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The JUNO Calibration System

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On behalf of JUNO collaboration

The Jiangmen Underground Neutrino Observatory (JUNO) is designed to primarily measure the neutrino Mass Hierarchy. Its Central Detector (CD) will be the largest liquid scintillator (LS) detector to measure the energy of neutrinos with an unprecedented energy resolution of 3% @1MeV and an energy nonlinearity better than 1%. Accordingly, a calibration complex is designed for multiple source deployment, the energy coverage of reactor neutrinos and CD full-volume coverage. In this proceeding, the design details and primary progress about JUNO calibration system are presented.

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1. Introduction of JUNO

The Jiangmen Underground Neutrino Observatory (JUNO) is designed to primarily determine the neutrino Mass Hierarchy(MH) and to discover other physics with energy resolution better than $3\%/\sqrt{E}$ [1] . JUNO central detector (CD)，an acrylic sphere with a diameter of 35.4m, is filled with liquid scintillator(LS) to measure the energy of neutrinos [2], so the calibration system is very critical [3,4,5].

2. Calibration System

JUNO energy response is strongly position-dependant, so a complete calibration complex including Automatic Calibration Unit (ACU), Cable Loop System (CLS), Guide Tube Control System(GTCS) and Remotely Operated under-liquid-scintillator Vehicles (ROV) has been designed for full coverage [6].

The radiation sources include neutron sources (^{241}Am-Be, ^{241}Am-^{13}C, ^{241}Pu-^{13}C, ^{252}Cf), positron sources (^{22}Na, ^{68}Ge, ^{40}K, ^{90}Sr) and gamma sources (^{40}K, ^{54}Mn, ^{60}Co, ^{137}Cs) will be used for calibration [6].

Table 1 key features of calibration sub-systems

Sub-system	Frequency	Positioning	Position Control	Positioning Error	Source change
ACU	Weekly	Rope Length	Spool drive (steel wire coated with Teflon Φ1.0) +Tension Control	a few mm	Manual
CLS	Monthly	Rope Length, CCD Ultrasonic receiver		10cm（rope） 3 cm (w/ sensors)	Automatic
GTCS	Monthly	Rope Length Metal Sensor		10cm（rope） 3 cm (w/ sensors)	Manual
ROV	When needed, seasonally or annually	Ultrasonic receiver CCD	Remotely Operated Vehicle	~4cm	Manual

3. Calibration Strategy

ACU, CLS and GTCS will be combined to deliver ^{40}K source to specified positions in one plane for non-uniformity correction, and ROV will be used for full volume scan when needed. On the other hand, ACU with multiple sources at CD center will be used for nonlinearity correction. Finally, the energy can be measured accurately.

JUNO response function can be calibrated by using the data from the given calibration points with ACU, CLS and GTCS (or ROV). A simple spline function is used to predicate the "blank" region and the energy response uniformity would be corrected with the correction function. Simulation shows that energy resolution for 1.022MeV uniformly distributed positron is 2.98% and that the bias of the mean value is ~0.04% [7].

Energy linearity is corrected by placing various sources at CD center with ACU. 9 gamma sources are used to study the detector`s linearity. Verification shows that the energy bias (non-linearity) to mono-energy positron at CD center is < 0.5% after correction [7].

The simulated mono-energy e^+ events are uniformly distributed in CD and the non-uniformity correction (response is obtained with ^{40}K) is applied. Analysis shows that the bias is less than 0.1% and the energy resolution is better than 3.0% [6], which satisfies the JUNO requirements.

References

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