Laser Calibration Studies Using the ALPHA-g Detector

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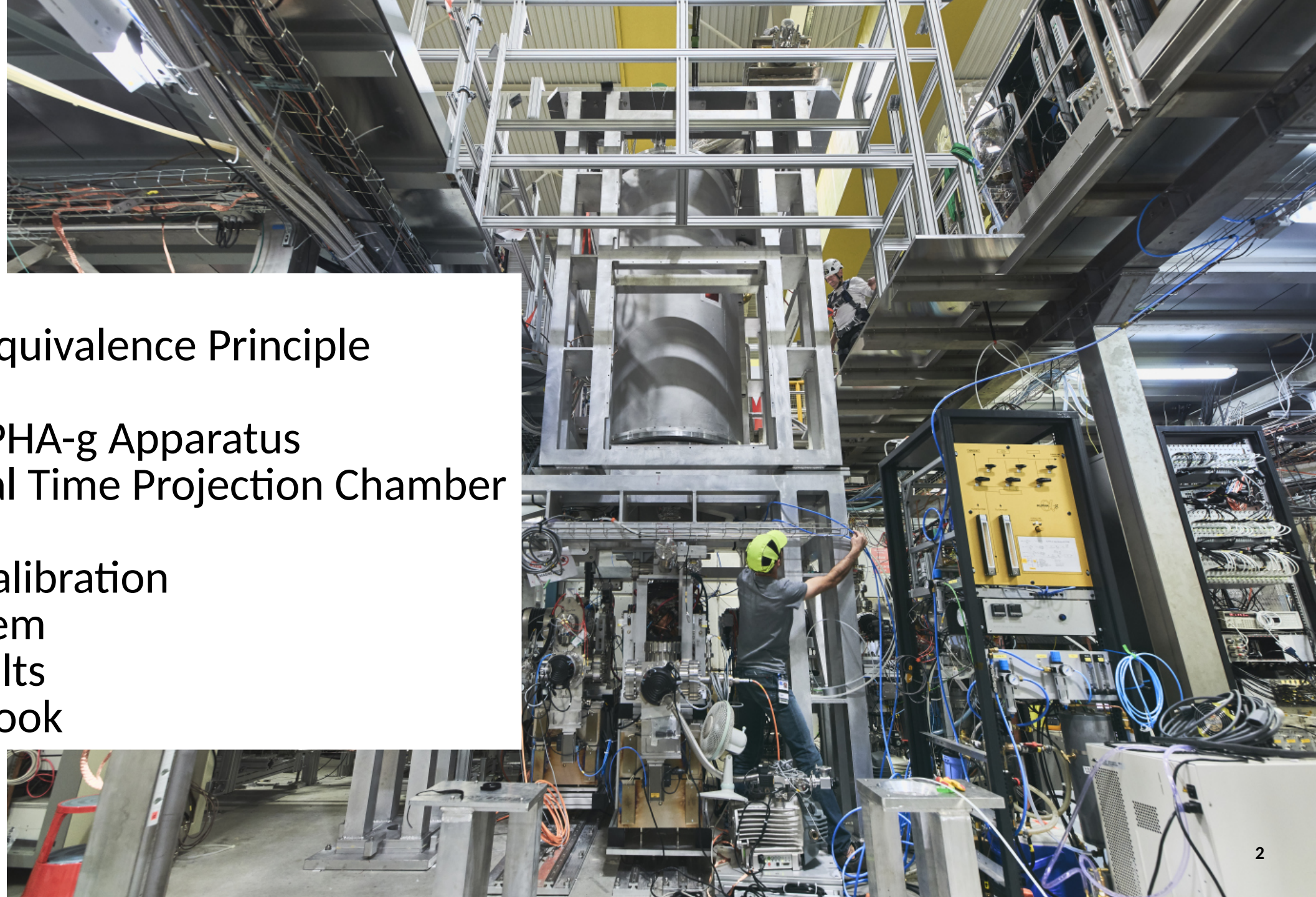
18.02.2023

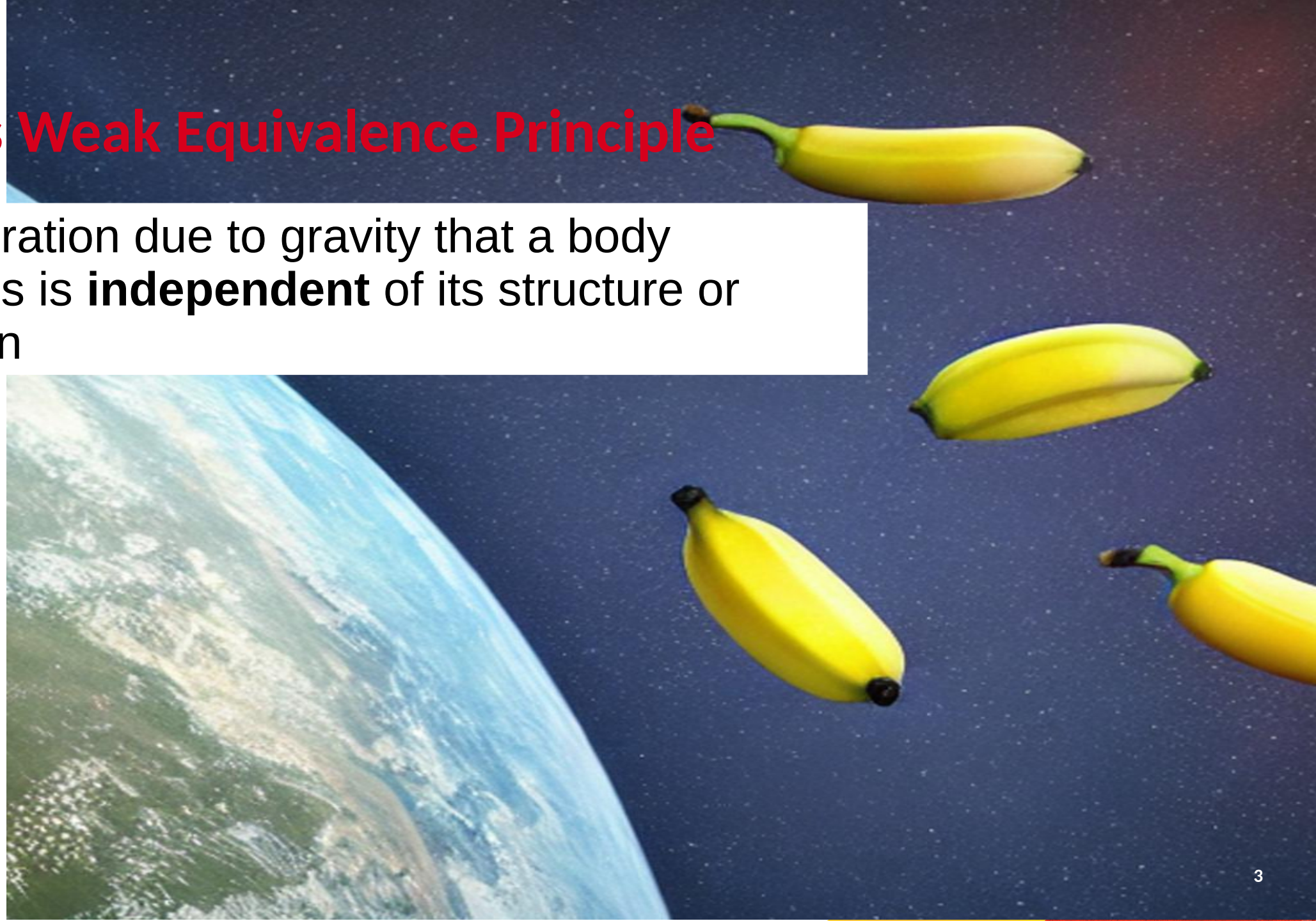
Outline



- Weak Equivalence Principle
- The ALPHA-g Apparatus
  - radial Time Projection Chamber
- Laser Calibration
  - System
  - Results
  - Outlook

Einstein's Weak Equivalence Principle

The acceleration due to gravity that a body experiences is **independent** of its structure or composition



Let’s skip the part where I explain how we make antihydrogen…

**Images are not to scale. Parts of the apparatus have been greatly exaggerated for clarity.

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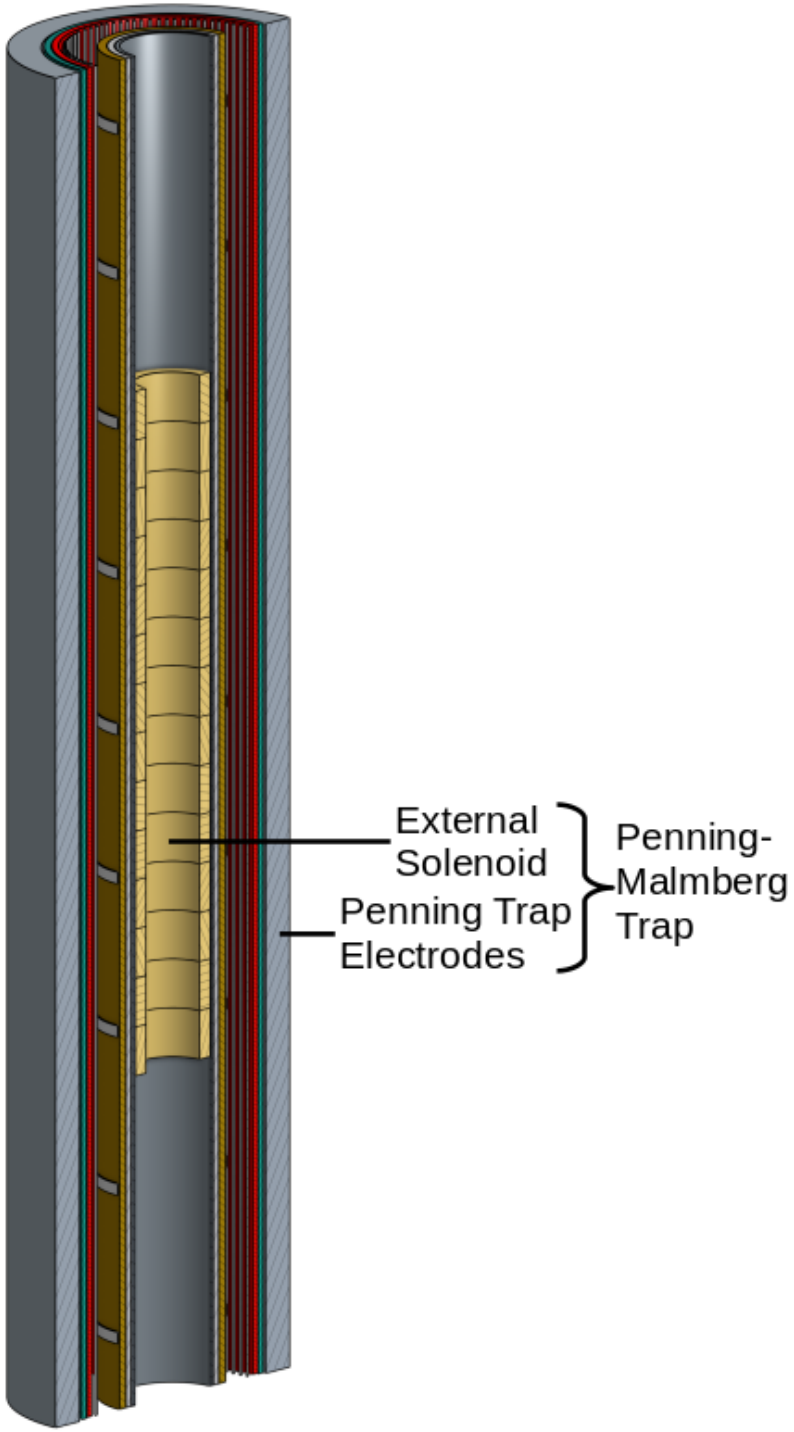

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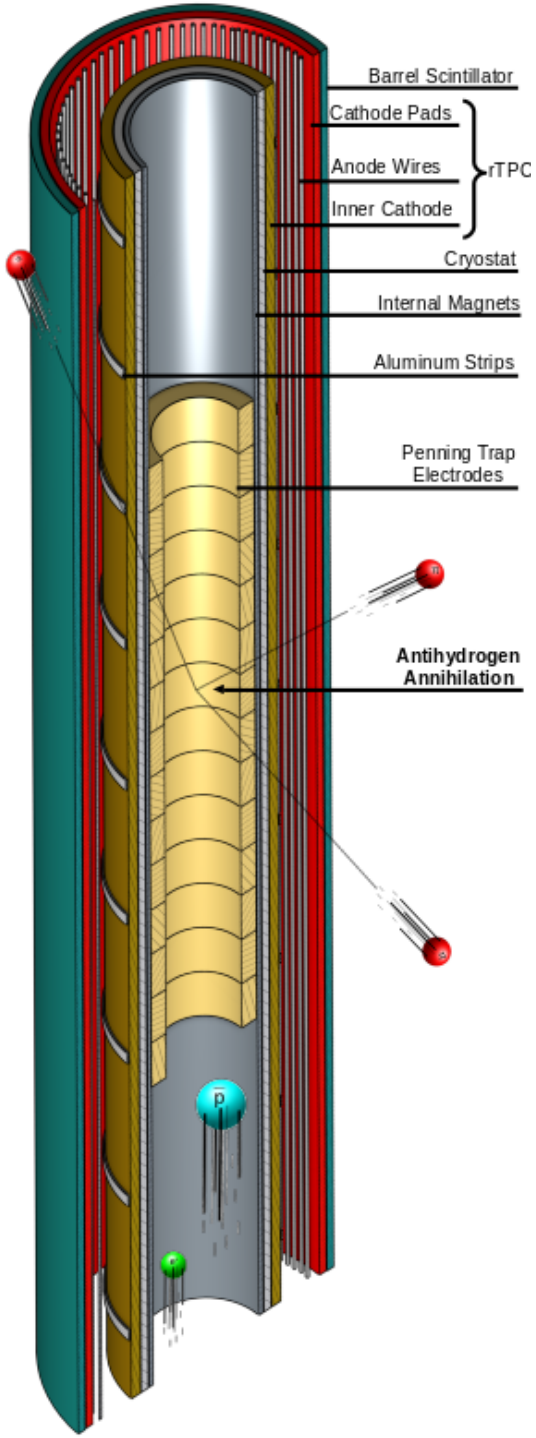
"Magnetic Fields During Gravitational Experiments with Antihydrogen"
Adam Powell at 9:45AM

**Images are not to scale. Parts of the apparatus have been greatly exaggerated for clarity.



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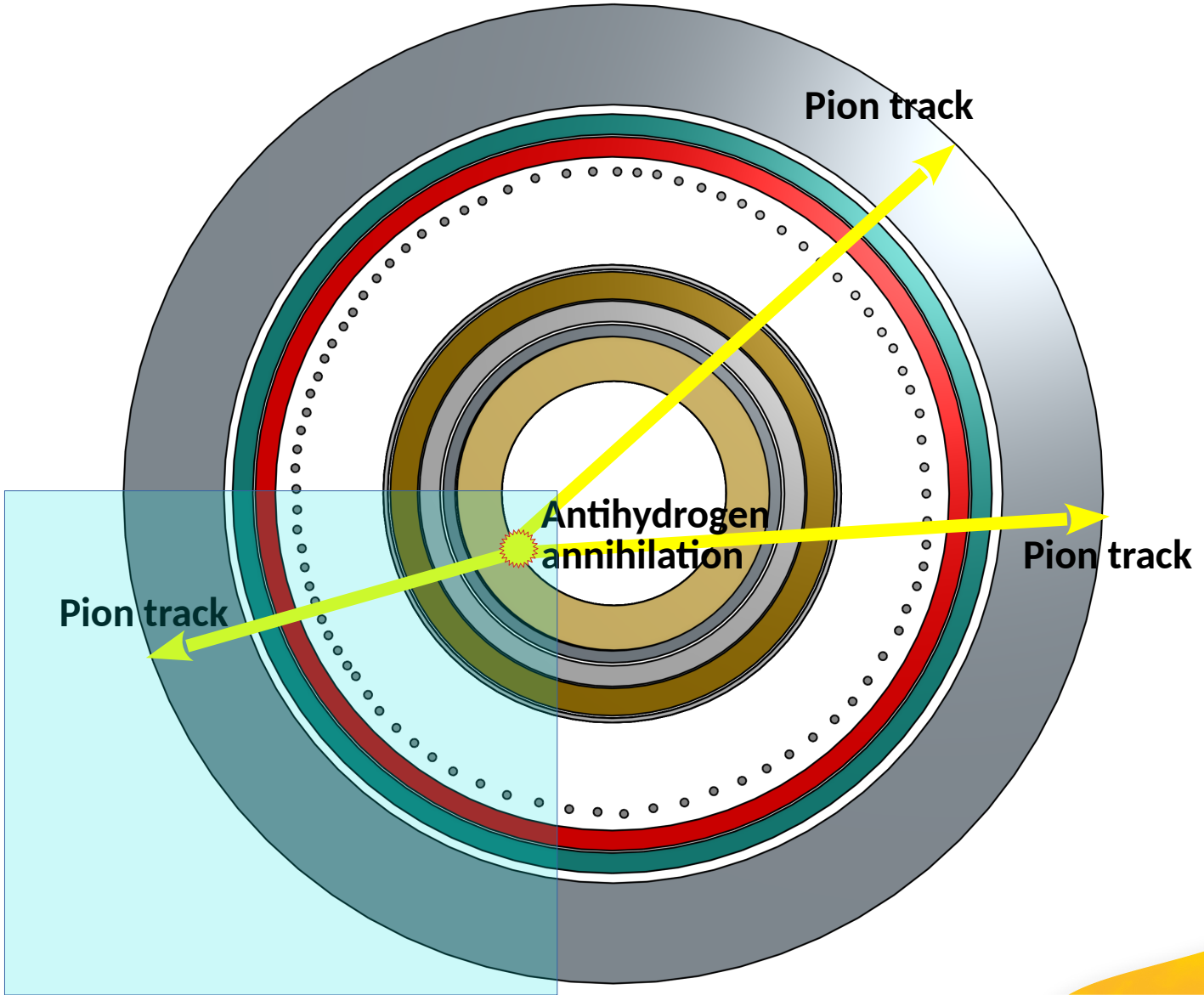
"Anti-hydrogen Detection and Background Rejection for ALPHA-g"
Gareth Smith at 9:30AM

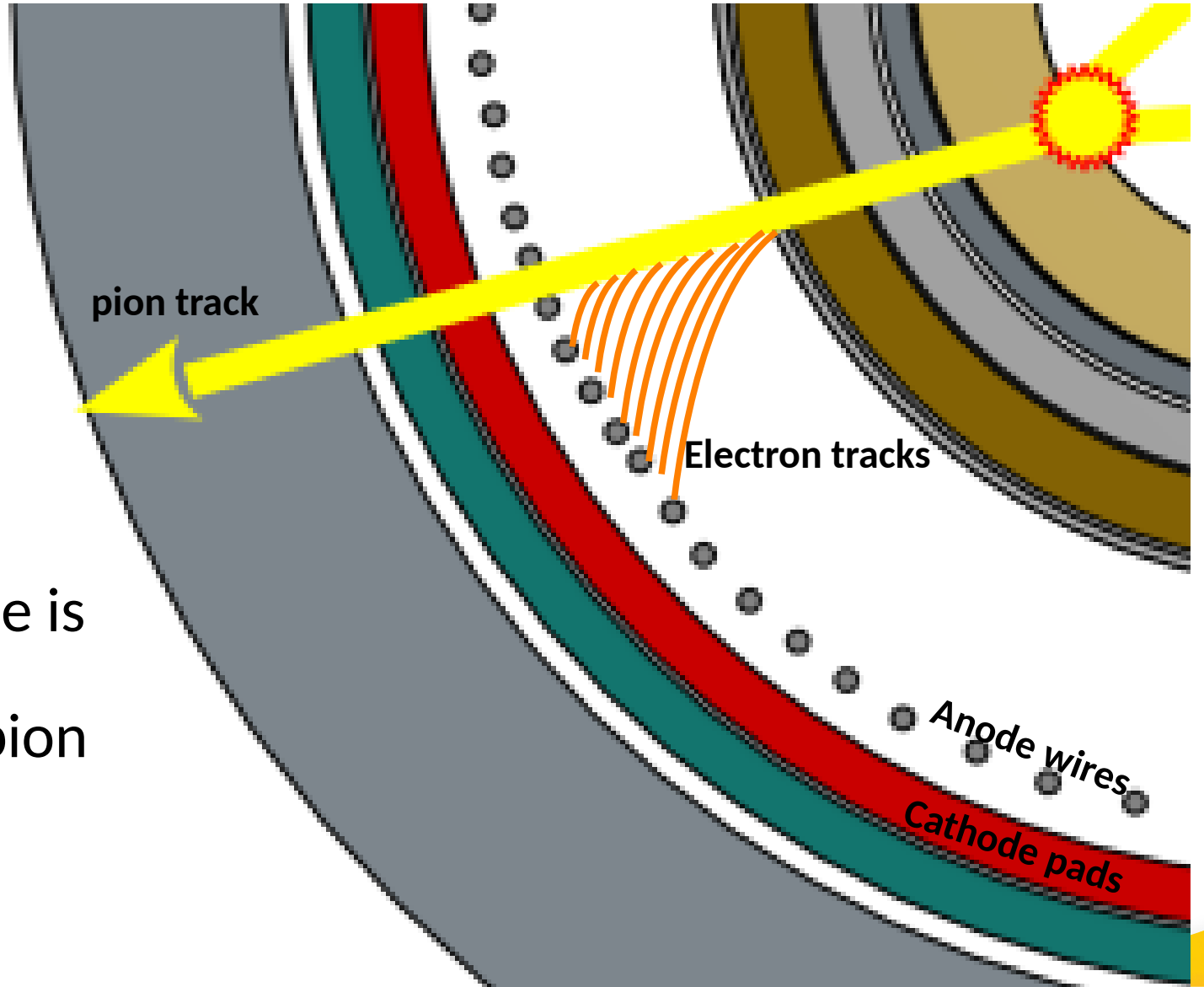
**Images are not to scale. Parts of the apparatus have been greatly exaggerated for clarity.

The radial Time Projection Chamber



**Bottom view of ALPHA-g apparatus, not to scale

The radial Time Projection Chamber

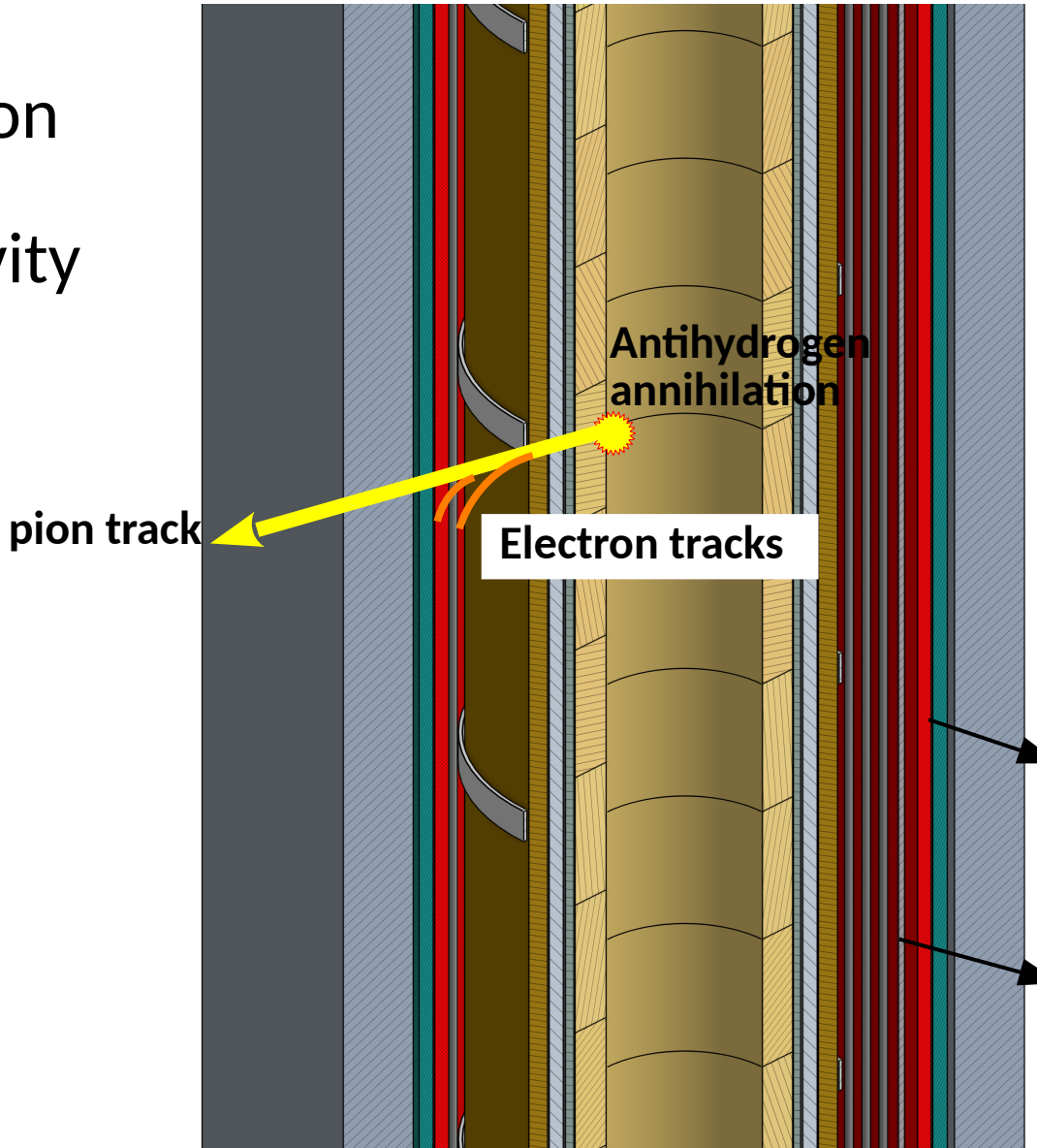


**Bottom view of ALPHA-g apparatus, not to scale

Electron drift time is necessary to reconstruct the pion track

The radial Time Projection Chamber

Timing and position information are critical to the gravity measurement



**side cross section of ALPHA-g apparatus, not to scale

Laser Calibration

Purpose

To understand the detector response in tracking particles in a non-uniform magnetic field

Key observable: **drift time**

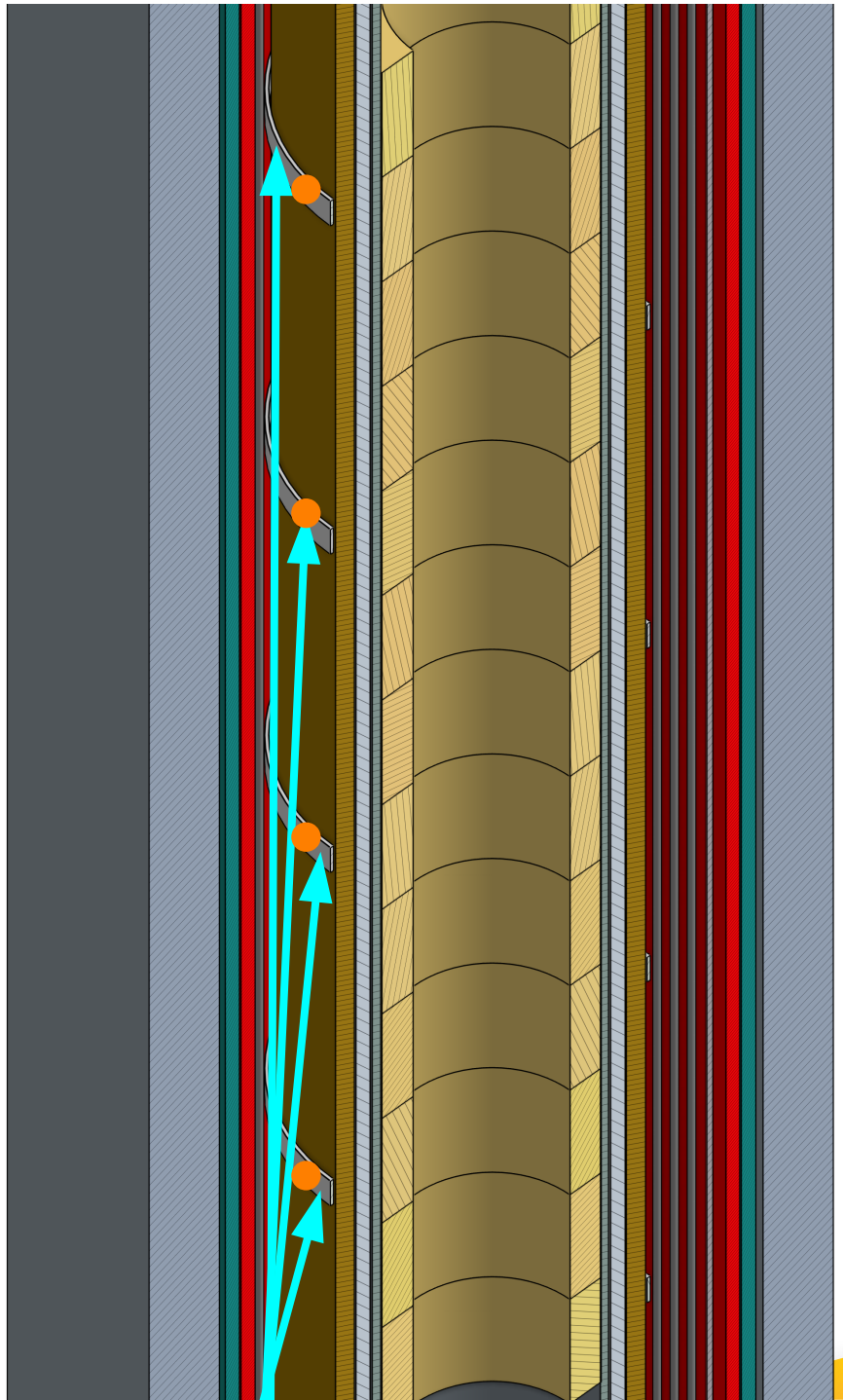
Factors that affect particle drift:

- Pressure
- Temperature
- Gas mixture
- Magnetic field

Laser Calibration

Technique

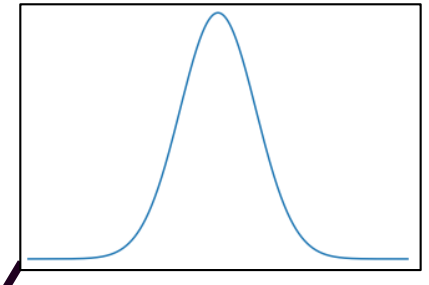
Laser type: Nd:YAG
Laser pulsed beam: 50 Hz
Wavelength: **266 nm**
Energy operated: < 0.1mJ
Al strip width: 6 mm

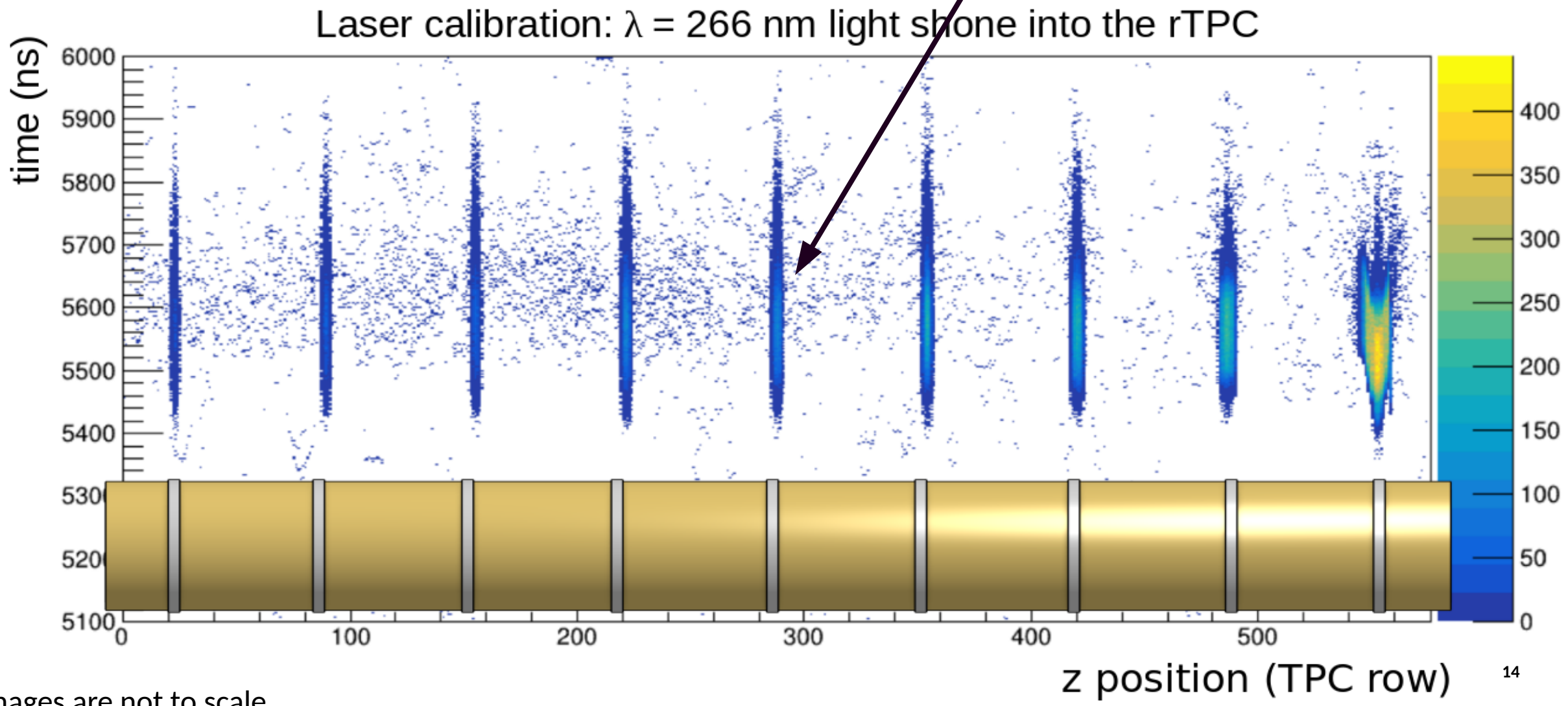


**Images are not to scale. Parts of the apparatus have been greatly exaggerated for clarity.

Laser Calibration

Proof of Concept





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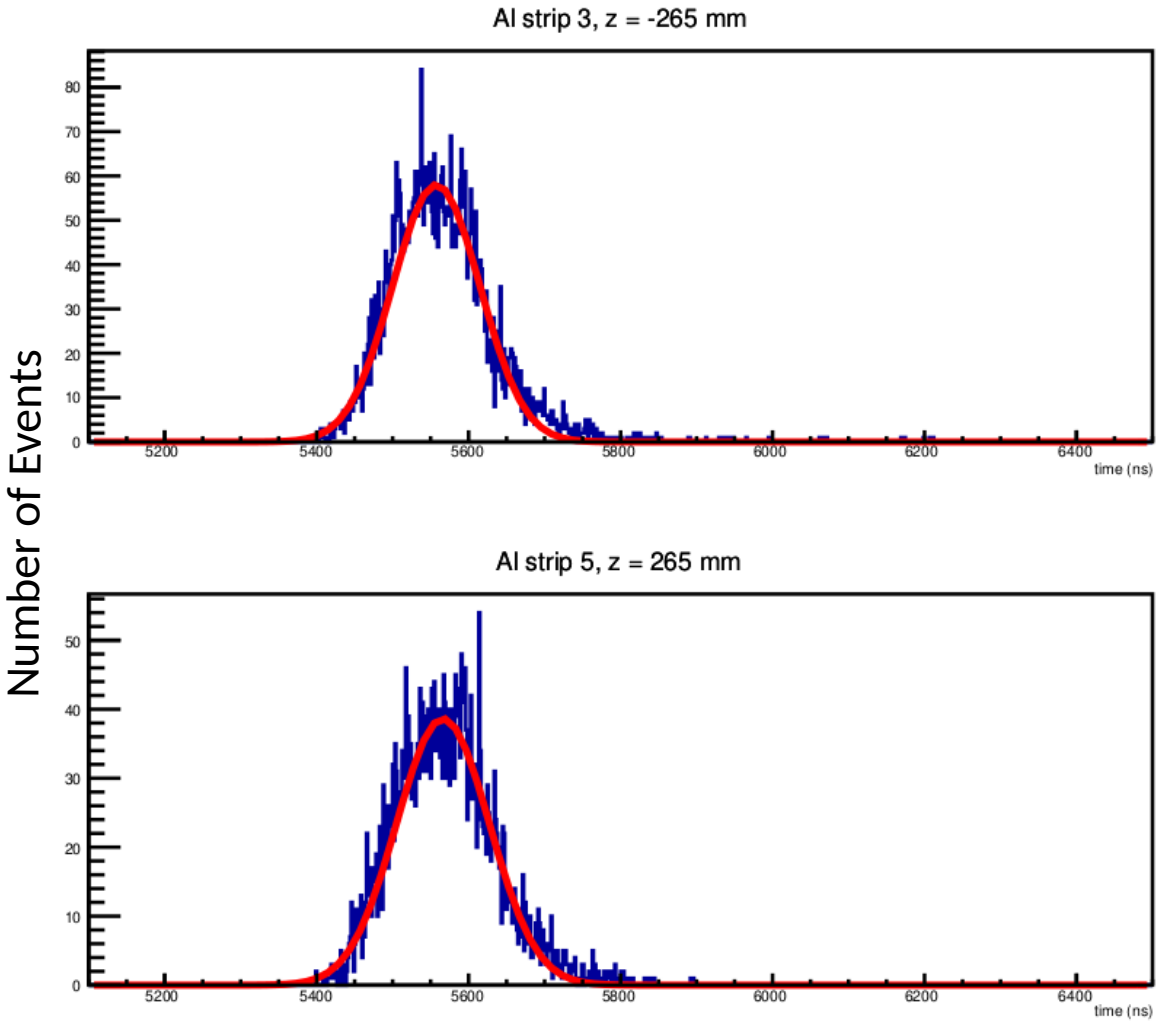
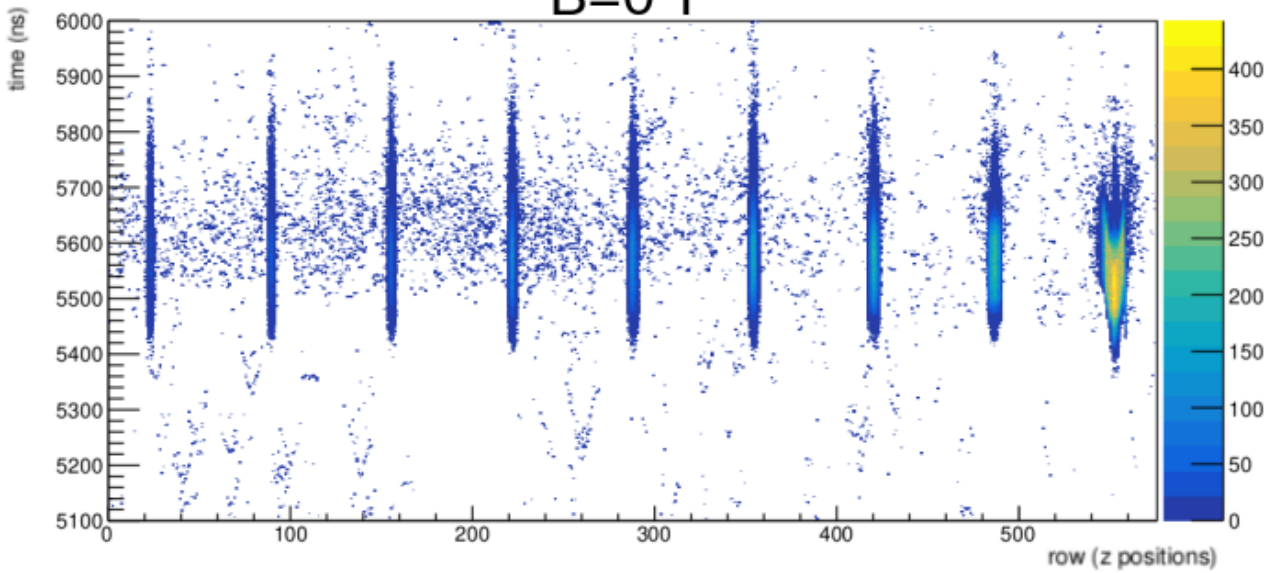
Laser Calibration

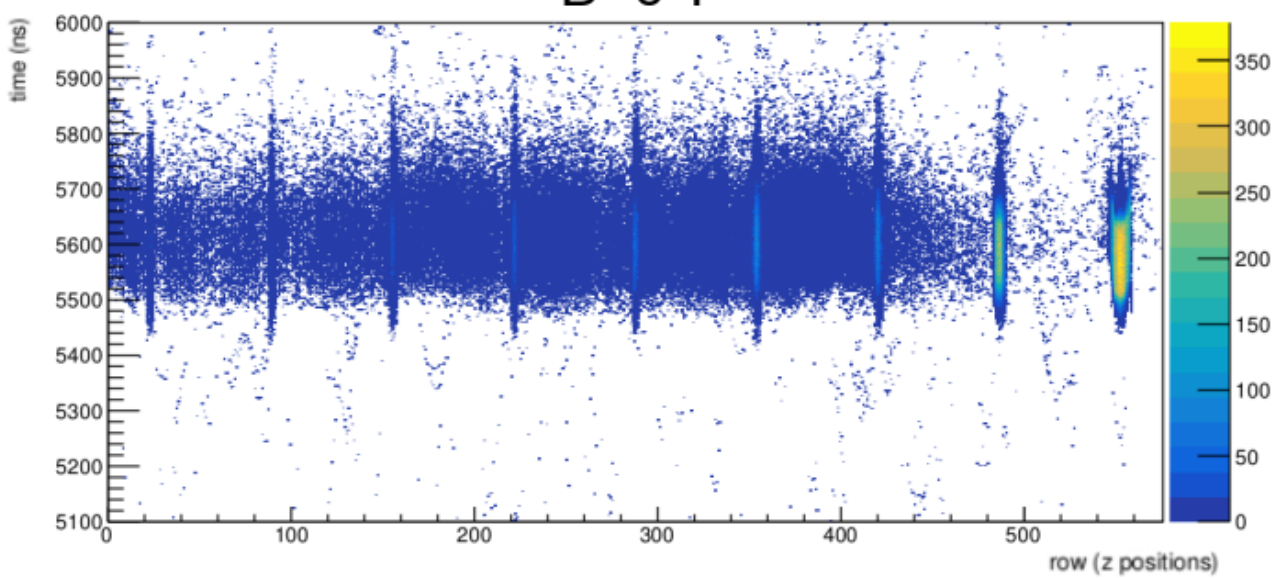
Proof of Concept



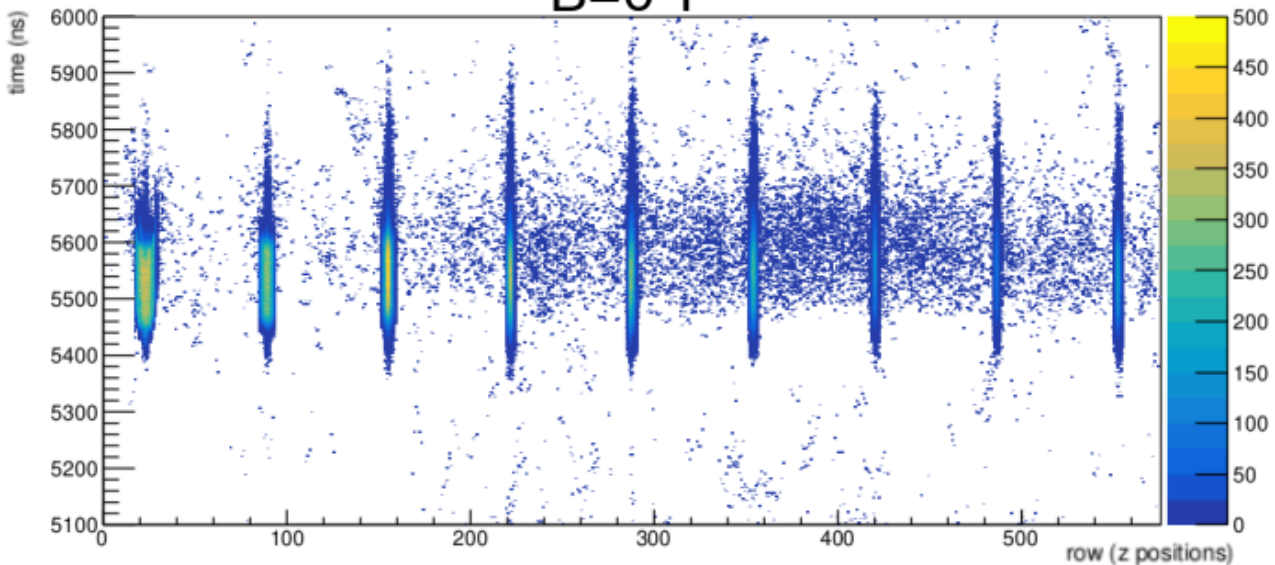
# Run 4943 Fibre T11 (Top of Detector)
B=0 T



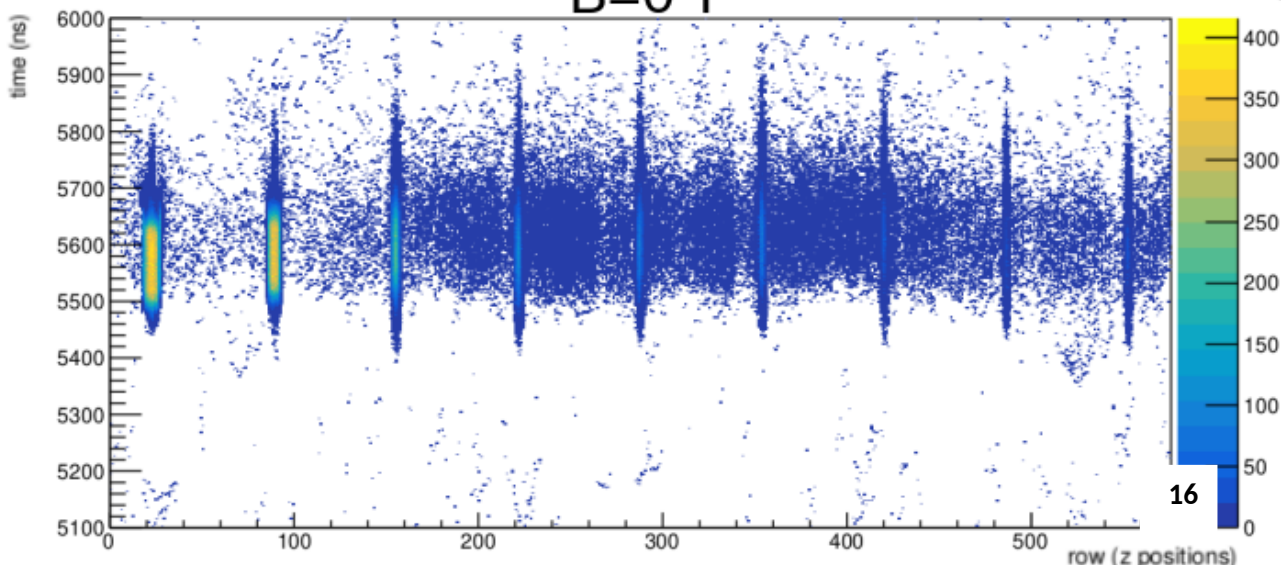
# Run 4947 Fibre T03 (Top of Detector)
B=0 T

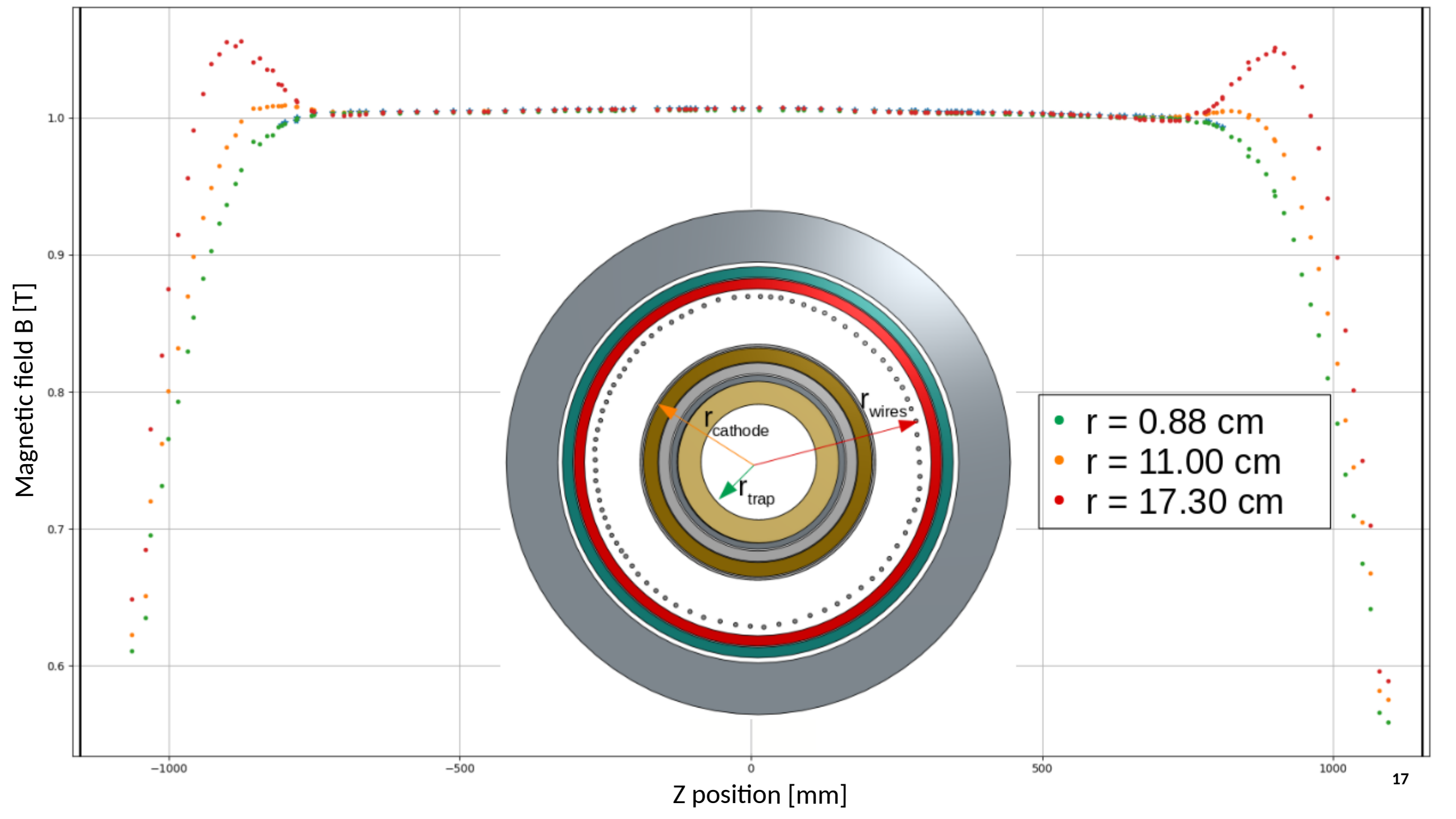


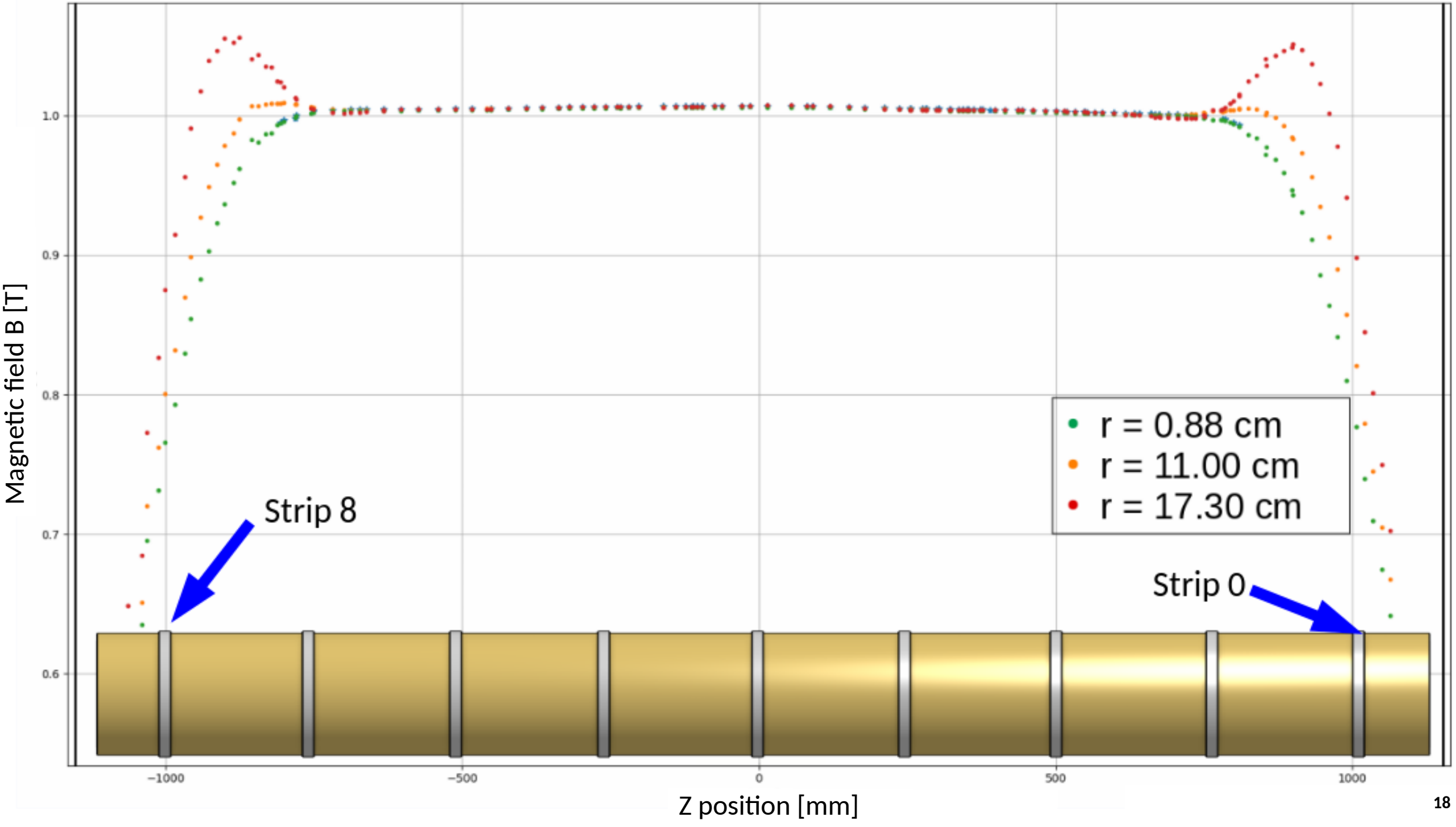
# Run 4949 Fibre B07 (Bottom of Detector)
B=0 T



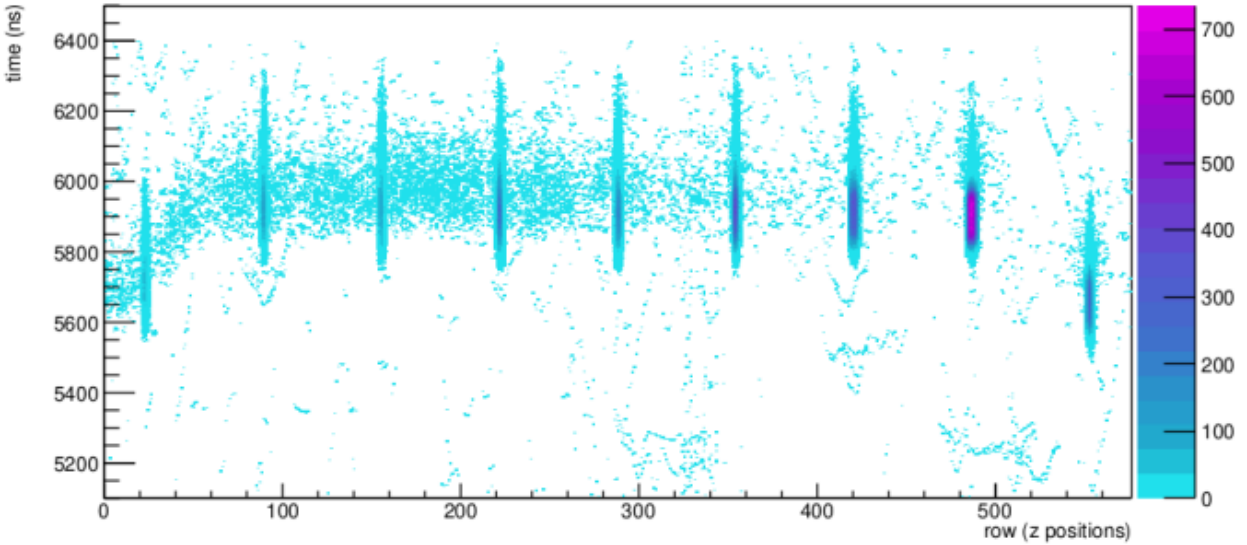
# Run 4951 Fibre B15 (Bottom of Detector)
B=0 T



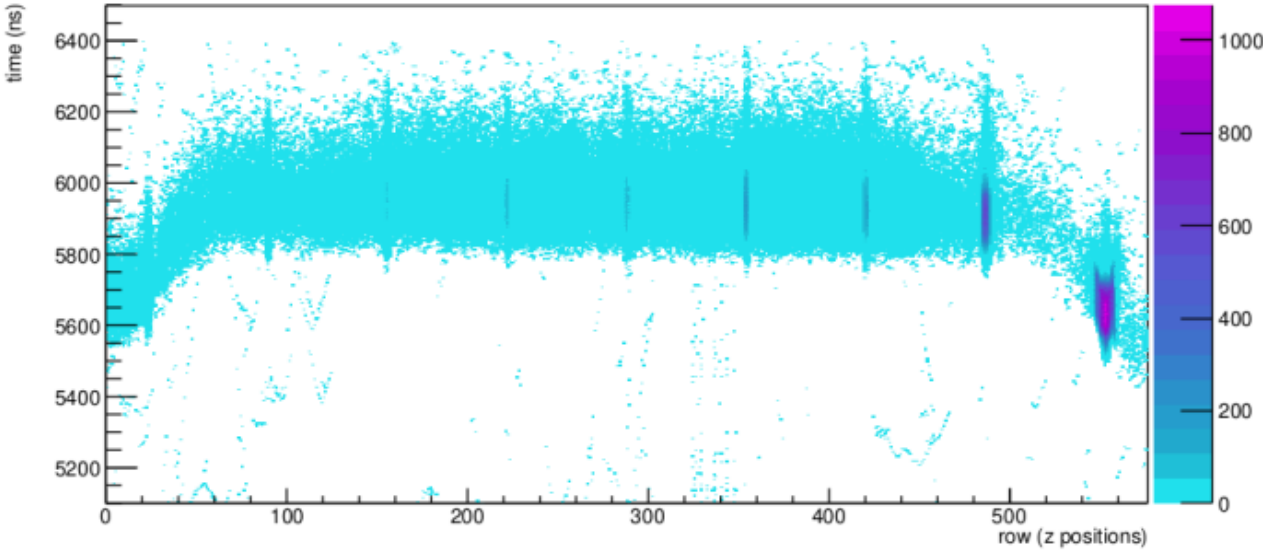

Magnetic field B [T]
1.0
0.9
0.8
0.7
0.6
−1000
−500
0
500
1000
Z position [mm]
r cathode
r wires
r trap
r = 0.88 cm
r = 11.00 cm
r = 17.30 cm


Magnetic field B [T]
1.0
0.9
0.8
0.7
0.6
r = 0.88 cm
r = 11.00 cm
r = 17.30 cm
Strip 8
Strip 0
−1000
−500
0
500
1000
Z position [mm]

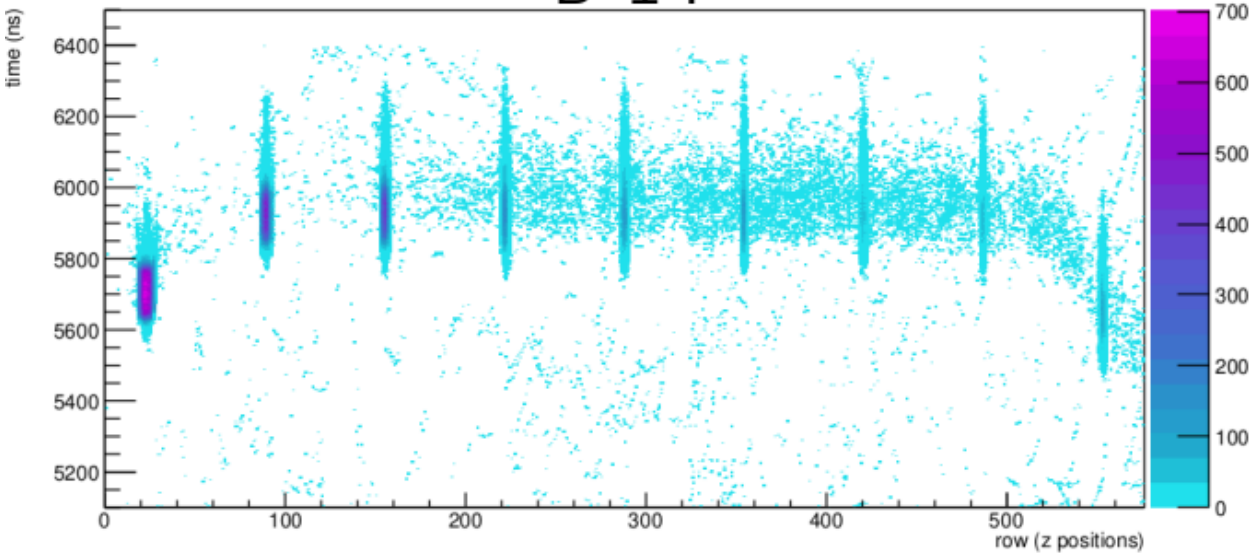
Run 6343 Fibre T11 (Top of Detector)
B=1 T



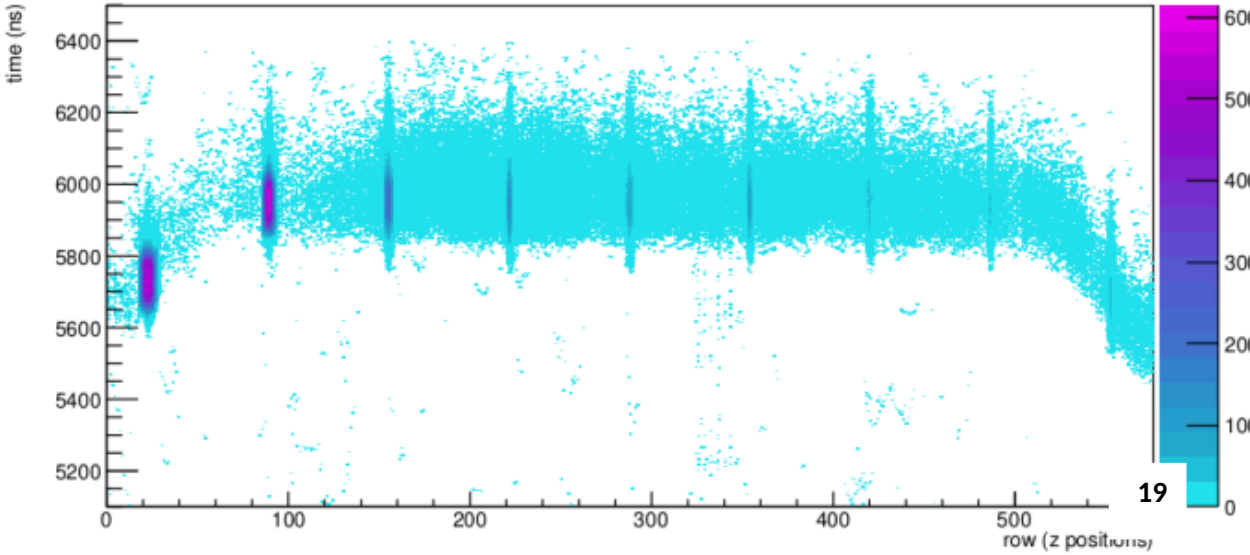
Run 6344 Fibre T03 (Top of Detector)
B=1 T



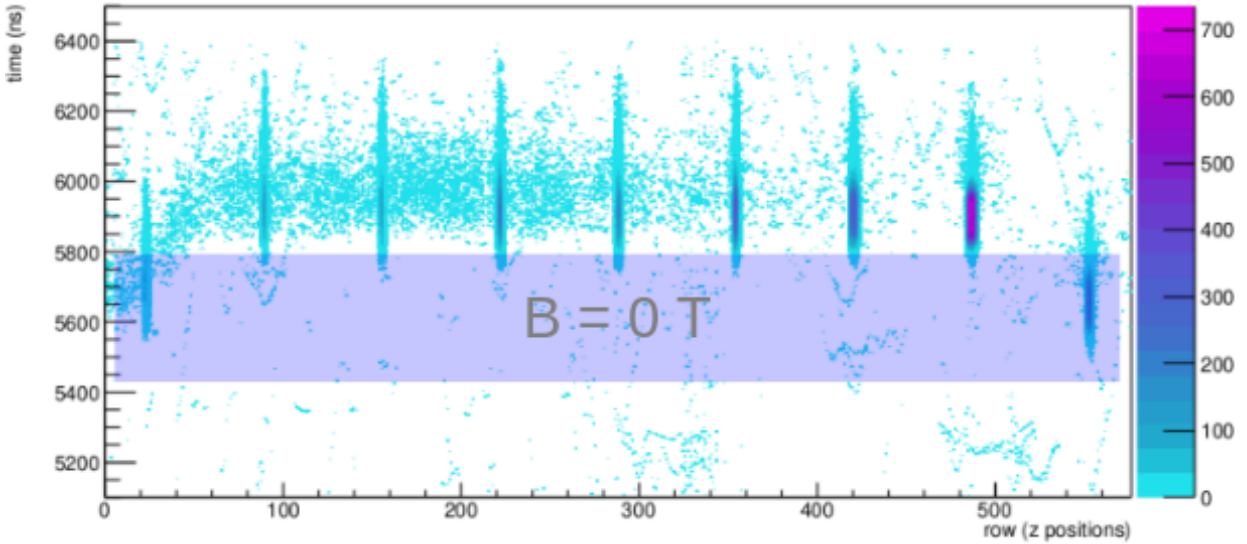
Run 6342 Fibre B07 (Bottom of Detector)
B=1 T



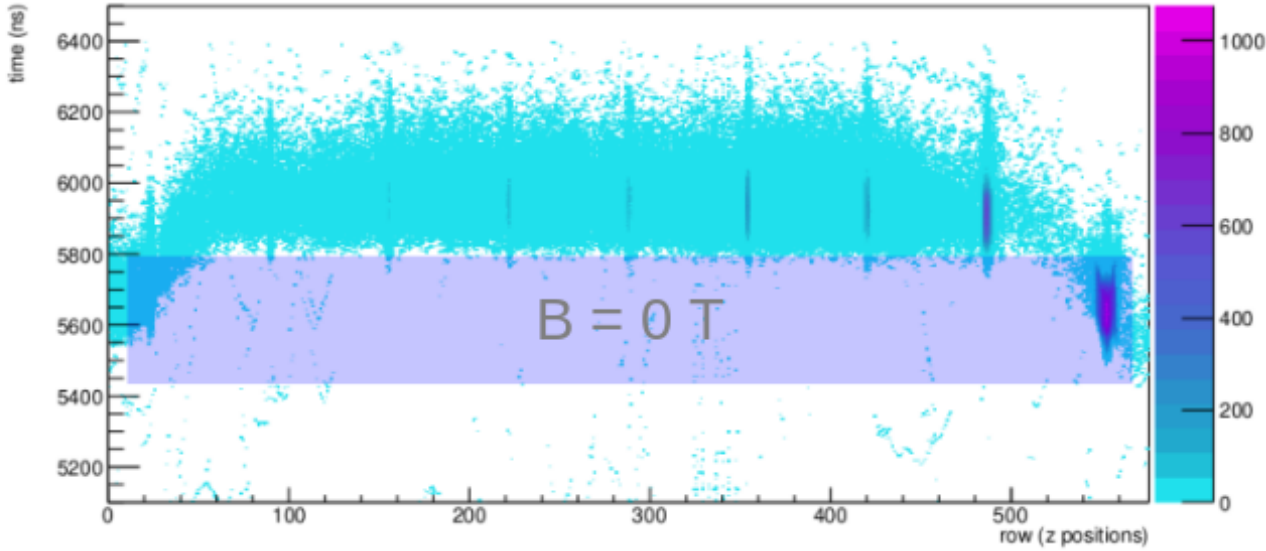
Run 6341 Fibre B15 (Bottom of Detector)
B=1 T



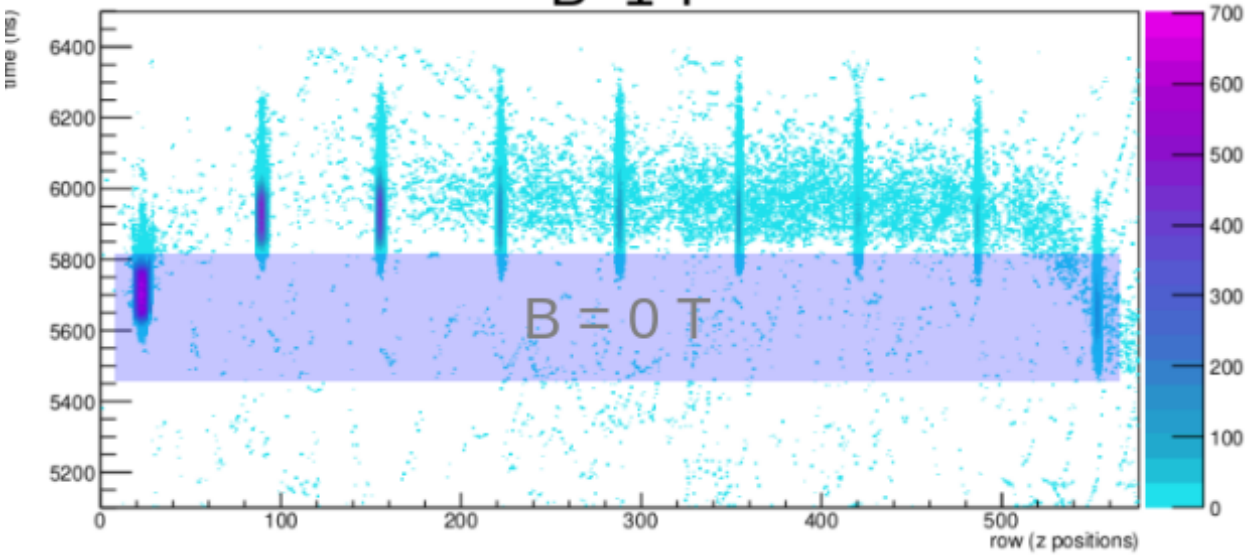
Run 6343 Fibre T11 (Top of Detector)
B=1 T



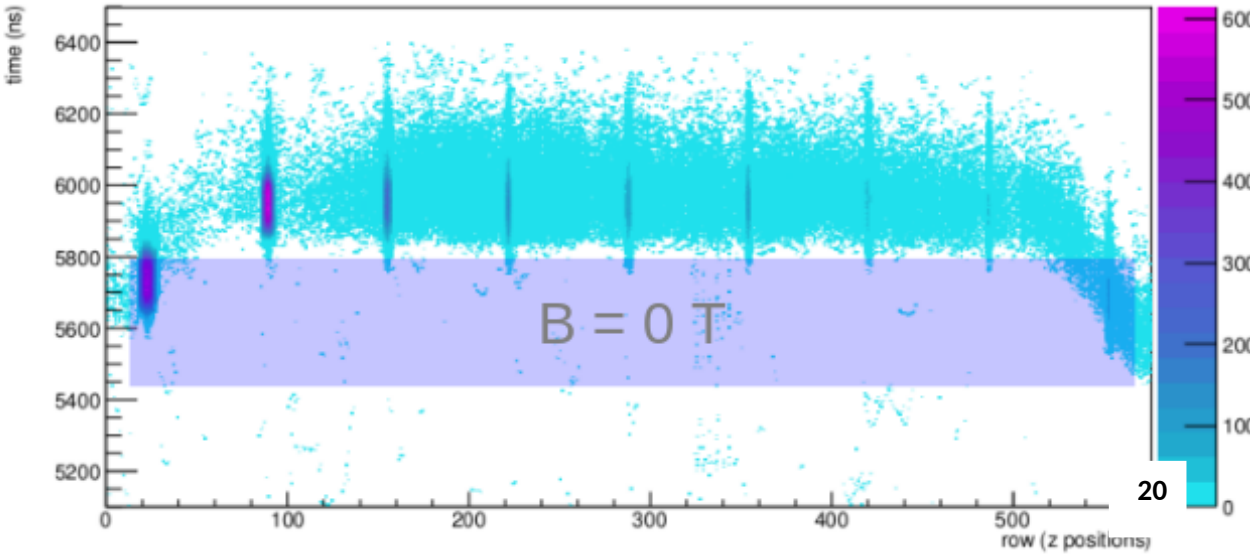
Run 6344 Fibre T03 (Top of Detector)
B=1 T



Run 6342 Fibre B07 (Bottom of Detector)
B=1 T

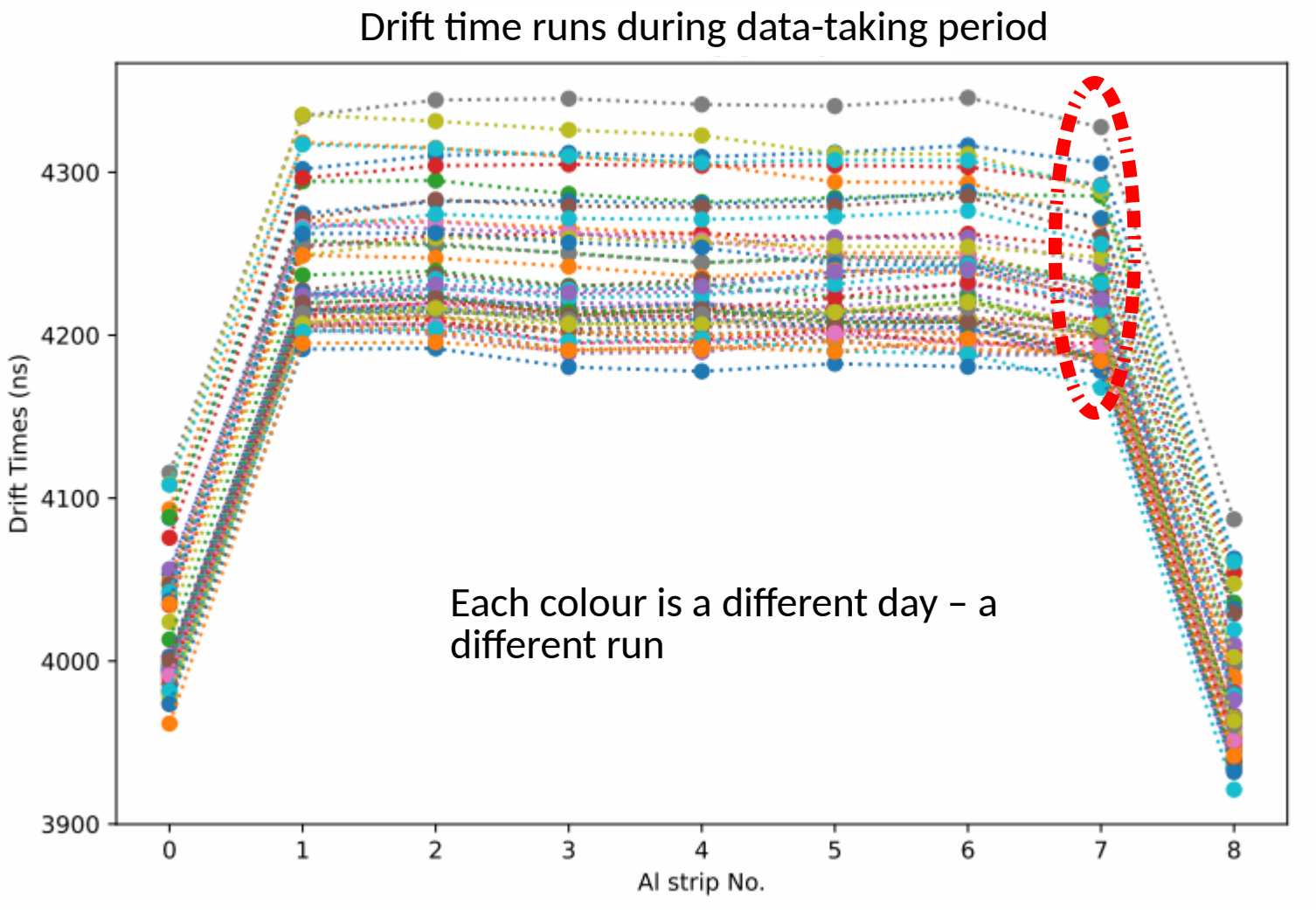


Run 6341 Fibre B15 (Bottom of Detector)
B=1 T



Laser Data Drift Times

drift time max change

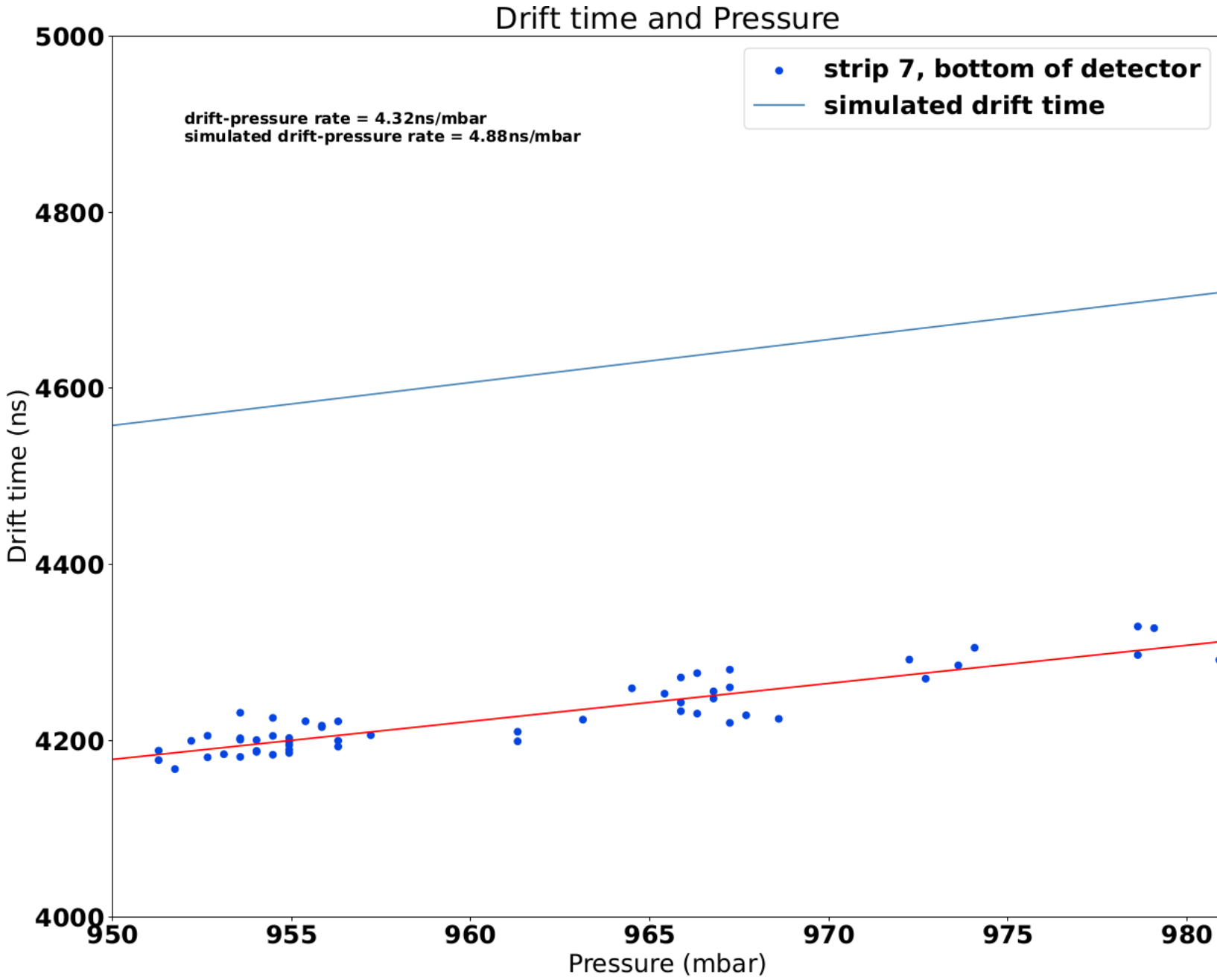


- Upper limit on drift time was found to be **165.9 ns** (or **4.2%** difference)
- During the time period of November 2 and December 15, 2022

Laser Data

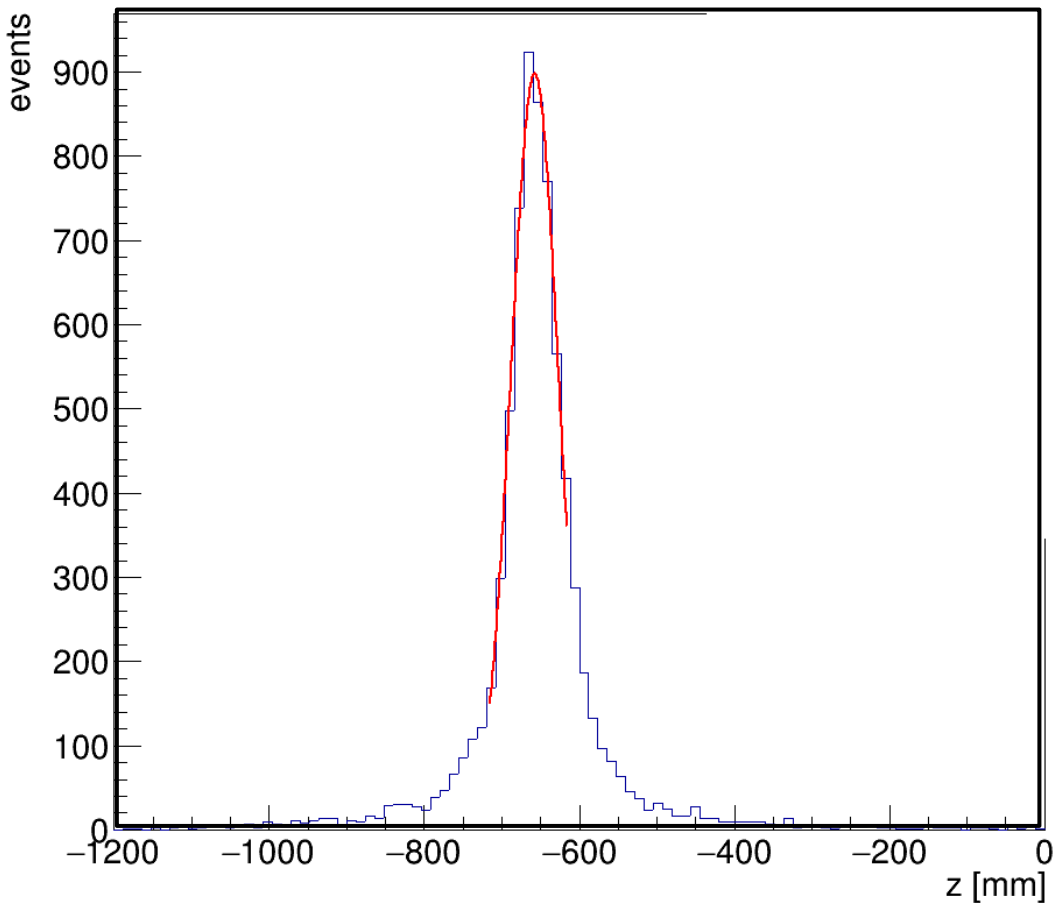
drift time vs pressure

- Nice linear correlation with pressure
- Over the same period, the pressure difference was **31.9 mbar**



Laser Data

drift time and z position



- Controlled antiproton for annihilation calibrations
- Adjust z position reconstructions to account for max drift of 4.2%

Drift time adjustment	z (mm)	z error (mm)	Sigma z (mm)	Sigma error (mm)
0%	-658.214	0.563535	31.1112	0.6065
4.2%	-657.672	0.556122	30.4971	0.5830

$\Delta z < 1$ mm

Conclusion

- ALPHA-g has successfully commissioned the detector to move forward with the experiment
- Laser calibration is crucial to determining key drift information in the rTPC
- Future laser calibration work includes analysis to determine observables such as the Lorentz angle to futher improve reconstructions

Thank you!

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ALPHA

CINP ICPN

NSERC CRSNG

INNOVATION
Canada Foundation for Innovation
Fondation canadienne pour l'innovation

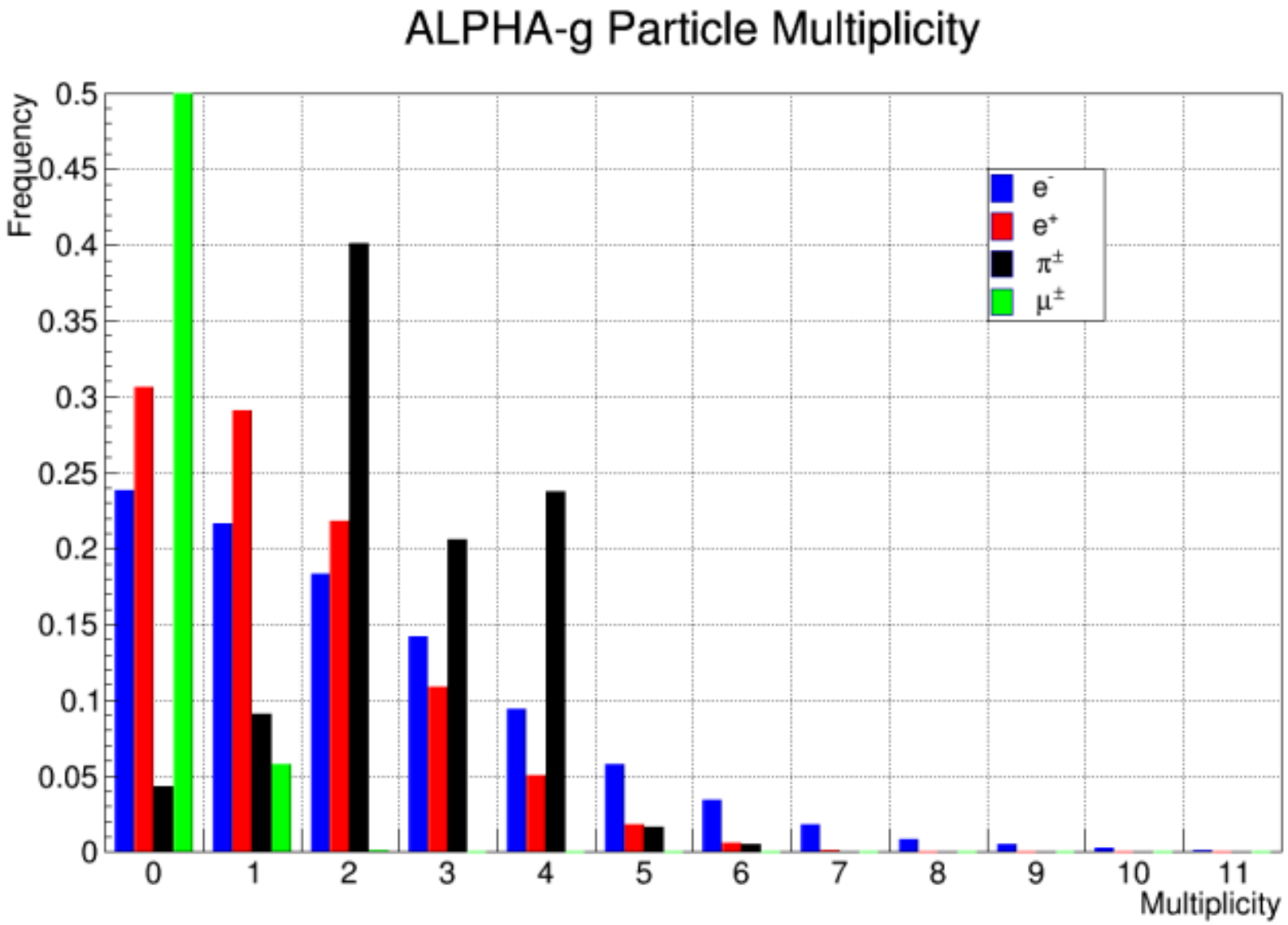
TRIUMF

CERN

rTPC gas mixture

- 70% Argon, 30% CO2

Particle Multiplicity



Work Functions