

# R&D status of FD-SOI-MOSFET Cold Amplifier

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## 1. Introduction

We are developing the Nb/Al-Superconducting Tunnel Junction (STJ) photon detector for the experiment to search the decay of cosmic neutrino background. The final goal is to measure mass of neutrino. We employed and are developing Fully Depleted Silicon On Insulator (FD-SOI) - MOSFET based cold pre-amplifier to increase signal to noise ratio of STJ detector.

## 2. Neutrino Decay Search

**Neutrino can decay:**  $\nu_3 \rightarrow \nu_2 + \gamma$  as shown Fig1.

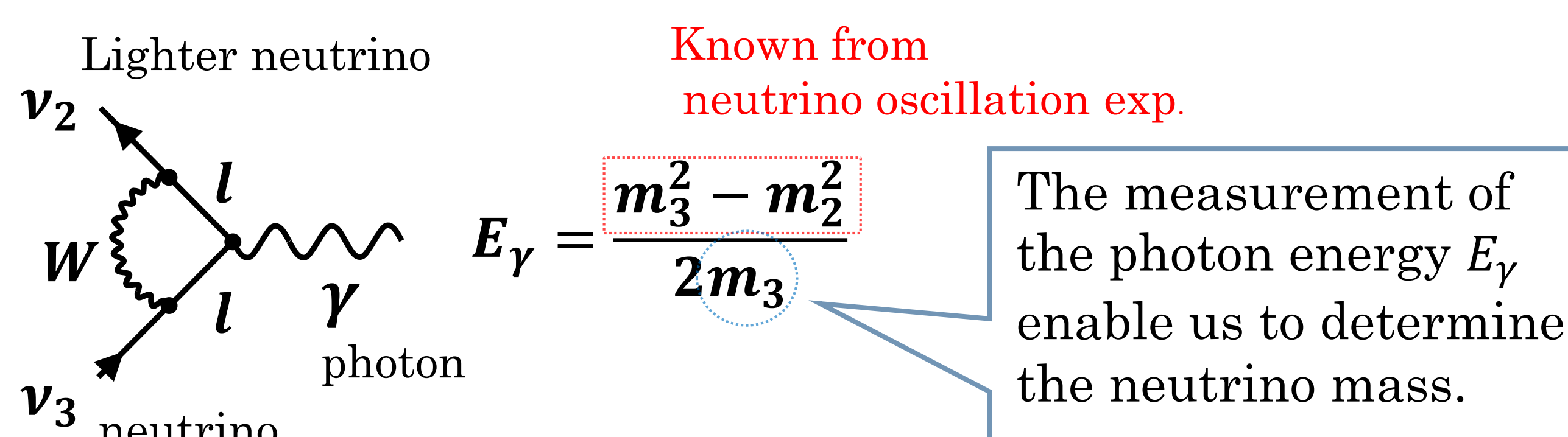


Fig1. Neutrino decay and photon energy

- **Decay lifetime is very long;**  $\sim 10^{17}$  years in L-R symmetric model.
  - We proposed searching the decay of an immense quantity of neutrino; **Cosmic neutrino background;**  $110\text{cm}^{-3}$ .
- **$E_\gamma$  is very small;** 25meV if neutrino mass  $m_3 = 50\text{meV}$ .
  - ➔ **We employed STJ detector for neutrino decay search**

## 3. Superconducting Tunnel Junction detector

**Superconducting Tunnel Junction (STJ)** is detector consist of Superconductor / Insulator / Superconductor. We are developing Nb/Al-STJ as shown fig3.

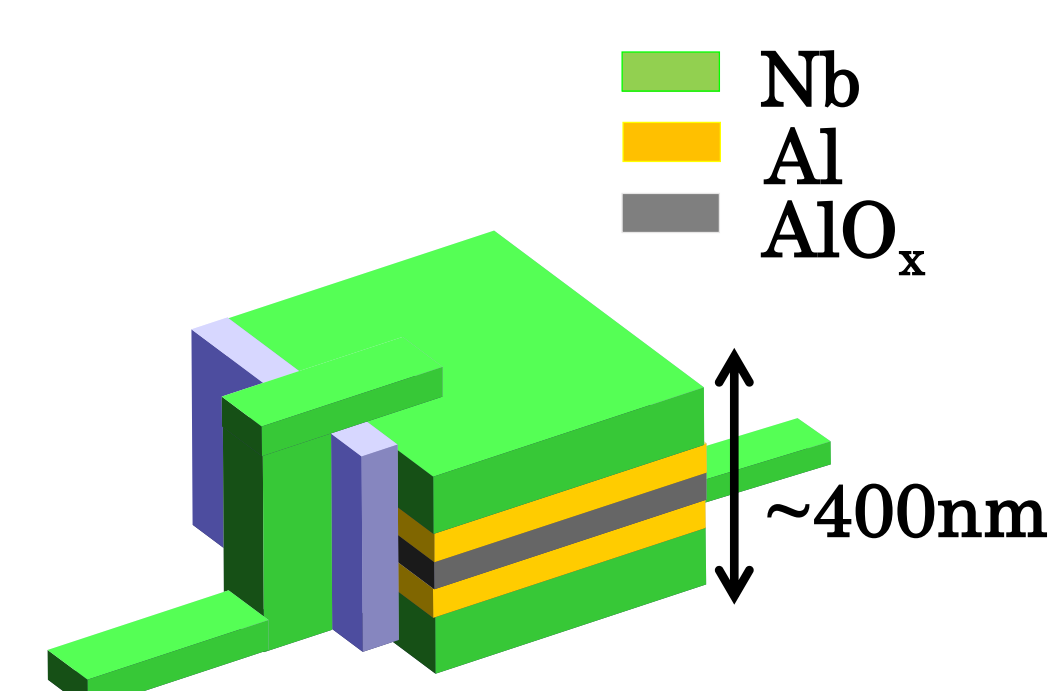


Fig3. Nb/Al-STJ detector

The characteristics of our Nb/Al-STJ are

- **Low band-gap energy;**  $\sim 0.5\text{meV}$ 
  - The signal is  $\sim 95$  electrons for a 25meV photon
- **Operation temperature  $\leq 800\text{mK}$**  for the best performance.
- **Operation voltage  $\sim 0.5\text{mV}$**
- **Leakage current is large;**
- **Detector capacitance is large;** 1nF for  $100 \times 100 \mu\text{m}^2$  Nb/Al-STJ
- **Signal width  $\sim$  a few  $\mu\text{sec}$ .**

However we cannot detect UV single photon due to noise and transmission loss in read-out system.

➔ **Introduction of a cold pre-amplifier**

**Requirement for cold amplifier**

- ✓ Can be operated at STJ operation temperature ( $\leq 800\text{mK}$ )
- ✓ Can amplify signal about  $\sim \text{MHz}$
- ✓ power  $\ll$  cooling power of the refrigerator  $\sim \mu\text{W}$ .
- ✓ Low noise

➔ **We employed FD-SOI MOSFETs**

## 4. FD-SOI-MOSFET Cold pre-amplifier

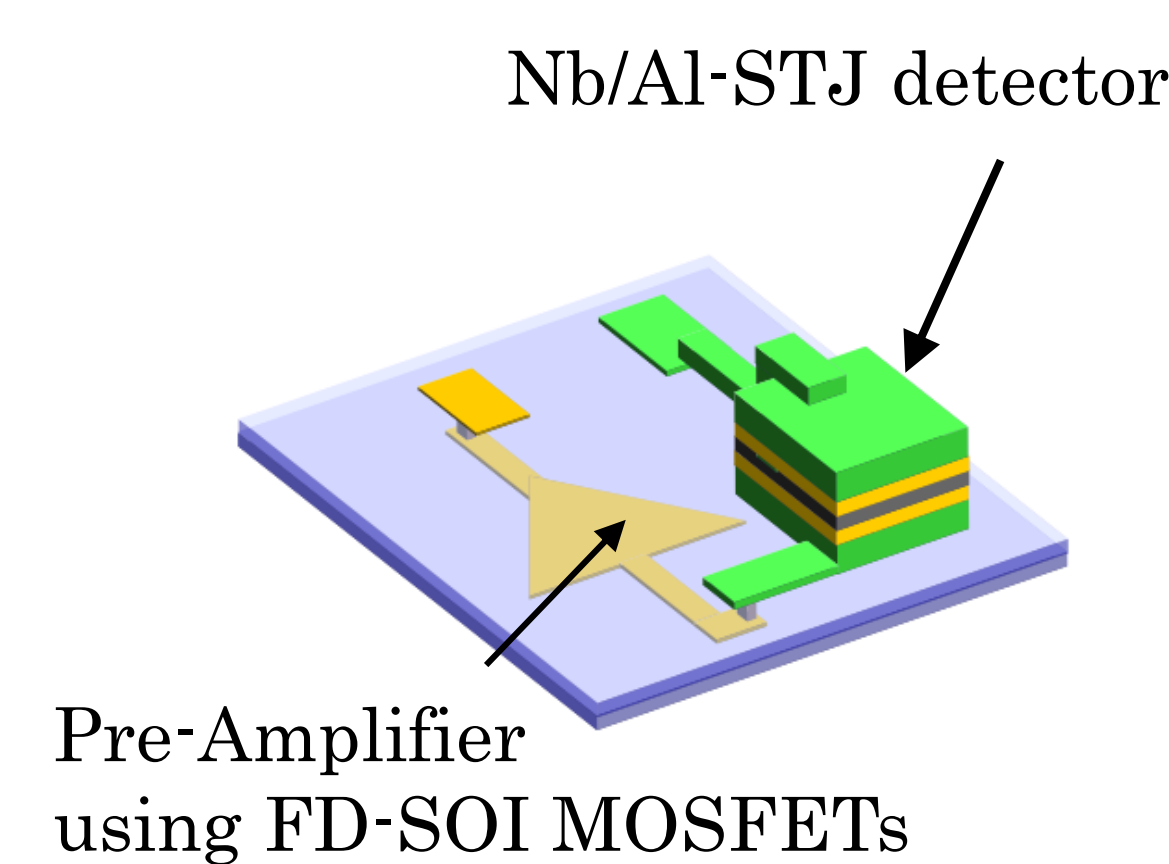


Fig5. STJ and Cold Amplifier

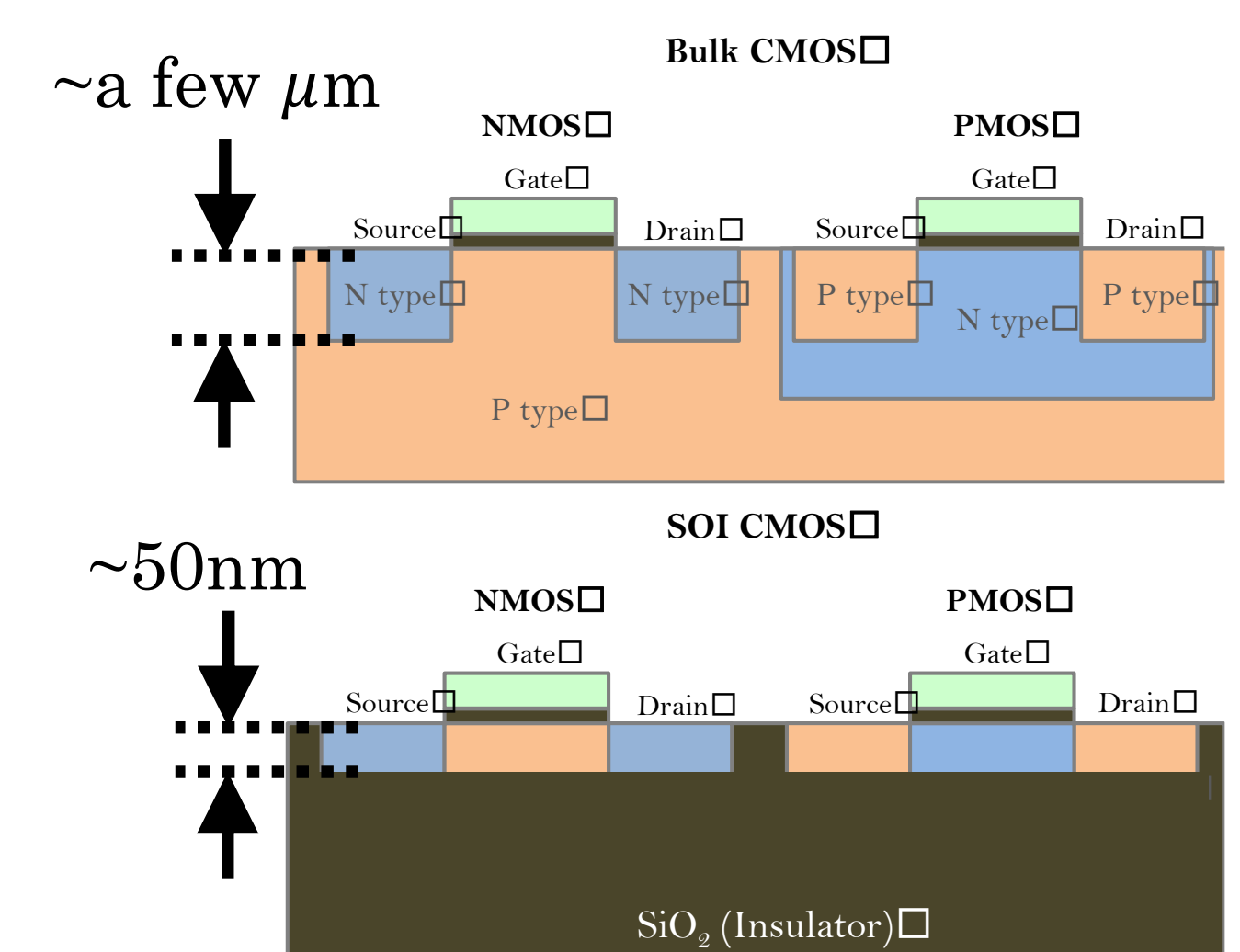


Fig6. Bulk MOSFET vs FD-SOI MOSFET

We are developing the Fully Depleted Silicon On Insulator (FD-SOI) MOSFET based cold pre-amplifier to increase the signal to noise ratio of the Nb/Al-STJ detector.

**FD-SOI MOSFET** is transistor that processed on SiO<sub>2</sub> insulator and have characteristics such as

- **Thin channel layer;** suppression charge-up of the body due to high-mobility carrier at low temperature.
  - **Can be operated  $\leq 800\text{mK}$**
- **Each devices are separated by insulator;** Parasitic Capacitance is small
  - **Low power to be operated**
  - **High speed**

**The Characteristic at Low temperature** are

- Threshold voltage and transconductance is increase
- Non-linear shape at low V<sub>d</sub>
- Kink effect appear at high V<sub>d</sub>

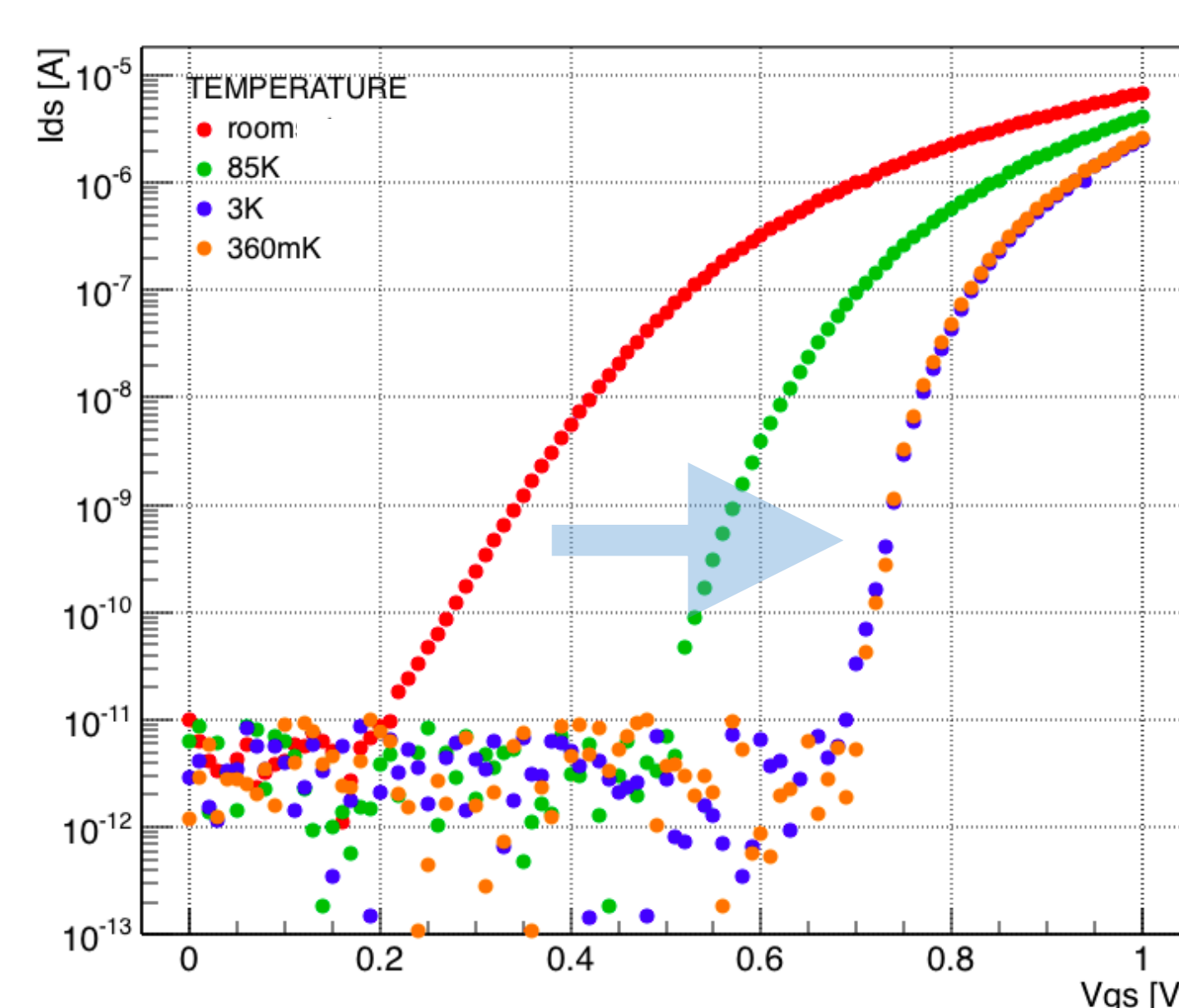


Fig7. Ids-Vgs of FD-SOI MOSFET

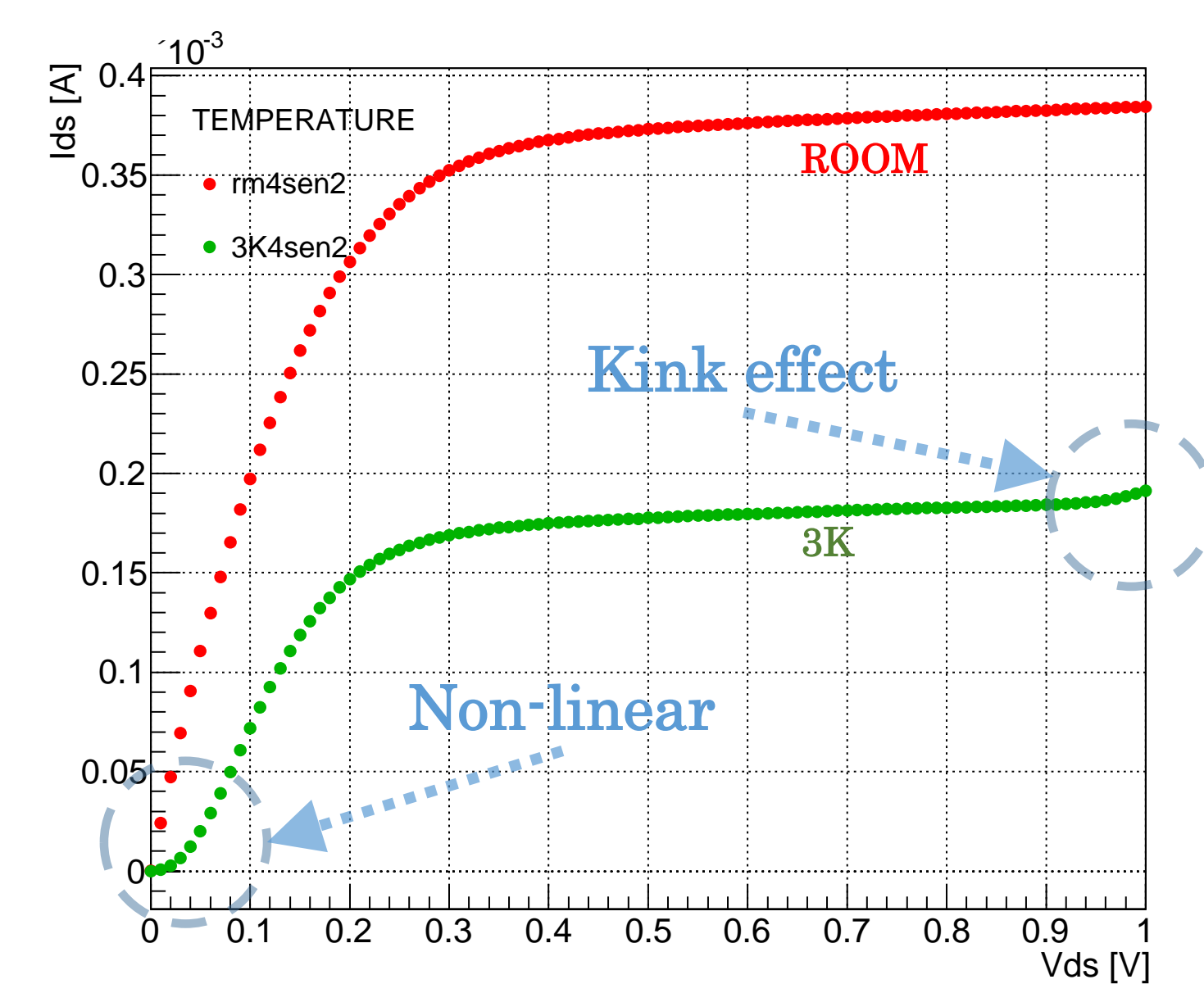


Fig8. Ids-Vds of FD-SOI MOSFET

**NEXT** we are measuring the characteristic to prepare SPICE simulation model at low temperature and will design the charge integration amplifier by using the model.

## 5. Summary

- We are developing Nb/AL-STJ detector which has high energy resolution for neutrino decay search
- To increase signal to noise ratio, we will design the FD-SOI MOSFET based charge integration cold pre-amplifier.
- FD-SOI MOSFETs show difference characteristics at low temperature compare with room temperature, which is under investigation.

## 6. Acknowledgement

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