Neutrinos from Core-Collapse Supernovae

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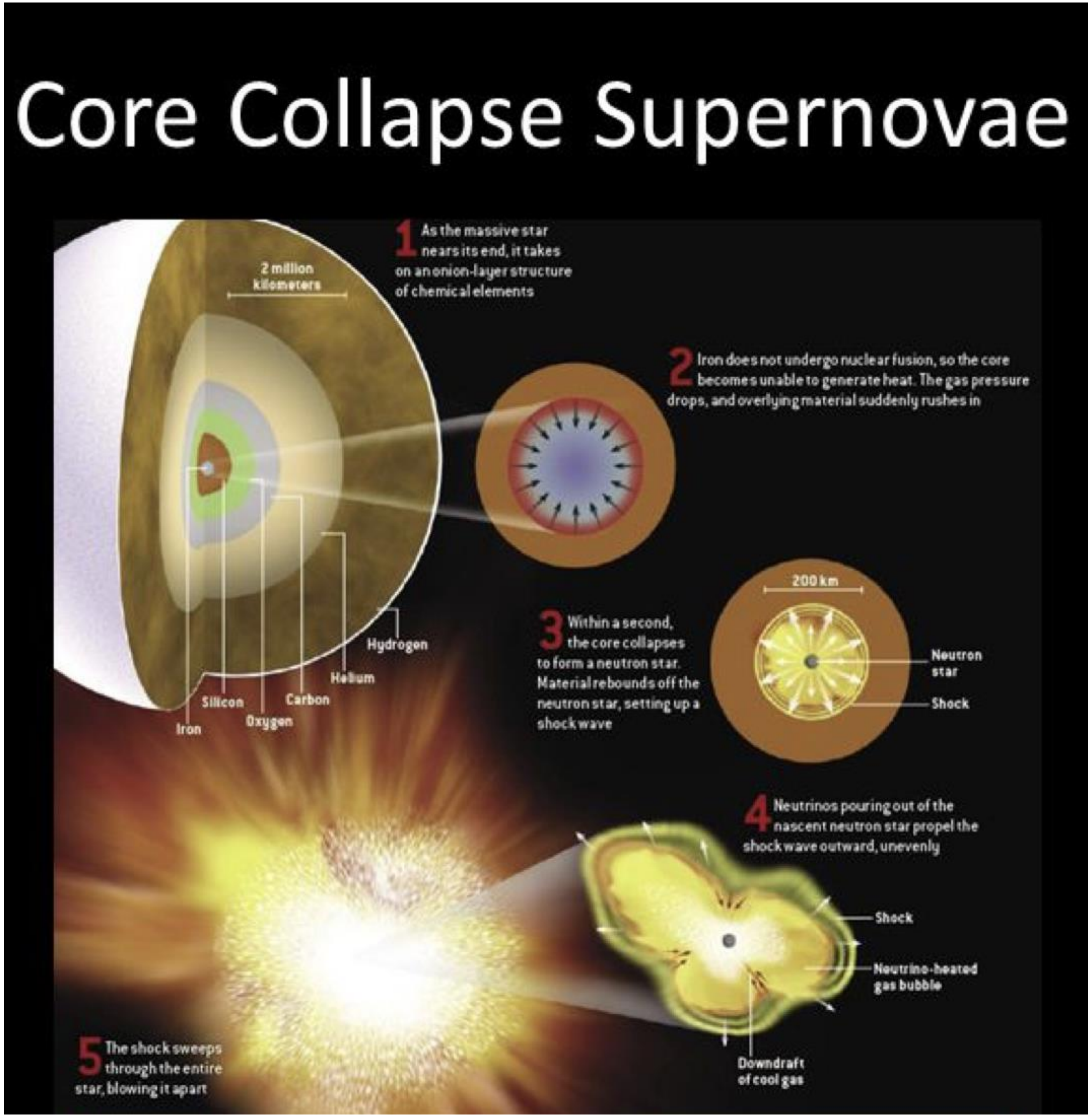
LNGS

GP and Ternes, *JCAP* 06 (2024) 022



Total Energy Released

$$e_B = (1-5)\times 10^{53}\, erg$$

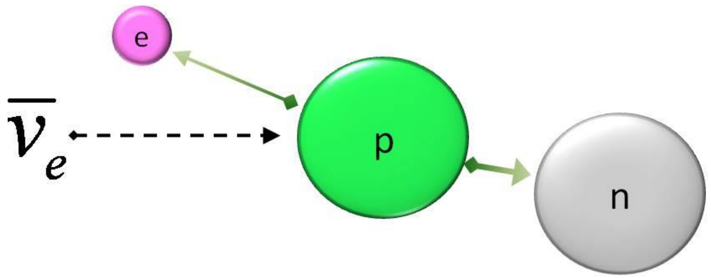
Energy Released in Neutrinos

$$e_n = 99\% \times e_B$$

Average Neutrino Energy

E_ν=10 MeV

Main Interaction Channel in H_2O and C_nH_{2n}

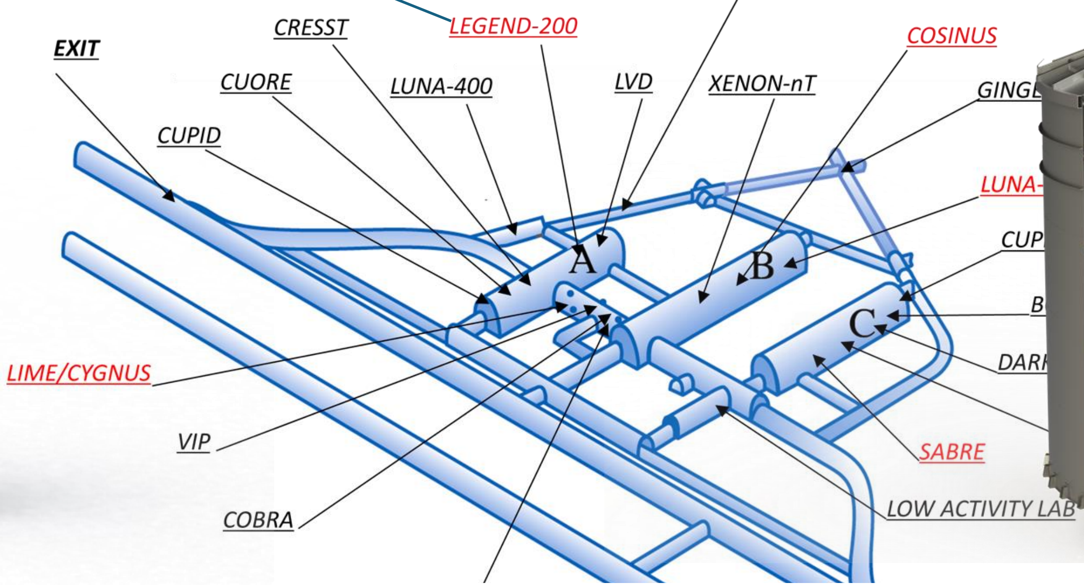


SN@LNGS

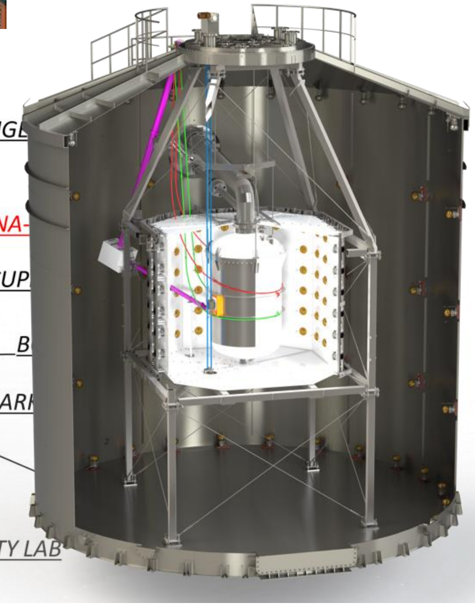
LVD (293 events)

SN@10 kpc -→H2O IBD and NO
XENONnT (700 ton) = 167
LEGEND 200 (590 ton) = 140
COSINUS (270 ton) = 64

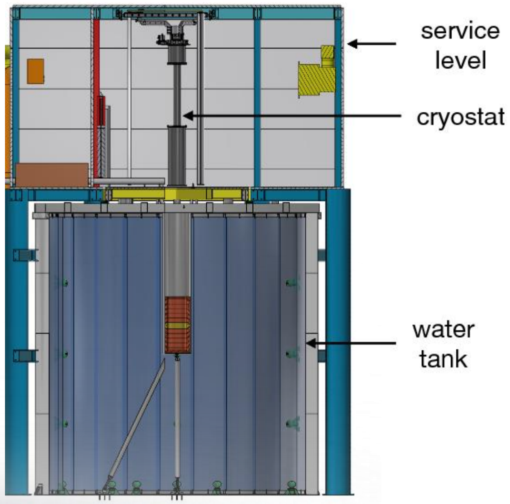
LEGEND-200



XENONnT

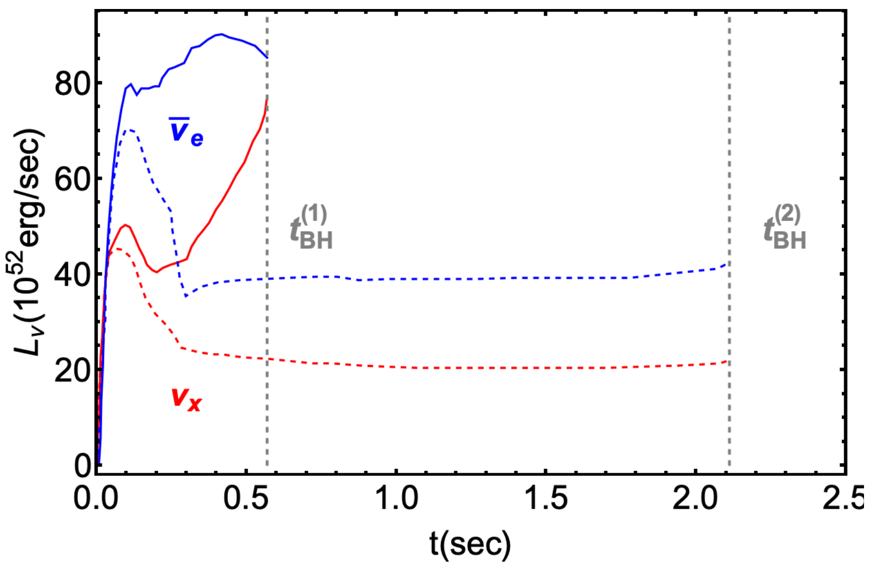


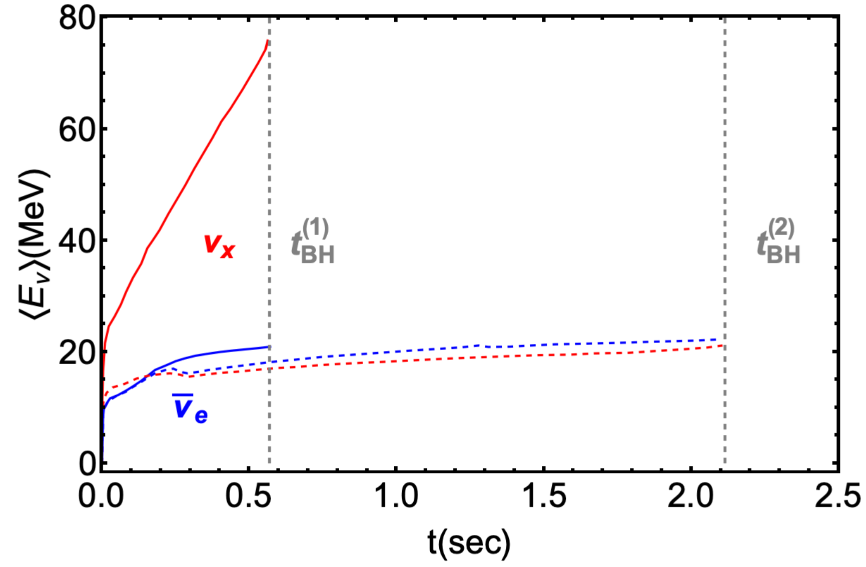
COSINUS



An infrastructure with several detectors sensitive to SN neutrinos: an interesting network of different detectors located in the same place. Combined Horizon: LMC. Very high duty cycle and fast coincidence in time (ms).

Failed Supernovae @ LNGS





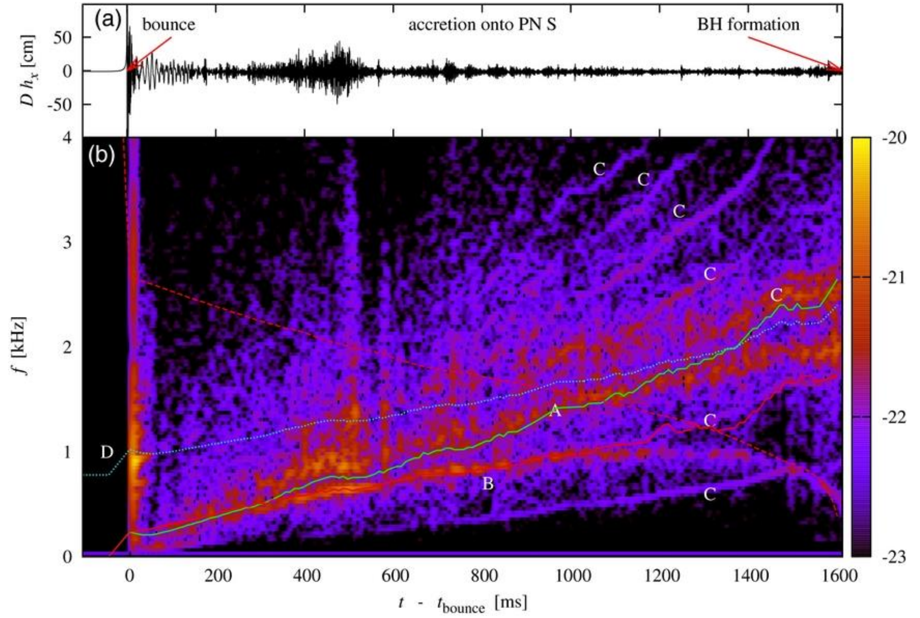
- The neutrino and GW emissions end abruptly at the time of the Black Hole formation.
- The EM counterpart of this event is easily missing.
- Let’s see the capability of the LNGS infrastructure to identify the time of the BH formation

Model 1: Woosley and Weaver, Astrophys. J. Suppl. 101, 181 (1995)

FAST BH formation after 0.568 s

Model 2: Woosley et.al , Rev. Mod. Phys. 74, 1015 (2002)

SLOW BH formation after 2.113 s



Pablo Cerdá-Durán *et al* 2013 *ApJL* **779** L18

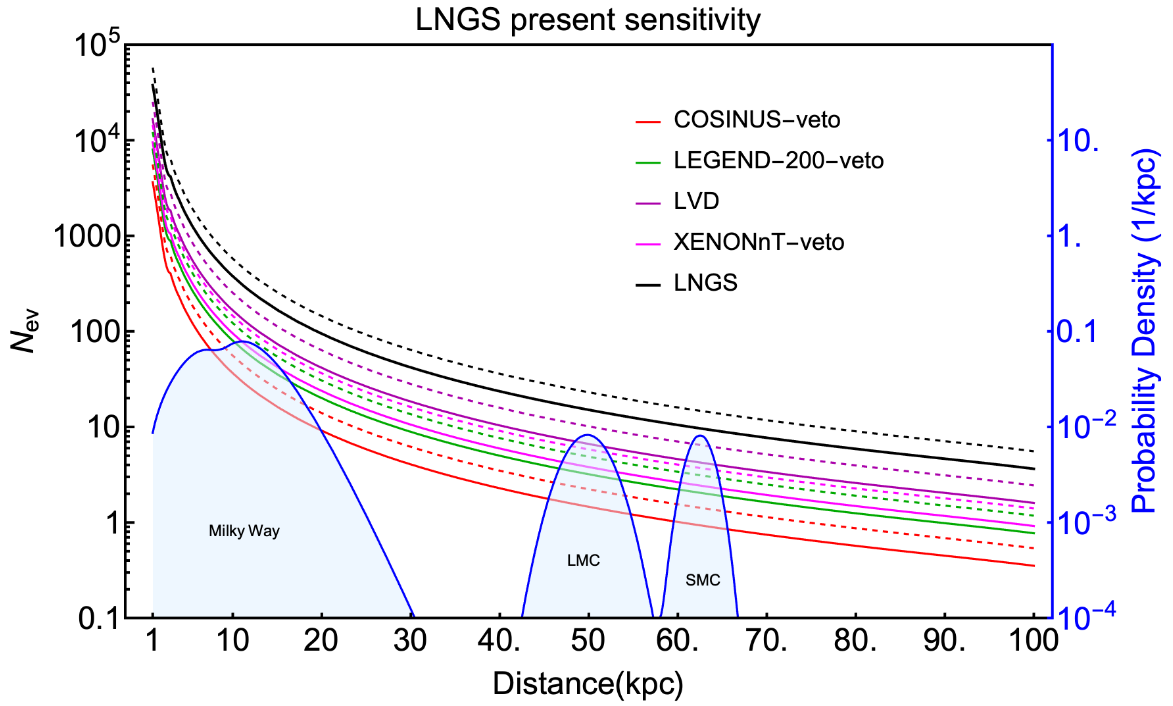
$$T_{BH}^{GW} = T_{BH}^{\nu} \pm t_{fly}$$
$$\boldsymbol{\delta} T_{BH}^{GW} = \boldsymbol{\delta} T_{BH}^{\nu} + \boldsymbol{\delta} t_{fly}$$

The Time of BH formation @ LNGS

Results for D=10 kpc

Future Exp.
Legend-1000 = 980 ton
Darwin = 1240 ton

Detector	$N_{\rm IDB}$	$t^1 \pm \delta t^1$ [s]	$t^{\rm last} \pm \delta t^{\rm last}$ [s]	$1/\xi$ [s]
LVD	293 (520)	0.017±0.008 (0.017±0.009)	0.567±0.001 (2.109±0.004)	0.002 (0.004)
COSINUS-veto	64 (114)	0.03±0.02 (0.04±0.02)	0.561±0.007 (2.09±0.02)	0.008 (0.018)
Legend200-veto	140 (249)	0.021±0.008 (0.03±0.01)	0.565±0.003 (2.107±0.006)	0.004 (0.008)
XENONnT-veto	167 (297)	0.023±0.009 (0.02±0.01)	0.565±0.003 (2.107±0.006)	0.003 (0.007)
Legend1000-veto	234 (415)	0.021±0.009 (0.02±0.01)	0.566±0.002 (2.108±0.004)	0.002 (0.005)
DARWIN-veto	511 (907)	0.014±0.006 (0.014±0.007)	0.5672±0.0009 (2.111±0.002)	0.001 (0.002)



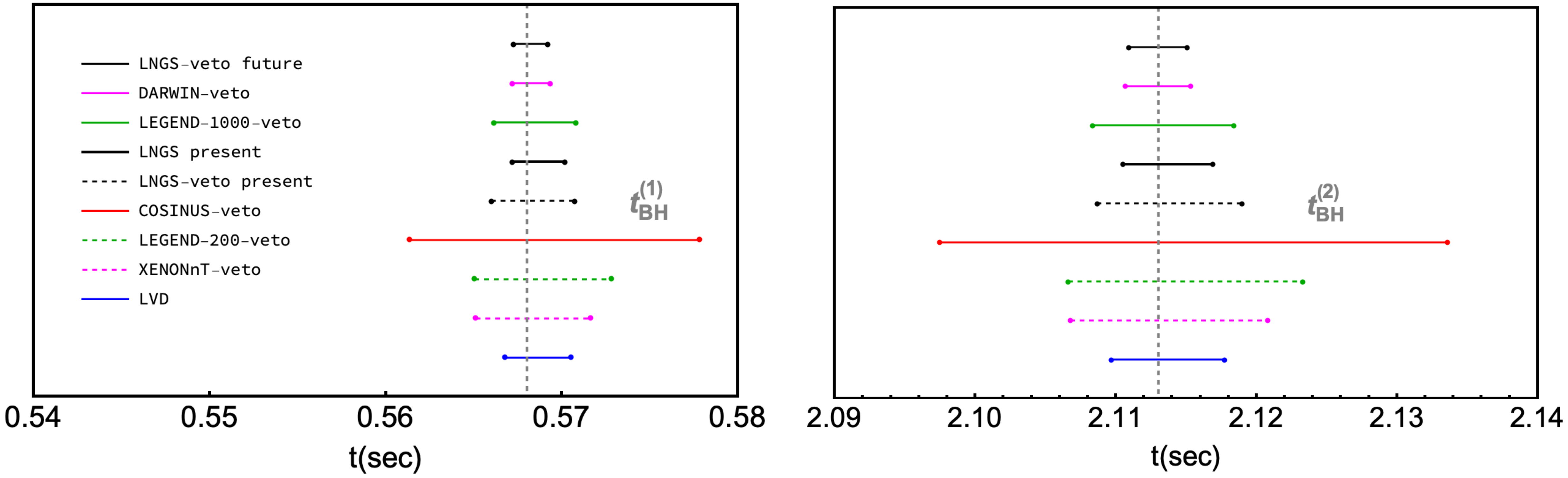
$$\xi = N_{\rm IBD}/(t^{\rm last} - t^1).$$

$$T^\nu_{\rm BH} = {\rm Max}[T_i^{\rm last}] + 1/\xi_{\rm Max}$$

$$\delta T^\nu_{\rm BH} = \sqrt{1/\sum_i (\xi_i^2)}$$

In agreement with
Sarfati et al.Phys.Rev.D 105 (2022) 2, 023011
Brdar et al. JCAP04(2018)025

The Time of BH formation @ GW det



LNGS – VIRGO

$$\delta T_{\rm BH}^{\rm GW} = \delta T_{\rm BH}^{\rm LNGS} + \delta t_{\rm fly} = 4\,{\rm ms}$$

SK– VIRGO

$$\delta T_{\rm BH}^{\rm GW} = \delta T_{\rm BH}^{\rm SK} + \delta t_{\rm fly} = 28.3\,{\rm ms}$$

GP and Ternes, *JCAP* 06 (2024) 022

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