TAUP 2025
XICHANG
SICHUAN, CHINA 2025.8.24 - 8.30
TAUP XICHANG

JUNO as 2 MeV Water Cherenkov Detector

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On behalf of
JUNO collaboration

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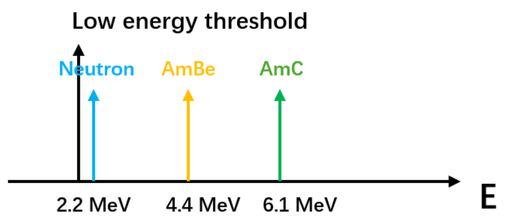
Introduction

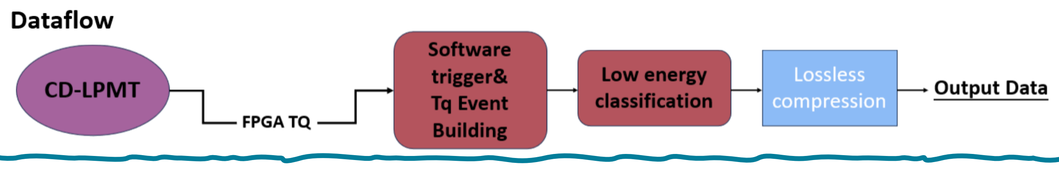
Motivation: Demonstrating the **low energy threshold** of JUNO detector in water-phase

- By observing **6.1 MeV, 4.4 MeV and 2.2 MeV** gamma event from ^{241}Am-^{9}Be (Am-Be) , ^{241}Am-^{13}C (Am-C) calibration sources and neutron capture on hydrogen (n-H) to check low energy threshold.



JUNO water-phase:

- JUNO was filled about **23 k tons pure water** in water-phase and **17 k 20-inches PMTs** are available. (**Large mass** and **high PMT coverage**)
- **Software trigger** was designed to collect low energy events.



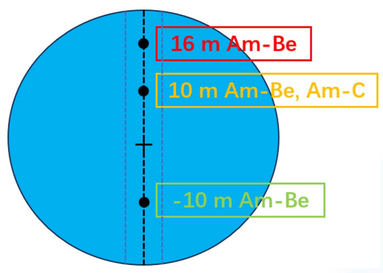
Am-Be, Am-C calibration sources

- JUNO performed a series of calibration measurements using **Am-Be and Am-C calibration sources** deployed at fixed positions inside the central detector:

$$^{241}_{95}\mathrm{Am} \rightarrow {}^{237}_{93}\mathrm{Np} + {}^{4}_{2}\mathrm{He}$$

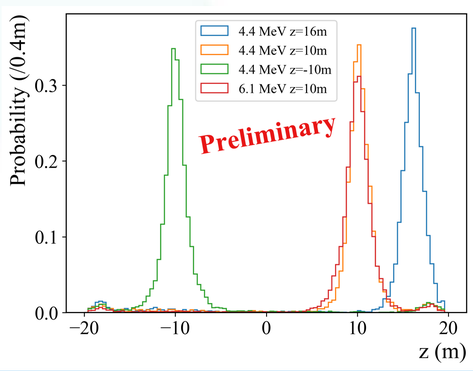
$$\begin{cases} {}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n} & \text{Am-Be} \\ {}^{13}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{16}_{8}\mathrm{O} + {}^{1}_{0}\mathrm{n} & \text{Am-C} \end{cases}$$

- Am-Be source at a height of 16 m (4.4 MeV gamma)
- Am-Be source at a height of 10 m (4.4 MeV gamma)
- Am-C source at a height of 10 m (6.1 MeV gamma)
- Am-Be source at a height of -10 m (4.4 MeV gamma)

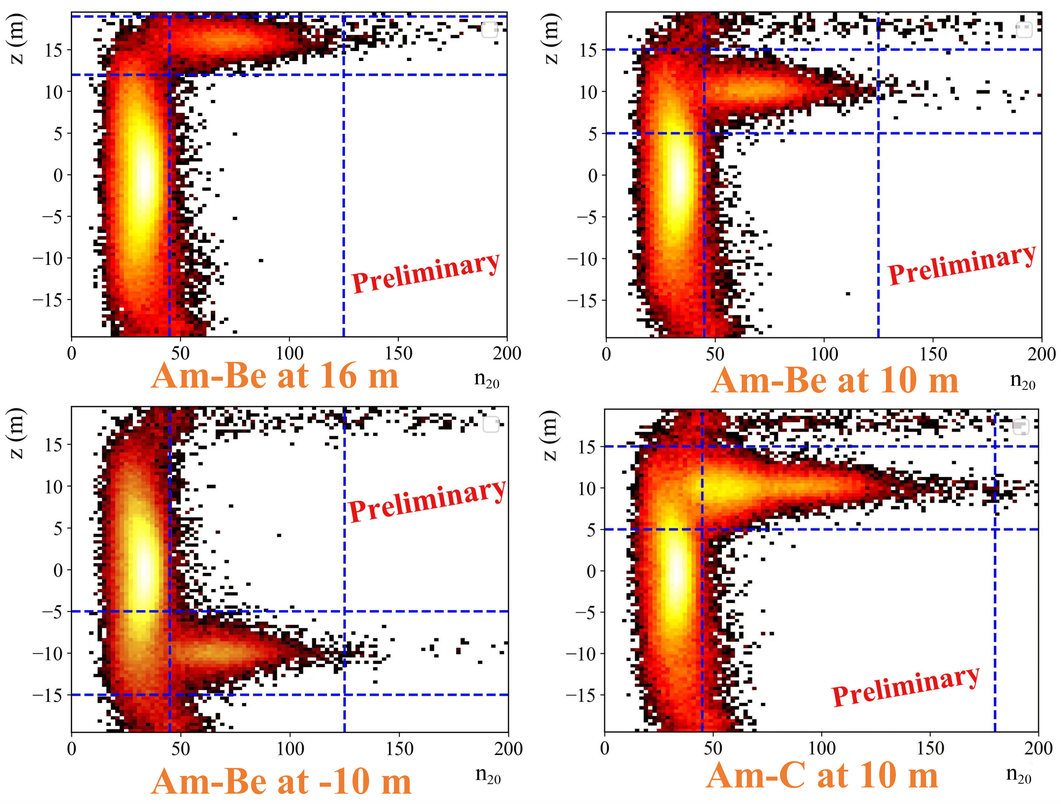


Center detector of JUNO

- Selecting 6 MeV and 4.4 MeV gamma events by using n_{20} (reconstruction energy) and z (reconstruction position z) 2D cut and Cylinder radius < 2 m:
  - **6.1 MeV** gamma event form Am-C and **4.4 MeV** gamma event from Am-Be can be observed. Distinct peaks in z correspond to different source positions
  - Event selection with n_{20} >45 ensures suppression of low-energy background. These distributions help constrain the spatial window for identifying n-H events.



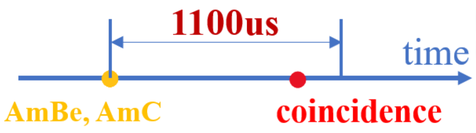
The reconstruction Pos-z of 4.4 MeV and 6.1 MeV gamma events



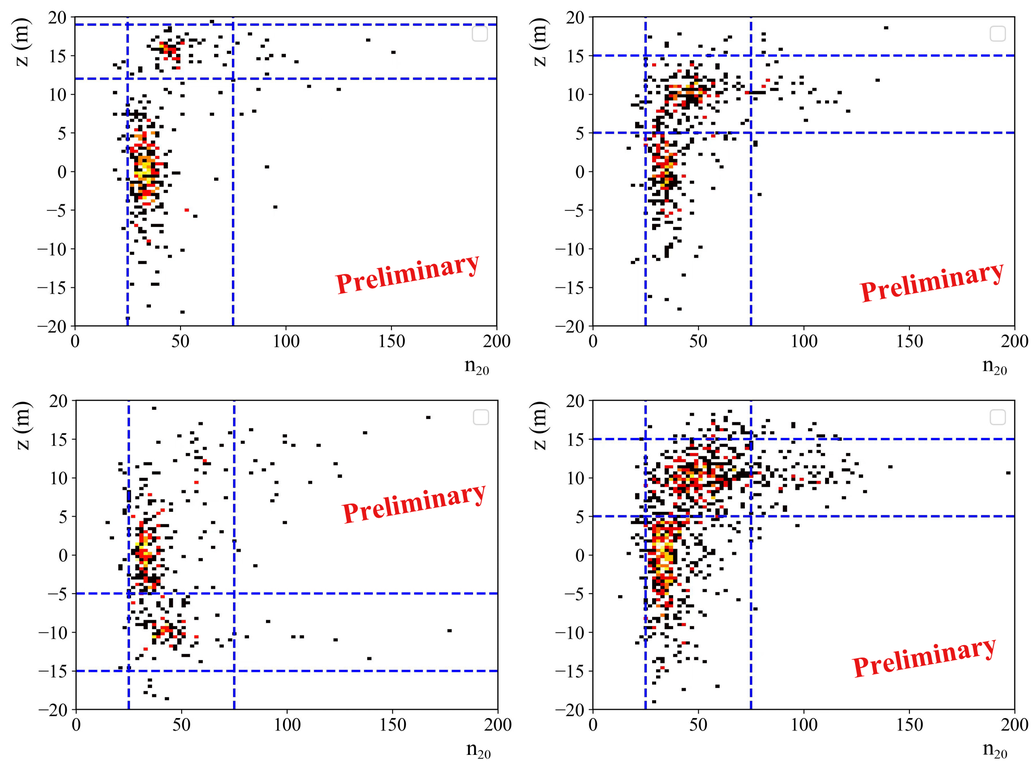
The 2D distribution of Am-Be and Am-C sources at different positions

Neutron capture observation

- Neutron will be released by Am-Be and Am-C source:
  - Free neutron will be captured by hydrogen nucleus and release 2.2 MeV gamma particle.
  - n-H events and 4.4 MeV and 6.1 MeV gamma events from radiation sources can form a pair of prompt and delay signal. The reference lifetime of n-H events is 207 us[1].
- Searching neutron capture events by looking for coincidence **delayed signal of 1100 us** after gamma events of 4.4 MeV and 6.1 MeV gamma events from Am-Be and Am-C sources:

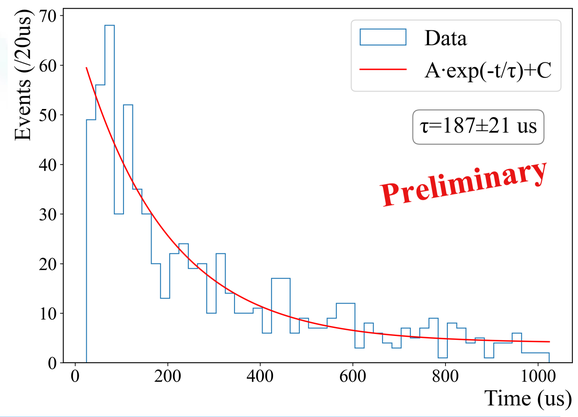


  - **2.2 MeV** n-H events are observed on n_{20} range 25 to 75 and height of corresponding radiation source.



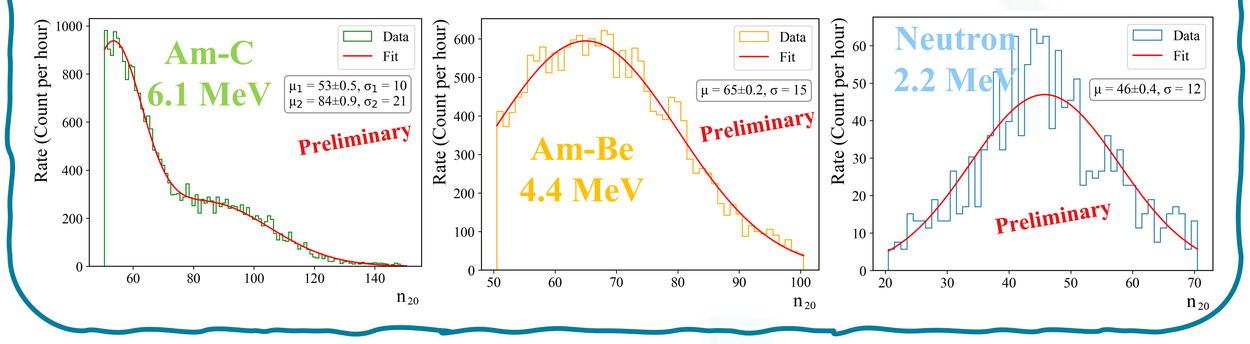
The 2D distribution of delayed signal

- The fitted lifetime of selected n-H candidates is **187±21 us**. Contain the reference value of 207 us within its 1σ uncertainty interval.
- Mean detection efficiency of n-H events for four configurations is **7.2%**.



The time difference between n-H candidates and prompt signals

Energy spectrums



Conclusions

- **JUNO Detector can achieve 2.2 MeV low energy threshold as water Cherenkov detector**
  - 6.1 MeV gamma event from Am-C source and 4.4 MeV gamma event from Am-Be source can be observed.
  - 2.2 MeV gamma from neutron capture on hydrogen can be observed by coincidence finding of Am-Be and Am-C events.

[1]. Anderson, M. R., et al. "Measurement of neutron-proton capture in the SNO+ water phase." Physical Review C 102.1 (2020): 014002.