DRIFT

Progress with DRIFT

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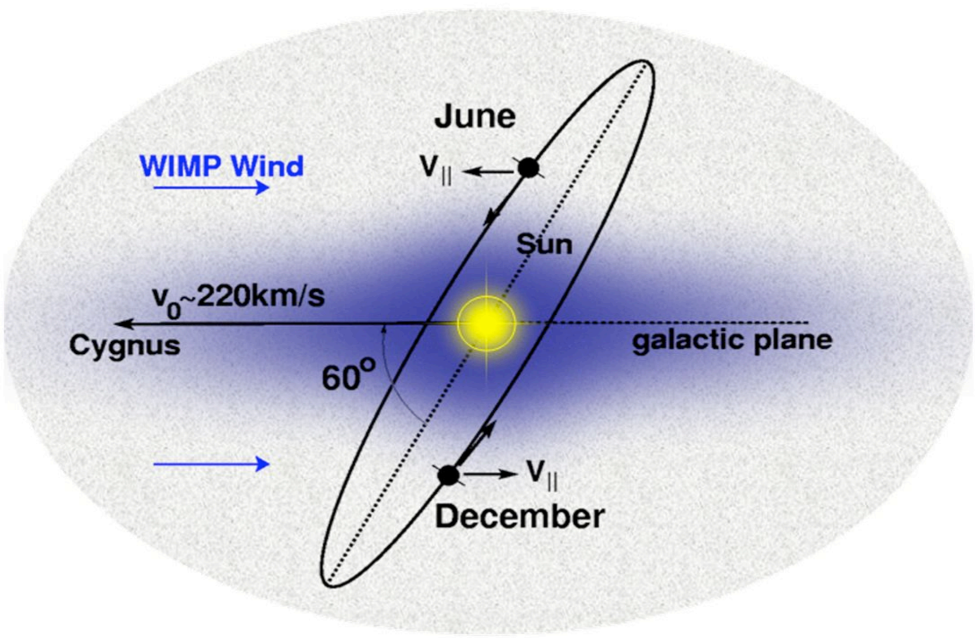
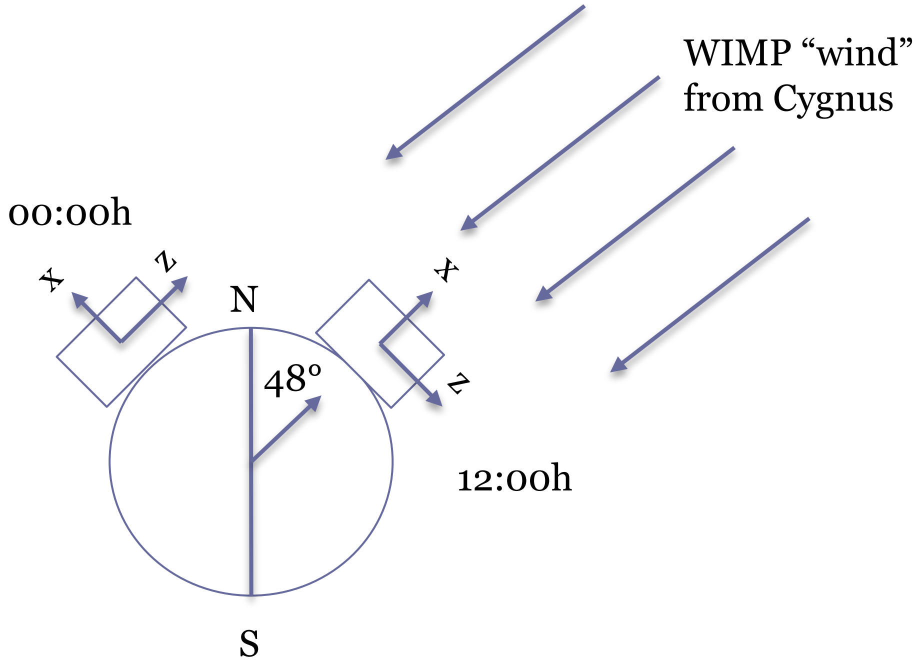
Dark matter signals – The WIMP wind

- Galaxy is within an isotropic WIMP halo.
- Motion of Earth through WIMPs creates apparent WIMP 'wind'.
- Orbit of Milky Way on galactic plane.
- Average velocity~220kms^{-1}, coming roughly from the direction of the constellation Cygnus.
- Rotation of Earth round the Sun creates a second component of the 'wind' velocity.
- Orbital velocity of $v_{orb} \approx 30$kms^{-1} at $i \approx 60°$.
- Modulation of $v_{orb}\cos(i) \approx 15$kms^{-1}.



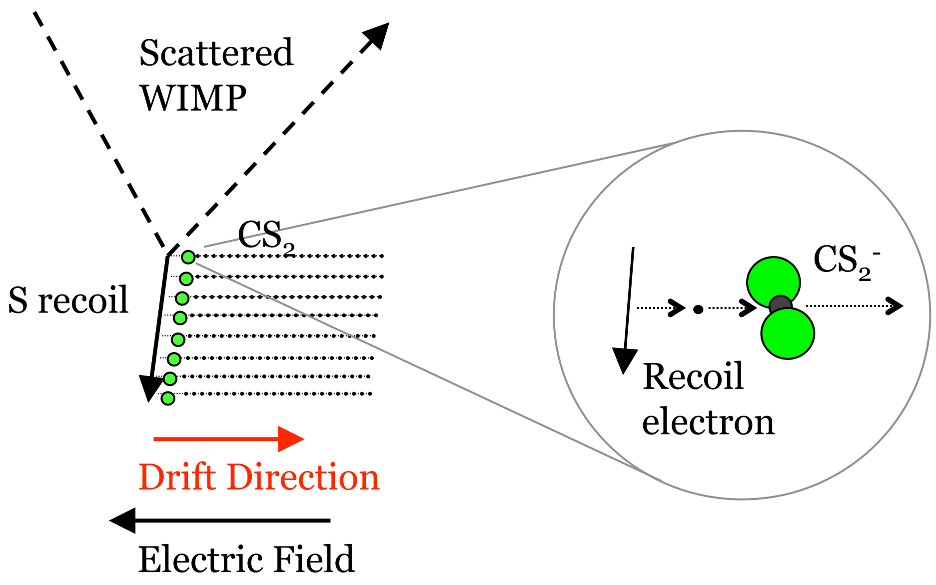
Directional dependence

- Change in the direction of the WIMP ‘wind’ caused by the Earths rotation.
- Detector at 48° North latitude.
- Sidereal day is out of phase with terrestrial day.
- Cannot be mimicked by any terrestrial background.
- Positive detection with only tens of events.



Directional detection with a negative ion TCP

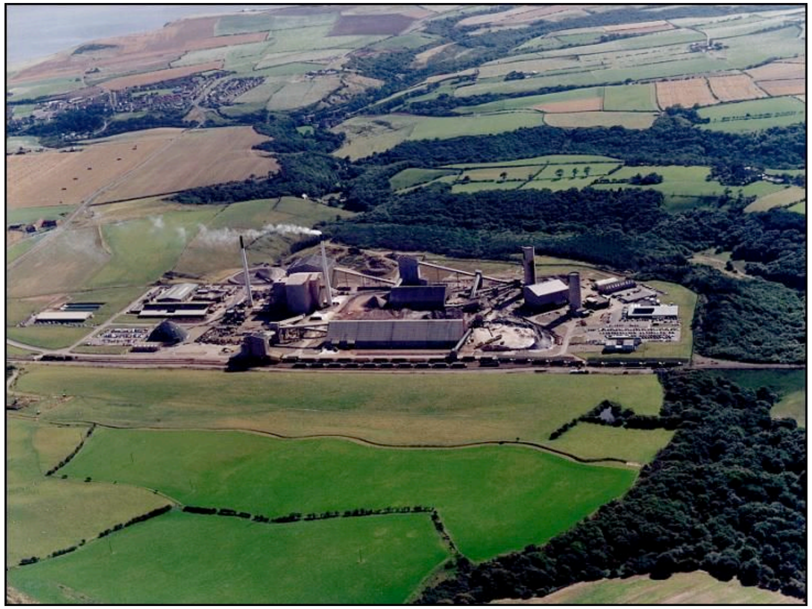
- Require long nuclear recoils for directional information
  - Use a TPC with a low pressure gas as a target material
- Require a reasonable target mass
  - Use a large volume detector
- Need to minimise diffusion of ionisation track
  - Negative Ion TCP

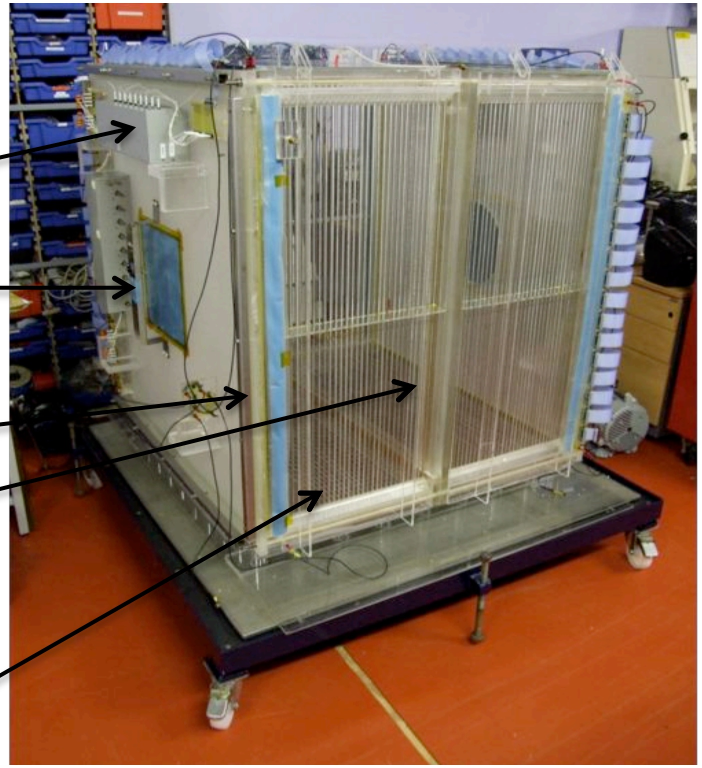


- Electronegative CS_2 molecules transport electrons to the MWPC readout plane with only thermal diffusion.
- At MWPC electrons are stripped from the CS_2^- ion and avalanche in the normal fashion.
- Standard TPC – electrons at ~1000ms^{-1}.
- NI TPC – ions at ~50ms^{-1}.
- Minimises diffusion
- Improves spatial resolution

DRIFT detector

- 1100m underground in Boulby mine, N. Yorkshire
- At a latitude of 54°.
- 1.5m×1.5m×1.5m stainless steel vacuum vessel.
- Polypropylene pellet neutron shielding – equivalent to 40gcm^{-2} solid hydrocarbon.
- 0.8m^3 fiducial volume – 134g CS_2 target mass.
- Central cathode plane– 512 20 μ m wires.
- MWPC - anode plane of 512 20 μ m horizontal wires sandwiched between two planes of 512 perpendicular 100 μ m wires (2mm pitch).
- Field cage – 31 stainless steel rings.





Recent publications

- Evidence of directional sensitivity (http://arxiv.org/abs/0807.3969)

S. Burgos et al., Nucl. Instrum. and Meth. in Phys. Res. A600 (2009) 417

  - Simulation - ^{252}Cf source produces S recoils similar to expected WIMP induced recoils.
  - ^{252}Cf source placed on each principal axis – directional bias seen in each case.
  - Demonstrated directional sensitivity to nuclear recoils at energy thresholds relevant to dark matter searches (1.5 keV/amu).

- Head-tail discrimination (http://arxiv.org/abs/0809.1831v1)

S. Burgos et al., Astroparticle Physics 31 (2009) 261

  - Demonstrated that neutron induced sulfur recoils in the DRIFT detector have a clear asymmetry.
  - Head-tail discrimination reduces no. of WIMP events required by an order of magnitude.

- Low energy thresholds (http://arxiv.org/abs/0903.0326v2)

S. Burgos et al., JINST 4 (2009) P04014

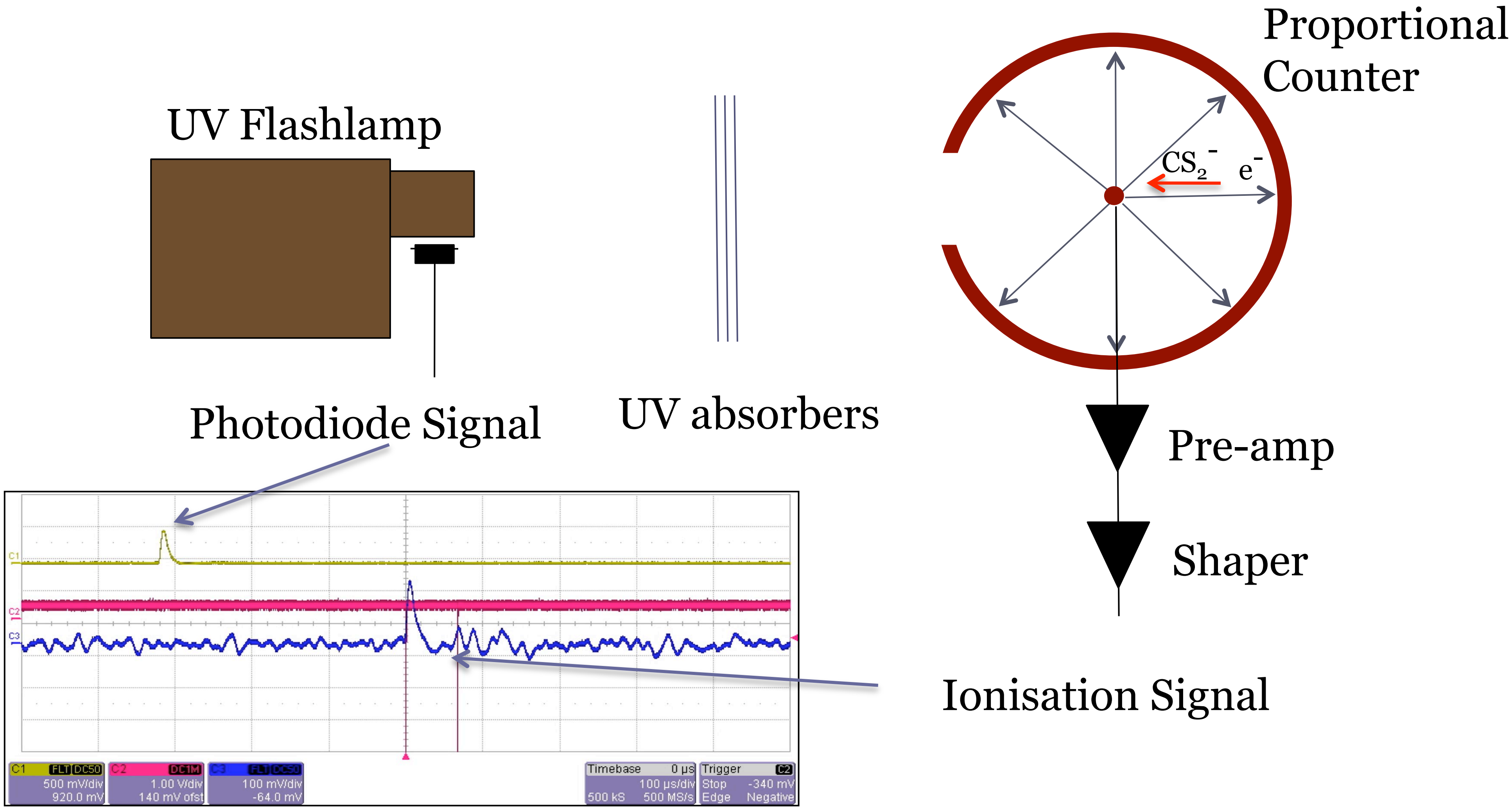
  - Digital polynomial filtering used to produce ^{55}Fe spectra with a visible escape peak.
  - Demonstrates the potential of DRIFT to detect sulfur recoils down to ~4keV.

Latest project: DRIFT with spin dependent gas mixtures

- DRIFT could be a competitive spin dependent dark matter detector with the addition of an odd nucleon gas.
- CF_4 is attractive candidate:
    - ^{19}F has two unpaired nucleons – high SD sensitivity.
    - ^{19}F has best known spin figure of merit of usable elements.
    - ^{19}F is light.
    - CF_4 is cheap, non-toxic, non-flammable.

- Can DRIFT operate with a CS_2-CF_4 gas mixture?
    - Is negative ion drift preserved?
    - How is MWPC readout affected?

Gas measurements with a single electron proportional counter



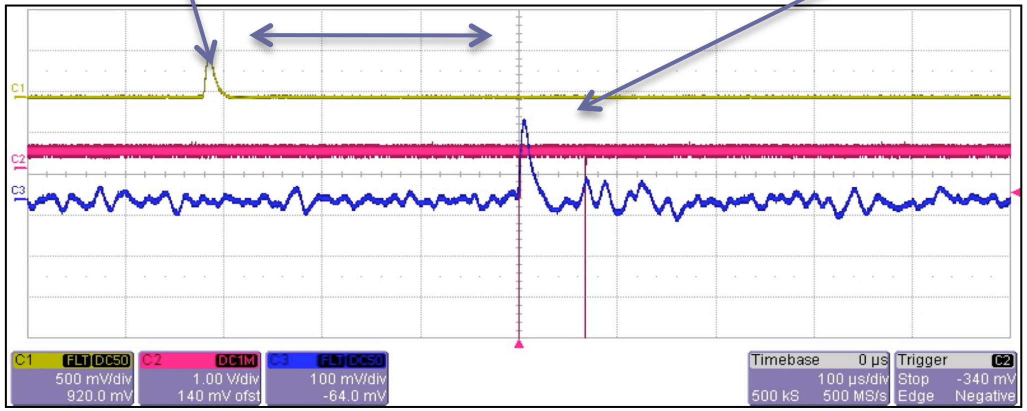
Thanks to Dan Snowden-Ifft, Occidental College

CF_4 - CS_2 tests: Mobility

PD Signal

Drift time

Ionisation Signal



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

- Negative ion drift is preserved up to mixtures with 75% CF_4.
- Mobility increases with CF_4 concentration.
- Above 75% CF_4 electron capture path length fluctuates substantially.

Gas Mixture CS2 – CF4 (Torr)	Voltage (V)	Drift time (μ s)	Reduced mobility, μ (cm² atm/Vs)
40 - 0	1600	270.8±0.2	0.54±0.02
30 - 10	1550	250.1±0.2	0.60±0.02
20 - 20	1350	251.0±0.3	0.69±0.02
10 - 30	1300	222.0±0.3	0.81±0.03

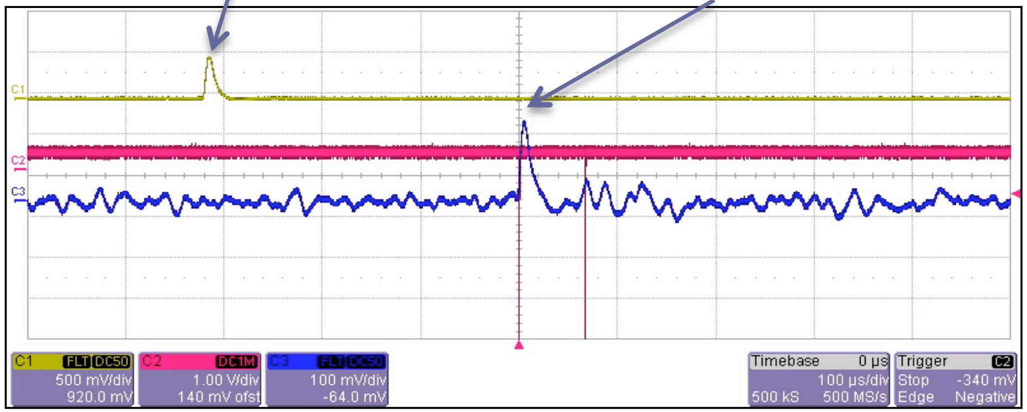
Thanks to Dan Snowden-Ifft, Occidental College

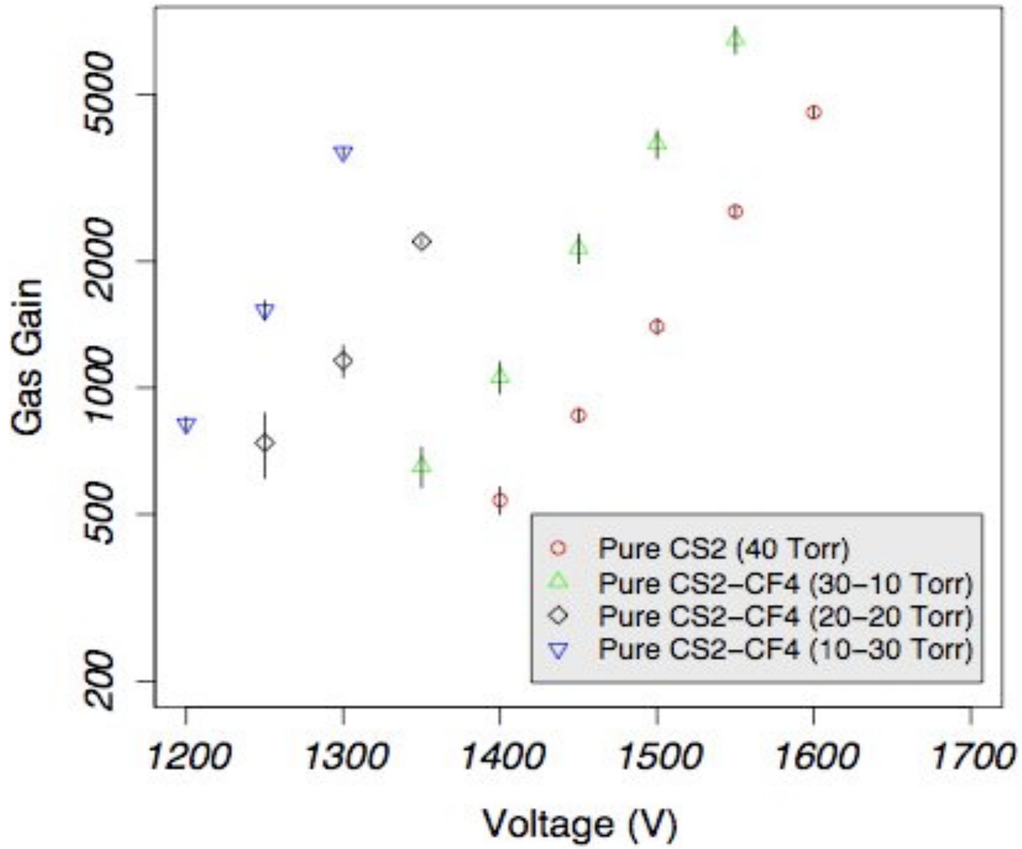
CF_4 - CS_2 tests: Gas gain

- Measure size of event from a single electron.
- We know the multiplication from the amplifier chain.
- Adding CF_4 increases gas gain.
- Improved sensitivity to low E events.
- Reduced stability of high voltage system.

PD Signal

Ionisation Signal





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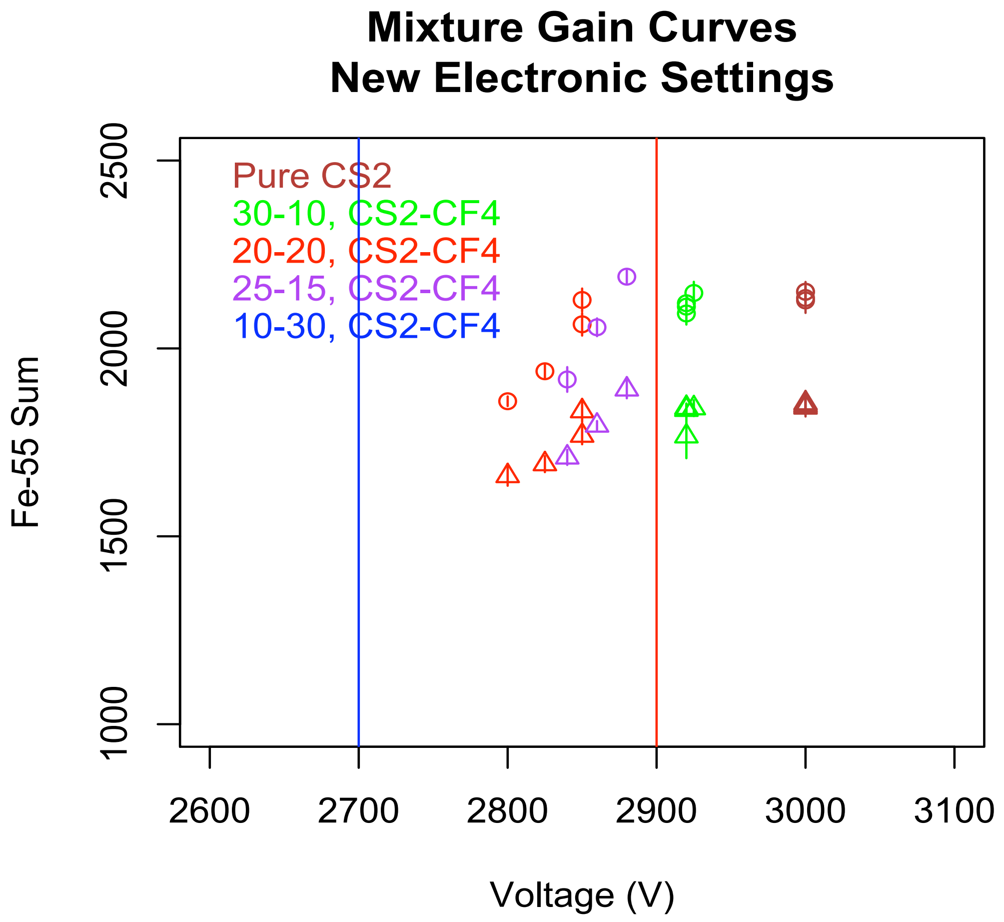
CS_2-CF_4 in full scale detector

- DRIFT detector concept still works with up to 75% CF_4.
- Gas gain increases.
- High voltage stability decreases.
- MWPC voltages were chosen such that ^{55}Fe ionisation yield × gas gain is constant in each mixture.
- Allows direct comparison of gas mixtures.



Neutron calibration data

- Increase in CF_4 -> increase in no. of target molecules -> increase in event rate.

Gas Mixture CS2 – CF4 (Torr)	# of target nuclei per 40 gas molecules	Event rate (Background subtracted - Hz)
40 - 0	80	0.66±0.02
30 - 10	100	0.84±0.03
25 - 15	110	0.97±0.03

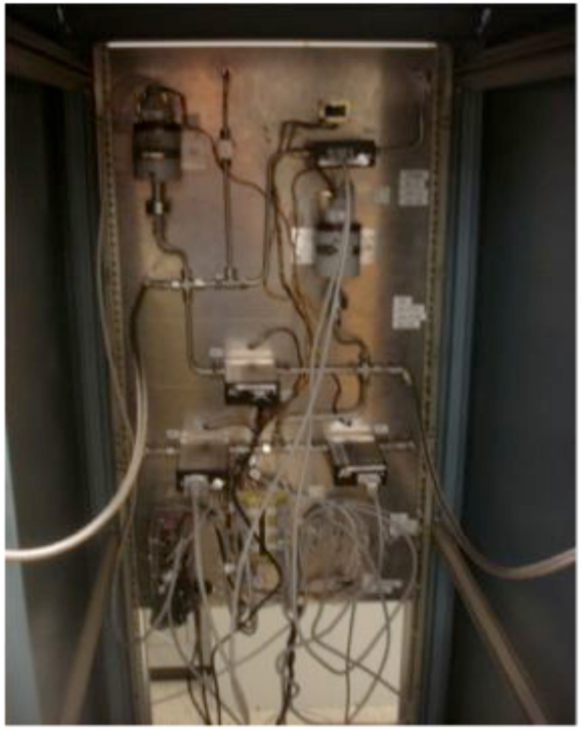
- F recoils are longer than S recoils-> increase in average recoil length.

Mixture CS2 – CF4 (Torr)	S:F ratio	Neutron Direction	Δz (cm)
40 - 0	80:00	z	0.254±0.002
30 -10	60:40	z	0.277±0.003
25-15	50:60	z	0.280±0.002

- We are seeing Fluorine recoils.
- Simulations are under way to further understand the gas mixtures.

Gas mixing system

- Require constant flow of mixed gas in vacuum vessel to maintain gas purity.
- Gas mixing system designed, built, and tested at Occidental College, Los Angeles.
- System of mass flow controllers and capacitance manometers to accurately control and monitor gas flow.
- Integrated into the current DRIFT slow control allowing remote monitoring and control.
- Installed underground at the Boulby mine and running within 2 days.
- First 10 days of continuous running.



Conclusions

- Much progress made in last two years - Published
  - Directional sensitivity in 1m³ detector.
  - Head-tail asymmetry in 1m³ detector.
  - Potential of DRIFT to detect low energy events.
- CS_2-CF_4 gas mixtures
  - Mobility and gas gain measurements using single electron proportional counter.
  - Operated a 1m³ NI-TPC DRIFT detector with various CS_2-CF_4 gas mixtures.
  - Neutron calibration data indicates that we are seeing F recoils.
  - Achieved stable runs in an underground detector.
- Current work
  - Simulations to further understand CS_2-CF_4 gas mixtures.
  - Further CS_2-CF_4 gas measurements – Diffusion.
  - Analysis of first underground runs.
- Next
  - Continue taking data.
  - Spin dependent limits.