Test of a prototype Topmetal chip for NνDEx experiment

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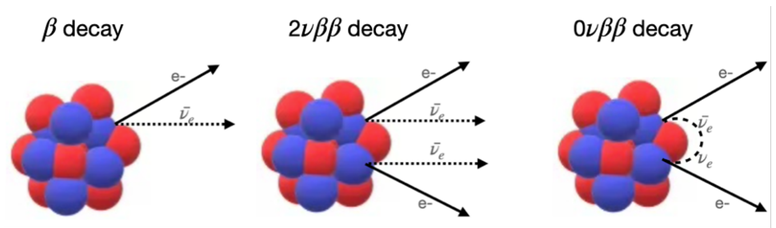
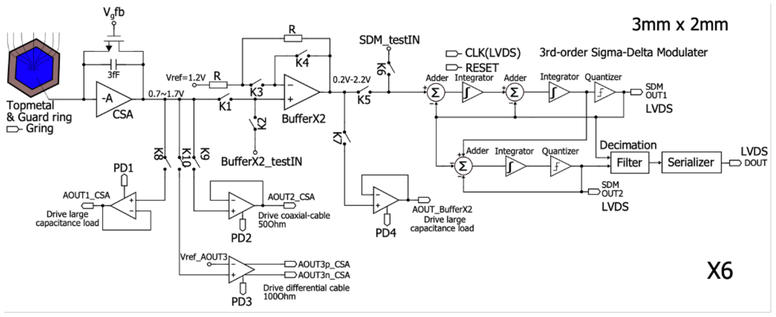
Abstract

NνDEx(No Neutrino Double-beta-decay Experiment) is a recently proposed experiment to search for the neutrinoless double beta decay of ^{82}Se with $^{82}SeF_6$ high pressure gas TPC. The readout plane made of Topmetal-S chips is the key to achieve the desired 1% FWHM energy resolution. We present the design of the prototype chip and the preliminary results of characterization of the second version chip. An ENC of 120e, measured using injected pules, could be obtained. This is a significant improvement comparing with the first version. Further refinement is under investigation and tests using gamma rays are planed.

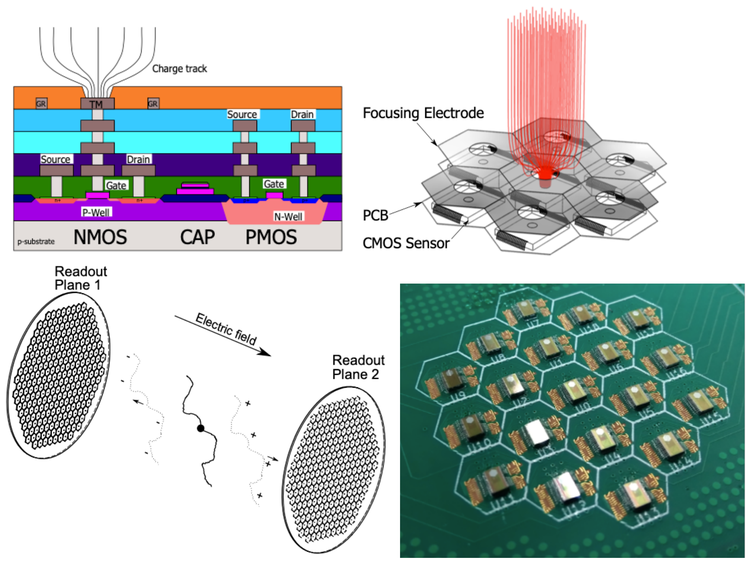
$0\nu\beta\beta$



Topmetal-S schematic diagram



Topmetal-S readout plane

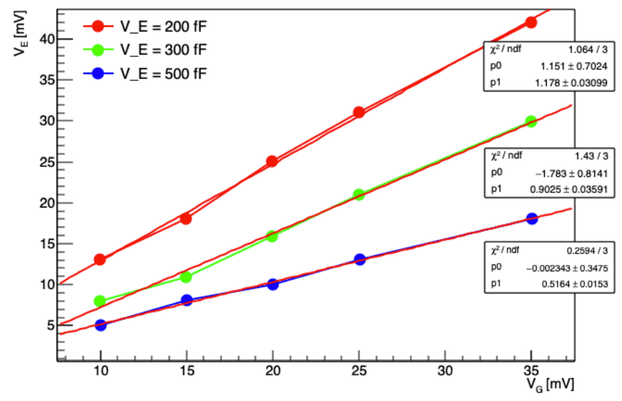


Topmetal-S V2 chip test result

1. Capacitance of guard ring

The capacitance of guard ring is measured by a circuit bridge. The relation between external capacitance and guard ring capacitance can be described by $\frac{C_E}{C_G} = \frac{V_G}{V_E}$, where C and V are the capacitance and injecting amplitude. G means guard ring and E means external capacitor.

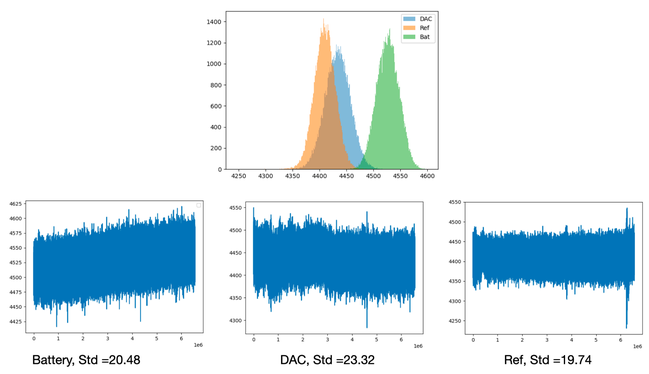
Three different external capacitor(200 fF, 300 fF, 500 fF) were used and the capacitance of guard ring is about 250 fF.



External cap (fF)	500	200	300
Guard ring cap (fF)	258.2 \pm 7.65	235.6 \pm 6.2 fF	270.8 \pm 10.8

2. Data taking and noise

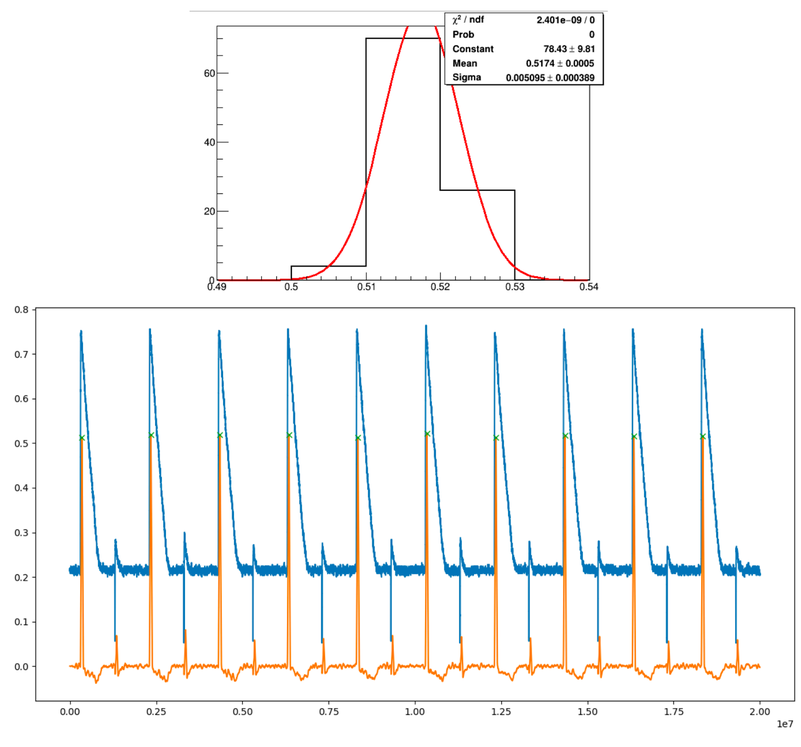
A readout board is used to record data continuously. It can provide max 125MHz sampling rate. In our test board, 3 sources of CSA bias voltages are available: DAC-8568 chip, battery and ADR4540 ref chip. Right figure shows the noise of baseline when using 3 different kinds of sources. The noise from DAC > battery > ref chip, but the difference is not large.



3. ENC

A trapezoidal filter is used to extract the amplitude of the output. By repeating the pulse injection, we can get the distribution of the output amplitude, and its mean (μ) and standard derivation (σ) are used to calculated the ENC:
$ENC = C_{in} \times V_{in} \times \frac{\sigma}{\mu}$
where $C_{in} \times V_{in}$ gives the number of injected electrons (250 fF $\times$ 8 mV).

The measured ENC is about 120e, much better than that of the first version, 600e, but still not good enough for NνDEx. The ENC is expected to be further reduced by fine-tuning the chip bias voltage and optimizing the data processing algorithms. Tests using γ rays are also planed.



Summary

Taking a number of advantages, NνDEx is a promising next generation $0\nu\beta\beta$ search experiment. The readout plane consisting of $\sim$ 10k Topmetal-S chips is crucial for ion drift detection to achieve the 1% FWHM energy resolution while having a good tracking capability.

Two versions of the Topmetal-S chips have been made, and the testing of the second version is ongoing. Some preliminary results are shown here. The issues found in the first version are fixed. The capacitance of guard ring measured using a circuit bridge is around 250 fF. And the ENC, measured by injecting pulses to the guard-ring, is around 120e. We are working on further optimizations. The test using γ rays will start soon.

In the future versions, other modules such as network readout will be added. And a final version is expected to be ready in 2025 along with the roadmap of NνDEx experiment.

Reference

[1] Yuan Mei, Xiangming Sun, and Nu Xu. Topmetal CMOS direct charge sensing plane for neutrinoless double-beta decay search in high-pressure gaseous TPC. 10 2020.

[2] D. R. Nygren, B. J. P. Jones, N. López-March, Y. Mei, F. Psihas, and J. Renner. Neutrinoless Double Beta Decay with 82SeF6 and Direct Ion Imaging. JINST, 13(03):P03015, 2018.5

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