Recent Gas Detector Work at Temple U.

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*good detector guys looking for postdoc jobs

- Old Stuff (for students)
- New Stuff
  - New NITPC gas- nitromethane (CH_3NO_2):CO_2
  - Mechanism of NI avalanche initiation
  - Hi-rez GEM TPC

Recoil Energy Distributions

(Smith & Lewin, 1996)

For isothermal spherical halo, ignoring form factors:

$$dR/dE_r \propto \exp\frac{-E_r}{\epsilon}$$

ε values in keV:

M_W	$A_{tgt}=$ 19	40	131
30	7.7	7.9	4.9
100	14	19	26**
300	18	33	68**

** large form factor suppression

There is a high rate premium on low energy thresholds.

Maximum Possible Recoil Energy

Galactic escape speed ~ 550 km/sec. Few or no wimps above this energy in isothermal sphere halo model.

Maximum possible E_r $(M_W \rightarrow \infty)$ in keV:

A_{tgt}=	19	40	131
	120	240	820**

** huge form factor suppression

There is a high premium on low energy thresholds.

Optimum Pressure wrt Tracking Threshold

* As tracking threshold improves, highest sensitivity is obtained by raising pressure
* Maximum sensitivity obtainable is inversely proportional to energy threshold for tracking

Rate of track-able events R = N_{tgt} * specific rate above threshold

$$N_{tgt} \propto P\,V$$

$$\text{specific rate} = \int_0^{E_{max}} (dR/dE_r)\,\epsilon(E_r)\,dE_r$$

Suppose: * ε(Er) =0 for R< R_m, =1 for R> R_m << $R_m(E_{max})$

* R α E per Lindhard

Then $E(R_m)$ α R_m P (to get a 1 mm track takes twice as much energy at 100 Torr as at 50 Torr)

Optimum Pressure cont'd

Then **$R \sim PV \exp(-kR_m P)$**

(k is a computable constant unfortunately depending on unknown parameters like M_W)

This event rate has a maximum for **$P_{opt} = 1/(kR_m)$**

At P_{opt}, the track-able event rate is proportional to $1/R_m$

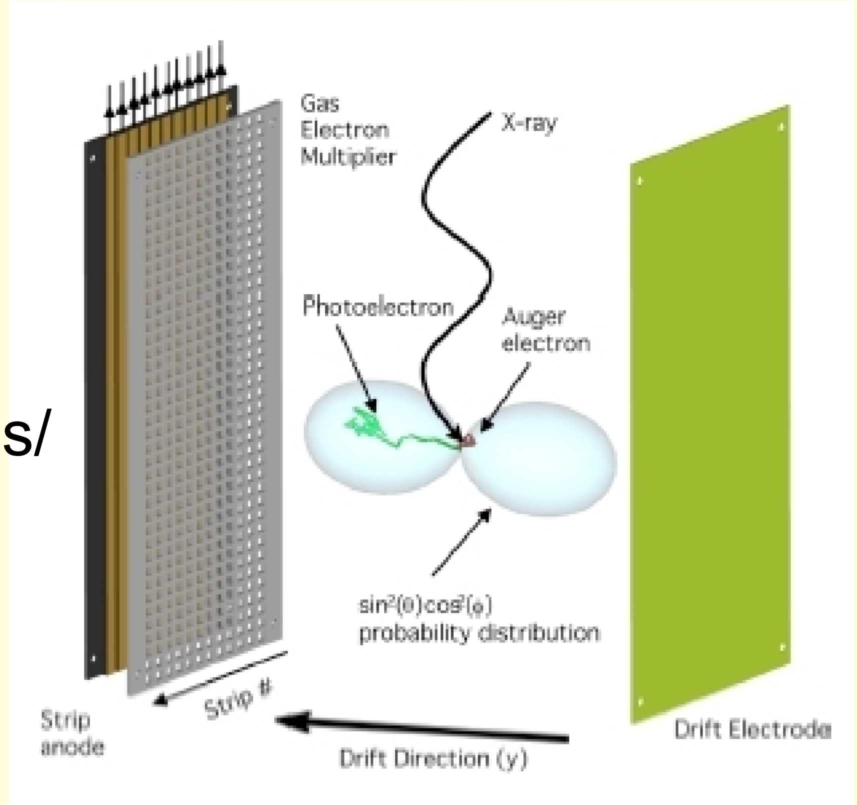
There is a high premium on low tracking threshold.

New Stuff

Negative Ions can keep σ_{diff} well below 1 mm for 1 meter drift.

Scales as $(1\ \mathrm{KV/cm}/E_d\ )^{1/2}\ (L/1\ \mathrm{m})^{1/2}$ up to tens of KV/cm Torr

Technique is finding new applications- space-based x-ray polarimetry (GEMS SMEX project at GSFC: http://heasarc.gsfc.nasa/gov/docs/gems/



Tracking photo-electrons from x-rays interacting in gas
Tracking threshold < 1 mm (readout pitch 130 um)

Nitromethane

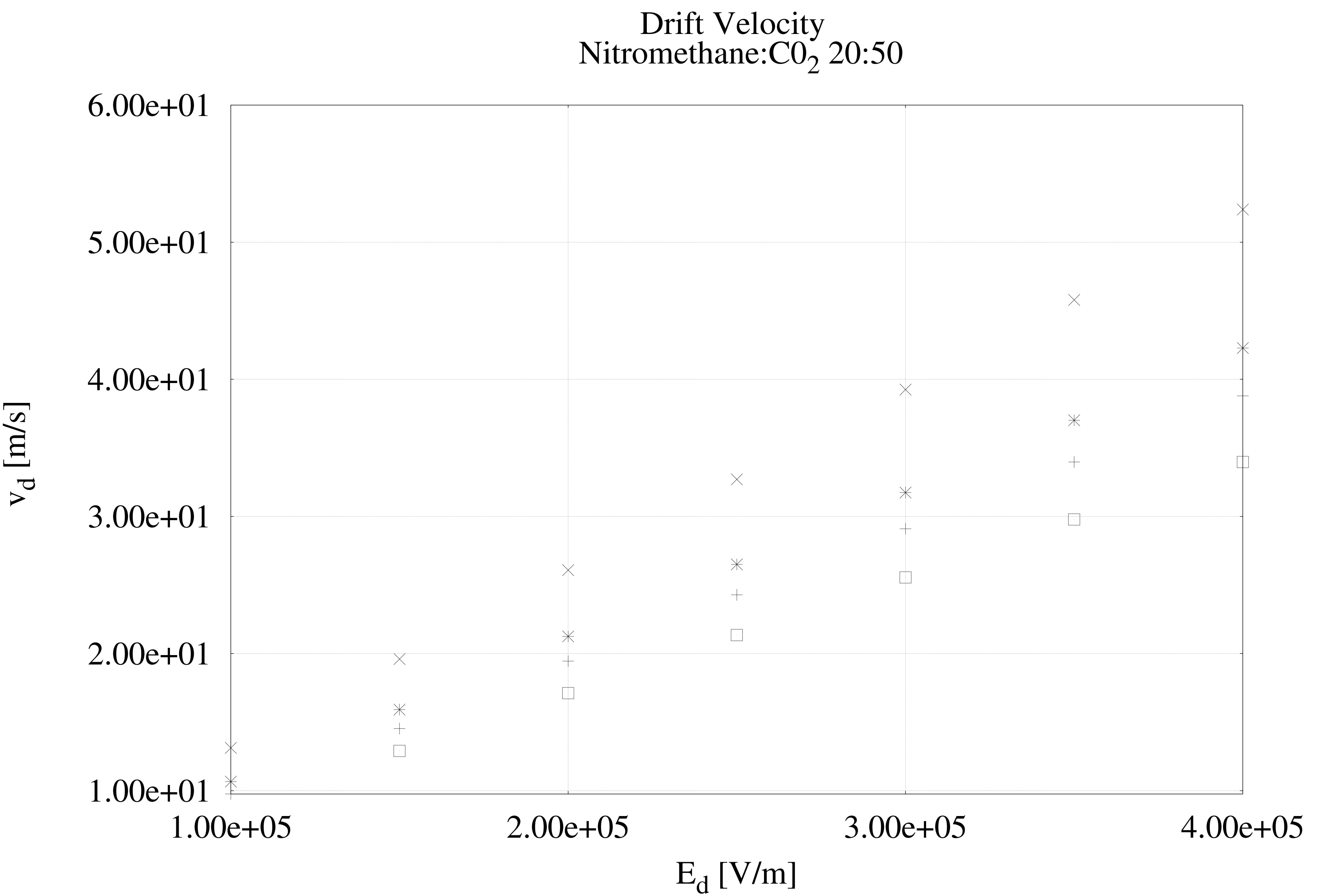
To track photoelectrons from 2-10 keV x-rays, NASA needed a lower-Z NI gas than CS_2:

* reduce multiple scattering
* photoelectron energy reduced by K-edge binding of highest Z element in gas

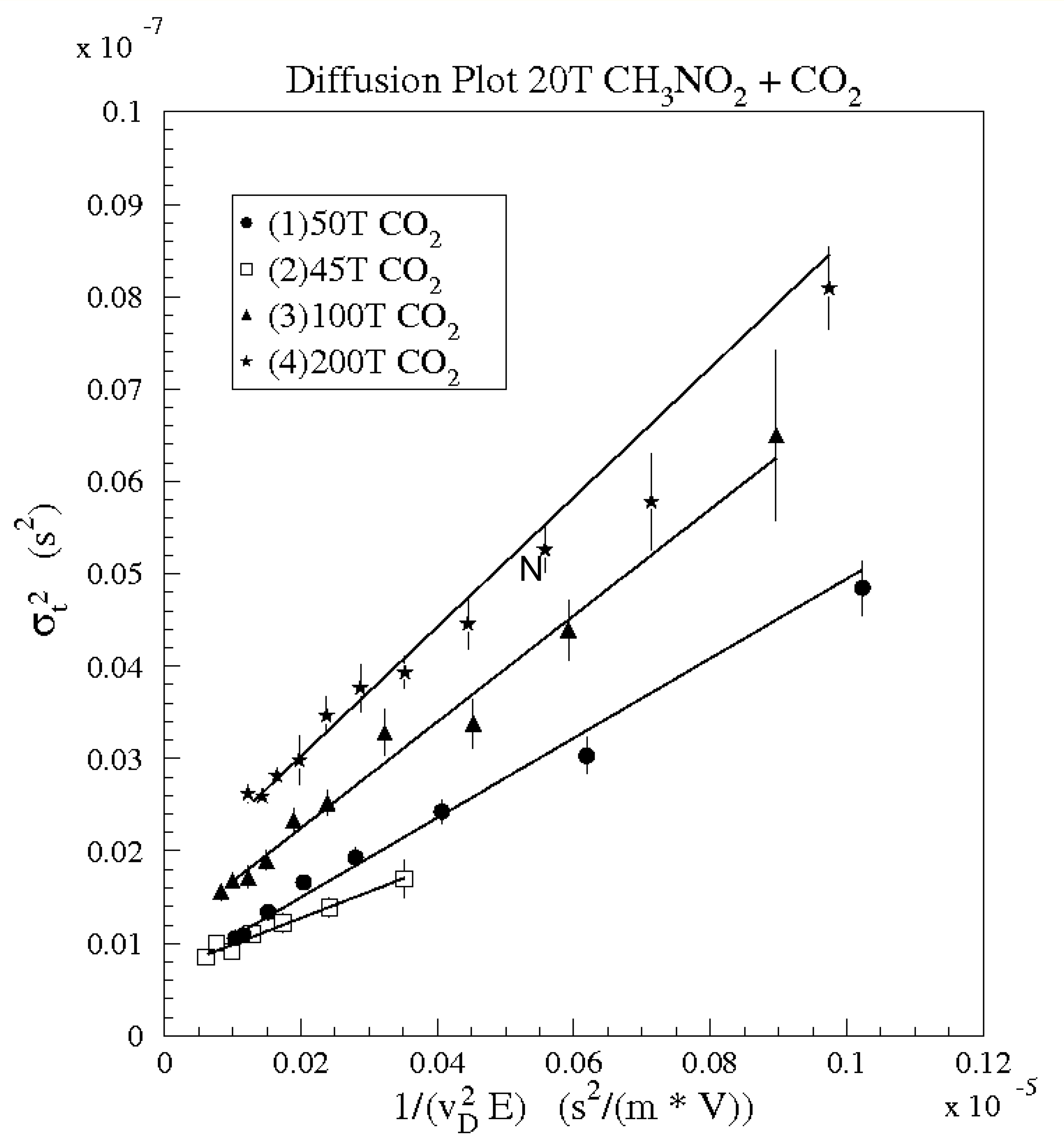
Study of chemistry literature led to Nitromethane (CH_3NO_2).

Addition of CO_2 was found necessary to insure electron capture in high drift fields.

Various mixtures with more CO_2 , noble gases, etc. also work up to very high fields.



Drift Velocity
Nitromethane:C0₂ 20:50
6.00e+01
5.00e+01
4.00e+01
3.00e+01
2.00e+01
1.00e+01
v_d [m/s]
1.00e+05
2.00e+05
3.00e+05
4.00e+05
E_d [V/m]



Martoff et al, NIM A 598, 501 (2009)

NI Avalanche Initiation Mechanism

The Diethorn Plot:

For avalanches in a proportional counter (1/r E-field) and assuming Townsend coefficient $\alpha = \beta$ E, ICBST:

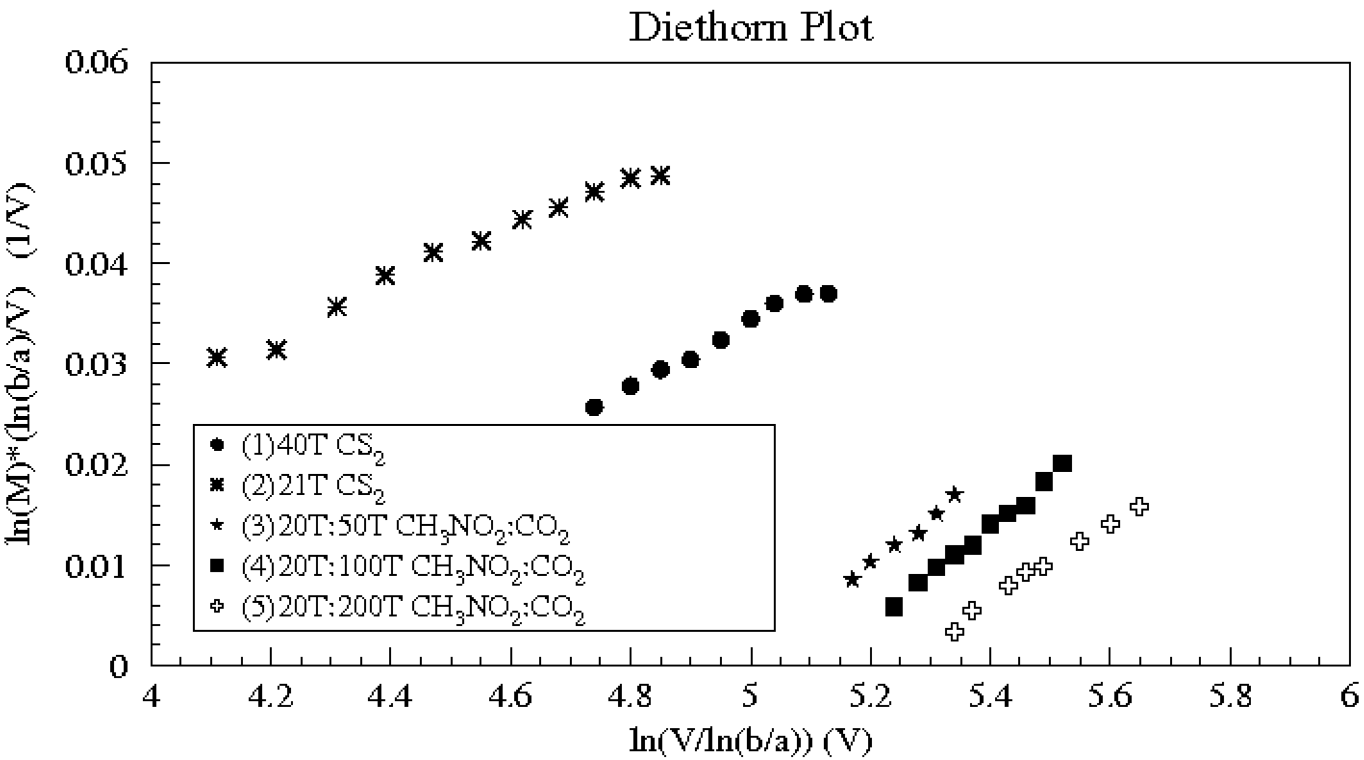
$$lnM = \frac{ln2\ V}{\Delta V\ ln(\frac{b}{a})} ln\left(\frac{V}{ln(\frac{b}{a}) a E_{min}}\right)$$

M = gas gain

E_{min} = electric field at radius where avalanche starts

ΔV = potential drop to generate one additional charge in avalanche

This can be turned into a linear plot of lnM/V vs. V, from which E_{min} and ΔV can be determined.



Diethorn Plot
ln(M)*(ln(b/a)/V) (1/V)
ln(V/ln(b/a)) (V)
0.06
0.05
0.04
0.03
0.02
0.01
0
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
(1)40T CS_2
(2)21T CS_2
(3)20T:50T CH_3NO_2:CO_2
(4)20T:100T CH_3NO_2:CO_2
(5)20T:200T CH_3NO_2:CO_2

Diethorn Fits for CS_2 and Nitromethane

Gas	ΔV (V)	E_{min} $\left(\frac{kV}{cm}\right)$
CS2 21 T	23.0 ± 0.3	64.2 ± 6.0
CS2 40 T	25.5 ± 0.1	27.1 ± 3.0
Nitro:CO2 20:50	15.2 ± 0.1	193.6 ± 13.1
20:100	13.4 ± 0.02	227.1 ± 2.4
20:200	18.0 ± 0.1	249.0 ± 6.8
e-gas *	23.6 ± 5.4	48 ± 3

*760T Ar(90%) + CH_4(10%)[55]

Table 4.10: Diethorn parameters for negative ion gas mixtures and an electron gas. The negative ion gas mixtures are identified in the legend of Figure 4.20.

Things to note:
* E_{min} is large in NI gases; E_{min}/P is VERY large

* E_{min} about doubles when pressure doubles in CS_2 i.e. E_{min}/P ~constant

E_{min}/P scaling in CS_2 consistent with collisional detachment initiating the avalanche.

CS_2 Collisional Detachment

Toy model: CS_2 negative ion must gain enough energy from drift field on one mean free path to detach its bound electron
$E_{min}\,\lambda = 2\,EA$

electron binding energy = EA = 0.6 eV)
Mean free path can be determined from measured drift speed:

$$v_d = \frac{eE}{M}\,\frac{\lambda}{v_{rel,th}}\,f(M)$$

Toy model prediction: = 55 KV/cm at 40 Torr (Diethorn: 64 KV/cm)
28 KV/cm at 21 Torr (Diethorn: 27

Collisional detachment explains CS_2 avalanche behavior well.

Nitro Mixtures Collisional Detachment?

E_{min} does not scale with pressure.
Mean free path from drift speed varies much more with pressure than E_{min} does, so toy model won't track E_{min}, though order of magnitude comes out correct.

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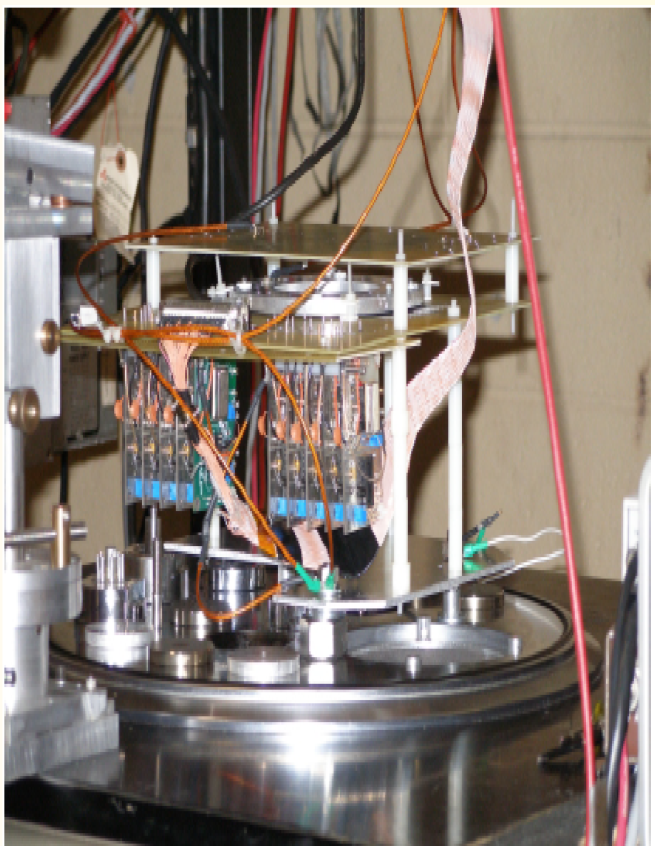
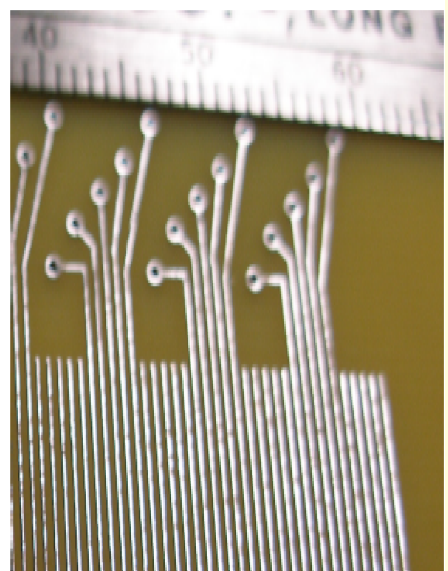
These mixtures are still under study.

Hirez NITPC Neutron Exposure

NASA “GEM-like device” - double foil w/ 100 micron holes
Paired to 700 micron pitch anode strips ganged onto 8 Ampteks

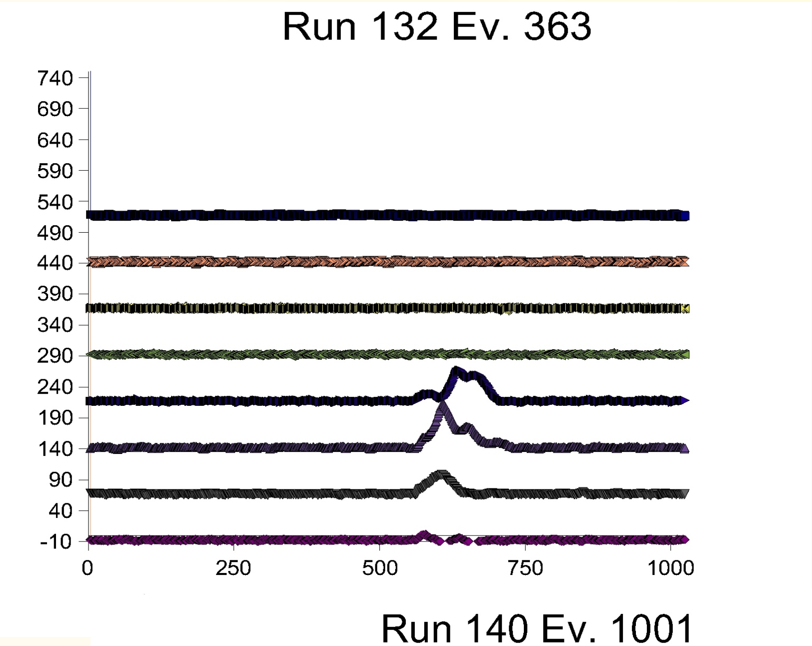


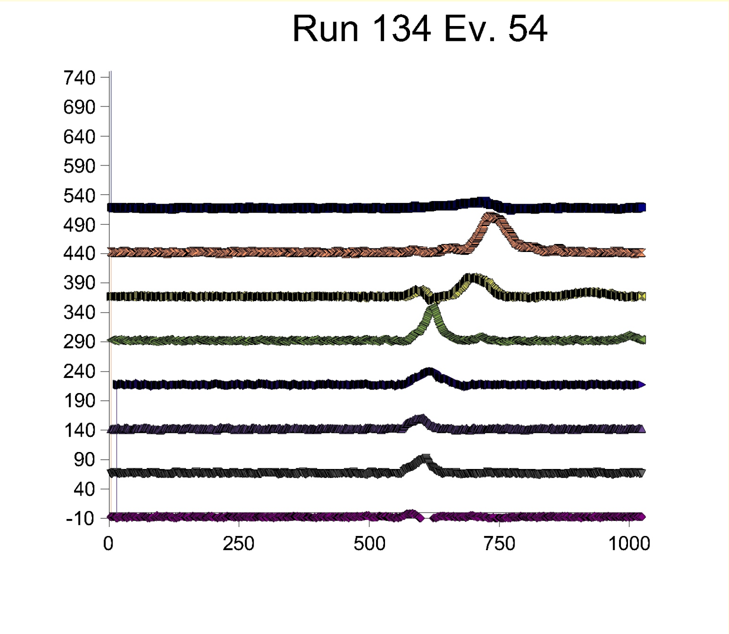


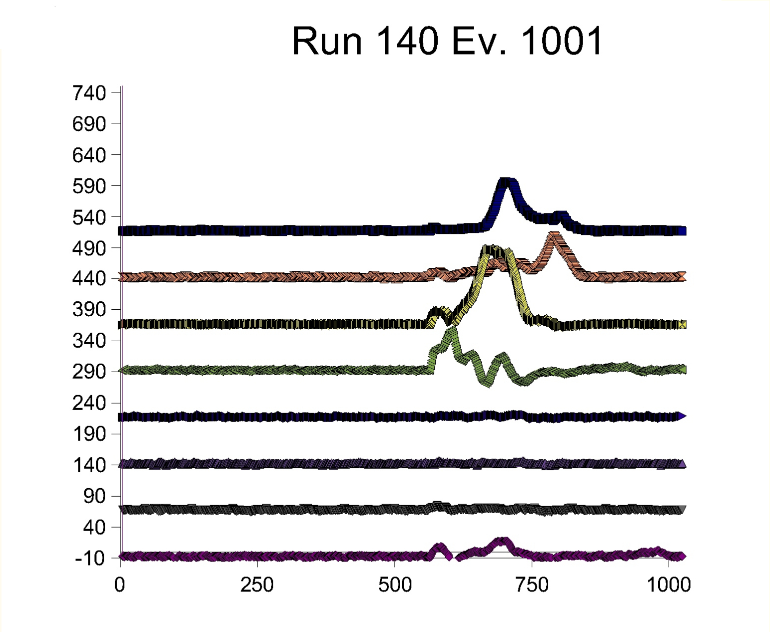
Neutron exposure w/ CS_2 fill at TUNL April 2009 now being analyzed.

Expecting 2.8 mm tracking threshold.

Hirez NITPC Neutron Events







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Grad student Mike Dion who built the apparatus and did most of the measurements & calculations discussed here is looking for a postdoc.

Winner of College of Science & Technology Teaching Award and contender for Research Award.

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