Transparency monitor for the filling system in JUNO

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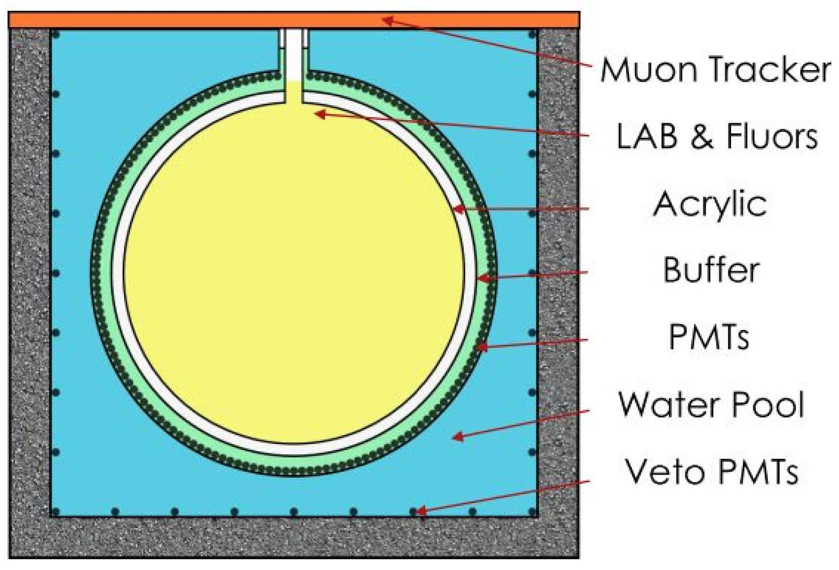
JUNO

The JUNO Detector

- 20kt of liquid scintillator
- Acrylic Sphere
  → 35m diameter of inner sphere
- 16,000 PMTs on stainless steel latticed shell
  → ≥75% coverage
- Water Cherenkov Detector
- Myon Top Tracker
- Resolution goal: ≤3%/$\sqrt{E(\mathrm{MeV})}$

→ High transparency imperative!
→ Precise knowledge of light output needed!



Schematic of the Jiangmen Underground Neutrino Observatory (JUNO).

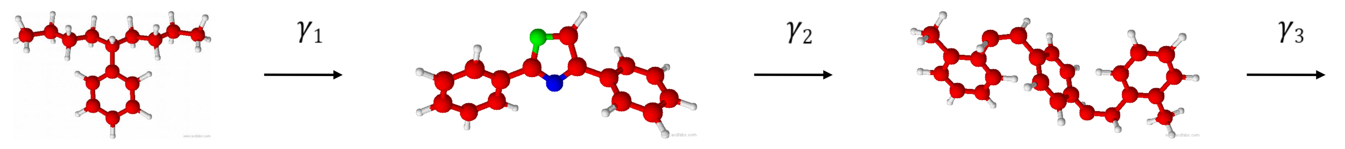
The Goal

- Determination of the neutrino mass hierarchy (sign of Δm_{32}^2)
- Precision measurement of solar oscillation
  - Parameters θ_{12}, Δm_{21}^2 and atmospheric oscillation parameter Δm_{32}^2 to better than 1%

Why Monitor the Transparency

- An energy resolution of at least 3%/$\sqrt{E(\mathrm{MeV})}$ is needed to resolve differences between NH and IH
  - Energy resolution depends predominantly on the PMT coverage,the light yield and transparency of the liquid scintillator
- In the run-up to JUNO the LS transparency is mainly measured in small scaled set-ups (value might change at larger distances)
- Transparency might also change over time due to aging effects
- Monitoring of the liquid scintillator transparency is mandatory

Liquid Scintillator & Transparency



Scintillation Mechanism

- π-electrons in benzene rings get excited by passing charged
- Particles fluorescent/phosphorescent light is emitted during d-excitation

Added Fluors as Wavelength Shifters

Flours absorb excitation energy and emit photons at lower energies/ higher wavelengths
→ Suppression of re-absorption and re-emission in the detector
→ Reduction of signal loss
→ Shifting of light wavelength to better match PMT efficiency maximum
Multiple wavelength shifters can be added to operate in sequence

Attenuation And Scattering Lengths

Intensity obeys Beer-Lambert-law:

$$I(x) = I_o \cdot \exp(-x/\Lambda_{Att})$$

characteristic material quantity: attenuation length

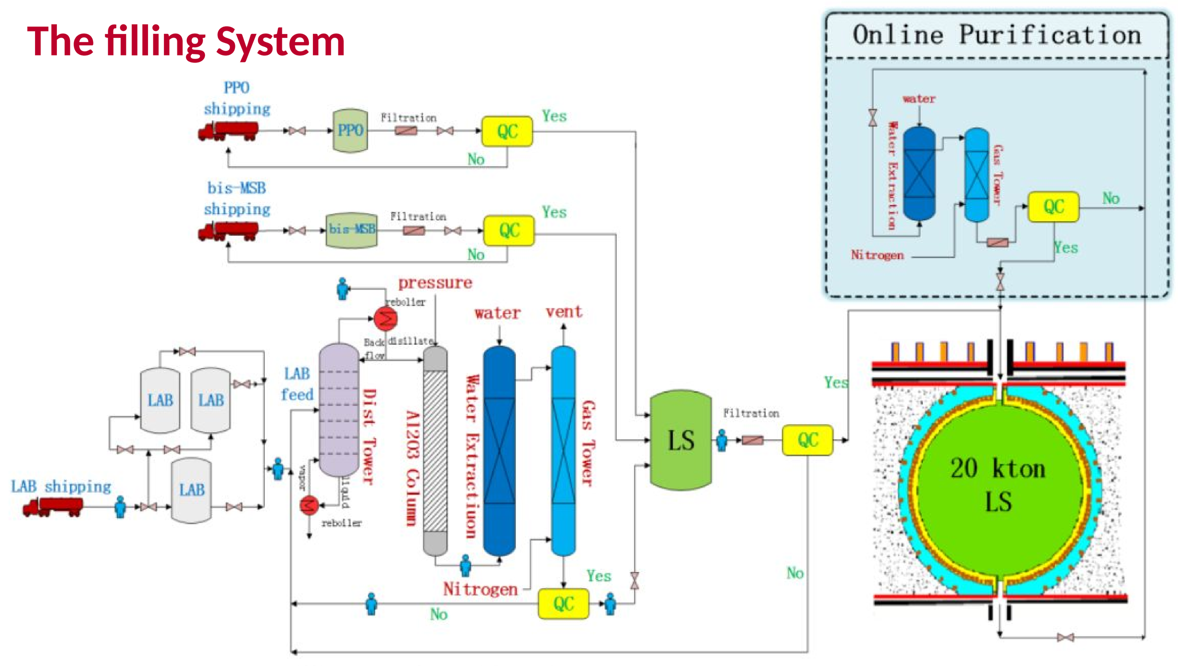
$$\frac{1}{\Lambda_{Att}} = \frac{1}{\Lambda_{Ab}} + \frac{1}{\Lambda_{ARe}} + \underbrace{\frac{1}{\Lambda_{Ray}} + \frac{1}{\Lambda_{Mie}}}_{1/\Lambda_{Scat}}$$

knowledge of characteristic lengths necessary for correct signal evaluation:

Λ_{Att}	attenuation	Λ_{Scat}	scattering
Λ_{Abs}	absorption	Λ_{Ray}	Rayleigh
Λ_{ARe}	reemission	Λ_{Mie}	Mie

Filling and Purification

The filling System



Filling and purification system

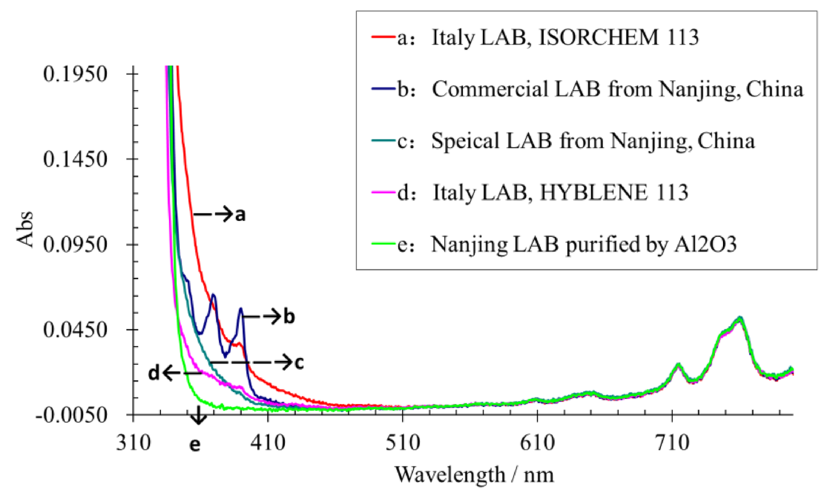
Purification

1. Distillation tower
2. Aluminum Column
3. Water Extraction
4. Gas Tower

Liquid scintillator purity

- Very high purity necessary
- Delivered LAB not good enough
- Purification gives desired quality
- Contamination of central detector would cause issues

→ Important to check quality during filling



Different qualities of LAB

Monitoring Liquid Scintillator Transparency

Monitoring of LS purity via the Absorption length

Purpose:

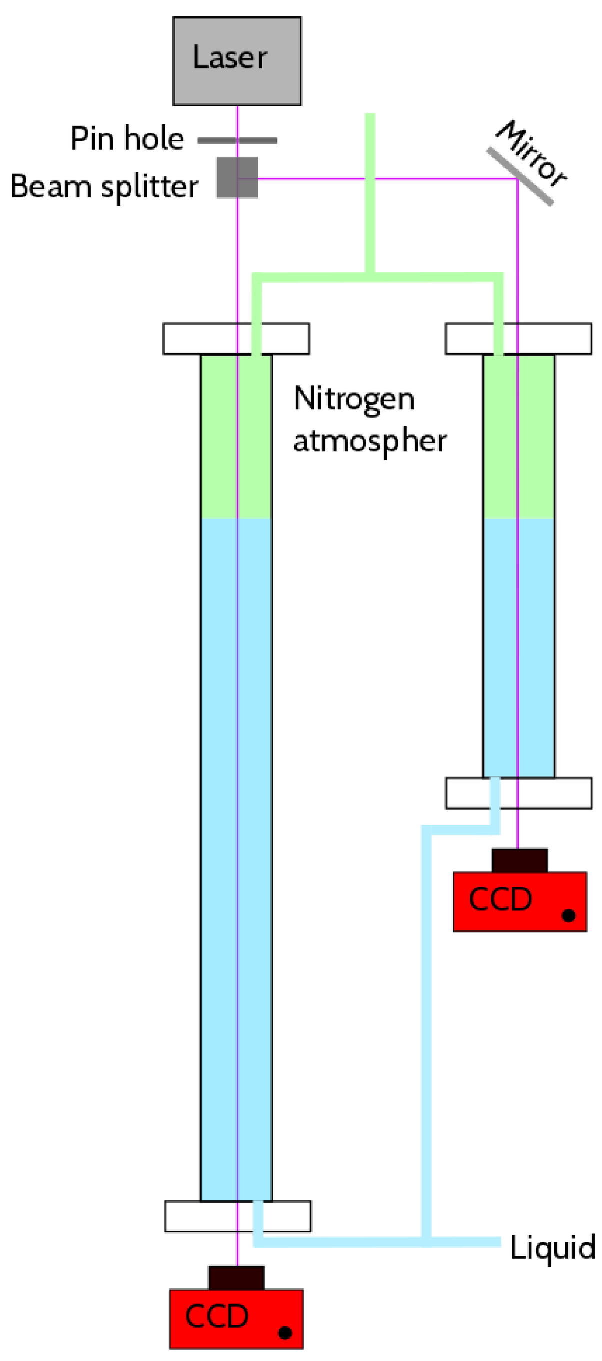
Monitoring of the Ls purity during filling
- Test LAB quality of every new batch
- On site
- Quasi-continuous measurement
- No LS has to be removed from system

Approach:

Measuring the absorption over tow different lengths

$$\Lambda_{Att} = \frac{x_1 - x_2}{\ln I(x_1) - \ln I(x_2)}$$

- Parallel measurement
- Identical light-sources
- Almost identical light path
  → Reduces systematics



Setup

- Laser
  → 405 nm
- Optical Components
  - Pin hole
  - Beam splitter
  - Mirror
- Tubes
  → Filled from bottom
  → Nitrogen atmosphere
- CCD Camera

Measurement

1. Tubes filled form bottom
2. Short pause for settling
3. Measurement
4. Analysis

Parallel Measurement

Reduce Systematics
- Effect of surfaces not relevant
- Slight fluctuations in laser can be neglected
- Chang of laser intensity over longer time nor relevant

Test Measurements

- First test measurements were successful
- Cameras are stable and have good linearity
  - Calibrate for dark noise
- Laser stable enough
  - Long time fluctuations not a problem
- Systematics are under control
  - Effect of mirror and beam-splitter considered
- Setup mostly stable
  - Strong vibrations can cause issues

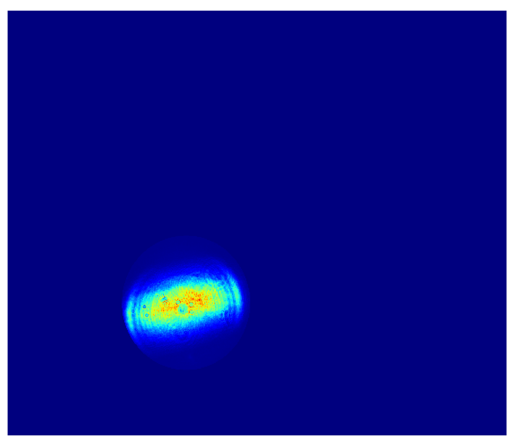


Fig. 1: Test setup for characterization of components. Here with the mirror
Fig. 2: Picture of laser using CCD Camera after passing through full test-setup.

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