TPC R&D for the $e^+ e^-$ Linear Collider Detector

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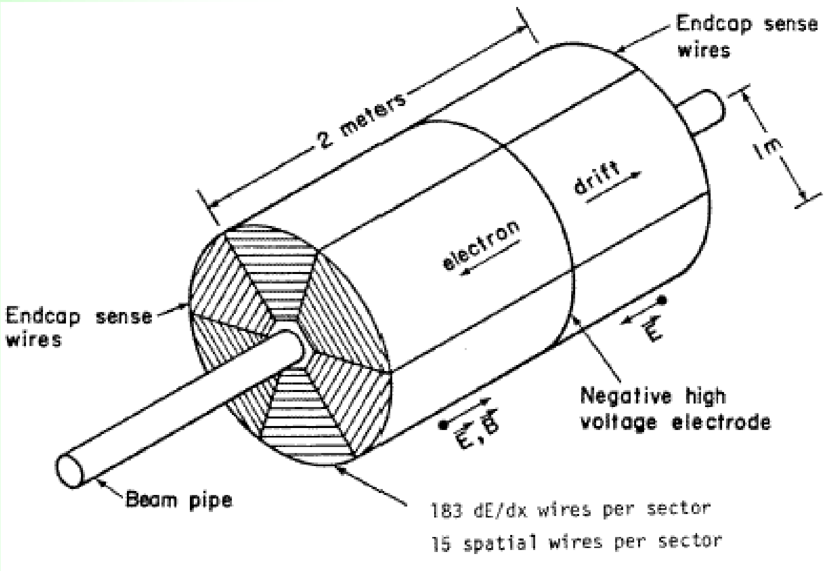
High energy $e^+ e^-$ physics after LEP

- Possible only with a linear collider (LC)
- Complements LHC physics
- Will be needed to clarify LHC discoveries
- Plus precision electro-weak, top and Higgs physics and probing new physics at TeV scale
- Major international R&D effort for $E_{CM} \geq 0.5$ TeV $e^+ e^-$ linear collider machine & detector for physics
- NLC (US), JLC (Japan), TESLA (Europe - TDR submitted to German Government in March, 2001)

The Time Projection Chamber (TPC)



(M.D. Shapiro, thesis, 1984)

- Proportional wire readout

z => electron drift time

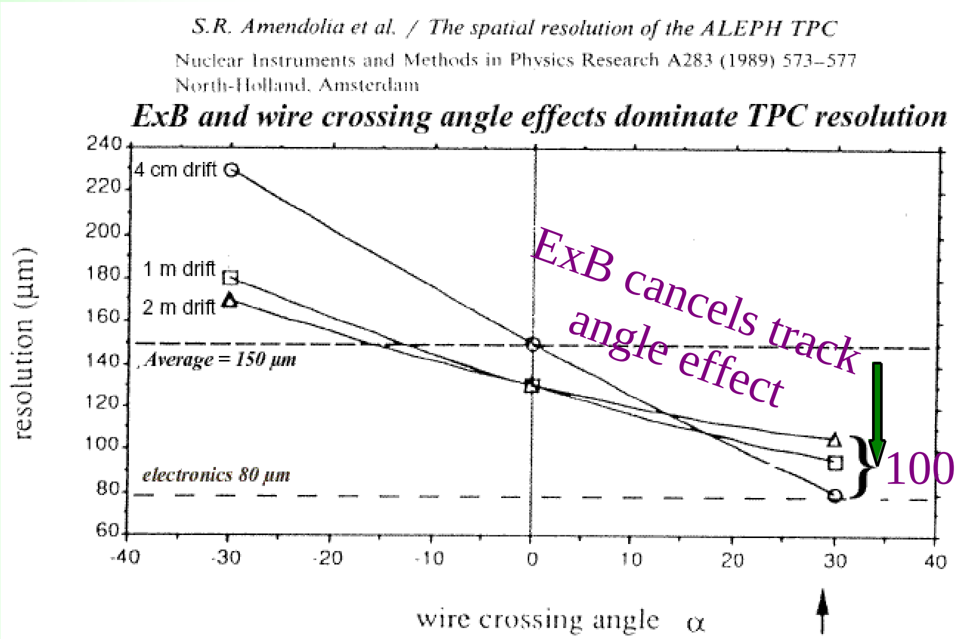
r => anode wire position

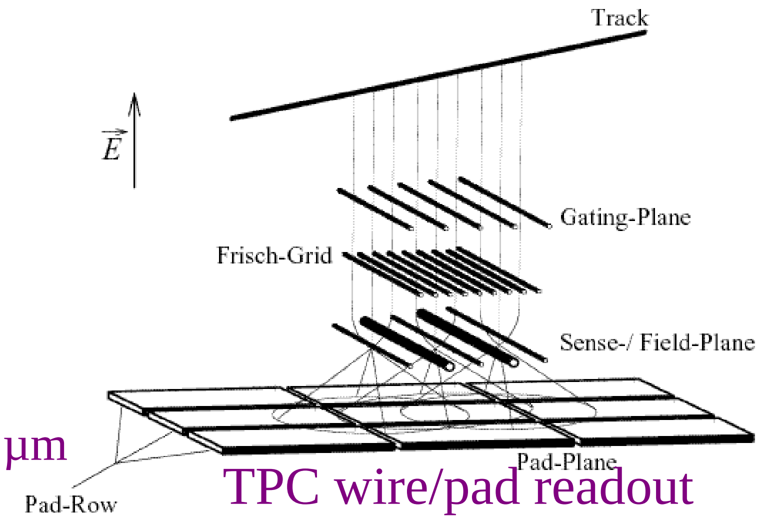
φ =>cathode pads

- Low mass, excellent pattern recognition

- Detector of choice for colliding beam experiments
  - -PEP4, Aleph and Delphi at LEP, STAR at RHIC
  - -L&P detectors for US NLC, TESLA TDR baseline

Why use a Microdetector for TPC readout?





- Negligible ExB, no preferred angles
- Ion space charge induced field distortions suppressed
- Better r-φ & Z resolution & 2-track resolving power
- Lower mass endcap - better for calorimetry

Gas Avalanche Microdetectors

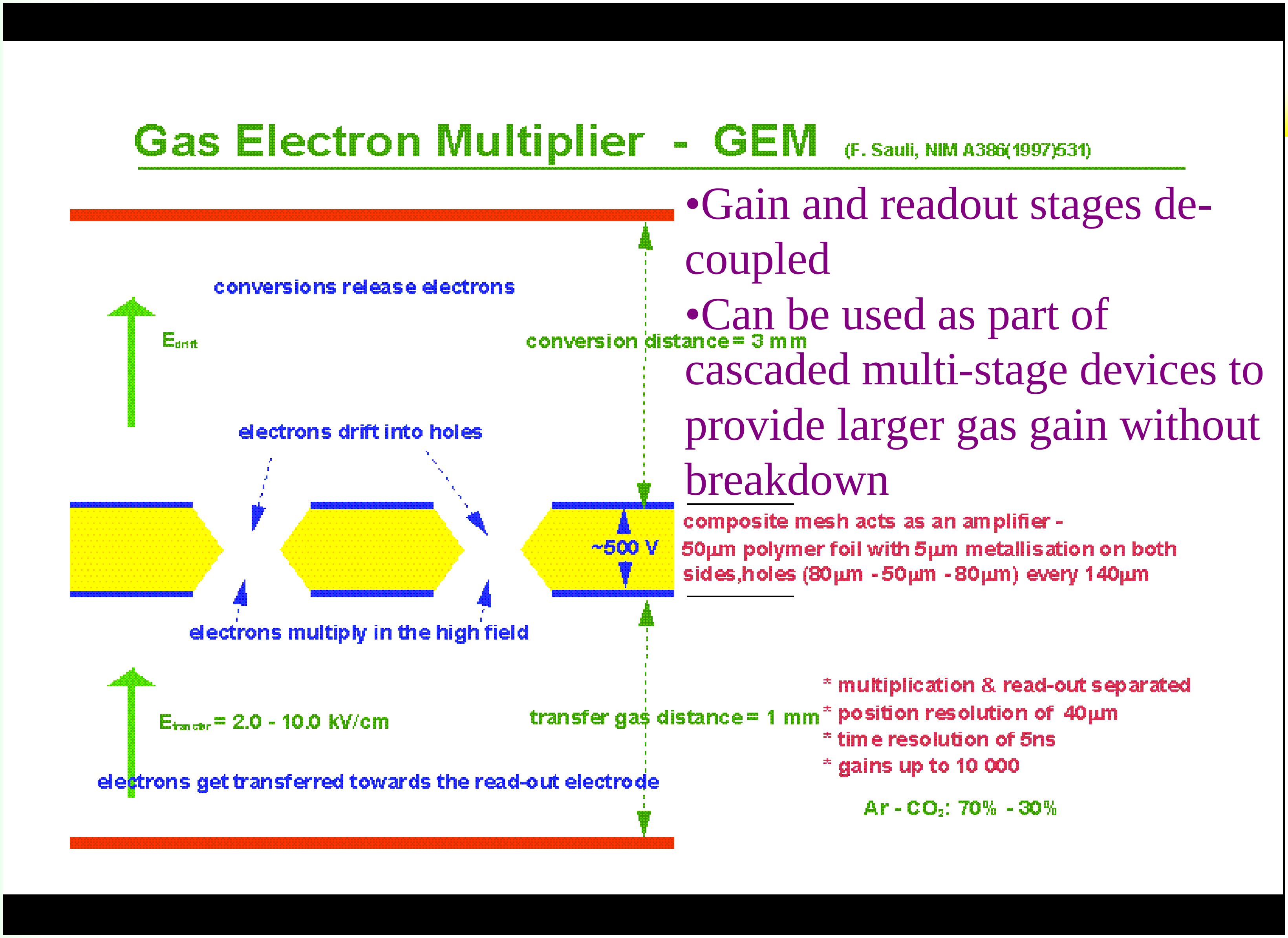
•Microfabricated high resolution multichannel proportional detectors

•Gas microstrip detector 1988-2000(?) [R.I.P.]

•Newer devices - GEMs, Micromegas
less expensive & much more robust

•Good ≈ 40 μm resolution with 200 μm readout

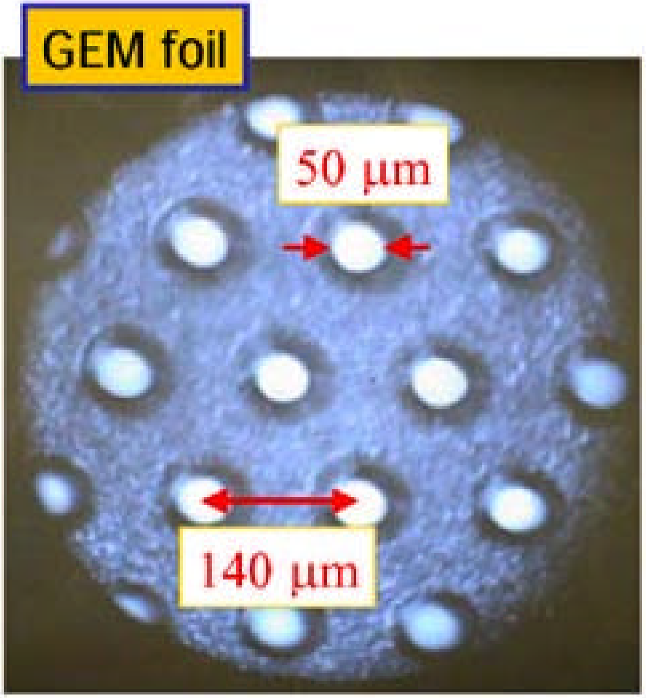
•Prohibitive TPC channel count for ~ 200 μm pads

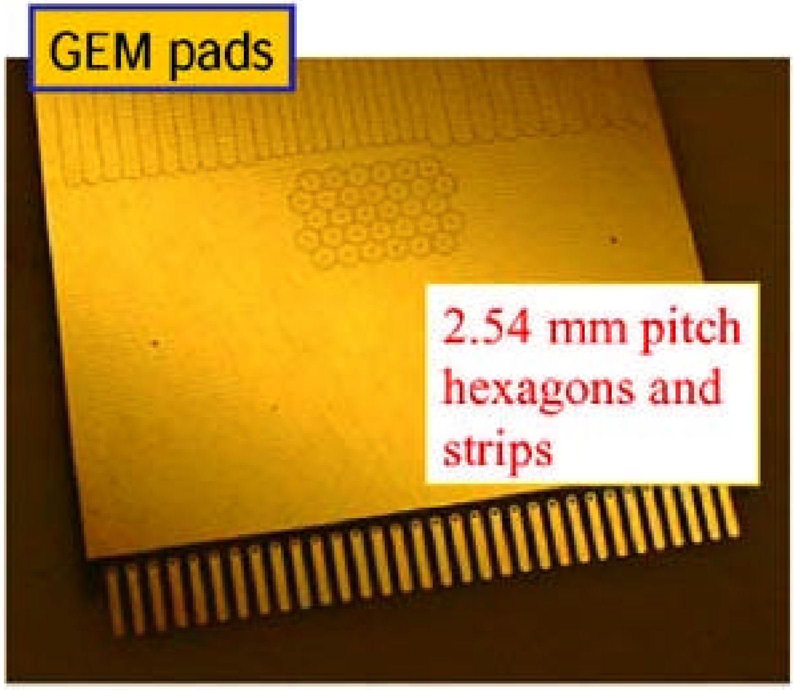


- Gain and readout stages de-coupled
- Can be used as part of cascaded multi-stage devices to provide larger gas gain without breakdown

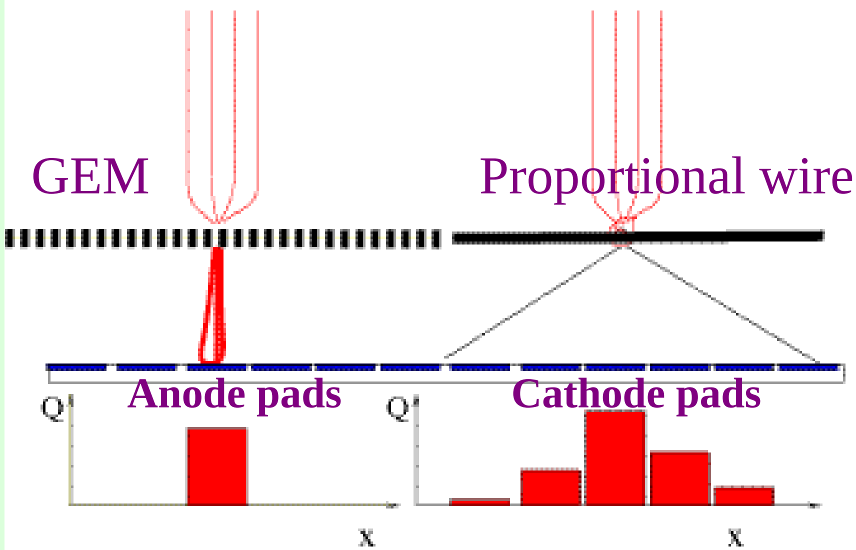
GEM foil & anode readout pcb

Fabricated at the CERN PCB workshop

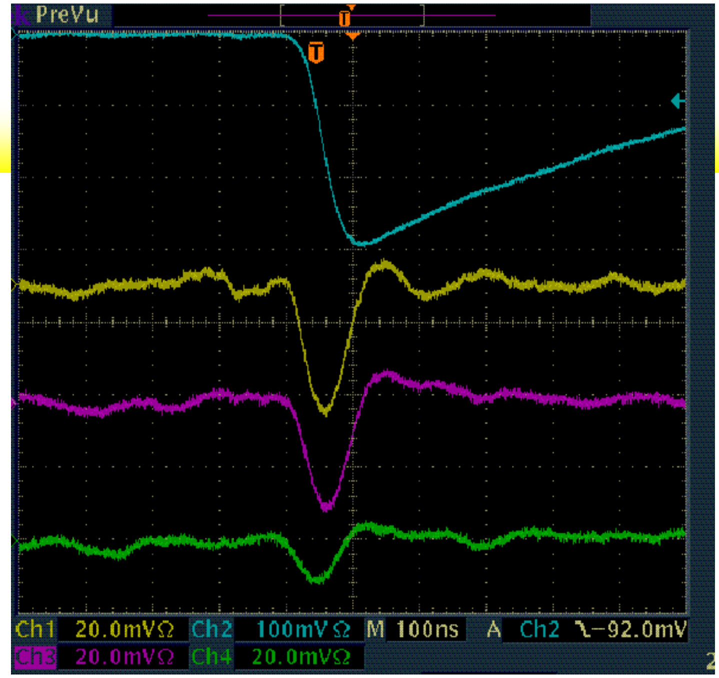




For the GEM readout, the charge may be collected by a single (~mm size) pad due to suppression of transverse diffusion in high magnetic field

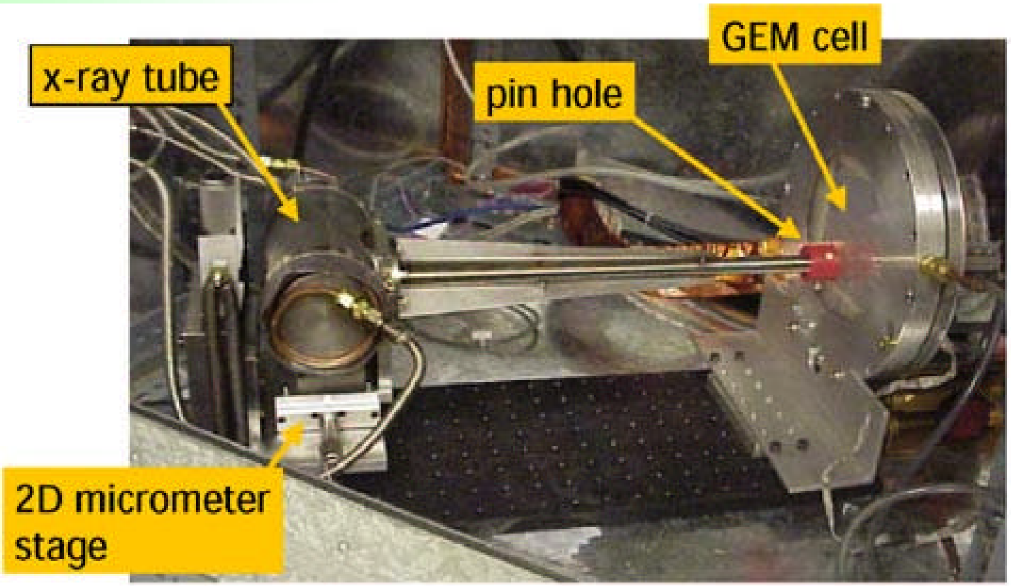


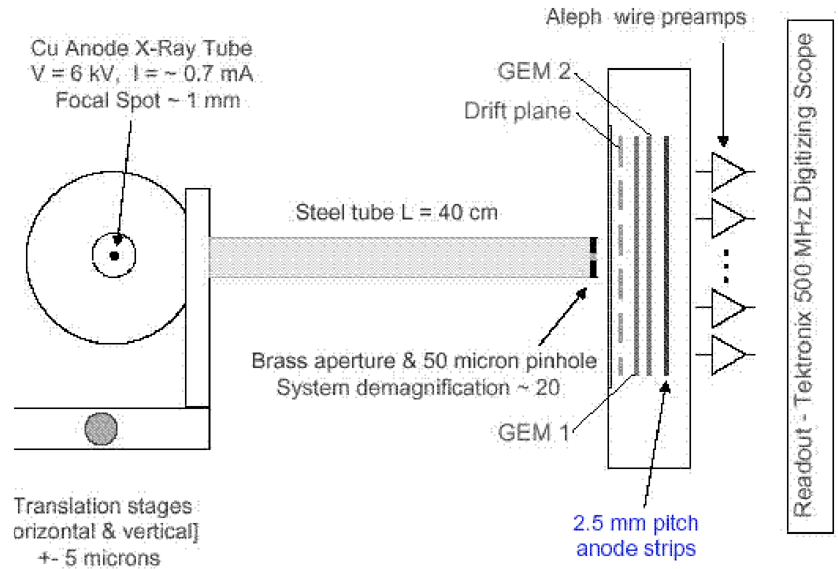
However, if the signal on the adjacent electrodes induced by electron drift in the GEM gap can be measured, charge centroid determination is still possible



- Short ~ 200 ns signal
- Traditional wire/pad integrating electronics cannot be used
- Need to sample signal shape to use induced pulse information

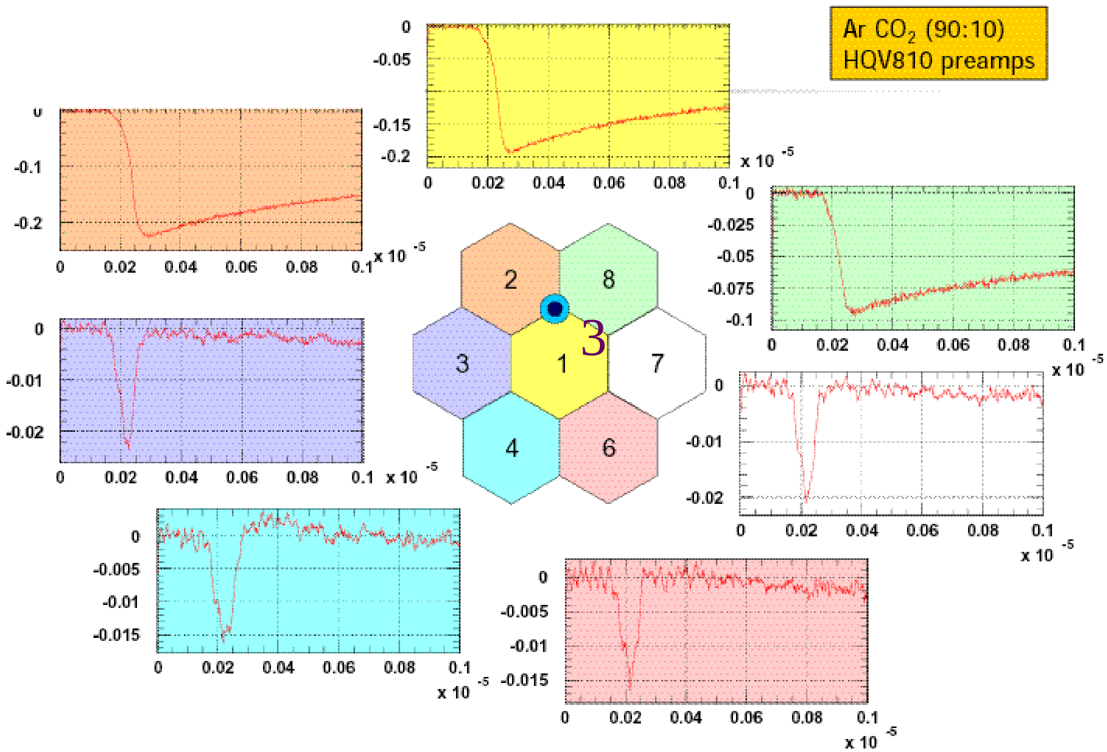
Setup for GEM resolution studies





- Point source ~ 50 µm collimated 4.5 keV x rays
- Hexagonal pads & long anode strips for read out
- Sampling readout - 500 MHz Tektronix digital scope

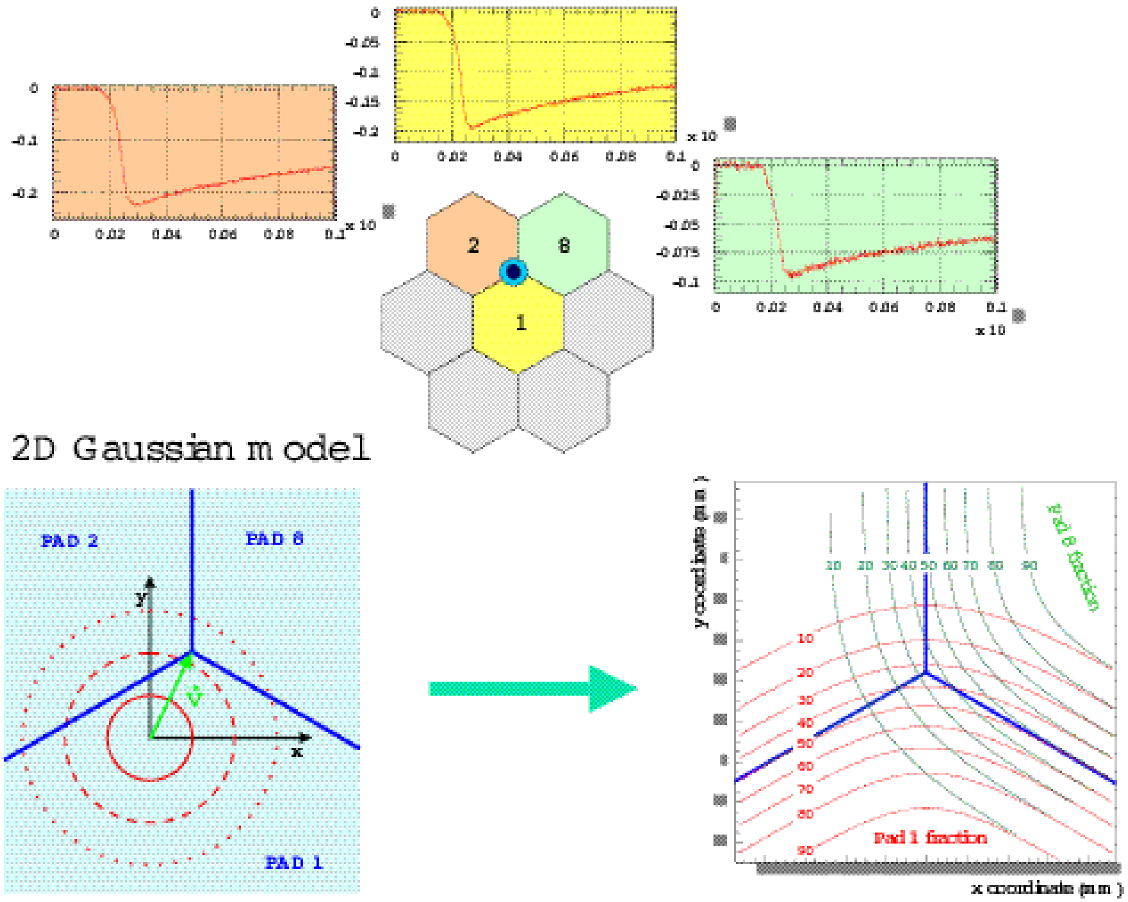
Resolution studies with 2.5 mm hex pad array



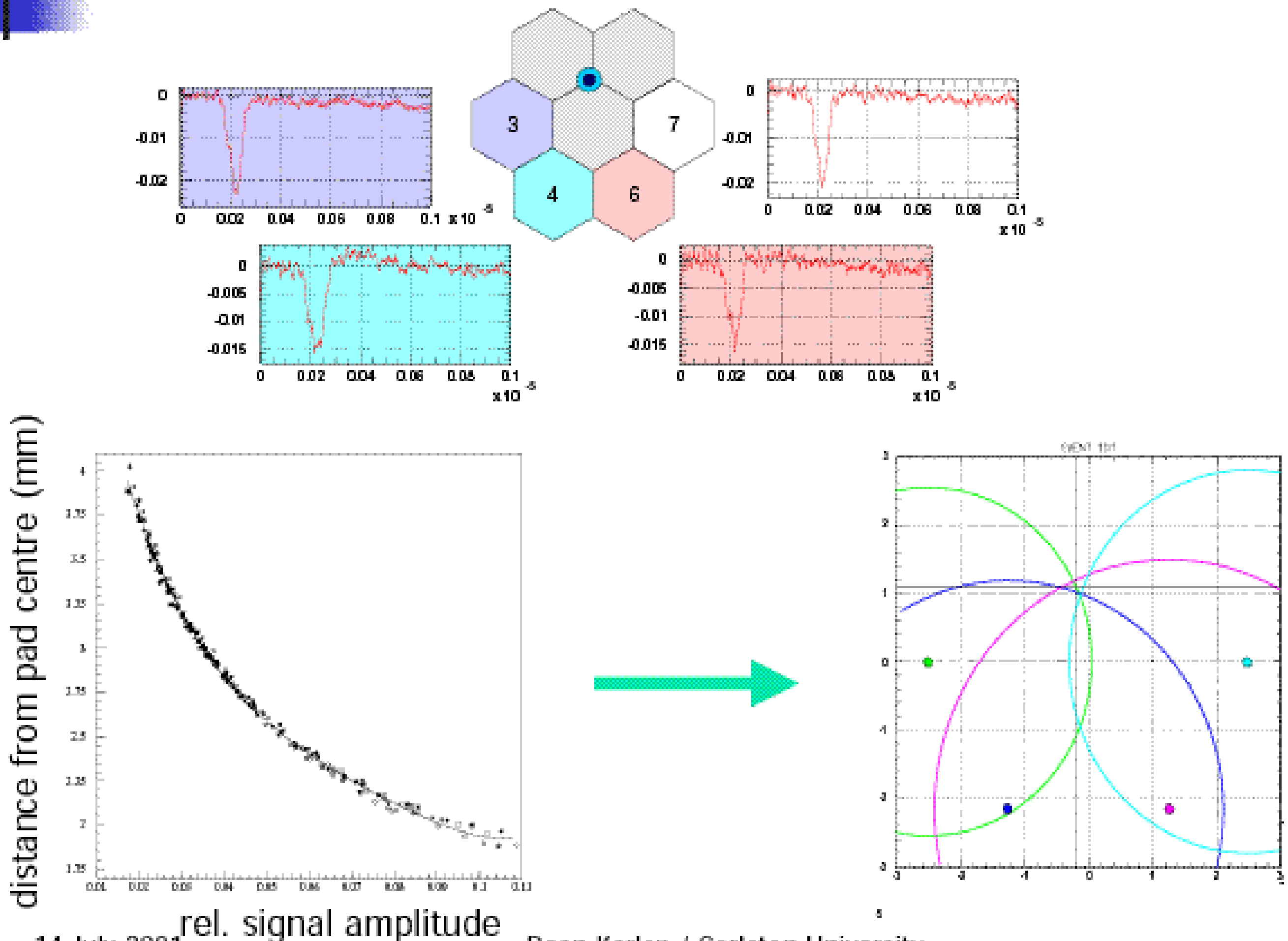
- Using combination of induced and direct charge signal pulse amplitudes:

$\sigma_x \approx \sigma_y \approx 70$ to $80\ \mu m$

Position estimates from charge sharing



Position estimate from induced signals



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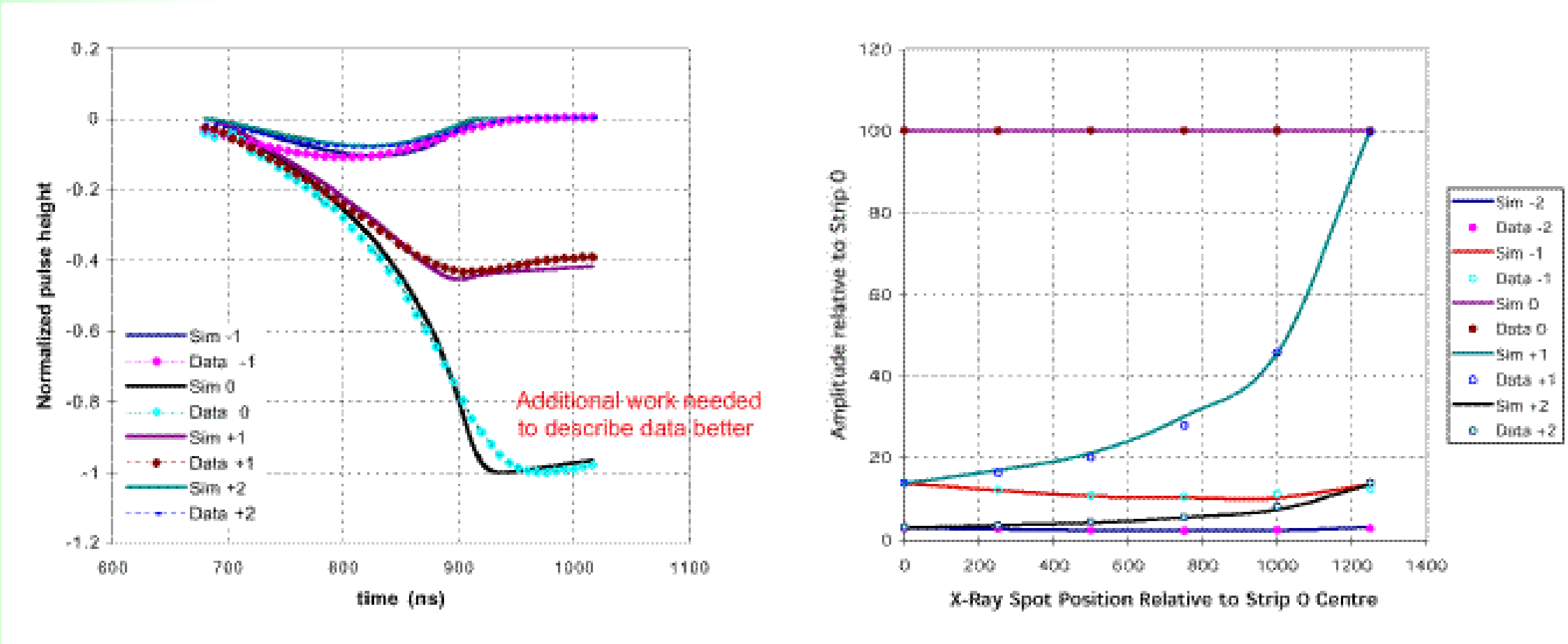
Simulation studies

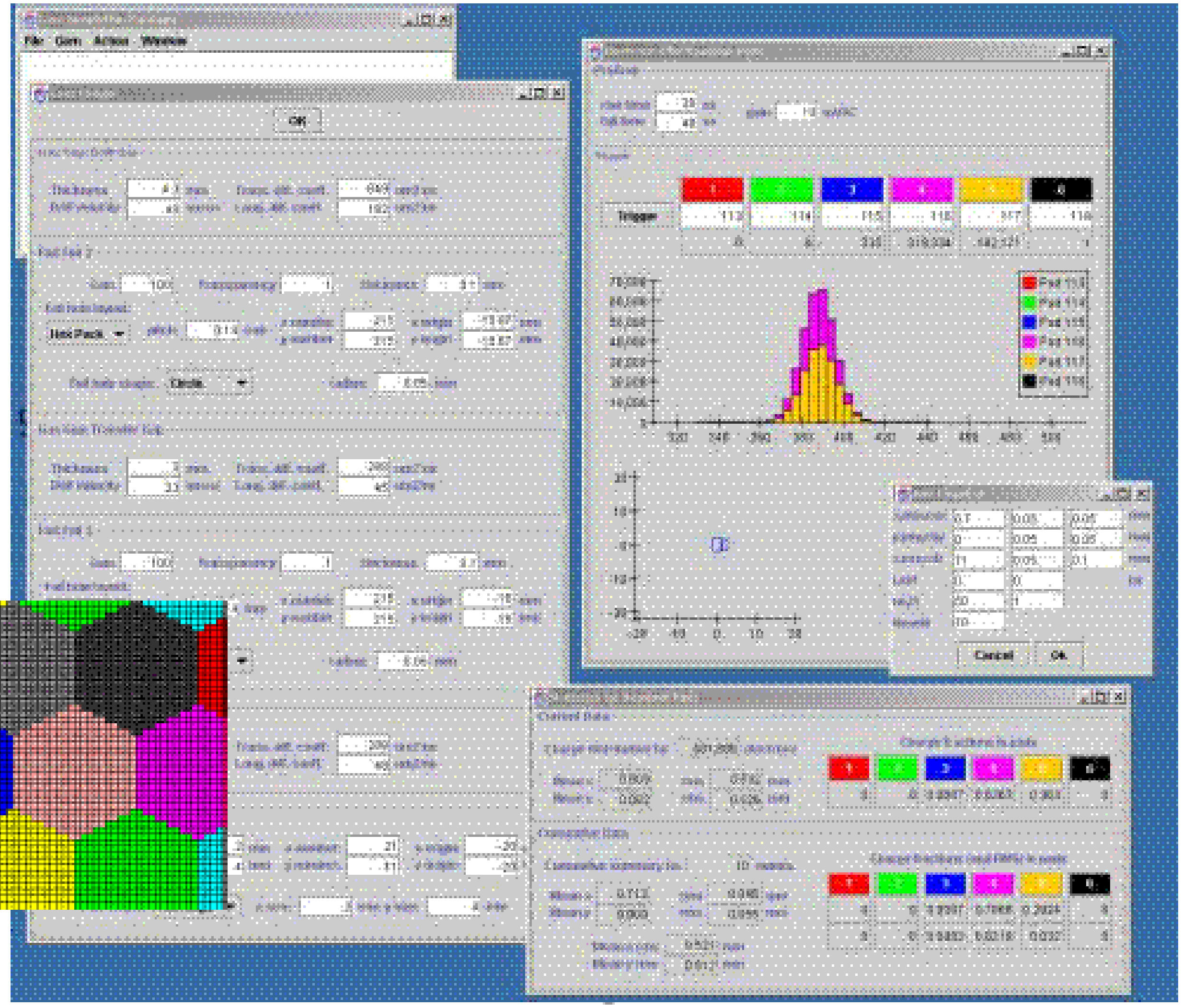
Measurement versus 1st principles Monte-Carlo

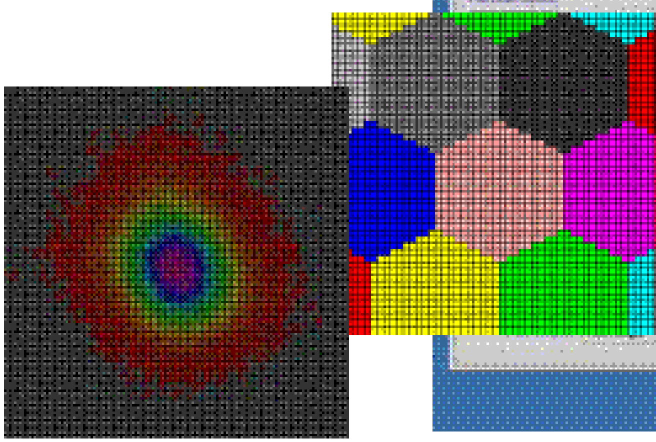
(2.5 mm anode strips)



Java simulation of GEM (under development)

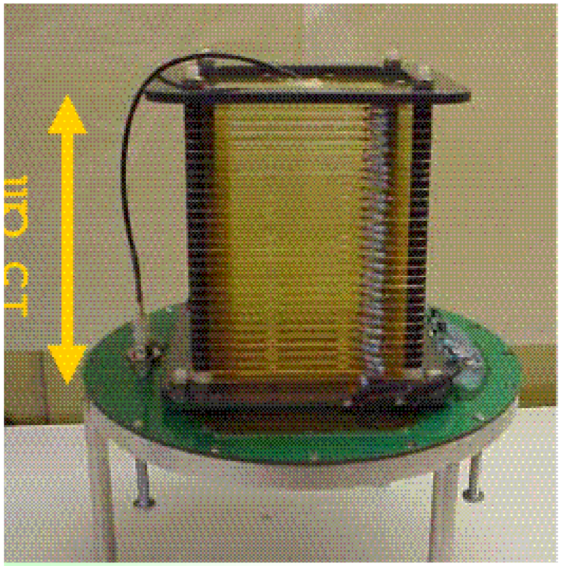
- Arbitrary GEM structure and pad geometry can be defined interactively
- Empirical simulation of pad signals





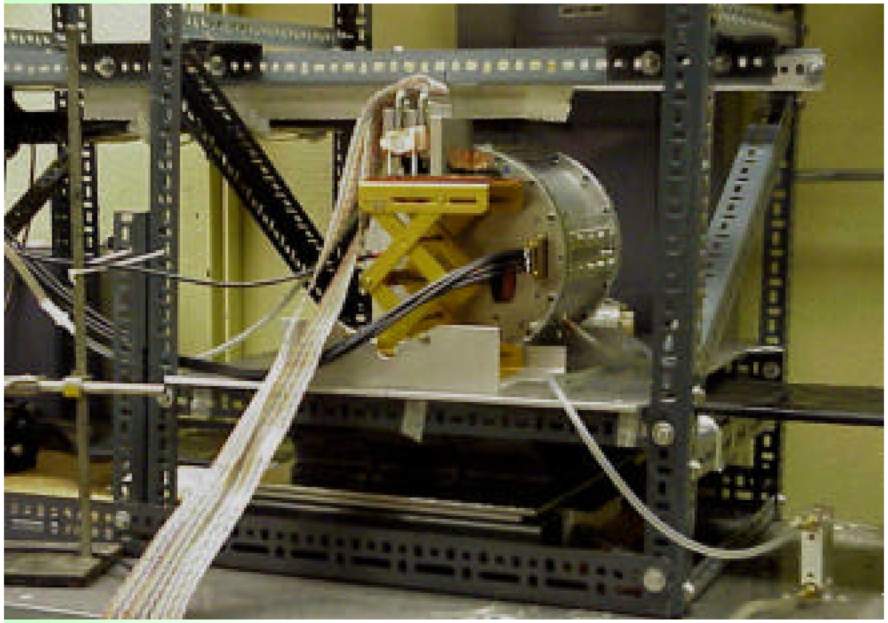
Recent progress

- New improved procedures for greater reliability of GEMs against HV breakdown
- 32 operating channels (8 modules) of U. Montreal built 200 MHz FADCs
- Mini-TPC rebuilt and commissioned
- TRIUMF/PSI 'Midas' DAQ system functional
- First cosmic ray tracks with muon trigger recorded

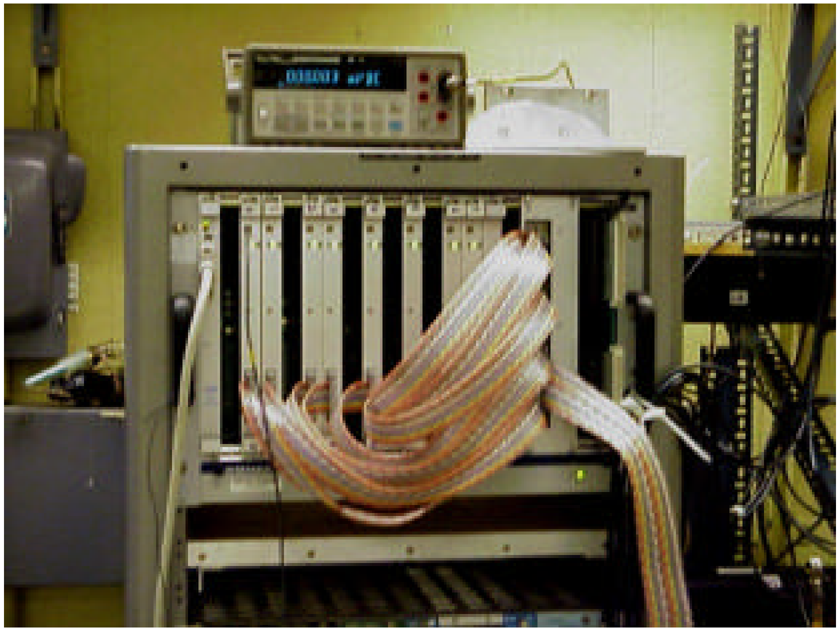


TPC drift field cage

Linux Midas DAQ

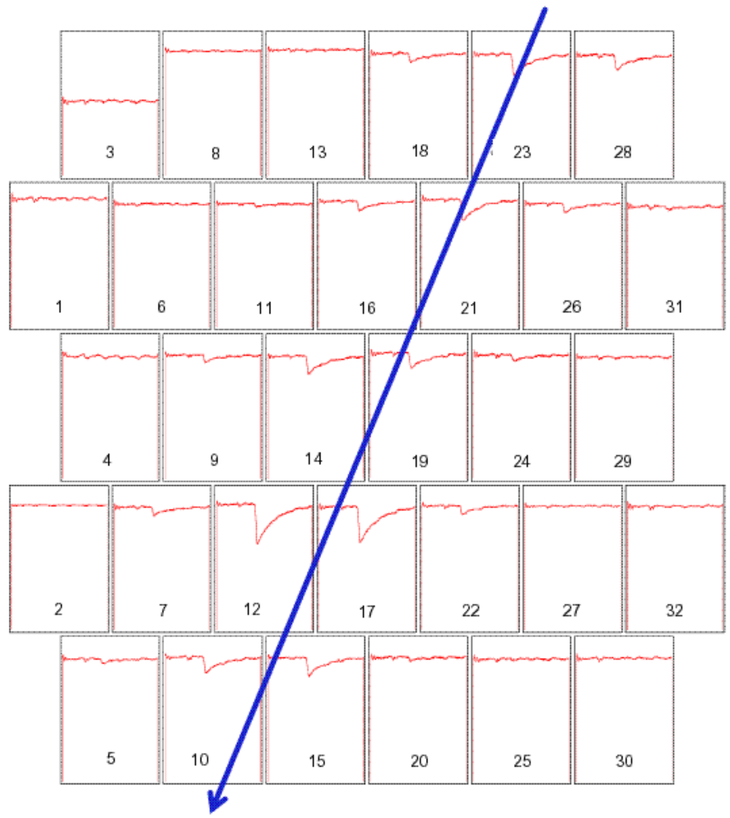


TPC cosmic ray test setup



U. Montreal 200 MHz FADCs

GEM-TPC pad signals - Rectangular Pads
200 MHz FADC Readout
(cosmic ray trigger)



Research plans

- DAQ system & program development
- GEM-TPC tracking resolution studies with cosmics
- Concurrent R&D on new/simpler readout concepts using GEMs & Micromegas
- Beam test of mini-TPC within a year
- Work on developing a realistic prototype for LC TPC in ~ 3 years from now – part of International LC TPC R&D proposal submitted to DESY PRC in Oct. 2001

Infrastructure support and personnel

- Carleton MFA & CRPP (until 2000)
  - J. Dubeau 50% Research Associate until Dec, 2000
  - COOP and summer students - L. Thompson (1999) & several others since
  - M. O'Neill - TPC & GEM readout & mechanical designs
  - E. Neuheimer - preamps, VME & 200 MHz FADC system & related electronics
  - V. Strickland - cosmic telescope & clean-room
  - P. Gravelle technical support
- Essential to meeting our goals