Status of LAr TPC R&D (2)

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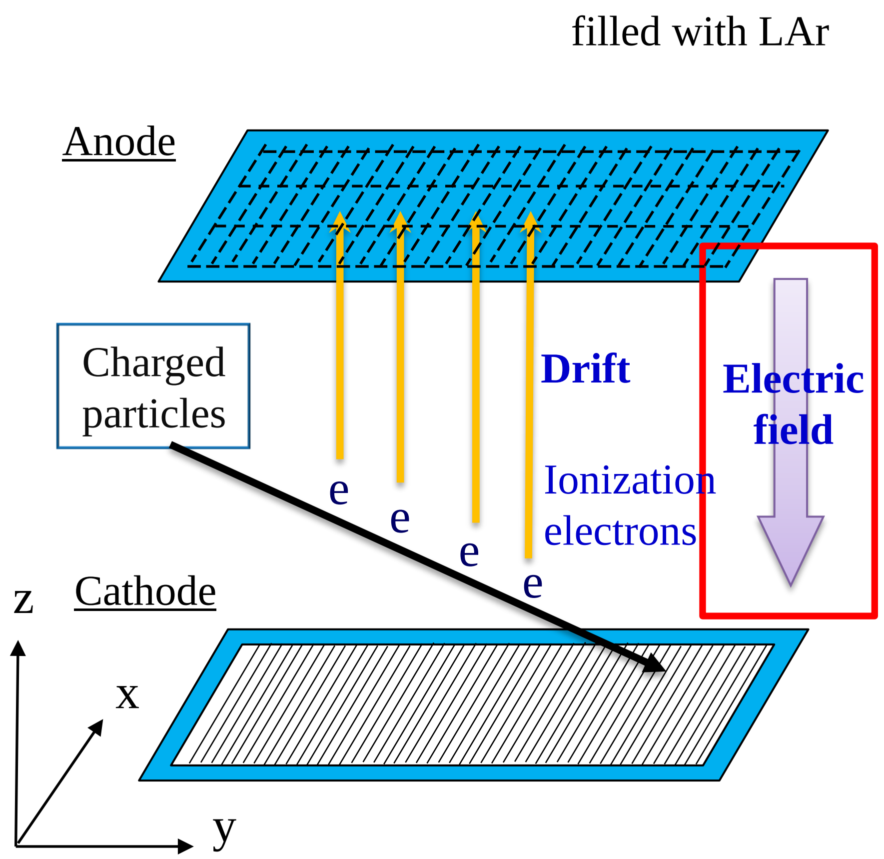
Introduction

<u>Principle of LAr TPC</u>

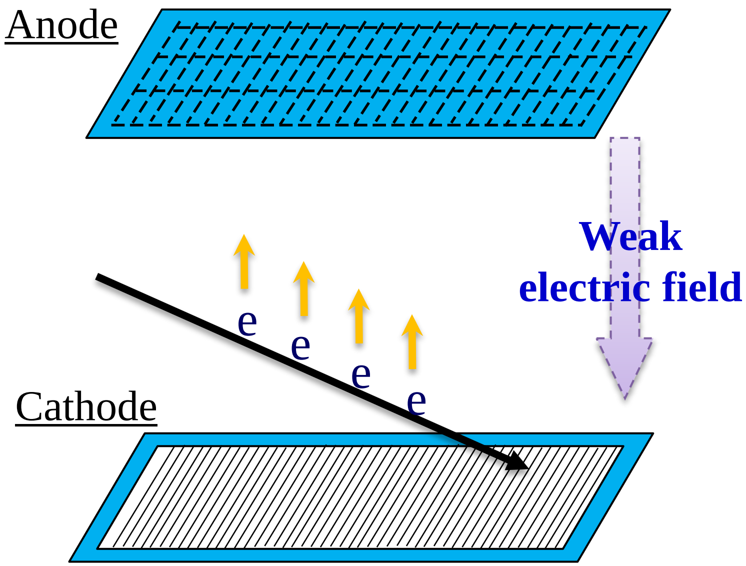
- TPC is stored inside the cryostat
- The cryostat is filled with LAr

1. Charged particles flying in LAr TPC
2. Flying particles reacts with LAr in TPC, the ionization electrons are generated
3. Ionizing electrons under the force of the electric field, drift to the anode side
4. The anode is divided into a grid-like, obtains the position information of the generated ionization electrons in two dimensions (x, y)
5. And obtaining position information of the z-direction from the time it took to drift to the anode from the generation position
6. The track of flying particles can be reproduced in a three-dimensional

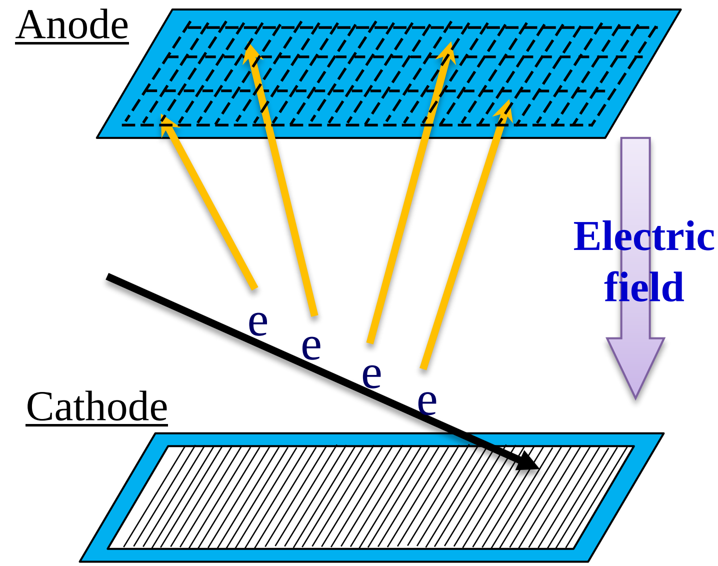


Agendas to generating electric field

1. When electric field is weak, ionization electrons can be captured by impurities before reaching the anode
   → More than v_e=1.6mm/μsec required
   → More than E=500V/cm required



2. When electric field is non-uniform, a mismatch between readout and generated position can happen



Agendas:

Today's discussion is about this.

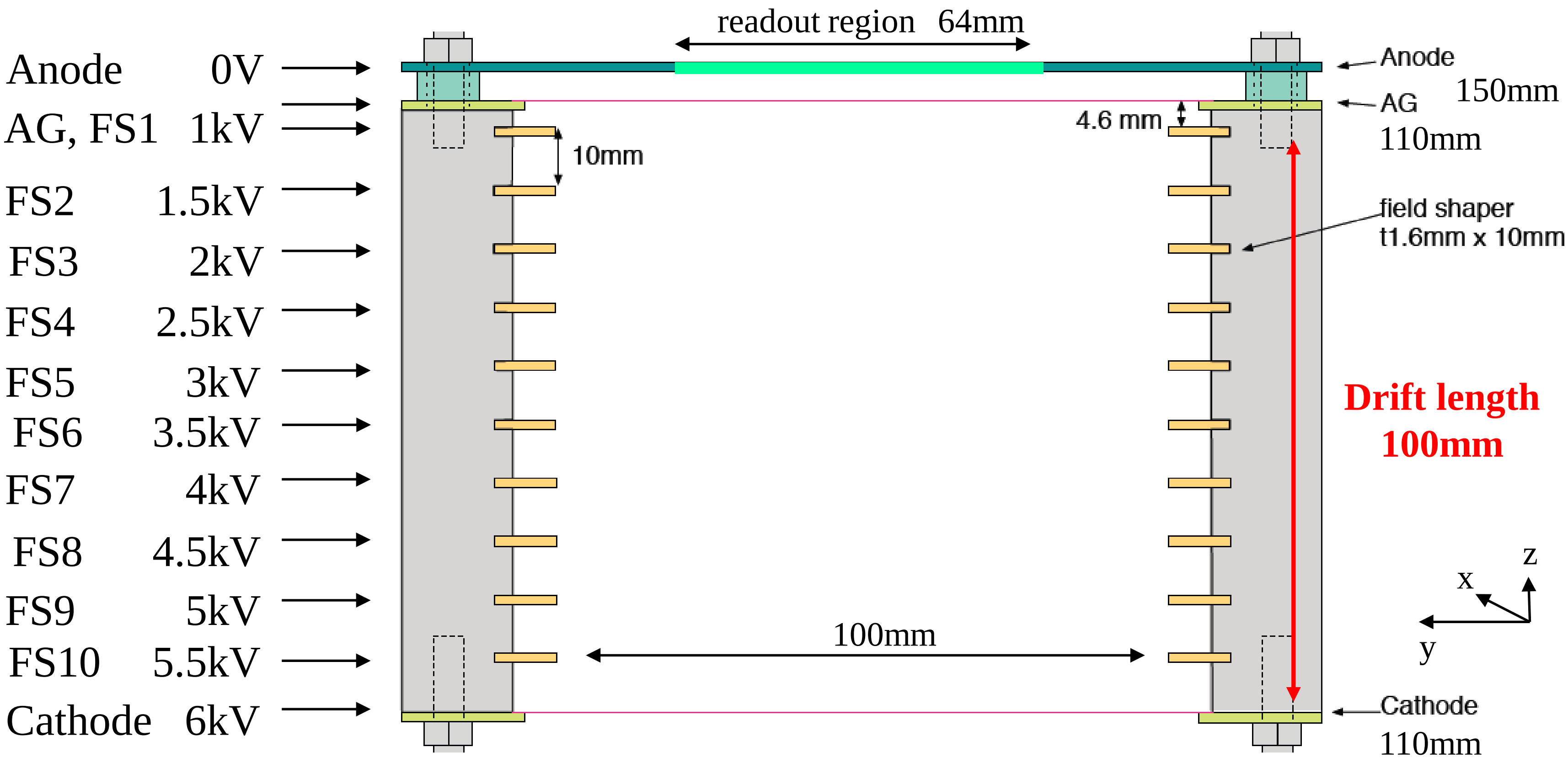
1. Generation of strong electric field (More than 500V/cm)
2. Uniformity of electric field

⇒ R&D on fundamental technology of HV using a small LAr detector (drift length 10cm)

Configuration of TPC

Field Shaper placed between the cathode - anode for the uniformity of the electric field in the prototype (drift length 10cm) in development.

Also, it sets out 500V/cm by supplying voltage to electrode (in the figure).



Generation of strong electric field

Two possible methods of generating strong electric field

1. Supplying HV from the outside of the cryostat through the feedthrough
2. Generating HV within the cryostat (filled in LAr)

When LAr TPC comes to be a large size (drift length several tens m), it's necessary to supply a voltage of several MV for generating electric field of 500V/cm

→ It’s difficult to supply from the outside of the cryostat by breakdown limit of feedthrough in MV supply

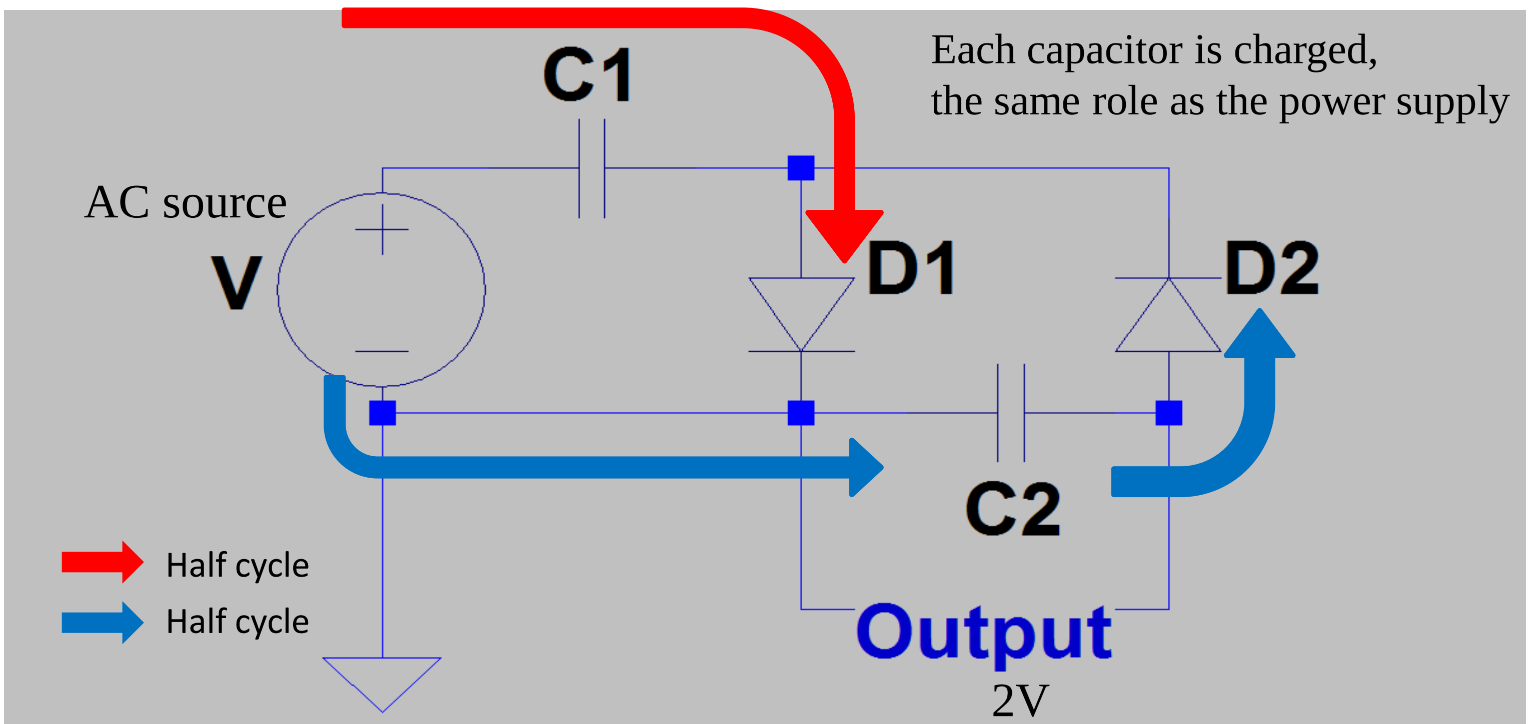
We adopt option 2:

Consider the Cockcroft-Walton(CW) circuit as the device

Cockcroft-Walton(CW) circuit

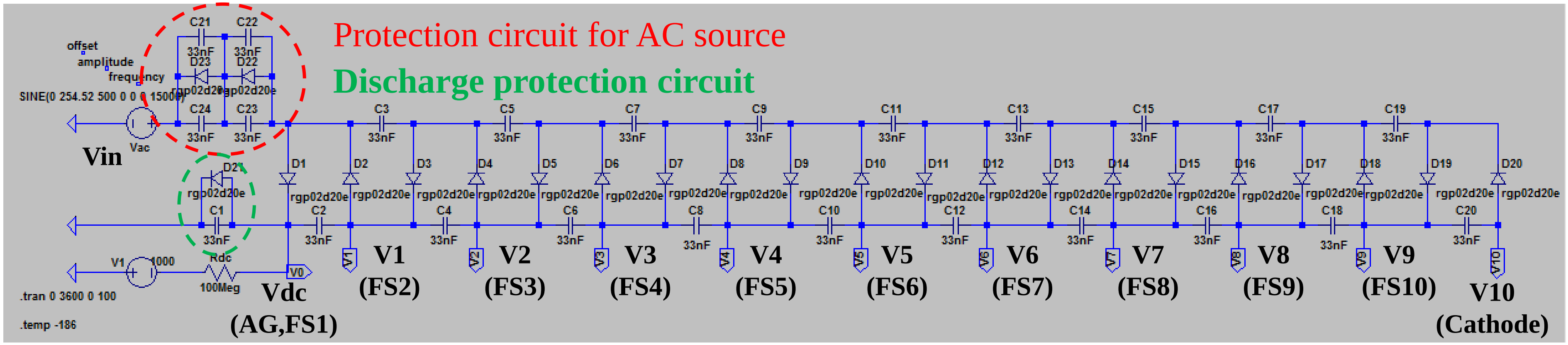
Feature

- This circuit generates a high DC voltage from a low voltage AC
- Circuit that combines a capacitor and diode
- Vout = 2Vin × (Number of stages)
- Since it can be output from each stage, it's compatible with TPC structure



Designed a CW circuit

Designed a 10-stage CW circuit for supplying HV in the prototype:



Understanding of CW circuit using circuit simulation (LTspice):

We will compare with an actual measurement in next step.

<u>Circuit simulation is carried out by simulating the actual operating temperature (-186 deg C)</u>

→ Important to use actual properties of each elementary devices at the low temperature

<u>We measured the low temperature properties(-196 deg C), and then create and optimize elementary device model in simulation</u>

Measurement properties of elementary device (Capacitor)

Measure the low temperature properties of the capacitor by LCR meter

filled with LN_2(-196 deg C)

put a capacitor
in the socket

put in a container

LCR meter (HP 4275A)

Capacitor PHE450 (EVOX RIFA)

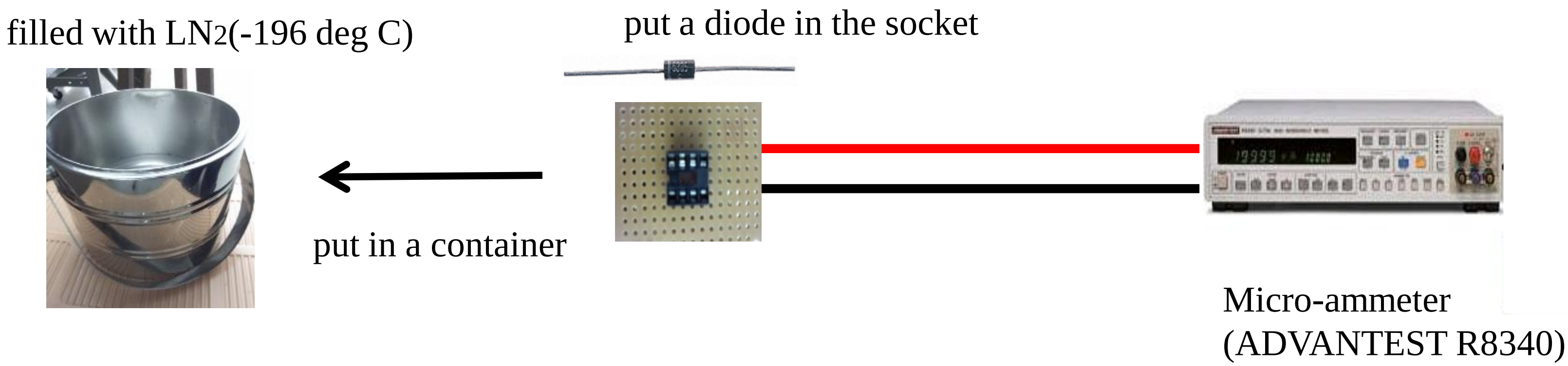
	sample_1	sample_2	sample_3	sample_4	sample_5	Average
Measurement results (-196 deg C)	33.63	33.40	33.00	33.32	33.00	33.27

Measurement result at room temperature(20 deg C) is 32.47nF(average)

According to measurement results,
create a elementary device model as the capacitance is 33.27nF

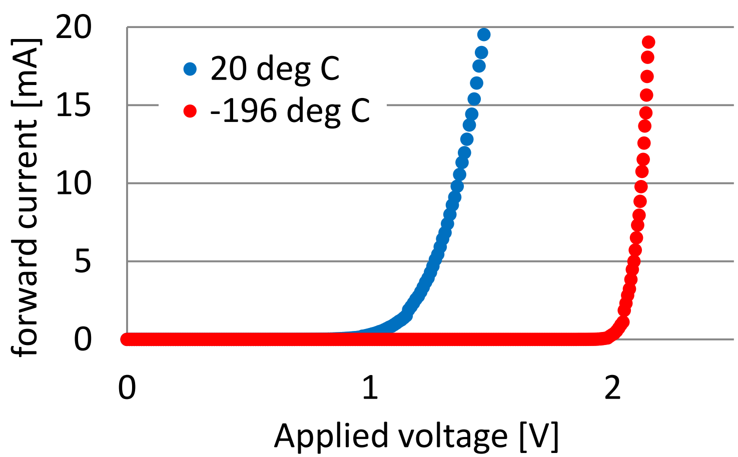
Measurement properties of elementary device (Diode)

Measure the low temperature properties of the diode by micro-ammeter

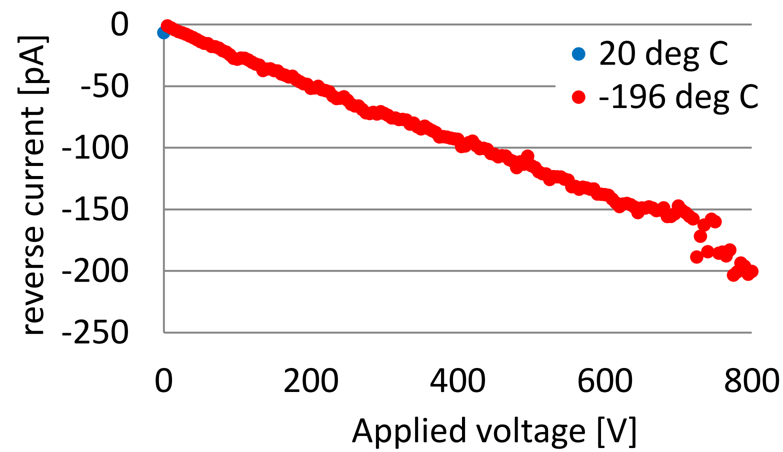


Diode rgp02-20e (VISHAY)

Forward characteristic



Reverse characteristic

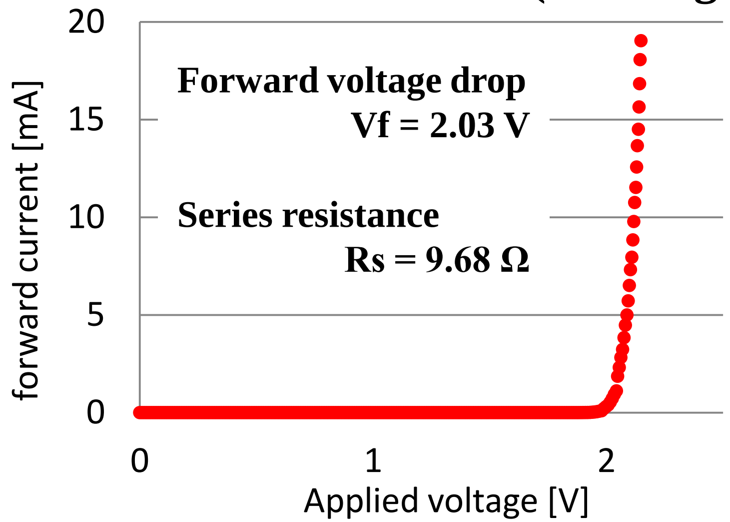


Create a model of diode to reproduce the measured results

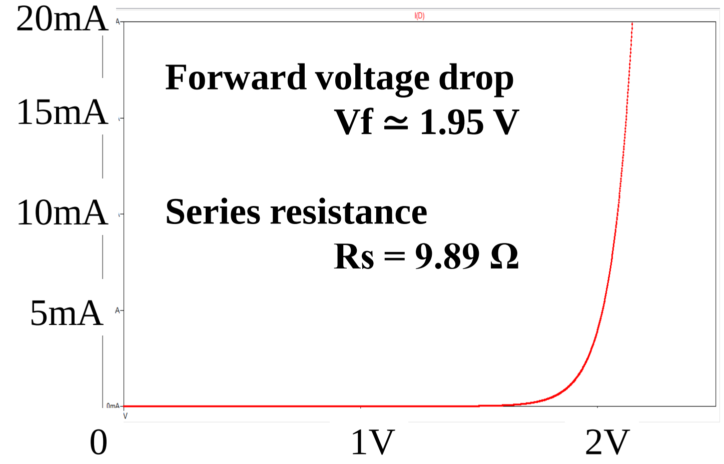
→ Making a comparison between the created model and measurement results in the next slide

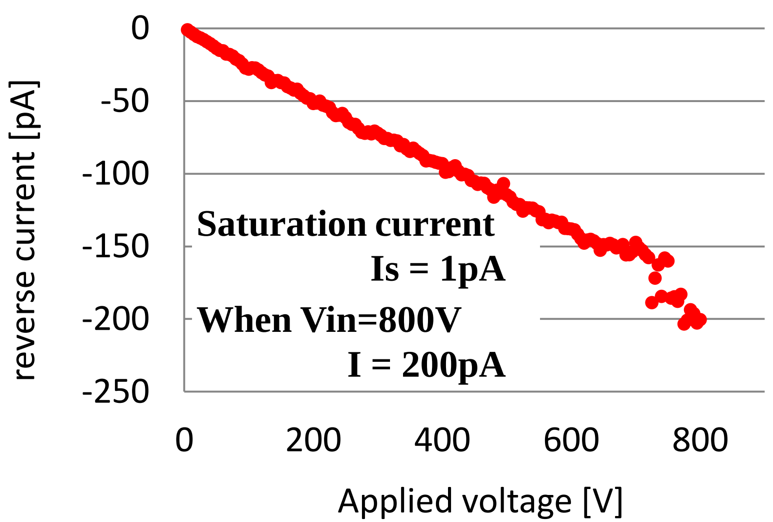
Optimization of device models

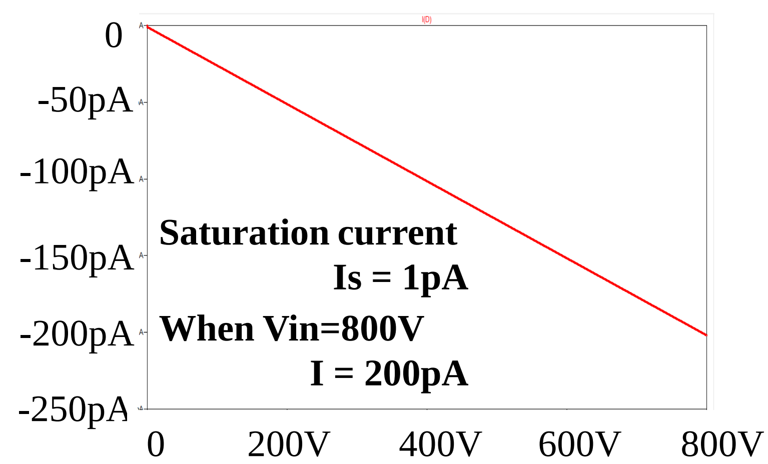
Measurement results(-196 deg C)



Created model



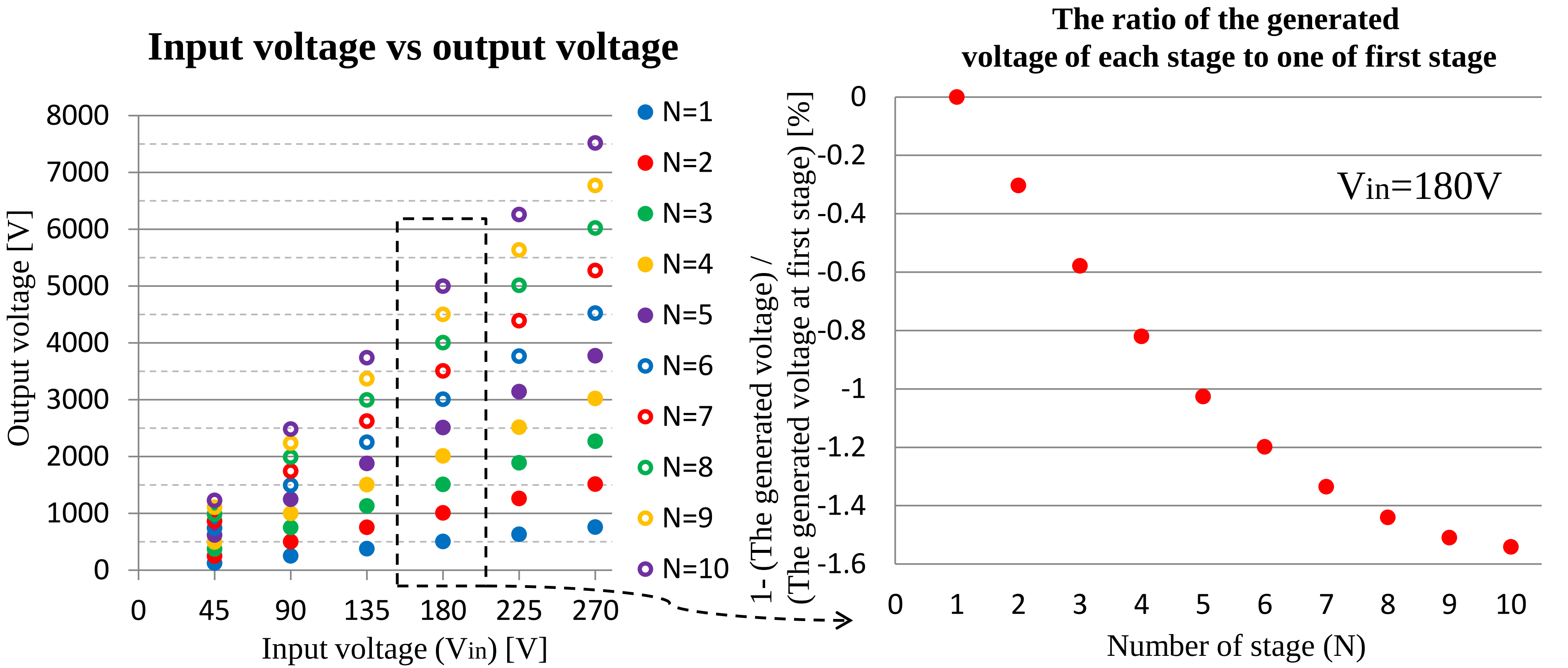




The successful creation of a model that low-temperature characteristics match

→ Characterization by circuit simulation

Results of circuit simulation (LTspice)



There is -1.6% of discrepancy of voltage at 10th stage compared with first stage

- A large influence of device characteristics in lower stage
- Since the device is increased along with the increase of the number of stages, the output voltage becomes non-linear

→ We will compare with actual measurement in next step

Summary

Development of generating electric field in LAr TPC

Generating electric field is one of key R&D subjects toward realization of a large scale LAr TPC

Agendas:

1. Generation of strong electric field

   We are developing CW circuit HV generator

   → Circuit simulation based on actual measurement of the elementary device properties at the low temp. is developed

   → We will compare with actual measurement

2. Uniformity of electric field

   Understanding with simulation software(COMSOL) is in progress

   → Plan to study with cosmic ray measurement