Status update on laser particulate counter

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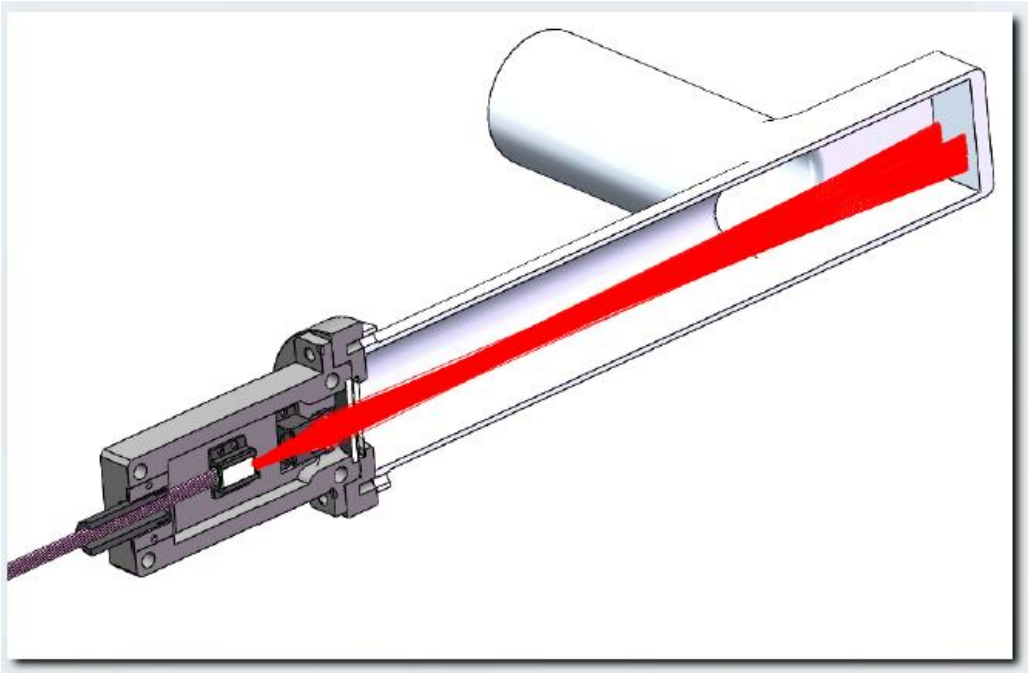
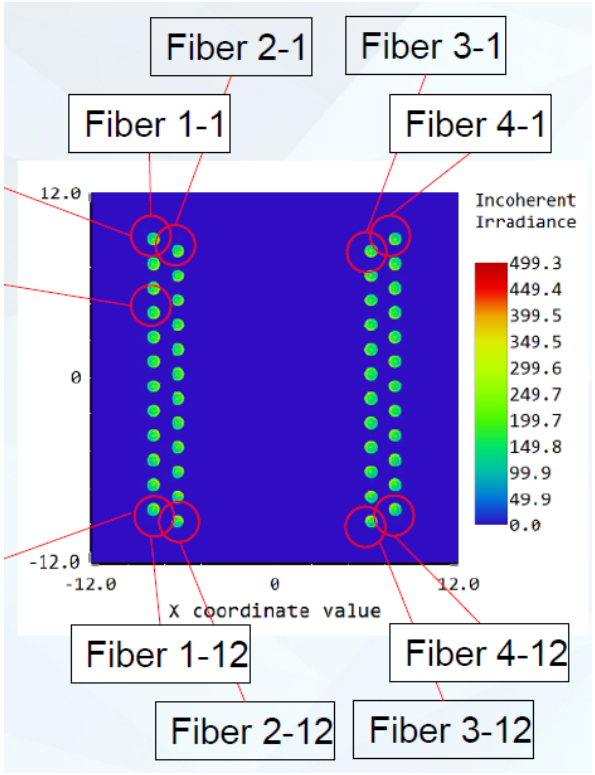
Monday, March 21, 2022

System concept

- Laser arrays for particle detection – error signal in reflected beam may indicate particle passage
- Goals: detect particulates ~ few um in size at ~ 1 m/s speed
- Particle detection area ~ 420 mm^2 across beam pipe diameter





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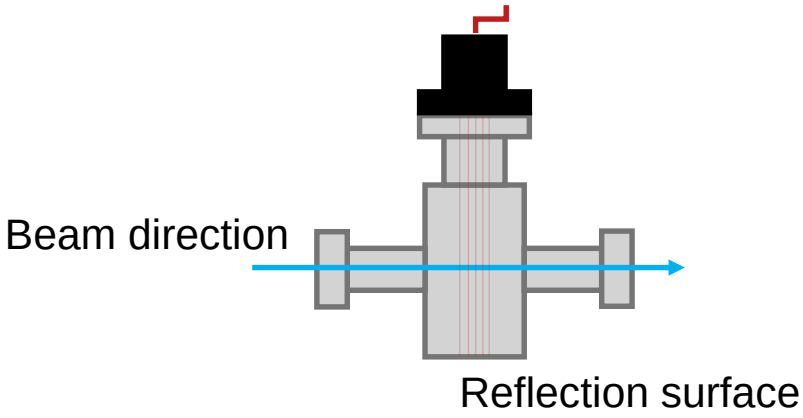
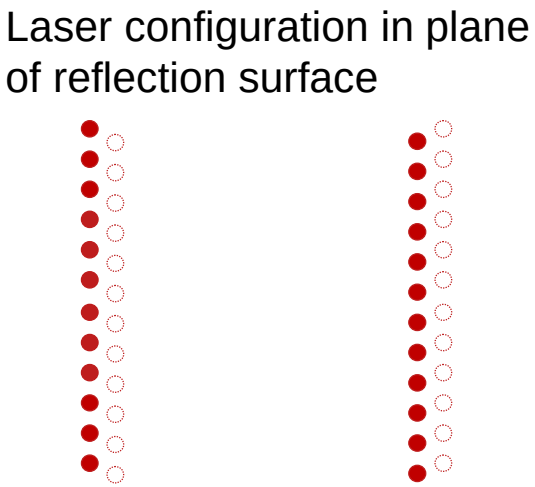
Timeline of activities

- 05/26-05/27/2021: First vendor on-site visit
  - Preliminary testing of 6-channel prototype
  - Simultaneous data recording of 2 channels
- 06/10-06/11/2021: Second vendor on-site visit
  - Simultaneous data recording of 6 channels
- 07/2021: Additional 18 channels delivered to JLab for complete 24 channel system
  - Newer sensor boards with improved SNR compared to initial 6 channels
- 08/2021: Pass/fail testing of the first 24 channel system
  - 6 initial channels failed this round of tests and were replaced by the vendor
- 11-12/2021: Second 24 channel system delivered to JLab; total 48 channels
  - New mounting system for POF designed and installed
- 01/2022: Survivability test of 8 channel POF and optical fiber in CEBAF tunnel
  - Cleared by RADCON and sent back to OSP for testing
- 02/2022-now: Testing of the 48 channel system
  - Data processing algorithm development, particle detectability studies

24-channel bench tests

- Detector mounted on viewport on spare pump drop

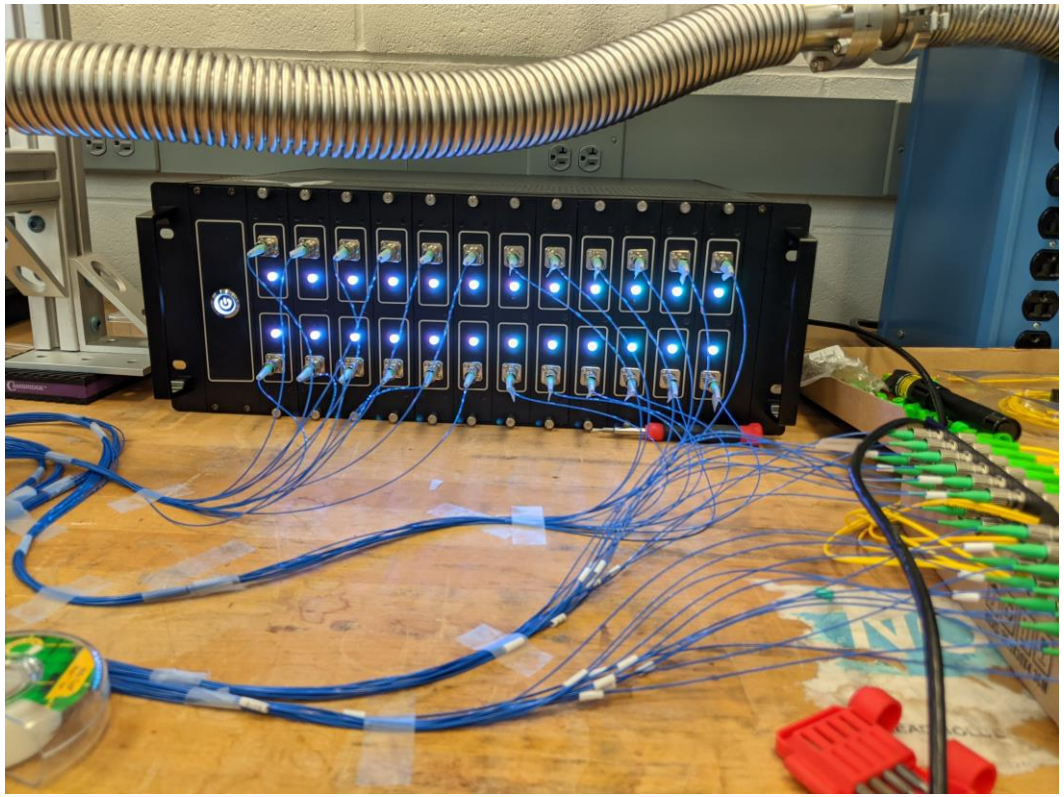




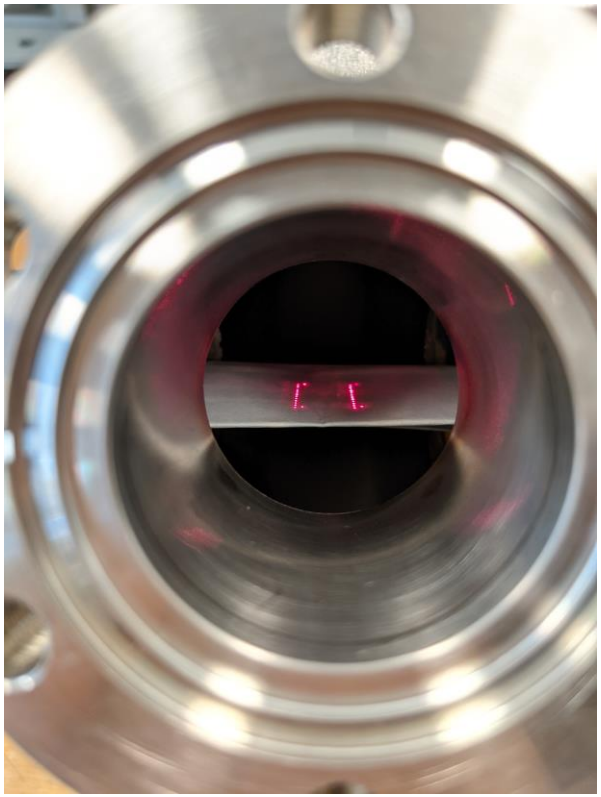
- Initial pass/fail testing: sweeping of 80 μm diameter wire across all channels (twice, back and forth) at approximately 1 Hz rep rate
  - Three datasets with approximately 34-36 wire sweeping events per dataset
  - Goal of capturing > 90% of wire sweeping events
  - False positive and false negative rates < 10%

24-channel bench tests

- On the bench in TL-1011



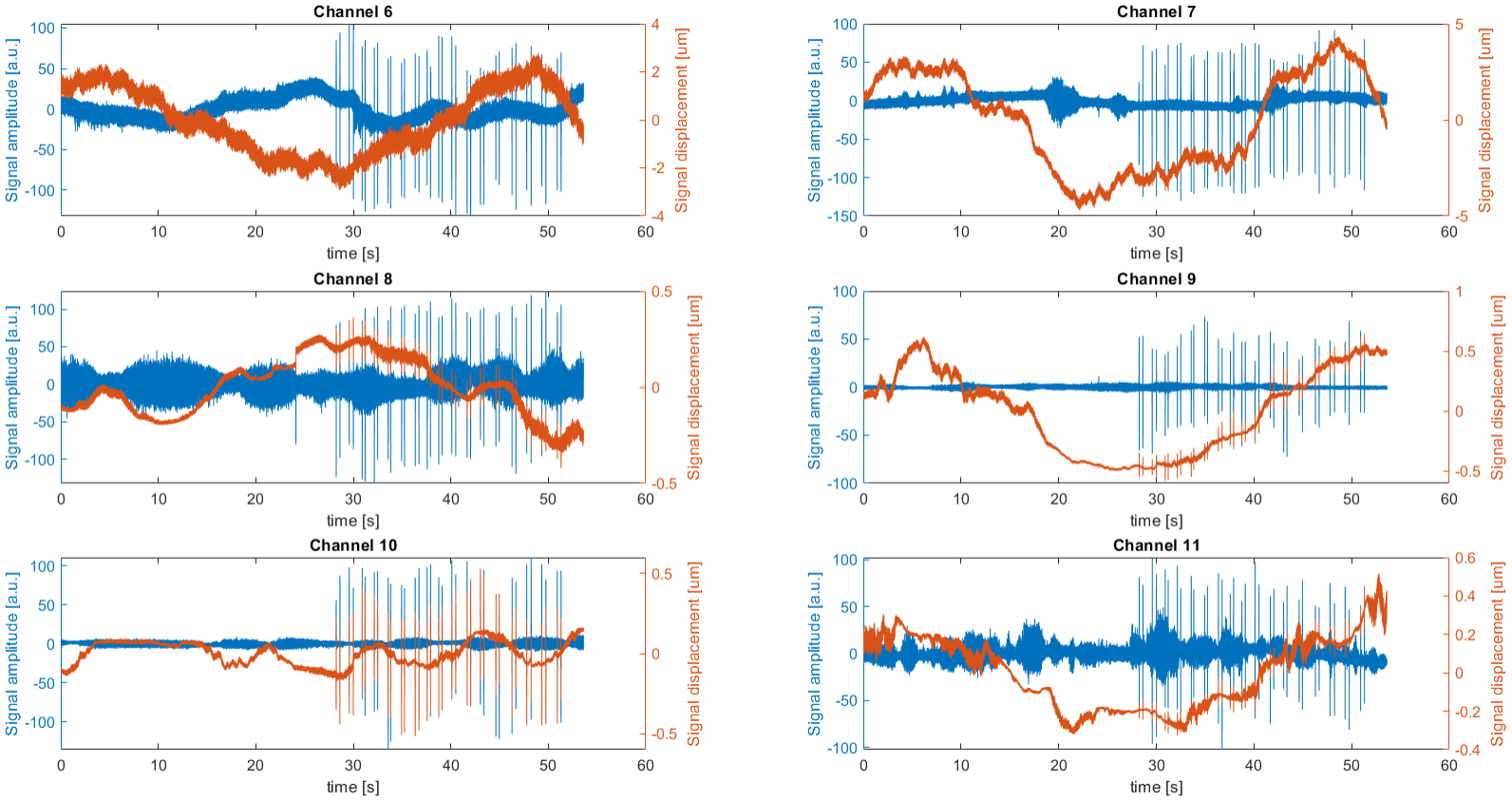
Chassis fully populated with 24 channels



Two 12 channel arrays
connected to visible light source

24-channel bench tests – pass/fail testing

- 20210820_015815 “raw” data (polynomial detrending)



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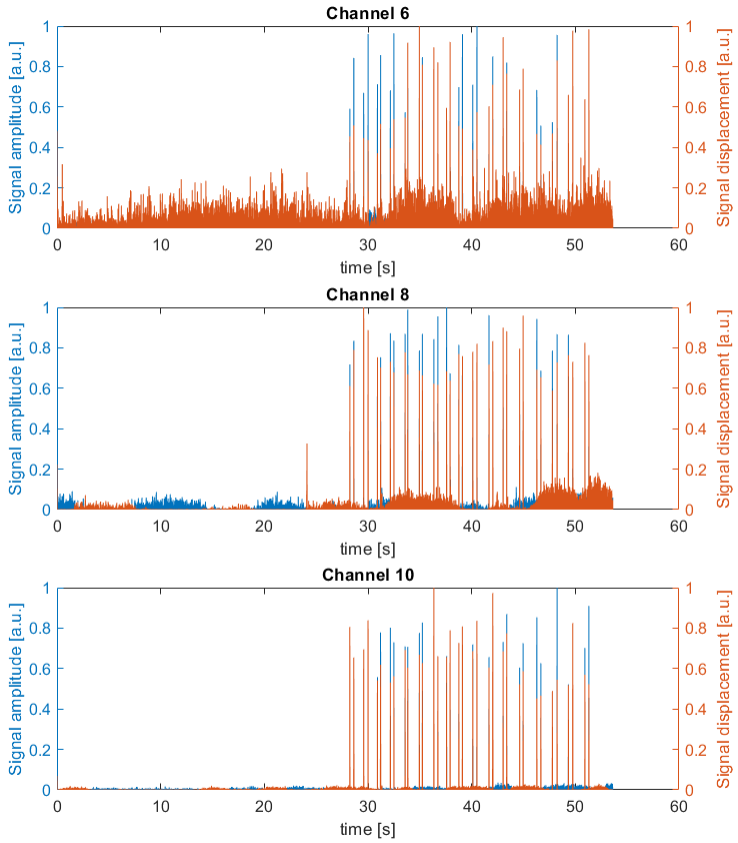
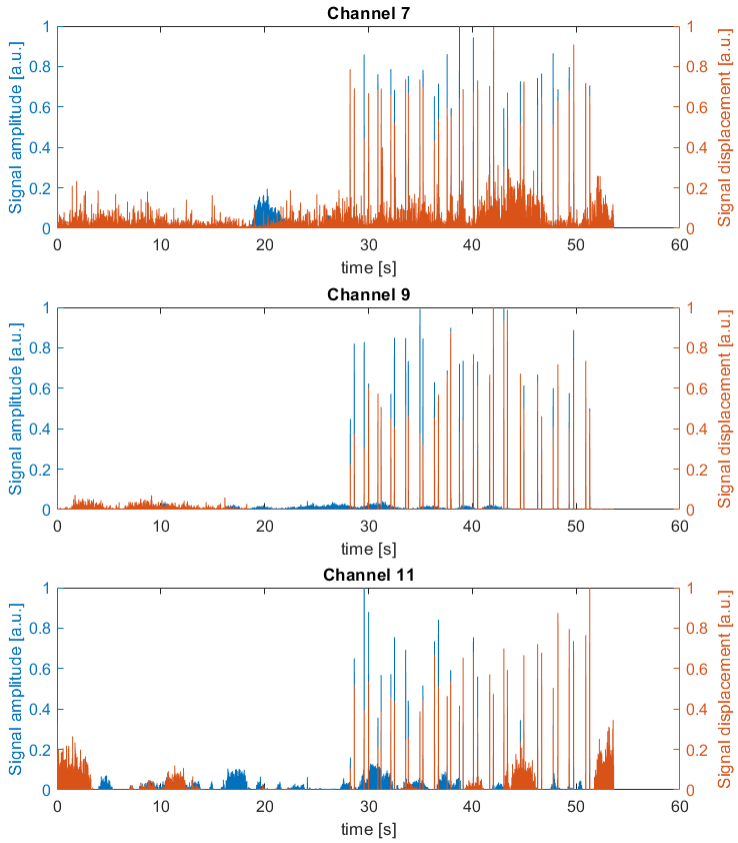
Data processing algorithm

- Raw data stored in binary format – extractable to MATLAB
- Current algorithm in MATLAB uses open source functions more commonly used in noise cancellation applications
- Noise floor calculated in first few seconds of dataset where no events are occurring by design
  - Each dataset begins with a window of time where wire is not swept
- Local peak-to-peak calculation used to improve SNR in wire sweeping datasets
- Data processing algorithm will evolve as the testing evolves, based on what signals we expect to see
  - Exploring dynamic threshold algorithm

24-channel bench tests – pass/fail testing

- 20210820_015815 postprocessed data, version 1





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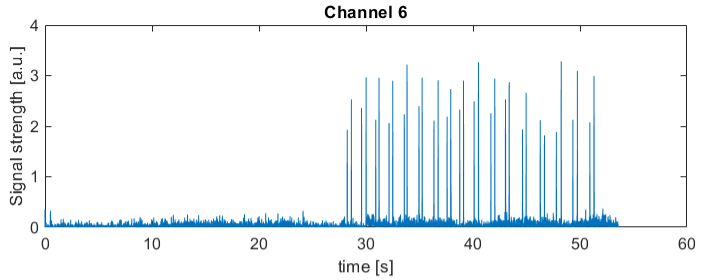
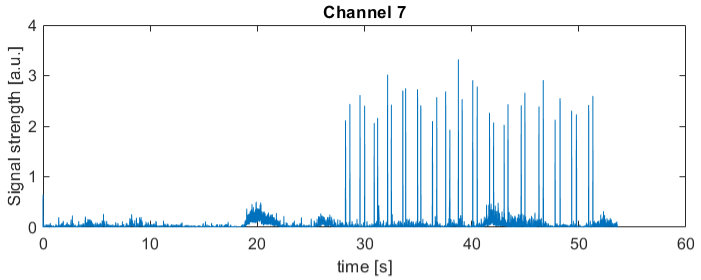
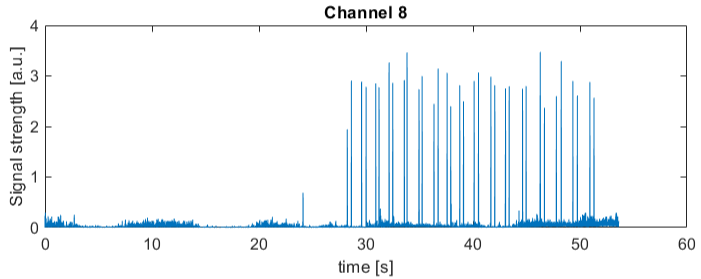
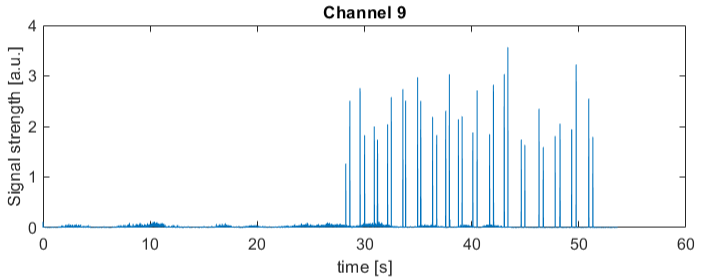
24-channel bench tests – pass/fail testing

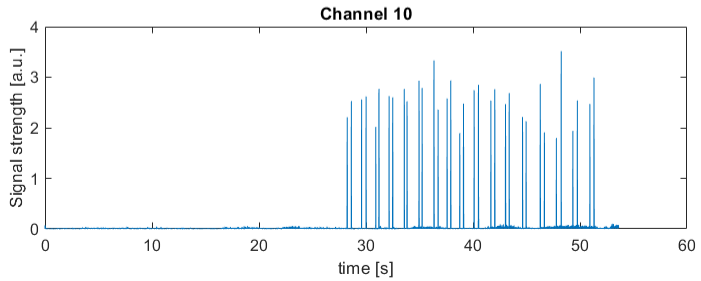
- 20210820_015815 postprocessed data, version 2 (peak-to-peak)

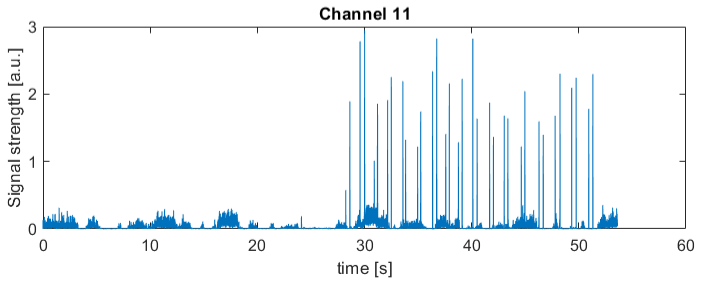






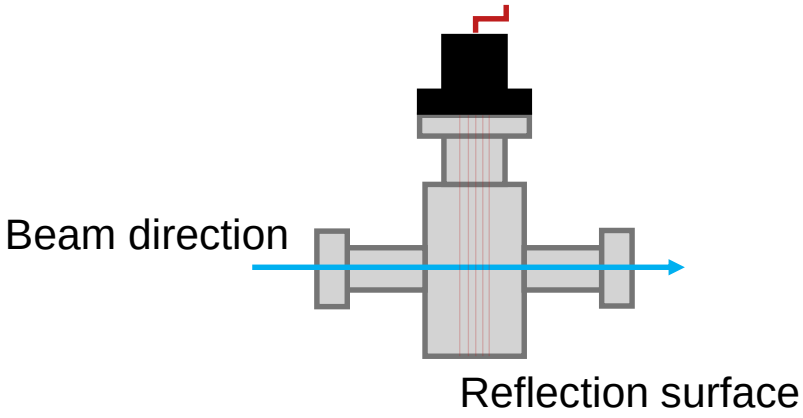




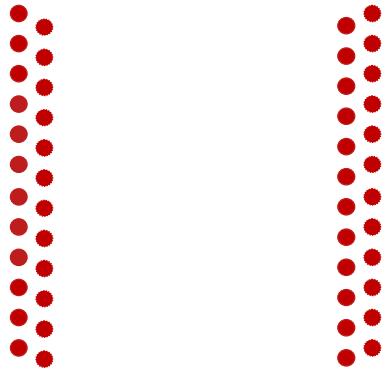


48-channel bench tests

- A second 24-channel system provides 48 total channels for better coverage of the detector active area across the beampipe
  - ~1 mm spacing between beam centroids in each array

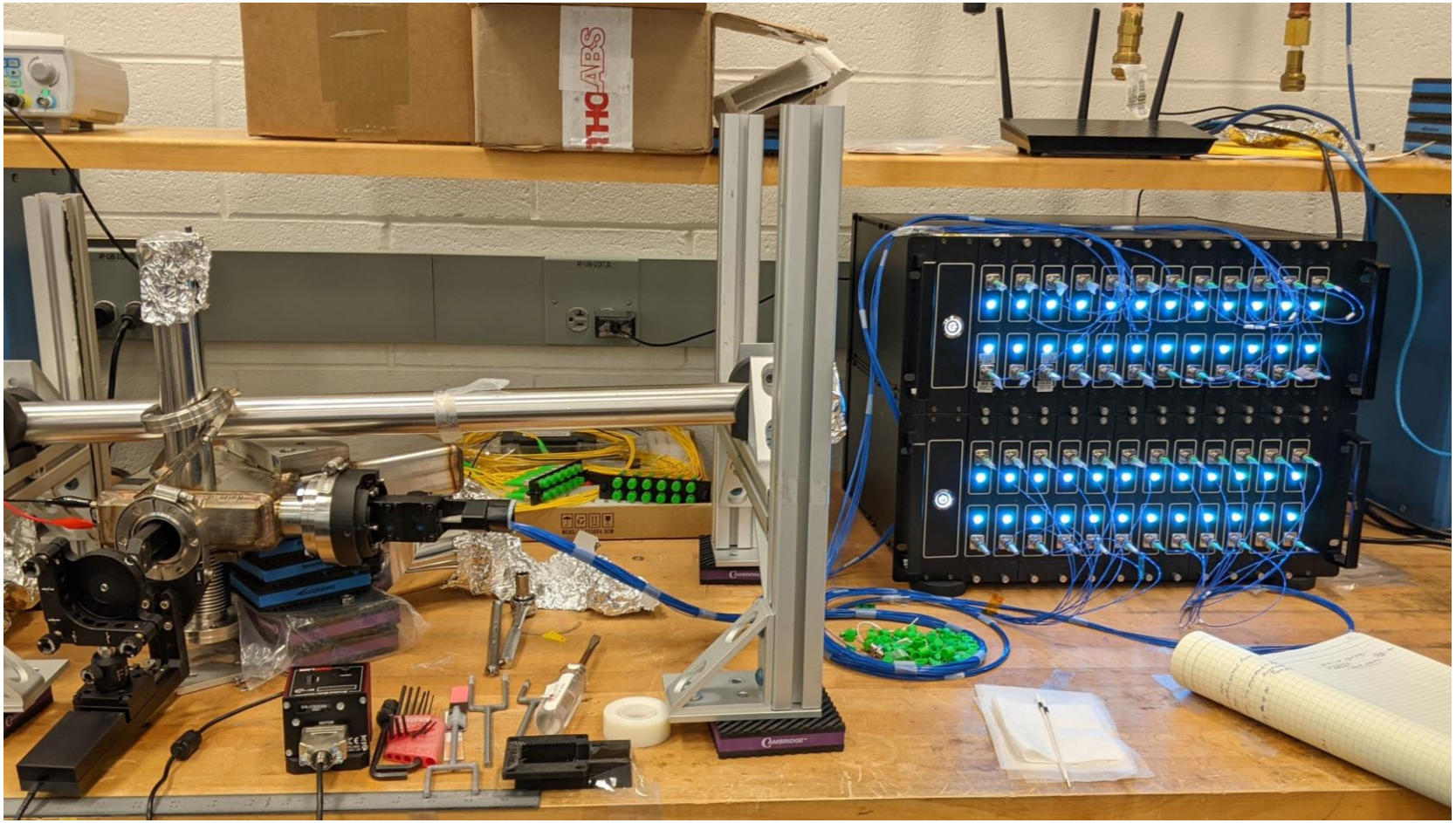


Laser configuration in plane of reflection surface



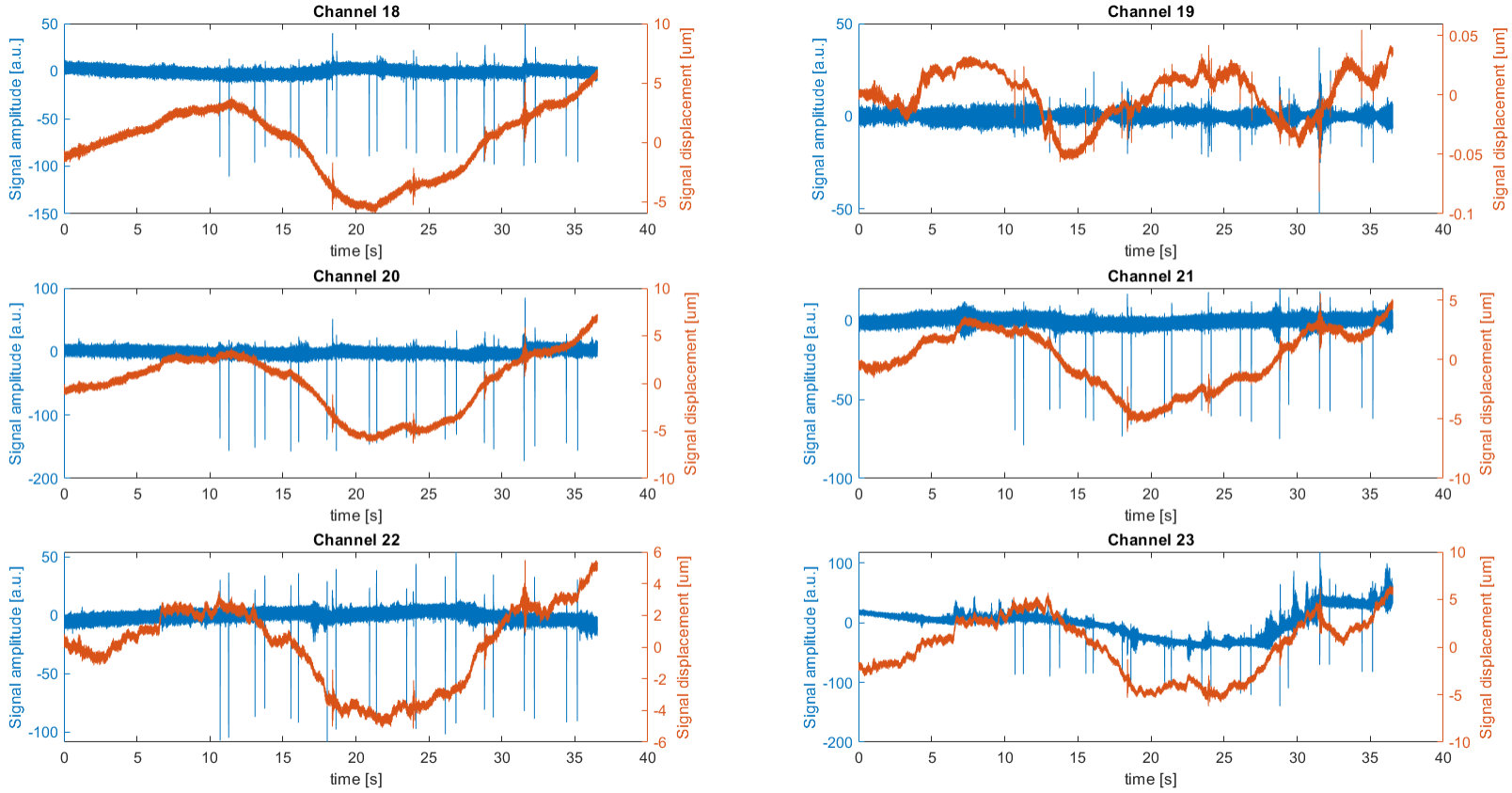
48-channel bench tests

- Delivered 12/2021 - on the bench in TL-1011



48-channel bench tests

- 20220207_142543 “raw” data for ~1 Hz sweep of 80 μm wire



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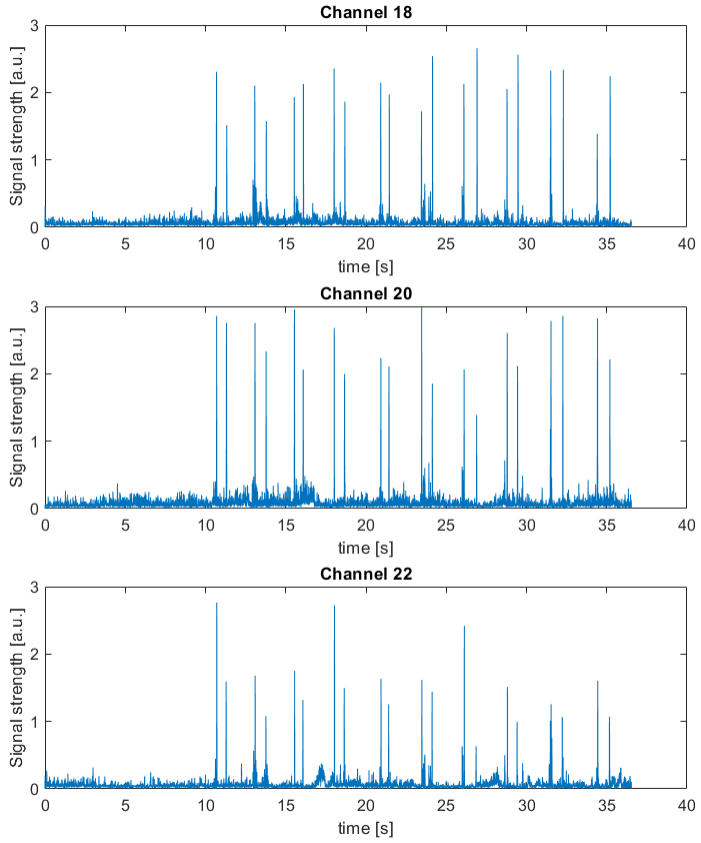
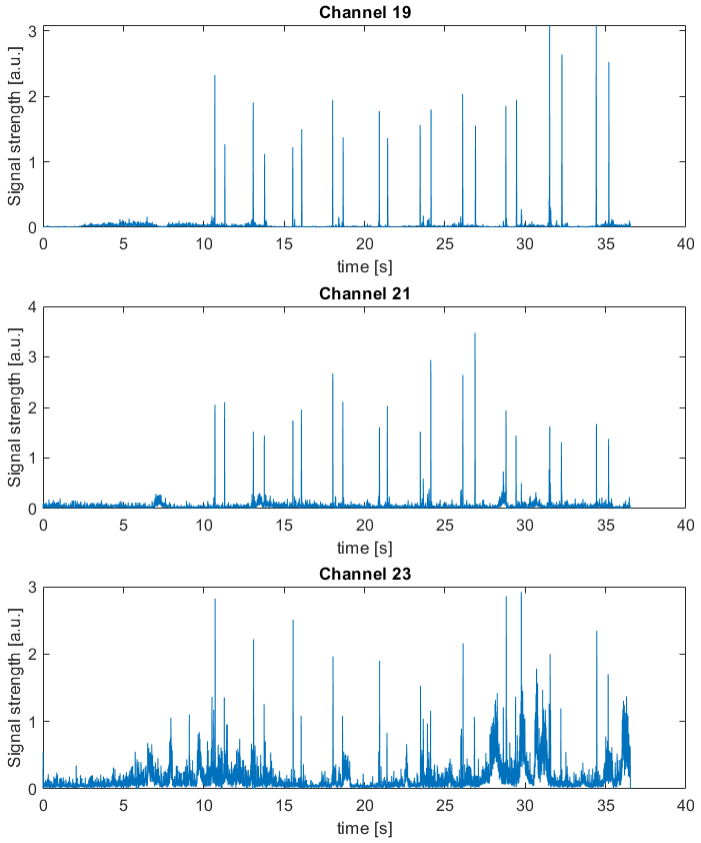
48-channel bench tests

- 20220207_132058 postprocessed data, version 2 (peak-to-peak)
  - Not quite optimized sensors





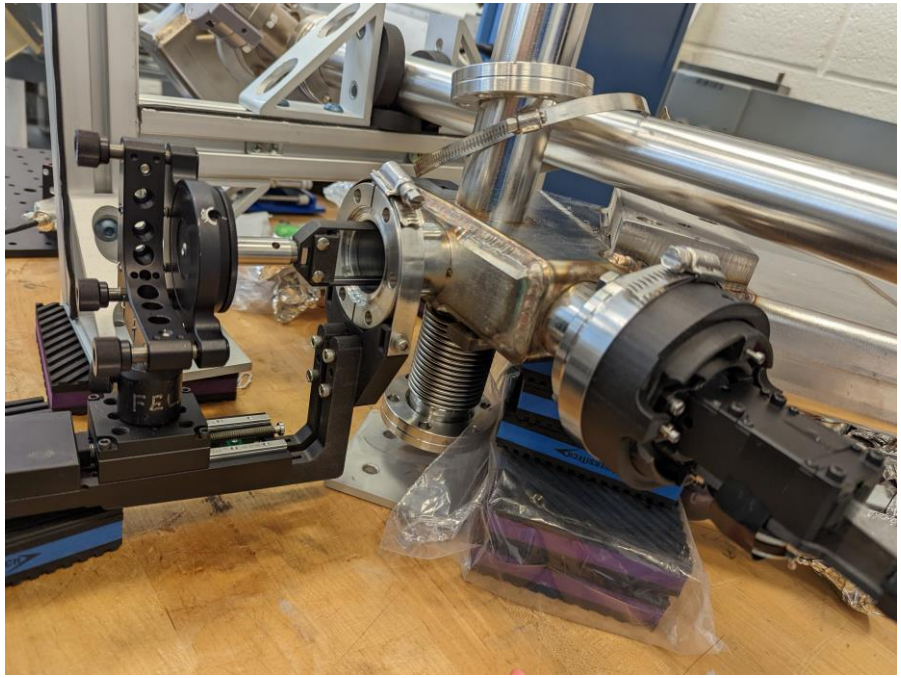
Particle detectability studies

- At this stage, trying to characterize the detector system as well as demonstrate detectability of events approximating free particles
  - Lower and upper limits on detectable event size
  - Lower limit on detectable event speed

- OSP simulations suggest a lower limit of ~100 μm for detectable particle size, based on change in received signal power
  - Also predicated on particle passing through a beam instead of clipping an edge or passing between beams

- First try: microscope slide on a translational stage, max speed 2.4 mm/s, translation range 53.45 mm

Particle detectability studies



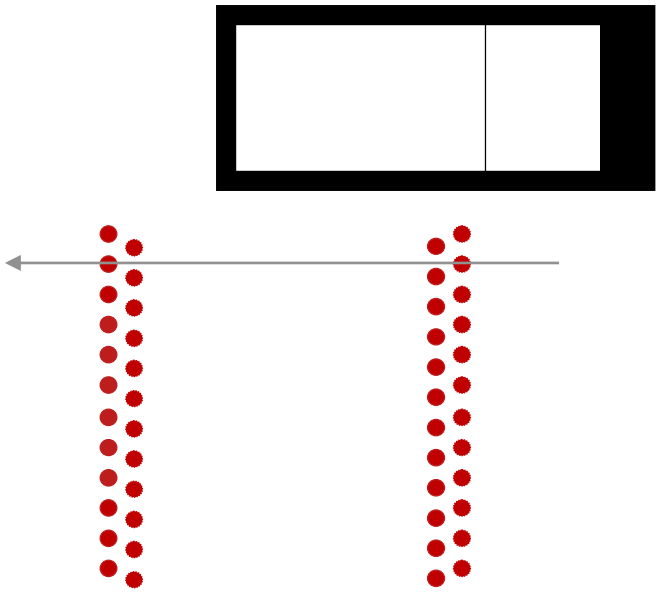
Translation stage with slide holder mounted on pump drop

~0.5 mm particle stripe, 20-70 μm “particles”

Particle detectability studies

- Particle stripe translated from fully extended to fully retracted within pump drop

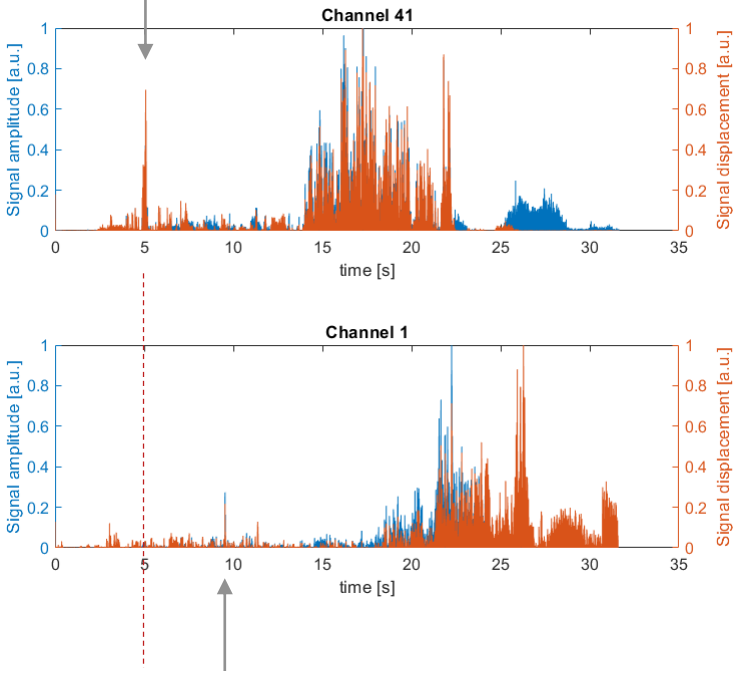
Microscope slide translated across laser arrays



Laser configuration in plane of reflection surface

Signal from stripe

Edge of slide holder



Signal from stripe
Δt=3.7 s ⇒ 9 mm spacing between these arrays

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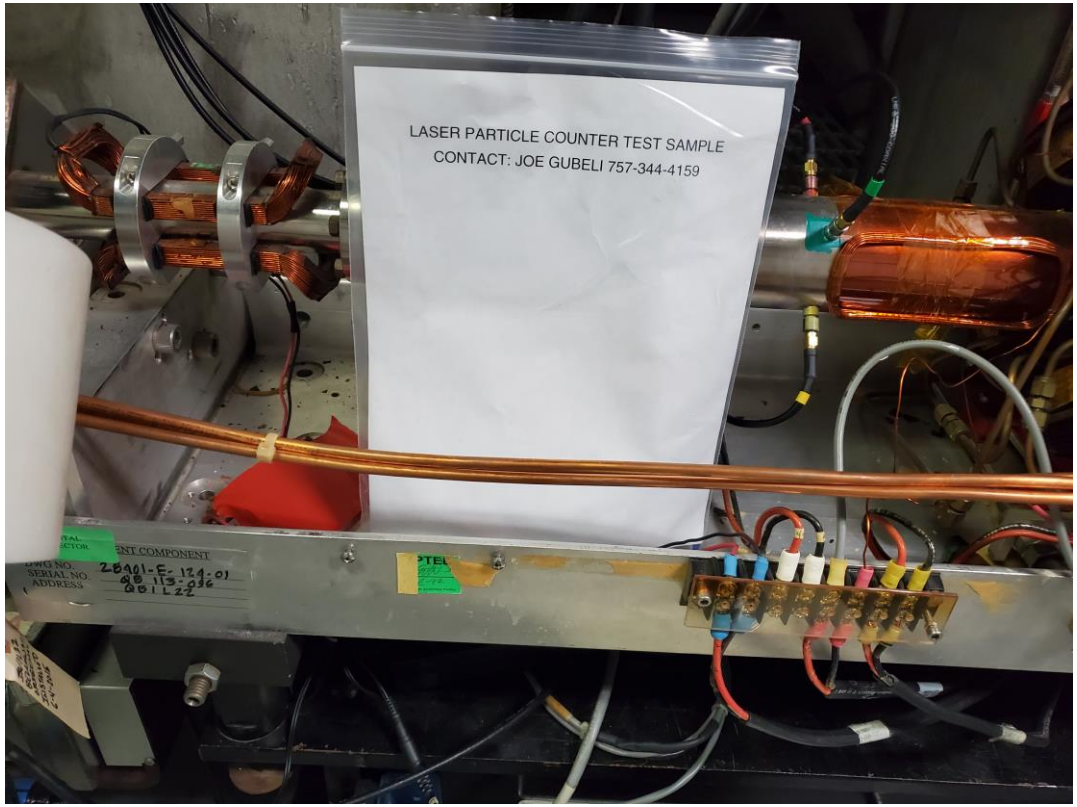
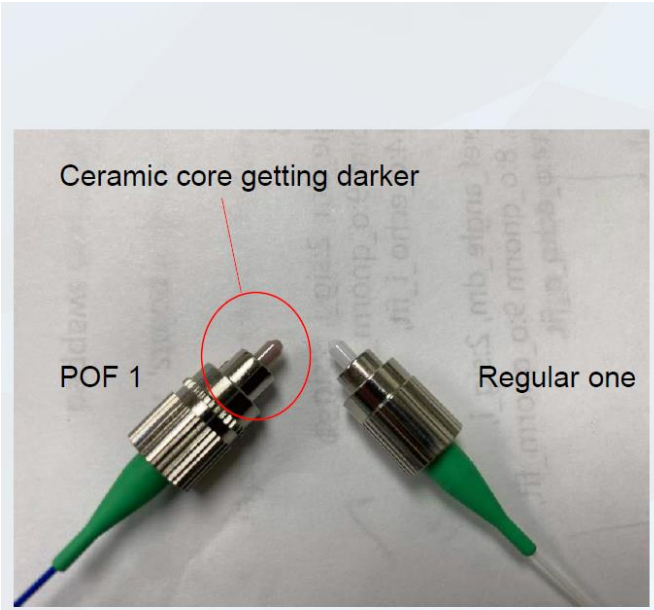
System survivability studies

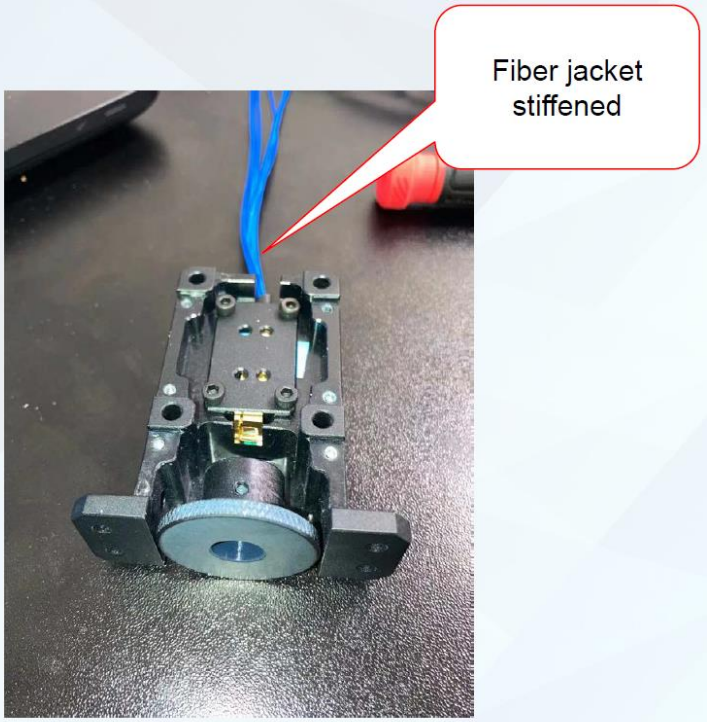
- Simplified POF and length of fiber optic cable placed on the girder between NL21 and NL22 during the last physics run
- Received about 300 krad integrated photon dose



System survivability studies

- Comparison studies between irradiated sample and a duplicate
  - Preliminary results indicate similar optical properties
  - Done after the fact – will continue to test irradiated sample with more time in the tunnel





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Current challenges and next steps

- Internal pump drop surface may not be ideal for robust detector operation
  - Surface roughness induces “dead spots” (?) – can’t adjust away by changing incidence angle
  - Starting a reflection surface study to find “best” surface and ideal detector operating conditions

- It’s hard to emulate free particles!
  - Opening up the test chamber for ease of “particle” introduction, calibration, reflection surface studies
  - Faster linear stage: 2.4 mm/s likely too slow
  - Particle drop studies with easily manipulatable things, 0.5-1 mm size
  - Some ideas for free particle introduction: dust aerosol generators, capillary tubes for droplet formation, ???

- Relocating to LERF lab space later this week