



Towards The DRIFT-III Directional Dark Matter Detector

Stephen Sadler on behalf of the DRIFT
collaboration



The
University
Of
Sheffield.

Colorado
State
University



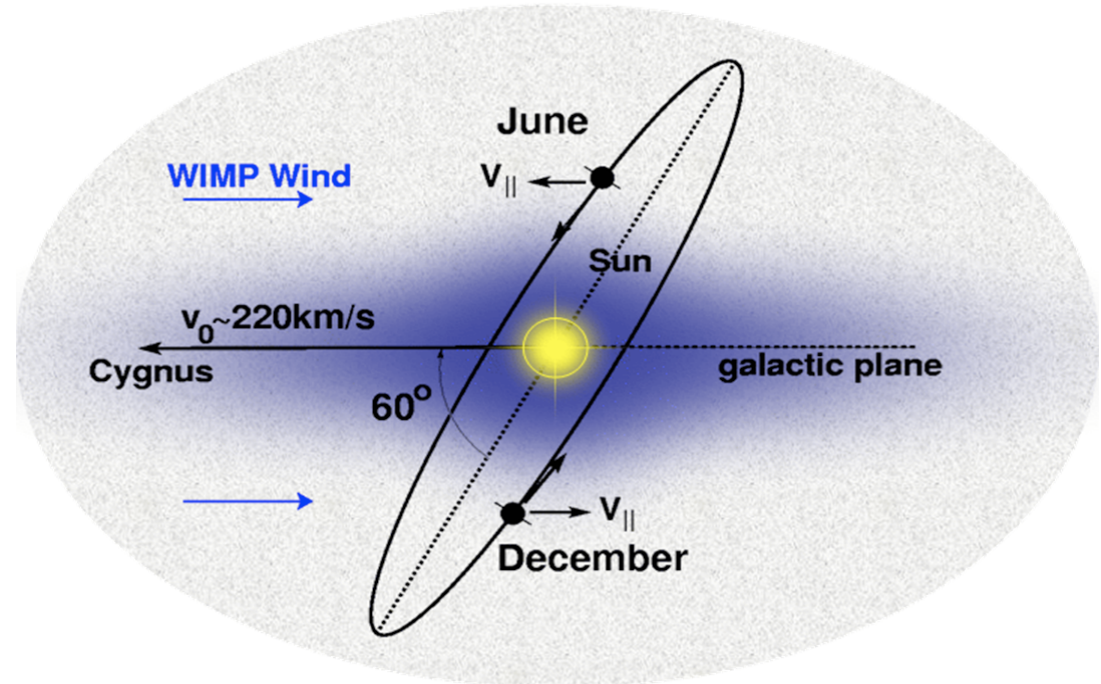
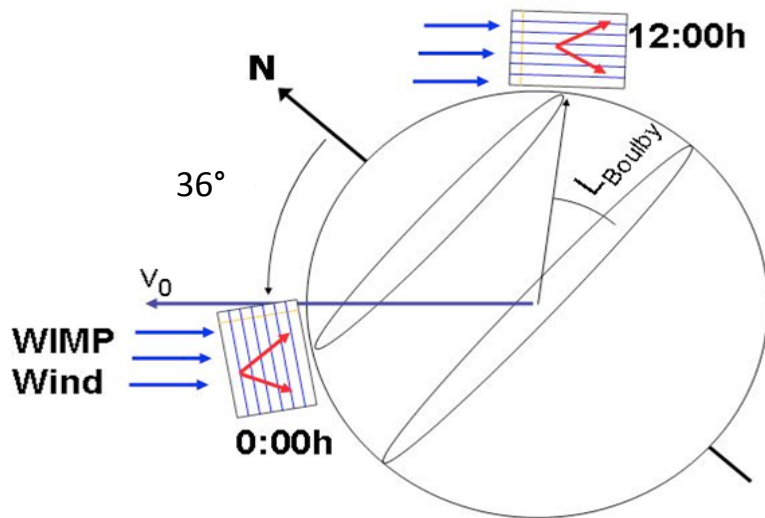
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Directional Detection

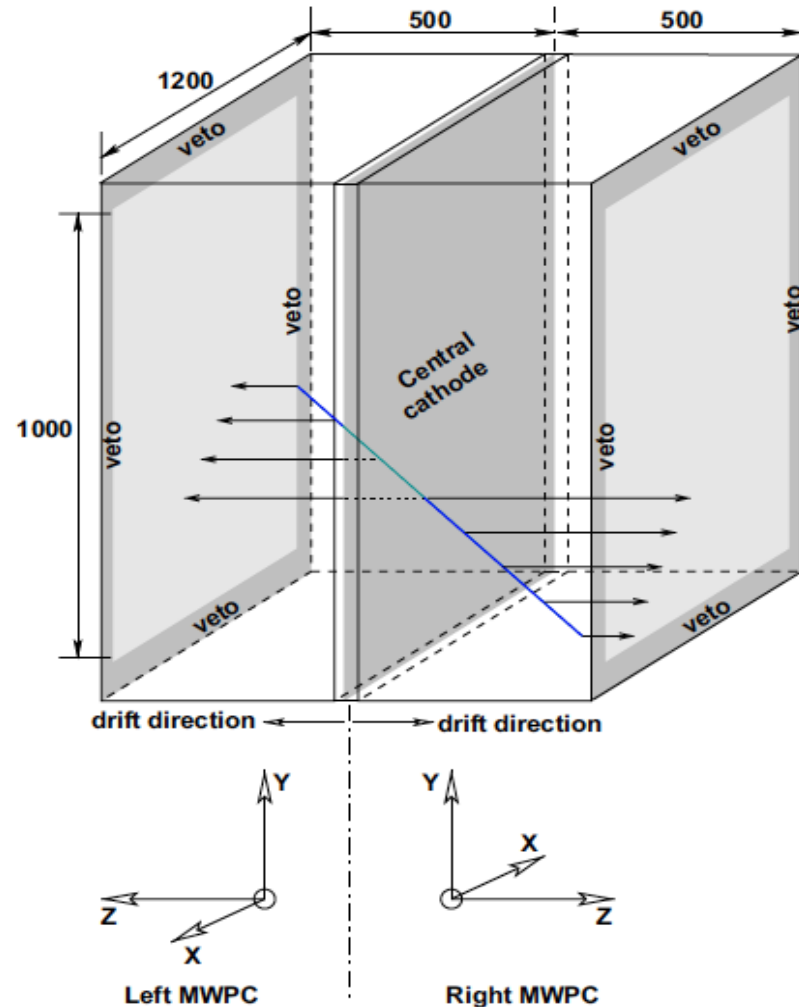
- WIMP wind caused by motion of Earth through stationary halo.
- Mean speed $\sim 220 \text{ km s}^{-1}$ coming from the direction of Cygnus



- Mean direction changes by $\sim 90^\circ$ every 12 hours due to Earth's rotation.
- Order 10 events needed to reject isotropy (Green & Morgan, Astropart. Phys. **27** (2007) 142).

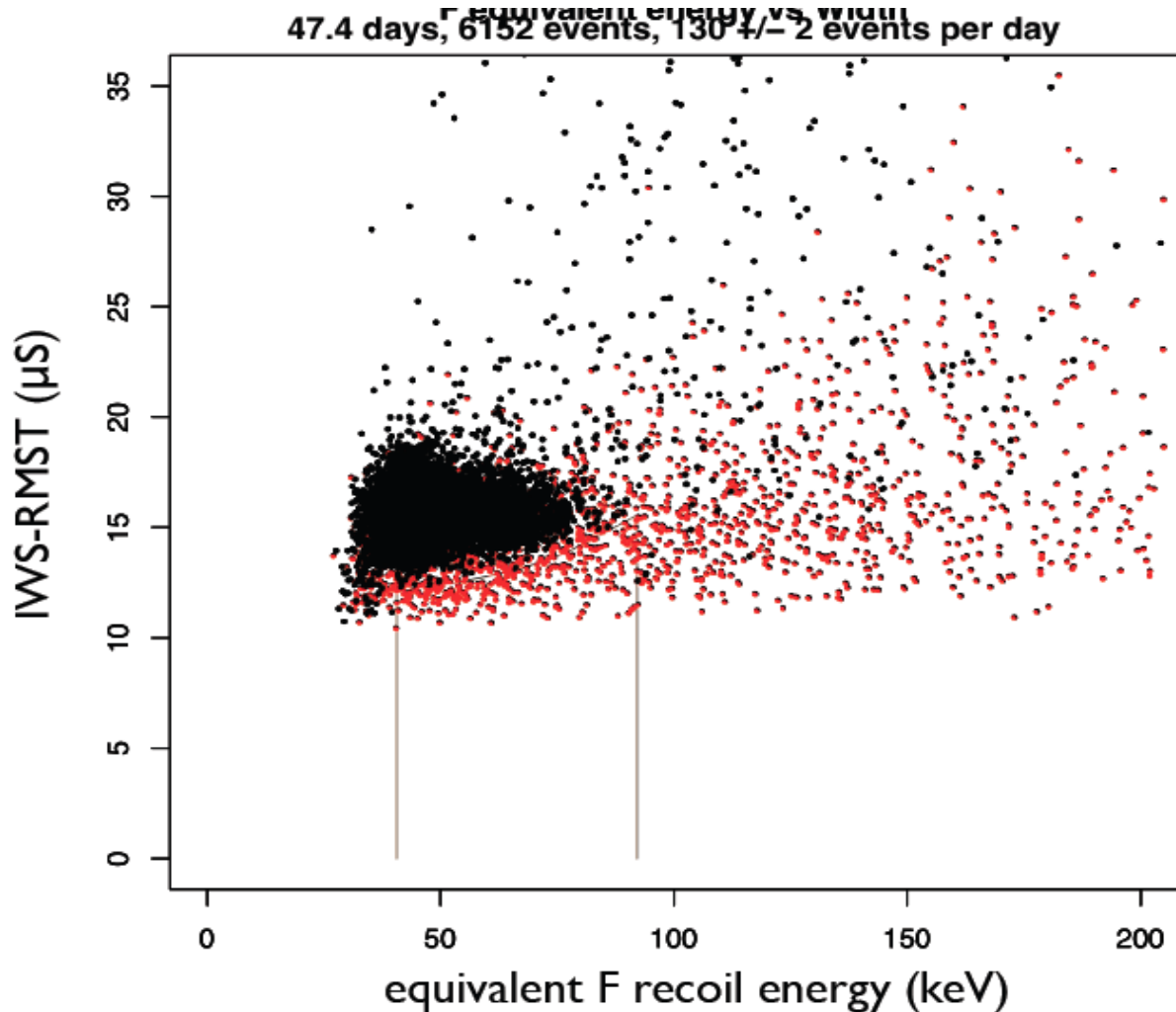
DRIFT concept

- 1 m³ Negative ion TPC read out by two MWPCs.
- Electronegative drift gas (CS₂) with J=1/2 target gas (CF₄) to probe SD interactions whilst maintaining low-diffusion.
- The shared central cathode defines two 624 V/cm drift regions.
- Every 8th wire grouped.
- Current iteration: DRIFT-IIcd is running at Boulby Mine in Cleveland, UK.
- > 67 cm polypropylene pellet neutron shielding on all sides.





Signal Region

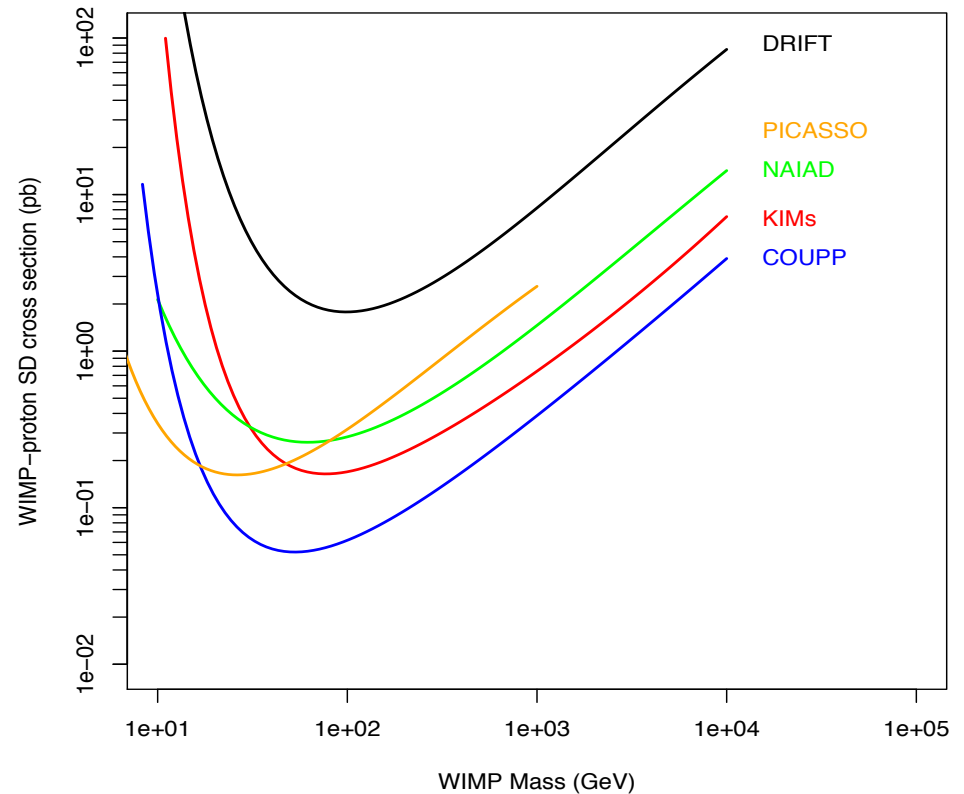


- Final stage cut: define signal region in RMST-Energy space.
- IWS-RMST: Induced-waveform-subtracted root mean square time.
- Crude measure of z-diffusion => z-position
- **Red**: neutron calibrations
- **Black**: background



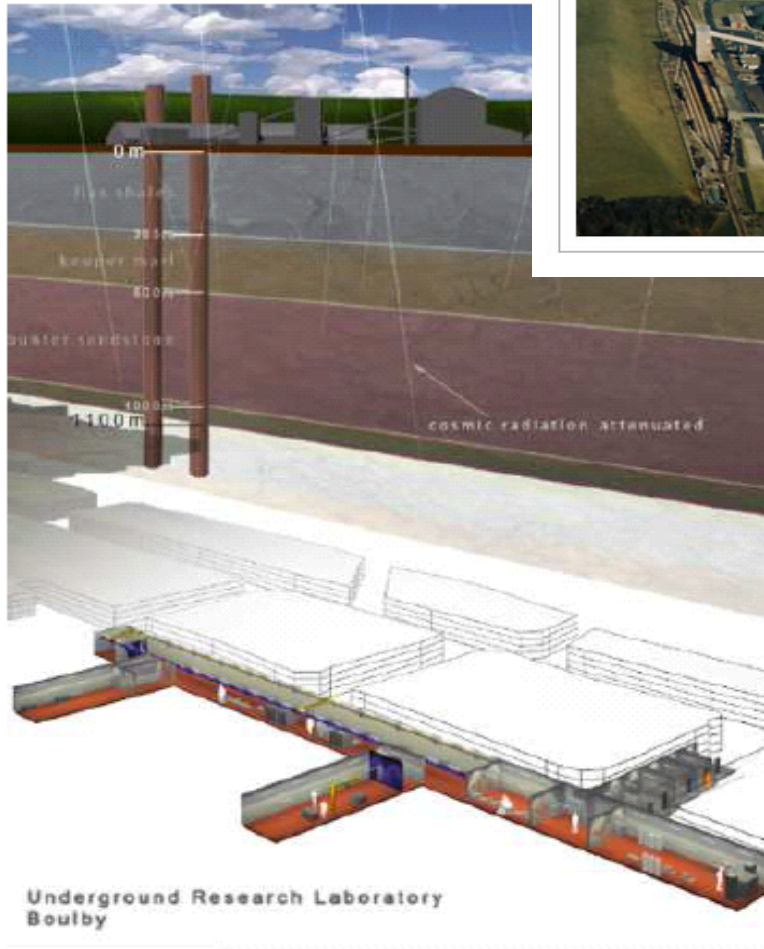
Current limits

- SD limits from an unblind analysis of 47.4 days of livetime published last year (Daw et al., Astropart. Phys. **35** (2011) 397).
- Competitive with higher-mass direct detection experiments.
- No compromise on directional sensitivity.





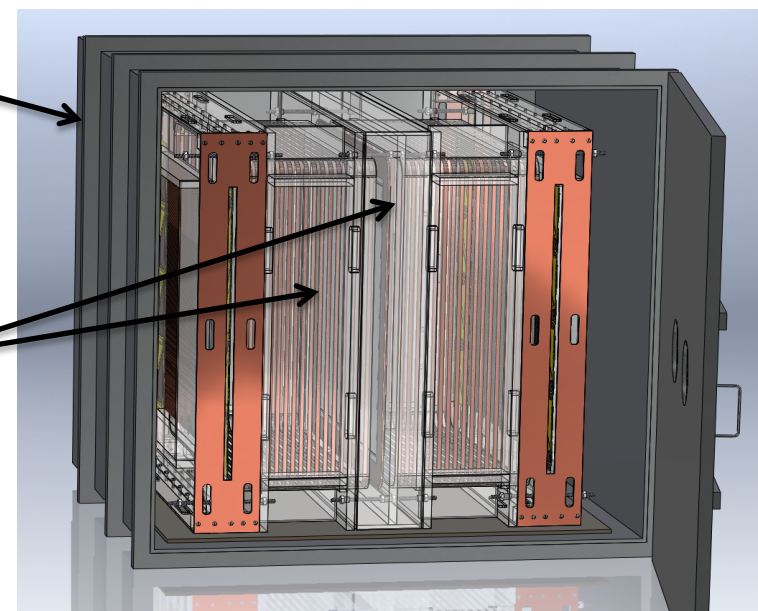
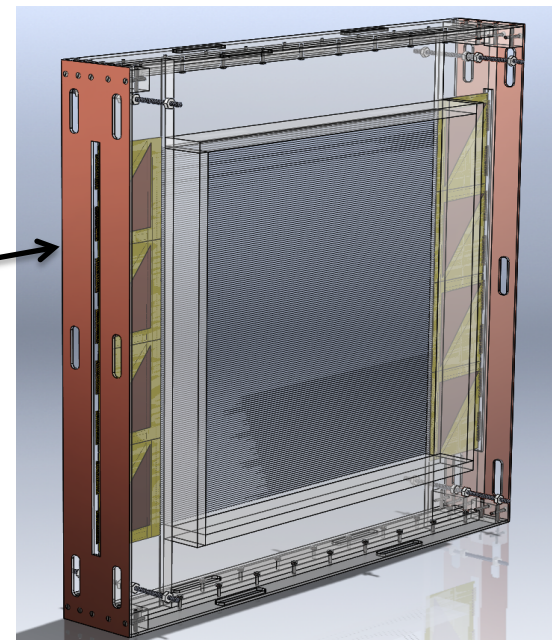
Boulby Mine



- 1.1 km rock overburden (2800 m.w.e).
- Cosmic ray muon flux reduced to $4.1 \times 10^{-8} \text{ cm}^{-2} \text{ s}^{-1}$ (Robinson et al., NIM A **511** (2003)).
- Continuing strong support from Cleveland Potash Ltd. going forward towards DRIFT-III.1

Prototype:DRIFT-IIe

- Next-generation MWPCs are built and in the process of being commissioned at **Occidental College**.
- Second vacuum vessel leak tested in **Sheffield** and ready for deployment at Boulby.
- Existing gas system will serve both DIIId and DIIe.
- Cathode and field cage development at the **University of New Mexico**.
- Readout R&D at **Colorado State University**.

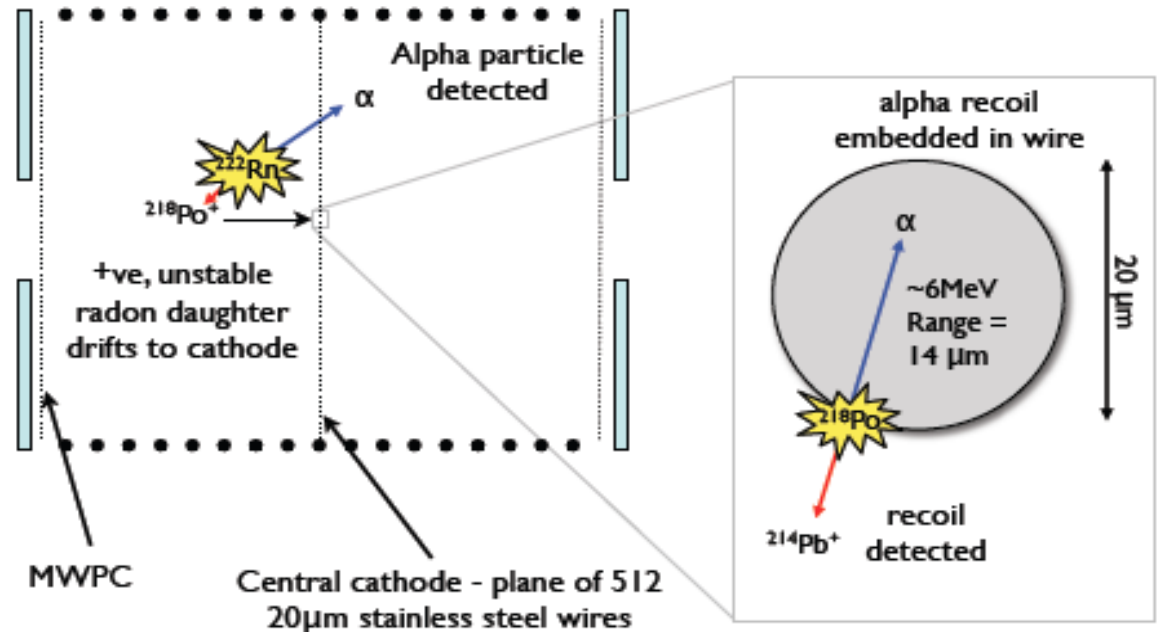


DRIFT-IIe inside the vacuum vessel



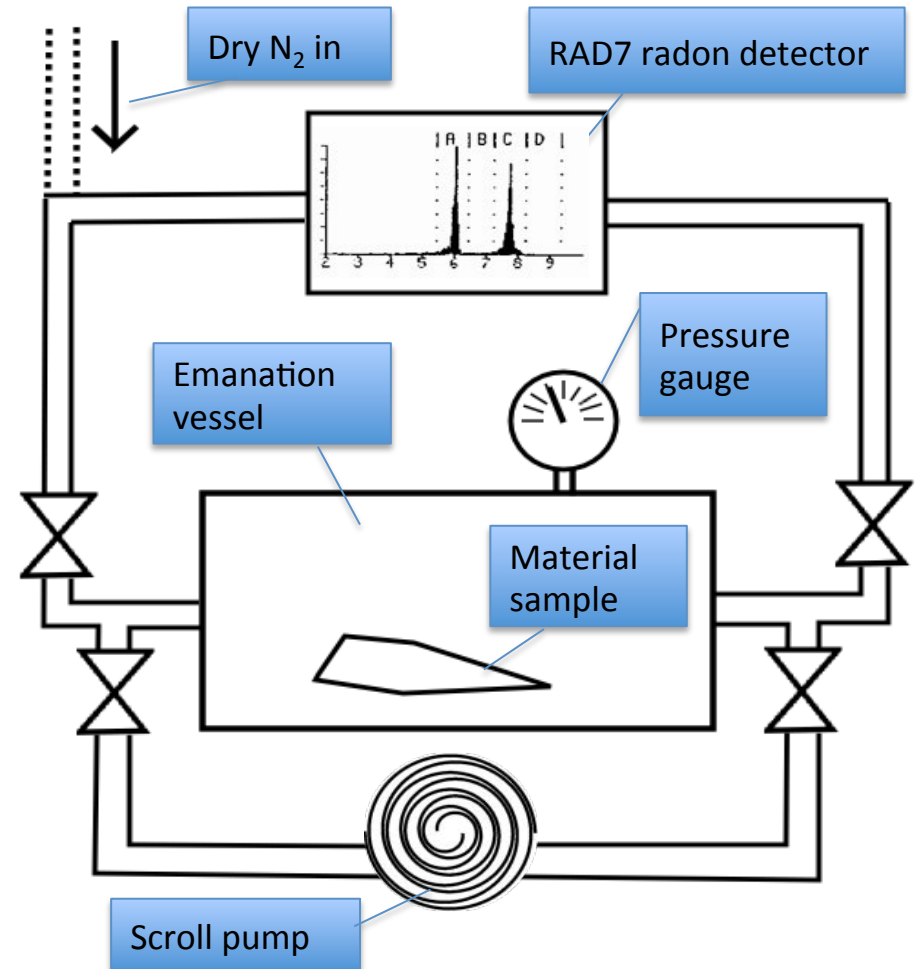
Radon Background

- Radon background due to decay of charged daughters plated-out on cathode wires – ‘Radon Progeny Recoil (RPR)’ events.
- RPRs are identified by alpha-tagging and rejected.
- RPR rate reduced by replacing detector materials with low Rn alternatives...



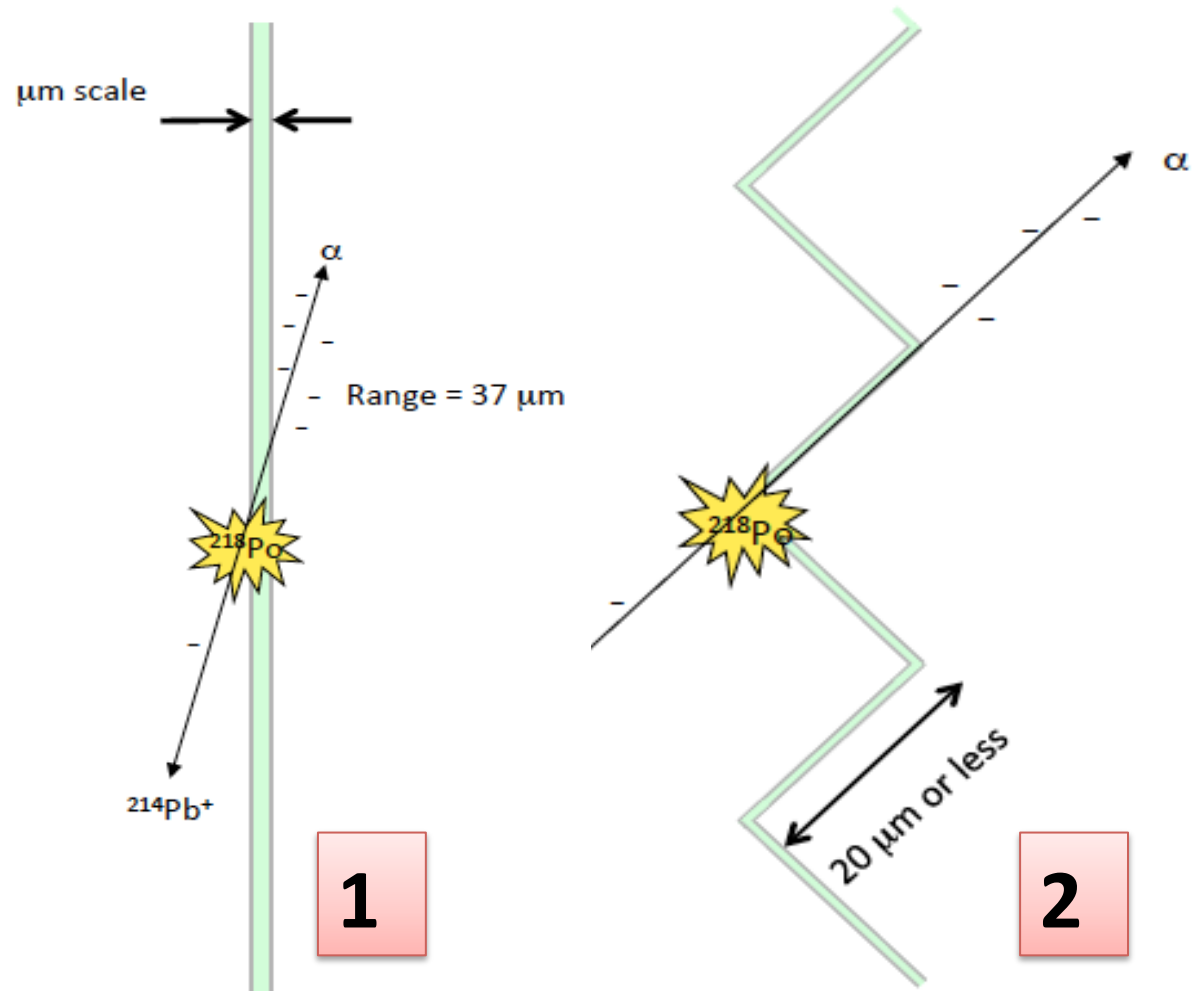
Radon Background Reduction

- Materials screened for Rn emanation using an off-the-shelf Rn detector (DurrIDGE RAD7).
- Has led to 11-fold reduction in Rn since 2005.
- Remaining emitters: HV cables and electronics boards (preamps).
- Technique under development to measure total Rn rate inside DRIFT.



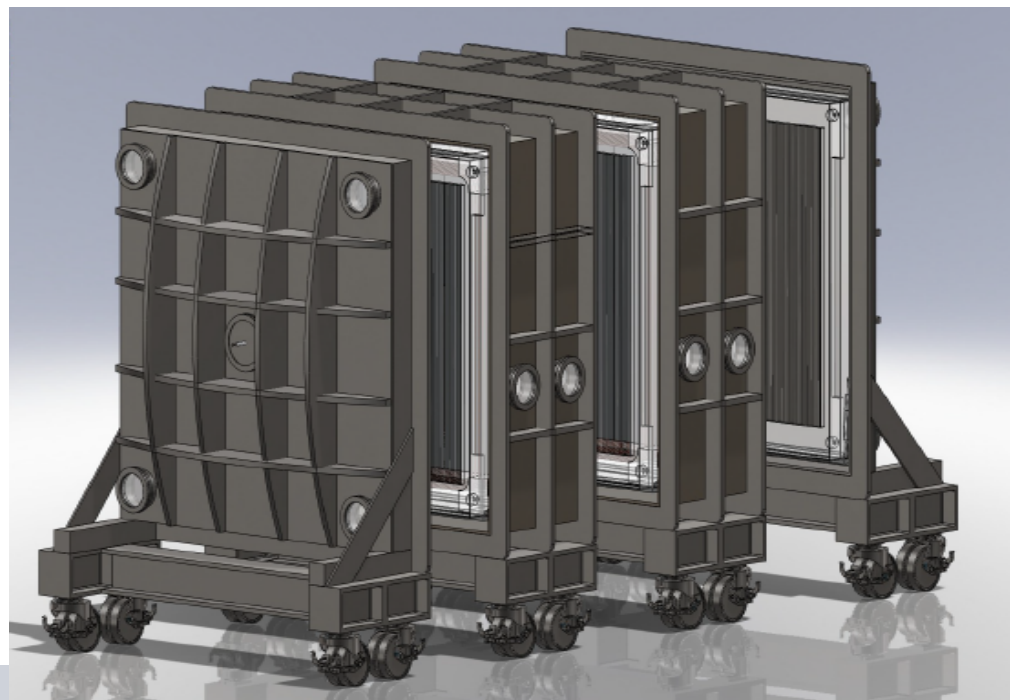
Development of a texturized thin film cathode

- Reduced RPR background by replacing wire cathode with $0.9 \mu\text{m}$ aluminized Mylar sheet.
- Alphas can now escape cathode and be tagged.
- Background reduced from 36 events/day \rightarrow 6.
- R&D on new texturized thin film is nearing completion, and will be deployed on DRIFT-IIe in the near future.

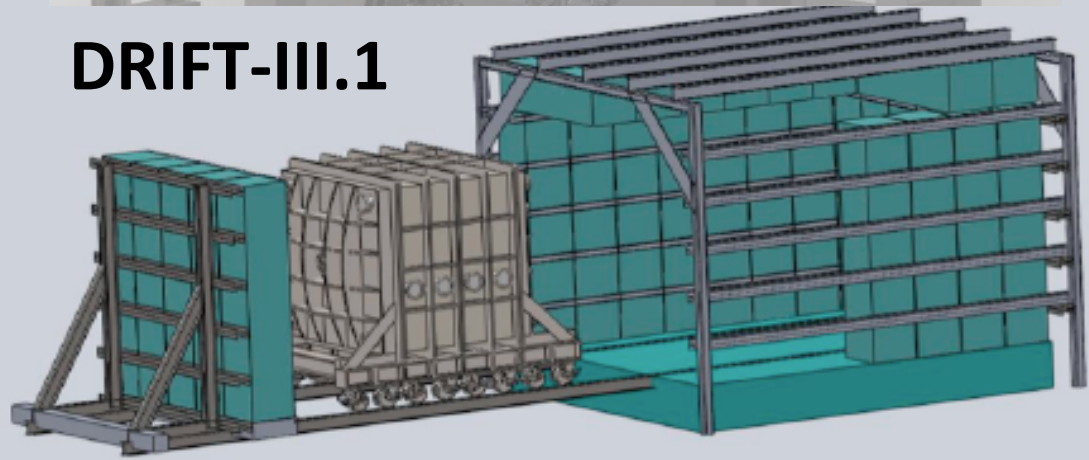


DRIFT-III Overview

- DRIFT-III aims to be the largest directional detector to date.
- Modular design for ease of further scale-up.
- Each segment contains 4m^3 30:10 torr $\text{CS}_2:\text{CF}_4$ (0.67 kg total target mass).
- DRIFT-III.1: 2 segments = 8m^3 .
- Water shielding replaces current polypropylene pellets.

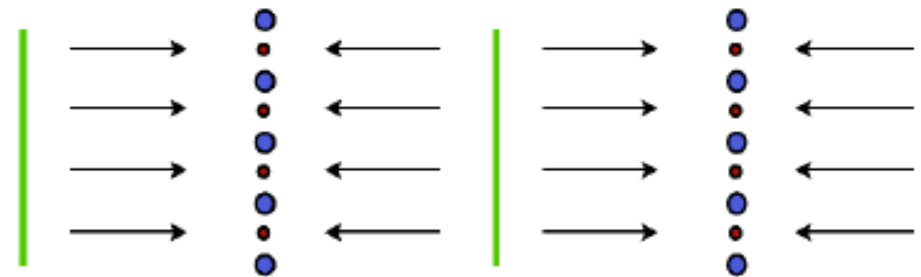
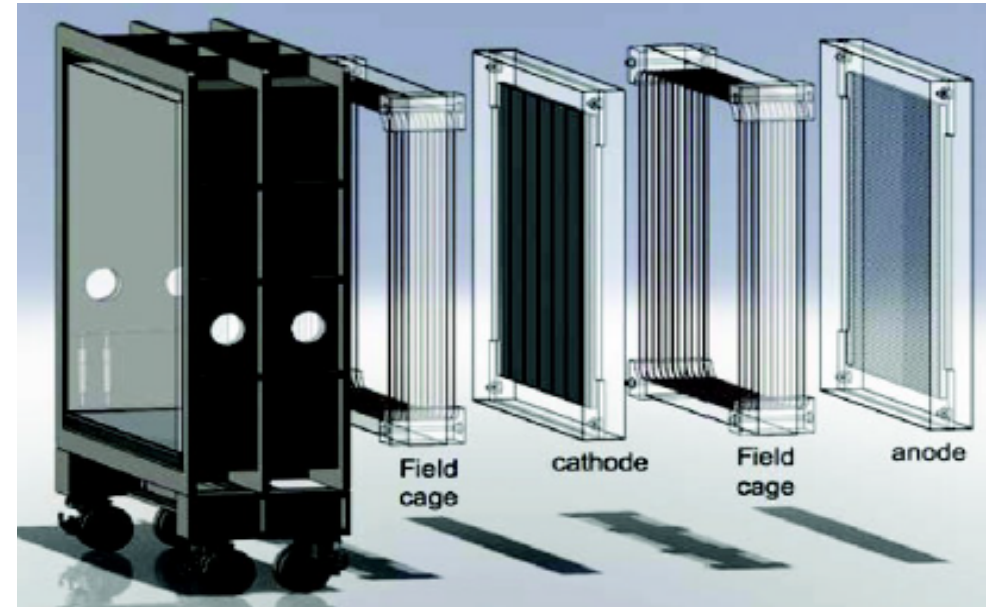


DRIFT-III.1



DRIFT-III Overview (continued)

- Single-plane means no need for 'strongback' support behind MWPC =>
- Transparent MWPCs read charge from either side.
- Alternating anode ($d=20\ \mu\text{m}$) and field ($d=100\ \mu\text{m}$) wires in a single plane.
- Anode and field wires parallel => moving towards a 2D detector.



Readout plane Thin cathode

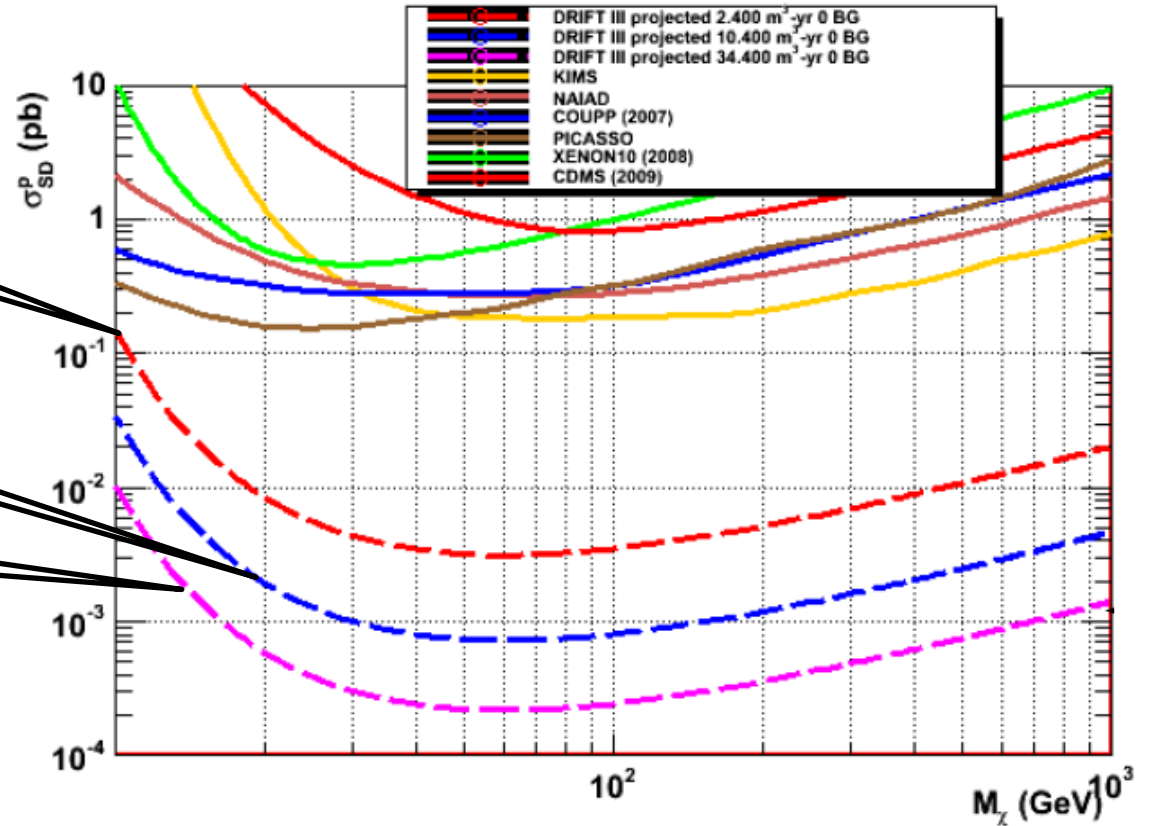


DRIFT-III Projected Limits (SD)

DRIFT-II d,e after 2 years (2.4m³-years, zero bg)

DRIFT-III.1 (10.4m³-years, zero bg)

DRIFT-III (34.4m³-years, zero bg)



Summary

- DRIFT-II d continues to run stably at Boulby.
- DRIFT-II e prototype will be deployed underground in the near future as a testbed for DIII technology (texturised cathode, single-plane MWPCs, low Rn materials etc).
- DRIFT-III.1 cavern excavation will be done by CPL in the near future.

Backup – Thin Film Pictures



Thin film cathode construction
underground

New texturised thin film detail



Backup – RMST definition

- IWS-RMST stands for Induced-waveform-subtracted root mean square time.
- It is a measure of the width in time of a pulse.
- Time deviations are weighted by sample voltage.
- Differs from FWHM because it takes account of the wings.

$RMST =$

$$\sqrt{\frac{\sum_{t=t_{\min}}^{t_{\max}} (V_t(t - \bar{t})^2)}{\sum_{t=t_{\min}}^{t_{\max}} V_t}}$$

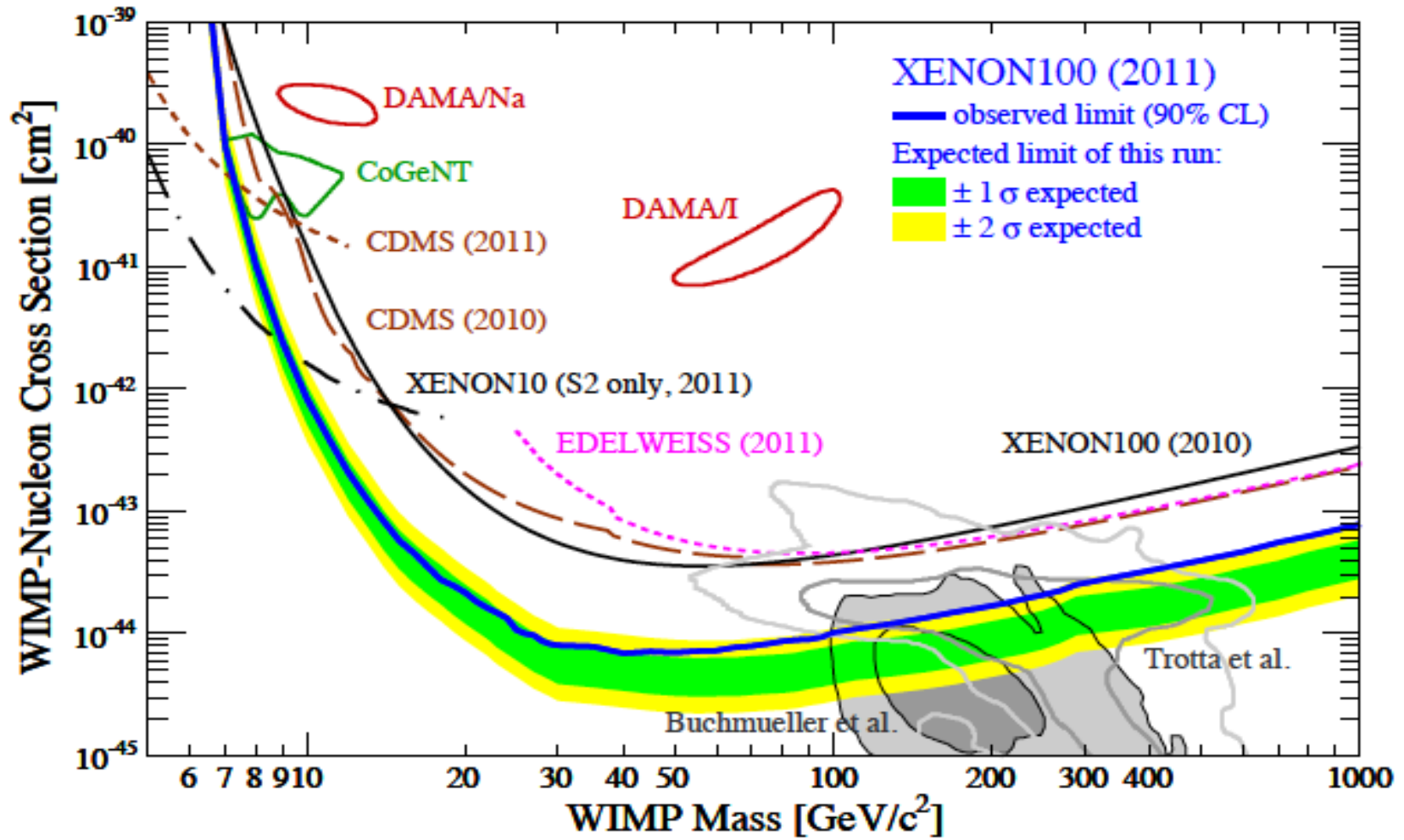


Backup – Table 1 from Green & Morgan [2007]

| Difference from baseline configuration | N_{90} | N_{95} |
|--|----------|----------|
| None | 7 | 11 |
| $E_T = 0$ keV | 13 | 21 |
| No recoil reconstruction uncertainty | 5 | 9 |
| $E_T = 50$ keV | 5 | 7 |
| $E_T = 100$ keV | 3 | 5 |
| $S/N = 10$ | 8 | 14 |
| $S/N = 1$ | 17 | 27 |
| $S/N = 0.1$ | 99 | 170 |
| 3-d Axial read-out | 81 | 130 |
| 2-d Vector read-out in optimal plane, raw angles | 18 | 26 |
| 2-d Axial read-out in optimal plane, raw angles | 1100 | 1600 |
| 2-d Vector read-out in optimal plane, reduced angles | 12 | 18 |
| 2-d Axial read-out in optimal plane, reduced angles | 190 | 270 |



Backup – Xenon100 SI Limits 2012





Backup – Picasso Limits 2012

