The Top Tracker of the JUNO experiment

LLR Paris, IPHC Strasbourg, IHEP Beijing, JINR Dubna, INFN Frascati, ULB Bruxelles

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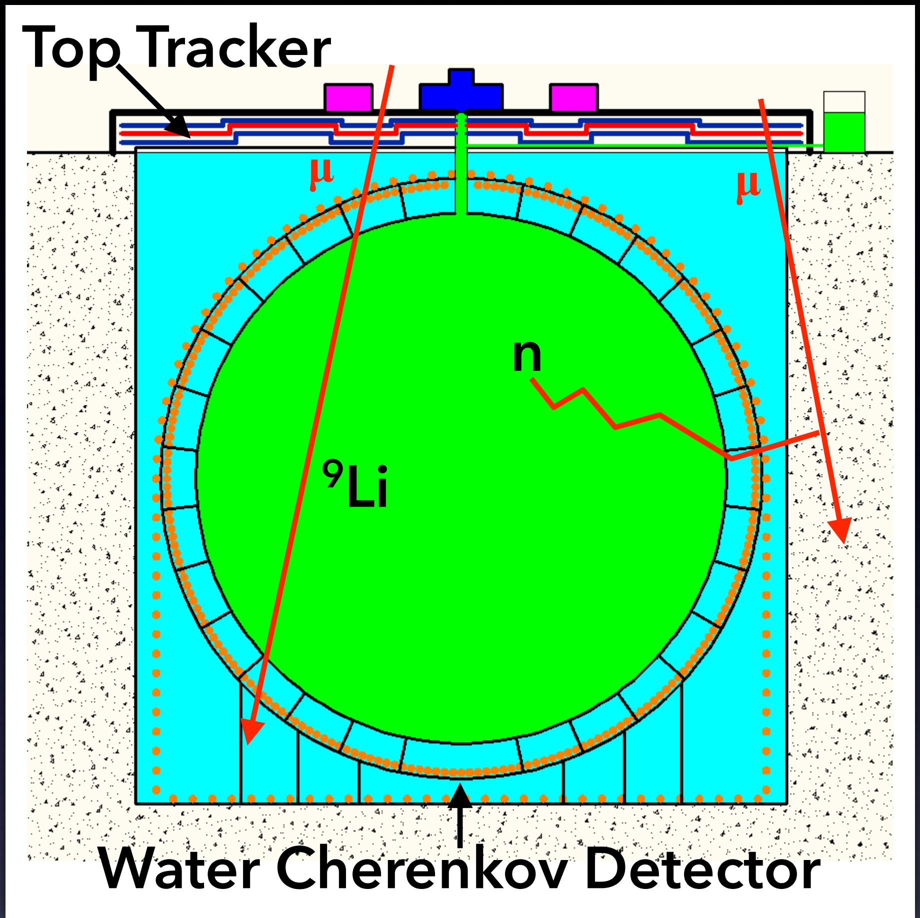
31st March 2016 - FCPPL Strasbourg

JUNO Veto

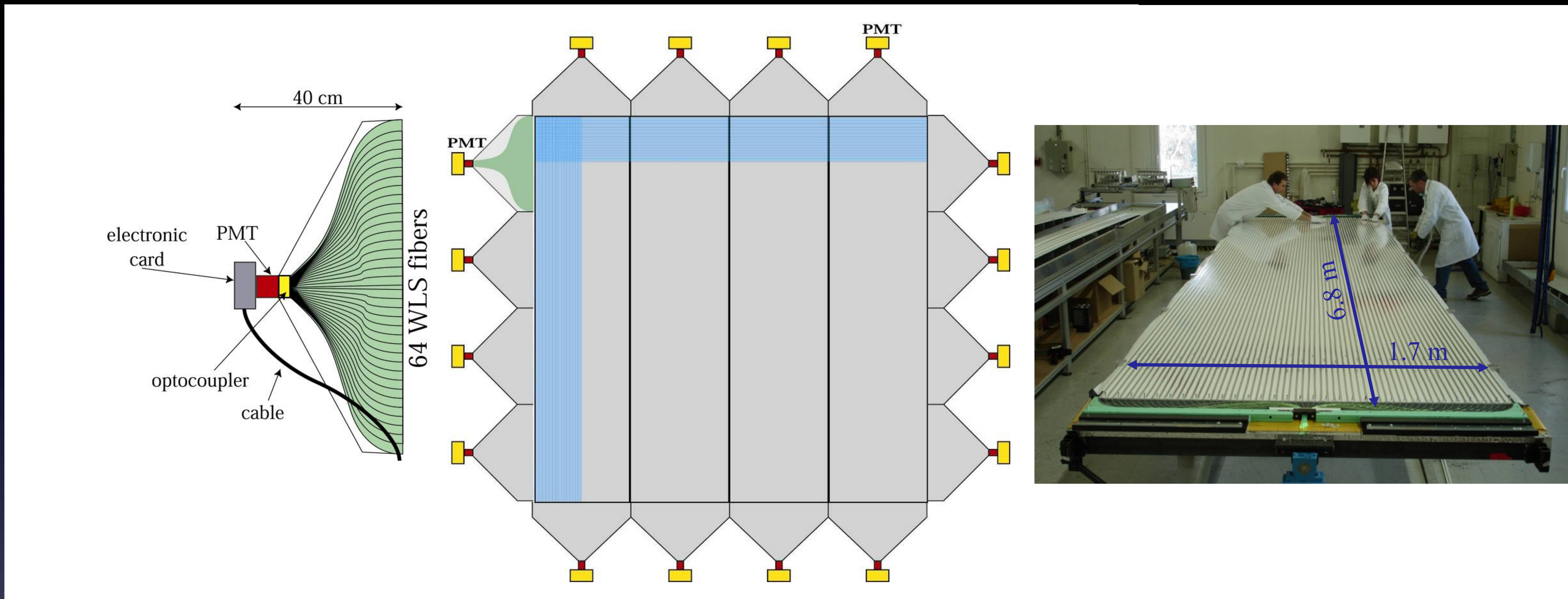
- The veto will be critical to reduce the background:
  - Gammas.
  - Cosmogenic isotopes rejection: good reconstruction of muon tracks and 1.2 s veto around them. To ensure a good IBD efficiency, the muon tracking should be accurate.
  - Neutrons rejection.
- The role of the Top Tracker will be to validate the muon tracking in the central detector (in particular, we expect 0.5 Hz of showering muons) and to accurately measure the muon distribution.



Efficiency, signal and background rates after each selection criterion

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

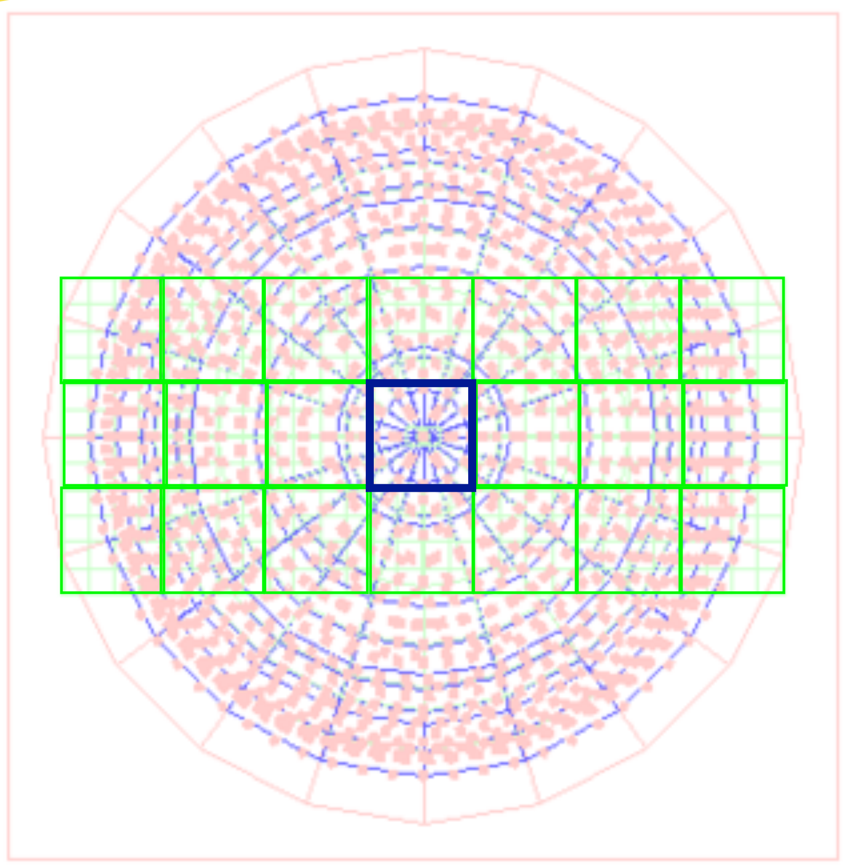
TT detector



- Whole detector constituted of 62 walls.
- 1 TT wall is made of 2 planes: one in the X direction and one in the Y direction.
- 1 plane is made of 4 modules.
- 1 module is made of 64 plastic scintillator strips with a wavelength shifting fiber inserted in a central groove.
- The 64 fibers are connected to a multi-anode Hamamatsu PMT on each extremity.
- The active surface is 415.4 m^2.

TT positioning

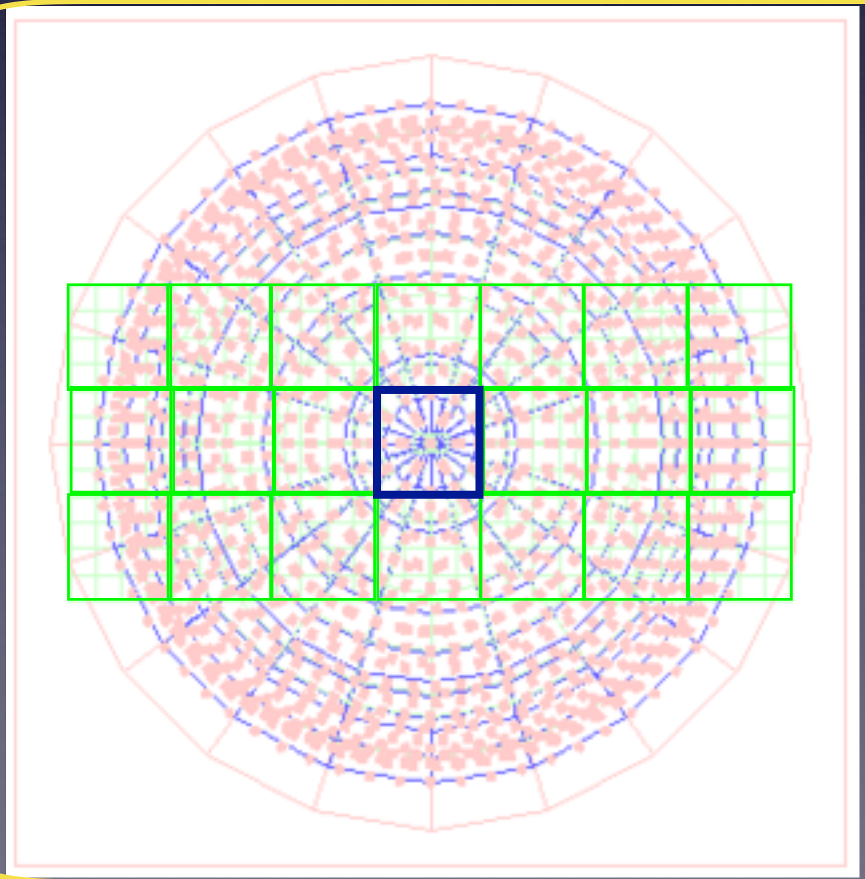
- The TT surface is smaller than the JUNO central detector and water pool ones, consequently the TT positioning was determined taking into account the mechanical constraints (access to the electronics) and the physics performance in terms of:
  - Cosmogenic nuclei/fast neutrons background tagging.
  - Muon angular precision reconstruction.
  - Muon tagging efficiency.
- Since the TT will be stored for around 4 years in China, degradation of its mechanical structure and of the light yield has been taken into account in the studies.
- The almost final geometry is:



- 3 layers of walls separated by 1.5 meters.
- 64% of central detector covered.
- 55% of water pool covered.
- Two adjacent walls are shifted by at least 5 cm in the vertical position to permit the accessibility to the electronics.
- 15 cm overlap between walls.

Physics performance of the TT

- Cosmogenic nuclei/fast neutrons background tagging:
  - About 37% of the ^{9}Li created in the detector will be generated by a muon crossing the TT.
  - The TT will be able to tag about 1.5% of the muons crossing the rock and not entering in the Water Pool.
- Muon angular precision reconstruction: the tracks crossing the TT will be measured at the bottom of the Water Pool with a resolution of 23 cm.
- Muon tagging efficiency: the muon rate observed by the TT will be about 2.30 Hz.



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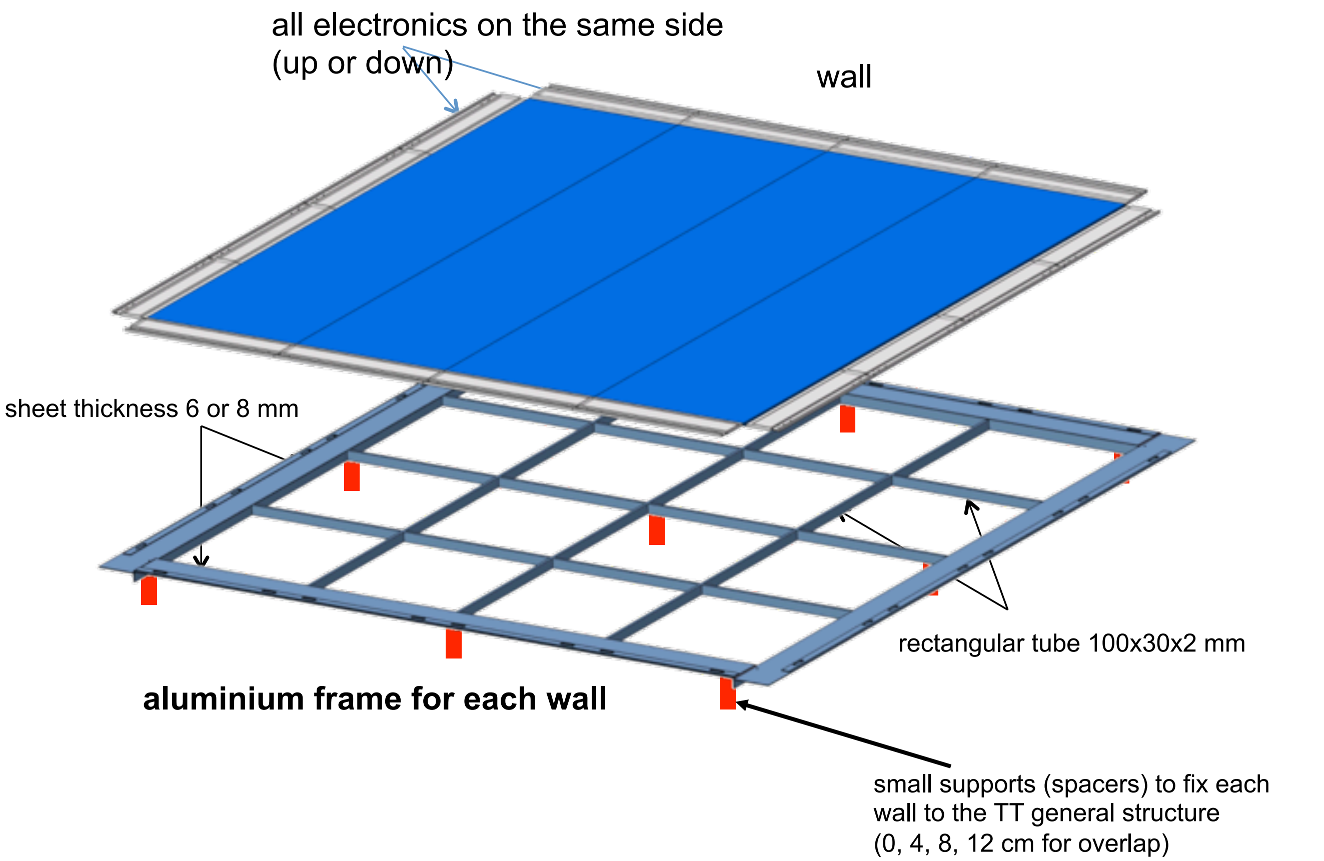
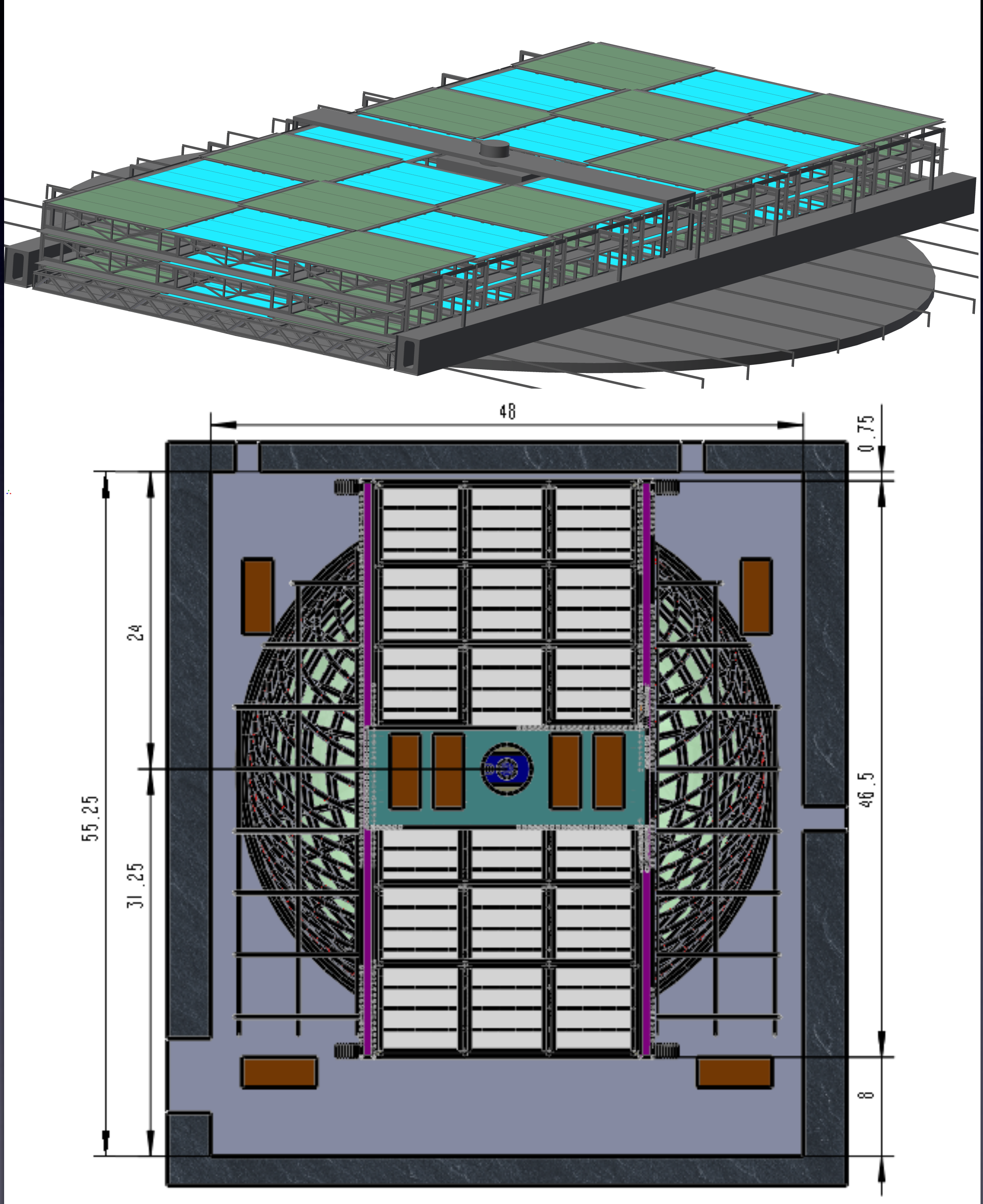
TT mechanical structure

- Mechanical drawings realized by the mechanics of IPHC.
- The mechanical supports will be realized by JINR Dubna and IHEP Beijing.

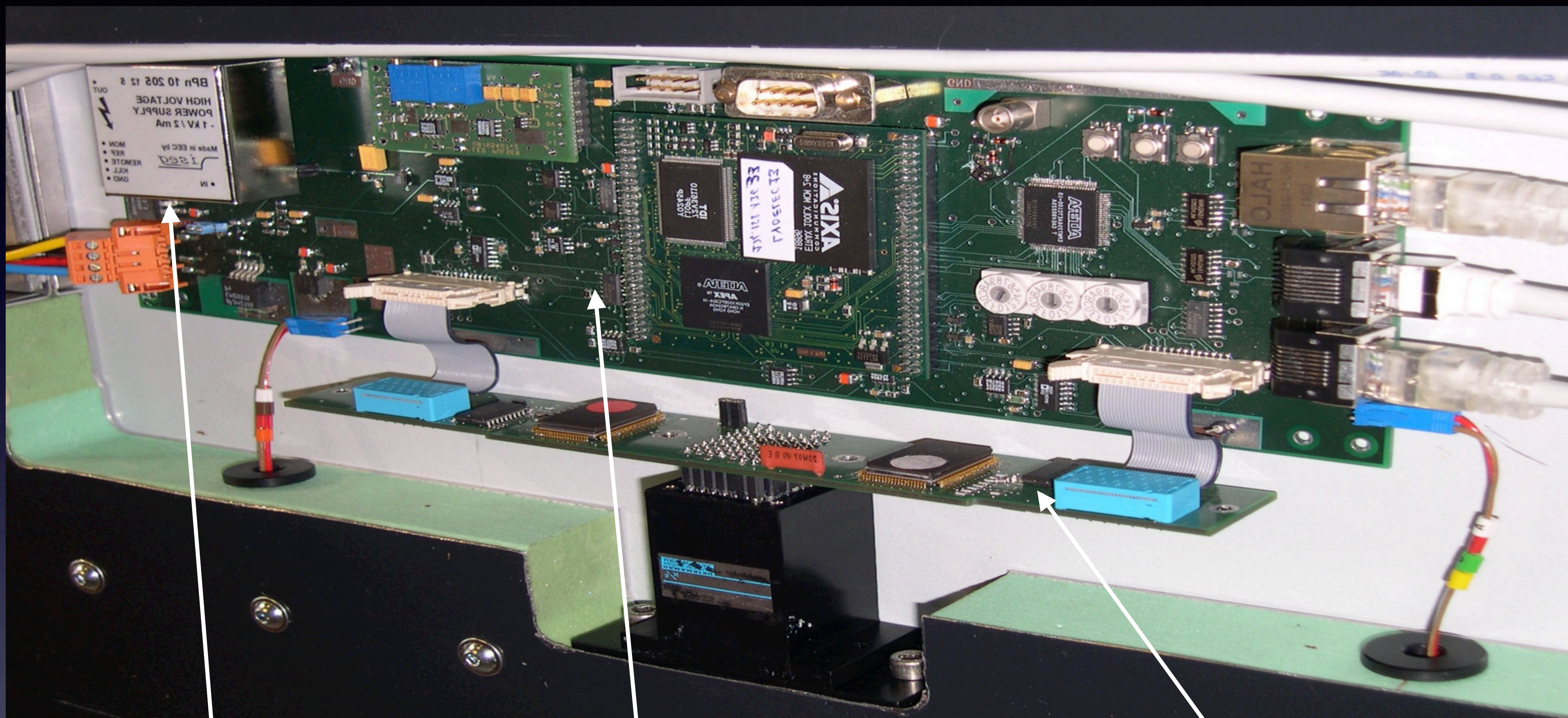
Structure of 1 TT wall



Positioning of TT



Electronics



The HV module and the light injectors will be kept.
The LV modules are also kept.

The DAQ card will be replaced in order to support the rate due to rock radioactivity.

Front-end card: the OPERA-ROC (obsolete, no spare) will be replaced by the MAROC3 (faster conversion and transfer time).

Counting rates due to the rock radioactivity

The radioactivity of the surrounding rock (110 Bq/kg in ^{238}U, 105 Bq/kg in ^{232}Th, 1340 Bq/kg in ^{40}K) will cause a high single rate of the PMTs and could result in reconstructed fake muon tracks.

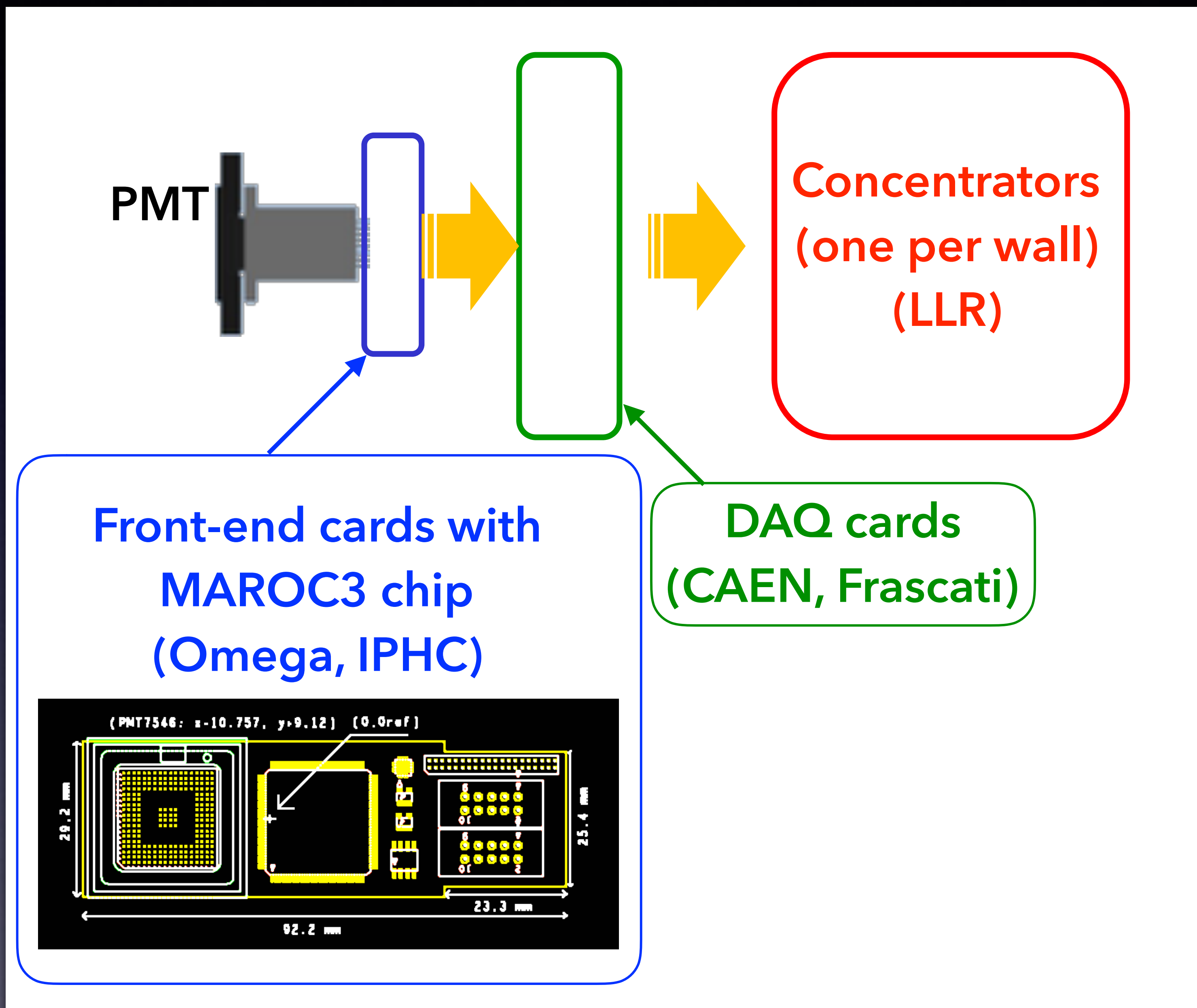
Rock Radioactivity

PMT Threshold	0.3 p.e.	1 p.e.
Rate (Hz/m^2)	7400	4990
Rate (Hz/PMT)	50800	34600
XY coincidences (correlated+accidental) (Hz)	1290	610
fake muons rate (Hz)	21.1	2.22
(true) muon rate (Hz)	2.30	2.22

The PMT rate could be reduced in two ways:

- Doing a trigger at the level of the wall to disentangle the muon and the radioactivity hits.
- Developing a pseudo-directional trigger with hardware XY coincidences since we have observed that fake muons tracks have large angle.

New Electronics



- Each concentrator receives the signals of all DAQ cards of 1 wall (16) and perform 1 XY coincidence.
- The signals of all concentrators will be combined to create an on-line trigger to remove fake muons signals.

TT schedule

2015

Task force to decide the TT positioning (3 or 4 walls).

Beginning of the TT dismounting.

2016

TT geometry frozen.

End of dismounting.

Prototyping of the electronics and final choice of the front-end chips (MAROC3).

2017

Final electronic design.

Shipment of the TT to JUNO site.

2018

Production and tests of the Electronics.

Creation of the online Software.

Production of the Mechanical parts.

2019

Installation on site (3 months) and commissioning.

2020

Start data taking of JUNO.

Conclusions

- The TT was built in 2005 and took data at Gran Sasso for 7 years with an efficiency of about 99%.
- Since 2005 less than 10% of aging has been observed and on the 63488 channels only 30 are no working.
- The robustness of the TT and its high efficiency allow us to use it again for a new experiment.
- Using the TT as veto in JUNO will permit to validate the tracking of the central detector which is essential to veto the most dangerous background without decreasing too much the IBD efficiency.
- The TT is currently being dismounted in Gran Sasso and will be installed on top of JUNO central detector in 2019. During the long storage, the TT light yield will be monitored thanks to a mobile DAQ.
- To take into account the rock radioactivity of the JUNO site, the DAQ system will be replaced to support a rate of 10 kHz. To work in the best conditions and to ensure a high efficiency the frond-end cards will be also replaced.

TT dismounting