Limit on the effective magnetic moment of solar neutrinos from Borexino Phase-II data

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Magnetic moment of solar neutrinos

**EM neutrino interaction**
- occurs at one-loop level (for massive neutrinos only)
- changes neutrino helicity (and possibly flavor)

\[ \nu_i l_a W^+ \gamma \nu_j \]

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\[ \mu_\nu \text{ can contribute to the } \nu - e \text{ elastic scattering} \]

\[ \frac{d\sigma_{EM}}{d T_e} \propto \mu_{\text{eff}}^2 \left( \frac{1}{T_e} - \frac{1}{E_\nu} \right) \]

effective magnetic moment is \( \mu_\nu \) for a flavor mixture

**Borexino experiment**
- large mass (278 tons liquid scintillator)
- low threshold (\( \sim 200 \text{ keV on recoil electrons} \))
- energy resolution (\( \sim 5\% @ 1 \text{ MeV} \))
Borexino results

Electron recoil spectrum

Effective magnetic moment of solar neutrinos

1291.5 days livetime (Phase-II) spectral fit of solar neutrino data

Magnetic moments of mass and flavor eigenstates

Dirac neutrinos: $|\mu_{11}^D| < 3.4; \quad |\mu_{22}^D| < 5.1; \quad |\mu_{33}^D| < 18.7$

Majorana neutrinos: $|\mu_{12}^M| < 2.8; \quad |\mu_{13}^M| < 3.4; \quad |\mu_{23}^M| < 5.0$

Flavor eigenstates: $|\mu_e| < 3.9; \quad |\mu_\mu| < 5.8; \quad |\mu_\tau| < 5.8$

in $10^{-11}\mu_B$ (90% C.L.)