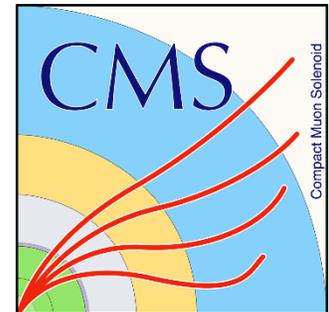


# R&D of a new type of micropattern gaseous detector: the Fast Timing Micropattern detector

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<sup>1</sup>Università & INFN Pavia



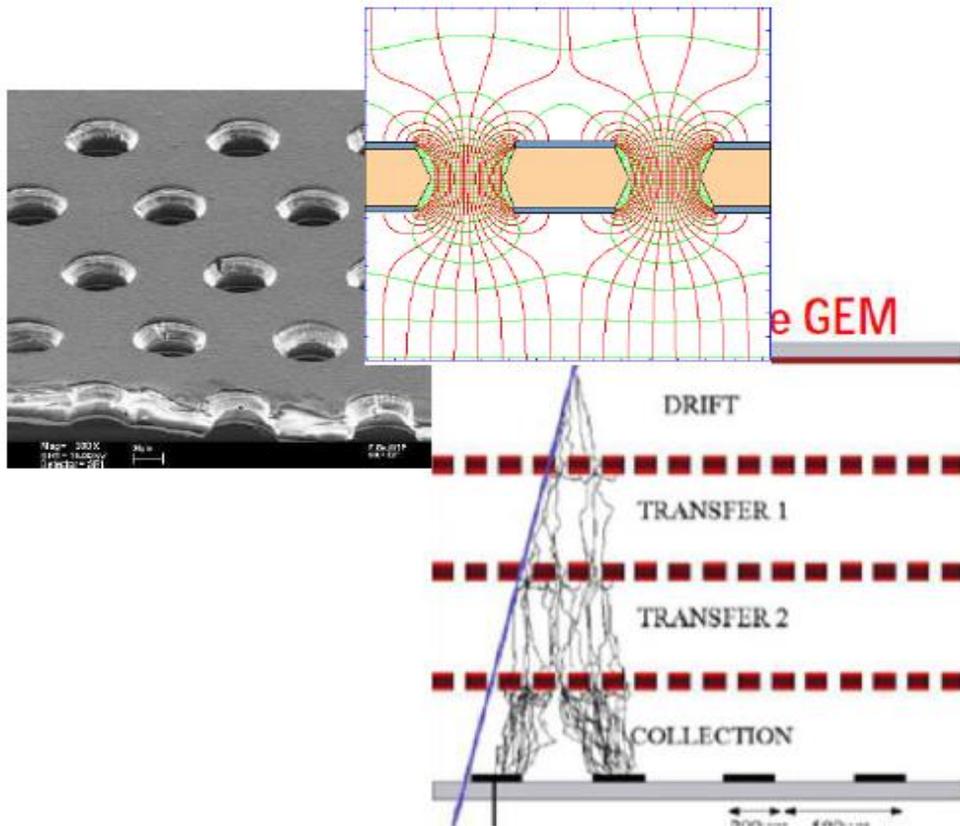
*Vienna Conference on Instrumentation 2016*

# Outline

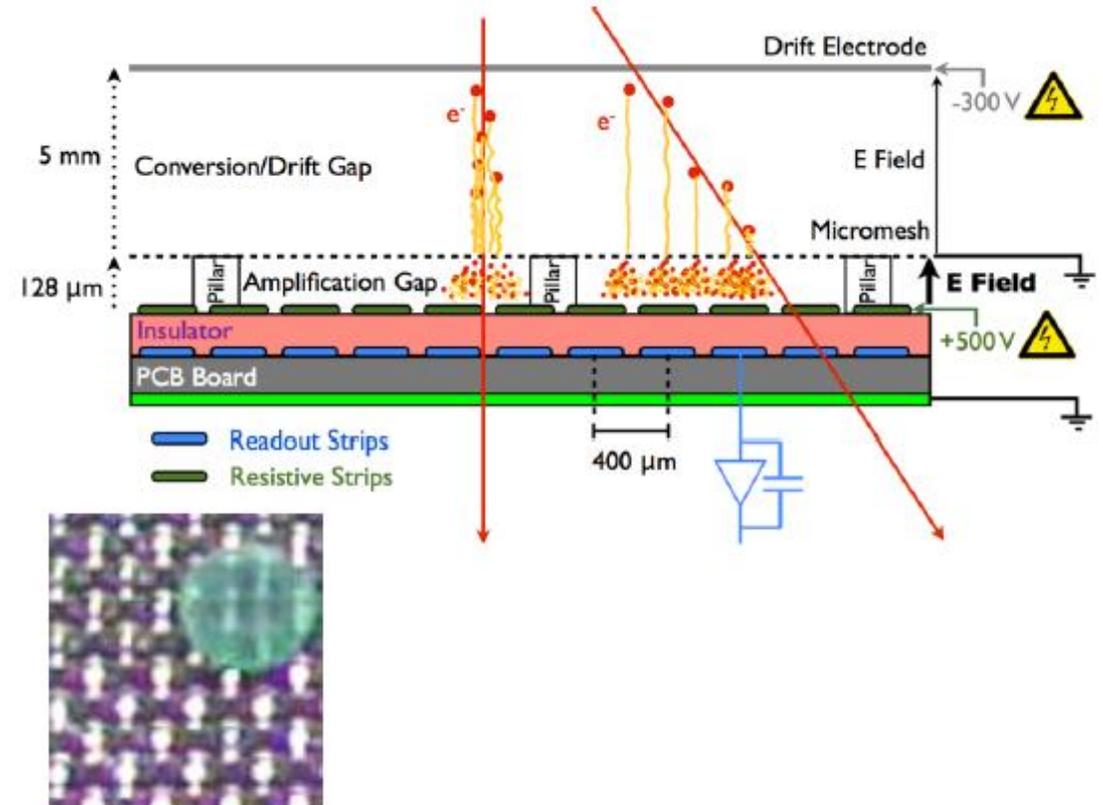
- Time resolution in MPGD
- The Fast Timing Micropattern (FTM) detector
  - Structure and working principle
  - Characterization results
  - Results from test beam
- Application in high energy physics experiments: the CMS muon system upgrade and the ME0 station
- Summary

# Classical MPGD: GEM and Micromegas

## Gas Electron Multiplier (GEM)

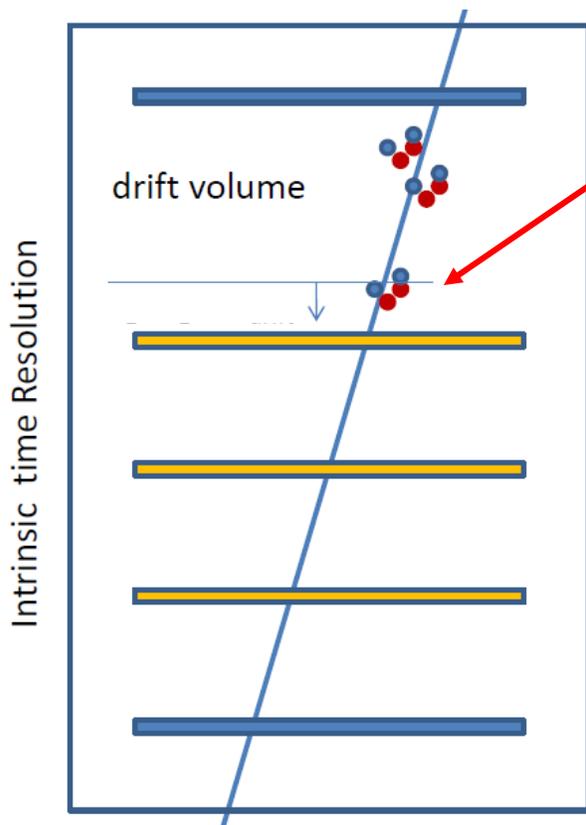


## Micromegas



# Time resolution in MPGD

Let's consider for example a GEM:



$d$  is the distance of the closest cluster to the first foil and it follows the distribution  $e^{-\lambda x}/\lambda$ , where  $\lambda$  is the average number of primary clusters generated by an ionising particle inside the gas per unit length

$v_d$  is the drift velocity, that depends on the gas mixture and the drift field applied.

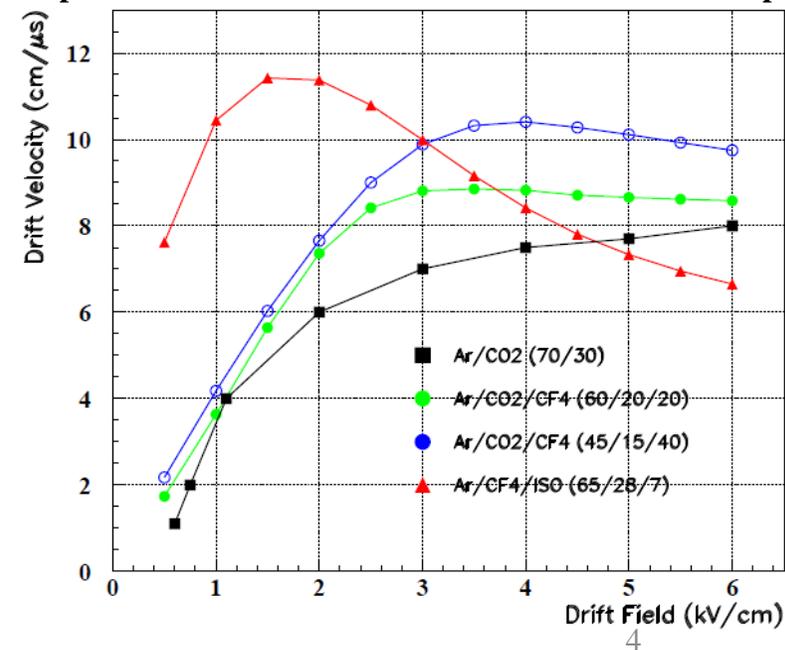
The **contribution** to the time resolution of the **drift velocity** is:

$$\sigma_t = (\lambda v_d)^{-1}$$

With a drift gap of the order of 3-4 mm and with a proper choice of the gas mixture, these detectors can reach a time resolution of the order of **5-10 ns**.

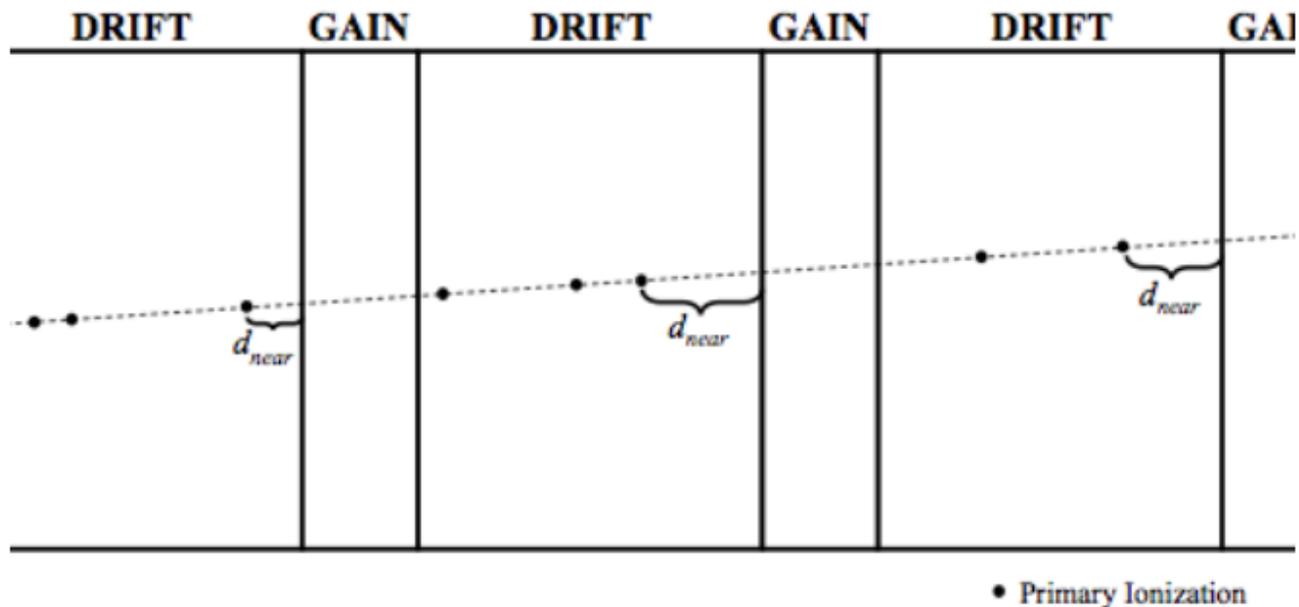
*Simulated drift velocity for different gas mixtures.*

<https://cds.cern.ch/record/940631/files/thesis-2006-013.pdf>



The same considerations are valid also for MicroMegas detectors.

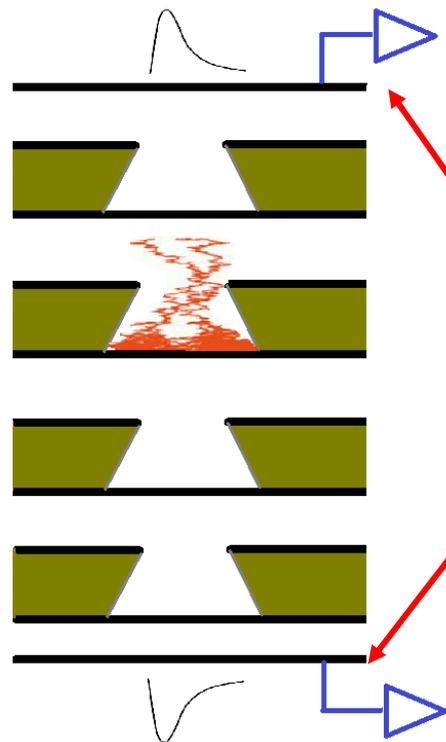
# Improving time resolution...



The idea is to divide a single thick drift region in many thinner drift regions, each coupled to its amplification stage.

The reduction in time resolution is **proportional to the number of stages  $N_D$  employed:**

$$\sigma_t = (\lambda v_d N_D)^{-1}$$



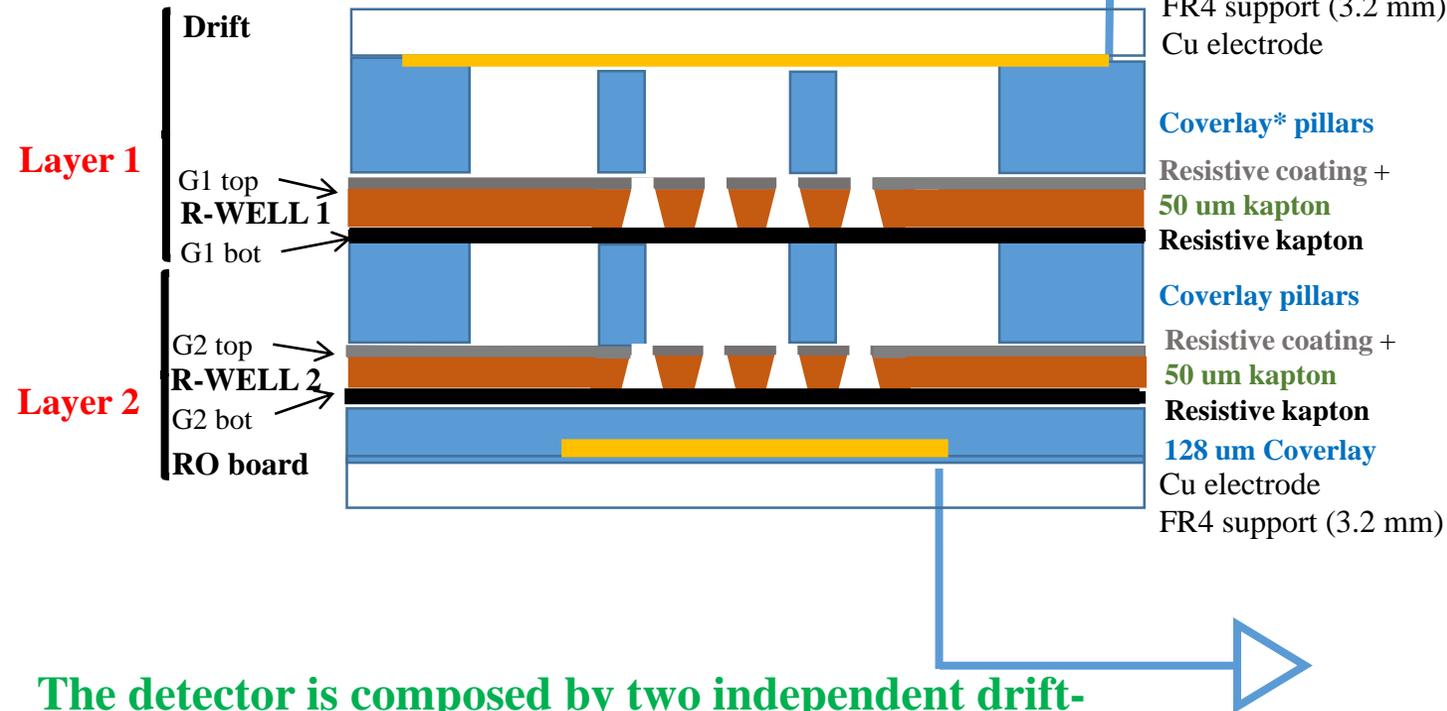
When the avalanche grows in one drift-amplification stage, the signal is induced on the top and bottom readouts.

The **first prototype of Fast Timing Micropattern (FTM) detector** exploits this principle using two 250  $\mu\text{m}$ -thick drift gaps, each coupled with an amplification region composed by a fully resistive WELL.

The construction of consecutive drift-amplification stages is allowed by the use of resistive layers to polarize drift and multiplication volumes. The overall structure is then transparent to the signal, that can be extracted at every amplification stage.

# The Fast Timing Micropattern detector (FTM) – First prototype

## Transversal view



The detector is composed by two independent drift-amplification stages (Layer 1 & 2 in the picture above).

Each amplification region is based on *a pair of polyimide foils* stacked due to the electrostatic force induced by the polarization of the foils:

- The first foil, perforated with inverted truncated-cone-shaped holes (bases 100  $\mu\text{m}$  and 70  $\mu\text{m}$ , pitch 140  $\mu\text{m}$ ), is a 50  $\mu\text{m}$  thick Apical KANECA, coated with diamond-like carbon (DLC) technique, to reach up to 800  $\text{M}\Omega/\square$  resistivity.
- The second foil is 25  $\mu\text{m}$  thick XC Dupont Kapton, with a resistivity of 2  $\text{M}\Omega/\square$ .

The *drift volumes are 250  $\mu\text{m}$  thick*, with planarity ensured by coverlay pillars, with diameter 400  $\mu\text{m}$  and pitch of  $\sim 3.3$  mm.

The active area (circular) is about 20  $\text{cm}^2$ .

\***Coverlay:** acrylic-based material used as spacer and for insulation.

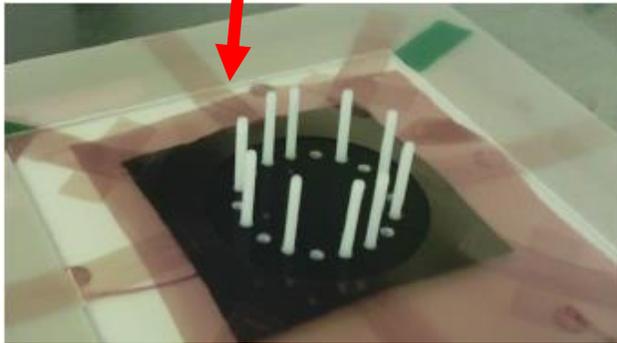
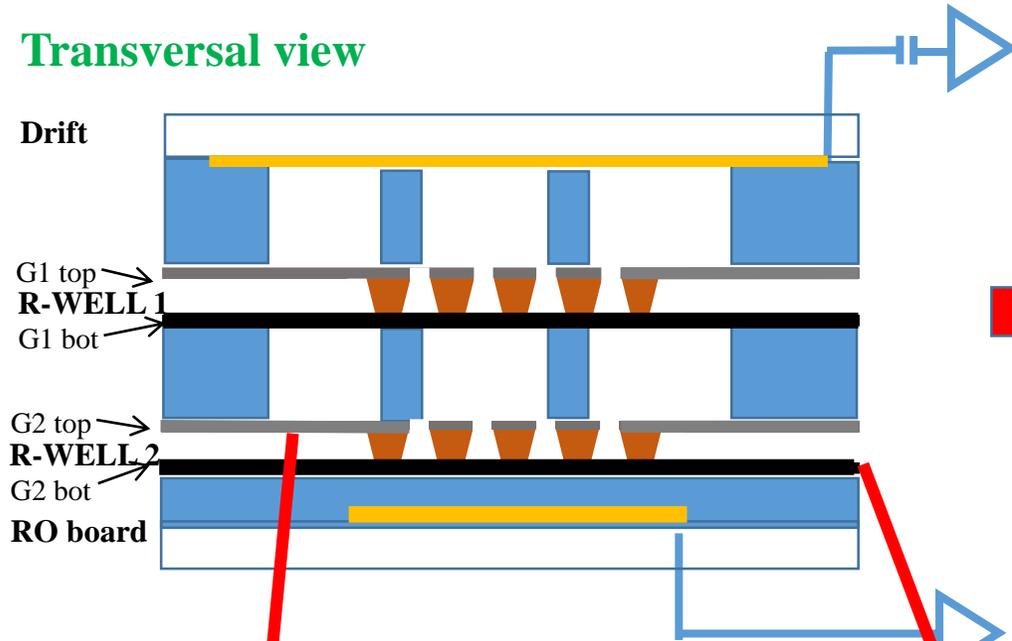
Reference: [arXiv:1503.05330v1](https://arxiv.org/abs/1503.05330v1)

European Patent Application 14200153.6

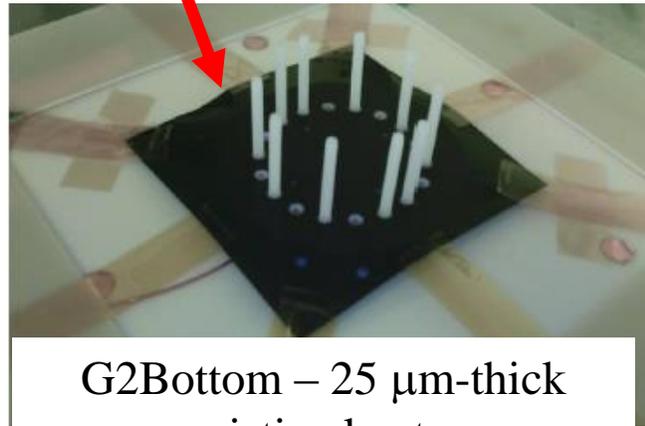
M. Maggi, A. Sharma, R. De Oliveira

# Some pictures of the assembly

## Transversal view

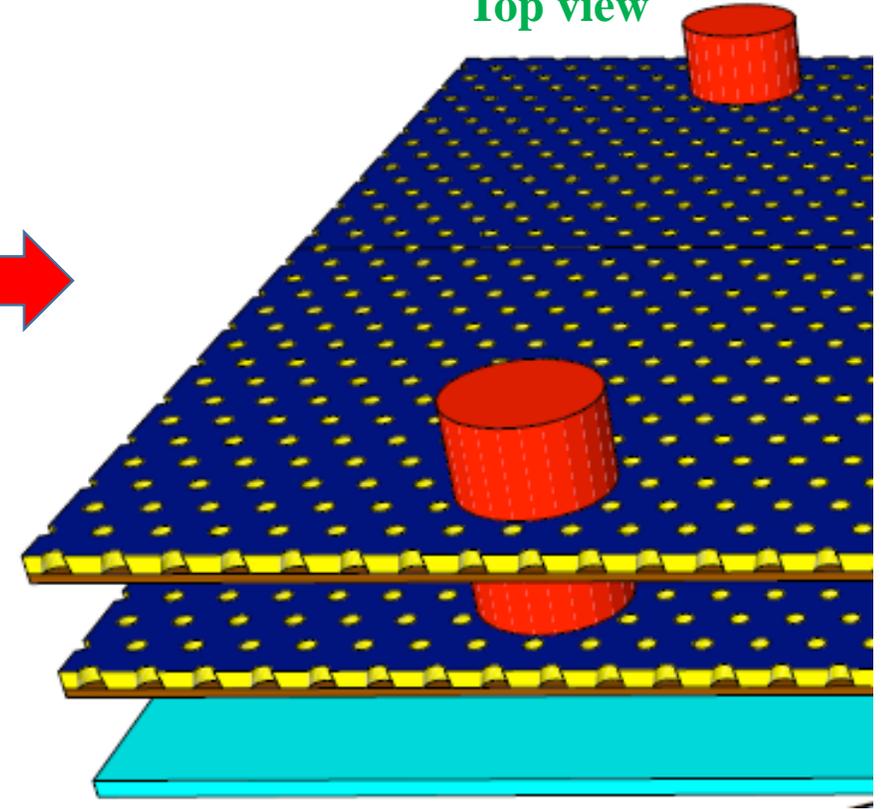


G2Top – resistive coated 50 μm-thick kapton



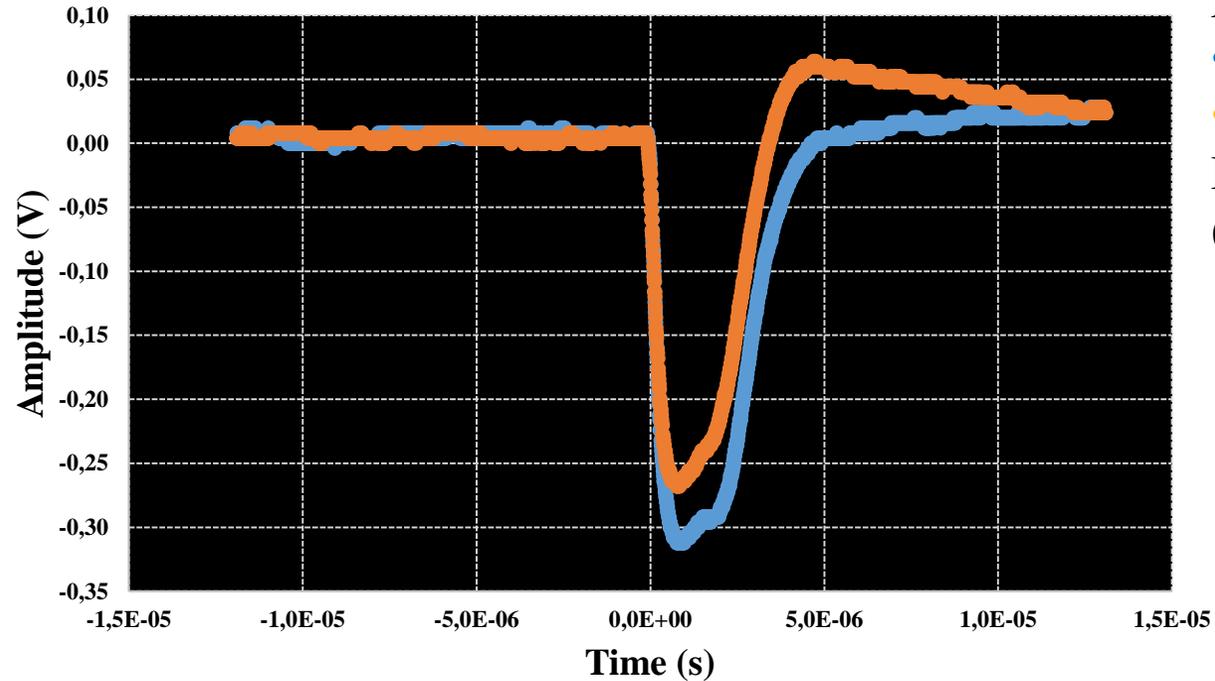
G2Bottom – 25 μm-thick resistive kapton

## Top view



- **DLC coating on the top**
- **Chemical etched kapton foils (50 μm)**
- **Resistive kapton foils (25 μm)**
- Two layers separated by **Pillars**
- **Pick-up electrode**

# Lab characterization: linearity and electrical transparency



Example of signals from:

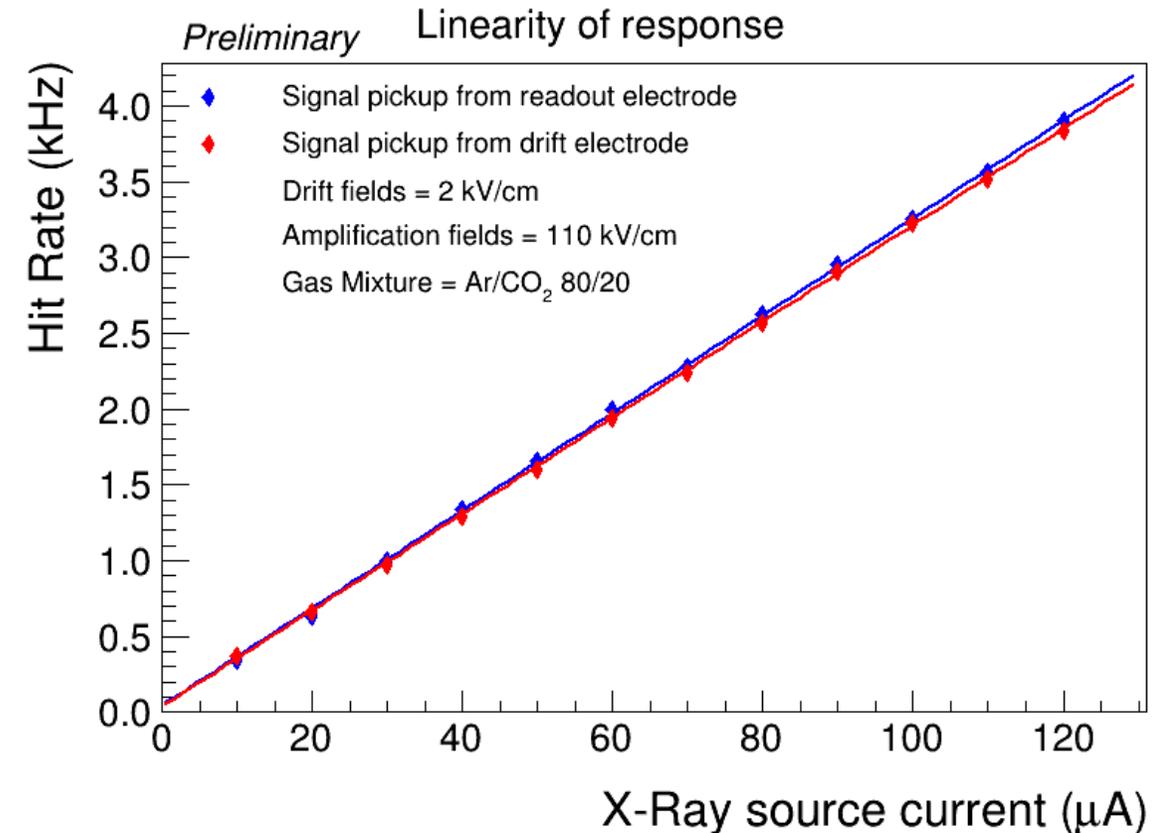
- *Readout electrode*
- *Drift electrode (inverted)*

Both the signals are read with a preamplifier Ortec 142PC (x40000) and an amplifier Ortec 474 (x20)

The rates measured from the readout and the drift electrodes are increasing proportionally with the flux. In addition the two datasets are compatible →

- The detector response is *linear* with the flux
- The detector is *electrically transparent*

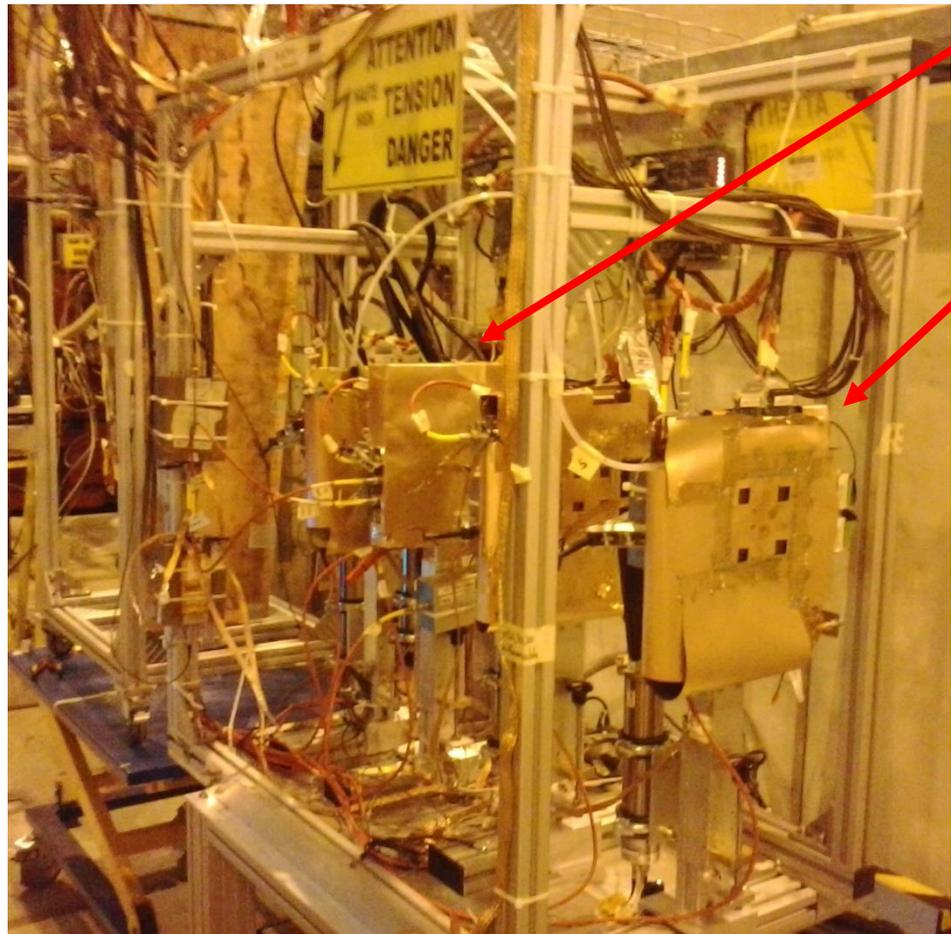
The source used is a Mini-Xray Amptek with Ag cathode.



# Test Beam: installation at SPS

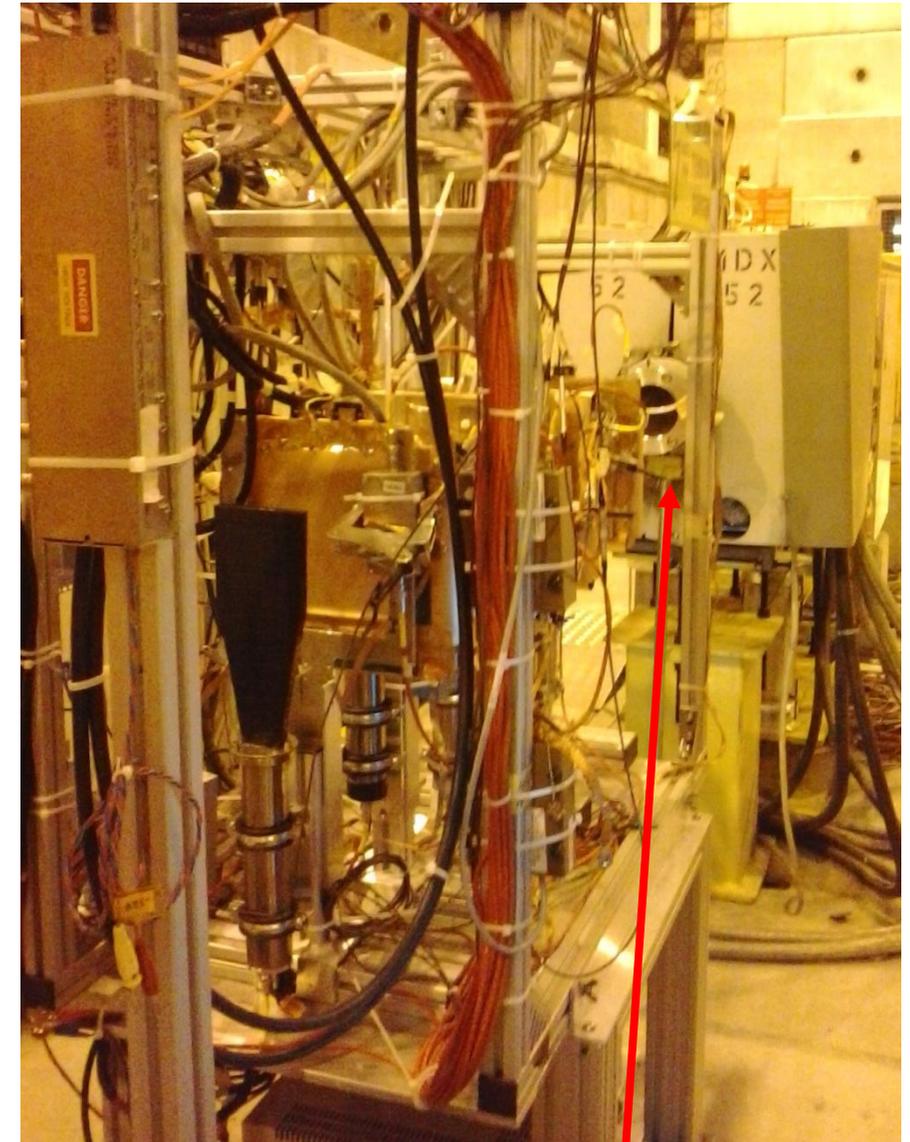
The used stand housed:

- The FTM detector
- 4 scintillators, including one finger scintillator, for triggering
- 3 GEMs 10x10 cm<sup>2</sup> for beam alignment



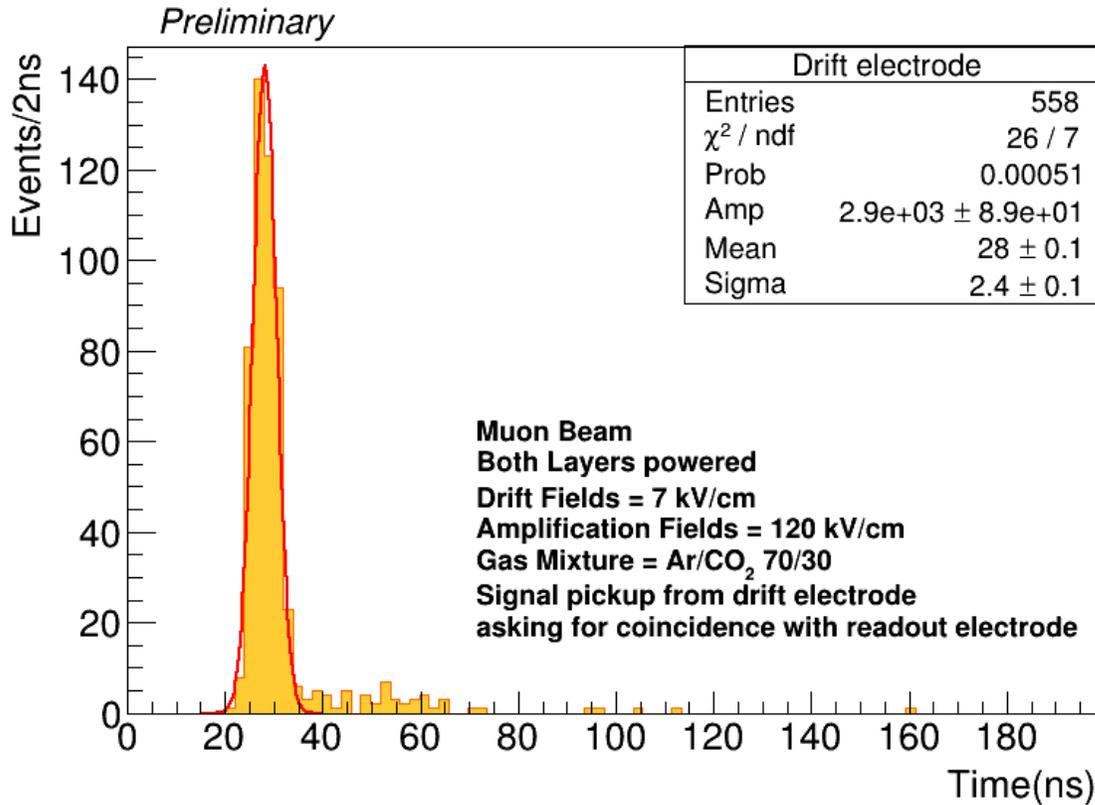
FTM

GEMs for alignment



Beam line 9

# Timing results

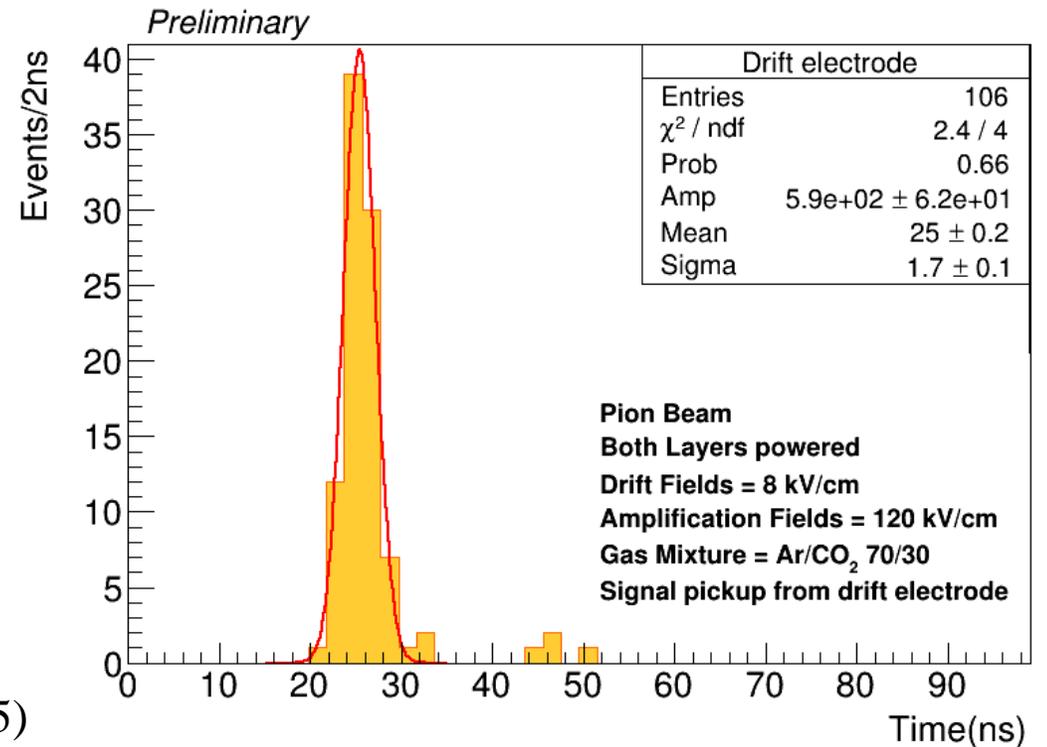


The time resolution is estimated from the *sigma of the gaussian fit* of the distribution.

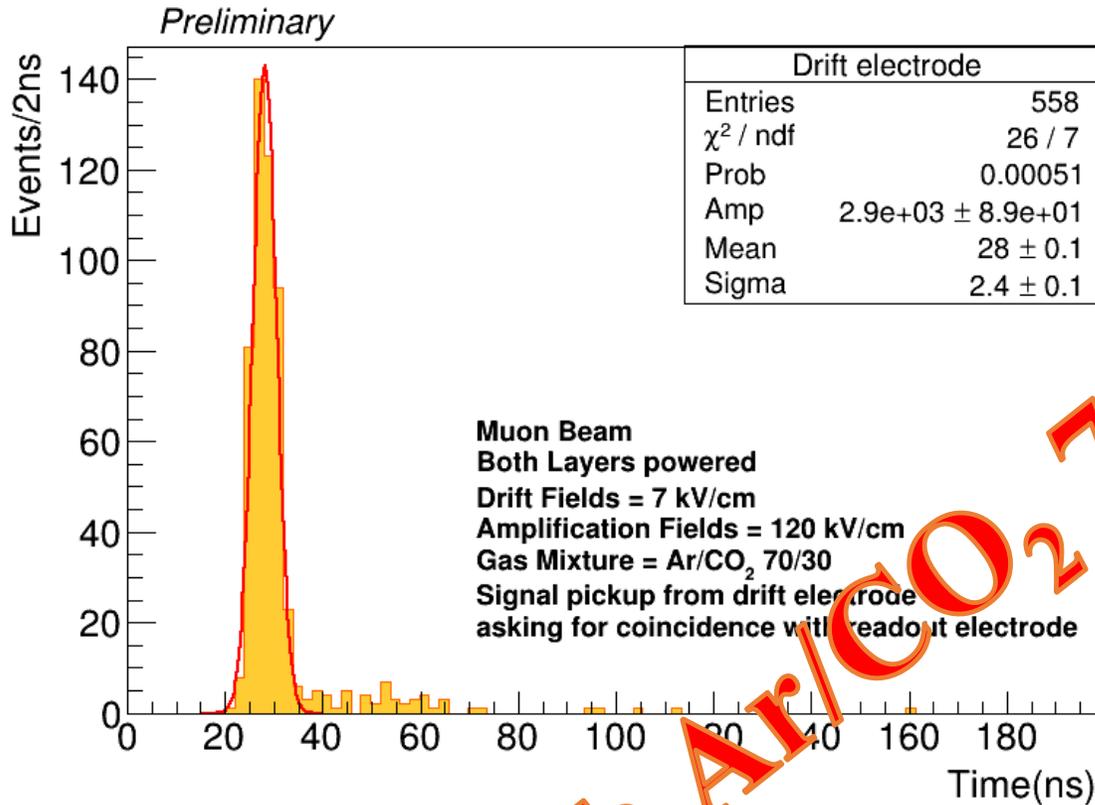
The electronics chain used to readout the signals was composed by a Cividec broadband amplifier (x100) and a Lecroy linear amplifier (x7.5)  
→ **Different electronics from lab test**: faster for timing measurement!

The test beam was focused on the estimation of the *time resolution* of the detector.

The plots show the time distribution of the signal pickup from the drift electrode, with *muon beam (top left)* and *pion beam (bottom right)*.

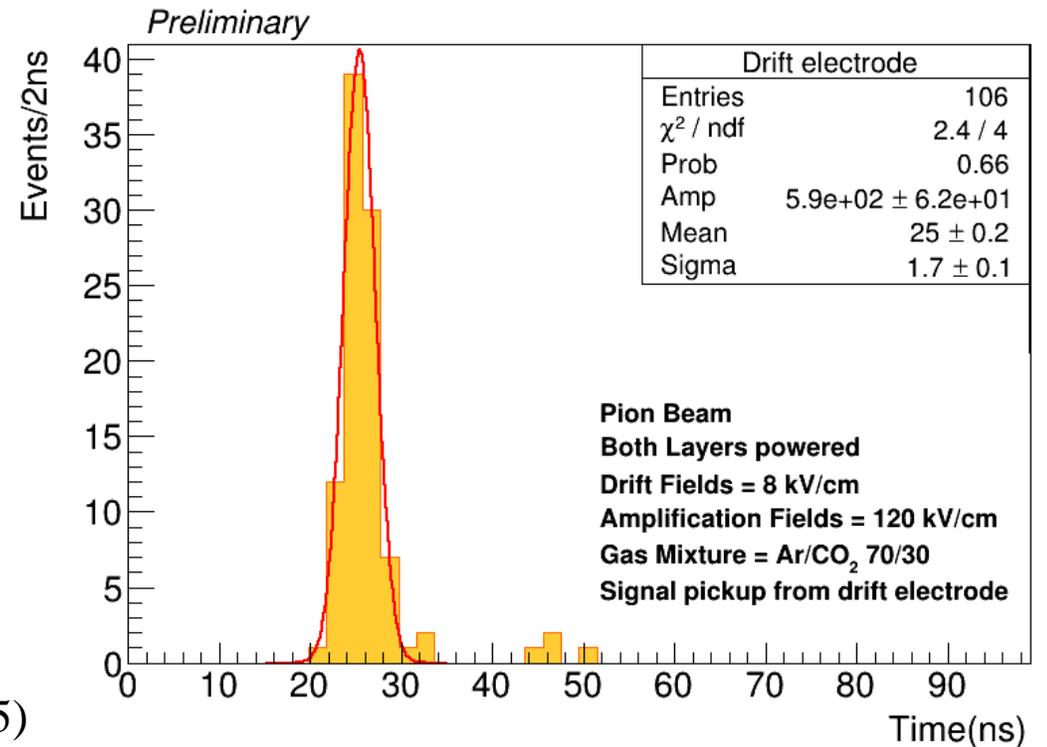


# Timing results



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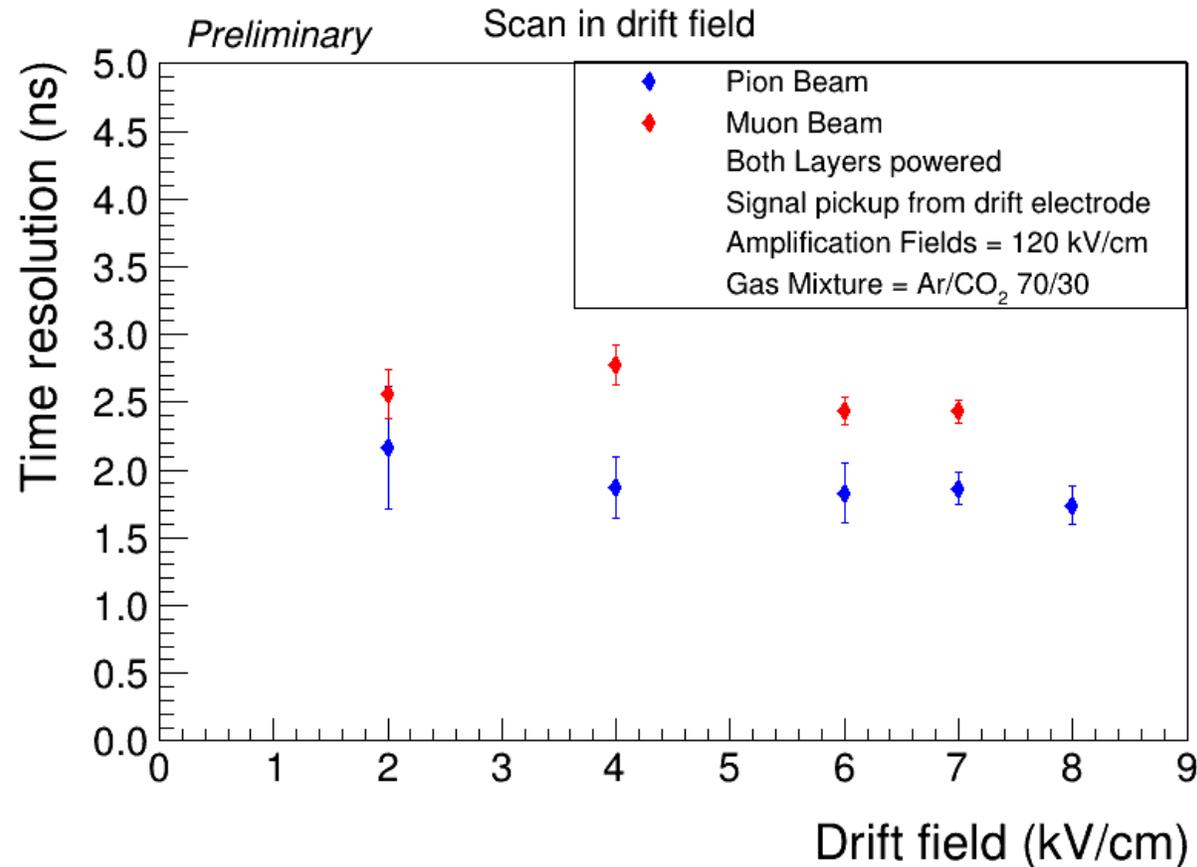
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The electronics chain used to readout the signals was composed by a Cividec broadband amplifier (x100) and a Lecroy linear amplifier (x7.5)  
→ **Different electronics from lab test**: faster for timing measurement!

# Time resolution at different drift fields



The time resolution has been evaluated at *different values of applied drift field*, keeping constant the amplification field, with both muon and pion beams.

The time resolution of the detector seems to be *not affected by a change in drift field*, why?

- ✓ The two drift regions are only *250 μm deep* → even with a very low drift field, the time used by electrons to cross the drift region is very short.
- ✓ The *drift velocity* for Ar/CO<sub>2</sub> 70/30 mixture can be considered *almost constant*, with variations of the order of 5%, for drift fields between 2 and 10 kV/cm.

From slide 5,  $\sigma_t = (\lambda v_d N_D)^{-1}$ :

with  $\lambda \sim 33 \text{ cm}^{-1}$  (for a mip),  $v_d \sim 8 \text{ cm}/\mu\text{s}$ ,  $N_D = 2 \rightarrow \sigma_t \sim 1.9 \text{ ns}$

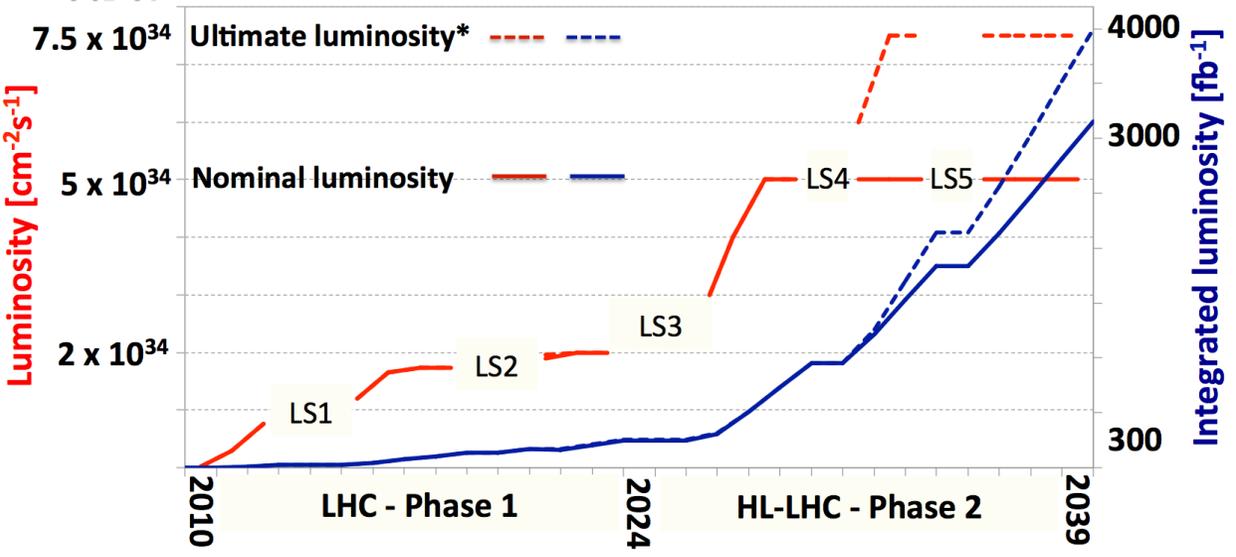
Good agreement with the expectations

The time resolution measured with pions is 0.5 ns lower than the one measured with muons → pions deposit a bigger charge in the detector due to showering → possible effect on the time resolution

# Application in high energy physics experiment: the CMS muon system in HL-LHC

During HL-LHC the flux through the detectors will greatly exceed that in previous running → *how to keep the same performance of Run 1?*

*Let's focus on the muon system...*

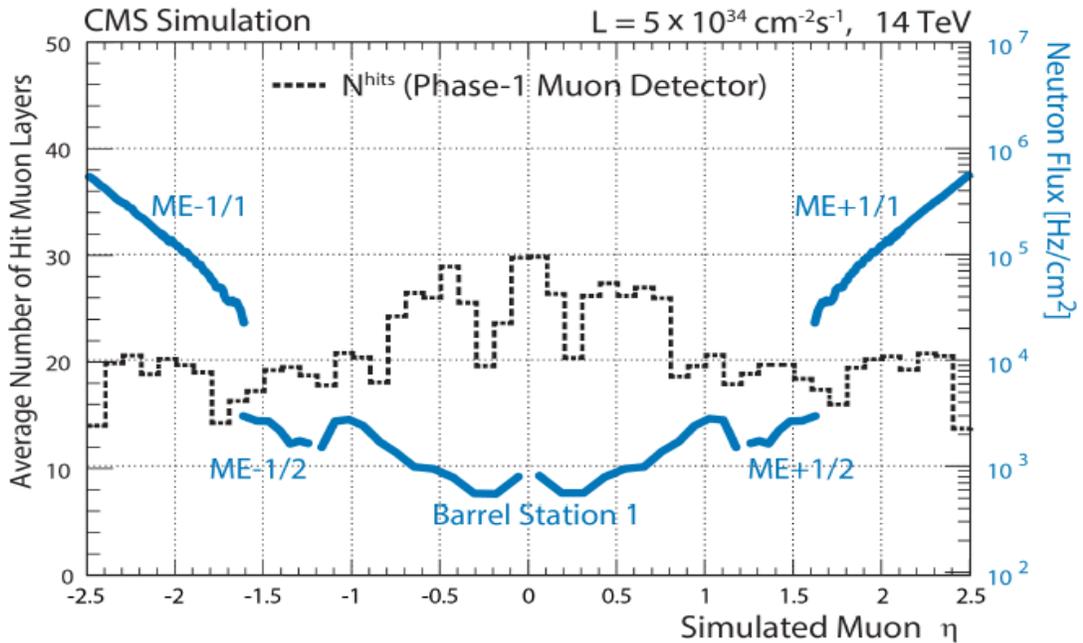


## Challenges of the high η region (η > 1.6)

- **Redundancy**: this is the muon system region with the highest rates but the fewest muon layers.
- **Rate**: is increasing towards higher η, where there is also the worst momentum resolution.

...but also

- **Detector longevity**: after years of LHC operation the accumulated charge will reach values of the order of C/cm<sup>2</sup>
- **Electronics longevity**: the existing electronics is not able to handle these high occupancies/rates and latencies (DT-CSC upgrades).



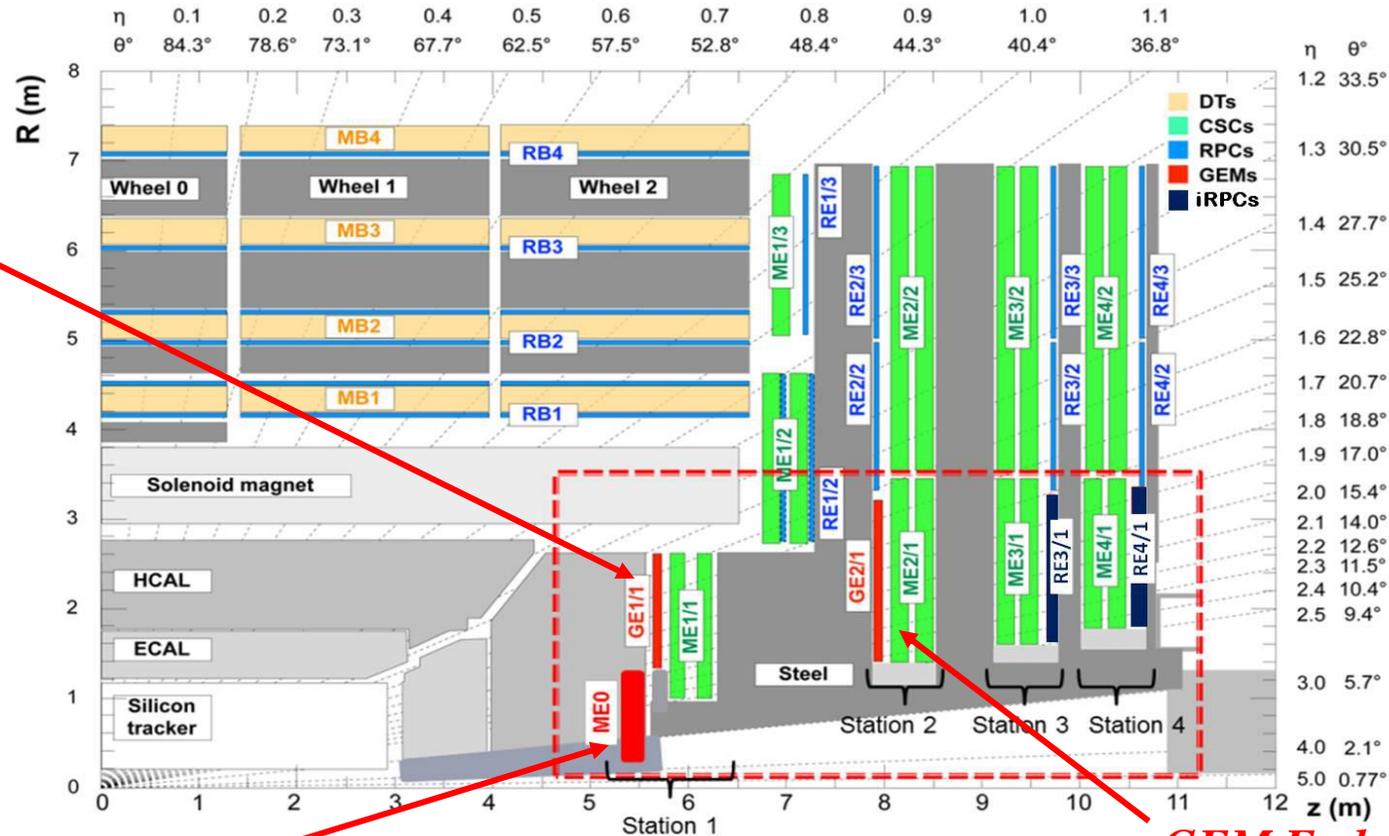
# The high $\eta$ region upgrade with MPGD for Phase 2

See the poster “[Overview of large-area gas electron multiplier detectors for the forward muon system of the CMS experiment at the high-luminosity LHC](#)” by J. Sturdy for an overview of the CMS GEM upgrade.

**GEM Endcap GE1/1:**  
station to be installed in  
LS2,  $1.6 < |\eta| < 2.2 \rightarrow$   
*GEM technology*

**Muon Endcap ME0:** station  
proposed for LS3,  $\eta < 3.8 \rightarrow$  2  
technologies under  
consideration:

- *GEM*: GE1/1-like station,  
with more layers to reject  
background - Baseline
- *FTM* - Option



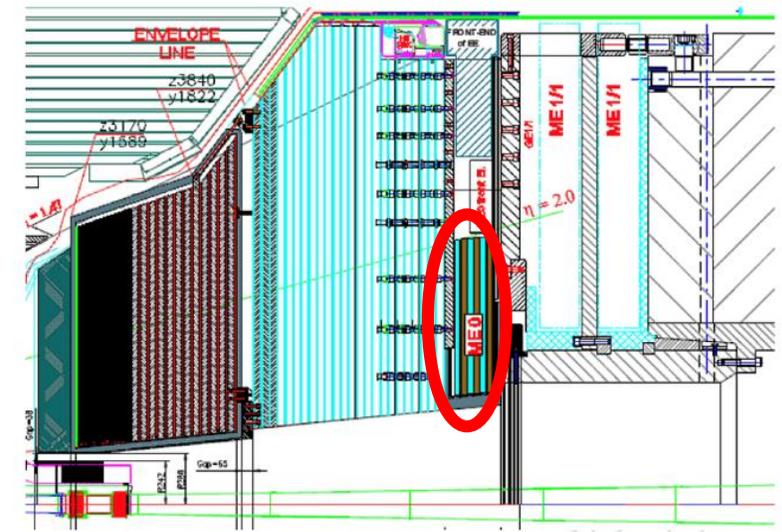
**GEM Endcap GE2/1:** station  
proposed for LS3,  $\eta < 2.4 \rightarrow$  2  
technologies considered:

- *GEM technology* - Baseline
- $\mu$ RWELL\* - Option

\*See the talk “Advances in micro-Resistive WELL ( $\mu$ -RWELL) detectors” by G.Bencivenni in this session.

# The ME0 station: challenges...

Increase the pseudorapidity coverage == **increase acceptance** up to  $|\eta| < 3$  and reducing background due to the “lost leptons” in many physics channels.

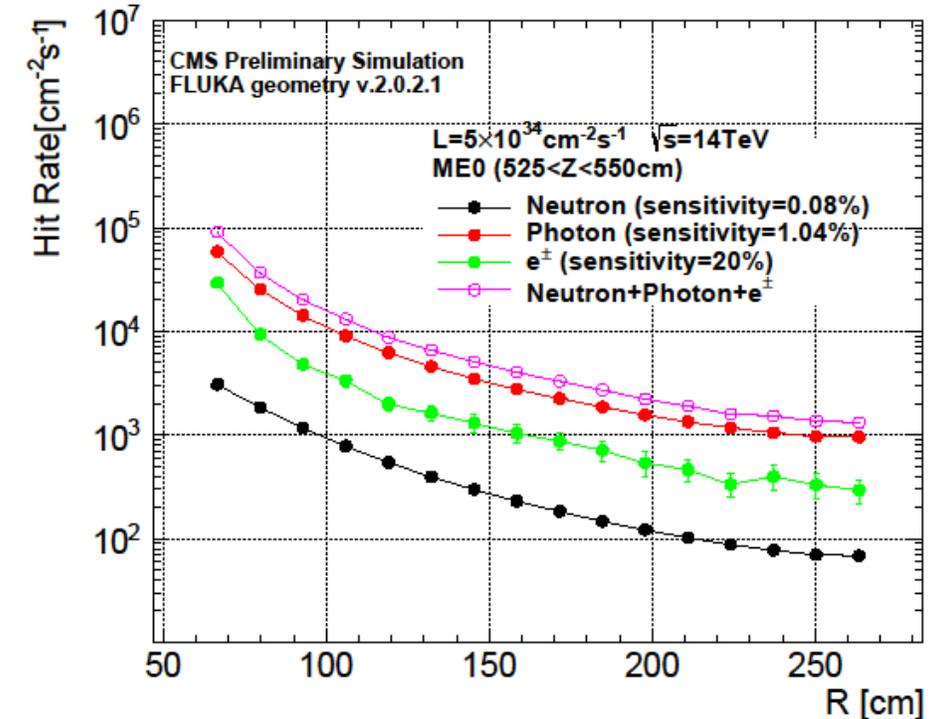
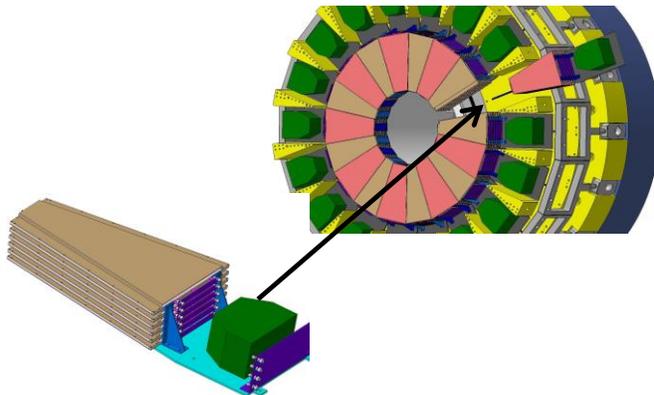


In addition, a new tracker will provide triggering up to  $|\eta| < 2.4 \rightarrow$  **ME0 should provide:**

- A **robust muon trigger** with low  $p_T$  threshold up to  $|\eta| < 2.4$  to match high-precision tracks.
- **Muon tagging** to tag muons.

...but, in which conditions?

- **Very high pile up:** 140-200  $\rightarrow$  large pile up background
- **Very high background:**  $\sim 100$  kHz/cm<sup>2</sup>



# ...and requirements

✓ **High granularity and spatial segmentation to allow:**

- $p_T$  assignment through  $\Delta\phi$  measurement
- Improvement of pile-up rejection

✓ **Multi-layered structure to allow:**

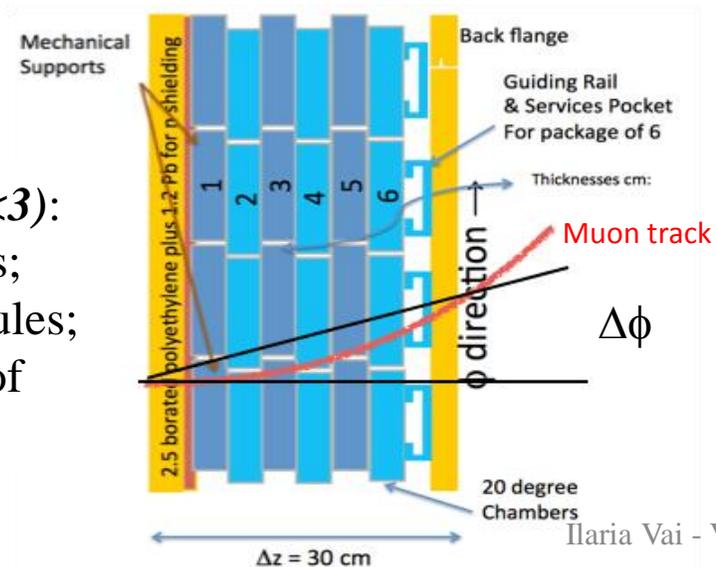
- Improvement of local muon track reconstruction
- Discrimination between muons (generating a segment) and neutrons (uncorrelated hits).

✓ **Timing to allow:**

- Object reconstruction
- Reduction of in-time PU and help in vertex association
- **Mitigation of part of the neutron background:** if detection location is known precisely, only small time windows are compatible with genuine muon hits from the interaction point. → **Need very good time resolution!**

**ME0 baseline layout ( $2 < |\eta| < 3$ ):**

- 216 triple-GEM chambers;
- Thirty-six  $20^\circ$  super-modules;
- each consists of 6 layers of triple GEMs.



Optional Proposal: new generation MPGD → **Fast Timing Micropattern (FTM) detector**

# Summary

This contribution introduces the first measurement performed on a new prototype of MPGD, the so-called *Fast Timing Micropattern (FTM) detector*.

The first prototype of this new detector proved to have a linear response to the rate and to be electrically transparent. The *time resolution* has been measured with muon and pion beams, obtaining a first estimation of the order of *1.5 – 2.5 ns*.

The detector is being considered for application in high energy physics experiments, like CMS. Indeed, the very high time resolution that can be reached by these prototypes makes the FTM a viable and interesting optional proposal for the instrumentation of the new muon stations proposed for LS3.

The R&D is ongoing with the design of a *new prototype fully PCB-based*, with at least 4 independent stages. In the next months additional *test beam* periods at the SPS and with high gamma background at the *GIF++ facility* at CERN are planned, in order to deepen our knowledge of the technology, with estimations of time resolution, efficiency and spatial resolution.

Thanks for your attention!