PROCEEDINGS OF SCIENCE

The JUNO Calibration Strategy and Simulation

Kangfu Zhu[1], Qingmin Zhang[2] on behalf of the JUNO collaboration

Department of Nuclear Science and Technology, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an 710049, China

The Jiangmen Underground Neutrino Observatory (JUNO) is designed to primarily measure the neutrino Mass Ordering (MO) by detecting reactor anti-neutrinos via inverse beta decay. JUNO also has other rich physical potentials. Its Central Detector (CD), which is an acrylic sphere with a diameter of 35.4 m, filled by approximately 20 kton of liquid scintillator (LS), is equipped with large photomultipliers (18k for the CD + 2k for the Water Pool) and small photomultipliers (25,600) to measure the energy resolution of neutrinos with an unprecedented energy resolution of $3\%/\sqrt{E}$ and an energy non-linearity better than 1%. Accordingly, a calibration complex, including Automatic Calibration Unit (ACU), Cable Loop System (CLS), Guide Tube Calibration System (GTCS) and Remotely Operated under-liquid-scintillator Vehicles (ROV), is designed to deliver multiple radioactive sources for the energy coverage of reactor neutrinos and CD full-volume. In this proceeding, the new design details and up-to-date progress about JUNO calibration system are presented.

40th International Conference on High Energy Physics - ICHEP2020
July 28 - August 6, 2020
Prague, Czech Republic (virtual meeting)

[1]*Speaker, E-mail: zhukangfu@stu.xjtu.edu.cn*

[2]*Corresponding author, E-mail: zhangqingmin@mail.xjtu.edu.cn*

PoS(ICHEP2020)817

1. Introduction of JUNO Energy Response

The Jiangmen Underground Neutrino Observatory (JUNO), which will be constructed at Kaiping, Jiangmen in South China, is designed to determine the neutrino mass ordering by detecting reactor anti-neutrinos, with an expected precision of 3σ reached in 6 years of data taking [1]. Its Central Detector (CD), which is an acrylic sphere with a diameter of 35.4 m, filled by approximately 20 kton of liquid scintillator (LS), is equipped with large photomultipliers (PMTs, 18k for the CD + 2k for the Water Pool) and small PMTs (25,600) to measure the energy resolution of neutrinos with an unprecedented energy resolution of $3\%/\sqrt{E}$ and an energy non-linearity better than 1% [2]. JUNO energy response is strongly position-dependent due to the detector's complicated structure and large dimension, so the calibration system is very critical and has been designed [3].

2. JUNO Calibration System and its Calibration Strategy

The calibration system has been designed for full volume coverage, as shown in Fig.1. It uses many radioactive sources for the energy coverage of reactor neutrinos.

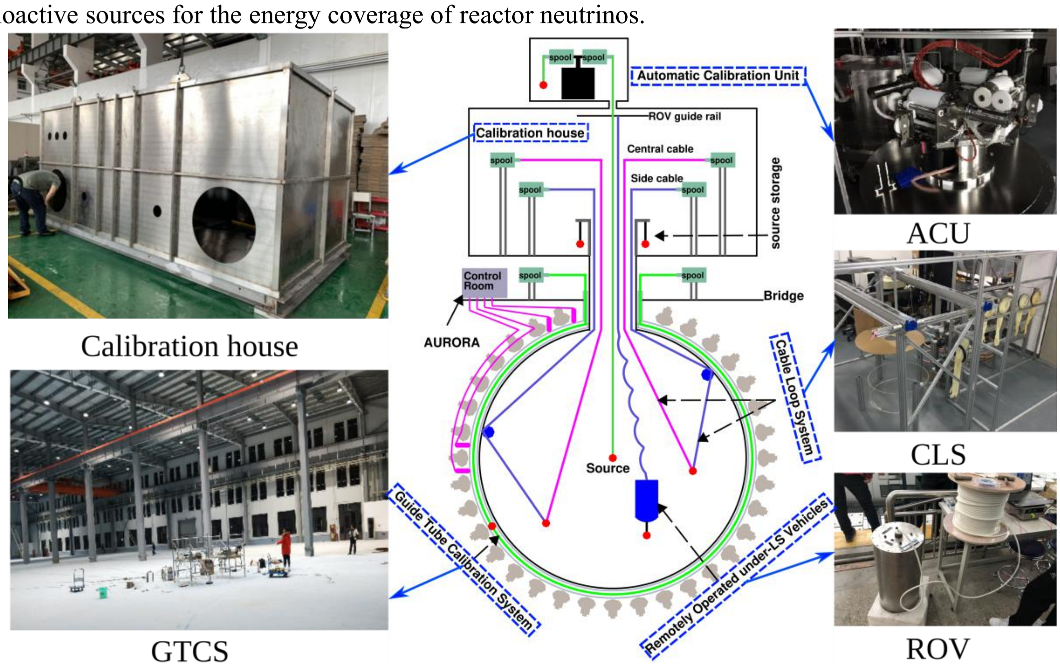
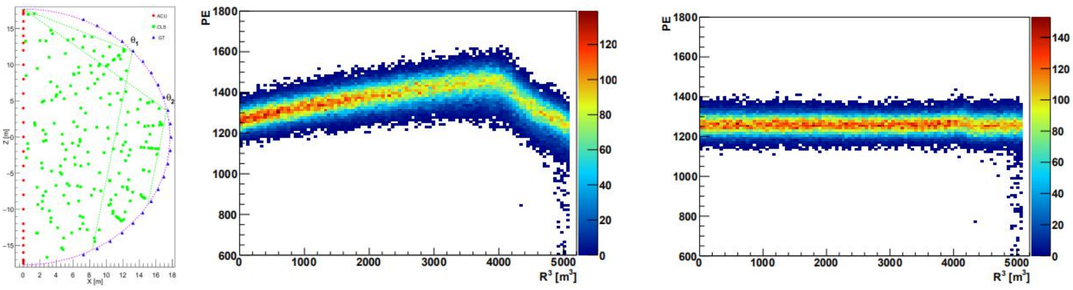


Figure 1: Scheme of JUNO calibration system.

3. JUNO Calibration Simulation

In the calibration simulation, we used 3 calibration systems to deliver different sources to specified positions to perform non-uniformity and non-linearity corrections. Finally, we combined the data from them to get an accurate energy measurement [4] .

3.1 Non-uniformity Correction



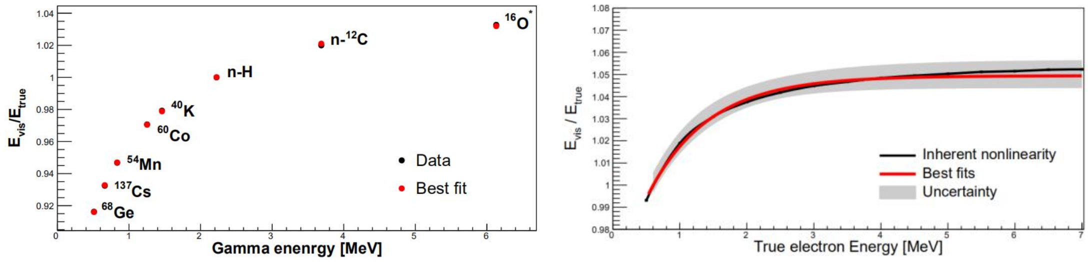
(a) (b) (c)

Figure 2: (a) 250 calibration points obtained with Am-C source from ACU/CLS/GTCS. (b) Energy resolution, displayed in photoelectrons (PEs), before correction is 7%. (c) Energy resolution after correction reaches 3.02%.

JUNO response function can be calibrated by using the data from the given calibration points with ACU, CLS and GTCS (or ROV), see Fig. 2(a). A simple spline function is used to predict the "blank" region and the energy response uniformity is corrected with the correction function obtained from the calibration [5]. As shown in Fig. 2, an effective energy resolution of 3.02% has been achieved after correction [6].

3.2 Non-linearity Correction

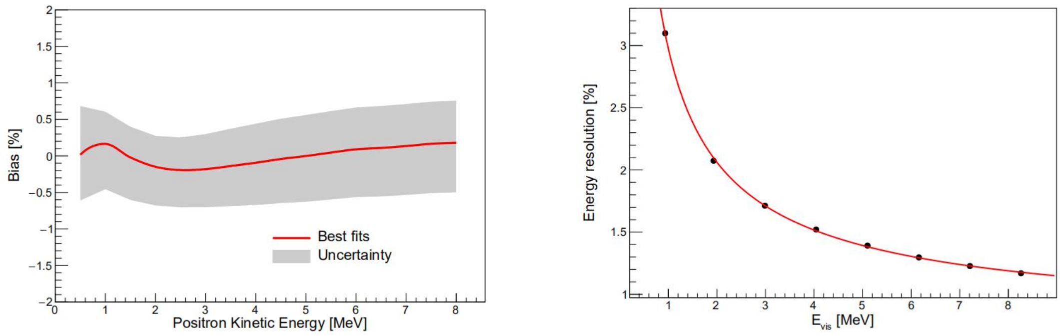
Energy linearity is corrected by placing various sources at CD center with ACU. Eight different gamma sources, specified in Fig. 3(a)[6], are used to study the detector`s linearity. As a verification test, the energy bias (non-linearity) to mono-energetic electron positioned at CD center is simulated, which is found to be < 1% after non-linearity correction, see Fig.3(b) [7].



(a) (b)

Figure 3: (a) Gamma non-linearity. (b) Electron non-linearity.

3.3 Overall Energy Resolution



(a) (b)

Figure 4: (a) Mean bias after correction. (b) Energy resolution after correction.

The simulated mono-energetic positron events are uniformly distributed in CD and the non-uniformity correction is applied. As shown in Fig.4 [6], the bias is less than 0.1% and the energy resolution is approximately 3.0% [8].

References

[1] J. Cao, *Daya Bay and Jiangmen Underground Neutrino Observatory (JUNO) neutrino experiments* (in Chinese)[J]. Sci Sin-Phys Mech Astron, 2014, 44:1025–1040, doi: 10.1360/SSPMA2014-00174.
[2] Y. K. Heng, *Towards a comprehensive neutrino program: the design and progress of JUNO* [R], APS April Meeting, Columbus, 2018.
[3] F. Y. Zhang, *Consideration of Calibration Plan* [R], Beijing: IHEP, 2019.
[4] Q. M. Zhang et al., *The JUNO Calibration System* [J], 39th International Conference on High Energy Physics, Seoul, Korea,4-11 July, 2018, Proceedings of Science, PoS(ICHEP2018).
[5] F. Y. Zhang, *Calibration for energy non-linearity and resolution* [R], Beijing: IHEP, 2018.
[6] F. Y. Zhang et al,*Calibration strategy of the JUNO experiment*[J].10.1007/JHEP03(2021)004, ID,10.1007/JHEP03(2021)004.
[7] F. Y. Zhang, *Consideration of Calibration Plan* [R], Beijing: IHEP, 2019.
[8] F. Y. Zhang, *Calibration Strategy of the JUNO Experiment* [R], Beijing: IHEP, 2020.