Novel Technique for Measuring the Purity of Noble Liquids

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1 Motivation

Noble liquids, such as Argon (LAr) and Xenon (LXe), are widely used in the physics community to build large detectors to search for weakly interacting particles or rare processes such as dark matter or neutrinoless double beta decay. Noble liquids are chosen because of their:

- Chemical inertness
- High atomic number Z
- High density in liquid form
- Scalability to large volumes
- Target material is the detector at the same time

Building bigger detectors requires a higher purity of the noble liquid in order to extract the e^- signal due to an event happening inside the detector. While meter-long drift distances of e^- have been demonstrated in LAr detectors this is a harder challenge in LXe.

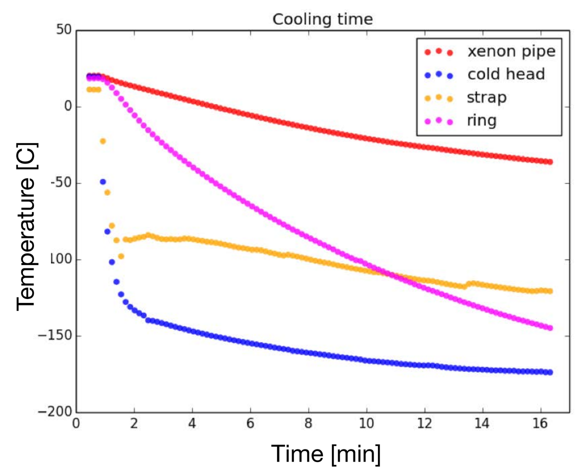
We are building a small scale experiment capable of measuring possibly up to several meters of drift distance for the first time (typically stated as electron lifetime) and be sensitive to impurities on the parts per trillion (ppt) level.

2 Cryostat Design

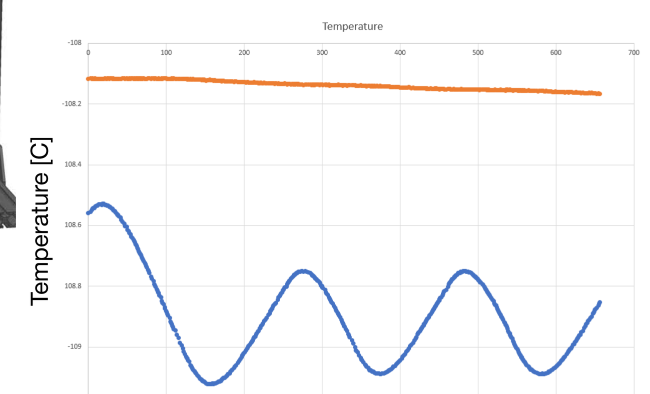
The Yale Purity Monitor overcomes the need for a big detector to do a precise measurement of electron lifetimes. It is capable to liquefy about ~2 kg of xenon and uses only chemically clean and LXe compatible materials such as stainless steel, copper, gold and Kapton. The system shines a Xe flash lamp at the copper photocathode and then:

- e^- are emitted and drift towards the cathode due to an high electric field of ~500V/cm between anode and cathode
- Once the e^- reach the switching region they will get trapped by switching the high electric field at a frequency of few kHz to mimic a meter long drift length
- e^- are collected at the anode

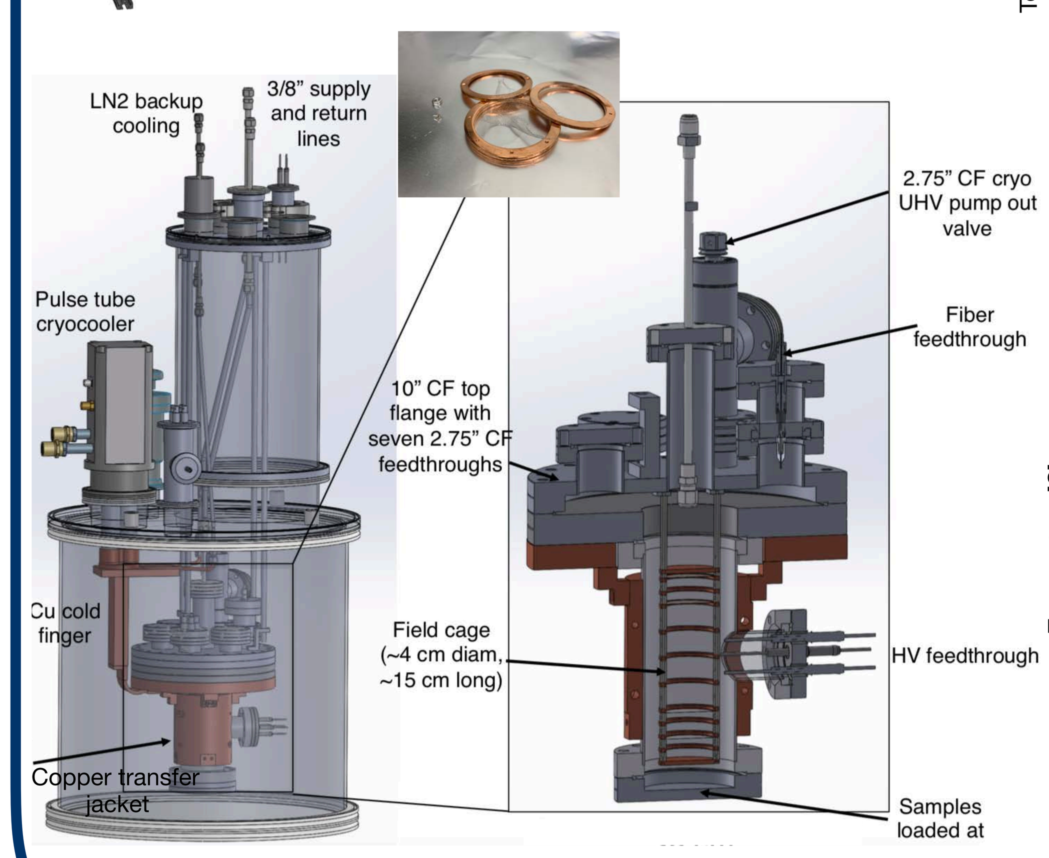
In order to prevent pickup and induced currents onto the anode and cathode two 1D grids with almost full transparency are placed above and under the cathode and anode as a Frisch grid, respectively.

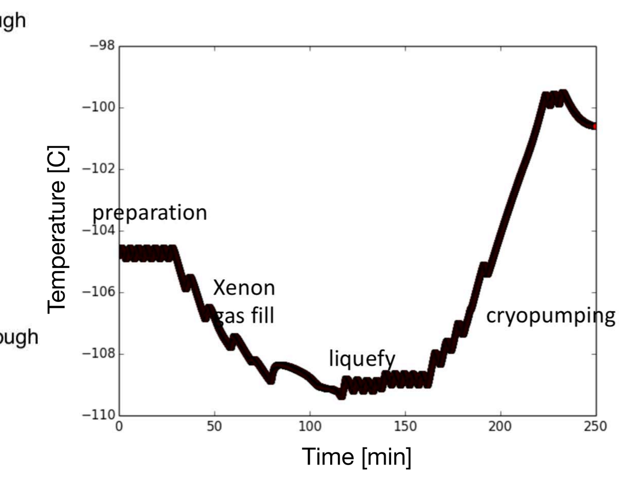


Temperature control at 4 different location in the setup

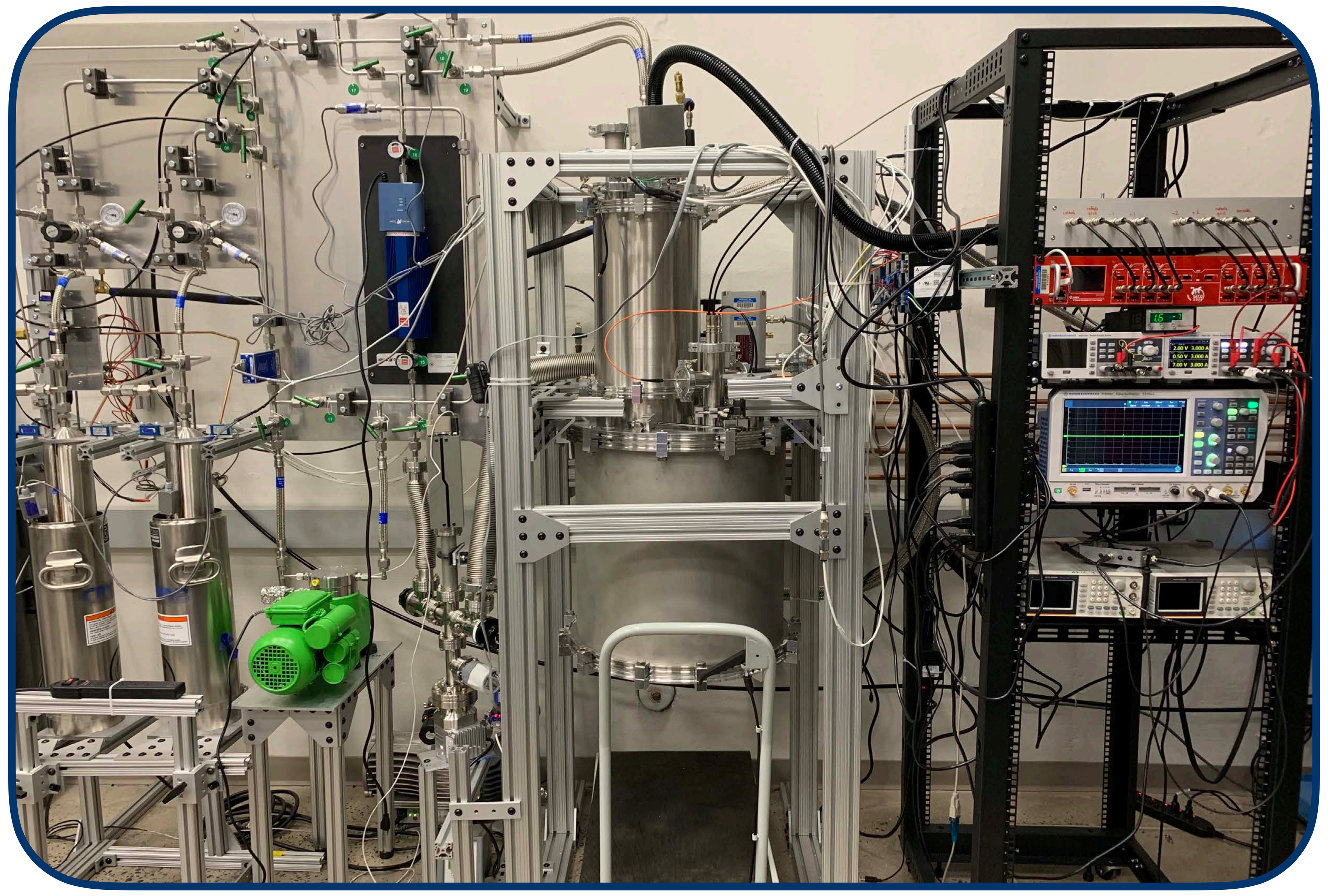


Temperature stability within 0.2K in xenon cell



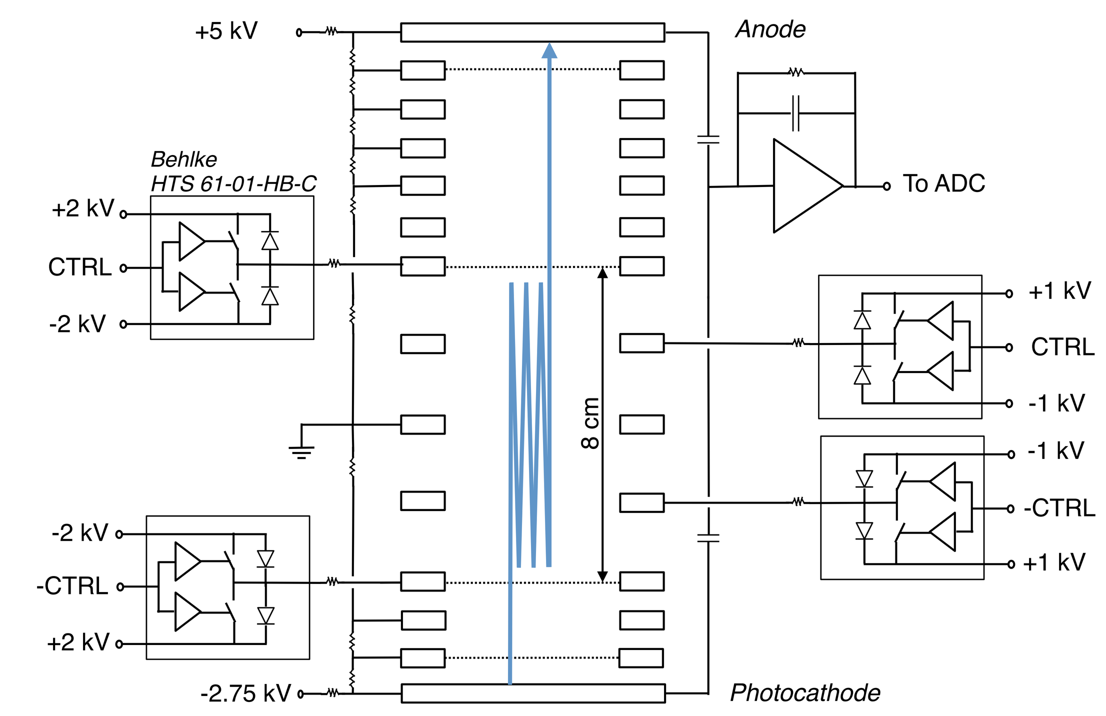


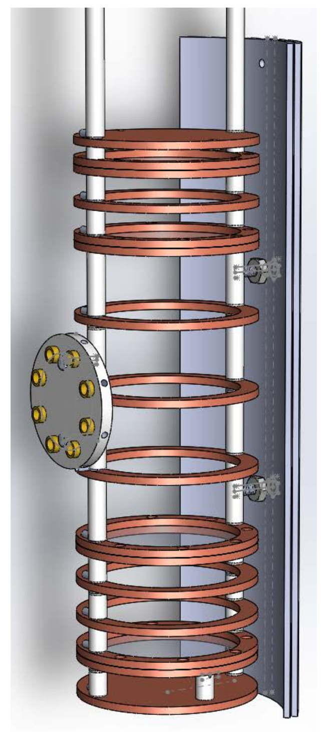
Temperature control and stability during liquefaction

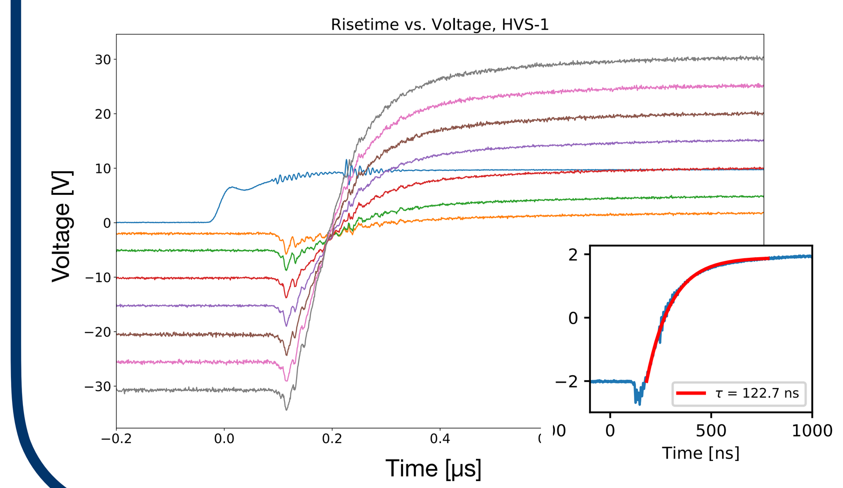


3 High Voltage Switching

- Electrons are being drifted from the cathode to the anode
- In order to measure high lifetimes (or large drift lengths) we need to trap the electrons inside the drift region
- This requires fast switching of voltages up to 2kV realized by BEHLKE HV switches

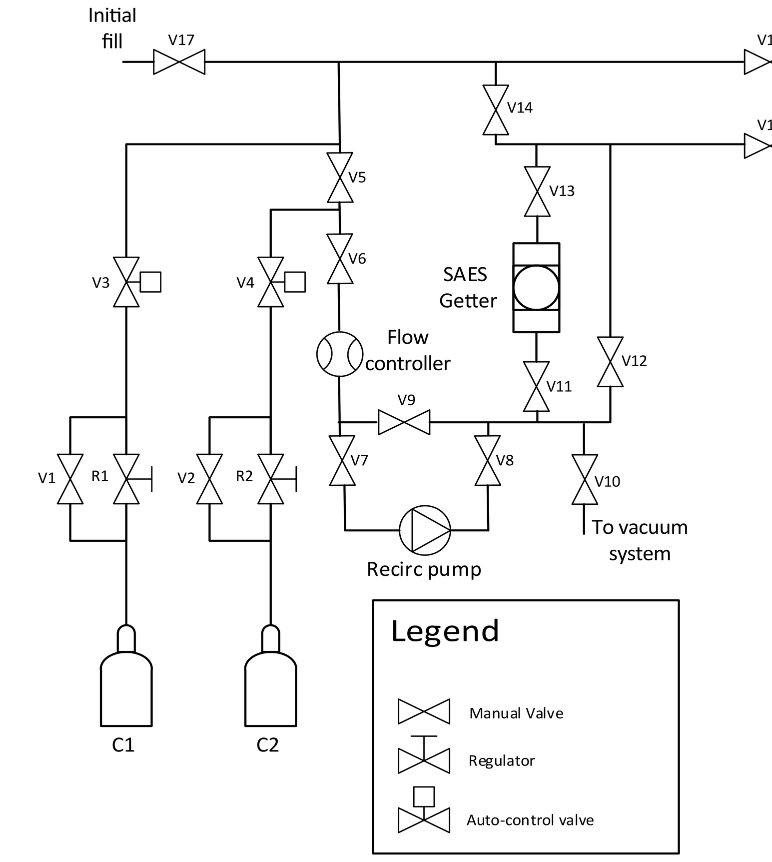


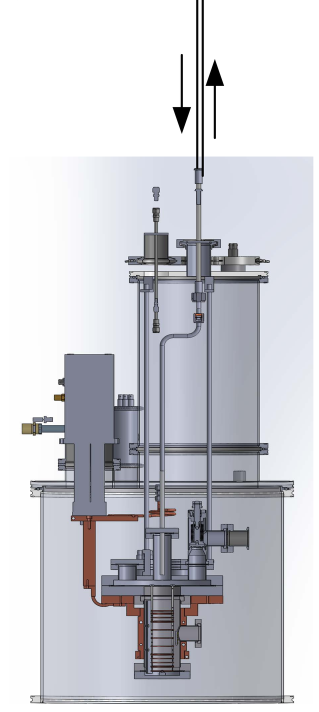




4 Gas Handling System

- The system is designed and built to be free from contamination and leaks. The parts are mostly made of stainless steel and are VCR compatible.
- The system is cleaned by vacuum pumping the gas out with a turbo pump to 10^{-8} mBar, achieving below ppt contamination of air.
- Noble gas is circulated inside the system and purified with a SAES gas purifier.

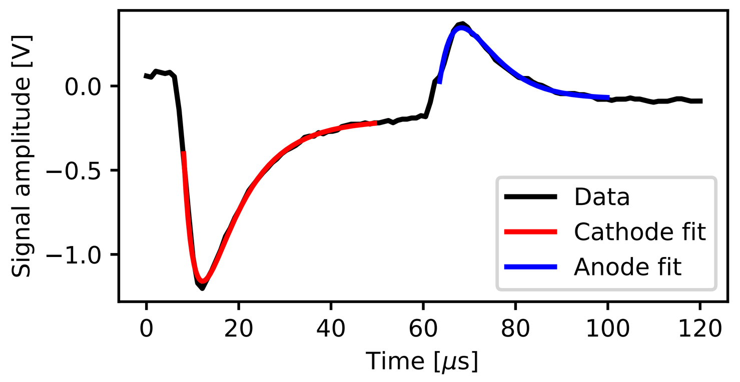


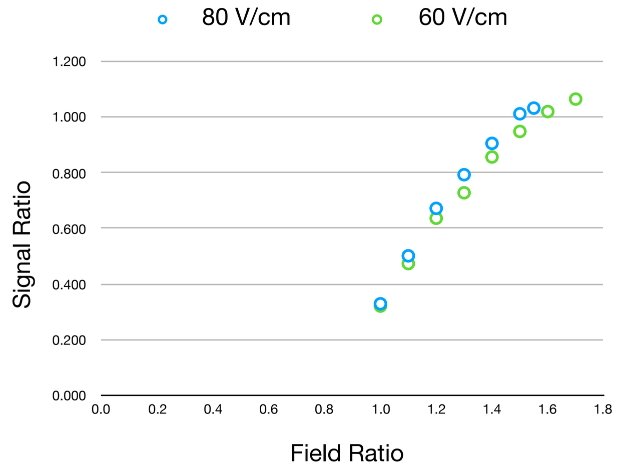


5 Readout Electronics and Tests

Initial tests were done to

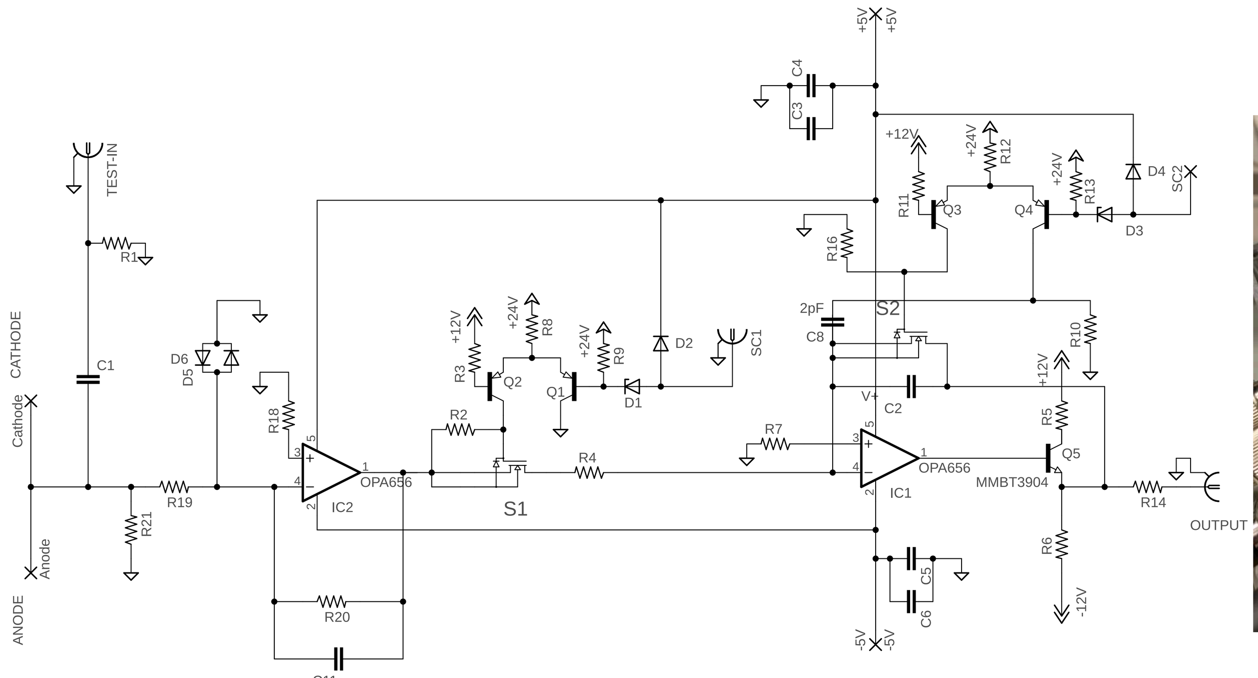
- Characterize the flash lamp as a trigger for our signal
  - Time offset between trigger and flash
  - Pulse amplitude
  - Jitter in the trigger
- Measure electron drift velocities in gas
- Measure transparency of grids





During the HV switching operation we will encounter a significant amount of induced currents at the anode and cathode. In order to remove unwanted pickup noise in our readout we designed a hold and sample integrator circuit using NMOS transistors as switches coupled to long-tailed pairs of PNP transistors to

- Mitigate pickup from the HV switching
- Reduce the amount of charge injection noise from the switch itself
- Be sensitive to charge on the order of 50fC



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