Comparing Sensitivities of Counting and Fitting Methods in Neutrinoless Double Beta Decay Experiments

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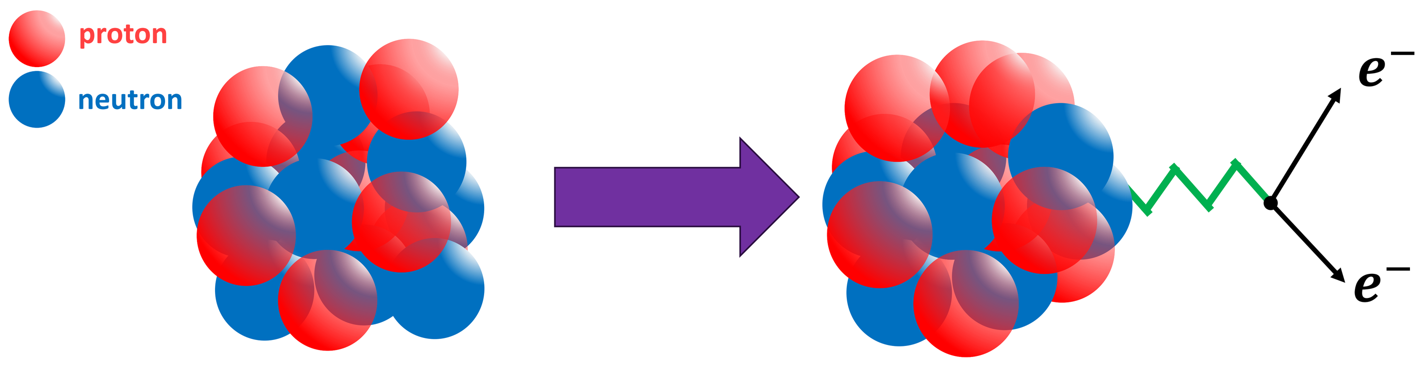
I. Motivation

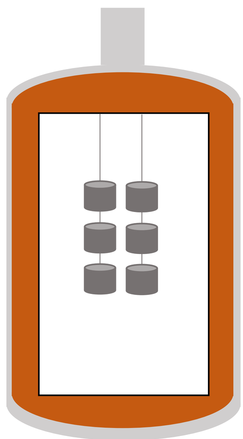


$$^{A}_{Z}X \rightarrow {}_{Z+2}{}^{A}Y + 2e^- + 2\bar{\nu}_e$$

- Finding neutrinoless double beta decay would provide evidence for the violation of lepton number conservation and indicate that neutrinos are Majorana particles;
- Although so many experimental efforts have been made, the process has yet to be observed;
- Search experiments often use different approaches to derive the limits of half-lives, which may raise issues regarding sensitivity.

II. Methods to detemine the half-lives

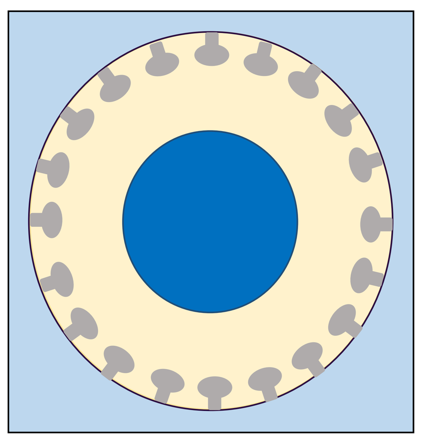
Crystal detector



- High **energy resolution** which can achieve 0.3%;
- Excellent energy resolution, together with the low background in the Region of Interest, makes the **Counting method** a simple solution.

- Counting method is widely used in many experiments like Gerda[2] and Cuore[3].

Scintillation detector



- Extremely high **exposure.** The sensitive mass can over 10,000 ton;
- Despite the limited energy resolution, well-defined background conditions make the **Fitting method** the practical solution.

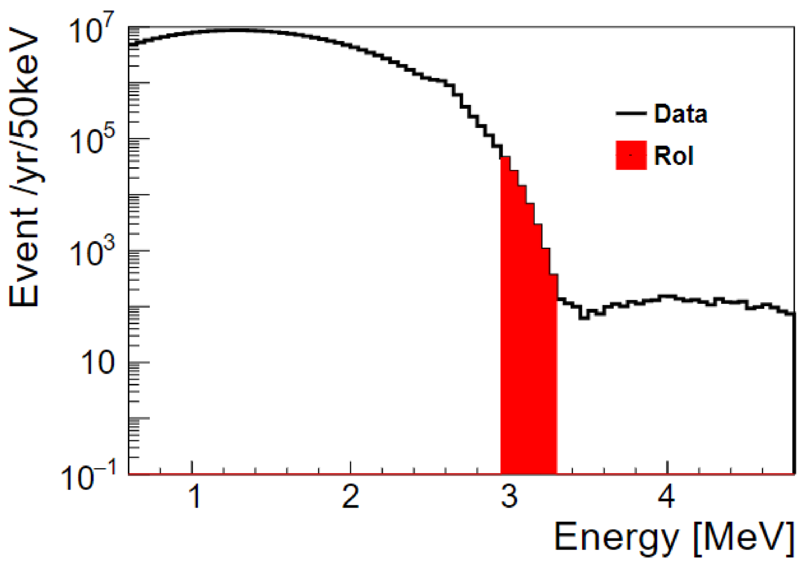
- KamLand-Zen[1] experiment, which employed the fitting method, has obtained **the best 0νββ half-life results to date.**

III. How to determine the Sensitivity?

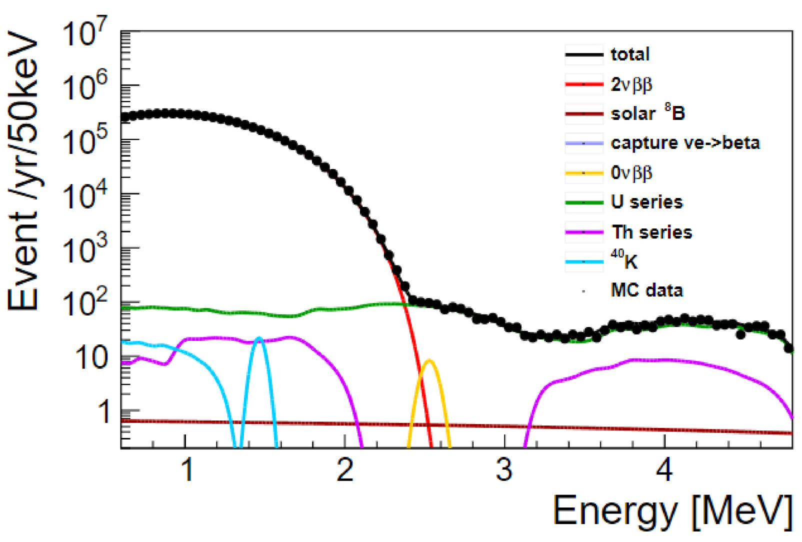
Counting Method

$$T_{12}^{0\nu}(n_\sigma) = \frac{N_A \times ln2}{n_\sigma}\frac{a \times \varepsilon}{W}\sqrt{\frac{M \times t}{b \times \triangle E}}$$

- Where N_A is Avogadro number, ε is the detection efficiency, a and W are the isotopic abundance and the atomic weight and n_σ is C.L.



Fitting Method

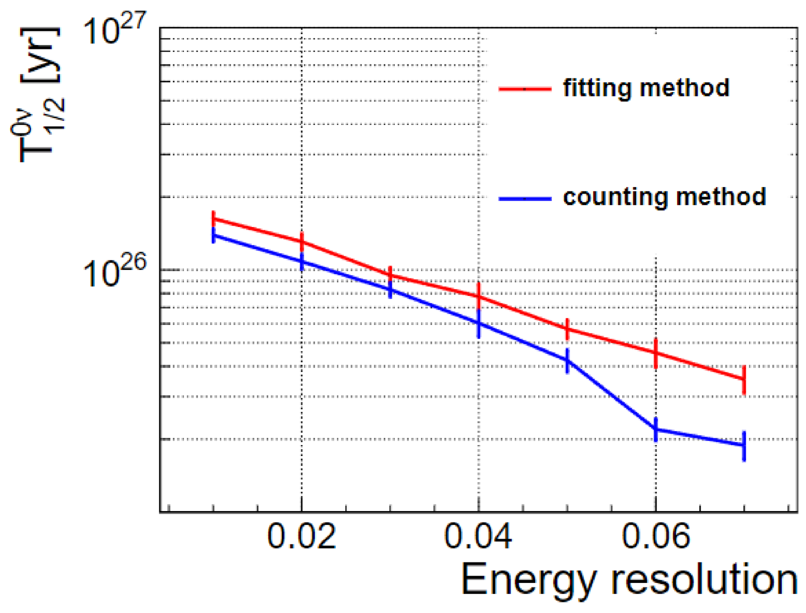


- A χ^2fitting is performed for spectrum fitting:

$$\chi^2 = \chi^2_{signal} + \chi^2_{penalty}$$

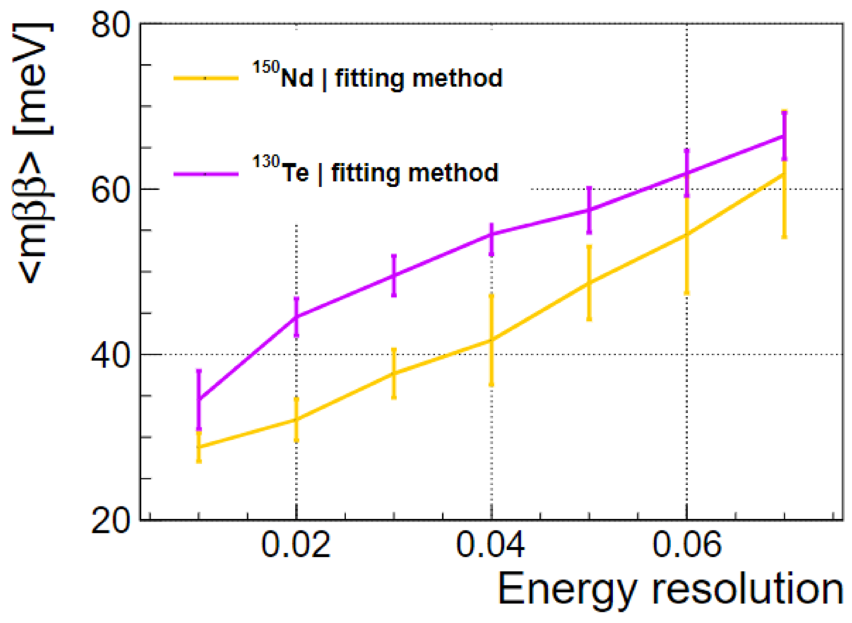
- Where χ^2_{signal} is the sum of the Poisson probability for all bins within the fitting range, $\chi^2_{penalty}$ is a penalization term for the mearsured background component.

IV. Comparison results

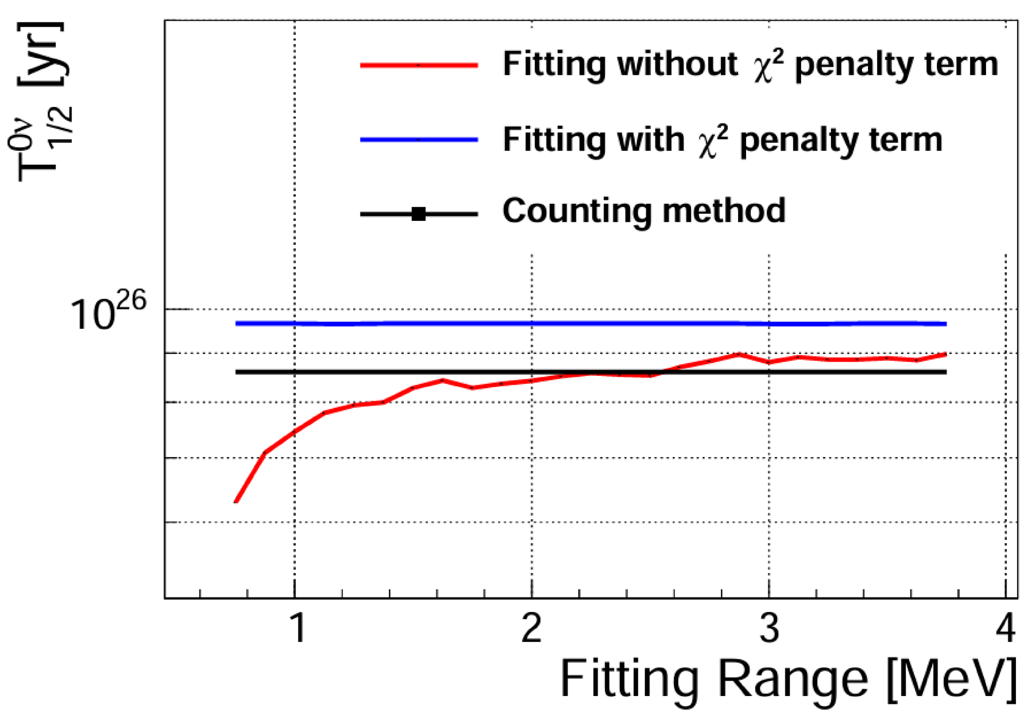


- Simulated a **500-ton liquid scintillation detector** with **10%** nature Nd (equal to **2.85 ton** ^{150}**Nd**) with 1 year run time.
- It indicated **fitting method** gives a better 0νββ half-life sensitivity (90% C.L.), which is higher than counting method approximately by a factor of 1.25.

- The comparison work between ^{150}**Nd** and ^{130}**Te** indicates that under the same experimental conditions and choose the $G_{0\nu}$ and $M_{0\nu}$ from a same model [4], the ^{150}**Nd** provides a better sensitivity of effective neutrino mass.



V. Origin of advantages of Fitting method



- In **fitting method**, a lower fitting range resultes in a lower half-life sensitivity;
- Indicates that fitting method exhibits better sensitivity due to the **additional information** outside the RoI.
- In the case of χ^2 fitting, this information can be derived from the **penalty term** in the χ^2 formula.

VI. Conclusion and remarks

- **Fitting method** shows a **better** performance than **counting method**;
- When both using nature nucleus, ^{150}**Nd** gives a better sensitivity of **effective neutrino mass** than ^{130}**Te**;
- **Fitting method**'s better performance may come from the **extra information** outside the RoI.
- This extra information can also be derived from the penalty term in the χ^2 fitting formula.

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References

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