NEXT

Results from NEXT-White

And Roadmap Toward the $\beta\beta_{0v}$ Search

EPS-HEP Conference 2019, Ghent, Belgium

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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+$\beta\beta_{2\nu}$

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

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

This talk

2009-2014

~1kg

2015-2019

~5 kg

2019-2025

~100 kg

P. Novella, NEXT@EPS2019
Searching for the $\beta\beta 0\nu$ decay

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

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

Energy resolution
Background rejection
Scalability

$\beta\beta 0\nu$ experiment

NEXT

Calorimeters
Tracko-calos
Bolometers

NEXT: HP Gas-Xe TPC

- Sensitivity to the $\beta\beta0\nu$ decay:

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

- $Q_{\beta\beta} = 2.48$ MeV
- Scint/Ionization
- Cheap/Easy to enrich
- Long $\beta\beta2\nu$ mode

R. Luescher et al, PLB 434 (1998)

Good $\Delta E$

3D track

Source = Detector

S/B improves with L
The NEXT TPC Concept

Gas TPC with 2 dedicated readout planes

TPB coated surfaces

10-20 bar

$^{136}$Xe

EL: linear gain, no avalanche fluctuations: optimize $\Delta E$
R&D: Proving the technology

2012-2014

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

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

“Intrinsic” $\Delta E$: 0.5% @ $Q_{bb}$

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

Complete prototype: PMT+SiPM

$\Delta E$ in large volume: $<1\%$ @ $Q_{bb}$
Proof of topological signature

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
**NEXT-White: Physics @ LSC**

**TPC:**
- 5 kg active region
- 50 cm drift length

**Pressure Vessel:**
- Steel, up to 30 bar

**Energy Plane:**
- 12 PMTs
- 30% coverage

**Tracking plane:**
- 1792 SiPM
- 1 cm pitch

**Inner shield:**
- 6 cm of copper

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

**Ultimate goal:**
- Physics program:
  - $\Delta E<1\%$ FWHM @ $Q_{\beta\beta}$
  - Event Topology
  - Certify technology
  - BG Measurement (2019)

**First phase of the NEXT-100 experiment**

P. Novella, NEXT@EPS2019
The NEXT-Withe Detector

- Steel vessel
- 6cm inner Cu shield
- Field cage + teflon reflector
- Cooper rings
- Energy plane
- Hamamatsu R11410-10
- Tracking plane
- Kapton boards
- SensL C-series SiPM
- Teflon masks

JINST 13 (2018) no.12, P12010
P. Novella, NEXT@EPS2019
NEXT-White @ LSC

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

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

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

- Calibration XY maps:
  - Geometric corrections
  - Lifetime corrections

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

- e- lifetime measurement and monitoring:

- $\Delta E = 0.6\%$ FWHM @ $Q_{\beta\beta}$

- $1/\sqrt{E}$ extrapolation:

- Temp drop @ LSC
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 @ $Q_{\beta\beta}$

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 (~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$0v [2.3-2.7 MeV] MC studies:
- ~90% signal efficiency for ~10% background acceptance
NEXT-White Background

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

$10$ bar

Depleted Xe

arXiv:1905.13625 (submitted to JHEP)
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

- 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

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NEXT-White $\beta\beta$ Backgrounds

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

- Background rate $> 1$ MeV: $0.248 \pm 0.10$ mHz
- $\beta\beta2\nu T_{1/2}$ $3\sigma$ measurement after 300 days with $^{136}$Xe (5 kg!)
- Background in $Q_{\beta\beta} \pm 100$ keV consistent with expectation
- Topological rejection factor in $Q_{\beta\beta} \pm 100$ keV: $\sim 17$
- Room for improvement: data samples, reconstruction and selection

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**ββ2ν @ NEXT-White**

- NEXT-White operated with ~5 kg of $^{136}$Xe since Feb 2019 (Run-V)
- $ββ2ν$ analysis using Run-IV and Run-V data:

  - $\chi^2$/ndof = 1.06
  - p-value = 24%
  - $T_{1/2} = (1.47 \pm 1.05) \times 10^{21}$ y
  - Error consistent with sensitivity studies
  - **EXO-200**: $T_{1/2} = (2.17 \pm 0.06) \times 10^{21}$ y

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

Enriched $^{136}$Xe

Work in progress!

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The NEXT-100 Detector

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

2019-2023

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

Fully funded!
Physics Case of NEXT-100

- **Background model**
- **Background rejection**

![Graph showing background rate vs. background rejection](image)

**Total BG:**

$5 \times 10^{-4}$ c/keV/kg/y

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

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

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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

- R&D
- Topology
  - $\Delta E < 1\%$ FWHM
  - 2012-2014

- NEXT-White
  - Since 2016

- NEXT-HD
  - NEXT-100
  - NEXT-BOLD
  - NEXT-White

- $\Delta E < 1\% @ Q_{\beta\beta}$
- Topo. BG rejection
- BG model validated
- Next: $\beta\beta 2\nu$ (2019)
- NEXT-100
  - 2019-2025
The NEXT Collaboration

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