New Frontiers in Subnuclear Physics
September 12-17 2005, Milano

Test of CMS muon drift tube chambers with cosmic rays

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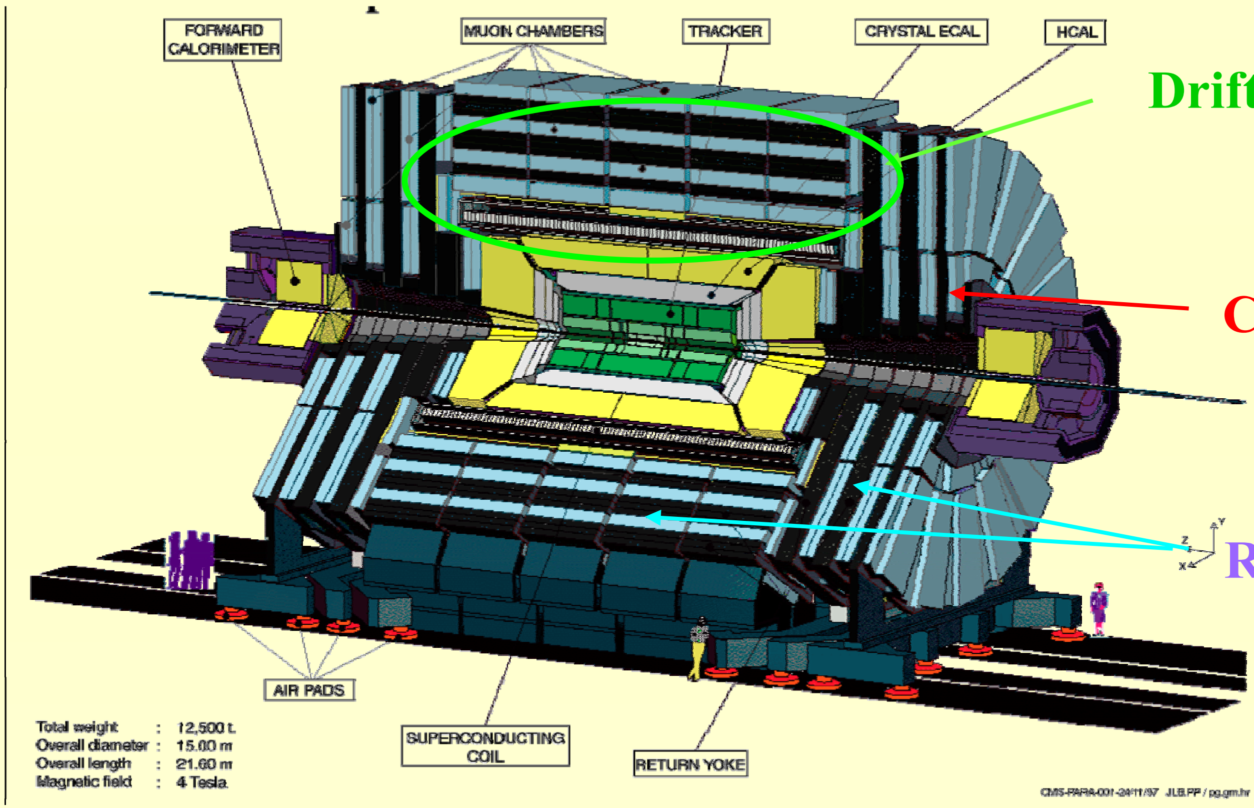
- Layout and properties of the detector;
- Quality control tests at the assembly sites;
- Measurements with cosmic muons and comparison with test beam results.

Muon detectors in CMS

Robustness and redundancy ensured by 3 different muon sub-detectors:



Drift Tube Chambers (DT)

Cathode Strip Chambers (CSC)

Resistive Plate Chambers (RPC)

4 layers of chambers. At least 3 track segments for a μ track.

CMS barrel muon chambers

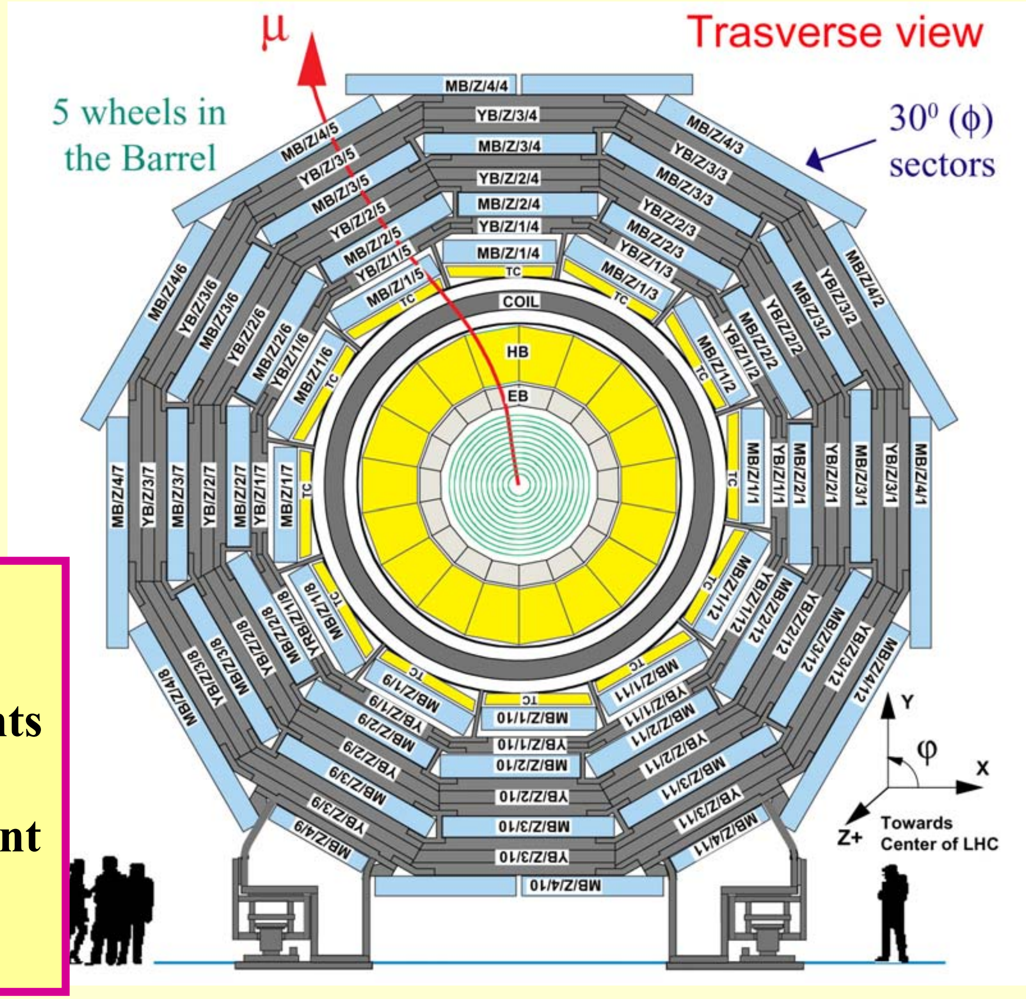
4 concentric shells of wire drift tube chambers

250 DT chambers

$2.0 \times 2.5\ m^2$ (MB1)

$4.0 \times 2.5\ m^2$ (MB4)

$\sim 2 \cdot 10^5$ channels

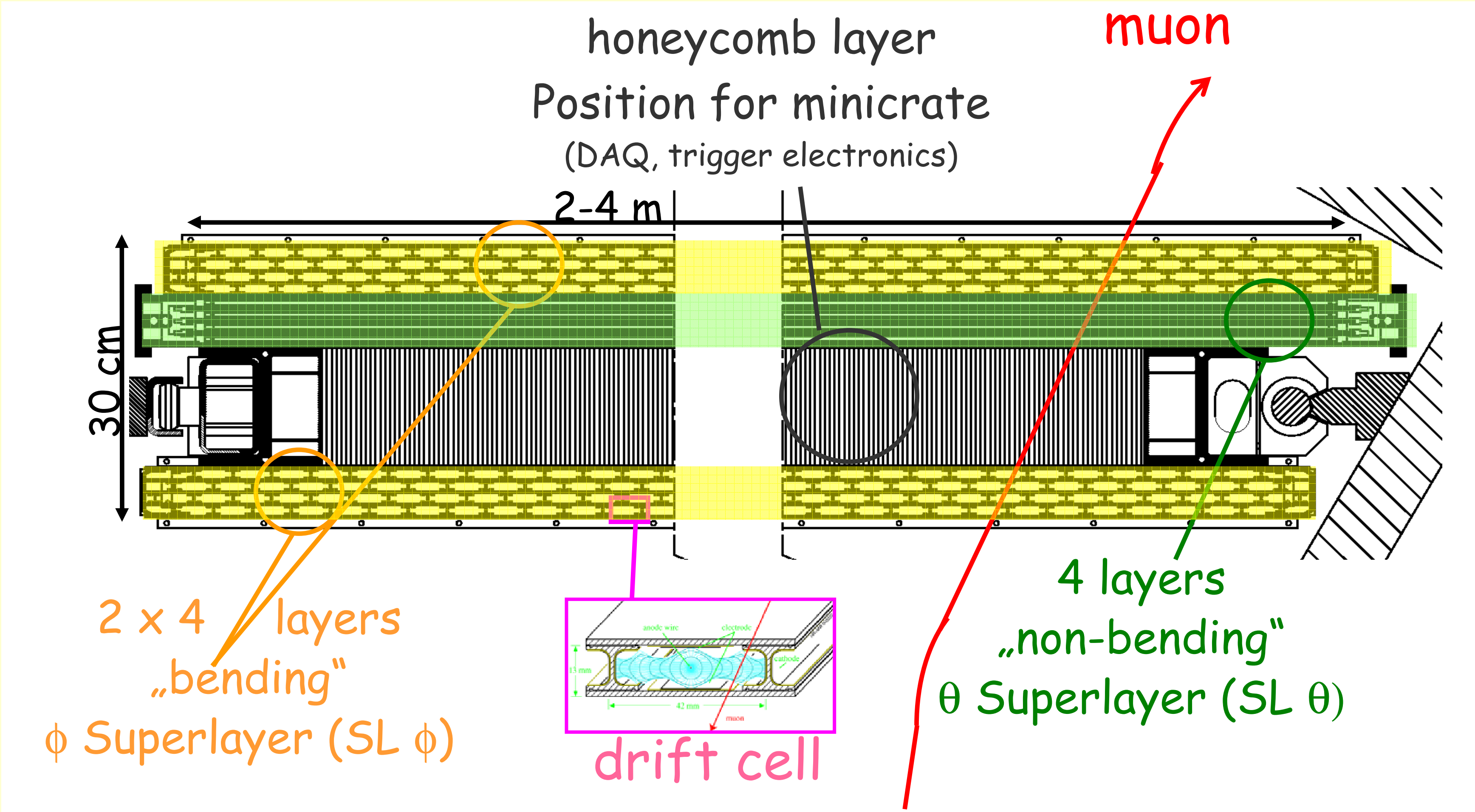


Requirements:

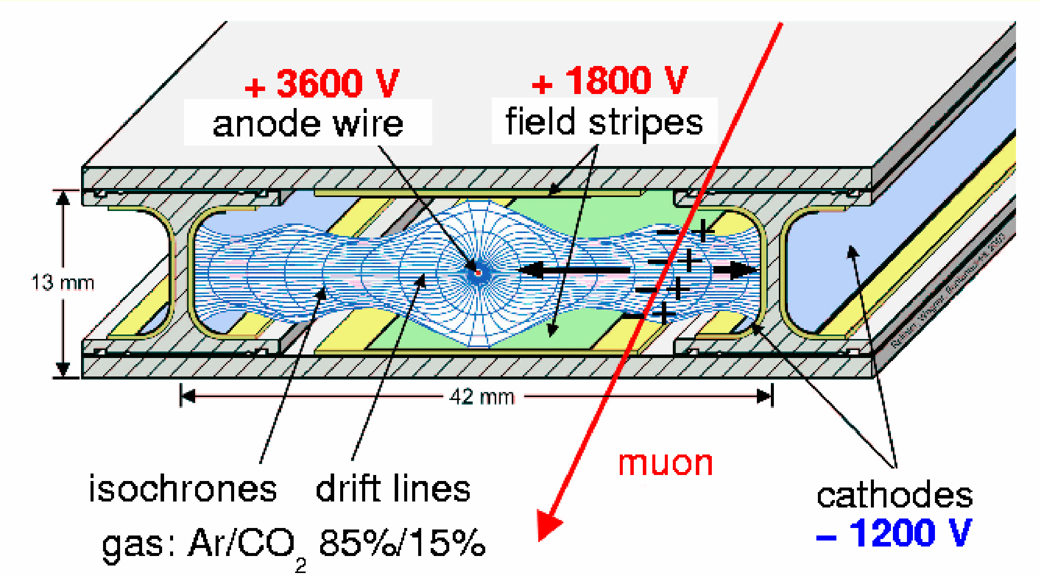
- **Trigger on single and di-muons events**
- **Bunch crossing assignment**
- **Stand-alone momentum measurement with resolution $\Delta p_t/p_t \sim 10\ \%$**
- **Charge assignment up to few TeV**

Chamber structure

Each chamber is made of 3 or 2 (MB4) independent structures (SuperLayers)
Each SL consists of 4 layers of drift tube cells, staggered by half a cell.



Drift Cell structure



Gas mixture:

Ar(85%)+CO_2(15%)

at atmospheric pressure

Gain = 3÷5 10^5

Requirements:

Chamber spatial resolution ~ 100 μm

Single cell spatial resolution ~ 250 μm

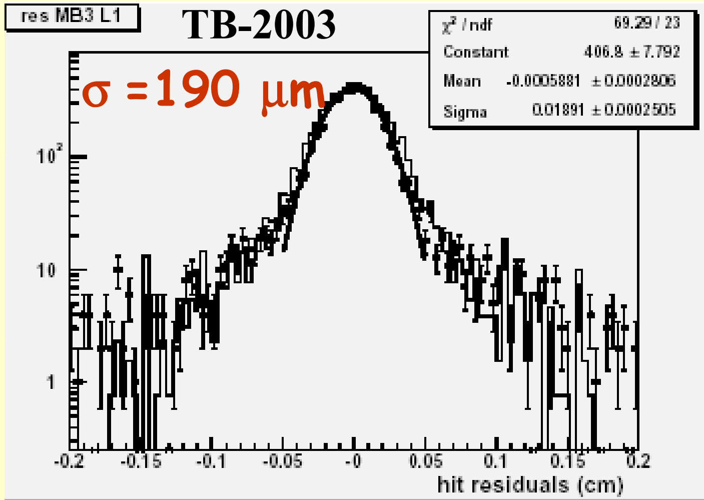
Trigger requirement:

disalignments between layers below few hundreds μm

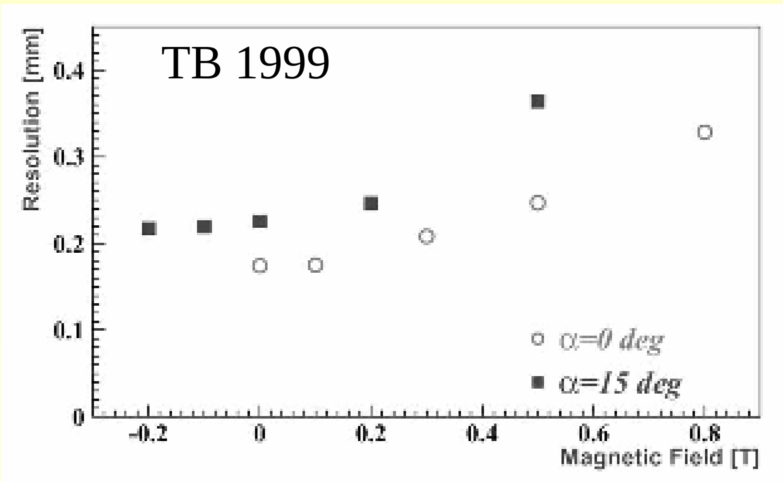
DT chamber performance

Chamber performance from tests on beam

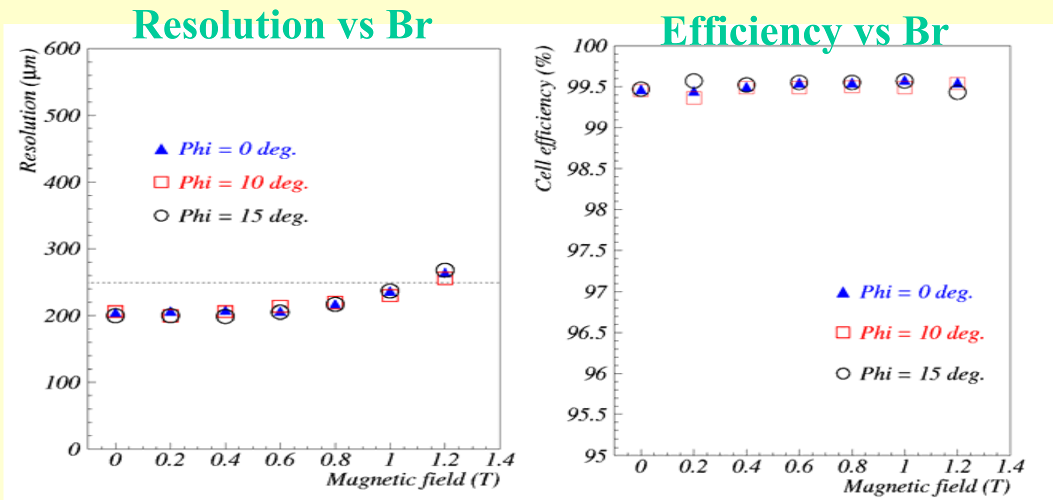
- Single cell resolution < 200 μm
- Cell efficiency > 99 %
- Resolution and efficiency not affected by radiation noise
- Deviations from linearity within 100 μm in most of the drift length



B_z – component along the ϕ wire



B_r – component orthogonal to the chamber

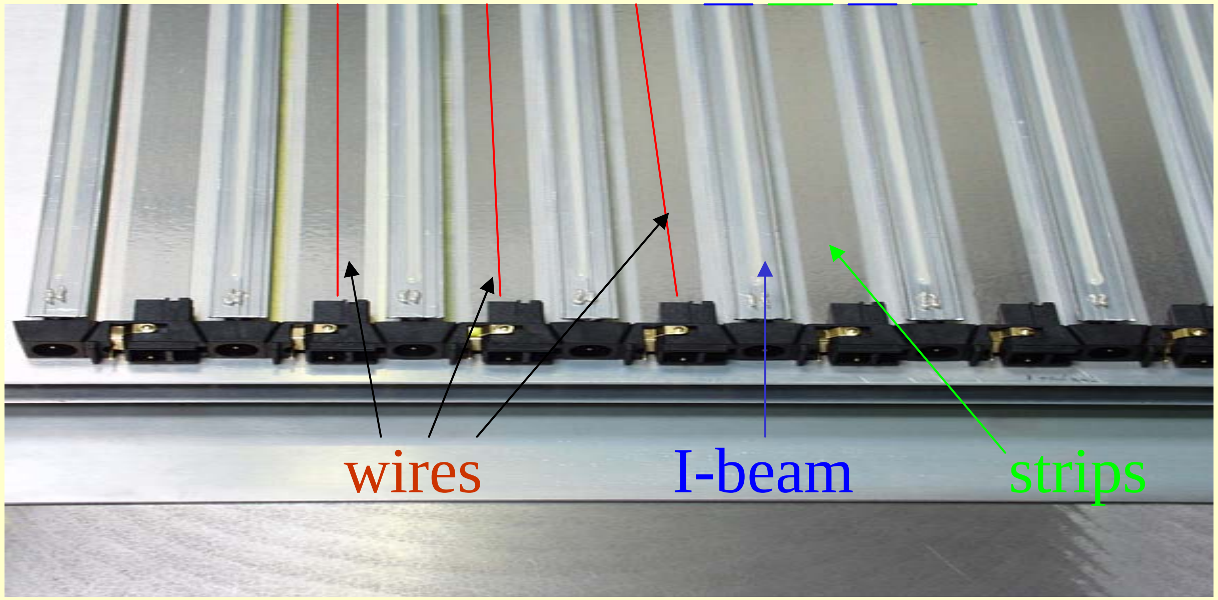


Quality control tests

4 assembly sites:

Aachen	**(MB1) 70+4+1**
Madrid	**(MB2) 70+4+1**
Padova	**(MB3) 70+4+1**
Torino	**(MB4) 40+4**

The chamber production will be completed by April 06



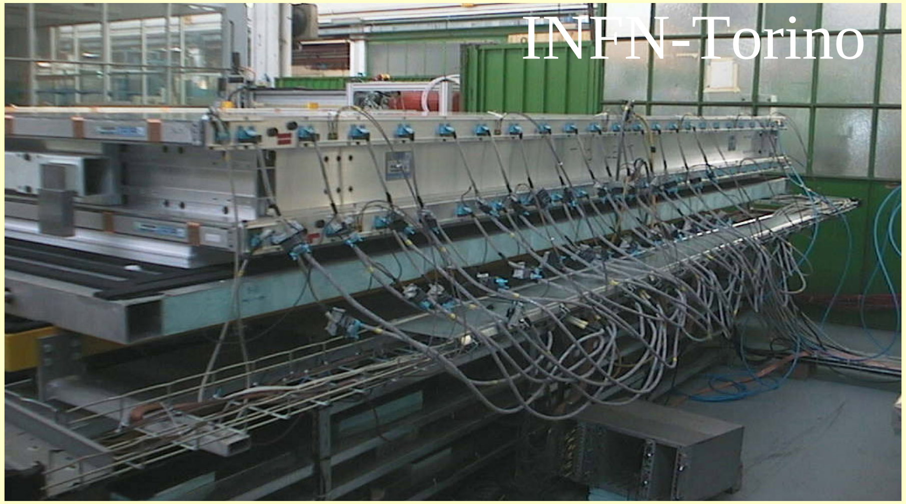
Quality control tests:

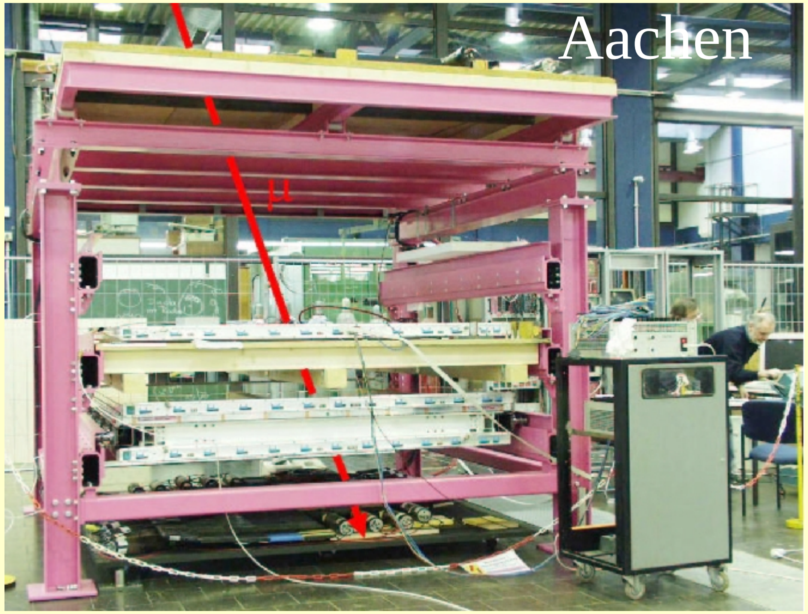
Assembly phase:
- **HV tests of strips and cathods**
- **Measurement of the wire tension**
- **Wire and cathode positions with CCD**

Tests on the assembled SL:
- **Planarity**
- **Gas tightness**
- **HV behaviour**
- **noise**

Tests with cosmics

Measurements with cosmic muons are performed in each production site to certificate the chamber performance.



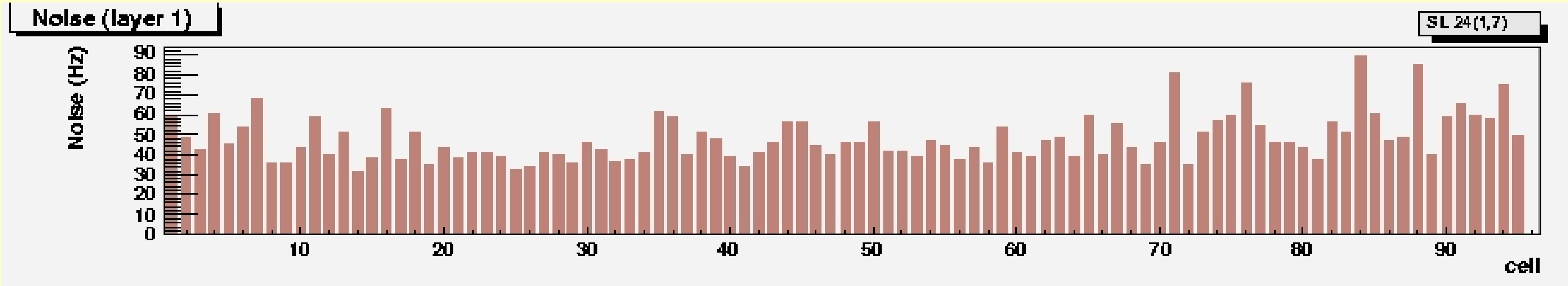


Cosmic-ray events are triggered by an external scintillator system.
Drift times are measured with external TDCs and custom DAQ.
Tipical trigger rates 50÷100 Hz → 10^6 events in few hours.

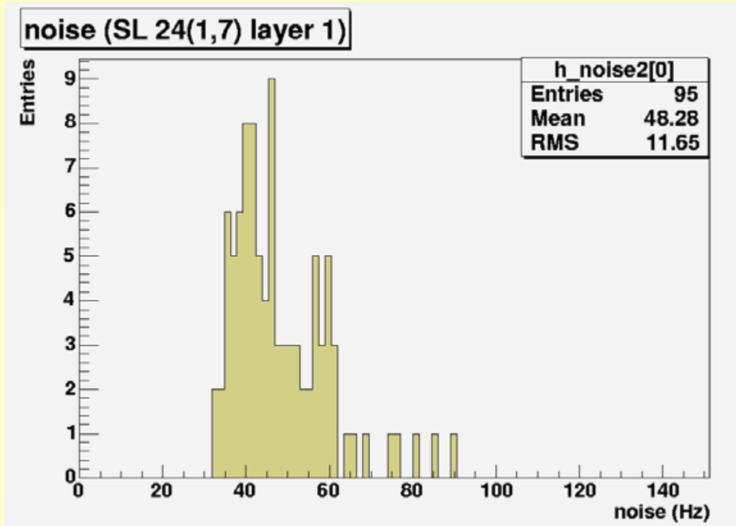
Hit rate

Measured with TDC (random triggers) or scalers.

Typical hit rate distribution in one layer:

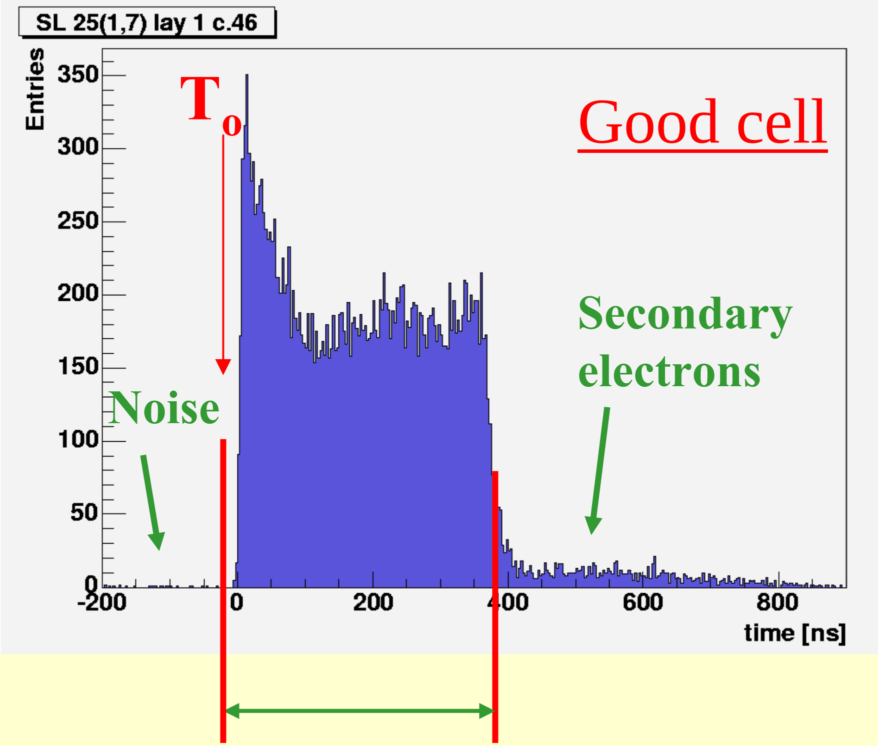


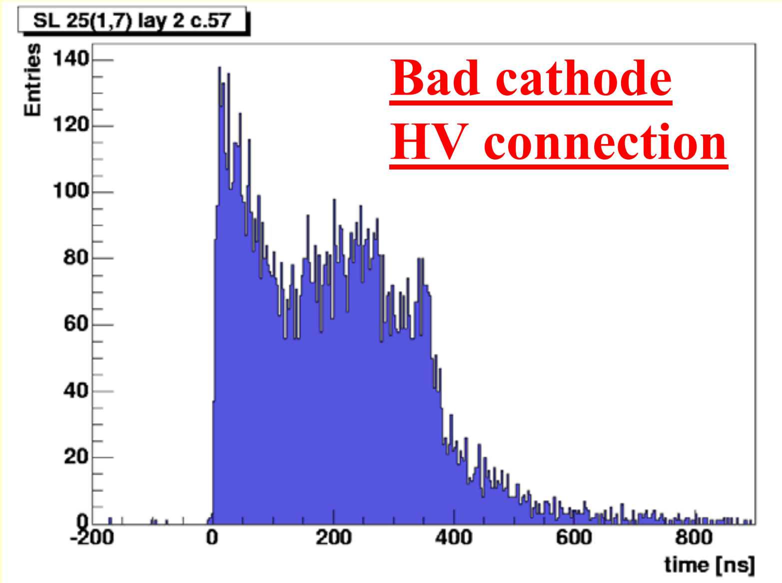
High noise levels in one or more channel could indicate FE problems, wrong HV behaviour, problems in the capacitive coupling, etc.



Drift time distribution

Unconnected cathods can be easily identified from the drift time distribution.

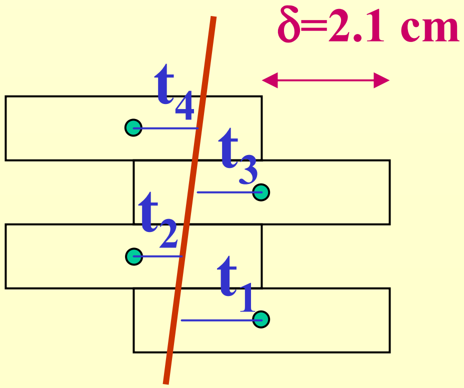




Max.drift time ~ 380 ns → **v_{drift} ~ 55 µm/ns**

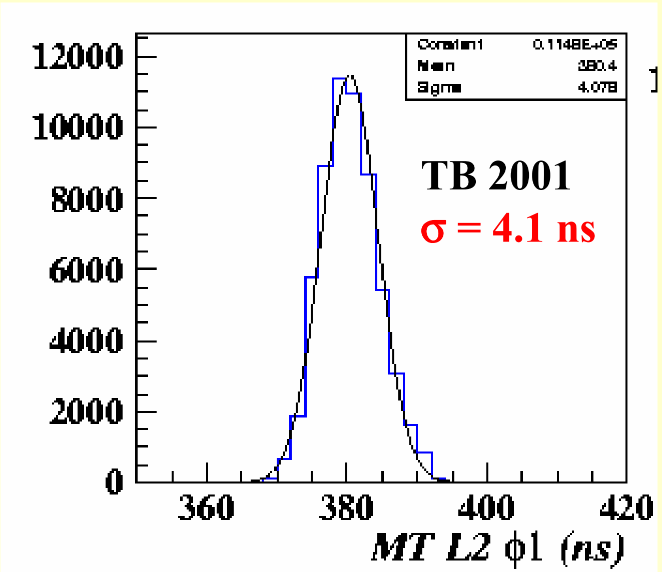
Fraction of disconnected cells (mainly for HV problems): ~ 0,08 %

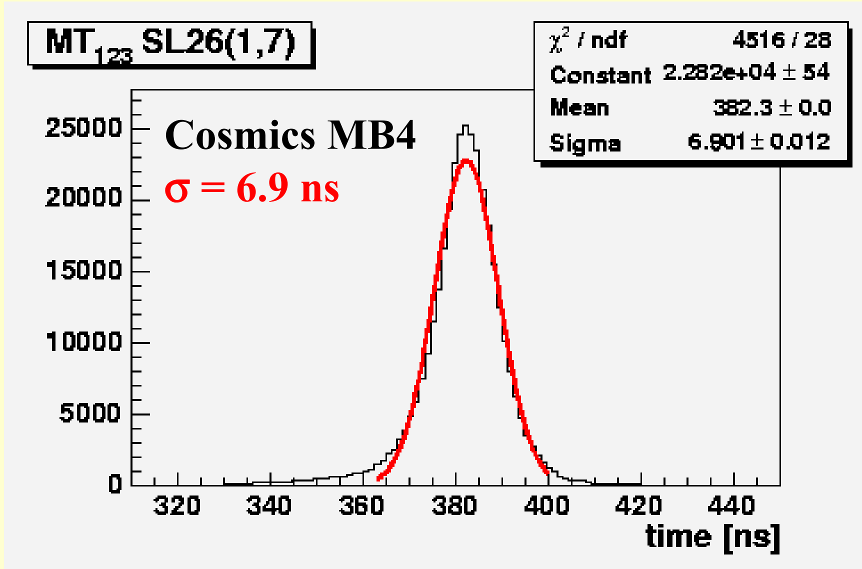
Mean Time



$$MT_{123} = \frac{t_1 + t_3}{2} + t_2 \qquad MT_{234} = \frac{t_2 + t_4}{2} + t_3$$

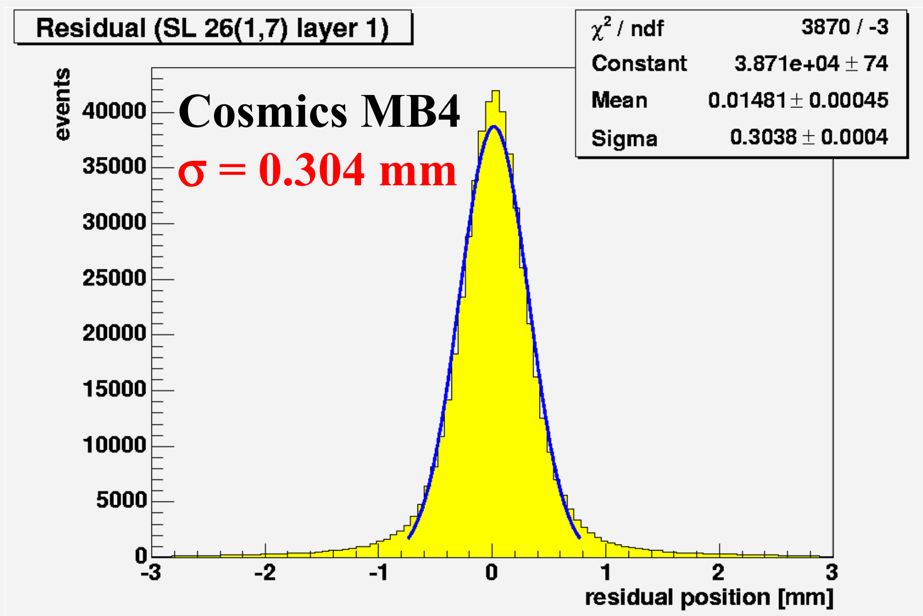
$$MT_{123} = MT_{234} = T_{max} = \frac{\delta}{v_d} \qquad \sigma_{MT} = \sqrt{\frac{3}{2}} \cdot \frac{\sigma_x}{v_d}$$



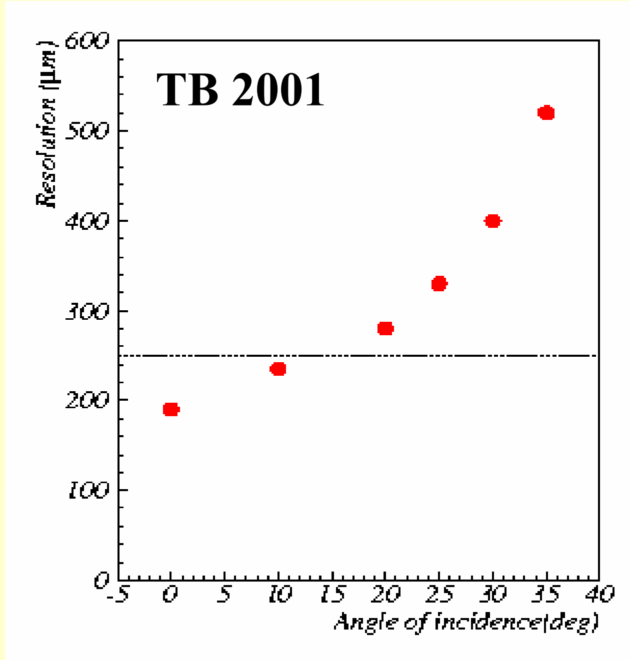


$\sigma_{MT} \sim 7.0$ ns → $\sigma_x \sim 310$ μm

Cell resolution

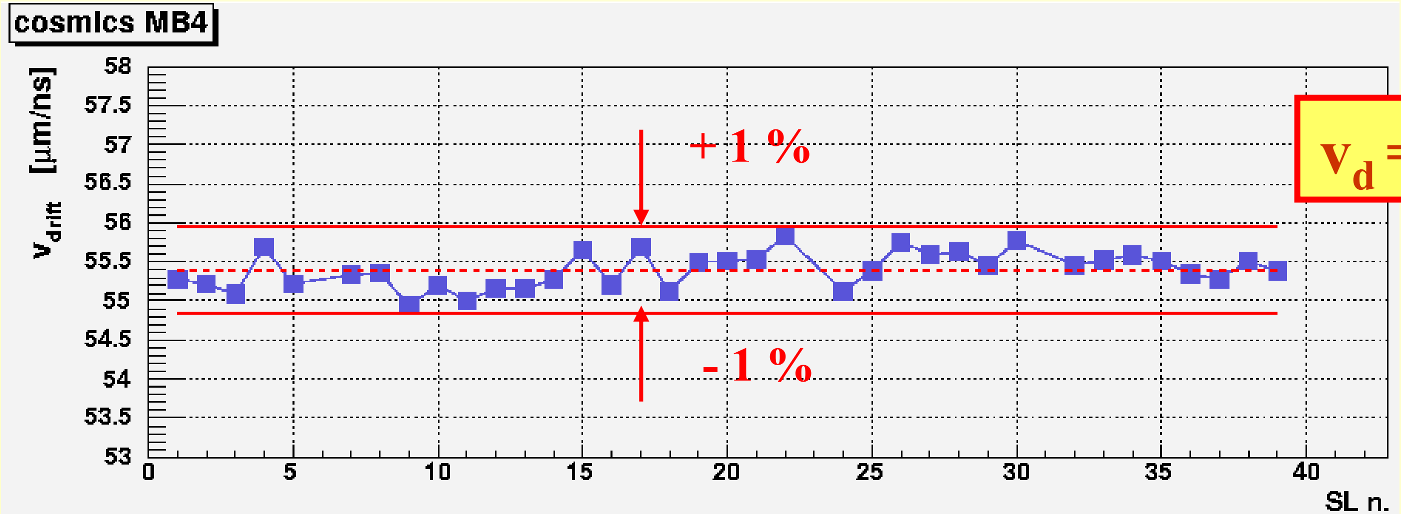


Resolution vs angle of incidence



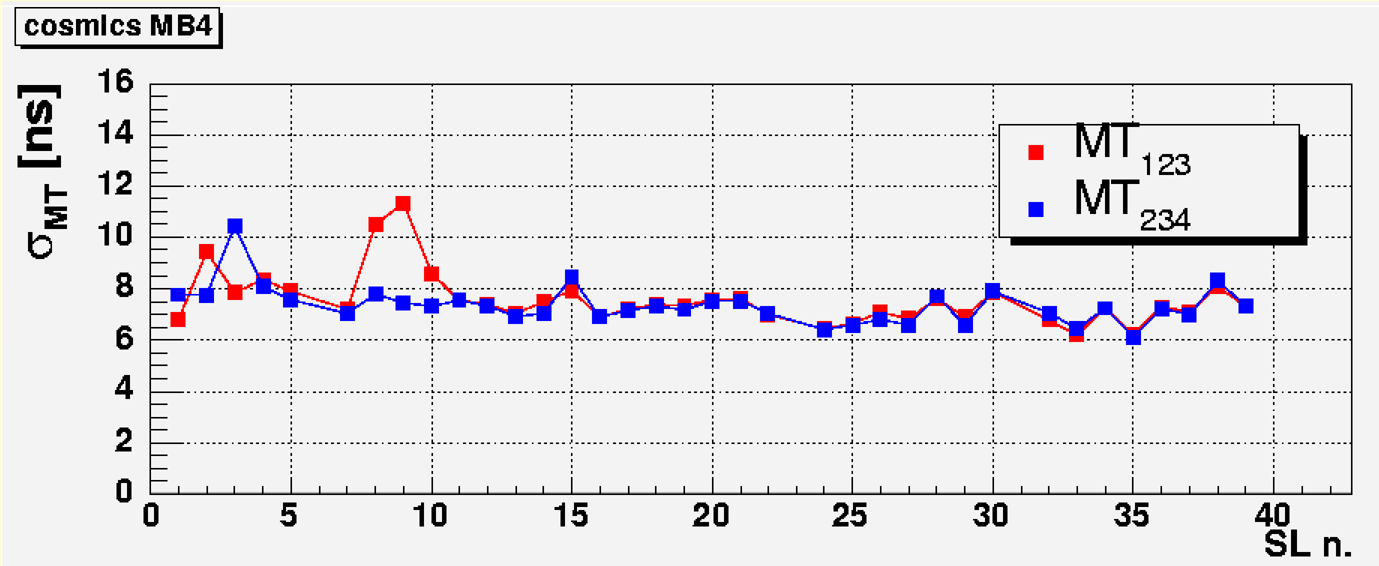
The cell resolution measured with cosmics is higher than that measured from test beam data **(wider angular distributions, multiple scattering from low energy muons, trigger timing resolution)**

Calibration stability



v_d = 55.4 μm/ns

stable within ± 1 %

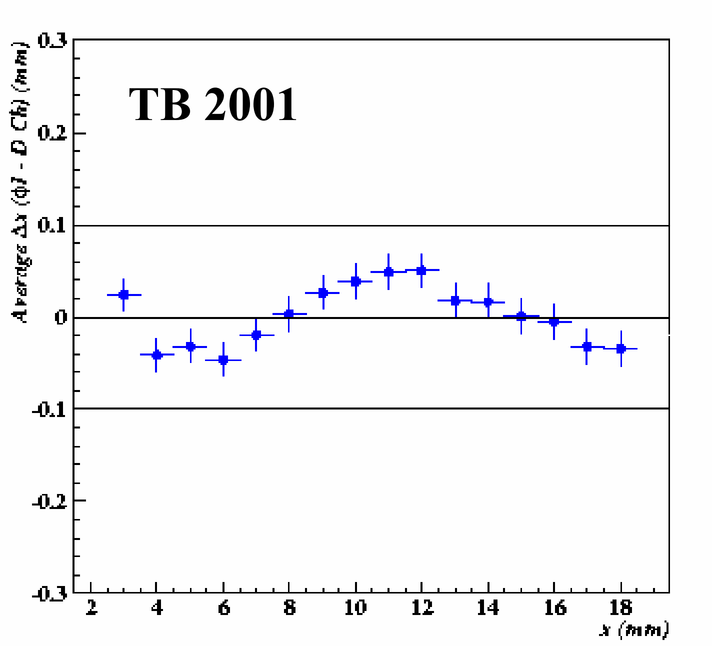


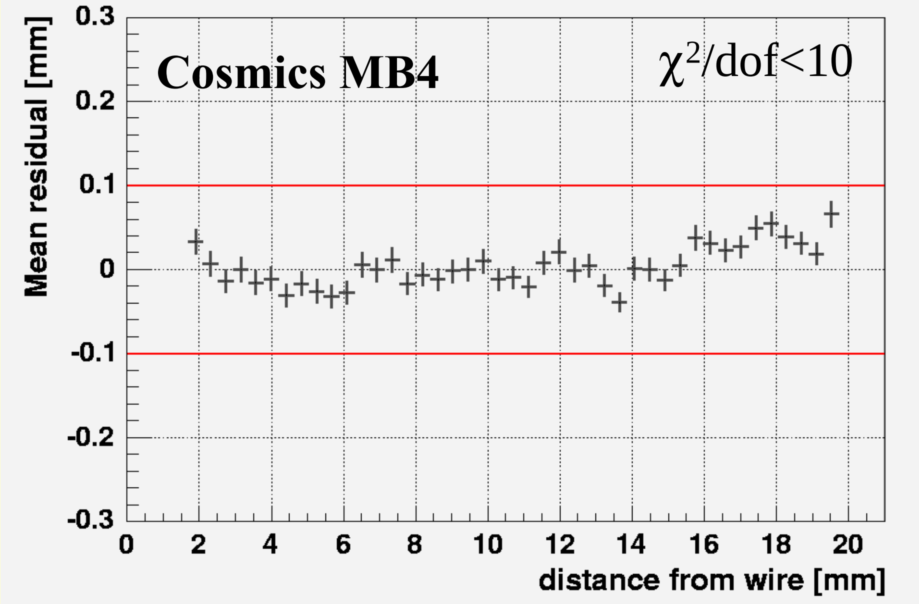
High σ_{MT} in the first MB4 SLs !

Linearity

SL local linear fit assuming linear drift parameterisation.
2D segment reconstruction.

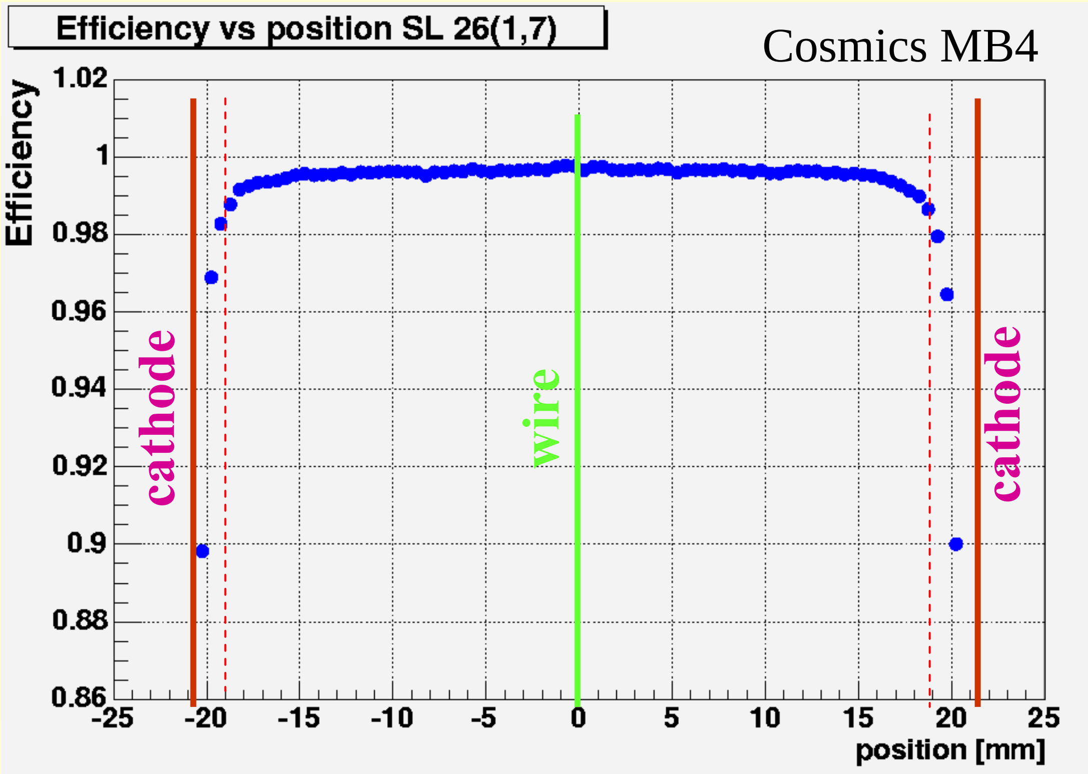
Residual vs position inside the cell





Deviations from linearity < 100 µm excluding few mm close to the wire and the cathode

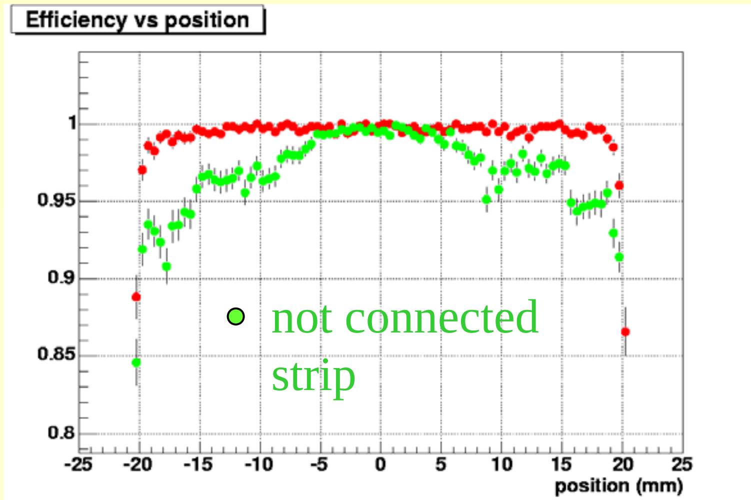
Cell detection efficiency



$$\varepsilon_{\mathrm{cell}}(\mathbf{x}) = \frac{\mathbf{N}_{\mathrm{cell-found}}}{\mathbf{N}_{\mathrm{cell-expected}}(\mathbf{x})}$$

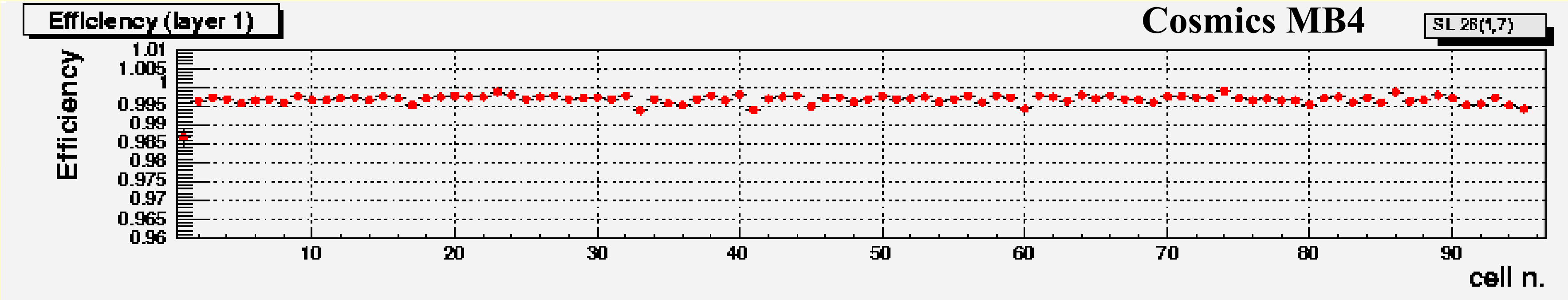
Detection efficiency in the active region ≥ 99 %

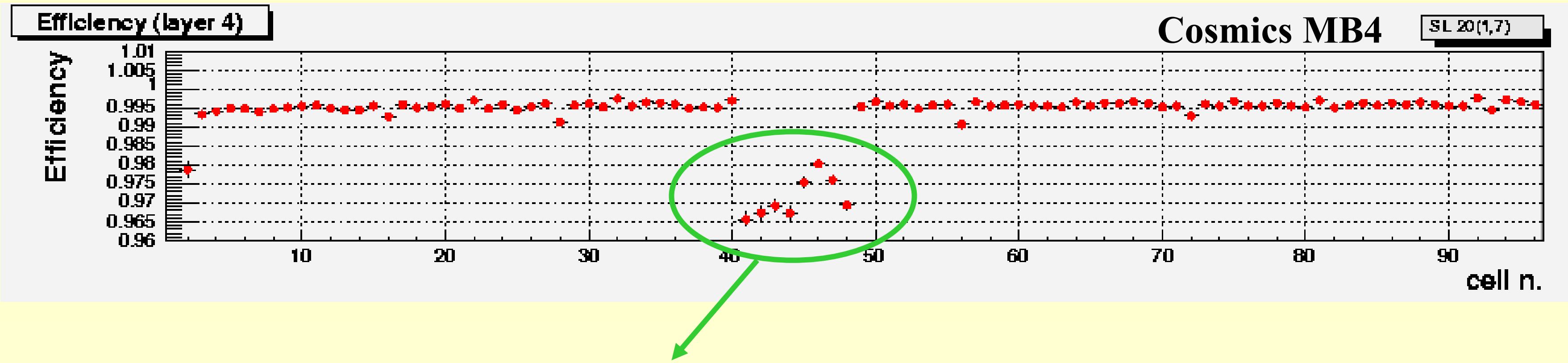
Lower efficiency for cells with bad HV connections



Cell detection efficiency

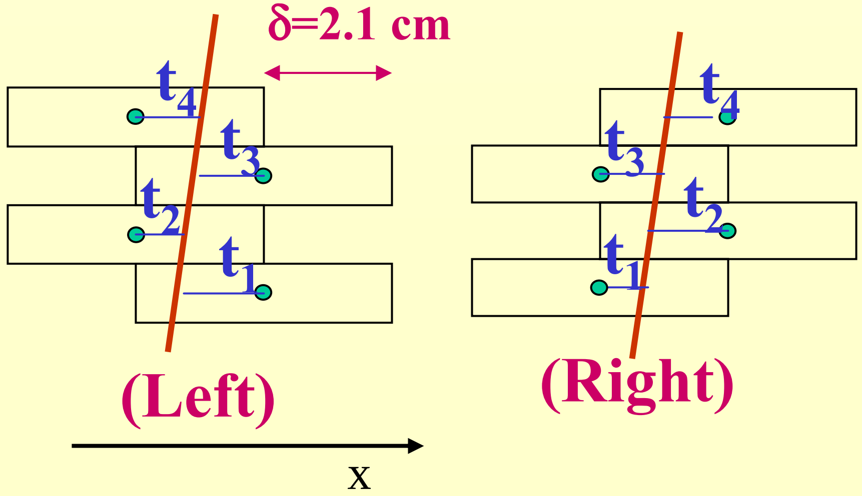
Mean efficiency ~ 99,5 %





Cells with not connected strips

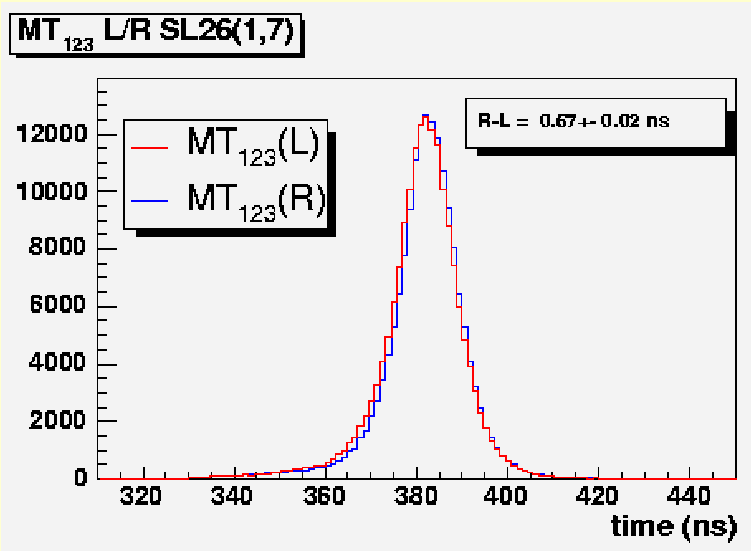
Layer relative alignment

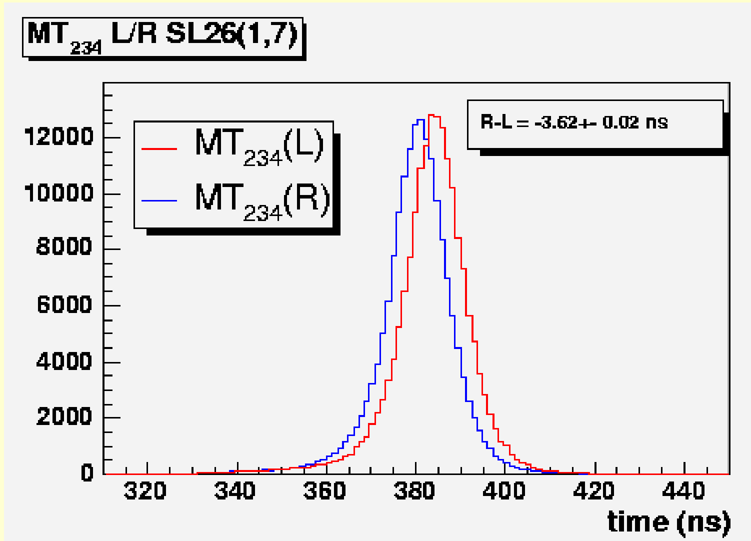


Δx_i = shift of the layer position with respect to the nominal position ($\Delta x_1 = 0$)

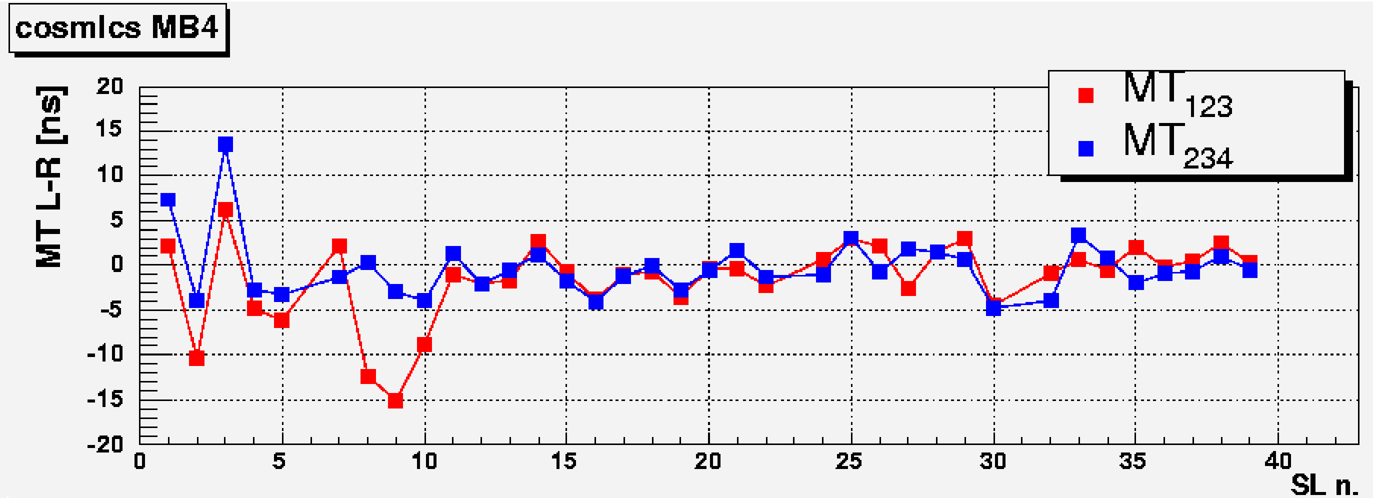
$$MT_{123}(R) - MT_{123}(L) = \frac{1}{v_d} \cdot (-\Delta x_3 + 2 \cdot \Delta x_2)$$

$$MT_{234}(R) - MT_{234}(L) = \frac{1}{v_d} \cdot (\Delta x_2 - 2 \cdot \Delta x_3 + \Delta x_4)$$

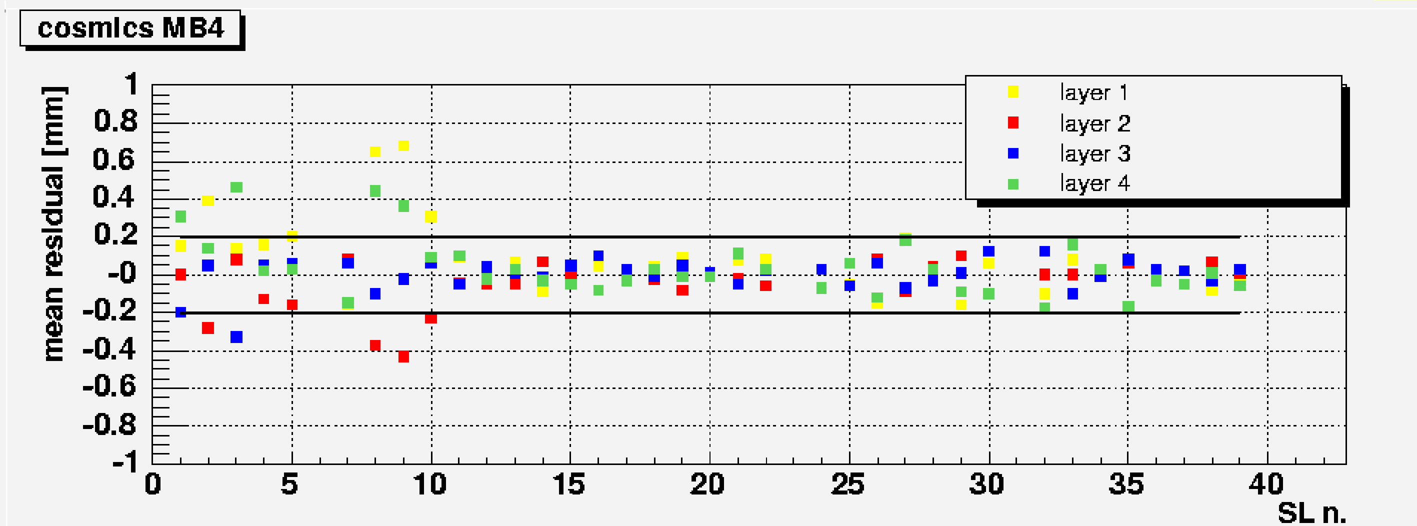




Layer relative alignment



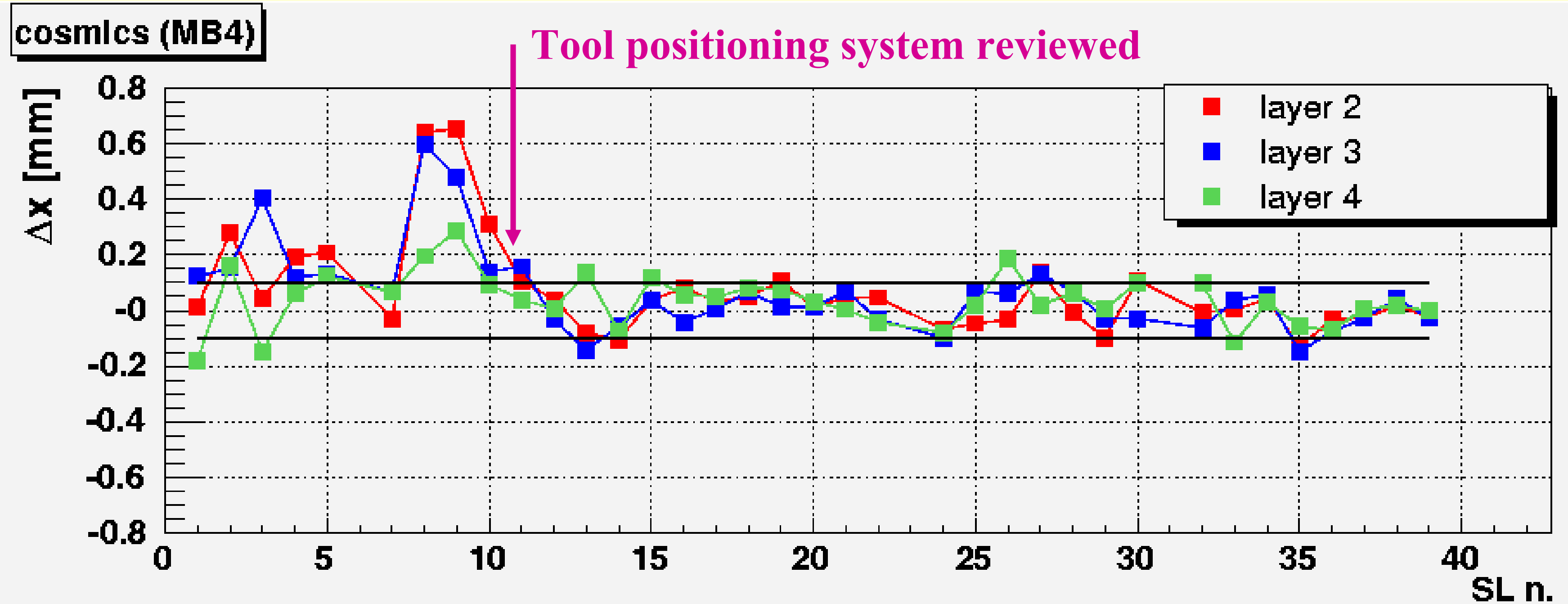
Indication of relatively large disalignment effects for SL n.≤ 10 . . .



. . . confirmed by the mean layer residuals

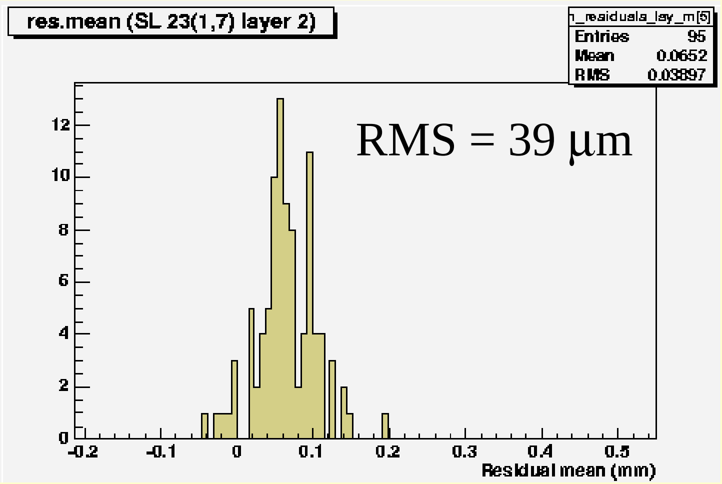
Layer relative alignment

The plane disalignments Δx_i are determined assuming a cosmic angular distribution symmetric with respect to the vertical direction.

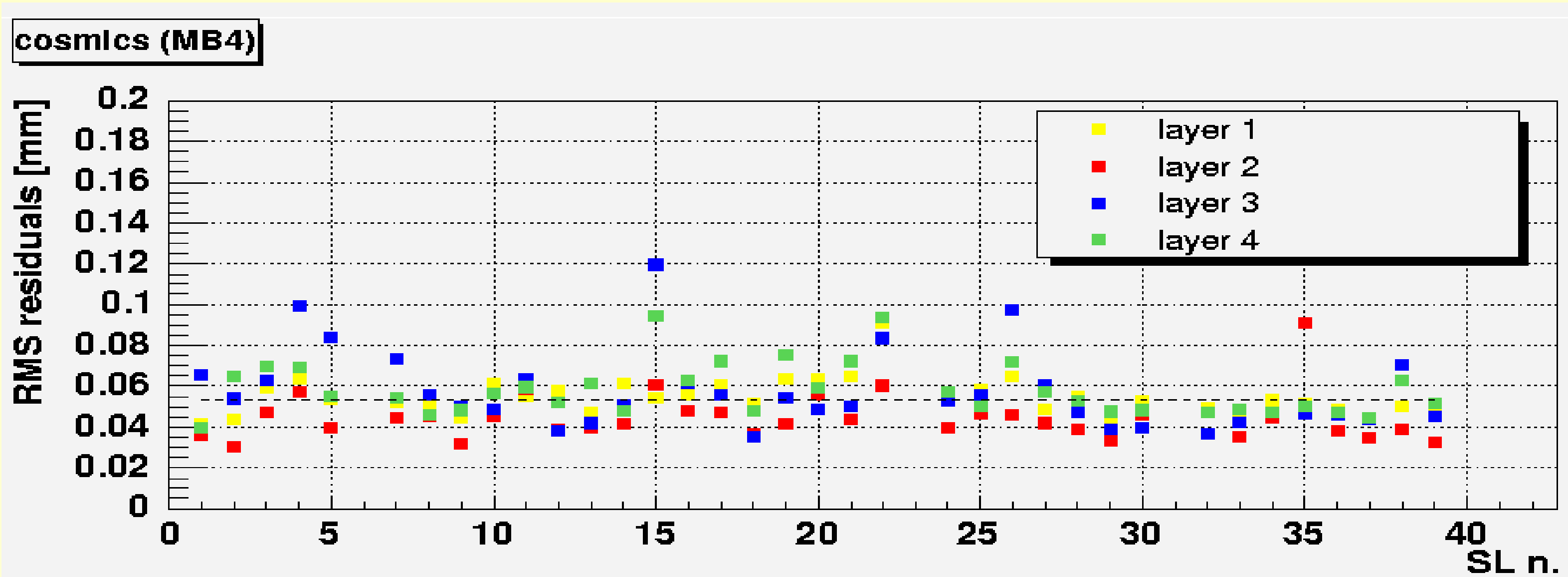


Better alignment in other production sites (smaller chambers)

Wire positions



The RMS of the mean residual distribution for the cells in one layer is < 100 µm



Conclusions

Data with cosmics provide a fast and efficient way to analyse the chamber performance on a cell-by-cell basis and to detect potential problems.

All Drift Tube chambers are certified with cosmics:

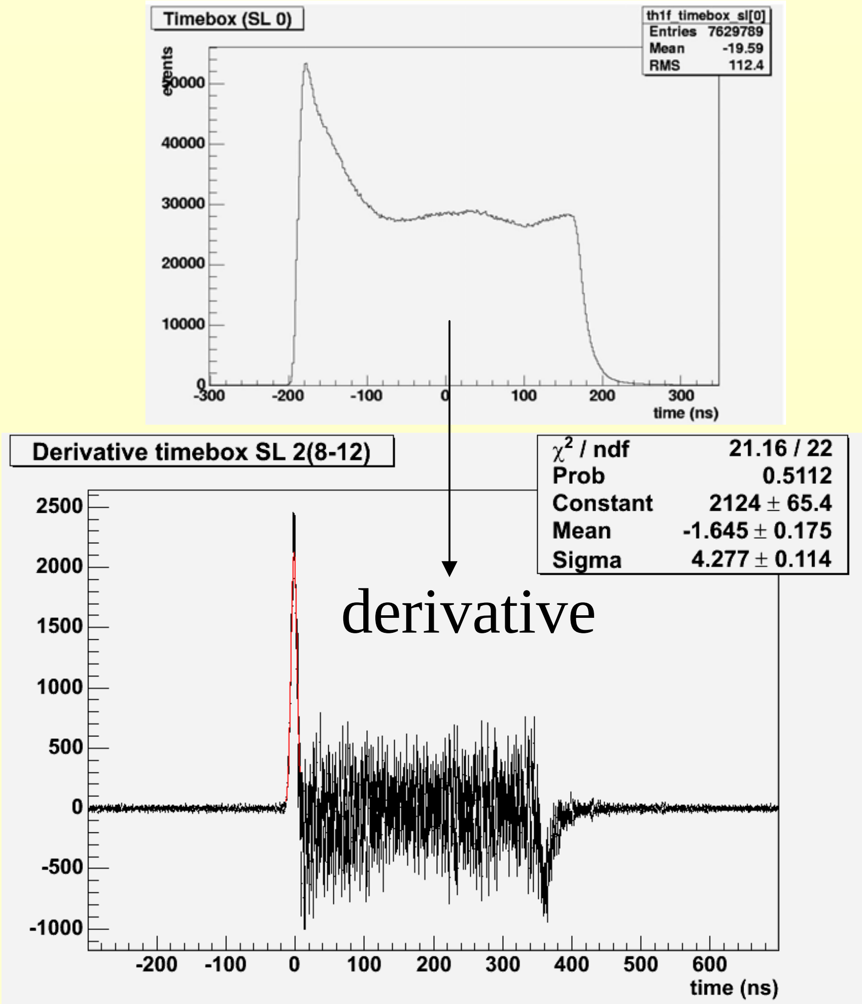
- **at the assembling sites**
- **at CERN before the installation**
- **on the CMS wheels after the installation**

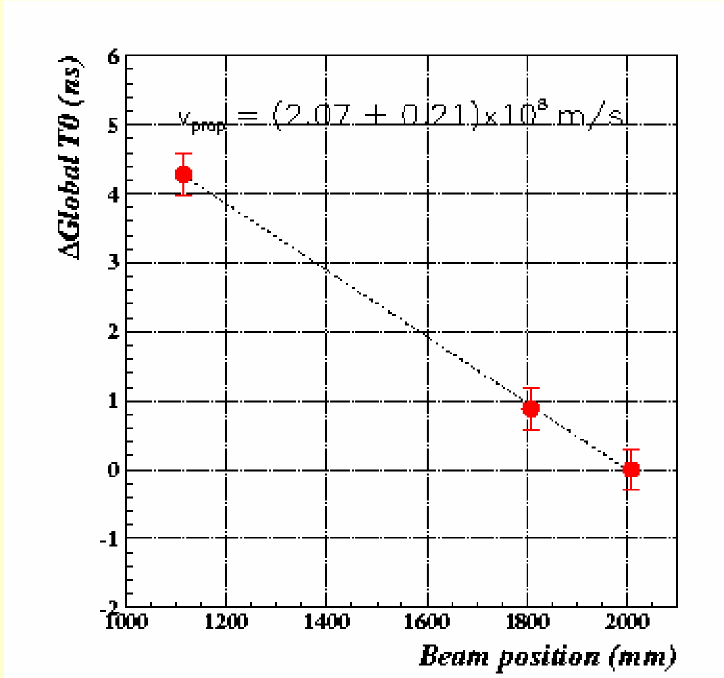
At the moment, data taking with cosmic muons is the only way to commission and calibrate the detector.

In 2006 a crucial combined test of all the CMS sub-detectors is foreseen.

Data collection with cosmics will be used for validation of the trigger/DAQ system and detector alignment studies.

Timing calibration



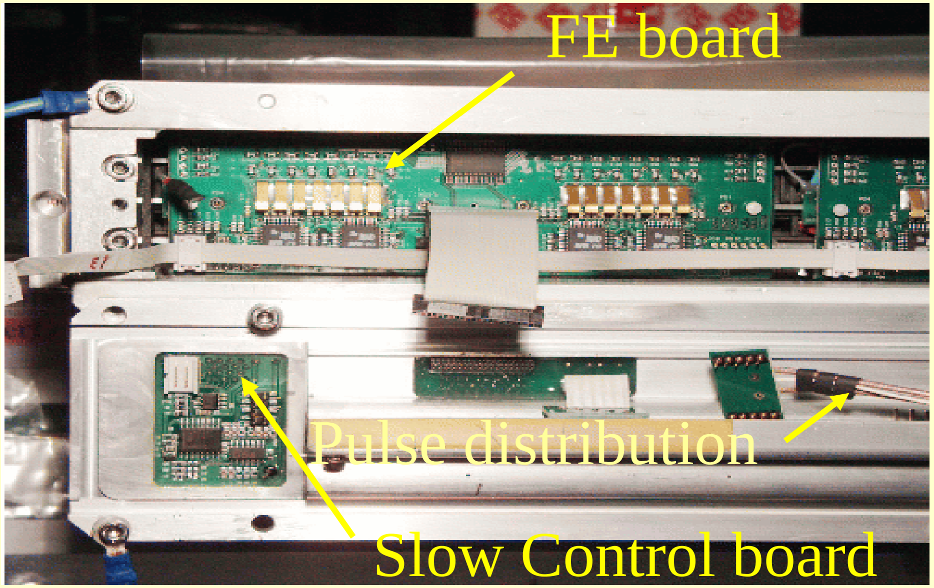


Corrections due to the propagation time along the wire taken into account.

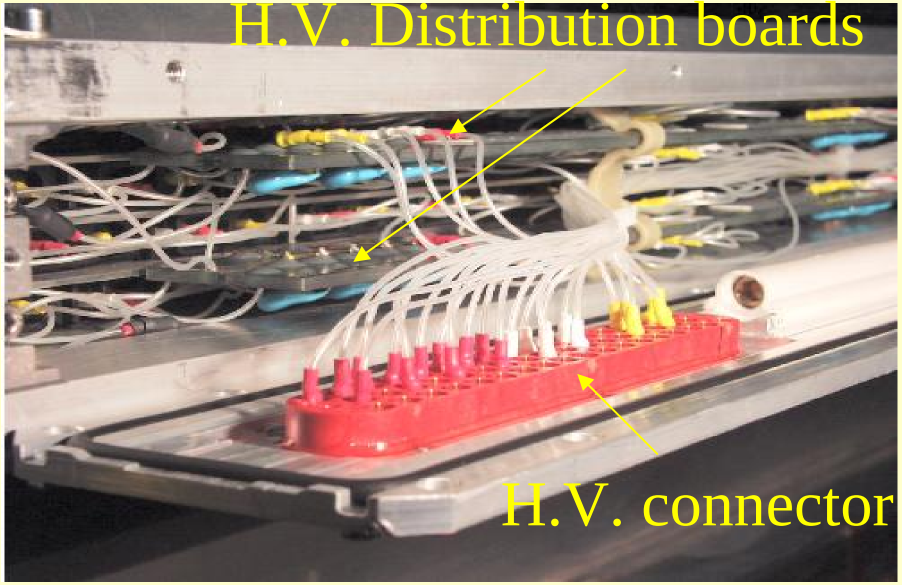
Wire-to-wire offsets measured with pulses

The peak of the derivative defines the time of particles crossing the wire.

Construction phases (II)



F.E. side



H.V. side