Probing Dark Matter with RES-NOVA's archaeological Pb-based Detectors

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SN neutrinos and CEνNS

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

- Neutrinos mainly scatter off neutrons
- Coherent enhancement
- Flavor-independent
- $\mathcal{O}$(10)MeV neutrinos deposit $\mathcal{O}$(1)keV energy
- SM process
- First observation:

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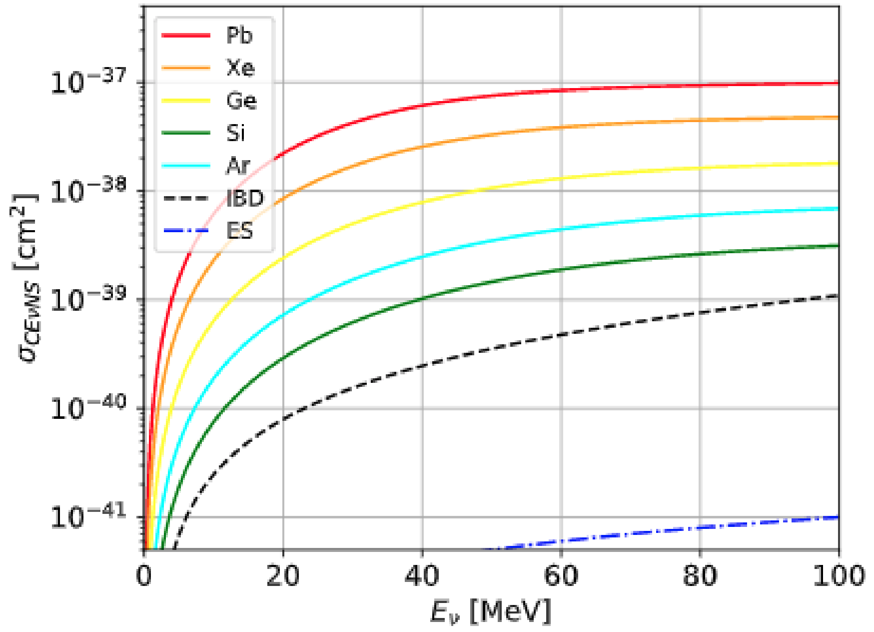
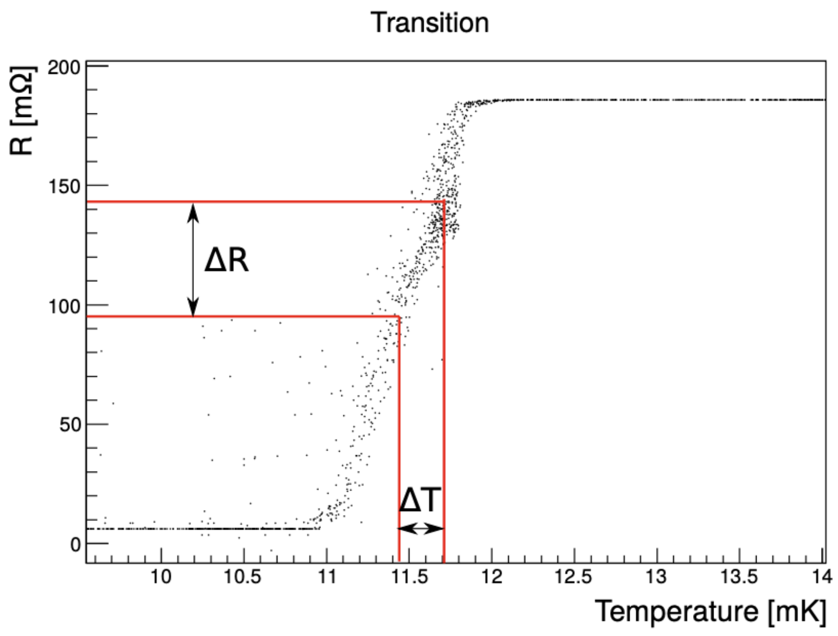


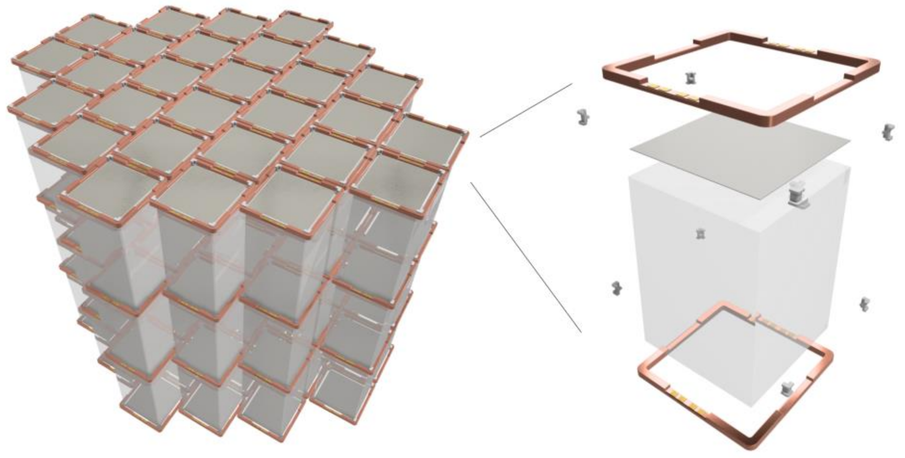
FIG. 2. Coherent elastic neutrino-nucleus scattering (CEνNS) cross sections as a function of the energy of the incoming neutrino for different target nuclei. The dashed lines show the inverse-beta decay (IBD) and neutrino elastic scattering on electrons (ES) cross-sections for comparison. Given the high cross-section, CEνNS has the potential to provide large statistics with small detector volumes.

Phys. Rev. D 102, 063001 (2020)

The RES-NOVA detector

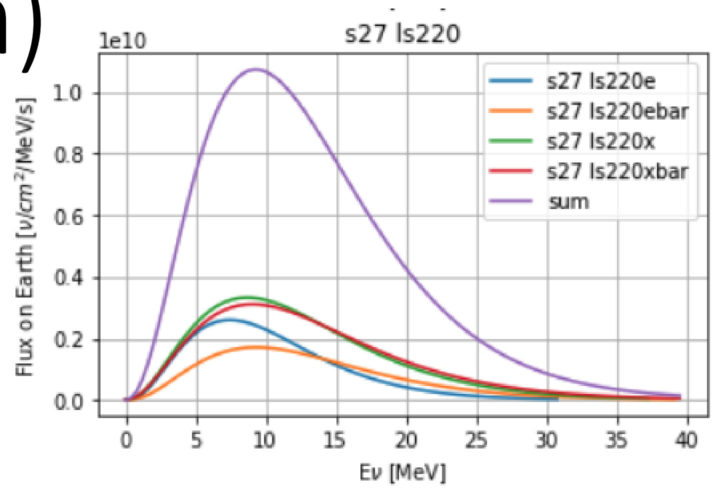
- Array of $PbWO_4$ crystals operated as (scintillating) cryogenic detectors
- Scintillating cryogenic detectors provide powerful background rejection thanks to the simulaneous read-out of phonon and light channels Time coincident analysis of different detector modules allows for further background suppression
- Energy measured by means of sensitive Transition Edge Sensors
- TESs have already demonstrated the capability of sub-keV nuclear recoil energy threshold

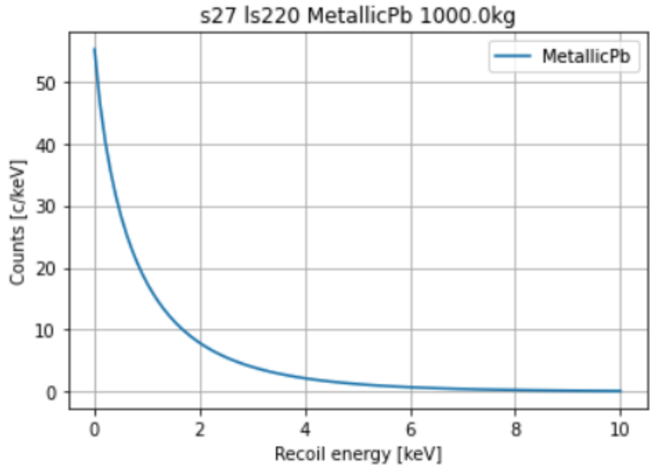




SN CEνNS in Pb Target (on Earth)

- The emitted neutrino spectrum is (almost) Maxwell-Boltzmann distributed (pretty much like the WIMPs)
- Observed nuclear recoil spectrum follows an exponential raising towards the lower part of the recoiling energy (Similar to the WIMPs)





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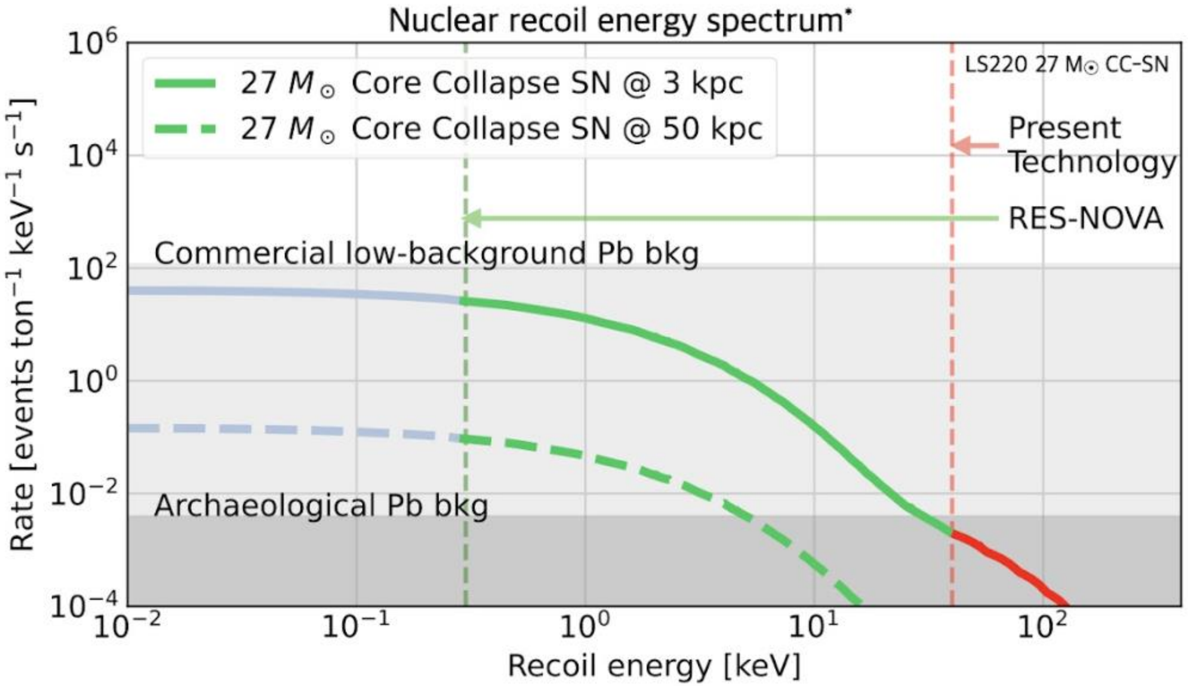
The downfall of Pb

Commercial Pb has 10^4 Bq/ton of radioactive ^{210}Pb (Q-value 63 keV, $\tau_{1/2}$=22 y). That's bummer!



And the solution

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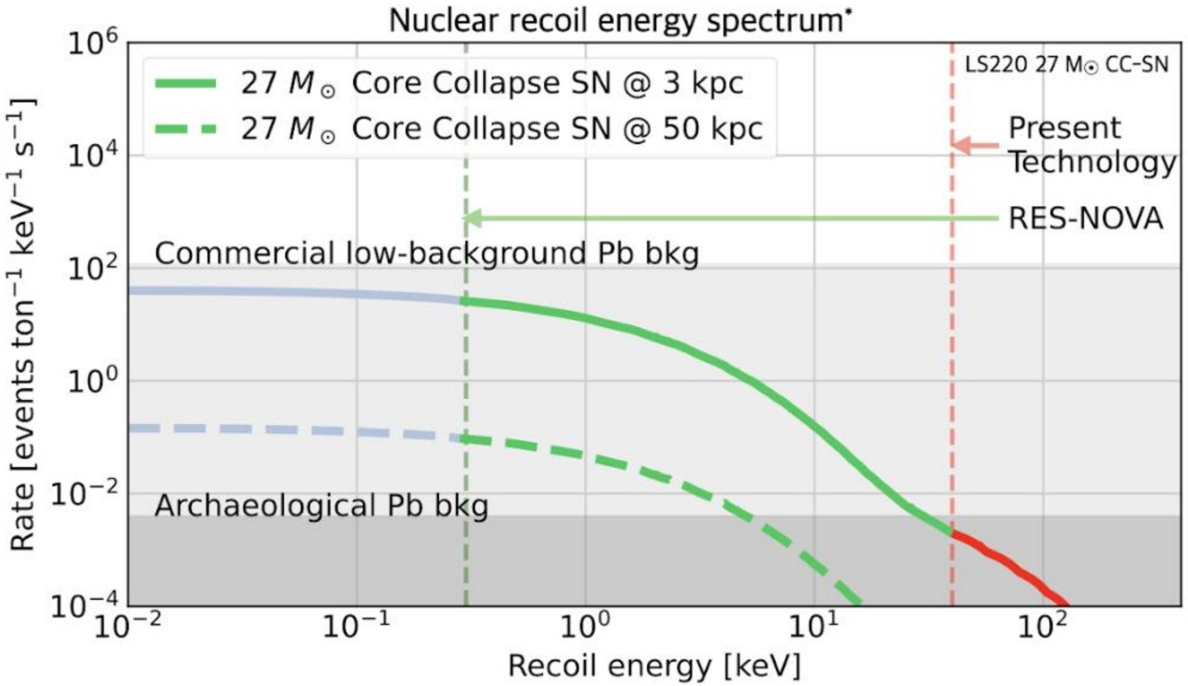


We will deploy $PbWO_4$ grown with 2000years old archaeological lead ^{210}Pb is expected to be below 1mBq/kg

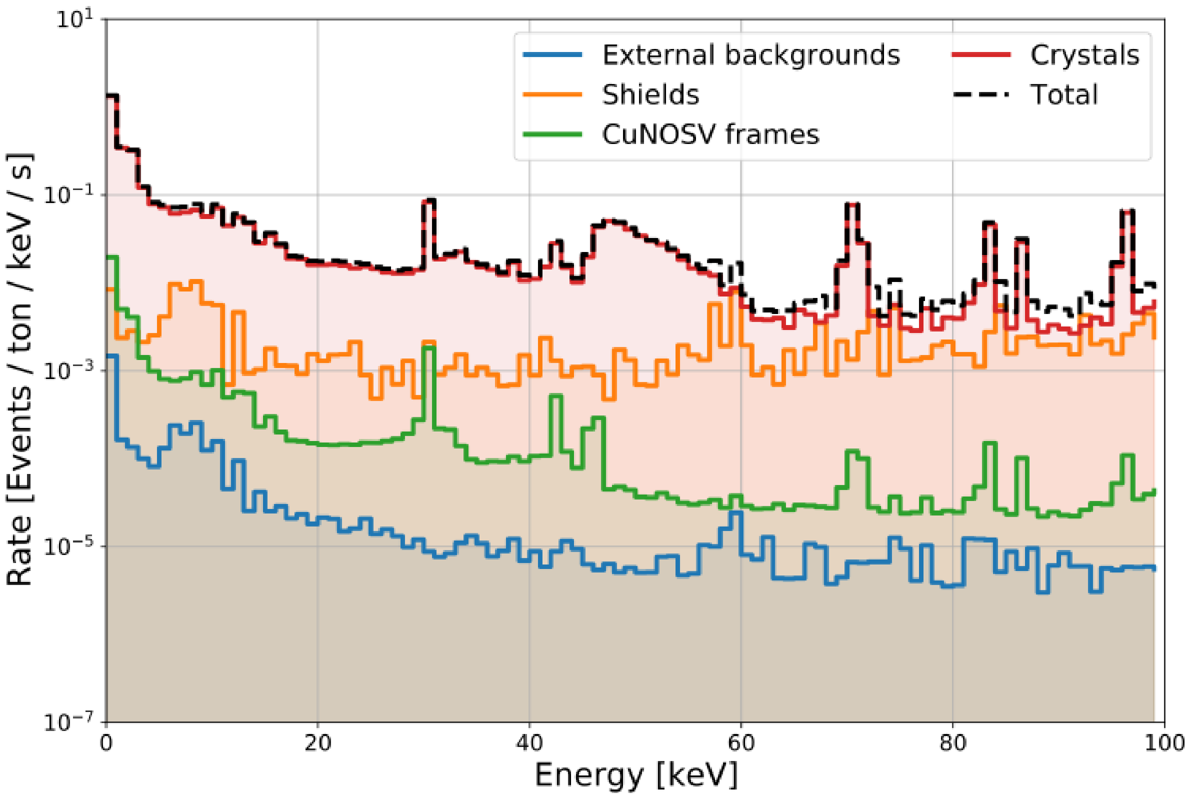
From SN neutrinos to Dark Matter

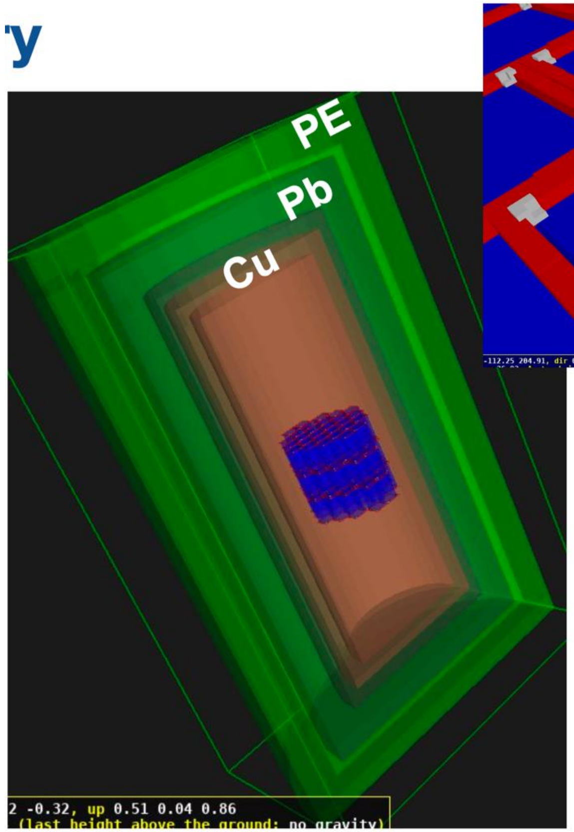
- Pb can proble N^2 weak-scattering down to $10^{-38}/10^{-39} cm^2$
- (Spin-independent) Dark matter couples to A^2 gaining a factor 10^3

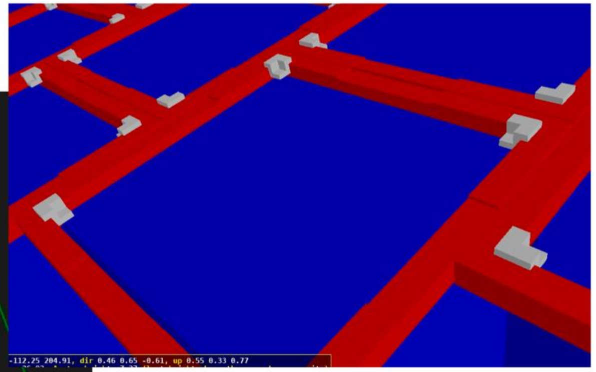
- Dark matter is a always-on source, making its flux 10^7 greater than SN neutrinos (for a 1y measurement).
- Of course the background scales with time too, so we don't expect the full 10^7 improvement

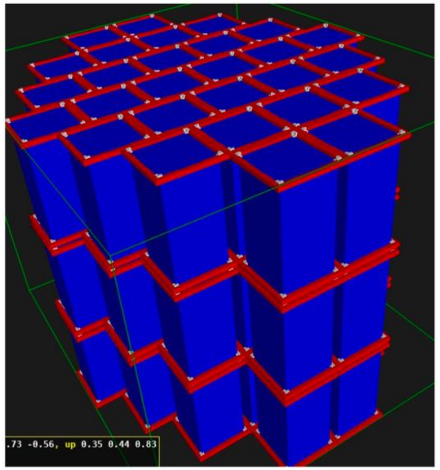
A detailed calculation yields that we can reach 10^{-43} cm^2 of sensitivity

Our background model - complete

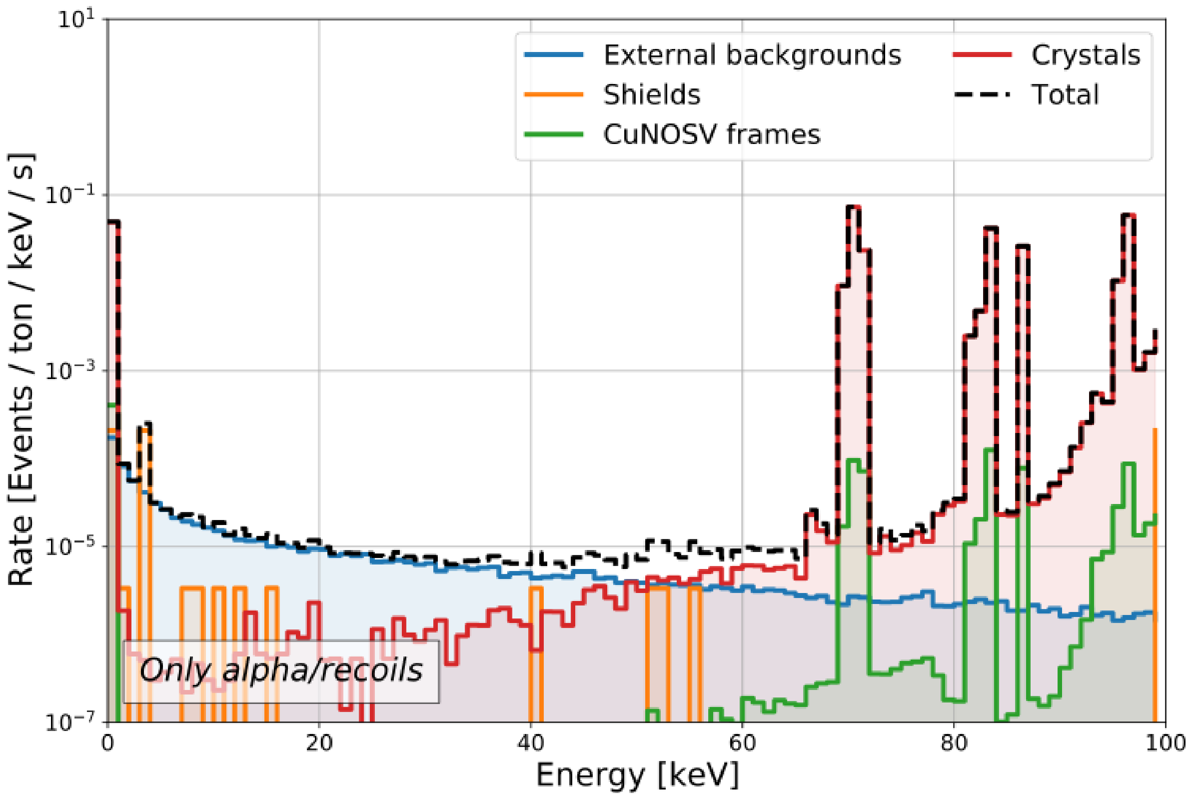


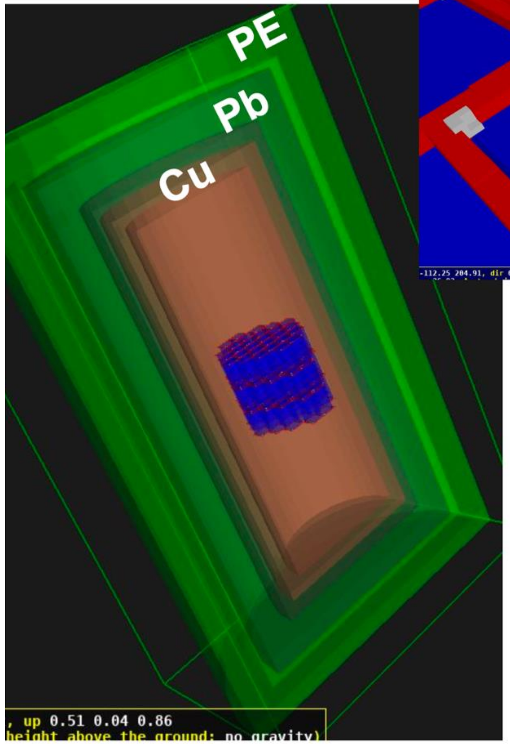


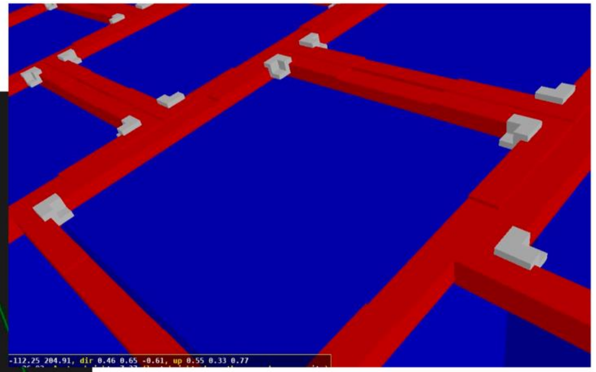


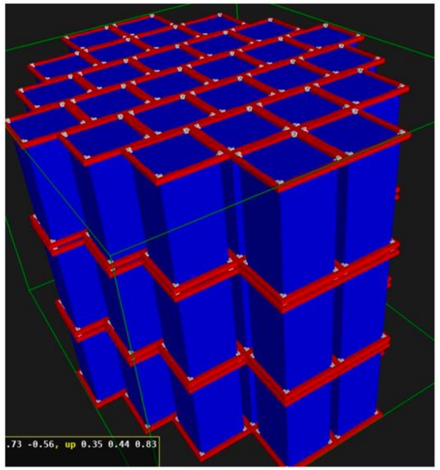


Our background model – nuclear recoils





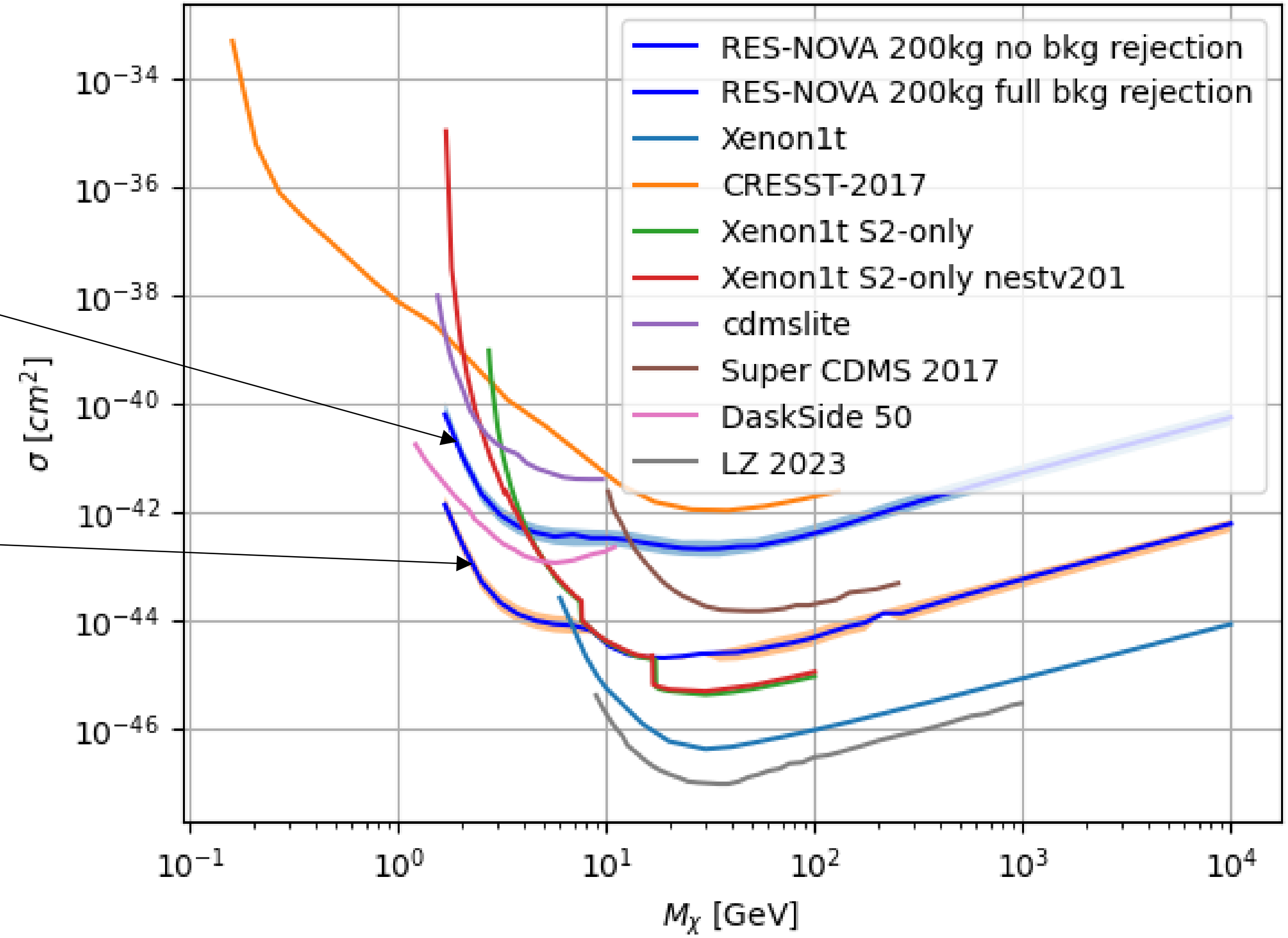




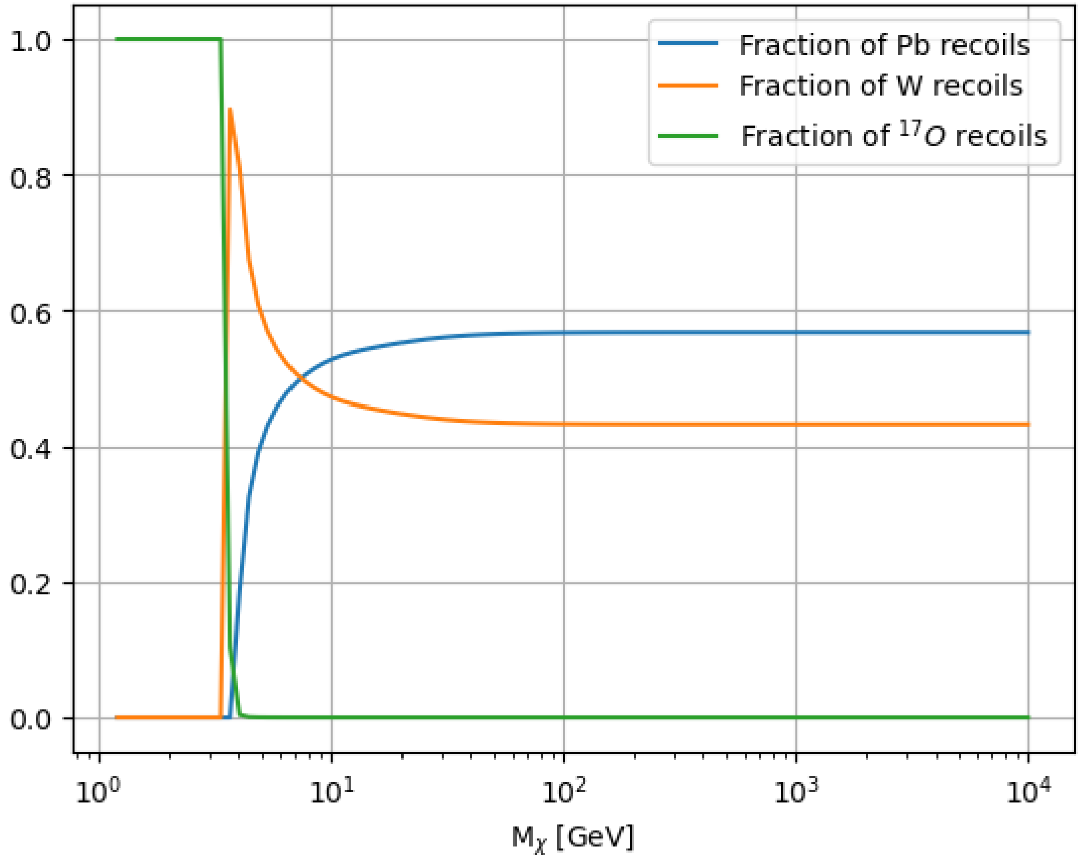
Projected sensitivity – spin independent

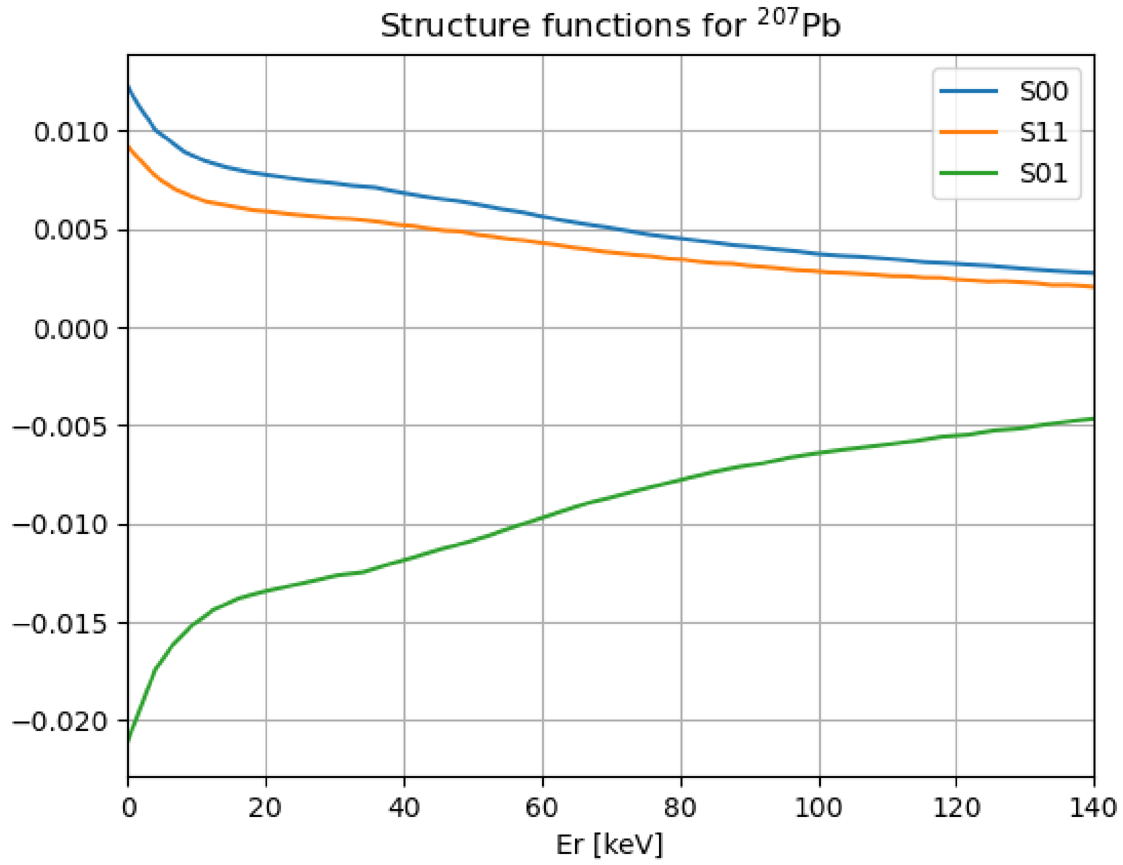
No bck rejection

Full e/gamma bck rejection



Spin-dependent sensitivity





Kosmas, T. S. and Vergados, J. D. Cold dark matter in SUSY theories, 10.1103/PhysRevD.55.1752

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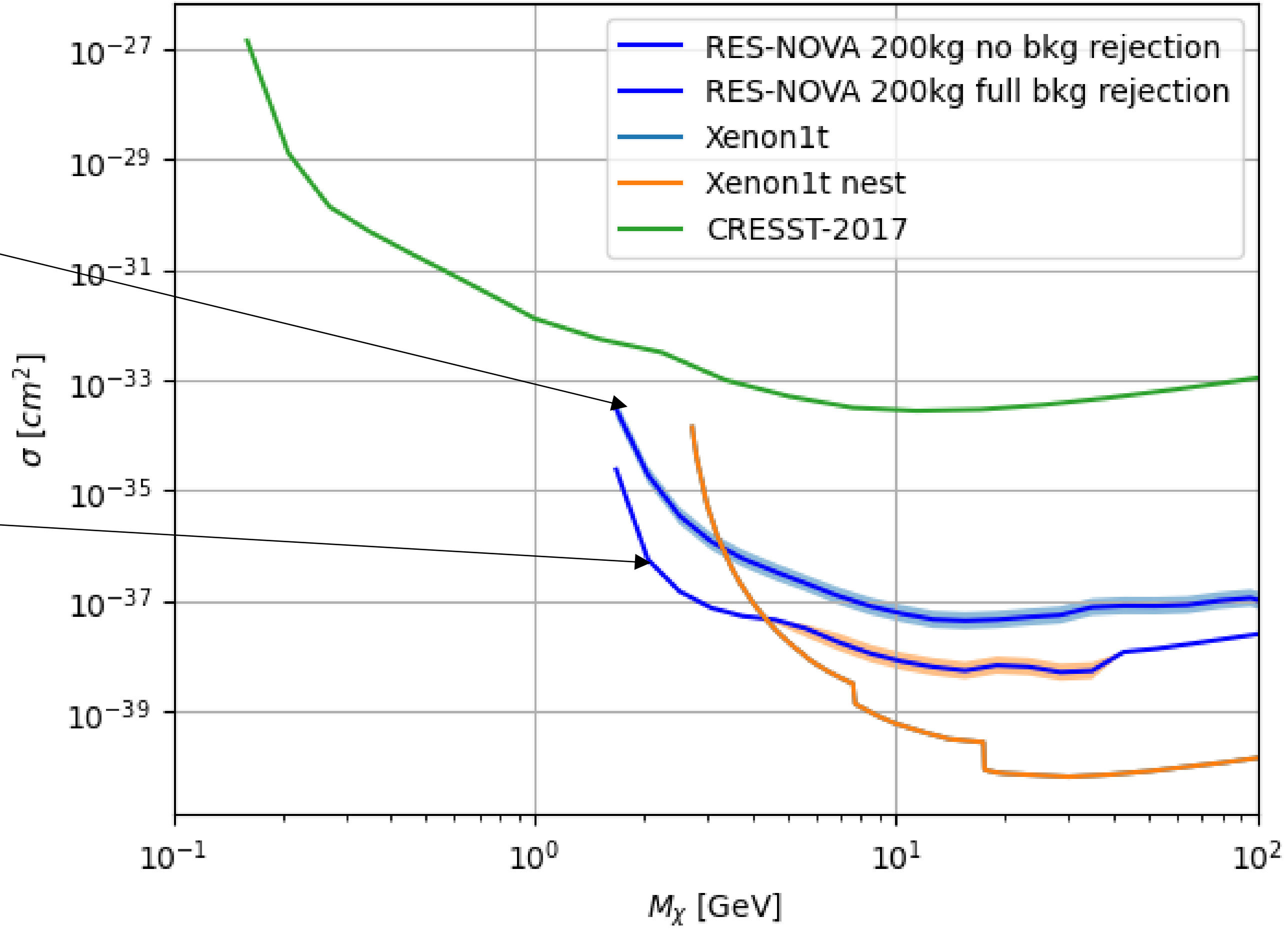

Conclusions

- SN neutrino searches based on NC faces challenges similar to those for dark matter searches
- Depending on background and performance Res-Nova has the potential to play a leading role as direct dark matter search
- The use of Archaeological Pb opens for the first time the possibility to deploy a great target (possibly the best) in a low background experiment!

Thank you!