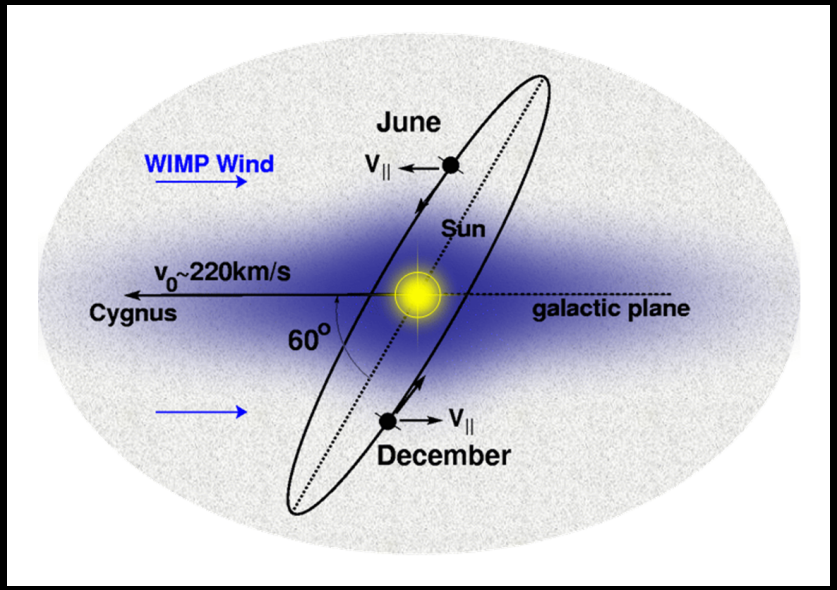
DRIFT

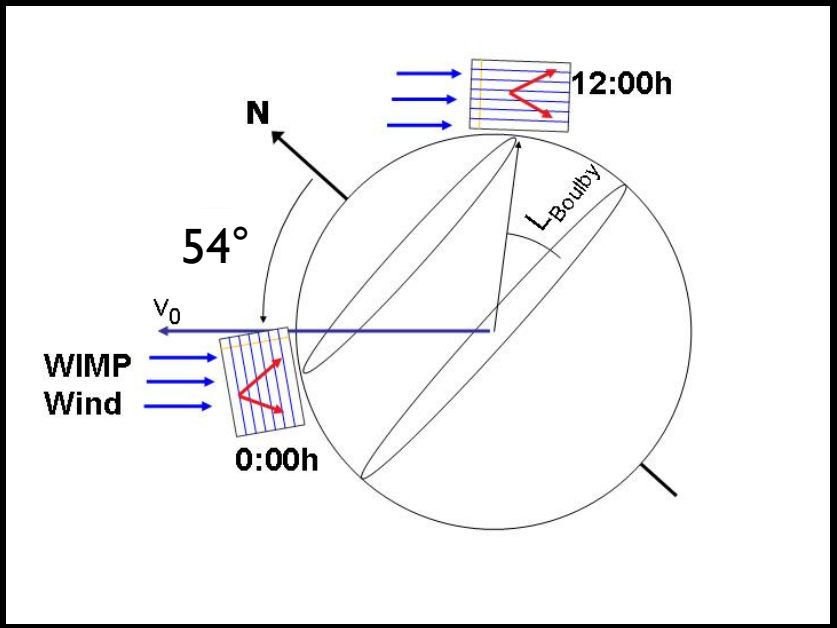
Spin-dependent limits from DRIFT - a directionally sensitive dark matter detector

Mark Pipe

The 'WIMP wind'

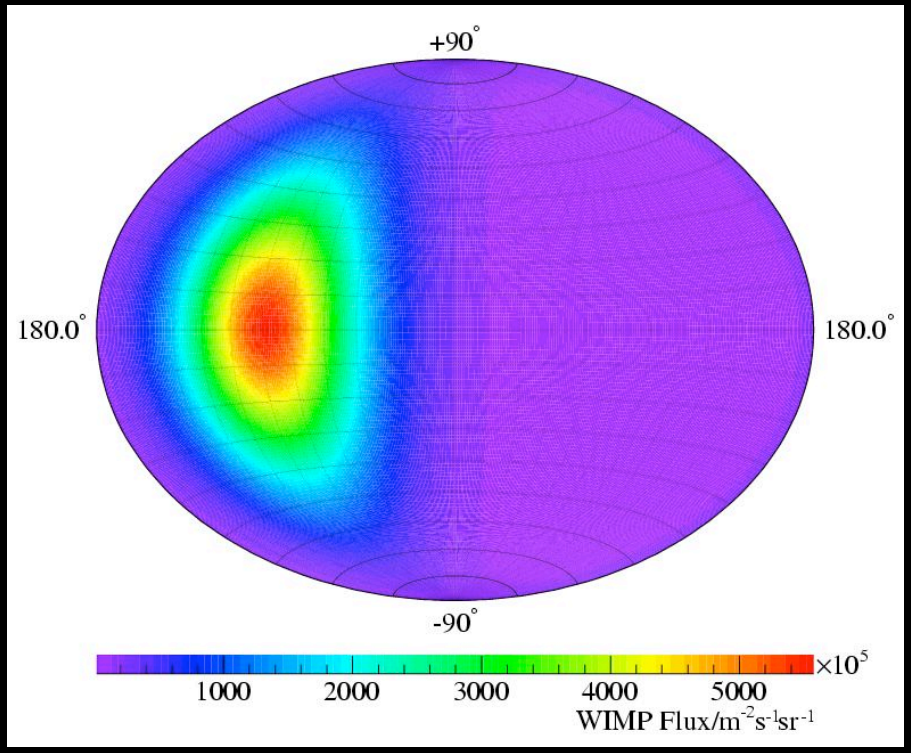
- Galaxy is within an isothermal halo of essentially static WIMPs
- Motion of Earth through WIMPs creates apparent 'WIMP wind'
- Mean velocity ~220kms^{-1} from the constellation Cygnus - orbit of Milky Way about Galactic Centre
- ~15kms^{-1} annual modulation due to Earth's orbit of the Sun
- ~90° diurnal modulation due to Earth's rotation on its axis





Directional dependence

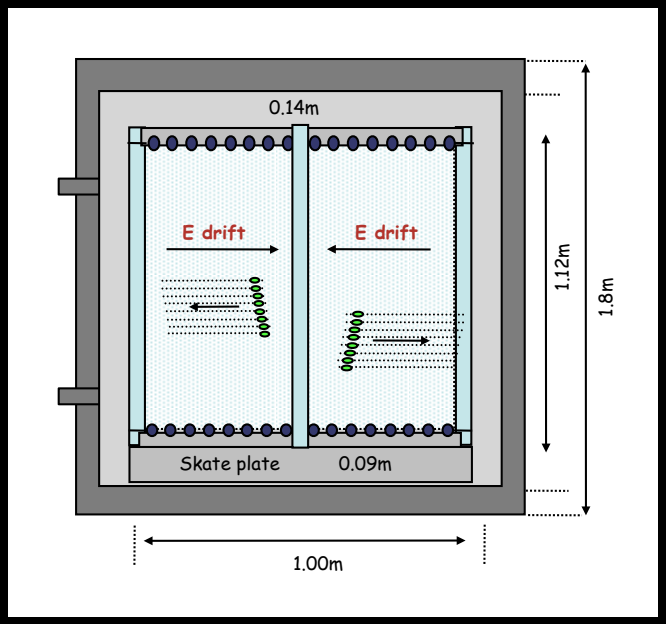
- Distinct signature in incident WIMP direction
- Nuclear recoils caused by WIMP collisions will be biased in the direction of the WIMP wind
- Extremely strong signal from motion of Earth through WIMP halo. Cannot be mimicked by terrestrial source.

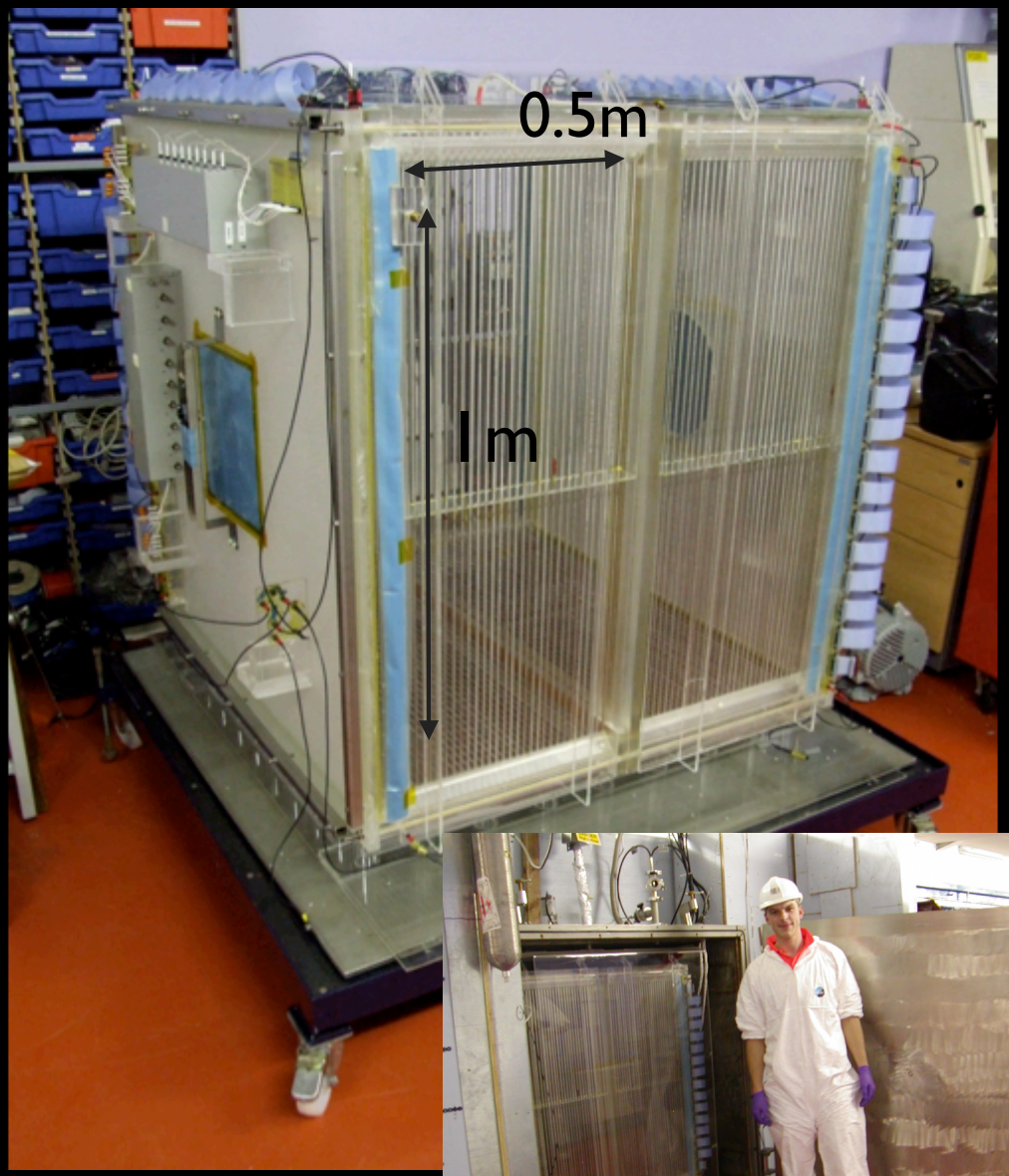


Green, Morgan. ApJ 27 (2007) 142–149

DRIFT-IId

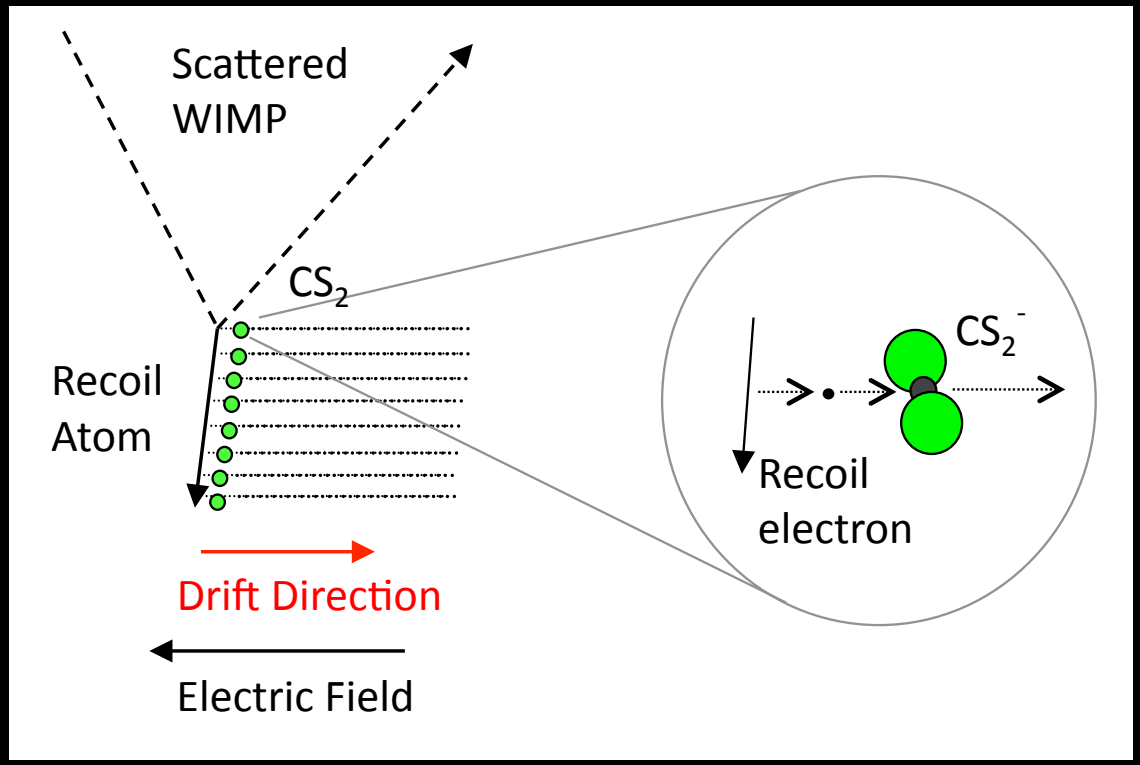
- Two back-to-back low pressure gas TPCs
- $1m^2$ central cathode
- $1m^2$ MWPC readout planes
- 0.5m drift region
- Housed in stainless steel vacuum vessel maintaining low pressure target gas (e.g. 40 Torr CS_2)
- Fiducial volume = $0.8m^3$ = 134g CS_2





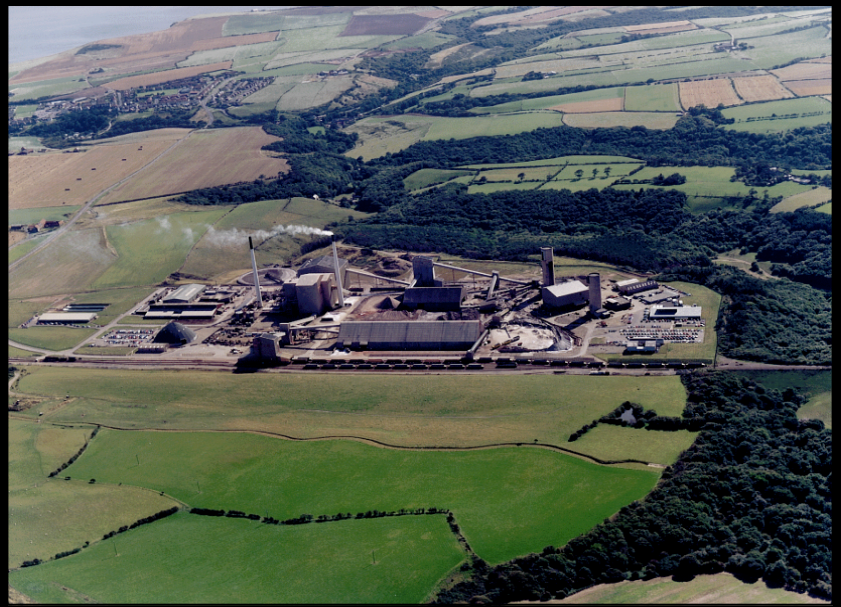
Negative ion drift

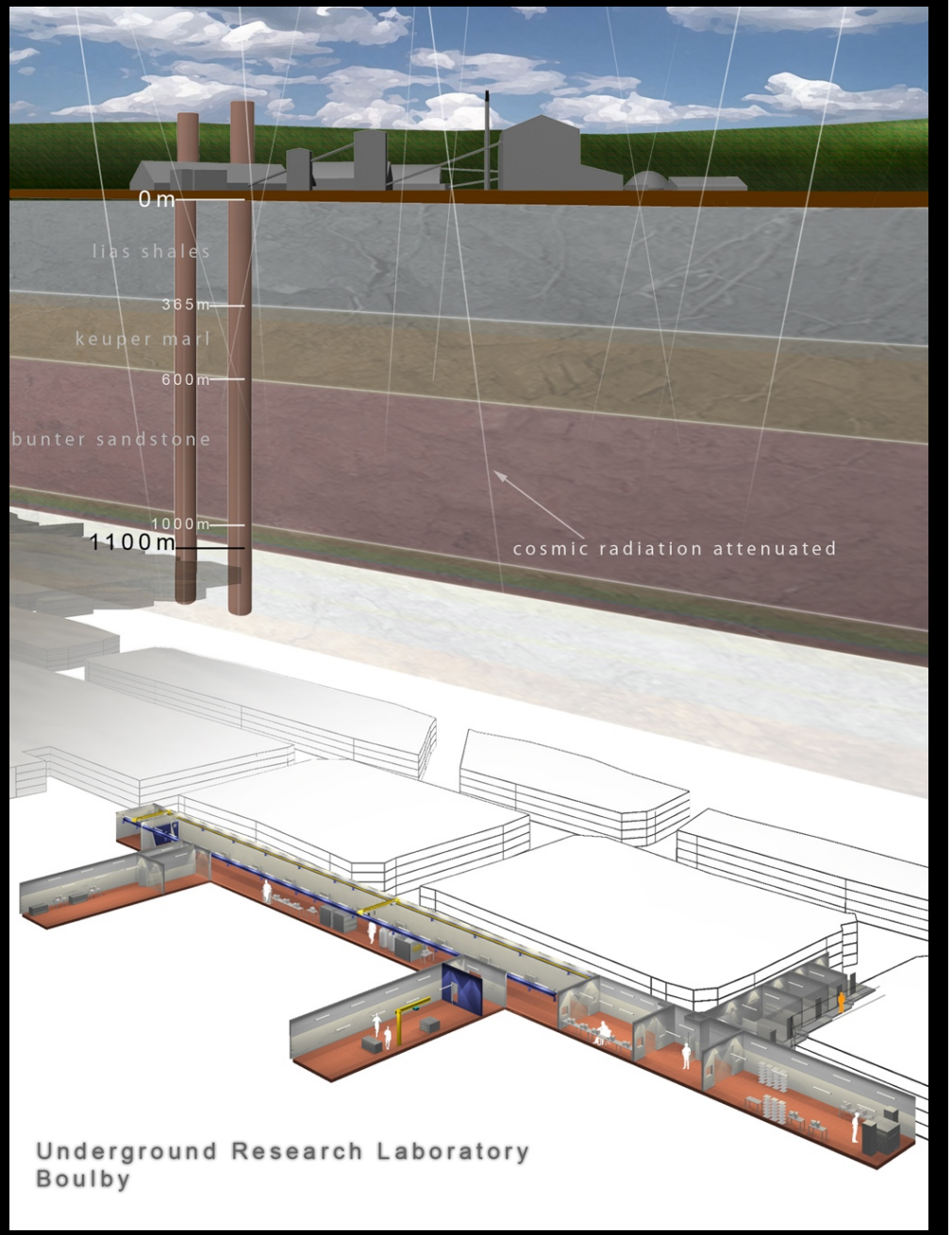
- WIMP interaction causes ionisation track of few mm
- Electronegative gas creates track of negative ions
- Negative ions drift
- Massive ions suffer only thermal diffusion
- Preserves directional information



Boulby Mine, NE England, UK

- 1100m underground ≈ 2800 m.w.e.
- Cosmic rays reduced by factor of 1 million

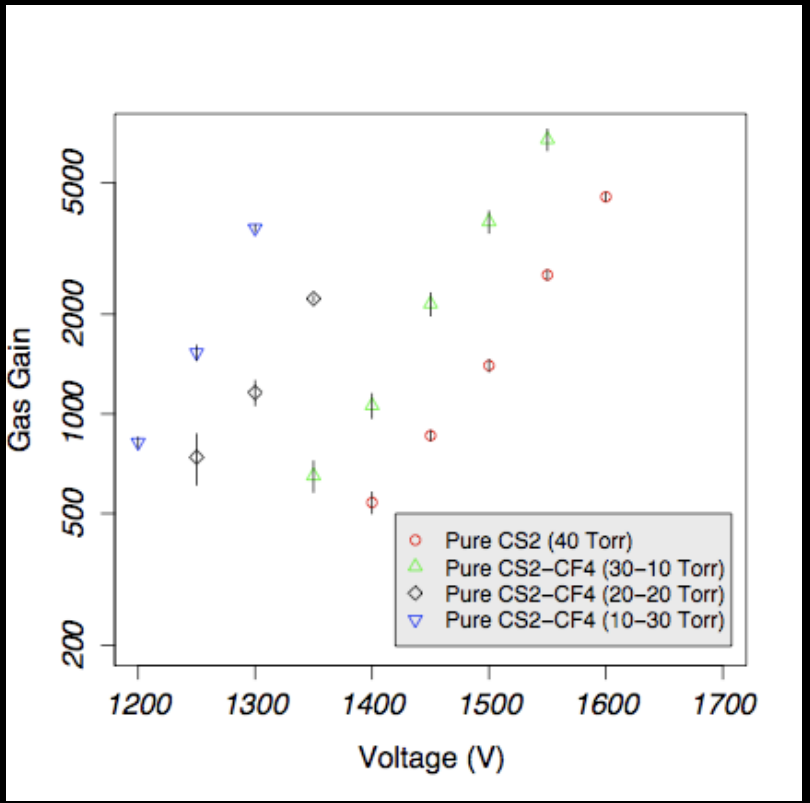




CS_2-CF_4 mixtures in DRIFT

- CS_2 required for low diffusion but not sensitive to SD interactions
- CF_4 added as ^{19}F is ideal target for SD measurements
- Single wire proportional counter measurements of gas gain, W-value and mobility in CS_2-CF_4 mixtures

Gas gain - Increases with CF_4 concentration

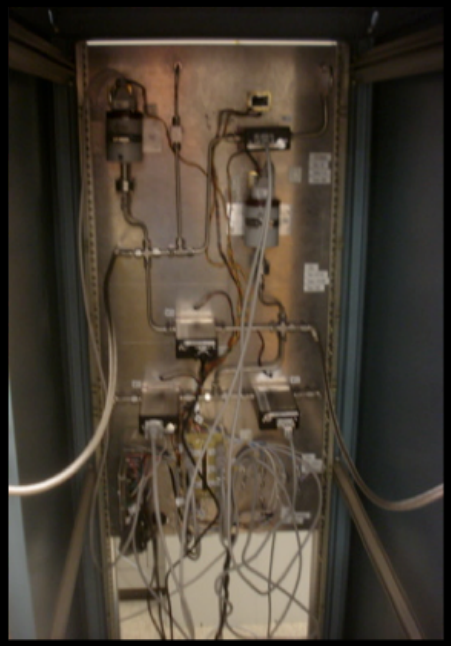


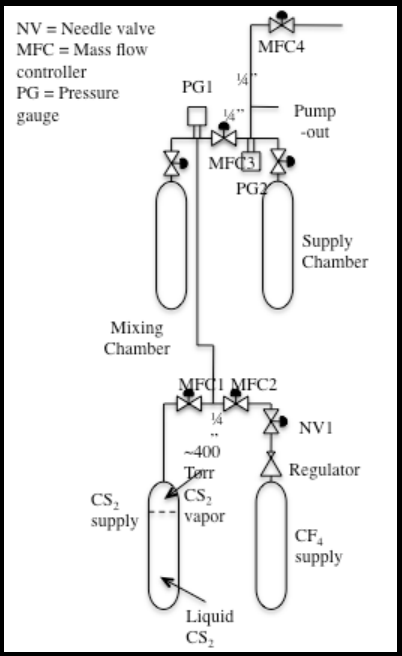
Mobility - Negative ion drift preserved up to 75% CF_4

Gas Mixture CS_2 – CF_4 (Torr)	Reduced mobility, μ (cm^2 atm/Vs)
40-00	0.54±0.02
30-10	0.60±0.02
20-20	0.69±0.02
10-30	0.81±0.03

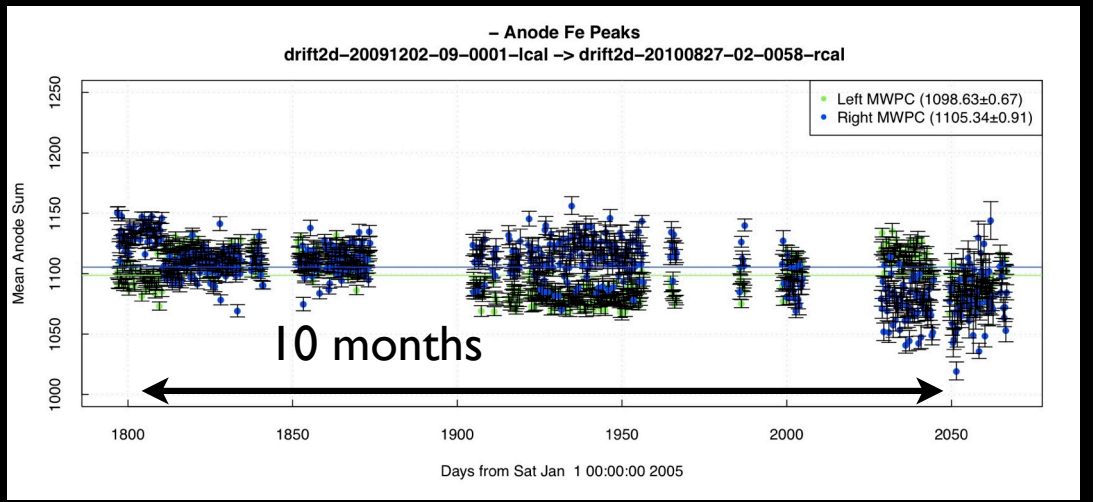
[K. Pushkin, NIM A 606 (2009) 569]

Gas mixing system

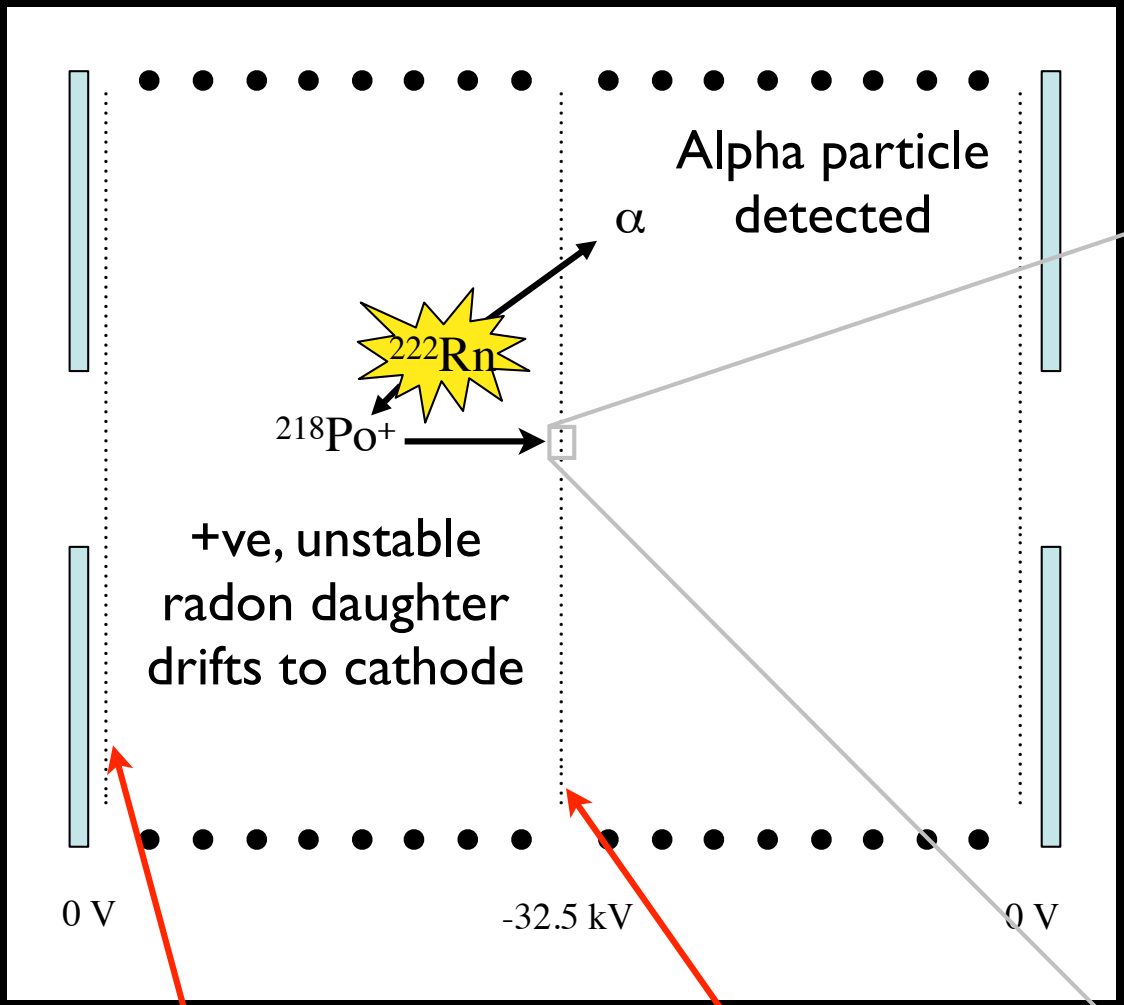




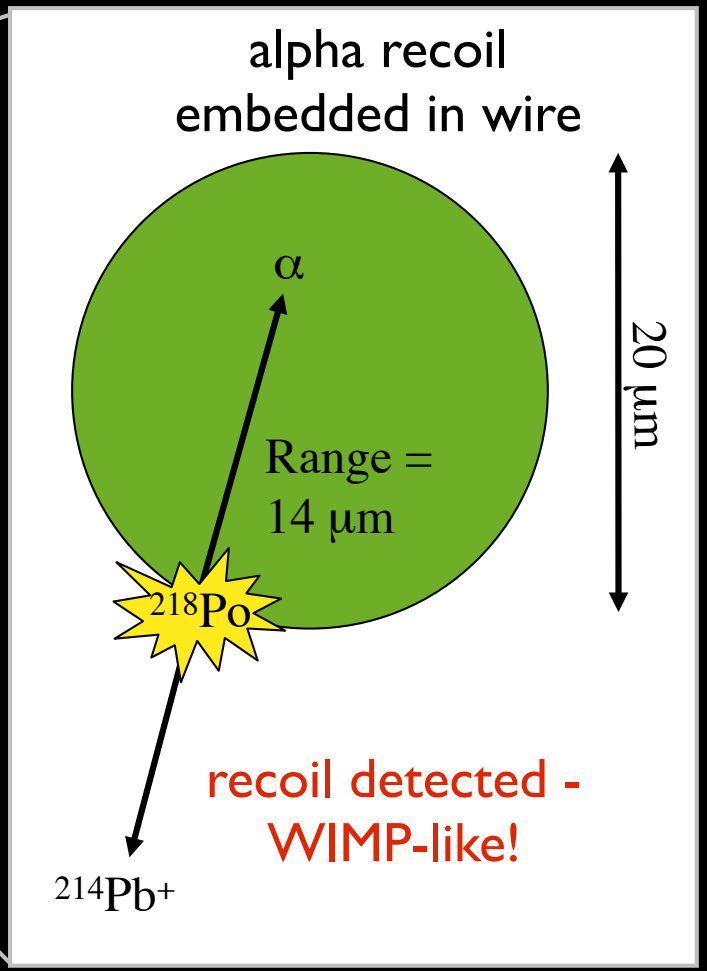
- System installed underground
- Operating with 30 Torr -10 Torr CS_2-CF_4 gas mixture
- ~ year of stable running



DRIFT-II's dominating background - Radon Progeny Recoils (RPRs)



~ 40% probability



RPR reduction

1) Reduce radon in the detector:

Sample (Emanating into vacuum)	Fill gas	Emanation time (days)	Humidity (%)	Raw result (Bq/m^3)	Adjusted result ($Rn\ atoms.s^{-1}$)
RG58 coax cables (72m)	Dry N2	12.5	24	9.4 +/- 0.7	0.36 +/- 0.03
Electronics boxes	Dry N2	12	37	1.5 +/- 0.3	0.05 +/- 0.02
Ribbon cables	Dry N2	6.5	23	10.1 +/- 0.7	0.50 +/- 0.04
Electronics & PCBs	Dry N2	10	37	0.3 +/- 0.2	<0.02 *
Single core & thin coax cables	Dry N2	7	19	1.3 +/- 0.3	0.04 +/- 0.02
Field cage parts	Dry N2	7	33.3	0.6 +/- 0.2	<0.03 *
				Total	0.95 +/- 0.5

(S. Paling, Sheffield)

2) Clean the plated out ^{210}Pb from the cathode

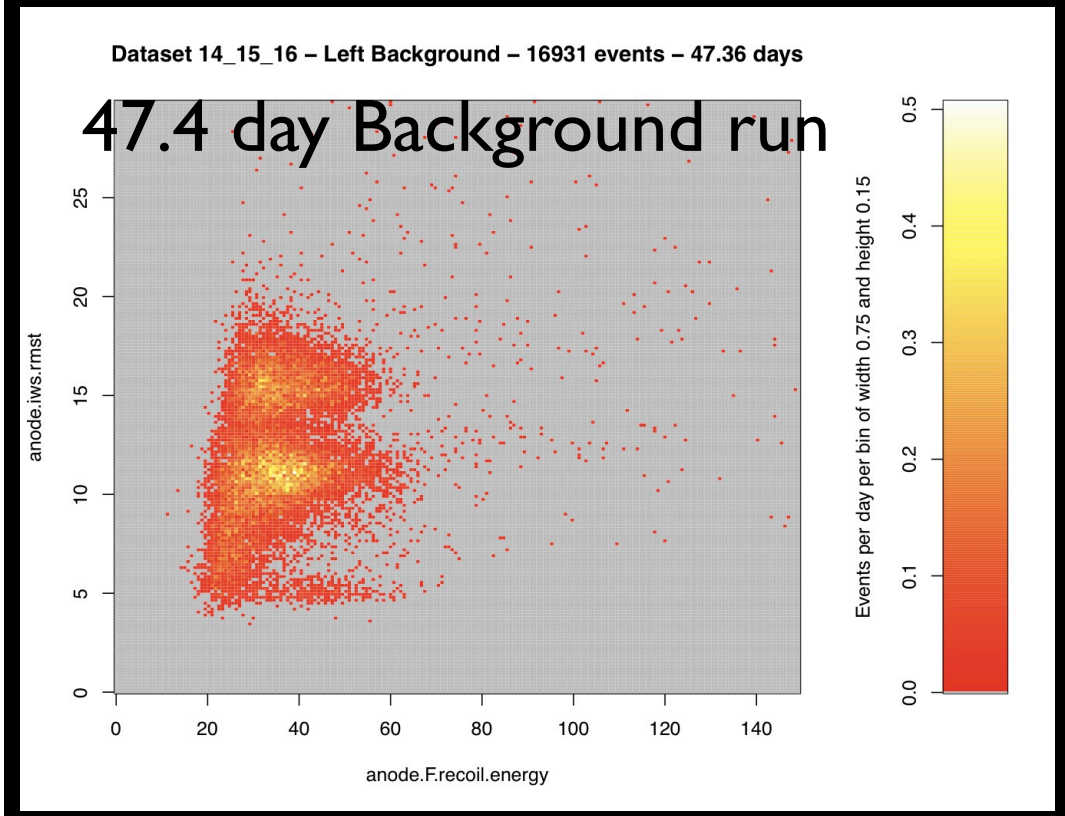
<u>Together, these reduced RPRs by 96% relative to D-IIa rate</u>

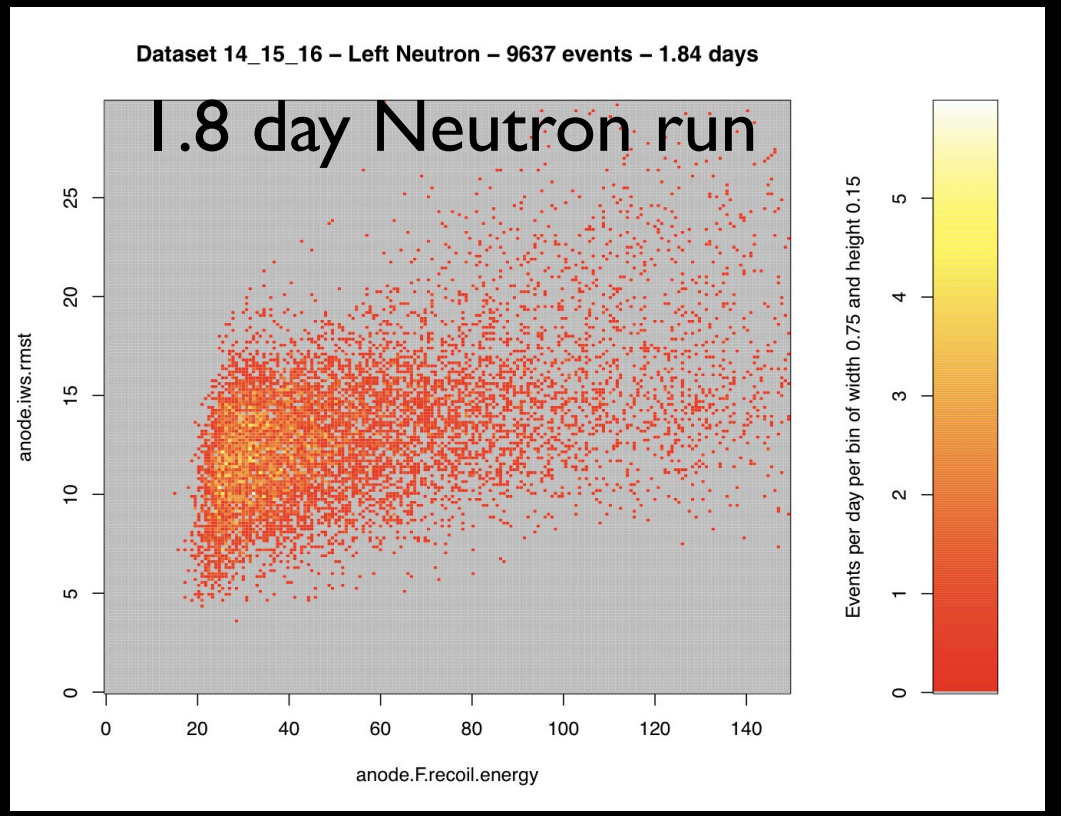
[D. Snowden-Ifft, Oxy, J. Turk, UNM, PhD thesis 2008)

Backgrounds

- X-axis - equivalent F recoil energy (keV)
- Y-axis - IWS-RMST - (Induced Waveform Subtracted - Root Mean Square Time) - measure of diffusion of the track in the drift field dimension

- Three main background populations:
  - Low RMST - sparks consistent with shaping time of amplifiers
  - Mid RMST - events in the MWPC (RPRs?)
  - High RMST - RPRs coming from the central cathode





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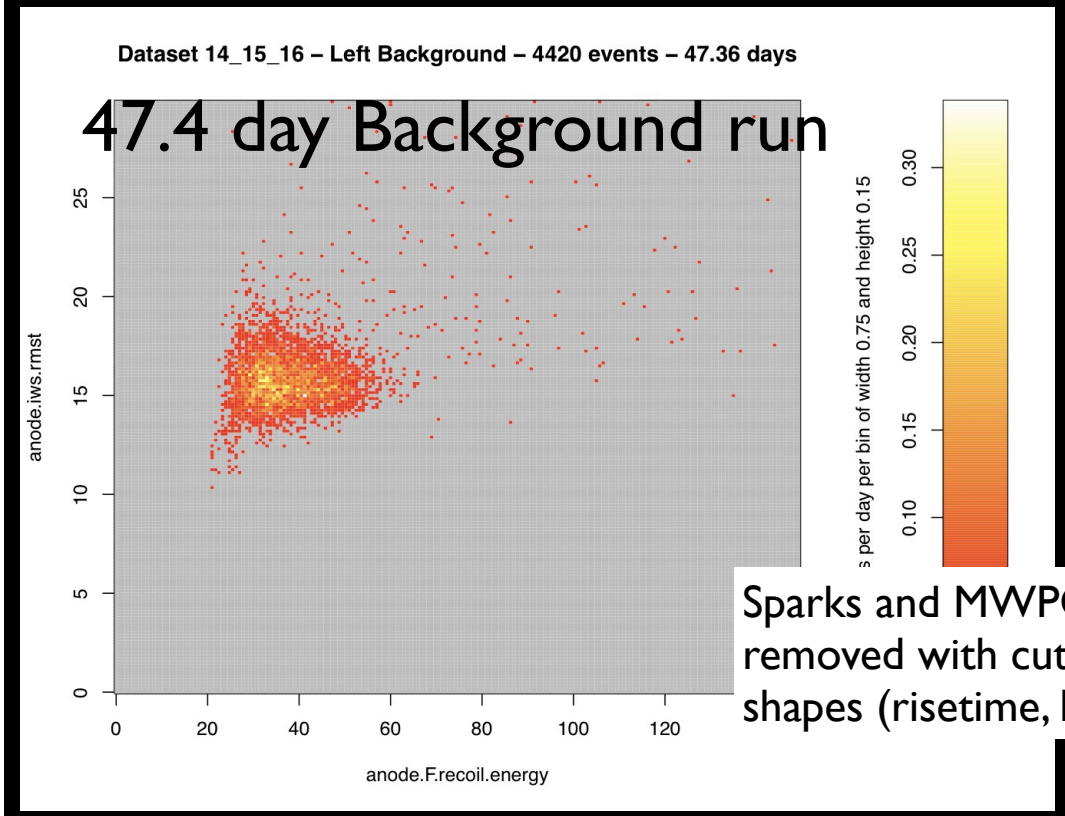
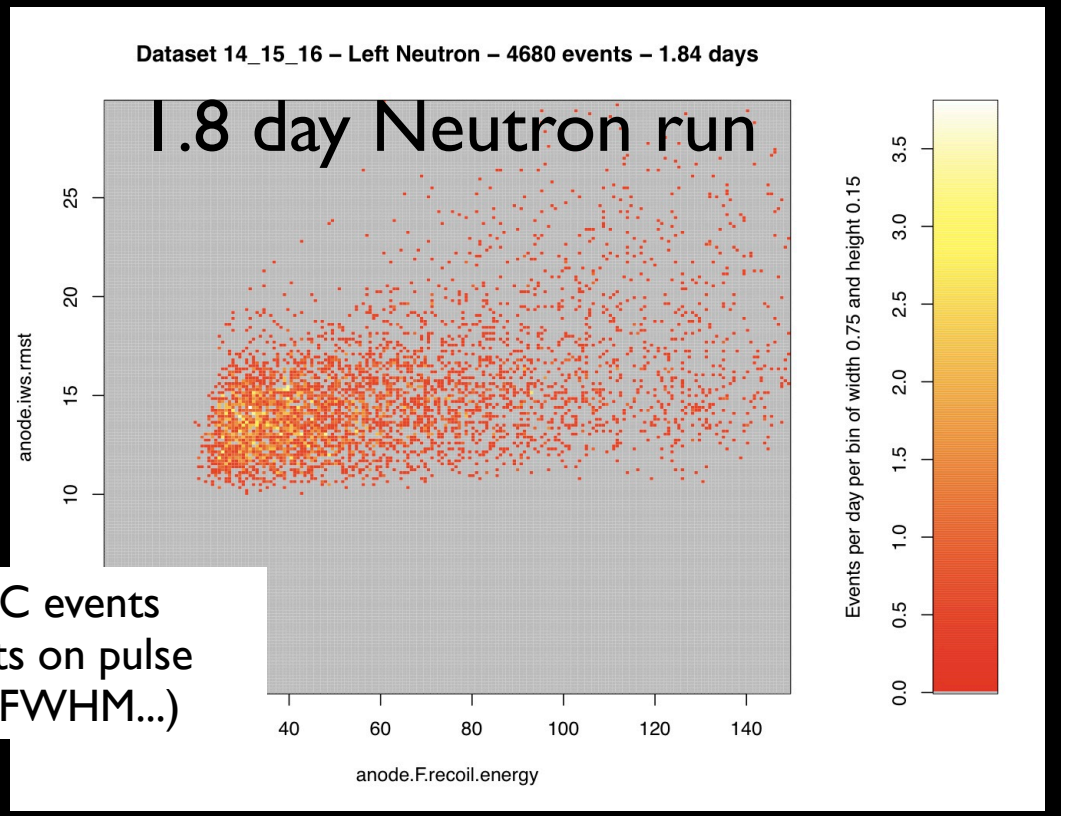
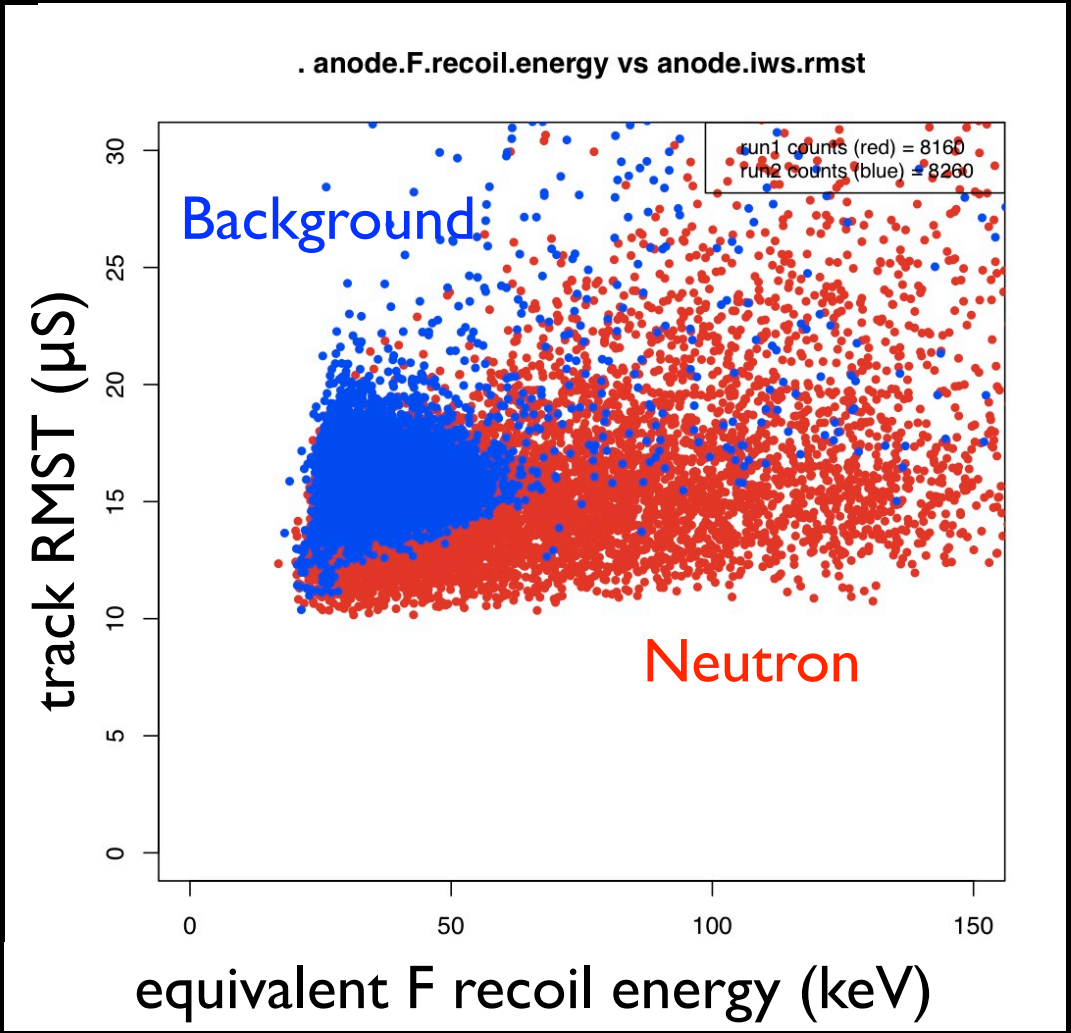


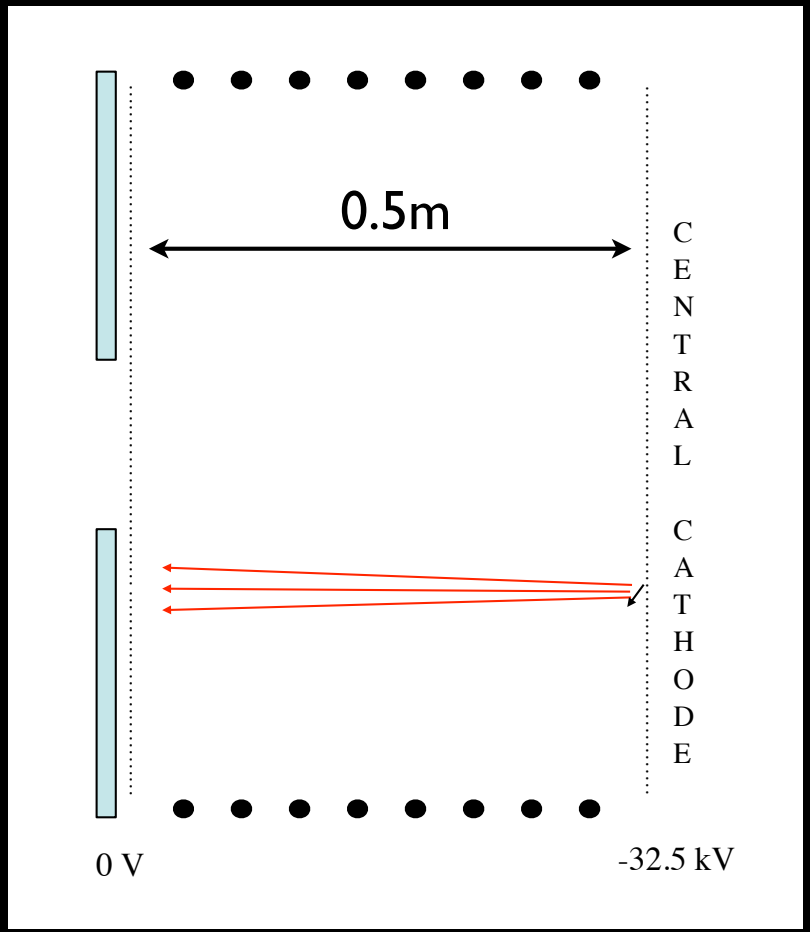
Sparks and MWPC events removed with cuts on pulse shapes (risetime, FWHM...)



RPR reduction

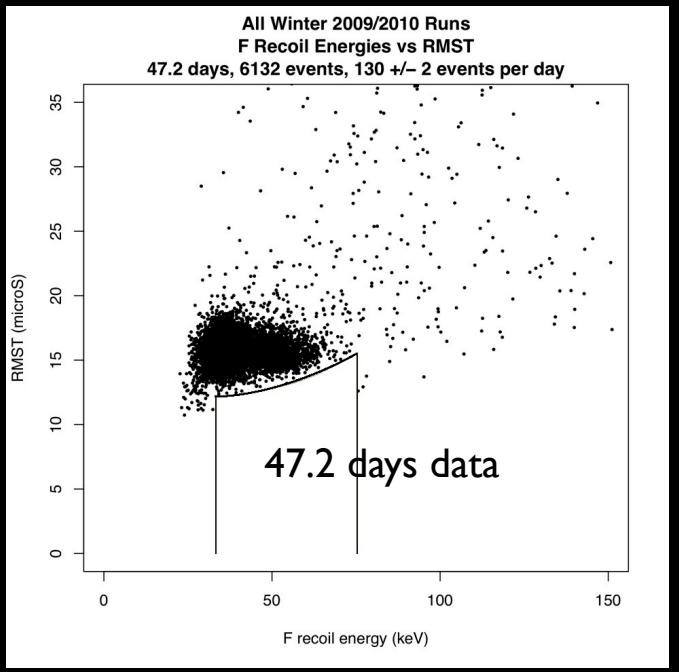
- Neutrons occur throughout the detector volume
- RPRs come from the central cathode and suffer maximum diffusion - on average have higher IWS-RMST

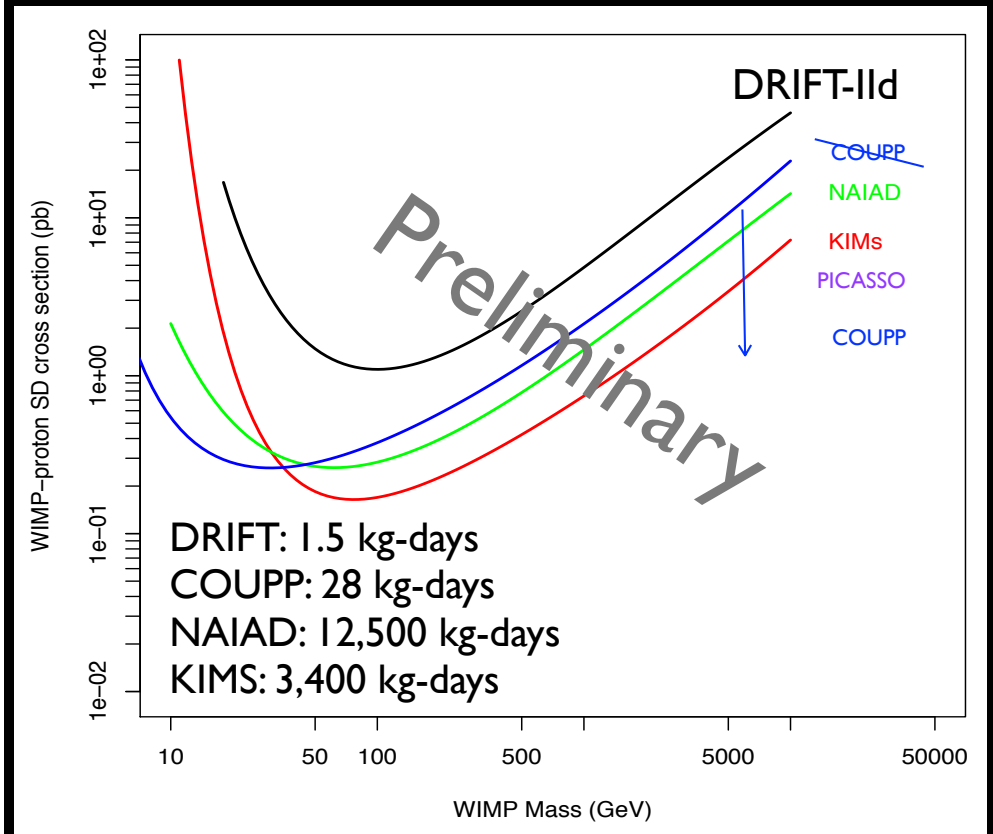




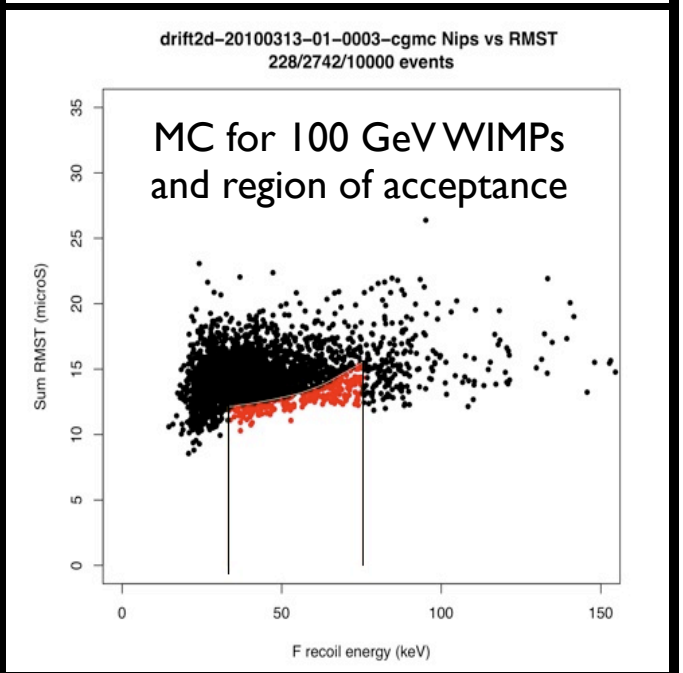
SD 'Limit' from 47.2 days (not blind)

- 30 Torr -10 Torr CS2-CF4, 47.2 days background data
- 1.5kg-days (^{19}F) with no compromise on directional sensitivity.
- Signal region chosen by eye for zero events (not a blind analysis)
- MC simulation calibrated by neutron data
- Further 65 days data on disk for a full blind analysis



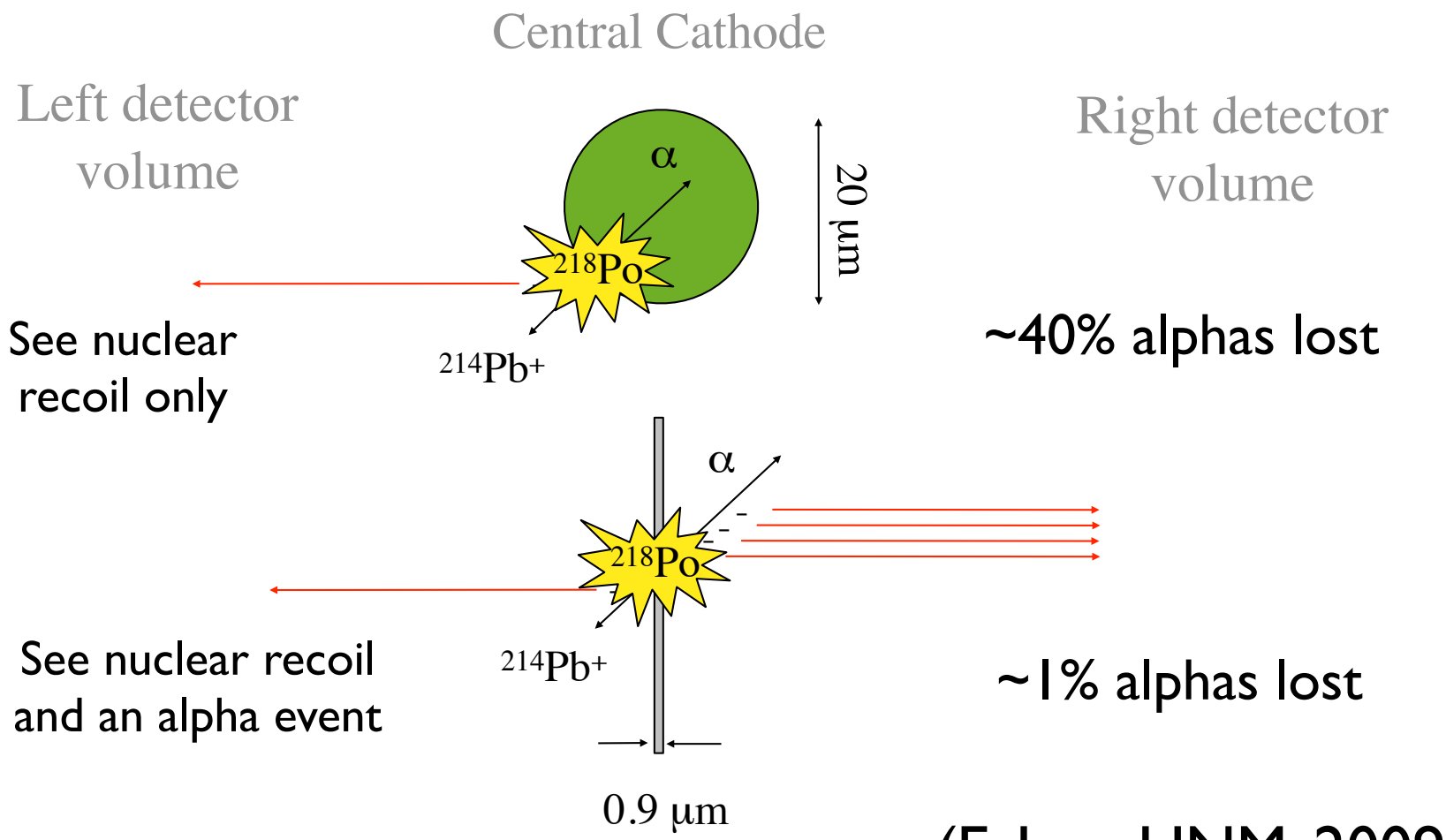


Min. SD limits, directional detectors:
DRIFT: 1.2 pb
NEWAGE: 5400 pb
DM-TPC: 2400 pb



Further RPR reduction

A cathode highly transparent to α's from RPRs will provide a tag to veto these events

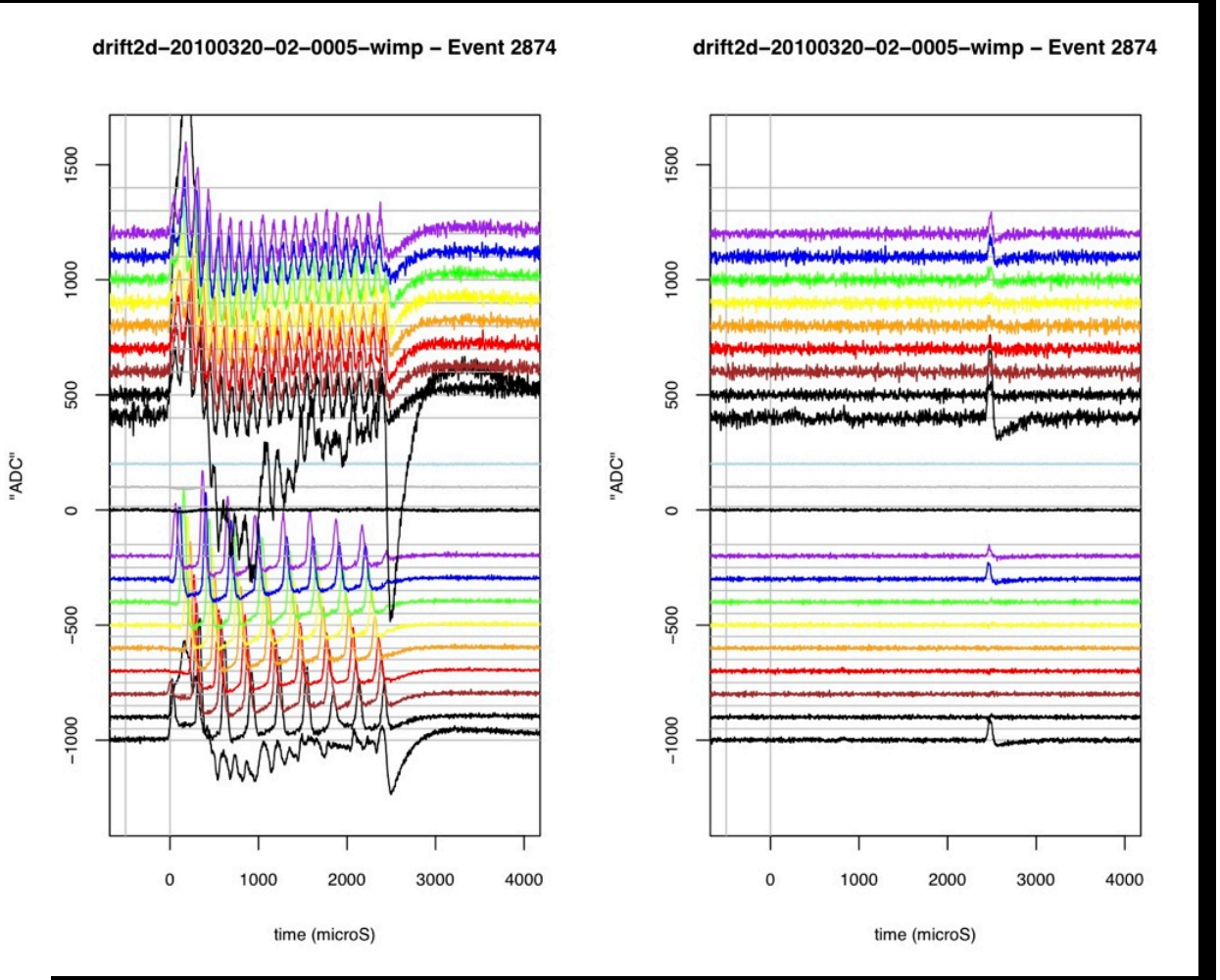


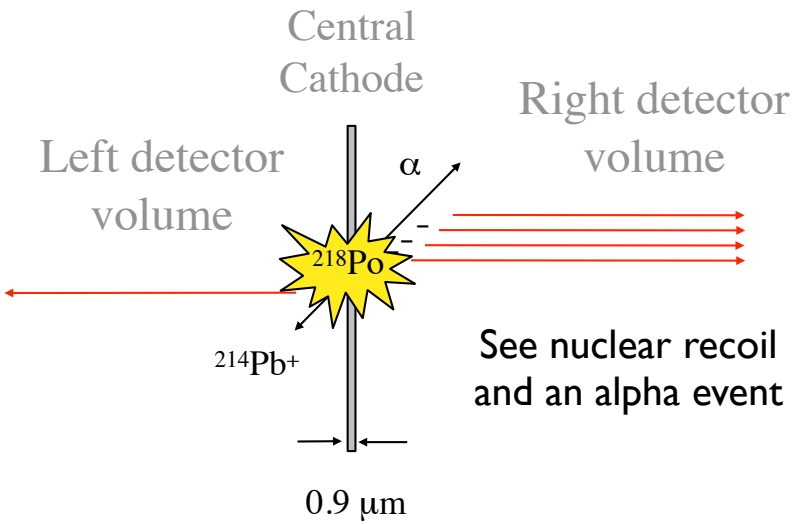
(E. Lee, UNM, 2009)

0.9µm thin film cathode installed on DRIFTII at the Boulby Mine

Tagged RPRs

- Alpha on one side, WIMP-like event on the other
- With the thin film data we expect less WIMP-like background, more tagged RPRs



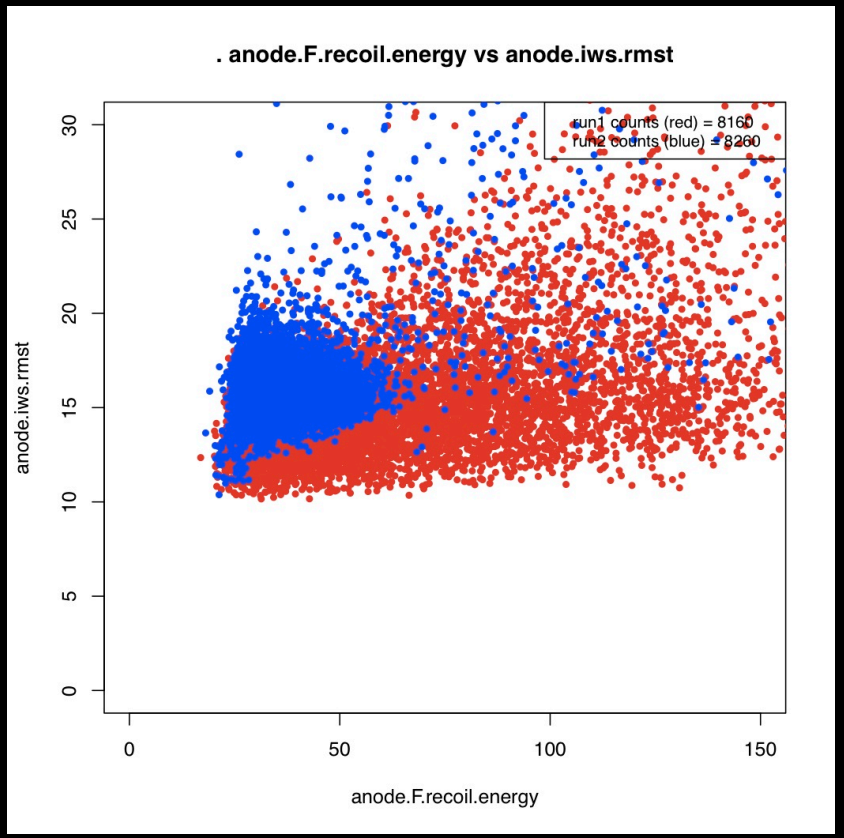


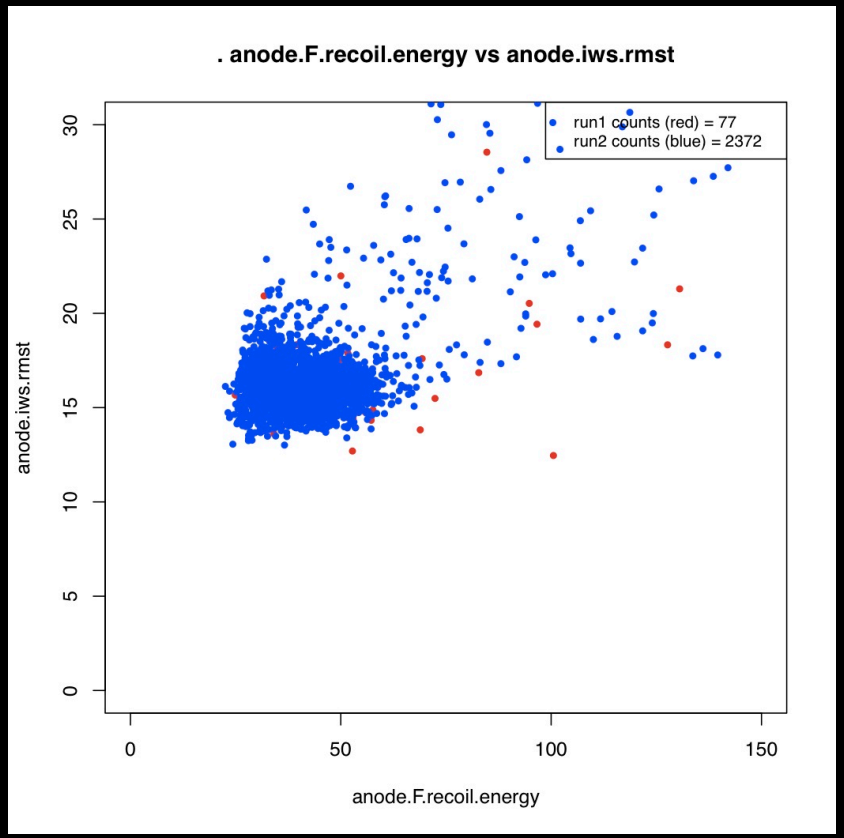
See nuclear recoil and an alpha event

20μm wire central cathode

Background events
174 events/day

Tagged RPRs
50 events/day





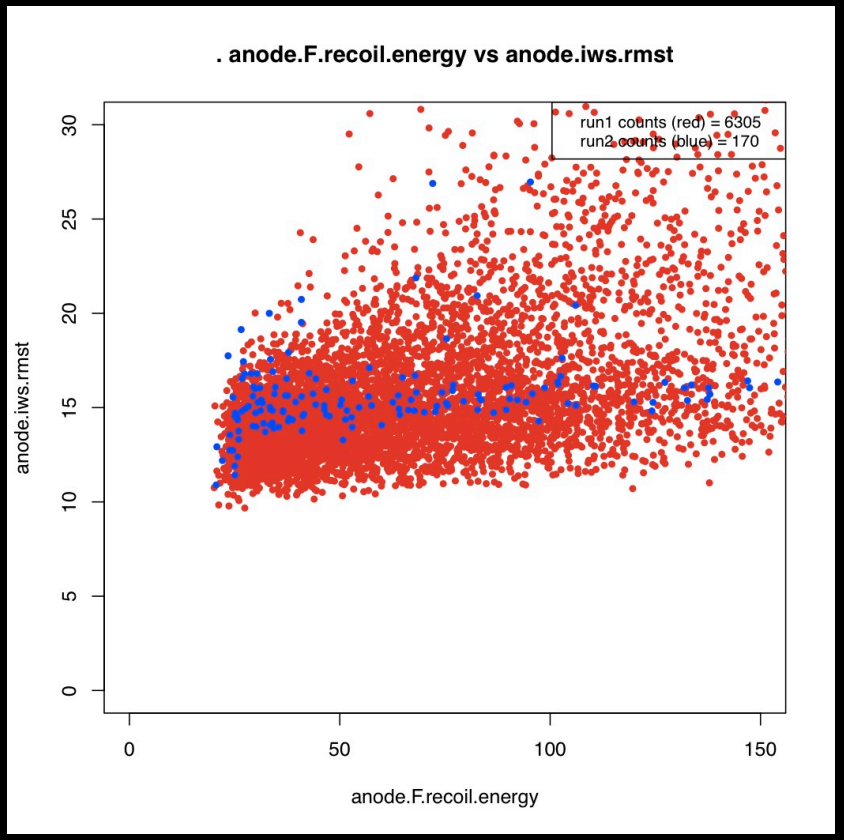
0.3 tagged RPRs per background event

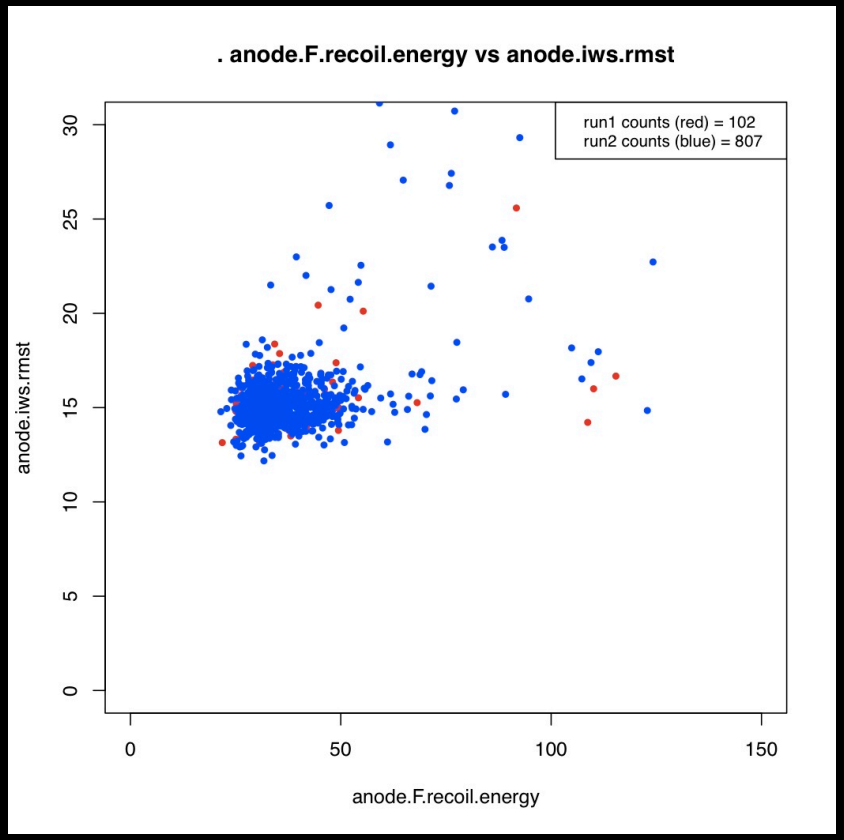
47.2 days data used to set limit

0.9µm thin film central cathode

Background events
14.7 events/day

Tagged RPRs
70 events/day





4.7 tagged RPRs per background event

11.6 days - 64.5 days on disk ready for full blind analysis

Conclusions

- DRIFT-IId at the Boulby Underground Laboratory (UK) now running with CS_2-CF_4 gas mixture for SD sensitivity
- Unblind analysis of 47.2 days produced SD limit of ~1.2pb (100 GeV WIMP). No compromise on directionality
- Thin film cathode installed and analysis shows large reductions (factor >15) in RPR background from thin film cathode
- 65 days of data with thin film cathode is on disk - full blind analysis coming soon