Liquid scintillators for Daya Bay Reactor Neutrino Experiment and Jiangmen Underground Neutrino Observatory

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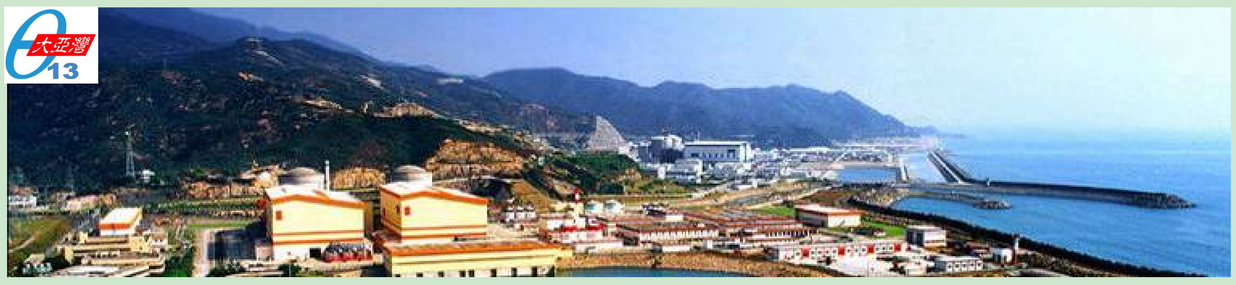
Introduction

Daya Bay Reactor Neutrino Experiment is designed to measure the mixing angle θ_{13} using 8 identical Anti-neutrino detectors (AD). Each AD contains 20-ton Gadolinium-loaded liquid scintillator (Gd-LS) as the target for catching neutrino. Optical properties and stability of Gd-LS are of great important for the experiment. Here we report Gd-LS recipe and production of 185-ton Gd-LS. Both results based on periodical characterization of Gd-LS and data taken from AD show 185-ton Gd-LS meets the requirements of Daya Bay experiment.

Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose neutrino experiment which is going to use a huge detector containing 20-kiloton liquid scintillator for catching neutrino. Requirements for JUNO LS, such as attenuation length, light yield and radio-impurity content, are very strict because of the size of the detector. Pre-study of LS at IHEP show production of 20-kt qualified LS are very promising.

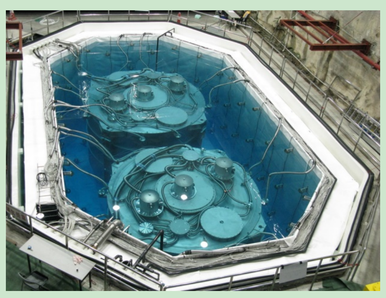
Key words: liquid scintillator, linear alkyl benzene, purification, neutrino

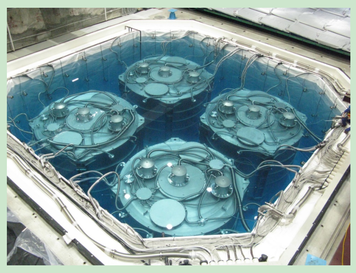


185 ton Gd-LS for DYB

DYB Gd-LS recipe:

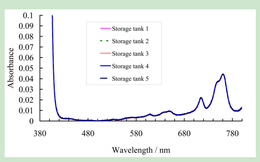
0.1%Gd (Gd-TMHA complex), 3g/L PPO, 15mg/L bis-MSB in linear alkyl benzene.

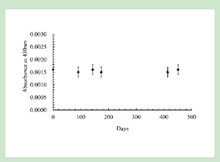




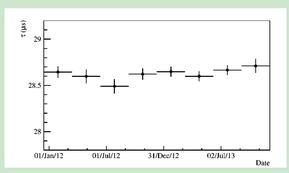
Characterization and Long-Term Monitoring of DYB Gd-LS

- **Optical Transparency**
- Abs@430m = 0.0016±0.0002 over 500 days





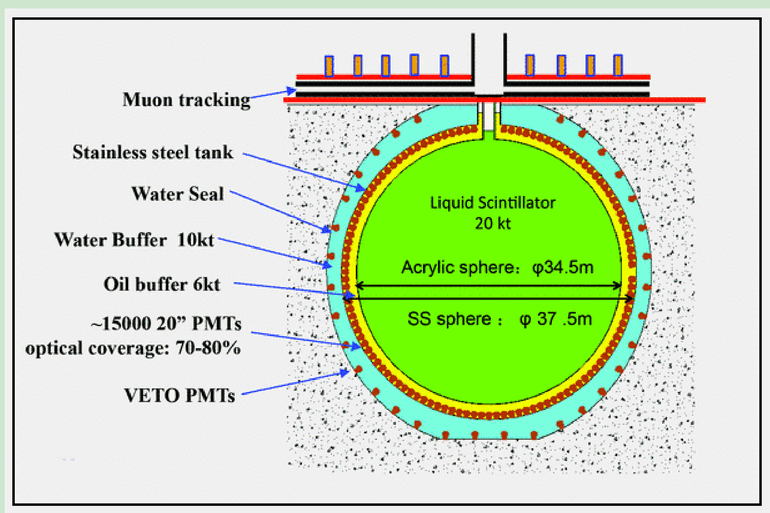
- **Attenuation Length**
- ~15 meters at 430 nm (3 apparatus); A slow degradation, ~1.3% per year, of the energy scale in terms of photoelectrons per MeV was observed.
- **Gd concentration**
- A variation of ±0.2μs in capture corresponds to ± 0.1% relative variation in [Gd] concentration in two years.



- **Light-Yield**
- ~50% of that of anthracene
- **Backgrounds from Gd-LS**
- The rate of >0.7 MeV singles was measured to be ~60 Hz in all ADs. The contribution by the radioactive impurities in the Gd-LS has been measured to be ~4.5 Hz; The $^{13}C(a,n)^{16}O$ background rate was estimated to be 0.04-0.08 per day for different Ads. The successes of the raw material purifications and the cleanness control throughout the Gd-LS production
- **Neutron capture time and Gd capture ratio:** The Gd capture fraction variation among ADs is within 0.1%, which meets the requirement.

Requirements for 20kt LS

- Attenuation length @430nm: >22m
- Light yield: >10000 photon/MeV
- Energy resolution > 3%
- Radio active background: $<10^{-15}$g/g



JUNO LS recipe (preliminary)

- 3g/L PPO, 15mg/L bis-MSB in LAB

LAB Purification

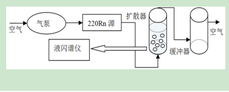
- Column purification (Al2O3)
  - High column capacity
  - No sample discrimination
  - High Efficiency in removing optical impurities
  - Radio-impurities in Al2O3?
- Vacuum distillation
  - No extra contaminants will be introduced into LAB
  - Good way for removing radio-impurities
  - Usually cause the degradation of LAB optical properties
  - High energy consuming method

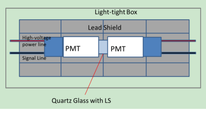
LAB/LS Characterization

- UV-Vis spectra
- Attenuation length
- Impurity analysis by GC-MS
- Rayleigh scattering measurement

Radio-purification of LS at IHEP

- Radioactive Spike Test
- Efficiency of different radio-purification methods
- Al2O3 column: 99.41%
- Vacuum distillation: 99.64 %
- Water extraction: 88.67%
- Gas stripping: in progress

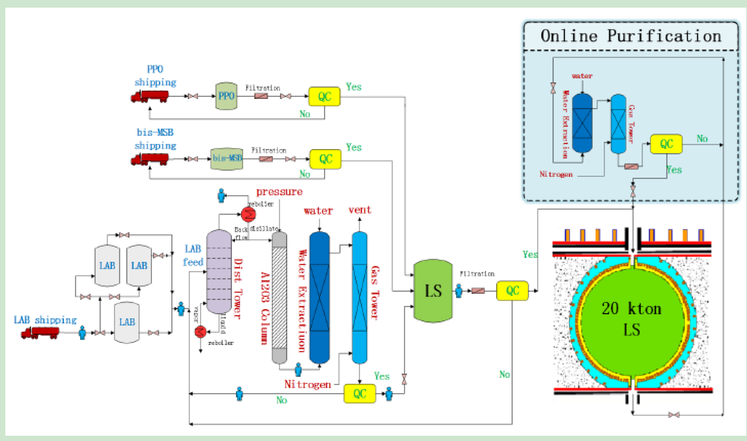




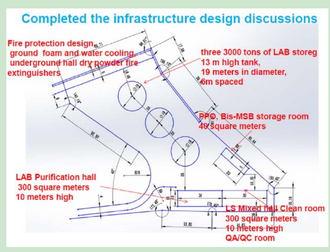
20,000 ton LS for JUNO

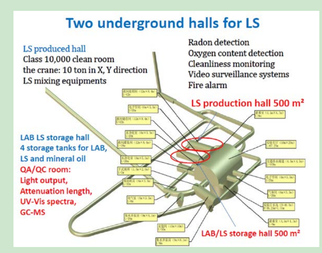
MS production

- **Flow chart (conceptual design)**



- **Civil construction**





- **Chemicals**
- LAB: 20kt
  - Nanjing LAB plant, Nanjing China
    - Provide 388t LAB for Daya Bay experiment
    - The A.L. of Nanjing special LAB ~20m
  - Jintung petrochemical corporation Ltd.
  - European LAB producers: SASOL, South Africa/Italy, CEPSA (Petresa), Spain/Canada, HELM (Saybolt), Germany/Egypt
- PPO: 3g/L, ~70t in total
- bis-MSB: 15mg/L, ~350kg

Medium-size test at Daya Bay?

- Pre-study for JUNO LS mass production
- Check radioactive background by using Daya Bay AD
- To determine which purification method can be used for JUNO LS and how to combine them together?
- Study the effects of light emitting substance, concentration to light yield and energy nonlinearity……

JUNO LS group

- IHEP, CAS, China
- INFN-milano, Italy
- JINR, Russia
- TUM, Germany
- NJU, China
- WHU, China
- UCAS, China
- JGU, Germany
- University of Oulu, Finland
- ……

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