

IOP Annual Conference 2026

The NEXT experiment: Results from the NEXT-100 detector

John Waiton
on behalf of the NEXT collaboration

Neutrinos are confusing...

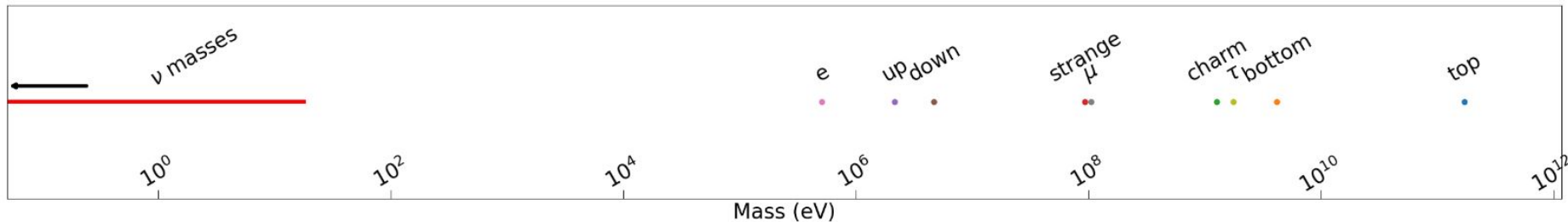
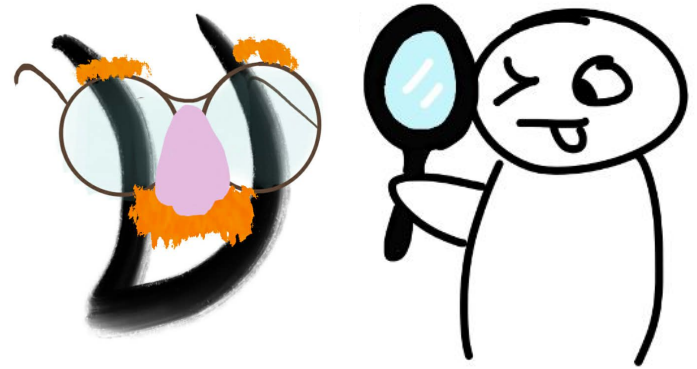
Oscillations demonstrate **they have mass**, but:

- mass mechanism not **determined**,
- mass scale is tiny in comparison to SM fermions.

Only **left-handed neutrinos** & **right-handed anti-neutrinos** observed & within SM.

Dirac fermion explanation may not be ideal...

Could there be another explanation?



Majorana justification

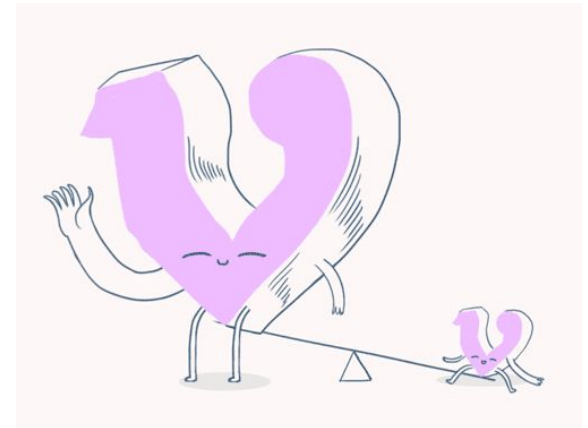
The **Majorana** treatment assumes neutrinos are their **own antiparticles**.

Motivates the idea that **heavy right-handed sterile neutrinos** explain **observable light neutrinos** (See-Saw mechanism).

How would we **prove** the Majorana hypothesis for neutrinos?

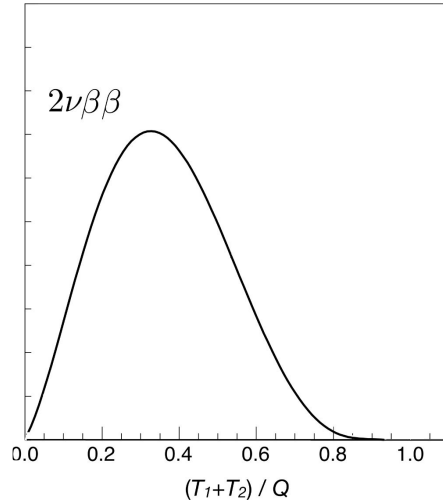
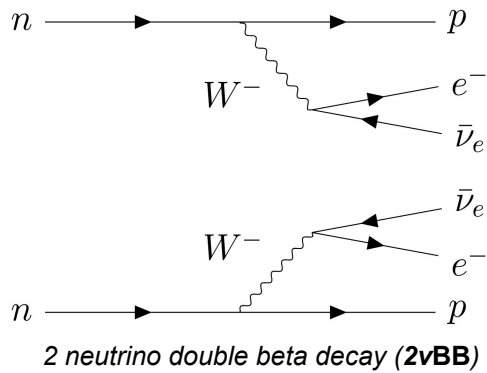


Ettore Majorana



[Symmetry magazine](#) - Ana Kova w/ Sandbox Studio

Two neutrino double beta decay (2νBB)



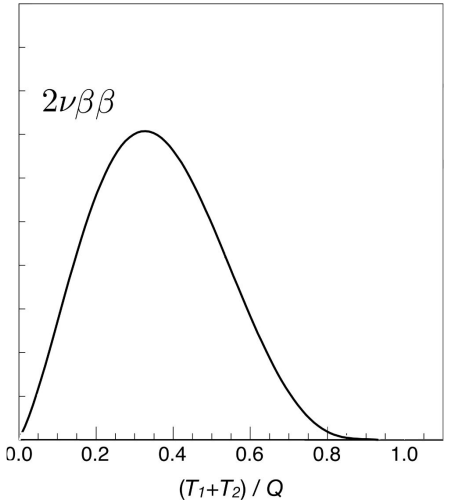
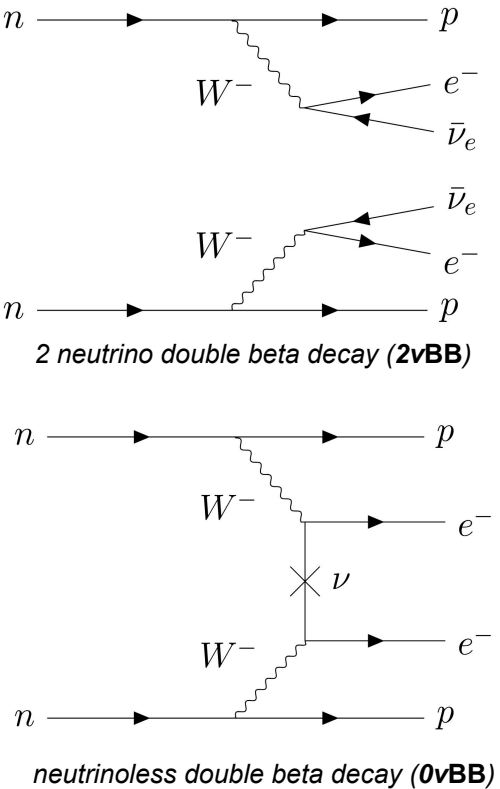
Expected energy spectrum of the two electrons (T_1 and T_2) scaled to total output energy Q (known as Q_{BB}).

2νBB occurs across **many isotopes**
 (^{136}Xe , ^{48}Ca , ^{76}Ge , ^{130}Te , ...).



Maria Goeppert-Mayer

Neutrinoless double beta decay (0νBB)



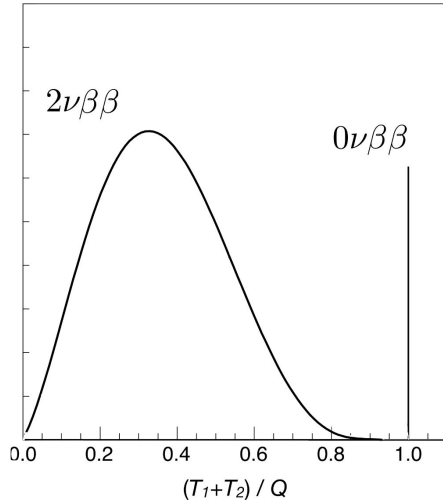
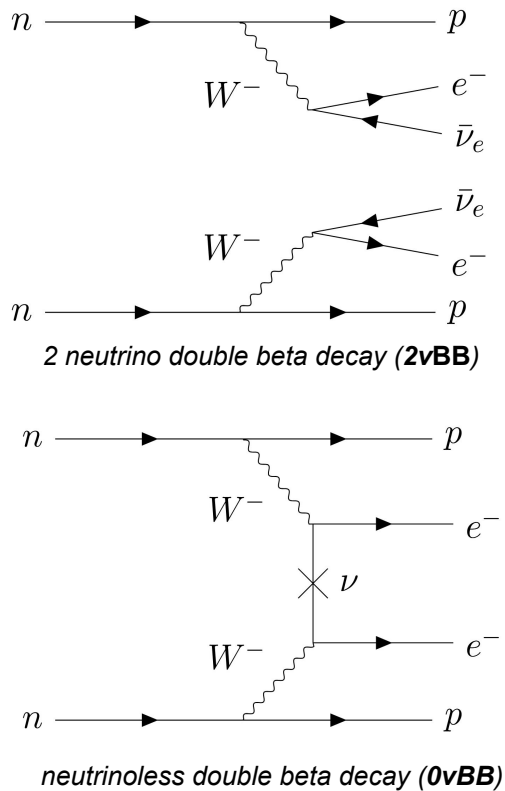
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Wendell. H Furry

Neutrinoless double beta decay ($0\nu\text{BB}$)



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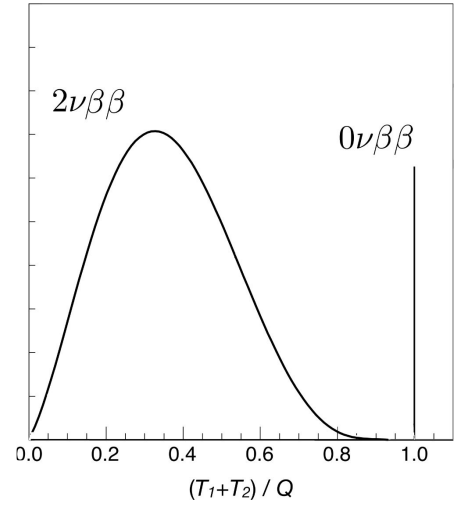
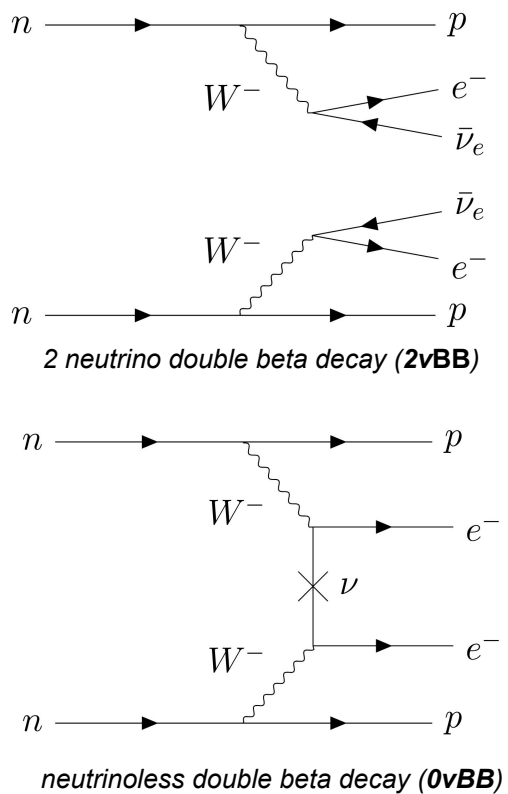
$2\nu\text{BB}$ occurs across many isotopes (^{136}Xe , ^{48}Ca , ^{76}Ge , ^{130}Te , ...).

Occurrence of $0\nu\text{BB}$ decay would **demonstrate** the Majorana nature of the neutrino.



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Neutrinoless double beta decay ($0\nu\text{BB}$)



Expected energy spectrum of the two electrons (T_1 and T_2) scaled to total output energy Q (known as Q_{BB}).

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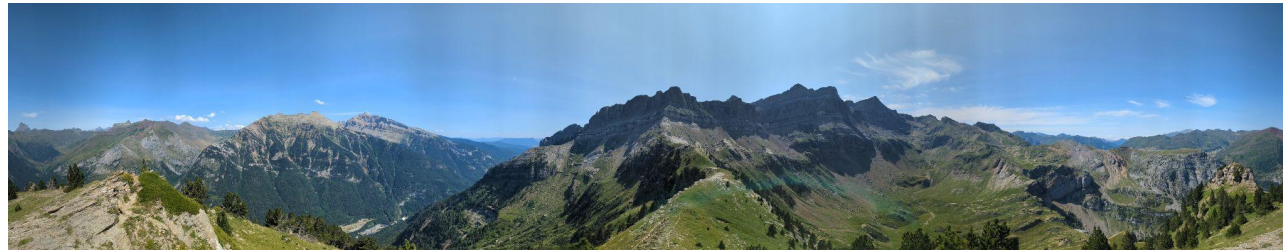
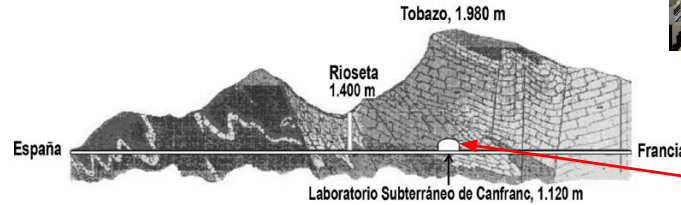
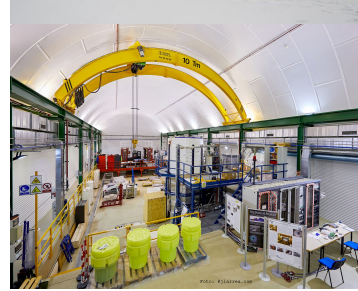
Occurrence of **$0\nu\text{BB}$** decay would **demonstrate** the Majorana nature of the neutrino.

Which **isotope** to use? Pros & Cons to each...

In this talk I'll be focusing on the NEXT experiment, which utilises ^{136}Xe .

0vBB half-life limits currently at $\sim 10^{26}$ years, so need an environment with **very little background**.

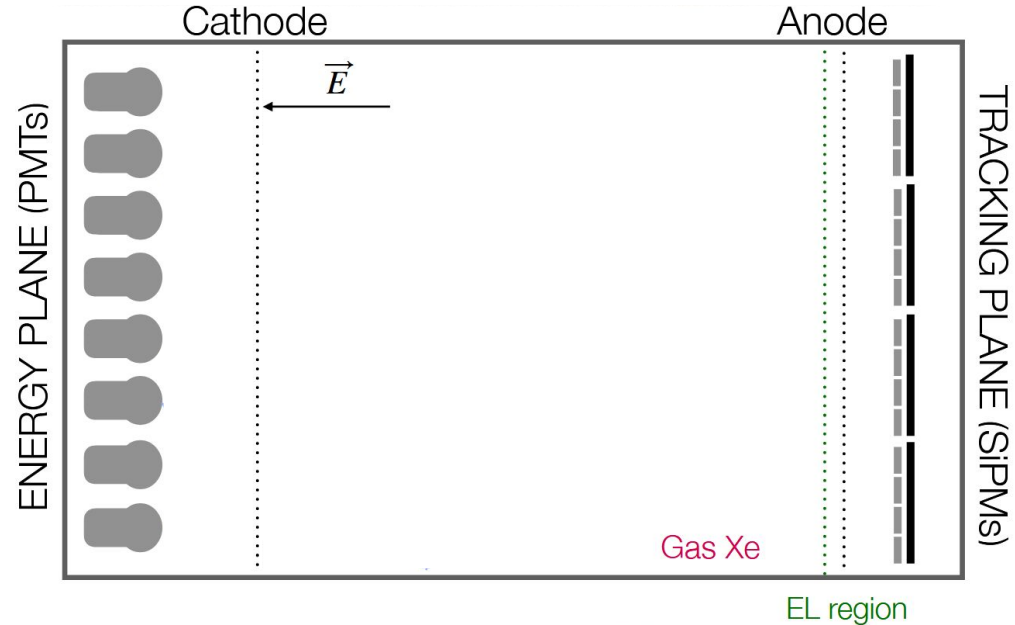
NEXT experiment hosted deep underground in the **Laboratorio Subterráneo de Canfranc** in the Pyrenees mountains.



The NEXT experiment

NEXT utilises **noble element time projection-chamber** (TPC) technology with **high pressure gaseous xenon**.

Four key features of importance here:

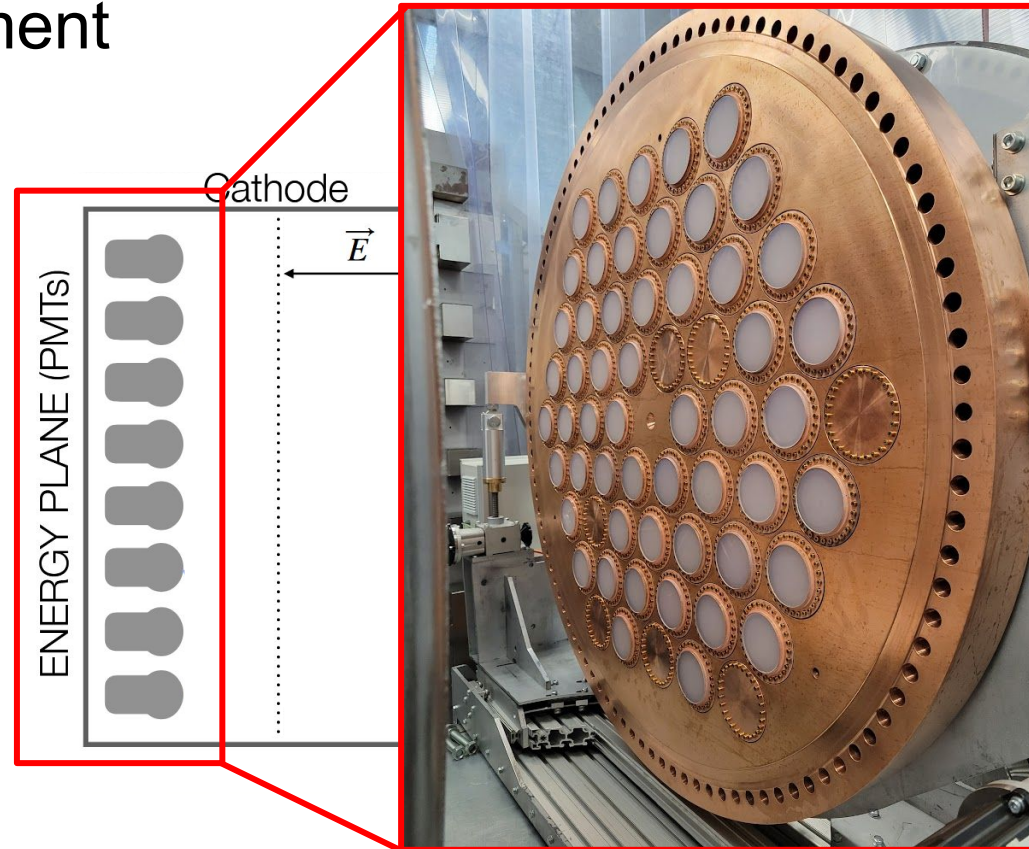


The NEXT experiment

NEXT utilises **noble element time projection-chamber** (TPC) technology with **high pressure gaseous xenon**.

Four key features of importance here:

- **Energy plane** for high resolution energy readout,



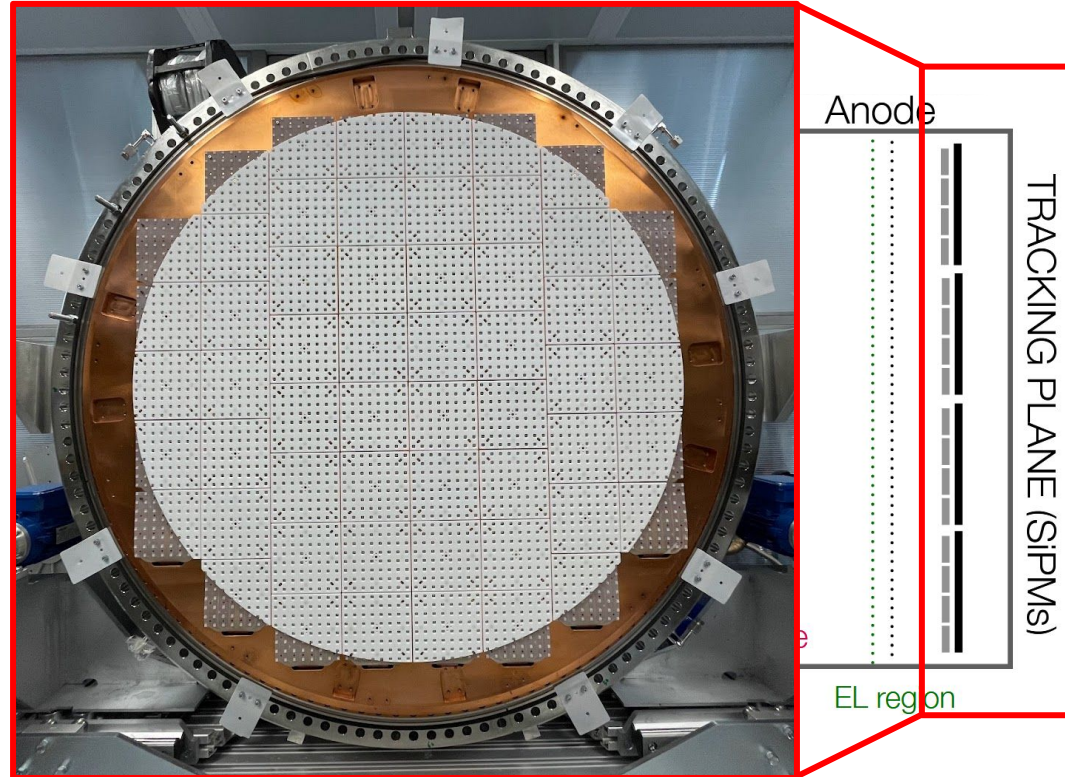
Energy plane

The NEXT experiment

NEXT utilises **noble element time projection-chamber (TPC)** technology with **high pressure gaseous xenon**.

Four key features of importance here:

- Energy plane,
- **Tracking plane** for topological readout,



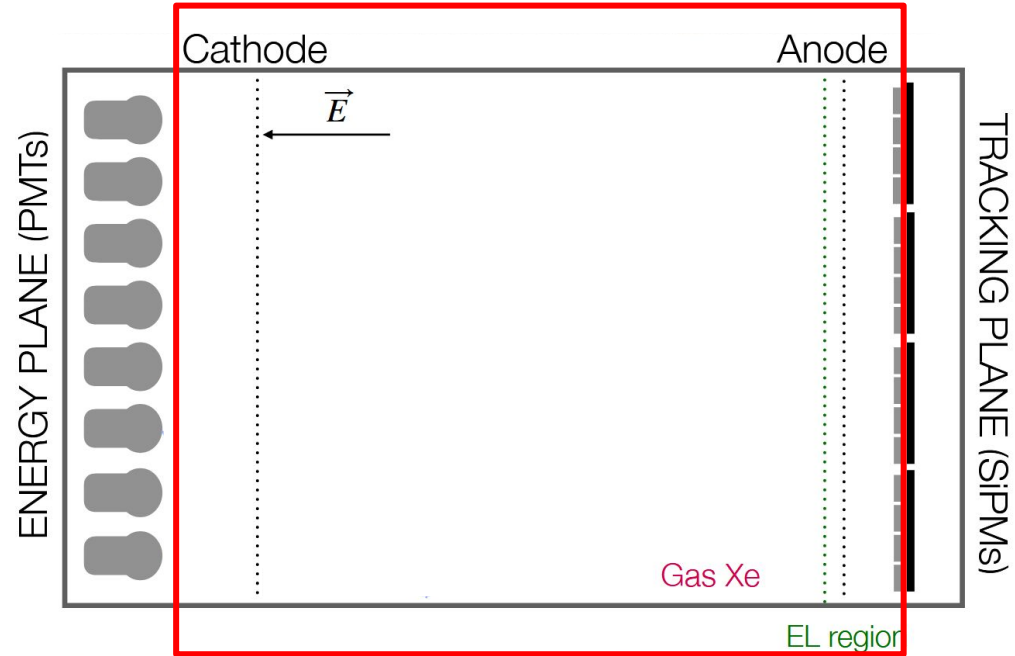
Tracking plane

The NEXT experiment

NEXT utilises **noble element time projection-chamber** (TPC) technology with **high pressure gaseous xenon**.

Four key features of importance here:

- Energy plane,
- Tracking plane,
- **Drift region**, where a **field cage** applies a constant electric field.

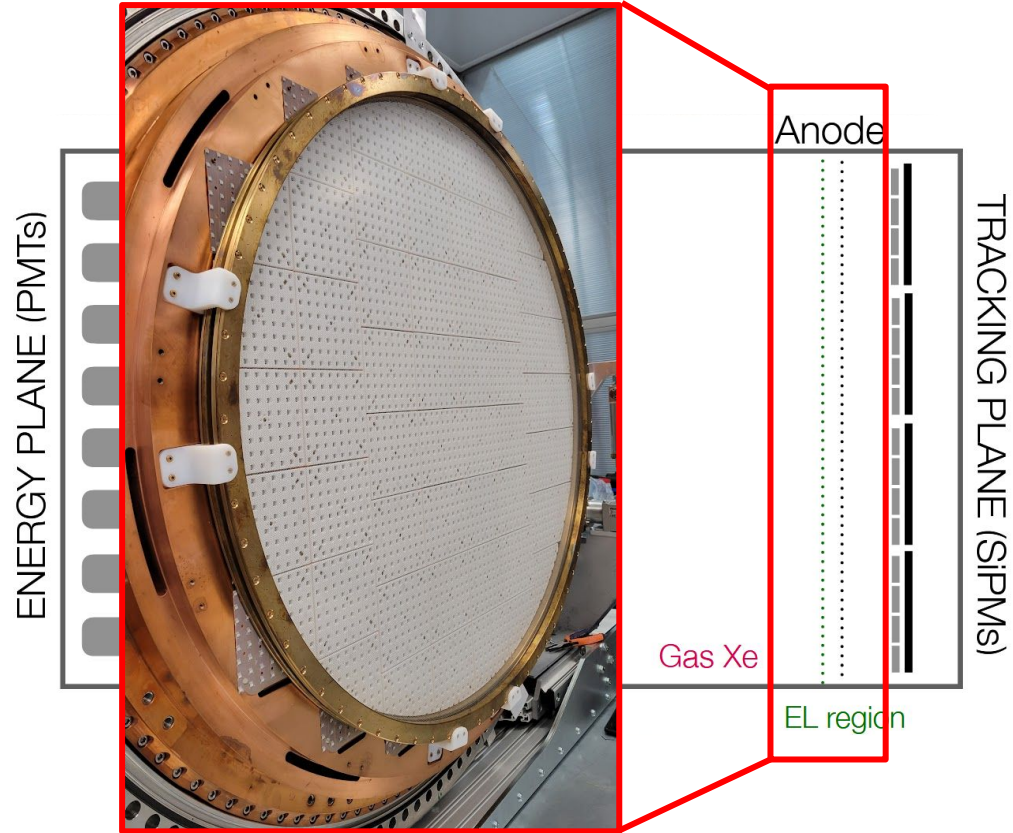


The NEXT experiment

NEXT utilises **noble element time projection-chamber** (TPC) technology with **high pressure gaseous xenon**.

Four key features of importance here:

- Energy plane,
- Tracking plane,
- Drift region,
- **Electroluminescence (EL) region**, where a significantly higher E-field is produced.



EL meshes in front of tracking plane

[\[JINST 19 P02007\]](#)

[\[arXiv:2505.01002\]](#)

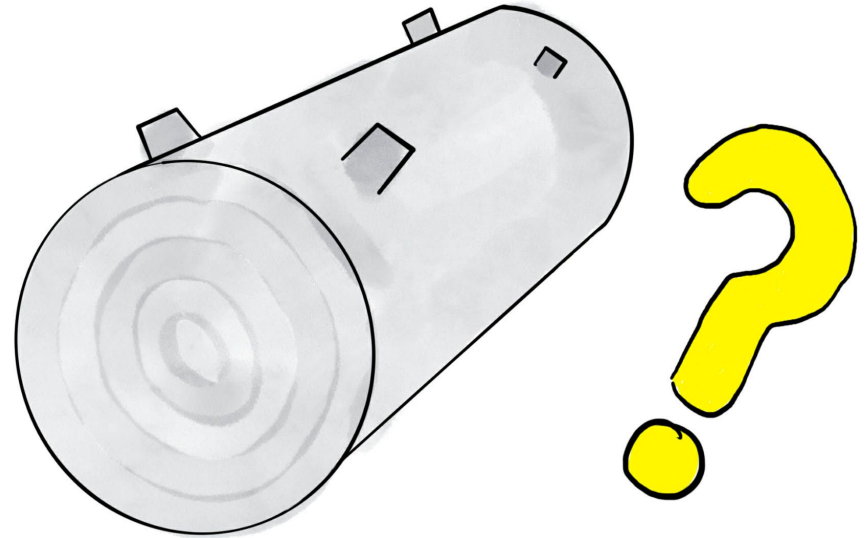
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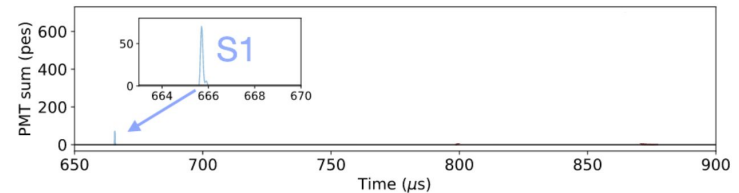
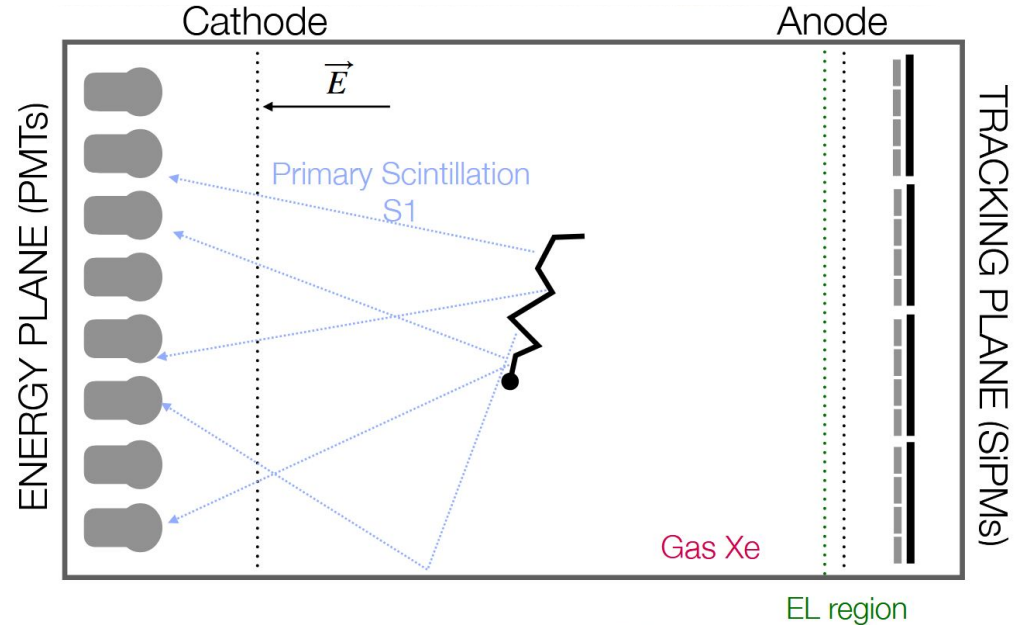
So how does it work?



The NEXT experiment

Charged particles produce initial scintillation light (**S1**).

Treated as the ‘initial trigger’, providing the z coordinate.

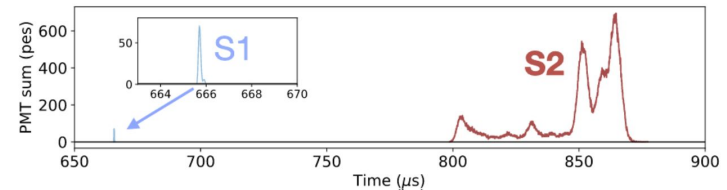
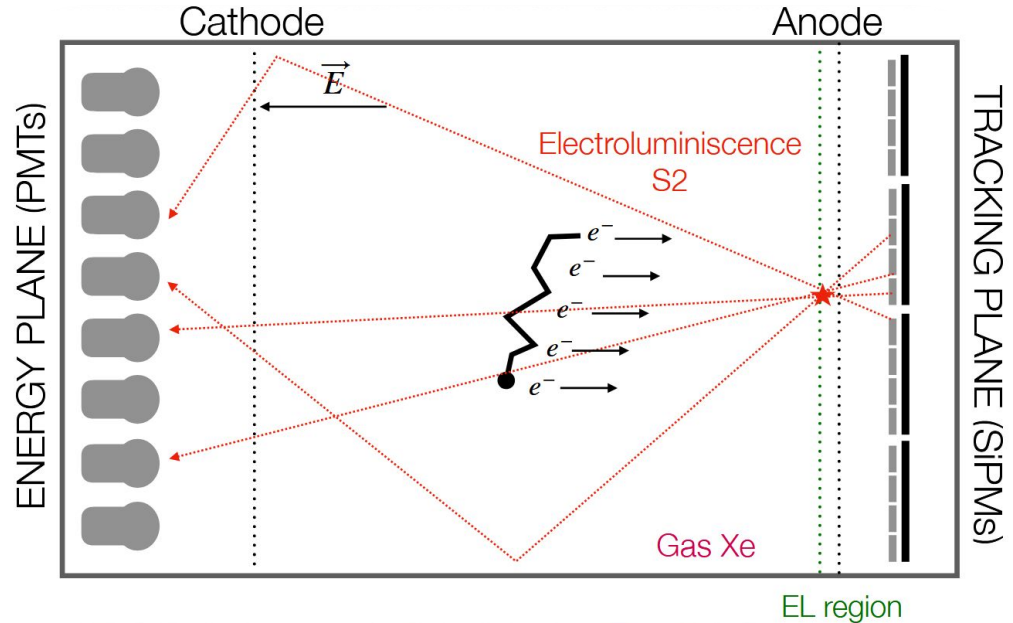


The NEXT experiment

Ionisation electrons from the charged particle track drift towards the EL region.

Electrons are accelerated rapidly within EL region, emitting light (**S2**).

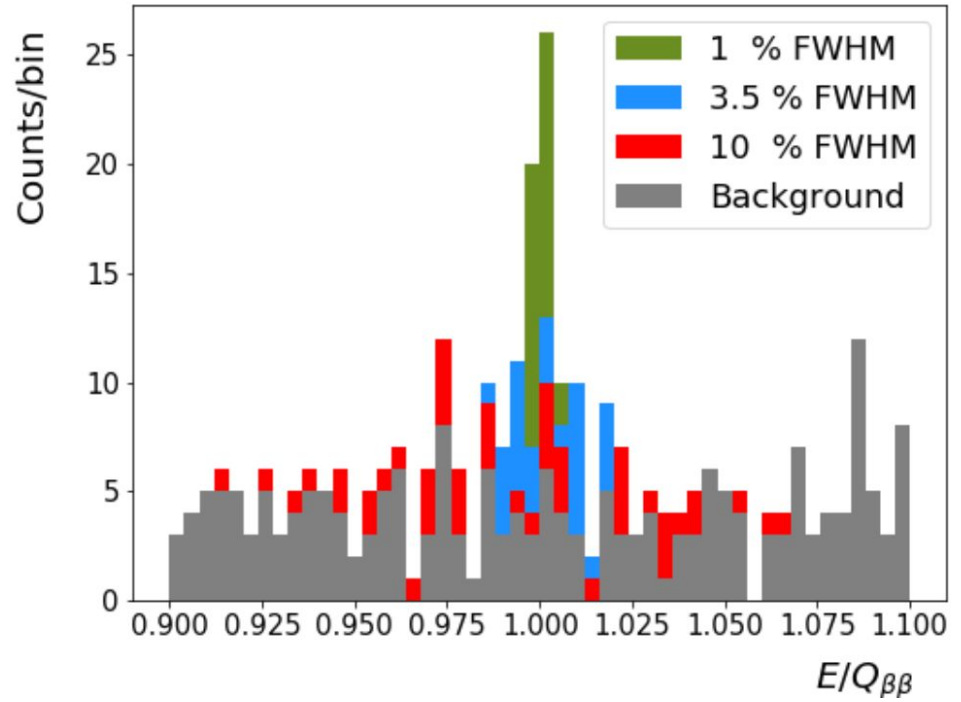
S2 used to determine **energy** and **topology** of tracks.



The NEXT experiment

Advantages:

- excellent energy resolution,

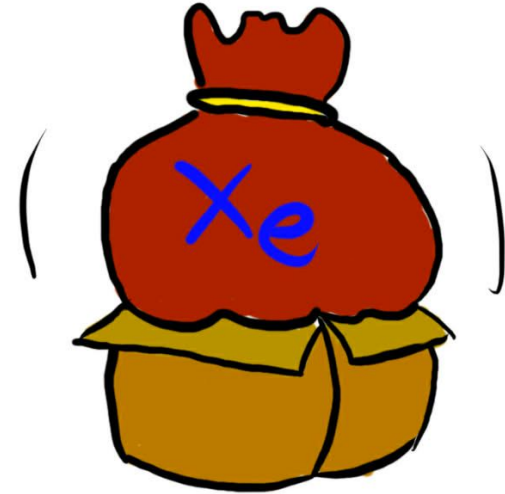


Visualisation of the energy resolution effect at the Q_{00} value w/ background rate of 1 count/keV

The NEXT experiment

Advantages:

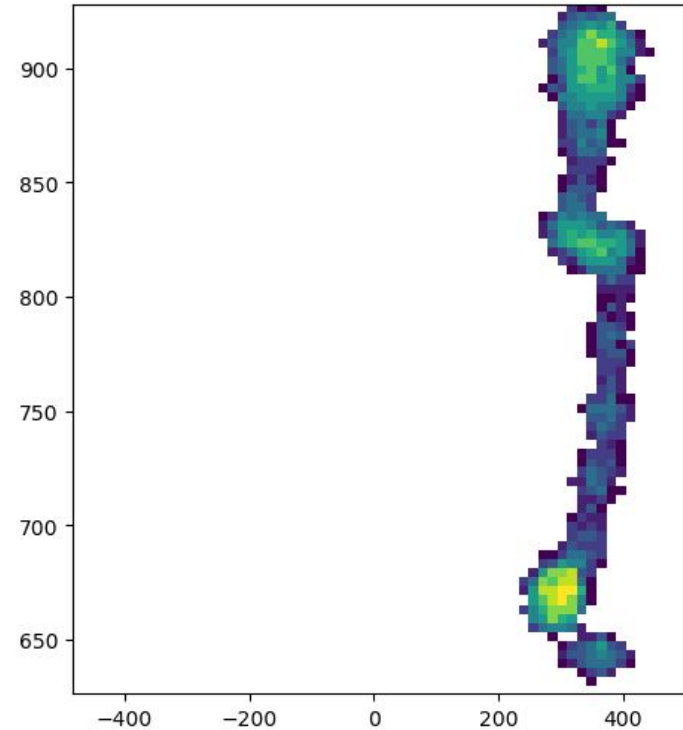
- excellent energy resolution,
- **high pressure** → **increased target mass**
→ **increased exposure,**



The NEXT experiment

Advantages:

- excellent energy resolution,
- increased target mass,
- **low background** due to:
 - **topological** discrimination,
 - **radiopure** materials.



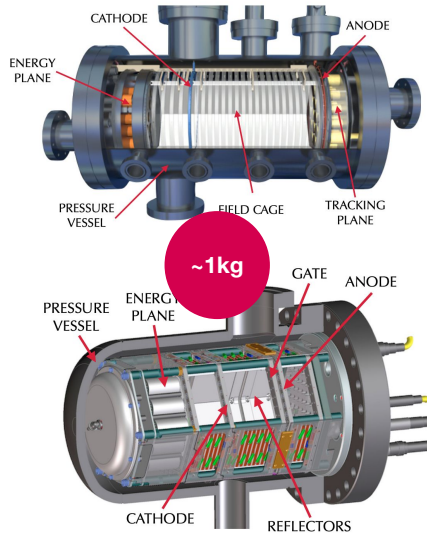
Charged particle track candidate.

NEXT timeline

PROTOTYPES

2009/2014

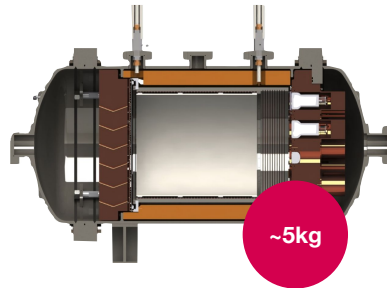
Demonstration of the detector concept



NEXT-WHITE (NEW)

2015/2021

Background model assessment
 $2\nu\beta\beta$ measurement for ^{136}Xe

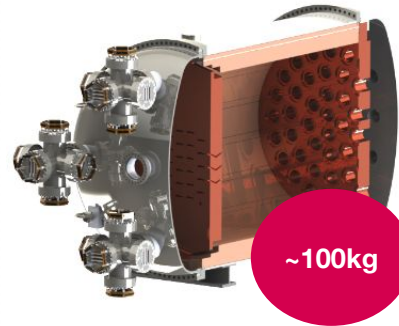


Laboratorio Subterráneo Canfranc

NEXT-100

2024/2030

Scalability
Background improvement
Neutrinoless double beta decay search in ^{136}Xe



Laboratorio Subterráneo Canfranc

NEXT-HD

~2030

Neutrinoless double beta decay search through inverted neutrino mass ordering

NEXT-BOLD

Barium tagging for background-free experiment
inverted neutrino mass ordering

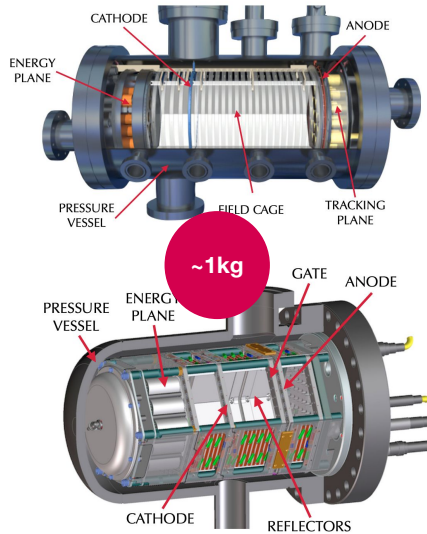


NEXT-100: the middle child

PROTOTYPES

2009/2014

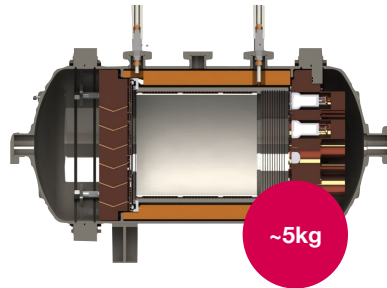
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Barium tagging for background-free experiment
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NEXT-100: the middle child

Features:

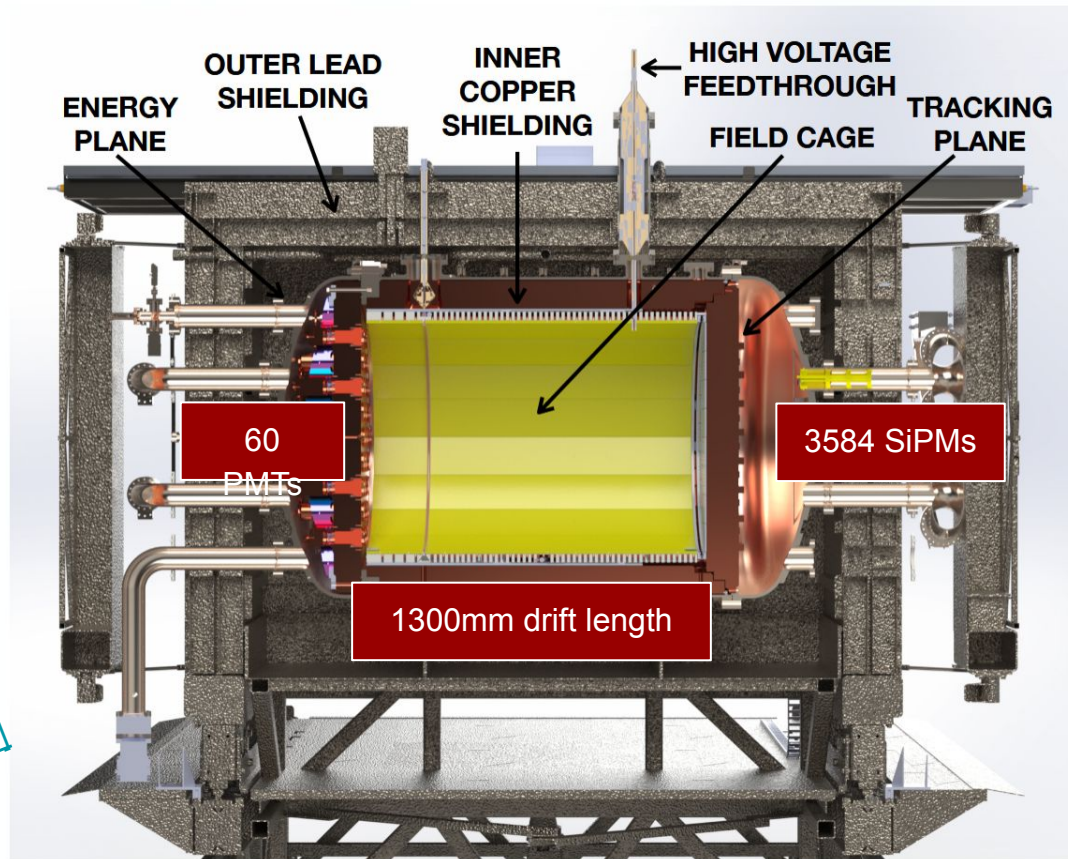
- Mass: ~100kg at 15 bar
- Sensitivity: 6.0×10^{25} y after 3 years
- Background: 1 counts/(keV ton yr)

Objectives:

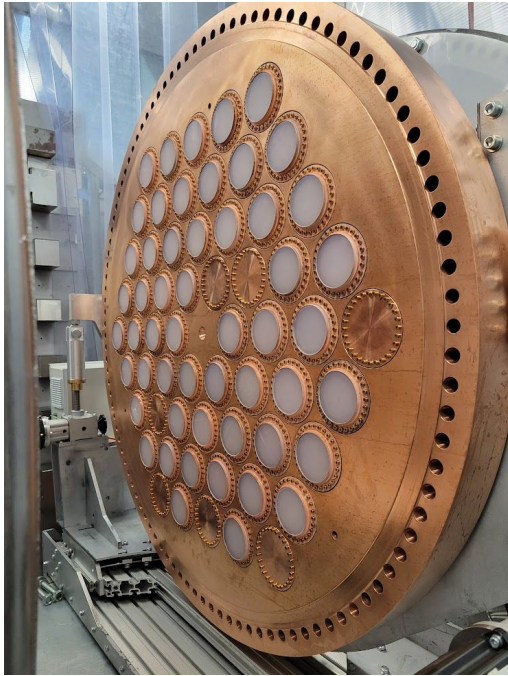
- Demonstrate **scalability** of NEXT technology
- **Sub 1% energy resolution @ 2.6 MeV**
- Competitive search for 0vBB

Assembly completed **2023**.

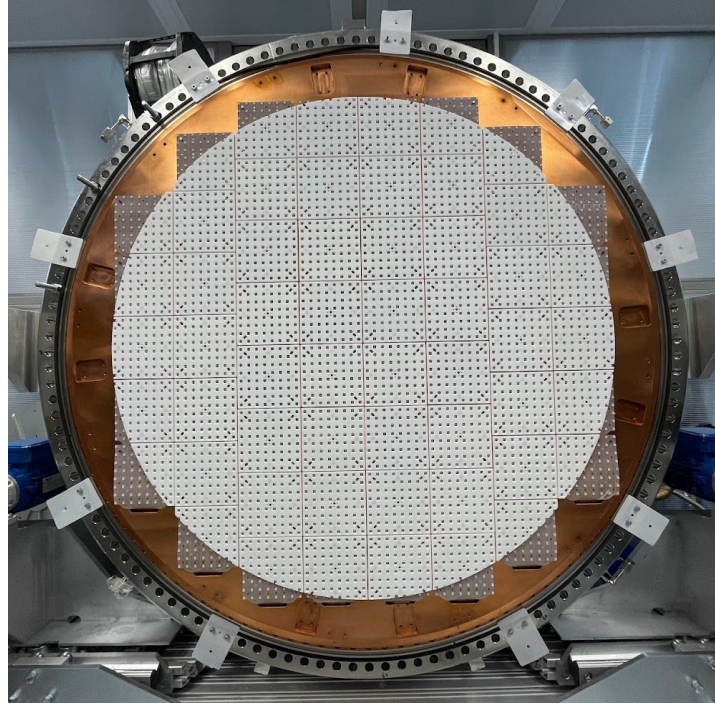
[JHEP05(2016)159]



NEXT-100: the middle child



Energy plane



Tracking plane



EL meshes in front of tracking plane

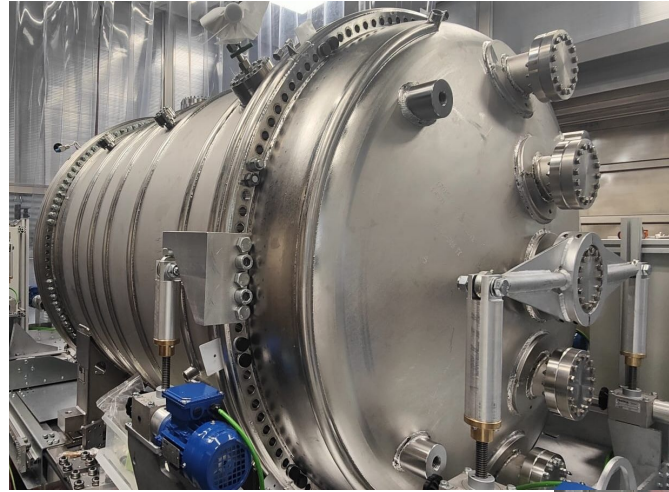
[\[JINST 19 P02007\]](#)

[\[arXiv:2505.01002\]](#)

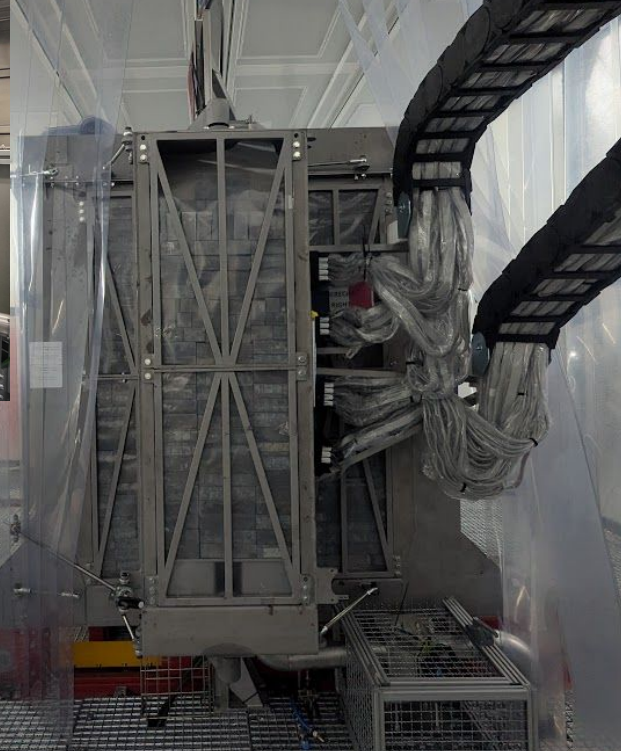
NEXT-100: the middle child



Cathode



Pressure vessel



Closed lead castle

NEXT-100: the middle child

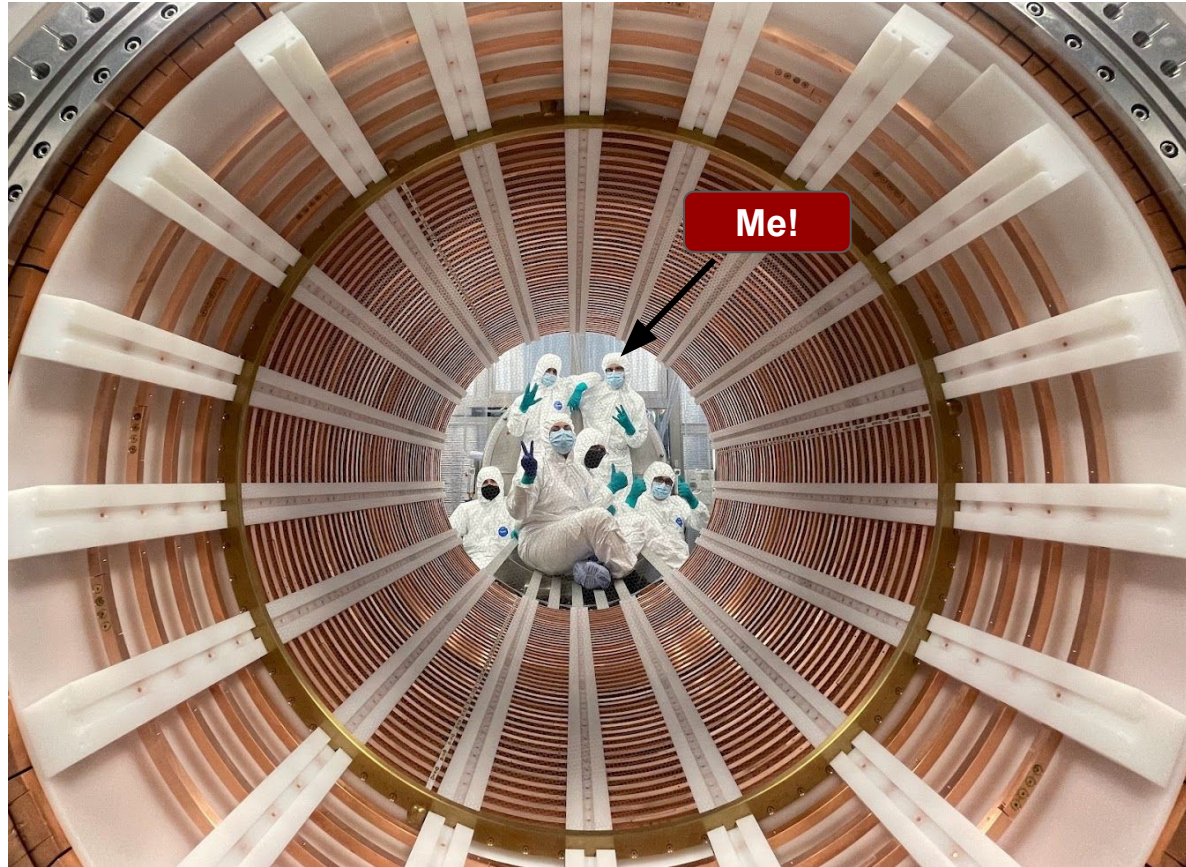
Commissioning & calibration complete:

- initial studies in argon,
- low pressure (4 bar) xenon calibration (**focus of this talk**).

Detector recently upgraded, high pressure run starting **summer 2026**.

Future upgrades of NEXT-100 will be useful for demonstrating **different technologies** for future NEXT detectors.

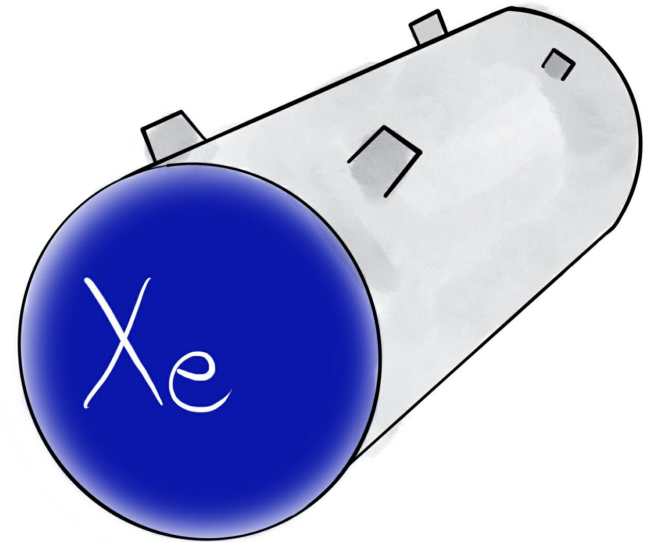
How do we demonstrate that the detectors **works as expected**?



NEXT-100 Field Cage [\[2505.01002\]](#)

The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

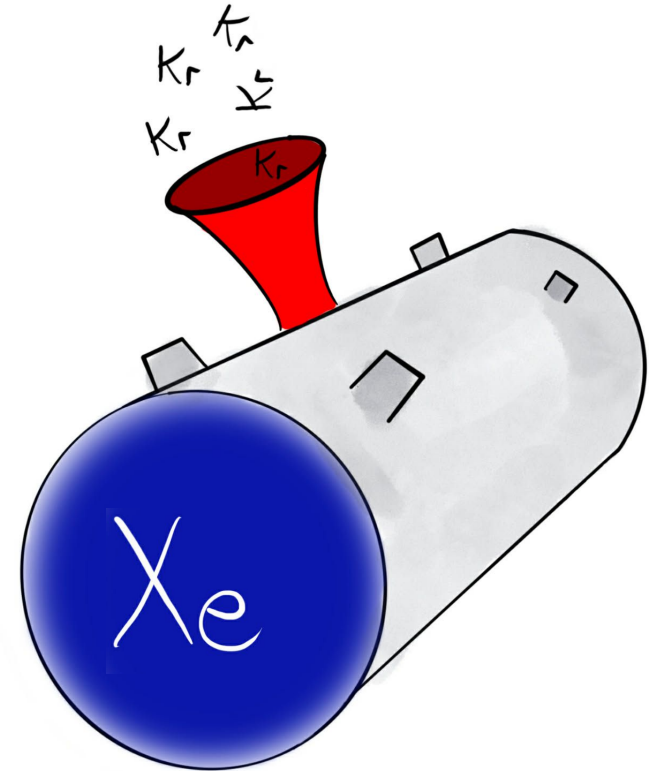


The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- **Low energy calibration**

→ ^{83m}Kr is introduced into the gas system,

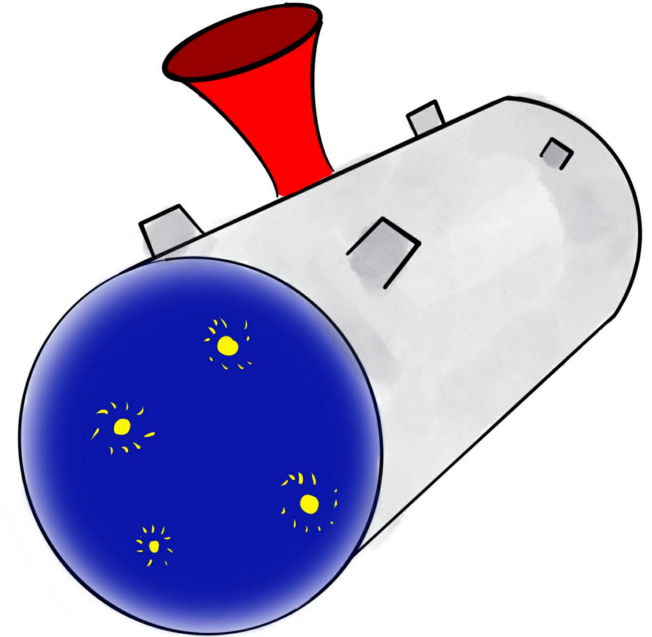


The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- **Low energy calibration**

- $^{83\text{m}}\text{Kr}$ is introduced into the gas system,
- decays within the detector volume emitting **point-like** electrons at ~ 41.5 keV



The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

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This allows us to:

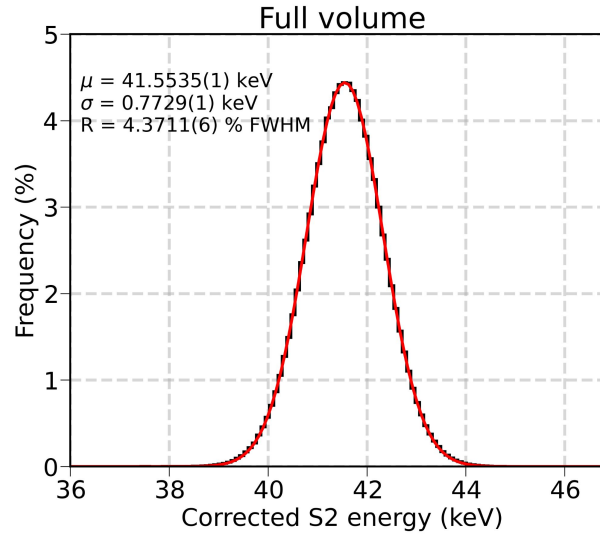
- correct for:
 - **geometrical** effects,
 - **electron lifetime** effects,
- calculate **electron diffusion** wrt Z,
- provide an **energy resolution @** low E,
- demonstrate **stability & scalability** of detector technology.



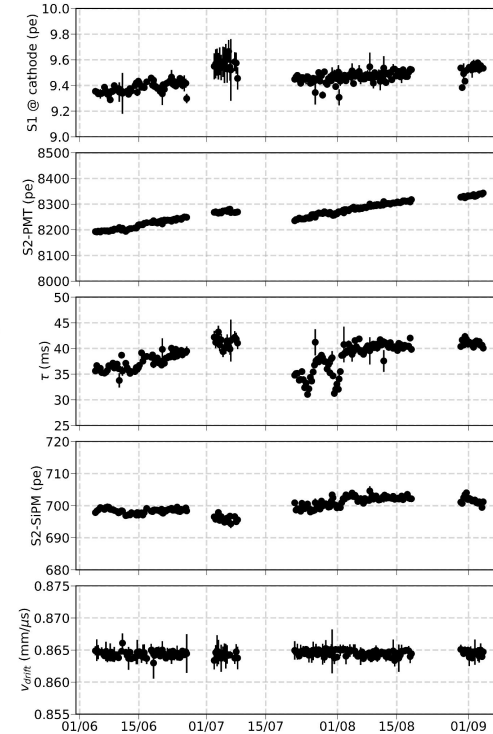
NEXT 100 low energy calibration

Energy resolution of **4.37% FWHM @ 41.5 keV**

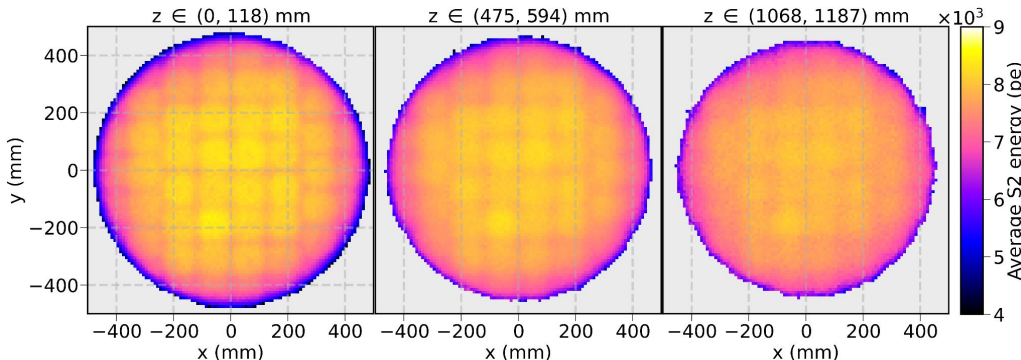
Naively, energy resolution can be extrapolated to **0.5% FWHM @ Q_{BB}**



Energy resolution plot for 83m krypton decay



Detector stability demonstrated over run period

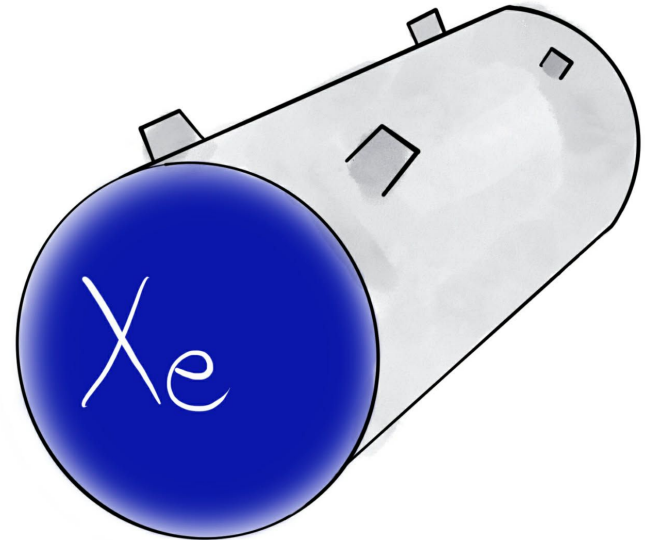


Visual of average deposited energy across differing z ranges.

The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

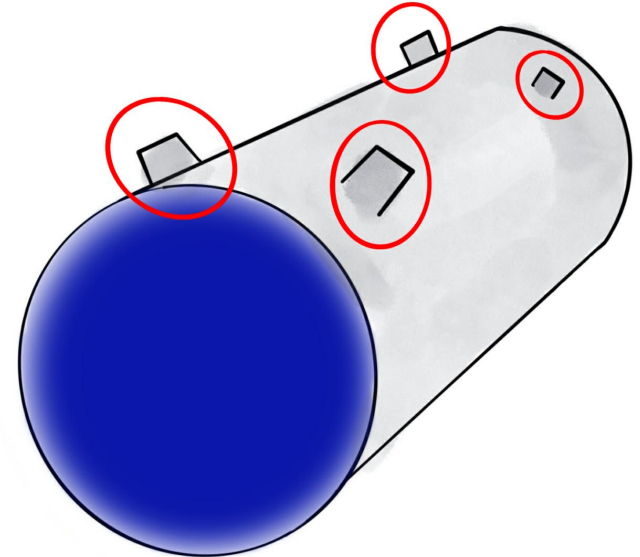
- Low energy calibration ✓



The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- Low energy calibration ✓
- **High energy calibration**

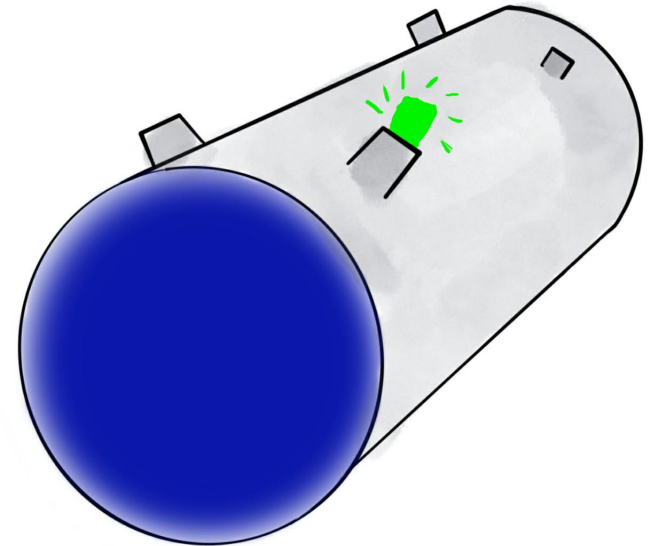


The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- Low energy calibration ✓
- **High energy calibration**

→ ^{228}Th source introduced into detector port



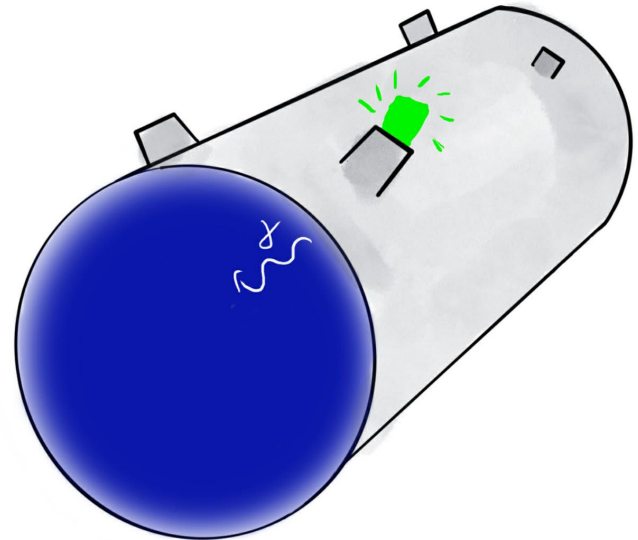
The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- Low energy calibration ✓
- **High energy calibration**

→ ^{228}Th source introduced into detector port

→ **Photons** emitted in the decay are useful for studying two things:



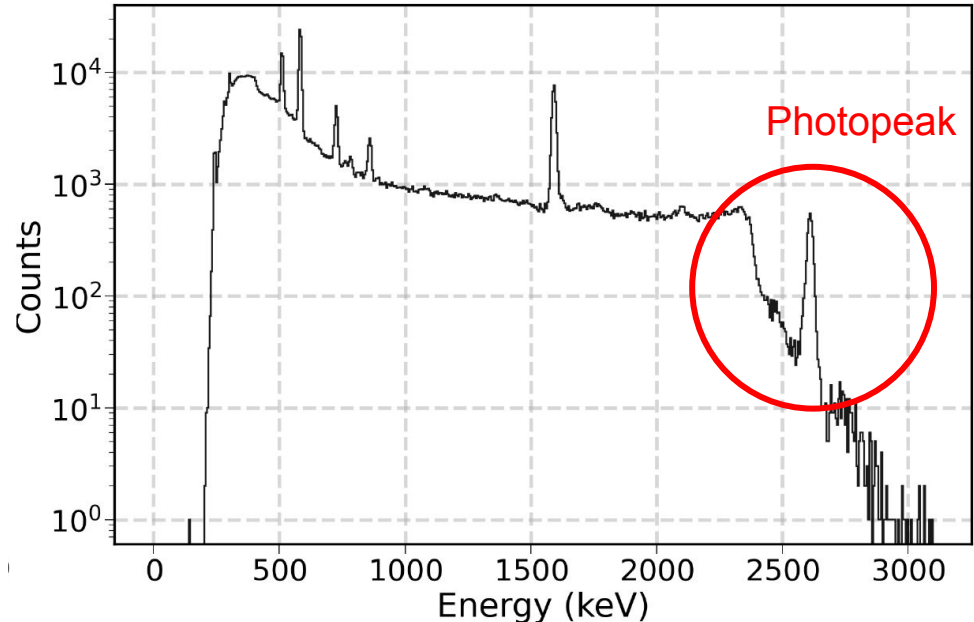
The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- Low energy calibration ✓
- **High energy calibration**

→ ^{228}Th source introduced into detector port
→ **Photons** emitted in the decay are useful for studying two things:

- **Energy resolution @ 2.6 MeV** (near the Q_{BB}) and for other peaks,



Observed energy spectrum for ^{228}Th

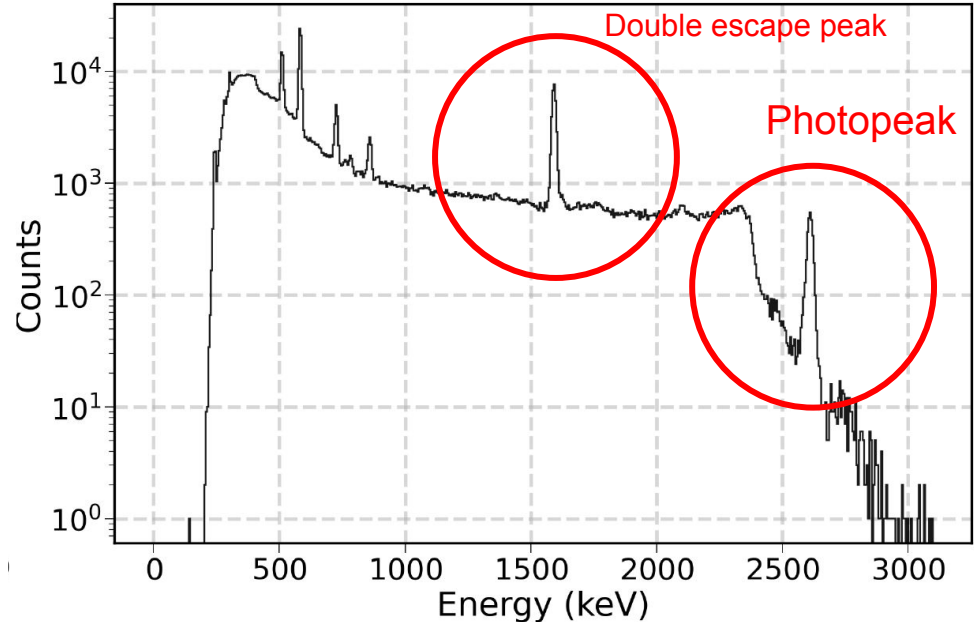
The NEXT calibration recipe

NEXT commissioning and calibration has two major phases:

- Low energy calibration ✓
- **High energy calibration**

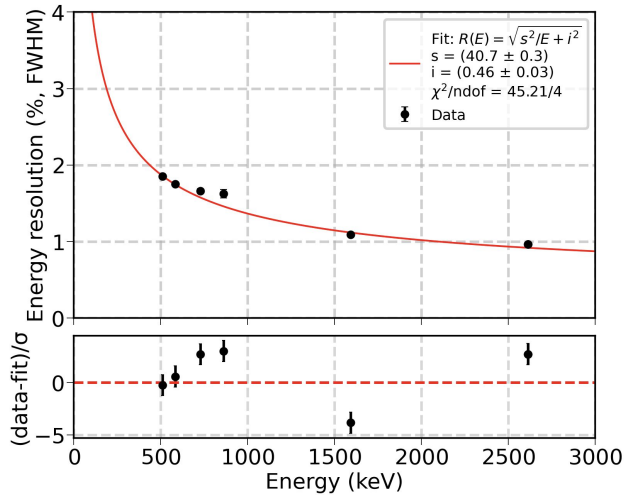
→ ^{228}Th source introduced into detector port
 → **Photons** emitted in the decay are useful for studying two things:

- **Energy resolution @ 2.6 MeV** (near the Q_{BB}) and for other peaks,
- Double escape peak (**DEP**) tracks are useful for **topological discrimination**.

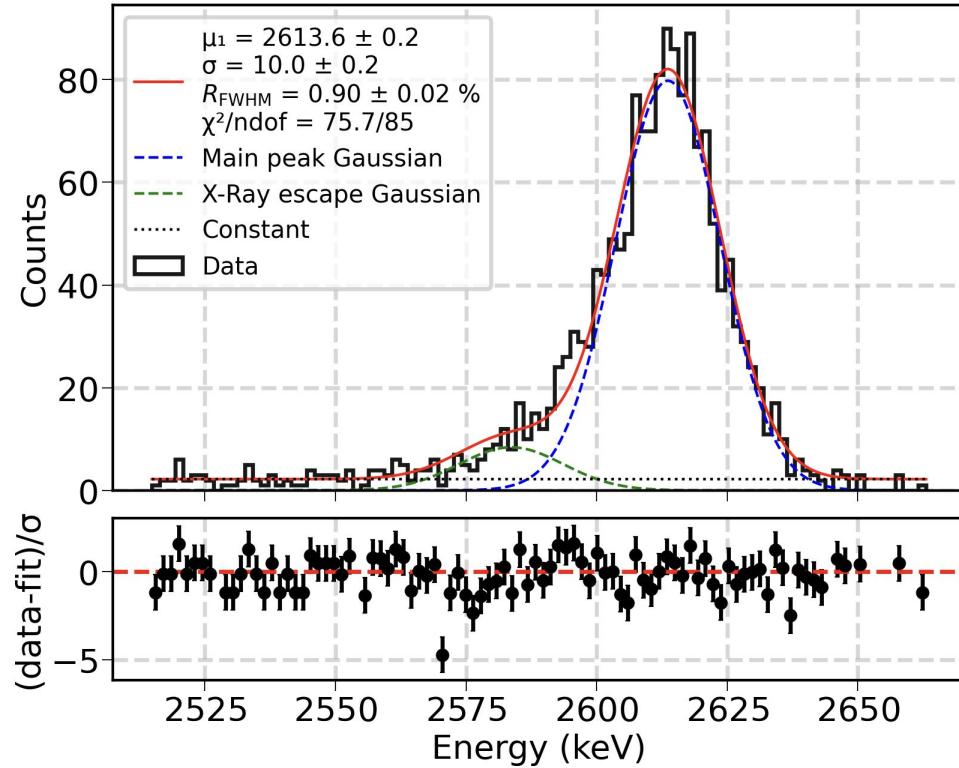


Observed energy spectrum for ^{228}Th

Recent study demonstrates energy resolution at ^{208}Tl photopeak: **0.90% FWHM @ 2.6 MeV.**



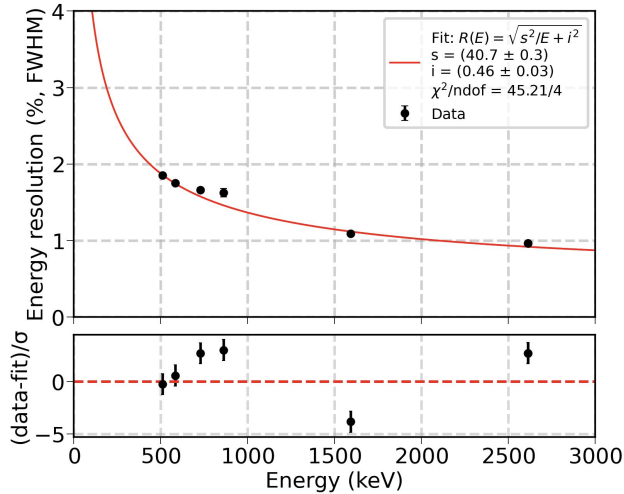
Energy resolution across differing peaks



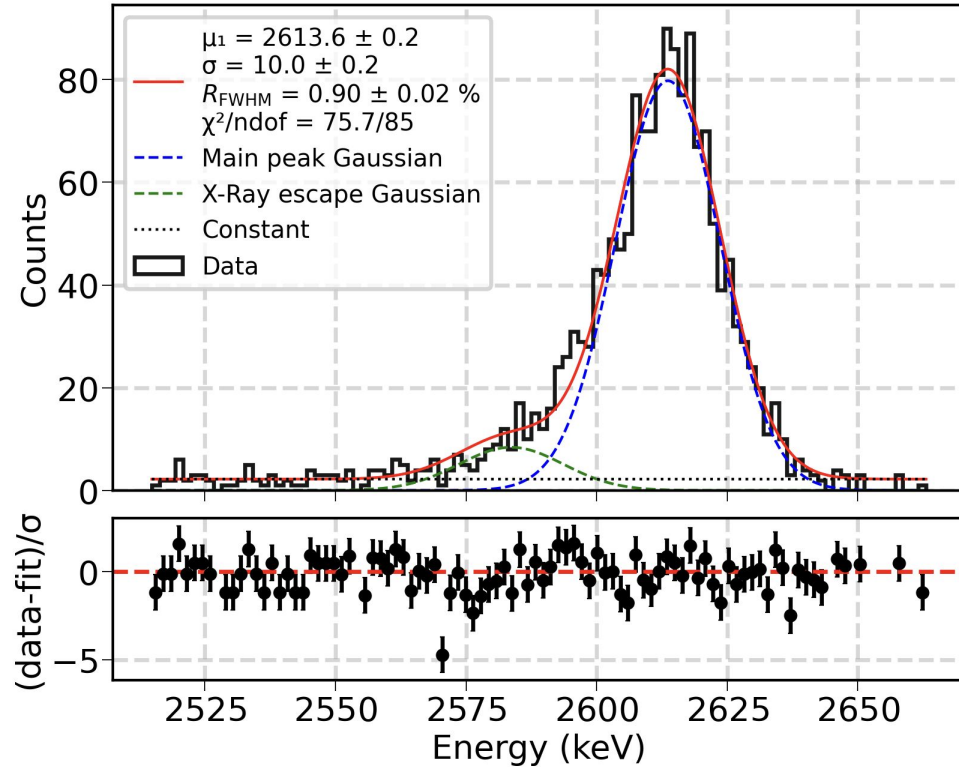
Energy resolution of ^{208}Tl photopeak

Recent study demonstrates energy resolution at ^{208}Tl photopeak: **0.90% FWHM @ 2.6 MeV.**

But what about the topology?



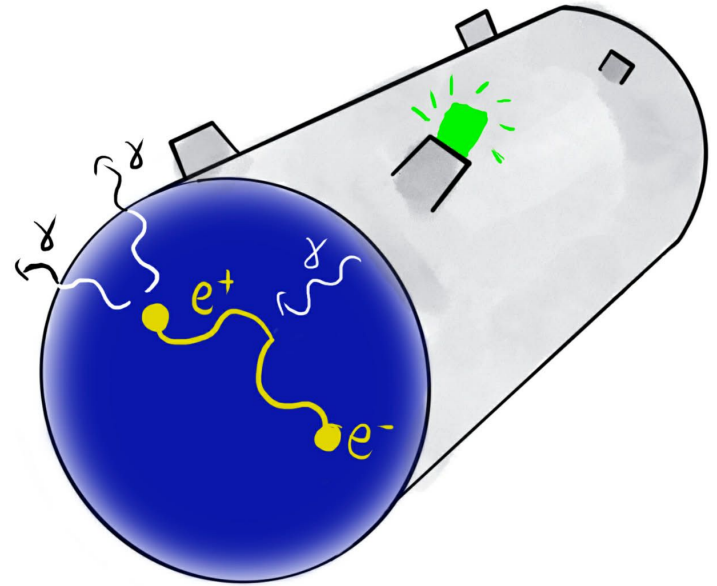
Energy resolution across differing peaks



Energy resolution of ^{208}Tl photopeak

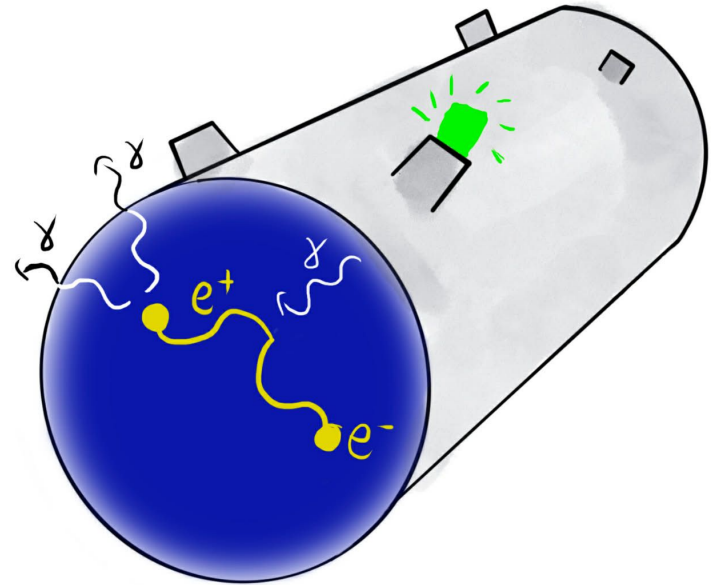
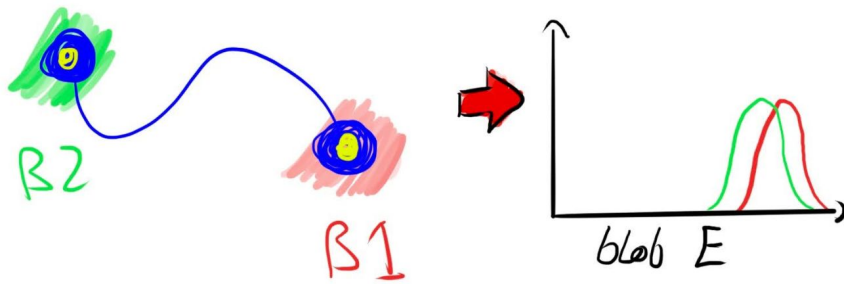
Topology in NEXT

Double escape peak (DEP) events imitate expected **0vBB topology**.



Topology in NEXT

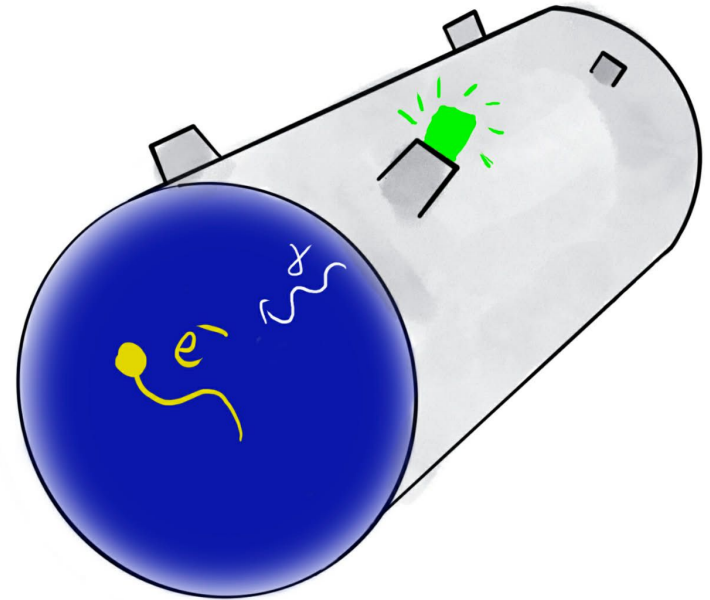
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Topology in NEXT

Double escape peak (DEP) events imitate expected **0vBB topology**.

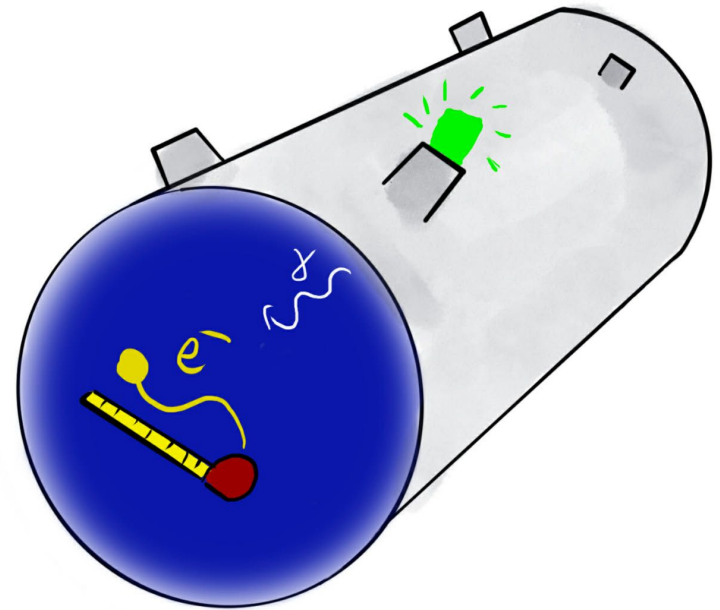
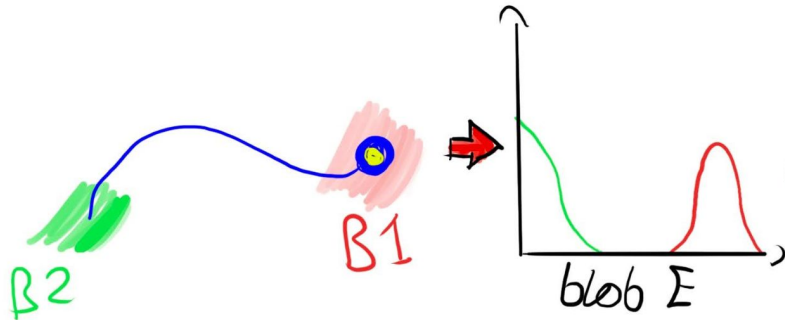
We can treat everything else as **background**.



Topology in NEXT

Double escape peak (DEP) events imitate expected **0vBB** topology.

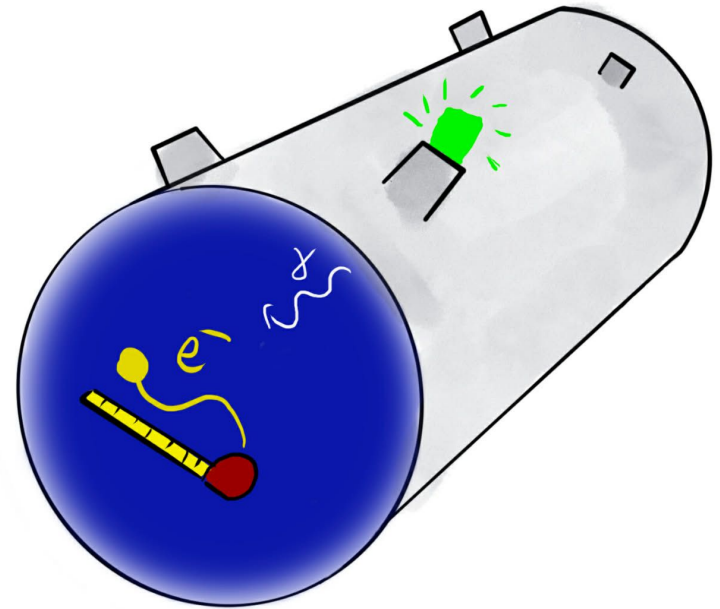
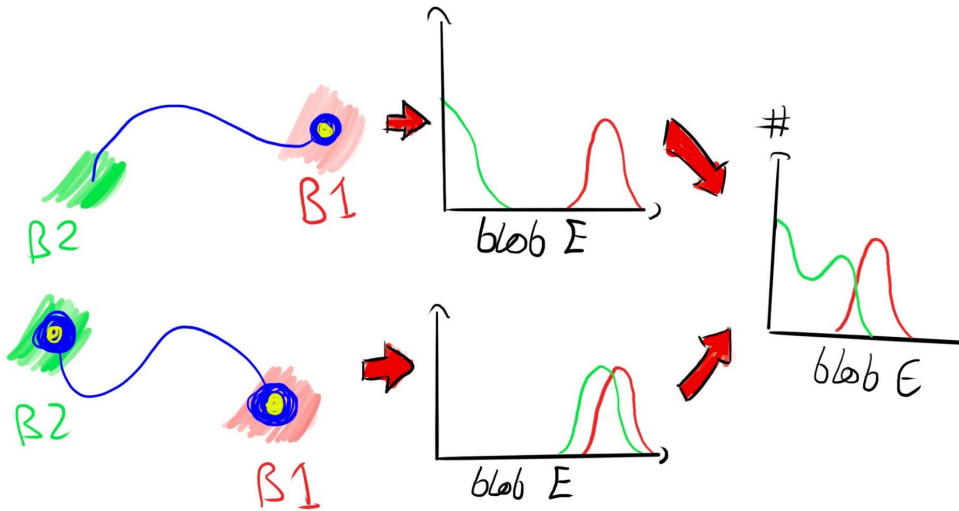
We can treat everything else as **background**.



Topology in NEXT

Double escape peak (DEP) events imitate expected **0vBB** topology.

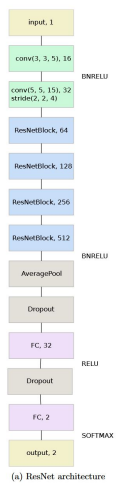
We can treat everything else as **background**.



Topology results in the past

CNN architecture for signal/background discrimination

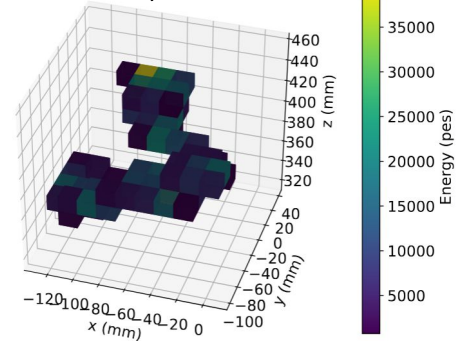
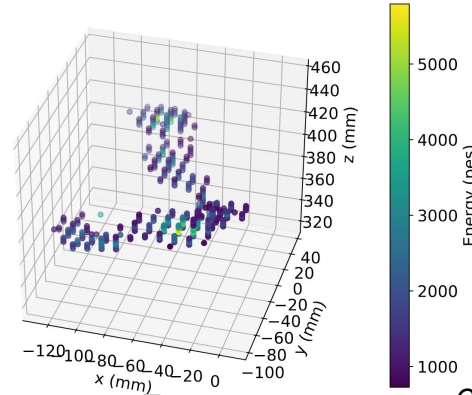
[\[JHEP01\(2021\)189\]](#)



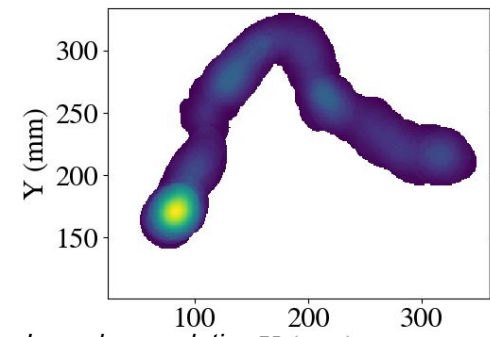
Lots of work done on topology across prior detectors (NEXT-WHITE in particular).

Improvements come in differing forms, **NNs**, improving **resolution**, improving **algorithms...**

Work still ongoing! Very active area of research.



Classical reconstruction
[\[JHEP10\(2019\)052\]](#)



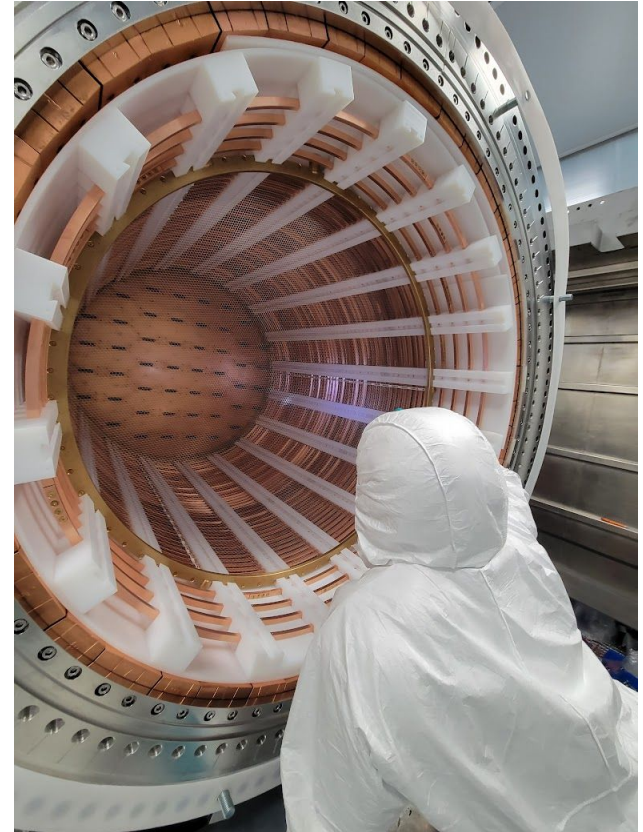
Richardson-Lucy deconvolution X (mm)
[\[JHEP07\(2021\)146\]](#)

What NEXT for NEXT-100?

High pressure run begins this summer, includes:

- **Low background** run,
- **0vBB** search.

Future upgrades testing new technologies in the works, to be introduced over the next few years.

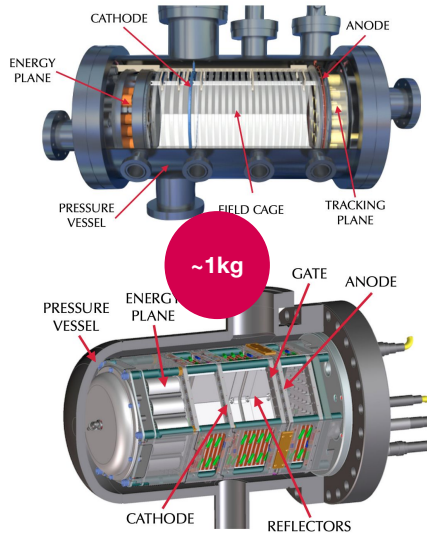


NEXT into the future

PROTOTYPES

2009/2014

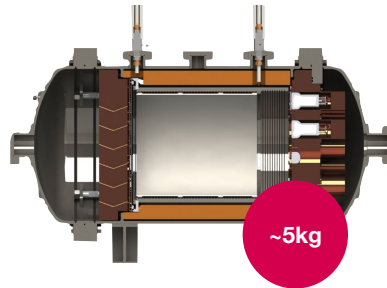
Demonstration of the detector concept



NEXT-WHITE (NEW)

2015/2021

Background model assessment
 $2\nu\beta\beta$ measurement for ^{136}Xe

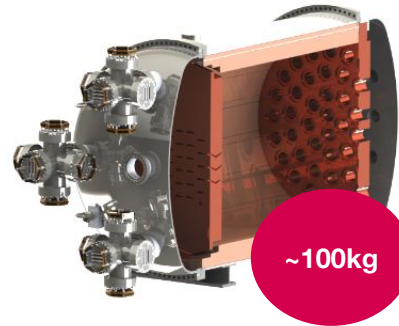


Laboratorio Subterráneo Canfranc

NEXT-100

2024/2030

Scalability
Background improvement
Neutrinoless double beta decay search in ^{136}Xe



Laboratorio Subterráneo Canfranc

NEXT-HD

~2030

Neutrinoless double beta decay search through inverted neutrino mass ordering

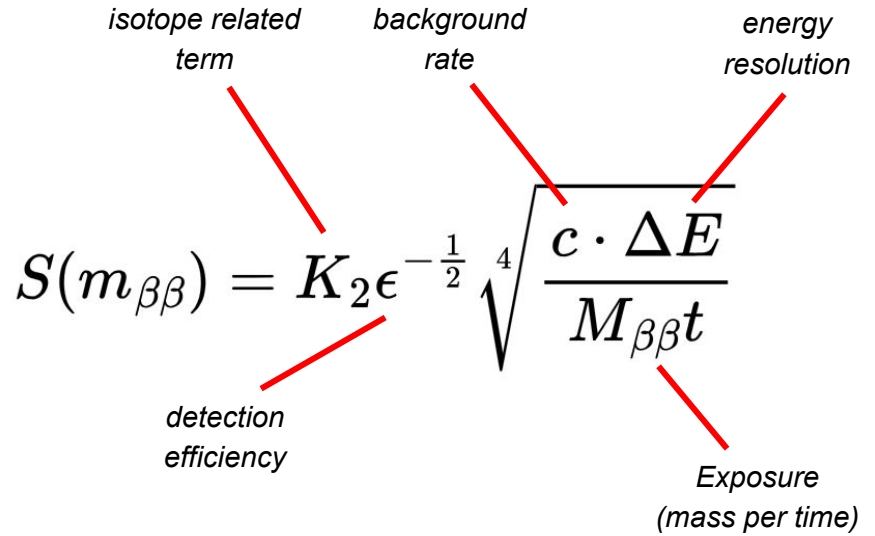
NEXT-BOLD

Barium tagging for background-free experiment
inverted neutrino mass ordering



NEXT into the future

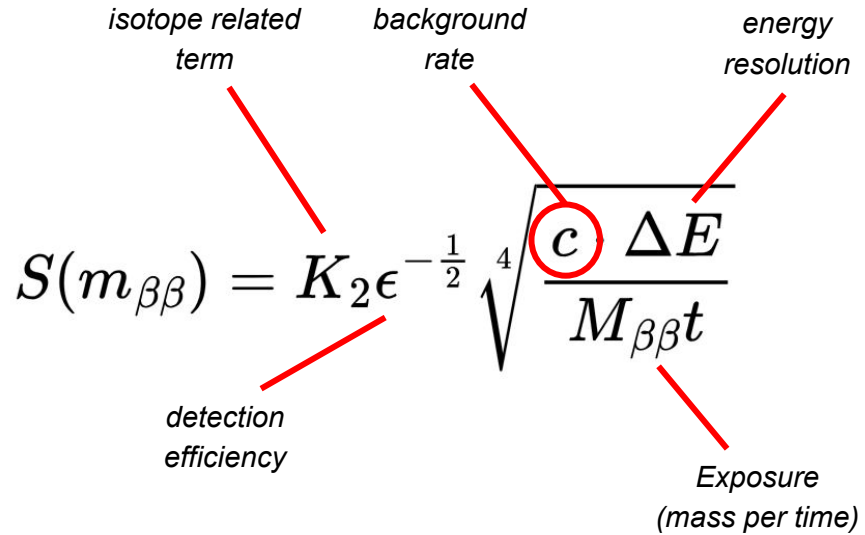
Improvements for sensitivity to neutrinoless double beta decay (for NEXT) depends on a few things:



NEXT into the future

Improvements for sensitivity to neutrinoless double beta decay (for NEXT) depends on a few things:

- **background rate,**



$$S(m_{\beta\beta}) = K_2 \epsilon^{-\frac{1}{2}} \sqrt[4]{\frac{c \Delta E}{M_{\beta\beta} t}}$$

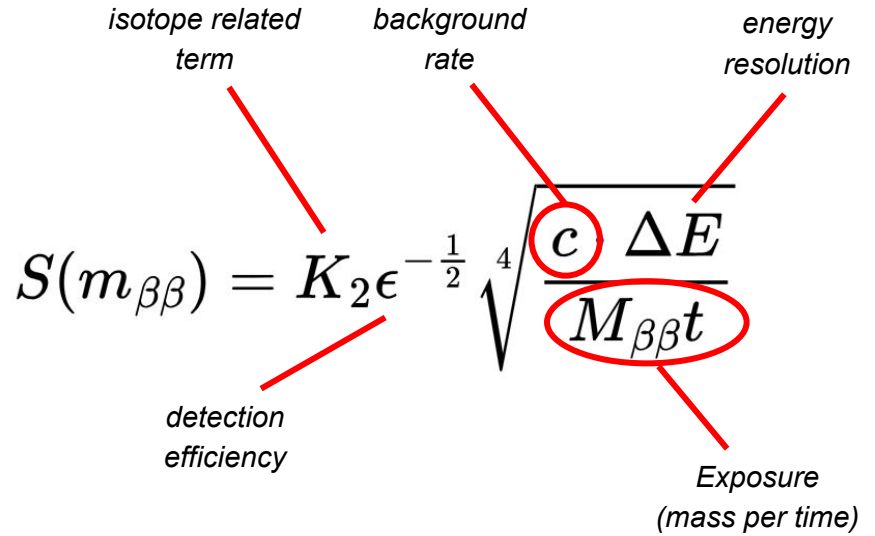
The diagram shows the following labels and their corresponding parts in the equation:

- isotope related term* points to K_2
- background rate* points to $\epsilon^{-\frac{1}{2}}$
- energy resolution* points to ΔE
- Exposure (mass per time)* points to $M_{\beta\beta} t$
- detection efficiency* points to c (which is circled in red)

NEXT into the future

Improvements for sensitivity to neutrinoless double beta decay (for NEXT) depends on a few things:

- background rate,
- **exposure.**

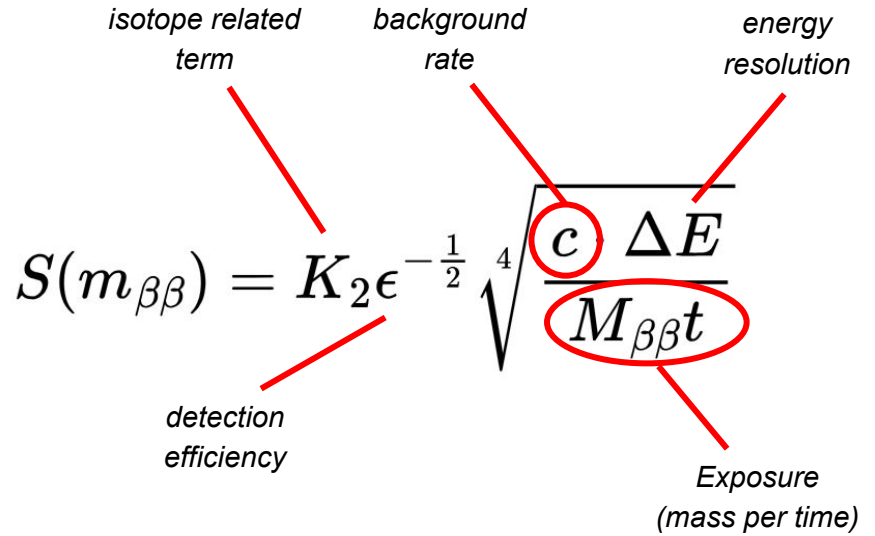


NEXT into the future

Improvements for sensitivity to neutrinoless double beta decay (for NEXT) depends on a few things:

- background rate,
- exposure.

How do we improve these two areas for future detectors?



NEXT-HD - increasing exposure

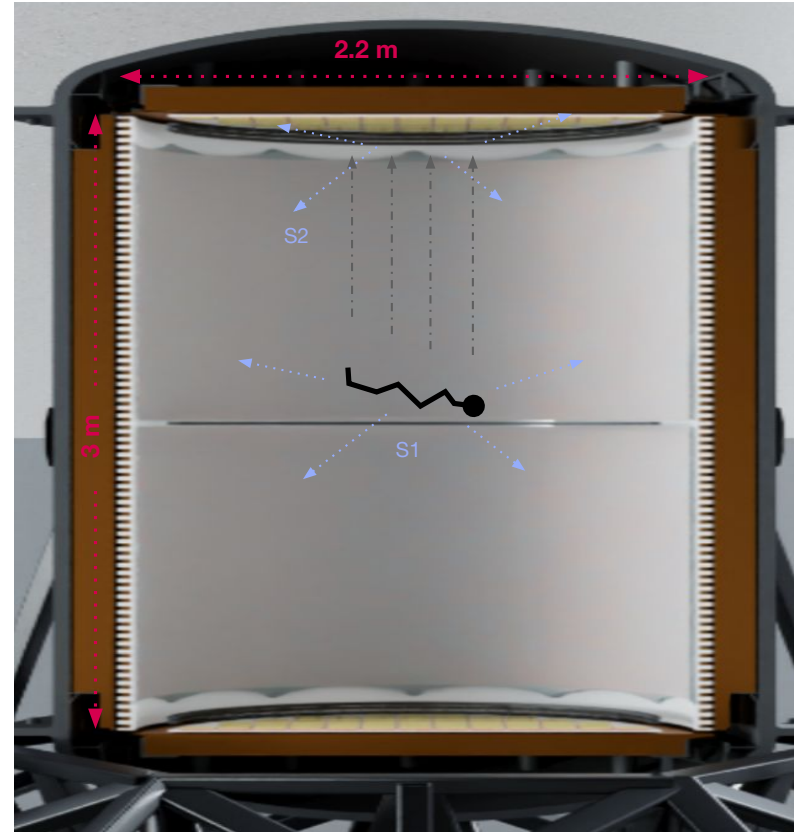
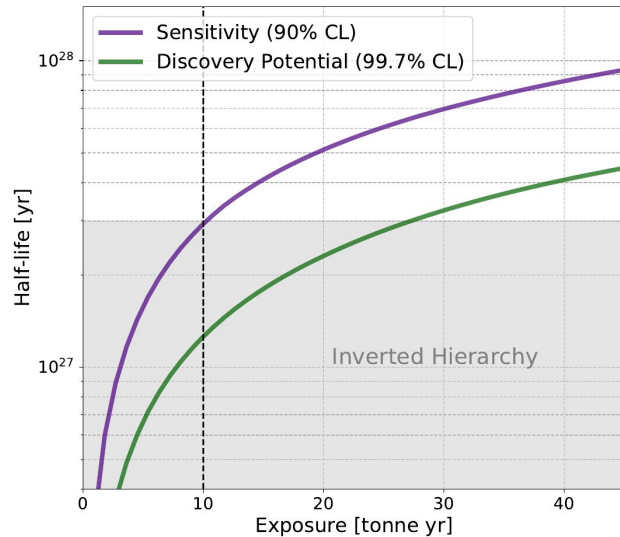
Projected for 2030s

Mass: ~1000 kg at 15 bar

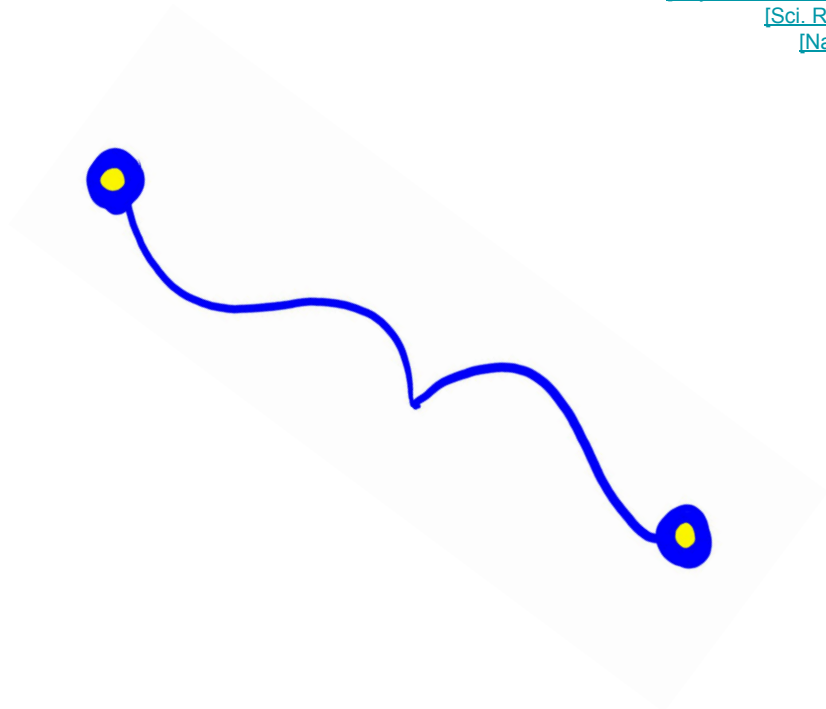
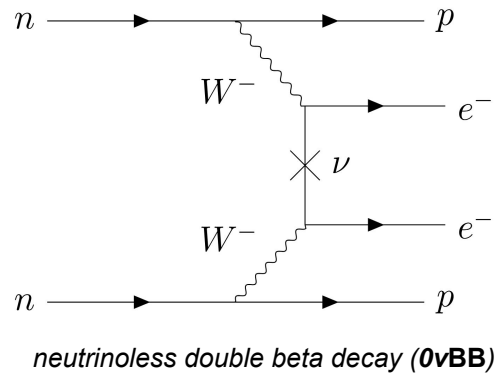
Sensitivity: 1.2×10^{27} y after 5 years

Background: 0.01 counts/(keV ton yr)

Same technology, scaled up!

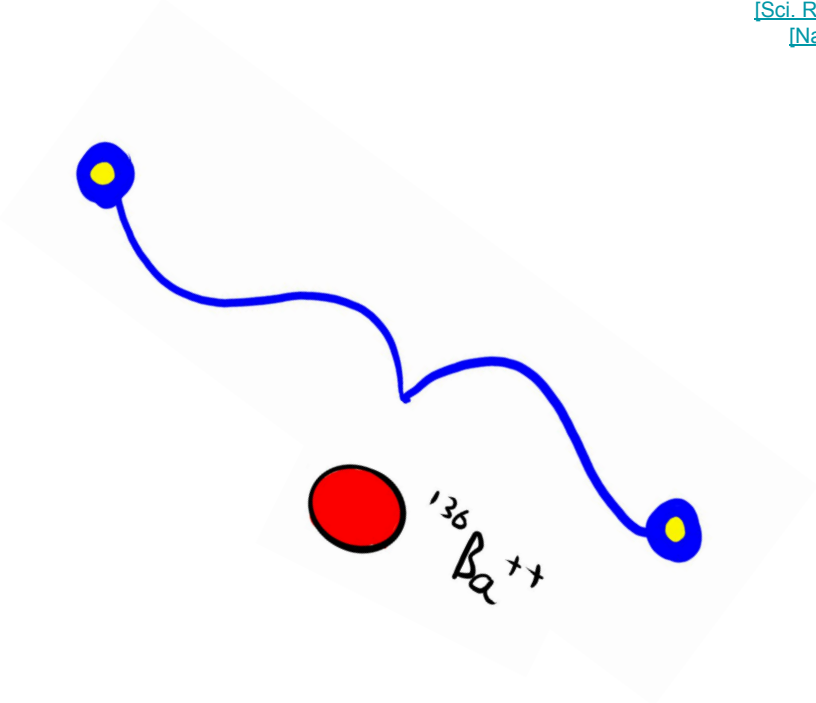
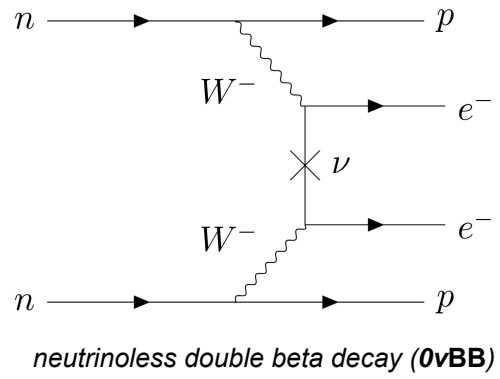


NEXT-BOLD - rejecting background



NEXT-BOLD - rejecting background

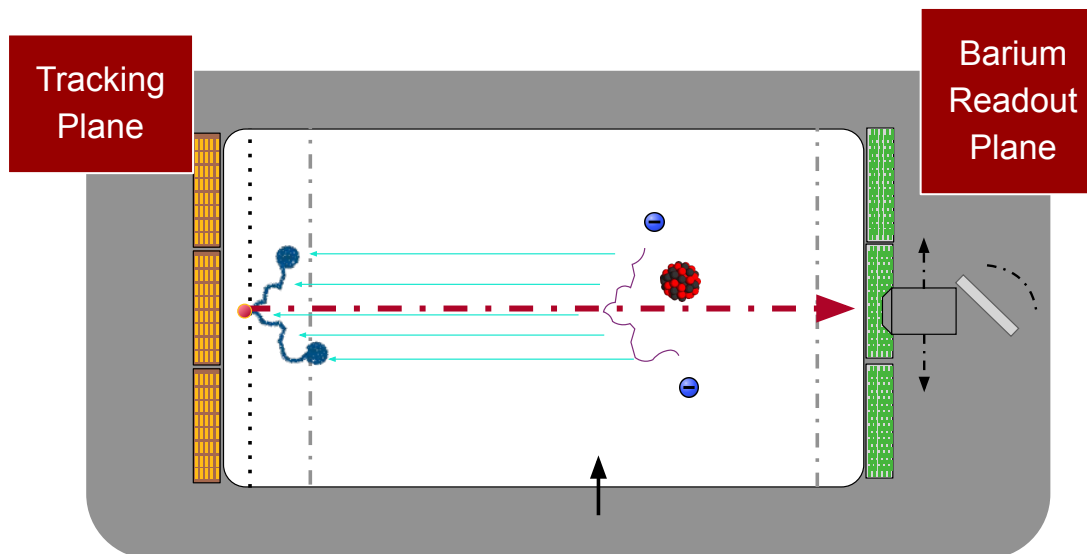
Coincidence of Barium ion and neutrinoless double beta decay energy/topology would allow for exceptional background discrimination!



NEXT-BOLD - rejecting background

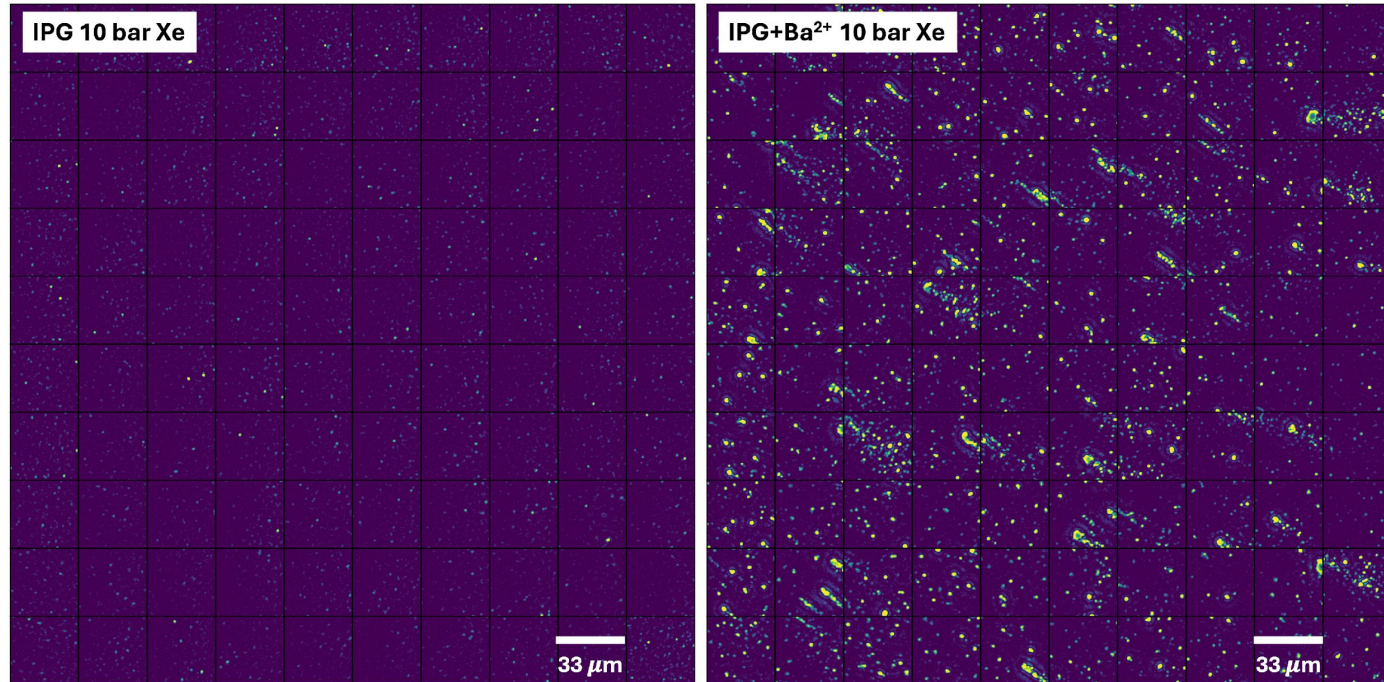
Research into barium ion readout for NEXT ongoing!

Fluorescence of barium ion with designed molecules **demonstrated**.



NEXT-BOLD - rejecting background

Research into barium ion readout for NEXT ongoing!



*Visual of molecular
fluorescence due to barium in
10 bar Xe*

Key takeaways

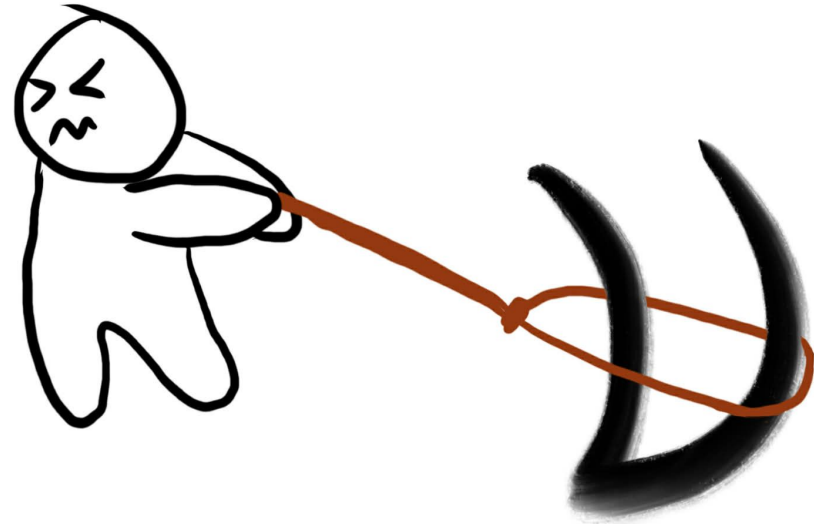
NEXT-100 was successfully commissioned and completed its low pressure run at 4 bar:

- detector **calibration** @ low and high energy **achieved** expected goals,
- achieved energy resolution **<1% FWHM @ 0vBB** Q value,
- detector **stability** and **scalability** from prior detectors has been demonstrated,
- work on topological performance continues to improve!

NEXT-100's high pressure run will begin soon, more exciting results on their way!

Upcoming upgrades will allow for testing **new technologies** for **future detectors**.

Lessons learned and skills achieved in **assembly, commissioning & calibration** will be key for the future tonne scale detector.



Grappling with neutrinos is good fun!



Thanks for listening!



[2nd workshop on future 0v searches in Xe](#)
Sept 14 - 18 @ University of Manchester

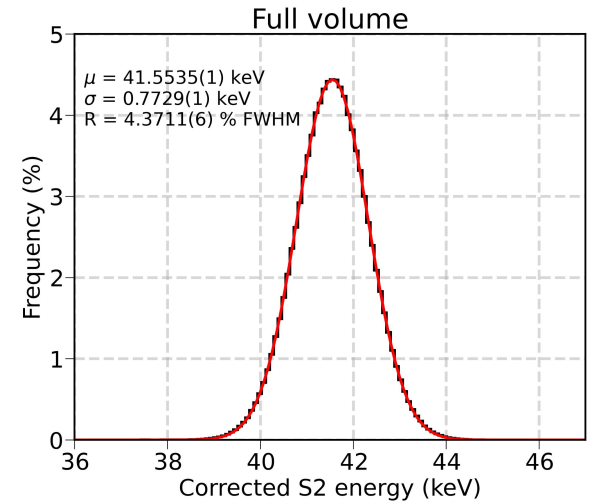


BACKUP

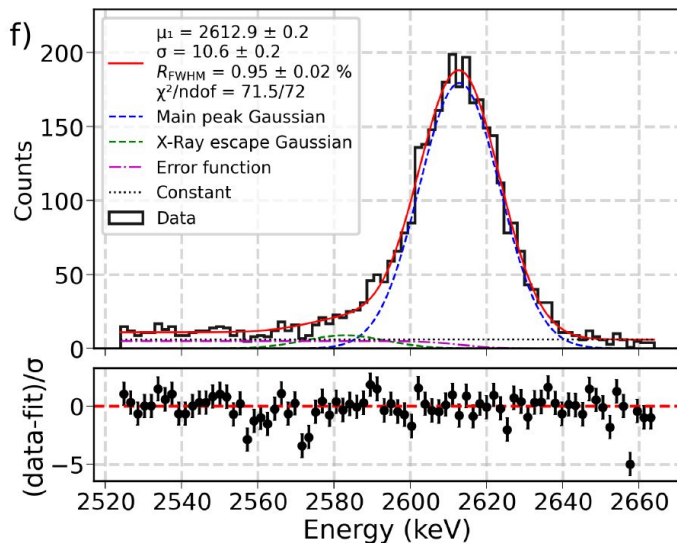
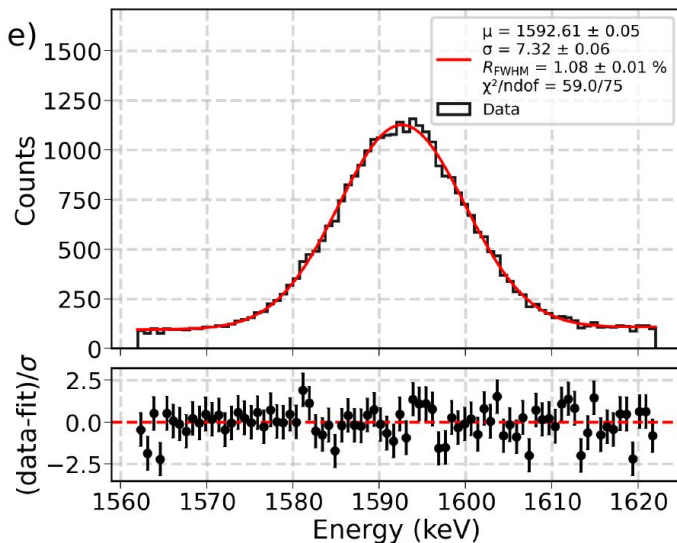
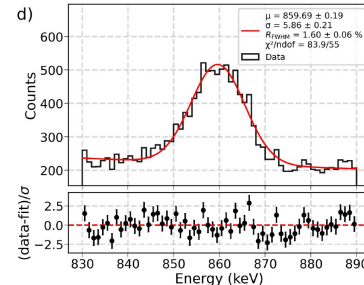
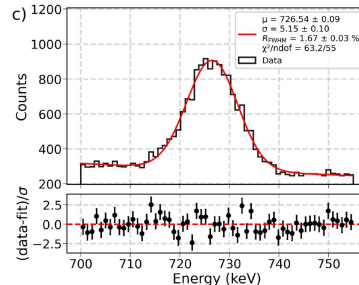
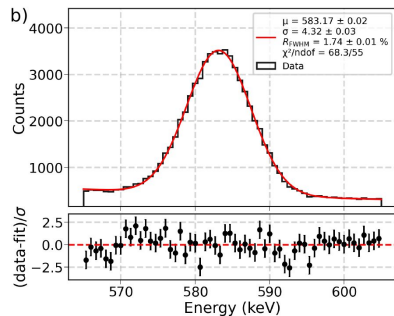
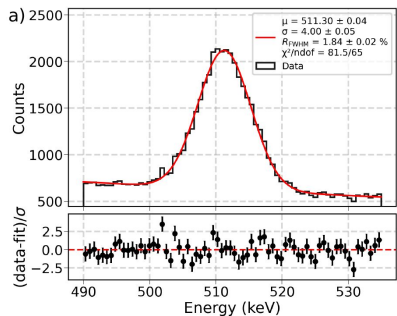
Kr energy resolution

Naive assumption that we can scale energy resolution wrt energy as shown:

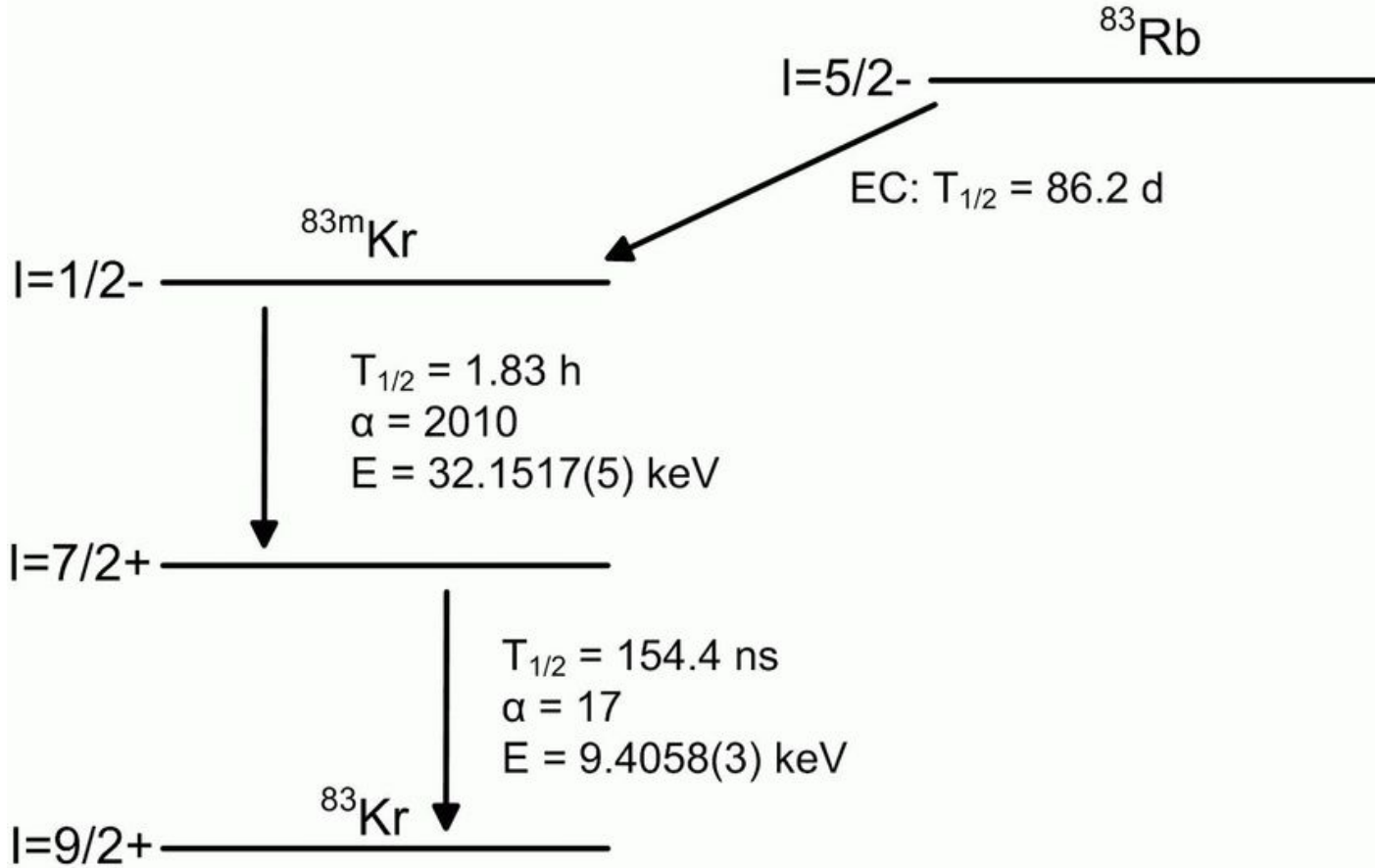
$$4\% * \sqrt{41.5\text{keV} / 2458\text{keV}} = 0.52\%$$



He calibration peaks



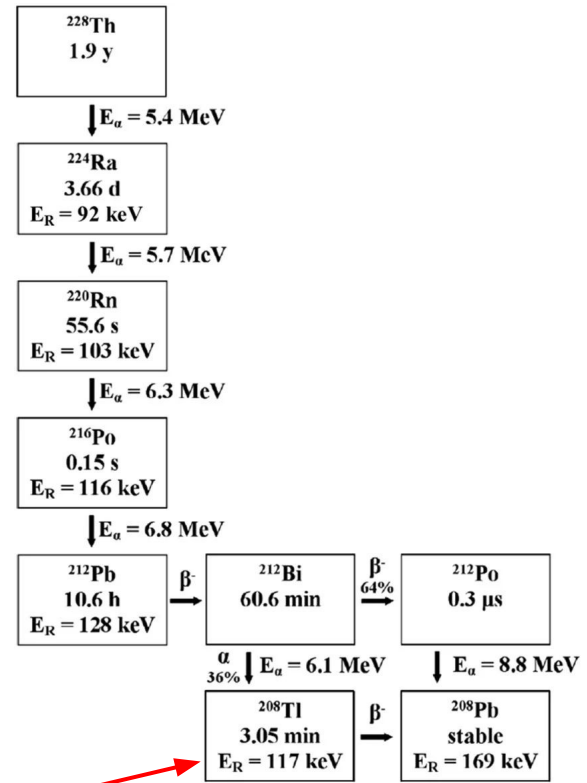
rubidium → krypton decay chain



thorium decay chain

Energy (keV)	Intensity (%)
2614.511 10	99.754 % 4

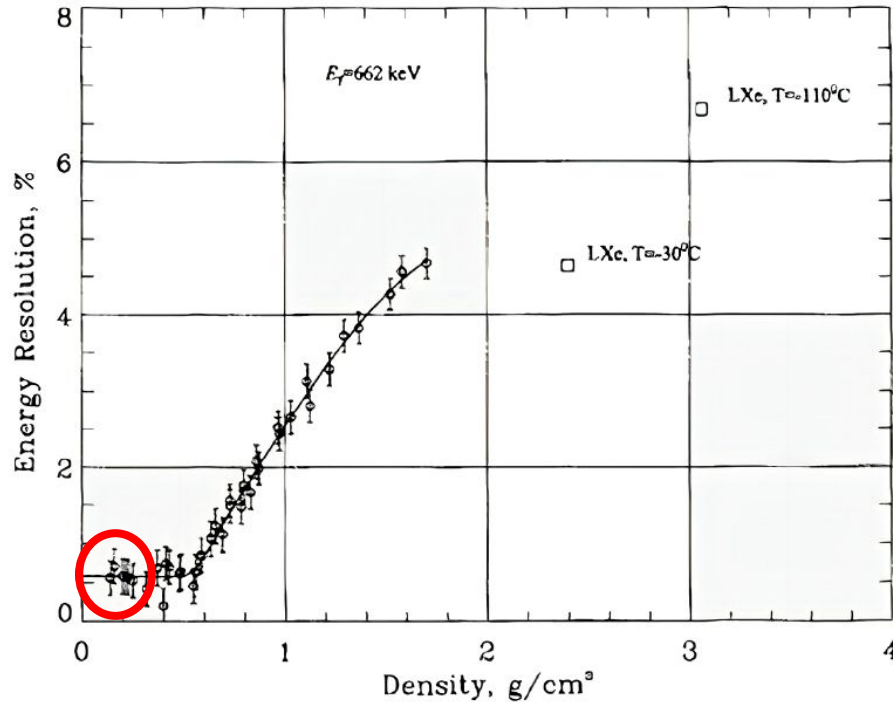
De-excitation of 208Tl emits gamma with energy shown above
 From: <https://www.nndc.bnl.gov/nudat3/decaysearchdirect.jsp?nuc=208Tl&unc=NDS>



We care about this bit



energy resolution against density



A. Bolotnikov and B. Ramsey, *The spectroscopic properties of high-pressure xenon*, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 396, 360 (1997).

Quantifying reconstruction: Blob-2 FOM

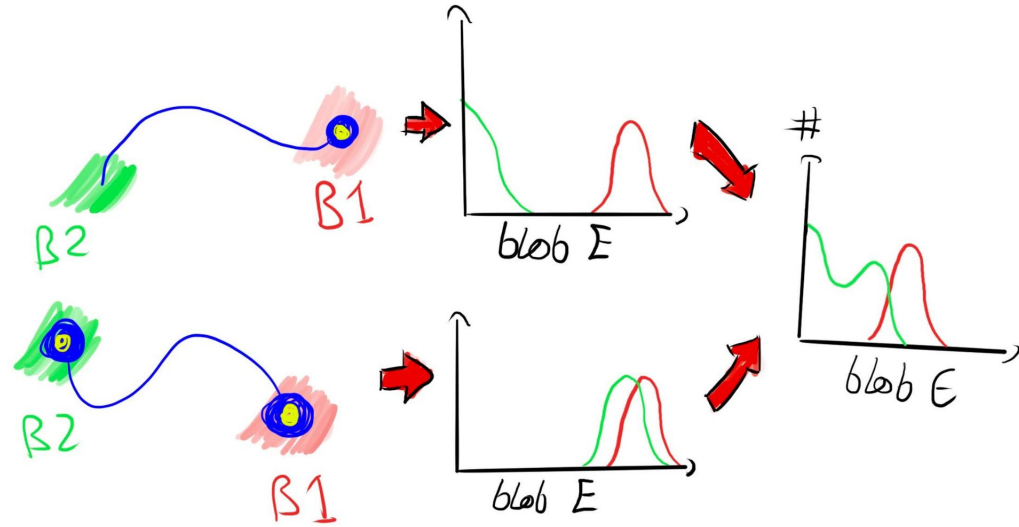
RECAP
[1847]

Like 0nubb events, DEP events contain two **high density energy deposits (blobs)** at each end of the track.

This allows for them to be separable from **background events** (compton scattering, failed track reconstruction) which will have **one bragg peak**.

So how distinct the signal and background populations are wrt blob energies makes a **good metric for reconstruction quality**.

Use a **figure of merit (FOM)** approach for this, cutting across blob 2 energy to remove background.



Difference between blob energies for background and signal (exaggerated).

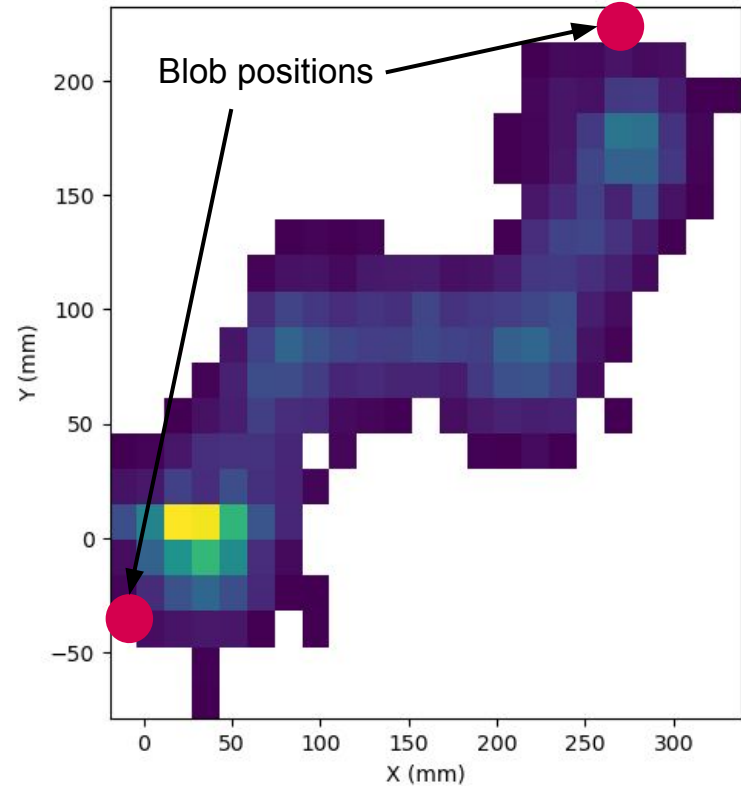
$$e^i = \frac{N_s^i}{N_s^o} \quad b^i = \frac{N_{bkg}^i}{N_{bkg}^o} \quad \text{fom} = \frac{e^i}{\sqrt{b^i}}$$

Number of signal and background events is determined by the use of a fit (described later).

Topology - Simple classical improvement

Originally, simple graph theory algorithms are used to ascertain the track ends.

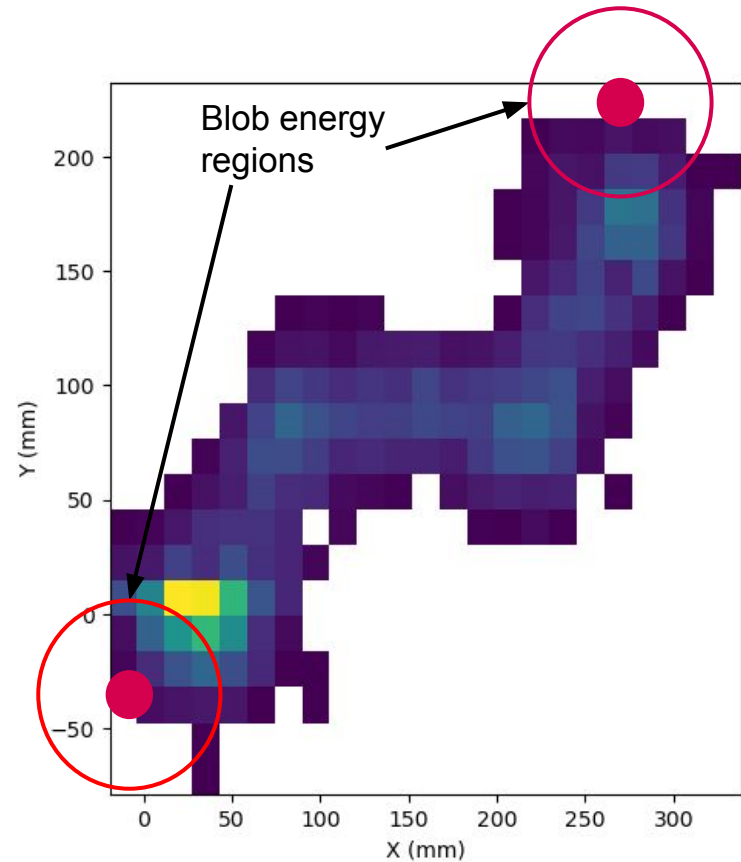
Blob energy extraction was then centred around these blob positions.



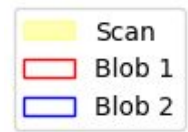
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Topology - Simple classical improvement



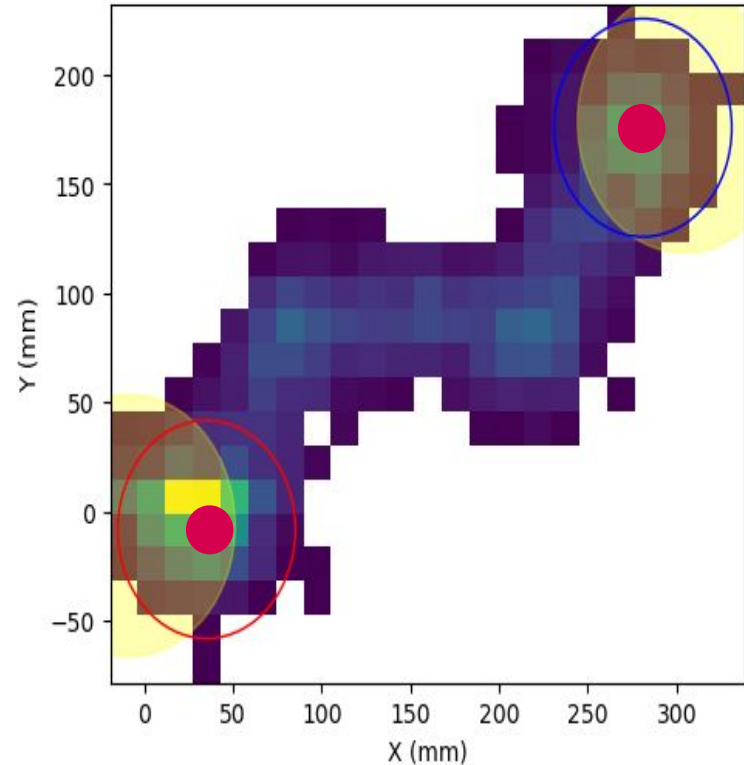
Originally, simple graph theory algorithms are used to ascertain the track ends.

Blob energy extraction was then centred around these blob positions.

Simple solution → provide an **initial scan** to chose blob centre before integrating blob energy.

Significantly boosted topological discrimination capabilities!

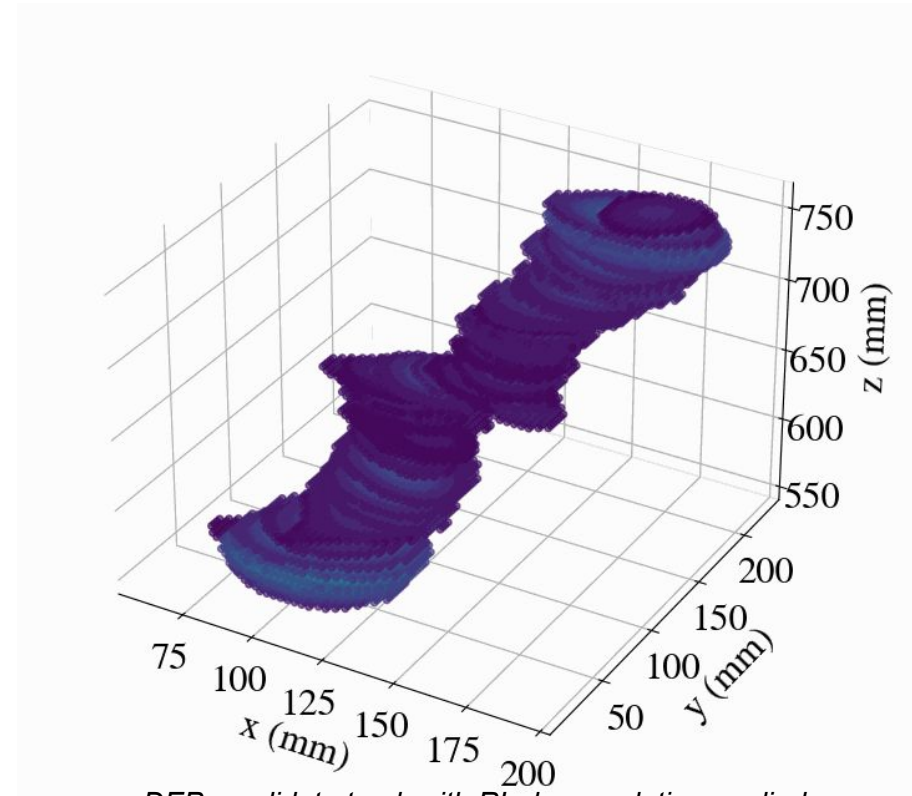
We are **continuously developing** new methods for further improving this process.



NEXT 100 - Richardson-Lucy Deconvolution

Was shown to perform exceptionally well in the **NEXT-WHITE** detector @ high pressure.

Currently working on optimisation of RL & topological parameters for **low pressure**.



DEP candidate track with RL deconvolution applied.

Sensitivity with more context

Slide from:
[Brais Palmeiro](#)
[XXI Workshop on neutrino telescopes](#)

Sensitivity to $\beta\beta\nu$

Detection efficiency

Background rate

Energy window (Resolution)

$$S(m_{\beta\beta}) = K_2 \epsilon^{-1/2} \sqrt[4]{\frac{c \cdot \Delta E}{M_{\beta\beta} t}} \propto T_{1/2}^{-1/2}$$

$$K_2 = \sqrt{k} K_1 = \sqrt{k \frac{W_{\beta\beta}}{\log 2 N_A} \frac{m_e^2}{G^{0\nu} |M^{0\nu}|^2}}$$

(isotope)

Exposure

The NEXT program and status of the NEXT-100 detector

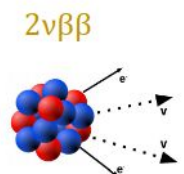
Brais Palmeiro

2

Backgrounds in Gas Xenon TPCs

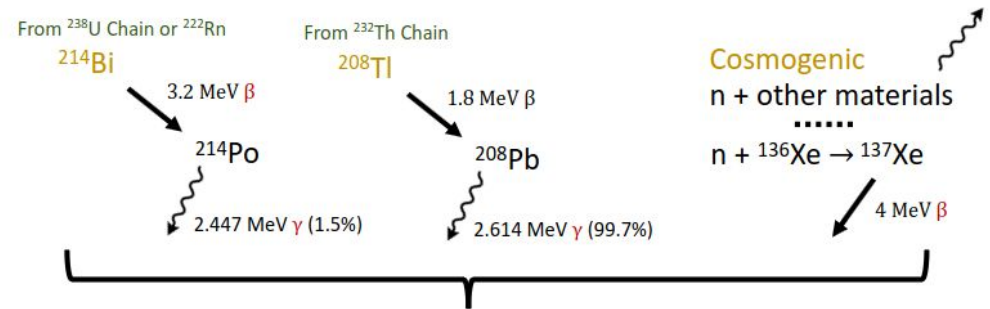
- $^{136}\text{Xe} \rightarrow ^{136}\text{Ba}^{2+} + 2e^-$ ($Q_{\beta\beta} = 2.46 \text{ MeV}$)

Slide from:
[Krishan Mistry](#),
[12th Symposium on Large TPCs for low-energy rare event detection](#)



Double electron signature

Remove with 1% FWHM energy resolution



Single electron signature via gammas or betas

Reduce with deep underground, radiopurity, detector shielding, muon veto

★ Then utilize topology for two-electron vs one-electron classification!

NEXT 100 - Richardson-Lucy Deconvolution

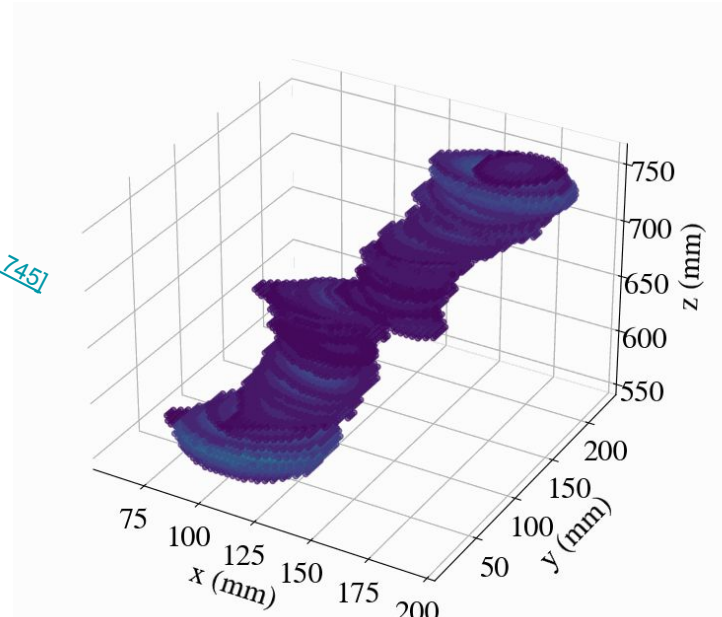
[J. Opt. Soc. Am. 62, 55-59]
[Astronomical Journal, Vol. 79, p. 745]

NEXT applies Richardson-Lucy (RL) deconvolution to reverse **blurring effect** from **electron diffusion** and **EL light production**.

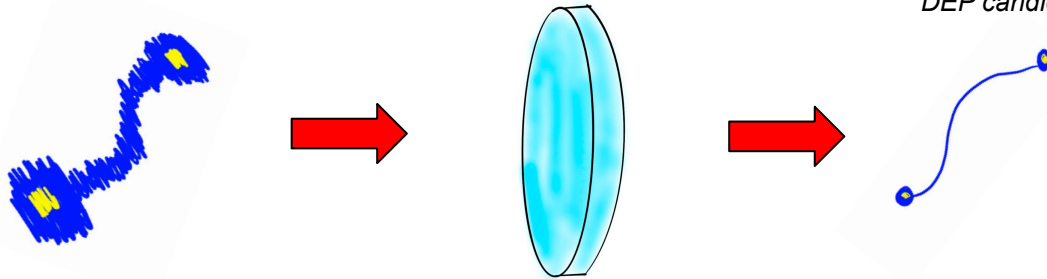
This requires a **point-spread function (PSF)**: a description of how the above effects **alter** the readout signal for point like events.

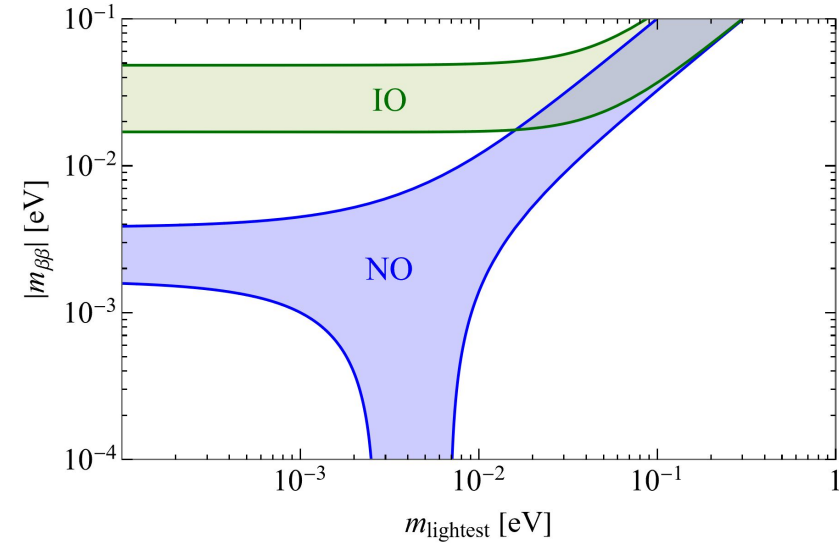
This is used to significantly enhance detector **resolution** and was shown to improve signal/background discrimination in NEW [\[2102.11931\]](#).

Work on this for NEXT-100 @ LPR is ongoing!



DEP candidate track with RL deconvolution applied.





x-axis → lightest neutrino

y-axis → majorana mass component

ranges for inverted and normal ordering