Jiangmen Underground Neutrino observatory

Conceptual Design Report

(liquid scintillator)

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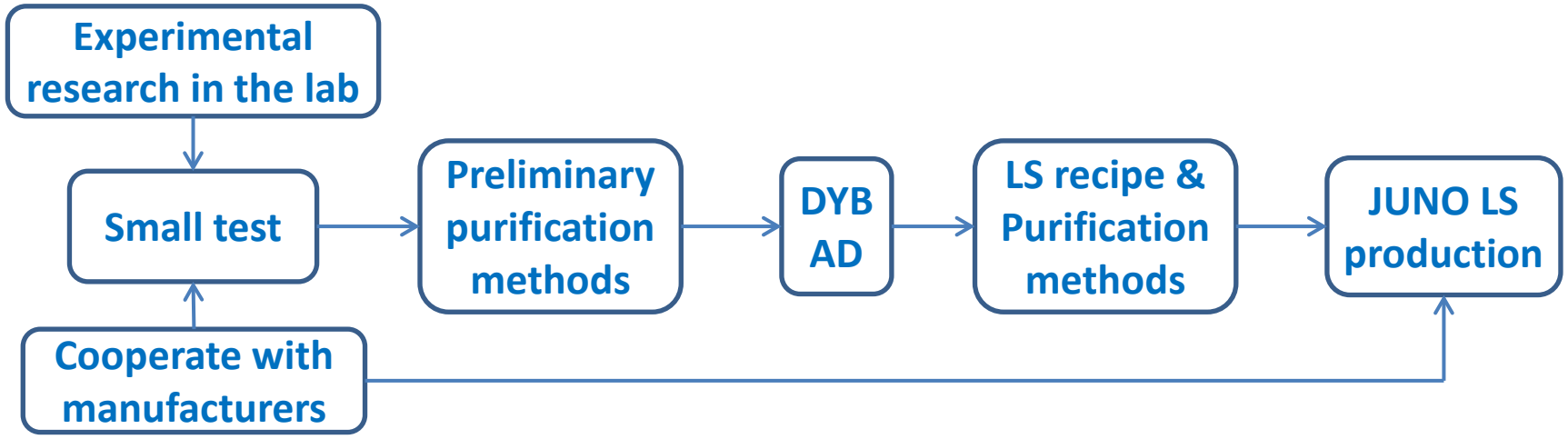
Outlines

- Section 1: Brief introduction of JUNO LS
- Section 2: Requirements for JUNO LS
- Section 3: Luminescence property of LS
- Section 4: Light propagation of LS
- Section 5: Purification of LAB and fluors
- Section 6: Radioactive background of LS
- Section 7: Mass production
- Section 8: Risk assessment
- Section 9: Annual plans

Sect. 1. Brief introduction of JUNO LS

- 20 k-ton LS for JUNO detector, target for catching neutrino
- Key points:
  - Higher light yield
  - Longer attenuation length
  - Lower radioactive background
- Schedule

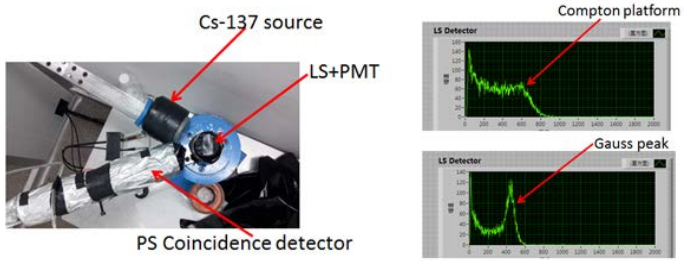


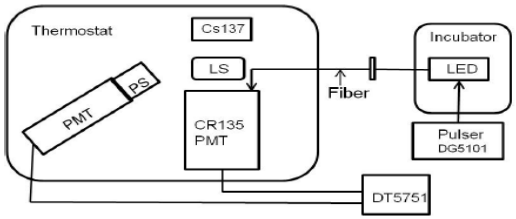
Sect. 2. Requirements for JUNO LS

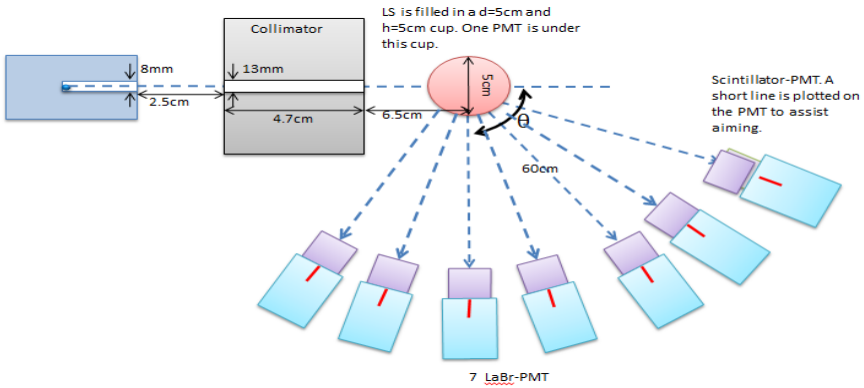
- **Total weight**: 20,000 ton
- **Recipe**: 3g/L PPO, 15mg/L bis-MSB in LAB (needed to be optimized)
- **Light yield**: 1100 pe/MeV, R.L.Y.≥45% (anthracene)
- **Transparency**: Attenuation length ≥22m, Abs@(430nm)≤0.003
- **Radioactive impurities**: U, Th and K^{40} should be lower than 10^{-15} g/g

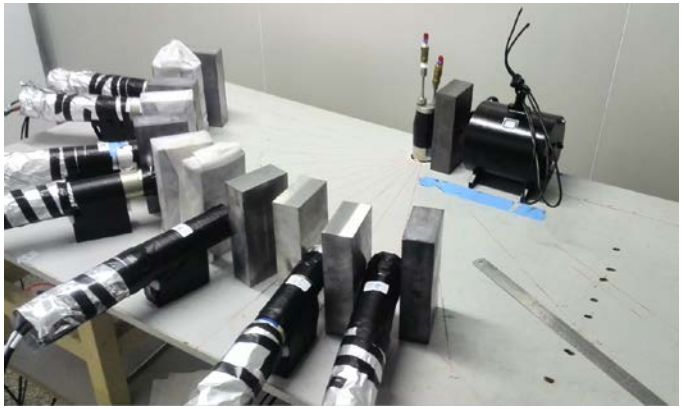
Sect. 3. Luminescence property of LS

- Light yield measurements
  - 1100 pe/MeV, energy resolution≥3%
  - Measuring system has been built at IHEP
- Temperature response
  - Goal: to increase L.Y. of LS
  - Temperature of LS changed from 30°C to 5°C, Light Yield of LS get a raise of ~7%;
- Nonlinear energy response
  - To reduce the experimental system error



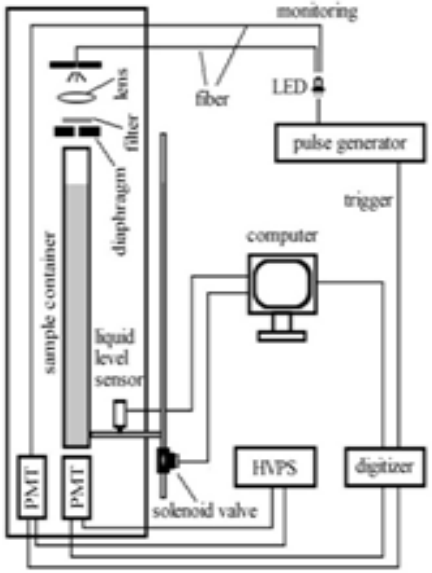






Sect. 4. Light propagation of LS

- Measurements of LS absorption spectra
  - Quick method for real-time monitoring of LAB/LS
  - Suitable for LS long-term stability test
- Measurements of LS Attenuation length
  - More stable light source, higher accuracy, higher level of automation
  - One set-up has been installed at IHEP
  - Another set-up will be installed in Jiangmen

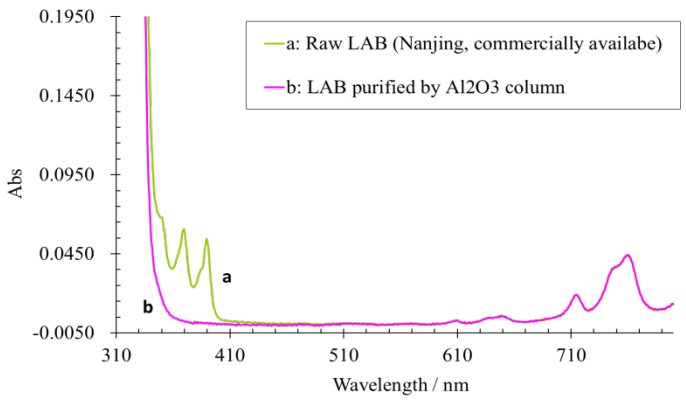


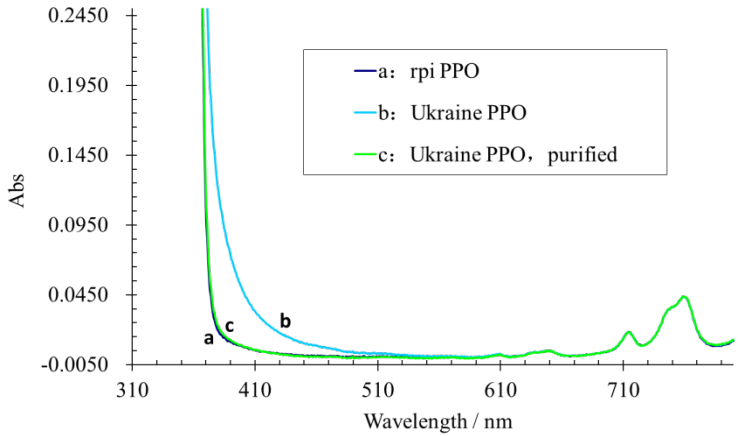
Sect. 4. Light propagation of LS

- Analysis of impurities in LAB
  - Based on GC-MS
  - Identify the impurities in LAB
- Measurements of LS Rayleigh scattering length
  - The Rayleigh scattering length of LS will directly effect the reconstructed original points in the simulations, which will effect the energy resolution of the center detector and the design of experiment
- Long-term stability of LS
  - Stainless steel, glass, high temperature
  - Items: light yield, A.L., absorption spectra
  - Will be finished in 2015

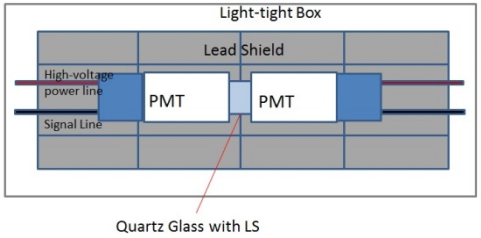
Sect. 5. Purification of LAB and fluors

- 5-1: Purification of LAB
  - Distillation: not so effective to remove optical impurities
  - Al2O3 column purification: the most promising purification method
  - Water extraction and gas stripping
- 5-2: Purification of fluors
  - Optimization of the content of PPO/bis-MSB
  - Influence of impurities on LS

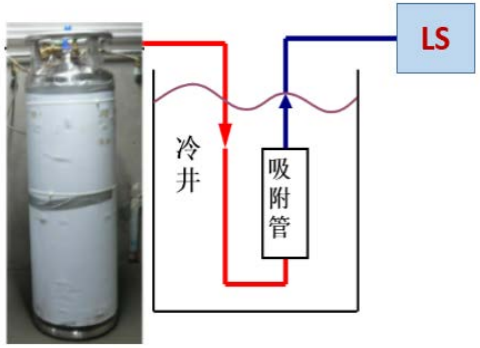




Sect. 6. Radioactive background of LS



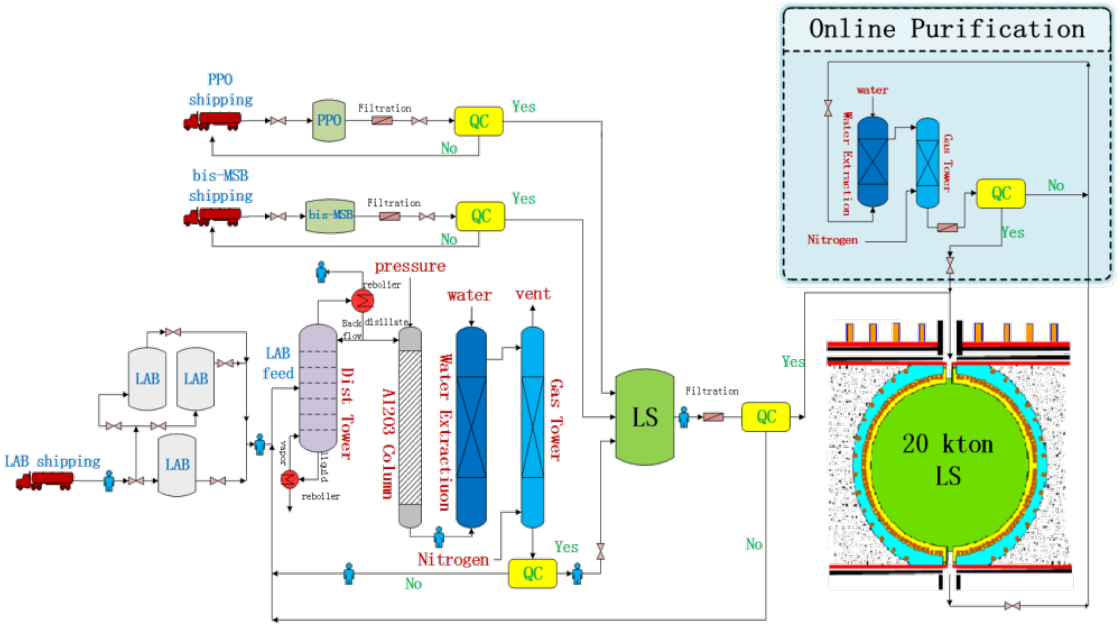
- Pre-study of LS radioactive background
  - Removal efficiency of radio-impurities in LAB
    - ^{220}Rn will be loaded into LAB as tracer; different purification methods
    - Add fluors into LAB to form LS, then count cascade decay event number (from the branch-chain Bi212-Po212-Pb208) by two PMTs' coincidence measurement.
  - Radio-purification methods for LAB:
    - Al2O3 column: 99.4%
    - Distillation: 99.6%
    - Water extraction & gas stripping



- Ultra pure N_2
  - Used to reduce the radiation background of LS
  - Cold trap to absorb radioactive noble gas in N2
- Study on JUNO LS recipe and purification methods based on DYB AD
  - Test various purification methods
  - Detector date taken before and after purification, LS recipe and purification efficiency

Sect. 7. Mass production

- Raw materials:
  - LAB: produced and transferred under control
  - PPO & bis-MSB
- LAB purification and LS production onsite, 100t /day, 200days
- On line circulating purification of LS



Sect. 8. Risk assessment

- Limited space 700m deep underground
- Chemicals (risk of leakage, fire protection)
  - 20 K-ton LAB; 7000 t mineral oil
  - 70 ton PPO and 350 Kg bis-MSB
- Complex equipment and operations: hoisting equipment, high-altitude operations, accurate positioning, electrical heating device
- Risk of storage & usage of large amount of nitrogen underground

- Fire protection, leakage proof, rules and regulations, …
- Safety training for JUNO LS members

Sect. 9. Annual plans

- 2013
  - Start measurements of LS, LAB impurity analysis, Rayleigh scattering length measurements
- 2014
  - LAB purification method study; Rayleigh length measurement by depolarization ratio of specific angle
  - 2014-2018: cooperate with manufacturers of LAB, PPO and bis-MSB
- 2015
  - Design LS purification system for DYB AD
  - Start to build ancillary systems (Ultra pure water system & ultra pure N2 system)
  - Start measurement of nonlinear energy response of LS
  - Start to build DYB AD purification system on-site
  - Make QA/QC items for PPO & bis-MSB

Sect. 9. Annual plans

- 2016
  - Jan. to Jun., installation and adjustment of DBY AD purification system
  - Jul. to Dec., start purification; DYB AD data taking and physical analysis
- 2017
  - Determine JUNO LS recipe
  - Sign LAB purchase contract; start to design and manufacture LAB purification system
  - Sign fluors purchase contract; production will be start at the end of the year
  - Complete investigation of LAB storage containers

Sect. 9. Annual plans

- 2018
  - Sign purchase contract of LAB storage containers
  - Start construction of storage containers
  - Installation of purification system will start at the end of the year
- 2019
  - Complete the tune of LS purification system before Jun.
  - Complete the installation of ancillary systems
  - Complete the tune of the whole production system before Jun.
  - Start and finish 8 k-ton LS production
- 2020
  - Start and finish 1.2 K-ton LS production before Mar.
  - Water extraction and gas stripping systems will be moved underground after Jun.