Directional Direct Detection Beyond the ν Floor

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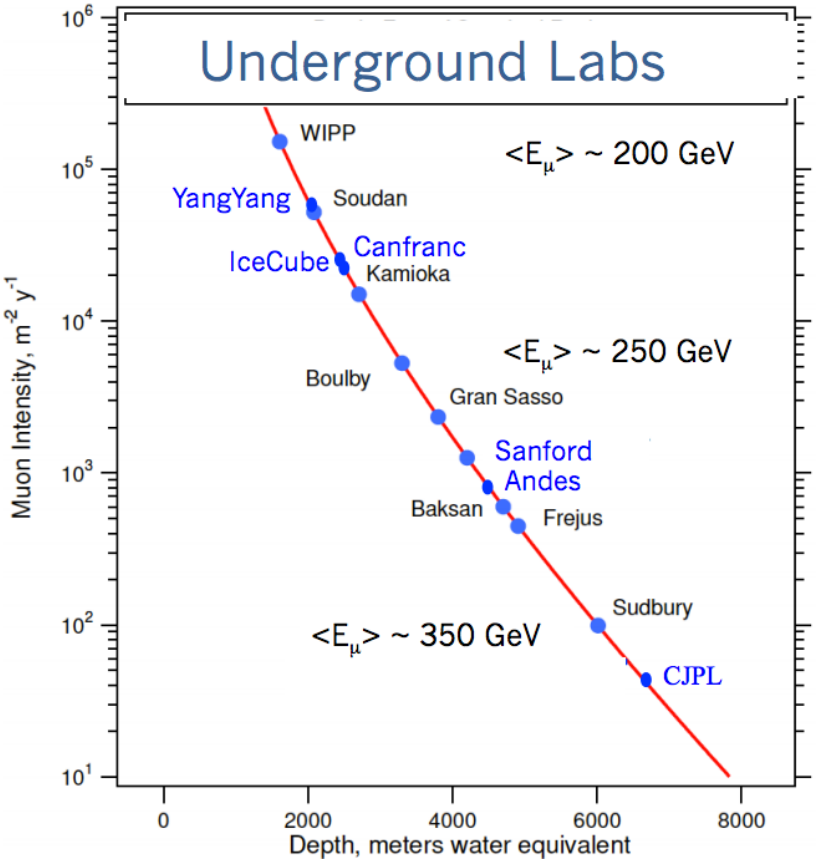
Overview

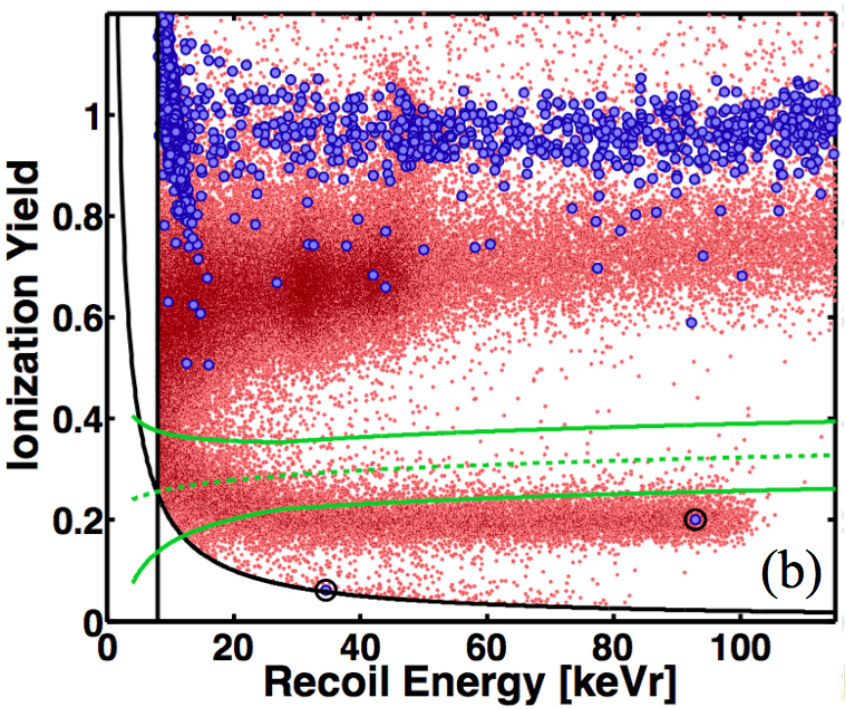
- Direct detection background discrimination
- A new type of background: coherent ν scattering
- Directional detection: discriminating between WIMPs and solar νs
- Current technologies
- Challenges for directional detection

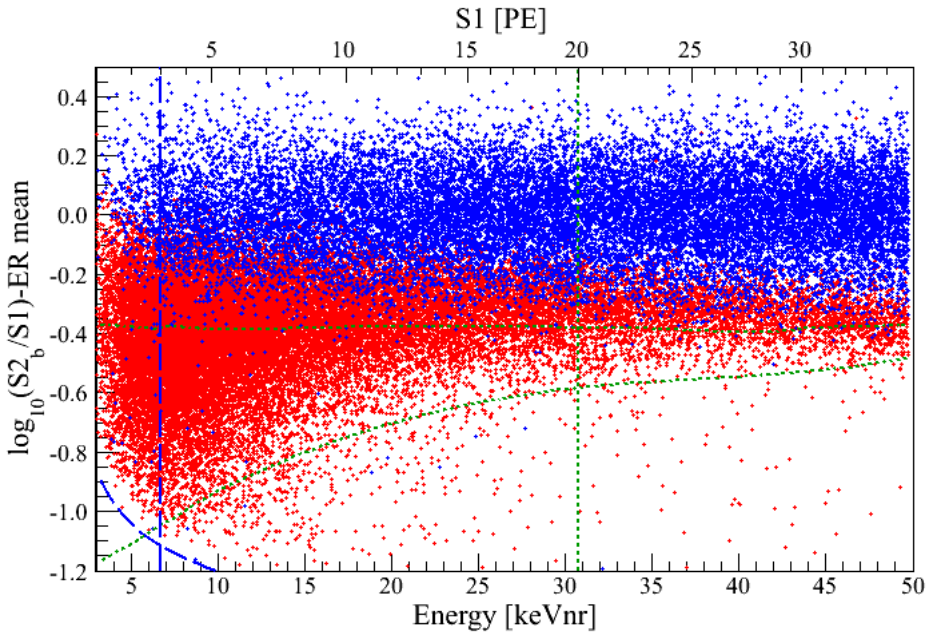
The problem: cosmic rays

The solution: Go underground and shield!

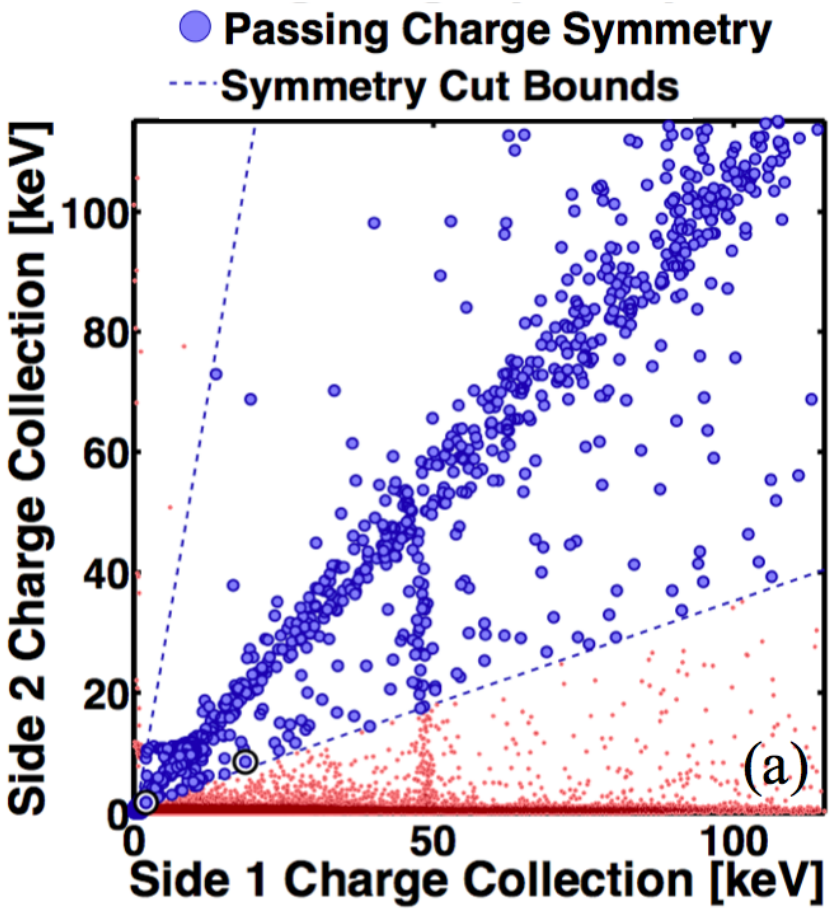


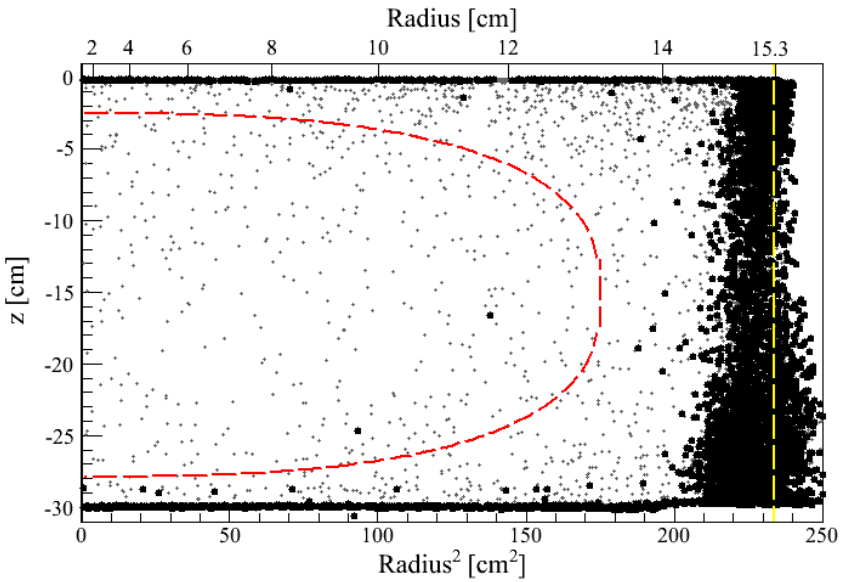
The problem: electron recoils
The solution: Use multiple signals



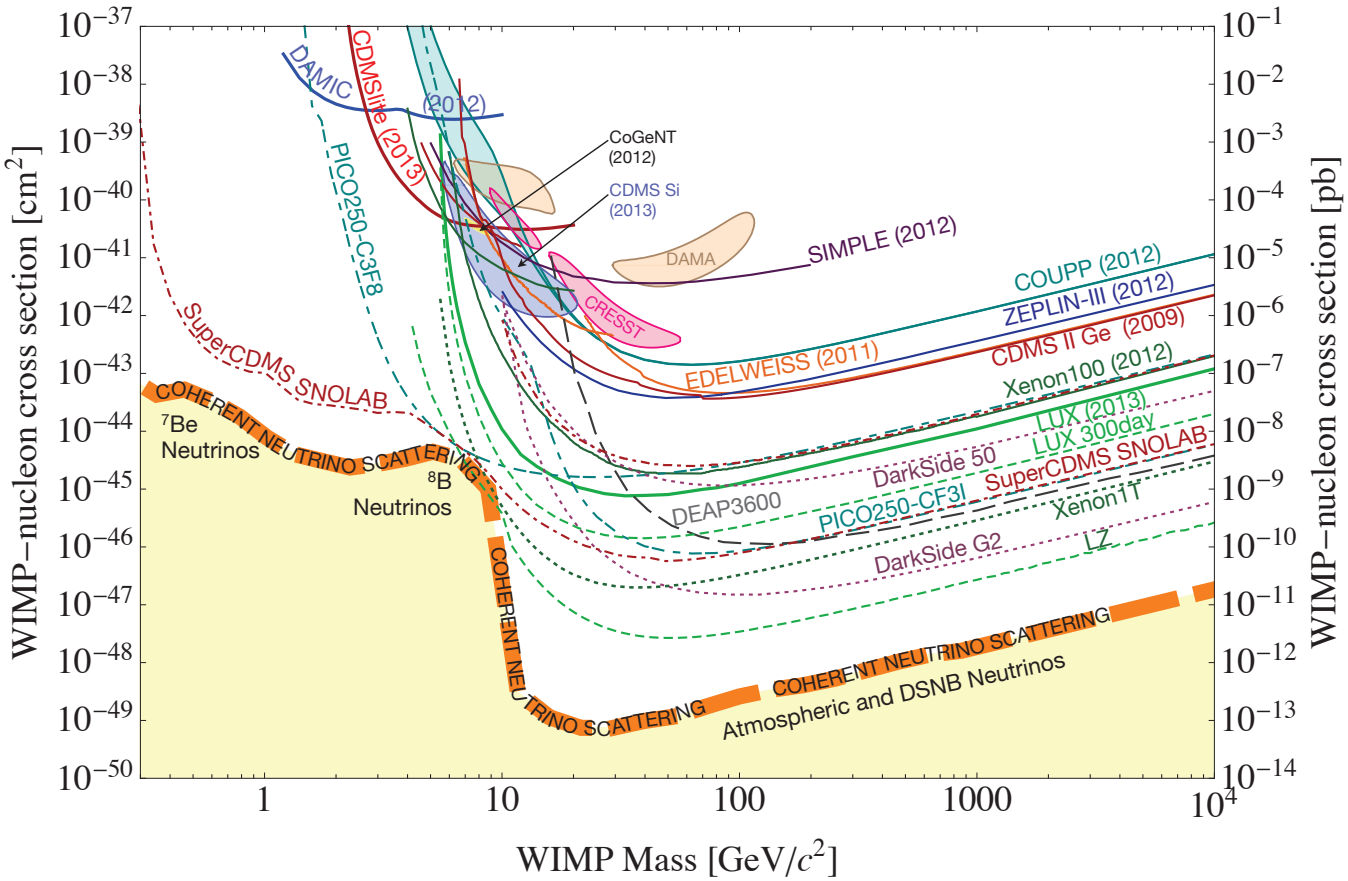


The problem: surface contamination
The solution: fiducialize





The problem: coherent ν scattering produces nuclear recoils



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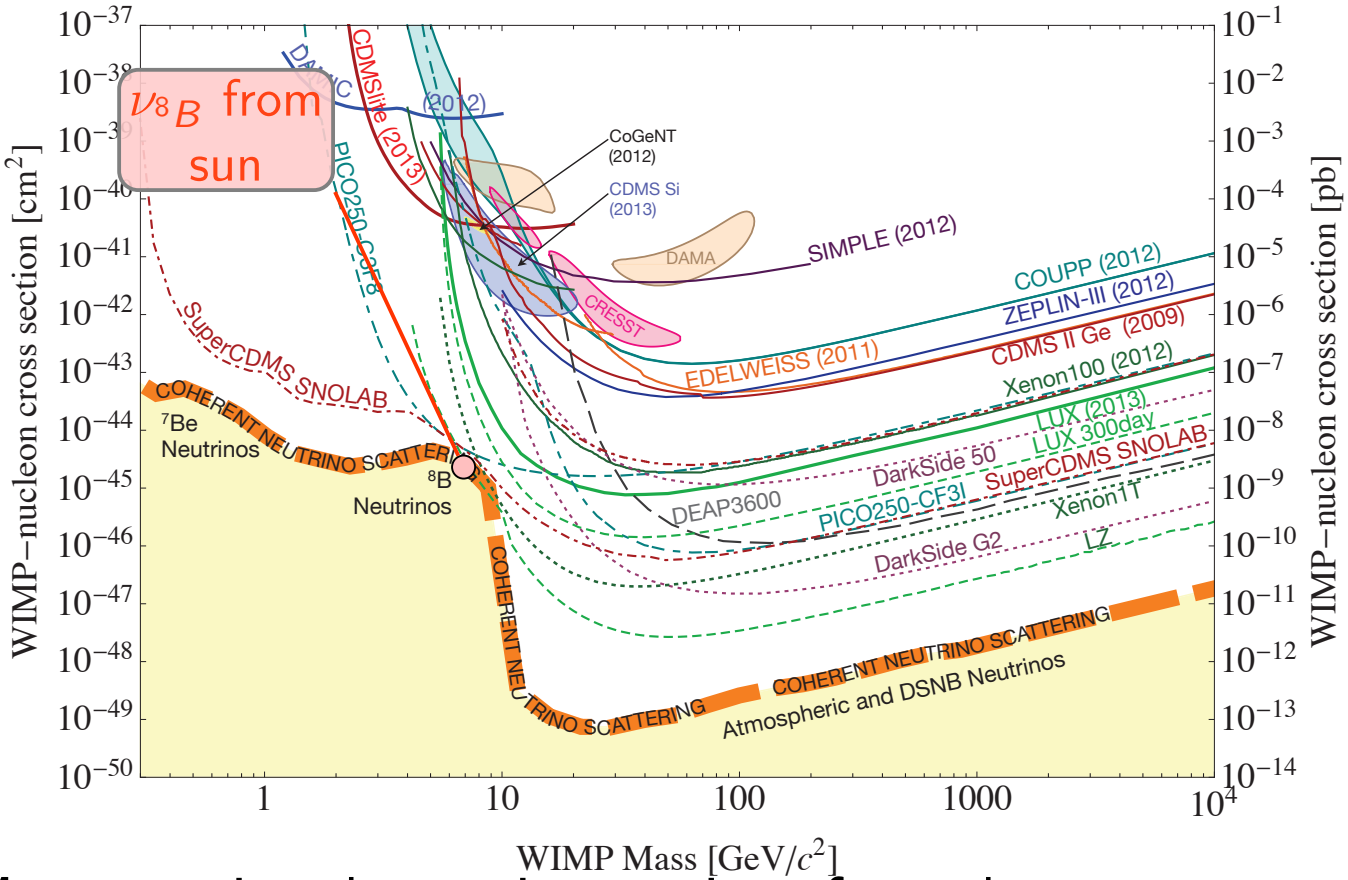
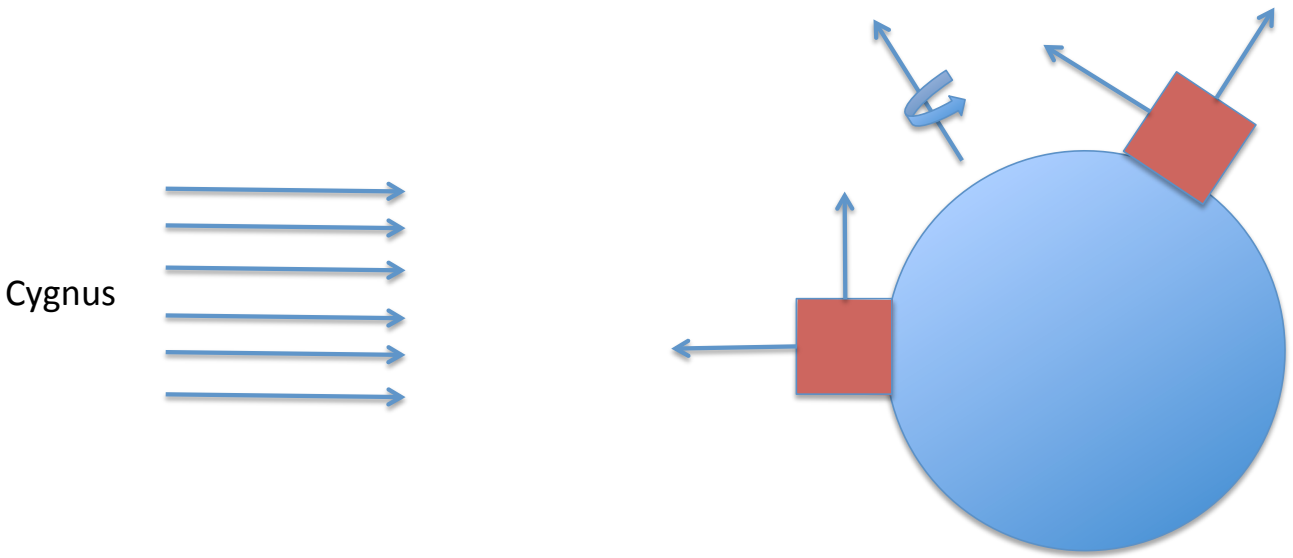


- Most pressing danger is neutrinos from the sun
- Reconstructing the direction can remove these events!

A Naive Picture



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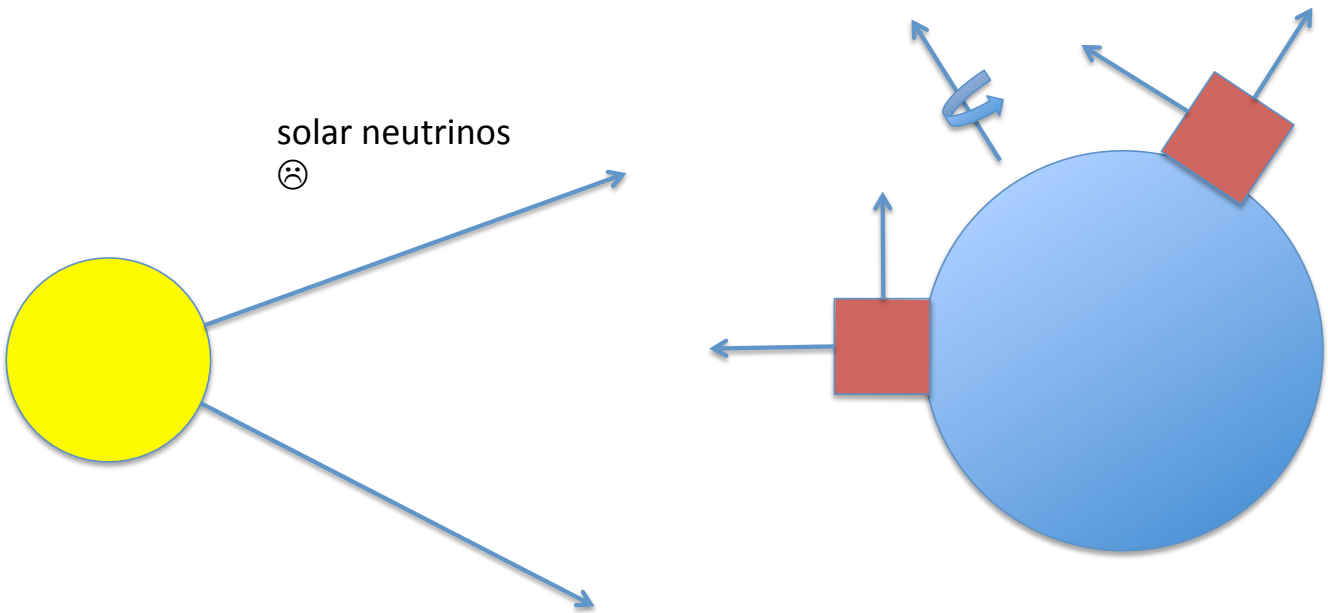

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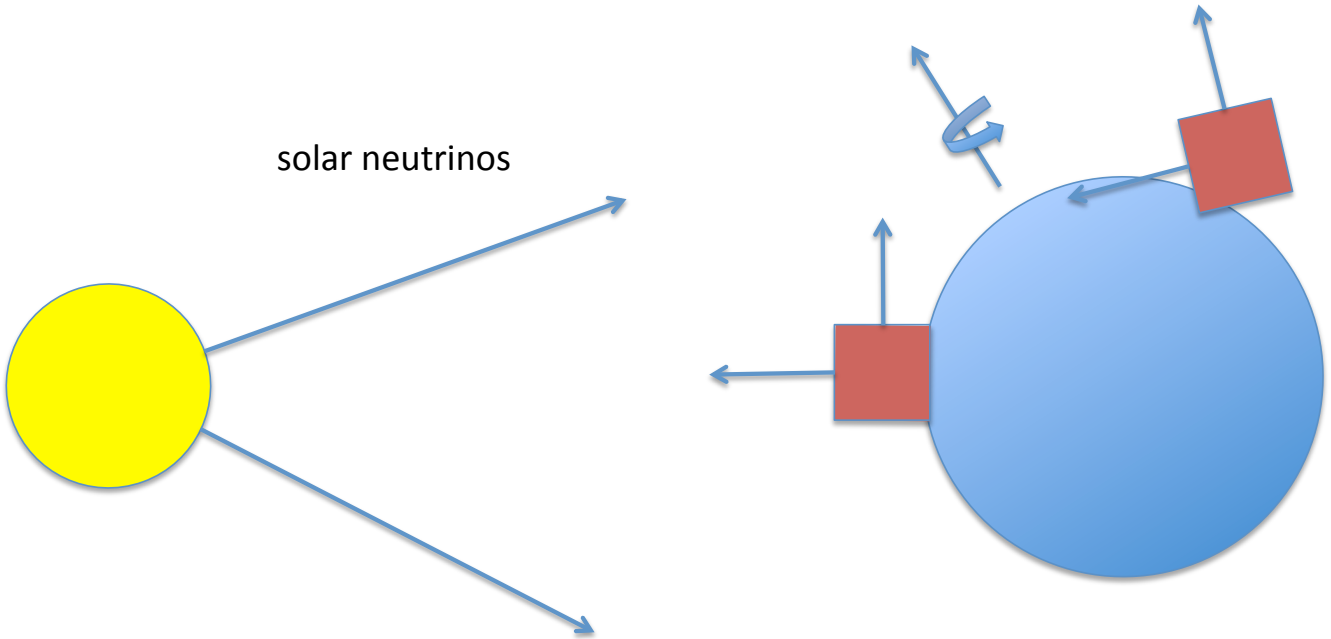
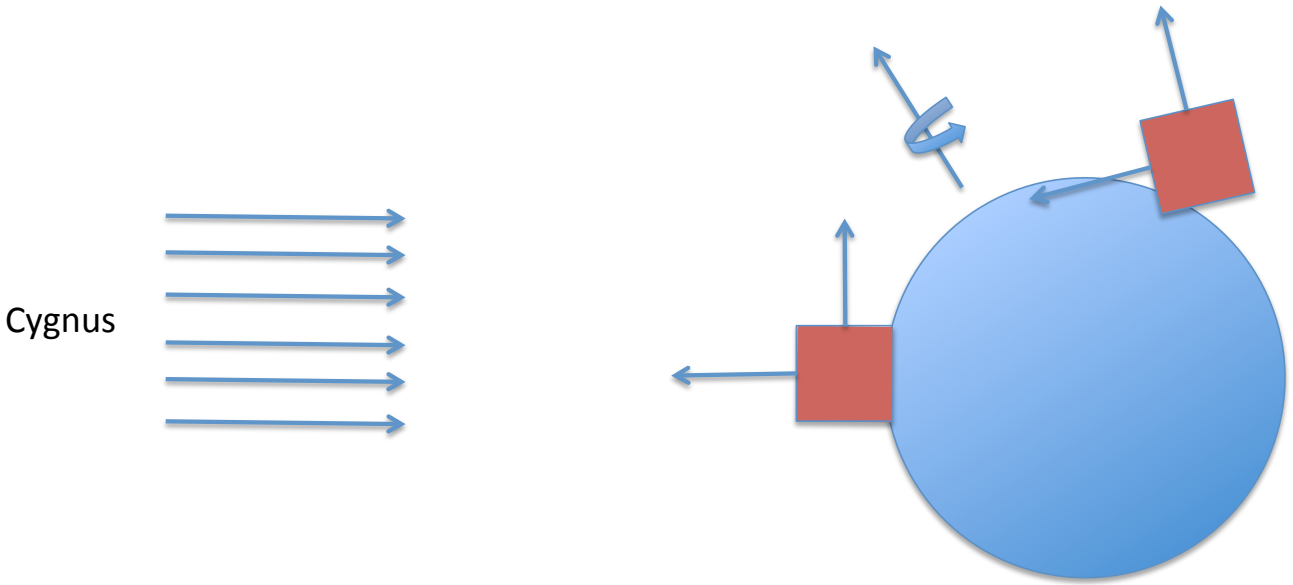
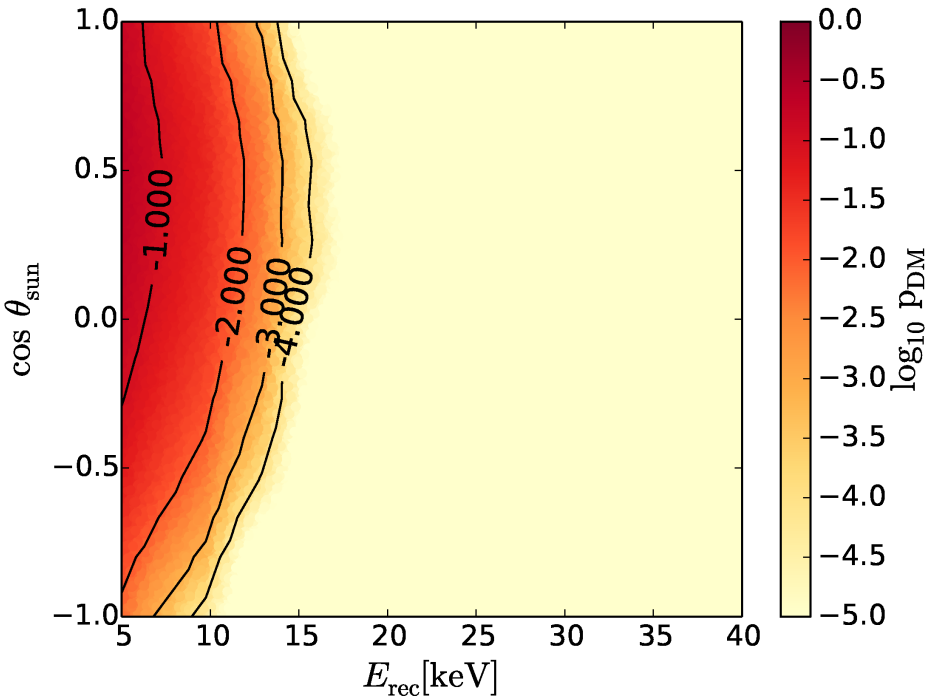


A Naive Picture

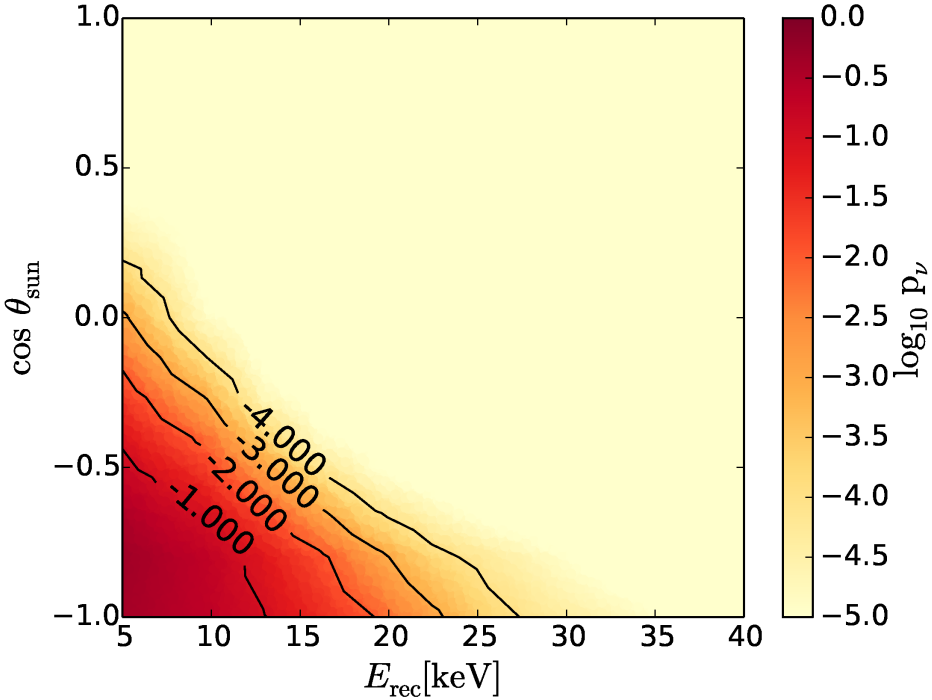


Event distributions in CF_4 with 5 keV threshold

Dark matter (from Cygnus)

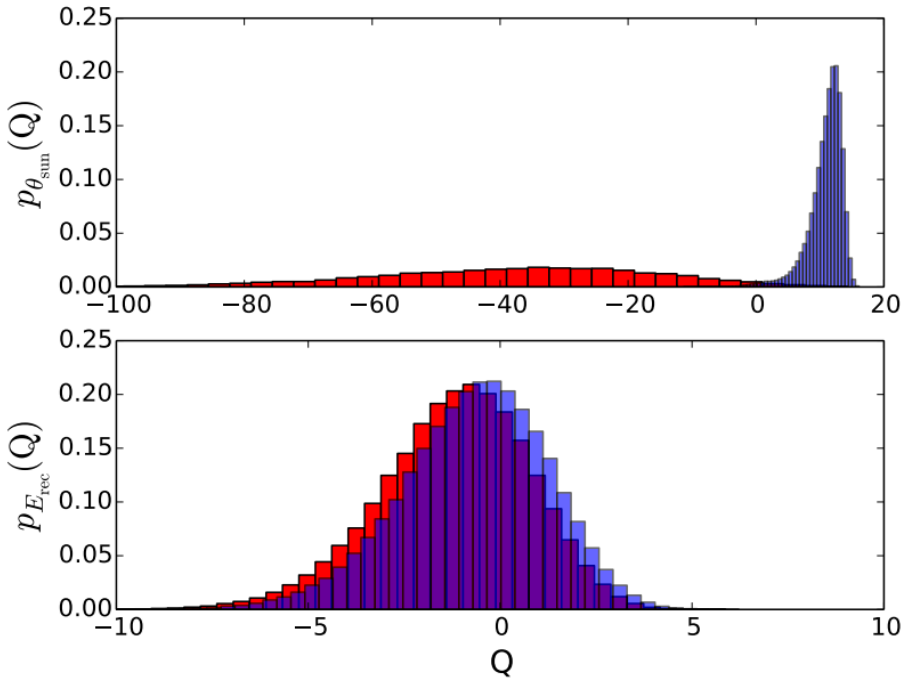


Neutrinos (from the sun)



P Grothaus, M Fairbairn, J. Monroe, arXiv:1406.5047

Simulated pseudo-experiments with ν background



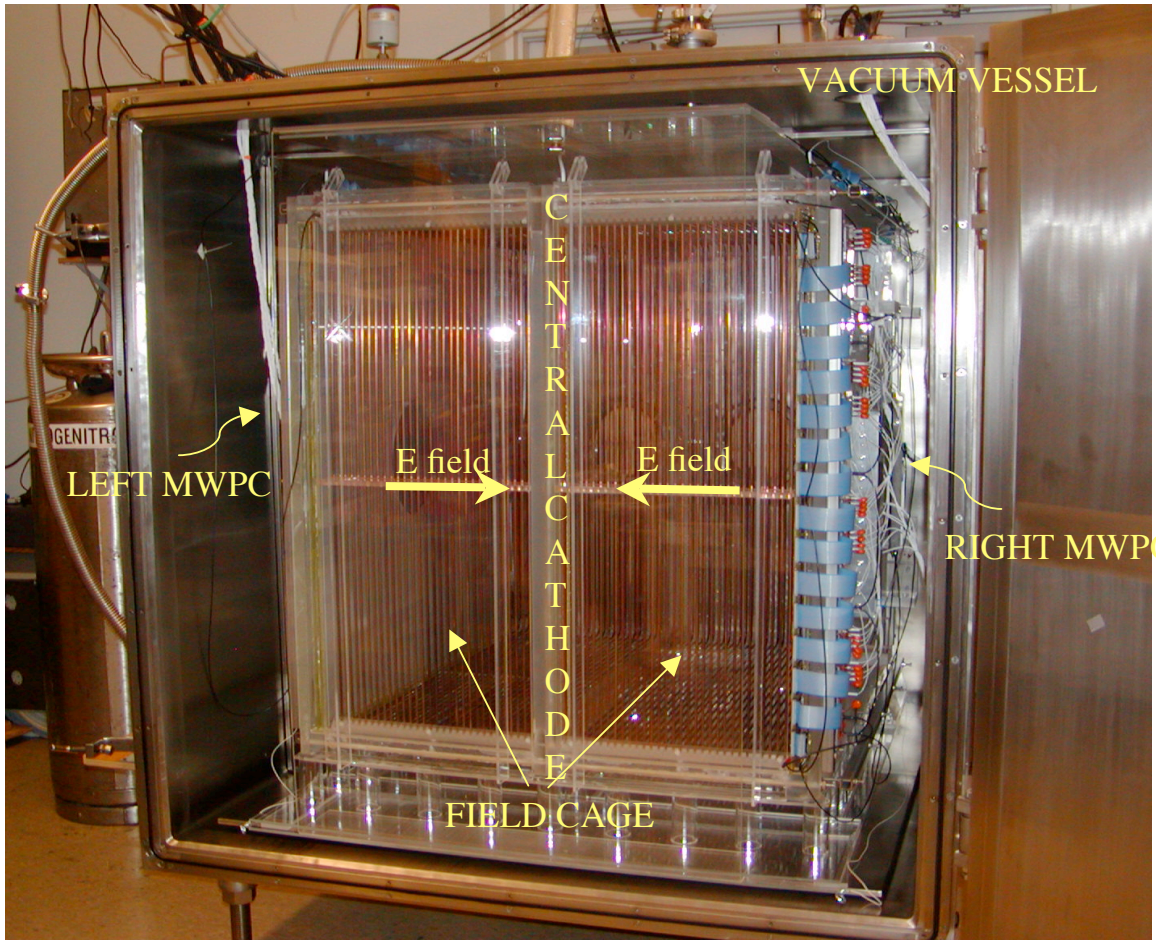
- Signal + background (red) are easily distinguishable from background-only (blue) when directional information is included

P Grothaus, M Fairbairn, J. Monroe, arXiv:1406.5047

The DRIFT-IId detector in the Boulby Mine

The detector volume is divided by the central cathode, each half has its own multi-wire proportional chamber (MWPC) readout.

0.8 m^3 fiducial volume, 10/30 Torr CF_4/CS_2 --> 139 g

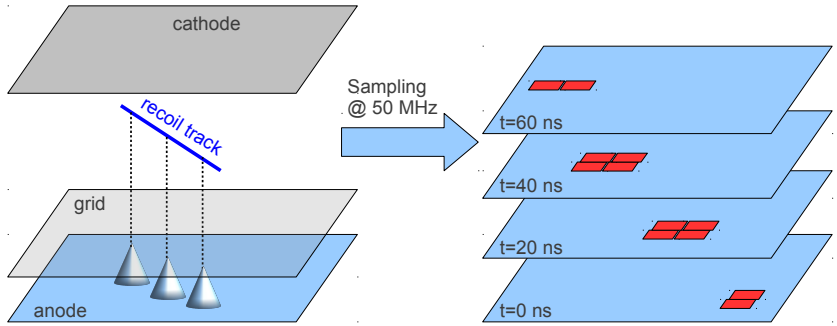


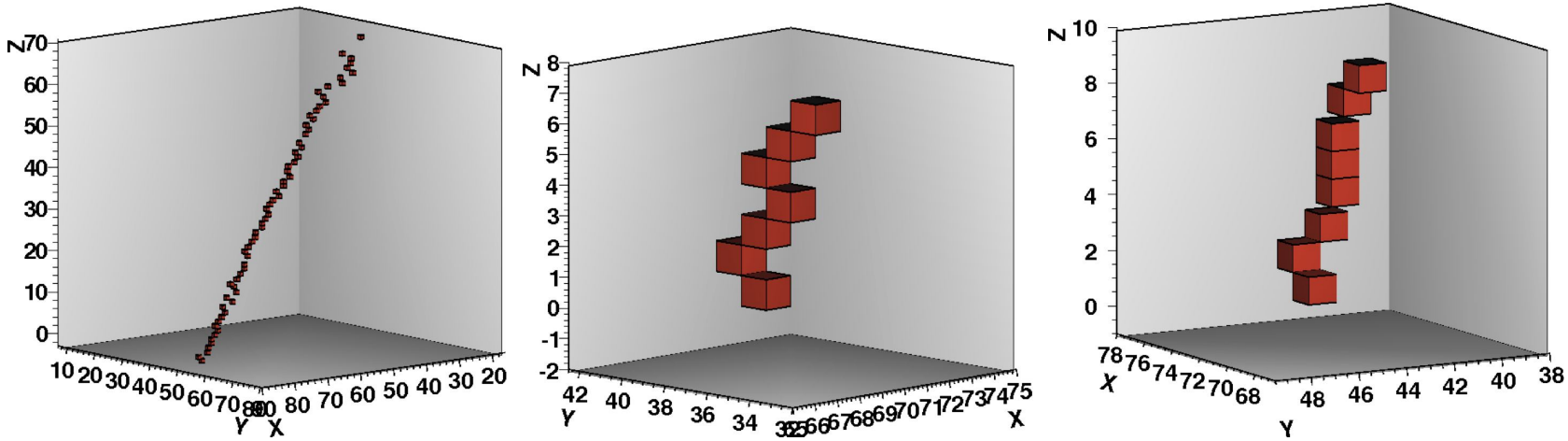
Dinesh Loomba

MIMAC (MIcro-tpc MAtrix of Chambers)

Modular TPC matrix with low thresholds

- Make a matrix of $10 \times 10 \times 25$ cm sensors
- Read out at 50 MHz





Left to Right:

- Recoil of 5.5 MeV He nuclei in 350 mbar 4He + 5%C_4H_{10}
- 8 keV H nucleus in 350 mbar 4He + 5%C_4H_{10}
- 50 keV ionization from F nucleus in 55 mbar 70% CF_4 + 30% CHF_3

Columnar Recombination

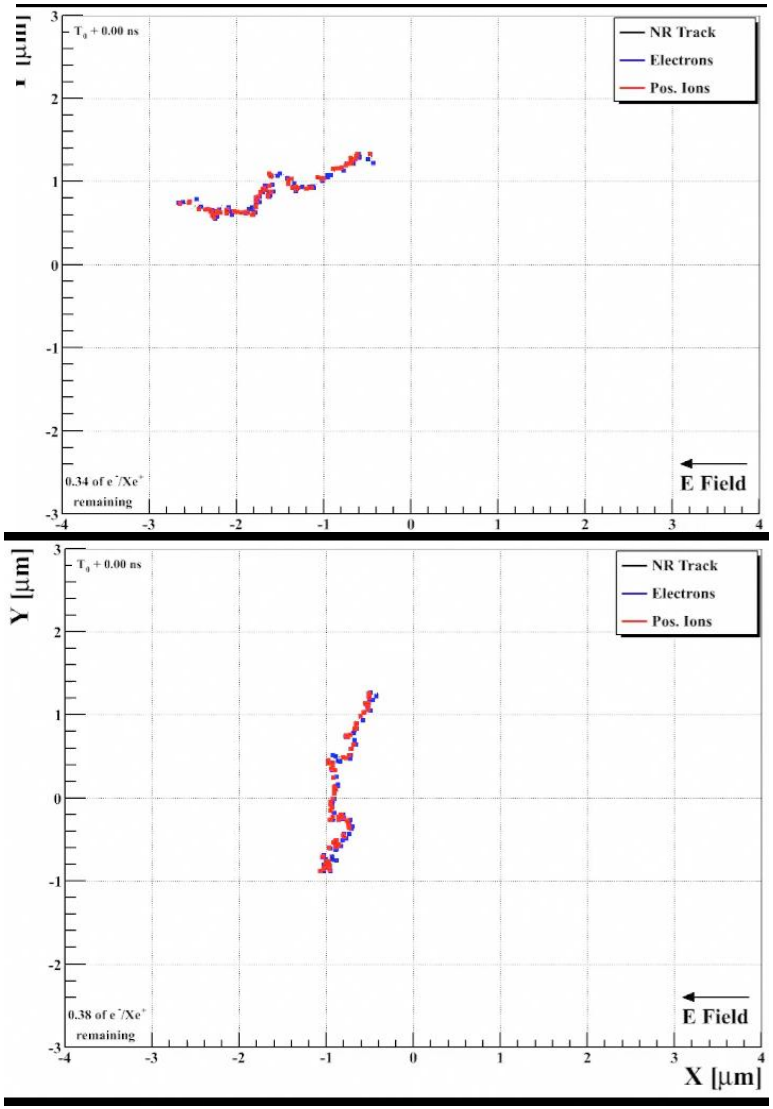
- Comparing rate of recombination to ionization rate provides alternative handle on directionality
- Allows higher densities, on the order of 10 bar, larger target masses, more feasible
- Discrimination ability defined by *columnarity*

$$C = \frac{R}{r_o}$$

- Represents maximal difference in recombination from track angle
- R is the nuclear recoil track length
- R_o is the Onsager radius

$$r_o = \frac{e^2}{\epsilon E_e}$$

- ϵ is the dielectric constant and E_e is the kinetic energy of the electron

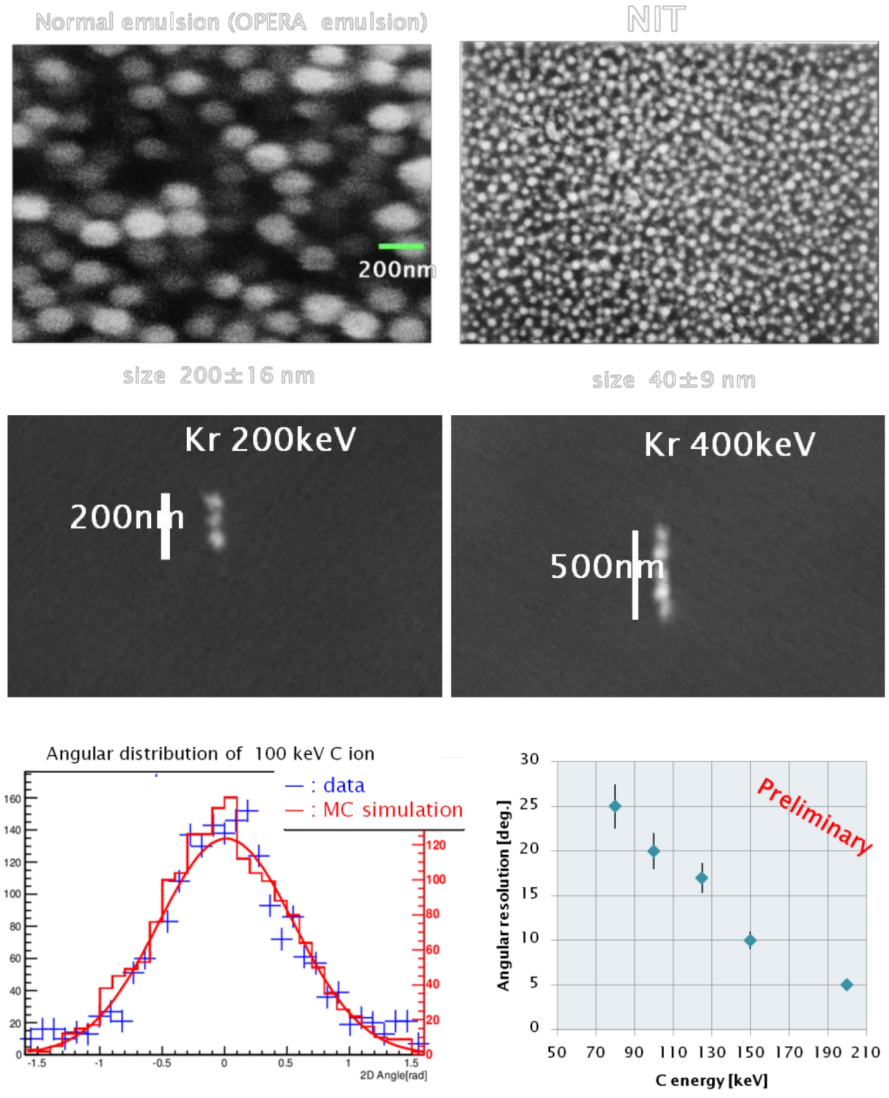


doi:10.1088/1742-6596/460/1/012006

LIDINE2013 Talk by V. Gehman

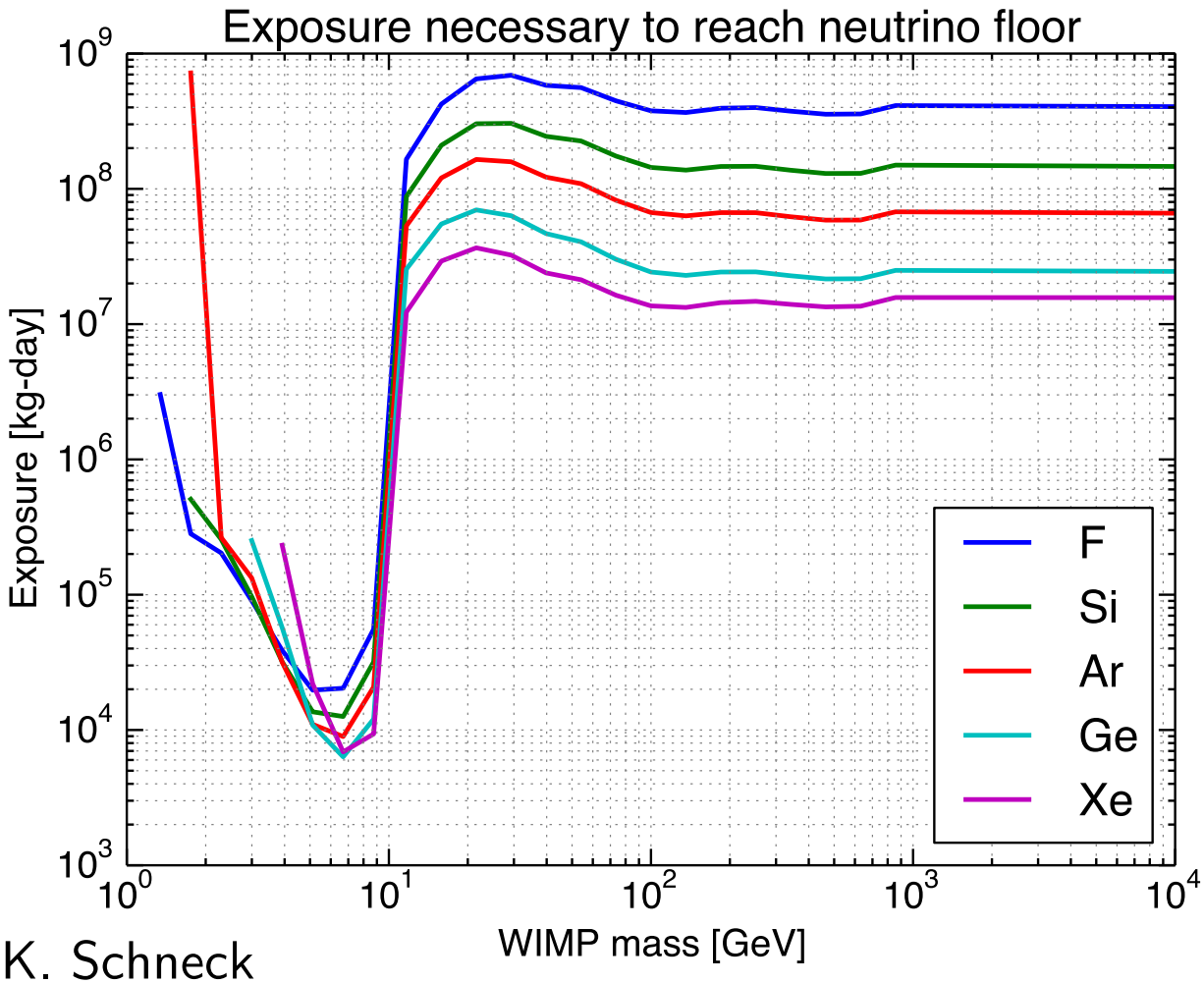
Nuclear Emulsion

- Nuclear recoil track: order of 100nm.
- Grain size: previous 200 nm, now 40 nm to 20 nm
- Composition: Ag(39.7%), Br(29.0%), C(11.7%), O(11.8%), N(4.6%). Good for low mass
- Optical automated microscopes for preselect, X-ray microscopes to detect single grain



doi:10.1088/1748-0221/9/01/C01043

A problem of scale...



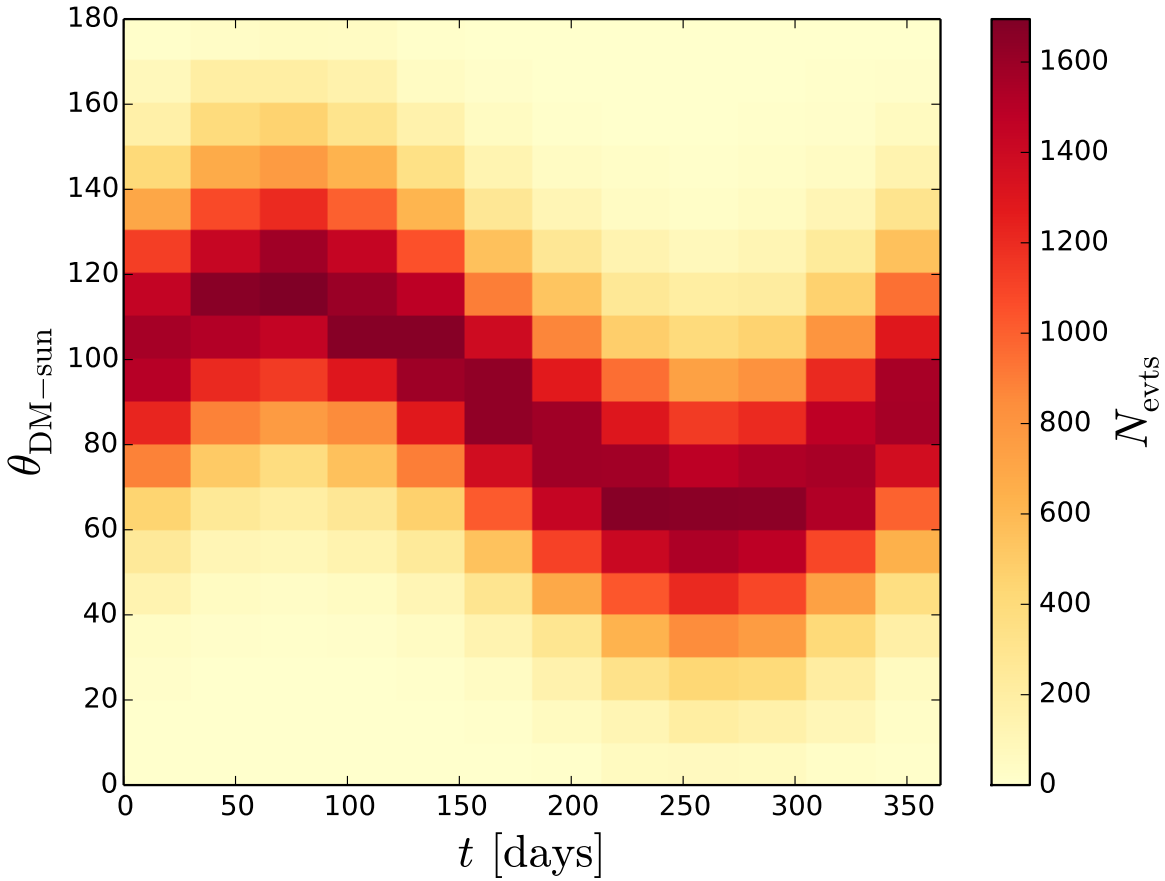
Courtesy of K. Schneck

Conclusions

- We can get below the ν floor with directional detection
- Many detector technologies are being developed now
- Scalability/Resolution are the biggest obstacles

Backup Slides

Signal from MC from pointing



ssDNA

http://arxiv.org/abs/1206.6809