Detecting Supernova Neutrinos using the DUNE Photon Detection System

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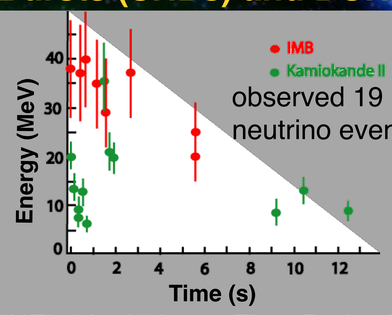
DEEP UNDERGROUND NEUTRINO EXPERIMENT

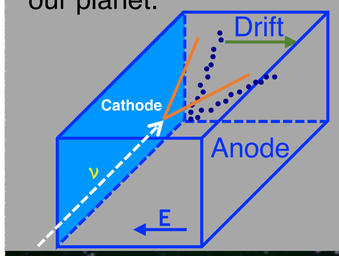
Colorado State University

1. Supernova Neutrino Bursts (SNBs) and DUNE

- Neutrinos of all flavors, few tens of MeV energy were produced from a core-collapse Supernova (SN).
- Neutrinos were observed from SN1987A, 50 kpc away from our planet.

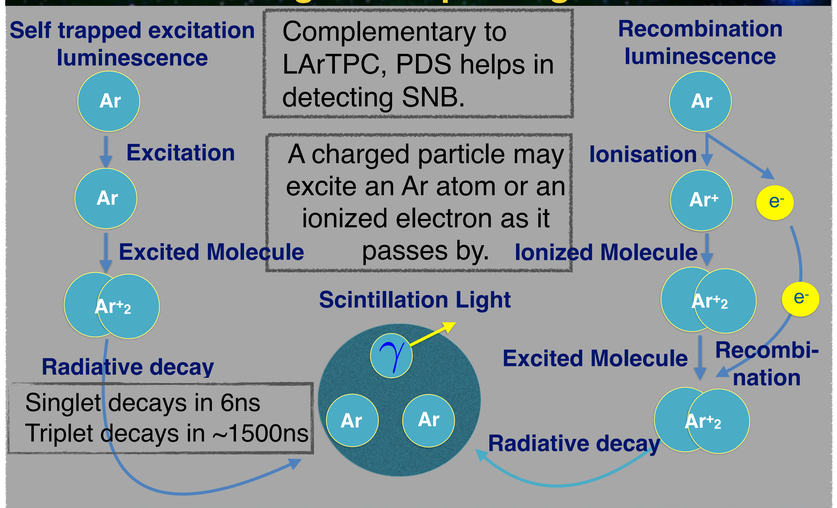


observed 19 neutrino events.



- DUNE's Liquid Argon Time Projection Chamber (LArTPC) detects low energies supernova neutrino events.
- DUNE uses ARAPUCA[1] photon detectors to trap photons of a certain wavelength.

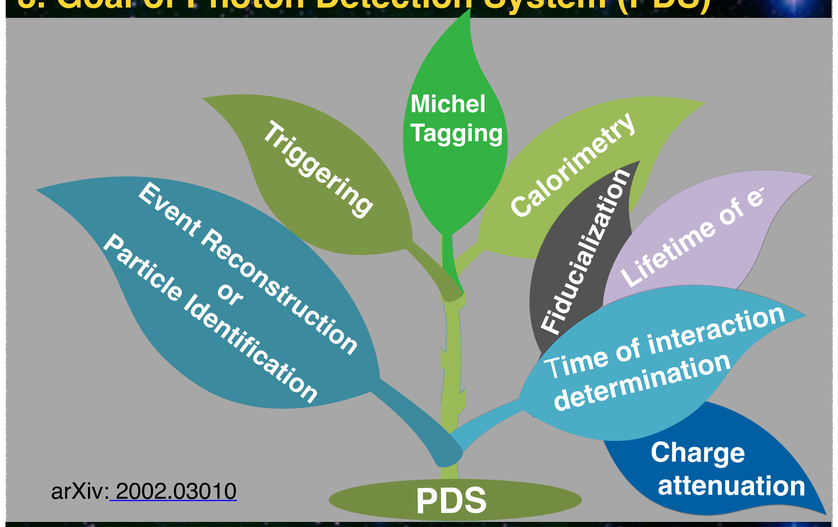
2. Scintillation Light in Liquid Argon



Complementary to LArTPC, PDS helps in detecting SNB.

A charged particle may excite an Ar atom or an ionized electron as it passes by.

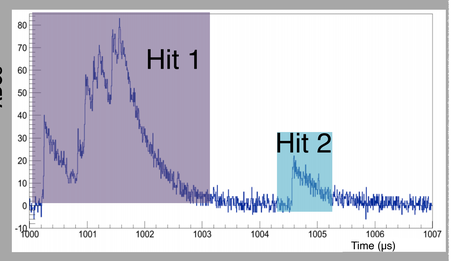
3. Goal of Photon Detection System (PDS)



arXiv: 2002.03010

4. Identifying Activities in the PDS

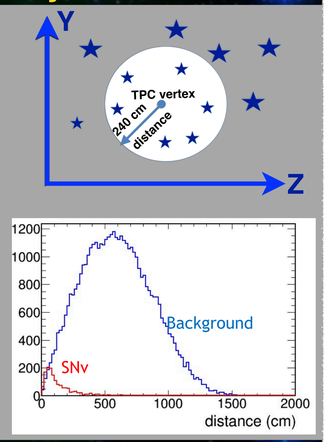
- **Hit Finding**: Process every waveform and identifies signals, above a threshold.
- Hit time is assigned to the first peak.
- We integrate for converting the ADCs to Photoelectrons(PEs).



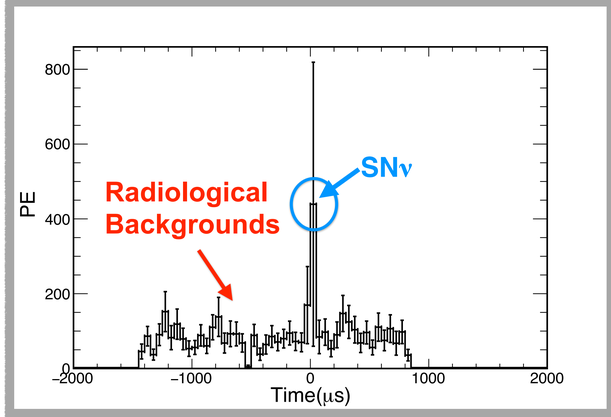
- **Flash Finding**: Flash is collection of hits in an event from different photodetectors (PDs).

5. Matching PDS and TPC Activity

- **Flash Matching**: Coincidence between PDS flash and TPC positions will reduce the rate of uncorrelated background in the two systems.
- **Matching PDS and TPC events requires:**
  - The flash be within one drift time before the TPC time.
  - Vertex reconstruction is within 240 cm for PDS and TPC event in the Y-Z plane.
  - Consider the largest flash that remains as the match.

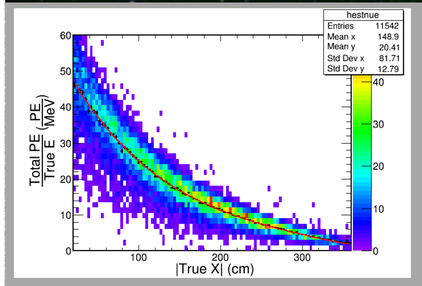


6. Supernova Neutrino Calorimetry

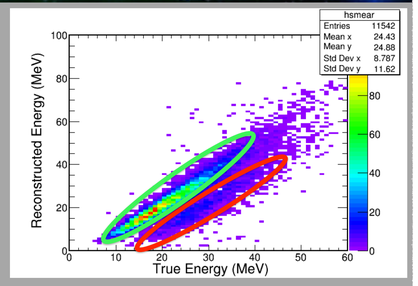


SN neutrinos are embedded with lots of radiological backgrounds and signal peaked at time zero micro second.

7. Reconstruction of Neutrino Energy



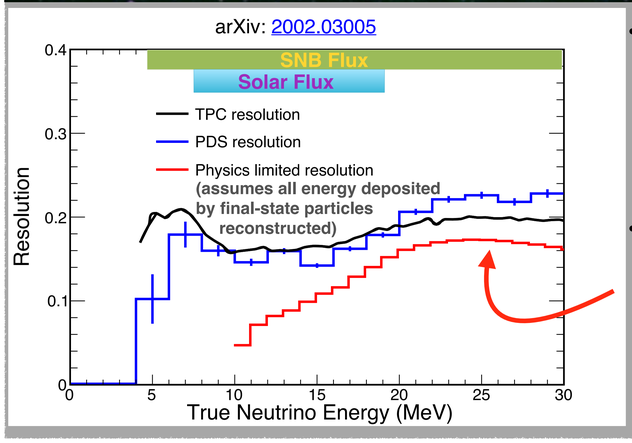
Rayleigh scattering attenuates the observed light yield as a function of the distance to the PDS detectors.



Two populations: events **with** and **without** neutron emission.

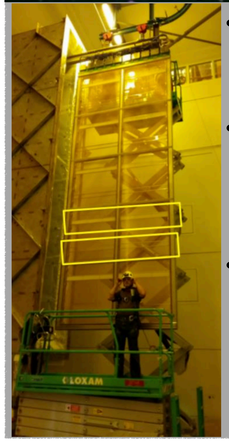
8. Energy Resolution for Low ν_e CC Interaction

arXiv: 2002.03005



- The PD System provide complimentary to TPC resolution.
- The higher resolution at higher energy represents loss of energy from neutrons.

9. Summary



- DUNE has selected the novel X-ARAPUCA concept for photon detection to supplement the physics sensitivity of the TPC.
- A full reconstruction of simulated scintillation photons suggests we can reconstruct drift time with PDS information even for low-energy neutrinos.
- Preliminary studies show energy resolution is comparable to that achieved by the TPC for energies relevant for supernova and solar events.

References: DUNE TDR VOLUME II: arXiv: 2002.03005
DUNE TDR VOLUME IV: arXiv: 2002.03010
[1]Marinho, Paulucci, Machado, Segreto; arXiv 1804.03764

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