

# Resistive anode readout

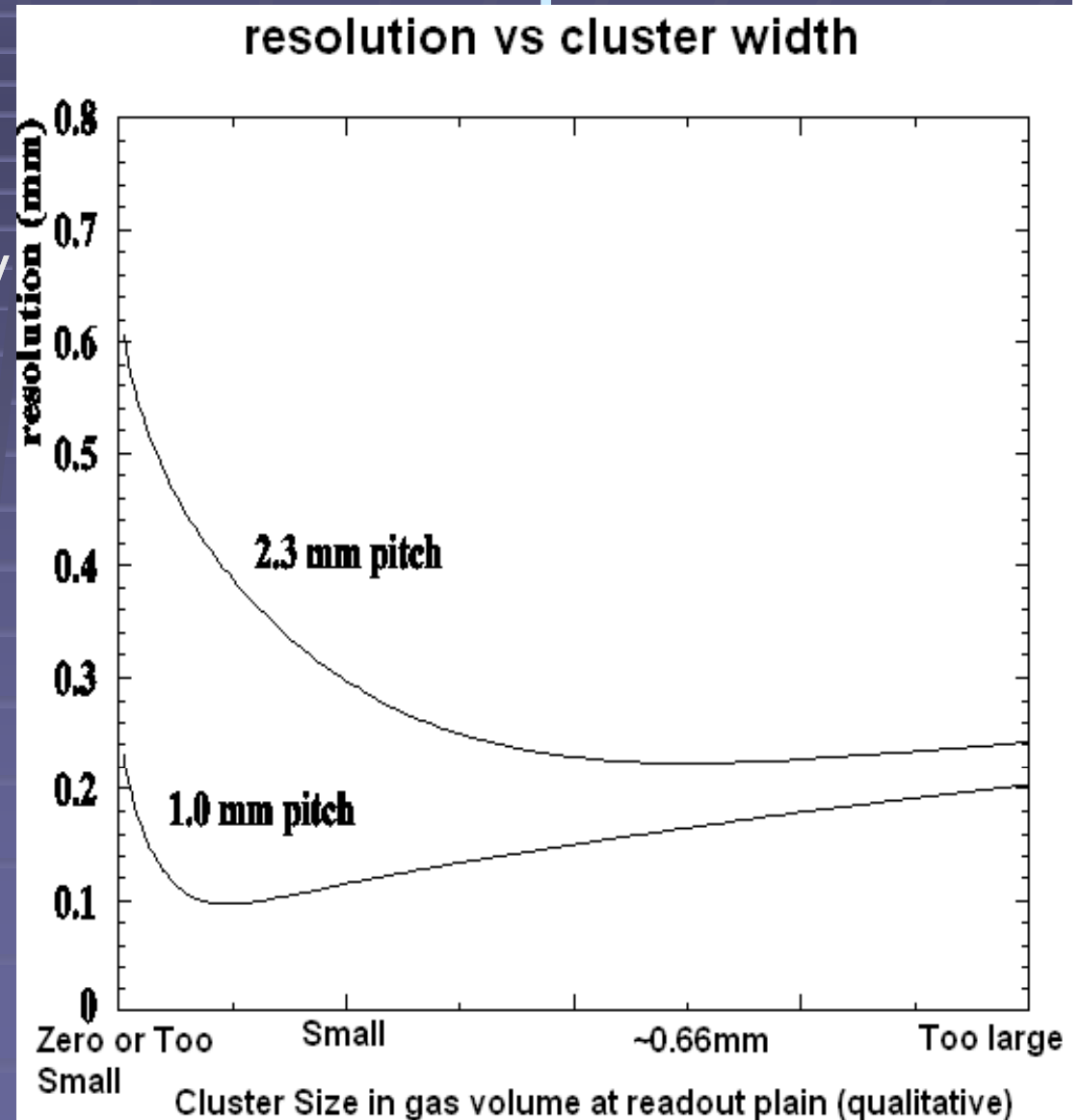
Stephen Turnbull CEA IRFU Saclay

# Quick overview

- **Why resist?** (if you can't beat them join them)
  - The physics problem :  $\sigma/w$
  - The resistive solution : electronic signal dispersion
- **It really works** (or at least it really ought to)
  - In theory : some brief math
  - And in practice ; COSMo
- **Ok, good start, now make it more versatile**
  - The technical hurdles
  - The pad response function question
  - A new thin pad regime maybe possible?
  - The construction methods / functional regimes
- **Possible applications for resistive films**
- **Conclusions**

# The charge distribution problem

- Spatial resolution when using conventional readout pads is limited by cluster sigma (width) to pad width ratio and the effective number of electrons in each cluster.
- If the cluster's size is too small number of pads with signals is too small for good position reconstruction.
- If the cluster's size is too large position diluted for constant # e- statistics.



# Resistive solution

- The dispersion of localized charge clusters depends on the material properties and geometry.
- By choosing different resistivities and different thicknesses (capacities) it will be able to optimize the dispersion of incoming clusters for the pitch of our readout pads and electronics maximizing resolution / functionality.

It's not only a figment of  
imagination!

How it works, and a brief  
showcase of an experiment.

# RC Telegraph equation: Theory

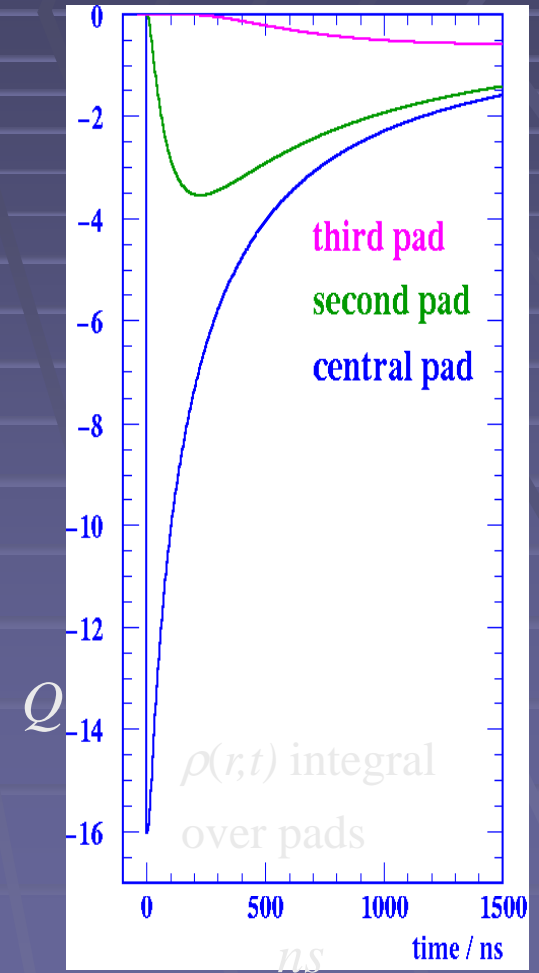
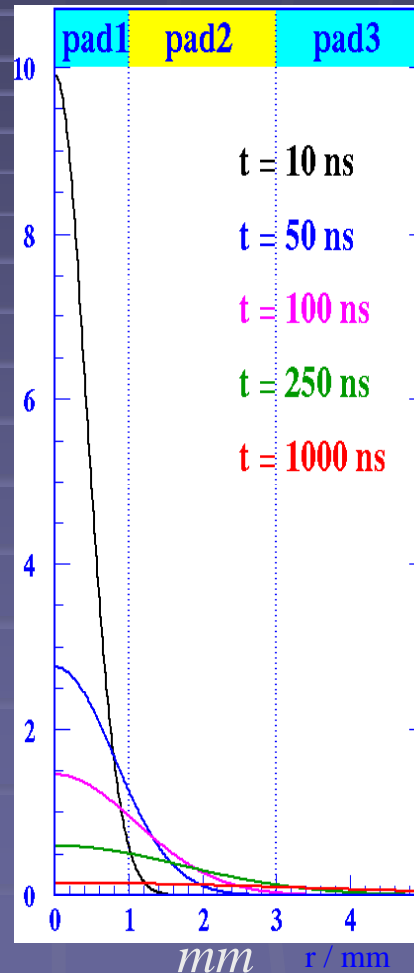
- Resistive anode: high resistivity film bonded to a readout plane with an insulating spacer, or other methods
- 2-dimensional continuous RC network defined by material properties & geometry.
- Calculations done for point charge at  $r = 0$  &  $t = 0$  disperses with time.
- Time dependent anode charge density sampled by readout pads.

Equation for surface charge density function on the 2-dim. continuous RC network:

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC} \left[ \frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r} \frac{\partial \rho}{\partial r} \right]$$

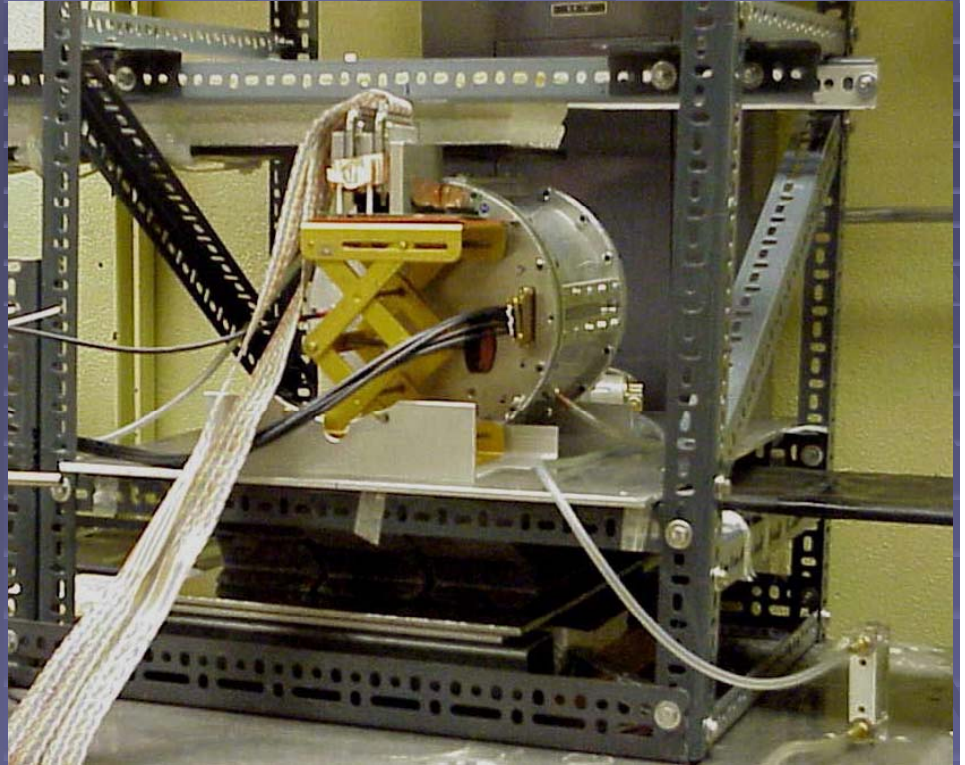
$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{-\frac{r^2 RC}{4t}}$$

$\rho(r)$



# COSMo and its Specifications

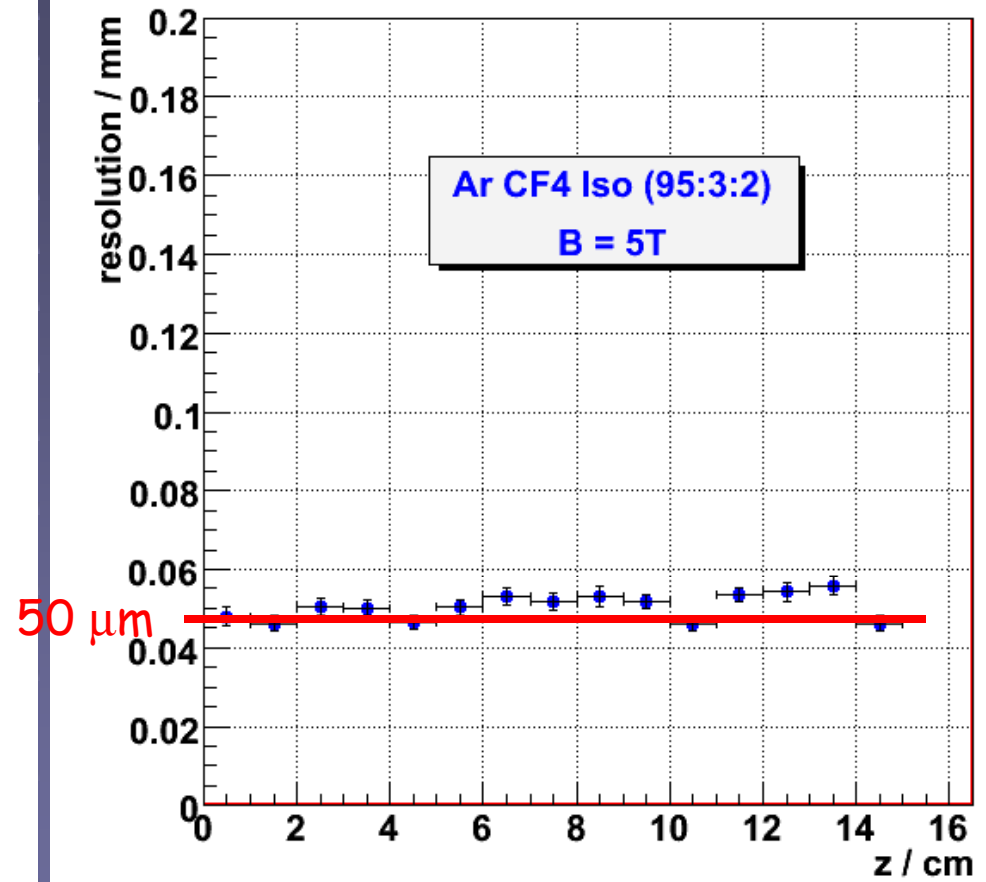
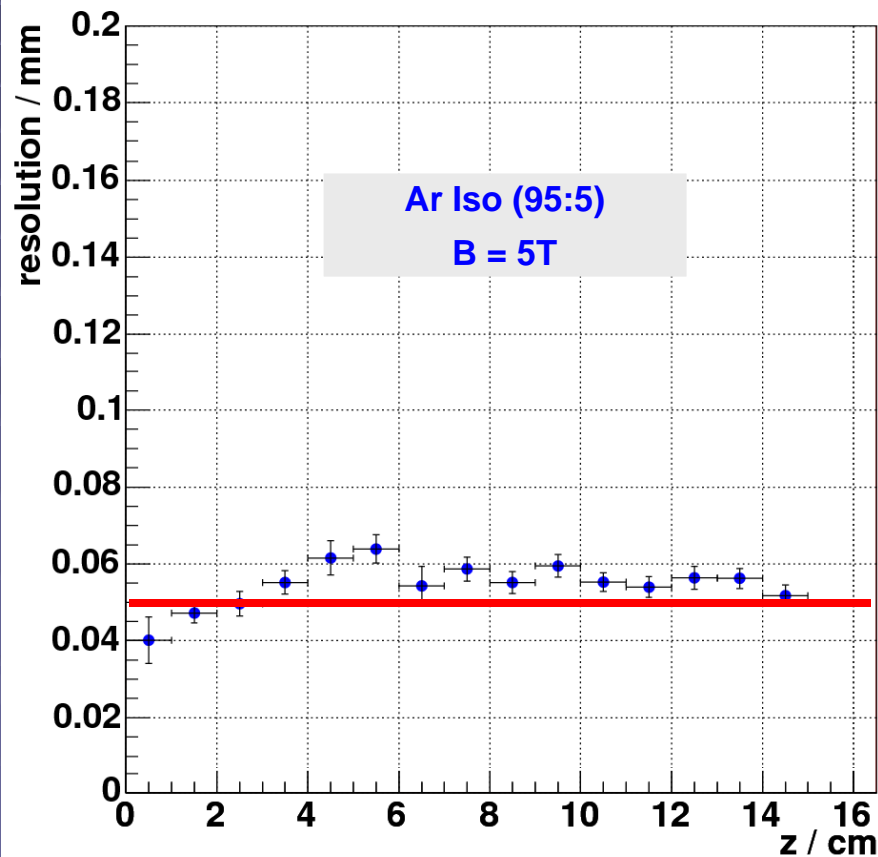
- Carleton Ottawa Saclay  
MONTreal TPC:
- 15 cm drift length with  
Micromegas + resistive  
readout
- Aleph charge preamps.  
 $\tau_{\text{Rise}} = 40 \text{ ns}$ ,  $\tau_{\text{Fall}} = 2 \mu\text{s}$ .
- Currently using 200 MHz  
FADCs but method remains  
effective at FADC speeds as  
low as 25 MHz.
- 60 tracking pads ( $2 \times 6 \text{ mm}^2$ )
- Mounted in the DESY 5 T  
test magnet.



# Resolution at 5T vs. gas mixtures

→  $\sigma \sim 50 \mu\text{m}$  independent of the drift distance!!

→  $\sigma \sim 1/40^{\text{th}}$  of pad width!! (to compare  $\sqrt{12} \sim 3.5$ )





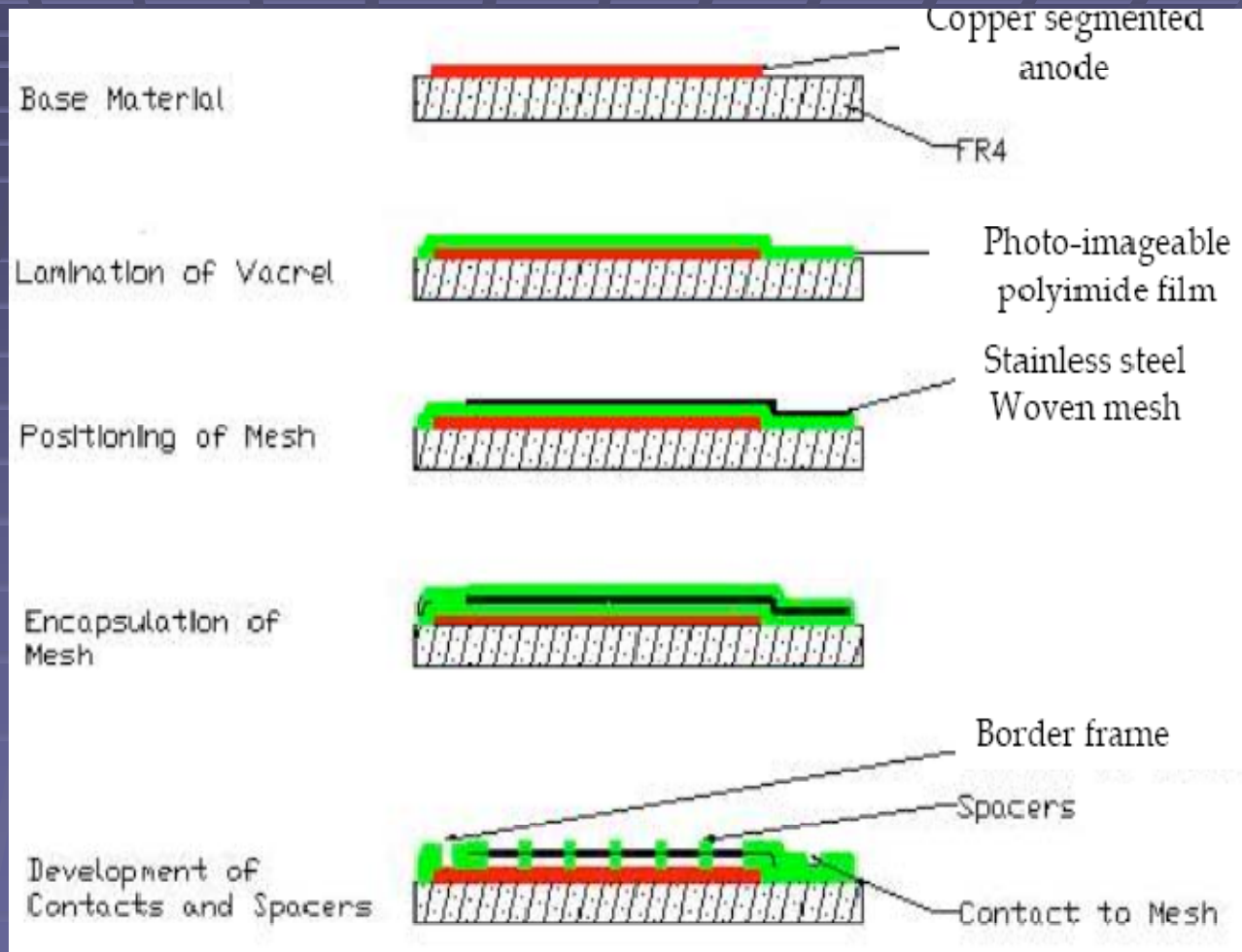
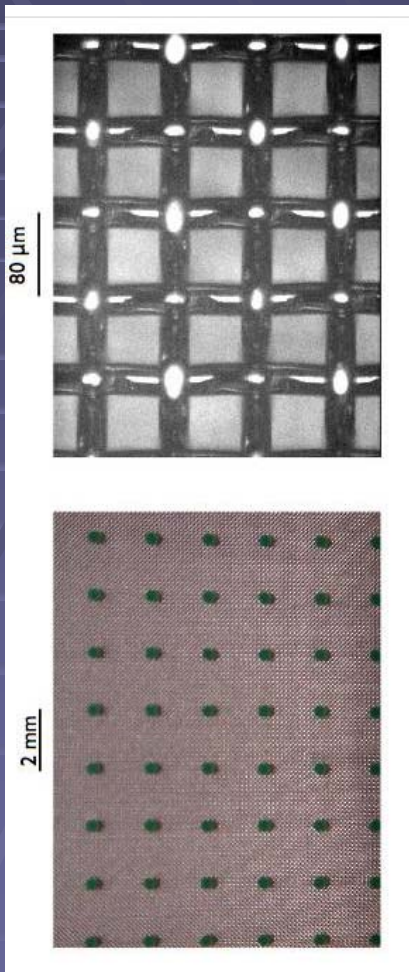
# Concept → Reality

Making a versatile and valid  
technology.

# Technical Hurdles.

- Resist technology must be Micromegas Bulk Technology compatible, if it is to be used with Micromegas
  - Resistive layers must be able to withstand heat, chemical washing, mild friction...
  - Must be producible on large surface areas, preferably at low cost
- Cost/unit area must be kept low (as always).
- Charge evacuation rate from the surface of the resistive layer must be consistent with expected signal frequency to avoid signal pileup/gain fluctuations.
- Further studies on both actual and desirable charge distributions are required to maximize and understand achievable resolution.
- The effects on two track resolution must also be evaluated.

# The Bulk technology





2 μm-thick microcrystalline silicon film  
deposited on 30cmx40cm glass  
substrate  
IMT

## Pad Response Function (PRF) Question(s): Charge distribution questions.

- What is the best PRF for a given pad pitch/layout?
- What types of PRFs are possible;
  - Are multi-dimensional PRFs capable of achieving better resolution given the strong dependency on location of rise time for neighboring pads?
  - Is the complete parameterization of resistively distributed signals possible?
- How is the charge distributed to the pads dependent on the resistive layer properties?
- Can low resistivity films be used to channel signal conductively into the different pads, rather than inducing signal via capacitance coupling?
  - Would this be better in any way?

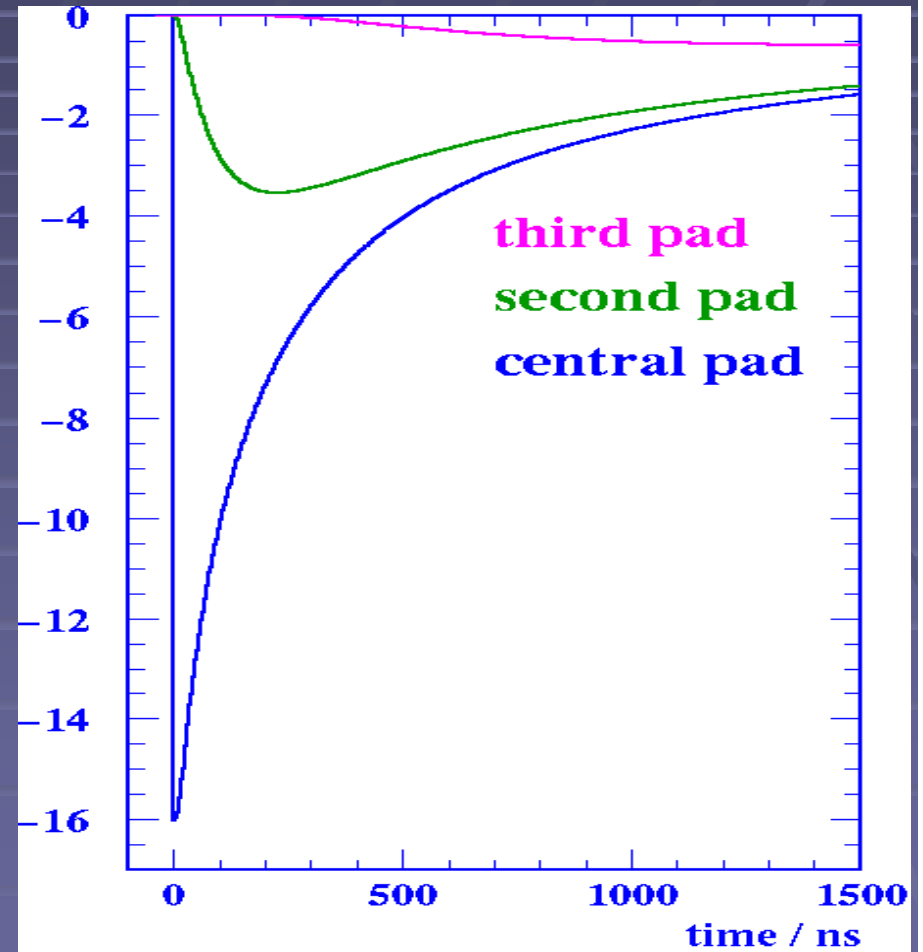
# One Quick note on Multi dimensional PRF

For resistive films electrically isolated from the readout pads, where a grounding guard ring is used to evacuate charge from the film, the total charge summed over central pad, plus the two pads to the left and right rises, then remains constant for a period of time.

The signal decays off the central pad, and onto neighboring pads in turn, becoming shallower in amplitude and slower in rise time each consecutive pad till the charge is evacuated by the guard ring.

The rate which it decays onto a neighboring pad is also dependent on where the charge was deposited on the principle pad. . . so by measuring the rise times of the central pad, and its neighbors one can also extract position information.

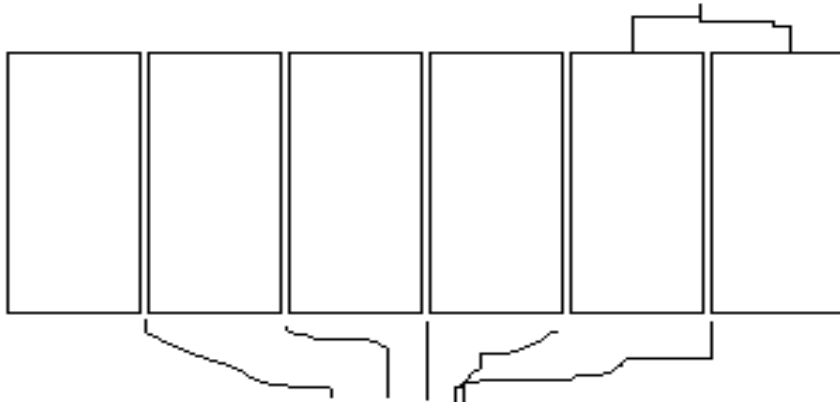
This second dimension of information can be processed in parallel with amplitude information to yield a multi-dimensional PRF



# A neat new idea?: Another possibility for pads, Thin.

## Current System

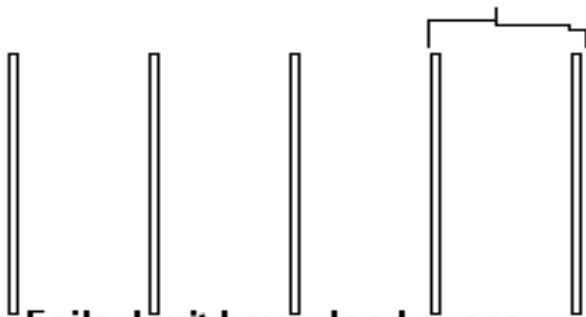
Pitch: 2.x mm



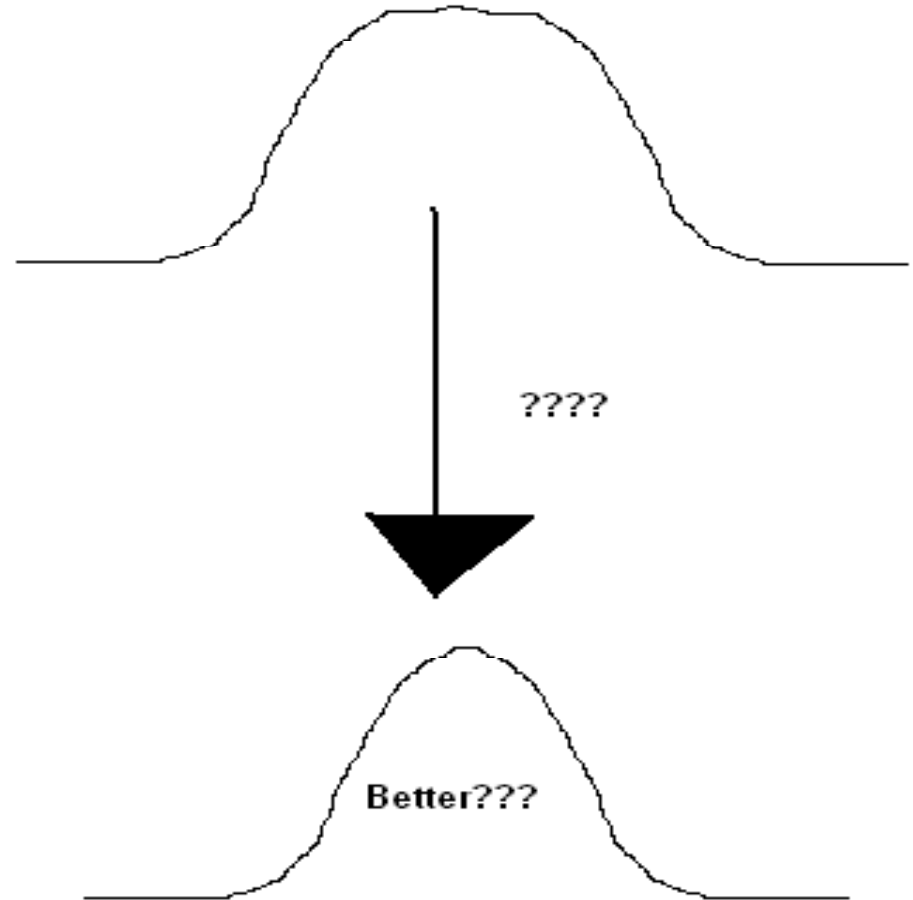
'Dead' space between pads kept as small as possible.

## A possible proposed system?

Pitch: 2.x mm



Resistive Foils don't have dead space. . .  
So why not make pads thin, and gain resolution by eliminating the flat top of the PRE.



# How resistive are we talking?

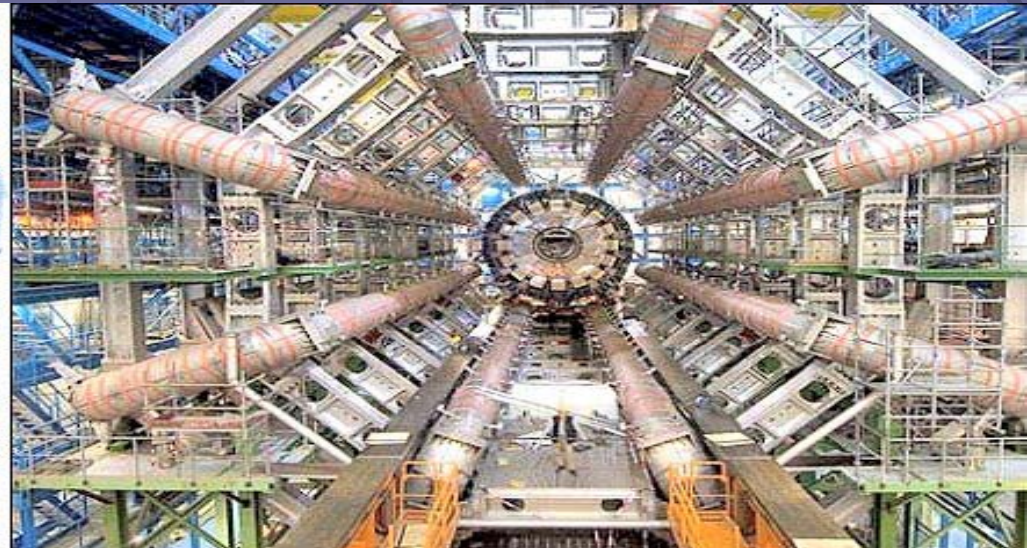
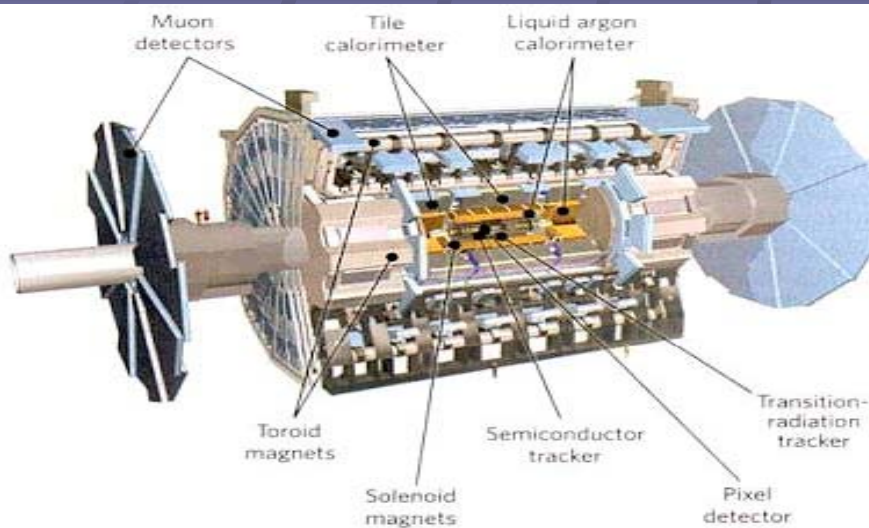
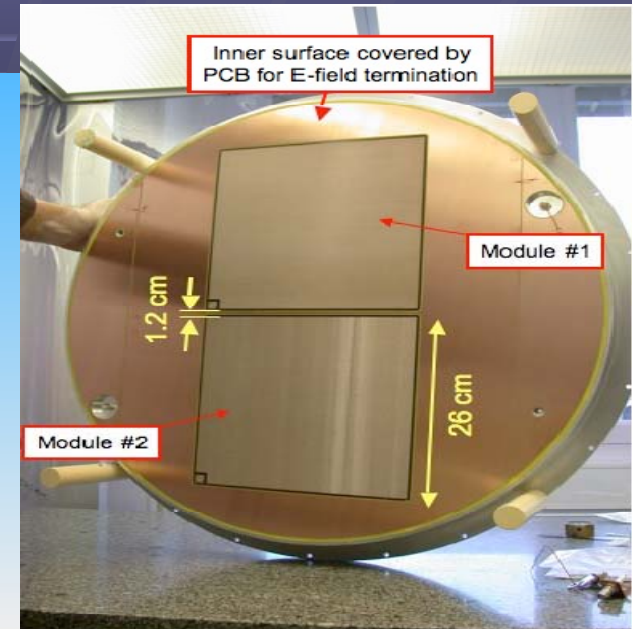
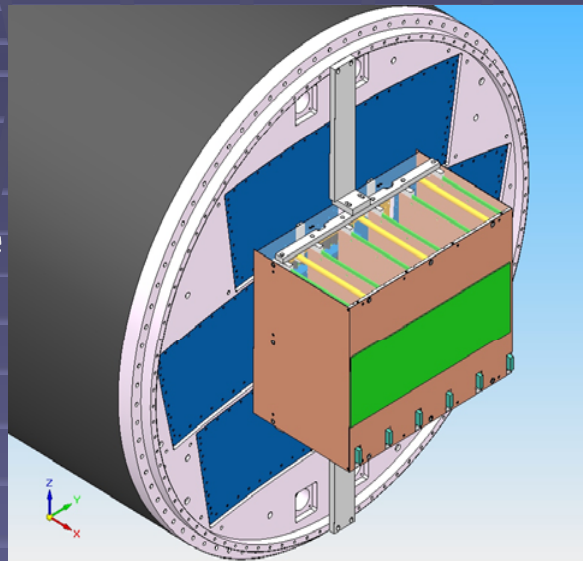
## Methods and regimes

- **Films from CERN: stereography**
  - 20  $\mu\text{m}$  ( $\sim 4000$  ohm-cm, or  $\sim 16000$  ohm-cm) (2 and 8 Mega Ohm / Square)
  - Bulk compatible (Saclay already has one and is testing it now)
  - Either with electrically insulating glue layer or without.
- **Films Via Carleton: Kapton film with sputtered distributed resistance on one side.**
  - Similar process to COSMo TPC: It's been done, and it works
  - Kapton film is press-glued onto readout board in a lamination process.
  - May be difficult to incorporate with bulk Technology, depending on thickness and robustness of sputtered layer
- **Films Via Neuchâtel: deposited amorphous silicon**
  - Two deposited layers of amorphous silicon doped to varying degrees to control conductivity.
  - First possible regime: Carleton-esque  $10^4$  ohm cm layer sitting on a  $10^{11}$  ohm cm isolating layer.
  - Second possible: semi-conductive solution  $10^{-1}$  ohm cm layer sitting on a  $10^4$  ohm cm conductive layer, charge is split conductively as opposed to via capacitance coupling.



# Possible Applications

- ILC
- T2K
- S-LHC Atlas Upgrade
- Compass
- Timepix



# Conclusions

- Resistive film technology is possible, and is being used to break resolution records with large pads.
- We still have much to learn about resistive films and how to best use them; either to protect sensitive Timepix chips, or to protect large pad electronics and improve resolution of large pad systems.