# A Setup to Study the Effect of Atmospheres on Fractures as a Background in Scintillators

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# Introduction

- In 2001, the CRESST dark matter detection experiment found an unexpected background
- This was later attributed to fractures in the sapphire crystals used for detection
- In 2013 CRESST II, which used scintillators also had an unknown background.
- Therefore, we became interested in the question "Can fractures cause a background in scintillators?"

# Goals

- We have demonstrated that the fracture in scintillators can generate a background if not carefully handled [1,2]
- We will characterize the emissions of fractures in scintillators
- Will determine how atmosphere affects fracture emissions
- Understanding the mechanisms of fractures in scintillators could reduce the risk of background in rare event searches

[1] A. Tantot et. al. “Sound and Light from Fractures in Scintillators”, Phys. Rev. Let., vol 111, October 2013
[2] A. Tantot et. al. “A multi-channel setup to study fractures in scintillators”, *Meas. Sci. Technol., vol 27, October 2016*

# Apparatus

- 20x5x3mm BGO ($Bi_4Ge_3O_{12}$) crystal with crystal lattice oriented with edges
- Force is applied on the 5x3mm faces

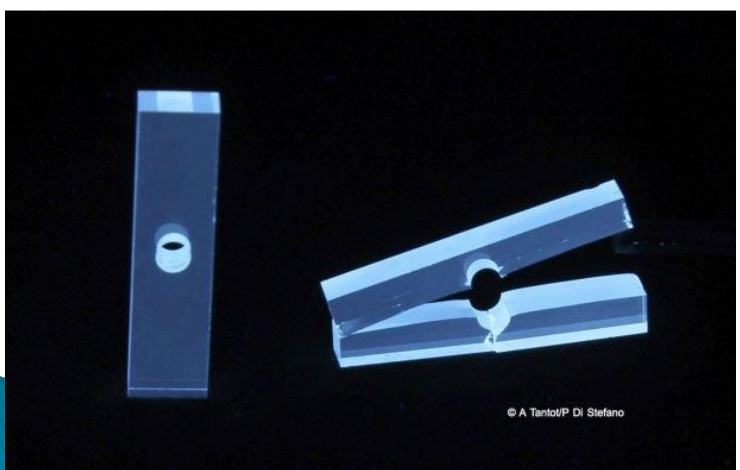



Figure 1: BGO crystal in DCDC geometry before and after fracture

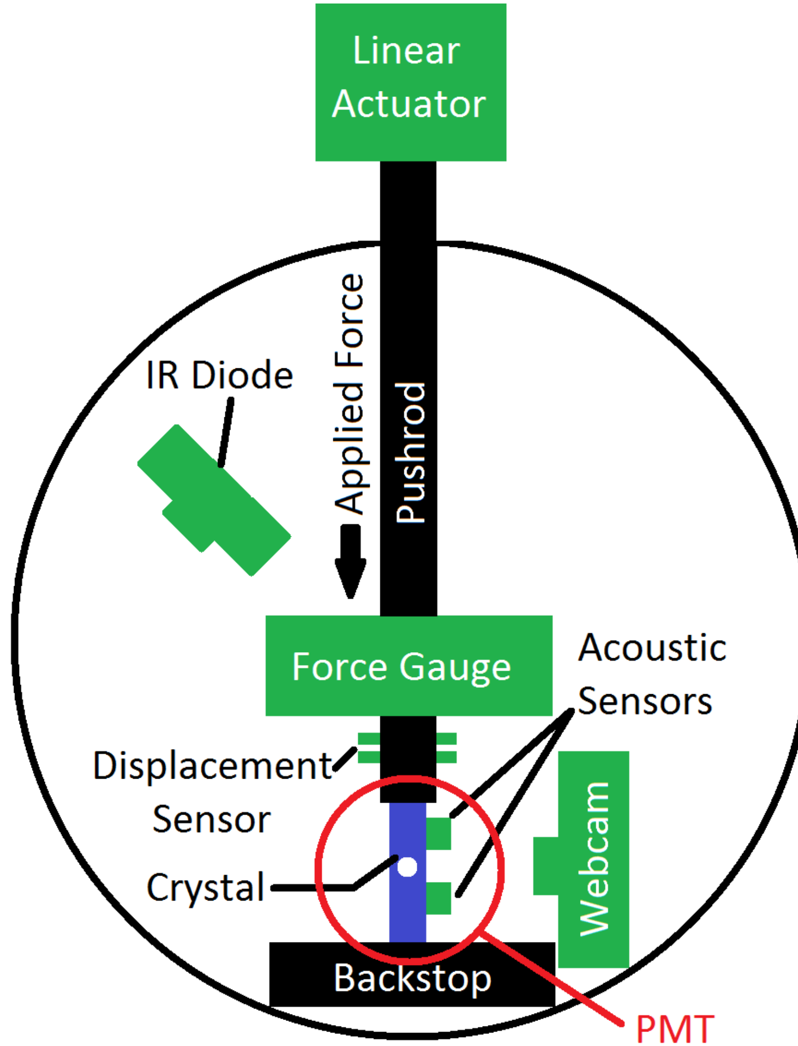



Figure 2: Diagram of the apparatus used. Green denotes measurement device, Blue represents the crystal and red represents the shadow of the PMT which is positioned above the chamber facing the crystal through a IR filter

# Apparatus

- Crystal held in place with the linear actuator
- Apparatus uses:
  - Force Gauge
  - Displacement sensor
  - Acoustic Sensors
  - Webcam (with IR diode for backlight)
  - PMT
- Webcam can measure the crack length and provide real time images of the evolution

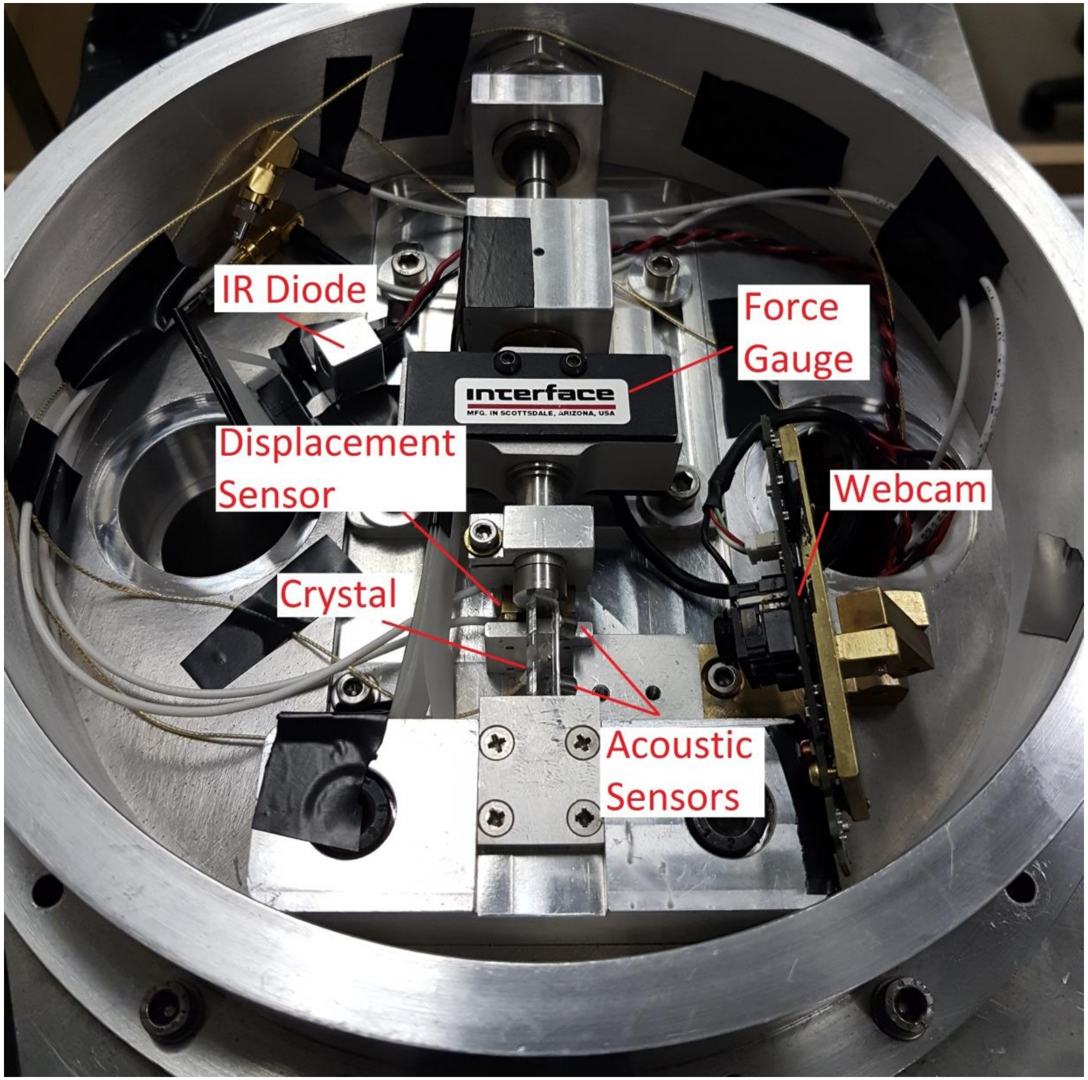



Figure 2: Internal apparatus for examining fractures in BGO crystals

# Apparatus

- Sample in vacuum chamber with port for PMT
- IR filters in PMT port reduce noise from IR LED
- Linear actuator controls force on sample

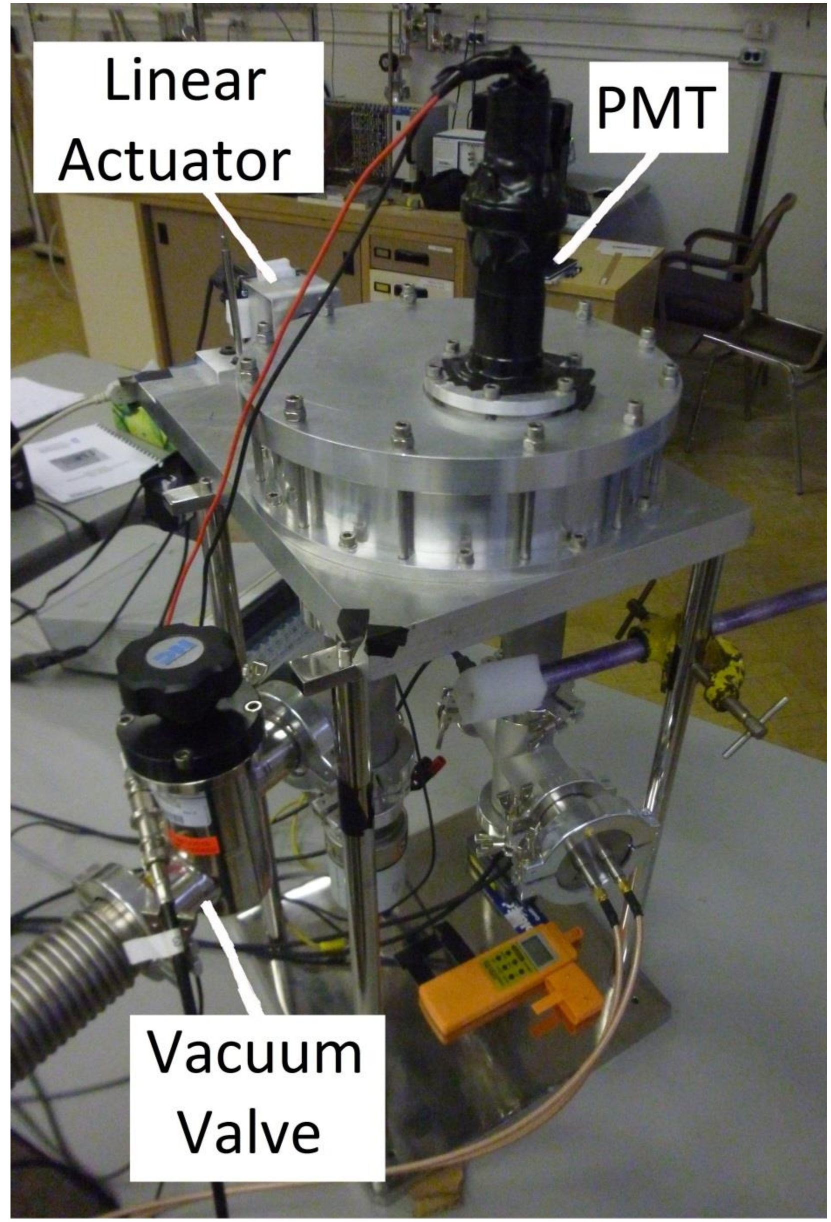


Figure 3: Exterior view of fracture apparatus

# Crack Length Measurements

- Webcam films at 15fps
- By comparing each frame to the first frame, the length of the crack is determined
- Provides 0.02mm resolution of crack length on both sides

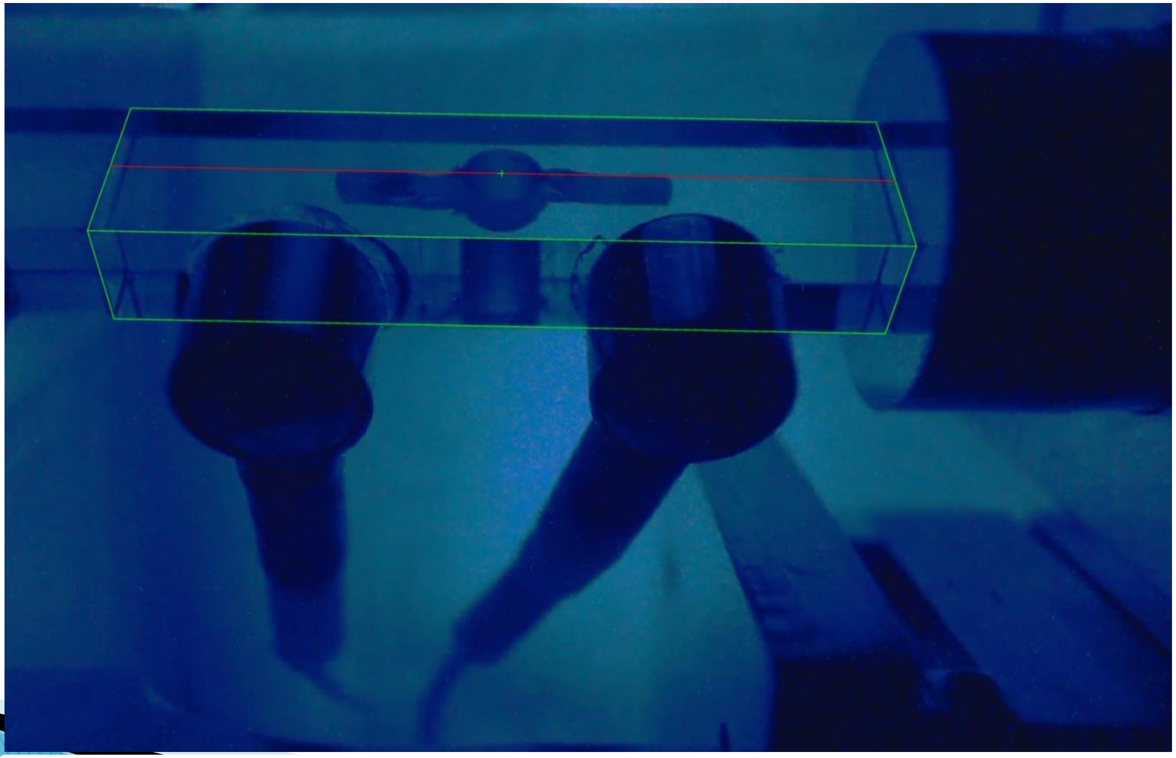


Figure 4: Webcam image of crystal demonstrating how crack length measurements are made

# Acoustic Event Measurement

- Acoustic sensors are placed on the crystal near each crack
- Signal dominated by noise from linear actuator
- Software filter can extract the high frequency signal from the raw data

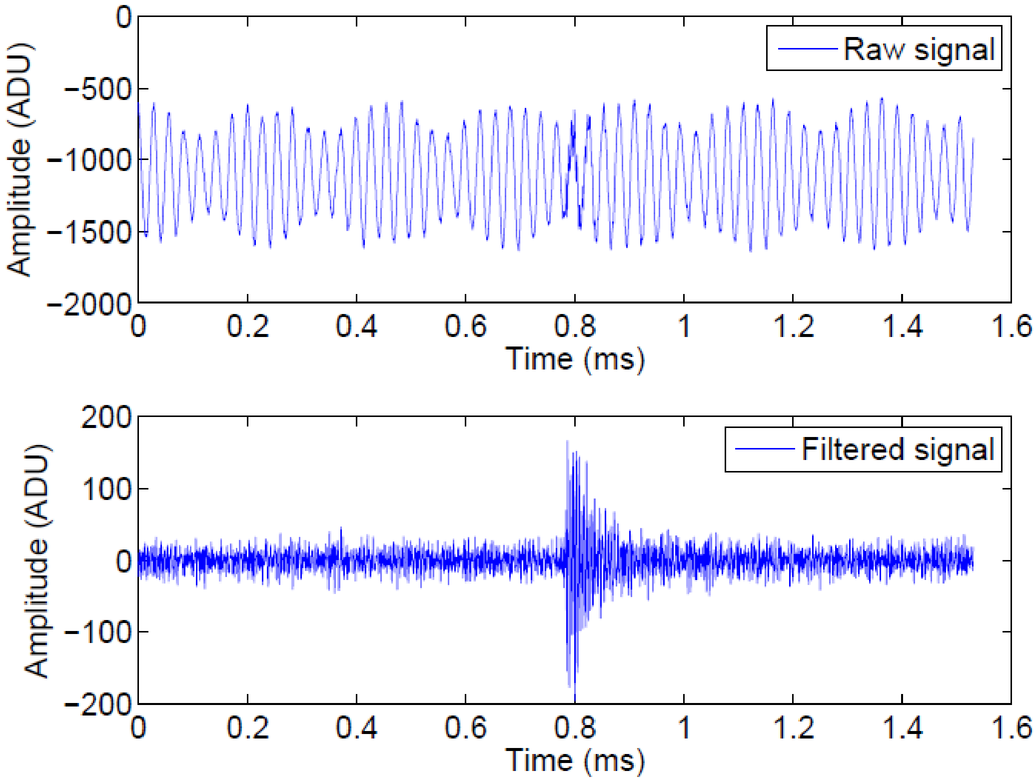



Figure 5: (Top) Raw data measured by the acoustic sensors. (Bottom) Digitally filtered signal

# Light Event Measurement

- Ndigo5G samples PMT at 5GHz
- When the light signal exceeds the threshold, a packet past the trigger is saved with a short period before
- If the voltage is still above the threshold, another packet is saved with the previous packet
- This continues until the voltage falls below the threshold

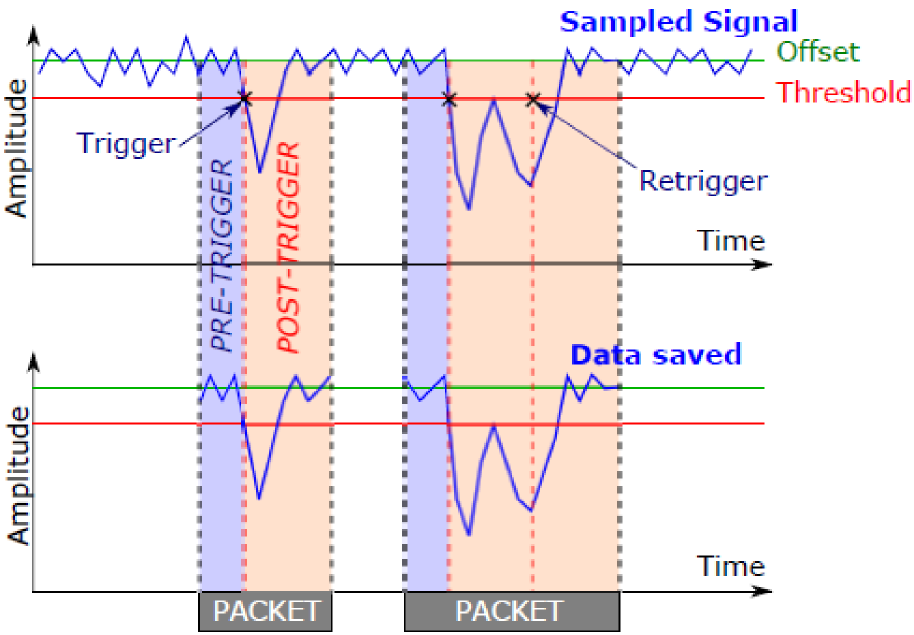



Figure 6: Demonstration of how light events are processed by the DAQ

# Determining Scintillation Events

- Size of packet determined by hardware limitations, not scintillation physics
- If the time between two packets is less than twice the lifetime of scintillation events for BGO ($2\tau = 600ns$), it is considered a single event
- The scintillation event lifetime (300ns) is a known property of BGO

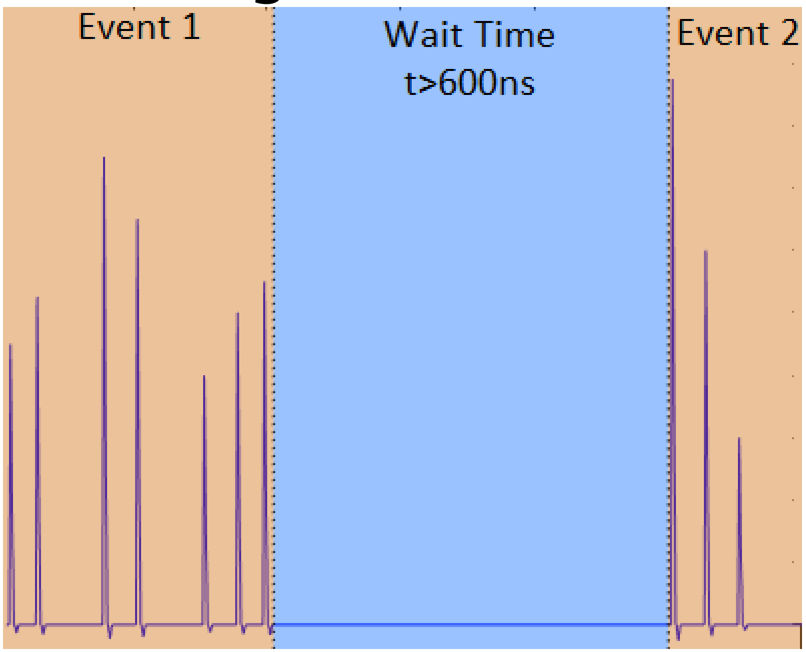



Figure 7: Example scintillation event after processing. Each spike is a separate packet

# Ambient Experiment (Prelim.)

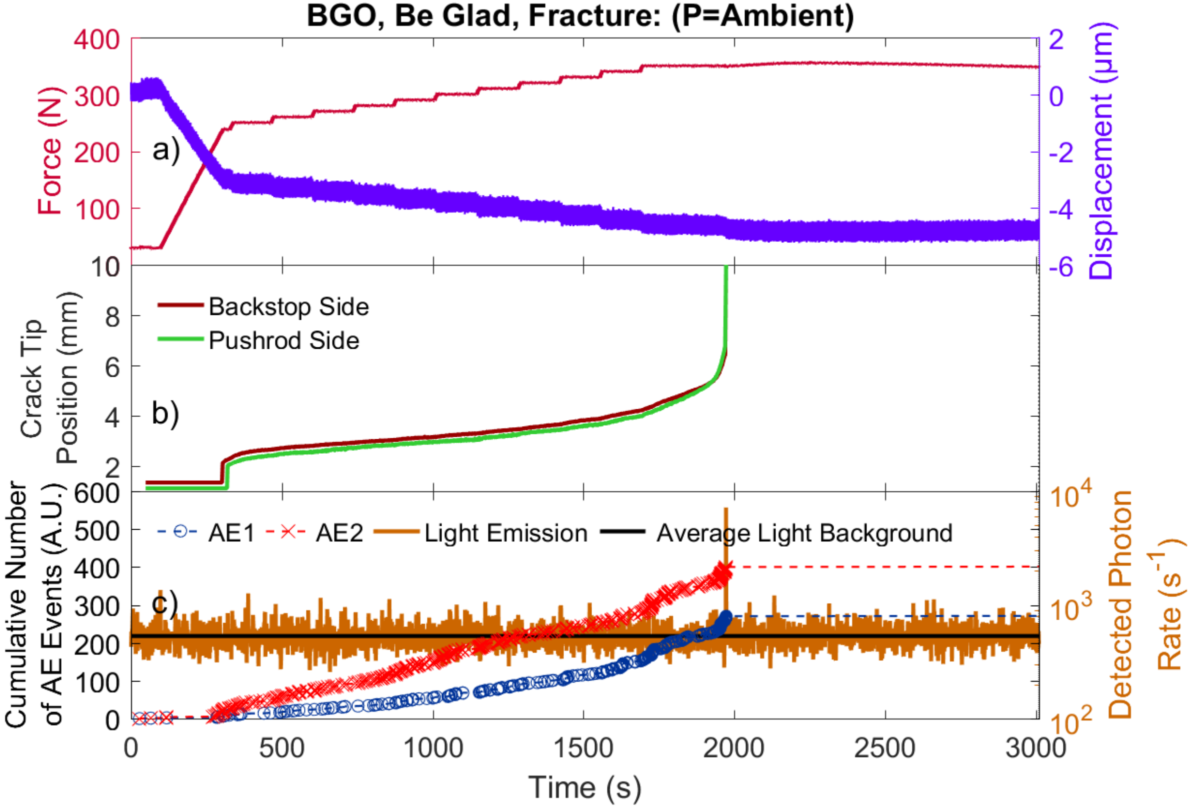



Figure 8: Results from an example ambient pressure experiment including crack length, force, acoustic and light events. Blue region represents time with diode off for calibrations

- Fast fracture at 340N
- Light output primarily due to fast fracture
- No visible peaks in light events during slow fracture

# Vacuum Experiment (Prelim.)

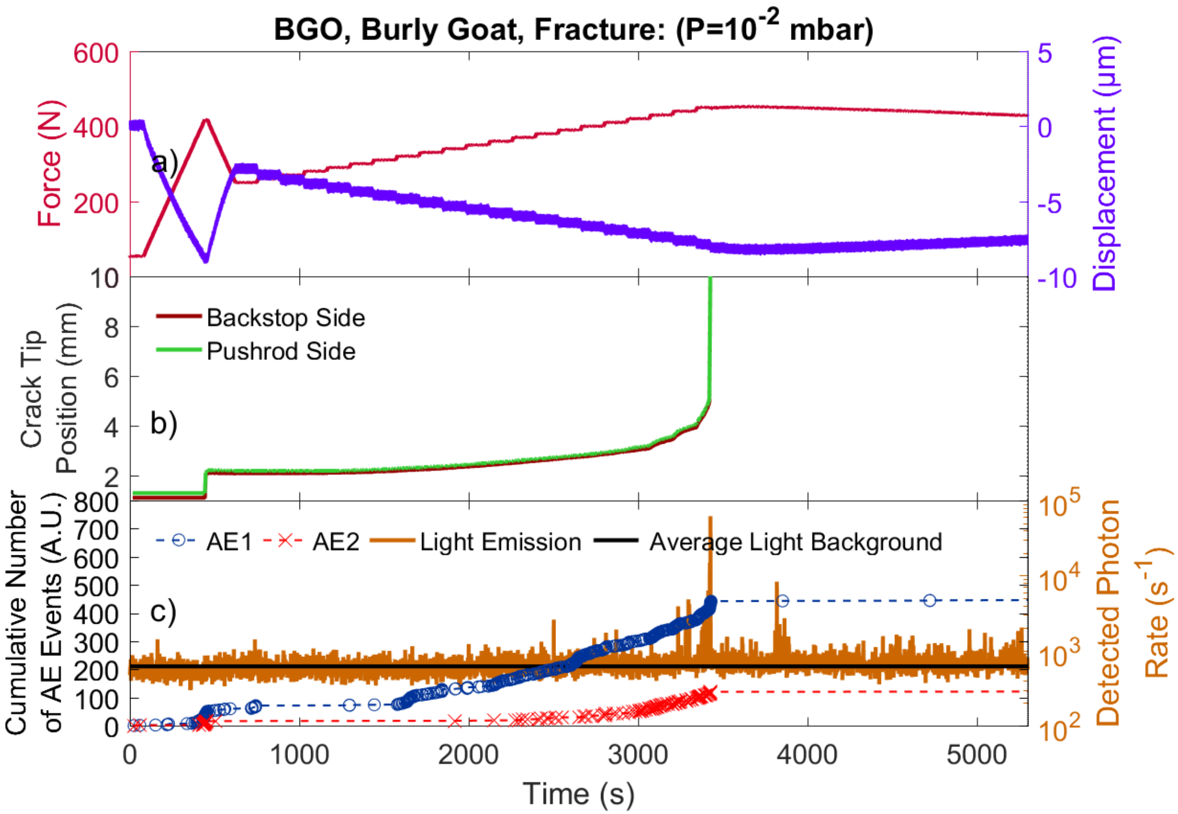



Figure 9: Results from an example ambient pressure experiment including crack length, force, acoustic and light events. Blue region represents time with diode off for calibrations.

- Fast fracture at 450N
- There is an indication of light emission before and after main fracture

# Effect of Atmosphere (Prelim.)

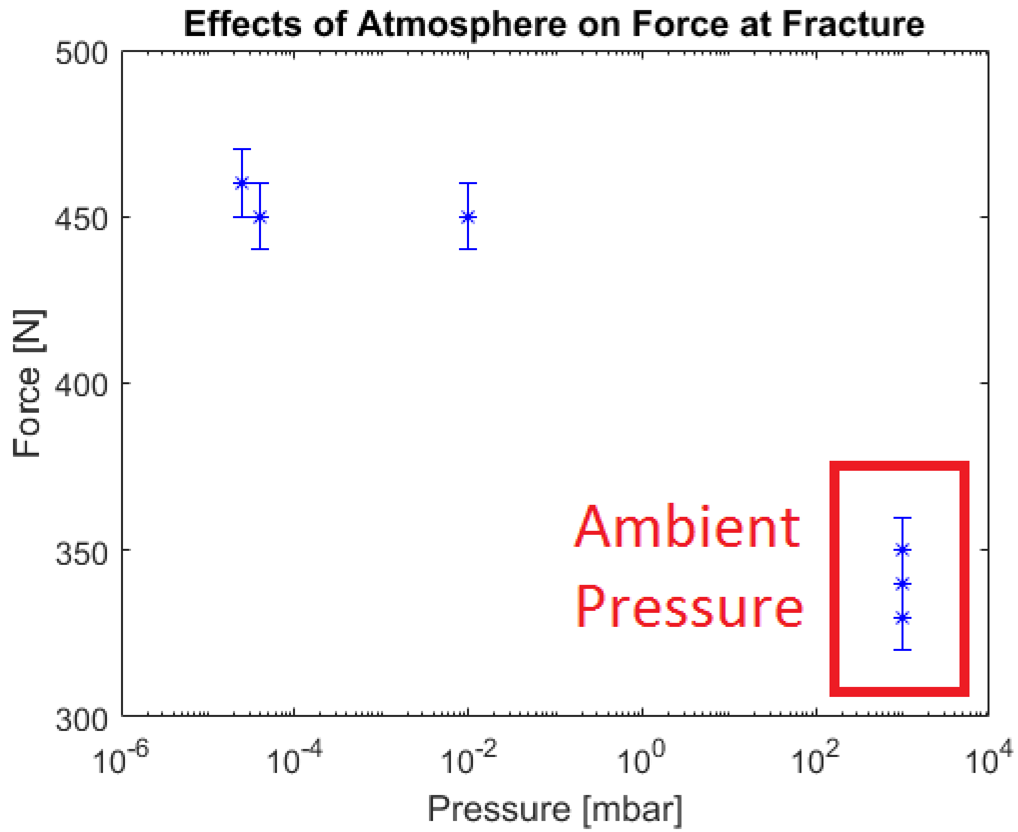



Figure 10: Force required to fracture the crystal at varying atmospheric pressures

- Force required to fracture crystal increases in vacuum
- Analysis of how light is generated based on atmosphere is ongoing
- Future measurements will analyse the effect of humidity in atmosphere

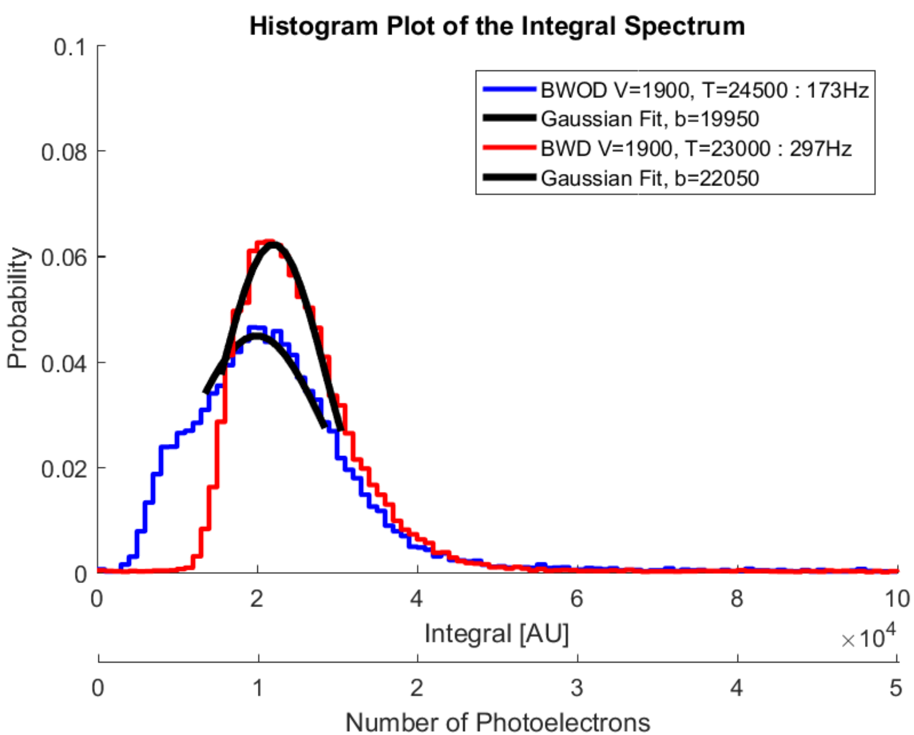
# Conclusion

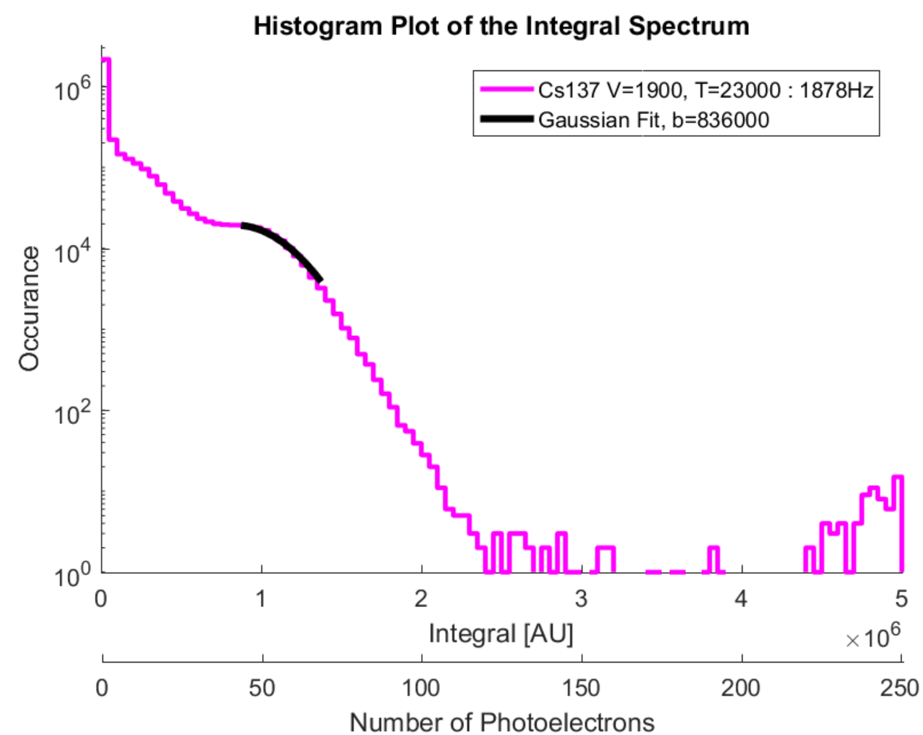
- We have commissioned an experiment to measure the sound and light released from the fracture of scintillators
- Fractures at vacuum pressure have shown an increase in force required to fracture
- Analysis and further measurements are underway to better understand the link between atmosphere and fracture emissions
- Future experiments will examine the effects of a nitrogen atmosphere
- It is important to handle scintillators carefully to avoid the background from fractoluminescence
- Long term goal to examine the effect of temperature

# Additional Slides

# Calibrations

- Measure background to determine average single photoelectron integral
- Measure integral of $^{137}$Cs Peak and compare with single photoelectron and light yield of BGO to determine the efficiency of the PMT



# Crack Length Measurements