Carleton University — Canada's Capital University | Ontario Premier's Research Excellence Awards | ilc

Resolution studies in a MPGD-TPC with charge dispersion on a resistive anode

Presented by

Khalil Boudjemline

On behalf of

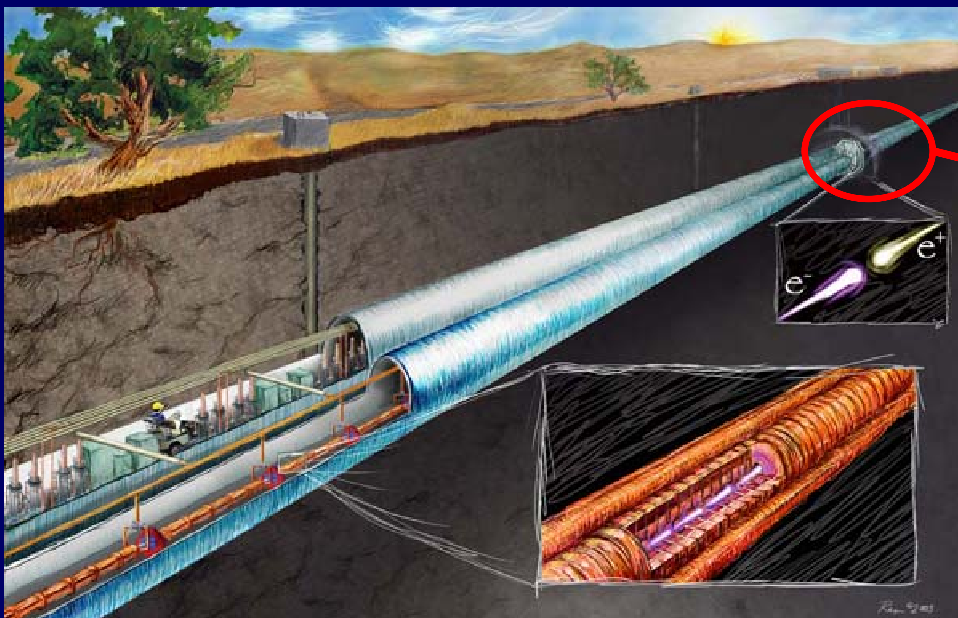
A subset of the ILC-TPC R&D collaboration

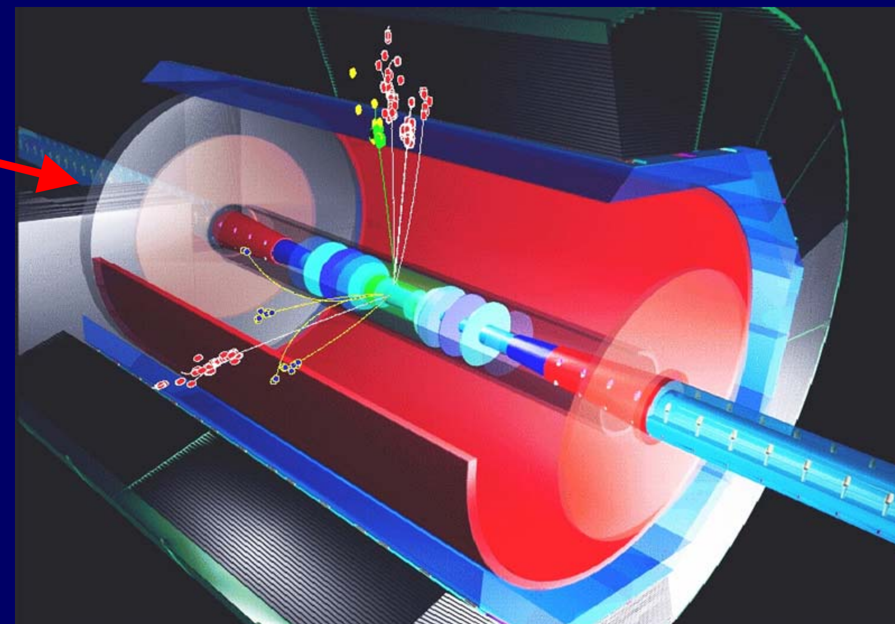
CAP Congress 2006, Brock University
St Catharines, Ontario

Outline

1. ILC central tracking detector: the TPC
2. Charge dispersion using a resistive anode
3. KEK beam tests
4. Results: comparison to cosmic data
5. Summary

Main Tracker at the International Linear Collider





Central (main) tracking requirement

- Excellent track reconstruction efficiency and momentum resolution over a large solid angle.

- Hermetic & minimized material.

- Robust, reliable, stable………

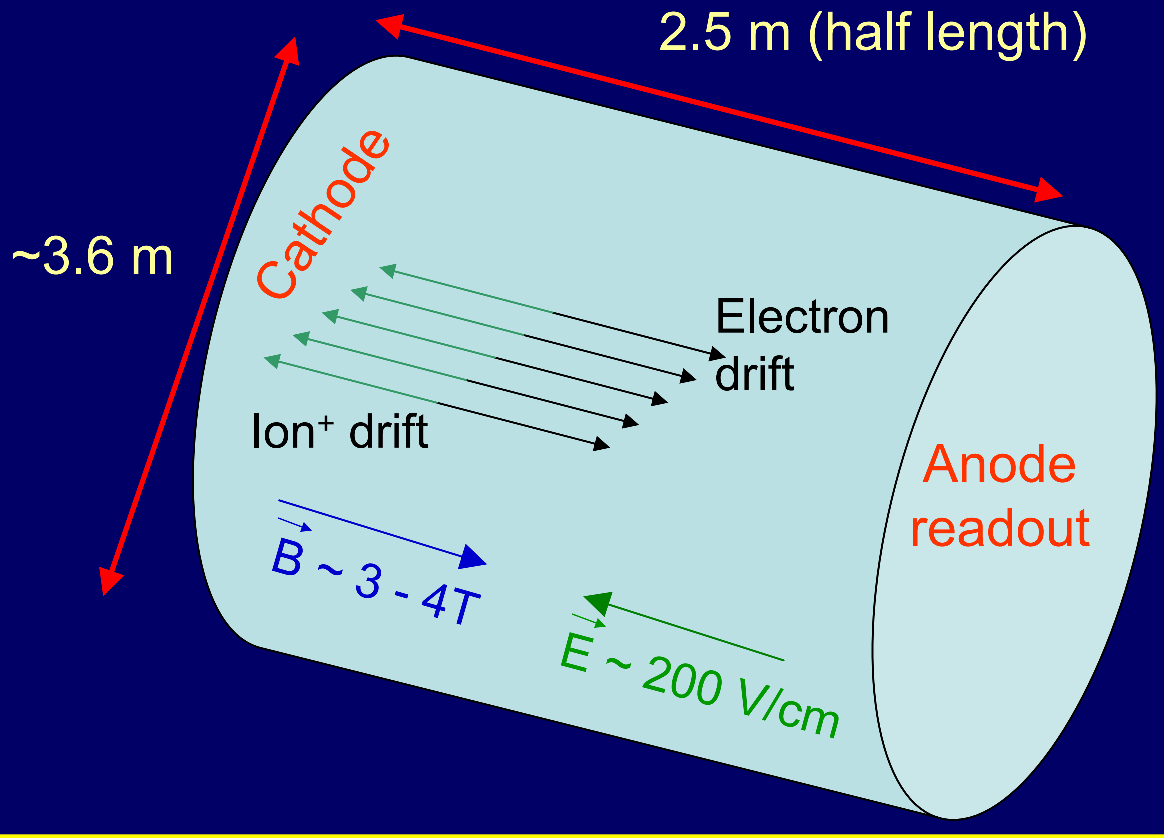
Time Projection Chamber

ILC-TPC challenge:

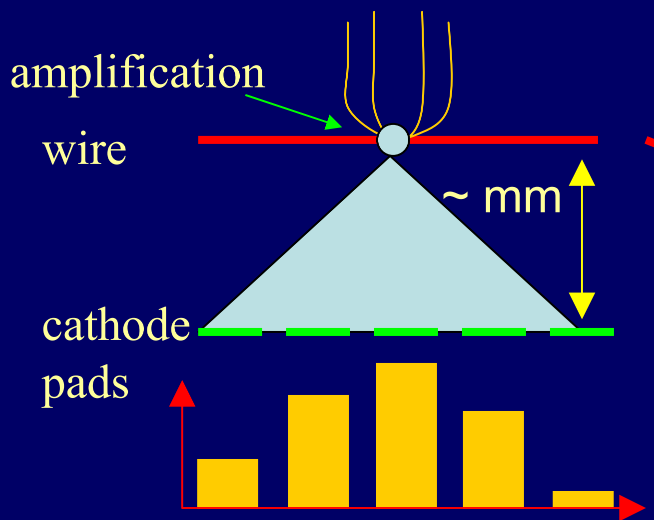
- $\sigma_x \sim 100\ \mu m$, 200 pads, ~ 2 x 6 mm^2

near the ultimate limit from diffusion & electron statistics.

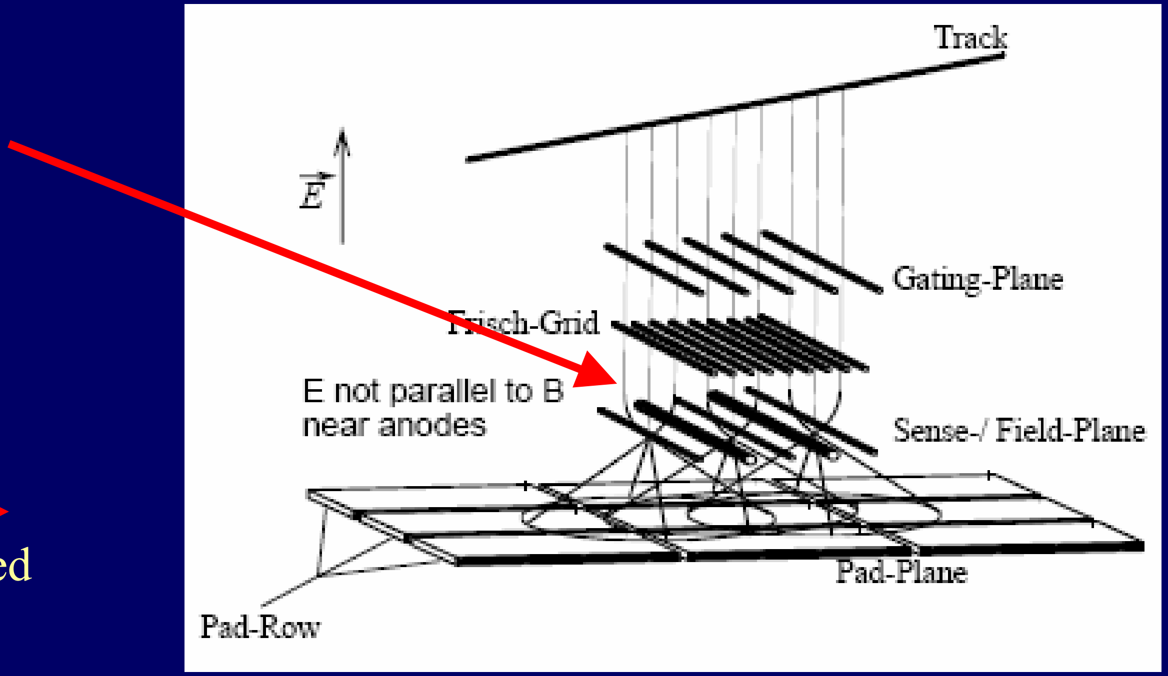
- the goal is ~ 2 times better than conventional TPC readout.



Tradional Readout: wire/pad



Induced signal determined by geometry

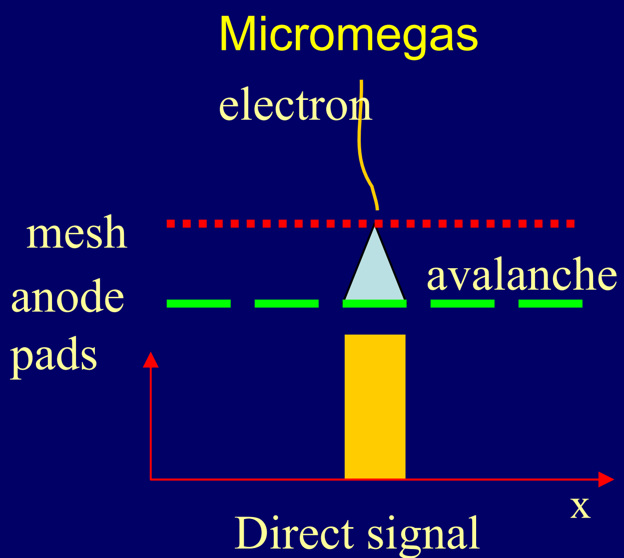


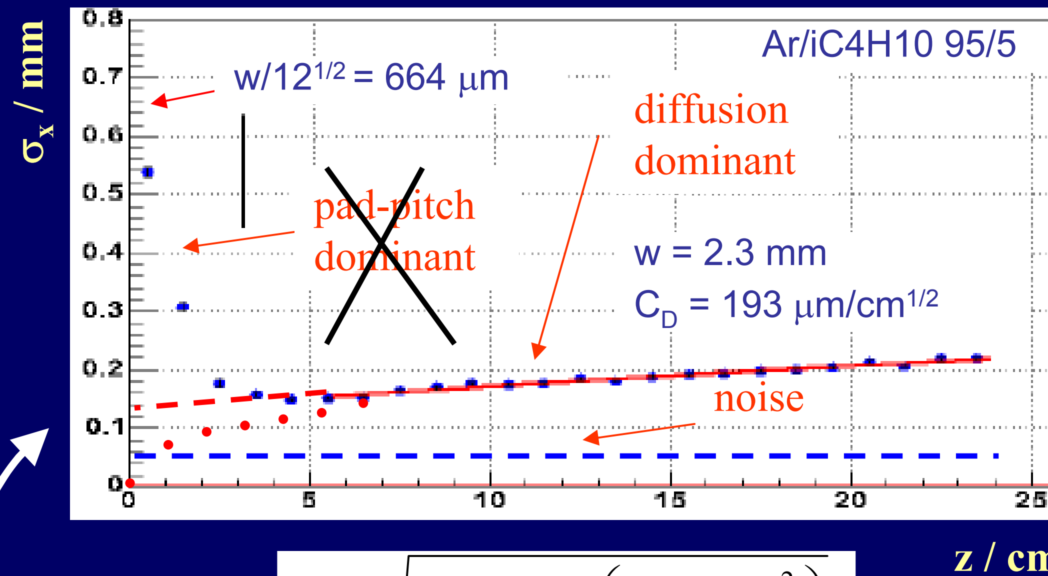
Disadvantage

- E×B effect and track angle systematic effect → worse spatial resolution

Use the MPGD readout (Micromegas or GEM) to reduce the E×B effect.

Micro Pattern Gas Detectors





$$\sigma_x = \sqrt{\sigma_0^2 + \frac{1}{N_{eff}}\left(C_D^2 z + \frac{w^2}{12}\right)}$$

Solutions:

1- decrease by a factor >5 the pad width → huge number of channels

2- diffuse the charge after the amplification
→ impossible with Micromegas
→ very difficult with GEM

3- set a resistive foil on the pad plane

Resistive anode / charge dispersion

- a high resistivity film bonded to a readout plane with an insulating spacer

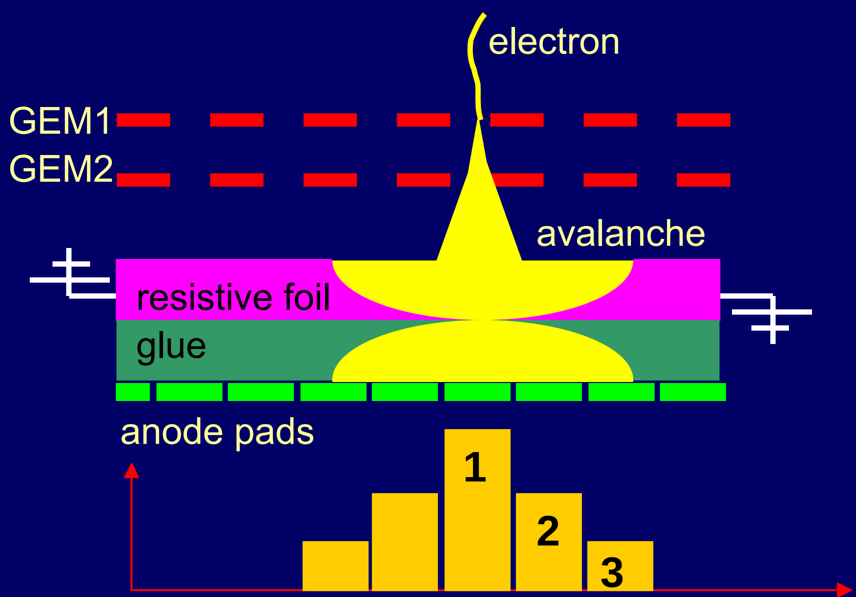
- 2 dim continuous RC network defined by material properties and geometry.

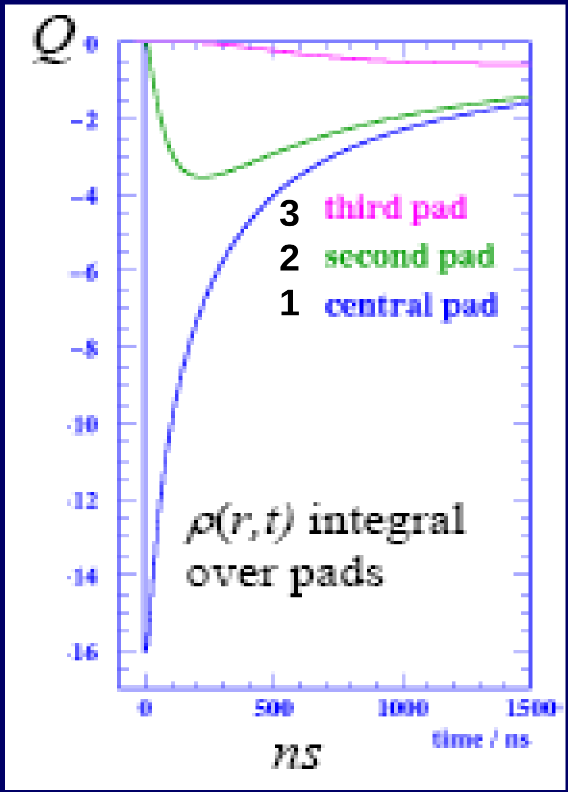
- point charge at r = 0 & t = 0 disperses with time.

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

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

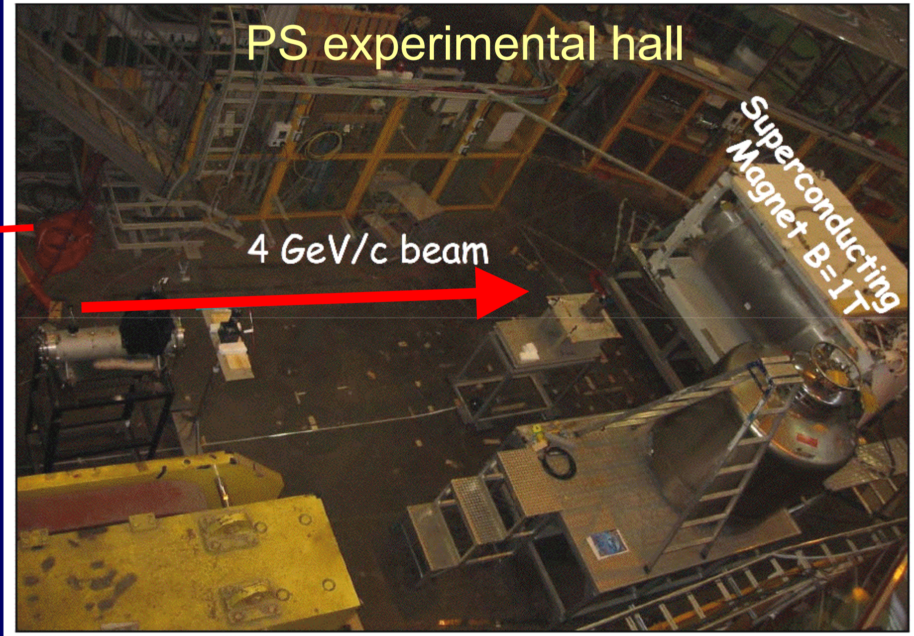
Double GEM + resistive anode

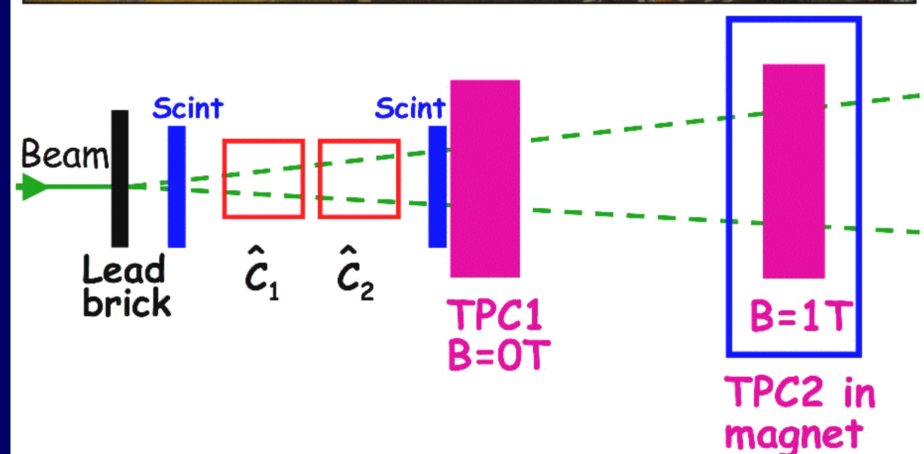




KEK beam test

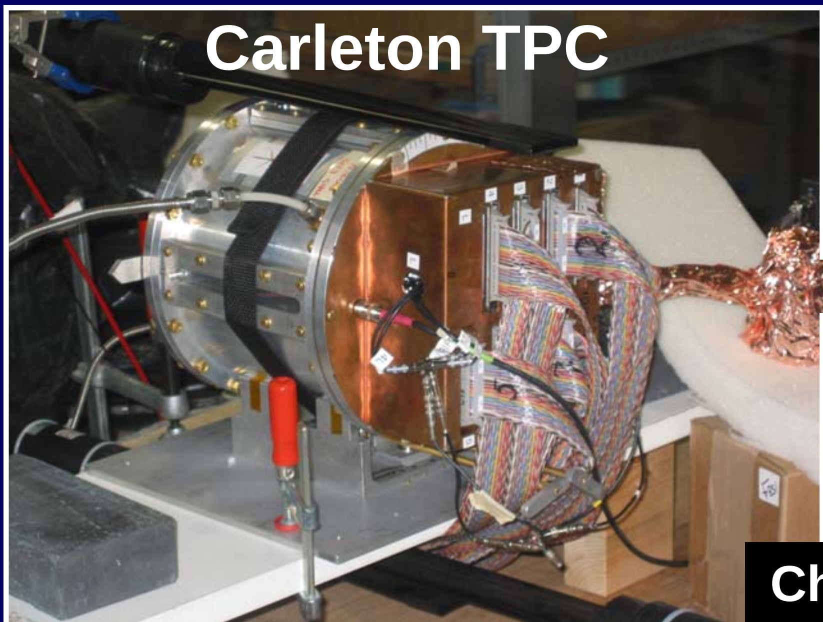
KEK complex, Tsukuba, Japan

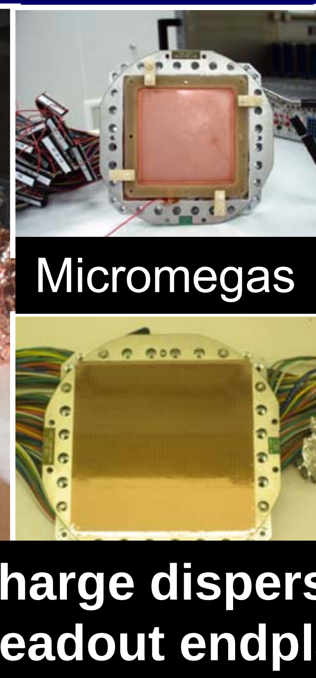


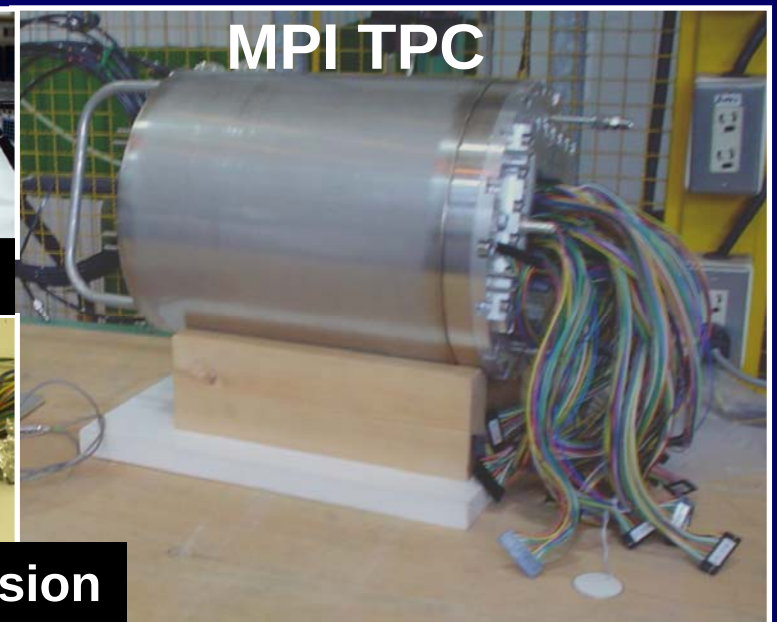


- 4 GeV/c hadrons
0.5 & 1 GeV/c electrons
- Super conducting 1.2 T magnet
- Inner diameter : 850 mm
- Effective length: 1 m

Tested prototypes







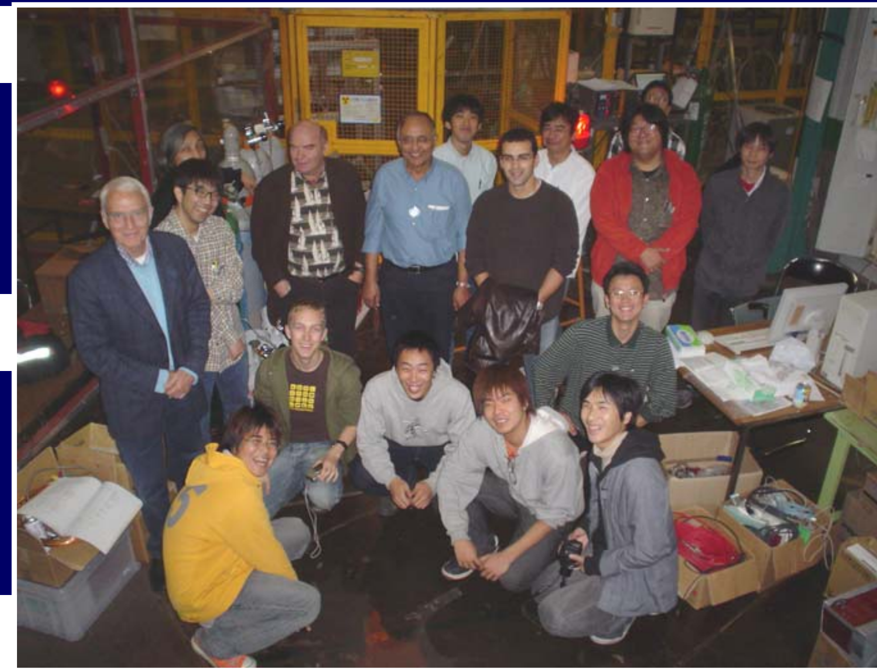
- Micromegas 10 x 10 cm^2
- Drift distance: 16 cm
- 126 pads, 2 x 6 mm^2 each in 7 rows
- ALEPH preamps + 200 MHz FADCs

- Micromegas & GEMs 10 x 10 cm^2
- Drift distance: 25 cm
- 384 pads, 2.3 x 6.3 mm^2 each in 16 rows
- ALEPH preamps + 11 MHz Aleph Time Projection Digitizers

Beam Test Team

CANADA

Carleton University: *A. Bellerive, K. Boudjemline, M. Dixit, J. Miyamato, E. Neuheimer, E. Rollin, K. Sachs & Y. Shin*
University of Montreal: *J.-P. Martin*



FRANCE

DAPNIA CEA Saclay: *D. Burke, P. Colas, A. Giganon & I. Giomataris*
LAL Orsay: *V. Lepeltier & Th. Zerguerras*

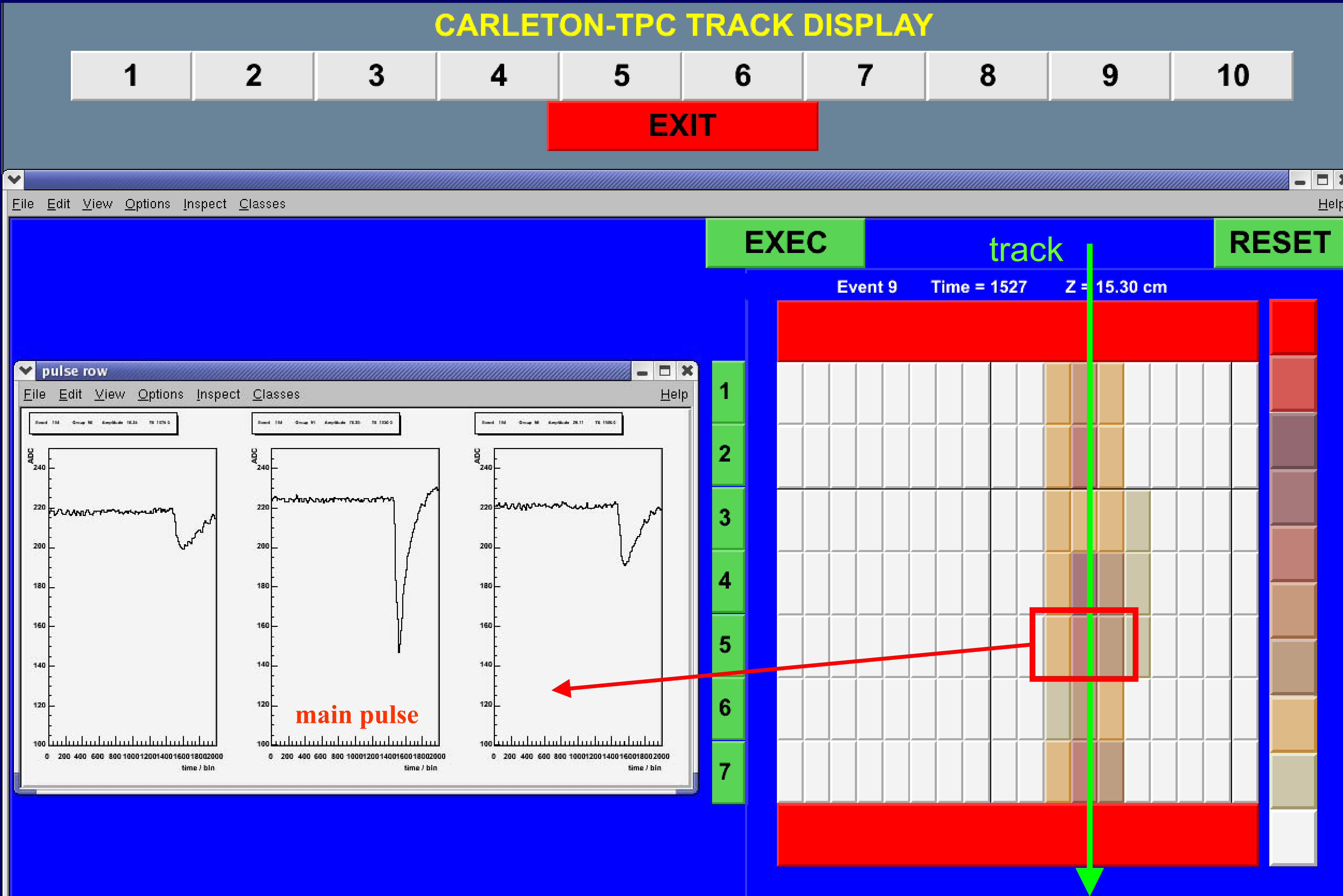
GERMANY

MPI (Munich): *R. Settles*

JAPAN

Hiroshima University: *H. Kuroiwa & T. Takahashi,*
KEK/IPNS: *K. Fujii, M. Kobayashi, T. Matsuda & H. Yamaoka*
Kinnki University: *Y. Kato*
Kogakuin University: *T. Watanabe*
Saga University: *T. Araki, H. Fujishima, T. Higashi, K. Kodomatsu, A. Sugiyama, T.Yamamoto & Y. Tanaka*
Tsukuba University: *A. Yamaguchi*
Tokyo University of Agriculture &Technology: *M. Habu, S. Matsushita, K. Nakamura & O. Nito*

Example of a track

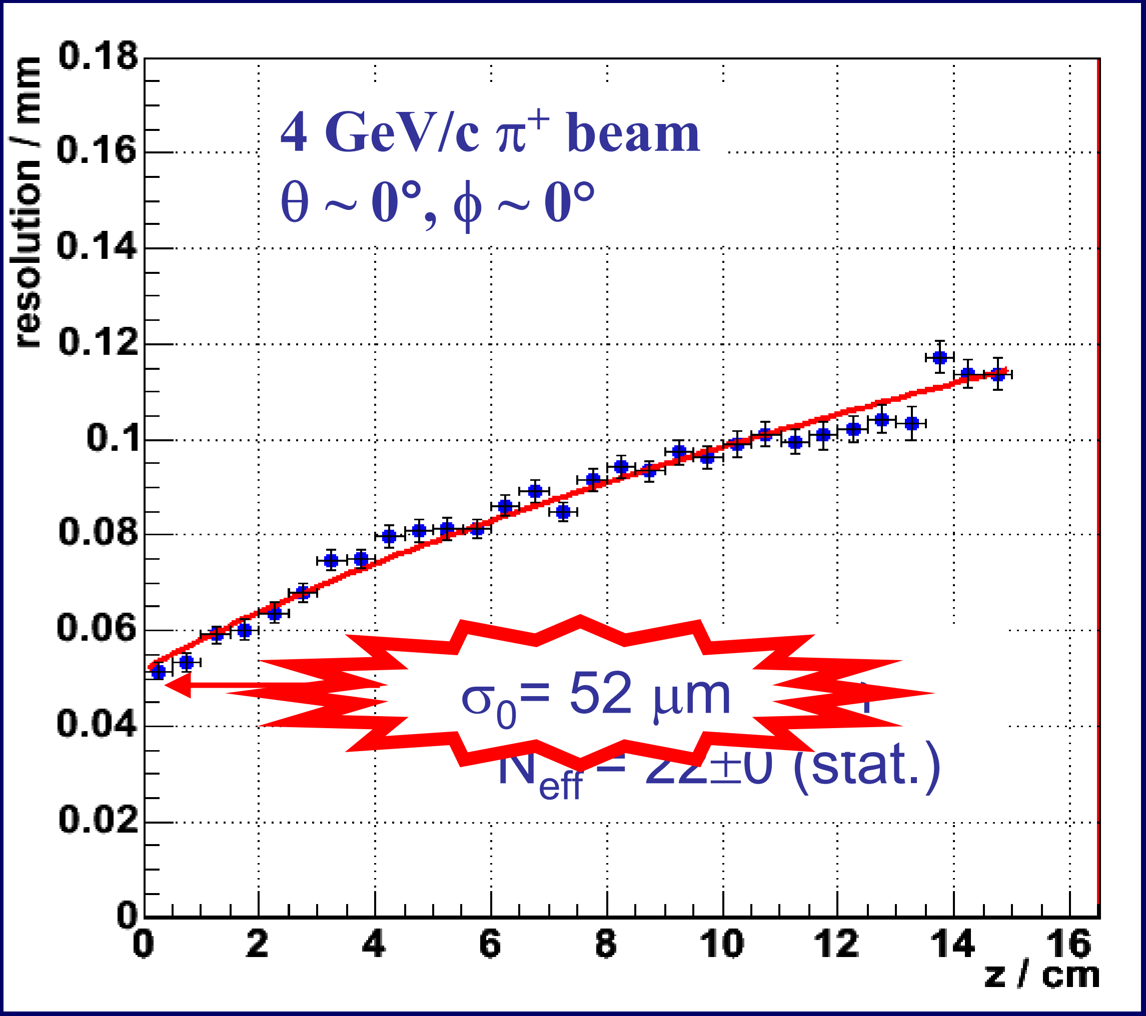


Transverse Spatial Resolution

Carleton TPC

- Ar/iC4H10 95/5
- 2 X 6 mm^2 pads
- B = 1 T
  $\rightarrow C_D = 125\ \mu m/cm^{1/2}$

$$\sigma_x = \sqrt{\sigma_0^2 + \frac{C_D^2 z}{N_{eff}}}$$

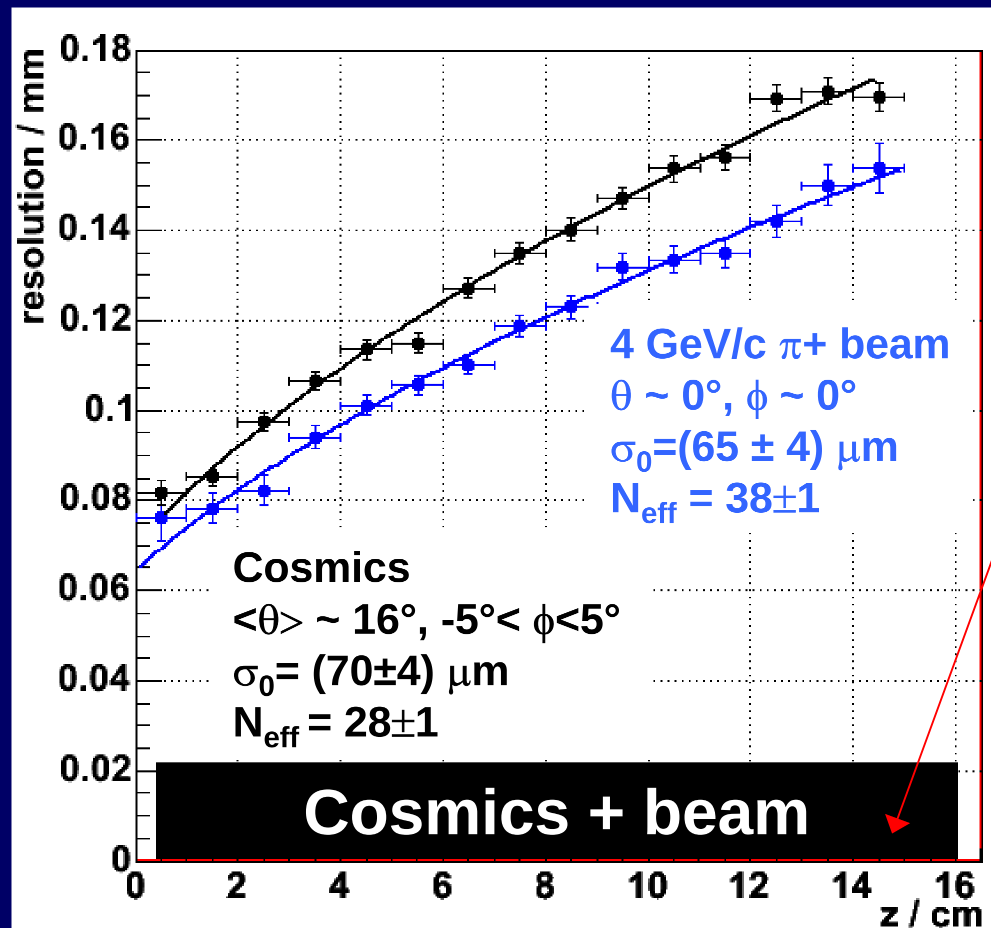


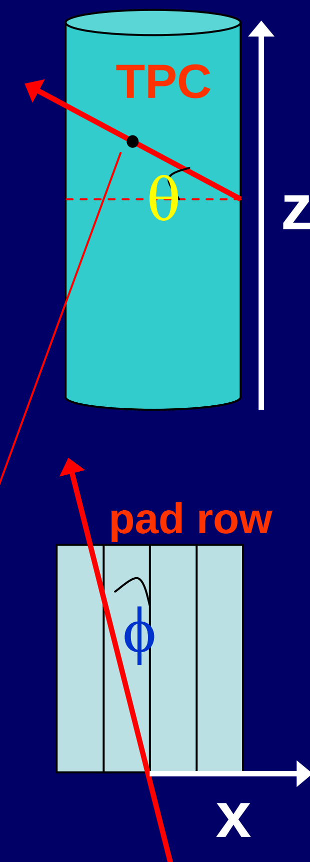
Transverse Spatial Resolution

- Ar/CO2 90/10
- 2 X 6 mm² pads
- B = 0 T
  → C_D = 223 μm/cm$^{1/2}$

$$\sigma_x = \sqrt{\sigma_0^2 + \frac{C_D^2 z}{N_{eff}}}$$

Carleton TPC





Summary

- A first demonstration of the charge dispersion readout concept for the MPGD-TPC in a magnetic field.

- ~ 50 μm spatial resolution for short drift distances with 2 x 6 mm^2 pads in a 1 T magnetic field.

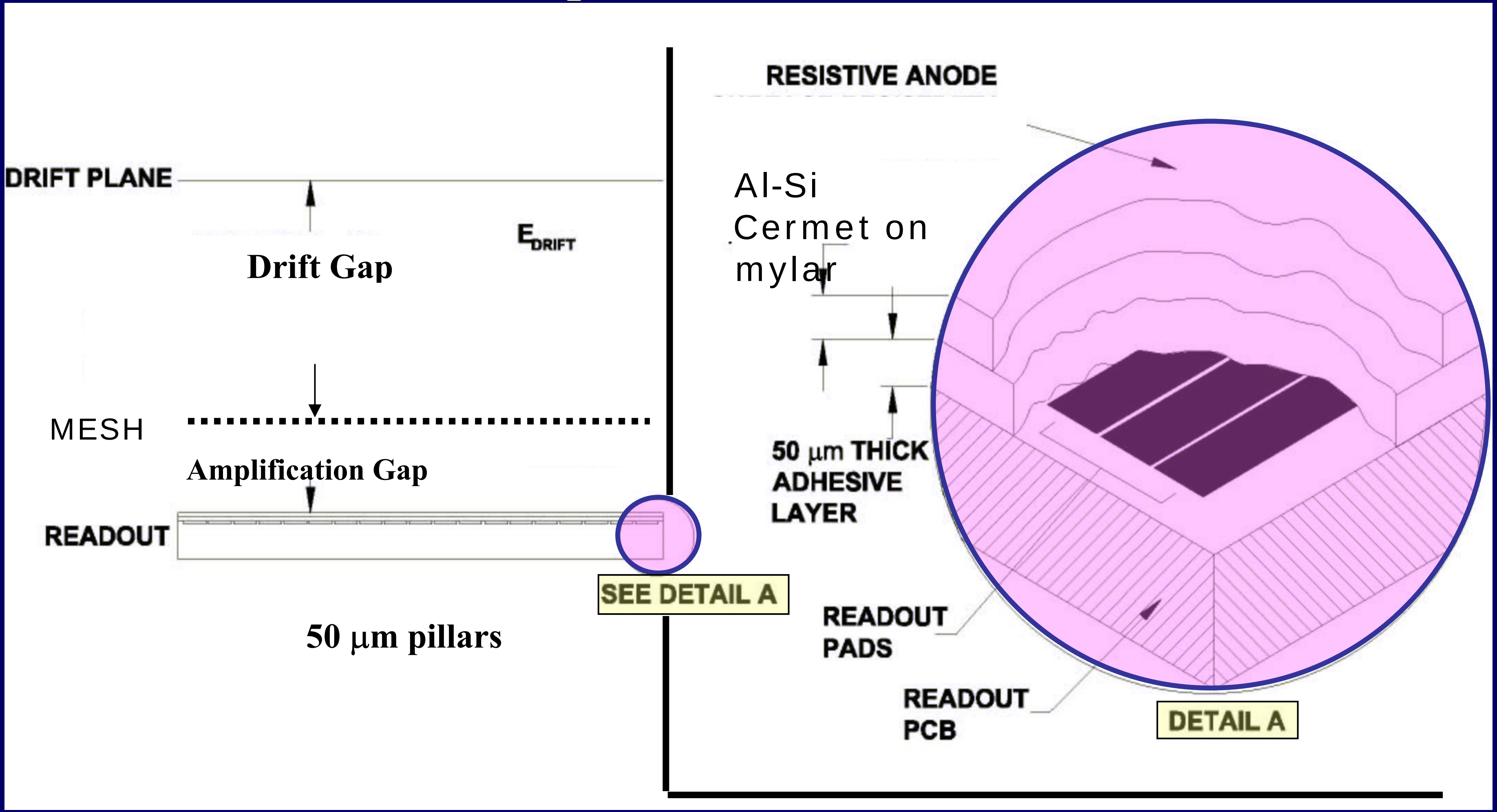
- With smaller transverse diffusion at ~ 4 T magnetic field, the 100 μm resolution goal appears within reach for the ILC-TPC using a resistive anode.

Future

Cosmic tests at DESY this summer at 4T.
Built a large prototype TPC.

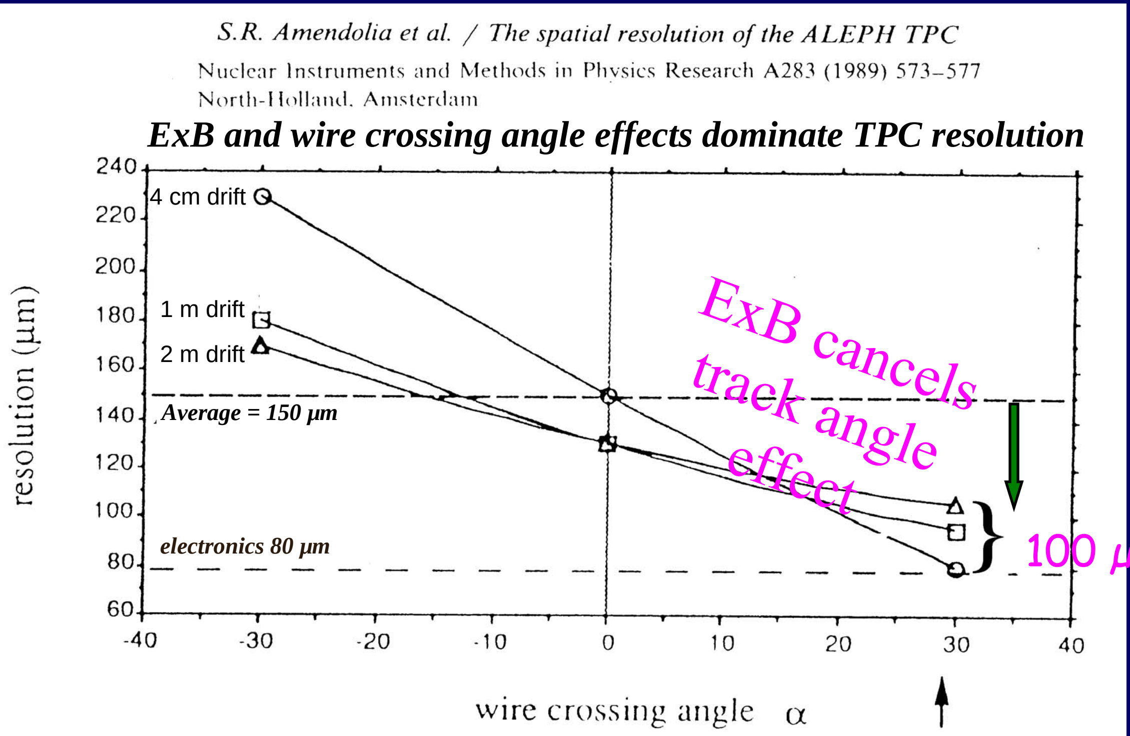
EXTRA SLIDES

Micromegas with a resistive anode for the charge dispersion readout

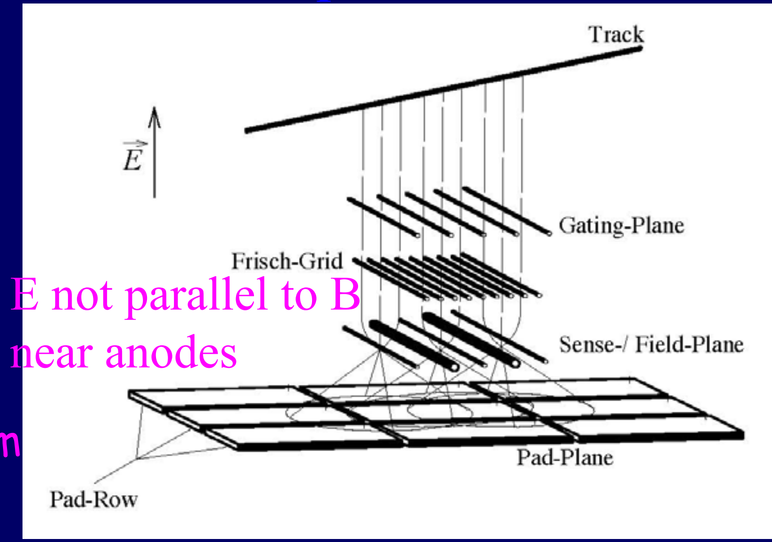


EXTRA SLIDES

When there is no ExB effect, the wire/pad TPC resolution approaches the diffusion limit for the Aleph TPC

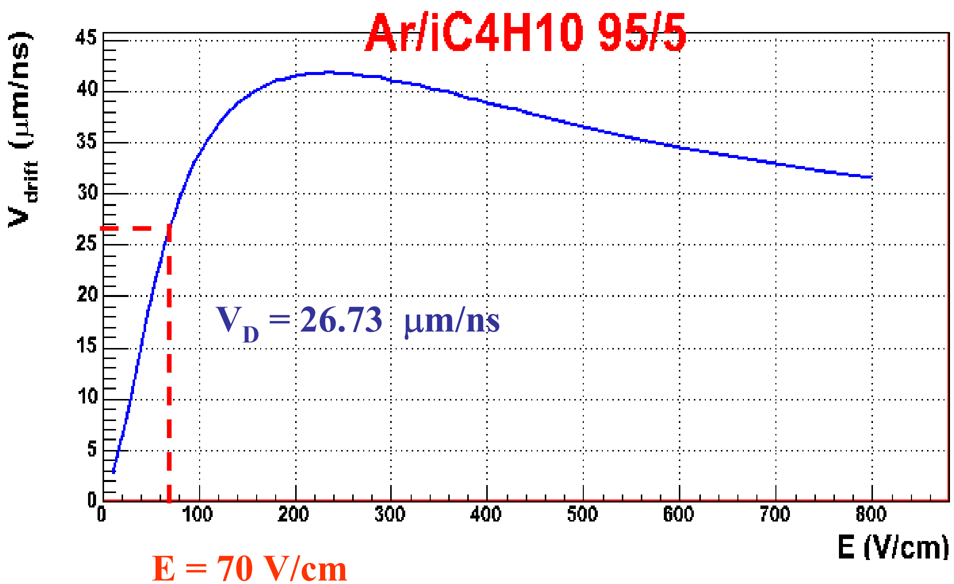


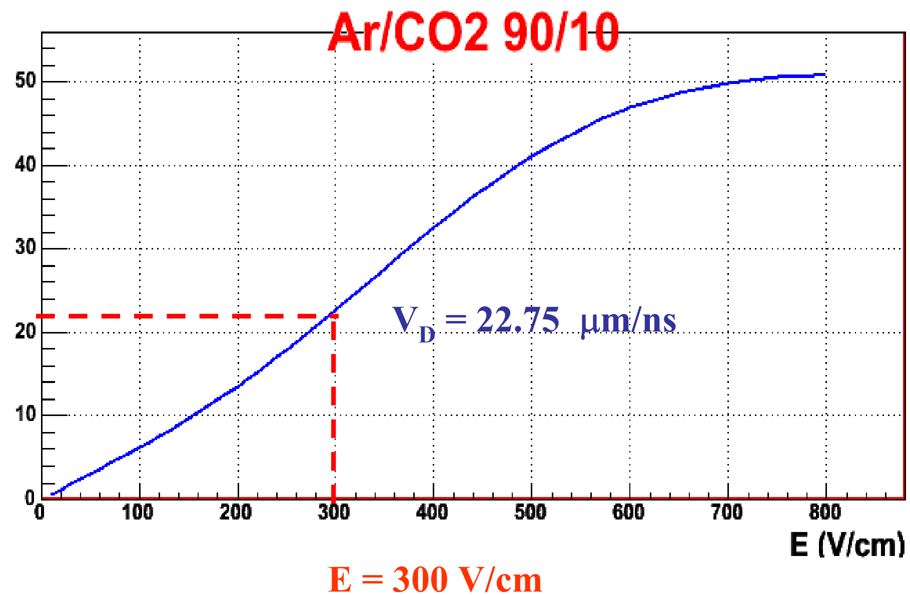
TPC wire/pad readout

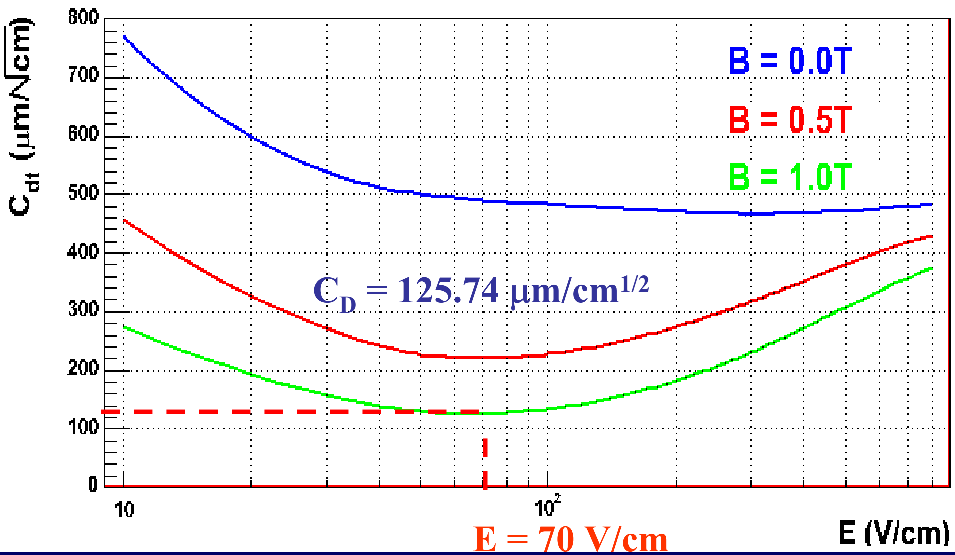


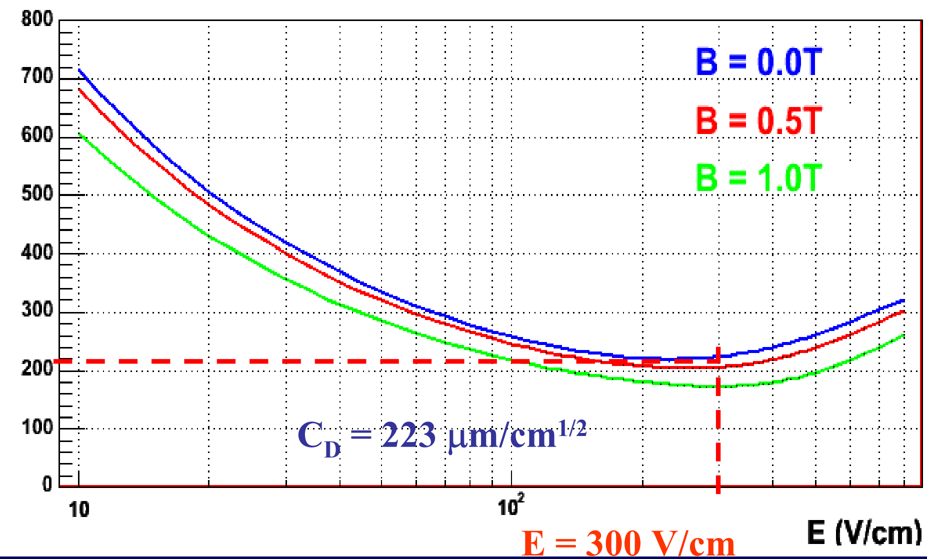
Average Aleph resolution ~ 150 μm.
Resolution ~ 100 μm even for 2 m drift.
Limit from diffusion σ (10 cm drift) ~ 15 μm; σ (2 m drift) ~ 60 μm.

Beam test motivations



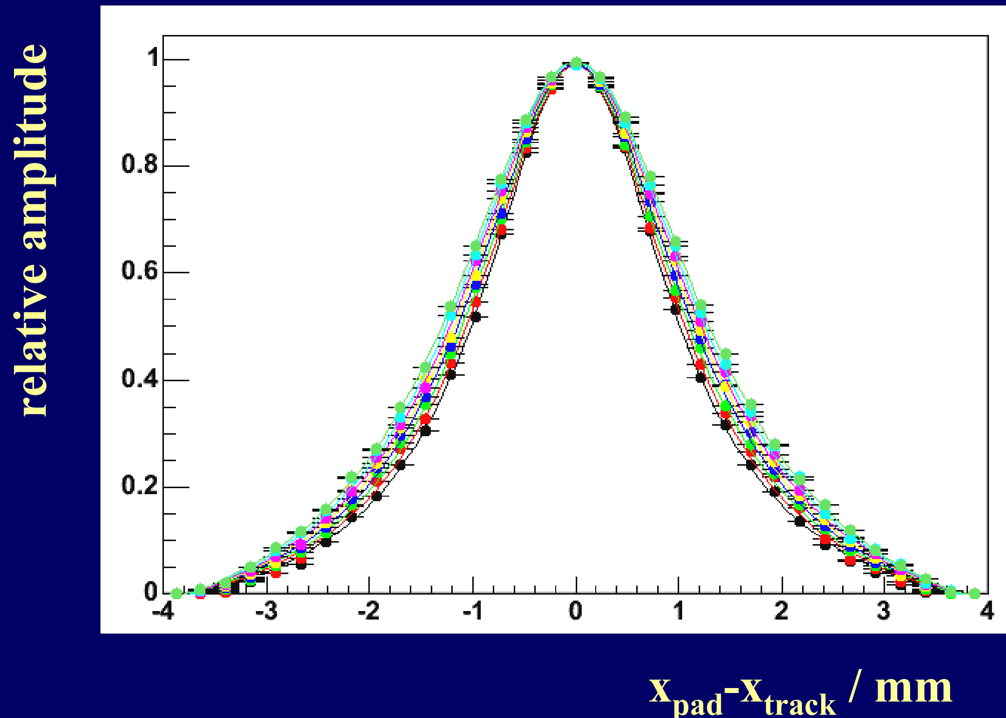


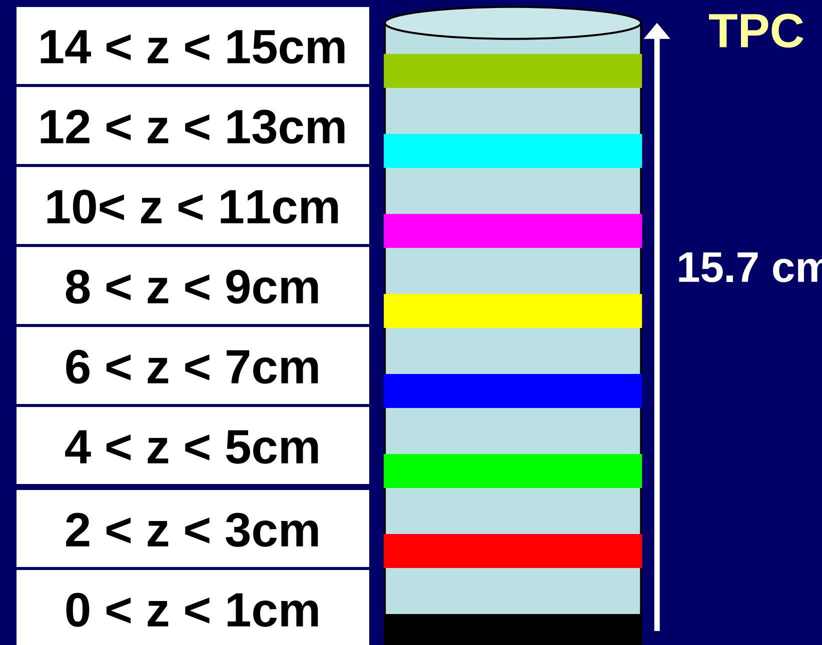




Pad Response Function

Ar/iC4H10 95/5



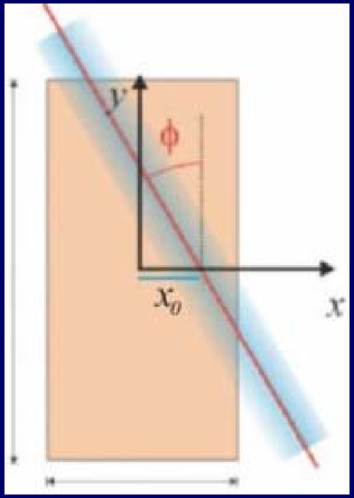


$$PRF[x,\Gamma(z),\Delta,a,b] = \frac{1 + a_2 x^2 + a_4 x^4}{1 + b_2 x^2 + b_4 x^4}$$

Track fit method

track

6 mm



2 mm

- using the PRF to fit the pad signals
- track fit: linear fit $x_{track} = x_0 + \tan(\phi)\, y_{row}$
- χ^2 minimization $\chi^2 = \sum_{rows} \sum_{i=pads} \left(\frac{A_i - PRF_i}{\partial A_i} \right)^2$

  → x_0 and ϕ

Definitions:

- residual: x_{row}-x_{track}
- bias: mean of x_{row}-x_{track} = $f(x_{track})$
- resolution: σ of the residuals

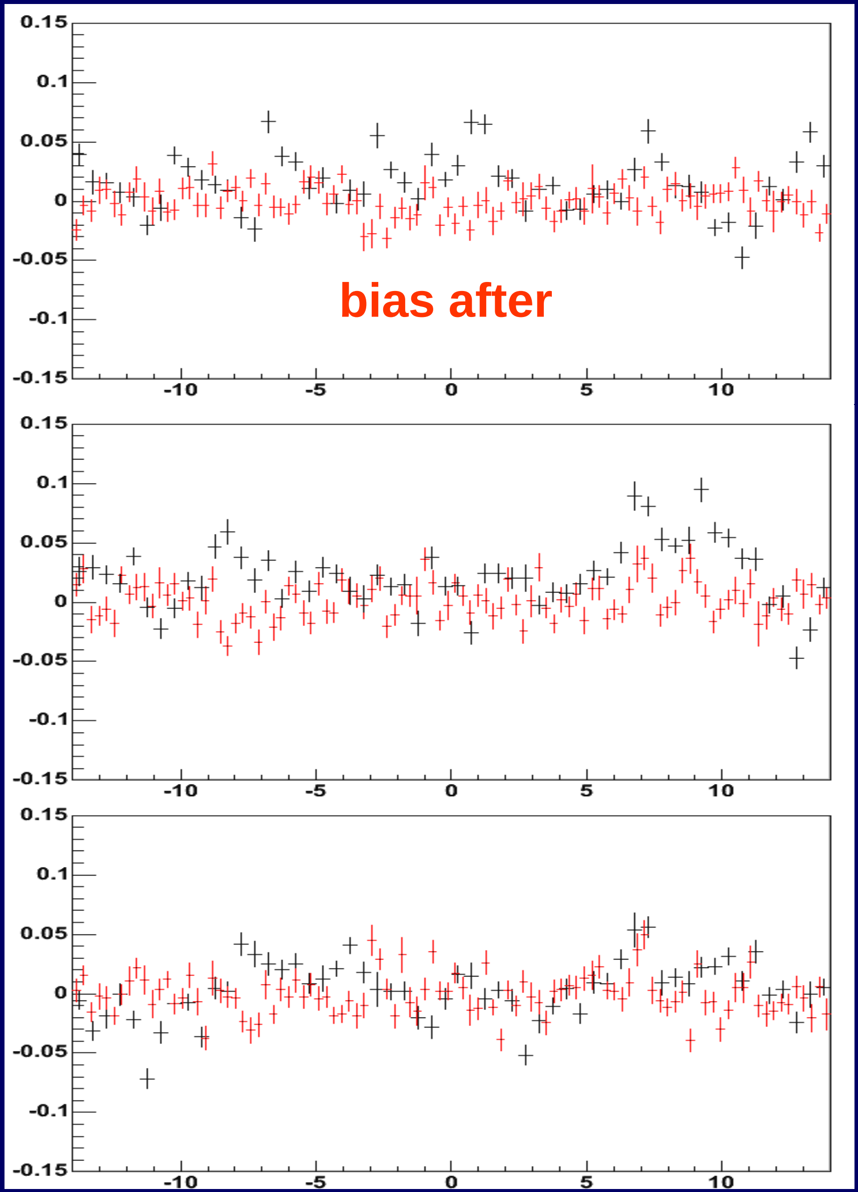
Bias for central rows

row 3

row 4

row 5

Residual / mm



± 20 μm

x_{track} / mm

Pulse shape origin

Transverse diffusion

$$T(x) = \frac{1}{\sigma_x \sqrt{2\pi}} \exp\left(\frac{-x^2}{2\sigma_x^2}\right)$$

Longitudinal diffusion

$$L(t) = \frac{1}{\sigma_t \sqrt{2\pi}} \exp\left(\frac{-t^2}{2\sigma_t^2}\right)$$

Intrinsic rise time

$$R(t) = \frac{t}{T_{rise}} \quad \text{for} \quad 0 < t < T_{rise}$$
$$= 1 \quad \text{for} \quad t > T_{rise}$$
$$= 0 \quad \text{for} \quad t < 0$$

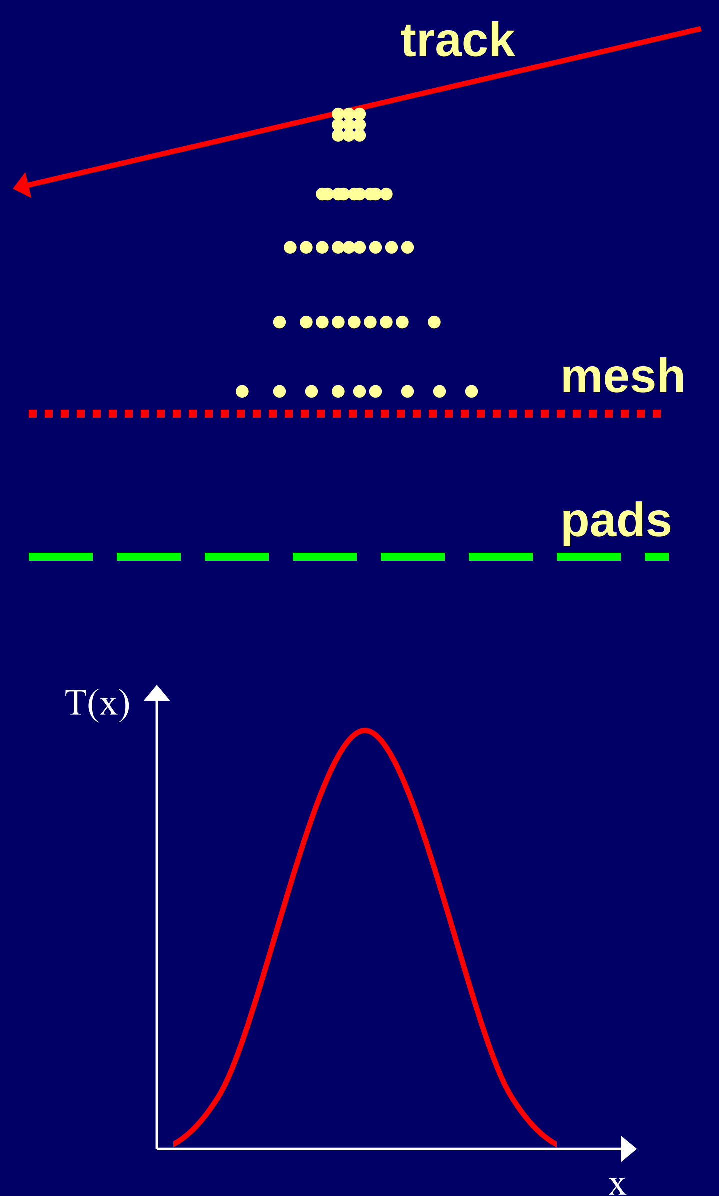
Preamplifier effect

$$A(t) = \exp\left(-\frac{t}{t_f}\right)\left(1 - \exp\left(\frac{t}{t_r}\right)\right) \quad \text{for} \quad t > 0$$
$$= 0 \quad \text{for} \quad t < 0$$

Resistive foil + glue

$$\rho(x,y,t) = \left(\frac{1}{\sigma_t \sqrt{\pi t h}}\right)^2 \exp\left(\frac{-(x^2+y^2)}{4th}\right)$$

$$h = 1/RC$$



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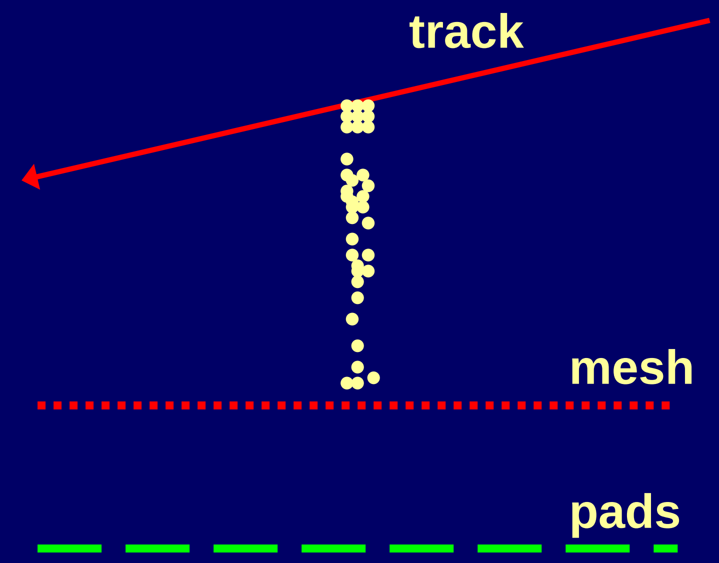

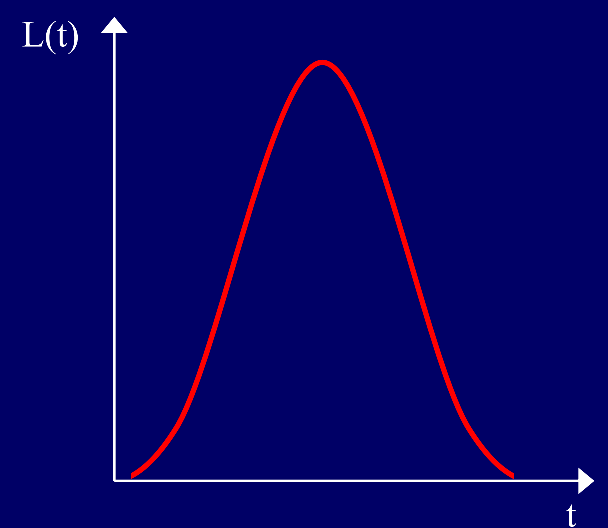

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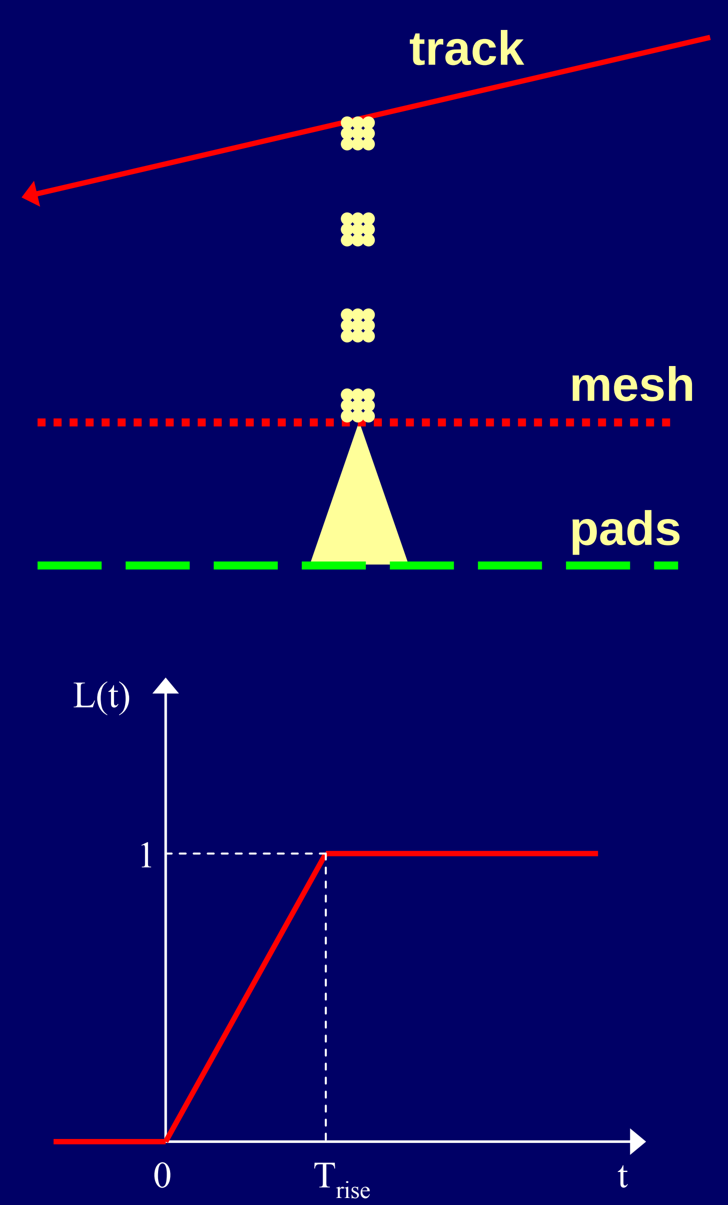

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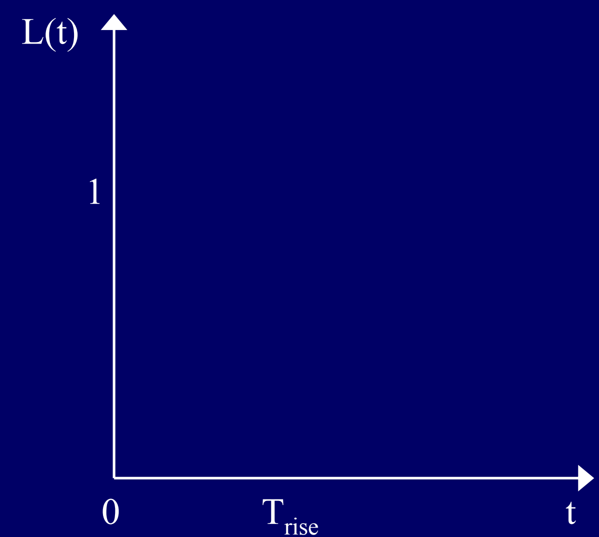

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see slide 6