Results of the ZEPLIN-III first science run

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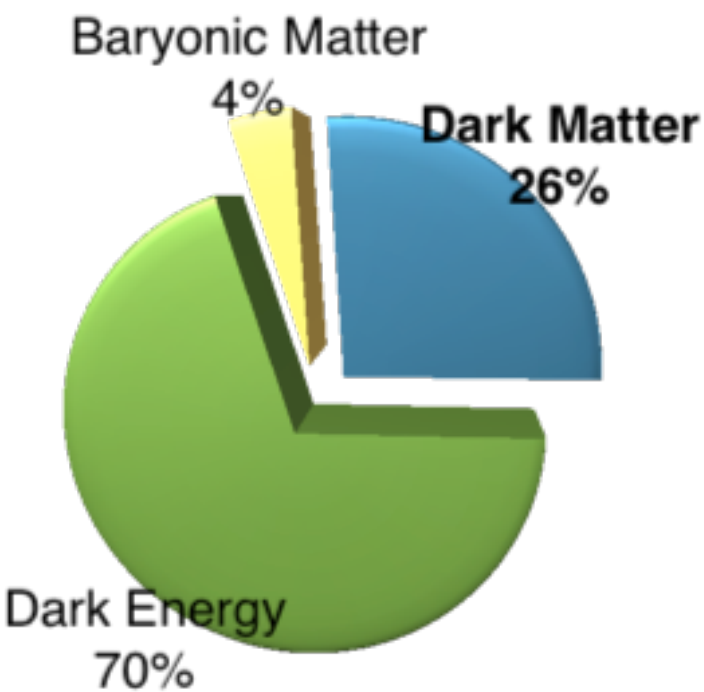
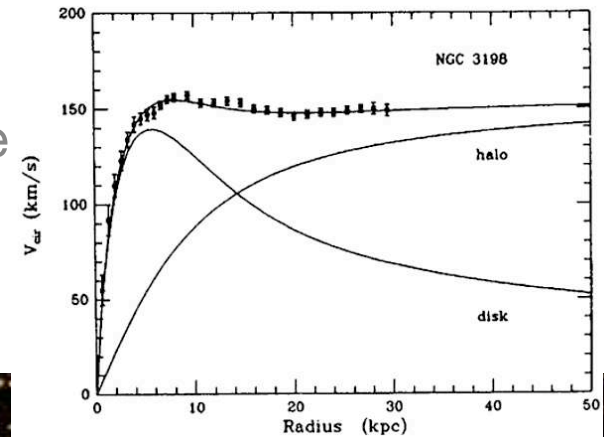
on behalf of the ZEPLIN-III collaboration

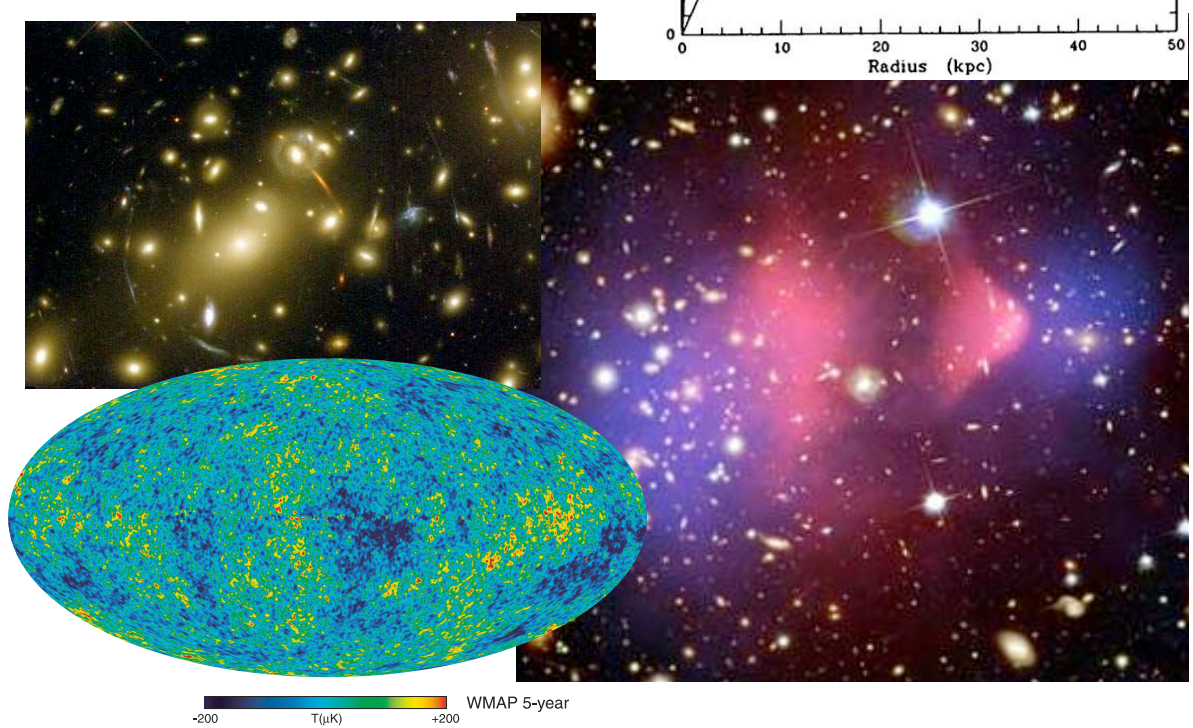
IOP HEPP Particle Physics 2009, Oxford
7th April 2009

WIMP Dark Matter

- Many pieces of evidence which demonstrate the need for a significant non-baryonic dark matter component.
- Weakly Interacting Massive Particles (WIMPs) such as the neutralino (lightest supersymmetric particle) are the favoured candidate.
- See overview talk tomorrow!

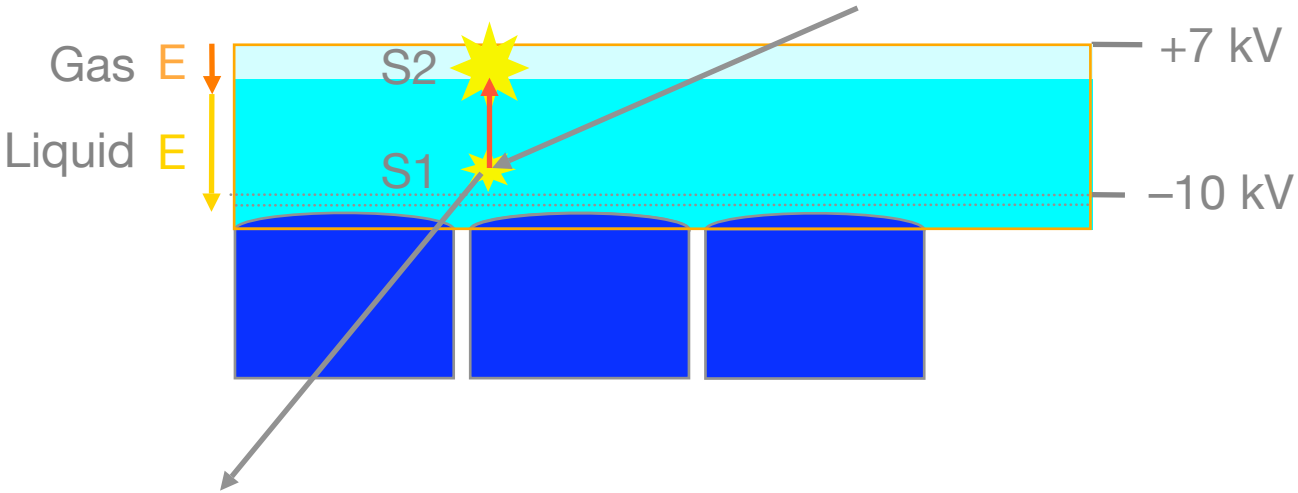


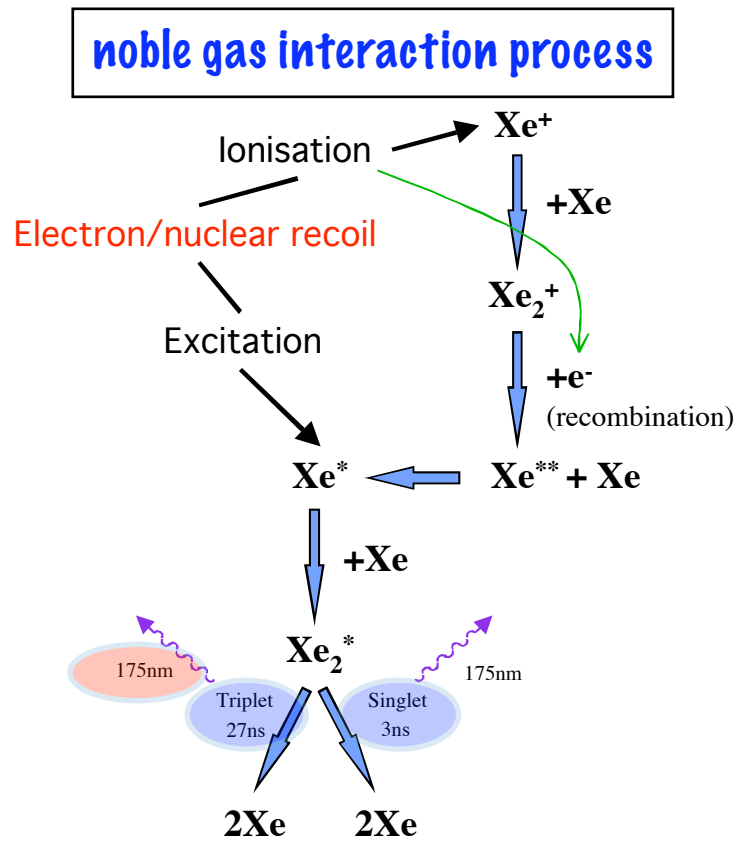




Detection Technique: Two-phase xenon

- Particle interactions in LXe produce scintillation and ionisation.
- Ratio of ionisation to scintillation provides discrimination.





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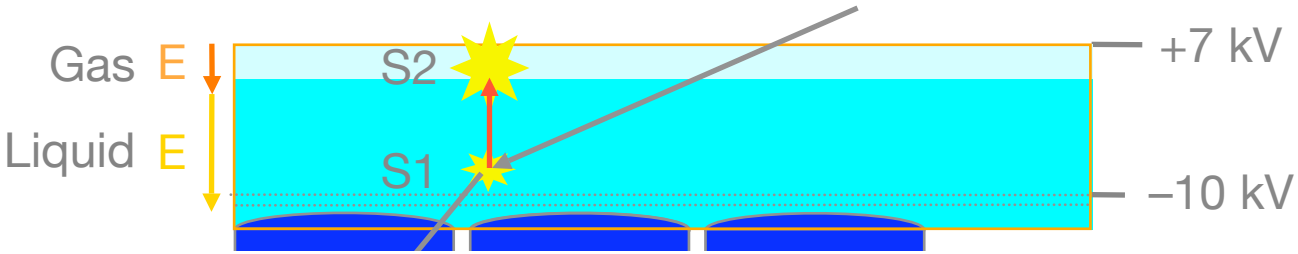

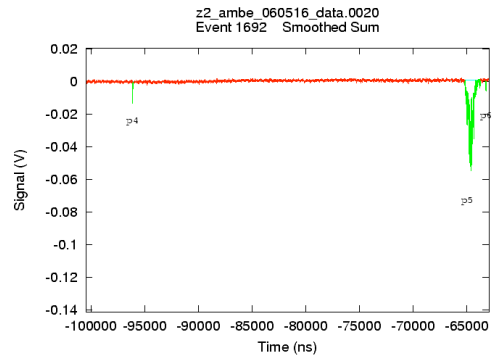

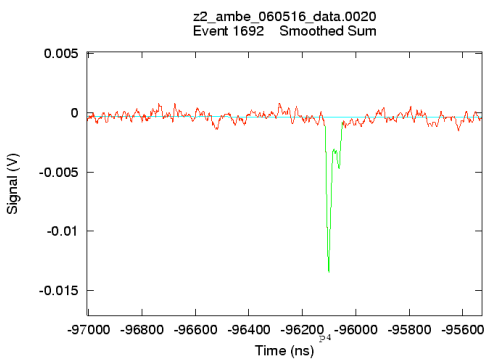

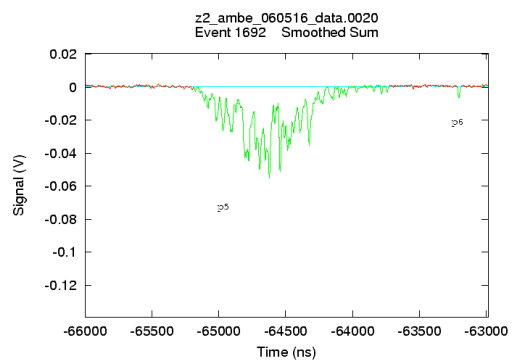

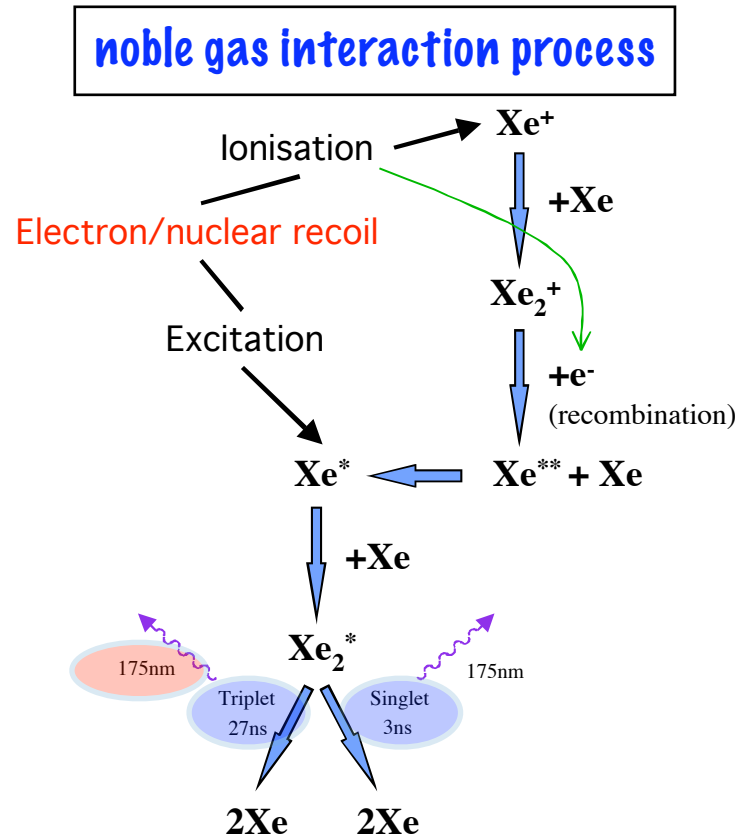

Nuclear recoil event

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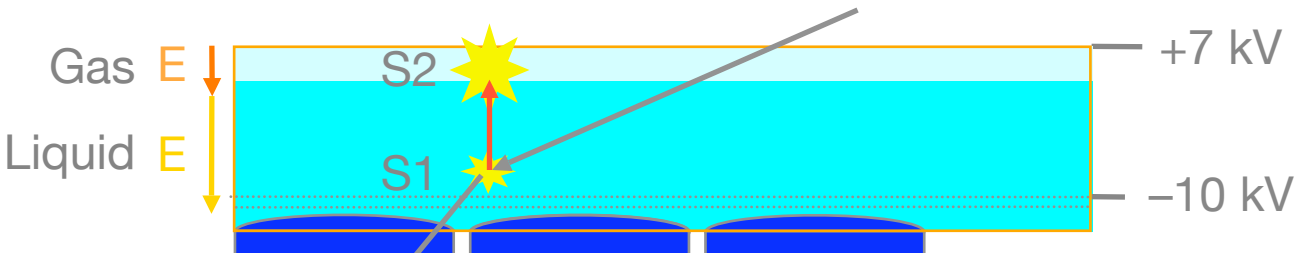
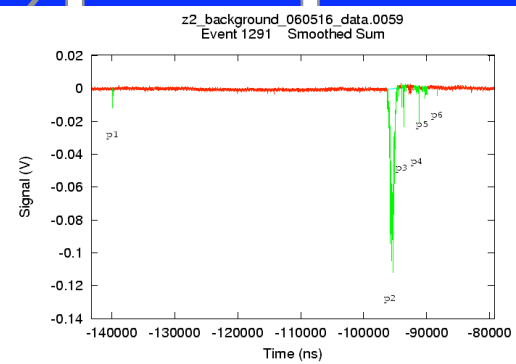
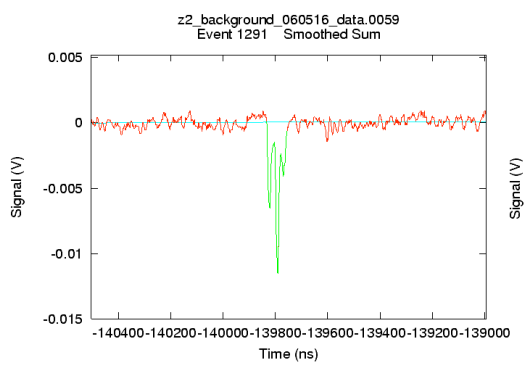
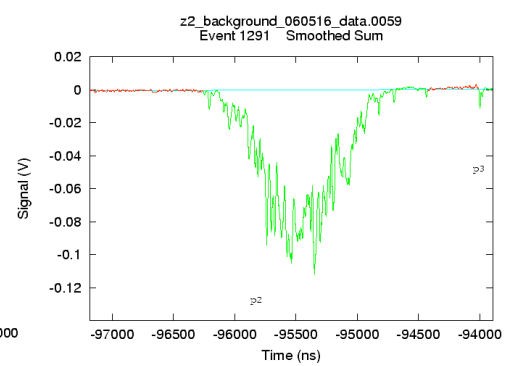
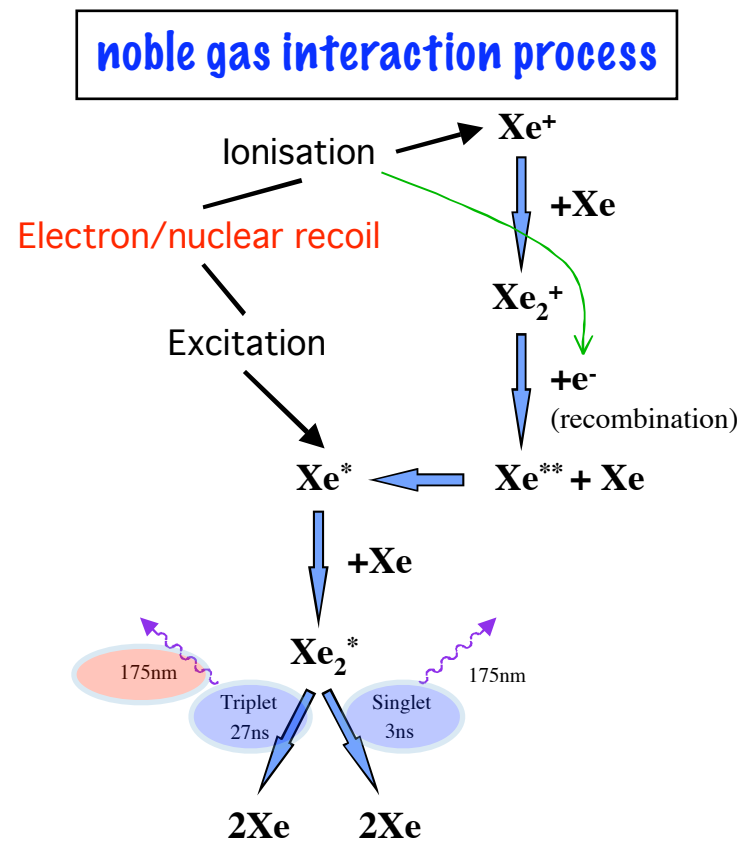






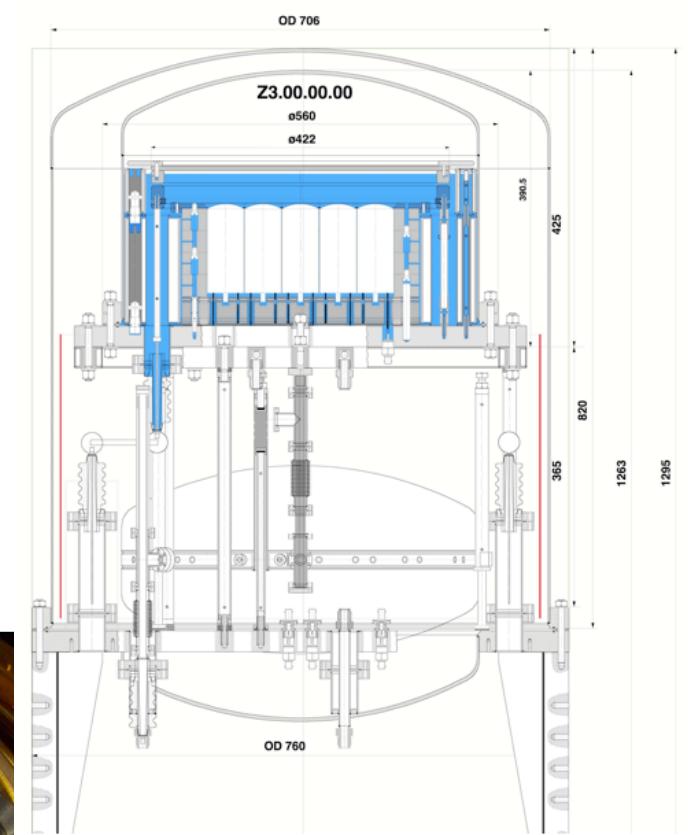


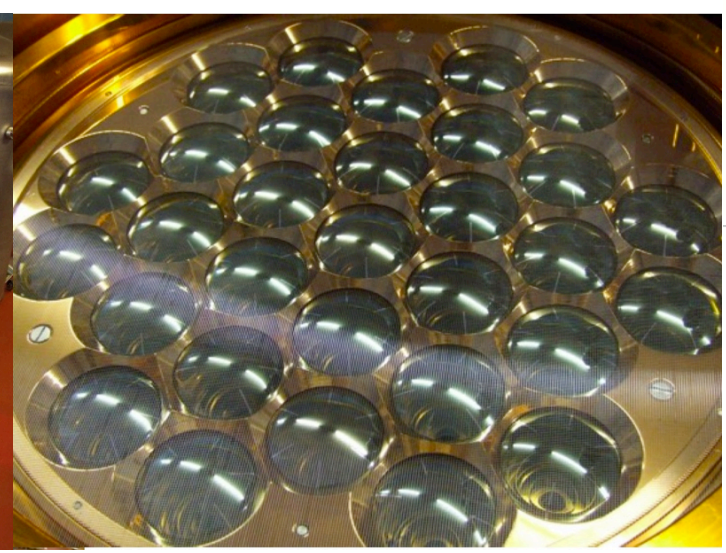


Electron recoil event

ZEPLIN-III: The Detector

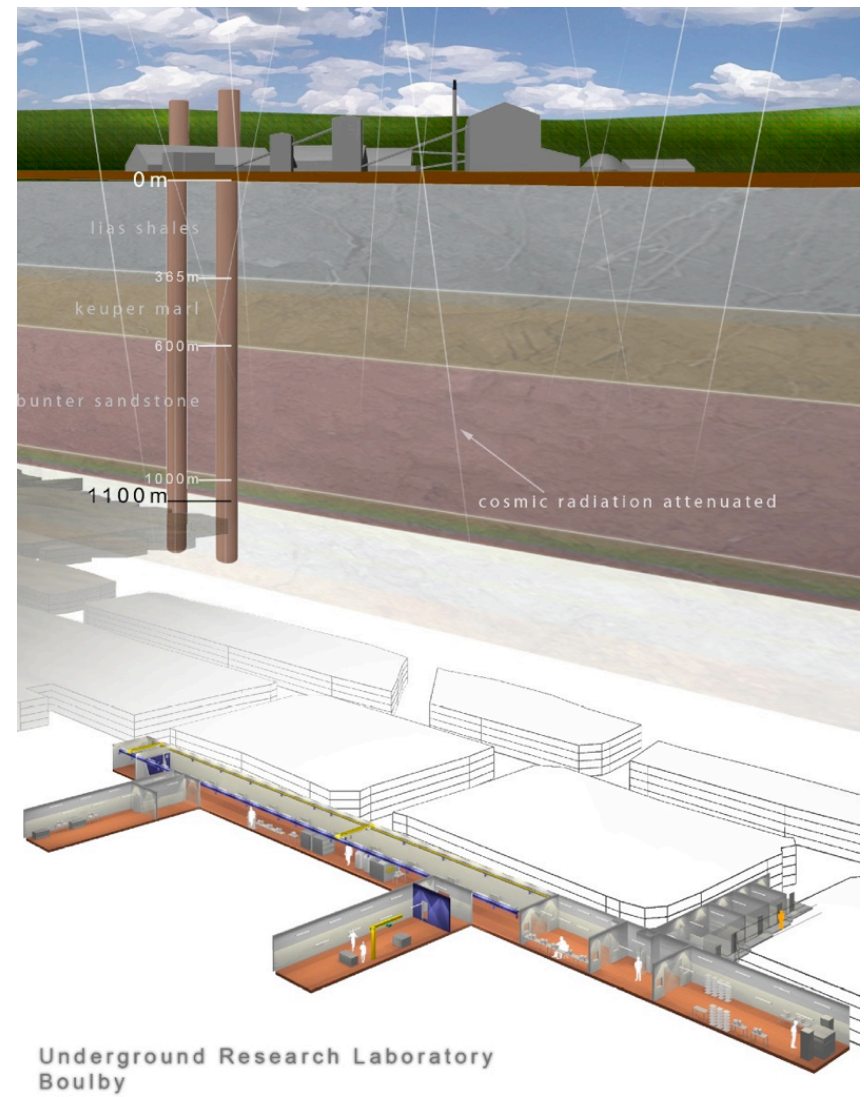
- PMTs in liquid to improve light collection
- 31 2-inch PMTs for fine position sensitivity
- 12 kg active target mass
- High E-field (3.9kV/cm) -> better n/γ discrimination
- 3.5 cm drift depth, 0.5 cm gas gap
- open plan – no surfaces - reduced feedback
- Low-background xenon (40 yr old - low Kr)
- All copper construction - electron beam welded





Boulby Underground Laboratory: The Location

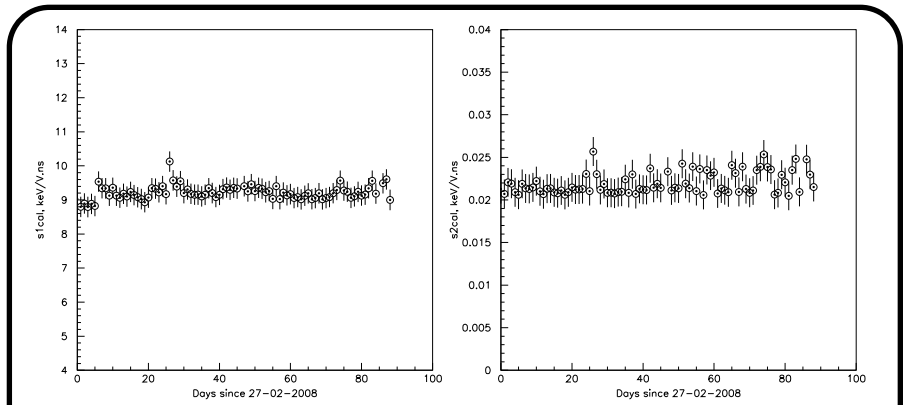
- Located in Boulby mine, North-East England
- 1100m UG (2600m water equivalent)
- Reduces muon flux by a factor of ~10^6



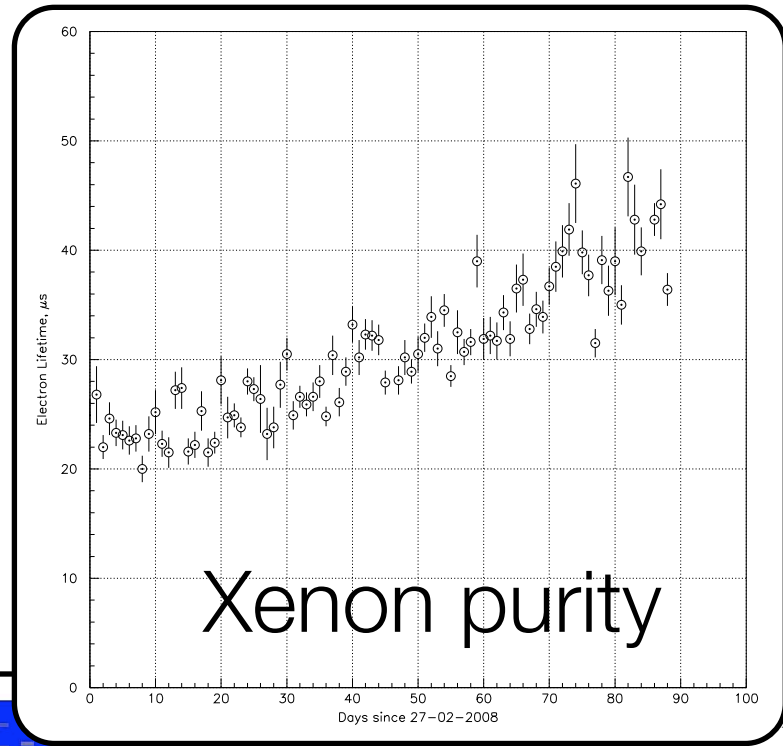
- Low-background environment enhanced by lead+hydrocarbon shield providing combined attenuation factor of 10^5 for both rock gammas and neutrons

Detector Monitoring

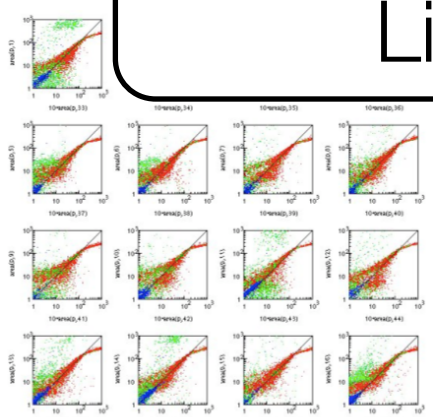
- Stability of the detector and data quality monitored with automated analysis code.
- Electron lifetime, detector tilt, S1 and S2 yield measured allowing for correction of the data.



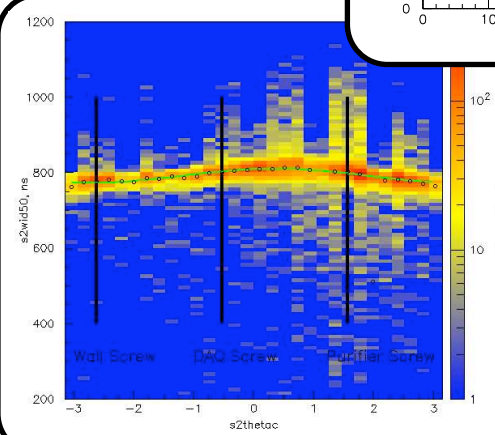
Light yield

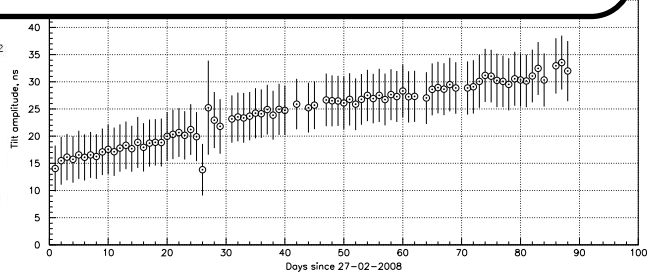


Xenon purity



Channel Amplification Check

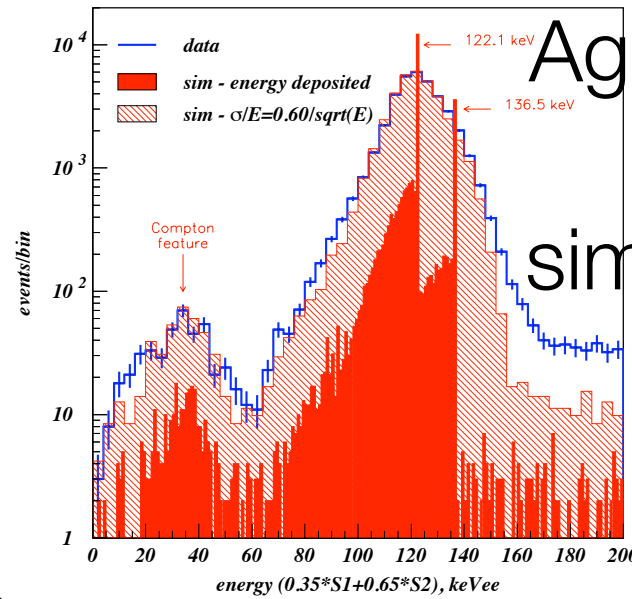




Detector level/tilt

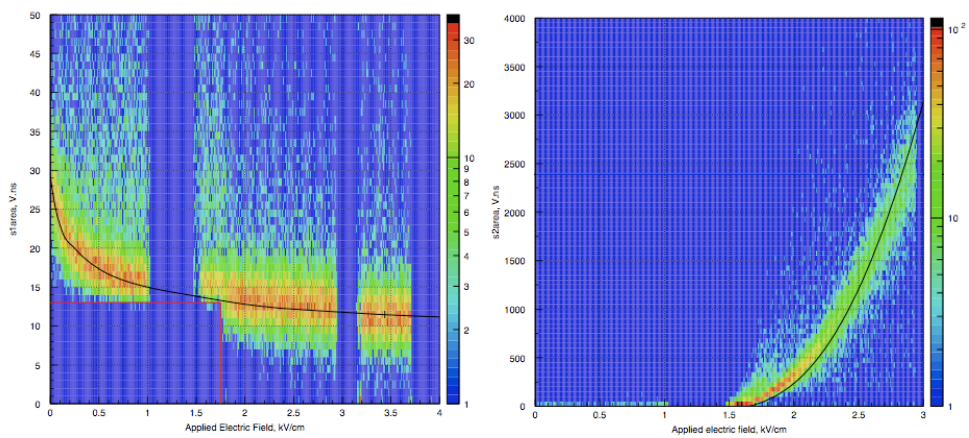
^{57}Co Calibrations

- Daily ^{57}Co calibration for stability checks and scintillation response
- Light yield 1.8 p.e./keVee at operating field of 3.9kV/cm
- Full volume resolution (after flat fielding) of σ= 5.4% @122keV in correlated signal
- S1 only σ= 16.3% @ 122keV
- S2 only σ= 8.8% @ 122keV
- Comparison to GEANT4 simulation shows expected Compton feature at ~35keV
- Expected field-dependent responses measured.



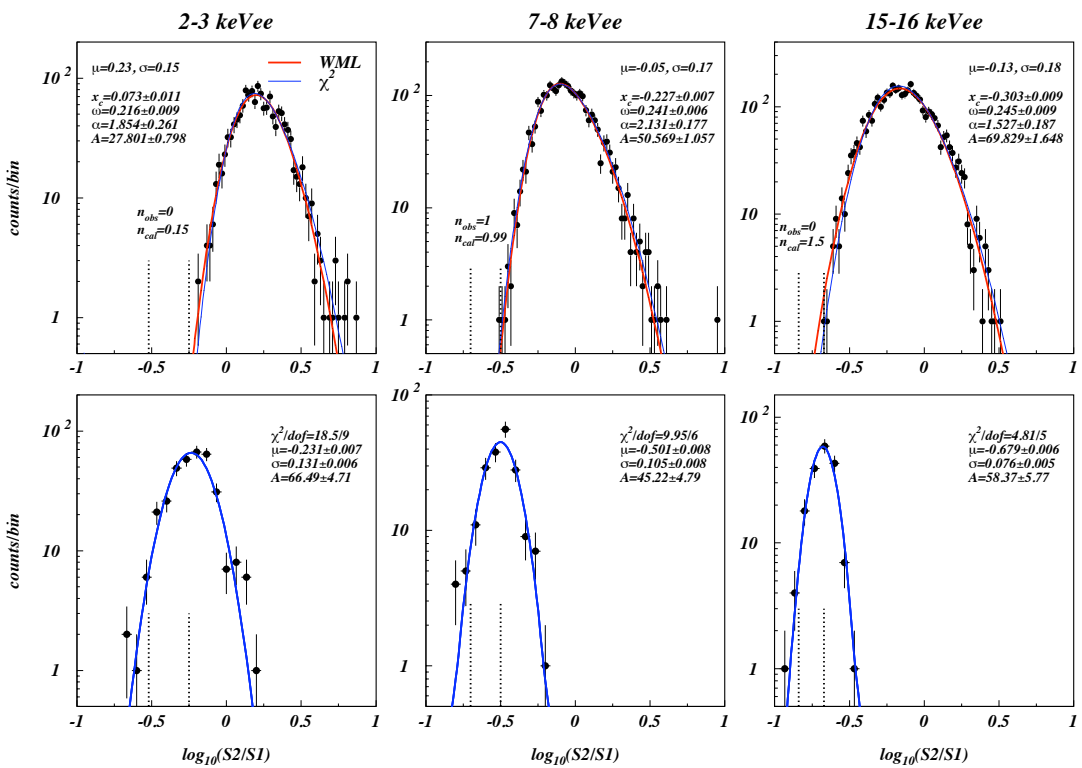
Agreement with simulations

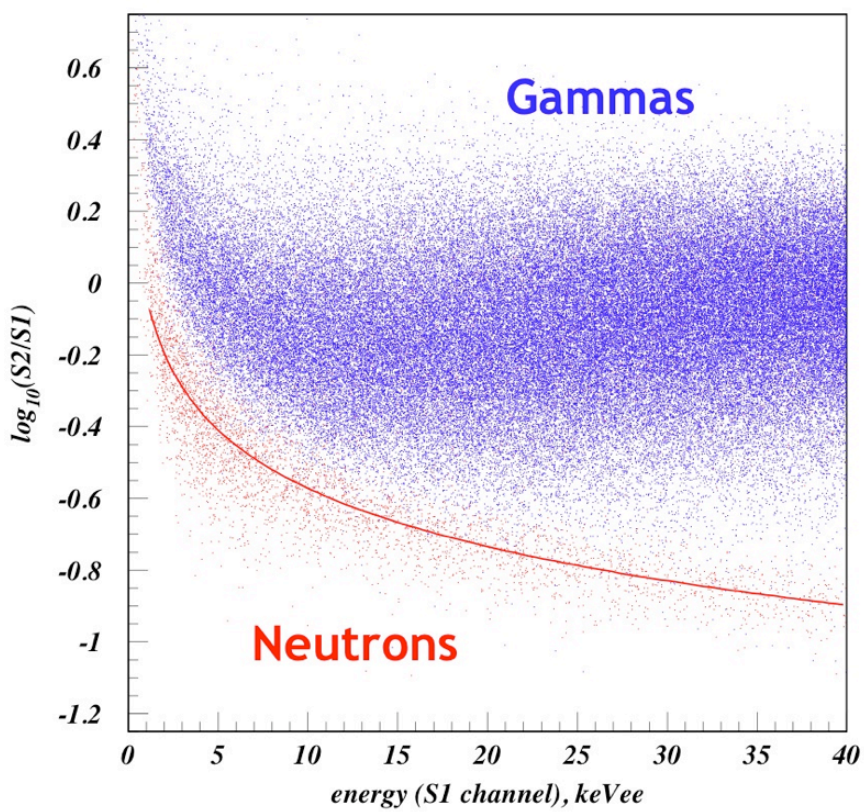
Field-dependent response



Detector Calibrations

- Electron recoil background calibrated with ^{137}Cs.
- Expected WIMP nuclear recoil signal mimicked with AmBe neutron calibration.
- High-quality fits characterise the populations.
- Excellent discrimnation demonstrated at high-field, ~5x10^3.



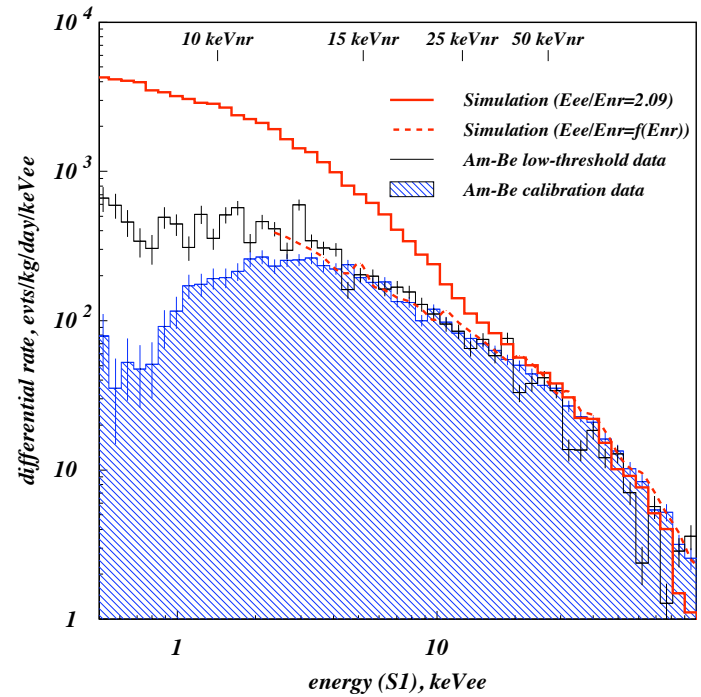


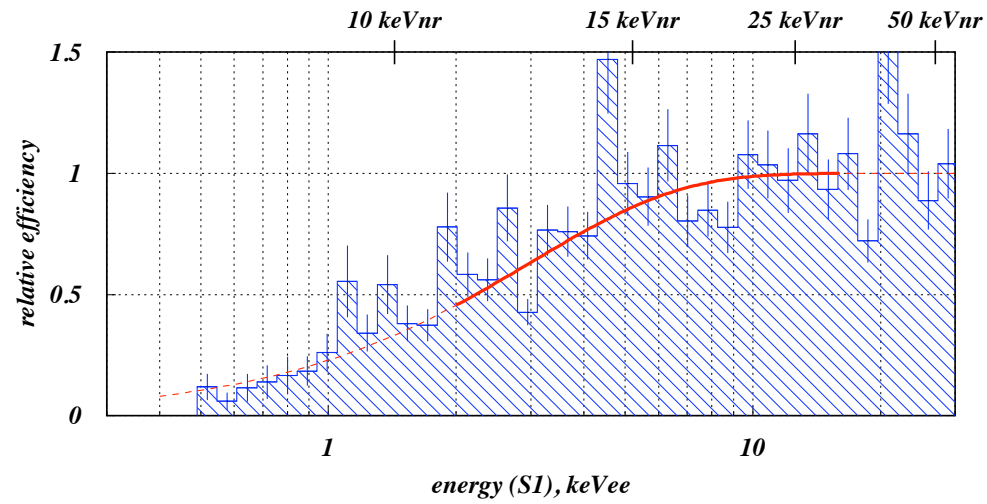
Energy conversion & efficiencies

- Conversion of energy from electron equivalent to nuclear recoil.

$$E_{nr} = \frac{S1}{L_y} \frac{S_e}{L_{eff} S_n}$$

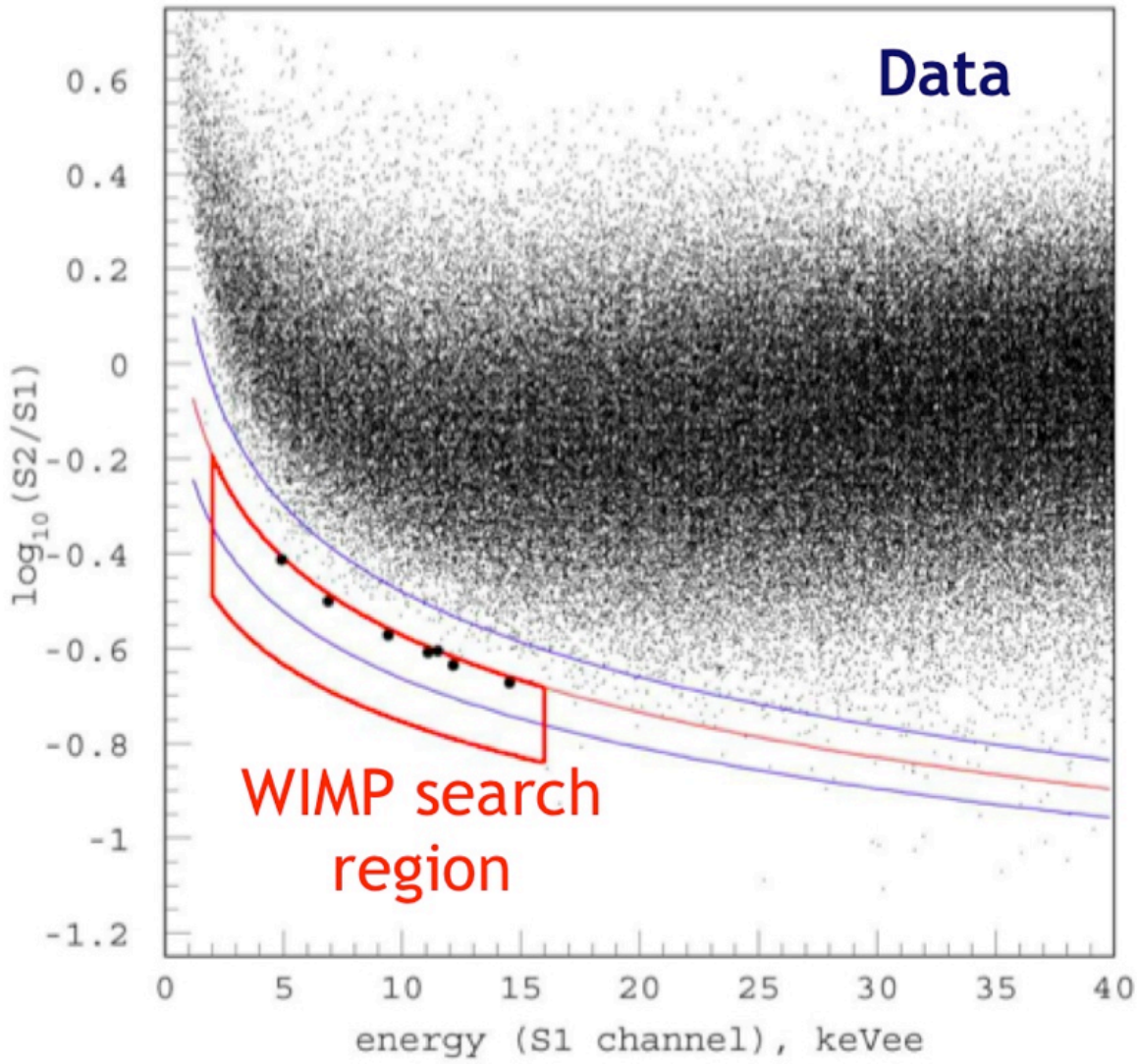
- Mis-match observed between nuclear recoil calibration (AmBe) and G4 simulation
- Many studies to determine if efficiency loss, simulation failure, etc.
- Can be matched by varying L_{eff} (or S_n) below ~6keV$_{ee}$, from higher energy value of 0.19 & 0.9
- Variation determined through ML matching of simulation (similar to XENON10 analysis)
- Recent measurements of L_{eff} also show dip at lower energy.





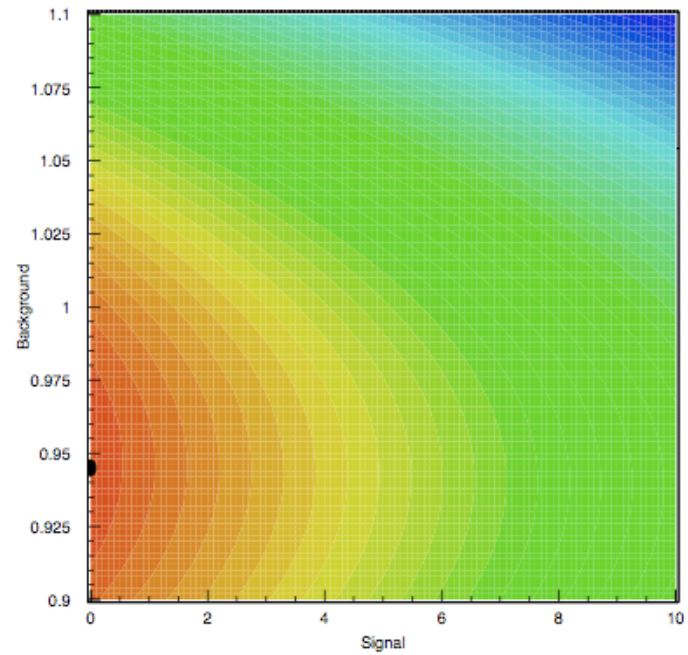
The First Science Run Data

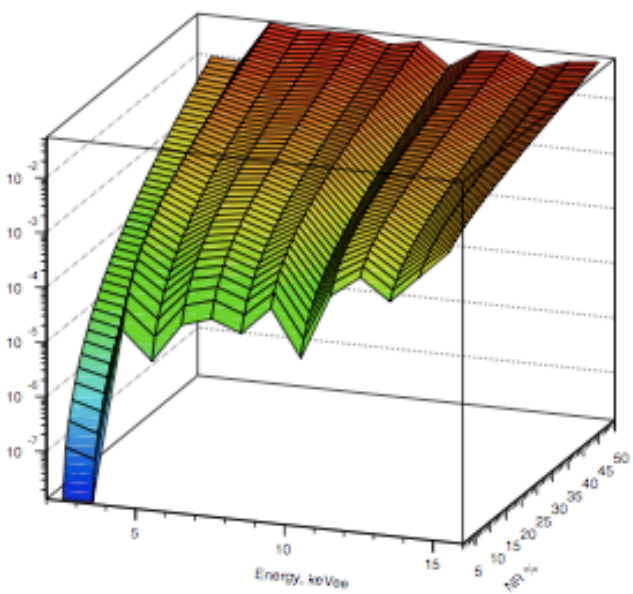
- 83 days operation @ 84% livetime
- Collecting 847 kg.days of raw data
  - ➡ 267.9 kg.days effective fiducuial exposure
- Secondary selection rules on event topology (S1,S2) to remove MSSI double scatter events
- 7 Events observed within search box, extrapolation from electron recoil population fits gives expectation of 11.3±3.0 in the box

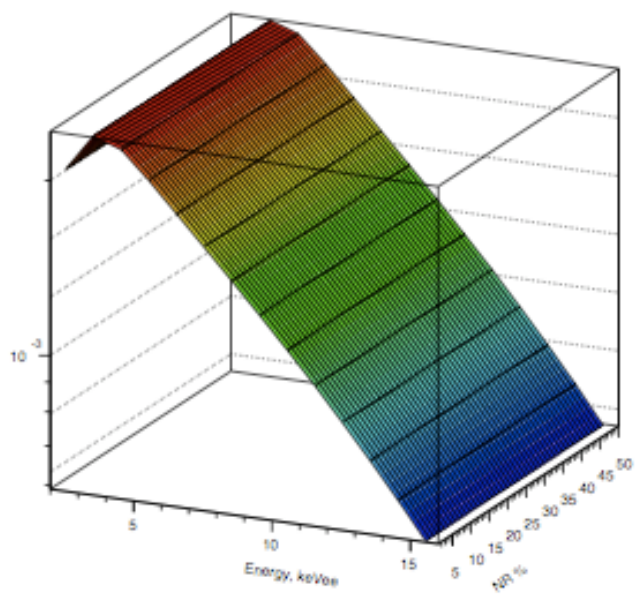


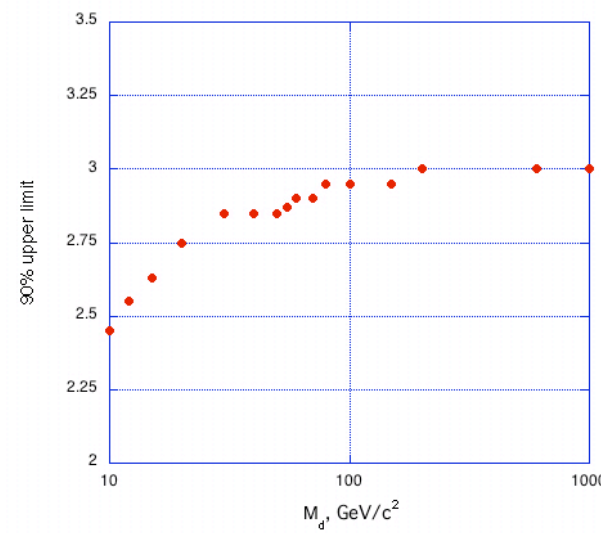
Statistical Analysis

- Binned maximum likelihood analysis to determine most likely signal and background ('parent' populations)
- Allow skew-Normal fits to vary within errors
- MC experiments to determine the 90% c.l. upper limit to this signal
- Two-sided frequentist approach, repeated for different WIMP masses.





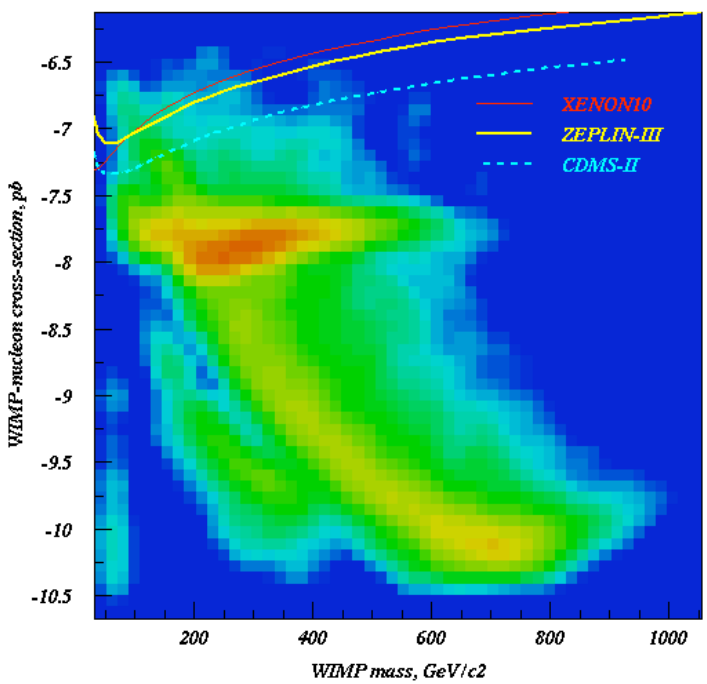


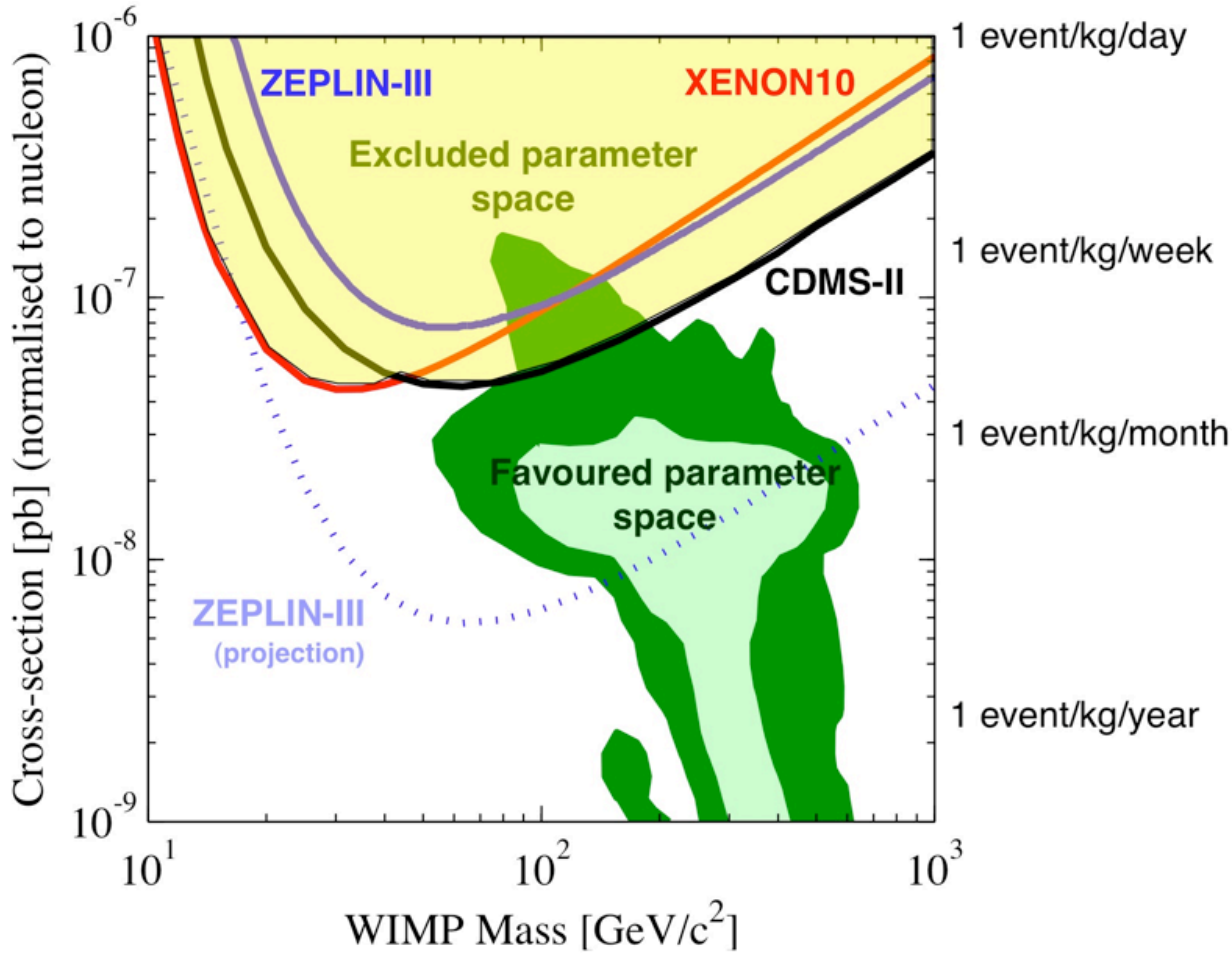


The Dark Matter Result - spin-independent

- Limits placed on the WIMP-nucleon spin-independent scattering cross-section:

⋆ **7.7×10^{-8} pb @ M_d = 55 GeV/c^2**

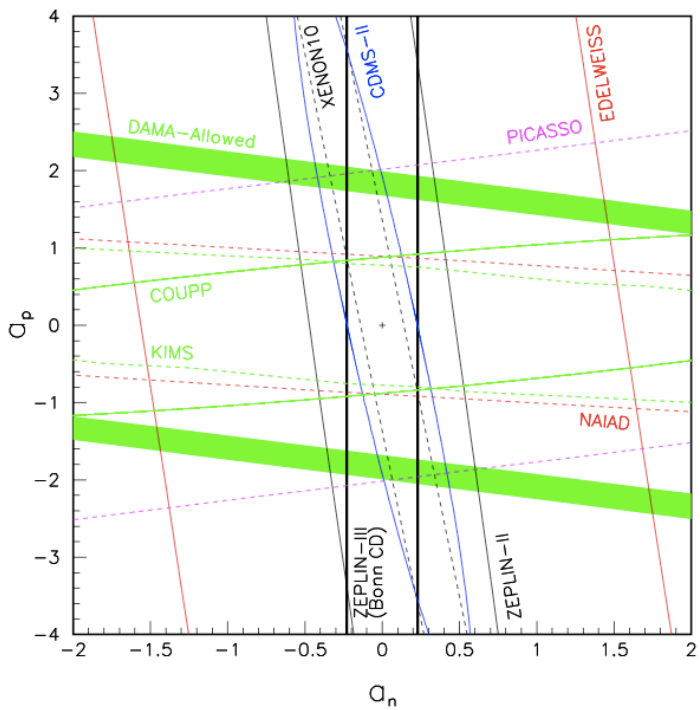


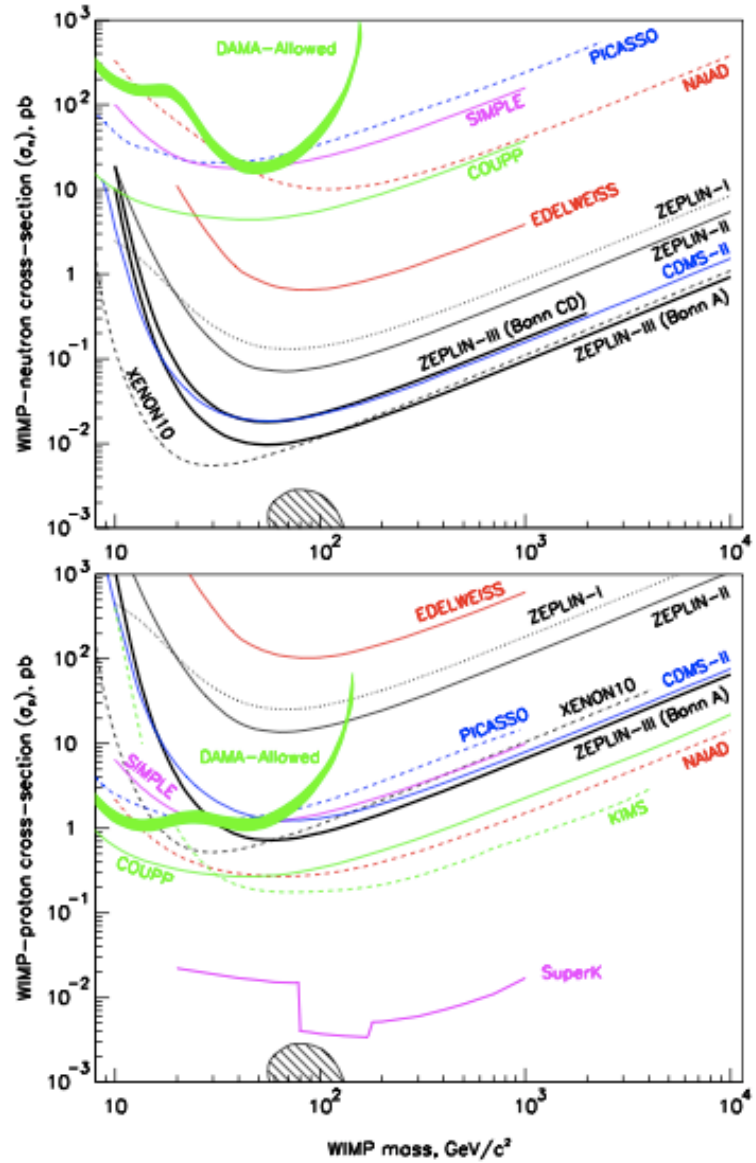


Available from: V.N.Lebedenko et al., arXiv:0812.1150

The Dark Matter Result - spin-dependent

- Limits also placed on spin-dependent interactions, on ^{129}Xe and ^{131}Xe.
- With CDMS-II and XENON10 we place the best constraints on the WIMP-neutron cross-section.





Available from: V.N.Lebedenko et al., arXiv:0901.4348

Summary

- ZEPLIN-III successfully deployed in first stage configuration
- Detector operated stably during 2008
- First science run completed
  - 847 kg.days total exposure, 453.6 kg.days fidcual
  - 126.7 kg.days exposure after all cuts
  - Effective threshold 1.7 keV_{ee}
- Full analysis completed
  - 90% c.l. Limit at 7.7 $x10^{-8}$ pb @ 55GeV WIMP mass
- World competitive limits on spin-independent and spin-dependent scattering.
- Demonstrated excellent discrimination at the higher operating field
- Upgrades planned - see Emma's talk next