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SuperNova Early Warning System (SNEWS)

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▶ **SNEWS - SuperNova Early Warning System**

<http://snews.bnl.gov/>



▶ **Purpose of SNEWS:**

- 1. Neutrinos emerge earlier than electromagnetic signal.
Neutrinos take the majority of the energy loss (IIa)
Provide astronomical community a prompt alert
Early stage light curve**
- 2. Optimize global sensitivity
Lower each experiment's threshold
Downtime coordination**

New J. Phys. 6 114



Member experiments

- ▶ Current experiments: Super-K, LVD, IceCube, Borexino, KamLAND, and Daya Bay
- ▶ November 2014: [Daya Bay](#) joins SNEWS after Daya Bay internal and Daya Bay-SNEWS tests. arXiv:1505.02501
- ▶ LIGO experiment to join

Basic principle

- ▶ For individual experiments
a SN gives a burst
of neutrinos



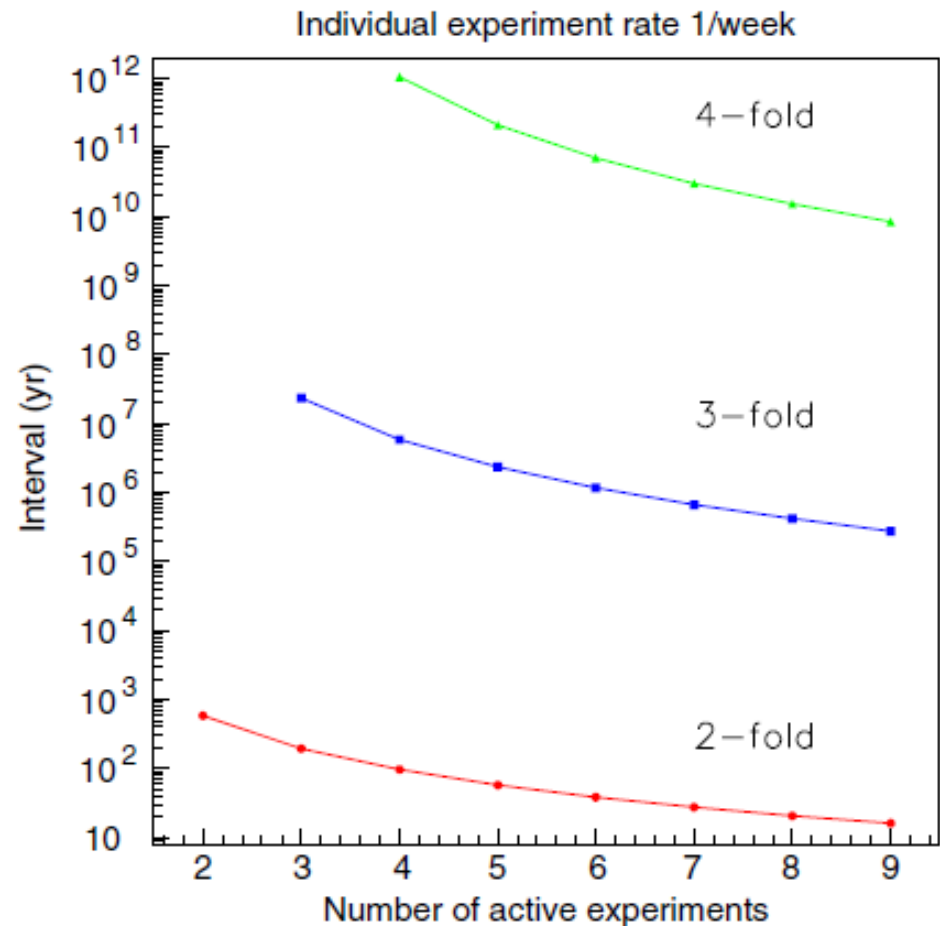
- ▶ Individual Exp. alarm rate
1/week



- ▶ 2- or 3-fold coincident
rate within 10 s is less
than 1/century



- ▶ 1/century is consistent
with our theoretical
expectation of SN rate



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A little more detail

- ▶ Individual experiment send: **GOOD, POSSIBLE, RETRACTED, OVERRIDE**, or TEST alarm to SNEWS

- ▶ SNEWS makes coincidence test and issue **GOLD** or **SILVER alert**

- ▶ Background:
 1. Accidental coincidence
 2. Non-astrophysical correlated bursts
electrical noise, ambient pressure, seismic,
solar activity, solar flares
 3. Malicious actions

With 8 AD at Daya Bay, we observed many coincidence with power fluctuations, thunder storms ...



SNEWS coincidence definition

▶ **GOLD** alert

1. Two- or more-fold **alarm** coincidence within 10 s
2. Two experiments are at physically separated laboratory
3. Two or more individual input trigger are GOOD
4. The individual rate in the past month of the individual trigger is less than 1/week

▶ **SILVER** alert

1. No 1 is satisfied but one of 2, 3, and 4 is not satisfied.



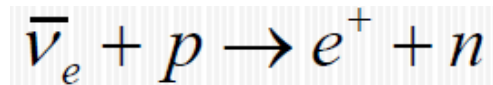
Neutrino signals and detectors

- ▶ Scintillator
- ▶ Water
- ▶ Heavy water
- ▶ Long string PMTs
- ▶ Liquid argon
- ▶ Heavy metal
- ▶ Radio-chemical

Every detection has its own feature.

Scintillator

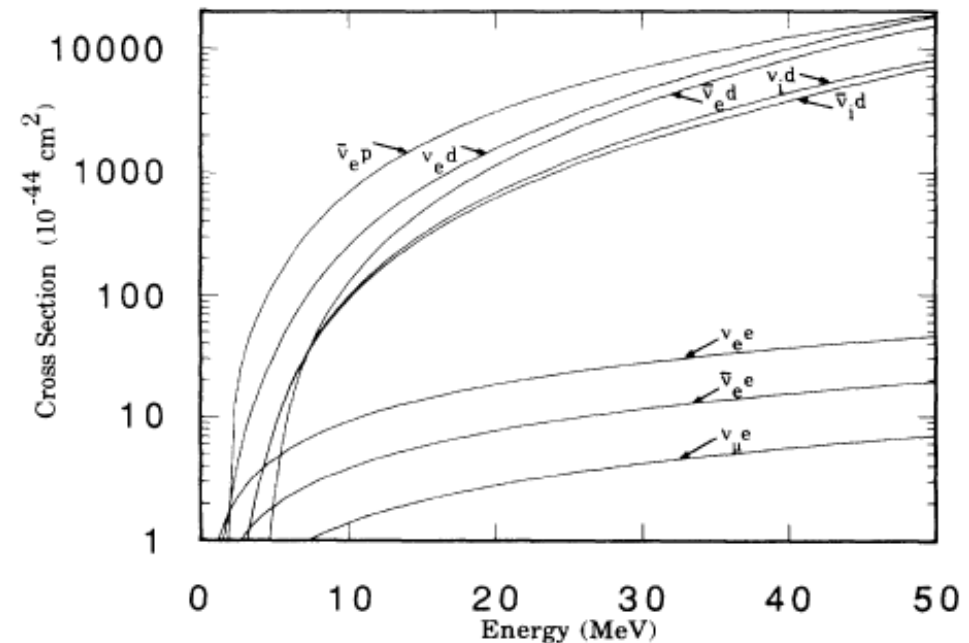
- ▶ Material: C and H
- ▶ Dominant process: Inverse Beta Decay, anti- ν_e only



- ▶ Minor process: ν -e scattering, ν -p scattering

▶ IBD

1. Cross-section: high
2. Neutron tagging
3. CC process
4. Threshold: 1.8 MeV
5. $E_{\text{anti-}\nu_e} = E_{e^+_{\text{vis}}} + 0.8\text{MeV}$
6. Detector thres.: 200 keV
7. High energy resolution
8. No directionality



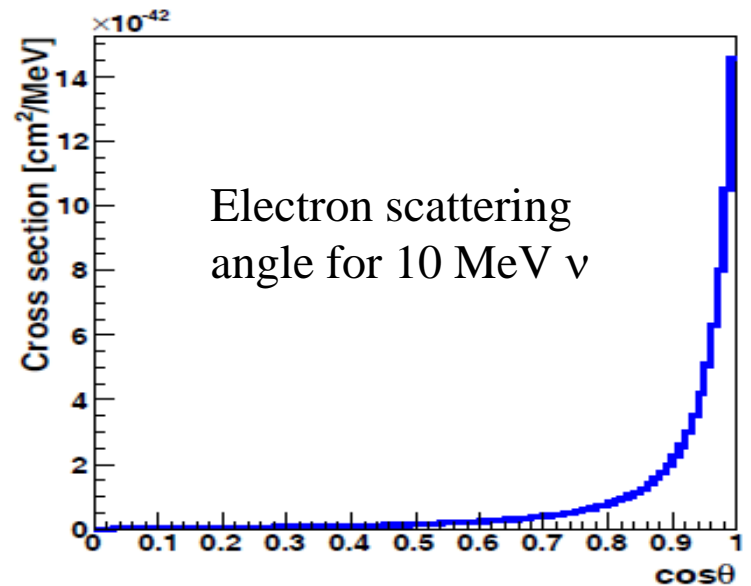
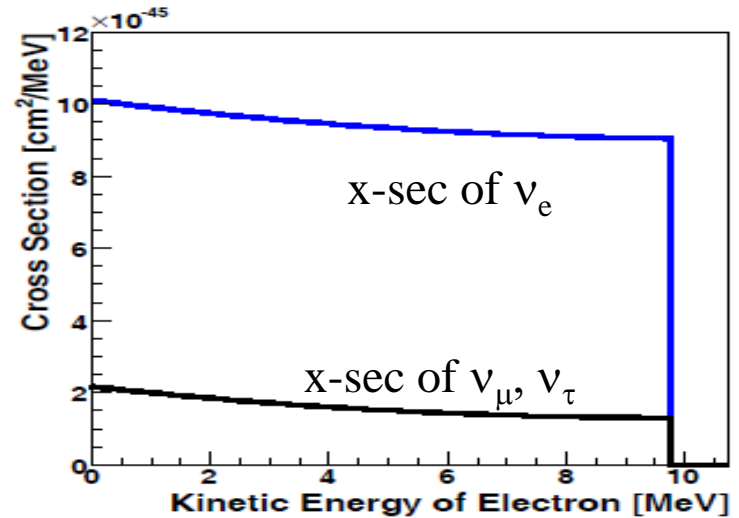
PRD 45, 3361

Water

- ▶ Material: O and H
- ▶ Dominant process: IBD
- ▶ Minor process: ν -e scattering

- ▶ IBD
 1. Weak neutron tagging
 2. Detected as single signals
 - Forced neutron trigger (THU)
 - Gd-water may come online

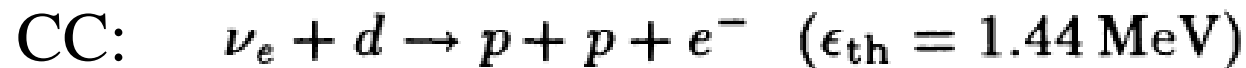
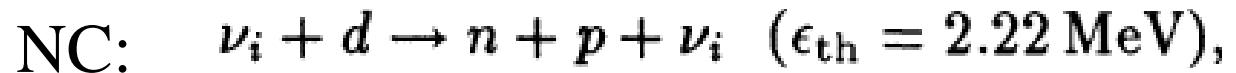
- ▶ ν -e scattering
 1. NC and CC process
 2. ν_{μ}, ν_{τ} x-section is $\sim 1/5$ of ν_e
 3. Involve all flavors
 4. Directionality
 5. ~ 5 MeV threshold at SK and SNO



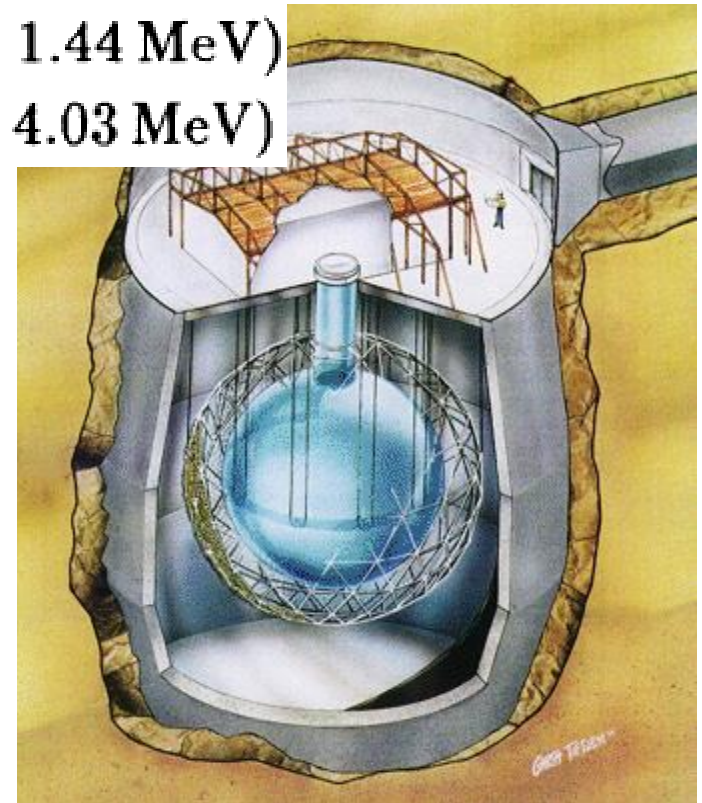
Heavy water

- ▶ Material: D and H

- ▶ Detection process:

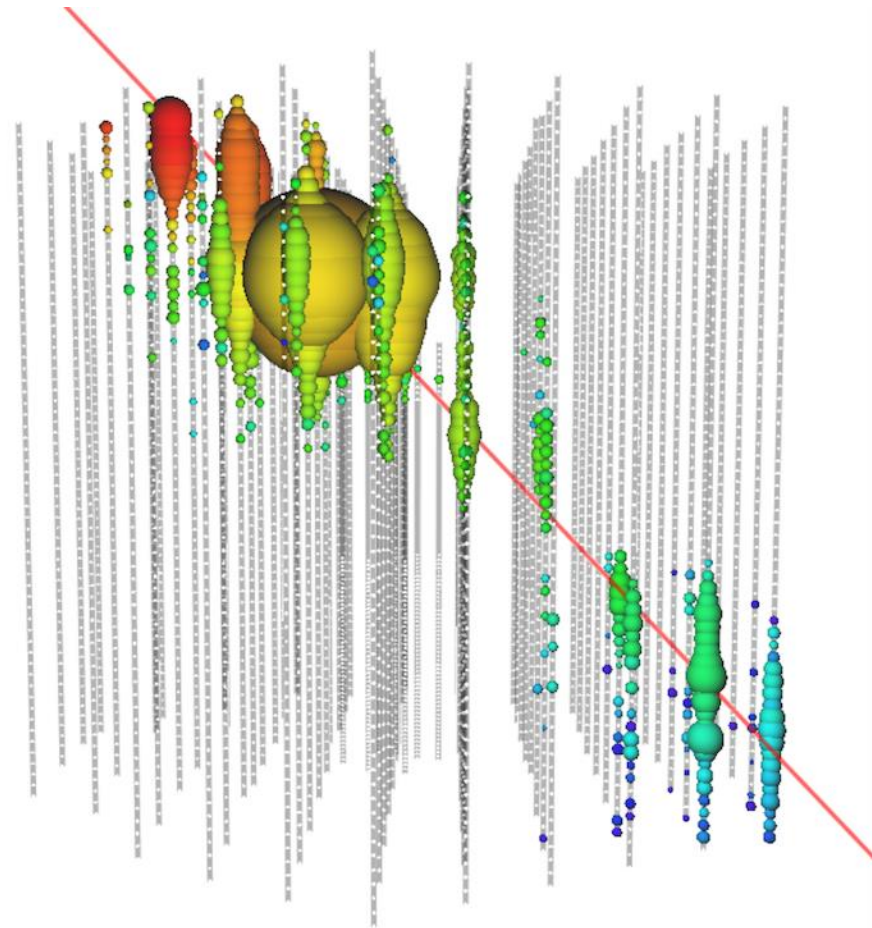


- ▶ Different combination of CC and NC process to resolve degeneracy
- ▶ Last CC process has directionality
- ▶ ~5 MeV threshold at SNO
- ▶ SNO (D_2O) has finished.
- ▶ SNO+: liquid scintillator now



Long string PMTs

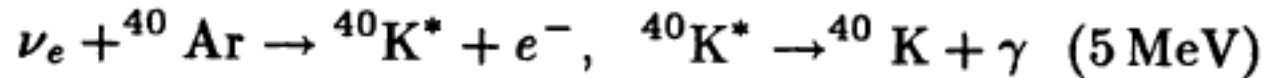
- ▶ IceCube
- ▶ >5000 PMTs in ice
- ▶ IBD and ν -e scattering
- ▶ Designed for TeV neutrinos
- ▶ Supernova burst neutrinos show itself as a global PMT noise increase
- ▶ Very good to check the neutrino luminosity curve



Liquid argon

- ▶ Process:

ν -e scattering



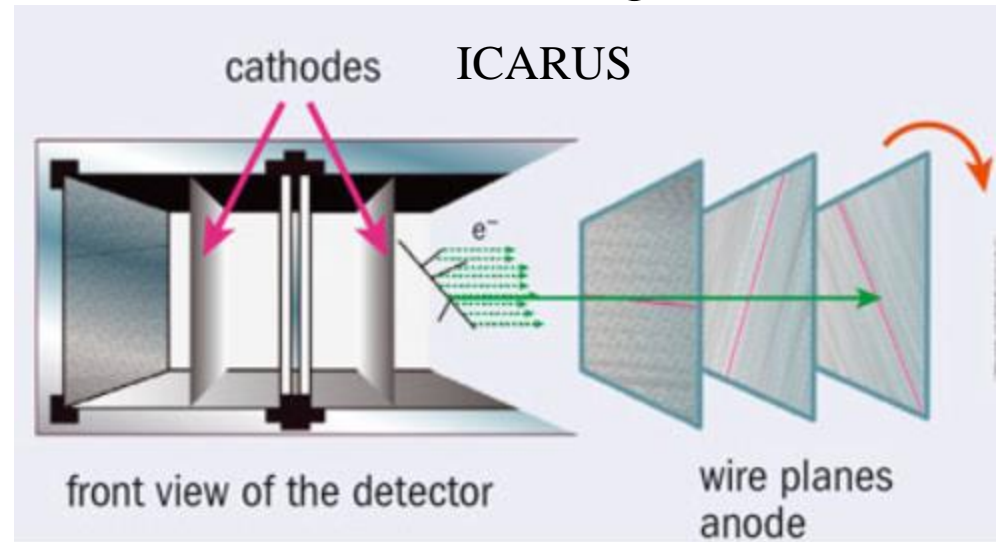
- ▶ Neither is dominant

ν -Ar cross section is high, but number of e is high.

- ▶ LAr as a scintillator detector

- ▶ LAr TPC (DUNE)

1. Threshold > 10 MeV



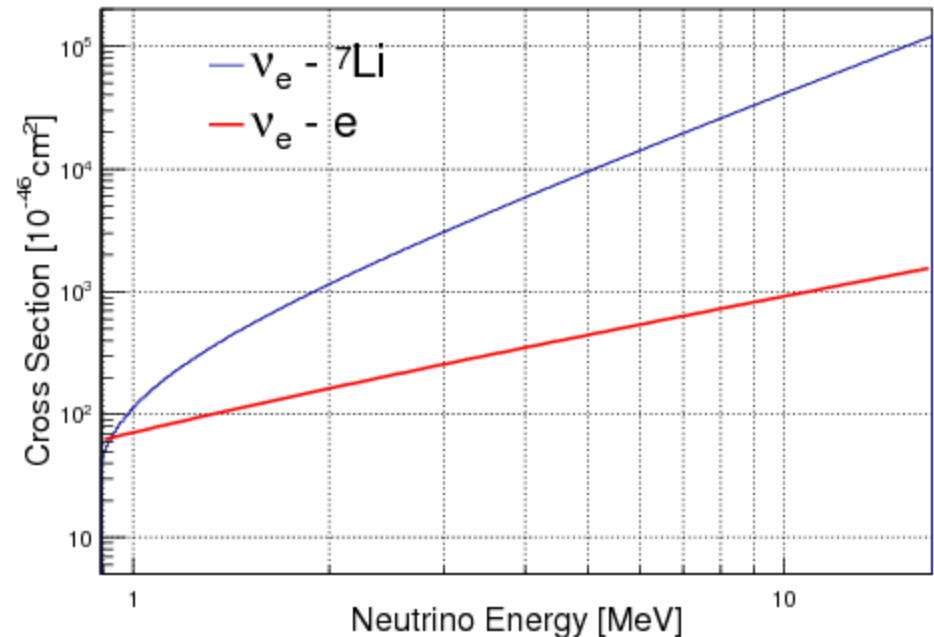
Heavy metal

- ▶ CC cross section of neutrino on some heavy metals are 100 times than ν -e scattering

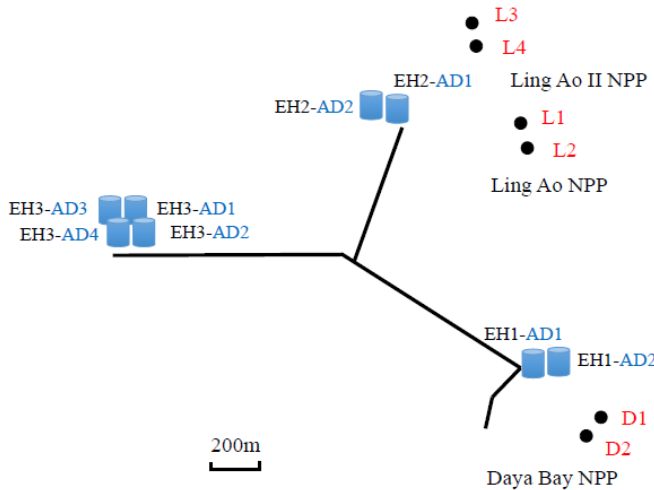
1. ${}^7\text{Li}$, ${}^{37}\text{Cl}$, ${}^{71}\text{Ga}$

- ▶ However, similar to Ar, the target number is much less than electrons or free protons.

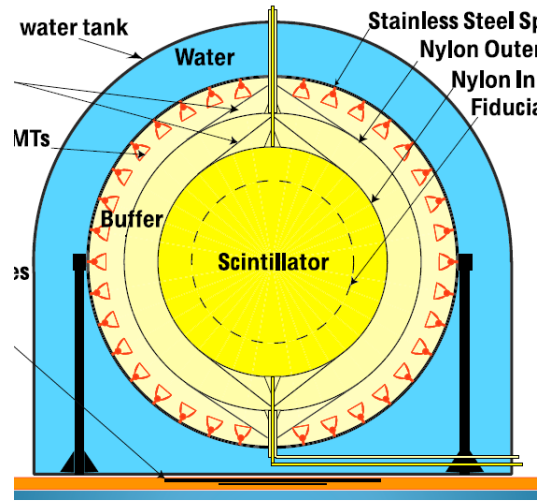
- ▶ So far no realistic detector



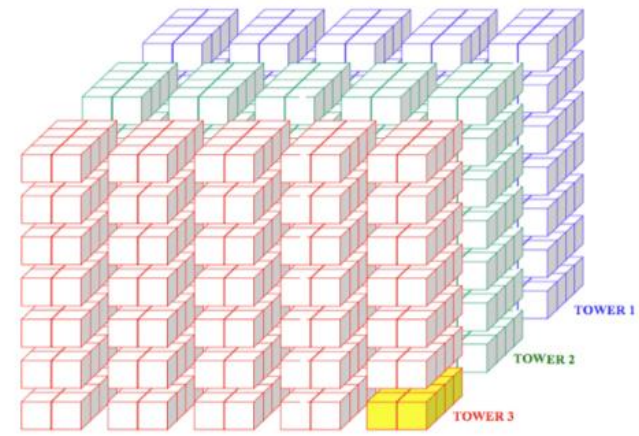
Daya Bay, KamLAND, Borexino, and LVD



Daya Bay 8 separate detectors



Borexino 1 detector
KamLAND 1 detector



LVD: many small modules
Each one has 1.2 ton LS and viewed by 3 PMT,
Poor resolution and threshold

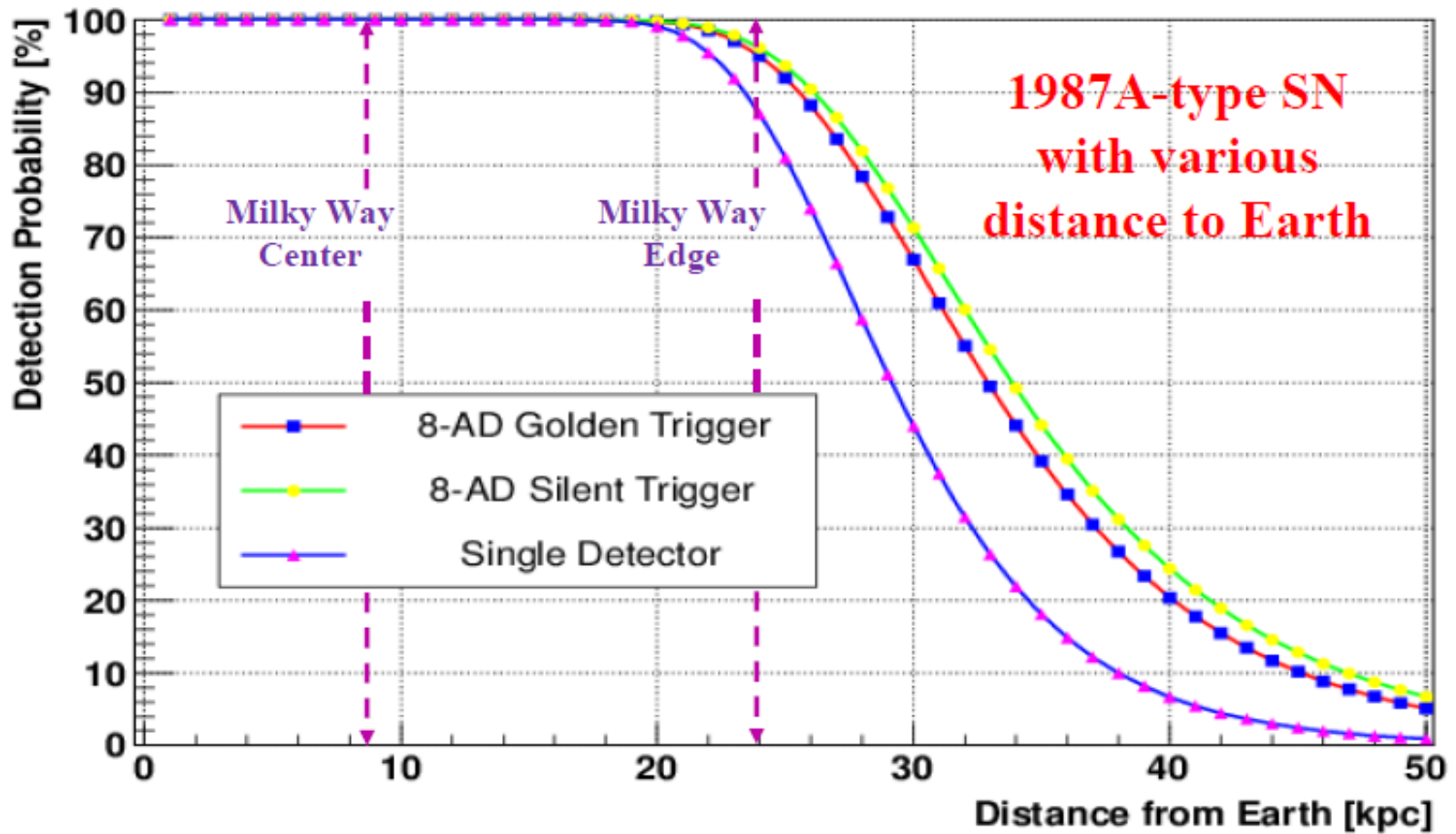


Feature of Daya Bay experiment

- ▶ Measure IBD process
- ▶ Offer best energy resolution: $\sim 7\%$
- ▶ Offer the lowest energy threshold: ~ 0.5 MeV
- ▶ Multi-module: best muon background suppression

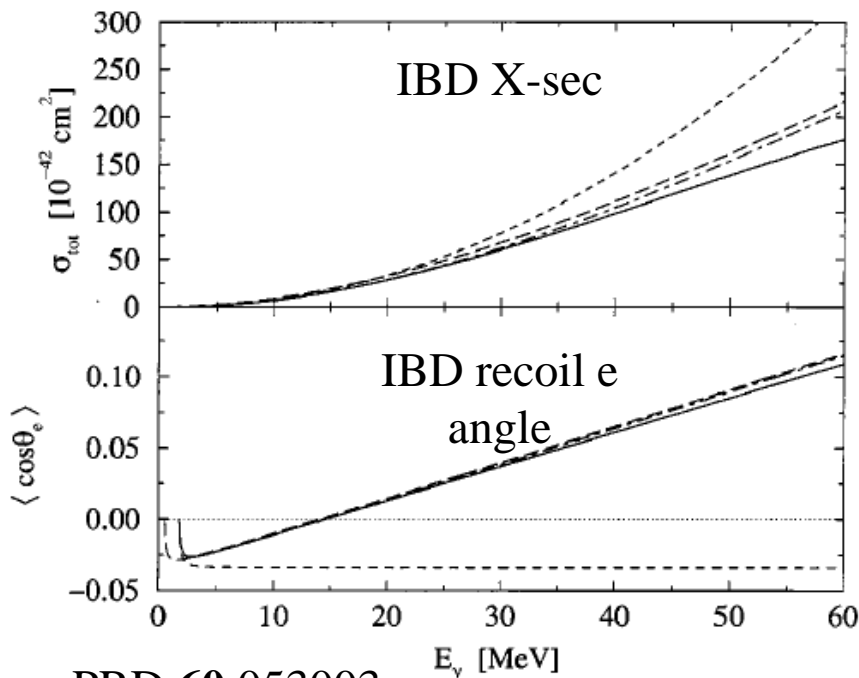
Detector	Type	Location	Mass (kt)	N_{IBD}	E_{th} (MeV)
IceCube	*L.S. Ch.	Antarctic	0.6/PMT	N/A	-
Super-K	Water Ch.	Japan	32	7000	7.0
LVD	Scint.	Italy	1	300	4.0
KamLAND	Scint.	Japan	1	300	0.35
Borexino	Scint.	Italy	0.3	100	0.2
Daya Bay	†M.S. Scint.	China	0.33	110	0.7

Sensitivity of Daya Bay Experiment

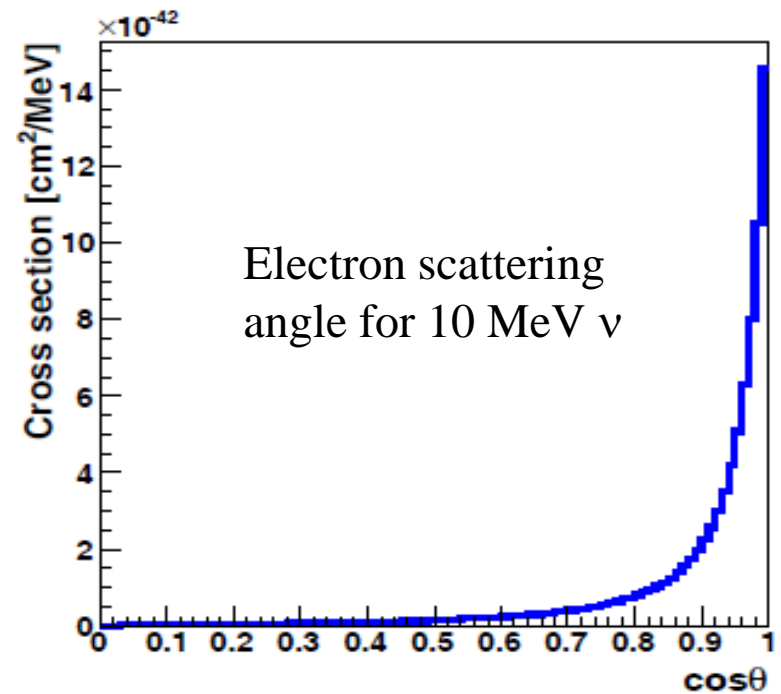


Pointing ability

- ▶ SNEWS no direction information in the near future
- ▶ Water Cherenkov detector can
- ▶ Triangulation is very crude PRD 60, 033007



PRD 60 053003





Alert to astronomical community

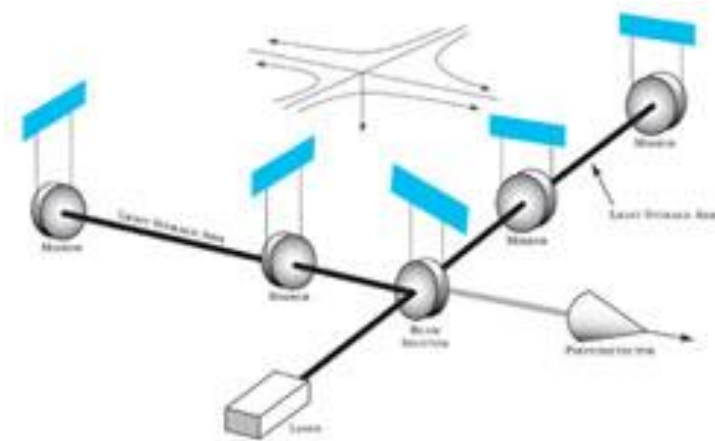
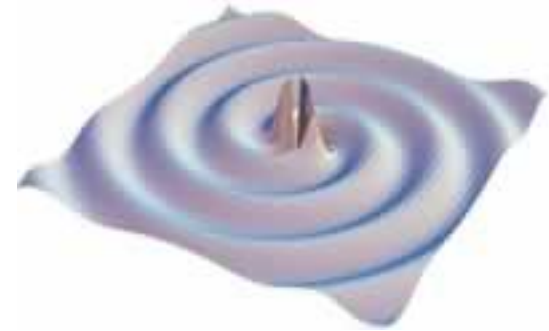
- ▶ Alert is sent out through SNEWS two mailing lists.
- ▶ GOLD: Sky & Telescope and Hubble Space Telescope astronomers
- ▶ SILVER: neutrino experiments only

Right ascension:	Test by Sky & Telescope Received over 80 responses Six of them are correct	13 ^h 38 ^m
Declination:		+8.1°
Uncertainty radius:		13°
Expected magnitude:		unknown

Please check this region of the sky as soon as possible using your naked eyes, binoculars, a telescope, or a camera. You are looking for a starlike point of light...

New development with SNEWS

- ▶ Gravitational wave during SN burst



May be detected by precise laser interference experiment

- ▶ **LIGO** experiments etc. are considering to join SNEWS
- ▶ T_0 of neutrino signals



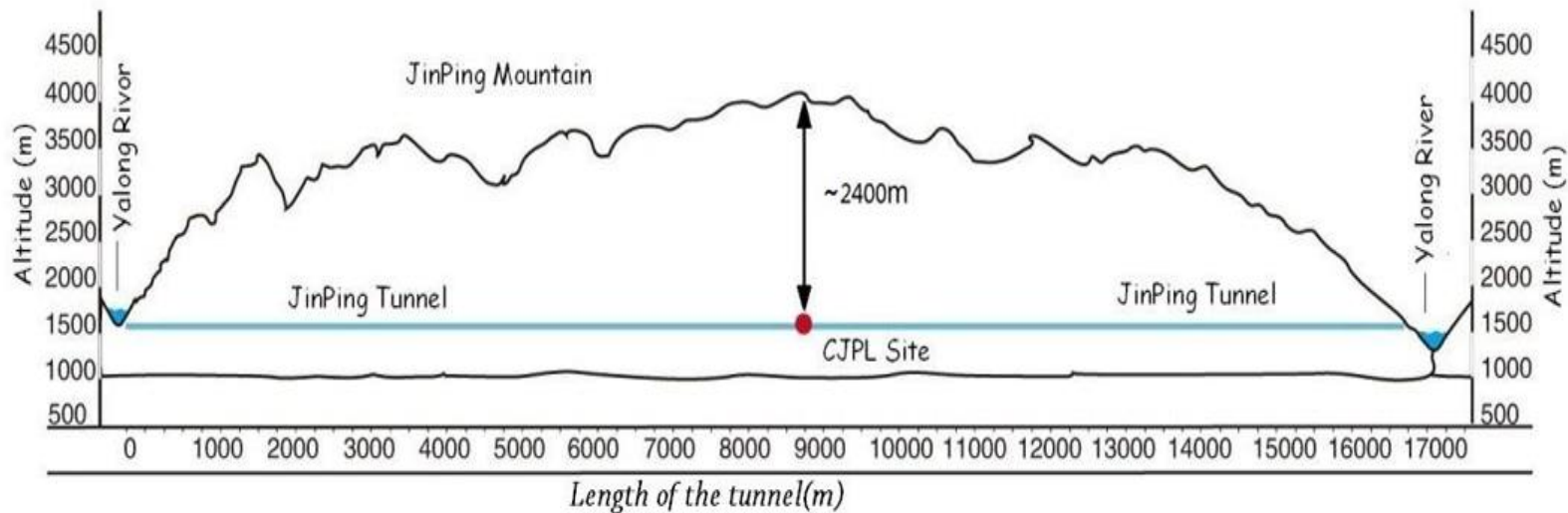


Summary

- ▶ SNEWS: real-time monitor and coordination of supernova neutrino alarm of individual experiment
- ▶ Within ~10 minutes, you can receive a GOLD alert
- ▶ So far no direction info is available
- ▶ Scintillator detector is necessary in all detection methods
 1. energy threshold
 2. background
 3. quick time response
 4. resolve flavor components
- ▶ Gravitational wave detection exp. is coming soon.
- ▶ For time reason, no detail of the trigger design in each exp. is introduced.



Jinping Underground Low Energy Neutrino Experiment



- ▶ **JULENE** is featured by its low cosmic-ray muon background and low reactor neutrino background
- ▶ Offer precise measurement of Solar and Geo- neutrinos
- ▶ **Discover Solar CNO neutrinos by $>5\sigma$**
- ▶ Precise measurement of U and Th geoneutrinos and ratio
- ▶ Large potential for **supernova burst and relic neutrinos**

<http://hep.tsinghua.edu.cn/CJPLNE/>

Thank you.
Welcome questions and comments.