Directional detection and the neutrino background

Ciaran O'Hare

with A. Green, J. Billard, E. Figueroa-Feliciano and L. Strigari

- Neutrino backgrounds to direct detection
- Directional readout strategies
- Overcoming the "neutrino floor" - ideal detector
- Experimental limitations

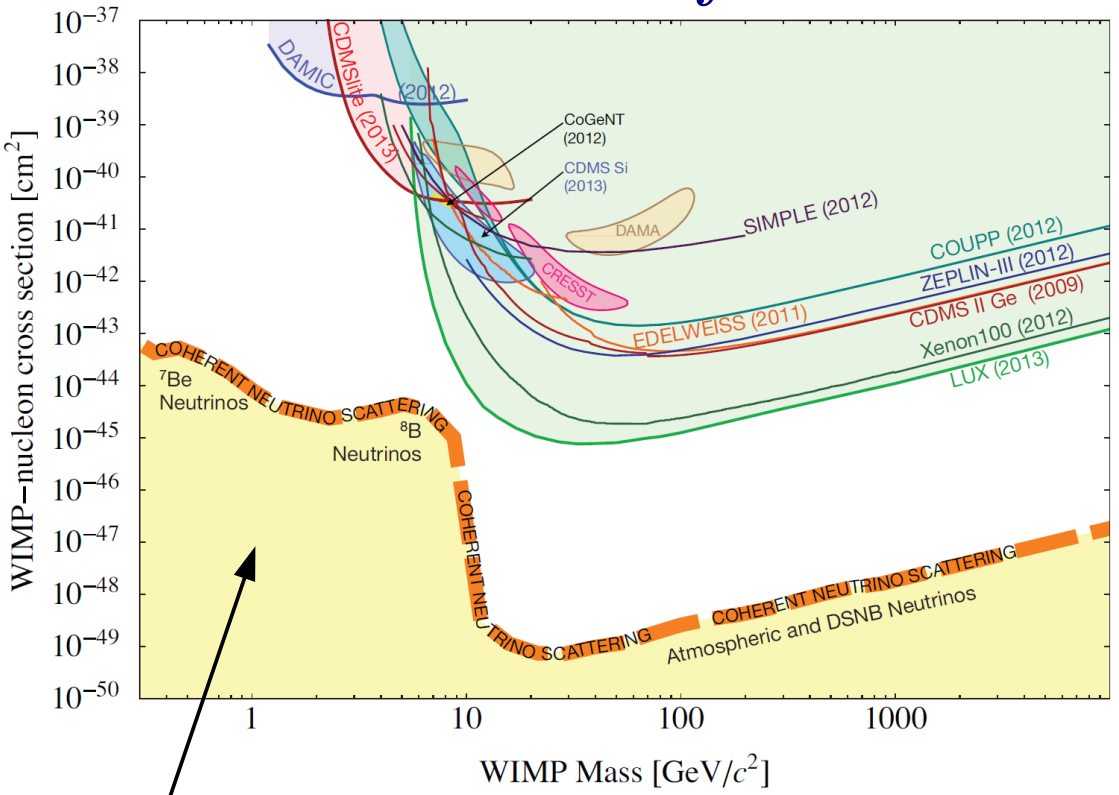
The University of Nottingham

Based on arXiv:1505.08061

Neutrino backgrounds

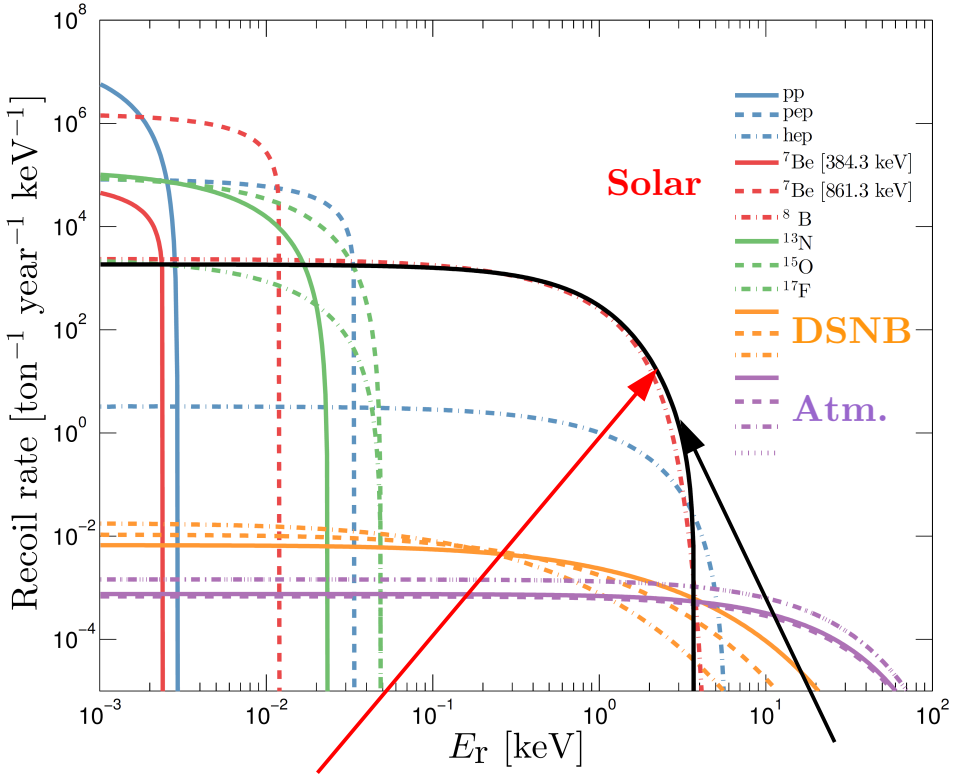
- Coherent neutrino-nucleus scattering (CNS)
- Sources: Solar, atmospheric, diffuse supernova background (DSNB)

SI Discovery limits



J. Billard *et al* [1307.5458]

Xe recoil rates



Neutrinos present a "floor" to dark matter discovery

Solutions

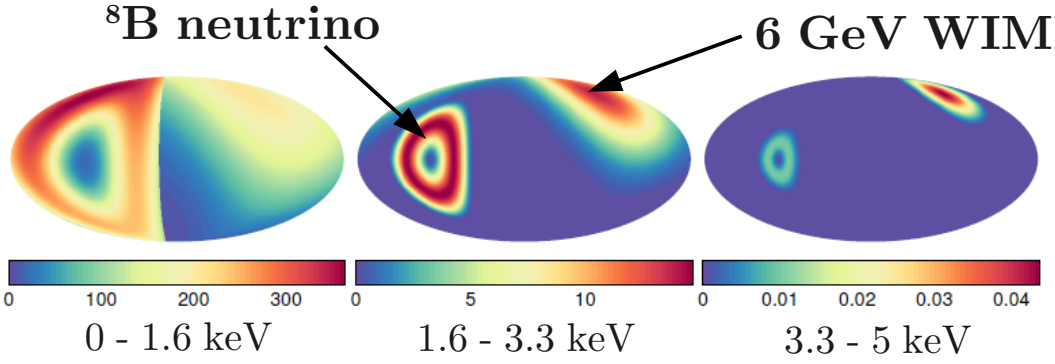
- Target - F. Ruppin *et al.* [1408.3581]
- Time - J. Davis [1412.1475]
- Direction - P. Grothaus *et al.* [1406.5047]

Readout strategies

- Is there a neutrino floor with only 1-d or 2-d projections of the recoil track?

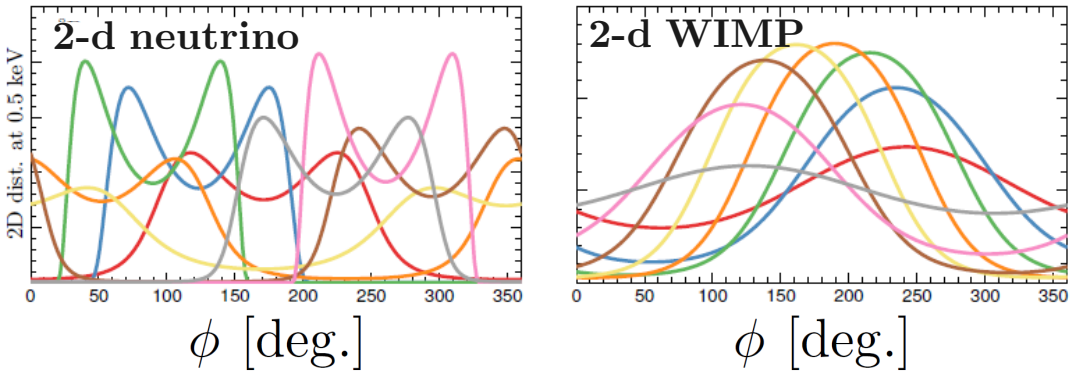
Lab frame co-ords: North West Zenith

$$\hat{\mathbf{q}} = \sin\theta\cos\phi\,\hat{\mathbf{x}} + \sin\theta\sin\phi\,\hat{\mathbf{y}} + \cos\theta\,\hat{\mathbf{z}}$$



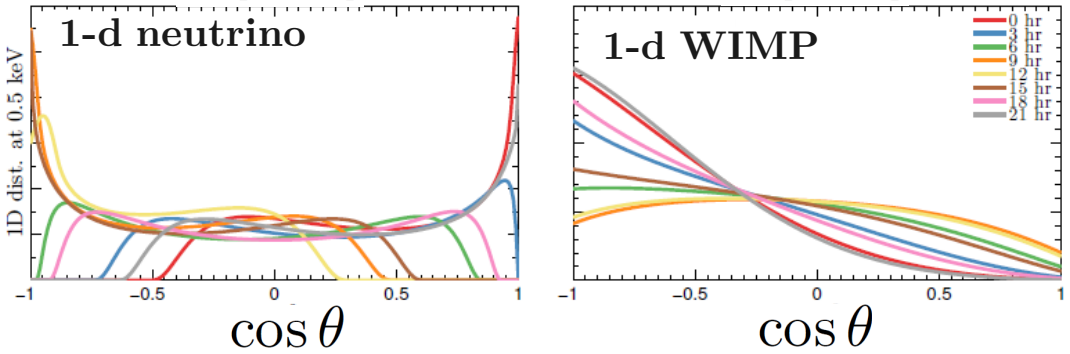
3-d readout: e.g., low pressure gas TPC

$\{E_r, \theta, \phi, t\}$



2-d readout: e.g., low pressure gas TPC (without time-sampling of anode)

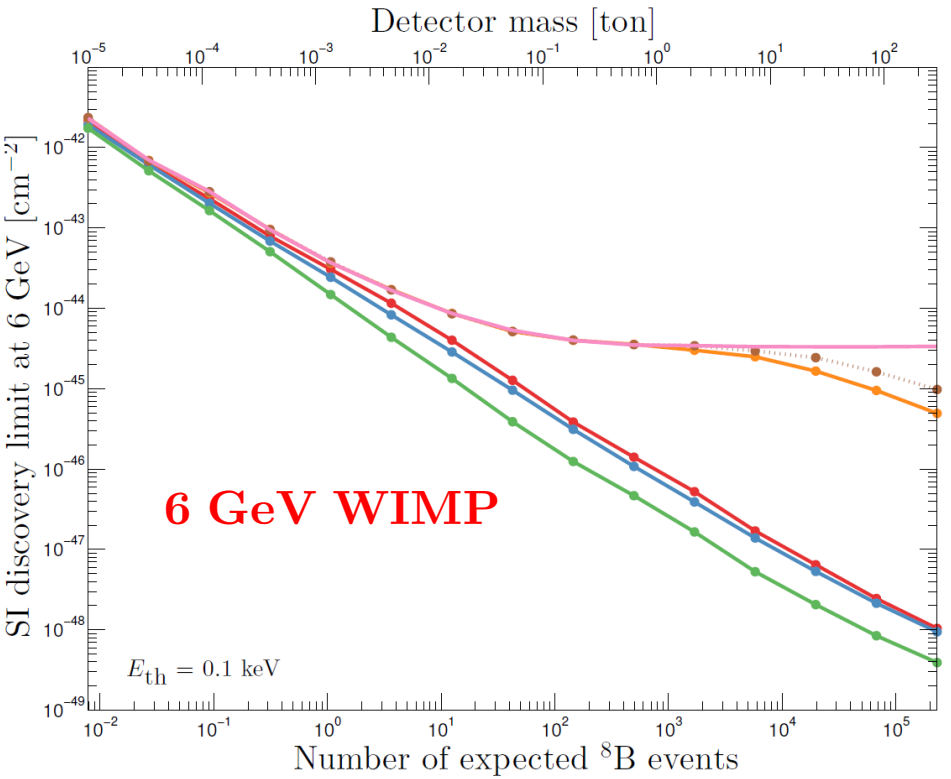
$\{E_r, \phi, t\}$

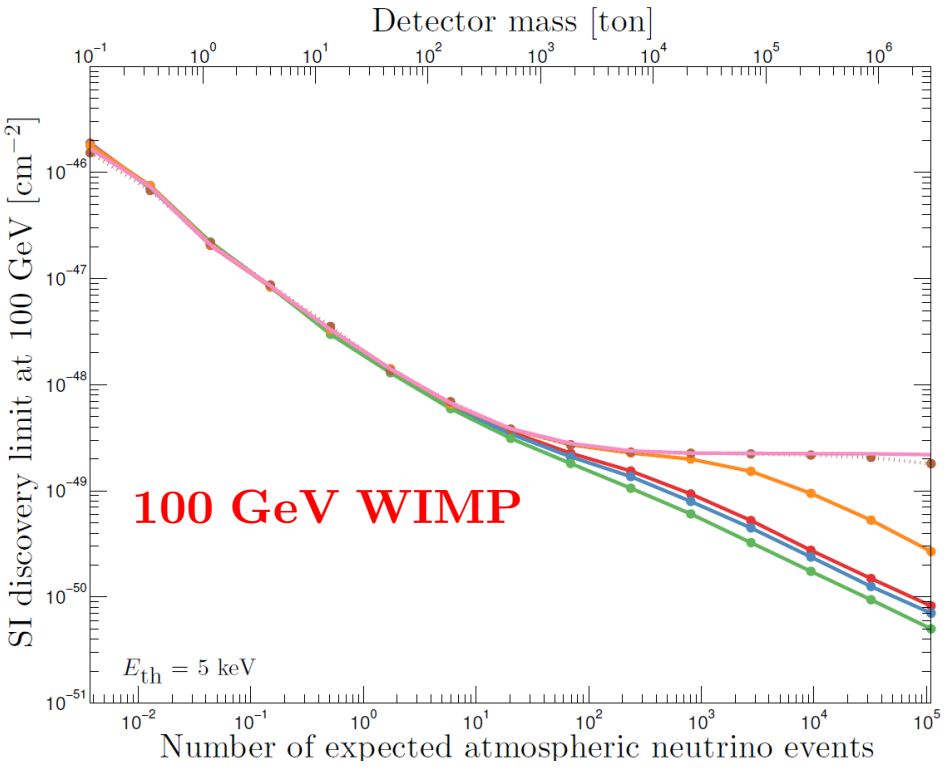


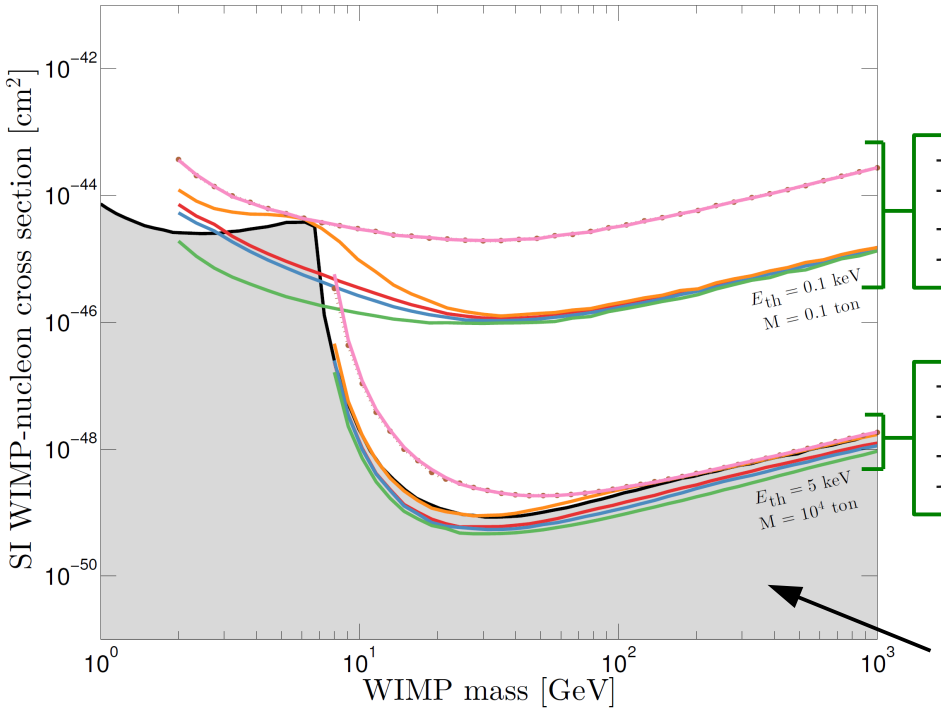
1-d readout: e.g., columnar recombination (D. Nygren) see 1503.03937

$\{E_r, \theta, t\}$

Discovery limits for Xe detector with 1 year exposure:





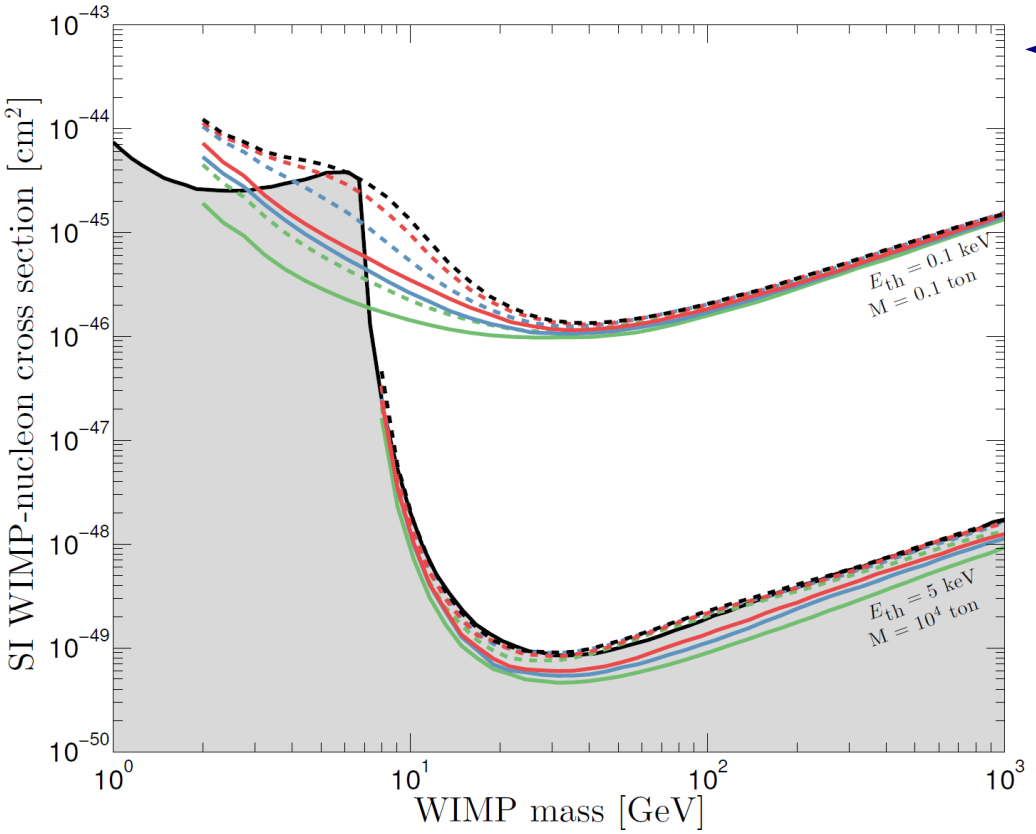


E_{th} = 0.1 keV
M = 0.1 ton

E_{th} = 5 keV
M = 10^4 ton

Counting
Time
Energy + Time
1-d + Energy + Time
2-d + Energy + Time
3-d + Energy + Time

Shaded region: nu floor from J. Billard [1307.5458]



Sense recognition

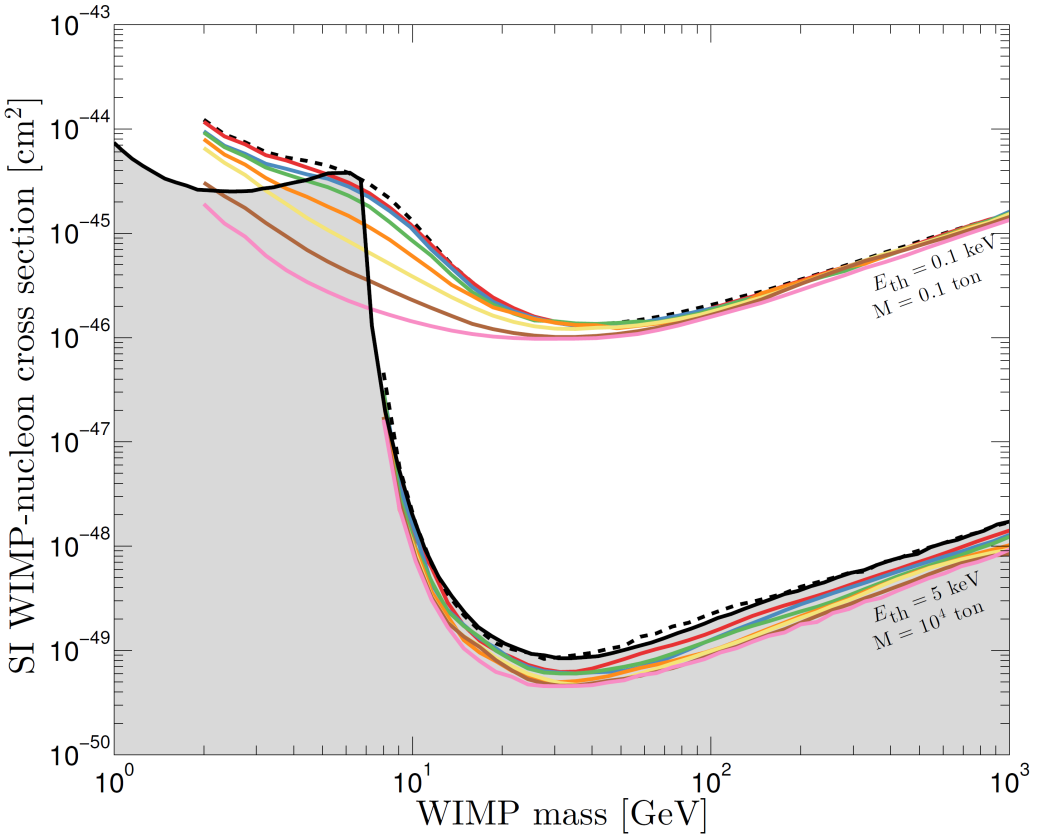
- Reduces WIMP dipole in signal
- Important for 1-d and 2-d readouts, and for WIMP masses around 100 GeV

3-d + Energy + Time
2-d + Energy + Time
1-d + Energy + Time
dashed – no sense rec.

Angular resolution

- Need to resolve WIMP and neutrino distributions separated by 60 - 120 deg.
- Very important for dealing with Solar neutrinos

angular res. = 60° 50° 40° 30° 20° 10° 0°



Summary

Directionality is a powerful tool for subtracting neutrino backgrounds

- **Comparing readout strategies (ideal detector):**
  - 3-d readout most powerful – best possible discovery limits
  - 2-d and 1-d readout also circumvent neutrino floor to lesser extent
  - Energy+time alone escapes floor only for very large exposures/detector masses

- **Sense recognition:**
  - Necessary for dealing with atmospheric neutrinos
  - Not as important for Solar neutrinos but only if 3-d readout can be achieved

- **Angular resolution:**
  - For subtracting Solar neutrinos need angular resolution better than 60 deg.
  - For subtracting atmospheric neutrinos angular resolution not a crucial issue

Based on arXiv:1505.08061