The HELIX Project: Calibration of Aerogel for Cherenkov Counter

PRESENTED BY THOMAS ROSIN

FOR HELIX COLLABORATION

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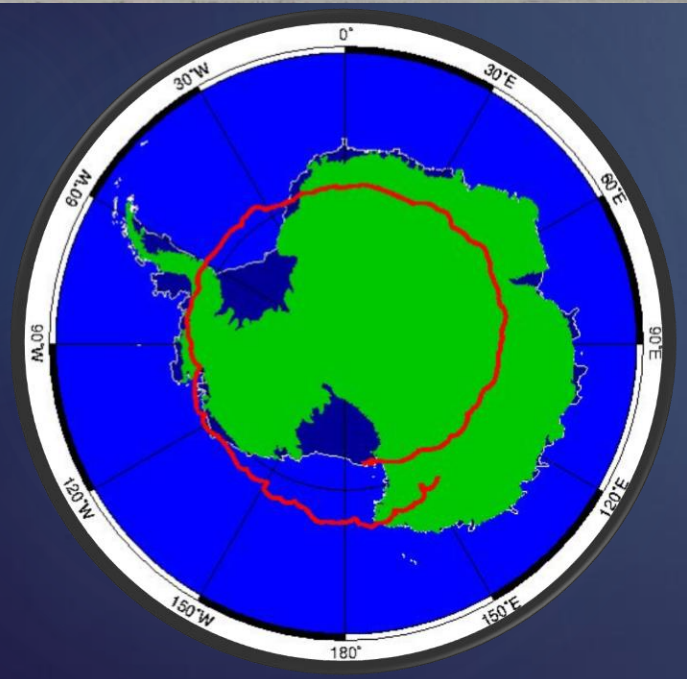


High Energy Light Isotope eXperiment

- What is it?

A balloon-borne detector designed to measure the chemical and isotopic abundances of light cosmic ray nuclei.

- When and Where?

Two stage experiment

Stage 1 : 14 day flight(depend on He consumption) from NASA's McMurdo Station facility in Antarctica during the 2020/21 austral summer.

Stage 2 : 28 day flight

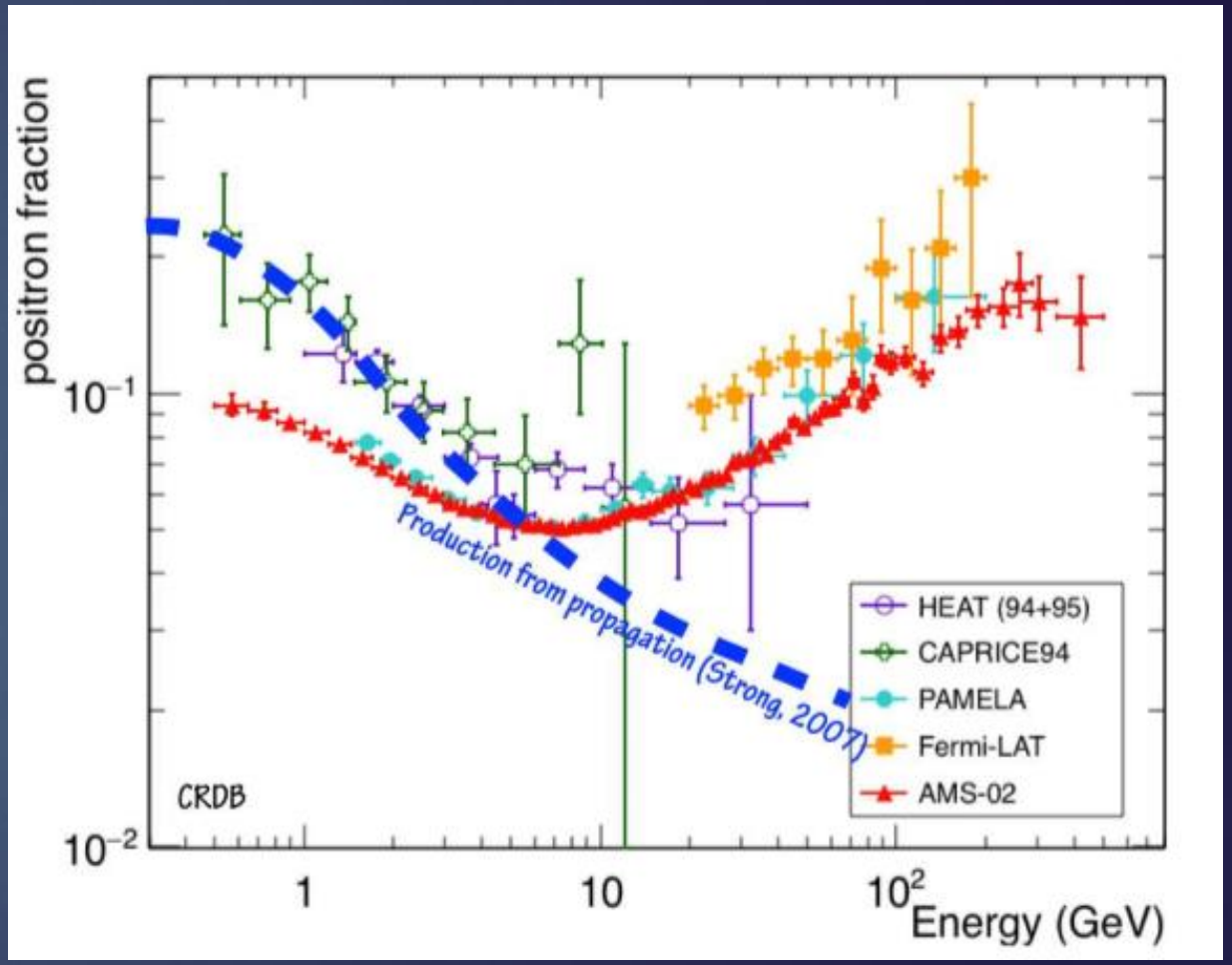
The collaboration

- McGill University
  - David Hanna, Emma Ellingwood, Thomas Rosin
- University of Chicago
  - Scott Wakely, Dietrich Müller , Nahee Park, Ian Wisher
- Indiana University
  - James Musser, Mark Gebhard, Brandon Kunkler, Mark Lang, Gerard Visser
- Pennsylvania State University
  - Stephane Coutu, Isaac Mognet
- Northern Kentucky University
  - Scott Nutter
- University of Michigan
  - Michael Schubnell, Gregory Tarle, Andrew Tomasch, Noah Green
- Ohio State University
  - Jim Beatty

INDIANA UNIVERSITY
THE OHIO STATE UNIVERSITY
UNIVERSITY OF MICHIGAN
McGill
PennState
THE UNIVERSITY OF CHICAGO
NKU NORTHERN KENTUCKY UNIVERSITY

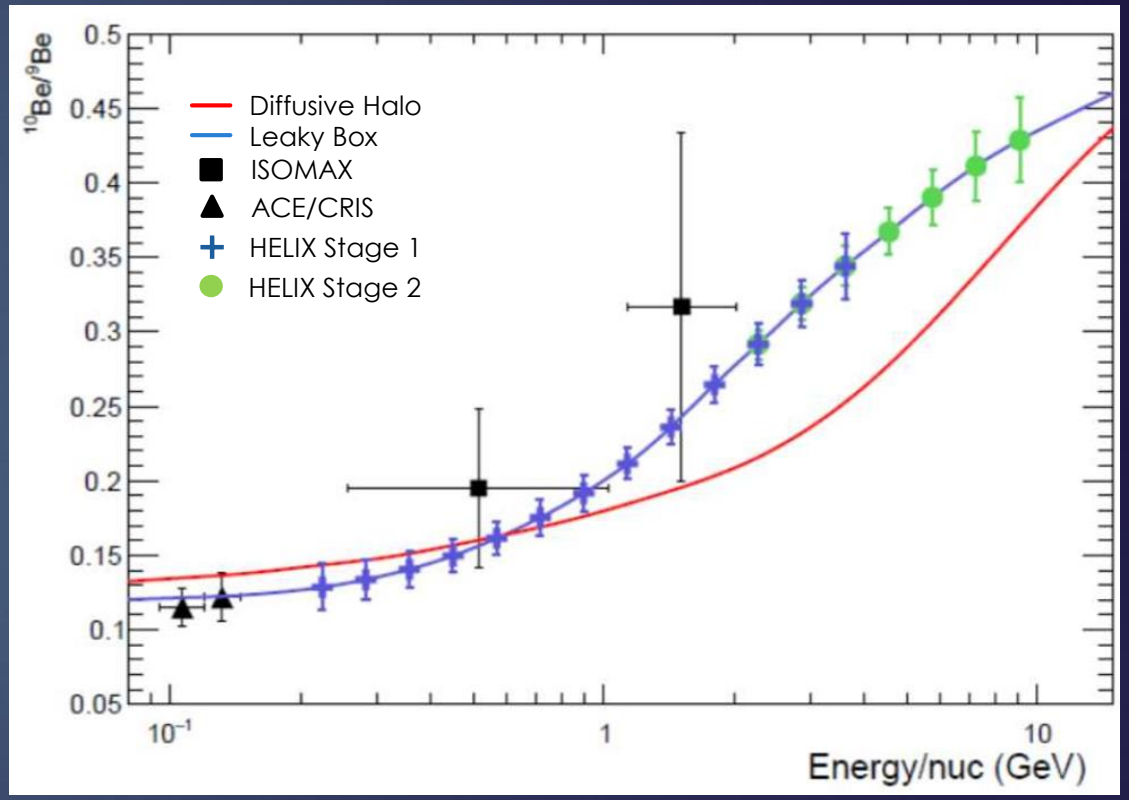
Cosmic Ray Propagation

- We wish to explain the recent results from AMS-02(Alpha Magnetic Spectrometer).
- The positron fraction excess can't be explained by current cosmic ray propagation model.
- Positron fraction = $\frac{e^+}{e^+ + e^-}$
- Hypothesis:
  - Positron production by nearby pulsars
  - Annihilation or decay of dark matter

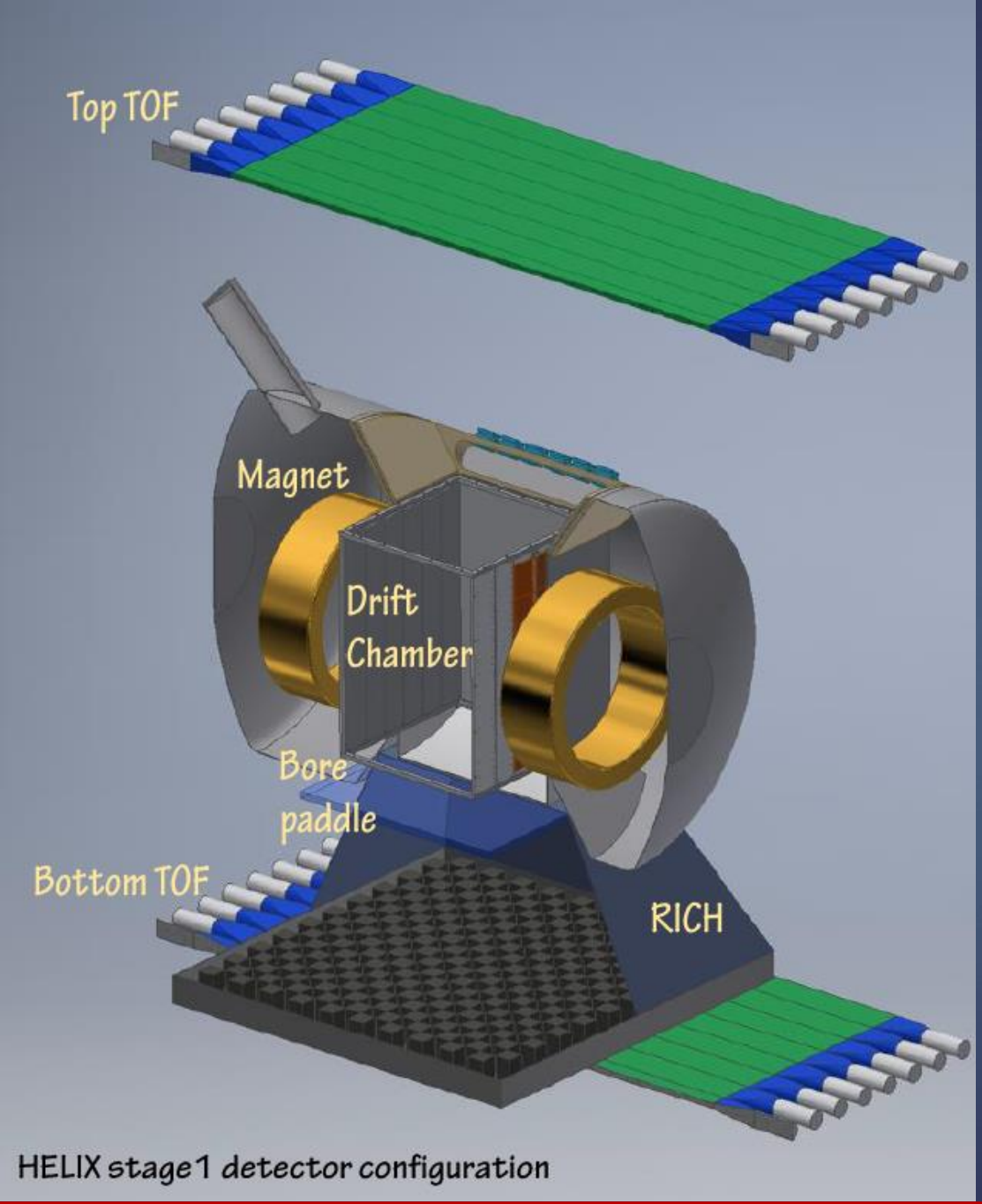


Beryllium-10 Clock Isotope

- Properties of ^{10}Be:
  - Made in spallation reactions with interstellar medium
  - Unstable element with half life of 1.5Myr ("**clock isotope**").
- A $^{10}Be/^{9}Be$ measurement give an estimate of how long the cosmic ray have been travelling. This helps discriminate between many propagation models.
- AMS-02 can't make this measurement
- Goal: Measuring $^{10}Be/^{9}Be$ between 0.1 to 3 GeV/n for Stage 1 up to 10 GeV/n for Stage 2



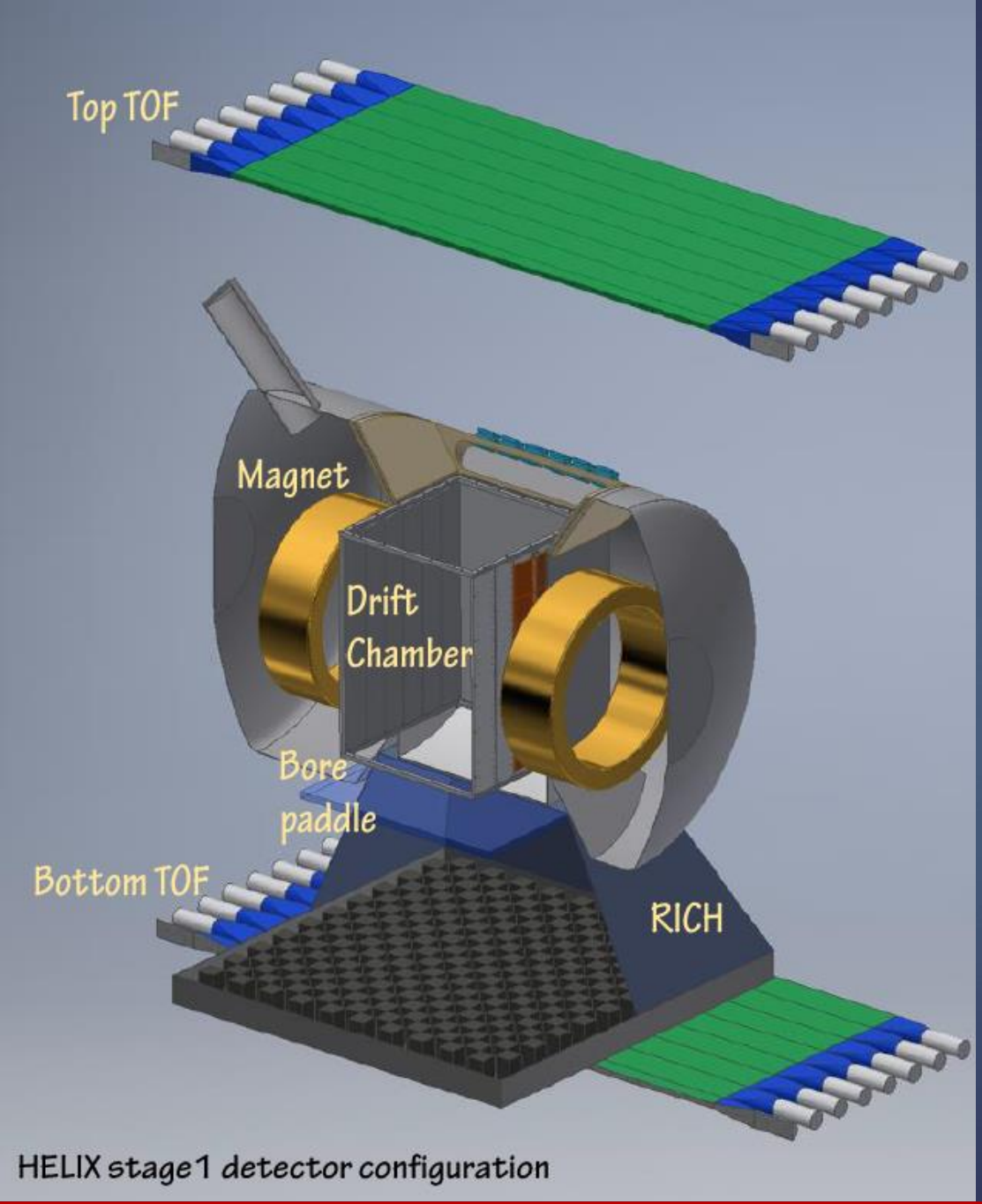
$$Cosmic\ ray + {}^{14}_{7}N \xrightarrow{ISM} \mathbf{{}^{10}_{4}Be} + {}^{4}_{2}He + e^{+} + \nu_e + spallation\ byproduct$$



HELIX stage1 detector configuration

HELIX Payload

- Experimental Method
  1. Measure **charge** to get Berylium
  2. Measure **rigidity**(momentum)
  3. Measure β(**velocity**)
  4. Particle ID using mass spectrometry
- Magnet
  - 1T superconducting magnet
- Drift Chamber Tracker
  - Multiwire drift chamber with 72 sense layers
  - Spatial resolution ~65 μm for Z>3
  - Measure **rigidity**
- Time-of-Flight(TOF) and Charge System
  - 1.5cm thickness scintillator, readout by SIPMs, 2.3m separation
  - Timing resolution <50 psec for Z>3
  - Measure **charge** (indentify Be element)
  - Measure **velocity** up to 1GeV/n

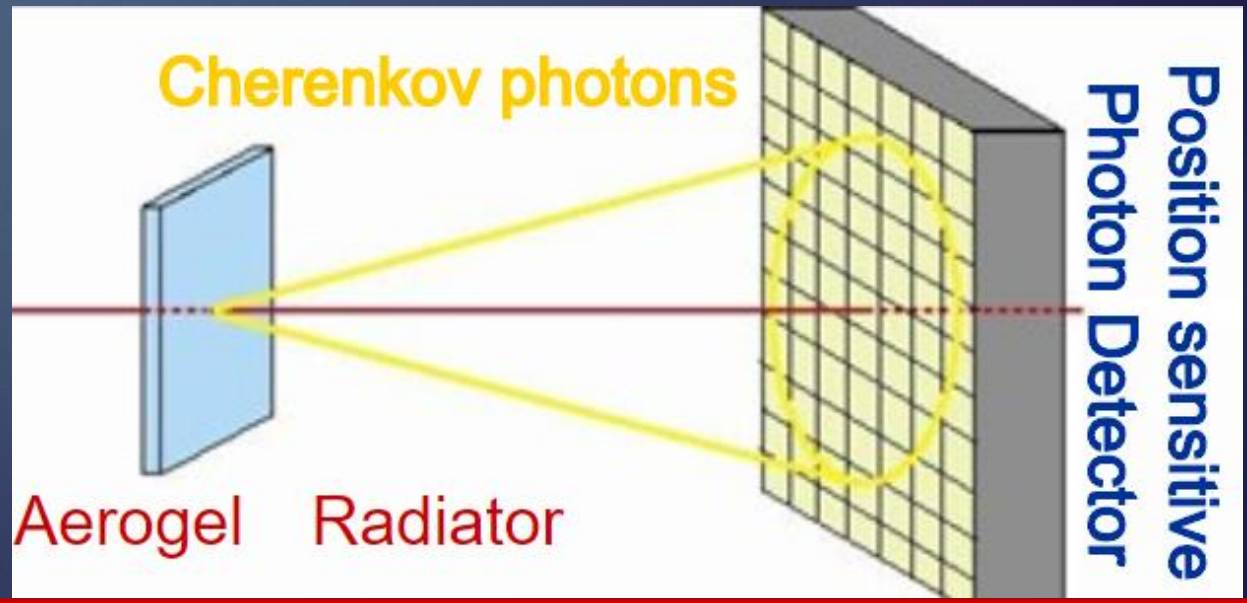


HELIX Payload

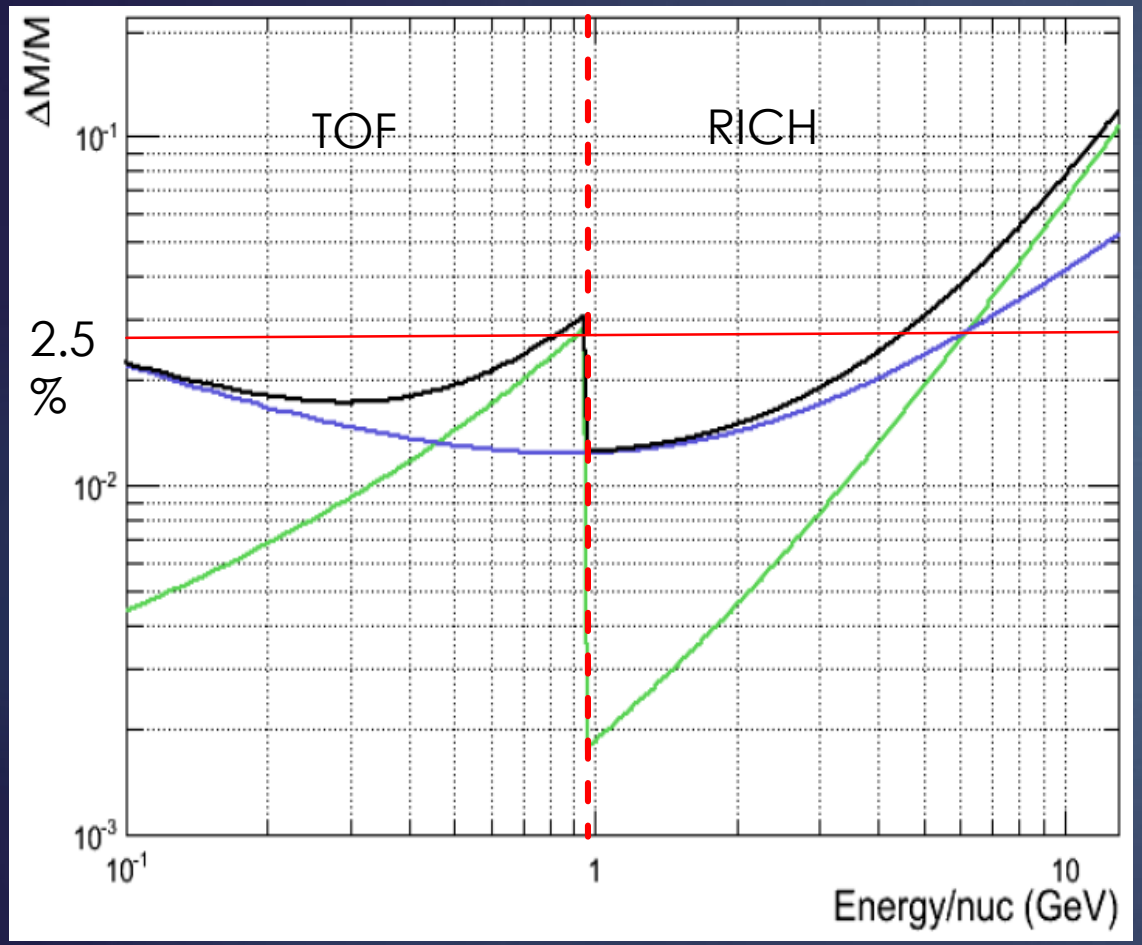
- Ring Imaging Cherenkov Detector(RICH)
  - Particles with v>c/n generates Cherenkov Photons emitted at an angle:

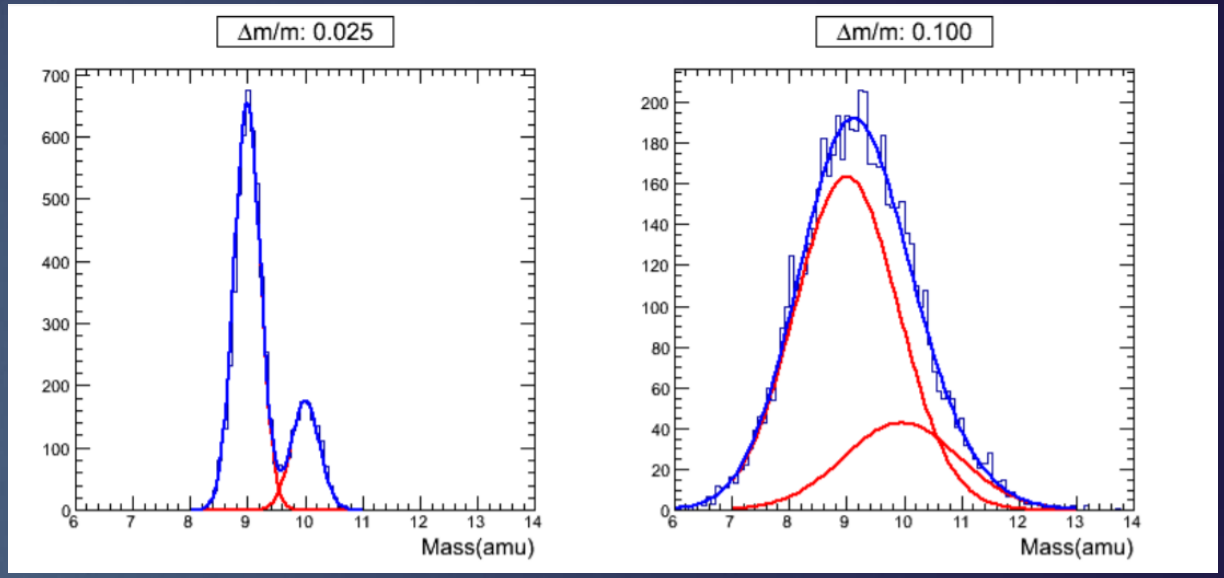
$$\cos(\theta_c) = \frac{1}{n\beta}$$

  - θ_c can be measured to get β
  - 70 cm x 70 cm aerogel radiator n~1.15
  - 1.3 m^2 readout plane covered by SiPMs arrays
  - Measure **velocity**

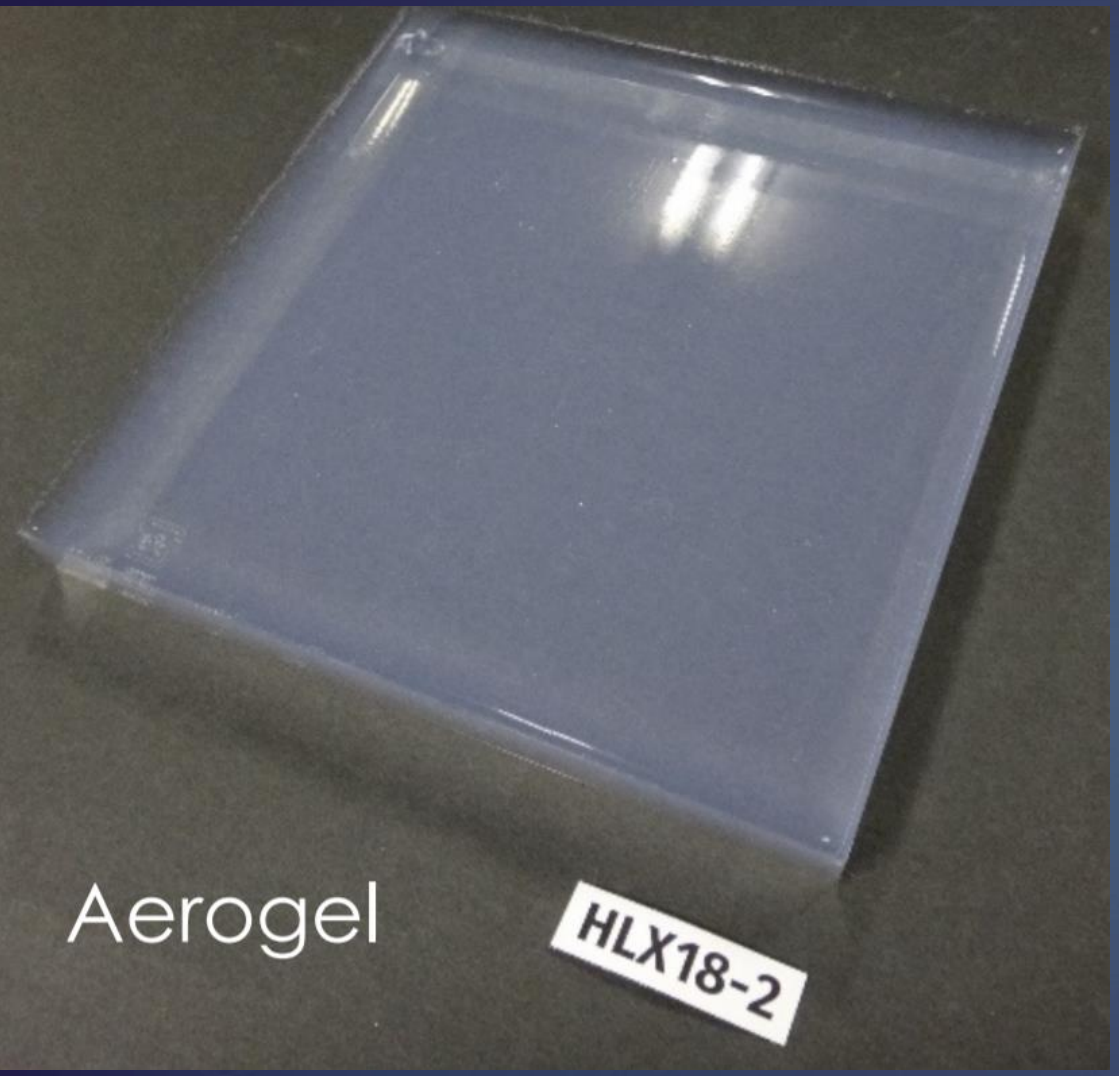


Mass Spectrometry





$$\left(\frac{\Delta m}{m}\right)^2 = \left(\frac{\Delta R}{R}\right)^2 + \left(\gamma^2 \frac{\Delta \beta}{\beta}\right)^2$$



Aerogel Calibration

- Radiator: Aerogel with refractive index 1.15
- Aerogel Properties:
  - refractive index is intermediate between gases (near 1.00) and conventional materials (water 1.33, glass 1.5) and can be tuned during production.
  - optimize the geometry of the detector
  - perform proximity focusing
- n needs to be calibrated to a precision of $\frac{\Delta n}{n} = 7 \times 10^{-4}$ to get accurate β measurements.
- The refractive index and the thickness have to be measured on a fine grid to calibrate the apparatus.
- Produced in Japan by Makoto Tabata from Chiba University
- 92 aerogel tiles to calibrate

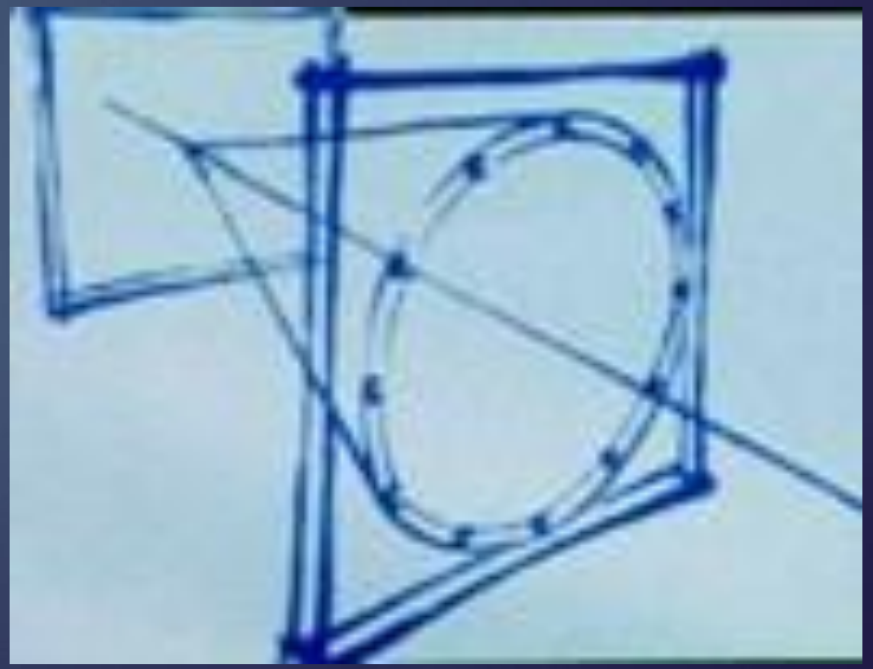
Calibration of Aerogel : Beam Calibration

NRC linac

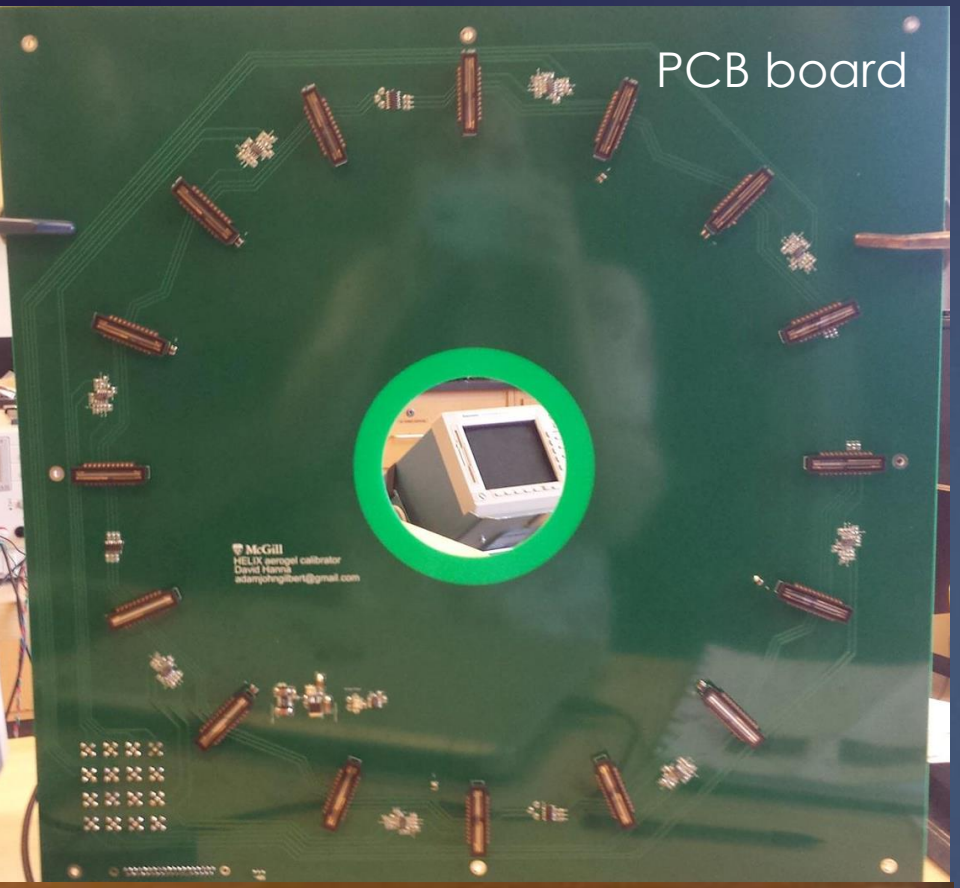
- Idea:

Scan the aerogel tile with an relativistic electron beam to find n.

- Beam test at NRC: 35MeV electron linac in Ottawa

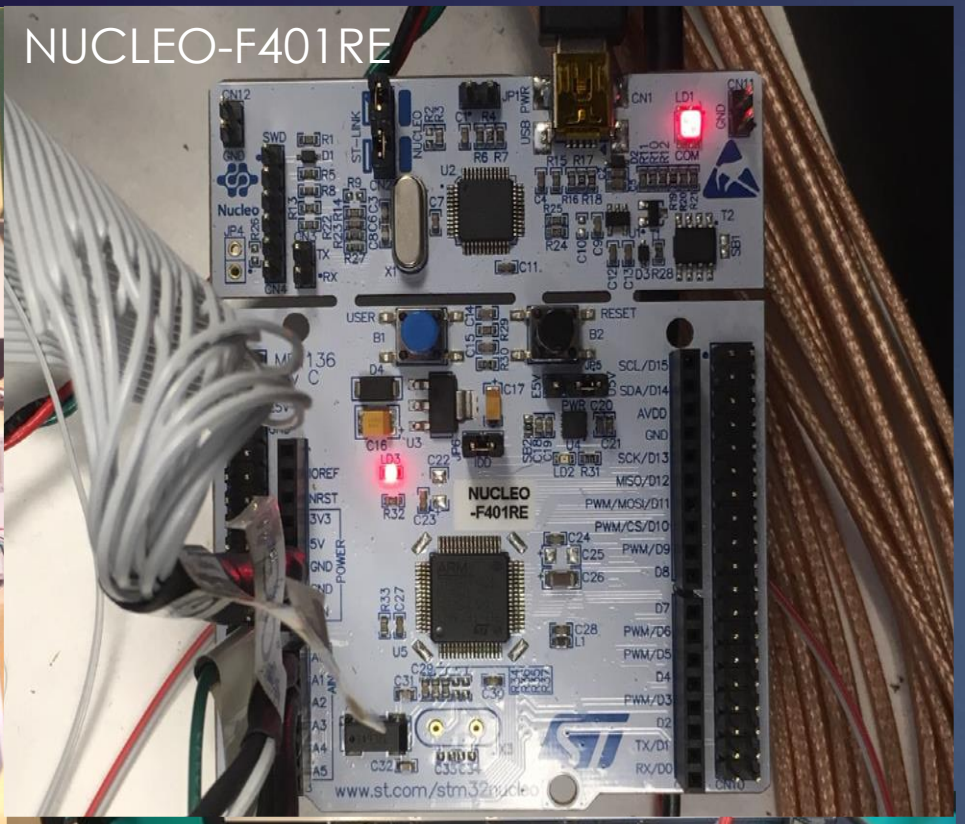


Calibration of Aerogel : Beam Calibration



- Use a circle of 16 one-dimensional CCDs to measure the Cherenkov ring
- Nominal radius is 200 mm
- We chose the Toshiba TCD1304AP:
  - 3648 pixels
  - 8 µm x 200 µm each
  - electronic shutter
  - high sensitivity low noise
- Control signals from STMicroelectronics / NUCLEO-F401RE
- readout into Acqiris DC270 FADC digitizers (8-bit 1 GS/s)

Calibration of Aerogel : Beam Calibration



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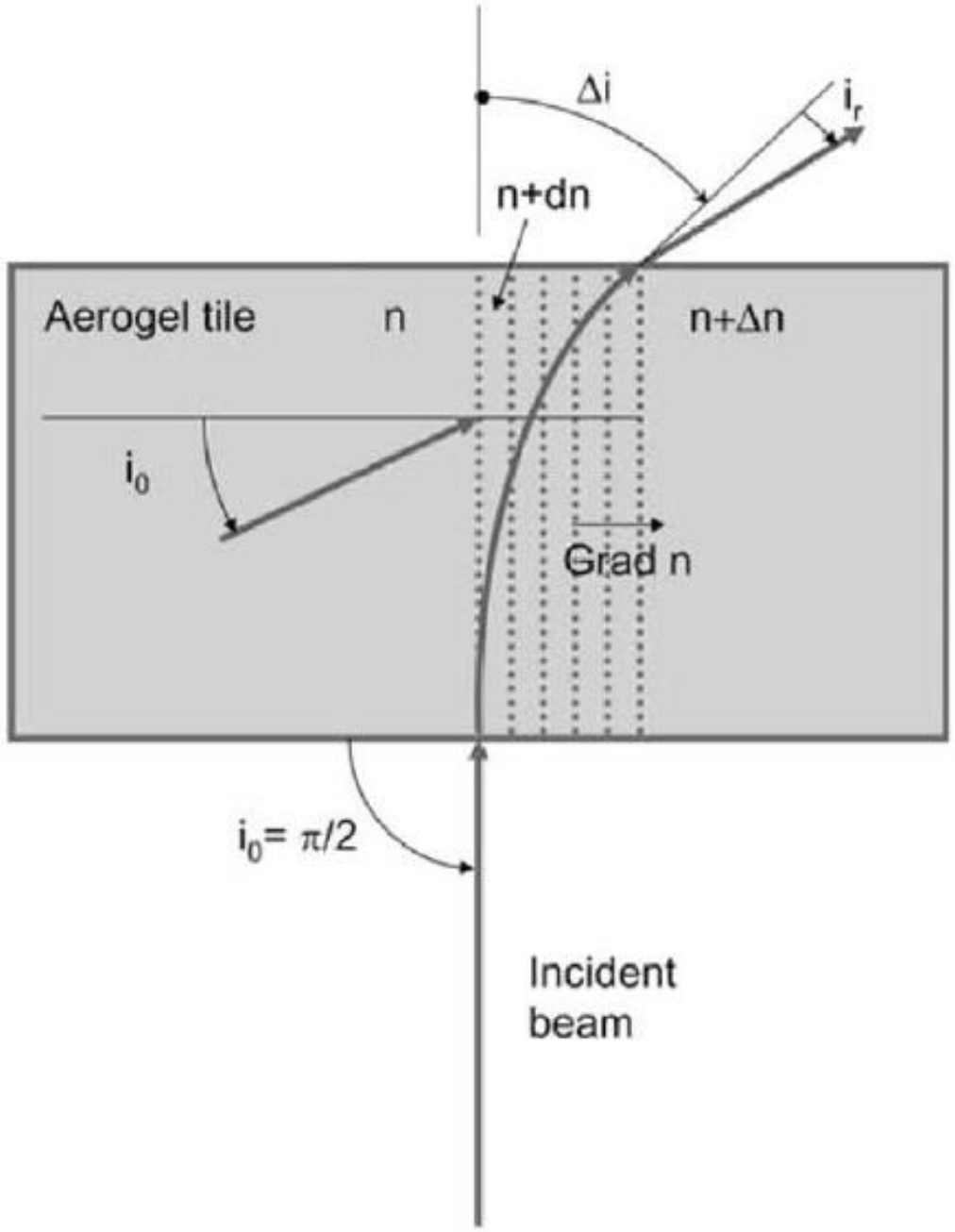
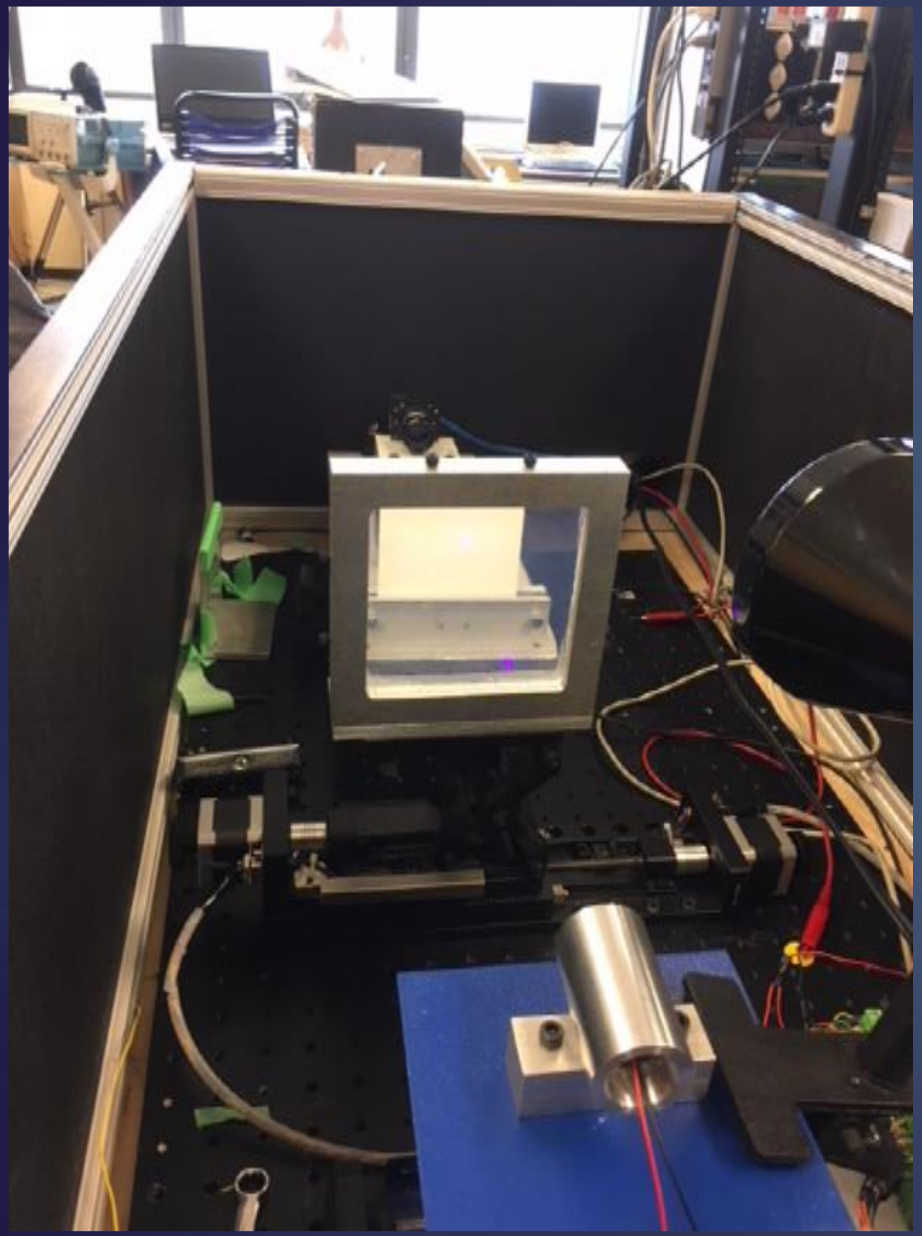
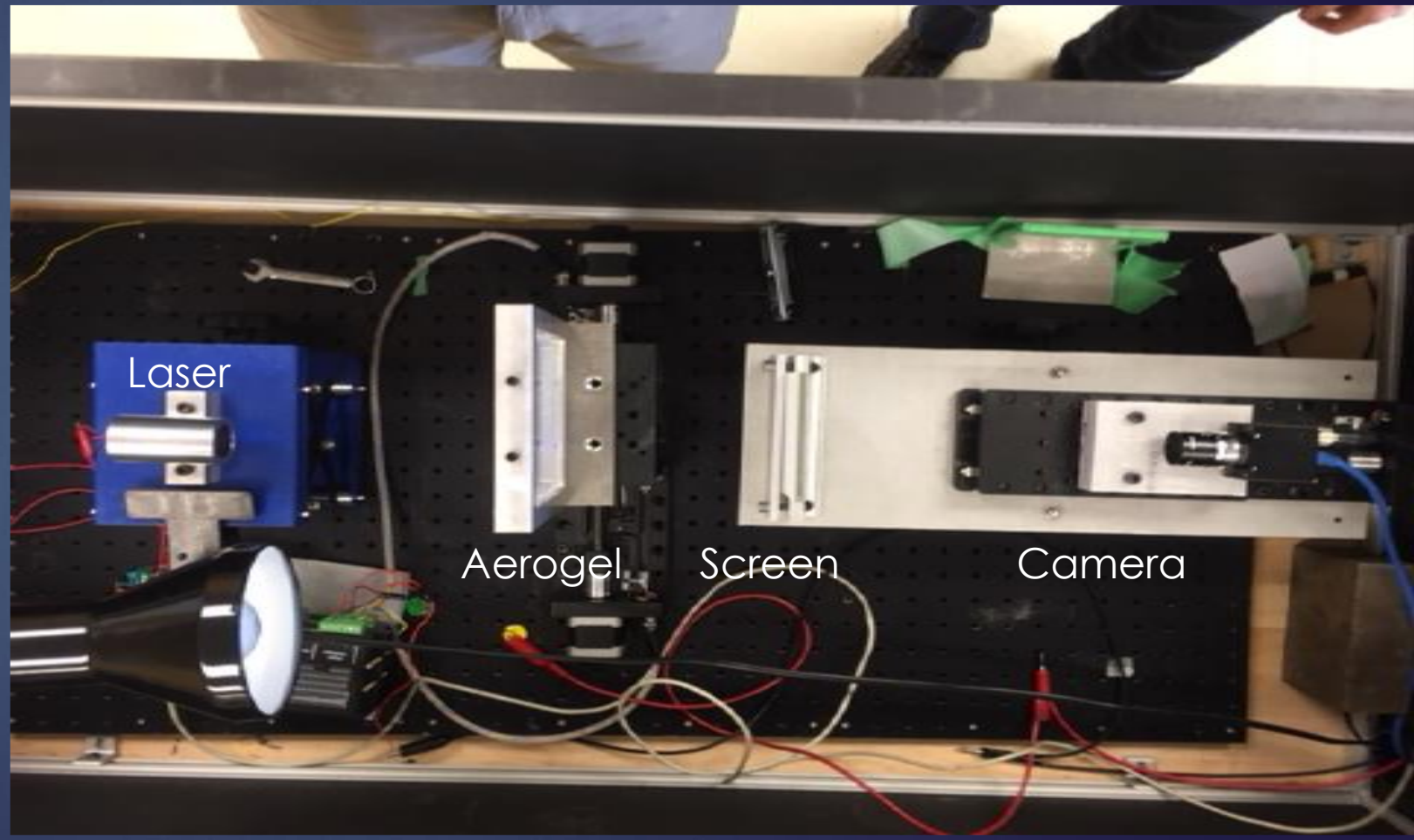
Calibration of Aerogel : Gradient Index

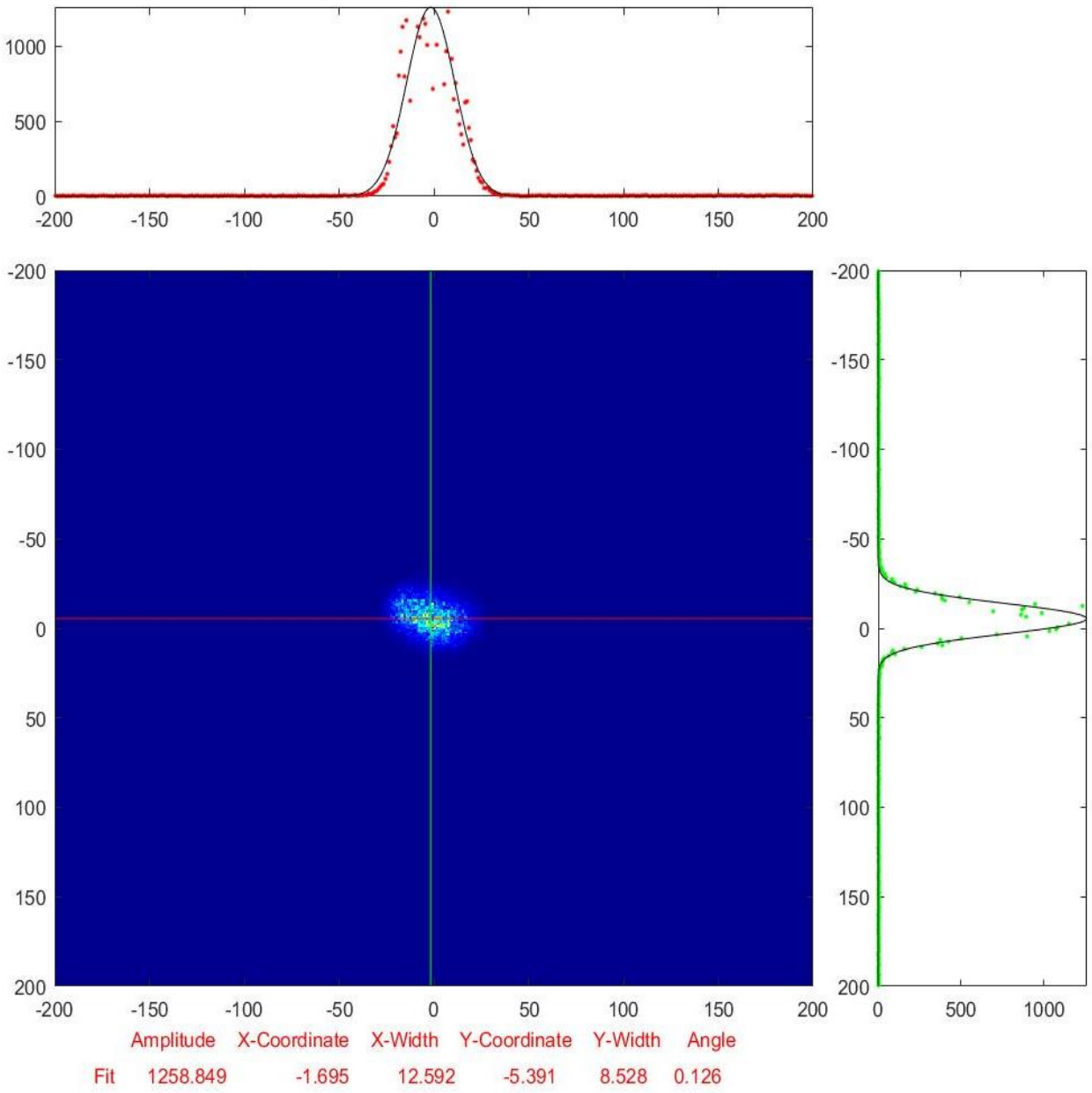


- based on Fermat's principle of least action
- gradient in the refractive index can deflect a laser beam traversing the tile
- needs a knowledge of tile thickness
- limited by surface roughness and Rayleigh scattering

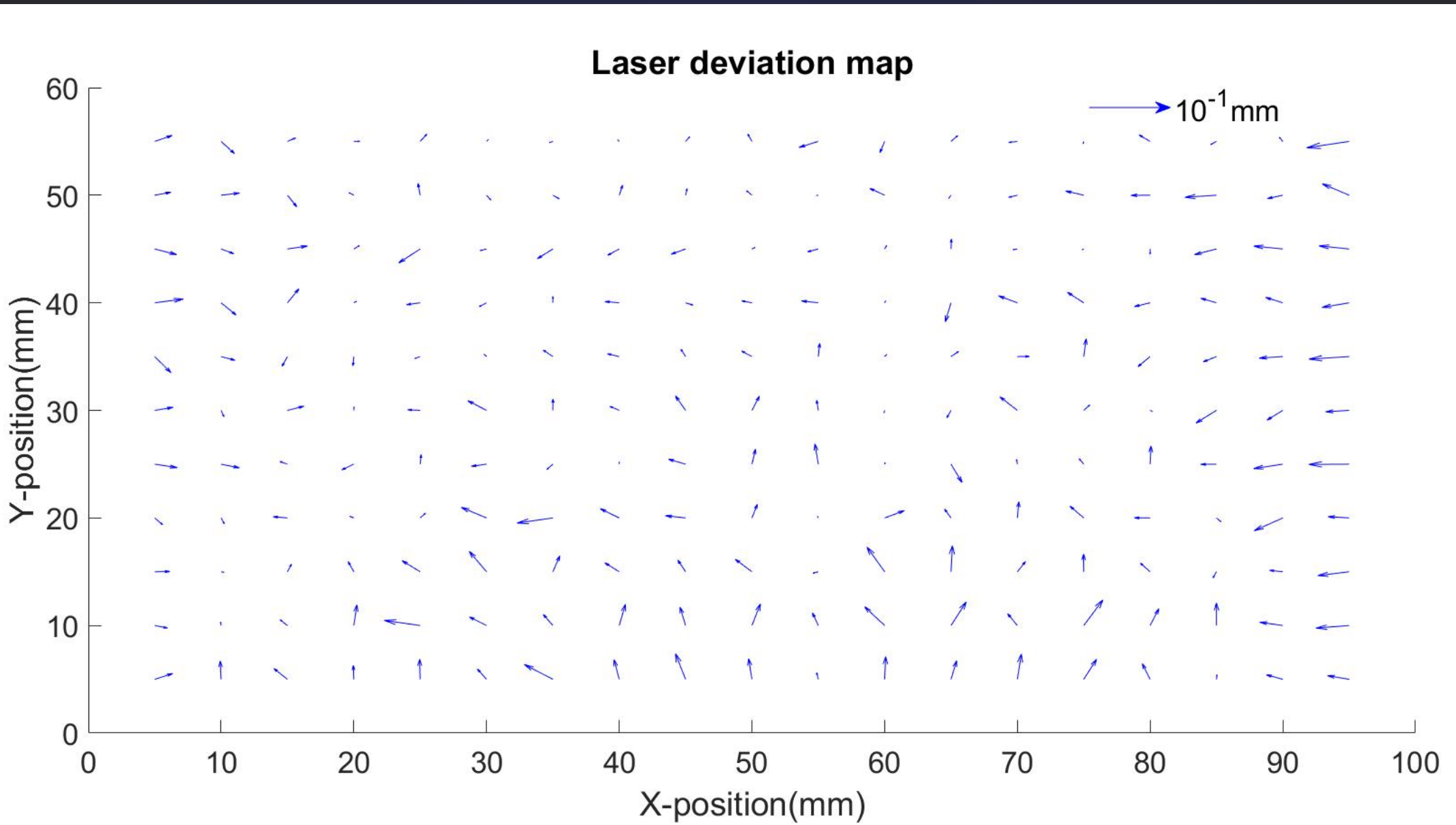


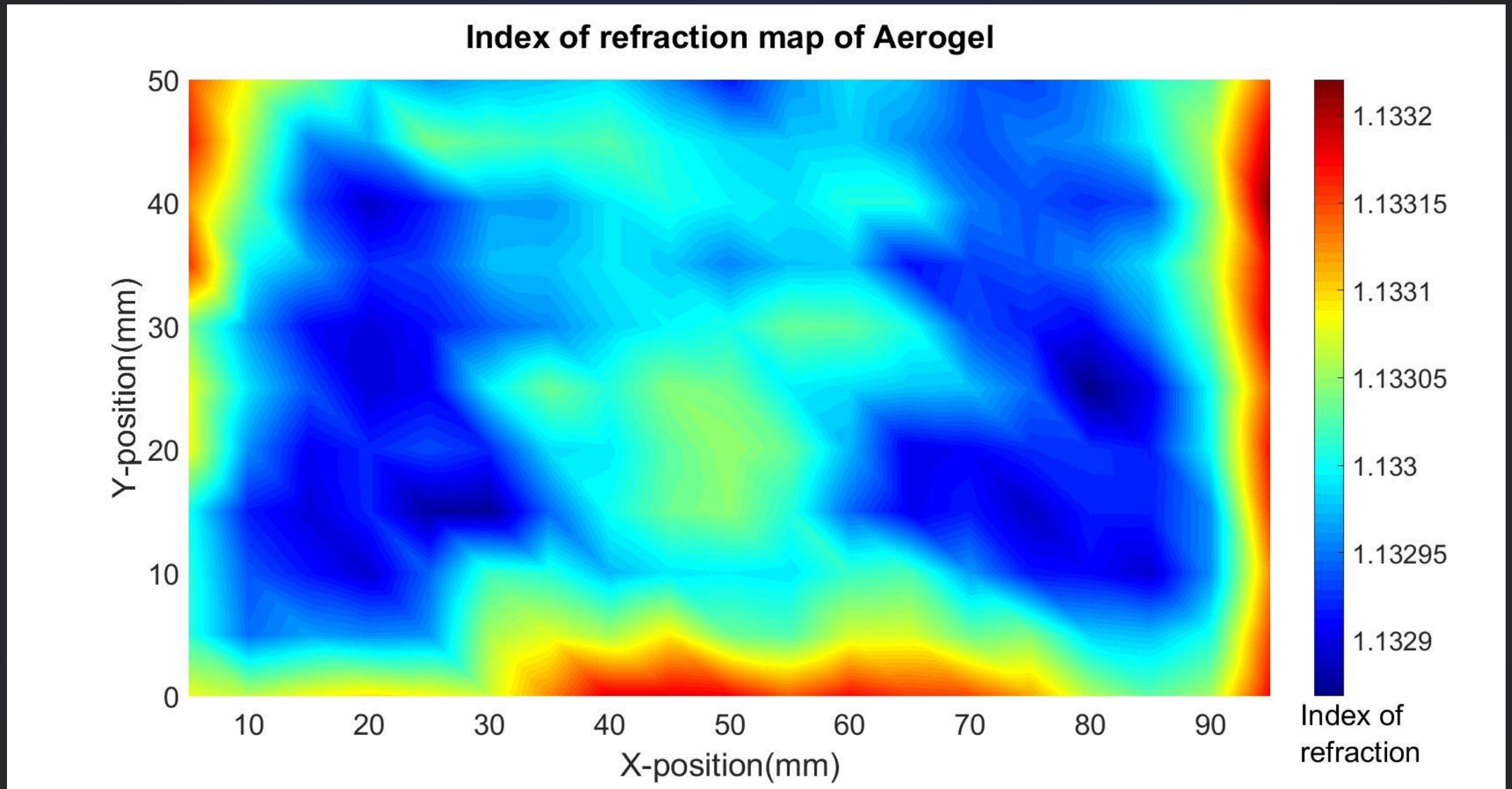

Laser
Aerogel
Screen
Camera

Calibration of Aerogel : Gradient Index



- Scan tile in x and y
- Measure deflection in x and y direction for each scan point
- Compute index map using minimization algorithm
- Correct using thickness map made with CMM(coordinate measuring machine)


Laser deviation map
10^{-1}mm
Y-position(mm)
X-position(mm)
0
10
20
30
40
50
60
70
80
90
100


Index of refraction map of Aerogel
Y-position(mm)
X-position(mm)
0
10
20
30
40
50
10
20
30
40
50
60
70
80
90
1.1332
1.13315
1.1331
1.13305
1.133
1.13295
1.1329
Index of refraction

Questions?