KM3NeT's sensitivity to the next core-collapse supernova

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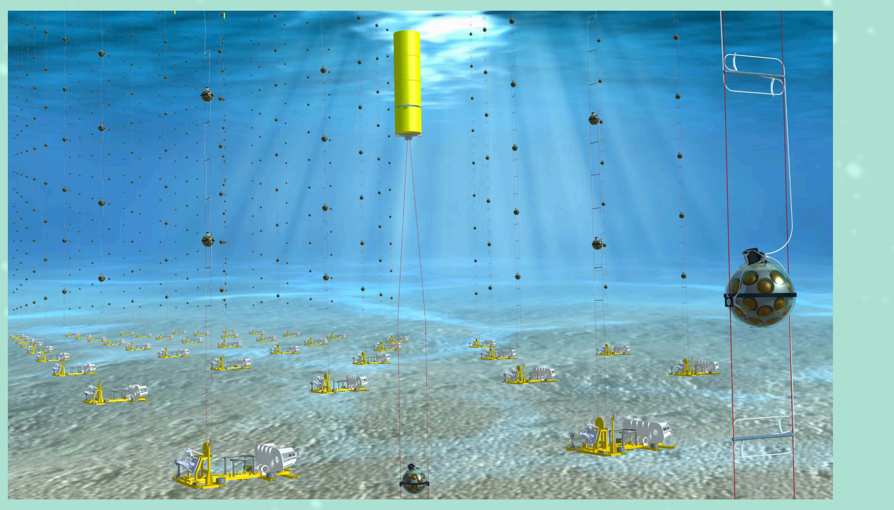
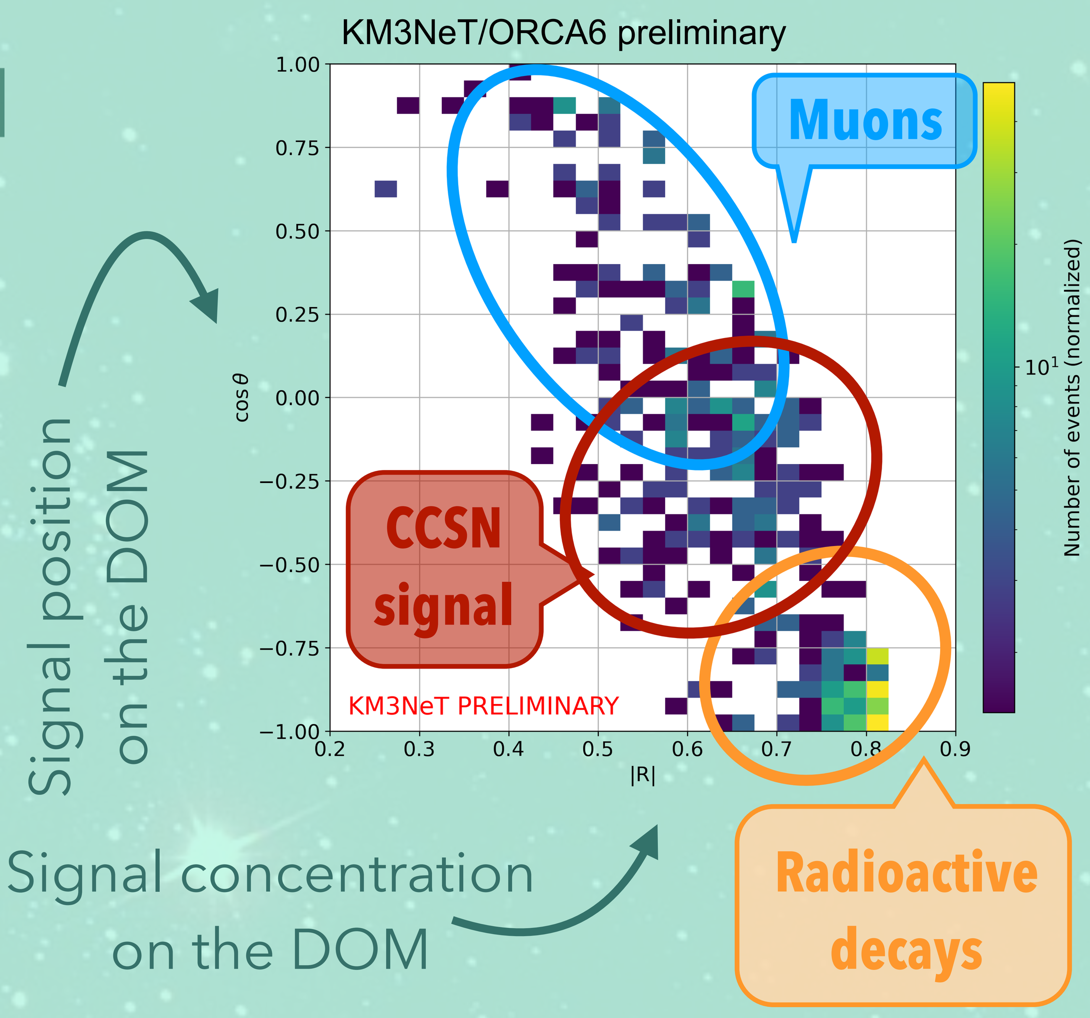
Motivation: Core-Collapse supernovae (CCSNe) are the end of life of heavy stars ($8M_\odot$ and above), whose core collapses in a fraction of a second, often leading to a powerful explosion whose mechanism is not yet completely understood. The detection of 25 neutrinos from supernova 1987A has demonstrated that CCSNe are associated with an intense neutrino emission. If another CCSN occurs in or near our Galaxy, the detection of the resulting $\mathcal{O}(10)$ MeV neutrino burst would provide invaluable information on the CCSN mechanism and neutrino properties. This burst could be intense enough to be detectable at experiments targeting higher-energy neutrinos such as KM3NeT.

KM3NeT: 3D grid of digital optical modules (DOMs) in the Mediterranean Sea, currently under construction at two different sites: ORCA (Toulon, France) and ARCA (Sicily, Italy) [1].



CCSN neutrinos will activate individual DOMs: Each KM3NeT DOM (radius of 21.6 cm) hosts 31 small photomultipliers (PMTs) [2]. We use single-DOM observables to maximise the signal-to-noise ratio: the multiplicity (number of PMT hits in a DOM within 10 ns), $|R|$, $\cos\theta$, Δt (temporal spread of the signal) and the total time over threshold (signal intensity).

DOM with an example of an event of **multiplicity 4**

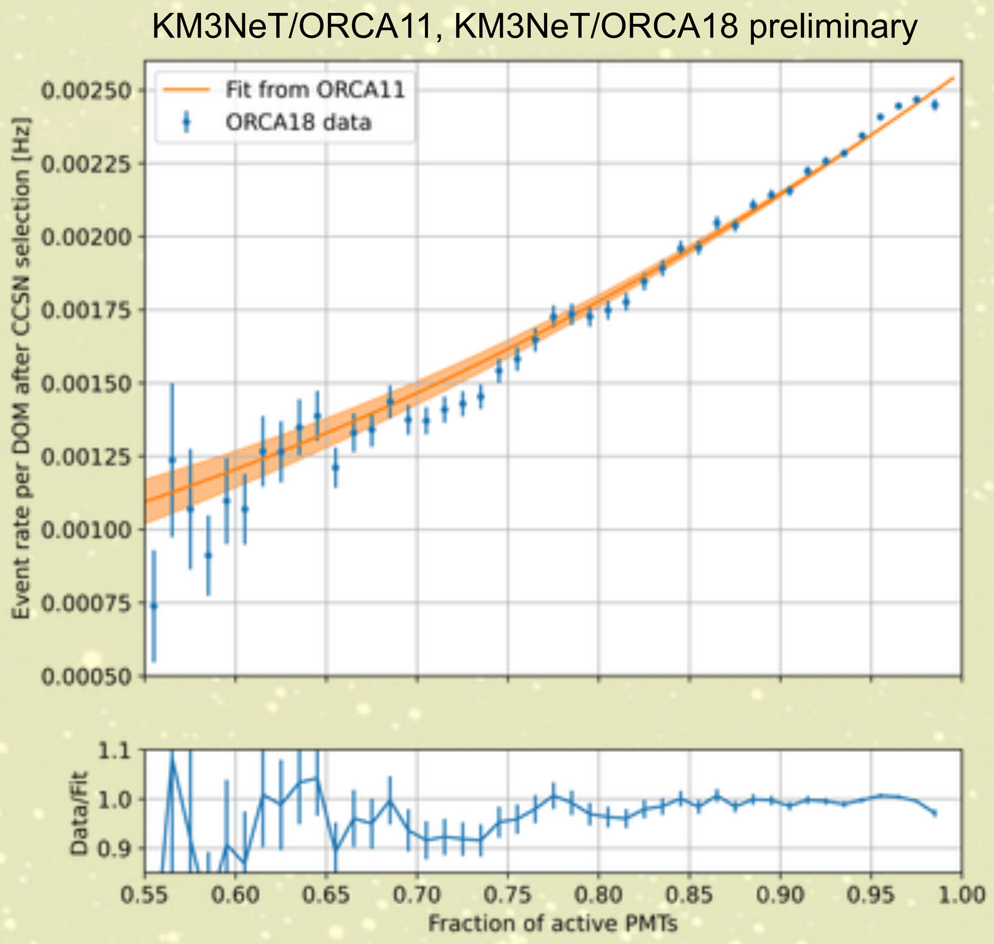


Boosted decision trees (BDTs): we train them on these features to distinguish signal from background.

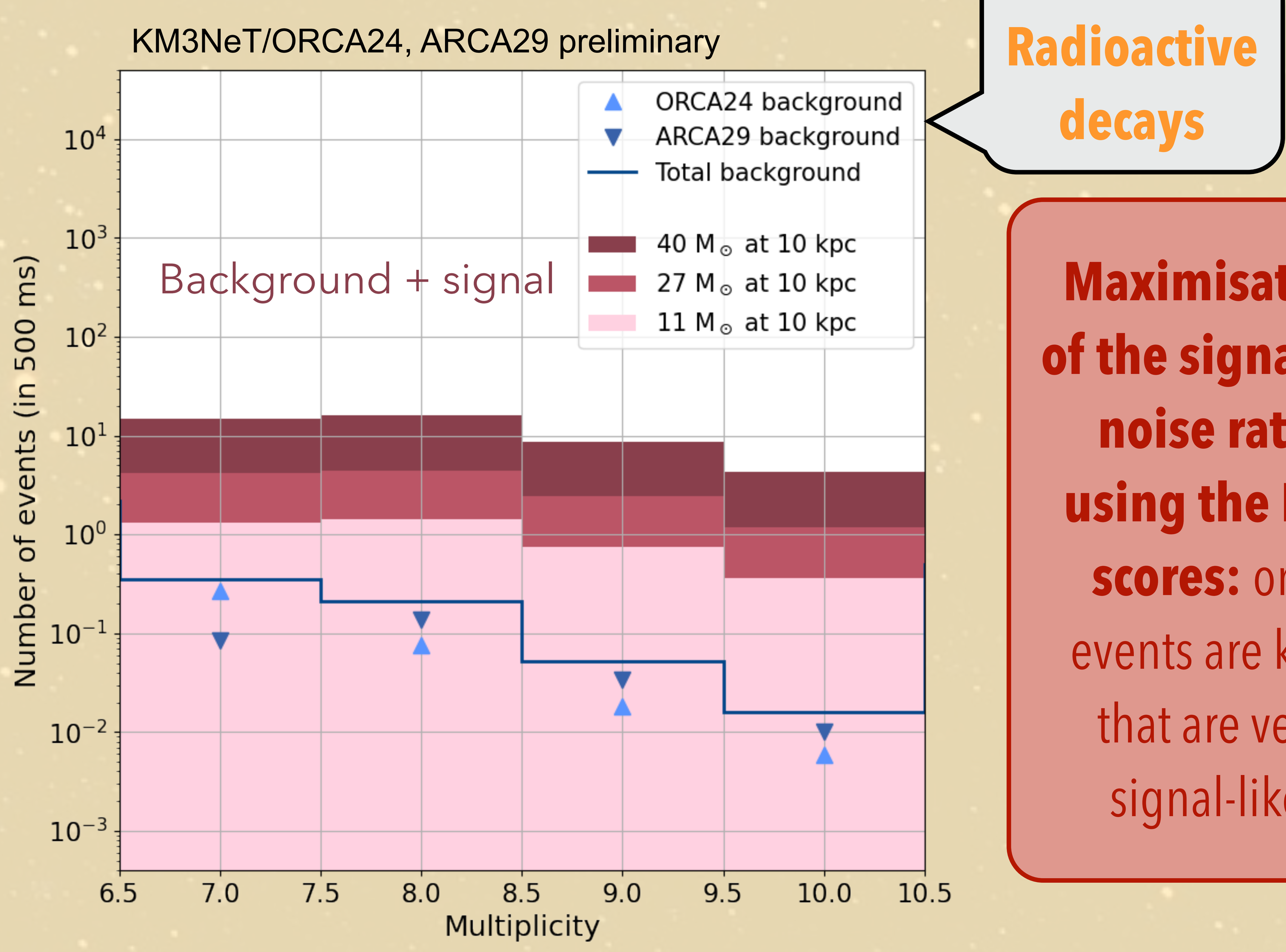
Adaptive background estimation at KM3NeT: During bioluminescence bursts, a small fraction of PMTs is suppressed. We fit the background dependence on the fraction of active PMTs using recent data and rescale to the current detector configuration to obtain an estimate of the present expected background.

Fit performed on ORCA11 data and **rescaled** and compared to **ORCA with 18 lines**

Introduction of an **uncertainty** of **~5%**



Search for CCSN neutrinos: If the neutrino burst from a nearby CCSN is intense enough, associated events will register as a rise of the number of recorded single-DOM events at ORCA & ARCA.

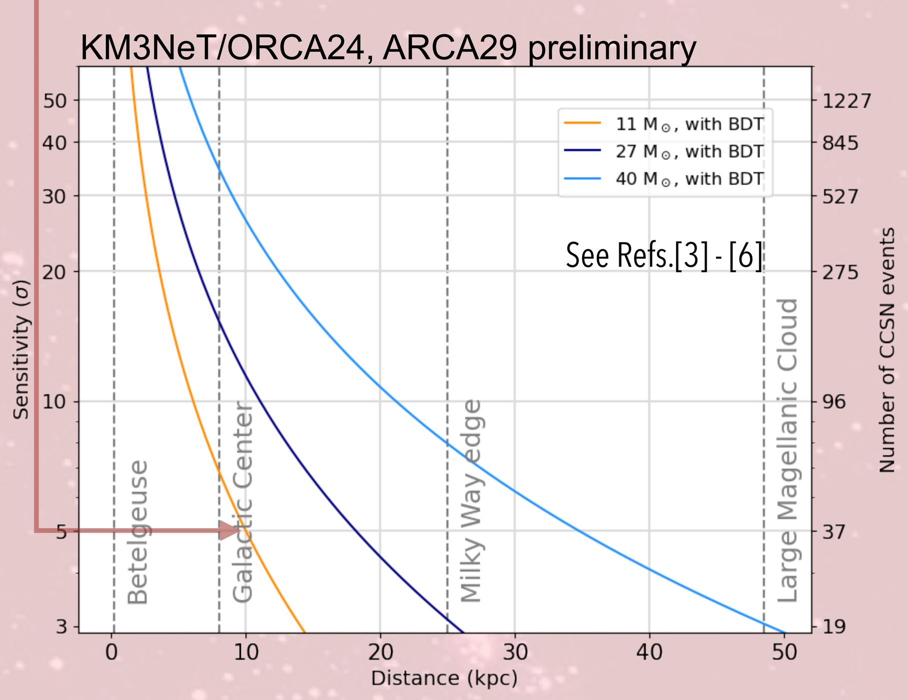


Maximisation of the signal-to-noise ratio using the BDT scores: only events are kept that are very signal-like.

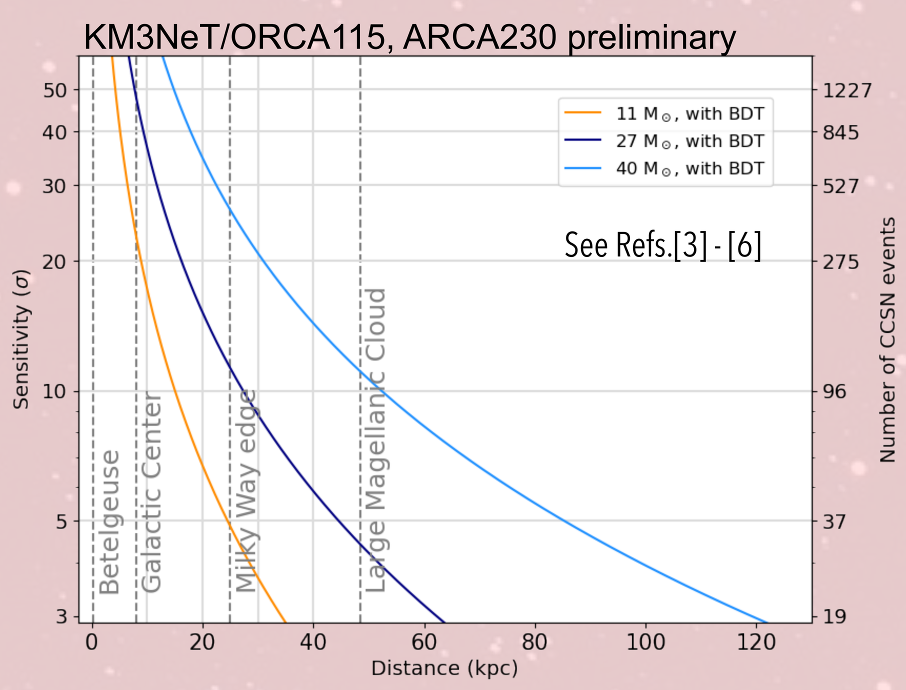
How far can KM3NeT reach?

With the **near future ORCA and ARCA configurations** at KM3NeT, it is possible to probe the **dense region around the center of the Milky Way**, even for the case of the lightest CCSN progenitor. If the exploding star were particularly massive, **almost all our Galaxy** would be covered.

ORCA24 & ARCA29



ORCA115 & ARCA230



The method described in this contribution is already implemented in **KM3NeT's real-time analysis platform** (see *M. Mastrodicasa et al., poster 375*).

[1] J. Phys. G: Nucl. Part. Phys. 43, 8, 084001 (2016).
[2] JINST 17, 7, 07038 (2022).
[3] Phys. Rev. Lett. 111, 12, 121104 (2013).
[4] Phys. Rev. D 90, 4, 045032 (2014).
[5] Phys. Rev. D 101, 12, 123013 (2020).

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