Discovering neutrinoless double-beta decay in the era of precision cosmology

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Introduction

- Neutrinoless Double Beta Decay ($0\nu\beta\beta$) is a nuclear beta Decay which emmits two left-handed electrons but no neutrinos.
- This could be possible due to the possible Majorana nature of neutrinos.
- The next-Gen $0\nu\beta\beta$ experiments are funded and designed to investigate the whole parameter space of Inverted Ordering.
- Questions adressed in this work are:
  →How is the Discovery Probability (P_D) of these experiments in case of Normal Ordering?
  →And how is the $0\nu\beta\beta$ hunt influenced by cosmological measurements of the neutrino mass sum?

Discovery Probability of $0\nu\beta\beta$-experiments

- The half life for $0\nu\beta\beta$ can be calculated via

$$\frac{1}{T_{1/2}} = G\, g_A^4\, \mathcal{M}^2 \left(\frac{m_{\beta\beta}}{m_e}\right)^2, \qquad (1)$$

  where G is the kinematically allowed phase space factor, $g_A^4 \simeq 1.276$ is the axial-vector coupling, $\mathcal{M}$ the nuclear matrix element (NME).
- The crucial parameter is the effective majorana mass $m_{\beta\beta}$ which is calculated the following way

$$m_{\beta\beta} = |c_{12}^2 c_{13}^2 m_1 + s_{12}^2 c_{13}^2 m_2 e^{i\alpha_1} + s_{13}^2 m_3 e^{i\alpha_2}|, \qquad (2)$$

  where c_{ij} and s_{ij} are the cosines and sines of the oscillation angles, m_i the eigenvalues of the neutrino mass eigenstates and α_i are the so-called Majorana phases.
- We calculate a combined posterior of data from neutrino oscillation experiments, cosmology and previous $0\nu\beta\beta$ experiments.
- By sampling from the posterior, we generate pseudo-data sets for the future $0\nu\beta\beta$-experiments and calculate the Posterior Odds.
- We define our **Discovery Criteria** as follows

$$\mathcal{O}_1 = \frac{P(D|H_1)}{P(D|H_0)}\frac{P(H_1)}{P(H_0)} > 10, \qquad (3)$$

  where $P(D|H)$ are the probabilities of the data given the hypothesis that $0\nu\beta\beta$ exists (H_1) or not (H_0), and $P(H_{1/0})$ their corresponding priors which are assumed to be equal.

Results

- **We perform a scan over m_1 for different NME models.**
- We find that the P_D starts rising for values of $m_1 > 1meV$.

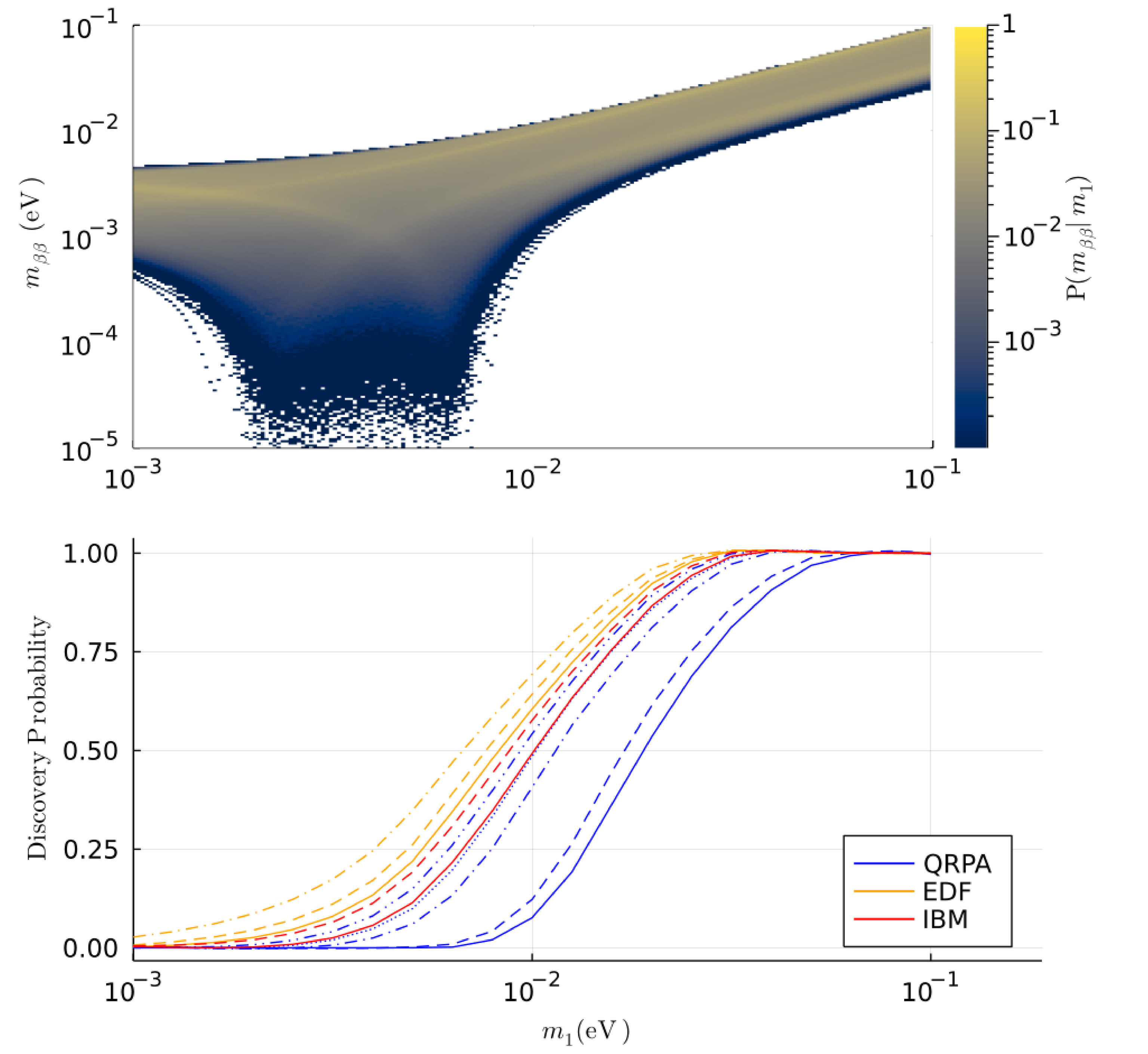

Figure 1:(Top) Conditional one-dimensional posterior probabilities for $m_{\beta\beta}$ computed for a scan of fixed m_1 values. (Bottom) Discovery probability, P_D, for a combined analysis of CUPID, LEGEND and nEXO as a function of the true value of $_1$.

- **In the second analysis we investigated the influence of current cosmological bounds and possible future detections or bounds on the neutrino mass sum.**
- The most optimistic scenarios reach a P_D up to $80 - 90\%$.
- The most pessimistic scenario can still reach a P_D up to 50%.
- All calculations are heavily influenced by the chosen NME model (horizontal ticks in FIG.2).

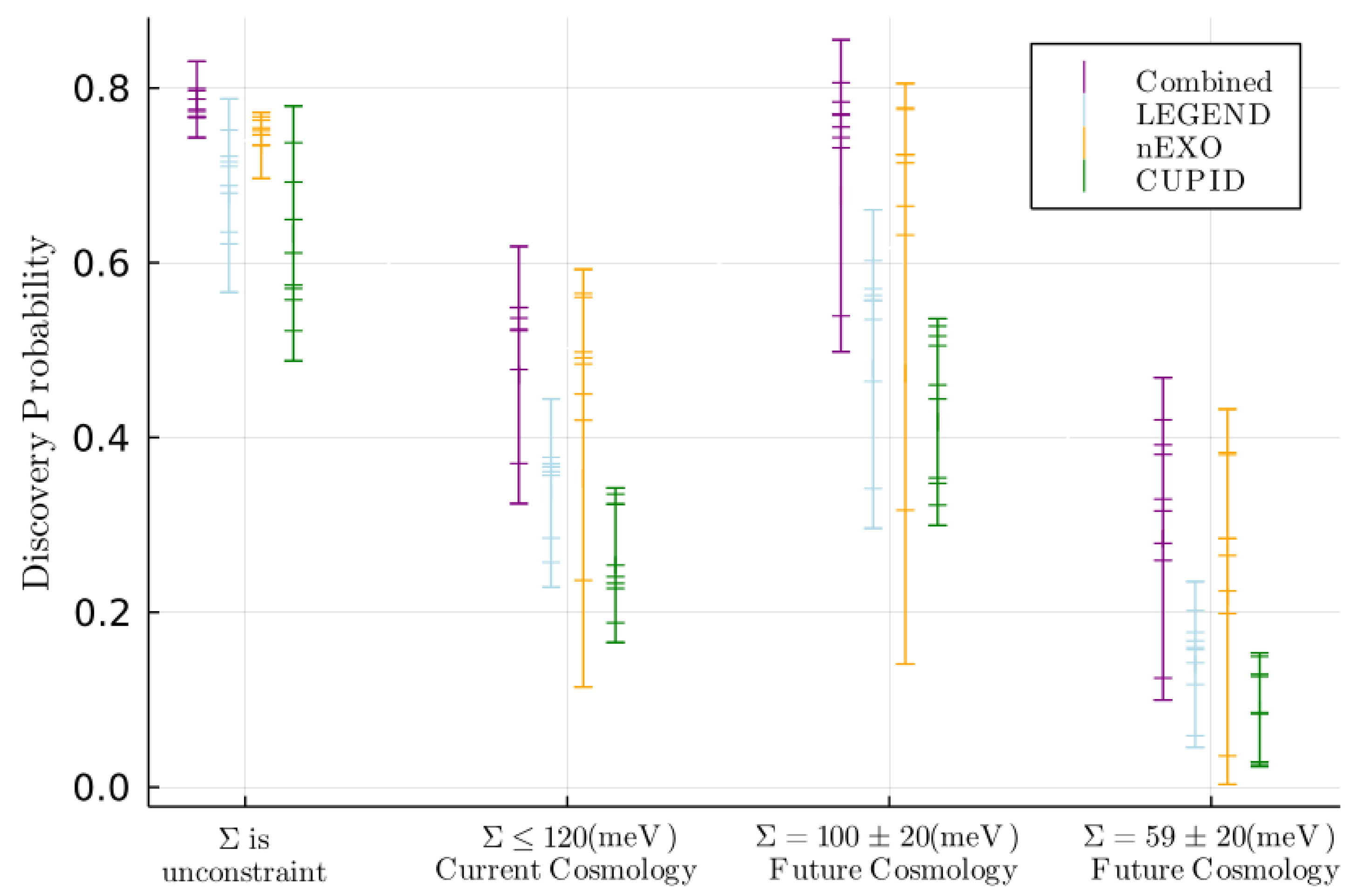

Figure 2:Discovery probabilities for a selection of proposed experiments and their combination under different scenarios and set of NME values. The calculation has been performed using fixed sets of NME values.