Alpha Particle Events as a Detector Diagnostic in DRIFT-II

'What have alpha particles ever done for us?'

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Talk Overview

- Analysis Procedure
  - Data reduction
  - Parameters / definitions
- Types of alpha particle
  - Rn decay
  - Rn-progeny decay
- Drift velocity measurements
  - D-IIa / D-IIb
  - Alpha range spectroscopy
- NIPs-suppression
- Monte Carlo simulations
  - Rn emanation rate
  - Progeny uncharged fraction
- Conclusions / summary

Alpha Analysis Procedure

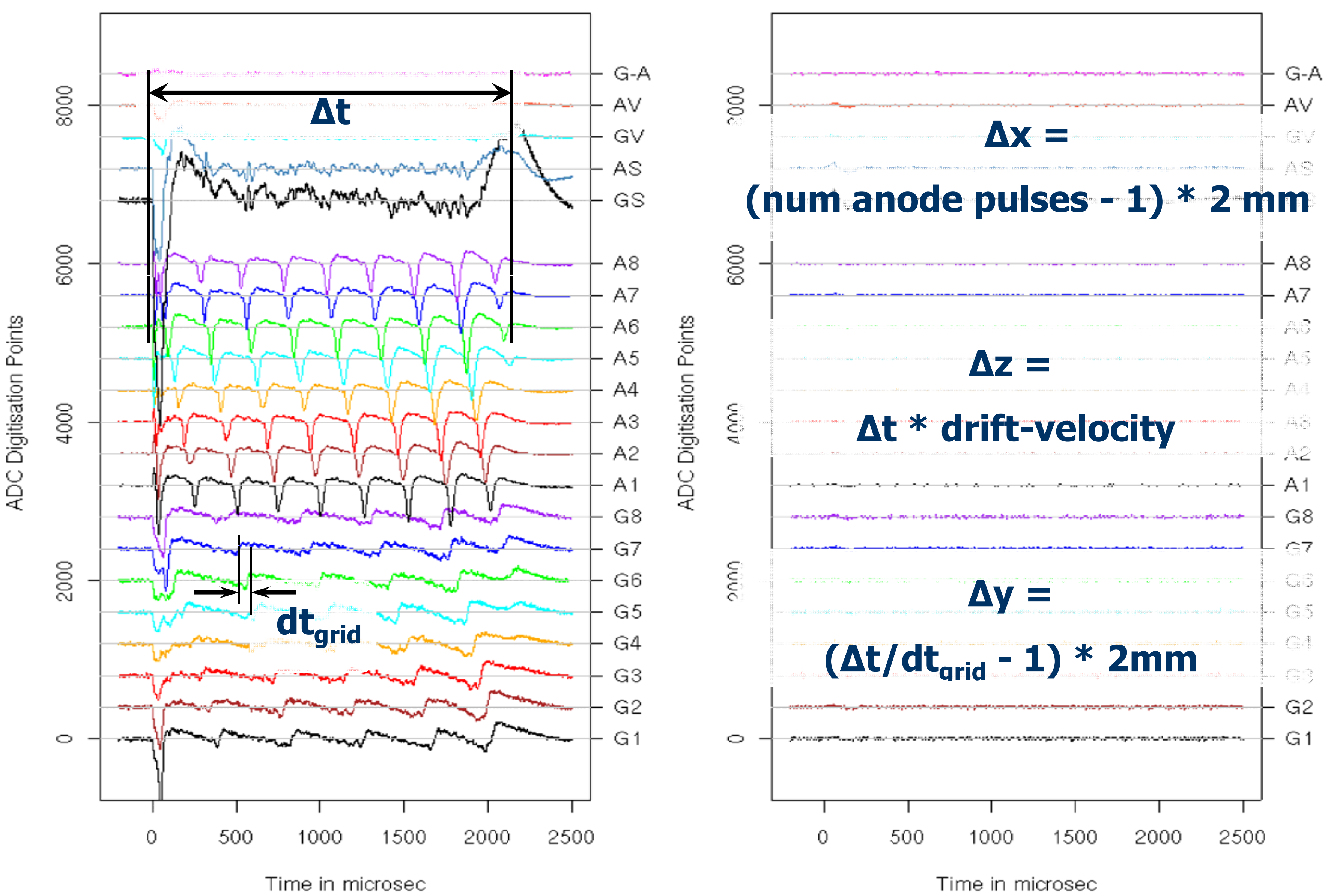
- Raw data reduced to ~19(?) parameters (pulse-height, area, time-stamp, etc…)
- Relational database used to interrogate data on track-types, event-types and individual pulses (‘signal-profiles’)
- Signal profiles can be of either polarity
- Effective minimum analysis threshold = ± ~9 ADCs (see Demitri for details…).

Alpha Analysis Procedure (cont…)

- Alpha tracks are defined as a sequence of:
  - >8 negative-going signal profiles appearing on
  - all anodes channels of an MWPC with
  - |height| > 45 ADCs.

- This catches ~99% of genuine alpha tracks plus small amount of other stuff:

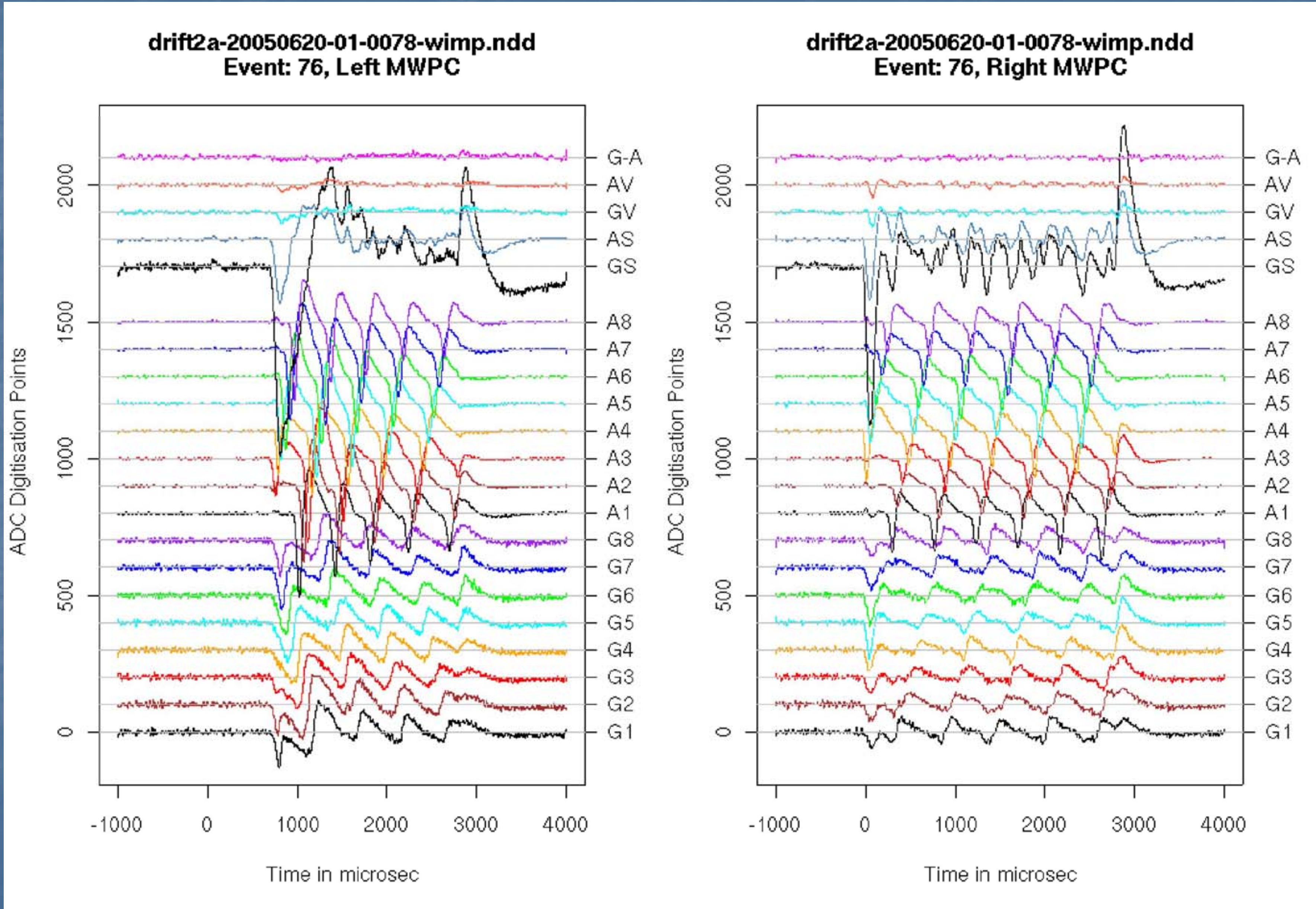
Typical Alpha Event



Alpha Analysis Procedure (cont…)

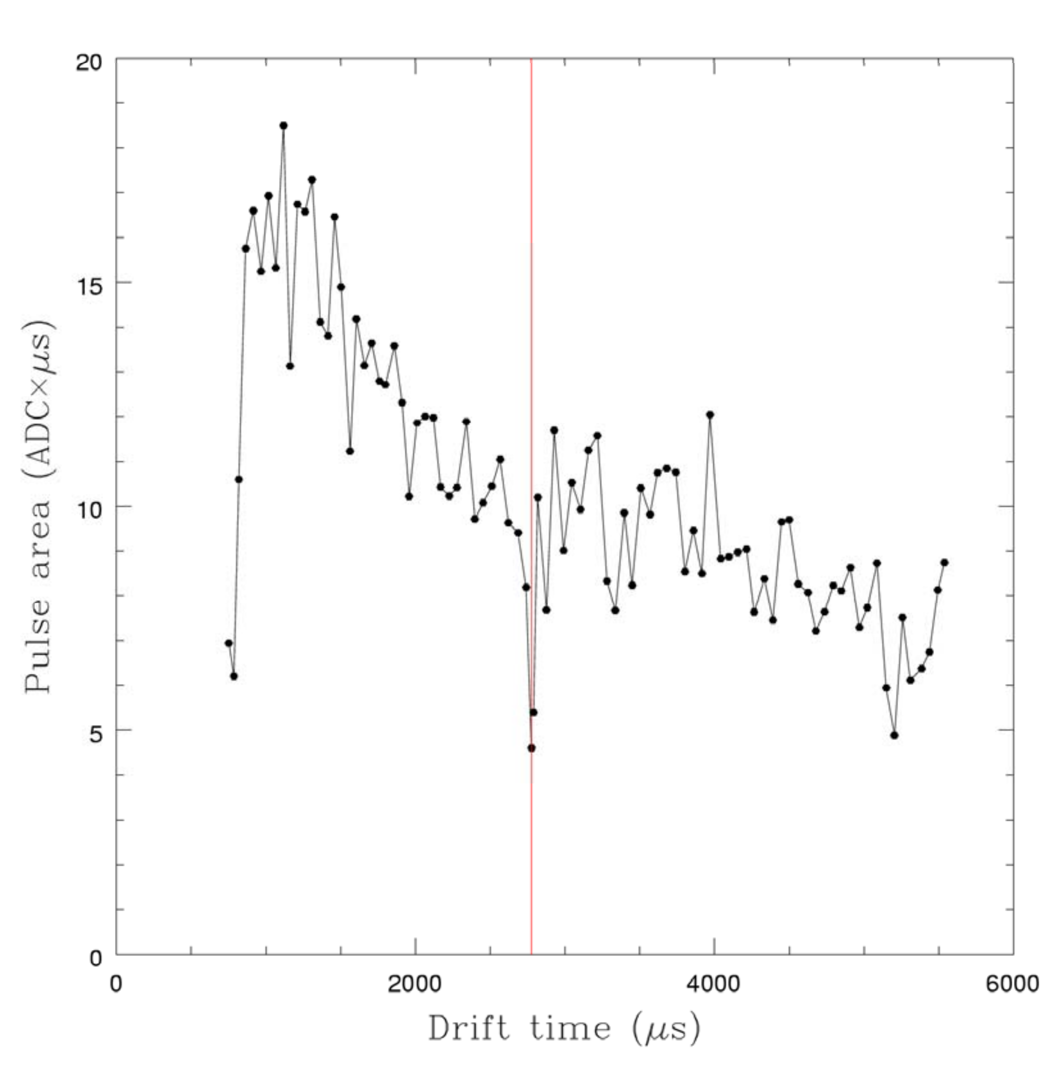
- The following selection criteria are then applied to these tracks to retain only 'Gold Plated Cathode-Crossing' alphas (GPCCs):
- Alpha tracks appear on both MWPCs for this trigger,
- The mean anode pulse-area < 30 V.μs,
- Total anode area/MWPC > 30 V.μs,
- No signals on veto-difference channel with height > 45 ADCs,
- On either MWPC, track starts after t = -100 μs and ends before t = 3000 μs.

Typical GPCC



...and its Bragg Curve

- Changing area of pulses along track reveals variations in dE/dx
- In this case decay occurred in right MWPC. Alpha stopped in left MWPC
- Slight suppression of pulse area where track crosses cathode - field-distortions? Charge-division between MWPCs?



Types of Alpha Event

Alpha decay of:

- ^{222}Rn 5.49 MeV, R=334 mm
- ^{218}Po 6.00 MeV, R=383 mm
- ^{214}Po 7.69 MeV, R=567 mm

Produce recoils (RPRs):

- ^{218}Po 101 keV, R=578 μm
- ^{214}Pb 112 keV, R=628 μm
- ^{210}Pb 147 keV, R=745 μm

- ^{220}Rn 6.29 MeV, R=413 mm
- ^{216}Po 6.68 MeV, R=464 mm
- ^{212}Po 8.79 MeV, R=701 mm

→

- ^{216}Po 117 keV, R=632 μm
- ^{212}Pb 128 keV, R=682 μm
- ^{208}Pb 169 keV, R=818 μm

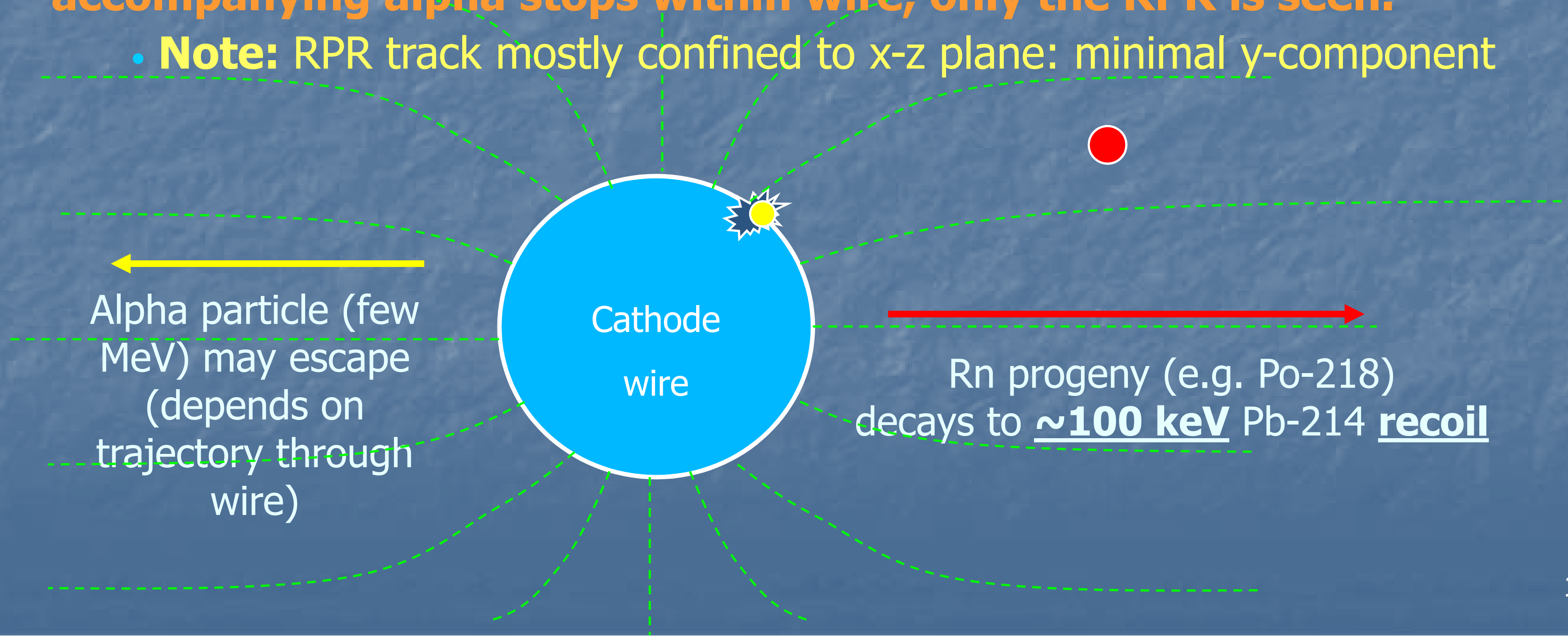
Most recoils are produced positively charged but not all -
Uncharged progeny can produce GPCC events (see later)

Radon Progeny Recoils (RPRs)

- Radon and uncharged progeny diffuse thoughout main volume & decay, producing alphas (some of which are GPCCs).

- Resulting +charged progeny plate-out on high voltage central cathode wires, where they undergo further alpha decays. *

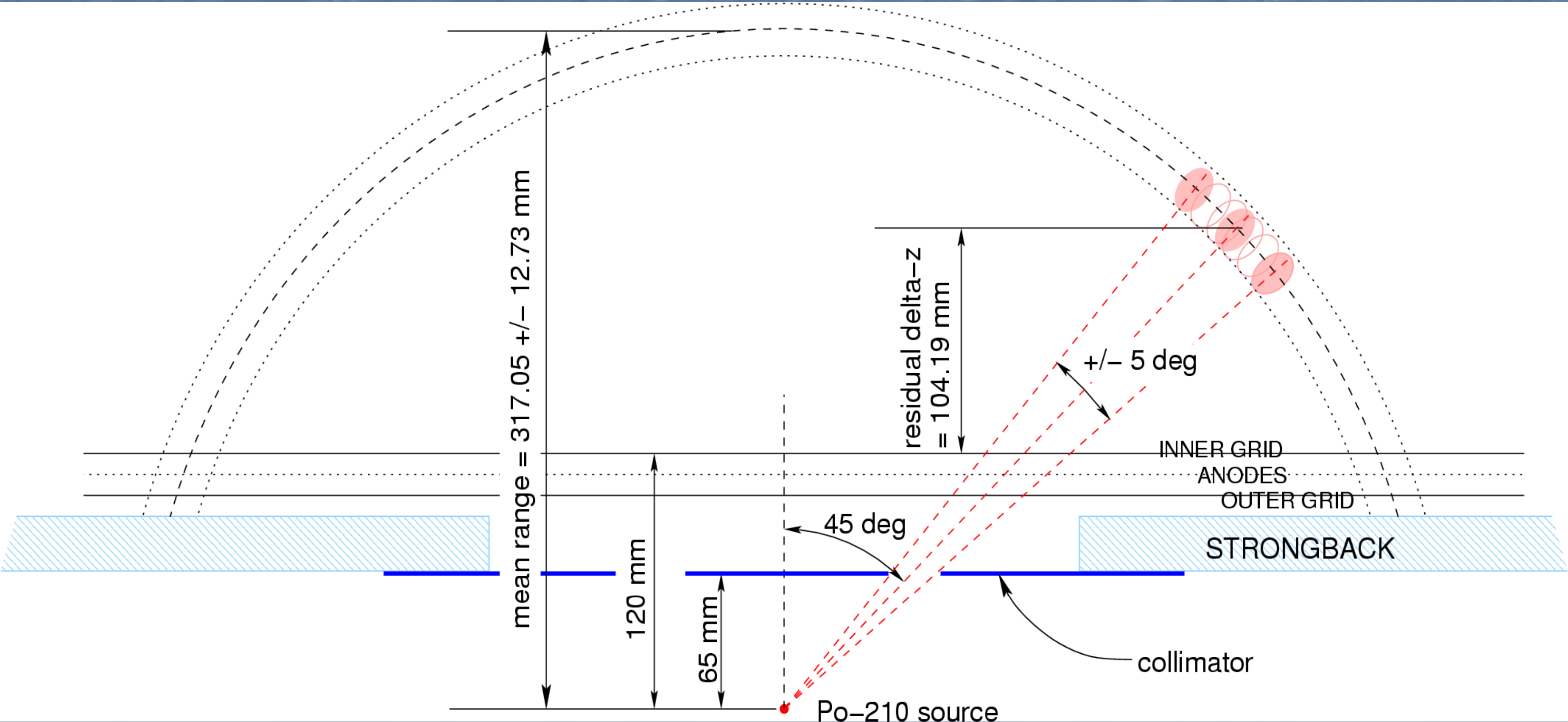
- Decay of progeny cause daughter nuclei to RECOIL into the fiducial volume. **If accompanying alpha stops within wire, only the RPR is seen.**
    - **Note:** RPR track mostly confined to x-z plane: minimal y-component



Drift Velocity Measurements

1st, need to know ratio of drift fields in different modules to compare v_{drift} ($v_{drift} = \mu E$). E(IIb)/E(IIa) = 0.94. Then, have choice of 2 methods…

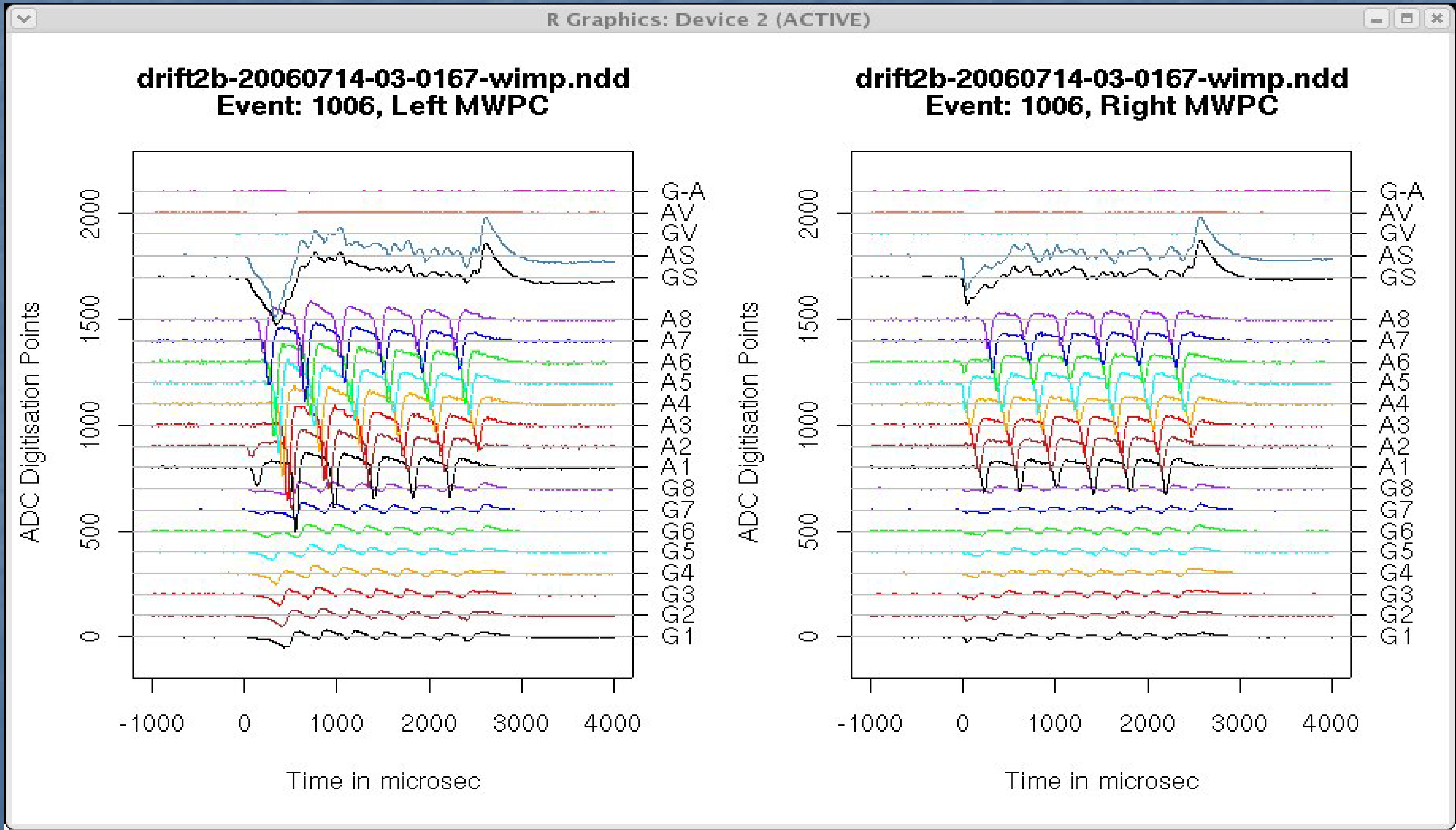
Method 1: ^{210}Po alphas collimated to 45° from drift-direction (data taken in right MWPC of DRIFT-IIb, Mar/Apr 06 - ~1400 events selected).



Drift Velocity Measurement 1 (cont…)

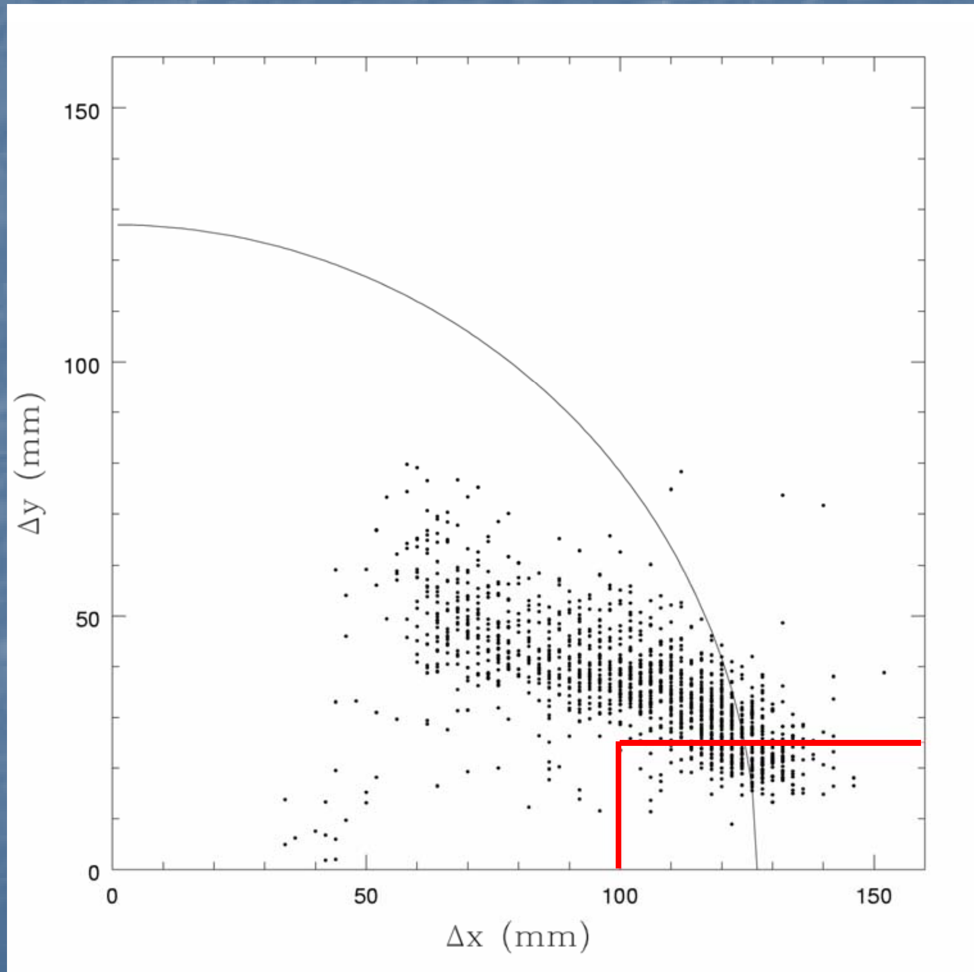
Results:

• Expected even illumination across X-Y plane - didn't see this. Grid signals on D-IIb in 2006 data were v. small - some 'pulses' missed (c.f. slide 7).



Δy Measurement - D-IIb

- Systematic error on Δy: σ_y (sys) ~ Δy, whereas σ_x (sys) ~ 2 mm
- So, events selected with Δy<25 mm and Δx>100 mm
- Reduced statistics from 1410 to 241

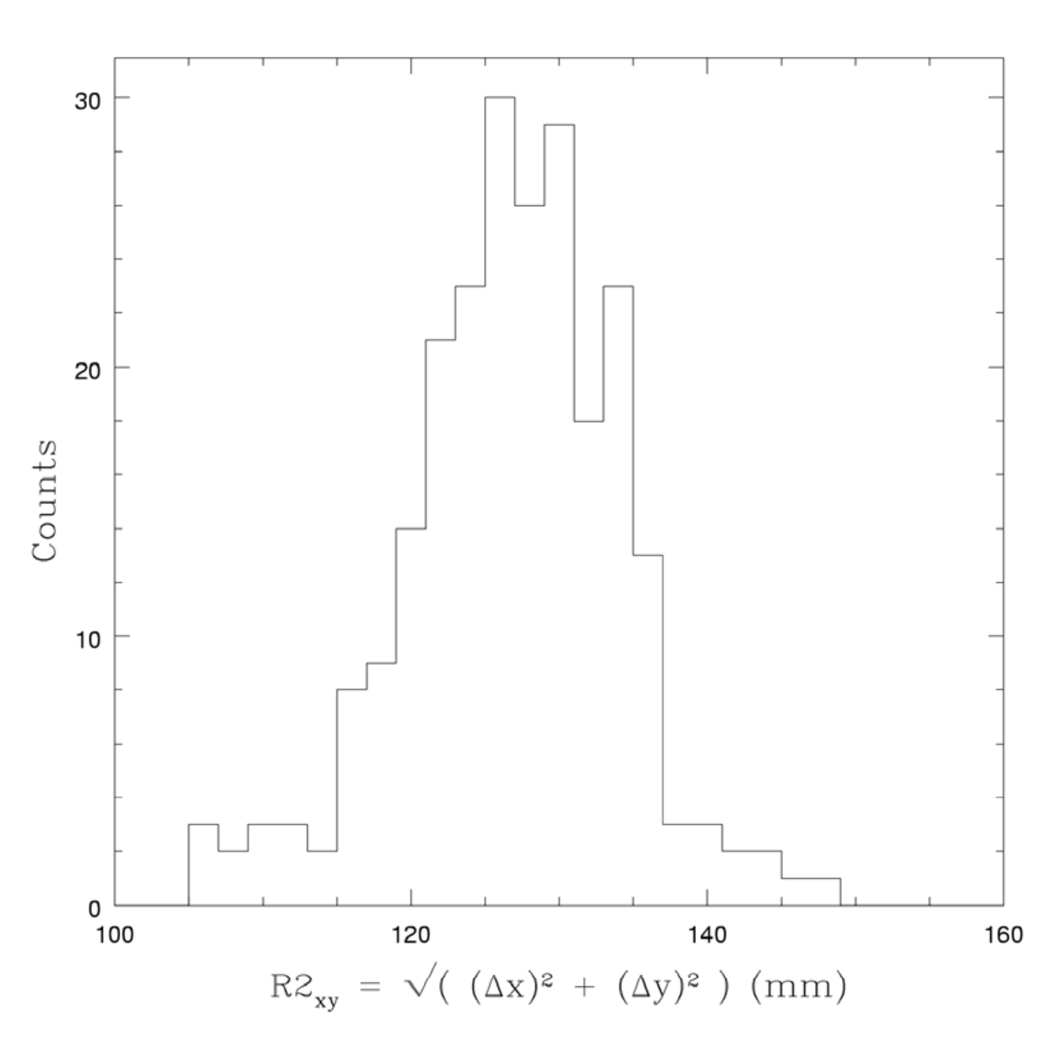


Drift Velocity Measurement 1 (cont…)

- Mean 2-dimensional range $R2_{xy}$ = 127 ± 5 mm (accounting for errors in Δx, Δy and θ)

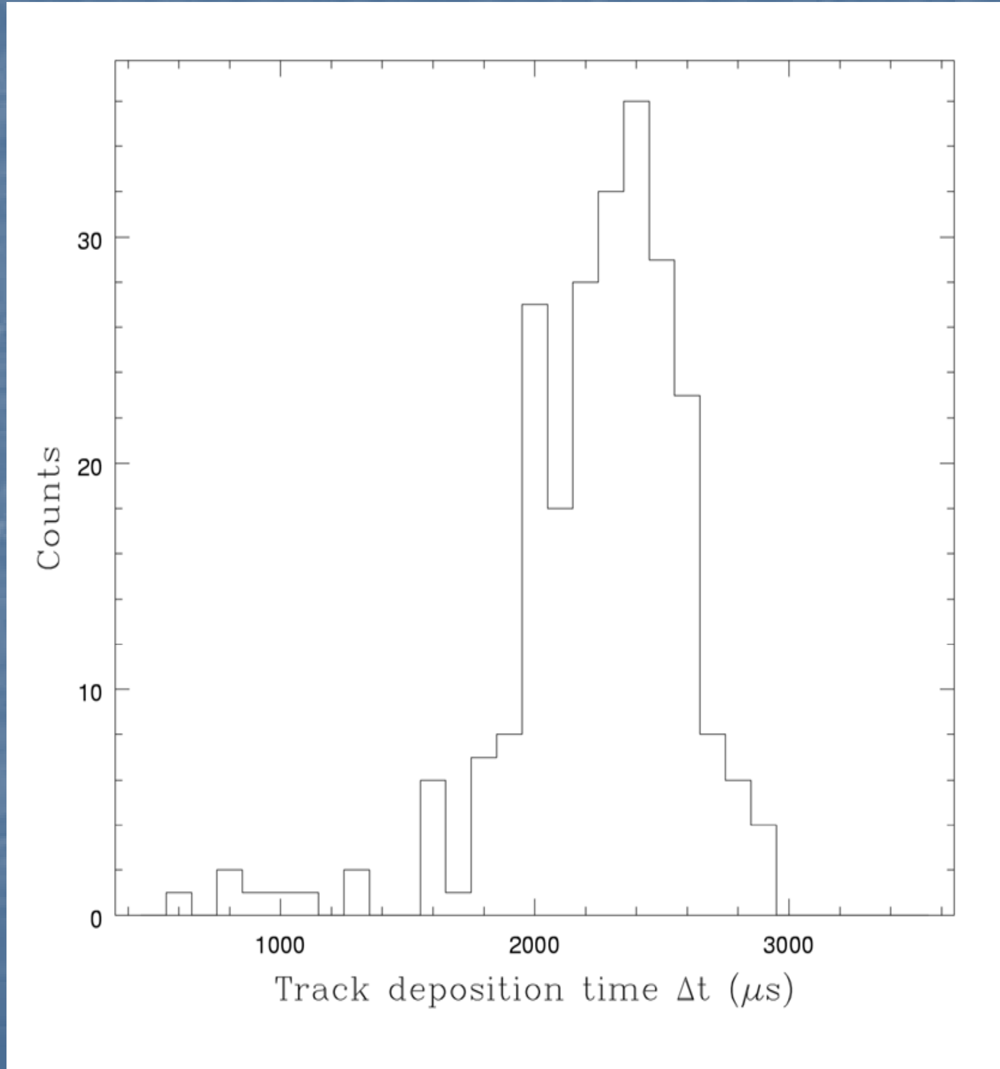
- Δz = 127 ± 7 mm

- Full range R = 349 ± 7 mm - ~10% more than SRIM2003 prediction.



Drift Velocity Measurement 1 (cont…)

- Mean drift time Δt = 2252 ± 33 μs.
- v_{drift} (IIb) = $\Delta z / \Delta t$ = 57 ± 4 m/s
- v_{drift} (IIa) = 61 ± 4 m/s



Drift Velocity Measurement 2

Method 2: 3D reconstruction of background alphas in DRIFT-IIa

- This method is recursive:
  - First, guess a value of v_{drift}, calculate ranges and histogram R
  - Repeat with different guesses until peaks in histogram tend to minimum width* (see next slide)
- Apply cuts in R to select only Rn-222 events
  - The procedure up to this point ensures selection of a single species
- Allow track range R to vary as a free parameter and calculate v_{drift} using:

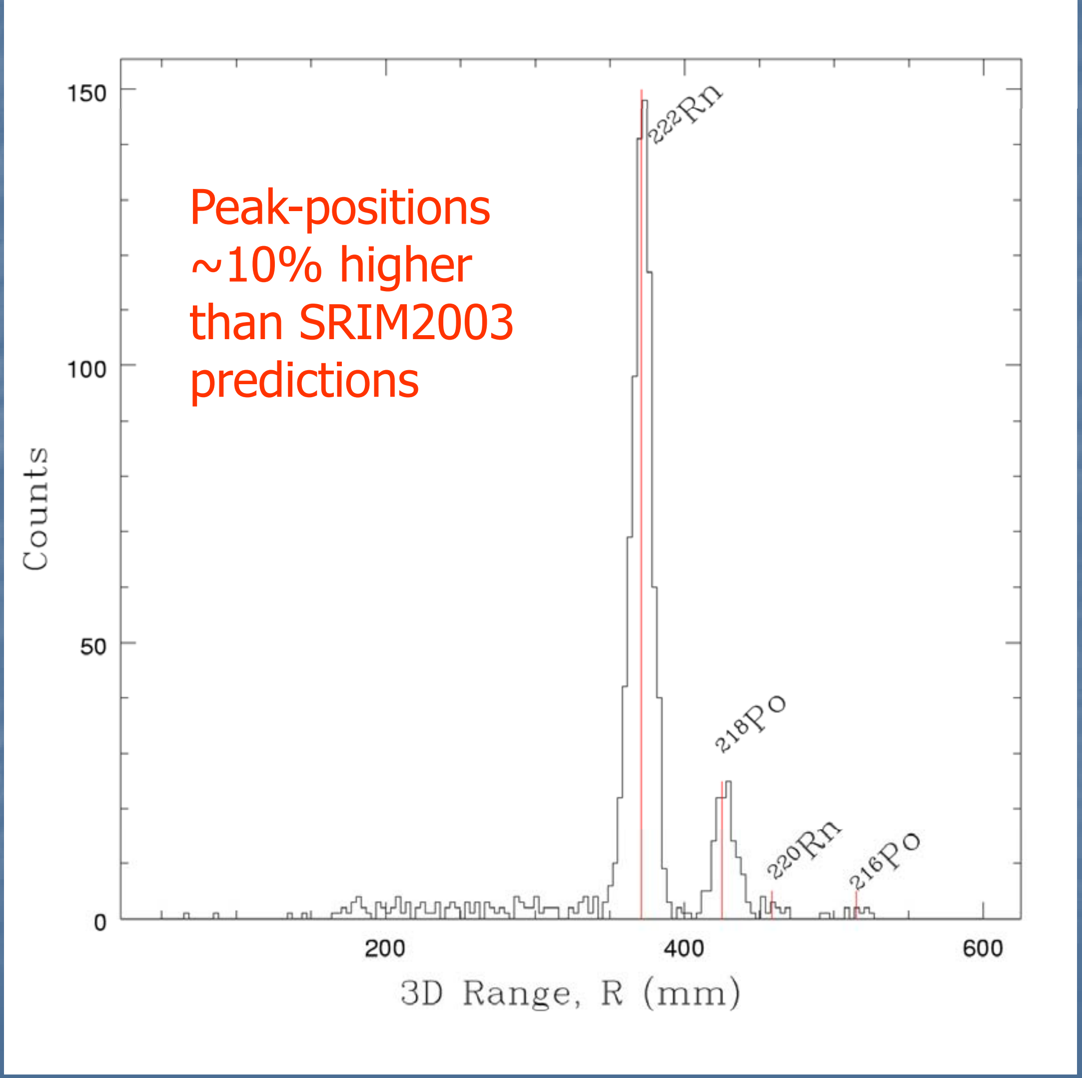
$$v_{drift} = \frac{\sqrt{R^2 - \Delta x^2 - \Delta y^2}}{\Delta t}$$

- Vary R until distribution of v_{drift} tends to minimum width

Range Discrimination

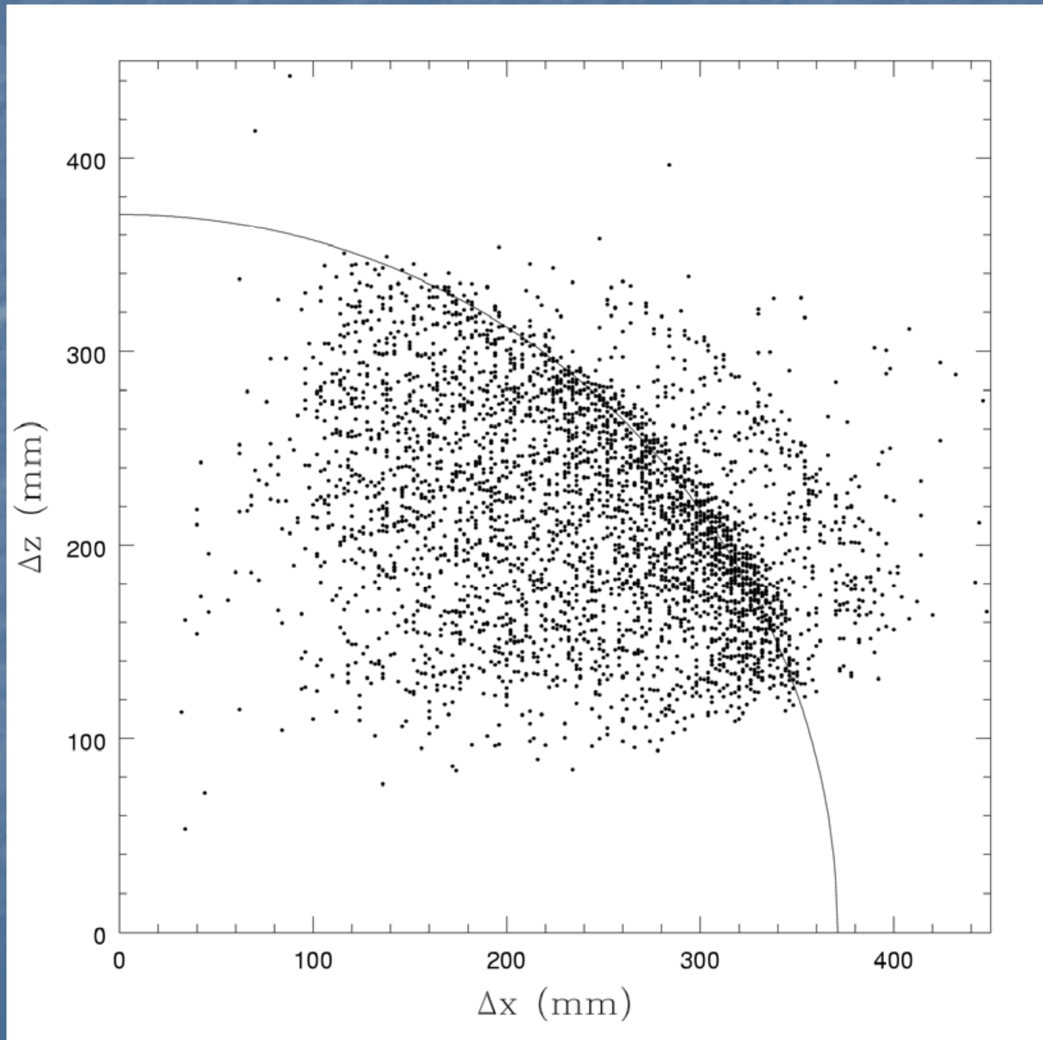
Reconstructed 3D ranges for ~2 weeks worth of GPCCs in D-IIa:

- Peak positions match those expected for ^{222}Rn, ^{218}Po, ^{220}Rn, ^{216}Po (assuming ~10% increase on SRIM2003).
- We see Po GPCCs - some fraction must be produced *uncharged.*
- Uncharged fraction dictated by relative sizes of peaks:
  - 22 ± 2% of ^{218}Po produced uncharged (c.f. ~15% in air)
  - 100 + 0 - 35% of ^{216}Po produced uncharged.



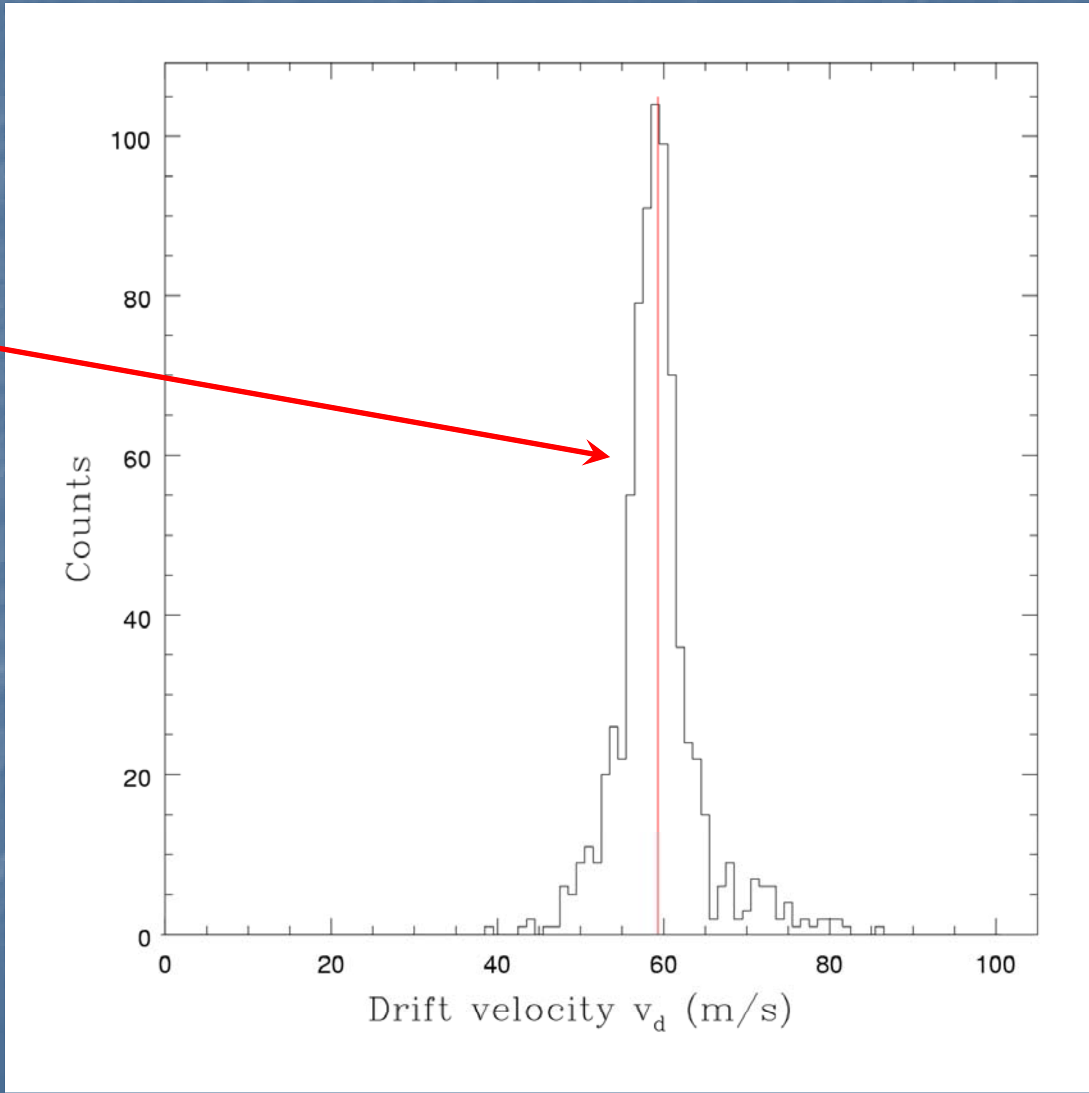
Range Discrimination (cont…)

- Although grid signals are bigger in D-IIa, Δy still inaccurate forcing a cut: Δy < 60 mm.
- Appropriate choice of v_{drift} shows Δx and Δz distributions in good agreement (as expected)
- Two main alpha track populations visible as arc-like features:



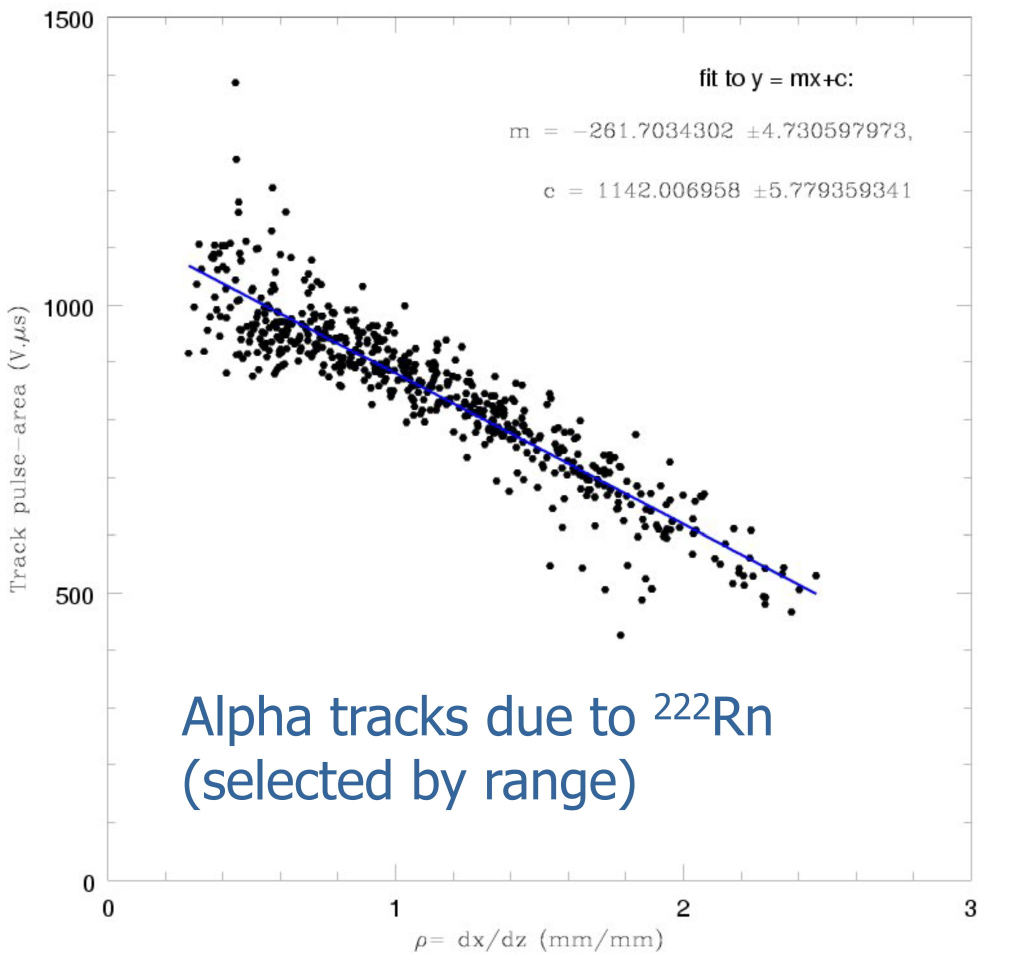
Drift Velocity Measurement 2 - results

- DRIFT-IIa:
  v_{drift} = 59.3 ± 7.7 m/s
  (c.f. 61 ± 4 m/s from method 1)
- DRIFT-IIb:
  v_{drift} = 55.6 ± 7.2 m/s
  (c.f. 57 ± 4 m/s from method 1)



Orientation dependence of NIPs

- Define $\rho = \Delta x / \Delta z$:
  - small ρ means few anode hits / long deposition time,
  - large ρ means many anode hits in a short time
- Large ρ associated with suppressed NIPs!
  - Pulse pile-up / overshoot in signals?
  - This measurement should be repeated with new electronics (see Ed Daw's talk)

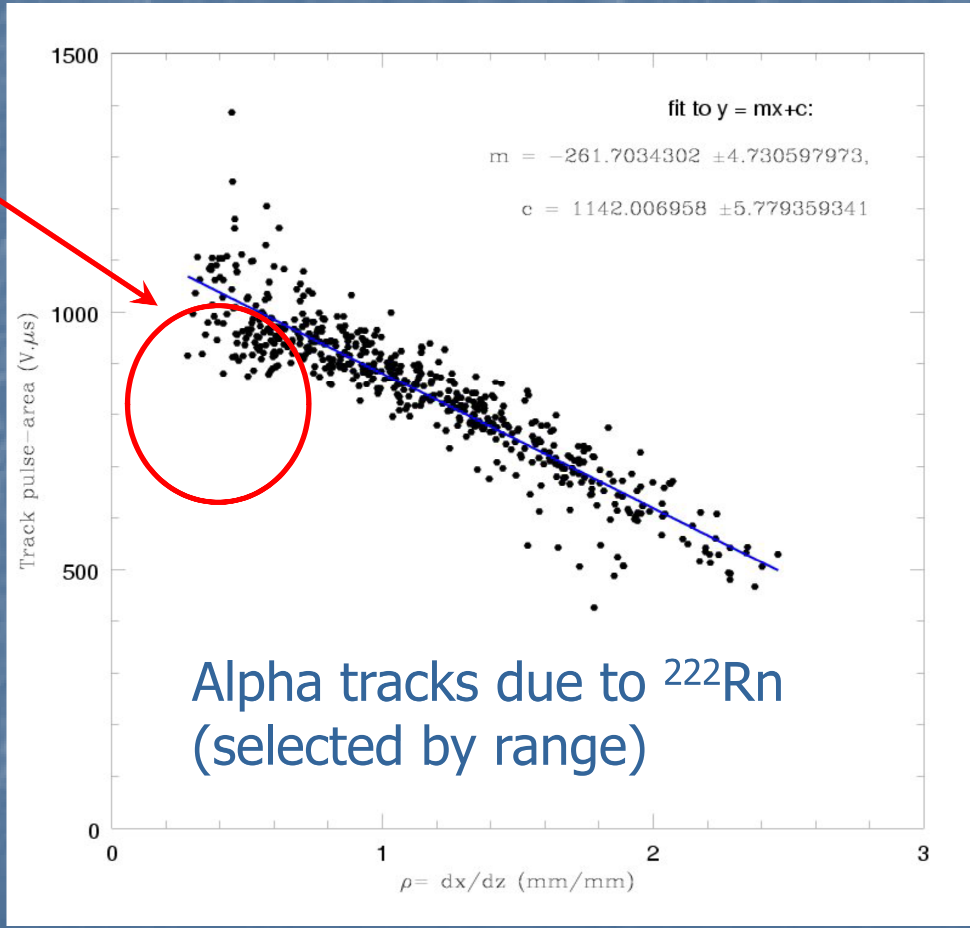


Alpha tracks due to ^{222}Rn (selected by range)

Orientation dependence of NIPs (cont…)

- There's a hint of a downward trend at very low ρ (alpha cuts mean we don't see this part of the population).
- Tracks well aligned to drift direction may experience increased charge recombination before + and - charges are fully separated
  - This would result in less observed charge (& NIPs)
  - Charge-recombination might produce visible fluorescence
- RPR tracks are more likely to be in this category

  - veto using fluorescence signal?



Monte Carlo Simulations

- GPCC cuts select a fraction, g, of all alpha events occurring within the vessel - what is this factor?
- Fiducial MC written to determine:
  - g for Rn-decay events, given drift velocity, alpha ranges and max deposition time,
  - Proportion of Rn:Po events as a function of drift velocity, range and Po uncharged fraction, f_U.
- Rate of Rn decays in vessel D_{Rn} given by:

$$D_{Rn} = \frac{k}{g(1+\tau/\rho)}\left(1-\exp[-t/\tau]\exp[-t/\rho]\right)$$

Where:

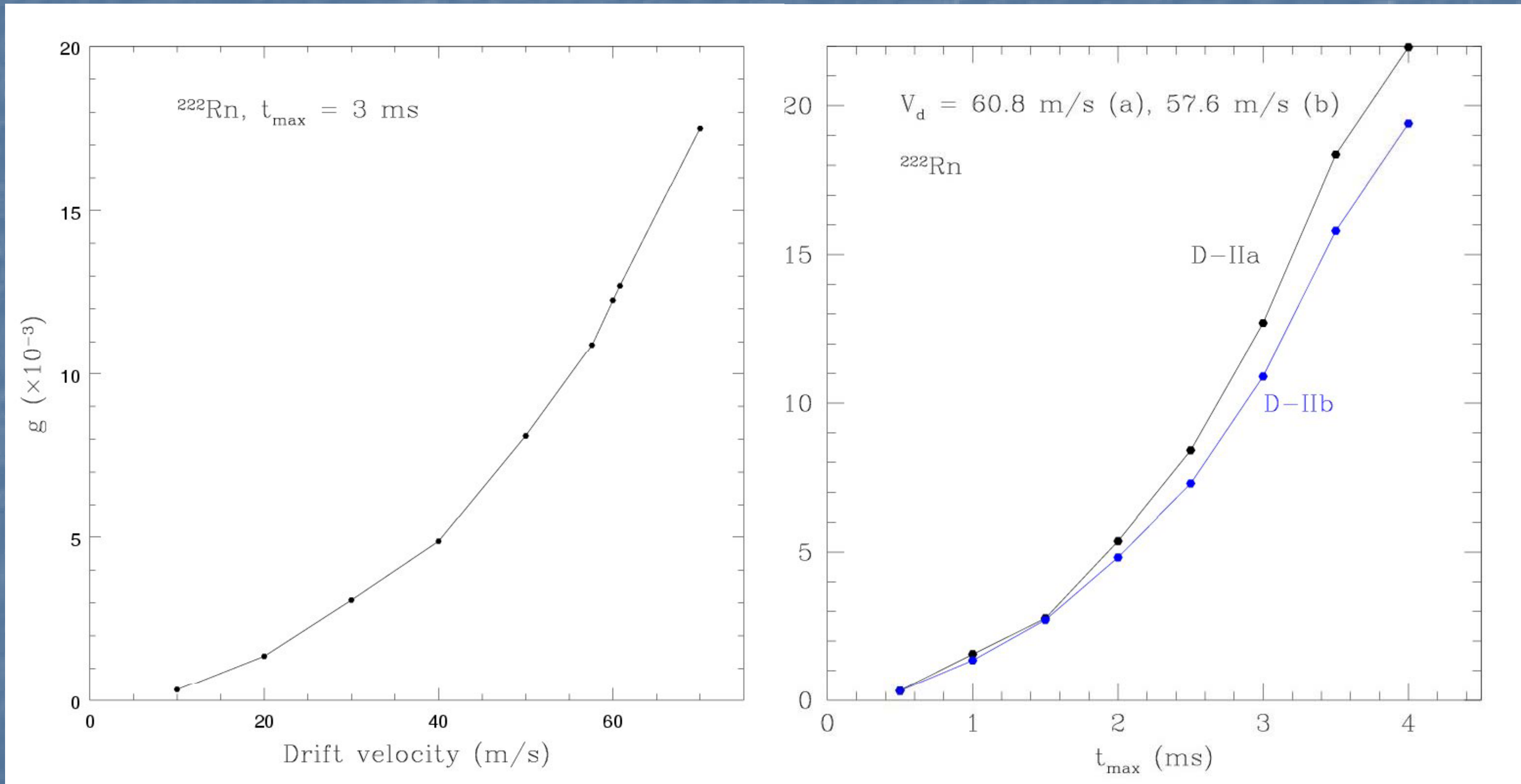
• k/g = Emanation rate E_{Rn} of Rn into vessel and k = fraction of emanated Rn that produced GPCC events,

• τ = Rn lifetime (5.52 days for ^{222}Rn),

• ρ = 1/e flushtime of vessel (3.15 days for D-IIa).

Monte Carlo Simulations

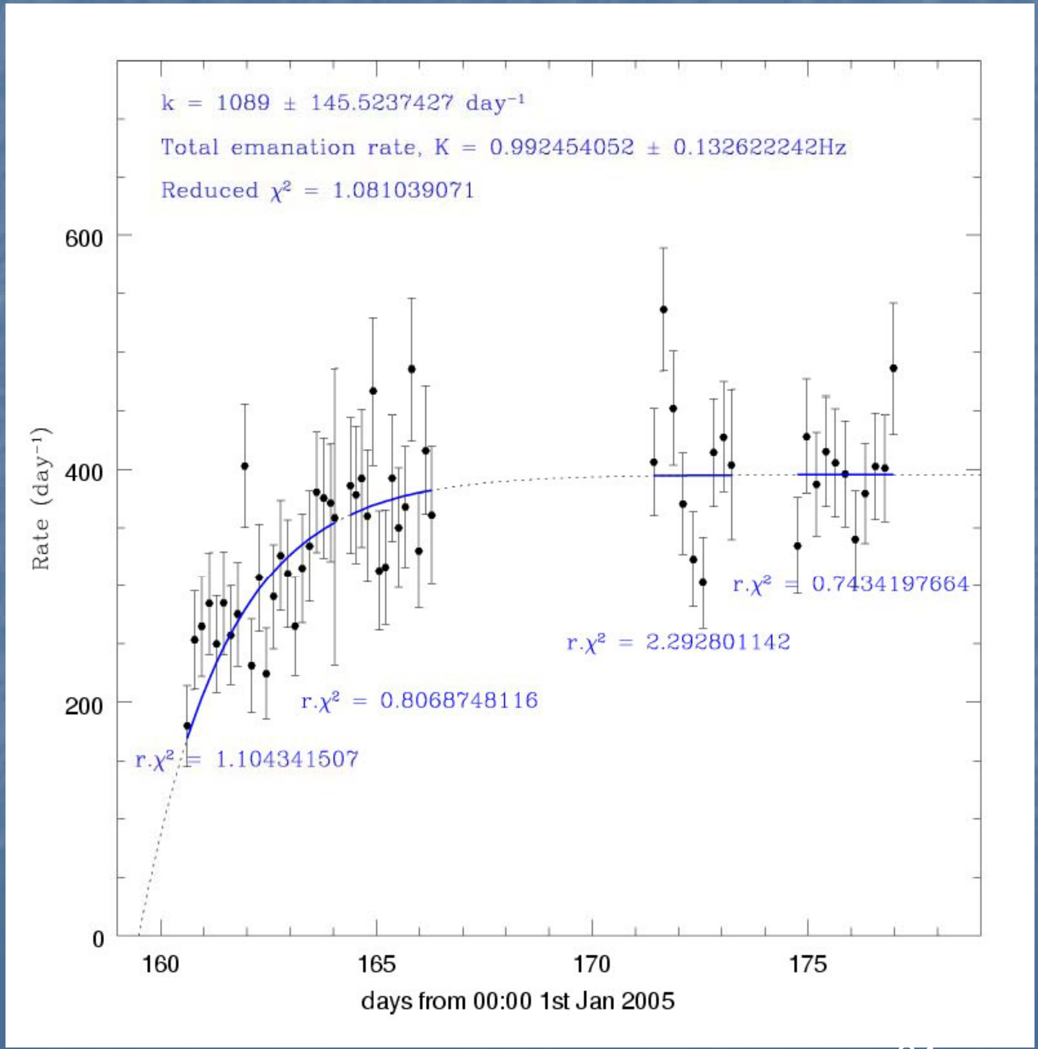
- Some results:



Allowing calculation of…

Radon Emanation Rates

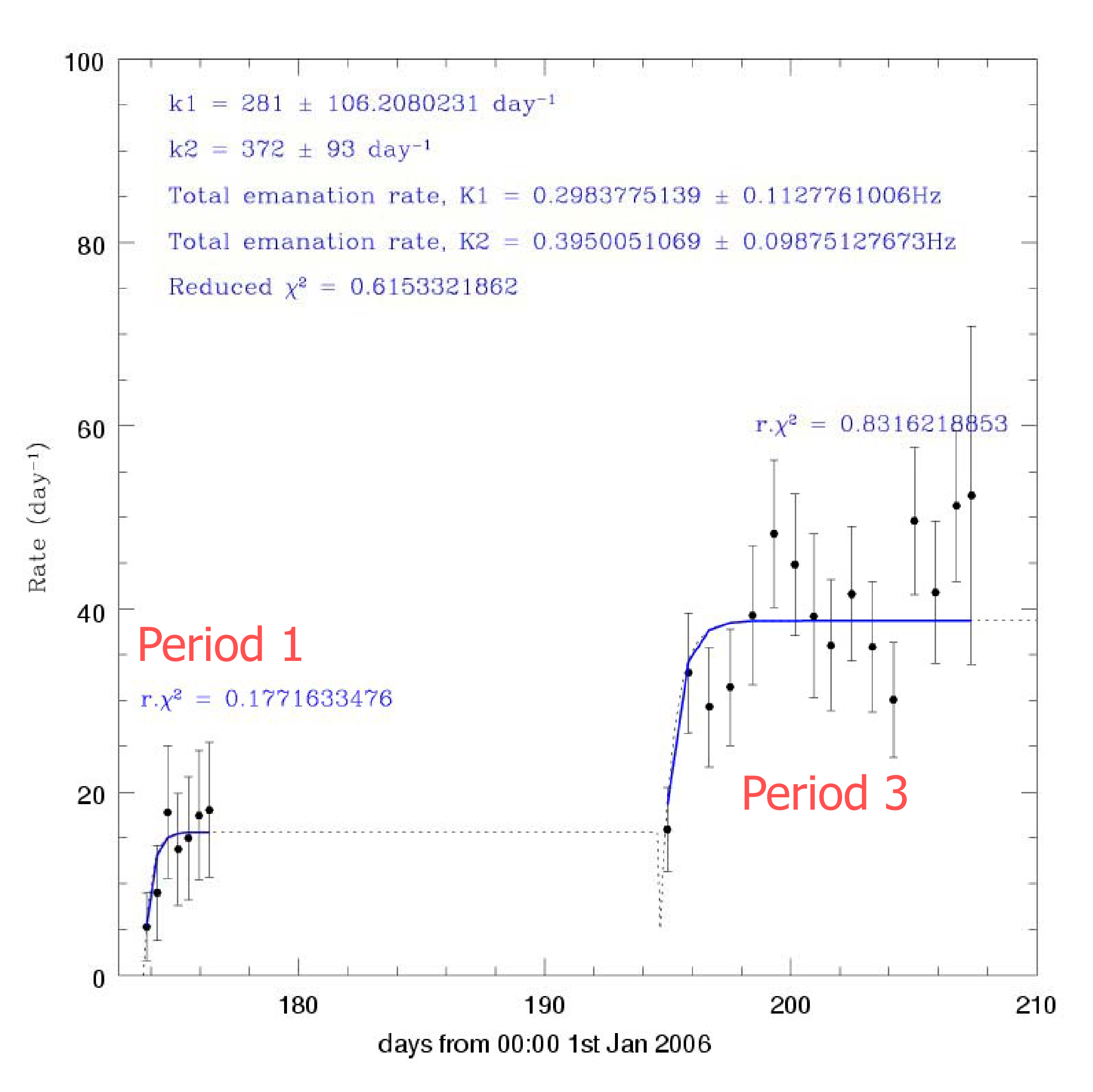
- Key period in 2005 data - vessel flushed & refilled.
- GPCC rate increases then flattens out as expected
- Equilibrium rate consistent with emanation rate of 1 ± 0.1 Hz.
- Direct measurements of materials (Sean) give rate of 0.95 ± 0.05 Hz.



DRIFT-IIb Alpha Rate Data

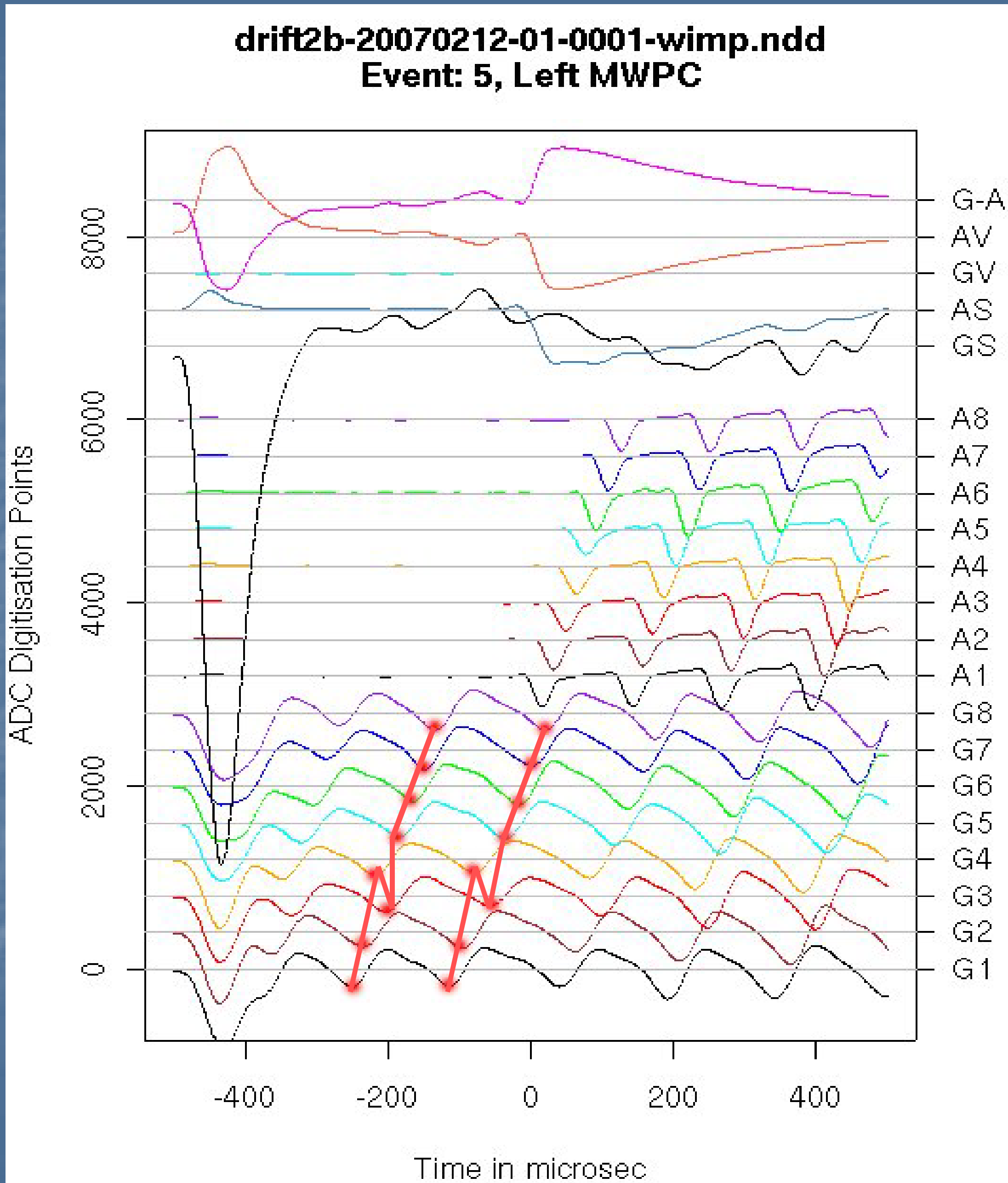
Periods of interest in 2006 data:

1. 23rd-26th June - fresh gas, flow-rate = 2 ch/day (1.176 kg/day)
2. 29th June-5th July - fresh gas, 2 ch/day
3. 14th-28th July - fresh gas, 1 ch/day (0.588 kg/day)
4. 28th-30th July - SAME gas, NO FLOW.



Finally…

Observation of Feb 2007 data reveals grids 3 and 4 on left detector are swapped - probably my fault!

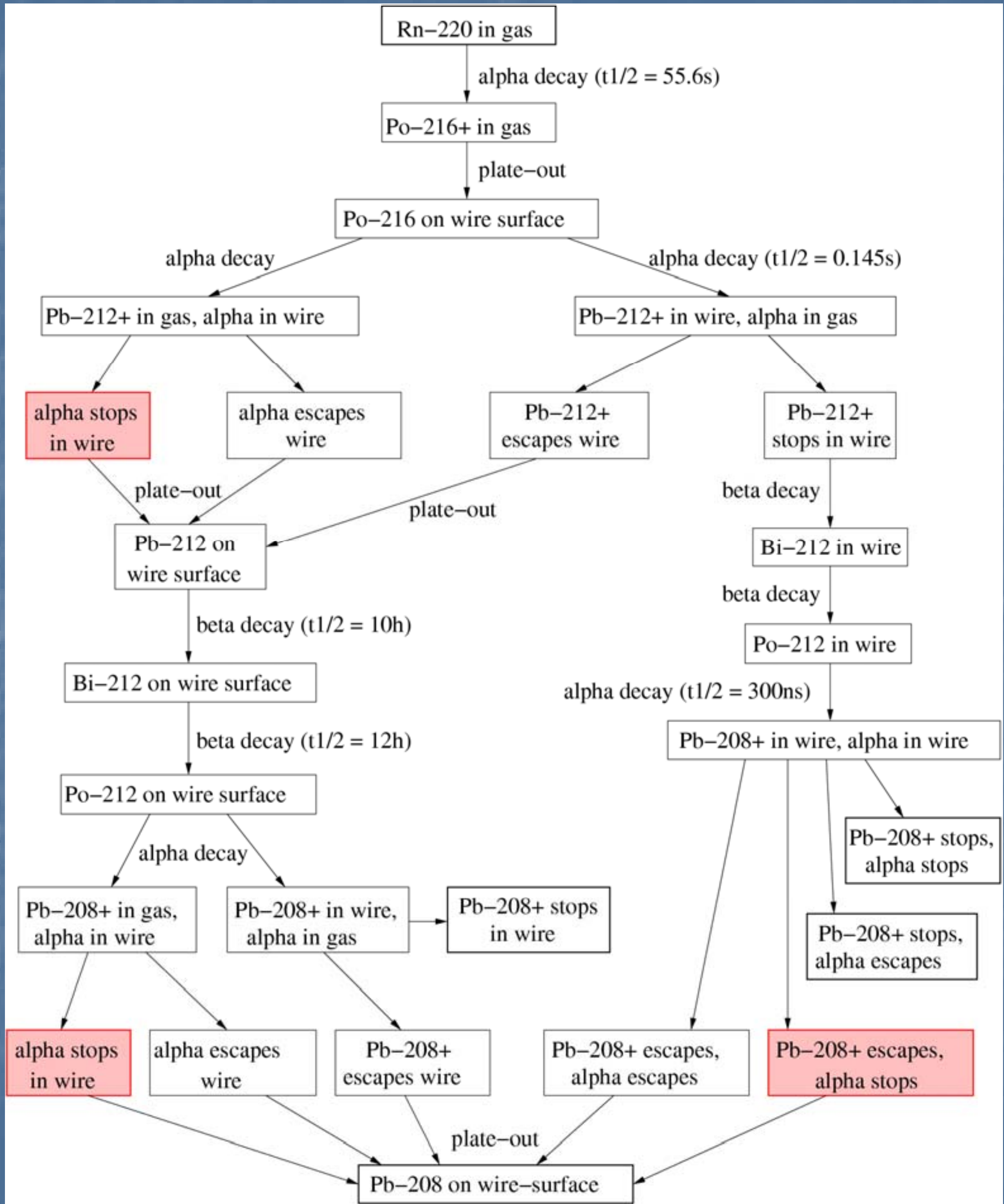


Apart from:

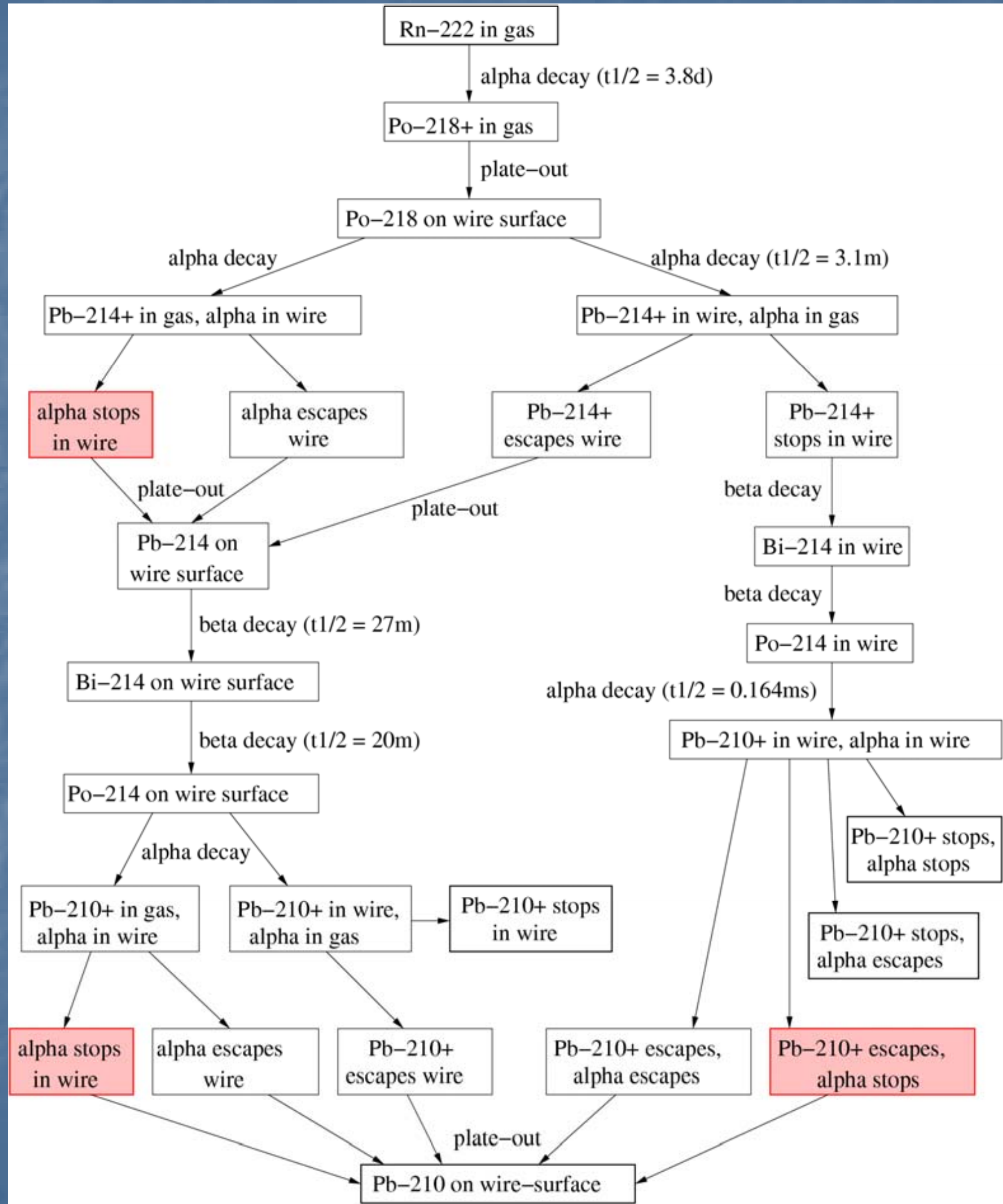
- Drift velocity measurements,
- Identification of subtle charge-loss mechanisms,
- Range discrimination,
- Identification of main alpha-emitting species
- Measurement of RPR charged fraction
- Estimate of Rn emanation rate
- Identification of wrong/bad cable connections

\- What have alphas ever done for us?

Spare stuff…



Rn−220 in gas
alpha decay (t1/2 = 55.6s)
Po−216+ in gas
plate−out
Po−216 on wire surface
alpha decay
alpha decay (t1/2 = 0.145s)
Pb−212+ in gas, alpha in wire
Pb−212+ in wire, alpha in gas
alpha stops in wire
alpha escapes wire
Pb−212+ escapes wire
Pb−212+ stops in wire
plate−out
plate−out
beta decay
Pb−212 on wire surface
Bi−212 in wire
beta decay
beta decay (t1/2 = 10h)
Po−212 in wire
Bi−212 on wire surface
alpha decay (t1/2 = 300ns)
beta decay (t1/2 = 12h)
Pb−208+ in wire, alpha in wire
Po−212 on wire surface
Pb−208+ stops, alpha stops
alpha decay
Pb−208+ in gas, alpha in wire
Pb−208+ in wire, alpha in gas
Pb−208+ stops in wire
Pb−208+ stops, alpha escapes
alpha stops in wire
alpha escapes wire
Pb−208+ escapes wire
Pb−208+ escapes, alpha escapes
Pb−208+ escapes, alpha stops
plate−out
Pb−208 on wire−surface



Rn−222 in gas
alpha decay (t1/2 = 3.8d)
Po−218+ in gas
plate−out
Po−218 on wire surface
alpha decay
alpha decay (t1/2 = 3.1m)
Pb−214+ in gas, alpha in wire
Pb−214+ in wire, alpha in gas
alpha stops in wire
alpha escapes wire
Pb−214+ escapes wire
Pb−214+ stops in wire
plate−out
plate−out
beta decay
Pb−214 on wire surface
Bi−214 in wire
beta decay
beta decay (t1/2 = 27m)
Po−214 in wire
Bi−214 on wire surface
alpha decay (t1/2 = 0.164ms)
beta decay (t1/2 = 20m)
Pb−210+ in wire, alpha in wire
Po−214 on wire surface
Pb−210+ stops, alpha stops
alpha decay
Pb−210+ in gas, alpha in wire
Pb−210+ in wire, alpha in gas
Pb−210+ stops in wire
Pb−210+ stops, alpha escapes
alpha stops in wire
alpha escapes wire
Pb−210+ escapes wire
Pb−210+ escapes, alpha escapes
Pb−210+ escapes, alpha stops
plate−out
Pb−210 on wire−surface