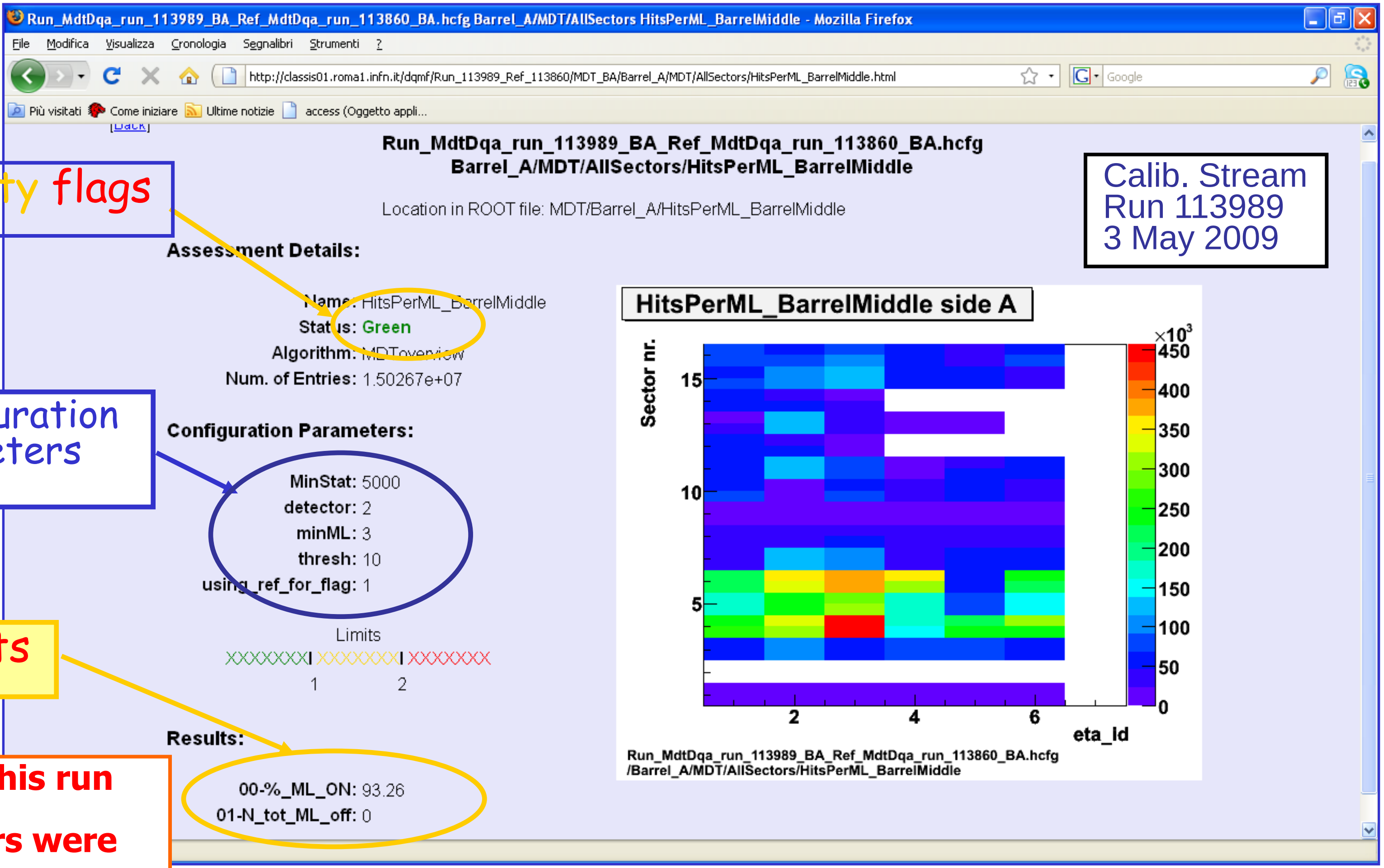
Barrel side A, Middle station, sector φ VS station η

Quality flags

Configuration Parameters

Results

e.g. In this run 93% of detectors were active.



Calib. Stream
Run 113989
3 May 2009

The quality flags are "propagated" from each folder up to the main one (according to a defined logic).

RPC/L1 Calibration

[Lecce, Napoli, Roma 1, Roma 2]

RPCs Calibration Stream Analysis

The analysis is aimed at the determination of several quantities:

- Efficiency
- Cluster Size
- Spatial residuals
- Others...

These quantities are stored in the Conditions DB

- Analysis exploits the precise tracking from the MDTs:
  - extrapolation to RPC layers takes into account materials and magnetic field
  - precise tracking allows to determine spatial resolution and to study small local effects.

<u>Spatial Resolution</u>

- Considering only η view to exploit MDT tracking precision.

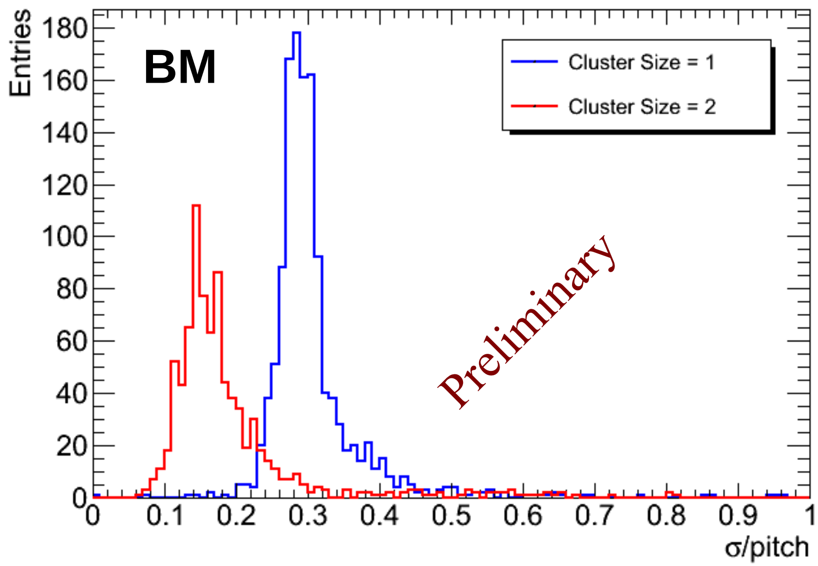
  Separate cluster size = 1, 2, >= 3
- Gaussian fit of residual distribution. Residuals are normalized to strip pitch (~ 30 μm) to ease the comparison between different chambers

<u>Efficiency</u>

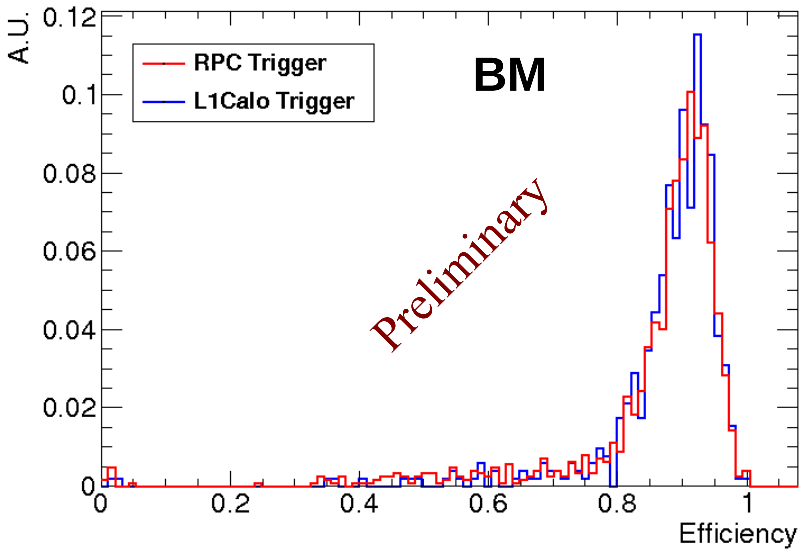
- The presence of an RPC within 70 μm around the track extrapolated point on the RPC plane

Thanks to
Andrea Di Simone
&Giordano Cattani

RPCs Calibration Stream Analysis: Results with Cosmic Rays



- Only BM chambers are selected
- Spatial resolution for cluster with size 2 is better as expected due to the small region traversed by muons



- Only BM chambers are selected
- Data were taken with chambers operating at Working Point parameter values (HV = 9.6 kV, V_{th} = 1.0 V)

- Results shown here are obtained using *full stream.* The same analysis could be performed without any changes on the *calibration stream.*

Thanks to
Andrea Di Simone
&Giordano Cattani

RPCs Calibration Stream Analysis @NA Tier-2

- Calibration analysis is splitted in two separate steps

  1) Creation of dedicated RPC calibration ntuples
     - Time consuming
     - Requires running reconstruction on raw data (or running on already produced ESDs)

  2) Processing of the ntuples to obtain calibration results
     - Relatively fast, but still ~4h per 10 million events

- In order to gain time, both steps need to be parallelized

- Main tool for remote usage (i.e. @NA) is ganga

  1) Ntuple production via "normal" athena job

  2) Calibration results obtained through ROOT macro
     - Output is text file in a custom format with a summary of all relevant information
     - Written to a dataset as well

Thanks to
Andrea Di Simone
&Giordano Cattani

RPCs Calibration Stream Analysis : L1 calibration

RPC/ L1 timing calibration and the corresponding DQ will be runned on Naples Tier2:

- Up to ntuple production, time calibration and RPC efficiency & resolution calculation (described in previous slides) will share the same infrastructure.
- L1 timing will then be computed separately starting from different variables in the ntuples (raw data).

Work done:

1. validation of the stream data content
2. insertion of new variables to the ntuples
3. validation of the code.

Thanks to
Guido Ciapetti

Offline RPC Monitoring and DQA at Tier0

Thanks to
The Lecce Group

Processing data @Tier0 to produce characterization constants and DQA histograms and flags.

Monitoring algorithms:

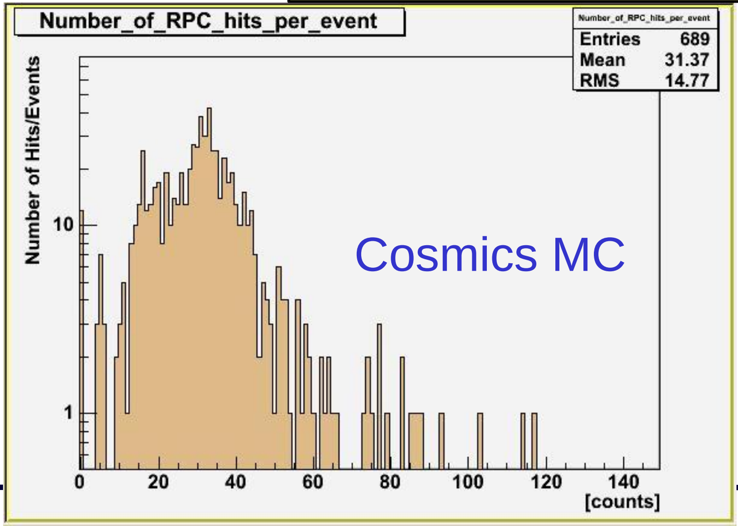
- **RPCLV1**: LV1 readout channel monitoring and DQA
- **RPC**: RPC readout strip monitoring and DQA
- **MDTvsRPC** MDT tubes vs RPC eta strip

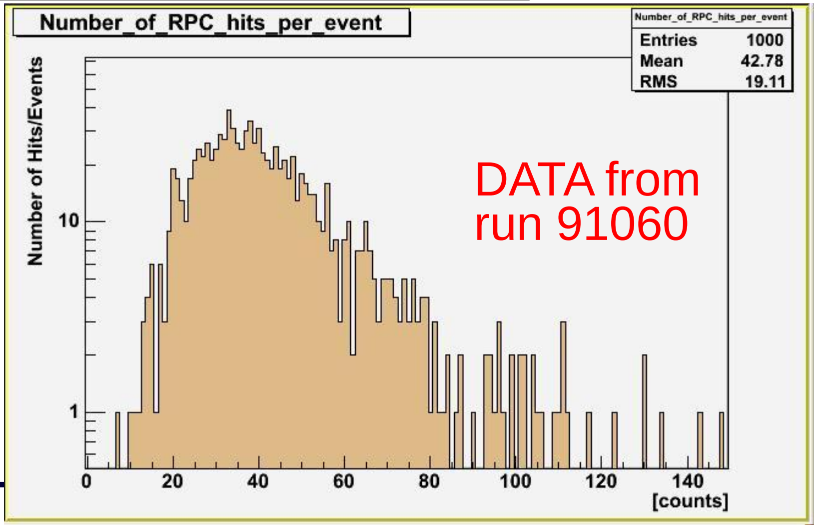
At Tier-0 histograms are produced for every data-block and then merged.
An algorithm post-process the histos to produce:

- quantities for panels: Efficiency, Gap Efficiency, Occupancy, Noise, Cluster size, Residuals and time.
- Quantities for strips: Profile of single strip (↔ noise and dead strips)

There are plans to run Monitoring and DQA also on the Calibration Stream on Naples Tier2

Validation with commissioning data and MC





Offline RPC Monitoring and DQA at Tier0

Thanks to
The Lecce Group

DQA histograms and flags

Plots for offline shifter: barrel C / A and Global

run_94462: Monitoring and Automatic Checks

From file:
94462_han.root

- Overall Status: Green
  - RPC: Green
    - GLOBAL: Green
    - RPCBA: Green
      - TotalNumber_of_RPC_hits_per_events_BA: Green
      - rpc2DEtaStationTriggerHits_BA: Green
      - rpc2DEtaStationTriggerHits_BA_Evol: Green
      - rpctime_BA: Green
    - RPCBC: Green
      - TotalNumber_of_RPC_hits_per_events_BC: Green
      - rpc2DEtaStationTriggerHits_BC: Green
      - rpc2DEtaStationTriggerHits_BC_Evol: Green
      - rpctime_BC: Green

Select run with enough statistic

Check RPC coverage

Check RPC stability during the run

Check RPC time alignment

Flag results are directly stored at tier0 in flag DB

Characterization constants

Two Folders to allocate the characterizarion results:

Table for detector studies:

- contains full information (from Tier0 and Calib stream)
- it is a private db replica accessible from lxplus (too big to be copied daily)

Table for reconstruction and simulation studies:

- Contains: efficiency, resolution, Noise, Cluster Size and relative errors (only for panel); List of Dead Strips
- Automatic writing to Cool DB under development.

Muon Momentum Calibration with Z $\rightarrow \mu\mu$

[Frascati, Roma 3]

Muon Momentum Calibration with Z → μμ

Two-steps procedure:

1) Data correction:
Correction of the measured muon momenta using the Z peak constraint.
This requires a reasonable statistics and probably could not be used with first data.

2) Momentum Scale Determination:
Determine, through a minimization procedure, how the muon momentum in MC samples has to be affected (deteriorated) in order to match the (corrected) data samples.
Also in the case the data correction in step 1 is done, it is used to account for residual effects.

2 INDEPENDENT samples used so far:

1. 'MC' sample (simulated Z events from MC08 production). Standard events without misalignments.

2. 'data' sample: events with known misalignments in the Muon Spectrometer.

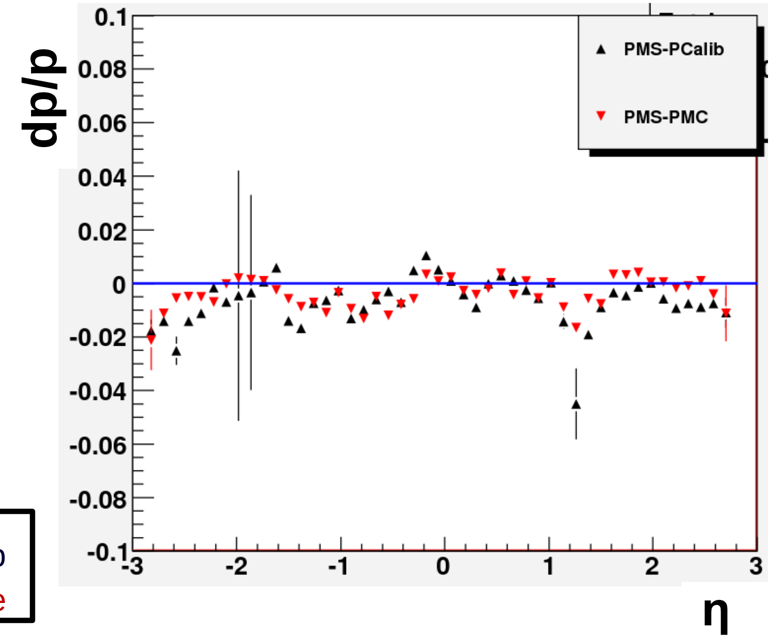
Data correction

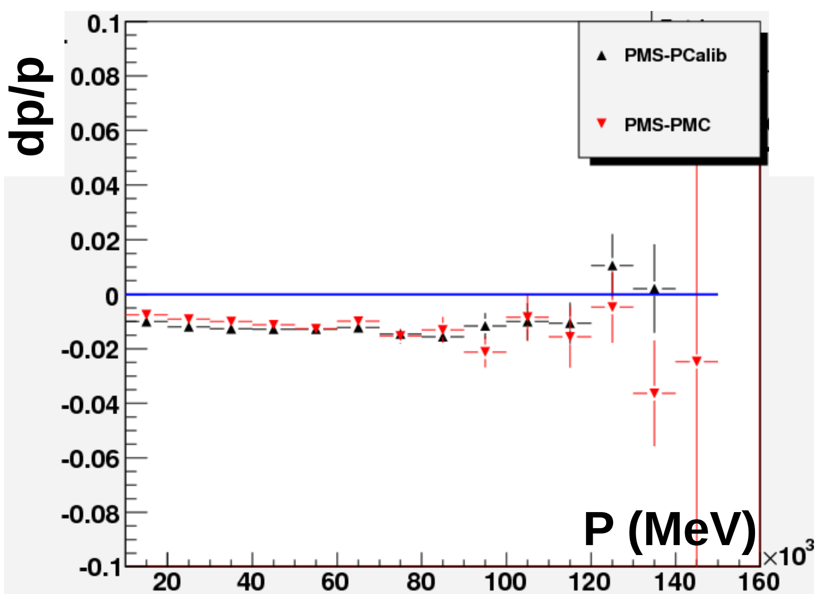
Thanks to Marianna Testa

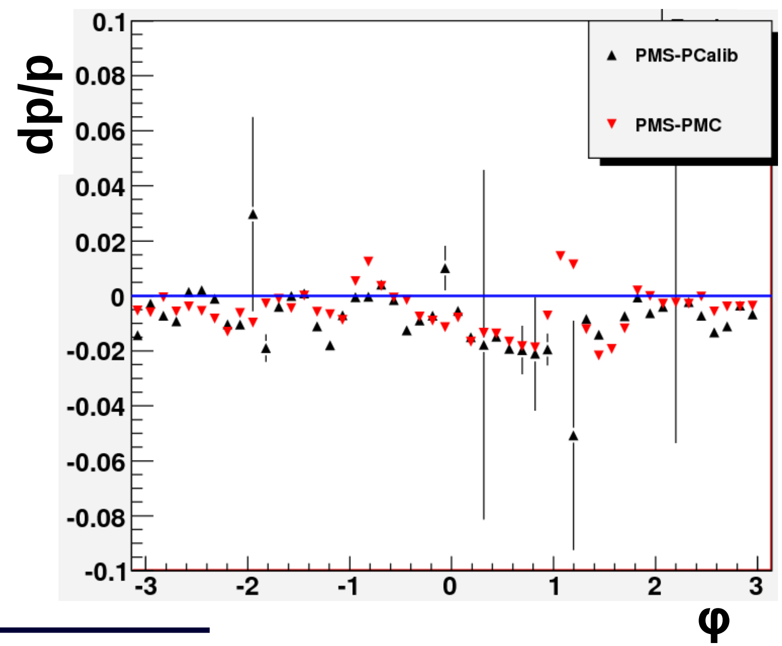
The calibrated momentum is obtained using the Z mass constraint.
The spectrometer is divided into towers and for each tower a correction is computed.

Here the momentum miscalibration (as obtained for standalone muons) is shown as a function of several variables.
200k events were used.

$p_{meas} - p_{calib}$
$p_{meas} - p_{true}$







Momentum Scale

Correct the MC muon momentum as follows:

$$p_{corr} = p \cdot (r_{\alpha,\beta} + \delta_\alpha)$$

r: momentum scale
δ: rnd number extracted with mean 0 and sigma= σ_α additional smearing ($\sigma_{pcorr}{}^2=\sigma_p{}^2+\sigma_\alpha{}^2$)
α: barrel/endcap ; **β**: mu+/mu-

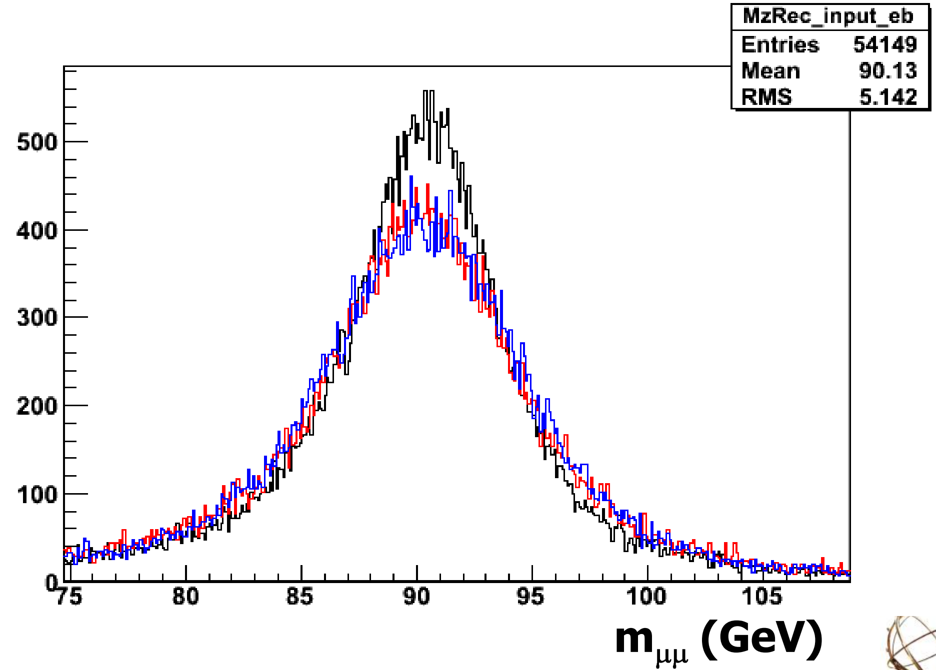
- the 'MC' Z lineshape is computed using p_{corr} ;

- **r,δ** are determined fitting the obtained 'MC' Z lineshape distribution to 'Data' Z lineshape ;

Black: MC sample (before the fit)
Red: data sample (misal 500 mm)
Blue: MC sample (after the correction)

Start sample: 250k events
Event selection:

- two muons with opposite charge
- p_t> 20 GeV and $|\eta|$<2.5

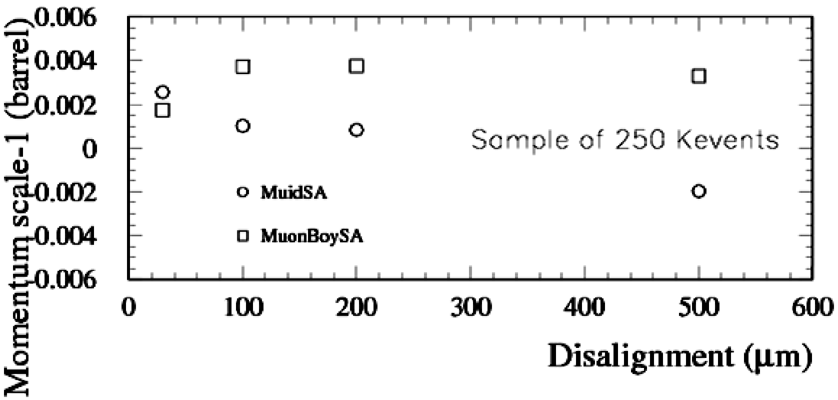


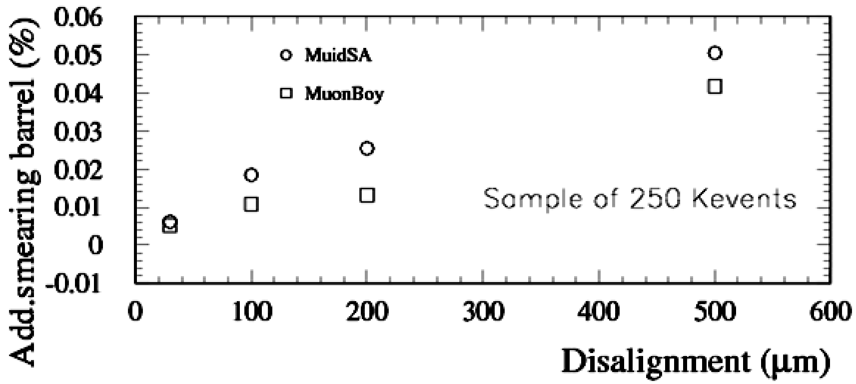
Momentum Scale

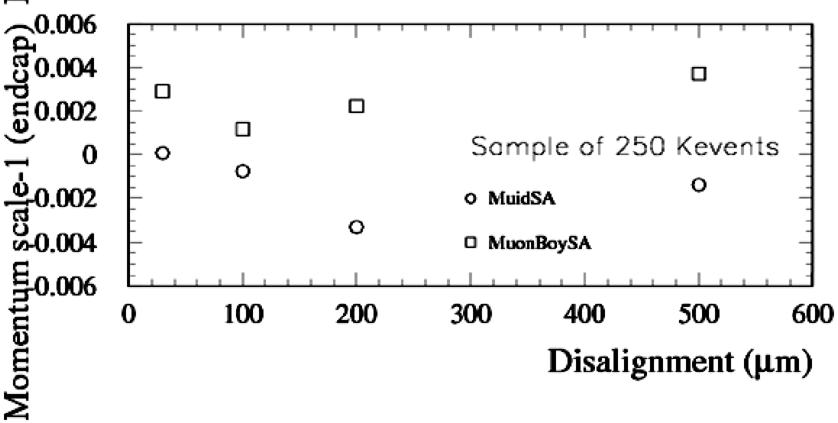
Momentum scale and additional smearing as a function of the sample misalignment.

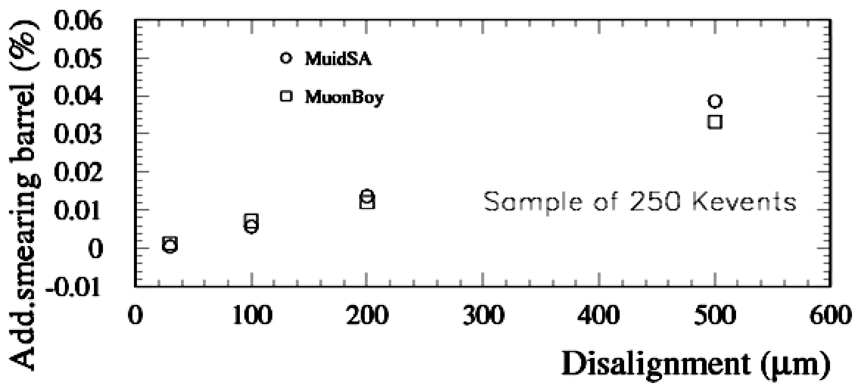
- 250k events used.
- StandAlone variables (Muid & MuonBoy).

An additional smearing increasing with the misalignment is observed (as expected). MuonBoy gives a lower add.smearing and an higher scale wrt MuidSA (systematics to be carefully investigated).







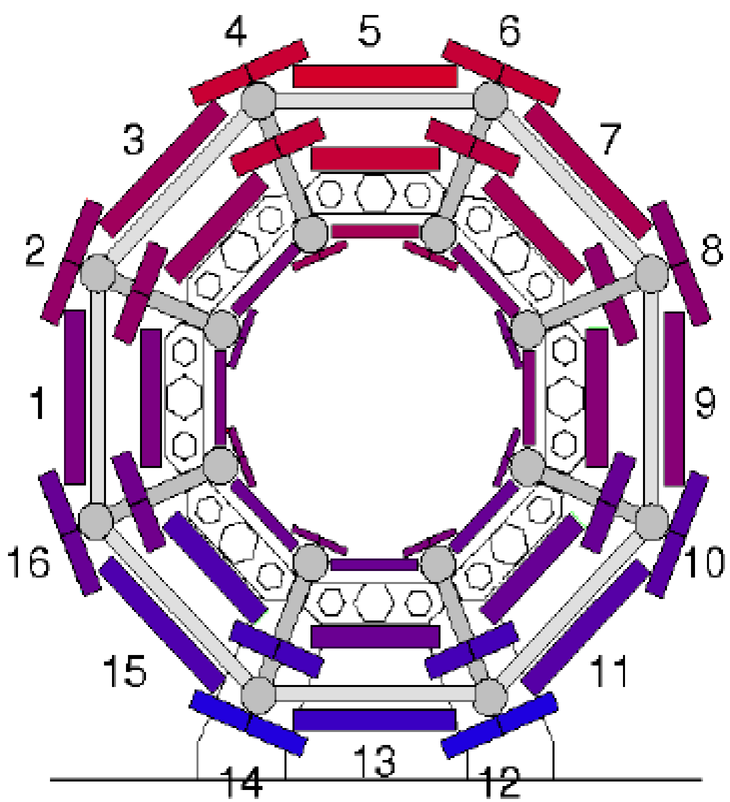


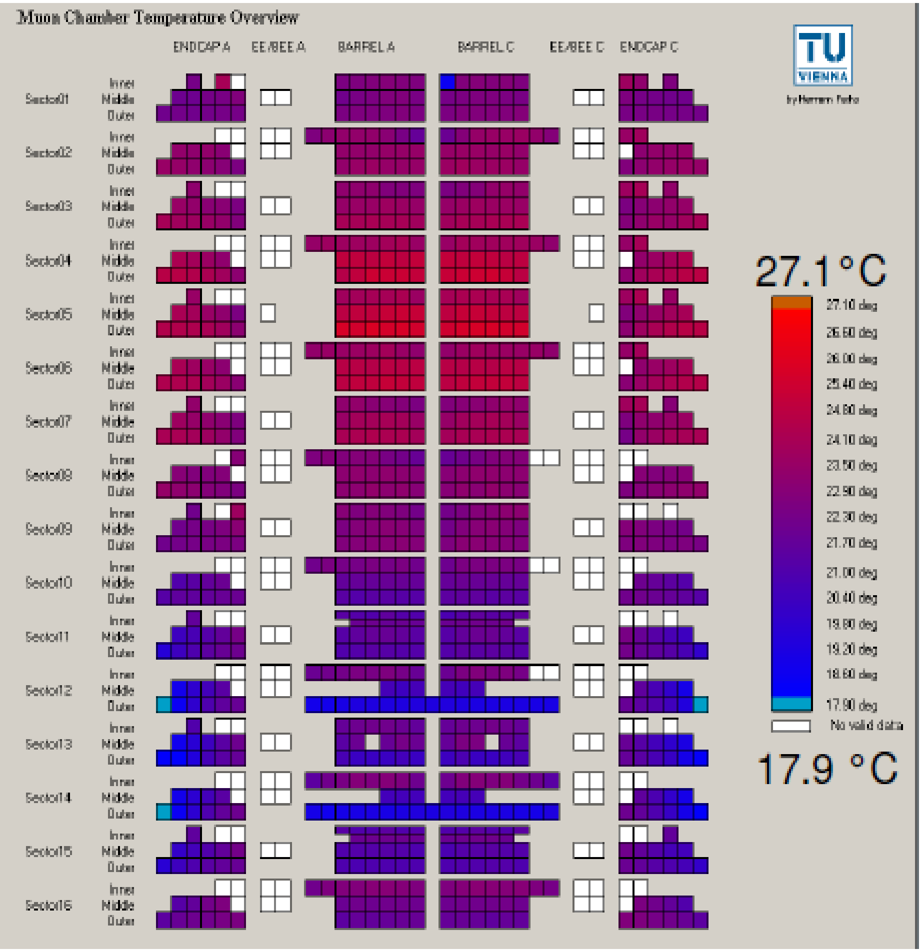
Outlook - Muon momentum calibration

- Improve towers definition in the method for data correction.
- Study the method as a function of the statistics and of the misalignments.
- Optimize the parametrization of the momentum scale correction and improve the algorithm.
- Migrate the code from the present ROOT macro into an athena tool to be used into EWPA and benchmark analysis.
- Add new effects in the ‘data’ sample other than chamber misalignment (i.e. errors in the magnetic filed)
- Start to introduce background samples.

BACKUP SLIDES

MDT calibration concept, impact of temperature gradients





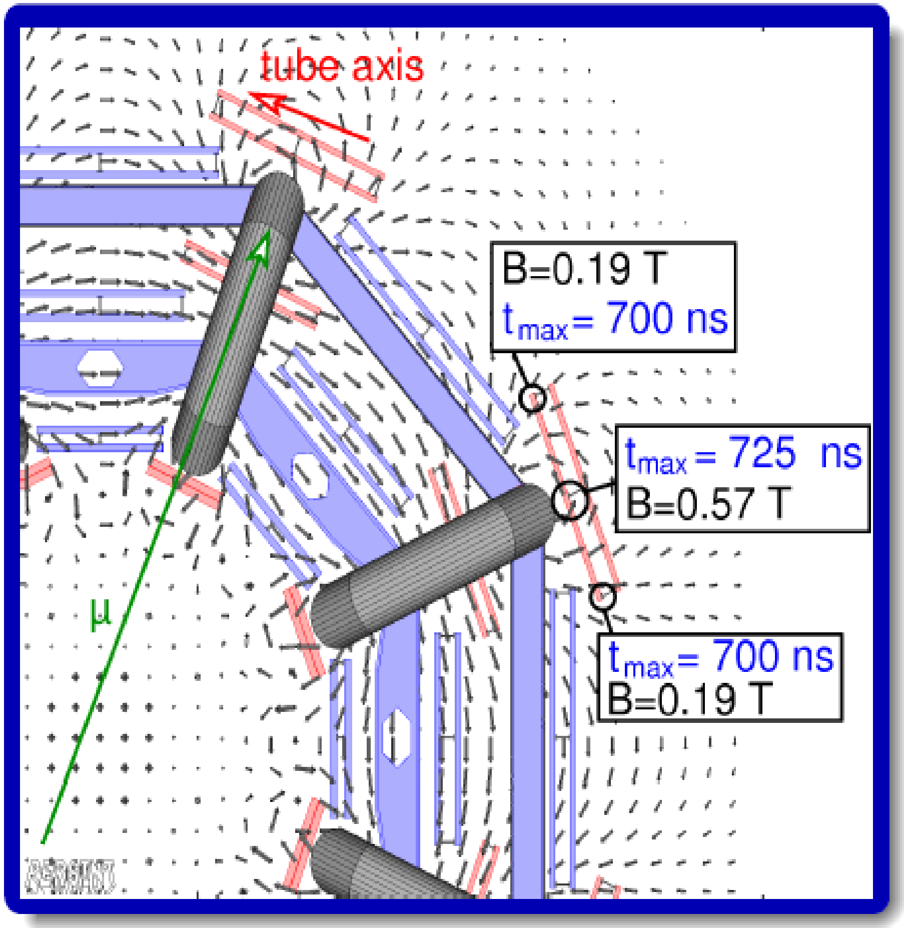
Temperature variations with time ~ 0.2 K.

Temperature difference between bottom and top: ~8 K.

$\Rightarrow \Delta t_{max} \sim 20$ ns $\hat{=}\ \delta r_{max} \sim 0.4$ mm.

$\Rightarrow$ **Calibration per chamber to avoid large temperature corrections!**

MDT calibration concept, non-uniform magnetic field



Average magnetic field: 0.4 T.

In chambers on the toroid coils:

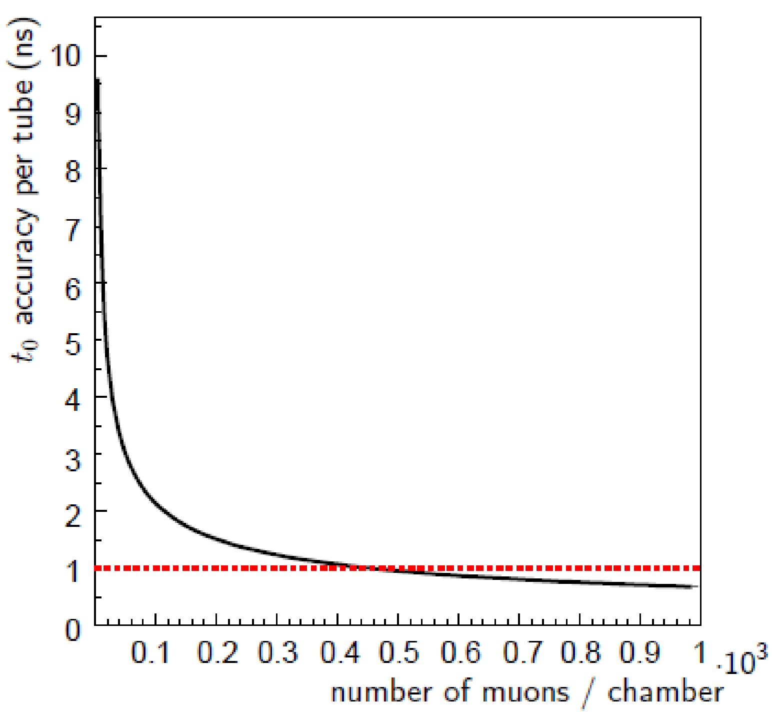
- Large gradients of the magnetic field along a tube.

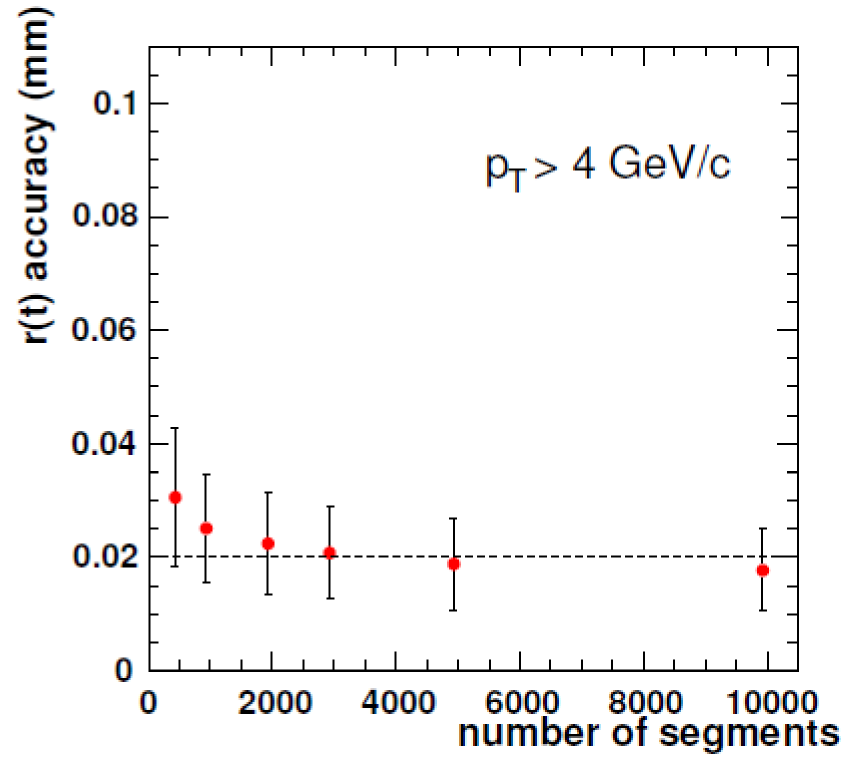
⇒ Large variations of the maximum drift time t_{max} along a tube: $\Delta t_{max} \approx \frac{70\ \mathrm{ns}}{T} B^2$

Correction for the Lorenz angle effect within a chamber required!

⇒ **Basic calibration concept:** Calibration per chamber including Lorentz angle and wire-sag corrections!

MDT calibration: required statistics



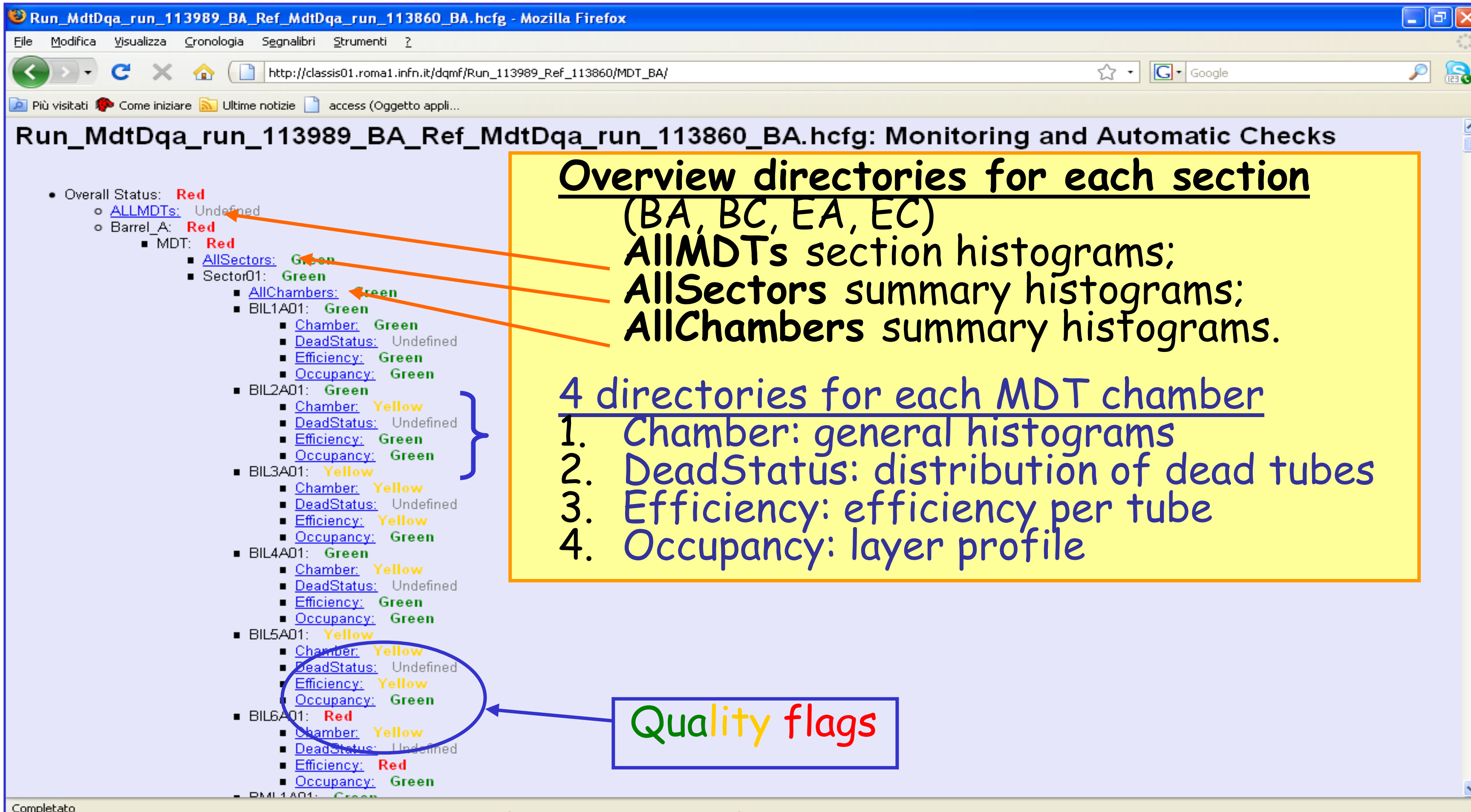


- >0.5 M tracks per chamber needed to achieve required t0 accuracy per tube.
- Initial muon rate in pp collision not sufficient.
- Could rely on relative t0 determined with commissioning data (good RPC timing required).

- Required *r-t* accuracy achieved with ~5000 tracks per chamber.
- t0 accuracy limiting the achivable *r-t* accuracy in early pp data..

WEB display

http://classis01.roma1.infn.it/dqmf/



The quality flags are "propagated" from the chamber folders up to the main one (according to the logic defined later).

Samples used

Signal sample (no misalignment):

mc08.106051.PythiaZmumu_1Lepton.recon.AOD.e347_s462_r541_tid028727

Misaligned signal samples:

•4 datasets produced for 4 different Muon Spectrometer misalignments, with respectively 30, 100, 200, 500 μm translations and 15, 50, 100, 250 μrad rotations of MDT chambers

•Datasets available on the grid (~250k events each).

user09.FulvioGaleazzi.PythiaZmumu_1Lepton.mc08.106051_misal.recon.AOD.e347_s462_r541_tid028727_misal_30u
user09.FulvioGaleazzi.PythiaZmumu_1Lepton.mc08.106051_misal.recon.AOD.e347_s462_r541_tid028727_misal_100u
user09.FulvioGaleazzi.PythiaZmumu_1Lepton.mc08.106051_misal.recon.AOD.e347_s462_r541_tid028727_misal_200u
user09.FulvioGaleazzi.PythiaZmumu_1Lepton.mc08.106051_misal.recon.AOD.e347_s462_r541_tid028727_misal_500u

• Produced with RecExCommon (release 14.5.0) on the Roma Tre Tier3, starting from a local copy of centrally produced RDO (Muon Spectrometer geometry tags provided by the Saclay group)

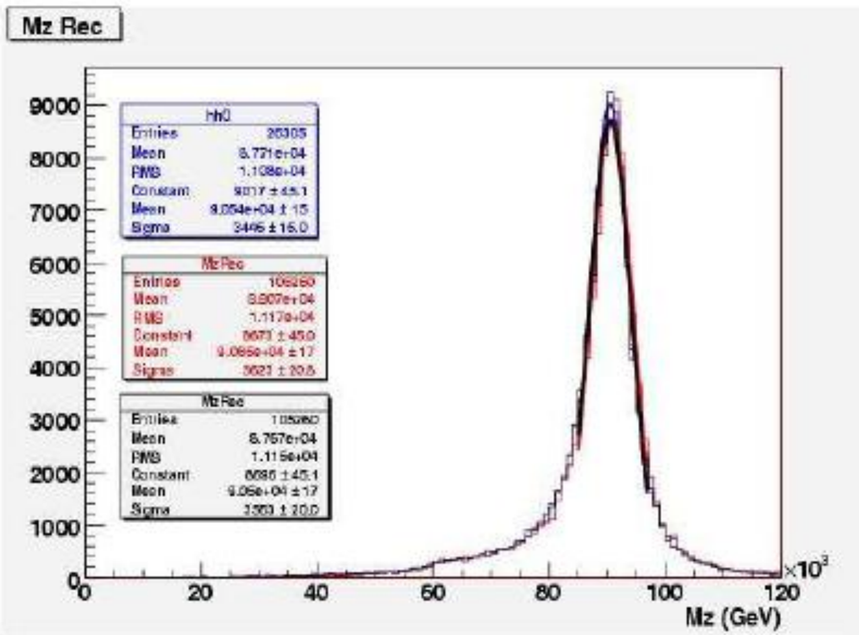
• D3PD produced with EWPA

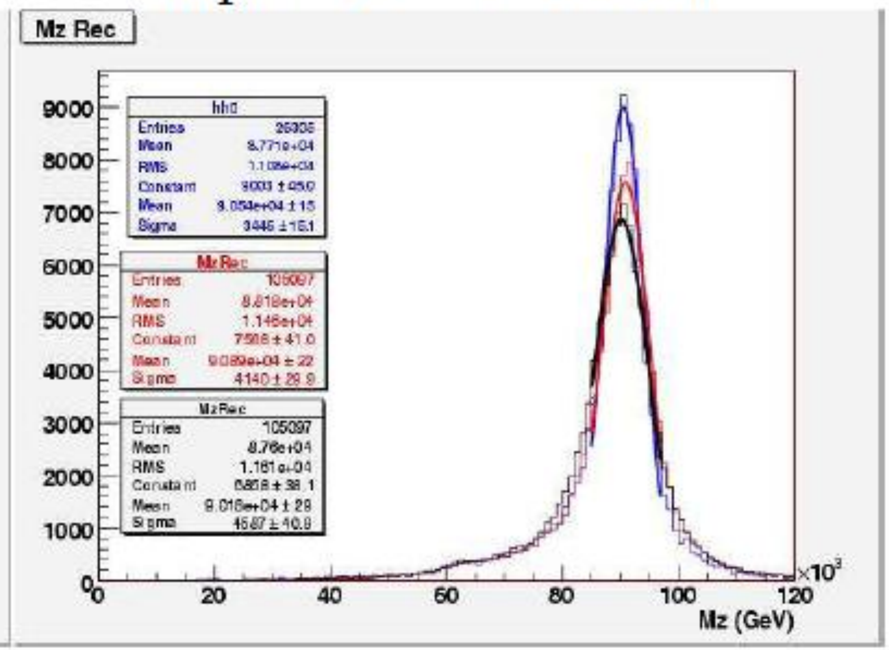
•Analysis is presently done in ROOT on D3PDs, we will soon migrate the code into an athena tool

Campone allineato:
$\sigma \sim 3.5$ GeV

30 u:
σ prima $\sim \sigma$ dopo $\sim$ 3.6 GeV

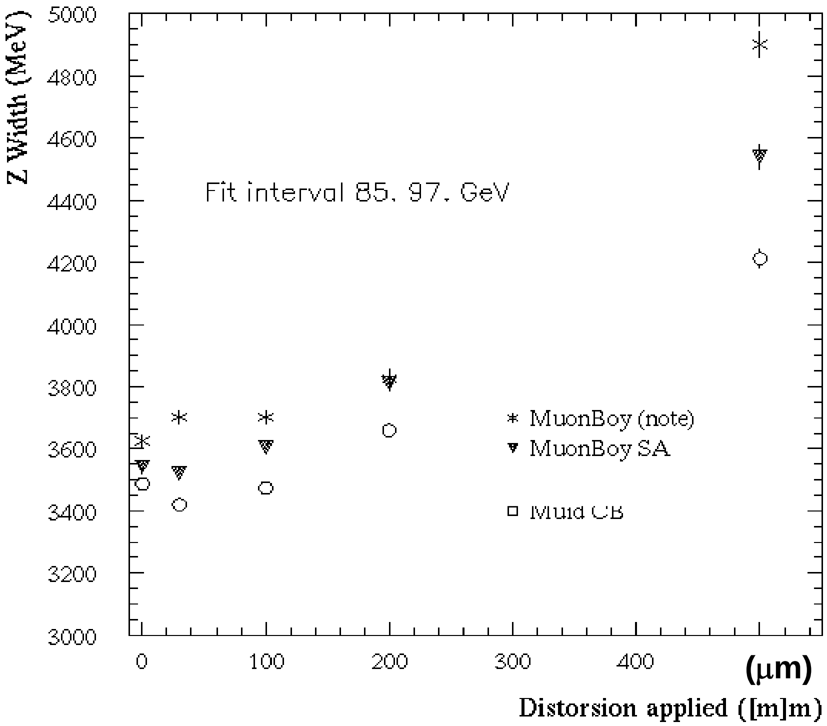
500 u:
prima $\sigma \sim 4.6$ GeV
dopo $\sigma \sim 4.1$ GeV

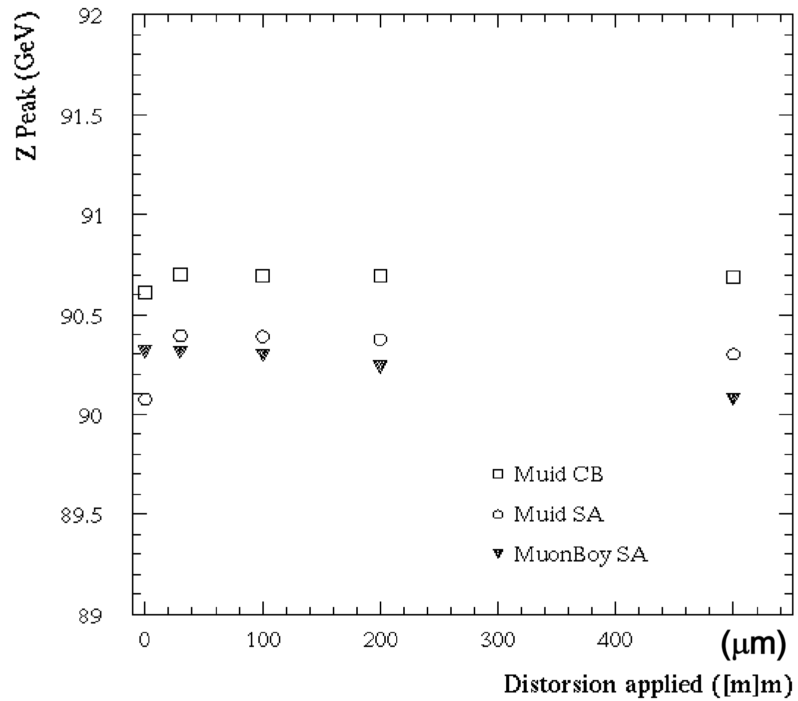




Z mass from datasets with misalignments

In the left plot we show a comparison with similar results obtained last year by the Saclay group with the CSC samples (ATL-PHYS-COM-2008-053):





Different dataset used by the Saclay group:
misal1_csc11.005145.PythiaZmumu.digit.RDO.v12003103_tid003850
The observed discrepancy is mainly due to differences in the MC samples

Status of MC production for background samples

Most of the background samples that we asked in January have been produced but we still miss the following samples (fast simulation):

bbmu15X (9 M events requested)
ccmu15X (9 M events requested)

For the bbmu15X the complete evgen dataset is available:

mc08.108405.PythiaB_bbmu15X.evgen.EVNT.e388_tid042962

Therefore we have recently agreed, with T. LeCompte and B. Kersevan, to proceed with a private production (atlfast II) on the italian cloud, using the available evgen dataset and all the official production scripts. A small sample of 100 k events is being produced in these days, we will use this sample to validate our private production.

A production test was performed few weeks ago on the Roma Tre Tier3 with release 14.5.1 (1 M events):
Production chain: EVNT-> HITS -> RDO -> AOD
We store HITS, RDO and AOD since we plan to re-run reconstruction with different conditions.

We should clarify a.s.a.p., with the production group, which is the status for the production of the ccmu15X