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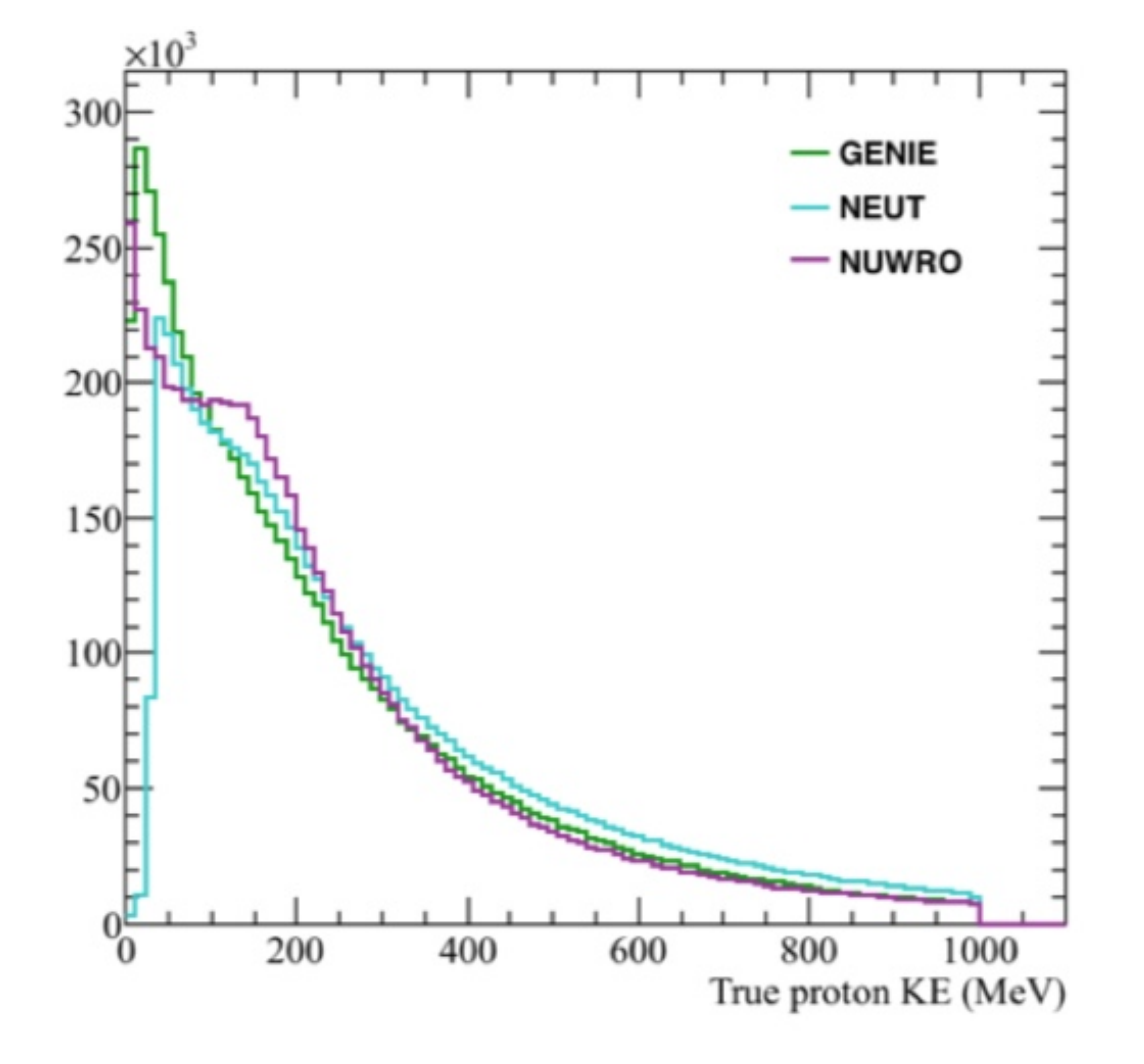
PROTOTYPE HPTPC: LIGHT MEASUREMENTS IN THE VISIBLE / NIR WITH A HIGH PRESSURE TPC

CONTENTS

INTRODUCTION

- Among the leading sources systematic uncertainties in ν oscillation experiments are the final state interactions (FSIs) of nucleons
- Large discrepancies on FSIs between Monte Carlo generators below 250 MeV/c
- Prototype HPTPC: Gaseous High Pressure Time Projection Chamber for use in a proton test beam:
  - Make measurements of the proton-argon cross-section at low proton momentum
  - Provide a platform for testing high pressure technology for global neutrino program



INTRODUCTION

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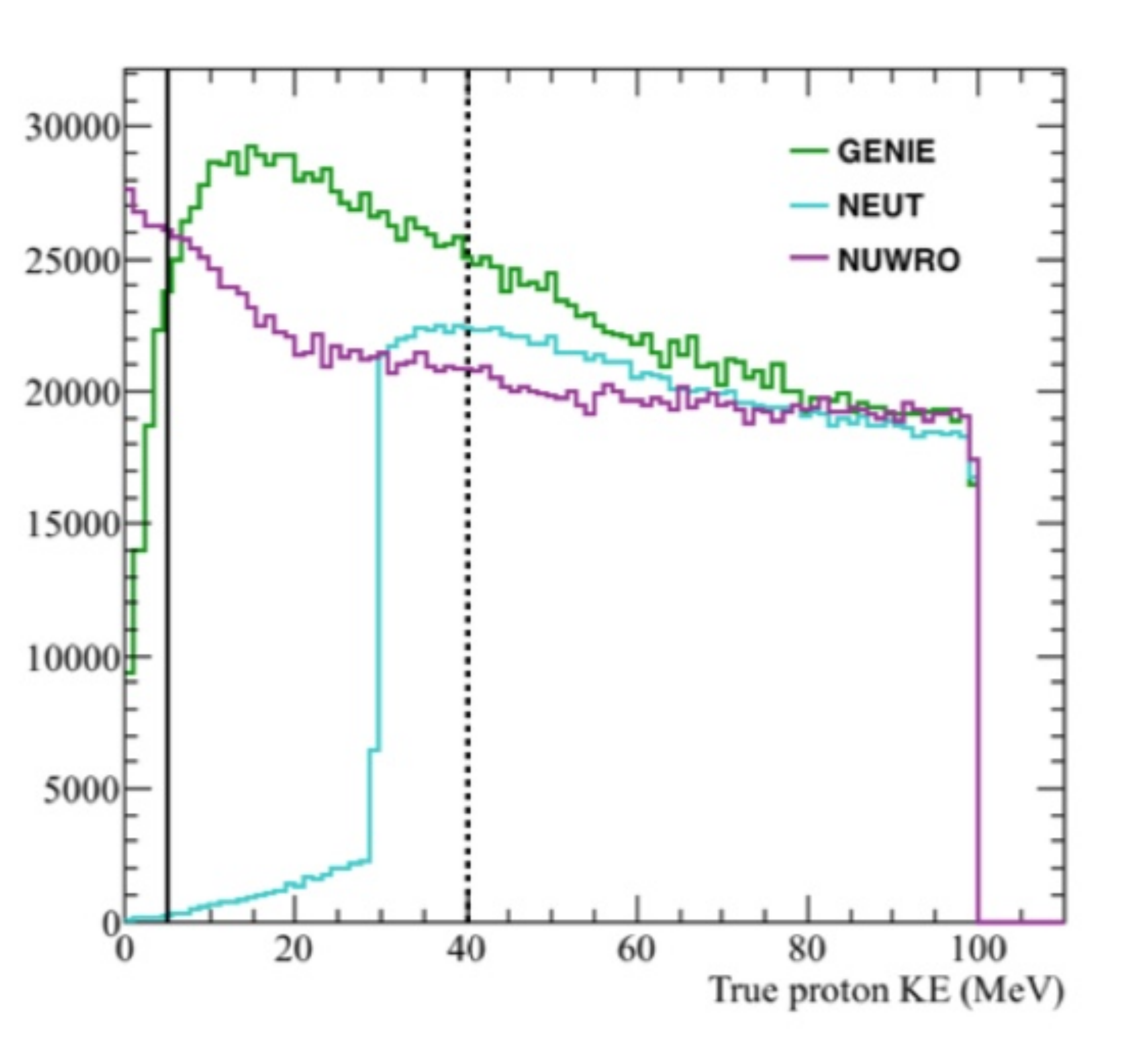
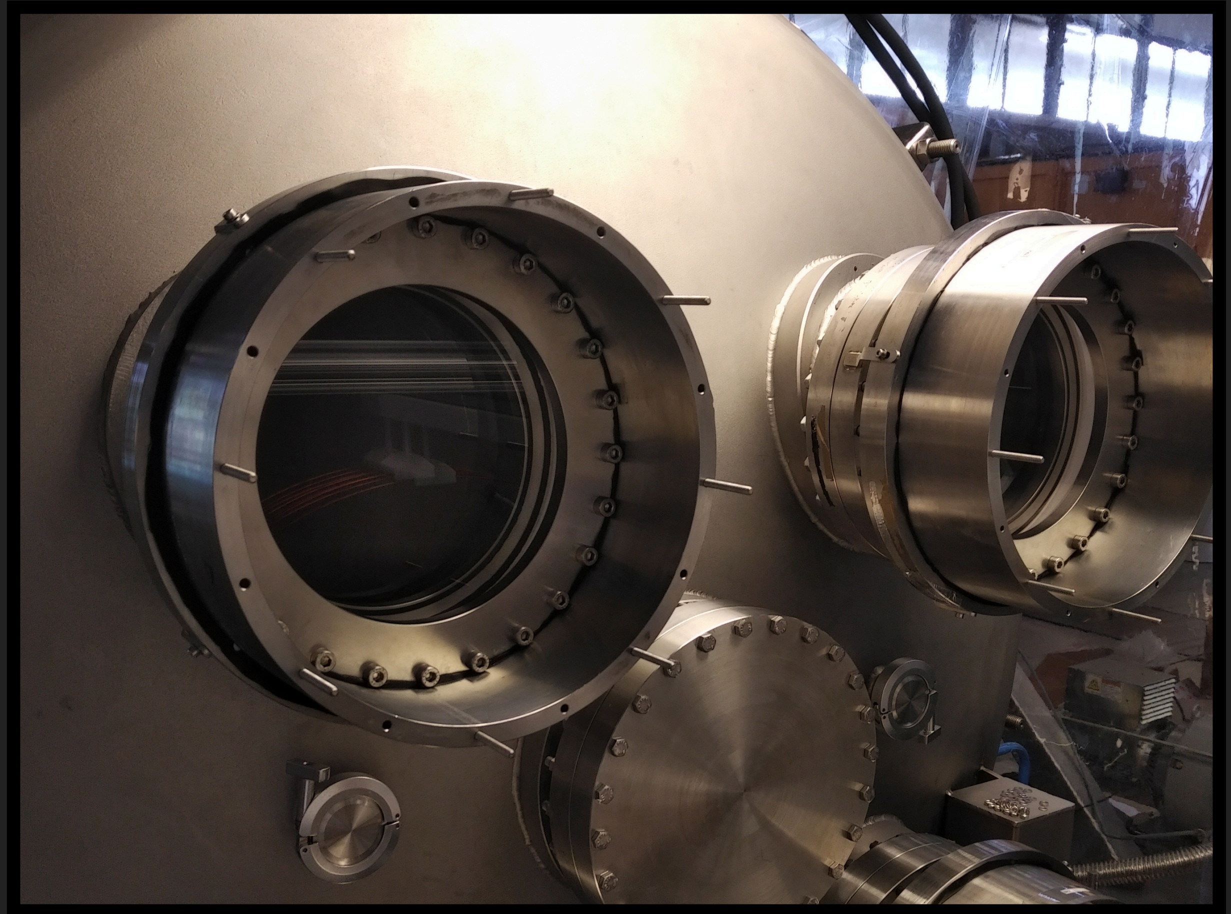
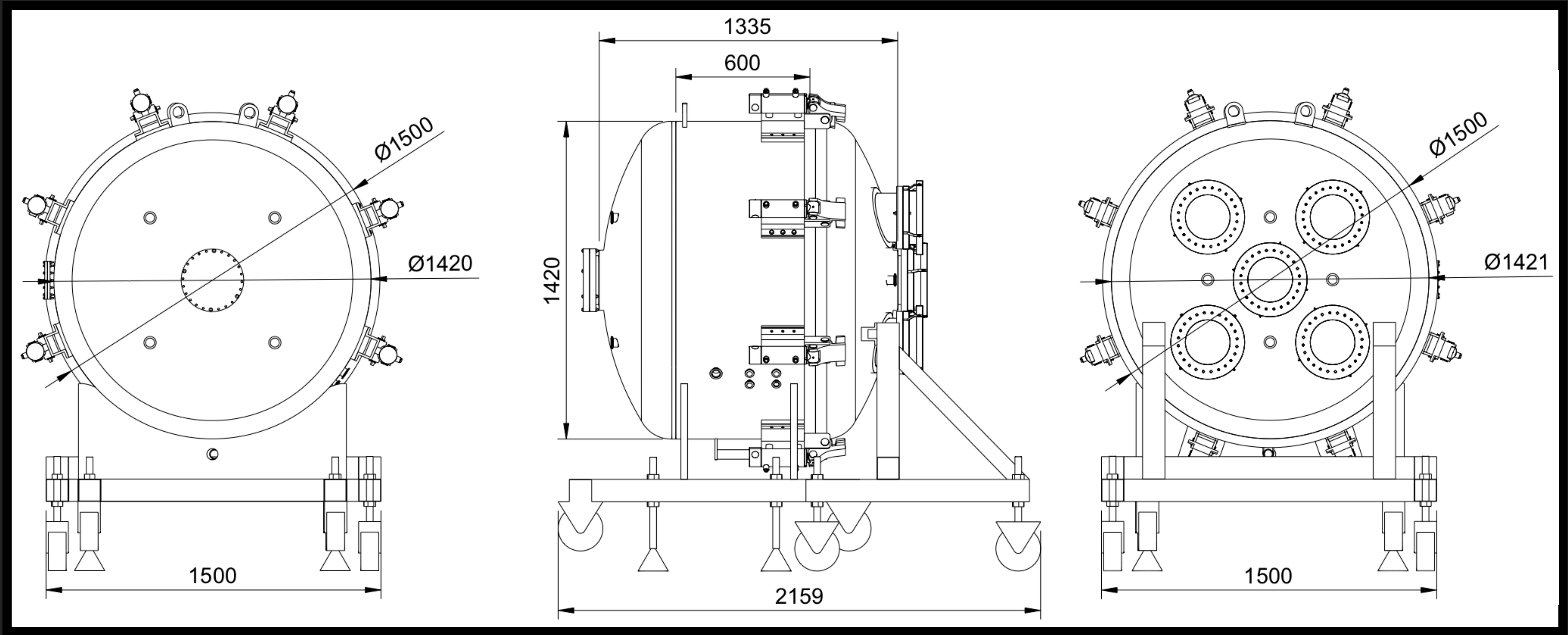


HIGH PRESSURE VESSEL

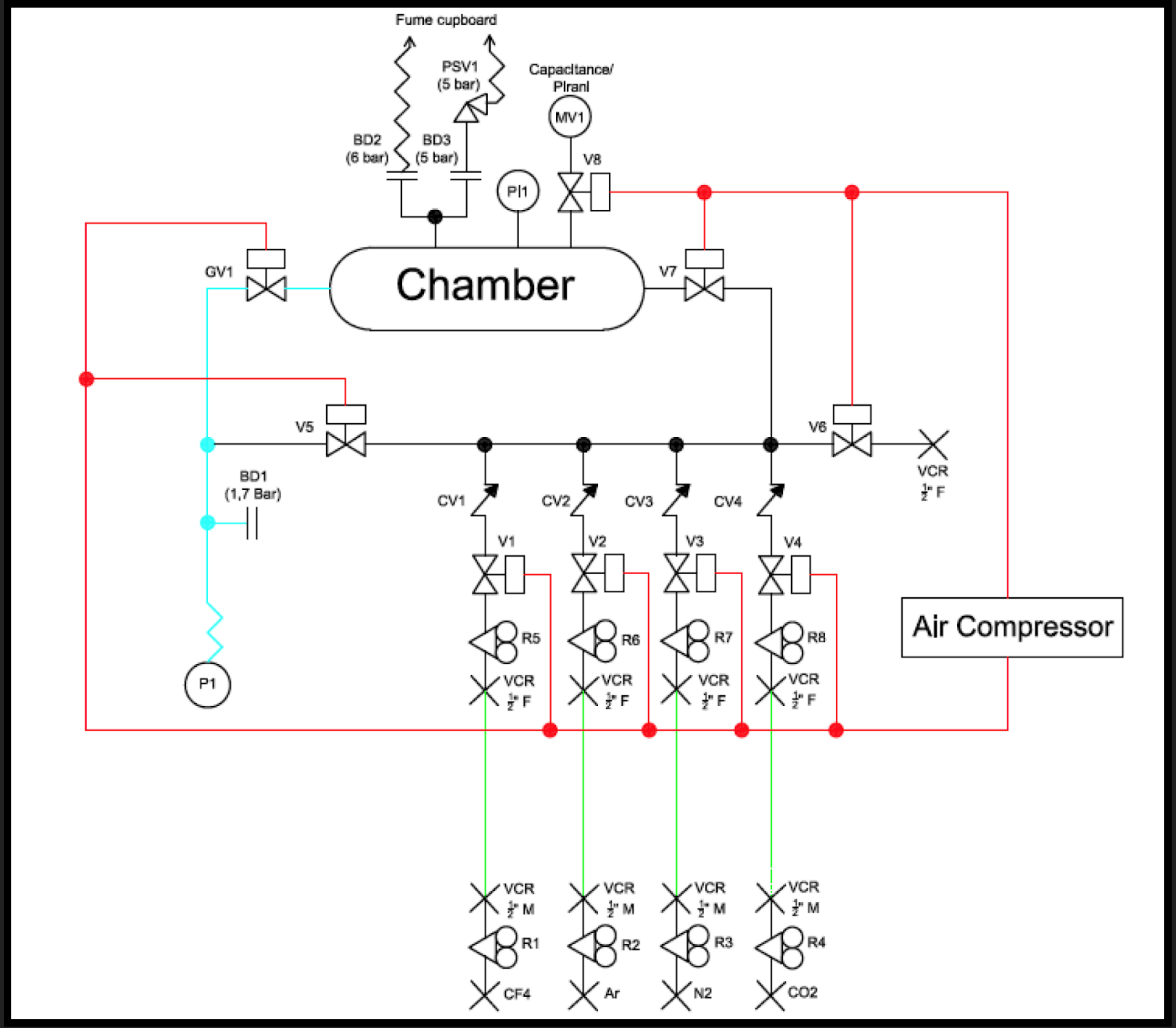
- Stainless steel high pressure vessel
- 10 mm wall thickness, inner diameter of 1400 mm and total length of 1335 mm
- Weighing 2370 kg
- Flanges:
  - Door end (fully detachable) attached using 1500 mm flange and eight hydraulic arms
  - Five 200 mm flange equipped with 60 mm thick quartz optical windows
  - A number of 25 mm and 40 mm flanges all sides for high voltage, gas, vacuum and safety systems





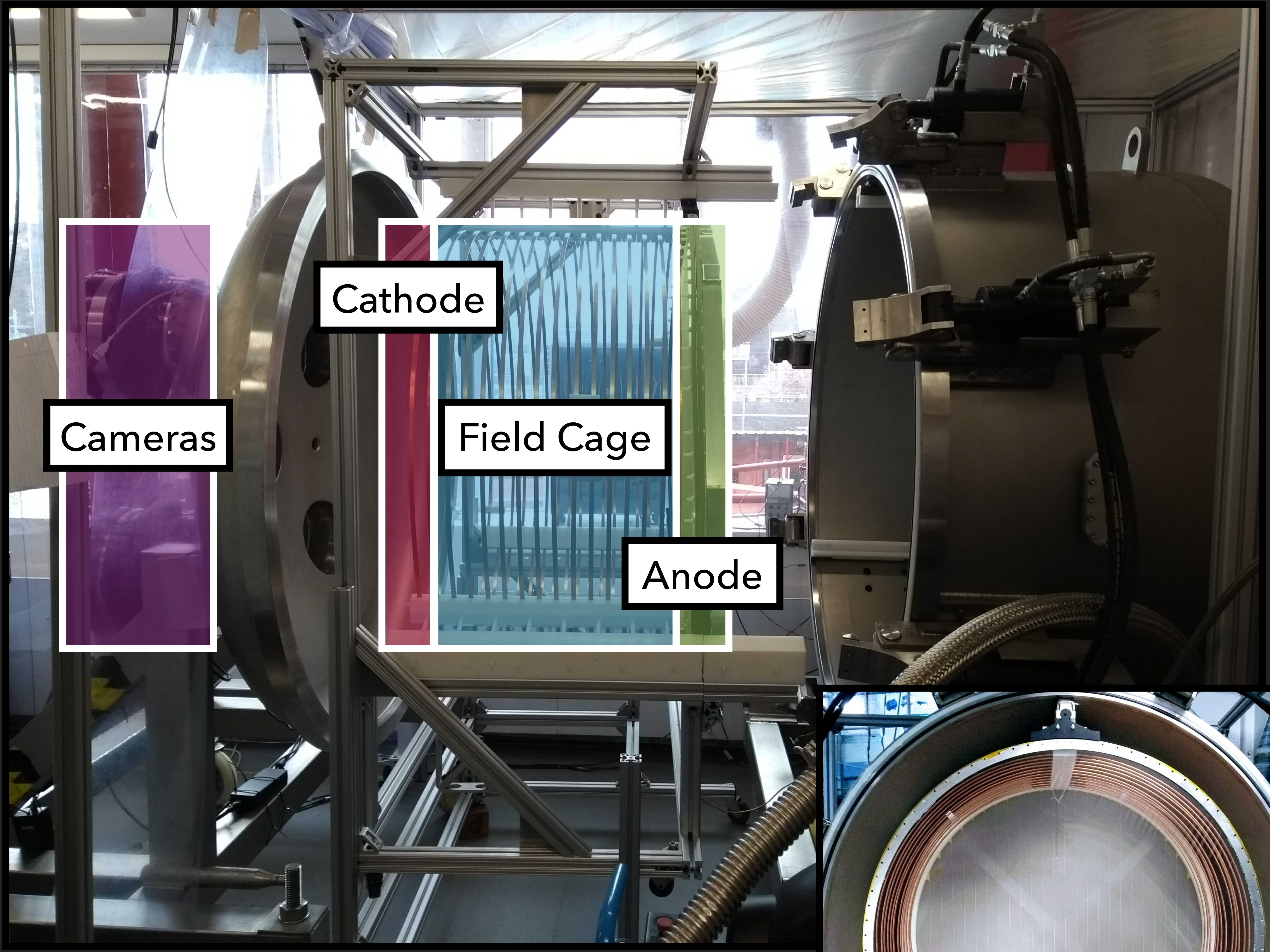
GAS SYSTEM

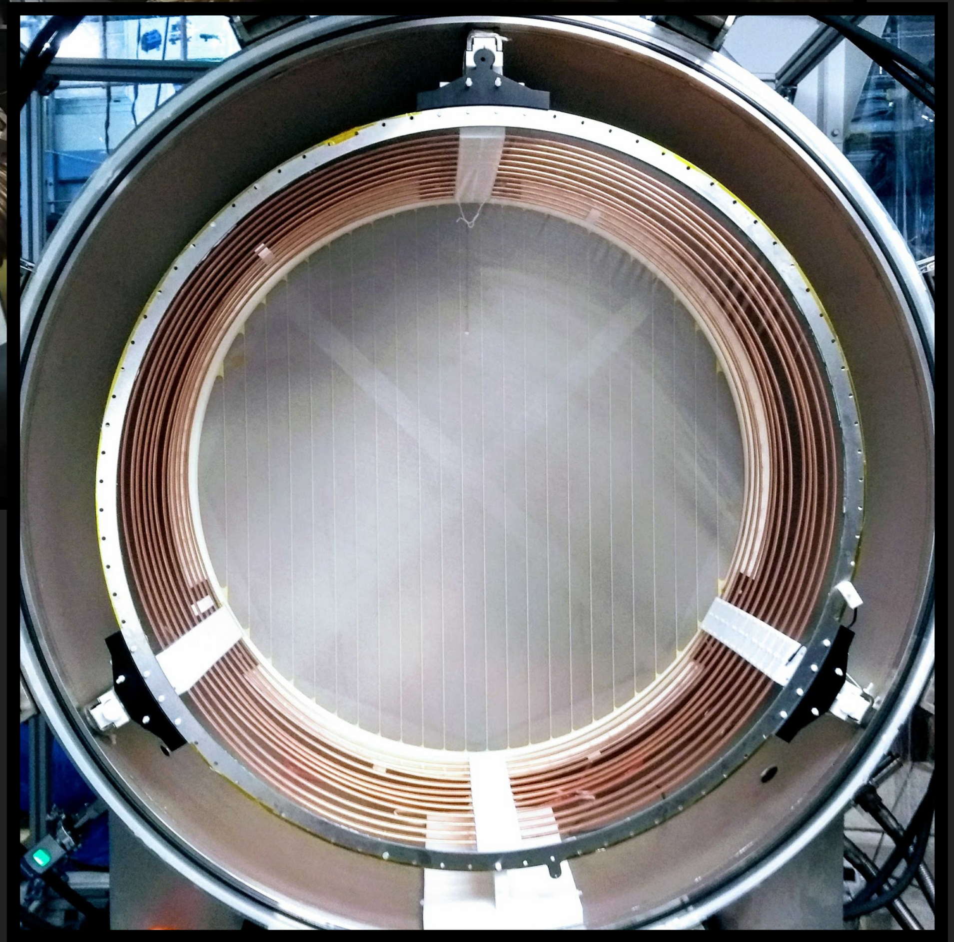
- Vessel is evacuated to ~ 1 x 10^{-6} BarA before filling using a Agilent Triscroll 800 dry pump
- Operate at a pressures up to 5 bar absolute
- Gas system allows for mixing of gases from up to 4 different inputs
- This talk only covers pure argon data



TIME PROJECTION CHAMBER

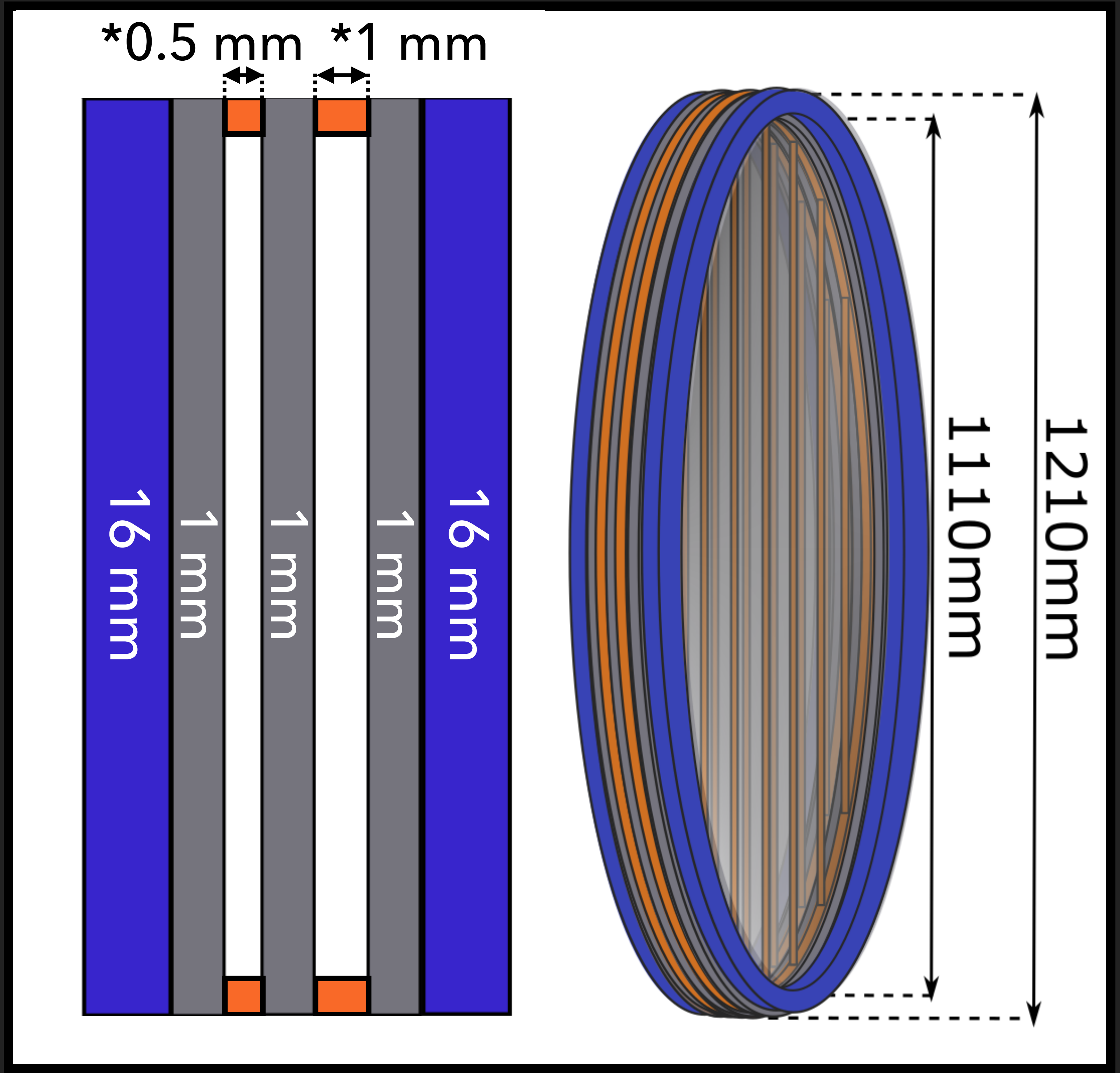
- TPC features both optical and charge readout
- The TPC consists:
  - ~97% transparent cathode mesh
  - Low mass modular field cage -> 447 mm long drift region with 1110 mm diameter
  - A three anode mesh amplification region

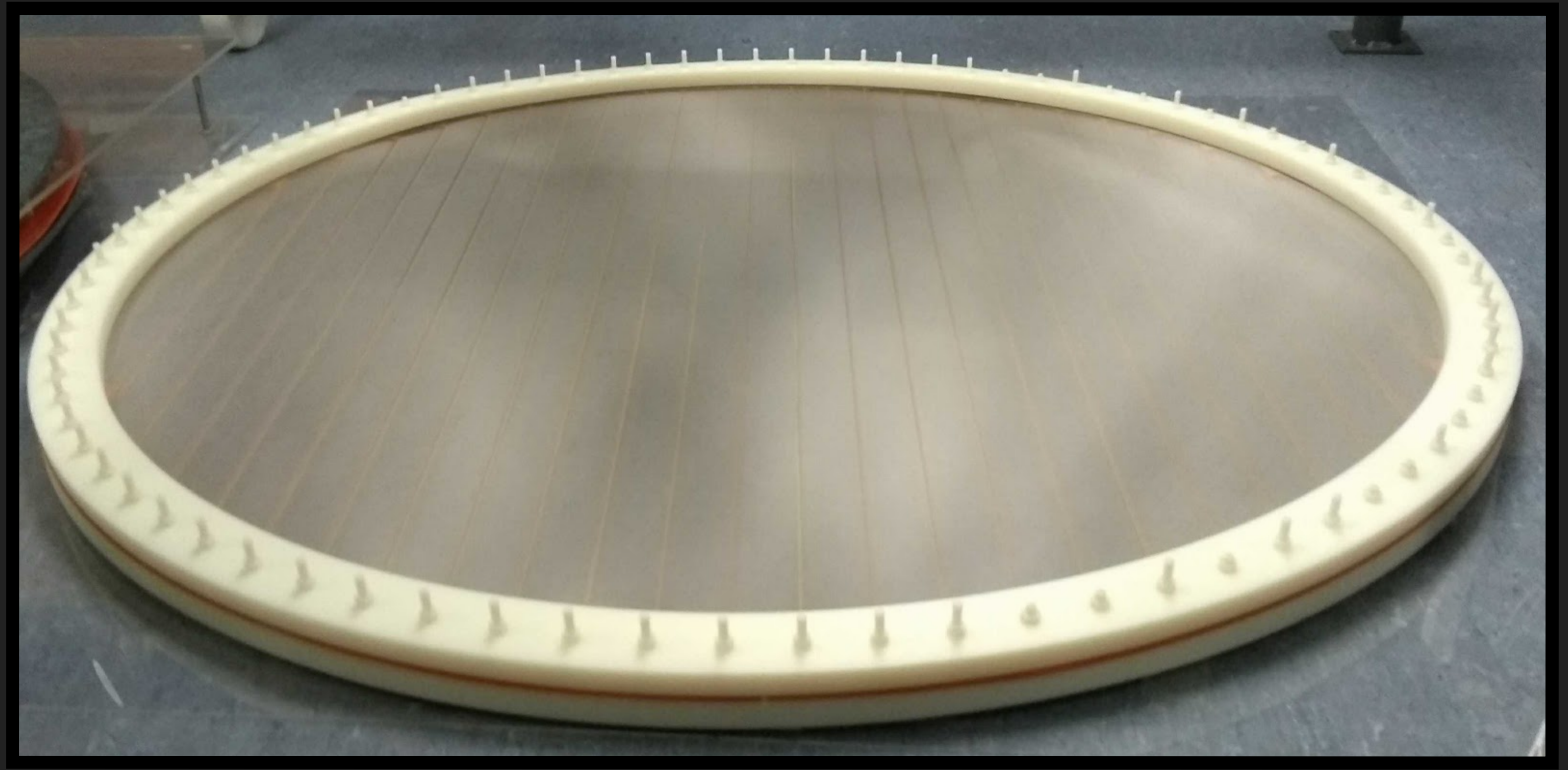




AMPLIFICATION REGION

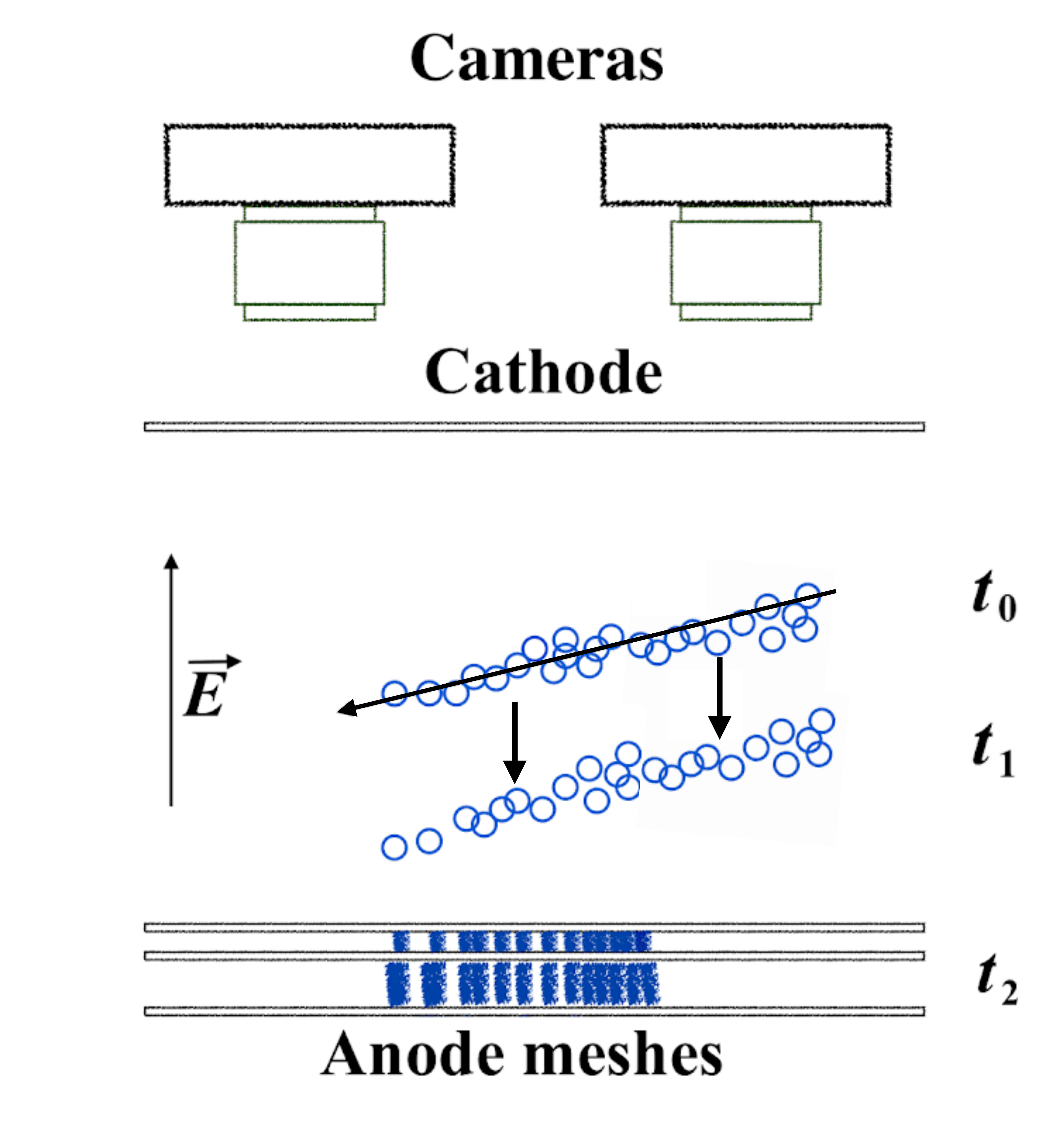
- Three high tension (19 ± 1 Nm) stainless steel anode meshes:
  - made from 39 lines per mm, 25 micron wire with an optical transparency of 89%
  - each glued to a 1 mm thick steel ring (grey)
- One 0.5 mm thick and one 1 mm thick polyester spacers (orange) separate the anode meshes
- Two 16 mm thick nylon support rings (blue)





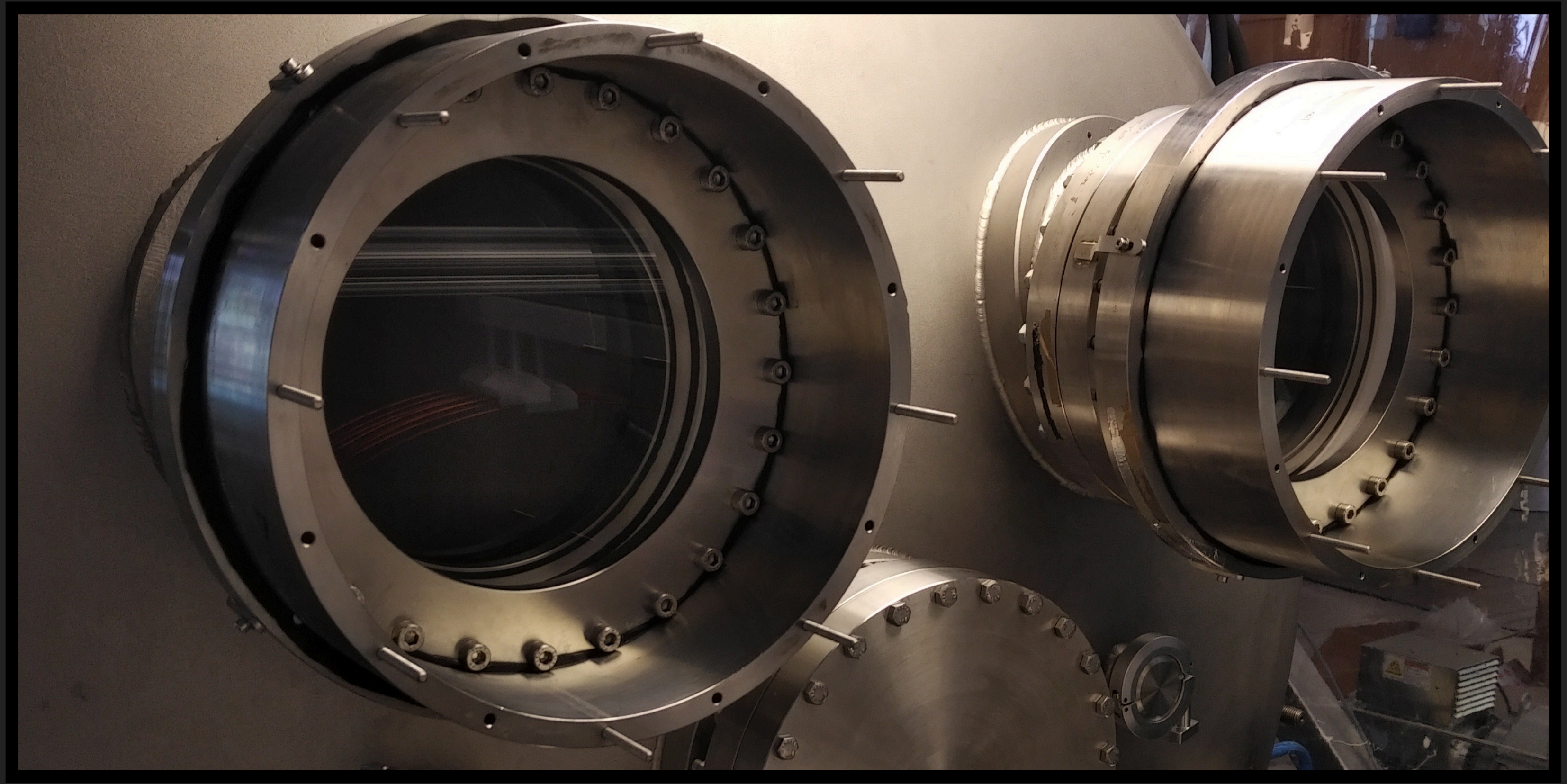
TPC OPERATION

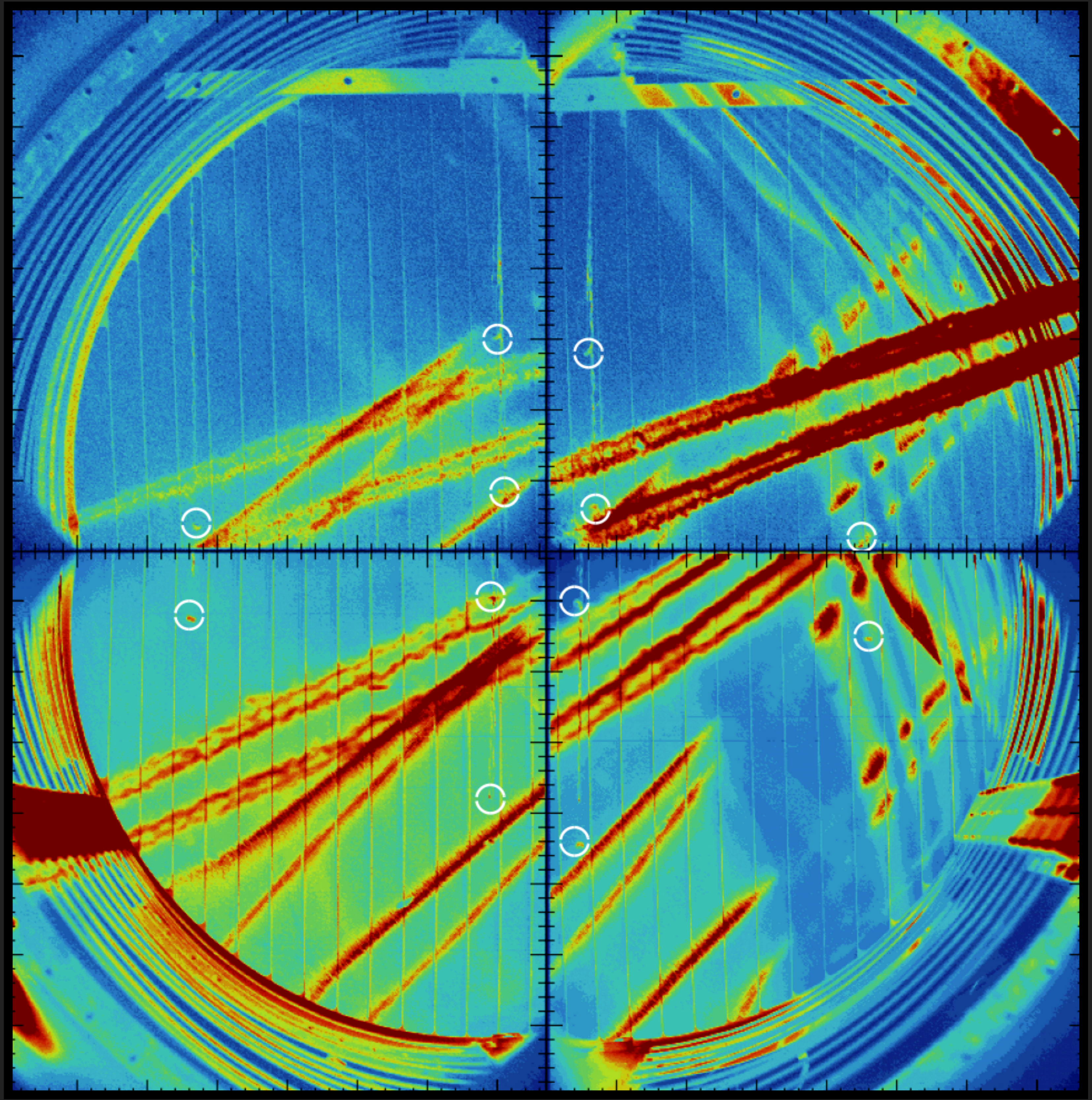
- Fine optical readout of scintillation photons created at the amplification region
- Three anode mesh amplification region:
  - Charge readout at each of the anode meshes
  - Addition of the third mesh was chosen to achieve increased amplification



OPTICAL READOUT SYSTEM

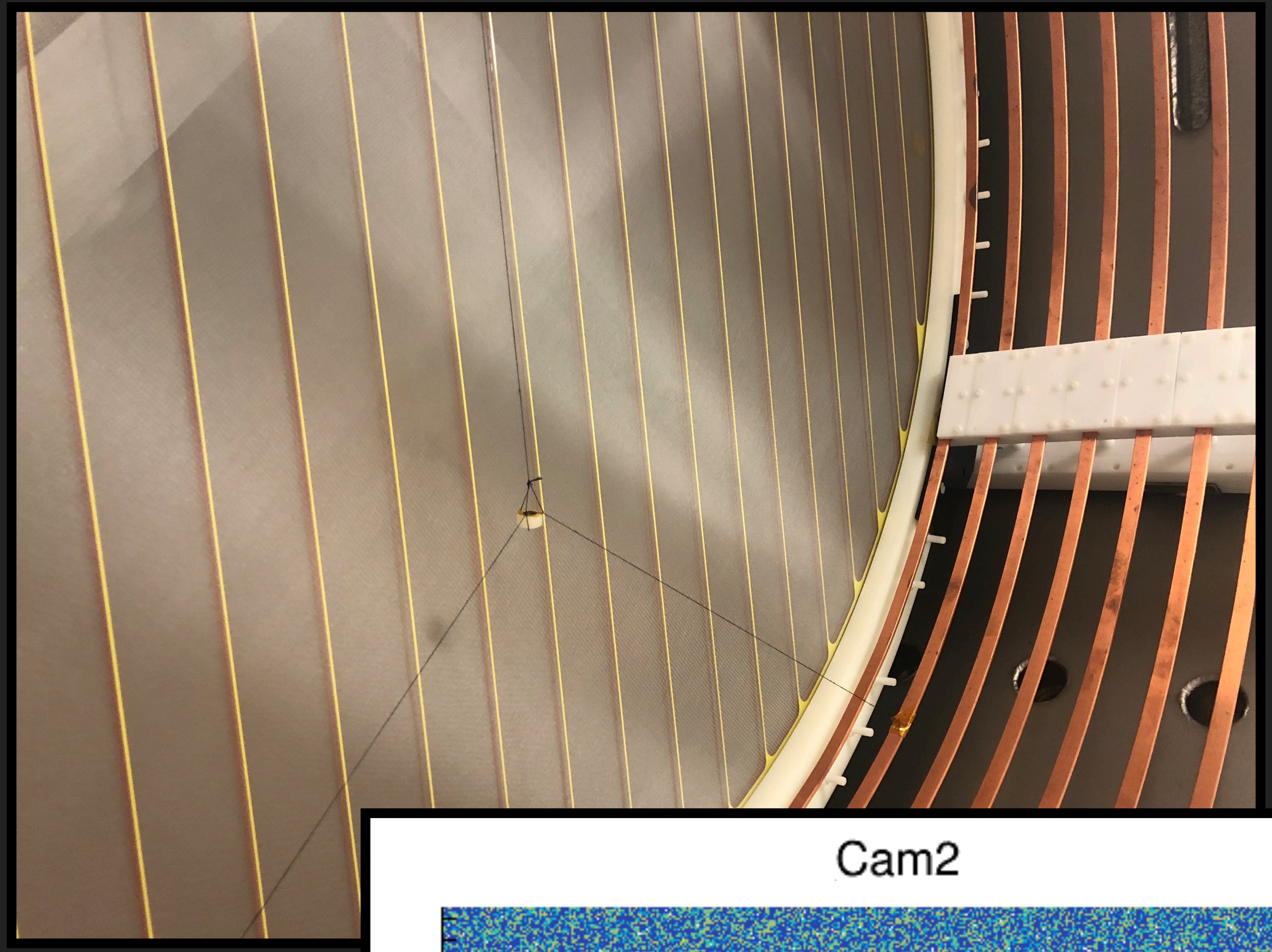
- Four 9.3 MP FLI Proline PL09000 CCDs each with 3056 x 3056 active pixels images one (71 x 71 cm^2) quadrant of the anode meshes
- Each pixel acts as a single readout channel focused on a 230 µm by 230 µm region of the amplification (a 230 µm vixel)
- CCDs quantum efficiency 50%-70% (>20%) between 475 nm and 750 nm (350nm and 925 nm)
- Images are taken through the quartz windows (shown top) and the ~97% transparent cathode mesh

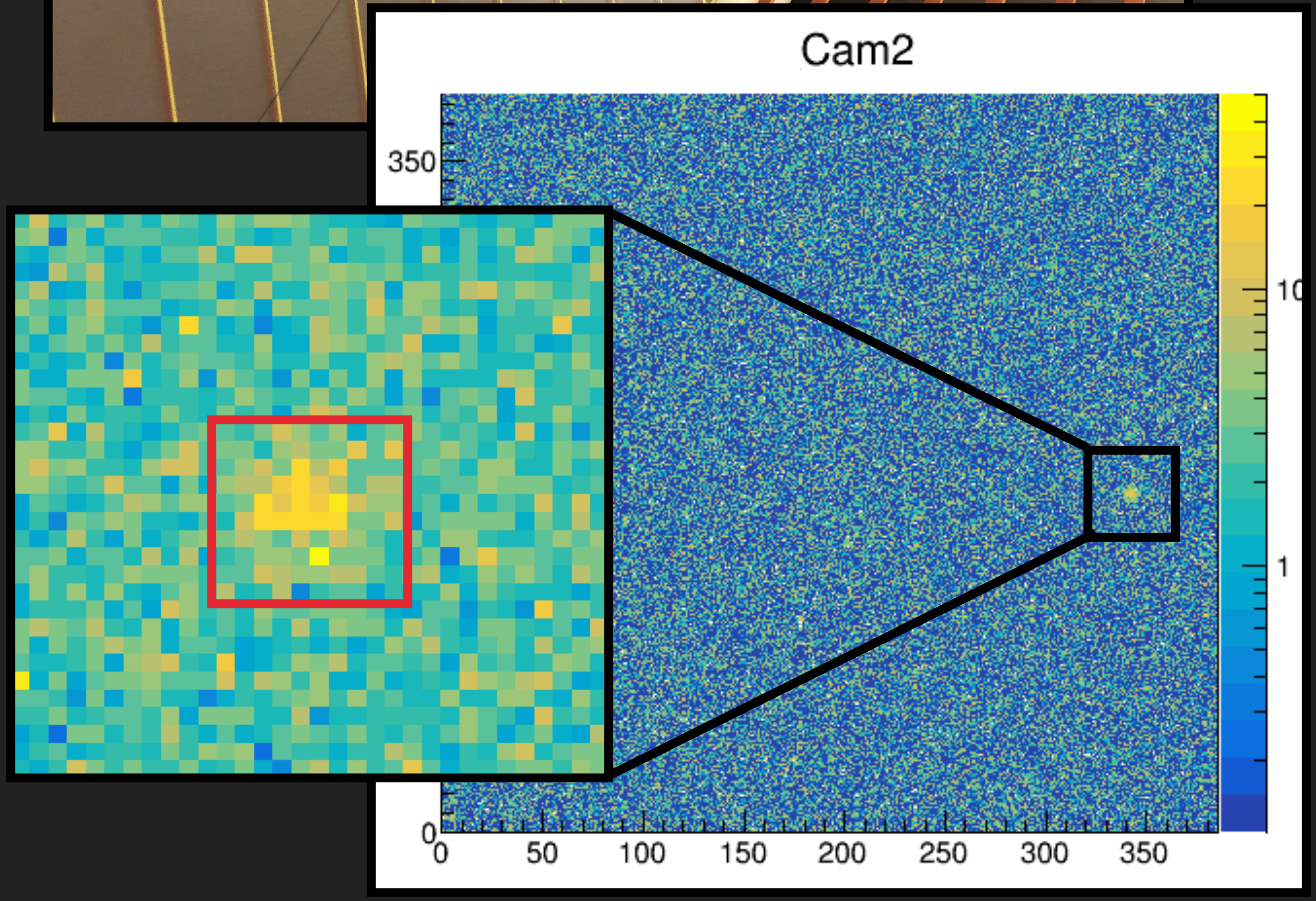




LIGHT CALIBRATION MEASUREMENTS

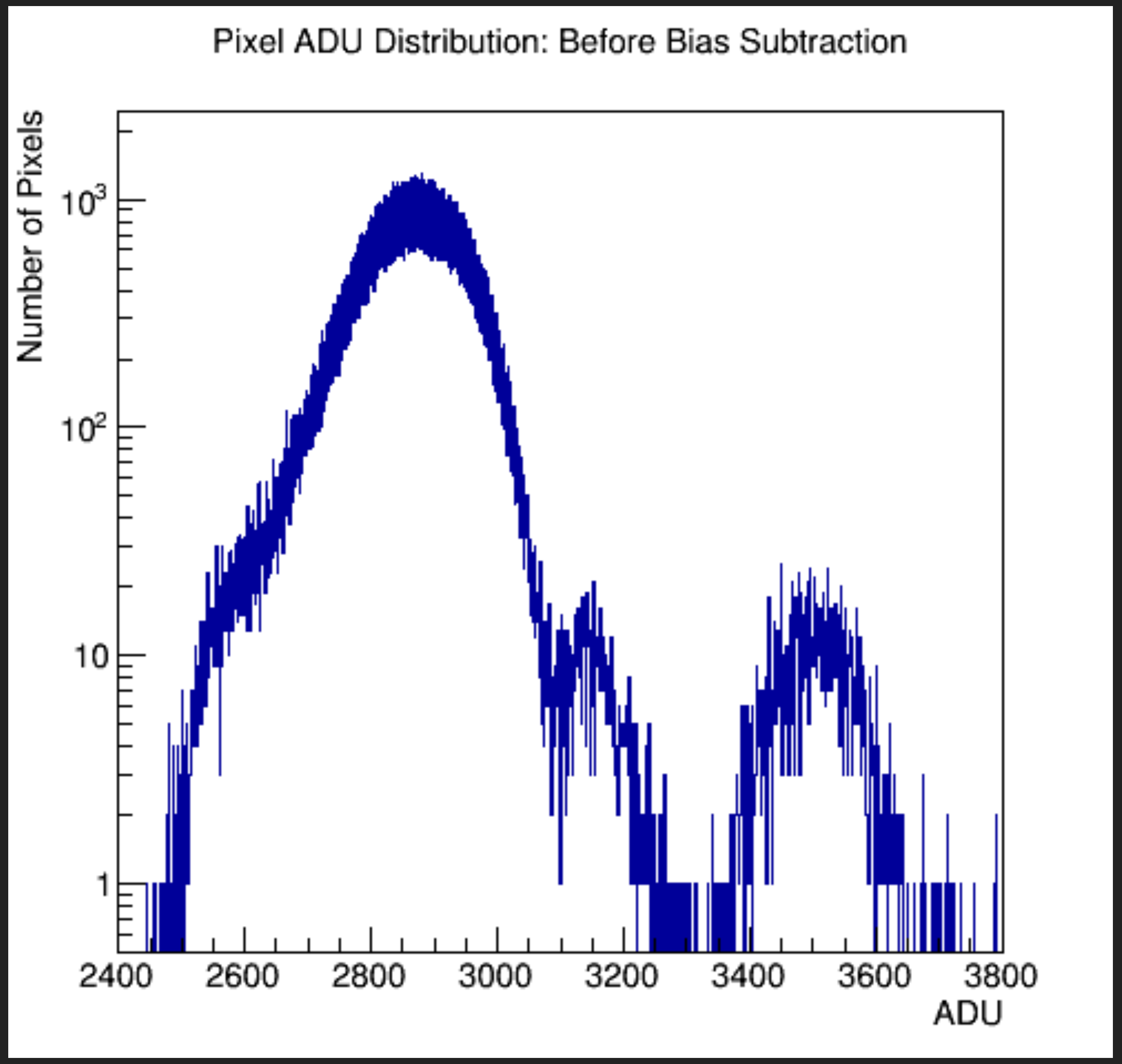
- For light calibration tests we use an encapsulated ^{241}Am source inside of the vessel (emitting ~ 5 MeV alpha particles)
- Fill vessel with target gas
- Ramp the cathode and anode meshes to voltage
- Take a number of event frames and bias frames
- Locate and box source
- Sum pixels within box to produce an integrated ADU measurement

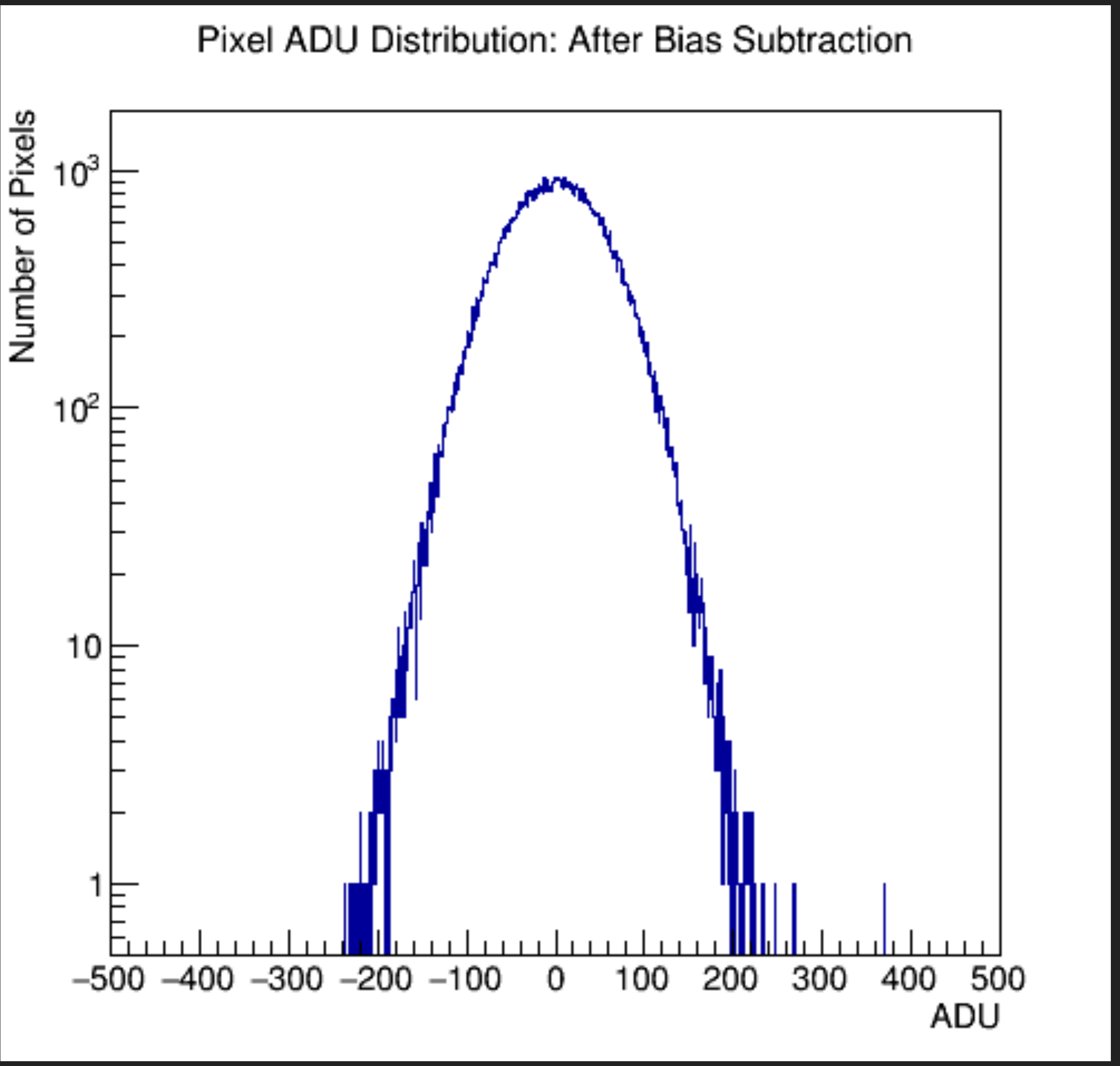




PEDESTAL SUBTRACTION: BIAS FRAMES & NOISE

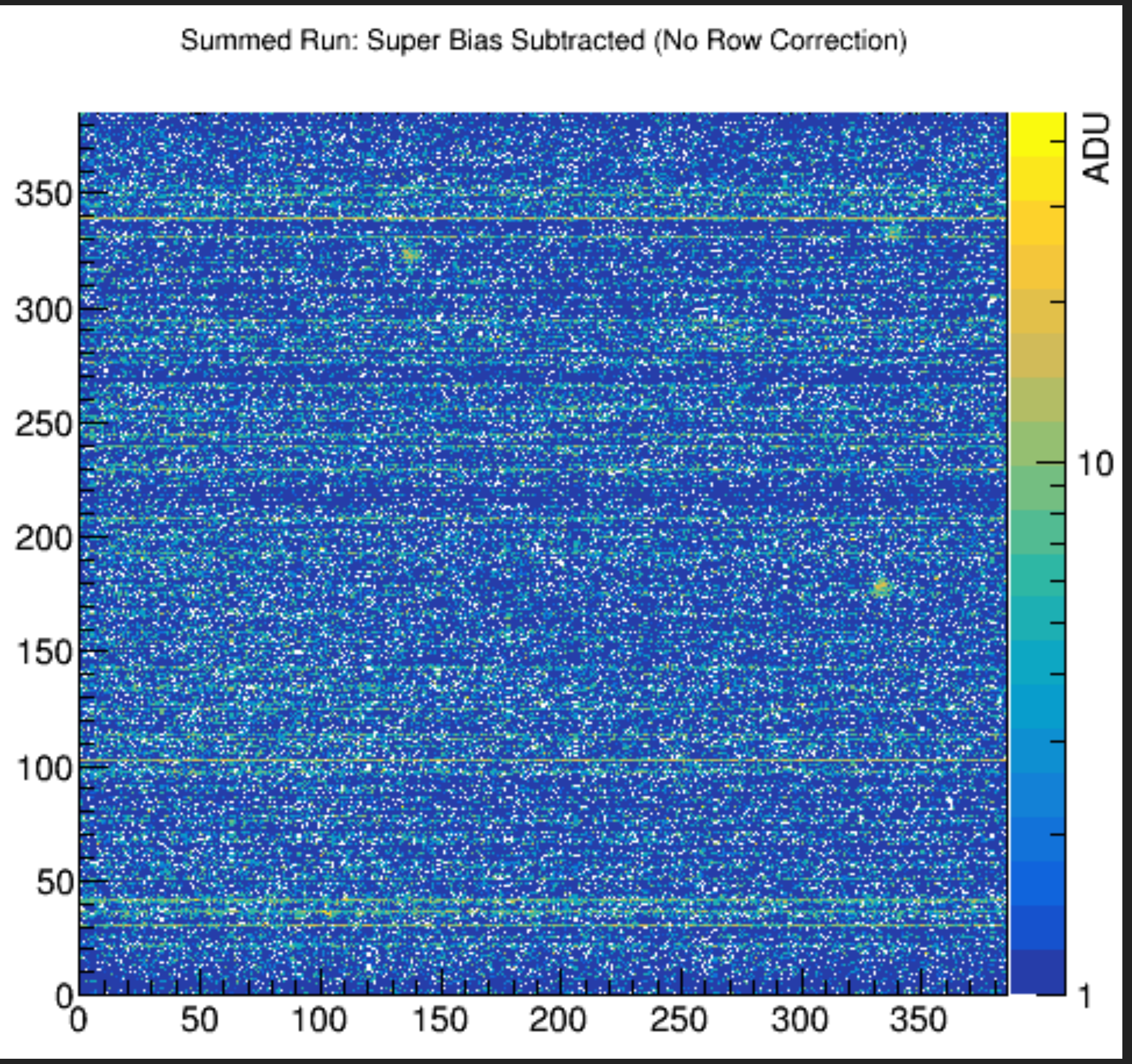
- Remove any spacial non-uniformities by background subtracting the images
- The total noise per pixel is calculated as follows:
  $\sigma_{total} = \sqrt{\sigma_{dark} + \sigma_{read} + \sigma_{shot}}$
- Dark Shot Noise (σ_{dark}) - Temperature dependant noise from dark current (thermal excitation of electrons)
- Read Noise (σ_{read}) - Electronics converting the electrons released in the silicone to a voltage and then Analogue-to-Digital Units (ADUs)
- Photon Shot Noise (σ_{shot}) - Statistical variation of number of electrons collected for each incident photon
- To minimise the noise per pixel we can average multiple bias and event frames

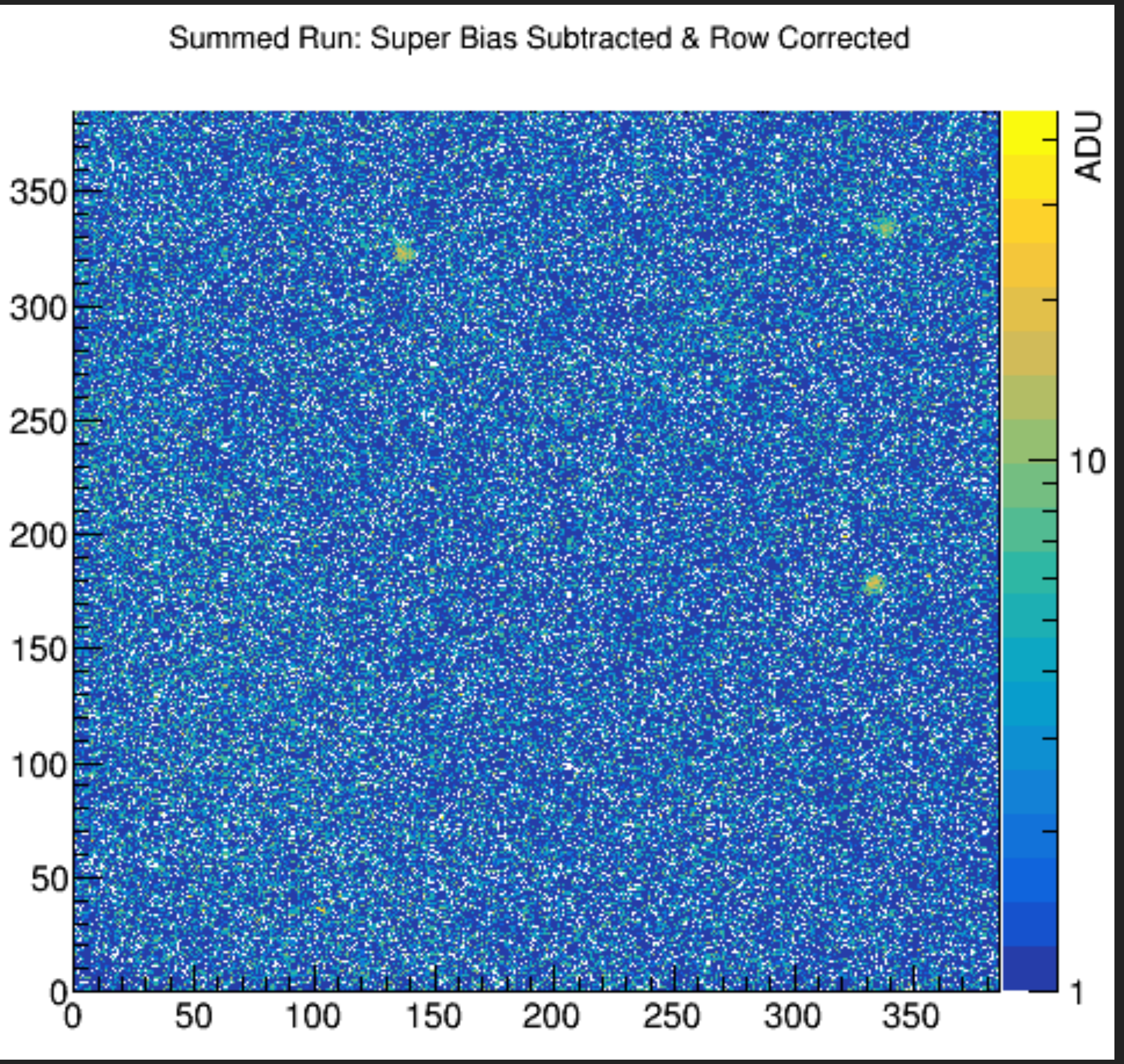




OPTICAL CALIBRATION: TIME DEPENDANT CORRECTIONS

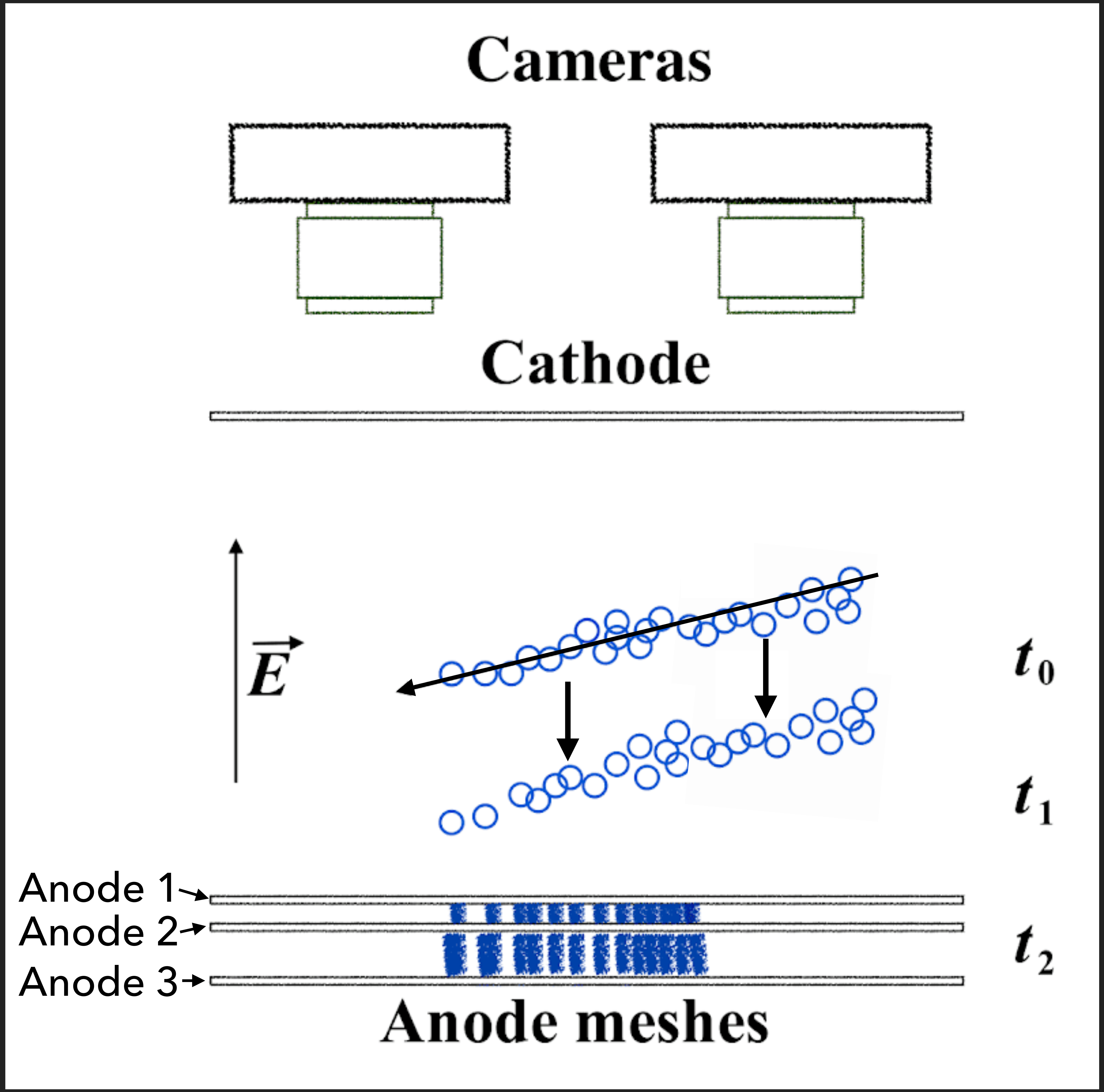
- Averaging multiple images increase the probability to introduce time dependant effects
  - Hot and cold pixels -> can be identified and removed
  - Image pedestal drift from temperature change of the CCD -> can measured and corrected
  - Row pedestal fluctuations-> apply row correction
- Row Correction: Subtract each rows average pixel value (after omitting hot and cold pixels and pixels near sources) from each pixel with the row





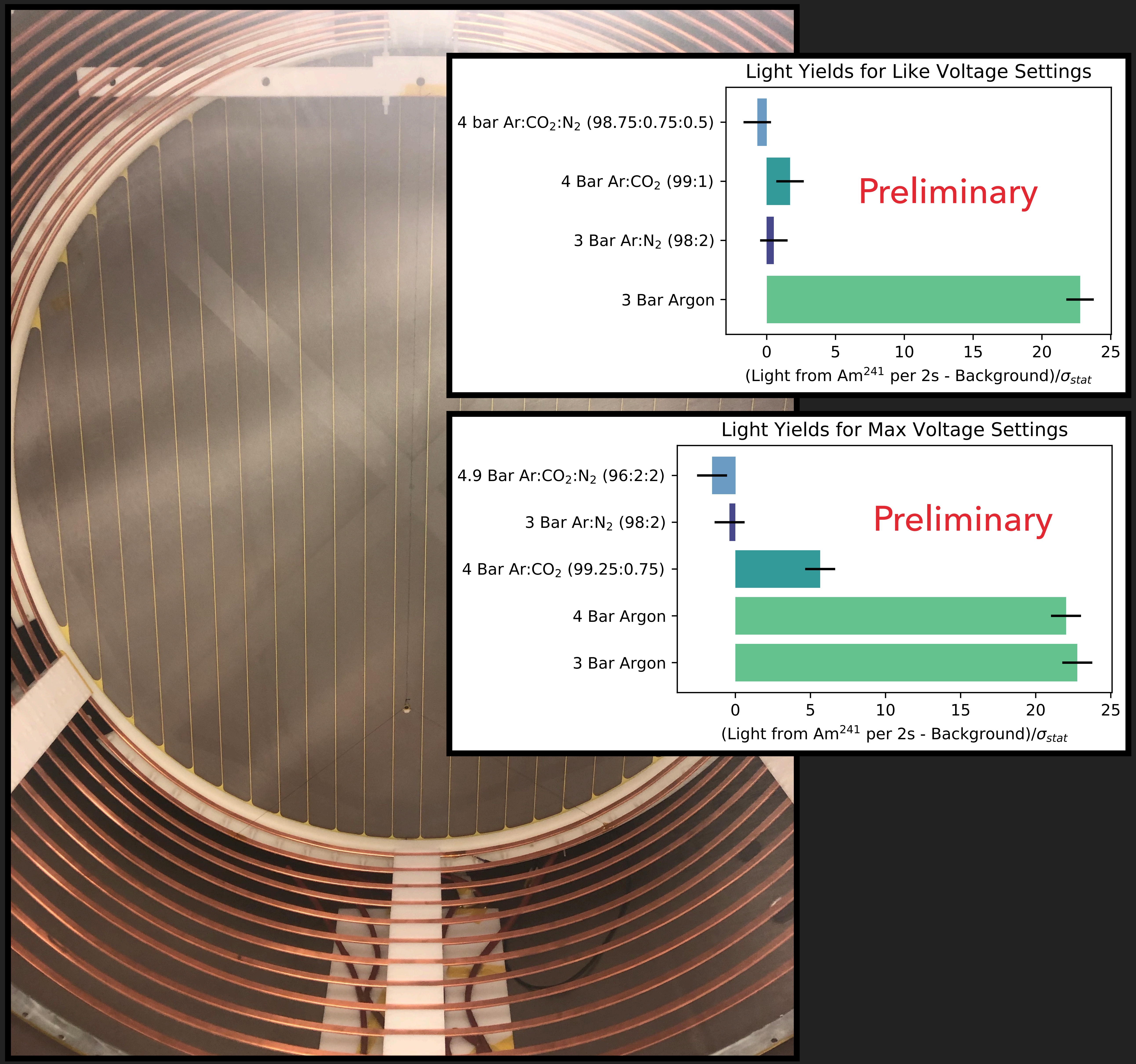
AIM OF CALIBRATION MEASUREMENT

- Aim: To measure the light gain as a function of anode voltages
- We are using a novel three anode mesh amplification region with optical readout
- We want to understand:
    - How the light gain is affected by the absolute voltage of the anodes
    - How the light gain is affected by the potential difference between anodes i.e. potential difference between anode 1 (2) and 2 (3)



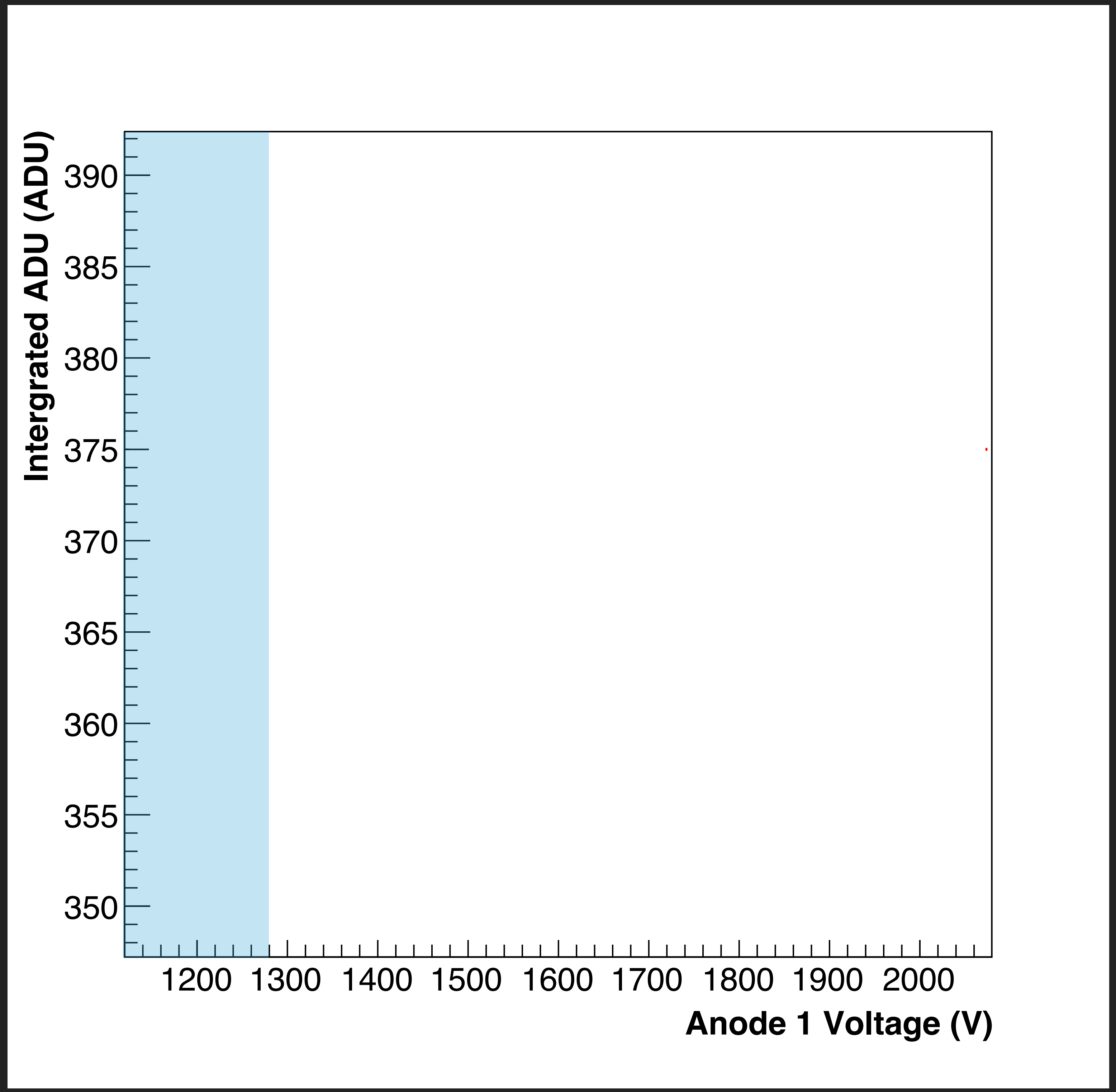
EXPERIMENTAL SETUP

- Use a single ^{241}Am alpha source suspend close to the amplification region
- Took measurements in 5 BarA to maximise light yield
- Took between ~1.4 and 2 hrs of total exposure time at each of the chosen voltage setting
- We chose three voltage scheme



RESULTS: ABSOLUTE VOLTAGE

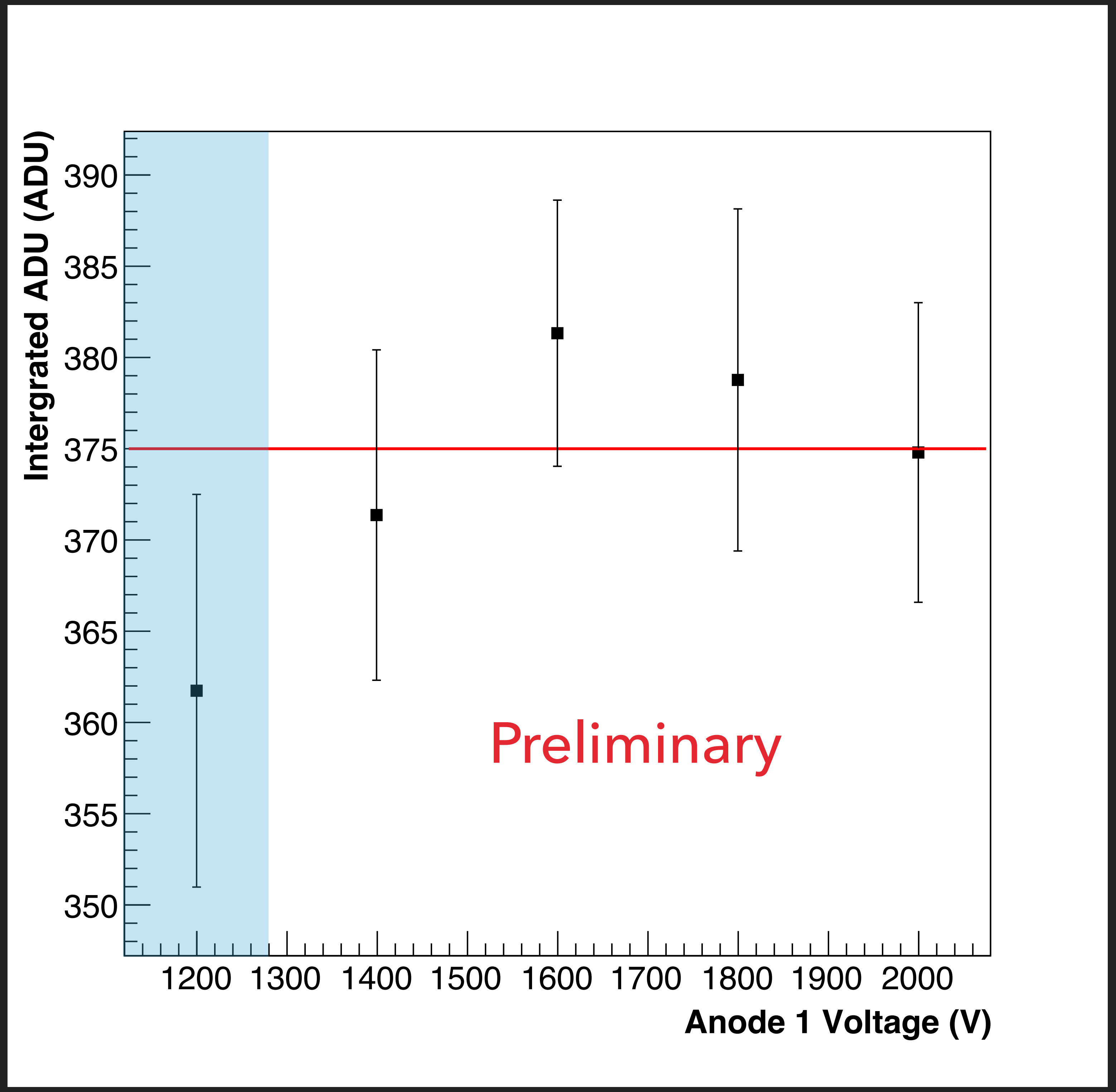
- How the light gain is affected by changes to absolute anode voltage when the potential difference between anodes was kept fixed
- Starting voltages (blue): Anode 1 = 1200 V, Anode 2 = 2400 V and Anode 3 = 3600 V
- Increasing all anodes voltages by the same amount for each step
- Therefore the potential difference between any pair of anodes is maintained fixed



Anode 2 voltage = Anode 1 Voltage + 1200 V
Anode 3 voltage = Anode 1 Voltage + 2400 V

RESULTS: ABSOLUTE VOLTAGE

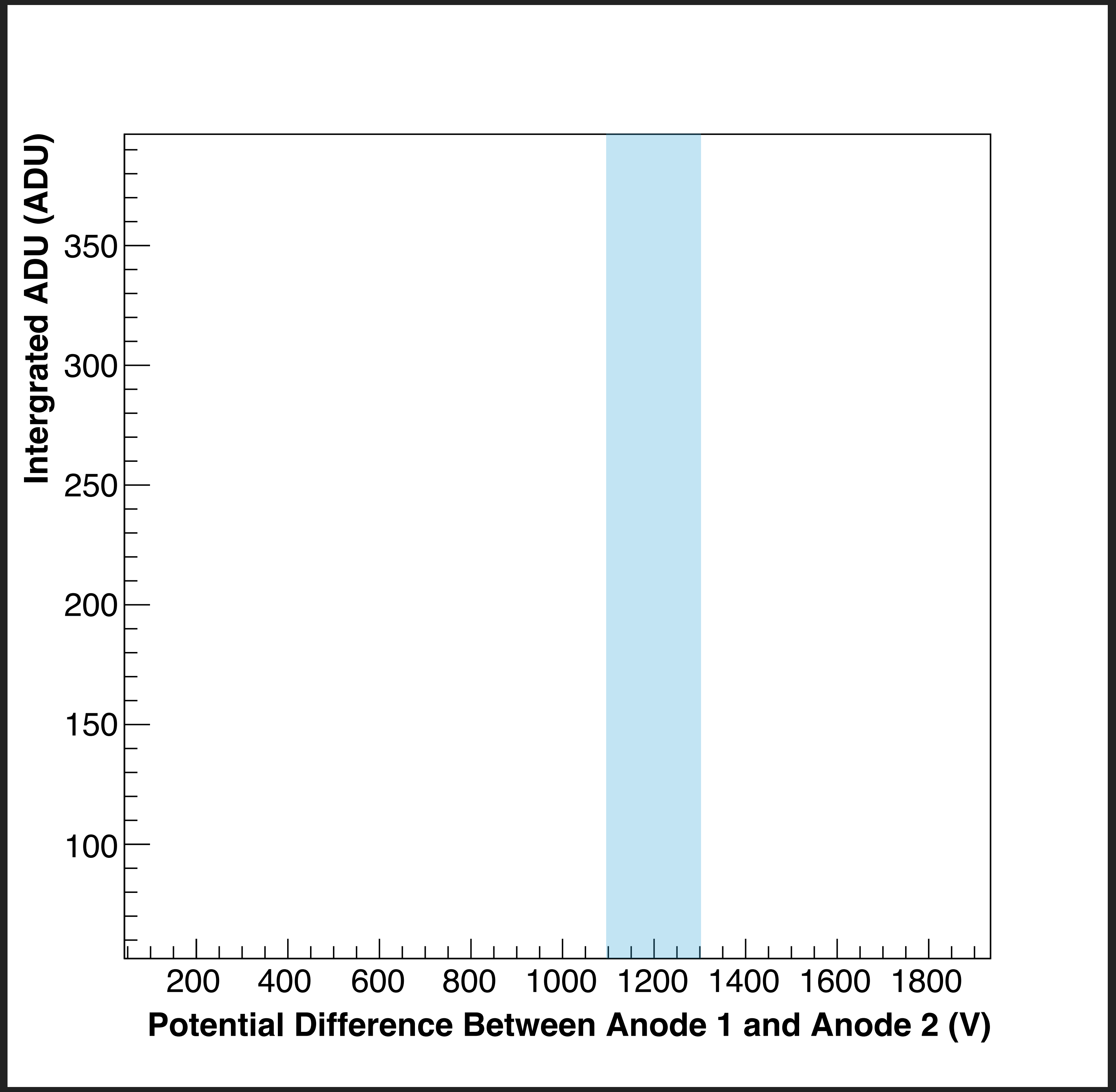
- We found the data to be consistent with no change in light gain
- Light gain likely only dependant on the potential difference between anode meshes
- The next two voltages scheme were designed to measure this dependancy



Anode 2 Voltage = Anode 1 Voltage + 1200 V
Anode 3 Voltage = Anode 1 Voltage + 2400 V

RESULTS: POTENTIAL DIFFERENCE ANODES 1 AND 2

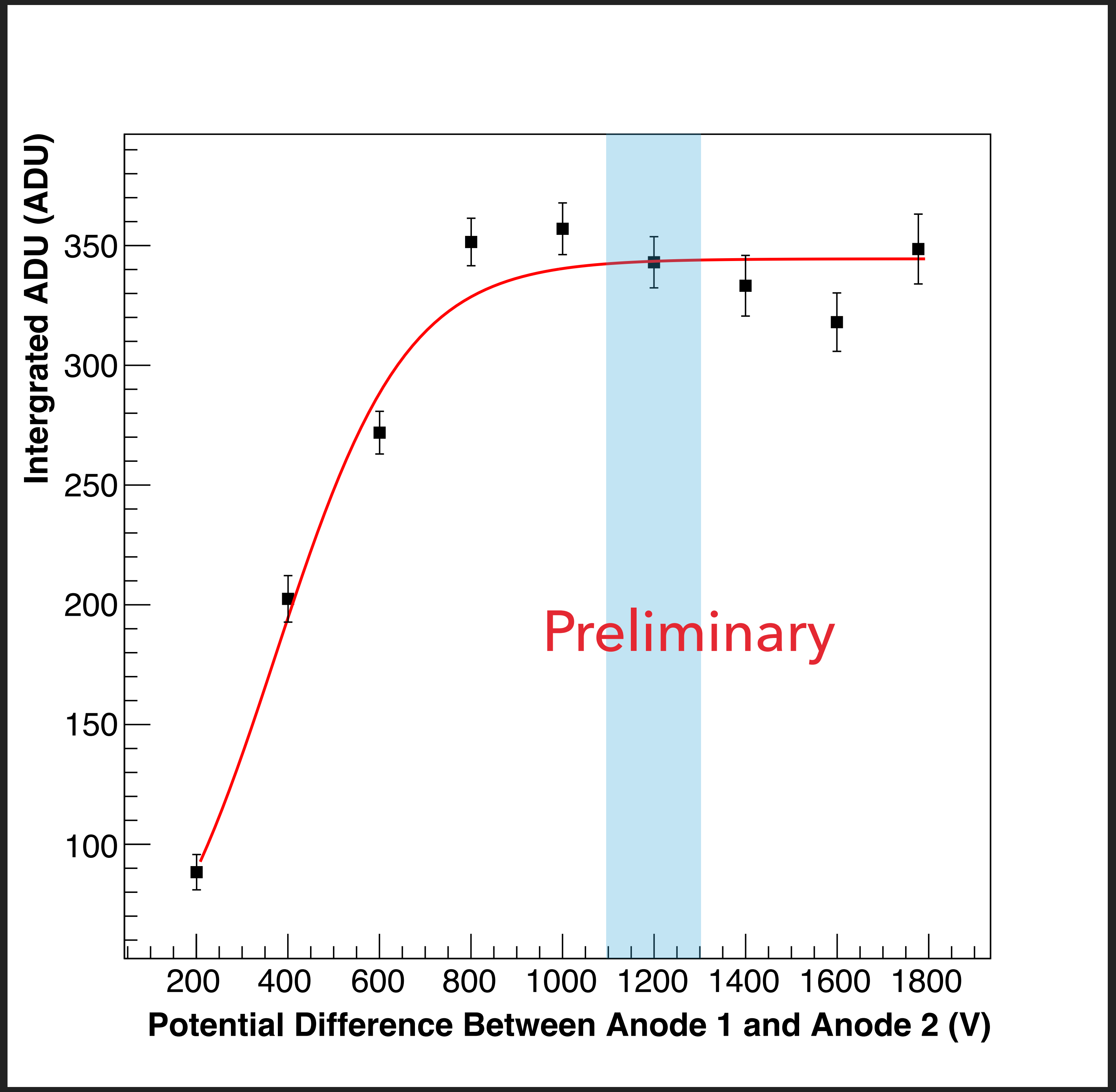
- How is the light gain affected by changing the potential difference between anodes 1 and 2 while keeping the potential difference between anodes 2 and 3 fixed?
- Starting voltages (blue): Anode 1 = 1200 V, Anode 2 = 2400 V and Anode 3 = 3600 V
- Varying the voltage of anodes 2 and 3 by the same amount for each step therefore keeping the potential difference between these anodes fixed



Potential difference between Anode 2 and 3 = 1200 V

RESULTS: POTENTIAL DIFFERENCE ANODES 1 AND 2

- The light gain seems to increase linearly with potential difference between anodes 1 and 2
- However it plateaus at somewhere between 600 V and 800 V
- This region is consistent where we would expect the electric field between anodes 1 and 2 to equal that between anodes 2 and 3



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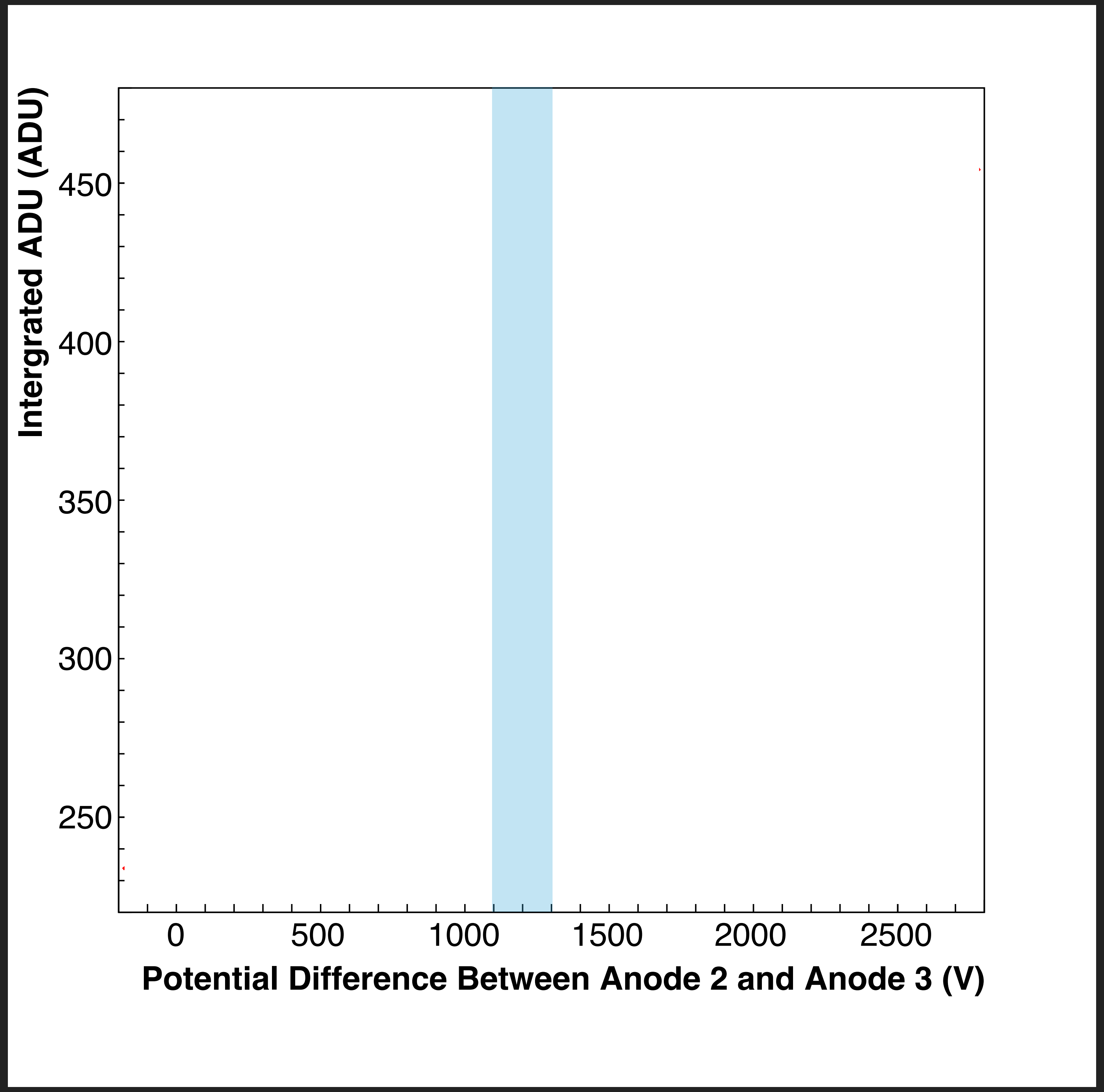
RESULTS: POTENTIAL DIFFERENCE ANODES 2 AND 3

- How is the light gain affected by changing the potential difference between anodes 2 and 3 while keeping the potential difference between anodes 1 and 2 fixed?
- Starting voltages (blue): Anode 1 = 1200 V, Anode 2 = 2400 V and Anode 3 = 3600 V
- Increasing the voltage of anode 3 only therefore keeping the potential difference between anode 1 an 2
- Here we found a linear relationship between light gain an the potential difference between anodes 2 and 3



Potential difference between Anode 1and 2 = 1200 V

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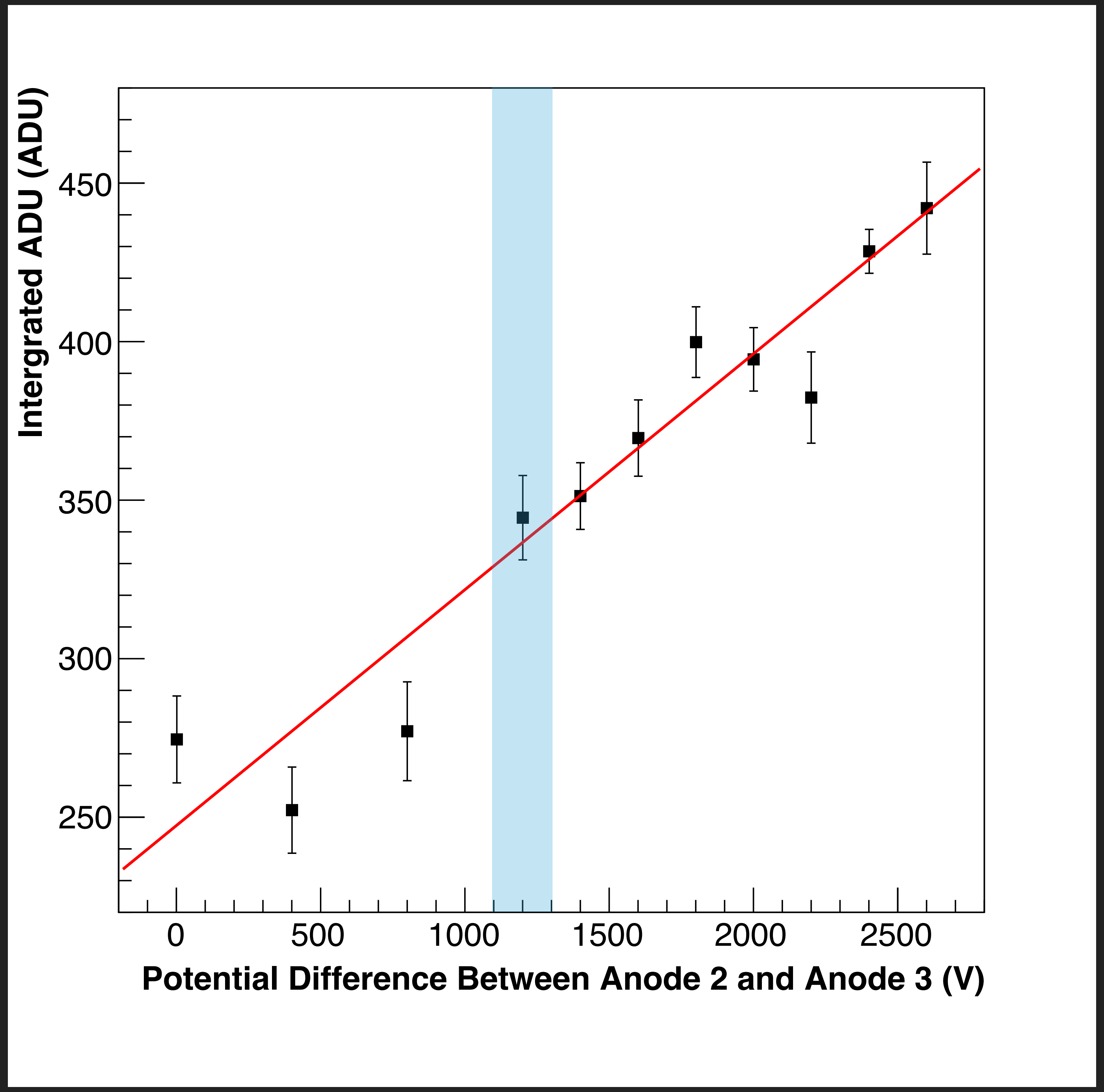
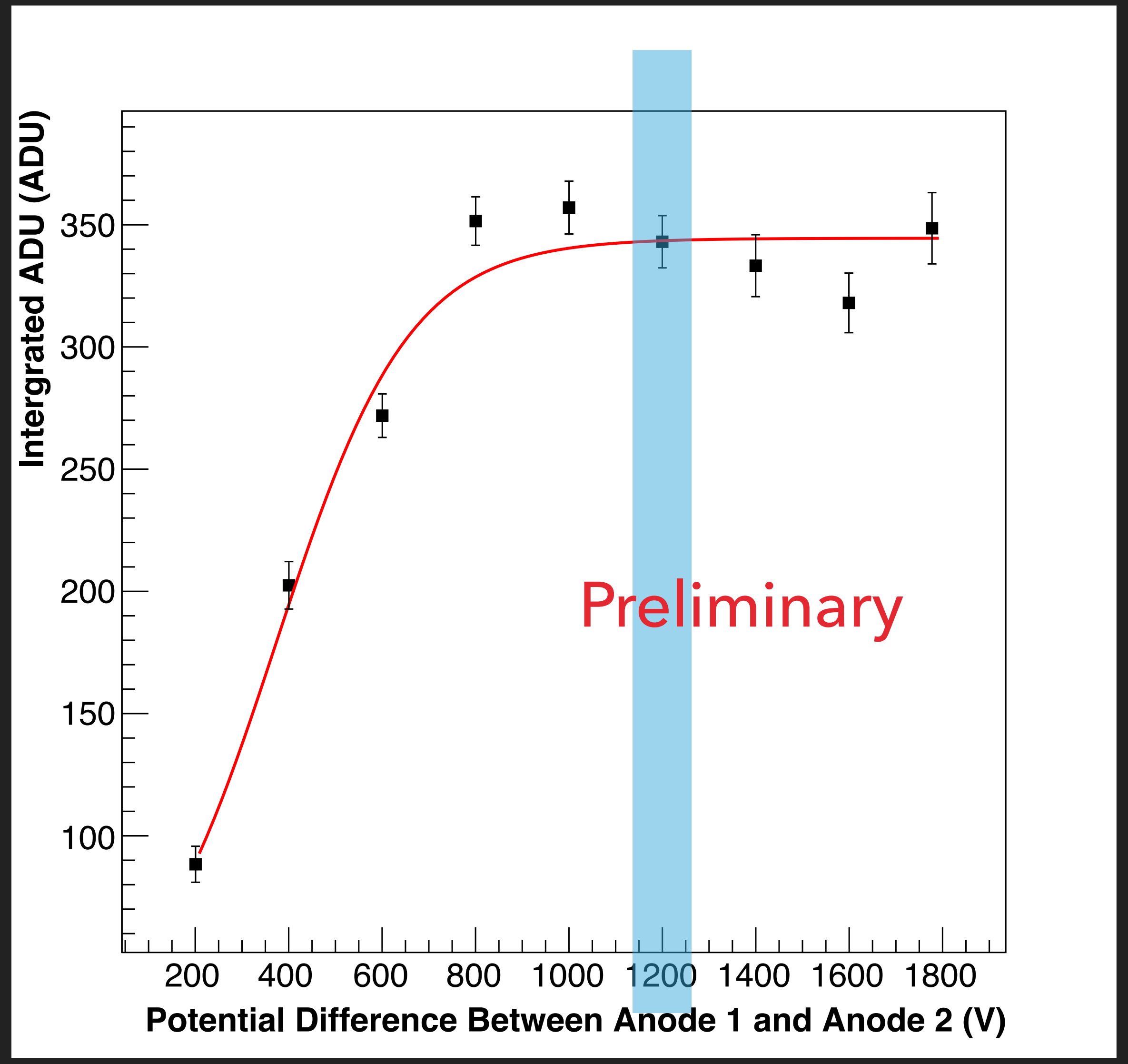


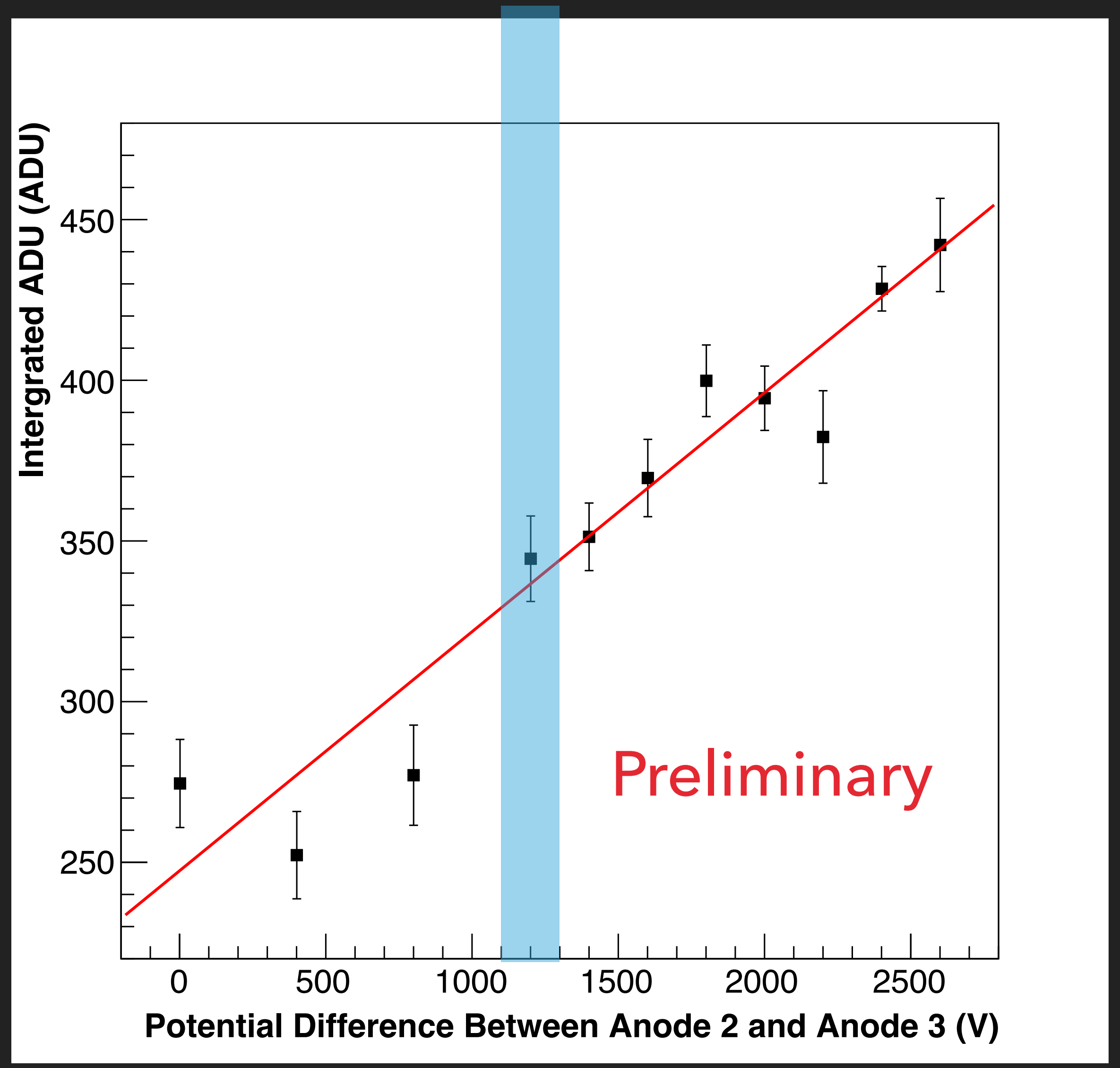
Potential difference between Anode 1and 2 = 1200 V

SUMMARY

- Successful operation of:
  - A high pressure gaseous TPC; with
  - Optical readout; and a
  - Three anode mesh amplification region
- Light measurement in visible / NIR showing linear light gain dependancy with potential differences between anodes
- Light gain dependancy vs potential difference between first two anodes plateaus where the electric field between both pairs of anodes is equal



Potential difference between Anode 3 and 2 = 1200 V



Potential difference between Anode 2 and 1 = 1200 V