# Neutrino Magnetic Moment

- Interesting because a magnetic moment $\leq 10^{-15}$ implies the neutrino is a Dirac particle (and a Majorana particle otherwise)
- Current experimental limits are from GEMMA and Borexino, approx. $2.9 \times 10^{-11}$
- Observable is the electron recoil energy *T* from nue-electron scatters
- IsoDAR should produce an order of magnitude more nue-electron scatters than these experiments

How much better can we do?

# Cross sections

Weak-only cross section is:

$$\frac{d\sigma}{dT} = \frac{2G_F^2 m_e}{\pi}\left[g_R^2 + g_L^2\left(1 - \frac{T}{E_\nu}\right)^2 - g_R g_L \frac{m_e T}{E_\nu^2}\right]$$

(arXiv 1307.5081)

EM cross section from magnetic moment:

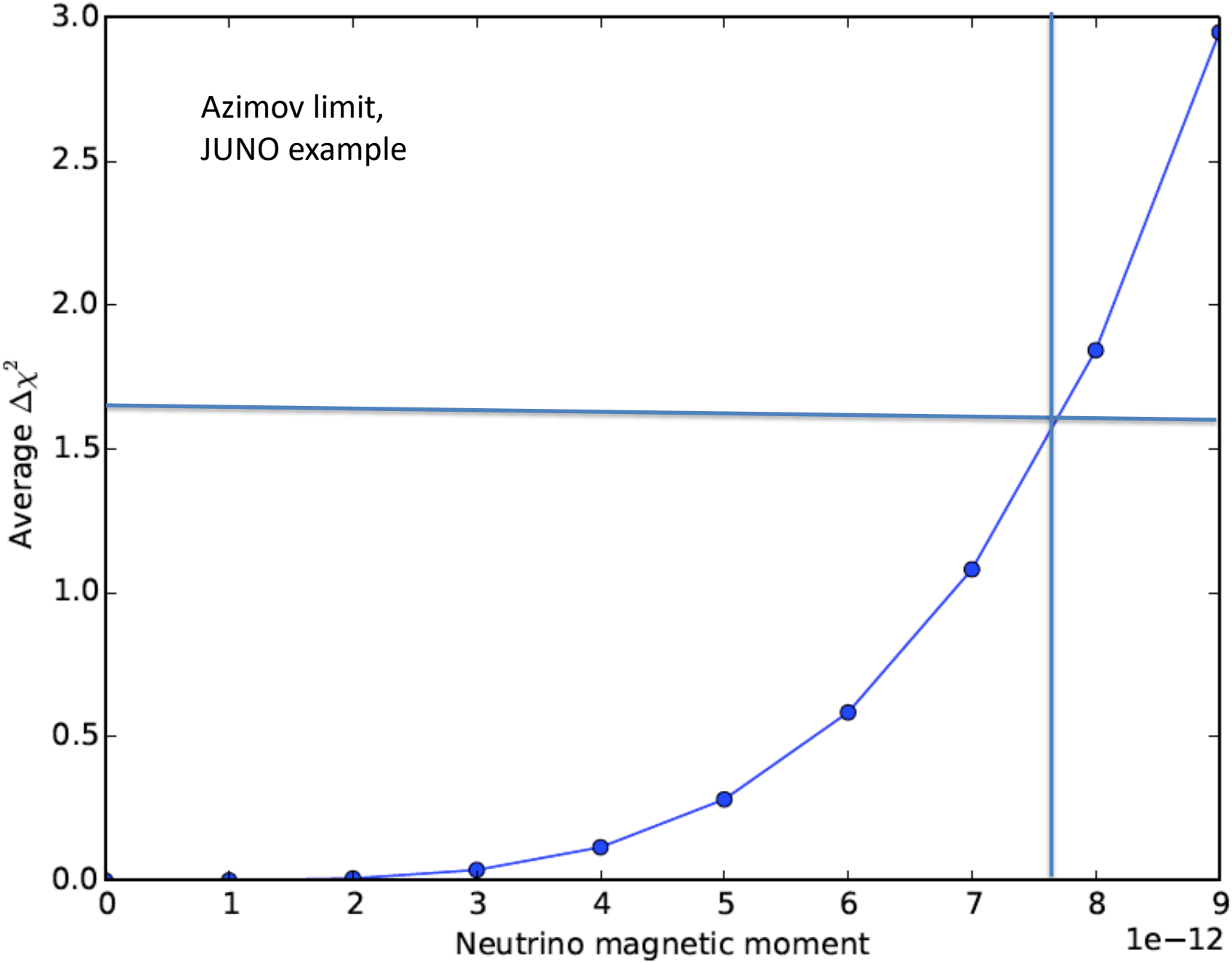
$$\left(\frac{d\sigma}{dT}\right)_{\mu_\nu} = \frac{\pi\alpha_{em}^2 {\mu_\nu}^2}{m_e^2}\left[\frac{1 - T/E_\nu}{T}\right]$$

(arXiv 0605006)

# What we tried

Our free parameter is the normalization, then:

1. Get the prediction for the weak-only case in T bins, integrated over the flux.
2. Get the statistical errors on each T bin
3. Add an extra bin which is the normalization pull term with err=0.7%
4. Find the chi2 for a weak only fit.
5. Loop over magnetic moment values for a weak+em fit
6. Azimov sensitivity at 90% CL is where the delta chi2 crosses critical value (1.64 for 90%)
7. We have no backgrounds (yet)


Azimov limit,
JUNO example
Average $\Delta\chi^2$
Neutrino magnetic moment
1e−12
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
1
2
3
4
5
6
7
8
9

# Summary of Magnetic Moment 90% CL sensitivity (Azimov method)

| Location | Threshold | Nevents | Norm constraint | Limit @90% CL |
|---|---|---|---|---|
| KamLAND | >3 MeV | 3000 | 0.7% | 4.4E-11 |
| KamLAND | >1 MeV | 7500 | 0.7% | 2.6E-11 |
| JUNO | >3 MeV | 80k | 0.7% | 2.5E-11 |
| JUNO | >1 MeV | 200k | 0.7% | 1.5E-11 |
| JUNO | >0.2 MeV | 280k | 0.7% | 7.6E-12 |
| SNO (maybe) | >0.2 MeV | 10.5k | 0.7% | 1.5E-11 |

# Light vector exchange

- Replace the additional em component from the mag moment with this:

$$\frac{\sqrt{2}G_F m_e g_v g_{\nu,Z'} g_{e,v}}{\pi\left(2E_R m_e + m_{Z'}^2\right)} + \frac{m_e g_{\nu,Z'}^2 g_{e,v}^2}{2\pi\left(2E_R m_e + m_{Z'}^2\right)^2}$$

make all g's equal
m_z = 0

(From Pedro's paper)

**Physics from solar neutrinos in dark matter direct detection experiments**

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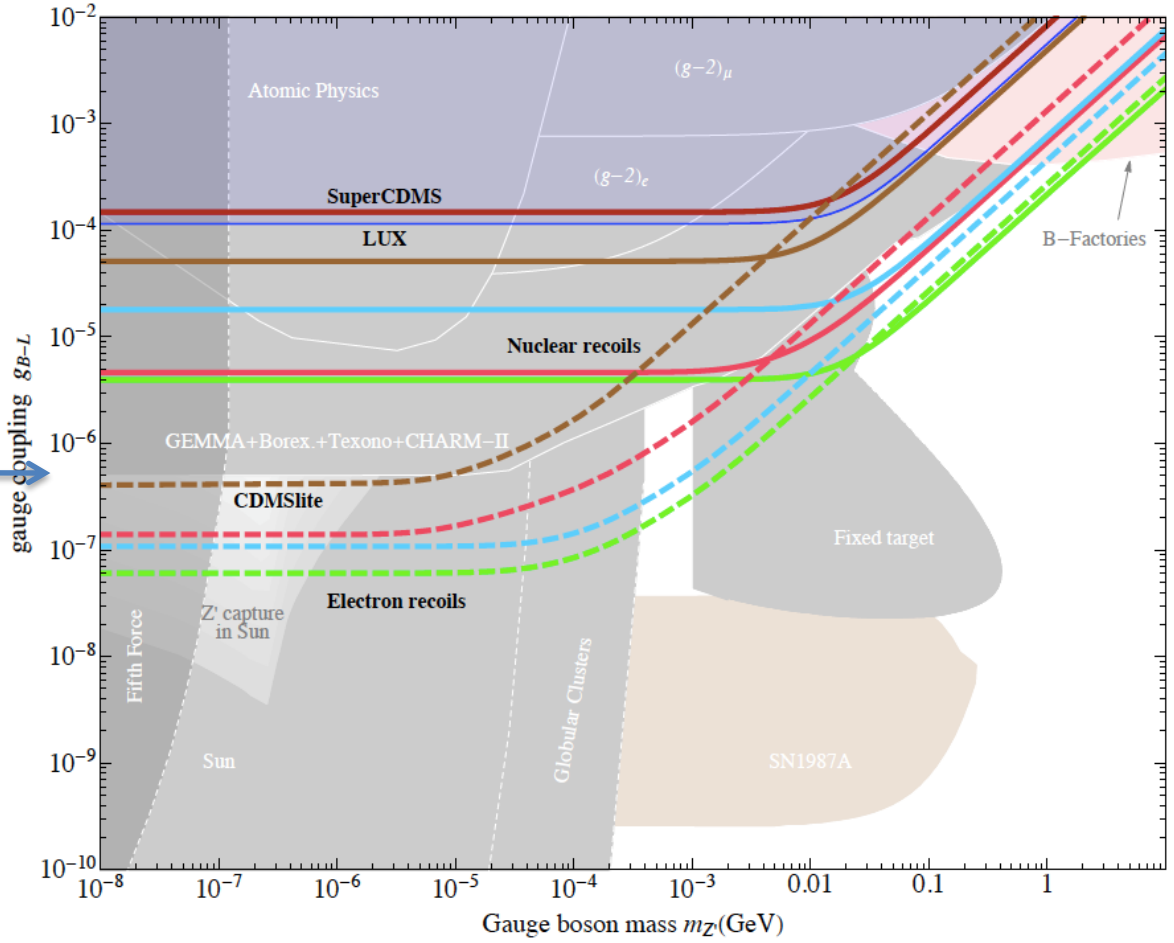
Pedro A. N. Machado,[3,4] Aaron C. Vincent,[1] and Céline Bœhm[1,5]

# Current limit

about 5E-7



# Summary of light vector exchange 90% CL sensitivity (Azimov method)

| Location | Threshold | Nevents | Norm constraint | Limit @90% CL |
|---|---|---|---|---|
| KamLAND | >3 MeV | 3000 | 0.7% | 2.35E-6 |
| KamLAND | >1 MeV | 7500 | 0.7% | 1.75E-6 |
| JUNO | >3 MeV | 80k | 0.7% | 1.75E-6 |
| JUNO | >1 MeV | 200k | 0.7% | 1.25E-6 |
| JUNO | >0.2 MeV | 280k | 0.7% | 6E-7 |
| SNO (maybe) | >0.2 MeV | 10.5k | 0.7% | 8.5E-7 |

# Why we think we cannot do this at DUNE

Georgia says:

- $10^{10}$ Ar42→ K42 decays in 5 years, with endpoint = 3 MeV
- We only get 250,000 events total (no threshold) in 5 years.

Even if we could reconstruct to point back, it seems unlikely we can reduce the rate sufficiently!

Question:

- Can we build a DUNE module that is good for low energy studies?
- Looks very hard with argon!