The ATLAS Micromegas Upgrade Project

(Muon ATLAS MicroMegas Activity)

Yorgos Tsipolitis

NTUA

Arizona, Athens (U, NTU, Demokritos), Brookhaven, CERN, Harvard, Istanbul (Bogaziçi, Doğuş), Naples, Seattle, USTC Hefei, South Carolina, St. Petersburg, Shandong, Thessaloniki

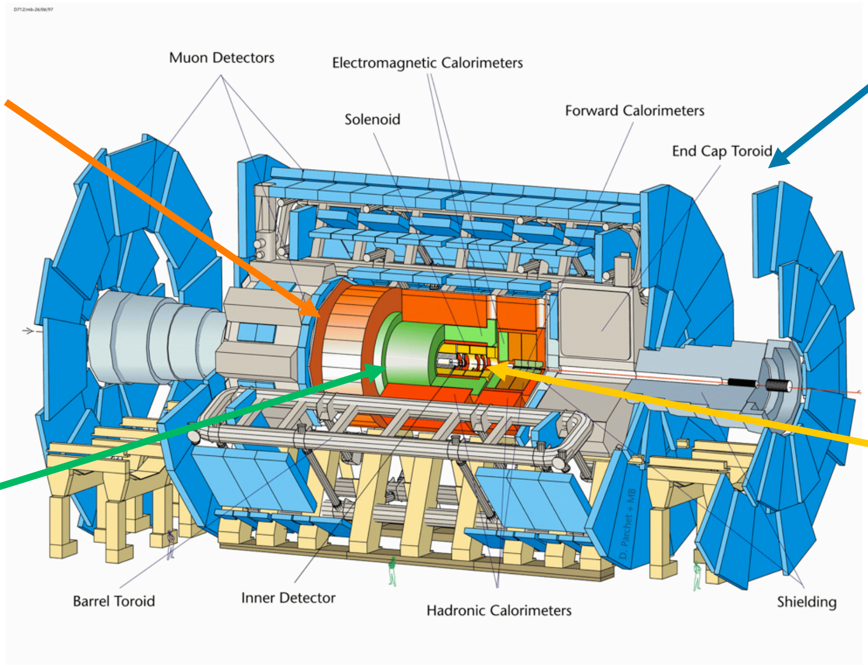
ATLAS @ LHC

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

ATLAS upgrade for 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)

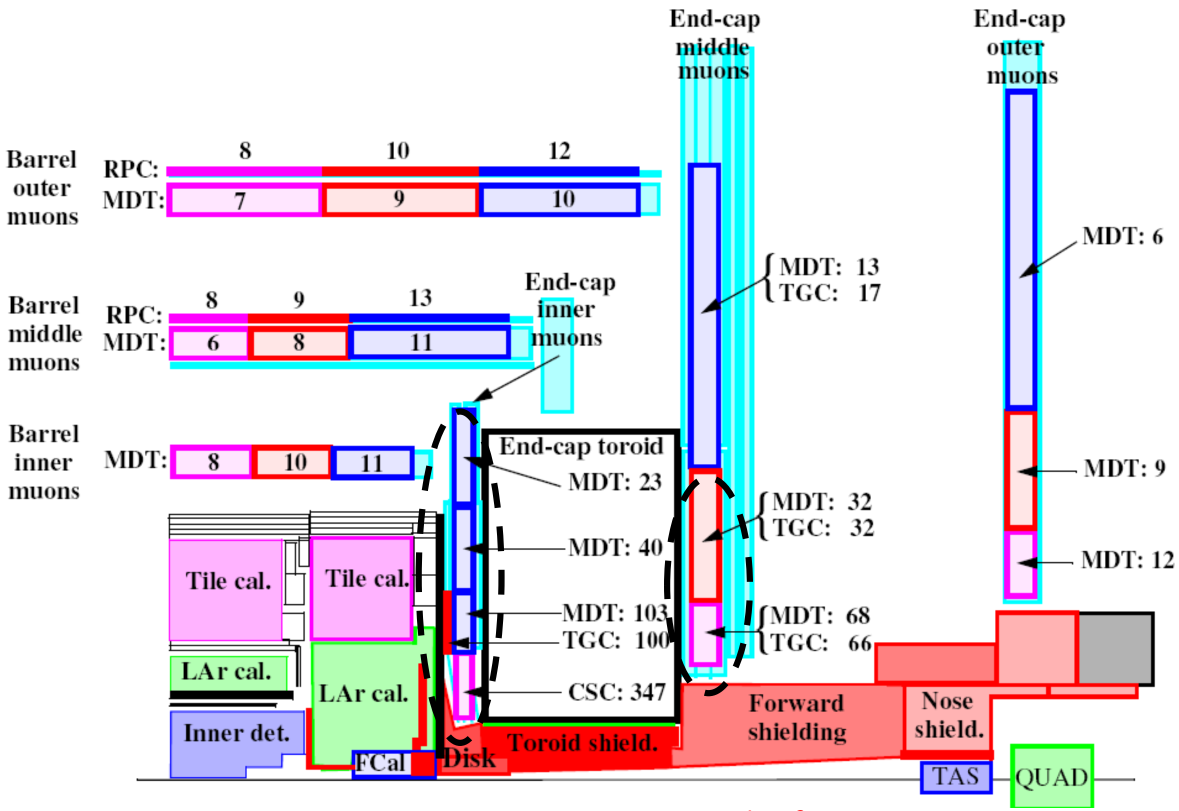
Muon Spectrometer affected regions :

- 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

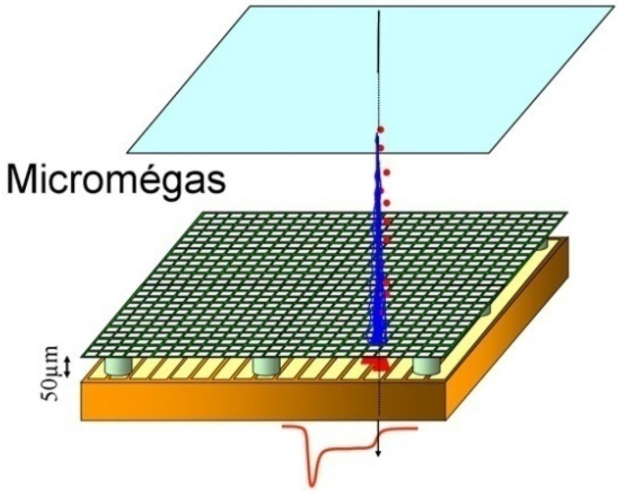
Counting rates to be measured with first LHC collisions → Reduce uncertainty



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

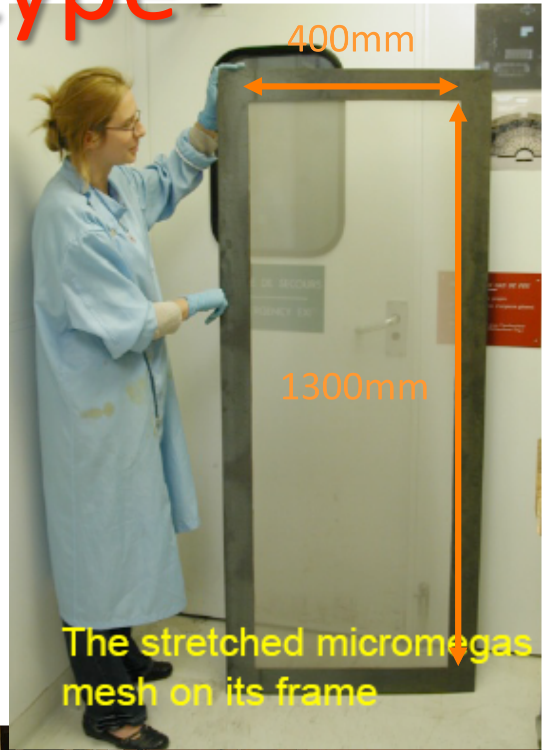
Micromegas for ATLAS Muon upgrade

- Combine triggering and tracking functions
- Matches required performances:
  - Spatial resolution <80 μm (θ_{track}< 45°)
  - Good double track resolution
  - Time resolution ~ 5 ns
  - Efficiency > 99%
  - Rate capability > 5 kHz/cm^2
  - 200 Hz/cm^2 due to neutrons with E>100 keV
  - Stability over about 5 years at phase-1 luminosity (≅1000 fb^{-1})



- Potential for going to large areas ~1m x 2m with industrial proc.
  - Cost effective & Robustness

The ~½ full size prototype



A half size prototype at CERN

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

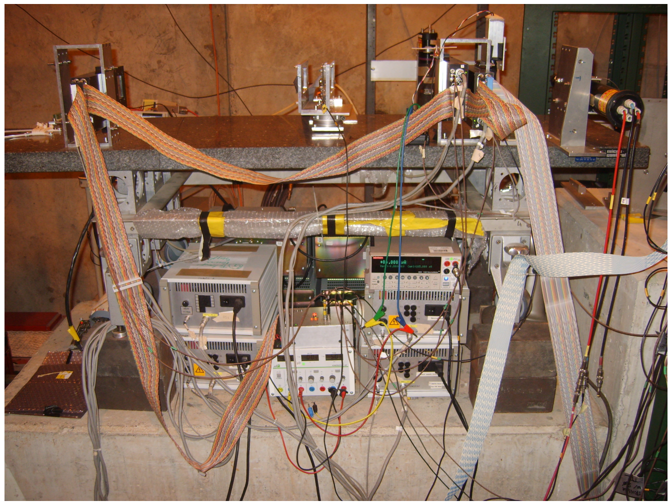
Test Beam Setup @ CERN

- P1 tested @ CERN H6 beam line in November 2007, June to August 2008 & July 2009
- P2 tested during July 2009
- 120 GeV pion beam
- Scintillator trigger
- External tracking with three Si detector modules (Bonn Univ.); independent DAQ
- Three non-flammable gas mixtures with small isobutane percentage used in 2008:

  $Ar:CO_2:iC_4H_{10}$ (88:10:2), $Ar:CF_4:iC_4H_{10}$ (88:10:2), $Ar:CF_4:iC_4H_{10}$(95:3:2)

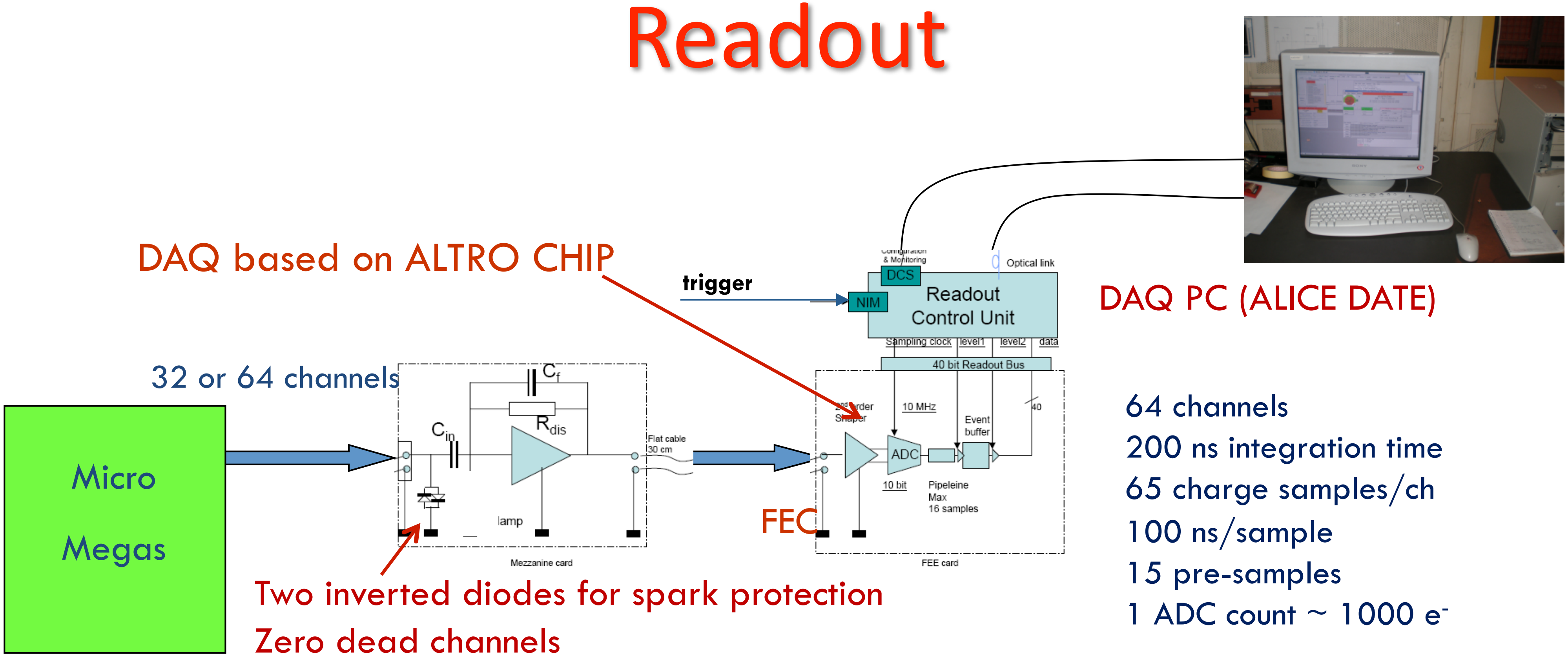
  $Ar:CO_2$ (85:15) for P2
- Data acquired for 4 different strip patterns and 5 impact angles (0 to 40 degrees) for P1 and P2

2008 Test beam set up



2009 Test beam set up

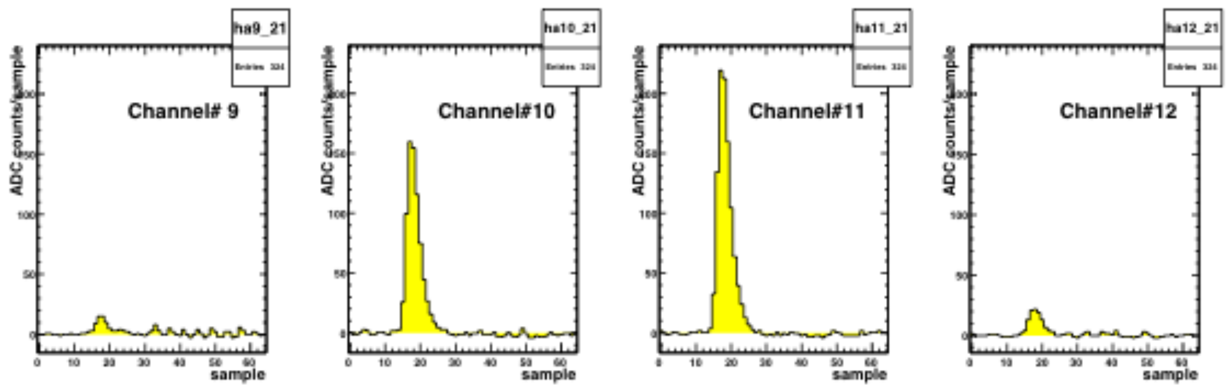
Readout



64 channels
200 ns integration time
65 charge samples/ch
100 ns/sample
15 pre-samples
1 ADC count ~ 1000 e^-

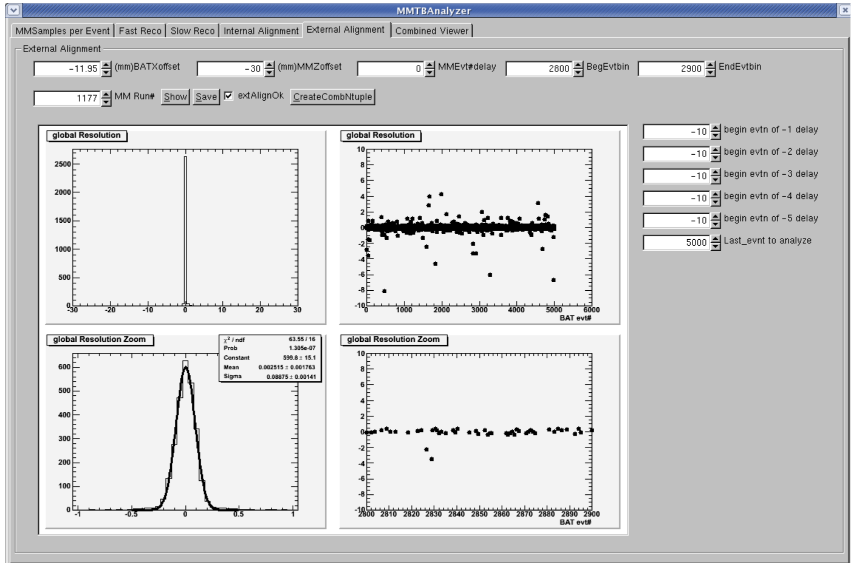
Typical ADC spectra

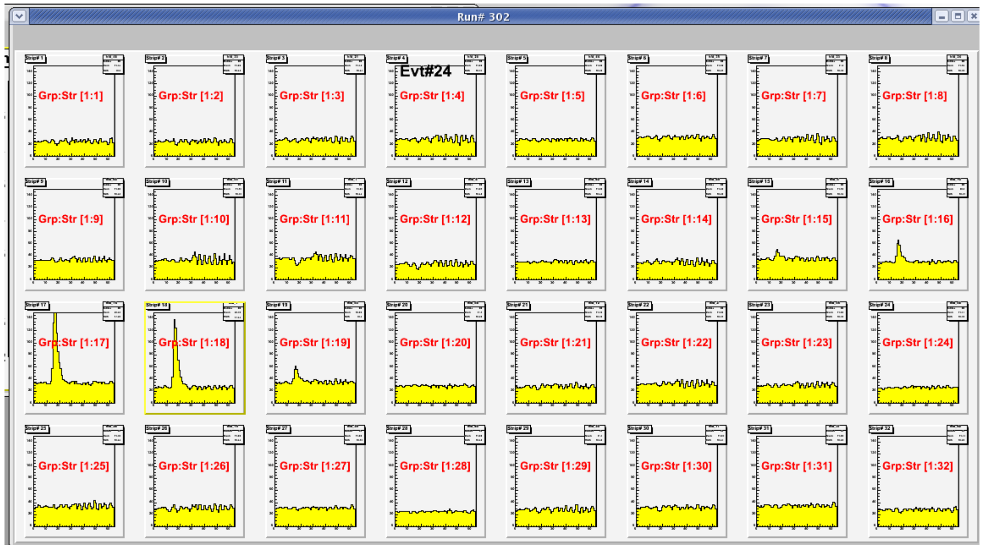
- Noise subtraction (from 12 pre-samples)
- Custer position from center of gravity



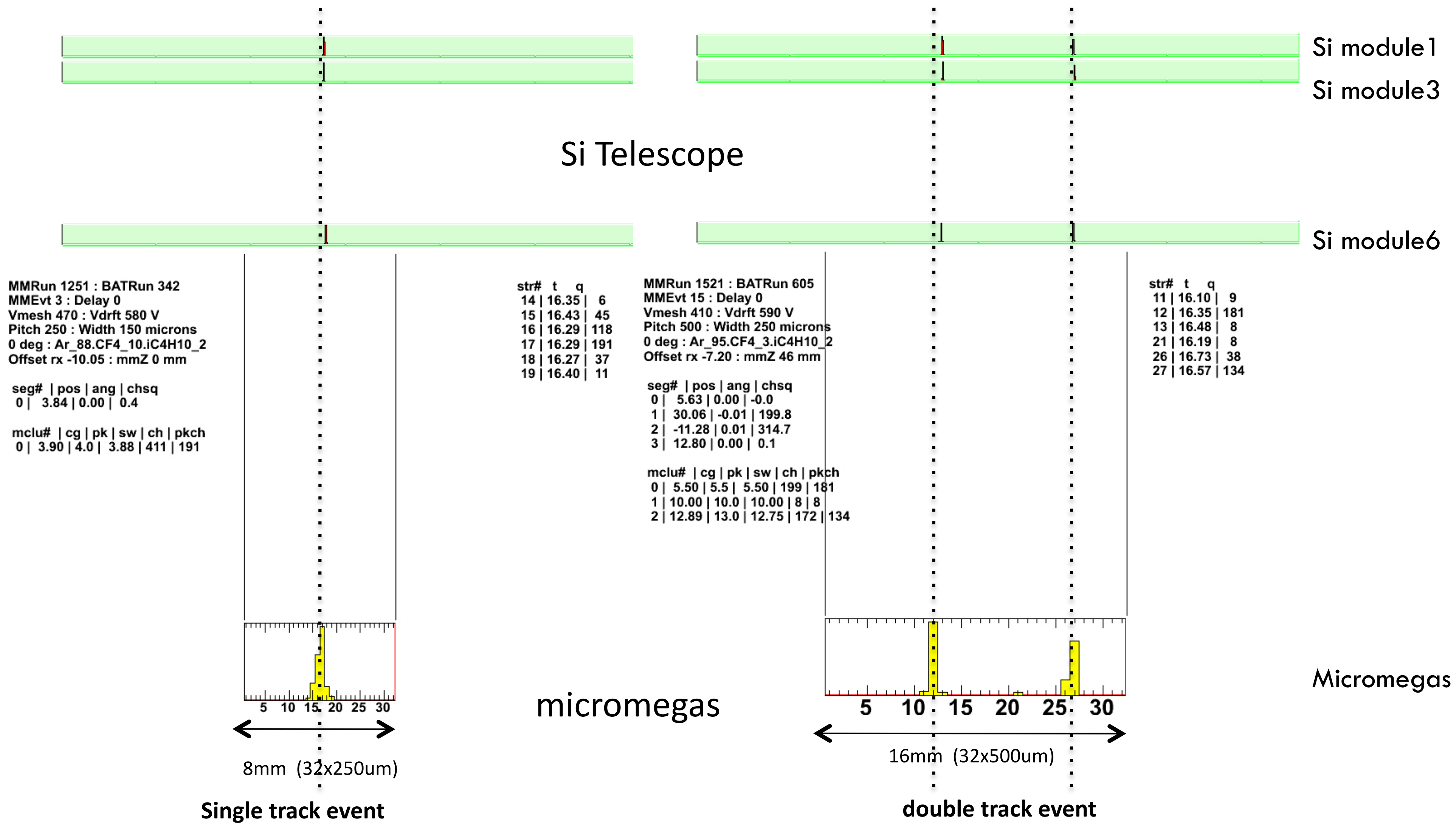
Software

- Software tool for quasi online and off-line reconstruction (based on ROOT)
- Permits alignment of Si tracker modules with MM chamber
- Combines data from Si tracker and MM
- Provides 'online' resolution
- Also: simple event display

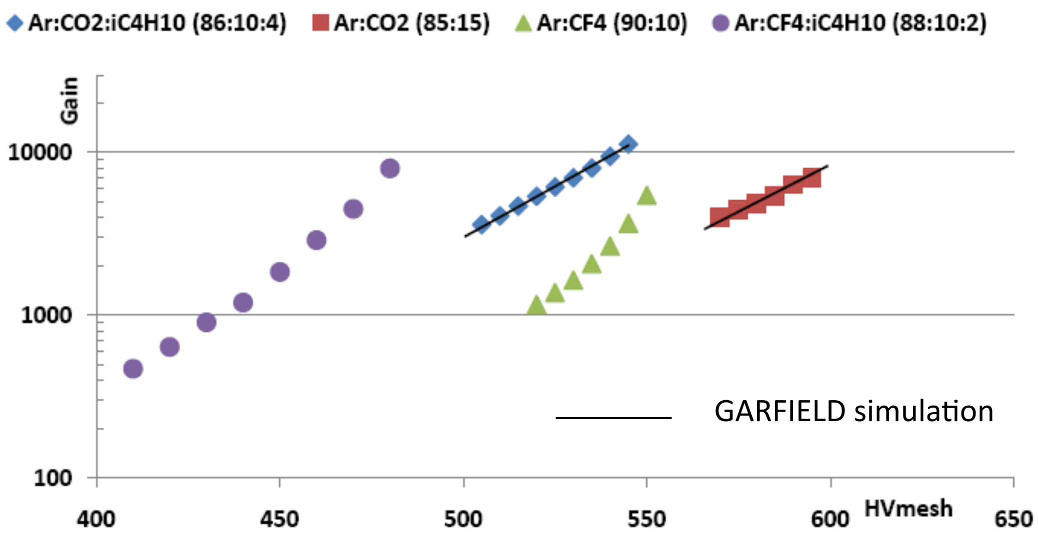




Event Display

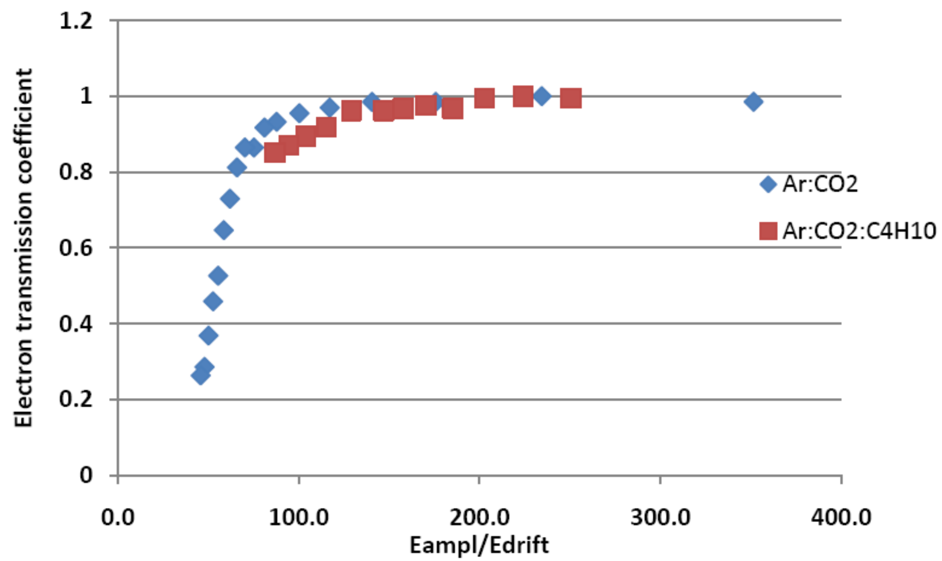


Gain Measurements

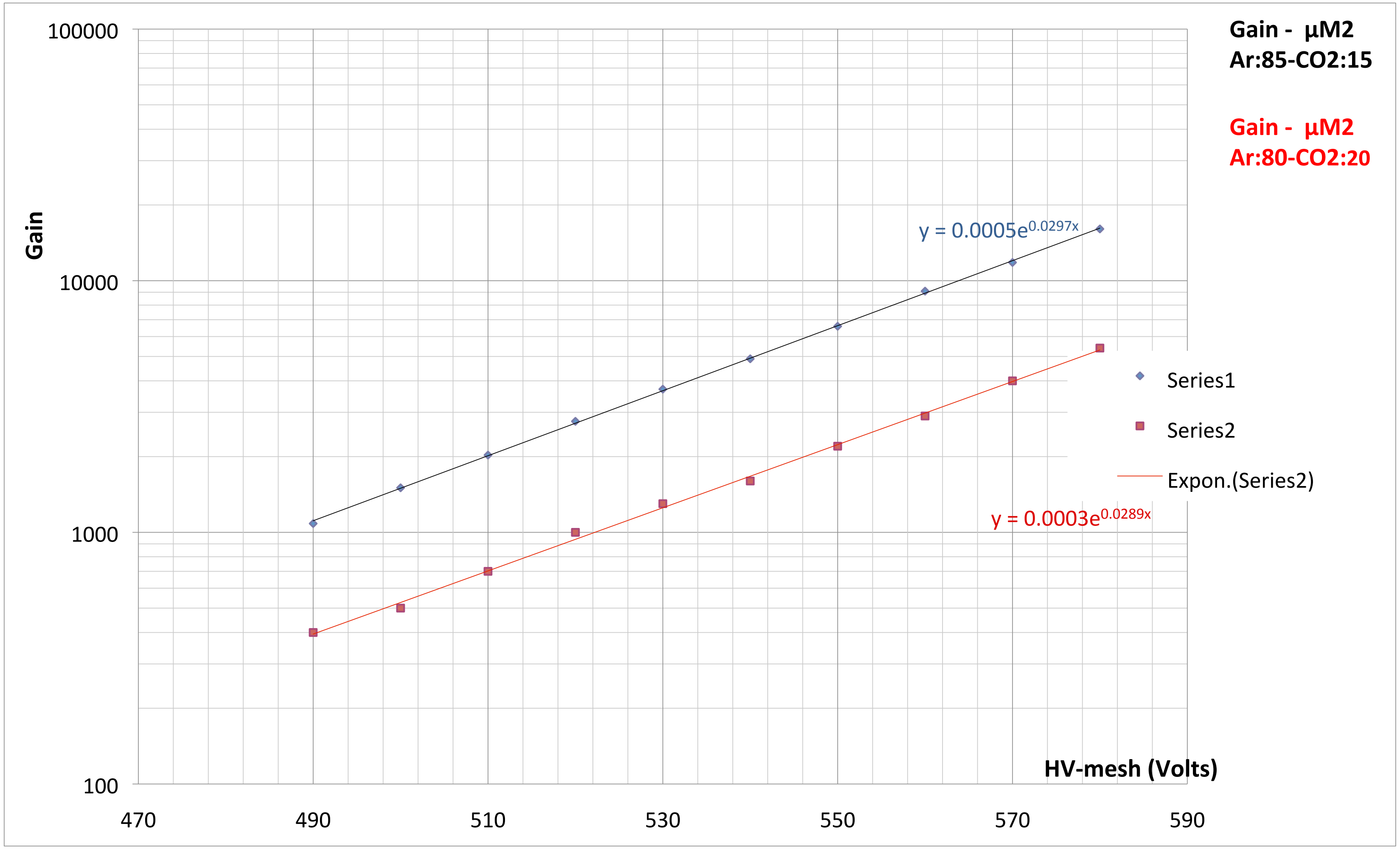


Gas gain in the 10^3-10^4 region obtained without problems.
Measurements in agreement with simulation

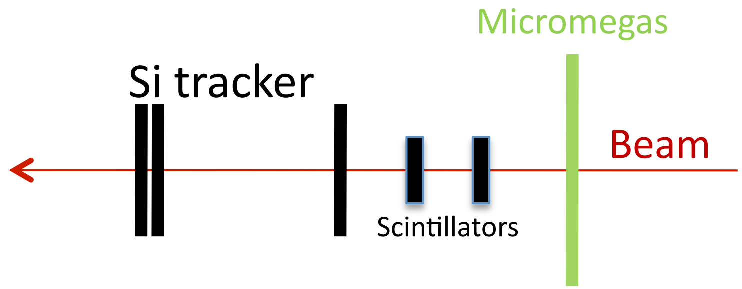
Electron mesh transparency >95% for field ratio >150



Gain Measurement



Spatial Resolution (online)

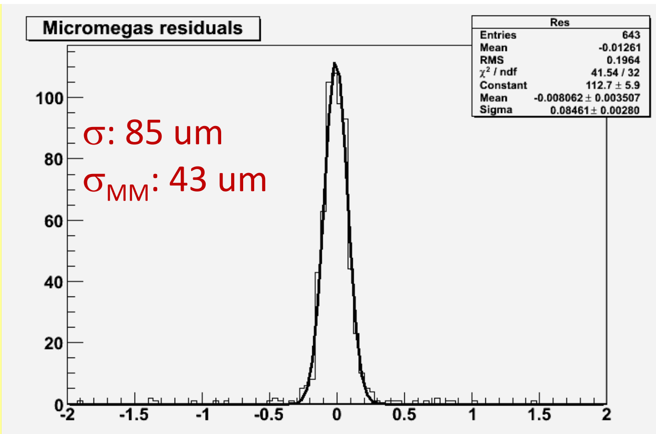


Gas: Ar:CF_4:iC_4H_{10} (88:10:2)
Drift field: 200 V/cm

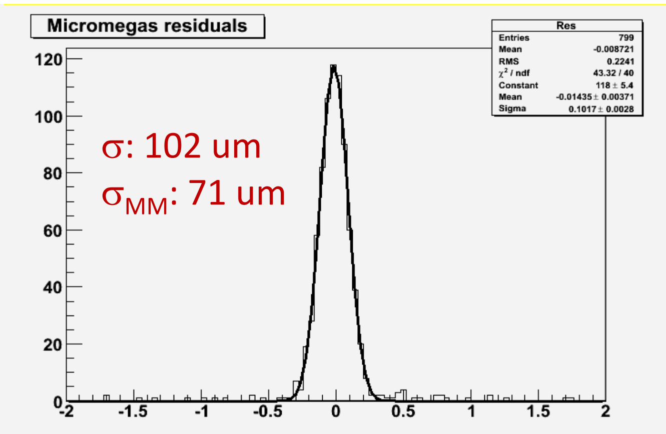
- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
  - Intrinsic MM resolution
  - Tracker resolution (extrapolation)
  - Multiple scattering

  } ~73 μm (tracker resolution and multiple scattering)

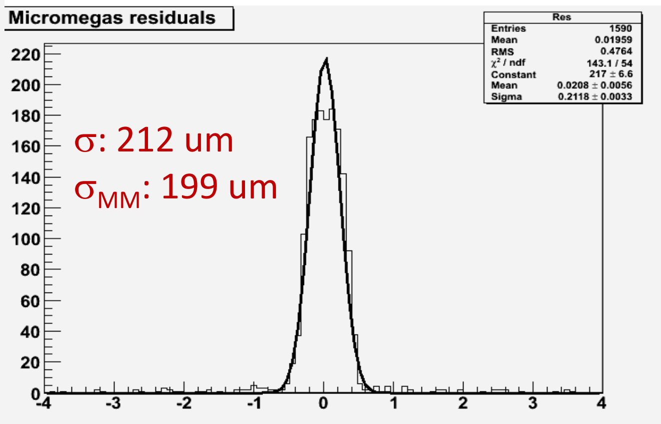
Strip pitch: 250 μm
Strip width: 150 μm



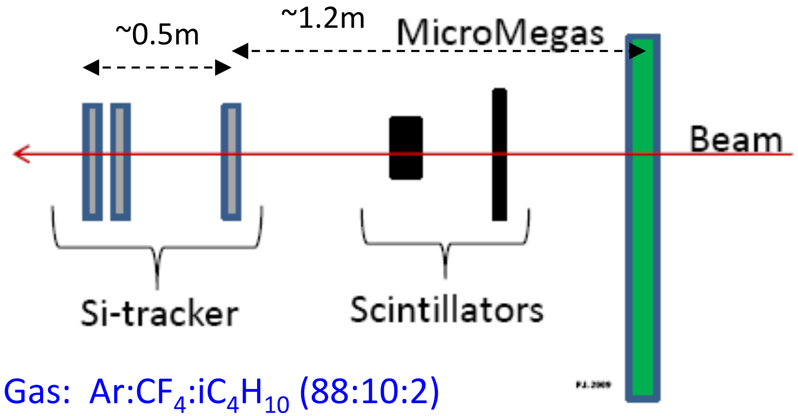
Strip pitch: 500 μm
Strip width: 400 μm



Strip pitch: 1000 μm
Strip width: 900 μm



Spatial Resolution (offline)



Residuals of MM cluster position and extrapolated track from Si.

Three contributions to width of distribution :

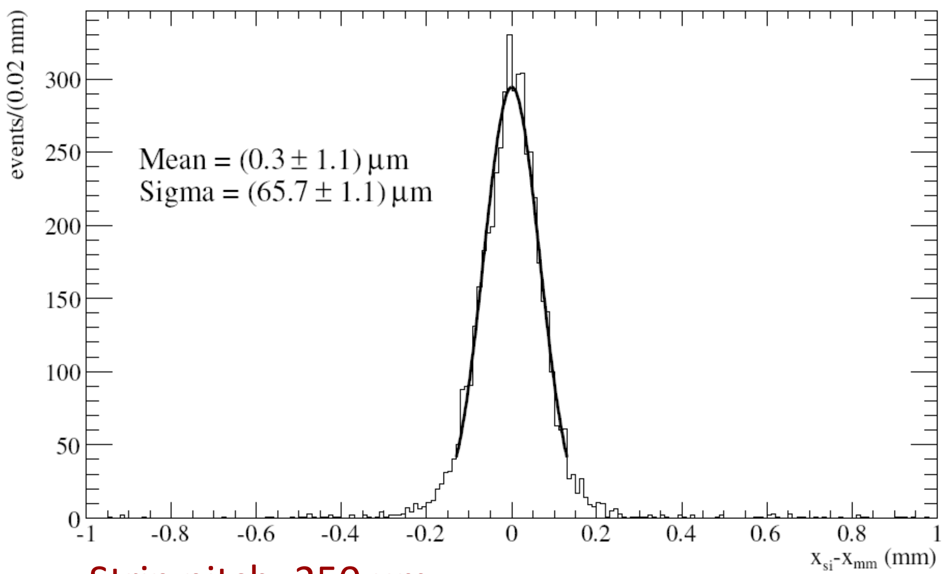
- Si Telescope extrapolation @ μM → ~30 μm
- Multiple scattering → ~53 μm
- Intrinsic μM resolution

} ~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

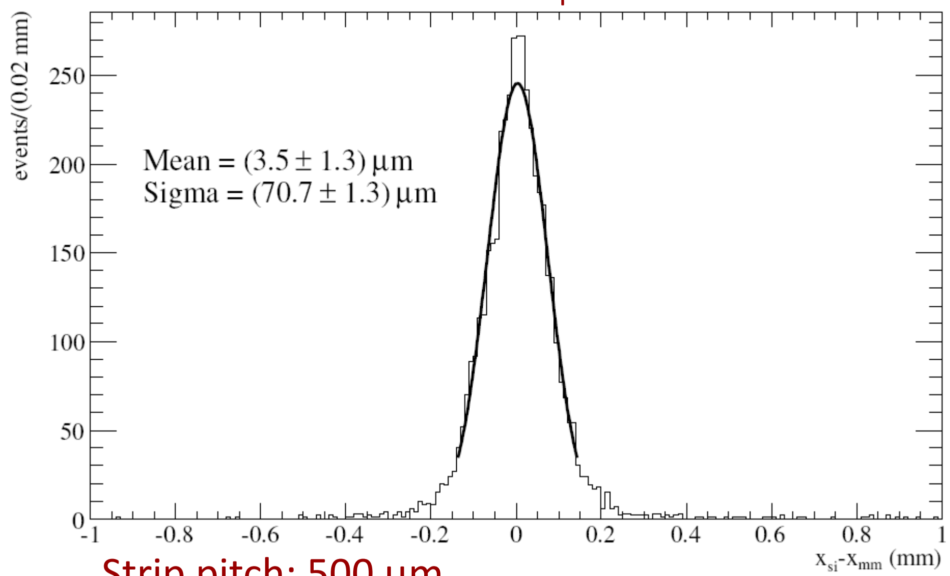
Required <80μm

$\sigma_{\mu M}$ = (24±7) μm



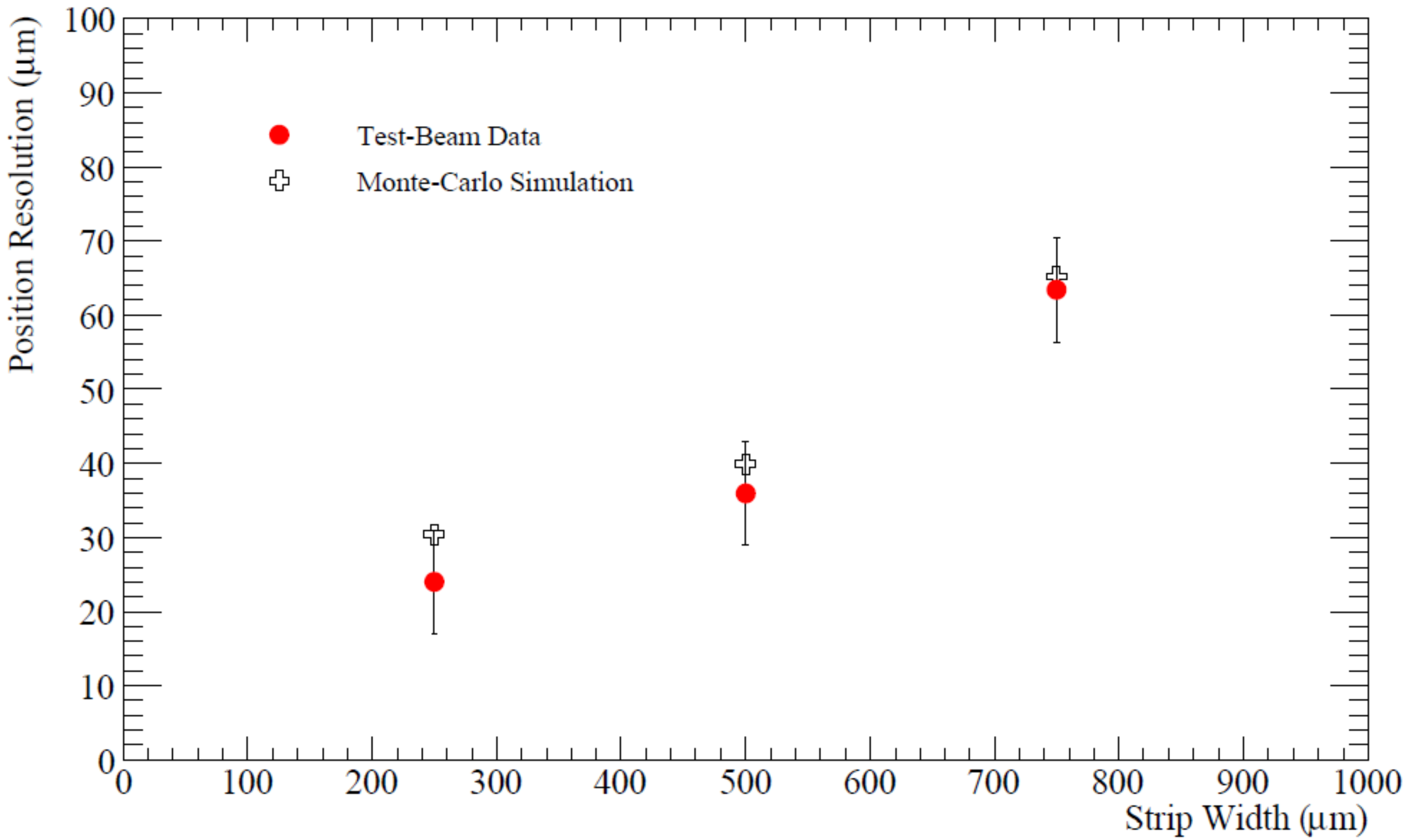
Strip pitch: 250 μm

$\sigma_{\mu M}$ = (36±5) μm

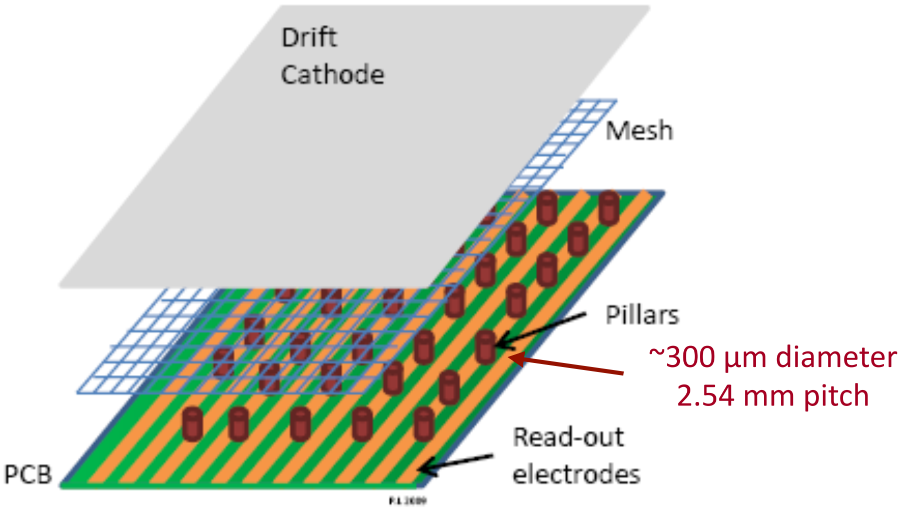


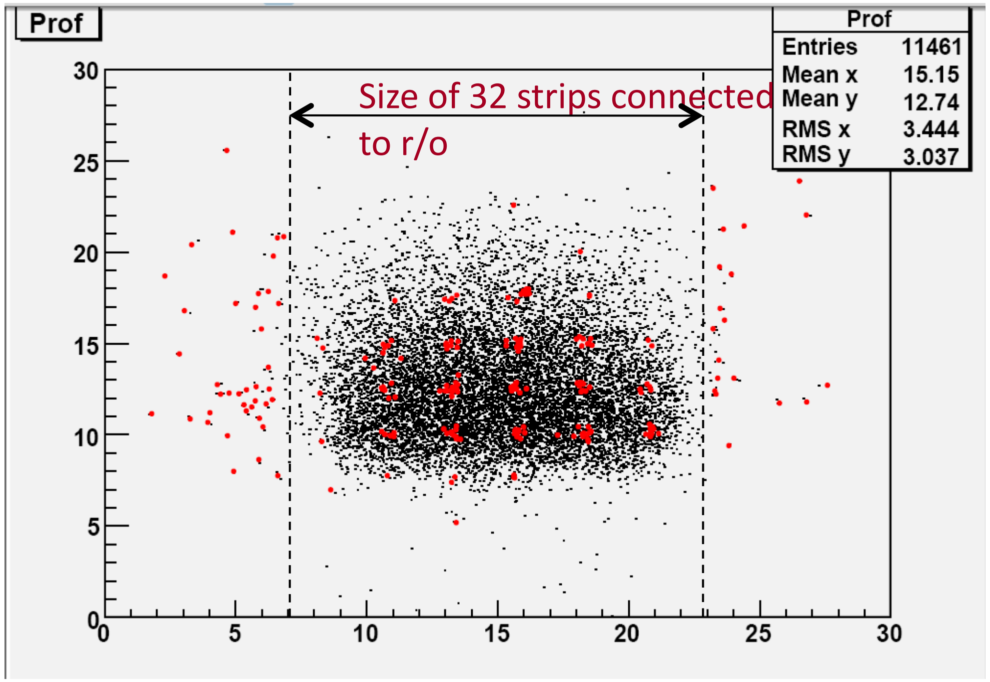
Strip pitch: 500 μm

Resolution Data vs MC



"mapping" with beam





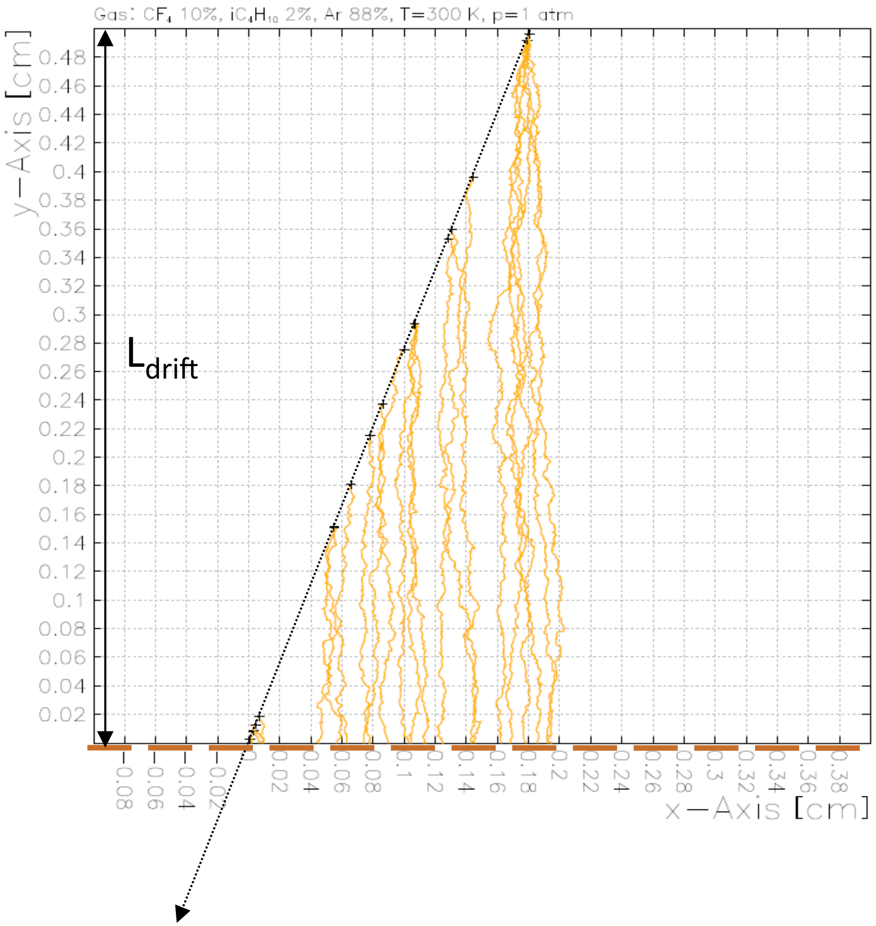
- Ar:CF_4:iC_4H_{10} (88:10:2)
- Strips: 500 μm pitch
- V_{mesh} = 450 V (35.2 kV/cm)
- Drift field = 200 V/cm

Black: beam profile

Red: tracks w/o Micromegas hit

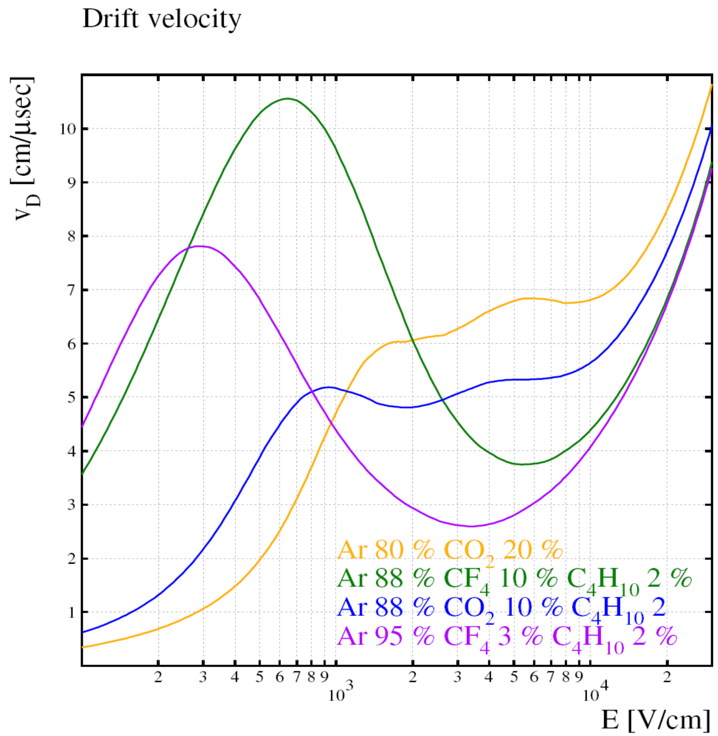
Pillars contribute to the geometrical inefficiency of the chamber at the ~1% level.

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

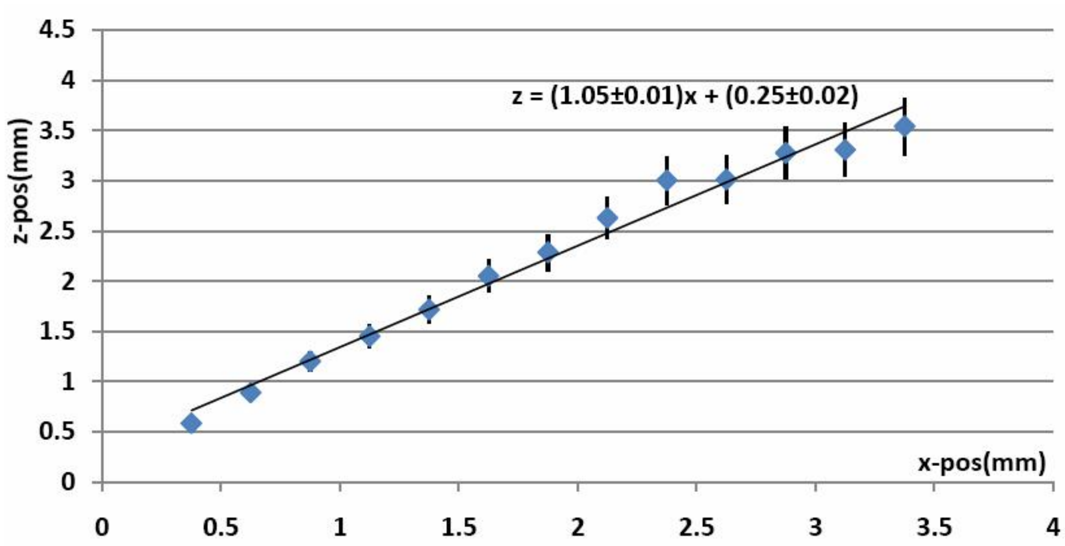


Time resolution 1ns → σ_y ~ 5 -10 μm

ATLAS @ LHC

Even with non-optimal r/o electr. measuring the arrival time on each strip it is possible to measure the drift velocity or, with known drift velocity, the drift distance

Local track direction can be advantageous for pattern recognition



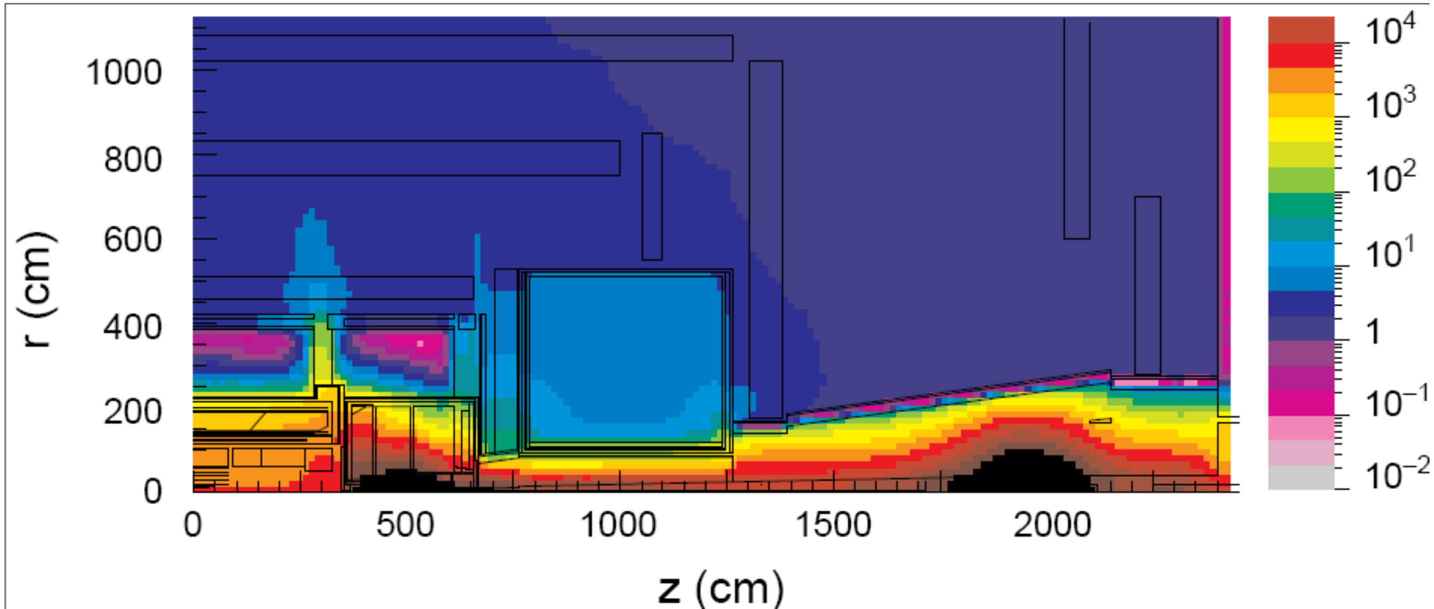
Example test-beam event

- 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

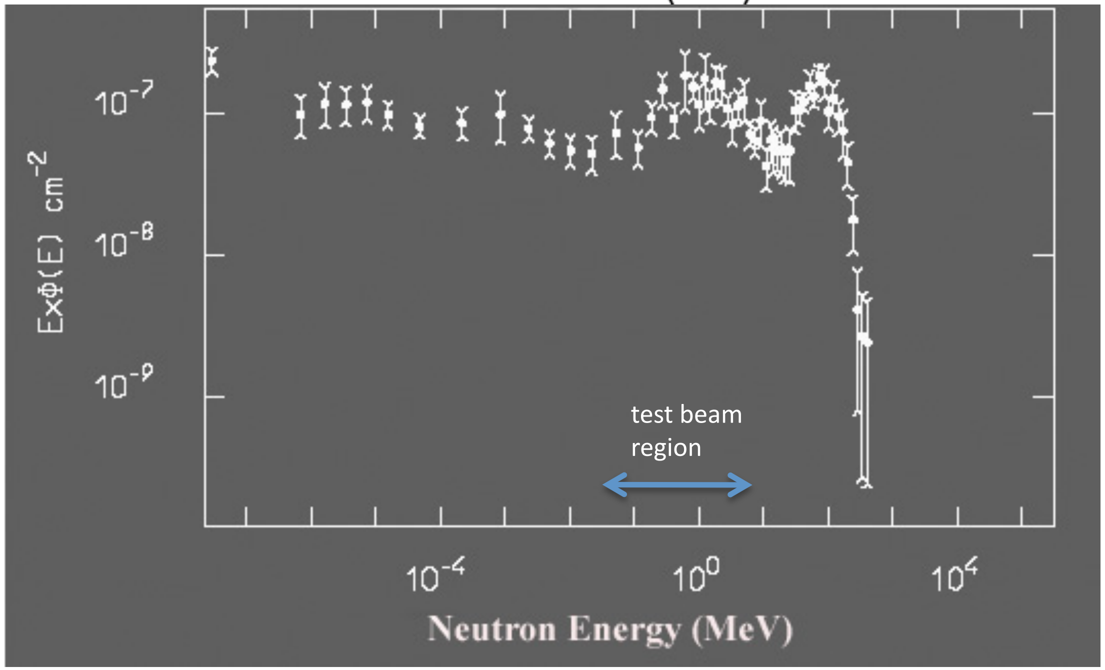
2008 electronics not ideal for this study
→ but 2009 setup is improved for this due to the timing measurement

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

Neutron Flux in ATLAS @ LHC



The expected neutron fluence (kHz/cm^2) in the ATLAS Hall (ATLAS muon TDR, 1997)



The energy spectrum of the expected neutron background radiation in the Atlas Hall (ATLAS muon TDR, 1997)

Tandem @ Demokritos

- 5.5 MV TN11 HV Tandem Van der Graaff accelerator
- Three neutron energy ranges can be produced by this facility, via three different nuclear reactions:

Nuclear Reaction	Proton/Deuteron Energy Range (MeV)	Neutron Energy Range (MeV)
$^{7}Li(p,n)^{7}Be$	1.9 to 8.4	0.1 to 6.7*
$^{2}H(d,n)^{3}He$	0.8 to 8.4	3.9 to 11.5**
$^{3}H(d,n)^{4}He$	0.8 to 8.4	16.4 to 25.7***

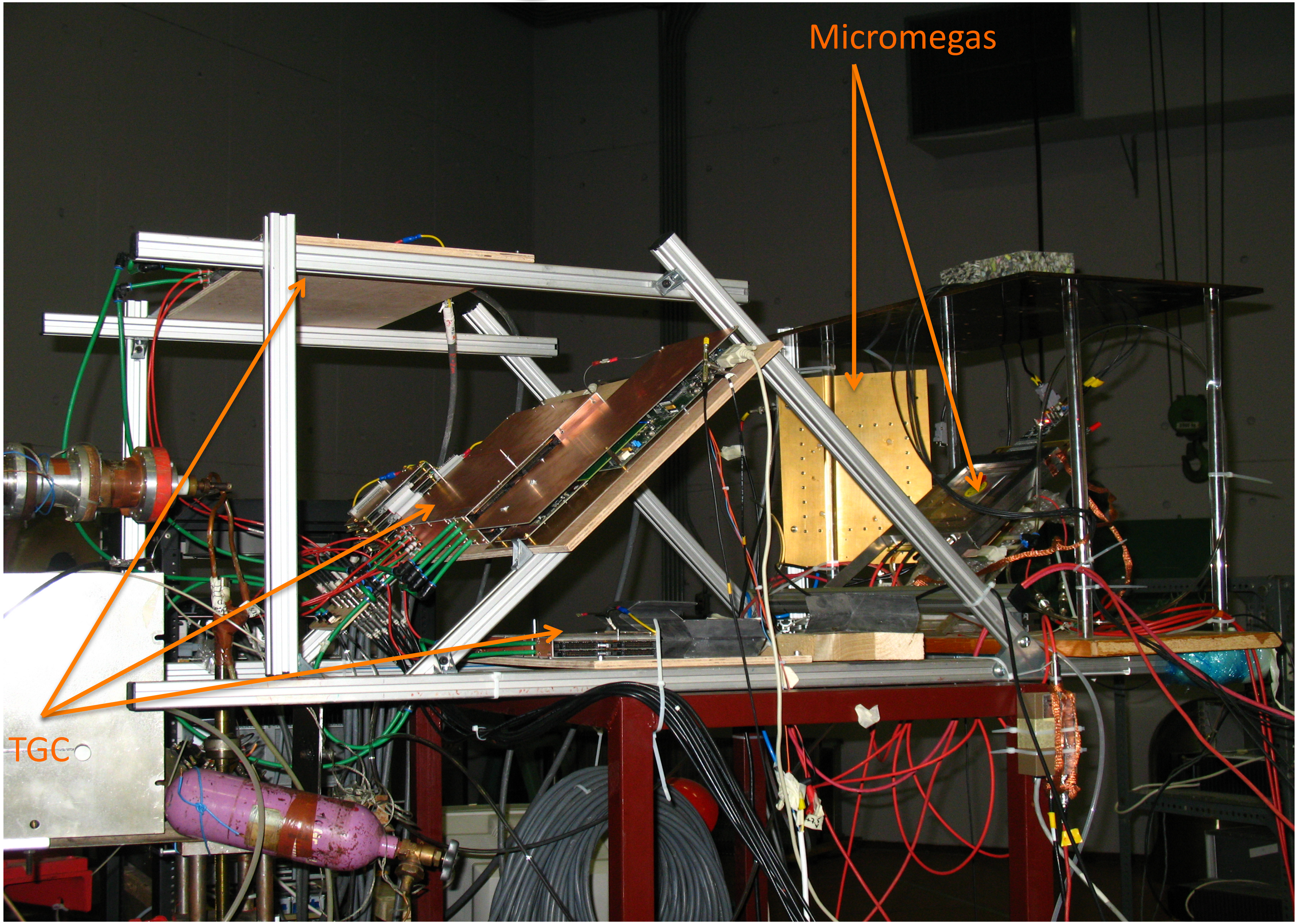
* Monoenergetic neutrons [0.1,0.5] MeV & quasimonoenergetic up to ~2.5 MeV

** Quasimonoenergetic neutrons up to ~7.5 MeV

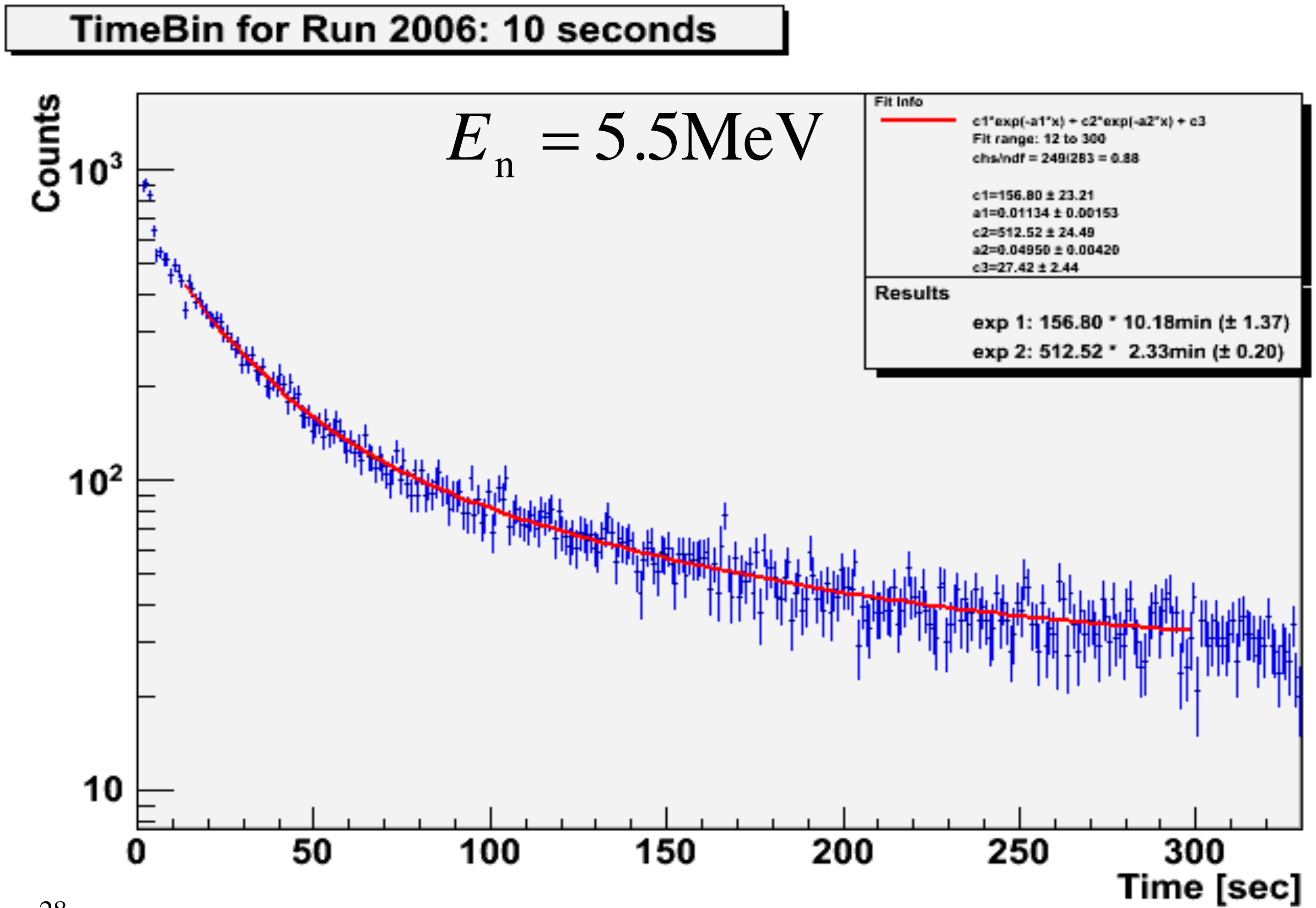
*** Monoenergetic neutrons [16.4,22] MeV

Neutron fluences can reach ~$5x10^{6}$ neutrons/cm^{2} s but for d-^{3}H is lower an order of magnitude compared to the d-^{2}H reaction due to cross section energy dependence

Test @ Demokritos



Activation of the Micromegas Material



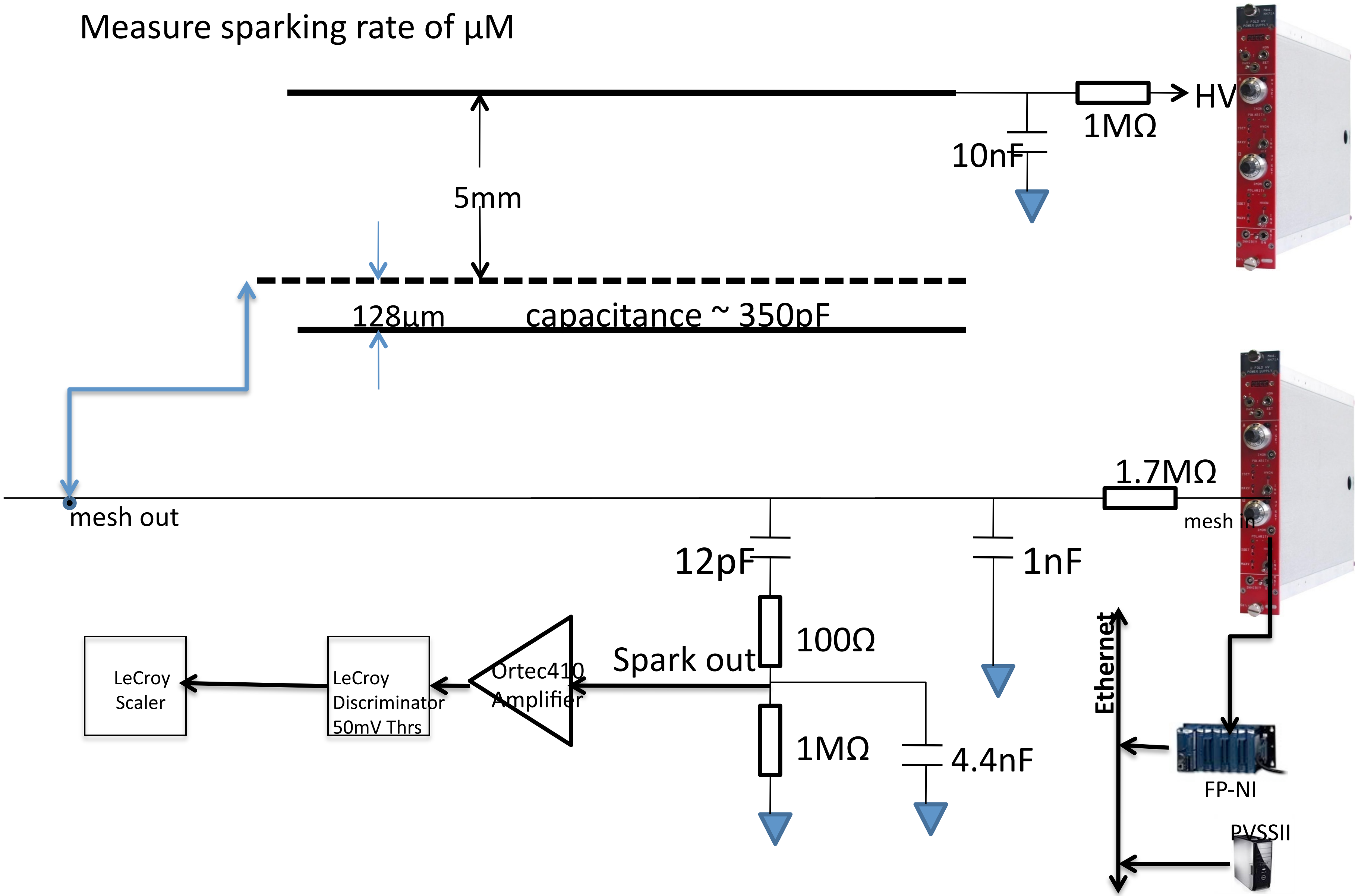
$^{27}_{13}\text{Al}(\text{n},\gamma)^{28}_{13}\text{Al} \quad \tau_{1/2} = 2.24\text{m},\ E_\gamma = 1.8\text{MeV}\ (100\%),\ E_e = 2.9\text{MeV}\ (99\%)$

$^{27}_{13}\text{Al}(\text{n,p})^{27}_{13}\text{Mg} \quad \tau_{1/2} = 9.46\text{m},\ E_\gamma = 0.8\text{MeV}\ (72\%),\ E_e = 1.6\text{MeV}\ (29\%)$

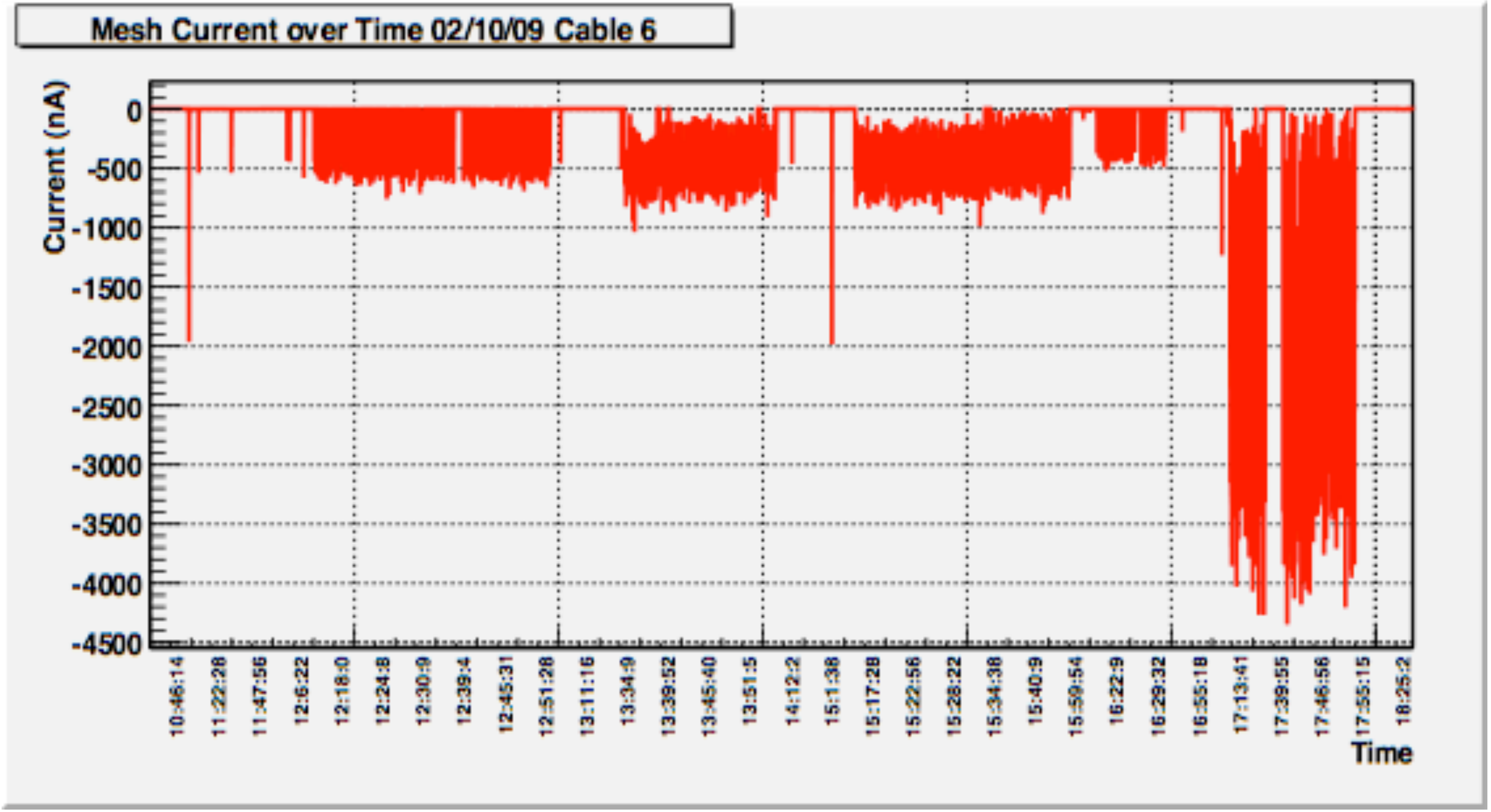
$E_\gamma = 1.1\text{MeV}\ (28\%),\ E_e = 1.8\text{MeV}\ (71\%)$

Sparking Measurement

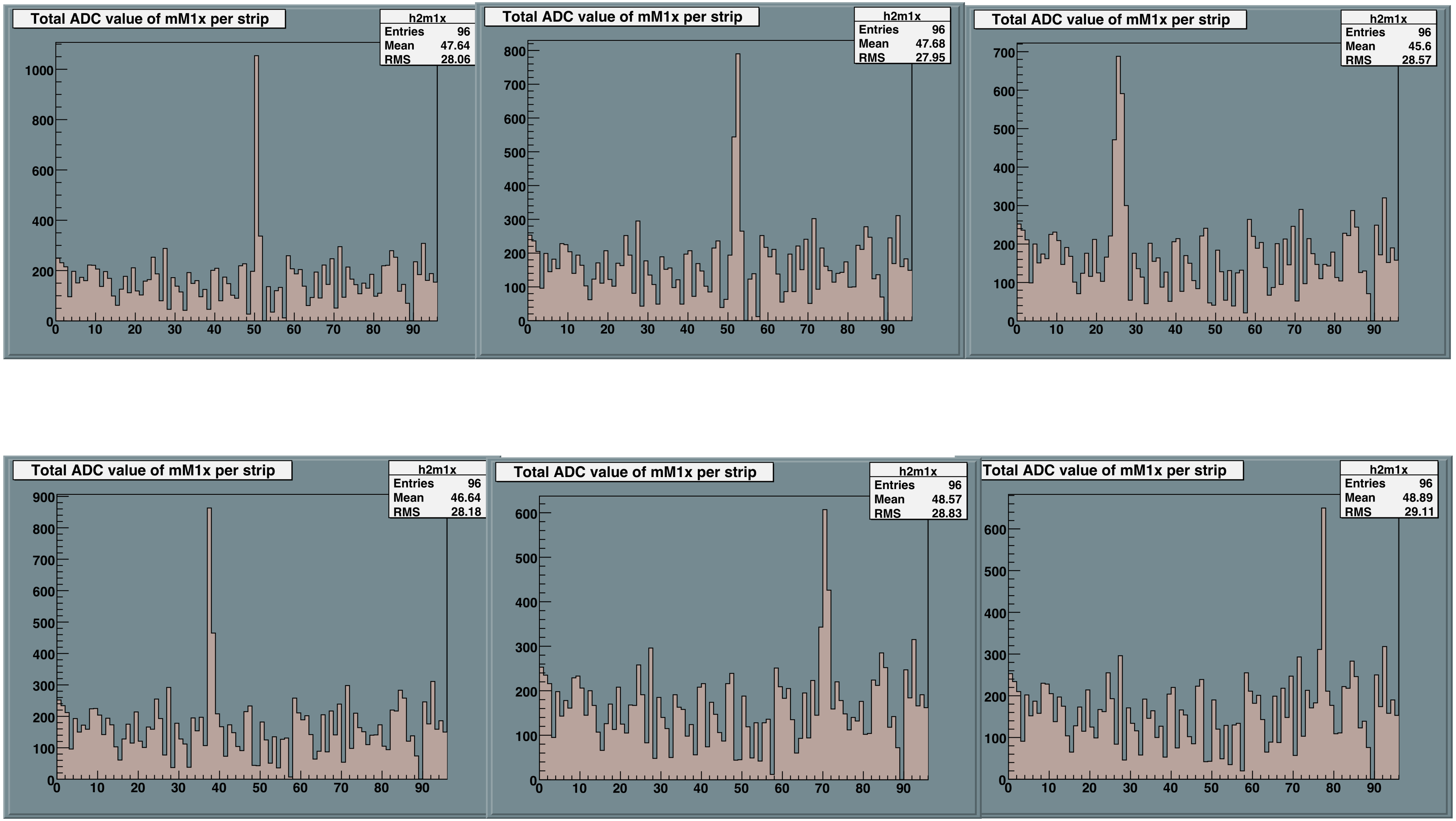
Measure sparking rate of μM



Monitor of the HV Current

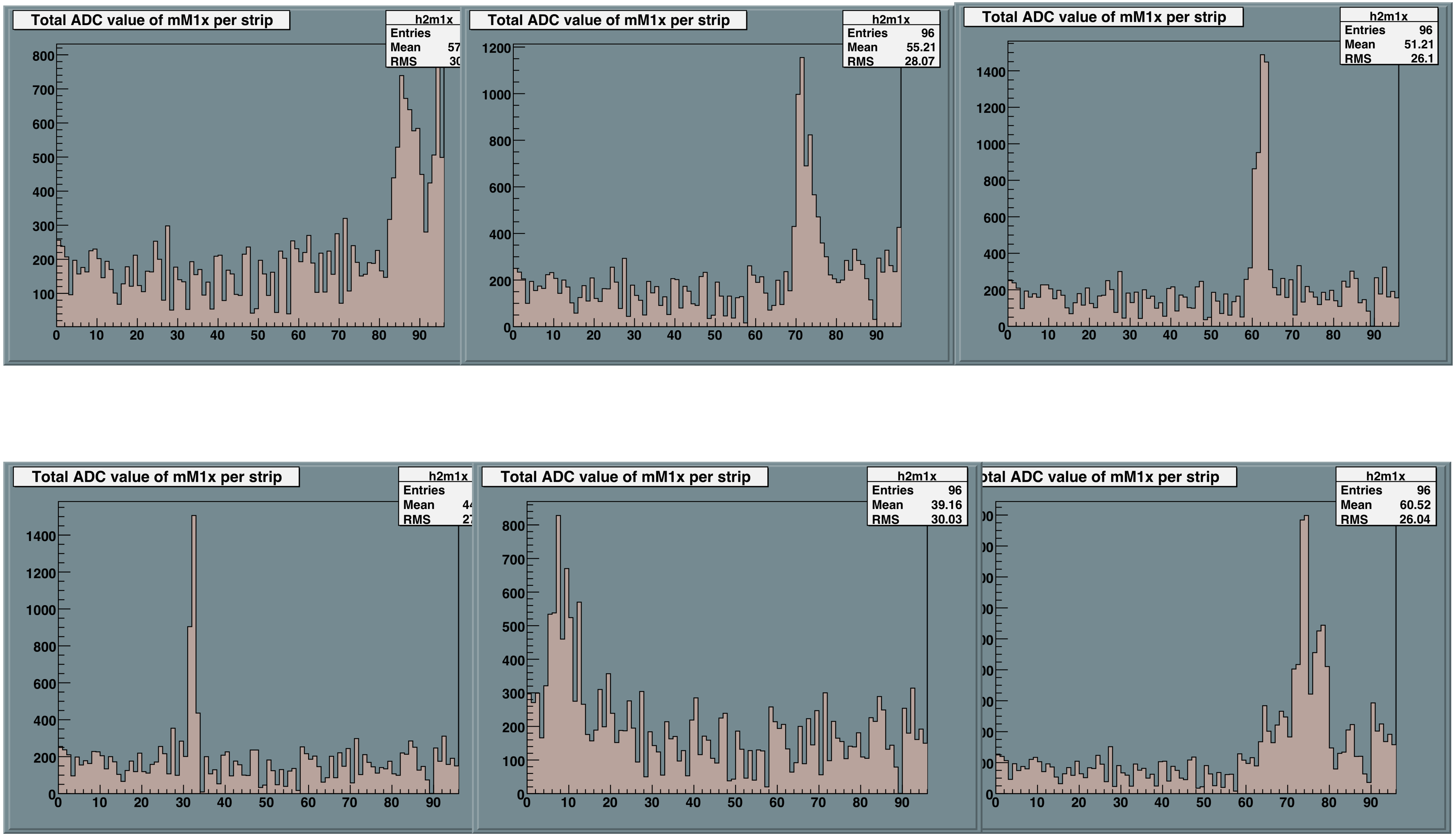


Fe^{55} Data



Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 47.64
RMS 28.06
Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 47.68
RMS 27.95
Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 45.6
RMS 28.57
Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 46.64
RMS 28.18
Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 48.57
RMS 28.83
Total ADC value of mM1x per strip
h2m1x
Entries 96
Mean 48.89
RMS 29.11

Neutron Data



Future Plans

Discharges due to localized large ionization from e.g. nuclear recoils from energetic neutron (E>100 keV) scattering is a serious concern at the LHC (ongoing testbeam activity)

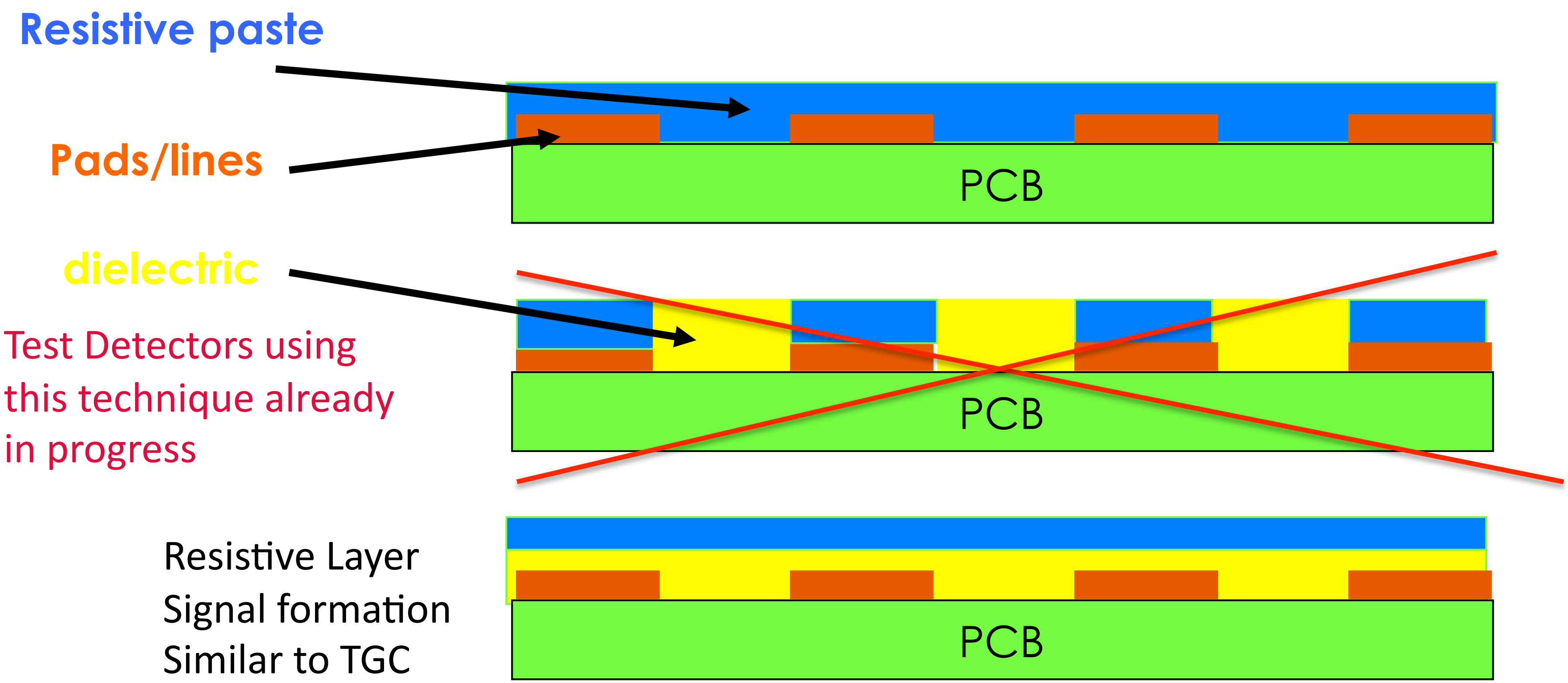
Micromegas electrodes see directly the avalanche

Discharges may damage the detector and/or result in dead time

Investigating different approaches:

- Segmented Mesh → Reduces stored energy
- Resistive Films/Paste → Reduces effect of discharge
- Double Amplification → Reduces discharge probability
- **Test large scale micromegas 1.5 m x 0.5 m**

Future Plans



Test Detectors using this technique already in progress

Resistive Layer
Signal formation
Similar to TGC

- Resistive epoxy based polymers : any decade up to 1Mohm/square
- Resistive polyimide based polymer : only a few values
- Deposition by: screen printing, painting, lamination

Summary

Lots of studies have been done with the Micromegas as an option for the ATLAS update

Spatial resolution <80 μm (θ_{track}< 45°)
Good double track resolution
Time resolution ~ 5 ns
Efficiency > 99%

} Achieved

Rate capability > 5 kHz/cm^2
200 Hz/cm^2 due to neutrons with E>100 keV

} Not there yet !

Stability over about 5 years at phase-1 luminosity (≅1000 fb^{-1})
Large area detectors

} To do