The JUNO veto detector system

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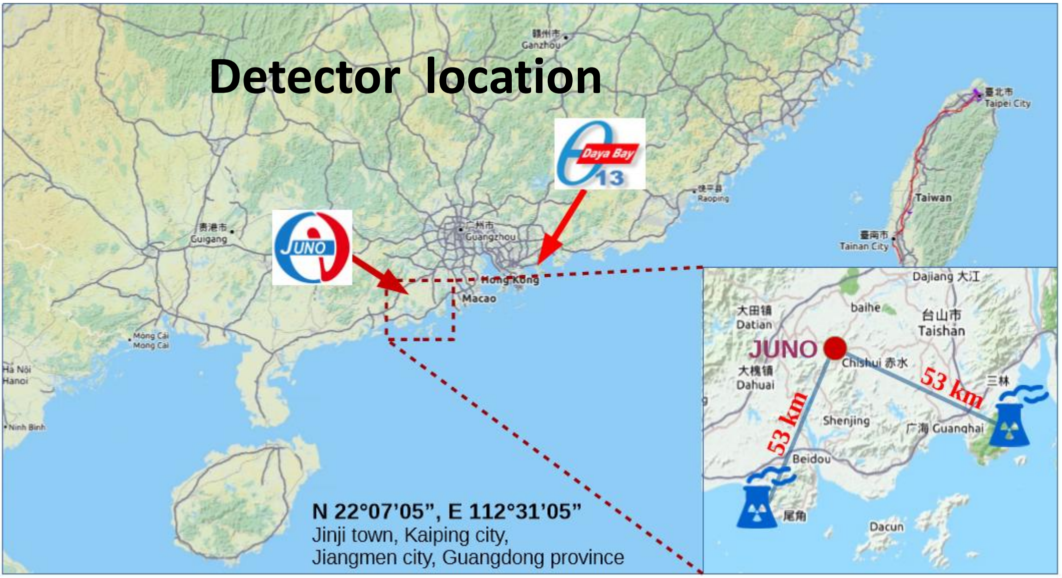
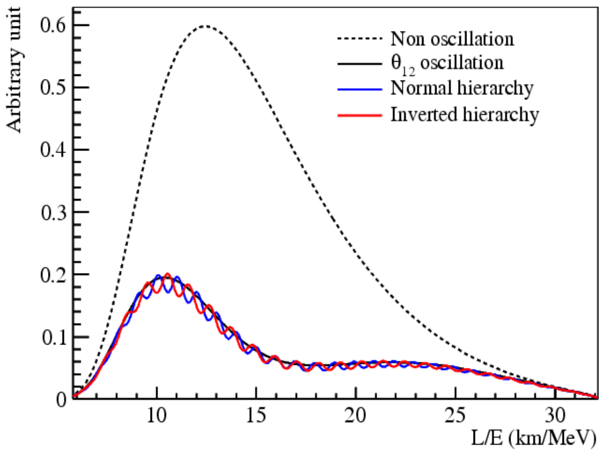
The Jiangmen Underground Neutrino Observatory (JUNO)



- Primary physics goal is for the neutrino mass hierarchy determination.
- Sources: reactor neutrinos, 6+4 cores (Yangjiang and Taishan NPP, under construction):
- Baseline : 53km
- Under 700 m deep underground for muon flux reduction.
- Detector: 20-kton liquid scintillator with 18k 20'' photomultiplier tubes (PMTs) + 25 k 3'' PMT

- **Measuring Mass Hierarchy with Reactor neutrinos**
  - Place detector at medium baseline (~50km) from reactors
  - Observe the distortion of energy spectrum
  - Oscillation probability independent of CP phase and θ_{23}



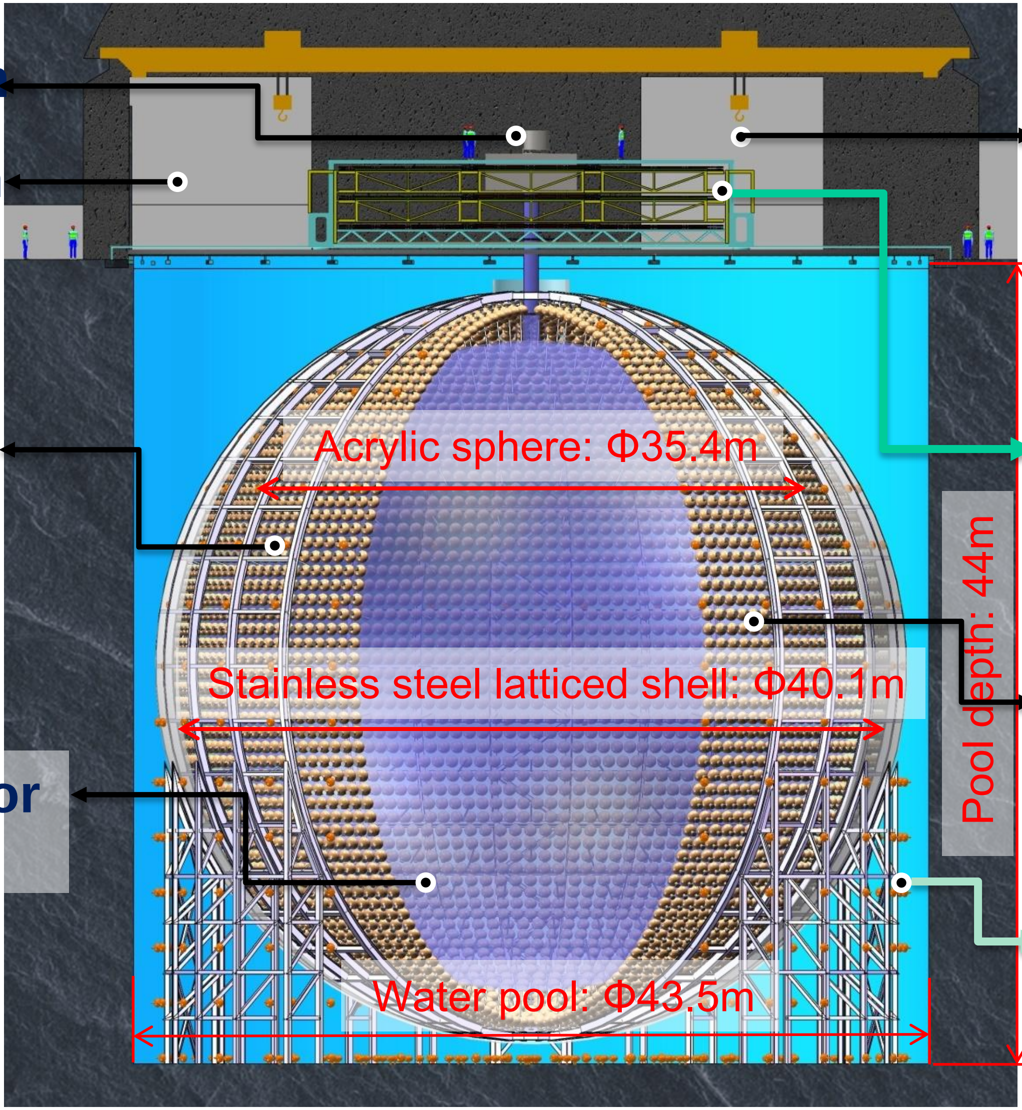
JUNO detector

Calibration room

Pure water room

Central detector
SS latticed shell
Acrylic sphere

Liquid scintillator
20 kton



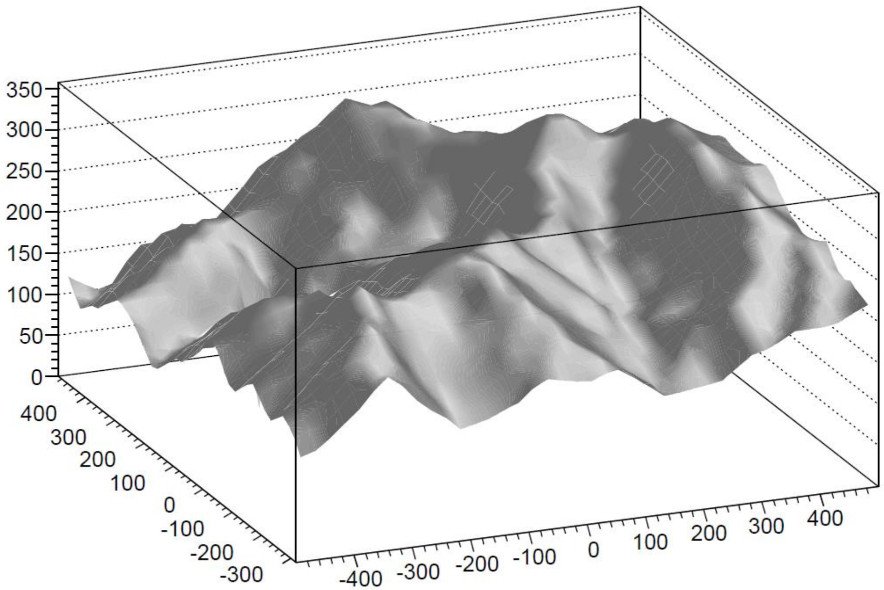
LS Filling room

Top Tracker

PMT
~18,000 20” PMTs
+ ~25,000 3” PMTs:
coverage >75%

Water Cherenkov
35 kton pure water
2,000 20” veto PMTs

Muon flux in JUNO site



Mountain profile at JUNO site

- Chose sufficient overburden to suppress the cosmogenic backgrounds.
- A modified Gaisser formula is used to describe the muon flux at sea level. With the mountain profile data, the cosmic muons are transported from the sea level to the underground JUNO detector site using the MUSIC package.

The simulated muon flux and mean energy at JUNO site.

Overburden	Muon flux	$< E_\mu >$	R_μ in CD	R_μ in WP
748 m	0.003 Hz/m^2	215 GeV	3.0 Hz	1.0 Hz

JUNO veto system

The JUNO experiment will be equipped with two veto systems for cosmic muon detection and background reduction:

Outer Veto:

Water Cherenkov detector

- Fast neutrons background rejection → passive shielding and possible tagging
- Radioactivity from rock → passive shielding by water

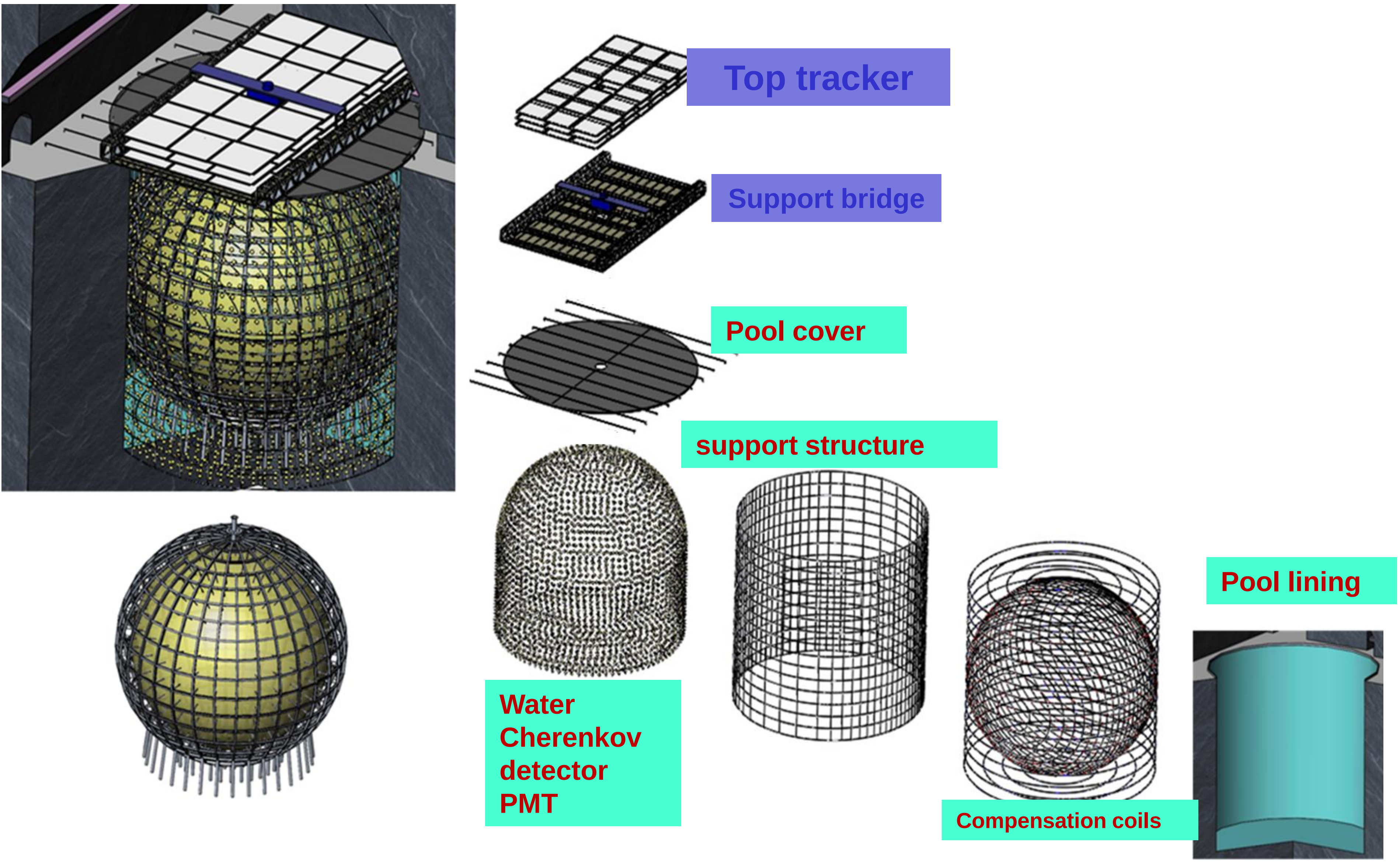
Top Tracker

Calibration of tracking algorithms using the CD data.

Precise muon tracking measurement

- Cosmogenic isotopes ($^{9}Li/^{8}He$)→ requires a precise muon track reconstruction

Main structure of the veto system

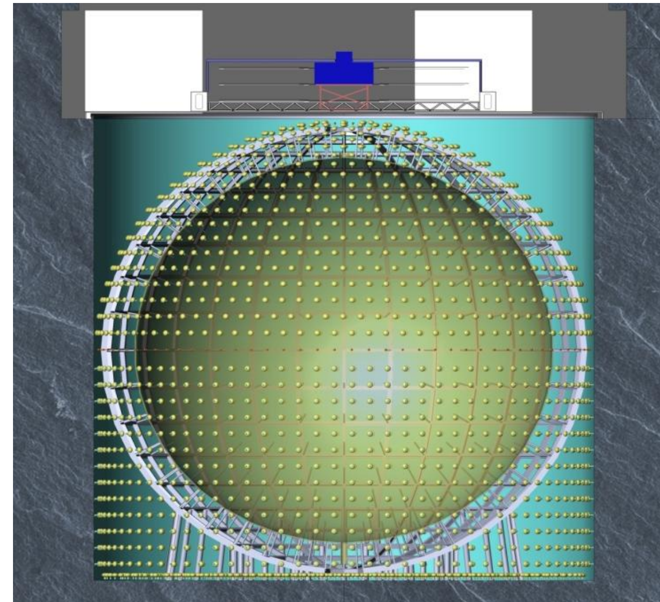


Water Cherenkov detector

- **Detector Characteristics**
  - 20 inch MCP-PMT used for veto system with number~2400
  - PMTs put on the surface of the sphere and of the wall of water pool after optimization
  - ~35 kton ultrapure water in the pool
  - Tyvek reflector film coated on surface to increase light collection efficiency
  - Detector efficiency is expect to be > 95%
- Water system
  - Employ a circulation/polishing water system (~2 week one volume circulation)
  - Keep a good water quality including radon control (<0.2 Bq/m3)
  - Water system radon control R&D is under test.

Background Estimation:

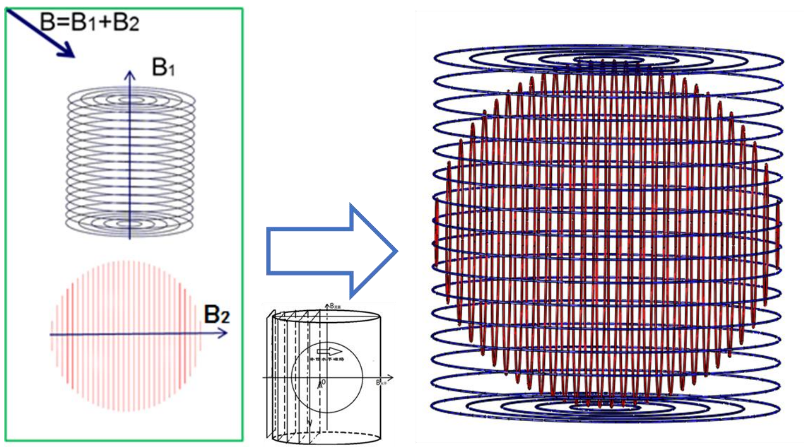
- Fast neutron background ~0.1/day
- Water buffer is 3.2m at equator from rock to central detector
- Radioactive background from rock is 7.4 Hz @3.2m water buffer



Radon control R&D

Earth magnetic field(EMF) shielding system

- **Requirement of the EMF shielding system：**
  - **The large dimension PMT is effected by the earth magnetic field.**
  - **We'll use double coils system for EMF shielding.**
  - **The intensity of central detector PMT region will be less than 0.05Gs after shielding, thus reducing the EMF effect to a PMT negligible level.**



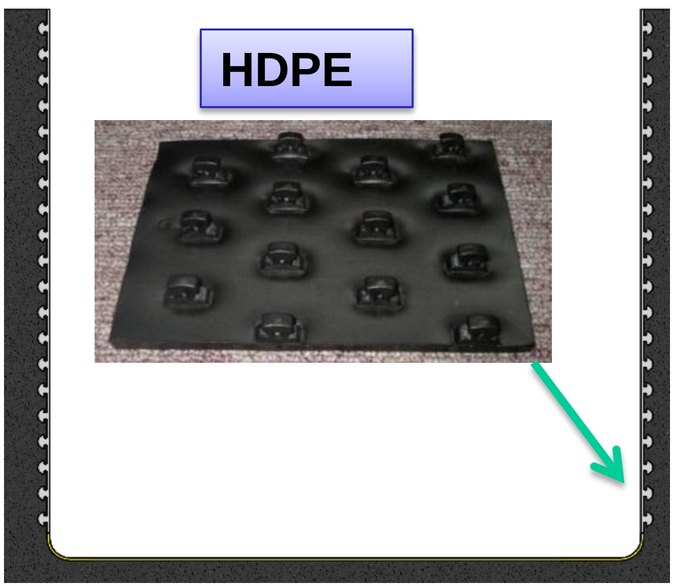
Double coils system

Coils prototype

- **A prototype of compensation coils system was built in IHEP.**
  - **The theoretically calculation and prototype data are consistent with each other.**
  - **It's a good validation for compensation coils design of JUNO.**

Pool Lining

- Pool lining
  - High Density Polyethylene (HDPE)
  - Prevent pool leakage
  - Block the radon penetration (at least 2 mm thickness)



welding

leakage detection

Top Tracker

- The Top Tracker is a complementary sub detector of the experiment with the outer veto which is essential for the background reduction strategy.
- The detector will reuse the Target Tracker of the OPERA experiment based on the well known plastic scintillator technology.

TT wall

TT Geometry

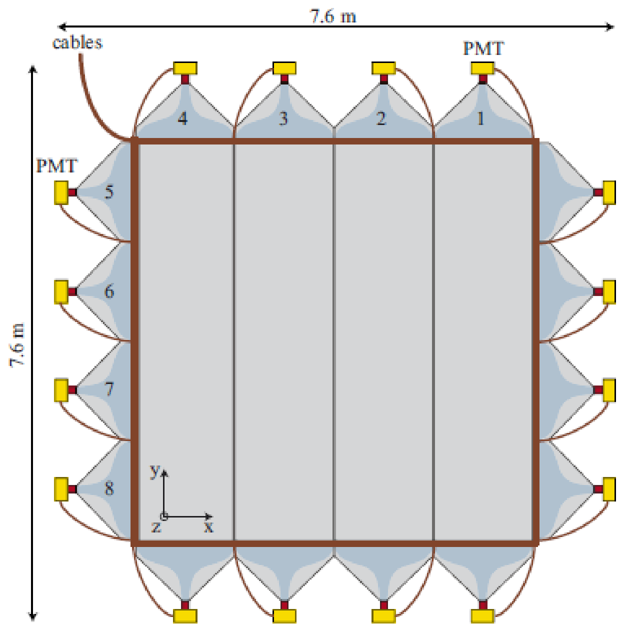
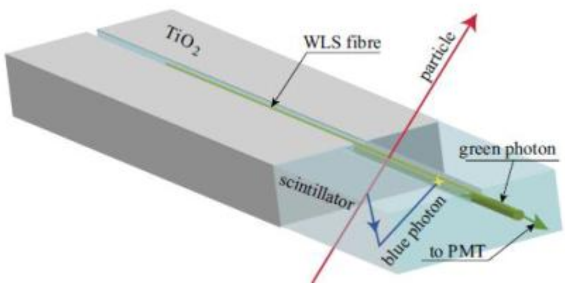


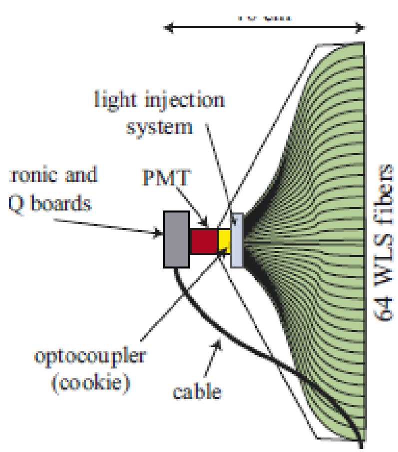
Fig. 3. Schematic view of a plastic scintillator strip wall.

Detector Performance

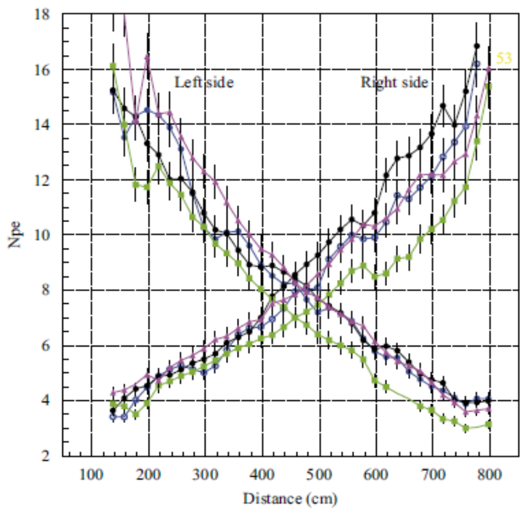
The Target Tracker consists of 62 walls. Each wall consists of 4 modules in horizontal position and 4 modules in vertical position, allowing a good tracking reconstruction capability. One module consists of 64 scintillator strips equipped with WLS fibers allowing a good detection efficiency and tracking performance.



Detection principle



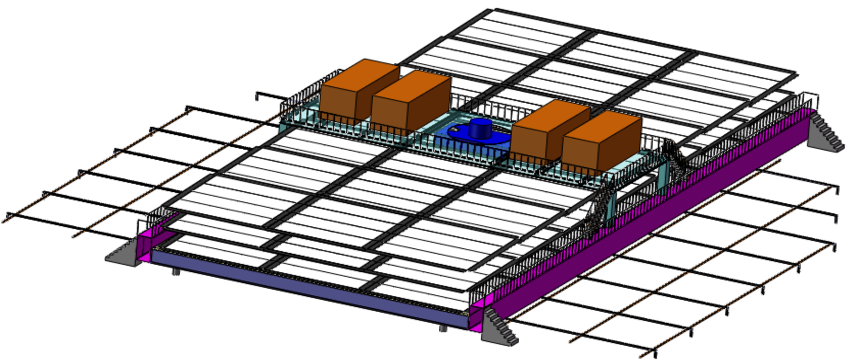
Module end cap



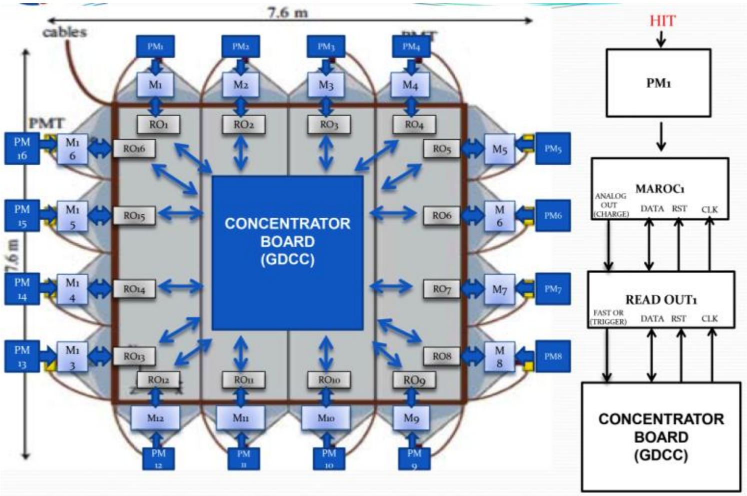
Light Yield

All the 64 WLS fibers of one module are read at both ends by two 64 channels multianode photomultipliers (MaPMT).

Top Tracker Electronics



TT tracker structure

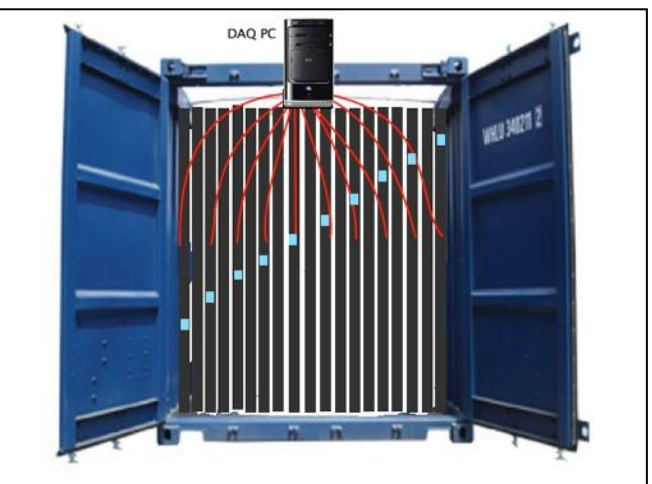


- If one trigger is detected by a PMT (front end card) a signal is sent to the Concentrator Board which validate events. The data are then transferred to the Global Board managing the 62 TT walls.
- The electronics prototype are under test.

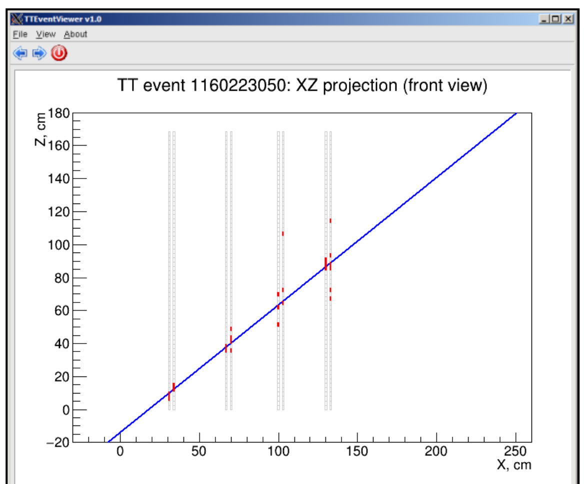
Transportation and monitoring

- The TT were stored in 7 containers in the underground lab of Gran Sasso waiting to be shipped to China.
- The containers are sealed and equipped, temperature and shock monitors.
- They are shipped to China(Zhongshan City) beginning of May.

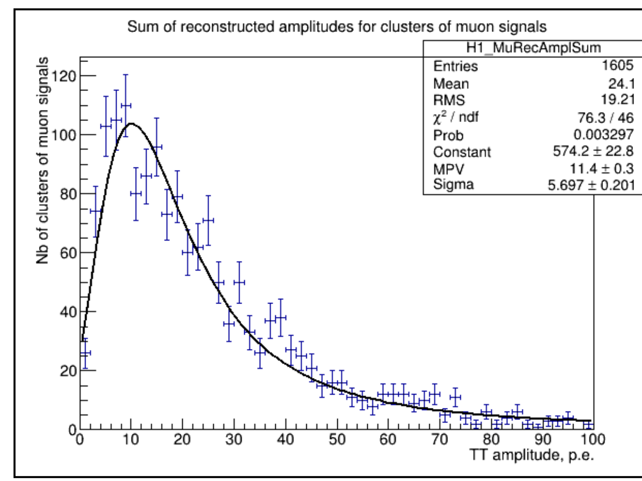
TT aging monitoring



TT modules with electronics inside the containers



reconstructed muon track



number of p.e.

Summary

Based on detector design, the event selection and background estimation is shown in the following table.

Anticipated signal/background

<table>
<tr><th>Selection</th><th>IBD efficiency</th><th>IBD</th><th>Geo-νs</th><th>Accidental</th><th>^{9}Li/^{8}He</th><th>Fast n</th><th>(α, n)</th></tr>
<tr><td>-</td><td>-</td><td>83</td><td>1.5</td><td>$\sim 5.7 \times 10^4$</td><td>84</td><td>-</td><td>-</td></tr>
<tr><td>Fiducial volume</td><td>91.8%</td><td>76</td><td>1.4</td><td rowspan="3">410</td><td>77</td><td rowspan="5">0.1</td><td rowspan="5">0.05</td></tr>
<tr><td>Energy cut</td><td>97.8%</td><td rowspan="3">73</td><td rowspan="3">1.3</td><td rowspan="3">71</td></tr>
<tr><td>Time cut</td><td>99.1%</td></tr>
<tr><td>Vertex cut</td><td>98.7%</td><td>1.1</td></tr>
<tr><td>Muon veto</td><td>83%</td><td>60</td><td>1.1</td><td>0.9</td><td>1.6</td></tr>
<tr><td>Combined</td><td>73%</td><td>60</td><td colspan="5">3.8</td></tr>
</table>

- Status:
  - Jan 2016, first review of the veto system has been finished.
  - Continue detector details design.
- Plan:
  - 2017-2019,detector construction, assembly, installation and LS filling
  - 2020, start data taking

Thanks!