Unique advantages can be obtained from the usage of a gaseous isotope in a neutrino-less double beta decay experiment, in particular when used as the filling gas of a Time Projection Chamber. Exemplarily, such a configuration allows the addition of suitable gas dopants that naturally increase, due to the enhanced primary ionization cooling, the sharpness of the reconstructed tracks by a factor nearing 300 relative to pure Xenon (down to the mm3 scale) while keeping the isotope content virtually unaffected, at 98-99% levels [1,2,3]. NEXT is the only projected experiment that will make use of the two-blob characteristics of the bb-events in order to suppress gamma-ray backgrounds from natural radioactivity; if the aforementioned position accuracy could be demonstrated in conditions in which enough light collection can be simultaneously achieved (an essential asset for NEXT), it would potentially mean an unprecedented 0.5% tracking precision of the (ca. 20cm-long) tortuous bb-tracks, with the anticipated enhancement in the corresponding background suppression factors. Systematically scanning the phase-space of plausible drift fields and admixtures requires of several high-end gas systems and setups in order to demonstrate the overall performance, before the technique can be safely ported to the main experiment. Setups focused on light readout at University Berkeley and LIP Coimbra [4,5] as well as charge readout at Zaragoza University [2,6] have been already developed by the collaboration and are already closing in the Xenon+TMA scenario. TMA (tri-methylamine) is one of the so called ‘Penning-fluorescent’ molecules, a small family of molecules to which few other amines (TEA, DMA) as well as few other rarer non-commercial molecules belong too. These mixtures are known to, besides reducing the electron diffusion and thus enhancing the track sharpness (as already mentioned), allow the recovery of a substantial part of the energy transferred to the medium by a bb event (through Penning-transfer reactions [6]), as well as to produce fluorescence light at 300nm, a much more convenient wavelength for detection than the natural Xenon emission, peaked at 170nm. Encouragingly, TMA shows the desired performance concerning wave-length shifting [4] and reduced diffusion [2], although the absolute yields for primary and secondary scintillation, as well as the optimal admixture, are still in the process of being determined.

*The present and future of gas additives in Rare Event Searches:*

* We foresee the exploration of the usage of additives along the master plan followed by the collaboration, which has been previously sketched. At Santiago University, it will be implemented through a 2-stage approach: first, the currently ongoing work for the characterization of Xenon-mixtures will continue through a collaboration with Zaragoza University, where a light-chamber is currently being commissioned, besides the existing charge one. By the time the project starts at Santiago University it is likely that the Xe-TMA system is largely described/understood. If successful, future work would focus on stablishing procedures for handling, mixing and separating the new gas, consolidating/replicating the results as well as developing highly granular (1mmx1mm) readouts, e.g. based on Micromegas [6], where the potential of the new low-diffusion gas could be maximally exploited. It is almost guaranteed, however, that work will continue along other unexplored mixtures (chiefly TEA, DMA) that may allow additional improvements as well as increasing the understanding of the underlying microscopic processes. During this first stage (1-1.5 years), a collaboration will continue with Zaragoza University in either of the aforementioned scenarios and, after this time period, the deployment of a minimal gas system for locally following up the measurements will take place at Santiago de Compostela University. With 4 world-quality setups (Berkeley, Zaragoza, Coimbra, Santiago) this will leave the collaboration in an optimal position for consolidating its leadership in the usage of Xenon gas mixtures for Rare Event searches.
* ‘Game-changing’ potential of additives. In parallel to this main-stream activity, the collaboration is exploring two possibilities that could become eventually ‘game-changers’ in the corresponding fields: i) the possibility of obtaining a directional Dark Matter signal by resorting to gas columnar recombination as well as ii) the possibility of performing ‘in situ’ laser Barium tagging by resorting to the fast charge transfer reaction Ba+++A -> Ba++A+ as well as de-shelving reactions Ba+\*(2D3/2)+A -> Ba+\*(2S1/2)+A.
  + The possibility of using columnar recombination as a ‘tool for physics’, put forward by D. Nygren in 2013 [7], has been recently demonstrated for Xe-TMA mixtures. A charge asymmetry Q0/Q90 (ratio of the charges collected in the direction parallel and perpendicular to the electric field) as large as 60% for alpha tracks was observed [8], and current work is focused on establishing the value of this figure for nuclear recoils under typical conditions. If the effect would be significant for nuclear recoils it will, in the most optimistic scenario, enable a future dual-purpose NEXT-1T experiment (DM and bb0). More realistically, it would greatly enhance the scientific impact of gas-based TPCs for DM searches [9] by providing a new discrimination handle. The latter could be applied to very light gas TPCs (e.g. He, Ne) forming conveniently optimized gas mixtures that would allow covering the low WIMP-mass region, a region that is hardly accessible to existing techniques and that is receiving increasing attention in view of the negative results obtained in the (a priori) better motivated ‘WIMP-miracle’ 100GeV/c2 region.
  + The second possibility, the ‘in situ’ Ba-tagging, was explored by the EXO-gas collaboration nearly 15 years ago [10] but was abandoned lately in virtue of a ‘extraction + tagging’ approach, based on considerations concerning precisely the lack of control on the effect that any used additives may have[11]. The basic idea of the ‘in situ’ approach is to exploit an unique property of the gas phase, the possibility of tagging the 136Ba daughter of a bb decay directly ‘in situ’ by resorting to a laser and making use of its characteristic atomic levels, without being blurred by the additional line broadenings present in the condensed phases. The fundamental (not only) requirements of an additive to work in the ‘in situ’ mode would be to allow for the charge transfer reaction Ba+++A -> Ba++A+ [10] as well as to allow for fast de-shelving collisional rates from the metastable Ba+\*(2D3/2) state, allowing for the production of multiple tagging-photons [11]. NEXT has started exploring these possibilities towards a future 1 Ton experiment, and the usage of low ionization potential (IP) additives (like TMA) seems at the moment of paramount importance, since otherwise Ba++ will largely remain in the doubly-ionized state, a state not susceptible of laser tagging at convenient wavelengths.

Pursuing the use of new additives finds a straightforward application in increasing the topological capabilities of the NEXT experiment and will cross-fertilize with our own developments of topological reconstruction algorithms. As mentioned, additional possibilities with potential for a strong scientific impact could stem from these activities, which would require of a minimal gas system (see below) to be deployed at Santiago de Compostela. The main characteristics of these type of systems can be understood from the extraordinary requirements needed for the operation of HP Xe-TPCs (and from the increasing price of Xenon), with required impurity levels as low as ppb-ppt (parts per billion-trillion). This generally requires the usage of mass spectrometers or residual gas analyzers (RGA), specialized filters/getters, a vacuum system and thermal jackets or IR-lamps for bake-out, as well as considerable expertise in high pressure design, safety and system handling, that the NEXT collaboration already has.

*Minimal gas system:*

The minimum requirements for a performing world-leading gas system for this type of physics are 0) physical space for the piping and auxiliary hardware, about 4mx4m at least, together with a small 2mx2mx2m external hut for storing the gas bottles; A) a vacuum line: including a mass spectrometer or RGA, vacuum pump, ultra-high vacuum pressure-gauges, B) a high pressure line: including a recirculation pump, O2–filters, high pressure-gauges and generic gas equipment: valves, gaskets, flanges and vessels. Additionally, the team in Santiago de Compostela University will further strengthen its collaboration with Zaragoza University and with the RD51 collaboration, through the acquisition of different micro-patterned sensors, focused on the radiopure *microbulk* micromegas devices [12], with designs depending on the needs that will arise during the development of the project. A cost estimate of the needed equipment is given below. There is no estimate for engineering or technical support, for which details have been explained in this call elsewhere.

|  |  |  |
| --- | --- | --- |
|  | Type | price |
| Vacuum pump | Vacuum line | 10kE |
| Re-circulation pump | Pressure line | 3kE |
| 3 HP gauges | Pressure line | 3x0.5kE |
| 3 ultra-LP gauges | Vacuum line | 3x1.5kE |
| Mass spectrometer or RGA | Vacuum line | 40kE |
| 2 Filters/Getters | Pressure line | 2x1.5kE |
| 5kg Xenon bottle | Pressure line | 15kE (price extrapolated to 2015) |
| various Micromegas sensors | Detection | 6kE |
| Piping + installation + hut | Infrastructure | 5kE |
| Gas components, gaskets, vessels | Infrastructure | 5kE |
| Bottles with additives | Pressure line | 5kE |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  | 98kE |

*References:*

[1] V. Alvarez et al., *‘*[*Description and commissioning of NEXT-MM prototype: first results from operation in a Xenon-Trimethylamine gas mixture*](http://inspirehep.net/record/1264316)*’***, JINST 9(2014)P03010.**

[2] V. Alvarez et al., *‘*[Characterization of a medium size Xe/TMA TPC instrumented with microbulk Micromegas, using low-energy](http://inspirehep.net/record/1264546)*[γ](http://inspirehep.net/record/1264546)*[-rays](http://inspirehep.net/record/1264546)*’,* **JINST 9(2014)C04015**.

[3] Diego Gonzalez-Diaz, *‘*First results from a 10bar Xe-TPC with 1kg fiducial mass, read out with micropattern gaseous detectors*’,* presented at **TIPP(2014)**, Amsterdam (05/06/14).

[4] A. Goldschmidt, *‘*Development of High Pressure Xenon Detectors for Dark Matter and Neutrino-less Double Beta Decay*’*, presented at NEUTRINO(2014), 02-06, Boston, USA.

[5] E. Freitas, *‘Study of CH4–Xe mixtures’* XV NEXT collaboration meeting, **IFIC, 15-2014**.

[6] S. Cebrian, T. Dafni, E. Ferrer-Ribas, I. Giomataris, D. Gonzalez-Diaz et al., MicrOMEGAs-TPC operation at high pressure in xenon-trimethylamine mixtures, **JINST 8(20013)P01012**.

[7] D. Nygren., *‘Columnar recombination: a tool for nuclear recoil directional sensitivity in a xenon-based direct detection WIMP search’*, **J. Phys.: Conf. Ser. 460 (2013) 012006**.

[8] D. C. Herrera, *‘Study of Columnar Recombination in Xe+trymethilamine Mixtures using a Micromegas-TPC’*, presented at **TIPP(2014)**, to be published in **PoS**.

[9] I. G. Irastorza et al., *‘*[*Status of R&D on Micromegas for Rare Event Searches: The T-REX project*](http://inspirehep.net/record/927771)*’,*  **EAS Publ.Ser. 53 (2012) 147-154**.

[10] M. Danilov et al., *‘Detection of very small neutrino masses in double-beta decay using laser tagging’*, **Phys. Lett. B 480(2000)12**.

[11] E. Rollin, *‘Barium Ion Extraction and Identification from Laser Induced Fluorescence in Gas for the Enriched Xenon Observatory’* **PhD thesis, 2011**.

[12] S. Cebrian et al., *‘[Radiopurity of Micromegas readout planes](http://inspirehep.net/record/855864)’* **Astropart.Phys.** **34(2011)354**.