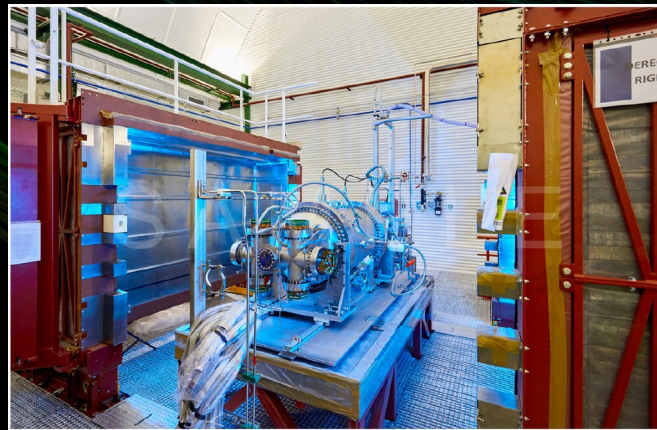


NEXT

Results from NEXT-White And Roadmap Toward the $\beta\beta 0\nu$ Search



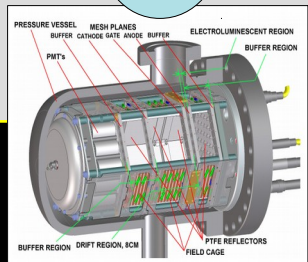
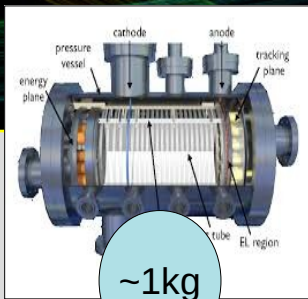
EPS-HEP Conference 2019, Ghent, Belgium

Pau Novella, IFIC (CSIC & U.V.)
On behalf of the NEXT Collaboration

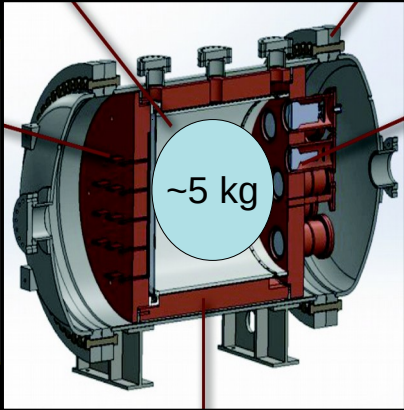
Overview: The NEXT Project

Search for the $\beta\beta 0\nu$ decay with a HPXe-TPC

R&D
Proof of Concept

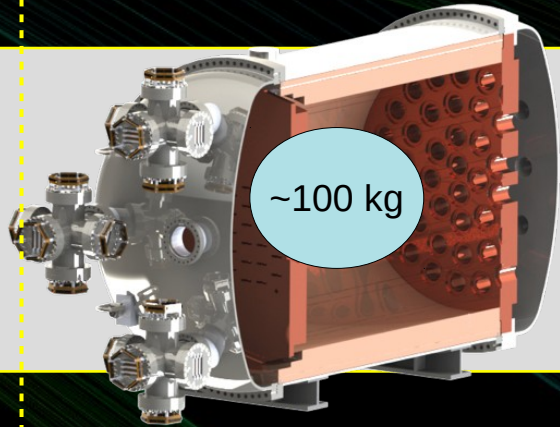


NEXT-White
Background+ $\beta\beta 2\nu$



2015-2019

NEXT-100 (+upgrades)
 $\beta\beta 0\nu$ search

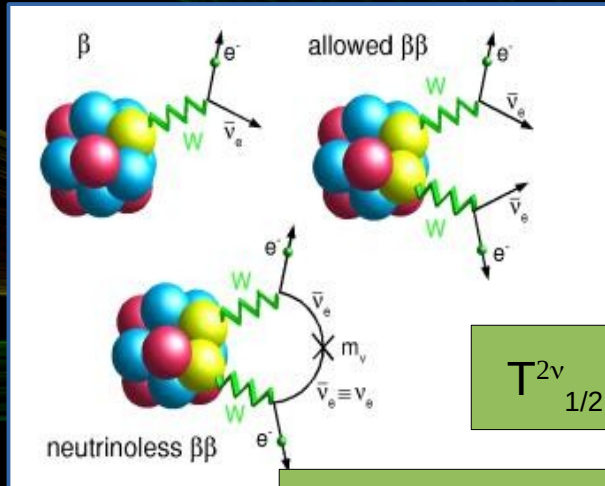


2019-2025

“NEXT-Tonne”
 $\beta\beta 0\nu$ search
In the IH land

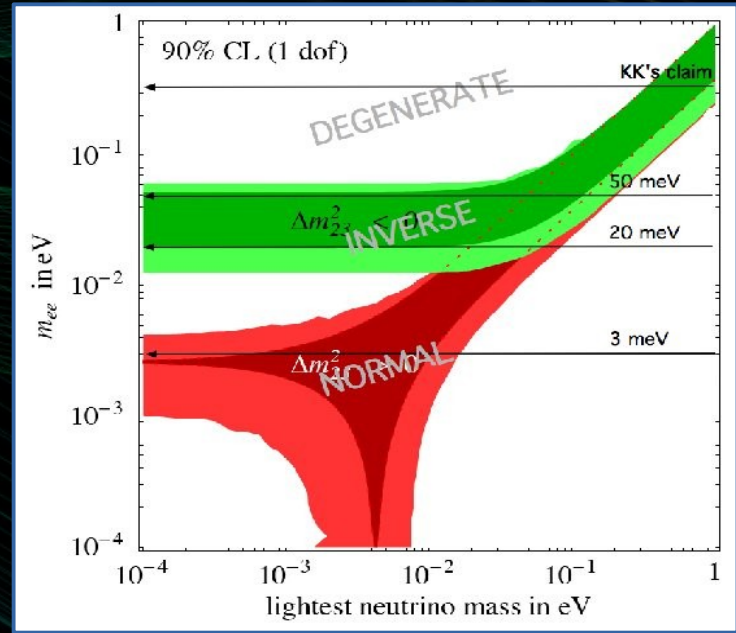
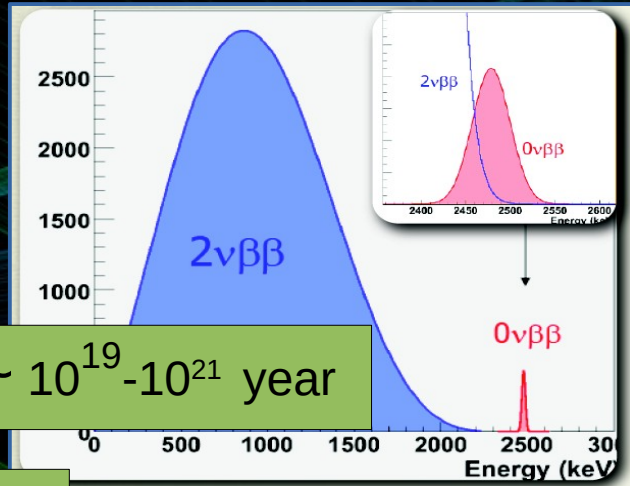
This talk

Searching for the $\beta\beta 0\nu$ decay



$T_{1/2}^{2\nu} \sim 10^{19} - 10^{21}$ year

$T_{1/2}^{0\nu} > 10^{25}$ year



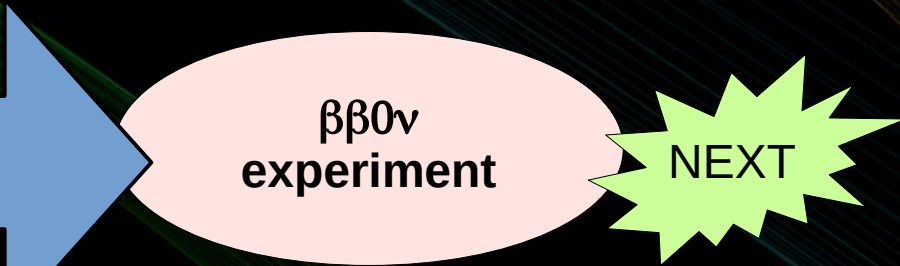
F. Feruglio et Al., Nucl. Phys. B 637 (2002)



Energy resolution

Background rejection

Scalability



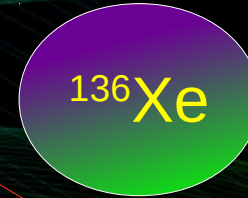
Calorimeters Tracko-calos

Bolometers

NEXT: HP Gas-Xe TPC

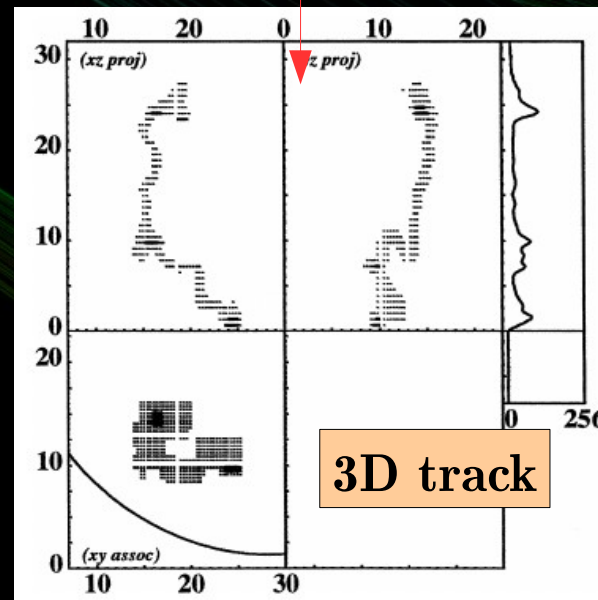
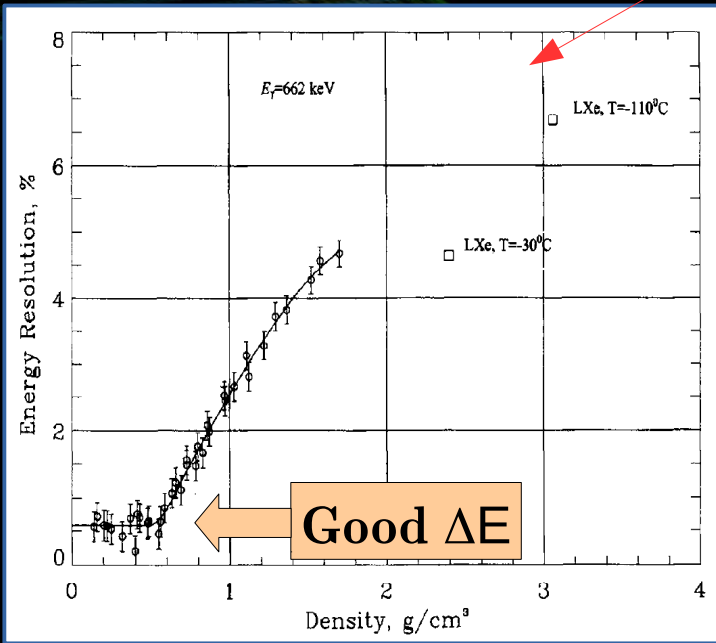
- Sensitivity to the $\beta\beta 0\nu$ decay:

$$T_{1/2}^{-1} \propto a \cdot \epsilon \cdot \sqrt{\frac{Mt}{\Delta E \cdot B}}$$

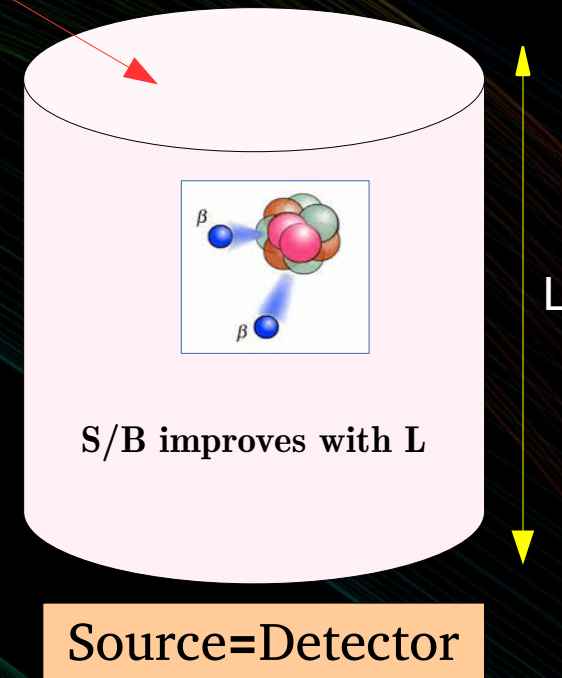


- $Q_{\beta\beta} = 2.48 \text{ MeV}$
- Scint/Ionization
- Cheap/Easy to enrich
- Long $\beta\beta 2\nu$ mode

Bolotnikov et Al. Nucl. Ins. Meth A 396 (1997)

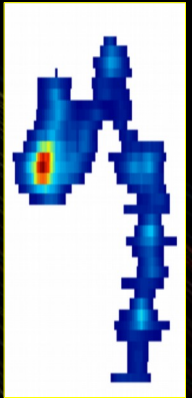
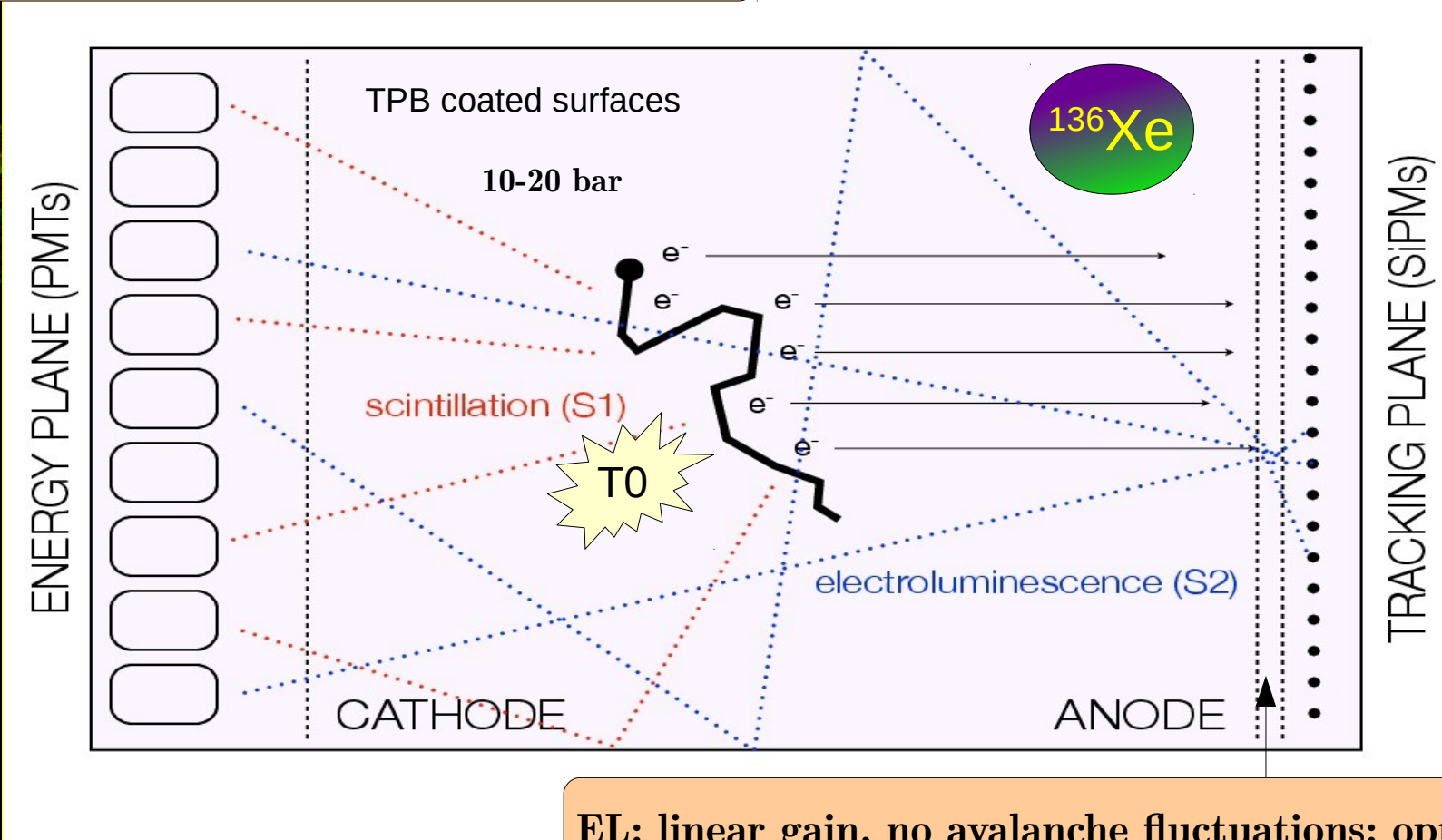
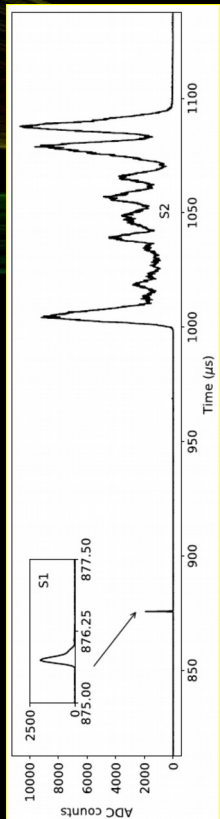


R. Luescher et al, PLB 434 (1998)



The NEXT TPC Concept

Gas TPC with 2 dedicated readout planes

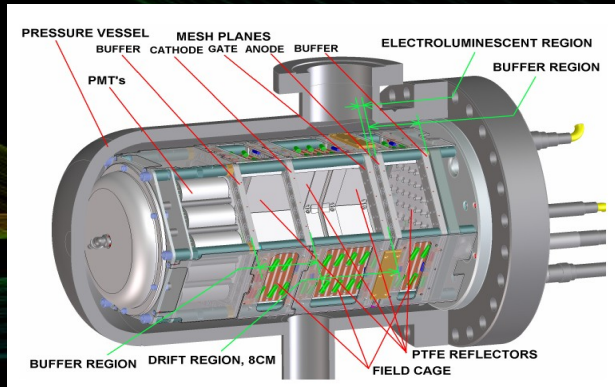


EL: linear gain, no avalanche fluctuations: optimize ΔE

R&D: Proving the technology

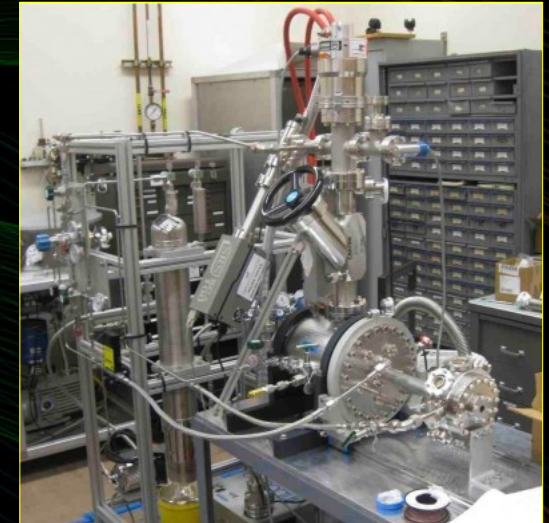
2012-2014

- The NEXT-DBDM @ LBL (1 kg Xe):



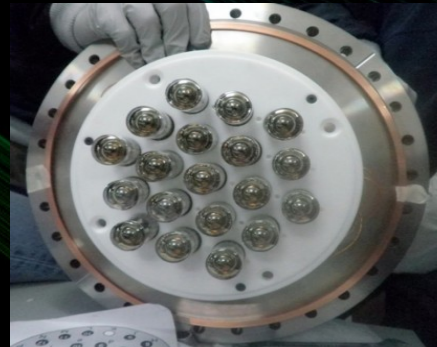
Gas Xe EL-TPC:
Energy resolution (only PMTs)

“Intrinsic” ΔE : 0.5% @ Q_{bb}



- The NEXT-DEMO @ IFIC (1.5 kg Xe):

Complete prototype: PMT+SiPM



ΔE in large volume: $\ll 1\%$ @ $Q_{\beta\beta}$

Proof of topological signature

Nucl.Ins.Meth. A708 (2013)

JINST 8 (2013) P0400

JINST 8 (2013) P09011

JINST 9 (2014) 10, P10007

JINST 8 (2013) P05025

JINST 10 (2015) 03, P0302

JHEP 1601 (2016) 1045



P. Novella, NEXT@EPS2019

NEXT-White: Physics @ LSC

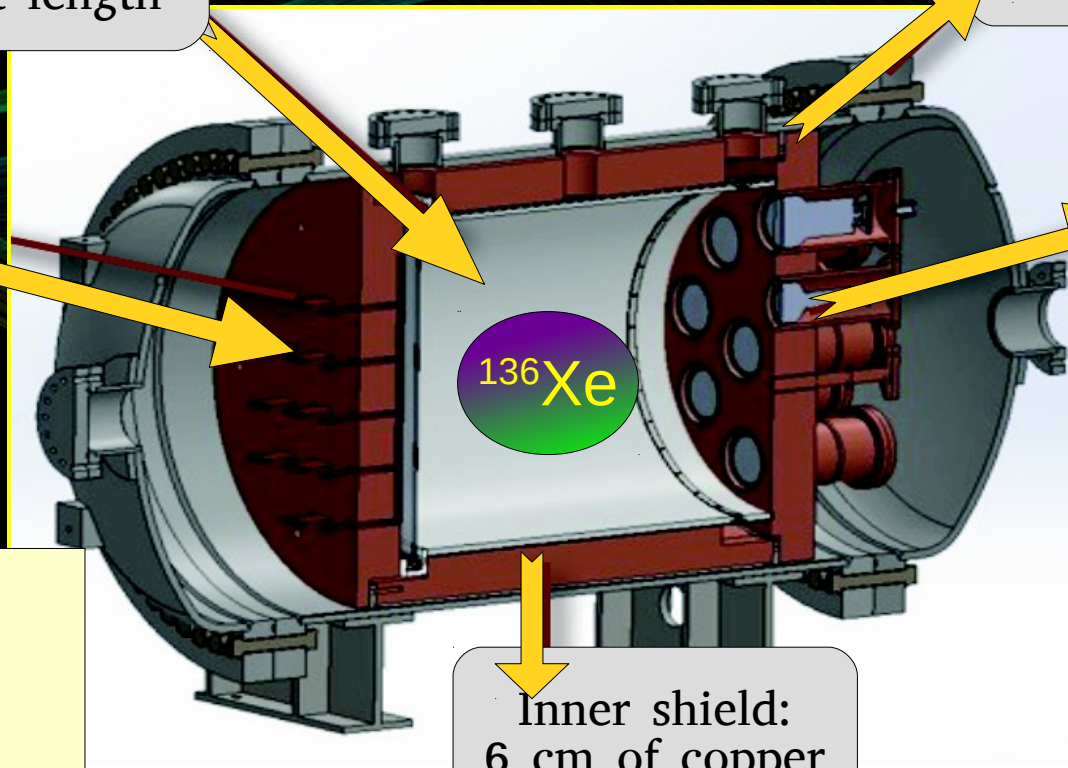
2015-2019

TPC:
5 kg active region
50 cm drift length

Pressure Vessel:
Steel, up to 30 bar

Tracking plane:
1792 SiPM
1 cm pitch

Energy Plane:
12 PMTs
30% coverage



Inner shield:
6 cm of copper

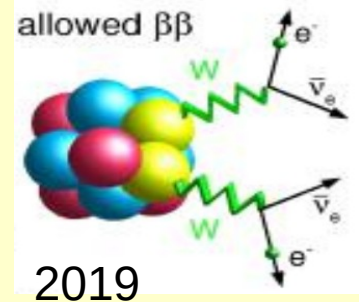
Physics program:

- $\Delta E < 1\%$ FWHM @ $Q_{\beta\beta}$
- Event Topology
- Certify technology
- BG Measurement (2019)

Achieved!

First phase of the NEXT-100 experiment

Ultimate goal:



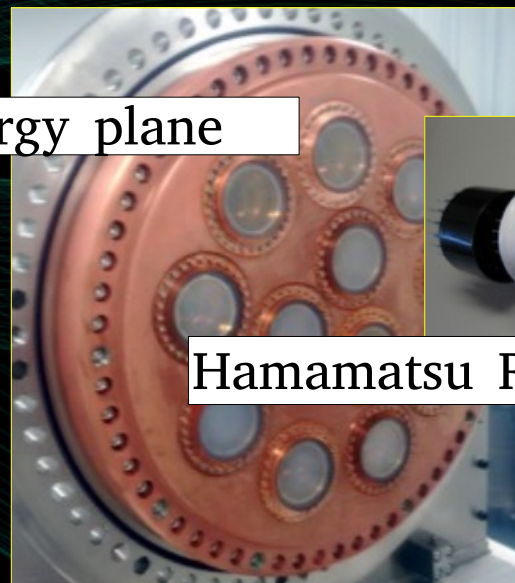
The NEXT-Withe Detector

Steel vessel



6cm inner Cu shield

Energy plane



Hamamatsu R11410-10



Field cage + teflon reflector

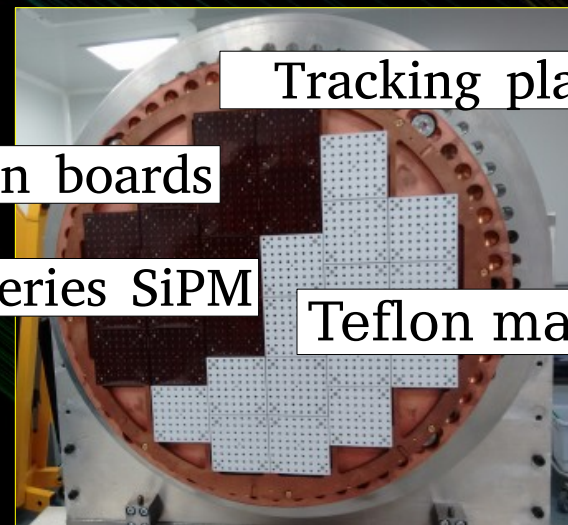


Kapton boards

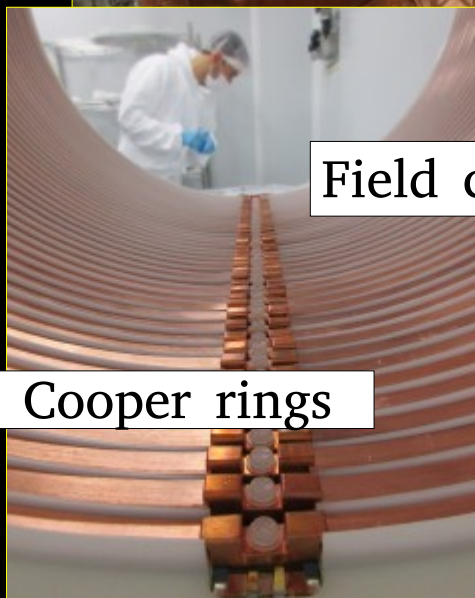
SensL C-series SiPM

Tracking plane

Teflon masks



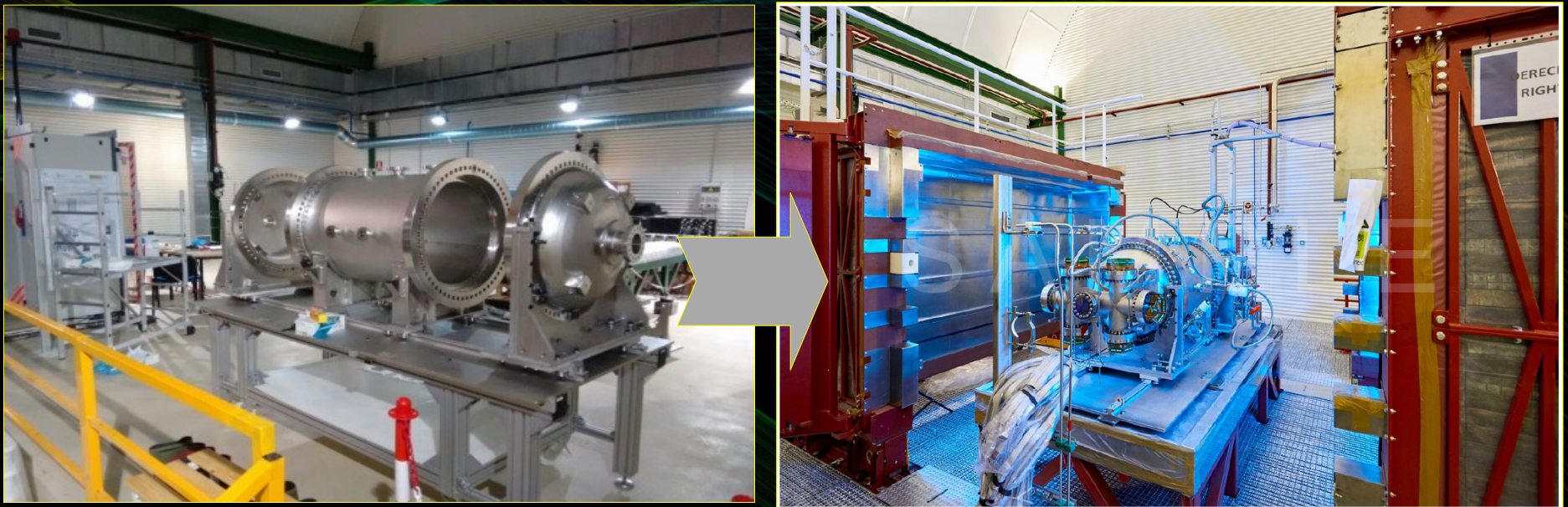
Cooper rings



JINST 13 (2018) no.12, P12010

NEXT-White @ LSC

- Infrastructures: seismic platform, lead castle, Rn abatement system
- Available xenon: 100 kg of ^{136}Xe and 100 kg of Xe depleted in ^{136}Xe ($\sim 3\text{-}5$ kg used)
- Installation/commissioning in 2015, stable operation since October 2016

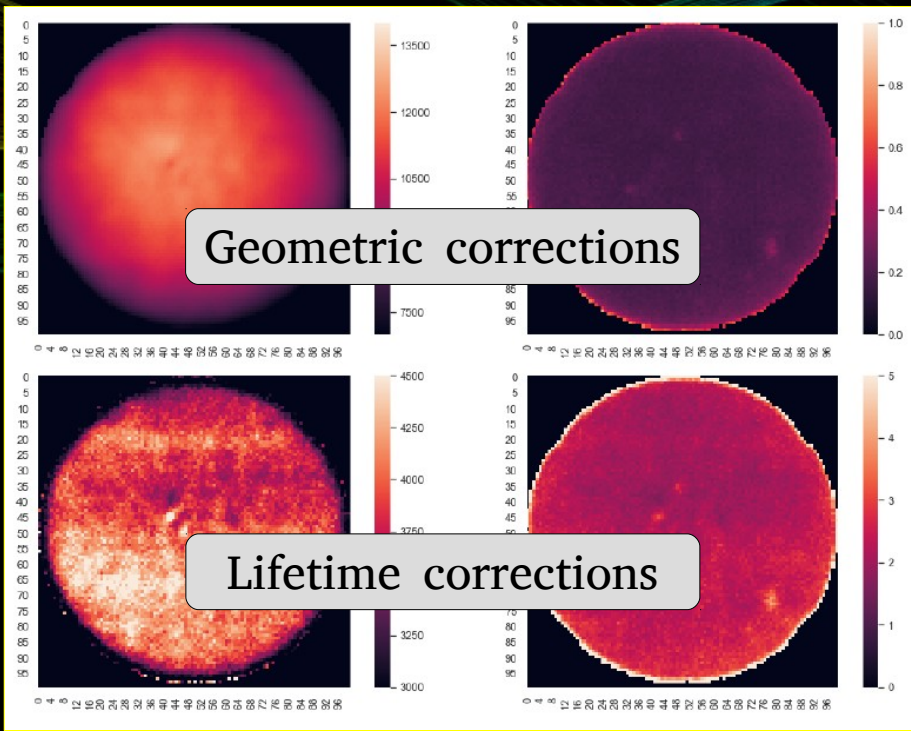


- Calibration campaigns @ 7/10 bar with depleted Xe: ^{83}Kr , ^{137}Cs , ^{228}Th (^{22}Na , ^{56}Co)
- 2018-2019: background measurement with depleted Xe (Run-IV)
- $\beta\beta 2\nu$ measurement ongoing with ~ 5 Kg of ^{136}Xe since Feb 2019 (Run-V)

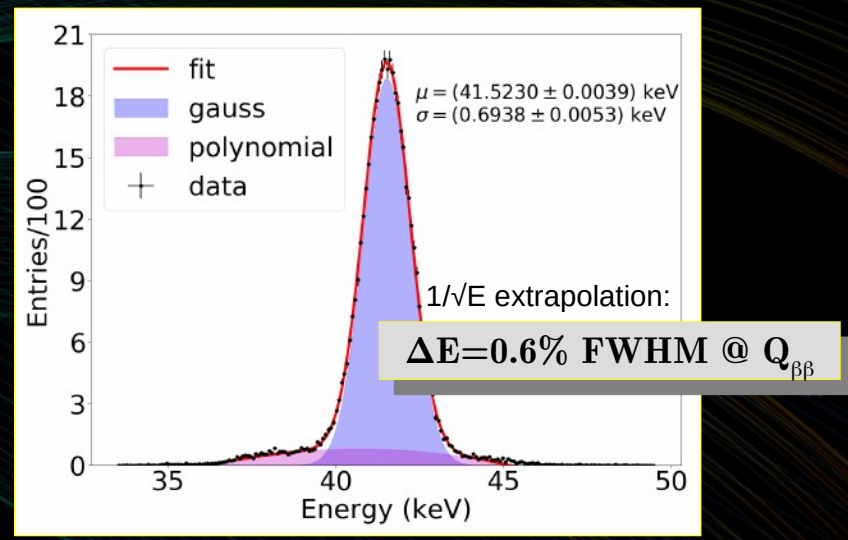
NEXT-White Calibration: ^{83m}Kr

- Point like source (41.5 keV) uniformly distributed in active volume (gas)

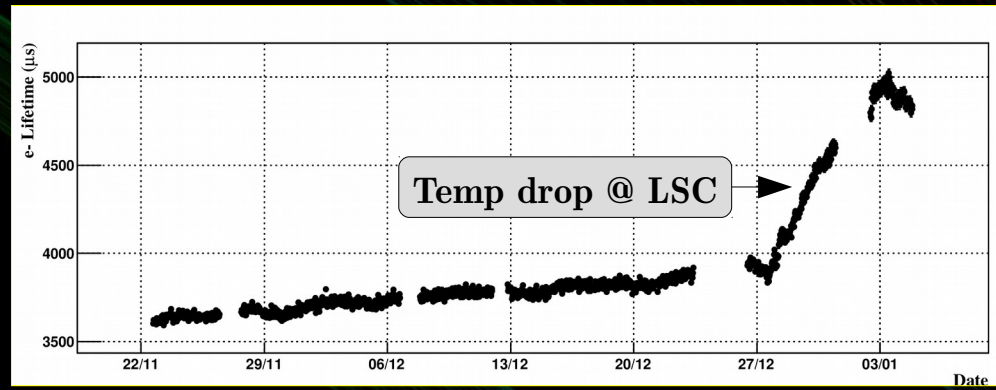
Calibration XY maps:



Energy resolution:



e- lifetime measurement and monitoring:

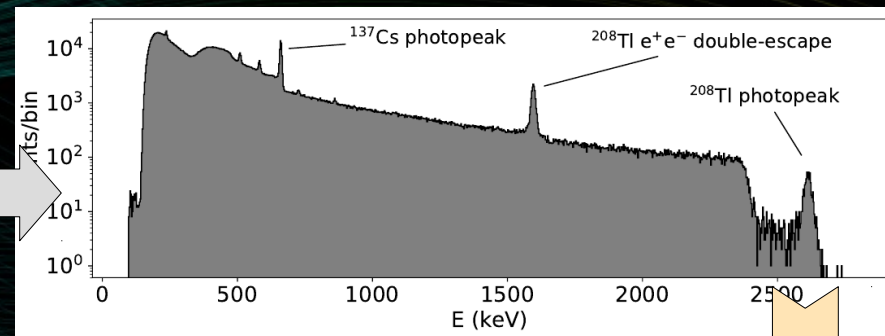
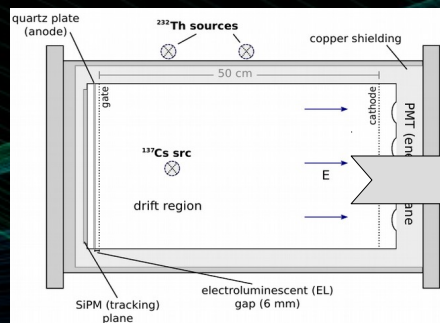
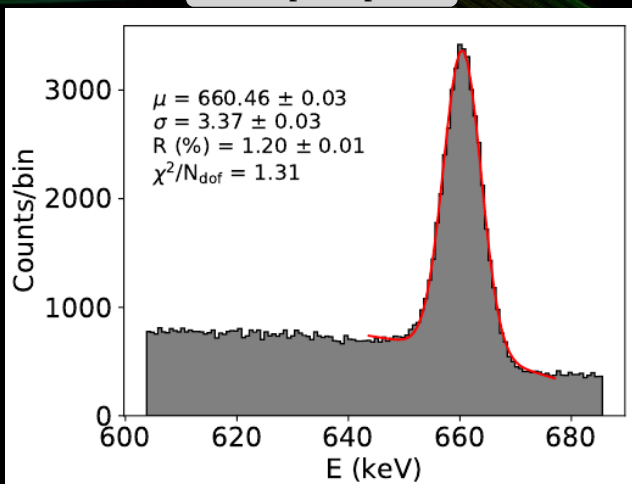
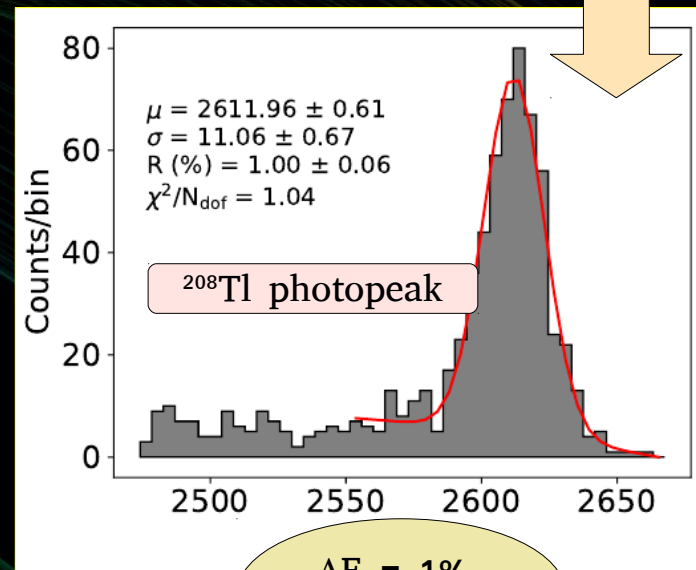
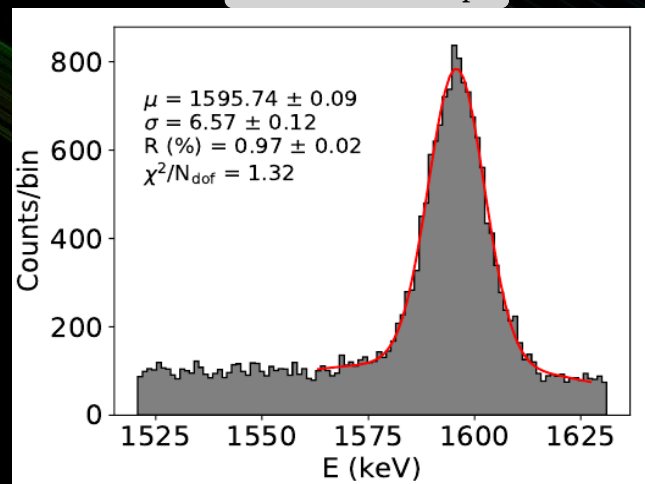


- Detector *continuously* calibrated
- JINST 13 (2018) no.10, P10014 (7bar)

NEXT-White Calibration: $^{208}\text{Tl}/^{137}\text{Cs}$

- $^{232}\text{Th}/^{137}\text{Cs}$ gamma-ray interactions from external sources

- Energy scale
- Energy resolution vs E
- Energy resolution @ $Q_{\beta\beta}$

 ^{137}Cs photopeak ^{208}Tl double-escape

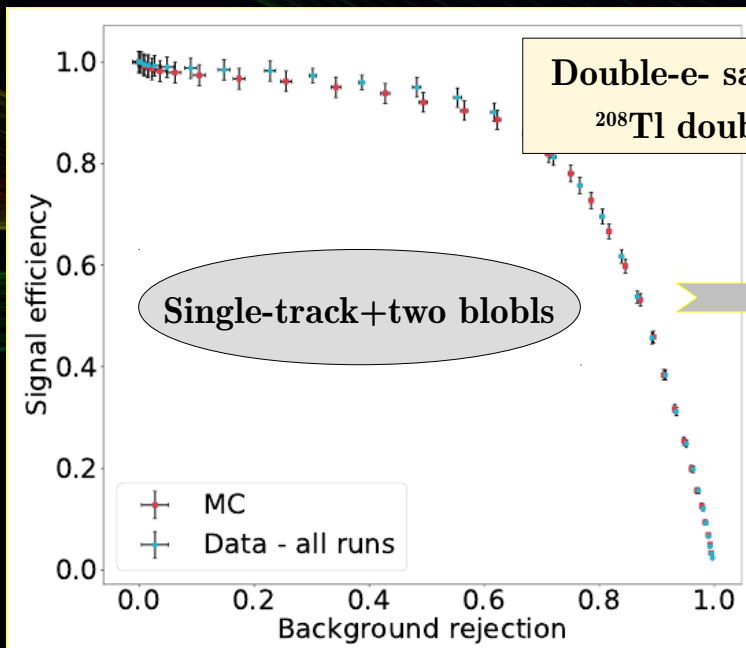
$\Delta E = 1\%$
FWHM @ $\sim Q_{\beta\beta}$

- ArXiv:1905:13110
- JINST 13 (2018) no.10, P10020 (7bar, only Cs and 1.6 MeV Tl peak)

Best energy resolution in Xe!

NEXT-White Topological Signal

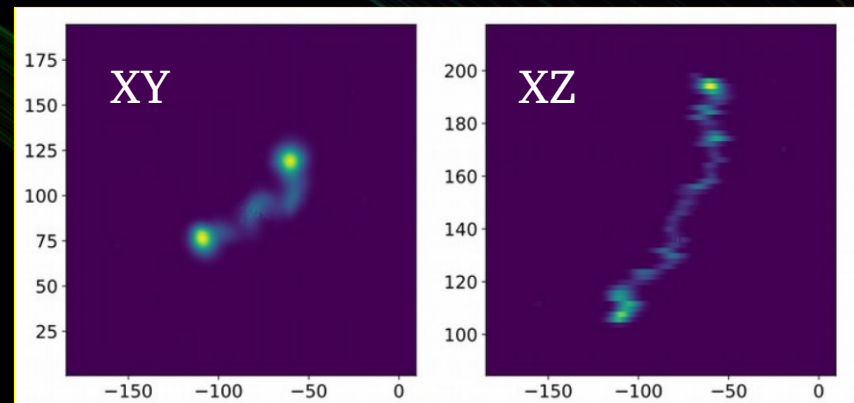
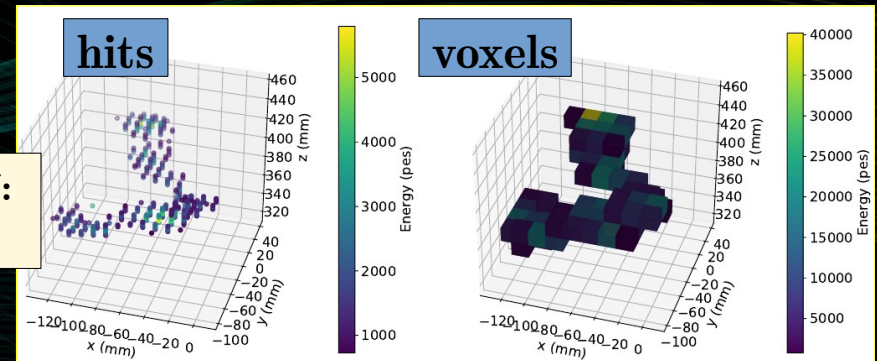
Signal efficiency/Background acceptance:



- 72% signal efficiency for 21% background acceptance (\sim MC)
- Performance improves at higher energies and larger volumes
- Room for improvement @ selection: DNNs
 - **JINST 12 (2017) no.01, T01004**
- Room for improvement @ Reconstruction:
 - Lucy-Richardson deconvolution:

- **ArXiv: 1905.13141** (submitted to JHEP)
- **Improvement w.r.t. DEMO: JHEP 1601 (2016) 1045**

Preliminary $\beta\beta 0\nu$ [2.3-2.7 MeV] MC studies:
 \sim 90% signal efficiency for \sim 10% background acceptance



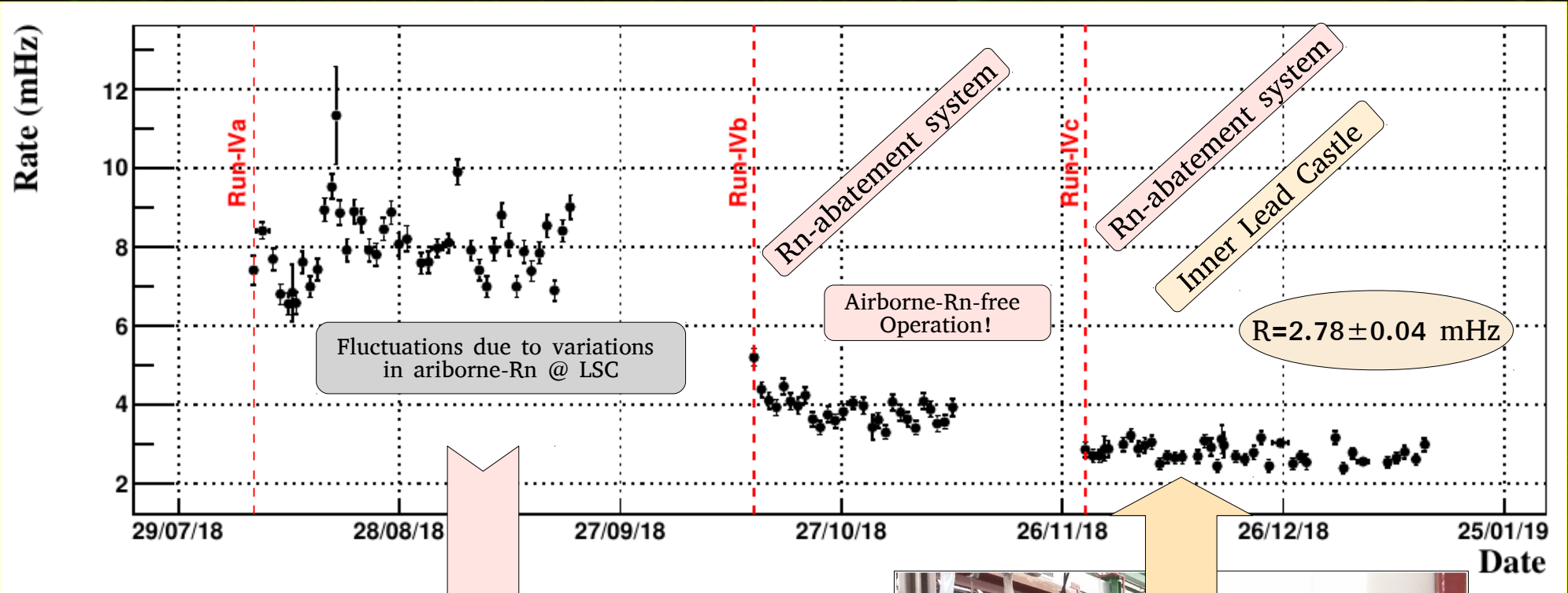
10 bar

Depleted Xe

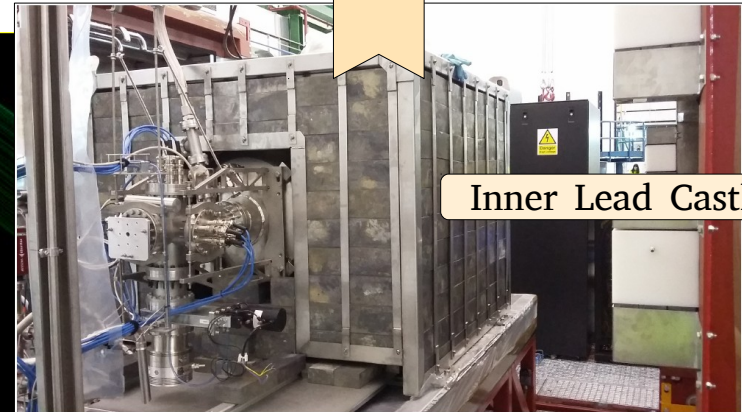
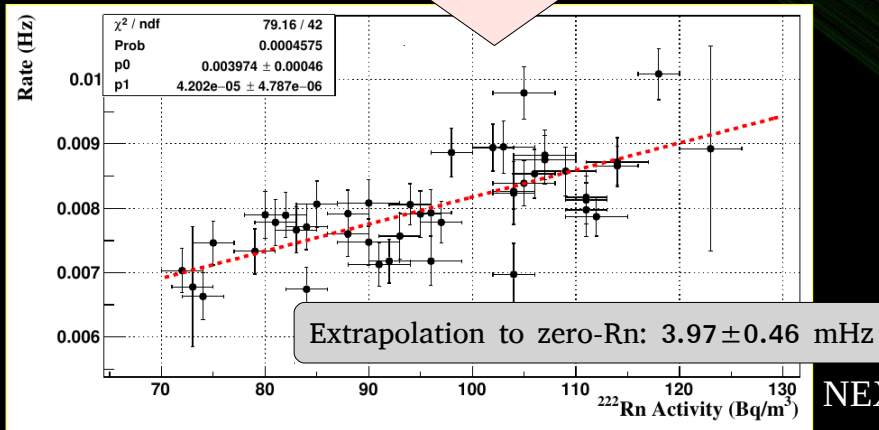
NEXT-White Background

- Rate of fiducial events with $E > 600$ keV:

arXiv:1905.13625 (submitted to JHEP)



Rn-induced BG measurement:
JHEP 1810 (2018) 112

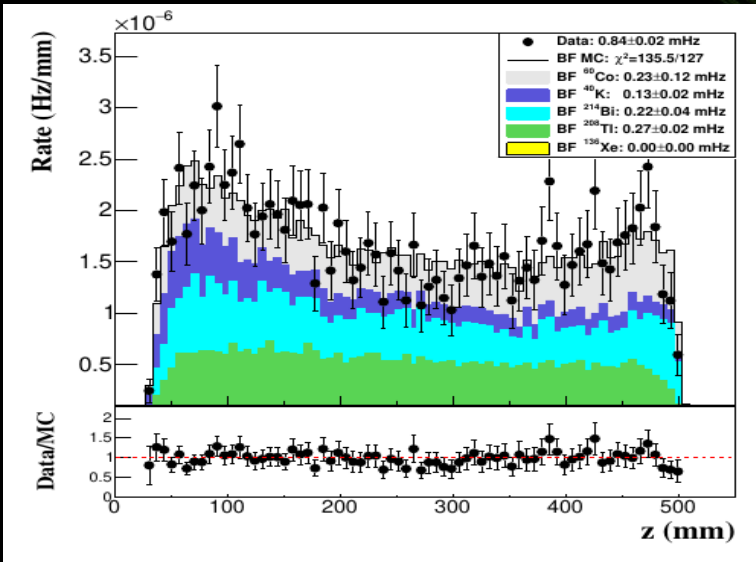
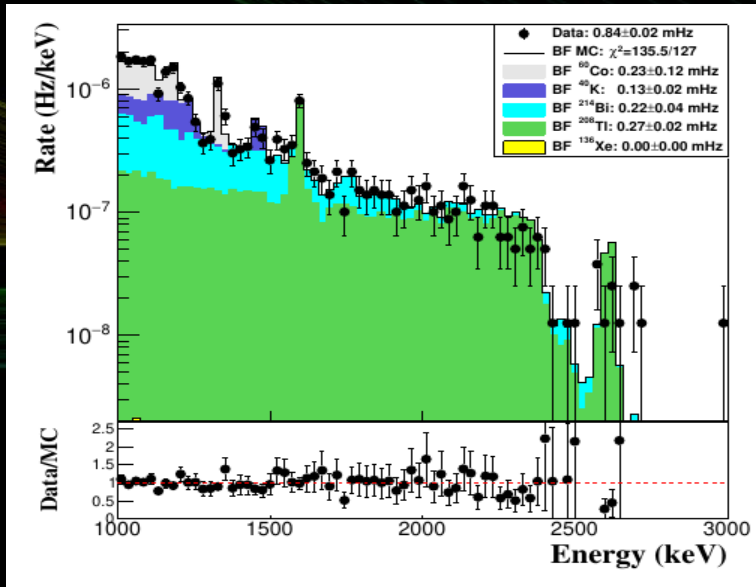


10 bar

Depleted Xe

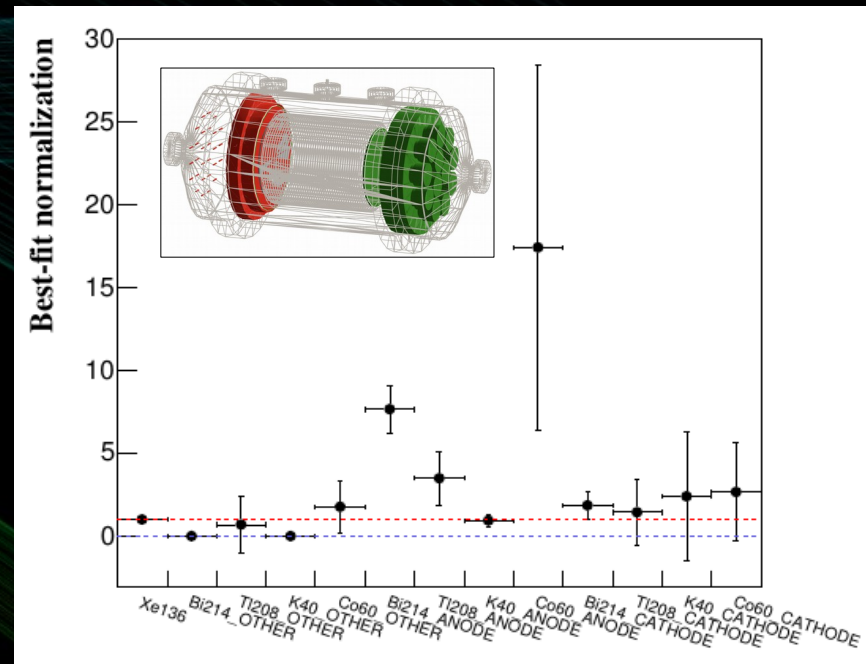
NEXT-White Background (II)

- Background model based on extensive radio-purity campaign (JINST 8 (2013) T01002, JINST 10 (2015) 05, P05006)
- Four isotopes (^{214}Bi , ^{208}Tl , ^{60}Co , ^{40}K) and 84 sources considered



- Fiducial background fit:
- R+S(E+Z), 4 isotopes from 3 effective volumes

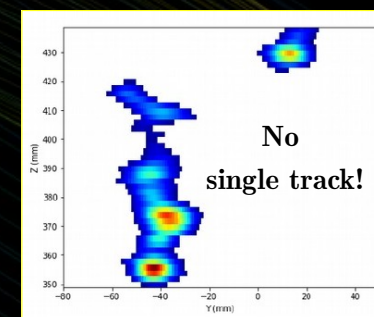
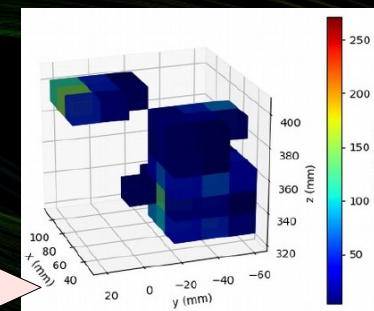
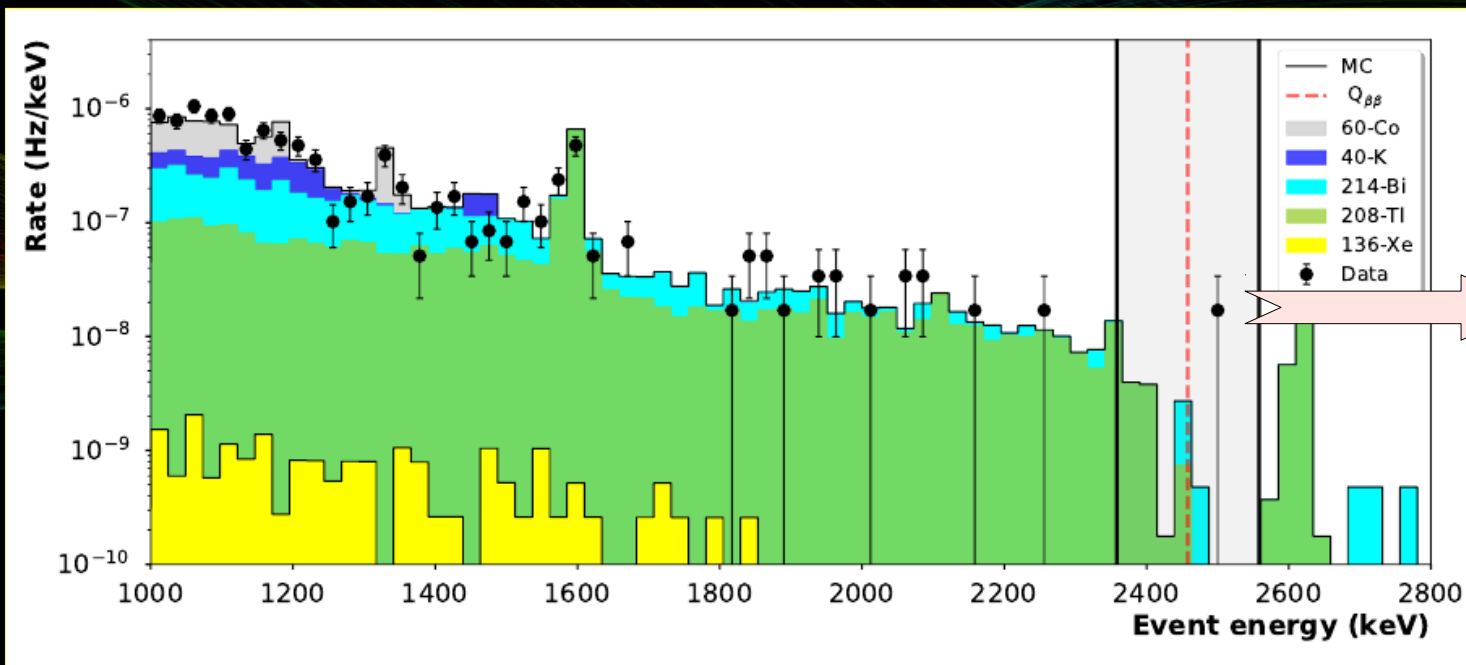
arXiv:1905.13625 (submitted to JHEP)



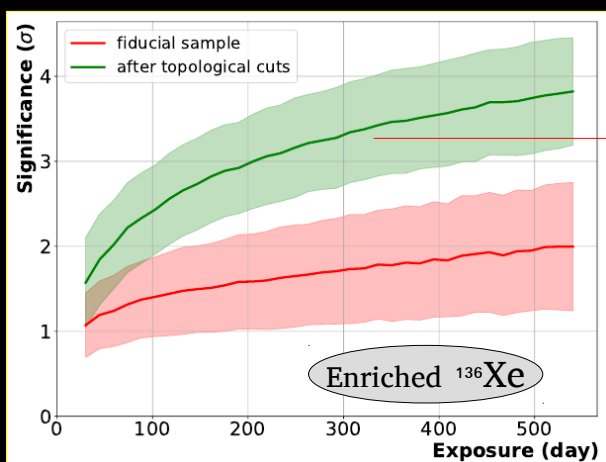
- Measurement of each isotope contribution
- Sensitivity to spatial origin of backgrounds
- Background model validated (some excess @ anode)
- Model validated: background expectation in $\beta\beta$ analyses

NEXT-White $\beta\beta$ Backgrounds

- Topological selection \rightarrow single-track with two blobs:



Lucy-Richardson decon.



- Background rate > 1 MeV: 0.248 ± 0.10 mHz
- $\beta\beta 2\nu$ $T_{1/2}$ 3σ measurement after 300 days with ^{136}Xe (5kg!)
- Background in $Q_{\beta\beta} \pm 100$ keV consistent with expectation
- Topological rejection factor in $Q_{\beta\beta} \pm 100$ keV: ~ 17
- Room for improvement: data samples, reconstruction and selection

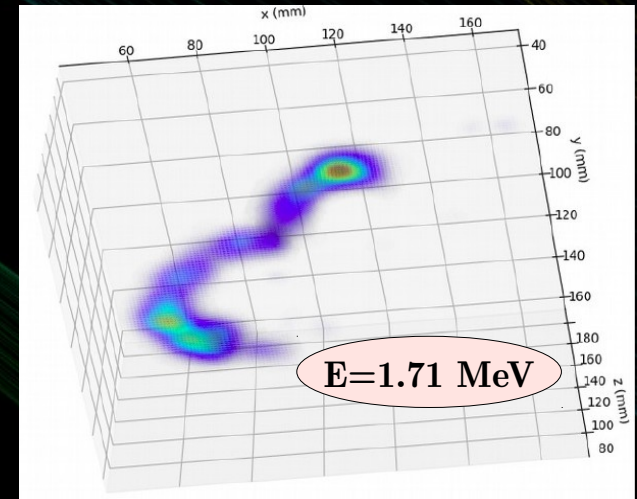
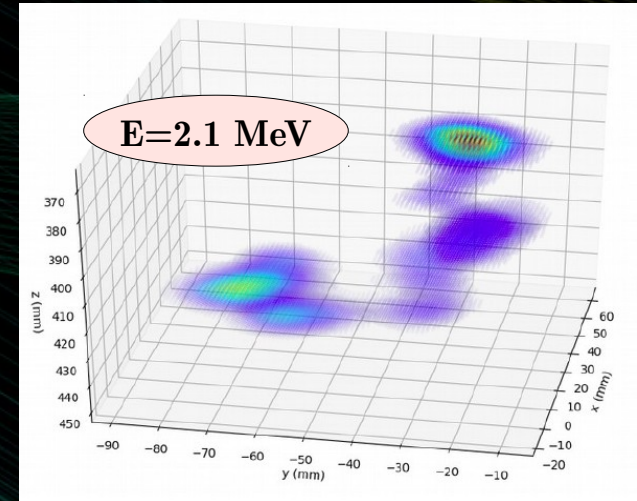
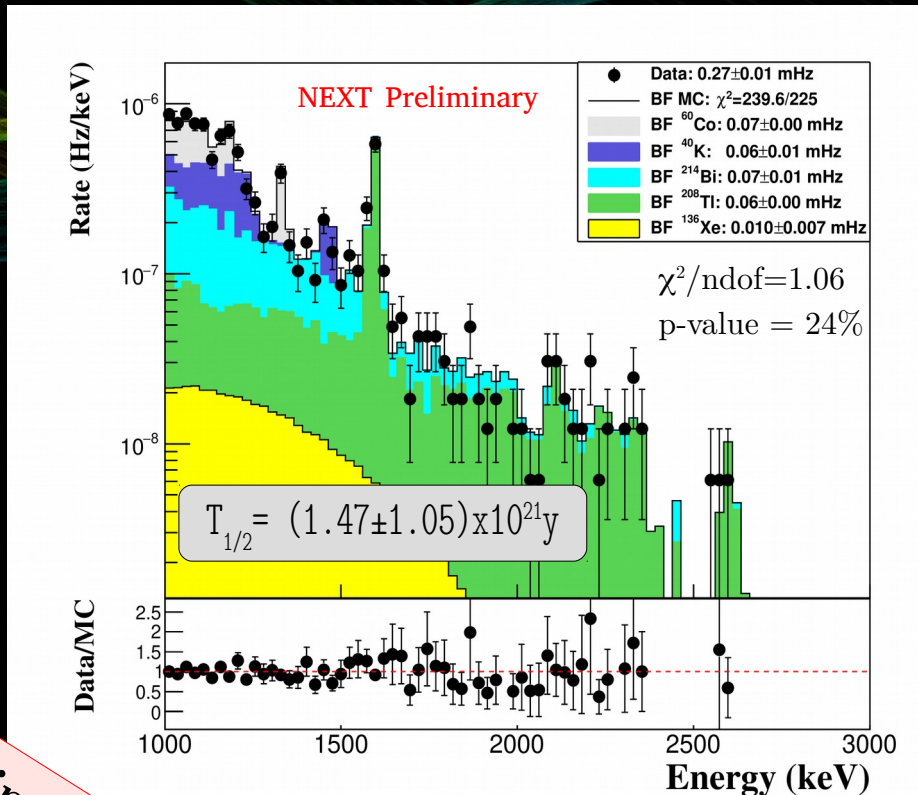
10 bar

Enriched ^{136}Xe

$\beta\beta 2\nu$ @ NEXT-White

- NEXT-White operated with ~ 5 kg of ^{136}Xe since Feb 2019 (Run-V)
- $\beta\beta 2\nu$ analysis using Run-IV and Run-V data:

78 days of ^{136}Xe data (Run-V)



^{136}Xe $\beta\beta$ track candidates

Work in progress!

- Error consistent with sensitivity studies
- EXO-200: $T_{1/2} = (2.17 \pm 0.06) \times 10^{21} \text{y}$

The NEXT-100 Detector

JINST 7 (2012) T06001

2019-2023

TPC:
100 kg active region
130 cm drift length

Pressure Vessel:
Steel, up to 15 bar

Energy Plane:
60 PMTs
30% coverage

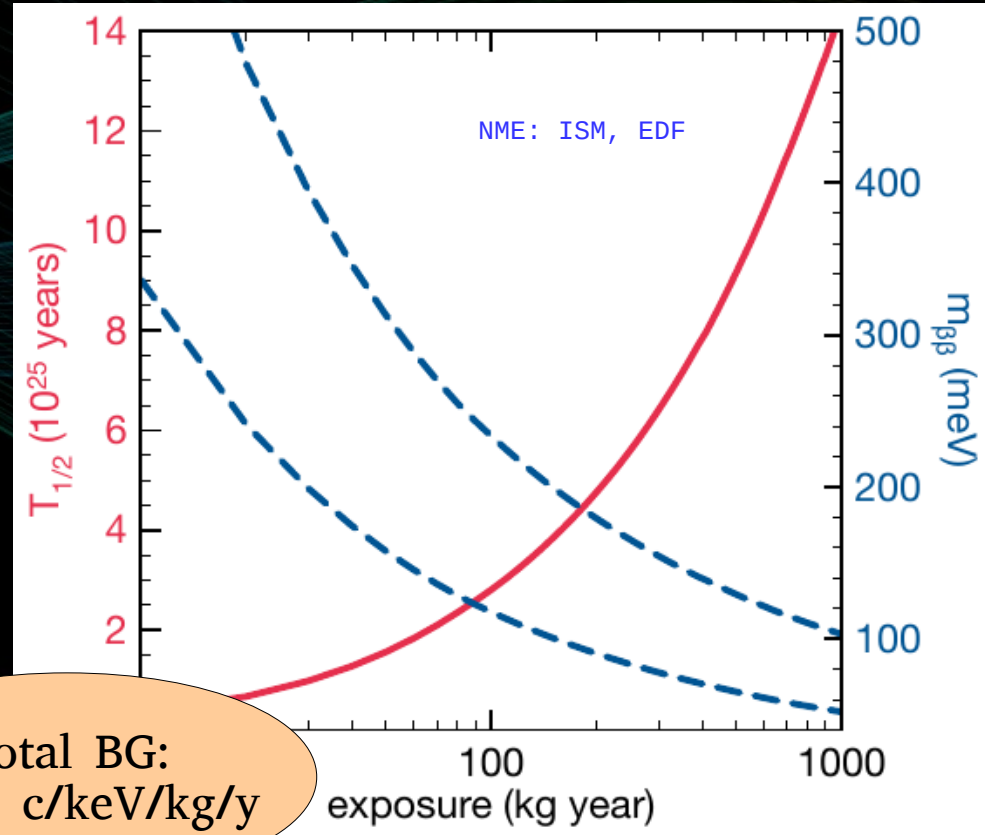
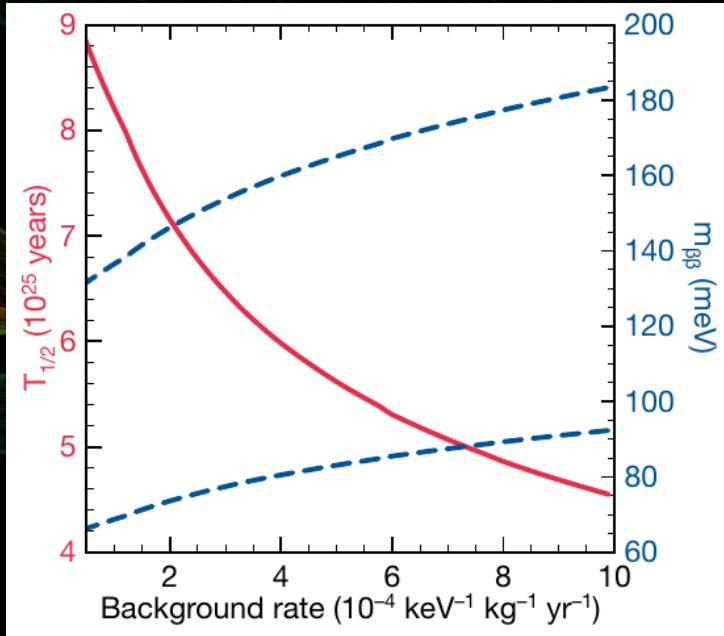
Tracking plane:
4000-7000 SiPM
1.0-1.5 cm pitch

Inner shield:
12 cm of copper

- 2019-2020: construction
- 2020: commissioning
- 2021: physics

Fully funded!

Physics Case of NEXT-100



Background model
 Background rejection
 ~validated with NEXT-White!

Total BG:
 $5 \times 10^{-4} \text{ c/keV/kg/y}$

$m_{\beta\beta} < 70\text{-}130 \text{ meV @ 90\% CL (5 years of data)}$

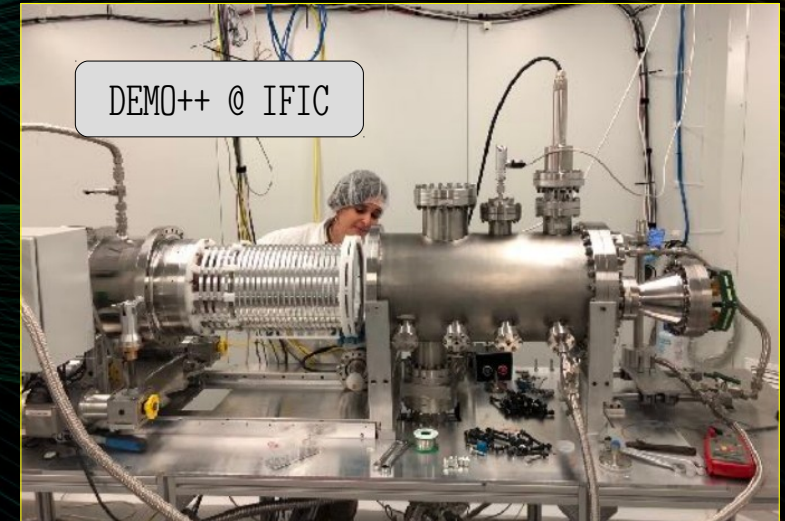
- Prove technology for ton-scale (+ gas additives, Ba tagging...)

NEXT @ Ton-Scale: R&D

- Goal: explore the IH region with a HPXe-TPC
- *Incremental approach* towards a ton-scale detector

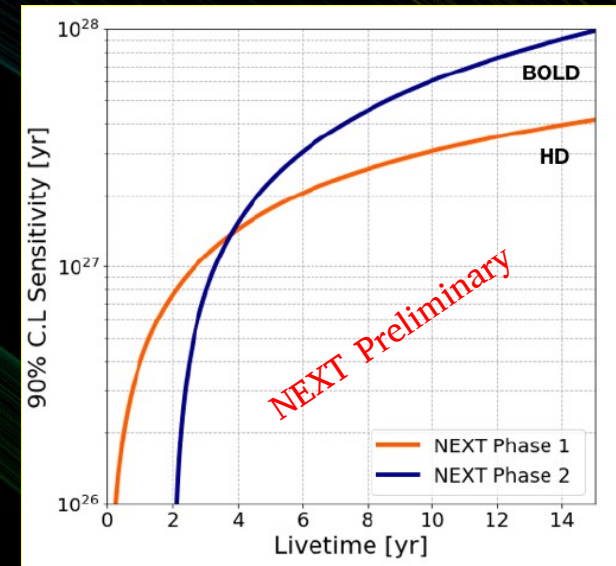
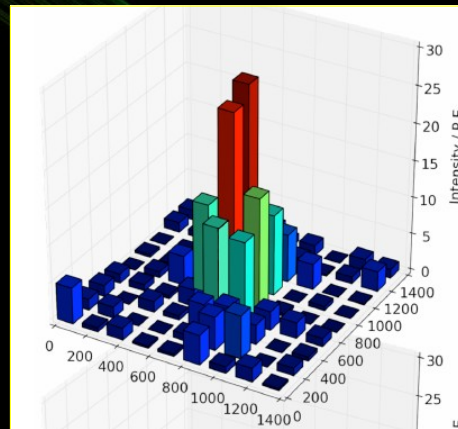
NEXT-HD

- SiPM instead of PMTs (main background source)
- Operation at low temperatures (reduce dark noise)
- Low diffusion gas mixtures (topological signature)
- R&D: DEMO++ (IFIC) and AXOLOTEL (BGU)
- [ArXiv: 1906.01743](#)

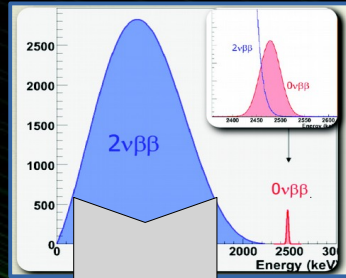
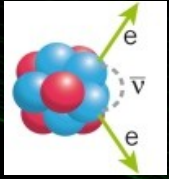


NEXT-BOLD

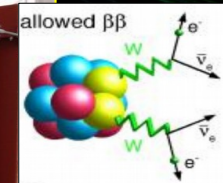
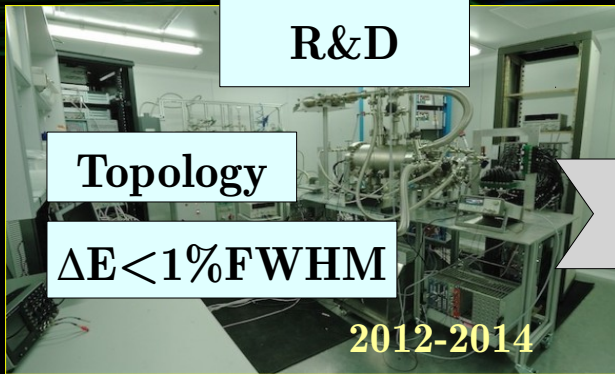
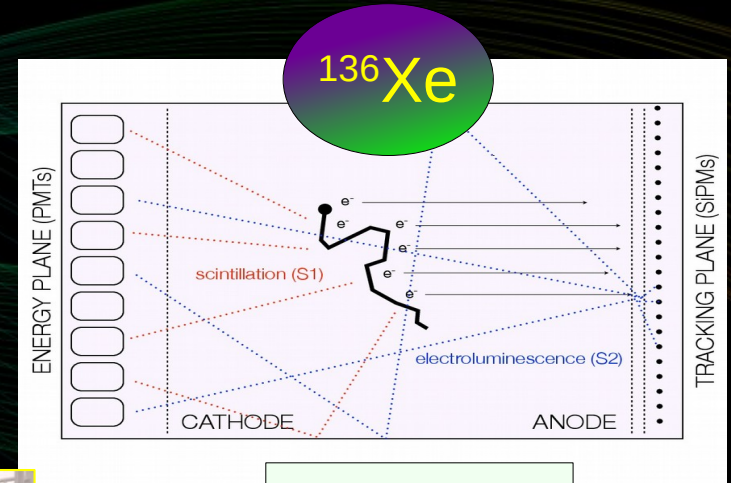
- Ba++ tagging using SMFI
- R&D: UTA and DIPC
- [PRL 120 \(2018\) 132504](#)



Summary

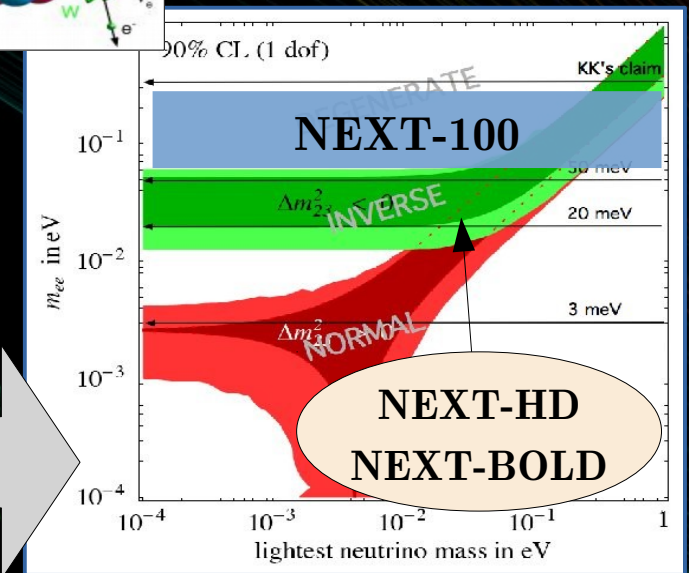
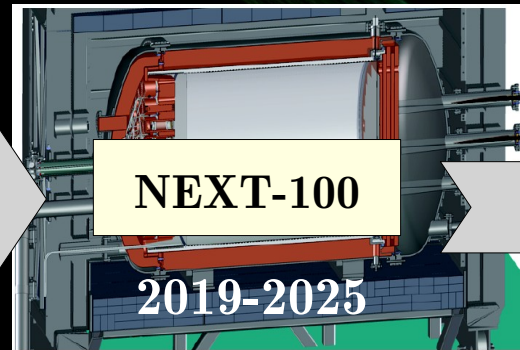


- Energy resolution
- Background rejection
- Scalability



Gas Xe TPC

- $\Delta E < 1\% @ Q_{\beta\beta}$
- Topo. BG rejection
- BG model validated
- Next: $\beta\beta 2\nu$ (2019)



The NEXT Collaboration



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



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



Aveiro · Coimbra LIBPhys · Coimbra LIP



A. Nariño



BGU

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

