WEAK INTERACTIONS AND NEUTRINOS
W±iν
2019
BARI ITALY

next

THE NEXT EXPERIMENT FOR NEUTRINOLESS DOUBLE BETA DECAY SEARCHES

LATEST RESULTS

B. PALMEIRO (IFIC) ON BEHALF OF THE NEXT COLLABORATION

IFIC INSTITUT DE FÍSICA CORPUSCULAR

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS CSIC

VNIVERSITAT DE VALÈNCIA

EXCELENCIA SEVERO OCHOA

The NEXT collaboration

Ikerbasque · DIPC · Girona · UAM · IFIC · Santiago · UPV · Zaragoza

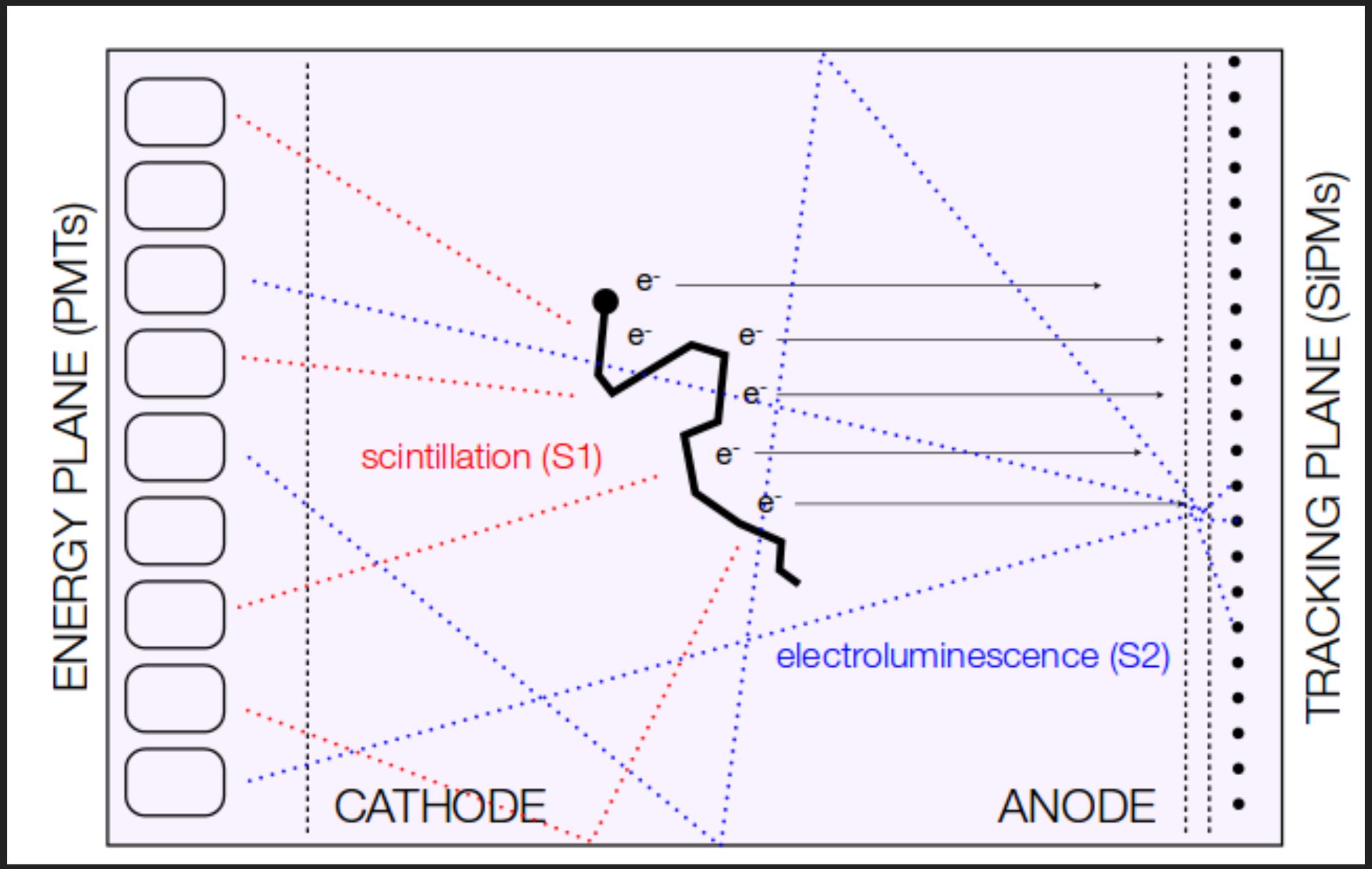
Iowa State · ANL · UTA · FNAL · PNNL · LBNL · Harvard · Texas A&M

Aveiro · Coimbra LIBPhys · Coimbra LIP · A. Nariño · BGU

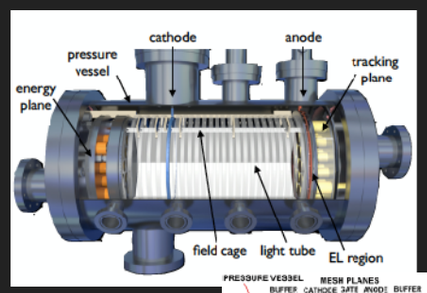
Spokespersons: J.J. Gomez-Cadenas (Spain), D. Nygren (USA)

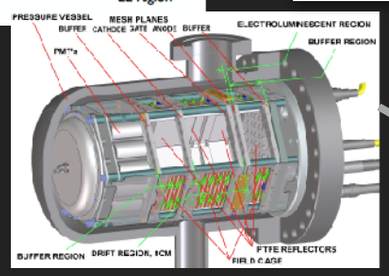
Funded by: erc · MARIE CURIE ACTIONS · GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD · GENERALITAT VALENCIANA · FCT Fundação para a Ciência e a Tecnologia · U.S. DEPARTMENT OF ENERGY · UNIVERSITY OF TEXAS ARLINGTON

What is NEXT?


ENERGY PLANE (PMTs)
scintillation (S1)
e-
e-
e-
e-
e-
e-
electroluminescence (S2)
CATHODE
ANODE
TRACKING PLANE (SiPMs)

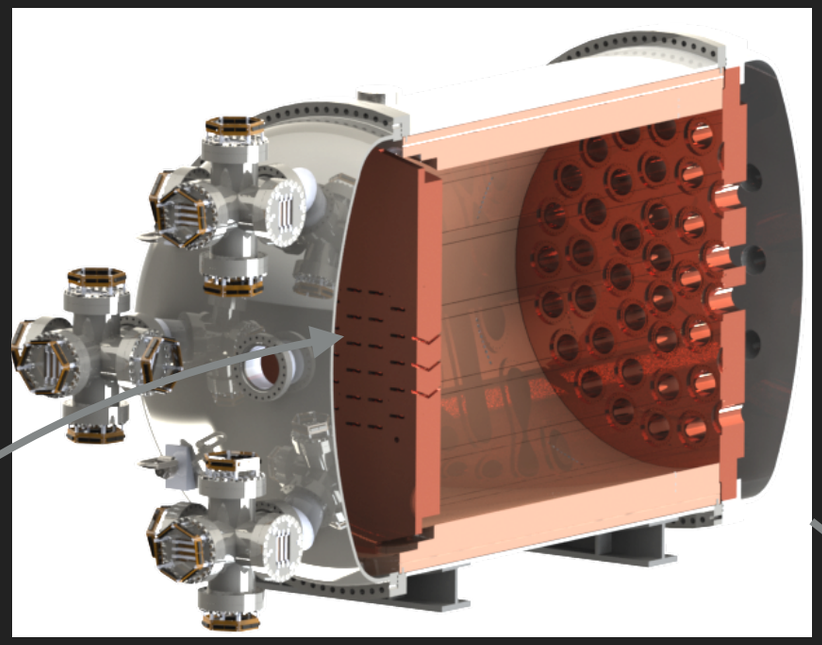
The NEXT program





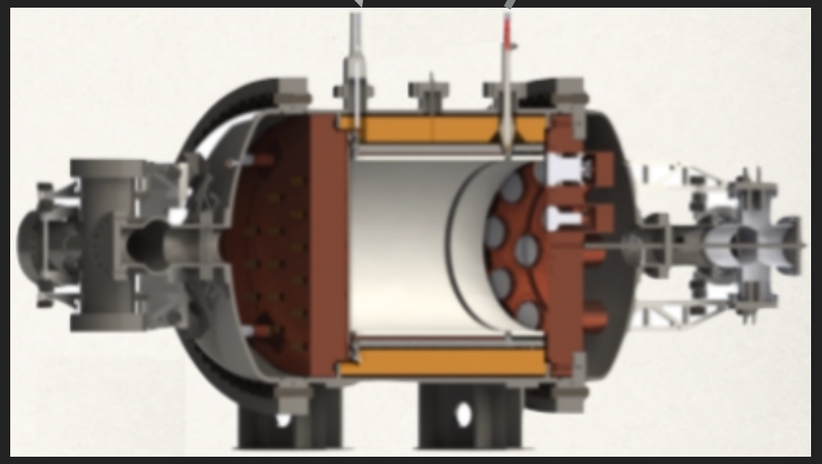
Demonstration of detector concept

Prototypes (~1 kg)
[2009 - 2014]



NEXT-100 (~100 kg)
[2019 - 2020's]

Neutrinoless double beta decay searches



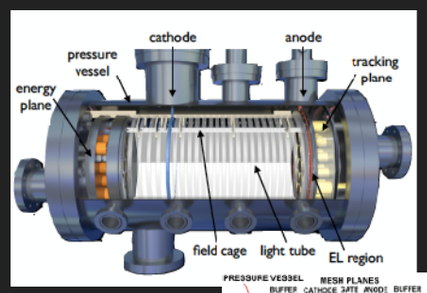
NEXT-White (~5 kg)
[2015 - 2019]

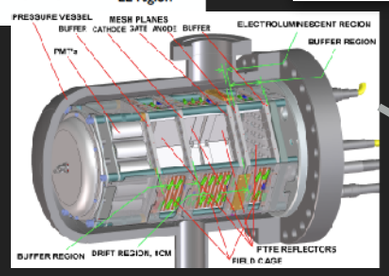
Two neutrino double beta decay searches

Background model assessment

NEXT-tonne (~1000 kg)
[future generation]

The NEXT program





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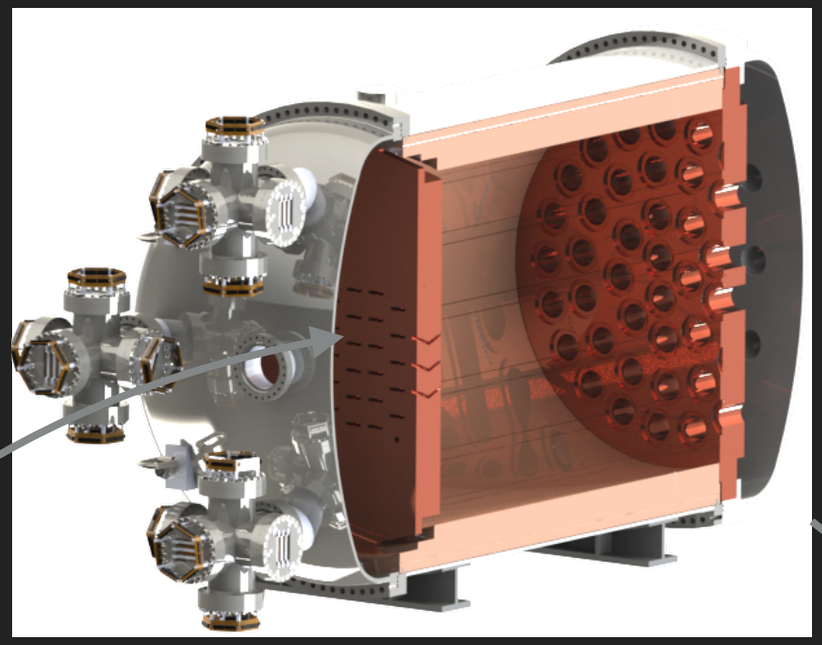

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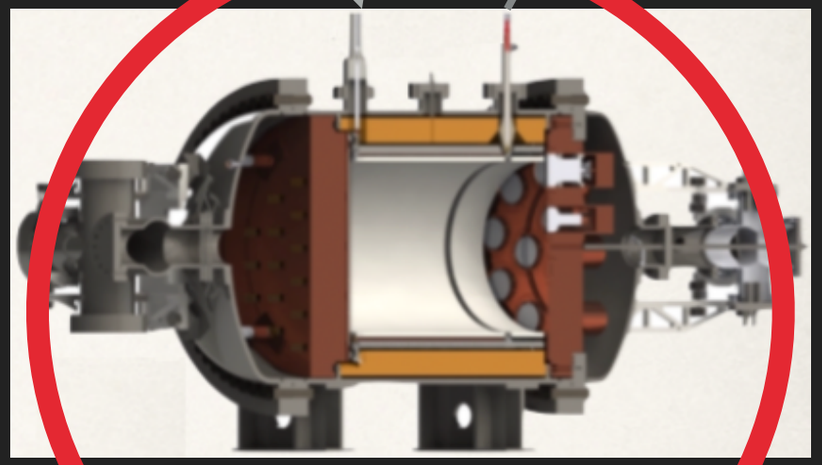


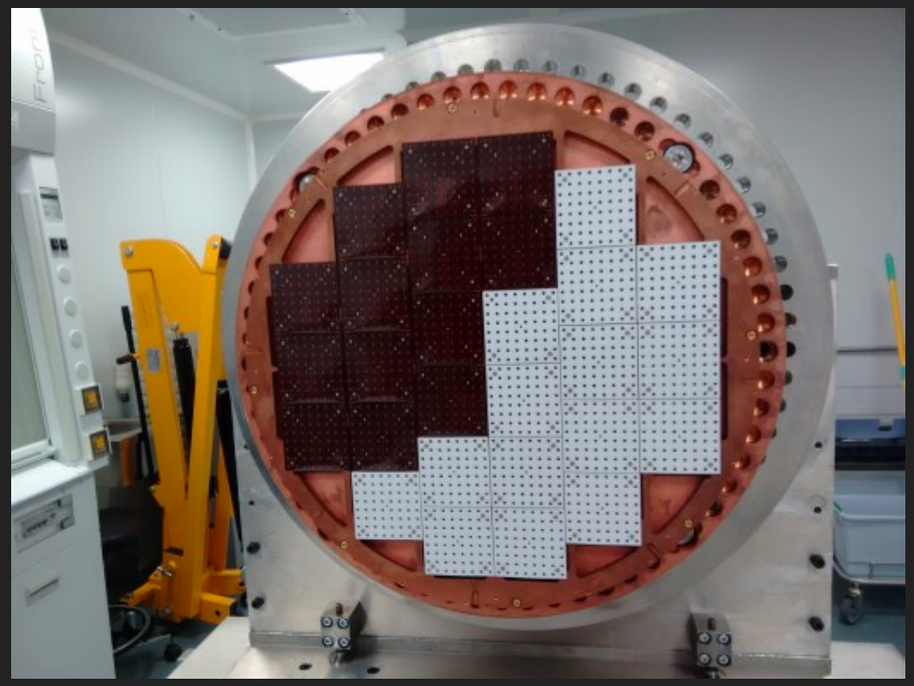
NEXT-White (~5 kg)
[2015 - 2019]

NEXT-tonne (~1000 kg)
[future generation]

NEXT-White (NEXT-10)

Location: LSC (Spain)
Status: Running
Mass: ~5 kg
Goals:

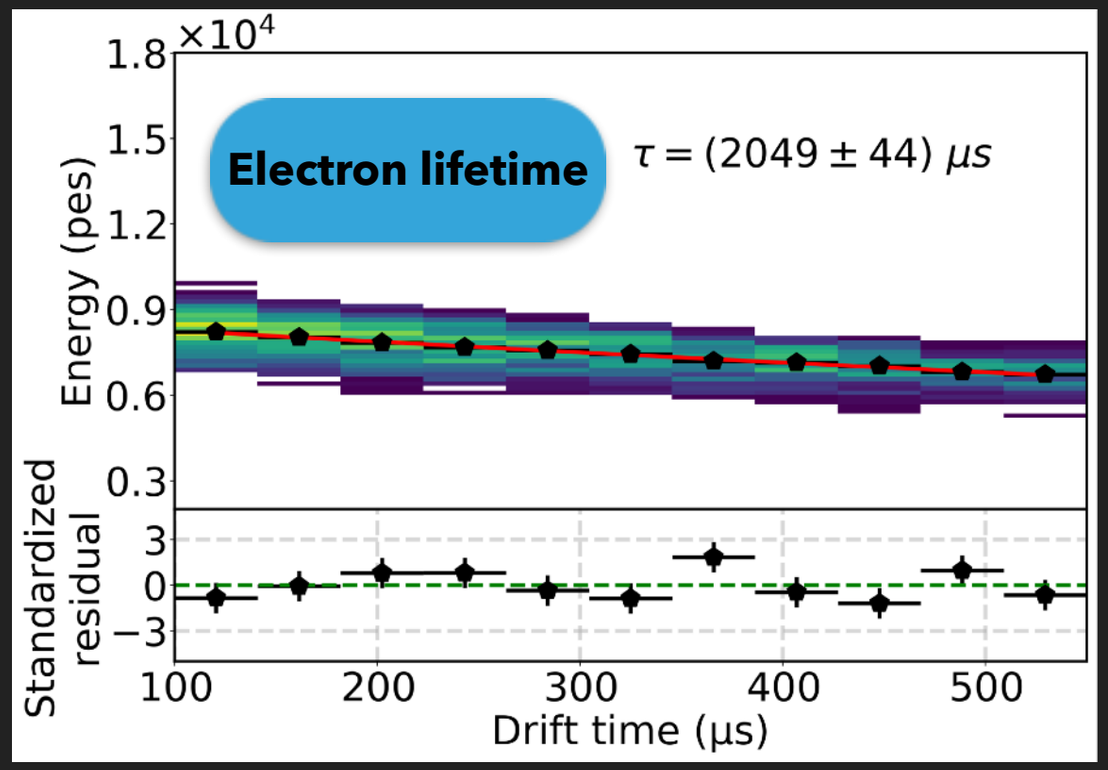
- Demonstrate technology is robust.
- Measure backgrounds to establish a reliable background model (and to improve it as needed).
- Demonstrate energy resolution and topological signature in a large-scale detector.

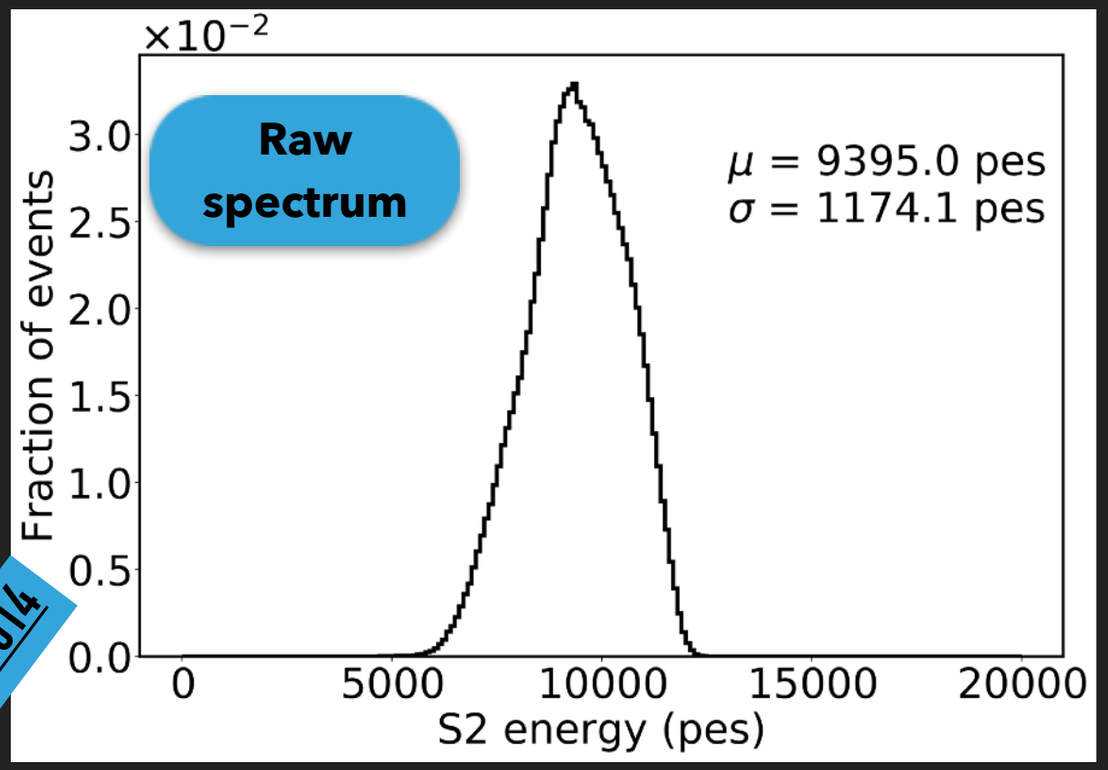


NEXT-White data taking

Run		Time		Goals	Comments
II		~03-11/2017		Calibration	No Radon abatement system No inner lead castle
IV	IVa	~08/2018 (41 days)	Depleted Xe	Calibration and Background characterization	Radiopurity improved No Radon abatement system No inner lead castle
	IVb	~10/2018 (27 days)			Radon abatement system ON No inner lead castle
	IVc	~11/2018 (40 days)			Radon abatement system ON Inner lead castle
V		02/2019 (ongoing)	Enriched ^{136}Xe	Double beta measurement	Radon abatement system ON Inner lead castle

Calibration of the NEXT-White detector using ^{83m}Kr decays





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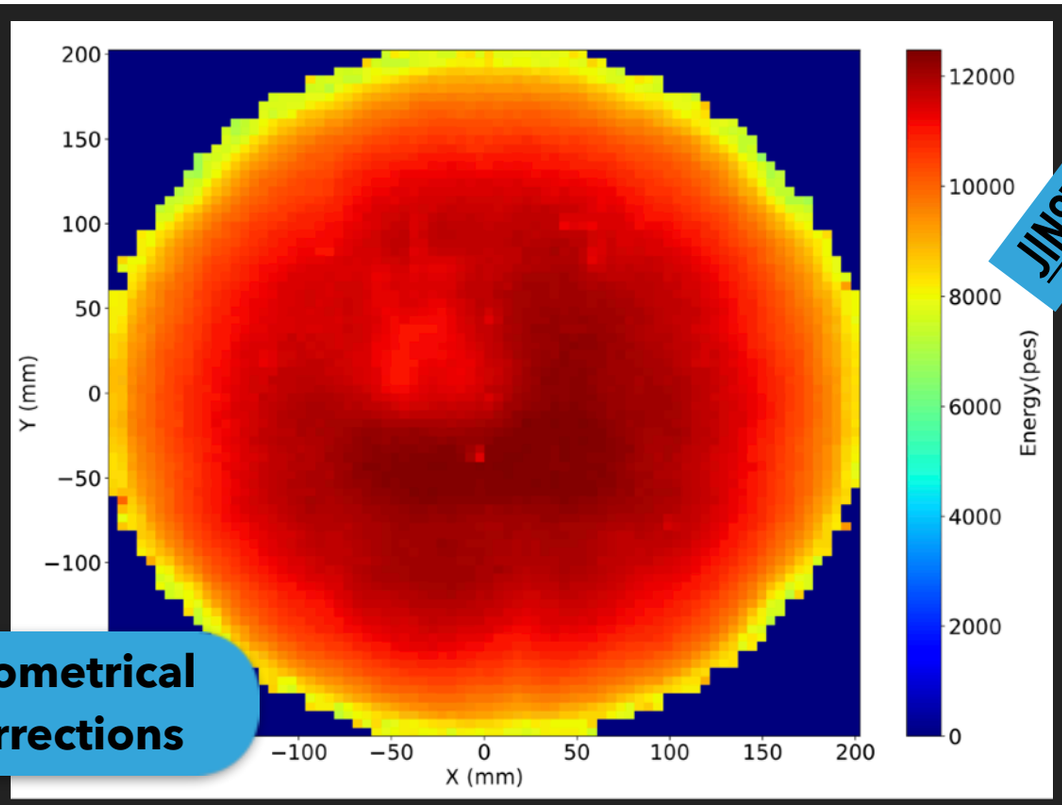
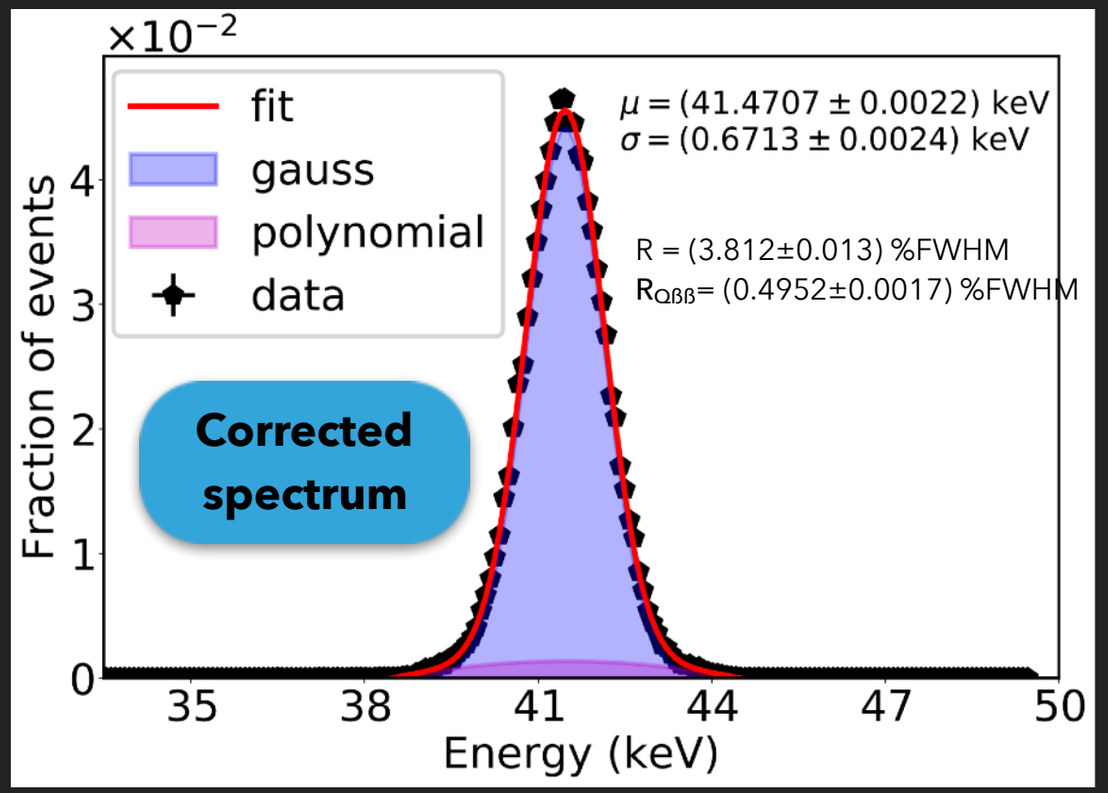
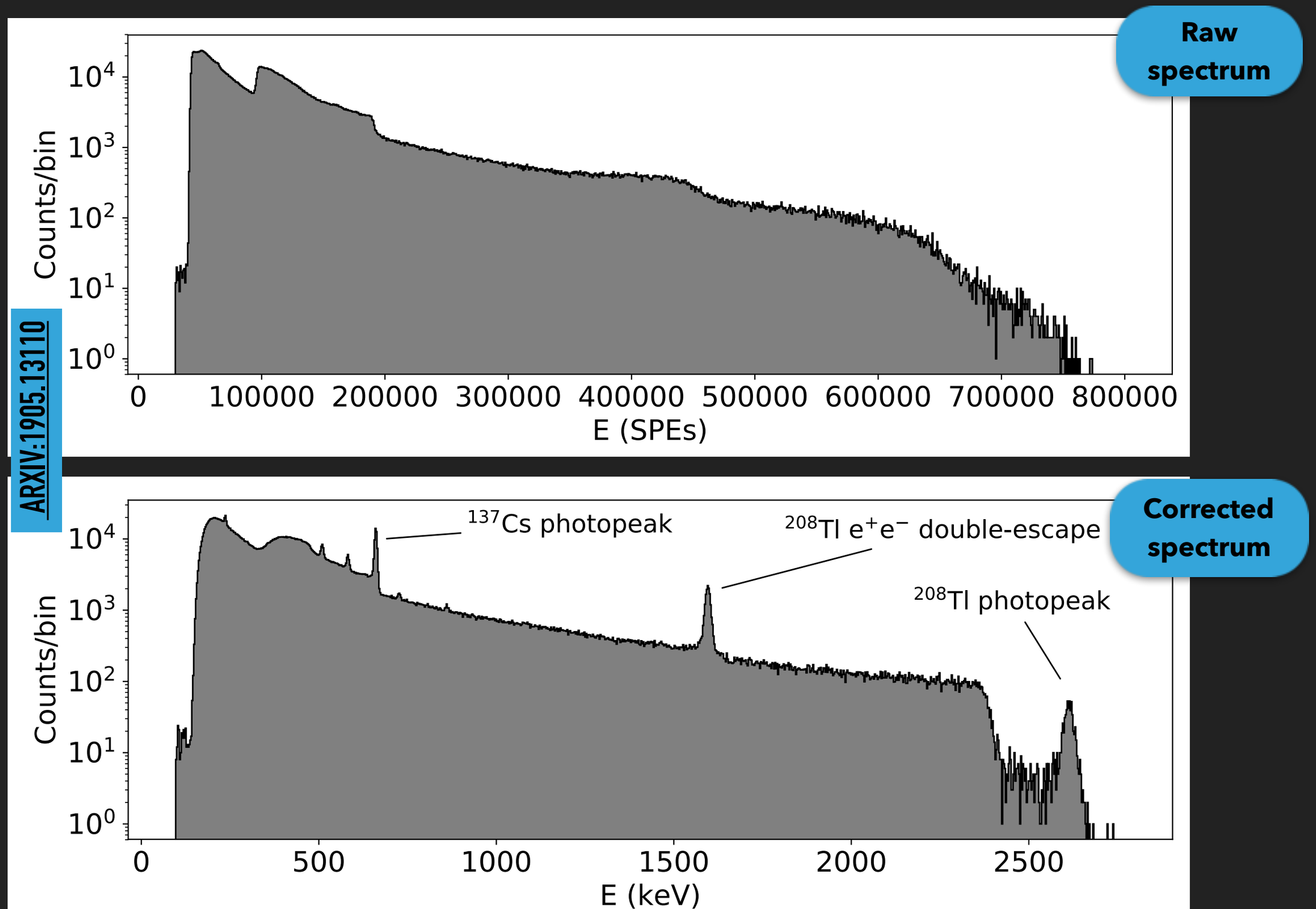




Energy calibration of the NEXT-White detector with 1% resolution near $Q_{\beta\beta}$ of ^{136}Xe



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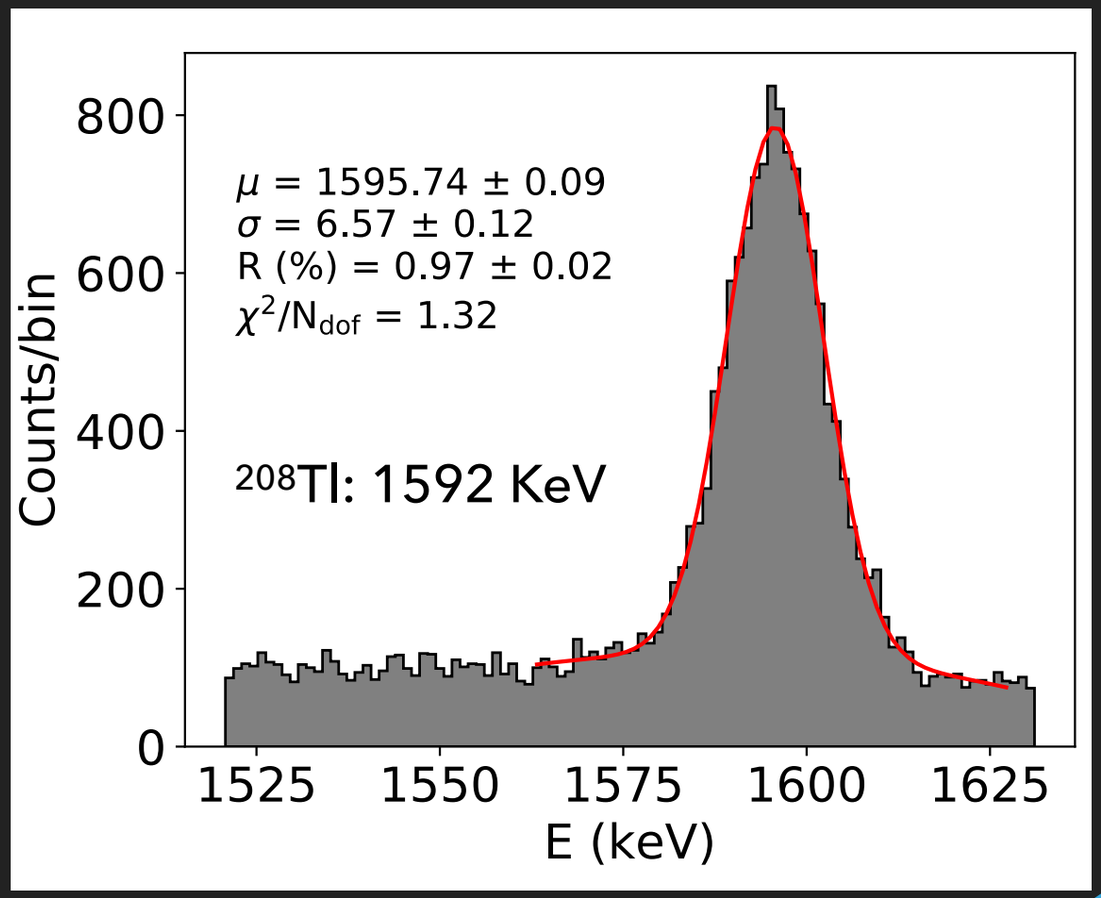
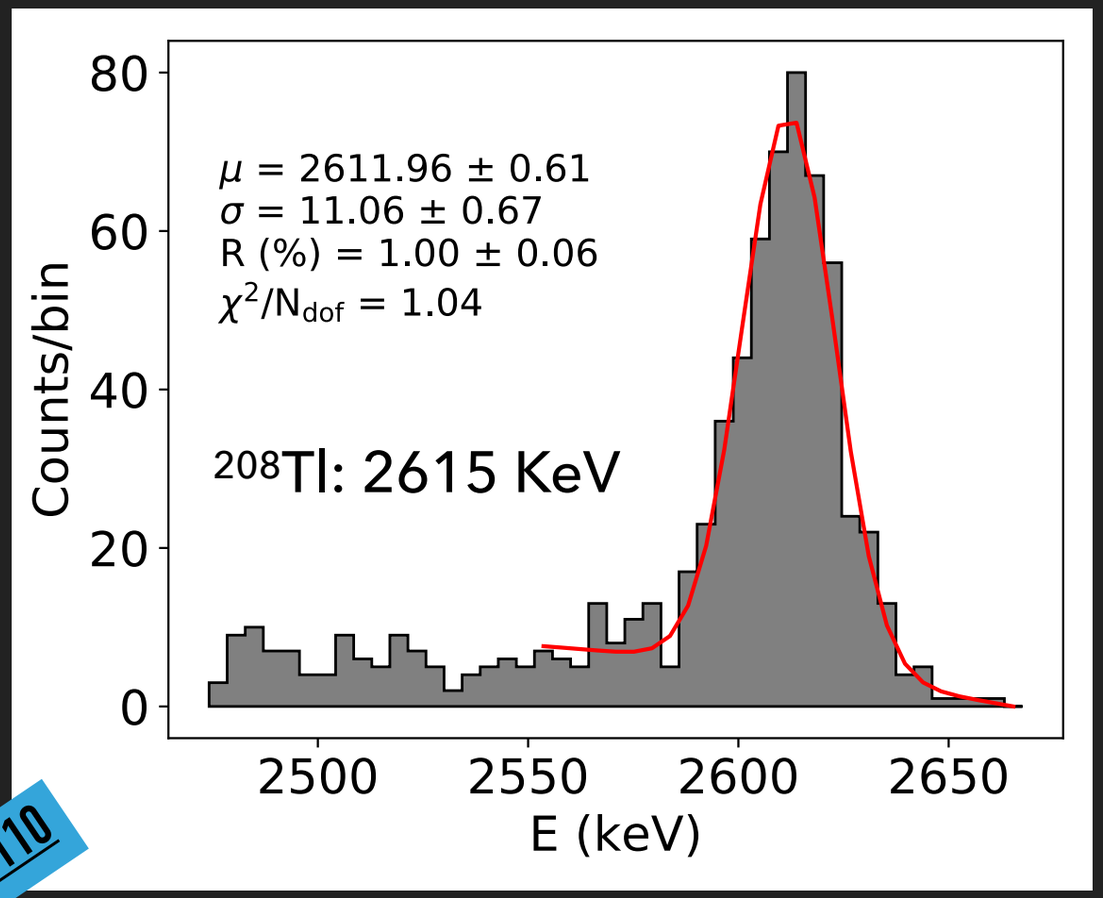
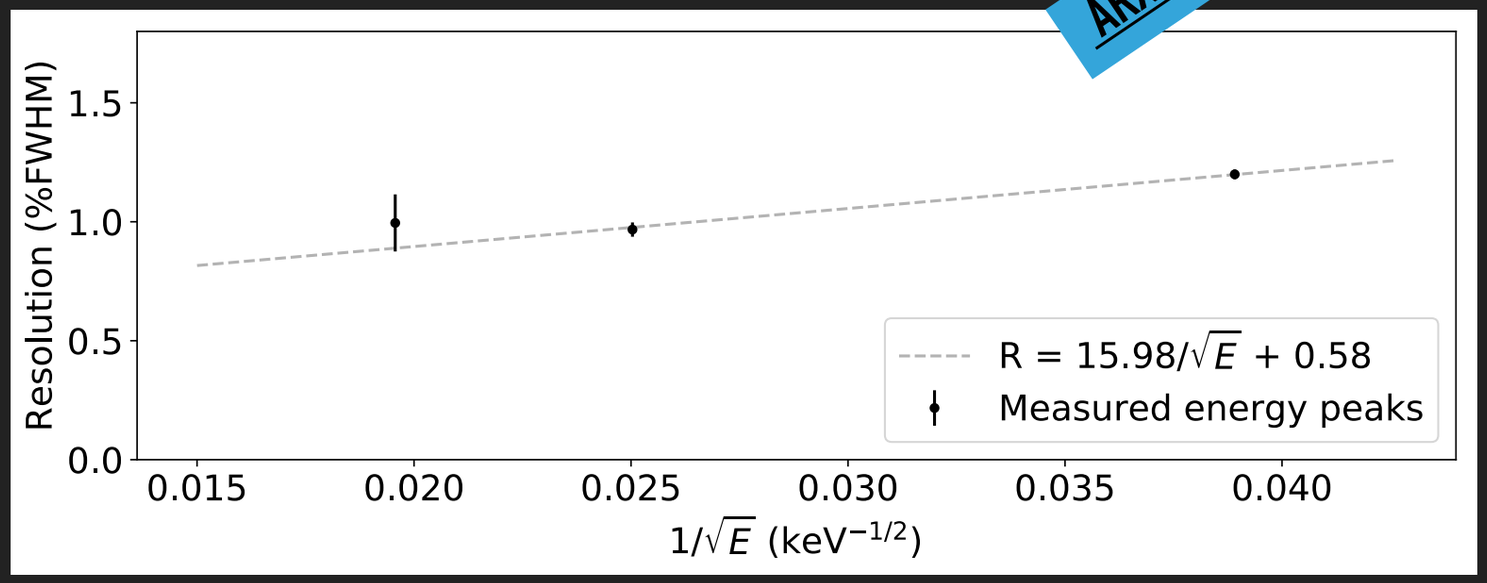




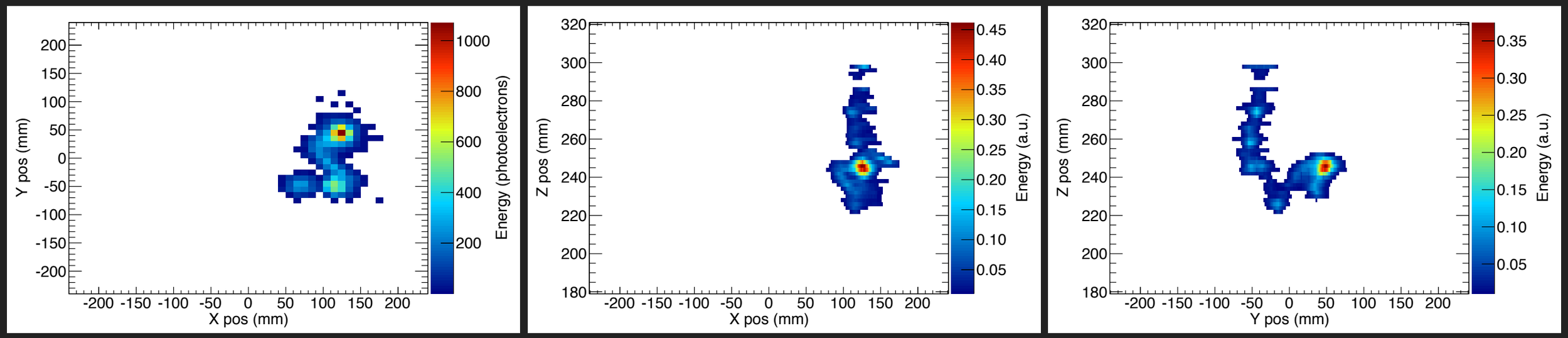
ARXIV:1905.13110



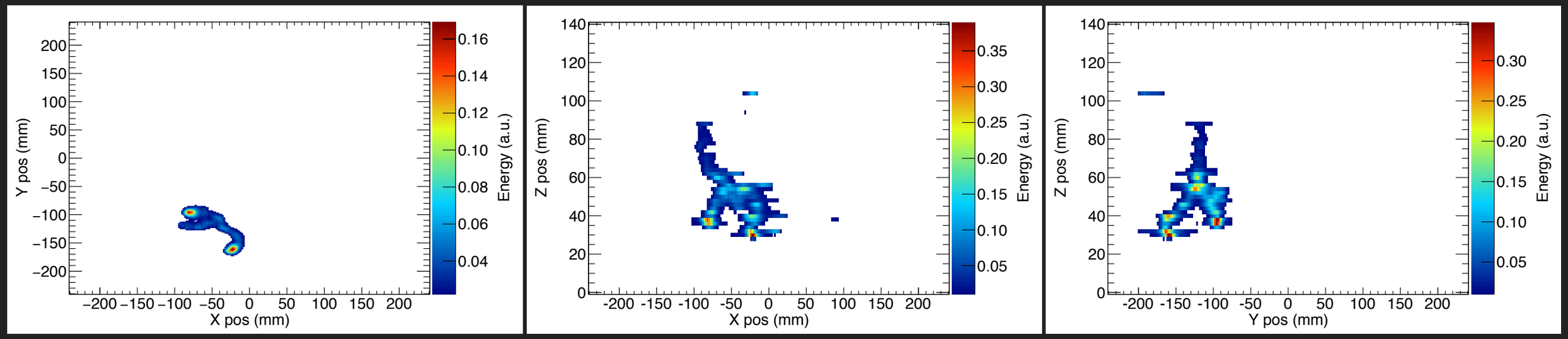
Resolution is shown to be 1%FWHM @ $Q_{\beta\beta}$ matching NEXT expectations

Track reconstruction

Single-electron like

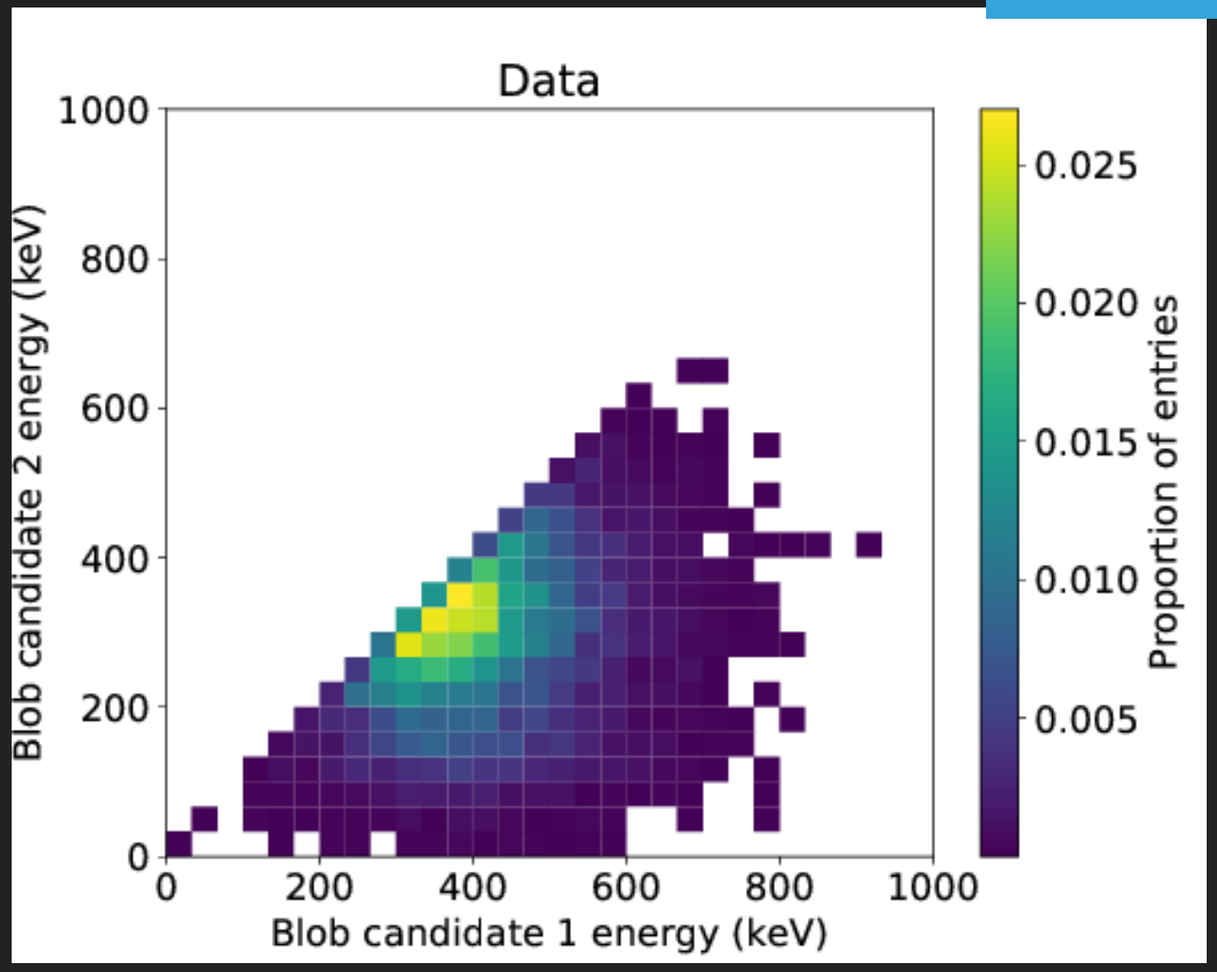


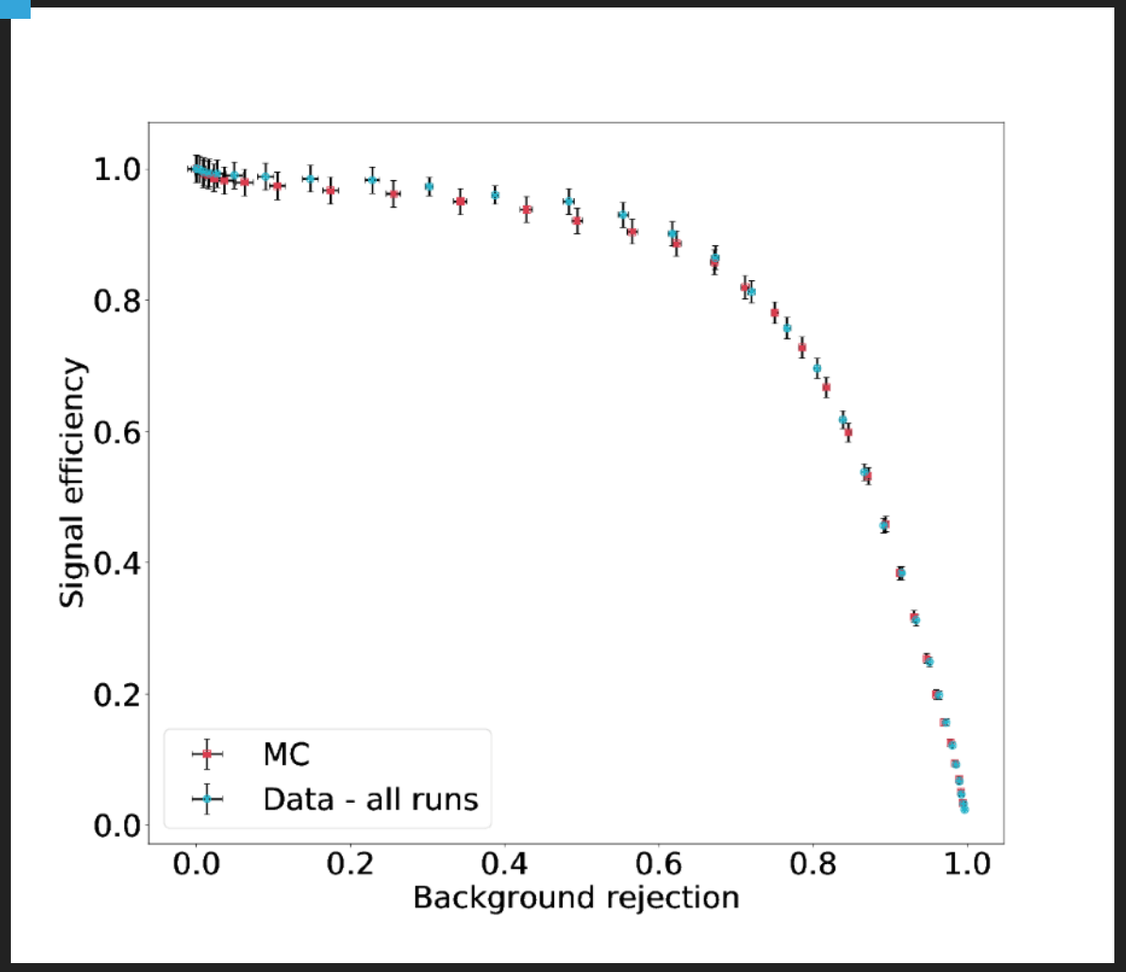
ββ-like electrons



Efficiency of the topological signature in the NEXT-White detector

ARXIV:1905.13141





Double escape peak events (signal-like) show a good performance of the topological reconstruction and blob characterization

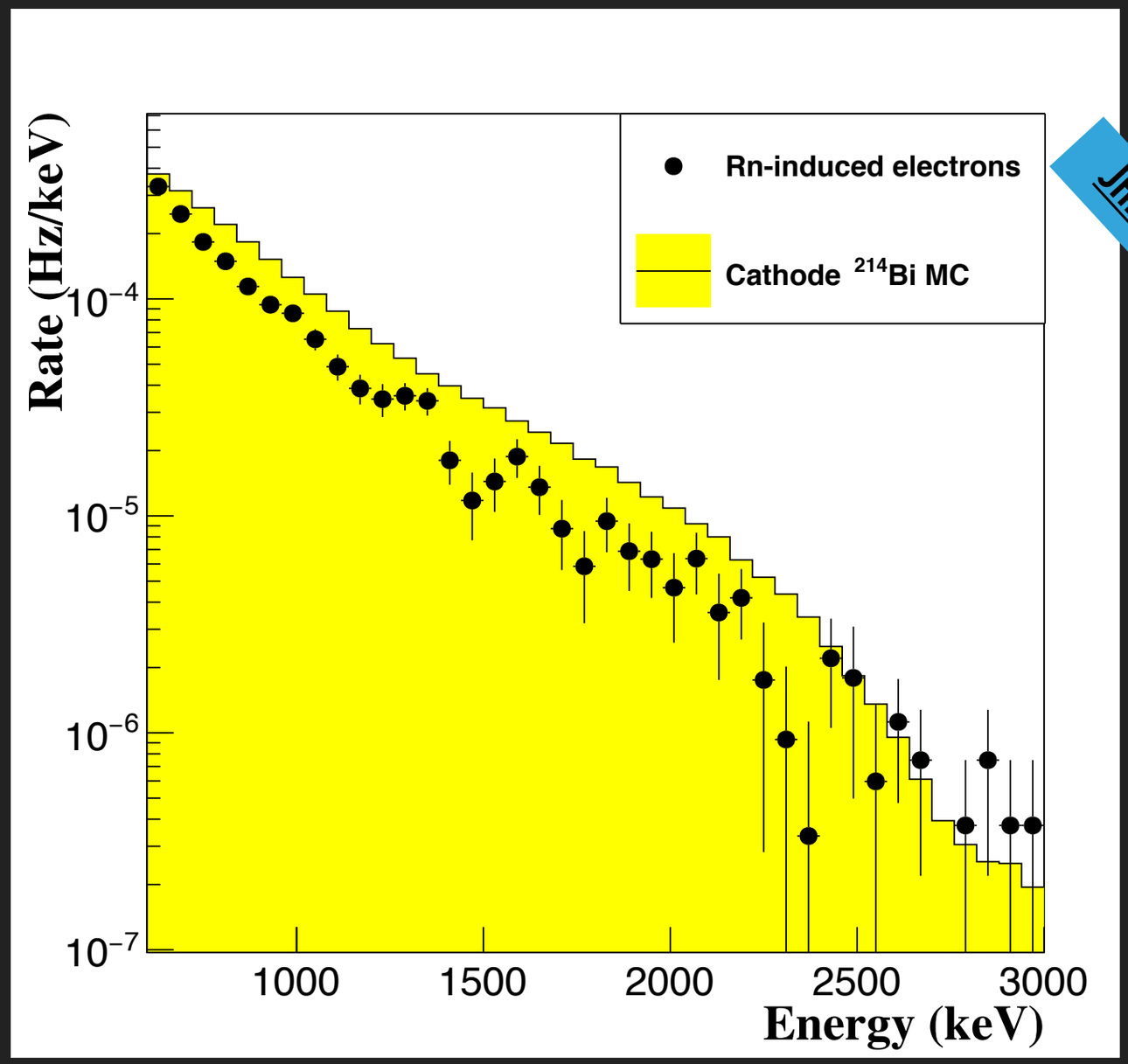
Signal efficiency signal-like events 71.3 ± 1.5% for a background acceptance of 20.3 ± 0.4% at Tl double escape peak (data).

Signal efficiency of 71.9 ± 0.1 (stat.)%, for a background acceptance of 13.2 ± 1.1 (stat.)% at $Q_{\beta\beta}$ (MC)

NEXT backgrounds

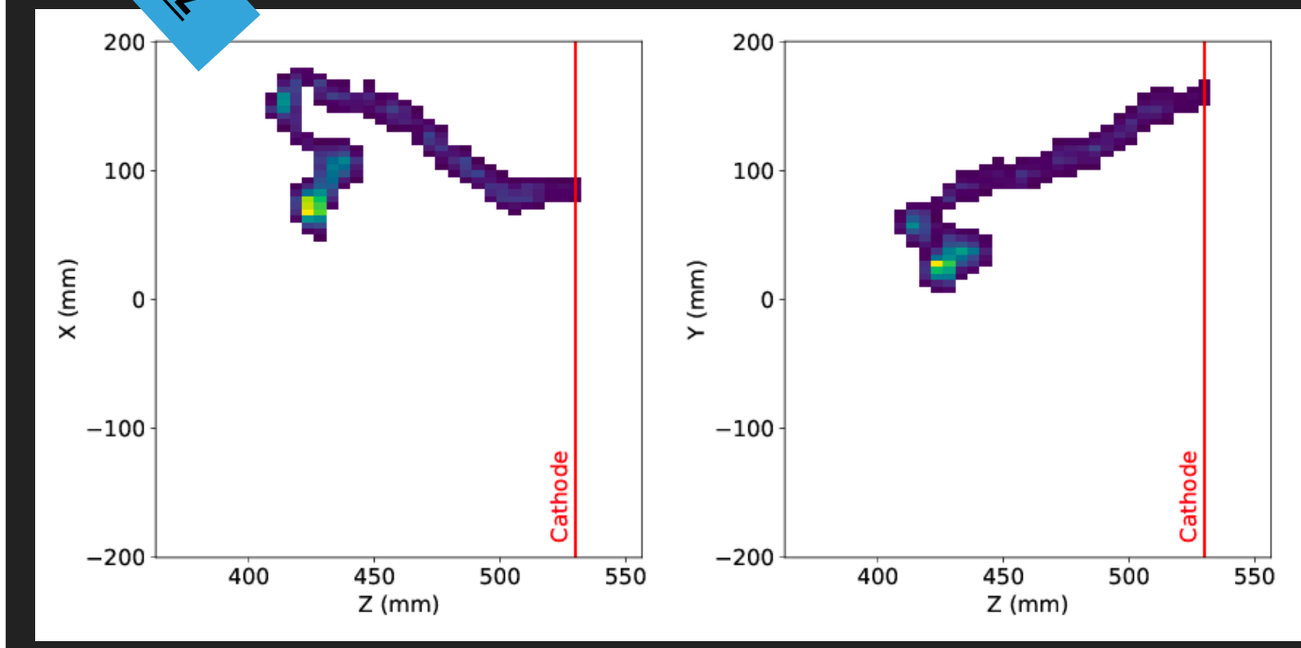
- **Radon**:
  - **Airborn**: radon gas in the air surrounding the detector.
  - **Internal**: emanation from the components inside the gas system external to the detector vessel or the inner detector components.
- **Radiogenic:** Inner materials are contaminated with different radioactive isotopes. Mainly ^{208}Tl and ^{214}Bi for ββ0ν searches and also ^{40}K, ^{60}Co for ββ2ν ones.
- **Cosmogenic**: Backgrounds induced by cosmic rays and their by-products.

Measurement of radon-induced backgrounds in the NEXT double beta decay experiment



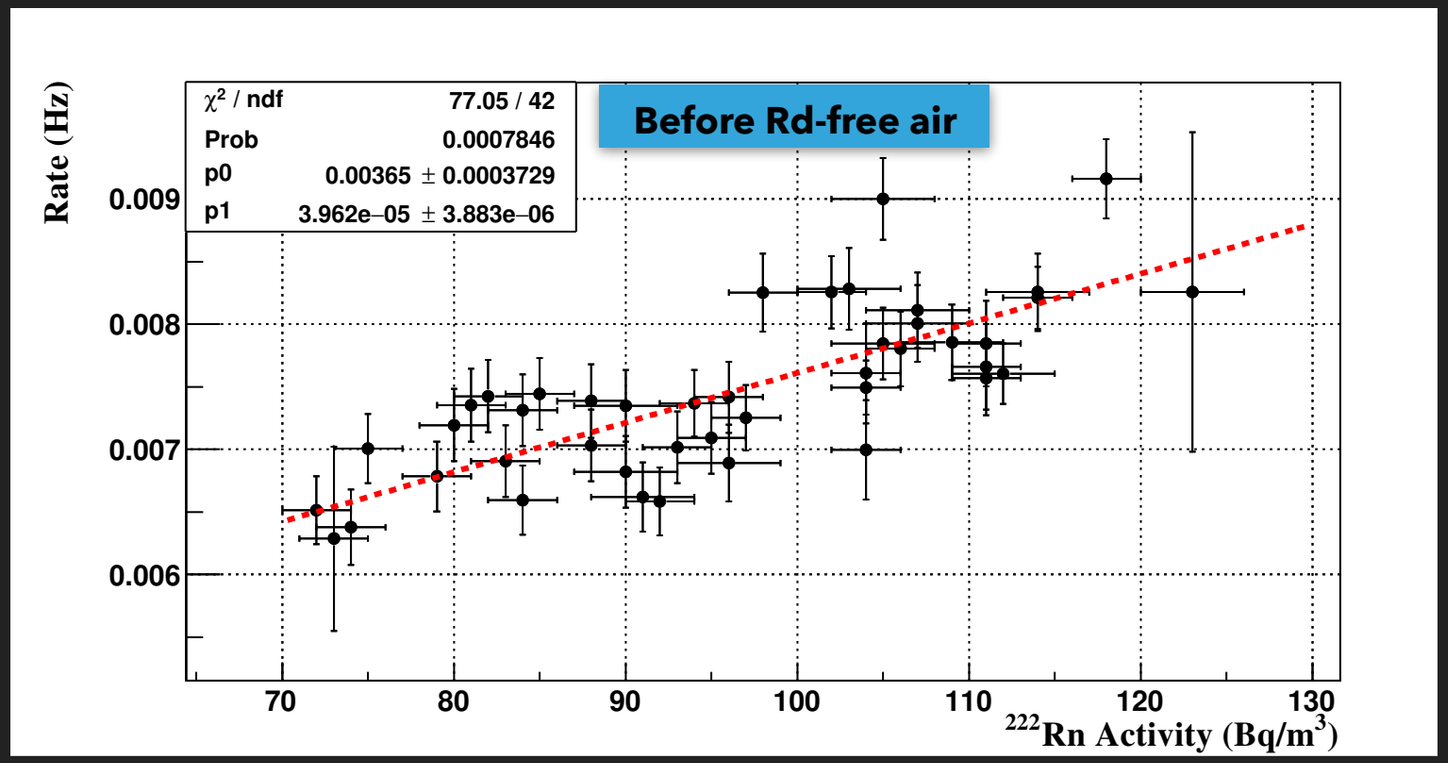
JHEP10(2018)112

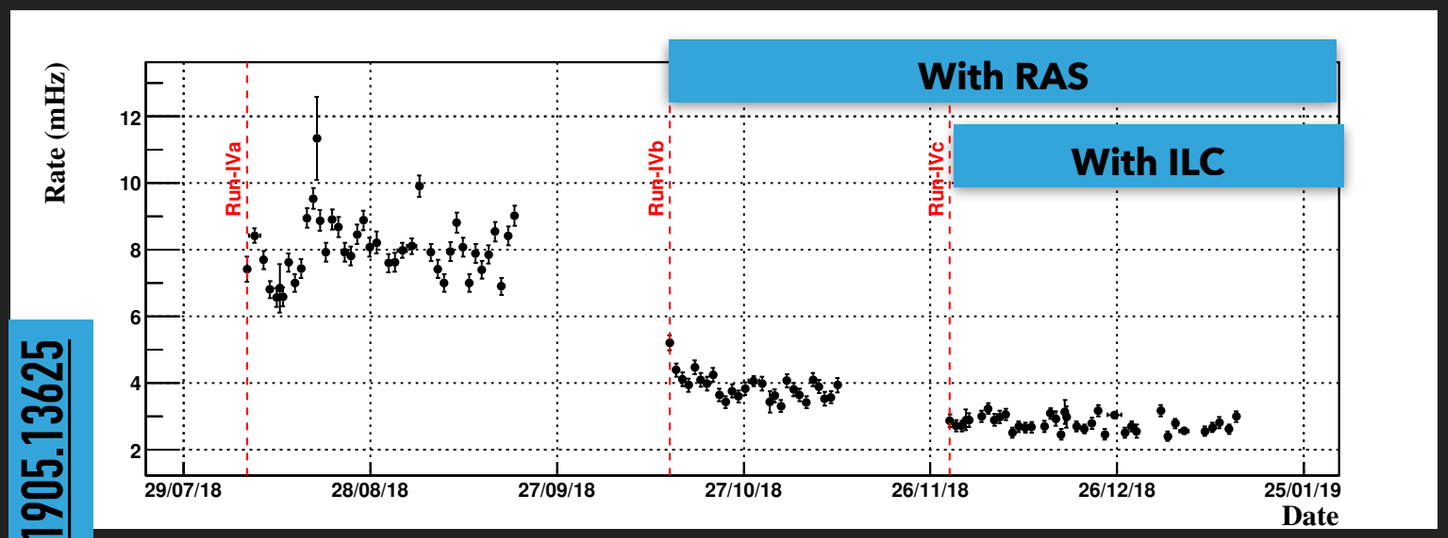
Internal radon



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

Measurement of radon-induced backgrounds in the NEXT double beta decay experiment





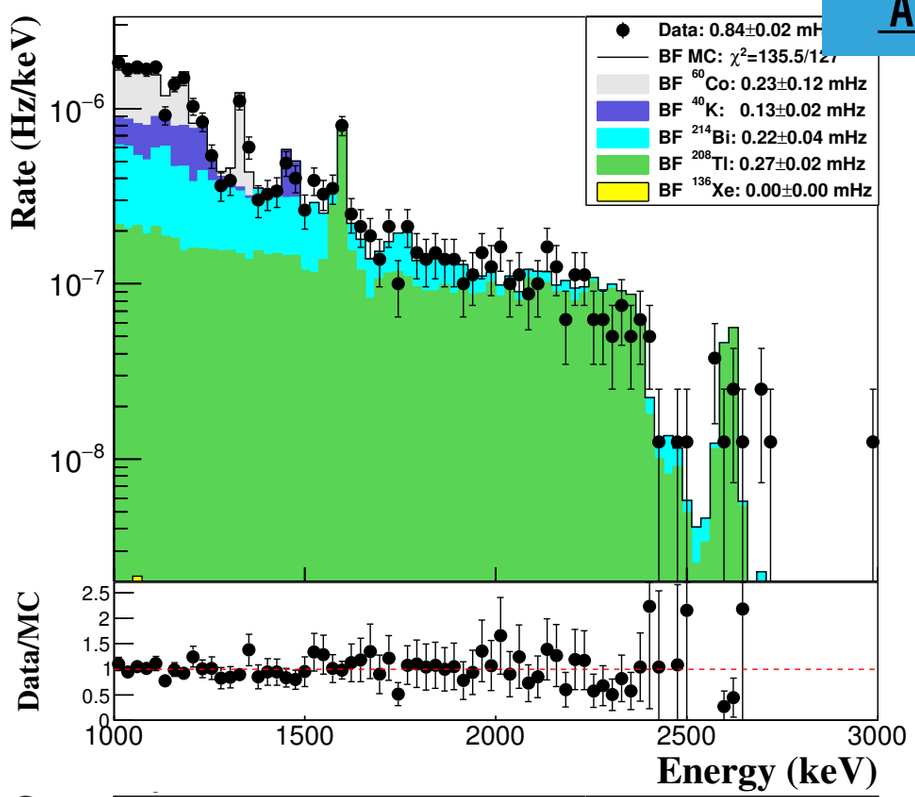
ARXIV:1905.13625

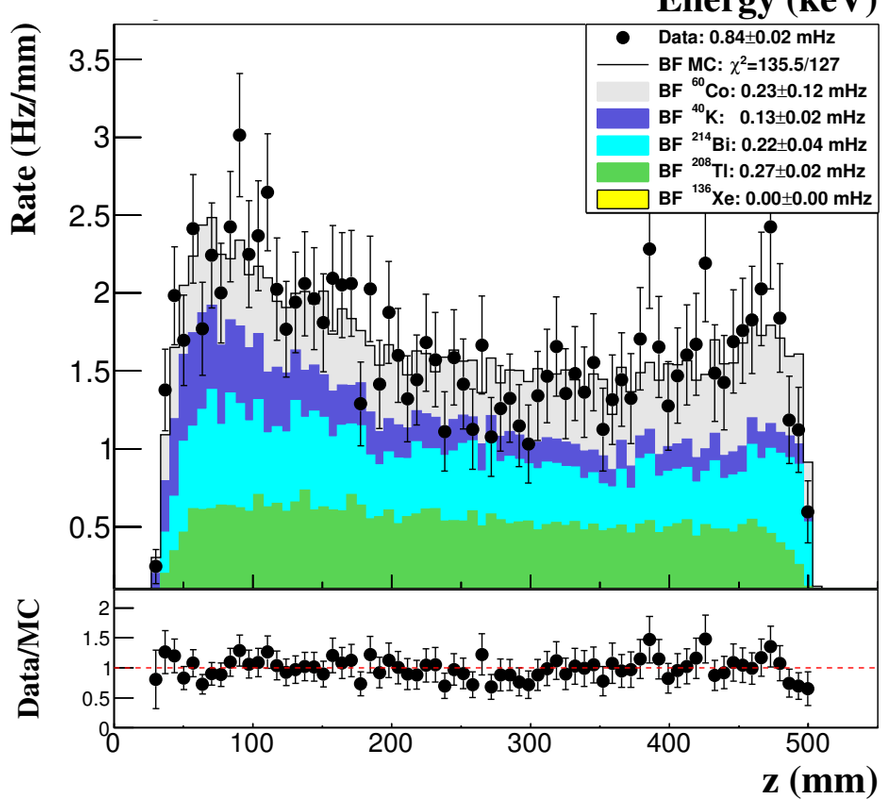
Airborne radon

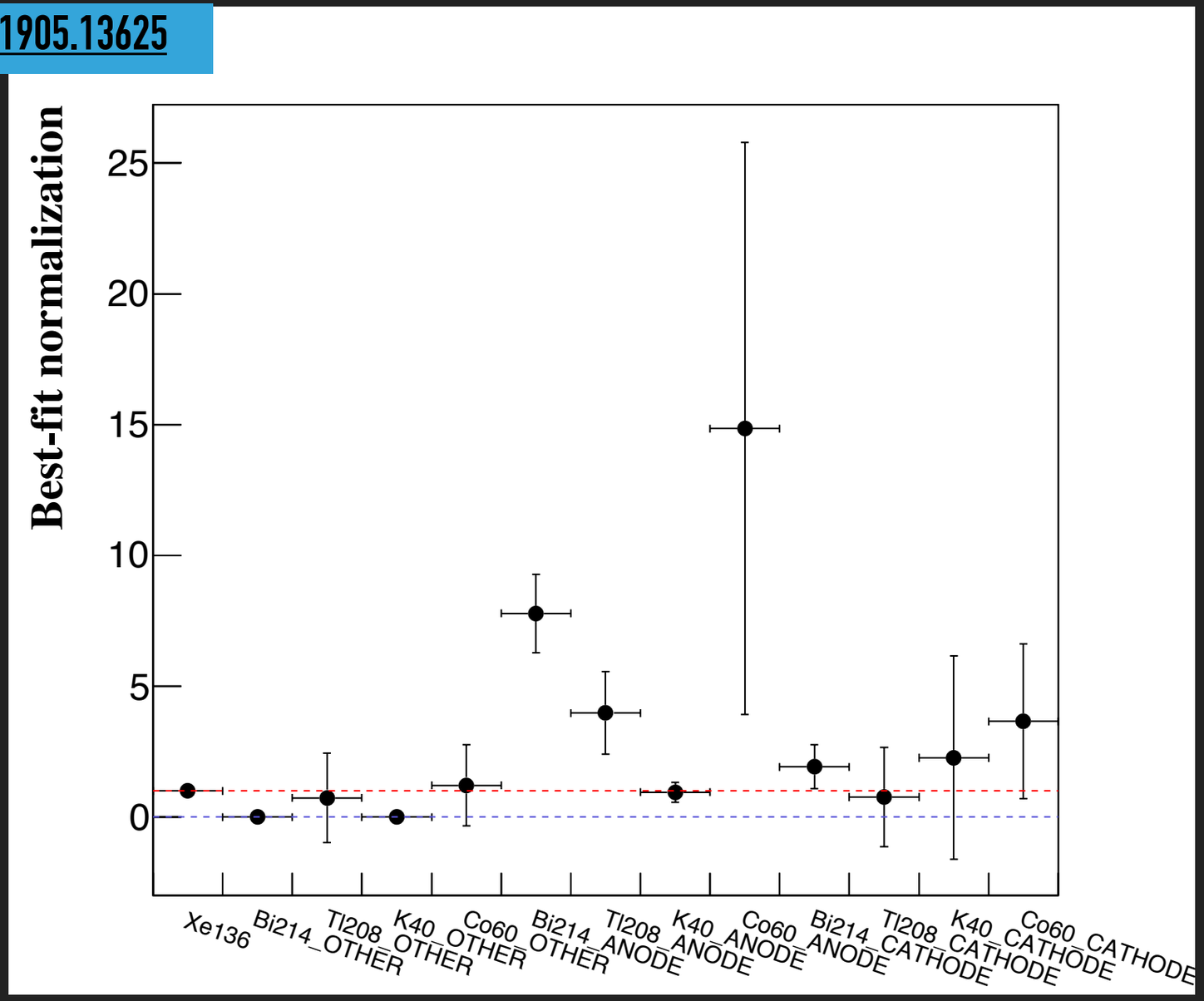
Backgrounds induced by airborne radon are eliminated by providing Rn-free air to the NEXT shielding structure surrounding the vessel

Radiogenic backgrounds in the NEXT double beta decay experiment

ARXIV:1905.13625



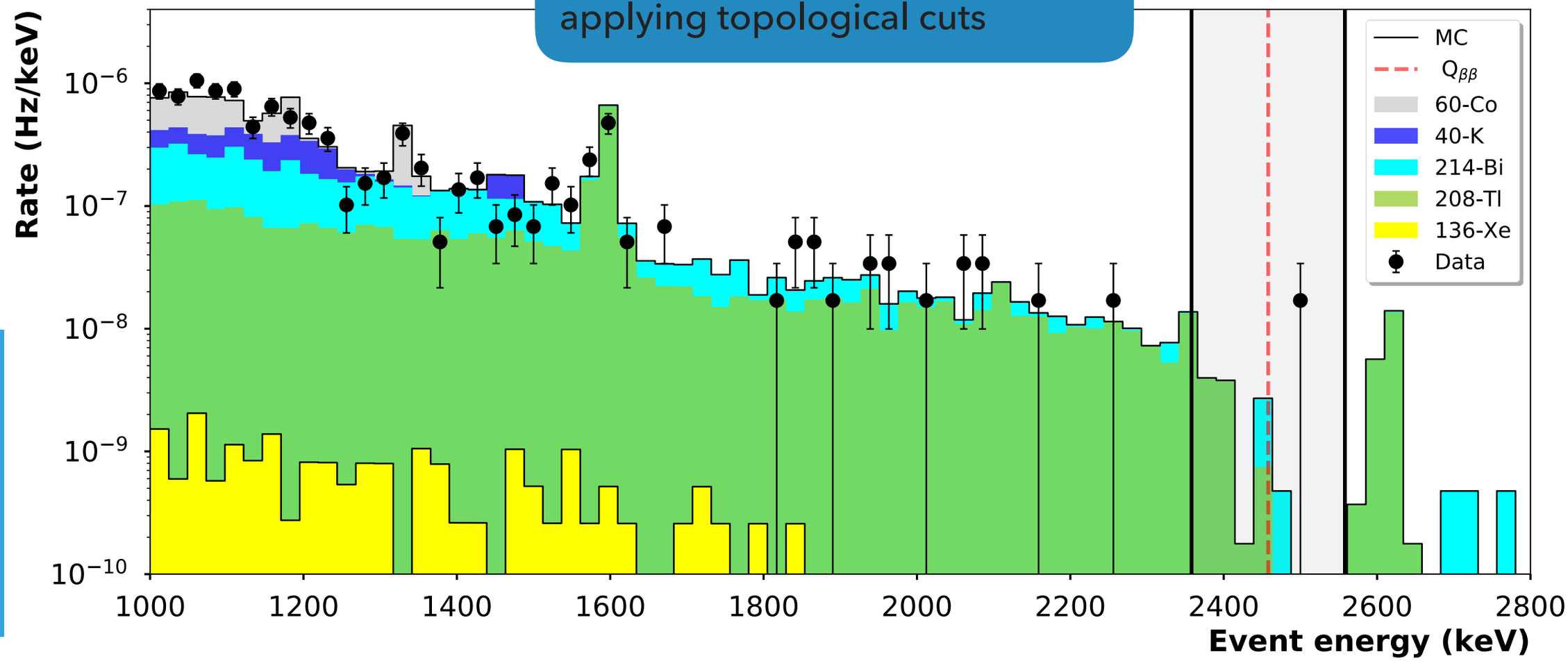




The fit takes into account the 4 isotopes and 3 regions. It describes the data reasonably well in energy and z showing that NEXT can also provide certain sensitivity to background origins!

Radiogenic backgrounds in the NEXT double beta decay experiment

Data and MC spectra after applying topological cuts

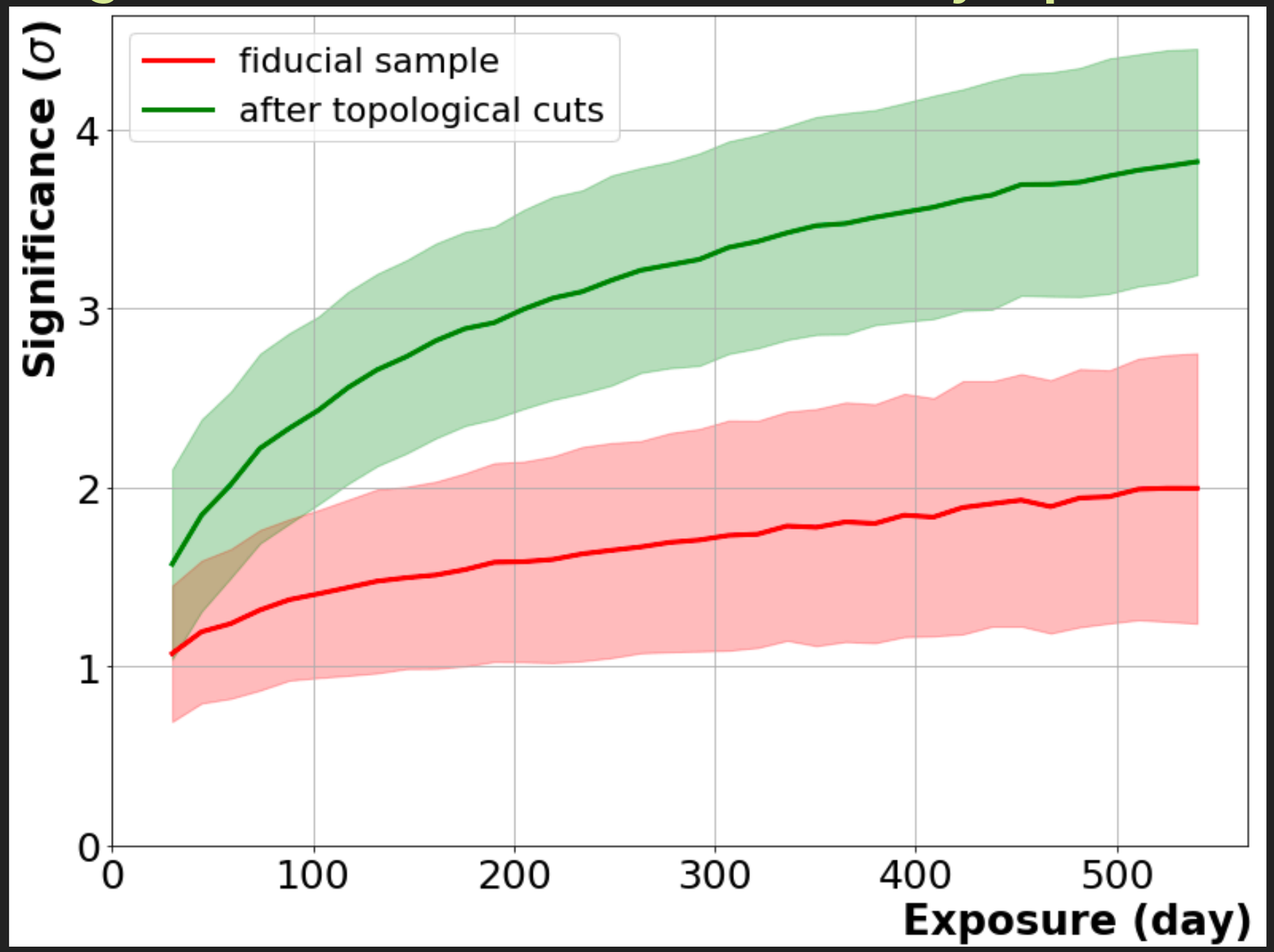


ARXIV:1905.13625

The consistency between the rates in data and MC ensures the validity of the background model also after the topological selection. The overall background rejection factor, with respect to the fiducial sample, is found to be about 3.4 for E > 1000 keV and 16.8±2.2 in a broad 200keV region around $Q_{\beta\beta}$.

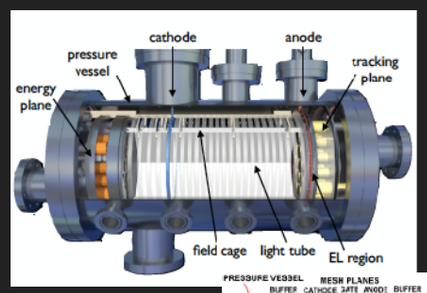
Radiogenic backgrounds in the NEXT double beta decay experiment

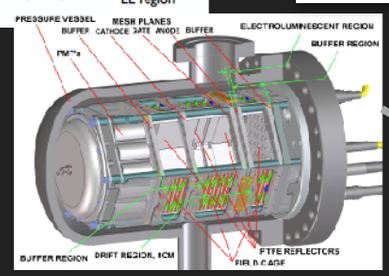
ARXIV:1905.13625



According to these results, a (3.5±0.6)σ measurement of the 2νββ half-life can be achieved in NEXT-White after 1 year with enriched xenon, applying topological cuts. The sensitivity deteriorates significantly if only fiducial cuts are applied.

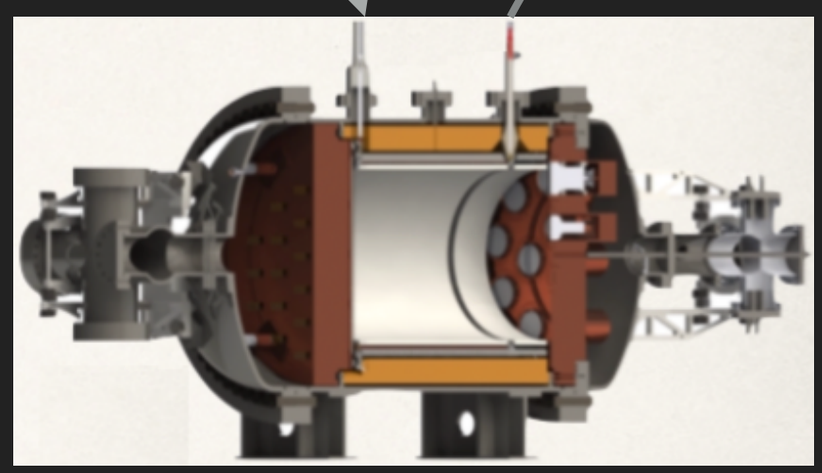
The NEXT program



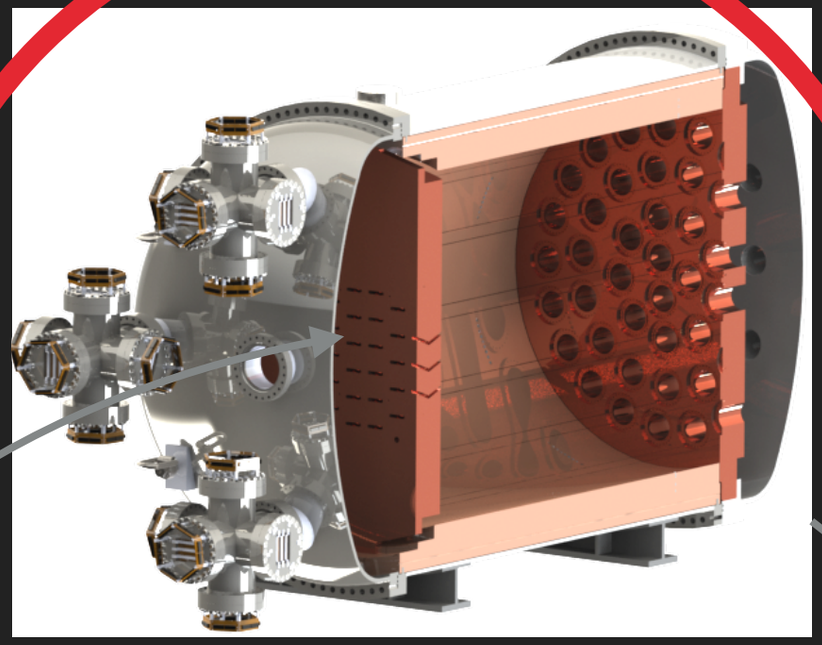


Demonstration of detector concept

Prototypes (~1 kg)
[2009 - 2014]



NEXT-White (~5 kg)
[2015 - 2019]



NEXT-100 (~100 kg)
[2019 - 2020's]

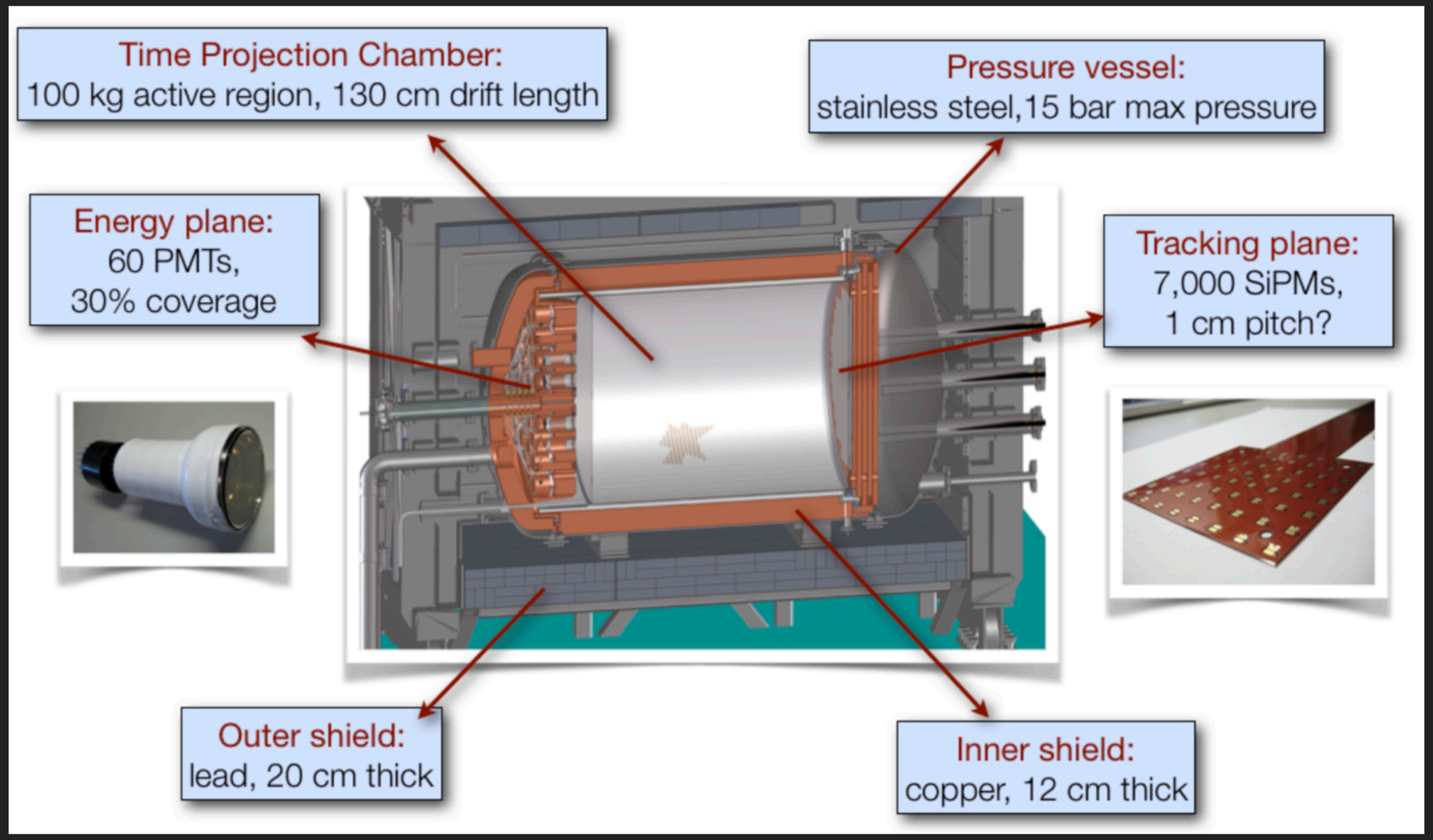
Two neutrino double beta decay searches

Background model assessment

Neutrinoless double beta decay searches

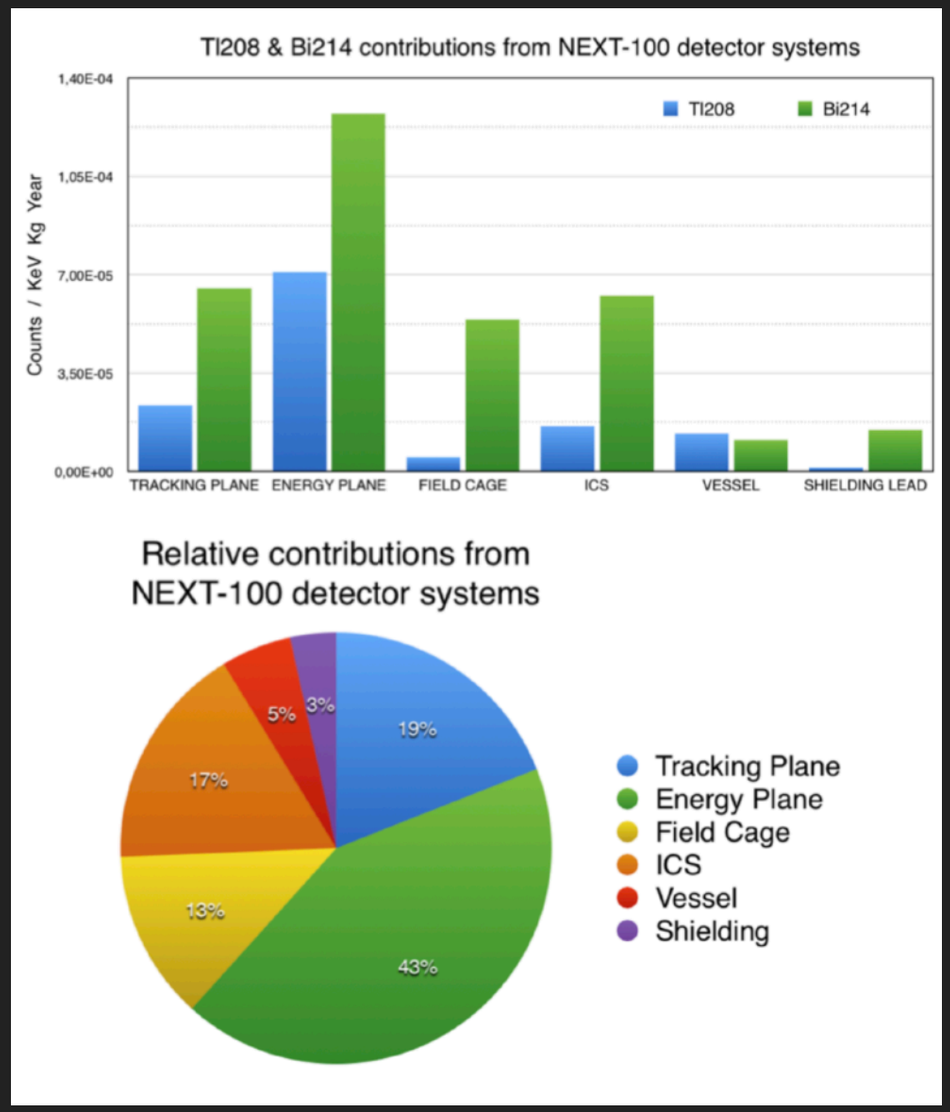
NEXT-tonne (~1000 kg)
[future generation]

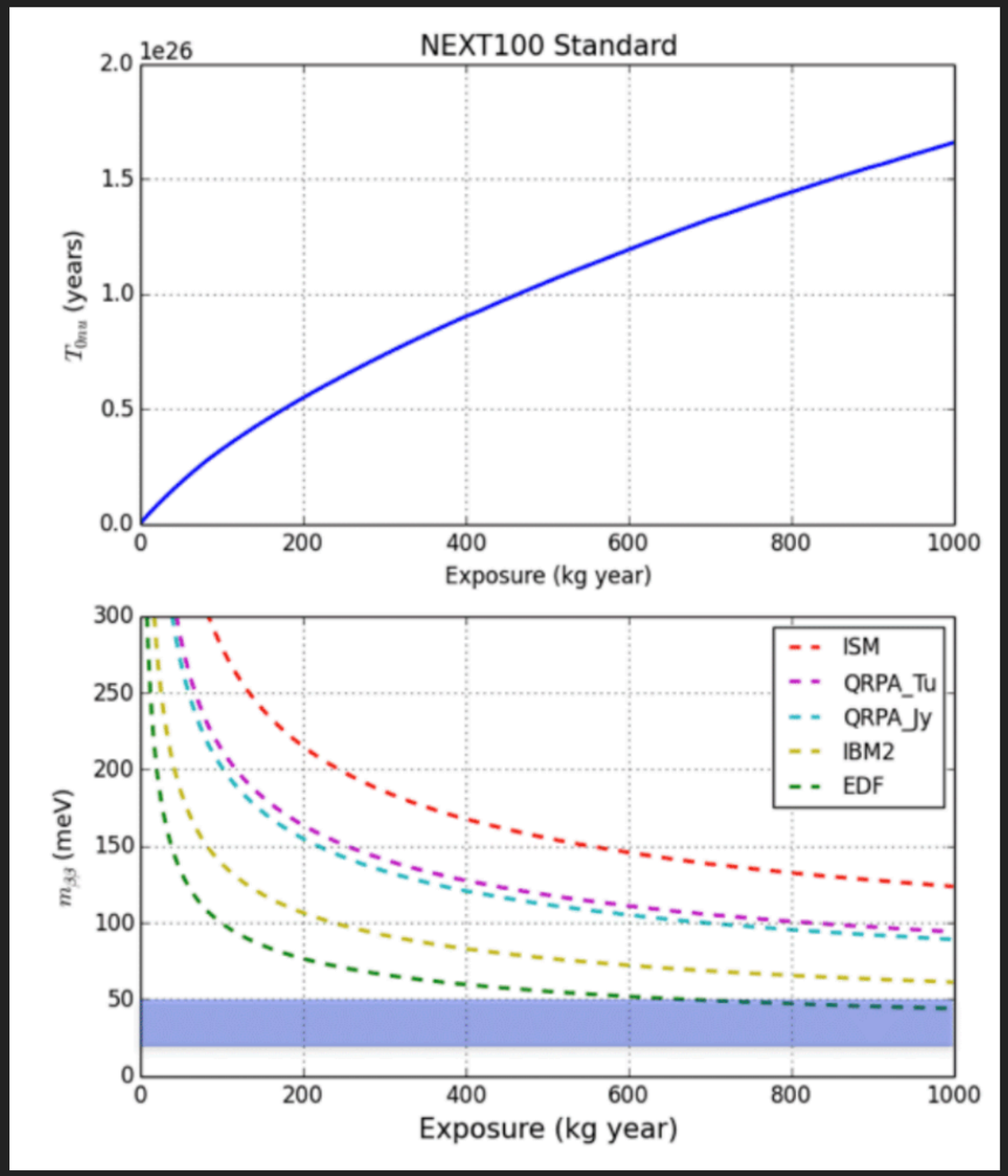
NEXT100



- Scales up NEXT-White by roughly 2:1 in dimensions.
- Currently in construction. Commissioning in 2020.

NEXT100

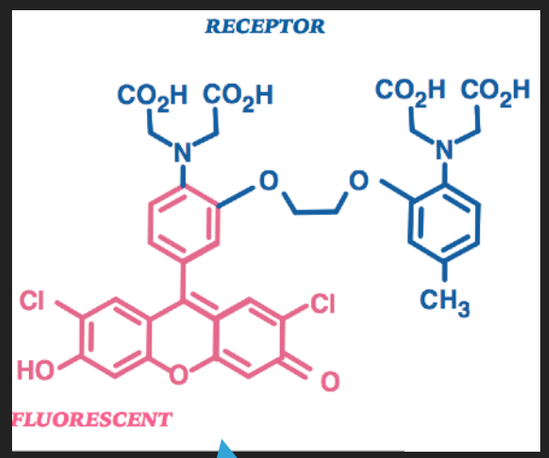


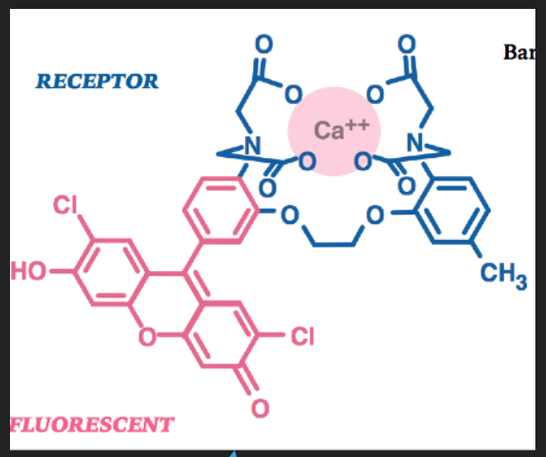


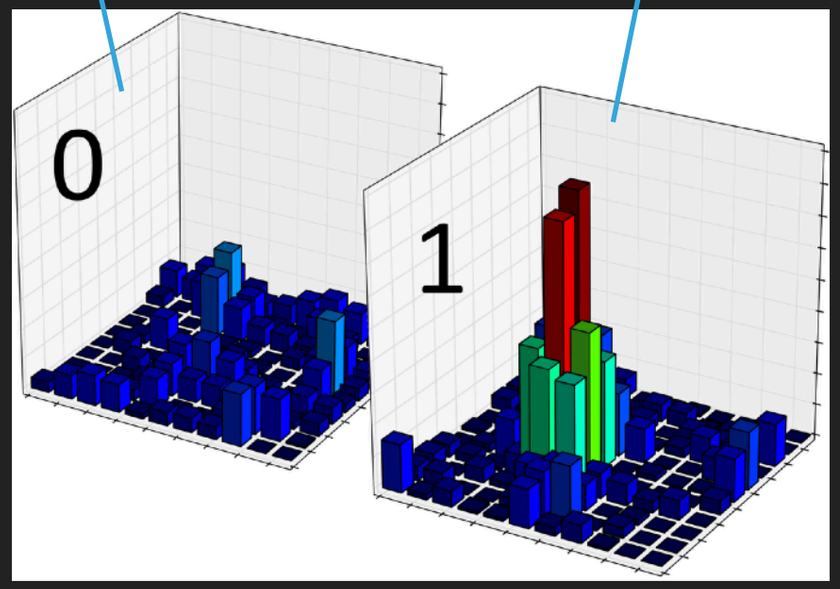
- Expected background rate:
  - 4×10^{-4}counts/(keV·kg·y)
- Expected background:
  - 1 event per year in ROI
- Dominant source: PMTs

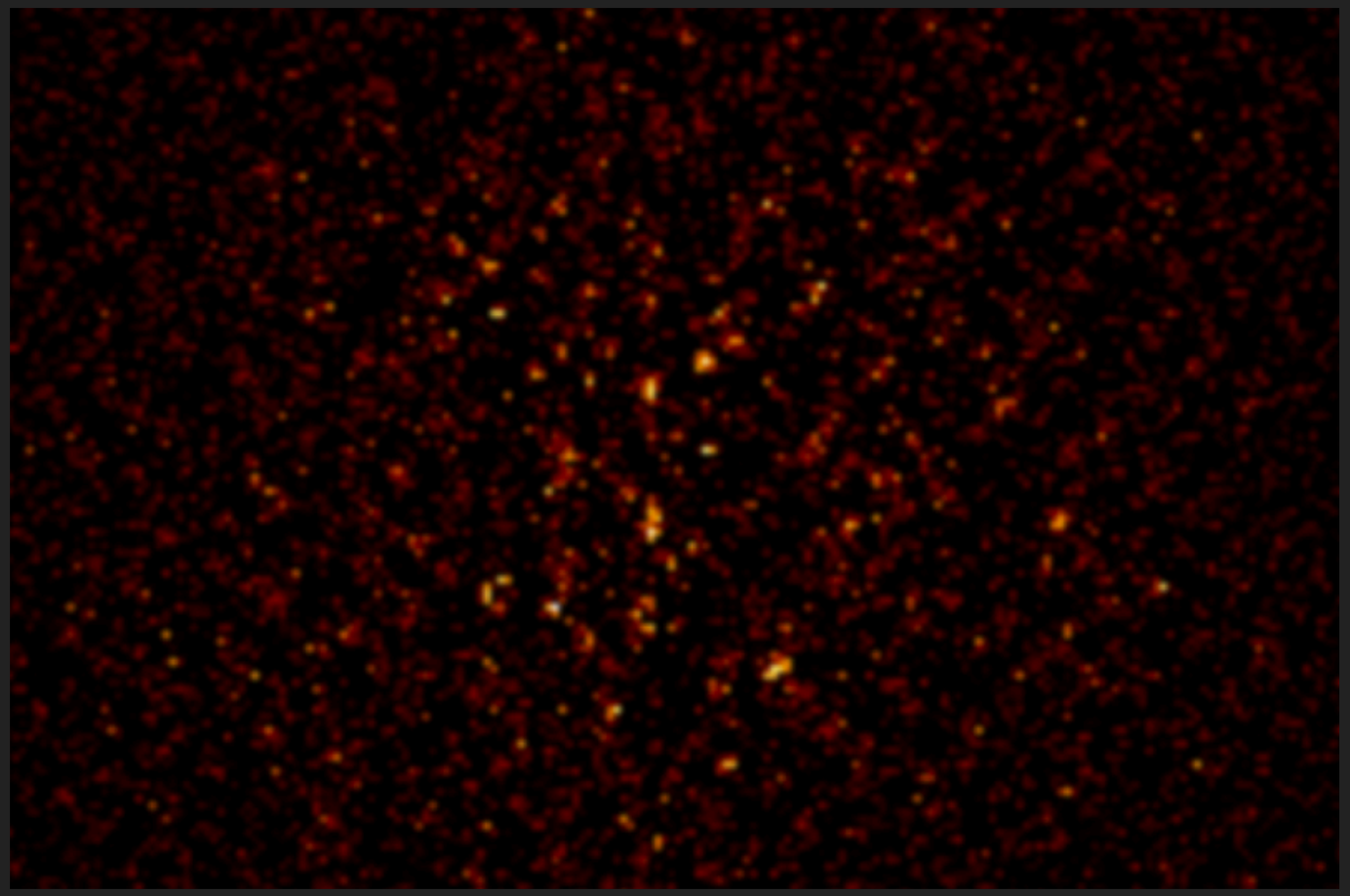
NEXT new ideas: Ba tagging

PHYS. REV. LETT. 120, 132504





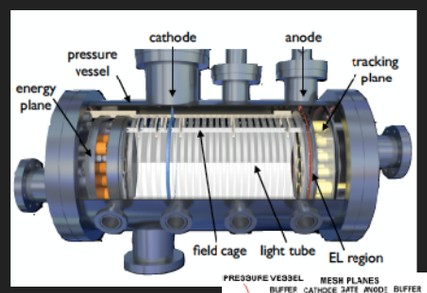


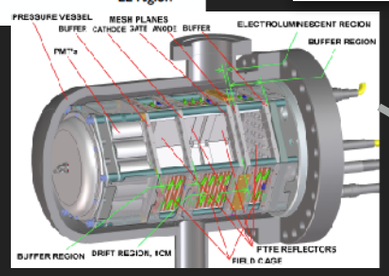


Single ion detectability has been demonstrated!

This can imply a background-free experiment!

THE NEXT PROGRAM





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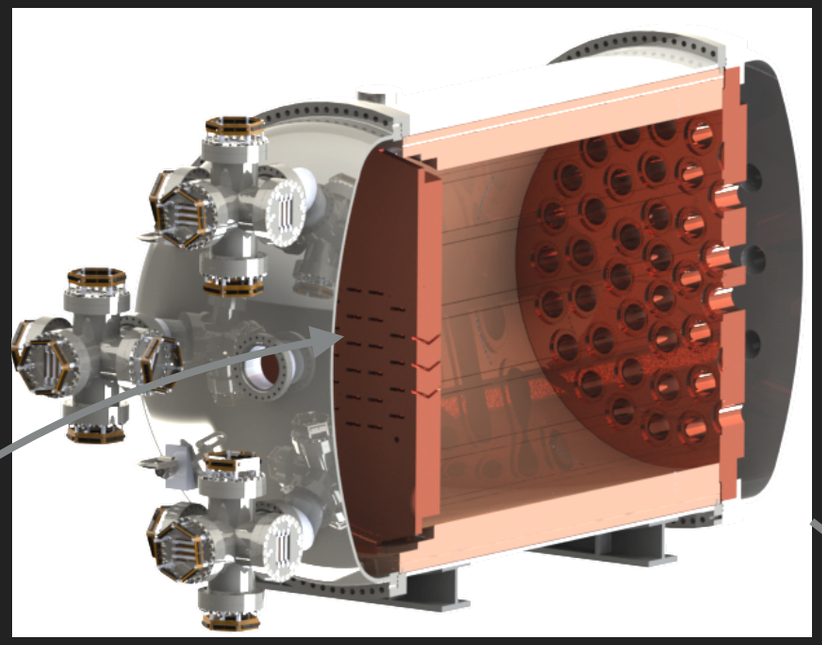

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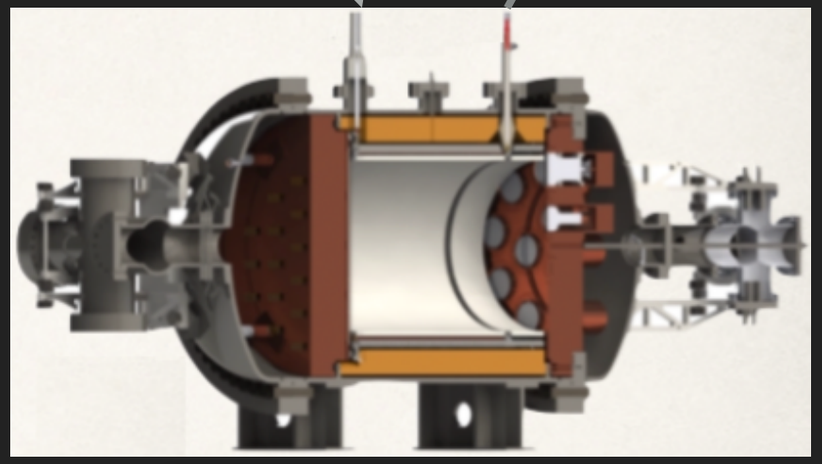

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[2015 - 2019]

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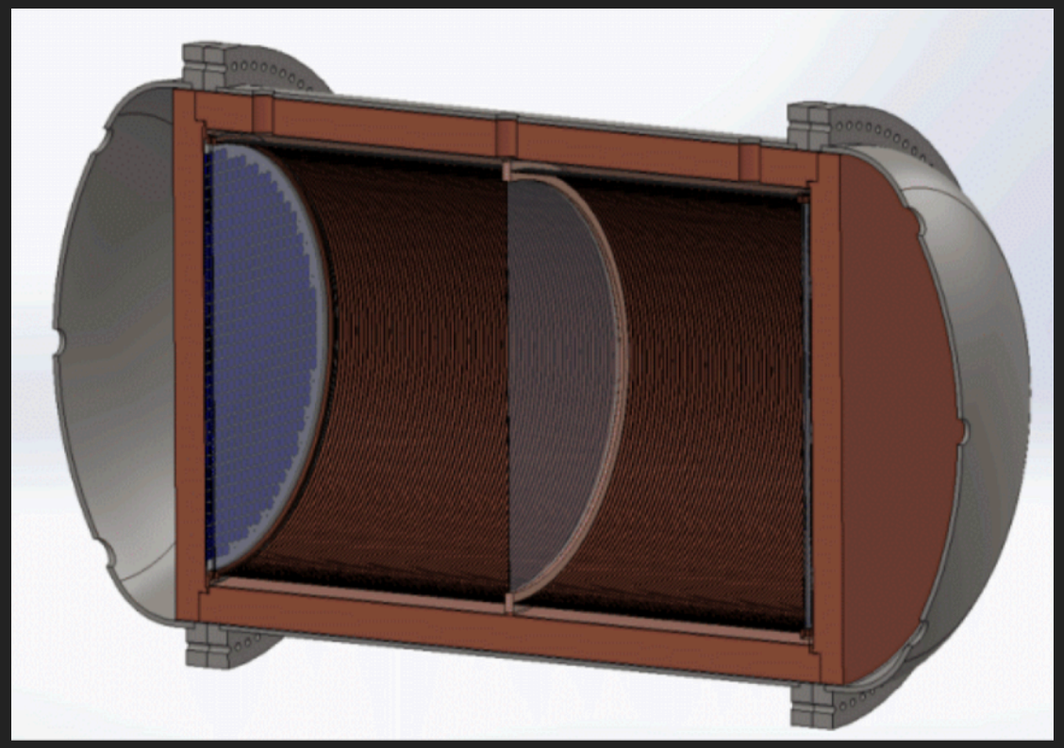
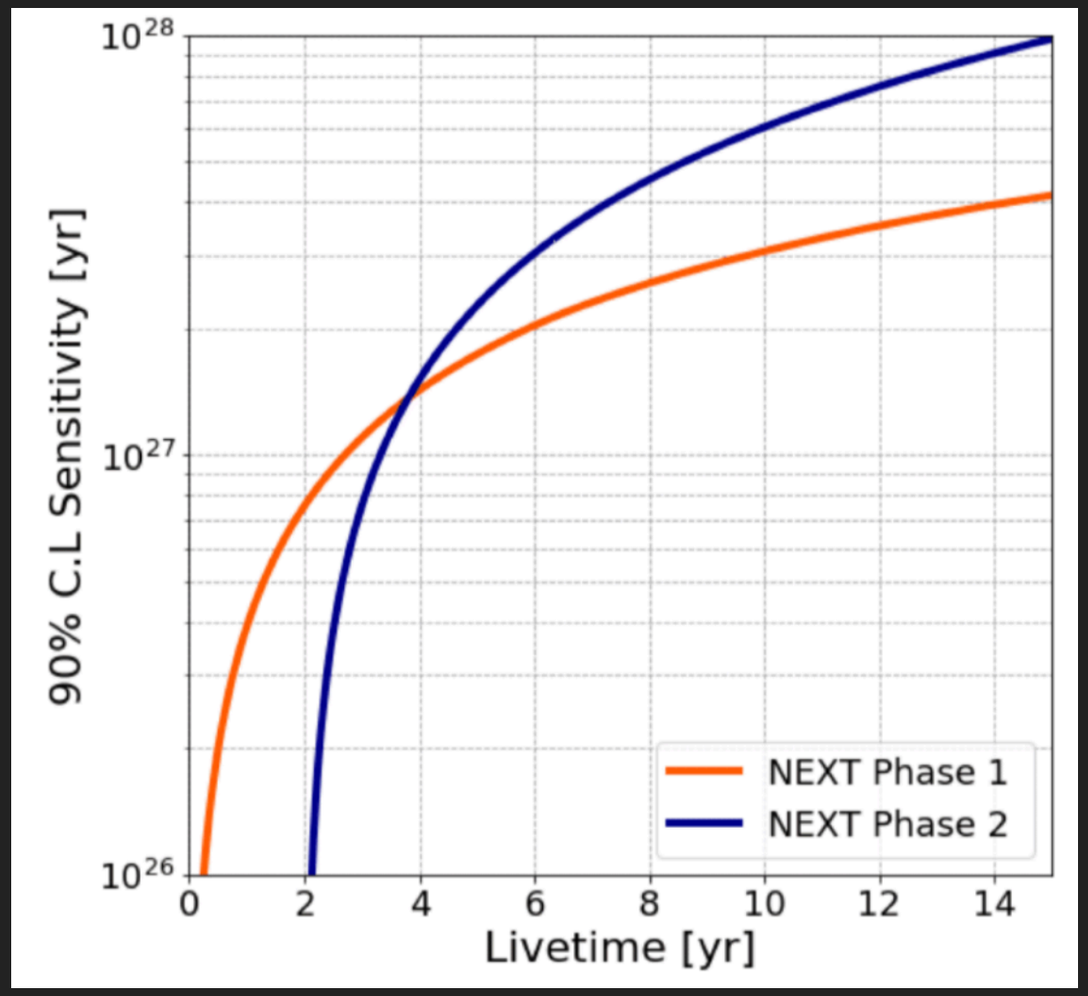
Background model assessment

NEXT-tonne (~1000 kg)
[future generation]

NEXT-ton (~2025)





Two approaches developed in parallel:

- Phase 1, High Definition: incremental approach, using/improving existing technology.
- Phase 2, Barium Tagging: based on disruptive new concept (SMFI Ba^{++} tagging).

Phased approach:

- ~1 ton of 136Xe introduced per phase.
- Ultra pure materials.
- SiPMs as the only sensor

Future plans

- Physics campaign with NEXT-White: ββ2ν measurement (ongoing) and ββ0ν limits.
- NEXT-100 construction planned for 2019. NEXT-100 physics data-taking in 2021.
- NEXT-Ton studies under development.
- Ongoing R&D for NEXT upgrades: barium tagging for HPXe-TPC, gas mixtures (w/ molecular additives, helium), gas cooling, sensor plane upgrades…

Summary

- Late results from NEXT-White demonstrate the performance of the detector technology and sufficiently low background levels for NEXT-White and NEXT-100.
- NEXT is a recent competitor, but a promising one due to its great energy resolution, topological discrimination and potential Ba tagging capabilities.

New data is yet to come and next generation is knocking at the door

Stay turned!

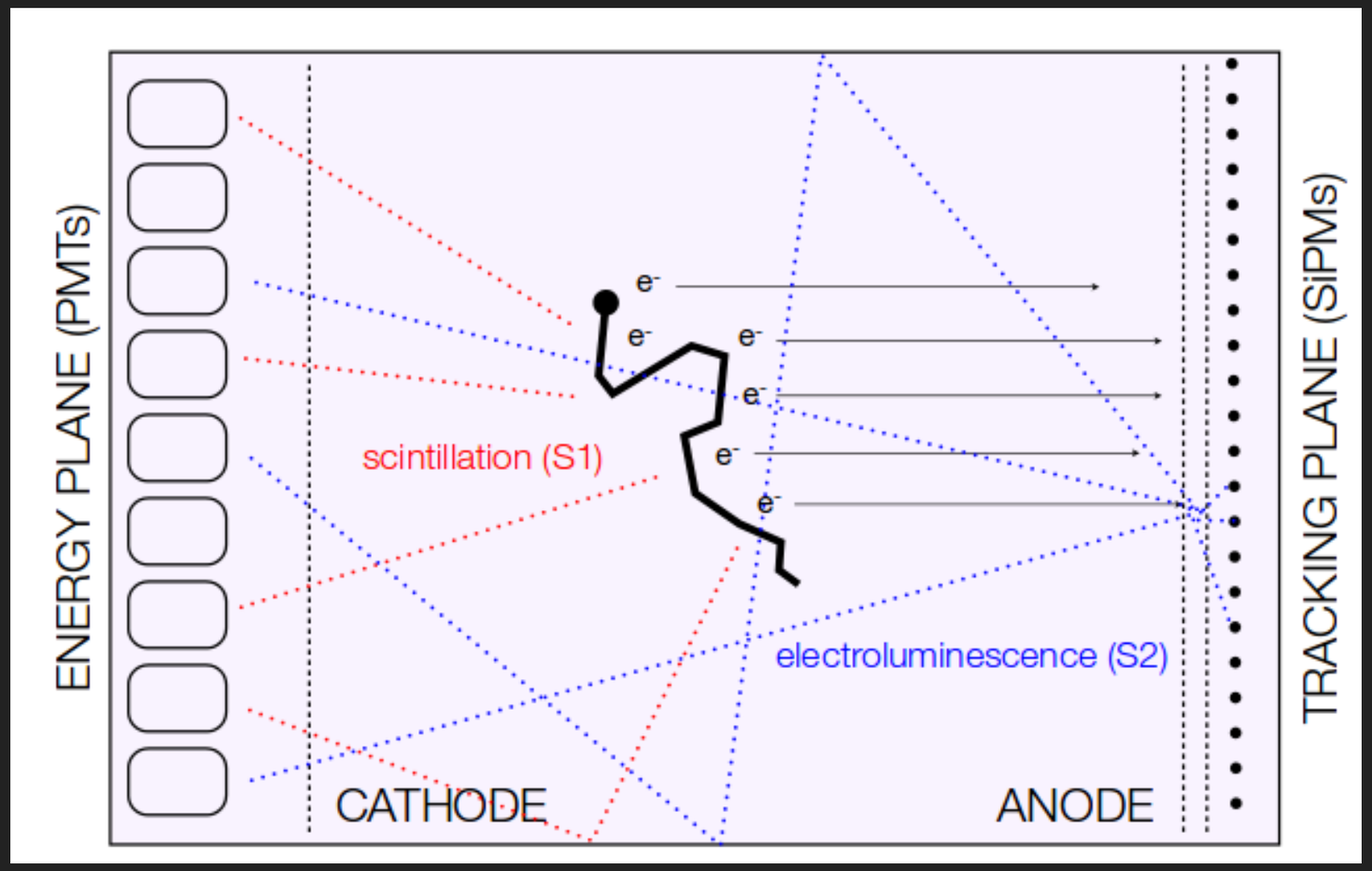
Thanks!

Backup

Other 2018 and 2019 publications

- The Next White (NEW) Detector (arXiv:1804.02409)
- Initial results on energy resolution with the NEXT-White detector (JINST 13 (2018) no.10, P10020)
- Electroluminescence TPCs at the Thermal Diffusion Limit (arXiv:1806.05891)
- High Voltage Insulation and Gas Absorption of Polymers in High Pressure Argon and Xenon Gases (JINST 13 (2018) no.10, P10002)
- Electron drift properties in high pressure gaseous xenon (JINST 13 (2018) no.07, P07013)
- Study of the loss of Xenon Scintillation in Xenon-Trimethylamine Mixtures (Nucl.Instrum.Meth. A905 (2018) 22-28)

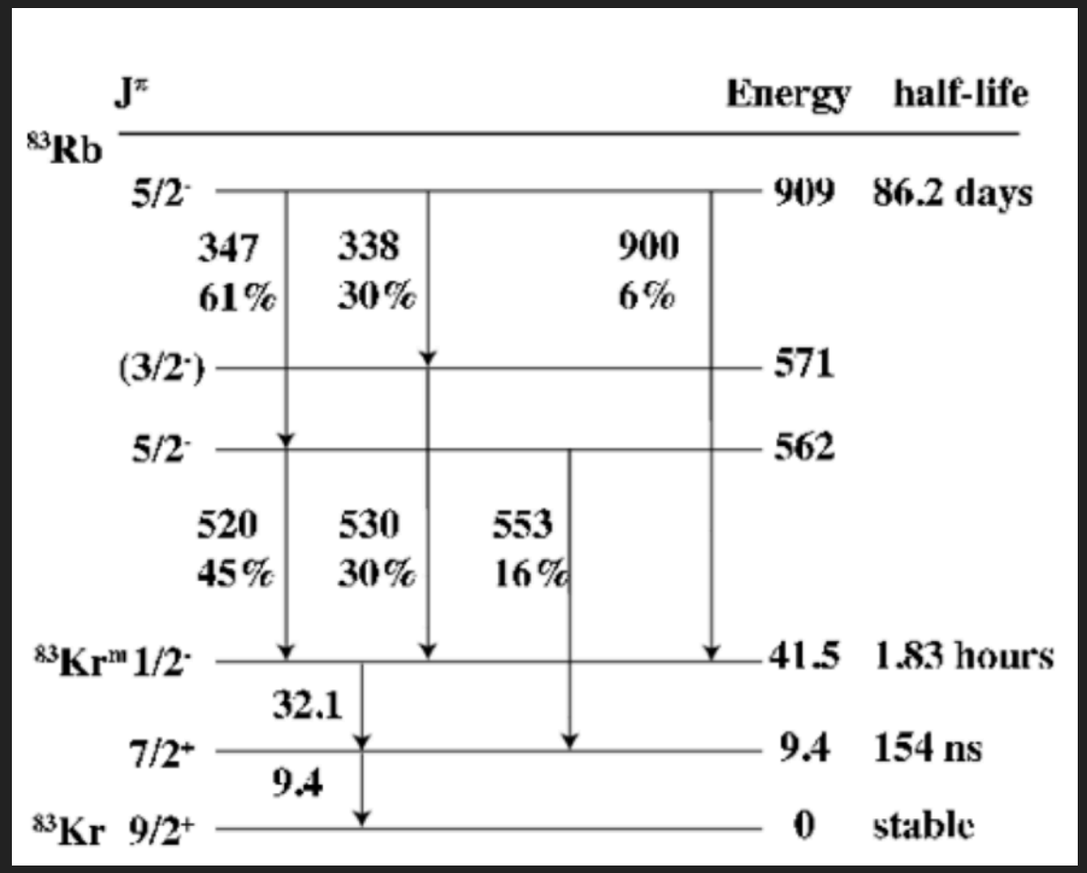
NEXT: event



- Electrons from the decay are emitted (yelling scintillation light, S1).
- These primary electrons loose energy while emitting secondary electrons until they are absorbed.
- Secondary electrons are drift by the electric field until the anode.
- When electrons reach the gate, they are highly accelerated by a stronger electric field and the gas is excited, generating electroluminescence light. Part of the light is recorded by PMTs (energy information) and some other is recorded by SiPM(tracking information).

Low-energy calibration of the NEXT-White detector

- 83Rb decays 75% of the time to a metastable state of 83Kr through internal conversion with a lifetime of 86 days.
- The metastable state decays to ground with a lifetime of 1.83 h emitting two conversion electrons of 32.1 and 9.4 keV.
- These low energy electrons create a very short signal, useful for calibration



Low-energy calibration of the NEXT-White detector

Objective:

- Obtain a fine description of the detector response to account for the signal losses.

- Optimize energy resolution

How:

- $^{83}Kr^{m}$ decays

    - Uniform XYZ distribution

    - Monoenergetic (41.5 keV) pointlike events

When:

- Data taken with the detector from March to November 2017

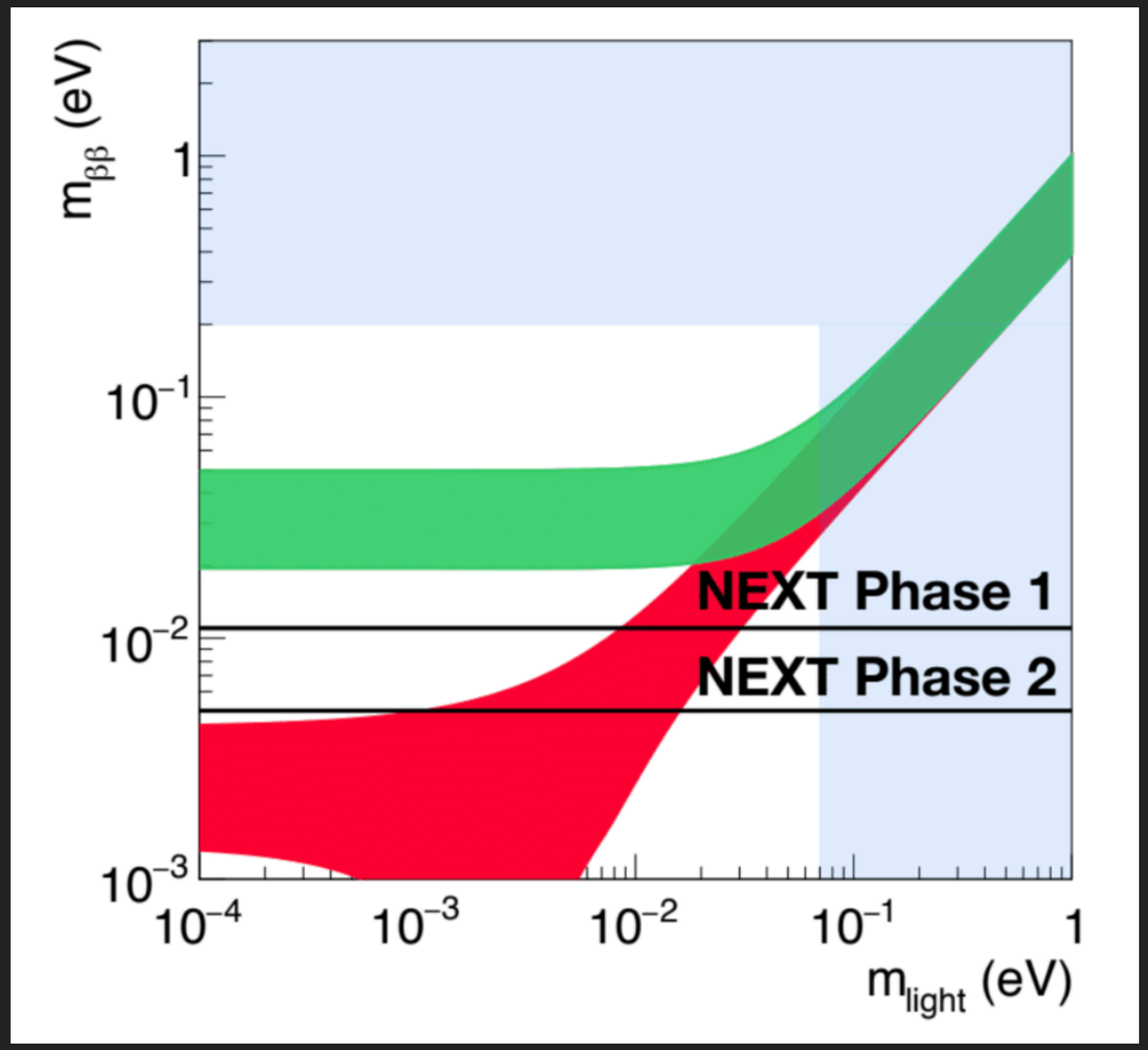
NEXT-ton (~2025)

Phase 1:

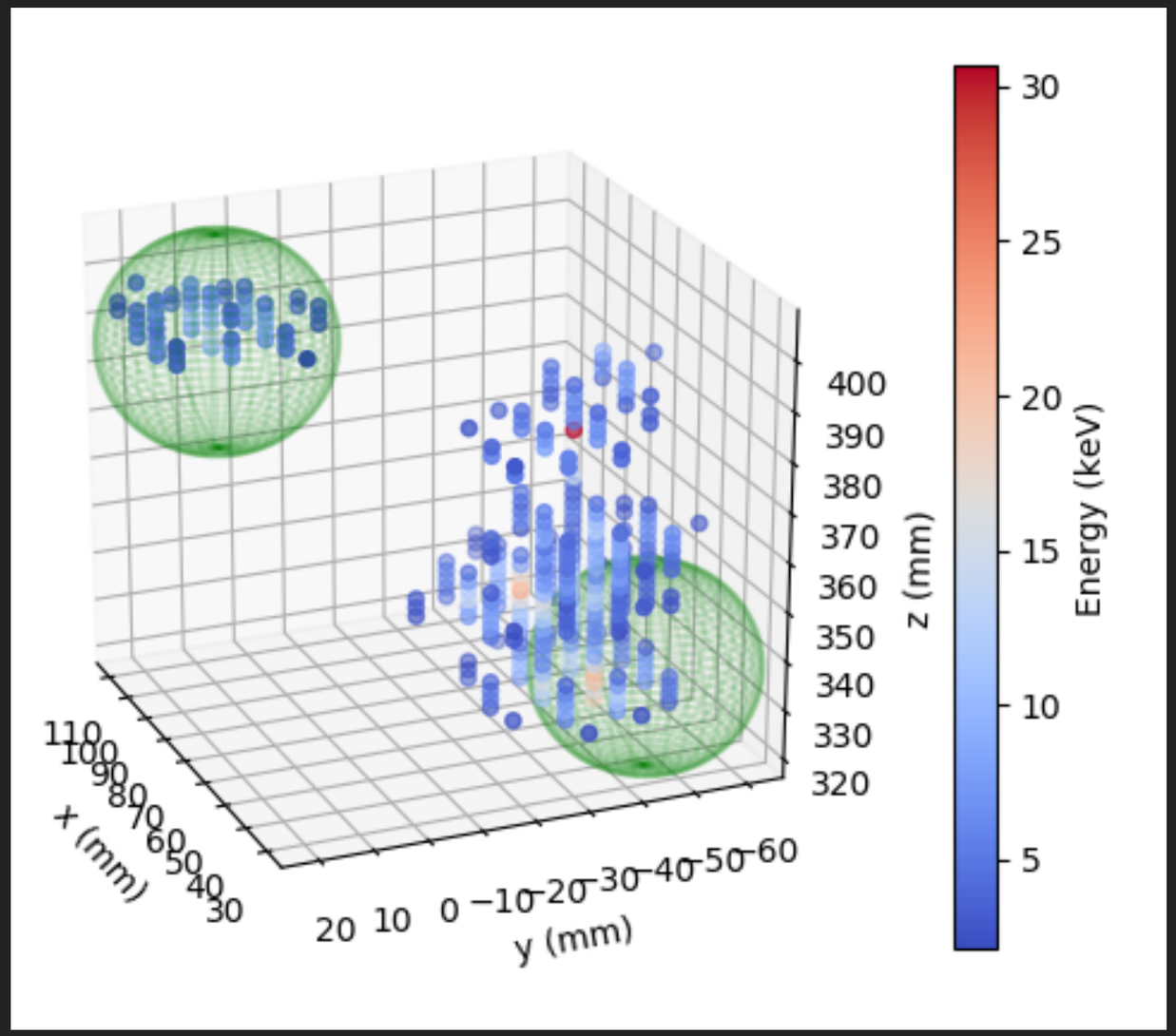
- Improves topological signature, improves energy resolution
- Reduces radioactive budget (no PMTs)
- Energy plane made of large area SiPMs (design similar to that of Dark Side)
- Potential to reduce SiPM dark count by cooling detector
- 2.6 x 10^{-6}cts / keV·kg·year total background rate

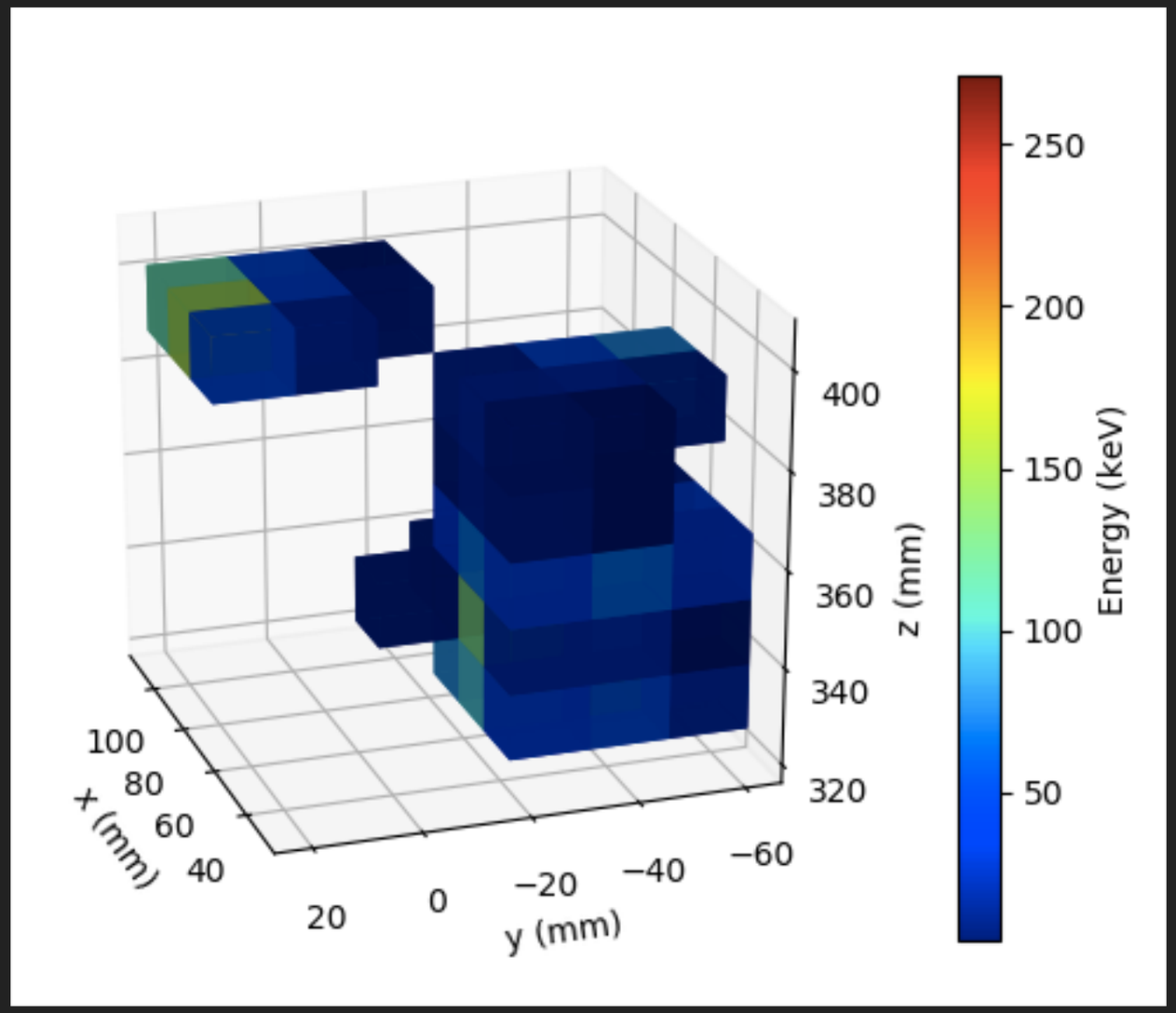
Phase 2:

- Tracking and energy measured in anode
- Cathode implements Barium Tagging System
- Virtually background free



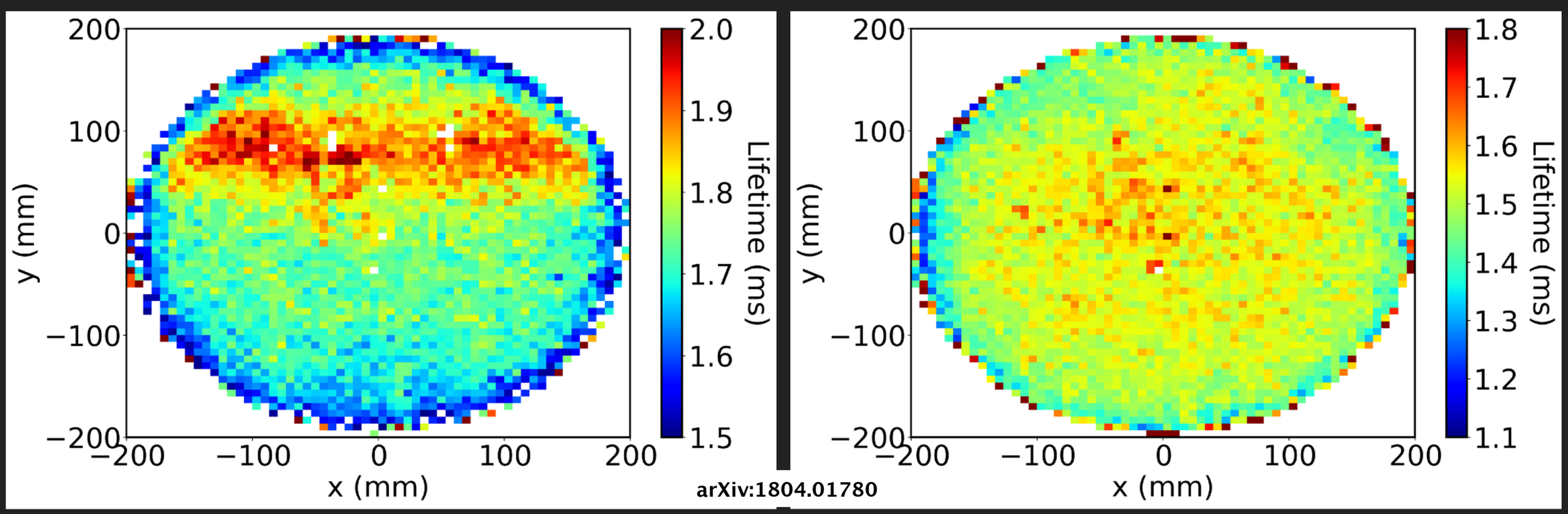
Event in the energy window





Electron lifetime

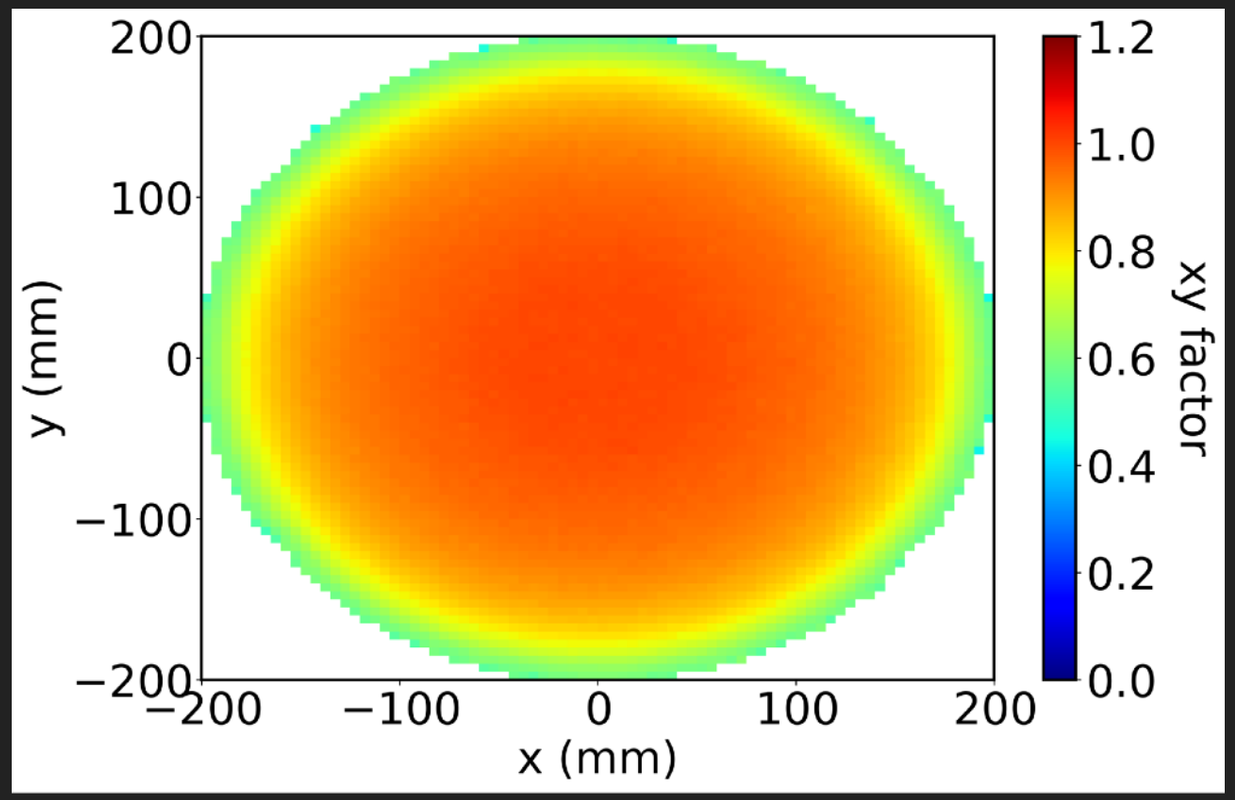
Life isn't that easy. We found that the electron lifetime depends on the transverse position of the event. And it changes!

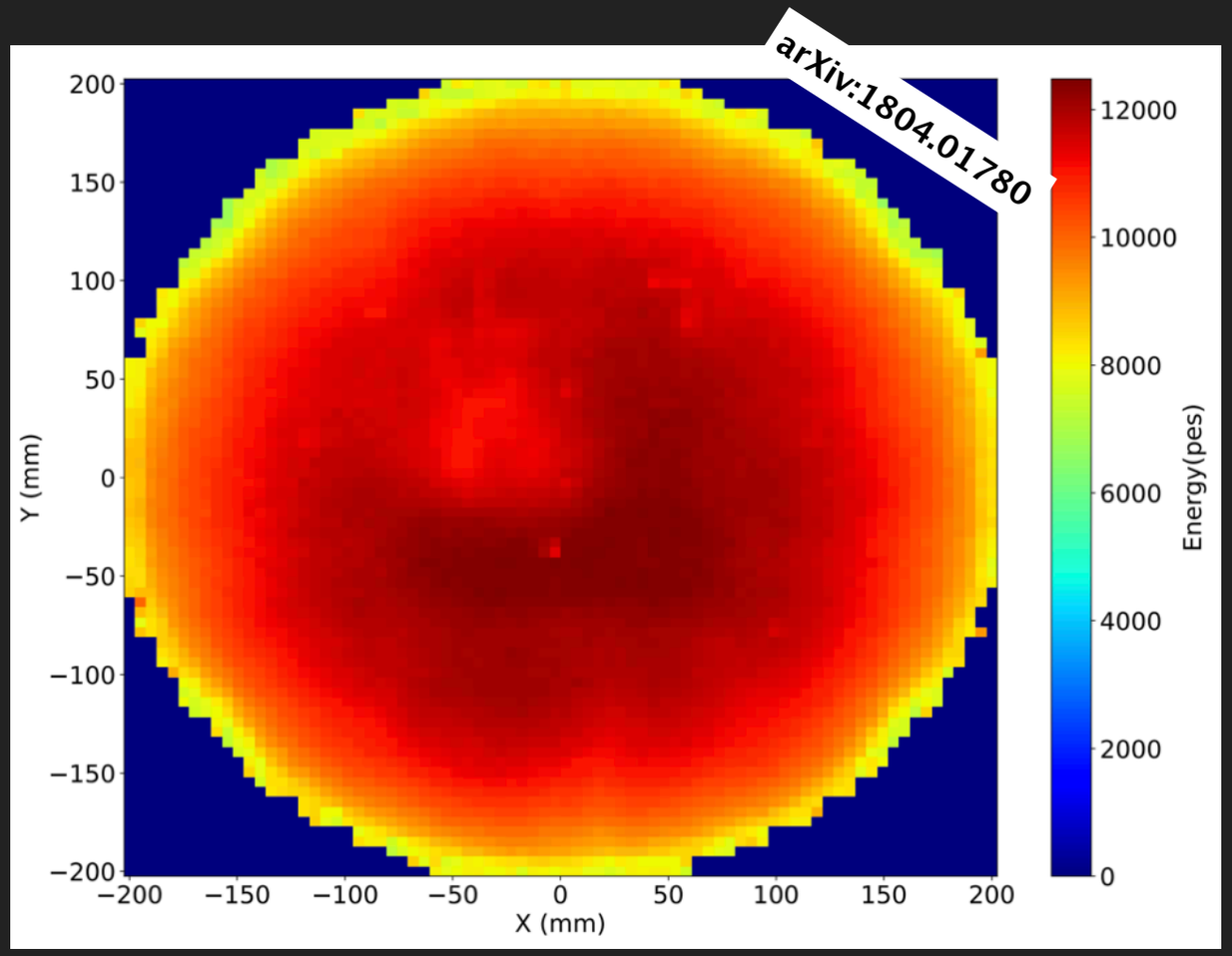


arXiv:1804.01780

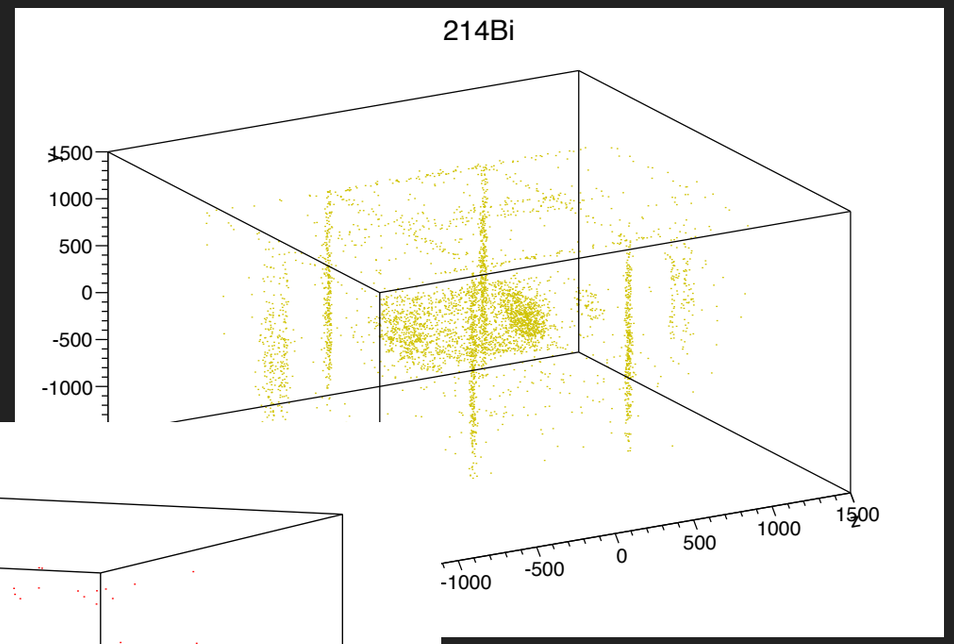
Light collection efficiency

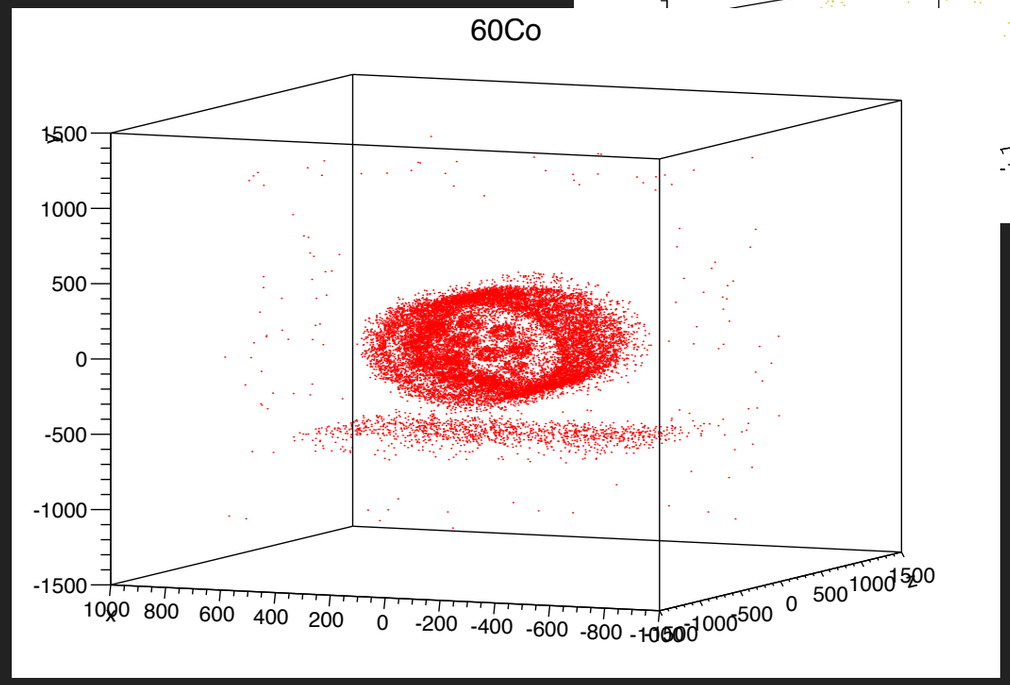
The amount of light detected depends on the transverse position of the event.
The simulations predict a smooth response with a steep drop at large R.



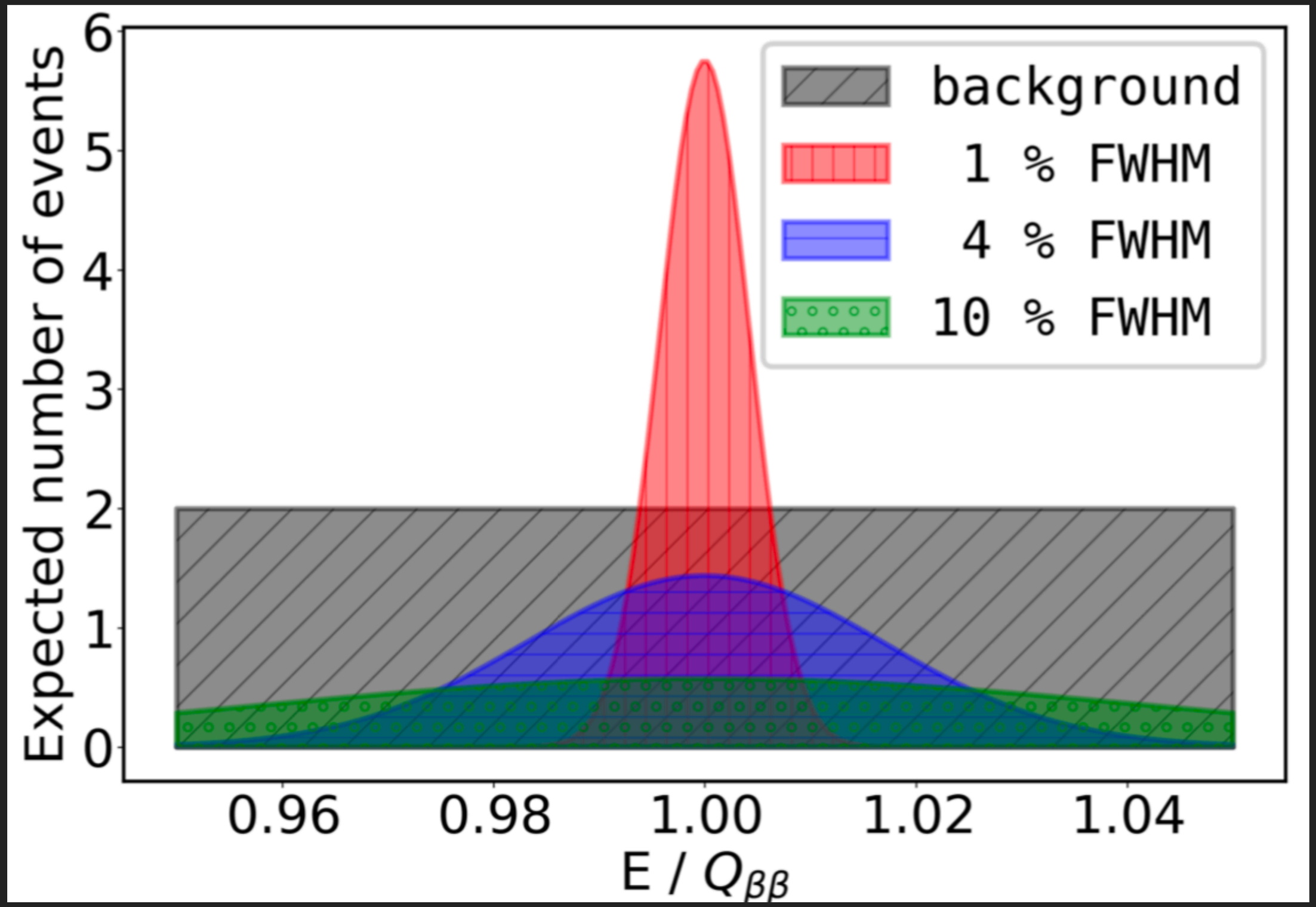


NEXT Background





	40K			60CO			208Tl			214Bi		
Part	Eff	Tot act (mB)	Evs 100 days	Eff	Tot act (mB)	Evs 100 days	Eff	Tot act (mB)	Evs 100 days	Eff	Tot act	Evs 100 days
ANODE_QUARTZ	4,26E-3	1,03E+0	38	3,935E-2	0	0	4,41E-2	5,41E-2	21	3,19E-2	3,34E-1	92
BUFFER_TUBE	1,04E-3	1,38E+1	124	1,782E-2	2,32E-1	36	1,30E-2	2,52E-2	3	9,94E-3	2,05E-1	18
CARRIER_PLATE	1,68E-4	1,33E+1	19	2,663E-3	8,82E+0	203	2,49E-3	3,23E-1	7	1,41E-3	2,58E+0	31
DB_PLUG	4,48E-6	9,52E+1	4	6,060E-5	8,40E-1	0	1,08E-4	5,60E+1	52	3,63E-5	1,79E+2	56
DICE_BOARD	2,20E-3	4,07E+2	7740	3,946E-2	2,27E-1	77	3,34E-2	3,30E-1	95	2,30E-2	2,12E+0	421
DRIFT_TUBE	2,36E-3	5,82E+1	1186	4,147E-2	9,66E-1	346	3,07E-2	1,72E-1	46	2,36E-2	1,05E+0	214
ENCLOSURE_BODY	9,84E-5	3,05E+0	3	1,526E-3	2,02E+0	27	1,42E-3	7,38E-2	1	8,23E-4	5,90E-1	4
ENCLOSURE_WINDOW	9,10E-4	3,40E-1	3	1,616E-2	0	0	1,04E-2	7,13E-2	6	9,06E-3	5,02E-1	39
ICS	5,24E-4	3,81E+1	173	8,496E-3	2,52E+1	1850	7,78E-4	9,23E-1	6	4,54E-3	7,38E+0	289
OPTICAL_PAD	8,71E-4	4,44E+0	33	1,554E-2	1,16E-1	16	1,05E-2	1,67E-1	15	8,35E-3	5,65E-1	41
PEDESTAL	7,26E-6	5,76E+1	4	9,619E-5	1,58E+3	1310	1,77E-4	5,40E+1	83	6,01E-5	1,66E+2	86
PMT_BASE	2,02E-4	2,55E+1	44	3,361E-3	2,03E-1	6	2,67E-3	1,90E+0	44	1,82E-3	7,03E+0	110
PMT_BODY	4,07E-4	1,45E+2	510	6,920E-3	4,56E+1	2730	5,22E-3	2,28E+0	103	3,71E-3	4,20E+0	135
SHIELDING_LEAD	9,93E-7	1,87E+3	16	1,182E-5	1,25E+3	128	2,82E-5	5,30E+2	129	7,97E-6	5,46E+3	376
SHIELDING_STRUCT	2,87E-7	2,41E+5	598	3,445E-6	8,19E+2	24	8,42E-6	6,77E+3	492	2,33E-6	6,83E+4	1376
SUPPORT_PLATE	3,16E-4	1,88E+1	51	5,185E-3	1,24E+1	555	4,84E-3	4,55E-1	19	2,74E-3	3,64E+0	86
VESSEL	3,10E-5	1,03E+2	28	4,620E-4	2,84E+3	11300	7,07E-4	9,68E+1	591	2,63E-4	2,97E+2	675


background
1 % FWHM
4 % FWHM
10 % FWHM
Expected number of events
0
1
2
3
4
5
6
0.96
0.98
1.00
1.02
1.04
E / $Q_{\beta\beta}$