JUNO Top Tracker

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for the JUNO Collaboration

IPHC/IN2P3/CNRS

April 27th, 2019

The JUNO Collaboration

Country	Institute	Country	Institute	Country	Institute
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Brazil	UEL	China	UCAS	Italy	INFN di Frascati
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Chile	UTFSM	China	U. of South China	Italy	INFN-Milano
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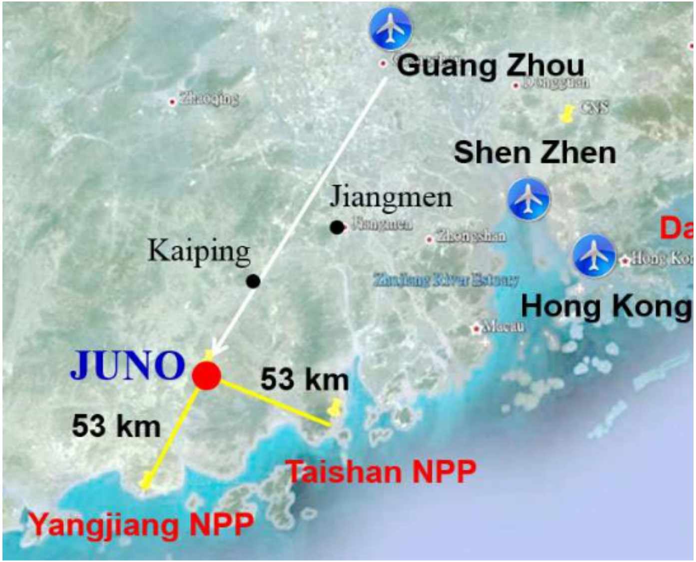
China	IGG-Wuhan	Germany	FZJ-IKP		

= 77 members

The JUNO Collaboration

January 2019, @SJTU

Introduction to the Jiangmen Underground Neutrino Observatory



J. Phys. G **43** (2016) no.3, 030401

- JUNO located 53 km from Taishan and Yangjiang NPP
  - TAO@JUNO planned in Taishan NPP
- Baseline optimized for Neutrino Mass Ordering determination
  - many other topics in reach
- First experiment to see both Δm^2 from ν oscillations
- Data taking start: 2021

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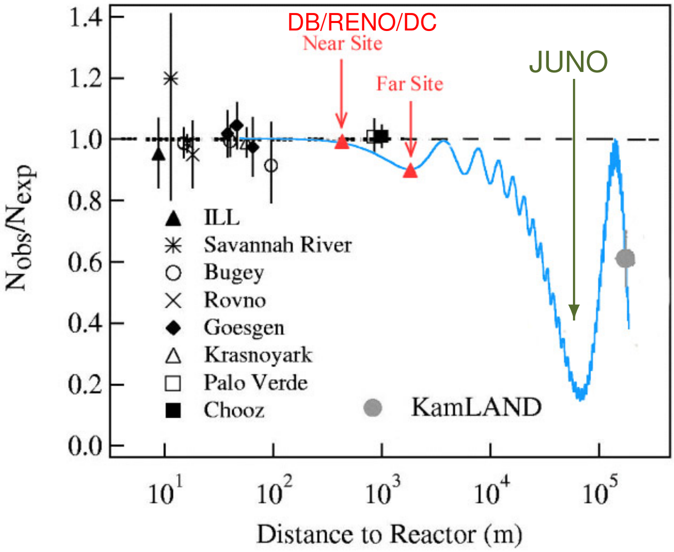

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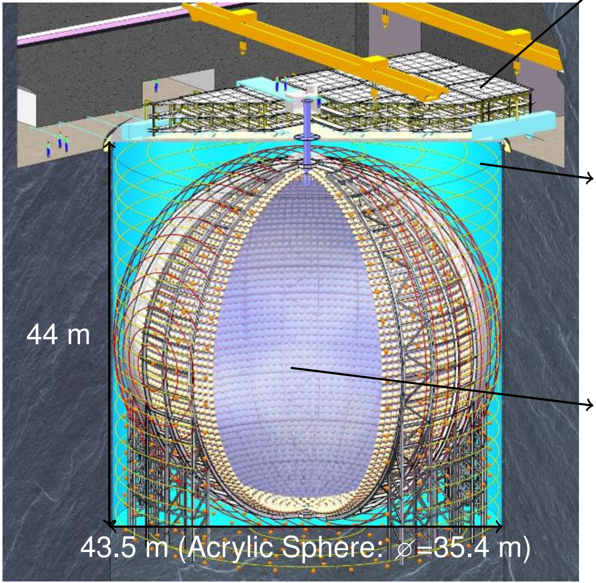
The JUNO Detector



Top Tracker (TT)

- Precise μ tracker
- 3 layers of plastic scintillator
- $\sim$ 60% of area above WCD

Water Cherenkov Detector (WCD)

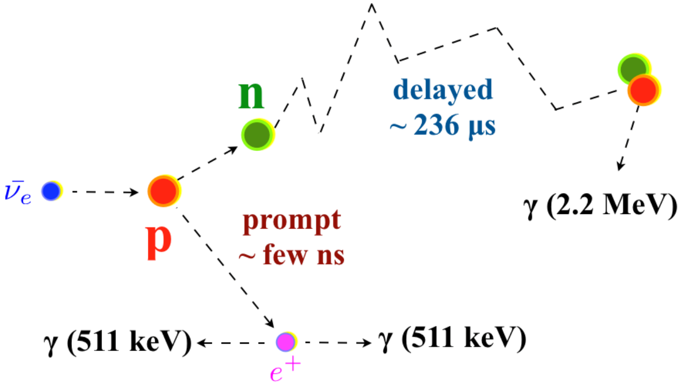
- 25 kton ultra-pure water
- 2.4k 20" PMTs
- High μ detection efficiency
- Protects CD from external radioactivity

Central Detector (CD) – $\bar{\nu}$ target

- Acrylic sphere with 20 kton liquid scint.
- 18k 20" PMTs + 25k 3" PMTs
- 3% energy resolution @ 1 MeV

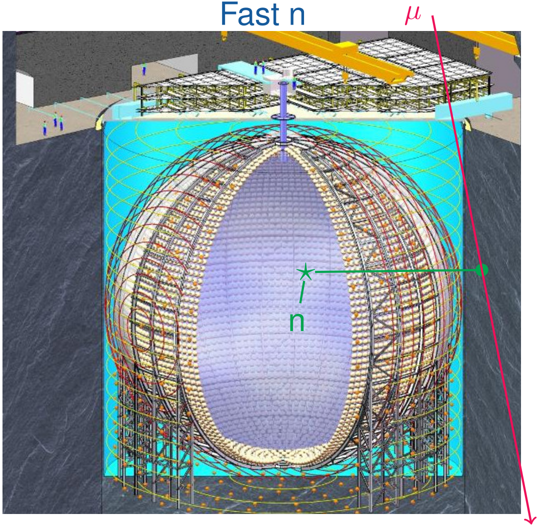
Measuring Reactor $\bar{\nu}_e$

- $\bar{\nu}_e$ detected via IBD: $\bar{\nu}_e + p \rightarrow n + e^+$
  - IBD used since discovery of $\bar{\nu}$
  - Prompt+delayed signal $\Rightarrow$ large background suppression
  - Expected event rate: 73/day (IBD-like in FV)

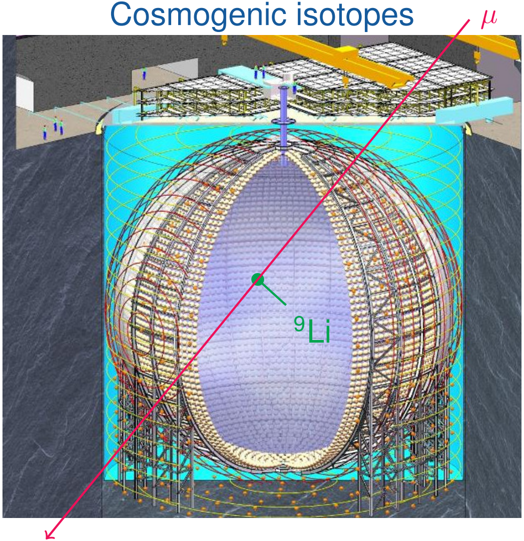


Measuring Reactor $\bar{\nu}_e$: μ-Induced Backgrounds

Fast n



Cosmogenic isotopes



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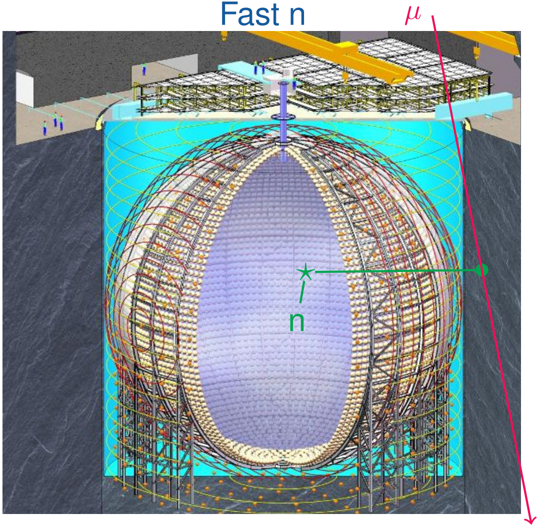

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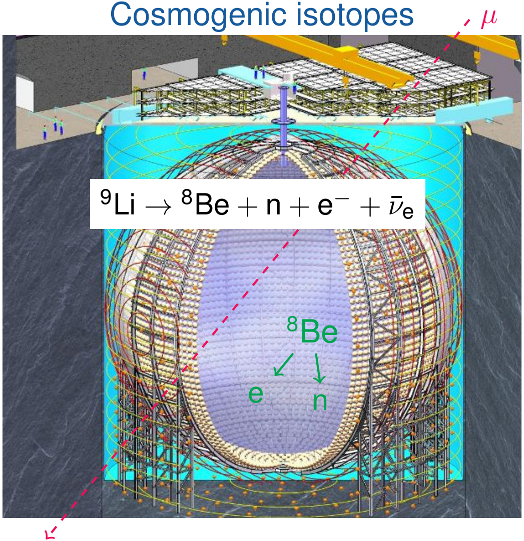

71/day (IBD-like in FV)

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JUNO μ Veto

- Goal: remove cosmogenic-induced IBD-like events
- Veto criteria:
  1. if μ tagged and direction known, reject events within 3 m of μ for 1.2 s
  2. if μ tagged in CD (WCD) but direction unknown, reject events for 1.2 s (1.5 ms)

$\Rightarrow$ Need to track μ well to avoid full detector veto!
  - 99% of μ expected to be in category 1
  - If cannot reco. μ (ie, 100% in category 2) $\Rightarrow$ 100% detector downtime

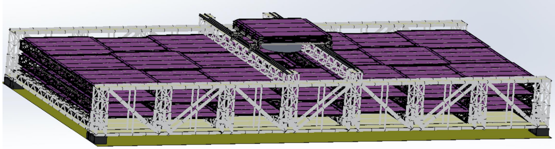
- Tracking μ going to rock also important to experimentaly evaluate fast n rate

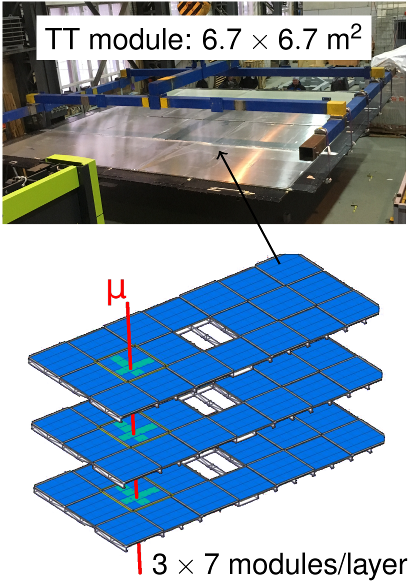
Selection	IBD efficiency	IBD	Geo-νs	Accidental	^{9}Li/^{8}He	Fast n	(α, n)
-	-	83	1.5	$\sim 5.7 \times 10^4$	84	-	-
Fiducial volume	91.8%	76	1.4		77	0.1	0.05
Energy cut	97.8%			410			
Time cut	99.1%	73	1.3		71		
Vertex cut	98.7%			1.1			
Muon veto	83%	60	1.1	0.9	1.6		
Combined	73%	60	3.8				

Table 2-1: The efficiencies of antineutrino selection cuts, signal and backgrounds rates.

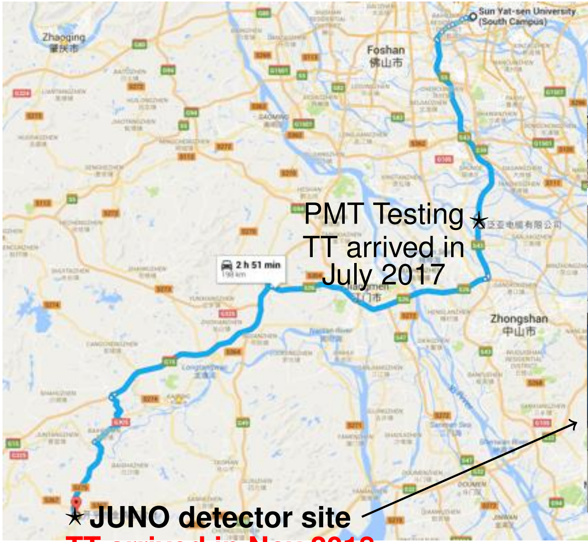
JUNO Top Tracker (TT): Overview

- TT refurbished from OPERA Target Tracker
  - 62 walls measuring (6.7×6.7) m^2 of plastic scintillator available
  - Walls distributed in 3×7 horizontal grid in 3 layers $\rightarrow$ cover $\sim$ 60% of surface above WCD
  - Monitoring of aging of detector essential
  - Upgrades needed on several systems: electronics, mechanical structure, ...
- Very precise μ tracking
  - Detector granularity 2.6×2.6 cm^2 in X–Y
  - 3 Layers separated by 1.5 m
  - $\Rightarrow$ 0.2° median resolution for μ tracks!



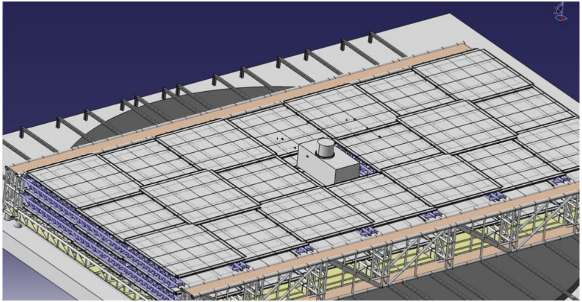


TT Modules Already Delivered at Detector Site!



TT arrived in Nov 2018

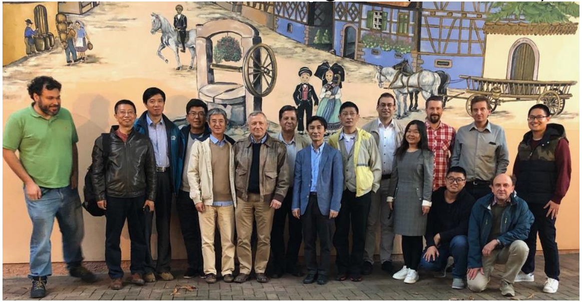
TT Mechanical Structure



- TT modules are flexible
- In OPERA modules placed vertically
  $\rightarrow$ no supporting structure needed
- In JUNO, horizontal placement requires strong structure to avoid sagging
- Easy access to electronics needed

- Final design review completed
  - TT wall supporting structure
  - TT chimney structure
  - TT bridge
- Tender ongoing

TT review in Strasbourg, FR (Oct. 2018)



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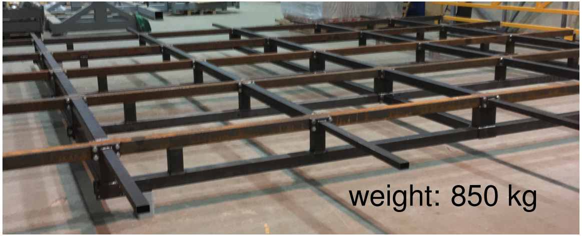
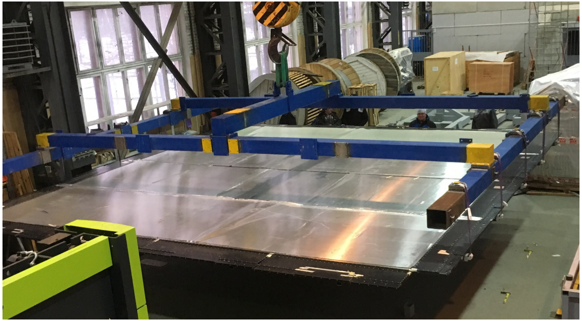
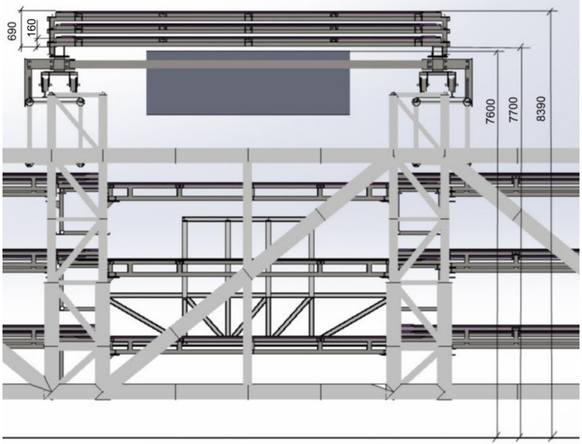
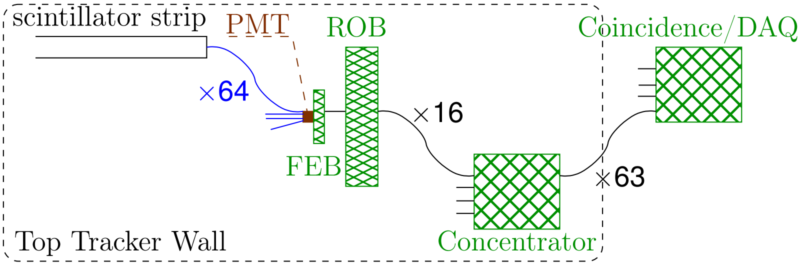




Supporting structure above Chimney



TT Electronics: Schematic View



Front-End Board (FEB): PMT interface and part of the PMT readout.

Read-Out Board (ROB): slow control, power supply, and finish PMT readout.

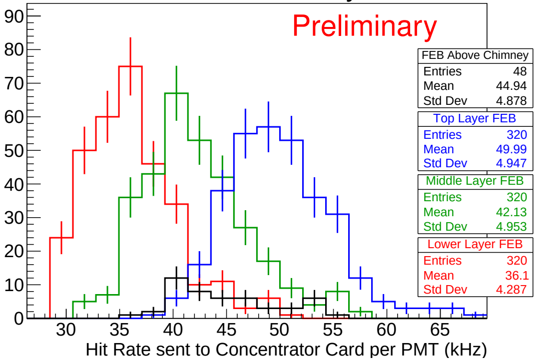
- Charge readout by FEB/ROB takes 8-15 μs
- Permanent Fast OR Trigger

Concentrator Board: gathers hits related to each wall, and create L1 trigger. Also time-stamps of all hits with a nanosecond precision.

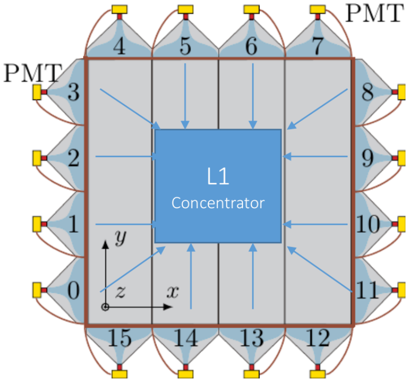
Coincidence Board: combine information from all L1 triggers to produce a L2 trigger.

TT Trigger Overview

From ^{40}K, ^{232}Th, ^{238}U dcy chains

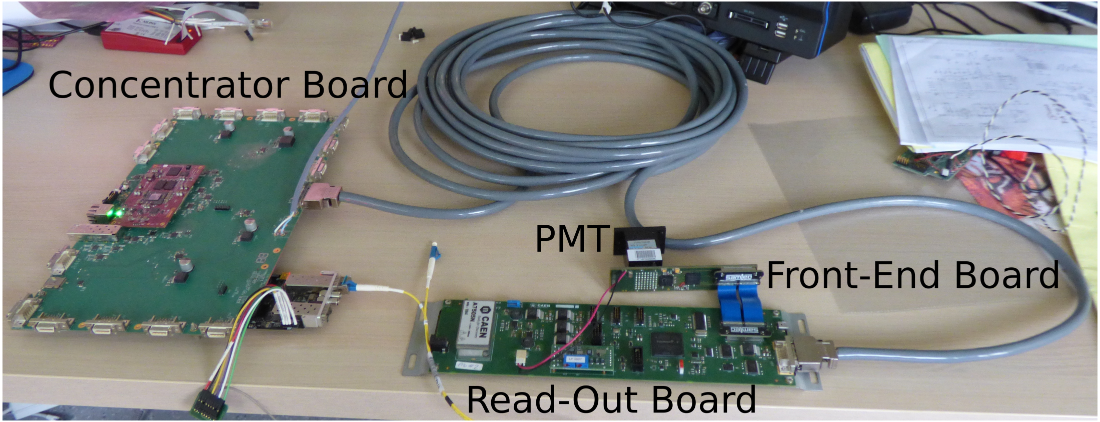


- Natural radioactivity @JUNO site is 100$\times$ larger than @OPERA site
- Need to quickly **reject** radiation (but not μ!) to reduce dead time



- L1 trigger: acts at "wall" level, looks for X–Y coincidences
  - Other algorithms under consideration
  - XY coincidence rate $\approx$ 40 kHz/wall
- L2 trigger: looks at the whole detector (looks for global alignment)
  - 3 walls aligned, TT rate $\approx$ 13 kHz

TT Electronics: Prototype Cards



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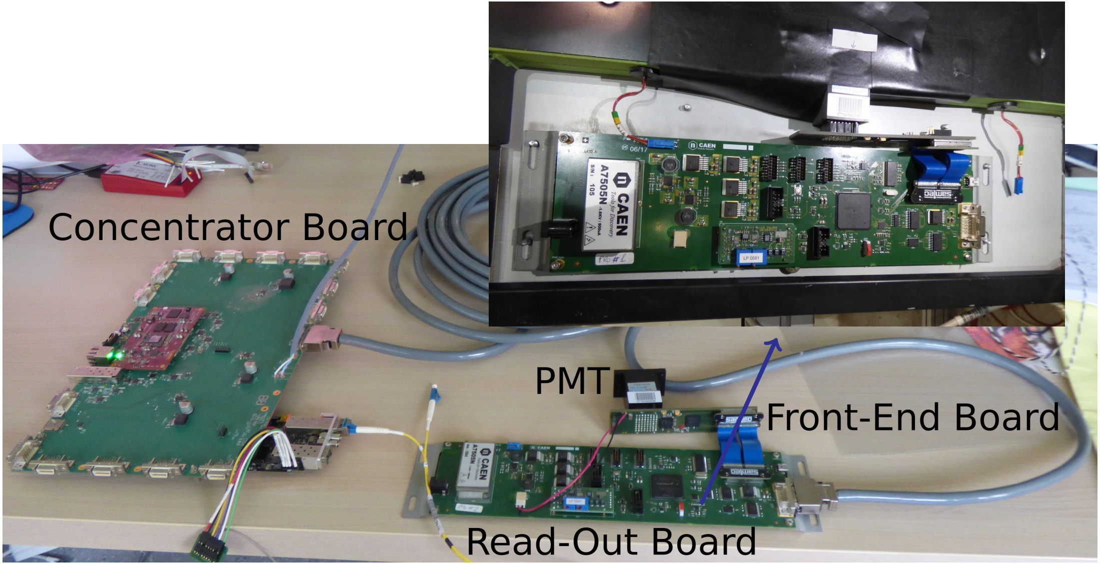

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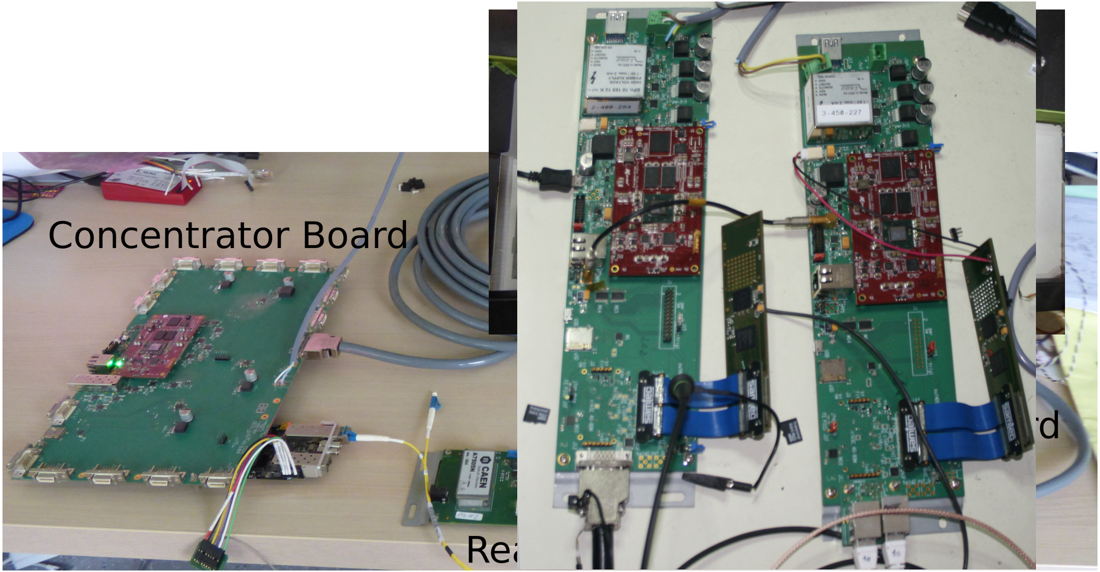

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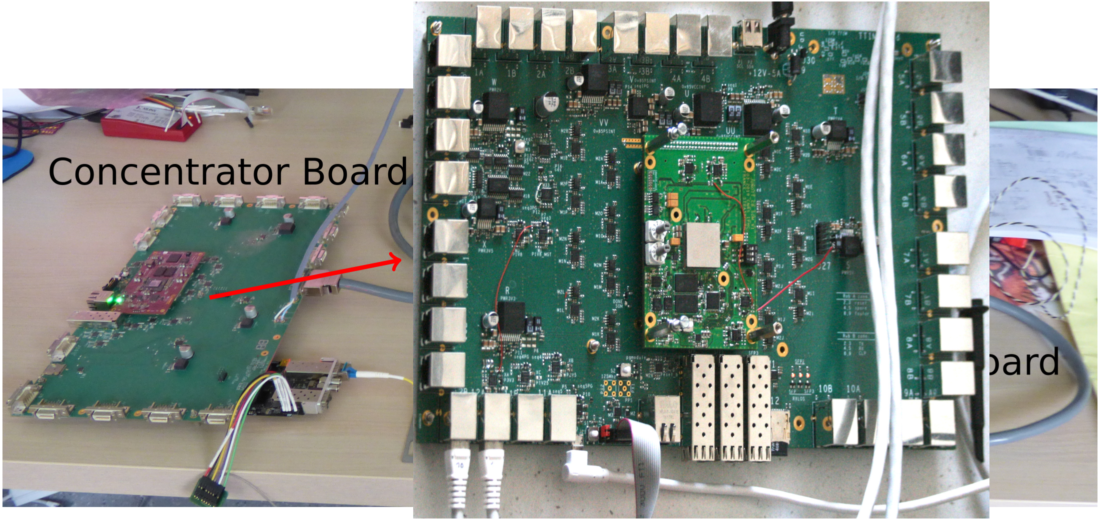

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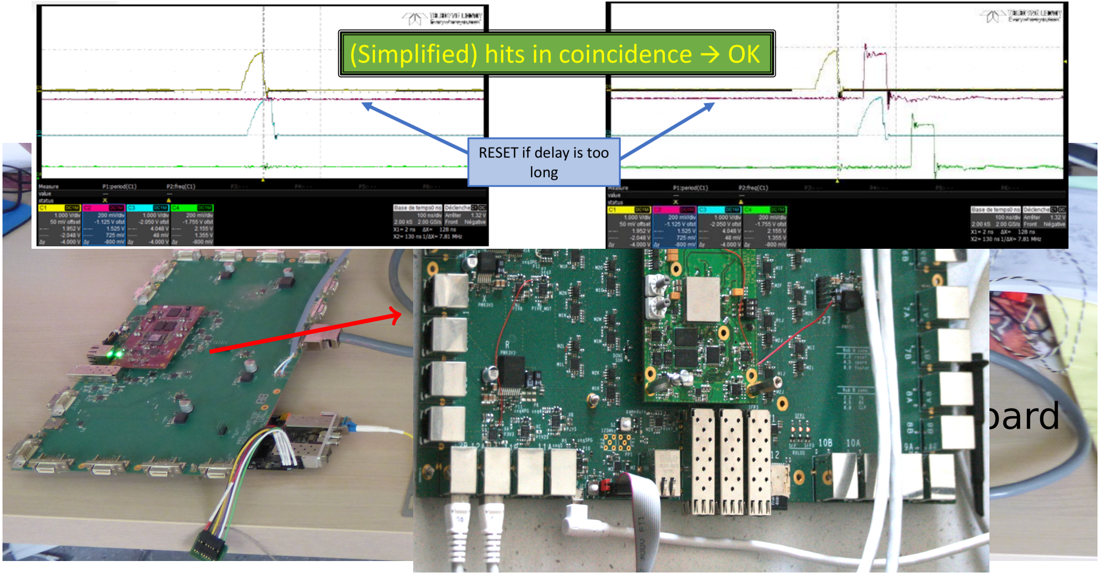
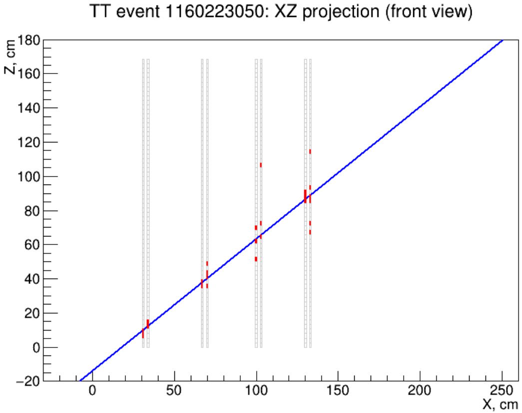
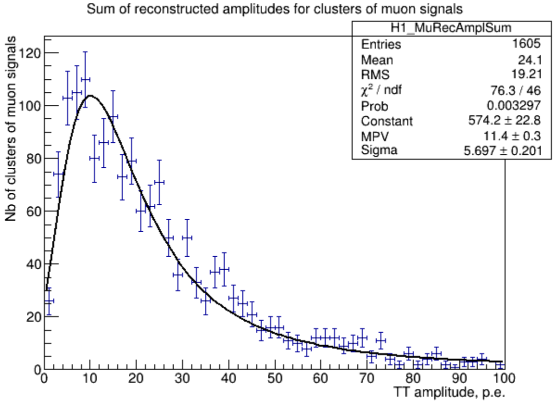


TT Electronics: Schedule

- Front End Board and Read Out Board
  - At final design and verification stages
  - Electronics cards for TT prototype to be ready a month from now
  - Scheduled final design review for July @ Beijing
  - Start production by fall this year
    - MAROC3 already produced and encapsulated
- Concentrator Board
  - 1^{st} prototype delivered in 2018
  - Currently working on 2^{nd} version of prototype
  - Final board prototype expected for beginning 2020
- Coincidence Board
  - Implementation options of L2 trigger under consideration now
  - Detailed design to be started after final review of FEB/ROB

TT Monitoring in PMT Testing Hall





- Use old electronics to take atm. μ data from TT modules in containers during storage
- No significant aging observed up to now

TT Prototype

- TT prototype in Strasbourg
  - build with a quarter of a TT wall
  - 4 X – Y layers (instead of 3 as in TT@JUNO)
- Perfectly adapted to test new TT Electronics Cards
  - FEB & ROB tested in with close to real conditions
  - Testing of some L1 & L2 trigger algorithms in small scale also possible
- Expect to equip prototype with 8 new TT Electronics Boards by end of next month

TT Global Schedule

- End 2018: final mechanical design ✓
  - Tender ongoing
- Mid 2019: final design of Front End and Read Out Boards
  - MAROC chips already available ✓
  - 2019-2020: production of 1200 FEB and ROB
- End 2019: Test full electronics chain on TT prototype
- 2020: produce 80 Concentrator cards
- Beginning 2021:
  - all electronics cards ready
  - final preparation of cables and remaining systems
- April – October 2021: TT installation and commissioning
  - Will happen at same time as filling and commissioning of CD

Summary

- JUNO Top Tracker is a part of the JUNO Veto system
  - Precise μ tracking is essential for rejection of cosmogenic background
    - also allows to study cosmogenic background spectrum
  - Fast n background measurement
  - To be used for calibration also
- TT monitoring shows no significant aging since OPERA
- Top Tracker preparation is well on schedule
  - Already completed design of mechanical components
  - Close to completed review of FEB and ROB
  - Large progress in Concentrator card in this past year
  - Gearing up to test all electronics system on TT prototype starting end of next month
- TT modules already at JUNO site!
- TT will be ready for installation in JUNO as planned in 2021

Backup