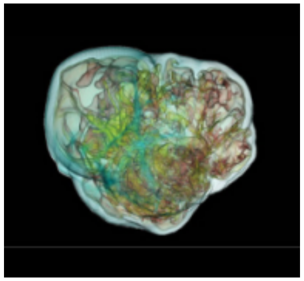
SuperNova Early Warning System

SNEWS 2.0 Workshop

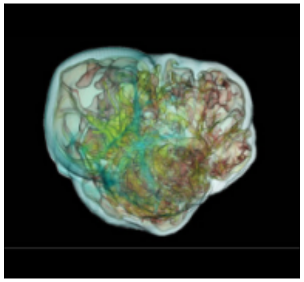
PANEL I

Moderator: Lindley Winslow (MIT)



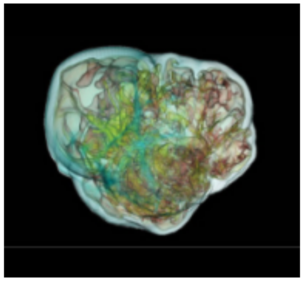
PANEL Members

- Alexis Coleiro (Université Paris Diderot)
- Koji Ishidoshiro (Tohoku University)
- Vincent Fischer (UC Davis)
- Volodymyr Takhistov (UCLA)
- Xunjie Xu (MPIK, Heidelberg)



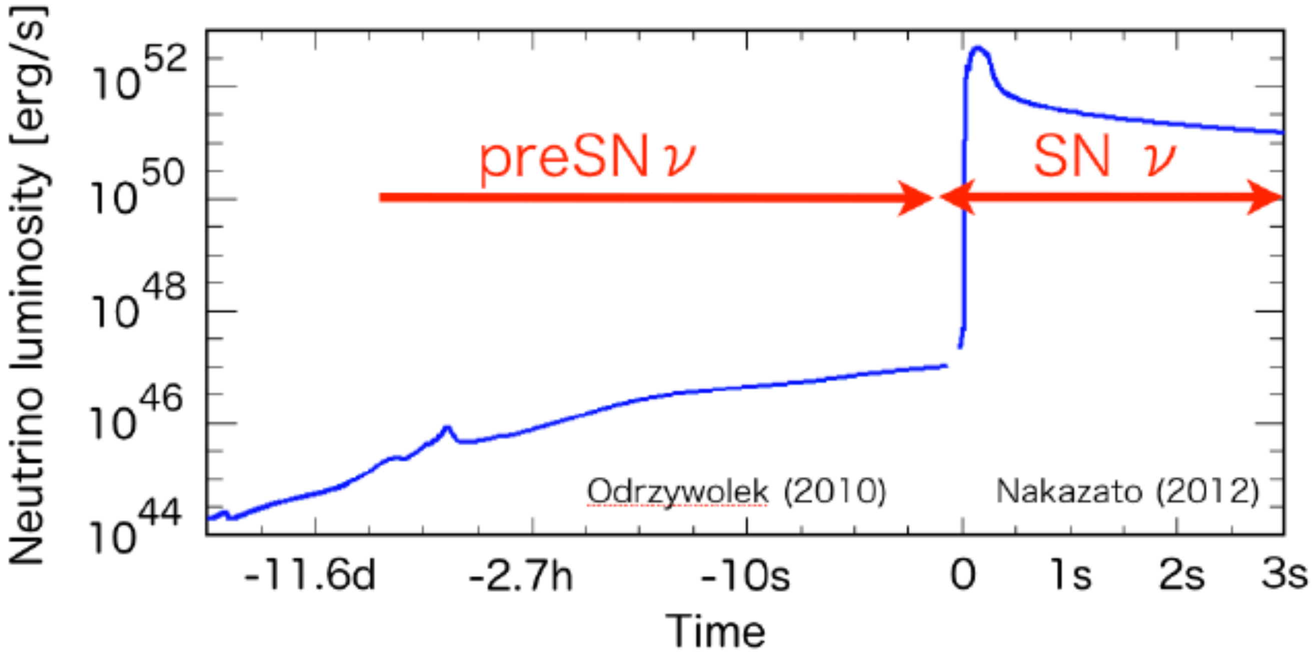
Panel I - Topics

- What are the best strategies for a pre-supernova alert?
  - Does it make sense to combine information, and how?
- What are the best pointing strategies?
  - Does it make sense to combine information for triangulation or other means?
  - How do we implement this is in SNEWS?



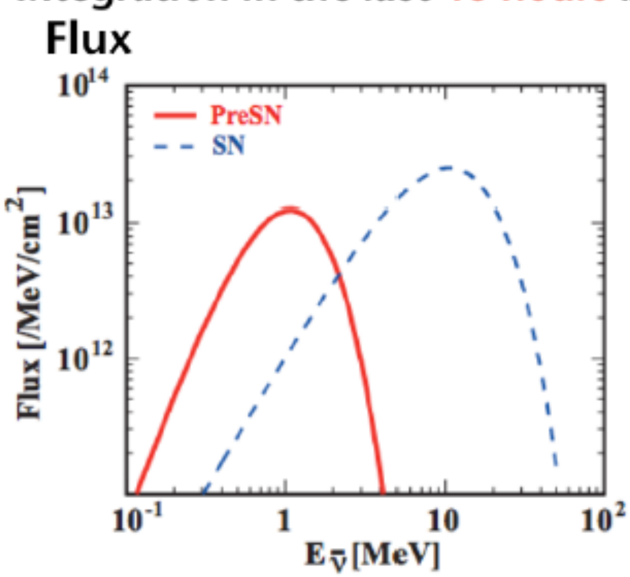
Pre-Supernova Signal

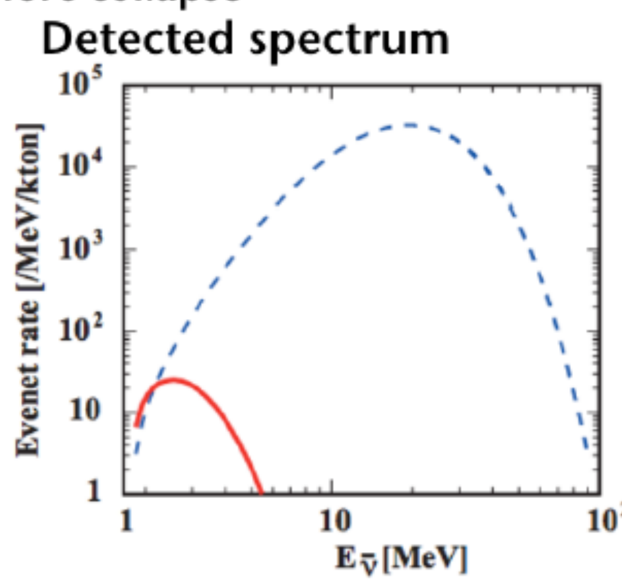
Pre-supernova neutrinos

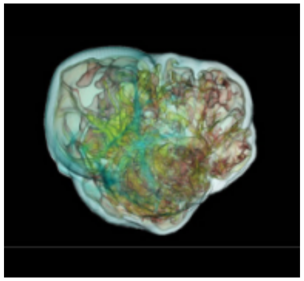


Assumption: d=200 pc (Betelgeuse)

Integration in the last 48 hours before collapse







DM Experiments for SN

Comments for Panel I

(Volodymyr Takhistov, UCLA)

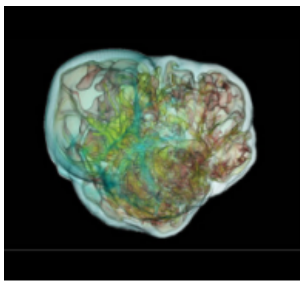
- Should start thinking of large DM experiments as "effective neutrino detectors"

- Some features: coherent scattering enhancement & very low thresholds
→ complementarity with dedicated neutrino telescopes

- Pre-SN detection:
  - don't suffer from oscillation effects or IBD energy threshold
  → signal information not identical to "standard" pre-SN detection approach
  - *O*(100) ton Argon/Xenon experiments are great pre-SN detectors
  (much smaller with improved threshold)

*** could implement pre-SN alarm via simple software trigger (e.g. 12-hr interval windows)

- SN pointing: capabilities not great



KamLAND Pre-Supernova Alarm

Panel discussion (Koji Ishidoshiro)

Combined alarm

- Possible SNEWS update
- Use of significance (sigma) and FAR
- Key: realtime BG estimation.

  Notice: Official reactor data with 2-3 weeks delay.

  We can obtain on/off status as figure from the web pages in JAPAN.

  -> Rough BG estimation might be possible. (error? delay? reliability?)

Pointing of pre-supernova neutrino

- Use of delayed-prompt vector

  See JCAP08(2015)032, Scientific Reports 4, 4708 (2014), arXiv:1208.3628

  Experimental demonstration and calibration: required

  KL has not found any anisotropy of the delayed-prompt vector.

  Chance with the IsoDAR experiment.

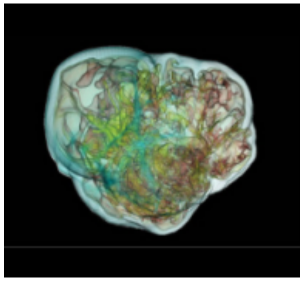
  Check of the consistency between JCAP08(2015)032 and KLGsim.

  Developments of ^{6}Li-LS and imaging detector for directional measurement

- Comparison with the observed signal from the expected signal.

  Unfortunately or fortunately, the number of possible targets are small.

  Updates of theoretical model and **precise distance**: required



Pre-Supernova Pointing

Vincent Fischer
UCDAVIS
UNIVERSITY OF CALIFORNIA

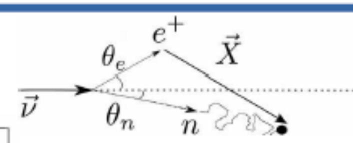
Presupernova neutrinos and pointing strategies in liquid scintillator detectors

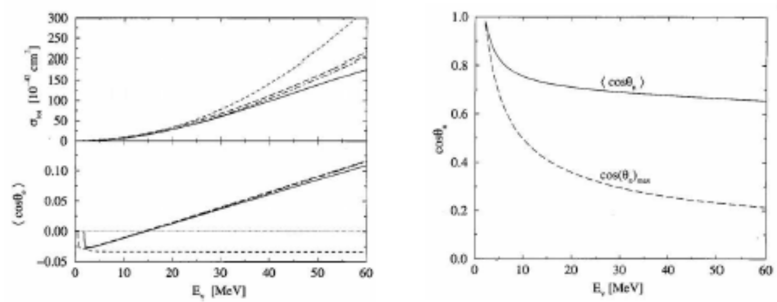
Presupernova neutrinos

- **KamLAND** (1 kt) → **3σ at < 690 pc** (25 $M_\odot$)
- **Adding** several detectors will **increase** the detection range and significance:
  - Current LLSD in **SNEWS** ~ **1.5 kt**
  - All LLSD expected in **2020** ~ **2.5 kt**
  - **JUNO** (20 kt) will be a **game changer**
- Time correlation not as important since preSN neutrinos arrive ~days before the SN neutrinos
- Efficient pre-detection requires all LLSD to:
  - Be **part of SNEWS**
  - Have a KamLAND-like **pre-SN trigger**
  - Have a good detection **efficiency < 5 MeV**
    → Unfortunately rules out LVD and NOvA

Supernova pointing with IBD

- **Angular distributions of e⁺ and n ≠ isotropic**
- Mostly **relevant for large statistics** (> 1000 evts)

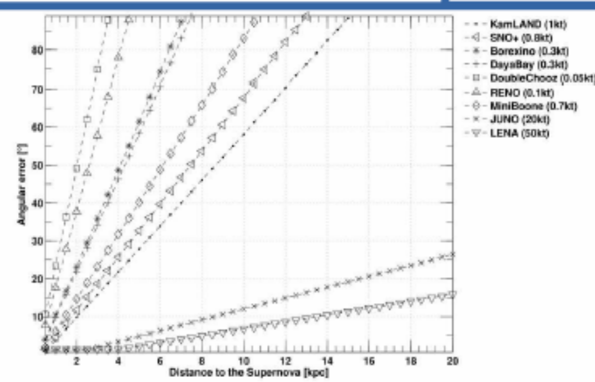


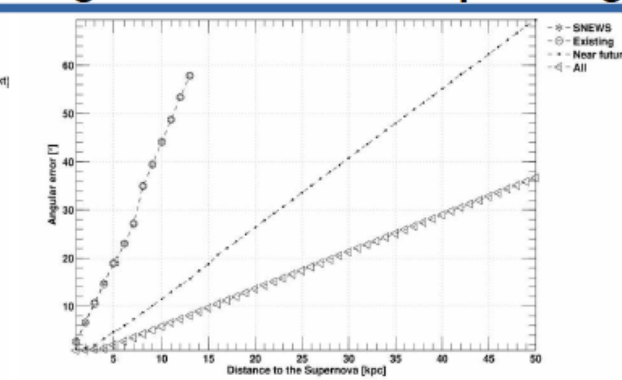


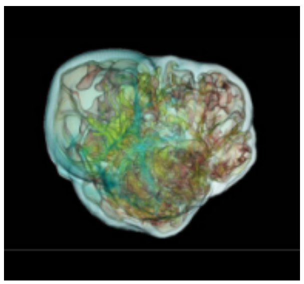
From JCAP 08 (2015) 032

Combining several LLSD for pointing

- **Pointing efficiency** of LLSD can be expressed as a **function of # detected events**
- Low capabilities compared to e-scattering in SK
- **Combining** detectors help reach **acceptable accuracies** (~12° at 10 kpc if JUNO added)
- Combined pointing:
  - Requires **fast online reconstruction** in (E, X)
  - Frequent **calibration** of each detector
  - **# of evts and preferred direction** (with significances) sent to **SNEWS server** and combined







Pointing Status

Neutrino astronomy with supernova neutrinos

— the triangulation method

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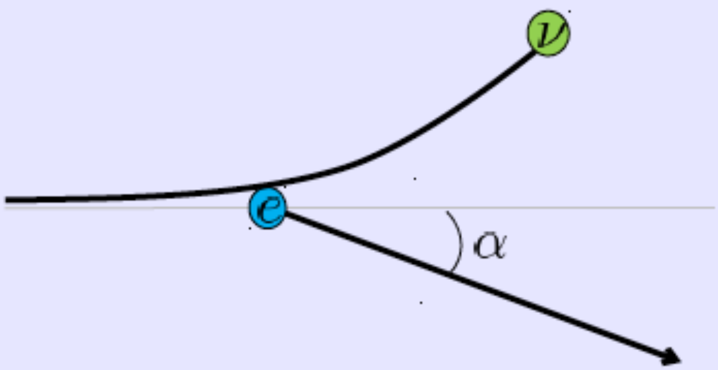
Talk at the SNEWS 2.0 workshop https://snews2.0.snolab.ca/
Based on: 1802.02577 (JCAP), in collaboration with Vedran Brdar and Manfred Lindner

Introduction

Two methods

Forward scattering

In $\nu + e$ scattering, α can be very small if E_ν is high.



$$\cos\alpha = \frac{E_\nu + m_e}{E_\nu}\left(\frac{T}{T+2m_e}\right)^{1/2}$$

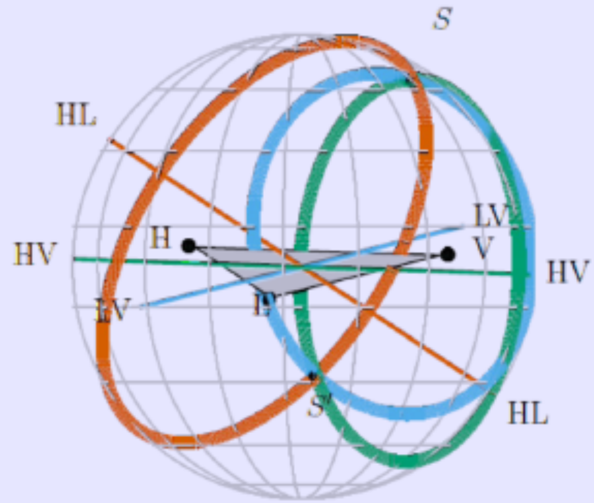
Triangulation

Need 3 or more detectors;

Measure $\Delta t \sim d/c \sim 40$ ms;

Only time information required;

Benefit from IBD (x-sec, bkg.).



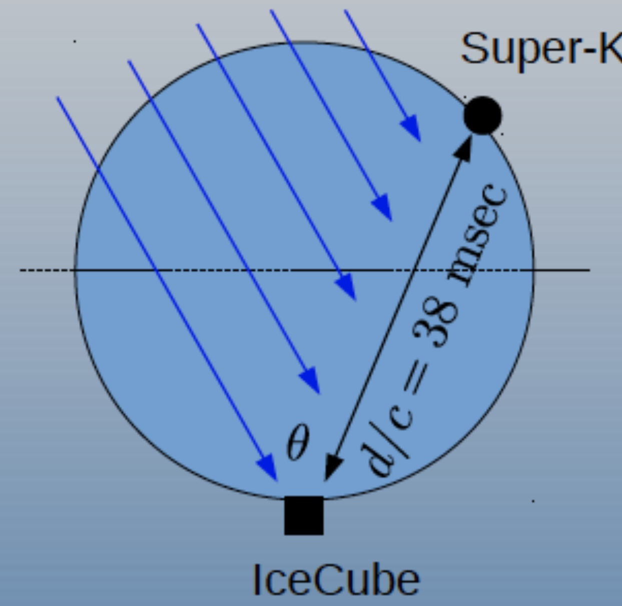
The triangulation method

Consider:

- an instantaneous neutrino pulse
- two dectors

Arrival time difference:

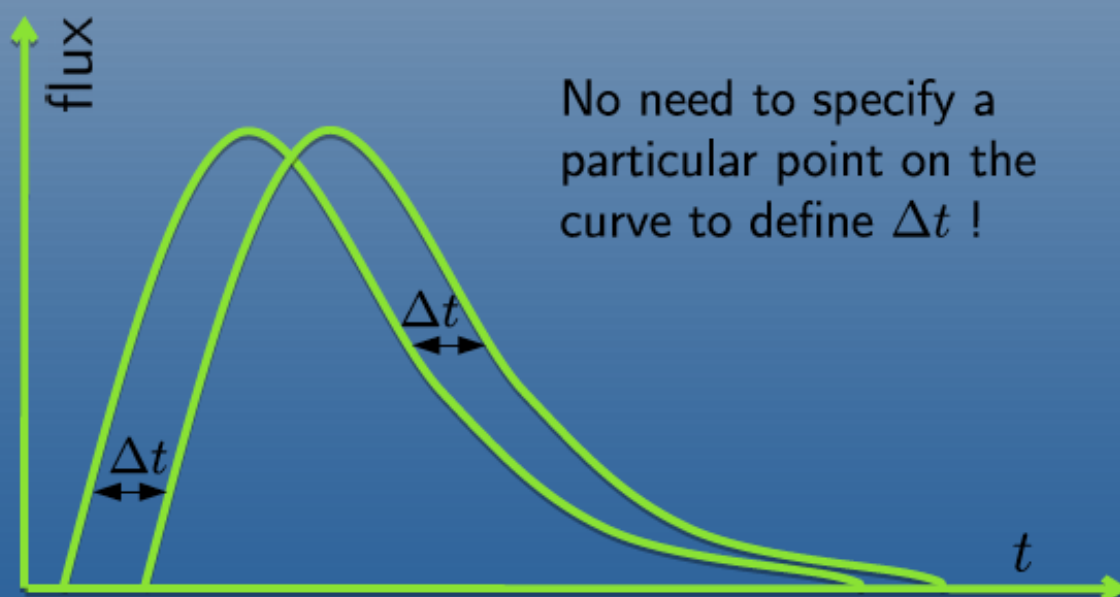
$$\Delta t = \frac{d}{c}\cos\theta$$



However, instantaneous ✗

How to define Δt properly?

— defined as time shift



No need to specify a particular point on the curve to define Δt !

Previous conclusion:

SNO: $\delta t = 15$ ms
Super-K: $\delta t = 3$ ms

$$\left.\begin{array}{l}\text{SNO: } \delta t = 15 \text{ ms} \\ \text{Super-K: } \delta t = 3 \text{ ms}\end{array}\right\} \delta(\cos\theta) = 0.5$$

HEP 1 records found Search

1. **Can a supernova be located by its neutrinos?**
John F. Beacom, P. Vogel (Caltech). Nov 1998. 10 pp.
Published in **Phys.Rev. D60 (1999) 033007**
DOI: 10.1103/PhysRevD.60.033007
e-Print: **astro-ph/9811350 | PDF**
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service; OSTI.gov Server
Detailed record - Cited by 118 records 100+

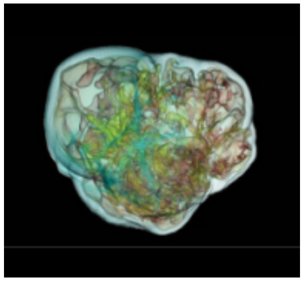
Today we have:

- more detectors
- better knowledge of the flux

Our result

SN$\rightarrow$ neutron star:
$1.5^\circ \sim 3.5^\circ$

SN$\rightarrow$ black hole:
$0.2^\circ \sim 0.5^\circ$

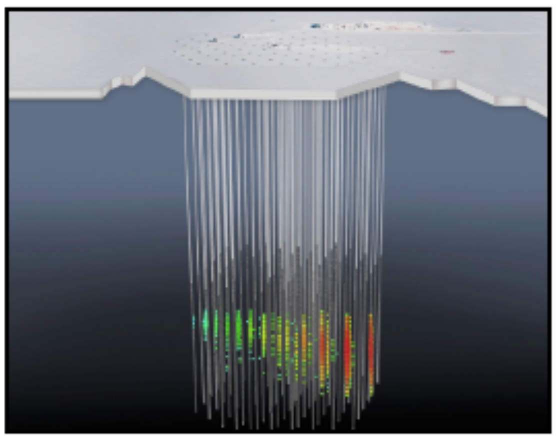


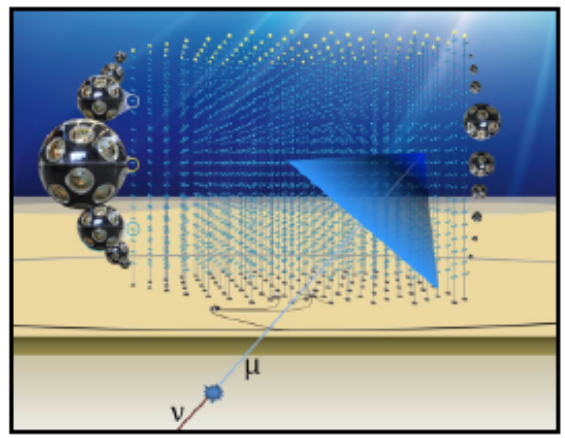
Time Series Data

What can we gain by exchanging time series instead of only alarms ?

Study (mostly) by Marta Colomer & Massimiliano Lincetto

joint KM3NeT/IceCube working group set up after
neutrino CCSN workshop held in Orsay (France) in July 2018.





Long string ice- or water-based Cherenkov neutrino detectors.
Do not reconstruct IBD interactions event-by-event but sensitive to an increase of the detection rate over the full array.

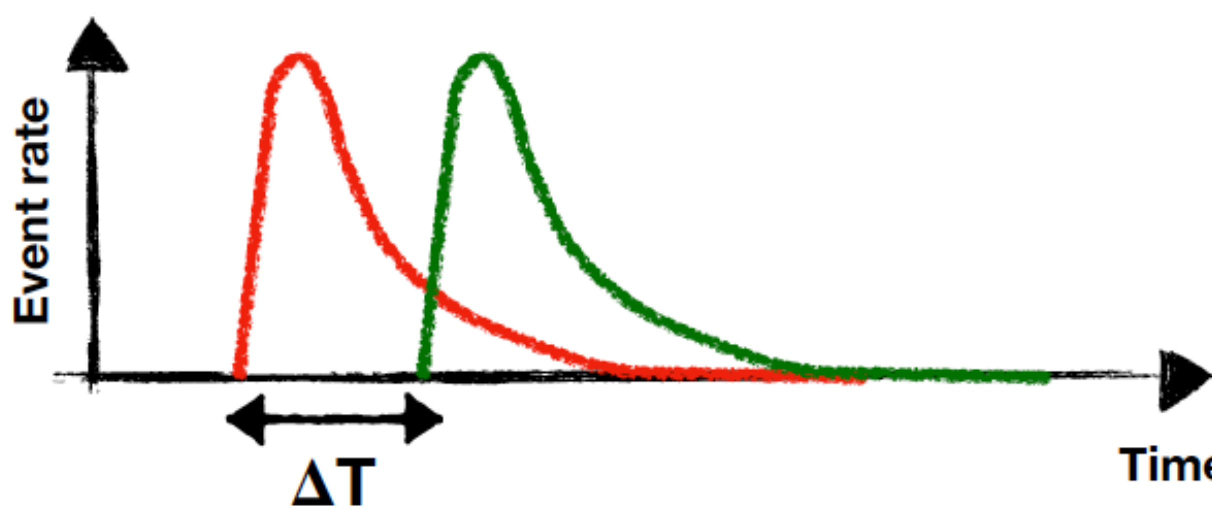
Why/how estimating time difference at two detectors ?

Why ?

- ΔT = time difference of CCSN neutrino arrival at two detectors.
- Arrival time difference at 3 or more detectors → infer CCSN direction + constrain t_0 for GW searches (see e.g. *Nakamura et al., 2016*).

How ?

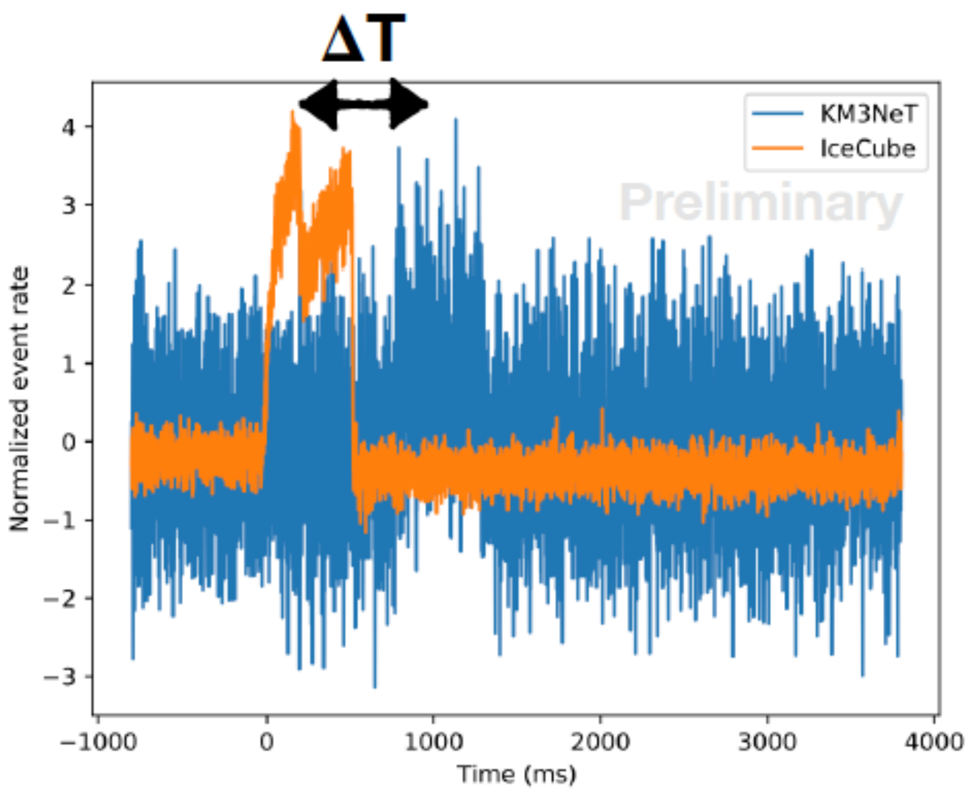
- Fit t_0 independently from each experimental lightcurve → compute ΔT
- Lightcurve matching: fit directly the shift between pairs of experiments

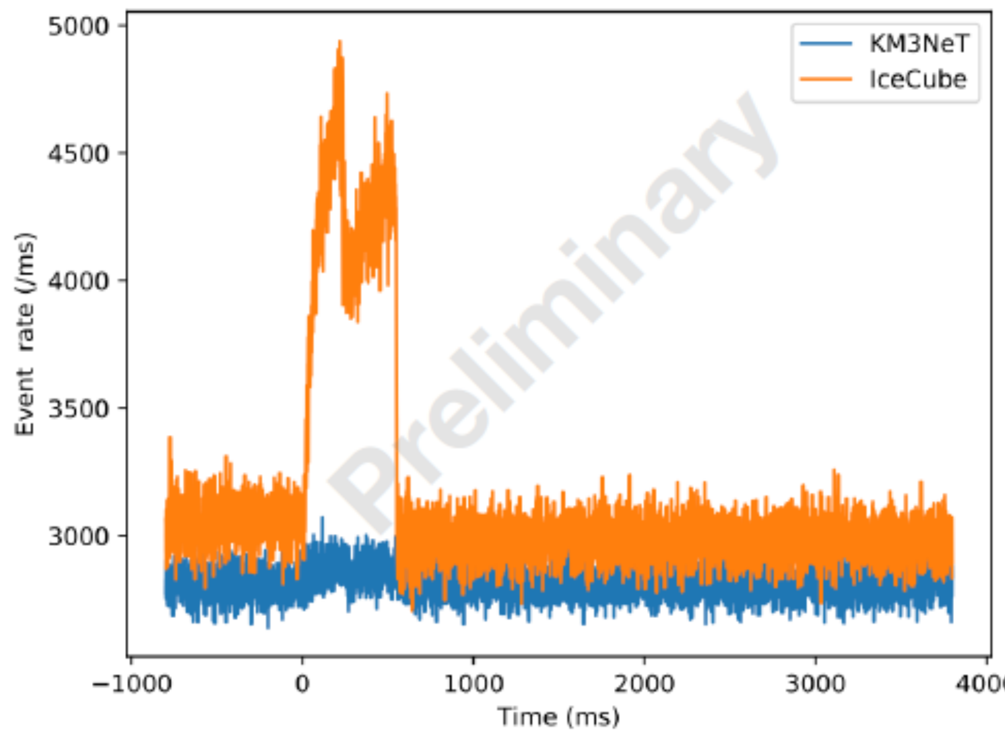


- χ^2 minimization
- Cross-correlation

Ongoing work

- Detector lightcurves can be different (baselines, energy threshold, interaction channel)
- Preliminary results: IceCube / KM3NeT (ARCA): ~7ms of uncertainty on ΔT for a CCSN at 10 kpc.





- Need to prove lightcurve matching works better than independent t_0 fitting.
- SNEWS infrastructure ? / data sharing agreement ?
- Extend this preliminary work to other experiments (sensitive to IBD)