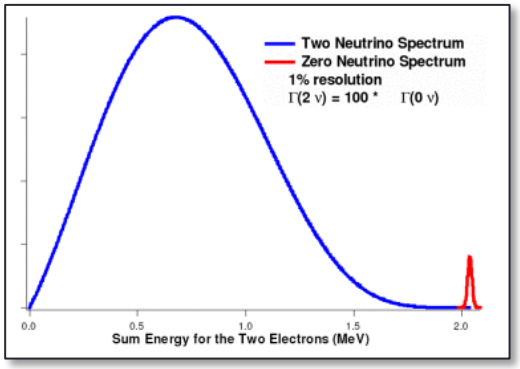
THE NEXT EXPERIMENT

Ben Jones

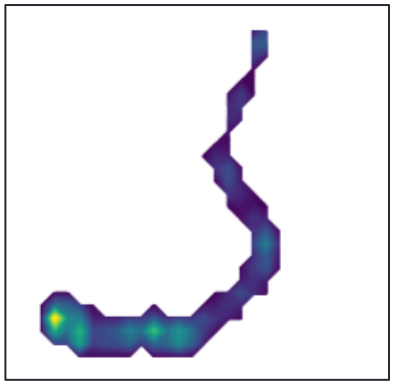
University of Texas at Arlington

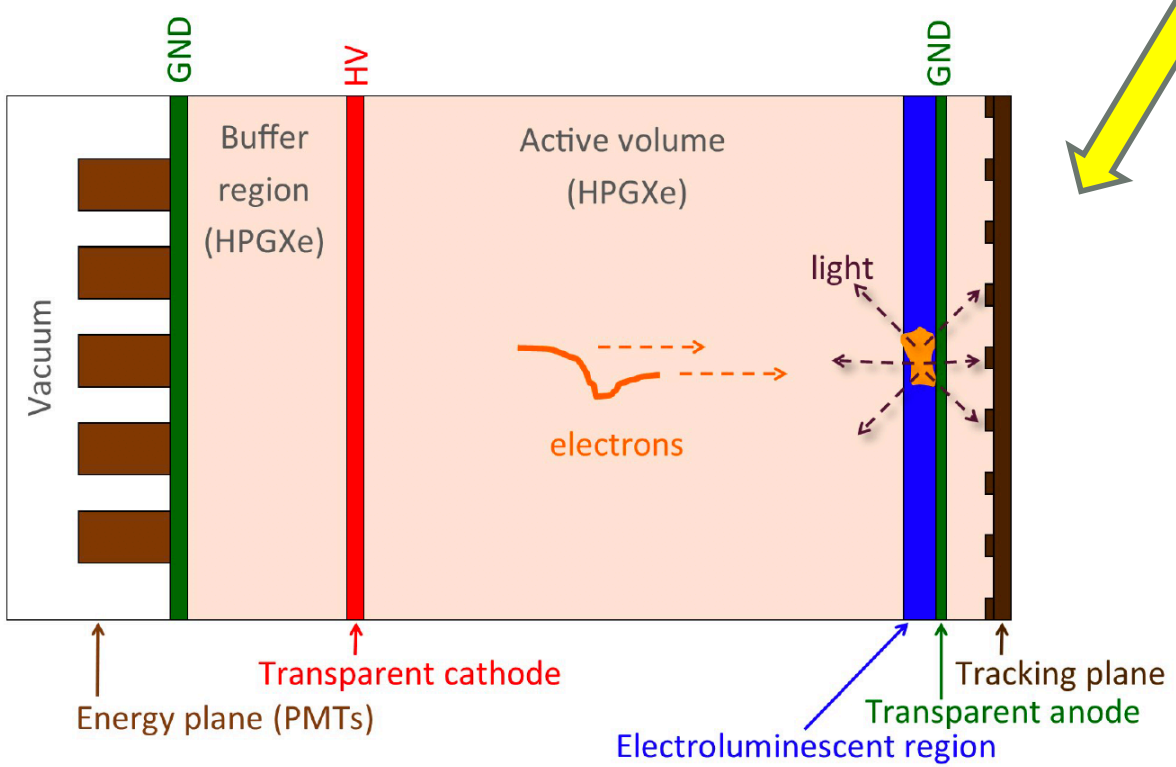
UNIVERSITY OF TEXAS ARLINGTON

Measure energy this end



Measure topology this end





The NEXT Program

- **Sequence of HPGXe TPCs, focused on achieving big, very low background xenon 0νββ detector**

→ NEXT-DBDM

(Berkeley, US)

→ NEXT-DEMO

(Valencia, Spain)

→ **NEXT-White**

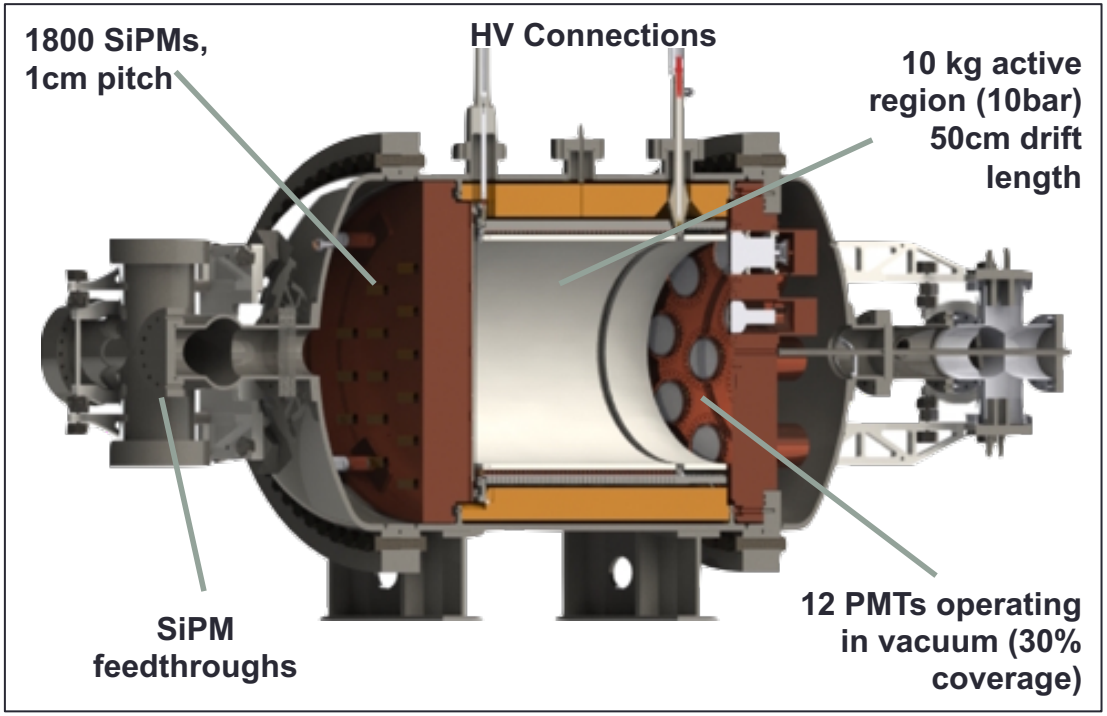
(Canfranc, Spain)

→ NEXT-100

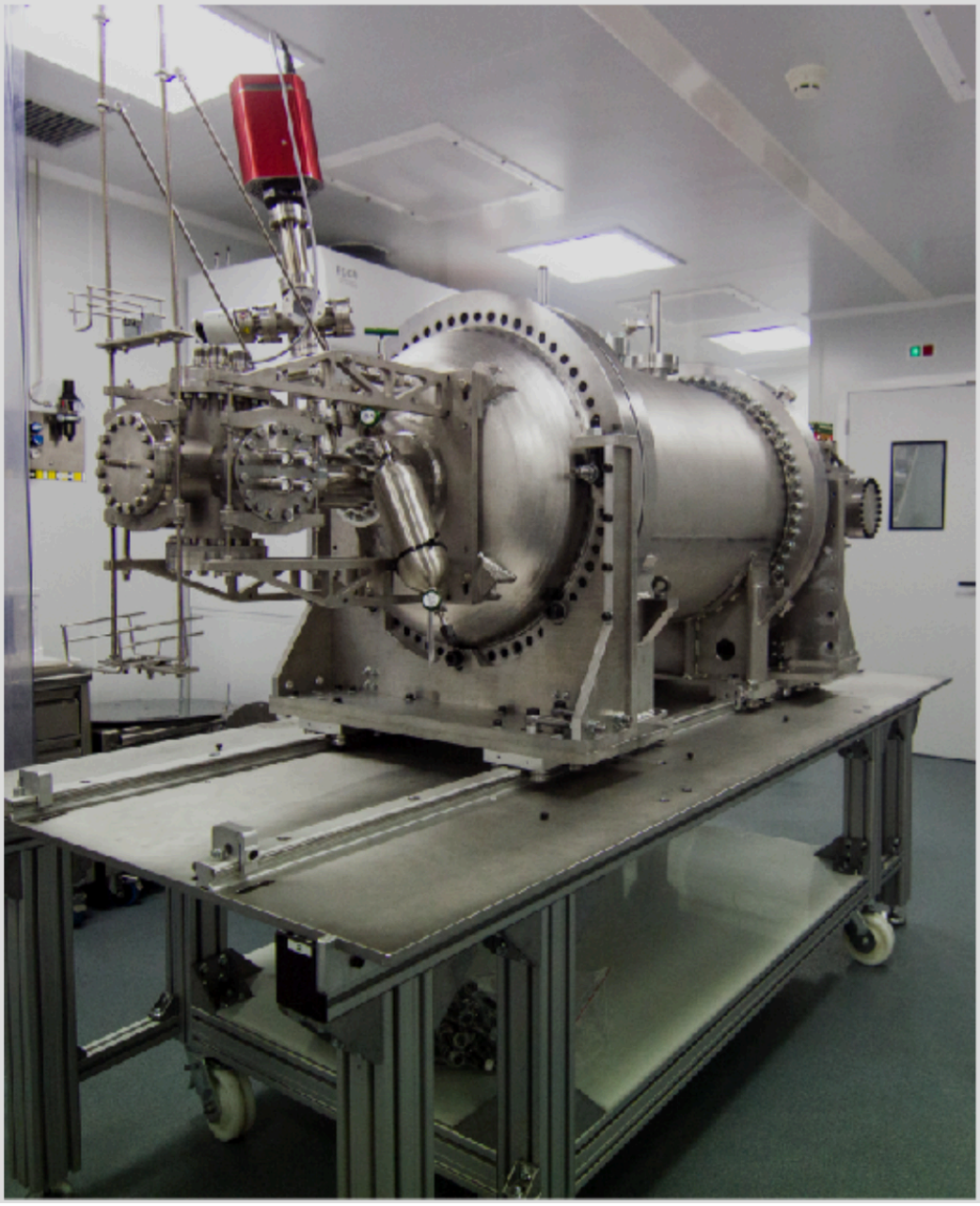
(Canfranc, Spain)

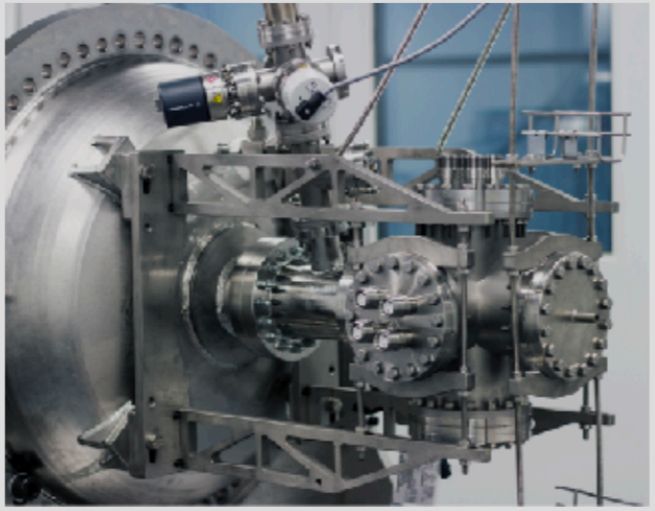
→ NEXT-HD

→ *NEXT-BOLD*



NEXT-White operating now
Full underground technology demonstrator @10kg scale





Demonstrating HPGXe

- 1) Energy resolution
- 2) Topology
- 3) Low background

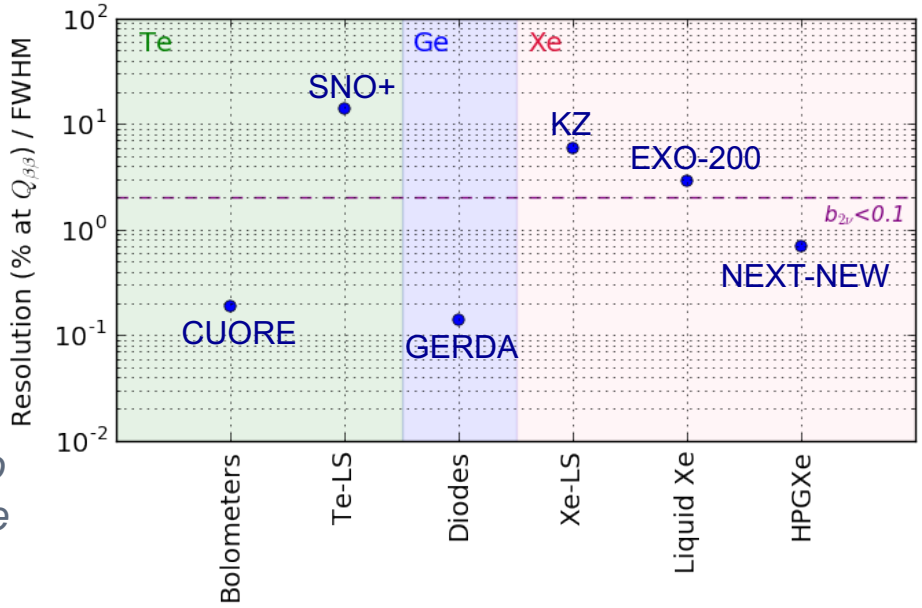
Demonstrating HPGXe

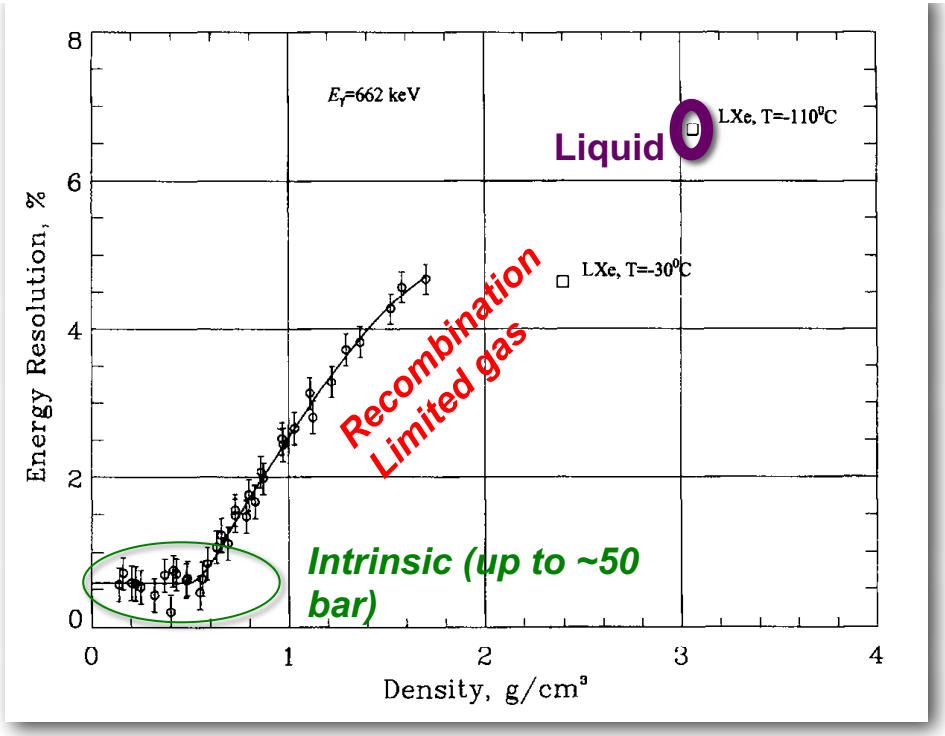
- 1) Energy resolution

  Fluctuation-less EL gain and low Fano factor produces resolution comparable with solid-state technologies in a monolithic TPC experiment

- 2) Topology

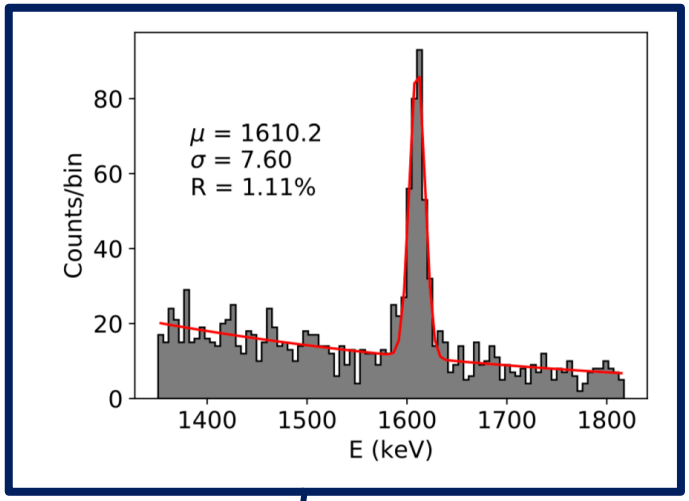
- 3) Low background

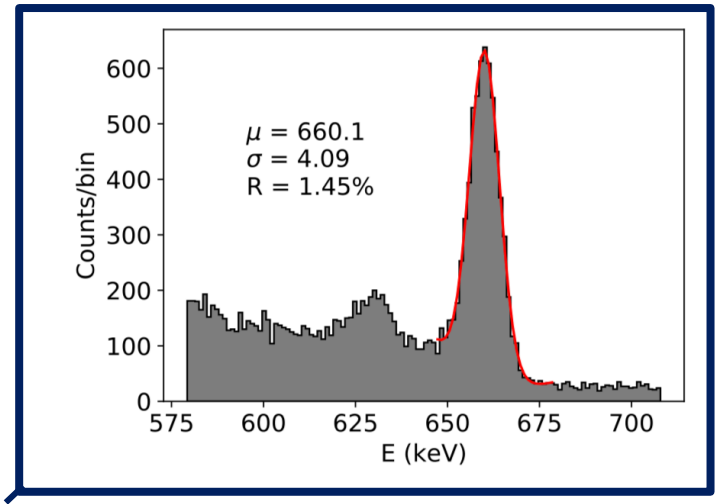




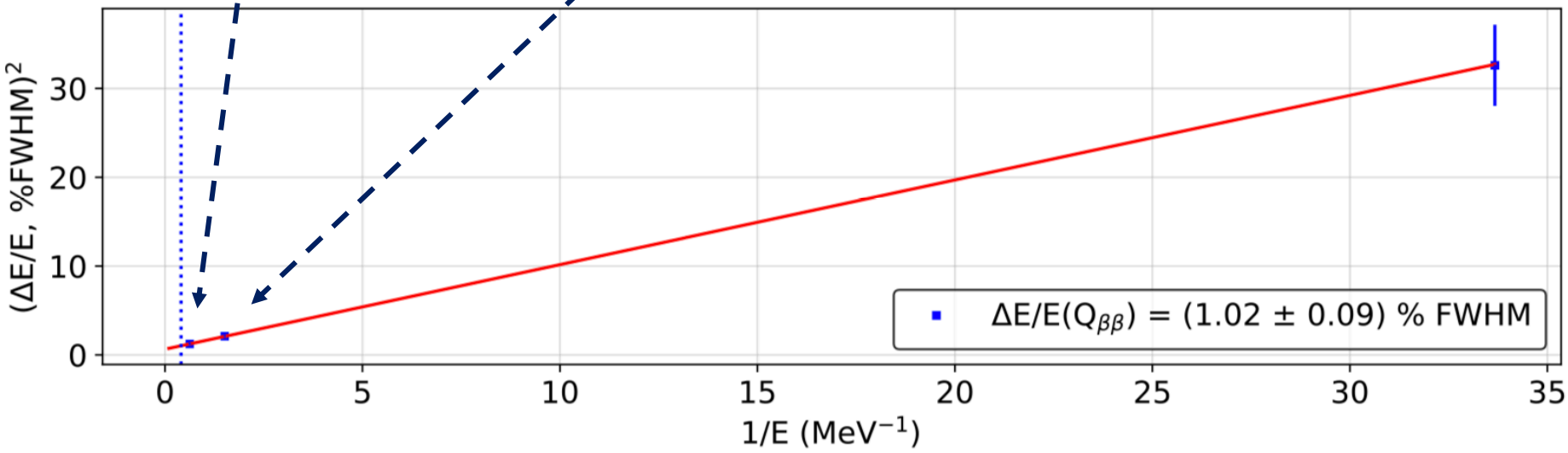
Bolotnikov and Ramsey. "The spectroscopic properties of high-pressure xenon."NIM *A* 396.3 (1997): 360-370

Initial results on energy resolution of the NEXT-White detector
JINST 13 (2018) no.10, P10020
Energy calibration of the NEXT-White detector with 1% FWHM resolution near Qββ of 136Xe
JHEP 1910 (2019) 230





Energy calibrations and stability still improving: presently sit at ~1% at Q_{bb}



Demonstrating HPGXe

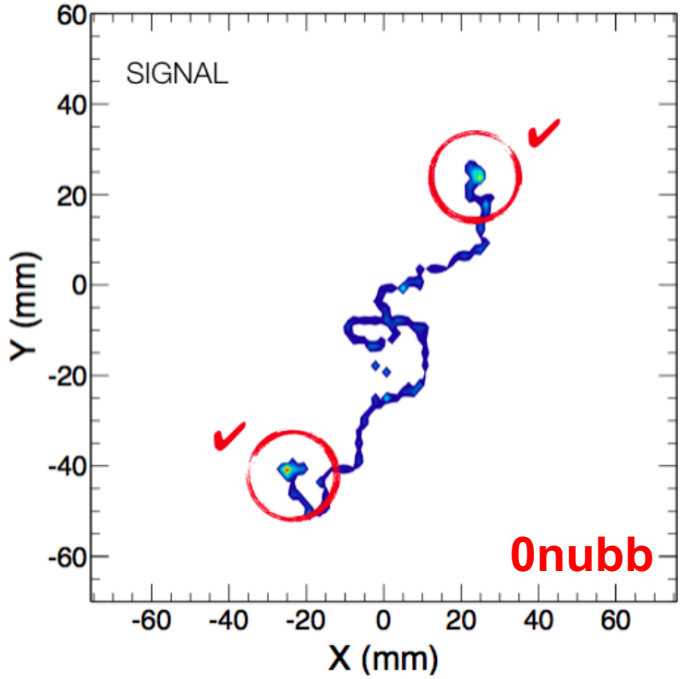
- 1) Energy resolution

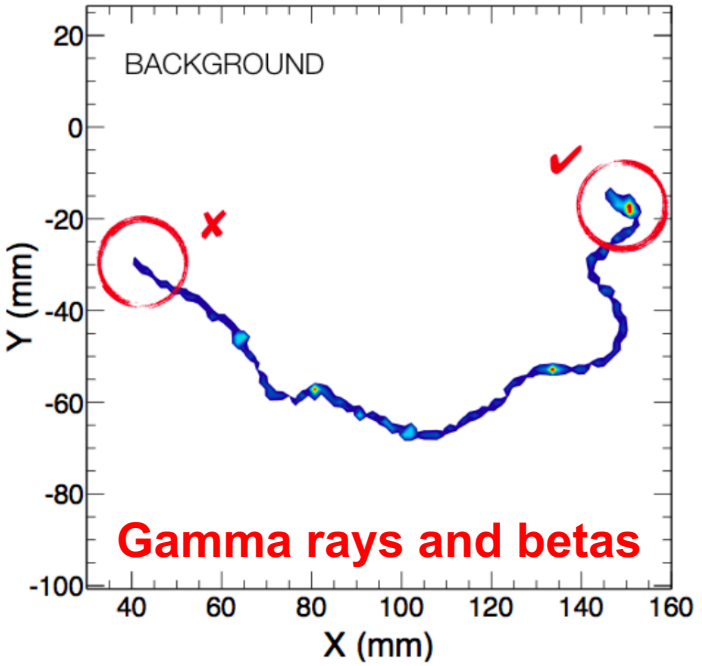
  Fluctuation-less EL gain produces resolution comparable with solid-state technologies in a monolithic TPC experiment

- 2) Topology

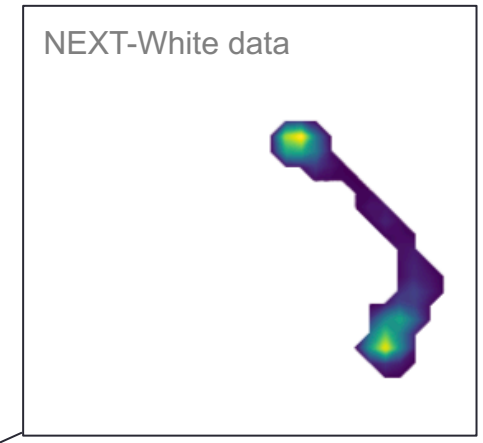
  Lower density allows powerful single-vs-multi electron and single-vs-multi-site topological background rejection

- 3) Low background

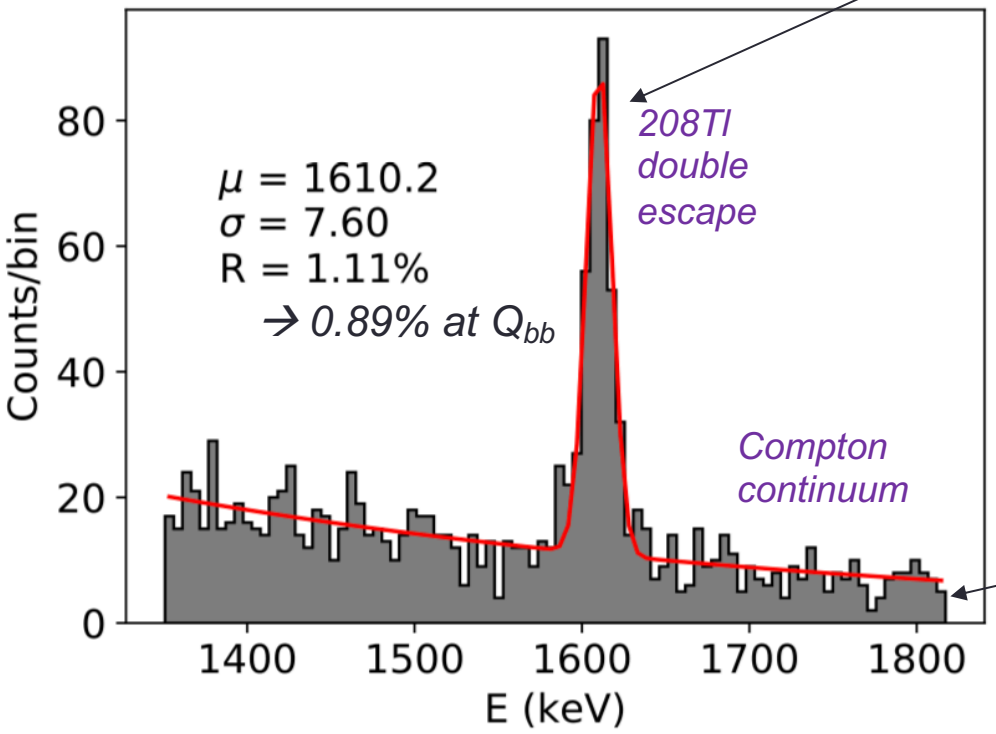


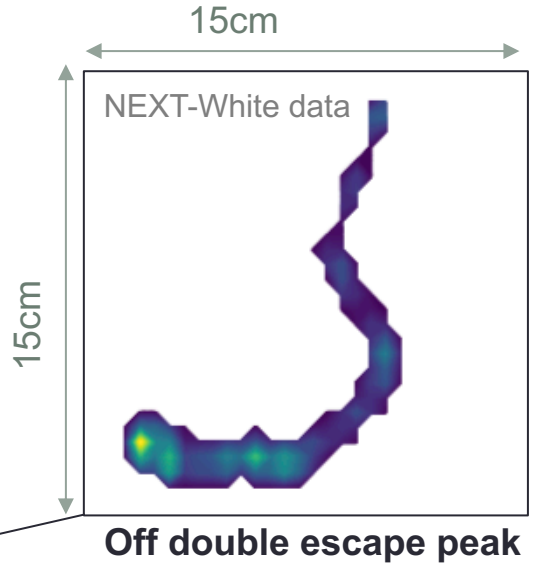


Topological Reco with Double Escape Peaks



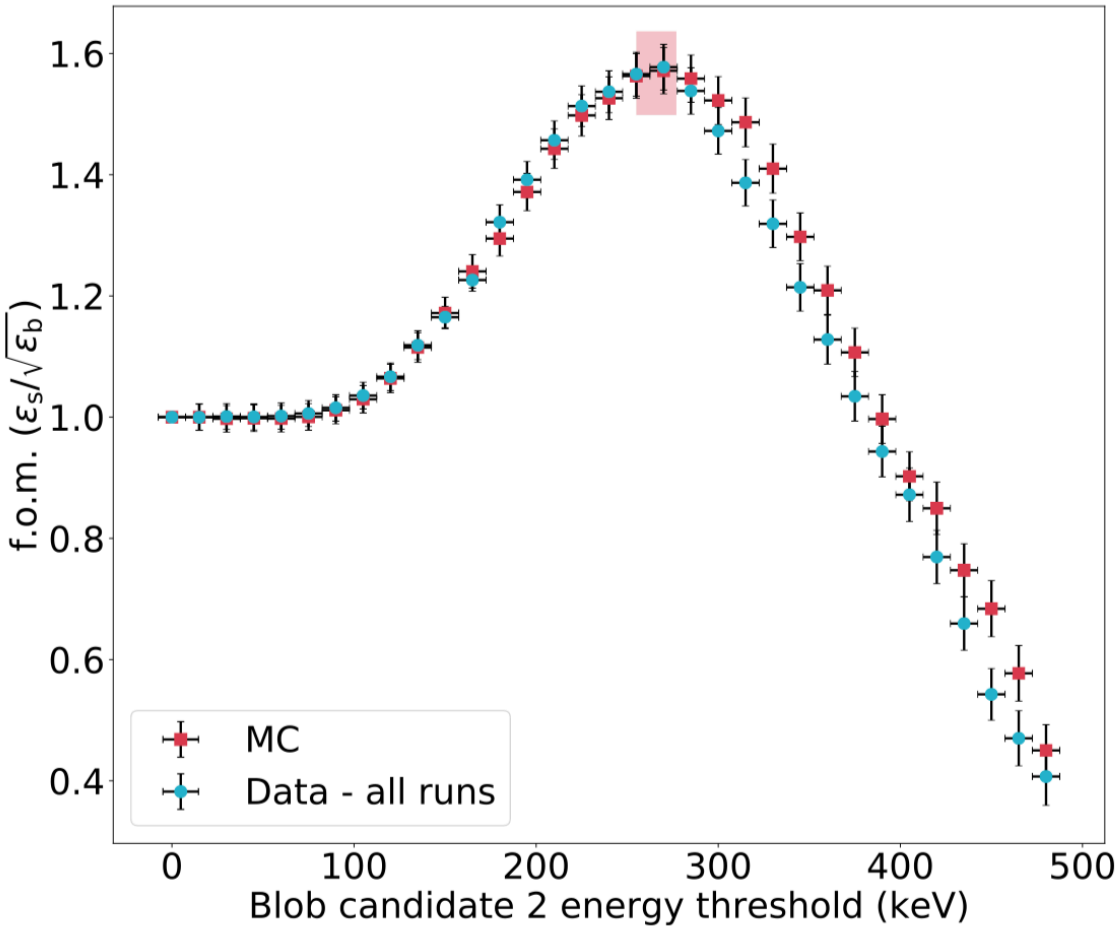
On double escape peak





Off double escape peak

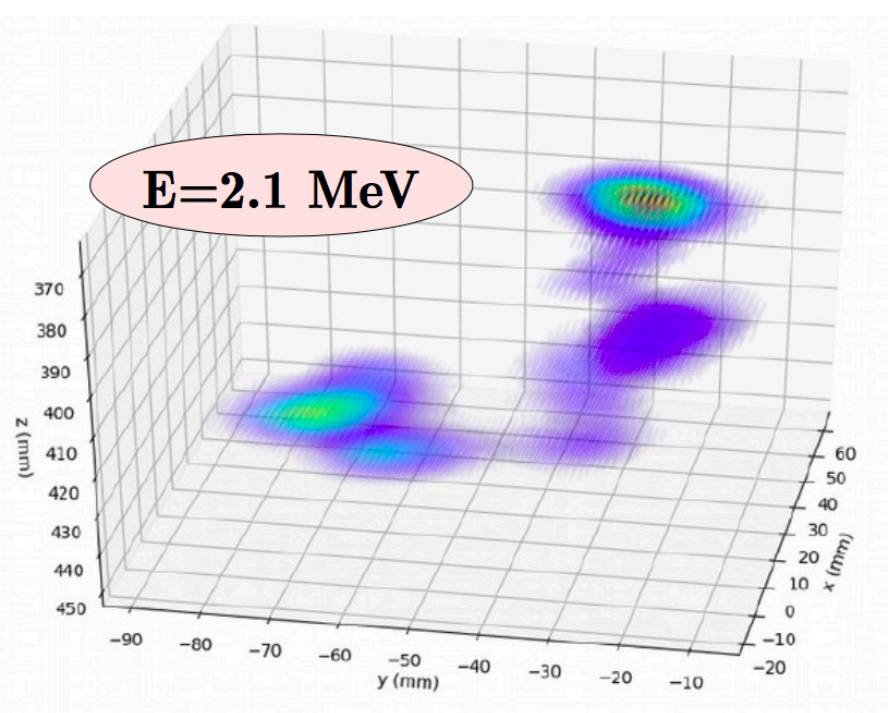
Data / MC agreement on topological signature

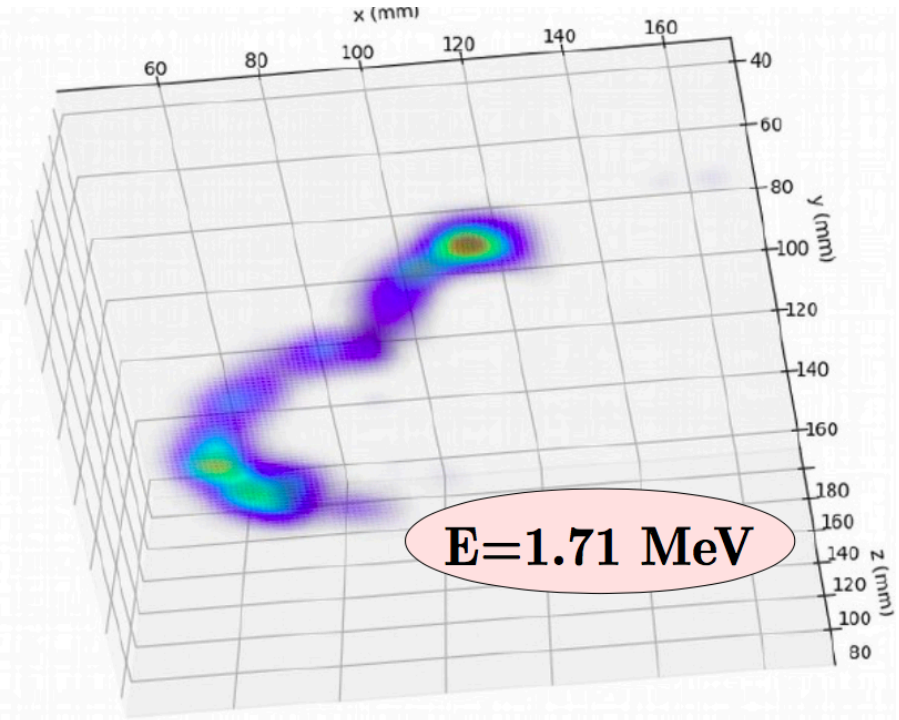


Efficiency of the 2-electron topological signature in the NEXT-White detector

Demonstration of the event identification capabilities of the NEXT-White detector
JHEP 1910 (2019) 052

Two-neutrino double beta decay candidates



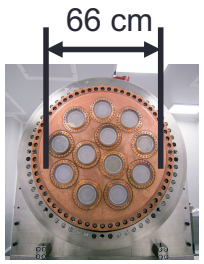


NEXT-White data

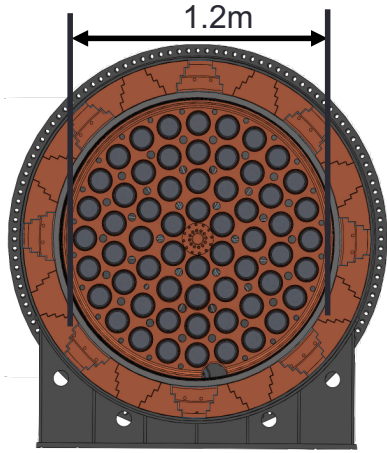
Topologically identified and energy-separated from double escape peaks

Demonstrating HPGXe

NEXT-NEW
Running



NEXT-100
2019



- 1) Energy resolution

  Fluctuation-less EL gain produces resolution comparable with solid-state technologies in a monolithic TPC experiment

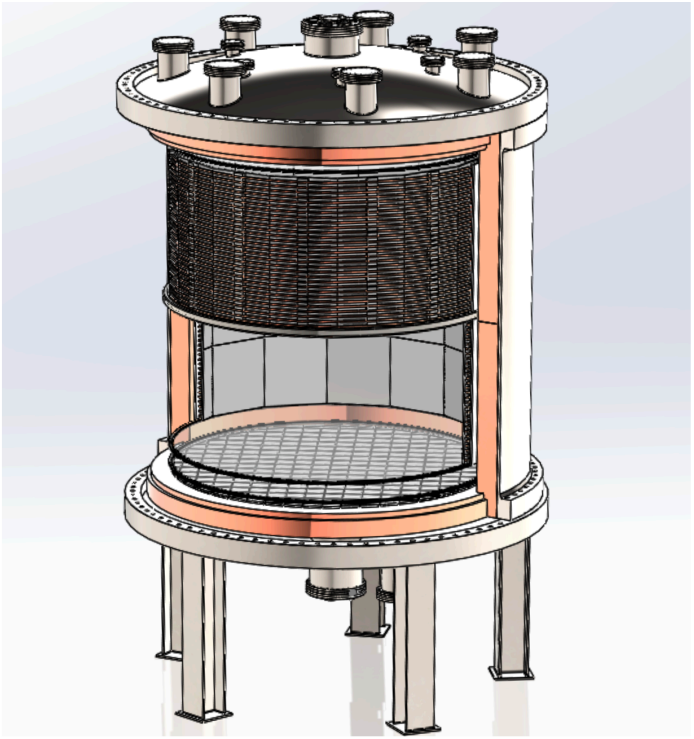
- 2) Topology

  Lower density allows powerful single-vs-multi electron and single-vs-multi-site topological background rejection

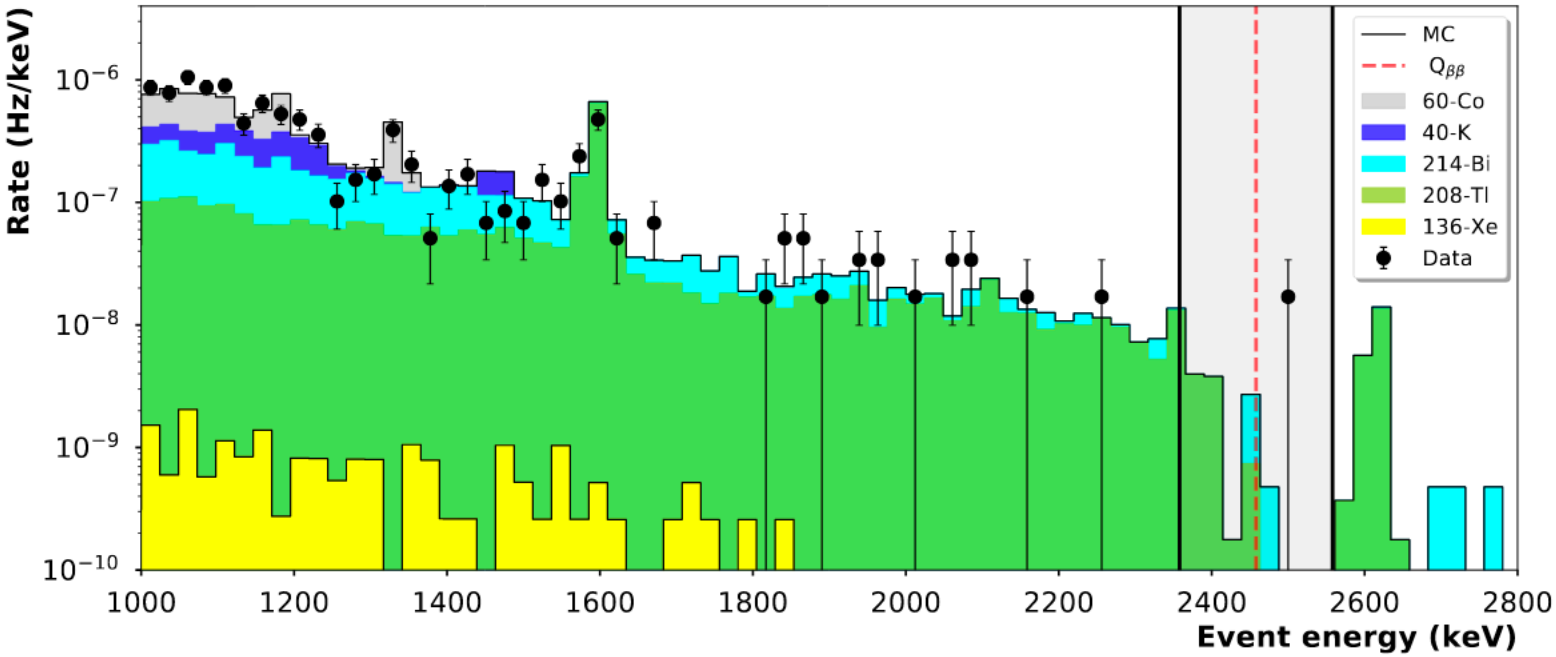
- 3) Low background

  Characterized backgrounds at small scales can extrapolate straightforwardly to large scales

NEXT-HD: *2023*



Background Model Validation

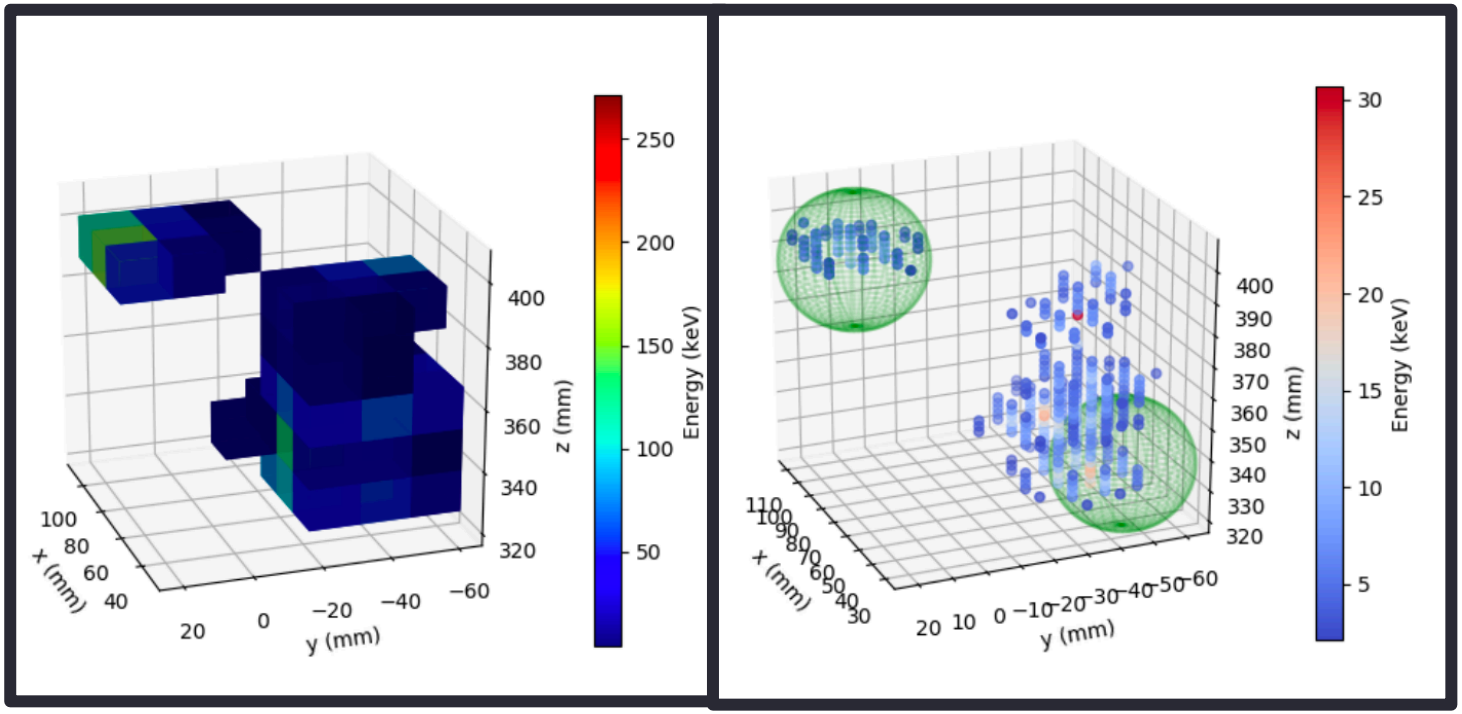


- $0.75 \pm 0.12_{stat} \pm 0.25_{syst}$ predicted in **wide** ROI
- 1 event observed

- **NEXT background model validated.**

Radiogenic backgrounds in the NEXT double beta decay experiment
JHEP 10 (2019) 51

Background Model Validation



- $0.75 \pm 0.12_{stat} \pm 0.25_{syst}$ predicted in **wide** ROI
- 1 event observed

- **NEXT background model validated.**

(and, under more modern analysis, one passing event is clearly rejected as a multi-site charge deposit)

Radiogenic backgrounds in the NEXT double beta decay experiment
JHEP 10 (2019) 51

The NEXT Program

- **Sequence of HPGXe TPCs, focused on achieving big, very low background xenon 0νββ detector**

→ NEXT-DBDM

(Berkeley, US)

→ NEXT-DEMO

(Valencia, Spain)

→ NEXT-White

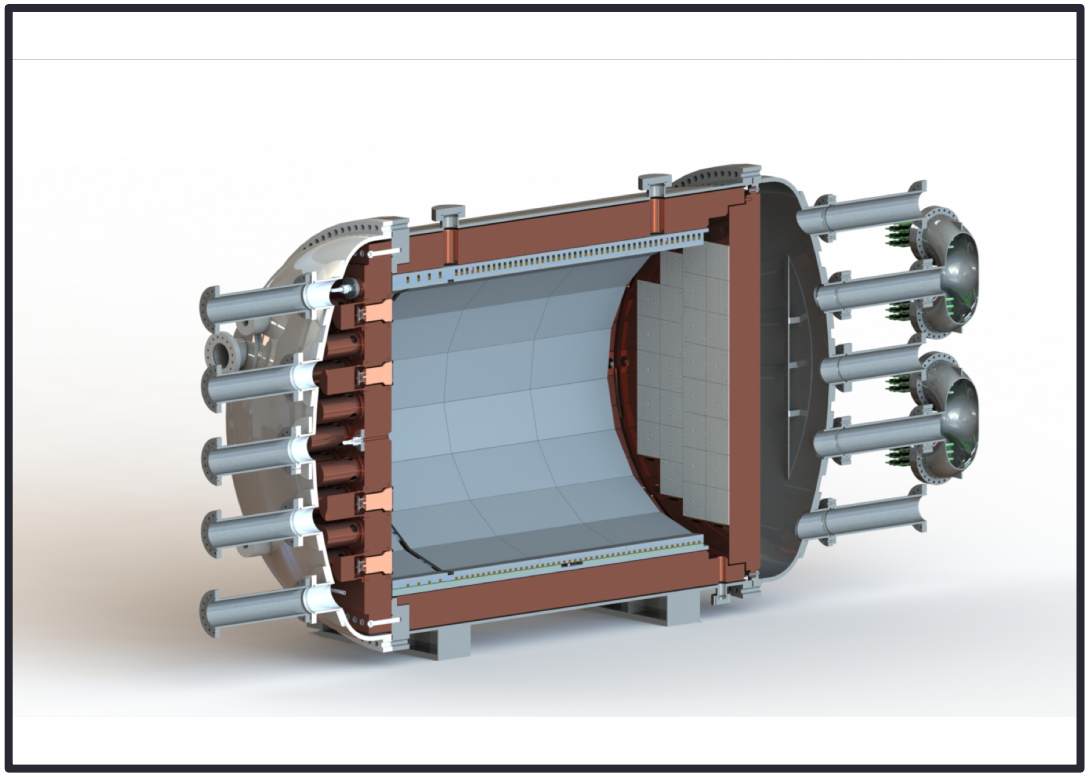
(Canfranc, Spain)

→ **NEXT-100**

(Canfranc, Spain)

→ NEXT-HD

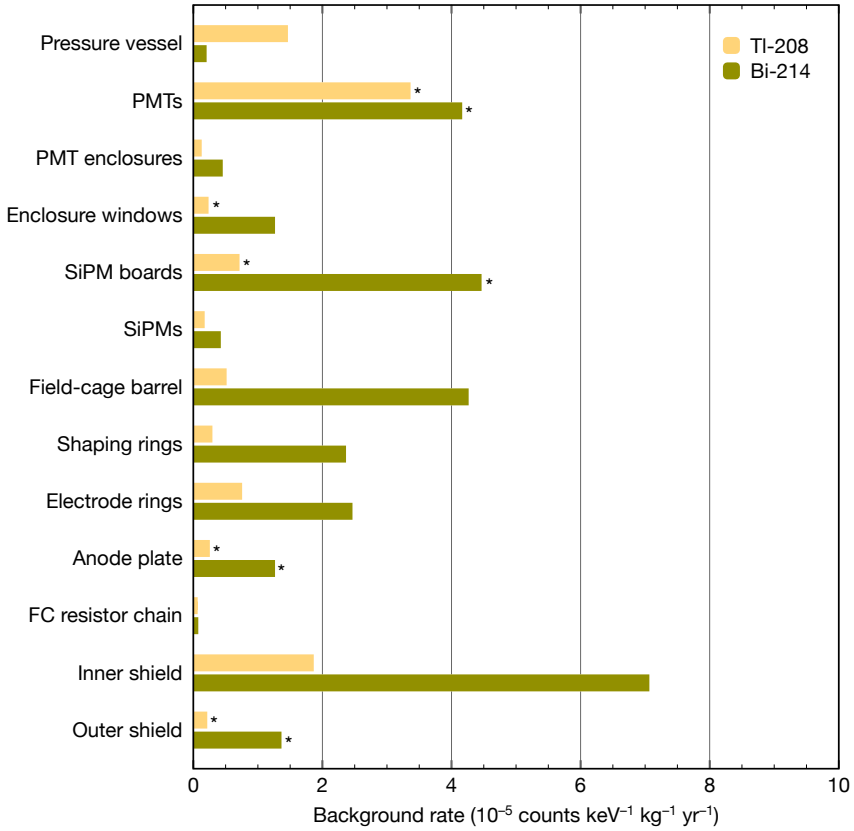
→ *NEXT-BOLD*

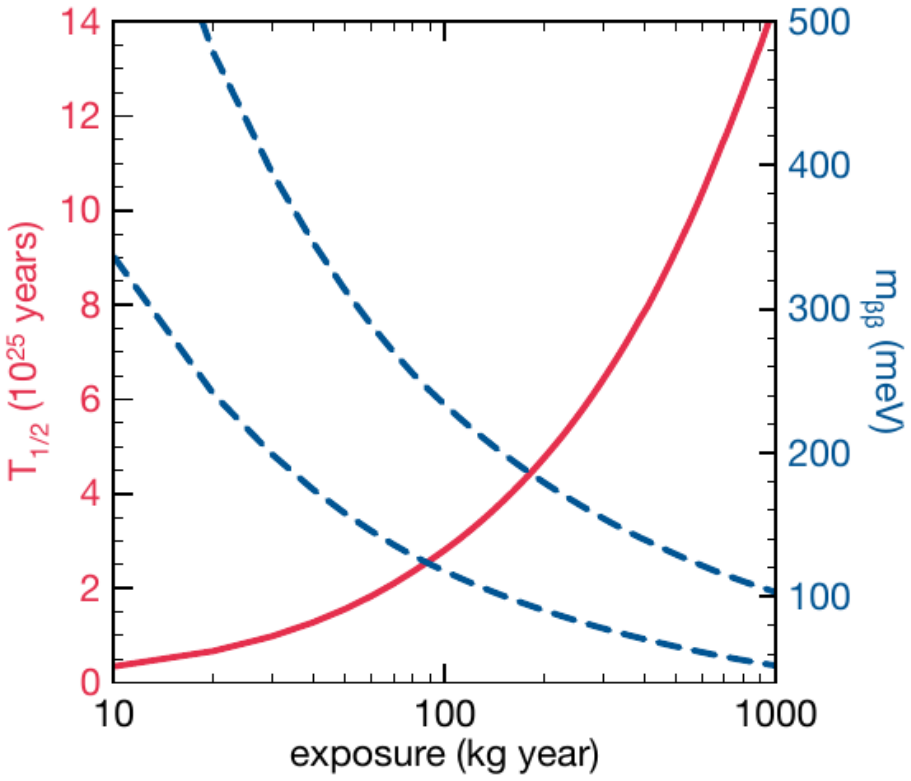


100 kg scale neutrinoless double beta decay search and background-study for ton-scale

NEXT-100 Sensitivity

- Projected near-background-free performance at 100kg scale - Total BG: 5x10-4 c/keV/kg/y, validated with NEXT-White.
- Presently under construction for operation in 2020.





The NEXT Program

- **Sequence of HPGXe TPCs, focused on achieving big, very low background xenon 0νββ detector**

→ NEXT-DBDM

(Berkeley, US)

→ NEXT-DEMO

(Valencia, Spain)

→ NEXT-White

(Canfranc, Spain)

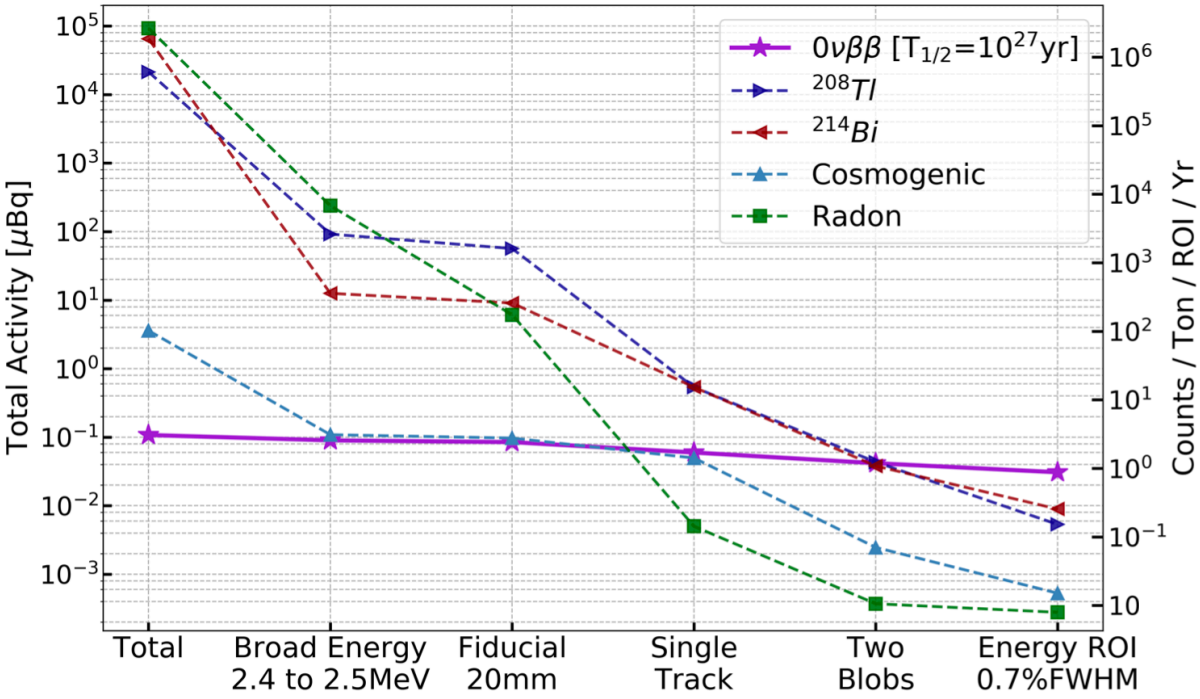
→ NEXT-100

(Canfranc, Spain)

→ **NEXT-HD**

→ *NEXT-BOLD*

Ton-scale experiment in conceptual design stage
I present projections and selected ongoing R&D



← NEXT-HD event selection assuming 0.7% energy resolution and demonstrated topological cut performance

NEXT-100 Background Model:

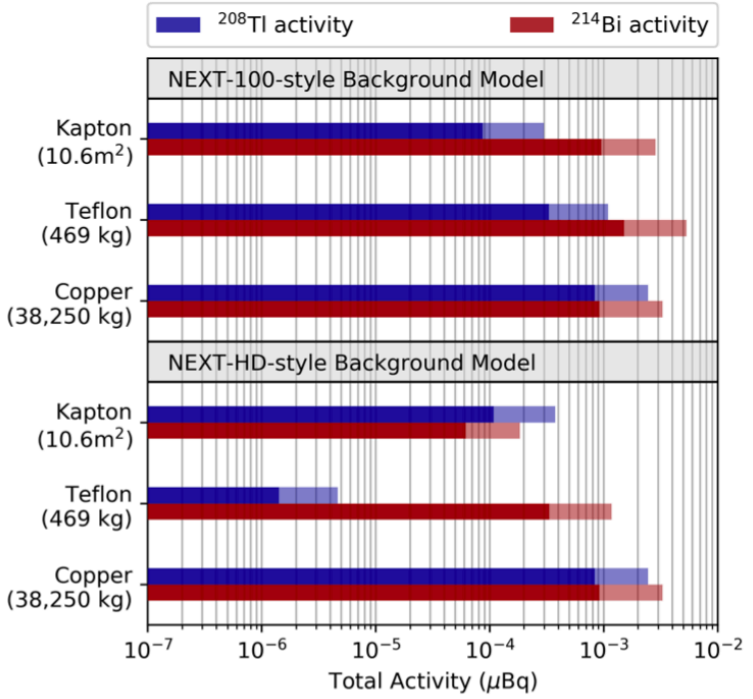
Only assayed materials for NEXT-100.

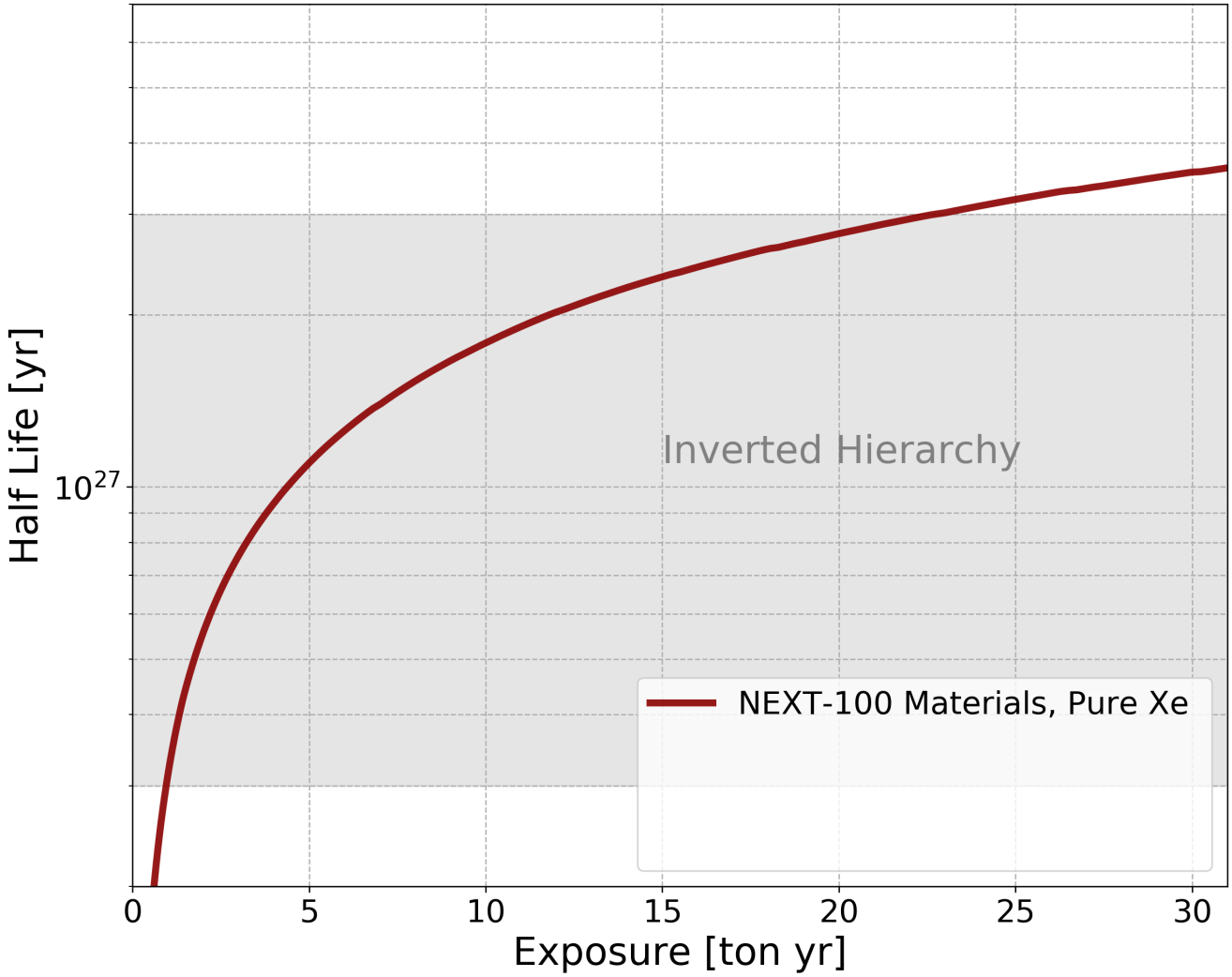
- 0.5 ct / [ton yr ROI];

NEXT-HD Background Model:

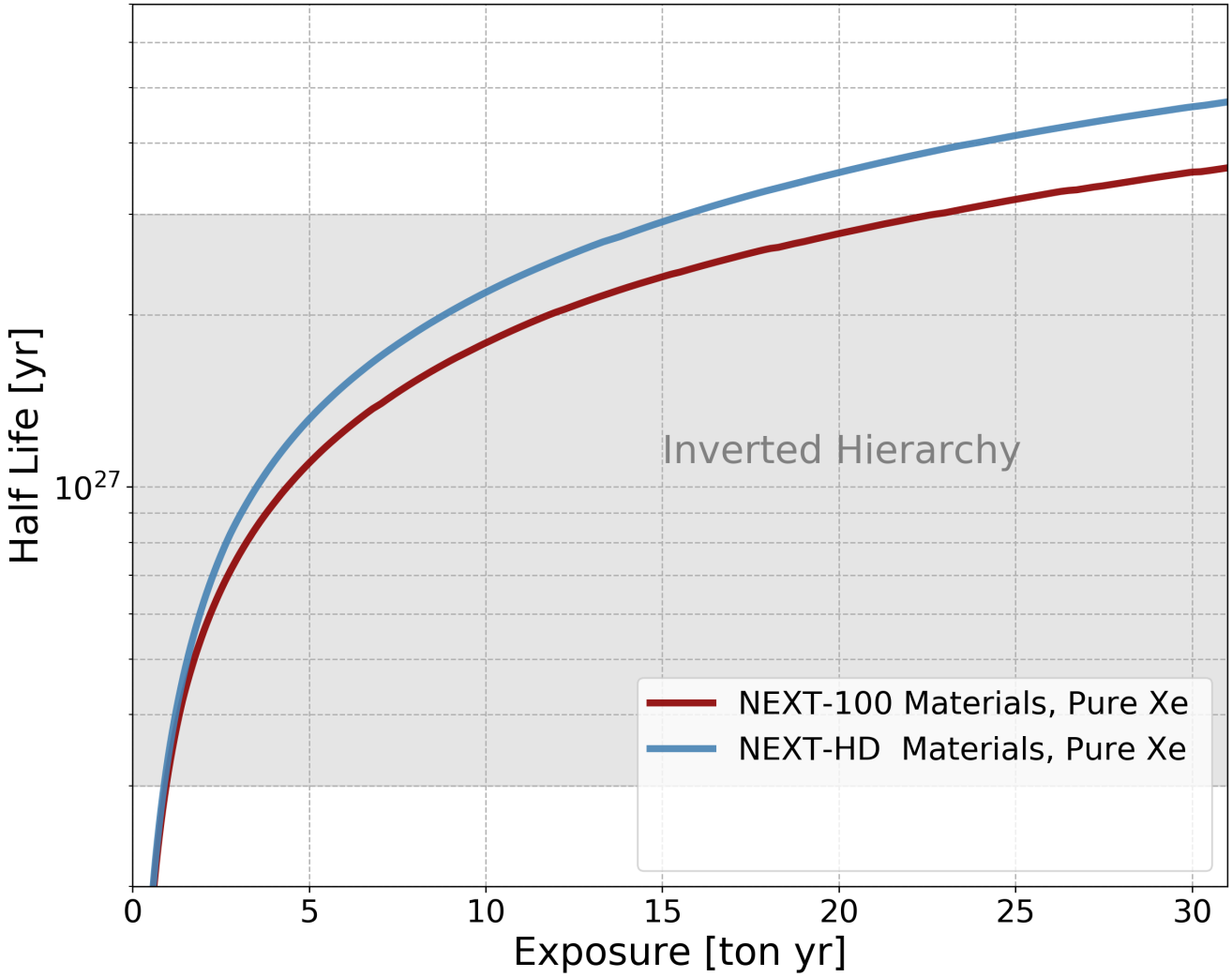
Cleaner Teflon and Kapton located by other collaborations:

- 0.25 ct / [ton yr ROI];





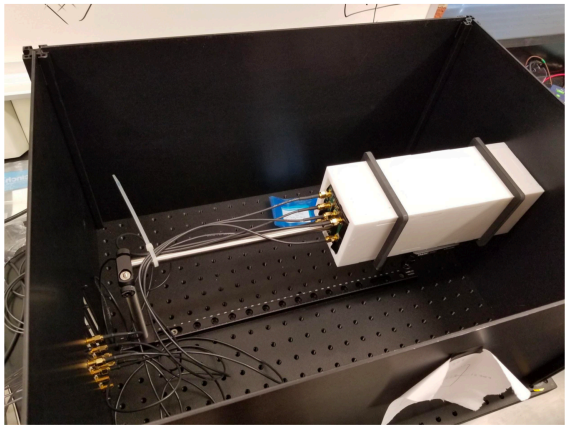
- **NEXT-100 background model** includes all assayed NEXT-100 materials.



- **NEXT-100 background model** includes all assayed NEXT-100 materials.
- **NEXT-HD background model** takes advantage of cleaner materials (Teflon and Kapton) already identified by other collaborations.

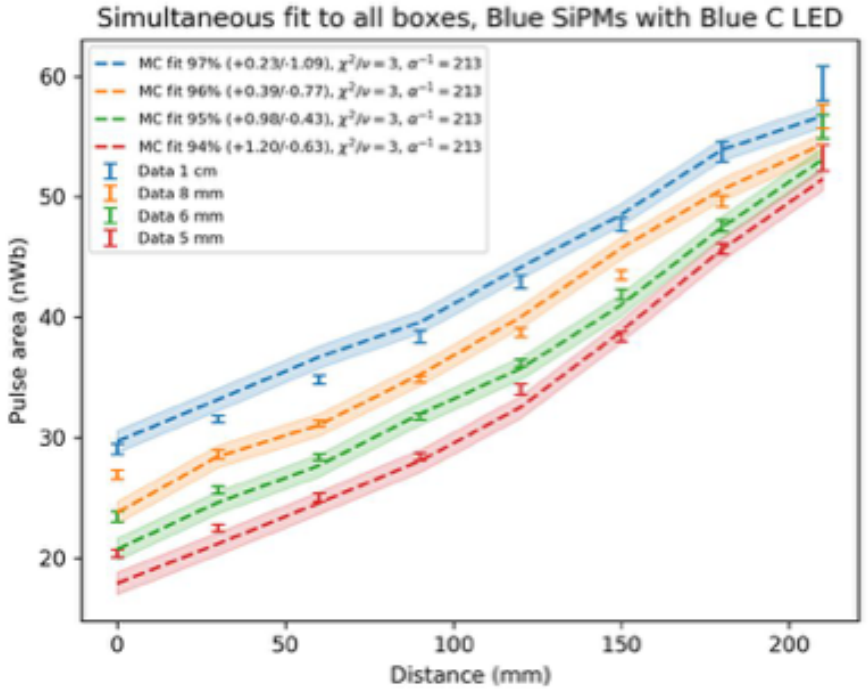
Optical R&D

- New Teflon reflectivity measurements at 175nm and 420 nm to inform NEXT Teflon selection and thickness.



Reflectance relative to 1 cm at 450 nm		
Thickness	**Box**	**Disk**
1 cm	100%	100%
8 mm	$98.9^{+1}_{-0.3}$%	98.8 ± 0.03%
6 mm	$97.9^{+2}_{-0.9}$%	97.9 ± 0.09%
5 mm	$96.9^{+0.4}_{-1.1}$%	96.0 ± 0.1%

Reflectance relative to 1 cm at 260 nm		
Thickness	**Box**	**Disk**
1 cm	100%	100%
8 mm	$101.1^{+0.12}_{-1.02}$ %	96.7 ± 0.1%
6 mm	$101.1^{+0.2}_{-0.31}$%	97.5 ± 0.2%
5 mm	$100.0^{+0.55}_{-0.44}$%	95.9 ± 0.2%

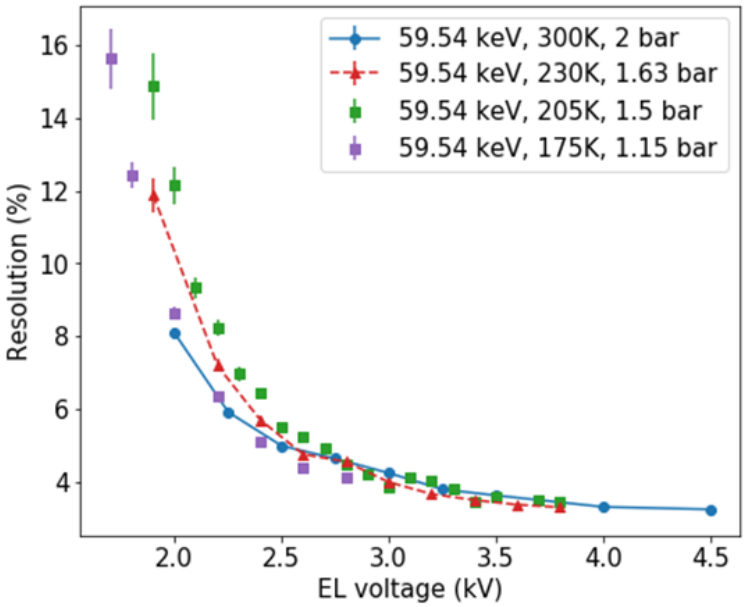


→ Teflon mass (a dominant background source) reduced by x2, strong reflectivity obtainable at 5mm.

Paper in preparation

Gas Cooling

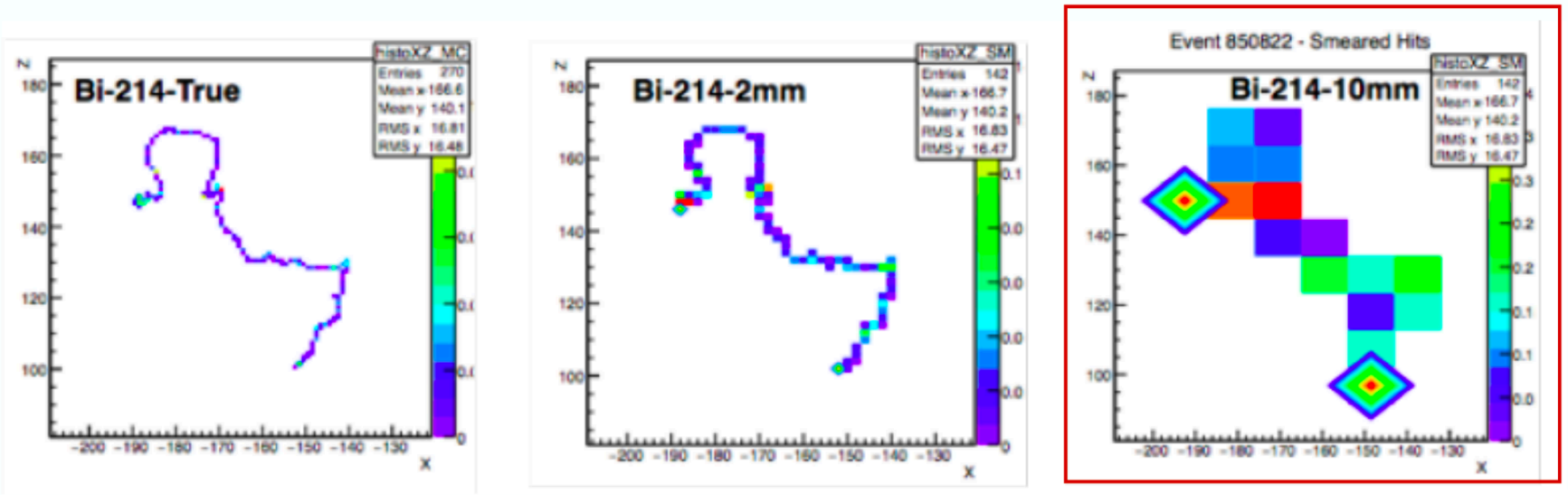
- **Motivations:**
  - Replace PMTs (source of radioactive background) with radiopure SiPMs, without suffering from dark rate.
  - Enable higher Xe mass at a given pressure
  - Minimize outgassing for better e^- lifetime
- **Key Question:**
  - will energy resolution degrade at low temperature?
- **First Results:**
  - Electroluminescence from 59.5 keV γ (1.2-2 bar)
  - Vary T from 300K to 175K
  - ***No observable degradation of energy resolution down to 175K***
- **3.8% FWHM at 60 keV, extrapolates to 0.6% FWHM at $Q_{\beta\beta}$**



Diffusion in NEXT

- In pure xenon diffusion of drifting electrons is very large. After 1 m of drift the electron cloud has a **transverse** rms of **∼10mm** and **longitudinal** rms of **∼5mm**
- Spatial resolution is dominated by diffusion in NEXT (detector configuration of tracking plane and EL are sub-dominant)

Background event ⇢ **Fake signal**

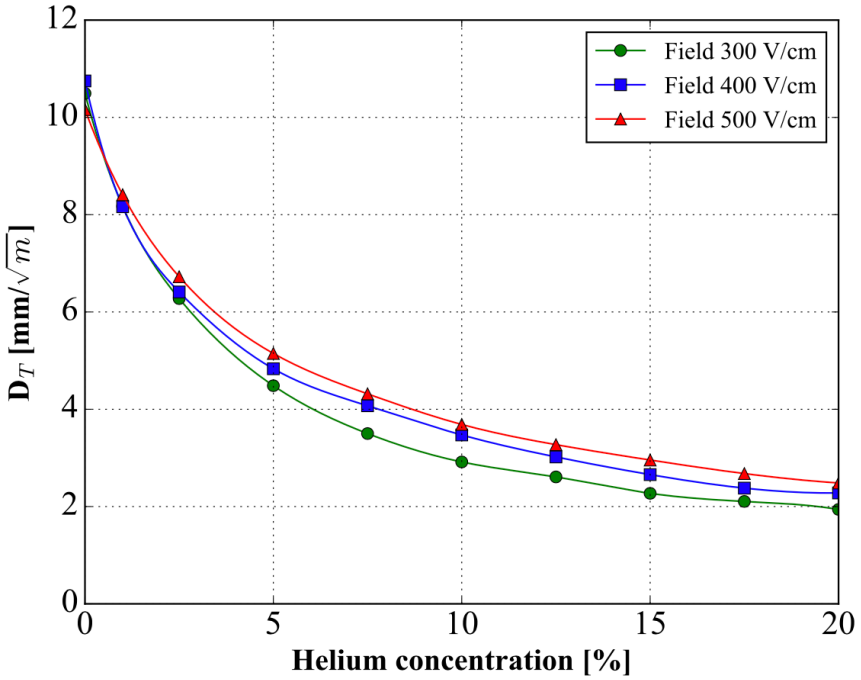


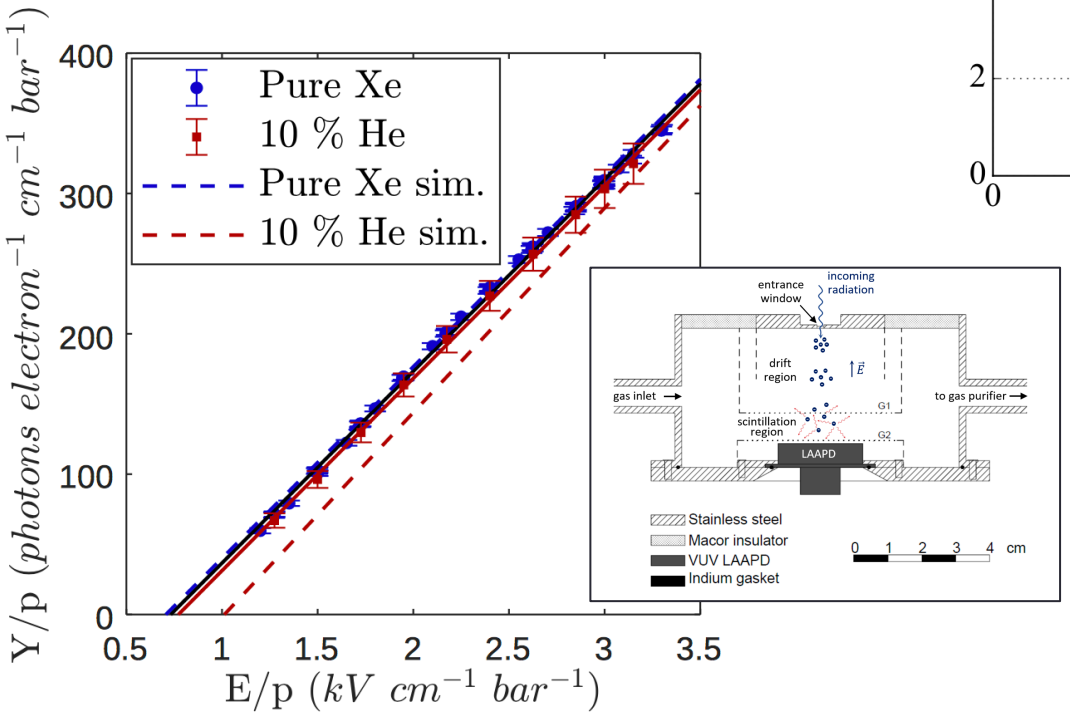
(Slide c/o Neus Lopez March, LIDINE)

NEXT with helium key results

Concept paper presenting helium diffusion reduction →

Nucl.Inst.Meth.2018.07.013





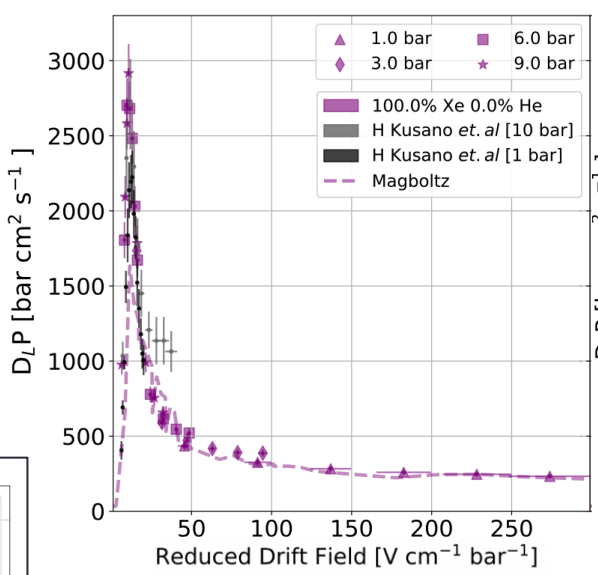
←Excellent electroluminescence properties preserved in the presence of helium additives to xenon gas

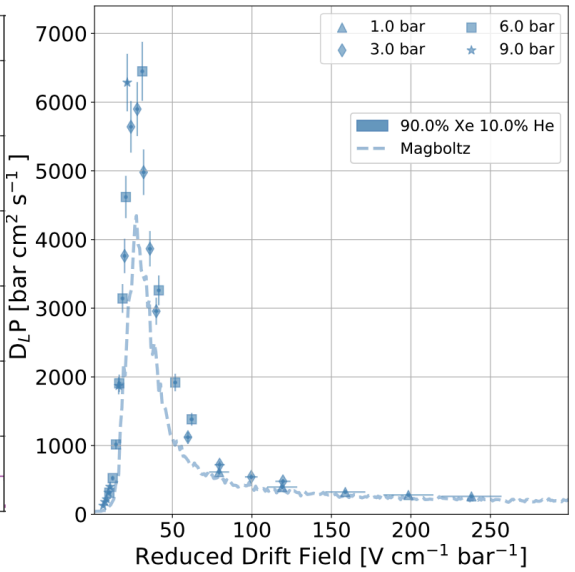
arXiv:1906.03984
sub to JHEP

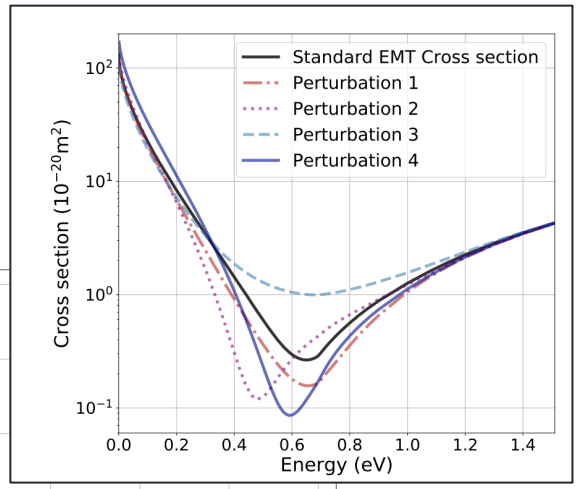
NEXT with helium key results

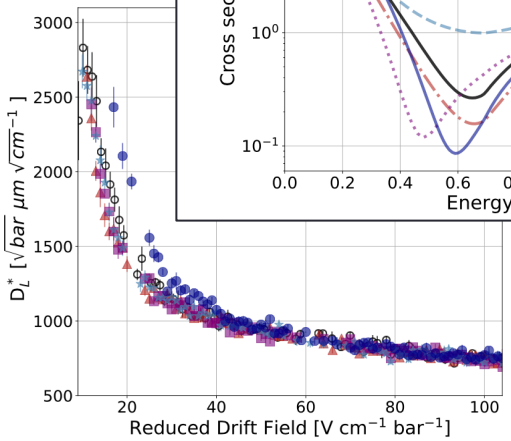
Helium impact on longitudinal diffusion quantified – diffusion larger than swarm simulations but workable

JINST 14 (2019) no.08, P08009









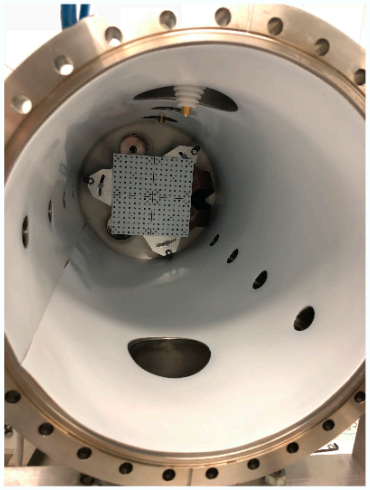
←Theoretical work on swarm microphysics ongoing to understand and fix 20% discrepancies in models.

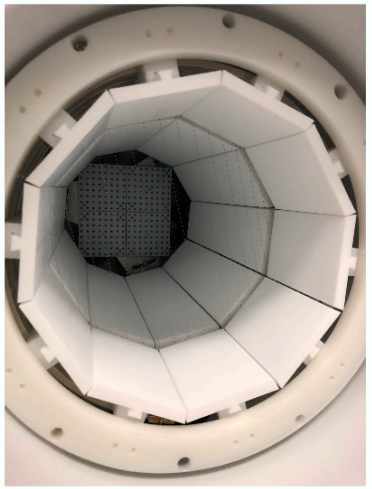
Refactored MagBoltz codebase into Python to enable these ongoing studies:

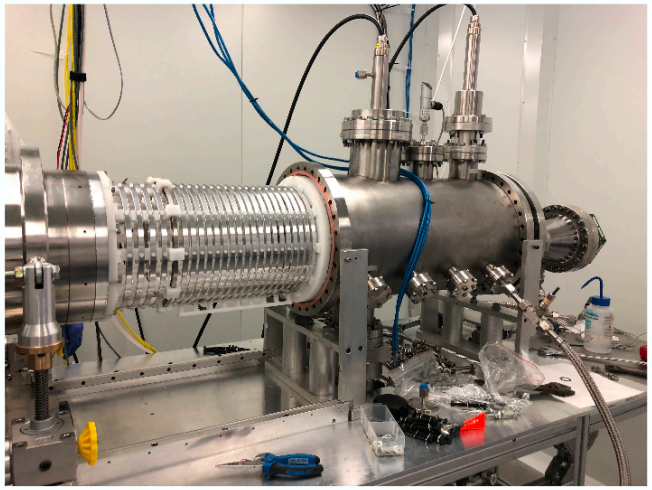
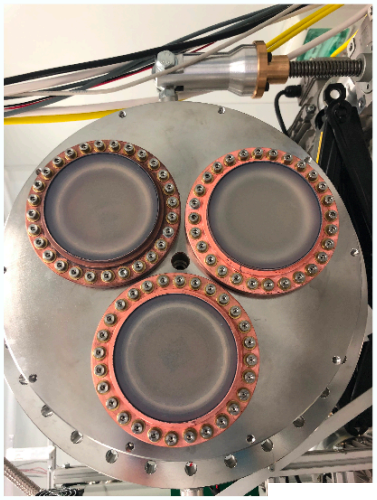
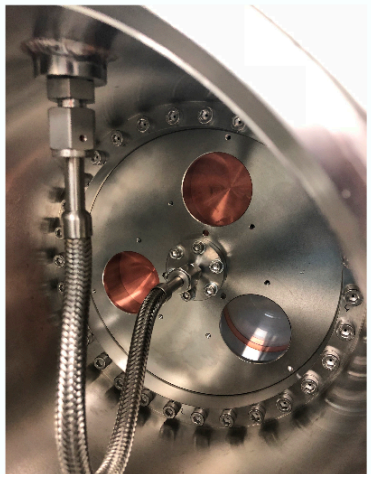
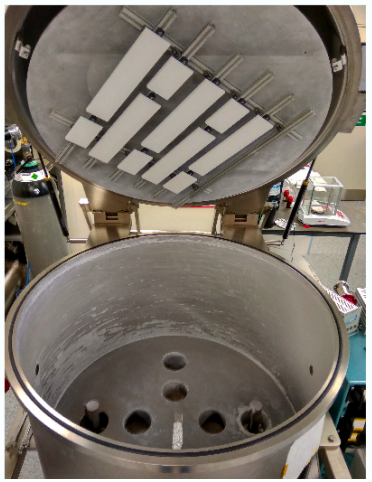
arXiv:1910.06983
sub to Comp. Phys Comm.

NEXT helium next steps

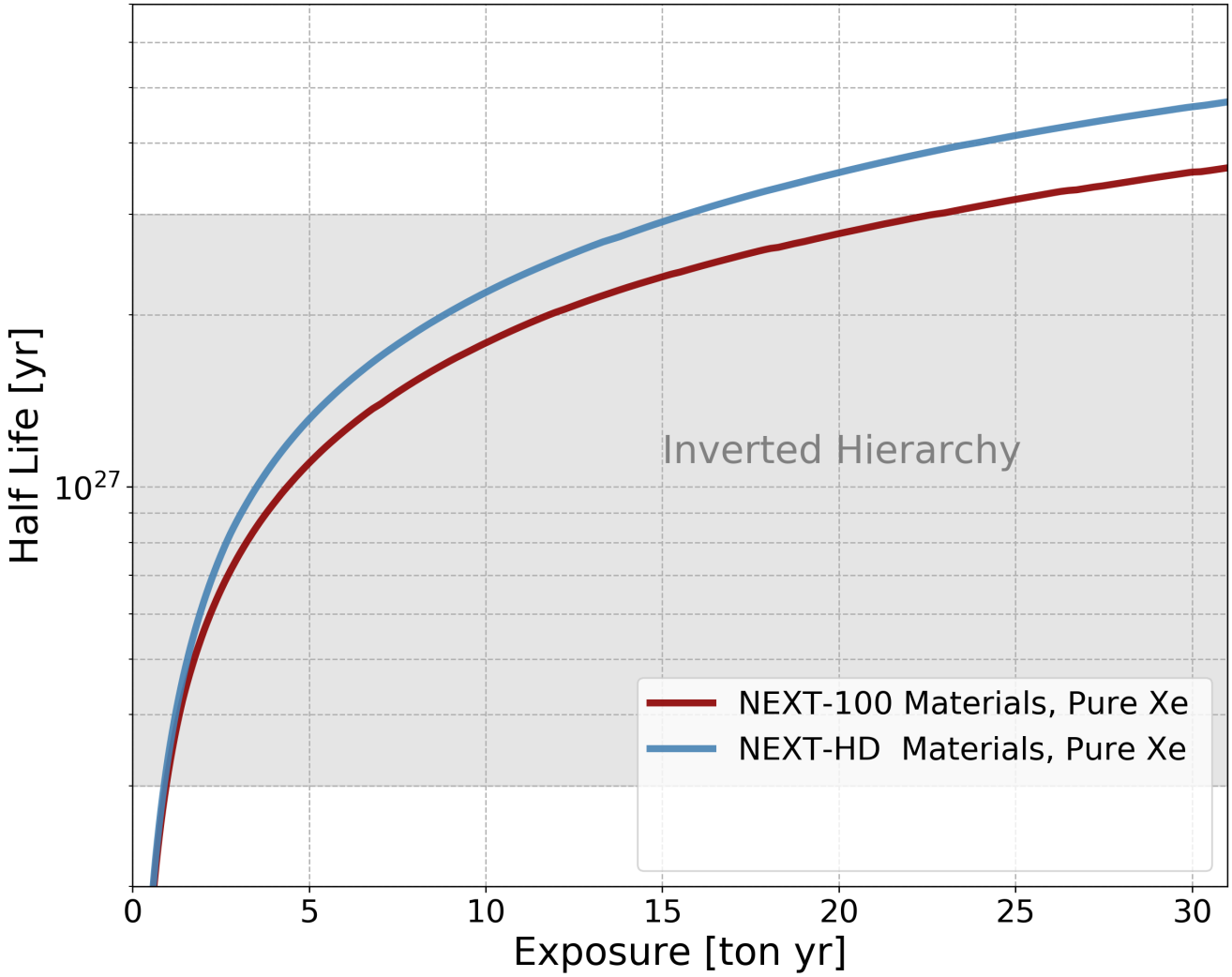
- Same sensors as NEXT-White and NEXT100 detectors
- Measure DT and actual effect on event topology from He additive
- Pmts kept at vacuum
- Next step in NEXT low diffusion program at IFIC, Spain



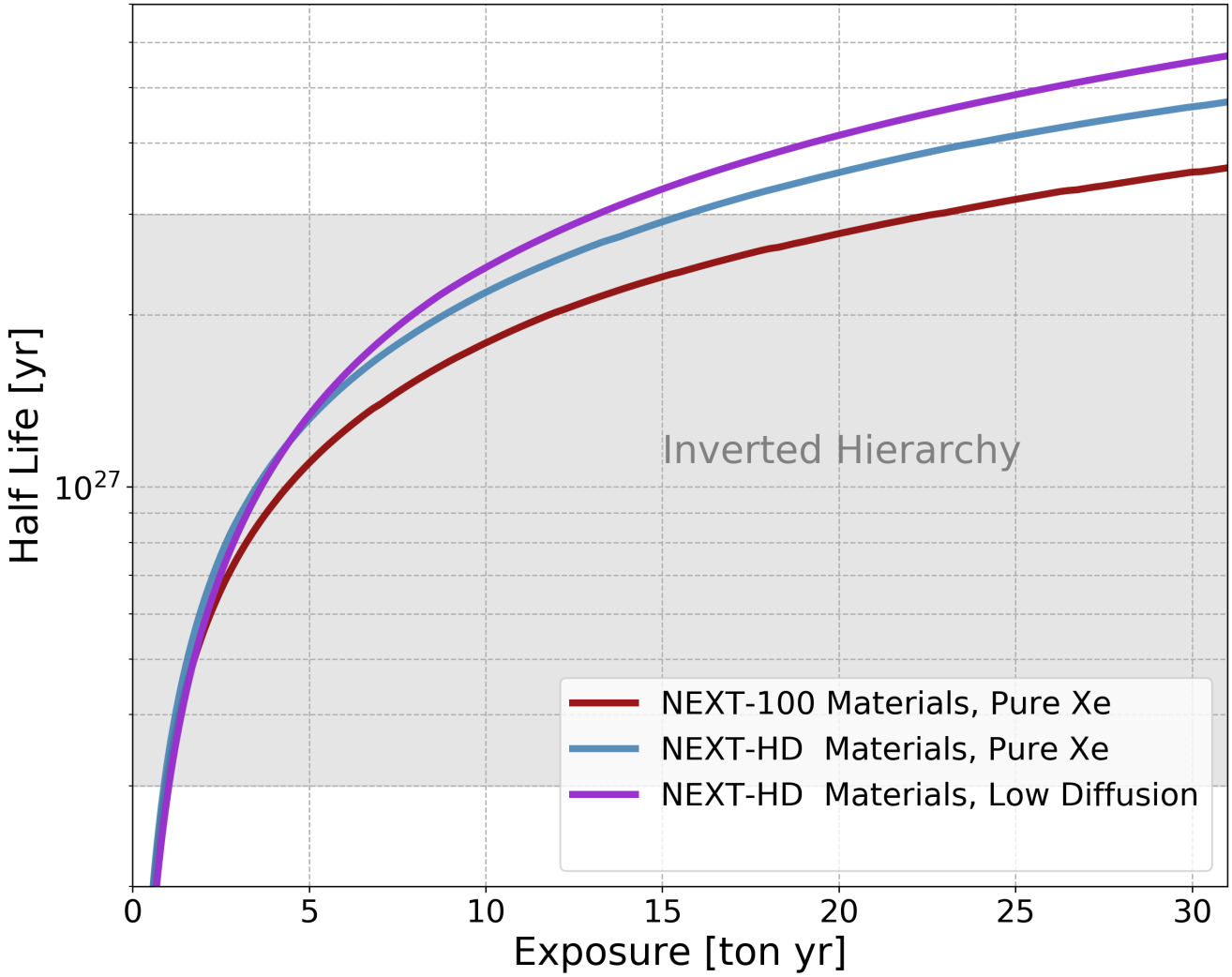


(Slide c/o Neus Lopez March, LIDINE)



- **Adding low-diffusion mixture predicted to improve quality of topological cuts**



- **Adding low-diffusion mixture predicted to improve quality of topological cuts**

The NEXT Program

- **Sequence of HPGXe TPCs, focused on achieving big, very low background xenon 0νββ detector**

→ NEXT-DBDM

(Berkeley, US)

→ NEXT-DEMO

(Valencia, Spain)

→ NEXT-White

(Canfranc, Spain)

→ NEXT-100

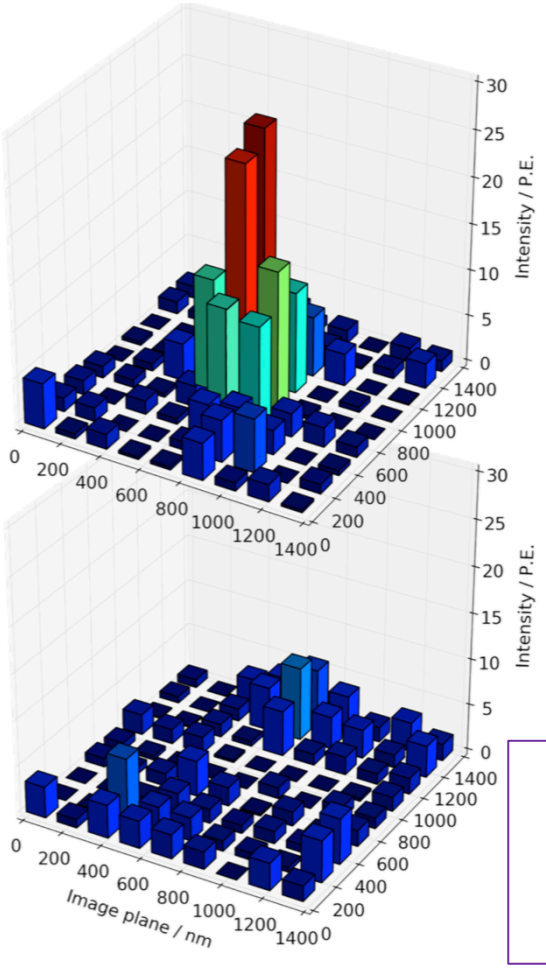
(Canfranc, Spain)

→ NEXT-HD

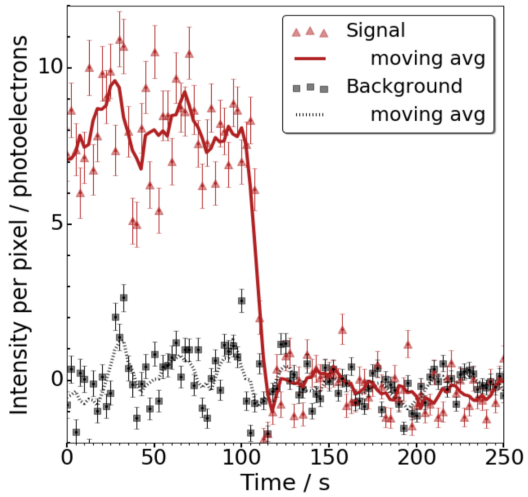
"traditional" approach

→ ***NEXT-BOLD***

w/barium tagging



Rapid Progress in Barium Tagging Technology



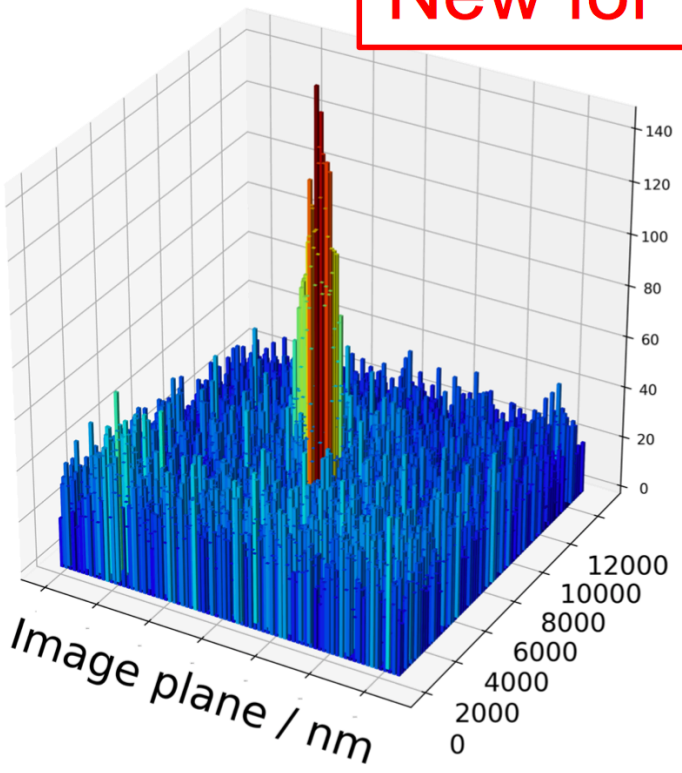
Phys.Rev.Lett. 120 (2018) no.13, 132504
Nature Sci. Rep. 9, (2019) 15097
Phys. Rev. A 97, (2018) 062509
JINST 11 (2016) no.12, P12011
arXiv:1909.02782, arXiv:1909.04677,
arXiv:1909.05860, arXiv:1901.03369,

First ever single molecule images in high pressure gas

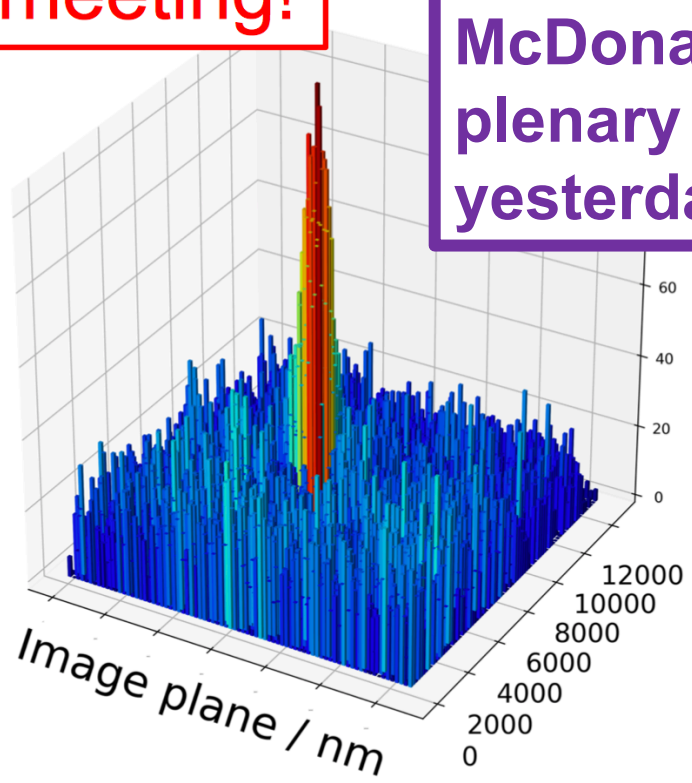
single Barium ions in 10 bar argon and xenon

New for this meeting!

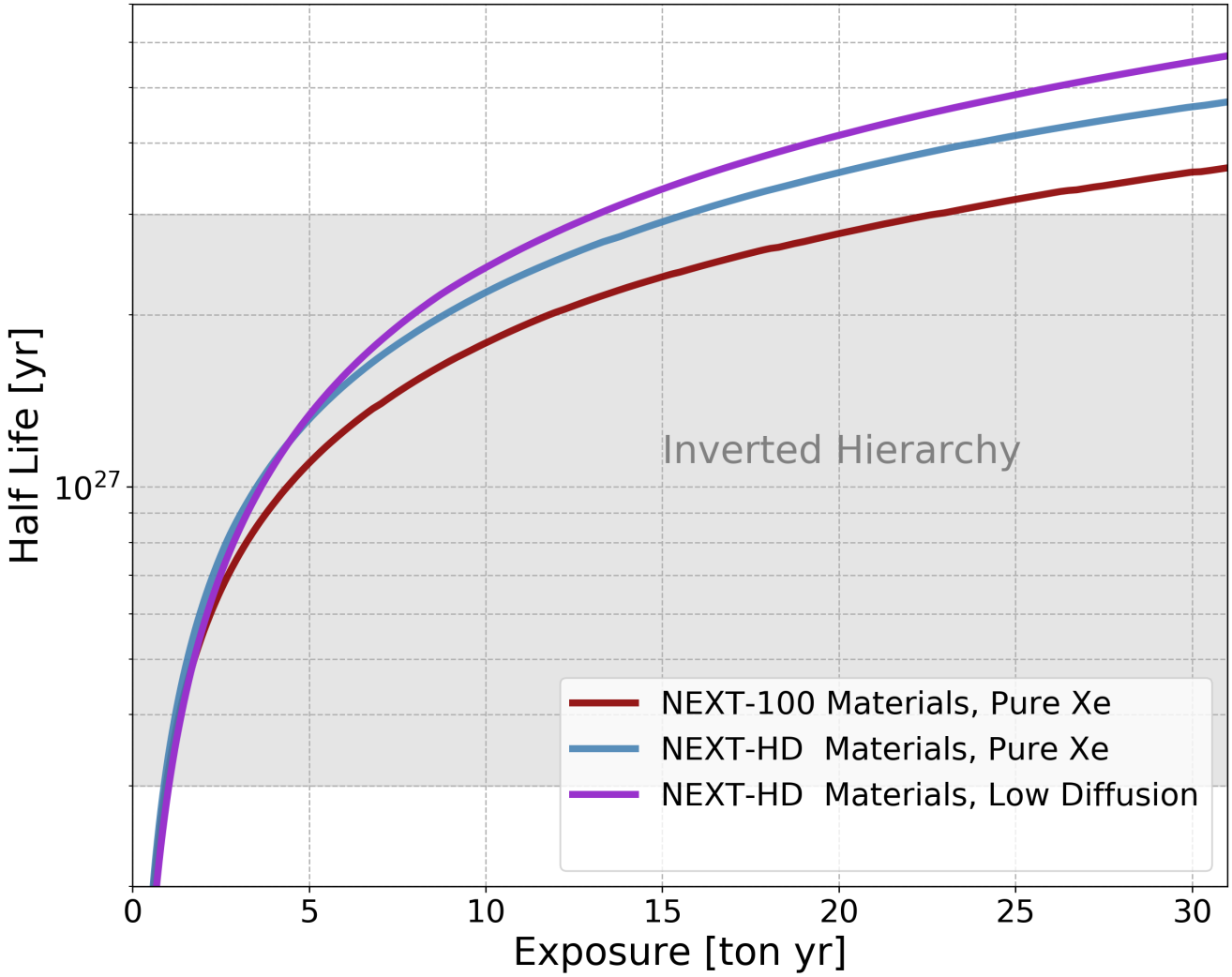
From Austin McDonald plenary yesterday



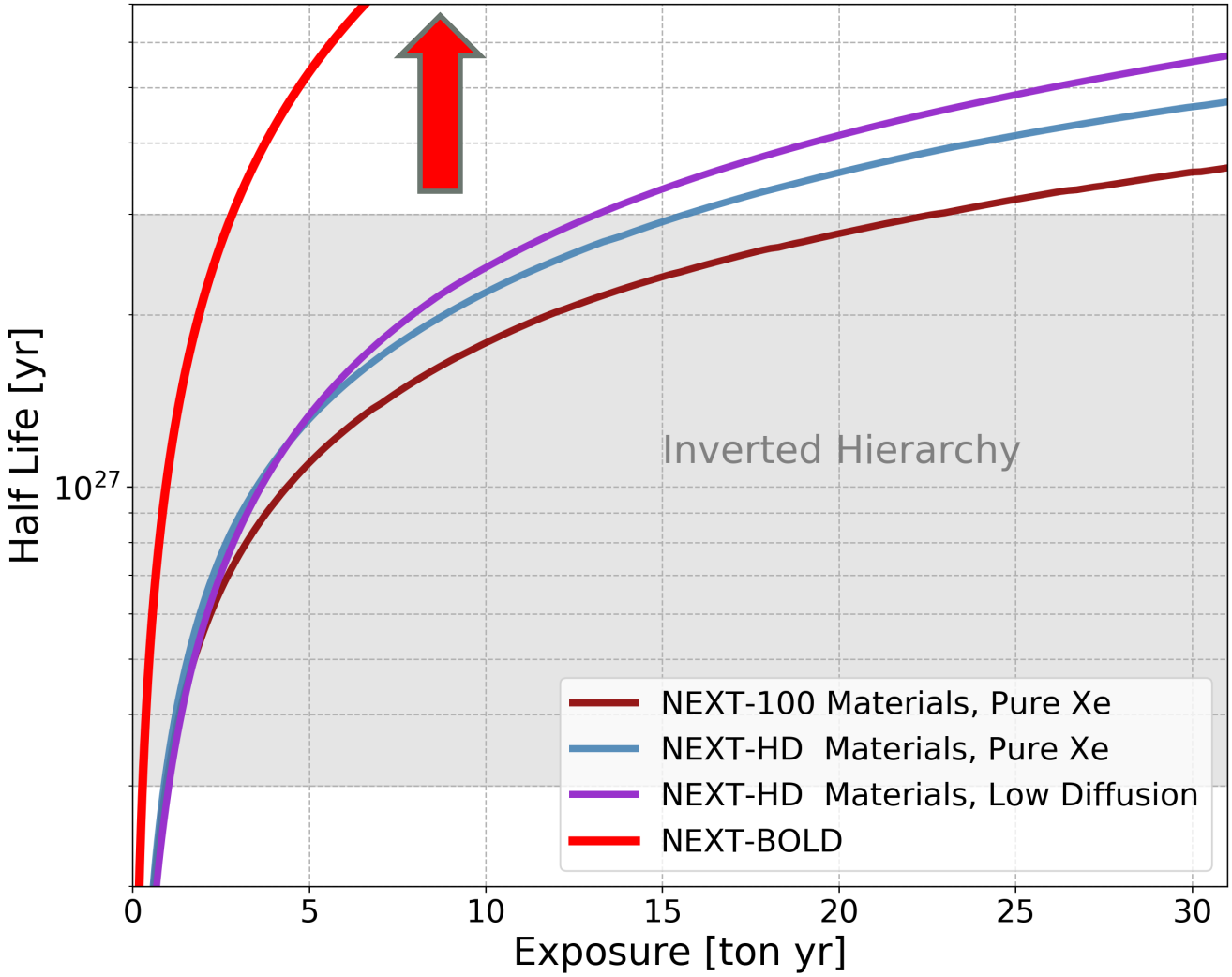
Ba^{++} ion / 10 bar xenon



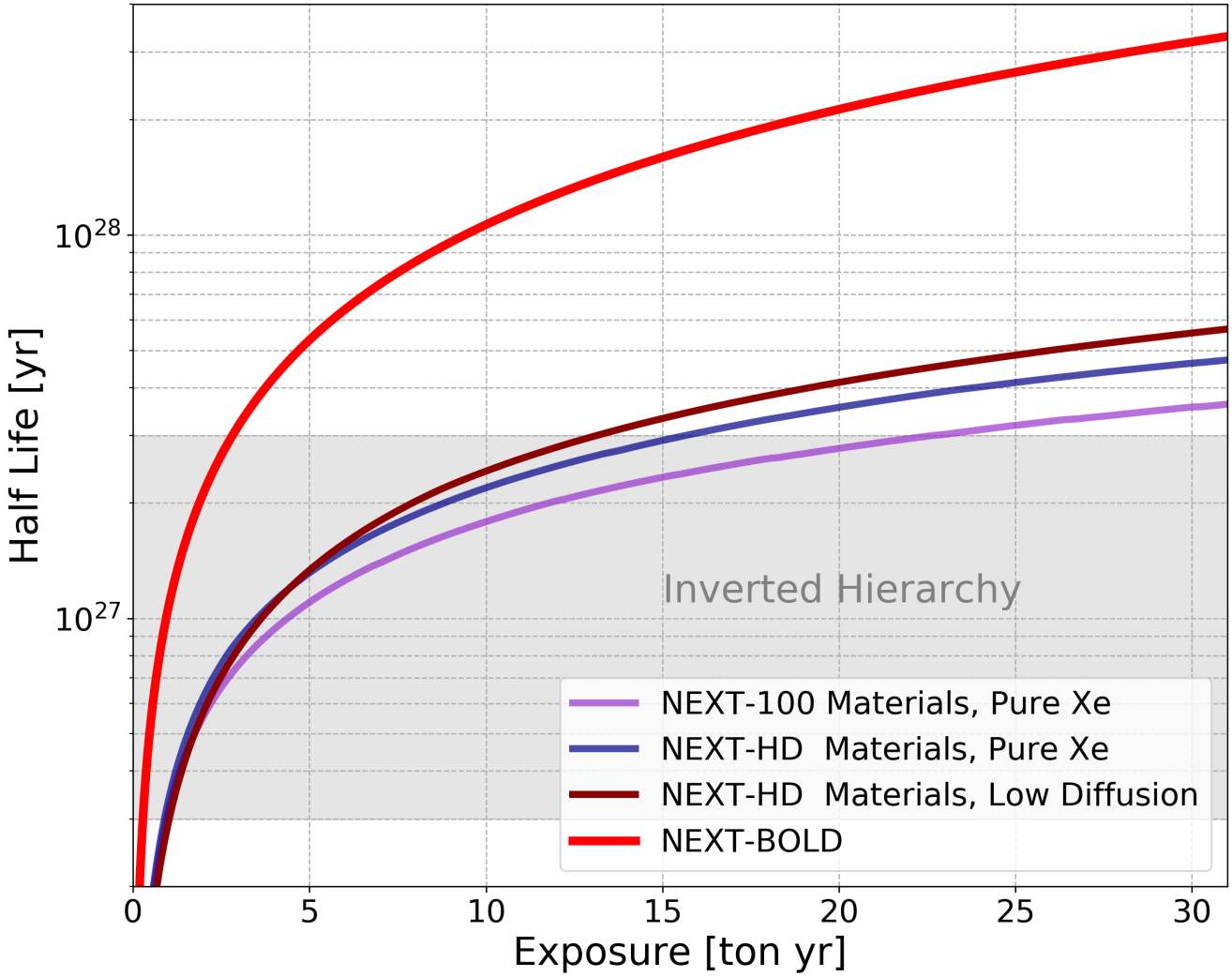
Ba^{++} ion / 10 bar argon



- **NEXT-BOLD would represent a dramatic sensitivity improvement through combination of signal efficiency increase and background reductions**



- **NEXT-BOLD would represent a dramatic sensitivity improvement through combination of signal efficiency increase and background reductions**



- **NEXT-BOLD would represent a dramatic sensitivity improvement through combination of signal efficiency increase and background reductions**

Conclusions

- NEXT is a phased program of high pressure xenon TPCs targeting an ultra-low background, ton-scale neutrinoless double beta decay experiment
- Results from NEXT-White validate technological performance
- NEXT-100 will demonstrate physics capability at 100kg scale with low background in xenon
- NEXT-HD extends demonstrated approaches to ton-scale, ongoing R&D continues to provide iterative (but substantial) performance improvements.
- Development of barium tagging technology for NEXT-BOLD may enable ultra-sensitive next-generation approach.