Minority Carriers: A Revolution for Low Background TPC Work

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7th Symposium on Large TPCs for Low Energy Rare Event Detection

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Directional Recoil Identification From Tracks (DRIFT)

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Dinesh Loomba - PI
Michael Gold – PI
John Matthews - PI
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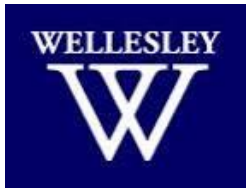

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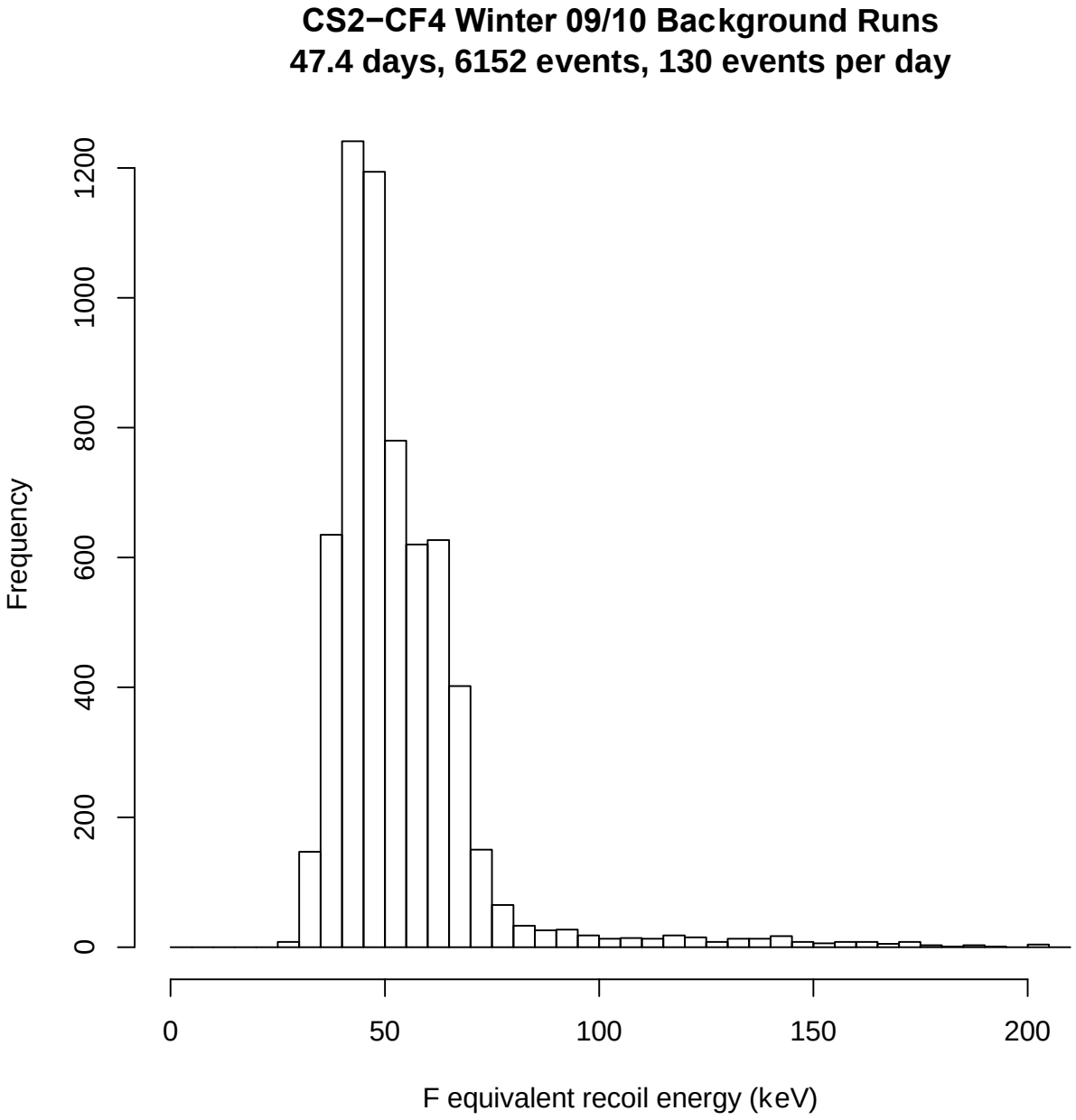
Emma Meehan
Louise Yeoman

Introduction to DRIFT

- Directional Recoil Identification From Tracks (DRIFT) is a directional dark matter detector (PRD, **61** (2000) 1, NIMA, **600** (2009) 417, AstroPle, **31** (2009) 261)
- DRIFT has been operating in Boulby since 2001
- DRIFT-I -> DRIFT-II (a-e)
- DRIFT-IId volume = 0.8 m^3, ~40 Torr gas
- MWPC readouts (NIMA, **555** (2005) 173)
- Negative CS_2 anion drift to limit diffusion (PRD, **61** (2000) 1)
- Phenomenal Compton background rejection (AstroPle, **28** (2007) 409)
- Many gas mixtures possible
- DRIFT-IId used a 30-10 Torr of CS_2-CF_4 to optimize for spin-dependent limits, 139 g target mass. (AstroPle, **35**(2007) 397)
- Relatively cheap, clean, stable and scalable technology.

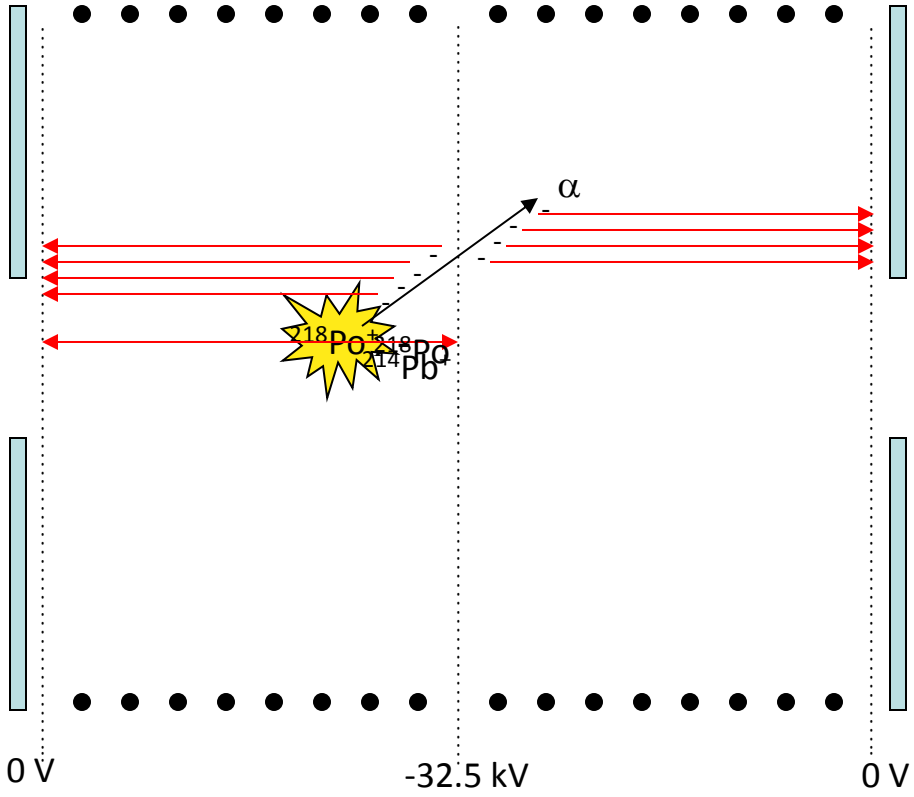
DRIFT-IId Data

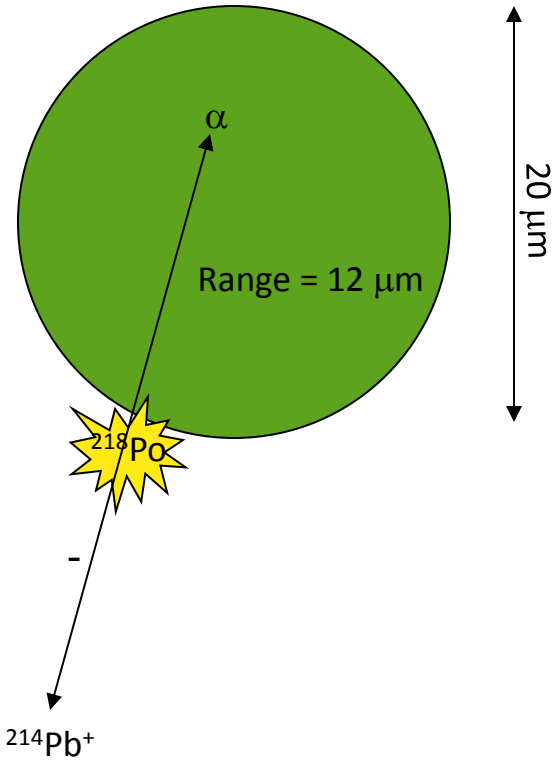


- 47.4 days of live time recorded
- A background of 130 events per day found

AstroPle, **35**, (2012) 397.

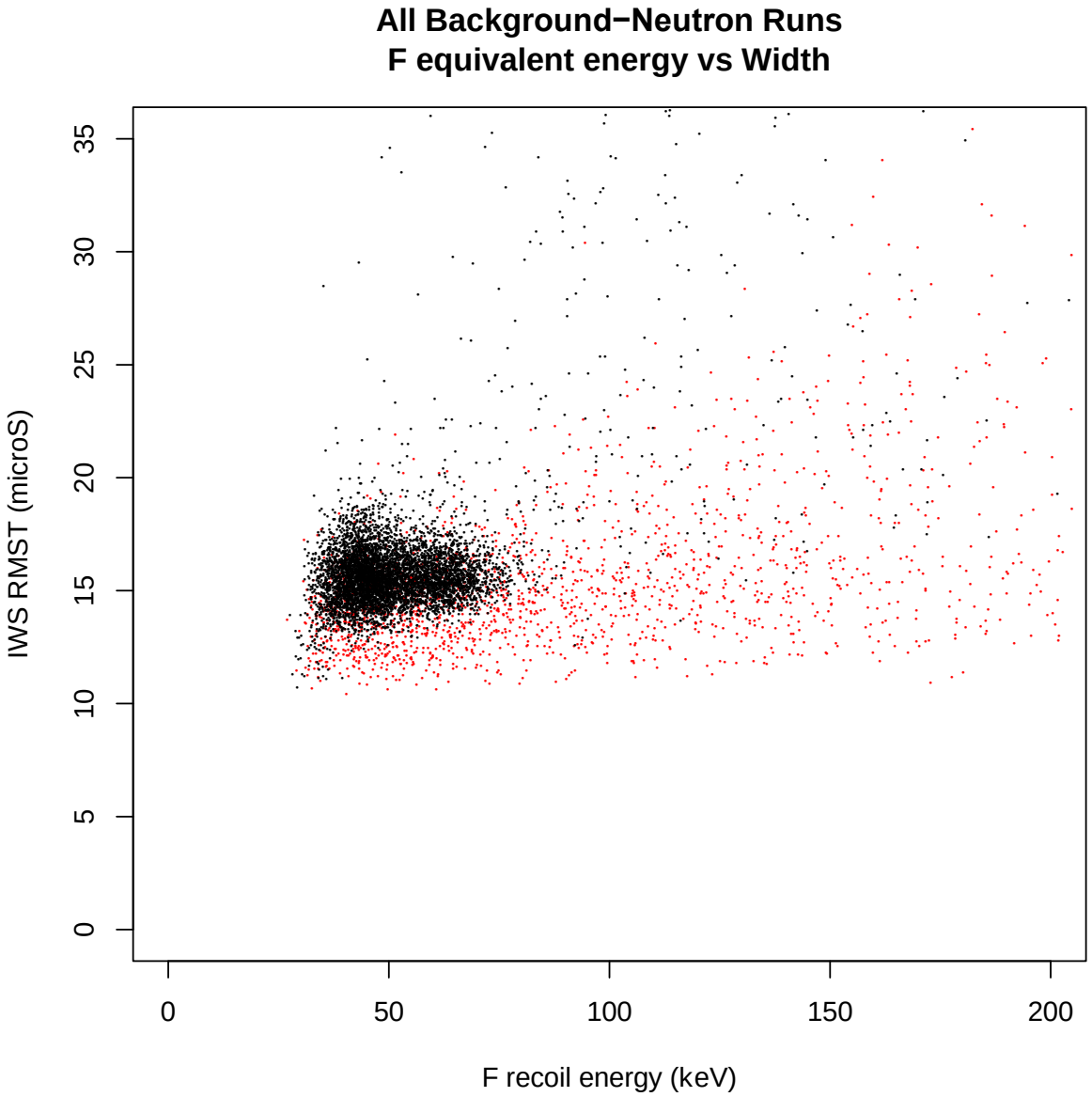
Radon Progeny Recoils





AstroPle, **28**, (2007) 409.

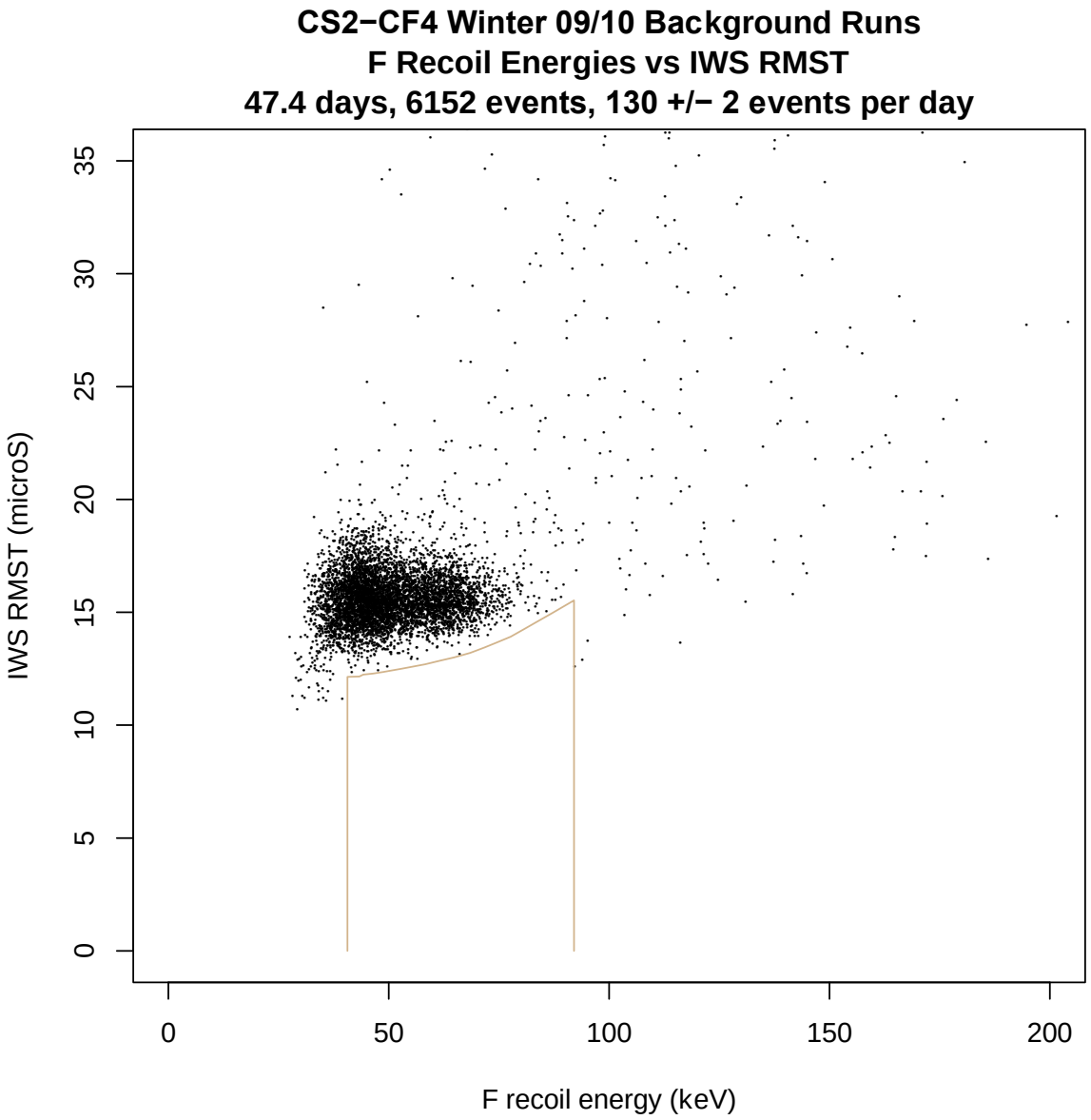
DRIFT-IId Data



- Diffusion of the RPRs from the central cathode increases their width
- So used width as a crude discrimination parameter
- Black = Background
- Red = Neutron recoils

AstroPle, **35**, (2012) 397.

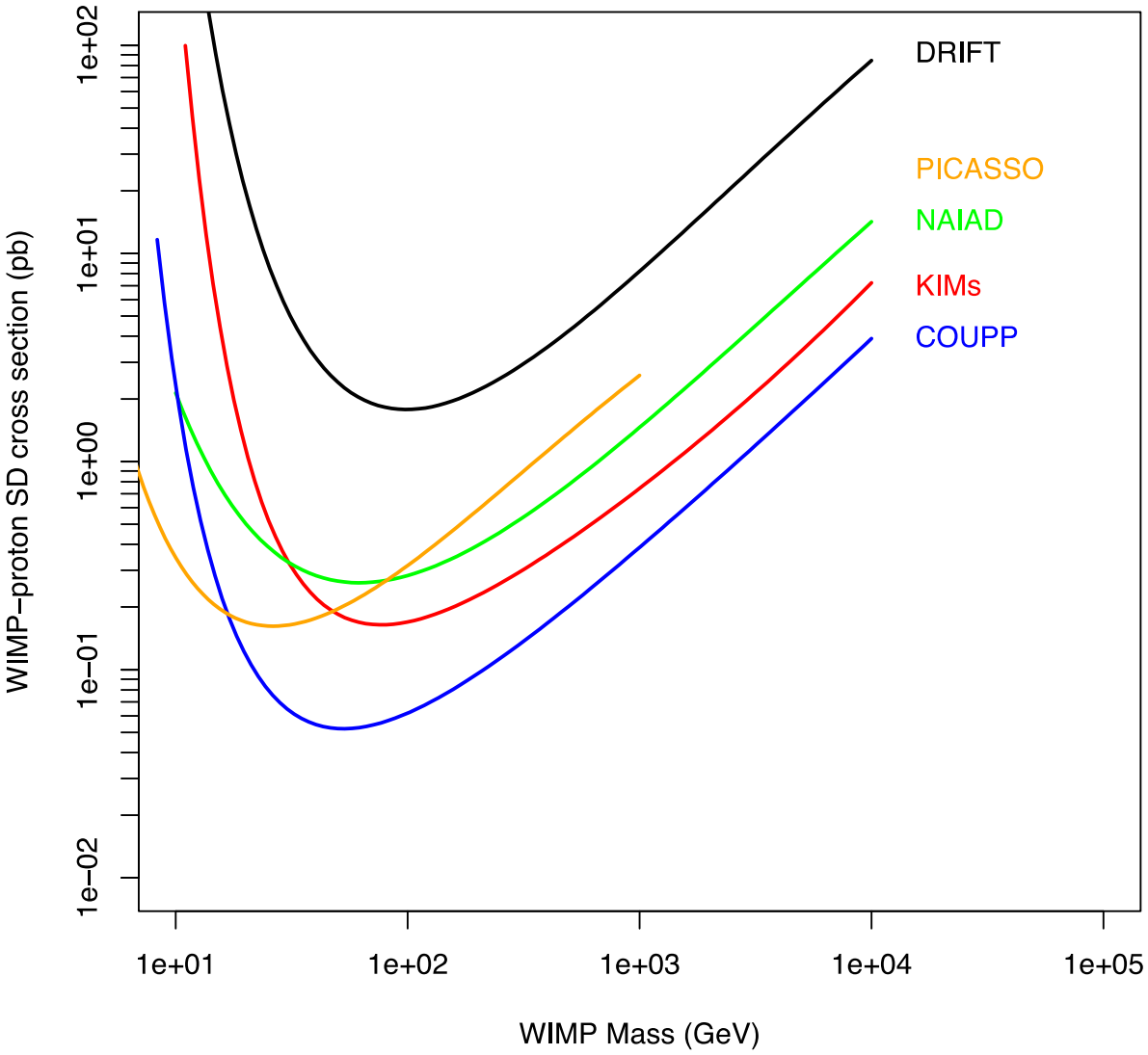
DRIFT-IId Data



- Select an signal window
- For 100 GeV WIMPs the signal window gives only 8% efficiency for events passing the cuts

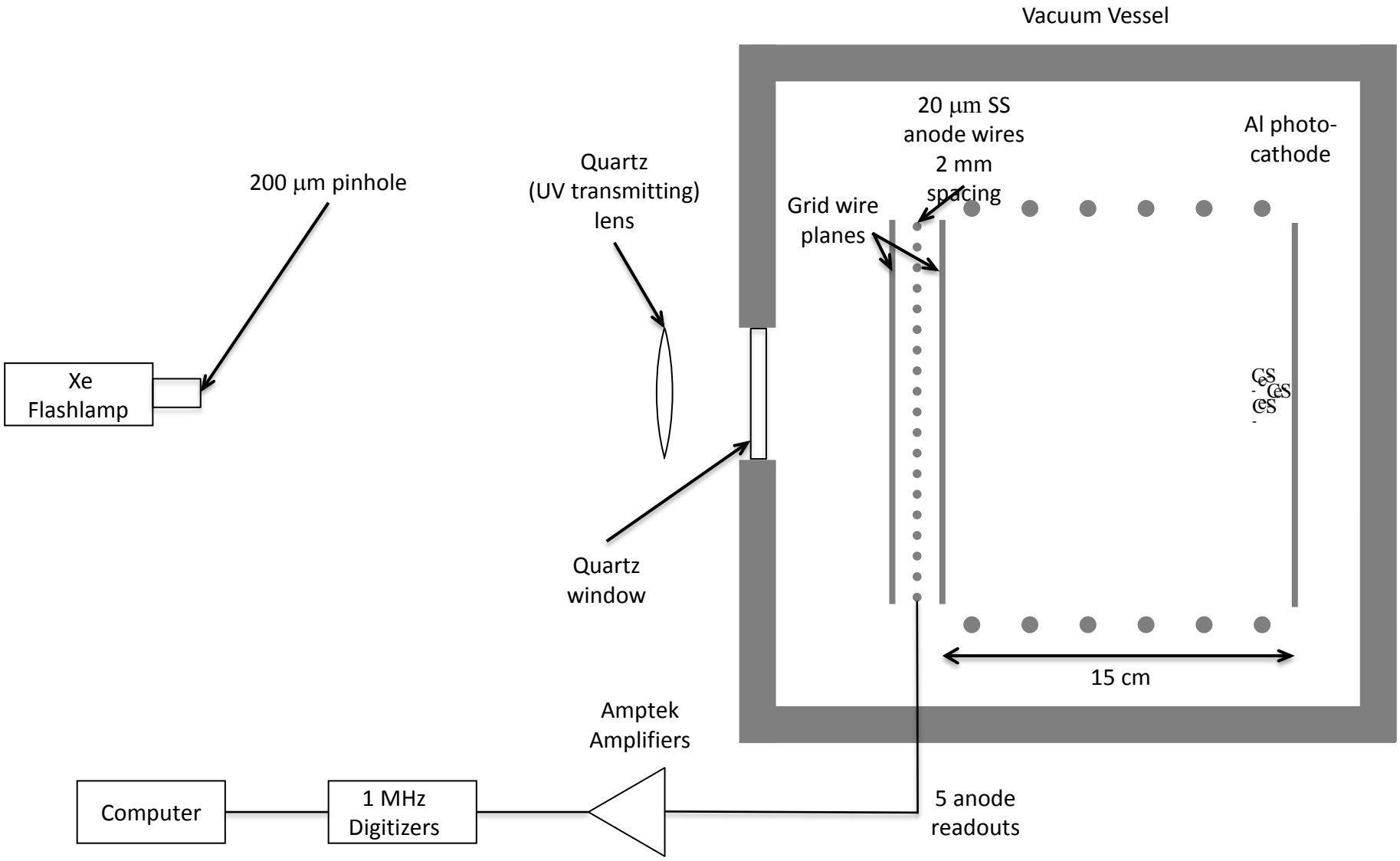
AstroPle, **35**, (2012) 397.

DRIFT-IId Spin-Dependent WIMP Limits

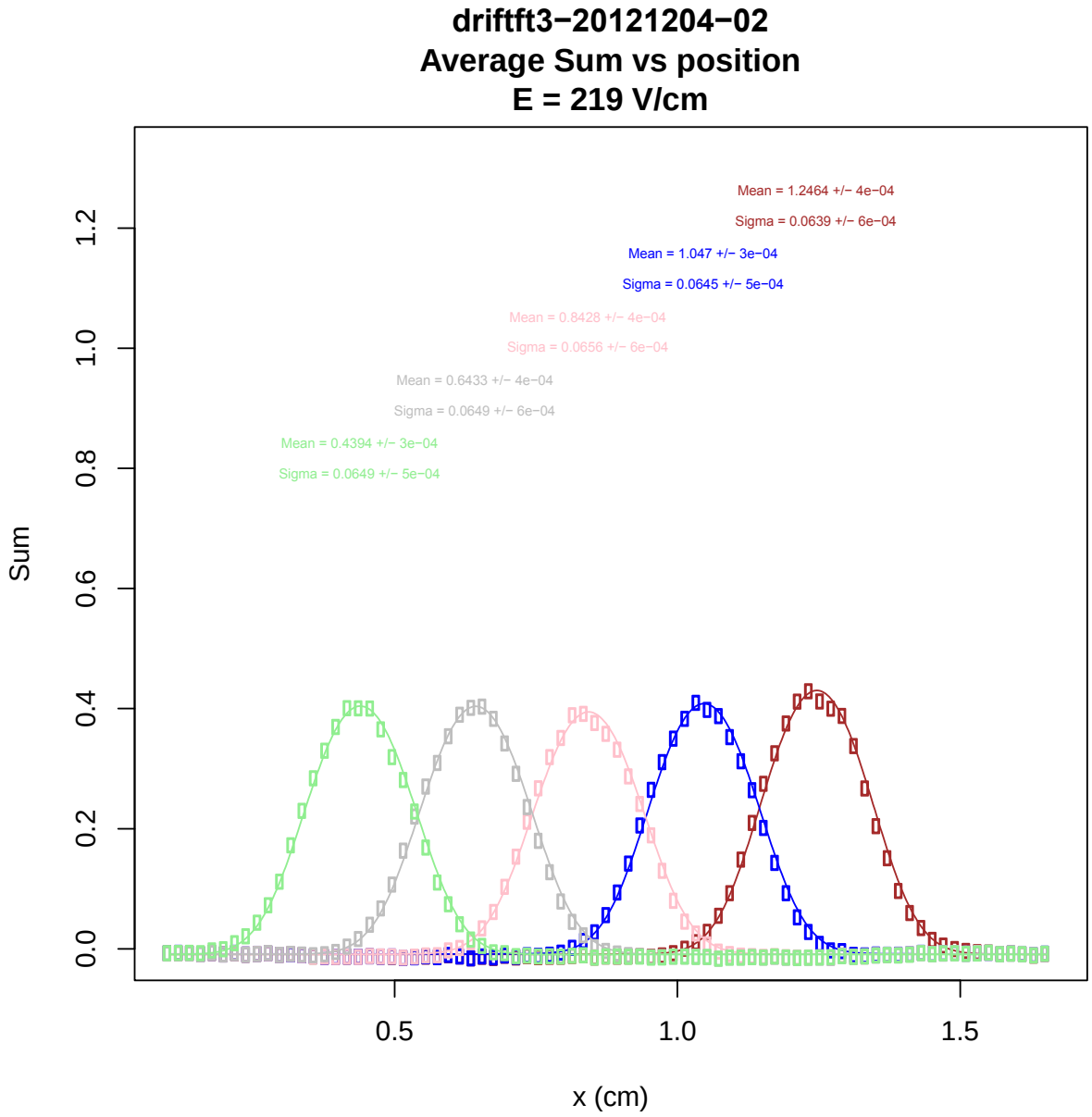


AstroPle, **35**, (2012) 397.

Mobility and Diffusion Experiment



Lateral Diffusion Measurements

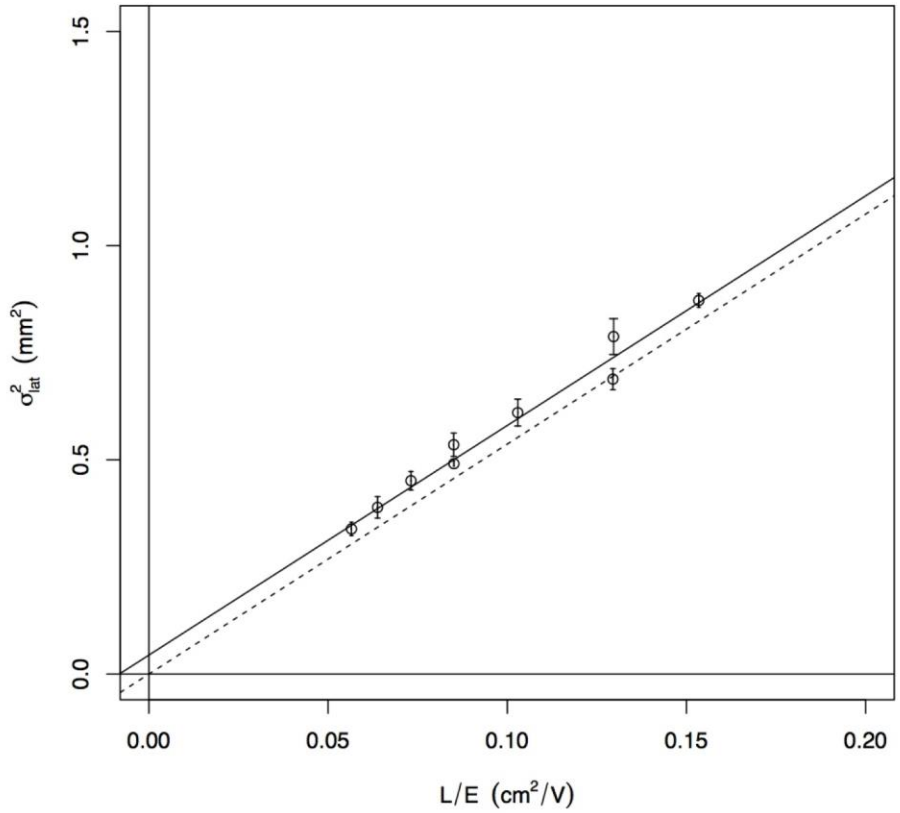


Diffusion Theory

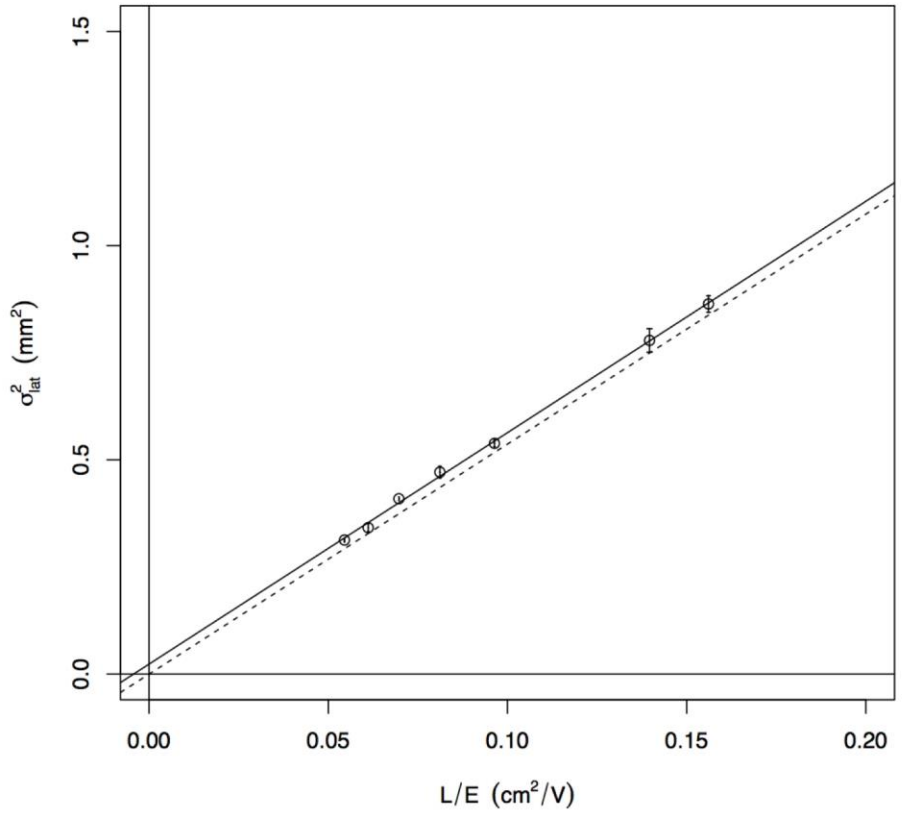
$$s^2 = \frac{2kTL}{eE}$$

Lateral Diffusion Results

40 Torr CS_2



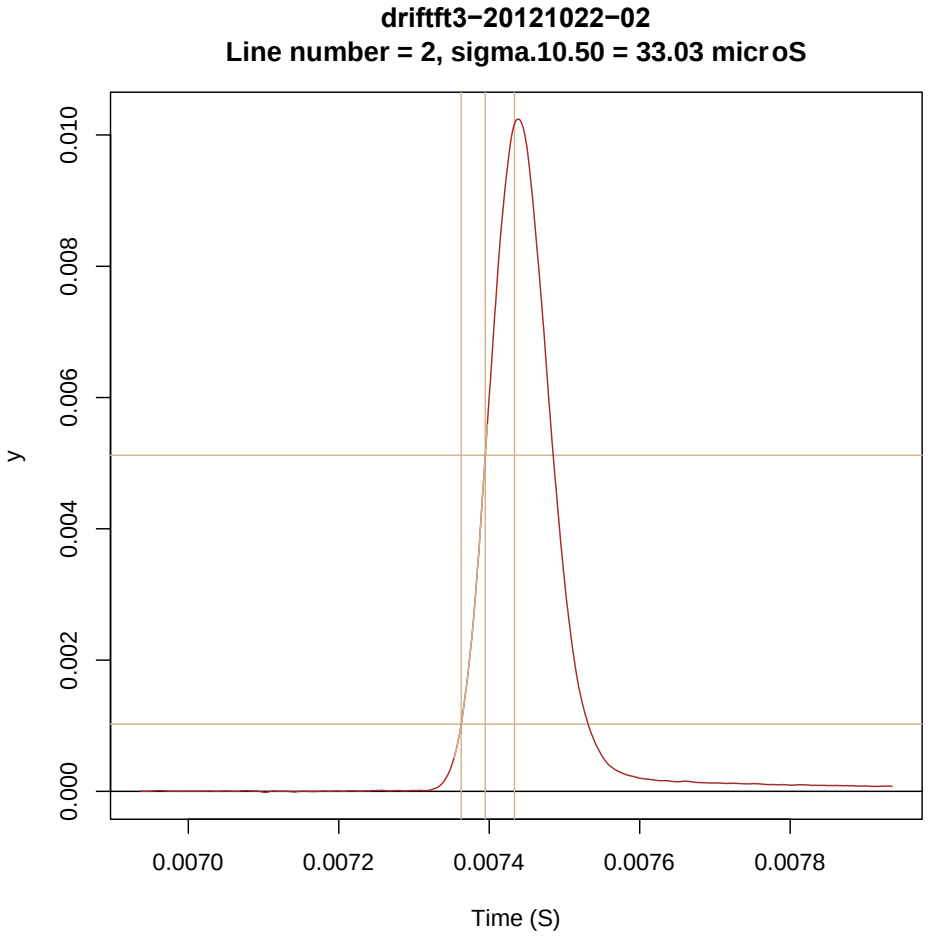
30-10 Torr CS_2+CF_4



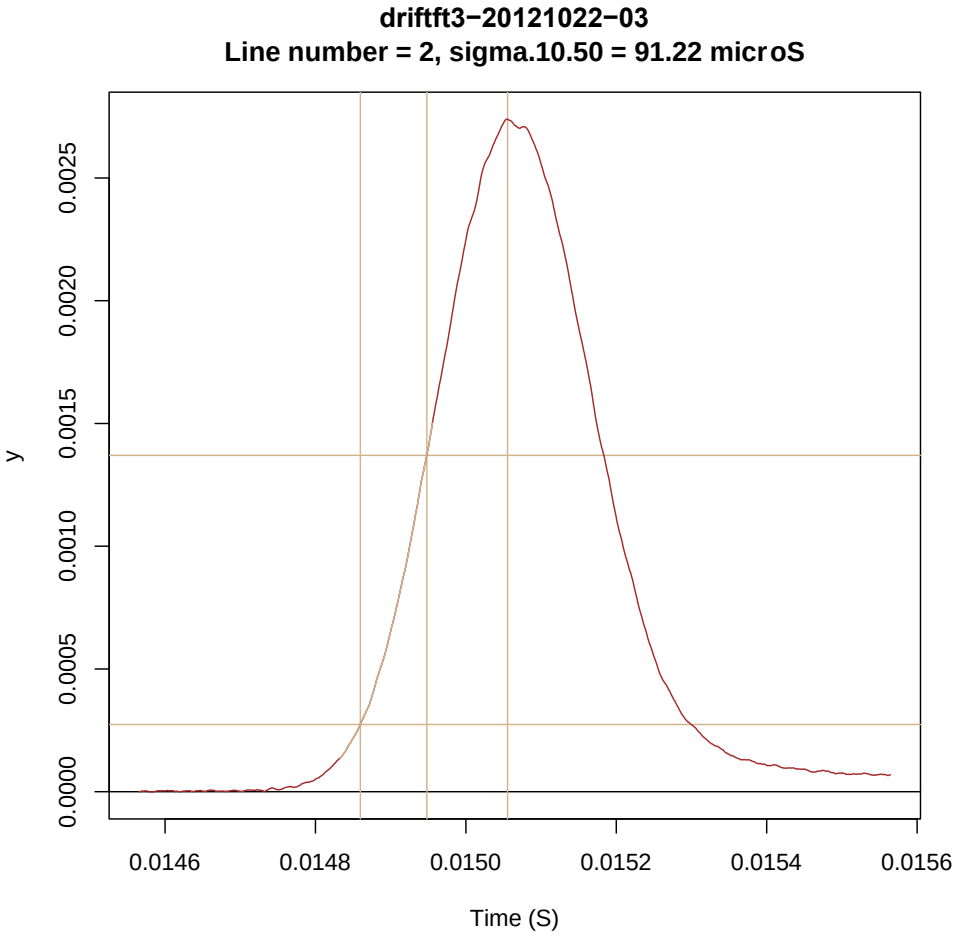
Rev. Sci. Inst., **84**, (2013) 1.

Longitudinal Diffusion Measurements

E = 239 V/cm



E = 118 V/cm



⟵ t = 0 => flashlamp pulse

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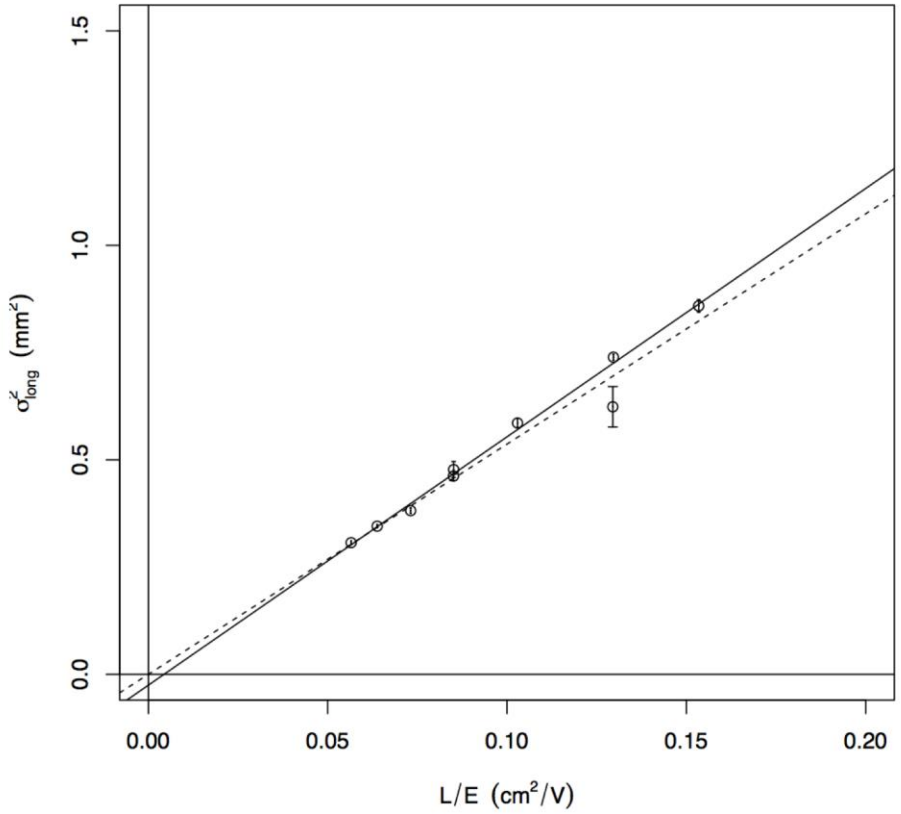
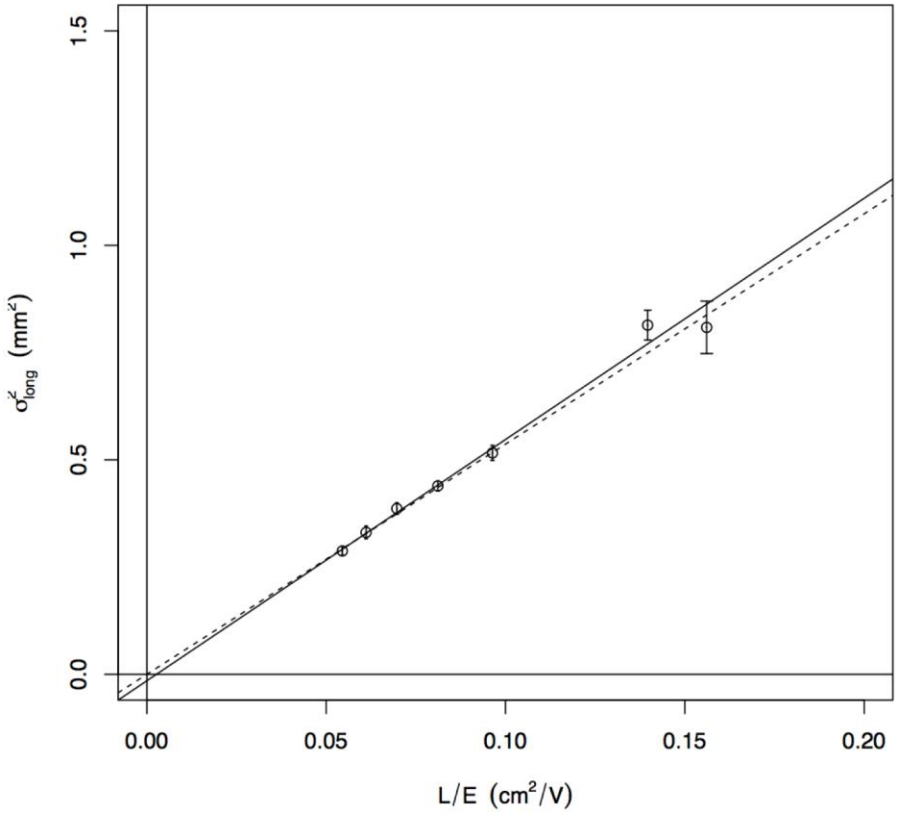
Longitudinal Diffusion Results

40 Torr CS_2



30-10 Torr CS_2+CF_4



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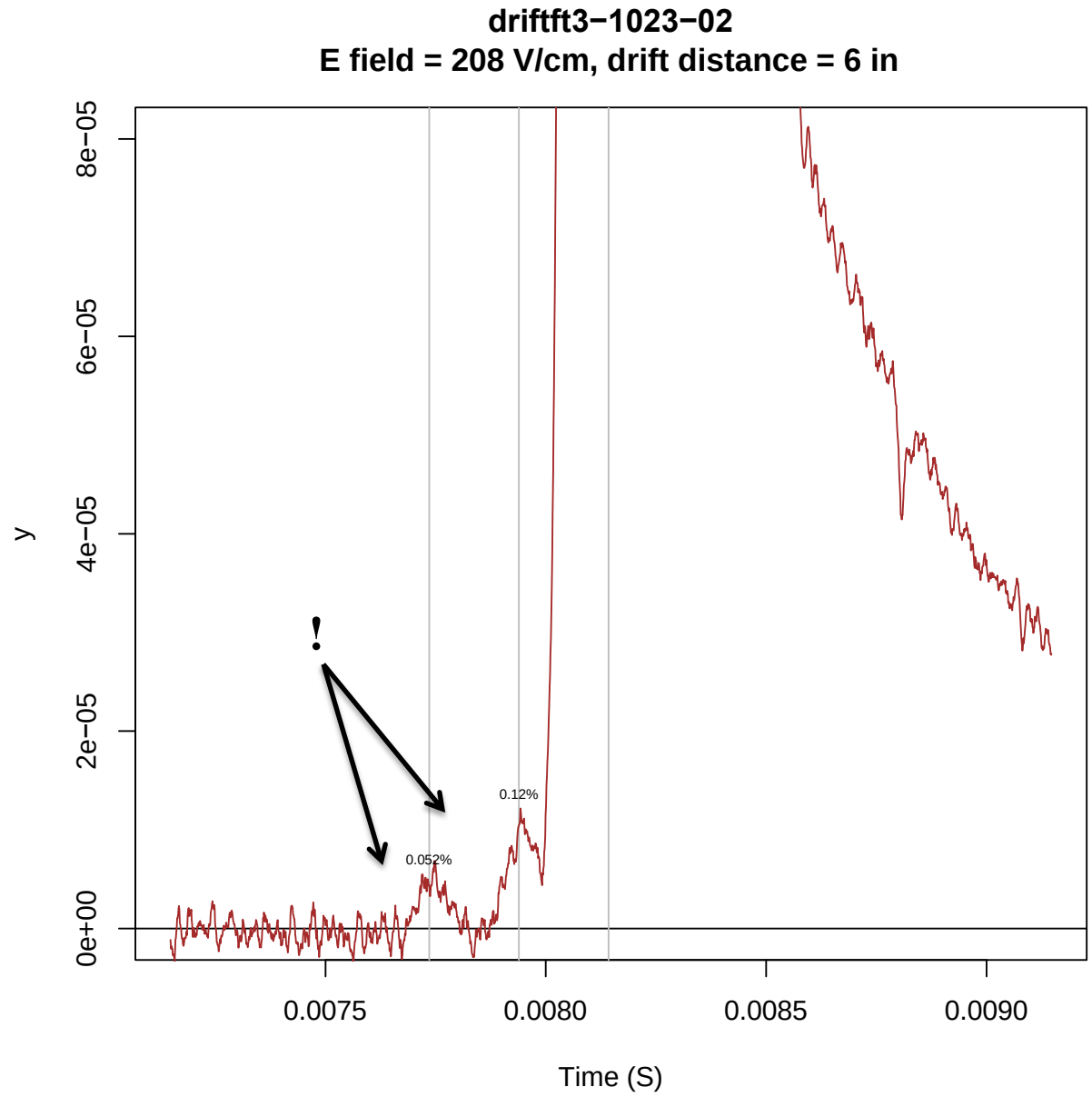
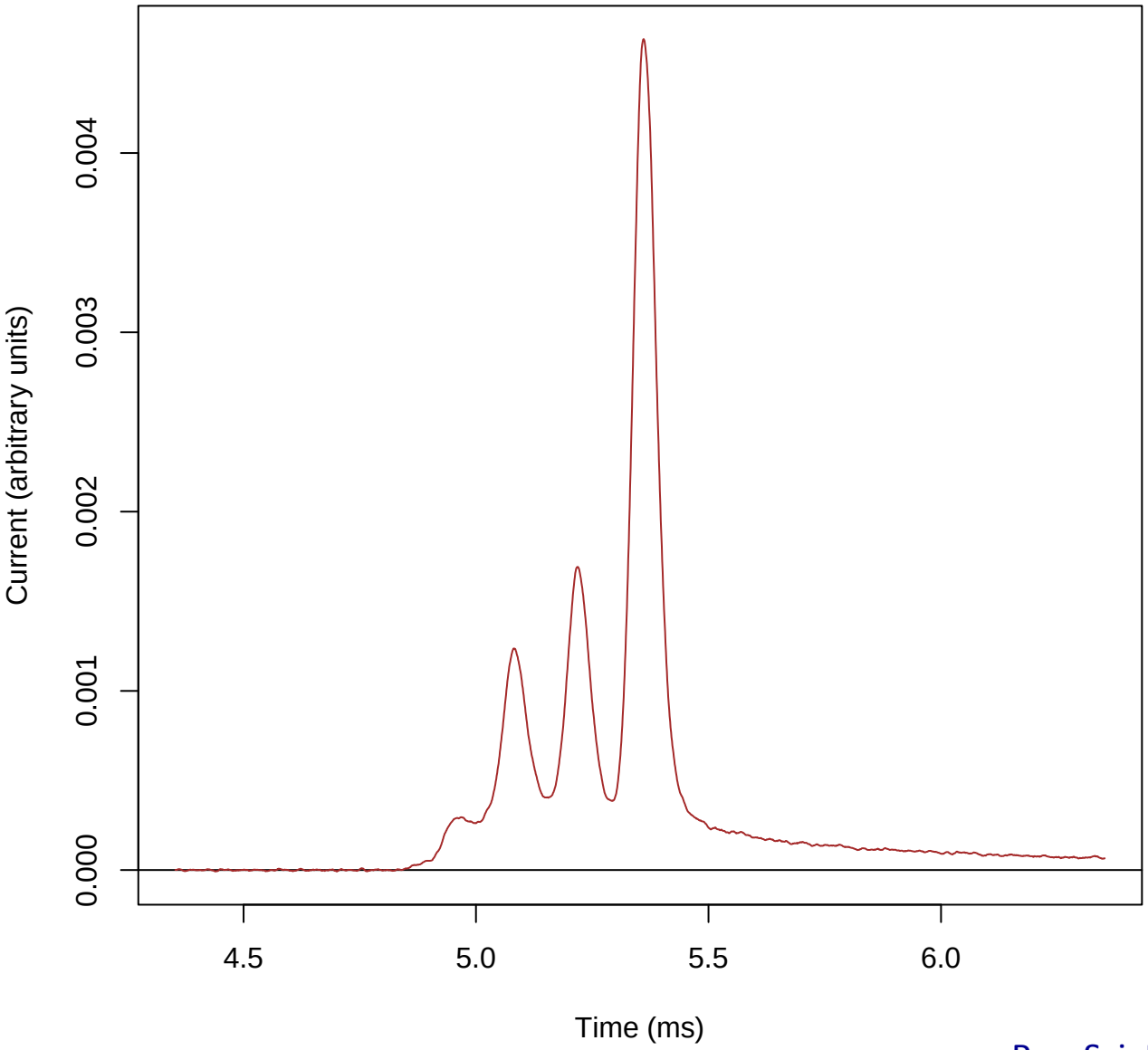
Minority Carriers



- As discussed here in 2012
- Separate peaks in the data indicate that other carriers, **minority carriers,** are generated at the site of the ionization and carry their charge **with different velocity** to the readout plane.
- An interesting puzzle but of little impact to negative ion drift detectors because of their tiny size.
- BUT…

Discovery of Minority Carriers in Mixtures of CS_2 and O_2



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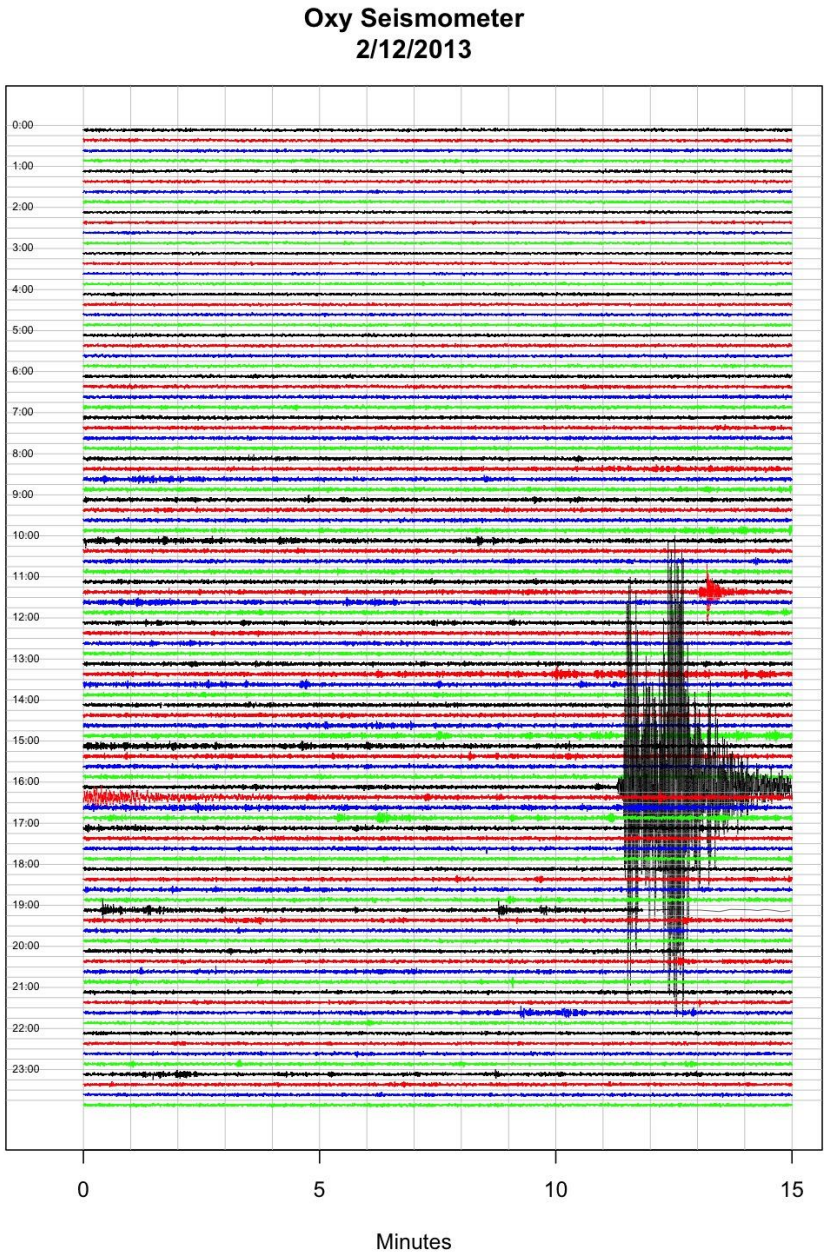
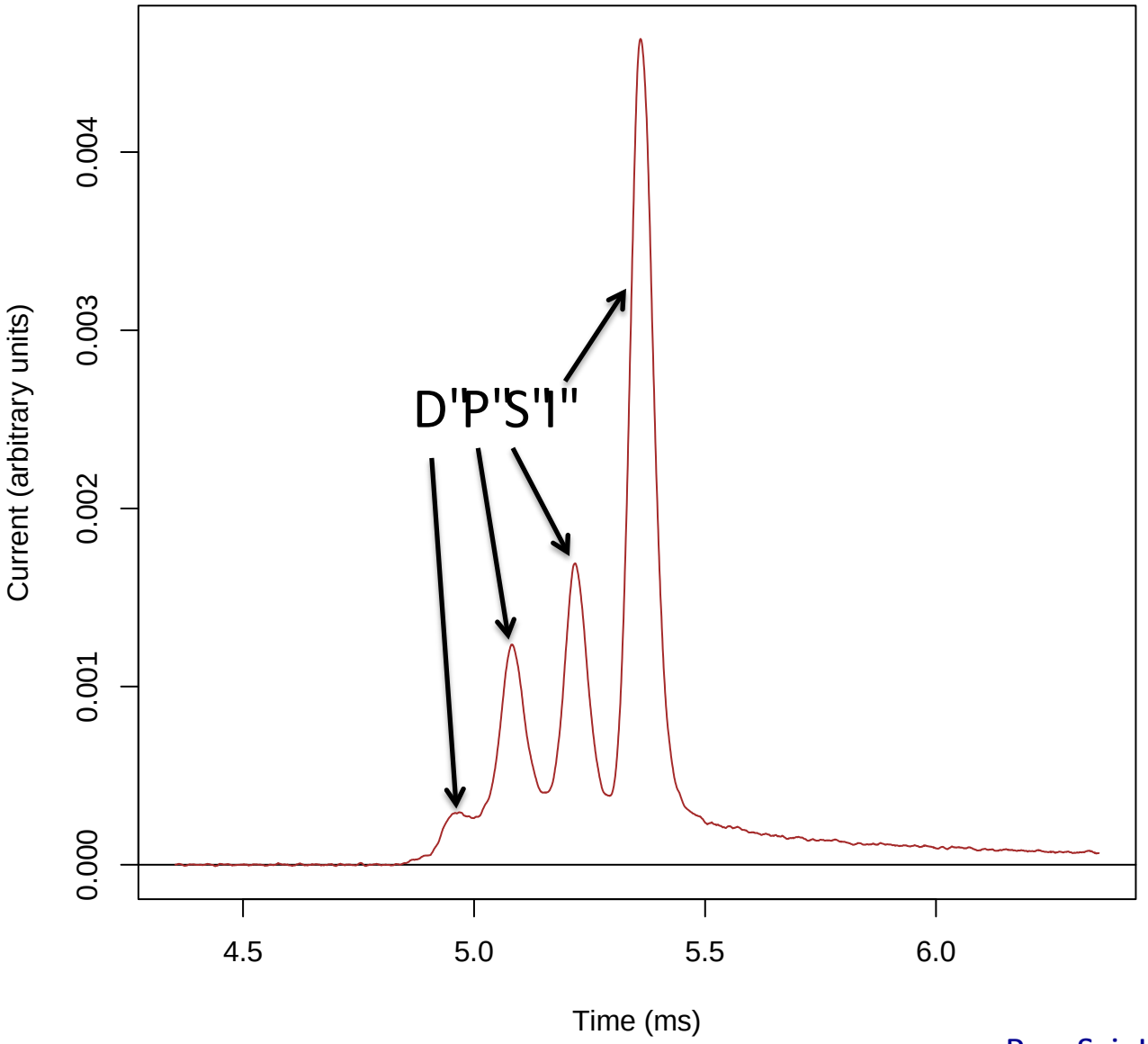
Earthquake Fiducialization



Discovery of Minority Carriers in Mixtures of CS_2 and O_2



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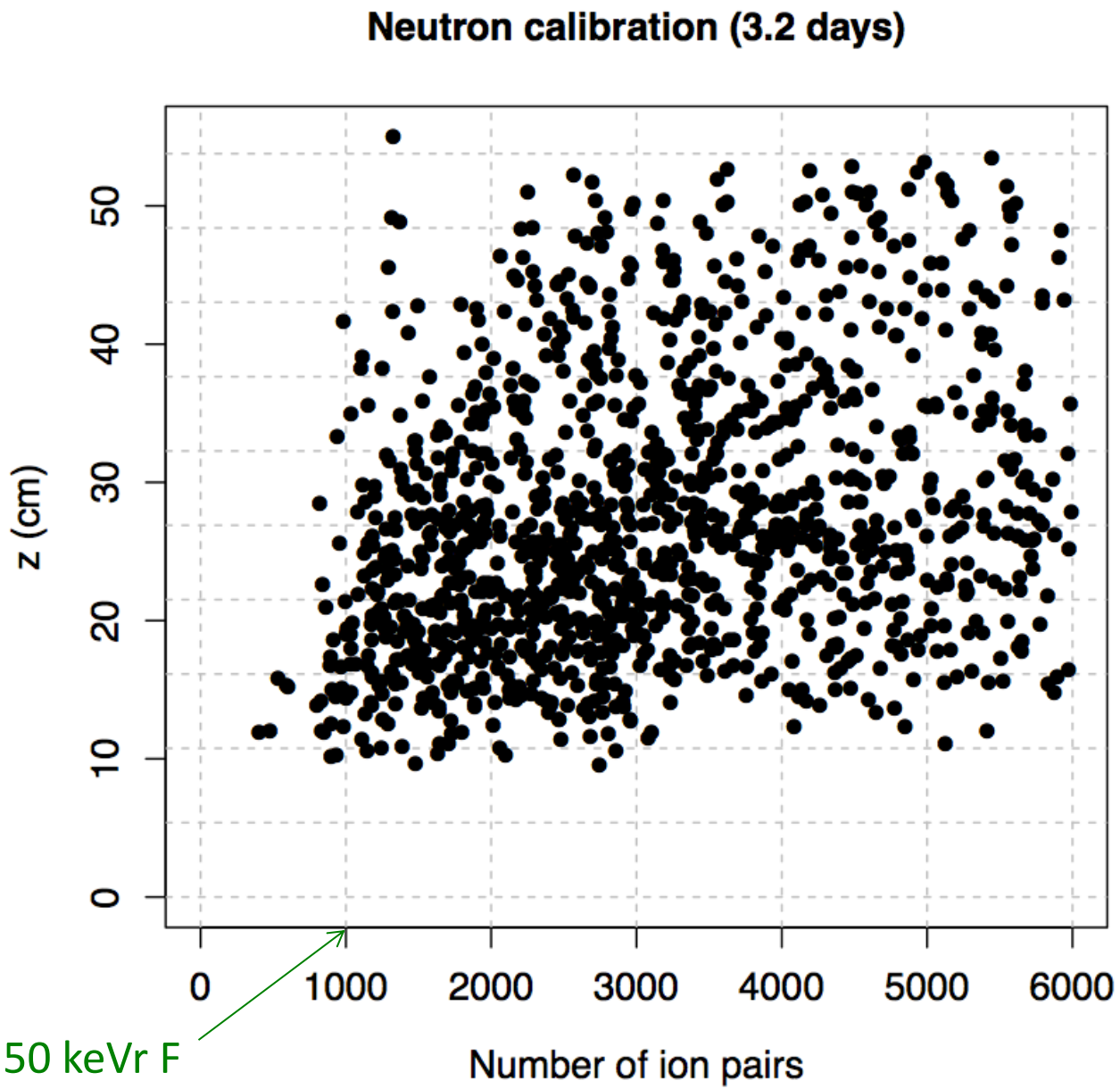
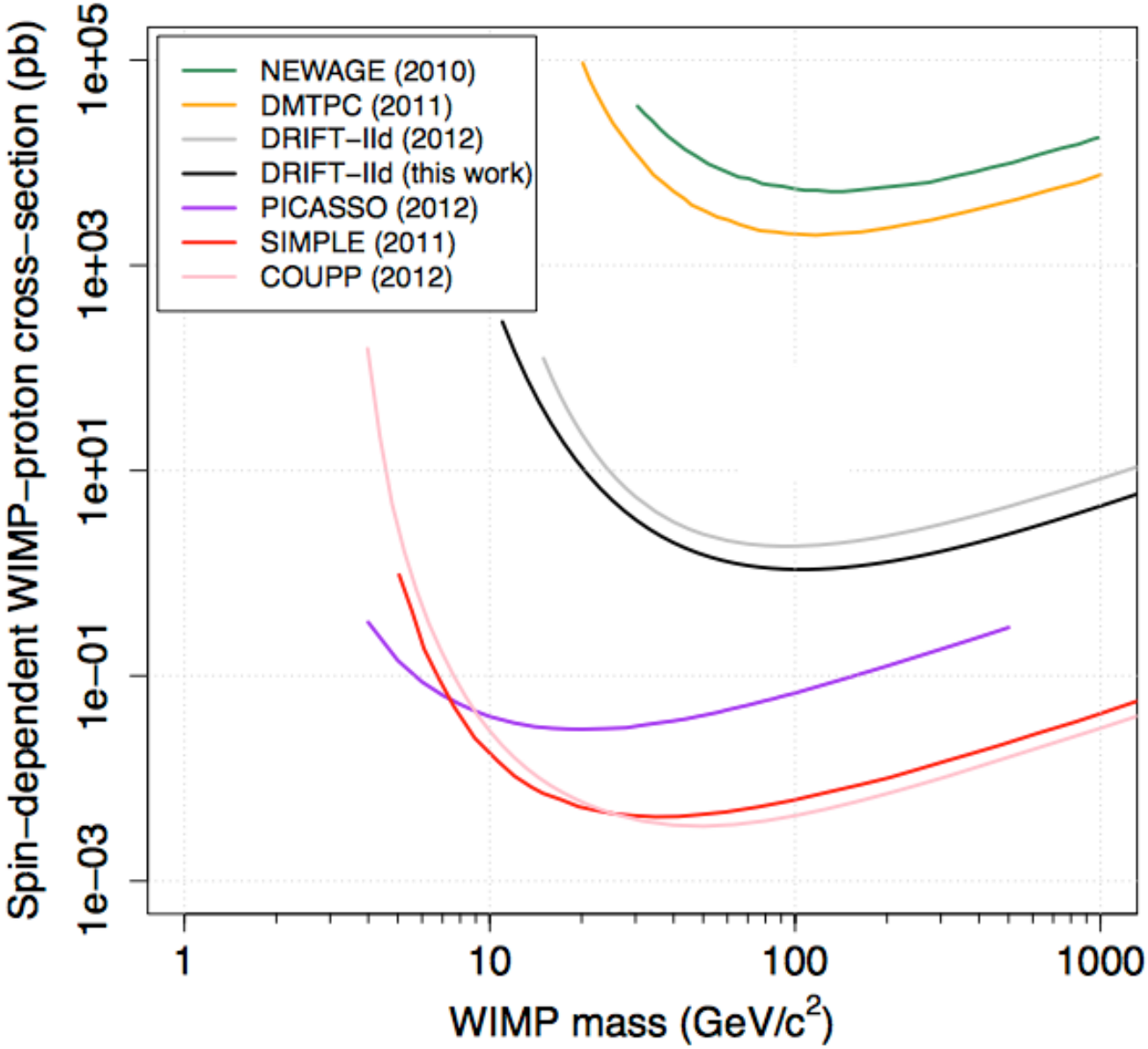
Fall 2013 DRIFT-IId Results with 30-10-1 Torr CS_2-CF_4-O_2

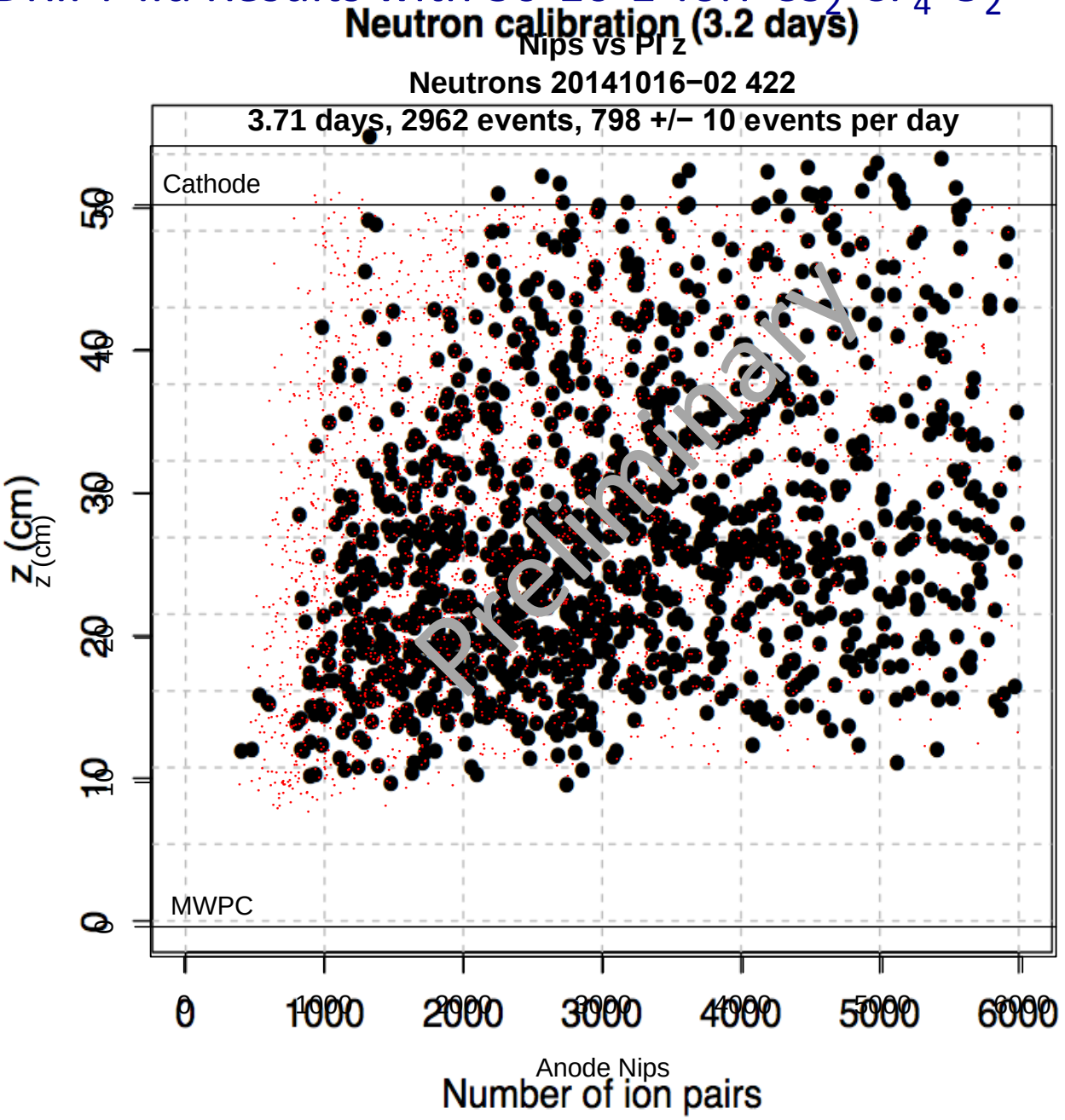


DRIFT-IId Results with 30-10-1 Torr CS_2-CF_4-O_2



ArXiv 1410:7821

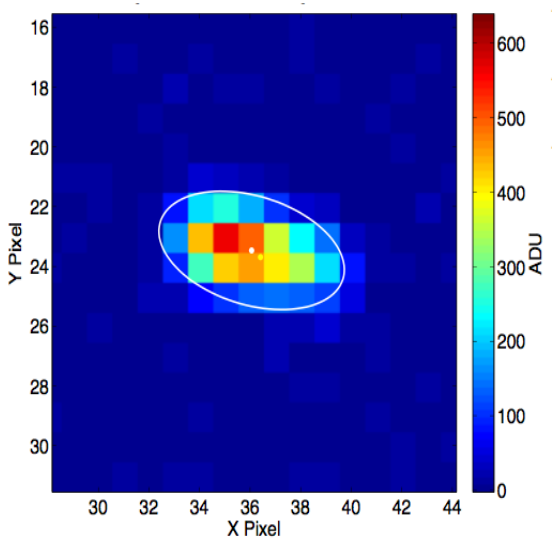
Fall 2014 DRIFT-IId Results with 30-10-1 Torr CS_2-CF_4-O_2



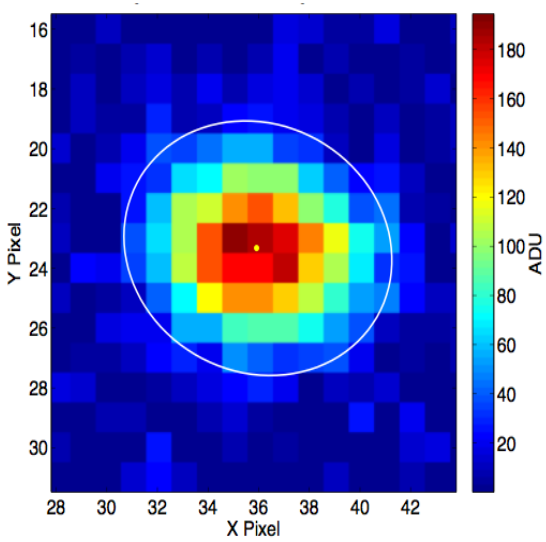
Deconvolution of Tracks

- Knowledge of the drift distance allows us to precisely calculate the diffusion (the PSF) of the ionization.
- Therefore we should be able to, like astronomers, deconvolve the observed track to get better knowledge of the actual track.
- Here is a theoretical (20 cm drift) simulation.

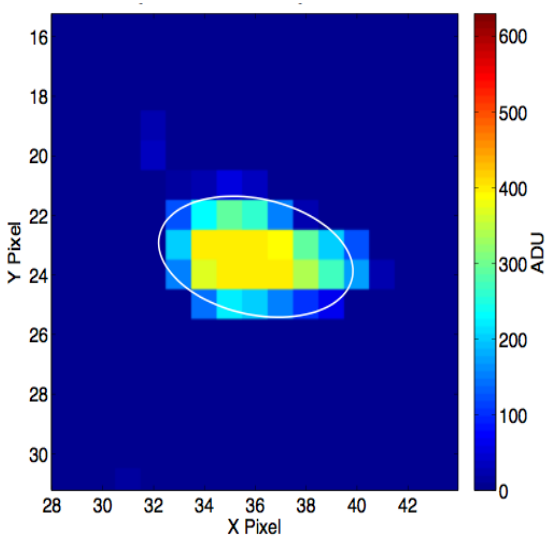
Actual



Diffused

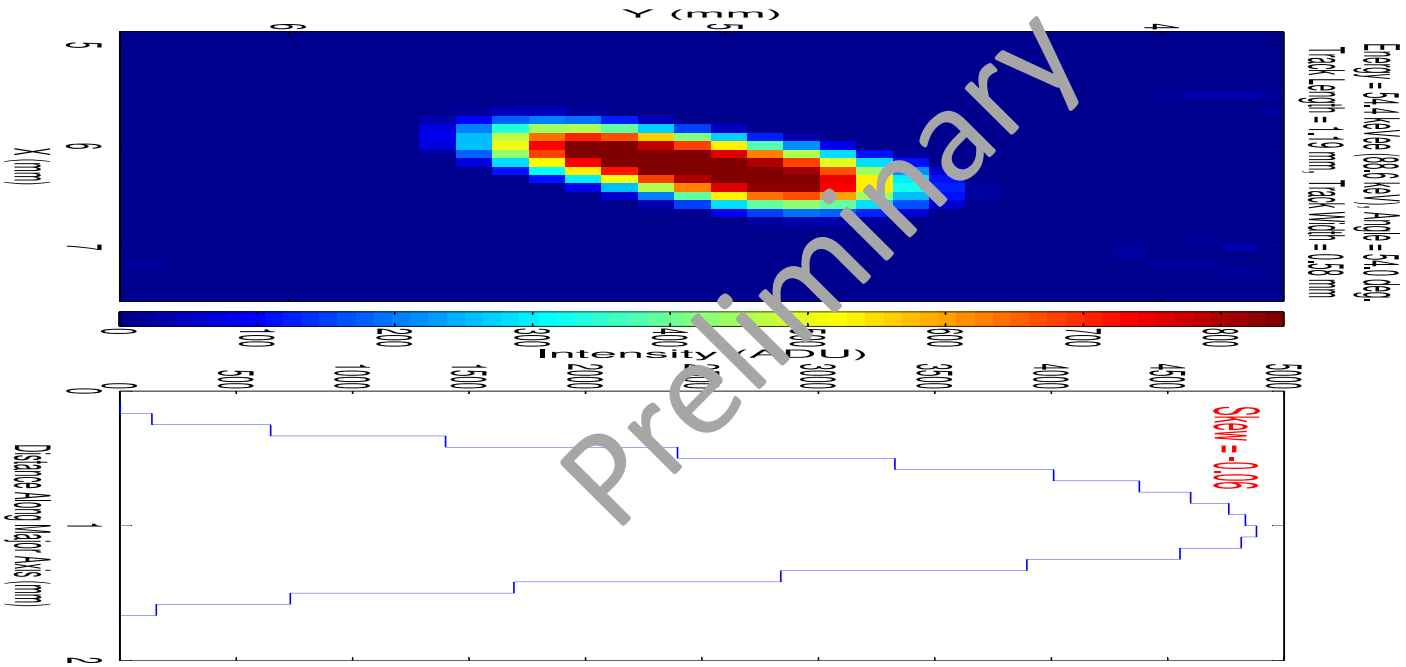


Deconvolved



Deconvolution of Tracks

- Here is some real data taken with a GEM-Optical readout TPC



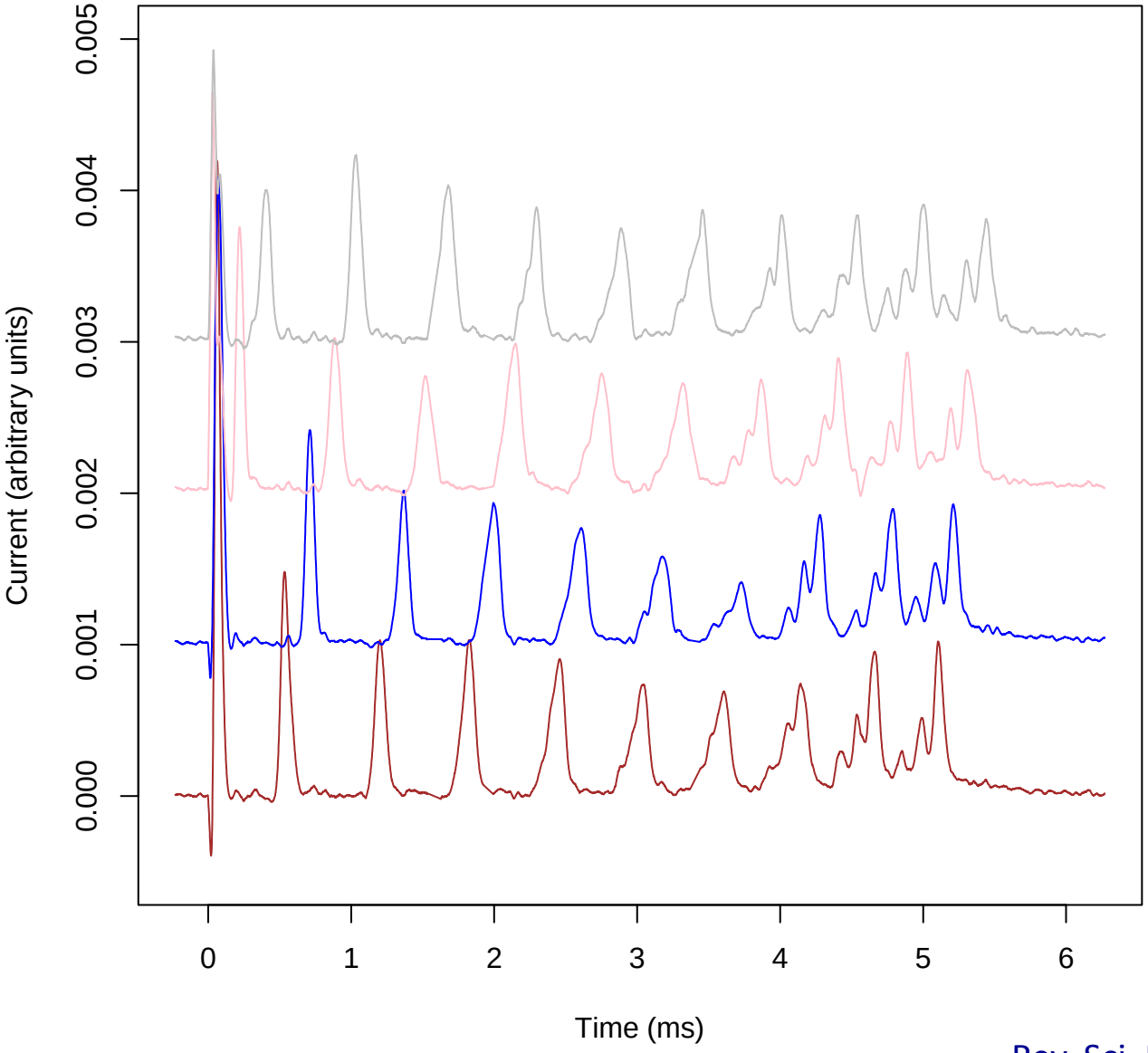
Conclusion

- The addition of O_2 to mixtures containing CS_2 produces abundant minority carriers.
- The minority carriers allow us to accurately measure the drift distance of segments of ionization.
- Fiducialization has revolutionized DRIFT's background rejection capabilities because our only known backgrounds come from the central cathode.
- New limits have been set and data for better limits are being taken now.
- Knowledge of the diffusion should allow DRIFT to deconvolve tracks to obtain better directional information.
- Vive la Révolution!

Thanks

Extra Slides

Alpha + O_2



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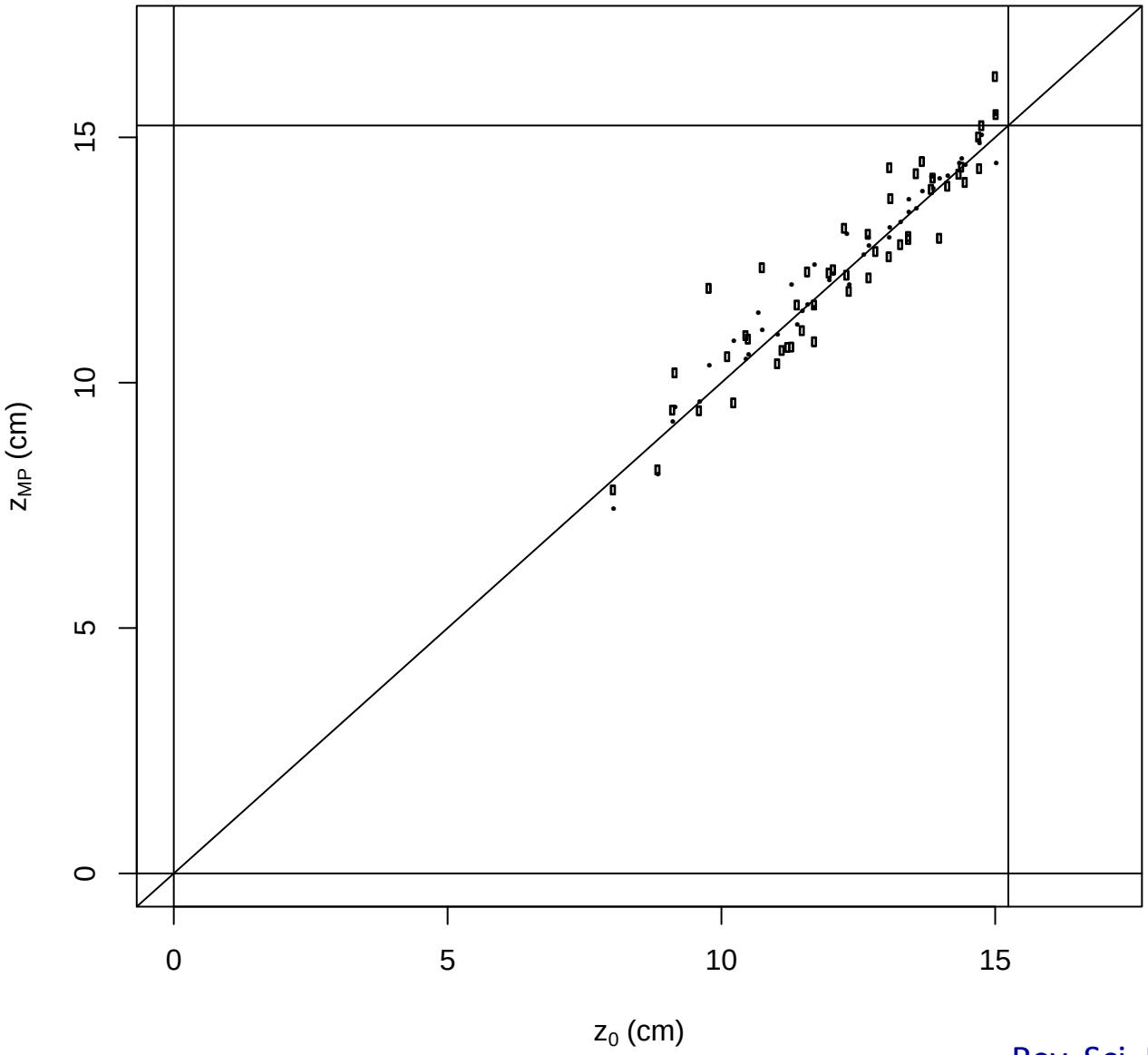
Triggerless Fiducialization



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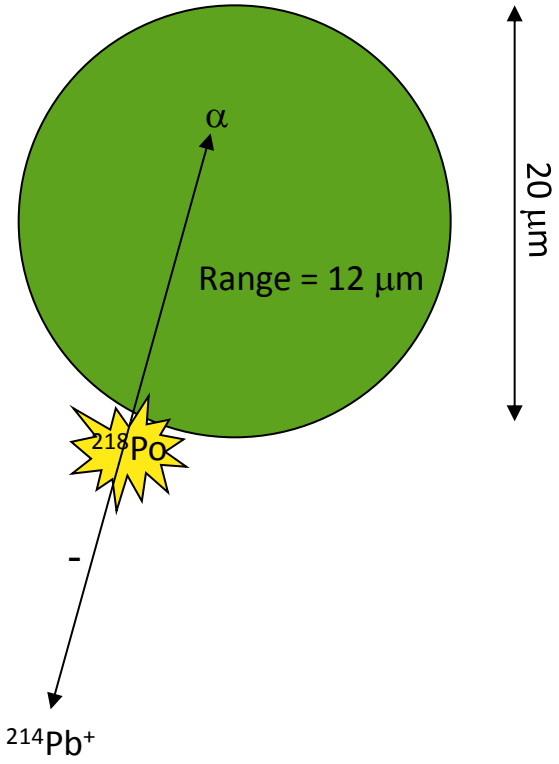
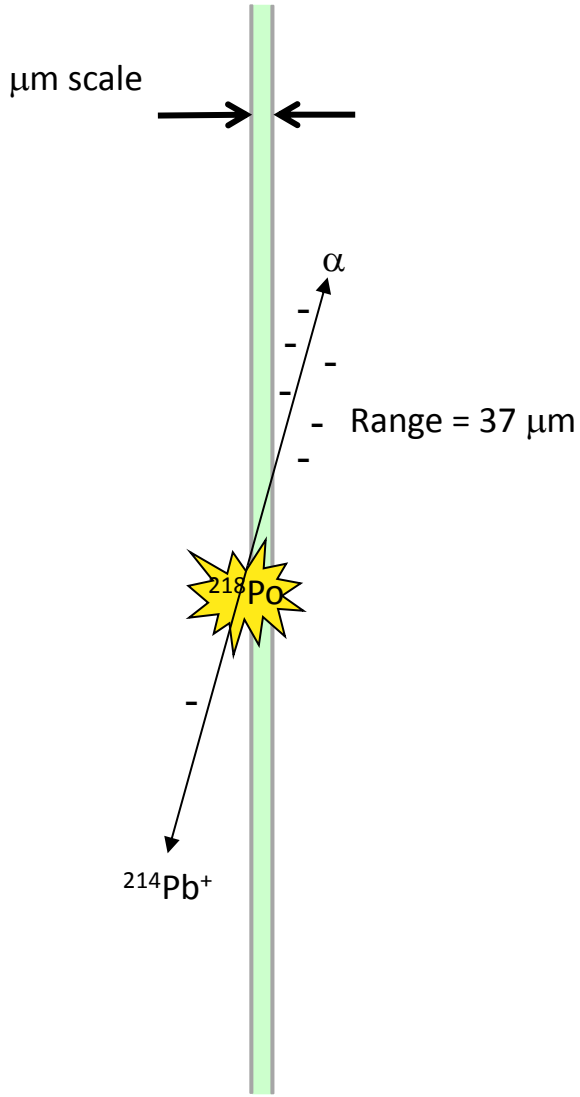
The problem

The 6 MeV Po-218 alpha can hide in central cathode wires.



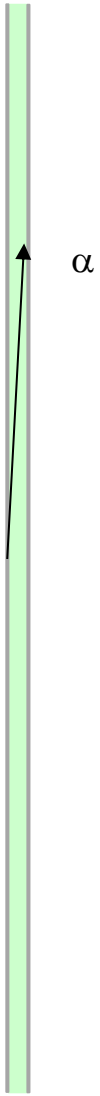
Thin film

Give the alphas few places to hide in an aluminized Mylar thin film.



Thin Film

Of course some alphas will find a way to hide



Thin Film

Give t film.

Texturized thin film

- Miraculously the guys at UNM have managed to create a texturized 0.9 micron thin film.
- This has been deployed on DRIFT-IId in Boulby.
- Preliminary results indicate a drop from 130 events per day down to ~1 event per day.
- Further improvements are expected with the deployment of DRIFT-IIe this spring.