Prospects for core-collapse supernova neutrino detection in IceCube-Gen2

Jakob Beise on behalf of the IceCube-Gen2 Collaboration

31 August 2023

IceCube GEN2

TAUP VIENNA 2023

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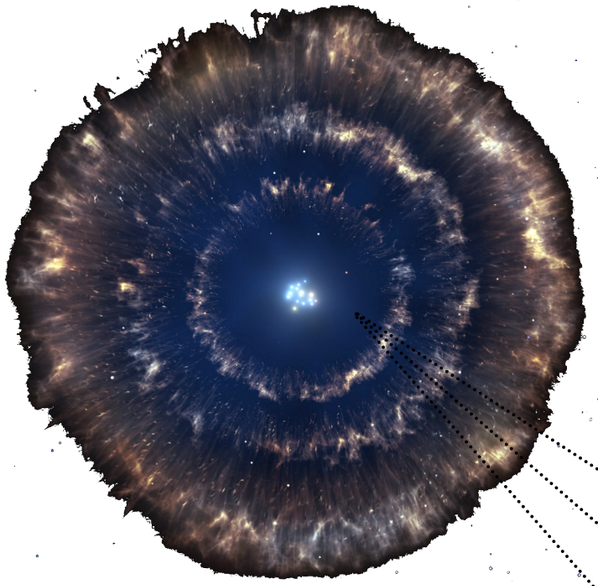
IceCube can detect supernova neutrinos



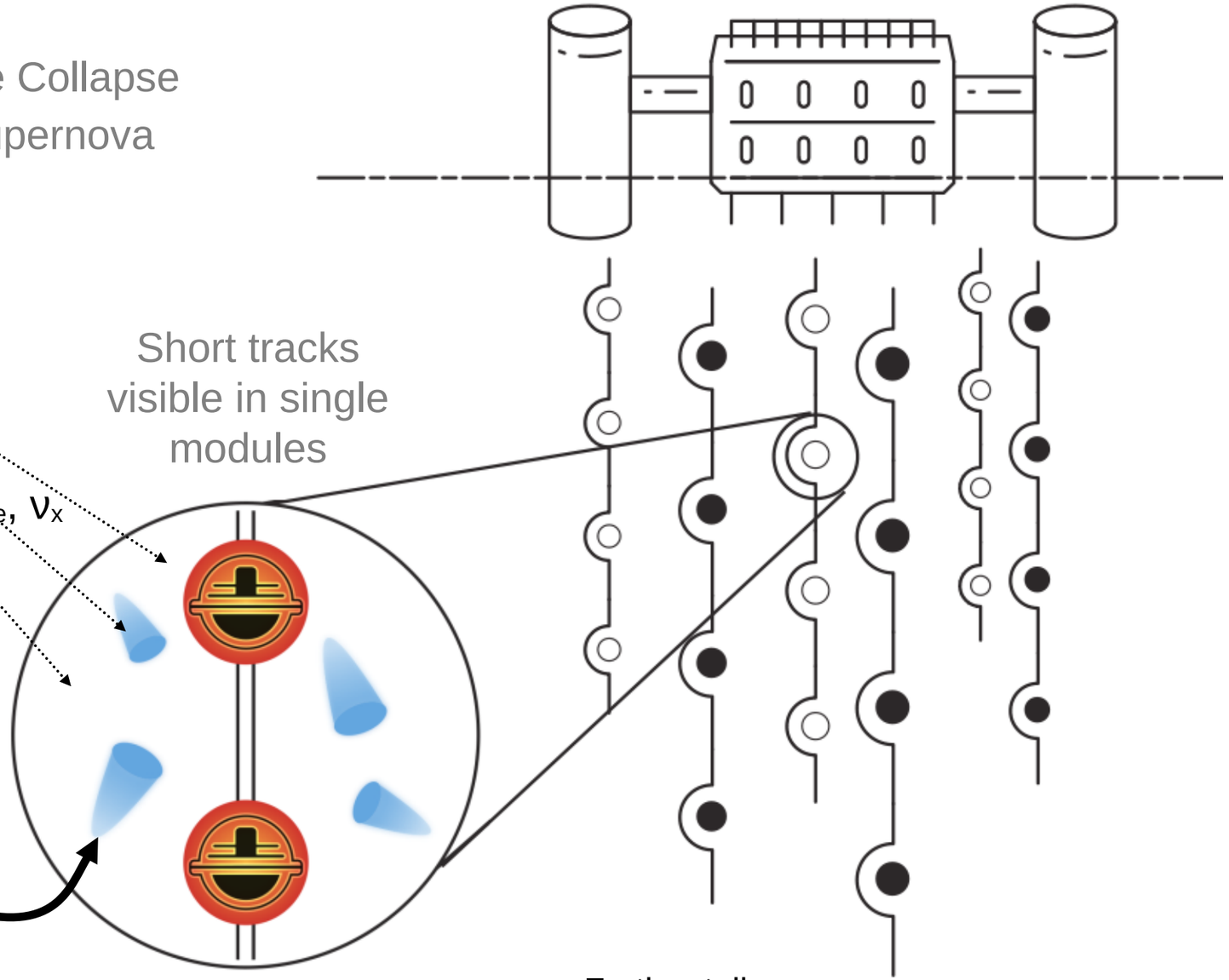
Crediti: Gabriel Pérez/SMM (IAC)

Core Collapse Supernova

$\overline{\nu}_e$, ν_e, ν_x

neutrino energies
E ~ O(MeV)

Short tracks visible in single modules



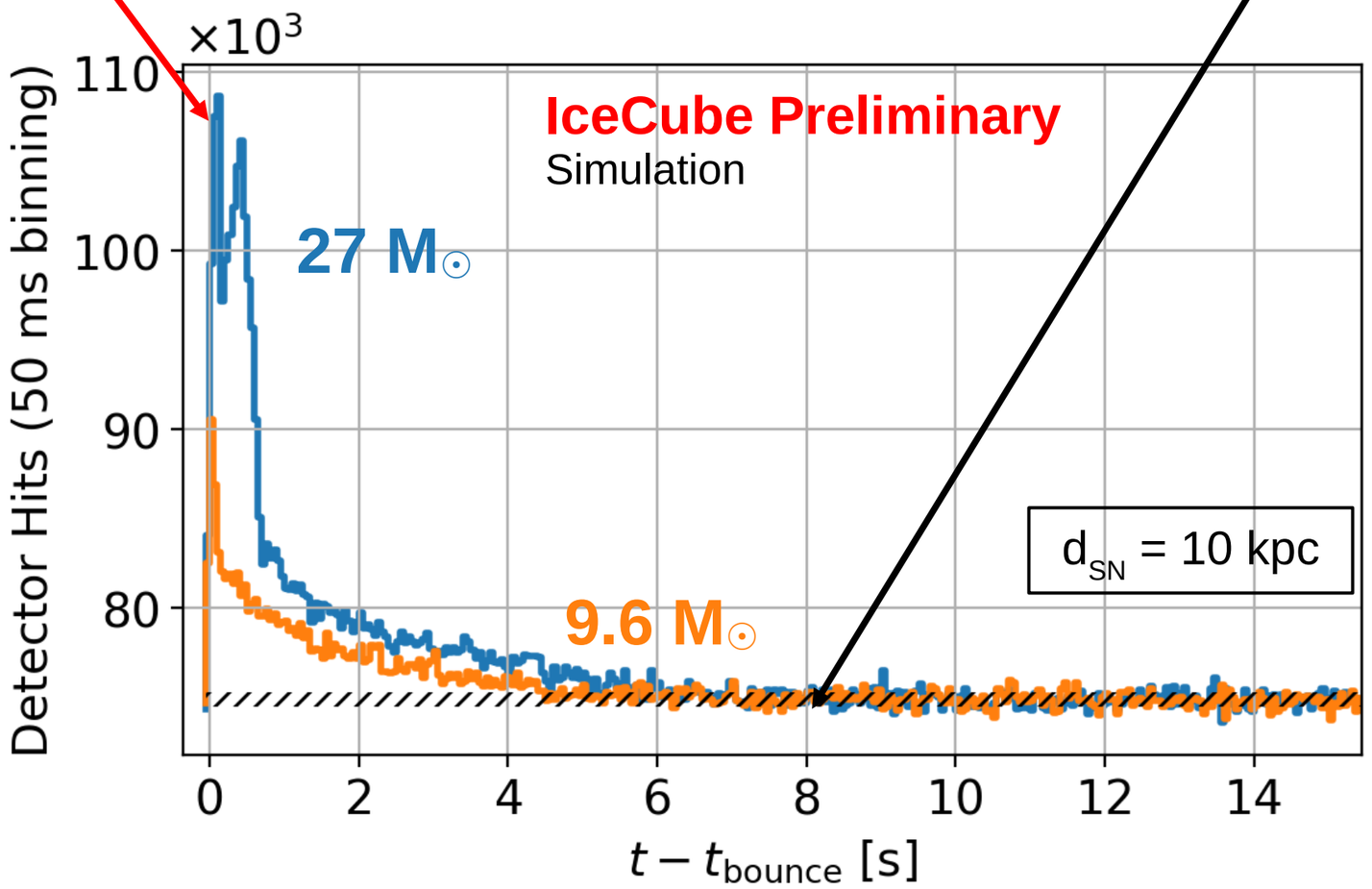
Credit: J. Parin WIPAC

$\overline{\nu}_e$ interact via inverse-beta decay

Further talks:
N. Valtonen-Mattila, session 8a

IceCube can detect supernova neutrinos

Detection: Excess of the detection rate over the background (noise hits)

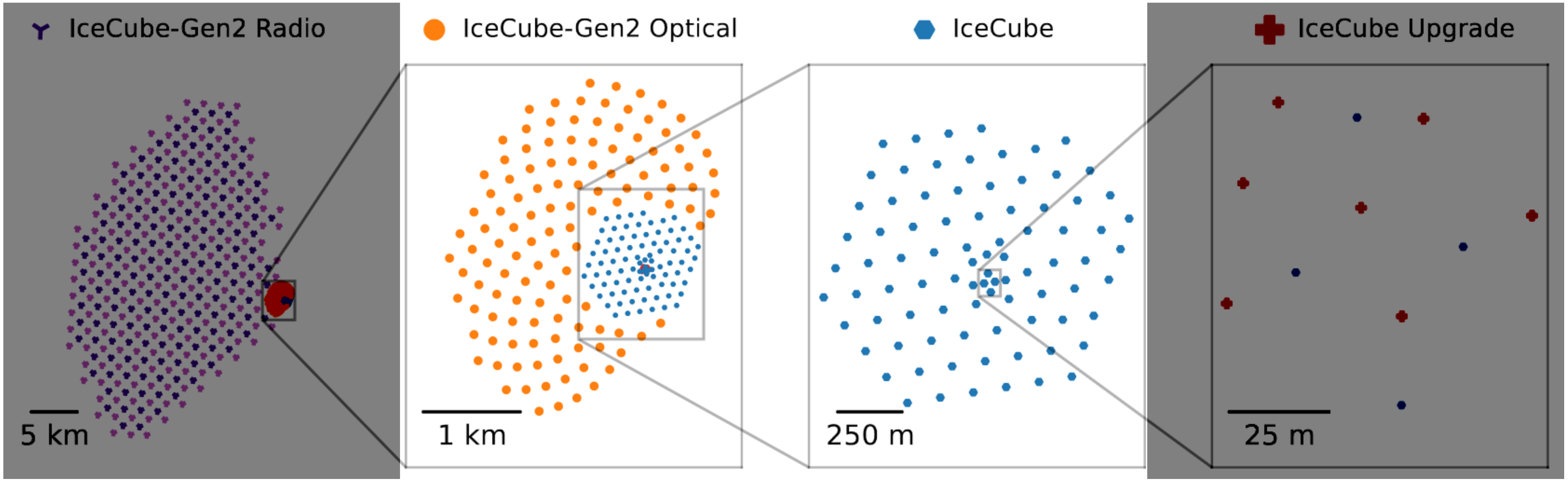


[Sukhbold et al. (2015)]

IceCube has sensitivity >10σ within the Milky Way

IceCube-Gen2

[IceCube-Gen2 TDR (2023)]



IceCube-Gen2 improves CCSNe detection by:

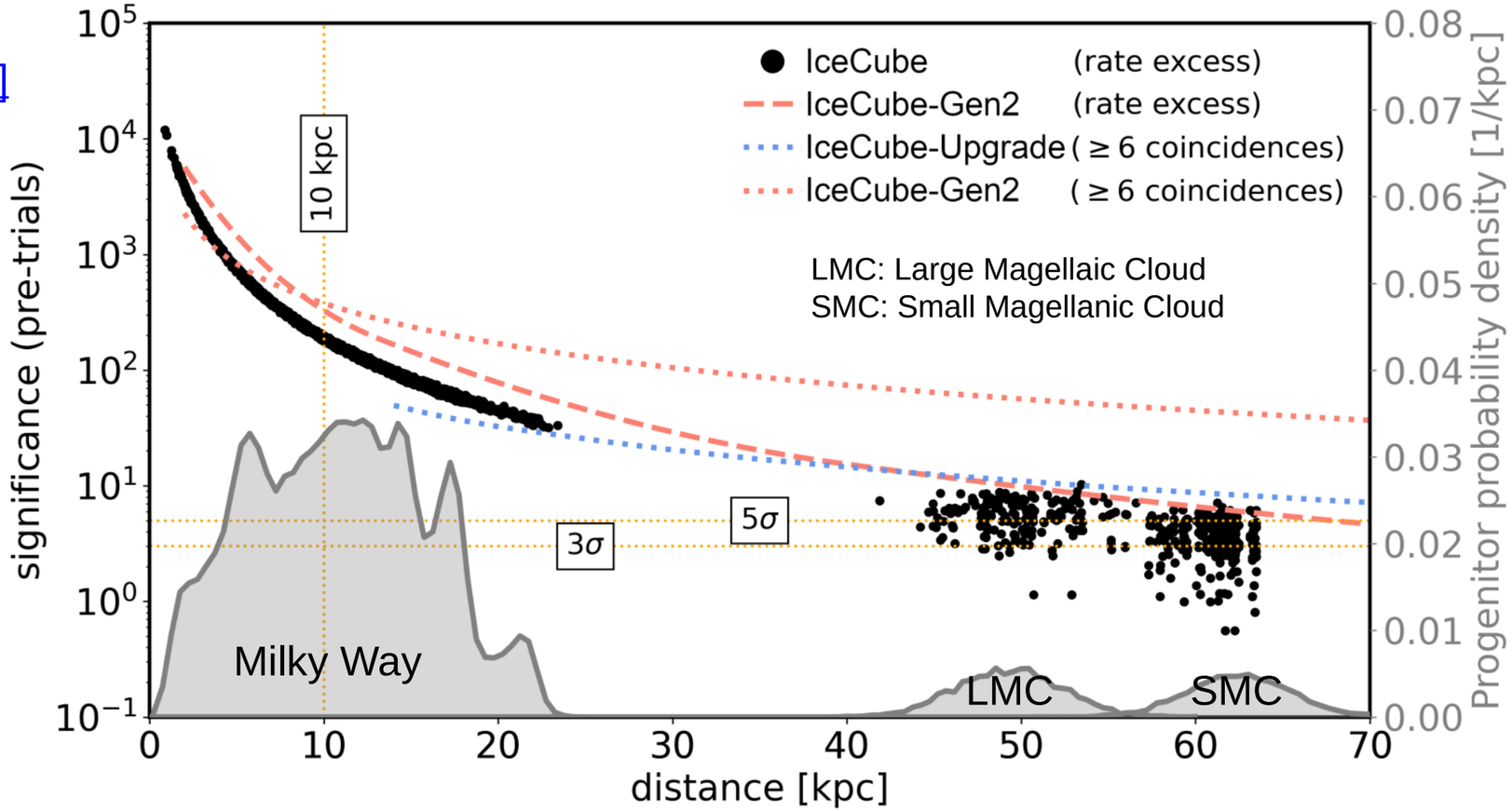
- Segmented sensors ➡ reduce noise
- More sensors ➡ increase sensitivity

Segmented sensors can reduce noise

Requiring local coincidences between PMTs of the same sensor efficiently reduces sensor noise

[Lozano Mariscal et al. (2021)]

[IceCube-Gen2 TDR (2023)]



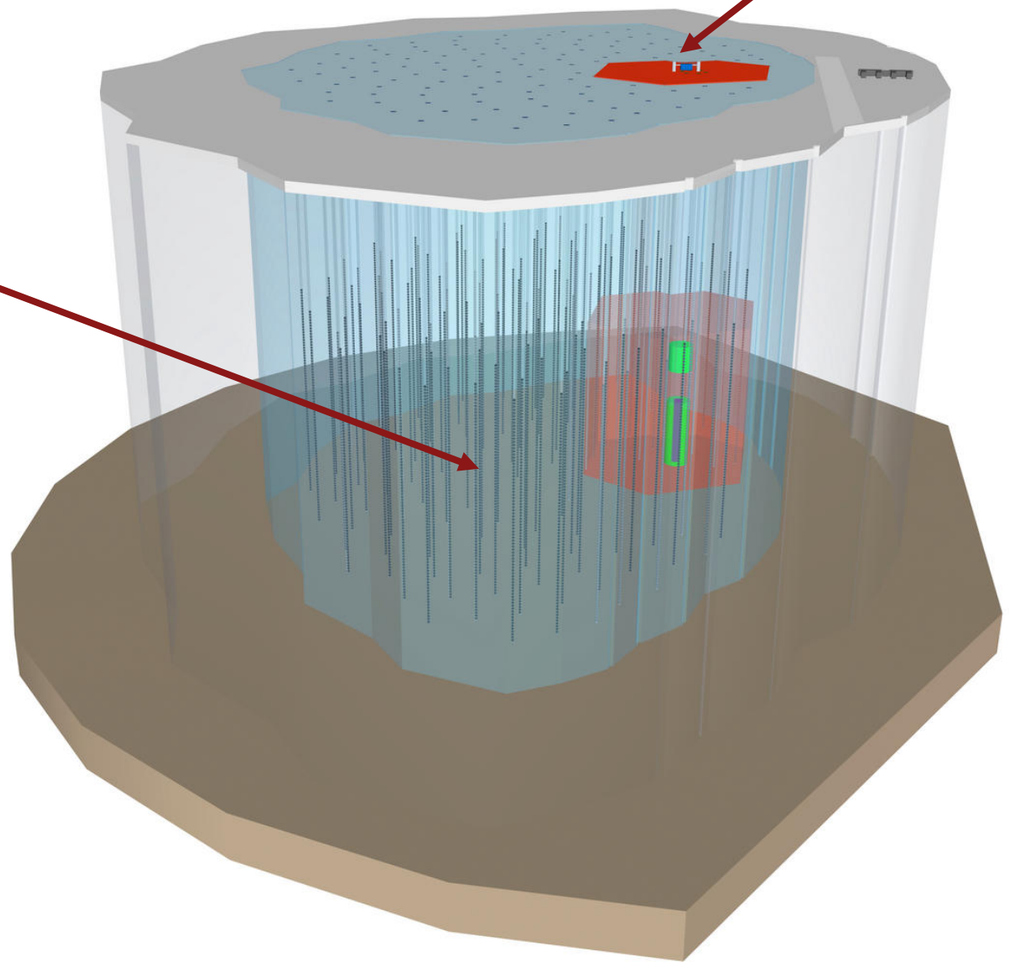
Local coincidences can extend the sensitivity to the entire Milky Way + LMC + SMC

More sensors increase sensitivity

10,000 new photosensors over 120 new strings.

[IceCube-Gen2 TDR (2023)]

current IceCube

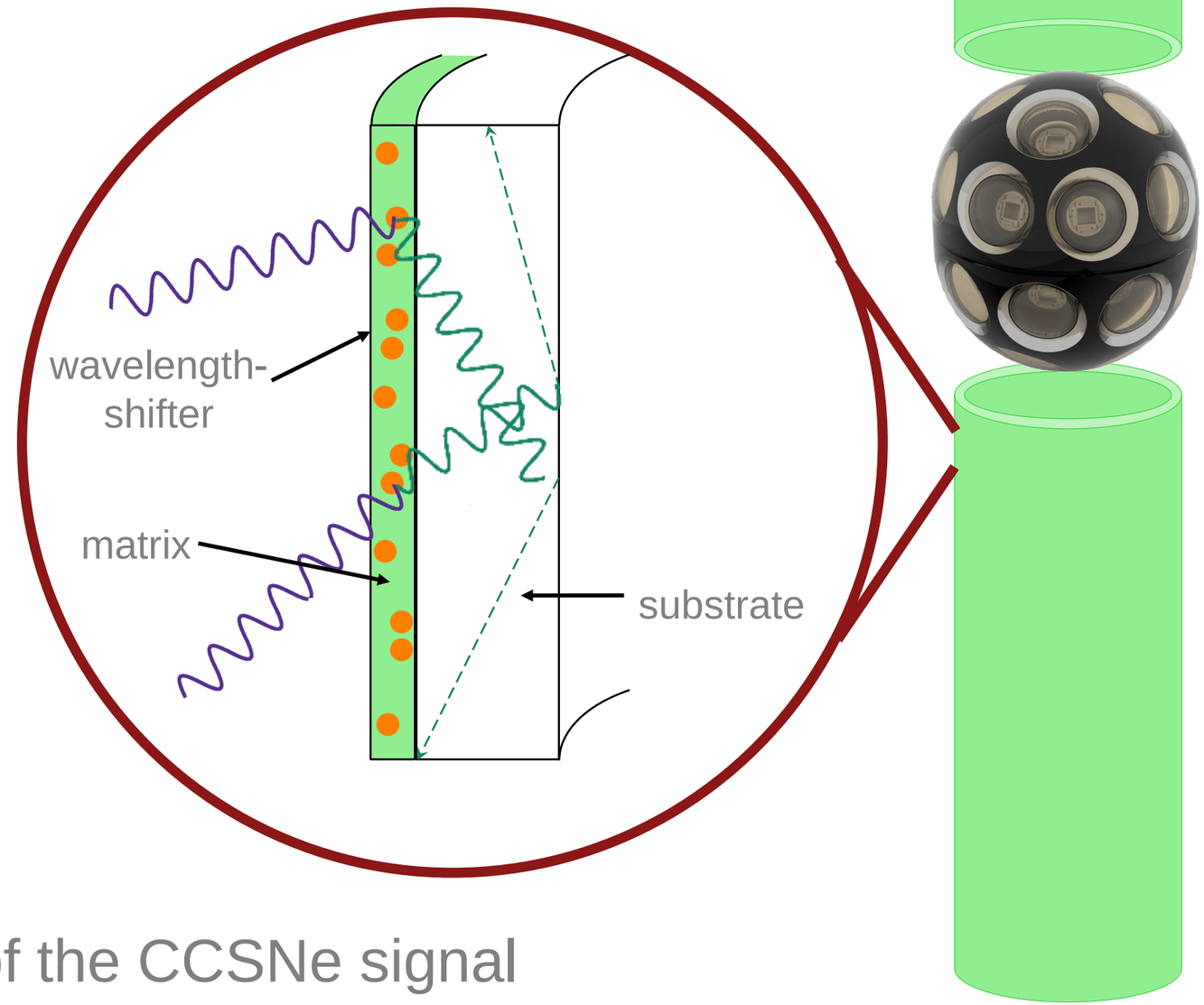


Wavelength shifters improve photon collection

[Bastian-Querner et al. (2022)]

Advantages:

- Low-cost add-on
- Increase photo collection
- Extend acceptance to UV
- Less sensor noise than additional PMTs

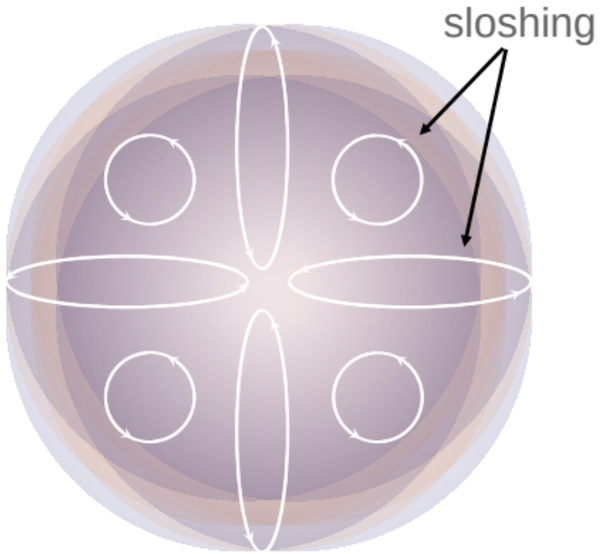


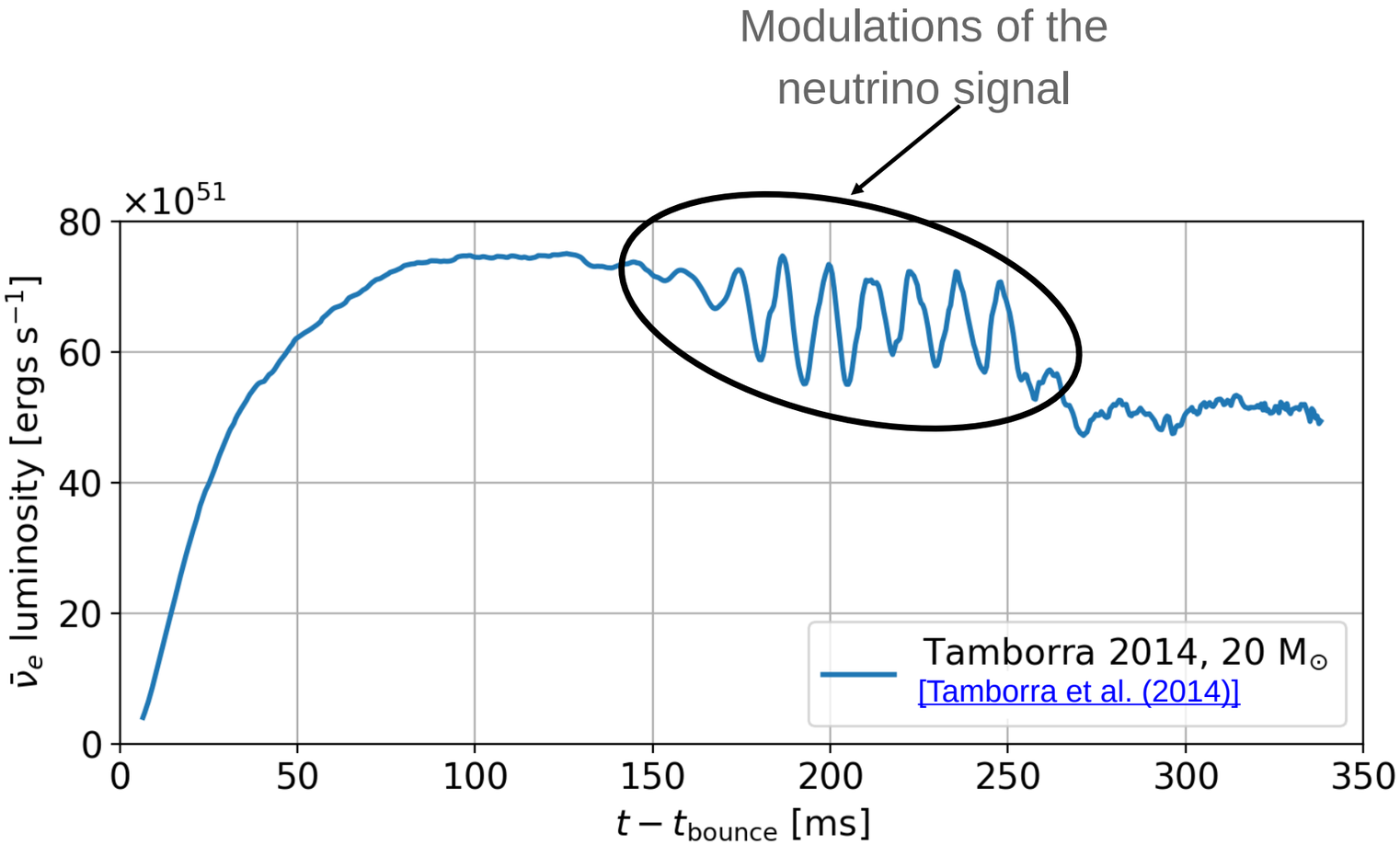
Improved photon collection

➡ Improved measurement of the CCSNe signal

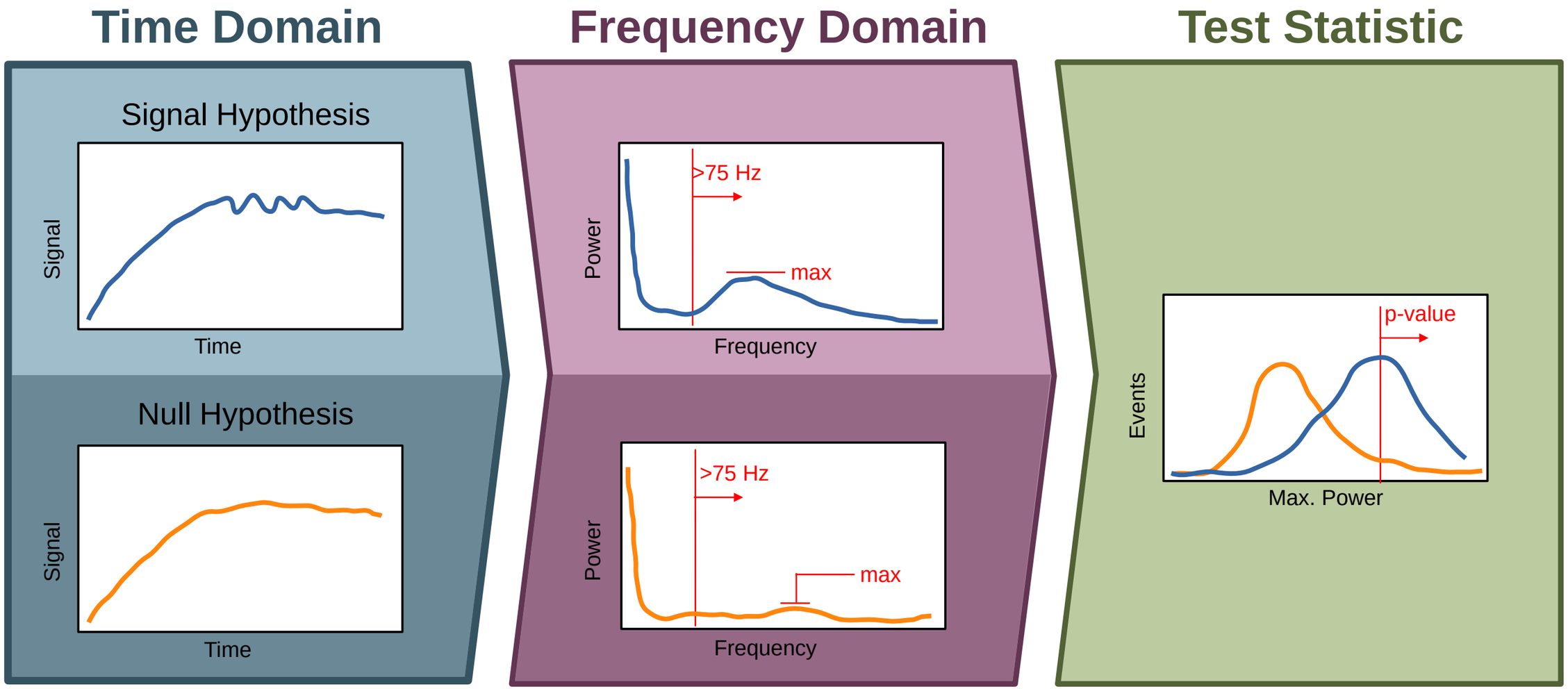
Standing Accretion Shock Instability (SASI)

Large-scale, convective streams inside a CCSNe during the accretion phase can cause sloshing

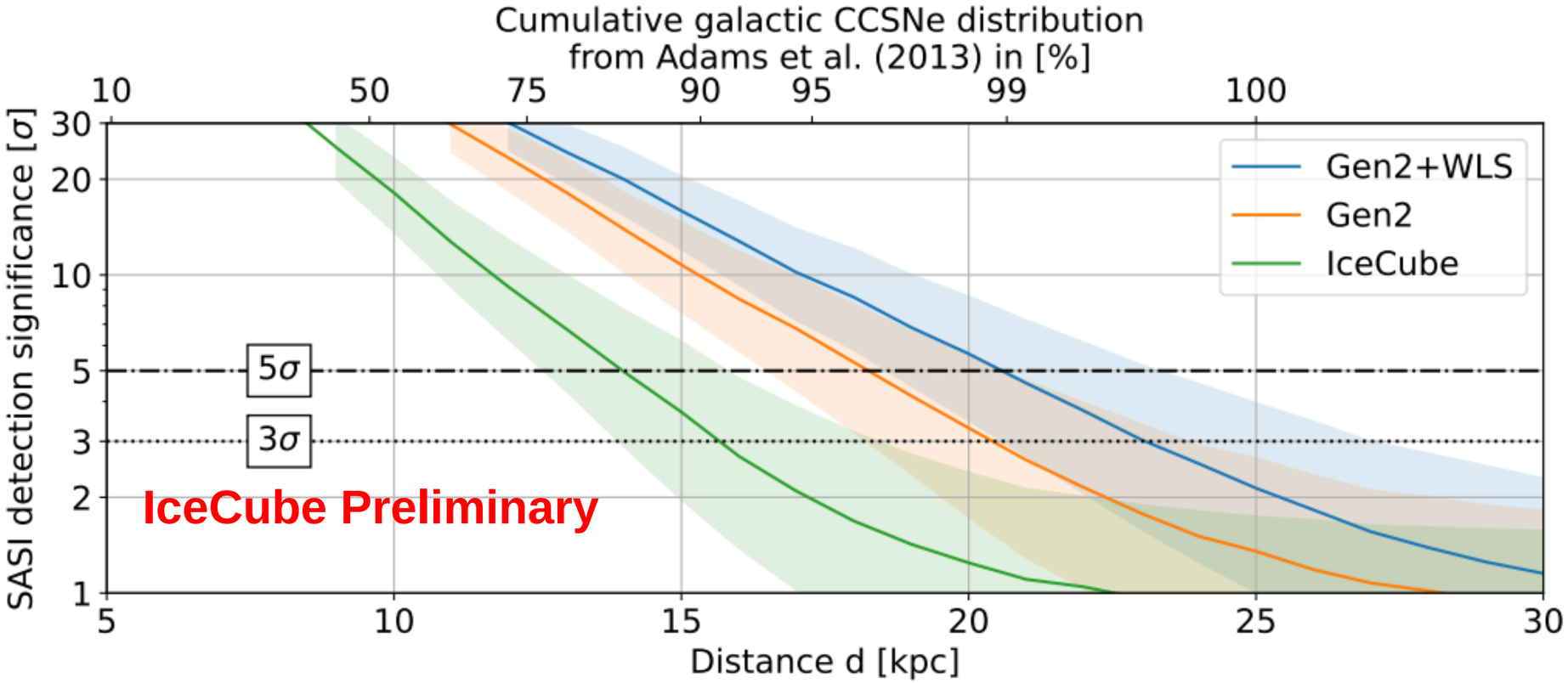




How well can we observe SASI modulations?



IceCube-Gen2+WLS covers the entire galaxy



IceCube-Gen2 + WLS covers 99% of the Galaxy at 5σ as compared to 97% (IceCube-Gen2) and 85% (IceCube).

Conclusion

- IceCube-Gen2 has the unique potential to improve the CCSNe detection capabilities.

- Wavelength shifters are cost-efficient, low-noise modules that are ideal for the precision measurement of CCSNe light curves.

- IceCube-Gen2 with wavelength-shifting modules allows us to detect this SASI model in 99% of the progenitors in the Milky Way (compared to 85% of the Milky Way with IceCube alone).

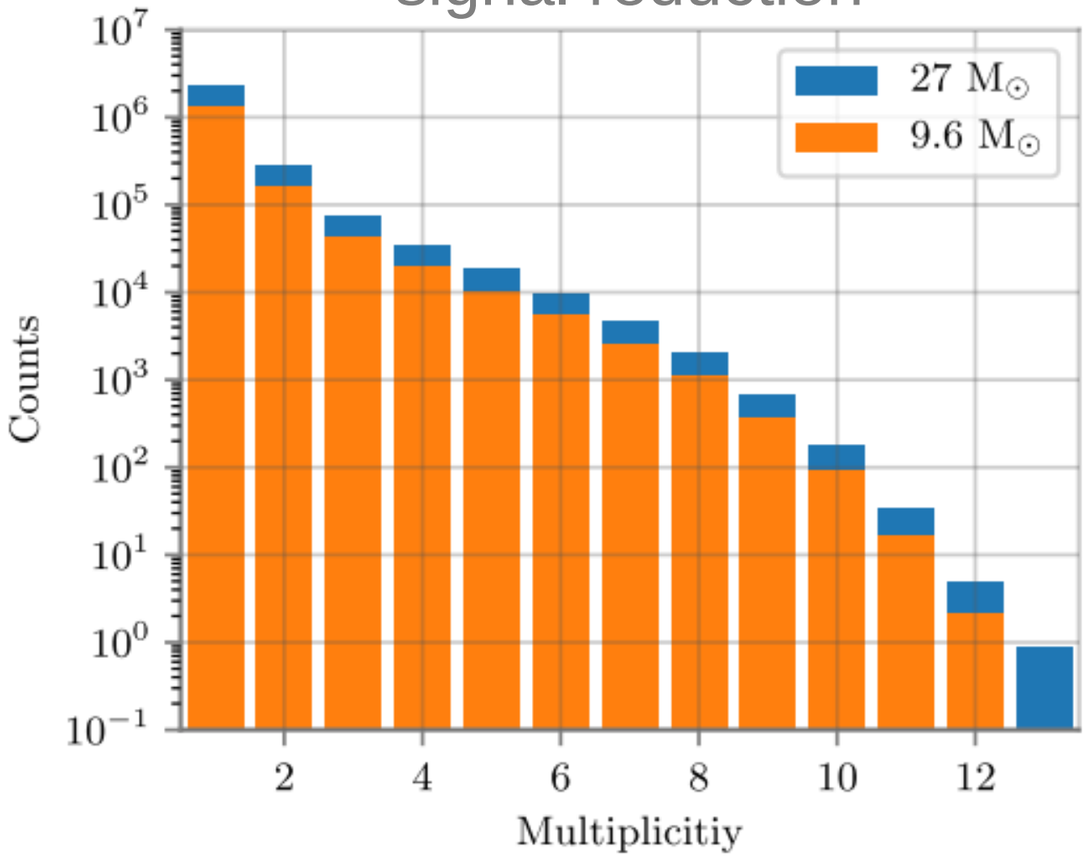
- In the future we want to generalize this study for model-independent predictions.

Back Up

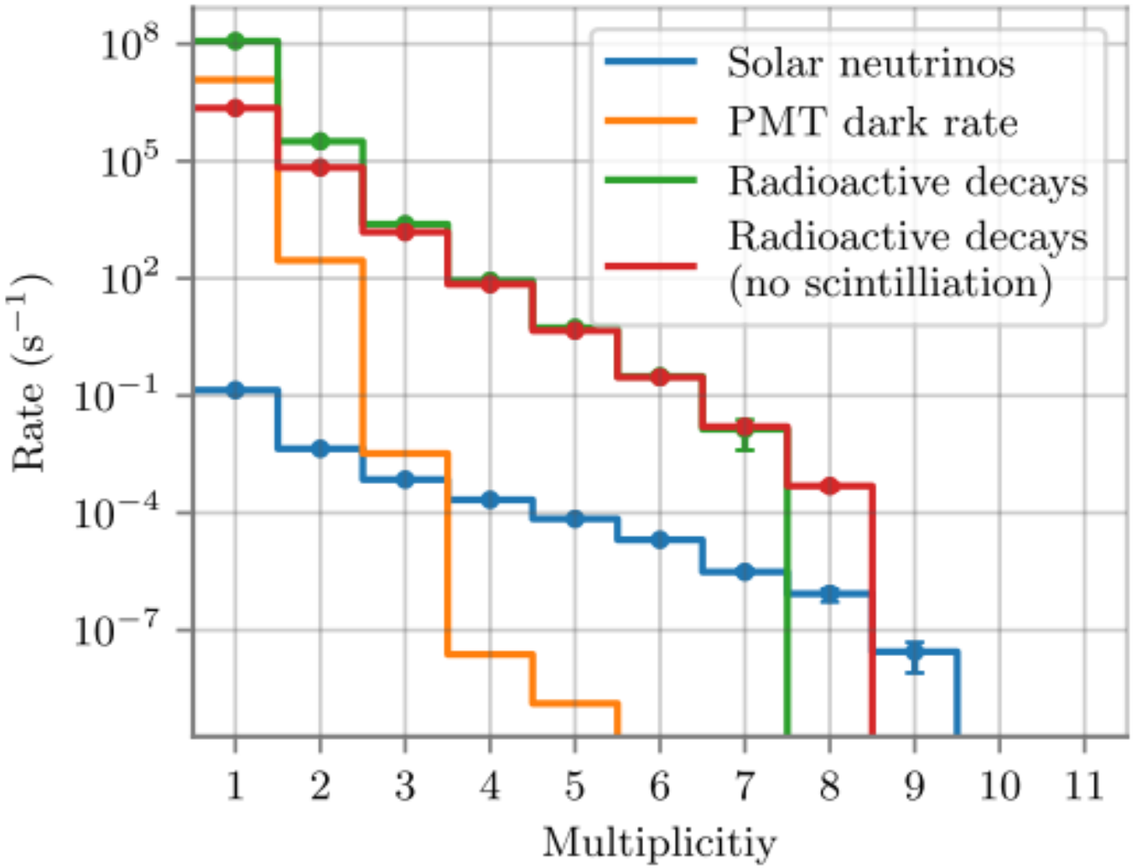
mDOM local coincidences

[Lozano Mariscal et al. (2021)]

signal reduction



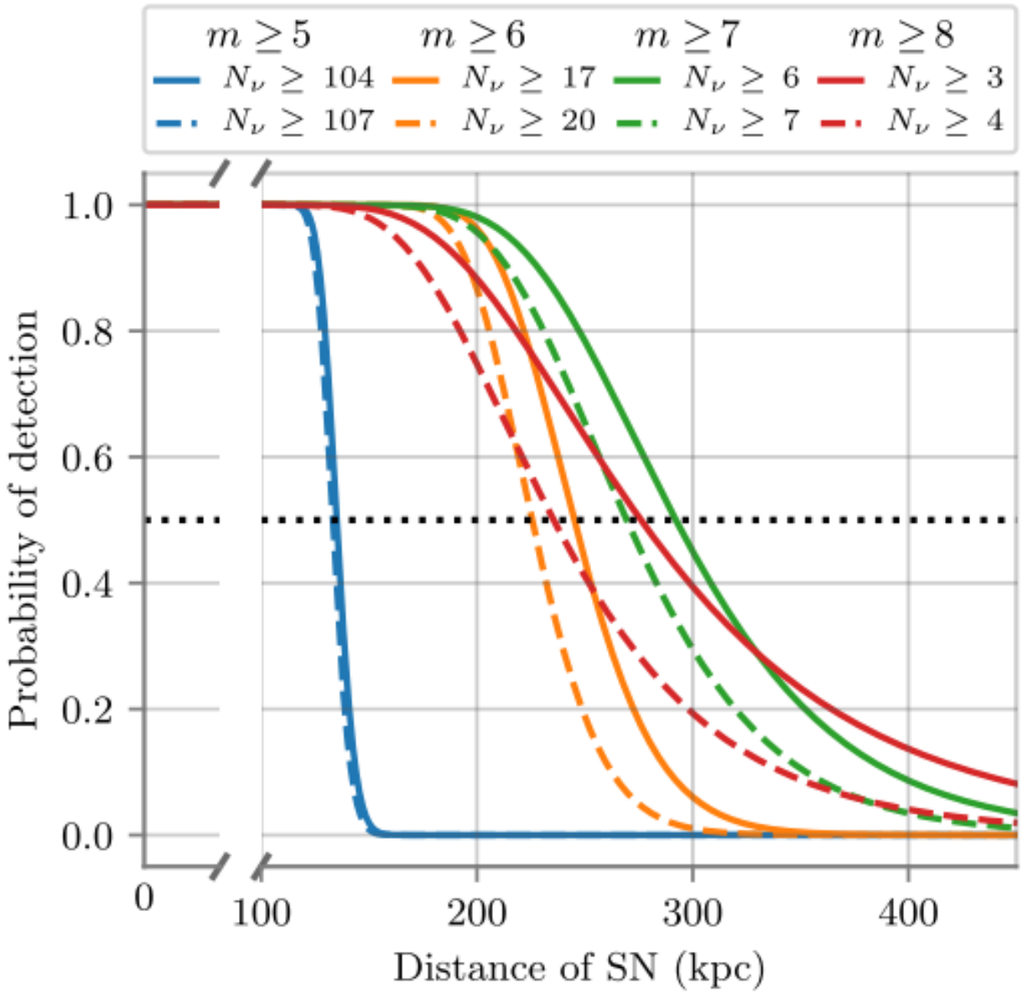
noise rejection



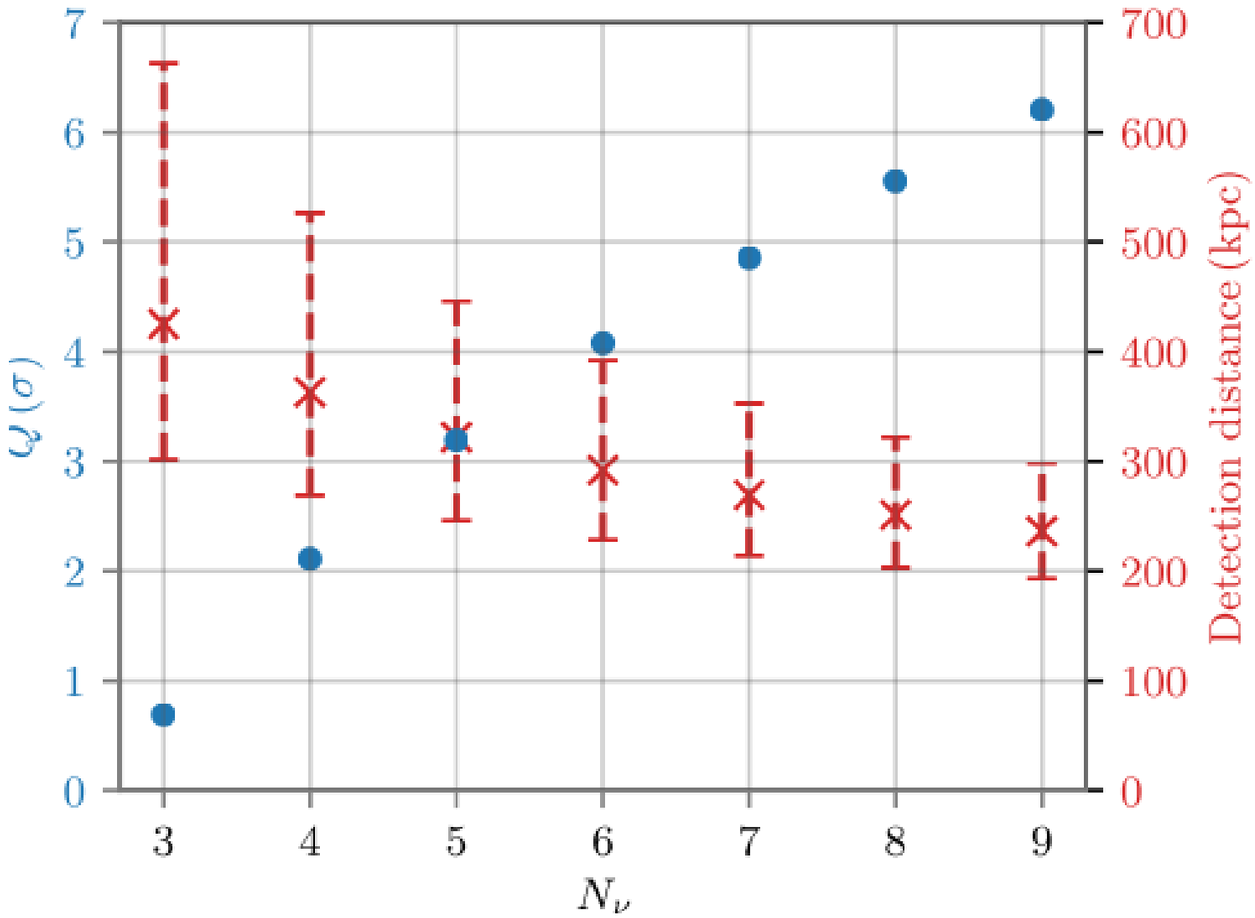
mDOM local coincidences

[Lozano Mariscal et al. (2021)]

detection probability



detection horizon & significance



Fast-time features