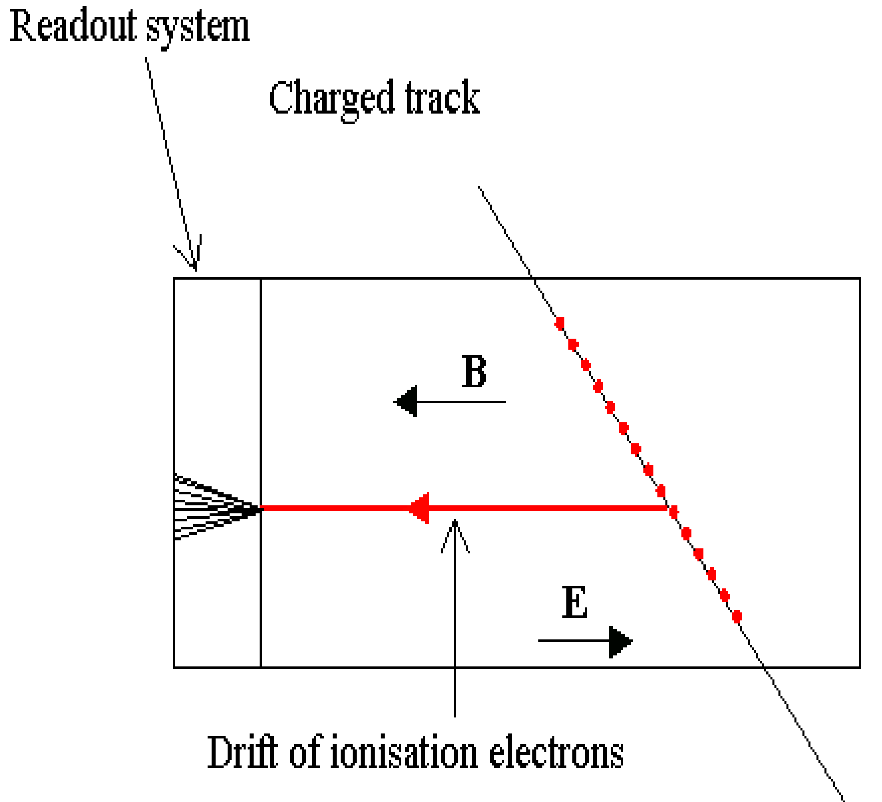
Time Projection Chamber (TPC) with MPGD

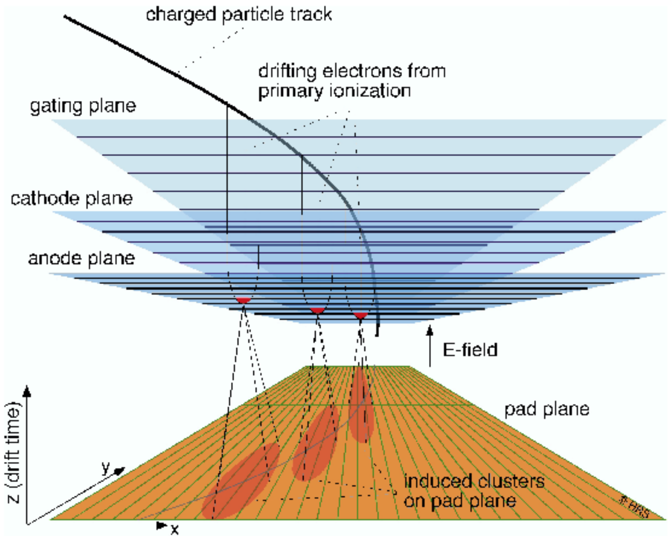
Motivation of a TPC

- 3D track reconstruction
- Good 2 track resolution
- Handle very dense events
- Minimal material
- Particle identification

TPC Basic Principle

- Charged particles ionise a medium
- They drift along an electric field towards a detection device (classically a proportional wire chamber)
- The magnetic field parallel to the electric field helps the electron clouds to be kept together.
- The drift time gives the longitudinal coordinate.





Time Projection Chamber → full 3-D track reconstruction

- x-y from wires and segmented cathode of MWPC
- z from drift time
- dE/dx Measurement of energy loss

Typical accuracy 3 to 7%

Space charge problem from positive ions, drifting back to medial membrane → gating

Motivation of using MPGDs compared to MWPC readout:

- Higher accuracy < 100µm
- Better two track resolution
- Precise dE/dX
- Highly reduced ExB effect
- Much higher Ion feed back suppression
- Large detectors by industrial process
- Low cost

Spatial resolution with TPC

Gas choice

The cloud rms size is modified by the magnetic field as

$$\sigma_{x,y}^{(B)} = \frac{\sigma_{x,y}^{(B=0)}}{\sqrt{1+(\omega\tau)2}}$$

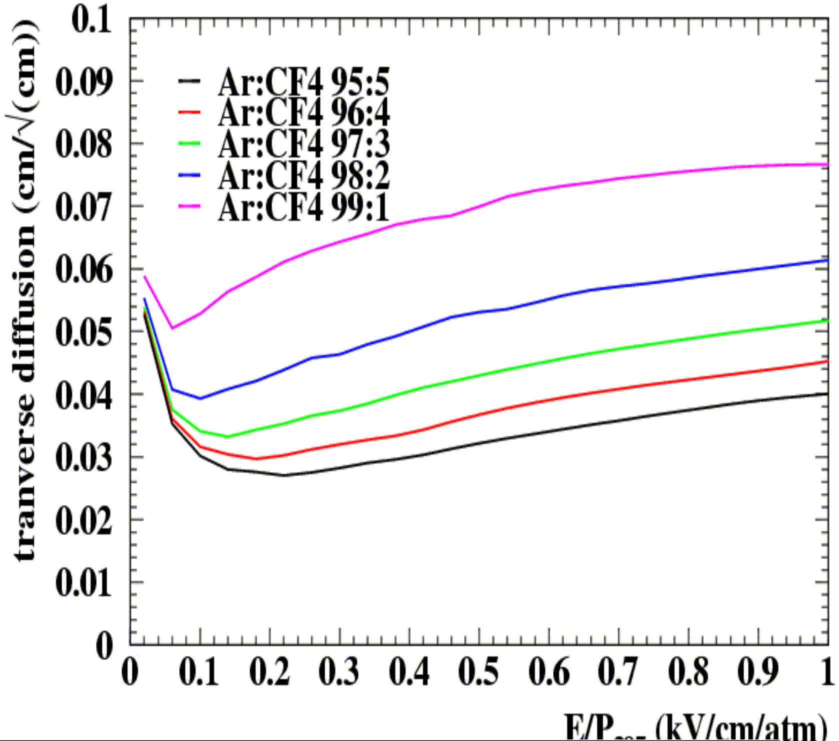
Approximate relation :

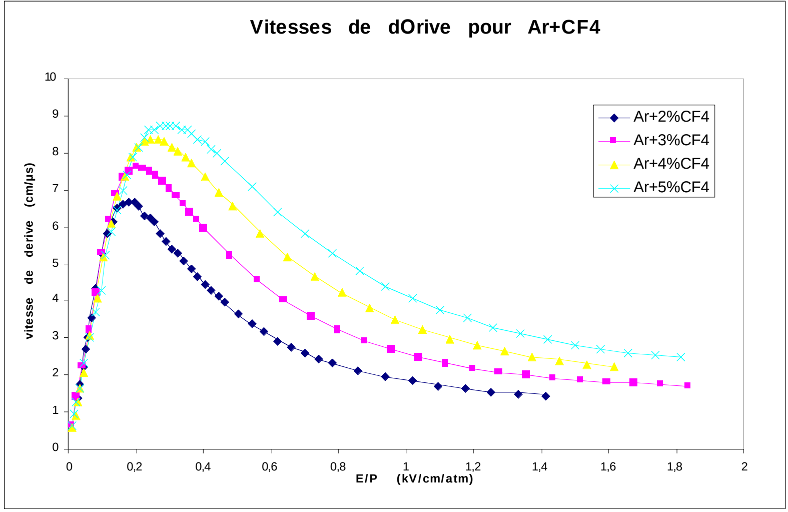
$$\omega\tau = \frac{B * V_e}{E}$$

Where ω is the cyclotron pulsation and τ is the time between collisions. Typically ωτ=7 for a LEP TPC and 20 for the LC TPC

Optimized gas mixture

- **Lowest diffusion coefficient**
- **Highest drift velocity at low electric field**





How to improve the spatial resolution?

- Spatial resolution σ_{xy}:
  - limited by the pad size (s_0 ~ width/√12)
  - charge distribution narrow ($RMS_{avalanche}$ ~ 15 µm)

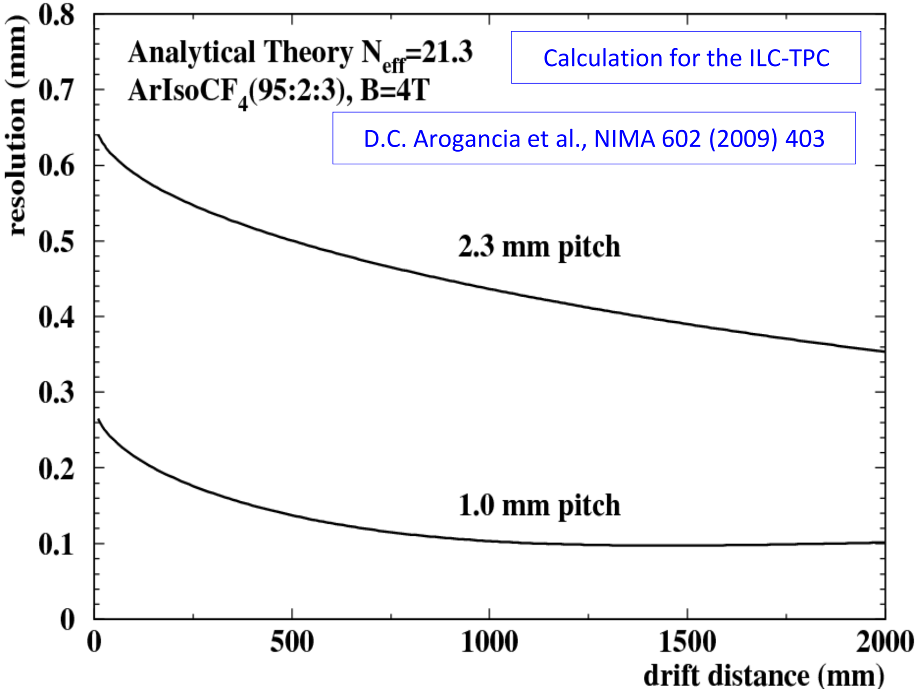
→ 1. Decrease the pad size: narrowed strips, pixels

  → - single electron efficiency

  - Large number of read-out pixels

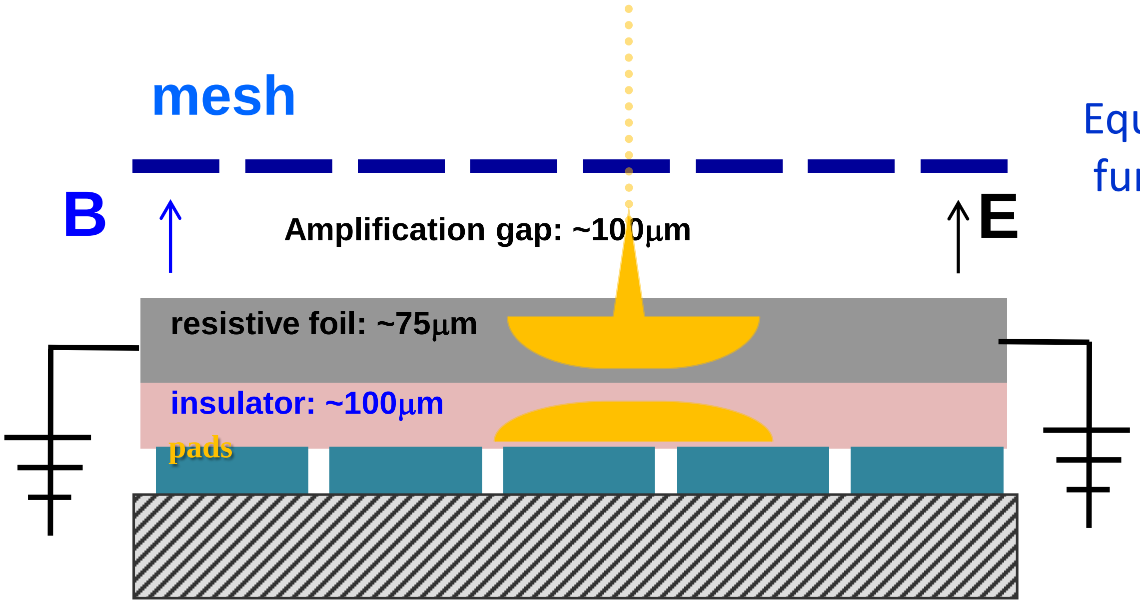
→ 2. Spread charge over several pads: resistive anode

  + reduce number of channels, cost and budget
  + protect the electronics
  – limit the track separation



Calculation for the ILC-TPC

D.C. Arogancia et al., NIMA 602 (2009) 403



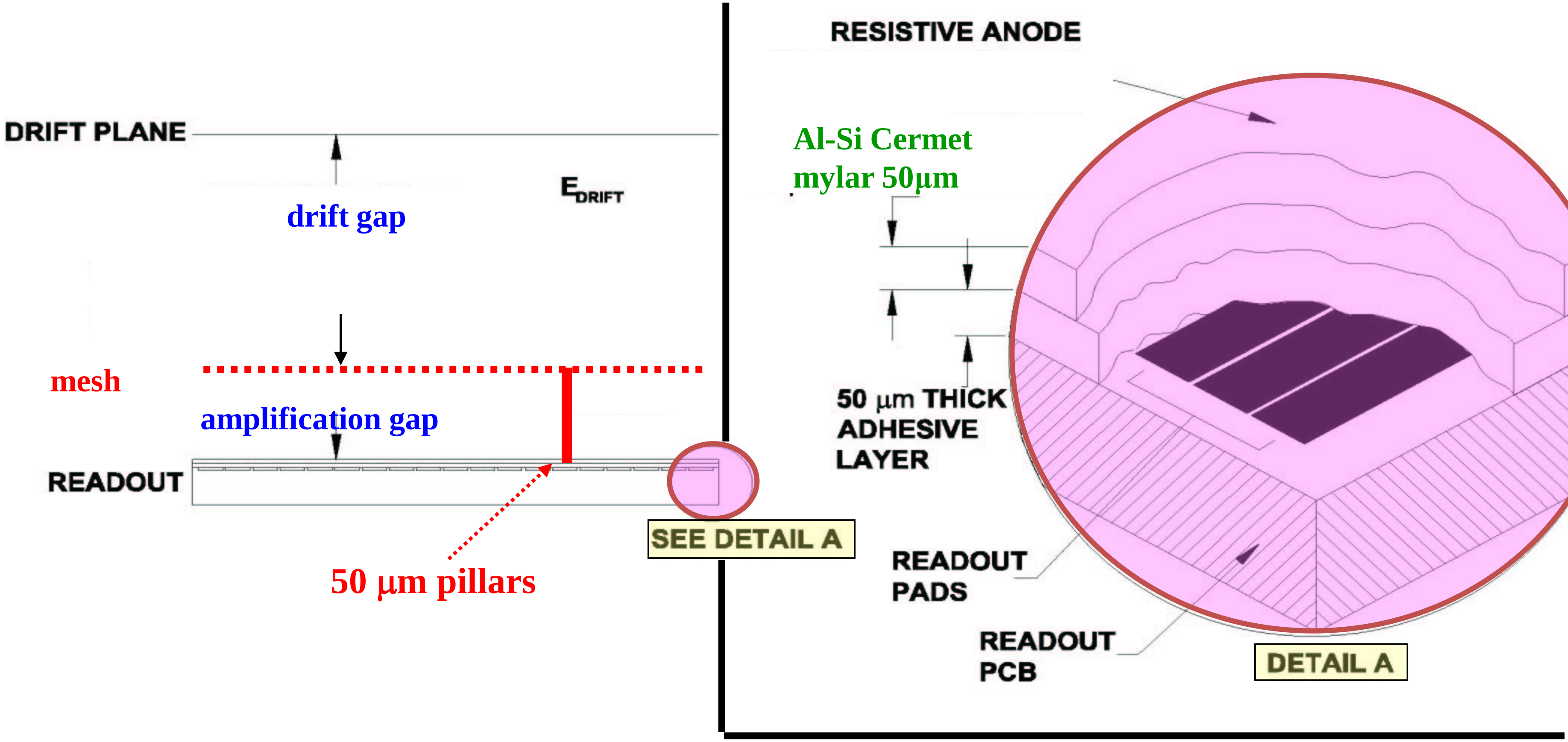
Equation for surface charge density function on the 2D continuous RC network:

$$\rho(r,t)=RC/2t\ exp(-r\uparrow 2\ RC/4t)$$

$\rho(r,t)$: the surface charge density
R: the surface resistivity of the resistive layer
C: the capacitance per unit area.

First resistive anode detector: Al-Si Cermet mylar 50µm

a uniform high resistivity 1 MΩ/□ Al-Si Cermet is glued on the pad plane

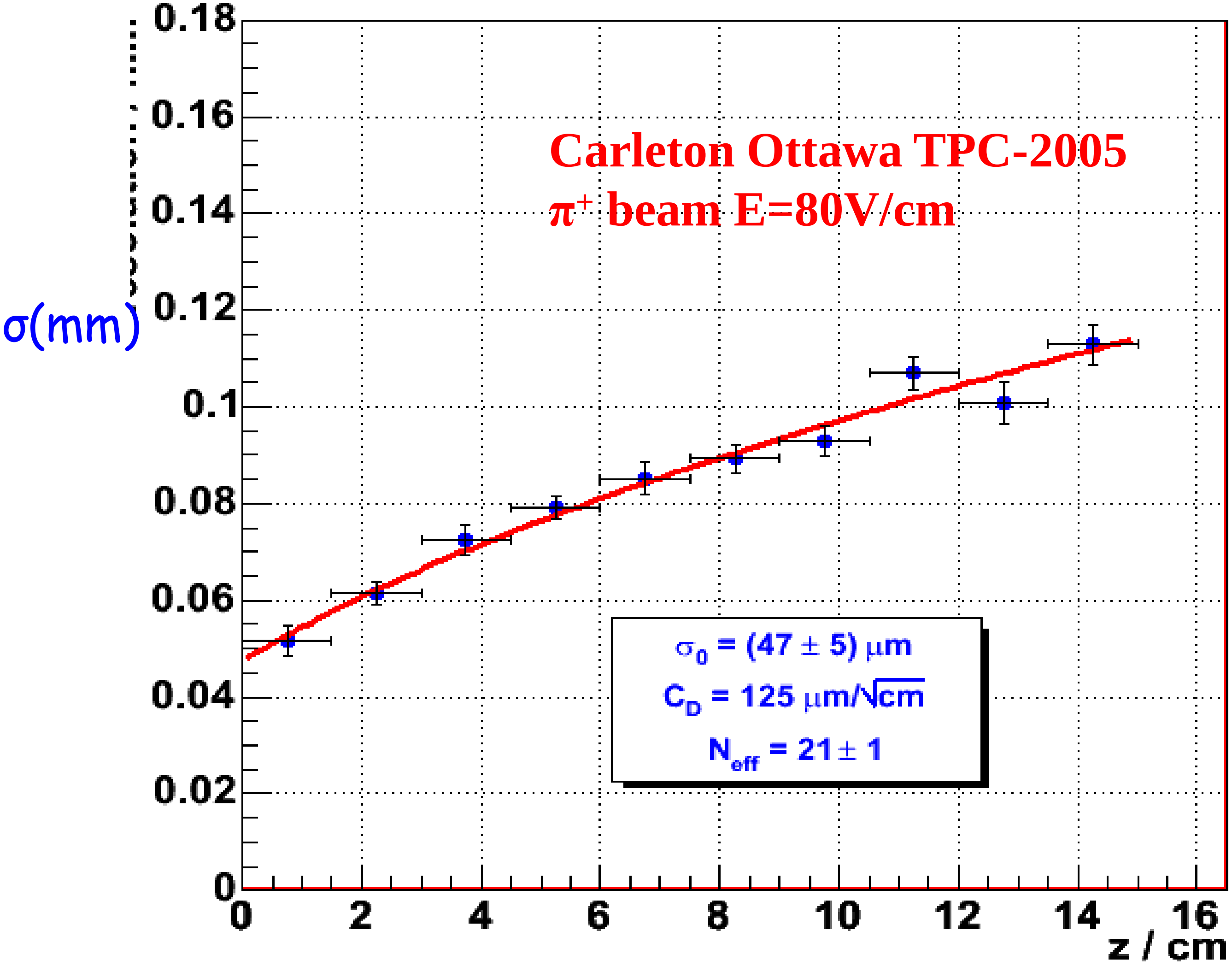


for more info: see presentation by Madhu Dixit at the ILC 2005 Snowmass workshop

First resistive anode results: resolution vs Z

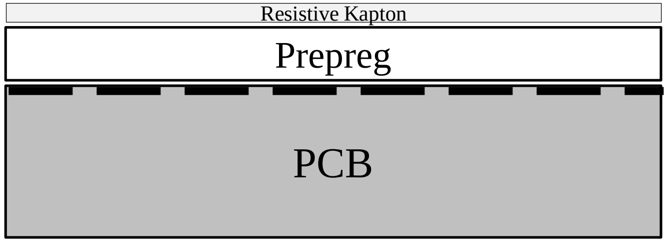
Ar/iC_4H_{10}:95/05@1T,

2.3 x 6.3 mm^2 pads

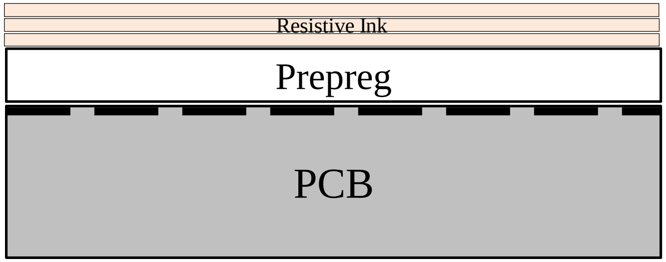


Second generation of resistive anodes

Resistive Kapton



Resistive Ink

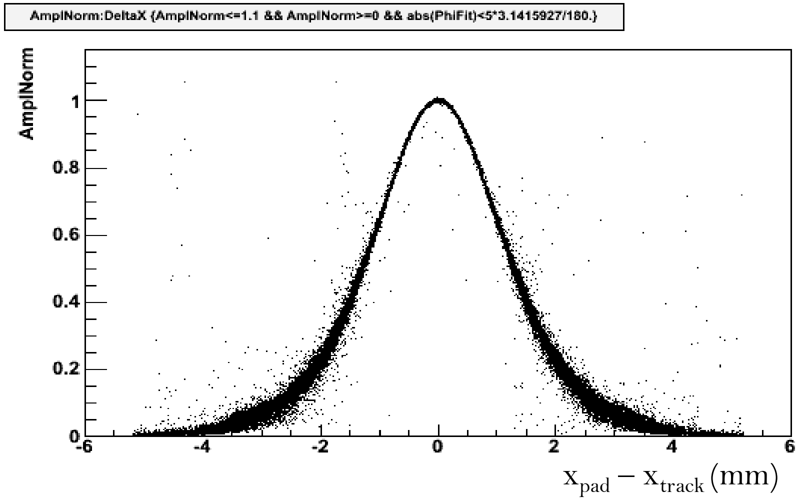


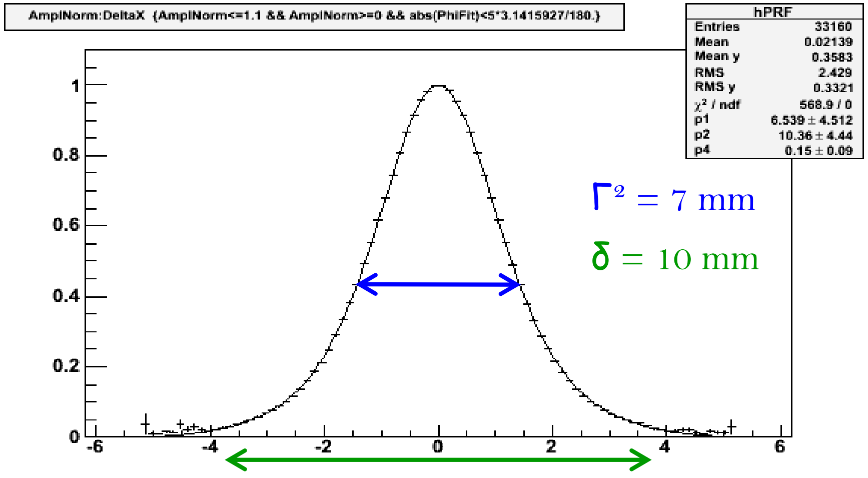
Detector	Dielectric layer	Resistive layer	Resistivity (MΩ/□)
Resistive Kapton	Epoxy-glass 75 μm	C-loaded Kapton 25 μm	~4
Resistive Ink	Epoxy-glass 75 μm	Ink (3 layers) ~50 μm	~1-2

Resistive module used

Pad Response Functions, z ~ 5 cm

Resistive Kapton



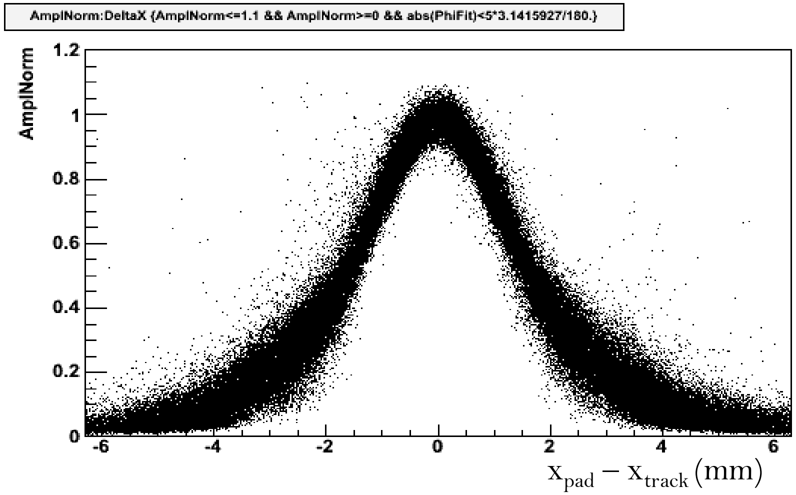


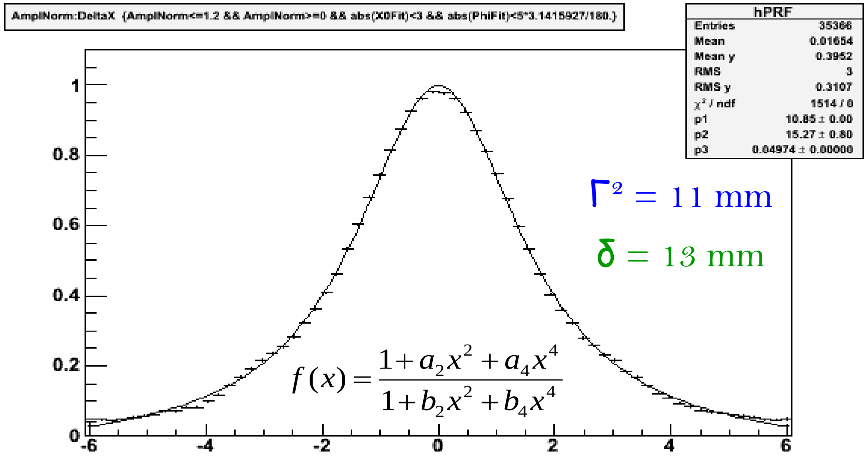
$\Gamma^2 = 7$ mm

$\delta = 10$ mm

→ $\sigma_{z=5\text{ cm}} = 68\ \mu m$

Resistive Ink





$\Gamma^2 = 11$ mm

$\delta = 13$ mm

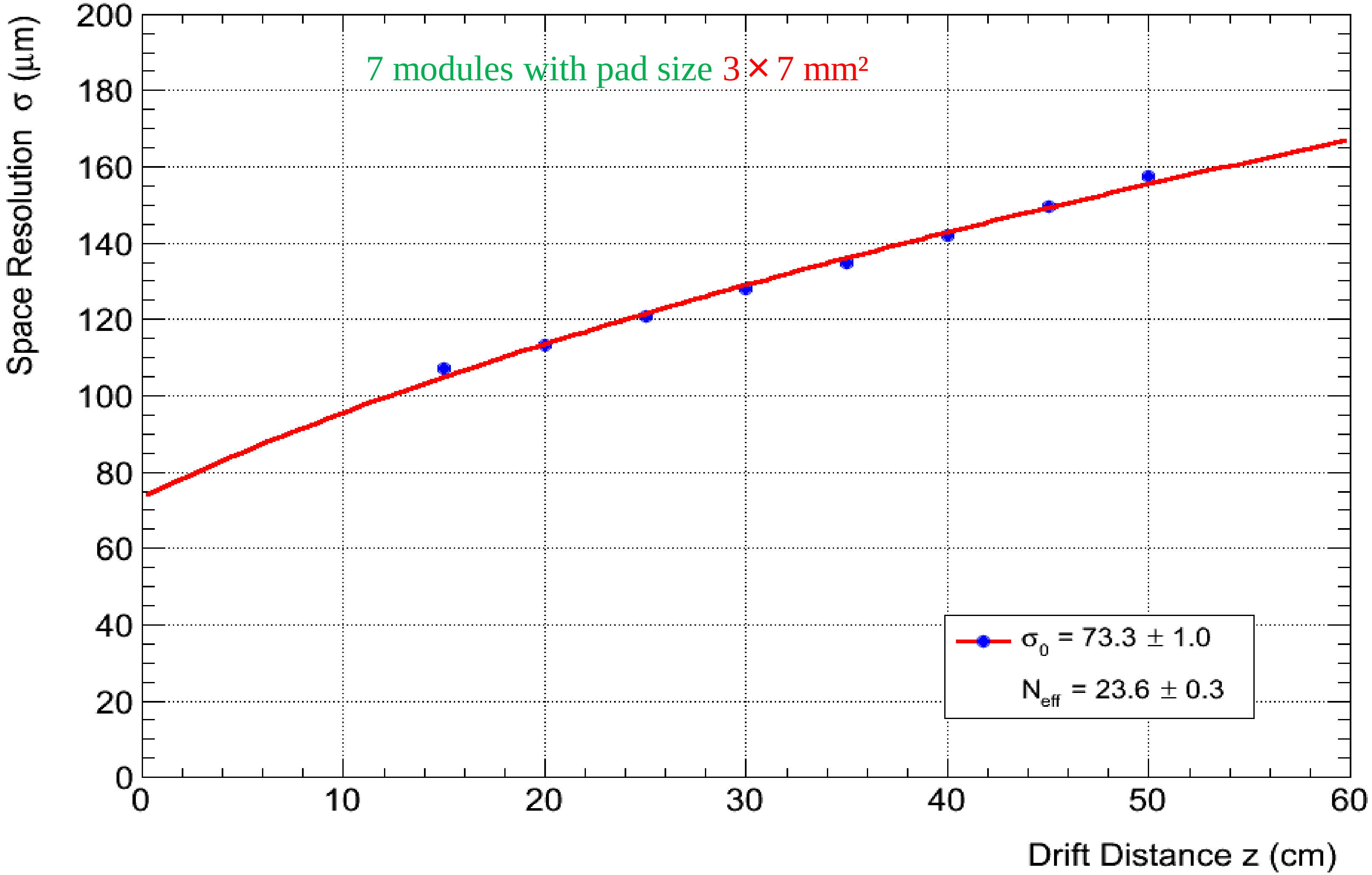
$$f(x) = \frac{1 + a_2 x^2 + a_4 x^4}{1 + b_2 x^2 + b_4 x^4}$$

→ $\sigma_{z=5\text{cm}} = 130\ \mu m$!

Resistive Micromegas space resolution

- E_{drift} = 230 V/cm
- B_{field}=1T

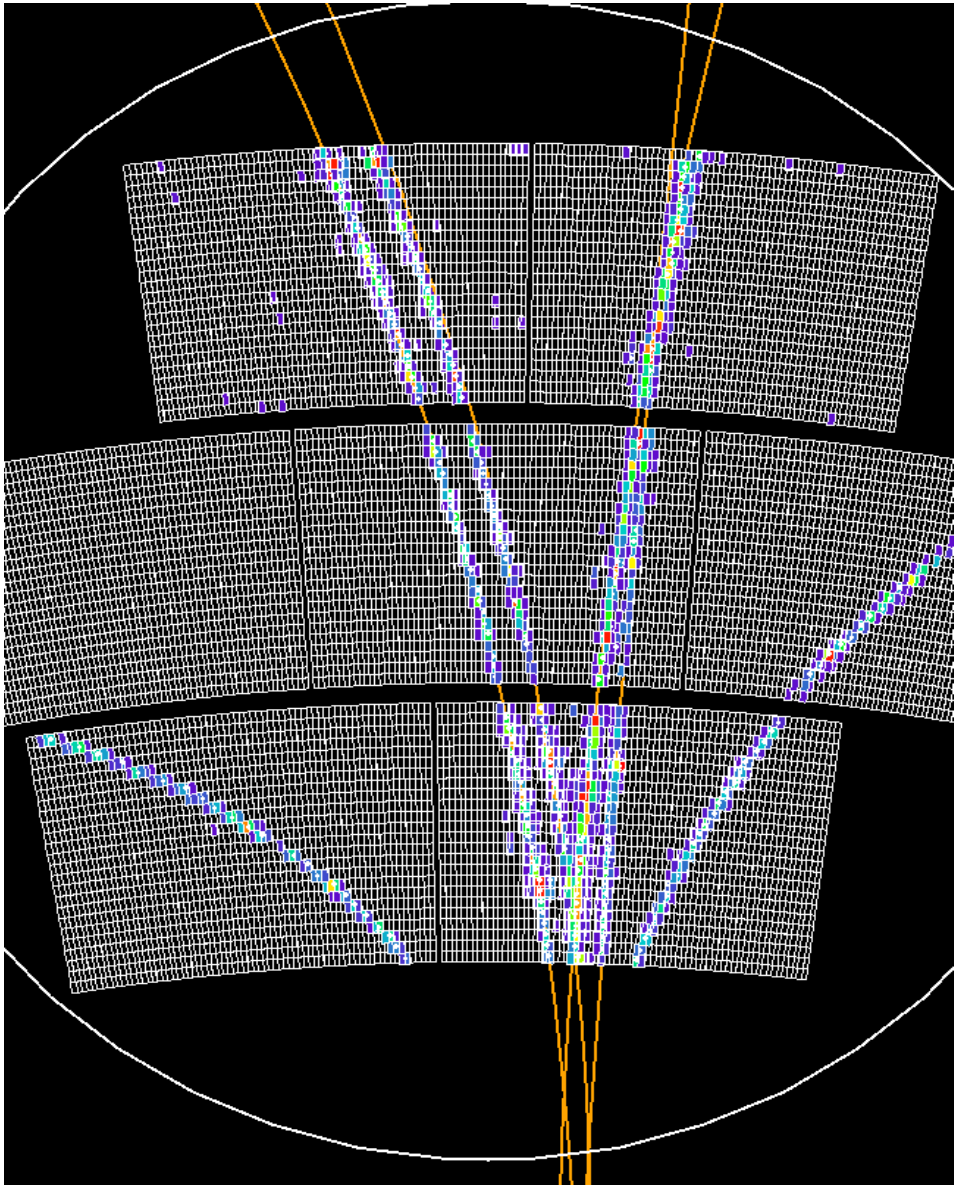
- V_{mesh} = 380 V
- Beam energy = 5 GeV



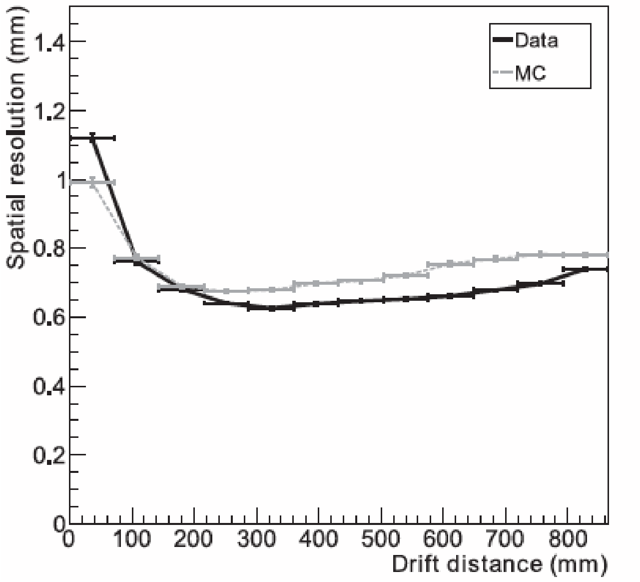
Resistive Micromegas: ILC Software analysis

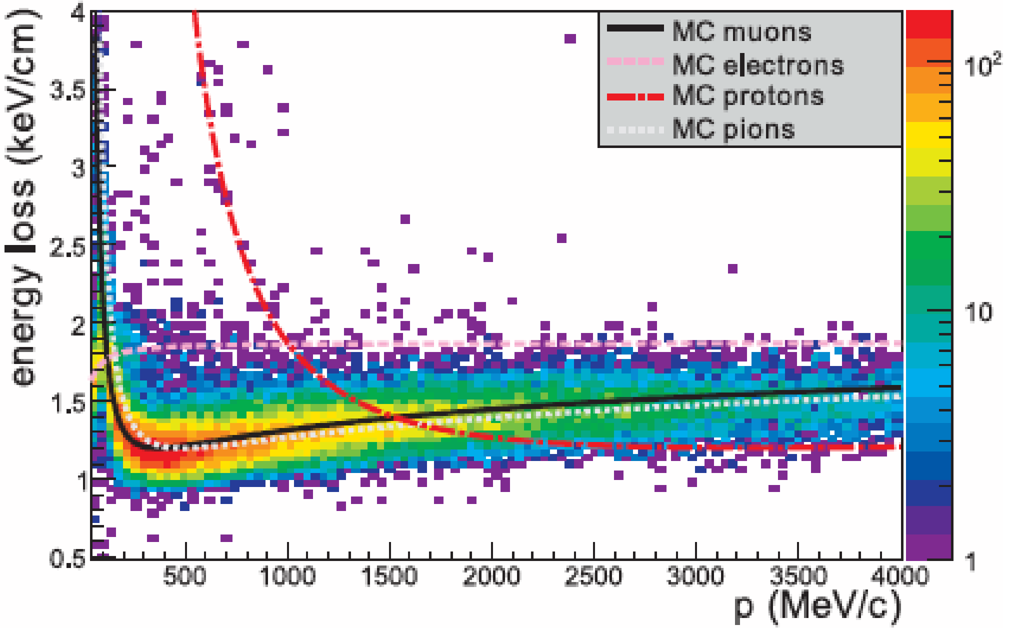
- Analysis done using ILCSoft framework:
  - Find the pulses in the detector
  - Obtain hit with PRF fit
    → (r, φ, z[t])
  - Tracks are reconstructed used a Kalman filter processor
  - Resolution, momentum, …

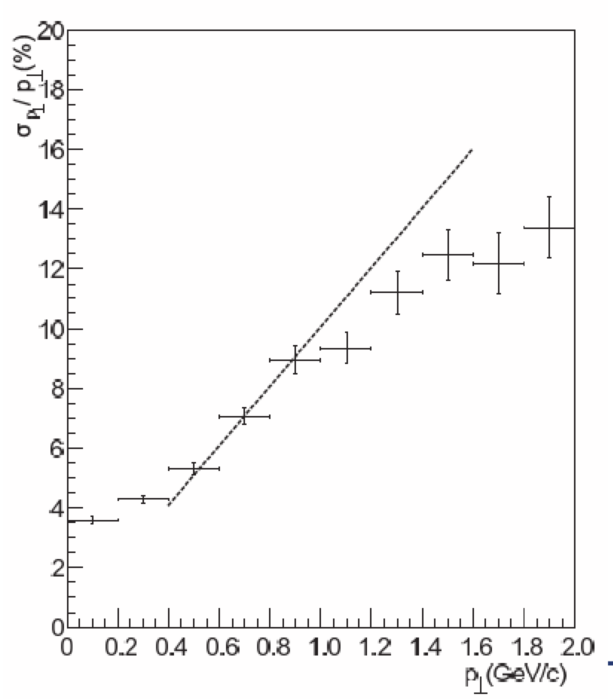
- No telescope was used to determined
  the position of the tracks

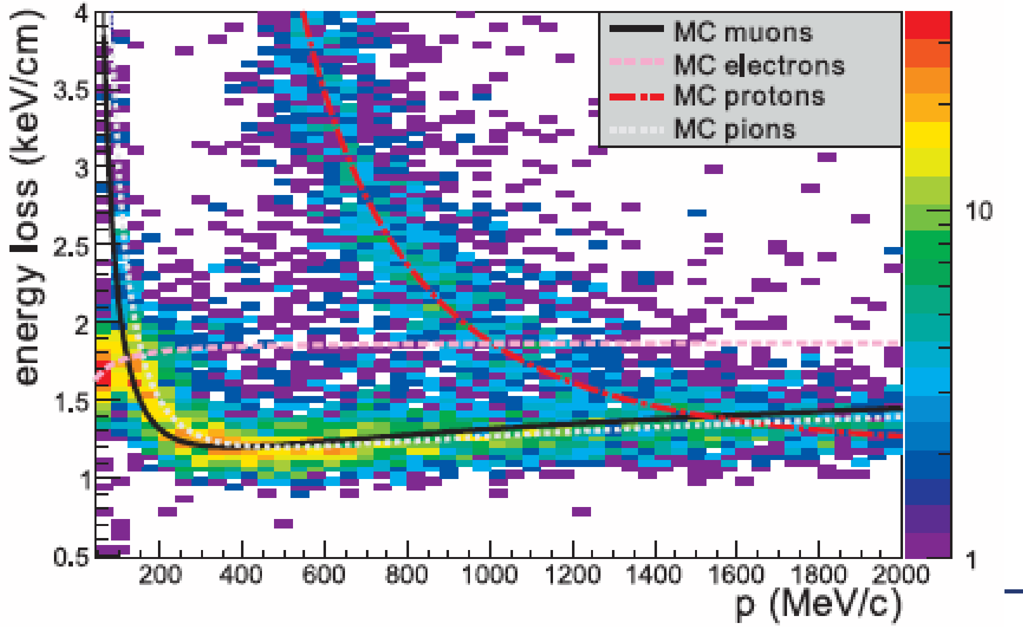


Resolution and dE/dX results from current T2K TPC









Fabricating large detector

Construction of large chambers in ATLAS

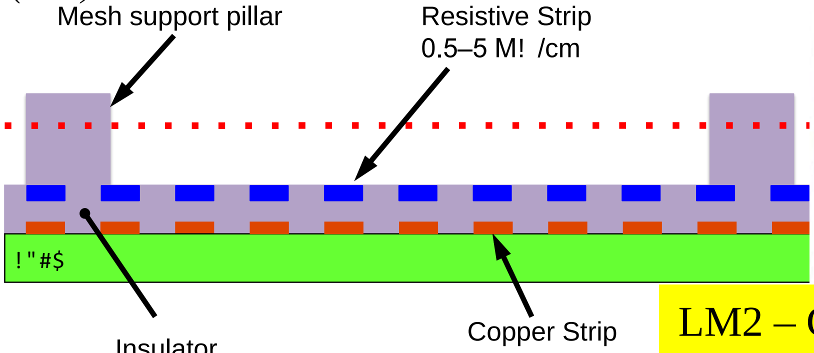
Goal : 1200 m2 total detector surface

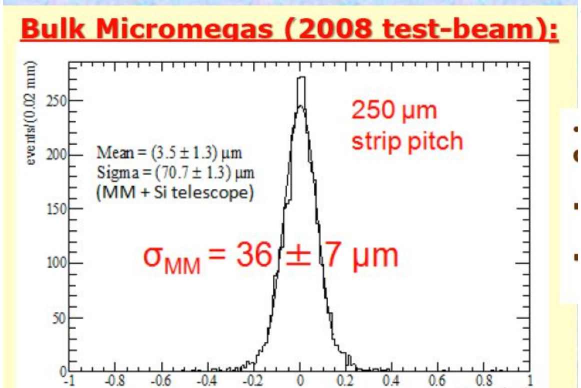
Industrialization is going on through ELVIA, ELTOS

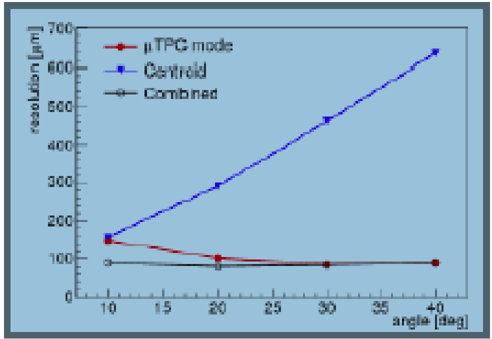
ATLAS Resistive strip technology

Joerg Wotschack, Mod.Phys.Lett. A28 (2013) 1340020

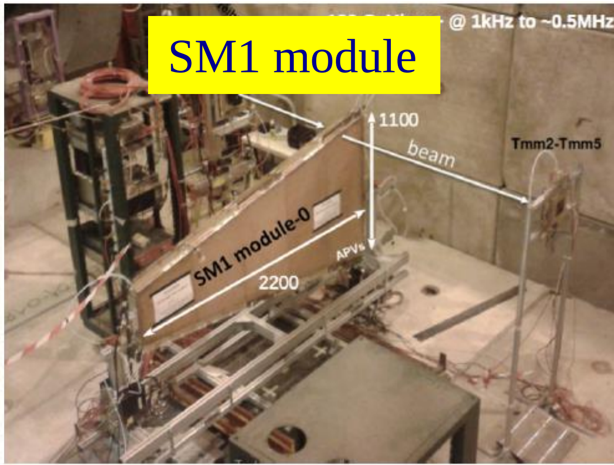
T. Alexopoulos, et al. Nucl. Instrum. Meth. A 640, 110-118, (2011).




Bulk Micromegas (2008 test-beam):



SM1 module



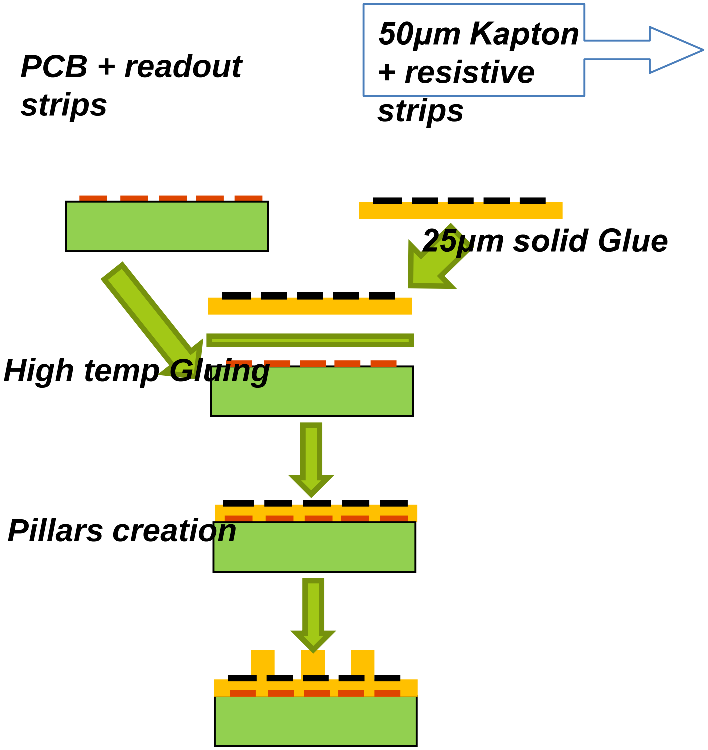
LM2 – CERN / Dubna -Thessaloniki

SM2 – Germany

At Saclay the large clean room is ready and operational

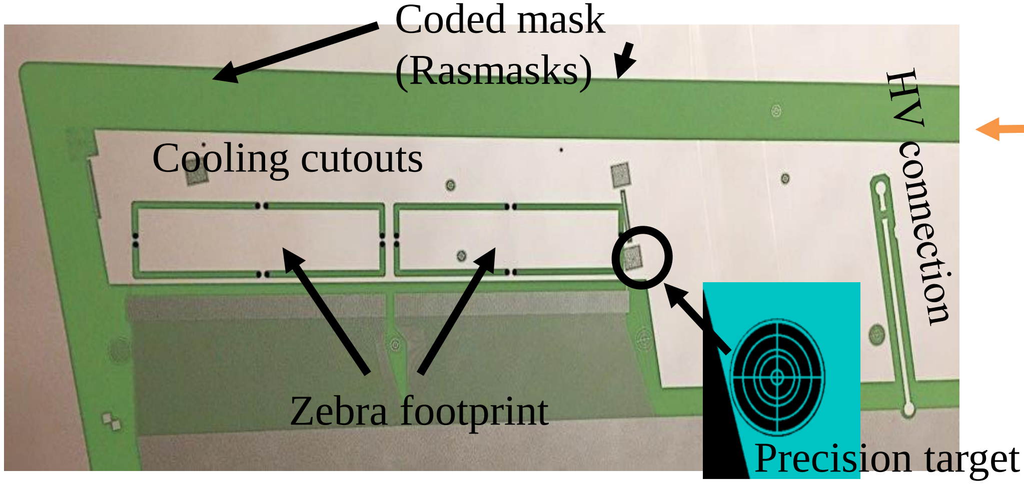
First M0 module is under construction and soon will be tested

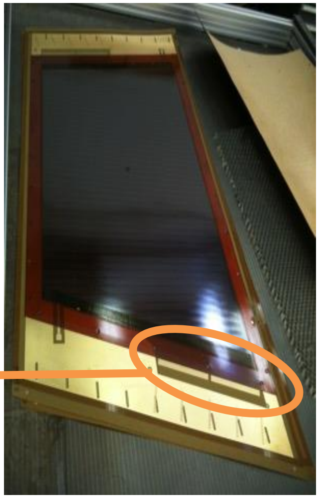
Industrial readout boards and 3rd generation resistive foils ATLAS muon project



2 techniques: sputtering or screen printing

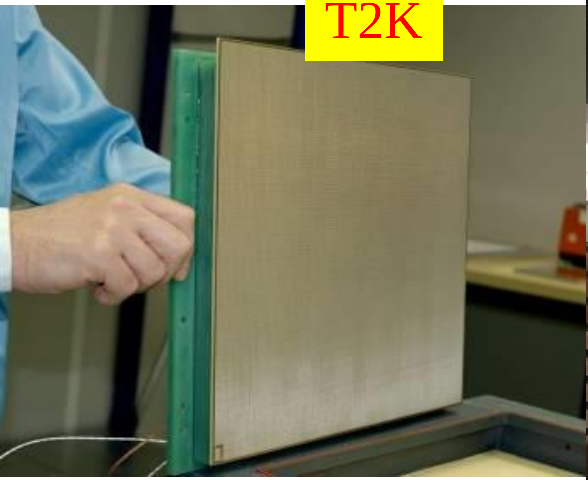
Typical resistivity **~ 10-20 MΩ/cm**
(~300-600 kΩ/□)





512 readout strips per side
for Zebra connection
(no connector soldered
on the boards)

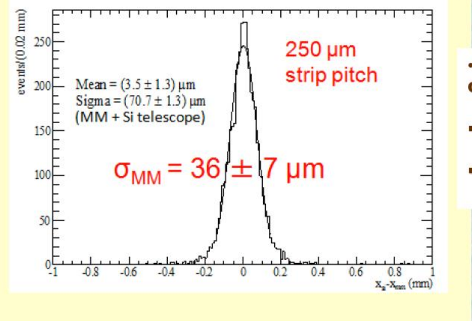
Some experiments using
Micromegas read-out TPC

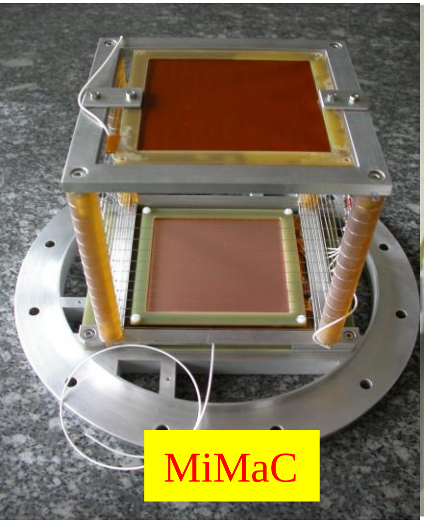

T2K

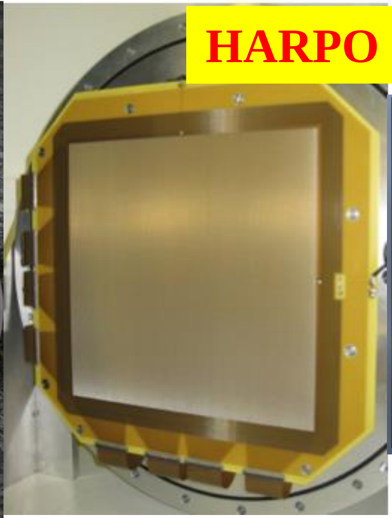

ILC/TPC

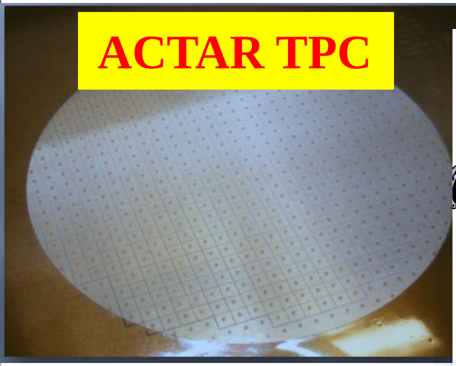

ATLAS-SLHC

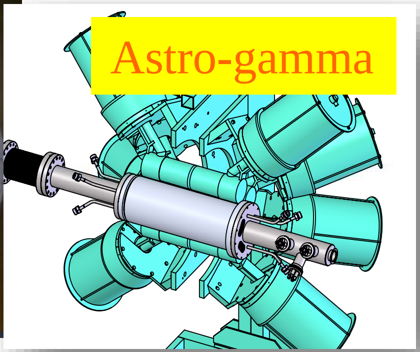
Bulk Micromegas (2008 test-beam):




MiMaC


HARPO


ACTAR TPC

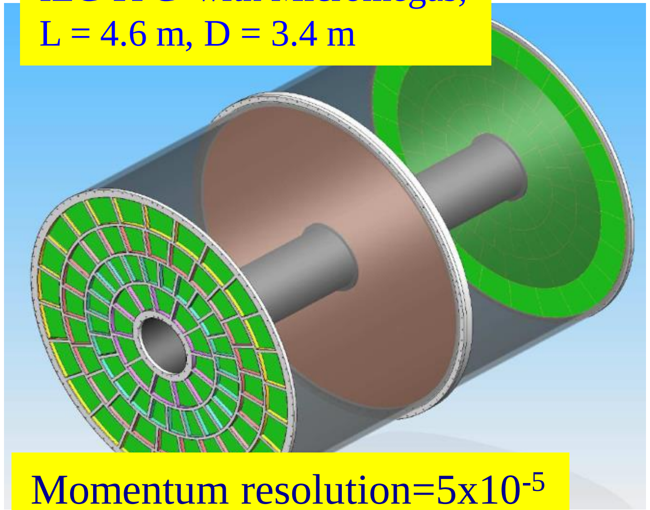

Astro-gamma


MINOS

ILC TPC project - *Large International collaboration*

G. Aarons et al., arXiv:0709.1893, M. S. Dixit et al., NIMA 518 (2004) 521, M. Kobayashi et al.,NIMA581(2007)265,

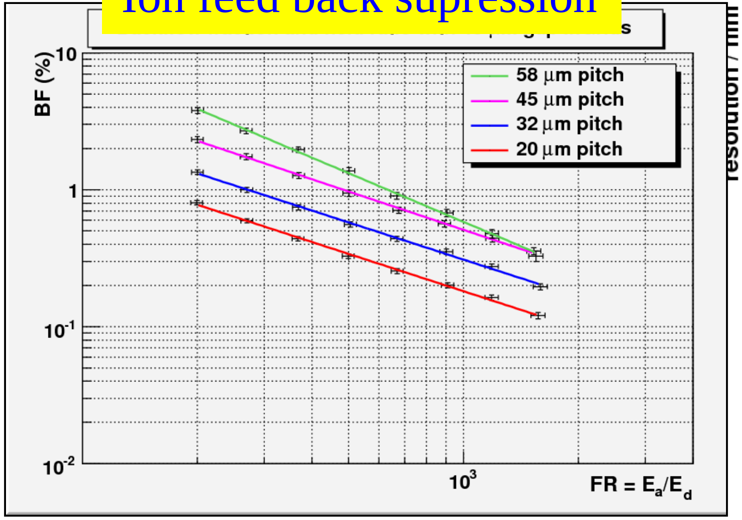
ILC TPC with Micromegas,
L = 4.6 m, D = 3.4 m



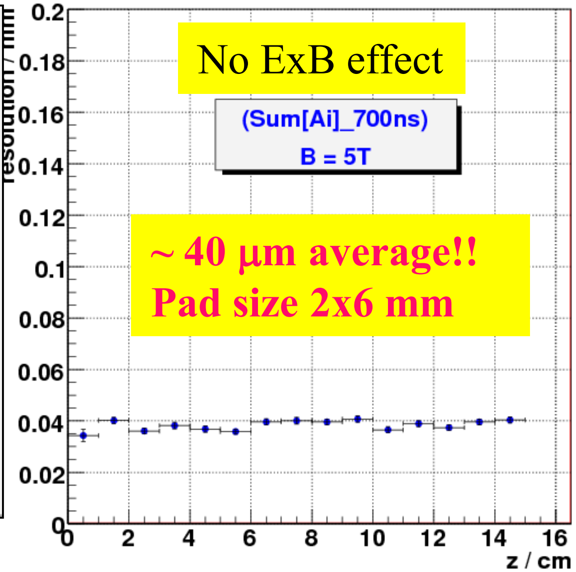
Momentum resolution=5x10^{-5}

ILC TPC prototype
with Micromegas

Ion feed back supression

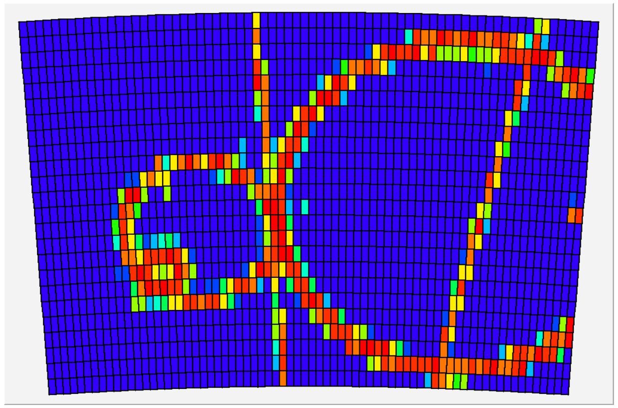


No ExB effect



~ 40 µm average!!
Pad size 2x6 mm

Event in DESY test beam



TPC Micromegas advantages

- Ion suppression .1%
- No ExB effect
- Great resolution ~ 40 µm
- Good energy resolution

Related Event

The eighth international symposium on "large TPCs for low-energy rare event detection" will be held in Paris on the 5th-7th of December 2016 : http://indico.cern.ch/event/473362/

The purpose of the meeting is an extensive discussion of curreny and future projects using a large TPC for low energy, low background detection of rare events (low-energy neutrinos, double beta decay, dark matter, solar axions).

Thank you