Calibration system of the JUNO experiment

Jiaqi Hui

Shanghai Jiao Tong University

On behalf of the JUNO collaboration

2023/10/26

Neutel2023

Overview of calibration system

Requirements:

Energy non-linearity better than 1%

Effective energy resolution better than 3%

Comprehensive system:

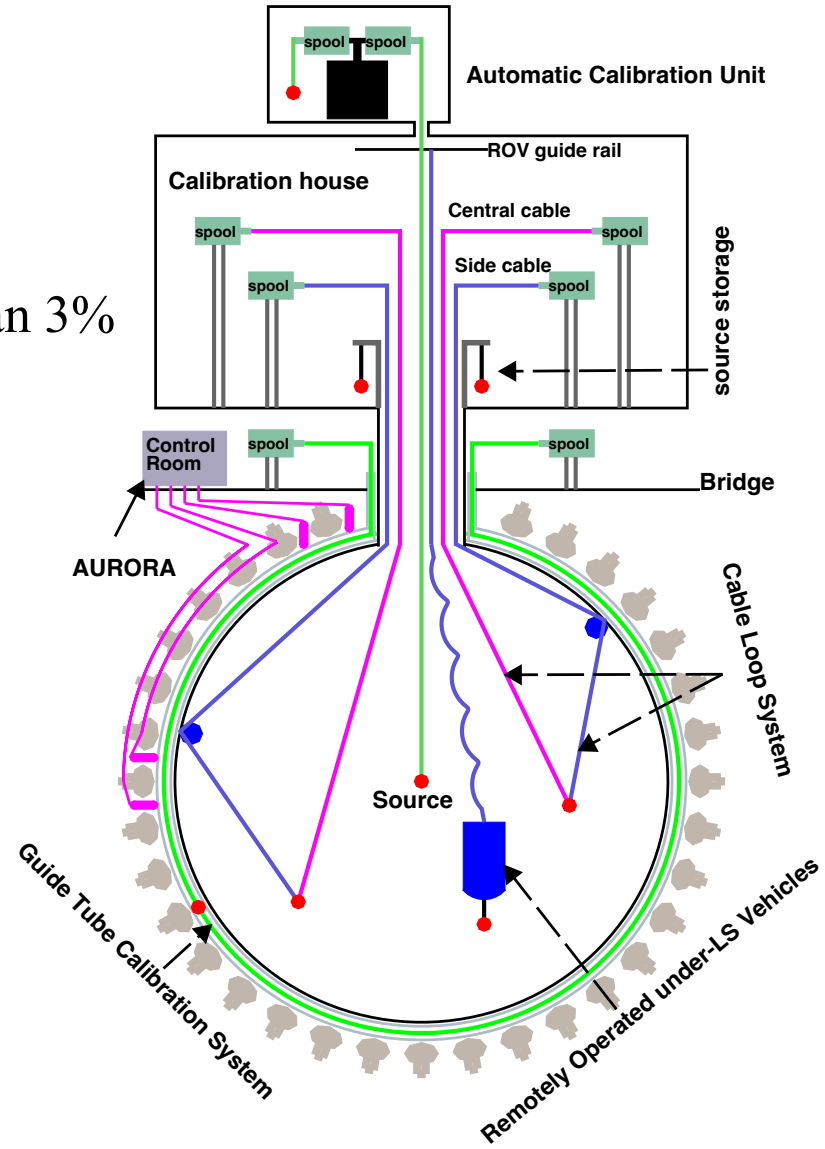
1D central axis scan

2D plane scan

2D boundary scan

3D scan

Auxiliary system



ACU: JINST 16 T08008 (2021)

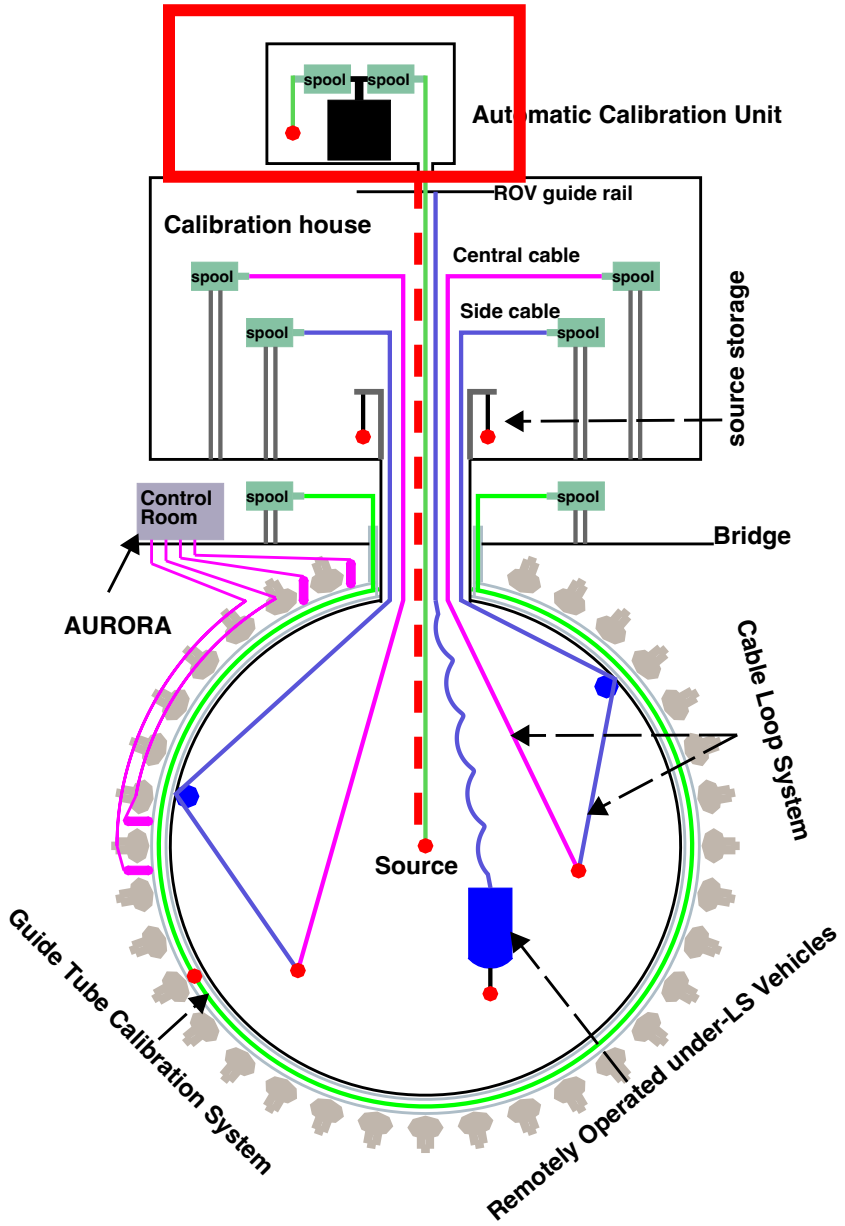
CLS: Nucl. Instrum. Meth. A 988 164867 (2021)

GTCS: JINST 14 T09005 (2019)

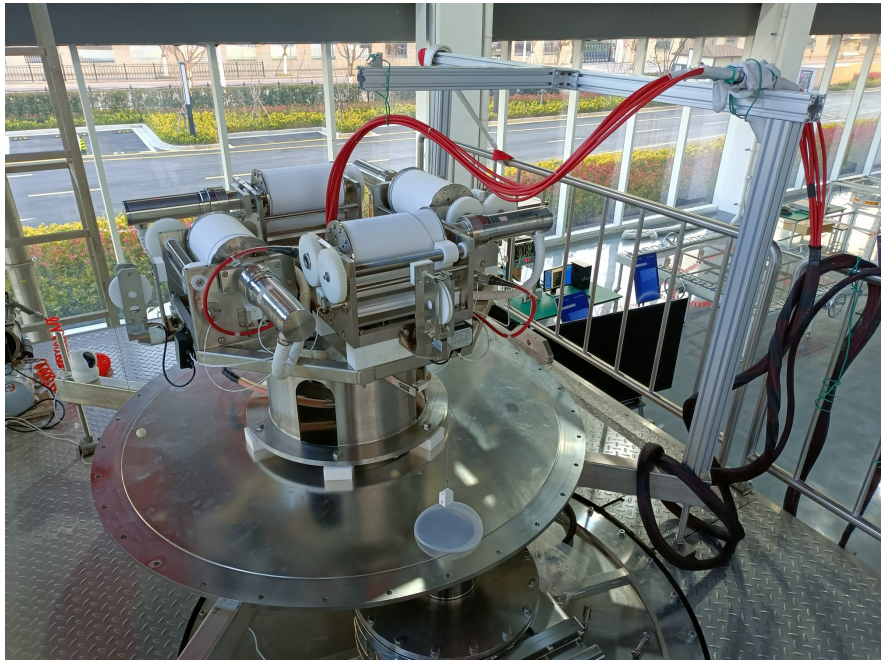
GTCS: JINST 16 T07005 (2021)

ROV: JINST 13 T12001 (2018)

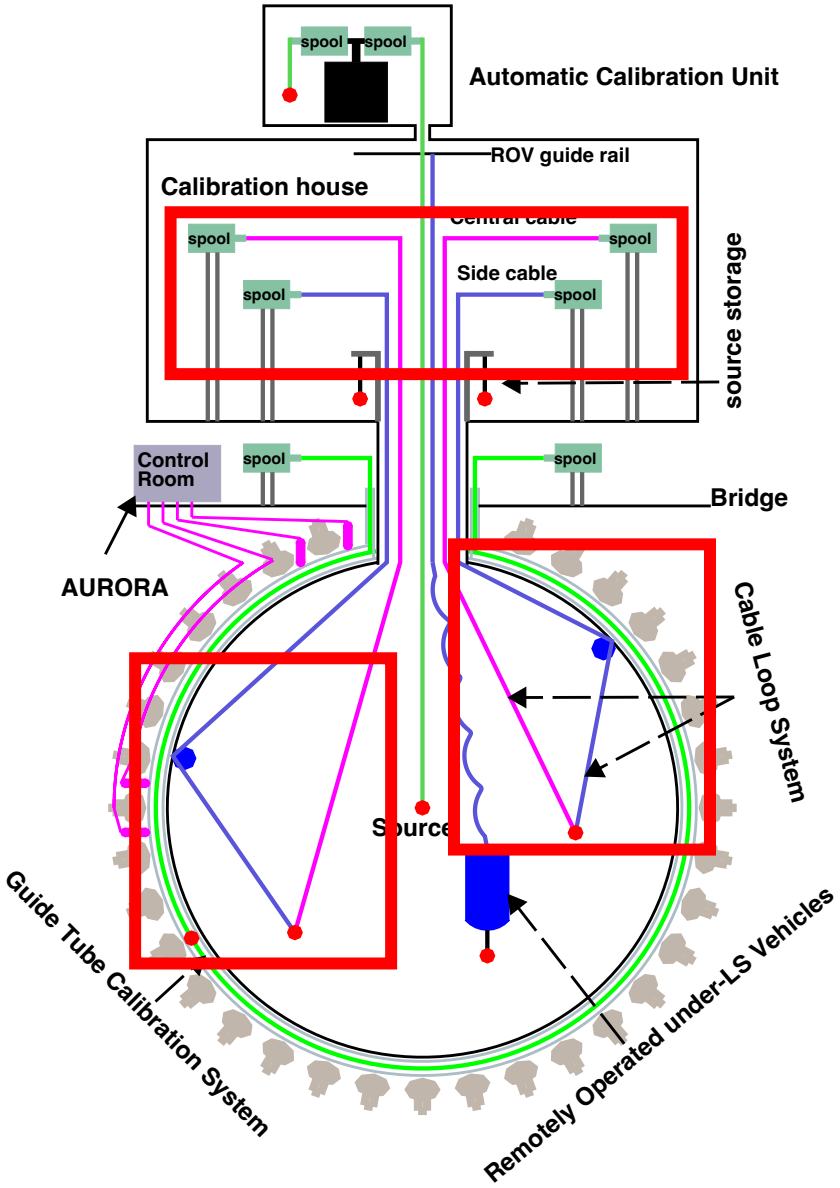
Automatic Calibration Unit (ACU)



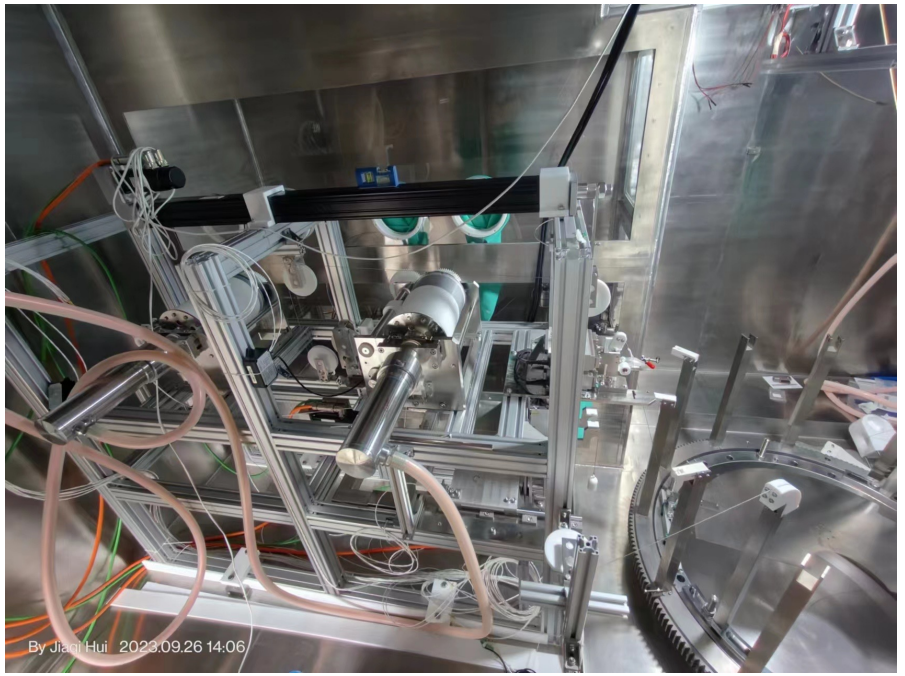
- 1D calibration non-linearity and partially non-uniformity
- 4 spools for radioactive sources and laser source deployment
- Turntable for source selection
- Better than 10 mm positioning accuracy



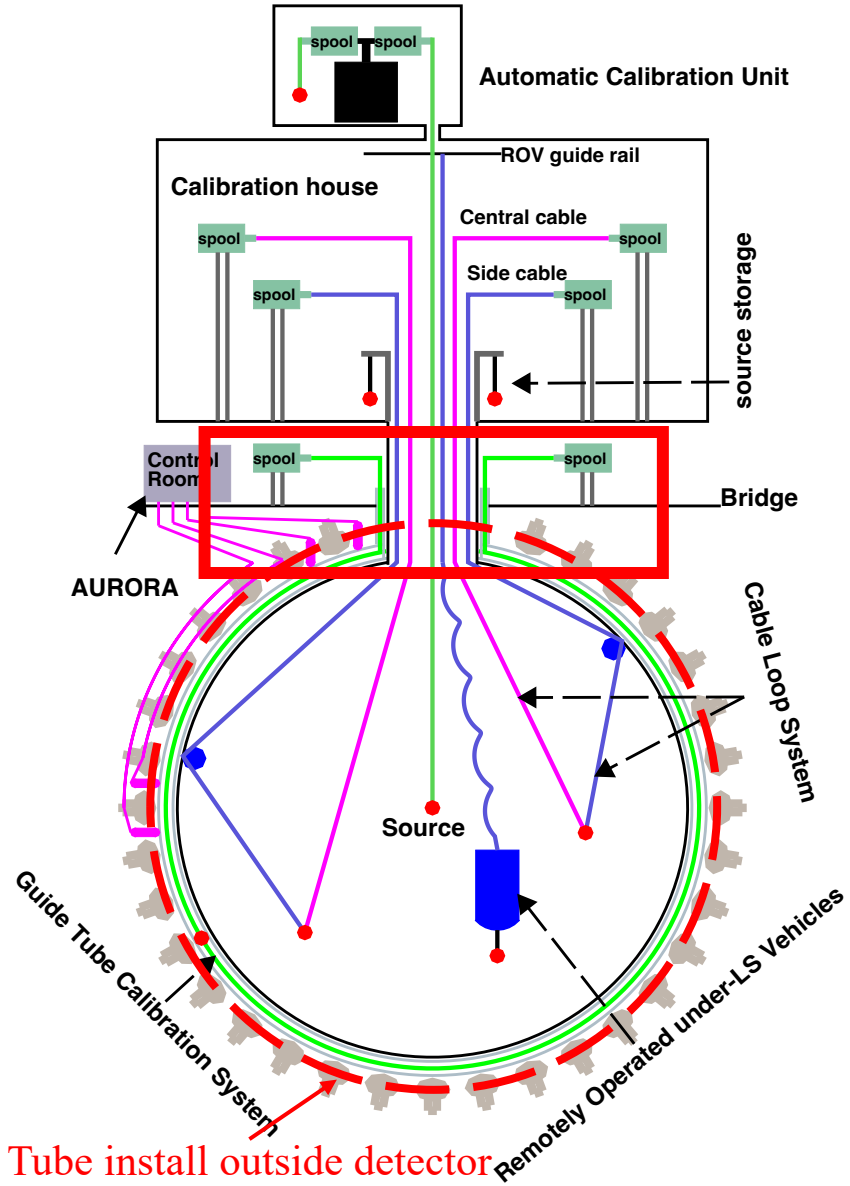
Cable Loop System (CLS)



- 2D calibration non-uniformity in a vertical plane
- 2 spools for radioactive sources deployment
- Automated source changing mechanism
- Better than 30 mm positioning accuracy



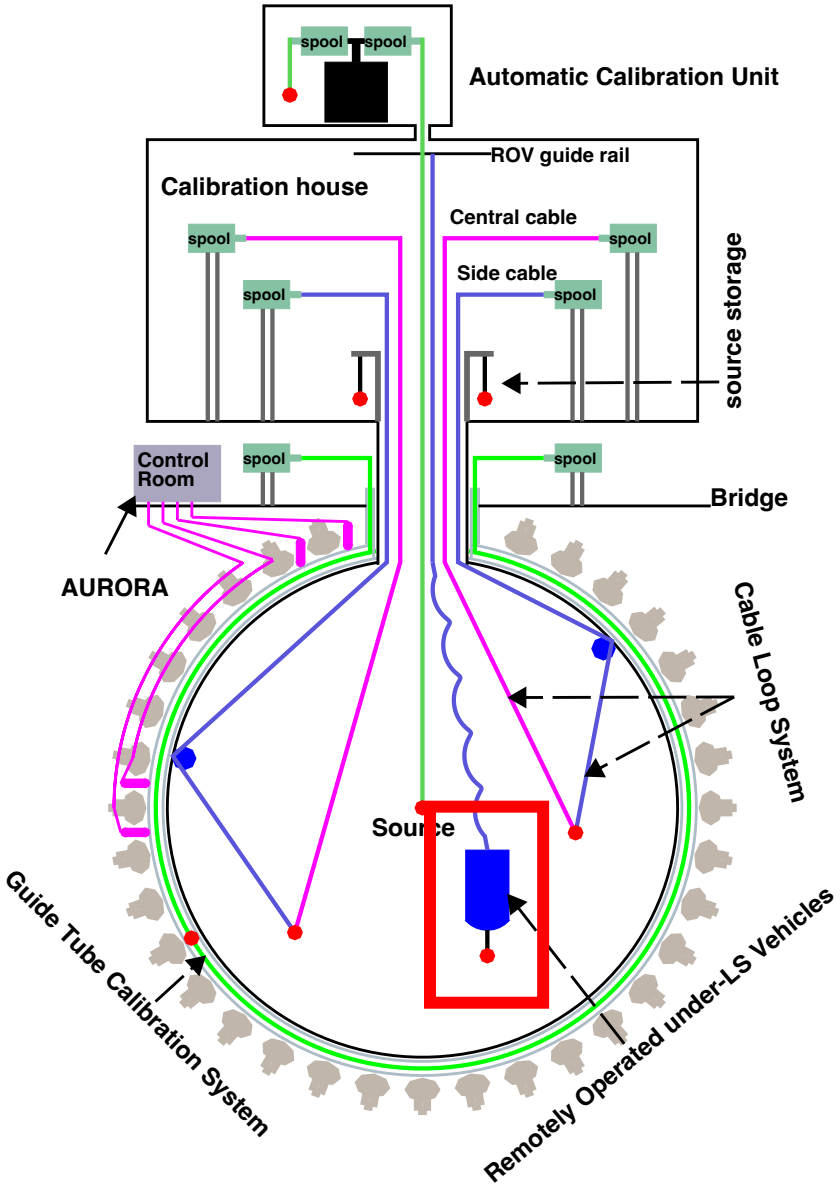
Guide Tube Calibration System (GTCS)



- 2D calibration boundary non-uniformity
- 2 spools for radioactive source deployment
- Better than 30 mm positioning accuracy

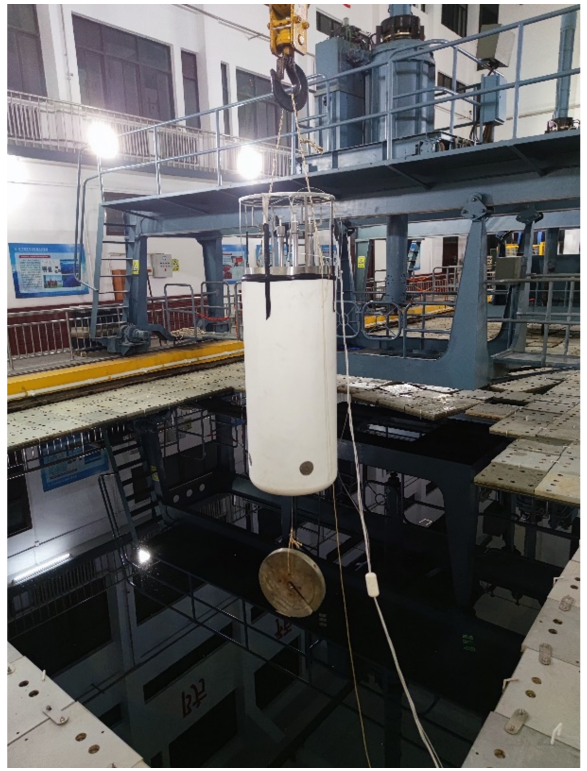
1:12 prototype

Remotely Operated under-LS Vehicles (ROV)



- 3D calibration non-uniformity
- Submarine with umbilical cable for radioactive source deployment
- 30 mm/5 min positioning accuracy

Umbilical cable



Auxiliary system of calibration system

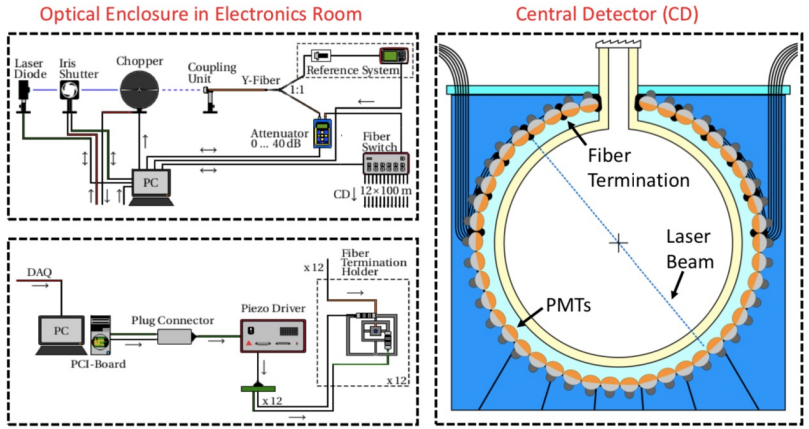
CCD camera and ultrasonic position system

Positioning tools for the CLS and ROV

Calibration house

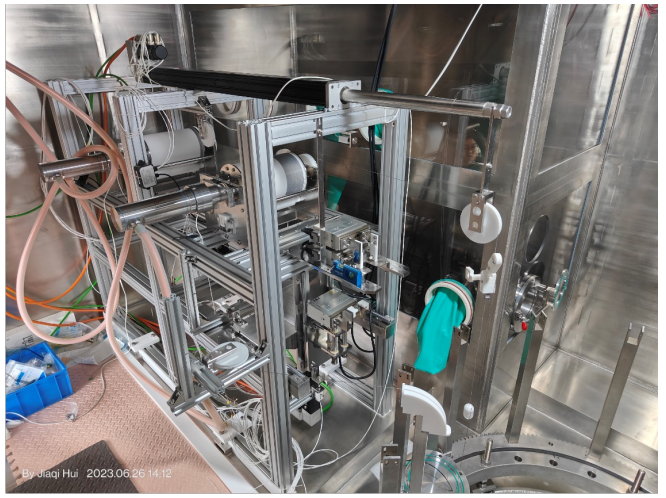
Air-tightness chamber for the CLS installation

A Unit for Researching Online the LSc tRAnsparency (AURORA)



Online LS transparency monitoring

Automated source changing mechanism



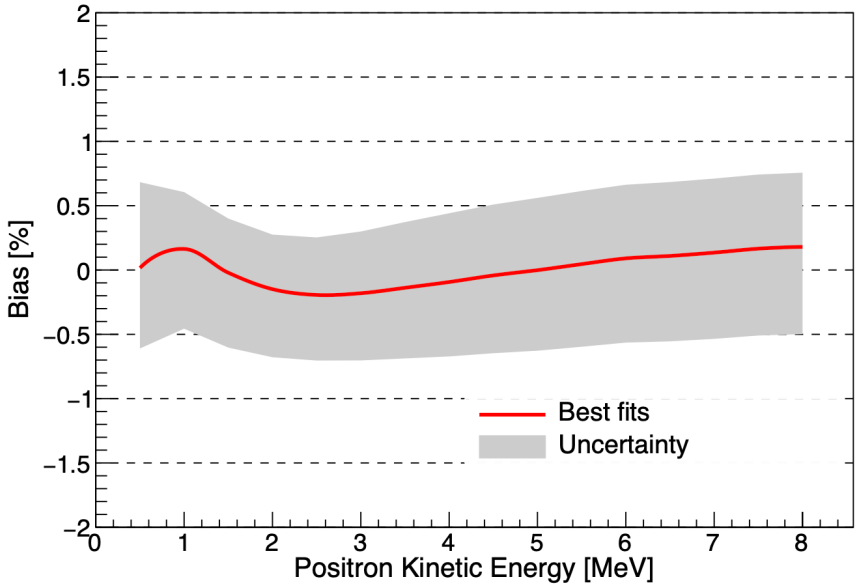
For the CLS source changing

Calibration strategy – non-linearity

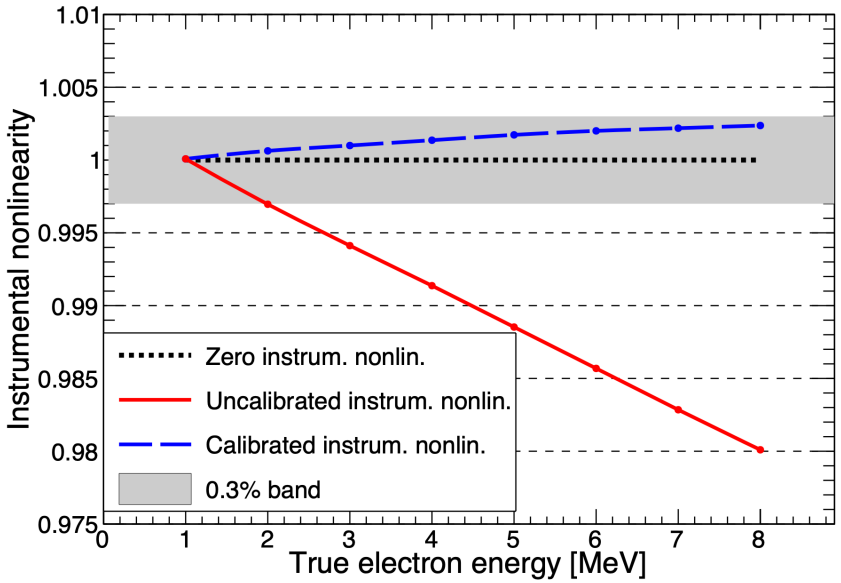
- **Physical non-linearity:**
  - From quenching effect and Cherenkov photon emission
  - Calibration – multiple radioactive sources (γ and e^+) and cosmogenic background (^{12}B)

JHEP 03 (2021) 004

- **Instrumental non-linearity:**
  - Calibration – LPMT and SPMT dual calorimetry + tunable laser source



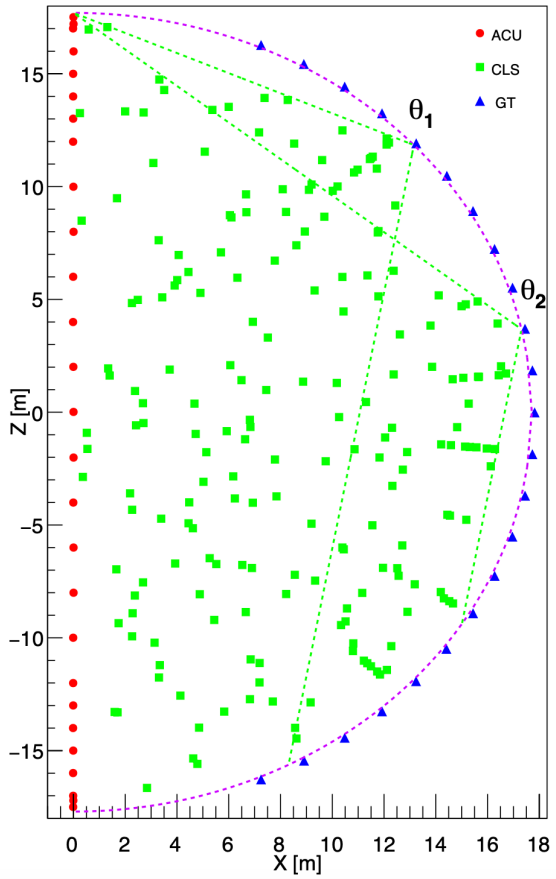
Non-linearity after calibration



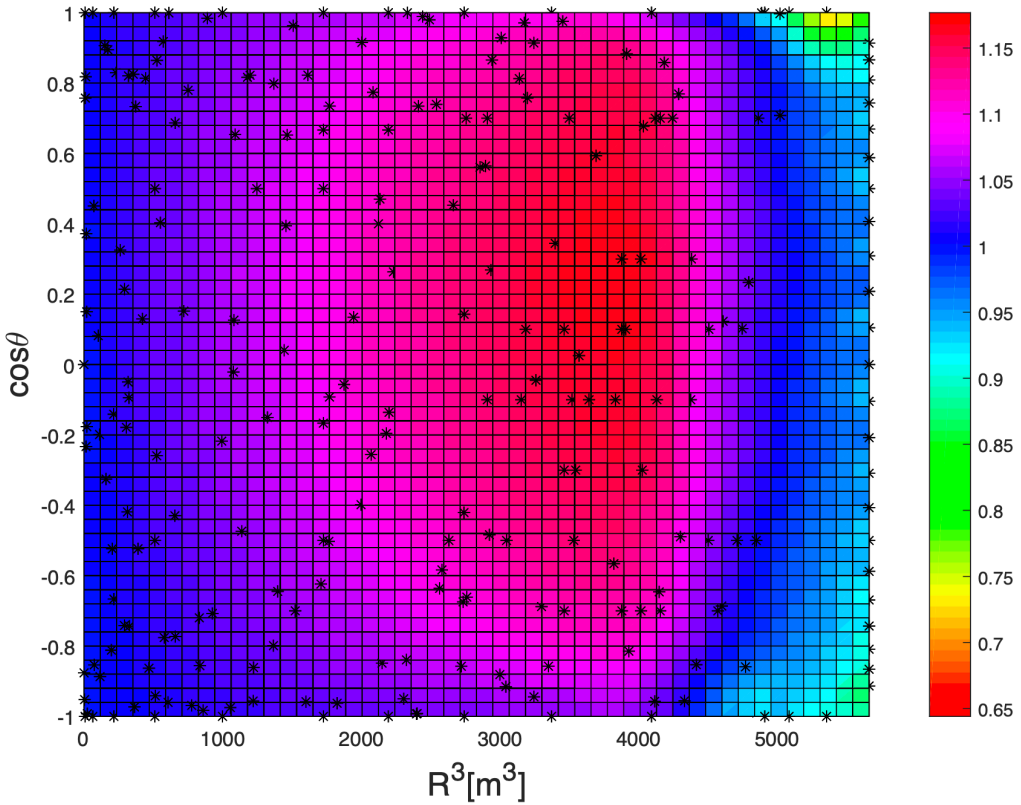
Instrumental non-linearity

Calibration strategy – non-uniformity

- Calibration – AmC neutron source in different positions



Calibration points of ACU + CLS + GTCS



Non-uniformity correction map

Position dependent effect:

less than 1%

JHEP 03 (2021) 004

Calibration strategy – energy resolution

Energy resolution:

$$\frac{\sigma_{E_{\mathrm{vis}}^{\mathrm{prompt}}}}{E_{\mathrm{vis}}^{\mathrm{prompt}}} = \sqrt{\left(\frac{a}{\sqrt{E_{\mathrm{vis}}^{\mathrm{prompt}}}}\right)^2 + b^2 + \left(\frac{c}{E_{\mathrm{vis}}^{\mathrm{prompt}}}\right)^2}$$

a – statistical term, ~2.7%

b – constant term, in JUNO dominated by non-uniformity (< 1% after calibration)

c – contribution of a background noise term, ~1%

Effective energy resolution:

$$\tilde{a} \equiv \sqrt{(a)^2 + (1.6 \times b)^2 + \left(\frac{c}{1.6}\right)^2} \leqslant 3\%$$

JHEP 03 (2021) 004
J. Phys. G43 (3) (2016) 030401

Summary

- A comprehensive calibration system has designed and produced for JUNO calibration
- With the calibration system and the calibration strategy, JUNO can achieve better than 1% energy non-linearity and a 3% effective energy resolution

Thanks!