ZEPLIN-III: Upgrades and status

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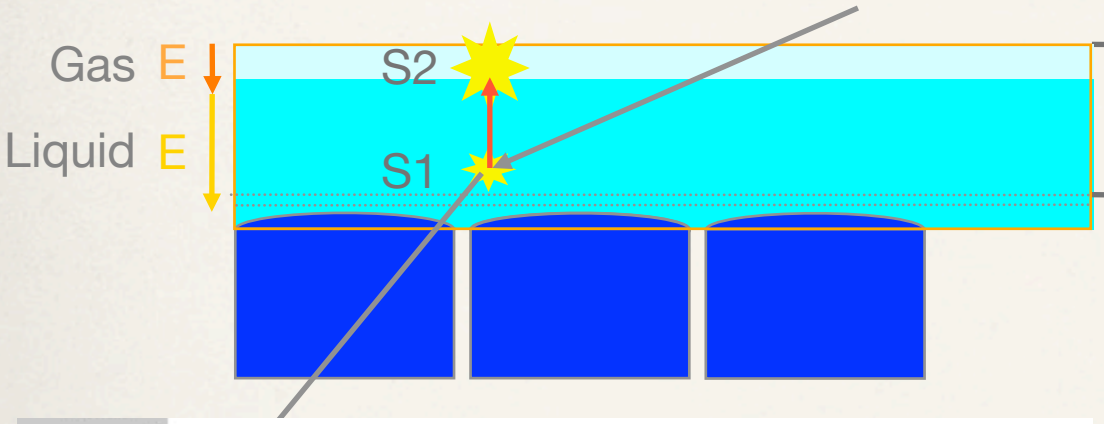
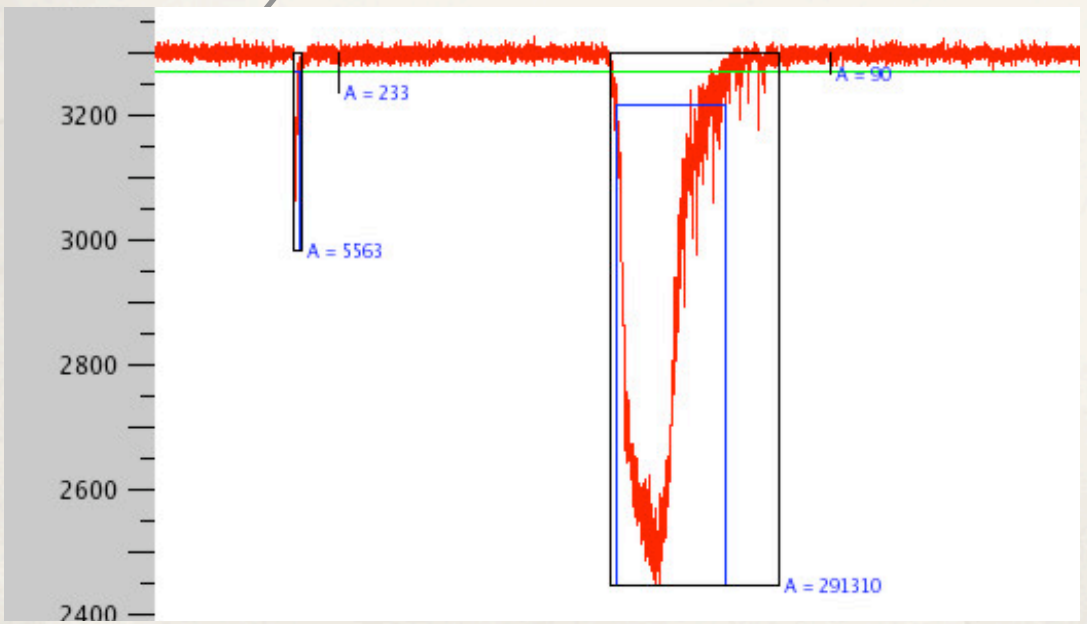
On behalf of the ZEPLIN-III collaboration

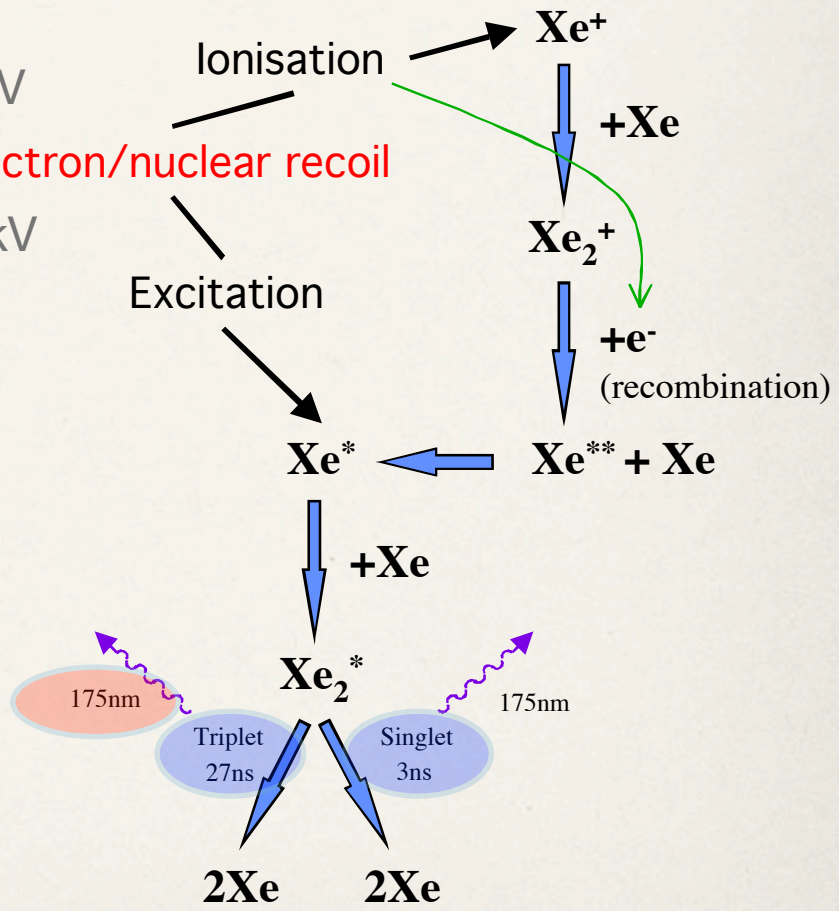
AXION-WIMP 2010, Zurich 07/07/2010

Operating Principle

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

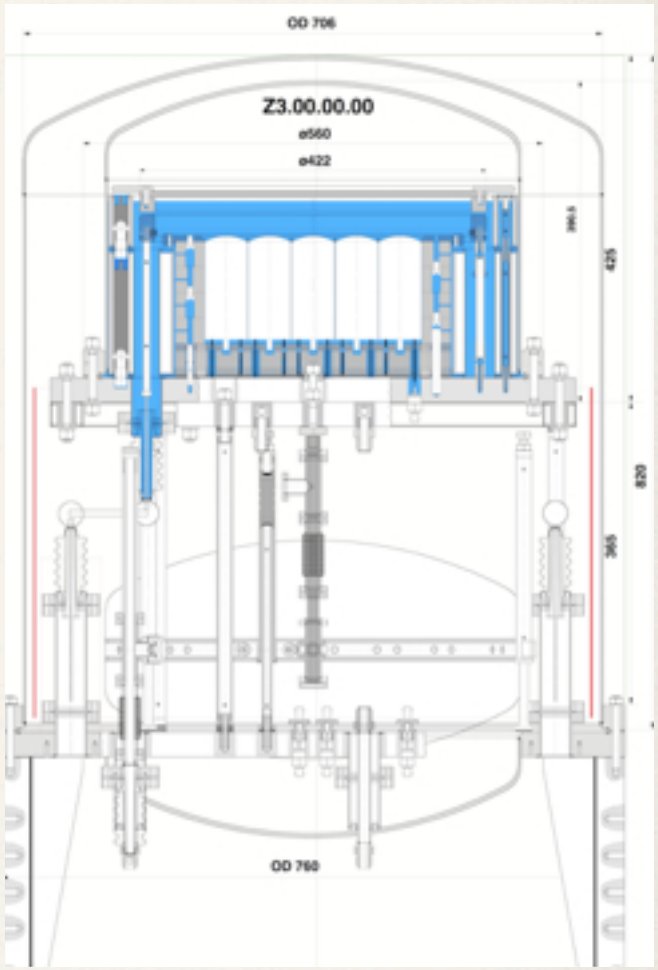


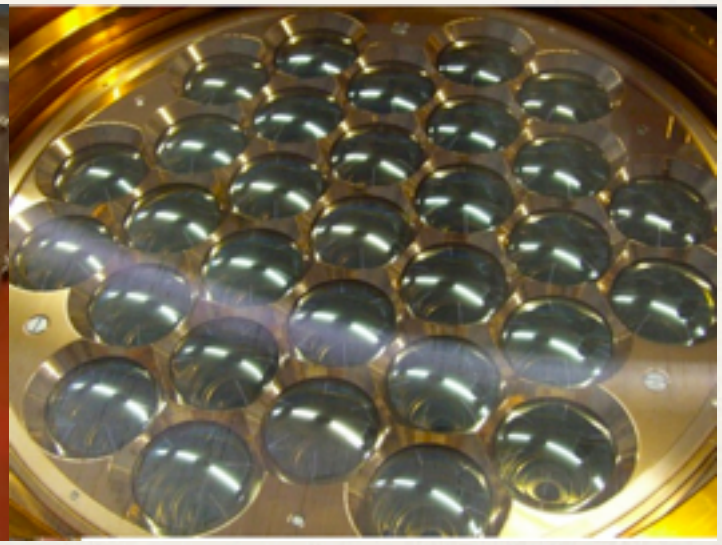




The Detector: ZEPLIN-III

- PMTs in liquid to improve light collection
- 31 two-inch PMTs for fine position sensitivity
- 12 kg active target mass
- High E-field -> better n/γ discrimination
- ~3.6 cm drift depth, ~0.4 cm gas gap
- open plan – no surfaces - reduced feedback
- Low-background xenon (40 yr old - low Kr)
- All copper construction - electron beam welded

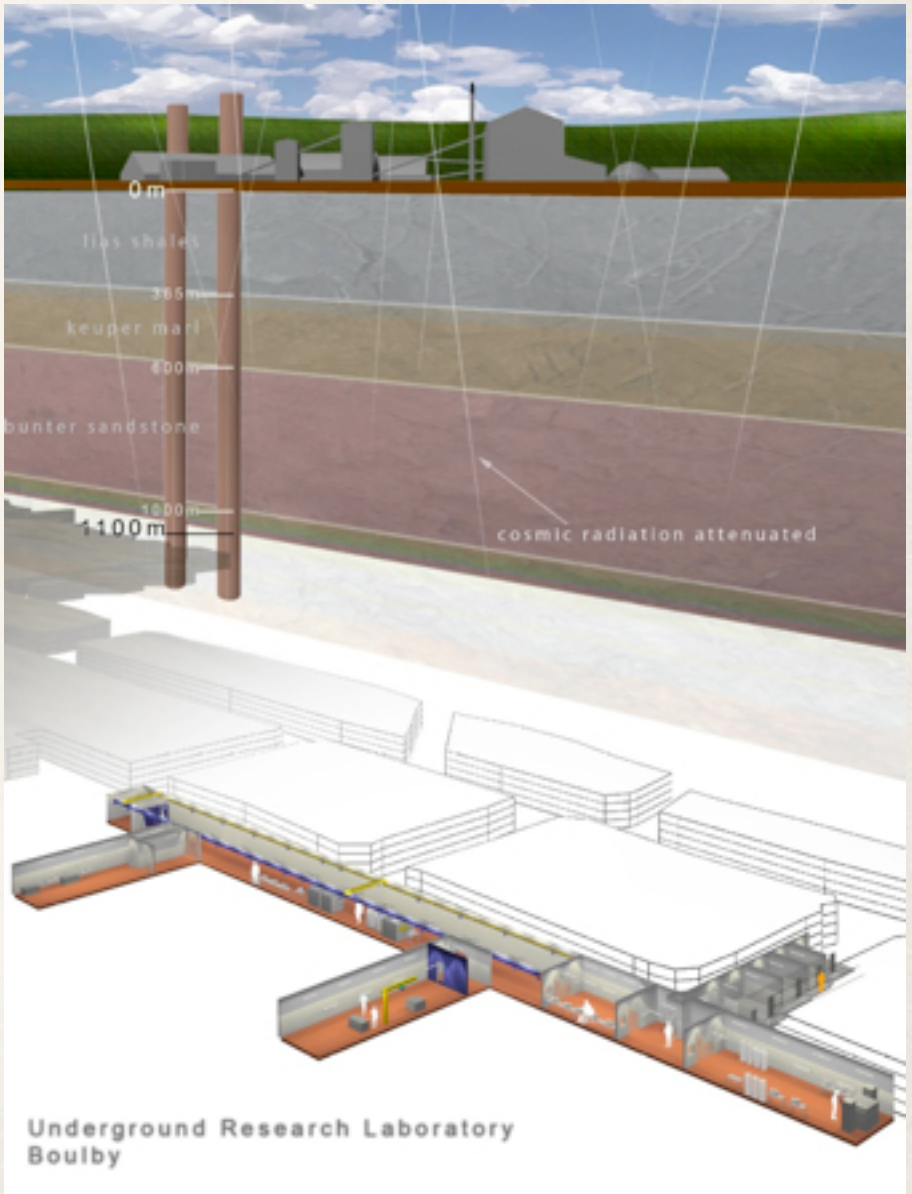




The Location: Boulby UG Lab

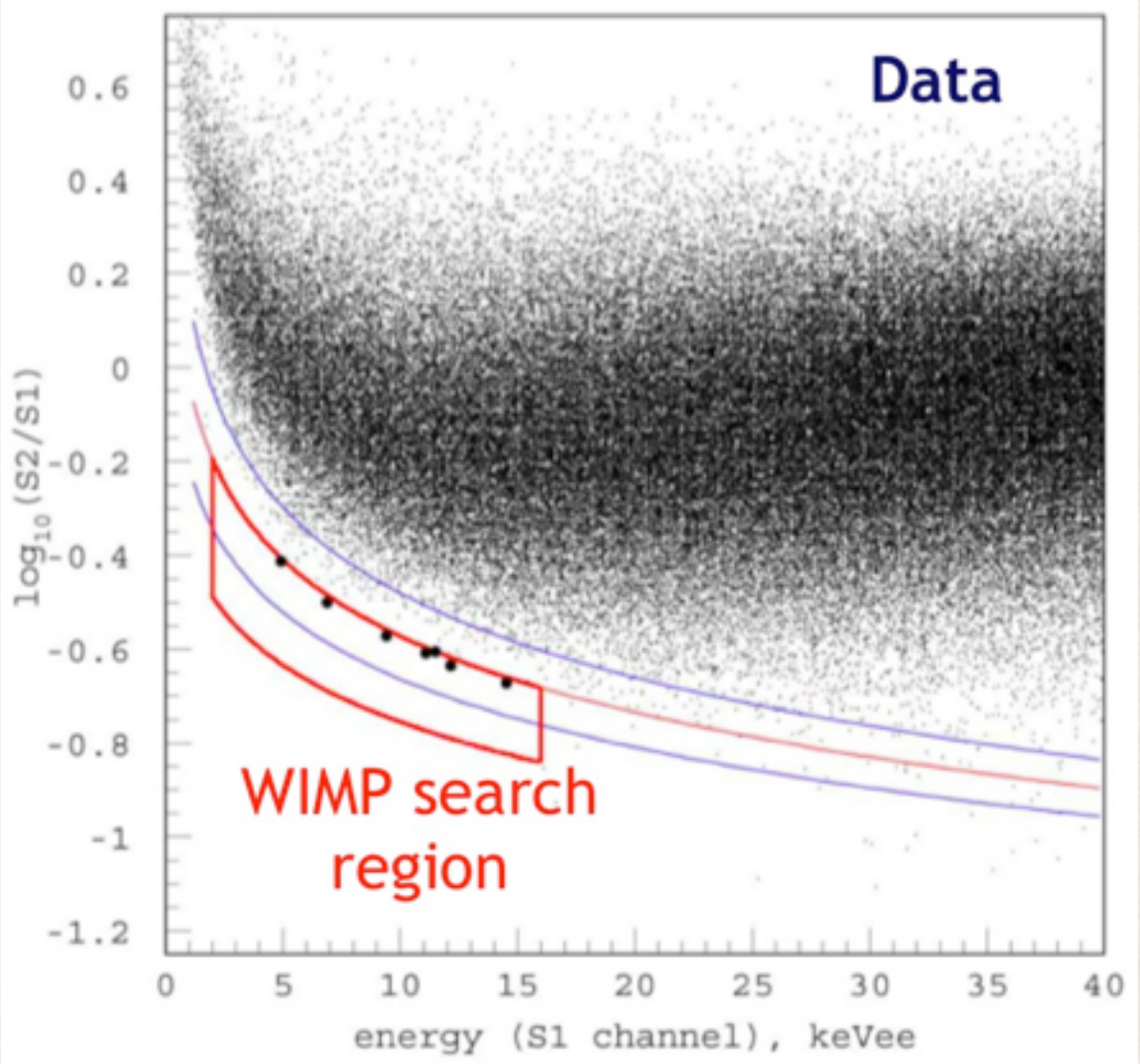
- Located in Boulby mine, North-East England
- 1100m UG (2600m water equivalent)
- Reduces muon flux by a factor of ~10^6

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



First Science Run Data

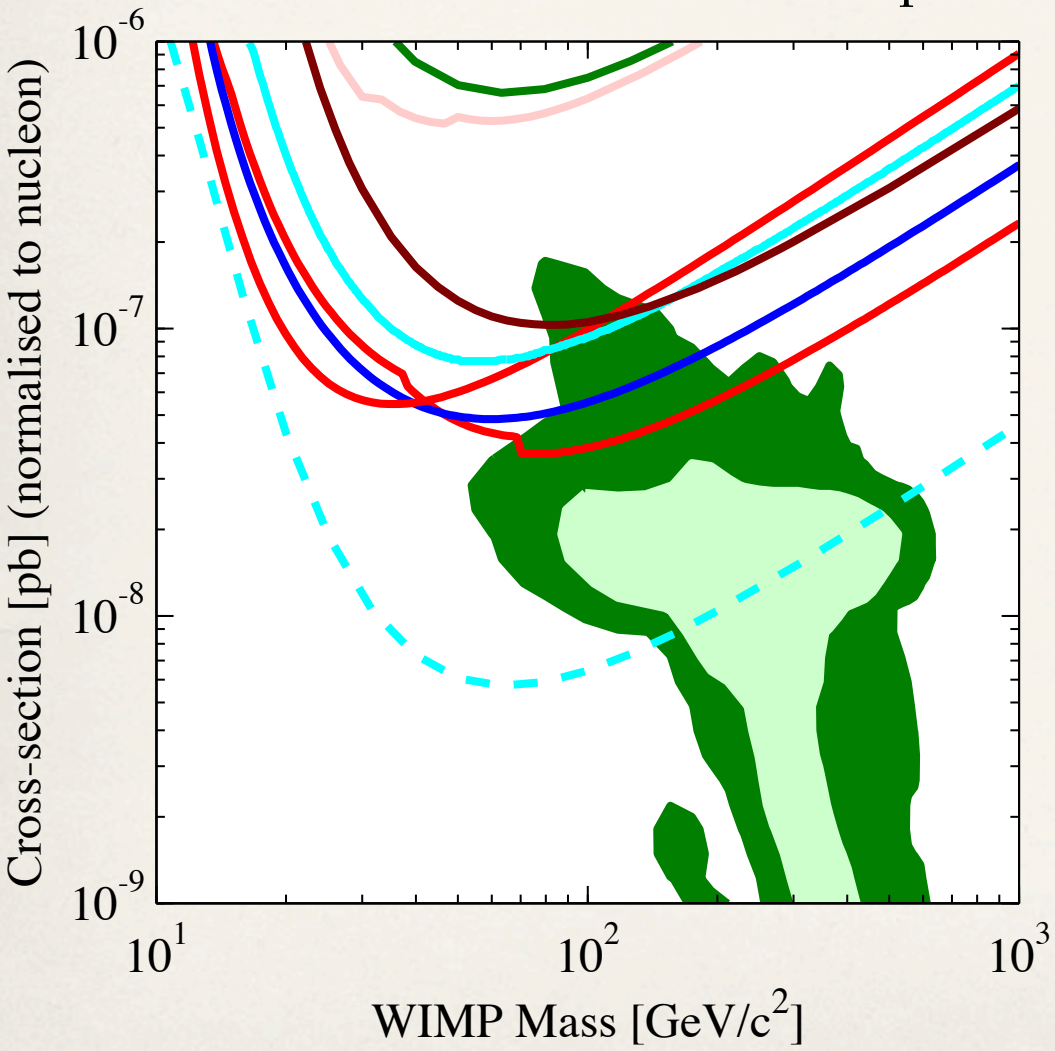
- 83 days operation @ 84% livetime
- Collecting 847 kg.days of raw data
  - ➡ 267.9 kg.days effective fiducial exposure
- WIMP search box defined from NR calibrations below 50% NR from 2-16 keV_{ee}.
- Secondary selection rules on event topology (S1,S2) to remove MSSI double scatter events
- 7 events observed within search box, extrapolation from electron recoil population fits gives expectation of 11.3 ± 3.0 in the box
- (nr/γ) discrimination of 1:7400 demonstrated!!



Spin-independent limit

- Simple Poisson analysis of data allows limits to be placed on the WIMP-nucleon spin-independent scattering cross-section:

8.1×10^{-8} pb @ $M_d = 55$ GeV / c^2

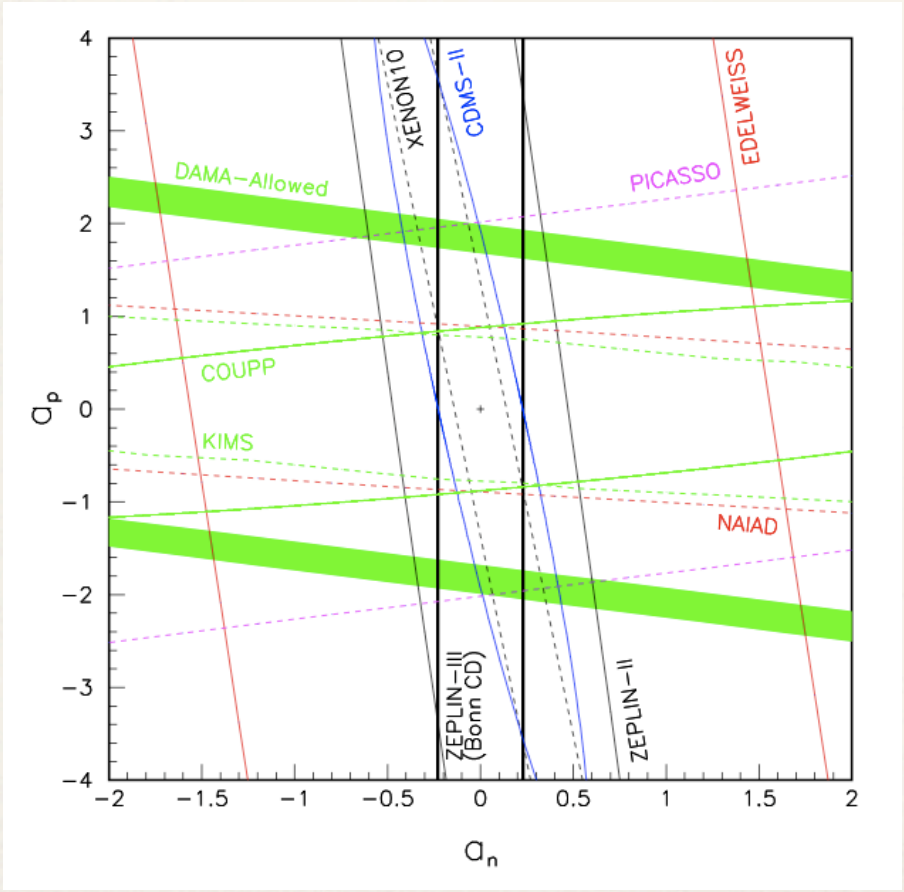


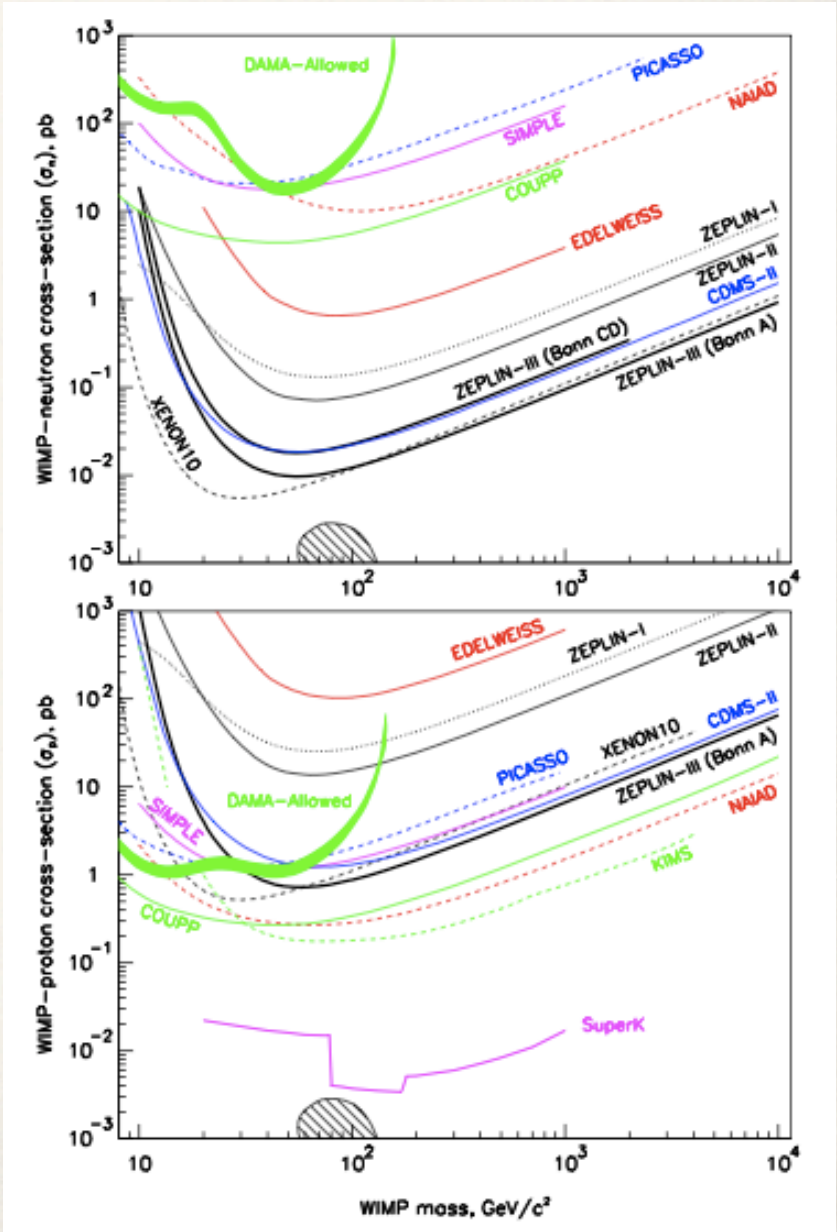
DATA listed top to bottom on plot
WARP 2.3L, 96.5 kg-days 55 keV threshold
ZEPLIN II (Jan 2007) result
CRESST 2007 60 kg-day CaWO4
Edelweiss II first result, 144 kg-days interleaved Ge
ZEPLIN III (Dec 2008) result
XENON10 2007, measured Leff from Xe cube
CDMS Soudan 2004-2008 Ge
CDMS: Soudan 2004-2009 Ge
ZEPLINIII(yr 3,with PMT upgrade) Proj. Sens.
Trotta et al 2008, CMSSM Bayesian: 68% contour
Trotta et al 2008, CMSSM Bayesian: 95% contour

V.N.Lebedenko *et al*, Phys. Rev. D 80:052010(2009)

Spin-dependent limits

- 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.

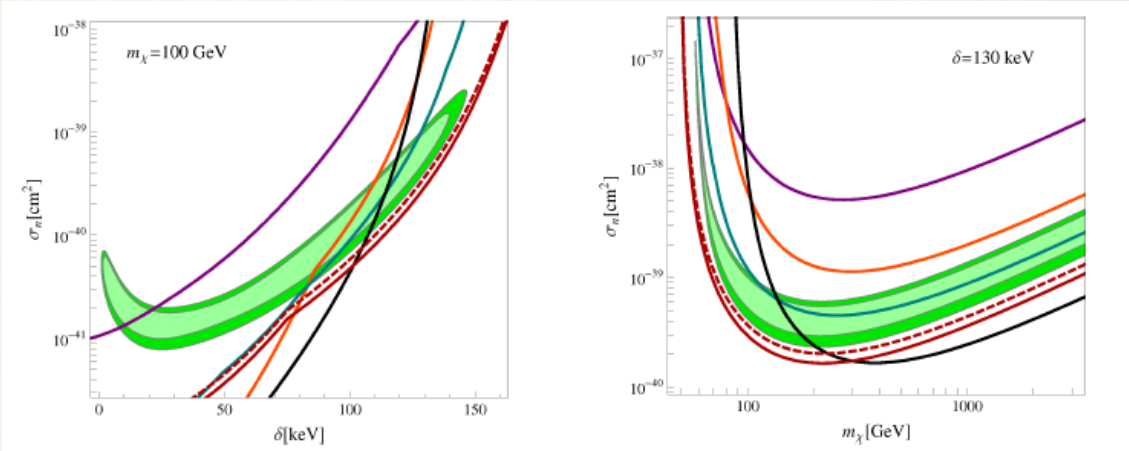


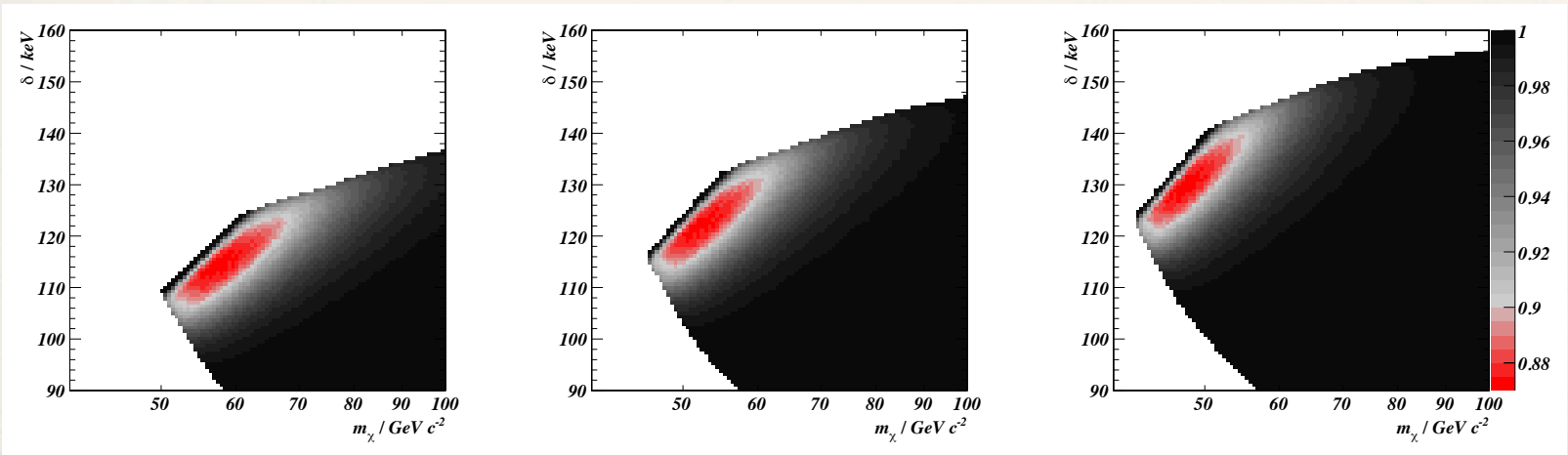


V.N.Lebedenko *et al*, Phys. Rev. Lett. 103:151302 (2009)

Inelastic DM

- Analysis of the ZEPLIN-III FSR dataset excludes most of the DAMA region with 90% confidence.
- Completely excludes region with >87% confidence.
- Xe target similar kinematically to DAMA (NaI).
- Paper submitted to Physics Letters B - arXiv:1003.5626





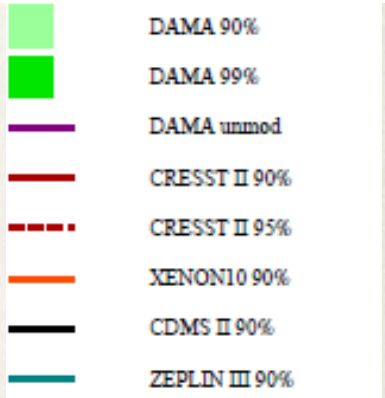
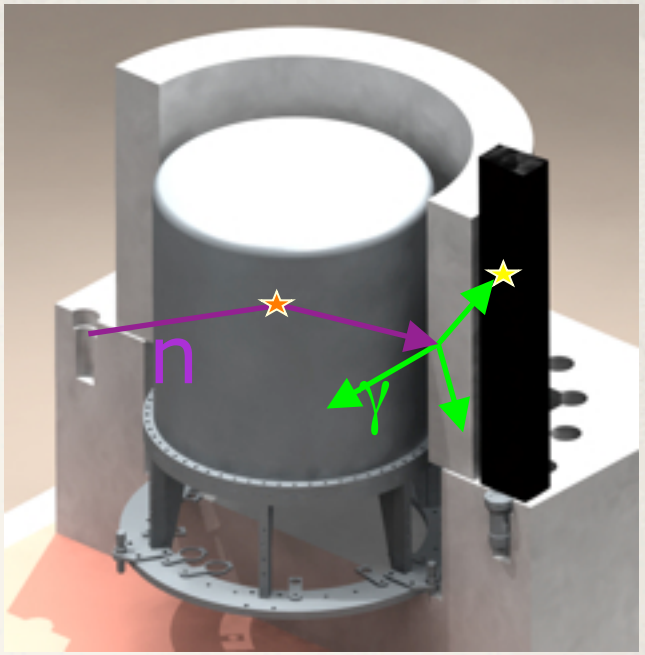
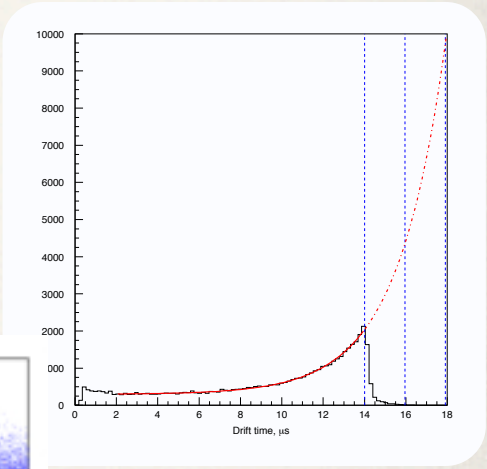


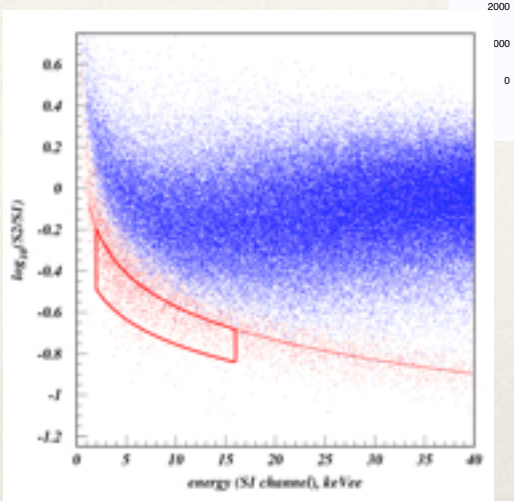
Figure 5: In m_χ–δ space, the confidence level at which ZEPLIN-III excludes the lowest value of σ_n consistent, at 99% CL, with causing the DAMA modulation. Three values of v_{esc} are shown: (from left) 500, 550 and 600 km s^{-1}.

The Upgrades: why?



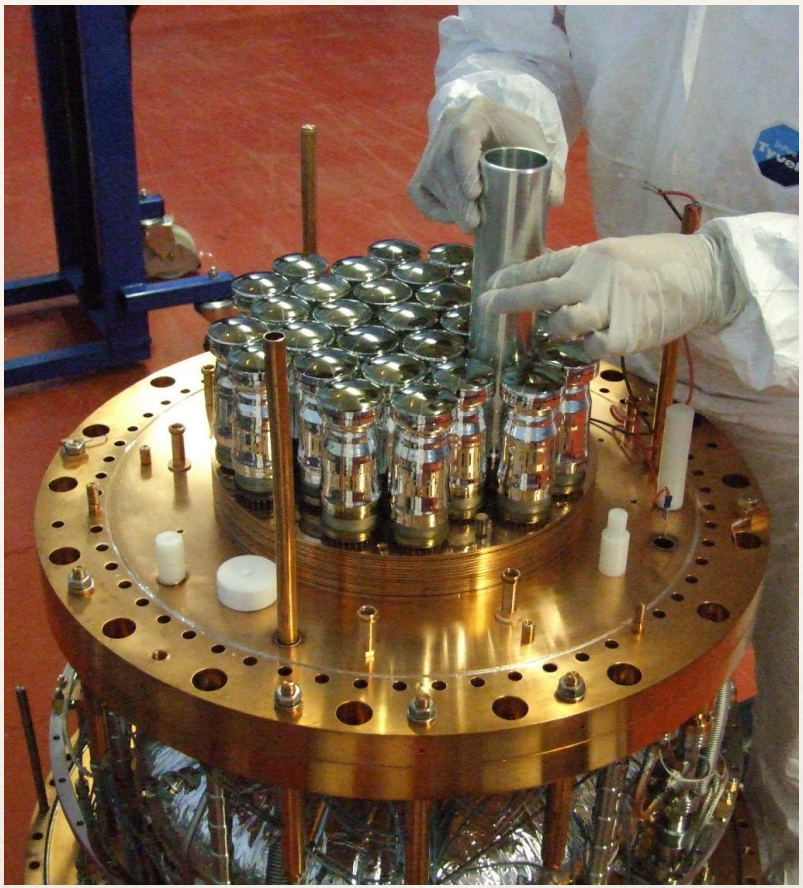
- Make it easier to find a DM signal!
  - Reduce neutron background
    - reduce internal sources, tag remaining neutrons, increase shielding
  - Reduce electron recoil background
    - reduce internal sources
  - Improve discrimination (aiming for 1:10,000!!)
    - improve stability and refined cuts
  - Increase exposure
    - improve duty cycle.





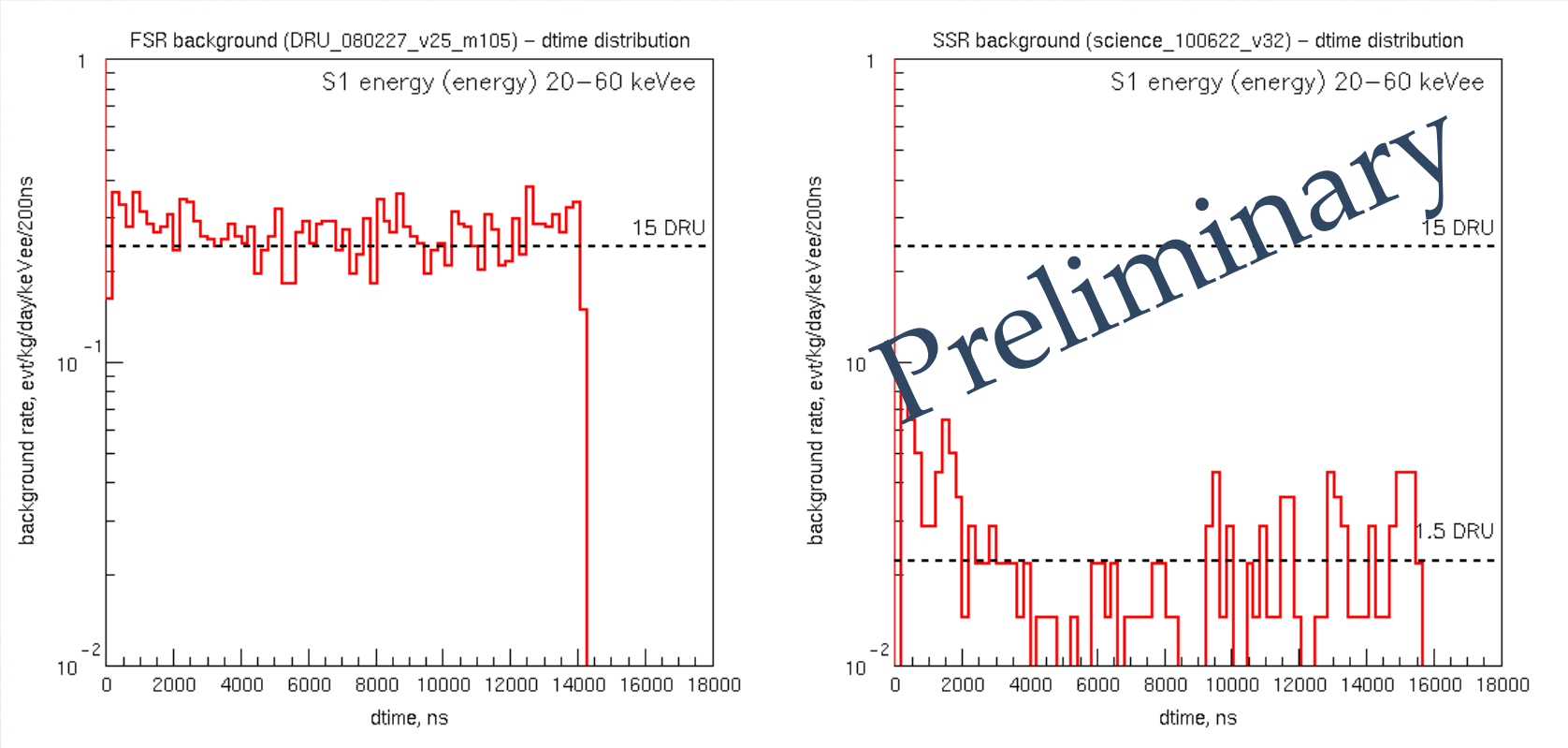
PMT Upgrade

- Existing PMTs limited sensitivity of first run (from μ-ray leakage at least).
- Custom design for ultra low-background tubes, pin-by-pin compatible.
- Detailed measurements of detector and new PMT components (with HPGe detector) to determine radioactivity of materials.
- Simulations used to predict the background in ZEPLIN-III.



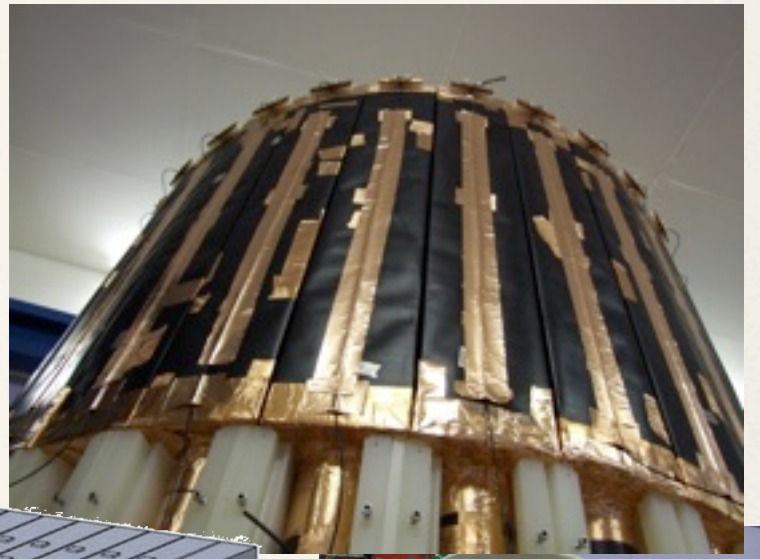
Background validation

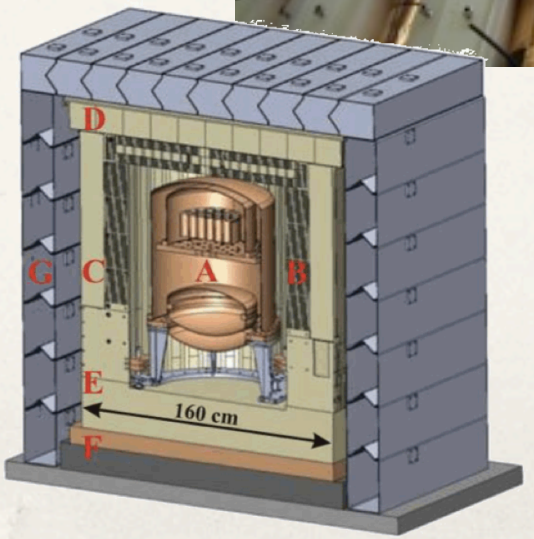
- Factor of >10 improvement in gamma-ray activity expected.
- Complete array installed and operational - Successful!!!
- ER background predicted at ~1.5 dru --> observed as predicted!!
- Neutron background for 1 year run calculated to be 0.2 events (after all cuts).



Active Veto

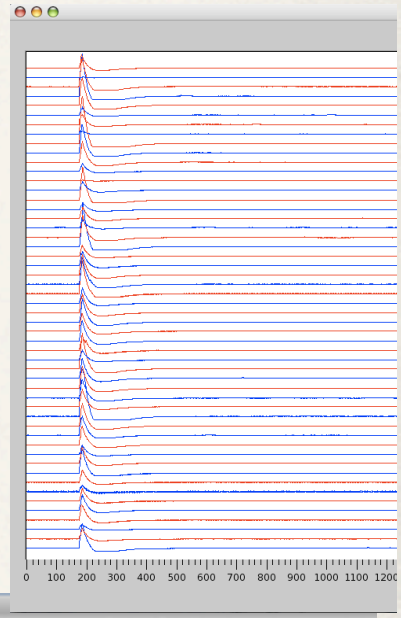
- Provides tagging of neutron (and gamma) backgrounds.
- 30 cm of neutron shielding (15 cm Gd-loaded plastic, 15 cm scintillator).
- Barrel and roof design providing > 3π coverage .
- 32 barrel sections and 20 roof segments (1 tonne plastic scintillator).
- Readout from 52 channels into separate DAQ system synchronised with ZEPLIN-III DAQ.
- Paper describing veto design and testing accepted for publication in Astroparticle Physics (arXiv: 1004.4207).

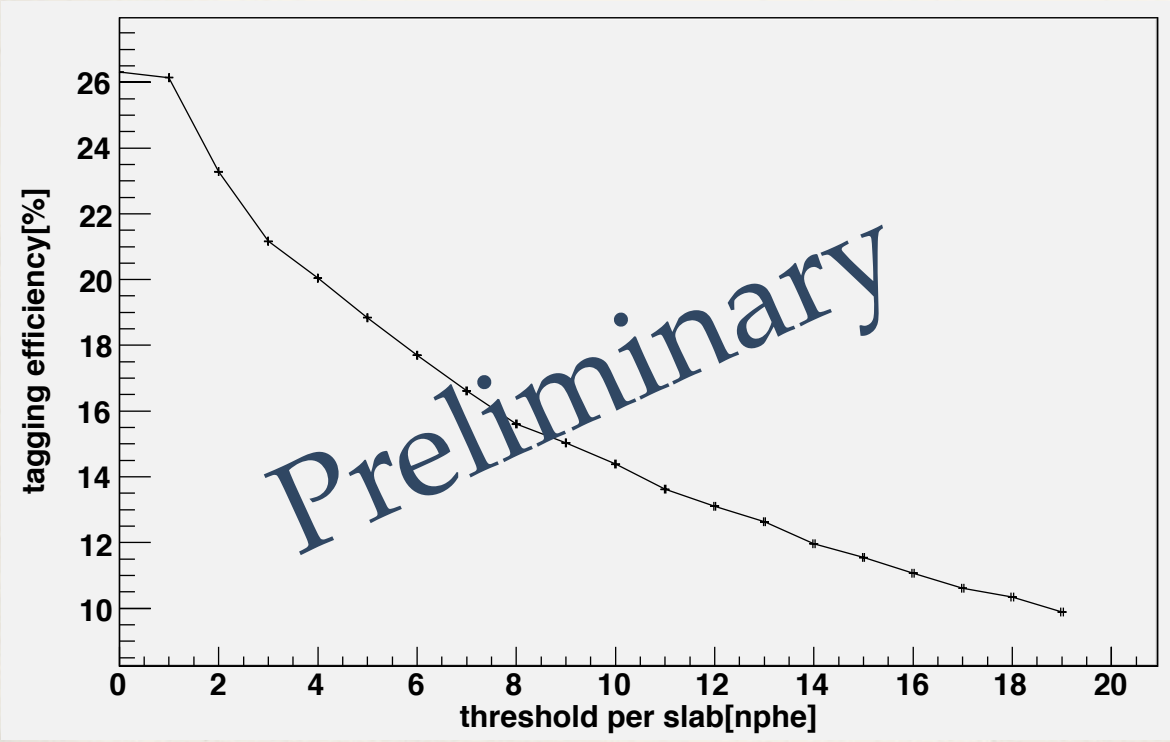


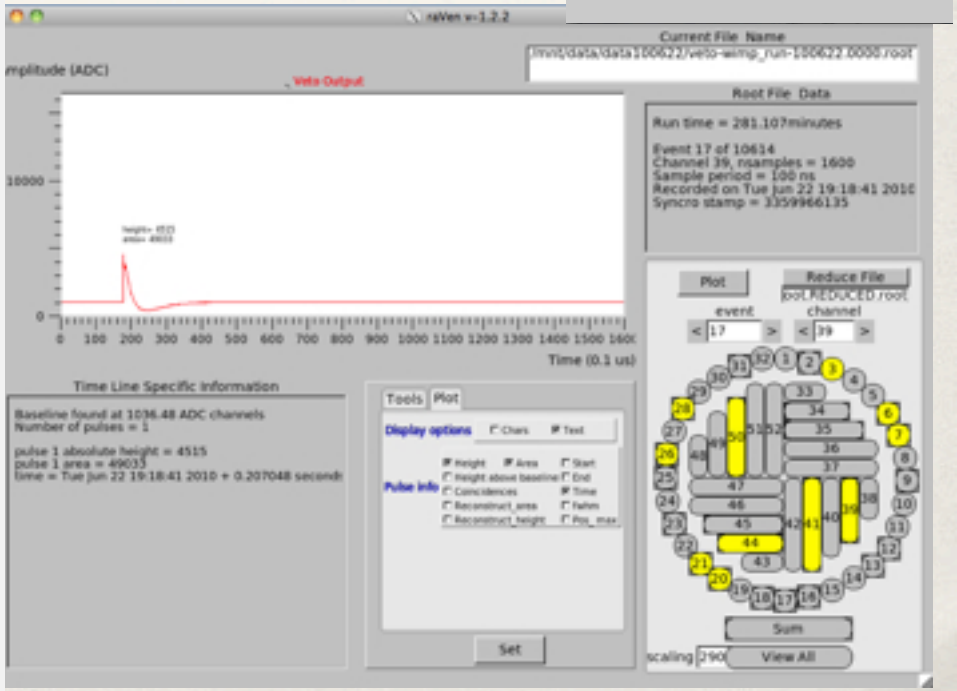


Veto performance

- All 52 channels working!
- Operation integrated into Z3 overall slow control systems.
- LED PMT calibration system operational.
- Gamma-ray tagging efficiency as expected (if not better!)
- Neutron tagging efficiency > 65%







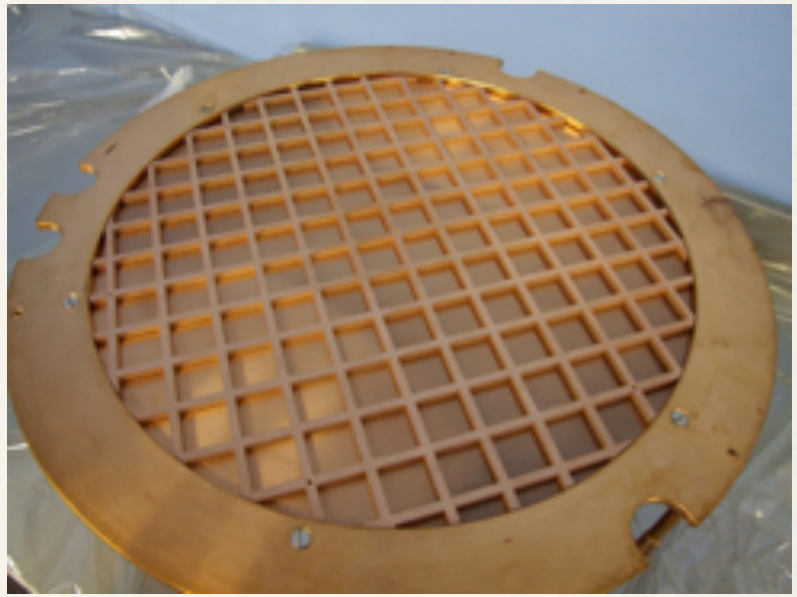
Other system upgrades

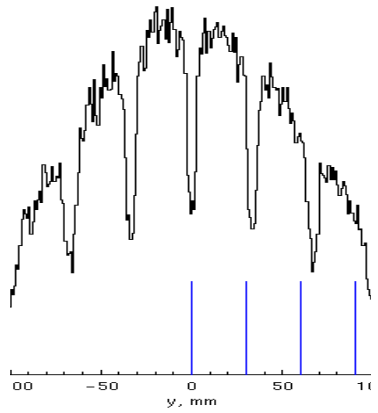
- Instrument operations fully automated to improve stability and duty cycle.
  - ✓ Successfully implemented, ~95% duty cycle achieved.

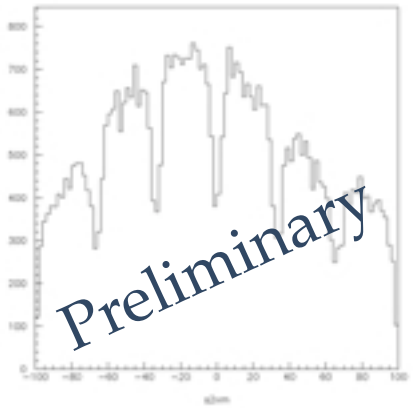
- Automated source delivery system to improve reproducibility and efficiency of daily calibrations.
  - ✓ Automated daily calibrations successfully implemented.

Other system upgrades

- "Phantom grid" to provide calibration of position reconstruction.
  - ✓ Successfully imaged in data
- Improved neutron calibrations
  - ✓ absolutely calibrated source allows for better MC measurement of L_{eff}.
- LED PMT calibration system
  - ✓ used to monitor stability of PMTs response.
- Improved analysis
  - ➡ building on previous analysis





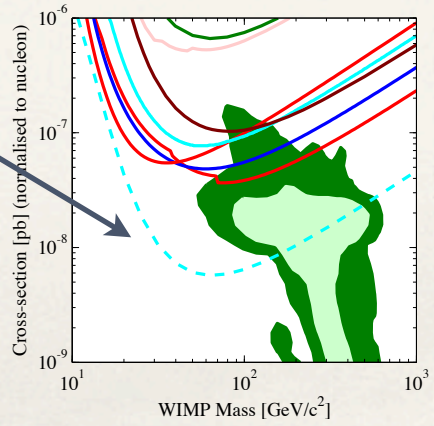


Simulation Data

Current status

- The detector is currently running and acquiring dark data.
- Automated operation providing very good stability and high duty cycle (~95%).
- Electron lifetime similar to FSR (~22 μs).

Now we just have to wait and collect the data!!



- Initial nuclear recoil and gamma calibrations completed.
- Analysis underway (based on the FSR foundations).

The collaboration

Thanks to everyone in the ZEPLIN-III collaboration.

Imperial College London

THE UNIVERSITY OF EDINBURGH

LIP

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