

Testing of beta and antineutrino spectra symmetry by the use of multi-kiloton detector

QUARKS-2026

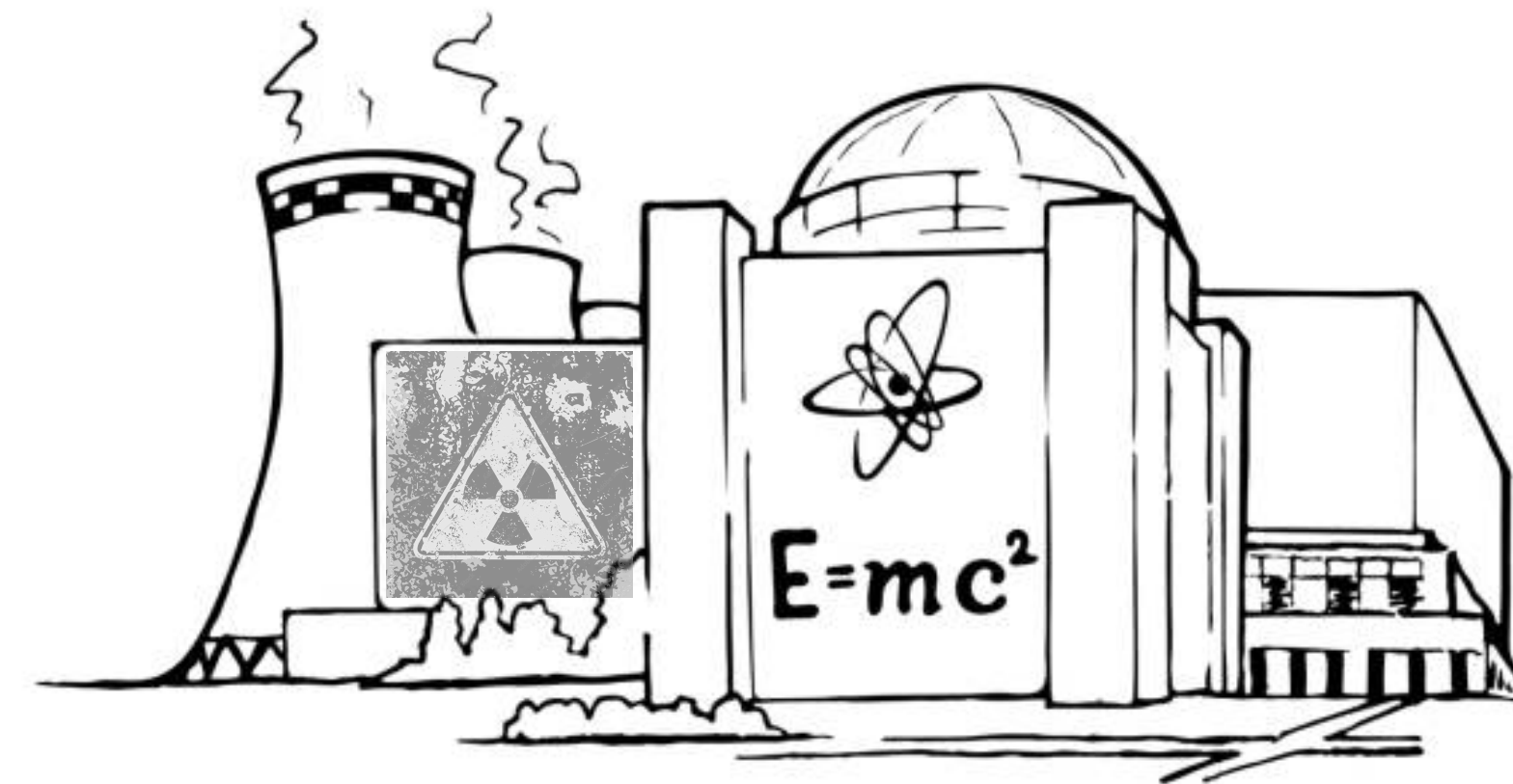
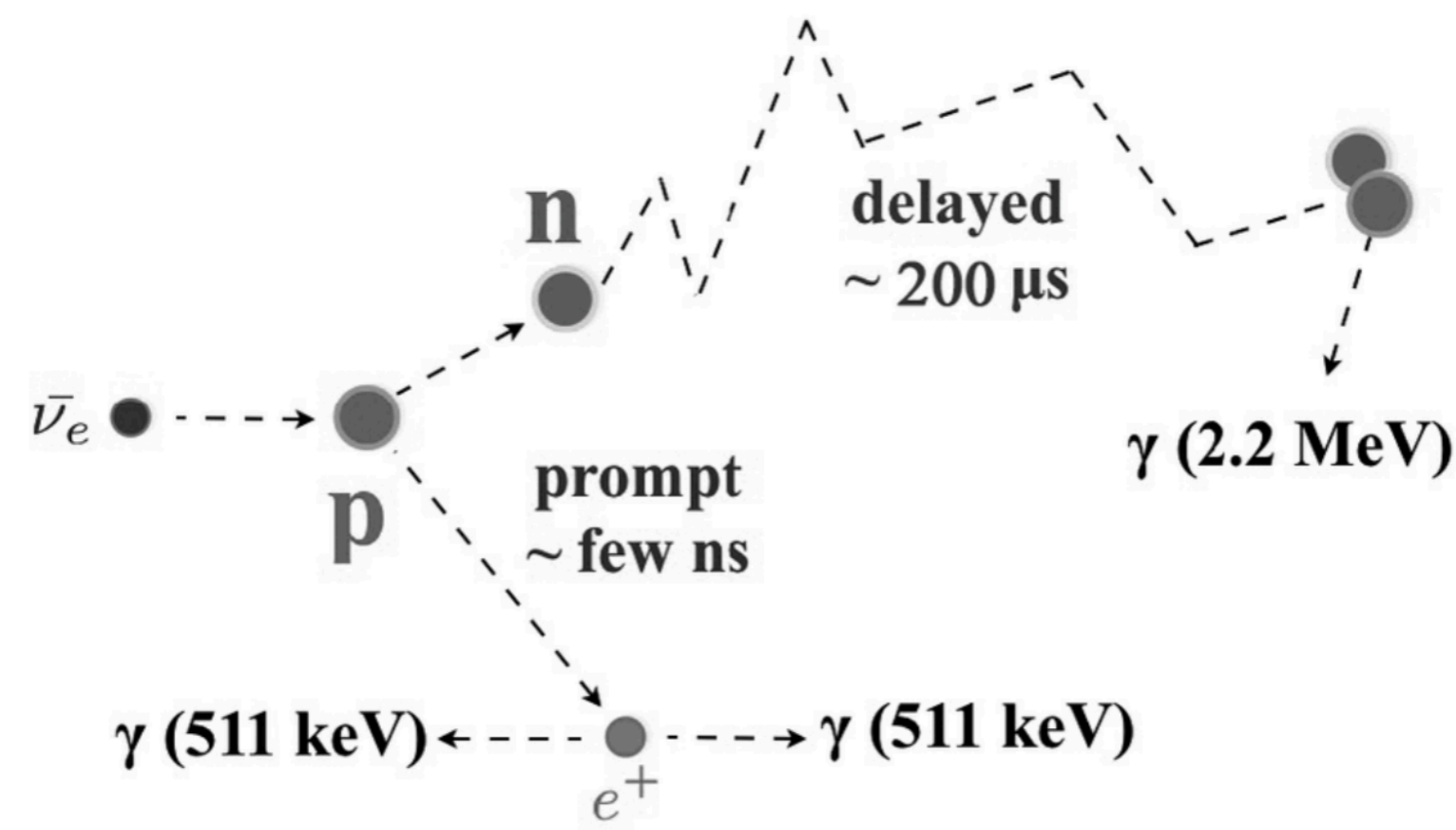
Motivation

- Antineutrino spectrum from individual isotope was never measured up to now. Only the spectrum containing thousands of individual spectra was measured in experiments with reactor antineutrinos.
- Using this spectrum is impossible to check if antineutrino spectrum is exactly mirrored relatively to the electron one.
- The check on the mirror symmetry of antineutrino spectrum and electron one can be done by measuring antineutrino spectrum directly using any known beta-decaying isotope and comparing it with the beta one.

We propose to make an experiment on measuring antineutrino spectrum using high activity radioactive source (**1-2 MCi**) that can be placed in the vicinity of existing now detectors (on the top) of ongoing kiloton detector experiments, as an example - **JUNO**.

Nuclear reactor

Nuclear reactors produce an intense flux of electron antineutrinos and thus are very good sources for experiments in neutrino physics. The antineutrino spectrum is composed of approximately thousand individual spectra produced by the fission products of ^{235}U , ^{238}U , ^{239}Pu and ^{241}Pu fissile isotopes.



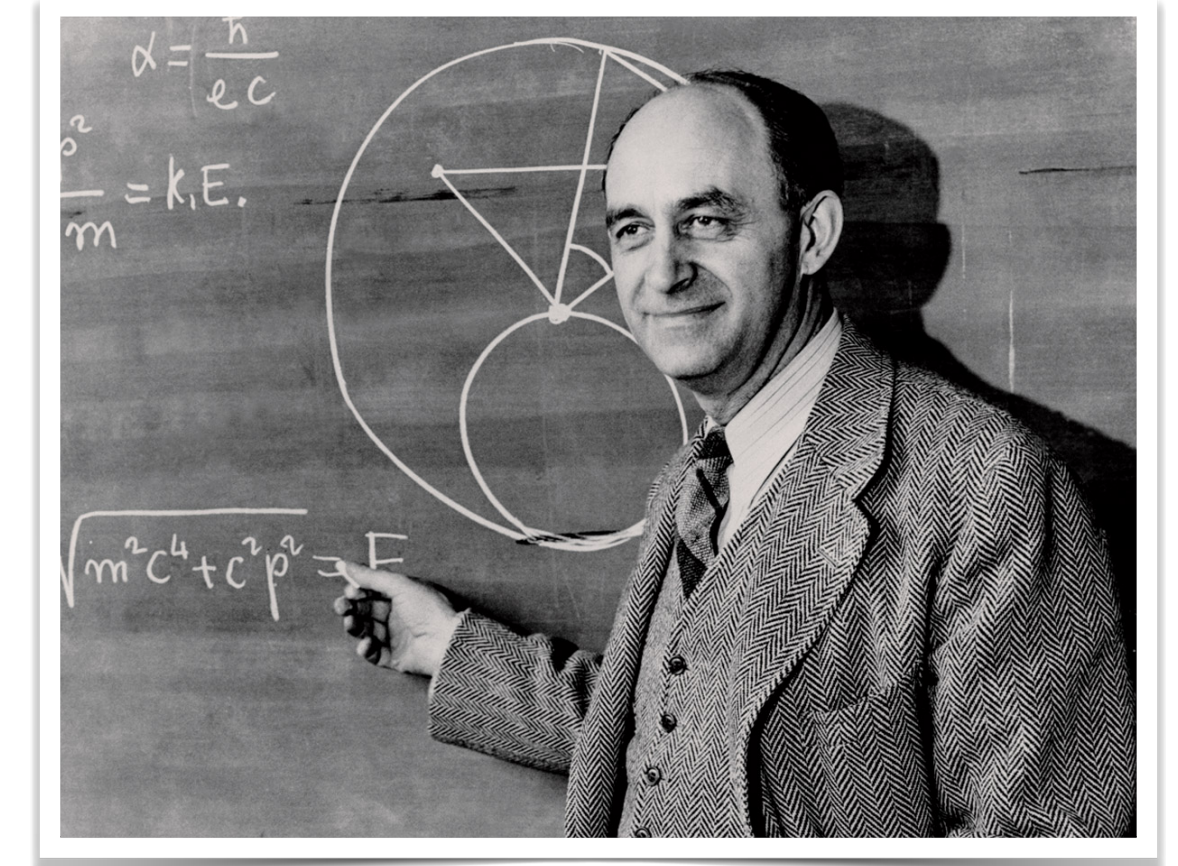
Beta-decay

In beta decay one nucleus is transformed into another one with the emission of electron (positron) and antineutrino (neutrino). Also a nucleus can capture one of own atomic electrons from electron shell and emit monoenergetic neutrino.

$$\beta^- : (A, Z) \rightarrow (A, Z + 1) + e^- + \bar{\nu}_e, \quad Q_{\beta^-} = M_p - M_d$$

$$\beta^+ : (A, Z) \rightarrow (A, Z - 1) + e^+ + \nu_e, \quad Q_{\beta^+} = M_p - M_d - 2m_e$$

$$\text{Electron capture (EC): } (A, Z) + e^- \rightarrow (A, Z - 1) + \nu_e, \quad Q_{\beta} = E_{\nu}$$



Where inside the nucleus electron and antineutrino are born is unknown. Enrico Fermi created theory of beta-decay and postulated that electron and antineutrino are born together exactly in the moment of beta-decay. Electron and antineutrino energy spectra are mirrored to each other relatively to the point in the middle of the spectrum

$$T_0/2, \quad T_0 \approx Q_{\beta}$$

Beta and antineutrino spectra shapes

Beta spectrum shape can be written as

$$S(E_e, E_0, Z) = K \cdot p_e E_e \cdot (E_0 - E_e)^2 \cdot F(Z, E_e) \cdot C(Z, E_e) \cdot (1 - \delta(Z, A, E_e)),$$

where K - is normalization factor, $p_e E_e$ - are momentum and energy of electron, $F(Z, E_e)$ - Fermi function accounting Coulomb field of the daughter nucleus, $C(Z, E_e)$ - the factor accounting momentum dependence of nucleus matrix element and $\delta(Z, A, E_e)$ - is correction factor to the spectrum shape.

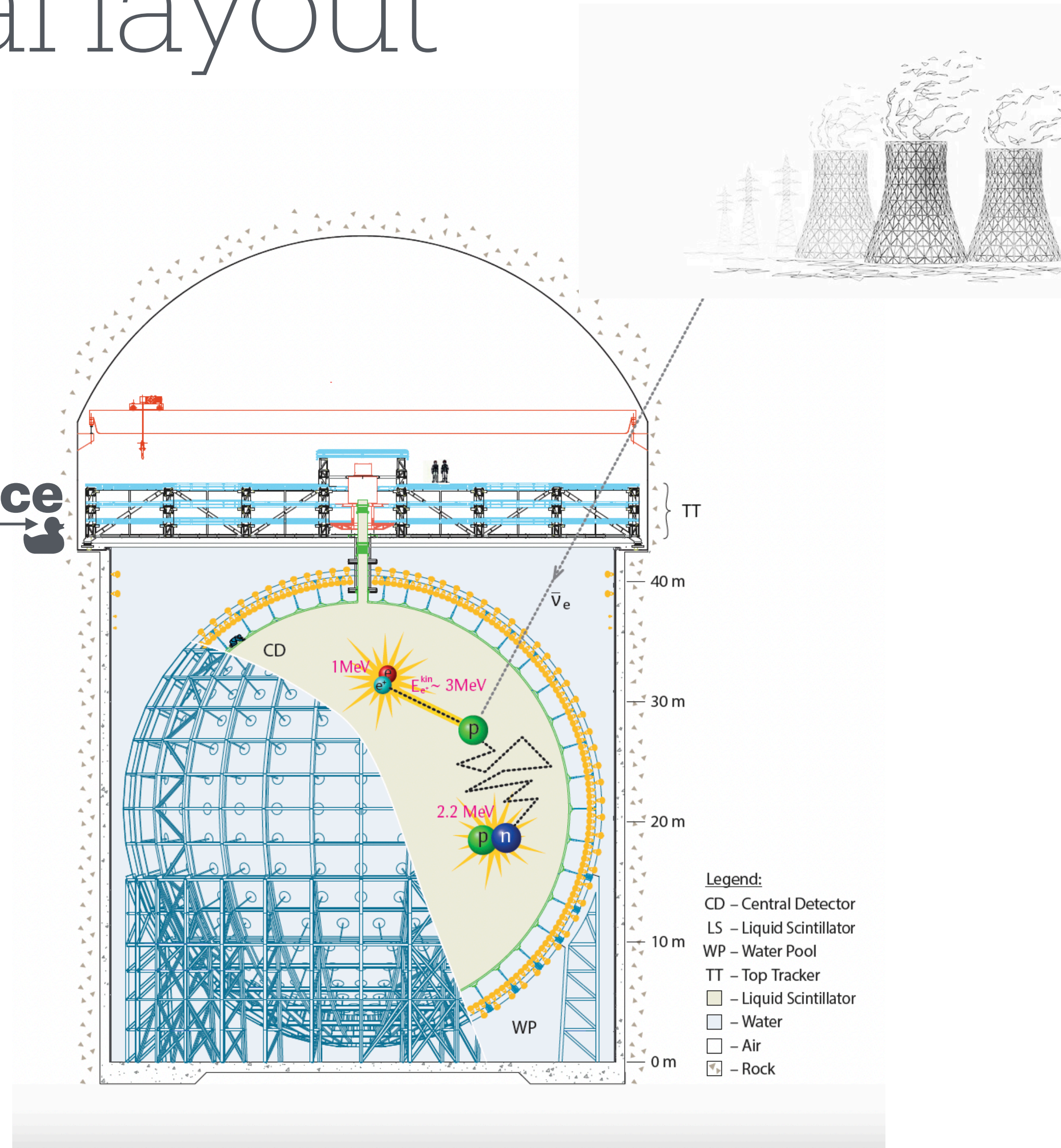
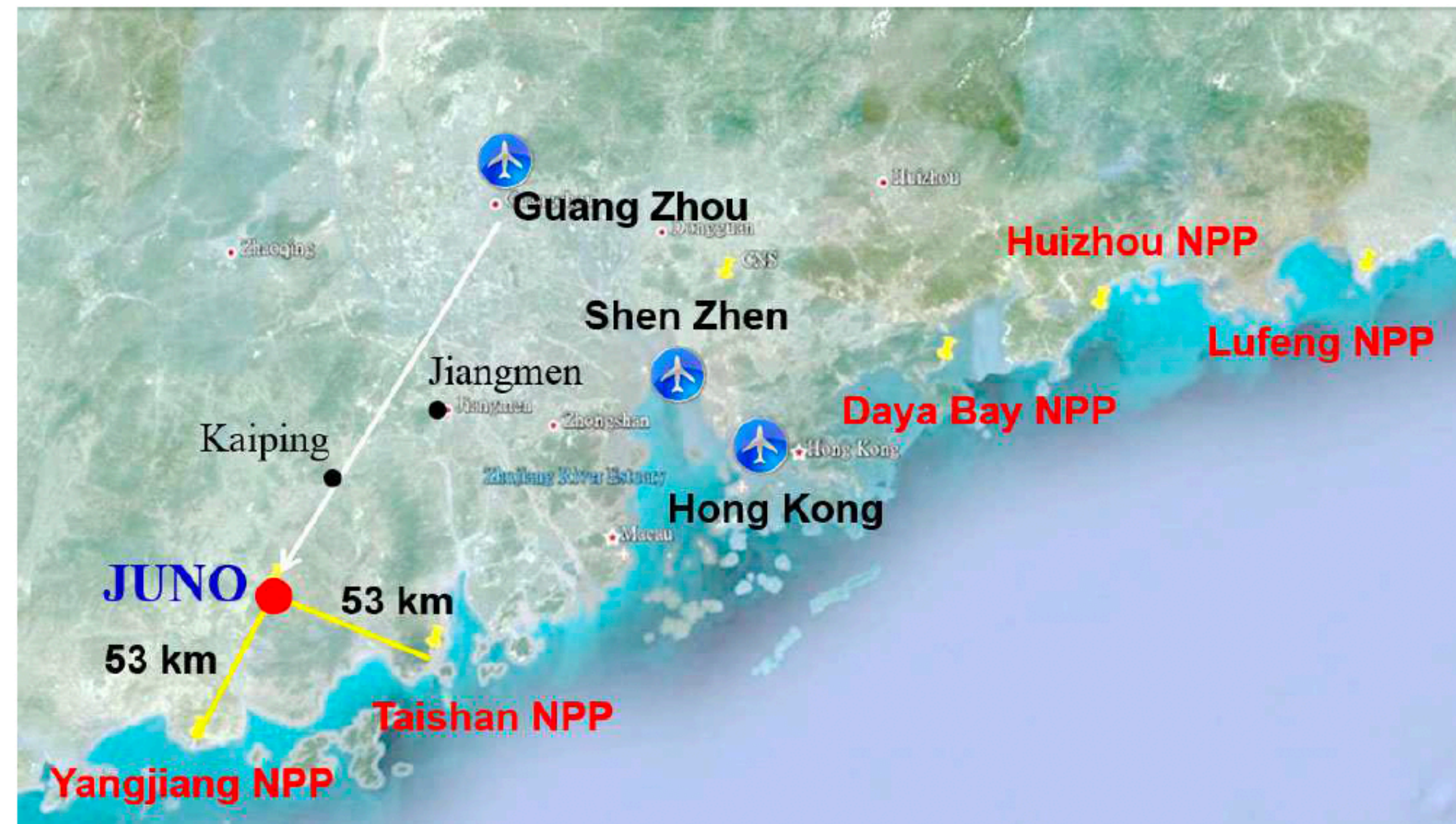
In our calculations, we set $C(Z, E_e) = 1$ and $\delta(Z, A, E_e) = 0$.

In order to calculate the antineutrino spectrum, $E_0 - E_{\bar{\nu}}$ should be substituted for E_e .

JUNO experimental layout

Cores	YJ-C1	YJ-C2	YJ-C3	YJ-C4	YJ-C5	YJ-C6
Power (GW)	2.9	2.9	2.9	2.9	2.9	2.9
Baseline(km)	52.75	52.84	52.42	52.51	52.12	52.21
Cores	TS-C1	TS-C2	TS-C3	TS-C4	DYB	HZ
Power (GW)	4.6	4.6	4.6	4.6	17.4	17.4
Baseline(km)	52.76	52.63	52.32	52.20	215	265

1 MCi source



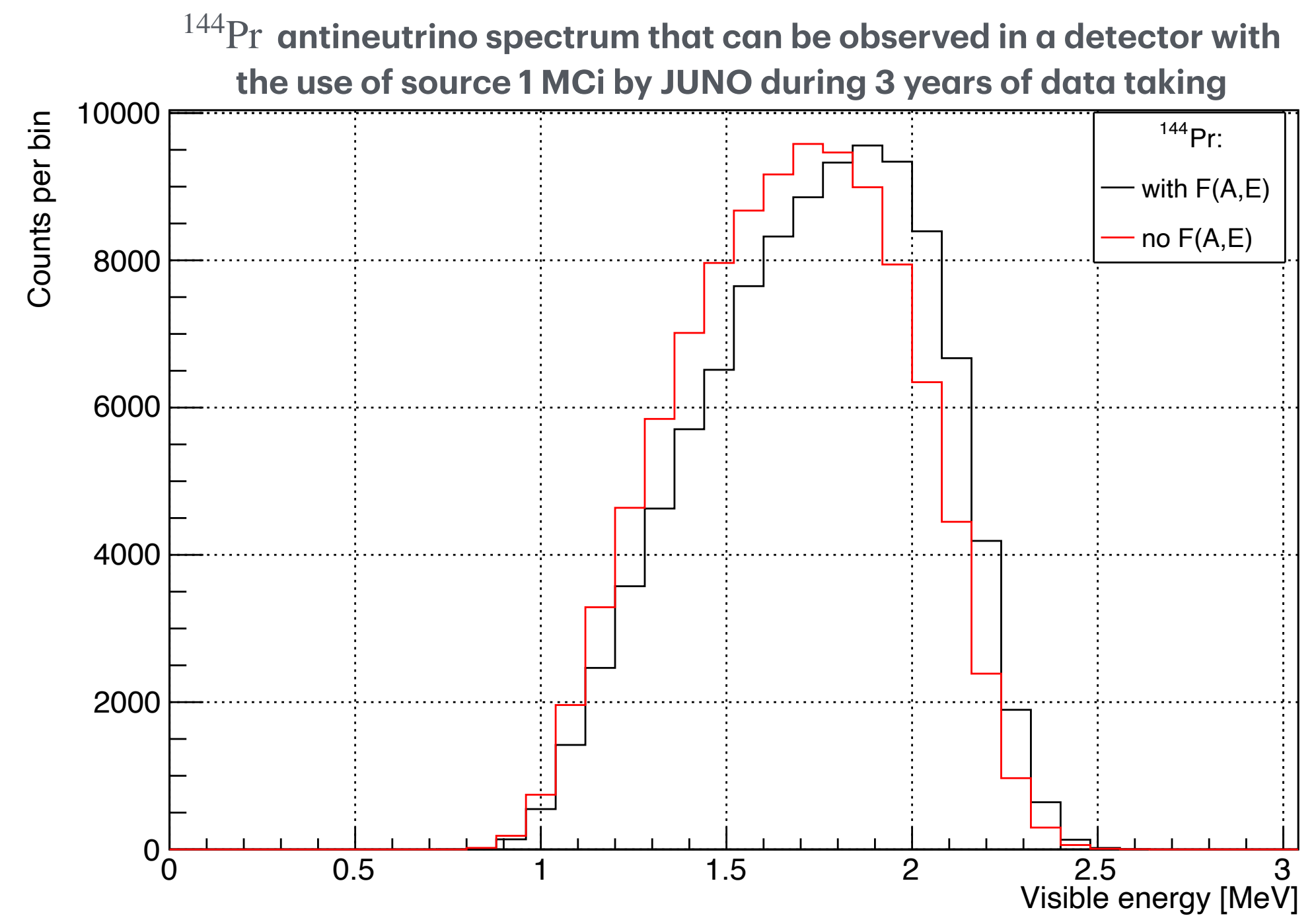
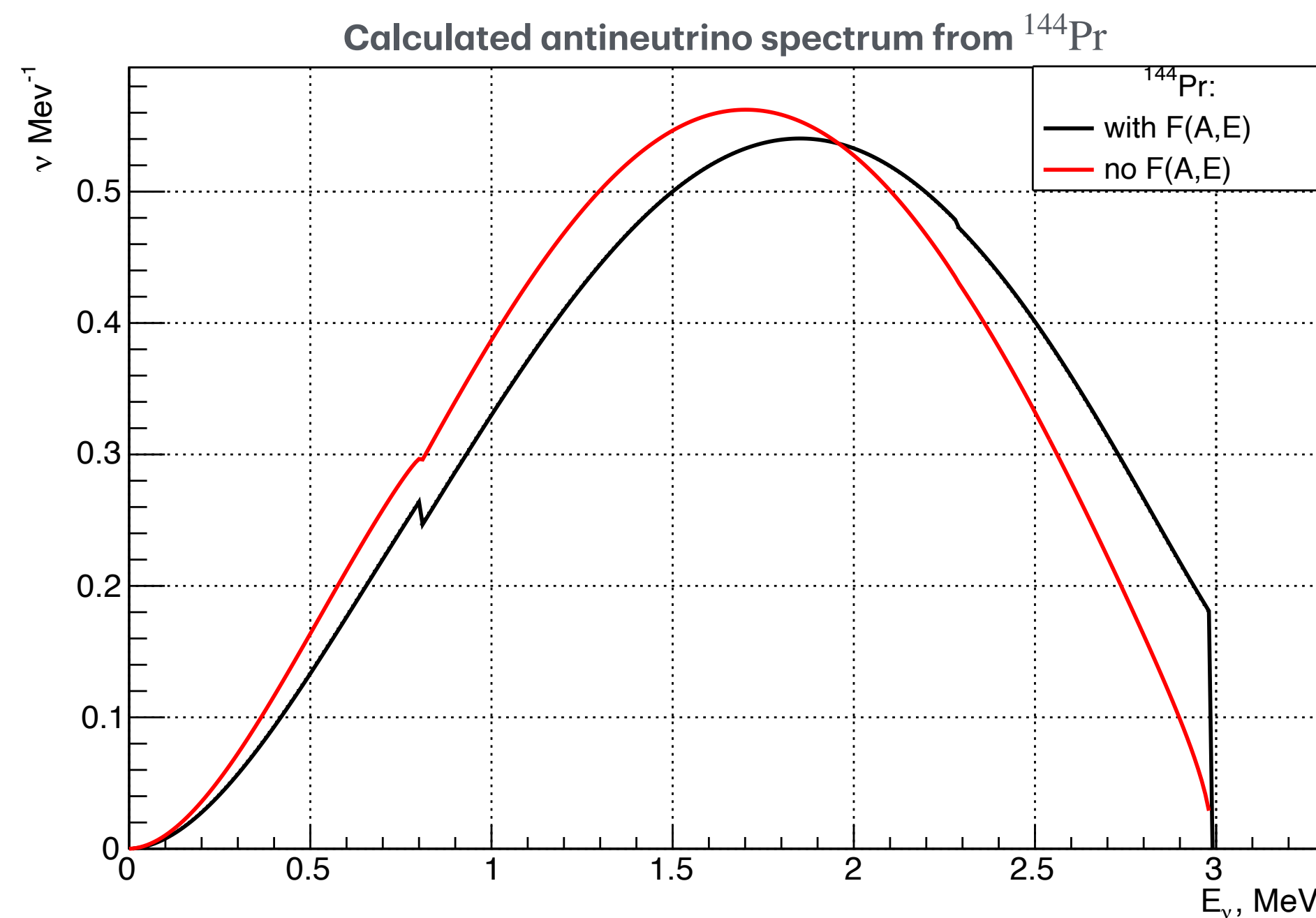
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Sensitivity to antineutrino spectrum shape using the source at a distance 15 m to the detector center

$^{144}\text{Ce} - ^{144}\text{Pr}$, with $Q_{\beta}(\text{Pr}) = 2.996$ MeV and $T_{1/2}(\text{Ce}) = 285$ days

The total event number from inverse beta decays with $F(A, E_e) = 1.20 \cdot 10^6$ and without $9.06 \cdot 10^6$ for 900 days of data taking.

1 year: with $F(A, E_e) = 4.87 \cdot 10^5$, without Fermi function $3.67 \cdot 10^5$. The source activity is **1 MCi**.

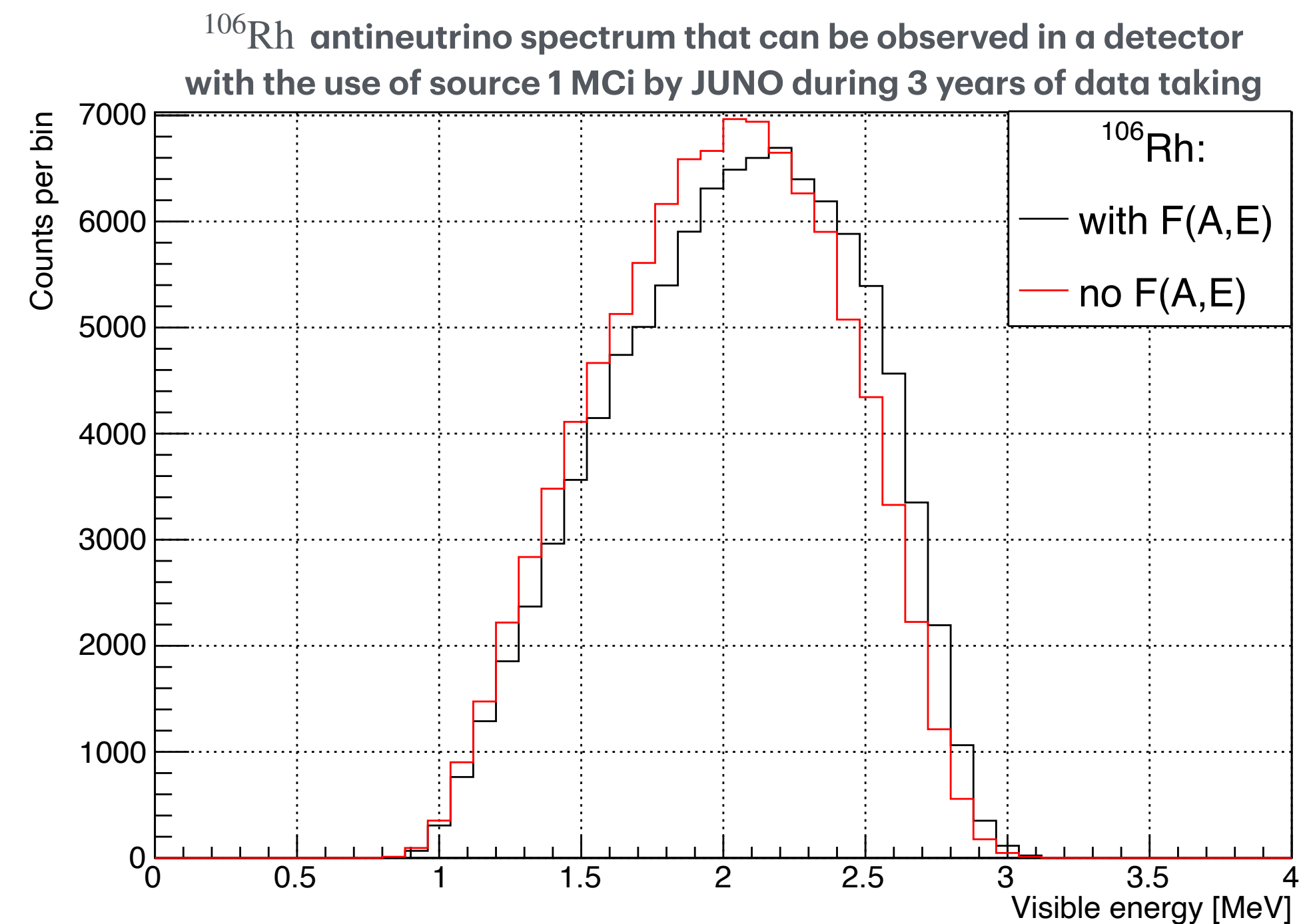
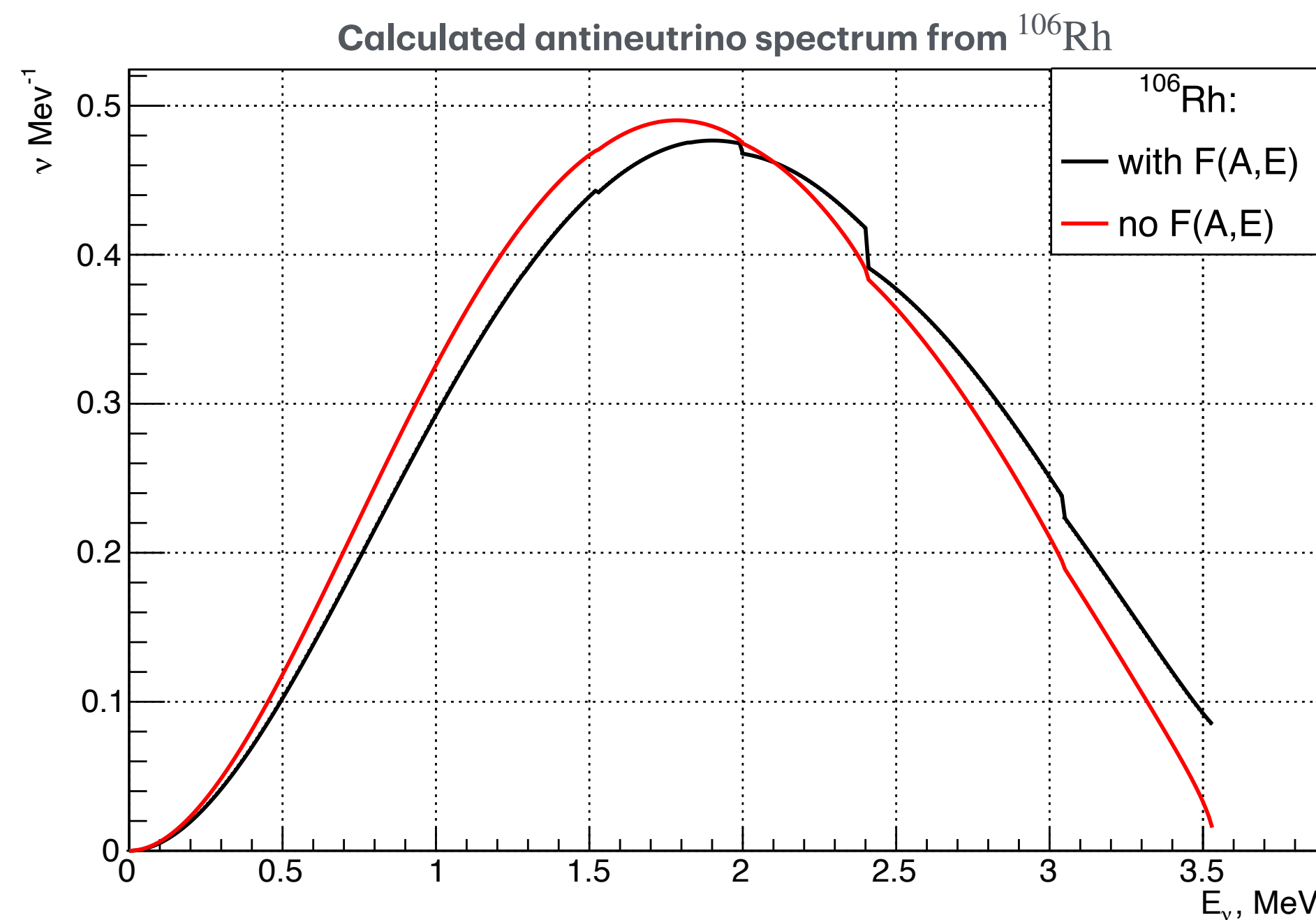


Sensitivity to antineutrino spectrum shape using the source at a distance 15 m to the detector center

$^{106}\text{Ru} - ^{106}\text{Rh}$, with $Q_\beta(\text{Rh}) = 3.54 \text{ MeV}$ and $T_{1/2}(\text{Ru}) = 372 \text{ days}$

The total event number from inverse beta decays with $F(A, E_e) = 1.20 \cdot 10^6$ and without $1.74 \cdot 10^6$ for 900 days of data taking.

1 year: with $F(A, E_e) = 8.32 \cdot 10^5$, without Fermi function $7.04 \cdot 10^5$. The source activity is **1 MCi**.

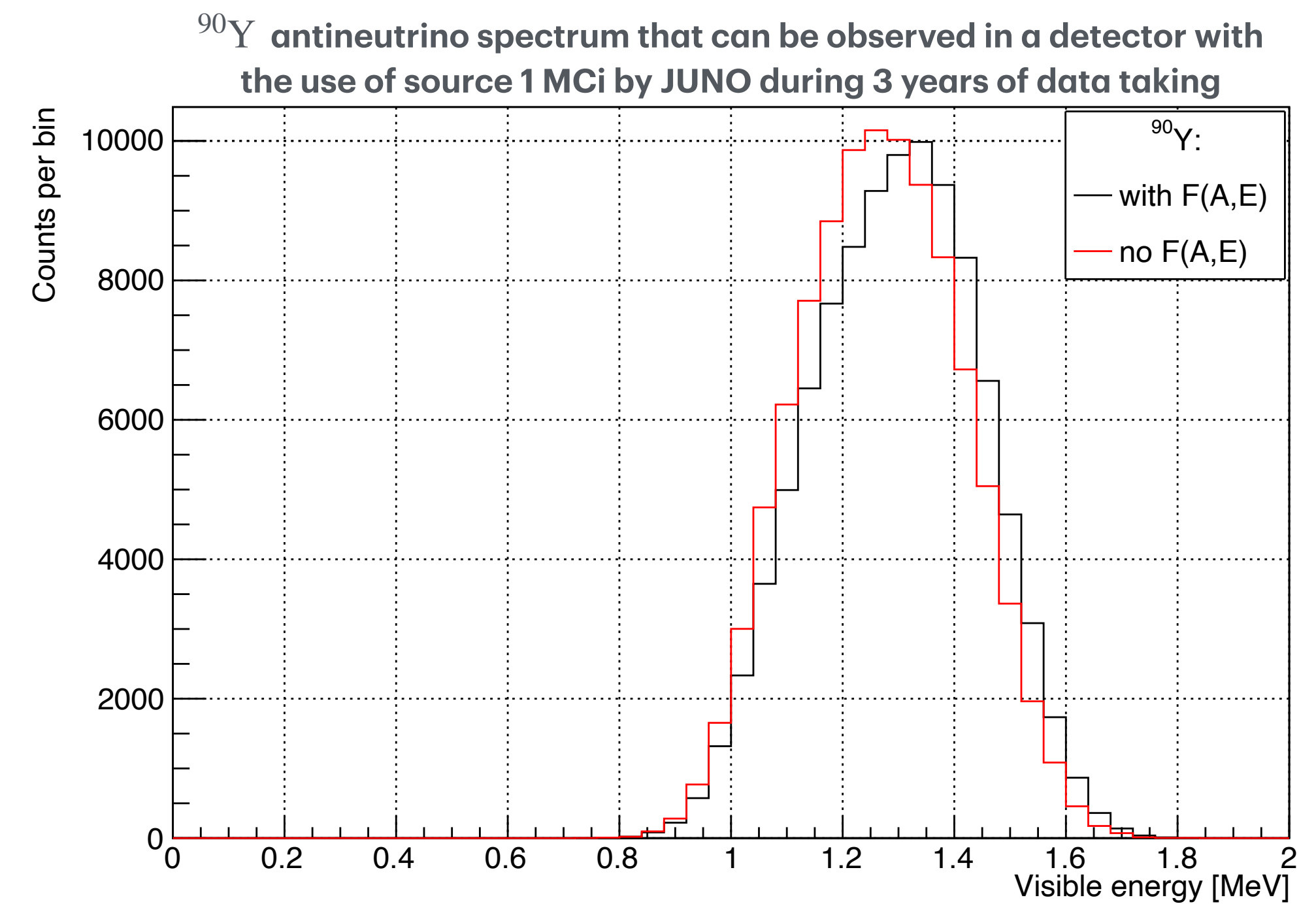
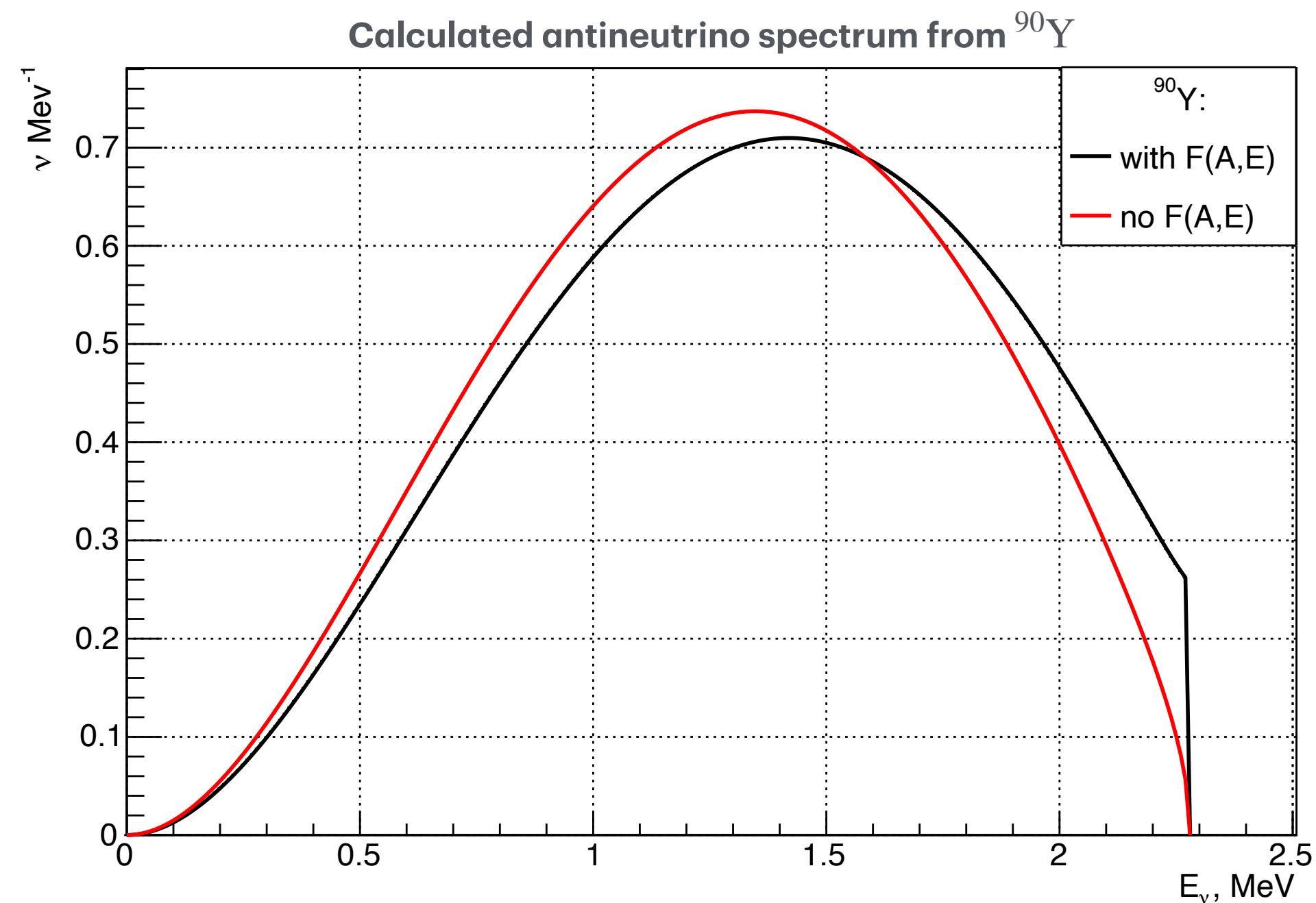


Sensitivity to antineutrino spectrum shape using the source at a distance 15 m to the detector center

$^{90}\text{Sr} - ^{90}\text{Y}$, with $Q_{\beta}(\text{Y}) = 2.28 \text{ MeV}$ and $T_{1/2}(\text{Sr}) = 28.9 \text{ years}$

The total event number from inverse beta decays with $F(A, E_e) = 1.93 \cdot 10^5$ and without $1.35 \cdot 10^5$ for 900 days of data taking.

1 year: with $F(A, E_e) = 7.80 \cdot 10^4$, without Fermi function $5.46 \cdot 10^4$. The source activity is **1 MCi**.



Conclusion

In this work we propose to check if antineutrino spectrum is really mirror symmetric to the beta one. There may be different experiments done to check the symmetry of antineutrino and beta spectra from one isotope.

We propose to make an experiment with artificial radioactive source $^{90}\text{Sr} - ^{90}\text{Y}$. Using this source of **1-2 MCi** activity located at the top of current experiment JUNO. We can expect in several years to reach appropriate statistics to make a conclusion on antineutrino spectrum shape. The experiment with $^{90}\text{Sr} - ^{90}\text{Y}$ source is convenient also for testing Standard Model. Weinberg angle can be measured with high accuracy.

Thanks for
your attention
and
please don't ask
too much

