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DARWIN

Neutrino Physics with DARWIN

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Introduction

Large-scale Xenon based dark matter detectors, that are under development, have detection capabilities for rare events beyond dark matter. DARWIN (DARk matter WImp search with liquid xenoN), a multi-ton liquid xenon detector can detect low-energy neutrinos, and also search for 0νββ decay of ^{136}Xe. With its 40 tons active liquid target, low-energy threshold and ultra-low background level, DARWIN will be able to detect solar neutrinos from pp and ^{7}Be channels with ~2% precision. It will be also sensitive to low energy signals triggered by neutrino interaction originating from coherent neutrino-nucleus scattering. One source of these neutrinos is core-collapse supernovae, where DARWIN will be sensitive to all neutrino flavors.

DARWIN Detector

www.darwin-observatory.org

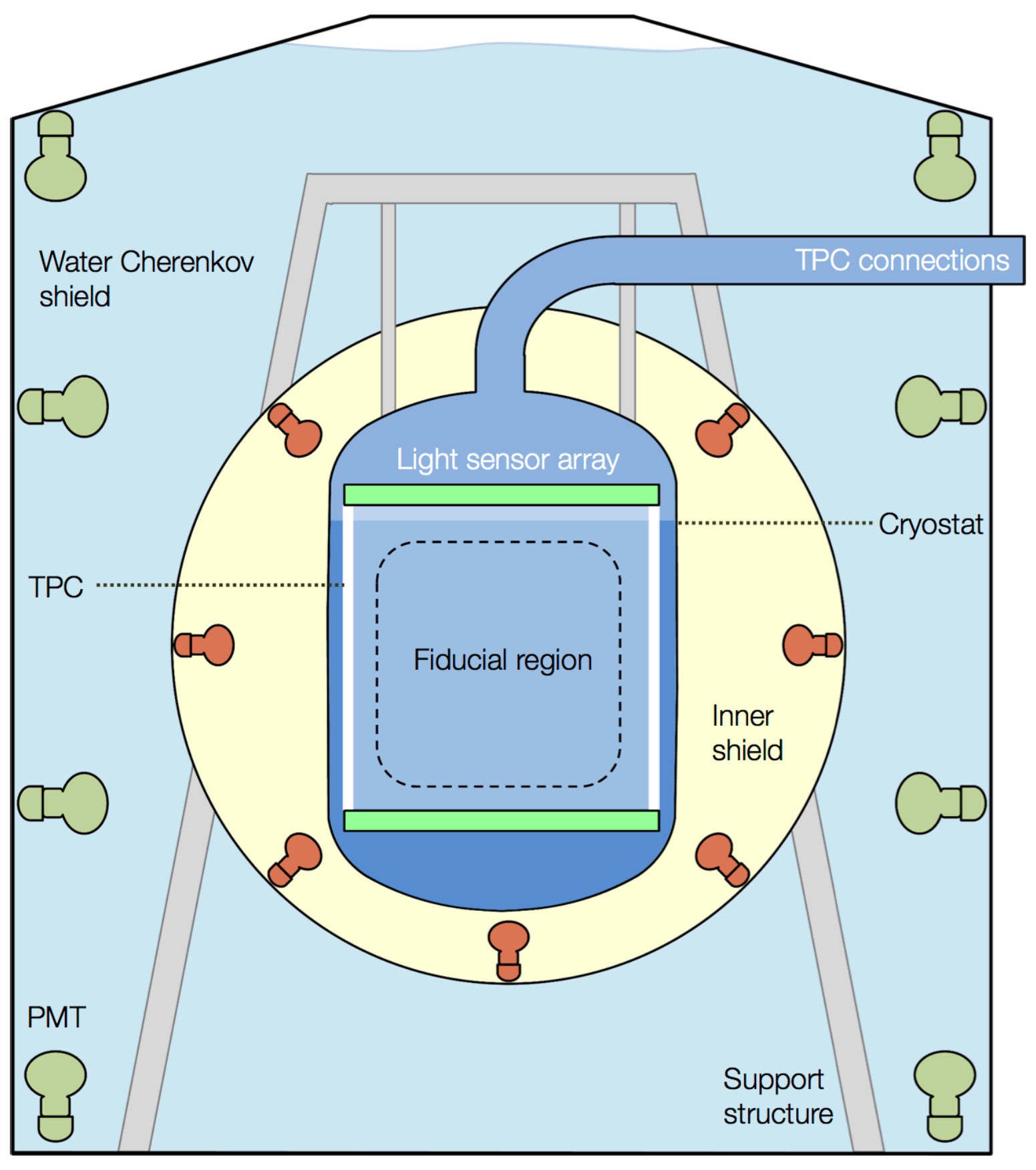

Figure 1. *A Sketch of the DARWIN Detector. The Cryostat surrounded by two shields: water Cherenkov and scintillation shield.*

- Physics goal is the search for WIMPs:
  - elastic and inelastic scattering
  - types of couplings: spin-dependent and spin-independent
- Working principle is based on dual-phase noble gas time projection chamber
  - Prompt scintillation light (S1) and delayed proportional scintillation light signal from the charge (S2) are measured
  - Both signals are used for vertex reconstruction
- It consists of:
  - Double-walled, low-background cryostat
  - Dual phase TPC filled with ~40 tons of Liquid Xenon
  - Arrays of VUV photosensors, on the top and bottom of TPC
  - Inner shield filled with liquid scintillator(optional)
  - Outer shield filled with water
  - Cryostat is filled with ~50t of LXe (Liquid Xenon)

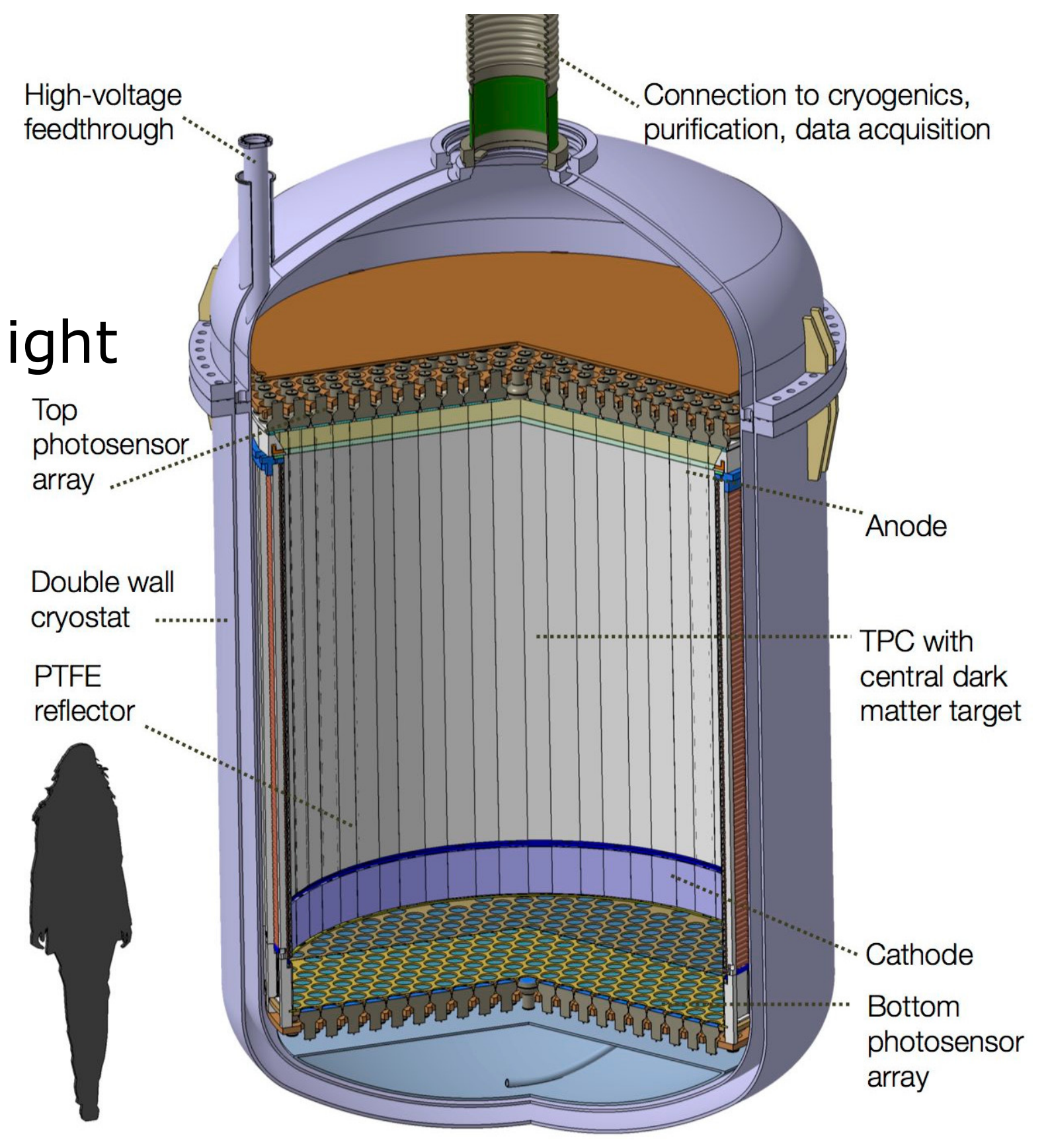

Figure 2. *DARWIN cryostat encompassing, the TPC and photosensors in 50t LXe.*

Potential Physics with DARWIN

Solar Neutrinos Detection

- The energy generated by the sun comes mainly from the *pp cycle* where 99.76% of solar neutrinos are produced from these channels:

$$p + p \rightarrow \ {}^{2}H + e^{+} + \nu_e$$
$$^{7}Be + e^{-} \longrightarrow \ {}^{7}Li + \ \nu_e$$

- Neutrinos are detected in DARWIN by elastic scattering:

$$\nu_x + e \quad \rightarrow \nu_x + e$$

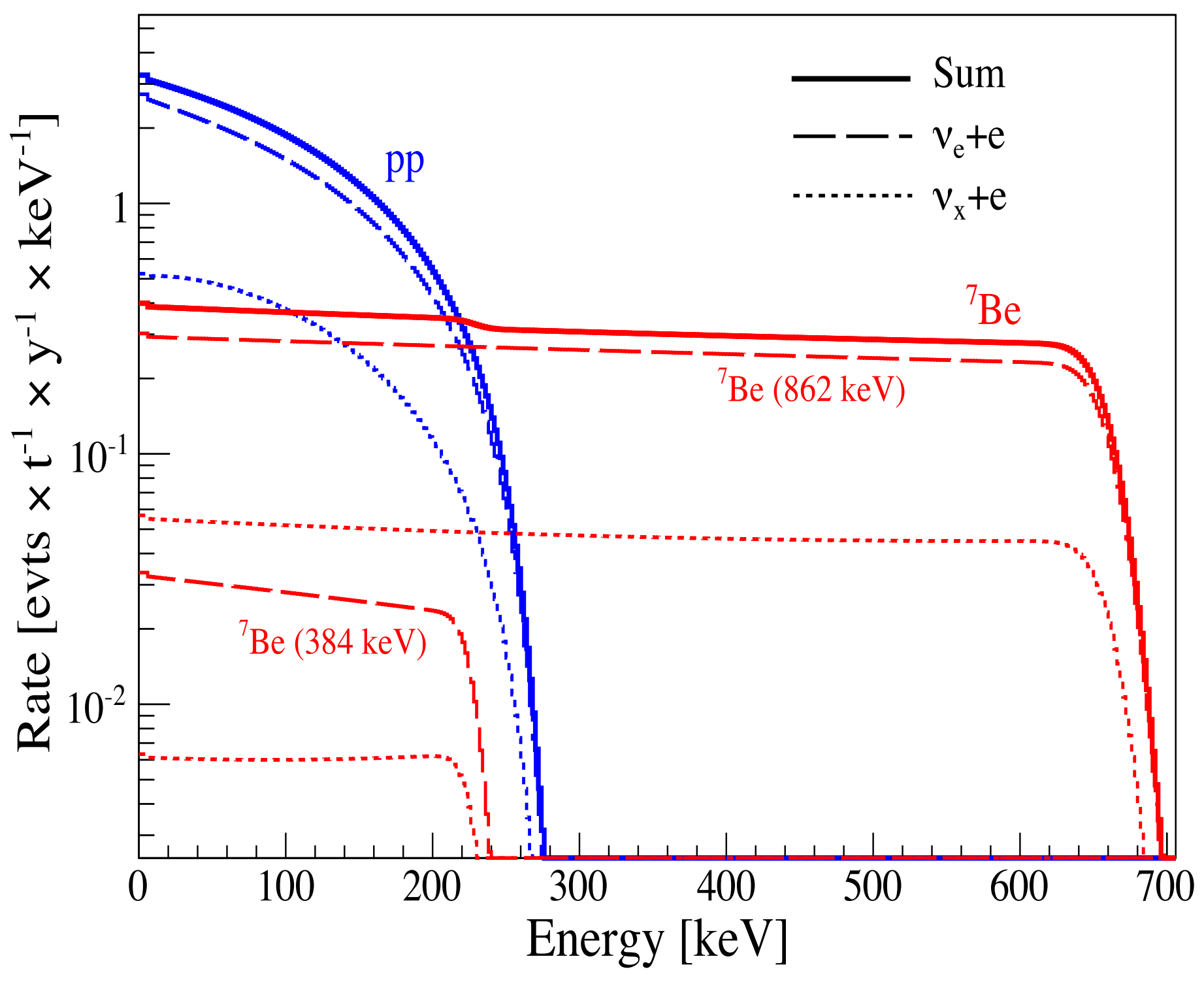

Figure3. *Differential electron recoil spectra for pp and ^{7}Be-neutrinos in LXe[1,2]*

- Assuming a 30t LXe fiducial mass and energy range 2-30 keV, DARWIN is expected to detect ~ *10^4 pp-ν* in 5 years[1]
- A <1% precision in pp ν-flux with DARWIN will:
  - Allow high precision real-time comparison between solar luminosity in photons, and luminosity inferred by the direct measurement of neutrinos

- Scattering ν-rates in the detector, depend on survival probability P_{ee}

$$P_{ee} = cos^4\vartheta_{13}(1 - 0.5sin^2\vartheta_{12}) + sin^4\vartheta_{13}$$

- Change of neutrinos flavor is governed by the LMA-MSW Effect
- LMA-MSW predicts for pp neutrinos a tiny matter affect, i.e. vacuum dominated oscillations

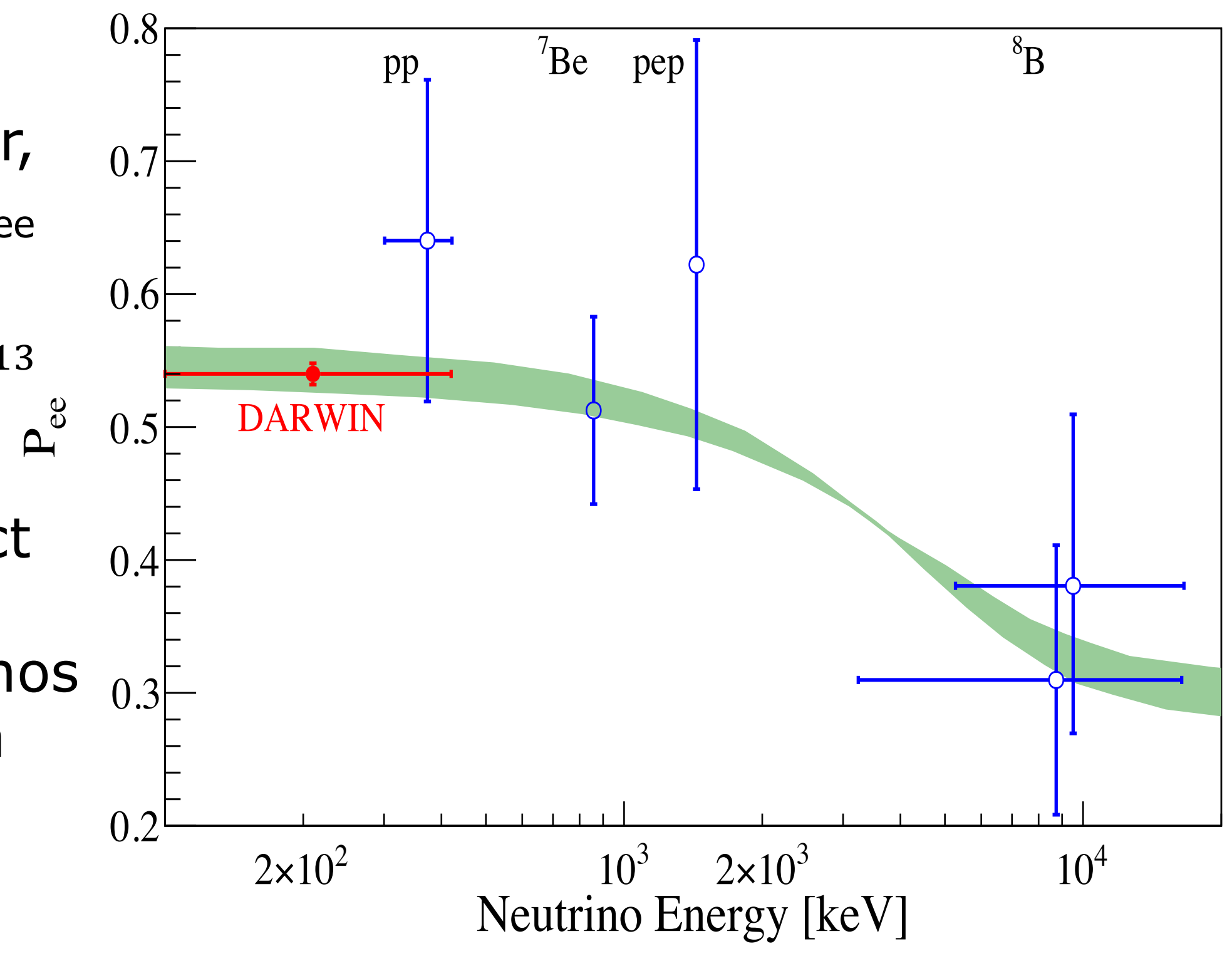

Figure4. *Survival probability of ν_e produced by different reactions in the sun[1].*

Sensitivity to 0νββ decay

- Neutrinos are not electrically charged
  - Possibility for neutrinos to be their own antiparticle, i.e. Majorana particles
- Search for the Majorana particle and lepton number violation, through the detection of the 0νββ decay
- ^{136}Xe is a good candidate for 0νββ with $Q_{\beta\beta}$ ~2.46MeV
- The overall background in DARWIN is dominated by detector materials
- Challenge: tune DARWIN to measure spectra at both O(10keV) & O(2MeV)
- σ_E ~1% allow DARWIN to be sensitive to 0νββ

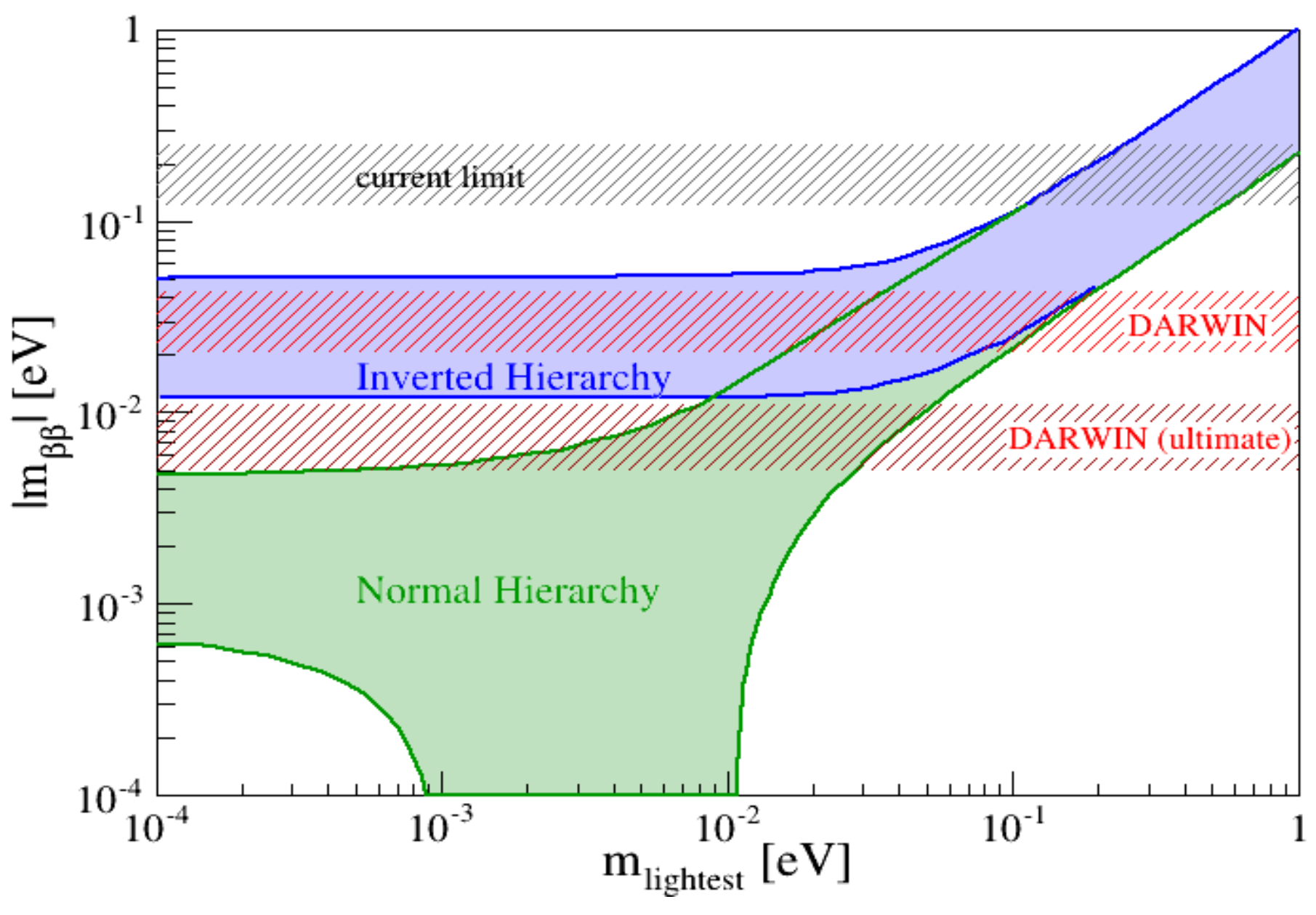

Figure 5. *DARWIN expected sensitivities to the effective Majorana neutrino mass. These sensitivities assumes a 30 t·y exposure of natural xenon and background dominated by the detector materials. The ultimate case with 140 t·y assumes no materials' background. In this case only background from ^{222}Rn, 2νββ and solar* neutrinos from ^{8}B is considered[1].

- With an exposure of 30 t·y, DARWIN is sensitive to $T_{1/2}>5.6 \cdot 10^{26}$y with 90%C.L
- There is no theoretical preference for a Normal or Inverted Mass Hierarchy
- DARWIN is sensitive to $|m_{\beta\beta}|$ in the range of 0.02-0.04eV
- The "ultimate" case assumes 140 t·y without materials' background

1- J. Aalbers, et al., DARWIN collaboration, arXiv:1606.07001
2- L. Baudis et al., JCAP 01 (2014) 044