Detection of Supernovae neutrinos with archaeological lead

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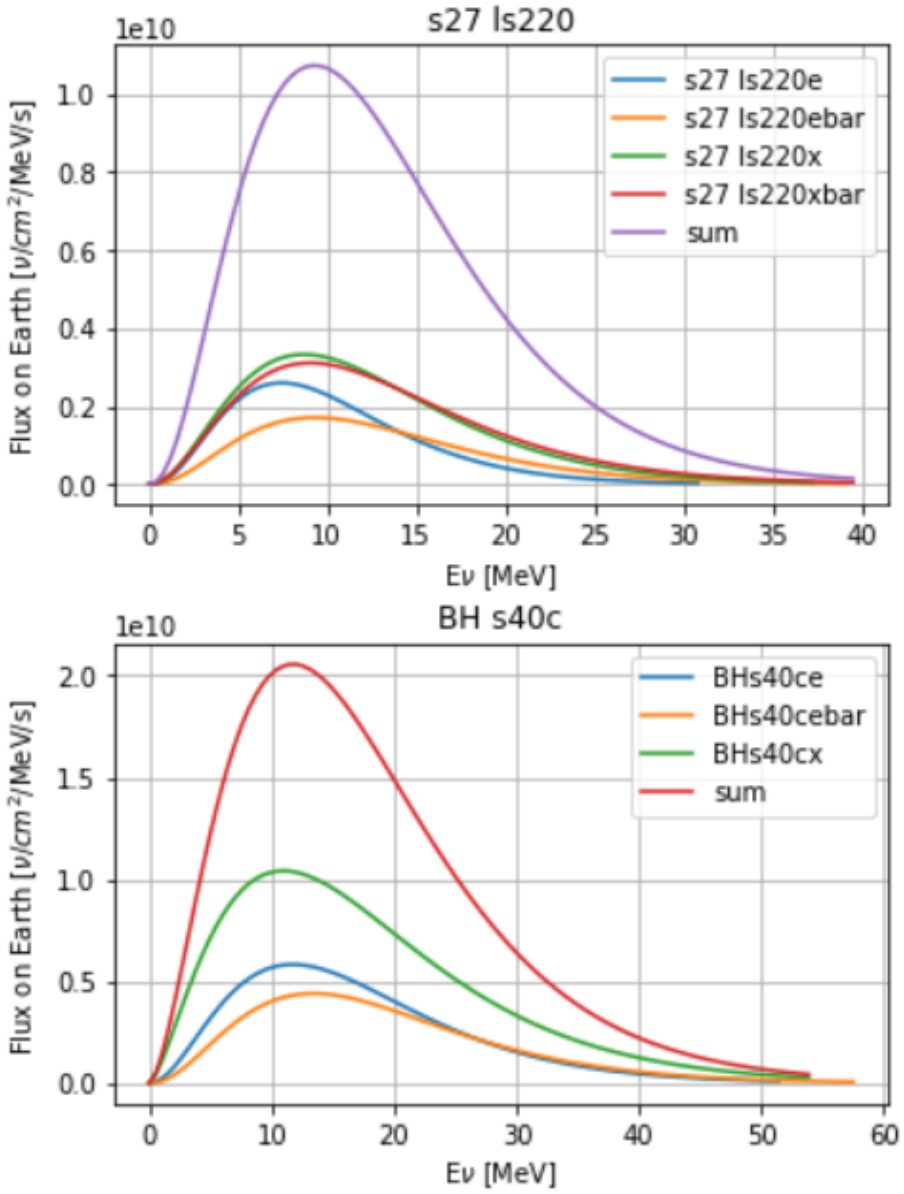
Supernovae as neutrino sources

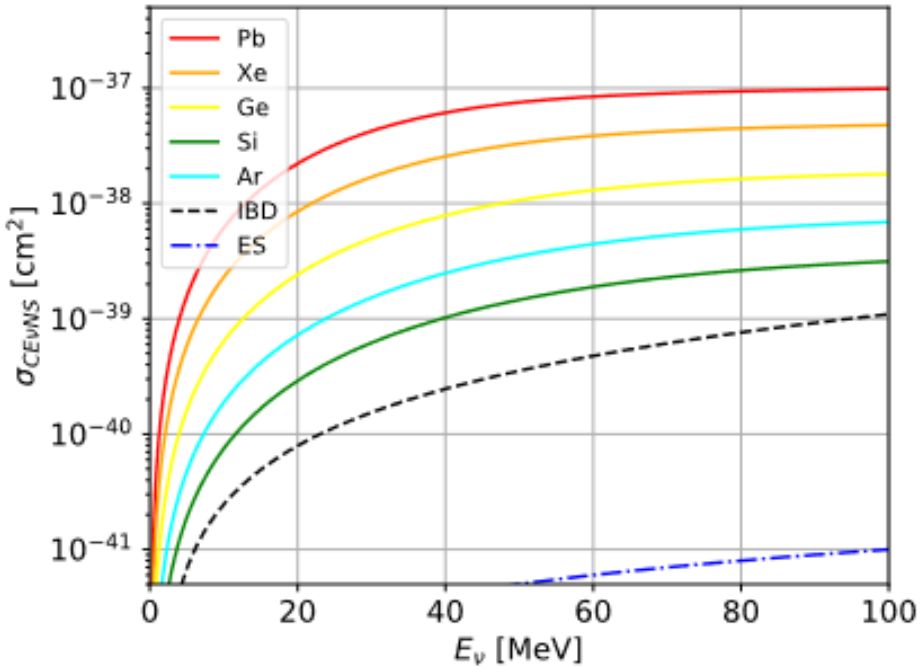
- O(10)s signal duration
- Thermal emission of all neutrino-flavors
- Average energy O(10)MeV
- Emitted energy O(10^{53})erg
- Flux on Earth O(10^{10}) ν/cm^2/MeV/s (@10kpc)

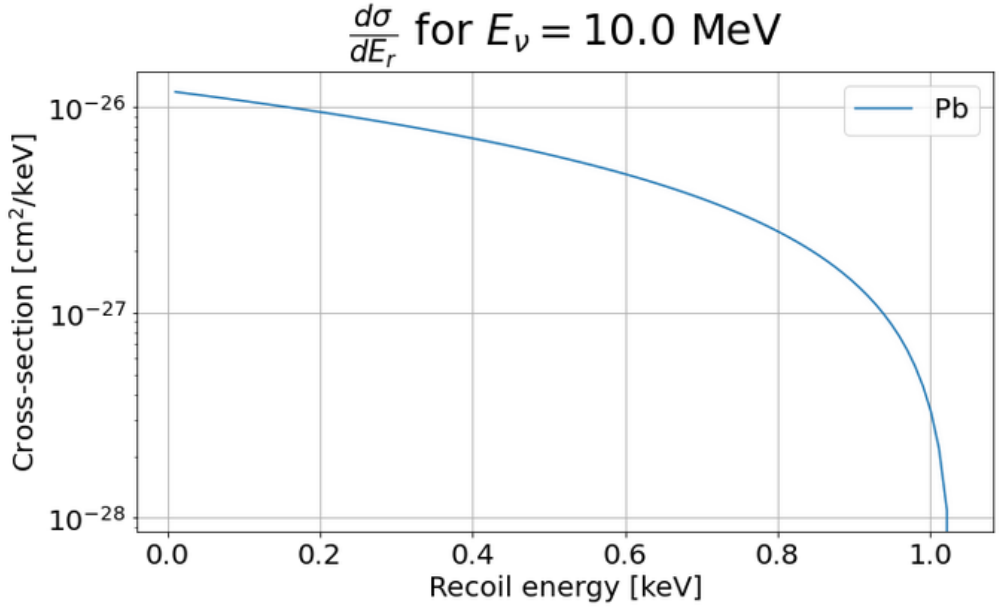


CEvNS in Pb

$$\frac{d\sigma}{dE_R} = \frac{G_F^2 m_N}{8\pi(\hbar c)^4}\left[(4\sin^2\theta_W - 1)Z + N\right]^2 \left(2 - \frac{E_R m_N}{E^2}\right)\cdot|F(q)|^2 \ ,$$

- m_N -> 208
- Er -> 1keV
- E -> 10MeV
- Total counts: 15-30 evt/ton





RES-NOVA

- 500 scintillating $PbWO_4$ crystals
- Operation as cryogenic detectors (keV and sub-keV nuclear recoil detection threshold)

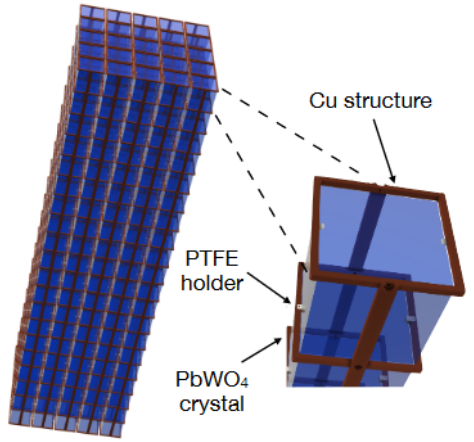


Figure 3. Illustration of the detector design. The crystal absorber are arranged in a tower-like structure. On each of the 20 layers, 25 crystal are placed. The detector structure is made of Cu, while the clamps which hold the detector in place and act as thermal link are made of PTFE.

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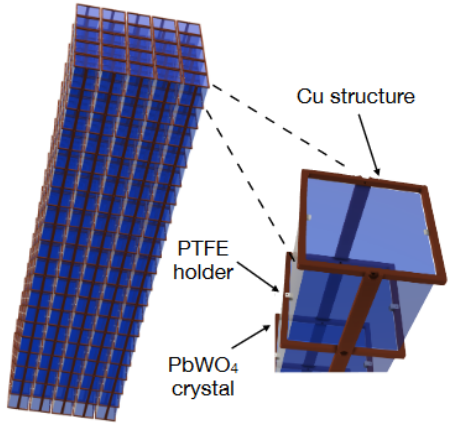
- 500 scintillating $PbWO_4$ crystals
- Operation as cryogenic detectors (keV and sub-keV nuclear recoil detection threshold)
- Phonon-Light readout for background rejection
- Pb of archaeological origin (bkg rate at 0.01 counts/keV/ton/s)



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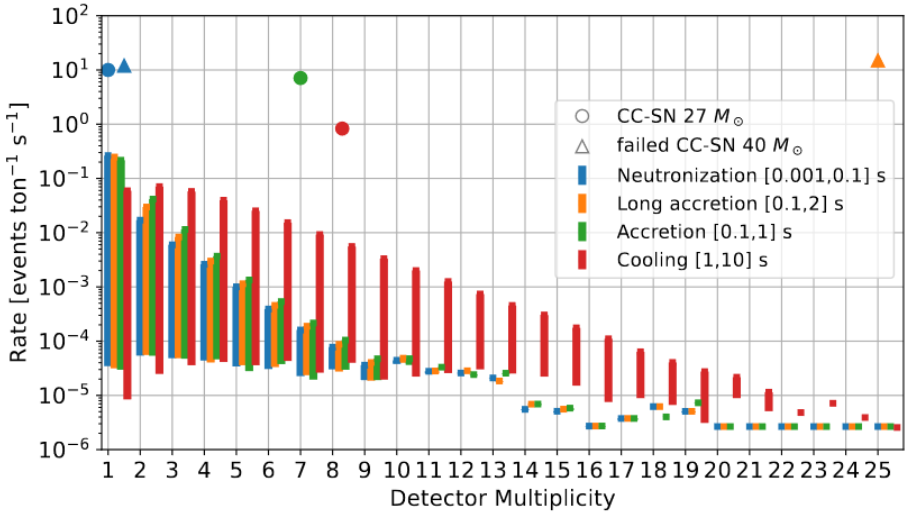

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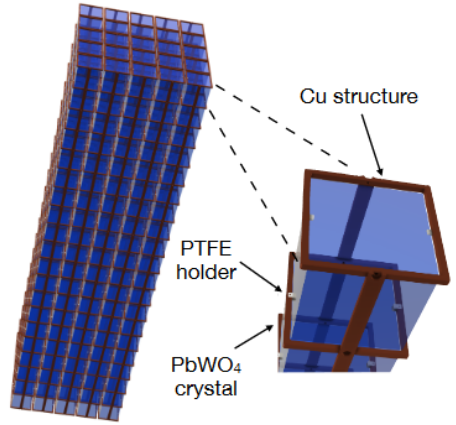

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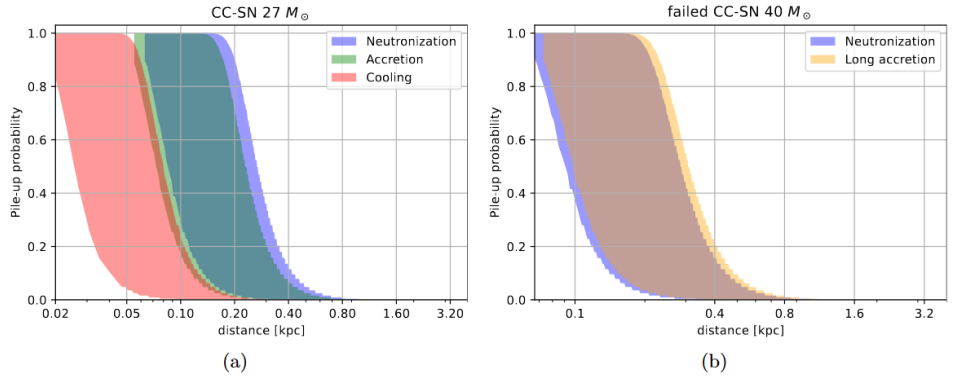

(a) (b)

Figure 7. Range of signal pile-up probabilities in RES-NOVA as a function of the distance for different neutrino emission phases from (a) a core-collapse and (b) a failed core-collapse SN. Background sources are neglected due to their negligible contribution (see Sec. 5). The signal rates are taken from Tab. 2. The width of the bands represents the pile-up rejection efficiency for a detector time resolution spanning from 100 μs (best case scenario - left side of the bands) to 1 ms (worst case scenario - right side of the bands). For details on the statistical approach see Sec. 7.1.

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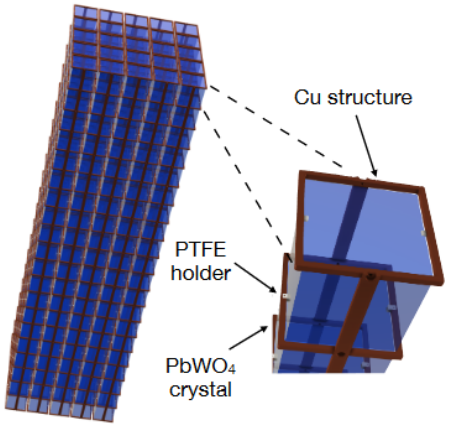
- Operation as cryogenic detectors (keV and sub-keV nuclear recoil detection threshold)
- Phonon-Light readout for background rejection
- Pb of archaeological origin (bkg rate at 0.01 counts/keV/ton/s)
- Modular design for robustness against pile-up (nearby SNe)
- Time-profiling of the neutrino emission



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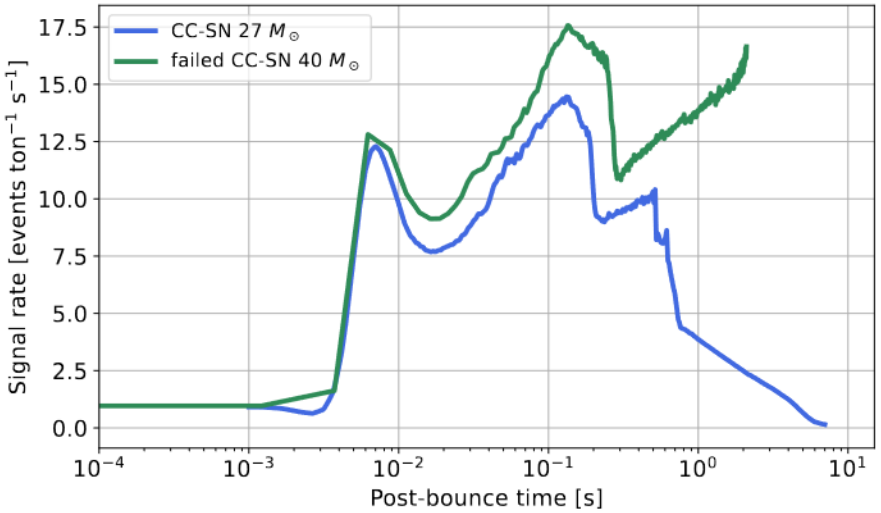
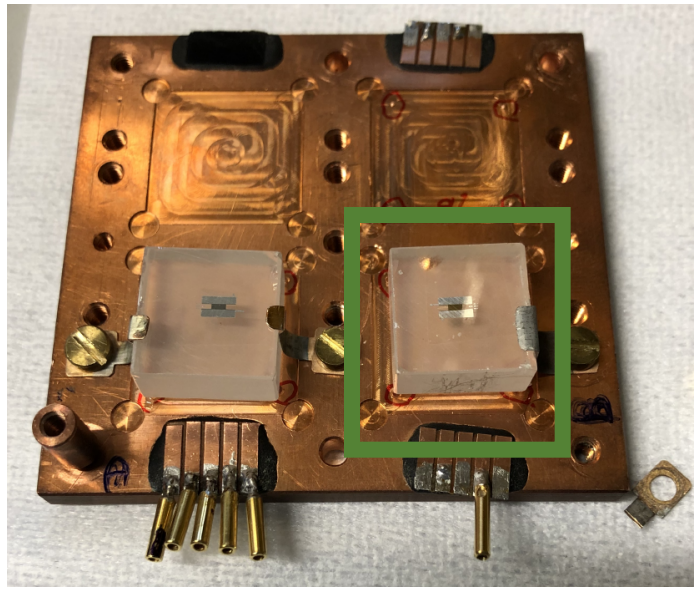
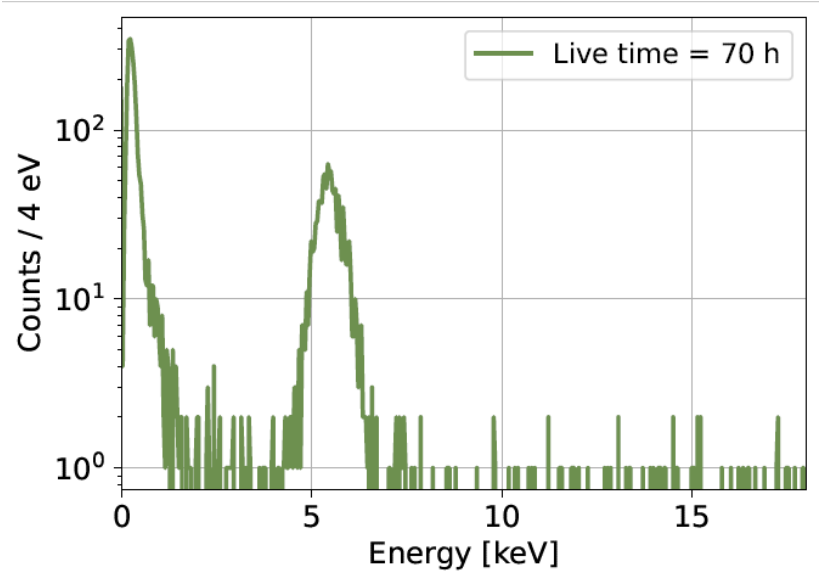


First test @MPP

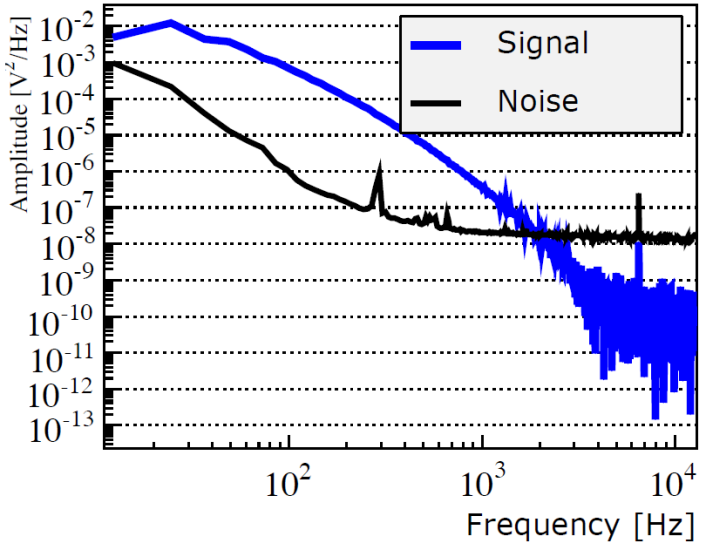
- 15.7g of $PbWO_4$
- Pb of archaeological origins
- 70h of operation
- ^{55}Fe calibration source

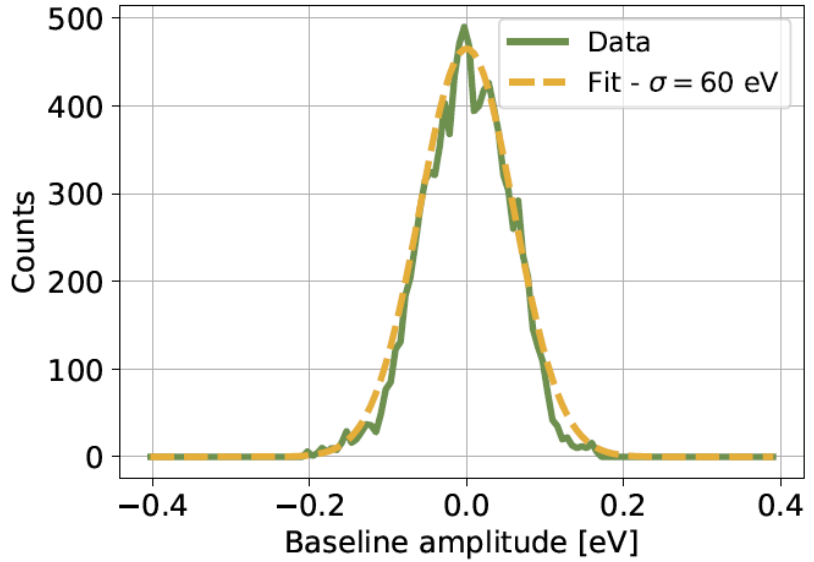




First test @MPP

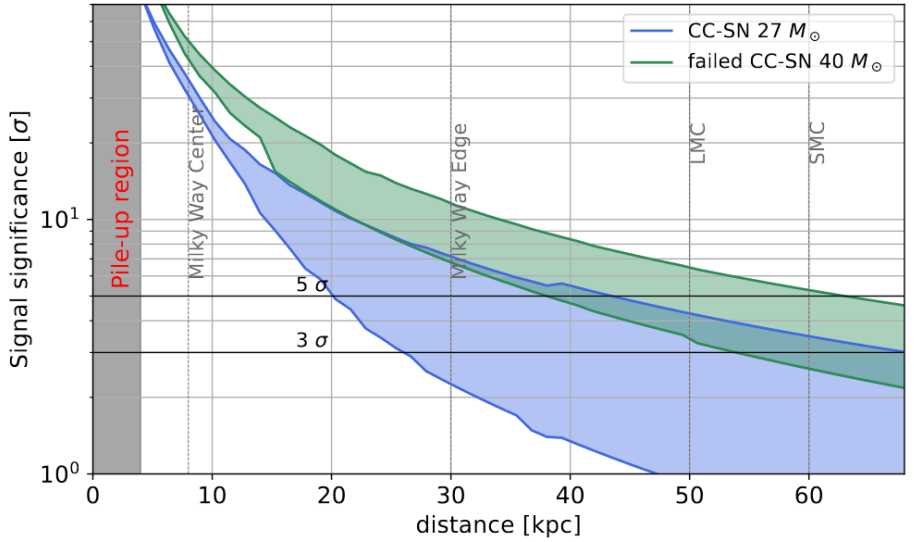
- 15.7g of $PbWO_4$
- Pb of archaeological origins
- 70h of operation
- ^{55}Fe calibration source
- dc-squid readout 200nA/Φ_0 and 1V/Φ_0
- Sensitivity 10.8keV/V
- Resolution 1σ@0keV = 60eV (optimal filtering)
- Detection threshold (5σ): 300eV





Conclusions

- Combining existing technologies will allow for all-flavor detection of neutrinos from the next galactic Supernovae
- (Archaeological) Pb is a great camdidate thanks to its high cross-section and low background
- First small scale proof of principle put in operation: 60 eV baseline resolution
- RES-NOVA can explore the entire milky way for SNe



L. Pattavina, N. Ferreiro, I. Tamborra, Phys. Rev. D 102, 063001 (2020)
RES-NOVA Group of Interest, arXiv:2103.08672, soon on JCAP (2021)