An Overview of North American R&D in Gaseous Tracking Detectors for the LC

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TRIUMF & Carleton University

International LC Tracking & Muon Conference

Amsterdam - 31 March 2003

R&D in Gaseous Tracking Options for the LC detector

TPC +

LC TPC R&D in Canada supported by NSERC

LCRD/UCLC TPC R&D proposals for US NLC

Benefit from R&D on STAR/Phenix TPC at RHIC

Forward tracker GEMs/Straw Tubes

Operational Technologies - LCRD & UCLC proposals for NLC

or

Drift chamber

R&D in Japan

TPC design goals:

~ 200 space points with resolution ≤ 100 μm

Better 2 track resolving power than a wire/pad TPC

Minimal positive ion feed back into the drift volume

Low mass and minimum photon & neutron conversions

R&D items:

- MPGD fabrication & readout options (μMegas & GEMs)
- Diffusion limit of resolution in an MPGD
- Spreading the track charge, resolution - pad geometry
- Choice of gases - hydrogen free to reduce neutron backgrounds
- Low power, low mass, high density electronics
- Mechanics & field cage design

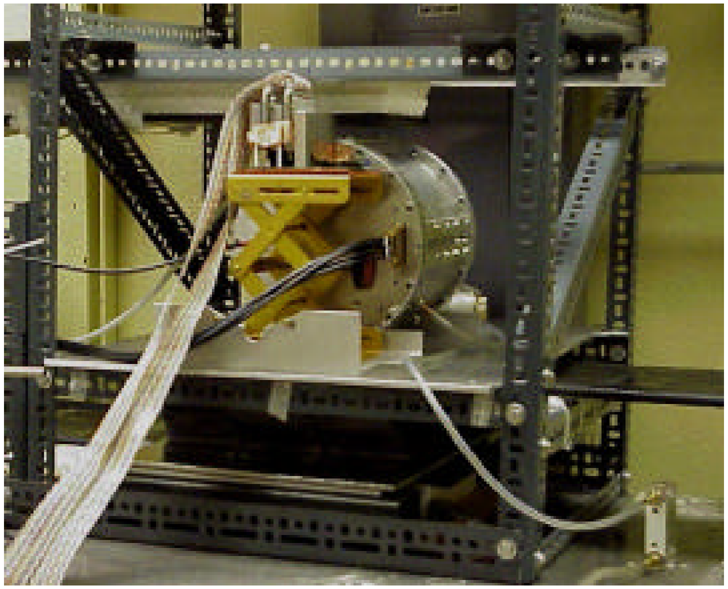
North American Gas Detector R&D: Current, New, & Planned

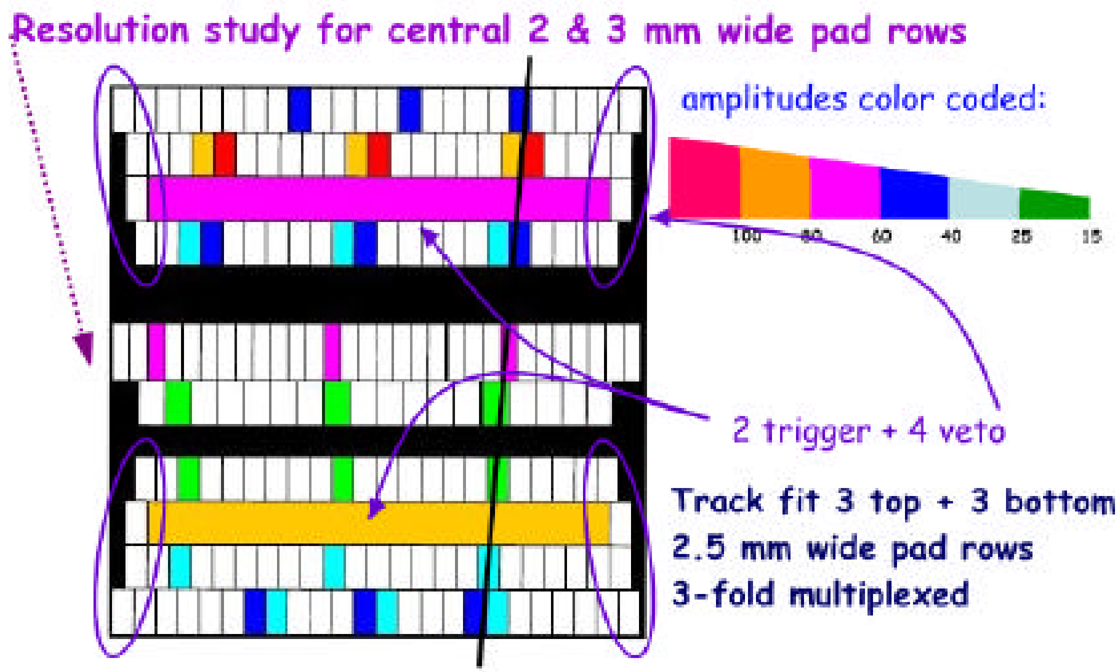
Activities	TPC R&D	MPGD R&D	Electronics & DAQ	MPGD fabrication & Forward Tracker
Berkeley Brookhaven	MPGD TPC prototypes, field cage design STAR/Phenix TPC R&D	MPGD gases, res/pad size studies	STAR FE support High density low mass electronics	Commercial MPGDs
Carleton Montreal	Small MPGD TPC cosmic/beam tests using FADCs	Position sensing GEMs with resistive anodes, resistive anode µMegas	200MHz FADCs Midas DAQ, STAR electronics	
Purdue Cornell	High rate and high B field tests of small MPGD TPC	Large Electron Multiplier (LEM) Ion feedback, gas, res/pad size studies		Mass produced GEMs
Hampton U				Straw tube forward tracker
MIT	TPC for GEM tests			Develop in-house GEM fabrication
U Oklahoma LouisianaTech				Manufacture GEMs, GEM forward tracker
Victoria	GEM TPC cosmic & B field tests		STAR electronics, Midas DAQ	
Temple Wayne State	Negative ion TPC			

TPC R&D

Double GEM TPC Cosmic Ray Tests

Carnegie, Dixit, Karlen, Martin, Mes & Sachs Carleton/Victoria/Montreal





•15 cm drift (no **B** field)

•Use ALEPH TPC preamps + Montreal 200 MHz FADCs

•**Pads can share track charge due to transverse diffusion**

- •Ar CO_2(90:10), small σ_T ~ 200 μm / √cm
- •P10 Ar CH_4(90:10), large σ_T ~ 500 μm / √cm

•Compute pad centroids, measure resolution for different width pads

Observed Transverse Diffusion in GEM TPC

Carleton/Victoria/Montreal

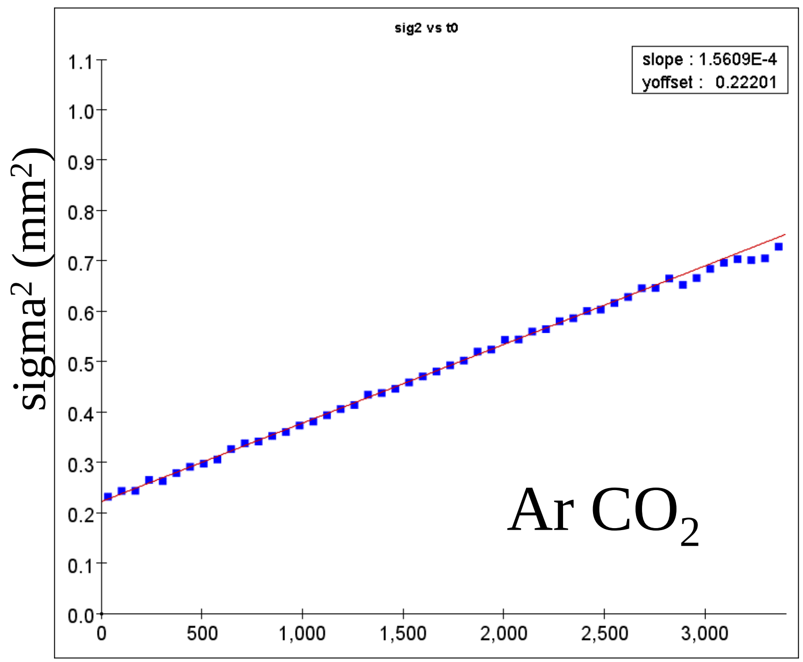
Transverse cloud size: $\sigma^2 = \sigma_0^2 + \left(\sigma_T \sqrt{d[\mathrm{cm}]}\right)^2$

σ_0 = 450-500 μm

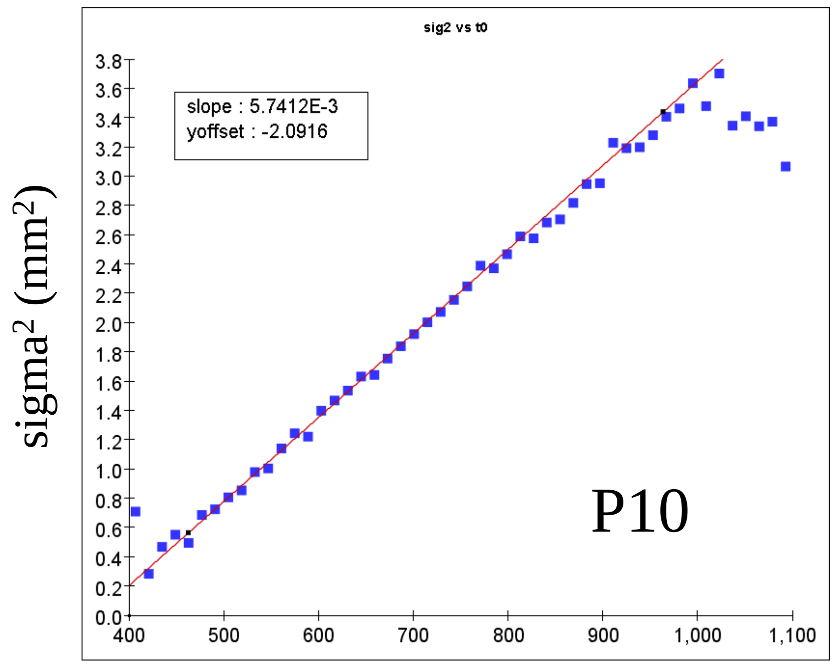
σ_T = 190 μm / √cm

σ_0 = 450-500 μm

σ_T = 500 μm / √cm



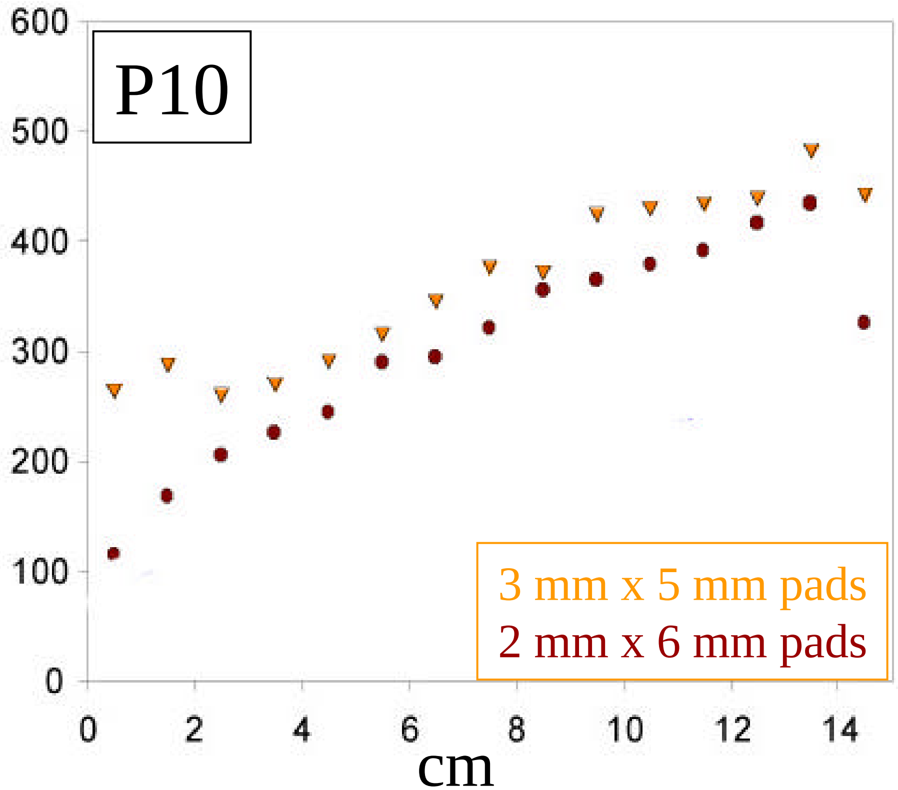
drift time (5 ns bins)

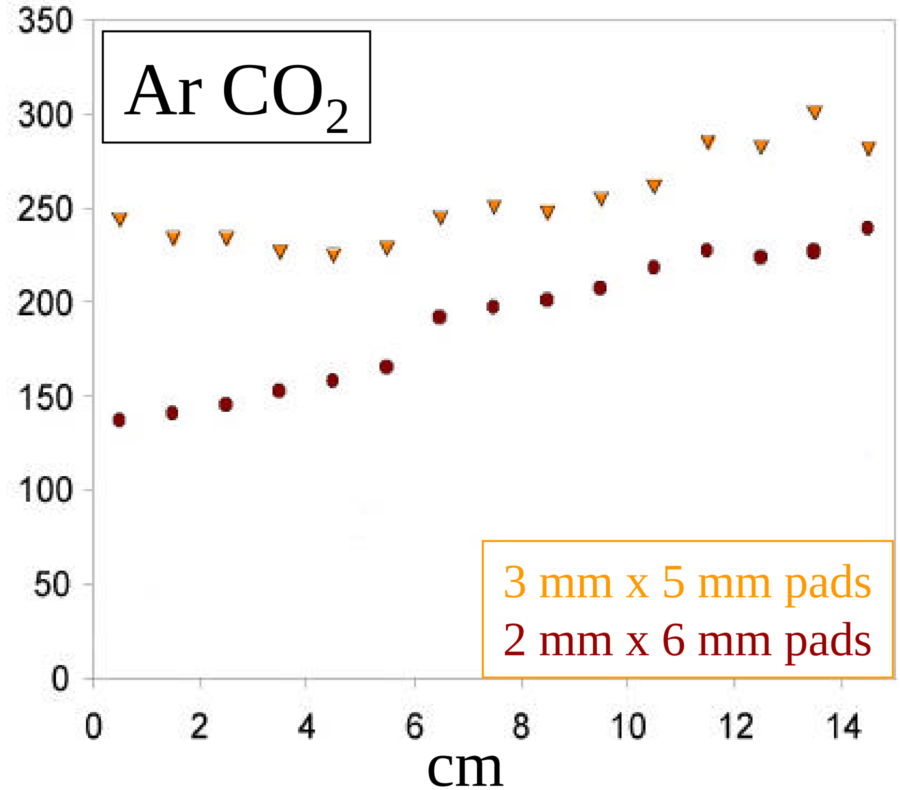


uncorrected drift time (5 ns bins)

Resolution vs Drift Distance for Different Pad Widths

$|\varphi| < 0.1$ Carleton/Victoria/Montreal



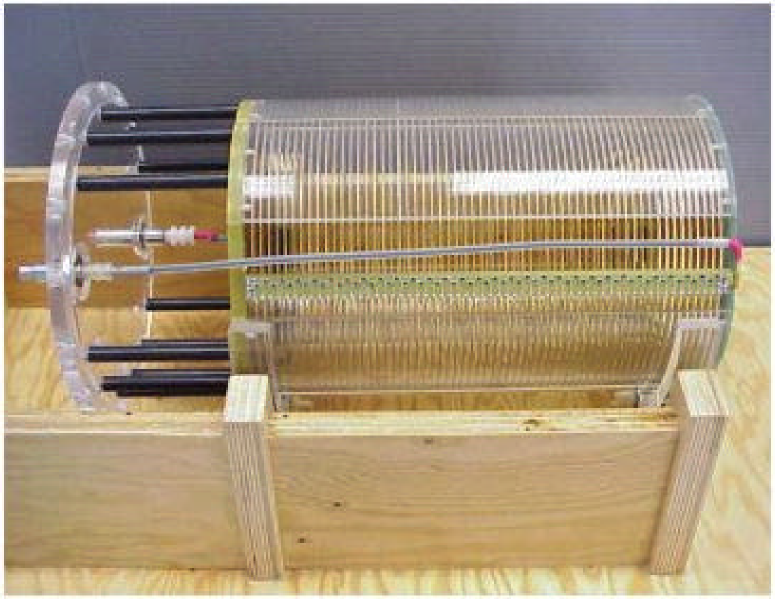


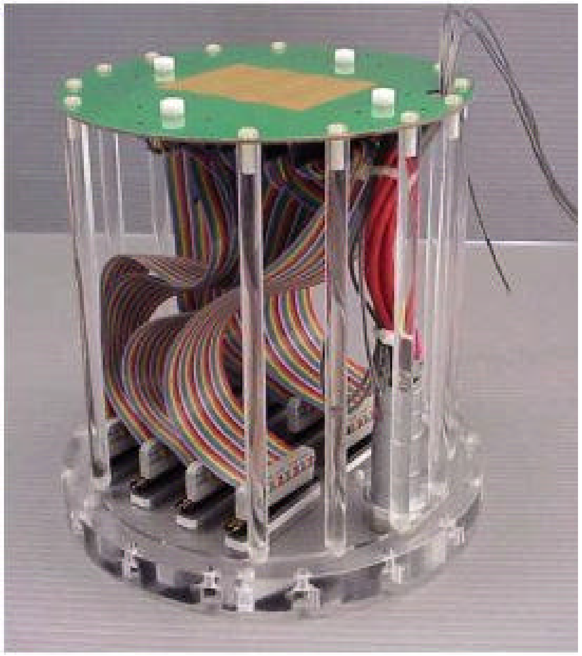
Large P10 transverse diffusion makes resolution less sensitive to pad width

Smaller $ArCO_2$ diffusion reduces charge sharing making resolution worse for wider pads

A Newly Operational GEM TPC Designed for B Field Tests

Karlen, Poffenberger & Rosenbaum Victoria

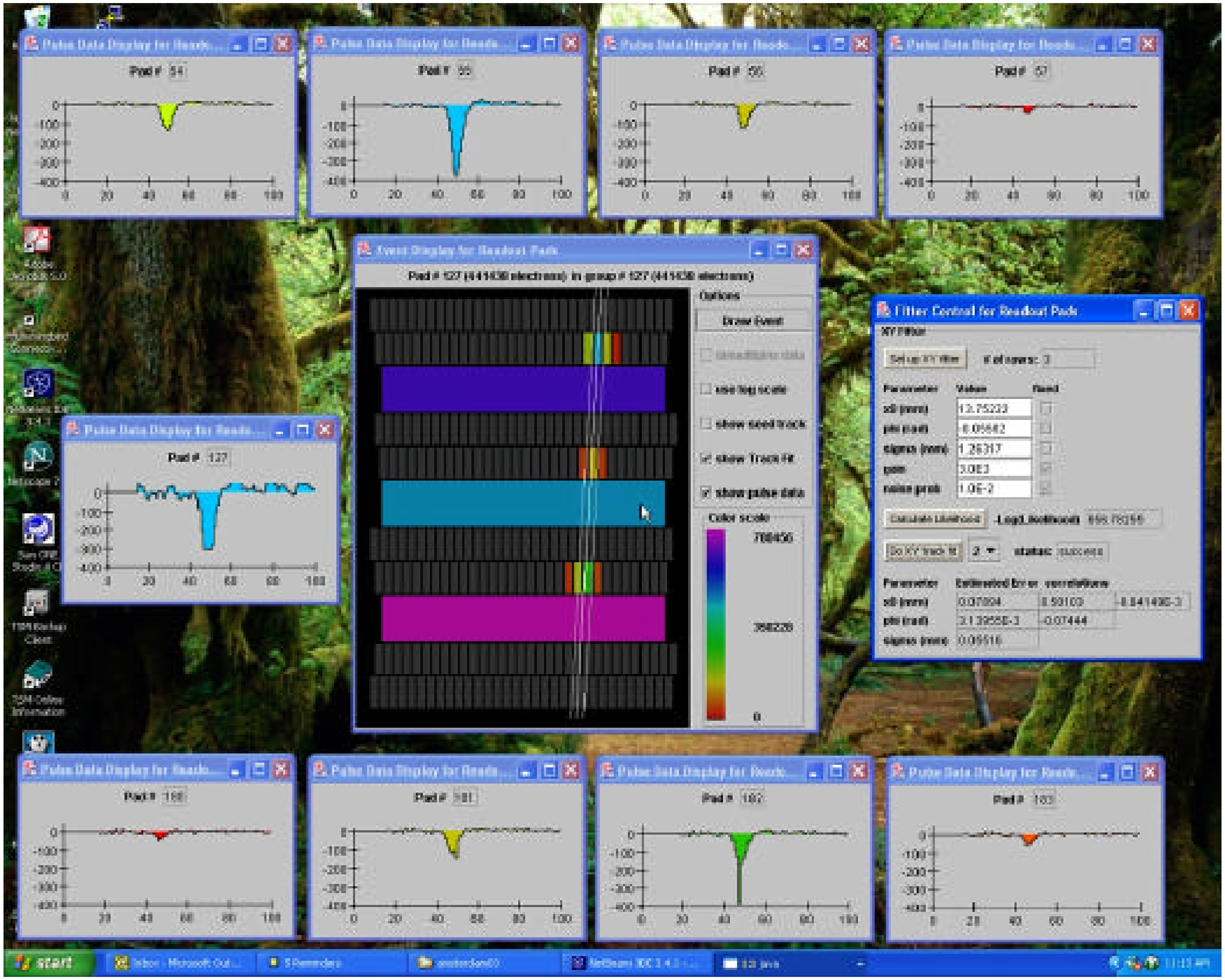




- 30 cm drift, 22 cm O.D.
- 256 readout pads (60 mm × 10 mm)
- Signals read out with STAR electronics
- Plans for magnetic field tests 1 T at TRIUMF & 5T at DESY

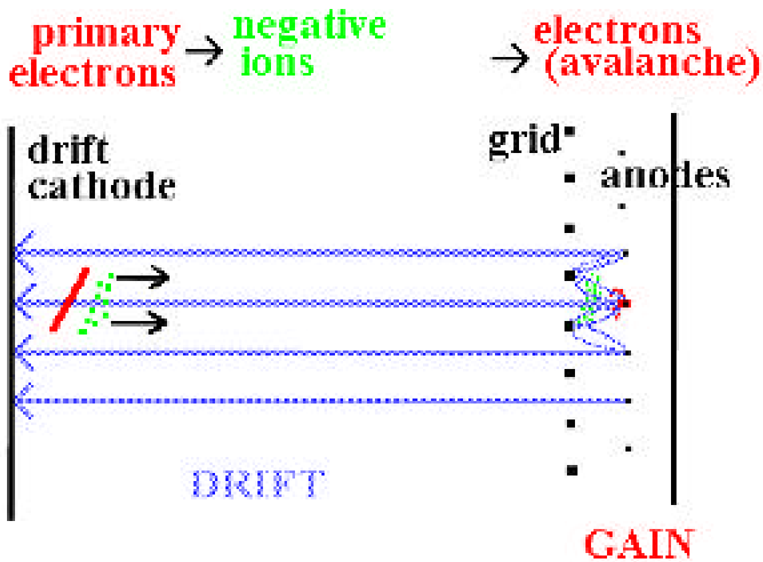
First Cosmic Signals observed with STAR electronic

Victoria



A Negative Ion TPC (NITPC) Proposal for the NLC Tracker

Bonvicini, Martoff & Ayad Wayne State/Temple



- Electronegative gas (CS_2 + He) captures ionization electrons & forms negative ions
- Slow ion drift

  V_D(ions) ~ V_D(electrons)/2000
- σ_{Tr}(ions, B=0) ~ σ_{Tr}(electrons, B ~ 2T)
- Better σ_{Long} than electrons

  σ_{Long} (ions) ~ σ_{Long} (electrons)/10
- High E field in gain region frees electrons
- Read out with gas avalanche detectors
- Negligible Lorentz angle (< 1°) for any B
- A 1 m^3 NITPC has been working for a year as a directional Dark Matter Detector

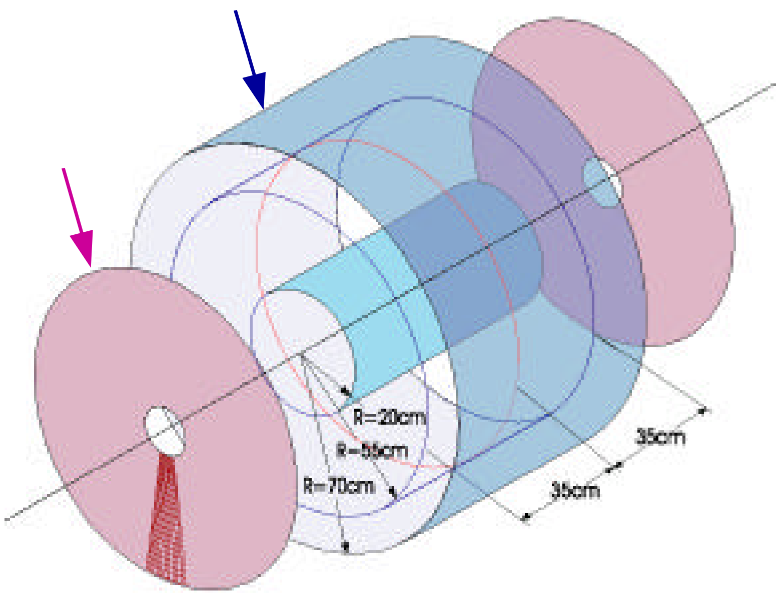
Negative Ion TPC for the LC

Temple/Wayne State

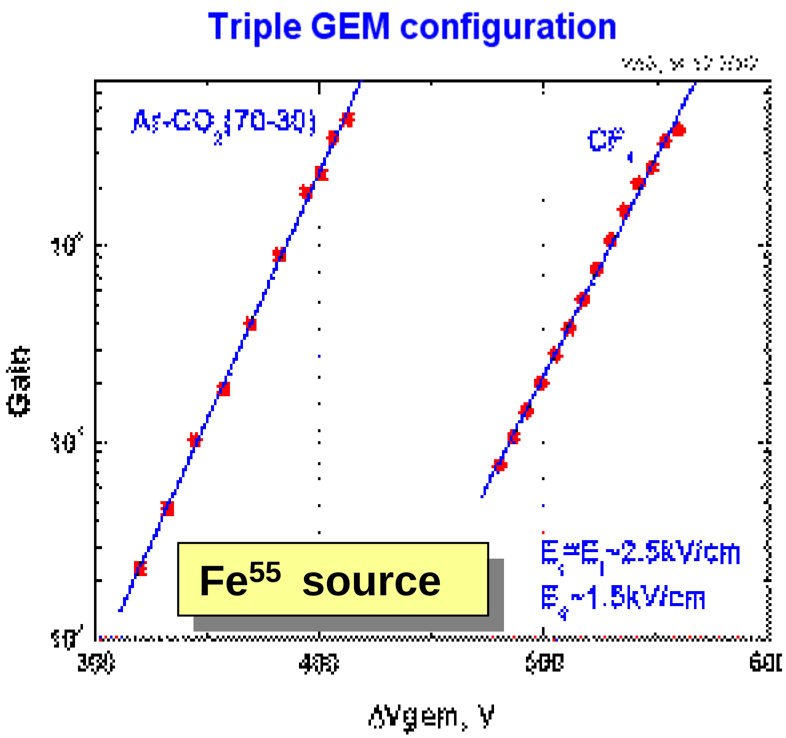
- Long ~ 100 ms ion drift time integrates many more beam crossings & could increase backgrounds
- However, backgrounds could be reduced and momentum resolution improved because of :
  - Reduced multiple scattering & fewer γ conversions in low mass He gas mixture
  - ~ 100 times more Z samples due to slow V_{drift} & smaller longitudinal diffusion
- May be better matched to 1 m size SD option for NLC

A Fast, Compact TPC & Cherenkov Detector for Use in Heavy Ion and Polarized Proton Collisions at RHIC

PHENIX   BROOKHAVEN NATIONAL LABORATORY   STAR



- R < 70 cm, L < 80 cm, T_{drift} ~ 4 μs
  ΔDφ ~ 2π, |η| ~ ± 1.0
  ΔDp/p ~ 0.02p
  e/π separation by dE/dx below 200 MeV
- Proximity focused windowless CF_4 radiator Cherenkov detector
  Transmissive CsI photo-cathode
  Electron ID with minimal signals for charged particles
-



Phenix/STAR Collaboration
GEM operation with pure CF_4

Itzhak Tserruya, *Weizmann Institute, Israel*

RHIC Detector Advisory Committee Review

BNL, Dec.19, 2002

Detector size:10x10 cm^2

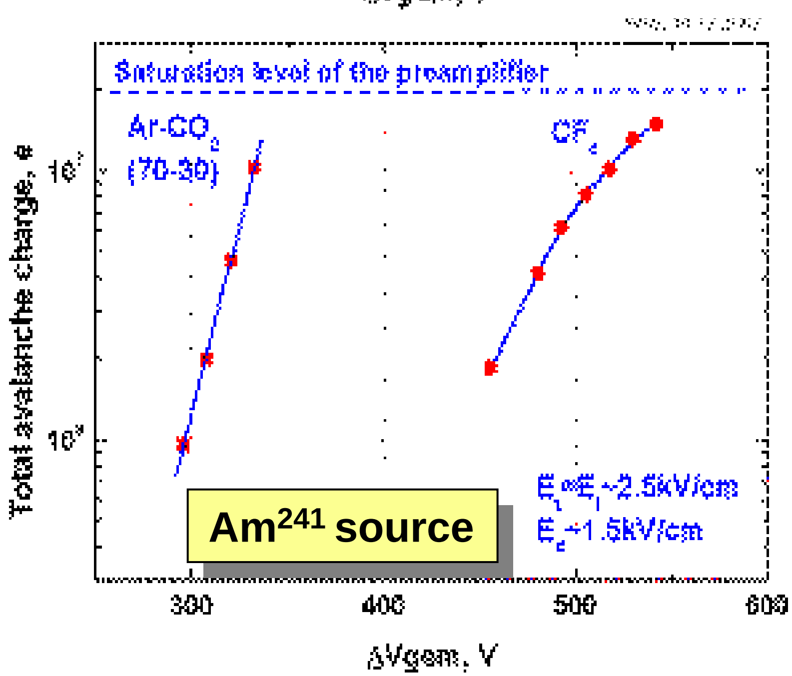
2 GEMs: sparks at a gain of 2 10^4

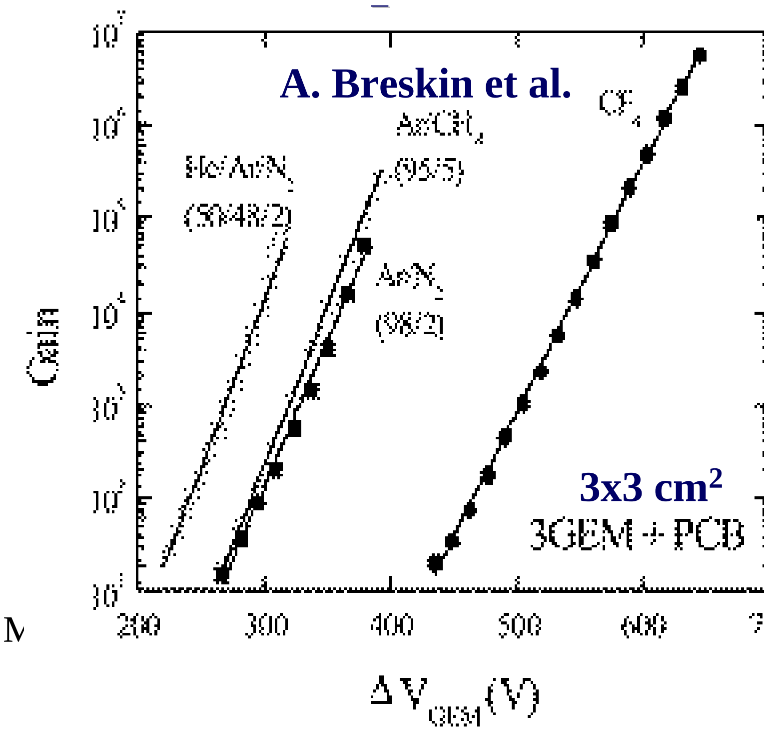
3 GEMs: much more promising

Fe^{55} spark threshold at gains close to 10^5

Am^{241} spark at total charge well in excess of 10^7

Existence proof: CF_4+GEM+CsI work!





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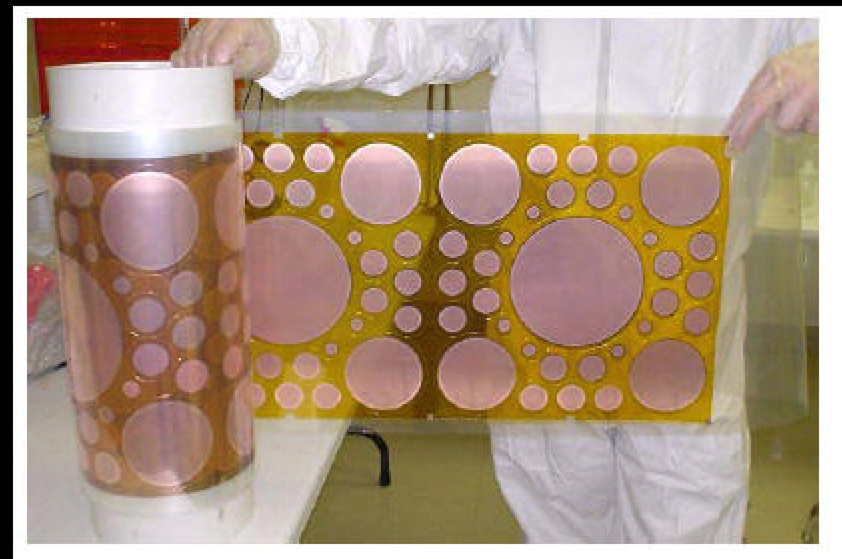
MPGD Fabrication & New Developments

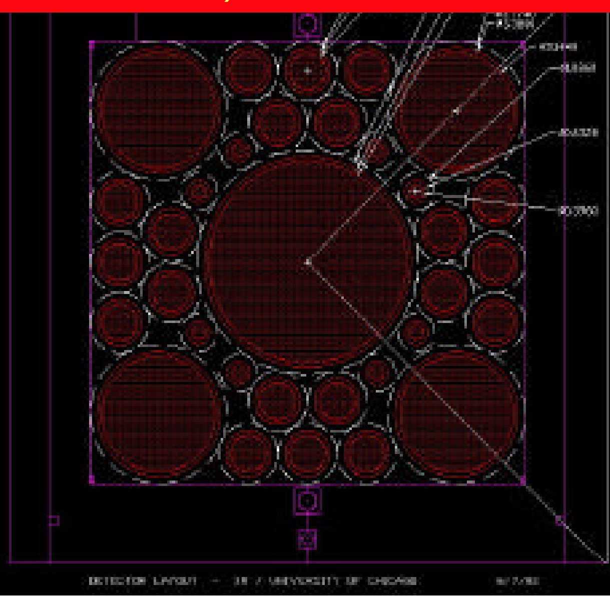
First Mass Production of GEMs

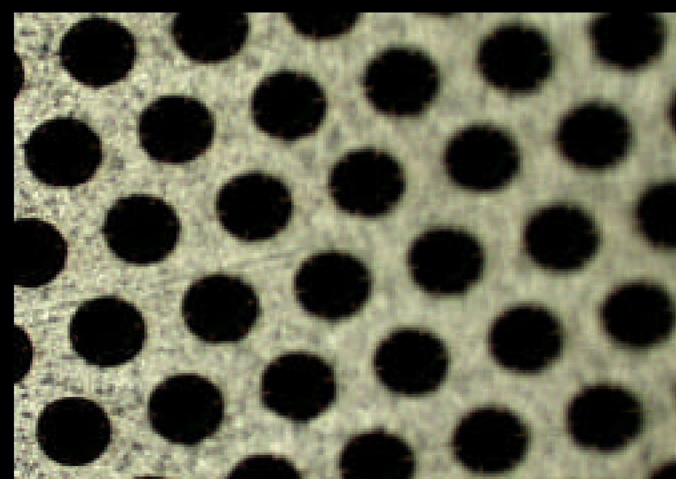
Chicago-Purdue-3M

P.S. Barbeau J.I. Collar J. Miyamoto I.P.J. Shipsey

- **3M Microinterconnect Systems Division** Reel-to-reel process, rolls of 16’x16’ templates of detachable GEMs in any pattern. Optional processes possible.
- First batch of 1,980 GEMs recently produced. Low cost per unit! (~2 USD/GEM not counting R&D)
- Two fabrication techniques (additive, substractive) tested.

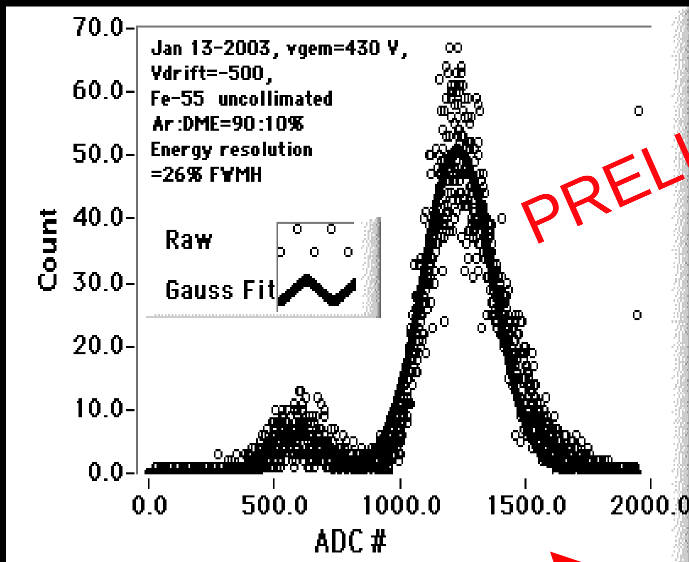


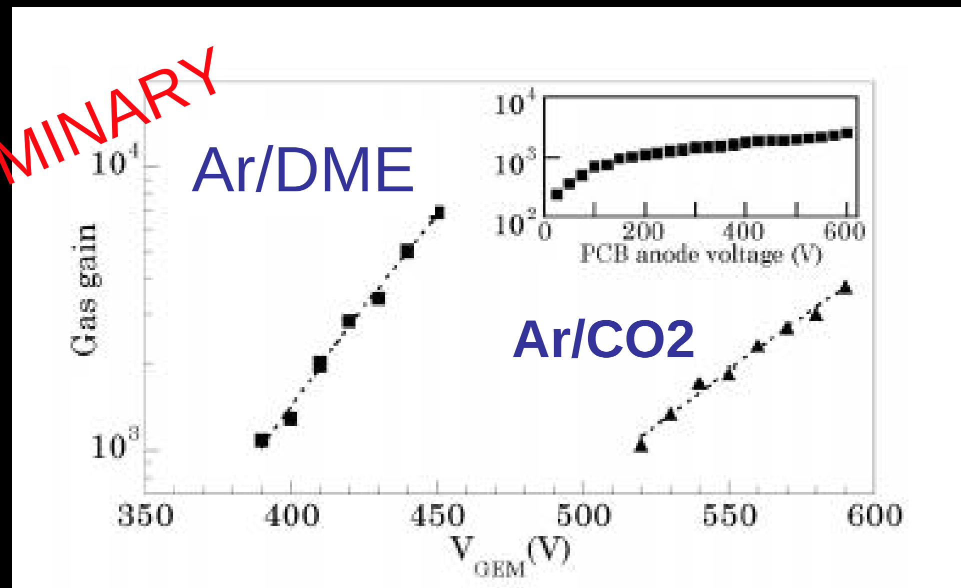


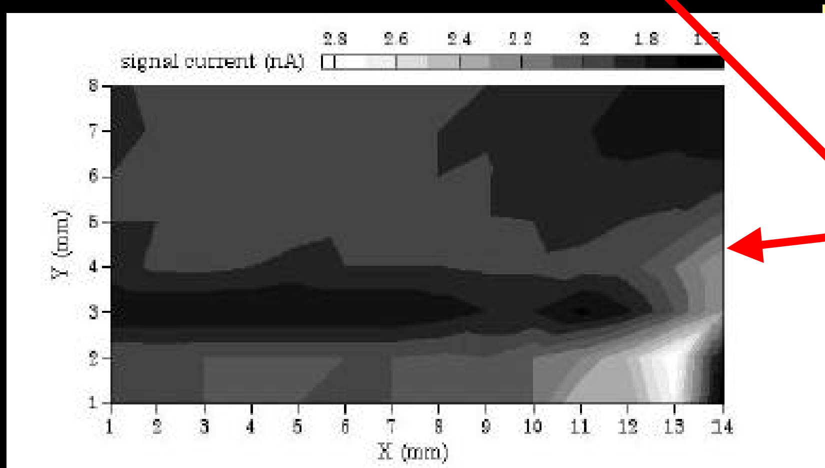


GEM Performance

Chicago-Purdue-3M







nA/cm² leakage currents (20 GEMs tested)

Subtractive:

Excellent energy resolution (14-26)%

- excellent gain uniformity (9% sigma)
- **Gains of 5,000 in Ar/CO2 7:3 & Ar/DME 9:1**

No ageing study yet

Preliminary results are highly encouraging

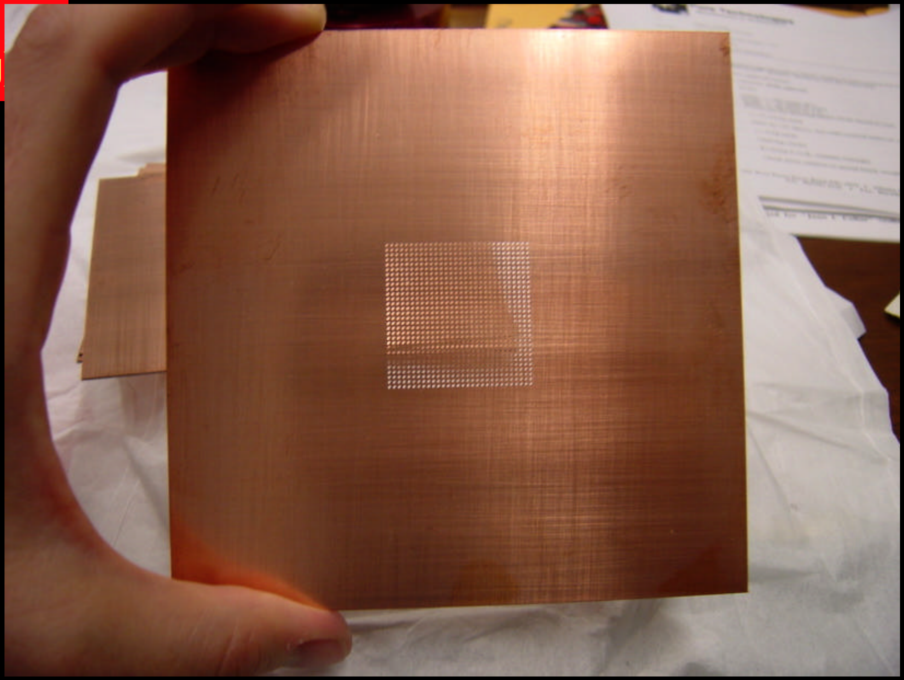
Large Electron Multipliers (a.k.a. capillary plates)

What is a LEM?
A large scale GEM (x10) made with ultra-low radioactivity materials
(OFHC copper plated on virgin Teflon)

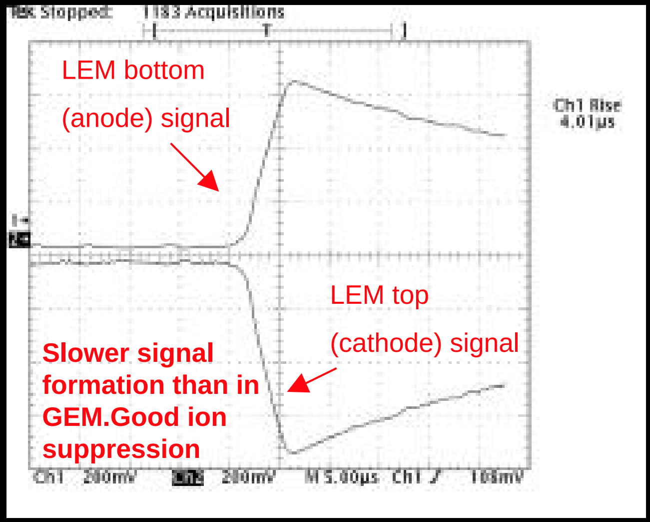
- In-house fabrication using automatic micromachining
- Modest increase in V yields gain similar to GEM
- Self-supporting, easy to mount in multi-layers
  Extremely resistant to discharges (lower Capacitance)
- Adequate solution when no spatial info needed
- Cu on PEEK under construction (zero out-gassing

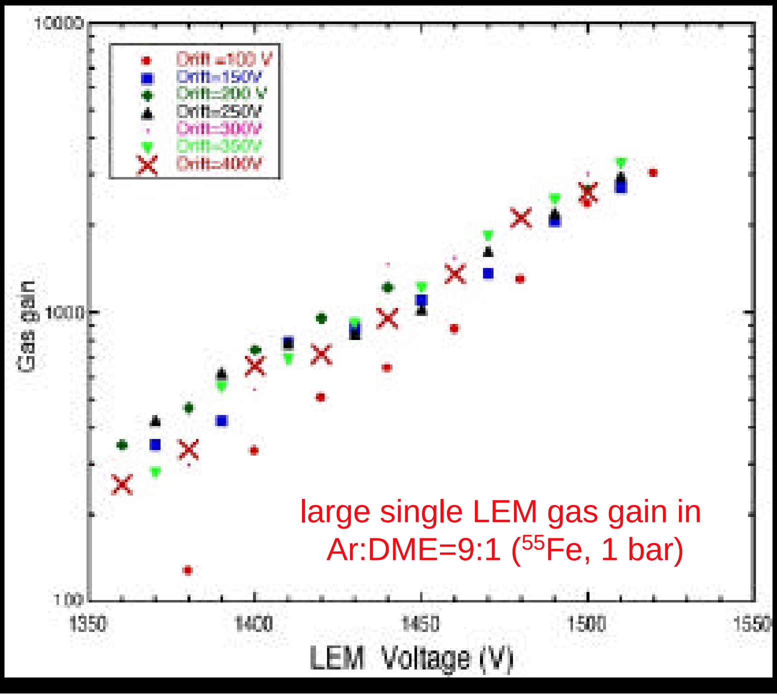
Chicago-Purdue
P.S. Barbeau J.I. Collar
J. Miyamoto I.P.J. Shipsey

Interesting detector for
low background physics
(as a single channel device)
and for TPC readout

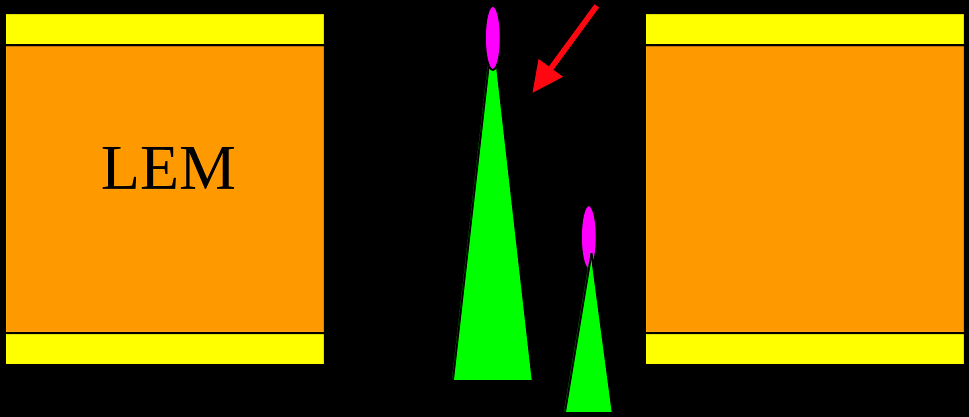


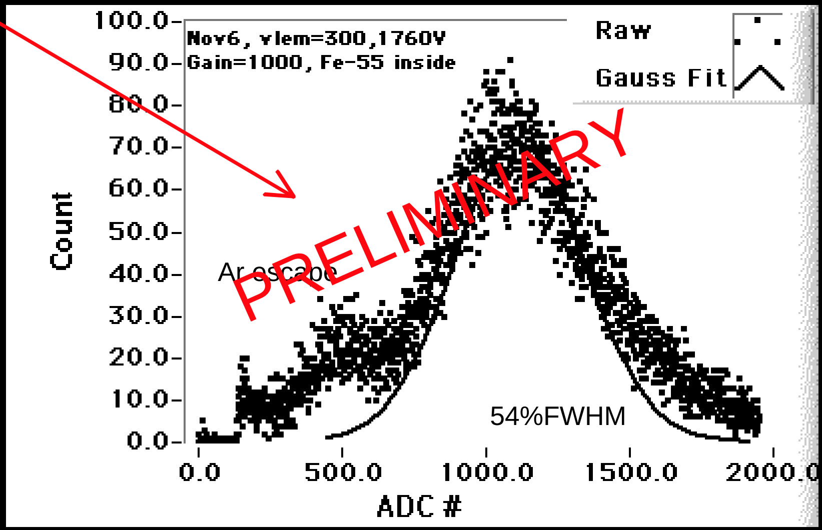
Large Electron Multipliers (a.k.a. capillary plates)





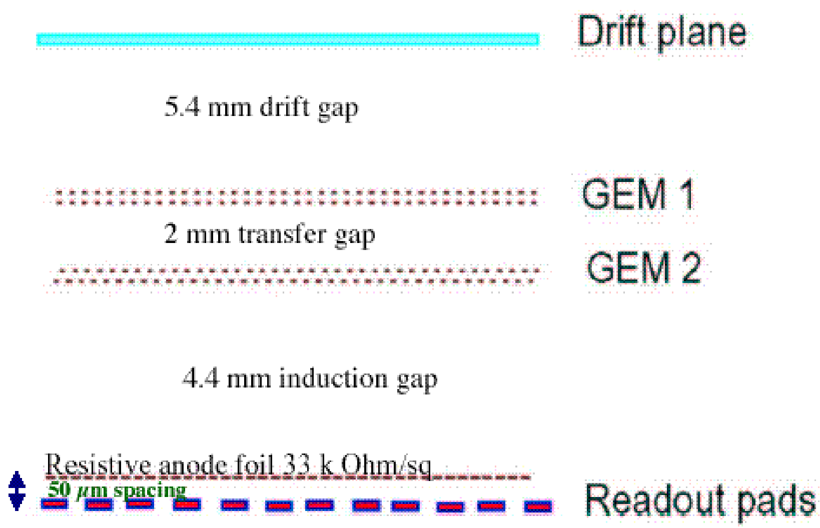
First 55Fe calibrations show diminished E resolution due to comparable drift and amplification lengths
Effect not relevant in TPC mode

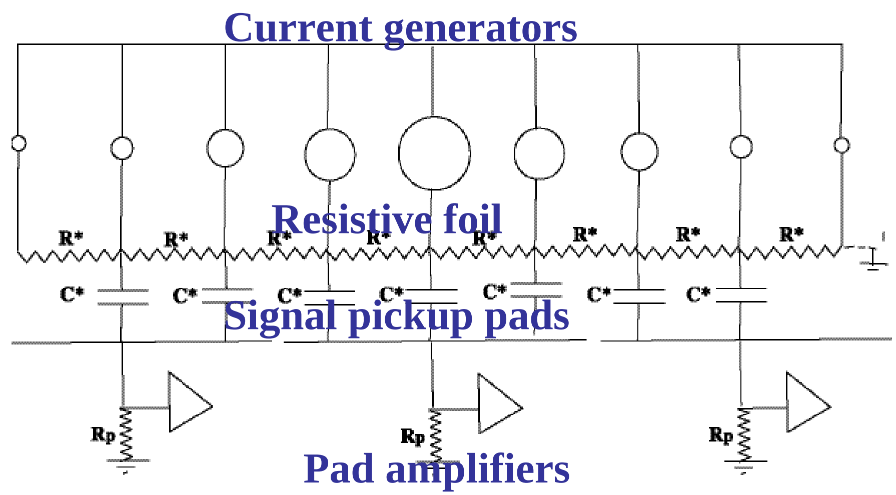




Position sensing from charge dispersion in a GEM with a resistive anode

Carnegie, Dixit, Martin, Mes & Sachs Carleton/Montreal



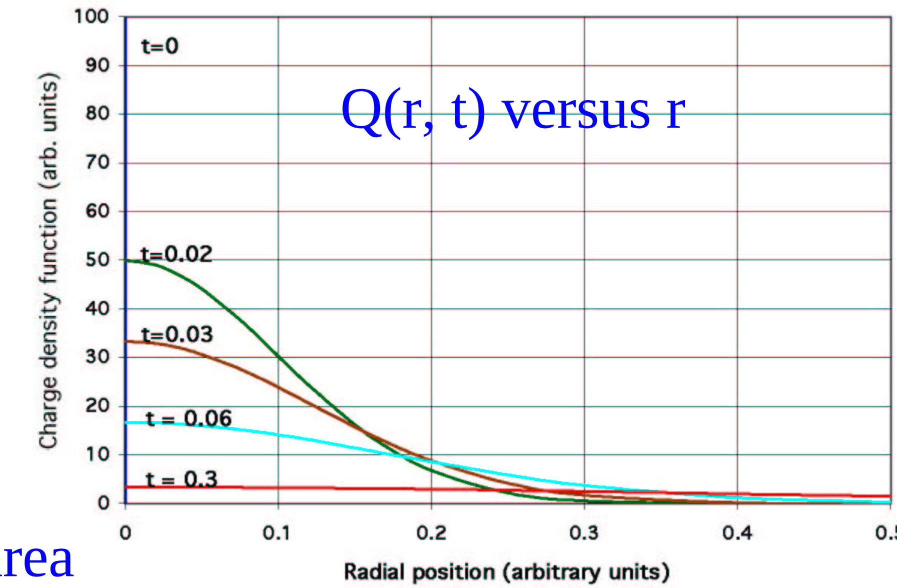


Deposit charge cluster at r=0 at t=0

Telegraph equation in 2-D

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

Charge density: $Q(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$



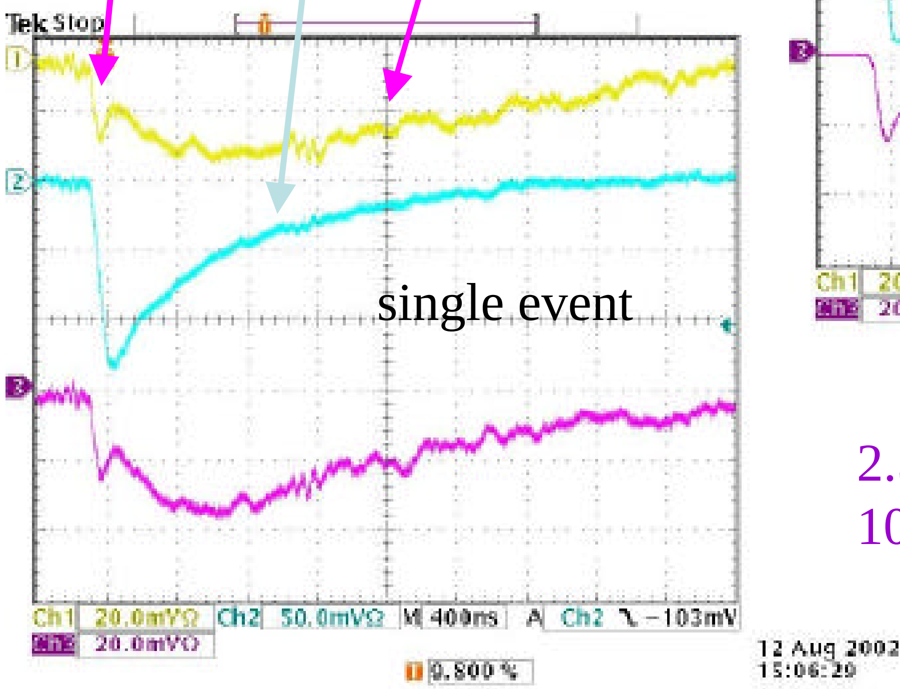
Signal = Integral of Q(r, t) over pad area

Resistive Anode GEM Resolution tests with 1.5 mm readout

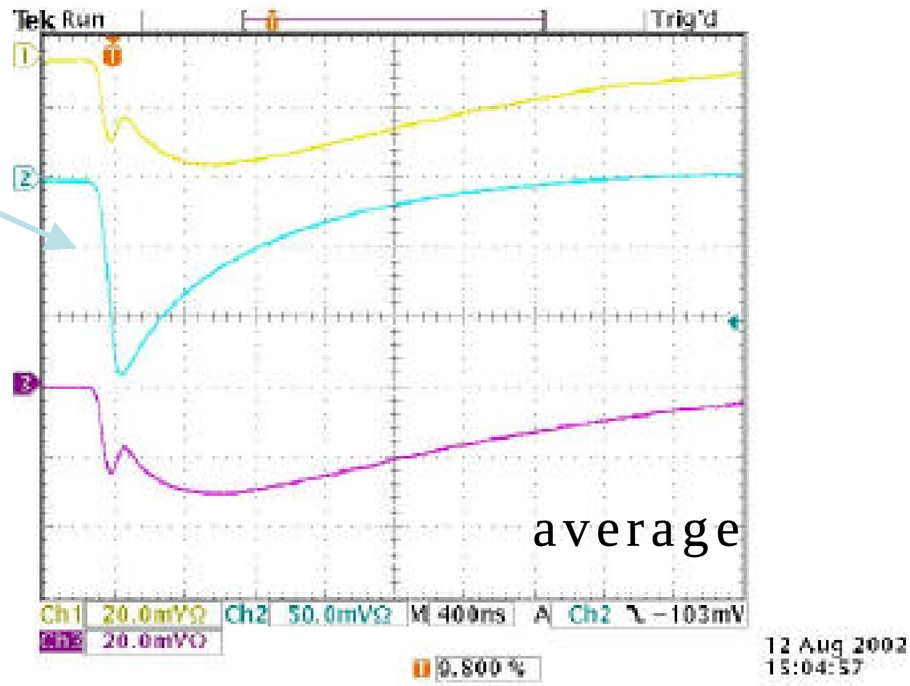
Ionization source 50 μm ^{55}Fe collimated x rays Carleton/Montreal

central strip: main pulse

adjacent strips with induced pulse + charge dispersion



single event



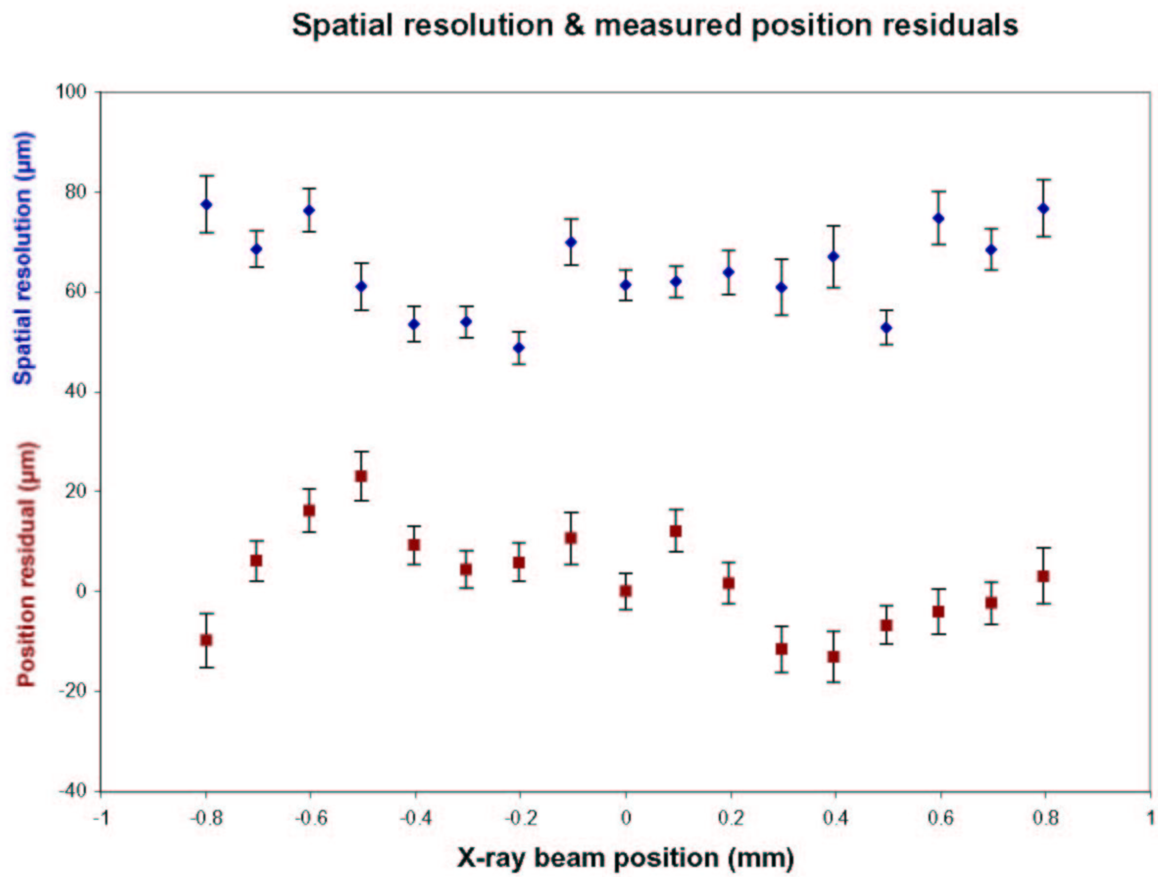
average

2.5 MΩ/❑ resistive anode
100 μm gap

Spatial Resolution in a GEM with Resistive Anodes

(1.5 mm x 7 cm readout strips, 50 μm collimated 4.5 keV x rays)

Carleton/Montreal



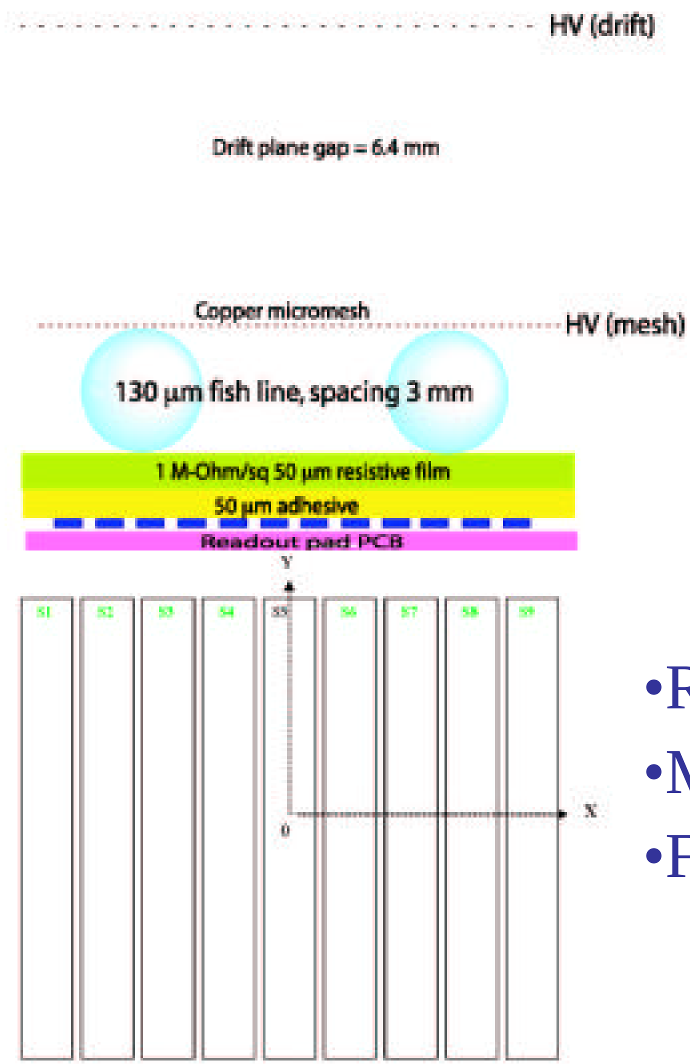
Spatial resolution

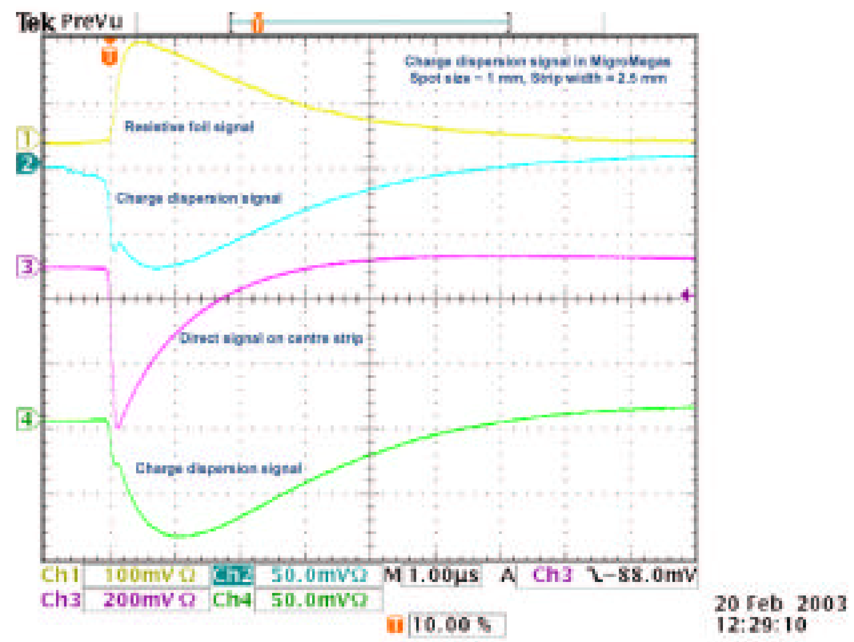
Position residuals

Observe Charge Dispersion Pulses in a Resistive Anode μMegas

Dixit, Sachs, Colas & Lepeltier Carleton/Orsay/Saclay

Signals on 2.5x70 mm² readout strips (^{55}Fe Ionization spot ~ 700 μm centred on strip 3)





- Resistive anode/readout same as GEM
- Micromesh on frame made by CERN
- For P10 (argon), optimum gap ~ 30 μm

Electronics and DAQ

•With help from Berkeley (Ronan) several groups have adapted STAR TPC FE electronics to meet interim needs

•STAR TPC front-end electronics (designed for +ve pad pulses) has been modified to increase the dynamic range for negative MPGD pulses (Berkeley, Carleton, Montreal)

•TRIUMF/PSI Midas suite of programs being adapted to meet current DAQ requirements (TRIUMF, Montreal, UVIC, Berkeley)

NLC Gas Detector Tracking Proposals in the US

University Consortium for Linear Collider R&D (UCLC)
and Linear Collider Research and Development (LCRD)

TPC R&D

Fabrication and investigation of Gas Electron Multipliers for charged particle tracking	Peter Fisher	MIT	LCRD
Tracking Detector R&D at Cornell and Purdue Universities	Dan Peterson	Cornell	UCLC
Negative Ion TPC as the NLC main tracker	Giovanni Bonvicini	Wayne State U	UCLC

Forward Tracker

Development and Testing Linear Collider Forward Tracking	Michael Strauss	U Oklahama	LCRD
Evaluation of a GEM based Forward Tracking Prototype for the NLC	Lee Sawyer	Louisiana Tech U	LCRD
Straw Tube Wire Chambers for Forward Tracking in the Linear Collider Detector	Keith Baker	Hampton U	UCLC

Milestones for the LC TPC

- Complete needed MPGD R&D
- Measure spatial resolution & two track resolution of small MPGD TPC prototypes in a high magnetic field
- Select LC TPC readout technology
- Complete R&D to develop electronics, mechanics & field cage for the LC TPC
- Design, construction & magnetic field tests of a realistic large scale prototype LC TPC with new electronics
- Finalize design of all LC TPC components
- Design, construct & install the LC TPC

Conclusion and outlook

- Significant ongoing & planned R&D activities in North America in gaseous tracking detectors for the LC
- Can benefit from R&D collaboration with STAR/Phenix TPC at RHIC
- However, a truly international effort will be needed on an aggressive time scale for the detector to be ready if the LC machine turns on by ~ 2013
- Thanks to North American colleagues for providing un-published material for this talk

Announcement for TPC with Micropattern Detector Workshop at the IEEE

There will be a a one day "TPC with Micropattern Detector Workshop" on Monday Oct 20th at the IEEE meeting in Portland this year. The workshop, being organized by Fabio Sauli and Craig Woody, should be useful for people working in this area. Everyone is invited.