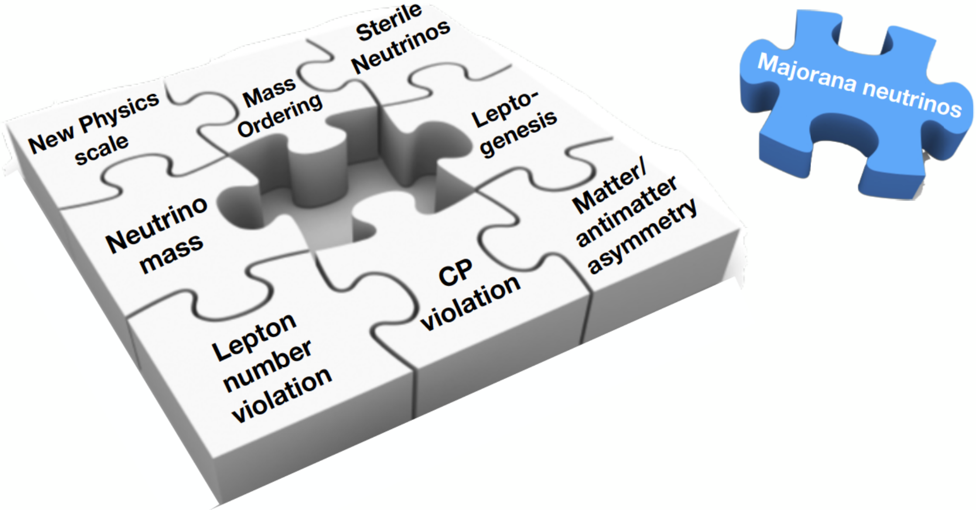
The NEXT Project

J.J. Gómez Cadenas/DIPC

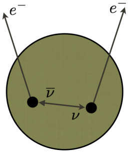
Donostia International Physics Center and Ikerbasque

November 20, 2025

Majorana neutrinos are central to new physics

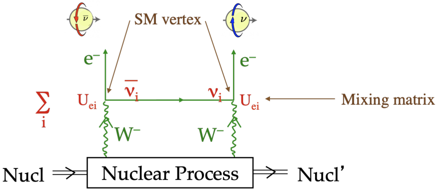


$\beta\beta0\nu$. If and only if neutrinos are Majorana Particles



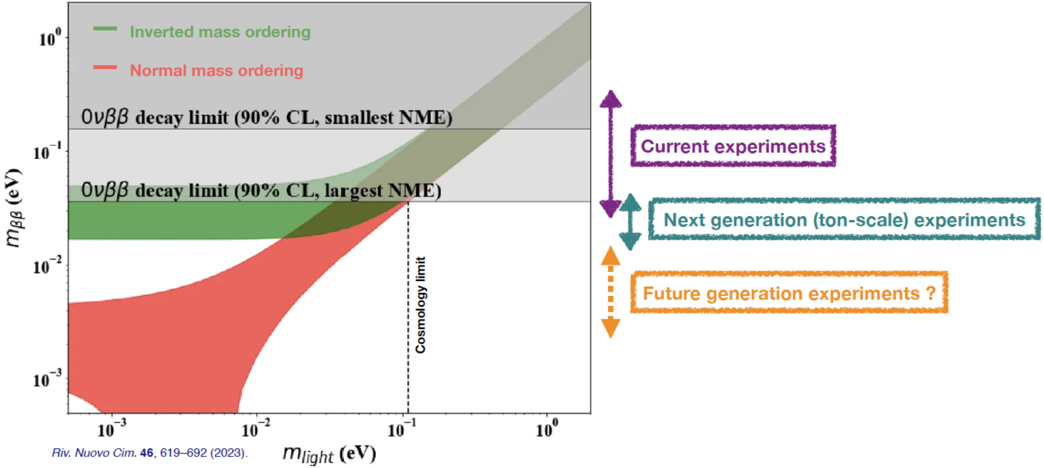
$\beta\beta0\nu$

$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu}(Q, Z)\ |M^{0\nu}|^2\ m^2_{\beta\beta}$$



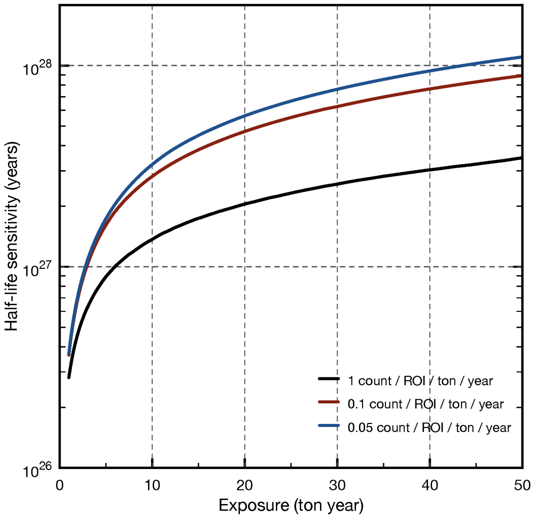
- Inverse of the lifetime is proportional to $m^2_{\beta\beta}$. For small neutrino masses this results in very long lifetimes (effect vanishes if the neutrino mass is zero).
- No neutrinos are emitted in the process, leading to a "golden signature".
- Knowledge of NME necessary (and difficult).

Searching for $\beta\beta0\nu$: the road to discovery



Riv. Nuovo Cim. **46**, 619–692 (2023).

The challenge for $\beta\beta0\nu$ experiments

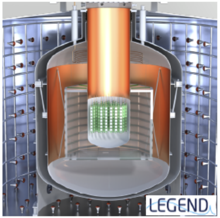


- Full exploration of the IH requires large exposures and tiny backgrounds.
- A Xe detector with an efficiency of 30% requires $\sim$ 50 kton· year to reach $(T^{0\nu}_{1/2})^{-1} \sim 3.5 \times 10^{27}(10^{28})$, for a background of $\sim\leq$ 1(0.1)/ton/year in the ROI (1 FWHM). Notice the law of diminished returns here. Gaining a factor 3 in sensitivity to lifetime requires reducing backgrounds by one order of magnitude.
- This implies (multi)-ton fiducial masses, long exposures (which in turn requires high stability), and detectors with high rejection power and ultra-low radioactive budgets.

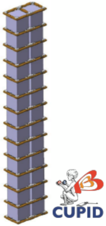
Experimental program to explore inverse hierarchy

- Currently proposed $0\nu\beta\beta$ tonne-scale experiments:

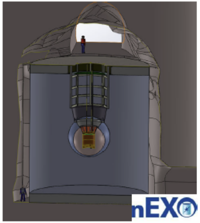
LEGEND-1000



CUPID



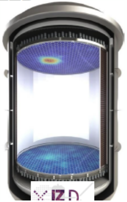
nEXO



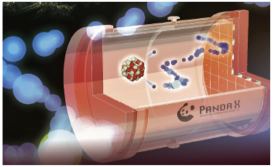
NEXT-HD

- Currently proposed multi-tonne-scale experiments for dark matter & $0\nu\beta\beta$:

XLZD



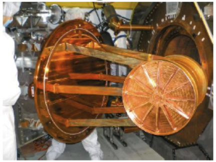
PandaX



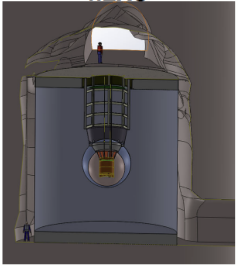
The learning curve in $\beta\beta0\nu$ searches

- Very ambitious (technical) goals for the ton-scale experiments

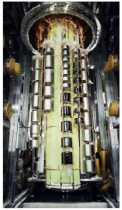
EXO-200



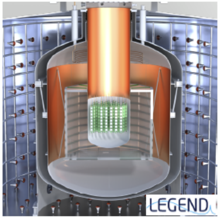
nEXO



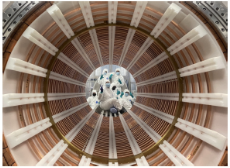
LEGEND-200



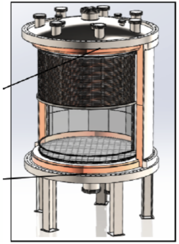
LEGEND-1tonne



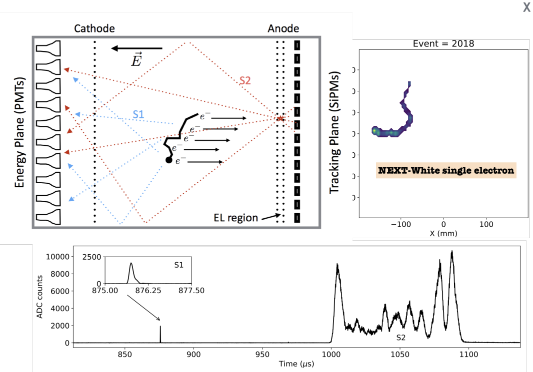
NEXT-100



NEXT-HD



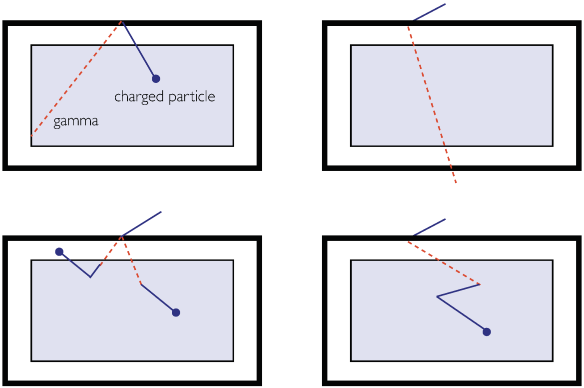
The NEXT concept: A HPXe EL TPC



https://arxiv.org/abs/1202.0721

- Primary scintillation S_1 signals the start-of-the-event, t_0.
- Secondary scintillation S_2 measures the energy of the event (energy plane, PMTs).
- Position in z obtained from time difference between S_1 an S_2. A measurement of t_0 is essential to fiducialize the events and remove the large rate of background events that accumulate at the electrodes, and to correct for charge losses occurring during charge drift. Without such corrections, the performance of the detector both in terms of background rate and resolution is seriously compromised.
- Position in x, y obtained from position and amplitudes of SiPMs (tracking plane).

Topology and background rejection



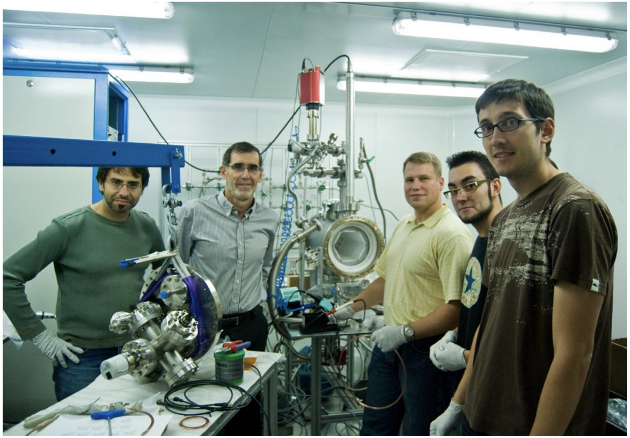
- 1) Many gammas simply do not interact in the gas; 2) any interaction not fully contained in the gas is rejected by the fiducial condition; 3) topology condition (worm with two heads) eliminates multiple side and pileup events.
- The only potential background is single electros in they “fake” the double-head signature

A meeting in Berkeley

- NEXT t_0. A meeting in Berkeley

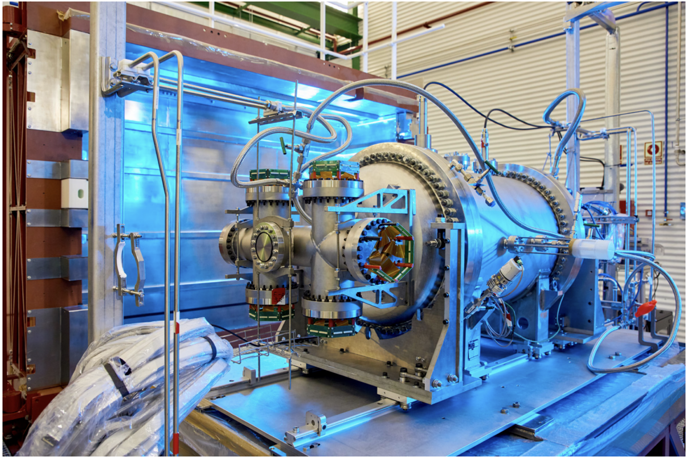
In 2009.

Early Prototypes



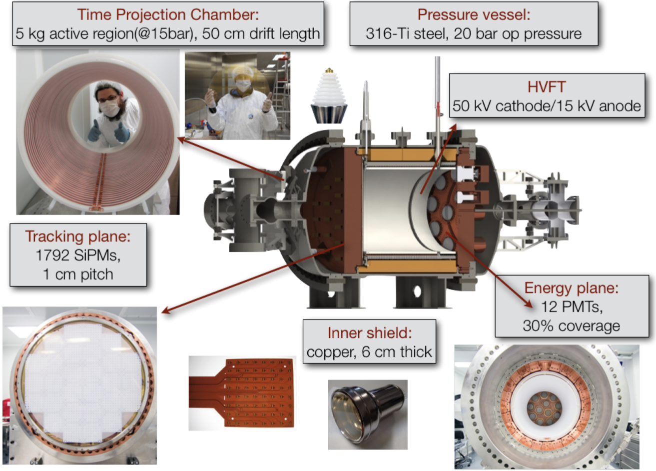
- Between 2009 and 2015 we operated two prototypes. DBDM at LBNL and NEXT-DEMO at IFIC, in Spain.

NEXT-White



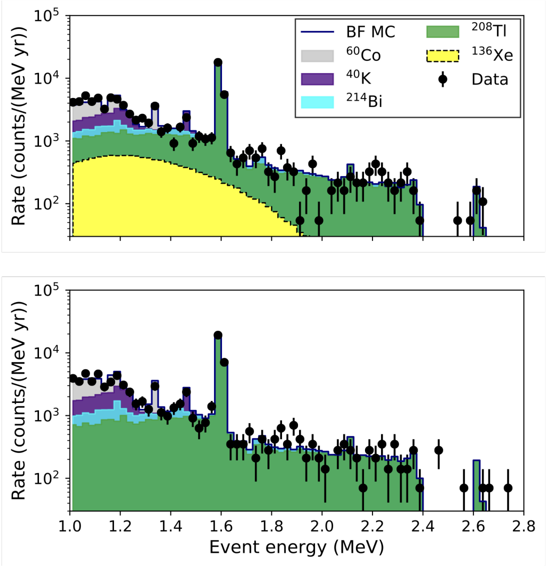
- NEXT-White (name in loving memory of James), was the first radiopure NEXT-detector. It operated at the LSC (Canfranc) from 2016 to 2022.

Anatomy of NEXT-White



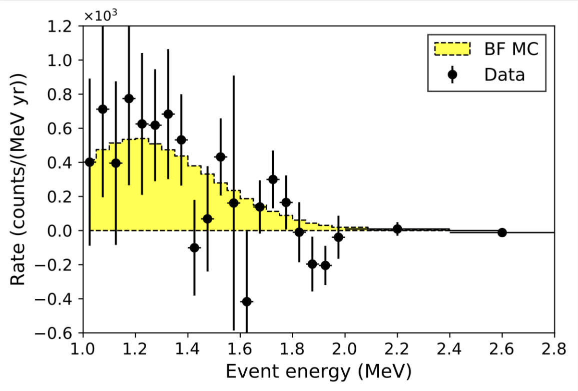
- NEXT-White was a full implementation of the (original) NEXT concept.

Energy Spectrum



- Energy spectrum measured by NEXT-White. A Xenon TPC like NEXT can run with depleted xenon (no $^{136}\mathrm{Xe}$) and with enriched xenon (90% of $^{136}\mathrm{Xe}$) and compared results, thus reducing very much the dependence with the Monte Carlo.
- Notice the hole around $Q_{\beta\beta}$, where a putative signal may show up.

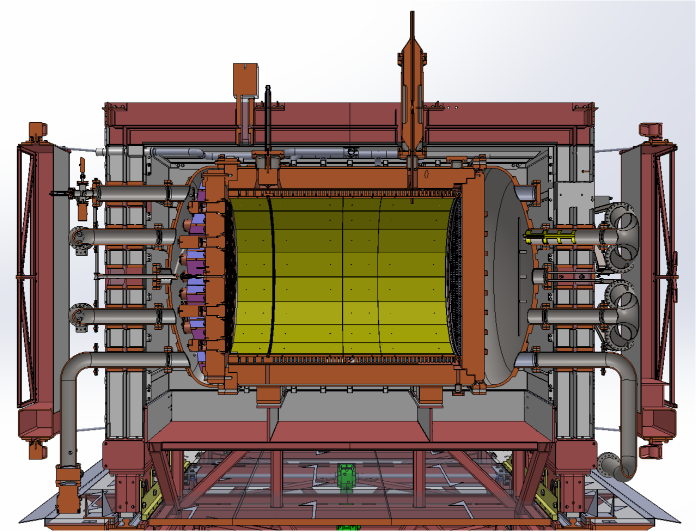
$\beta\beta2\nu$ mode



$$T_{1/2} = 2.34^{+0.80}_{-0.46}\ (\text{stat})\ ^{+0.30}_{-0.17}\ (\text{sys}) \times 10^{21}\ \text{yr}$$

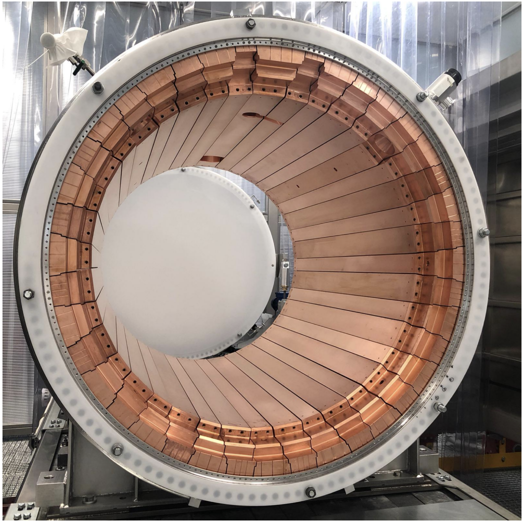
- Although NEXT-White is a relatively small detector (5 kg of active volume), it has been able to measure the $\beta\beta2\nu$ mode (St. Gotthard TPC, with a similar mass couldn't do it, due to backgrounds).
- In particular, in NEXT-White has been possible to measure the $\beta\beta2\nu$ mode using direct subtraction between the data with enriched and depleted xenon.

NEXT-100

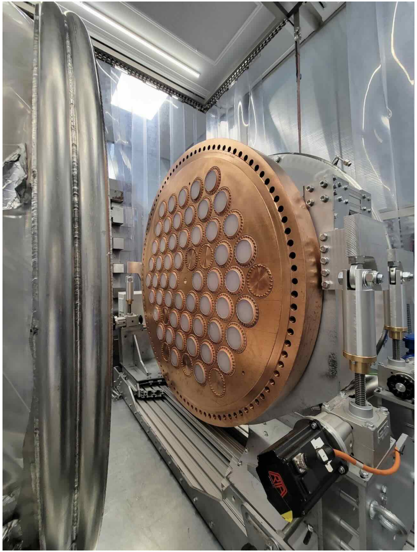


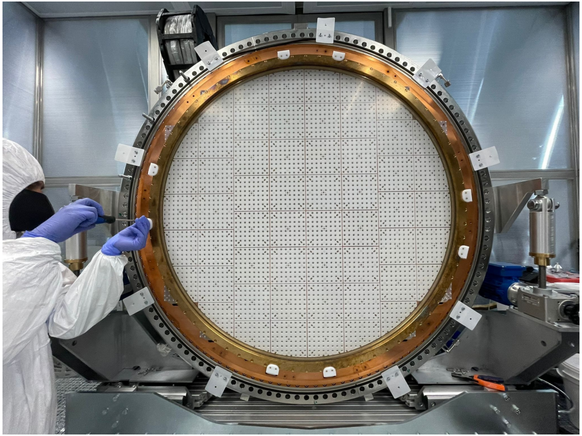
- Operating at LSC since 2024. Holds 100 kg of xenon enriched at 90% in $^{136}\mathrm{Xe}$ (at 15 bar).

Pressure Vessel & Inner Copper Shield



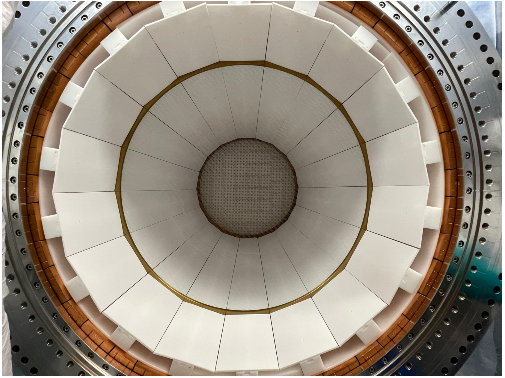
Energy & Tracking Plane





JINST 19 P02007

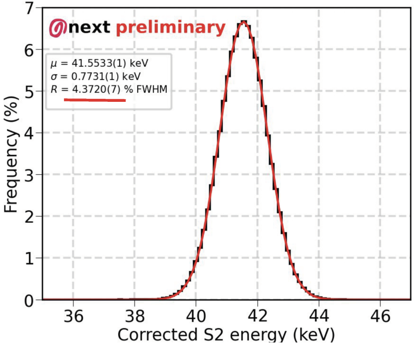
Field Cage & Light Tube



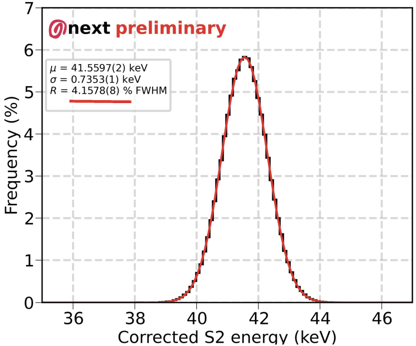
arXiv 2505.01002

Energy resolution

full volume

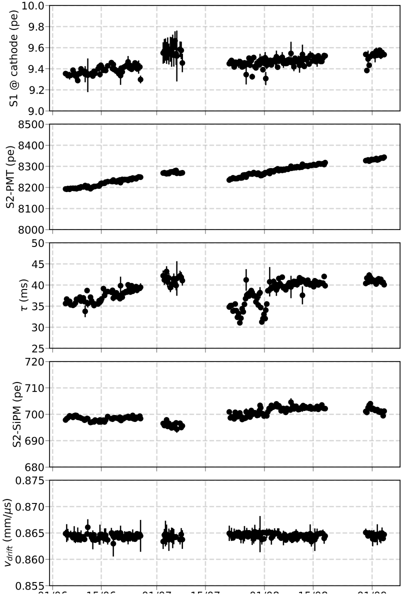


fiducial volume (~ high pressure)



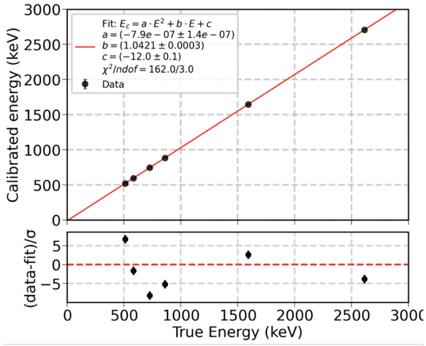
- Energy resolution in the full volume: 4.37 % FWHM @ 41.5 keV
- Extrapolation to high pressure: 4.16 % FWHM @ 41.5 keV
- $1/sqrtE$ extrapolation $\rightarrow$ 0.5 % FWHM @ $Q_{\beta\beta}$

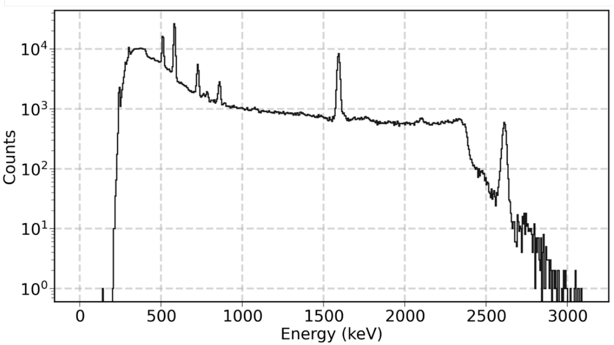
Detector stability: Monitoring



- $^{83}\mathrm{Kr}$ provides a continuous calibration of the detector!
- PMT response
- SiPM response
- Electron lifetime
- Drift velocity
- Good stability over long periods

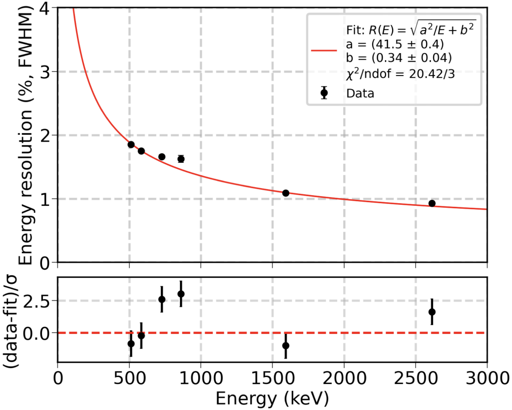
Calibration of the energy scale





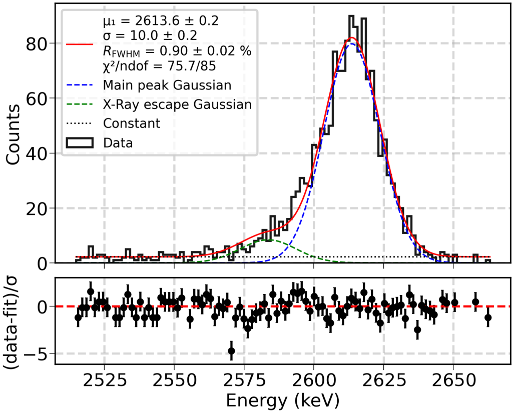
- Left: Kr-calibrated energy as a function of the true energy. The data are fitted with a second-degree polynomial to account for the slight nonlinearity in the detector response. Right: Energy spectrum corrected for residual non-linearity, with all the peaks produced by the γs emitted in the $^{228}\mathrm{Th}$ chain visible.

Energy resolution (full detector)



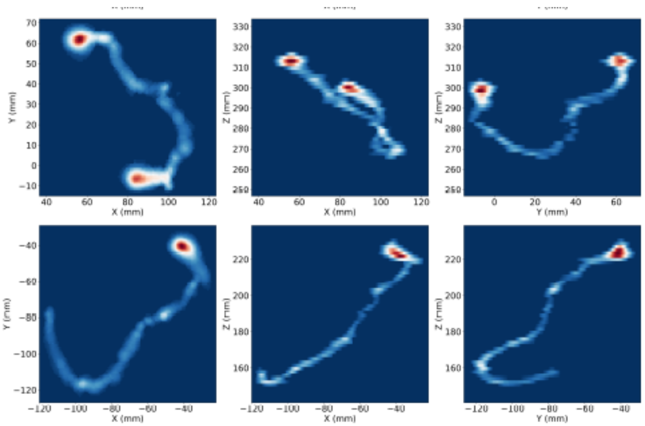
- energy resolution FWHM in percentage as a function of the energy, together with the fit result and the plot of the residuals.

Fitting the ^{208}Tl photopeak



- Single-cluster energy spectrum at the ^{208}Tl photopeak. The fitted function, fit parameters, and residuals are also shown.
- With this requirement, an energy resolution of $R_{FWHM} = (0.90 \pm 0.02)\%$ FWHM is obtained at the ^{208}Tl photopeak. The energy resolution at $Q_{\beta\beta}$ can be directly extrapolated from the $1/\sqrt{E}$ scaling (an excellent approximation given the proximity of both peaks) yielding $R_{FWHM}(Q_{\beta\beta}) = (0.93 \pm 0.02)\%$ FWHM.

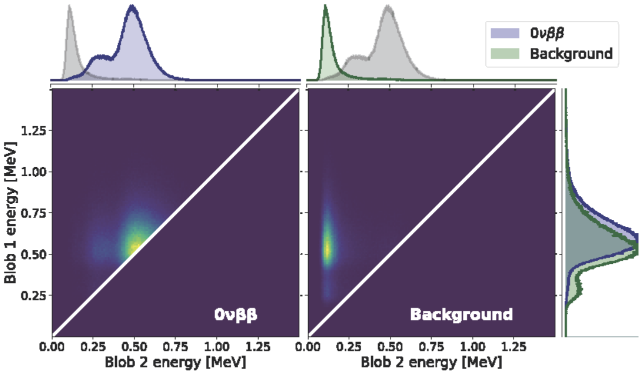
Topological signature



- Real data electrons and double electrons from the 1.6 MeV double escape peak of $^{208}\mathrm{Tl}$)

- The signature of a $\beta\beta$ event in NEXT is a single track in the fiducial volume, consistent with being a double electron. The energy of the double electron candiate must be in the detector ROI.

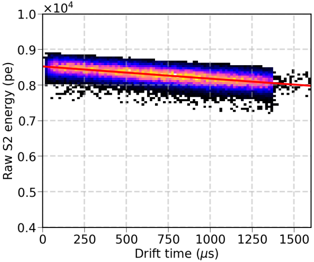
Double electron identification

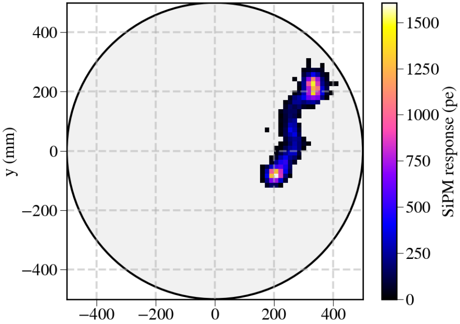


J. High Energ. Phys. 2021, 164 (2021)

- 1-electron vs 2-electron separation is illustrated plotting the energy of the two blobs in the extremes of the track. A double electron has similar energy in both blobs. A single electron has one blob with very little energy.

Status of NEXT-100





• Low pressure run (5 bar) completed. Detector very stable, long lifetime, good energy resolution electrons from double escape peak reconstructed.

• High pressure run (13-15 bar) starts in spring 2026 with the goal of measuring backgrounds, perform a high statistical measurement of the $\beta\beta2\nu$ signal and perform a search for $\beta\beta0\nu$ events.

First Results

arXiv > hep-ex > arXiv:2511.01710

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High Energy Physics – Experiment

[Submitted on 3 Nov 2025]

First results of the NEXT-100 detector using ^{83m}Kr decays

NEXT Collaboration: G. Martínez-Lema, C. Hervés Carrete, S. Torelli, M. Cid Laso, P. Vázquez Cabaleiro, B. Palmeiro, J.A. Hernando Morata, J.J. Gómez-Cadenas, C. Adams, H. Almazán, V. Álvarez, A.I. Aranburu, L. Arazi, I.J. Arnquist, F. Auria-Luna, S. Ayet, Y. Ayyad, C.D.R. Azevedo, K. Bailey, F. Ballester, J.E. Barcelon, M. del Barrio-Torregrosa, A. Bayo, J.M. Benlloch-Rodríguez, F.I.G.M. Borges, A. Brodoline, N. Byrnes, A. Castillo, E. Church, L. Cid, X. Cid, C.A.N. Conde, C. Cortes-Parra, F.P. Cossío, R. Coupe, E. Dey, P. Dietz, C. Echeverria, M. Elorza, R. Esteve, R. Felkai, L.M.P. Fernandes, P. Ferrario, F.W. Foss, Z. Freixa, J. García-Barrena, J.W.R. Grocott, R. Guenette, J. Hauptman, C.A.O. Henriques, P. Herrero-Gómez, V. Herrero, Y. Ifergan, A.F.B. Isabel, B.J.P. Jones, F. Kellerer, L. Larizgoitia, A. Larumbe, P. Lebrun, F. Lopez, N. López-March, R. Madigan, R.D.P. Mano, A. Marauri, A.P. Marques, J. Martín-Albo, A. Martínez, M. Martínez-Vara, R.L. Miller, K. Mistry, J. Molina-Canteras, F. Monrabal, C.M.B. Monteiro, F.J. Mora, K.E. Navarro, P. Novella, D.R. Nygren, E. Oblak, J. Palacio, A. Para, I. Parmaksiz, A. Pazos, J. Pelegrin, M. Pérez Maneiro, M. Querol, J. Renner, I. Rivilla, C. Rogero, L. Rogers, B. Romeo, C. Romo-Luque, E. Ruiz-Chóliz, P. Saharia, F.P. Santos, J.M.F. dos Santos, M. Seemann, I. Shomroni, A.L.M. Silva, P.A.O.C. Silva et al. (16 additional authors not shown)

We report here the first results obtained with NEXT-100 using low-energy calibration data from ^{83m}Kr decays, which allow mapping of the detector response in the active volume and monitoring of its stability over time. After homogenizing the light response, we achieve an energy resolution of 4.37% FWHM at 41.5 keV for ^{83m}Kr point-like energy deposits contained in a radius of 425 mm. In a fiducial region representing the operating conditions of NEXT-100 at 10 bar we obtain an improved energy resolution of 4.16% FWHM. These results are in good agreement with that obtained in NEXT-White, and an $E^{-1/2}$ extrapolation to $Q_{\beta\beta}$ yields an energy resolution close to 0.5% FWHM, well below the 1% FWHM design target.

Comments: 17 pages, 11 figures
Subjects: **High Energy Physics - Experiment (hep-ex)**; Instrumentation and Detectors (physics.ins-det)
Cite as: arXiv:2511.01710 **[hep-ex]**
(or arXiv:2511.01710v1 **[hep-ex]** for this version)
https://doi.org/10.48550/arXiv.2511.01710

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From: Gonzalo Martínez-Lema [view email]
[v1] Mon, 3 Nov 2025 16:19:35 UTC (2,847 KB)

First Results

arXiv > physics > arXiv:2511.02467

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Physics > Instrumentation and Detectors

[Submitted on 4 Nov 2025]

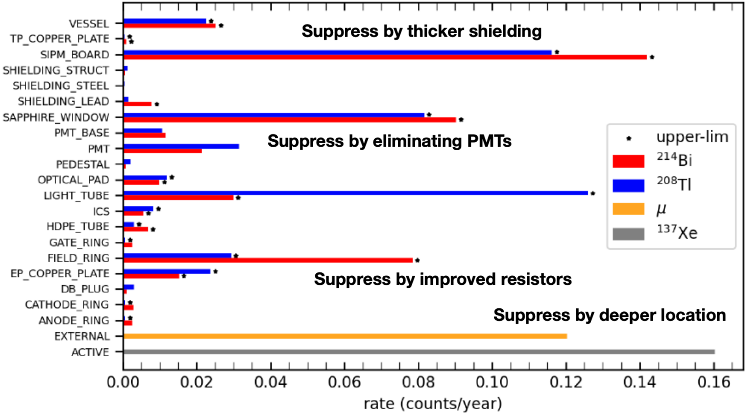
Demonstration of Sub-Percent Energy Resolution in the NEXT-100 Detector

NEXT Collaboration: M. Pérez Maneiro, M. Martínez-Vara, S. Torelli, G. Martínez-Lema, P. Novella, J.A. Hernando Morata, J.J. Gómez-Cadenas, C. Adams, H. Almazán, V. Álvarez, A.I. Aranburu, L. Arazi, I.J. Arnquist, F. Auria-Luna, S. Ayet, Y. Ayyad, C.D.R. Azevedo, K. Bailey, F. Ballester, J.E. Barcelon, M. del Barrio-Torregrosa, A. Bayo, J.M. Benlloch-Rodríguez, F.I.G.M. Borges, A. Brodoline, N. Byrnes, A. Castillo, E. Church, L. Cid, M. Cid, X. Cid, C.A.N. Conde, C. Cortes-Parra, F.P. Cossío, R. Coupe, E. Dey, P. Dietz, C. Echeverria, M. Elorza, R. Esteve, R. Felkai, L.M.P. Fernandes, P. Ferrario, F.W. Foss, Z. Freixa, J. García-Barrena, J.W.R. Grocott, R. Guenette, J. Hauptman, C.A.O. Henriques, P. Herrero-Gómez, V. Herrero, C. Hervés Carrete, Y. Ifergan, A.F.B. Isabel, B.J.P. Jones, F. Kellerer, L. Larizgoitia, A. Larumbe, P. Lebrun, F. Lopez, N. López-March, R. Madigan, R.D.P. Mano, A. Marauri, A.P. Marques, J. Martín-Albo, A. Martínez, R.L. Miller, K. Mistry, J. Molina-Canteras, F. Monrabal, C.M.B. Monteiro, F.J. Mora, K.E. Navarro, D.R. Nygren, E. Oblak, J. Palacio, B. Palmeiro, A. Para, I. Parmaksiz, A. Pazos, J. Pelegrin, M. Querol, J. Renner, I. Rivilla, C. Rogero, L. Rogers, B. Romeo, C. Romo-Luque, E. Ruiz-Chóliz, P. Saharia, F.P. Santos, J.M.F. dos Santos, M. Seemann, I. Shomroni, A.L.M. Silva, P.A.O.C. Silva, A. Simón et al. (16 additional authors not shown)

NEXT-100 is a high-pressure xenon time projection chamber with electroluminescent amplification, designed to operate with up to approximately 70.5 kg at 13.5 bar. It is the most recent detector developed by the NEXT collaboration to search for the neutrinoless double-beta decay ($\beta\beta0\nu$) of Xe-136. The NEXT gas TPC technology offers the best energy resolution near the Q-value of the decay ($Q_{\beta\beta}$ = 2458 keV) among xenon detectors, which is set by design to be <1% FWHM. We report here the high-energy calibration of the detector using a Th-228 source, demonstrating linear response and an energy resolution of (0.90 ± 0.02)% FWHM at the Tl-208 photopeak (2615 keV). This performance extrapolates to a resolution at the double-beta decay end-point of $R(Q_{\beta\beta}) = (0.93 \pm 0.02)$% FWHM, confirming the detector's capability for precision energy measurement in the search for $\beta\beta0\nu$.

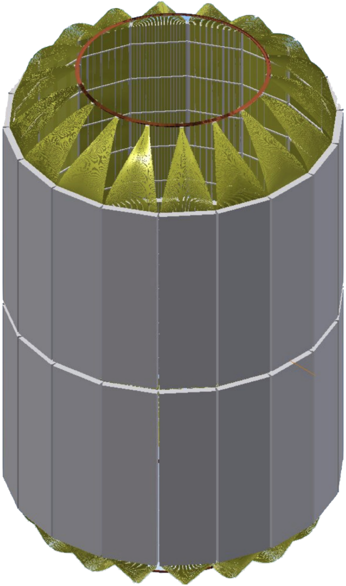
Subjects: **Instrumentation and Detectors (physics.ins-det)**

NEXT-100 Background Budget



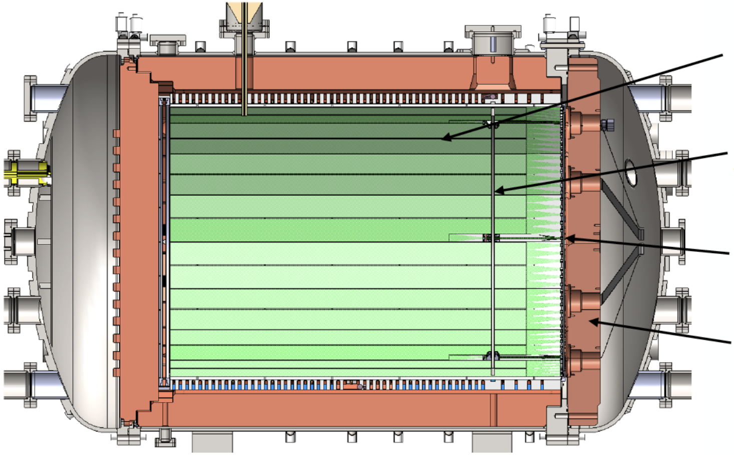
- NEXT-100 expected background at the level of **10 cts · ton/year** in the ROI.
- **"Easy target"**: reduce background level by a factor 10 and achieve $(T_{1/2}^{0\nu})^{-1} \sim 10^{27}$yr with an exposure of 1 ton· year.
- **"Hard target"**: reduce background level by a factor 100 and achieve $(T_{1/2}^{0\nu})^{-1} \sim 10^{28}$yr with an exposure of 50 ton· year.

Improving NEXT: Replace PMTs by a BFD



- PMTs are a no-go for ton-scale detectors. They need to be insulated from the main volume, which implies that EP plate must resit pressure. This is in contradiction with the need that EP plate is made of ultra-pure copper and does not scale to large surfaces.
- A BFD made of WLS optical fibres read out by (cooled) SiPMs can provide a measurement of S_1 and S_2 (depending on design of EL amplification region, see below).
- BFD made of radiopure plastic fibres, contributes to background budget a factor 10 less than PMTs.

NEXT 100 upgrade



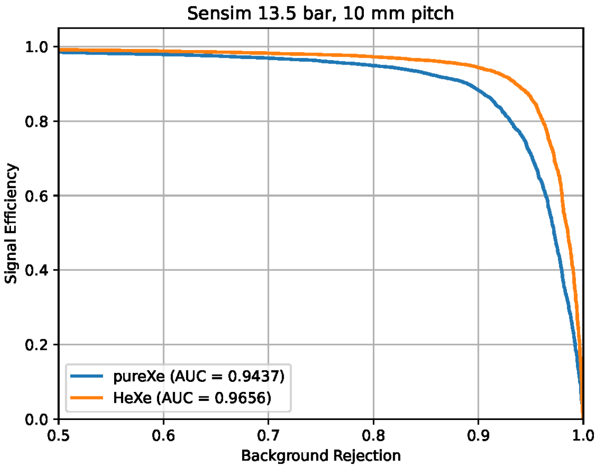
PTFE light tube replaced by panels with WLS fibers

New cathode ring, fibers pass on the outside

108 SiPMs placed on a cooled copper ring

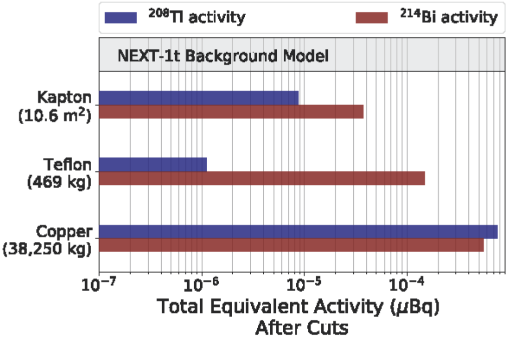
New copper plate with holes needed for SiPM cables

Xe-He mixtures



- Rejection factor (pure Xe) in NEXT is $\sim$ 93% (80% efficiency)
- Rejection factor (Xe-He 90/10) in NEXT is $\sim$ 97% (80% efficiency)

Improving NEXT-100: Background reduction



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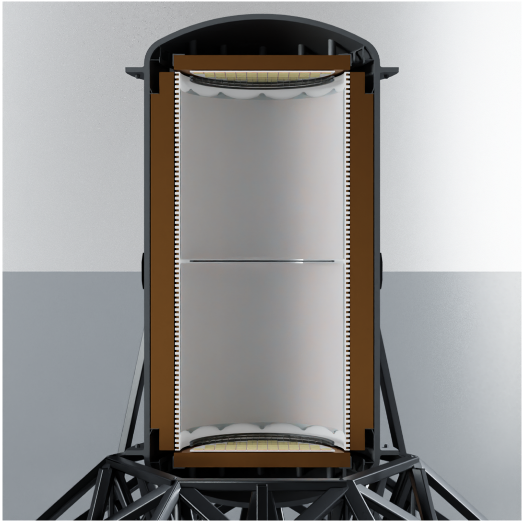
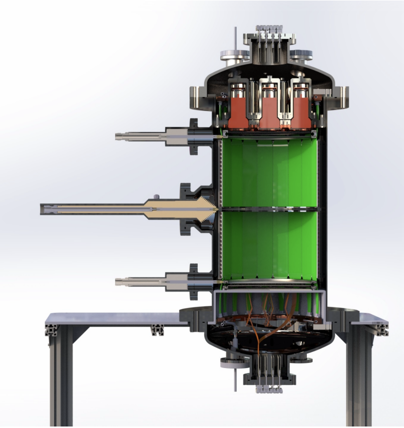
- We aim a factor 10 reduction w.r.t. NEXT-100 radioactive budget by: a) eliminating PMTs (and replacing then by a much lighter BFD in terms of backgrounds); b) further shielding in the TP and c) replacing the resistors in the field cage by lower radioactivity components (detector budget dominated by copper, Kapton and Teflon).

NEXT-HD First Module



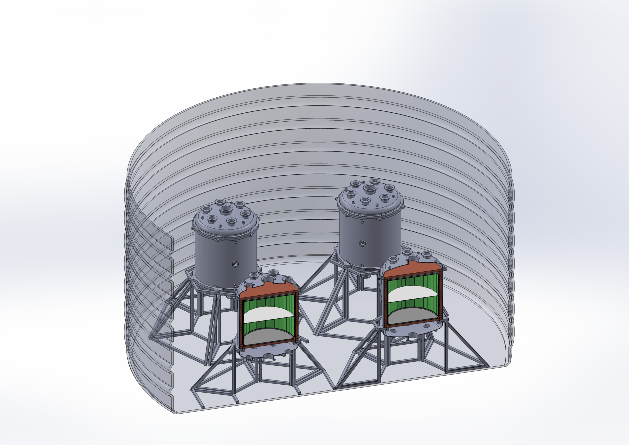
- A first HD module (HDFM) can be built within the next few years, ideally starting after the physics run of NEXT-100, thus in 2028. This would be a symmetric, vertical detector of 2×1.5 m length and 2.2 m diameter, "doubling size of NEXT-100", with capacity to host 1 ton of xenon at 15 bar.
- HDFM could measure background with normal xenon, which is much cheaper and easy to acquire than enriched xenon, thus providing extra time to acquire enriched xenon.

HD-demo prototype



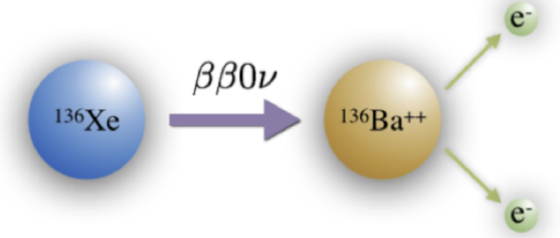
- We are also building a full prototype of NEXT-HD (HD-DEMO). The detector will be operational in 2026, and will demonstrate and refine new concepts, including: A barrel fiber detector, a new dense silicon plane and new ASICs electronics.

Scaling to multi-ton



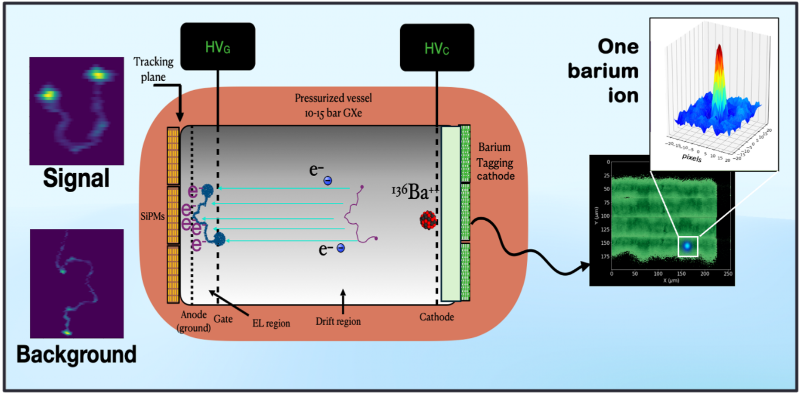
- Building on the performance of HDFM the HD concept can be scaled to larger modules.
- For examples, modules of 3 m diameter and 3 m length operating at 15 bar can hold 2 tons of xenon. After validating the technology and backgrounds with HDFM, one could build several such modules in parallel, aiming for a total deployed mass of 5-10 tons (can be done incrementally).

Barium Tagging



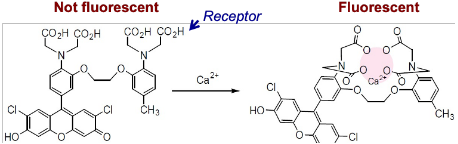
- Natural radioactivity does not produce Ba^{2+}.
- If the Ba^{2+} dication can be detected (tagged) in coincidence with the 2e signal (e.g, in the position predicted by the reconstruction of the vertex, at the time predicted from the arrival of the electron signal + t_0), then the combination of energy, topology and (delayed) coincidence of the Ba^{2+} observation can provide, a priory an essentially background free signal

NEXT-BOLD concept

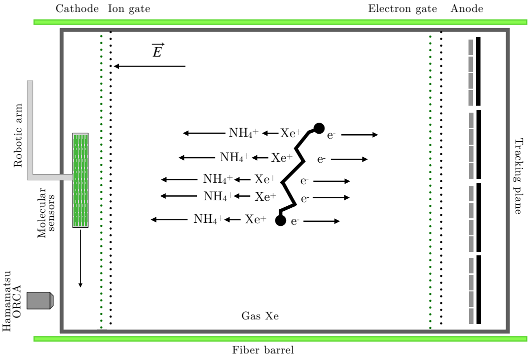


Phys. Rev. Lett. 120 (2018) 13, 132504;
ACS Sens. 6 (2021) 1, 192202
J.Phys.Conf.Ser. 650 (2015) no.1, 012002;
Nature volume 583, pages48–54 (2020)

Barium ions are imaged through single molecule fluorescence imaging.

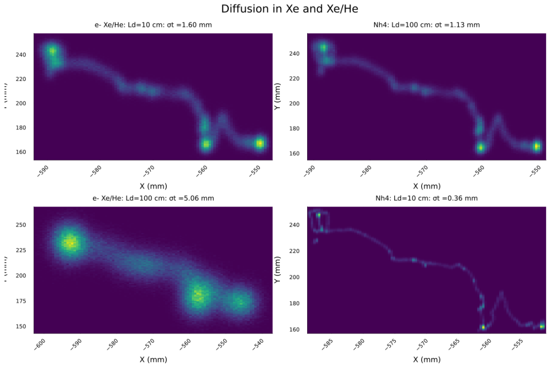


ITACA



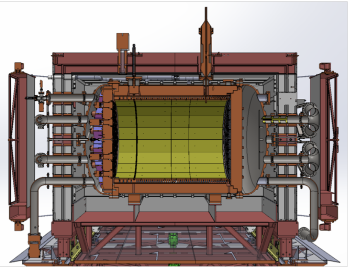
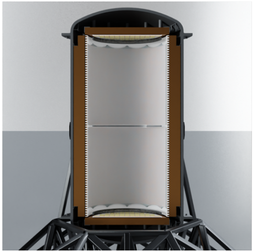
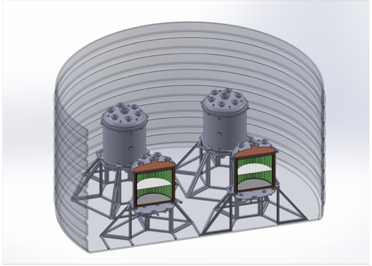
- Ion Tracking with Ammonium Cations Apparatus.
- Trace amounts (100 ppb) of ammonia (NH_3) are added to the xenon.
- In spite of the low concentration, this is enough to transform positive xenon ions into ammonium (NH_4^+), without quenching the EL light or affecting the electron drift.

Diffusion in eT and iT are anti-correlated



- The diffusion in ion and electron tracks is anticorrelated.
- The upper panel shows the case in which the electrons are near the anode (10 cm), and thus ions are far away from the cathode (100 cm).
- The bottom panel shows the inverse case. Ions are close to the cathode (10 cm) and thus electrons are far from the anode (100 cm). The availability of the ion track allows a uniform topological reconstruction across the detector.

The NEXT program

NEXT-100	HDFM	HDMM
		
2025-2029	2029-2039	2035-2040

Outlook

• The NEXT project has developed the technology HPXe-EL for $\beta\beta0\nu$ searches moving from small prototypes to a first radiopure demonstrator (NEXT-White) and now a large detector (NEXT-100).
• NEXT-100 is an essential part of the process to build larger and more radiopure detectors, such as NEXT-HD, NEXT-BOLD and NEXT-ITACA. The journey is also revealing unique, and potentially disruptive capabilities of the HPXe technology (Barium tagging, ion tracking).
• The capability to build large, radiopure detectors in combination with a sophisticated technology has the potential to position the NEXT project as a major player in the discovery of the Majorana nature of the neutrino.