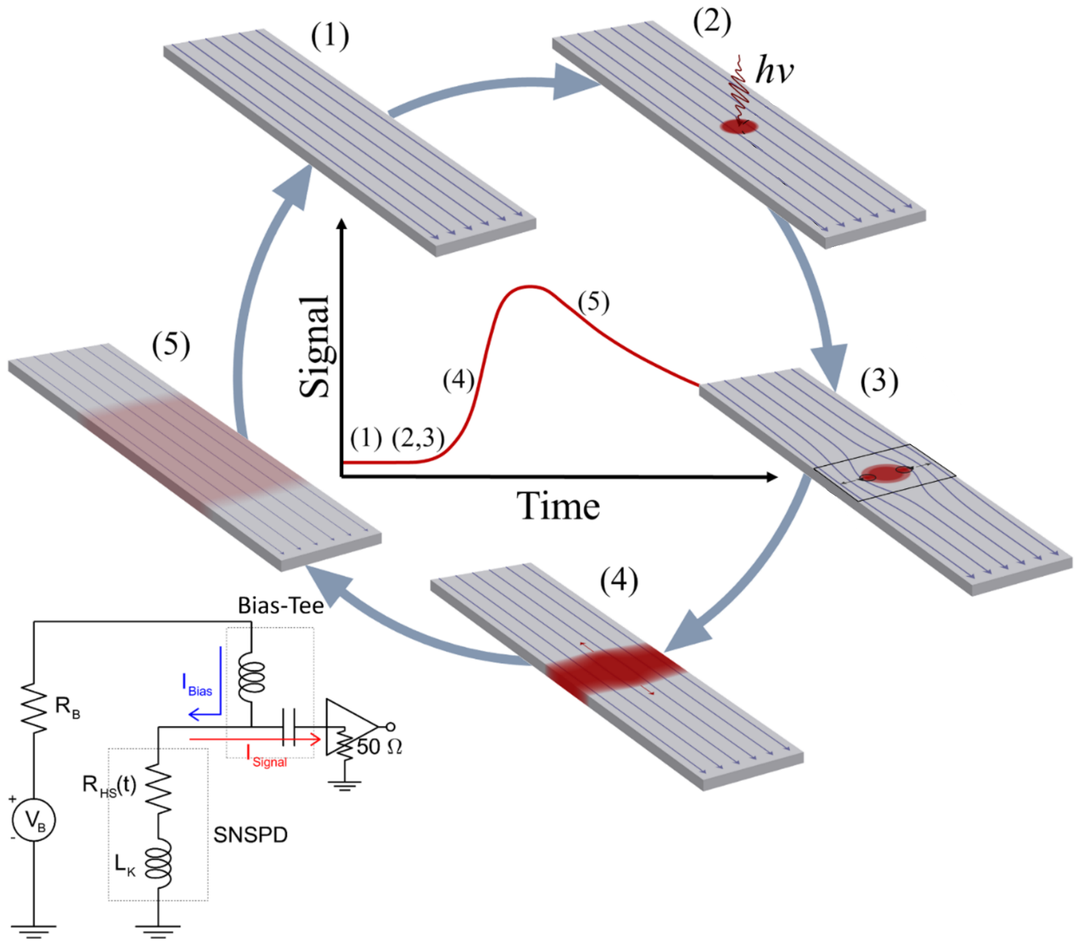
InfraBREAD — Reflector & SNSPD Characterization

Christina Wang (Fermilab)

2026 BREAD Collaboration Meeting
01/16/2026

BREAD
COLLABORATION

Superconducting Nanowire Single Photon Detector (SNSPD) for BREAD

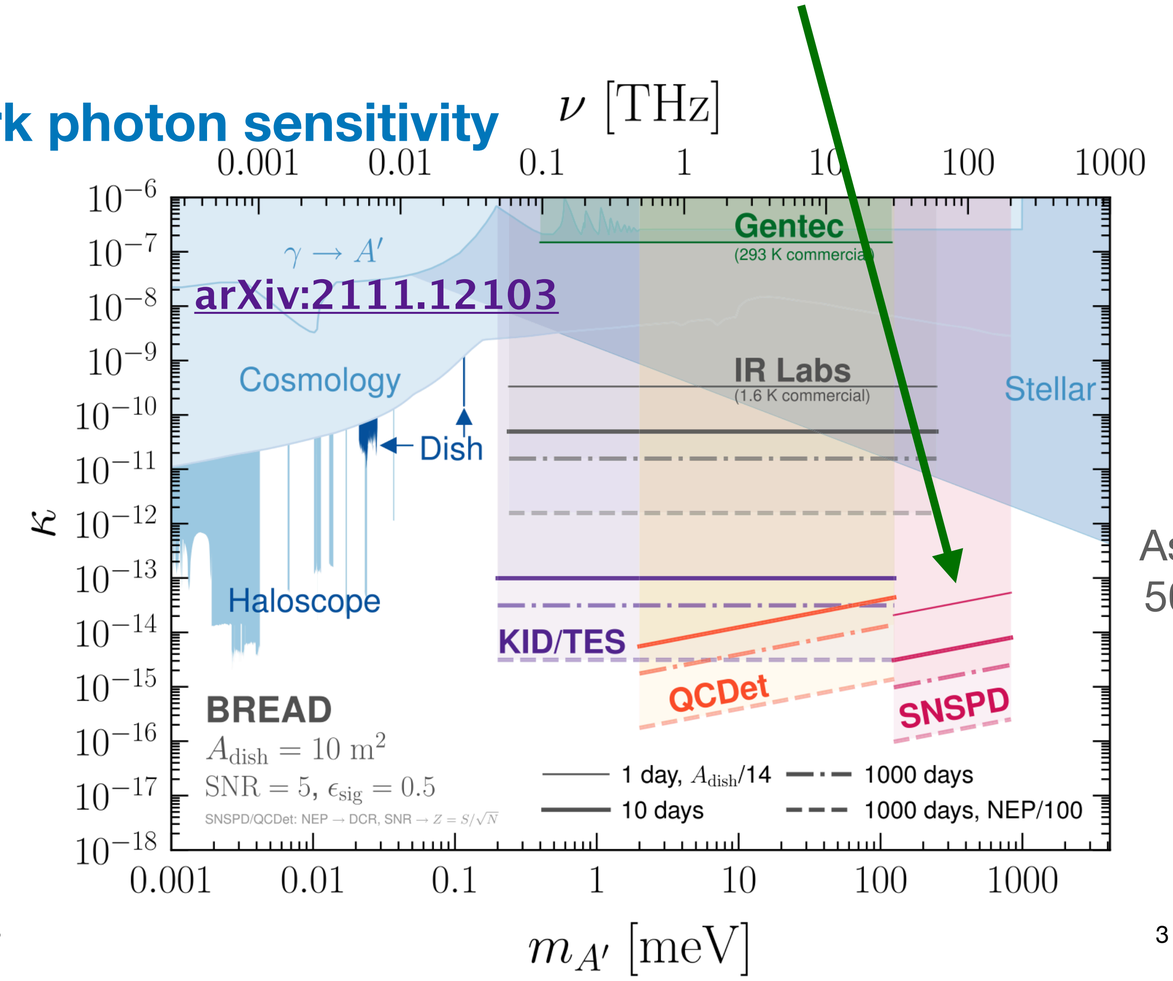


- SNSPDs are ideal photosensors for BREAD:
  - Broad spectral response: ultraviolet to infrared → sensitive to 0.1 - 1 eV dark photon/axions mass
  - Low noise: DCR < 10^{-3} Hz
  - mm^2-size active area
- Detection Mechanism:
  - Operating temperature : 1-4 Kelvin
  - Single photon triggers detector out of superconducting state
  - Resistance quickly (ps) jumps to few kΩ → bias current into readout

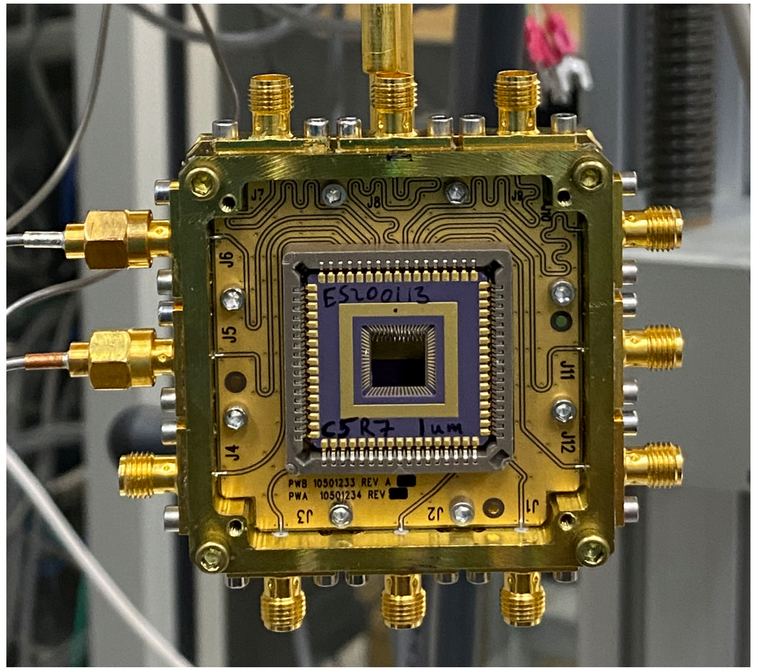
Pilot Experiment with SNSPDs

- SNSPD provides unique sensitivity for 0.1-1 eV dark photons and axions due to its sensitivity for 1-10um photons

Dark photon sensitivity

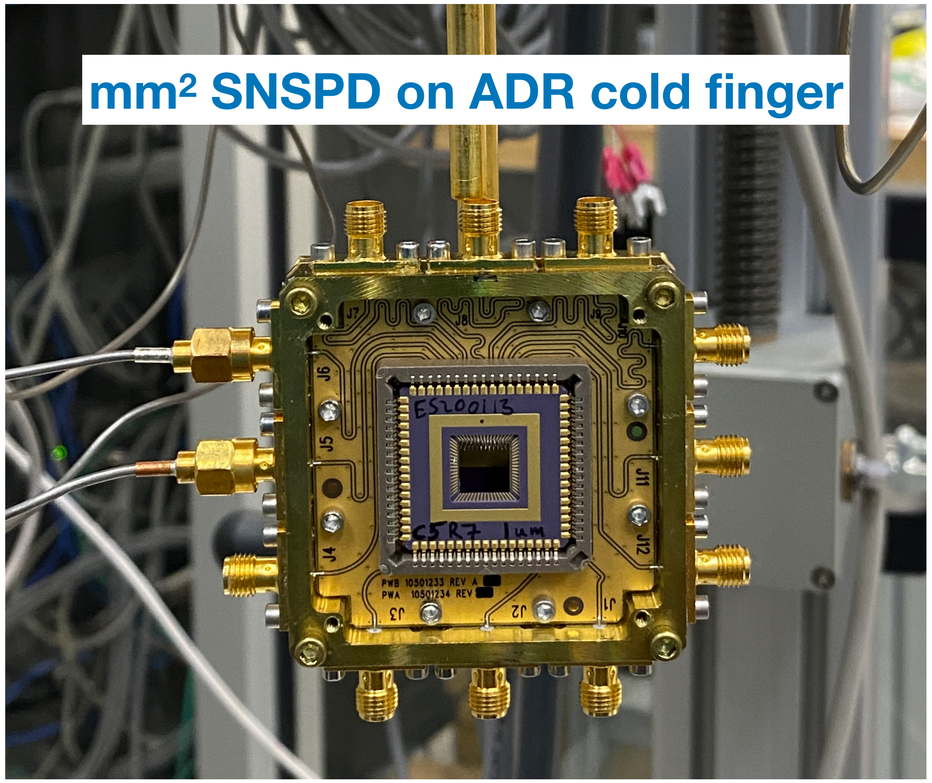


Assuming DCR ~1e-4
50% signal efficiency



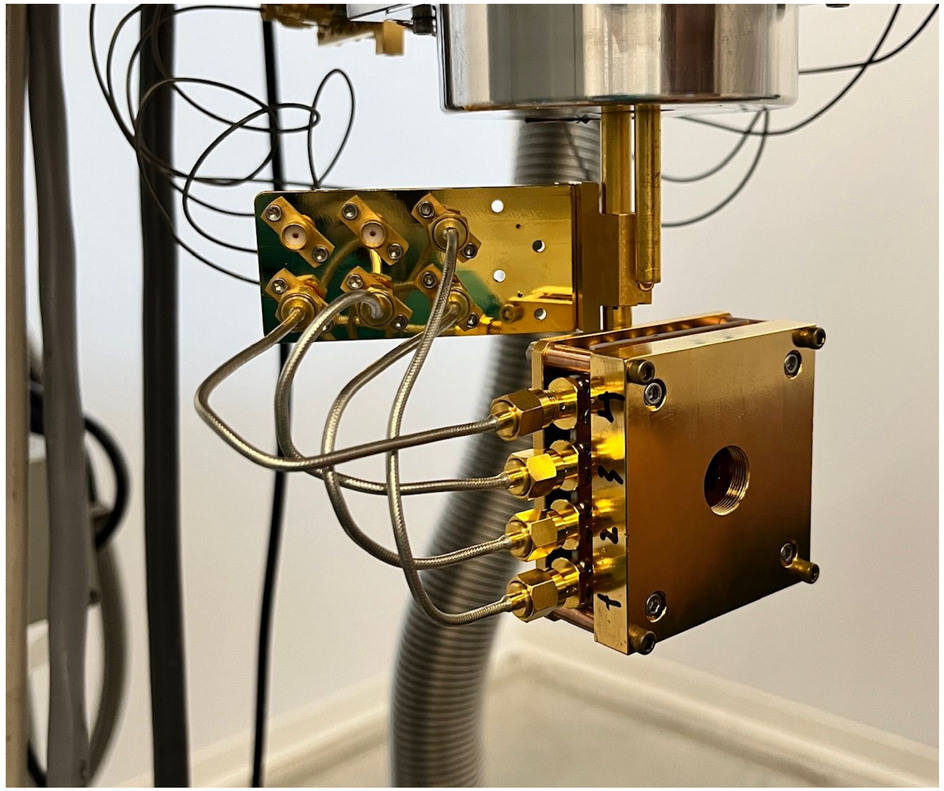
SNSPD Characterization at FNAL

- The sensors are mounted in an Adiabatic Demagnetization Refrigerator (ADR) cryostat in FNAL (0.1K base temperature)
- Our collaborators at JPL developed 4-channel mm² SNSPD



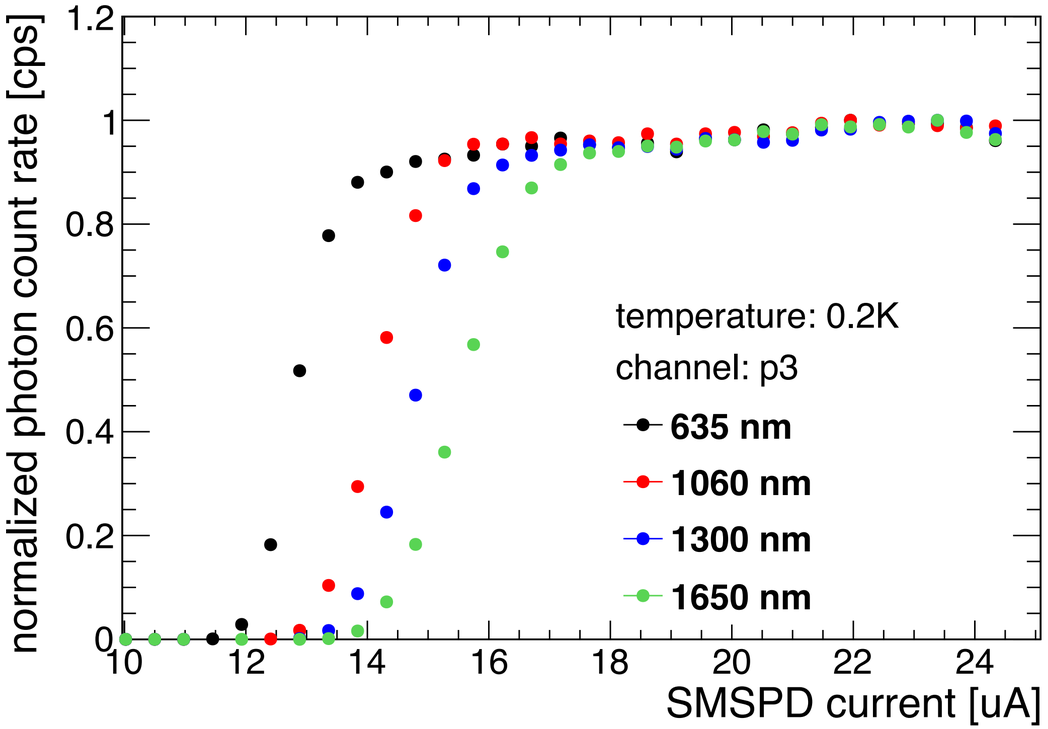
SNSPD Characterization at FNAL

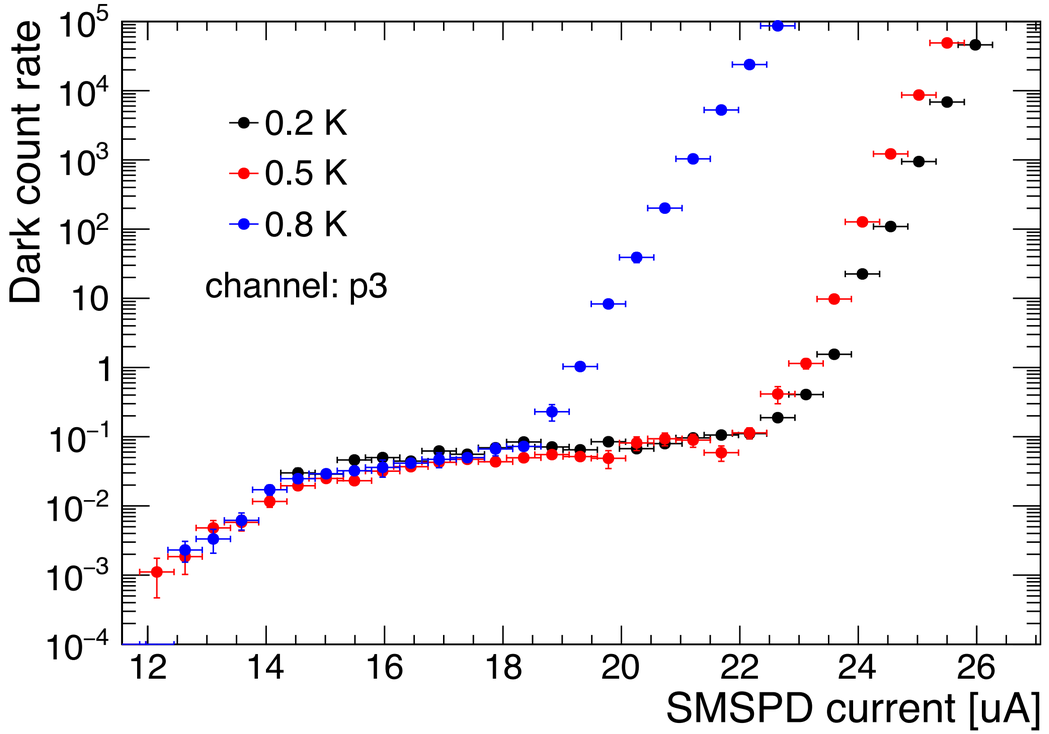
- Since last collaboration meeting, significant upgrade on our cryogenic and characterization infrastructure:
  - Moved the ADR setup from Sidet to the new IERC building
  - A new compressor was ordered and delivered, solved the high oil temperature tripping issue that caused a half-year downtime
  - Upgraded the cryostat to be able to bias and readout 3 channels simultaneously
  - Capable to measure time resolution with pulsed laser down to O(10 ps)
- 1x1mm^2 4-channel SNSPD with larger fill factor packaged in new dark box by collaborators at JPL
- **Report on characterization result of SMSPD at different temperatures (0.2— 1K)**



Photon Count Rate & Dark Count Rate

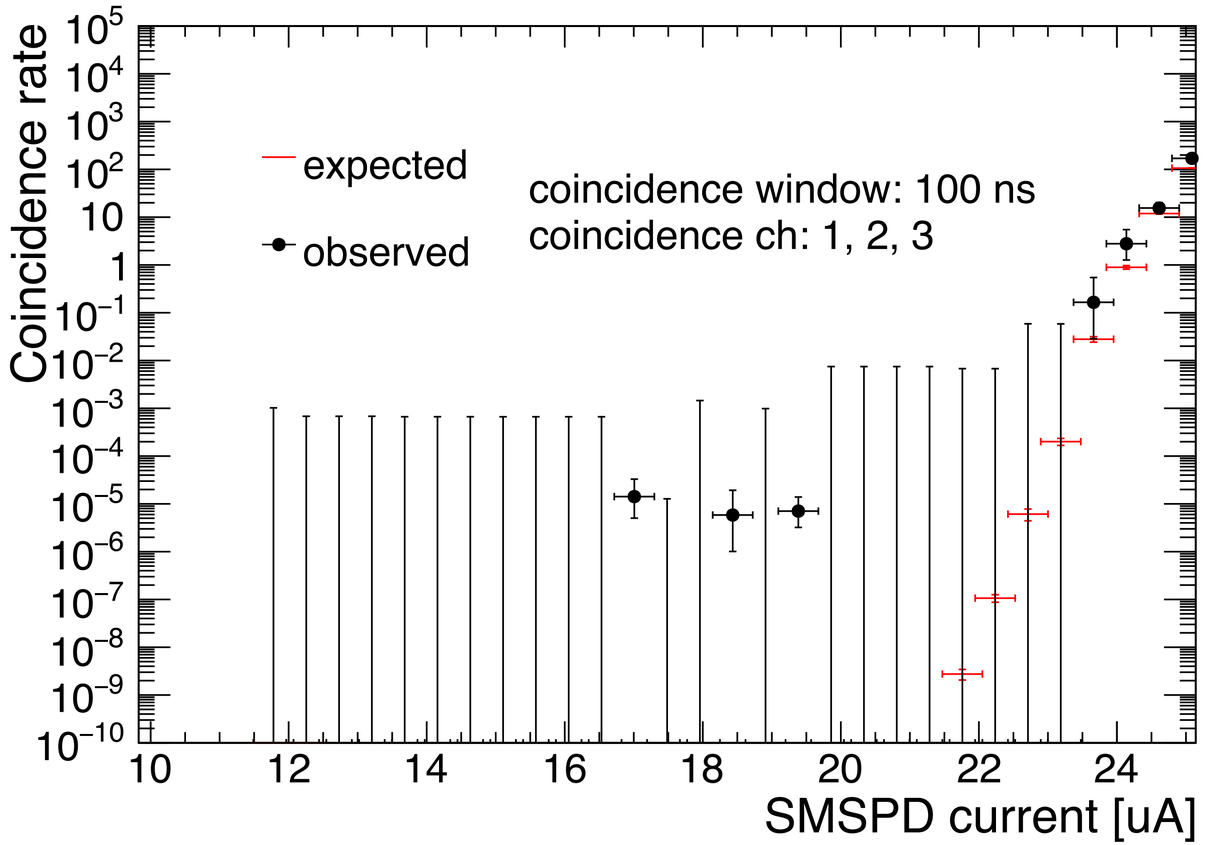
- Saturated internal detection efficiency for 635nm — 1650nm
  - Plateau is still very long for 1650nm





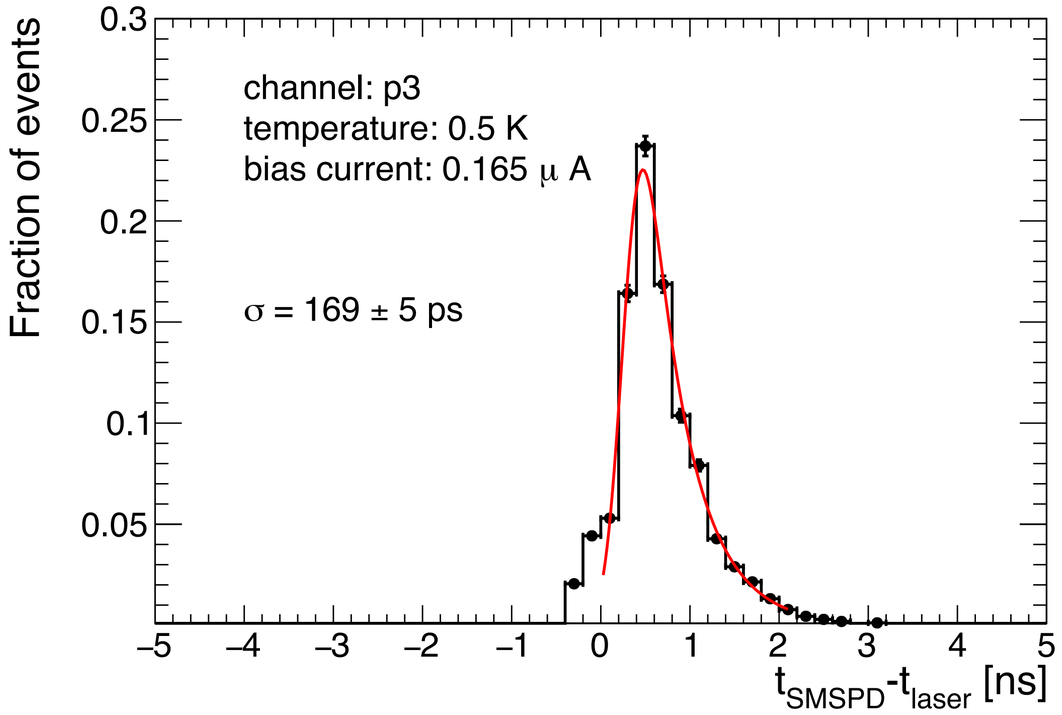
Correlated Dark Counts

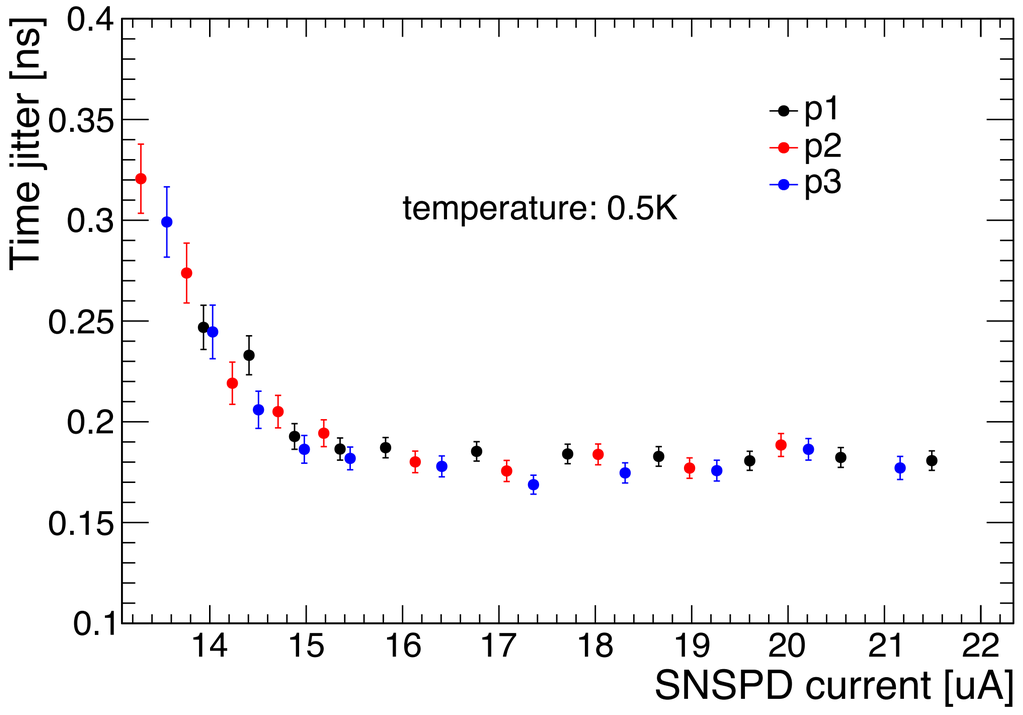
- First time able to readout more than one channels
- Studied 2- and 3-fold coincidences dark count across channels
- Observed clear excess above expected accidentals
  - Similar observations at different temperatures and combination of pixels



Time Resolution of Large Area SNSPD

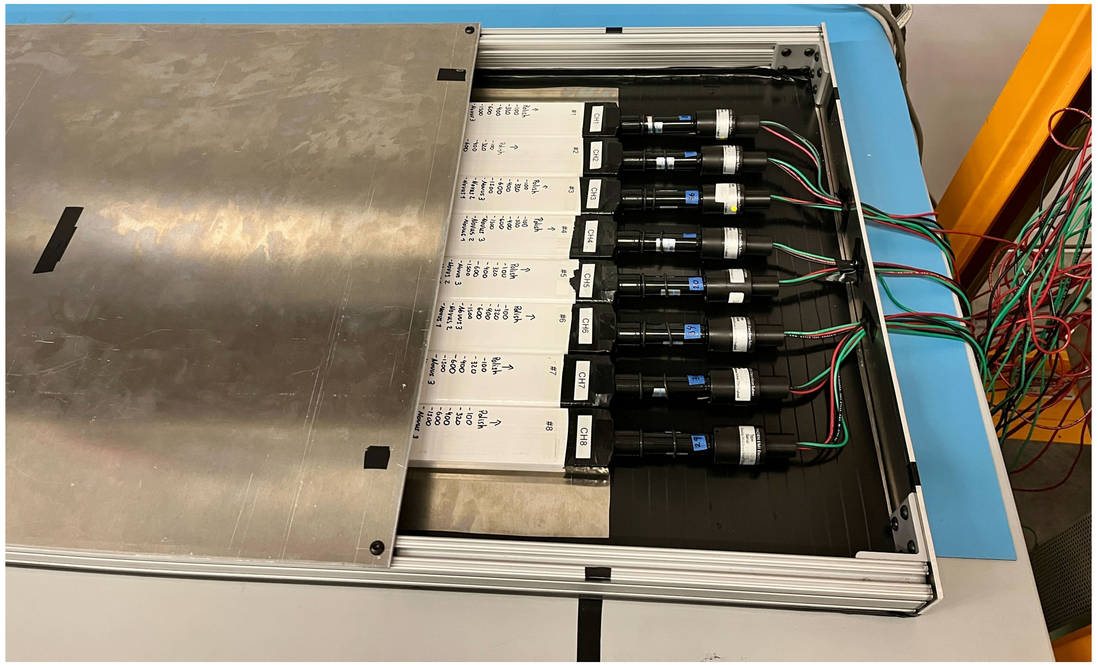
- Measured time resolution of large area SNSPDs for the first time
  - With ps-jitter pulsed laser system at 1060 nm
- Geometric jitter from time delays at different longitudinal positions could have a sizable contribution to the large resolution
- Working on a differential readout scheme to correct for it





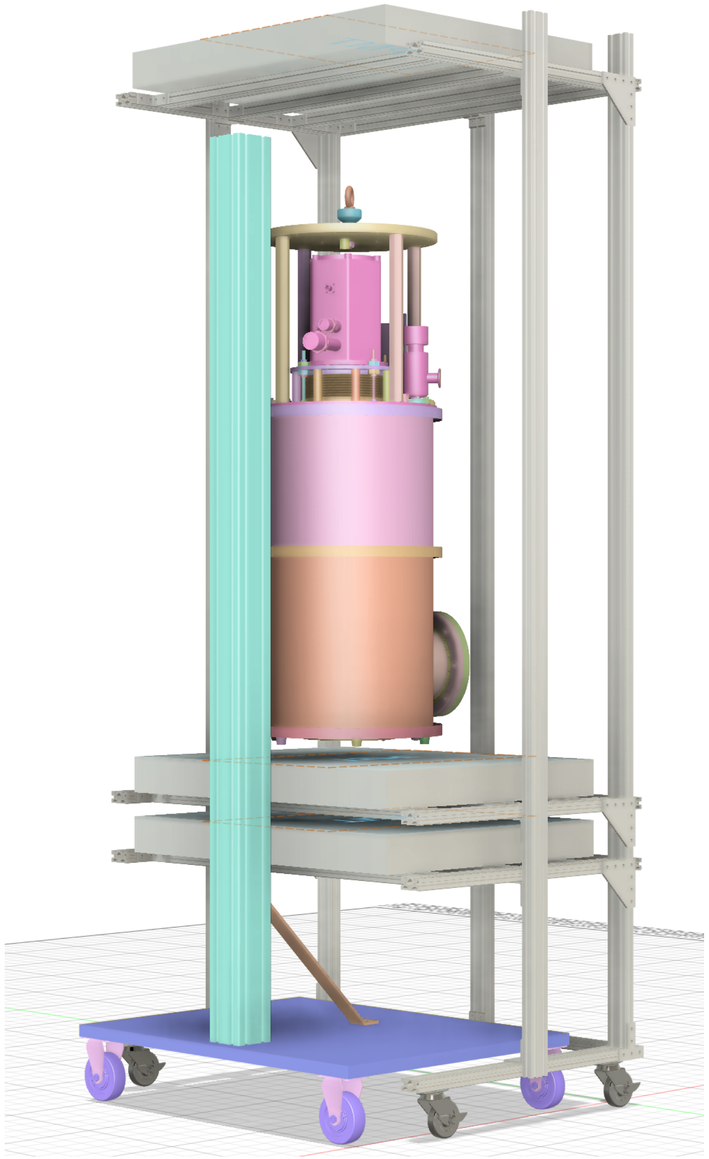
Cosmic Muon Tagger

- To further investigate the correlated background sources, we are building a cosmic muon tagger with PMTs and scintillator bars
  - 50*5cm bars
  - Polished surface to improve light collection efficiency
- Dedicated dark box for PMTs
  - **8 channels per box**



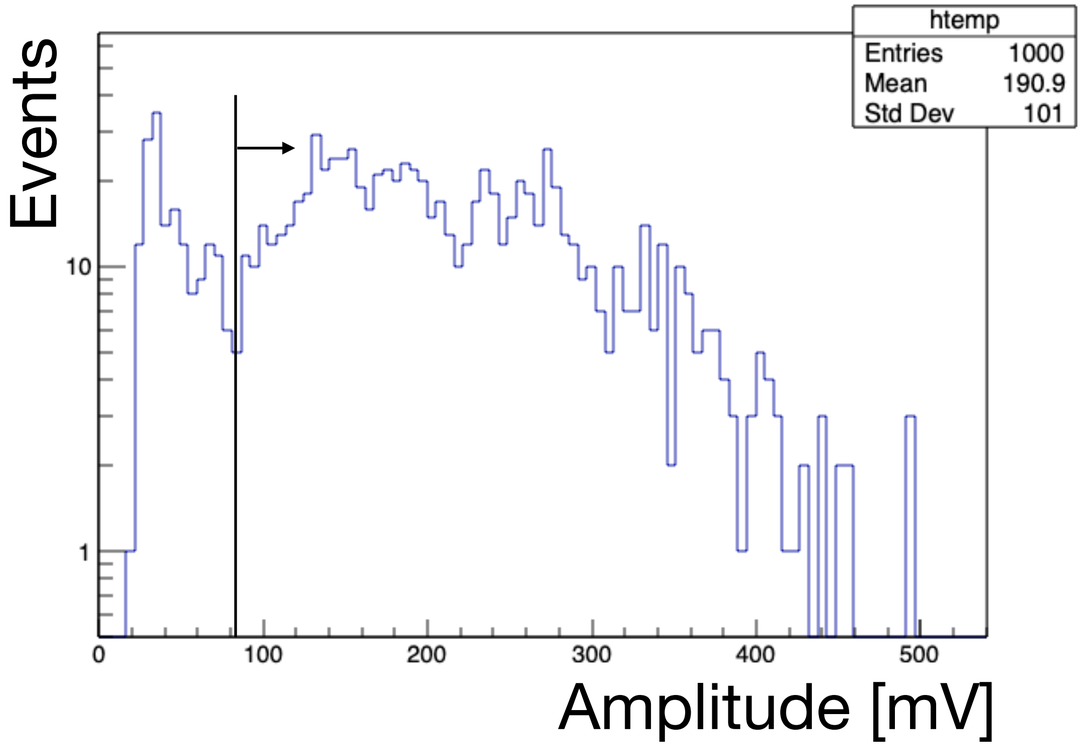
Cosmic Muon Tagger

- Plan to install one box above the ADR, two boxes below
- Built support frames with 80-20s to align the three planes and make the setup easy to move in and out of the ADR
- Currently testing the cosmic muon system without ADR



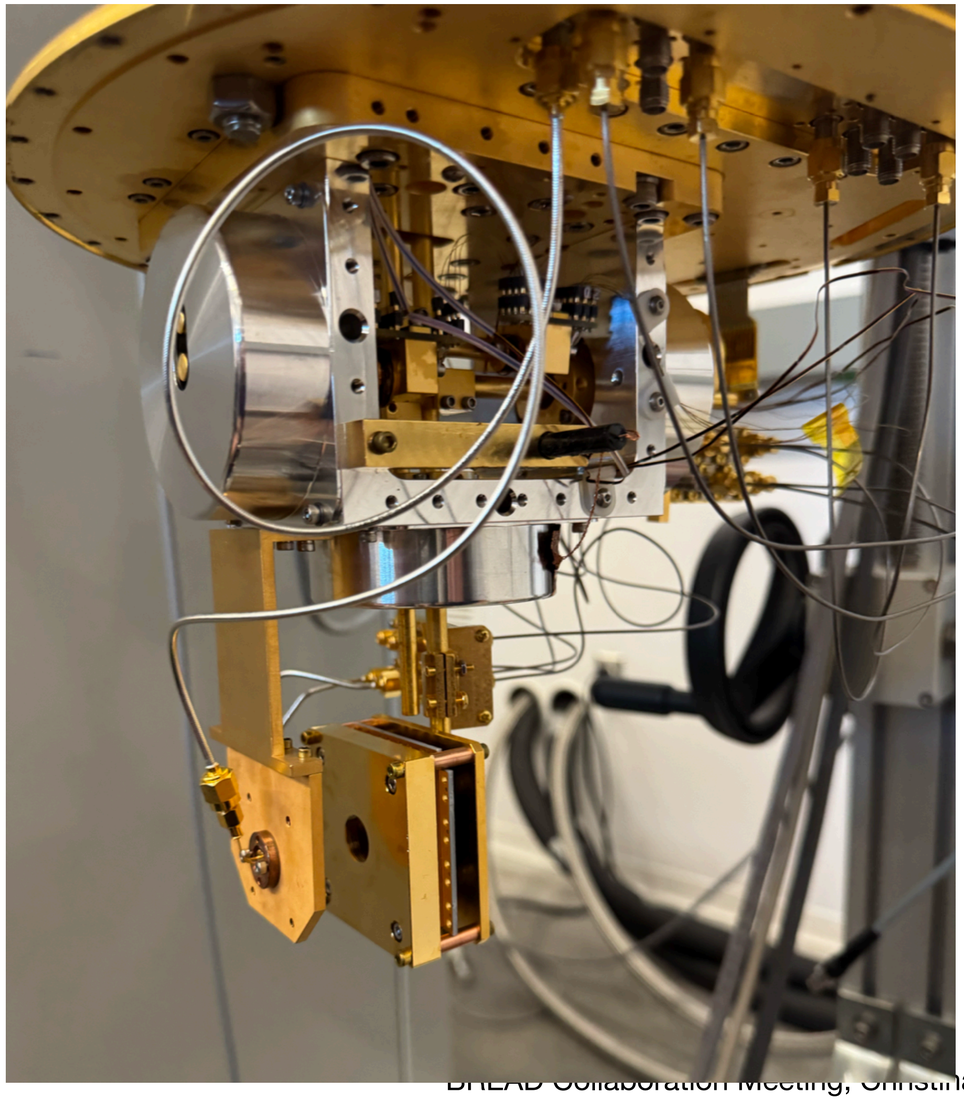
Cosmic Muon Tagger

- Got the PMTs for free from the DZero experiment
- Performing quality control of the PMTs



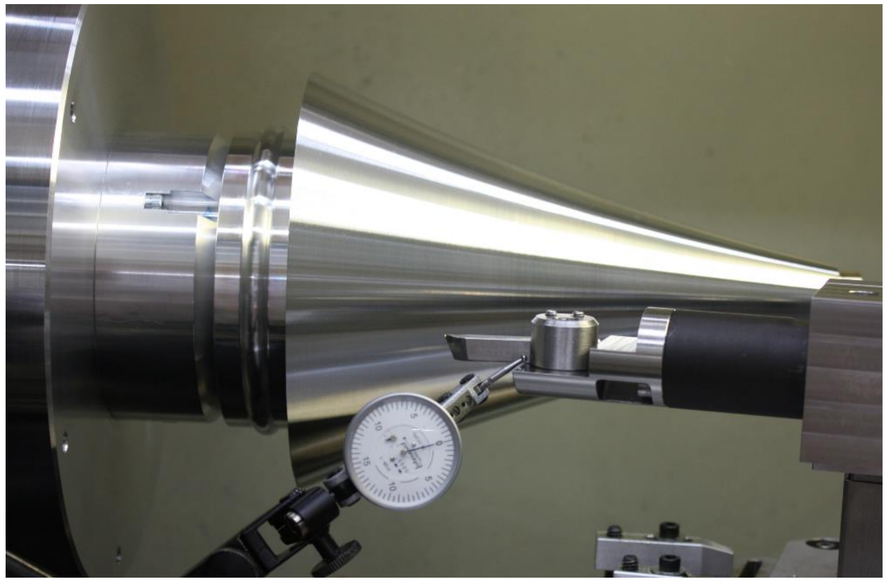
SNSPD Sensitivity to Longer Wavelengths

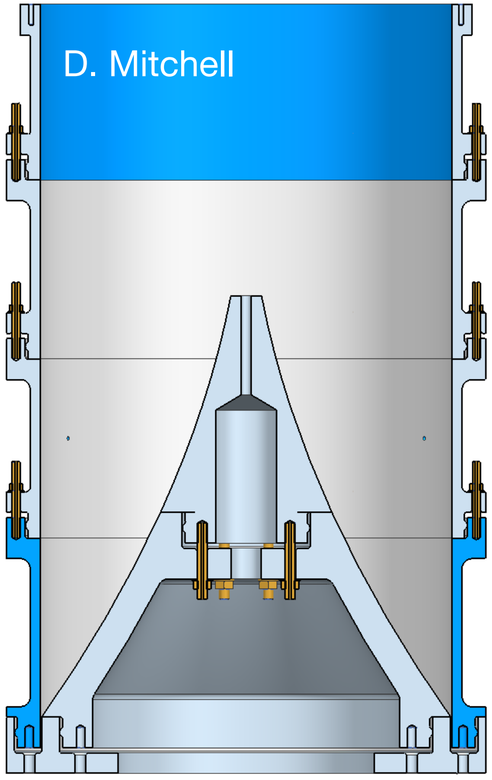
- Observed long plateau of PCR at 1650nm with existing sensor, plan to investigate the sensitivity to longer wavelengths with current sensor
- Built mechanical stand to hold a thermal source

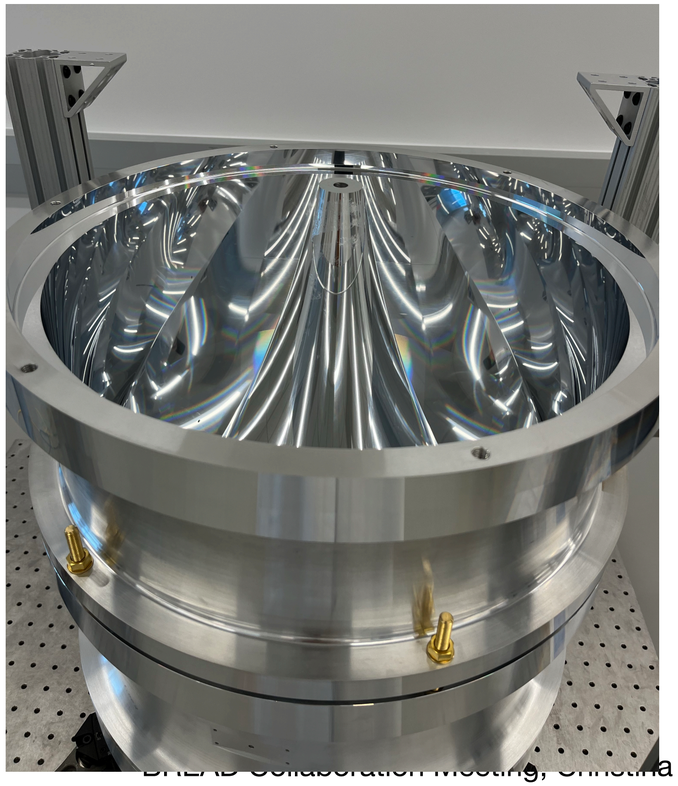


Status of the Pilot Bread Experiment — Reflector & Integration

- At optical wavelengths, need best possible focusing to limit size of photosensor.
- Reflector fabricated with diamond turning to achieve μm-level precision and smoothness
- Since last collaboration meeting, all parts diamond turned at LLNL and delivered to FNAL
- **Assembled both inner reflector parts and two outer barrels successfully!**
  - Heating of the outer circular ring with heat tape was essential to the tight fits

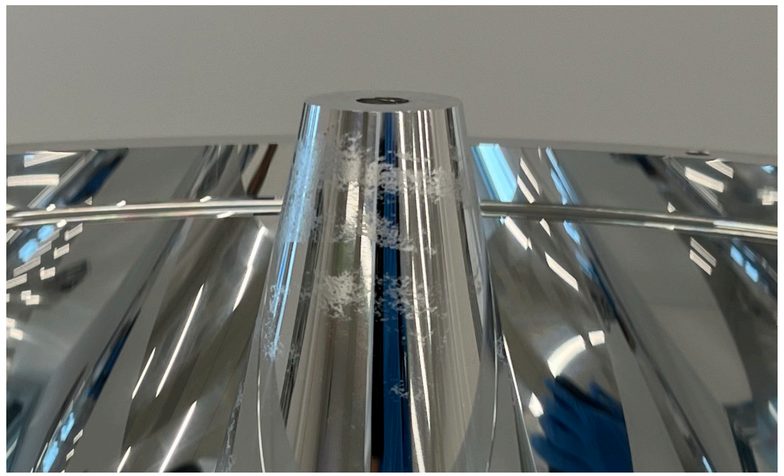


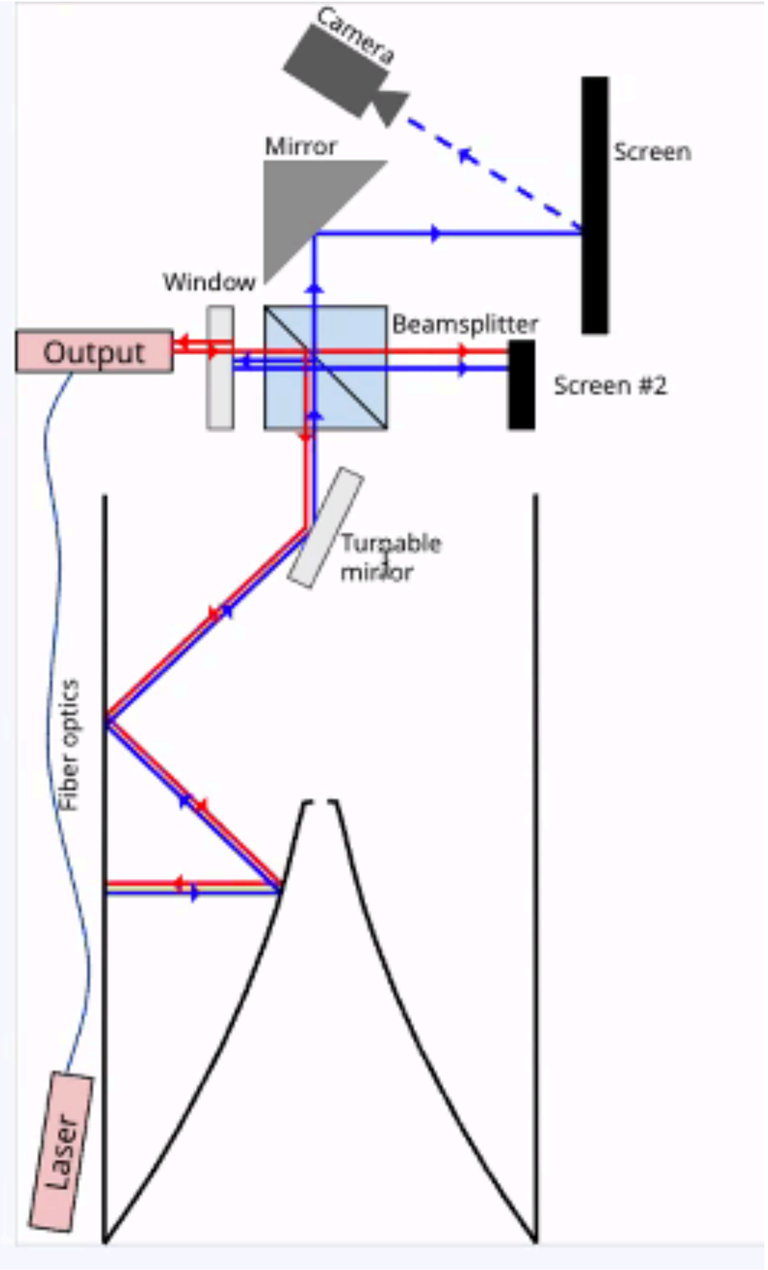




Optical Characterization

- Characterization of the optical properties of the reflector in progress
  - Setup optical characterization with laser/beam splitter building on Ethan's setup
  - Possibility to investigate other options that don't require laser alignment with Eyal (UChicago Undergrad)
  - Residues from protective coating observed, but have small surface area
  - Small machining marks/diffractions observed





Summary

- Upgraded cryogenic and characterization infrastructure allowed us to characterize the photon count rate, dark count rate, and time resolution of multi-pixel mm^2 SMSPDs
- Completed fabrication and assembly of optical reflector
- Next steps:
  - Further understand and remove the sources of background from SNSPDs
  - Develop system to measure calibrated efficiency as function of photon wavelength and incident angle
  - Develop system to characterize optical properties of reflector

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