Report from WG Q2
$0\nu\beta\beta$
DRAFT

Q2: What can we learn about neutrino mass and mass hierarchy from double beta decay experiments, and what is their future reach?

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The Future of ν mass measurements

Extracting ν mass from an observation of 0νββ

- Requires an understanding of the lepton number violating (LNV) interaction mechanism – must assume a model. For comparison purposes, experiments assume that LNV arises from light Majorana neutrino exchange with SM interactions (LMNEx).
- Requires calculation of theoretical nuclear matrix elements. NME predictions vary depending on the methods used, and result in a range of values that in some cases differ by a factor of ~2.

What are the prospects to determine ν mass from 0νββ?

- First need definite discovery of 0νββ - Observe 0νββ in 3-4 different isotopes, using a variety of experimental techniques. If one sees it in one, then one would expect to see it in the others. Calculated values of $\langle m_{\beta\beta} \rangle$ depend on the assumed LNV interaction.

- If 0νββ is observed, and $\langle m_{\beta\beta} \rangle$ were found to have a value in the range of 100 meV - 1 eV, then assuming that LNV is from LMNEx, one would expect that both β-decay and cosmology measurements should find similar values of m_ν. If not, then the 0νββ results are indicating that the LNV process is not from light Majorana neutrino exchange.

- In the LMNEx model, with the current lepton mixing matrix values, it is possible because of cancelations that $\langle m_{\beta\beta} \rangle = 0$, even if neutrinos are Majorana particles.

What is the future reach of ν mass for 0νββ?

Near term

- In the next 3-4 years, measurements with ~100 kg of material are expected be made in ^{76}Ge, ^{130}Te, ^{136}Xe, ^{150}Nd using a variety of different techniques.
- These experiments will have sensitivities to decay half-lives in the range of 10^{25} to 10^{26} years and $\langle m_{\beta\beta} \rangle$ sensitivities in the range of ~100 meV.
- Background reduction is the key to reaching these sensitivities.

What is the future reach of ν mass for 0νββ?

Longer term

- Assuming that backgrounds in the range of 10^{-3} to 10^{-4} counts/keV-tonne-year can be achieved by experiments at the 100 kg scale, then it is likely that 1-tonne experiments will be able to reach the 10-20 meV sensitivities, covering a large portion of the mass range expected by LMNEx. R&D efforts are underway for a variety of isotopes including ^{76}Ge, ^{82}Se, ^{100}Mo, ^{116}Cd, ^{130}Te, ^{136}Xe, and ^{150}Nd. These experiments will have sensitivities to decay half-lives in the range of 10^{26} to 10^{27} years. At these decay rates, one only expects to observe 5-10 decays per tonne-year.

- If one can reach backgrounds at the 10^{-4} to even the 10^{-5} counts/keV-tonne-year level, then measurements at the scale of 10 tonnes might be possible. Scalability will be a major factor for such experiments.

What can one learn about mass hierarchy from $0\nu\beta\beta$?

- For 1-tonne scale experiments, with sensitivity to $\langle m_{\beta\beta} \rangle$ at the level of 10-20 meV, it will not be possible to distinguish the inverted from the normal hierarchy.

What constitutes a discovery of $0\nu\beta\beta$-decay?

- **Evidence** : a combination of
  - Correct peak energy
  - Single-site energy deposit
  - Proper detector distributions (spatial, temporal)
  - Rate scales with isotope fraction
  - Good signal to background
  - Full energy spectrum (backgrounds) understood.
- **Further confirmation** : more difficult
  - Observe the two-electron nature of the event
  - Measure kinematic dist. (energy sharing, opening angle)
  - Observe the daughter
  - Observe the excited state decay(s)
- **Convincing**
  - Observe $0\nu\beta\beta$ in several different isotopes, using a variety of experimental techniques

Testing the Klapdor-Kleingrothus ^{76}Ge Result

- Discovery requires both:
  - Confirmation in ^{76}Ge by other experiments (GERDA and/or MAJORANA)
  - Observation of $\beta\beta$-decay in a different nucleus or nuclei (^{130}Te, ^{136}Xe, ...)

How do nuclear matrix elements influence the value of ν mass found from 0νββ and what are the prospects for reduced uncertainties?

- NME values generally vary smoothly as a function of A. Current calculations using different techniques only agree within a factor of ~2 for some nuclei.

- There are prospects for improvement, both from improved calculations and from additional ancillary measurements that can provide constraints or checks. For example the recent measurements in the A=76 region by John Schiffer have resulted in reducing the differences between calculations of NME for ^{76}Ge using different techniques (SM and QRPA).

- It is unlikely in the next 10 years that nuclear matrix elements will be "determined" at the 10% level, so there will be a range of neutrino masses from uncertainties of the NME.