

Construction of the JUNO Detector

Xiaoyan Ma

Institute of High Energy physics, CAS, China On behalf of the JUNO collaboration TIPP2023, Sep.4~8

Jiangmen Underground Neutrino Observatory



- Multi-purpose experiment
- ◆ 20 kton LS detector of unprecedented 3% energy resolution (at 1 MeV) at 700m underground ²

From surface to underground

Surface to Underground: day for people, night for cargo



Entrance of slope tunnel

Man car

Trailer for transporting cargo

Piping from surface to underground



Pipes in Slope tunnel

• Transporting in underground



Automated Guided Vehicle (AGV)

Layout of the JUNO underground lab

Civil construction finished at the end of 2021, then the detector construction started



Underground installation room

JUNO detector in Experimental hall



Difficult and Challenging construction

- The biggest LS detector in the world
- Huge size but very high assembly accuracy required
- >76% PMT optical coverage
- ♦ 3000 ton buoyancy force ⇒
 high safety requirement
- Low radioactivity background
- Most new technologies and methods applied

Installation status in experimental hall

- Detector installation started when the civil construction finished (Jan. 2022)
- □ SS structure: finished last June
- Acrylic: lower-semisphere assembly started
- PMTs, electronics, VETO started Jan.2023
- Minimize interference between acrylic and all the other installation tasks

Detector in water pool



Currently, acrylic installation is driving the schedule



The equator layer of acrylic vessel

PMTs outside acrylic⁶

Stainless Steel structure

- **D** Outer Diameter: 41.1m, as the support of acrylic vessel and PMTs
- More than 800 tons of low radioactivity stainless steel (<1PPb U/Th)
- Welded H-beams in manufacturer, unit pre-assembly in underground installation room
- Assembled by 120,000 sets of bolts, no welding onsite
- **□** 30 groups of supporting legs fixed with the base of water pool







Stainless Steel structure

- **•** Key points of connecting stainless steel by high strength friction
 - Special coarsening process to increase the friction coefficient of SS surface from 0.2 to >0.45
 - Special high strength lockbolt: fast speed, reliable, prevent loosening, avoid seizing on nut
- Get high assembly accuracy to satisfy the small clearance (Min. 3mm) of PMTs requirement
- Design radius: 20550mm VS. measurement radius after installation:
 20530 mm, deviation is 20 mm







Acrylic Vessel

- □ Inner Diameter: 35.4m, thickness: 120mm, total weight:~600 tons
- 263 panels(Max. panel is ~3mx8m, 3tons)+ top and bottom chimney: divided into 23 layers, bulk-polymerization onsite layer by layer from the top
- A lifting platform serving for the acrylic installation: diameter is changeable between 20m to 38m, initial working height is 38m







Acrylic Vessel

- Acrylic Panels: good transparency(>96%) and low background (< 1 ppt U/Th) through special production line, sanding, polishing, cleaning
- Panels transported from manufacturer to JUNO site ⇒ underground
- Process for each layer: Lifting, locating, bonding, annealing, sanding, polishing, cleaning and filming
- New technology of bonding multi panels at same time, to improve the speed
- **D** Critical points and potential risks during installation
 - ◆ Explosive polymerization during bonding: control of the gap and temperature(21±1°C)
 - Cracking: improve the annealing method to reduce the thermoforming stress







Connecting between SS and acrylic

- **5**90 connecting bars between SS and acrylic, ~3000 ton buoyancy force transfer to SS through them
- **D** Pulling force and pushing force of the bars will be transferred during filling
- **D** Distribute the load reasonably on the 590 support bars through design
- **D** The force of the bar is directly related to the stress level of the acrylic
 - 4 fiber grating (FBG) sensors and 1 temperature sensor installed on each bar to monitor the force changing during detector construction and filling
 - Bars installed when each layer of acrylic finished



Sensor installing and test on the connecting bar

Installing bars

PMTs, electronics and VETO

D PMTs

- CD LPMT: 20-inch, 6647of 17612 (38%) finished
- CD SPMT: 3-inch, 9280 of 25600 (35%) finished
- VETO PMT : 20-inch, 20% of 2400 finished
- □ Front-end Electronics (Under Water Boxes-UWBs)
 - 20-inch PMTs: 28% of 6681 (5878 CD + 803 VETO)
 - 3-inch PMTs: **28%** of 200

□ VETO

- HDPE lining of the water pool: side wall finished
- Veto main cable routing support on the pool wall: finished
- Earth magnetic field shielding (EMF)coils: 20 of 32 circles finished
- Tyvek refection film: ~ 14,000 m2 (SS surface, pool wall & bottom& top...) to improve light collection
- Top Tracker (TT): not start yet



CD LPMT and SPMT



PMTs, electronics and VETO

- Major installation sequence: CD LPMT module \rightarrow SPMT \rightarrow LPMT UWBs/Bellows
 - \rightarrow VETO PMT module \rightarrow EMF shielding coil \rightarrow Tyvek reflection film
- **D** LPMT: assembled as module in the clean room and then final installed on the SS
- **D** SPMT: 16 PMTs as a group, one by one installed on the truss
- leakage and electric testing for all bellows
- **D** Regular commissioning tests: light-off test, lunch test





LPMT module installation





Cables (bellows)/leakage, electric testing



SPMT installation

VETO module





LPMT/SPMT UWBs



EMF shielding coil/ Tyvek film

Calibration

- **D** 1D: Automatic Calibration Unit (ACU)
- **D** 2D: Cable Loop System (CLS): 2 sets, anchors were assembled
- **D** 3D: Remotely Operated under-LS Vehicle (ROV)
- Boundary: Guide Tube calibration system (GTCS): ½ circle were installed following the acrylic schedule
- USS and CCD positioning systems: 80% USS installation was completed and CCD installation will start soon



CLS and USS installed

CLS anchor

USS on the inner surface

GT installed on the outer surface



14

Cleanliness control of detector construction



Region 1&2

- Control of the detector installation
 - **Clean room management** in experimental hall (120000m³) : air shower, no dirty work
 - Cleanliness level: equivalent to class 10,000-100,000
 - Film protection to acrylic: inner surface (kept until acrylic installation completed), outer surface (PE \rightarrow removed before people can't access to)
 - Veto PMTs will be covered with clean cloth after installation of the magnetic shielding coil
 - After acrylic vessel finished: seal the acrylic and spray inside the sphere to reduce the particles in air, then do the final cleaning of inside 15

Summary

- Detector construction started in Jan.2022
- Installation is now at full speed: more manpower, two shifts
- ◆ The difficulties during detector construction make us gain some experience ⇒ should be useful to the future installation
- Plan to finish the detector installation and starting filling next year



Detector growing in the experimental hall



定 所 中 成 系 雲 除 と i angmen Underground Neutrino Observatory