Performance of the Drift Tube muon chambers for the CMS experiment at the LHC

Francesca Romana Cavallo - INFN Bologna

- ⋆ Introduction
  - Why to look for muons in *pp* collisions at 14 TeV
  - The LHC environment: detector requirements
  - The CMS muon system and the DT chamber concept
- ⋆ Results of beam tests on prototypes
- ⋆ DT production at LNL and tests with cosmics
- ⋆ Discussion and conclusions

Why to look for muons in pp collisions at 14 TeV

Aims of the LHC program:

- ⋆ Final test of the Standard Model: search for the Higgs Boson.

  "Golden" decay channel: $H^o \rightarrow Z^o Z^o \rightarrow l^+ l^- l^+ l^-$

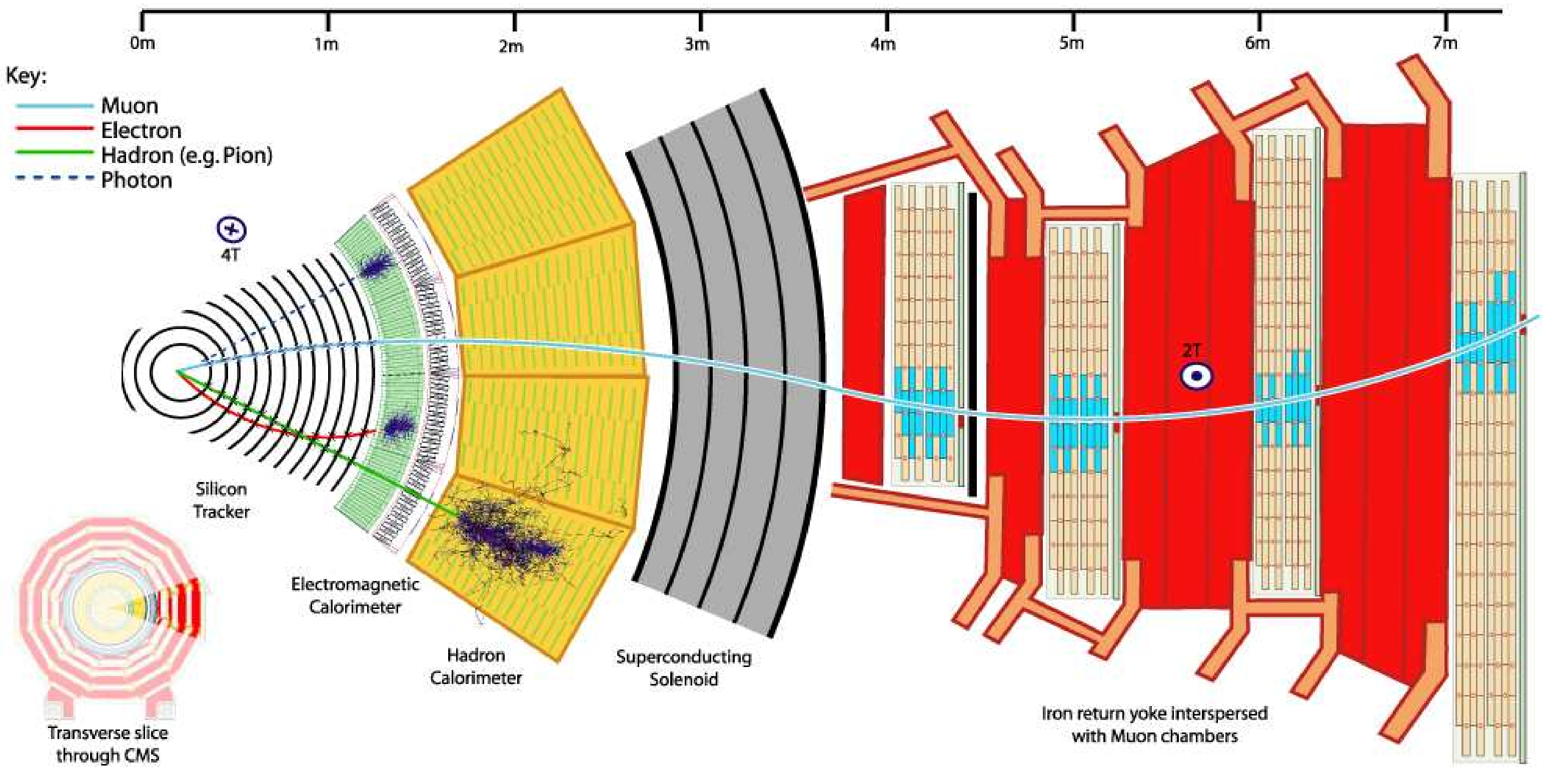
  Also: $H^o \rightarrow W^+ W^- \rightarrow l^+ l^- \nu\nu$

- ⋆ Search for SuperSymmetry ("immediadely beyond" the SM): $H, h, A \rightarrow l^+ l^-$

- ⋆ Search for new physics: e.g. $Z' \rightarrow l^+ l^-$

$l{=}\mu, e$ but ....

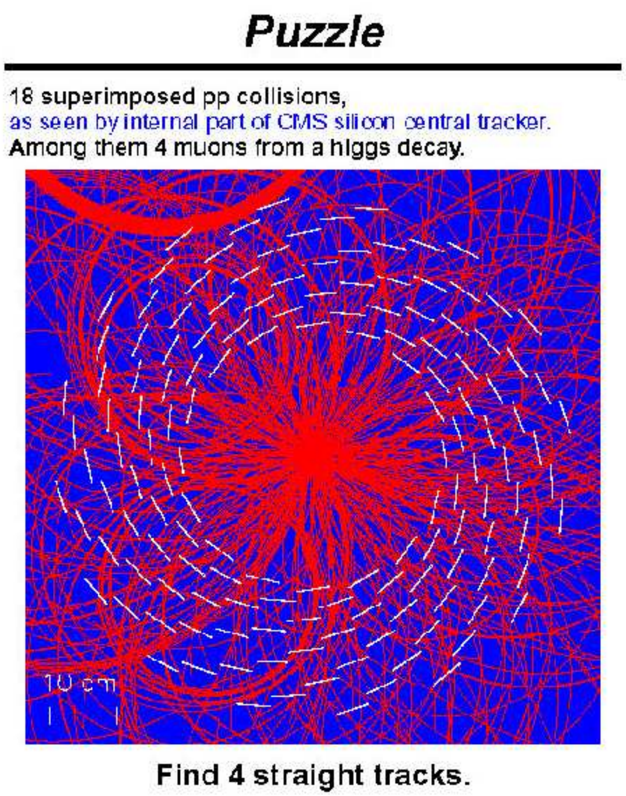
... muons are the only particles that travel across the whole detector
⇒ easy identification, clean signature

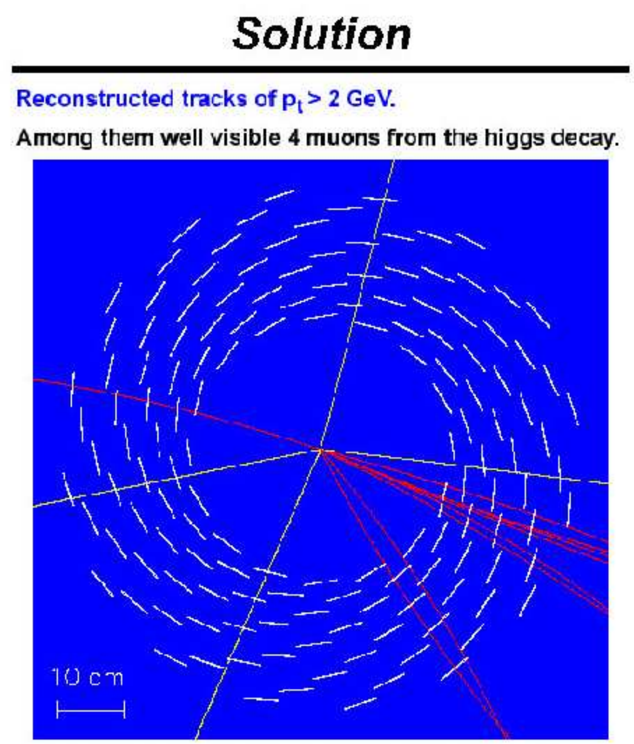


The LHC environment

Event rate: $\sim 10^9\, Hz$ (for $L = 10^{34} cm^{-2} s^{-1}$).

Possible Higss rate: $\sim 10^{-2}\, Hz$.





(Courtesy of G. Wrochna)

Muon detector tasks

- ⋆ Muon first level trigger (background filtering)
- ⋆ Muon identification and charge assignment up to 7 TeV
- ⋆ High resolution momentum measurement
- ⋆ Bunch crossing identification (BCO rate: $40 MHz$!)

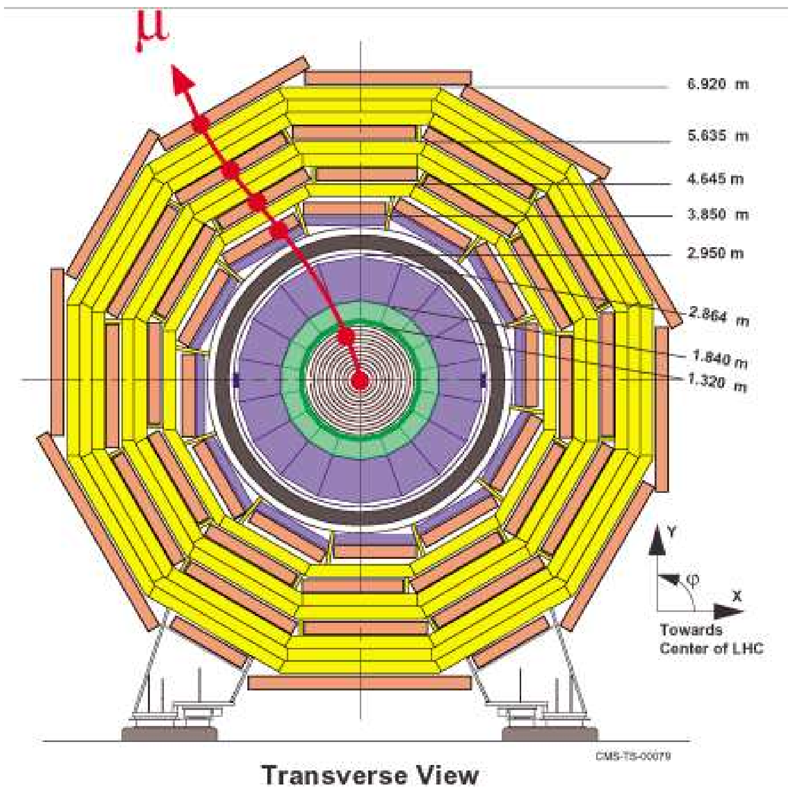
Therefore:

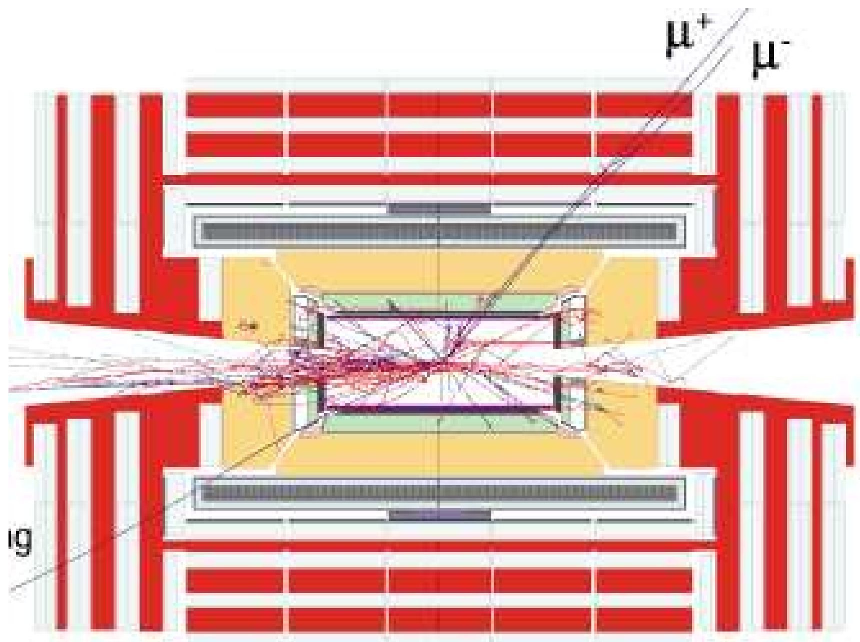
Muon detector requirements

- ⋆ Time resolution: $\ll 25\, ns$ ($\leftarrow$ interval between BCO's)
- ⋆ On line pattern recognition
- ⋆ Space resolution: $\leq 100\, \mu m$ ($\leq 250 \mu m$ for single point), $\sim 1\, mrad$

Moreover: **Radiation resistance !!!**

The CMS muon system





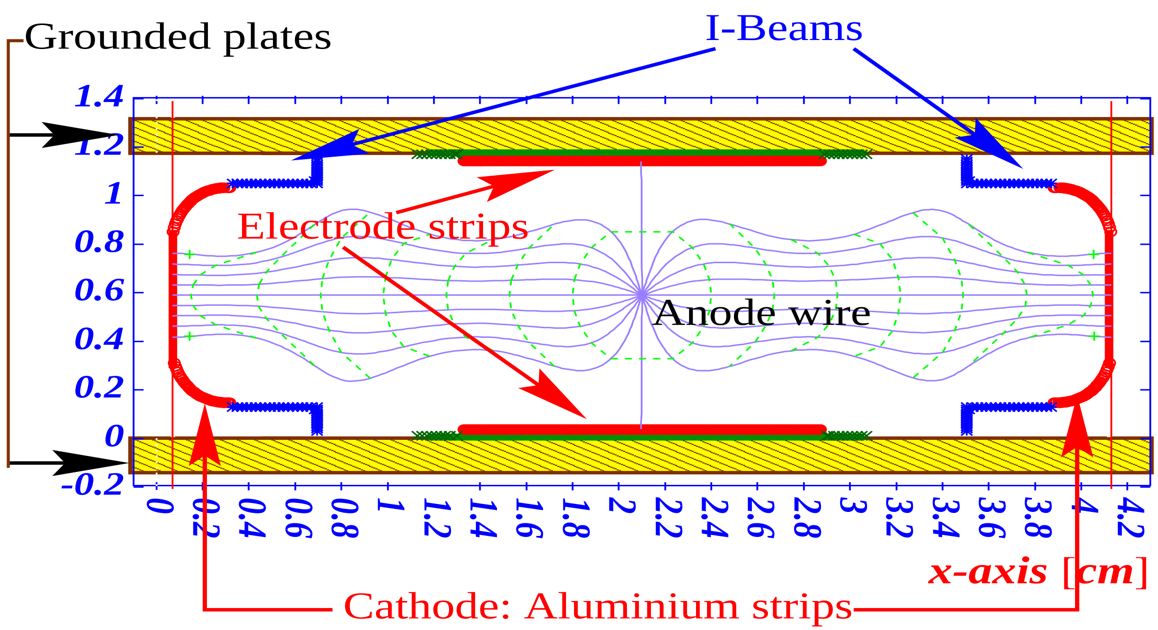
The Drift Tube chambers are in the barrel part of the detector

The Drift Tube chambers

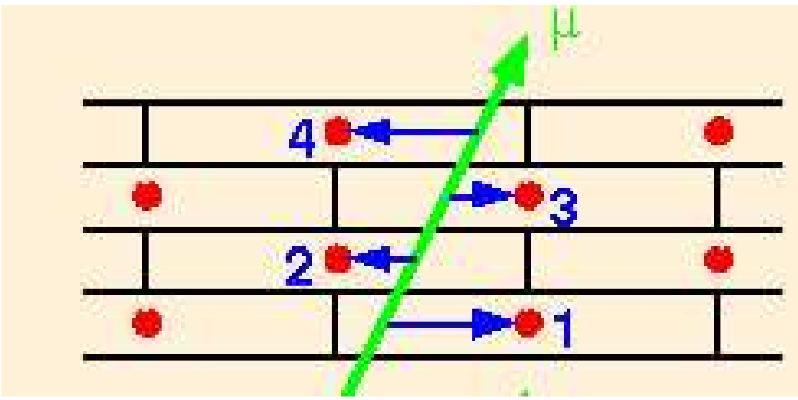
Basic element: a drift tube with a 42 × 13 mm^2 rectangular section, filled with Ar CO_2 85-15 %. Typical HV values:

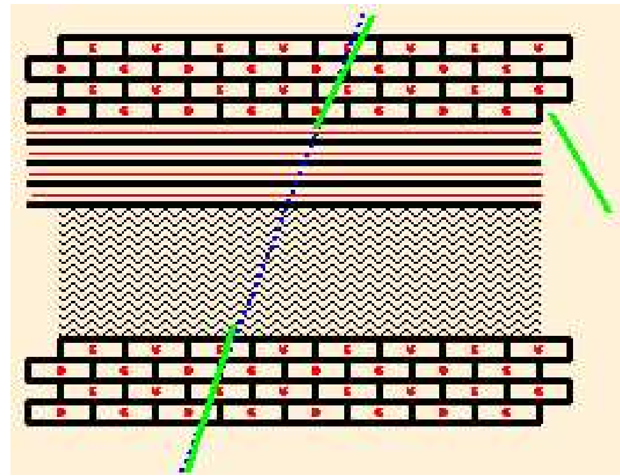
wire → +3600 V; cathode → -1200 V; strip → +1800 V.

Typical drift velocity: 56 $\mu m/ns$



The tubes are arranged in groups of 4 layers ("superlayers")





A full chamber is made with 3 superlayers, 2 measuring the $R\Phi$ and 1 the z coordinate.

The BTI (Bunch and Track Identifier) performs a hardware pattern recognition: identifies the bunch crossing and yields approximate values of the track position and slope to be used by the first level trigger.

Prototypes and Beam Tests

Most recent data taken at CERN with muon beams:

1999: prototype superlayer, final design, 16 tubes per layer;

2000: prototype set of BTI's added;

2001: full size, final chamber.

Relevant parameters:

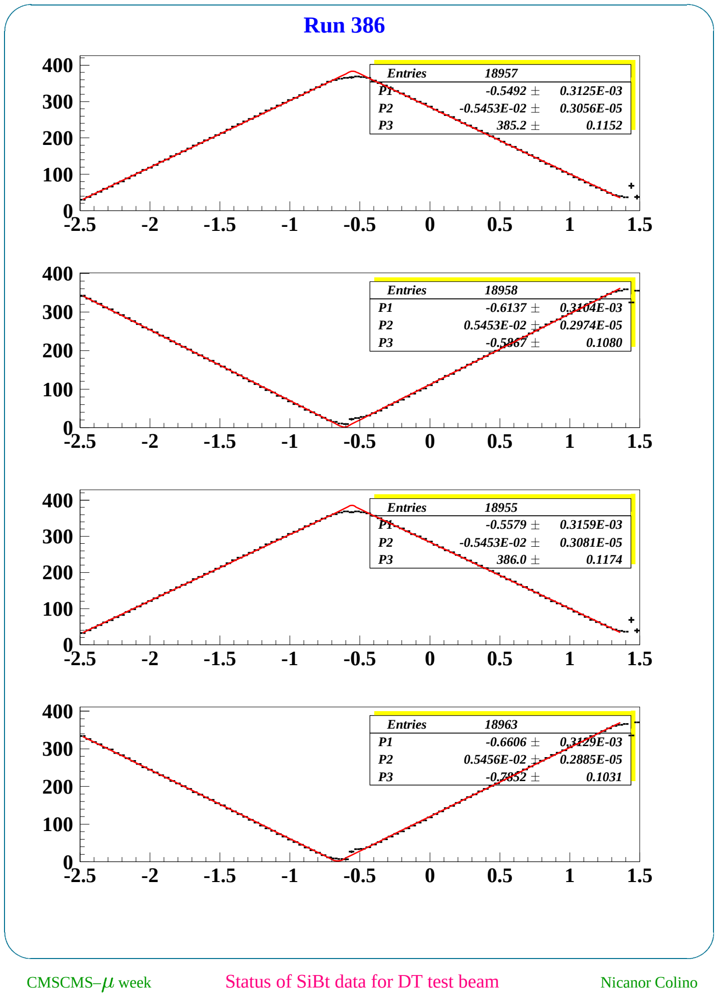
- (Thresholds)
- Voltages
- Muon angle of incidence
- Magnetic field

Relevant measurements:

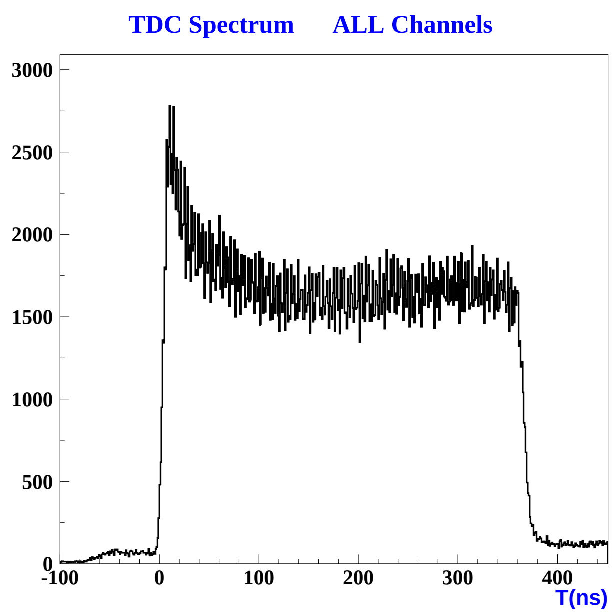
- Drift velocity and linearity check
- Time and space resolution
- Efficiency
- BTI efficiency

Drift velocity and linearity

Time vs position (4 layers) ⇒



Time distribution ⇓



Efficiency

Time resolution

Distribution of the "Meantime"

$$= \frac{1}{2}(t_1 + 2t_2 + t_3) = T_{MAX}$$

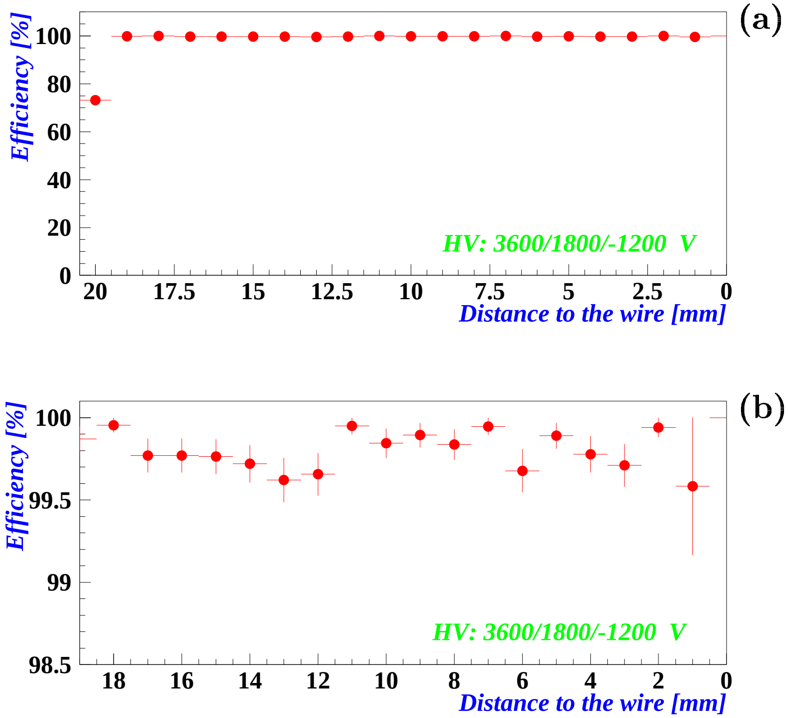
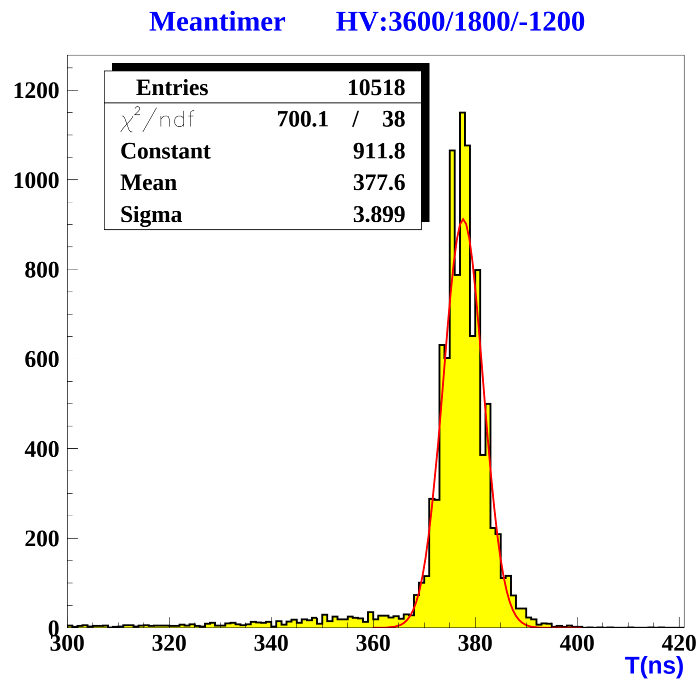


Fig.



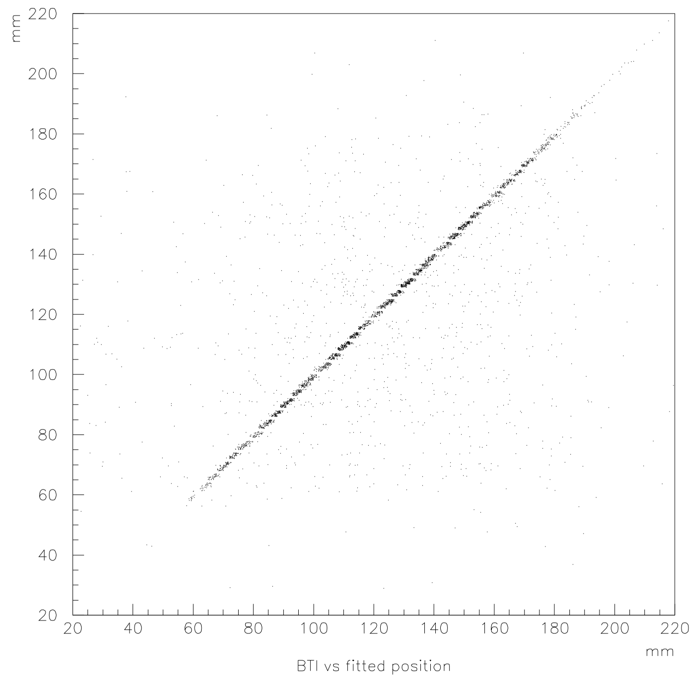
In these conditions: $T_{MAX} = 378\, ns \rightarrow v_{drift} = 55.6\, \mu m/ns;$

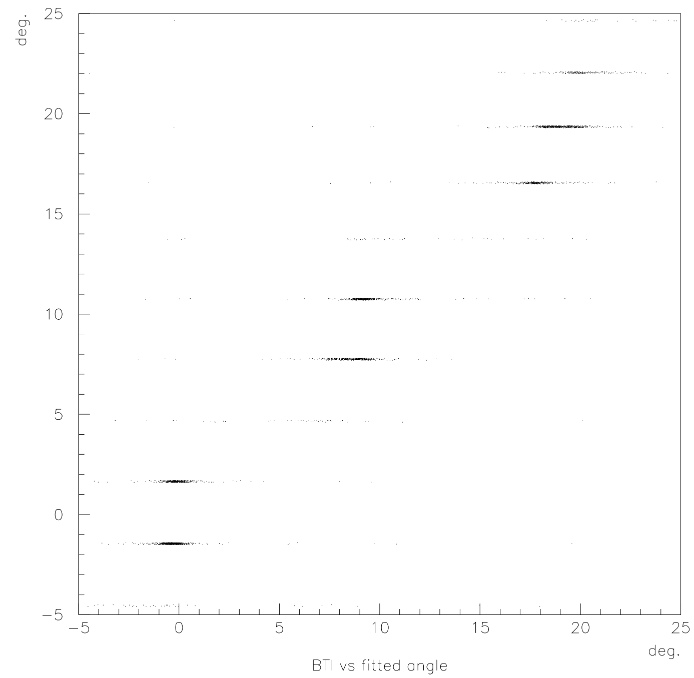
$$\sigma_t = 3.18\, ns \rightarrow \sigma_x = \sigma_t\, v_{drift} = 177\, \mu m$$

First level trigger: the BTI's

Fast, hardware reconstruction of position and angle,

using time slots of 25 ns.





BTI position vs fitted position

BTI angle vs fitted angle

Which parameter affects which measurement

Voltages:

⇒ v_{drift} depends on $(V_{Strip} - V_{Cath.}) = V_{Drift}$

From computation, it saturates at $v_{drift} \simeq 55\mu m/ns$ for $V_{Drift} \simeq 3000V$

⇒ The efficiency and

⇒ the time resolution depend on

$(V_{Wire} - V_{Strip}) = V_{Amp}$ as it determines the gas gain.

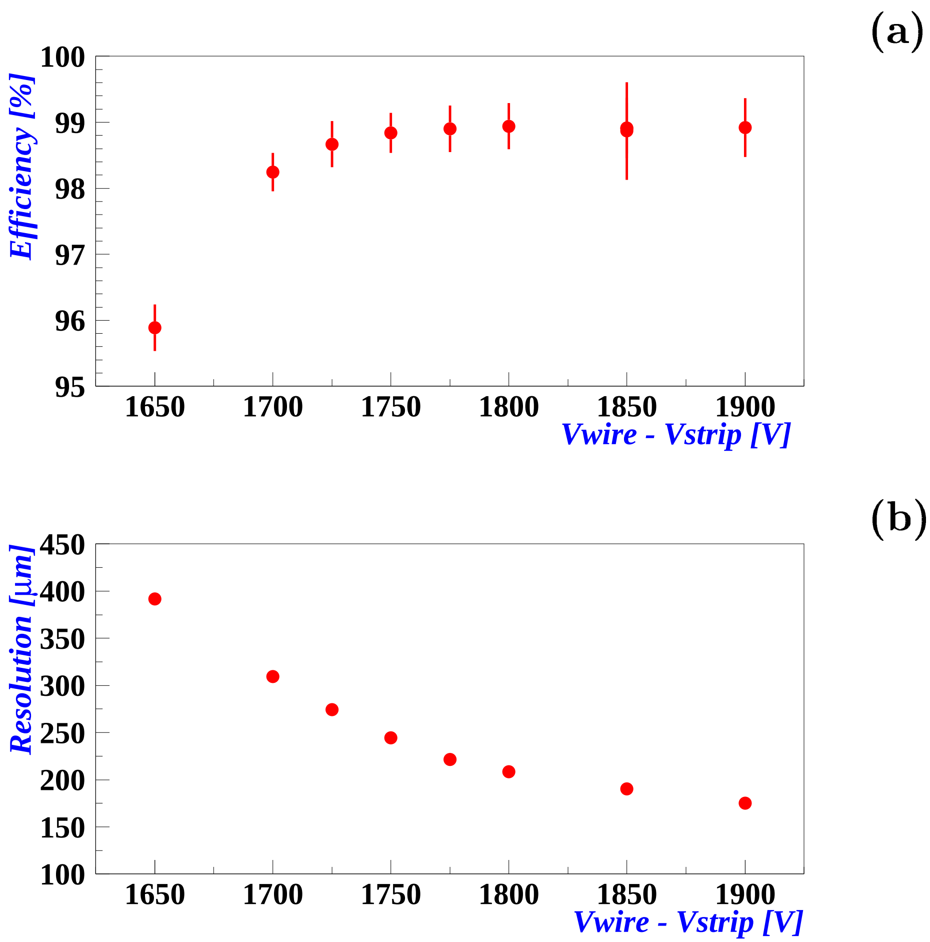


Fig.

$V_{Amp} \simeq 1800$ V and
$V_{Drift} \simeq 3000$ V lead to

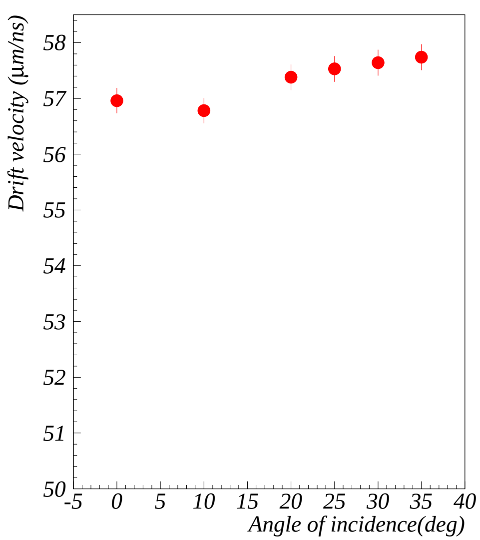
$$V_{Wire} = 3600V;$$
$$V_{Strip} = 1800V;$$
$$V_{Cath} = -1200V$$

Which parameter affects what ...(II)

Angle of incidence:

The relevant angle is the one on the plane normal to the wires

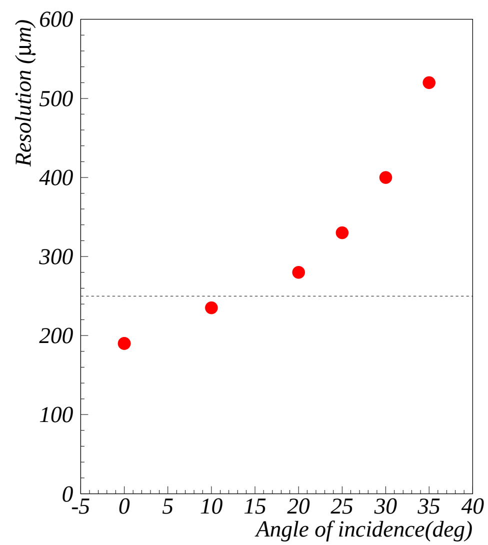
(e.g. φ for the Φ superlayers). φ causes a spread of the ionized charge $\rightarrow$ increases the apparent v_{drift} and spoils the resolution σ.



$\Leftarrow$ v_{drift} vs φ

σ vs φ $\Rightarrow$

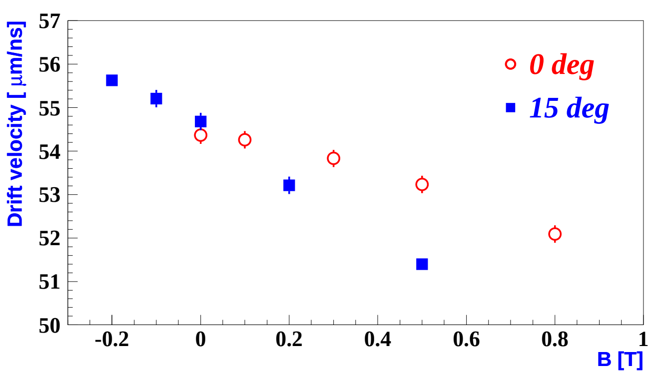
No effect on single wire efficiency



Which parameter affects what ...(III)

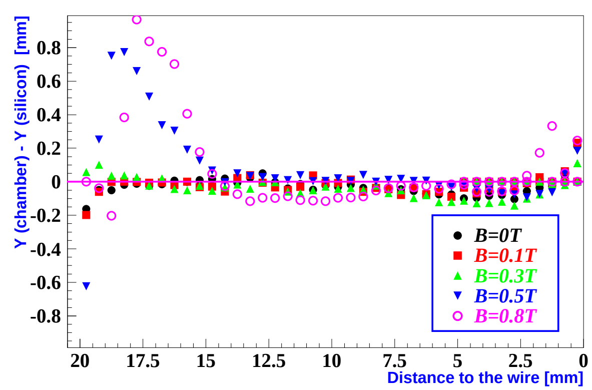
Magnetic field:

Both B_w (along the wire) and B_n (along the μ direction) cause a bending of the drift paths $\rightarrow$ the apparent v_{drift} decreases and σ increases. B_w also yields non-linearity effects $\rightarrow$ ε is reduced.



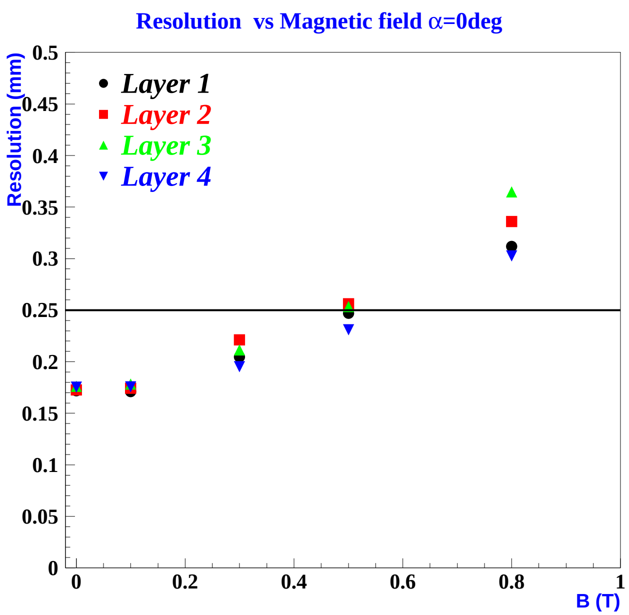
$\Leftarrow$ v_{drift} vs B_w

Dx vs x $\Rightarrow$ (for several B_w)

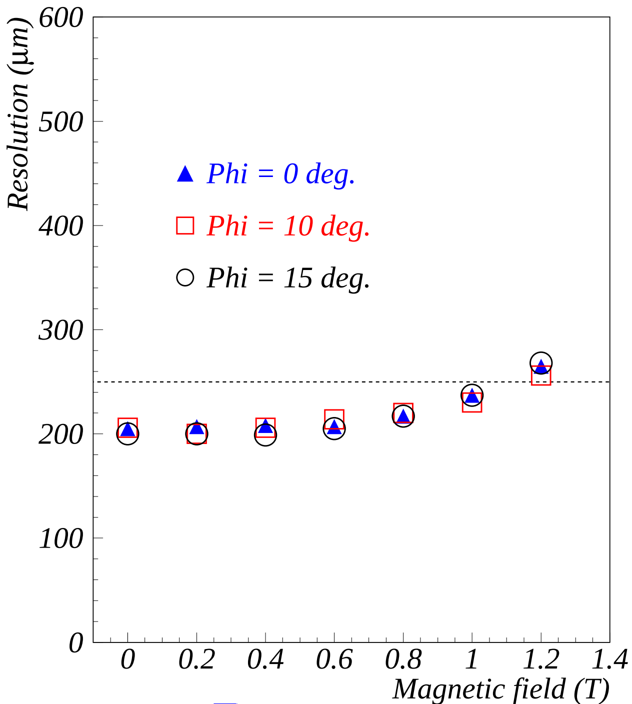


The effect of B_n on v_{drift} is similar but does not depend on φ.

.. more on magnetic field: effects on resolution



σ vs B_w



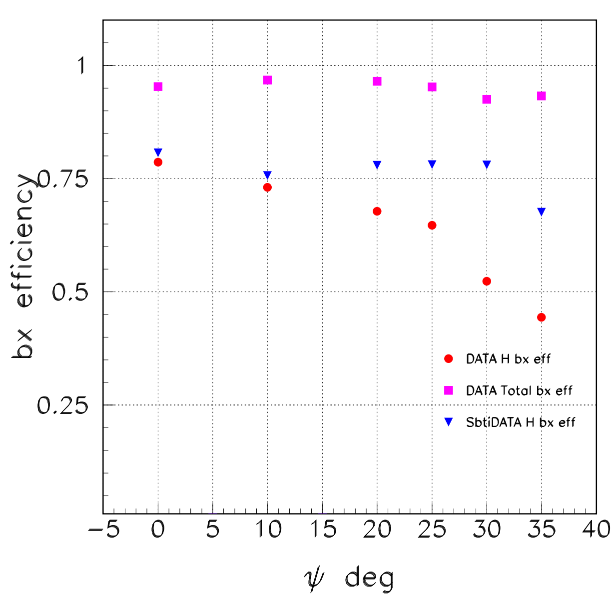
σ vs B_n

However the computed values in the gas are:

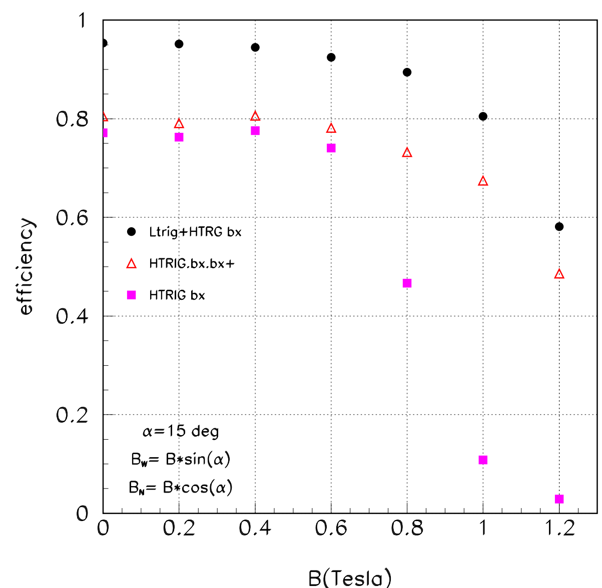
$B_w \leq\sim 0.4T, \quad B_n \leq\sim 0.8T$

Which parameter affects what ...(IV)

The BTI's efficiency



ε vs φ



ε vs B

The BTI parameter corresponding to v_{drift} must be tuned and set individually for BTI sitting in the regions with the highest B.

Chamber production at LNL and cosmic tests.

9 full chambers tested so far. After HV test and noise measurement, we use cosmic muons to check the efficiency and the uniformity of the resolution. The resolution itself is worse than at the test beam due to the scintillators used for triggering.

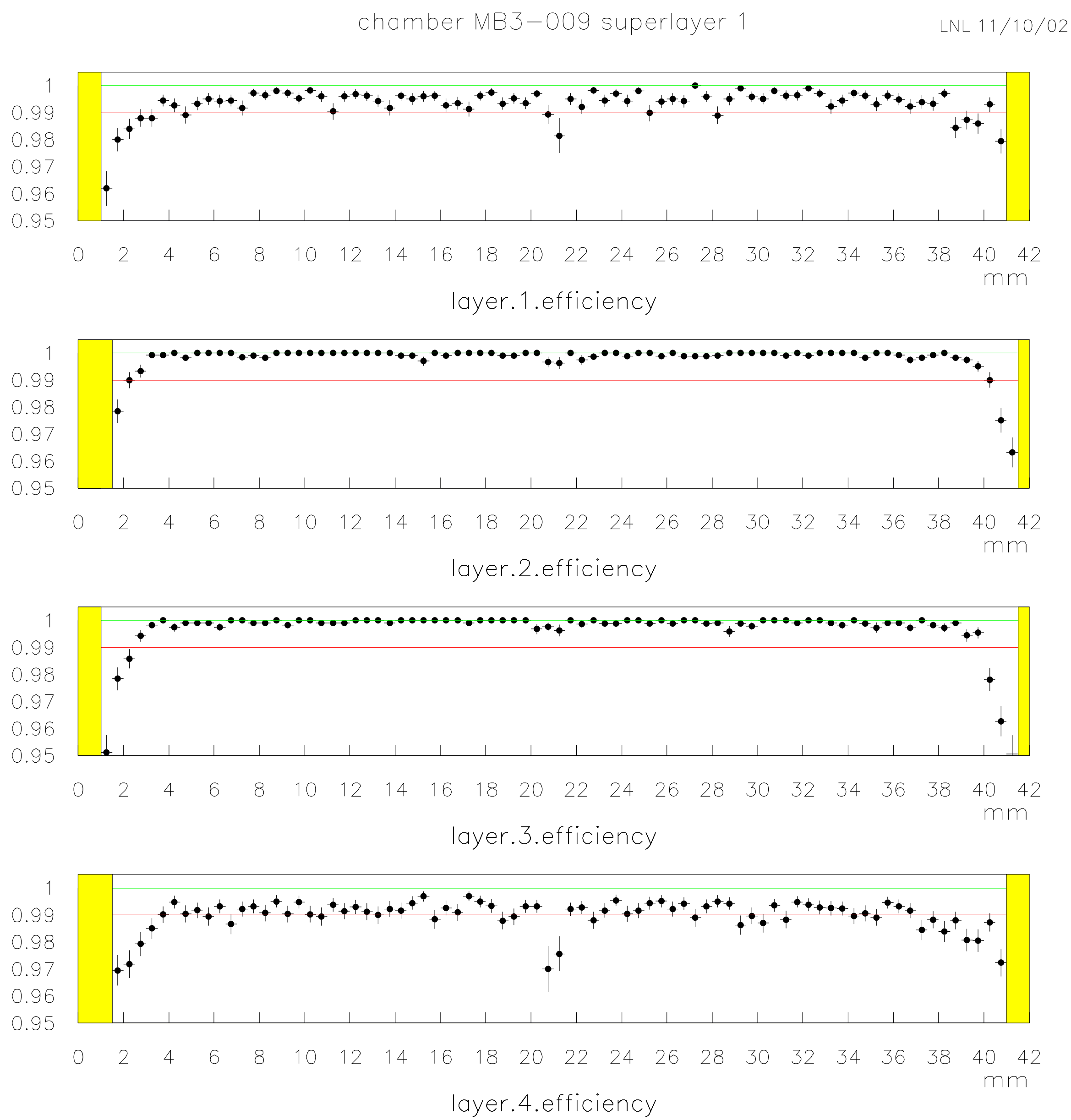
⇒ The position is determined by the extrapolation of the fitted track (at least 3 hits). The number of missing hits (within 1 cell) is used to compute the inefficiency.

⇒ The meantime is computed for layers 1,2,3 and layer 2,3,4.

Its gaussian fit provides the V_{drift} and the resolution.

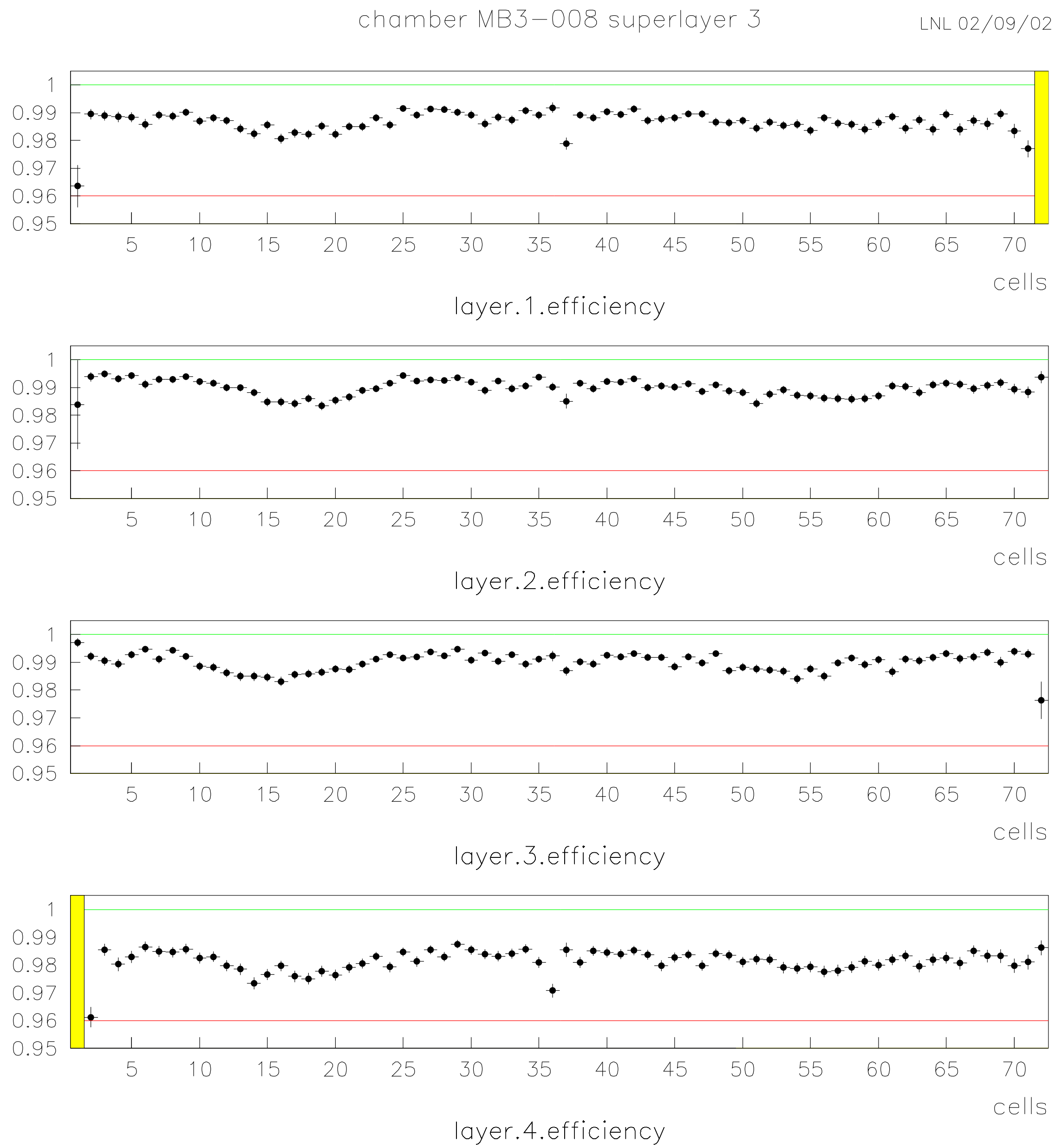
Efficiency

Efficiency vs drifting distance in the 4 layers. It is uniform and $> 99\%$ everywhere but on the cathode walls.



Efficiency II

Efficiency
cell by cell
in the 4 layers.



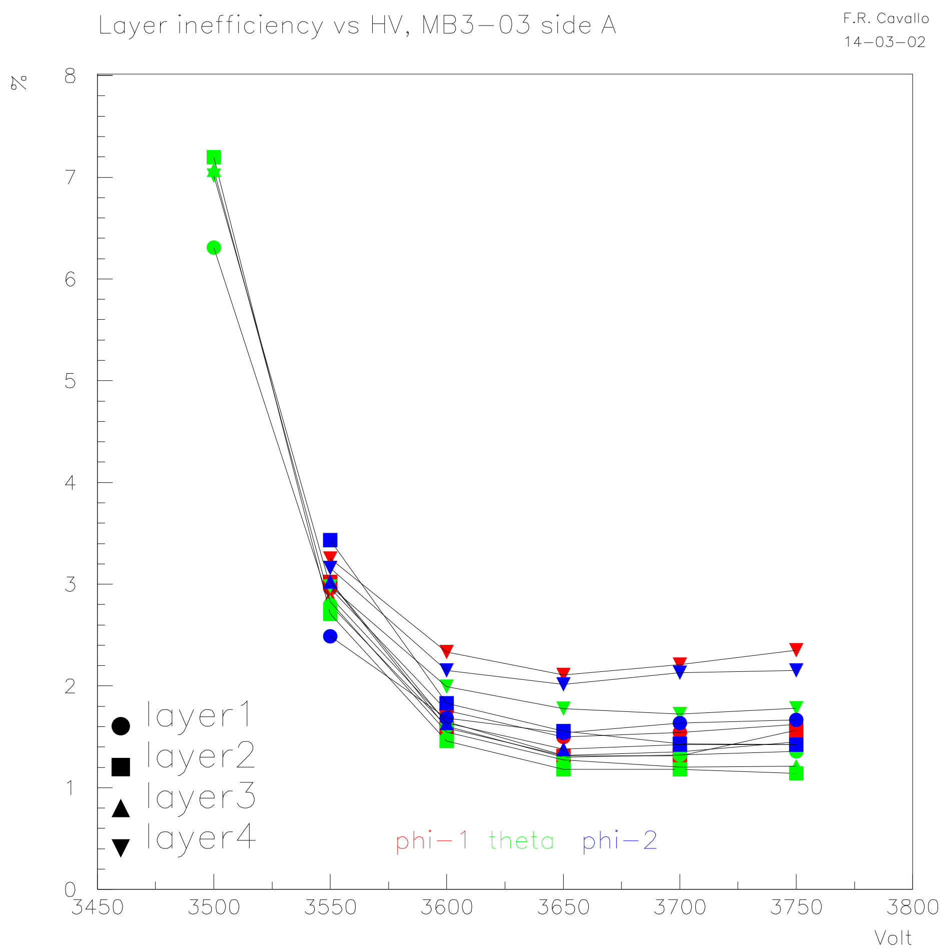
Efficiency III

Inefficiency

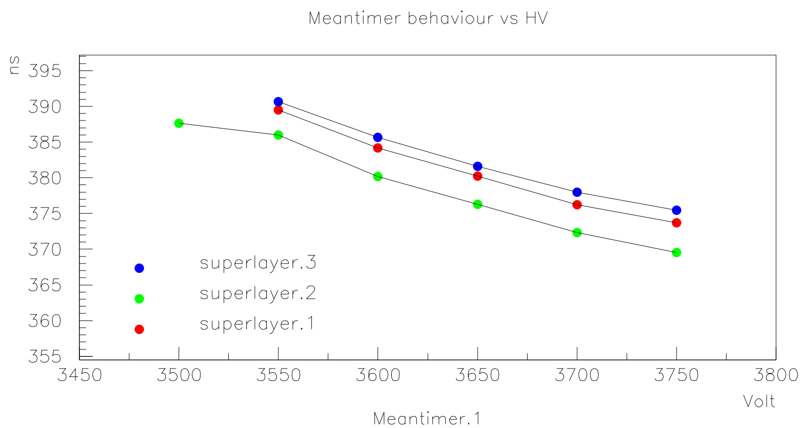
vs V_{Wire},

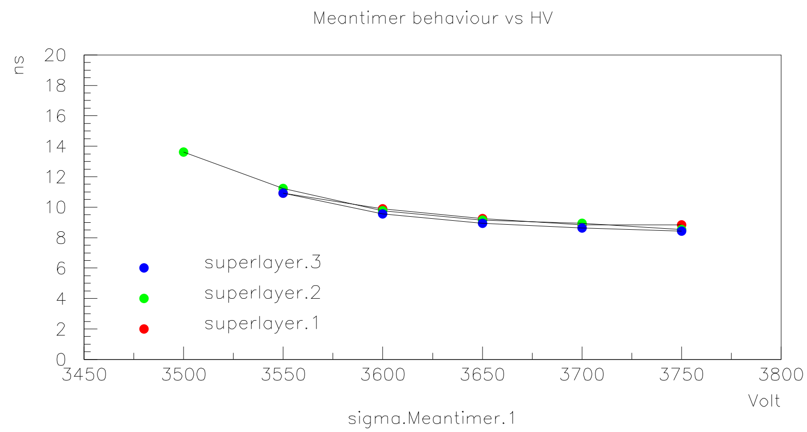
layer by layer

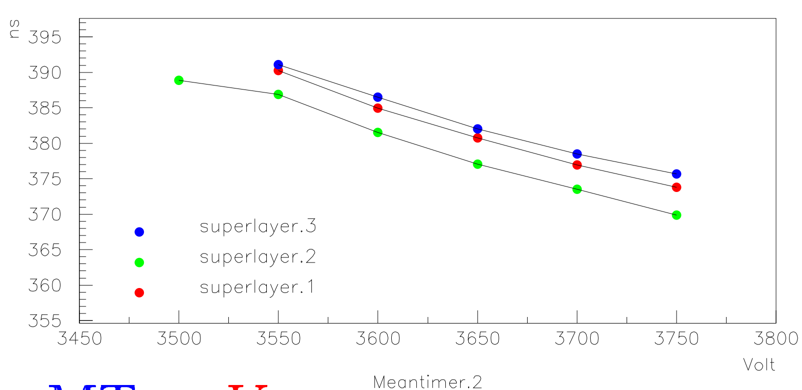
$(V_{Strip} = 1800\,V)$

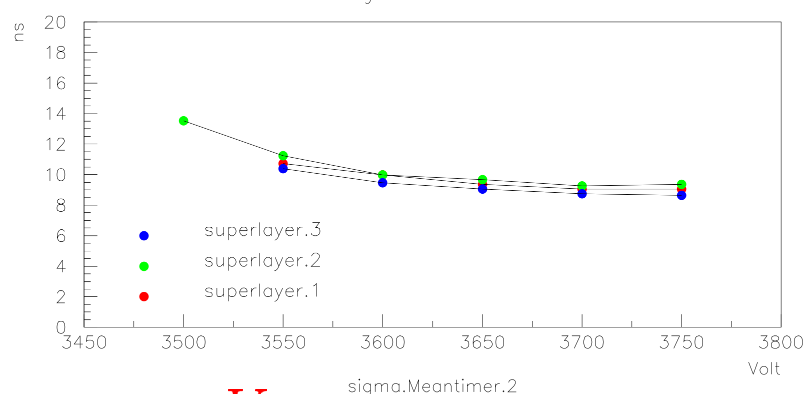


Meantime









MT vs V_{Wire}

σ vs V_{Wire}

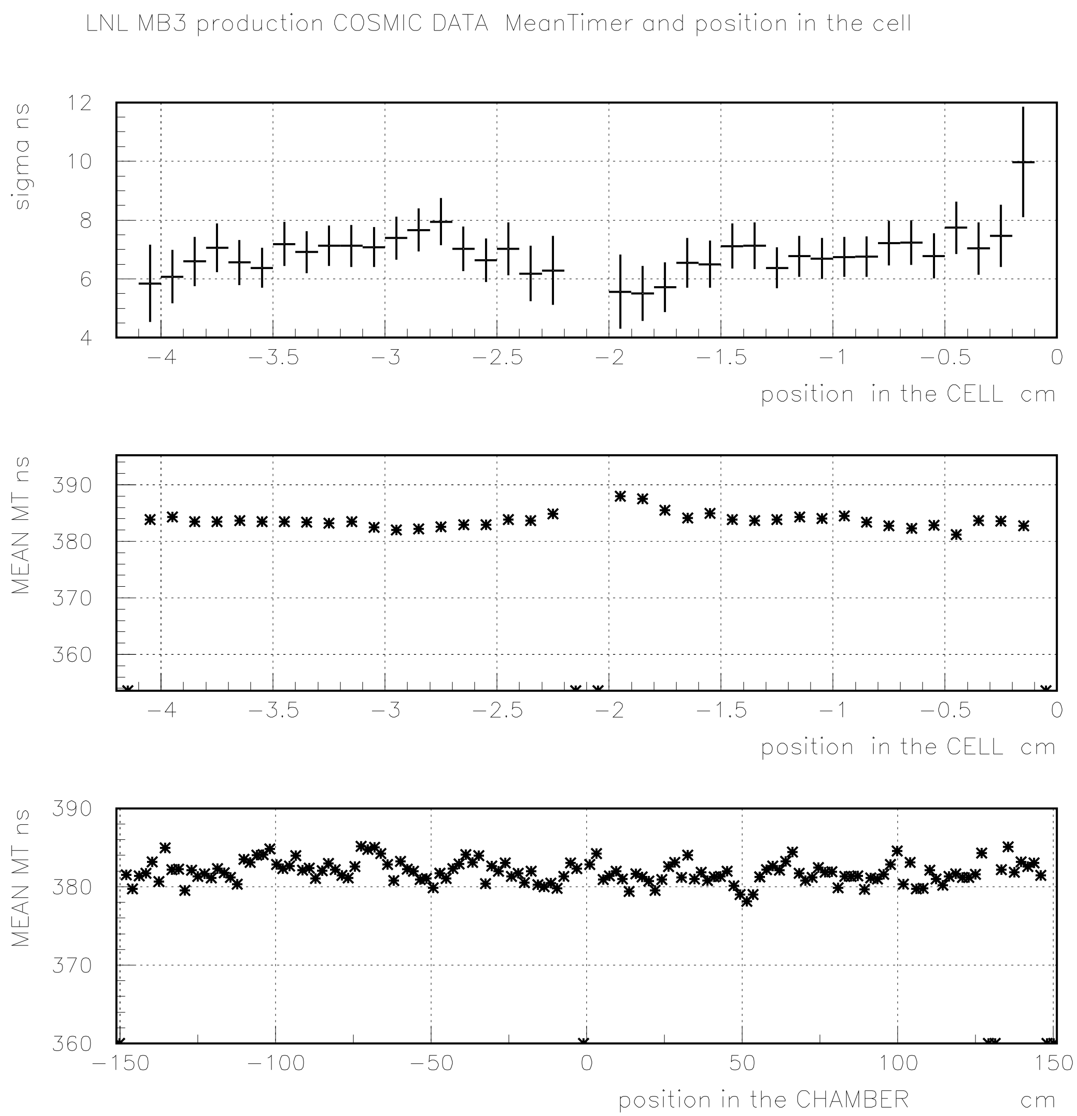
$$(V_{Strip} = 1800\,V)$$

Meantime vs position

Resolution vs position ⇒ in the cell

Meantime vs position ⇒ in the cell

Meantime vs position ⇒ in the chamber

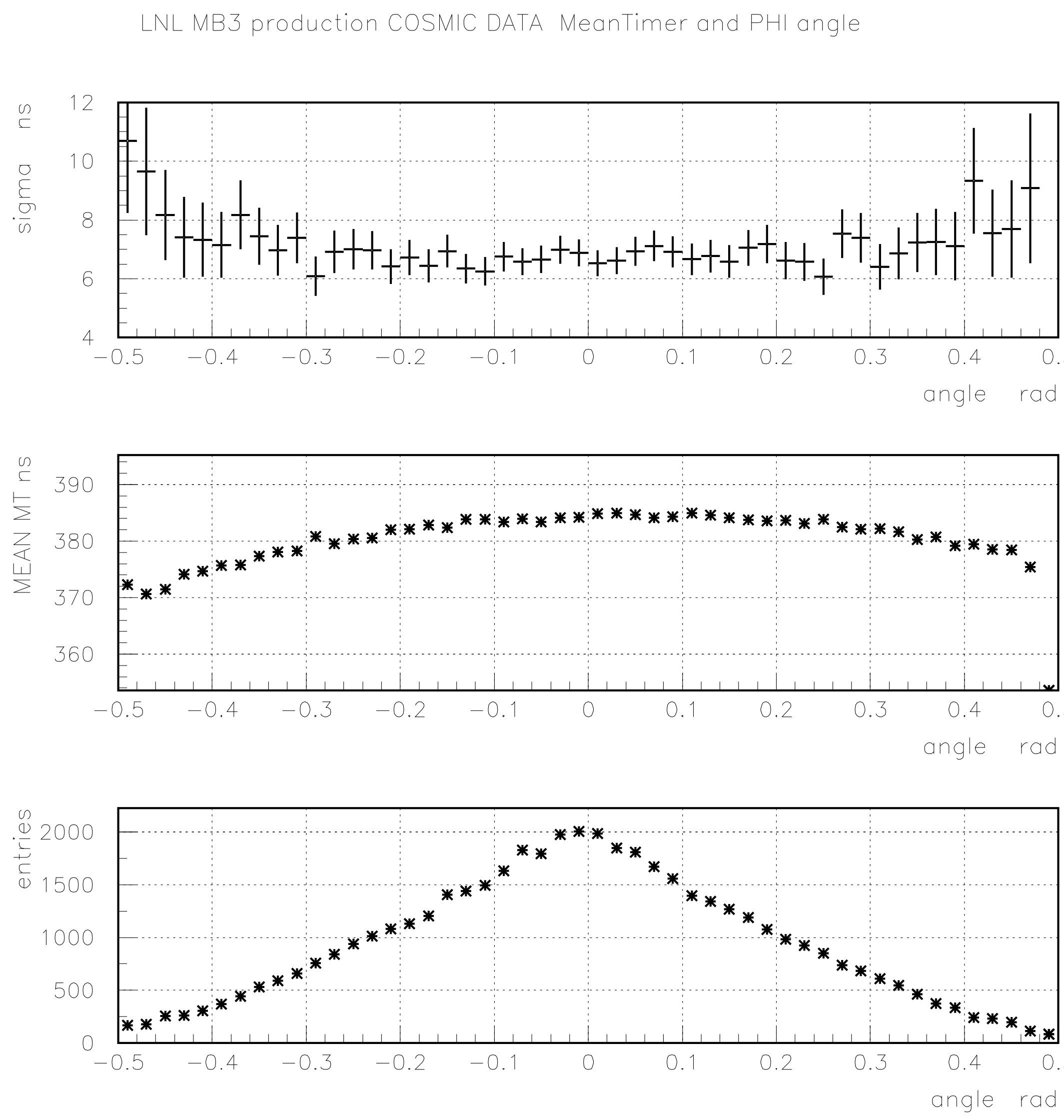


Meantime vs track angle

Resolution ⇒

Meantime ⇒

Track dist. ⇒



from $\sigma \sim 7\,ns$

and TMAX= 385 ns:

resolution $\sim 310 \mu m$

CONCLUSIONS

- ⋆ Our understanding and our confidence in the chambers we are building are increasing.
- ⋆ Several test beam runs and the present routine tests with cosmics have been producing a lot of useful data, consistent with each other.
- ⋆ The performance of the DT chambers and of the BTI for the first level trigger match the specifications for CMS in terms of efficiency and resolution, even for inclined tracks and with the expected magnetic field.
- ⋆ We look forward to see high P_t muons from pp interactions, hopefully opening new horizons to our microcosm.