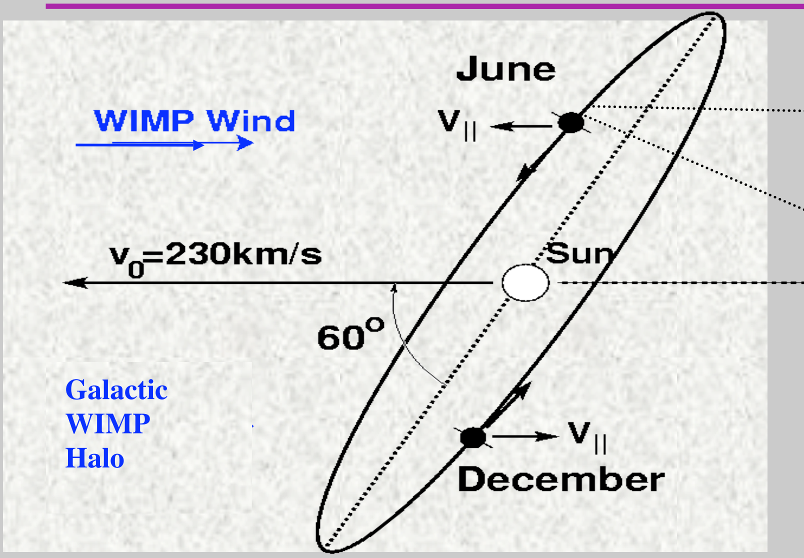
DRIFT - Dark Matter Directional Detection

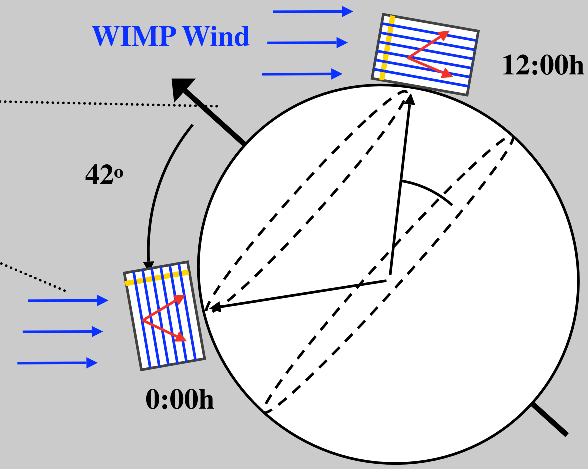
Neil Spooner (University of Sheffield) on behalf of the DRIFT collaboration

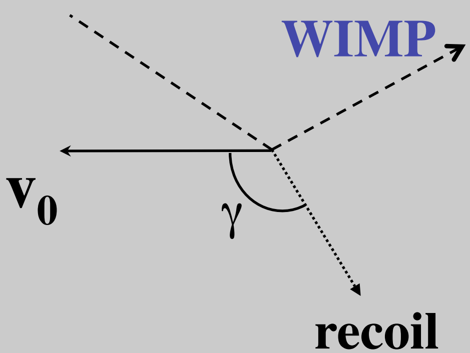
DRIFT (Edinburgh, Sheffield, Occidental LA, New Mexico)

Burgos et al, arXiv:0707.1488 (sub Astrop.Phys, 2007) - first DII data
Burgos et al, arXiv:0707.1758 (sub Astrop.Phys, 2007) - DII alpha results
Spooner, Majewski et al, arXiv:1107..- head-tail simulations DARK2007
Lightfoot et al., Astrop Phys, 27 (2007) 490
Tziaferi et al., Astroparticle Physics 27 (2007) 326
Spooner. J, Phys. Soc. Japan http://arxiv.org/abs/0705.3345
Alner et al., Nucl. Instrum. and Meth. in Phys. Res. A555 (2005) 173
Alner et al., Nucl. Instrum. and Meth. in Phys. Res. A 535 (2004) 644

Directional Motivation







A WIMP telescope?

Recent work here (4 papers in preparation):

(i) low threshold - use for axions searches

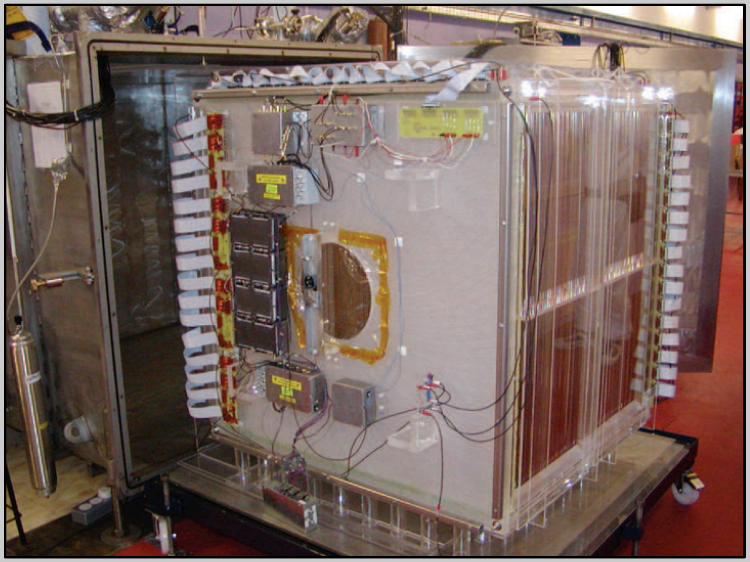
(ii) low background - radon progeny background

(iii) directional signals

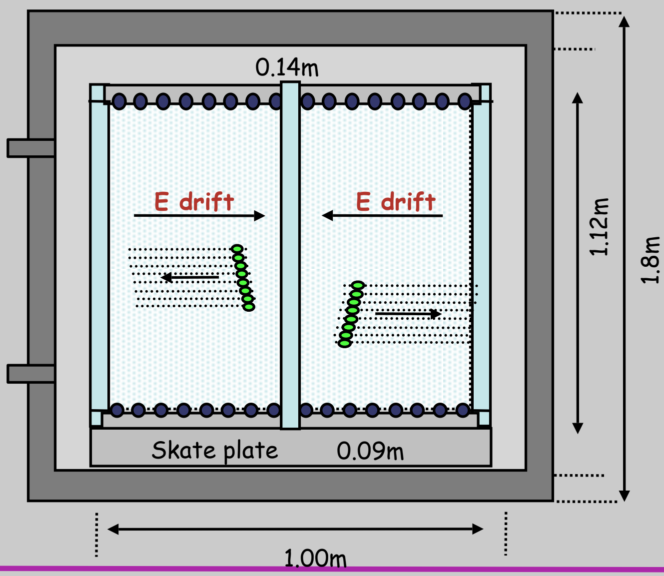
(iv) head-tail recoil vector discrimination

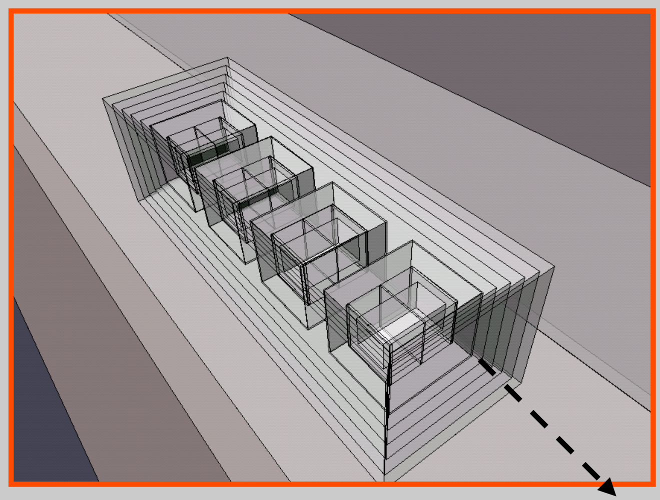
thanks to D. Muna, S. Paling, P. Majewski (USFD); D. Snowden-Ifft (Oxy)

DRIFT IIa,b,c design

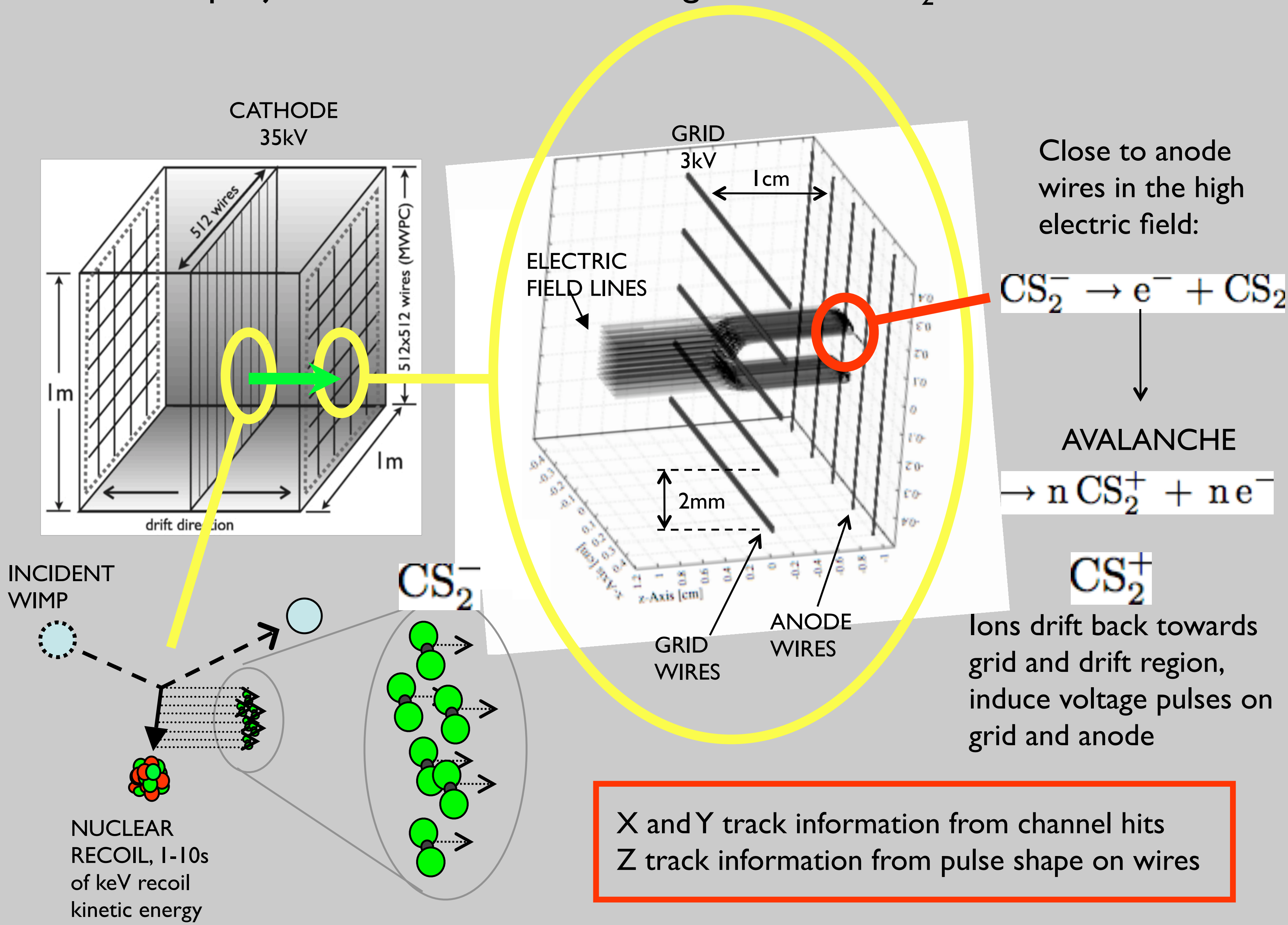


- 1 m³ active volume - back to back MWPCs
- Gas fill 40 Torr CS_2 => 167 g of target gas
- 2 mm pitch anode wires left and right
- Grid wires read out for Δy measurement
- Veto regions around outside
- Central cathode made from 20 μm diameter wires at 2 mm pitch
- Drift field 624 V/cm
- Modular design for modest scale-up





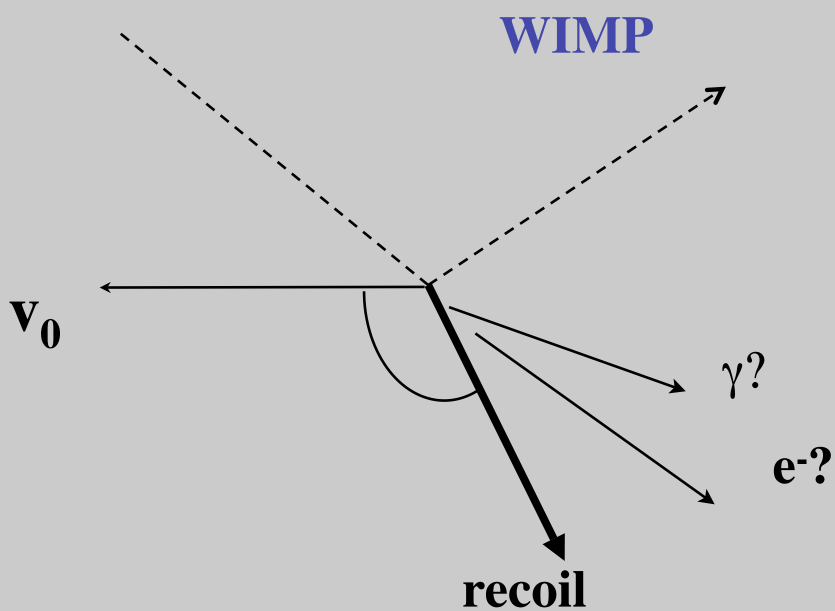
- 1.5 m^3 time projection chambers containing 40 torr of CS_2 with MWPC readout



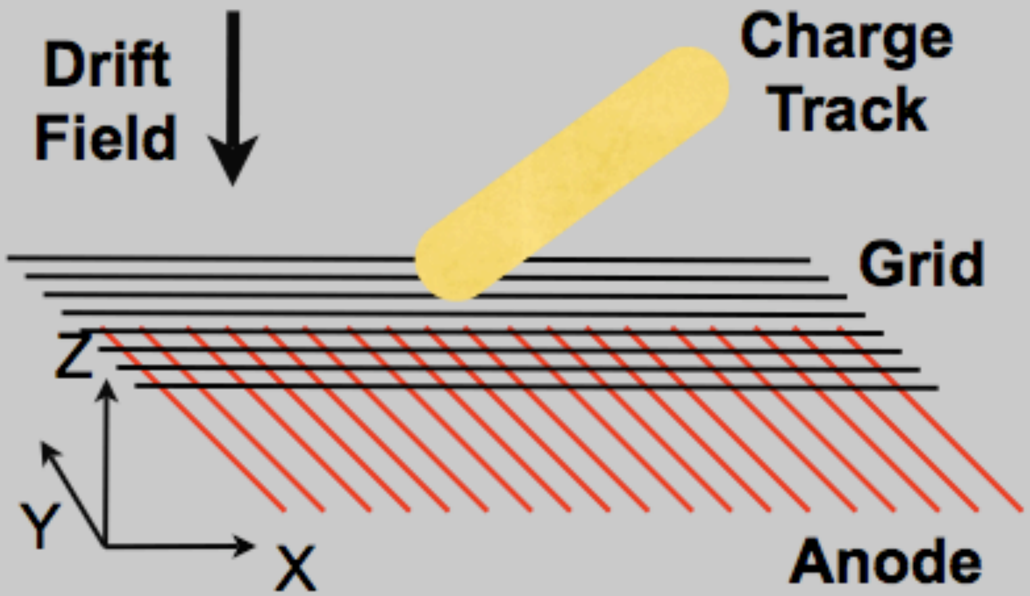
X and Y track information from channel hits
Z track information from pulse shape on wires

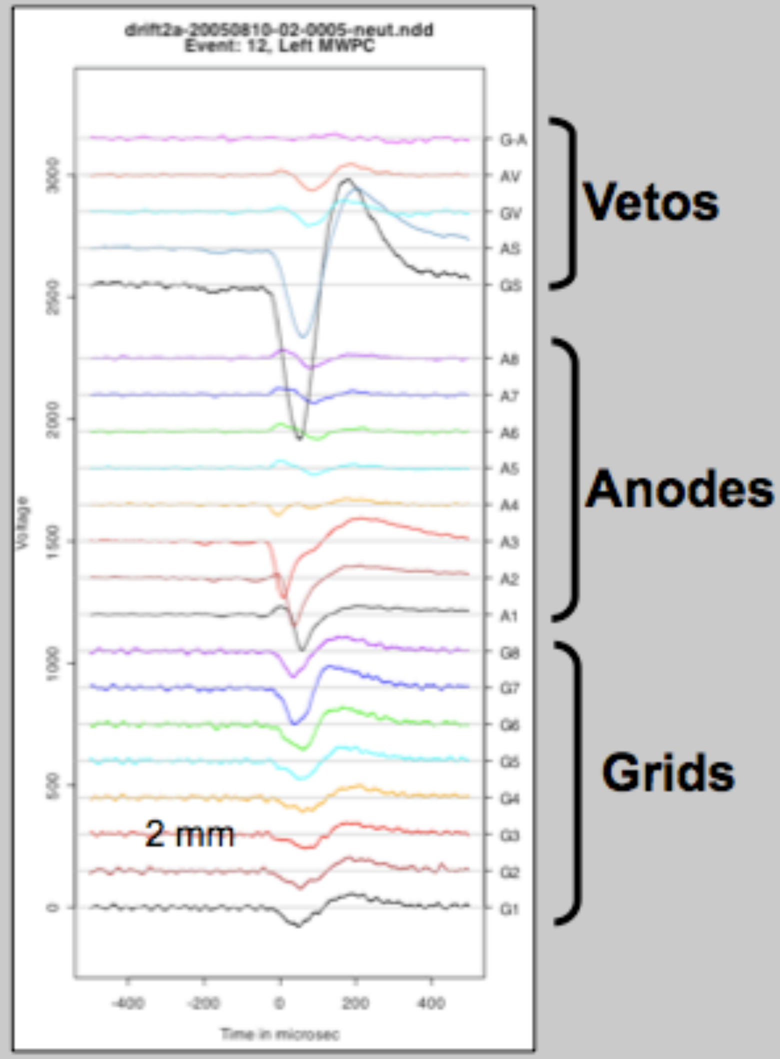
AIM

- event by event, maximum information
- gamma, electron, recoil tracking in space
- gamma, electron, recoil tracking in time
- at low threshold >1 keV
- multi-target - F, S, C, Xe... (SD and SI)
- recoil direction information
- including sense direction of recoils



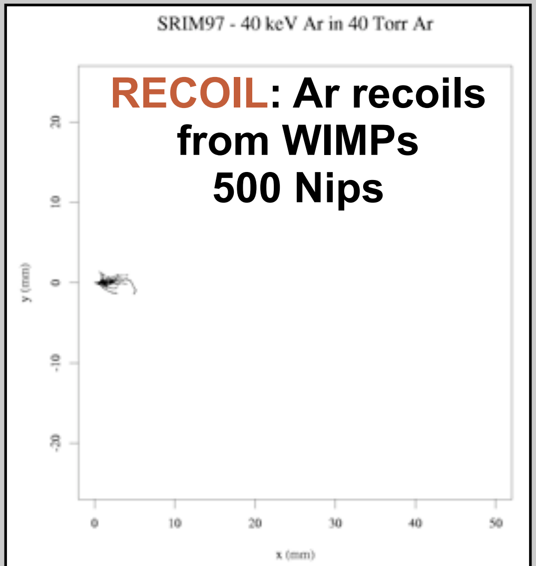
Track reconstruction, R2, R3

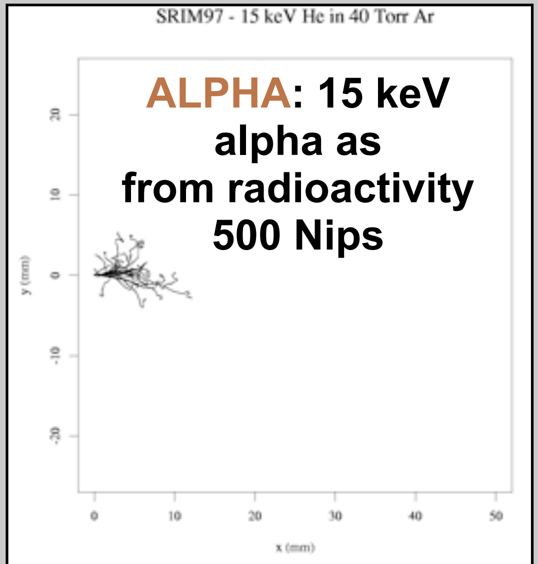


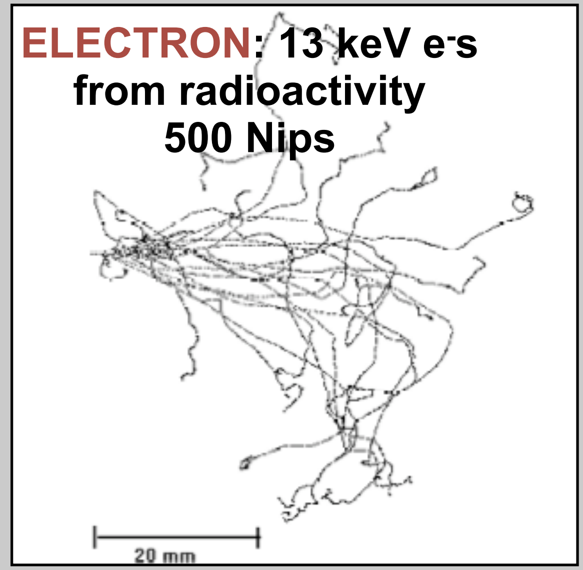


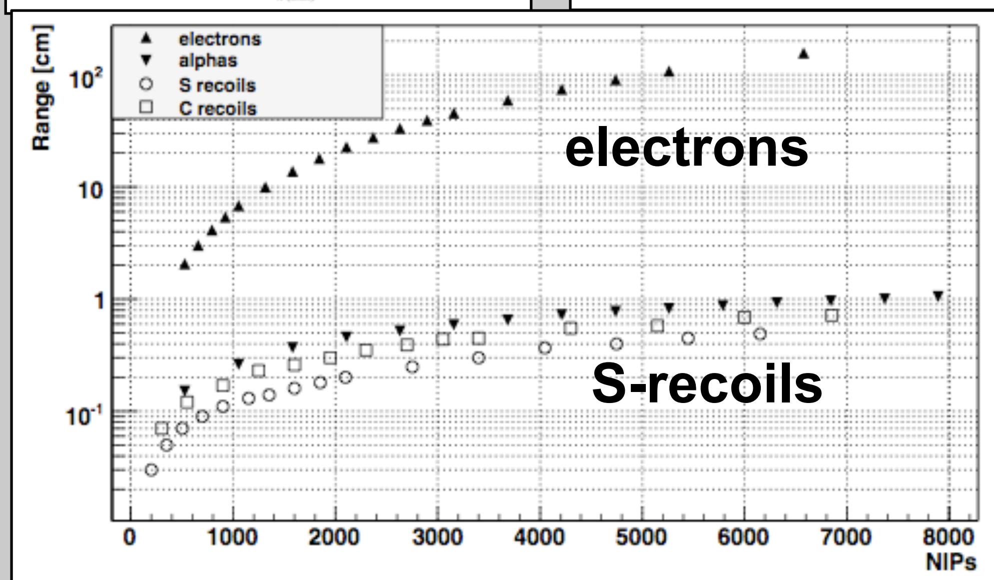
ΔX: Number of Anode Wires Crossed
ΔY: Progression across Grid Wires
ΔZ: Drift Time difference between start and end of track

Range/track discrimination





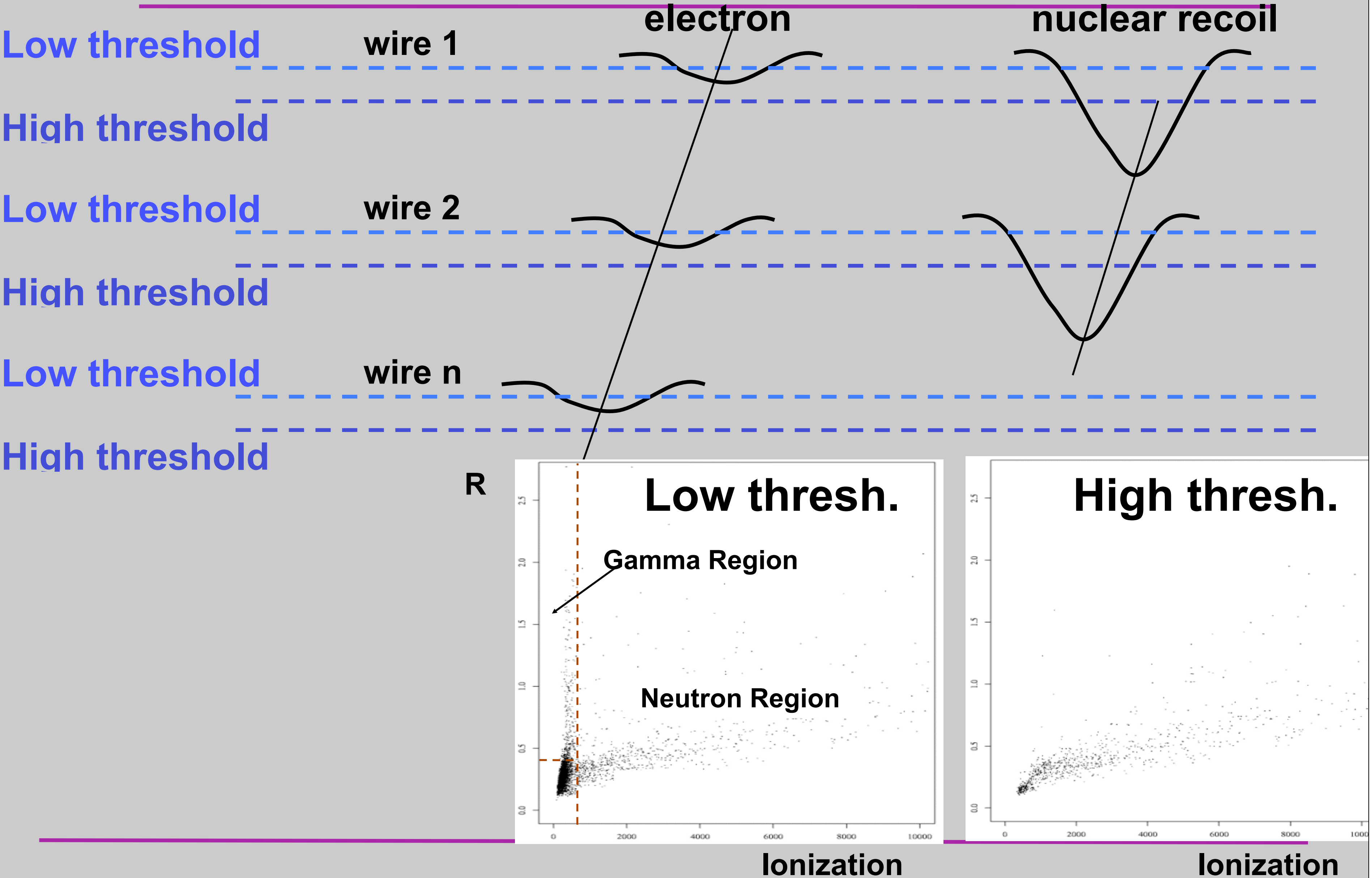




simulations

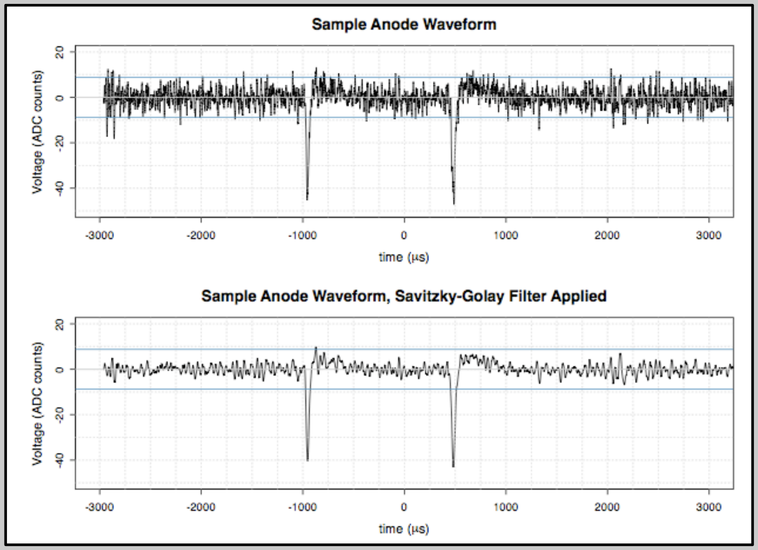
Key points: it's range discrimination - no doubt

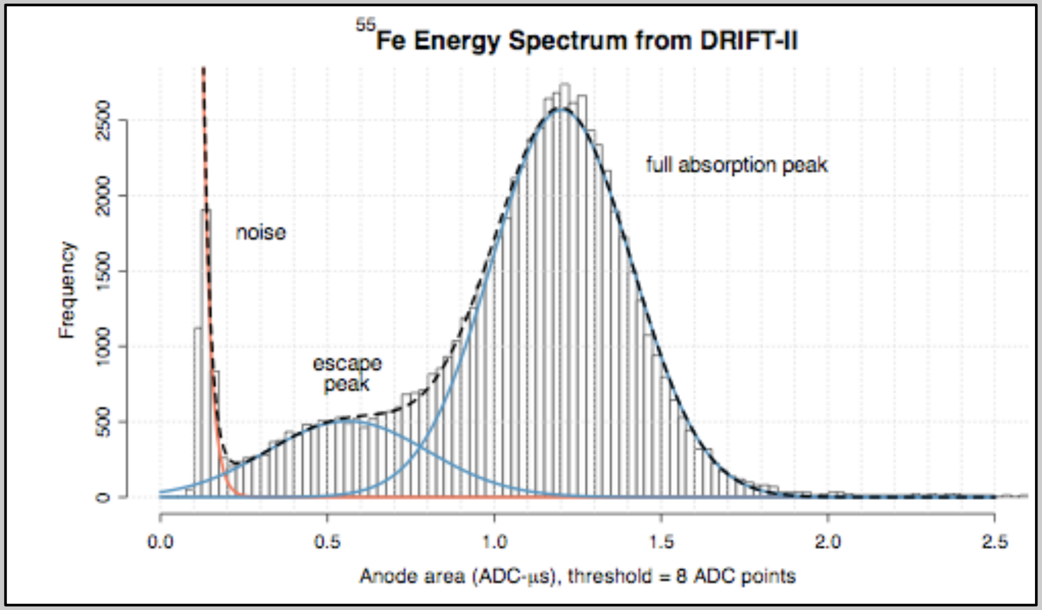
dE/dx discrimination



Threshold - new analysis

use of Savitzky-Golay digital filter





^{55}Fe track reconstruction and digital polynomial smoothing - data fit to exponential decay(noise) plus Gaussians (escape and full absorption peaks).

Energy thresholds -->

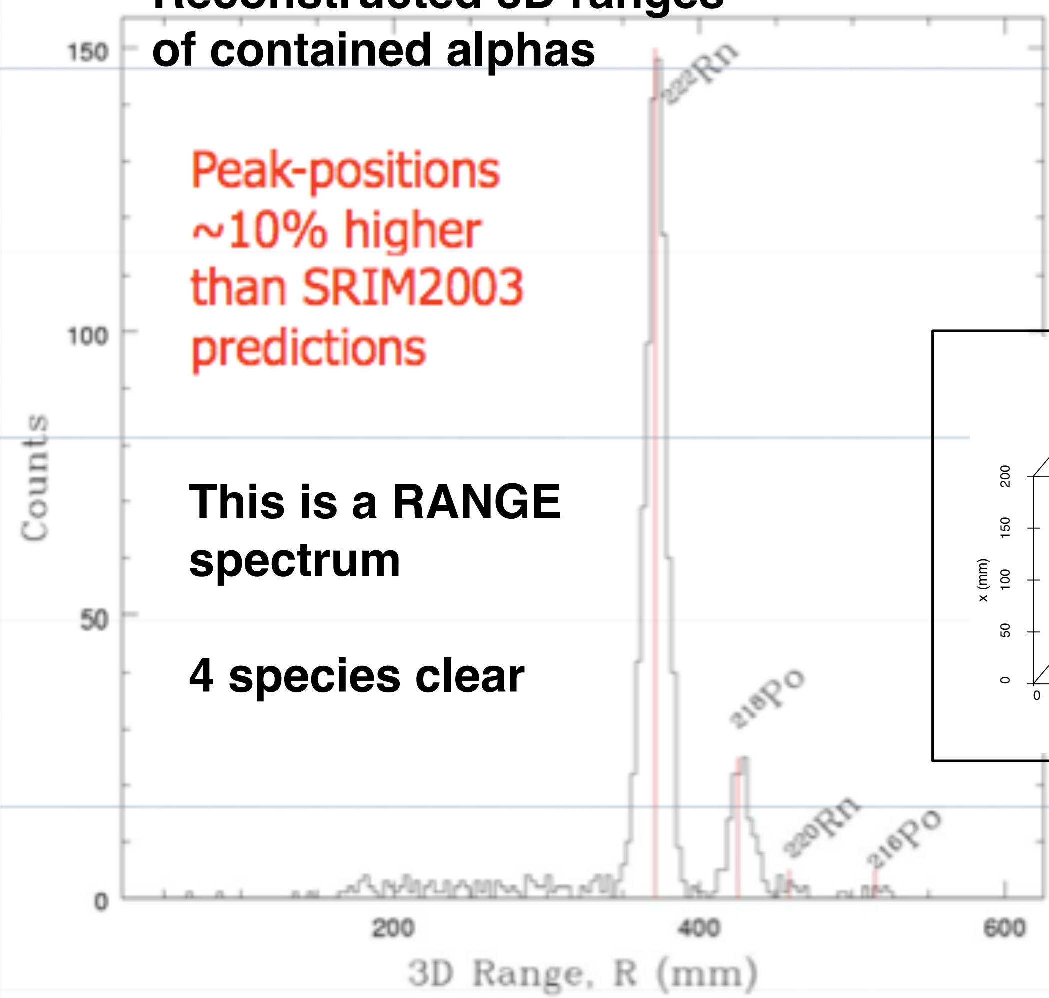
Source of Track	Energy (keV)
Electron	1.23
Alpha	1.23
Carbon nuclear recoil	2.15
Sulphur nuclear recoil	3.46

Note these are not the trigger thresholds yet

Paper in preparation - D. Muna

Alpha range data

Reconstructed 3D ranges of contained alphas

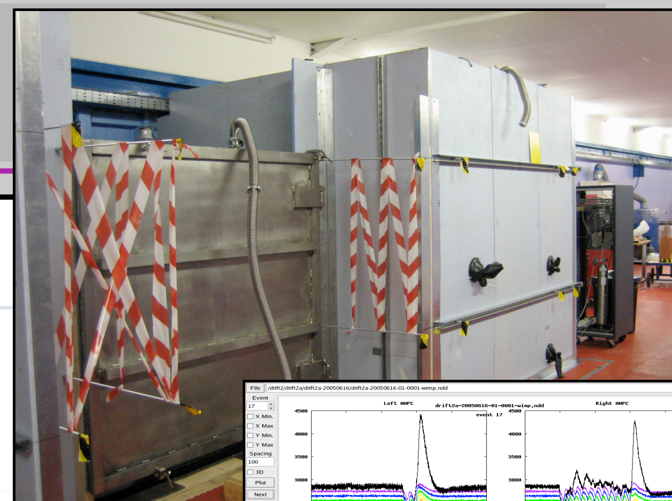


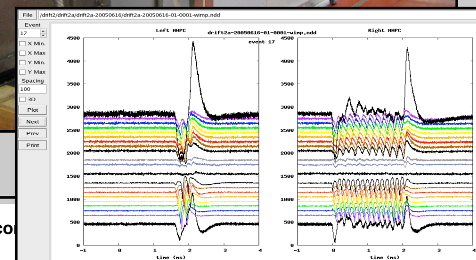
Peak-positions ~10% higher than SRIM2003 predictions

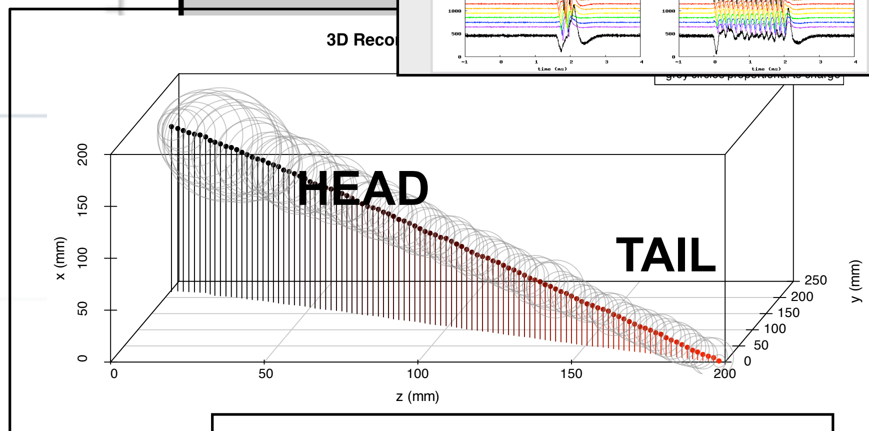
This is a RANGE spectrum

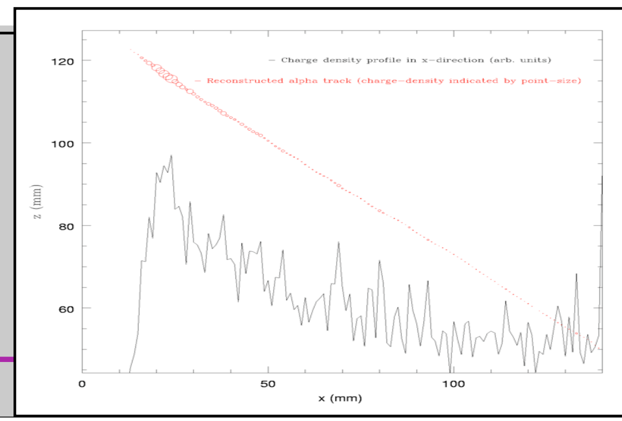
4 species clear

S. Burgos et al., Nucl. Instr. Meth. A 584, 114 (2008)







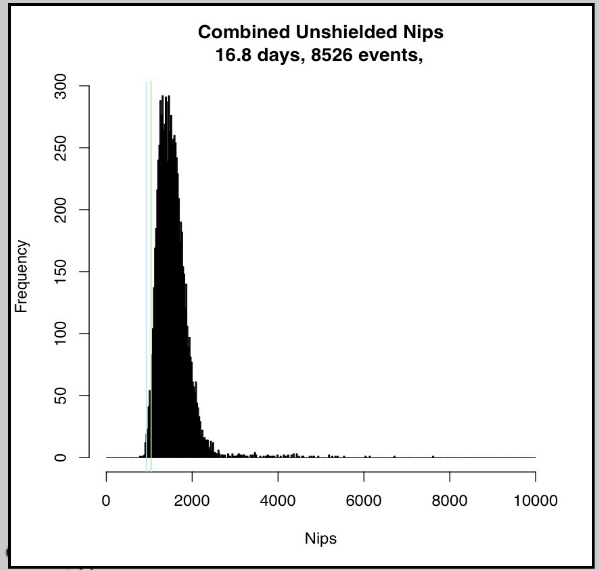


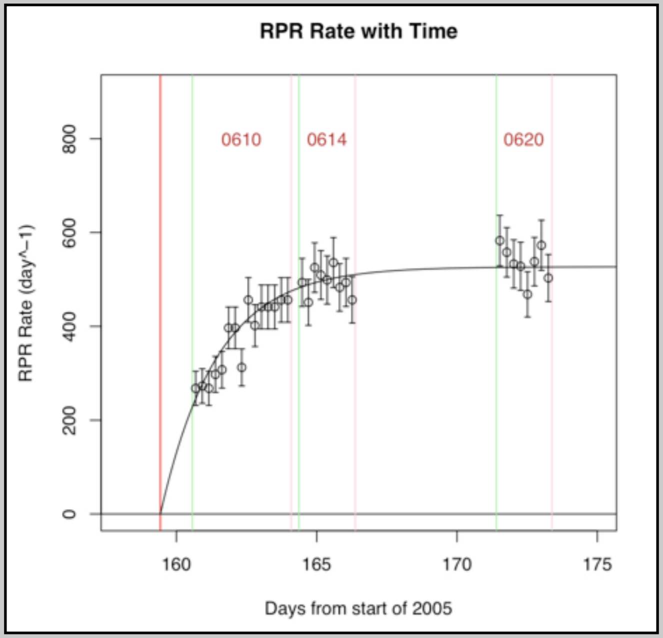
Radon Progeny Recoils (RPRs)

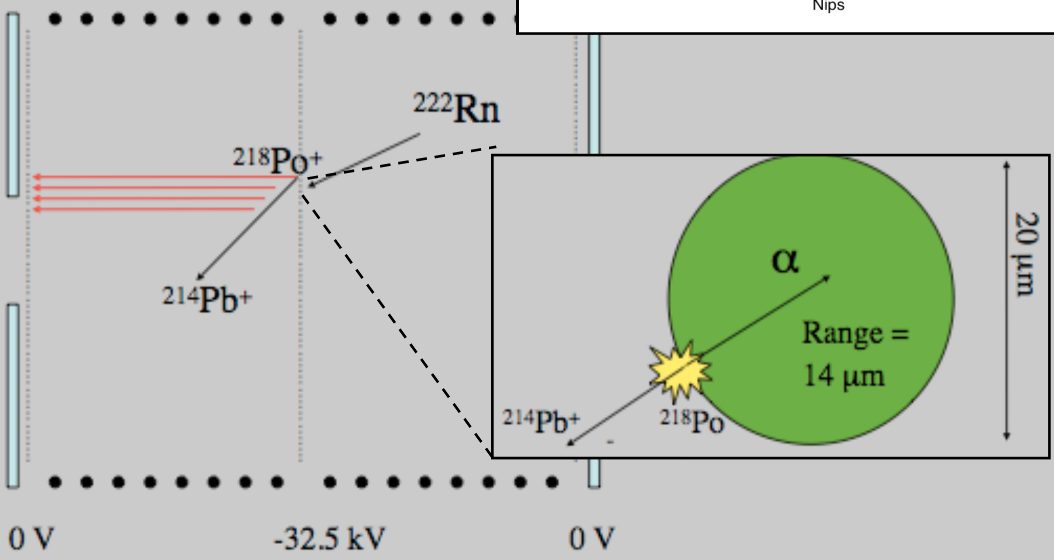
First low background runs of DRIFT-II see a recoil-like background ~200-600 / day (50-250 keV).

Increase with time consistent with Rn emanation.

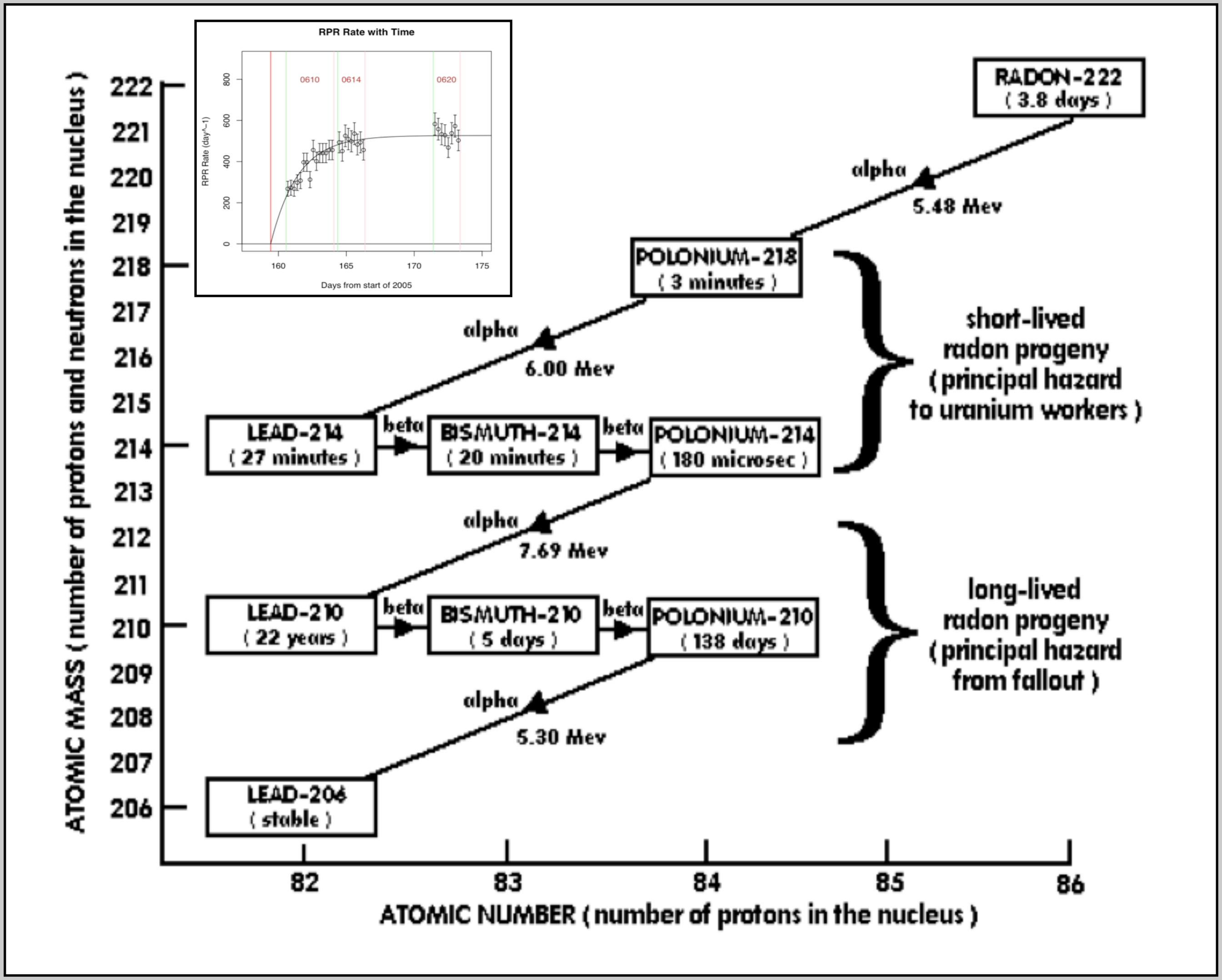
Hypothesis: Recoil of radon progeny on central cathode - with alpha absorbed in wire.





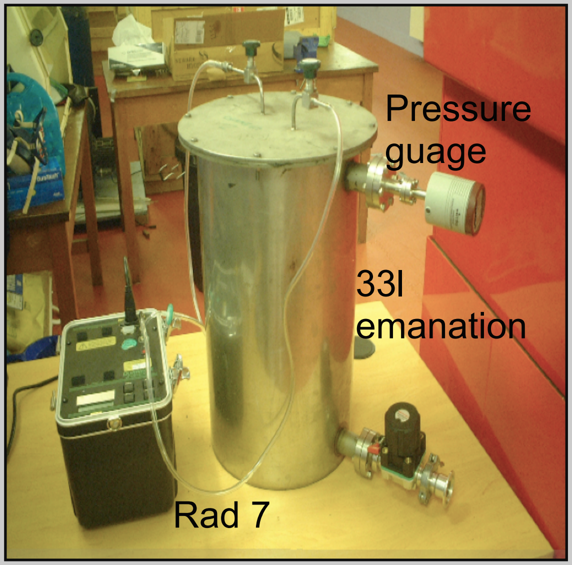


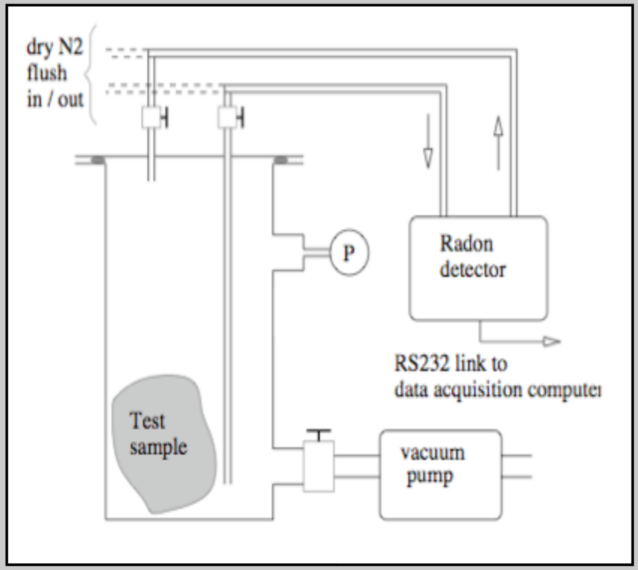
Rn decay chain

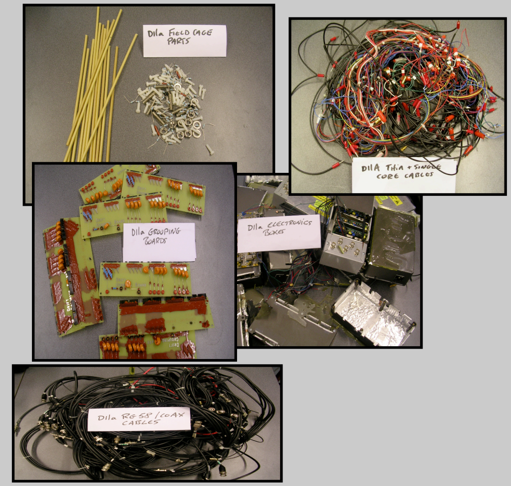


- Gaseous element in Uranium decay chain
- Rn222 half life = 3.8 days
- 4 alpha decays before reach stable Pb-206
- Radon levels at Boulby are actually very low! (~3 Bq/m^3)

Rn Emanation Facility - ^{218}Po







DIIa samples:

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 +/- 0.01
Ribbon cables	Dry N2	6.5	23	10.1 +/- 0.7	0.50 +/- 0.03
Grouping Boards	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 +/- 0.05

* The limit of sensitivity of the method (see above)

- **Main offenders = Ribbon cables and Coax. cables**
- **Total of items measured = 0.95 +/- 0.05 Rn atoms.s^{-1}:**

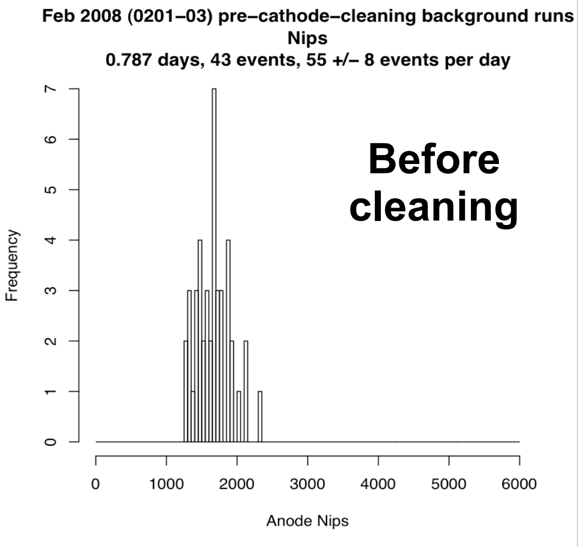
Central Cathode Cleaning

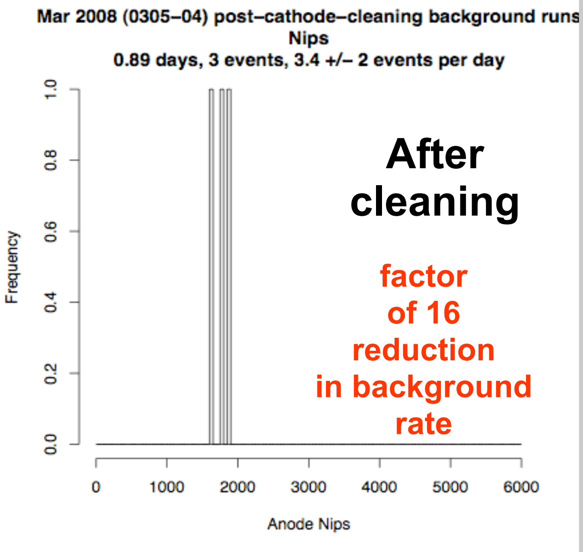
DRIFT II sees an excess of background events attributed to recoils of ^{210}Pb plated out on the detector. A likely region for build-up of ^{210}Pb is on the cathode wires.

Johanna Turk (University of New Mexico)

Mark Pipe (University of Sheffield)

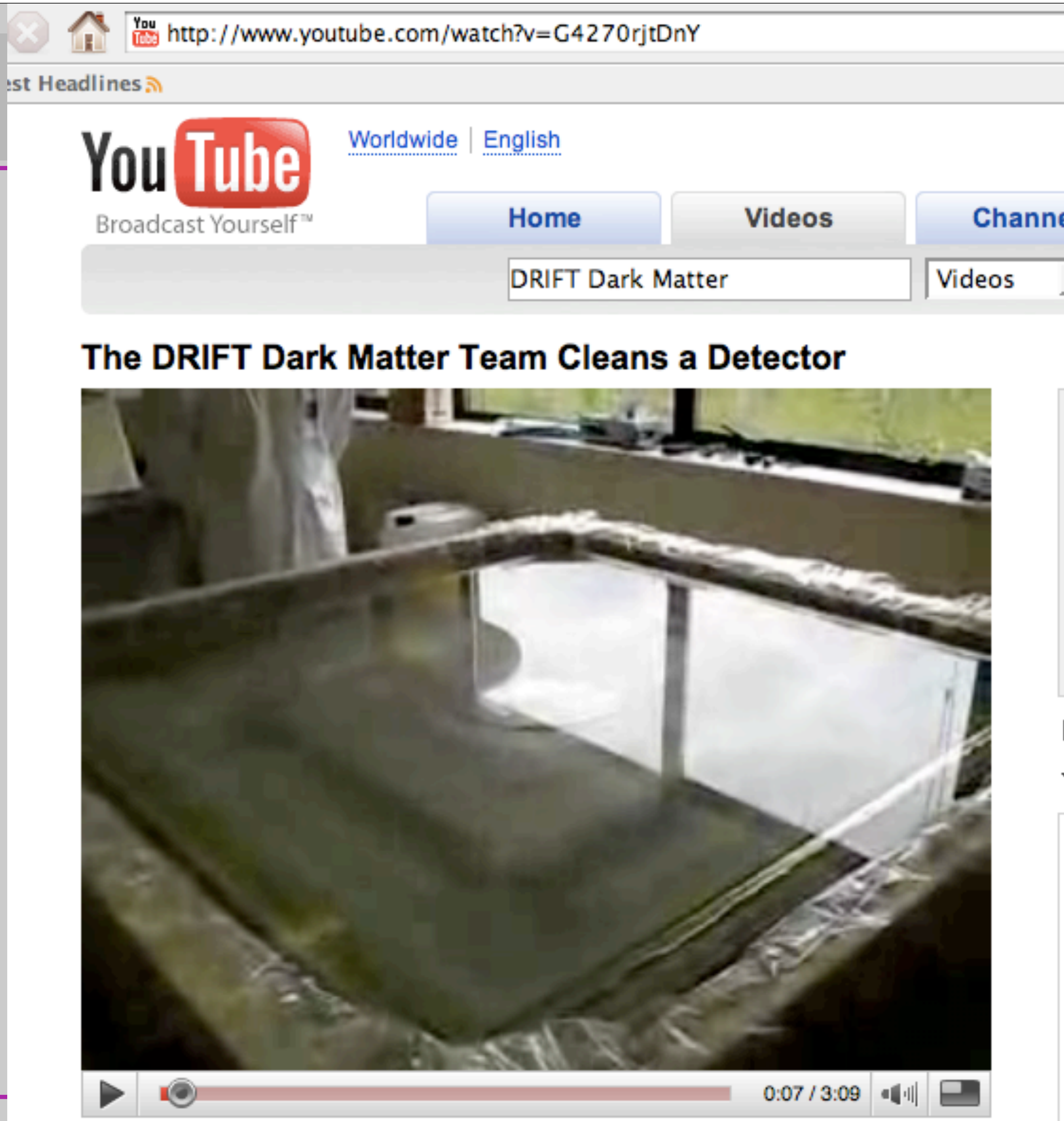
Kirill Pushkin (Occidental College)





Next step is to apply the same cleaning procedure to MWPC grid and anode wires.

Nitric acid radon plate out cleaning

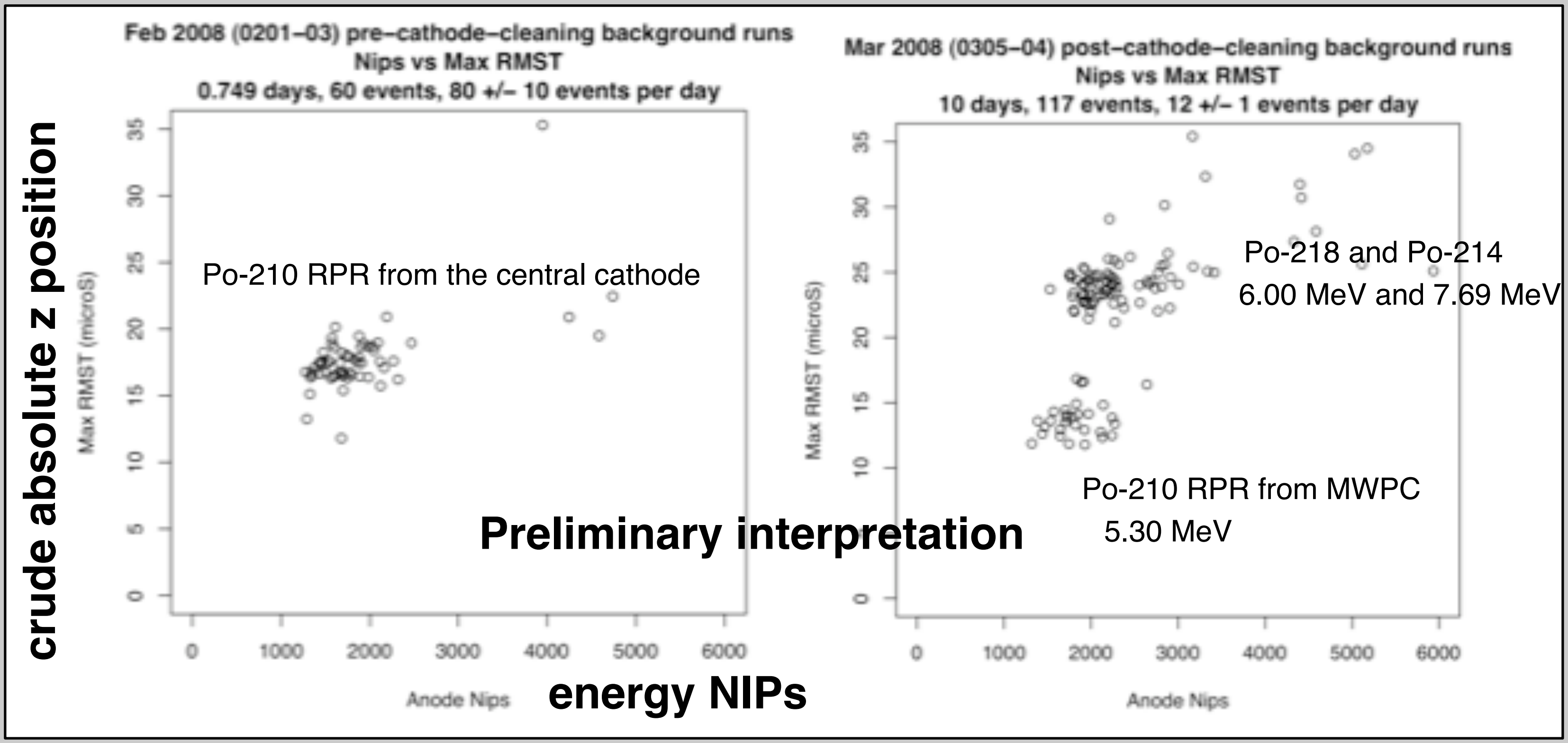


Cathode Cleaning Result

Main result: total RPR reduced by factor ~x5

Preliminary interpretation: cleaning has had a major effect on ^{210}Po (from ^{210}Pb) on central cathode, see remaining short-lived RPRs, and see rare RPRs now from MWPC

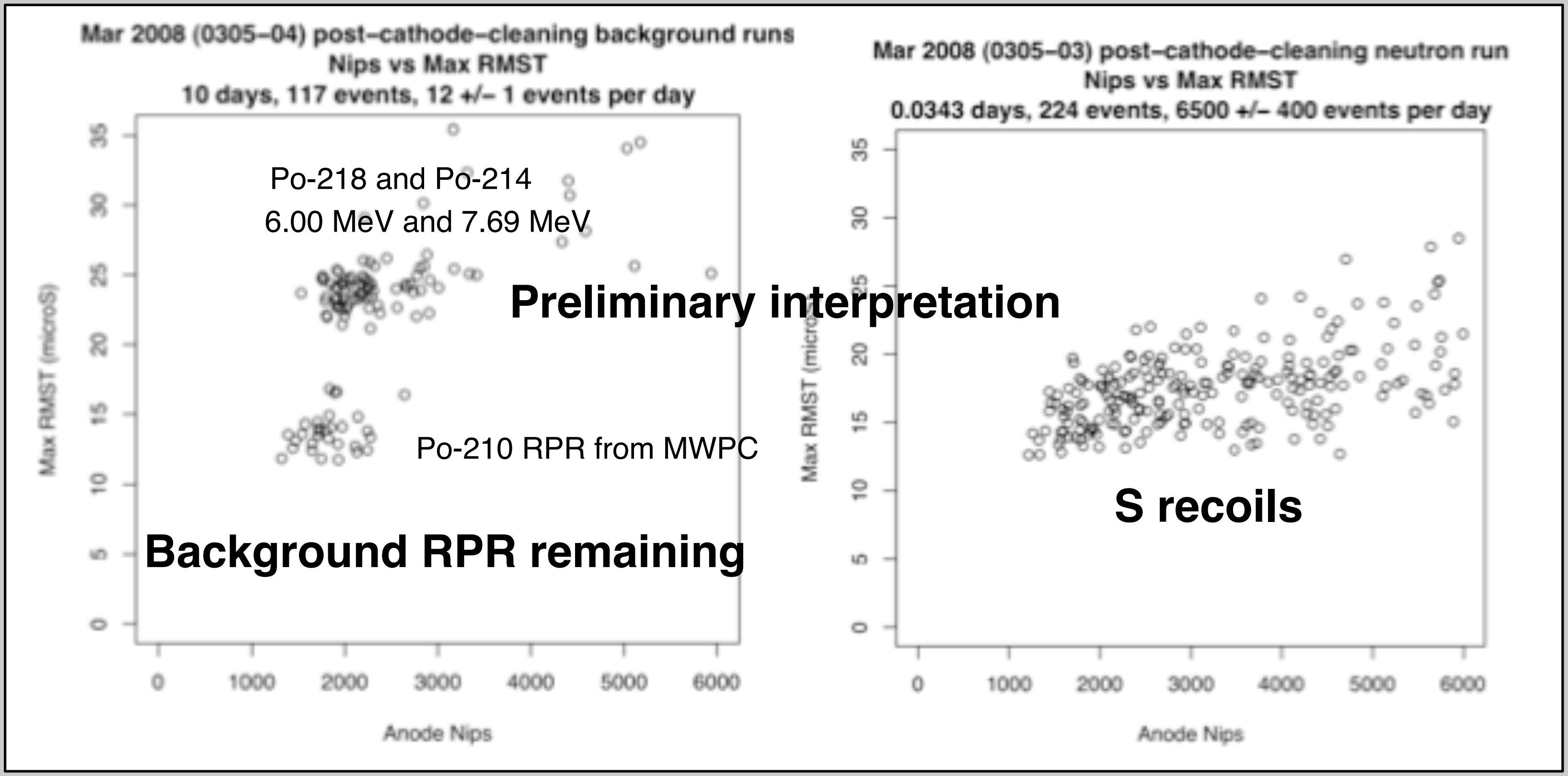
before cleaning **after cleaning (x13 more stats)**



Central Cathode Cleaning

Background RPRs vs neutrons

neutron calibration (S recoils)



Preliminary interpretation: (i) remaining short-life cathode RPRs can be cut and reduced by flushing, (ii) remaining MWPC RPRs (~1/day)

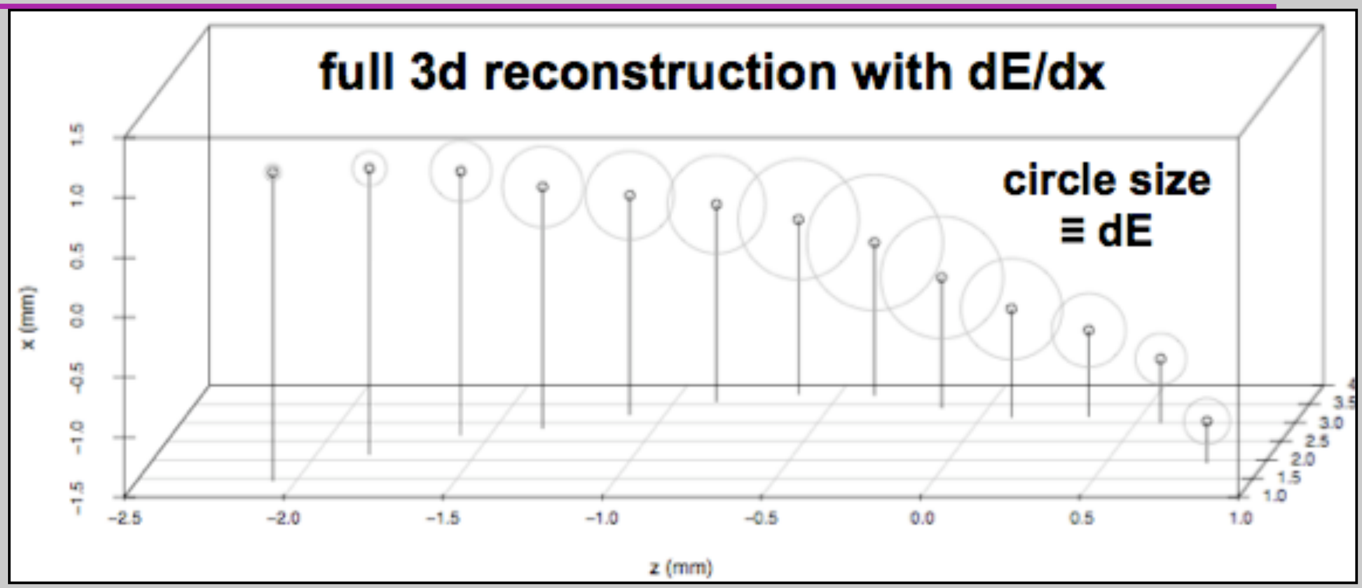
RPR Background history

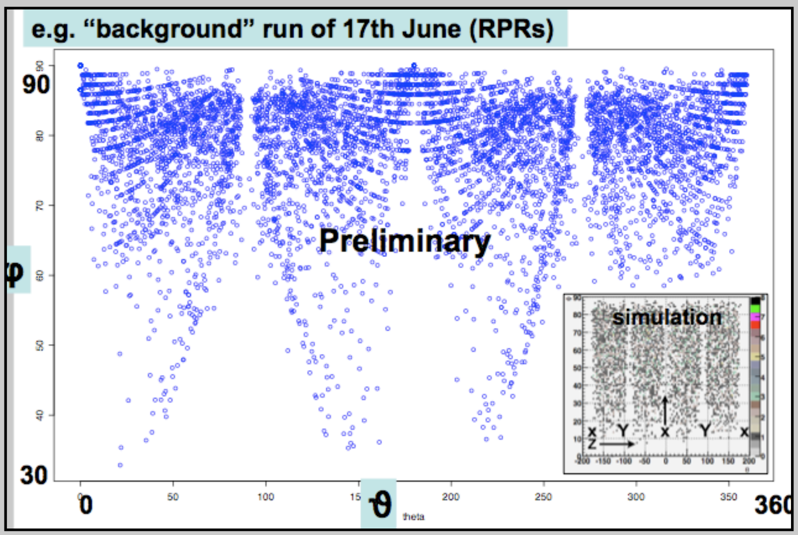
Run	Detector configuration	Gas flow rate (chg/day)	RPR rate (day^{-1})
(1) DIIa June 2005	Original state	1	500+/-20
(2) DIIb Feb 2007	RG58, teflon cables removed and inner detector sealed	1	40+/-2
(3) DIIb July 2007	As above	10	51+/-4
(4) DIIb Feb 2008	As (2) (with slight cuts change)	1	55+/-8
(5) DIIb Mar 2008	As (4) but cathode nitric cleaned	1	3.4+/-2
(6) DIIb Aug 2008	After MWPC nitric clean		awaited

Preliminary: background now ~1 event per 6 days
i.e. x3000 total reduction

3D recoil reconstruction data

example ~100 keV S recoil





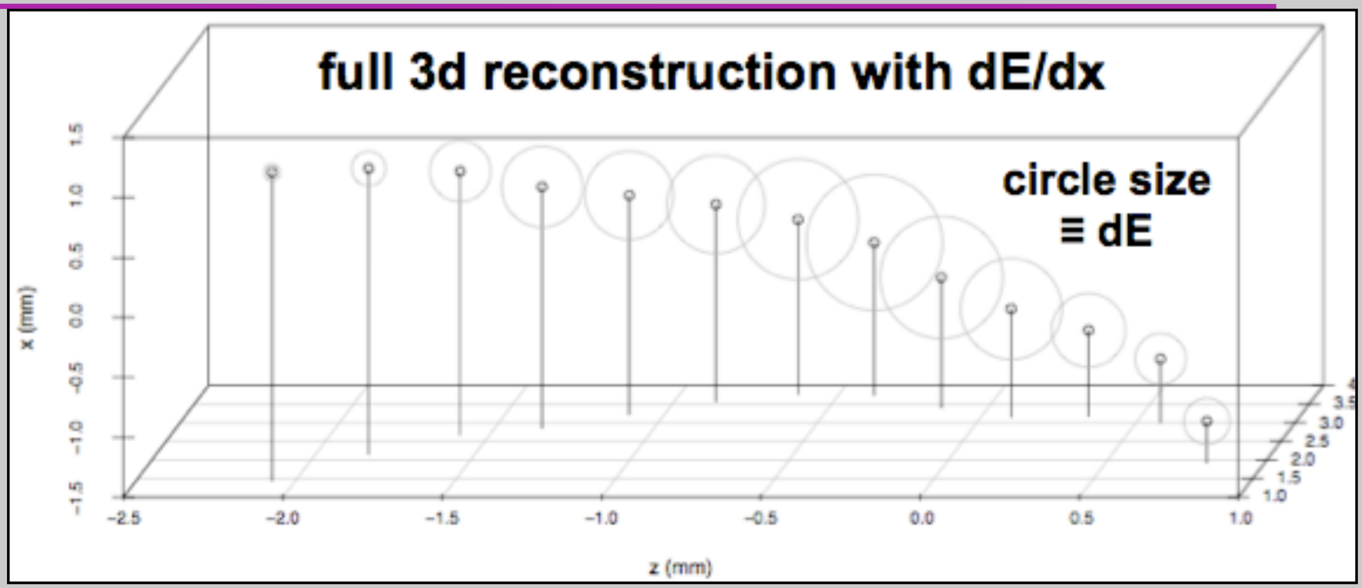
work in progress....

ϑ,φ direction sky map of data and simulation

DRIFTIIa electronics noise filter currently distorts y (and z) reconstruction

3D recoil reconstruction data

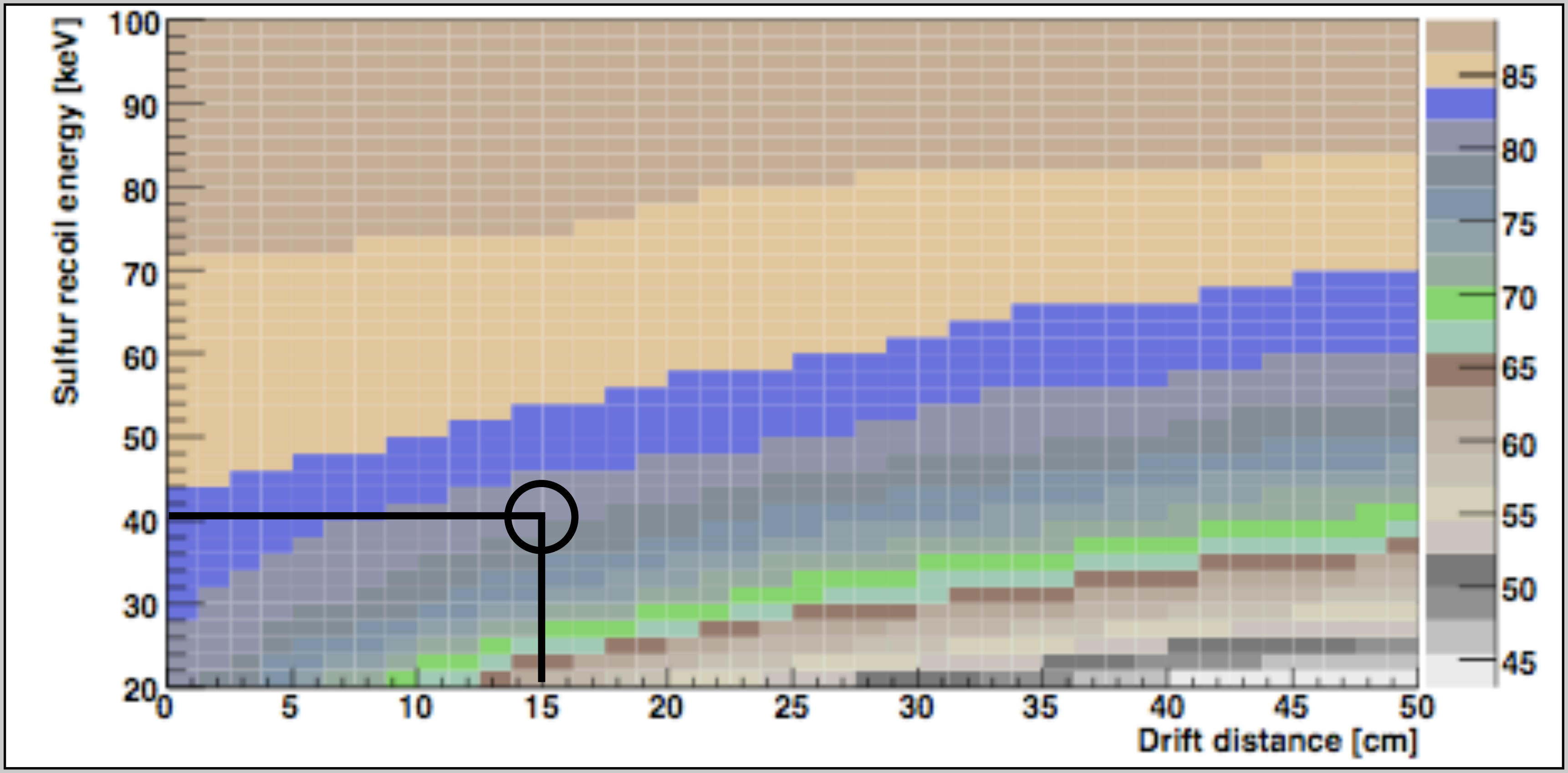
example ~100 keV S recoil



work in progress....

Recoil track pointing resolution

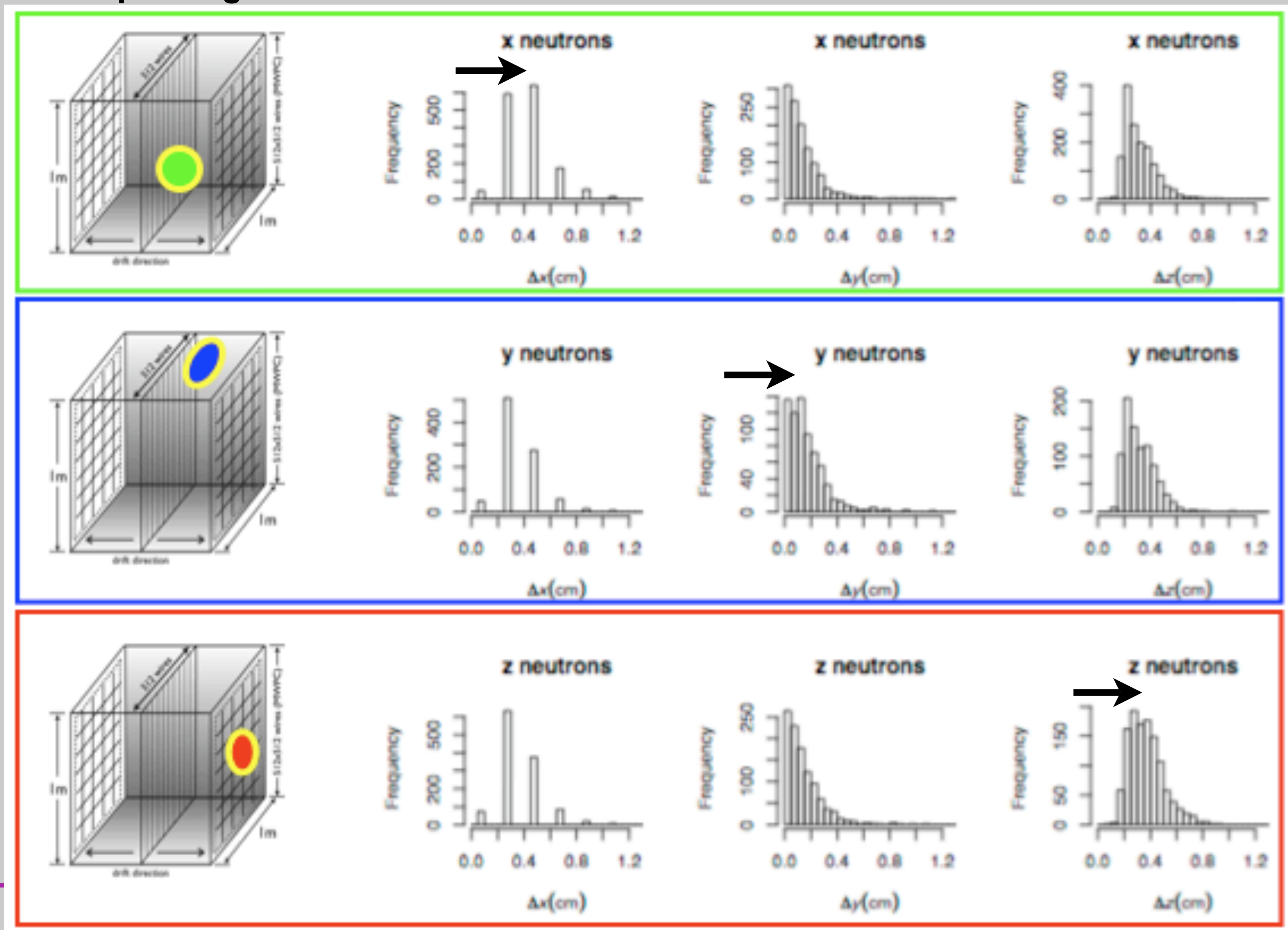
e.g. probability that Sulfur track is reconstructed to be within 30^0 of input initial direction (simulation)



e.g. for 15 cm drift distance 75% of 40 keV S recoils reconstructed within 30^0 of initial direction

Directional Signature

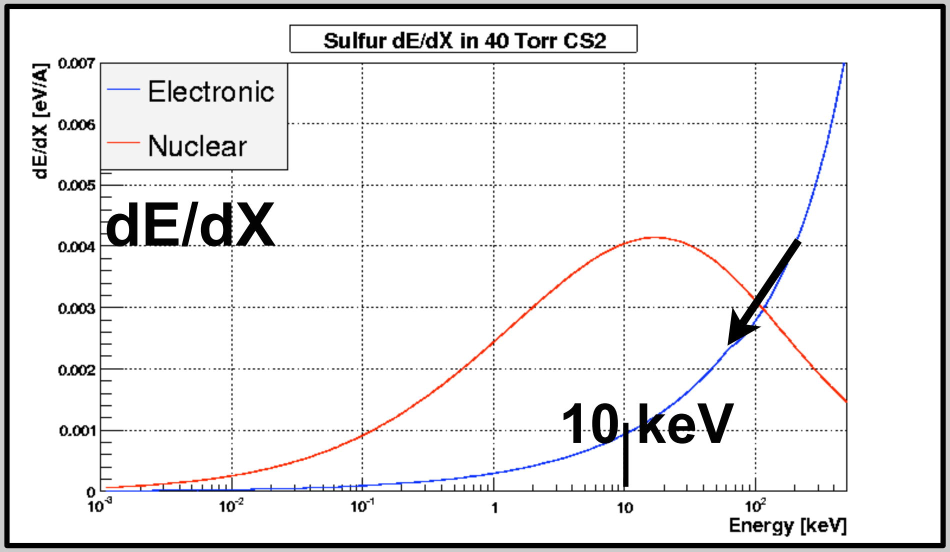
^{252}Cf neutron source placed on axes of DRIFT II. Show three components of the reconstructed track range for events passing selection cuts.



[grid wires are vertical, anode wires are horizontal]

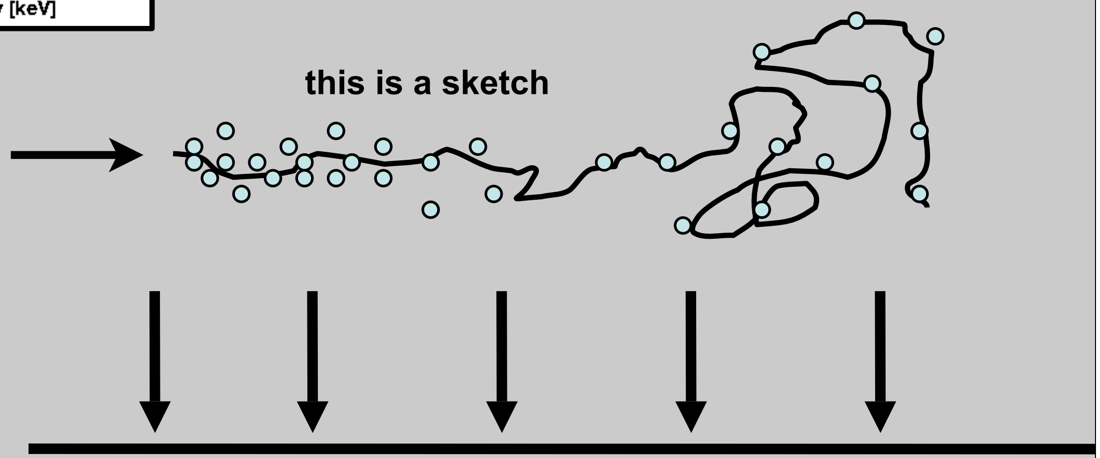
S. Burgos (2008) arXiv: 0807.3969

Head-Tail Signature



theory

Start → End



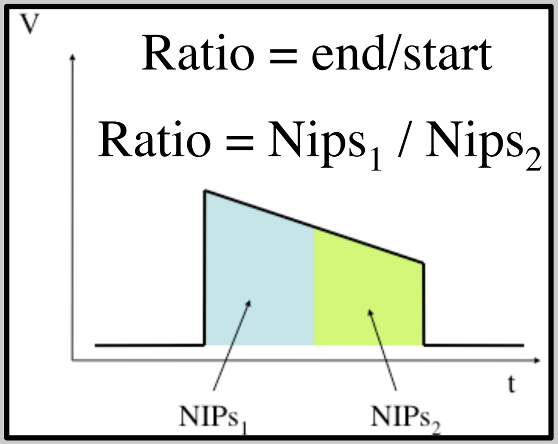
need to consider:

- W value
- diffusion
- readout projection
- event energy

Paper by P. Majewski et al.

project track for readout

Simulation Result



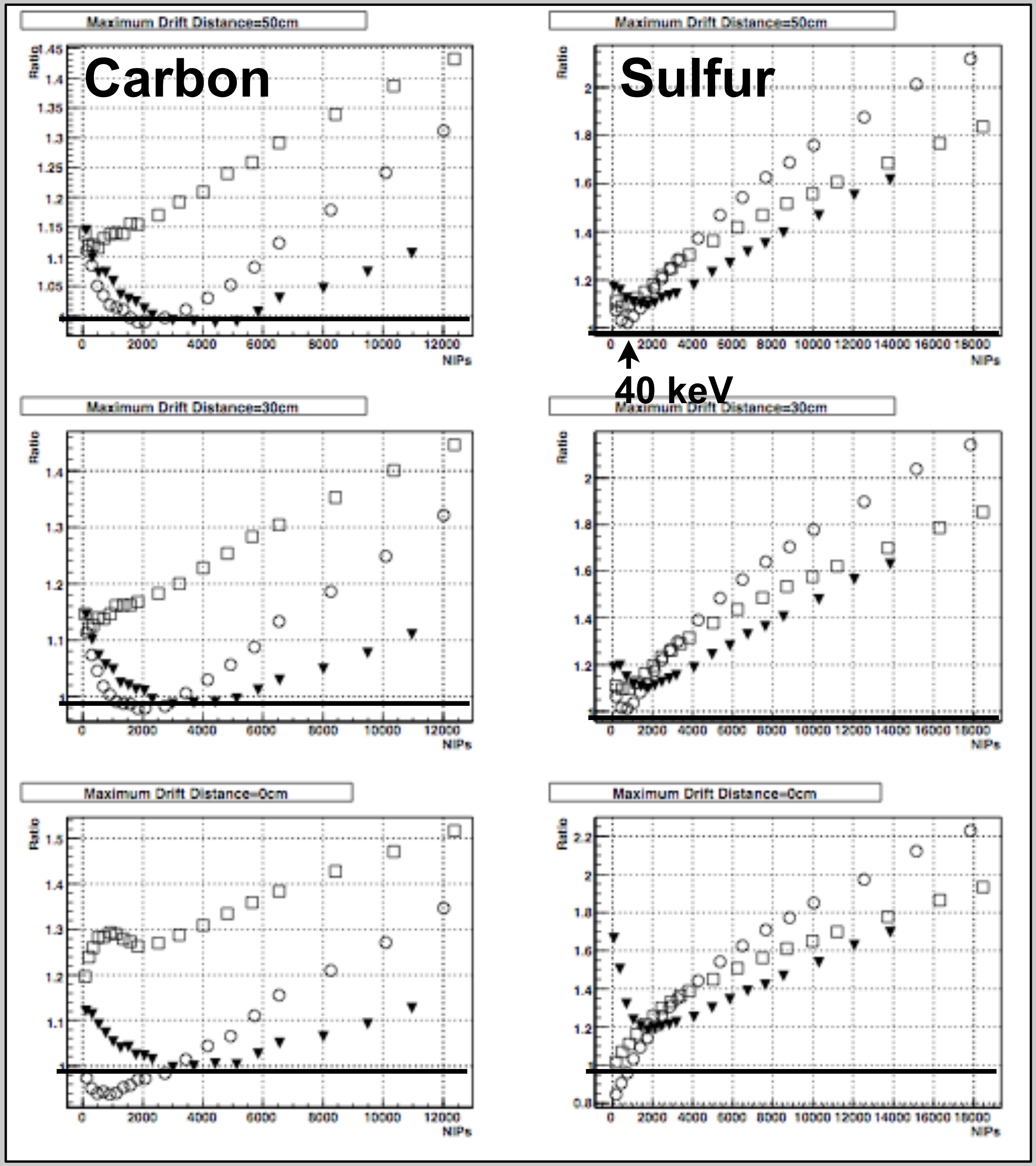
Position of mean of charge distribution along track

diffusion of 10cm, 30cm and 50cm

1 D projection case

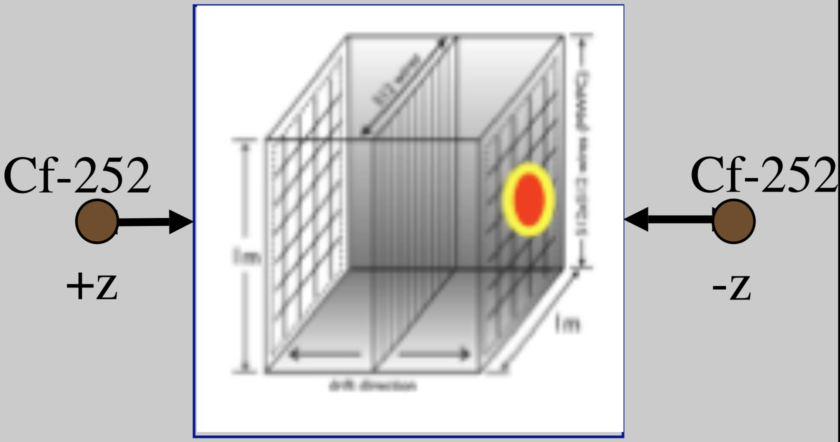
Conclusion:

- **expect head-tail**
- **expect more ionization at start (near interaction)**
- **depends on W**

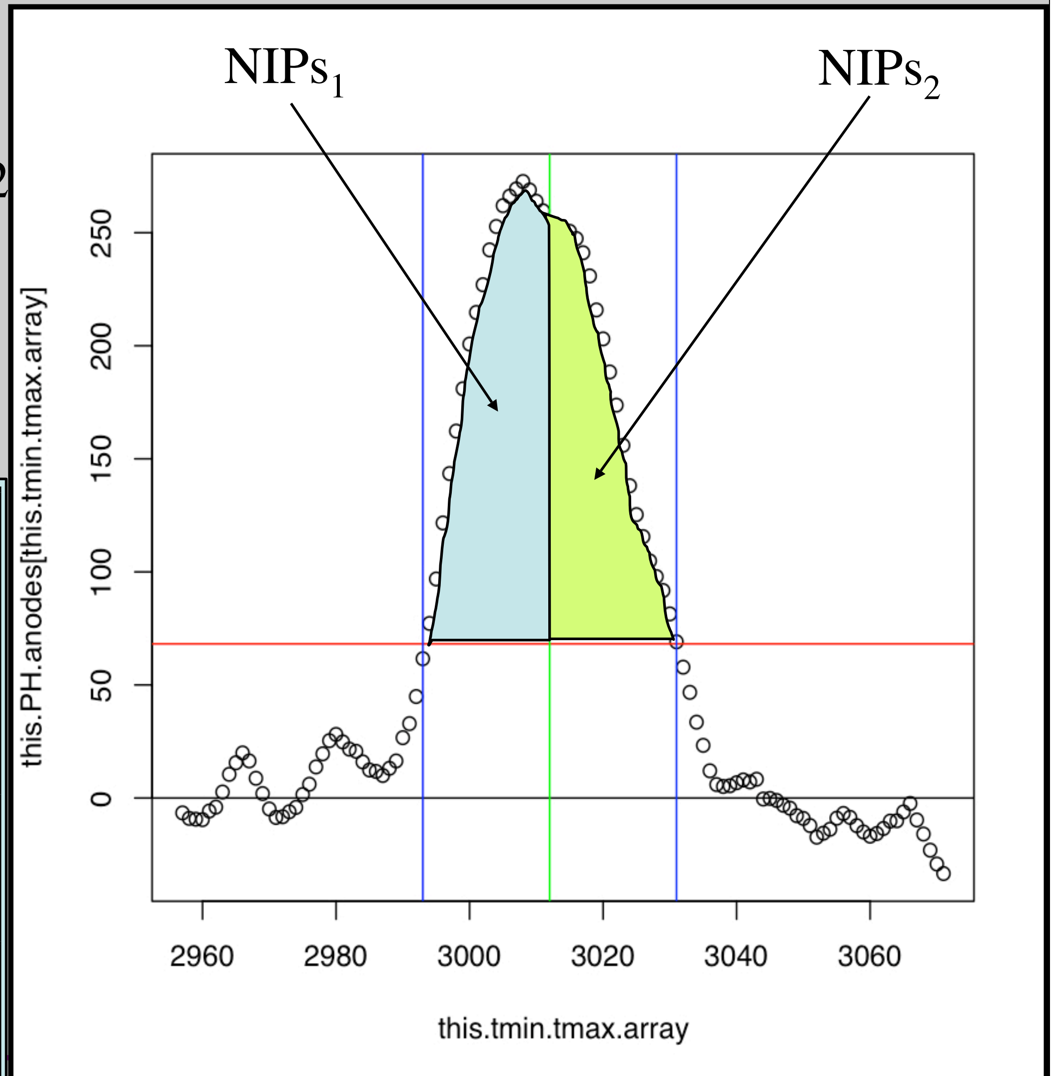


Head-Tail DRIFT II data analysis

Directed neutron runs (DRIFT IIc): +z, -z,+x, -y

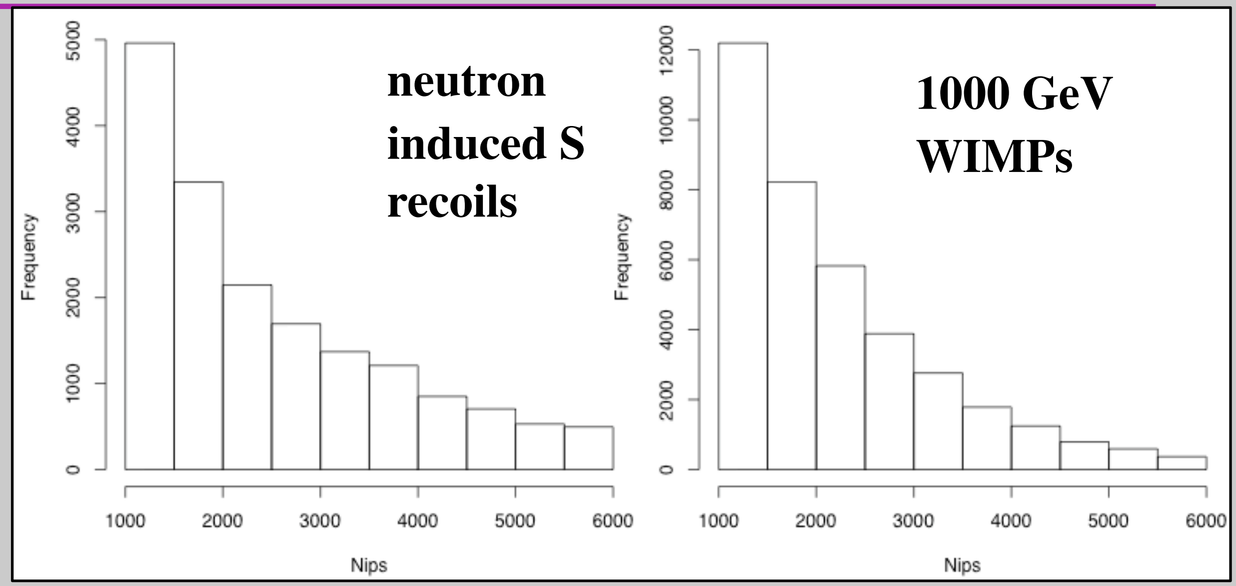


	Nips Ratio 1000-6000 Left	Nip Ratio 1000-6000 Right
+z (left to right)	1.145 +/- 0.009	1.007 +/- 0.006
-z (right to left)	0.995 +/- 0.006	1.143 +/- 0.005

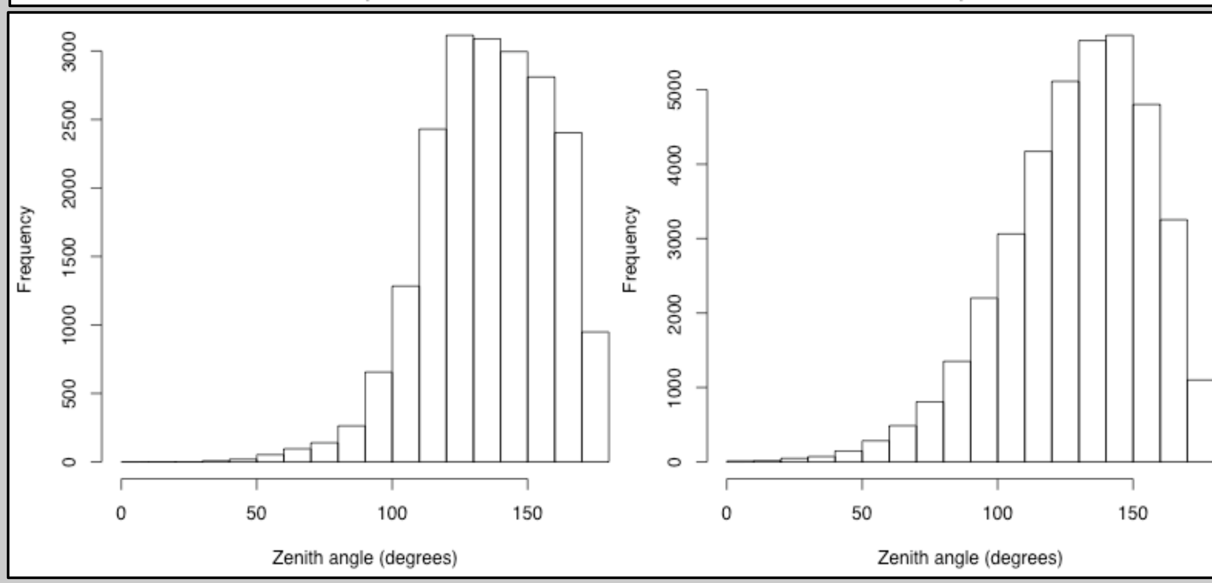


Neutrons vs. WIMPs

Predicted NIPs spectrum for (left) neutron induced S recoils; and (right) from 1000 GeV WIMPs (using GEANT)



(left) Monte Carlo spectrum >1000 NIPs of S recoil zenith angles (z axis) from z-directed ^{252}Cf neutrons; and (right) equivalent for 1000 GeV WIMP wind. The WIMP induced recoils are peaked slightly higher (using GEANT)



Head-Tail analysis

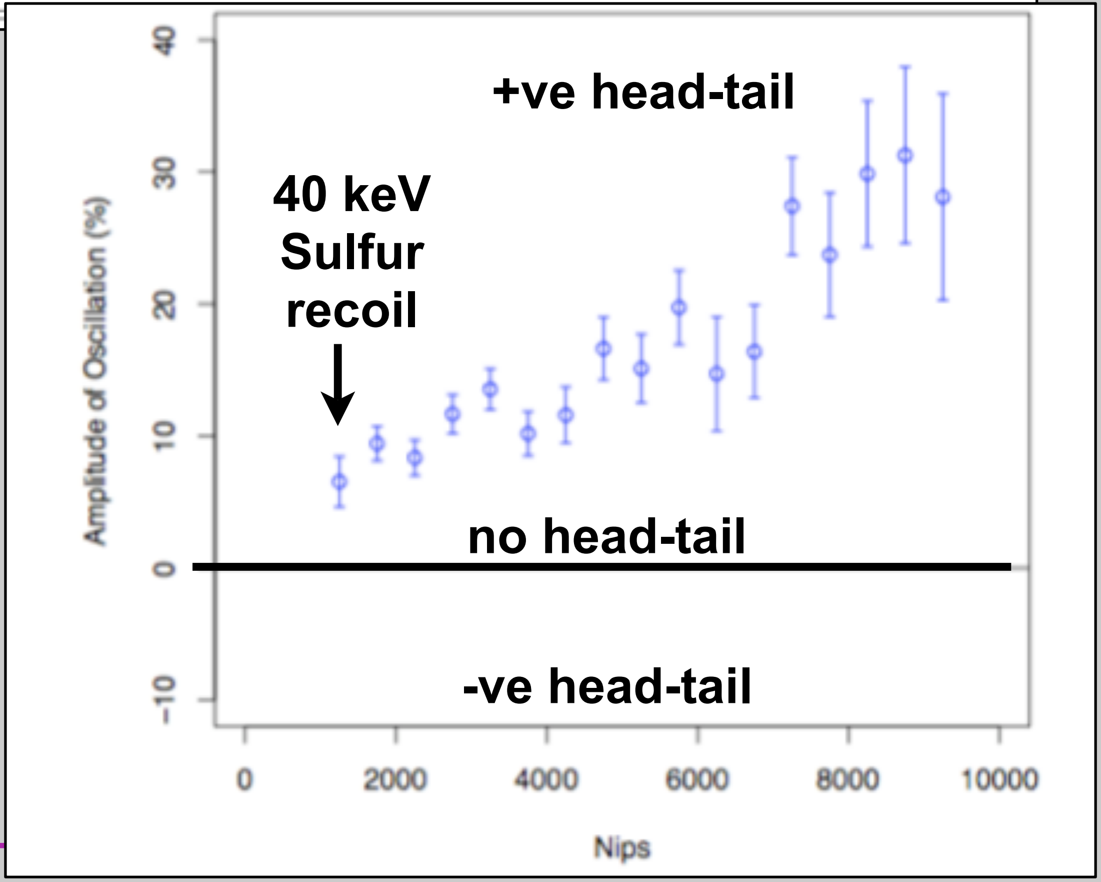
Run	N	Left	Right	Left-Right	S
+x	8673	1.074 ± 0.008	1.069 ± 0.004	0.005 ± 0.009	0.549
-y	5859	1.082 ± 0.006	1.083 ± 0.006	-0.001 ± 0.009	-0.121
+z	5829	1.145 ± 0.009	1.007 ± 0.006	0.14 ± 0.01	13.4
-z	8755	0.995 ± 0.006	1.143 ± 0.005	-0.147 ± 0.008	-19.2
-	-	-	-	Tail/Head-Head/Tail	-
Optimal (+z and -z)	14458	-	-	0.143 ± 0.006	23.8
Anti-optimal (+x and -y)	14397	-	-	0.005 ± 0.006	0.756

Amplitude of oscillation - Tail/Head - Head/Tail

Note: extrapolation indicates head-tail discrimination continues below current threshold

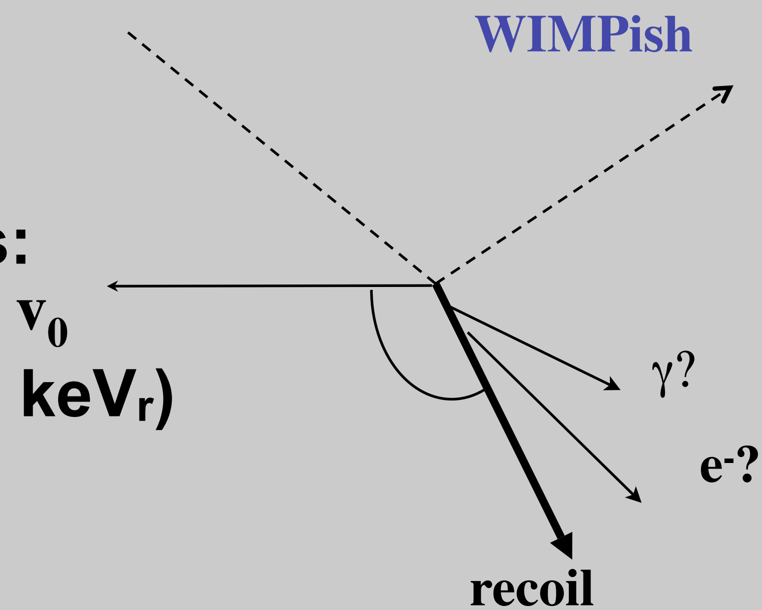
PRL ready

Clear head-tail discrimination (in 1 m^3 at low energy)!



Conclusion

Comment: we will need the maximum information on events to show definitively that WIMPs exist in the galactic halo!



Low pressure TPC (1m^3 DRIFT) has:

- low energy threshold (potential 3 keV$_r$)
- recoil tracking - 3D
- dE/dx discrimination
- range discrimination
- head-tail sense discrimination
- ability to identify multi-prong events (double-gamma - KK axion; recoil+gamma - DAMA?)
- background now <1/day.. nearly ready for full experiment

FUTURE - How big is big?

At 40 Torr a 1 ton target would occupy about 1/30th LNGS

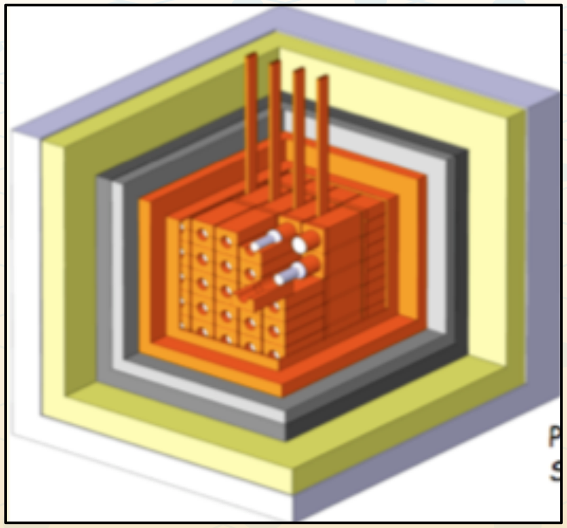
At 160 Torr (an achievable pressure increase) a 1 tonne target would for instance be ~25% smaller than MINOS

If head-tail discrimination is introduced there is a further ~x10 reduction in target volume for a given directional sensitivity

Underground space is, in principle, not a cost driver

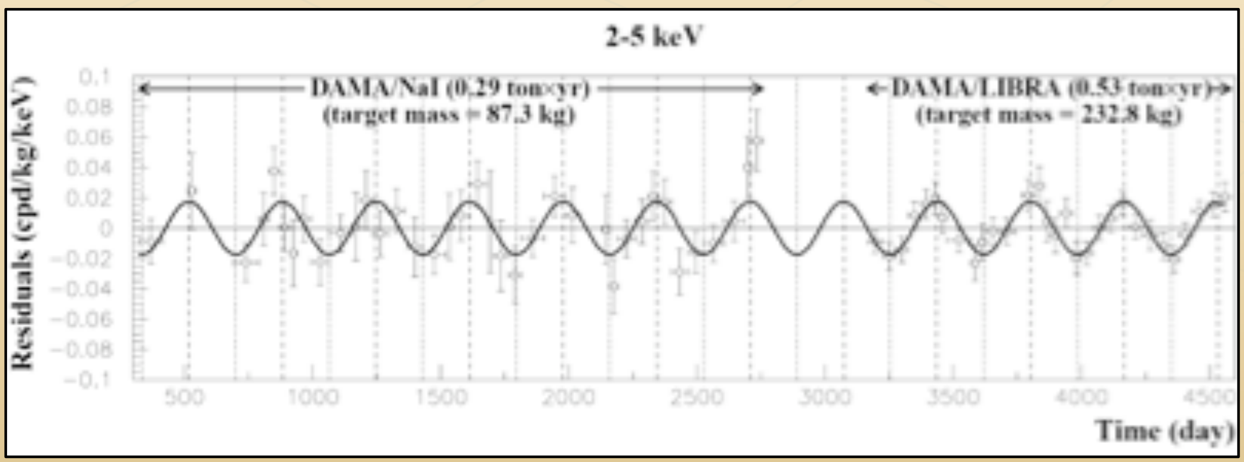
e.g. SuperK volume 50,000 m^3 - 50 ton DRIFT - enough for directional signals at 10^{-10}pb SI

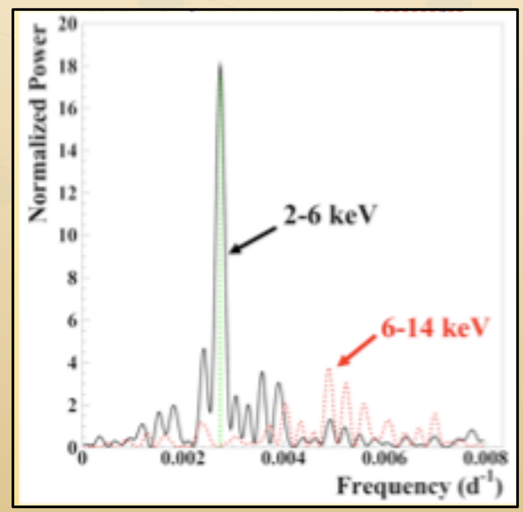
DAMA/Libra: annual modulation



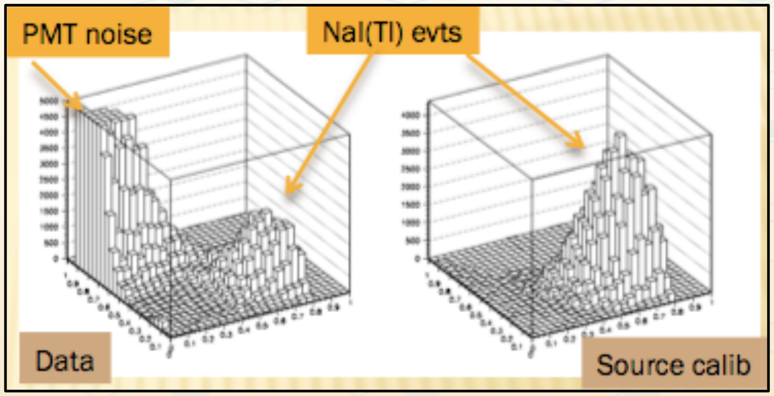
192,000 kg.days data from NaI array (25 modules)

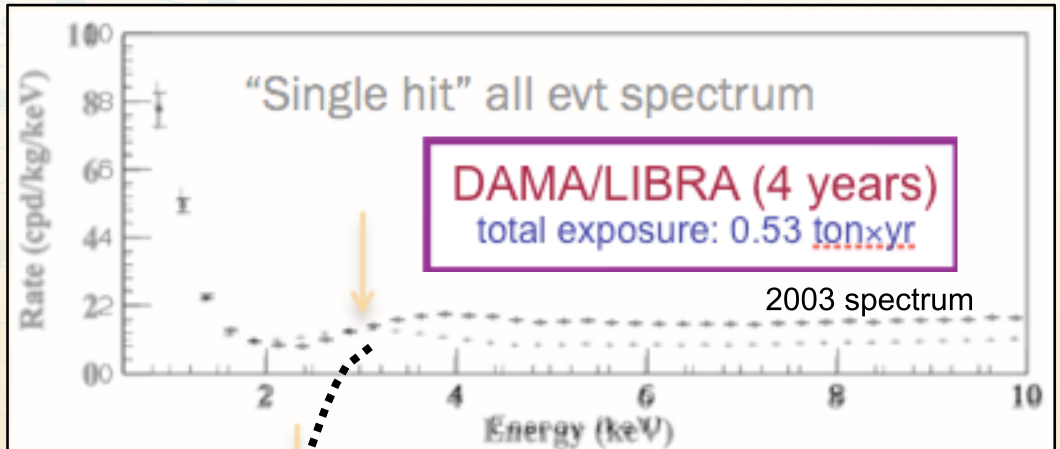
2-5 keV   A=(0.0176±0.0020) cpd/kg/keV   8.8 σ C.L.





DAMA/Libra: annual modulation





does the raw background look physical after signal subtraction?

Still many questions, e.g.:

- **influence of PMT noise cuts**
- **explain raw background after signal subtraction**