Spin Dependent Limits from DRIFT

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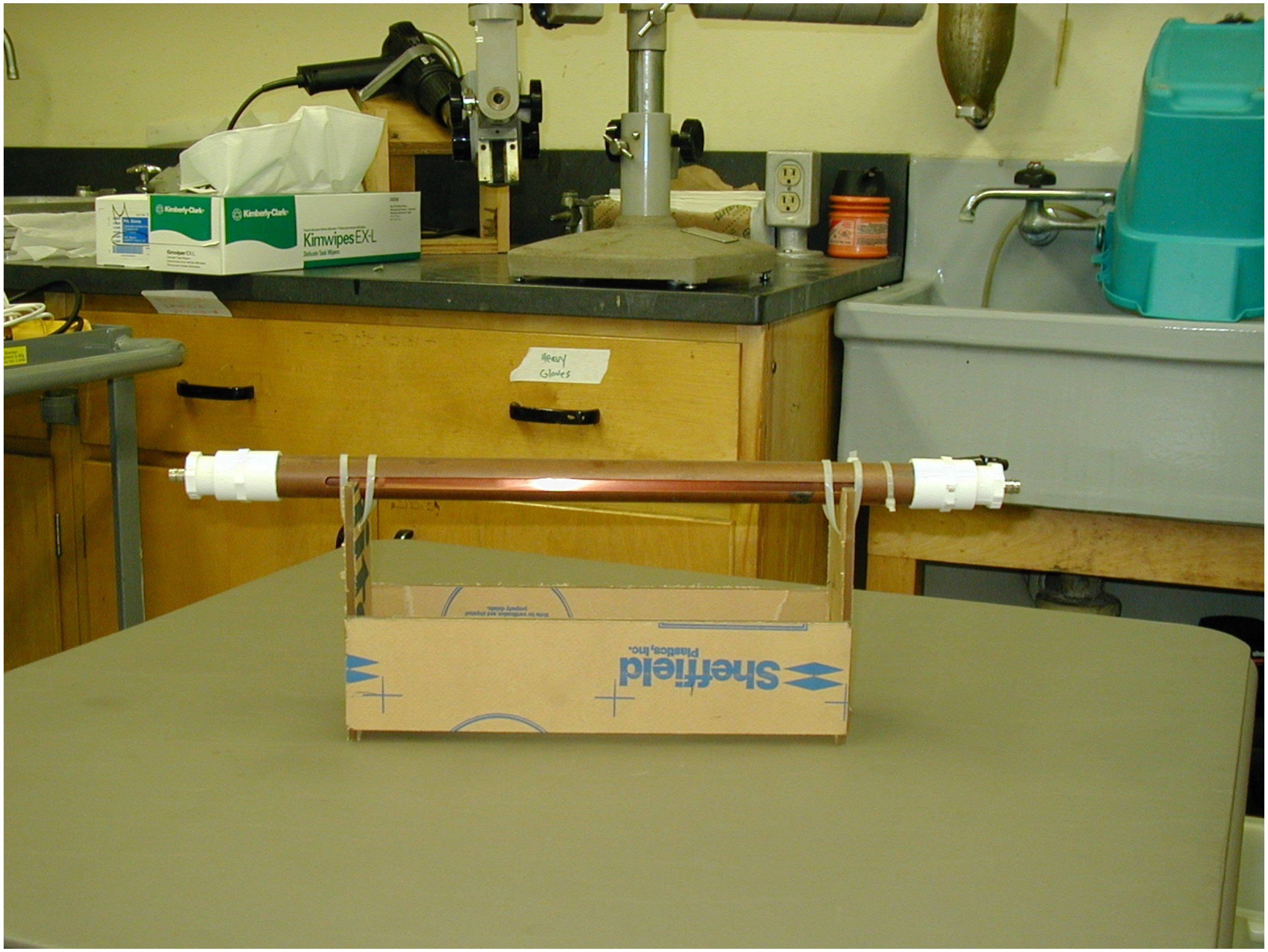
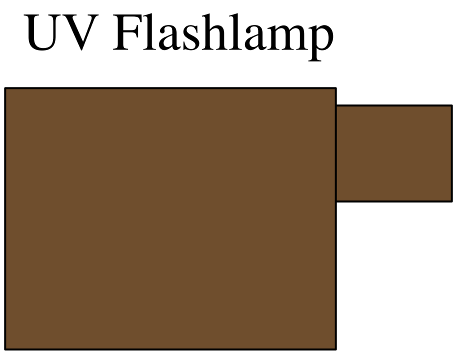
DRIFT with spin

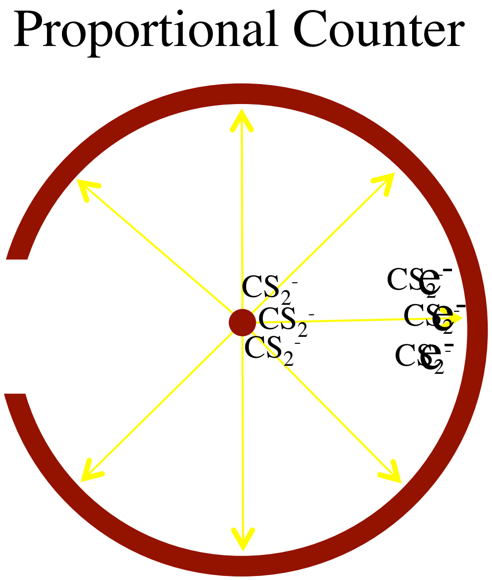
- CF_4 is an attractive candidate.
- Will it work? In the context of DRIFT the question is can we make a mixture which has a significant amount of CF_4 and preserve negative ion drift.
- We have explored various CS_2-CF_4 mixtures as well as other scintillation gas mixtures.

Single Electron Proportional Counter



Single Electron Proportional Counter





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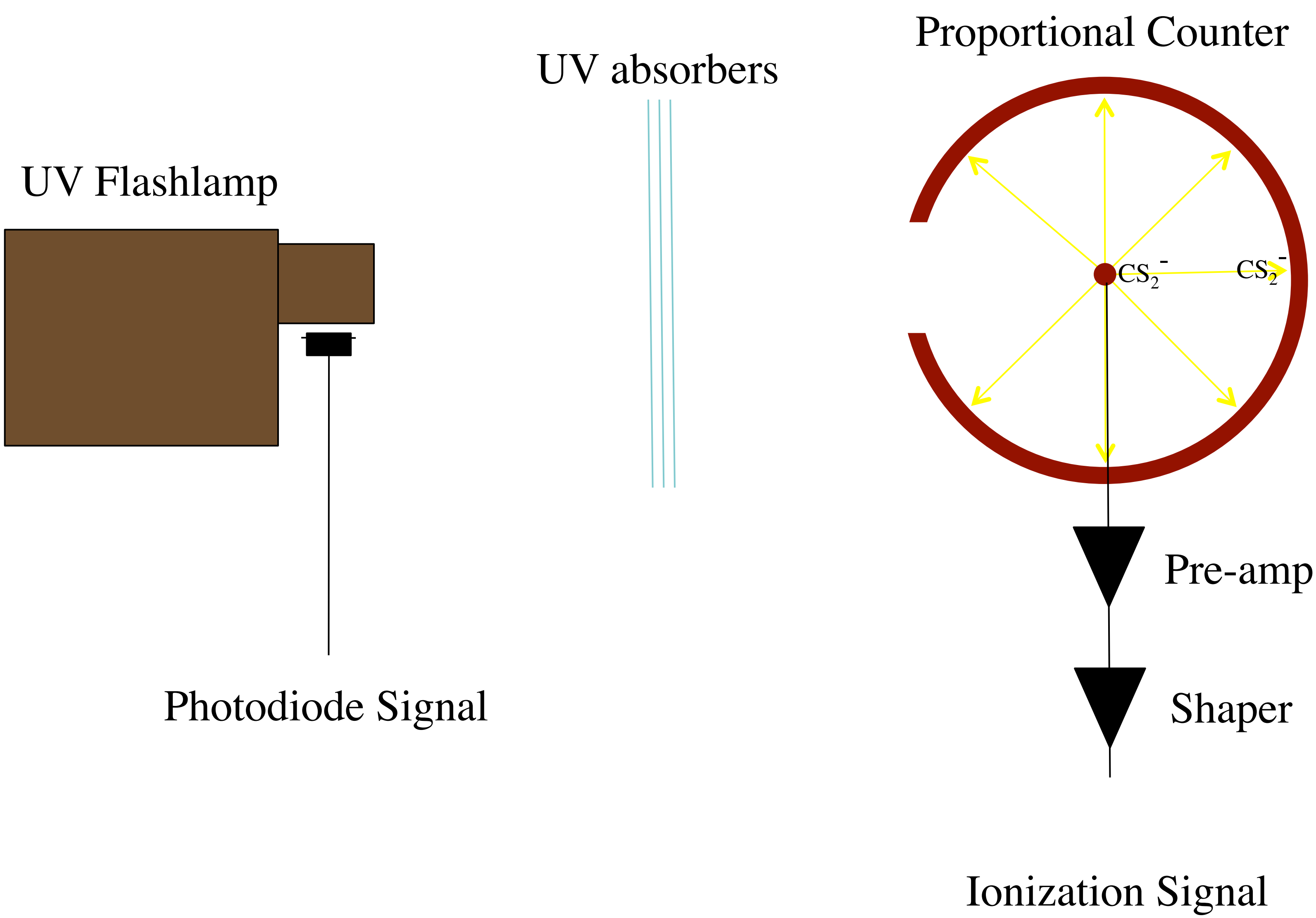
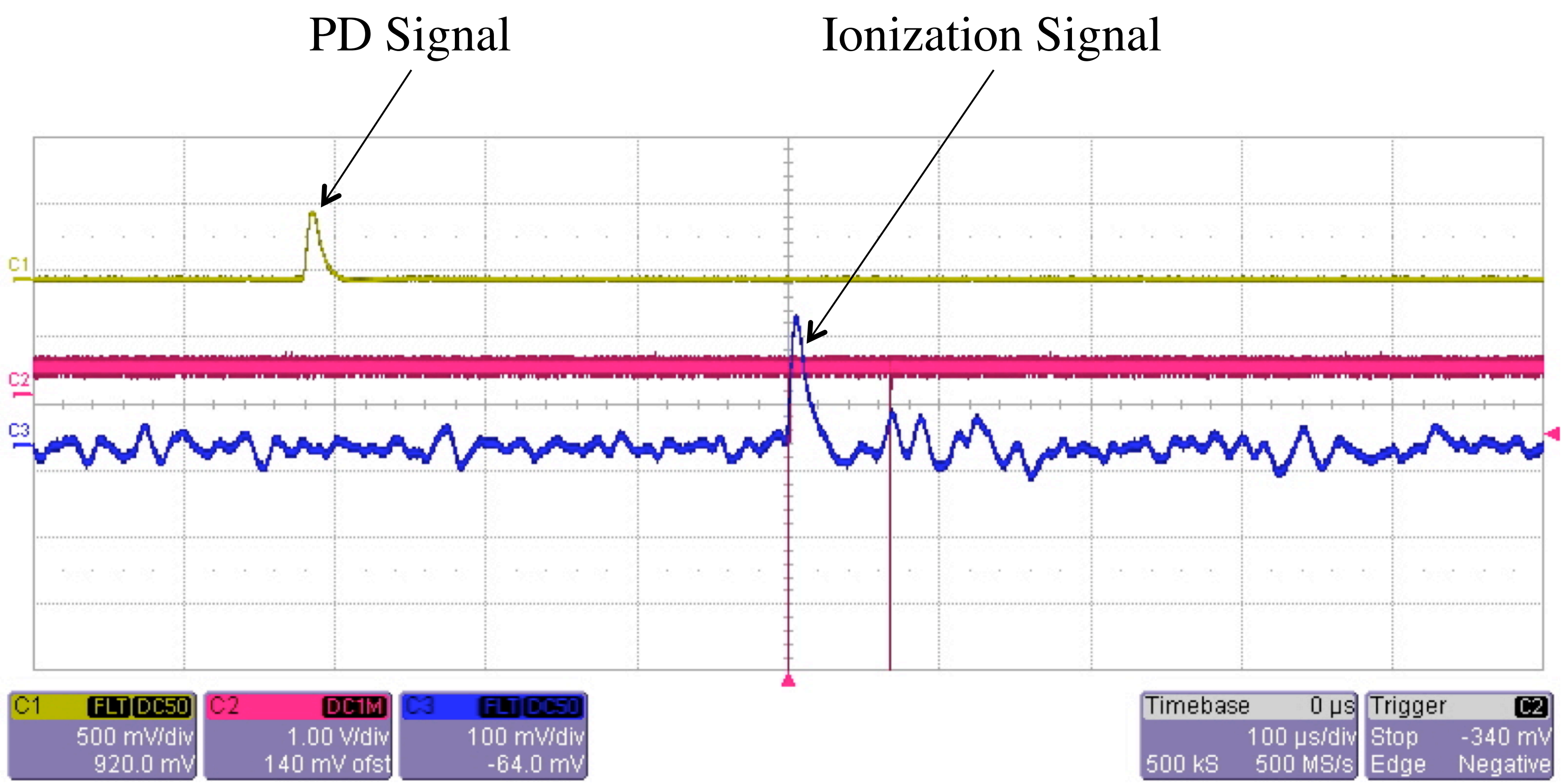


Single Electron Proportional Counter



We can measure the size of a single electron.

W Value

We know what the ionization yield, Y_{SE}, is for a single electron…and we can measure the size of the event, $\langle\Sigma_{SE}\rangle$, produced.

We then expose the proportional counter to Fe-55 X-rays and we measure the size of the event, $\langle\Sigma_{55}\rangle$, produced. The ionization yield for Fe-55, Y_{55}, is then,

$$Y_{55} = \frac{\langle \Sigma_{55} \rangle}{\langle \Sigma_{SE} \rangle} Y_{SE} = \frac{\langle \Sigma_{55} \rangle}{\langle \Sigma_{SE} \rangle}$$

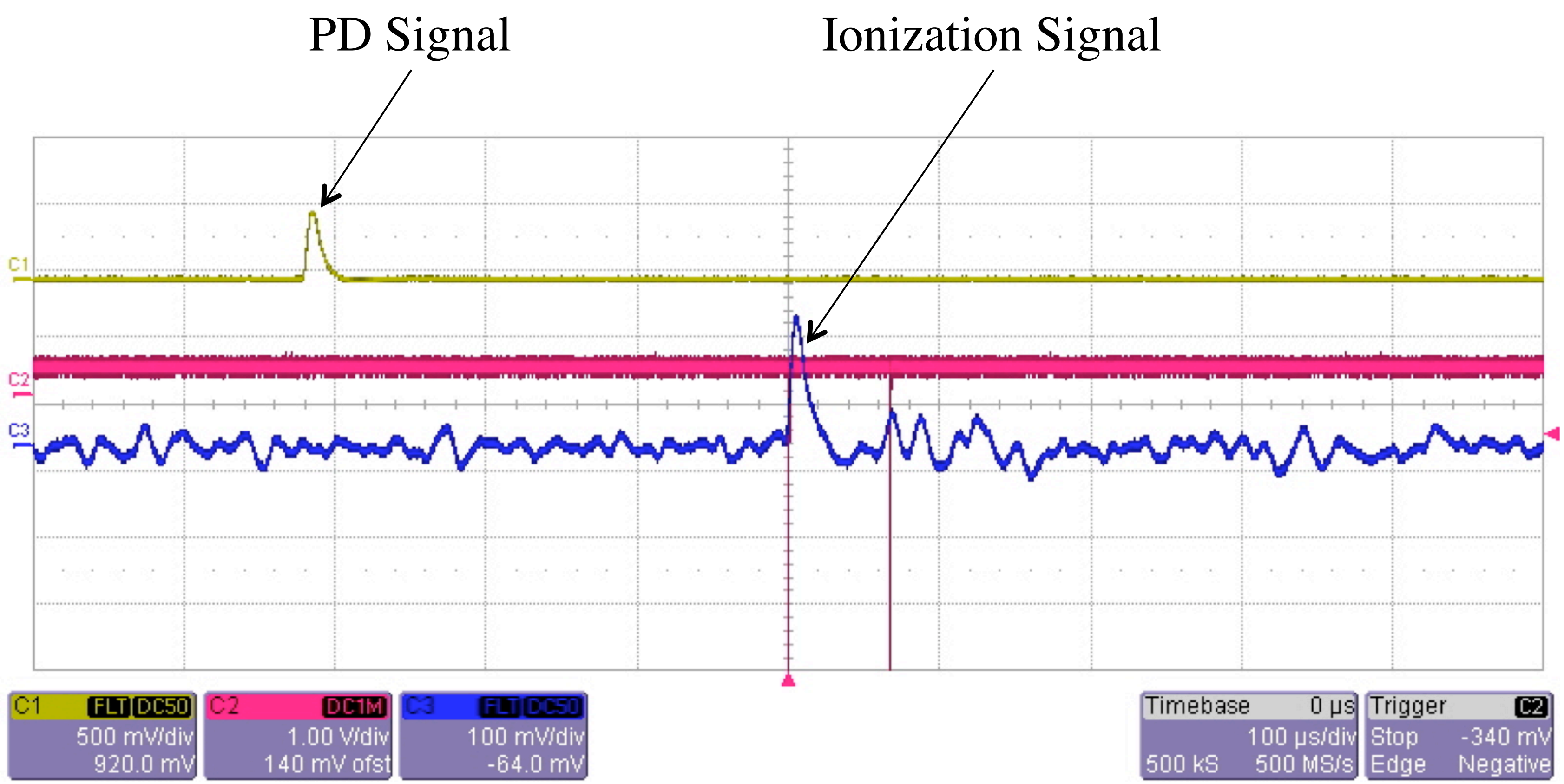
Fe-55 produces X-rays of energy E55 = 5.9 keV so,

$$W = \frac{E_{55}}{Y_{55}}$$

W Value

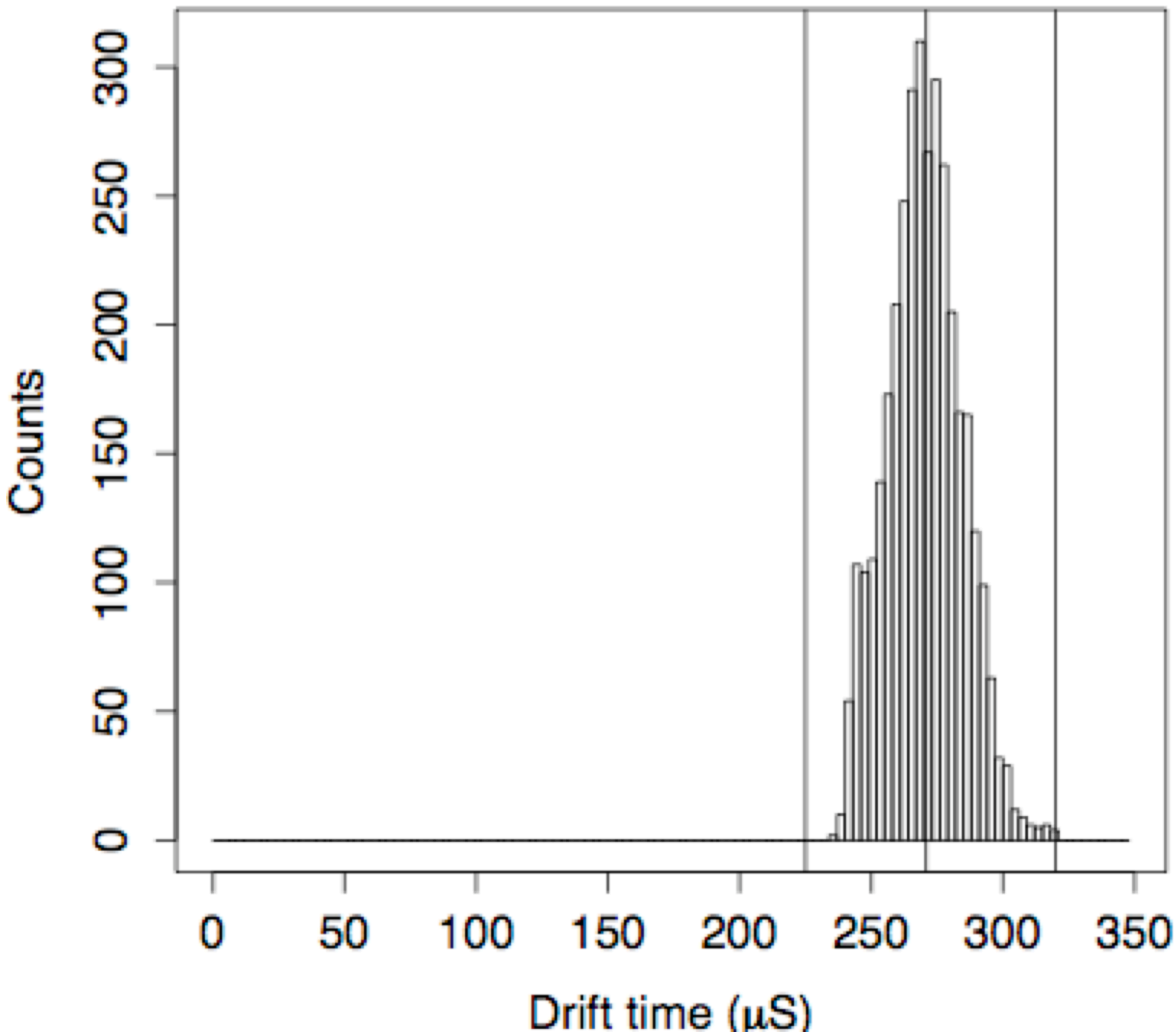
Gases, (Torr)	Voltage, V	Ionization yield	W-value, eV	W-value, eV Pure CS_2 (other works)
Pure CS_2, (40)	1600	237 ± 7	24.9 ± 0.8	24.7±0.7[18] 26.0±0.5 [19]
CS_2-CF_4, (30-10)	1550	234 ± 6	25.2 ± 0.6	
CS_2-CF_4, (20-20)	1350	202 ± 7	29.2 ± 1.0	
CS_2-CF_4, (10-30)	1300	179 ± 5	33.0 ± 1.0	
CS_2-He, (35-5)	1550	249 ± 8	23.7 ± 0.8	
CS_2-Ne, (35-5)	1550	253 ± 8	23.1 ± 0.8	

Mobility



We can measure the drift time of a single electron.

Mobility



Counts
0
50
100
150
200
250
300
0
50
100
150
200
250
300
350
Drift time (µS)

Mobility

Because of the 1/r field inside of the proportional counter we have to assume,

$$v = \frac{\mu E}{p}$$

With this assumption

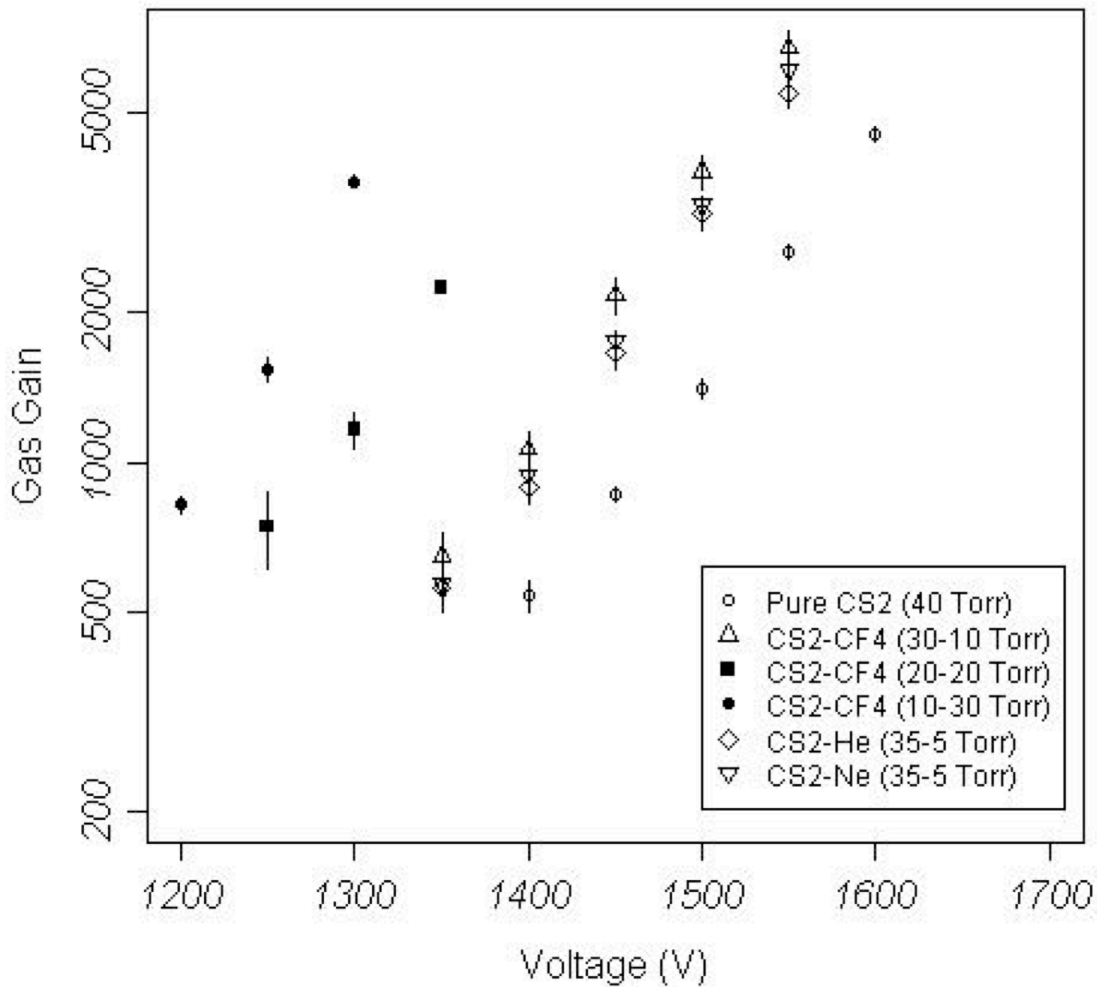
$$\mu = \frac{p \ln(\frac{b}{a})}{2 \Delta t \Delta V}(b^2 - a^2)$$

Mobility

Gases, Torr	Voltage, V	Drift time, μs	Reduced mobility, μ (cm^2 atm/Vs)	Reduced mobility, μ (cm^2 atm/Vs) (other works)
Pure CS_2, (40)	1600	270.8±0.2	0.54 ± 0.02	0.52 ± 0.02 [5]
CS_2-CF_4, (30-10)	1550	250.1±0.2	0.60 ± 0.02	
CS_2-CF_4, (20-20)	1350	251.0±0.3	0.69±0.02	
CS_2-CF_4, (10-30)	1300	222.0±0.3	0.81±0.03	
CS_2-He, (35-5)	1550	252.0±0.3	0.60 ± 0.02	
CS_2-Ne, (35-5)	1550	248.2±0.3	0.61 ± 0.02	

Gain

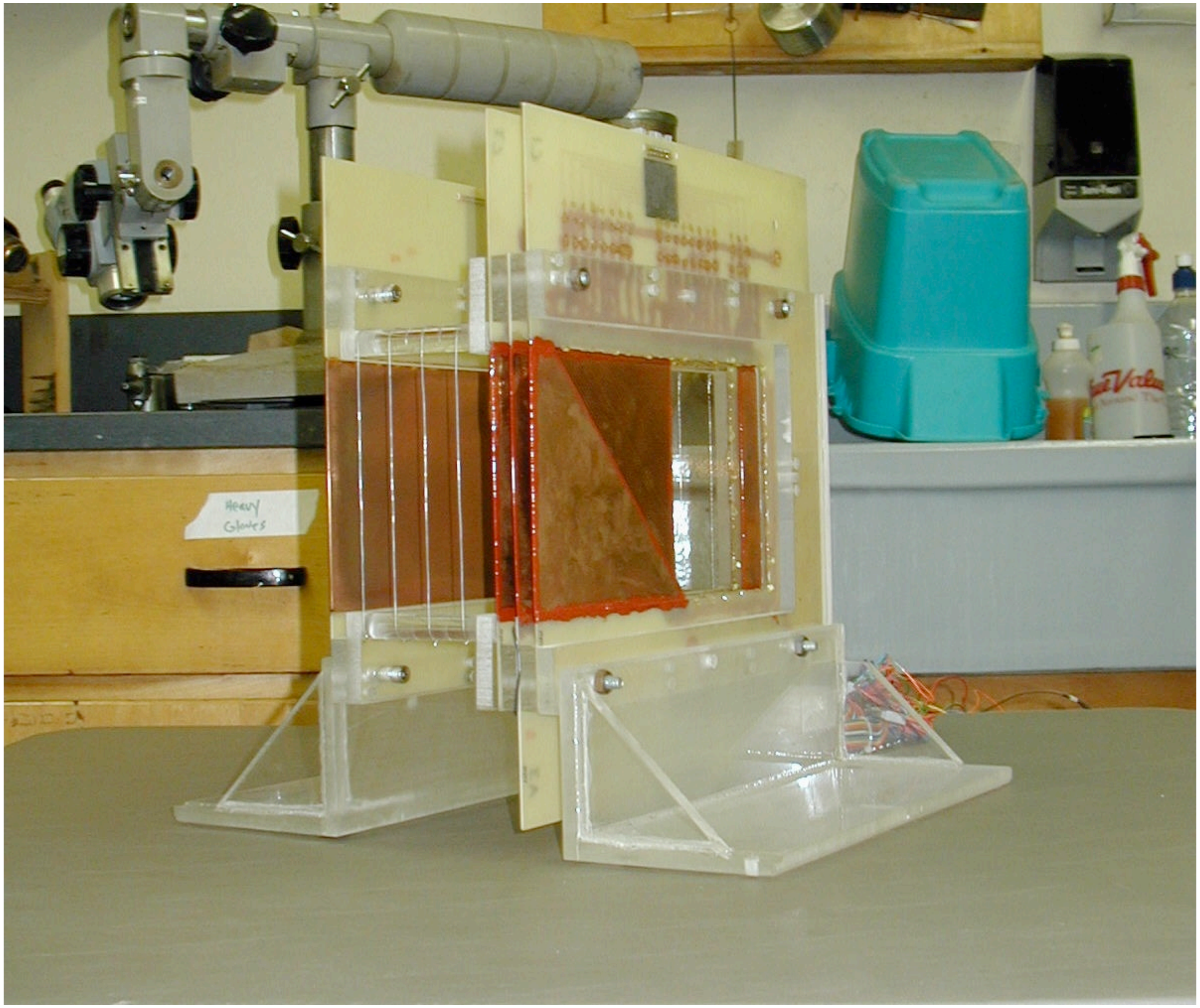
Knowing the size of the event and the amplifier chain allows us to get the gain of a single electron.



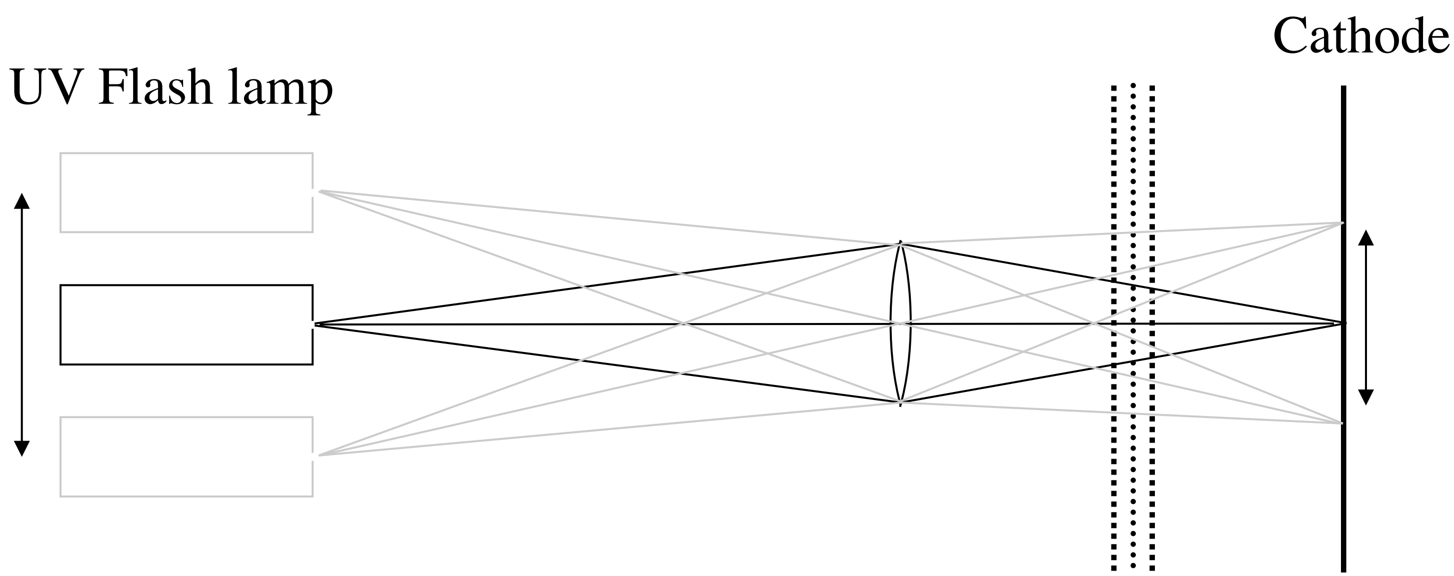
Published

Work on the W-value, mobility and gain has now been accepted for publication with NIMA

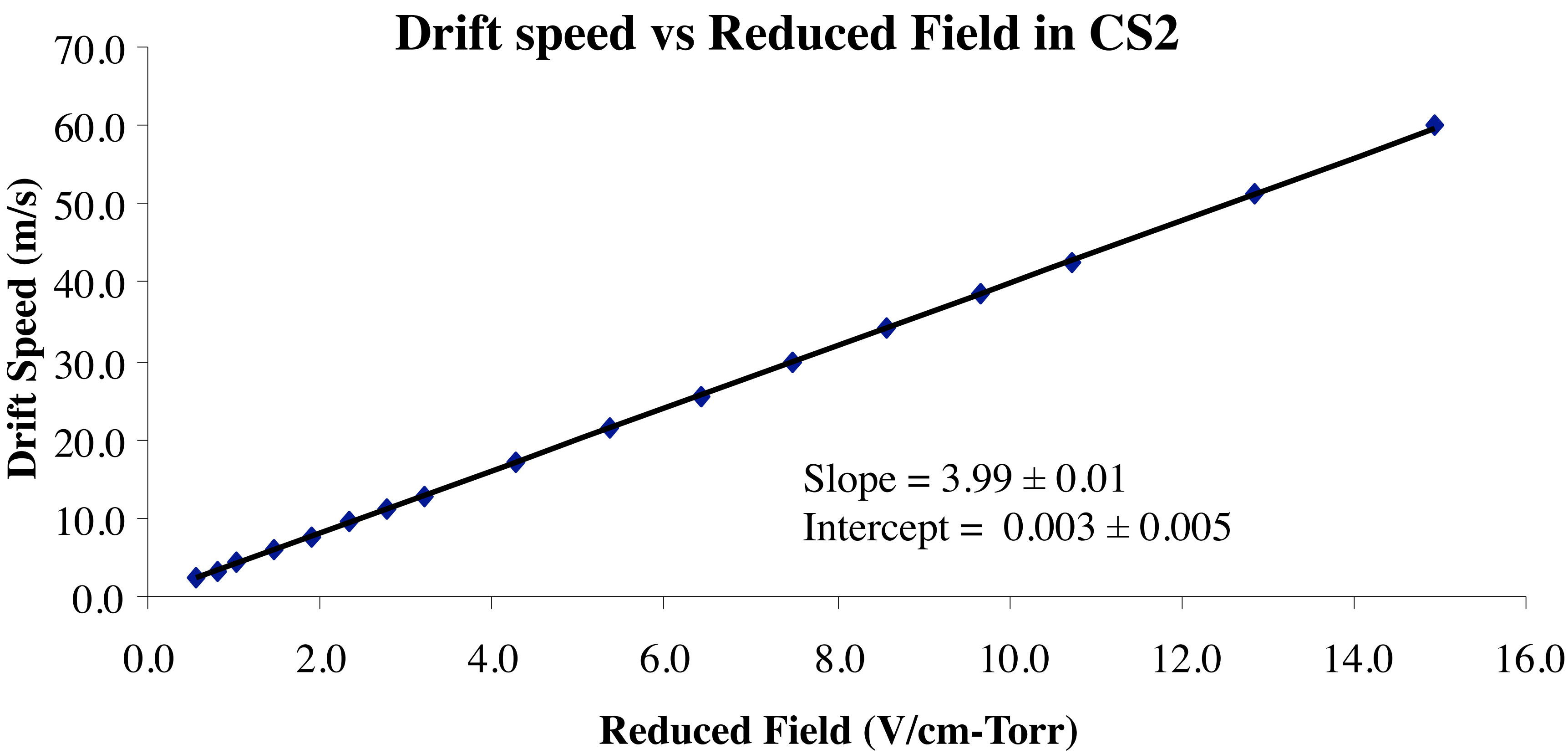
Diffusion Measurements



Diffusion Measurements

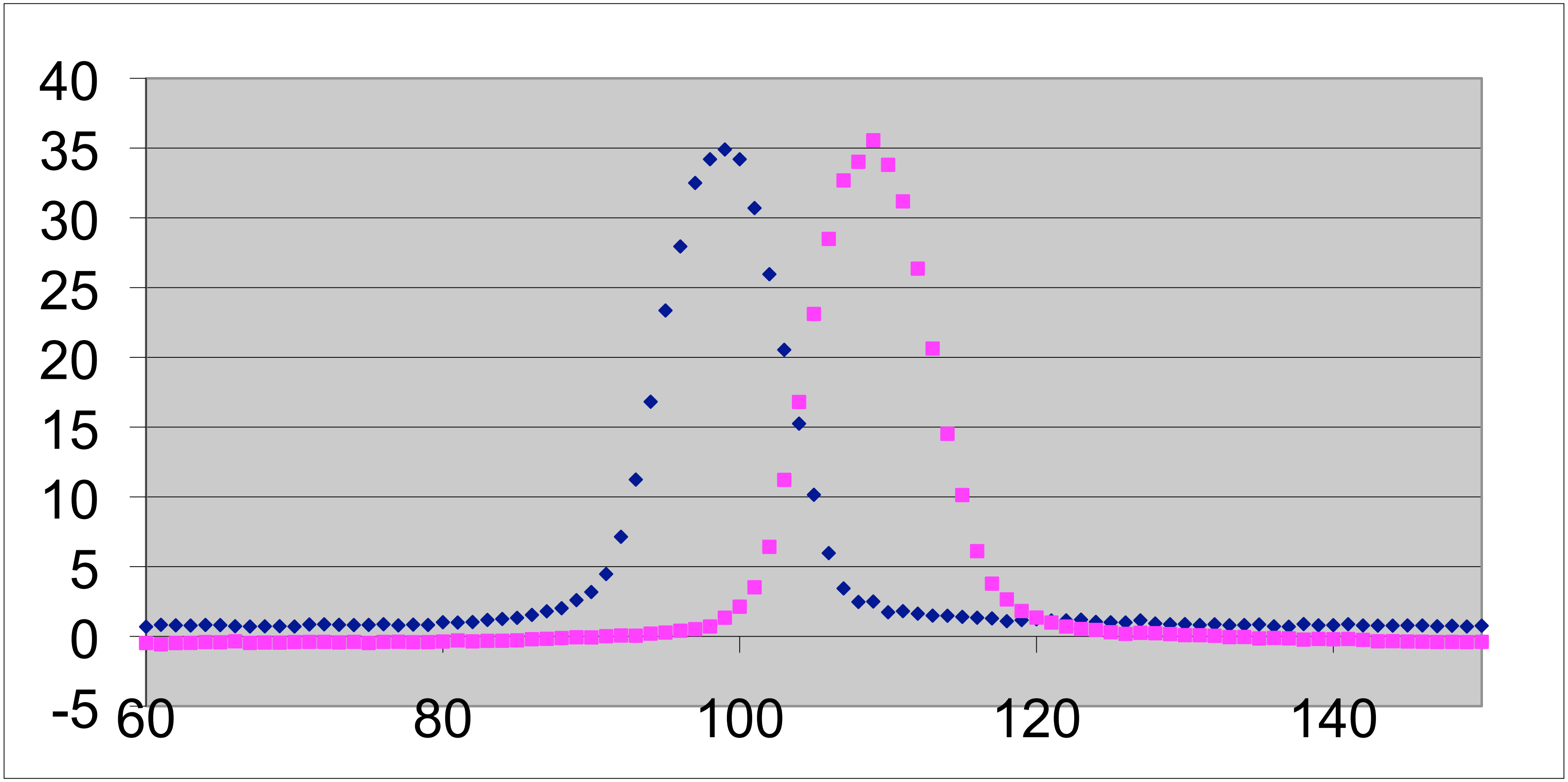


Diffusion Measurements



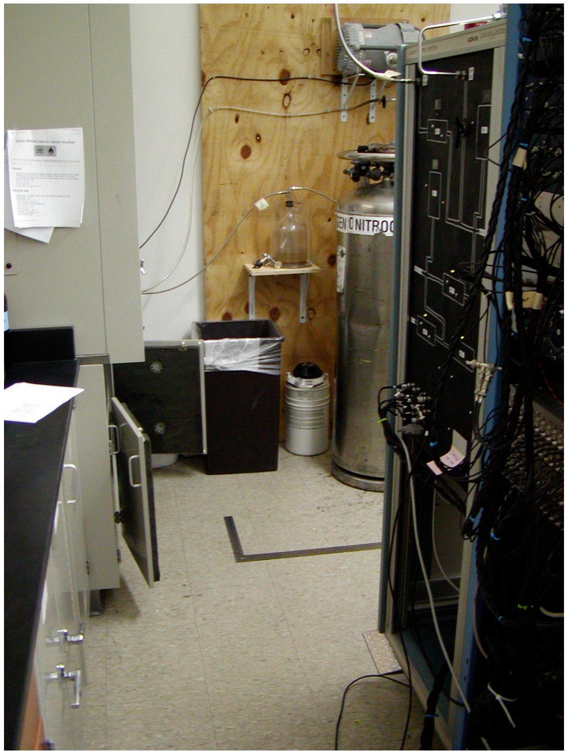
=> μ = 0.525 +/- 0.005 cm^2 atm/Vs

Diffusion Measurements

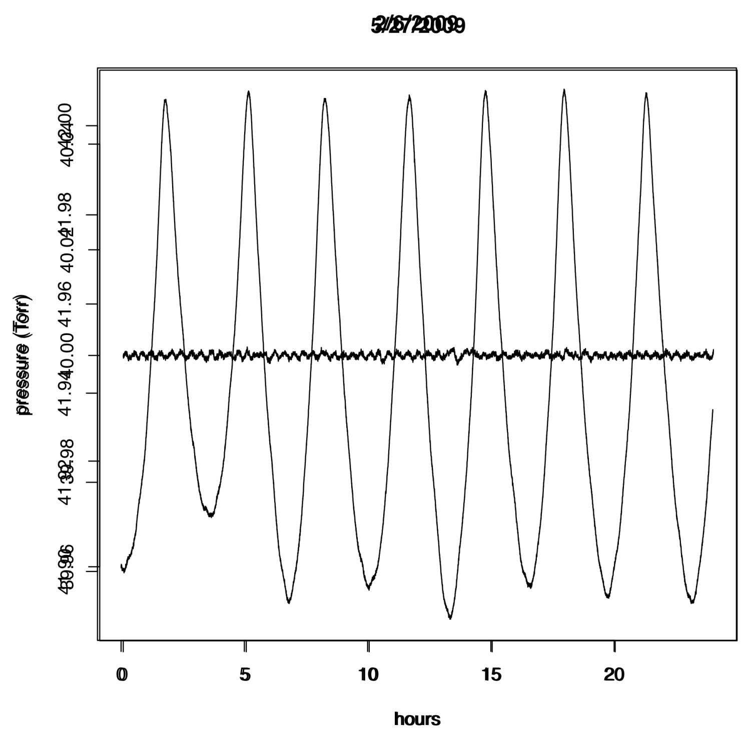


These results we hope to publish by the end of the summer.

Gas Mixture System



For a big DRIFT detector we require a system which can flow a mixture. This was designed and built at Oxy in the Spring of 2009.



Cf-252 neutron source results - Rates

• The gas mixtures were then exposed to a Cf-252 neutron source and recoils recorded.

• Is there any evidence for sensitivity to F recoils? Replacing a CS_2 molecule with a CF_4 molecule increases the number of target nuclei (2 S -> 4 F). Thus, everything else being equal, the rate should go up with increasing CF_4 concentration.

• Voltages for various CS_2-CF_4 gas mixtures were carefully adjusted so that our Fe-55 calibrations were identical, i.e. Y_{55} * gas gains were identical.

• For 3 different gas mixtures the accepted rate of events (after identical cuts) were calculated and backgrounds rates subtracted.

Cf-252 neutron source results - Rates

Mixture (CS_2-CF_4)	# S and F targets per 40 gas molecules	Rate – Background (Hz)
Pure CS_2	80	0.66 +/- 0.02
30-10	100	0.84 +/- 0.03
25-15	110	0.97 +/- 0.03

The observed rate tracks the increase in target nuclei.

Cf-252 neutron source results – Recoil lengths

- A crude calculation suggests that F recoils will be longer than S recoils in a given gas mixture.

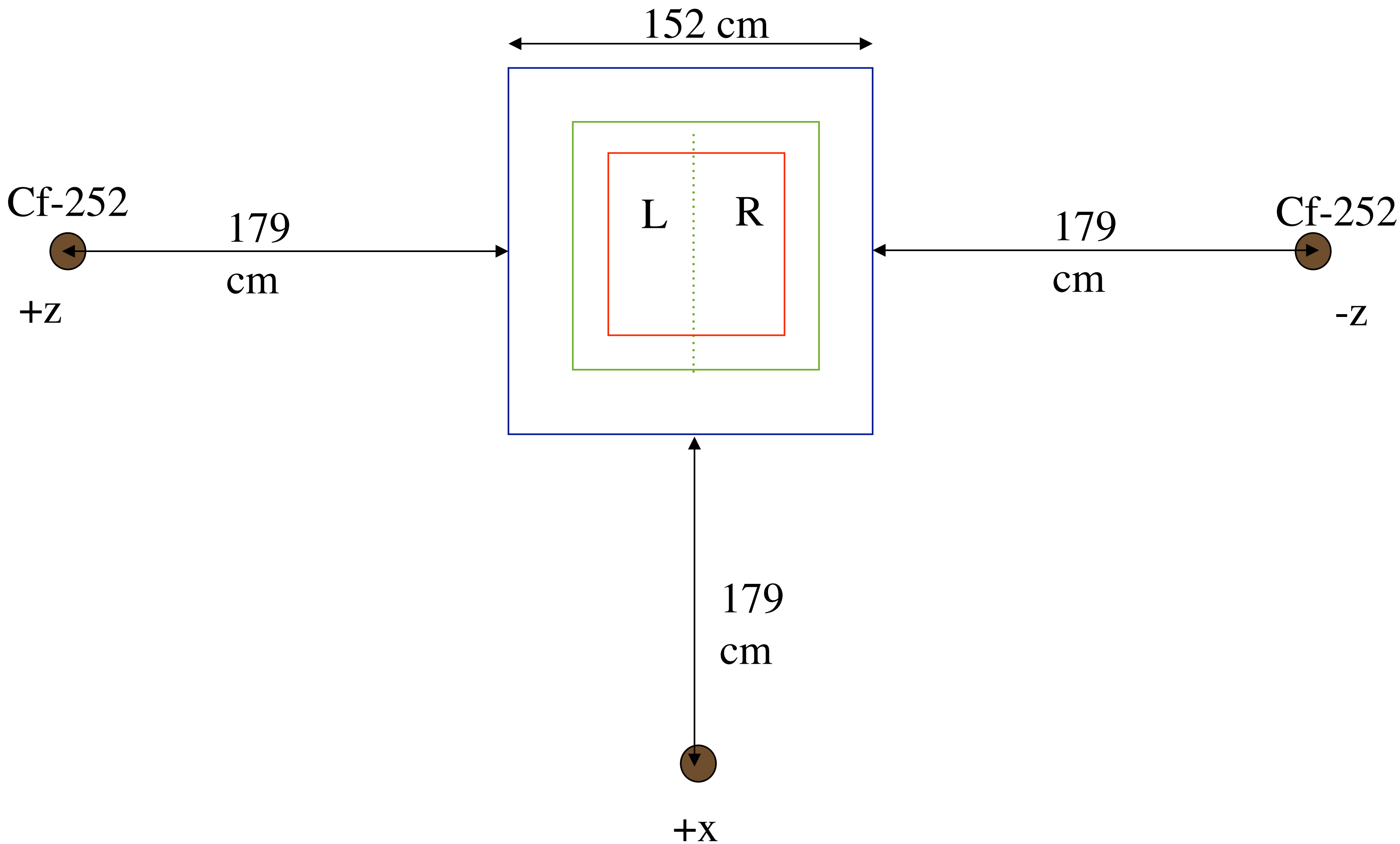
Mixture (CS_2-CF_4)	S:F ratio	<Δz> (cm)
Pure CS_2	80:0	0.254 +/- 0.002
30-10	60:40	0.277 +/- 0.003
25-15	50:60	0.280 +/- 0.002

The average length increases with increasing concentration of F.

Conclusion – We are definitely seeing F recoils in the data.

A word about directionality

- Recoils tend to align with the direction of the source particles be they neutrons or WIMPs.



A word about directionality

Mixture (CS_2-CF_4)	Neutron Direction	<Δz> (cm)
Pure CS_2	z	0.254 +/- 0.002
	x	0.244 +/- 0.002
30-10	z	0.277 +/- 0.003
	x	0.259 +/- 0.002
25-15	z	0.280 +/- 0.002
	x	0.264 +/- 0.002

As discussed in NIMA, 600, 417 (2009) we find difference between x and z directed neutrons reaffirming our claim for a range component signature (RCS) in DRIFT.

A word about directionality

Mixture (CS_2-CF_4)	Number of events (z/x)	Significance
Pure CS_2	1092/1447	3.5
30-10	1170/978	5.0
25-15	2726/1586	5.7

Conclusion – The RCS is at least as good with gas mixtures and may, in fact, be better than with pure CS_2.

We have also looked at the head-tail signature (HTS), discussed in more detail in APP, 31, 216 (2009), and found it to be slightly improved in the mixtures but not as much as shown above.

Gas mixture system moved to Boulby

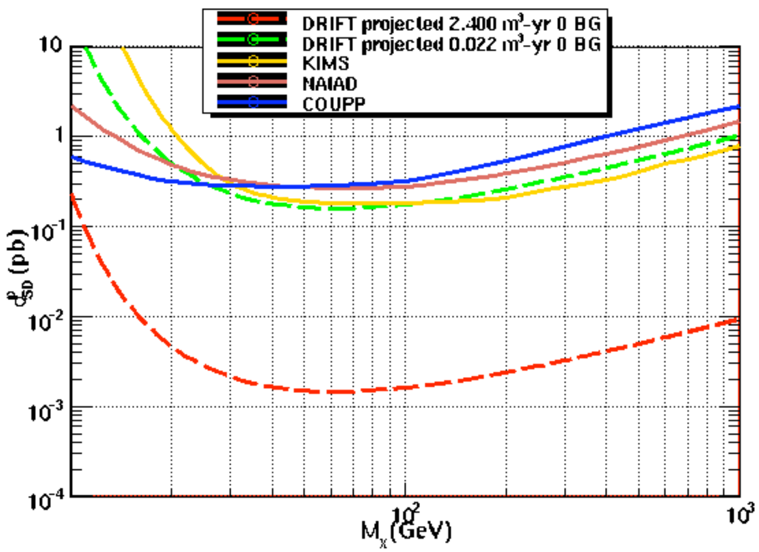
- Installed and operational in 1 day.
- DRIFT-IIb renamed DRIFT-IId
- Run for several days. Data taking to start next week.

The Plan

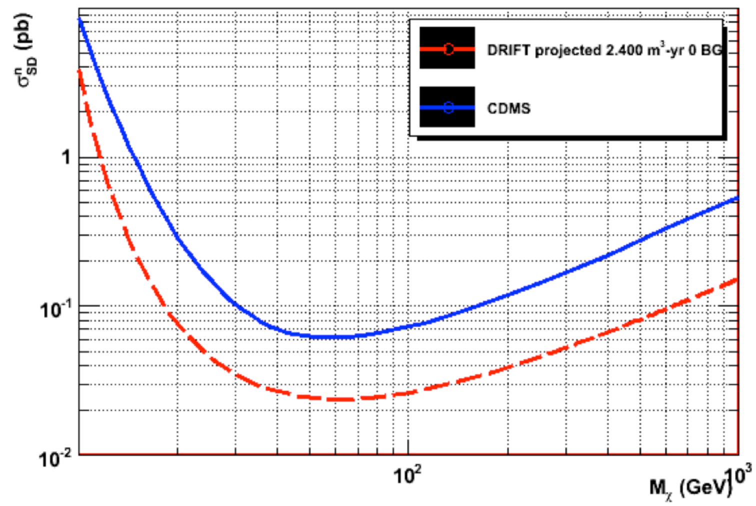
- We have recently received renewed funding from the NSF.
- Our plan is to run DRIFT-IId for 3 years starting next week.
- We also plan to leverage off of existing equipment, a spare vacuum vessel in Boulby, for instance, to build DRIFT-IIe.
- We hope to acquire 2.4 m^3-years of exposure starting next week.
- Much work remains to find the quenching factor and range for these gas mixtures – Santos.
- What could we expect from this data.

Expected Limits

SD WIMP-p Limits



SD WIMP-n Limits



SI Limits