The nEXO experiment

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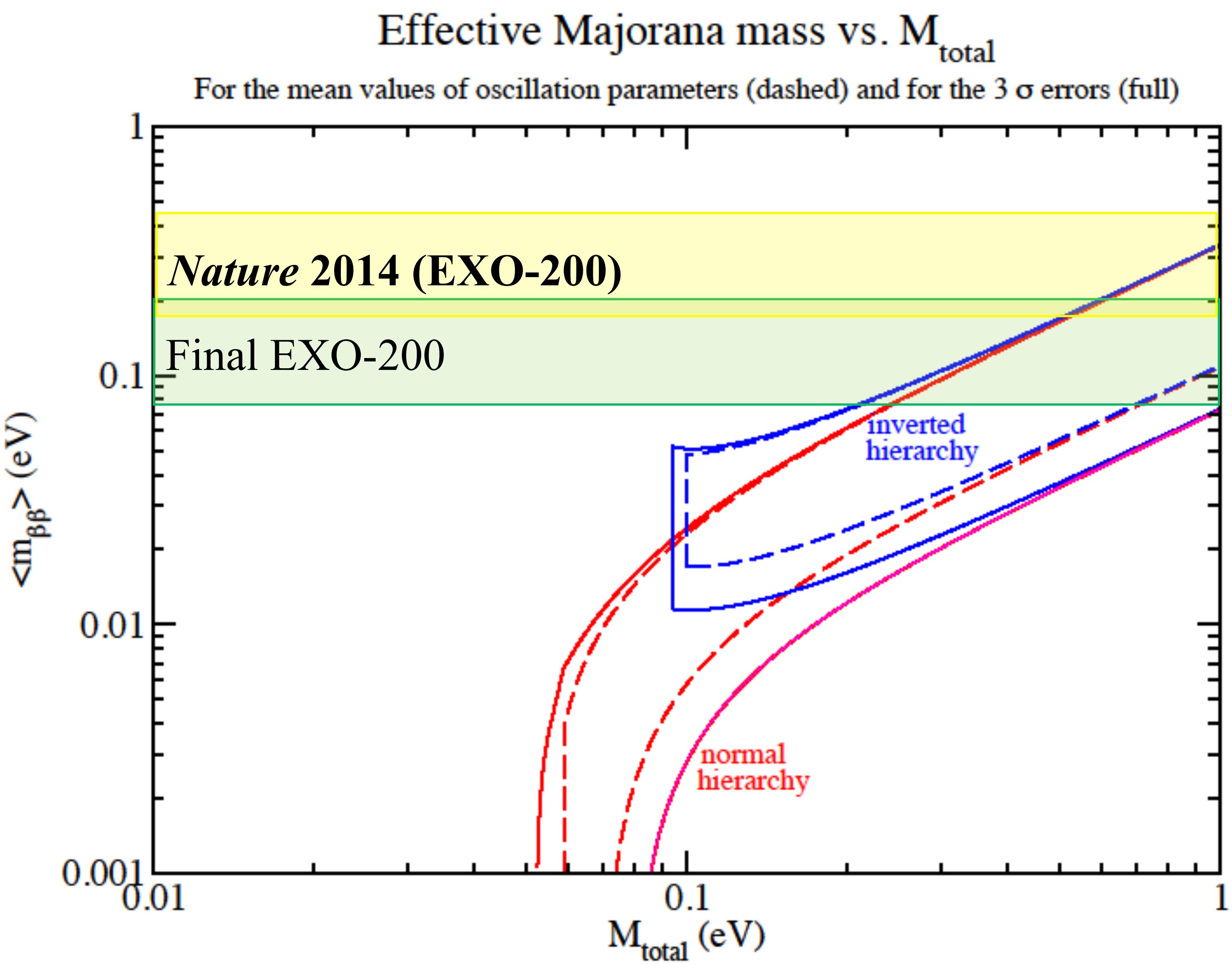
for the nEXO Collaboration

Motivation

- Current searches have not yet observed 0νββ
- The goal of the next generation of experiments is to push sensitivity down to cover the inverted hierarchy
- This requires >10 ton-year exposures along with corresponding reductions in backgrounds



The nEXO Collaboration

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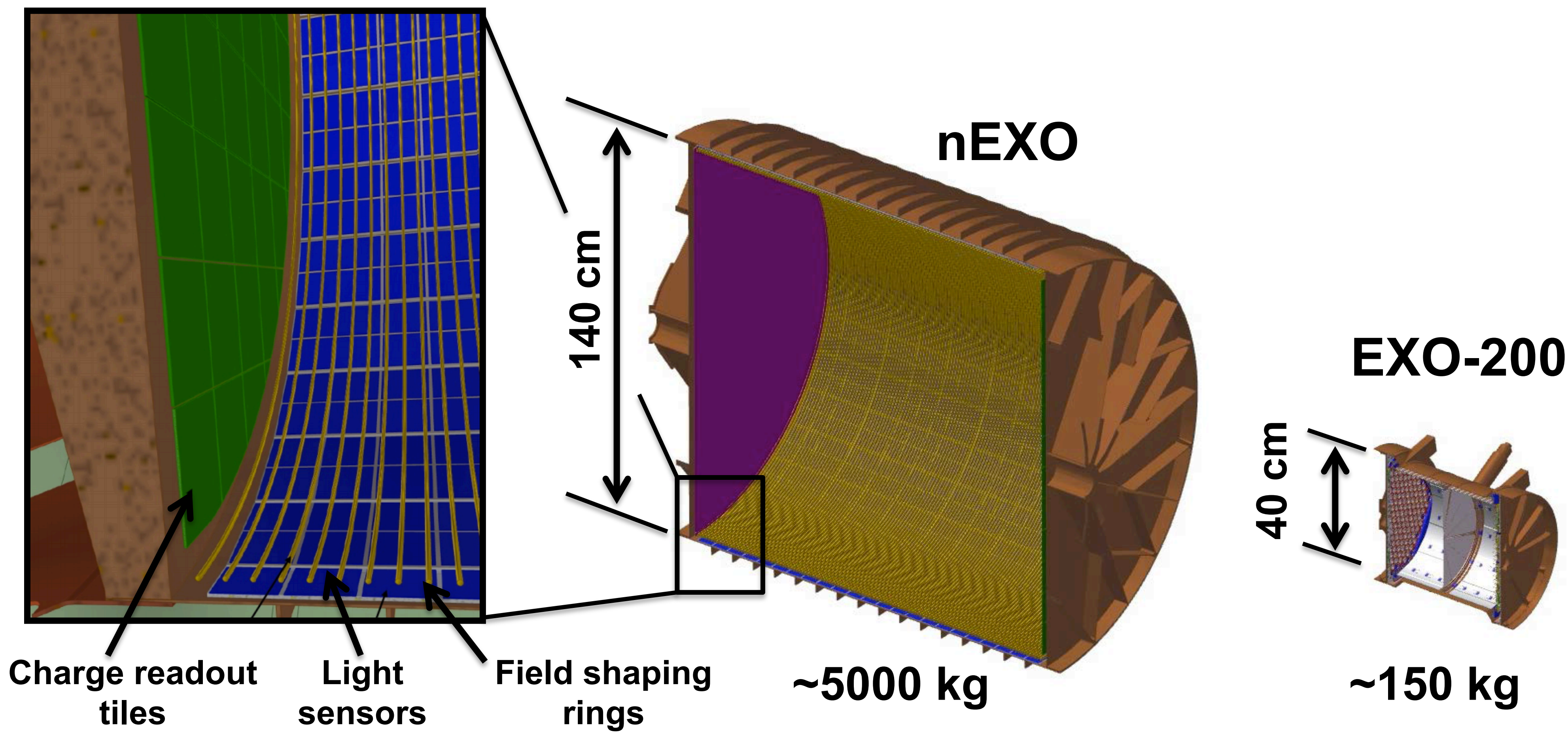
Design concept

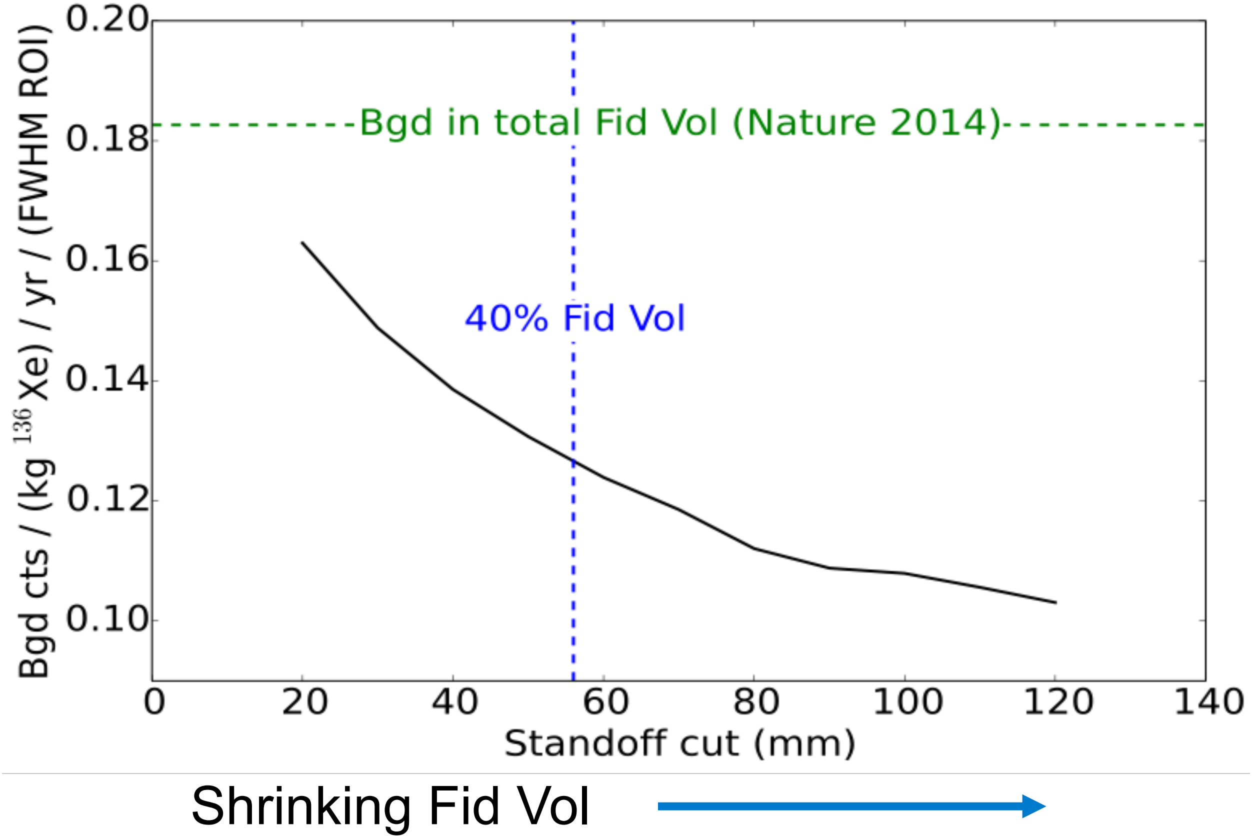
- A large, homogenous LXe TPC can allow the large exposure and background reduction necessary for next generation experiments
- This detector technology has been demonstrated in EXO-200, but becomes even more powerful in a large detector due to self shielding

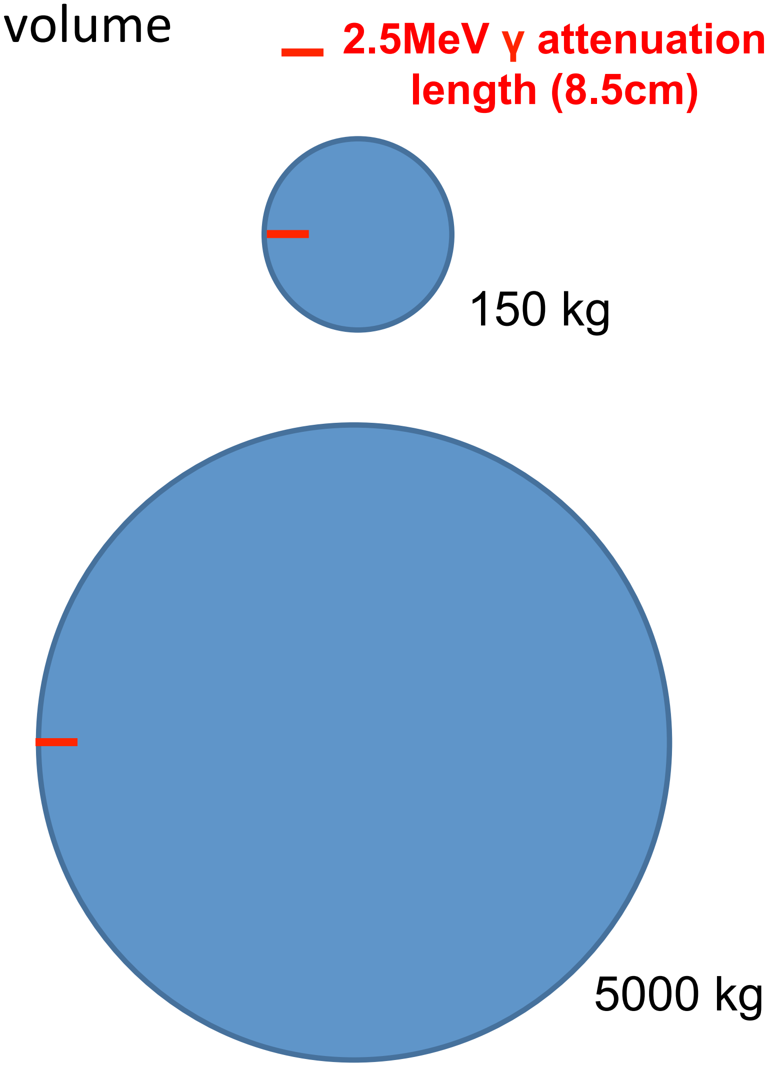


Self-shielding

- A large, monolithic detector provides significant attenuation of external backgrounds in the central volume

Measured reduction in backgrounds vs. standoff, EXO-200:



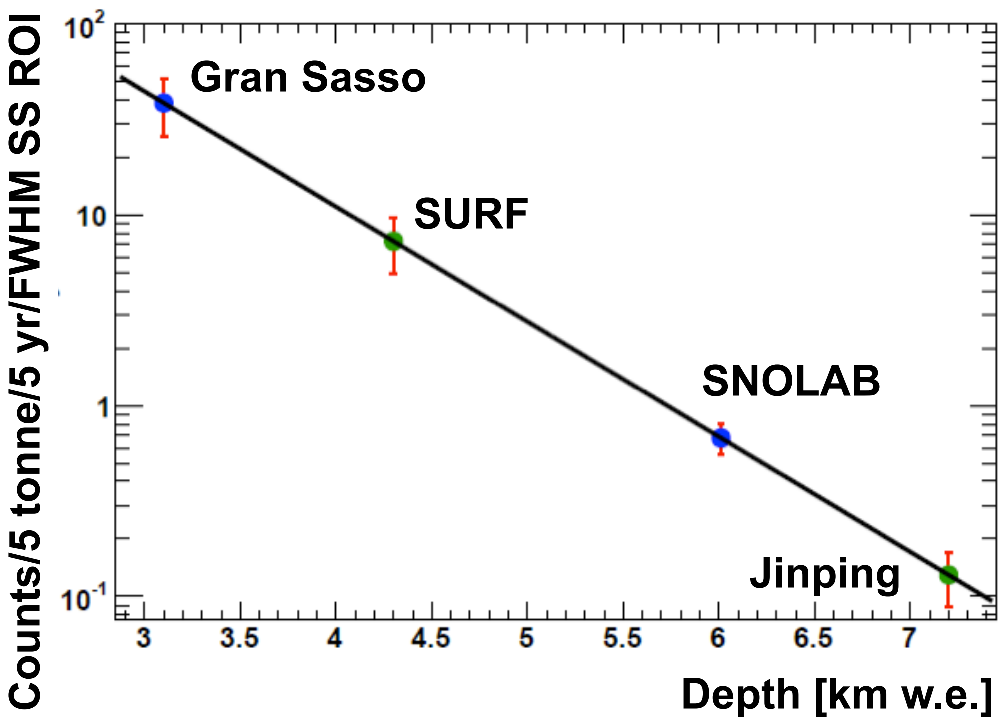


Experimental sites

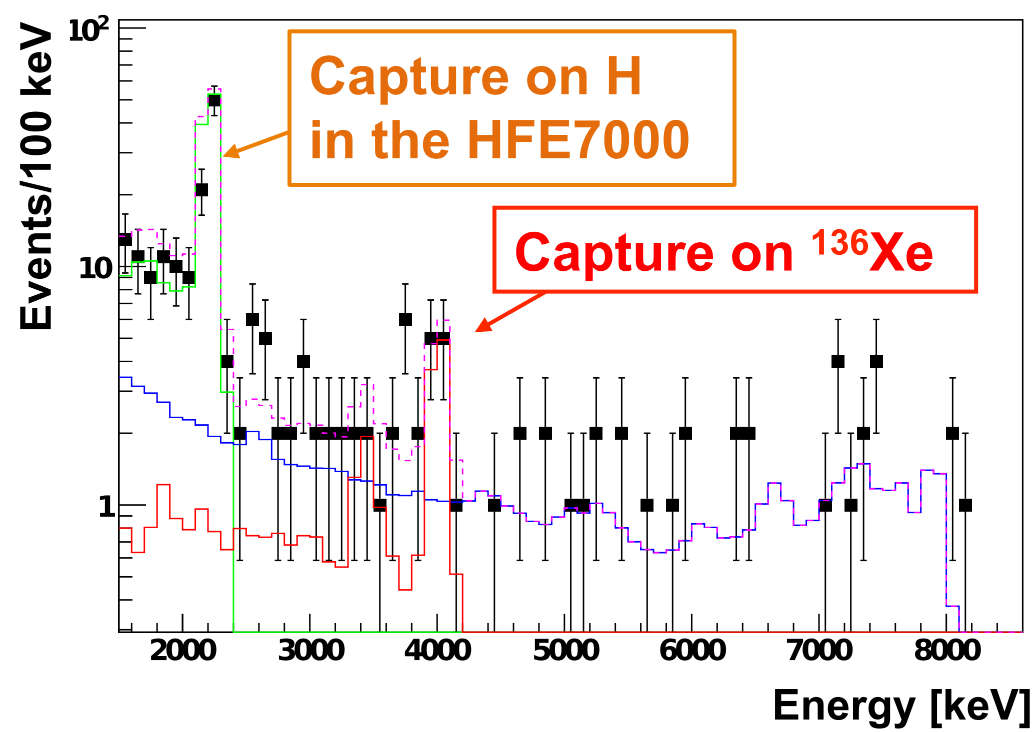
- Have simulated cosmogenic backgrounds for nEXO (cross-checked with EXO-200 data)
- Problematic backgrounds include β/γ emitters from n-capture (e.g. ^{137}Xe)

Site:	μ flux: [m^{-2} day]	Rock radioactivity: [Bq/kg] ^{232}Th:	^{238}U:
Gran Sasso (Italy)	22.3	0.25	5.18
SNOLAB (Canada)	**0.33**	**22.7**	**40.2**
Jinping (China)	~0.14	<0.27	1.8±0.2 (^{226}Ra)

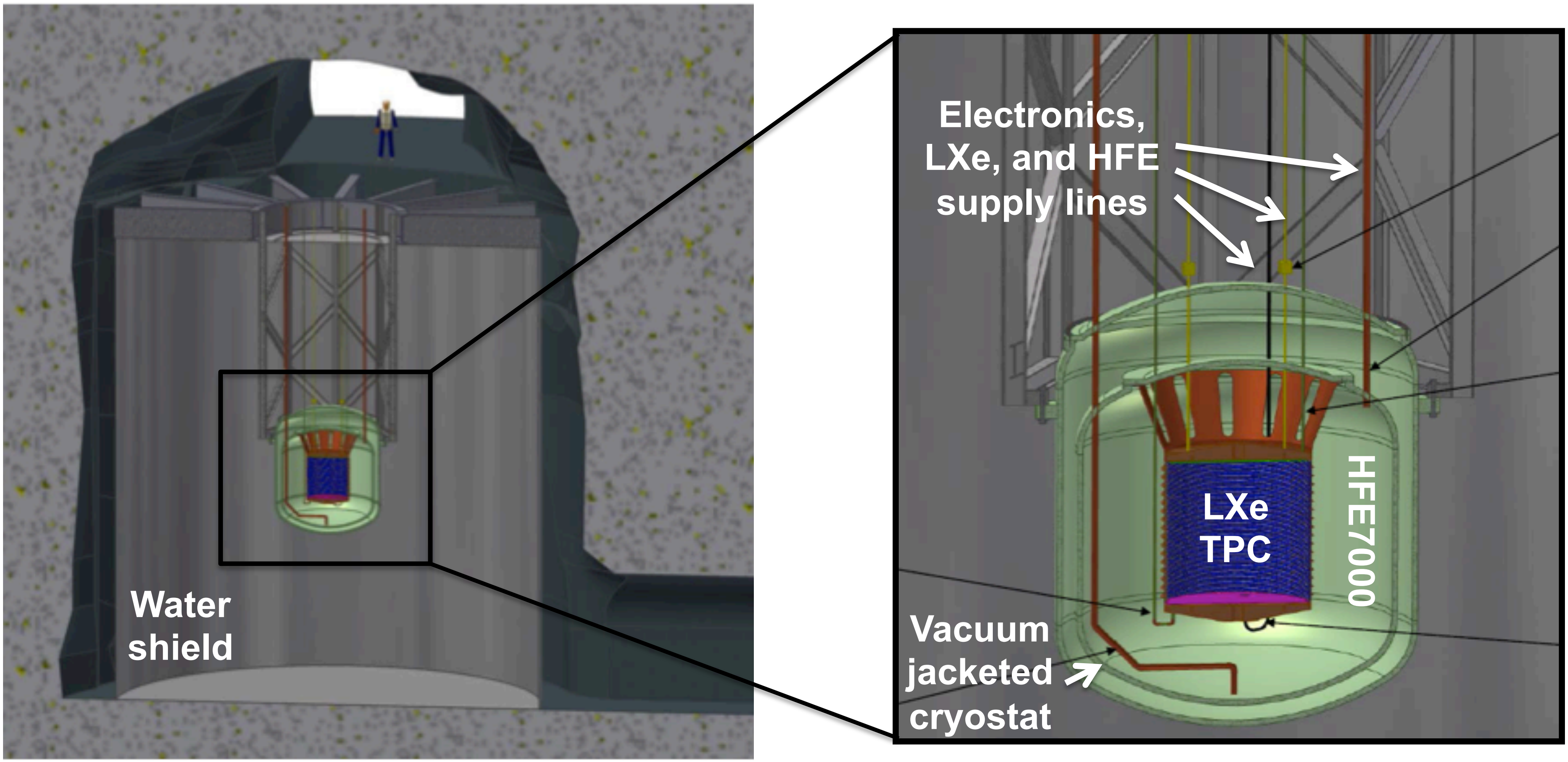
Cosmogenic background rate vs. site:



EXO-200 veto coincident spectrum:

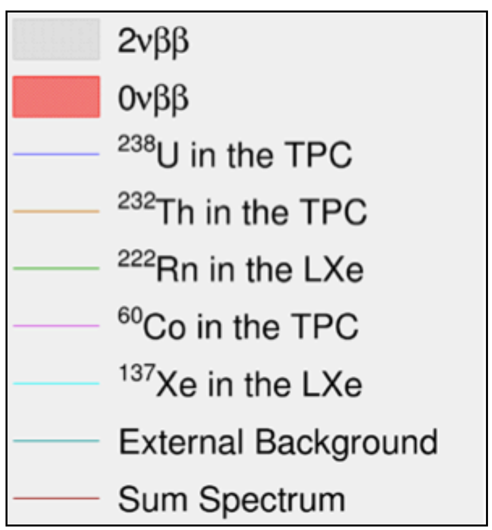


Conceptual design @ SNOLAB

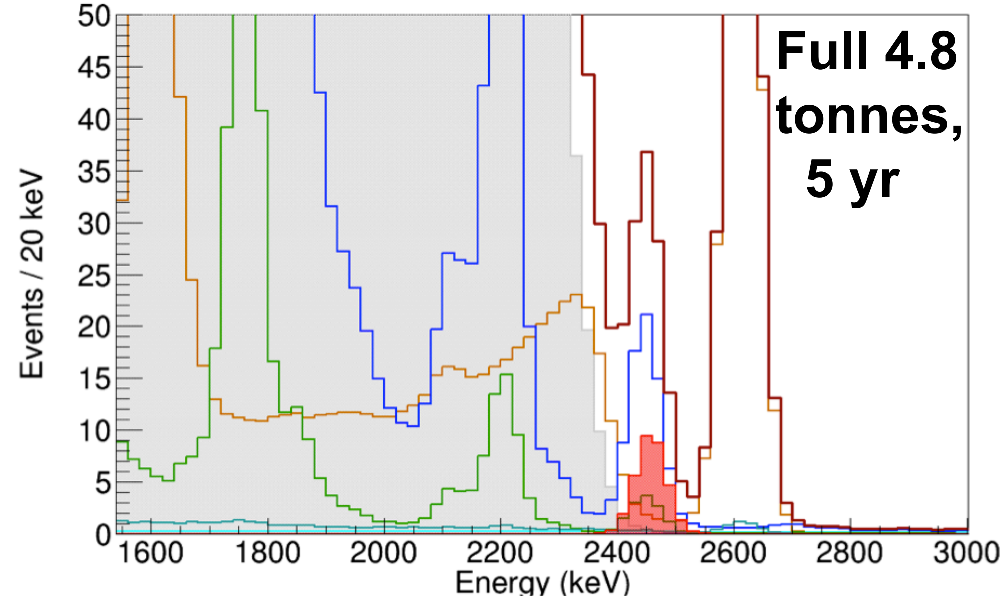


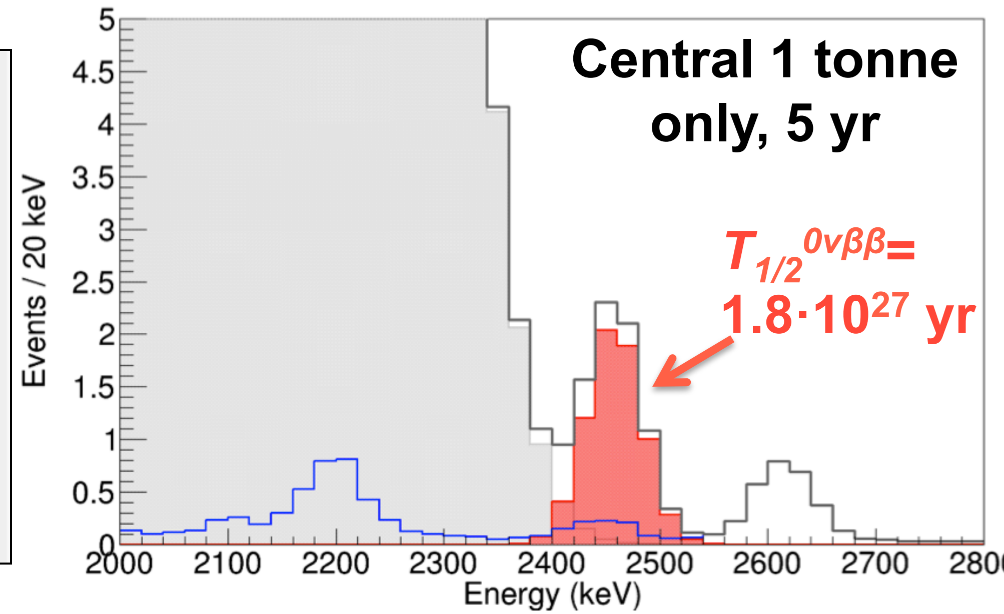
Backgrounds and signal

- Have developed Geant4 simulation for nEXO, using experience gained from EXO-200
- Spectra on right show expected backgrounds in 5 yr exposure, and 0νββ at discovery threshold
- Background calculation assumes measured activity for detector materials
- This procedure was verified with EXO-200 data, and assumes several improvements for nEXO



Simulated nEXO spectrum near single-site ROI:





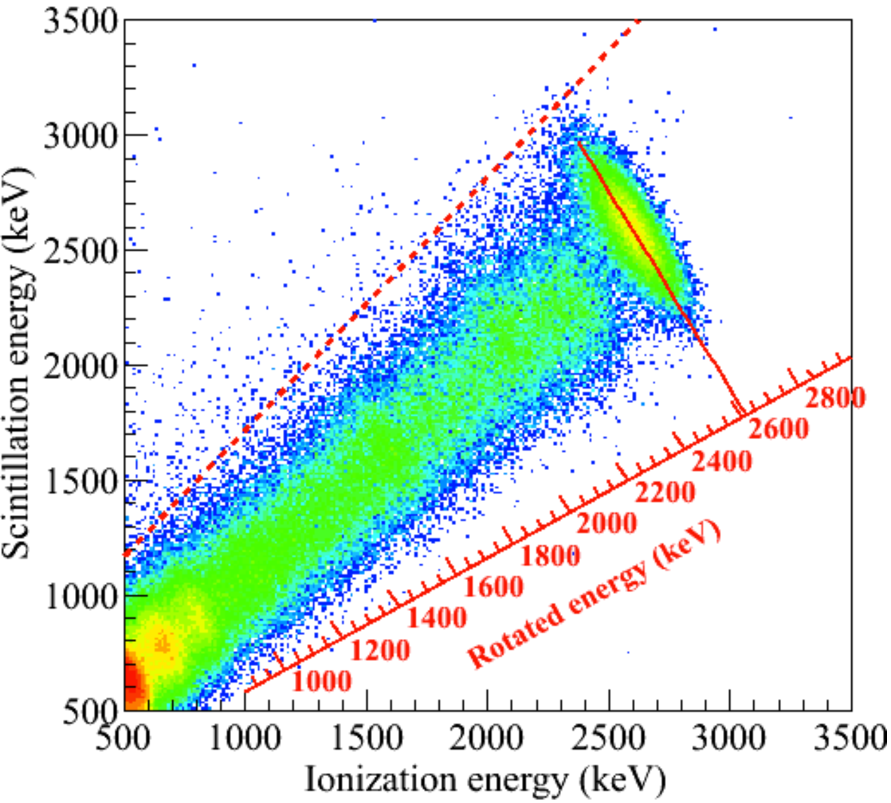
Background simulation

- nEXO backgrounds assume measured activities for all detector materials
- Have compared to EXO-200 data to confirm validity of these assumptions
- Measured background rate from EXO-200 is $\boldsymbol{B_{EXO\text{-}200}}$ **= 151 ± 19 ROI^{-1} ton^{-1} yr^{-1}**, (ROI = $Q_{\beta\beta}$ ± 0.5·FWHM) *Nature* ***510****, 229 (2014), arXiv:1402.6956*
- Agrees with predicted nEXO rate in outer 16.2 cm for same assumptions
- The following improvements over EXO-200 are assumed:
  - Improved energy resolution ($\sigma/Q_{\beta\beta} = 0.01$)
  - Improved SS/MS discrimination (3mm channel pitch)
  - Improved Cu activity from more sensitive radio assay
  - Reduced ^{137}Xe rate at SNOLAB
  - Reduced ^{222}Rn density, longer time window in ^{214}Bi-^{214}Po coincidence cut
  - Kapton cabling removed (using cold electronics instead)
- Total nEXO background prediction in outer 16.2 cm: $\boldsymbol{B_{nEXO}}$ **= 3.7 ROI^{-1} ton^{-1} yr^{-1}**
- Improvements give reduction of ~40x in background in background index relative to EXO-200

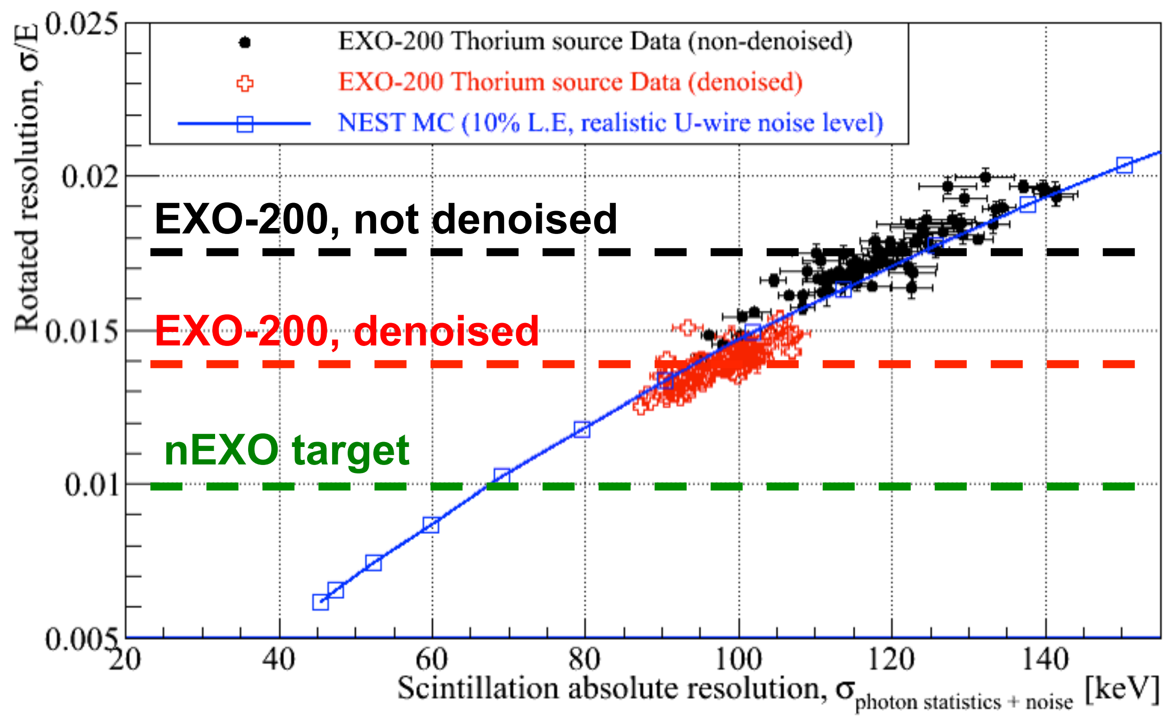
Energy resolution

- Require $\sigma_E/E < 1\%$ at $Q_{\beta\beta}$, which requires measuring both charge and light with minimal readout noise
- Have demonstrated 1.4% resolution in EXO-200, simulations indicate that 1% resolution is attainable with improved readout electronics for light sensors
- Planned upgrades to EXO-200 electronics should also achieve 1% resolution

Scintillation vs. Ionization, EXO-200 data:



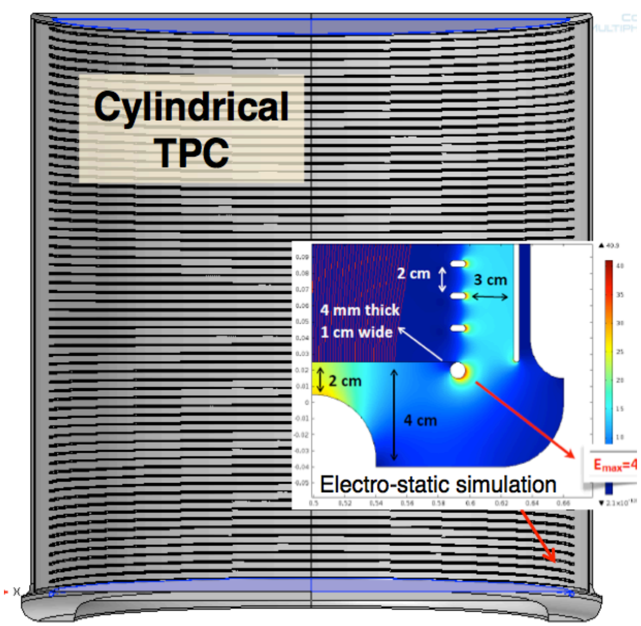
Simulated rotated resolution vs. readout noise:



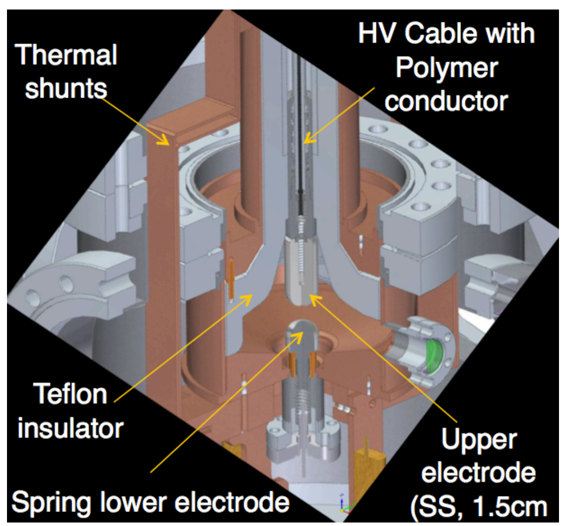
R&D

- R&D is in progress for several detector components:
  - Field cage design and electrostatic simulations
  - High voltage testing and prototyping
  - Characterization of light detectors (Silicon Photo Multipliers)
  - Design and testing of charge readout tiles

TPC E-field simulations:

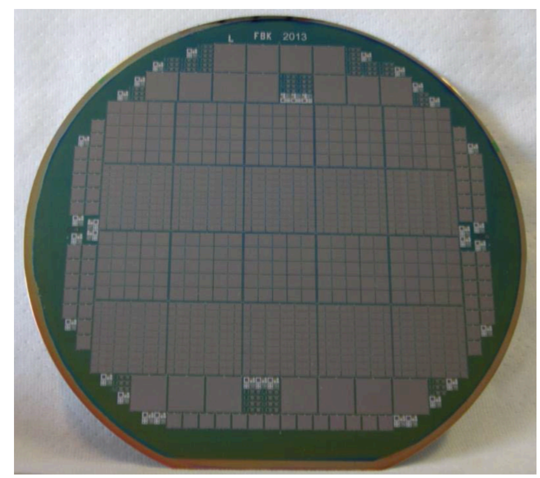


HV testing setup:



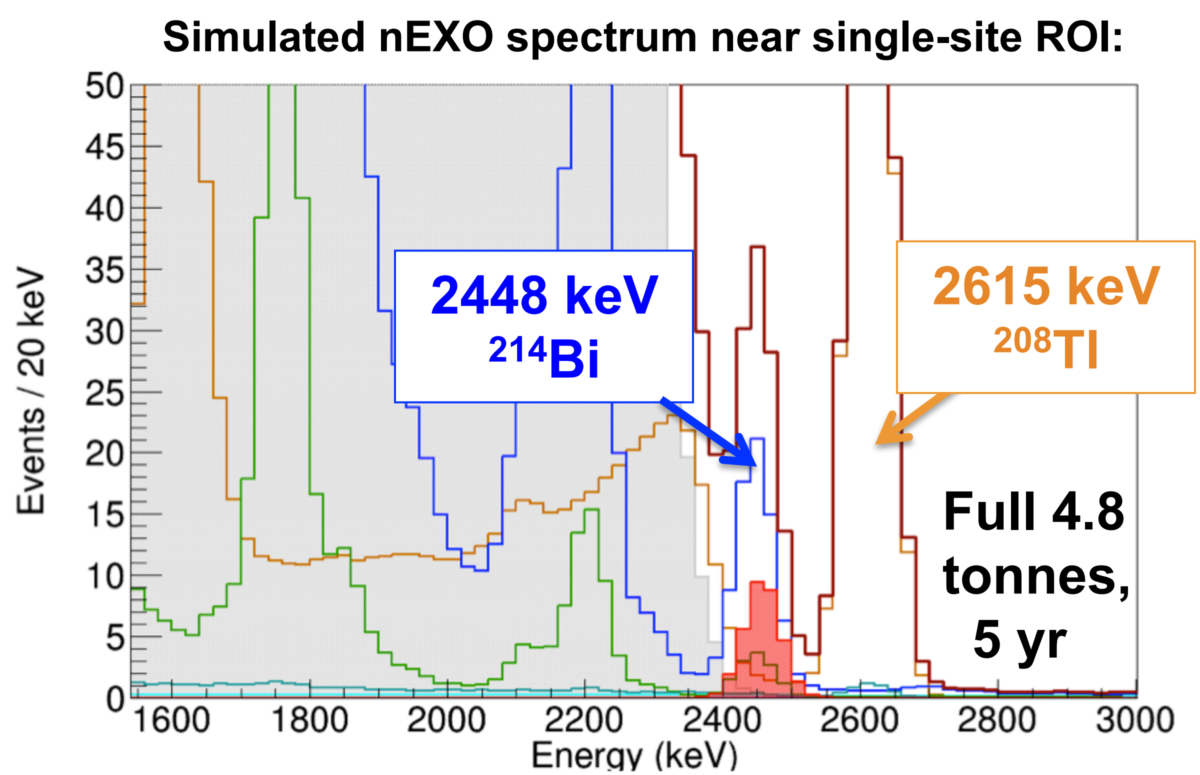
Charge readout LXe test cell:

SiPMs:



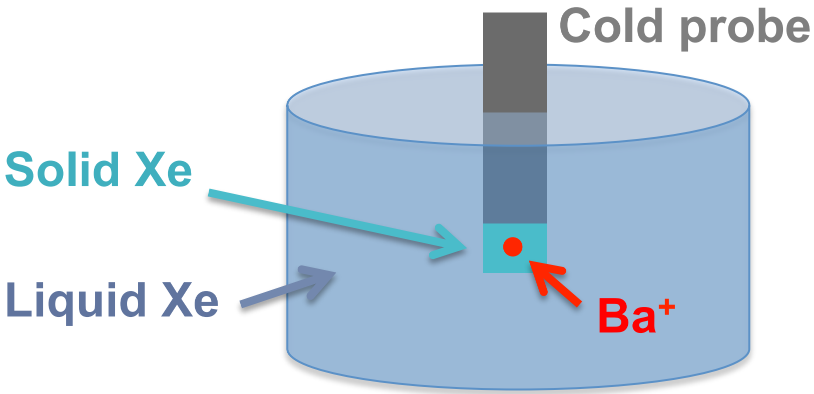
Ba tagging

- In addition, R&D to develop techniques to identify Ba daughter nucleus of 0νββ decay ("Ba tagging") is continuing
- Candidate 0νββ events would be identified in real time and daughter Ba ion collected by probe inserted into the TPC at the decay location
- Identity of Ba daughter can be confirmed spectroscopically
- This technology would eliminate all non-ββ backgrounds near ROI
- Could extend ultimate reach of nEXO into the normal hierarchy since full 5 tonne mass would be background free



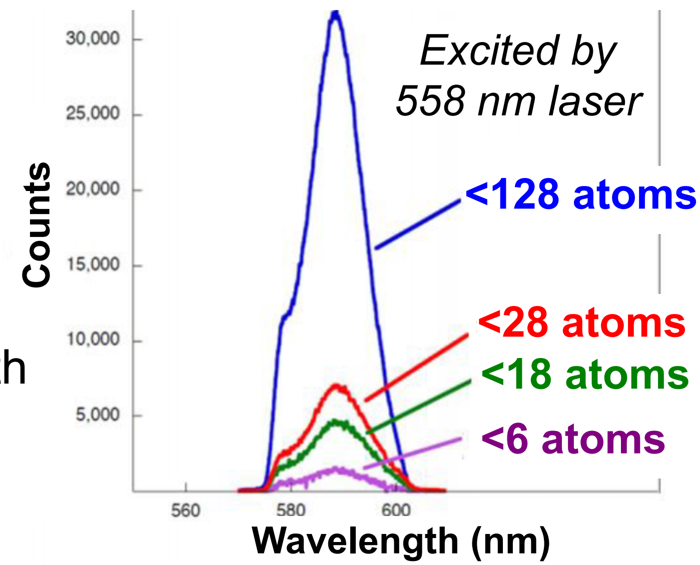
Ba tagging

- Several techniques are currently being pursued:
  - Tagging from solid Xe by fluorescence spectrum

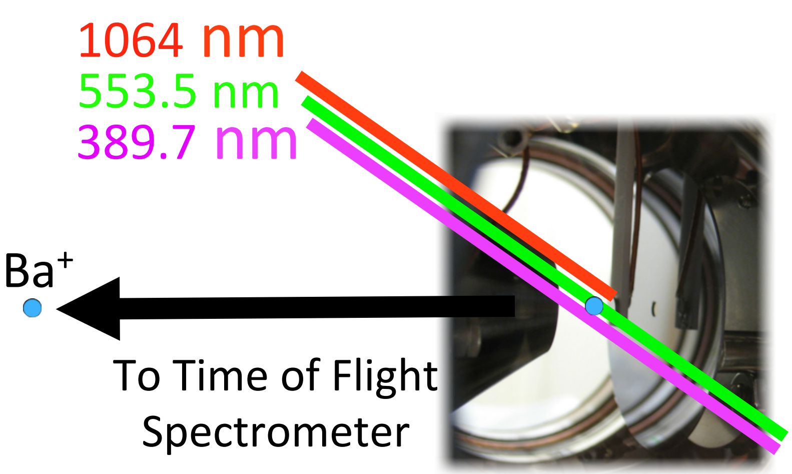


Detect single ion or atom on the probe with laser-induced fluorescence

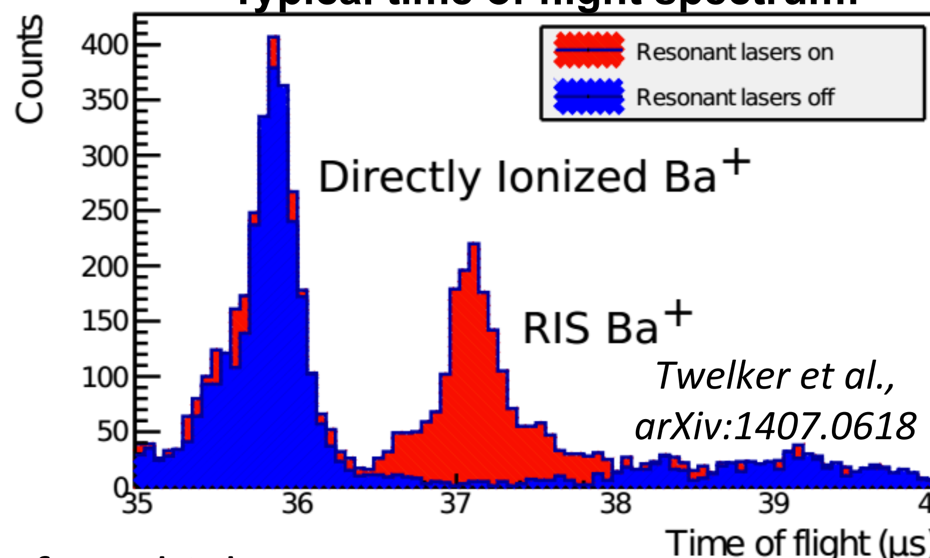
Fluorescence of Ba in SXe:



  - Resonance ionization spectroscopy (RIS):



Typical time of flight spectrum:



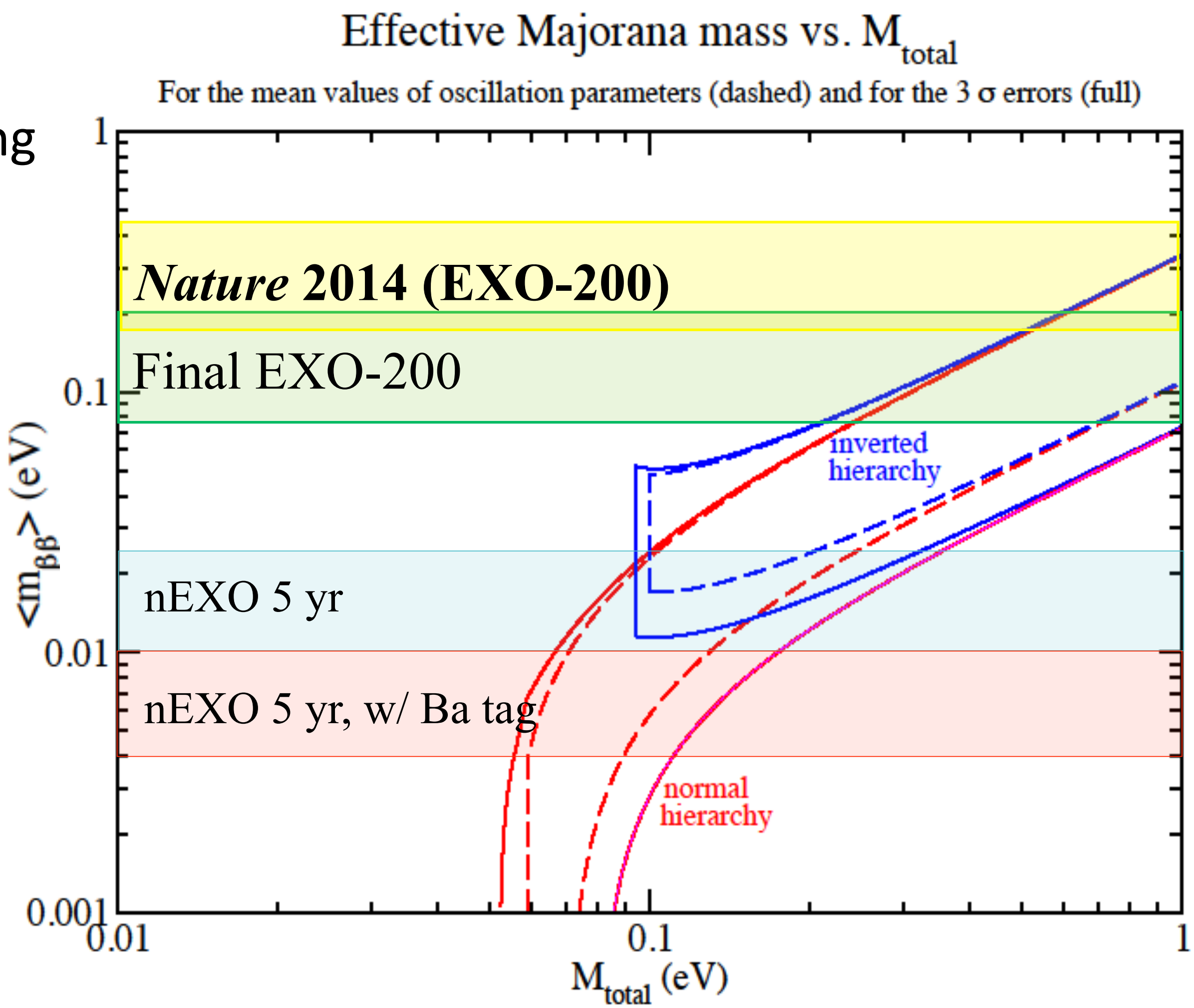
- Also studying ion extraction and tagging from high pressure Xe gas

Sensitivity

- Sensitivity projections computed using background simulations
- Self-shielding of nEXO gives significantly lower backgrounds, especially in inner region of fiducial volume
- Possible upgrade to include Ba tagging could eliminate remaining non-bb backgrounds

Comparison between nEXO and EXO-200:

Parameter	nEXO	EXO-200
Fiducial Mass (kg)	4780	98.5
Enrichment (%)	90	80
Data taking time (yr)	5	5
Energy resolution @ $Q_{\beta\beta}$ (keV)	58	88 (58)
Background wthin FWHM of endpoint ($evts/yr/mol_{136}$)	$6.1 \cdot 10^{-4}$	0.022 (0.0073)
Background within FWHM of endpoint inner 3000kg ($evts/yr/mol_{136}$)	$1.6 \cdot 10^{-4}$	



Summary

- nEXO is the proposed 5-tonne scale successor to EXO-200, which will search for $0\nu\beta\beta$ in ^{136}Xe with half-life sensitivity corresponding to the inverted hierarchy
- The design is based on EXO-200, but becomes even more powerful in a large, homogenous TPC due to self-shielding of backgrounds
- nEXO is currently in the R&D phase, focused on developing the key components
- R&D is also continuing for Ba tagging, which could allow an upgraded version of nEXO to probe well into the normal hierarchy