Optical Time Projection Chamber for the Realization of a Ton-Scale 0νββ Decay Demonstrator

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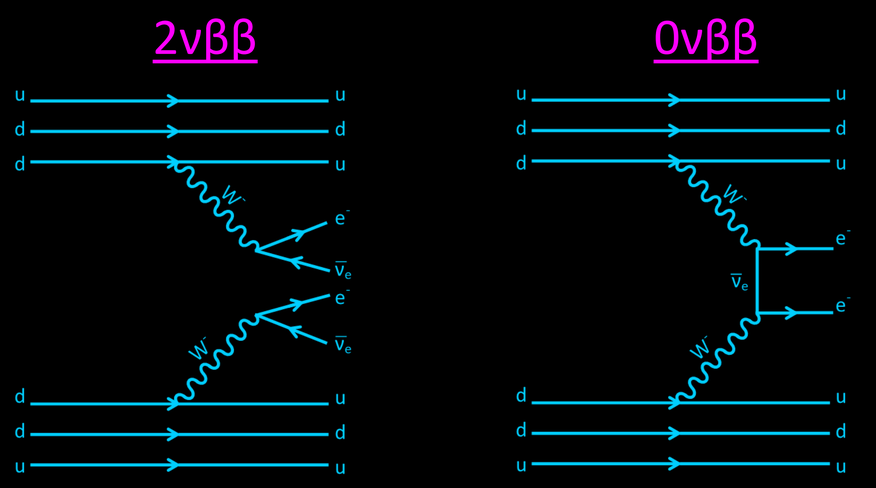
1. Neutrinoless Double Beta Decay



If discovered would prove:

1) Neutrinos are Majorana, i.e. Massive fermions exist that are neither matter nor antimatter

2) Lepton number conservation is violated; a prediction of Leptogenesis which could explain the matter-antimatter asymmetry of the universe

3) Mass generating mechanisms beyond the Higgs mechanism

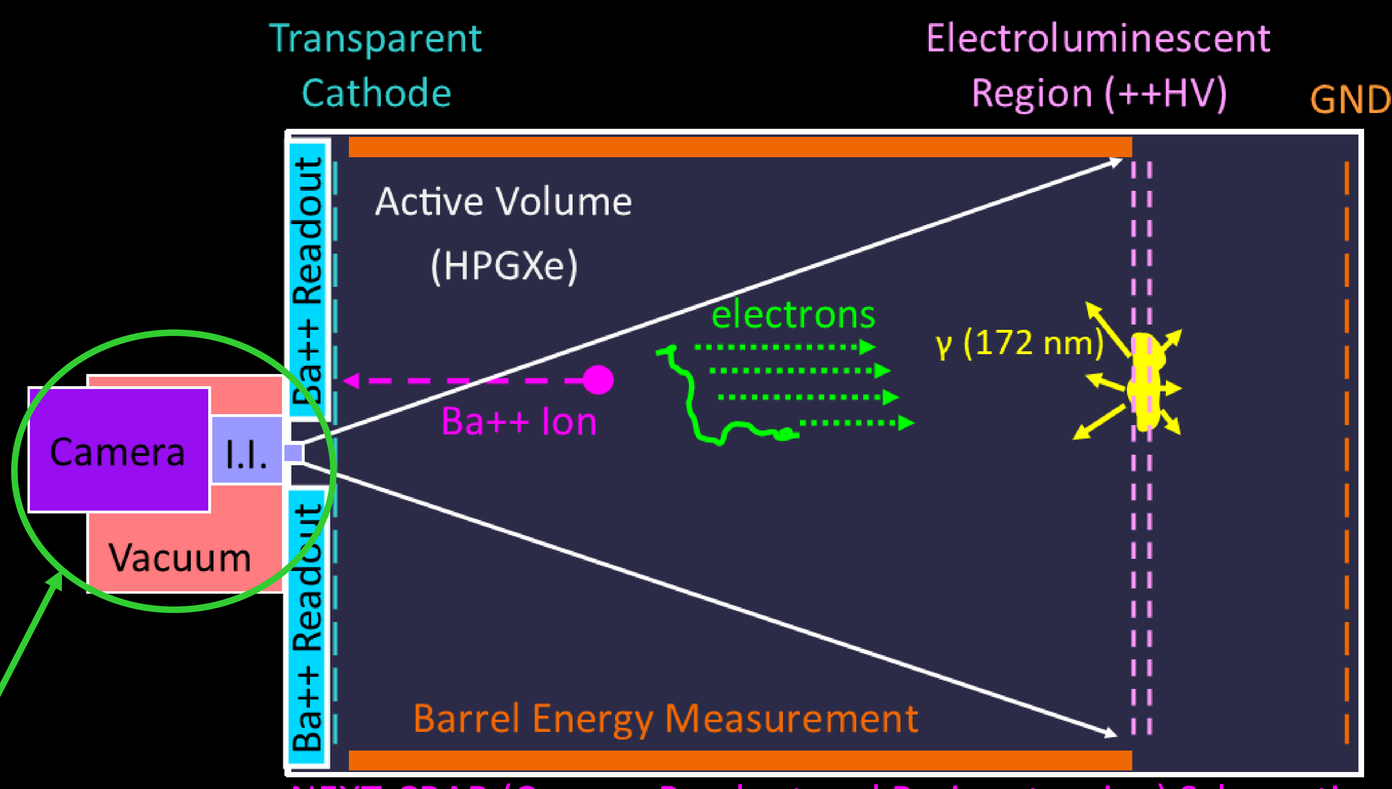
2. NEXT Detectors

NEXT (Neutrino Experiment with a Xenon TPC) uses xenon gas to search for 0νββ decay
(more on NEXT detectors, poster #362 by P. Novella)

When a decay occurs, it creates a track of ionized electrons and a single Ba^{++} atom

An electric field moves the electrons and barium ion in opposite directions. The timing of electrons reaching the electroluminescence (EL) region are projected into Z positions, with the X and Y imaged directly.

This imaging is usually done via a plane of SiPMs coated in a wavelength shifter, and placed directly behind the EL plane, such as in NEXT-White



NEXT-CRAB (Camera Readout and Barium tagging) Schematic

3. A background-free Concept for 0νββ

Observation of barium in coincidence with topological signal could completely suppress the radiological background
(more on barium tagging, posters #391 by Karen Navarro and #377 by Pablo Herrero Gomez)

To enable Barium Tagging there has to be a change in how topology is measured so the cathode is at ground rather than high voltage. Rather than SiPMs we introduce the use of scientific cameras

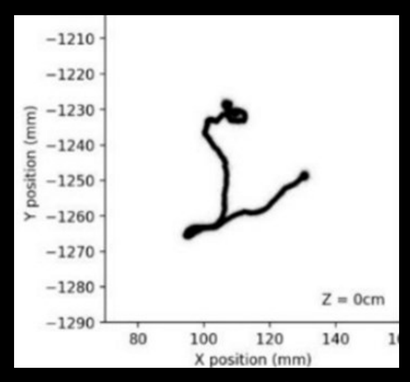
4. Why Use a Camera?

1) Entire readout system can be outside the vessel, improving radiopurity and heat load within the detector

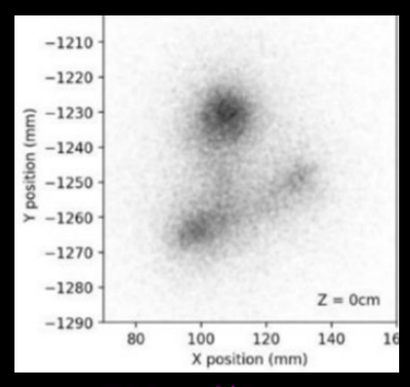
2) Simplified electronics

3) Relatively cheap, ~$300k vs >$1 million to cover the tracking plane with SiPMs

4) Focus from a distance rather than up close, freeing the cathode for Barium Tagging



Camera Readout



TPB + SiPms

	NEXT-White	NEXT-CRAB
Tracking Plane Diameter [cm]	45.4	34.3
Tracking Plane Area [cm^2]	1620	924
Number of Pixels	1792	65,536
Pixel Spacing [cm]	1	0.13
Feedthrough Channels	3600	0
Time Resolution	1μs	1.6ns

5. Optical Readout System

1) Image intensifier (I.I)

Single VUV photon sensitive; amplifies light and converts into the visible region, with a gain of 3000

2) Camera

2D tracks — EMCCD camera with 10 ms resolution
3D tracks — TPX3CAM with 1.6 ns resolution

3) Optics

To focus onto EL region

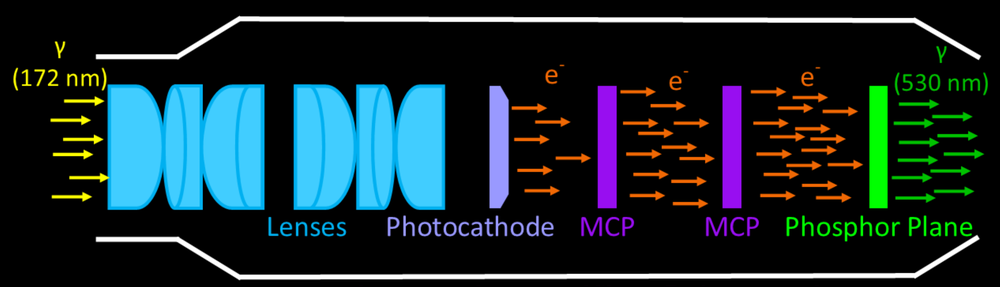
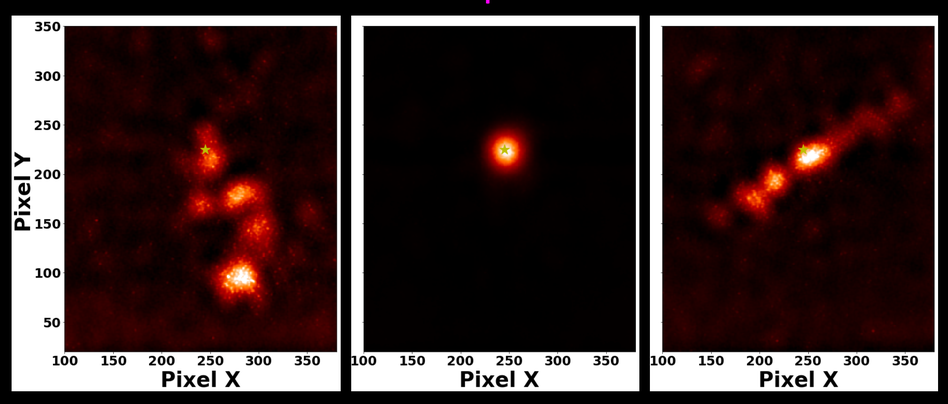


Image Intensifier Schematic

6. 2D Tracks

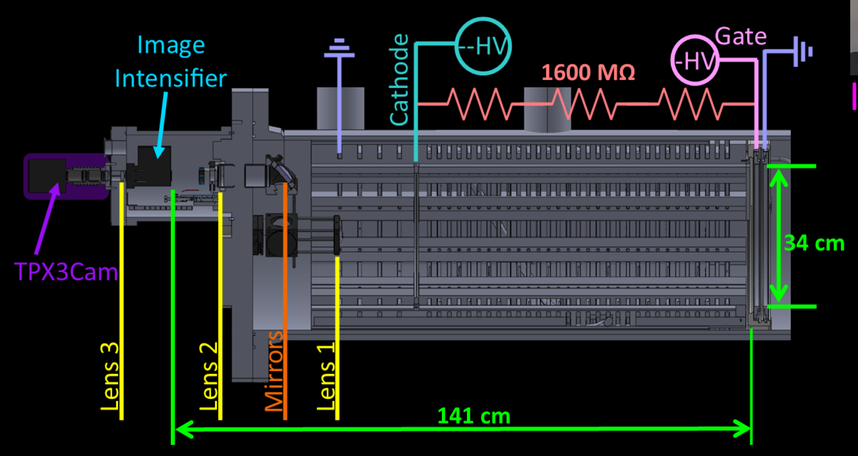
Small scale optical TPC demonstrated proof-of-concept with an EMCCD camera coupled to an Image Intensifier



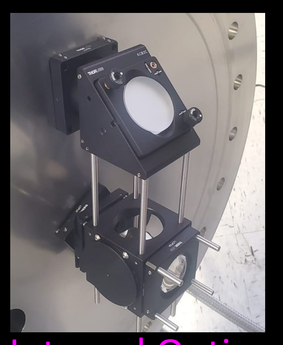
[1] N.K. Byrnes *et al* 2023 *JINST* **18** P08006

7. 3D Tracks

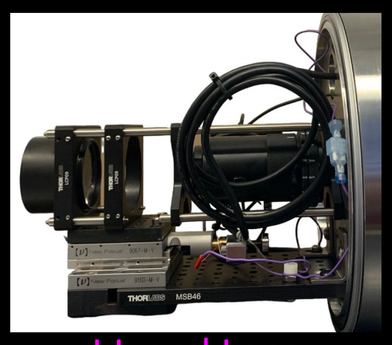
Large scale optical TPC using TimePix3 camera, built at Argonne National Lab with first tracks expected in the coming weeks



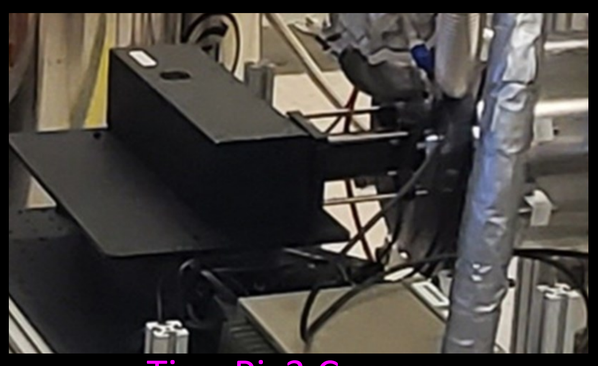
Large Scale NEXT-CRAB



Internal Optics



I.I. and Lens



TimePix3 Camera