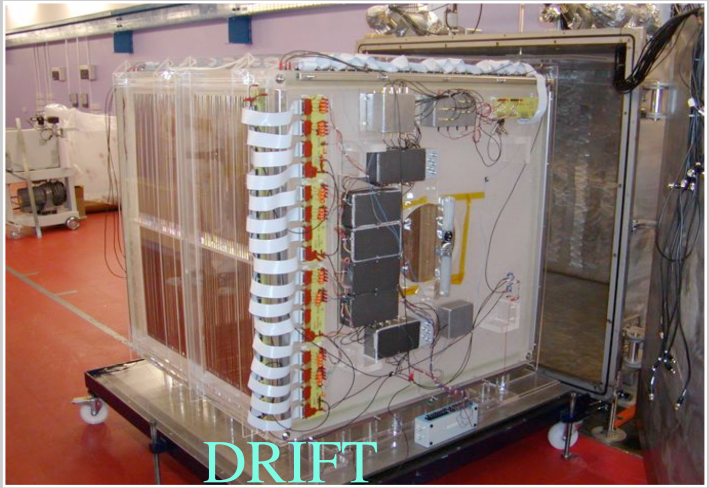
Directional Detection of Dark Matter

- **DRIFT IIa,b highlights**
- **Update on head tail**
- **Future and CYGNUS**
- **July 2007 run at Boulby**



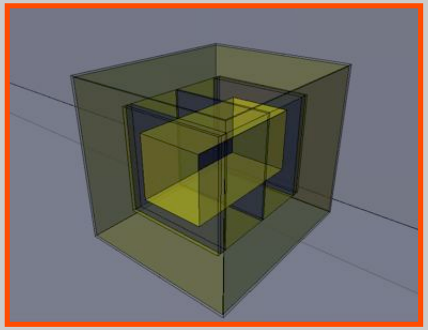
DRIFT-IIa @ Boulby

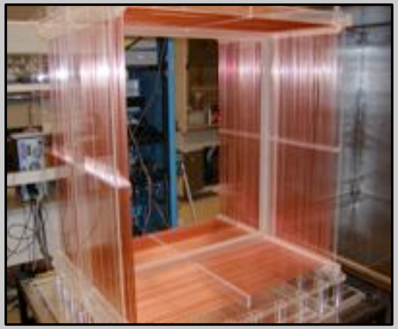
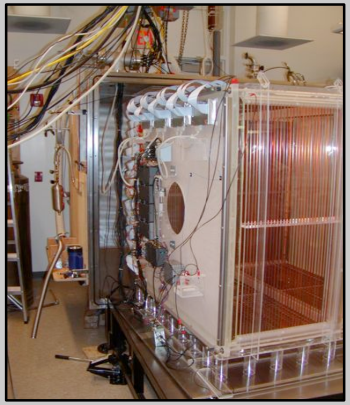
(UK work unless stated)

+Occidental, UNM....MIT

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
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

DRIFT IIa, built & run in 1 yr



at the Boulby laboratory 2005



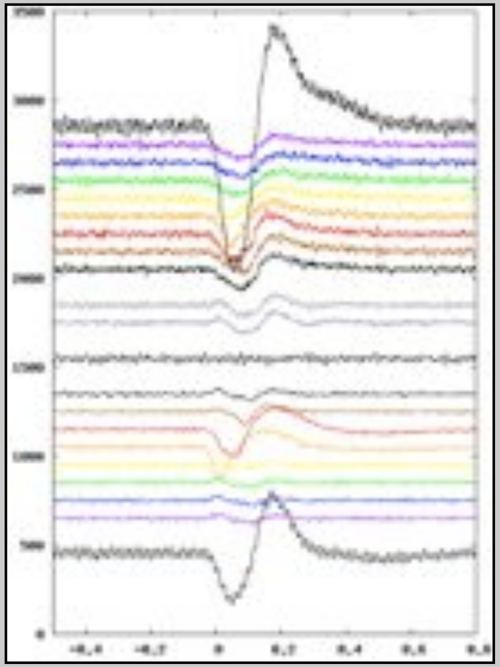
Stable and still working well...2007

DRIFT IIa - recoil cuts

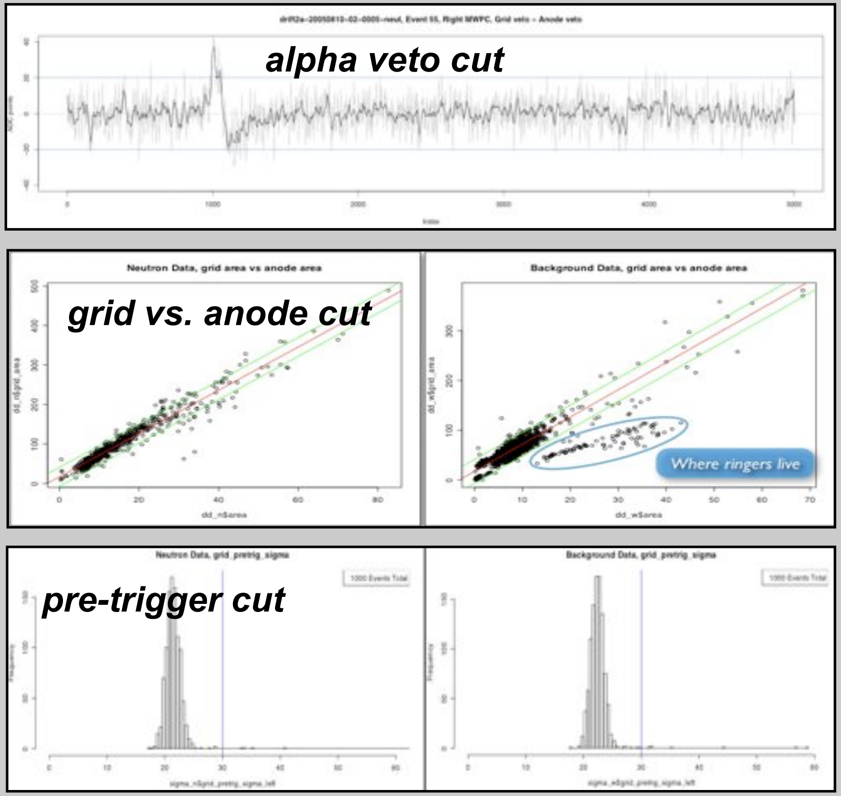
A large number of primary cuts reduced the raw background by a factor x20.

Neutron event (left detector)

- **Alpha (2 cuts)**
- **Event in pretrigger**
- **Veto**
- **Ringer**
- **Overshoot**
- **Sparks**
- **Narrow fwhm**
- **Non consec wire**
- **Simultaneity**
- **Sum Sum**
- **……**



Example cuts

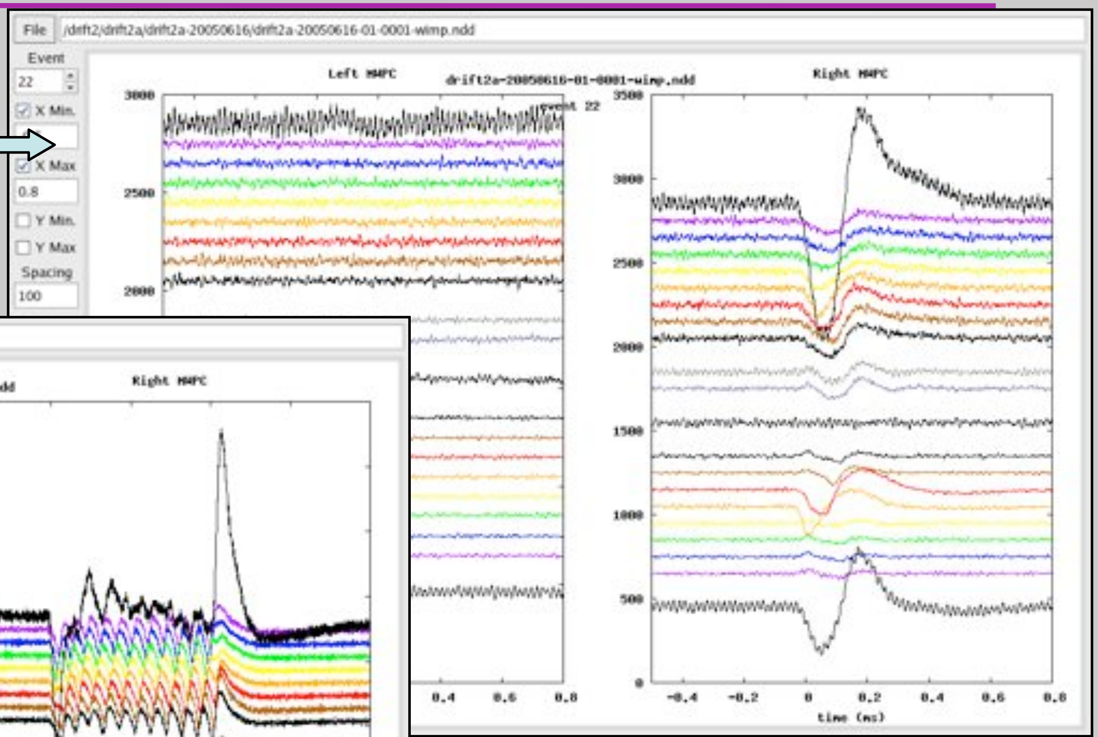


etc, etc….

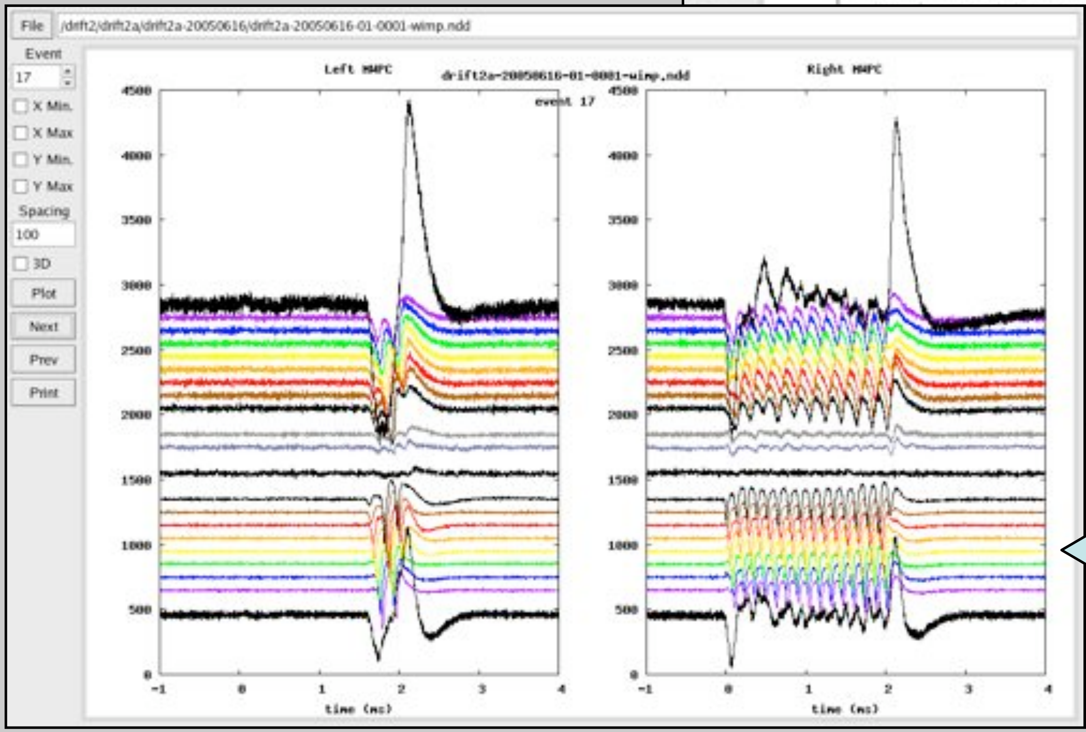
What effect do these cuts have on neutron-induced and WIMP recoils?

DRIFT IIa - typical events

Typical neutron calibration event in right detector



Background alpha crossing central drift-cathode (parts of track detected by both MWPCs)



Gamma rejection efficiency

Five x 0.52 mCi Co-60 sources placed on top of DRIFT-IIa unshielded vacuum vessel and 0.575 days of live time data were recorded.

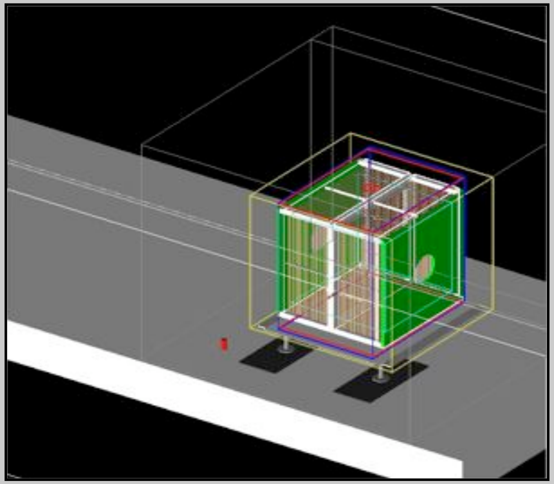
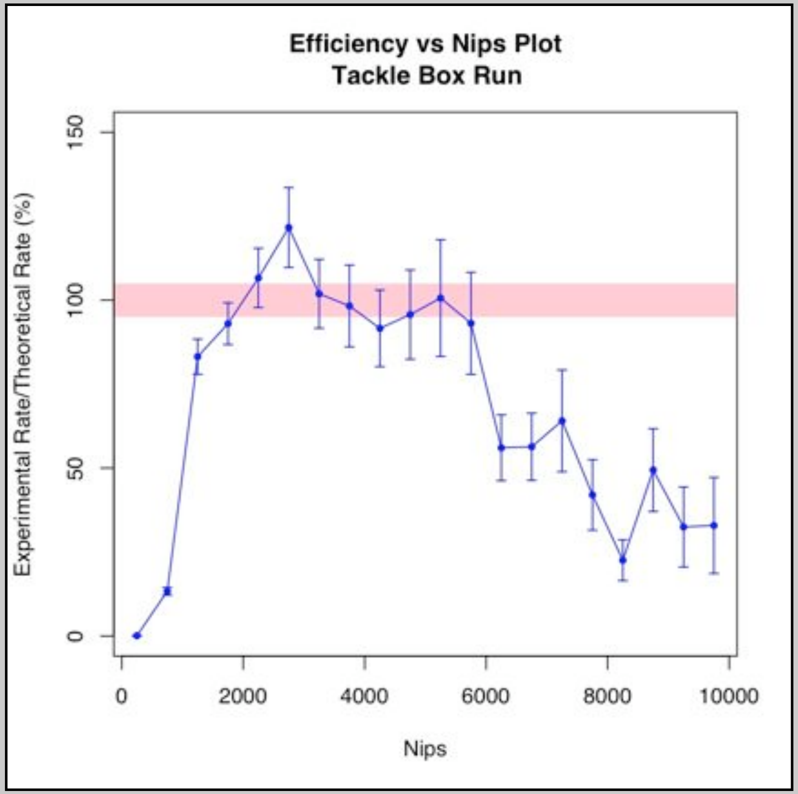


Table [Co-60 Results]

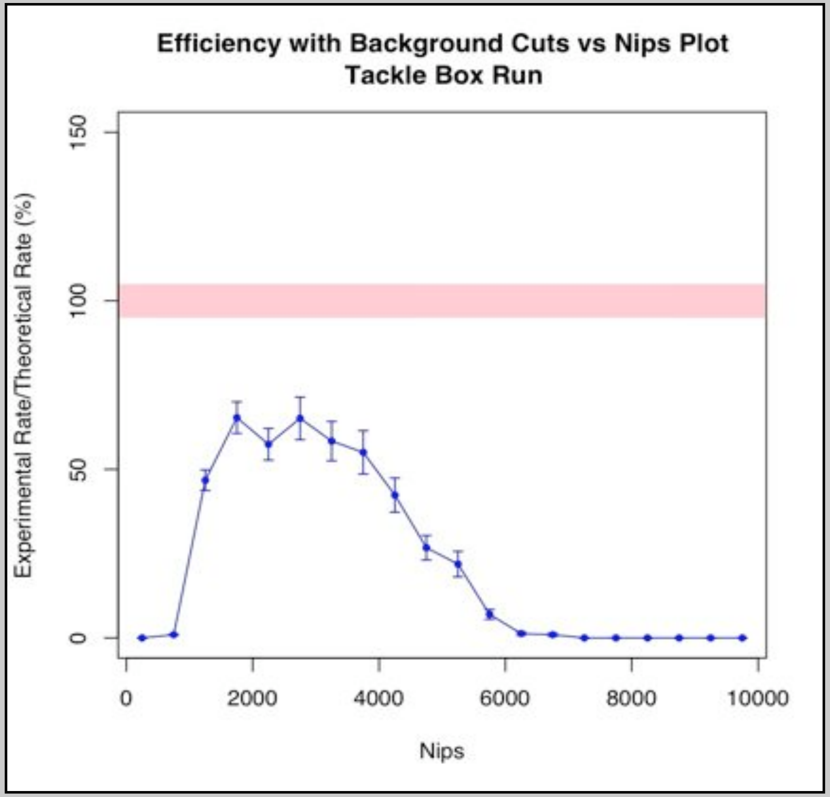
Nips Window	^{60}Co rate minus Background rate (Hz)	MC rate (Hz)	Rejection Factor Limits (90% C.L.)
1000-2000	$(-2+/-5)x10^{-4}$	77+/-1	$< 8x10^{-6}$
2000-3000	$(-1+/-1)x10^{-4}$	24.8+/-0.5	$< 5x10^{-6}$
3000-10000	$(2+/-6)x10^{-5}$	27.2+/-0.3	$< 3x10^{-6}$
1000-10000	$(1+/-3)x10^{-4}$	125.2+/-0.7	$< 3x10^{-6}$
1000-6000	$(1+/-3)x10^{-4}$	128.9+/-0.7	$< 3x10^{-6}$

Neutron efficiency with cuts

Efficiency vs NIPs with simple cuts



Efficiency vs NIPs with "background reducing" cuts

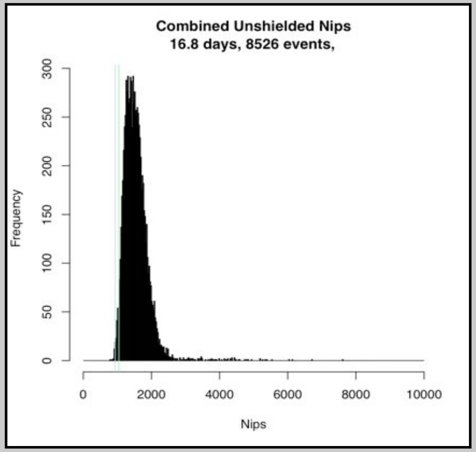


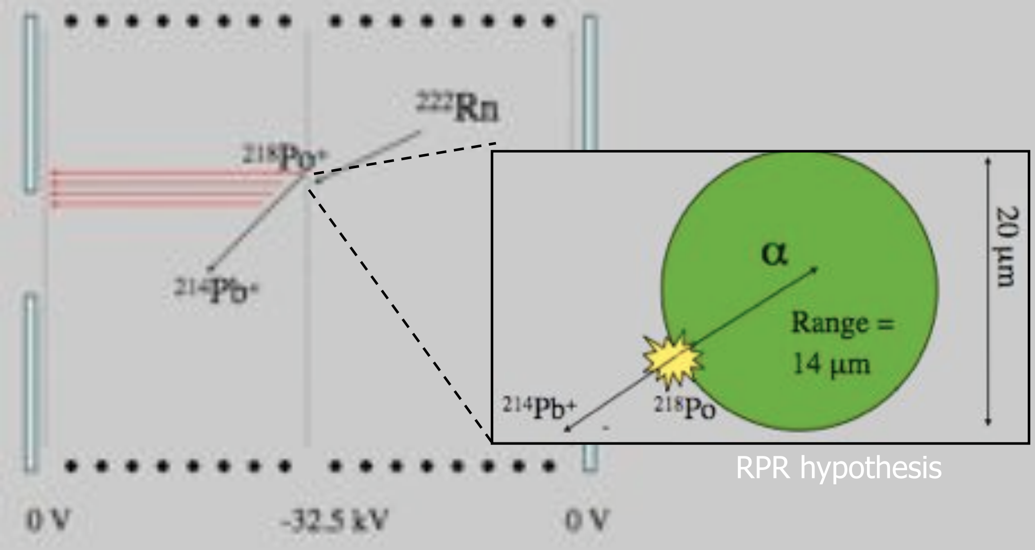
Radon Progeny Recoils (RPRs)

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.





RPR hypothesis

DIIa Background after RPR cuts

For typical analysis run - 4.36 days background, neutron run 0.97 hours (2005/6)

calibrated recoil efficiencies

Nips	Rate (Hz)	Efficiency (%)
1000 - 5000	0.075 ± 0.005	39 ± 3
2000 - 5000	0.066 ± 0.004	60 ± 7
2500 -5000	0.055 ± 0.004	70 ± 11

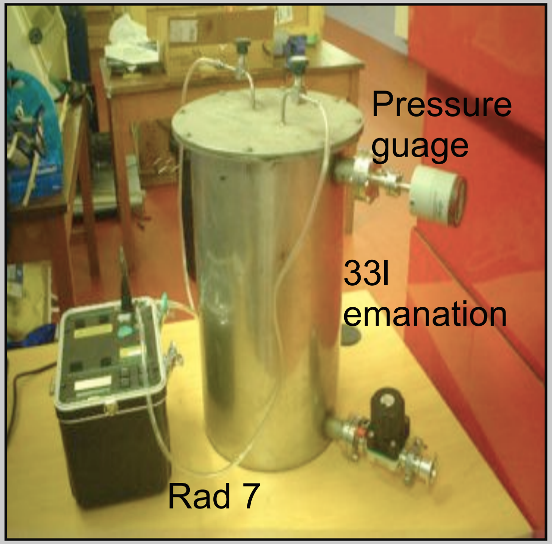
remaining rates

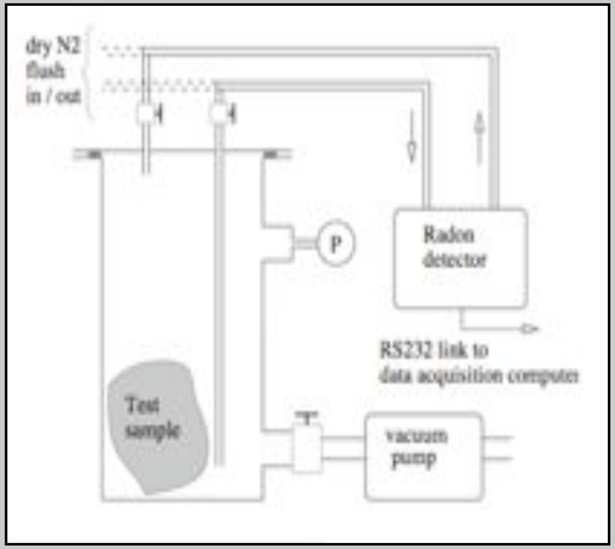
Nips	Rate (/day)
1000 - 5000	20 ± 2
2000 - 5000	15 ± 2
2500 -5000	7 ± 1

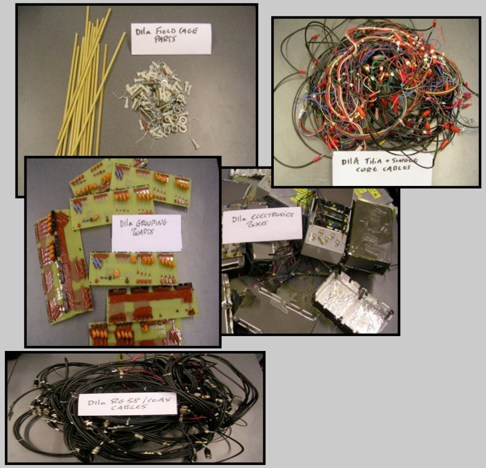
remaining events are <u>recoils</u>
identified as radon progeny recoils (RPR)

LIMIT published in Tziaferi thesis

Rn Emanation Facility







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)

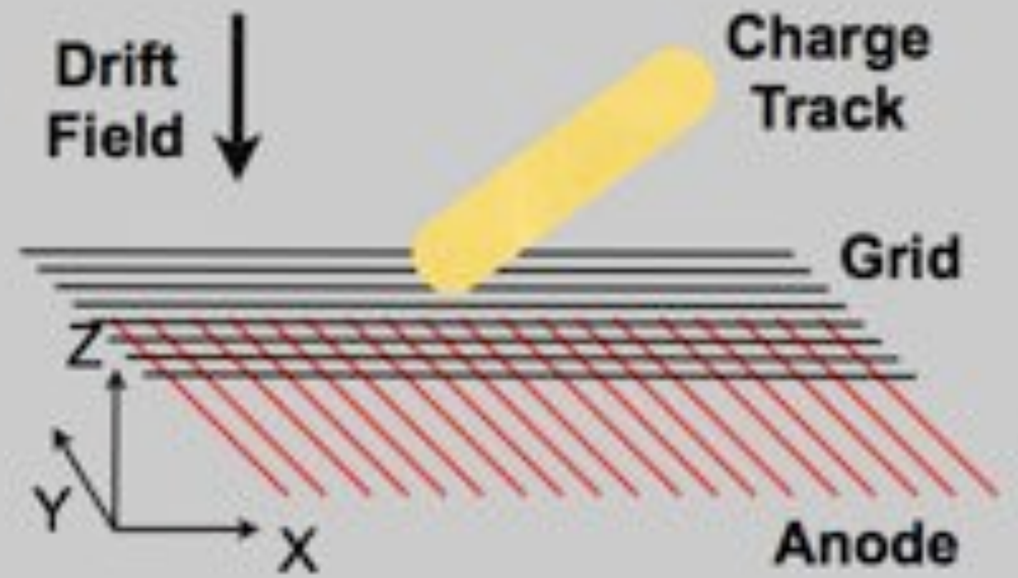
DRIFTIIa: July 2005
390 events / day

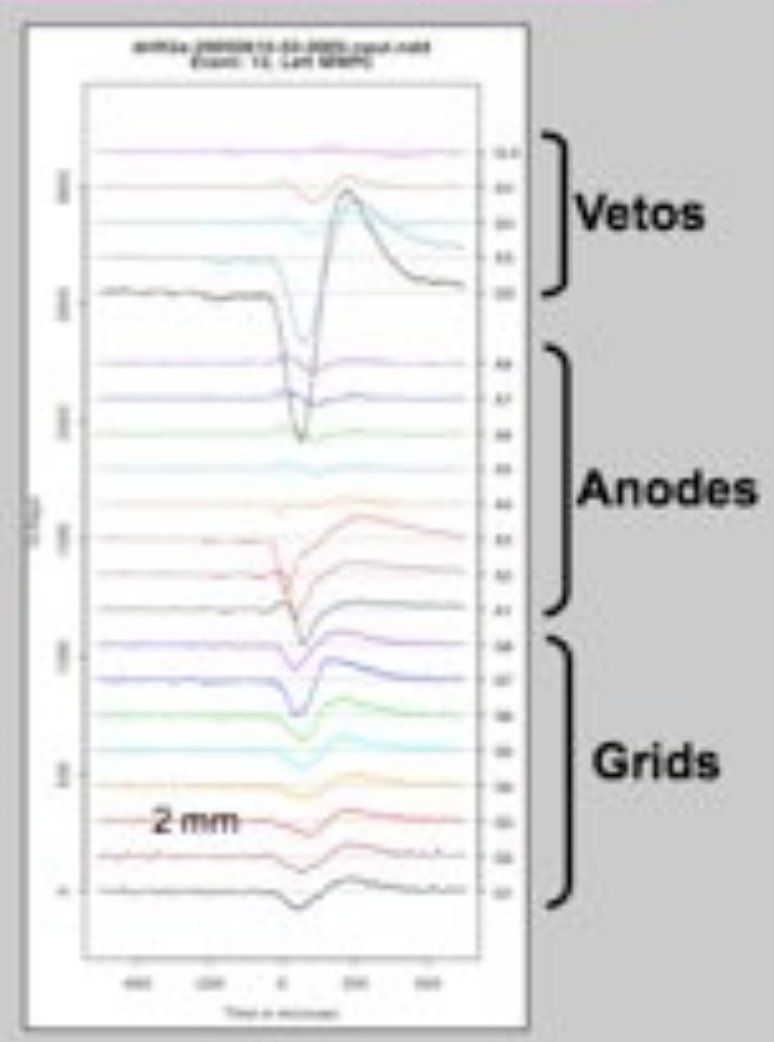
DRIFTIIb: June 2006
31.3 events / day

DRIFTIIb(refit 2): July 2007 expected.....

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

Directional Analysis

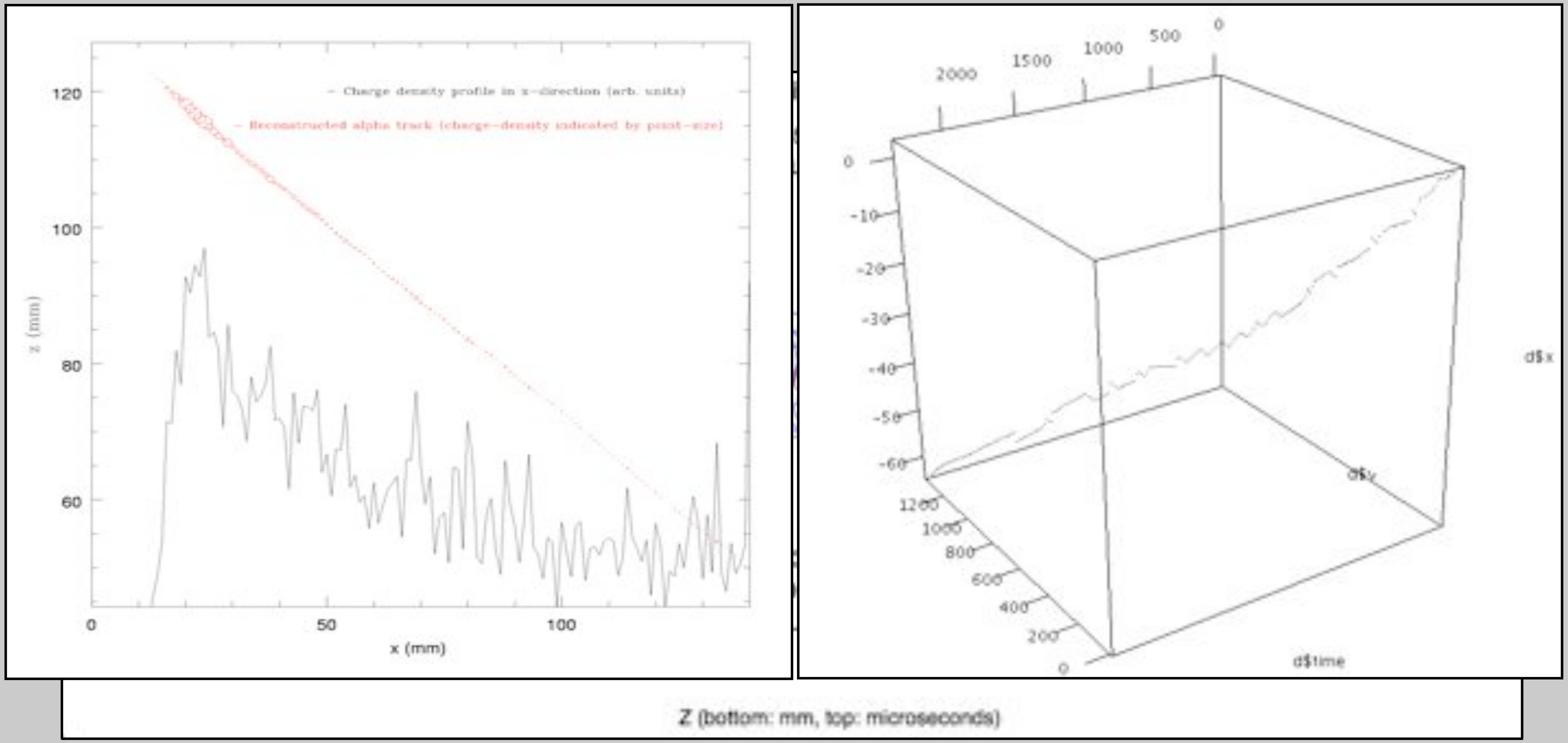




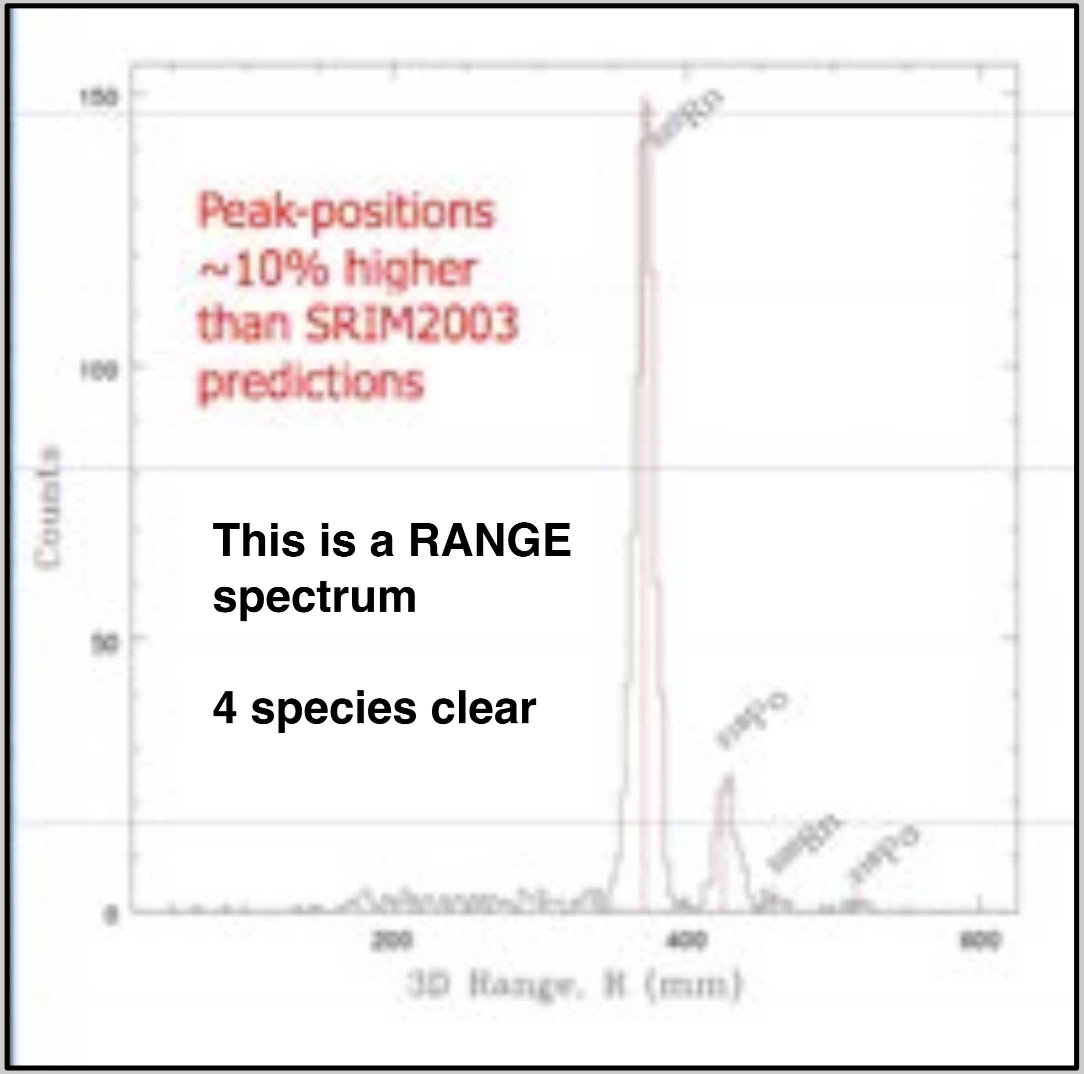
ΔX: Number of Anode Wires Crossed
ΔY: Progression across Grid Wires
ΔZ: Drift Time difference between start and end of track

DRIFT IIa - alpha track images

Based on the track finder analysis code using it is possible to reconstruct alpha and recoil tracks and Bragg curves

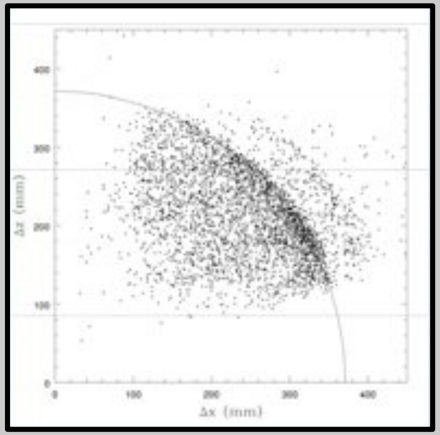


Alpha range analysis



This is a RANGE spectrum

4 species clear



Reconstructed 3D ranges of contained alphas

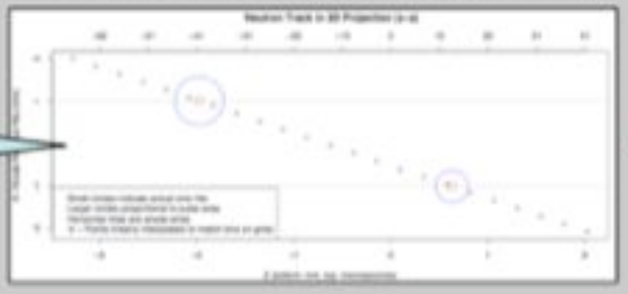
Observation of UNCHARGED Po

22% ^{218}Po produced uncharged

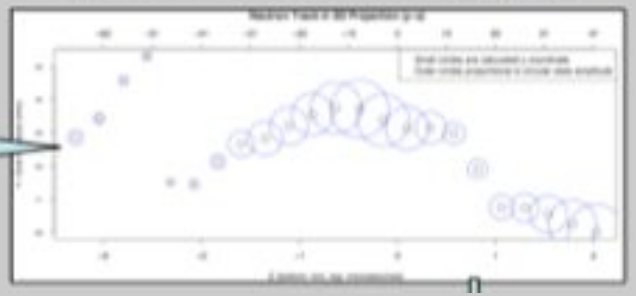
3D recoil reconstruction, sky-map

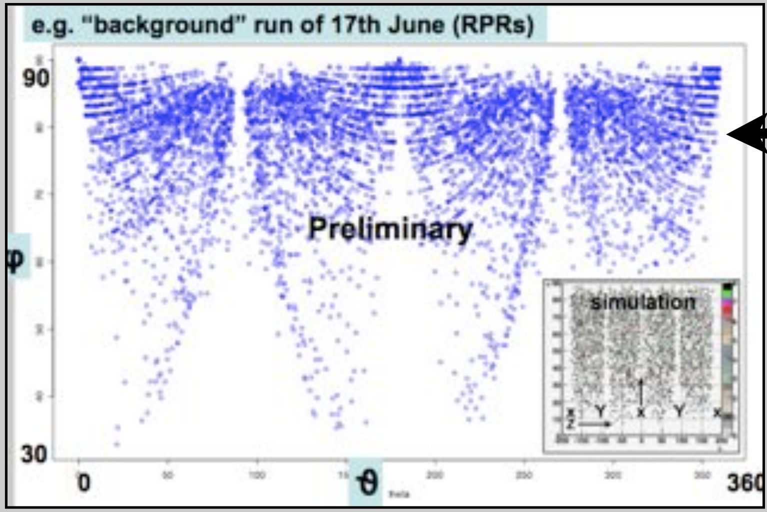
raw pulse

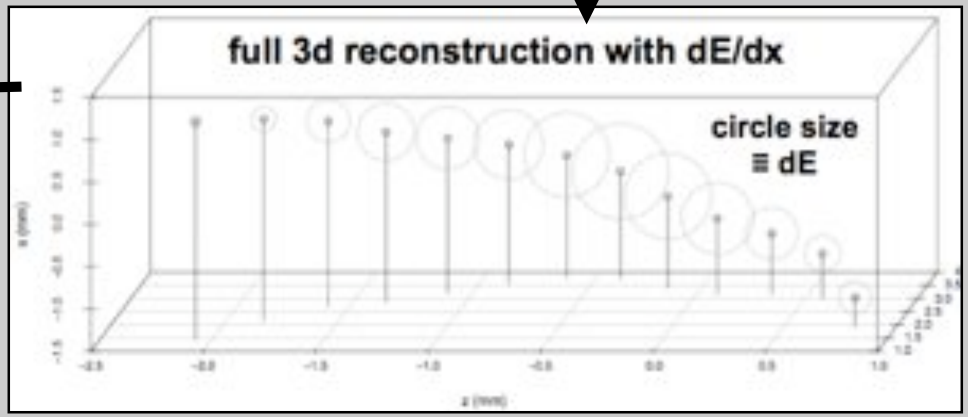
x-z reconstruction (anode)



y-z reconstruction (grid)



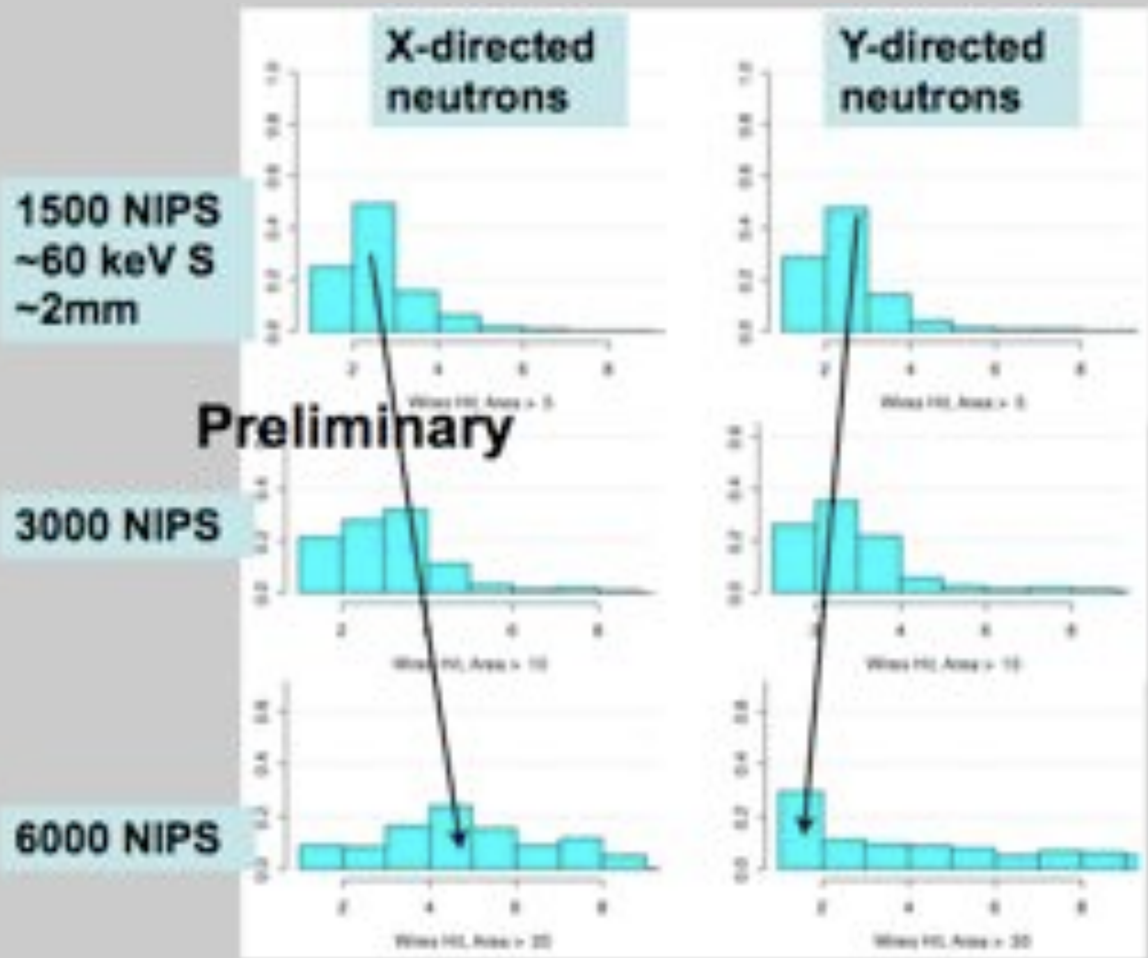


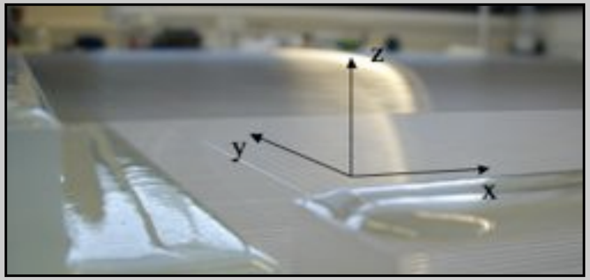


ϑ,ϕ direction sky map of data and simulation

DRIFTIIa (2005) electronics noise filter distorts y (and z) reconstruction

DRIFTIIa, 1D directionality



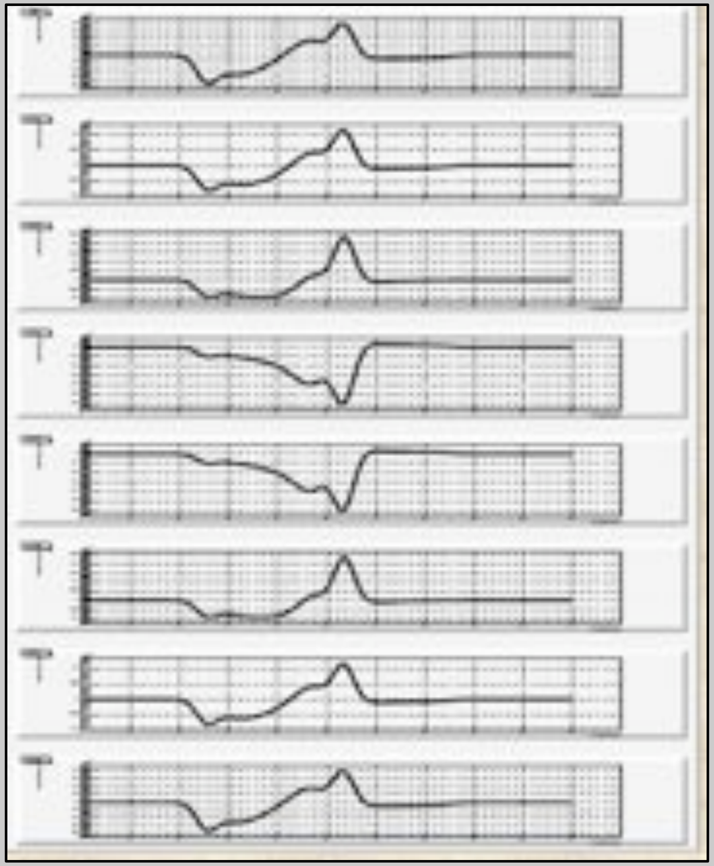


Directed neutron runs at Boulby

-1D direction sensitivity

DRIFTII - end to end simulation

Validation of DRIFTII operation and technology



(1) SRIM2006 tracks (S and C)

(2) Straggling (ball-up)

(3) Drift in E-field (Garfield)

(4) Diffusion

(5) NIPs generation in MWPCs (Garfield, induced pulses etc)

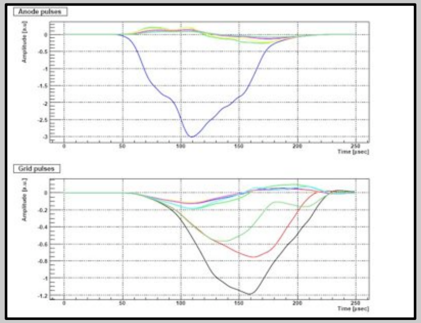
(6) Electronics simulation

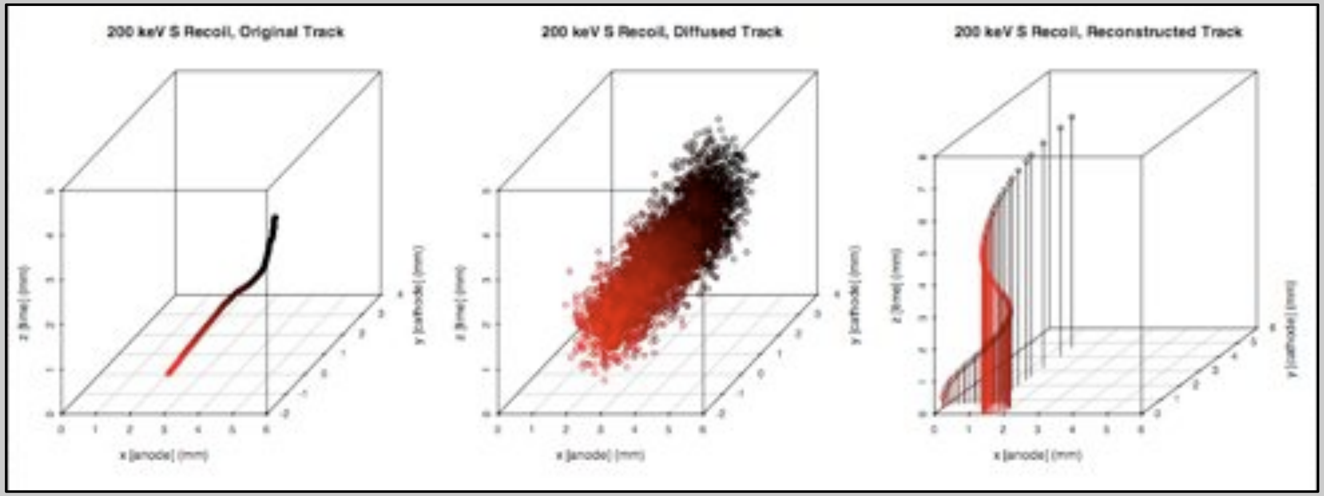
(7) Pulse generation

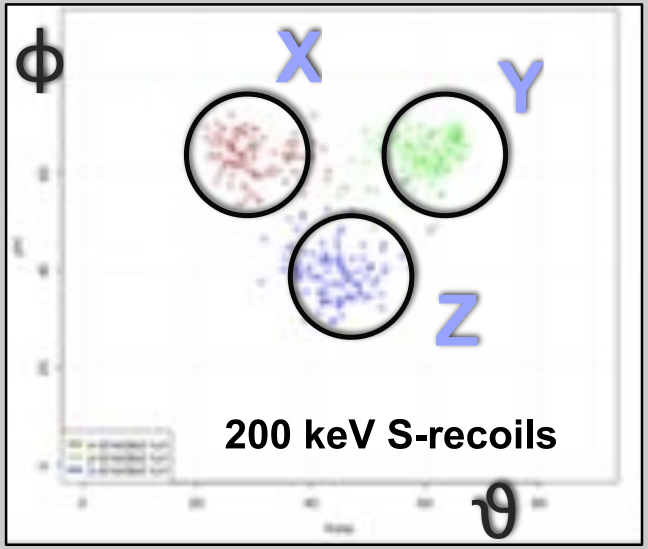
(8) Simulated data produced in correct format

→ **Head-tail simulation and data analysis**

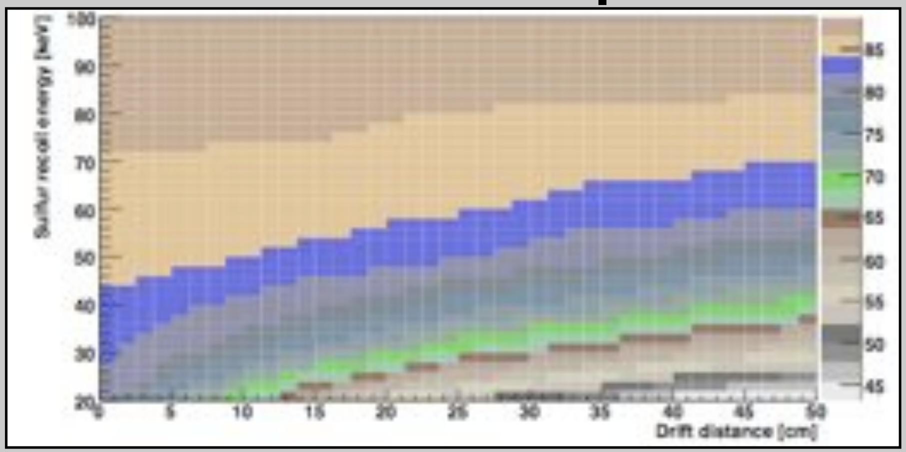
DRIFTII - end to end simulation



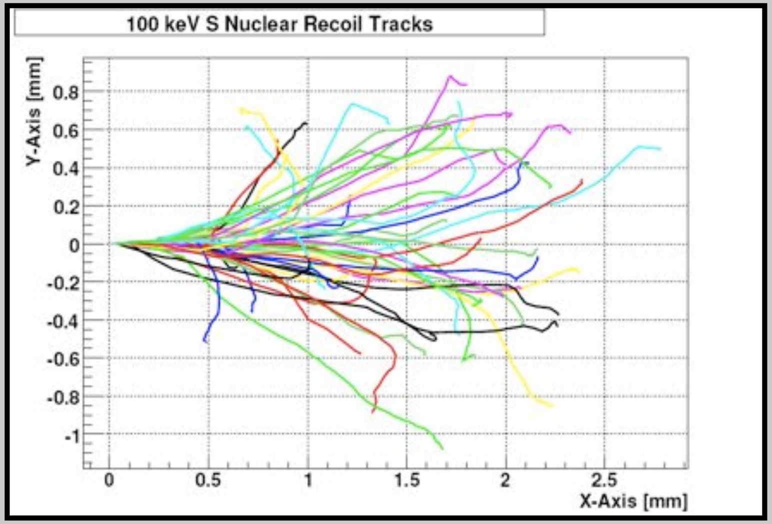




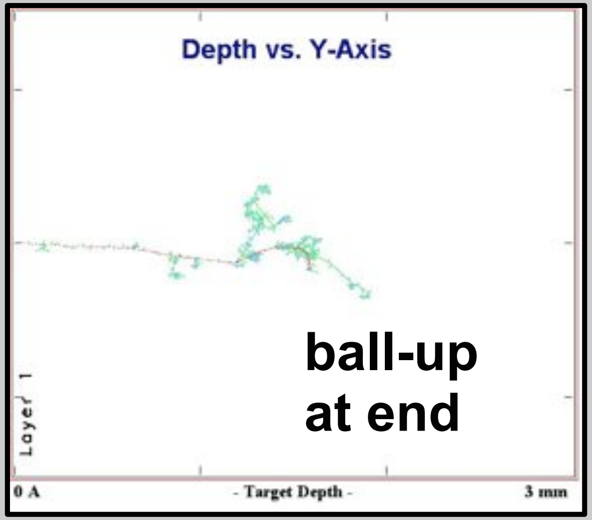
X,Y,Z - directed S-recoil reconstructed produce directional response matrix



Understanding Head-Tail

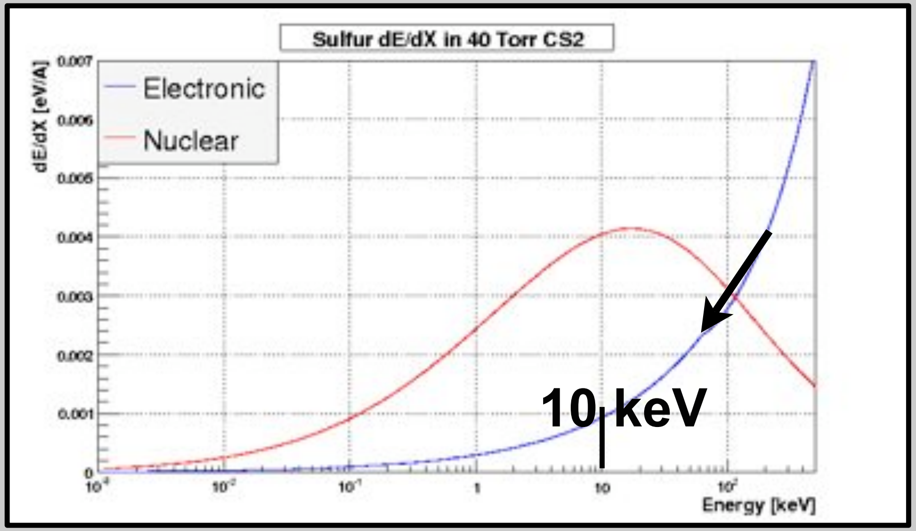


Example of the nuclear recoil cascade from 100 keV S ion in 40 Torr CS_2

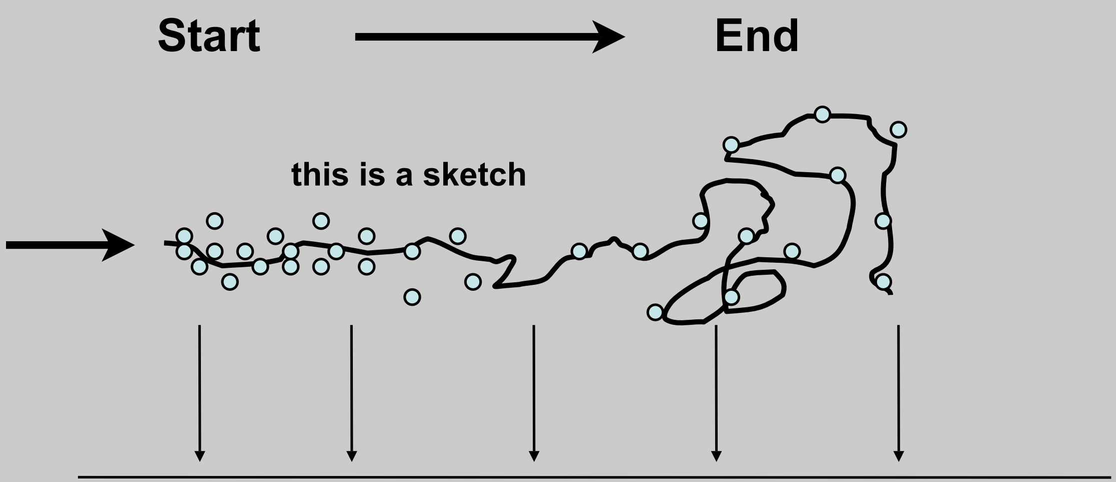


dE/dX

Electronic channel: more ions at start of track



Understanding Head-Tail

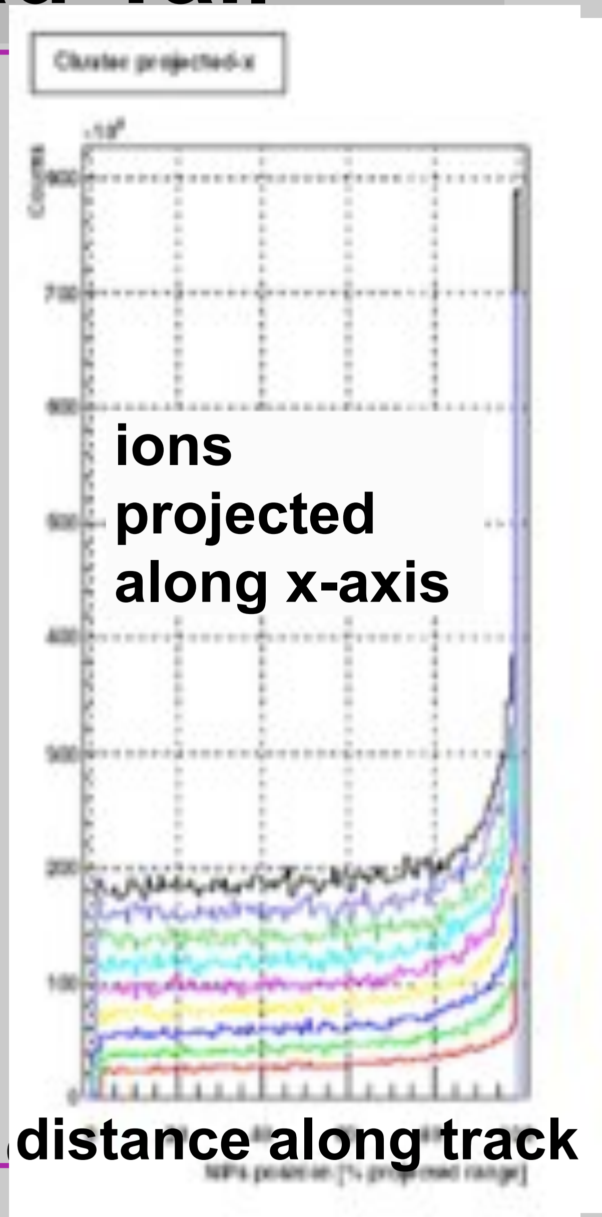


Two competing Issues from simulations:

(1) from dE/dX - more ions at start

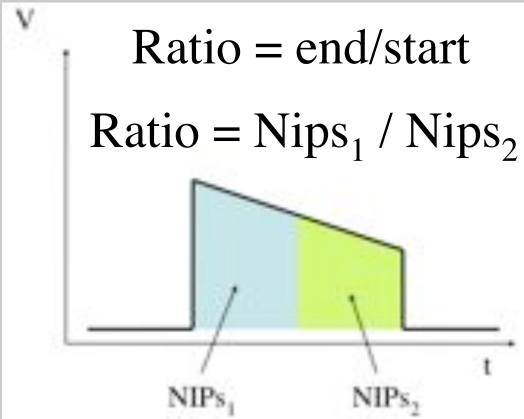
(2) get ball-up at end

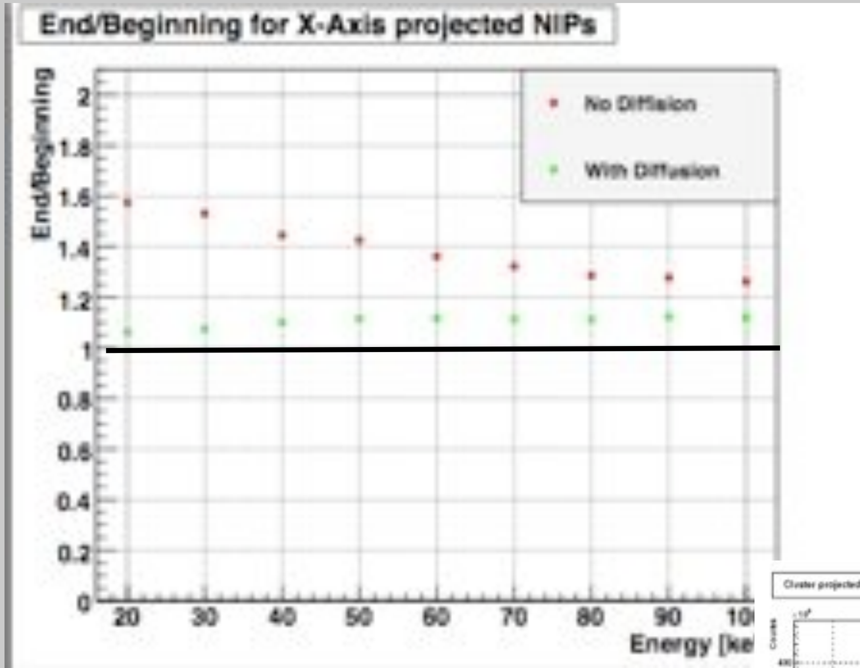
→ dominates?

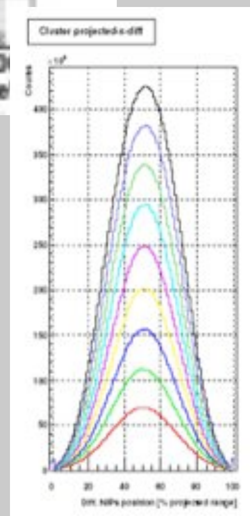


DRIFT II Head-Tail simulation

Take simple end/start ratio



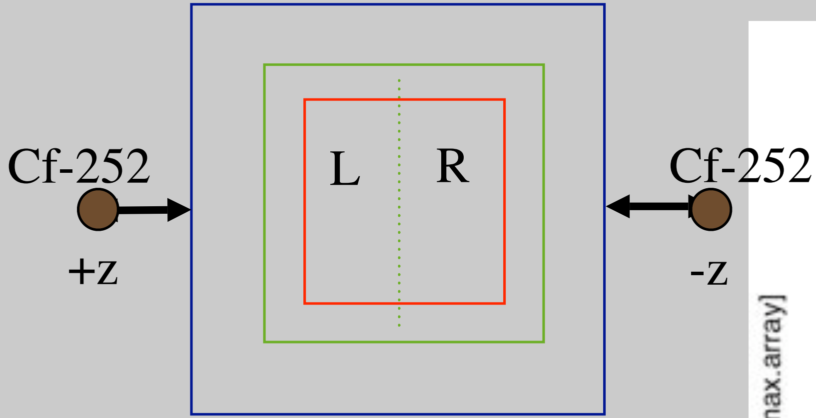




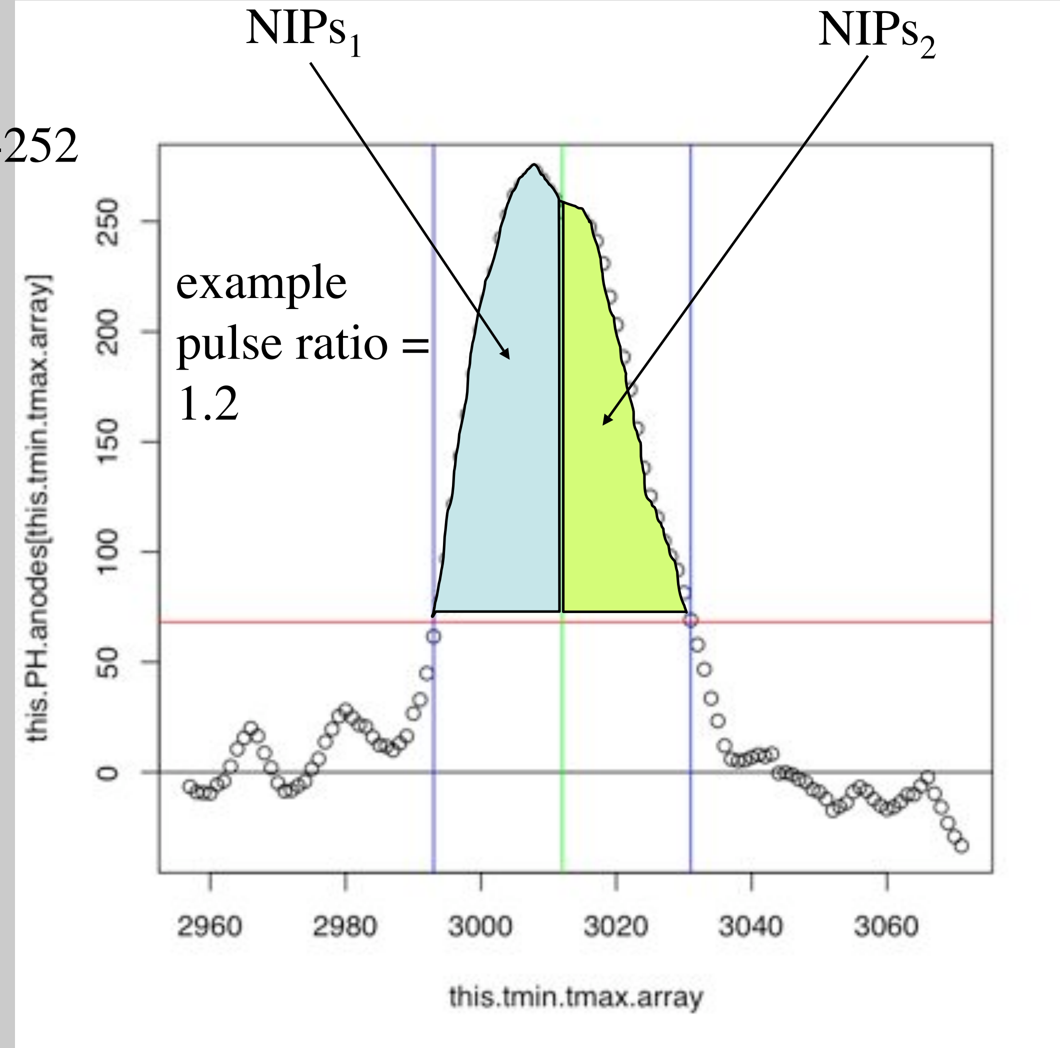
(1) Intrinsic head-tail (no diffusion):
~50% bigger end than start
best at low energy (more ball-up)

(2) head-tail for full DII (0-50cm diffusion):
still 10% bigger end than start

DRIFT II Head-Tail ANALYSIS



Directed neutron runs:



DRIFT IIc at Oxy

Right-Left results

	Average Ratio 1000-6000 Nips Left	Average Ratio 1000-6000 Nips Right
+z (left to right)	1.111 +/- 0.008	1.062 +/- 0.008
-z (right to left)	1.039 +/- 0.010	1.105 +/- 0.006

Conclusion (preliminary):

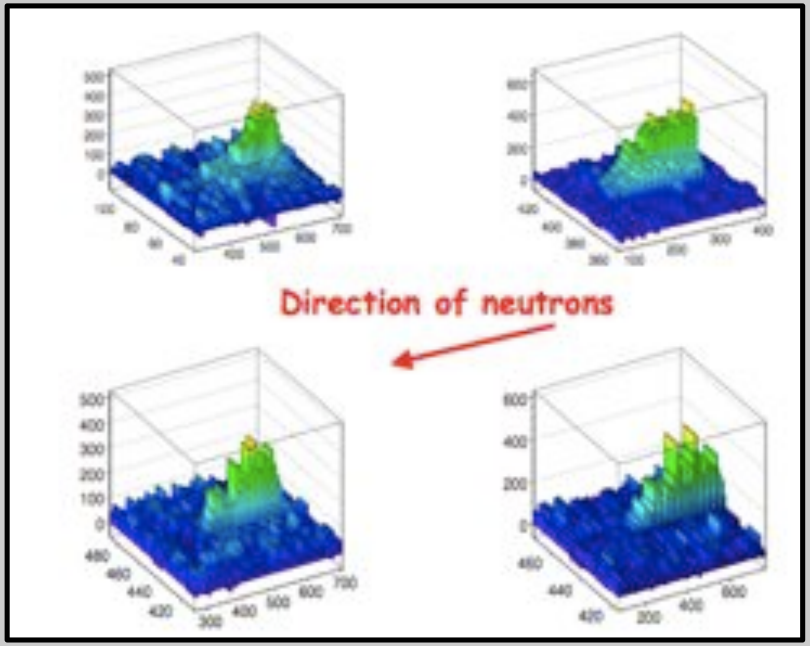
(1) even in crude DRIFT II may expect head-tail asymmetry at 10% level

(2) z, 1D analysis indicates it is there at ~10%

Confirmations by CYGNUS members

(1) MIT result with CCD readout (see CYGNUS web-site):

CCD images, 1D projections, of F-recoils from DT neutrons, show head-tail in CF-4



(2) A. Hitachi (Kochi, Japan): theory agrees (our experiments important for stopping power theory!)

(3) Indication also from UNM with micromegas readout

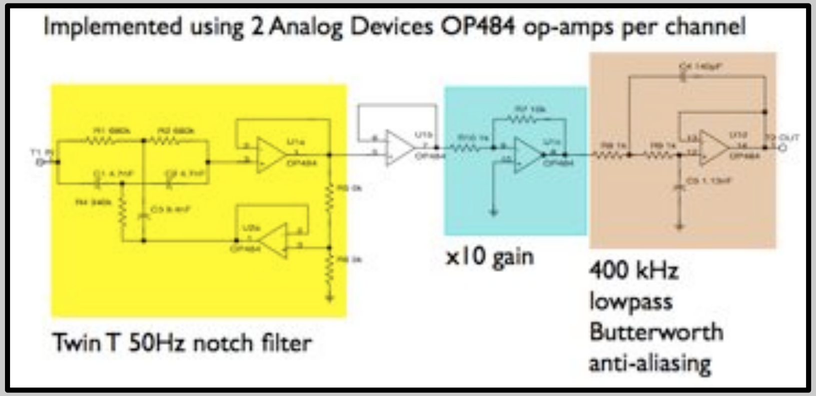
CAUTION: so head-tail depends strongly on readout projection - 1D, 3D, diffusion, energy

July 2007 Run (MIT, Shef, Oxy, UNM)

Objectives: (1) Improve directional electronics
-notch filter and anti-aliasing (Ed Daw)
-neutron runs
Objectives: (2) RPR reduction
-swap central cathode for clean one - done in a day
-high gas flow test - achieved as expected

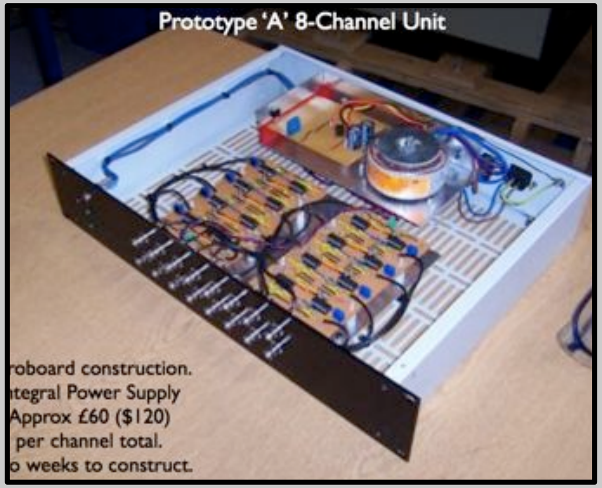
July 2007 @ Boulby

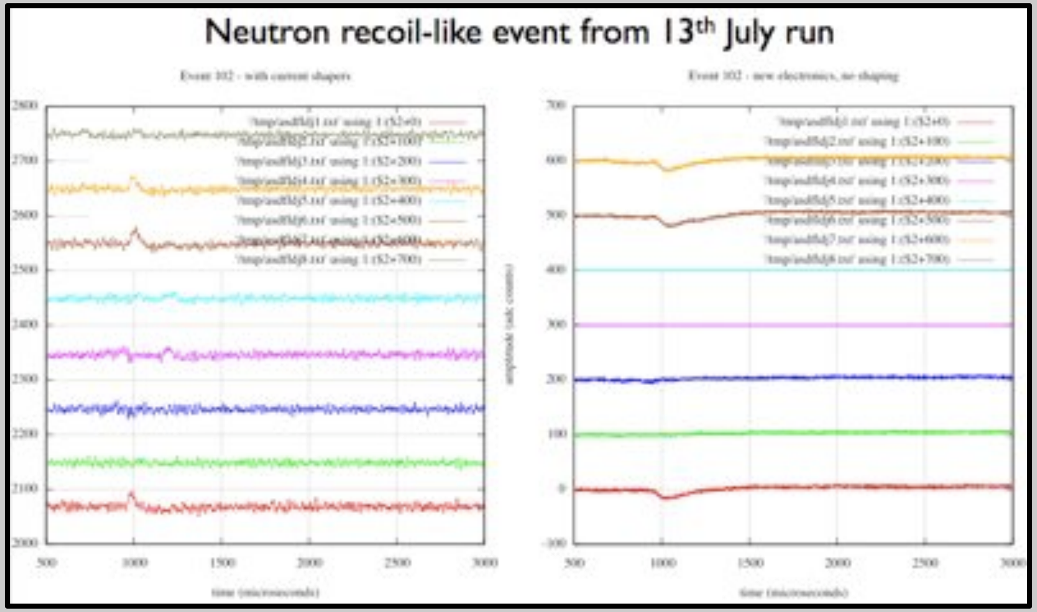
Upgrade electronics test (MIT, Shef)



Ed Daw

MIT funded at Sheffield





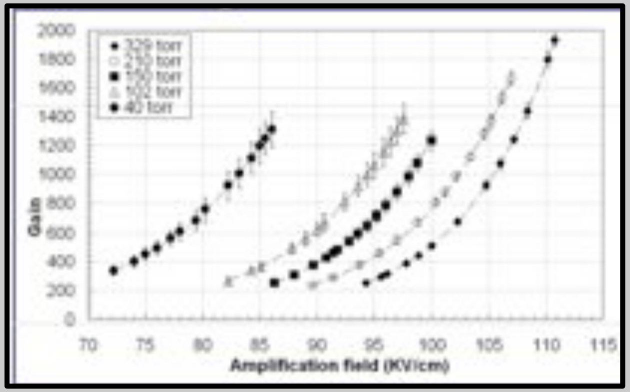
Prototype A electronics succeeds in removing overshoot on events studied without compromising SNR on neutron-like events

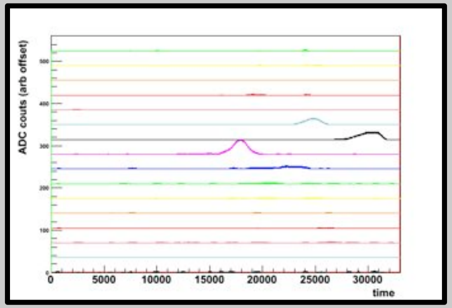
New directed neutron data under analysis

Scale-up Progress

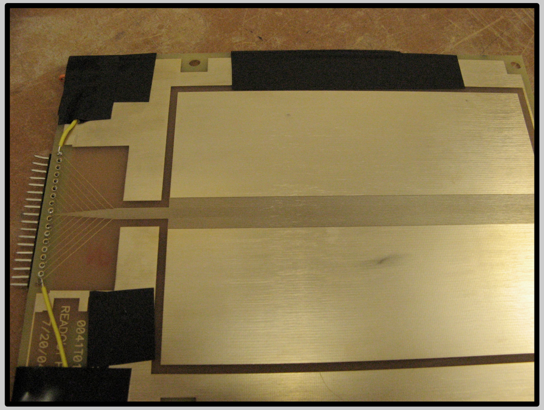
UK: first demonstrated CS2 with micromegas

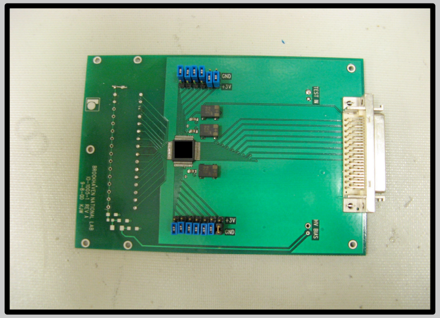
Shef/Saclay: bulk micromegas working (e.g. T2K TPC)





UNM: now have 300µm strip readout working (observe S-recoils)





CYGNUS Cooperation

DRIFT activity

MIMAC activity

CANFRANC.. activity

THEORY cosmology activity

NEWAGE (Japan), DRIFT (US), MIT

CYGNUS 2007

First Workshop on Directional Detection of Dark Matter

22-24 July 2007

Boulby Underground Laboratory, UK

ILIAS-N3 - advanced detectors meeting

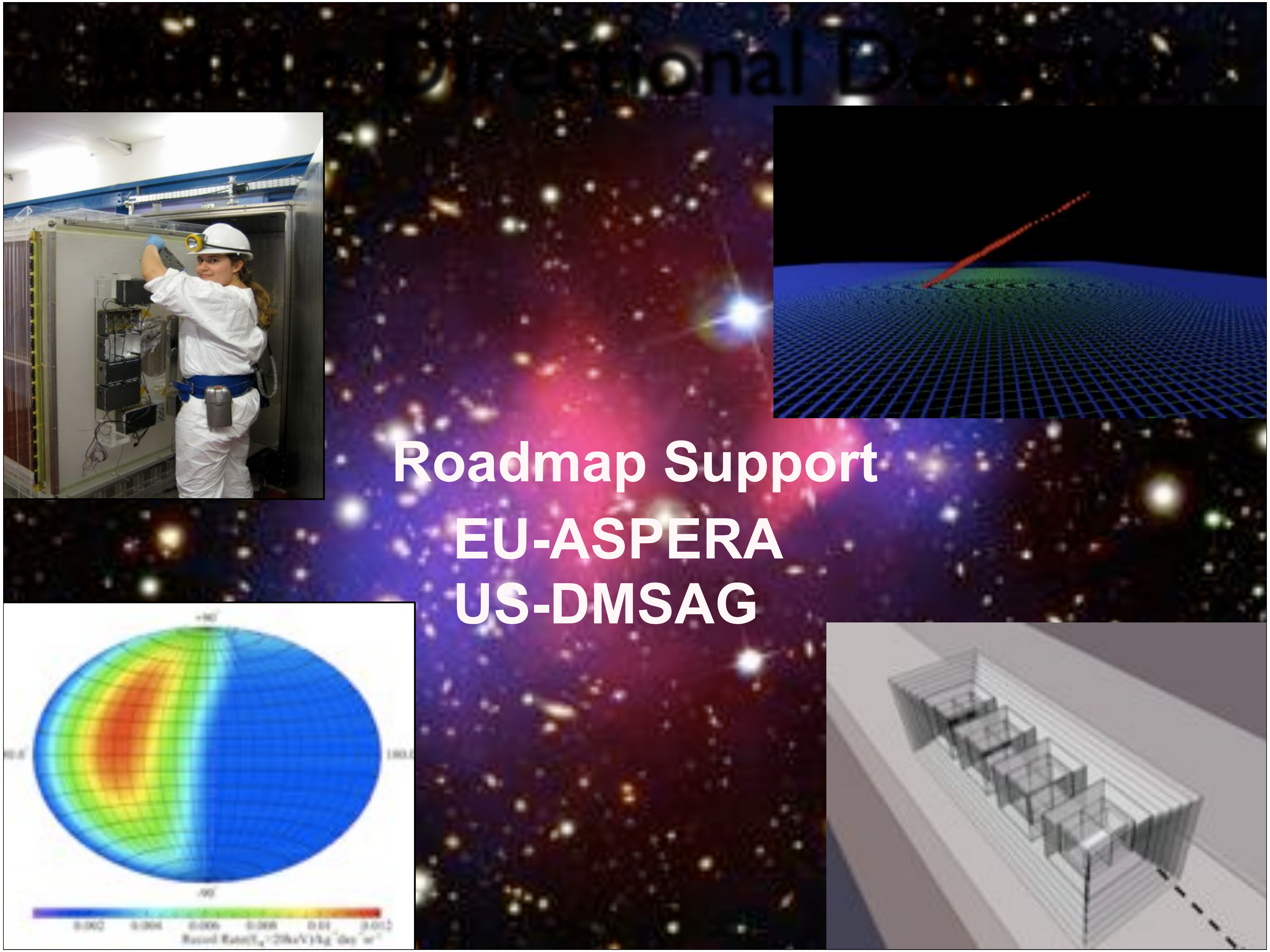
12 R&D Challenges

(1) Demonstration of 3D reconstruction at low threshold
(2) Demonstration of low background underground
(3) Demonstration of head-tail discrimination
(4) Understanding of quench factors and calibrations
(5) Selection of electronics and readout technology
(6) Optimisation of gas mixtures and pressures
(7) Demonstration of SD sensitivity with high pressure
(8) Demonstration of detector mechanical engineering
(9) Optimisation of veto shielding design
(10) Determination of underground infrastructure and safety
(11) Determination of relevant SUSY and cosmology
(12) Demonstration of capability for axion sensitivity

Directional Community

Organisation	Country	Short description of role
University of Edinburgh	UK	DRIFT - background simulations, operations
UC, London	UK	TPC - detectors, vessels, gas, large scale designs
University of Nottingham	UK	Directional cosmology theory
University of Sheffield	UK	DRIFT - design, daq, construction, analysis, operation
TU - Darmstadt	Germany	DRIFT - kk-axion search, electronics, analysis
NCSR, Demokritos	Greece	TPC micro-readout, electronics and analysis
University of Ioannina	Greece	Theory and simulations
University of Patras	Greece	kk- axion search
Saclay	France	MIMAC - Development of micromegas, TPC design
CNRS/IN2P3/LPSC	France	MIMAC - Electronics, readout, spin-dependent target
Institute Laue Langevin	France	MIMAC -Gas treatment and control, scintillation readout.
University of Granada	Spain	Spin dependent interaction (SUSY models)
University of Zaragoza	Spain	TPC - detector design, background, gas tests
Niels Bohr Institute	Denmark	Directional cosmology theory (TBC)
MIT	*US*	*DRIFT - electronics, daq, simulations*
University of Boston	*US*	*DRIFT - electronics*
University of New Mexico	*US*	*DRIFT - GEM readout, analysis, operations*
Occidental College, LA	*US*	*DRIFT - construction, analysis, scintillation readout*
[Kyoto University	*Japan*	*NEWAGE - cooperation]*

14 institutes also signed for the ILIAS-NEXT TPC LOI


Roadmap Support
EU-ASPERA
US-DMSAG

Achievements summary

(1) DRIFT II works - stable, room temperature
(2) Well calibrated - event by event discrimination
gamma rejection 10^6, neutron efficiency
(3) Comparison of rock neutron with direct scintillator flux measurement (NUTs) Astrop. Phys 27(5)(2007) 326
(4) RPRs discovered - well understood, reduced radon
(5) Directionality 1D, 3D first sky-maps,
(6) End-to-end simulations working, understood
directional response matrix
(7) First evidence for head-tail, agreement (?) with simulations and theory
(8) Scale-up routes - micromegas works

NEXT steps: Show low energy 3D sensitivity & head-tail
Solve RPRs