Multi-messenger and Low-threshold Trigger System at JUNO

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Abstract

With 20-kiloton liquid scintillator as detection medium, the Jiangmen Underground Neutrino Observatory (JUNO) will have highly competitive sensitivity to MeV-scale neutrino, and will play an important role in the emerging field of multi-messenger astronomy, especially for the transient events where high radioactivity background can be easily reduced. We present in this poster a multi-messenger trigger system, which is built on novel hardware/firmware and lowers the detector trigger threshold potentially by an order of magnitude -- to as low as 20 keV. This trigger system will enable the widest broadband real-time monitoring of the transient neutrino sky and possibly steady signal searches at the sub-MeV to GeV energies, and can communicate with other multi-messenger facilities around the world on the millisecond time scale.

Neutrino & Multi-messenger Astronomy

Potential Astrophysical Neutrino Sources

- Core-collapse supernovae : burst & pre-burst [1,2]
- Type-Ia supernovae [3]
- Neutron star mergers [4], Gamma ray bursts [5], Fast radio burst [6]
- Fundamental properties of neutrinos : absolute mass , mass ordering
- New physics : sterile neutrinos , axions , etc

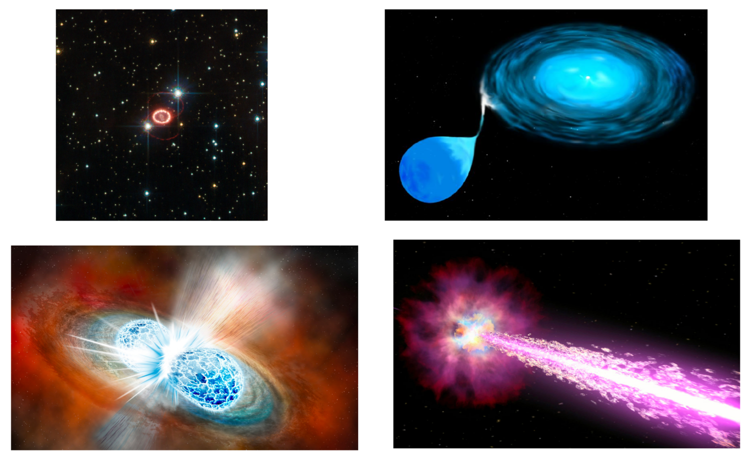


Figure 1 : Left to right : (1) core-collapse supernova; (2) type-Ia supernova; (3) neutron star merger; (4) gamma ray burst.

JUNO Detector

Detector

- 35.4 m diameter acrylic sphere
- 20 kiloton LS detector
- 18,000 20'' + 25,000 3'' PMTs
- 700 m underground
- 53 km to the nuclear reactors
- Muon veto : 35 kton water Cherenkov detector

Key Performance

- Energy resolution ~ 3% $/\sqrt{E(MeV)}$
- Light yield ~ 1200 PE / MeV
- Neutrino mass hierarchy : @ (3~4)σ by 2026
- Precision measurement of neutrino oscillation parameters
- Search for astrophysical neutrinos

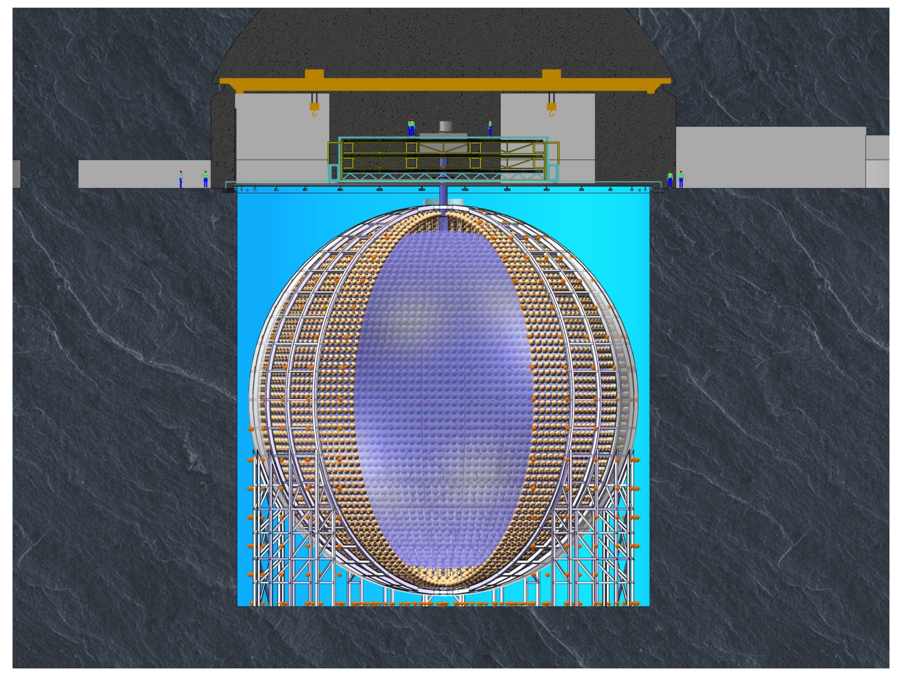


Figure 2 : Schematic illustration JUNO: central detector is an acrylic sphere filled with 20 kton liquid scintillator. Outer water pool provides shielding, and tags cosmic ray muons. A muon tracker is placed on top of the water pool [7].

Detection Channels

- Inverse beta decay (IBD)

  $\bar{\nu}_e + p \rightarrow e^+ + n$
- Elastic ν-p scattering

  $\nu_x + p \longrightarrow \nu_x + p$
- Elastic ν-e scattering

  $\nu_x + e^- \longrightarrow \nu_x + e^-$
- Neutrino-${}^{12}_{6}C$ interactions

Low-threshold Trigger System

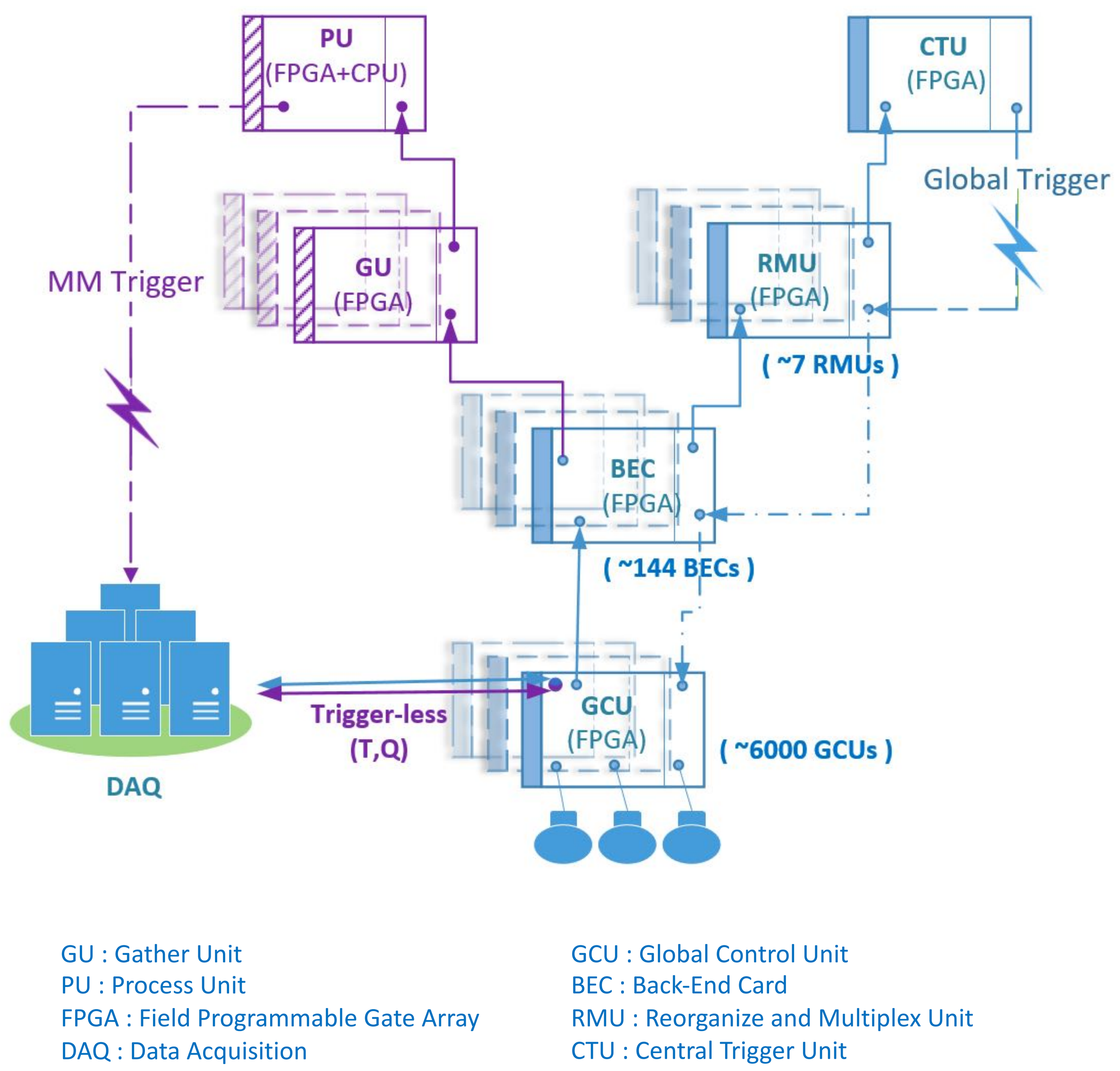


Figure 3 : Schematic design of the trigger systems in JUNO. The global trigger based on hit multiplicity has a higher threshold to avoid the ^{14}C radioactivity which has an end point of 156 keV. The multi-messenger trigger will lower the energy threshold to the O(10) keV regime.

Trigger Algorithms

- A fast likelihood algorithm with PMT hit time & position info within every 200 ns is employed on the FPGA onboard the MM Trigger hardware system
- 20-inch PMT dark noise rate ~ 25 kHz per PMT
- > 99.87% dark noise is filtered
- Resulting data volume ~ 2 PB/Yr with time and charge (T, Q) pair, written to tape onsite (40 kHz ^{14}C assumed)

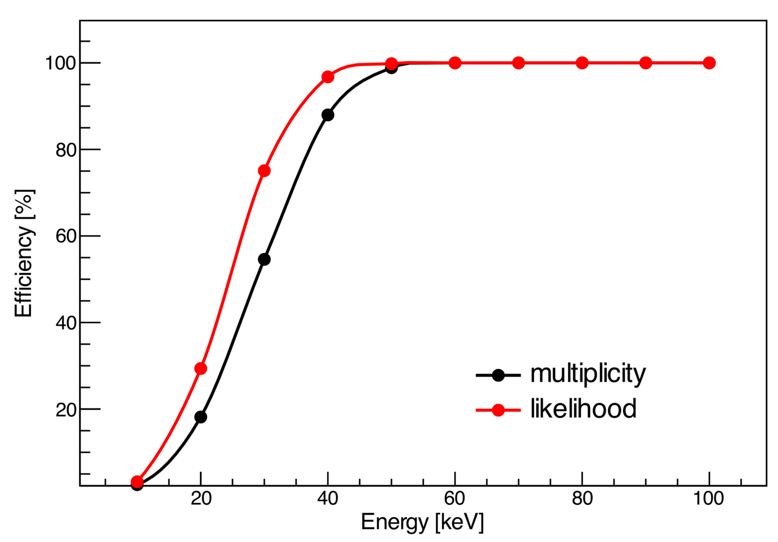


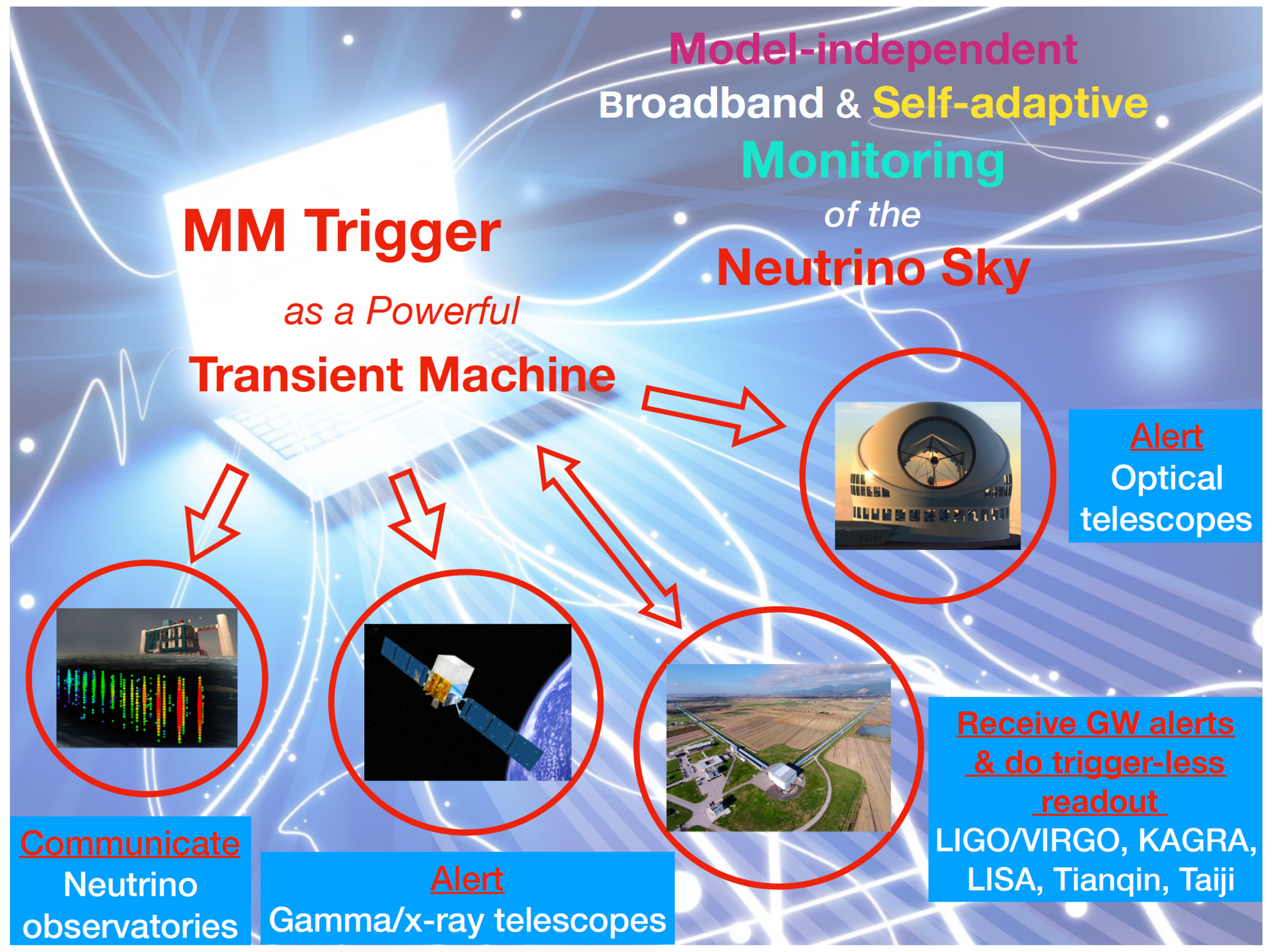
Figure 4 : physics (gammas) retention efficiency with fast filtering algorithms to be implemented on the FPGA

An Intelligent Transient Machine

MM Trigger ≈ an intelligent "robotic arm"

- It monitors the transient neutrino sky 24/7
- It tells DAQ to start recording the continuously-spit-out (T, Q) pairs when it "sees" a transient signal, e.g. a supernova
- It sends out preliminary alerts at ~millisecond latency
- It responds to external triggers such as LIGO and/or IceCube alerts, tells DAQ to prepare for trigger-less readout for some given time window, e.g. ±500s

Find out more on how it works at **Poster #154**:
Real-time Monitoring of Astrophysical Neutrinos with the Multi-messenger Trigger of JUNO



Conclusion & Outlook

Neutrino detection plays an important role in the new era of multi-messenger astronomy. JUNO, a 20 kiloton liquid scintillator detector, has great capability to observe astrophysical neutrinos from sub-MeV to sub-GeV energies. A preliminary multi-messenger trigger system has been designed to lower the energy threshold of the detector down to O(10) keV. With this system, we are looking to do real-time monitoring on neutrino clustering and issue alerts to multi-messenger networks, as well as do fast follow-up analyses in responses to other messengers such as gravitational waves and high energy neutrinos.

References

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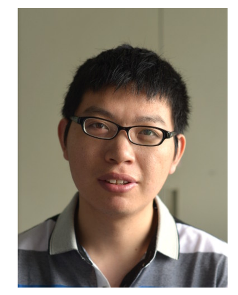

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