University of Athens

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The ATLAS experiment

The ATLAS Muon Micromegas R&D project

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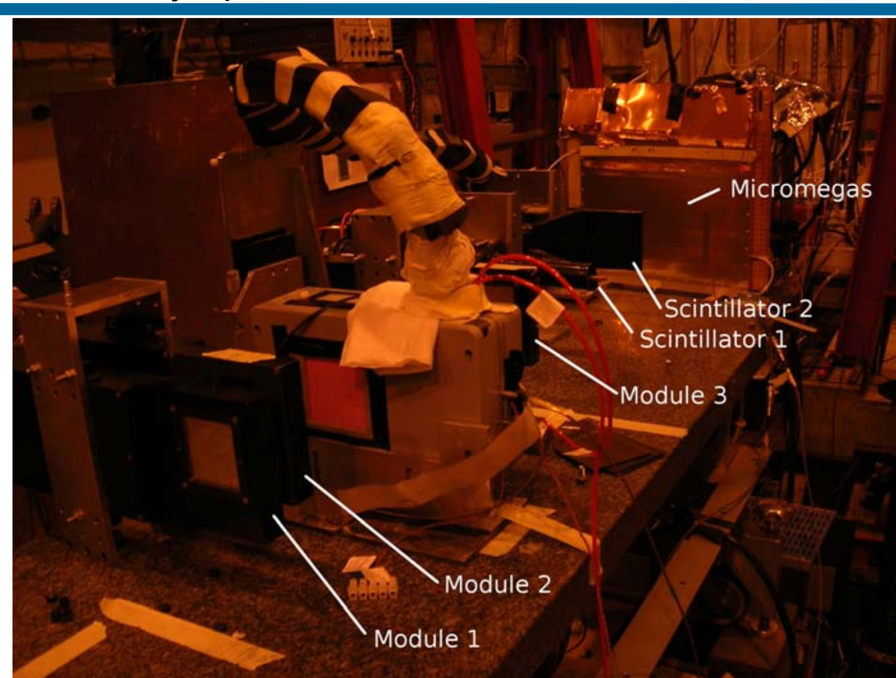
On behalf of the **M**uon **A**TLAS **M**icro**M**egas **A**ctivity

1st International Conference on Micro Pattern Gas Detectors
Kolympari, Greece, 12 -15 June 2009



ATLAS at LHC and the super-LHC scope

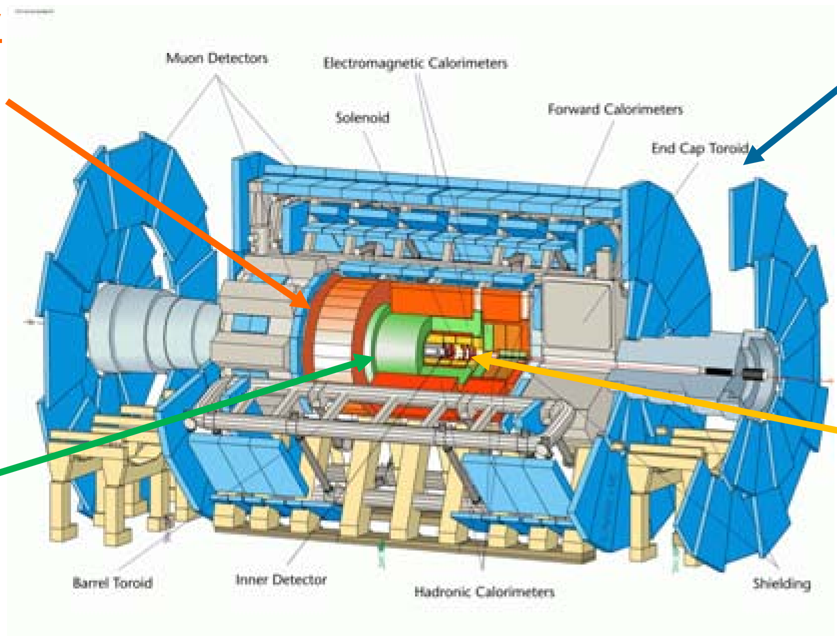
General purpose detector : study pp collisions at 14 TeV with a luminosity $10^{34} cm^{-2} s^{-1}$

→ aiming primarily to probe the source of the Electro-Weak Symmetry Breaking

Hadron Calorimetry

Fe/Sci + Cu/LAr

$\sigma/E \sim 60\%/\sqrt{E} \oplus 3\%$



E/M Calorimetry

Pb/LAr

$\sigma/E \sim 10\%/\sqrt{E}$

Muon Spectrometer

Air-core toroids,

Precision and Trigger chambers

P_T resolution:

~10% at P_T = 1 TeV (standalone)

~2.3% at P_T = 50 GeV (with InDet)

Inner Detector

2 T solenoid

Si Pixels and Strips

Transition Radiation Tracker

s-LHC to extend life-time of the accelerator, complete LHC's research program and bridge LHC with future activities (ILC? CLIC?) → moderate cost given LHC investment

Possible physics objectives: Higgs rare decays, couplings and Higgs potential,

if no Higgs → scattering of W and Zs

ATLAS upgrade for the s-LHC

LHC upgrade to happen in two phases

$L_{\text{Phase 1}} \sim 3\, L_{\text{LHC}}$ (~2014)

$L_{\text{Phase 2}} \sim 10\, L_{\text{LHC}}$ (s-LHC >2018)

Bunch Crossing = 25 ns / possibly 50 ns (Phase 2)

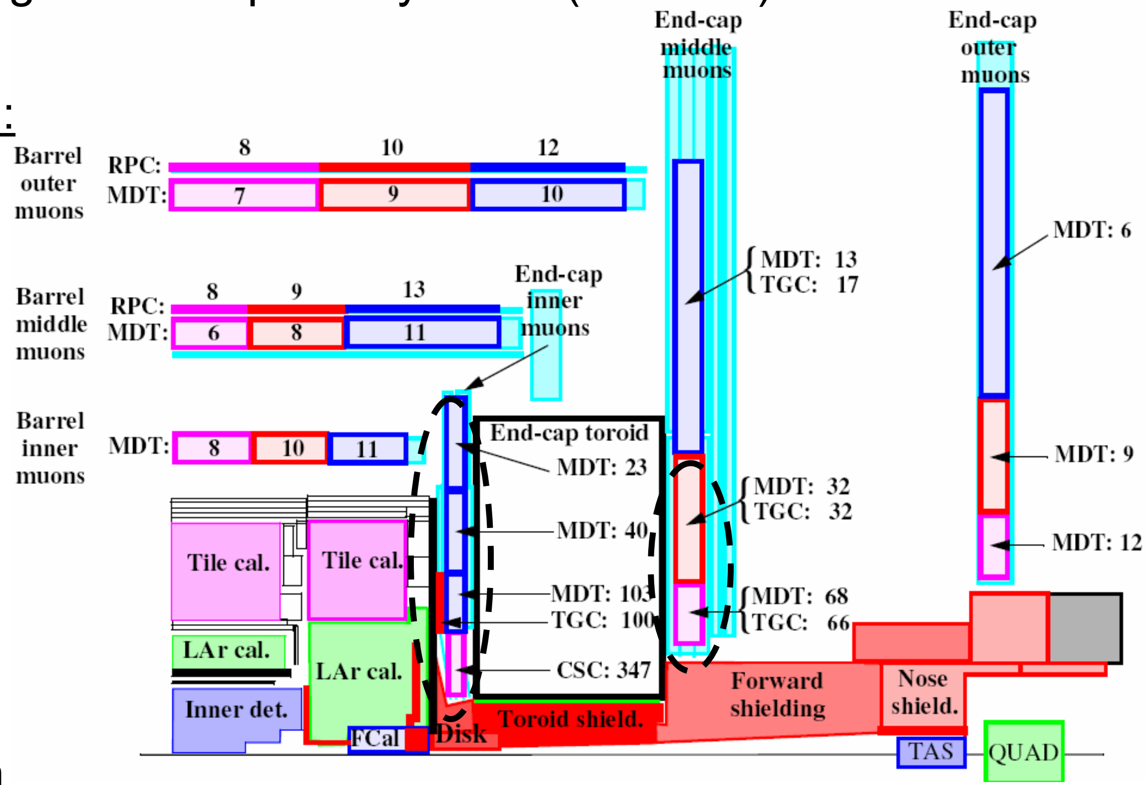
Muon Spectrometer affected regions :

- End-Cap Inner (CSC,MDT,TGC)
- End-Cap Middle |η|>2 (MDT,TGC)

Total area ~400 m^2

Phase I : augment the existing Cathode Strip Chambers

Counting rates to be measured with first LHC collisions → Reduce uncertainty



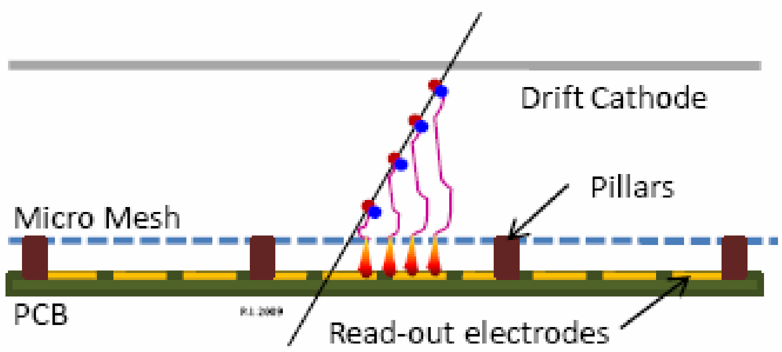
Average single plane counting rate (Hz/cm^2) at the nominal LHC luminosity (CERN-ATL-GEN-2005-001)

Requirements for the Muon System Upgrade

To meet goals of s-LHC

→ maintain good detector performance

- Operation in a **high counting rate** environment (>5 kHz/cm^2) including dense ionization
- High hit **reconstruction efficiency** (~98%)
- High **spatial resolution** (~100 μm) up to **large incident angles** (<45°)
- Good **time resolution** (~5 ns) to allow bunch crossing identification
- Good **two-track separation**



Bulk Micromegas promising technology for industrial production of large surface detectors (~1m x 2m)

- Cost effective
- Mechanically robust

→ Could provide both tracking and trigger

Aim : Study whether Micromegas solution suitable for such a large scale muon system

The MAMMA Collaboration

Arizona,

Athens (U, NTU, Demokritos),

Brookhaven, CERN,

Harvard, Istanbul (Bogaziçi, Doğuş),

Naples, CEA Saclay,

Seattle, USTC Hefei,

South Carolina, St. Petersburg,

Shandong, Stony Brook,

Thessaloniki

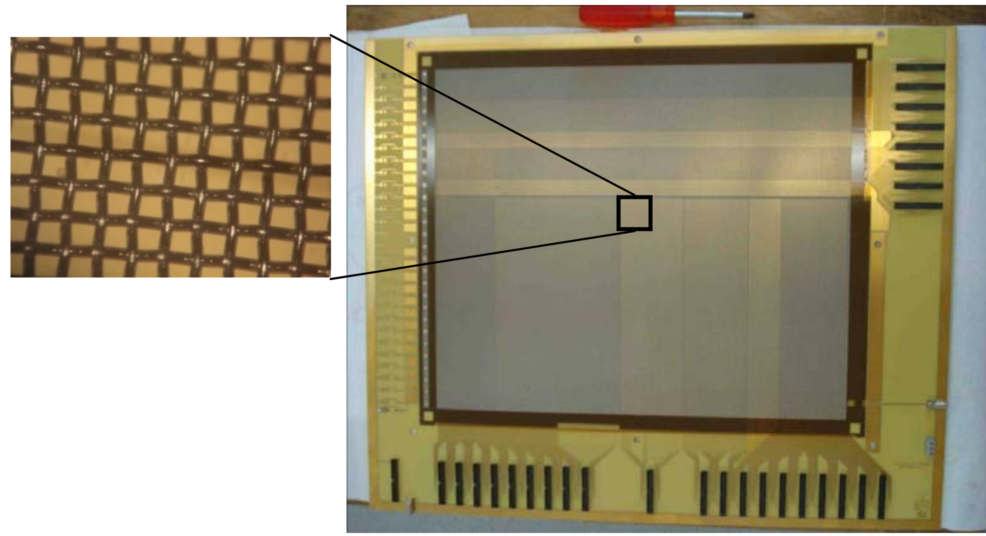
Interest in the project → Already 18 collaborating institutes

<u>Also part of RD51</u>

The first prototype (P1)

Standard bulk Micromegas fabricated at CERN in 2007

- Homogeneous stainless steel mesh
- 325 line/inch = 78.2 μm pitch
- Wire diameter ~25 μm
- Amplification gap ~ 128 μm
- 450 mm x 350 mm active area
- Different strip patterns
  250, 500, 1000, 2000 μm pitch
  450 mm and 225 mm long
- Drift gap : 2-7 mm



One of the largest Micromegas available at the time of its production

Read-out Electronics

Currently read-out based on ALTRO chip and ALICE DATE system.

<u>Operation parameters</u>

32 channels

200 ns integration time

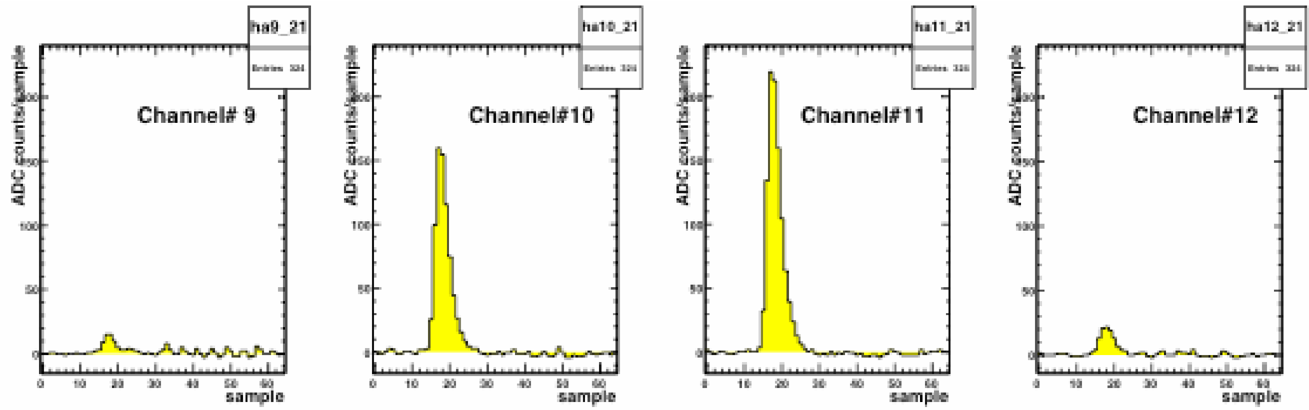
65 charge samples/ch

100 ns/sample

15 pre-samples

1 ADC count ~ 1000 e^-

No trigger time info recorded



<u>Requirements for the final read-out scheme</u>

Rate capability ~100 kHz

Peaking time in the 20 – 100 ns range

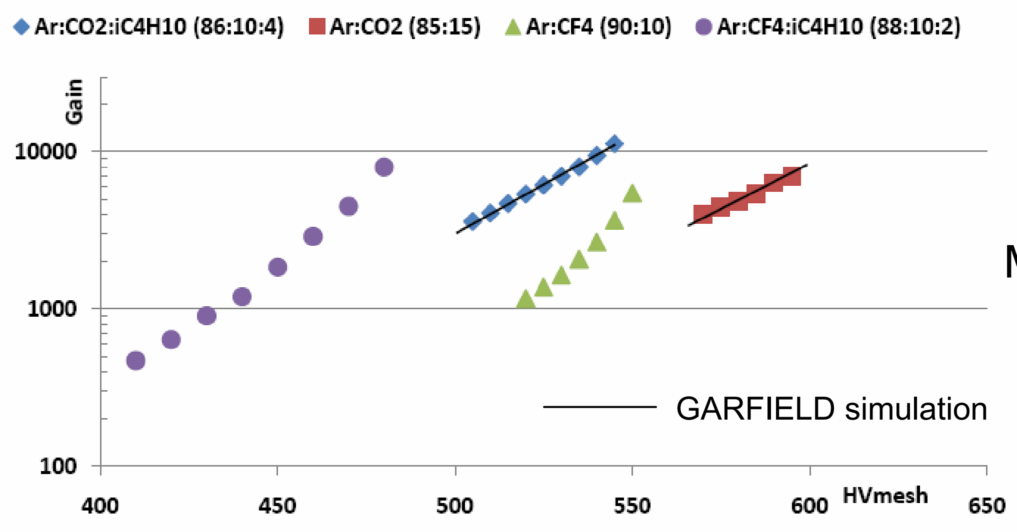
Time Resolution ~few ns

Charge Measurement Capability (likely 8 – 10 bit ADC)

Zero suppression (read-out link bandwidth limitations)

Radiation hardness / SEU tolerance

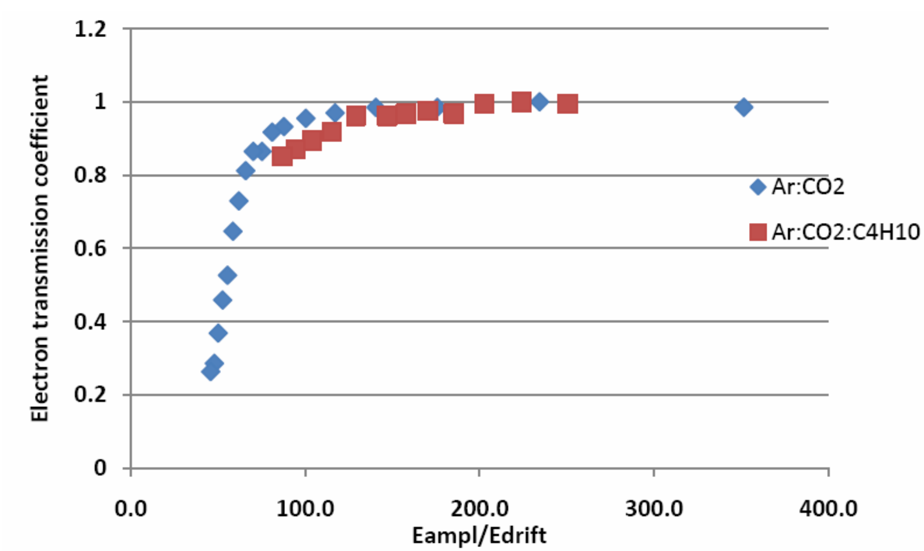
Laboratory tests on P1 with ^{55}Fe



Gas gain in the 10^3-10^4 region obtained without problems.

Measurements in agreement with simulation

Electron mesh transparency >95% for field ratio >150



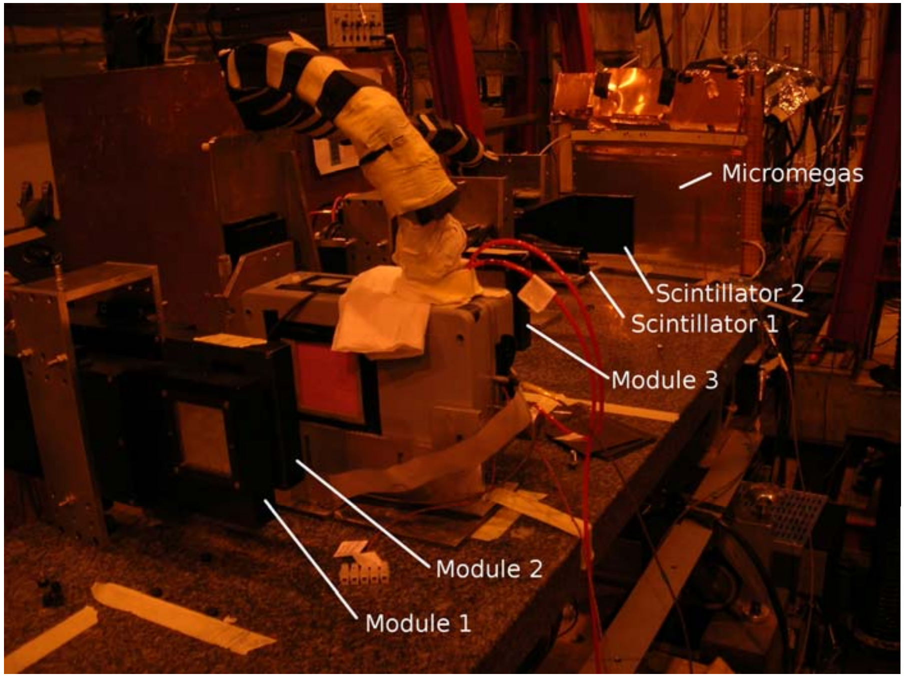
Test Beam : Summer 2008

CERN SPS beam line in 2008 using
120 GeV Pion beam

External tracking with three Si detector modules (Bonn Univ.)

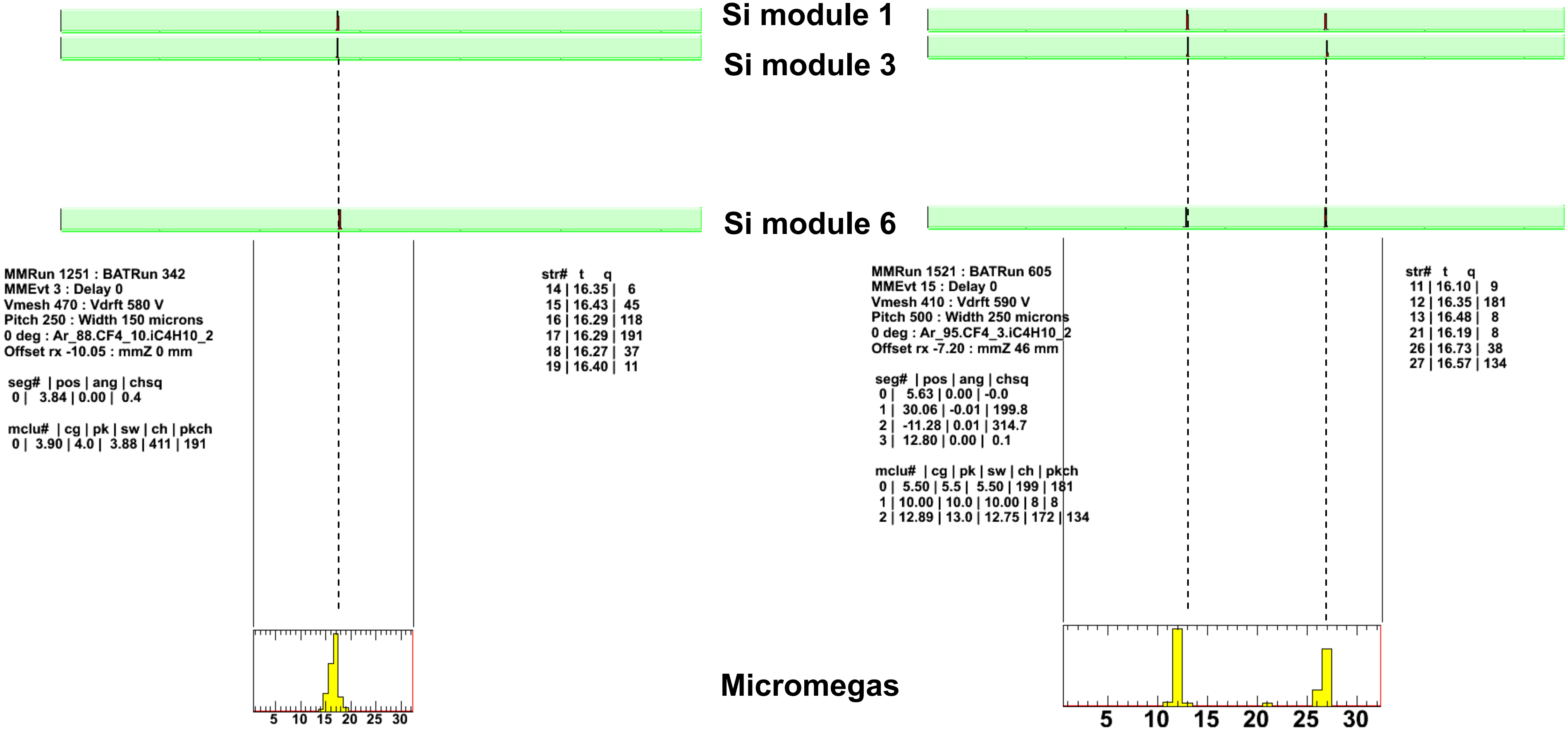
Three non-flammable gas mixtures with small iso-butane percentage:
$Ar:CO_2:iC_4H_{10}$ (88:10:2),
$Ar:CF_4:iC_4H_{10}$ (88:10:2),
$Ar:CF_4:iC_4H_{10}$ (95:3:2) ("T2K-gas")

Data acquired for different strip patterns and impact angles (0º to 40º)



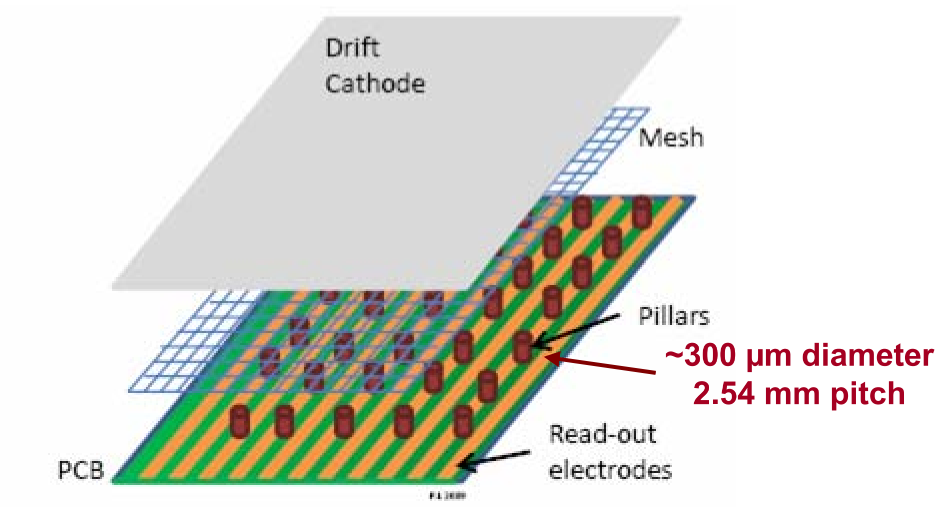
Event Display

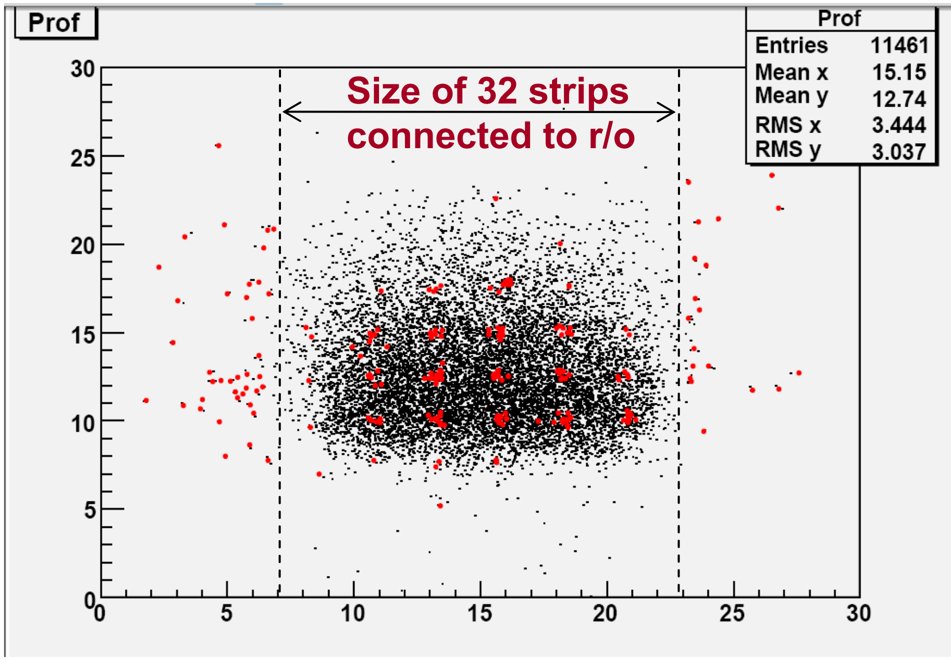
Single track event | Double track event



250 μm strips | 500 μm strips

“Geometrical” Efficiency





- Ar:CF_4:iC_4H_{10} (88:10:2)
- Strips: 500 μm pitch
- V_{mesh} = 450 V (35.2 kV/cm)
- Drift field = 200 V/cm

Black: beam profile

Red: tracks w/o Micromegas hit

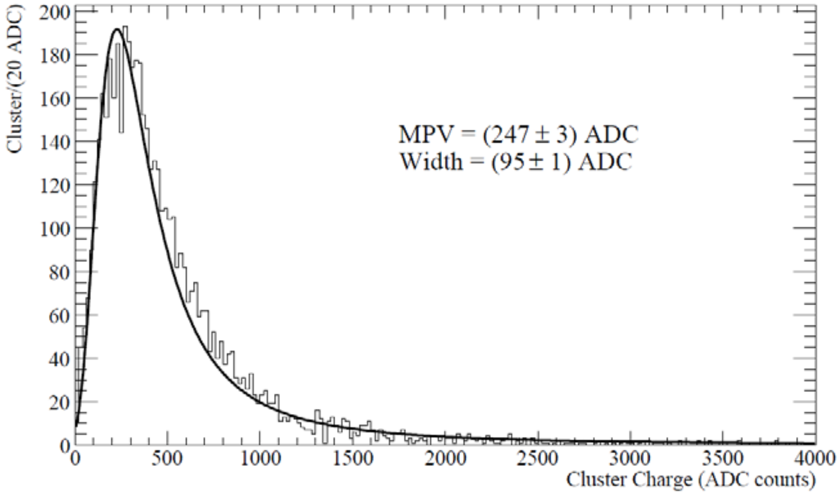
Pillars contribute to the geometrical inefficiency of the chamber at the ~1% level.

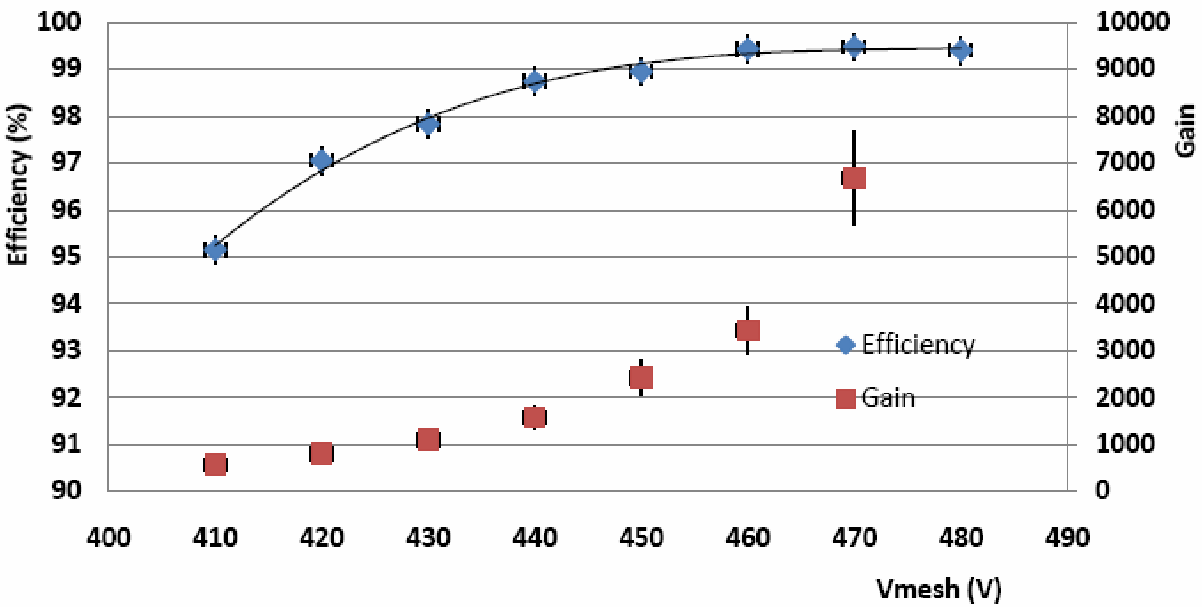
Efficiency Vs Amplification

$Ar:CF_4:iC_4H_{10}$ (88:10:2)

V_{mesh} = 470 V (36.7 kV/cm)

Drift field = 220 V/cm

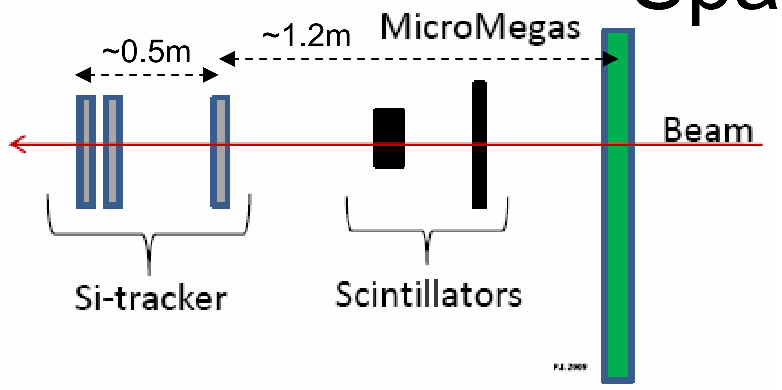




efficiency > 99%

for Gain > $3 \cdot 10^3$

Spatial Resolution



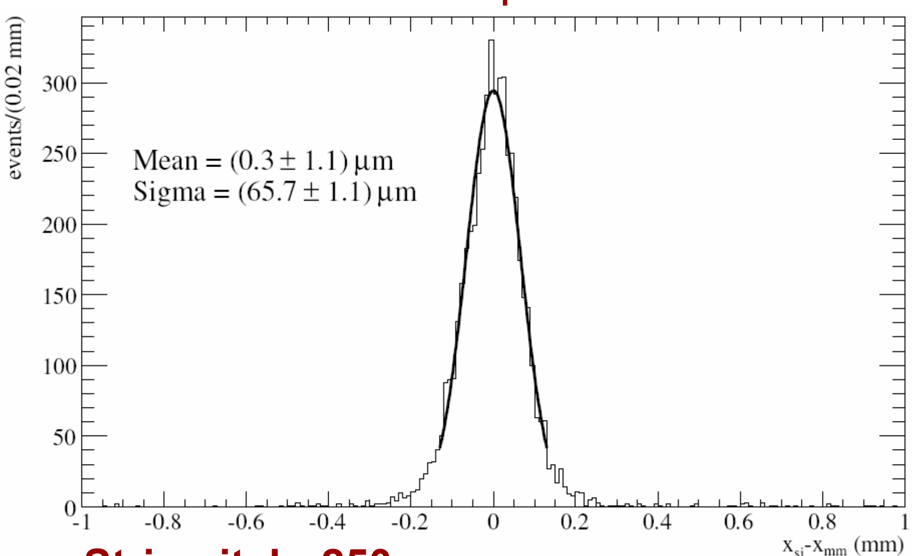
Residuals of MM cluster position and extrapolated track from Si.
Three contributions to width of distribution :

- –Si Telescope extrapolation @ μM → ~30 μm
- –Multiple scattering → ~53 μm
- –Intrinsic μM resolution

~61 μm

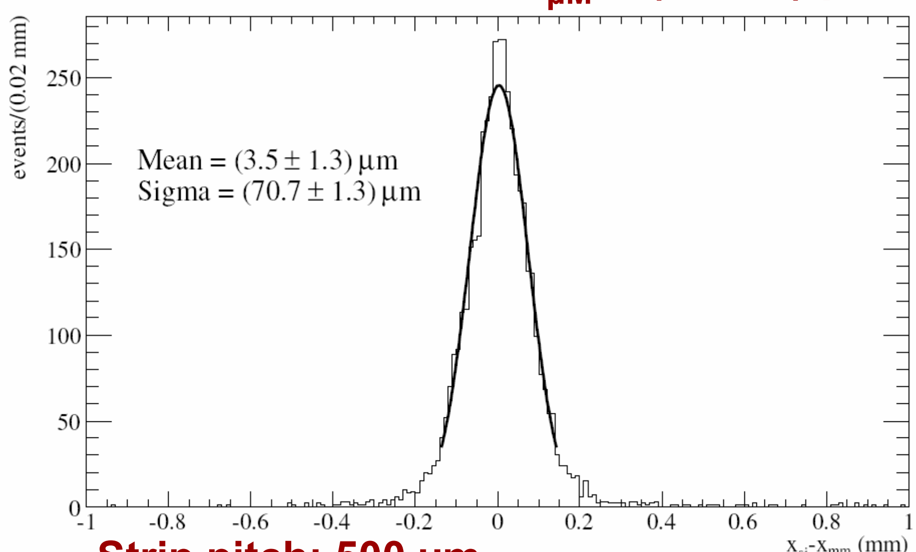
Gas: Ar:CF_4:iC_4H_{10} (88:10:2)
V_{mesh} = 470 V (36.7 kV/cm)
Drift field = 220 V/cm
Perpendicular tracks

$\sigma_{\mu M}$ = (24±7) μm



Strip pitch: 250 μm

$\sigma_{\mu M}$ = (36±5) μm



Strip pitch: 500 μm

Summary of prototype performance

The first prototype has been thoroughly tested in the lab and in test beams and it was found to have good performance

- **Efficiency >99% for Gain >$3 \cdot 10^3$**
- **Spatial resolution 24 μm (36 μm) for 250 μm (500 μm) strip width**

Simulation of the Micromegas detector

Effort to develop a simulation of the full chain

from the ionization to the read-out in order to :

- Understand performance of chamber in test beam

- Study performance of chamber for different parameter choice

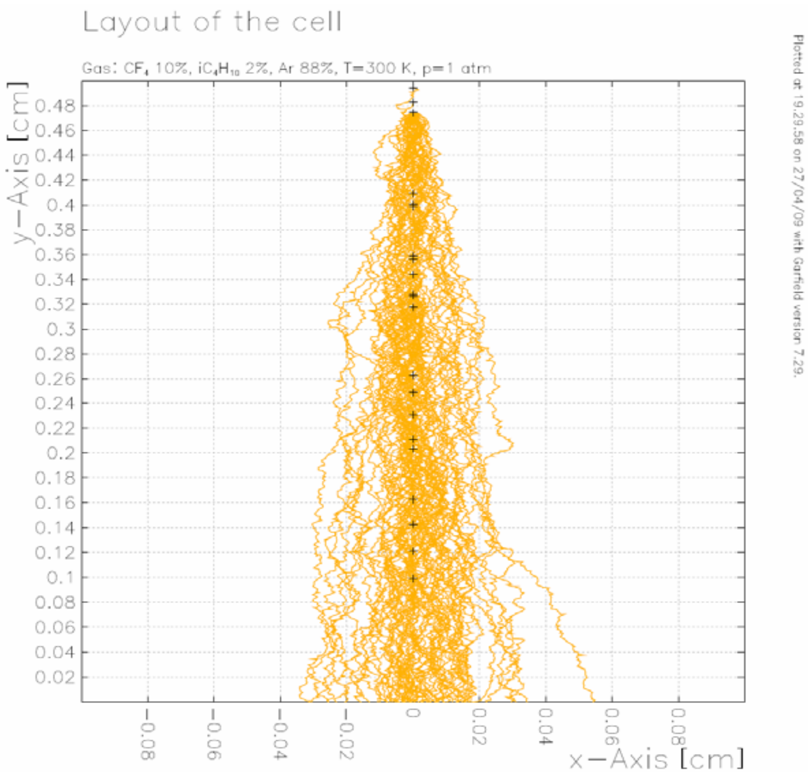
- Evaluate potential of new ideas

Simulation of the Micromegas detector (II)

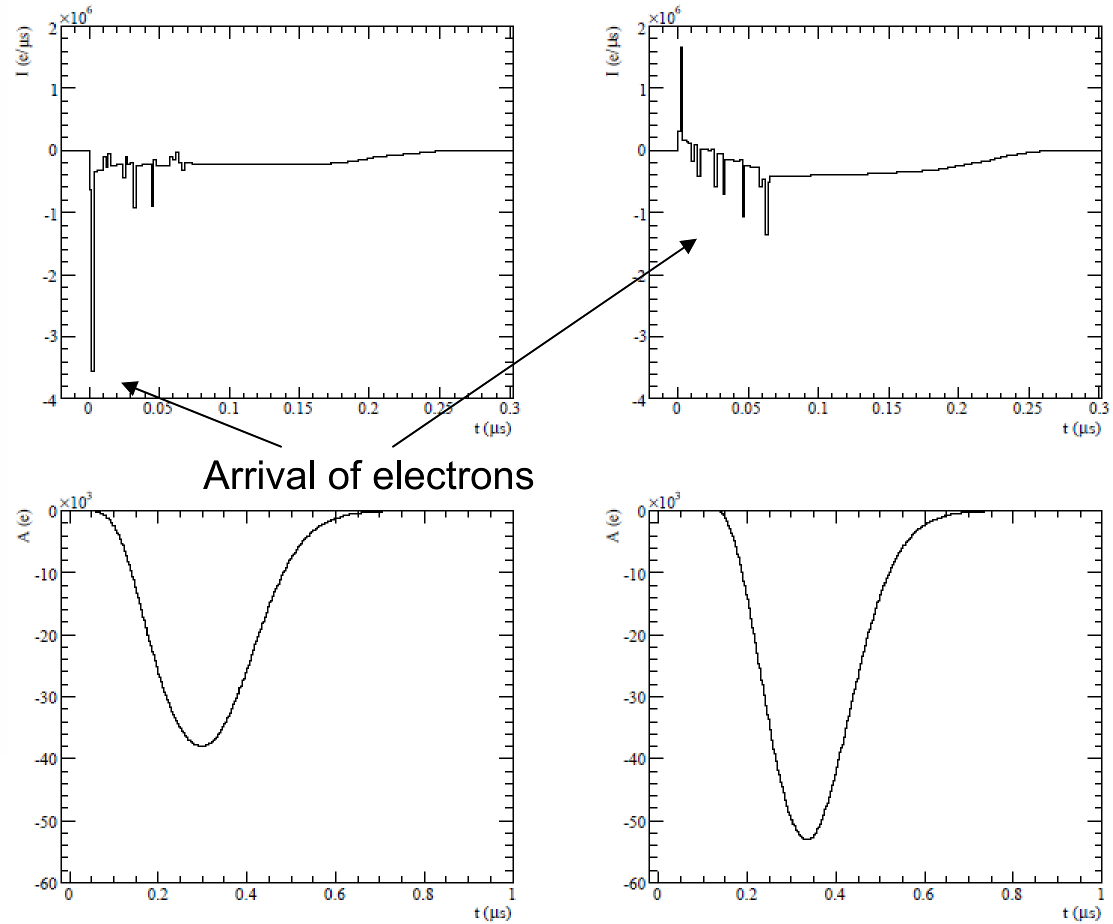
GARFIELD/HEED/MAGBOLTZ for electron production/drift.

Semi-analytical approximation for ion induced charge

/ include shaper / electronic noise e.t.c



Drift of ionization electrons from GARFIELD



Anode current and shaper output neighbouring strips

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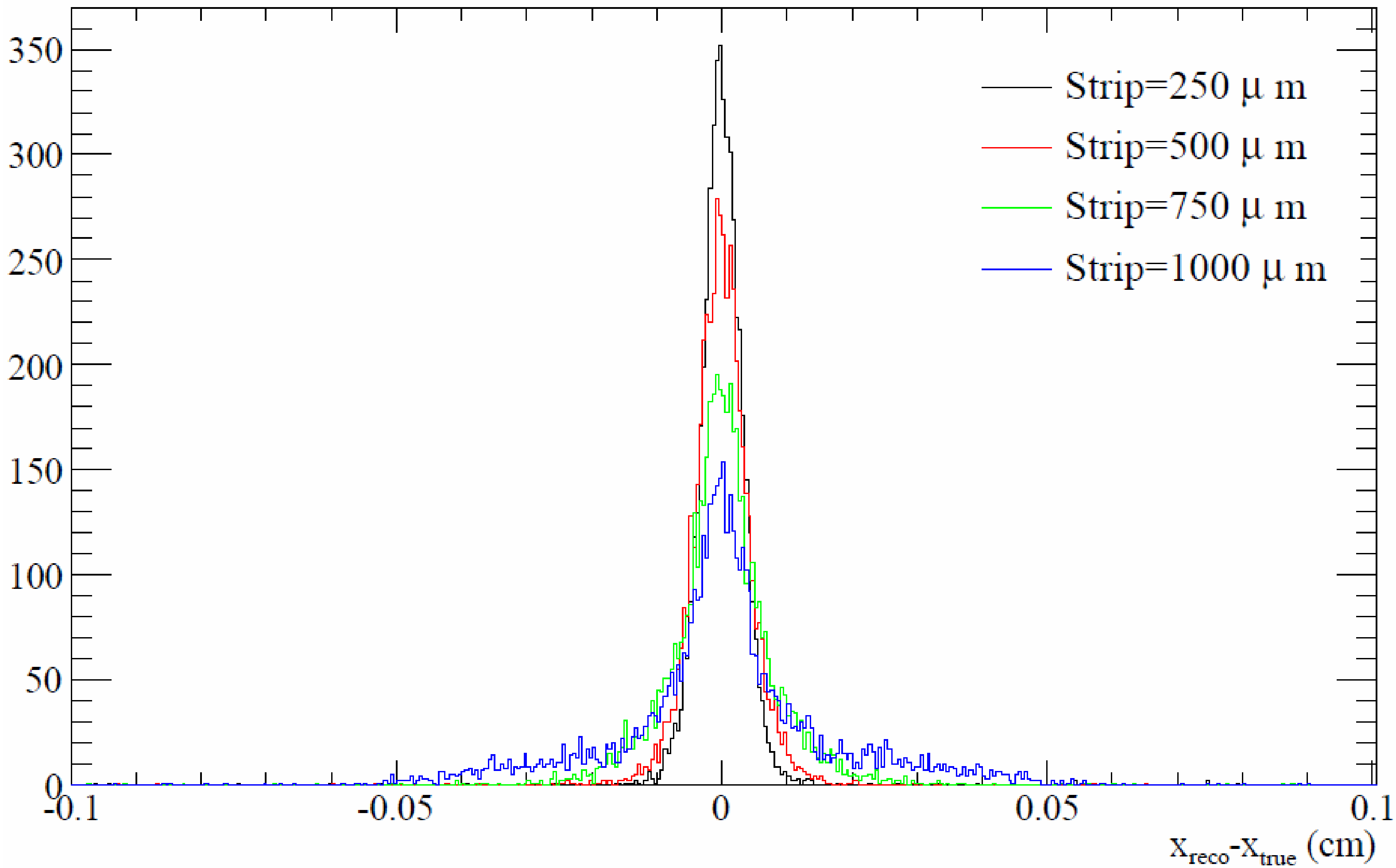
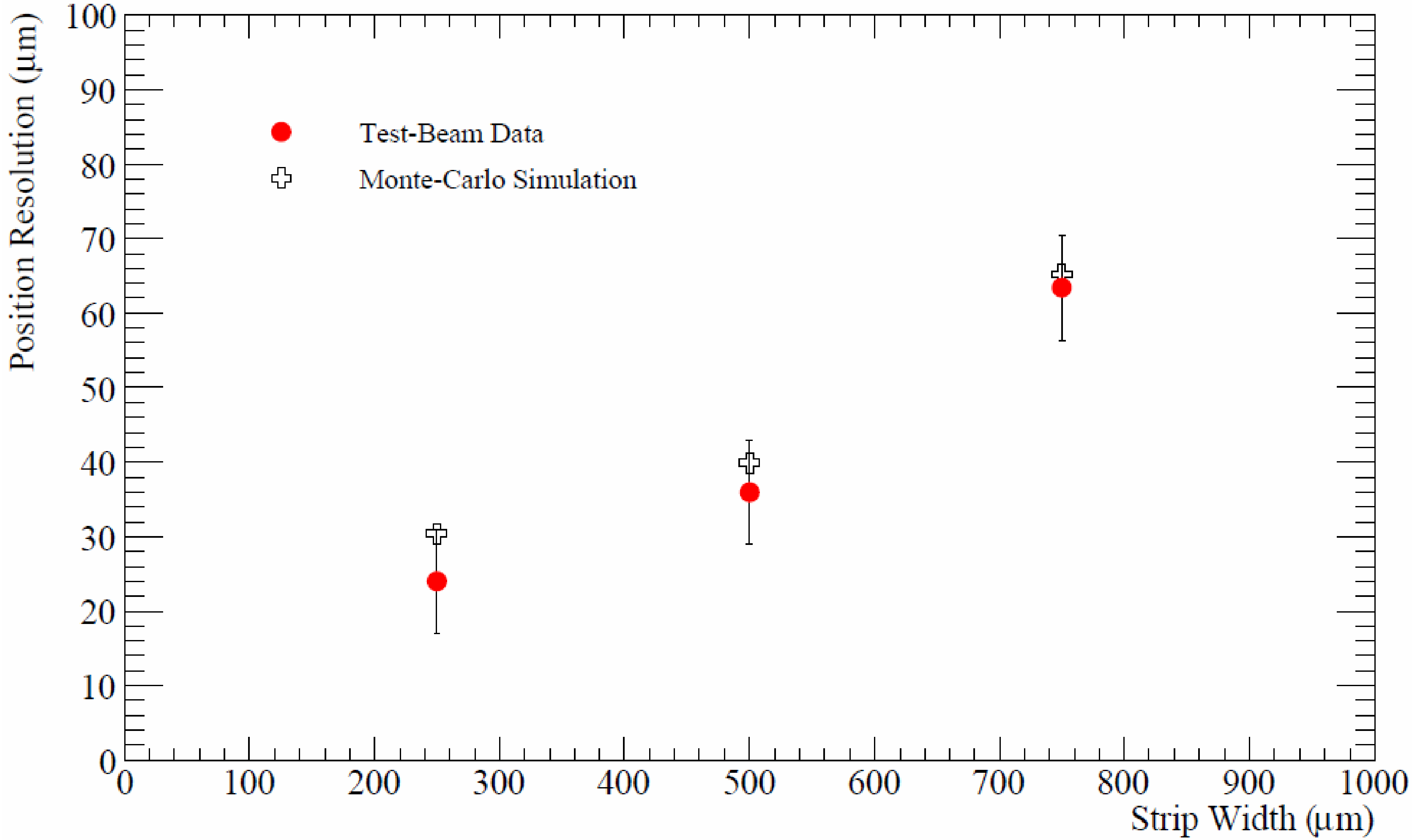
Simulation : Residual distribution



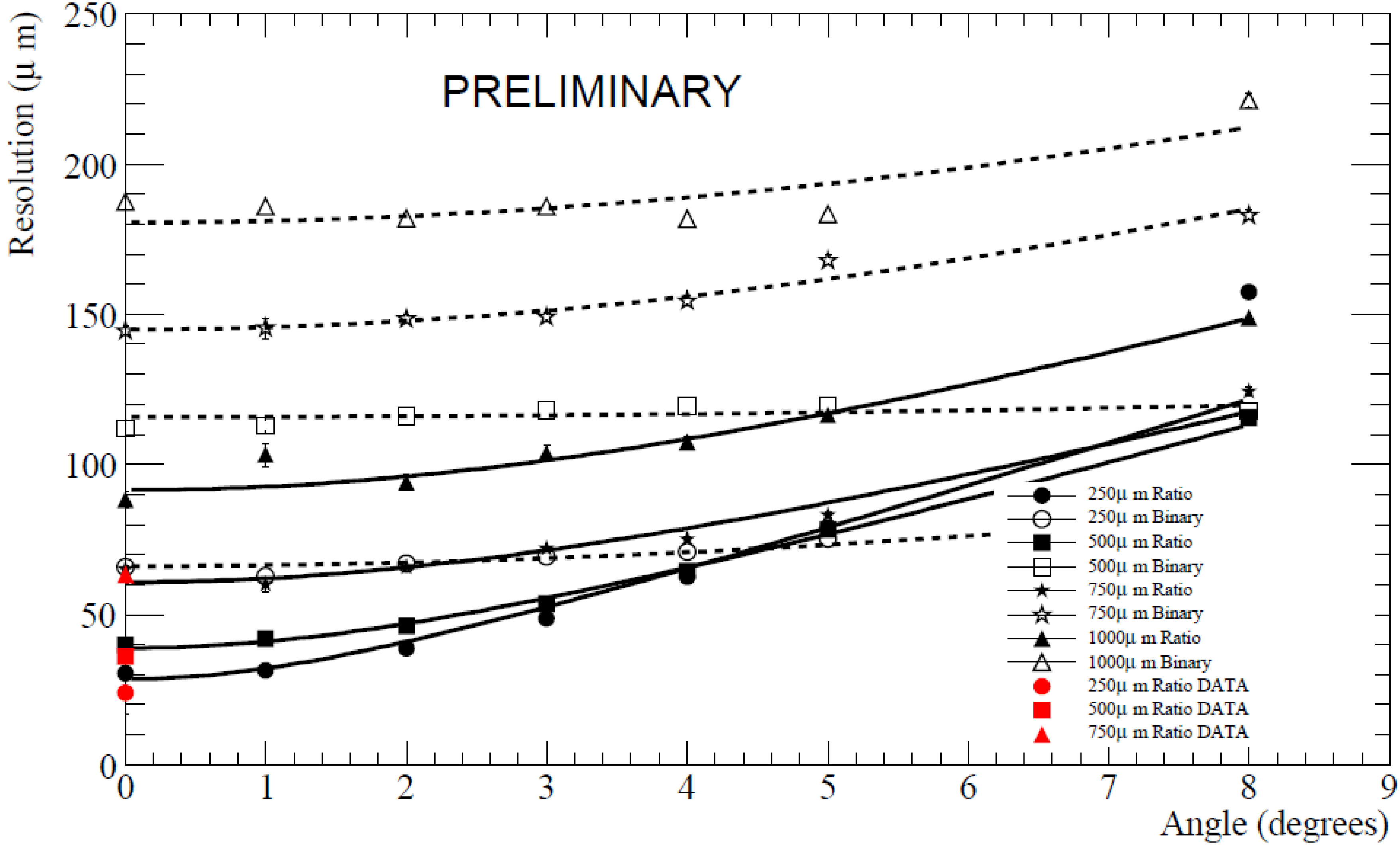
Simulated residual distribution as a function of strip width for uniform illumination

Comparison with real data



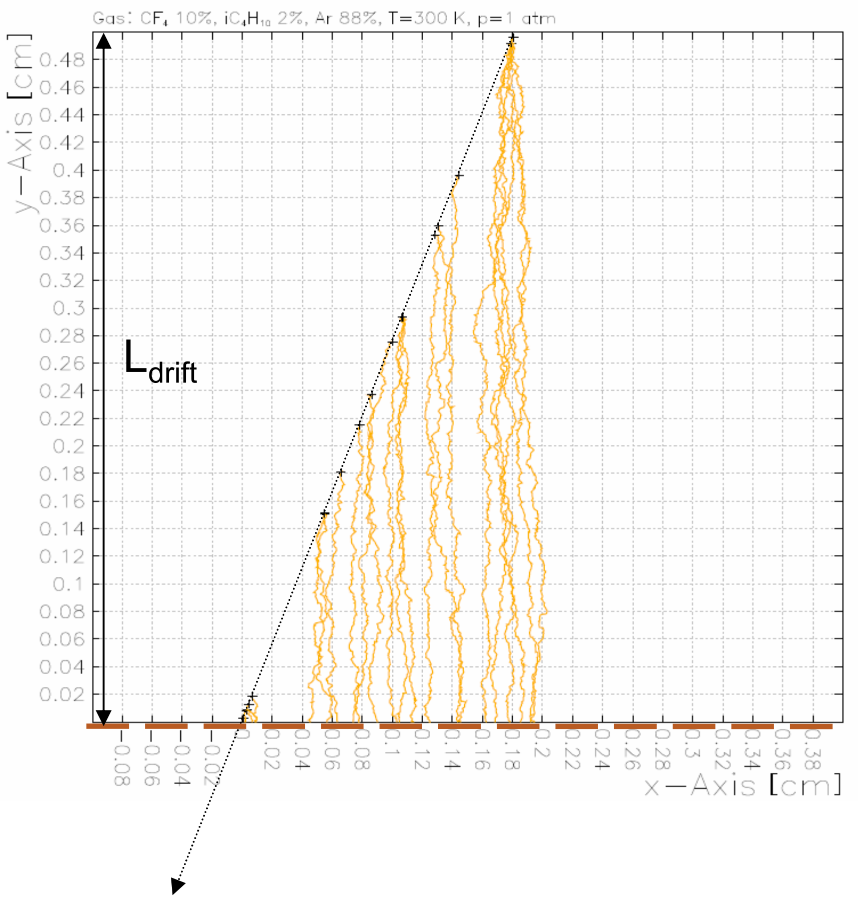
The simulated resolution is in agreement with the **test beam data** resolution

Resolution for Inclined Tracks



Spatial resolution for **charge interpolation** (ratio) and **binary** read-out as a function of the incidence angle and the strip width.

Micromegas as μ-TPC

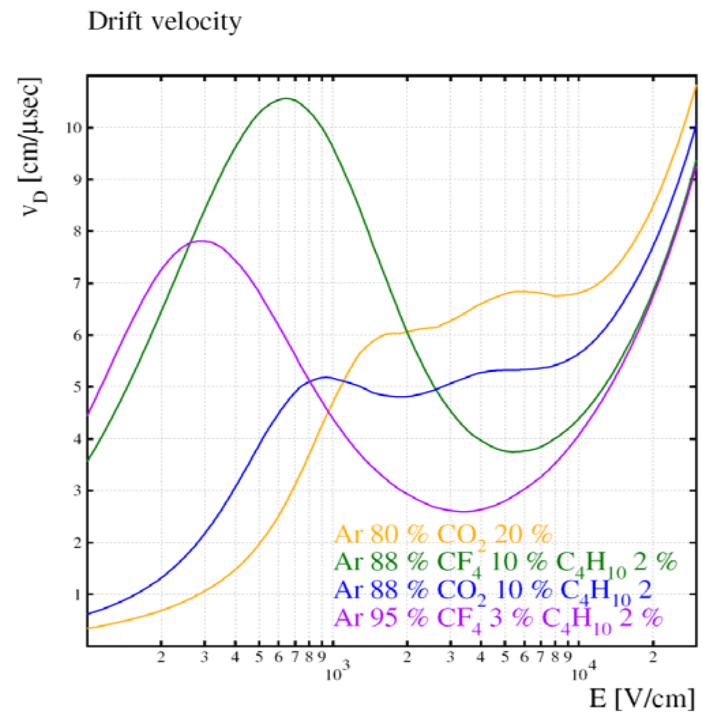


For non-perpendicular incidence

→ position resolution degraded due to fluctuation of charge deposition along the track

Use the Micromegas as a μ-TPC

→Measure arrival time of signals on strips and reconstruct space points in the drift gap

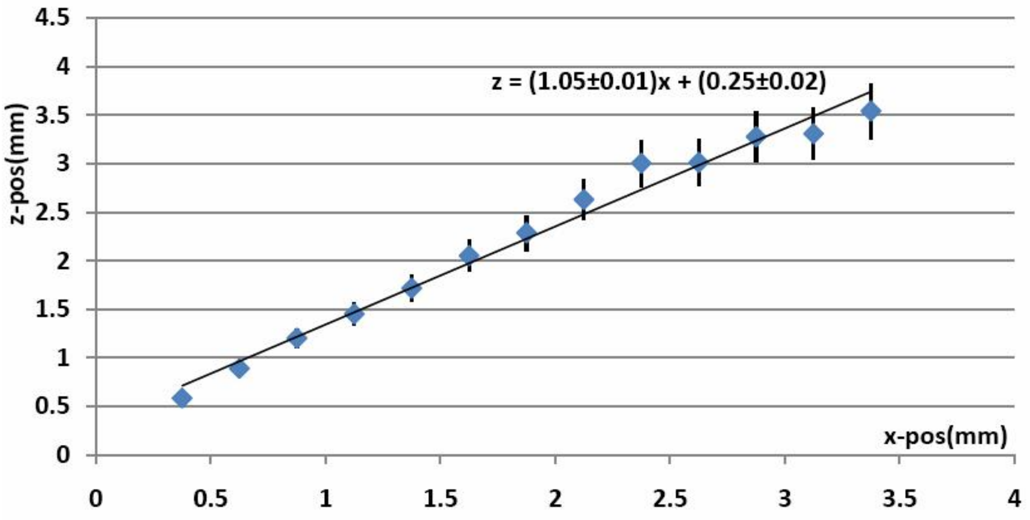


Time resolution 1ns → $\sigma_y \sim 5$ -10 μm

$\sigma_x = w/\sqrt{12} \sim 70 - 150$ μm

Micromegas as μ-TPC

Requirements for μ-TPC different wrt charge interpolation techniques. (optimize drift gap/short peaking times/moderate charge measurement)



Example test-beam event

<u>Local track direction can be advantageous for pattern recognition</u>

- Gas: Ar:CF_4:iC_4H_{10} (95:3:2)
- Drift field = 360 V/cm
- Drift velocity = 7.8 cm/μs (Magboltz)
- Chamber rotation = (40±3)º
- Reconstructed track inclination = (44±4)º

2008 electronics not ideal for this study

→ Try again with better setup

Promising/challenging → potentially solves angle problem → Interesting R&D

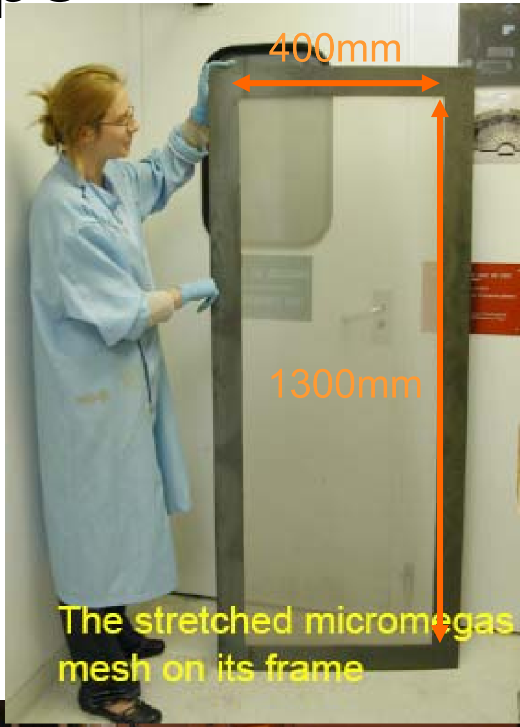
The ~½ full size prototype

A half size prototype is almost ready at CERN

- 400 x 1300 mm^2 active area
- "T2K" mesh
  450 line/inch = 56.4 μm pitch (calendered)
  18 μm wire diameter
  128 μm amplification gap
  Segmented
- Strip pitch: 250 μm and 500 μm
- Long (80 cm) and short (30 cm) strips

details in Rui de Oliveira's talk

<u>Study performance in lab and in test beam as soon as available</u>



Future Work

Evaluate chamber performance

- Half size prototype
- μ-TPC method

Study Spark Protection

- Resistive coating (Saclay)
- Double stage amplification

Behaviour in s-LHC enviroment

- Irradiation test in neutron facility on small chamber
- Ageing test (→as soon as materials are defined)

See :
"Micromegas study for the sLHC enviroment"
D. Attie *et al.*

See:
"A study of a Micromegas chamber in a neutron beam"
G. Fanourakis et al.

Define design parameters (chamber+electronics) for phase I upgrade

(~ 1m x 1m chamber in CSC region) by end of 2009

Demonstration of suitability for s-LHC LoI (2010)

→ Full size prototype (1m x 2m) / production procedures

/ optimized working points / electronics design

Summary

- 350 x 450 mm^2 prototype built and tested

→ Good performance in gas amplification and efficiency.

→ Spatial resolution ~ 24 μm (36 μm) with 250 μm (500 μm) strips.

- Inclined tracks → local track reconstruction possible (μ-TPC)
- Simulation →study performance dependence on various parameters
- 400 x 1300 mm^2 prototype almost ready : performance to be studied in 2009.

Bulk Micromegas technology is a promising candidate for s-LHC upgrade