The NEXT generation of neutrinoless double beta decay experiments

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Abstract. Neutrinos, unlike the other fermions, could be Majorana particles, that is, truly neutral particles identical to their antiparticles. This would have deep consequences in particle physics and cosmology. A unique signature of Majorana neutrinos is the observation of neutrinoless double beta decays ($\beta\beta^0\nu$). The discovery of neutrino oscillations — which has shown that neutrinos have masses — and the possible evidence of a $\beta\beta^0\nu$ signal in the Heidelberg-Moscow experiment have revolutionized the double beta decay community. A new generation of experiments with improved sensitivity is currently under design and construction. This paper reviews some of these proposals, with special emphasis in NEXT, that aims at building a 100-kg, high-pressure gas xenon TPC to be hosted in the new Canfranc Underground Laboratory (LSC), in Spain.

1. Majorana neutrinos and double beta decay
Neutrino oscillation experiments have demonstrated that neutrinos have masses and mix [1]. The mechanism responsible for generating neutrino masses may be related to the particle/antiparticle nature of the neutrino. They could be Majorana particles, that is, identical to their antiparticles. All other Standard Model fermions, being electrically charged, are instead Dirac particles, distinguishable from their own antiparticles. Majorana neutrinos provide an attractive explanation for the smallness of neutrino masses, the so-called seesaw mechanism. Besides, Majorana neutrinos violate lepton-number conservation. This, together with CP-violation, is a basic ingredient to help uncover the reasons why matter dominates over antimatter in our Universe.

The most promising experimental method to reveal the neutrino nature is the search for neutrinoless double beta decay ($\beta\beta^0\nu$, hereafter). Such a process is possible if and only if neutrinos are massive, Majorana particles. Furthermore, the measurement of the half-life of the $\beta\beta^0\nu$ decay would provide direct information on the absolute scale of neutrino masses.

Double beta decay ($\beta\beta$, in the following) is a rare transition between two nuclei with the same mass number $A$ that changes the nuclear charge $Z$ by two units. The decay can occur only if the initial nucleus is less bound than the final nucleus, and both more than the intermediate one.

There are two possible $\beta\beta$ decay modes. The two-neutrino double beta decay ($\beta\beta^{2\nu}$, hereafter), a SM-allowed process, was first proposed by Goeppert-Mayer in 1935 [2], and has since then been observed for many nuclei, such as $^{76}$Ge, $^{48}$Ca, $^{100}$Mo, $^{82}$Se or $^{150}$Nd. Typical lifetimes are of the order of $10^{19}$–$10^{20}$ years. The neutrinoless mode, $\beta\beta^0\nu$, where only the nucleus...
and two electrons are present in the final state, violates lepton number conservation. This mode was first proposed by Racah in 1937 [3], following the fundamental suggestion of Majorana [4] that same year. To date, no convincing experimental evidence for this mode exists.

Neutrinoless double beta decay can be mediated by many underlying mechanisms (involving, in general, physics beyond the SM), the simplest one being the exchange of light Majorana neutrinos. All of them imply nevertheless a Majorana mass term for the neutrino [5].

The inverse of the lifetime for $\beta\beta$ processes mediated by the exchange of light Majorana neutrinos can be expressed in terms of the phase-space factor $G^{0\nu}(E_0, Z)$ and the nuclear matrix element (NME) $|M^{0\nu}|$:

$$\frac{1}{T_{0\nu}} = m_{\beta\beta}^2 |M^{0\nu}| G^{0\nu}(E_0, Z).$$

The effective neutrino mass, $m_{\beta\beta}$, is defined as the $m_{ee}$ element of the neutrino mass matrix in the flavour basis, and therefore depends on the neutrino mass eigenstates and the elements the Pontecorvo-Maki-Nakagawa-Sakata (PMNS) mixing matrix, parameterized in terms of three mixing angle magnitudes and three complex phases.

Neutrino oscillation experiments have measured two mass-squared differences ($\Delta^2_{\text{atm}}$ and $\Delta^2_{\text{atm}}$) and two mixing angles ($\theta_{12}$ and $\theta_{23}$). The third angle ($\theta_{13}$) is known to be small. Current results do not allow to differentiate between the two possible mass orderings, usually referred to as normal and inverted hierarchies. In the former, the gap between the two lightest mass eigenstates corresponds to the small mass difference, measured by solar neutrino oscillation experiments, while in the second case the gap between the two lightest states corresponds to the large mass difference, measured by atmospheric neutrino oscillation experiments. In the particular case in which the neutrino mass differences are very small compared with its absolute scale, we speak of the degenerate spectrum, rather than of a hierarchical spectrum.

The lower and upper limits of $m_{\beta\beta}$ depend only on the mass eigenstates and on the absolute values of the mixing angles. Thus, if one observes $\beta\beta$ processes, the known values of the oscillation parameters can be used to deduce a range of absolute values for neutrino masses, as illustrated in Figure 1. Conversely, if a given experiment does not observe the $\beta\beta$ process, the result can be interpreted in terms of a bound on $m_{\beta\beta}$.

2. Search for neutrinoless double beta decay

The search for neutrinoless double beta decay relies on finding a faint signal at the transition endpoint of the $\beta\beta$ energy spectrum. Due to the finite energy resolution of detectors, $\beta\beta$ events, which should pile at $Q_{\beta\beta}$, spread over a larger region. Any background event falling into this region limits dramatically the sensitivity to the effective neutrino mass. In a background-limited experiment the sensitivity improves only as $(Mt)^{-1/4}$ — where $M$ is the total mass of $\beta$ source and $t$ is the experiment run time — instead of the $(Mt)^{-1/2}$ expected in the background-free case. Good energy resolution is therefore essential.

Unfortunately, resolution is not enough per se: a continuous spectrum arising from $\alpha$, $\beta$ and $\gamma$ radiation from the natural decay chains can overwhelm the signal peak, given the enormously long decay times explored. Consequently, extra handles to reject backgrounds are required.

Many experiments have searched for the $\beta\beta$ mode over the last fifty years. Lifetimes in the range of $10^{23}$–$10^{25}$ years have been explored, corresponding to $m_{\beta\beta} \sim 250$–1000 meV [7].

In particular, the Heidelberg-Moscow experiment [8] searched for the $\beta\beta$ decay of $^{76}\text{Ge}$ using five high-purity Ge semiconductor detectors enriched to 87% in $^{76}\text{Ge}$. The experiment achieved an exposure of 71.7 kg$\cdot$y and set the most stringent limit on the lifetime of the $\beta\beta$ process.

A group from this experiment also claims [9] a controversial 4σ evidence for $^{76}\text{Ge}$ $\beta\beta$ decay with a lifetime of about $1.2 \times 10^{25}$ y, corresponding to a $m_{\beta\beta}$ of 240–580 meV (best value: 440 meV). This claim (HM claim, in the following) sparked a debate (see, for example [10, 11]) in the
community because the signal peak is faint and the spectrum contains other unexplained peaks.

In addition, a similar experiment, which took data at the Canfranc Underground Laboratory, called IGEX [12] did not see any evidence for a signal, although its exposure (8.9 kg·y) was not enough to firmly exclude this claim.

Clearly, this controversial evidence must be confirmed or unambiguously refuted. This leads to the goal of the next-generation $\beta\beta^{0\nu}$ experiments, namely the exploration of the degenerate hierarchy ($m_{33} \sim 50-200$ meV) or, in terms of the lifetime, which is not affected by uncertainties on the NME, one would like to explore the region of $10^{26}$ years. To reach that sensitivity and do reliable measurements, about 100 kg of the decaying isotope are necessary.

In order to fully explore the inverse hierarchy one has to reach a sensitivity of $m_{33} \sim 20$ meV, or lifetimes of the order of $10^{27}$ y. Observation of $\beta\beta^{0\nu}$ decay at this mass scale would imply the inverted neutrino mass hierarchy, or a normal ordering within a quasi-degenerate spectrum. To establish the correct mass pattern, additional input from the overall neutrino physics program could be necessary. The study of this mass range requires experiments at the ton-scale.

The 1–5 meV $m_{33}$ region arises from the solar neutrino oscillation results and corresponds to the normal hierarchy. Reaching this range would require hundreds of tons of the decaying isotope (and a virtually background free experiment).

3. New experiments

Many new $\beta\beta^{0\nu}$ experiments have been proposed in the last 10 years, and most of them are already in the early stages of construction. This multiplicity is indeed a good strategy, since different nuclei are studied — thus minimizing the uncertainties associated to nuclear matrix elements — and several experimental techniques, with different impact of backgrounds and systematic errors, are used. Table 1 collects some of the most active projects.

The GERDA and MAJORANA Collaborations propose new Ge detectors to take advantage of the Heidelberg-Moscow and IGEX experiences. This is a well-established technique that
offers outstanding energy resolution (0.15% FWHM at the Q-value of the $\beta\beta$ decay) and high efficiency, but limited methods to reject backgrounds.

CUORE and its demonstrator, CUORICINO, are arrays of TeO$_2$ bolometers. Because $^{130}$Te has a large natural isotopic abundance ($\sim$34%), the need for enrichment is less important. The pros and cons of the technique are similar to those of Ge experiments: energy resolution is better than 0.5% at $Q_{\beta\beta}$, and the efficiency for the signal is $\sim$85%; background identification is not possible, but the segmentation of the detector allows the rejection of multiple-hit events.

SNO+ is a proposal to fill the Sudbury Neutrino Observatory (SNO) vessel with liquid scintillator. A mass of several hundred kg of double beta decaying material could be added to the experiment by dissolving a neodymium salt in the scintillator ($^{150}$Nd natural abundance is 5.6%). This would make SNO+ the largest $\beta\beta^{0\nu}$ experiment of the next generation. However, the energy resolution will be modest ($\sim$8% FWHM at 1 MeV) for a pure-calorimetric experiment.

SuperNEMO is the proposed expansion of the NEMO-3 detector, still in operation at the Laboratoire Souterrain de Modane. Its principle of operation is based on the use of thin foils of the $\beta\beta$ emitter surrounded by a tracking chamber and a calorimeter. Track reconstruction provides a topological signature useful to discriminate signal and background. However, this design suffers from a poor energy resolution, due to the use of plastic scintillator for the calorimeter, and from the fact that it is not a fully active detector.

The Enriched Xenon Observatory (EXO) will search for $\beta\beta^{0\nu}$ decay in $^{136}$Xe using a liquid-xenon TPC with 200 kg mass during its first phase. The ultimate goal of the Collaboration is to develop the so-called barium tagging, that would allow the detection of the ion product of the $^{136}$Xe decay, and thus eliminate all backgrounds but the intrinsic $\beta\beta^{2\nu}$ (which is suppressed by the good enough energy resolution of the detector).

For further details about the world-wide experimental program, the reader is referred to [13].

| Experiment | Isotope | Technique | Reference |
|------------|---------|-----------|-----------|
| CUORE      | $^{130}$Te | TeO$_2$ bolometers | [14] |
| EXO        | $^{136}$Xe | LXe TPC | [15] |
| GERDA      | $^{76}$Ge | Enr. Ge semicond. det. | [16] |
| MAJORANA   | $^{76}$Ge | Enr. Ge semicond. det. | [17] |
| SNO+       | $^{150}$Nd | Nd loaded liq. scint. | [18] |
| SuperNEMO  | $^{82}$Se | Se foils in tracko-calco | [19] |

4. The NEXT experiment

The Neutrino Experiment with a Xenon TPC (NEXT) is the new kid on the block of the double beta decay community. NEXT marries an old concept (a gas xenon TPC) and a new experimental approach (a SOFT, electroluminescent TPC), collecting many of the most desirable features needed for a successful $\beta\beta^{0\nu}$ experiment:

- Good energy resolution, probably better than 1% FWHM at $Q_{\beta\beta}$ (to be compared with 0.2–0.5 % of GERDA, MAJORANA and CUORE, 3–4% of EXO, 8% of SNO+ and 8–12% of SuperNEMO).
- Topological signature of the two electrons, used for background rejection (like SuperNEMO and unlike all the others).
- A fully active detector (like GERDA, MAJORANA, CUORE, SNO+ and EXO and unlike SuperNEMO).
A detector easy to extrapolate to larger masses (like SNO+ and EXO and unlike all the others).

Xenon is the only noble gas that has a $\beta\beta$ decaying isotope, $^{136}$Xe (with 9% natural abundance). In addition, it does not have other long-lived radioactive isotopes and can be enriched by centrifugation methods to high concentrations of $^{136}$Xe. Its $Q_{\beta\beta}$ value, 2480 keV, is acceptably high. The $\beta\beta^{2\nu}$ mode life-time, not yet measured, may be as long as $10^{22}$–$10^{23}$ y. Finally, the $\beta\beta^{0\nu}$ mode life-time is predicted to be almost as short as the one of the other commonly-used $\beta\beta^{0\nu}$ isotope, $^{76}$Ge [20]. Since xenon is a noble gas, it is possible to use it as a tracking gas in a Time Projection Chamber.

The Gotthard collaboration built a small (pressurized) gas TPC for $\beta\beta^{0\nu}$ searches in the 1990’s [21, 22]. This detector had a fiducial mass of 5 kg and operated a 5 bar. Its energy resolution was mediocre (6% FWHM at $Q_{\beta\beta}$) due, probably, to the addition of CH$_4$ (5%) — to stabilize the gas and increase the drift velocity —, that quenched both the ionization and the scintillation light, and the use of conventional gain amplification in a wire plane. Furthermore, the detector did not measure the start-of-event, resulting in large backgrounds due to tracks emanating from the anode and cathode.

Also, a liquid TPC, using 200 kg of enriched xenon, has been built to search for $\beta\beta^{0\nu}$ events, by the EXO collaboration. Clearly LXe TPCs have some advantages over high-pressure gas xenon (HPGXe) TPCs, the most important one being its compactness. The density of liquid xenon is about 3 g/cm$^3$, or 3 tons for a volume of 1m$^3$. In contrast, the density of gas xenon at 10 bar is 0.05 g/cm$^3$, corresponding to only 50 kg of xenon per cubic meter. A more compact detector has a smaller volume-to-surface ratio and offers, therefore, a smaller cross section to external backgrounds, such as gammas emanating from the laboratory walls or the detector vessel. It also requires less instrumentation, which in turn minimizes the internal radioactivity (per unit of active xenon mass). Furthermore, the apparatus itself provides a good self-shielding (external gammas will tend to interact near the detector wall) at the cost of a non-negligible efficiency.

Why consider a HPGXe TPC for $\beta\beta^{0\nu}$ searches, then? The answer has to do with the different properties of the liquid and the gas phases. The high density of the liquid—usually a blessing—is a curse when it comes to the observation of the signal topology. The characteristic signature from a $\beta\beta$ event is two electrons whose energies add up to $Q_{\beta\beta}$ (2480 keV). Electrons in this energy range are easily tracked in gas, but deposit all their energy in a blob in the much denser liquid. Therefore, while the gas TPC can resolve blobs within a single track topology, the liquid TPC cannot. Because of this, it is much more difficult for a LXe detector to distinguish between a $\beta\beta$ event and a gamma interaction that deposes by photoelectric or Compton effect an energy in the vicinity of $Q_{\beta\beta}$.

Consider now a $\beta\beta$ event produced in a HPGXe. The average energy of the two electrons is about 1250 keV, and at 10 bar each electron travels about 15 cm. The trajectory of the electron in the gas is completely dominated by multiple scattering. The resulting “topological signature” is a twisted track that includes both electrons. In terms of ionization, the track behaves like a minimum ionizing particle (MIP), depositing about 70 keV per cm, except at both ends, where each electron deposit 200 keV or more of energy as it ranges out. The picture is that of a “spaghetti with two meat balls” (Figure 2).

Perhaps even more important than the topological signature, and often not fully recognized as such, is the fact that a HPGXe detector can feature a much better energy resolution than a LXe one. The ionization of liquefied noble gases is accompanied by fluctuations much larger than predicted by Poisson statistics. However, the anti-correlation existing between $S$ and $I$ signals is

1 In practice, one can have some level of rejection in the case of Compton interactions if a second, separated energy deposit due to the absorption of the scattered gamma is observed.
exploited to improve the energy resolution from 4.2% FWHM (ionization-only) to 3.3% FWHM (ionization plus scintillation) at $Q_{\beta\beta}$ [23]. In the EXO200 detector, this is accomplished by simultaneously reading the $S$ signal by means of APDs, and the $I$ signal using two 60° crossed wire planes.

In HPGXe extremely low fluctuations — close to the theoretical limit — can be reached using electroluminescence (EL) to amplify the ionization signal: when an electron is accelerated in a moderate electric field (of the order of 3-5 kV/cm/bar), it produces secondary scintillation UV light. The field can be tuned to generate a large number of photons (of the order of 1000) per electron reaching the anode, thus producing a proportional signal, which is crucial for optimal energy resolution.

![Figure 2. The topological signature in NEXT is a “spaghetti with two meat balls”, that is, a track that ends in two “blobs” of energy, corresponding to ranging-out electrons. The trajectory of electrons contains no information, being dominated by multiple scattering in the dense gaseous xenon.](image)

5. The design of the NEXT TPC
NEXT is based in a new experimental concept that we call SOFT (Separated-Optimized Function for Tracking) TPC. The key idea is to use two different technologies of photosensors, one for the energy function and one for the tracking function. The energy function is implemented by instrumenting the chamber with about 250, 1 inch-size, squared PMTs. This represents a modest cost (400 k€) and relatively small radioactivity budget (200 mBq). The tracking function is based on the detection of the EL light via photo-sensors. In this case, the tracking must be provided by an array with better pixelization than the one for the energy function (pixels of 1-1.5 cm rather than 2.5 cm), and with less radioactivity and less cost per unit sensitive area. The energy resolution of the tracking cells does not need to be as good as the one of the energy cells, since the only purpose of such energy information is to distinguish “mip-like” from “blob-like” energy deposition.

We plan to use silicon photosensor devices, with the following advantages with respect to conventional PMT readout: a) smaller pitch, b) smaller cost (as low as 20 euros, to be compared with some 800 euros per PMT) and c) very low levels of radioactivity. The devices are placed inside a matrix formed by a Teflon piece which holds the silicon photosensors and defines the pitch (at about 1-1.5 cm). The entrance window is covered with glass or synthetic quartz coated with WLS (TPB) that shifts light to the region of maximum silicon photosensor quantum
efficiency. The photosensor, together with its holder, is placed in each cell of the matrix and receives the photons impinging directly on its surface.

6. Physics potential of NEXT

Next-generation $\beta\beta^0\nu$ experiments aim at exploring the so-called degenerate hierarchy, corresponding to effective neutrino mass values down to 50 meV. If no signal is found, the inverse hierarchy, extending from 20 to 50 meV will be accessible only to experiments that can simultaneously achieve large fiducial mass and negligible backgrounds.

In order to confirm or unambiguously refute the signal claimed by the group of the Heidelberg-Moscow experiment led by Klapdor-Kleingrothaus, one needs to be sensitive to $m_{\beta\beta} \sim 50 - 100$ meV or, in terms of the period, to $10^{26}$ years. In particular, to exclude a signal at 240 meV (lower limit of the HM claim) with a confidence level of $\sim 90\%$, a sensitivity of $m_{\beta\beta} \sim 110$ meV needs to be achieved. Conversely, if a detector with such a sensitivity founds a signal at 240 meV, it would be able to measure it with $\sim 3\sigma$.

Accordingly, the goal of the NEXT-100 experiment is to build and operate a 100 kg TPC capable of exploring down to $m_{\beta\beta} \sim 100$ meV, hence confirming or refuting the HM claim. Such a detector will be large enough to prove the feasibility of scaling the technology up to a 1-ton detector.

The importance of a background source in NEXT depends on the energy resolution and also on the track identification capabilities of the detector. Only those events with energy around or above $Q_{\beta\beta}$, and able to mimic a signal track can become a background.

Double beta decay events have a distinctive topological signature in HPGXe: a ionization track, of about 30 cm length at 10 bar, tortuous because of multiple scattering, and with larger depositions or blobs in both ends (Figure 2).

Background events with charged particles entering the active volume can be rejected defining a fiducial volume few centimeters away from the chamber walls. The reliability of such a veto depends on the accuracy of the $t_0$ measurement. High-energy photons create electrons far from the detector walls through Compton interactions, pair-creation and photoelectric absorption.

The $\beta\beta^0\nu$ peak of $^{136}$Xe is located in the energy region of the naturally-occurring radioactive processes. Although the half-life of the parents of the natural decay chains is comparable to the age of the universe, it is very short compared to the desired half-life sensitivity of the new $\beta\beta^0\nu$ experiments ($10^{26}$ years). For that reason, even a small quantity of these nuclides creates significant event rates.

In our case, the dangerous isotopes are $^{208}$Tl and $^{214}$Bi, from the thorium and uranium series, respectively. They emit beta radiation accompanied by alpha and gamma particles due to subsequent decays and nuclear de-excitations of their daughter nuclei.

The daughter of $^{208}$Tl emits a de-excitation photon of 2614 keV with a 100% intensity. The Compton edge of this gamma is at 2382 keV, well below $Q_{\beta\beta}$. However, the scattered gamma can interact and produce other electron tracks close enough to the initial Compton-electron so they are reconstructed as a single object falling in the energy Region of Interest (ROI). Pair-creation events are not able to produce single-track events in the ROI. Photoelectric electrons are produced above our ROI but can loose energy via bremsstrahlung and populate the window, in case the emitted photons escape out of the detector.

After the decay of $^{214}$Bi, its daughter emits a number of de-excitation gammas with energies above 2.3 MeV. The gamma line at 2447 keV (intensity: 1.57%) is very close to $Q_{\beta\beta}$. The photoelectric peak may infiltrate into the ROI for resolutions worse than 1.5–2%. The gamma lines above $Q_{\beta\beta}$ have low intensity (below 0.1%), but their Compton spectra can produce background tracks in the ROI.

A sketch of the ROI considering the above description can be seen in Figure 3.
All materials contain $^{208}$Tl and $^{214}$Bi impurities in a given amount. Careful selection of radiopure materials and purification is mandatory for all double beta decay experiments. Indeed, new-generation detectors are being fabricated from amazingly pure components, some with activities as low as $10 \mu$Bq/kg or less.

In addition, one has to worry about radon gas: either $^{222}$Rn (half-life of 3.8 d) from the $^{238}$U chain or $^{220}$Rn (half-life of 55 s) from the $^{232}$Th chain. As a gas, it diffuses into the air and produces background if it enters the detector. This contamination can be translated into $^{214}$Bi, for the $^{222}$Rn, or into $^{208}$Tl, for the $^{220}$Rn, their only decay products affecting the experiment. In case of equilibrium, the activity of the radon and that of their products is the same.

In both cases, the radon suffers from an alpha decay into polonium, producing a negative ion which is drifted towards the anode by the electric field in a TPC. Then, $^{214}$Bi and $^{208}$Tl contaminations can be assumed to be deposited on the anode surface. In such a way, 1 Bq/m$^3$ of radon will mean $\ell$ Bq/m$^2$ for its daughter, $\ell$ being the length of the chamber (assuming an anode covering the full base). Radon may be eliminated from the TPC gas mixture by recirculation through appropriate filters. Also, some underground laboratories have installed charcoal Rn scrubbers into the airstream.

Cosmic particles can also affect our experiment by producing high energy photons or activating materials. This is the reason why double beta decay experiments are conducted deep underground. At these depths, muons are the only surviving cosmic ray particles, but their interactions with the rock produce neutrons and electromagnetic showers. Muon veto detectors can easily eliminate this background contribution.

Before being stored underground, materials can be activated by energetic cosmic neutrons, which have sizable penetrating power. Once being underground, the capture of low-energy neutrons can also produce radioactive isotopes in the detector.

In summary, five types of background are foreseen:

(i) Radioactive contamination of detector materials: vessel, readout plane, etc. Careful

Figure 3. The landscape near the end-point of $^{136}$Xe, as a function of deposited energy. The normalization of the different peaks is arbitrary. The purpose of the plot is to show how the $\beta\beta^{0\nu}$ signal is sandwiched between the dominant $^{214}$Bi and $^{208}$Tl backgrounds.
selection of radiopure materials is necessary to suppress this background as much as possible.

(ii) Radioactive contamination of laboratory walls. In this case, only photons are able to reach the detector. This background can be attenuated by shielding.

(iii) Radioactive contamination of the shielding itself.

(iv) High energy photons due to muon interactions. The muon flux itself is strongly suppressed by operating in an underground laboratory.

(v) Neutron activation.

All this backgrounds have been recently evaluated by the NEXT collaboration [24]. Together with the excellent energy resolution, the topological signature of the processes taking place inside the TPC provides an extra handle to discriminate between signal and background events. A minimal set of selection cuts allows to reject background events with high efficiency. Total suppression factor is \(\sim 4 \times 10^{-7}\) for \(^{214}\text{Bi}\) and \(\sim 4 \times 10^{-6}\) for \(^{208}\text{Tl}\). Signal detection efficiency due to selection cuts is about 40%.

On top of the above selection one should apply now the condition that the track ends in two blobs. However, this selection criterium implies a pattern recognition algorithm which identifies the blobs and match them to the track with a certain goodness. The NEXT Collaboration is working on the optimization of such an algorithm, and preliminary results yield a rejection factor of about 1/50. The rejection power of this cut measured by the St. Gotthard TPC was roughly a factor 1/30, hence consistent with our preliminary estimations.

![Figure 4. Sensitivity to \(m_{\beta\beta}\) at 90% C.L. of the SOFT ASTPC as a function of the exposure, assuming energy resolution of 1% at \(Q_{\beta\beta}\). The solid line shows results with a standard 1-cm thick vessel made of radiopure steel (1 mBq/kg). The dotted line shows results for an optimized (introducing ten times less background) vessel. The dashed line represents the sensitivity when all backgrounds are negligible.](image)

Taking into account background estimates, signal detection efficiency and background rejection factors, we have estimated the sensitivity of the NEXT experiment to the \(\beta\beta^{0}\nu\) process, assuming the exchange of a light, Majorana neutrino. Results are given for a 90% confidence level (C.L.). The NME for \(^{136}\text{Xe}\) is taken from Reference [25]. The best case for the NEXT experiment is that one in which all external background have been suppressed down to a negligible level by means of shielding. For this particular scenario, the sensitivity achieved by the asymmetric SOFT TPC can be seen in Figure 4 for three different background assumptions.

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