nEXO: The next phase of EXO on searching 0νββ decay

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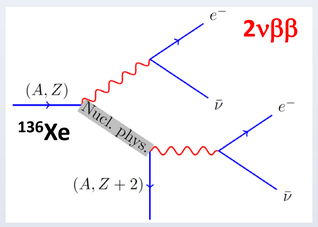
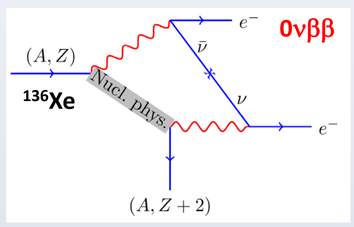
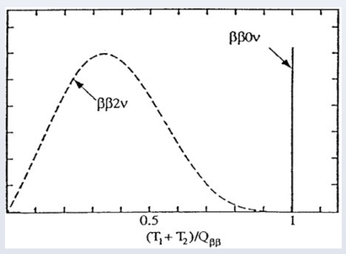
Physics Motivation

Search for neutrino-less double beta decay (0νββ) using isotope ^{136}Xe.

0νββ is the most sensitive probe of the Majorana/Dirac nature of neutrinos



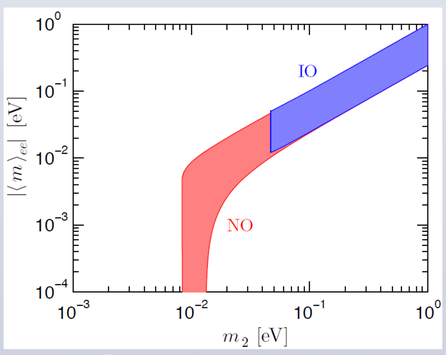




$$\langle m_\nu \rangle = \sum_{i=1}^{3} \left| U_{e,i} \right|^2 m_i \, \varepsilon_i$$

$$\langle m_\nu \rangle^2 = \left(T_{1/2}^{0\nu\beta\beta} \, G^{0\nu\beta\beta}(E_0, Z) \left| M_{GT}^{0\nu\beta\beta} - \frac{g_V^2}{g_A^2} M_F^{0\nu\beta\beta} \right|^2 \right)^{-1}$$

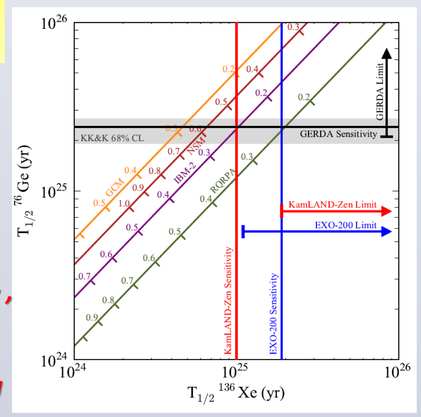
Effective Majorana ν mass



Z.Z. Xing, Y. L. Zhou, arXiv:1404.7001

NO 0νββ signal was found in current experiments.

The nEXO collaboration aims to build a 5-tonne scale experiment with ^{enr}Xe , named nEXO, to continue 0νββ search, with a sensitivity entirely covering the inverted hierarchy.

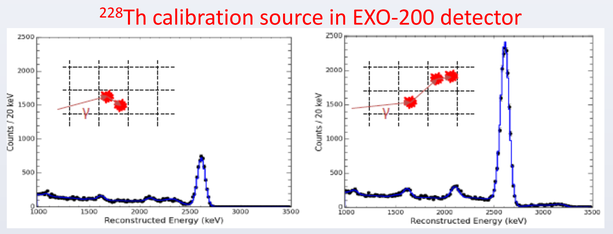


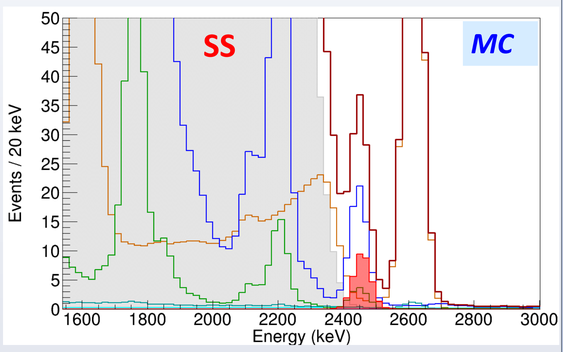
Current knowledge of EXO-200 to 0νββ

Backgrounds

3D tracking allows very good e-/γ discrimination, namely Single-site/Multi-site separation.

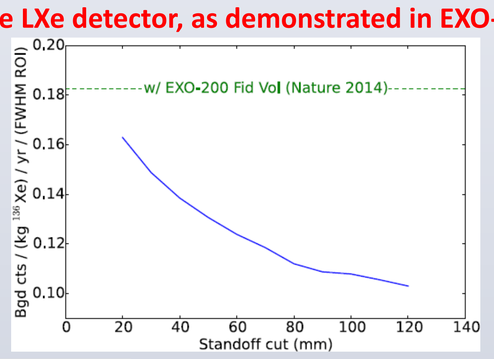
^{228}Th calibration source in EXO-200 detector

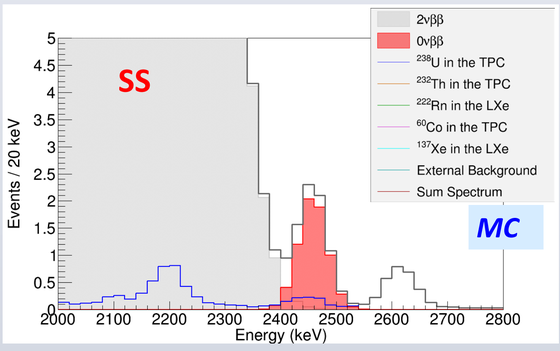




nEXO energy spectrum at the threshold of discovery: $T_{1/2}(\beta\beta)=1.8\cdot10^{27}$ yr (5yr data, *4.78 tonnes*)

In addition, 2.5 MeV γ has ~8.5 cm attenuation length in liquid Xenon → Very good self-shielding in a large LXe detector, as demonstrated in EXO-200:





nEXO energy spectrum at the threshold of discovery: $T_{1/2}(\beta\beta)=1.8\cdot10^{27}$ yr (5yr data, *central 1 tonne*)

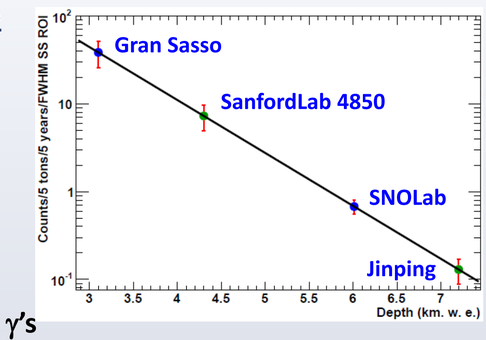
2νββ S/B ratio in EXO-200 — **11:1 @ standard Fiducial Volume; 19:1@ inner 40% Fiducial Volume**

Radioactivity Control to the detector Materials

a) NAA (Neutron Activation Analysis)
b) Low background γ-spectroscopy
c) α-counting
d) Radon counting
e) High performance GD-MS and ICP-MS

Possible Experimental Sites

Site	μ flux (/m²/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 (CJPL, China)	~0.14	<0.27	1.8 ±0.2 (^{226}Ra)



Very low muon flux → less cosmogenic backgrounds

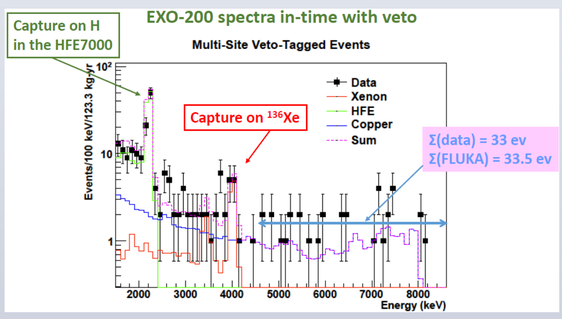
Low rock radioactivity → less cost on shielding ambient γ's

Major cosmogenic backgrounds: β/γ emitters due to n-capture on detector materials

Problematic background: ^{137}Xe by n-capture on ^{136}Xe

Estimate cosmogenic backgrounds in nEXO: FLUKA simulation, validated with actual EXO-200 data

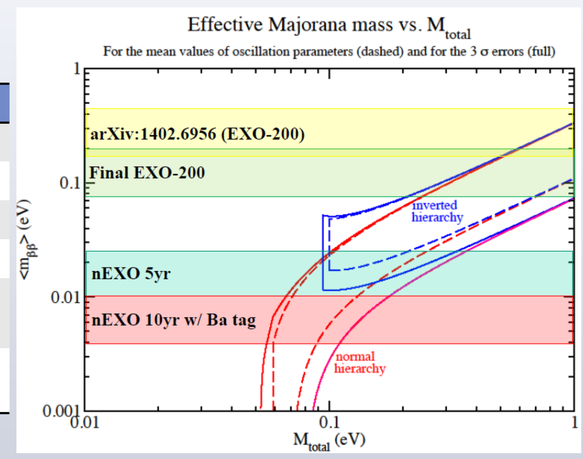
The coincidence between muon and ^{136}Xe n-captures allow a possible long veto to suppress the background



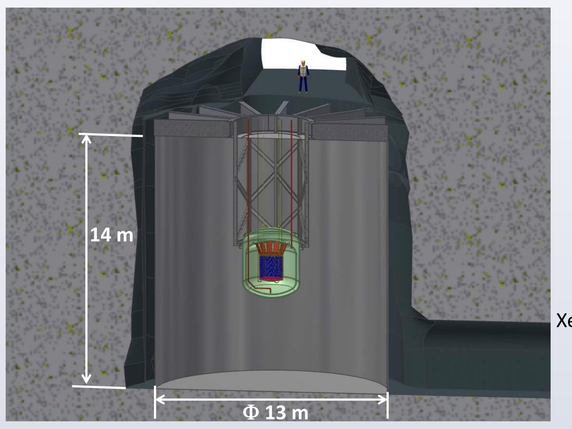
Sensitivity

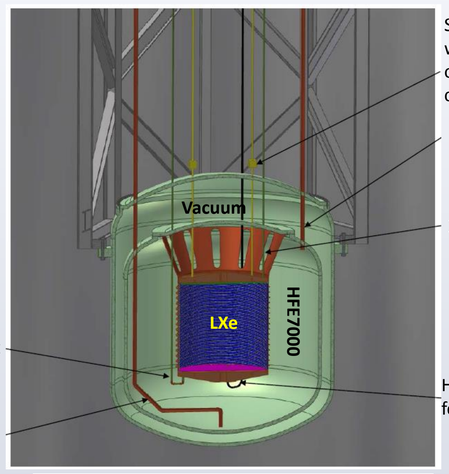
Comparison between nEXO and EXO-200

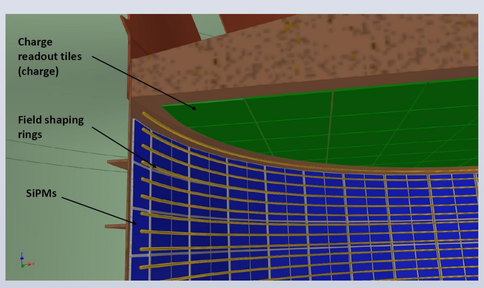
Parameter	nEXO	EXO-200
Fiducial Mass (kg)	4780	98.5
Enrichment (%)	90	80
Data taking time (yr)	5	5
Energy resolution @ $Q_{\beta\beta}$ (keV)	58	88 (58)
Background wthin FWHM of endpoint (evts/yr/mol$_{136}$)	$6.1\cdot10^{-4}$	0.022 (0.0073)
Background within FWHM of endpoint inner 3000kg (evts/yr/mol$_{136}$)	$1.6\cdot10^{-4}$	

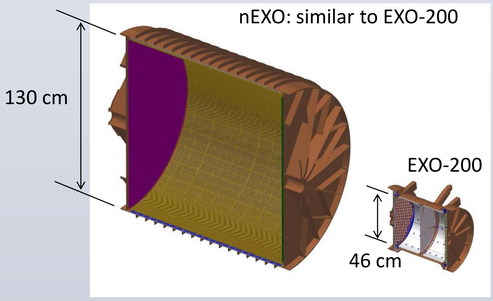


Detector Concepts









Energy Resolution

Requirement: σ/E @ $Q_{\beta\beta}$ < 1%

-- combine charge and light (anti-correlation)

-- sufficient light collection efficiency, low noise in light channel

-- high electron lifetime (> 10ms), low noise in charge channel

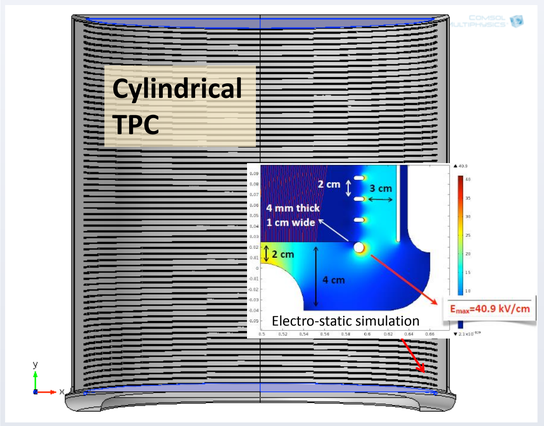
Geant4-based Simulation software for nEXO has been set up. Anti-correlation effects are simulated with NEST codes. (http://nest.physics.ucdavis.edu/site/)

Anti-correlation simulation is being verified with EXO-200 data, then used to predict resolution in nEXO.

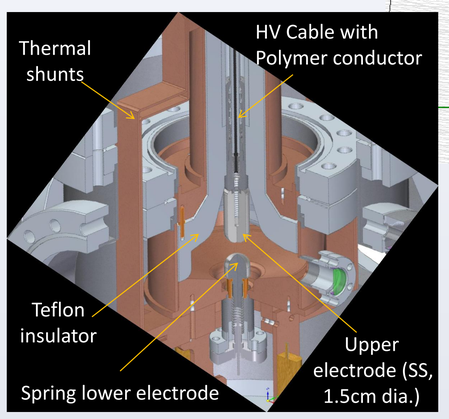
Absolute scintillation resolution in vertical slice consists of photon statistical fluctuations and noise in electronics

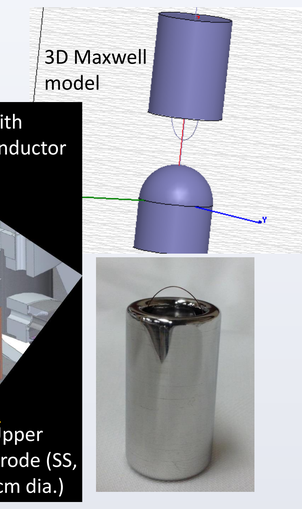
Research & Developments

Below is a selection of on-going R&Ds

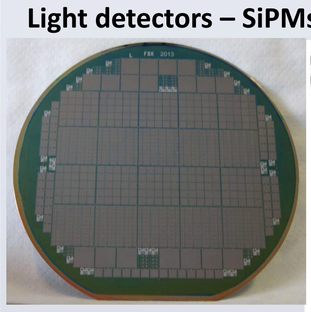


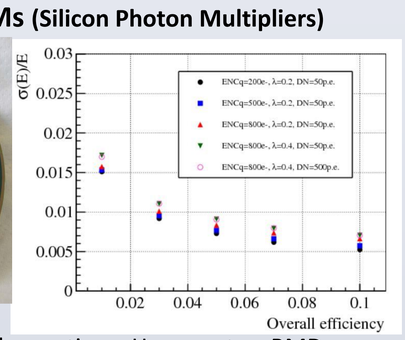
HV Test





Light detectors – SiPMs (Silicon Photon Multipliers)

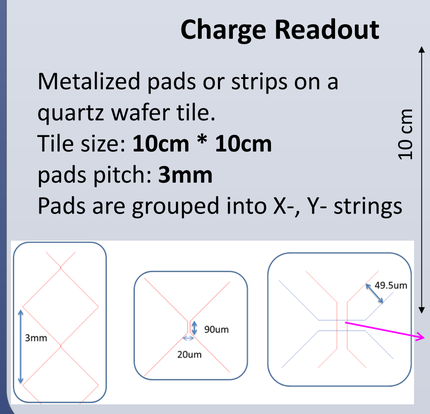




FBK primary partner. Other options: Hamamatsu, RMD, Zecotek MRS-APD (SiPM), KETEK, Excelitas, etc

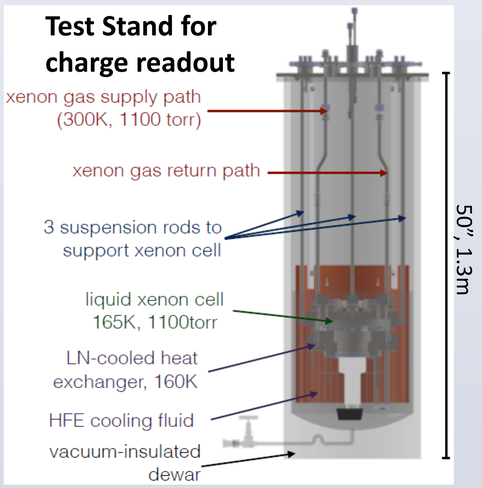
Charge Readout

Metalized pads or strips on a quartz wafer tile.
Tile size: **10cm * 10cm**
pads pitch: **3mm**
Pads are grouped into X-, Y- strings

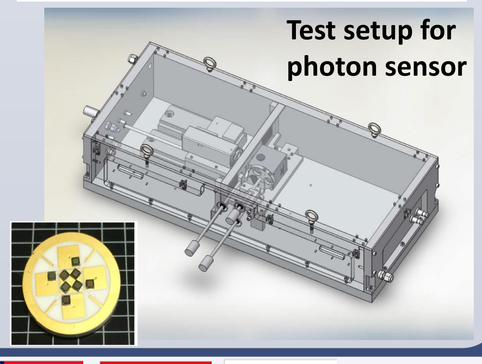


2μm thick SiO_2 insulator at the cross-sections

Test Stand for charge readout

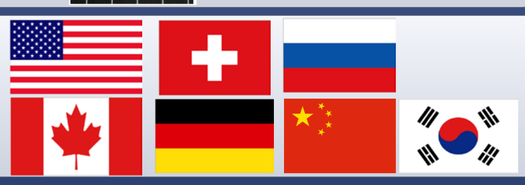


Test setup for photon sensor



International Collaboration

~110 collaborators
(90% scientists and students, 10% engineers)
22 institutions; 7 countries; 3 continents



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