# The Muon ATLAS MicroMegas Activity
## (Micromegas R&D for ATLAS/sLHC)


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On behalf of the **M**uon **A**TLAS **M**icro**M**egas **A**ctivity
(**MAMMA** R&D)

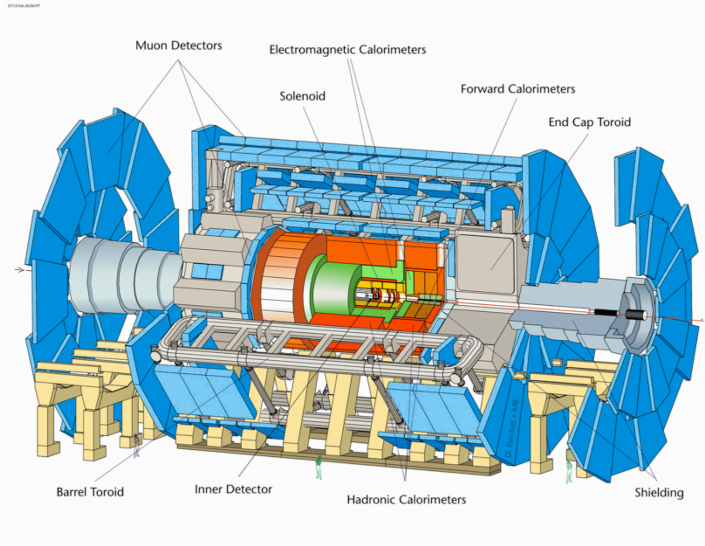

See also poster #1024

EPS – HEP 2011

# Outline

- Micromegas as an R&D project for ATLAS for sLHC
- Structure of Micromegas chamber with resistive strips
- Laboratory tests:
  - $^{55}Fe$ source
  - X-ray gun
- Neutron beam tests at "Demokritos" lab in Athens:
  - V-I characteristics under neutron beam
  - Spark probability
- Beam tests at H6-SPS/CERN:
  - V-I characteristics
  - Spark probability
  - Tests in ATLAS cavern
- Future Plans

# ATLAS upgrade for the s-LHC



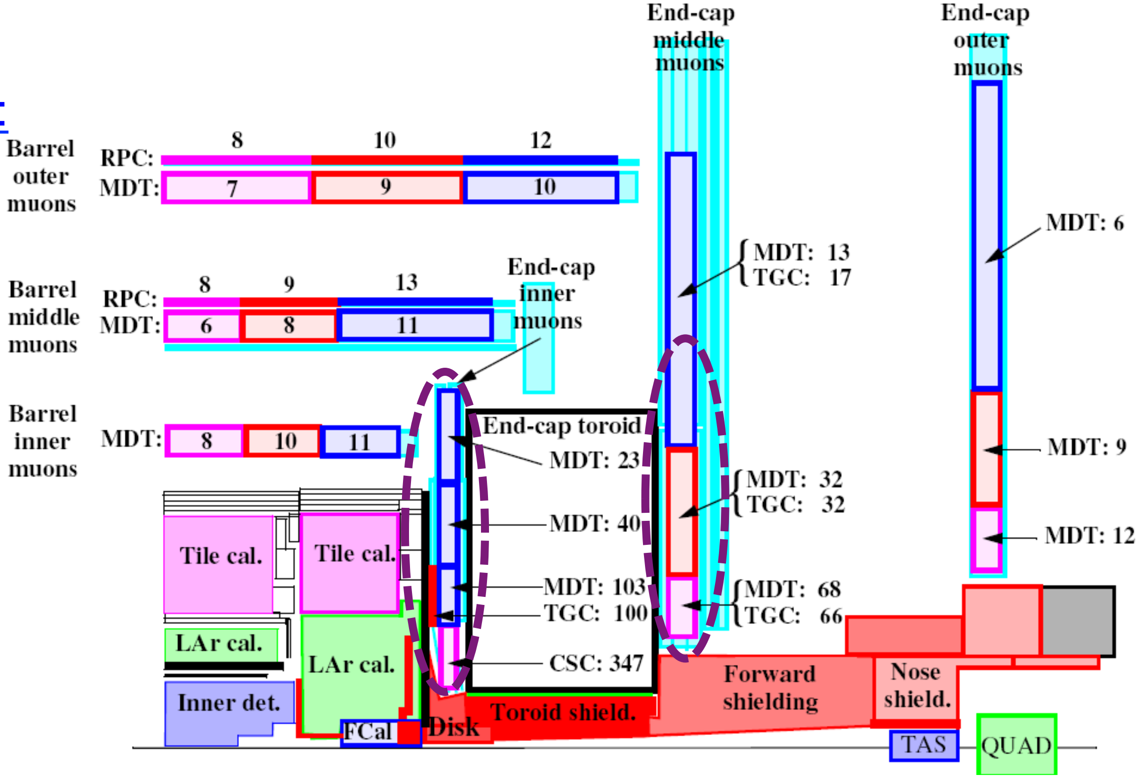

LHC upgrade to happen in two phases
$L_{\mathrm{Phase\ 1}} \sim 3\ L_{\mathrm{LHC}}$ (~2014)
$L_{\mathrm{Phase\ 2}} \sim 10\ L_{\mathrm{LHC}}$ (s-LHC >2017)
Bunch Crossing = 25 ns / possibly 50 ns (Phase 2)

Muon Spectrometer affected regions :

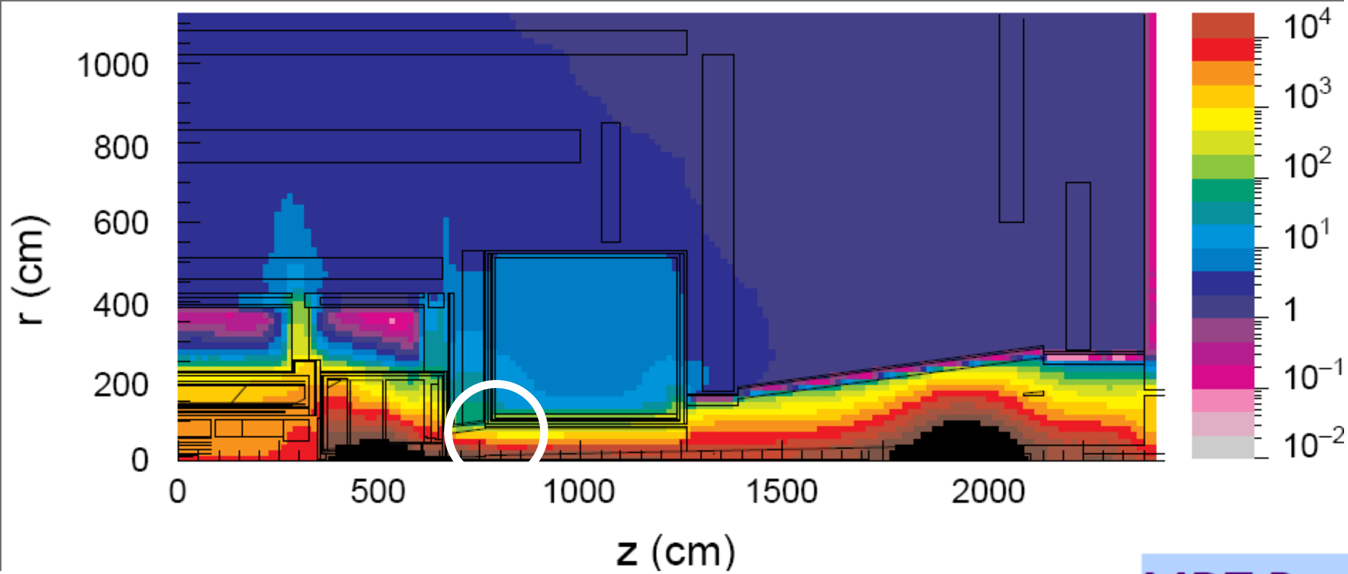
- End-Cap Inner (CSC,MDT,TGC)
- End-Cap Middle $|\eta|>2$ (MDT,TGC)

Total area ~400 m$^2$

Replace the
Cathode Strip Chambers (CSC)

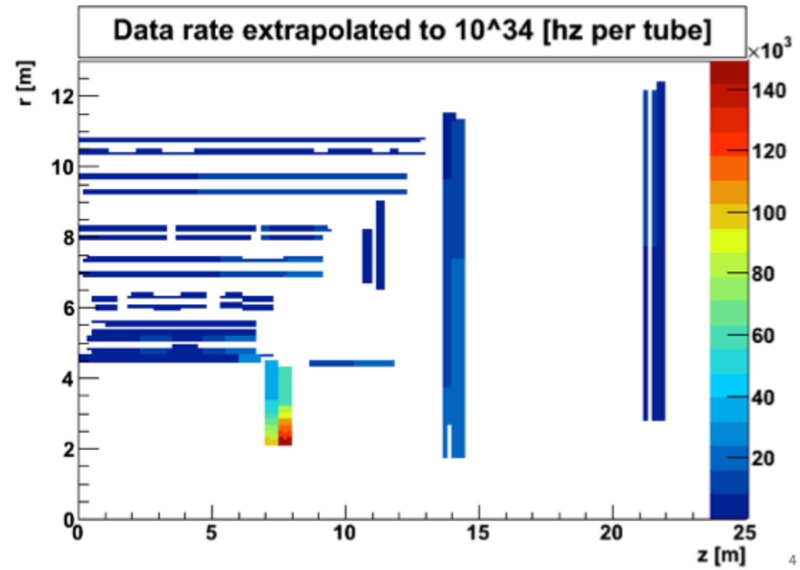



Average single plane counting rate (Hz/cm$^2$) at the nominal LHC luminosity (CERN-ATL-GEN-2005-001)

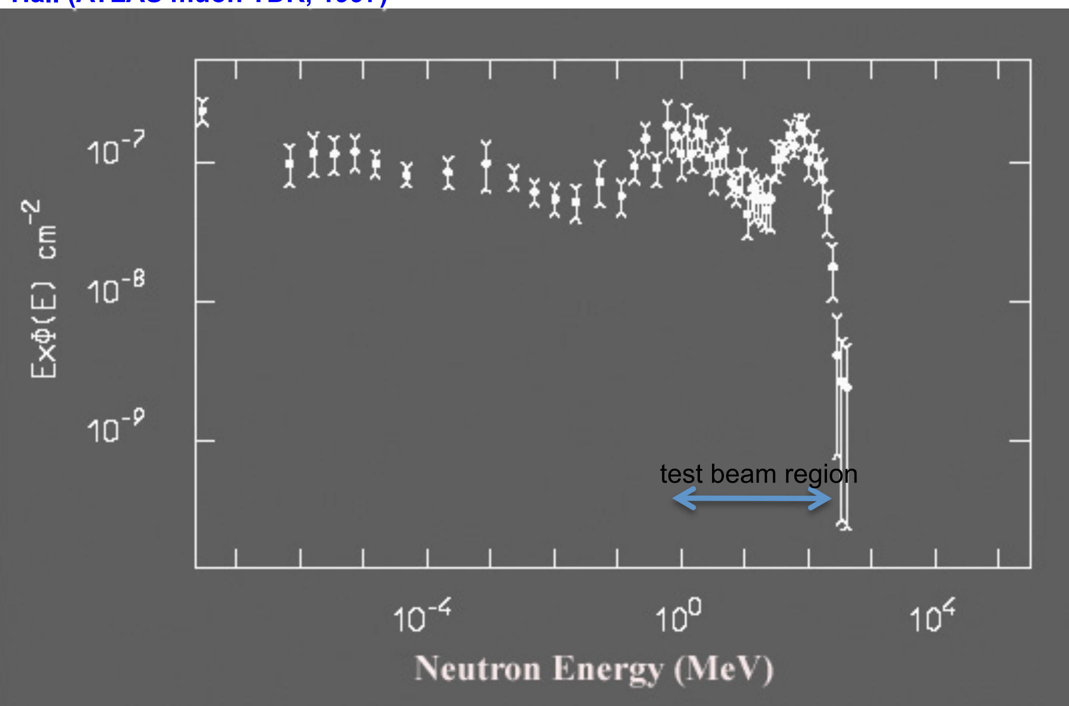



**The expected neutron fluence (kHz/cm$^2$) in the ATLAS Hall (ATLAS muon TDR, 1997)**

## MDT Backgrounds using hit rate




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

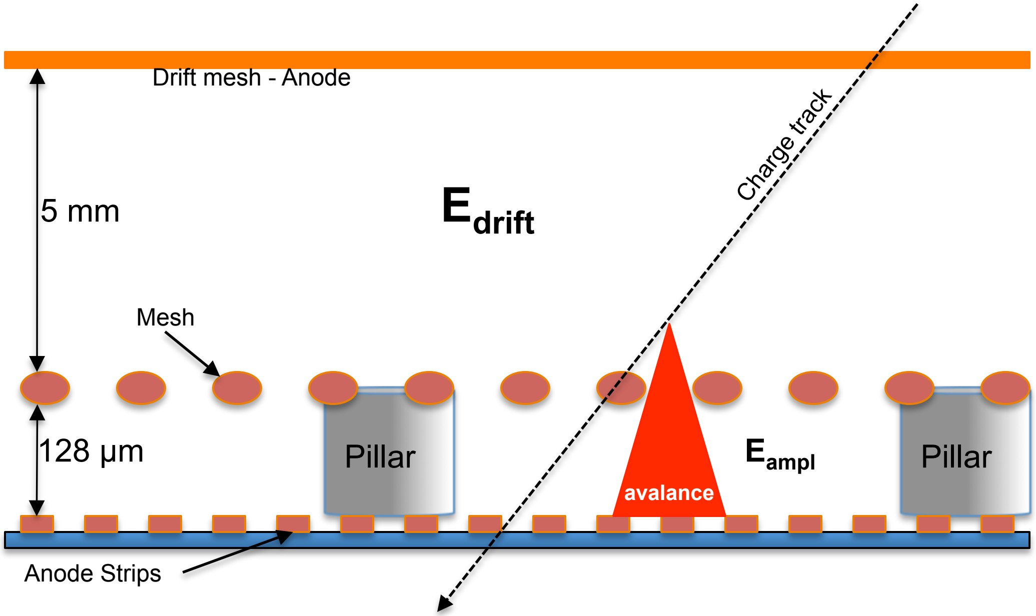


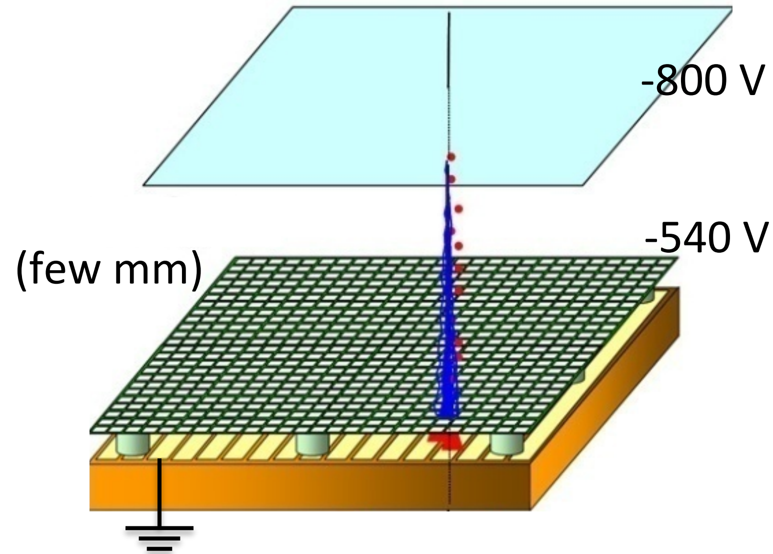
# ATLAS Muon upgrade Imposed Specs

- Combine triggering and tracking functions
- Matches required performances:
  - Spatial resolution <80 μm ($\theta_{track}$< 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$^{-1}$)

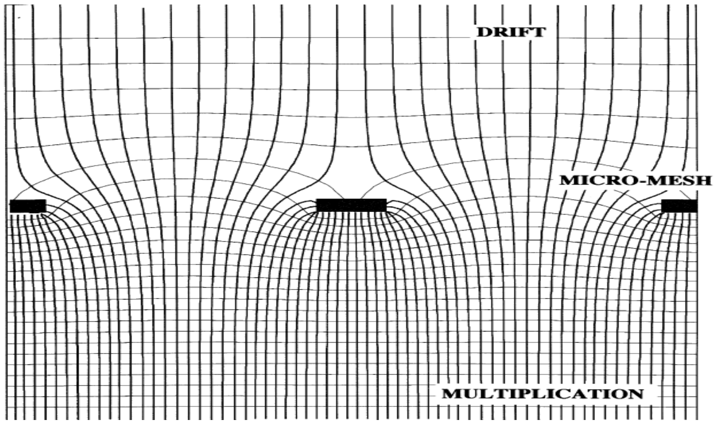
- Cover large areas ~1m x 2m with industrial process
  - Cost effective & Robustness

# Micromegas Structure

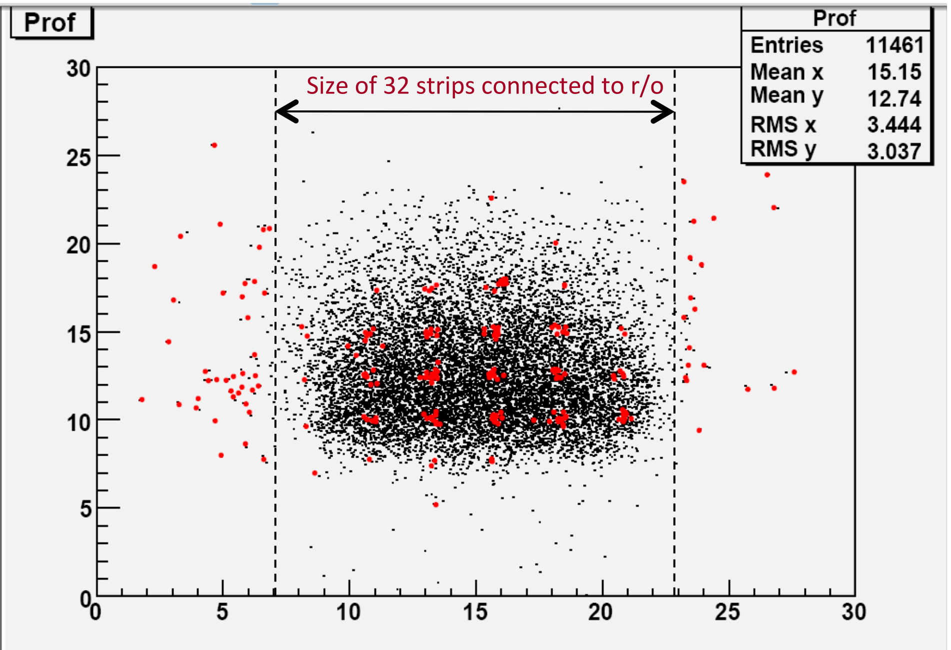


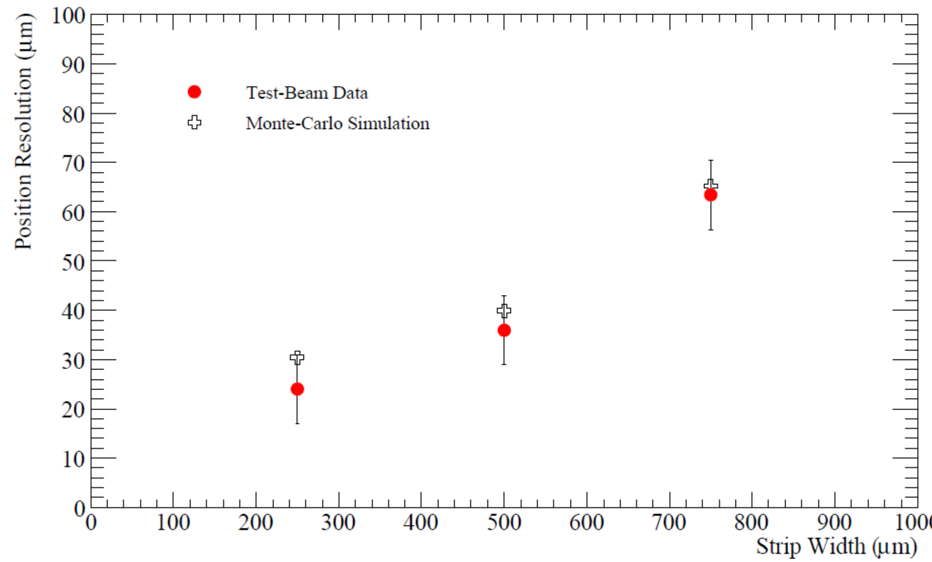

- Micromegas *(I. Giomataris et al., NIM A 376 (1996) 29)* are parallel-plate chambers where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh
- The thin amplification gap (short drift times and fast absorption of the positive ions) makes it particularly suited for high-rate applications



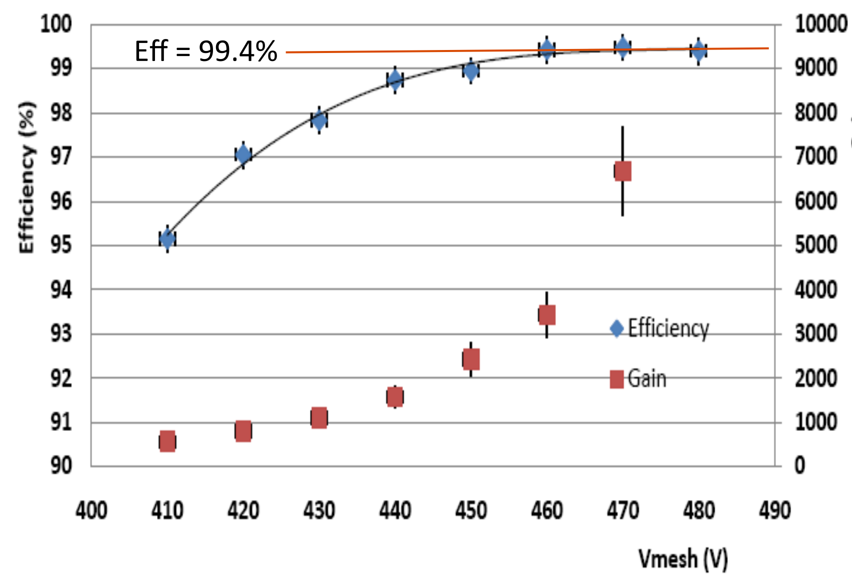
# 2008-2009: Demonstrated Performance




Black: beam profile
Red: tracks w/o Micromegas hit




- Safe operating point with excellent efficiency (gas gain: 3-5x10$^{3}$).
- Superb spatial resolution has been demonstrated in beam test.
- Timing performance sufficient for triggering
- Potential to deliver track vector in a single plane for track reconstruction and LV1 trigger



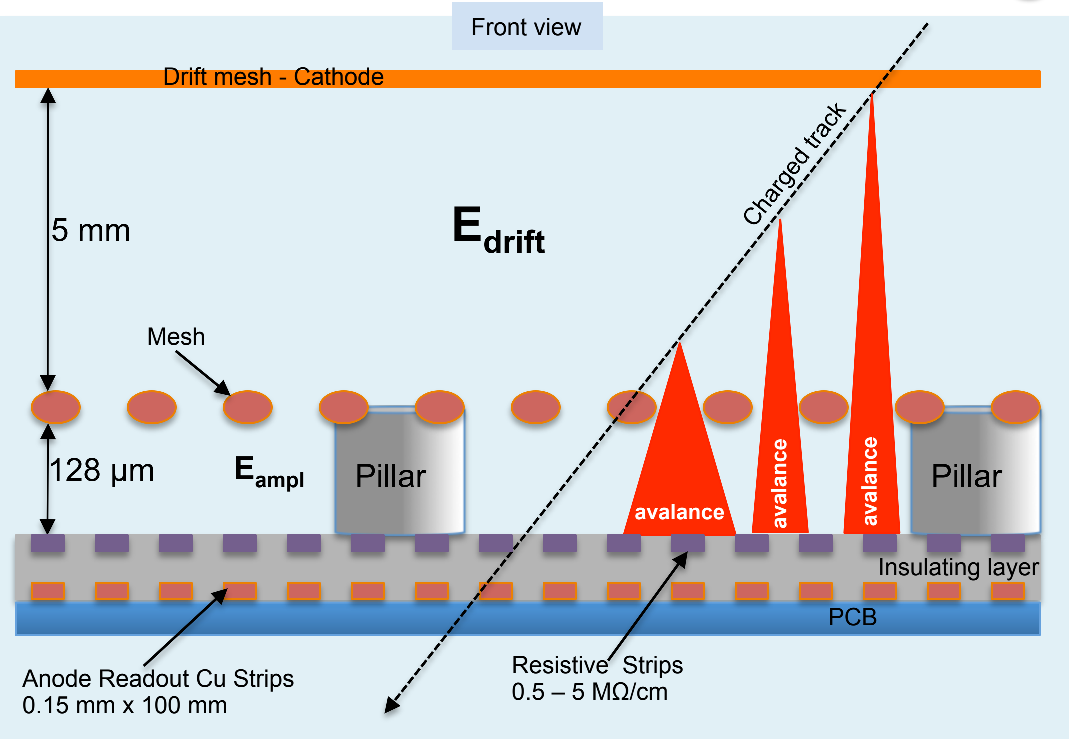

**Pillars contribute to the geometrical inefficiency of the chamber at the ~1% level.**

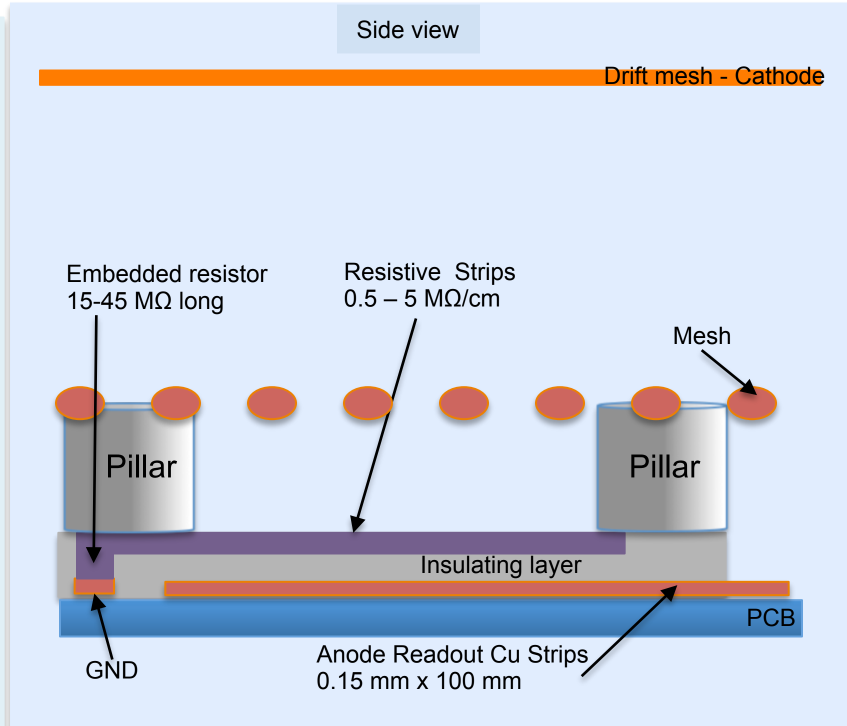
# Sparks/Discharges

- Sparks are a major concern: they can create dead time and/or damage in the detector
- Sparks develop when local electron charge concentrations exceed a few $10^7$ $e^-$ (Raether limit, $M<10^8$)

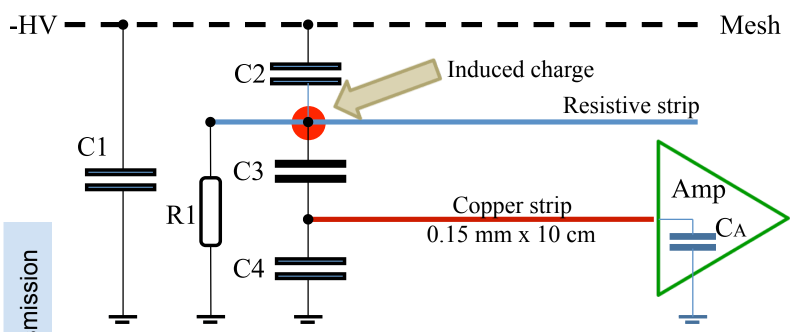
  For a gas gain of $10^4$ any ionization process creating $\geq 10^3$ electrons in a small volume risks the development of a spark, e.g. heavily ionizing particles induced by neutrons
- Two ways to approach the problem
  1. Avoid high concentrations of charge, e.g. by spreading the charge (multi-stage GEMs or Micromegas)
  2. Live with it and make the detector insensitive to sparks
- We opted for the latter and evaluated different resistive coating options … and it seems we found one doing the job

# Resistive Micromegas Structure

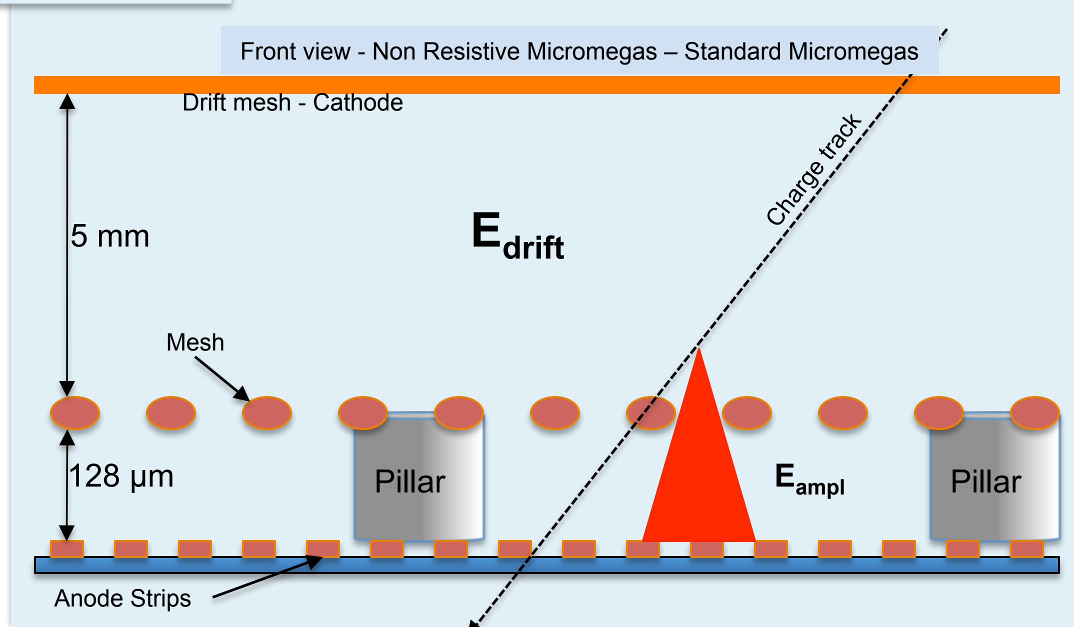



Signal transmission




C1 – capacitance Mesh to ground
C2 – capacitance R-strip to ground
C3 – capacitance R-strip to readout strip
C4 – capacitance readout strip to ground
$C_A$ – input capacitance of preamplifier

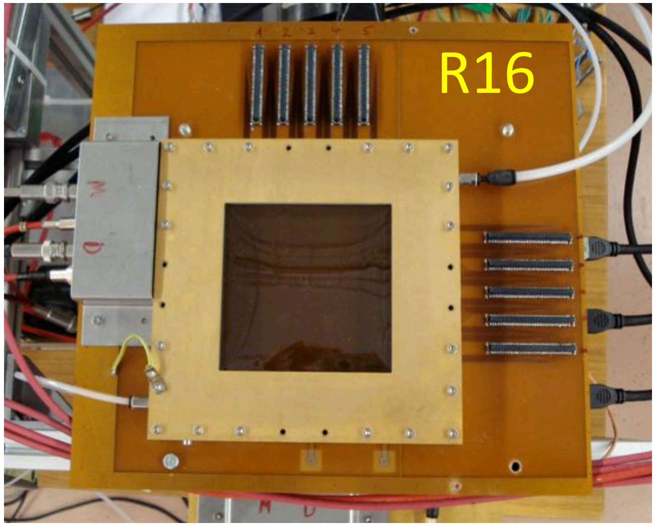


# Eight resistive strip detectors tested

- Small 9 x 8 cm$^2$ chambers with 250 µm r/o strip pitch

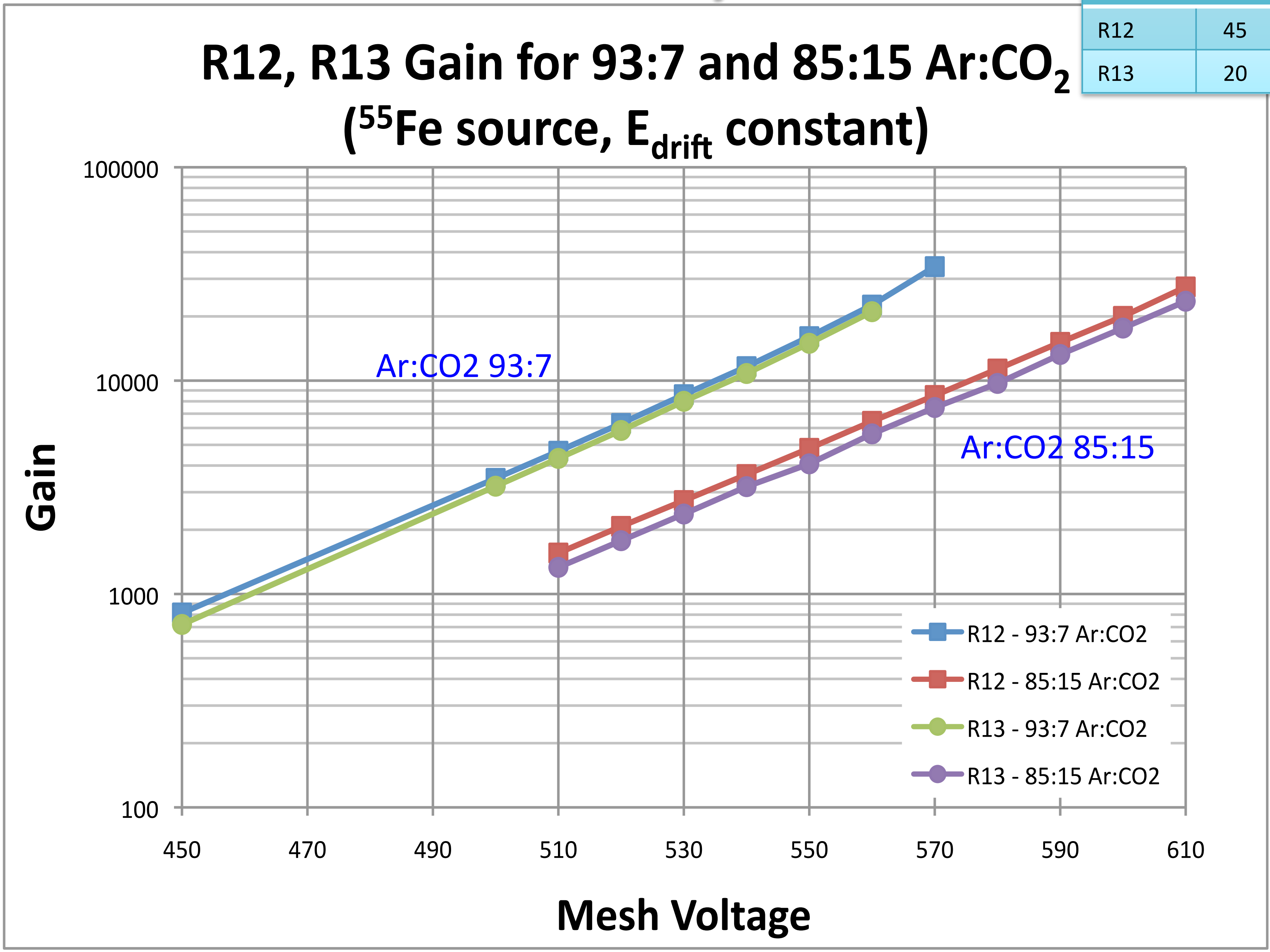
| Chamber | $R_{GND}$ (MΩ) | $R_{strip}$ (MΩ/cm) | $N_R:N_{ro}$ |
|---|---|---|---|
| R11 | 15 | 2 | 1:1 |
| R12 | 45 | 5 | 1:1 |
| R13 | 20 | 0.5 | 1:1 |
| R14 | 100 | 10 | 1:1,2,3,4,72 |
| R15 | 250 | 50 | 1:1,2,3,4,72 |
| R16 | 55 | 35 | x-y readout |
| R17 | 100 | 45 | x-y readout |
| R18 | 200 | 100 | x-y readout |
| R19 | 50 | 50 | xuv readout |

- Variety of resistance values
- Different configurations
- Gas gains
  - 2–3 x $10^4$
  - $10^4$ for stable operation

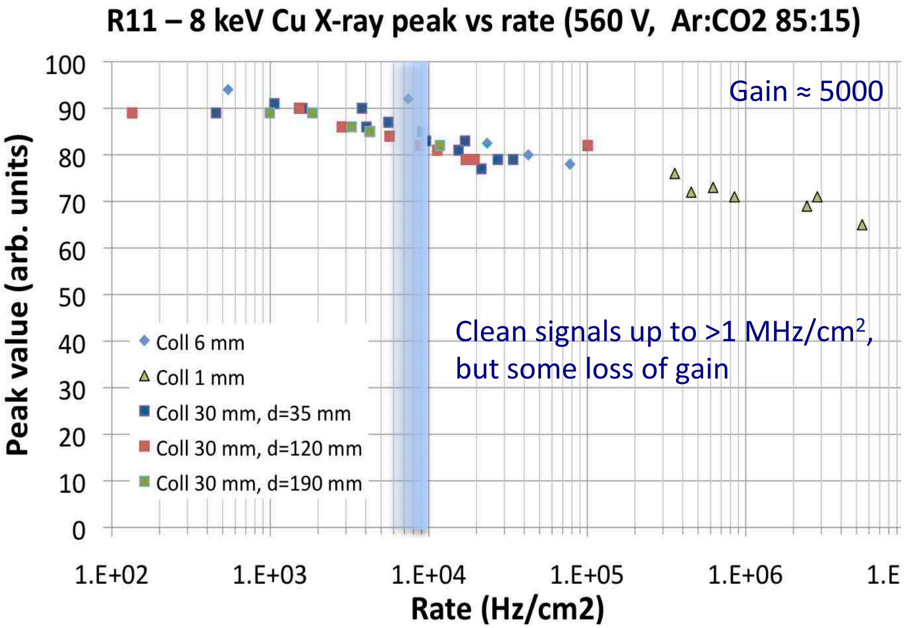


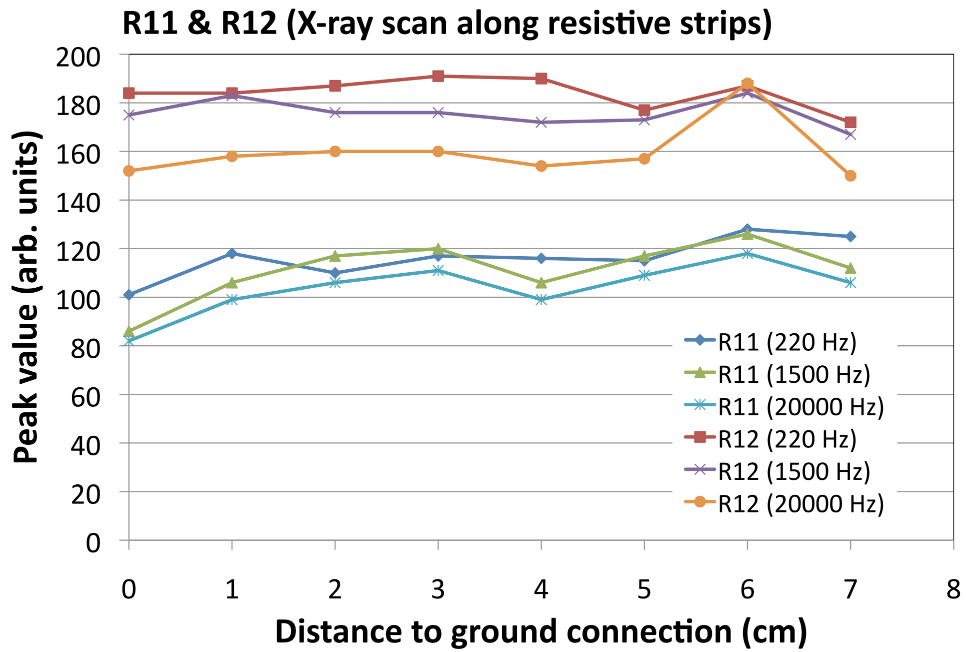
# Laboratory Tests

| Chamber | $R_{GND}$ (MΩ) | $R_{strip}$ (MΩ/cm) |
|---|---|---|
| R12 | 45 | 5 |
| R13 | 20 | 0.5 |

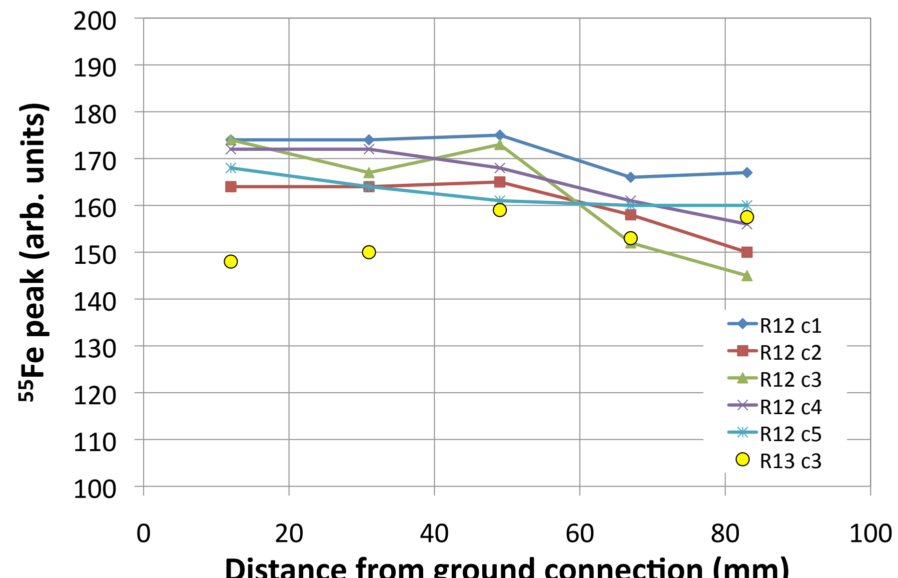


# Laboratory Tests




- R11, R12, and R13 are working fine with the $^{55}$Fe source and with X-ray gun.
- Very good homogeneity along the strips



# Neutron Beam Test at Demokritos

- Exposed R11,R12,R13,R16 and a standard MM in a neutron beam at Demokritos NRC (Athens); ***serves as a Micromegas beam test lab***
- Neutrons of 5.5 MeV with fluxes up to 1.5 x $10^6$ n/$cm^2$ s
- Gas mixtures tested: Ar:$CO_2$ (80:20; 85:15, 93:7)

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

**Neutron fluences can reach ~5x$10^6$ 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**

# Neutron Test Beam

## MM mesh currents in neutron beam

Gas: Ar:$CO_2$ (85:15) Neutron flux: ≈ $1.5 \times 10^6$ n/$cm^2$ s

**Standard MM:**

Large currents

Large HV drops, recovery time O(1s)

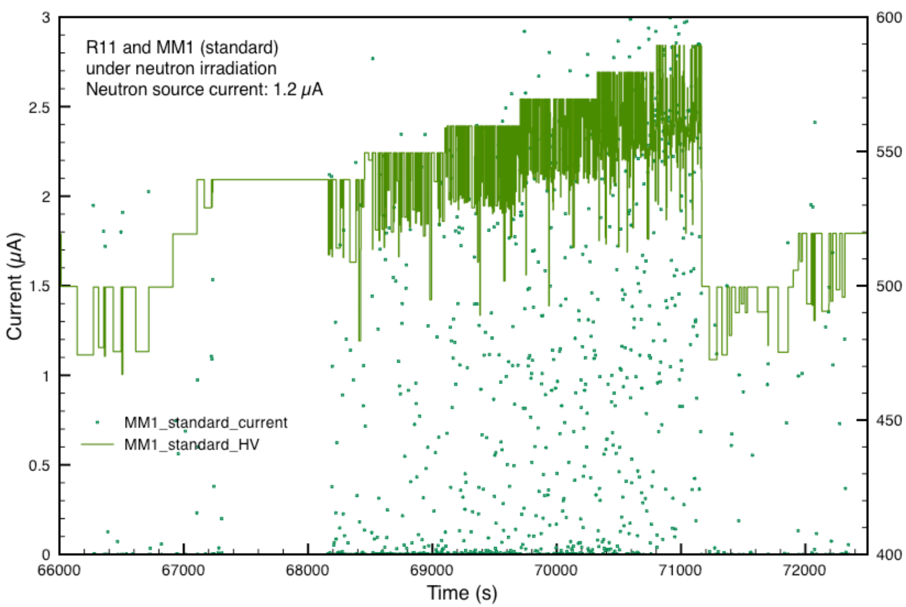
Chamber could not be operated stably

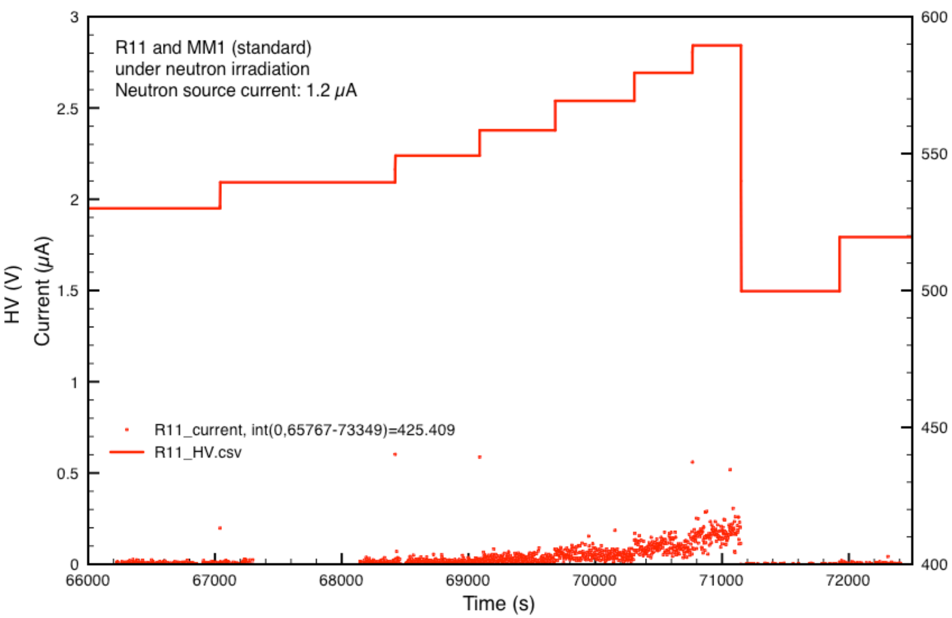
**R11:**

Low currents

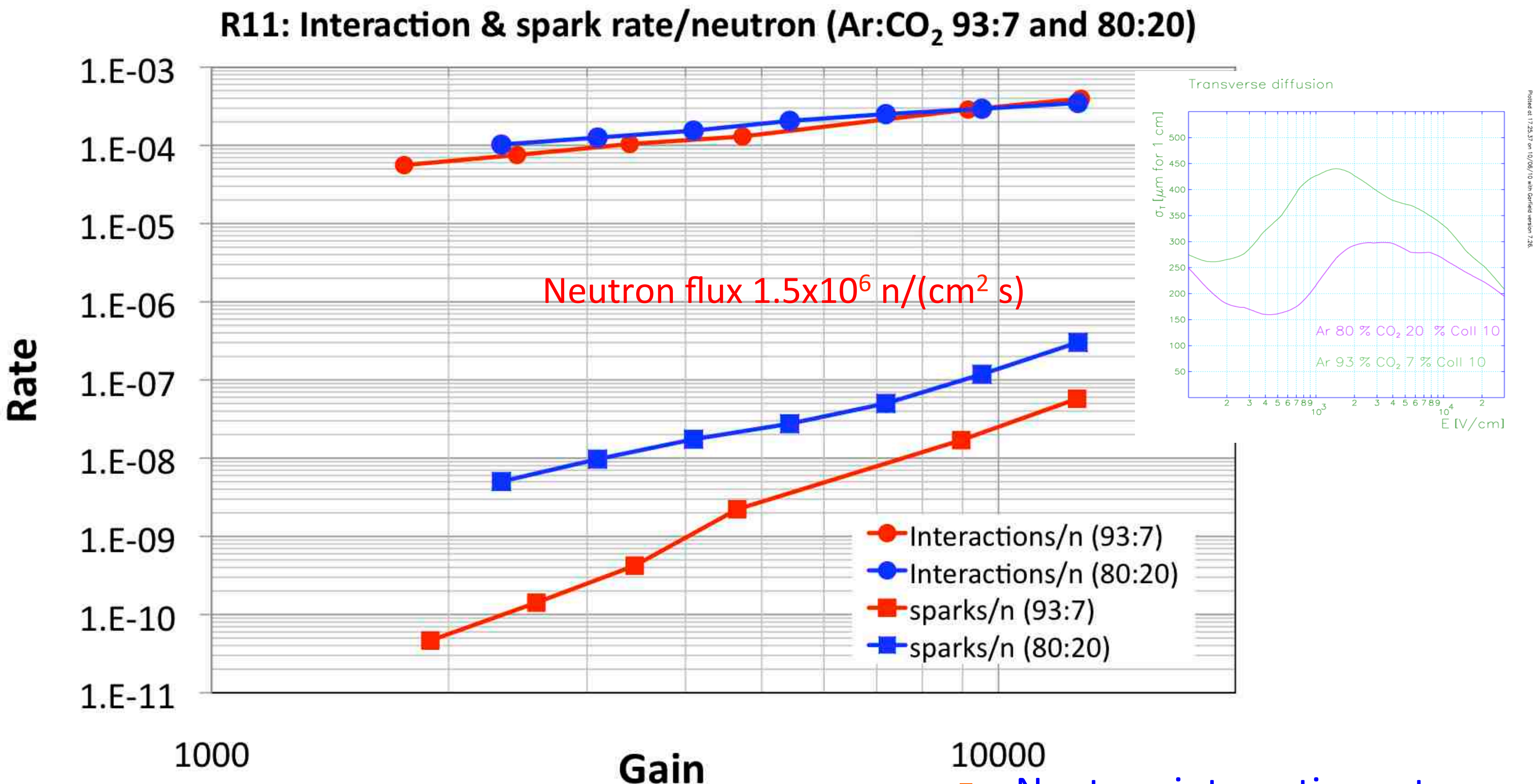
Despite discharges, but no HV drop

Chamber operated stably up to max HV



# Test Beam with 5.5 MeV Neutrons




- Typically a few sparks/s for gain $10^4$
- About 4x more sparks with 80:20 than with 93:7 Ar:$CO_2$ mixture
- Neutron interaction rate independent of gas
- Spark rate/n is a few $10^{-8}$ for gain $10^4$

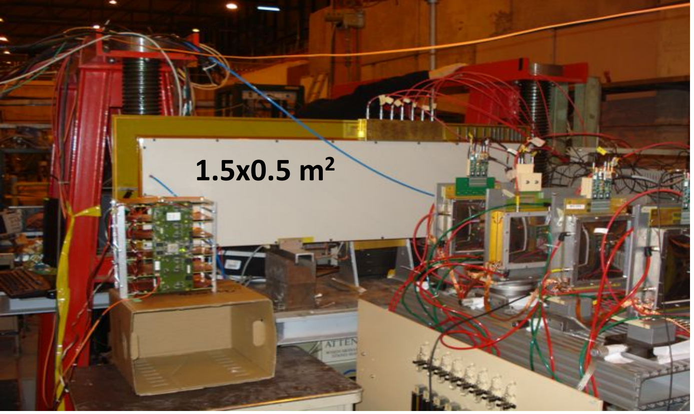
# Conclusions from neutron test

- R11,R12,R13,R16 worked fine in a neutron flux of up to $1.5 \times 10^6$ n/cm$^2$ s
- Despite sparks, no HV breakdown, no dead time
- Measured three Ar:$CO_2$ gas mixtures, 93:7 looks very interesting, with a spark rate almost a factor ~4 lower than for 80:20

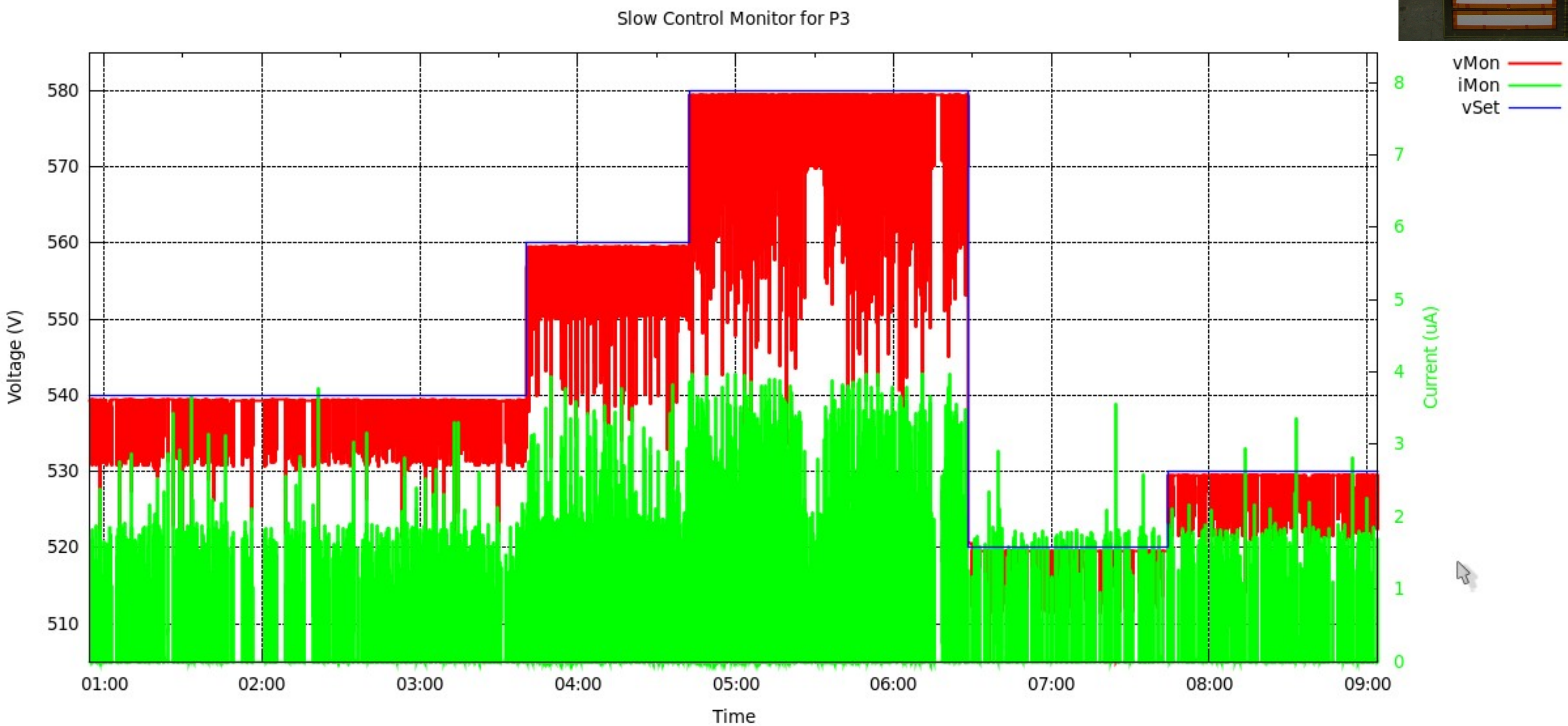
# Beam test in SPS/H6

- R11, R12, R13, and P3 chambers were tested in +120 GeV pion beam (intensities 40 kHz & 5 kHz) for two Ar:$CO_2$ mixtures, 85:15 and 93:7
- Main goals:
  - Study HV and current behavior of resistive and non-resistive chambers in a hadron beam
  - Measure performance (spatial resolution and efficiency) of resistive chambers
  - Study performance of long strips (0.4 m & 1m, non-resistive)
- A few million of events are being analyzed

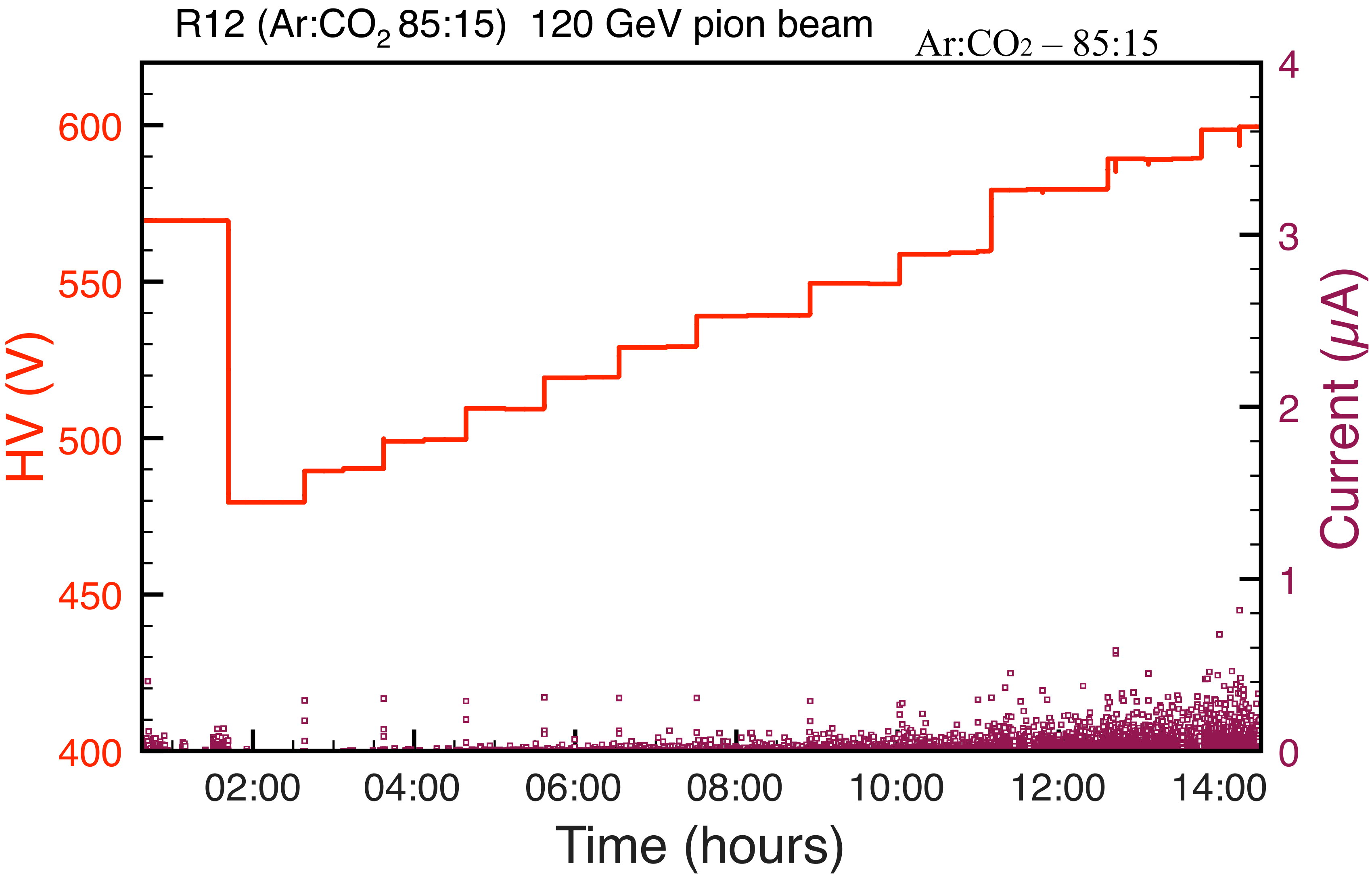
# Beam test in H6



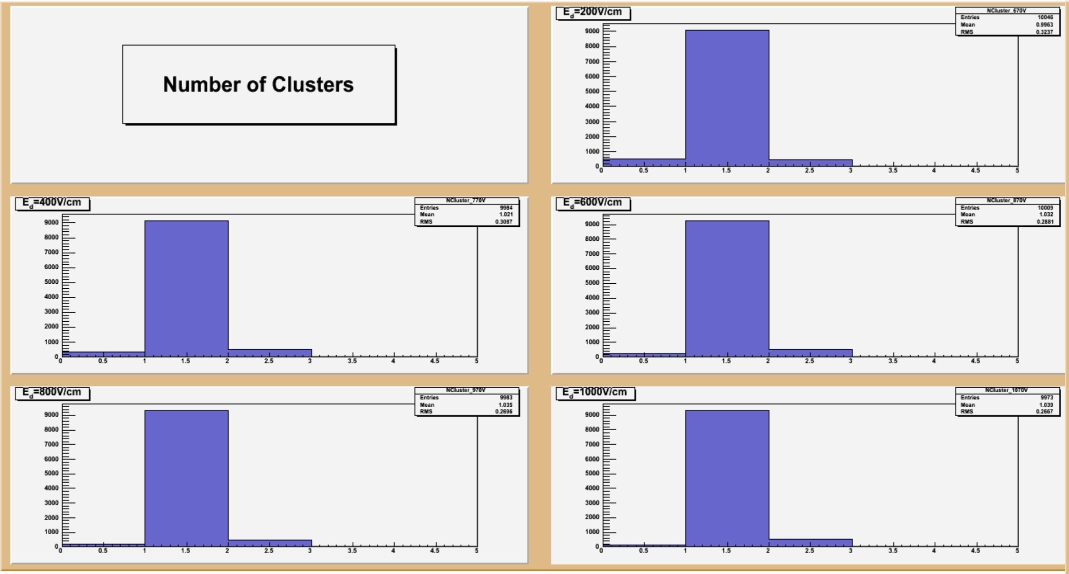

$Ar:CO_2$ – 85:15
+120 GeV pions

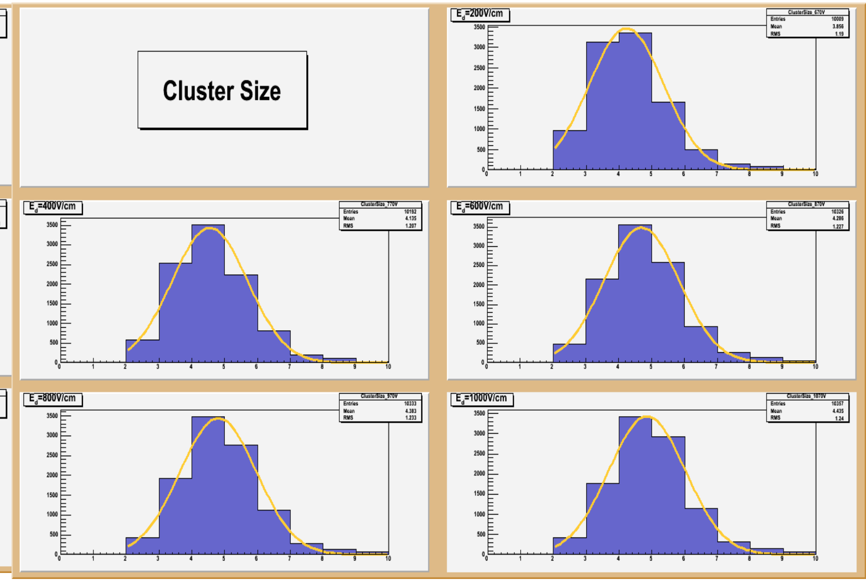


# Beam test in H6

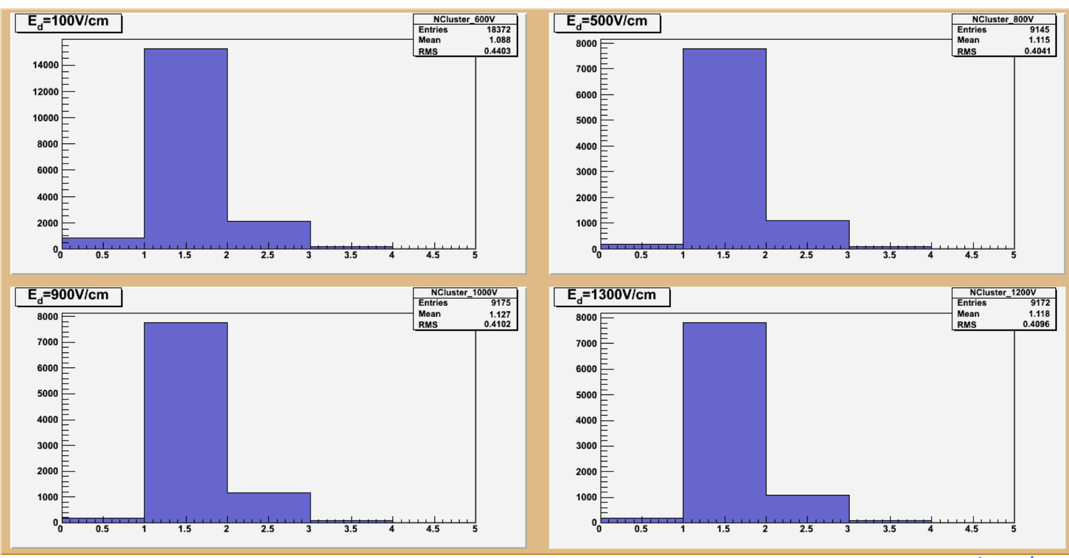


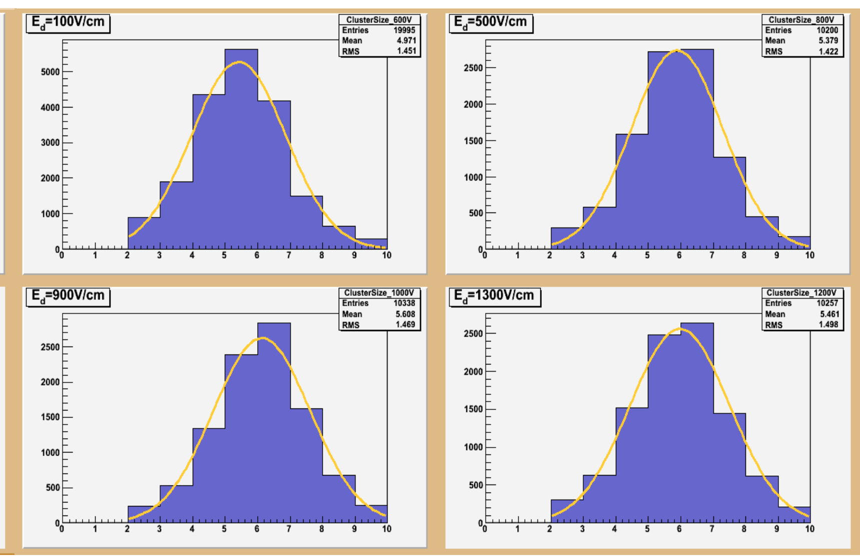
# Number of Clusters – Ar:CO2-85:15



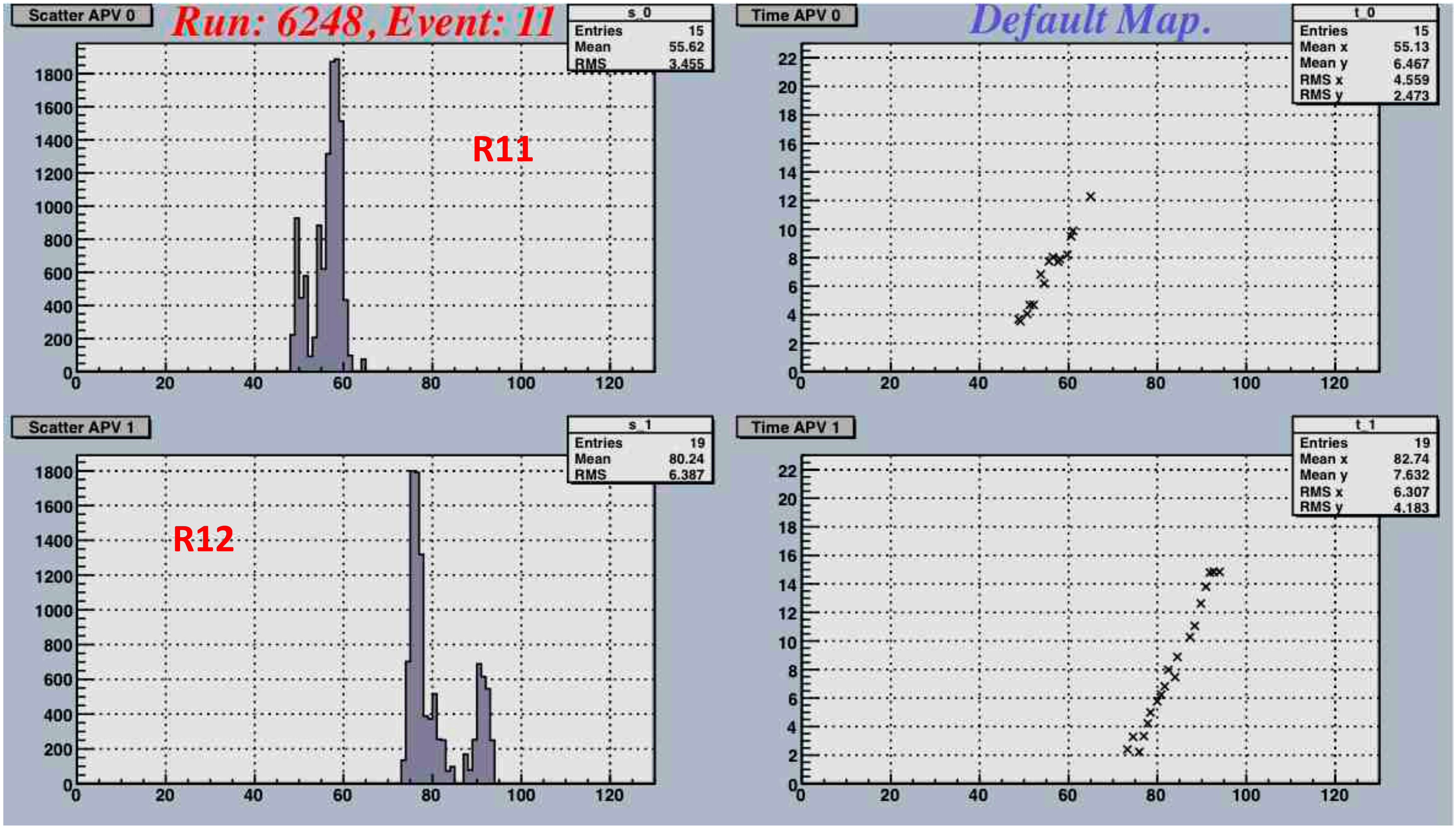




# Number of Clusters – Ar:CO2-93:7

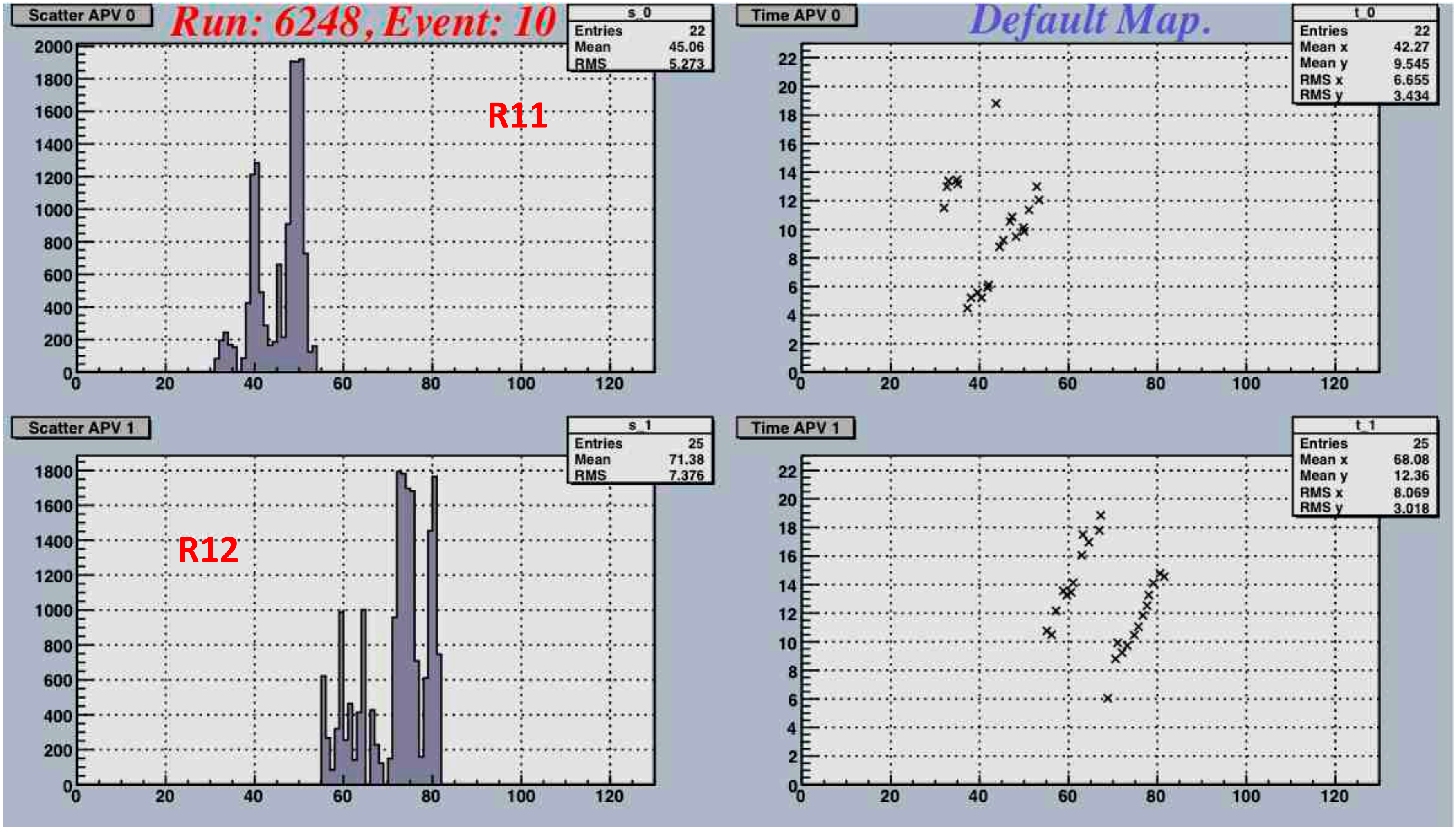


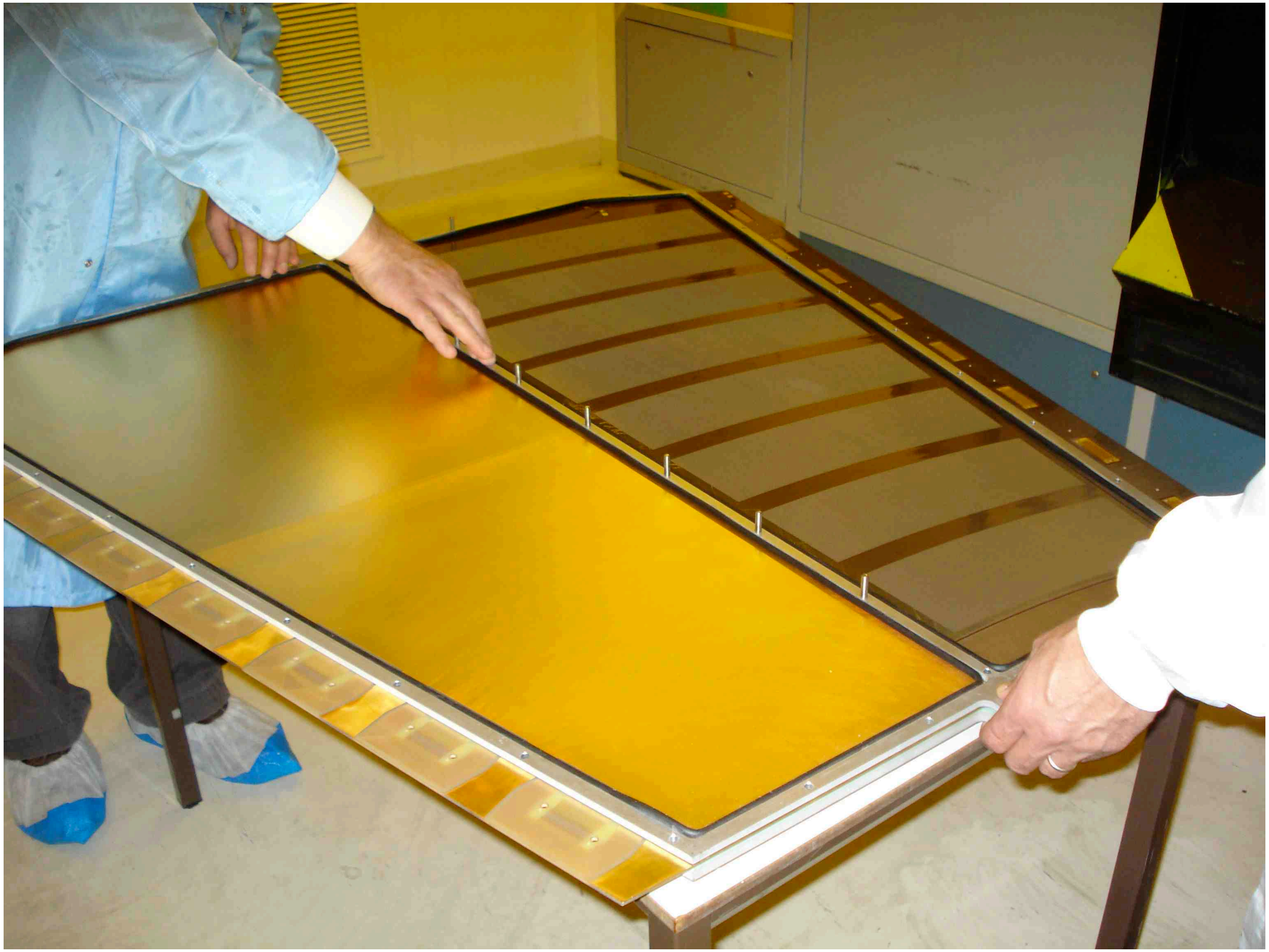
# Inclined tracks (40°) – µTPC



# … and a two-track event

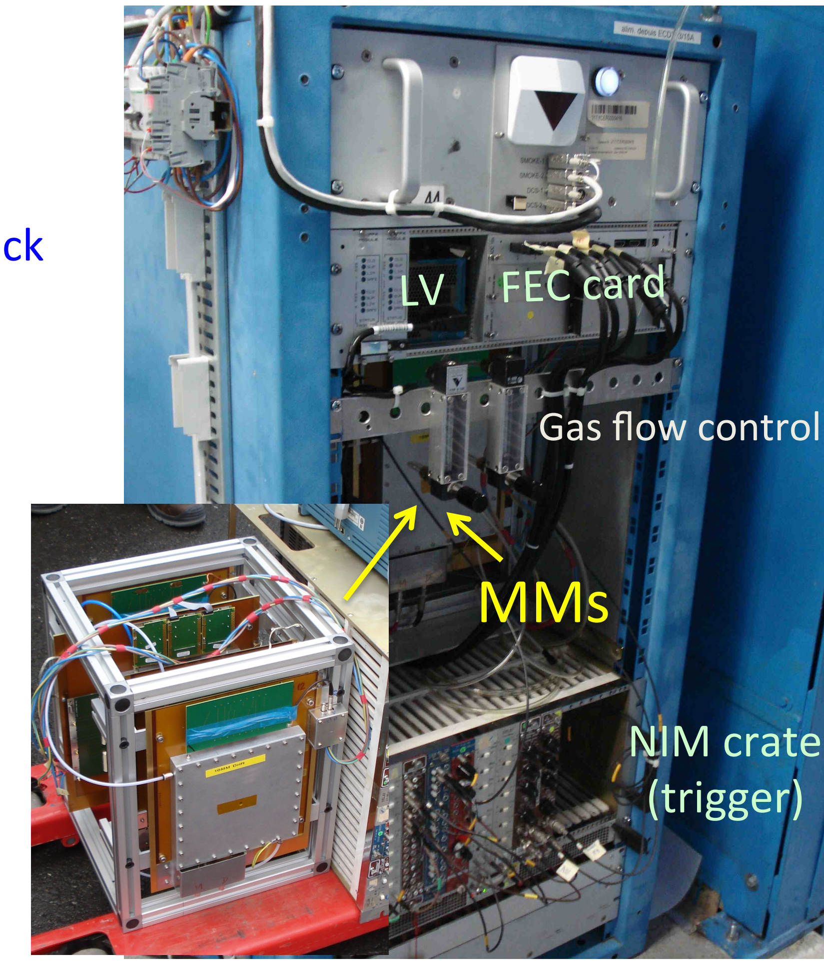


# Assembly of large resistive MM 1.2 x 0.6 $m^2$



# MM test in ATLAS cavern

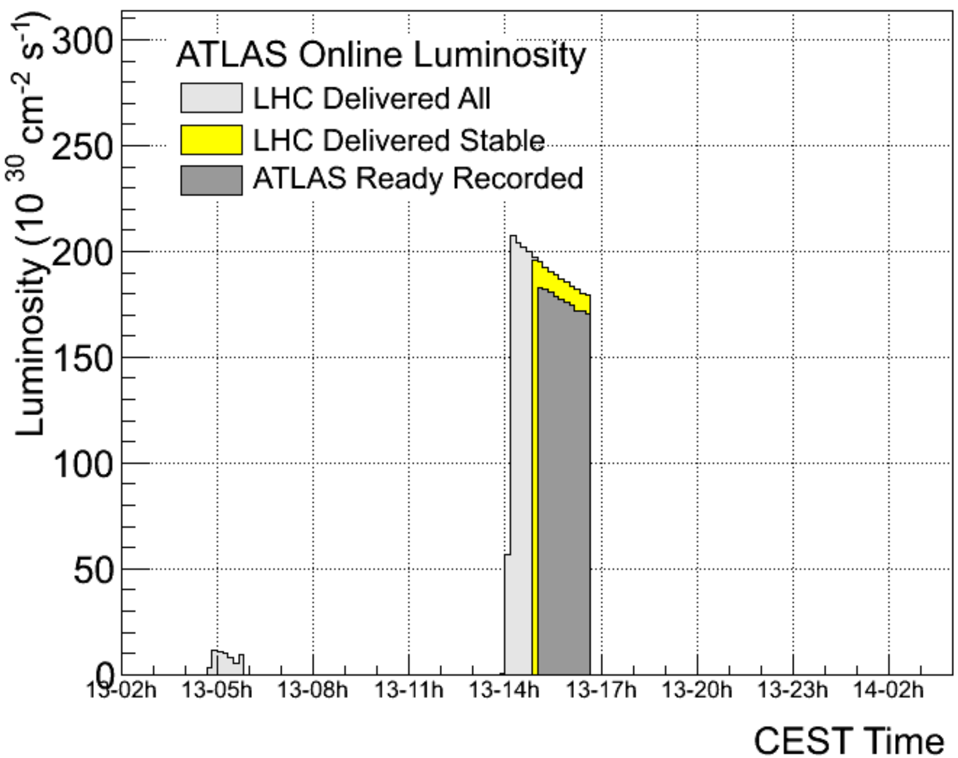
- During February the infrastructure was installed in the ATLAS cavern
  - Location on HO (side A) 6th floor, R=6 m
  - HV and ethernet cables to USA15; HV mainframe and DAQ PC in USA15
  - Gas pipe from GSX1 to location close to rack
  - Small rack connected to safety system
- End of March installation of MMs & DAQ
  - 2 MMs for triggering only (standalone)
  - 2 MMs (R16 with xy readout and R13)
  - DAQ using the SRS system and DCS

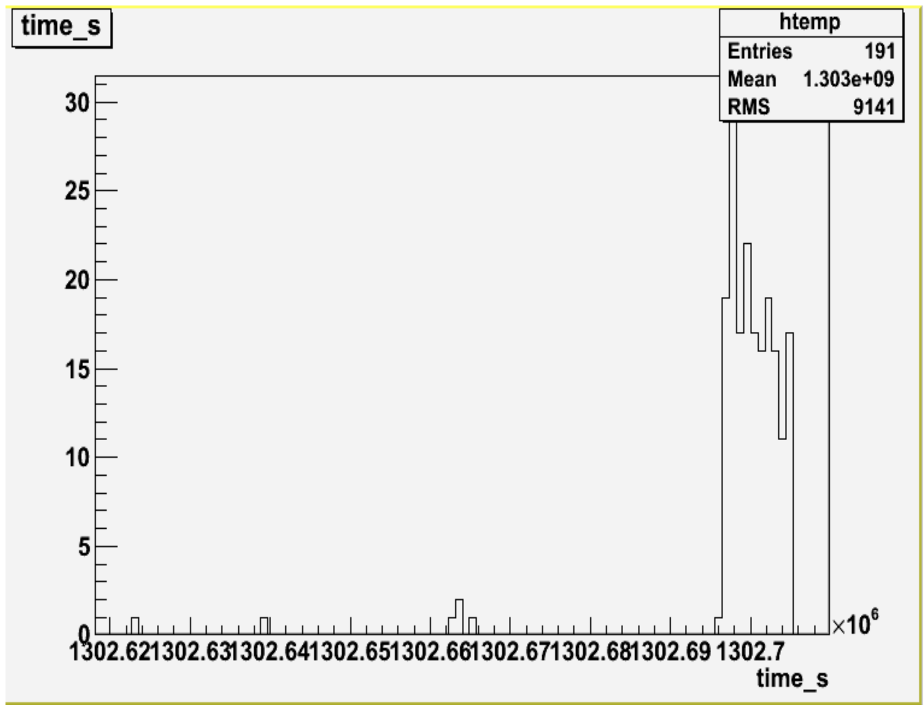


# MM test in ATLAS cavern

**Events as function of time taken 13.04.2011**

Rate at L ≈ 2 x $10^{32}$ $cm^{-2}$ $s^{-1}$ is about 1/minute



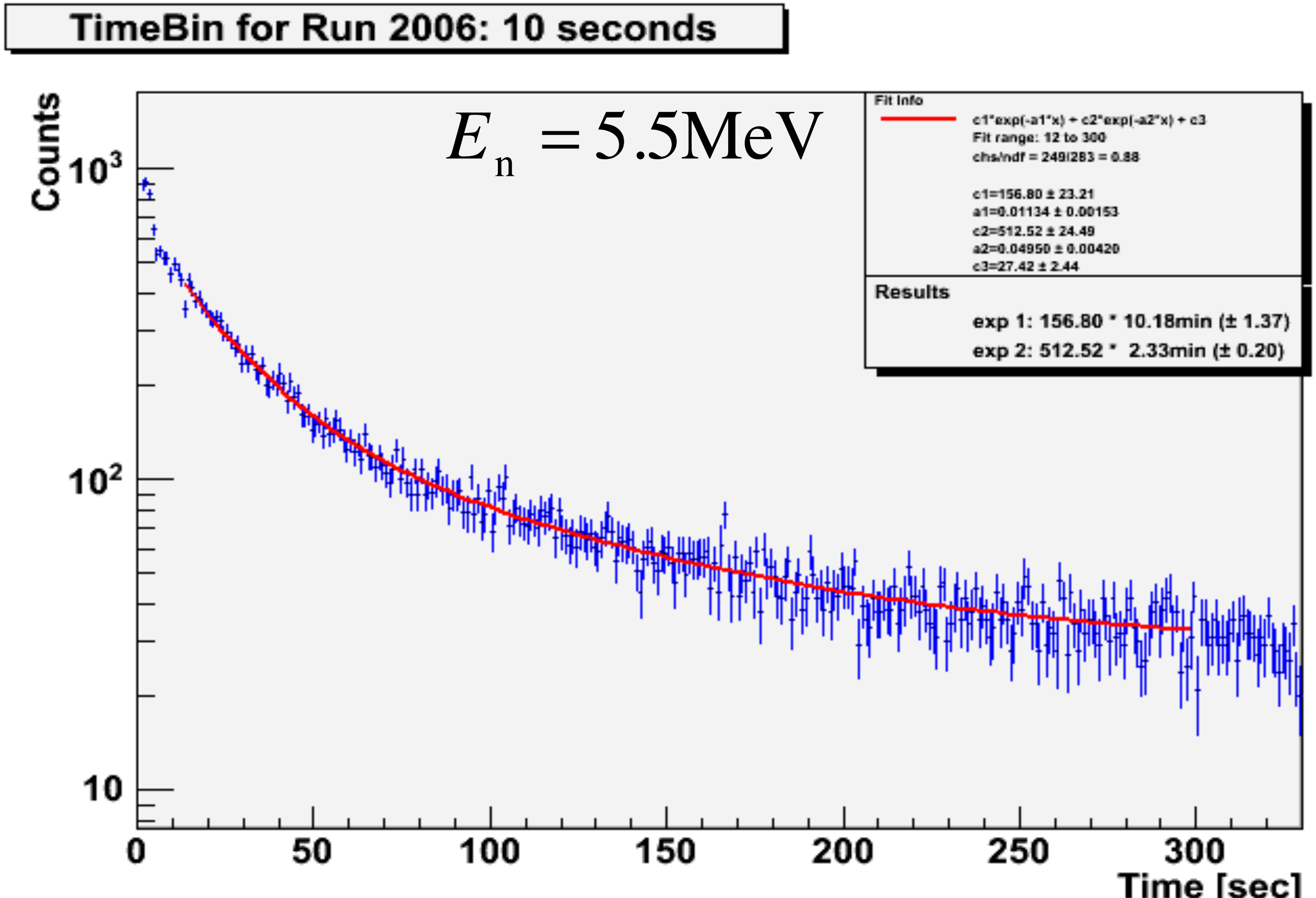



# Summary & Outlook

- Micromegas fulfills all the ATLAS imposed requirements; it seems to be a good candidate for the sLHC upgrade of the ATLAS small wheel
- More work underway: four small resistive-strip MM chambers were installed in the ATLAS cavern and are read out through the SRS; recorded the first clean LHC collision tracks.
- More neutron studies on the large scale Micromegas will be conducted in the near future.
- A lot of work ahead of us for a complete Micromegas+Electronics system!

# BACKUP SLIDES

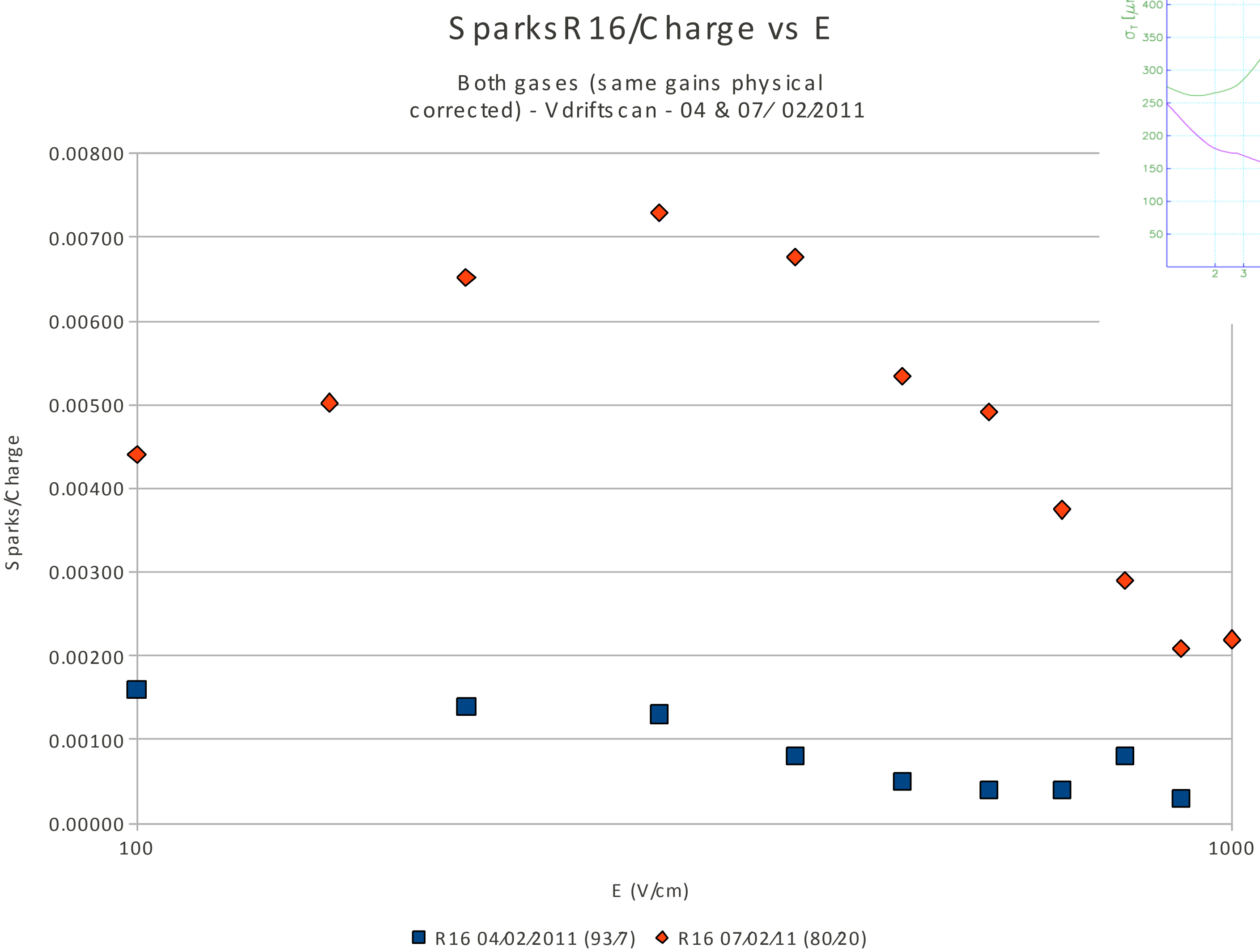
# Activation of the Micromegas Material

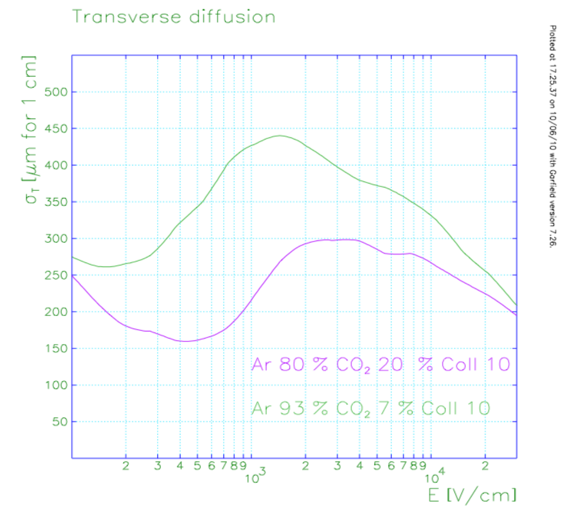



${}^{27}_{13}\text{Al}(\text{n},\gamma){}^{28}_{13}\text{Al}$ $\quad \tau_{1/2} = 2.24\text{m},\ E_\gamma = 1.8\text{MeV (100\%)},\ E_e = 2.9\text{MeV (99\%)}$

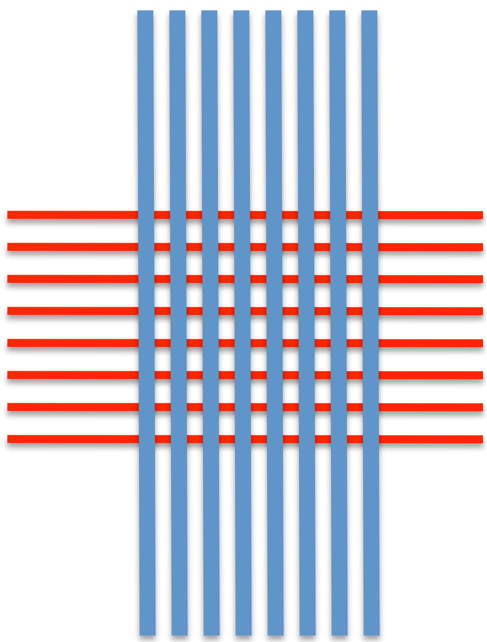
${}^{27}_{13}\text{Al}(\text{n,p}){}^{27}_{13}\text{Mg}$ $\quad \tau_{1/2} = 9.46\text{m},\ E_\gamma = 0.8\text{MeV (72\%)},\ E_e = 1.6\text{MeV (29\%)}$

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


Sparks R16/Charge vs E
Both gases (same gains physical corrected) - Vdriftscan - 04 & 07/ 02/2011
0.00800
0.00700
0.00600
0.00500
0.00400
0.00300
0.00200
0.00100
0.00000
Sparks/Charge
100
1000
E (V/cm)
R16 04/02/2011 (93/7)
R16 07/02/11 (80/20)

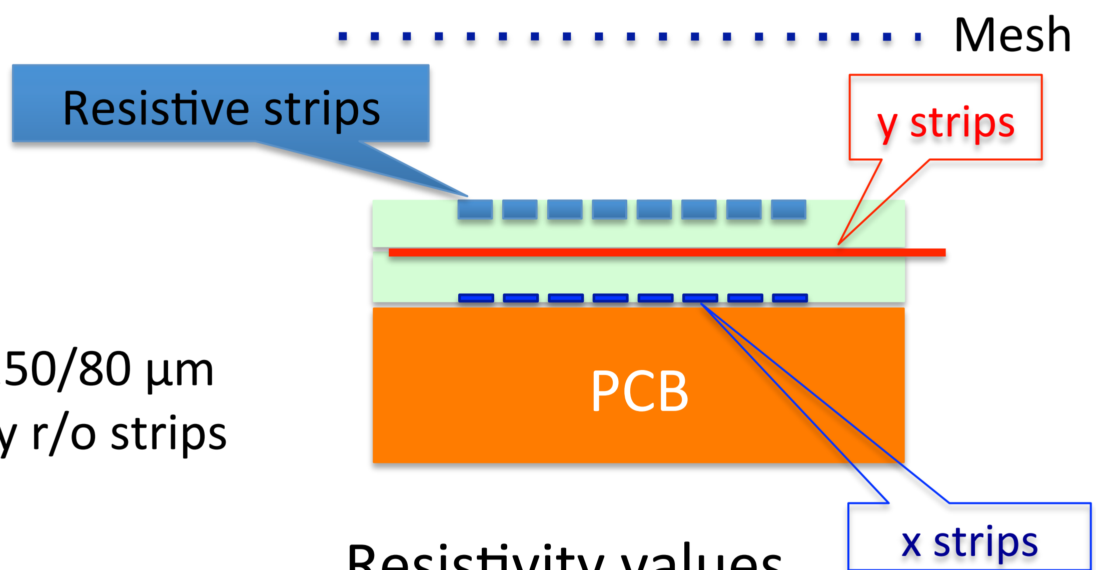

Transverse diffusion
Ar 80 % CO2 20 % Coll 10
Ar 93 % CO2 7 % Coll 10
E [V/cm]

# 2D readout: R16xy (R19xuv)



y: 250/80 µm
only r/o strips

x strips: 250/150 µm
r/o and resistive strips




Resistivity values

$R_G \approx 55\ M\Omega$

$R_{strip} \approx 35\ M\Omega/cm$

# R16 x-y event display ($^{55}Fe$ γ)