A Novel Front-End Amplifier for Gain-less Charge Readout in High-pressure Gas TPC

Wanhan Feng\textsuperscript{a,b}, Danfeng Li\textsuperscript{a,b}, Qingwen Ye\textsuperscript{a,b}, Guangming Huang\textsuperscript{a,b}, Xiangming Sun\textsuperscript{a,b} and Chaosong Gao\textsuperscript{a,b}

\textsuperscript{a}PLAC, Key Laboratory of Quark and Lepton Physics (MOE), Central China Normal University, Wuhan, Hubei 430079, China
\textsuperscript{b}Hubei Provincial Engineering Research Center of Silicon Pixel Chip & Detection Technology

\textbf{Abstract}

We present a novel low-noise Charge-Sensitive Amplifier (CSA) manufactured in a standard 0.13 μm CMOS process. The CSA is part of an integrated sensor, with an array of which, forms a charge readout plane in a high-pressure gaseous Time Projection Chamber (TPC) for 0νββ search. A novel front-end amplifier composed of a source-drain follower and a common-source amplifier is proposed. The potential on both the source and drain node of the input transistor follows its gate. Hence the effective input capacitance contributed by the input transistor is significantly reduced. If both the CCE and the input metal routing are also shielded and the shield is coupled to the source or drain node, the input capacitance can be greatly reduced. The simulation shows that the equivalent noise charge is about 30 e−.

\textbf{Introduction}

\textbf{Neutrino-less double beta decay is a low background and low noise experiment [1].} Topmetal sensor for a next-generation high-pressure gaseous TPC to search for neutrinoless double-beta decay (0νββ):

- Topmetal sensor advantage: directly collecting ionization charges without gas-electron multiplication
- Energy resolution: < 1% FWHM → ENC<30e−
- Charge Collection Electrode: 1 mm diameter
- Pitch: 5~10 mm
- 10\textsuperscript{4} sensors for a large plane

\textbf{Charge Collection Electrode (CCE)}

CCE:
- top metal exposed around media
- directly collecting ionization charge
- DC coupled to the front end
- hexagon shape with a diameter of \(d_1 = 1\) mm
- 4 pF capacitance
- top-metal guarding surrounding the CCE with a spacing of \(d_2 = 3.5\) μm and a width of \(d_3 = 4.7\) μm
- injecting charge by a parasitic capacitance of 0.834 fF
- focusing electric field

\textbf{Test Chip}

\textbf{Building Blocks:}
- CCE, CSA and Unit-Gain Buffer

\textbf{Simulation Results}

- The conversion gain of the CSA is about 890 mV/fC.
- The post-simulation results show that the equivalent noise charge of the CSA is 30 e−.

\textbf{Summary and Outlook}

A low-noise charge-sensitive amplifier has been tapped out in a 0.13 μm process. The post-simulation shows it has an equivalent noise charge of 30 e−. The characteristic satisfies the requirement of the 0νββ experiment. We will test the chip in the future.

\textbf{Acknowledgments and References}

This work is supported by the National Natural Science Foundation of China under Grant No. 11805080.

\textbf{Reference:}