MAYORANA School&Workshop, Modica , 4-14 July 2023

JUNO Detector:
scintillator purification with Distillation and Stripping plants

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on behalf of the JUNO Collaboration

JUNO Detector

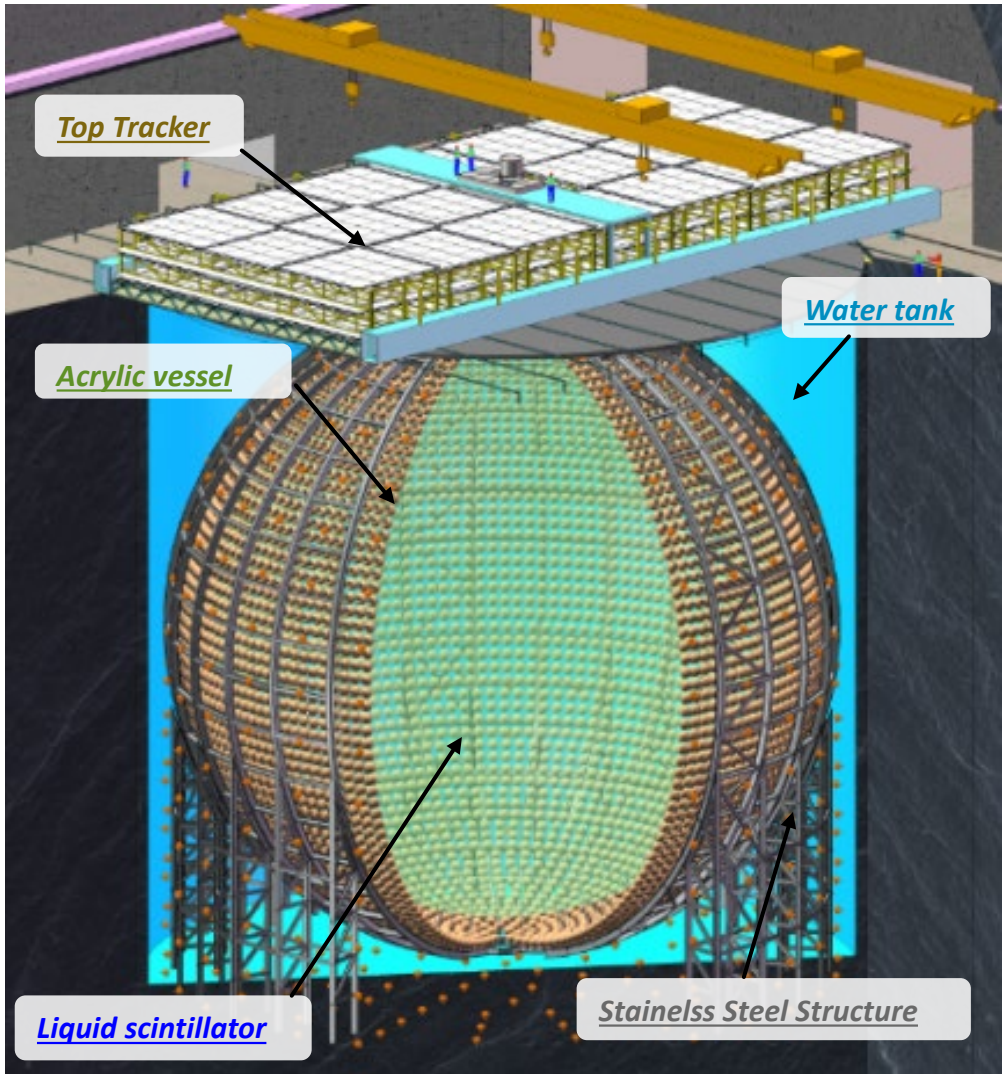
JUNO is an underground neutrino experiment

- Central detector (CD):
  - 35 m-diameter acrylic sphere with 20-kton liquid scintillator (LS)
  - 17.612 large PMTs (20-inch)
  - 25.600 small PMTs (3-inch)
  - 78% coverage, 3% energy resolution @1 MeV
- Water pool:
  - Muon veto and shielding from natural radioactivity
  - 35-kton ultra-pure water
  - 2.400 large PMTs (20-inch)
- Top tracker muon veto

Huge detector, constructive aspects driven by challenging engineering and technological solutions.

Main goal: neutrino mass ordering and oscillation parameters

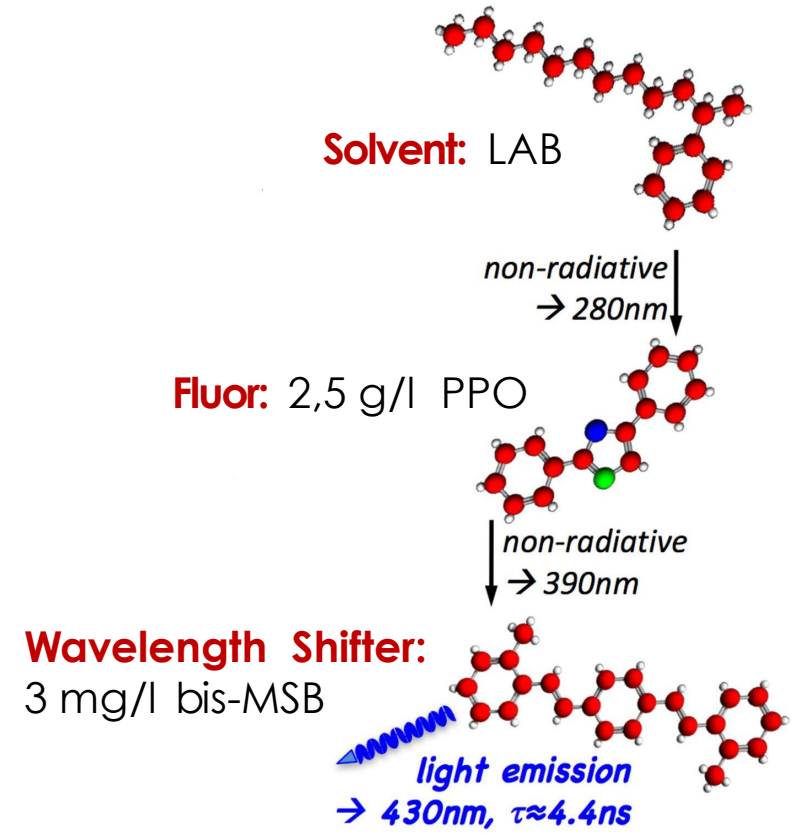
But also: diffuse supernova ν, supernova bursts, geo-ν, solar ν, atmospheric ν,…



Scintillator requirements

LS recipe : *solvent* **Linear Alkyl Benzene (LAB)** + *fluor* **2,5 g/L PPO** + *wavelength shifter* **3 mg/L bis-MSB**

- Optical requirements:
  - High light yield: ~10.000 Photons/MeV → ~1300 p.e./MeV
  - Attenuation length: > 20 m @ 430 nm (acrylic sphere radius: 17,5 m)
- Radio-purity requirements:
  - Reactor anti-neutrinos: $^{238}U/^{232}Th < 10^{-15}$ g/g
  - Solar neutrinos: $^{238}U/^{232}Th < 10^{-17}$ g/g
- Other requirements:
  - Energy response linearity
  - Long term stability (ageing)
- Technological Challenges:
  - Huge mass of LS (20.000 ton)
  - Constant delivery (24/7) of purified LS during 6 months-filling of CD
  - Underground laboratory
  - Reduce the risk of contaminating the purified LS



Scintillator requirements

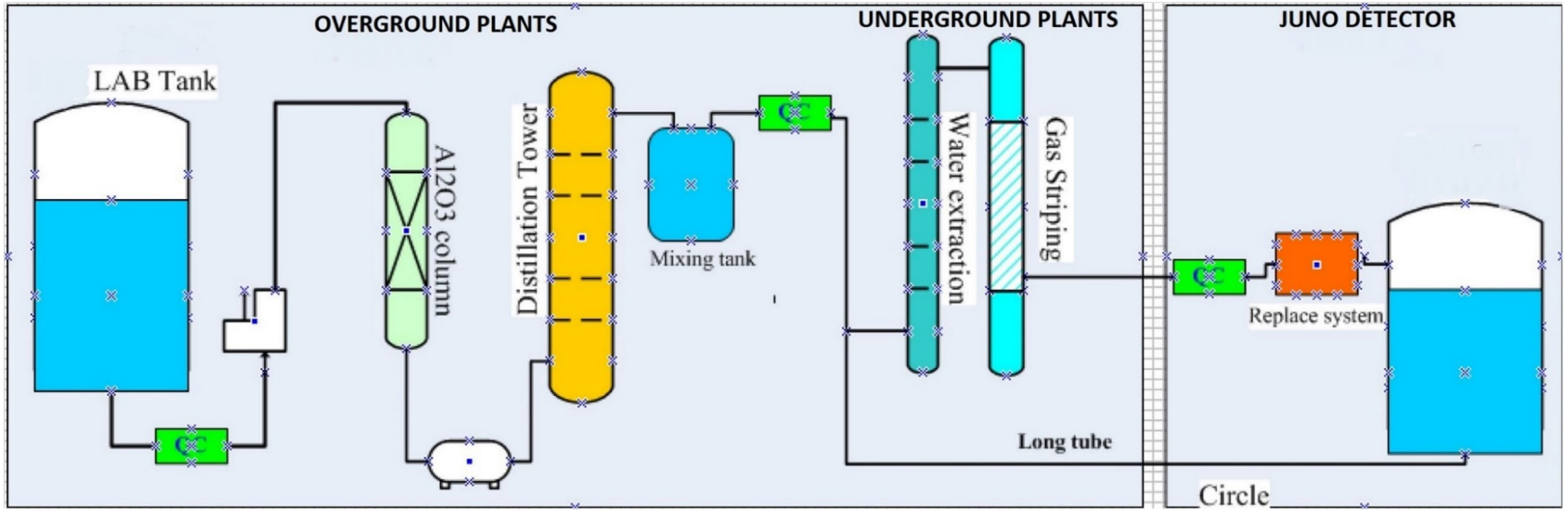
JUNO LS will be purified by a sequence of purification plants:

- Alumina Filtration columns: improve optical properties
- Distillation plant: removal of heavy metals, improvement of transparency
- Mixing system: production of the LS adding PPO and bis-MSB

OVER GROUND

- Water extraction plant: removal of metal ions by the water polarity
- Gas stripping plant: removal of gaseous impurities

UNDERGROUND



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UNDERGROUND

Done by INFN

- INFN is responsible for design, construction, installation and operation
- Test campaign done at Daya Bay Laboratories with pilot plants

Distillation plant

Main goal: remove from LAB the **heaviest impurities** (heavy metals, ^{238}U, ^{232}Th, ^{40}K) and improve its optical properties

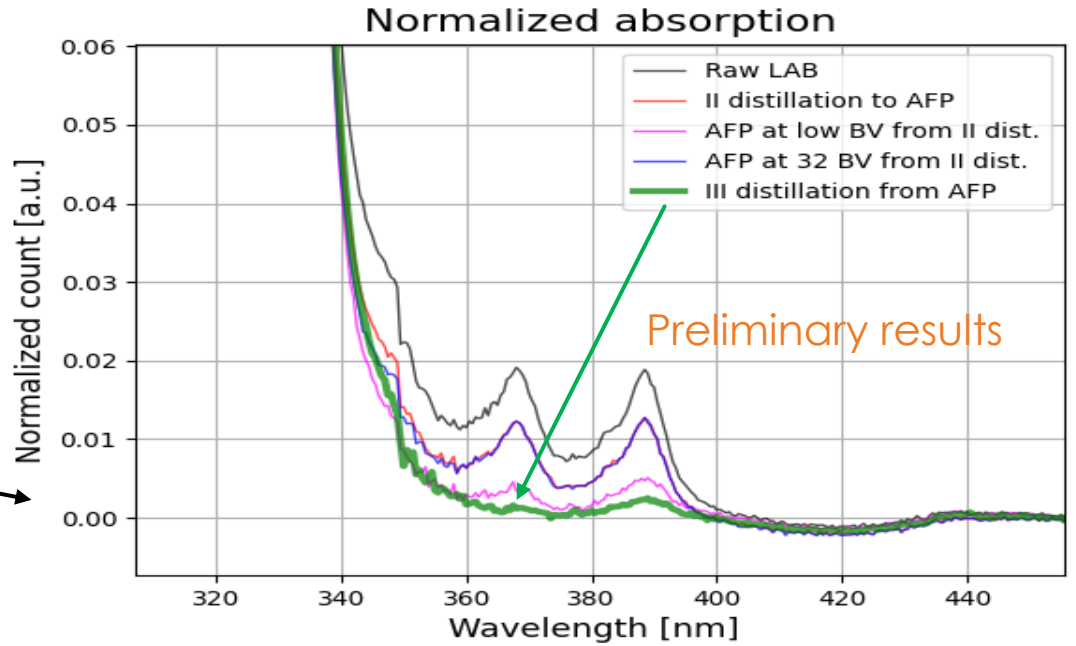
Distillation process: LAB is boiled in the bottom part of the column, the purified vapors are collected at the top and condensed

- Distillation performed in partial vacuum (8 mbar) to boil LAB at 215°C
- High-boiling impurities remain at the bottom and are discarded
- Column with 6 sieve trays, to ensure an intimate contact between the upward vapour and downward liquid (multiple equilibrium stages)
- Re-injected reflux up to 50%, to increase purification efficiency
- Huge plant (10 x 9 x 14 m), 7 m-high distillation column

Distillation plant: installation & commissioning

Installation location: Over Ground LS building @ JUNO site

- Challenging installation done from the roof of the building using a 200t-truck crane.
- Special procedures:
  - Dedicated cleaning procedures to reach class 50 of MIL standard 1246C
  - He leak test to certify plant sealing $< 10^{-8}$ mbar·L/s
  - Vacuum pumping & nitrogen purging for O_2 removal
- Distilled more than 250 m^3 in total. Operating parameters optimized.
  Installation and internal commissioning completed!
- QA tests on LAB samples (absorption and emission spectra, ICP-MS, attenuation length measurements, NNA). **Preliminary results** are very **promising**!

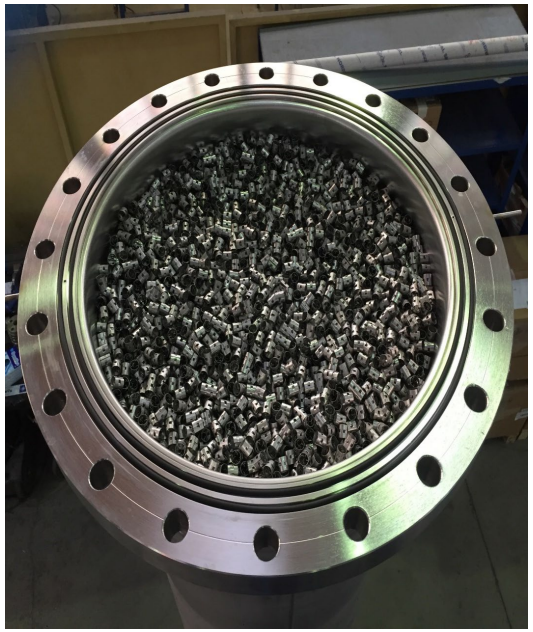


Stripping plant

Main goal: remove **gaseous impurities** dissolved into the LS, mainly ^{222}Rn, ^{85}Kr, ^{39}Ar (generate undesired signals) and O_2 (causes photon quenching in LS)

Stripping process: gaseous impurities dissolved into the liquid phase removed and transferred to the gas (stripping) phase by desorption mechanisms

- Stripping performed in partial vacuum (250 mbar) at 90°C, to reduce LAB viscosity
- Stripping gas: mixture of superheated steam and N_2
- 9 m-high column is filled with unstructured packing (Pall Rings) to increase the contact surface
- Gas fed from column bottom, LS from the top falling by gravity (counter current flow mode)
- Huge plant (6,5 x 9 x 12 m)



Stripping plant: installation & commissioning

Installation location: Underground LS Hall @ JUNO site

- Challenging transportation to the underground laboratory through the 1,5 km-slope tunnel
- Special procedures:
  - Final rinsing with UP-water at 55°C, to reach class 50 of MIL standard 1246C
  - He leak test to certify plant sealing $< 10^{-8}$ mbar·L/s
  - Vacuum pumping & nitrogen purging for O_2 removal
- Stripping process tested both with purified N_2 and water steam. Further studies on water-JUNO LAB compatibility are ongoing. We are studying the feasibility of stripping with water steam.
- Already produced the first batch of LS (28 m^3) for OSIRIS system

Next steps	
Autumn 2023	Joint commissioning with other purification plants
Early 2024	6 months-filling of CD with purified LS


INFN
Istituto Nazionale di Fisica Nucleare
JUNO
Thank you!