The NEXT program and status of the NEXT-100 detector

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XXI Workshop on Neutrino Telescopes

next

erc

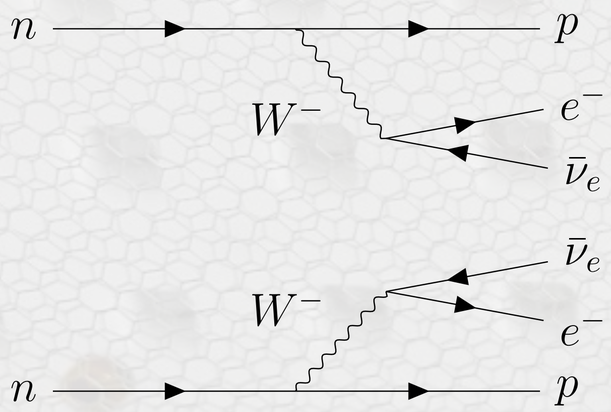
MANCHESTER 1824

The University of Manchester

Double beta decay

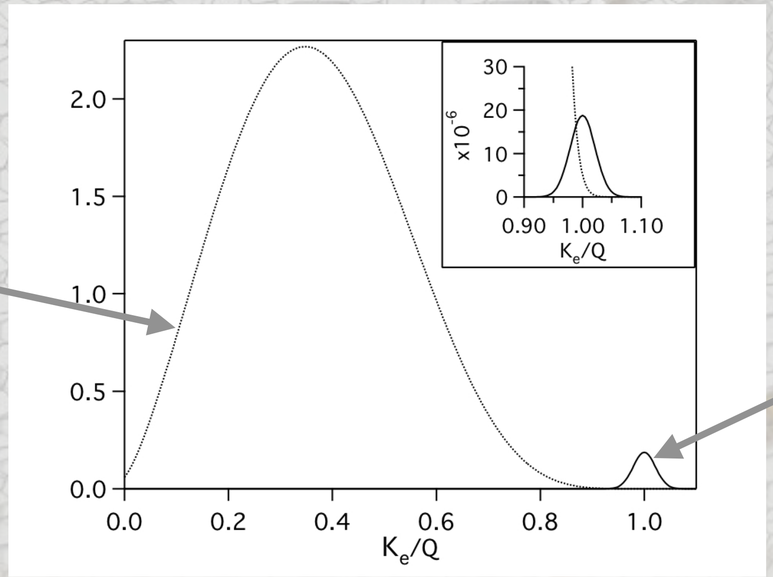
2νββ

$$^{A}_{Z}X \longrightarrow ^{A}_{Z+2}Y + 2e^- + 2\bar{\nu}_e$$



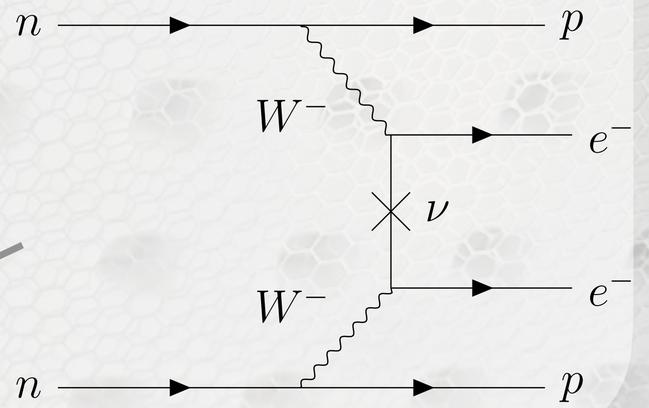
$$T^{\beta\beta 2\nu}_{1/2}(^{136}\mathrm{Xe}) = 2.165 \pm 0,016 \pm 0,059 \cdot 10^{21}\ \mathrm{y}$$

[Universe 6 (2020) 10, 159]



0νββ

$$^{A}_{Z}X \longrightarrow ^{A}_{Z+2}Y + 2e^-$$



Sensitivity to ββ0ν

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

Sensitivity to ββ0ν

Detection efficiency

Background rate

Energy window (Resolution)

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

Exposure

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

(isotope)

The next collaboration

*Neutrino Experiment with Xenon TPC

Isotope: ^{136}Xe

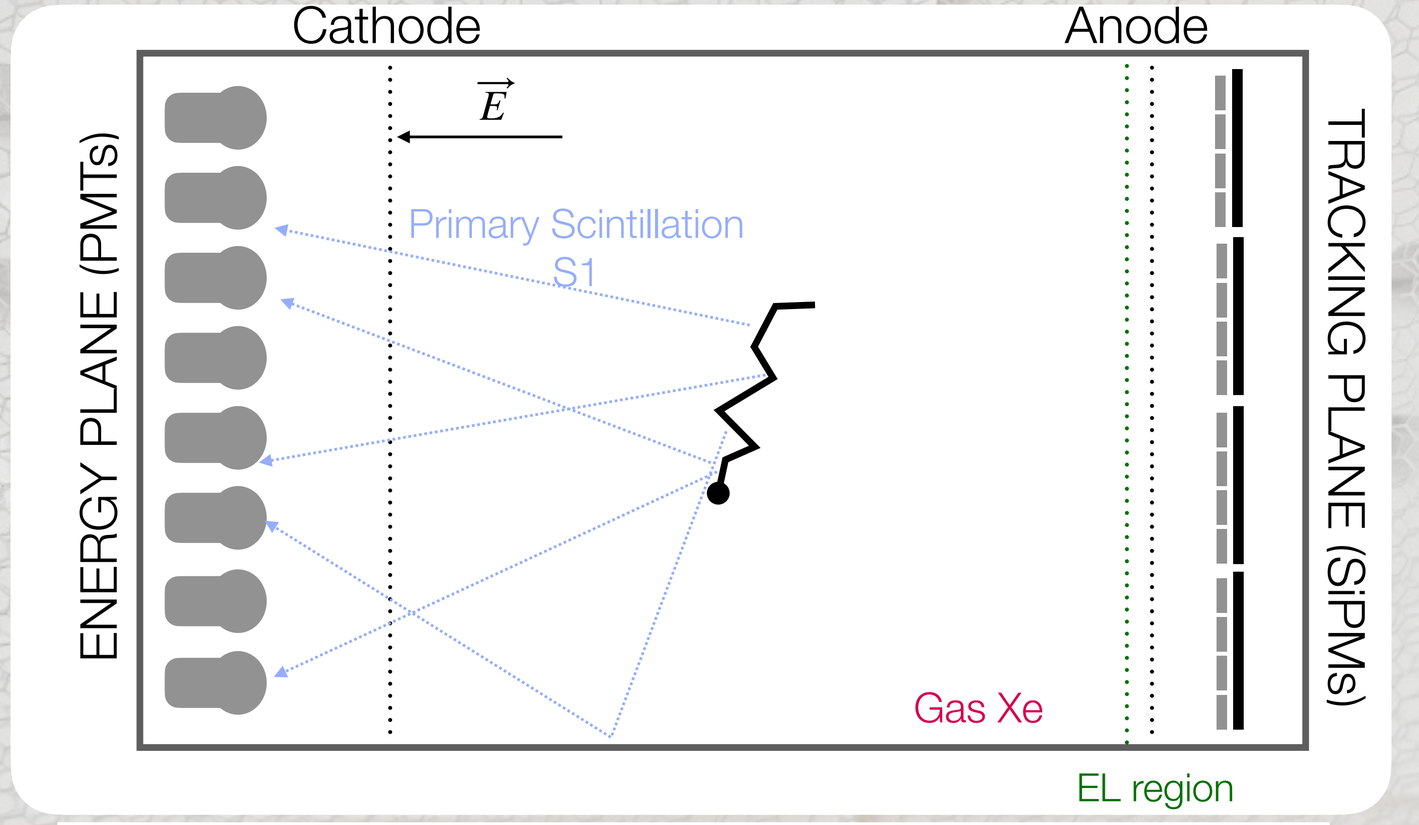
Detection method: High-pressure gas Xe TPC

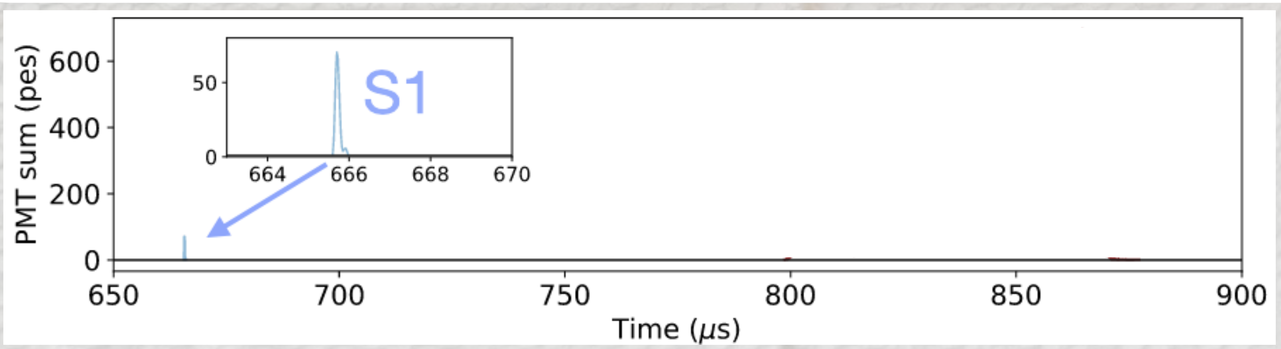
Q-value: 2.458 MeV

Advantages:

- Best resolution for Xe experiments (<1%FWHM@$Q_{\beta\beta}$)
- Low background
- Tracking information: Full tracks for signal vs background selection.

Principle of operation





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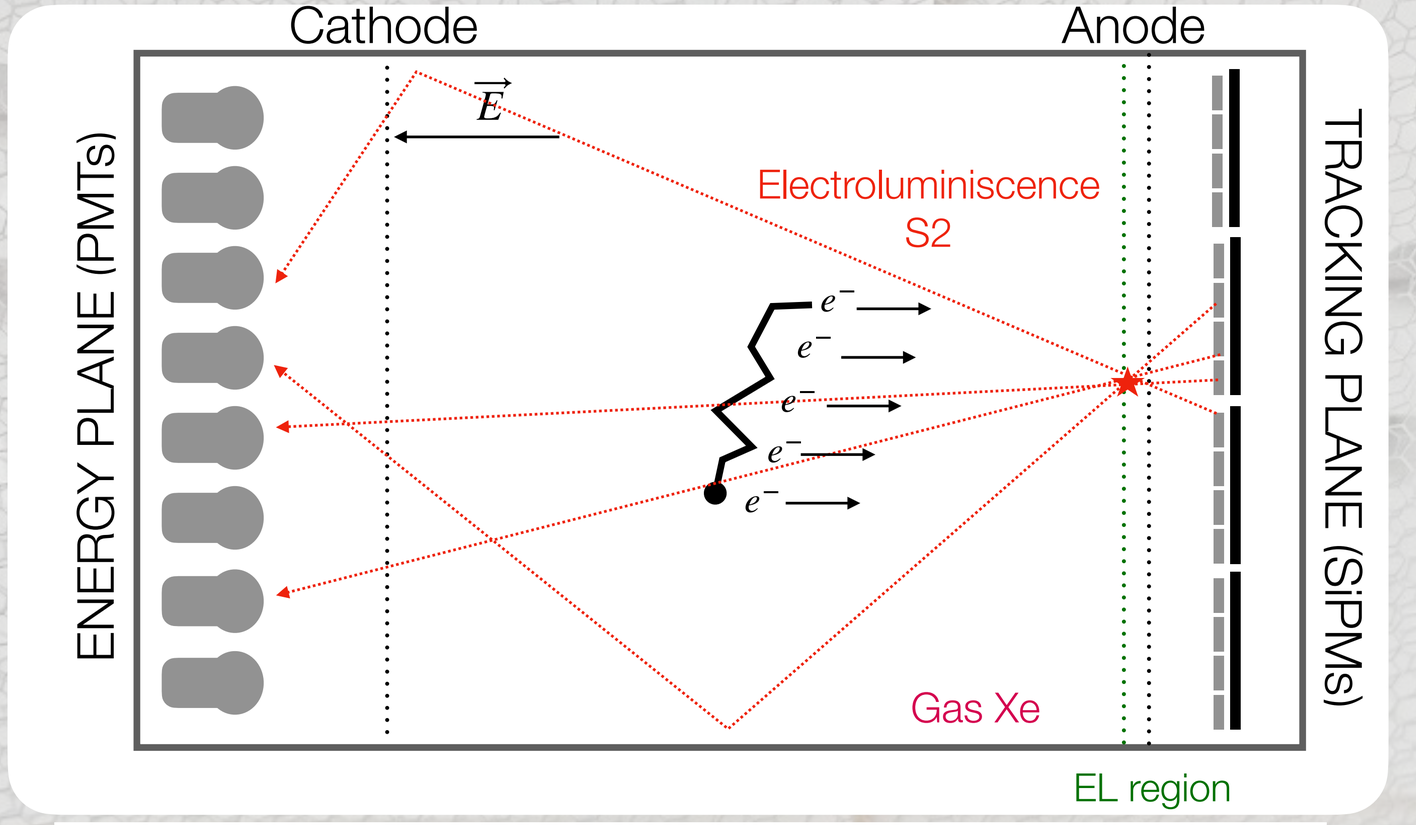
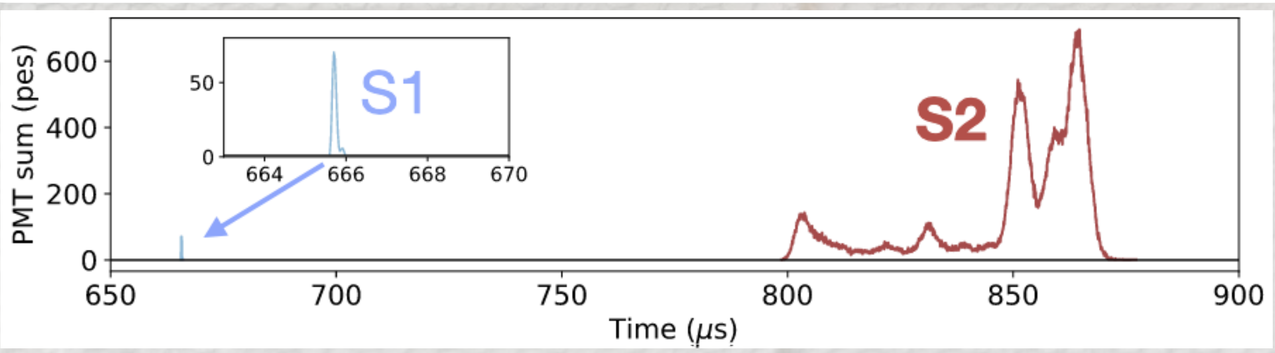
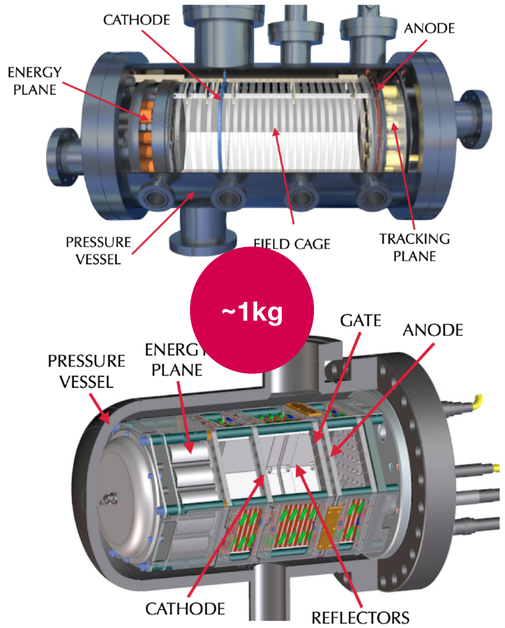




The next programme

PROTOTYPES
2009/2014

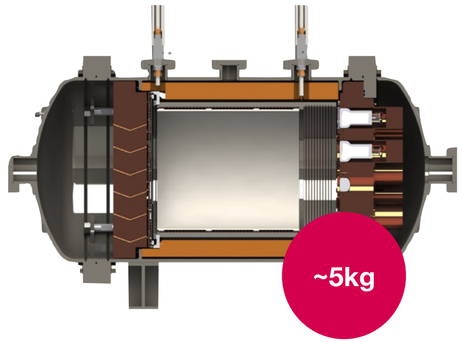
Demonstration of the detector concept



NEXT-WHITE (NEW)
2015/2021

Background model assessment

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



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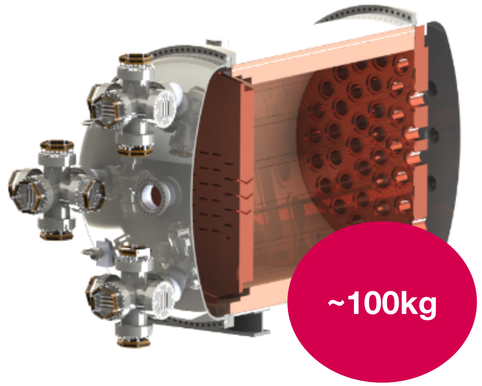
NEXT-100
2024/2030

Scalability

Background improvement

Neutrinoless double beta decay search in ^{136}Xe



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NEXT-HD
~2030

Neutrinoless double beta decay search through inverted neutrino mass ordering

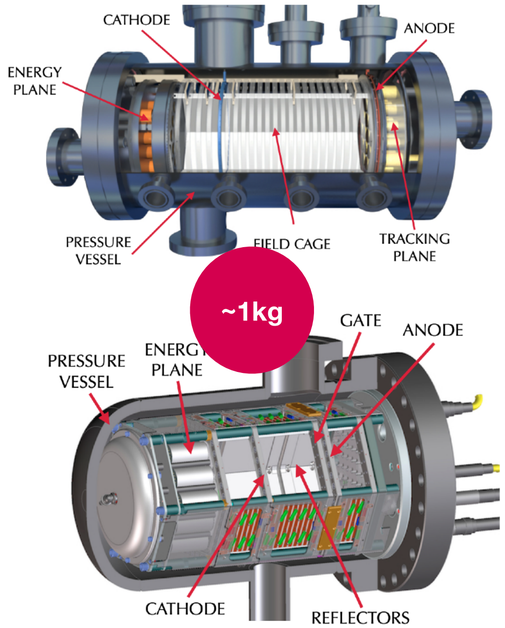
NEXT-BOLD

Barium tagging for background-free experiment inverted neutrino mass ordering

The next programme

PROTOTYPES
2009/2014

Demonstration of the detector concept



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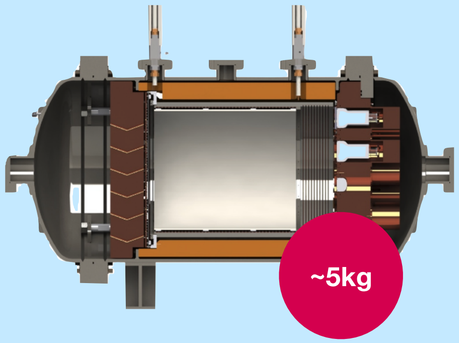

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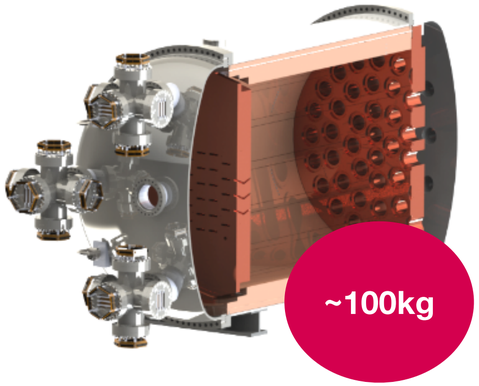
NEXT-100
2024/2030

Scalability

Background improvement

Neutrinoless double beta decay search in ^{136}Xe



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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

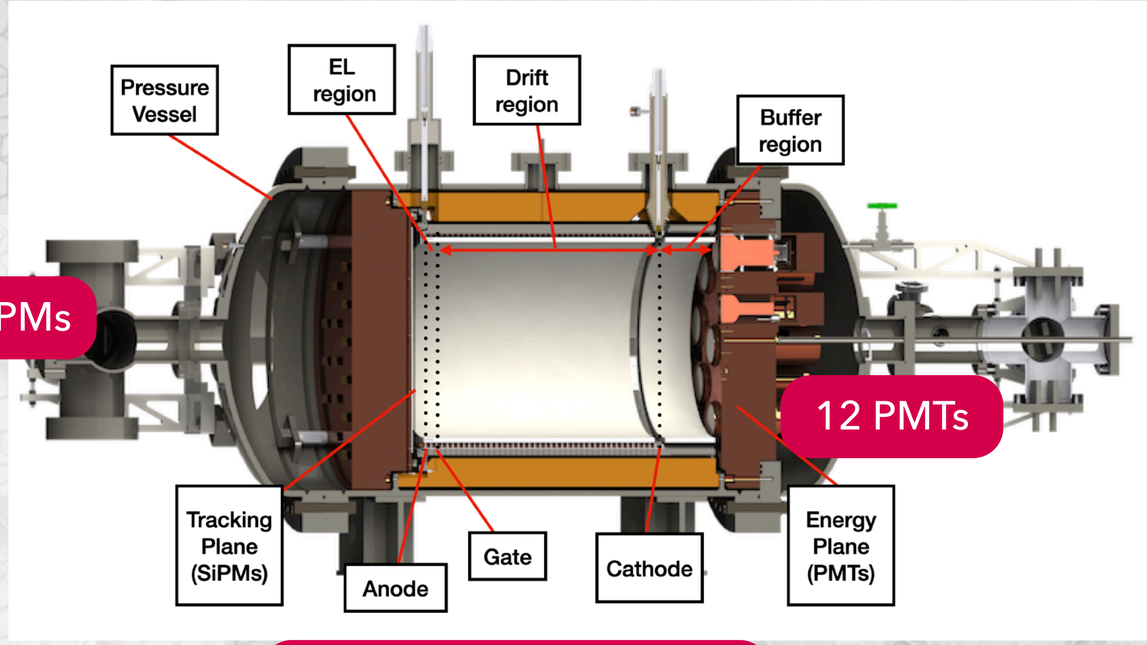
NEXT-White

Operation: 2016-2021

Mass: ~5 kg

Objectives:

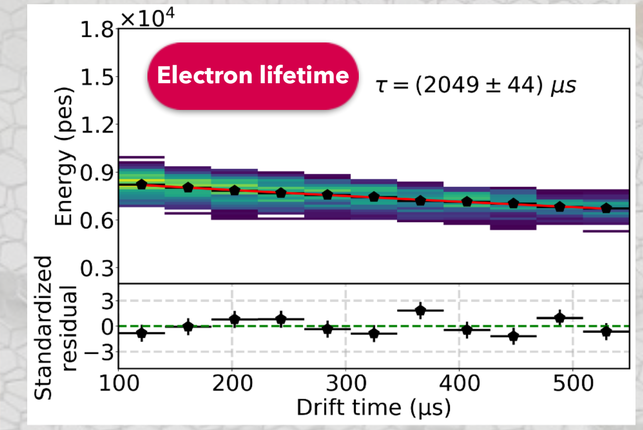
- Design and refine the calibration techniques
- Validation of the background model
- Measurement of the 2vββ and half-life limit for 0vββ
- Energy resolution close to the $Q_{\beta\beta}$-value
- Track characterization and background rejection



JINST 13 (2018) 12

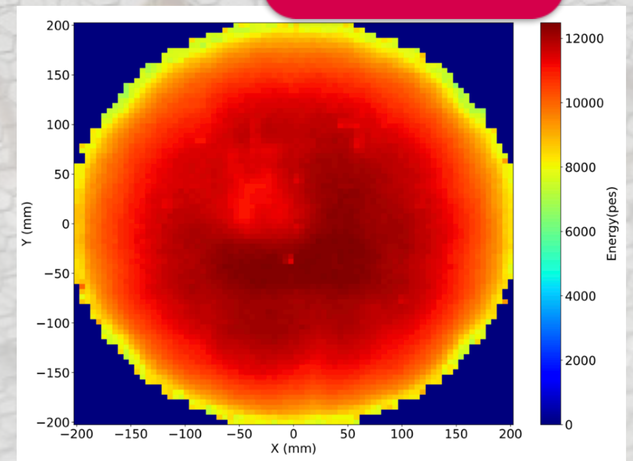
NEXT-White: Energy Calibration

Low energy calibration (^{83m}Kr)



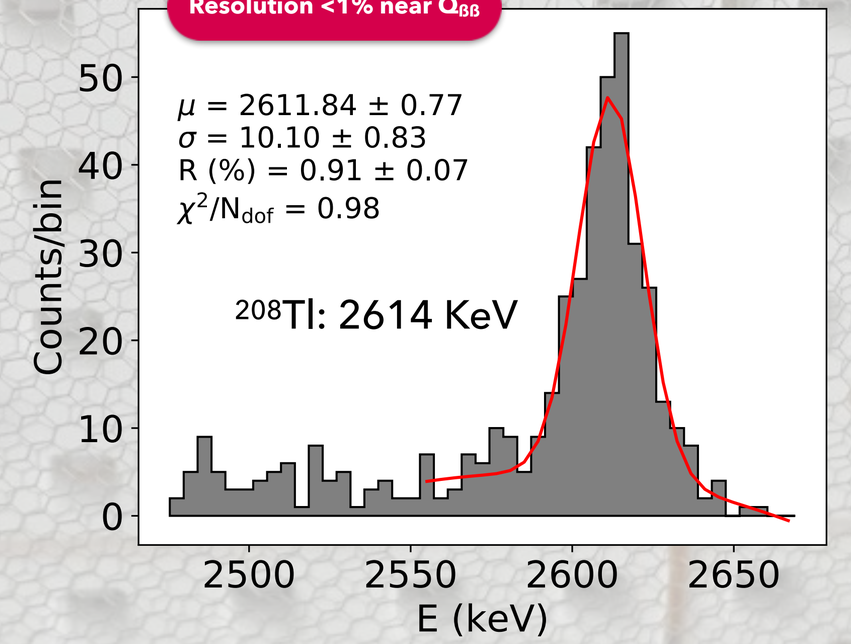
JINST 13 (2018) NO.10, P10014

Geometrical corrections



High energy calibration (^{137}Cs & ^{208}Tl)

Resolution <1% near $Q_{\beta\beta}$



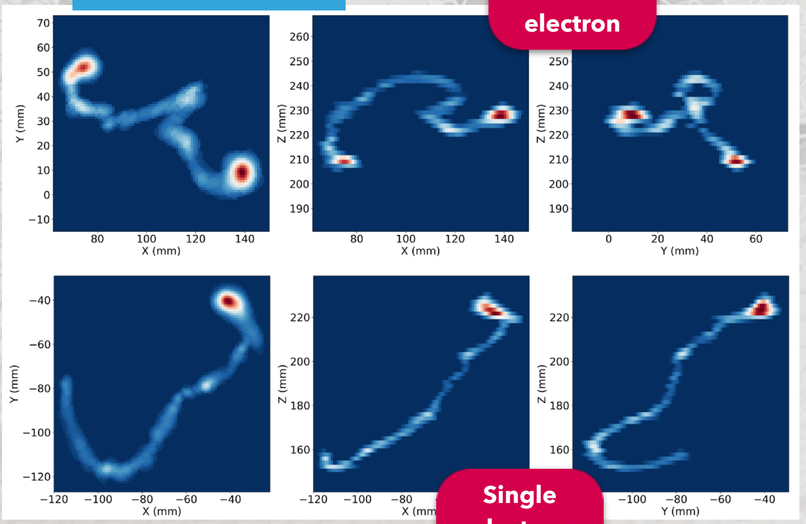
JHEP 10 (2019) 230

JINST 13 (2018) NO.10, P10020

Tracking and signal identification

JHEP 21 (2021) 146

Double electron



Single electron

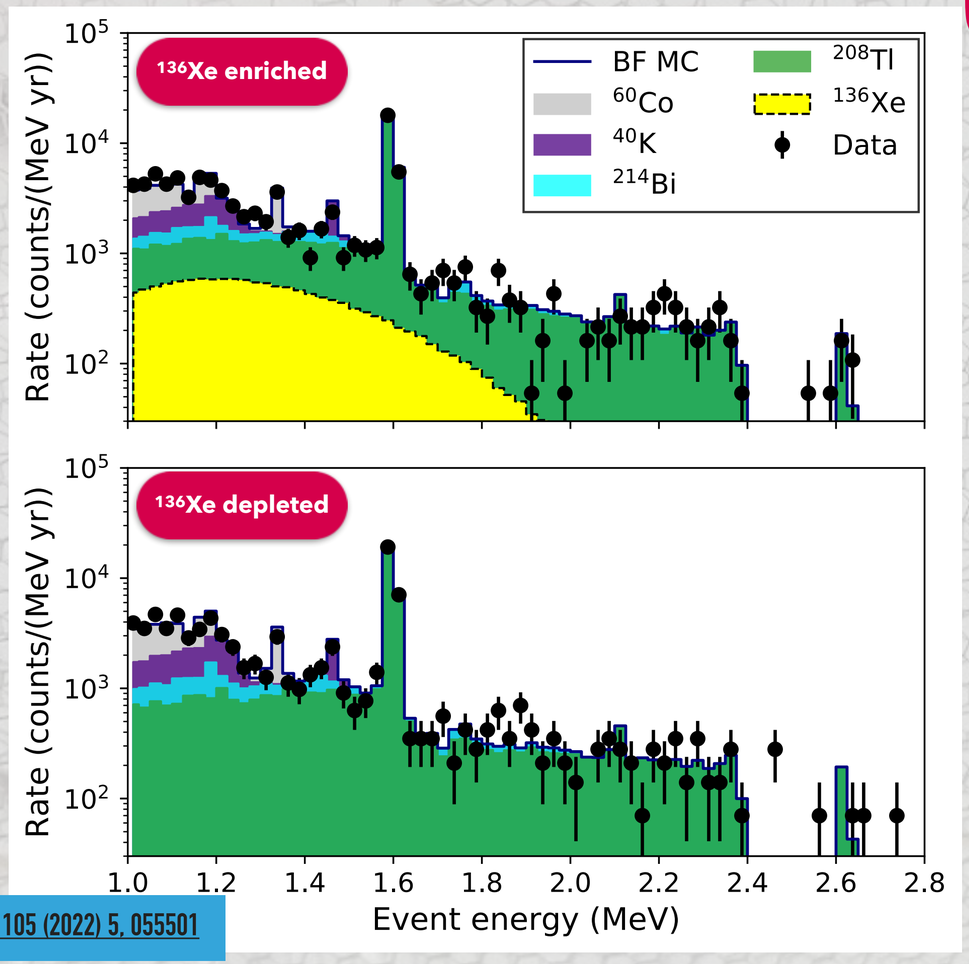
JINST 12 (2017) NO.01, T01004

JHEP 10 (2019) 052

JHEP 01 (2021) 189

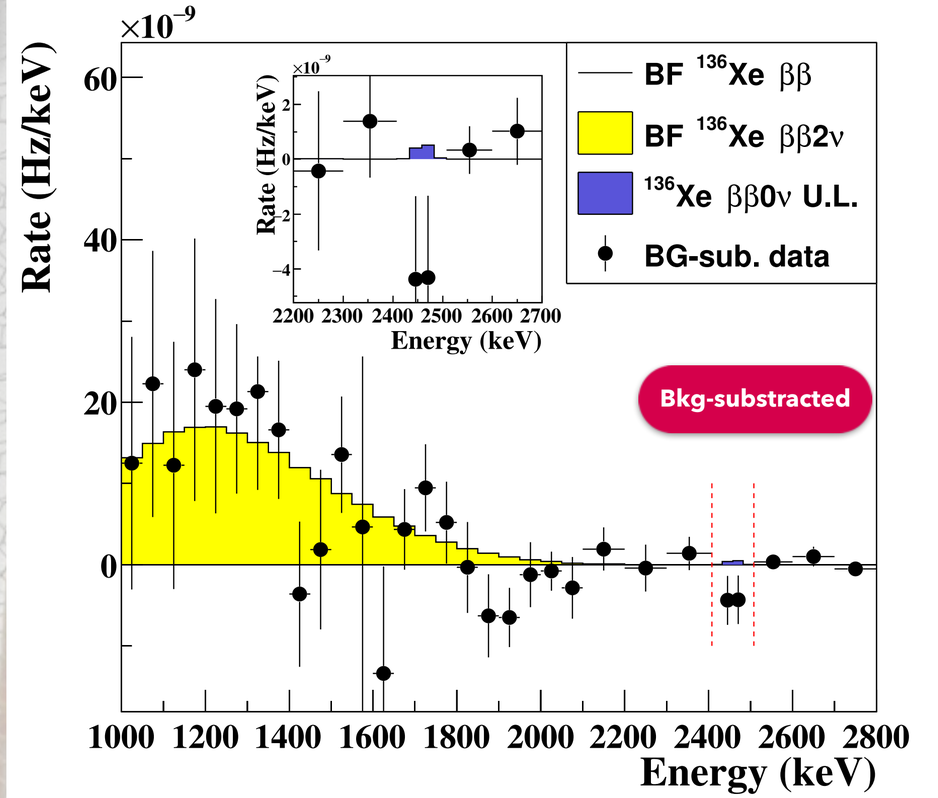
NEXT-White: ββ studies

First ever almost background-model independent double beta analysis!



PHYS.REV.C 105 (2022) 5, 055501

$$2.34^{+0.80}_{-0.46}\,(\text{stat})\,^{+0.30}_{-0.17}\,(\text{sys})\cdot 10^{21}\ \text{yr}$$



JHEP 09 (2023)190

$$> 1.3\cdot 10^{24}\ \text{yr}(90\%\ \text{CL})$$

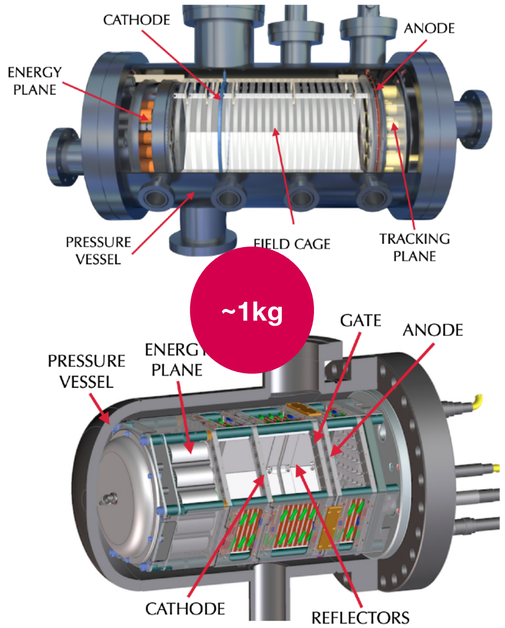
JHEP 10 (2019) 051

JHEP 10 (2018) 112

The next programme

PROTOTYPES
2009/2014

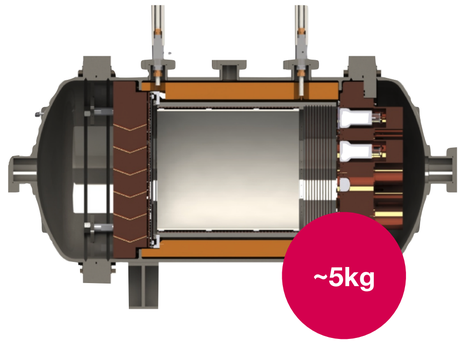
Demonstration of the detector concept



NEXT-WHITE (NEW)
2015/2021

Background model assessment

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



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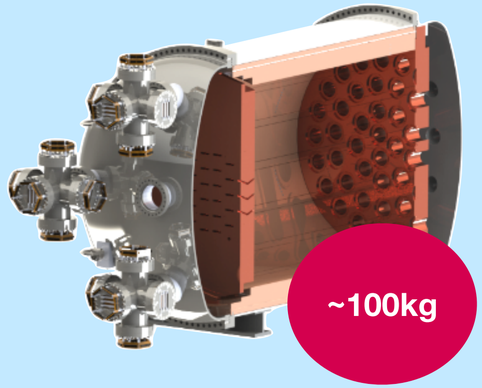
NEXT-100
2024/2030

Scalability

Background improvement

Neutrinoless double beta decay search in ^{136}Xe



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NEXT-HD
~2030

Neutrinoless double beta decay search through inverted neutrino mass ordering

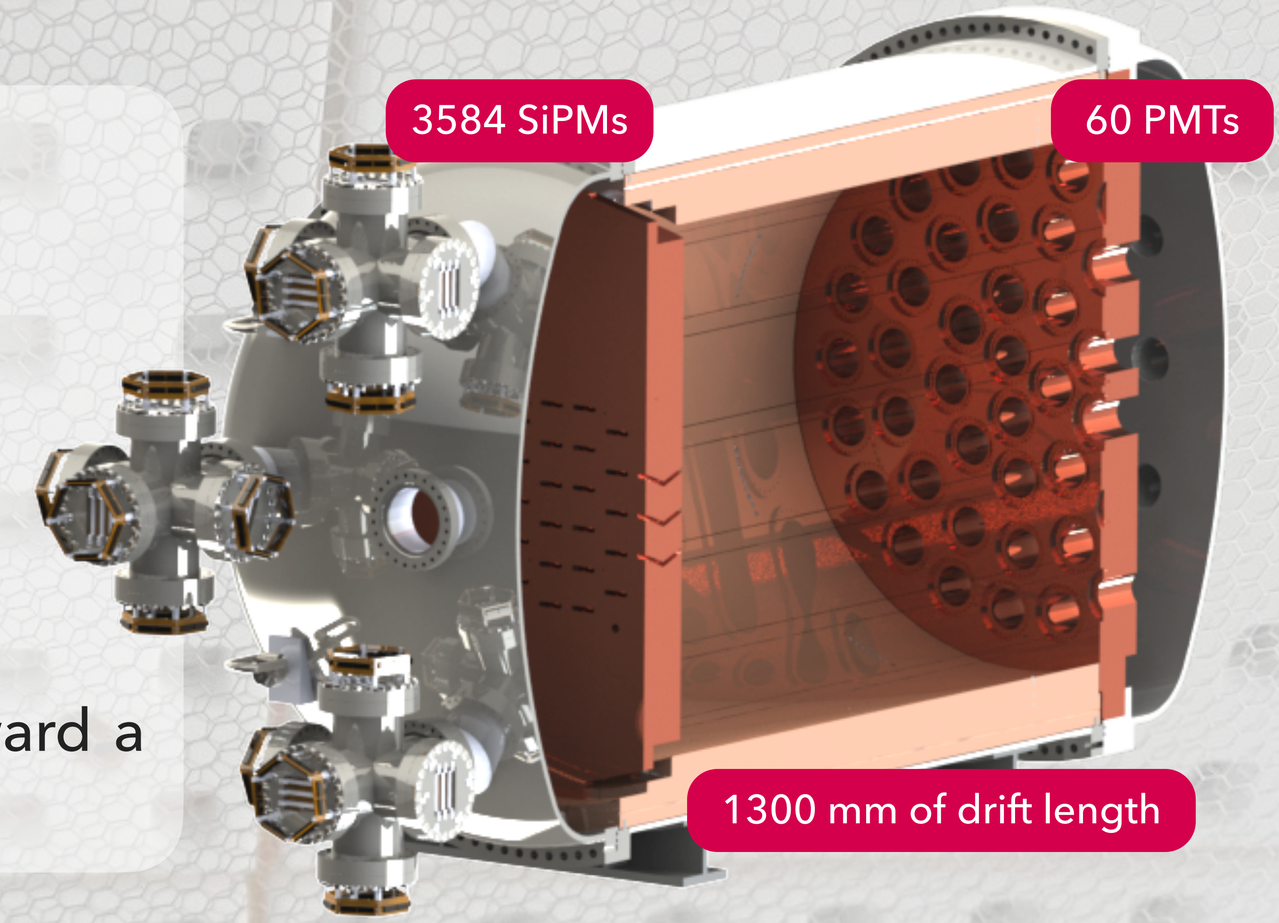
NEXT-BOLD

Barium tagging for background-free experiment inverted neutrino mass ordering

NEXT-100

Objectives:

- Demonstrate scalability
- Energy resolution close to the $Q_{\beta\beta}$-value
- Improve the radioactive budget
- Competitive search of the $\beta\beta0\nu$
- Test-bench for technology upgrades toward a tonne-scale detector



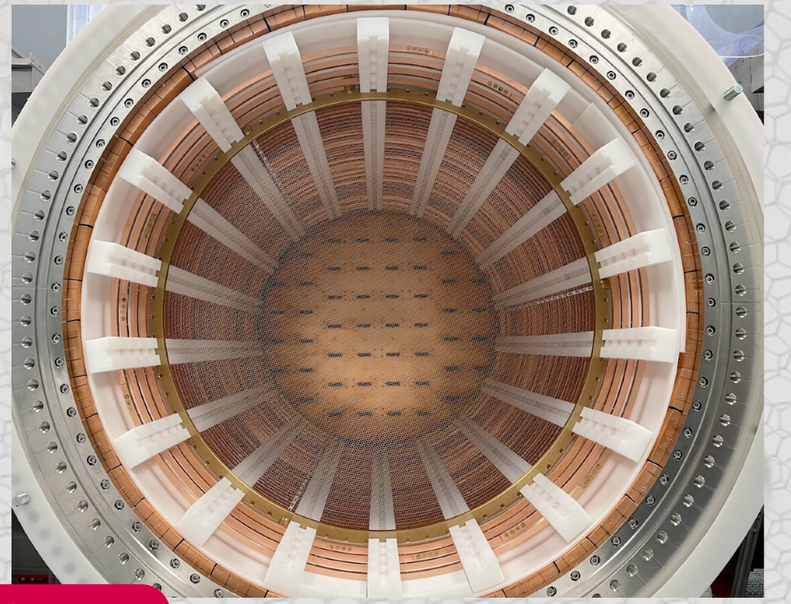
Mass: ~100 kg (at 15 bar)

JHEP 05 (2016)

Sensitivity: $> 10^{25}$ y after three years

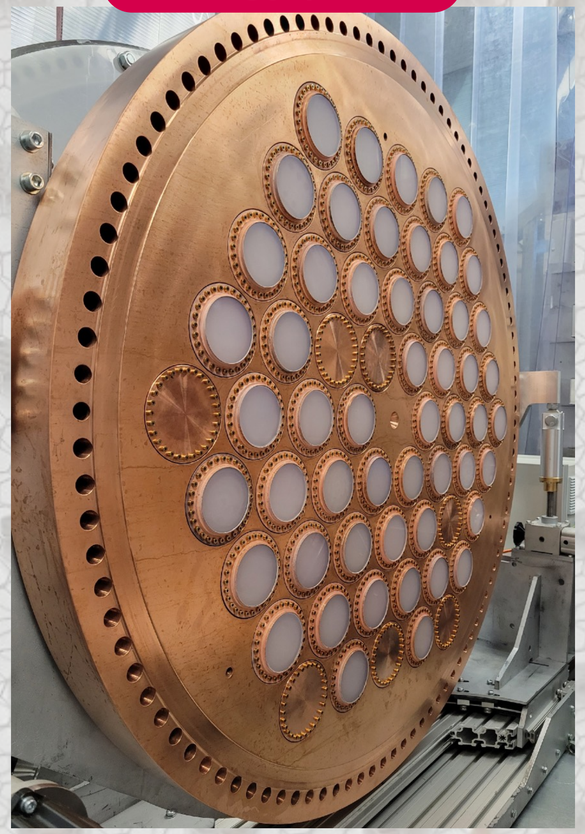
Background: $< 10^{-3}$ counts/(keV · kg · y)

NEXT-100: Assembly

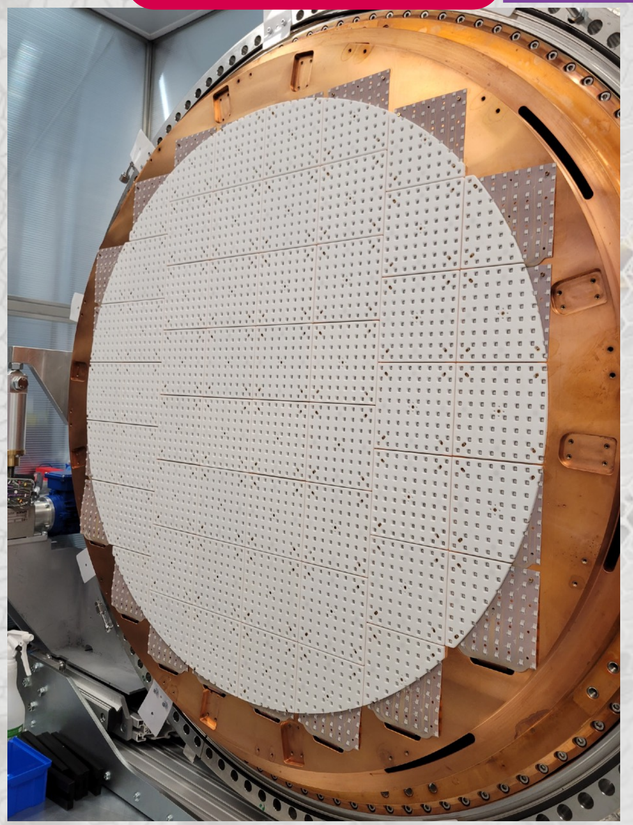


Field cage

Energy plane

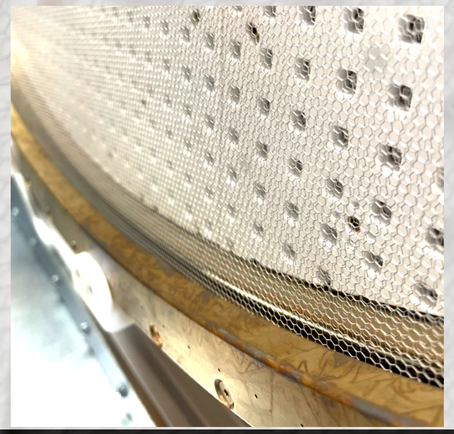


Tracking plane



EL meshes

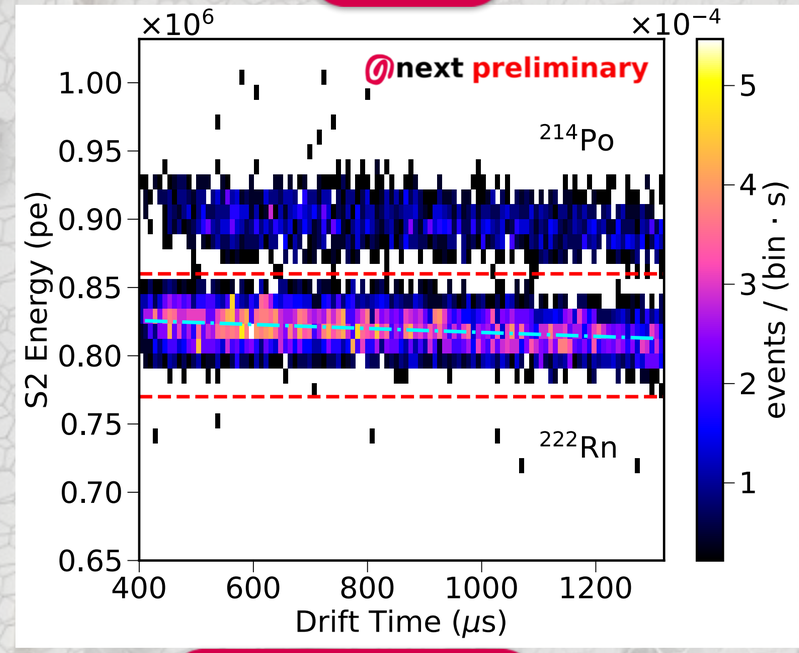
JINST 19 (2024) 02, P02007



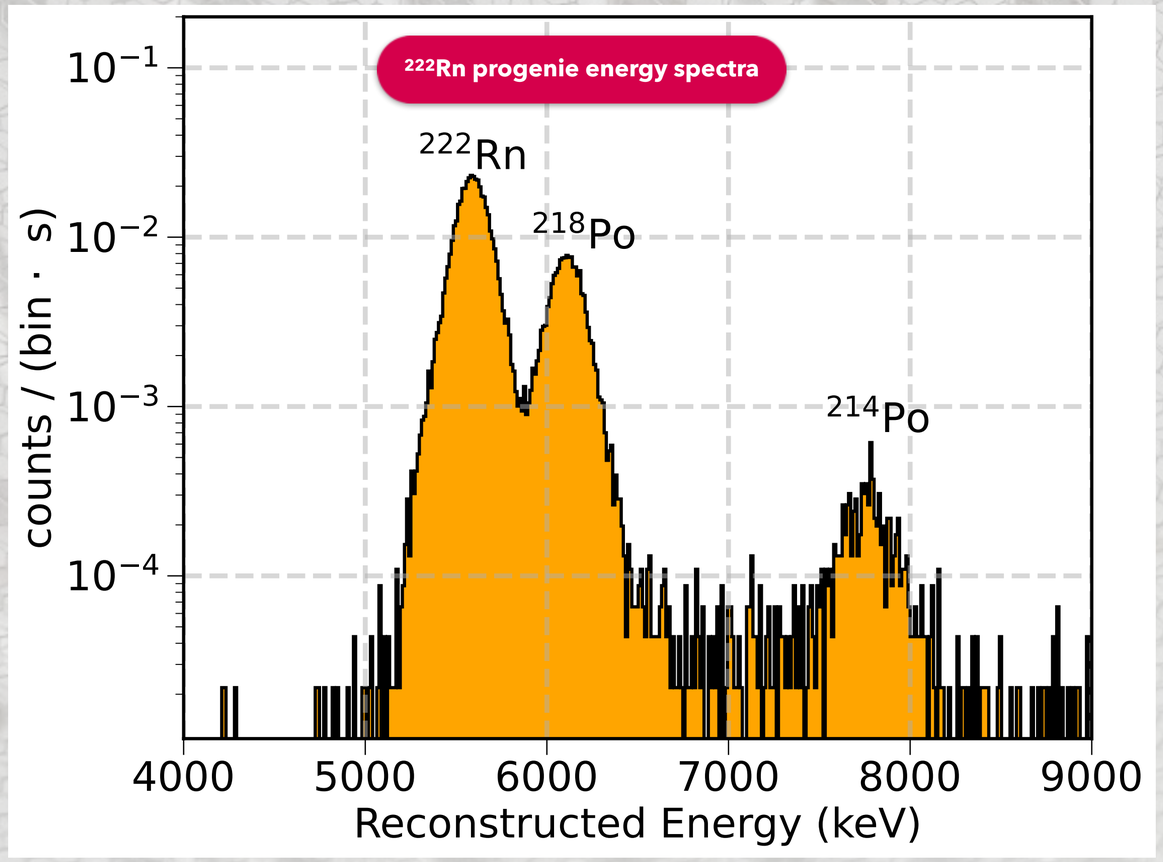
NEXT-100: Comisioning with Alphas

Operations started in May 2024 with argon and depleted xenon at 4 bar. The chamber was first characterized with ^{222}Rn decay chain data.

Lifetime

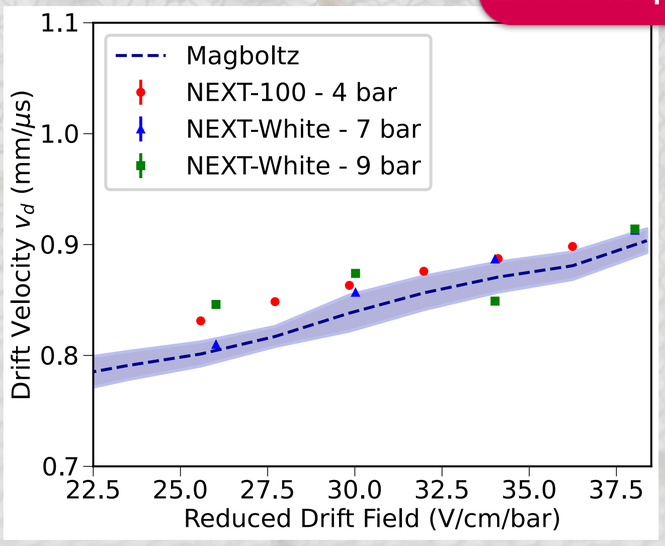


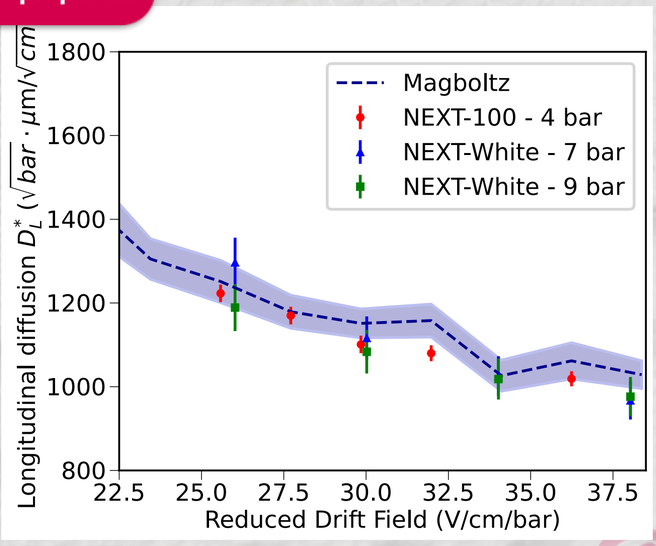
222Rn progenie energy spectra



ARXIV: 2505.17848

Electron transport properties

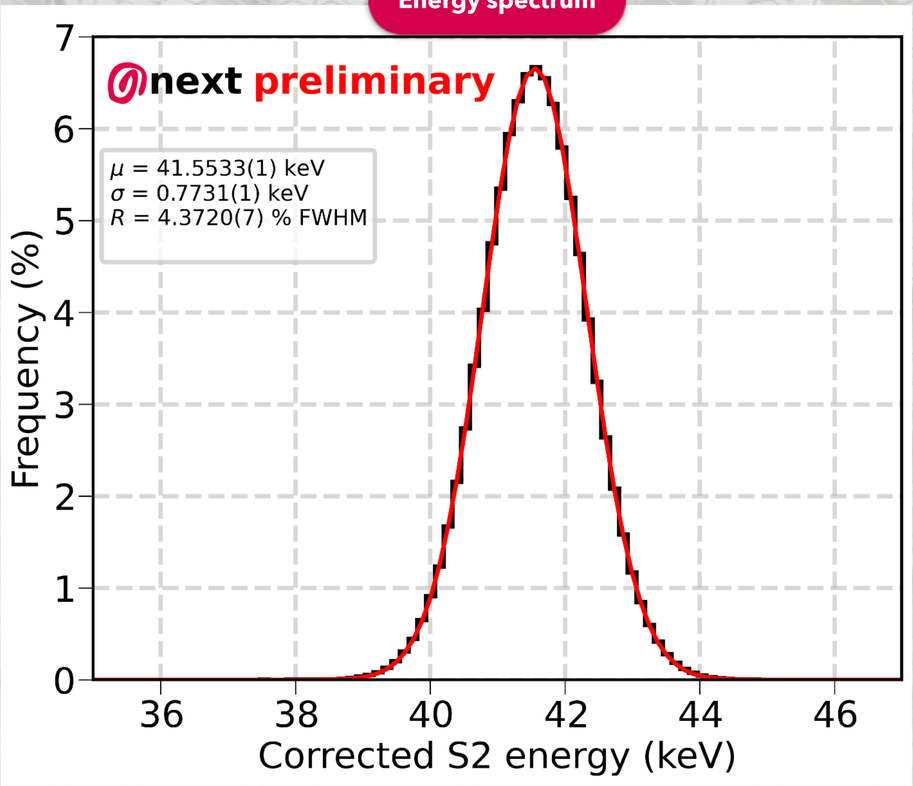




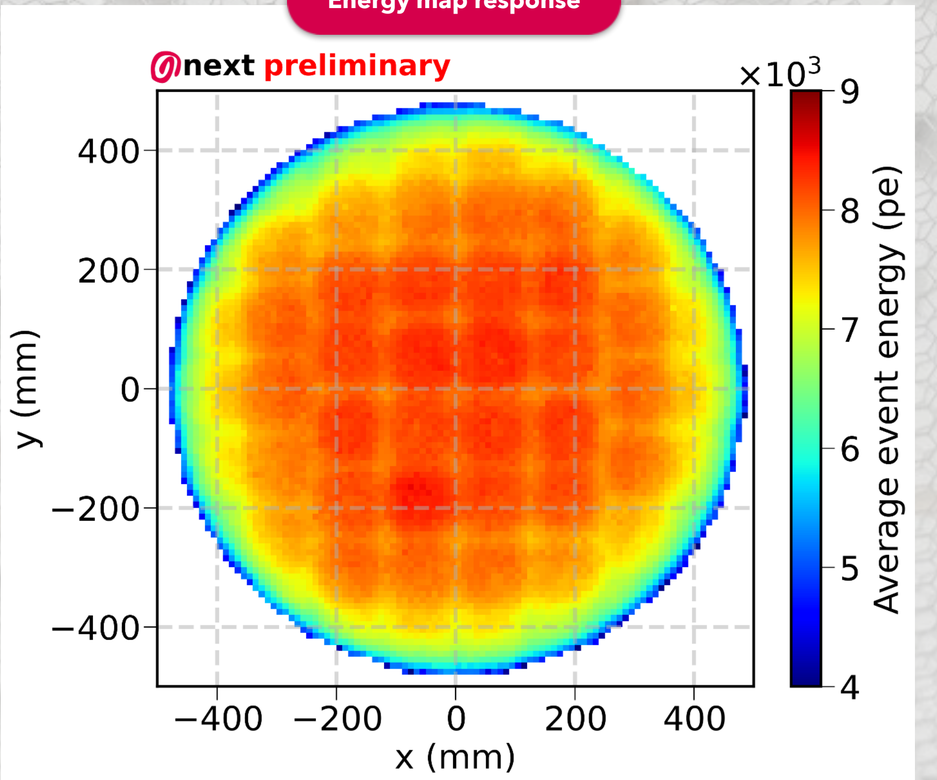
NEXT-100: Low energy calibration with ^{83m}Kr

Kr mono-energetic decay at 41.5 keV provides with pointlike and evenly distributed events thout the detector volume

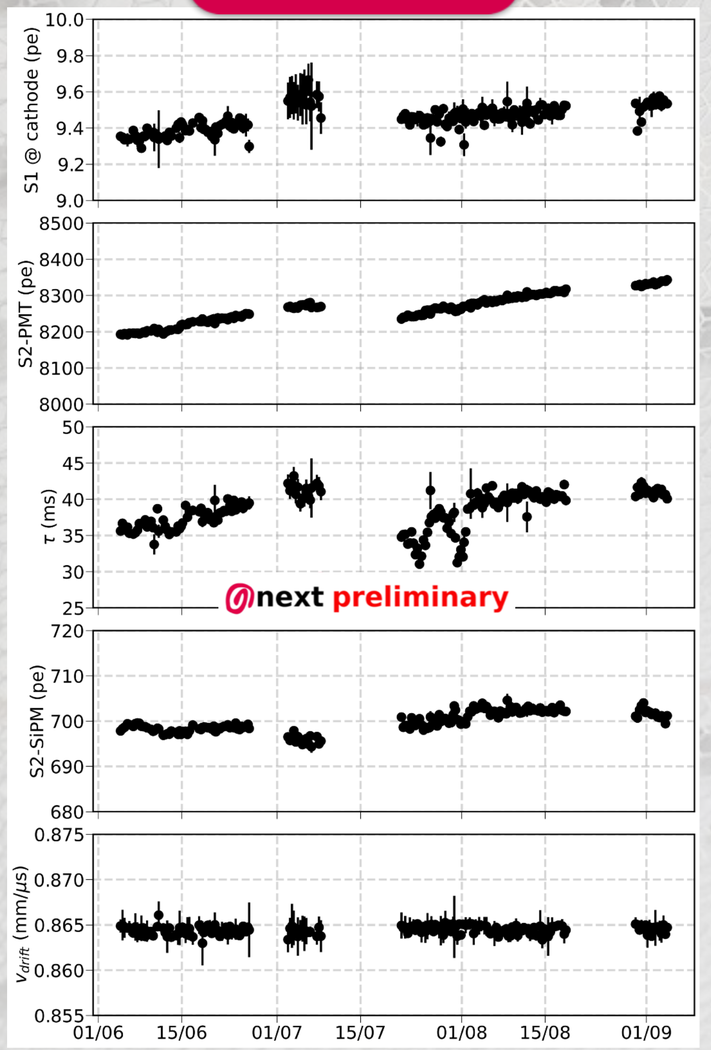
Energy spectrum



Energy map response



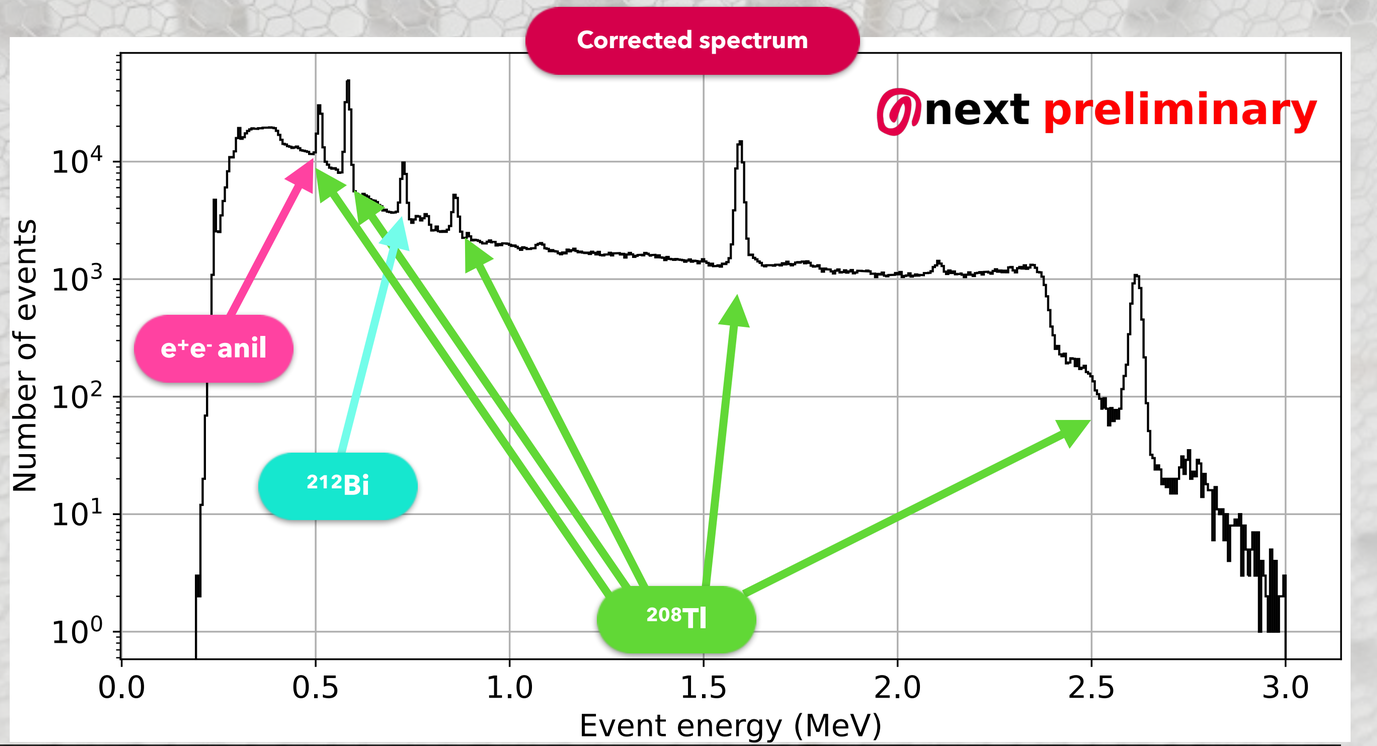
Detector stability



Resolution: 4.37% FHHM @ 41.5 keV

NEXT-100: High energy calibration with ^{208}Tl

The high-energy characterization of the chamber has been performed with a ^{232}Th source. Both the energy resolution and the tracking capabilities are assessed.



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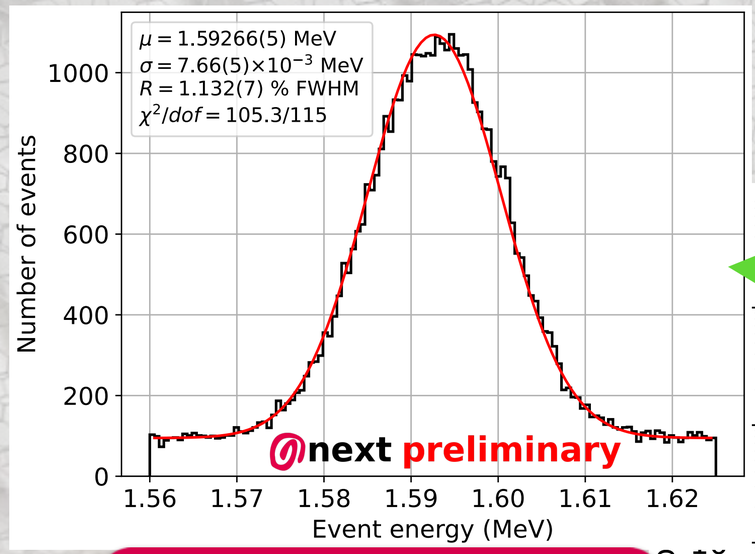
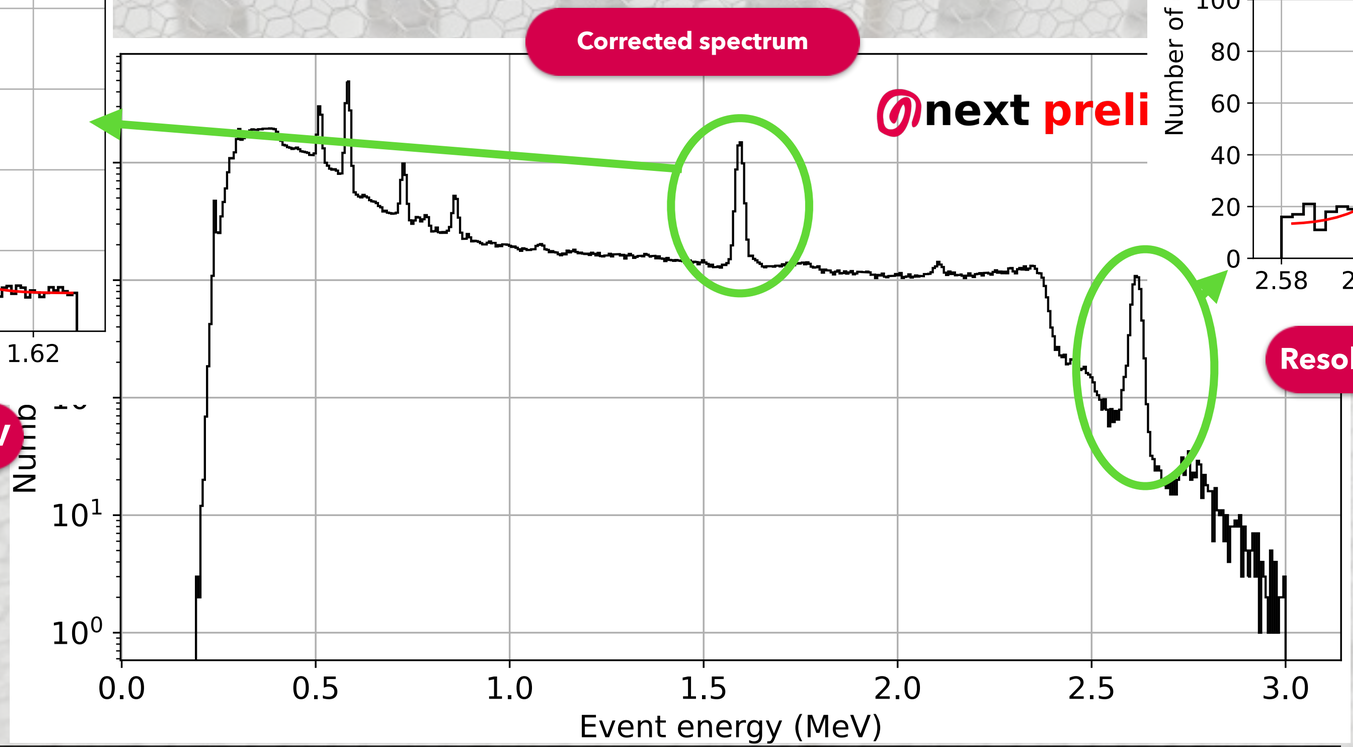
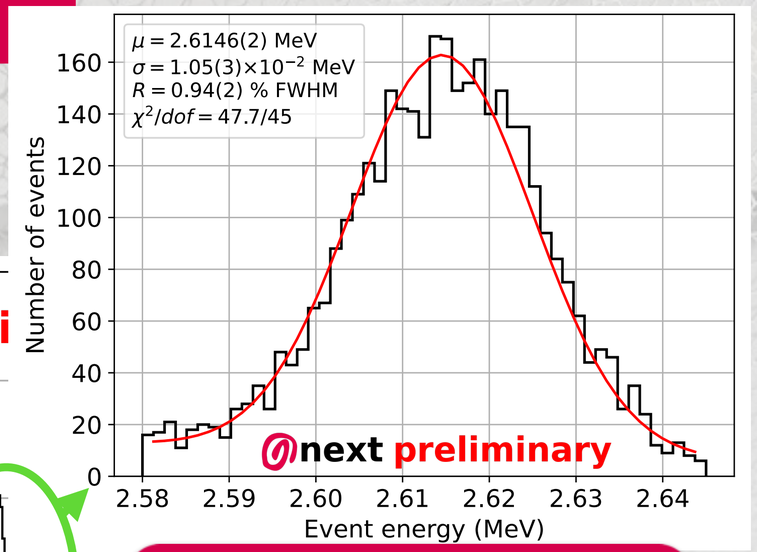


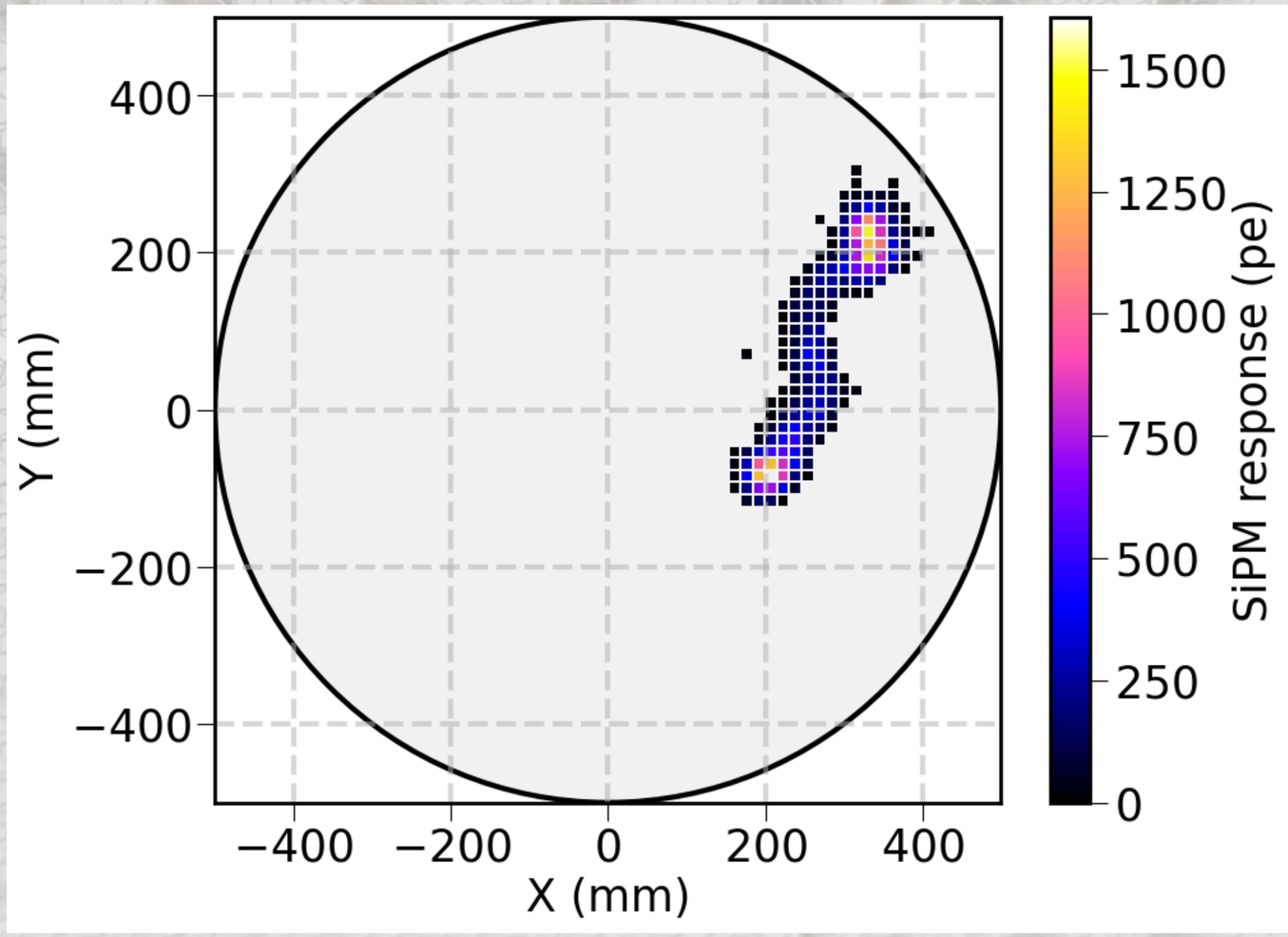
Resolution: 1.13% FHHM @ 1593 keV





Resolution: 0.94% FHHM @ 2615 keV

NEXT-100: High energy calibration with ^{208}Tl



Double electron track candidate from the double escape peak

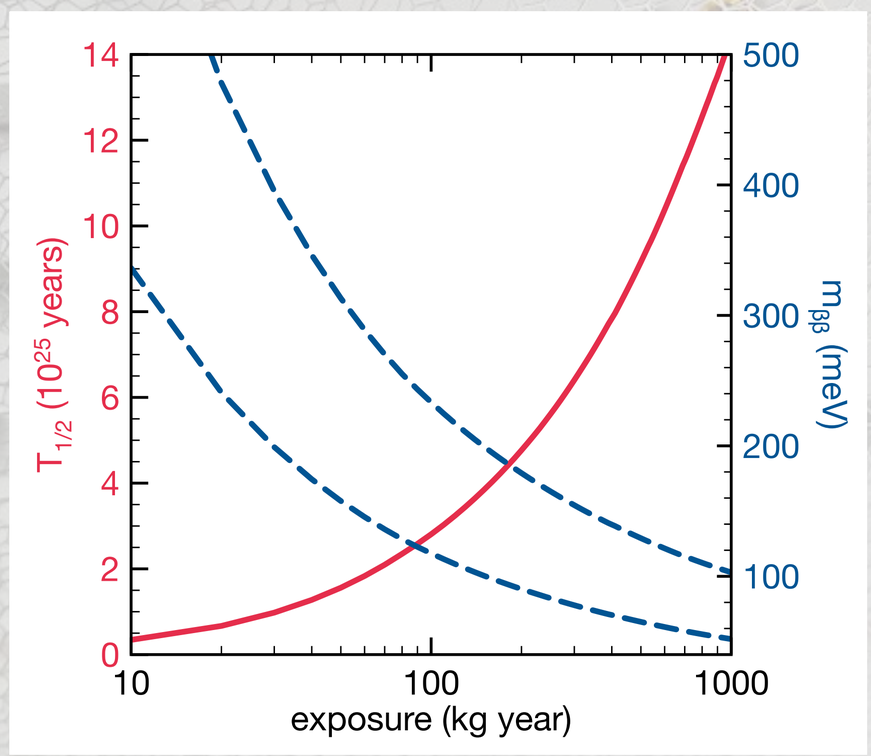
NEXT-100: next steps

Ongoing:

- Low background studies to inform possible hotspots

Close future:

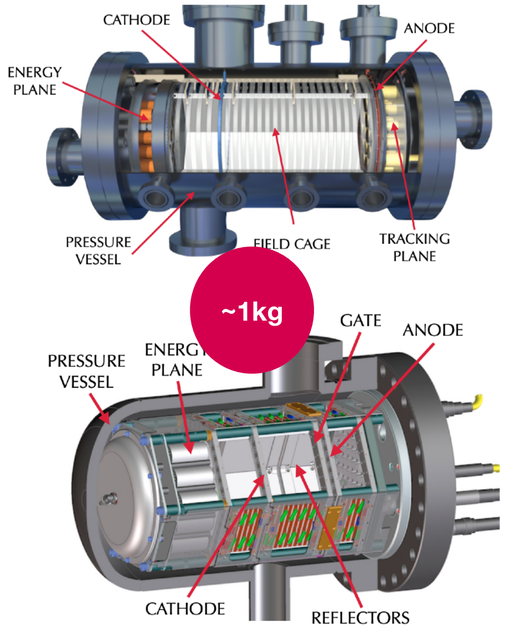
- Start operations at 10 bar
- Repeat characterization and calibration
- Background model assessment
- Measurement of $2\nu\beta\beta$ half-life
- Search for $0\nu\beta\beta$ decay!



The next programme

PROTOTYPES
2009/2014

Demonstration of the detector concept



NEXT-WHITE (NEW)
2015/2021

Background model assessment

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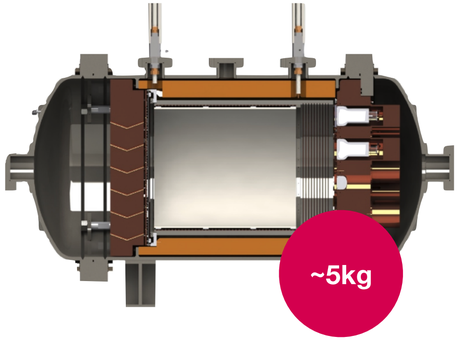

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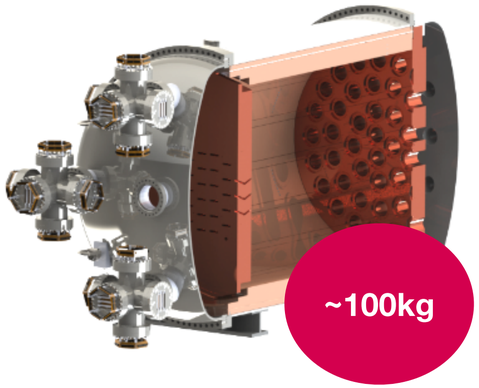
NEXT-100
2024/2030

Scalability

Background improvement

Neutrinoless double beta decay search in ^{136}Xe



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NEXT-HD
~2030

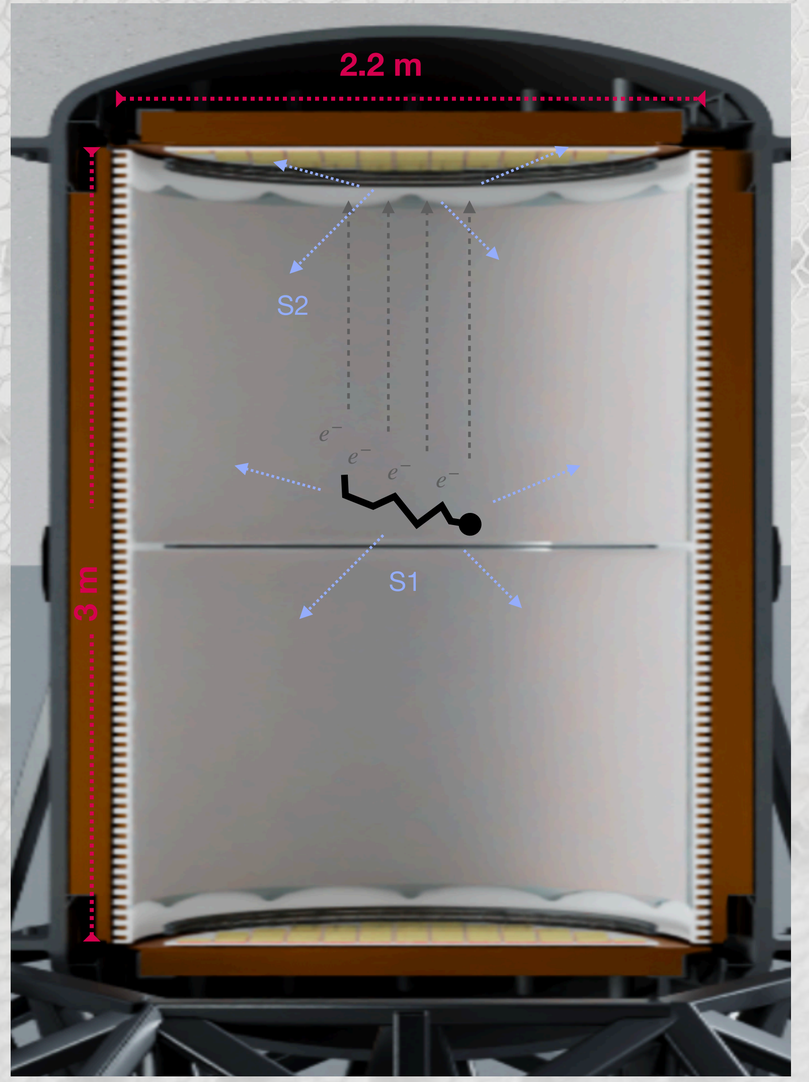
Neutrinoless double beta decay search through inverted neutrino mass ordering

NEXT-BOLD

Barium tagging for background-free experiment inverted neutrino mass ordering

NEXT-HD

- Symmetric design with central cathode
- Xe/He to reduce transverse diffusion
- Barrel instrumented with fiber optics for energy and S1 measurements
- External water tank shielding



Projected for 2027

Mass: ~1000 kg (at 15 bar)

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

Background: 0.01 counts/(keV · ton · yr)

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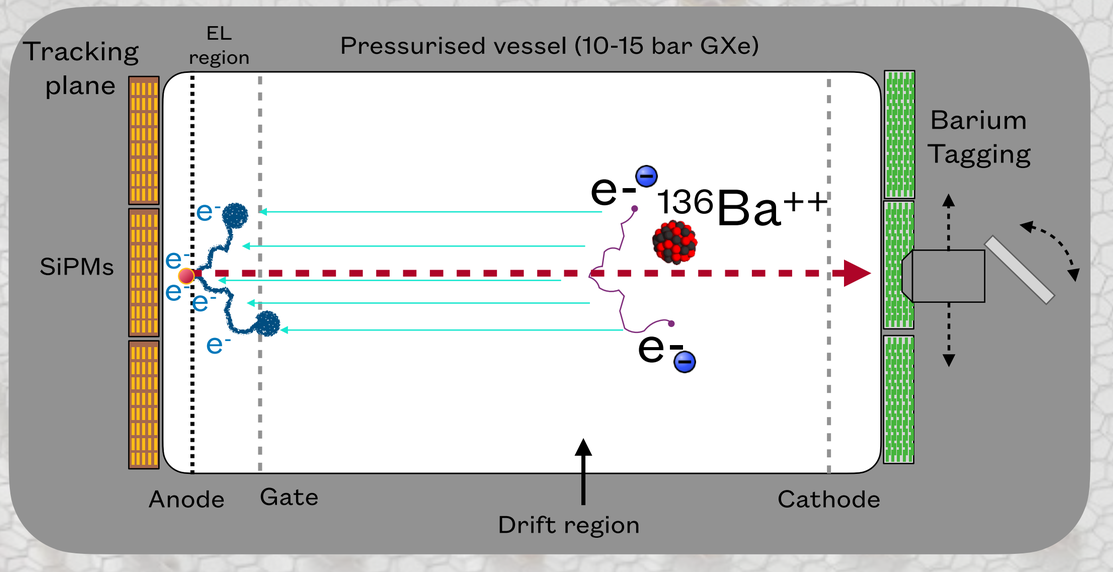
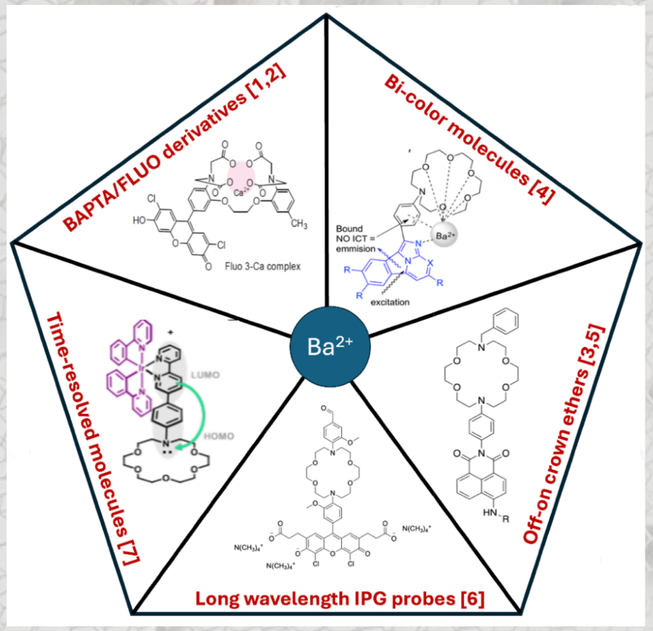
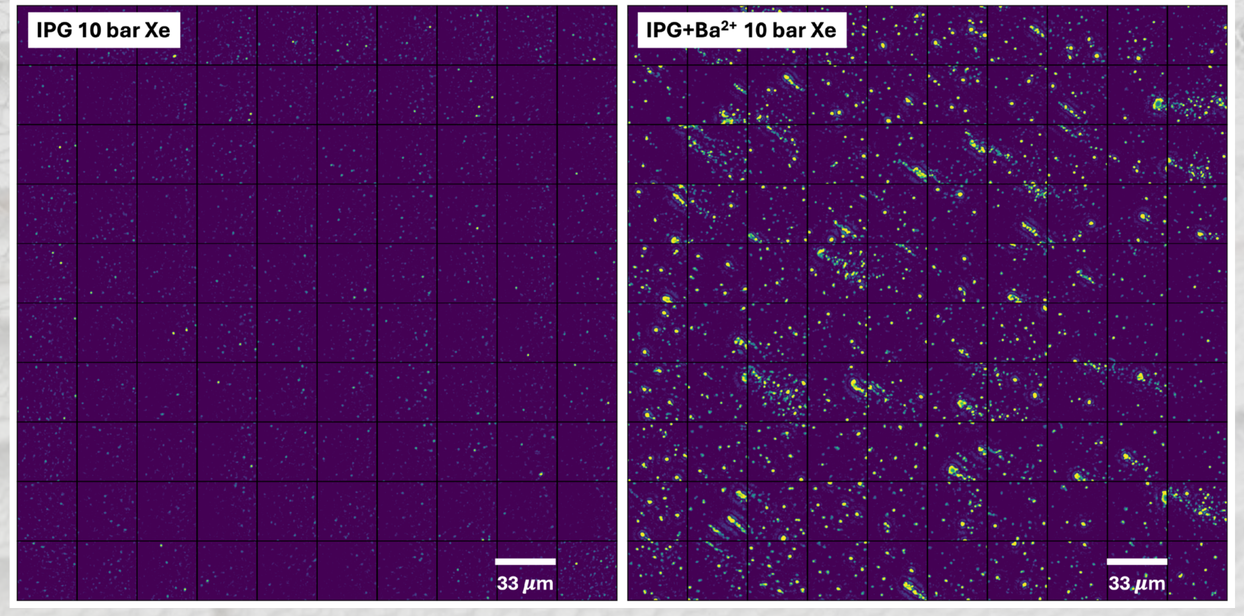
NEXT-BOLD

Designed to accommodate Ba tagging





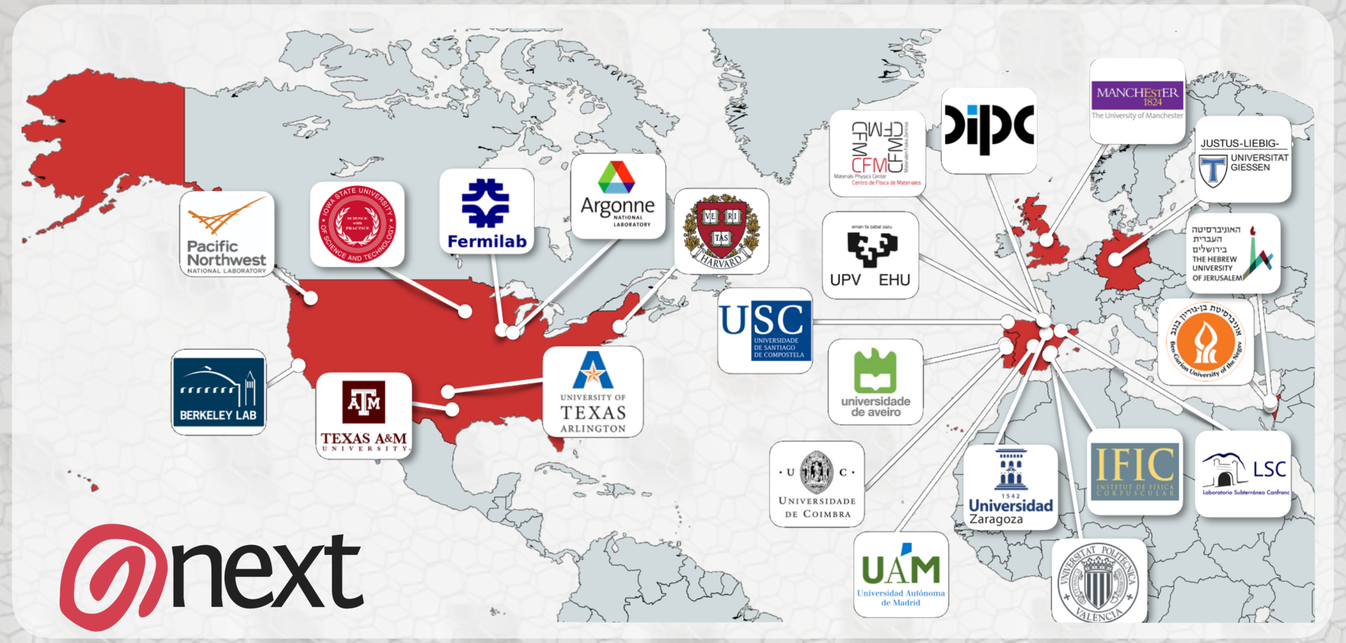
[1] JINST 11 P12011 (2016)
[2] Phys. Rev. Lett. 120, 132504 (2018)
[3] Sci. Rep. 9: 15097 (2019)
[4] Nature 583, 48 (2020)
RSC Appl. Interfaces, 2, 185–199 (2025)
[5] ACS Sensors 6, 1, 192–20 (2021)
[6] 10.26434/chemrxiv-2023-wxpbh (2023)
[7] ACS Sensors 2025, 10, 4, 2487–2498 (2025)



The viability of microscopy systems capable of imaging individual barium ions in high-pressure xenon gas is demonstrated

NEXT in Short

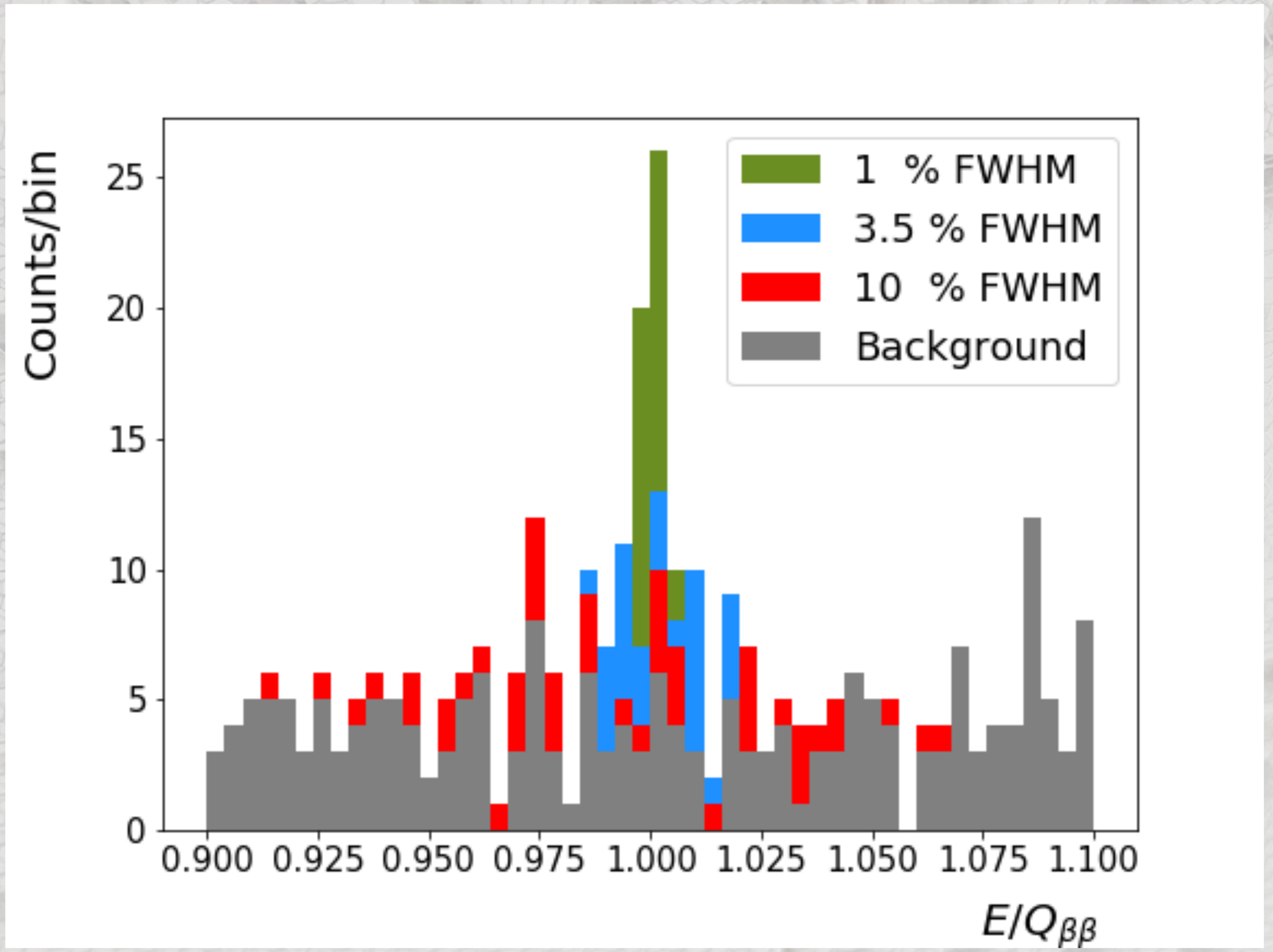
- All the results from NEXT-White demonstrate the performance of the detector technology and sufficiently low background levels for the program
- NEXT100 had successful commissioning and calibration at 4 bar.
  - ➡ Detector conditions are stable and have a high electron lifetime.
  - ➡ Initial resolution studies demonstrate the feasibility of <1% @ Qbb.
- NEXT100 will start operations at 10 bar soon.
- The success of the program is being transferred to the design of the upcoming tonne scale
- Barium tagging is knocking at the door!

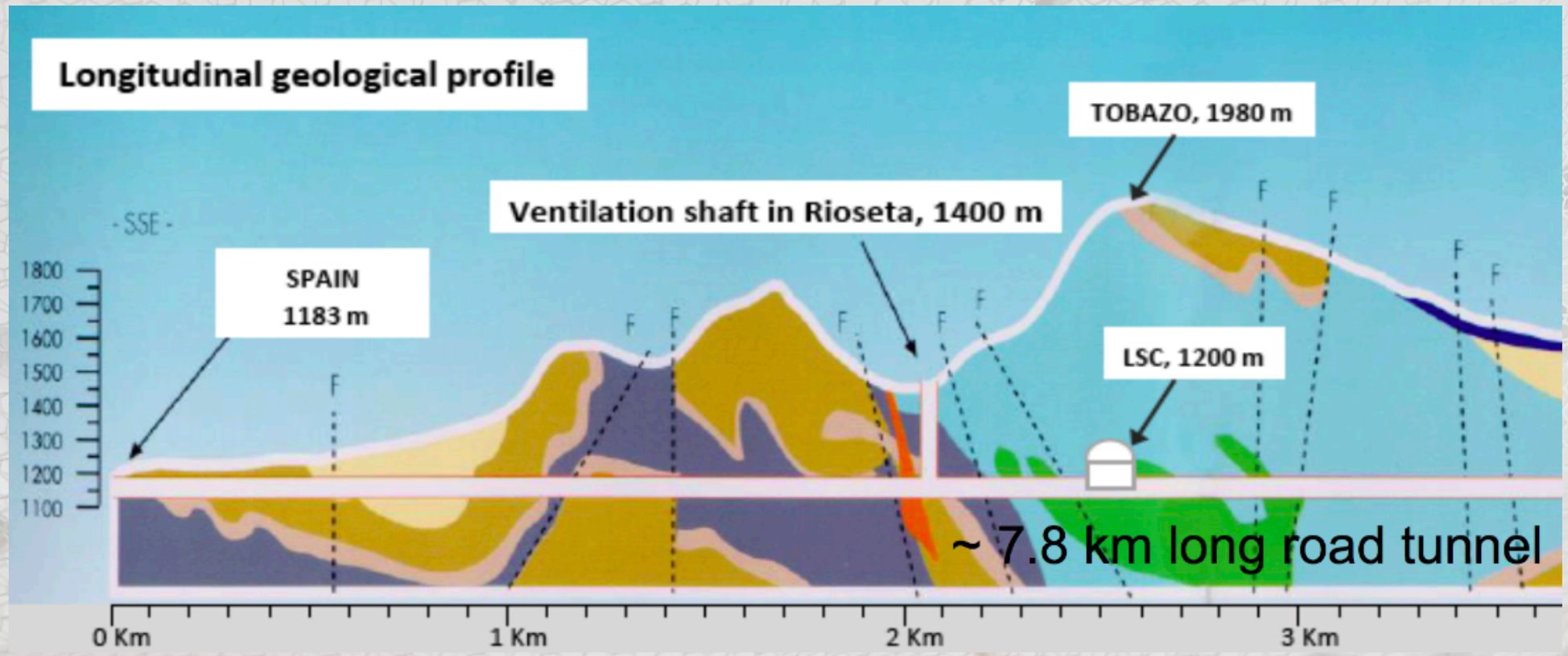


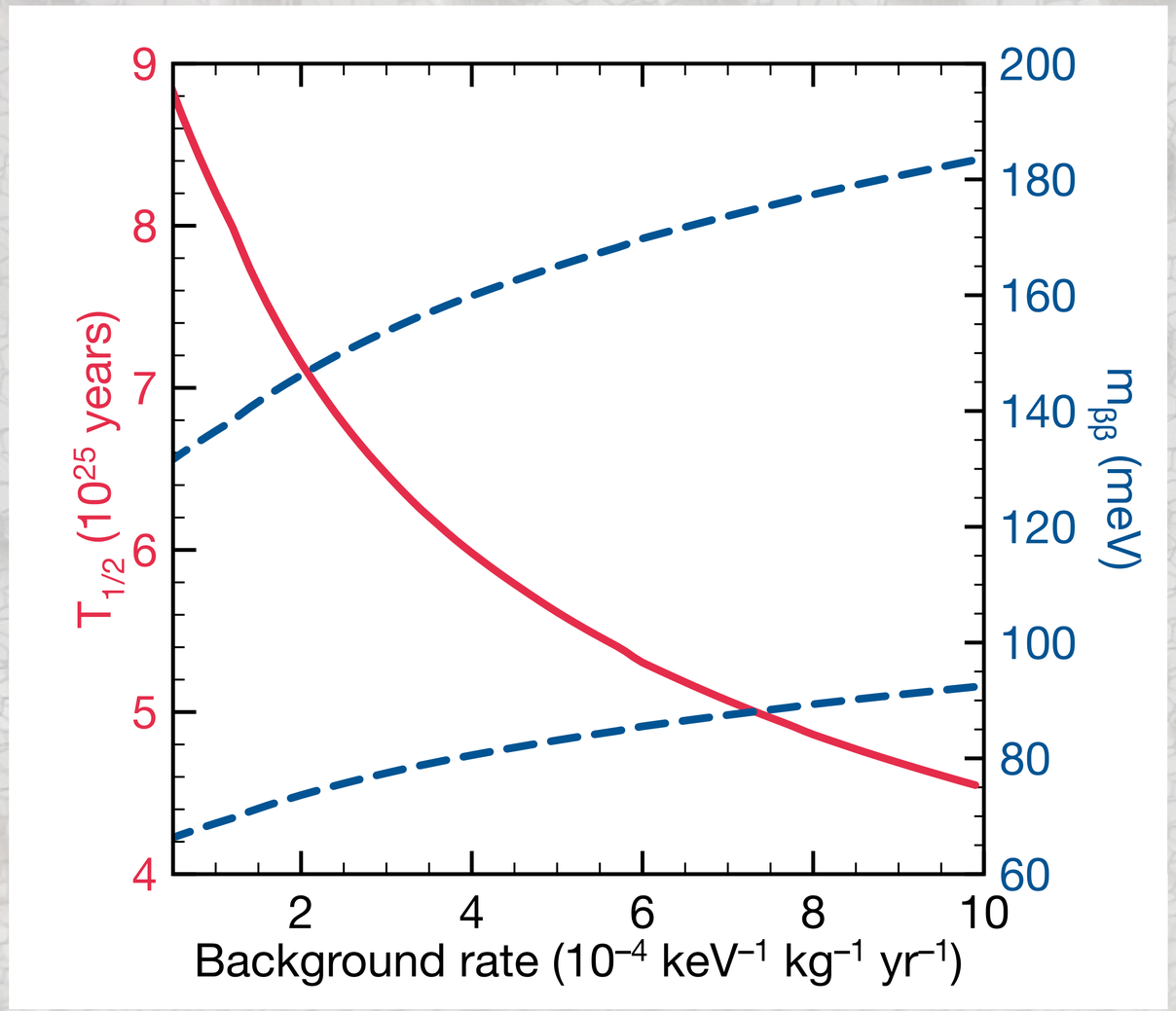
MANCHESTER 1824

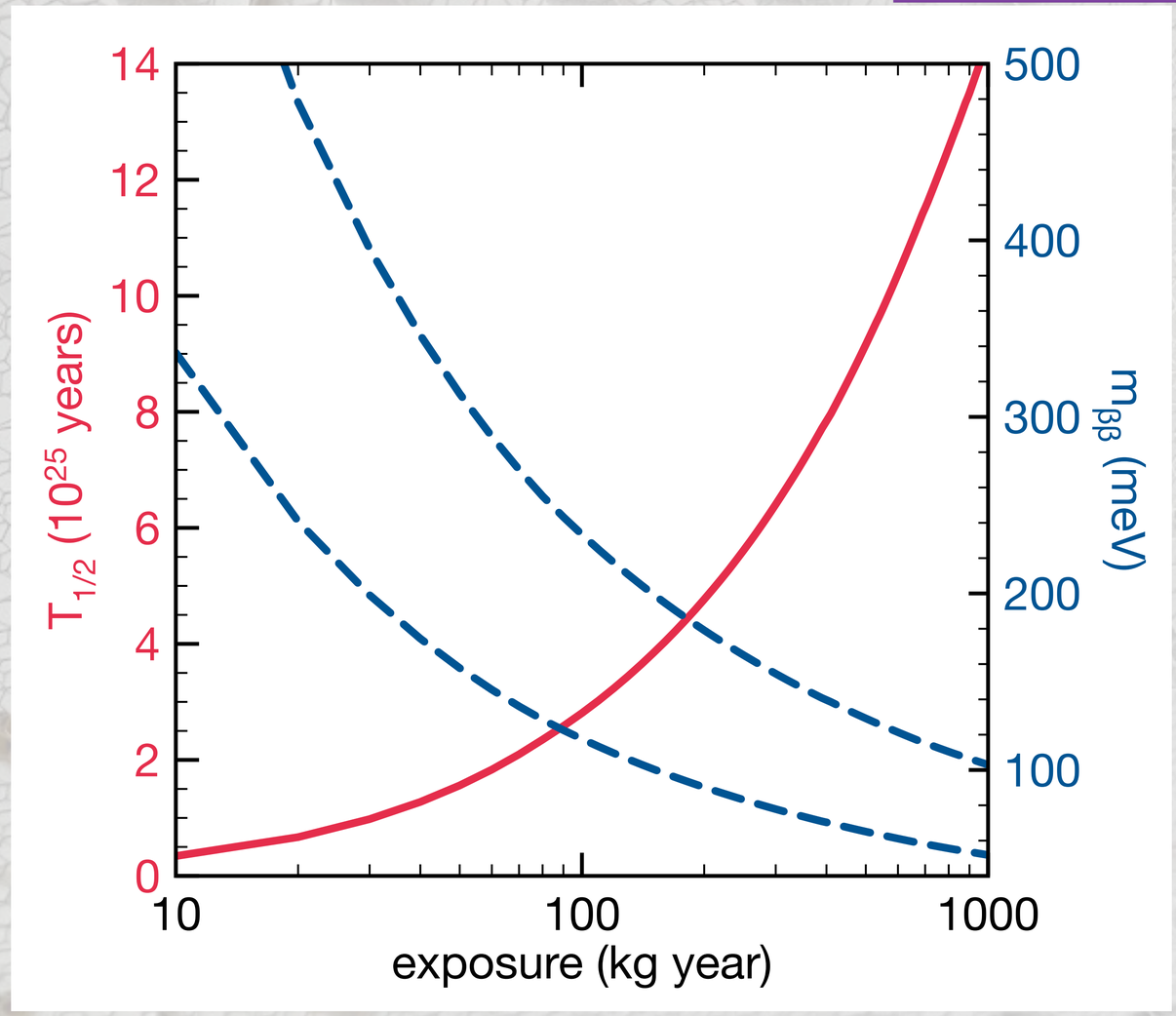
Thanks!

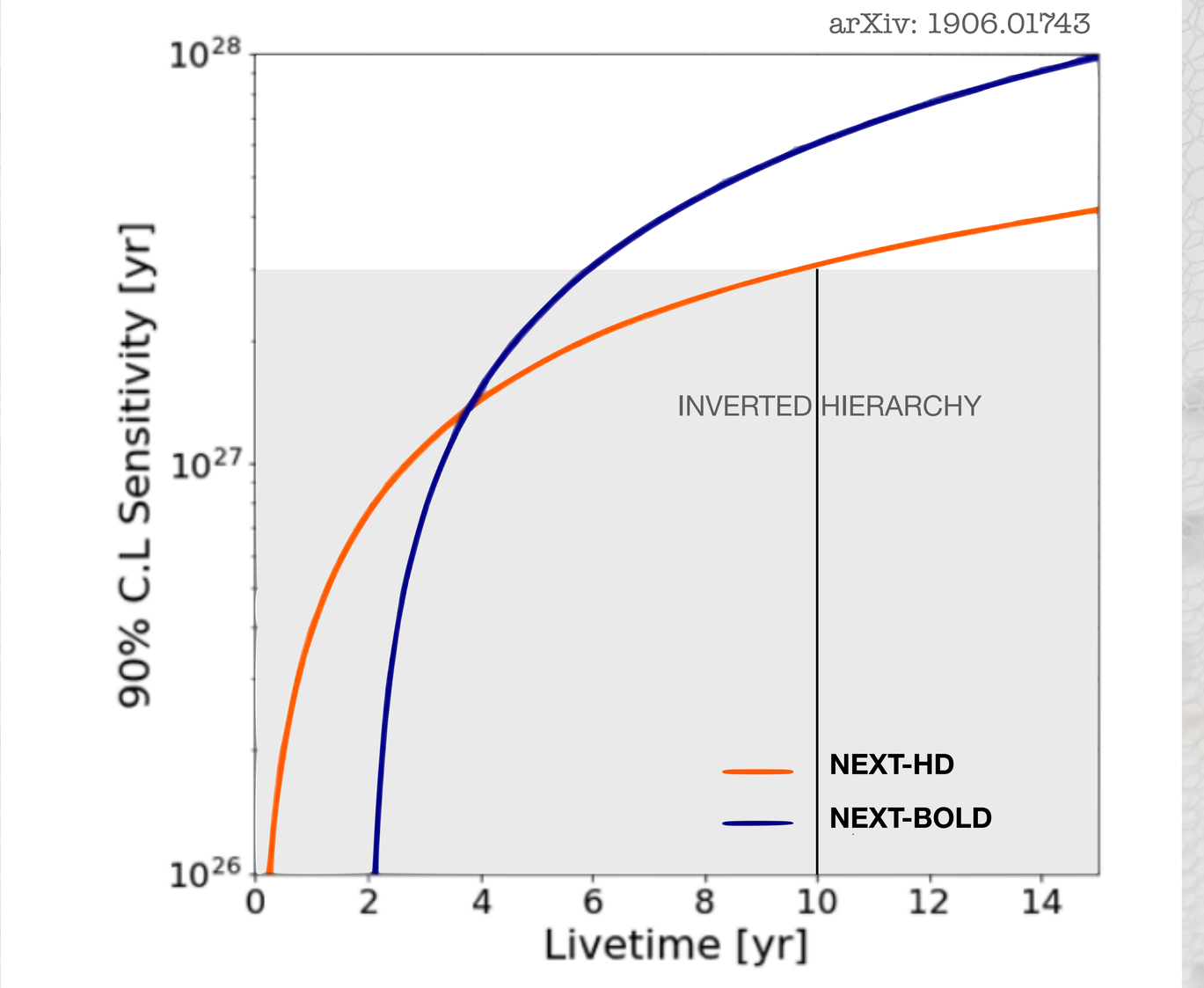
Back up

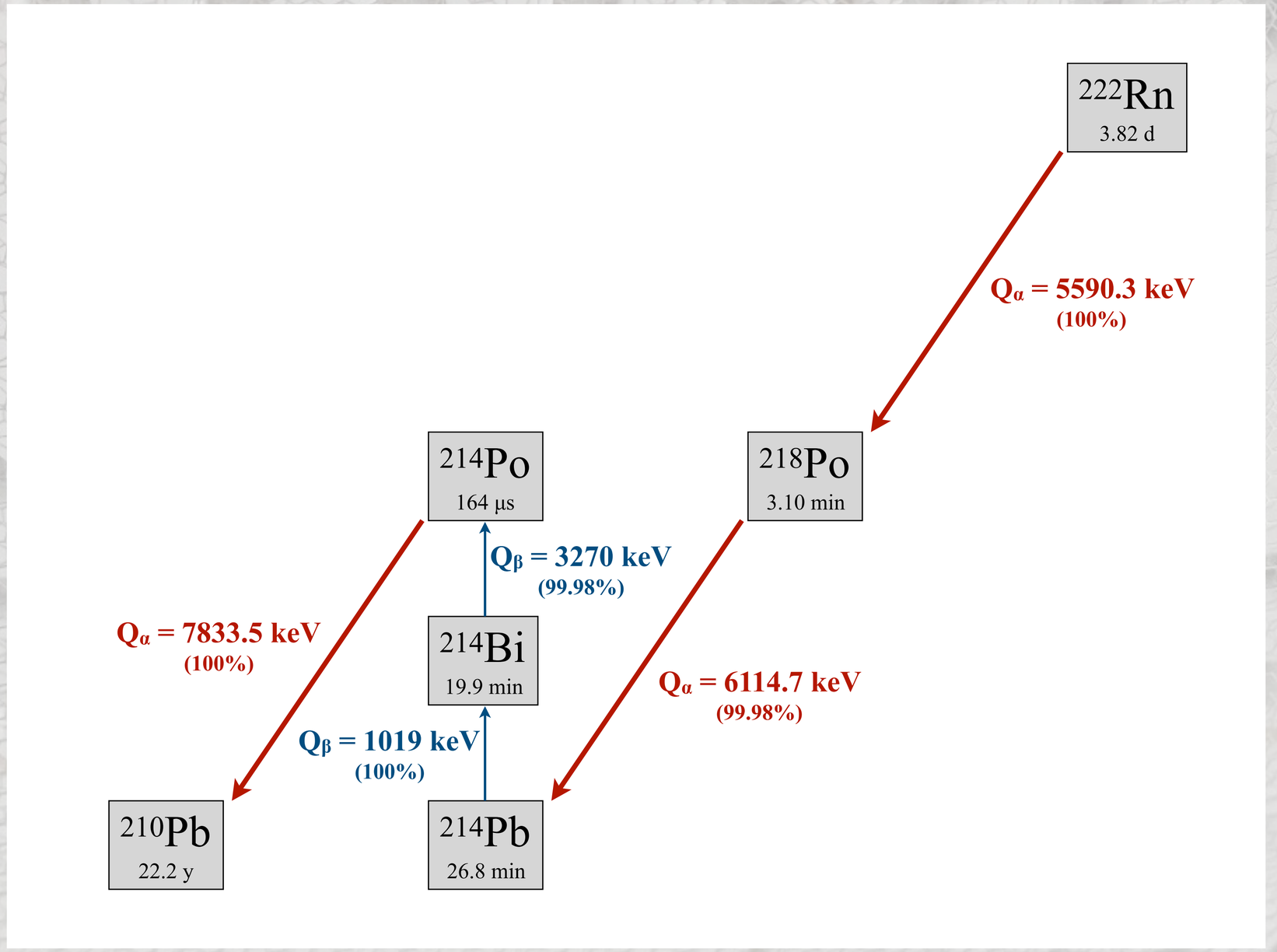

Counts/bin
25
20
15
10
5
0
0.900
0.925
0.950
0.975
1.000
1.025
1.050
1.075
1.100
$E/Q_{\beta\beta}$
1 % FWHM
3.5 % FWHM
10 % FWHM
Background


Longitudinal geological profile
TOBAZO, 1980 m
Ventilation shaft in Rioseta, 1400 m
- SSE -
SPAIN
1183 m
LSC, 1200 m
1800
1700
1600
1500
1400
1300
1200
1100
~ 7.8 km long road tunnel
0 Km
1 Km
2 Km
3 Km


9
8
7
6
5
4
200
180
160
140
120
100
80
60
2
4
6
8
10
$T_{1/2}$ (10^{25} years)
$m_{\beta\beta}$ (meV)
Background rate (10^{-4} keV^{-1} kg^{-1} yr^{-1})


14
12
10
8
6
4
2
0
500
400
300
200
100
10
100
1000
$T_{1/2}$ (10^{25} years)
$m_{\beta\beta}$ (meV)
exposure (kg year)


arXiv: 1906.01743
10^{28}
10^{27}
10^{26}
90% C.L Sensitivity [yr]
INVERTED HIERARCHY
NEXT-HD
NEXT-BOLD
0
2
4
6
8
10
12
14
Livetime [yr]


222Rn
3.82 d
Qα = 5590.3 keV
(100%)
218Po
3.10 min
214Po
164 µs
Qβ = 3270 keV
(99.98%)
Qα = 7833.5 keV
(100%)
214Bi
19.9 min
Qα = 6114.7 keV
(99.98%)
Qβ = 1019 keV
(100%)
210Pb
22.2 y
214Pb
26.8 min

NEXT-White: Background studies

Radon-induced backgrounds

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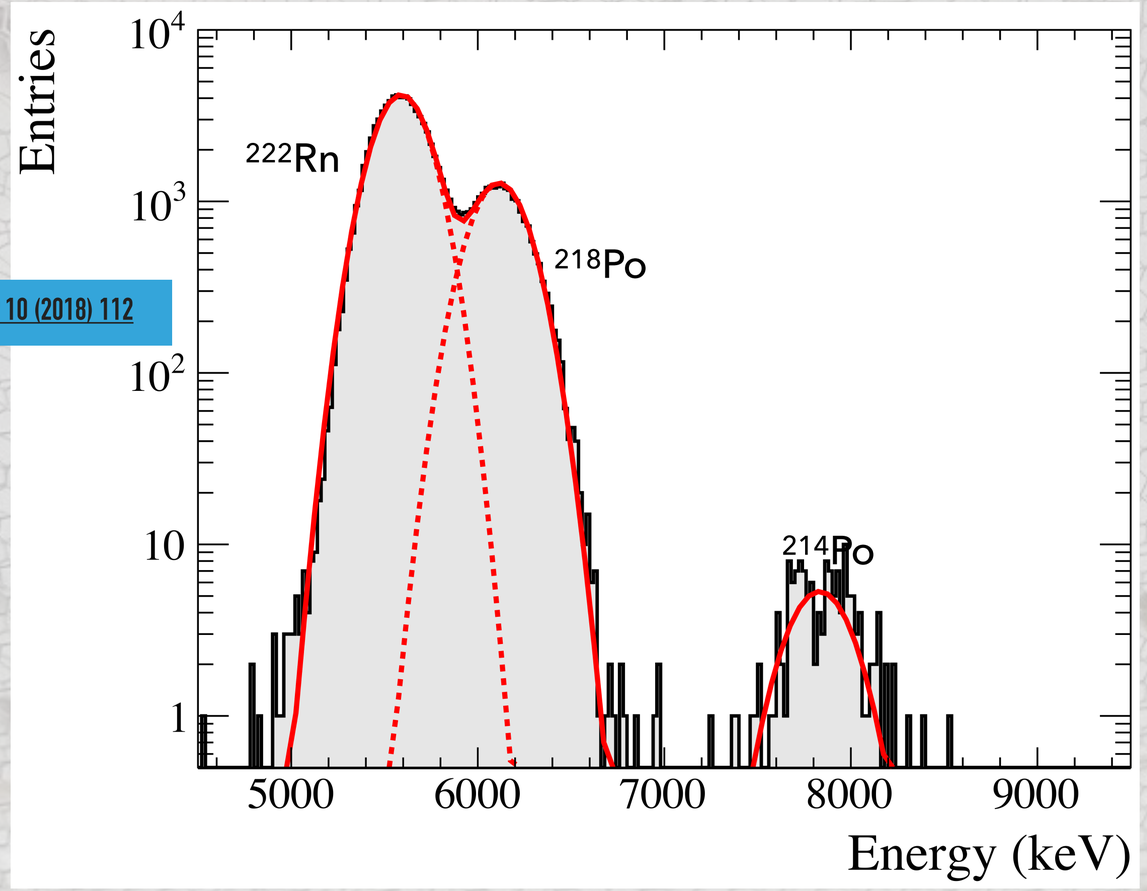
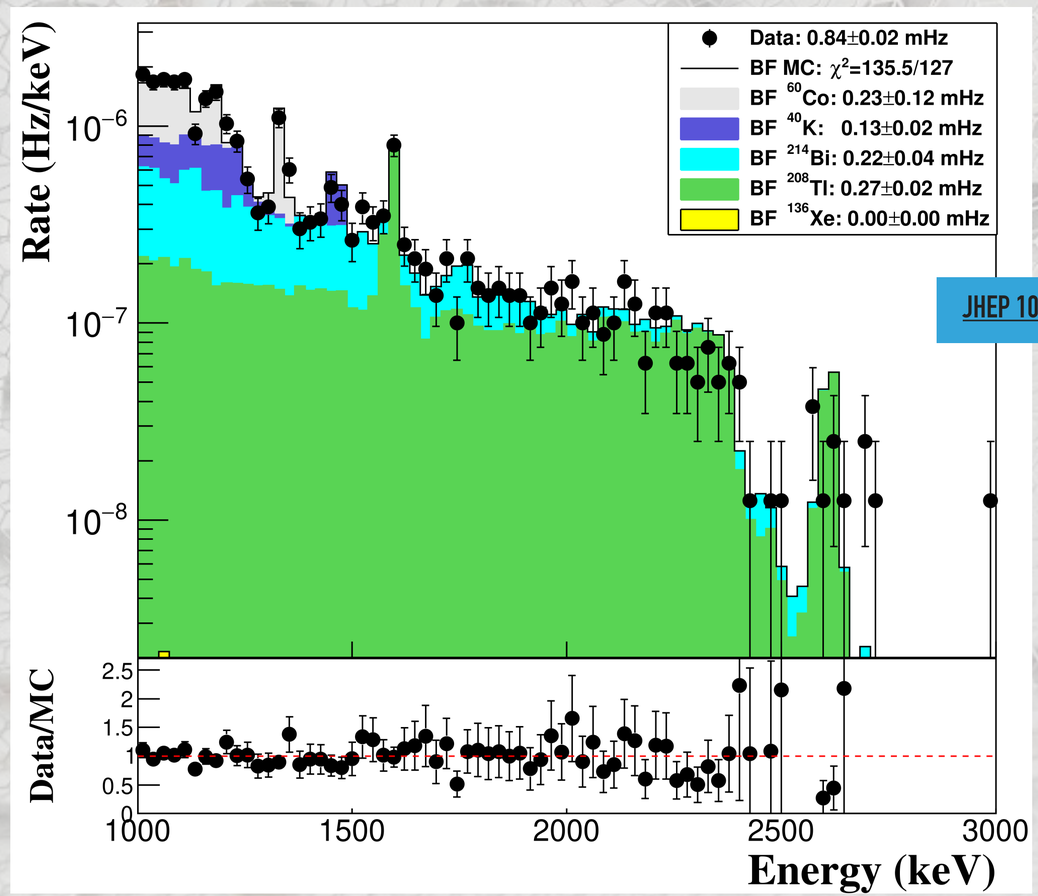


Internal radon has been characterized and measured. It is shown to be negligible for NEXT-100

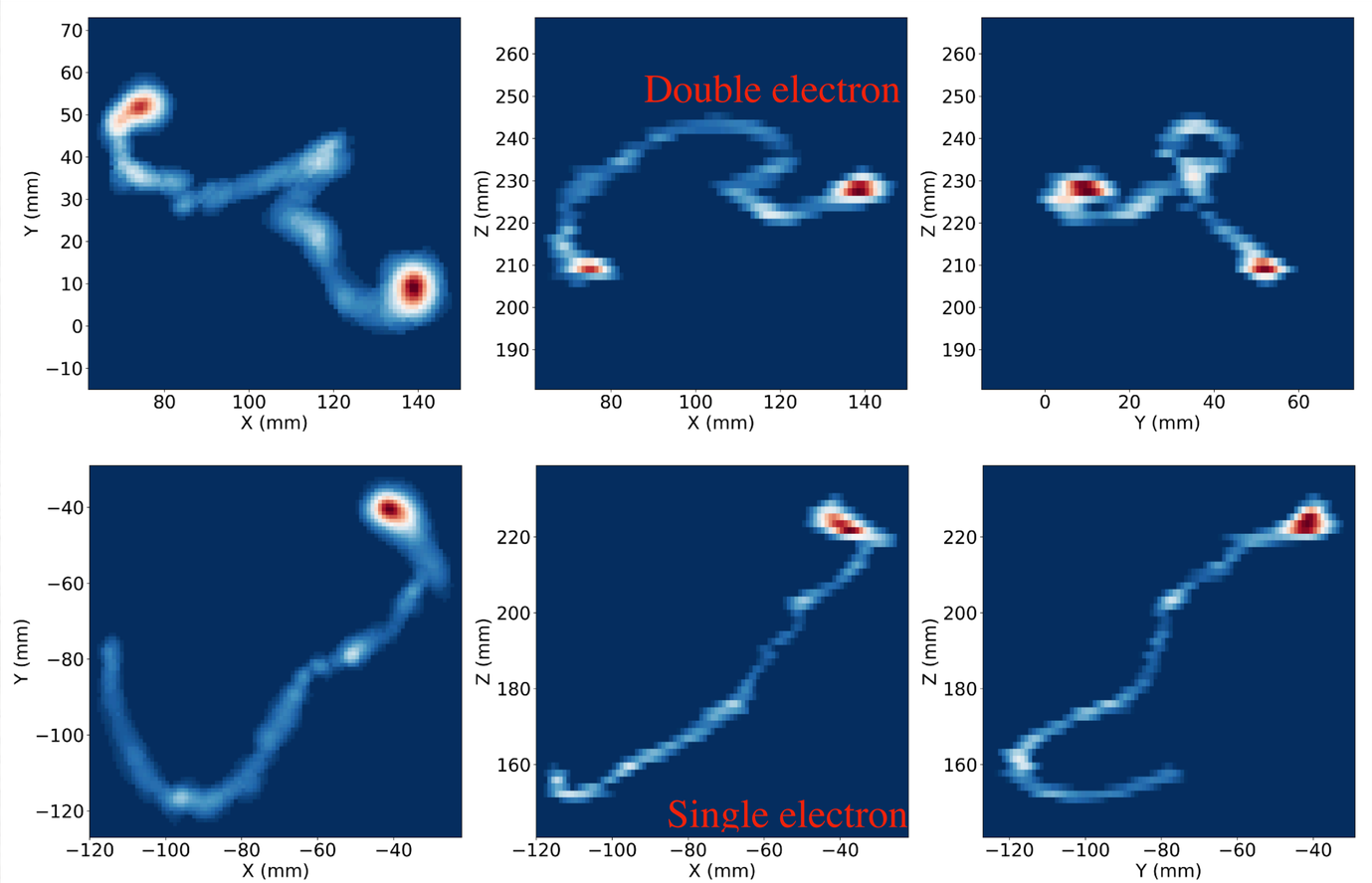
Radiogenic backgrounds

JHEP 10 (2019) 051

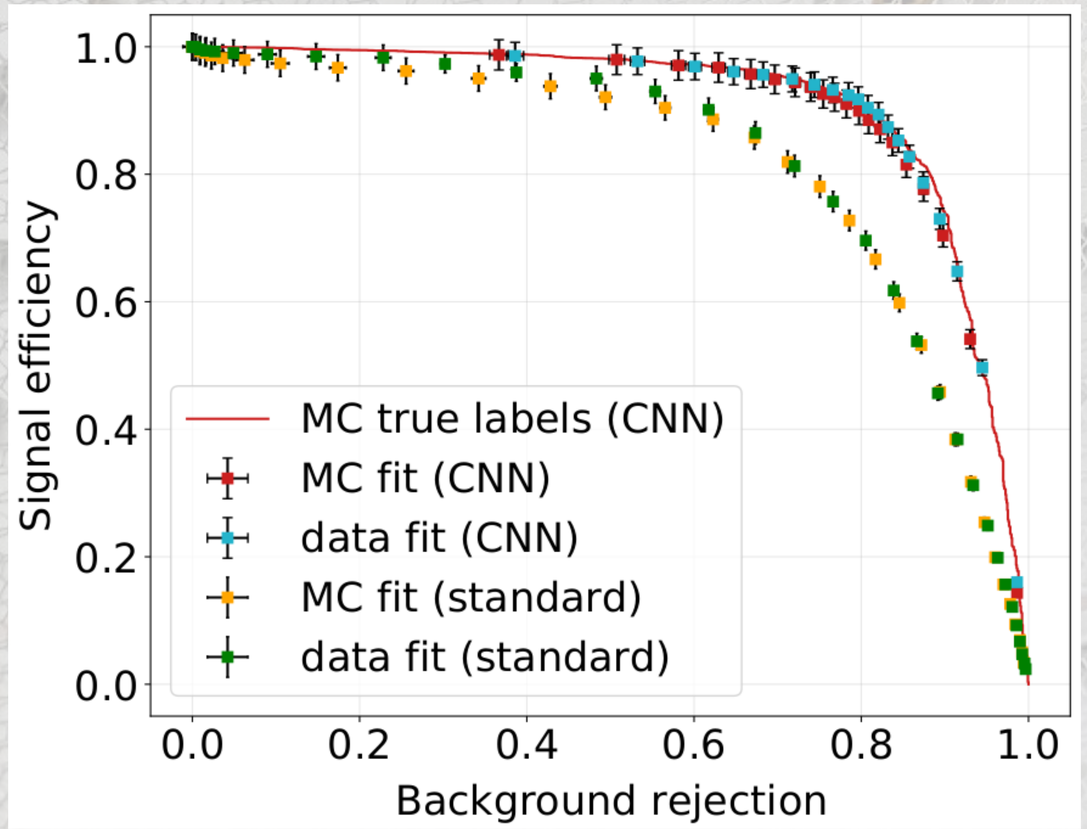


Background model has been validated!

NEXT-White: Event identification and background rejection



Performed both with a classical analysis (blob search) and a DNN approach.



Successful implementation of the Richarson-Lucy deconvolution algorithm.

JHEP 21 (2021) 146

JINST 12 (2017) NO.01, T01004

JHEP 10 (2019) 052

JHEP 01 (2021) 189