The NEXT Experiment: Status and Prospects

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Texas A&M University
on behalf of
the NEXT Collaboration
DM 2016

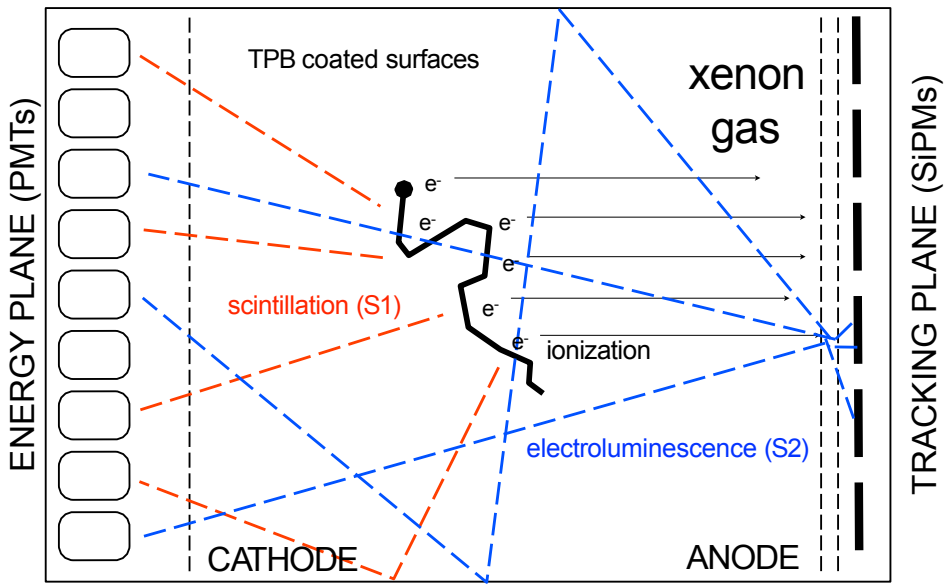
The 240 m-long building of the old Canfranc Estación railway station. The historic landmark is only a few kilometres away from the entrance to the Canfranc Underground Laboratory. (All image credits: LSC.)

NEXT: Neutrino Experiment with a Xenon TPC and the Search for $0\nu\beta\beta$ decays

The Collaboration

IFIC, UPV, US, UdG, UAM, UZ — Spain
UC, UA — Portugal
UAN — Colombia
UTA, TAMU, Iowa State, LBNL, FNAL— USA

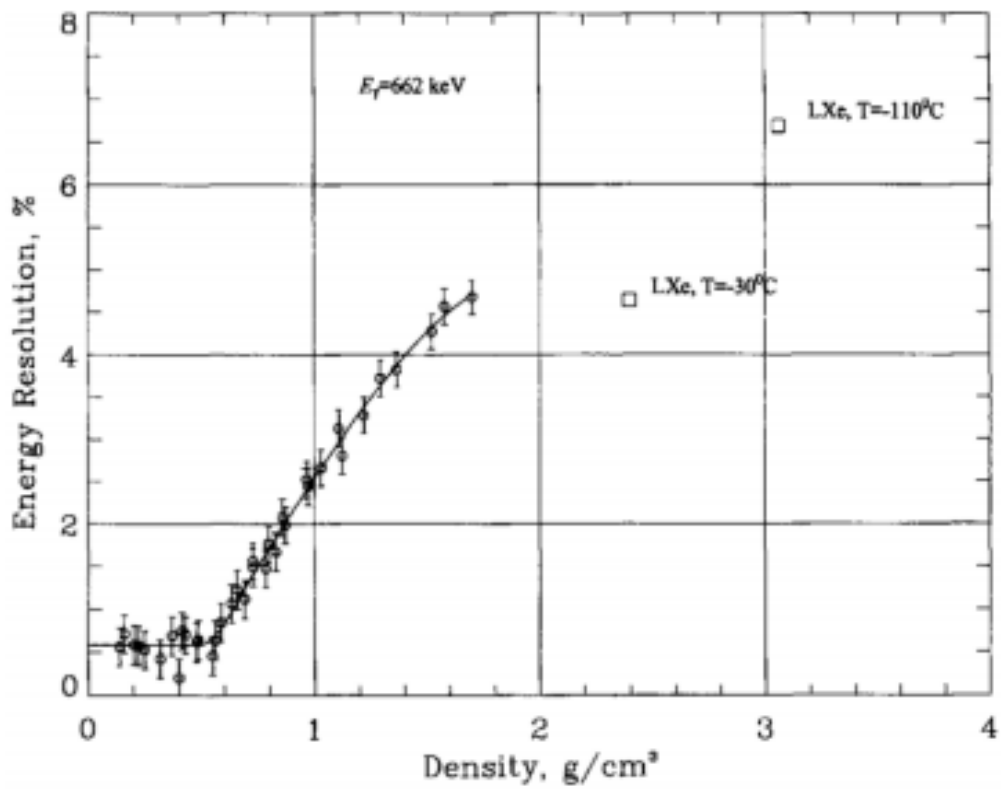
NEXT: A high pressure single phase TPC with light readout.



EL mode is essential to get linear gain, therefore avoiding avalanche fluctuations and fully exploiting the excellent Fano factor in gas

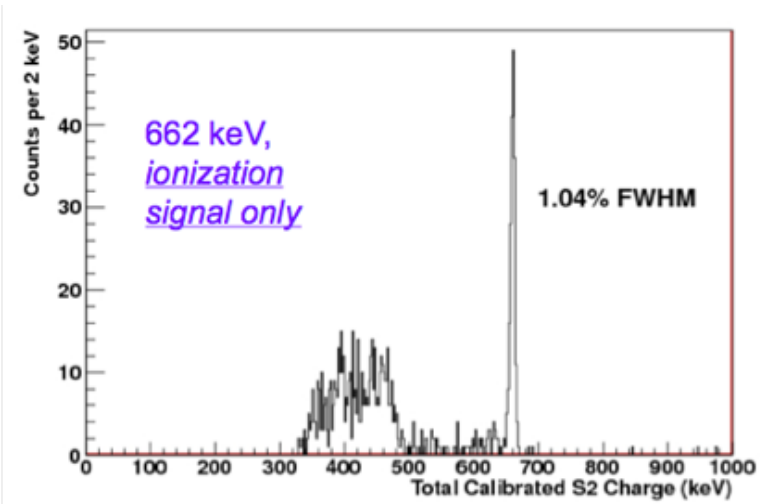
- It is a High Pressure Xenon (HPXe) TPC operating in EL mode.
- It is filled with 100 kg of Xenon enriched at 90% in Xe-136 (in stock) at a pressure of 15 bar.
- The event energy is integrated by a plane of radiopure PMTs located behind a transparent cathode (energy plane), which also provides t0 (timing).
- The event topology is reconstructed by a plane of radiopure silicon pixels (MPPCs) (tracking plane).

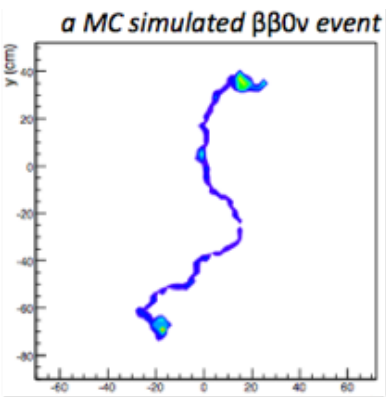
High Pressure for Energy Resolution

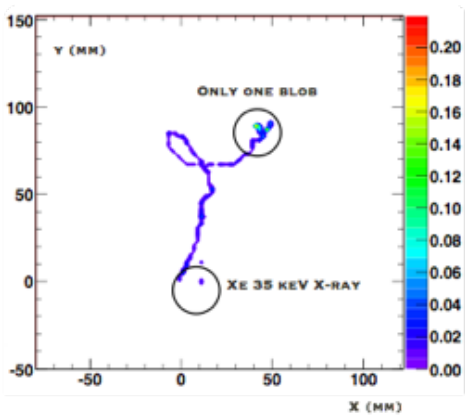


A. Bolotnikov and B. Ramsey, Nucl. Instrum. Methods A 396, 360 (1997), energy resolution starts to worsen at a density of ~0.6 g/cm^3

NEXT: Salient features







- Excellent resolution (~1% FWHM measured at 662 keV by NEXT prototypes, extrapolates to 0.5 % FWHM at Qββ
- Topological signature (TPS), eg. the ability to distinguish between signal ("double electrons") and background ("single electrons").
- Target = detector. Fiducial region away from surfaces.
- TPC: scalable. Economy of scale (S/N increases linearly with L)
- Xenon: the cheapest isotope to enrich in the market (NEXT owns 100 kg of enriched xenon).

The NEXT program

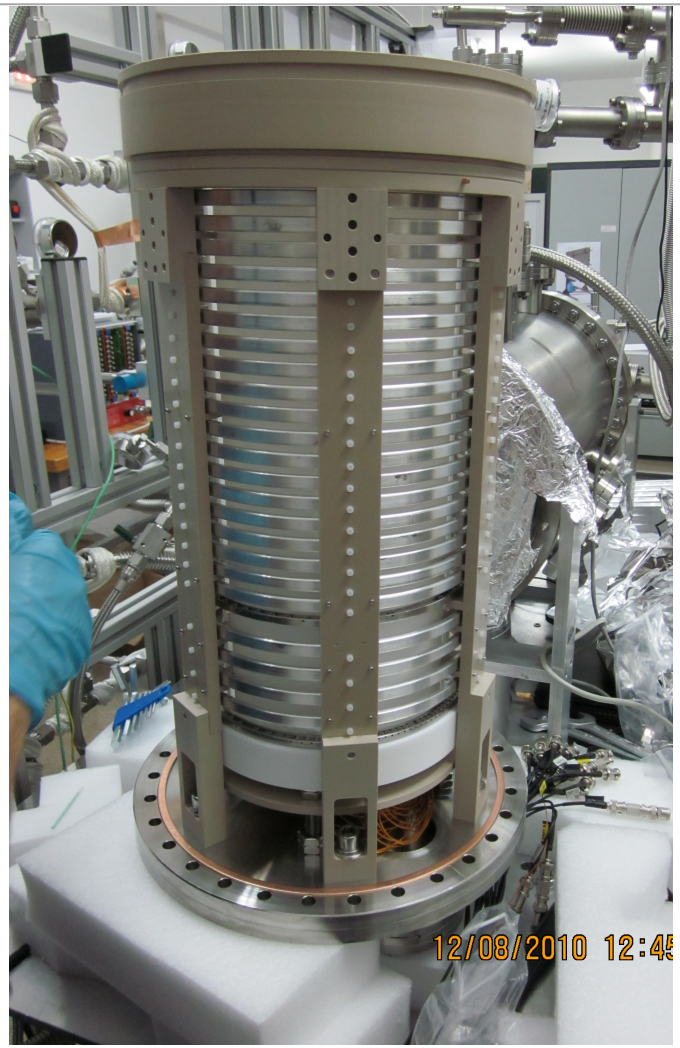
(2010–2014)
Demonstration of detector concept

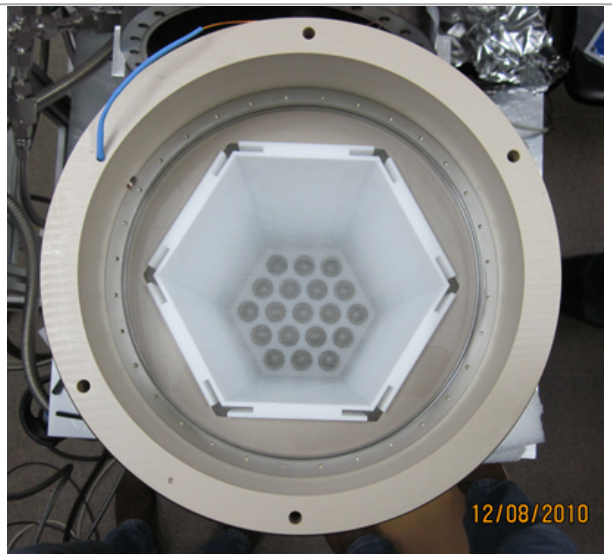
(2015–2017)
Test underground, radiopure operation

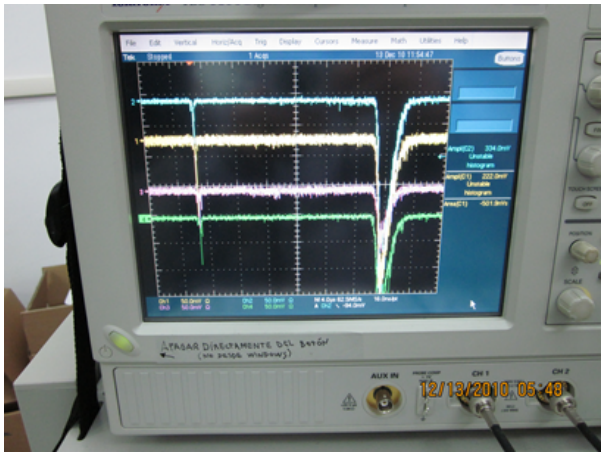
(2018–2020)
Neutrinoless double beta decay searches

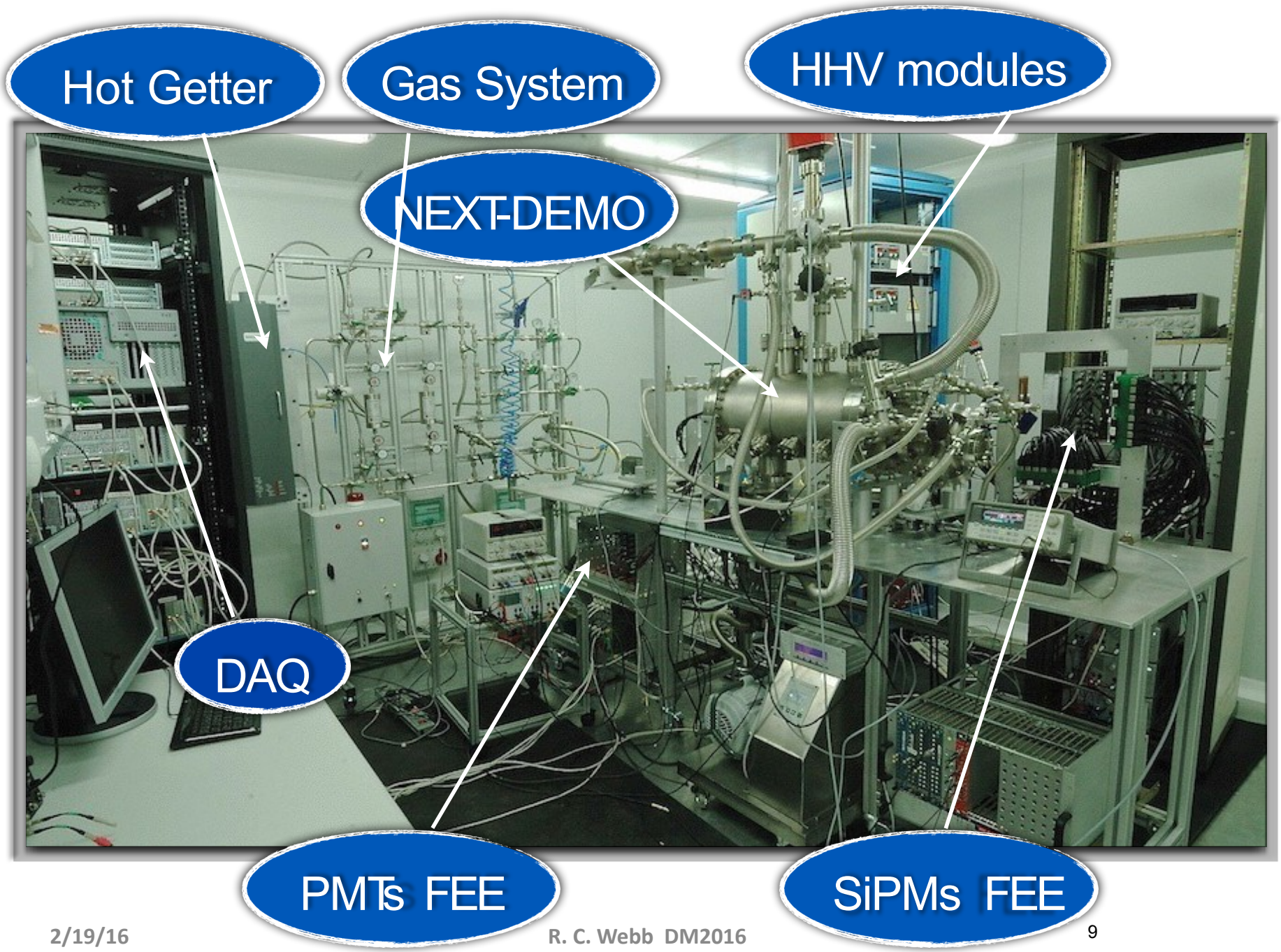

DEMO
(1kg)

NEXT-DEMO

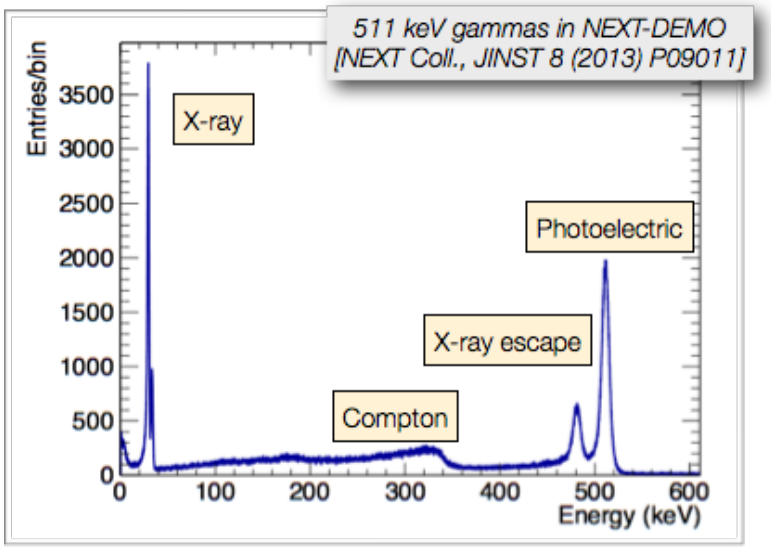


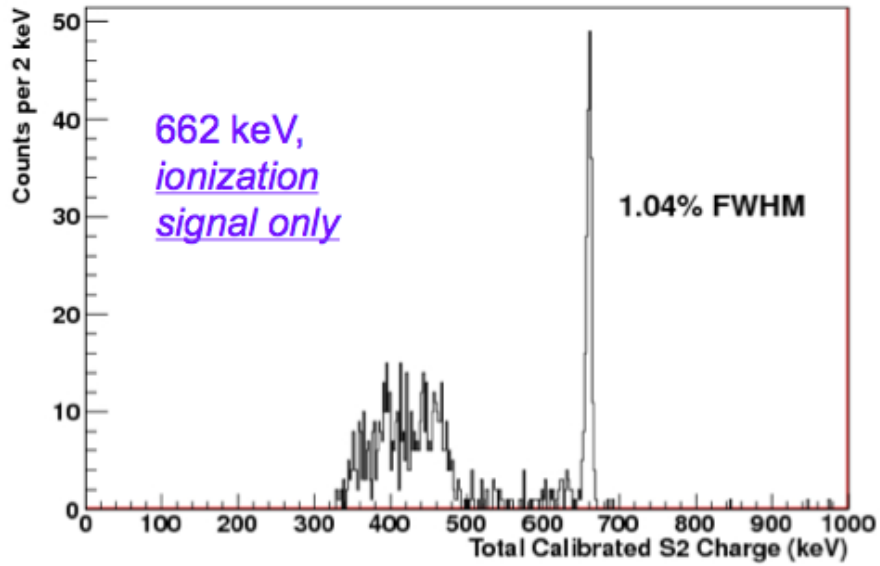





Hot Getter
Gas System
HHV modules
NEXT-DEMO
DAQ
PMTs FEE
SiPMs FEE

Energy Resolution

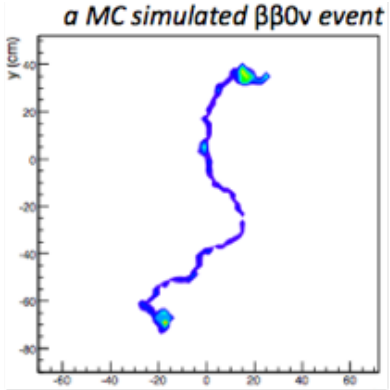


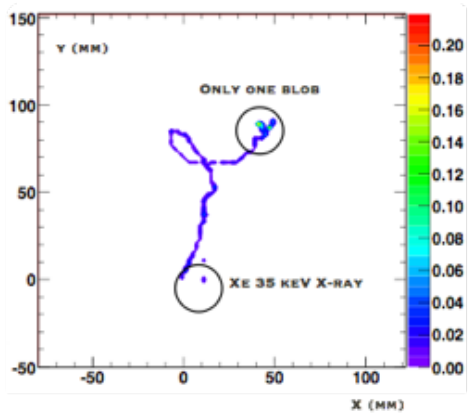


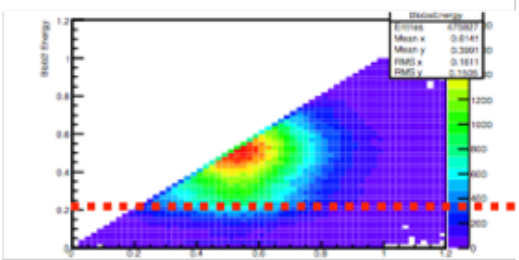
Energy resolution measured with prototypes DEMO (IFIC) DBDM (LBNL) extrapolates to 0.5 — 0.7 % FWHM at Qbb

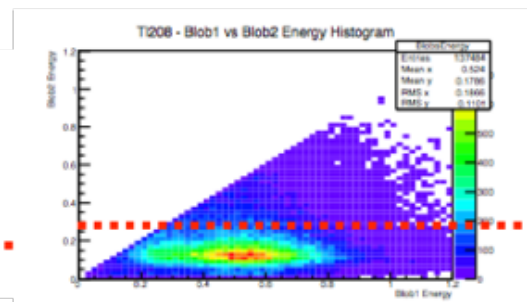
arXiv:1504.03678v2 [physics.ins-det] 17 Jun 2015

Topological signature









- Signal events (ββ0ν): TOP left MC event, two energetic blobs at the end of each electron (Bragg peak).
- Background events (Bi-214, Tl-208), single energetic electron, single blob, often with X-ray (xenon de-excitation)
- Bottom left, for signal event the energy of both blobs is high.
- Bottom right, for background events only one energetic blob.

Topological signature: “single track” (no floating x-rays) with two energetic blobs: Signal efficiency ~50 %, background suppression 1%

arXiv:1507.05902v6 [physics.ins-det] 18 Jan 2016

Validation of TPS with DEMO

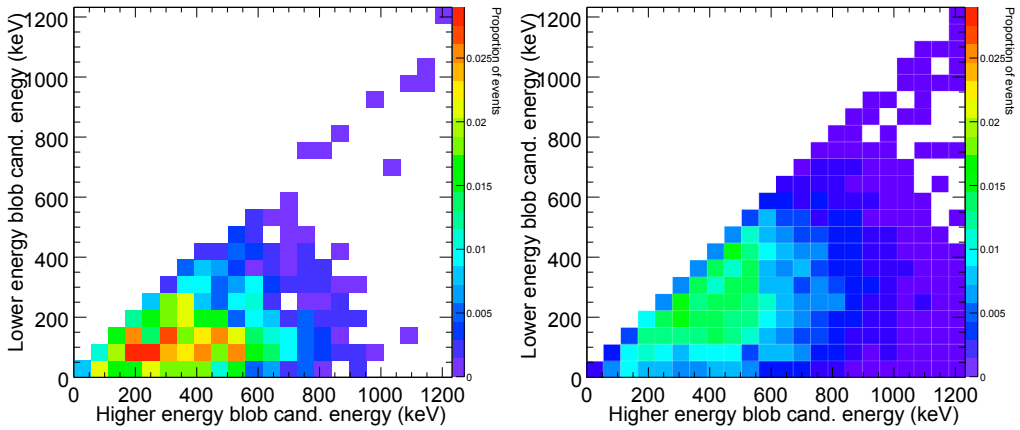


Figure 5. Energy distribution at the end-points of the tracks coming from ^{22}Na decay (left) and those coming from the ^{228}Th decay (right) for 2 cm radius blob candidates.

1. **First proof of topological signature in high pressure xenon gas with electroluminescence amplification**
   NEXT Collaboration (P. Ferrario *et al.*). Jul 21, 2015. 18 pp.
   e-Print: **arXiv:1507.05902 [physics.ins-det] | PDF**

TPS measured with DEMO data: "background", Na-22 gammas, giving single electrons, 1.275 MeV, "signal"; Tl-208 "double electrons" (e- e+, double escape peak), 1. 592 MeV

Analysis performed in Data and Monte Carlo simulation of DEMO with good agreement! First robust validation of Monte Carlo analysis for NEXT-100.

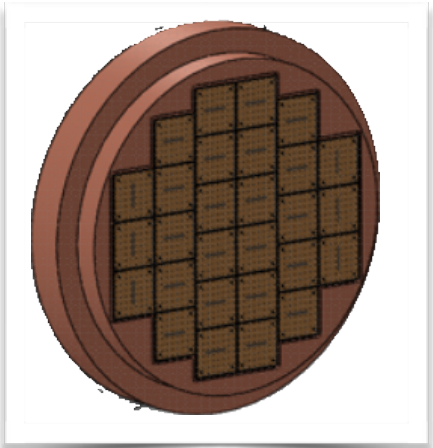

NEW
(10 kg)

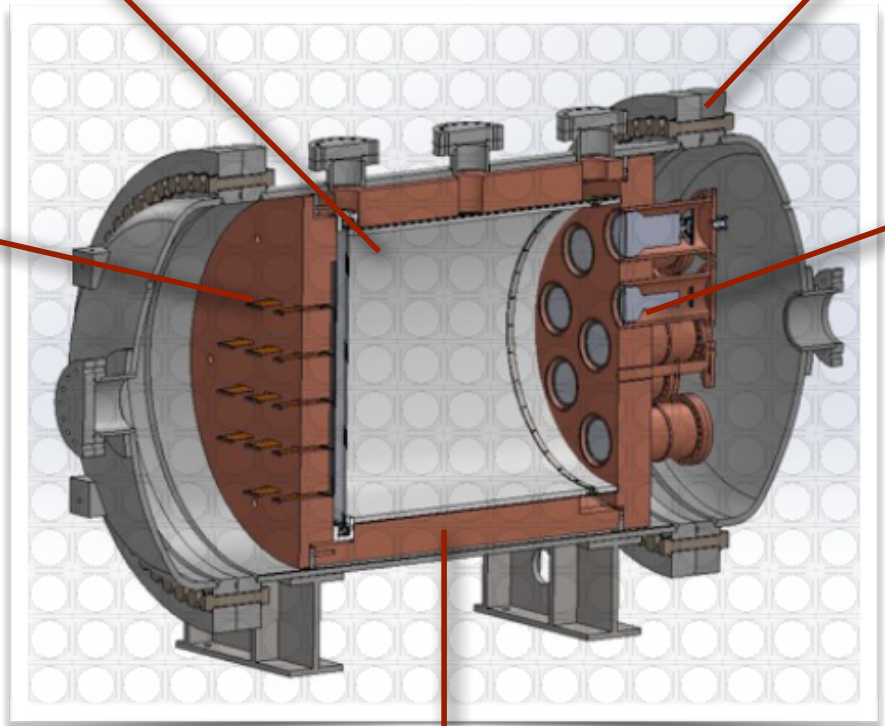
NEW (NEXT-WHITE)

Time Projection Chamber:
10 kg active region, 50 cm drift length

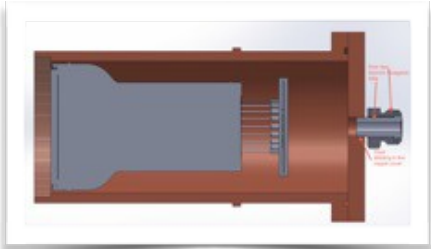
Pressure vessel:
316-Ti steel, 30 bar max pressure

Tracking plane:
1,800 SiPMs,
1 cm pitch



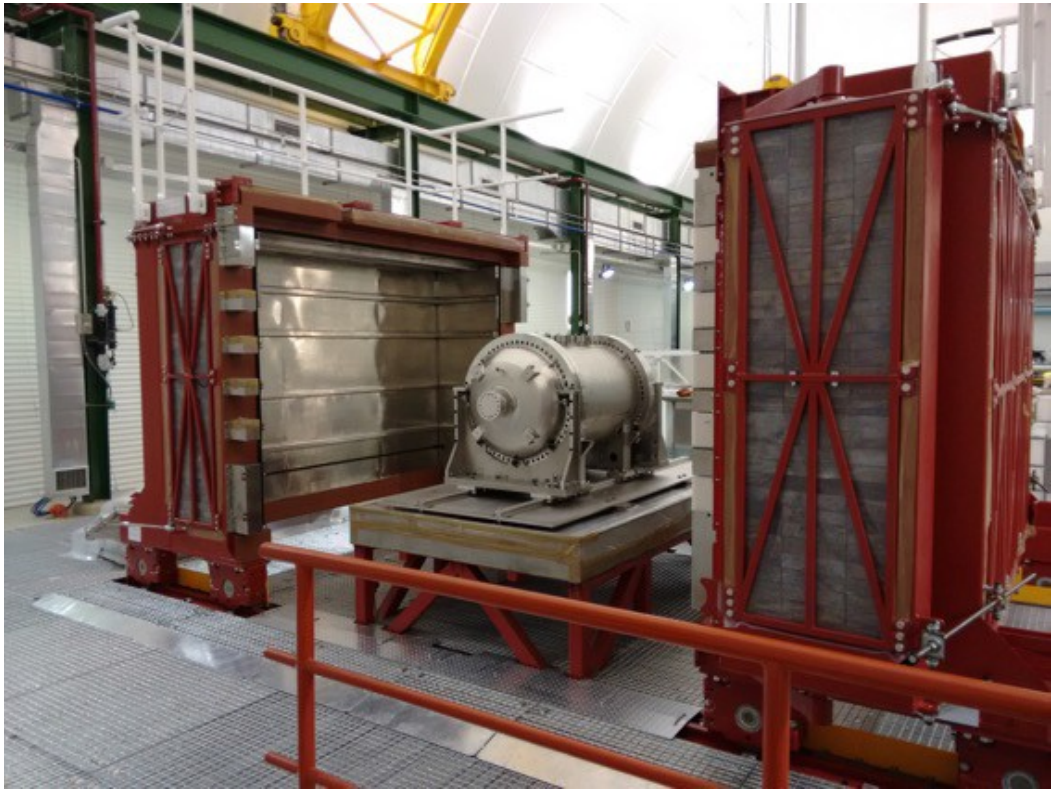


Energy plane:
12 PMTs,
30% coverage



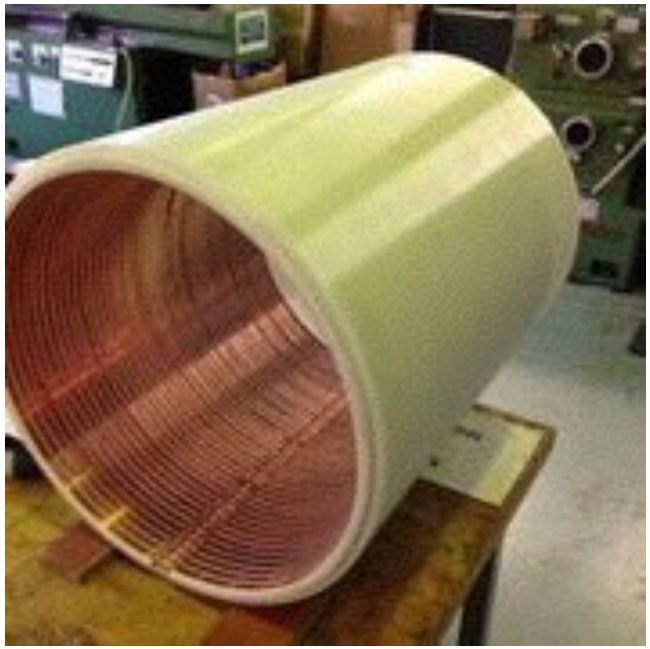
Inner shield:
copper, 6 cm thick

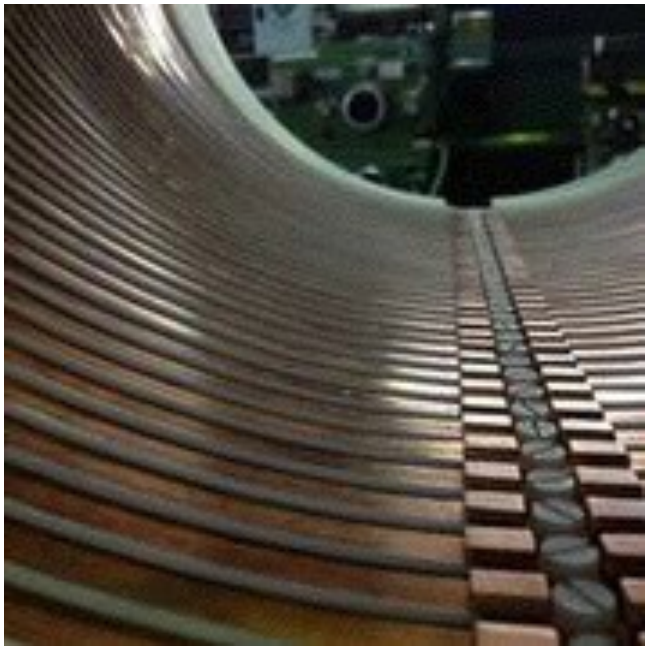
NEW (NEXT-WHITE) at the LSC



NEW on the seismic support table, inside the Lead Castle at the LSC

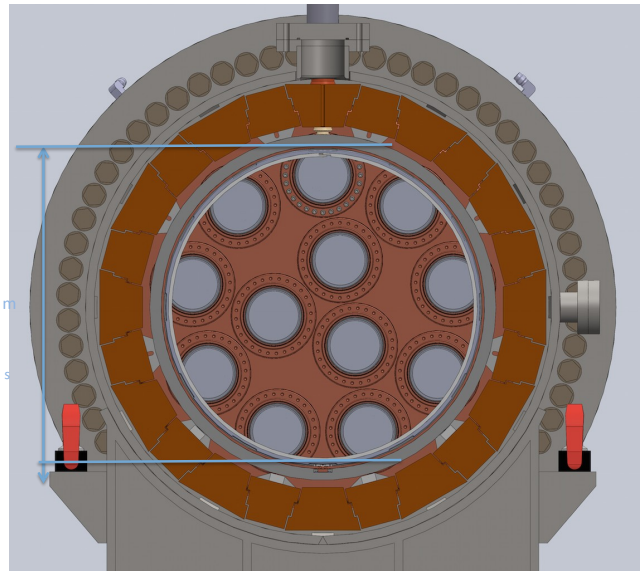
NEW field cage

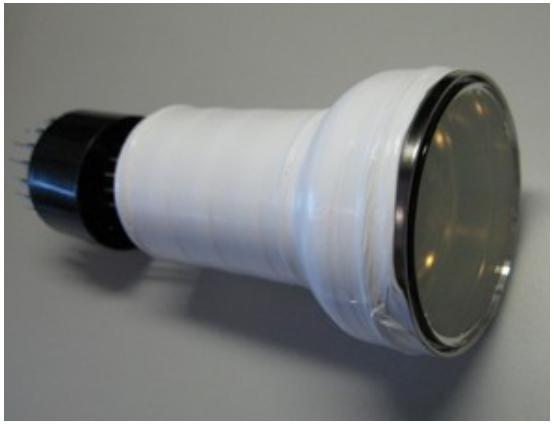




Field cage: 50 cm diameter, 50 cm drift length
Poly boy, copper rings connected by low-background resistors

Energy plane

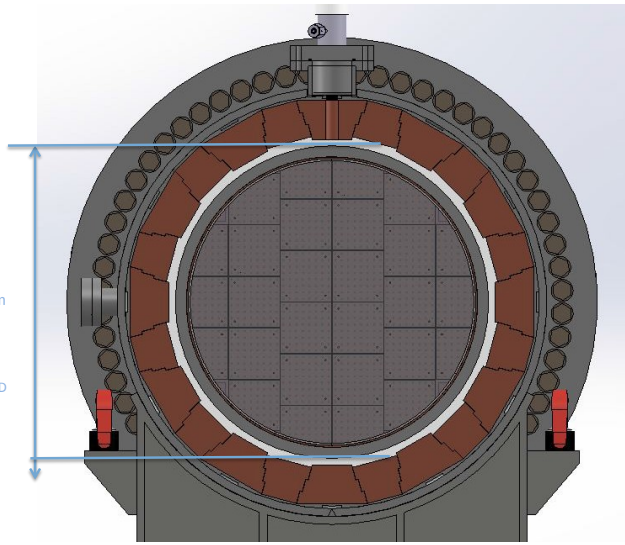


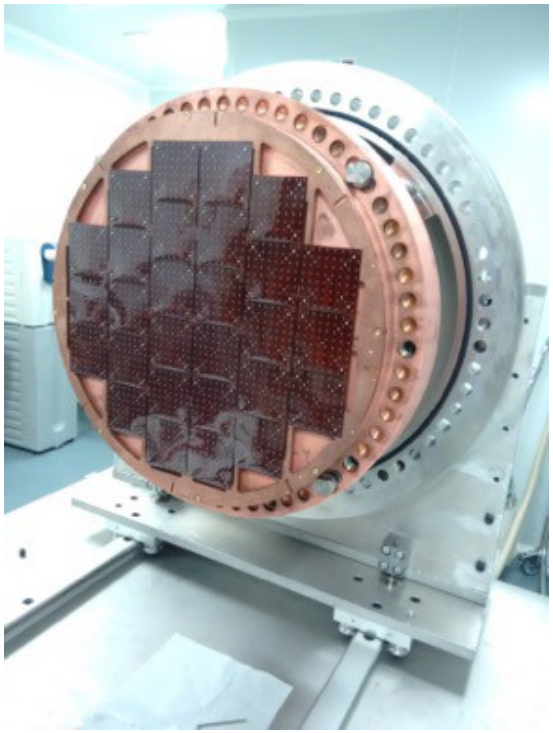


12 R11410-10 PMTs (Hamamatsu)
NEXT 100 will have 60
Excellent response (low noise very low dark current) in gas.
Radiopure (less than 1 mBq/PMT in Tl-208 and Bi 214)

Tracking plane

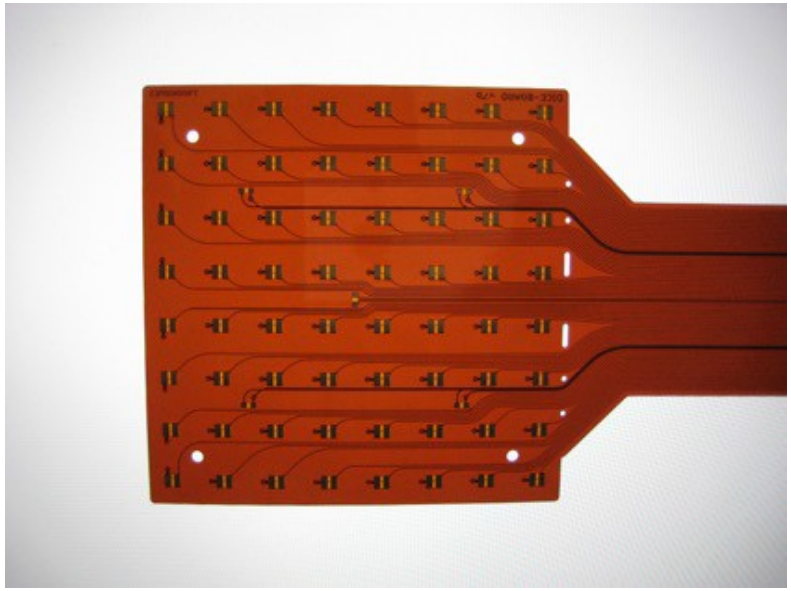
TP NEW

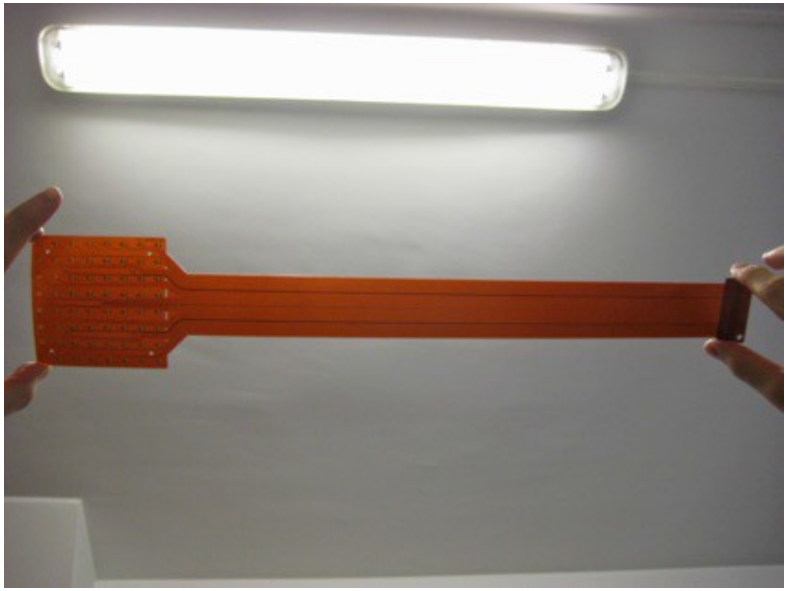




28 Kapton Dice Boards (KDBs) NEXT 100 will have ~100
Each KDB has 64 SiPMs from SENSL (thus, about 1,800 SiPms)
SENSL SiPMs are the most radiopure currently in market,

Tracking plane: KDBs



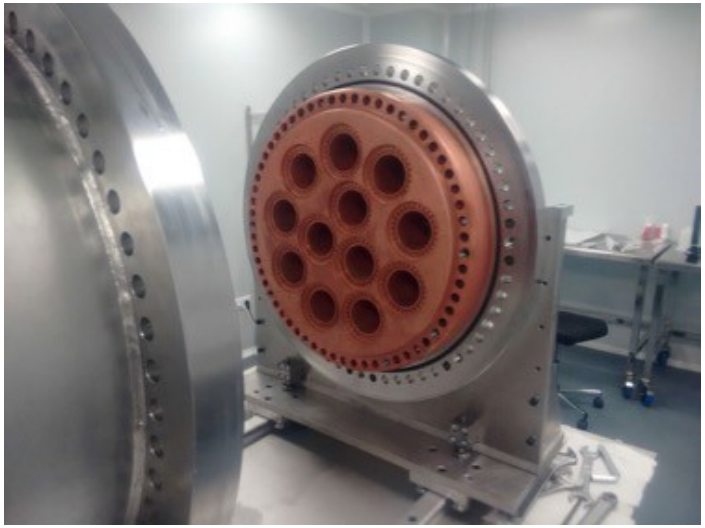


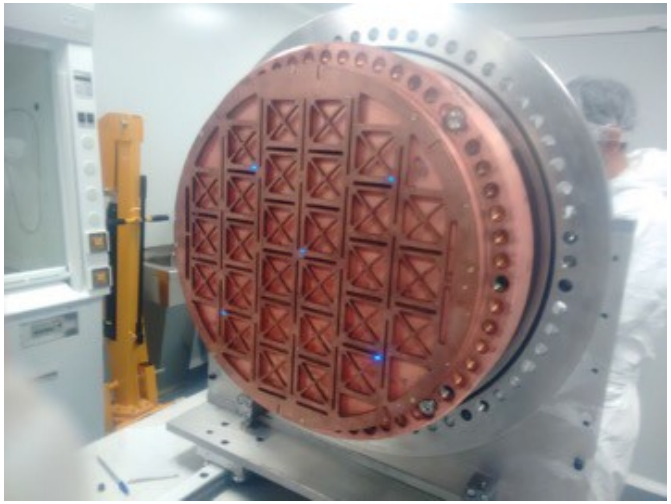
Made of low-background Kapton
Long pigtail runs through 12 cm of copper shield.
Connector BEHIND copper shield

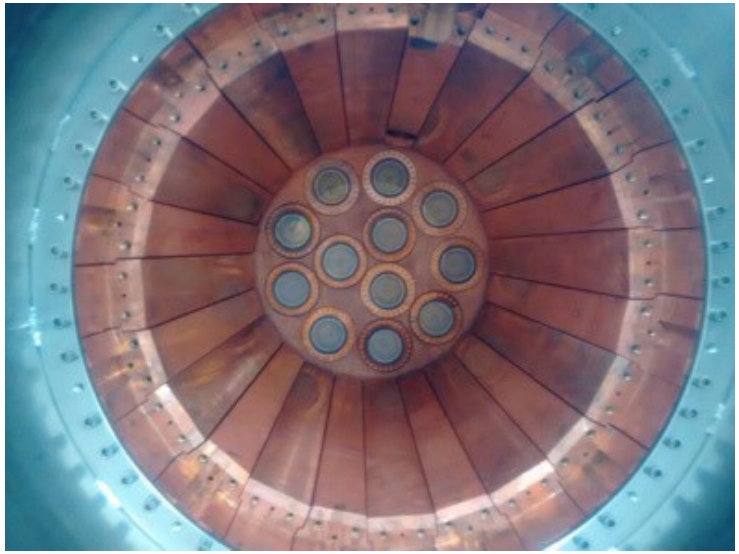
NEW Schedule

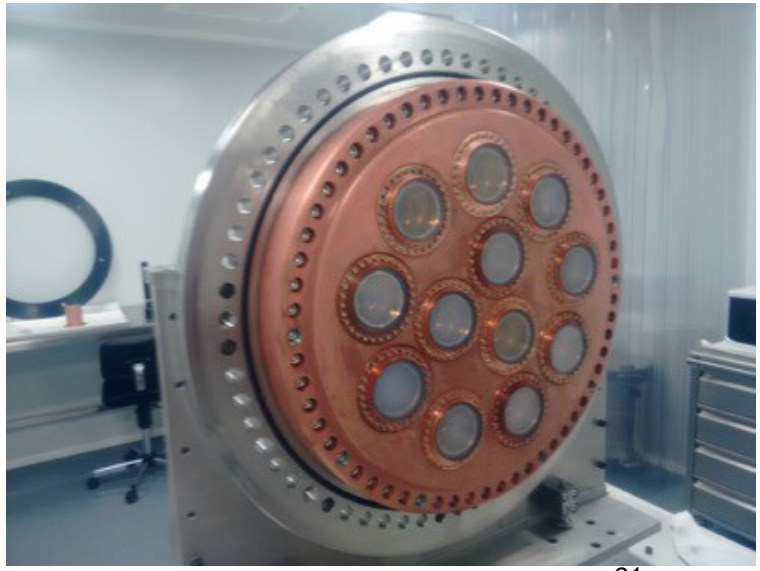
- Energy plane (EP) installed in July
- Commissioning of EP in September.
- Tracking plane installation and commissioning October — Mid November.
- Field Cage installation and commissioning: Mid November —End of year.
- Commissioning run (full detector): First Quarter (Q1) 2016.
- Calibration run (energy resolution, topological signature, gas mixtures): Q2-Q4 2016.
- Physics run (background model, $\beta\beta2\nu$): Q1-Q4 2017.

Energy Plane installation (July 2015)

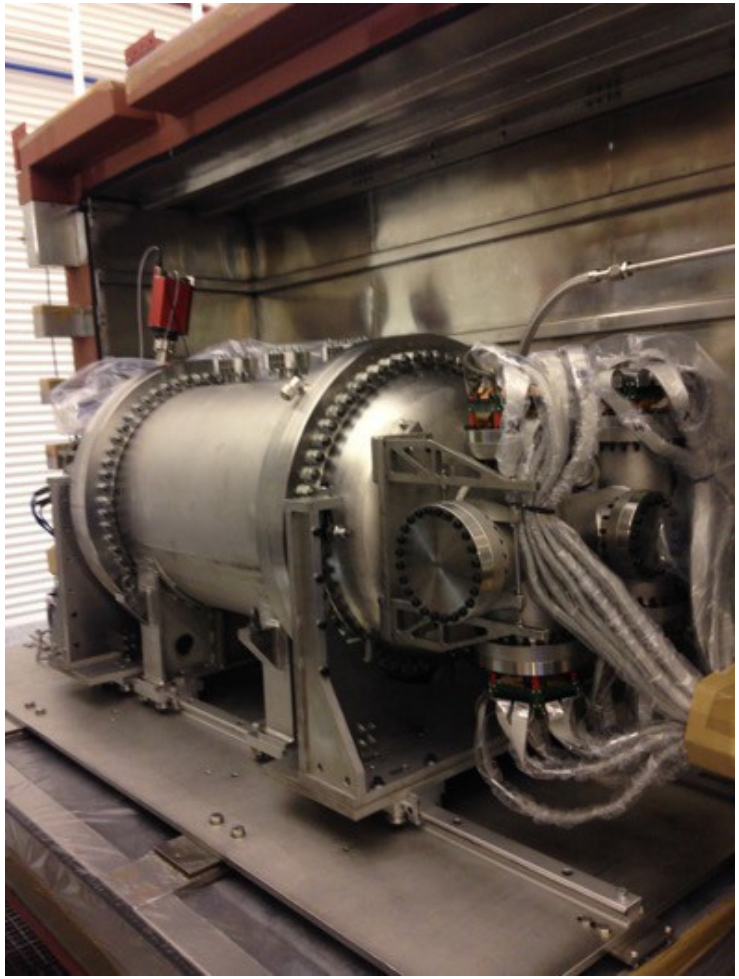




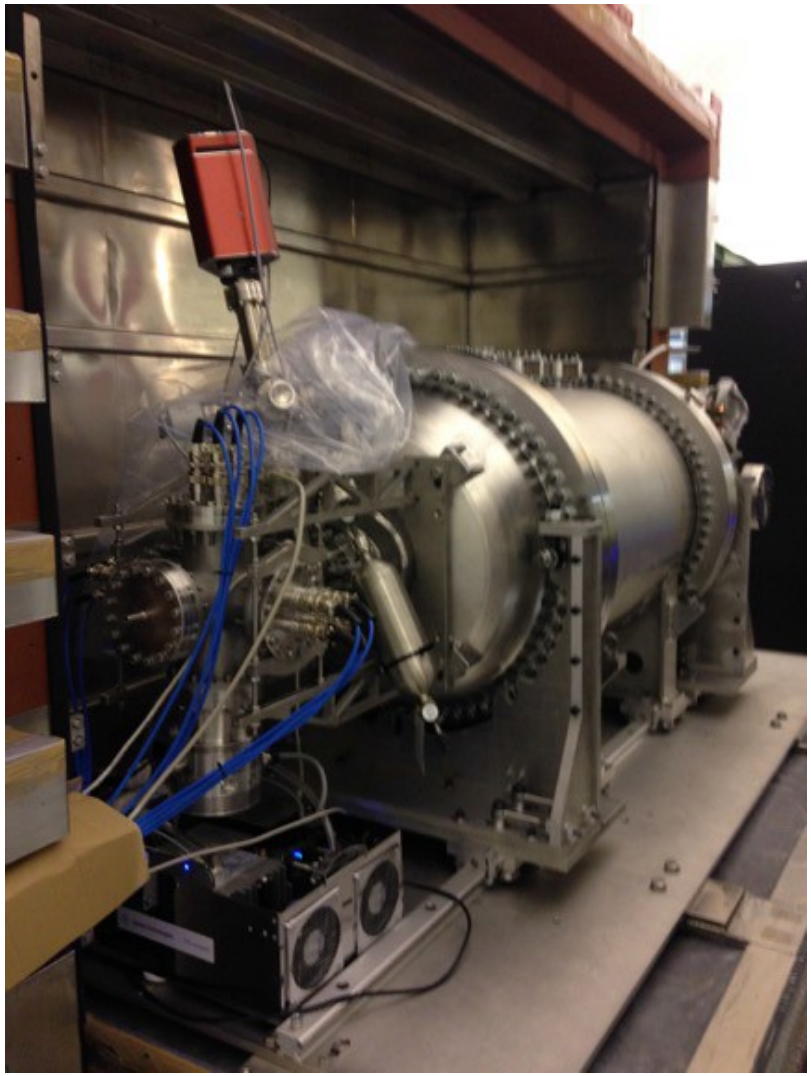


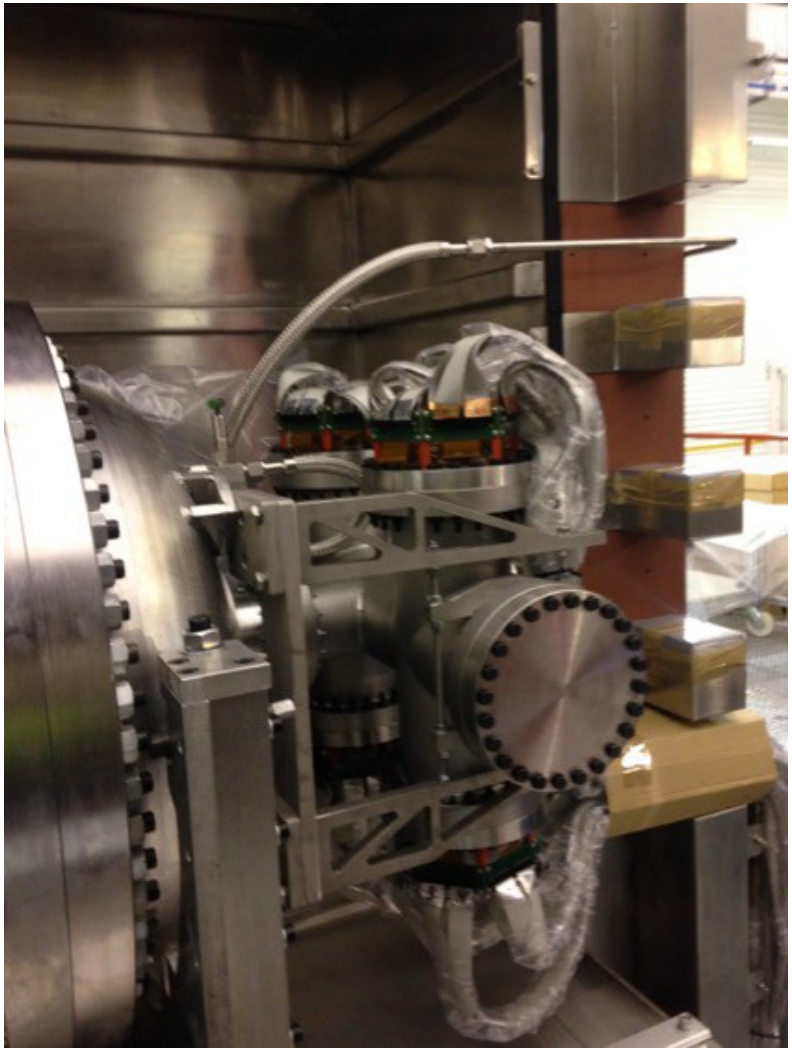


Tracking Plane installation (Nov 2015)



Tracking Plane installation (Nov 2015)





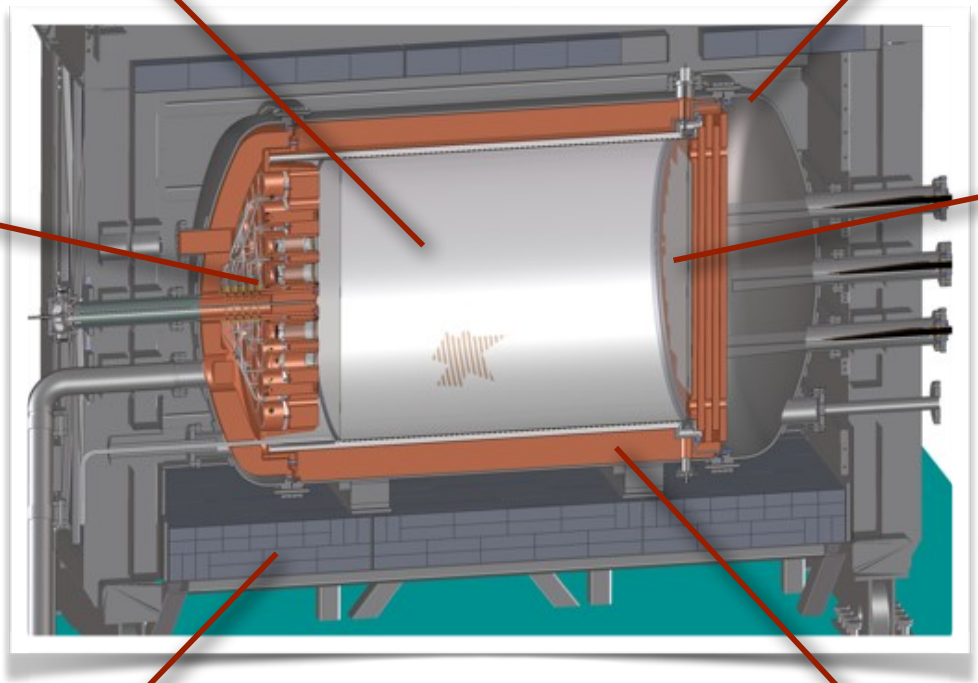

NEXT-100
(10O kg)

NEXT 100 kg detector at LSC: main features

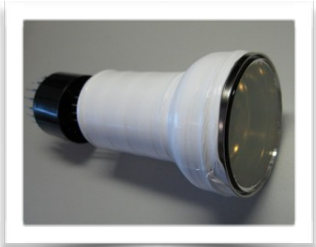
Time Projection Chamber:
100 kg active region, 130 cm drift length

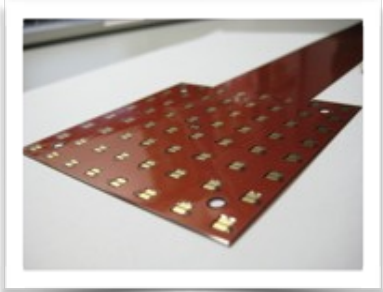
Pressure vessel:
stainless steel,15 bar max pressure

Energy plane:
60 PMTs,
30% coverage



Tracking plane:
7,000 SiPMs,
1 cm pitch

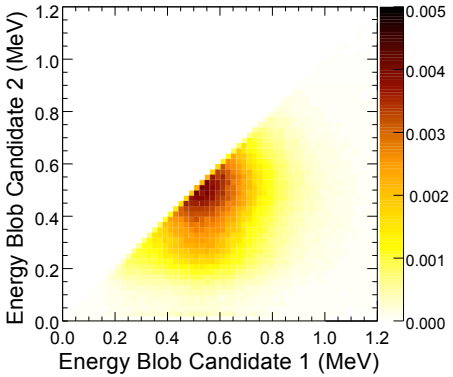


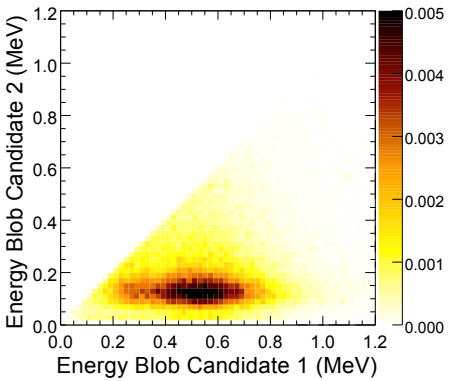


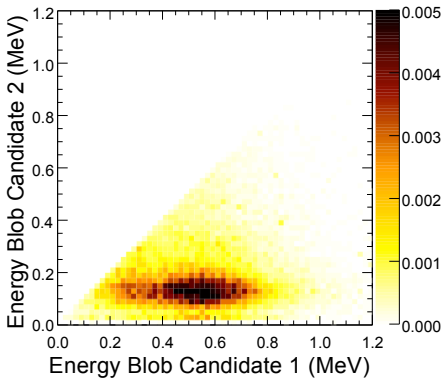
Outer shield:
lead, 20 cm thick

Inner shield:
copper, 12 cm thick

PERFORMANCE







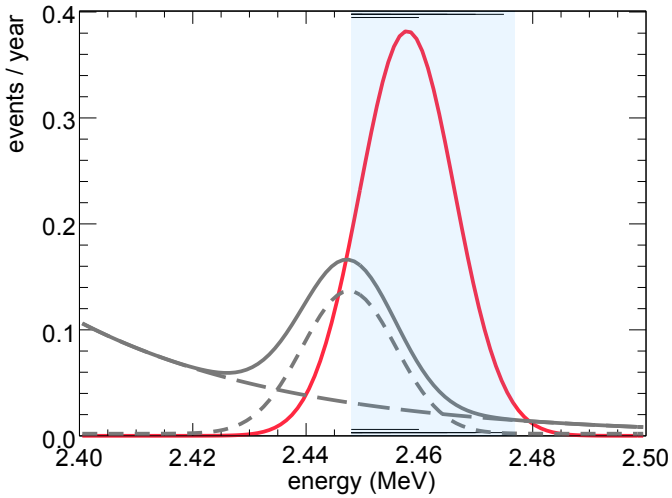
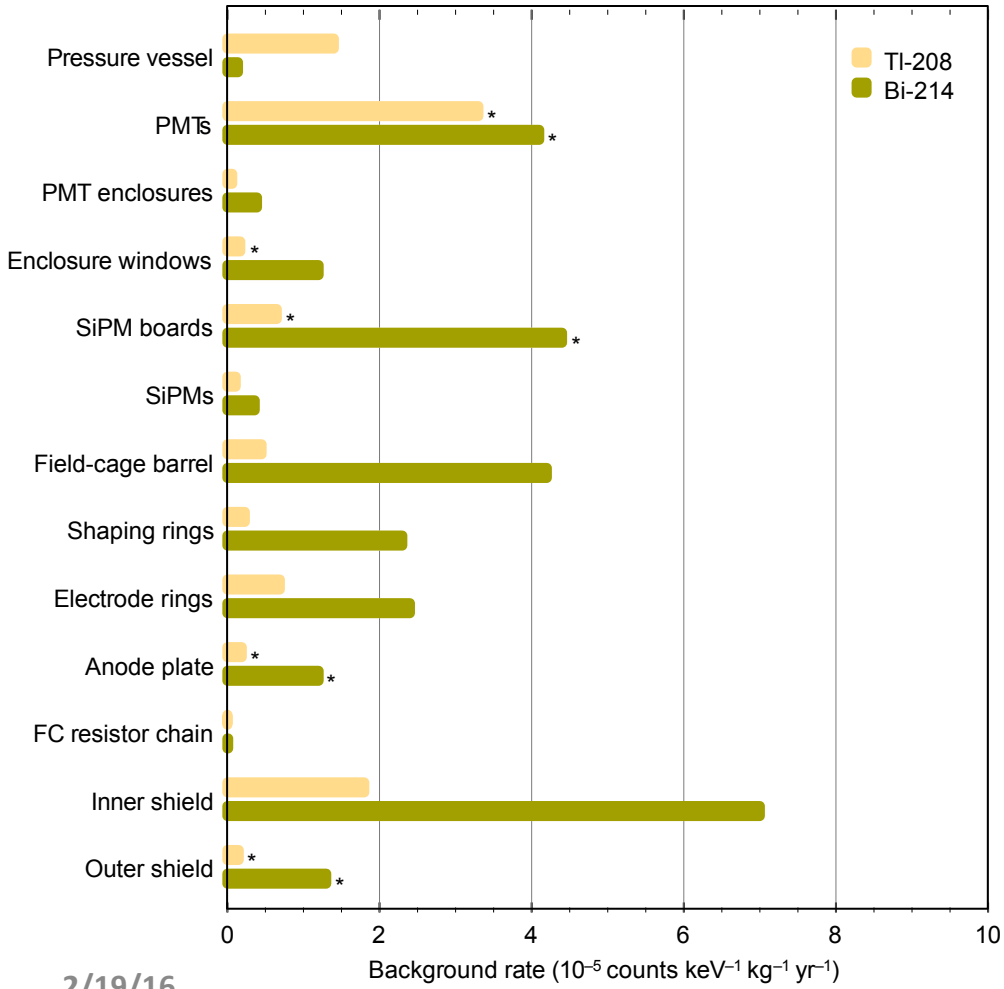


Figure 8. Energy spectra of signal (red, solid curve) and background (^{208}Tl: grey, dashed distribution; ^{214}Bi: grey, dotted distribution; total: grey, solid distribution) in the region of interest (ROI) around $Q_{\beta\beta}$. The optimal ROI (the one that maximizes the ratio of the signal efficiency over the square root of the background rate) is indicated by the shaded, blue region. The signal strength represented here corresponds to a neutrino Majorana mass of 200 meV, while the backgrounds are scaled to their expected values in NEXT-100 (6×10^{-4} counts/(keV kg y)), assuming an exposure of 91 kg yr.

Selection criterion	$0\nu\beta\beta$	$2\nu\beta\beta$	^{208}Tl	^{214}Bi
Fiducial, single track $E_2 \in [2.4, 2.5]$ MeV	0.4759	8.06×10^{-9}	2.83×10^{-5}	1.04×10^{-5}
Track with 2 blobs	0.6851	0.6851	0.1141	0.105
Energy ROI	0.8661	3.89×10^{-5}	0.150	0.457
Total	0.2824	2.15×10^{-13}	4.9×10^{-7}	4.9×10^{-7}

Table 4. Acceptance of the selection criteria for $0\nu\beta\beta$ and $2\nu\beta\beta$-decay events described in the text. The values for ^{208}Tl and ^{214}Bi correspond to one of the dominant sources of background in the detector.

Background budget



- Expected background rate: 4×10^{-4} ckky
- Leading sources: PMTs and SiPM boards (KDBs), which contribute with equal amounts. PMTs + KDBs ~10^{-4} CKKY in Bi-214
- Contribution of field cage and inner shield: only upper limits measured (taken as actual values, a conservative approach)

arXiv:1211.3961v3 [physics.ins-det] 25 Jan 2013

Radon

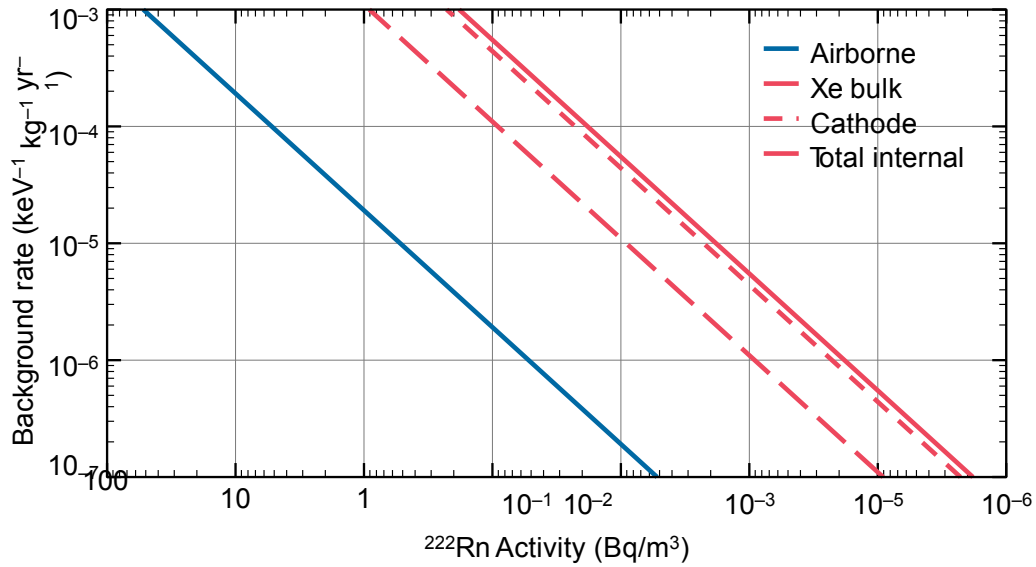
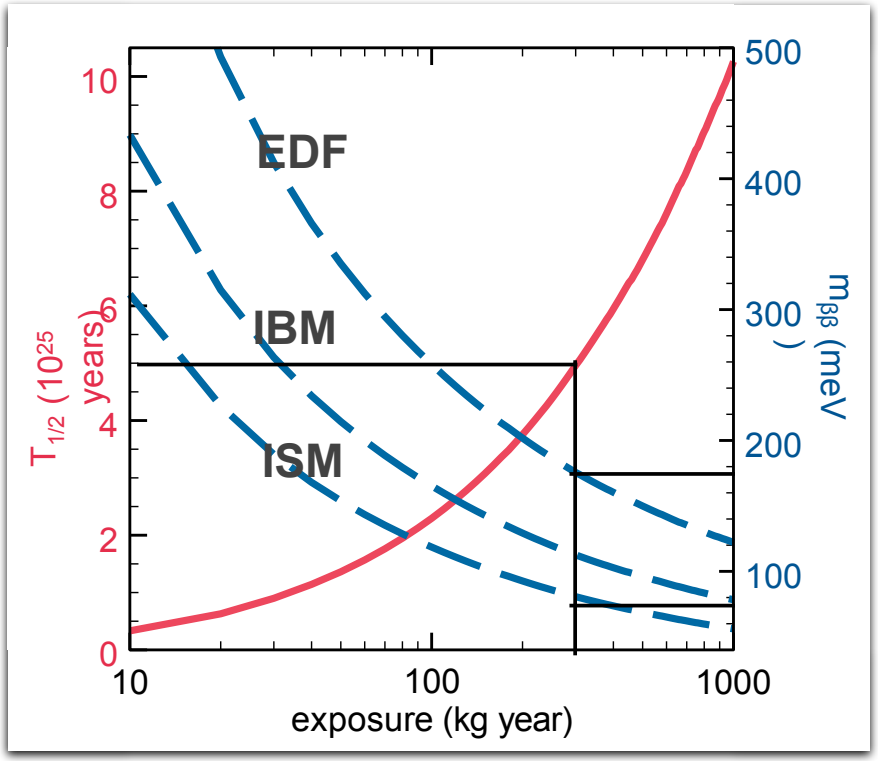


Figure 10. Background rate induced in NEXT-100 by airborne radon and radon contamination in the xenon gas (labelled as *internal*) in terms of the activity of ^{222}Rn.

NEXT-100 will operate inside Radon-suppression tent (a la NEMO): expect ~200 mBq/m3 in air. Best guess for internal is tens of mBq/m3. Contribution of Radon appears tolerable but needs to be understood by NEW operation

Sensitivity



- Expect to reach $T_{1/2} \sim 5 \times 10^{25}$ y in 3 years run (2018-2020).
- mbb ~[90-180] meV depending on NME.. (EDF, IBM, and ISM)

arXiv:1511.09246v1 [physics.ins-det] 30 Nov 2015

Summary

- NEW at LSC: commissioning in 2015, operation in 2016 and 2017. Currently energy and tracking plane installed and functional.

- DEMO analysis of Tl-208/Na-22 data with DEMO shows good topological separation and validates Monte Carlo calculations.

- NEXT sensitivity evaluated with last background model, results consistent with previous estimations.

- Expect a sensitivity to the period of 10^{25} y which translates in mbb ~[90-180] meV