Detector calibration in the sub-MeV range in JUNO

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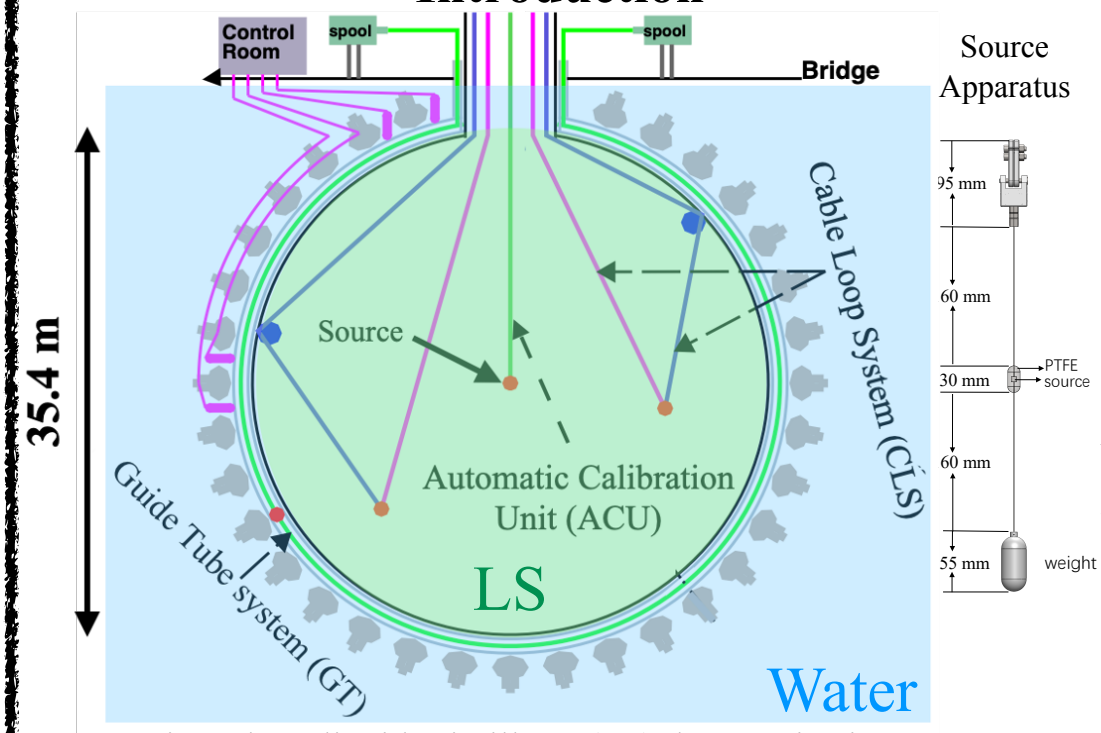
Abstract

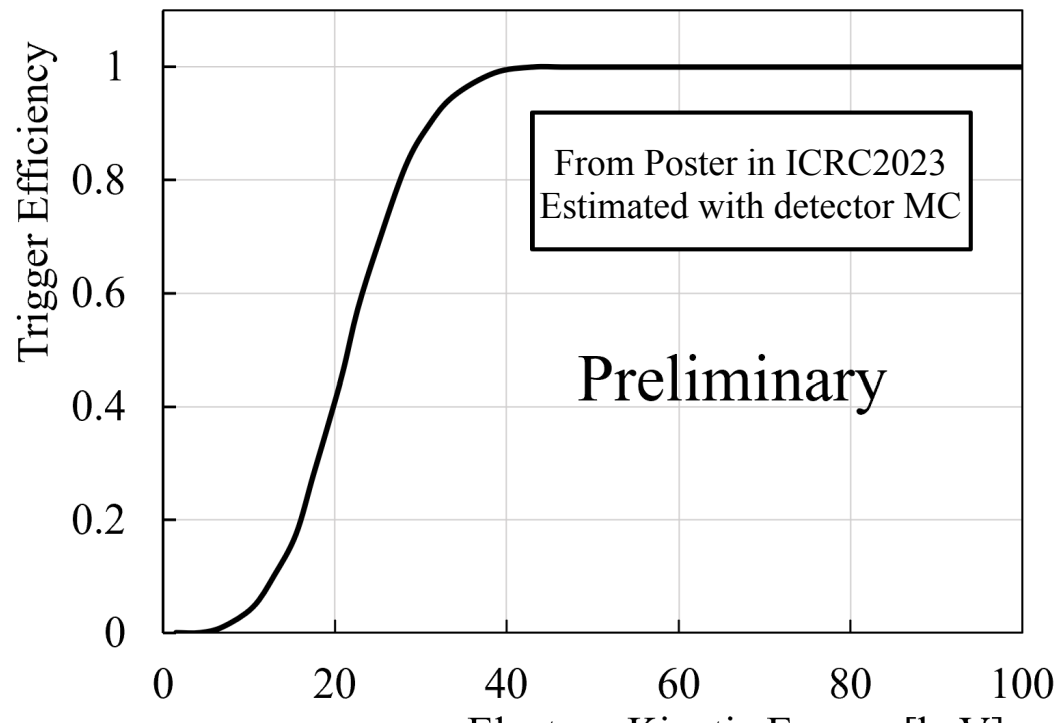
Newly developed intelligent event trigger system will enable to lower the JUNO energy threshold down to O(10) keV, and new calibration sources (such as ^{226}Ra (186 keV γ-ray), ^{241}Am (59.5 keV γ-ray)) are planned to be deployed to calibrate this low-energy region. The uncertainty in the energy scale calibration due to the source apparatus geometry and ^{14}C contamination effects has been estimated to be less than 1% level, and this poster also presents the status of the radioactive source (^{226}Ra) preparation.

Introduction



- JUNO is 20 kton liquid scintillator (LS) detector in Jiangmen, China.
- Expected to start the physics run in 2024.
- 17,612 20-inch PMTs & 25,600 3-inch PMTs are being installed.
- Various calibration source deployment systems to be installed.
- Multi-purpose detector:
  - Reactor/geo/solar/atmospheric/astrophysical ν observation, exotic searches, etc.

Exploring O(10) keV in JUNO

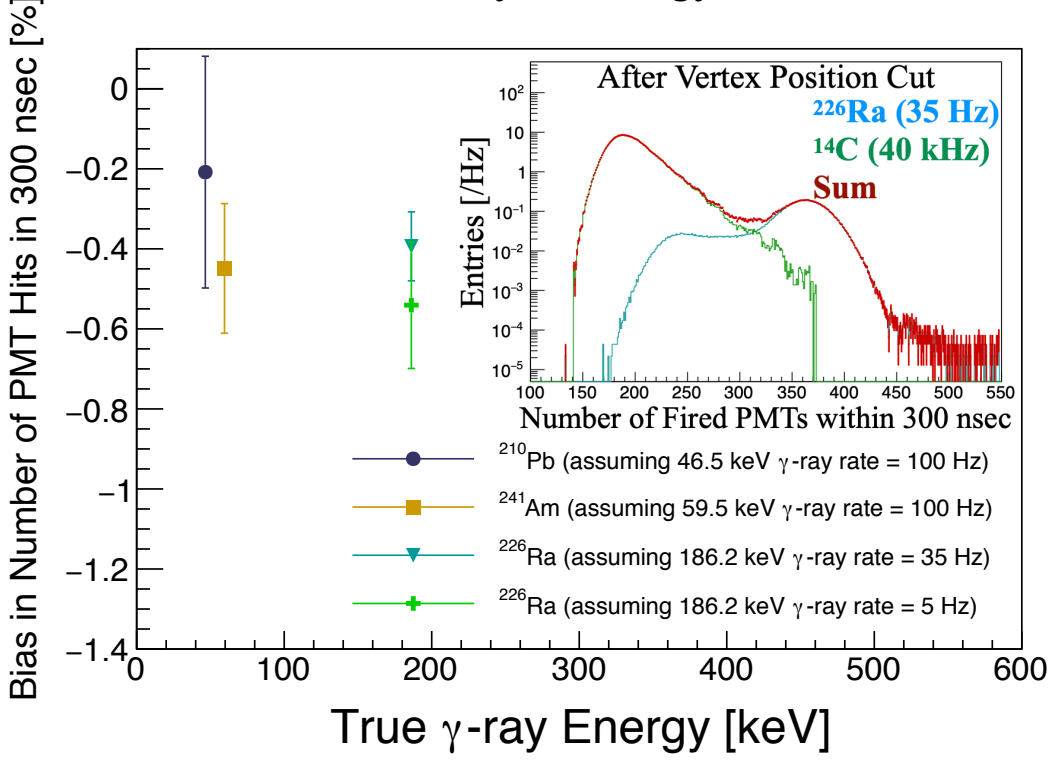


- Besides the JUNO standard trigger (E_{th} ~ 0.2 MeV), an intelligent (Multi-messenger) trigger system is planned to be introduced.
- Using the number of fired PMTs and their spacial distribution, the energy threshold is expected to be lowered down to ~20 keV level.
- According to the upgrade, the new calibration sources, which can calibrate this low-energy region, are under development.

Calibration in the sub-MeV Range

- New dedicated calibration sources:
  - ^{241}Am: After the α-decay, 59.5 keV γ-ray is emitted.
  - ^{241}Am is available from existing ^{241}Am^{13}C neutron source.
  - ^{226}Ra: After the α-decay, 186 keV γ-ray is emitted.
  - Daughter isotopes from ^{226}Ra, such as ^{214}Pb (352, 295, 242, 53.2 keV), ^{210}Pb (46.5 keV), also provide low-energy γ-rays.
  - ^{226}Ra source has been newly produced.
- Calibration feasibility has been studied using the JUNO simulation.

Estimated Uncertainty in Energy Scale Calibration

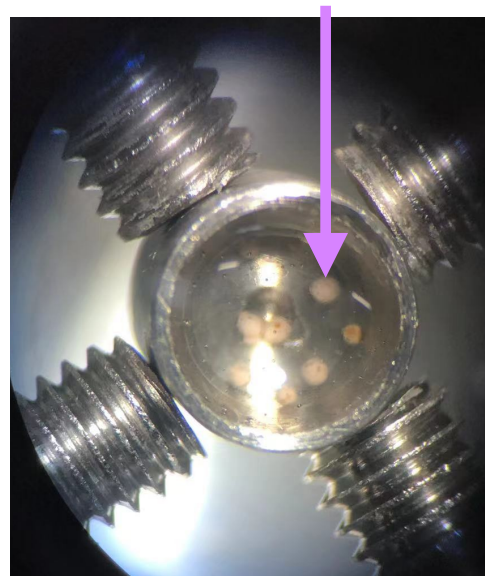


- Uncertainties due to the optical shadowing and energy losses in the source apparatus geometry, contaminations of ^{14}C (β-decay, Q value ~ 160 keV, exp. rate ~ 40 kHz, 10^{-17} g/g in LS) have been estimated to be less than 1%.
- ^{14}C backgrounds are reduced by strict vertex position cut and subtracted by "source-off (^{14}C only)" samples.

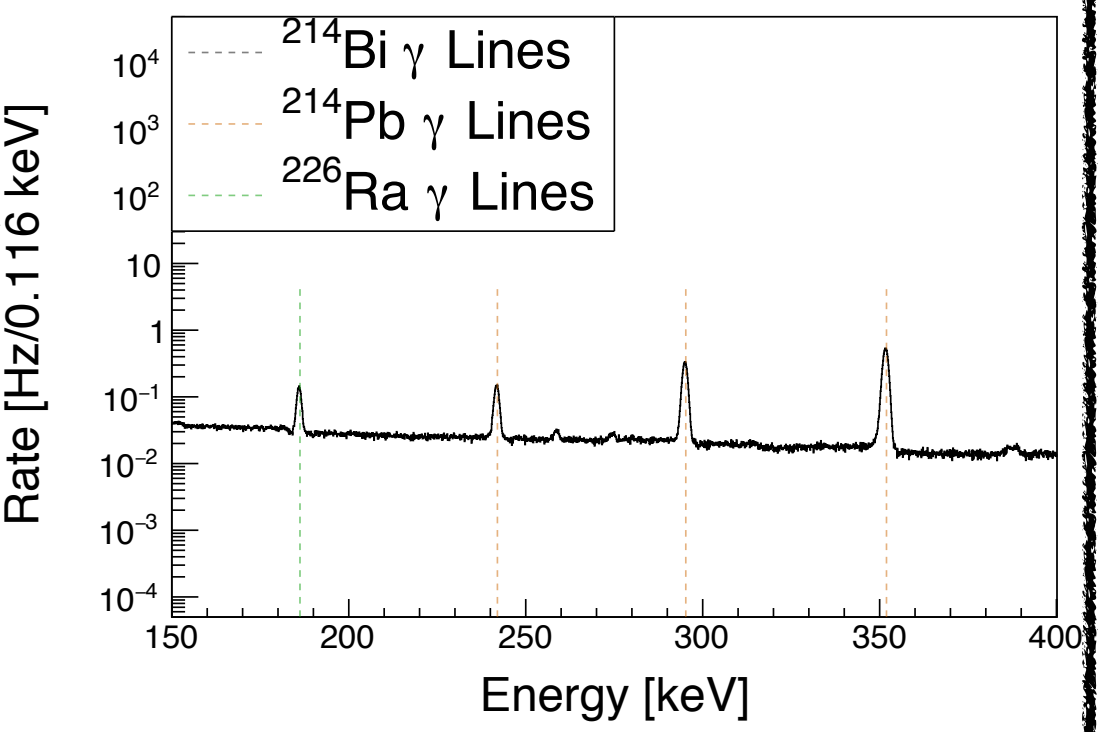
^{226}Ra Source Preparation

- ^{226}Ra-infused particulates have been packed into Ti calibration source capsules.
- They will be deployed by the source deployment system in JUNO.
- The radioactivity of the source has been measured with the Ge γ-ray detector at our university.
- 186 keV γ-ray rate is estimated to be 35 Hz after the Ge detector acceptance correction.
- Clear peaks from ^{226}Ra and its decay daughters have been confirmed.

^{226}Ra Source Particulates



Energy Spectrum (After Bkg. Subtraction)



References: [1]. arXiv:2011.06405 about the JUNO calibration strategy. [2]. New low-energy intelligent trigger. Poster #303 in Neutrino 2022