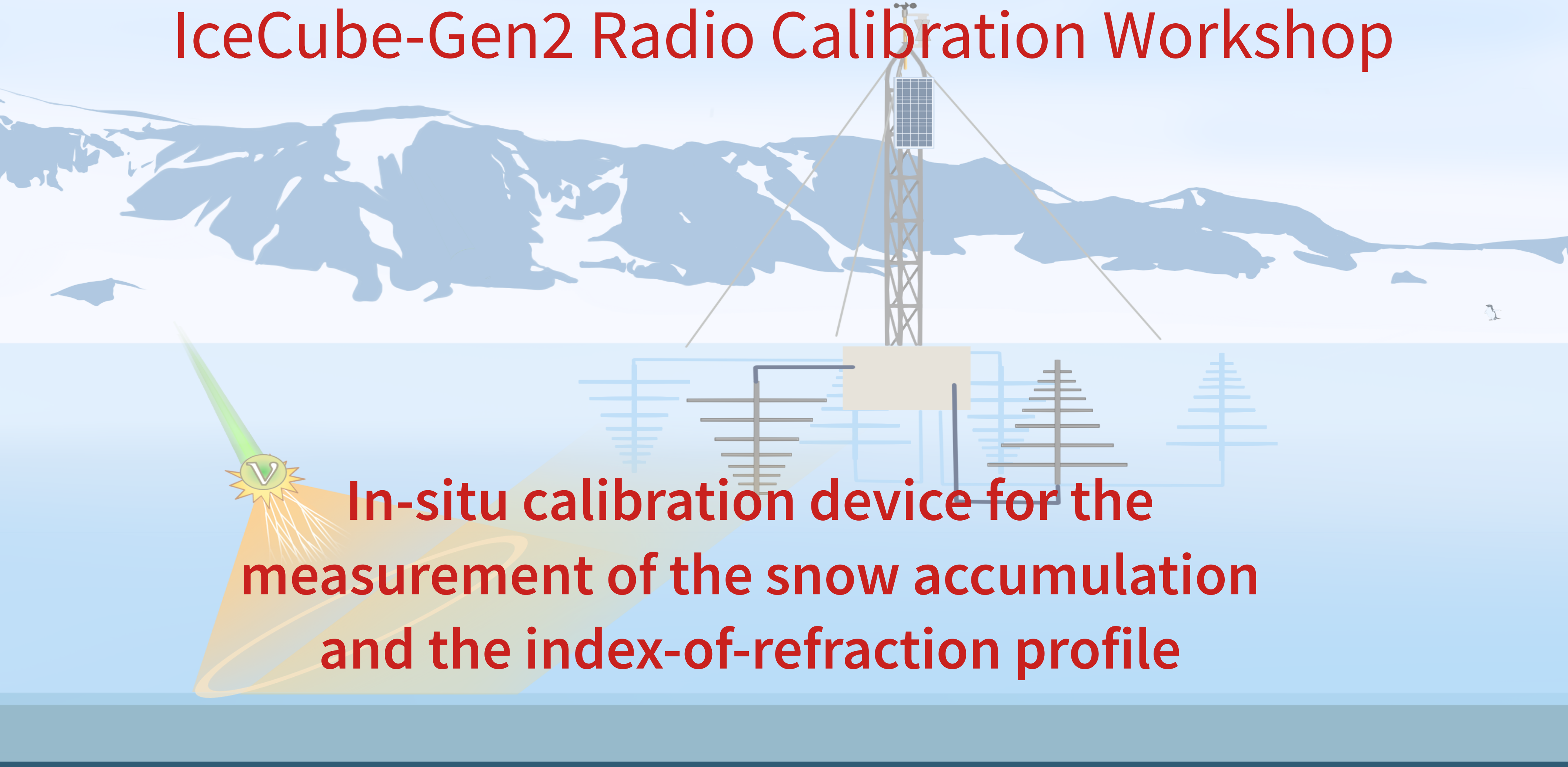
# IceCube-Gen2 Radio Calibration Workshop



## In-situ calibration device for the measurement of the snow accumulation and the index-of-refraction profile

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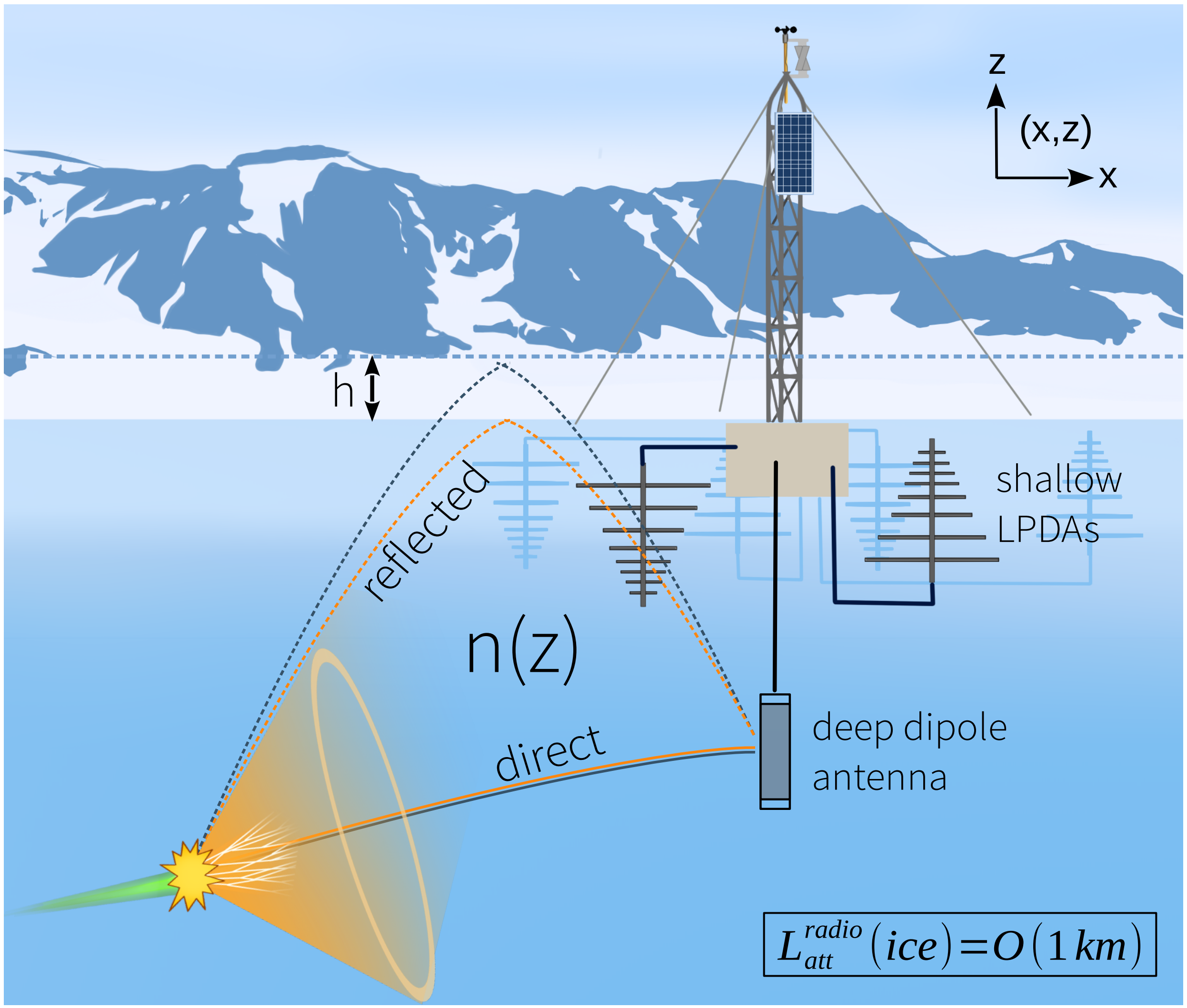
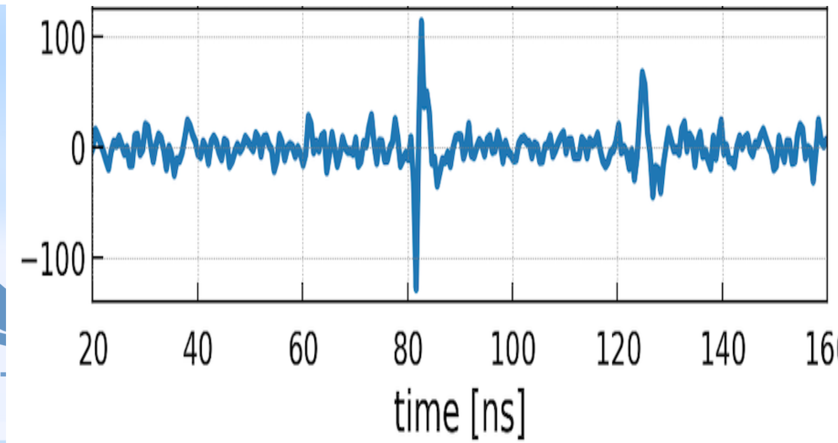
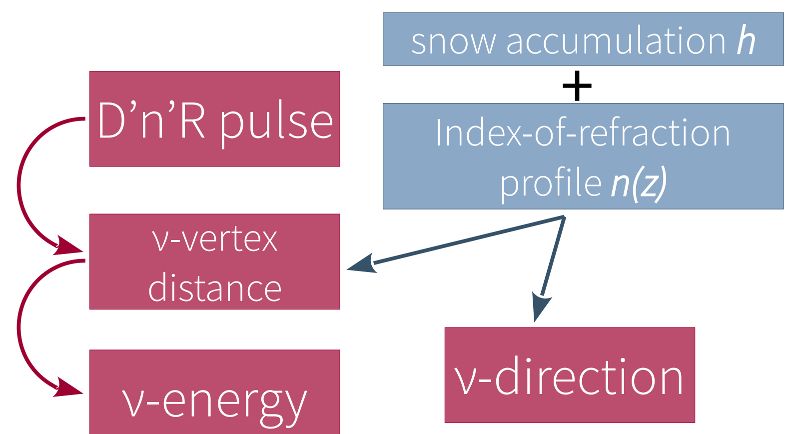
# Firn properties and D’n’R technique

Credit: ARIANNA Collaboration,
Journal of Cosmology and Astroparticle Physics 11(2019)030



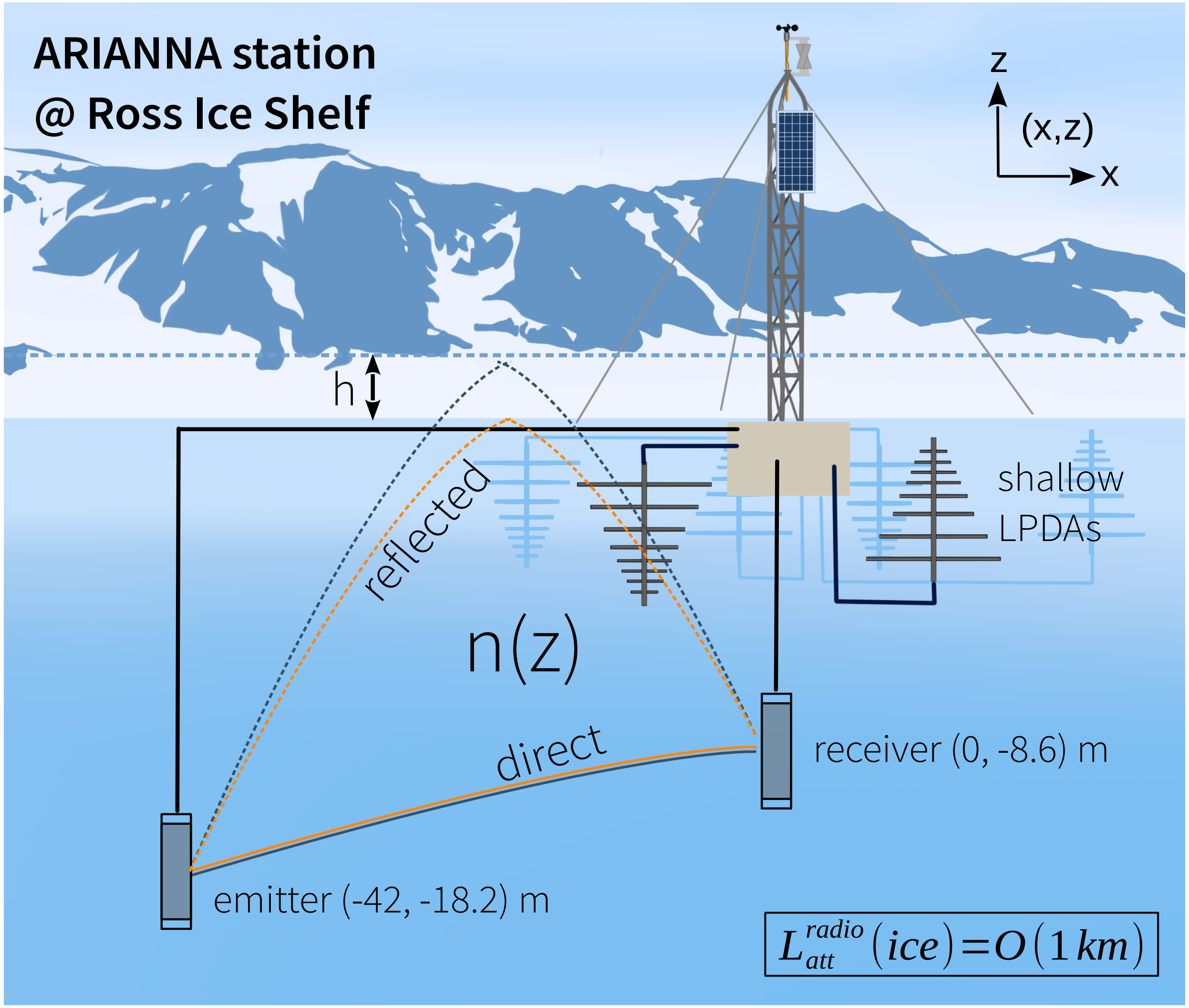



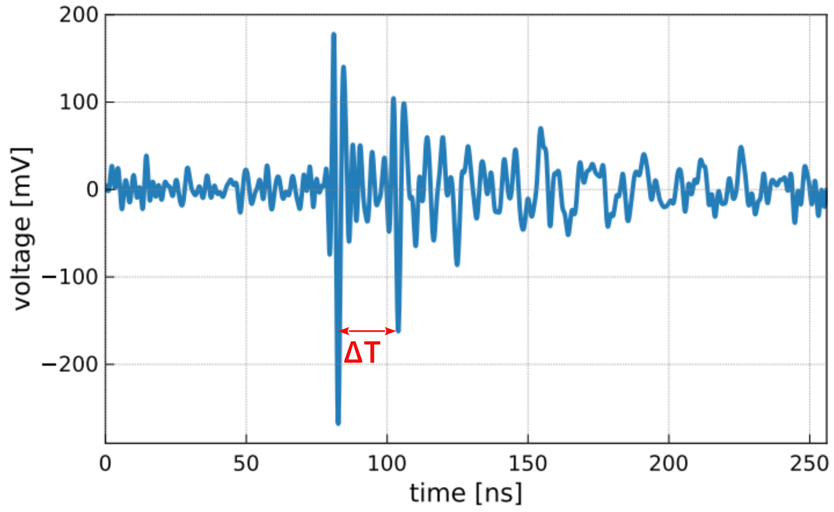

D’n’R technique:



# Set-up for the snow accumulation measurement

Credit: ARIANNA Collaboration,
Journal of Cosmology and Astroparticle Physics 11(2019)030



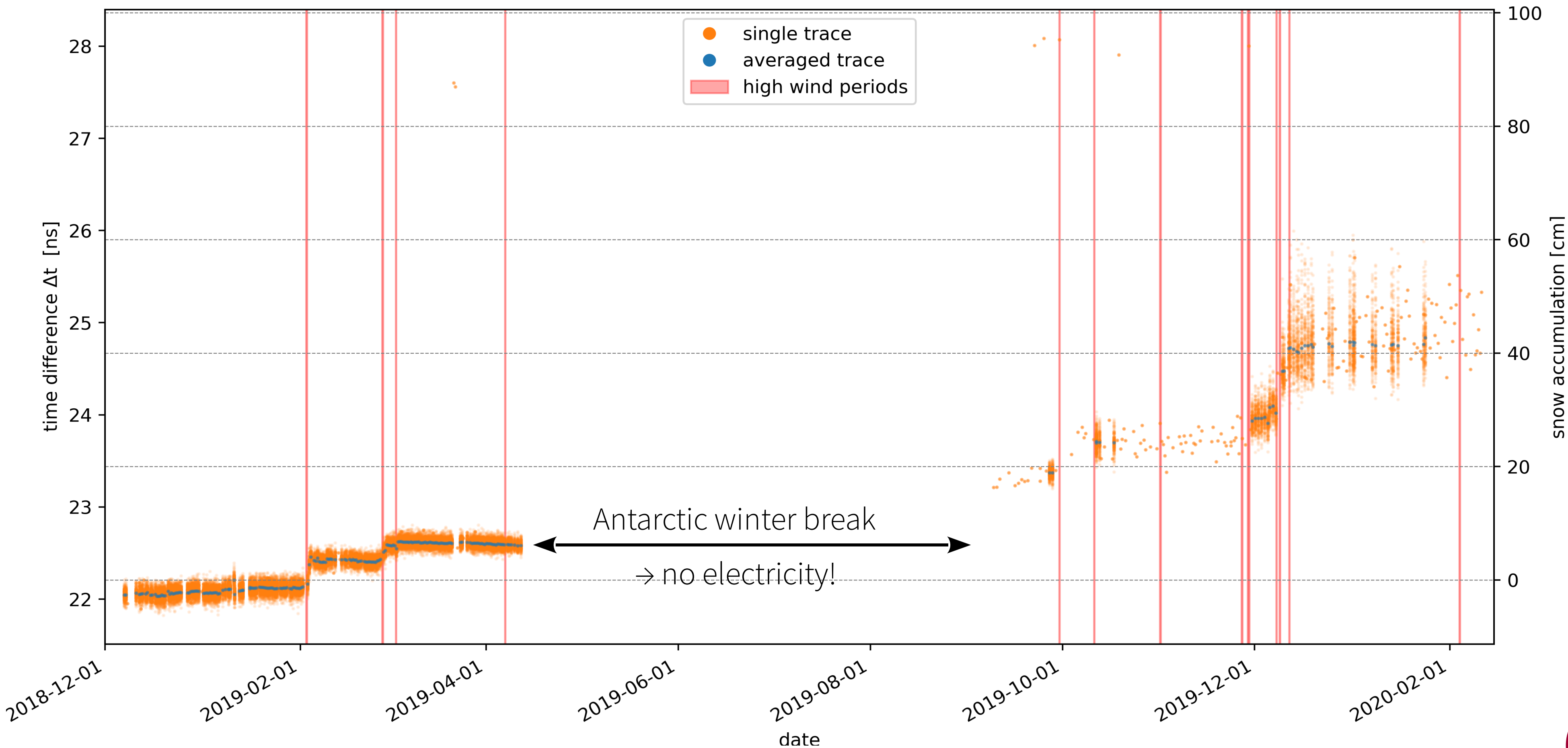




- Pulser triggers emitter generating a burst of 150 events every 12 h
- h~ΔT using known geometry and n(z)

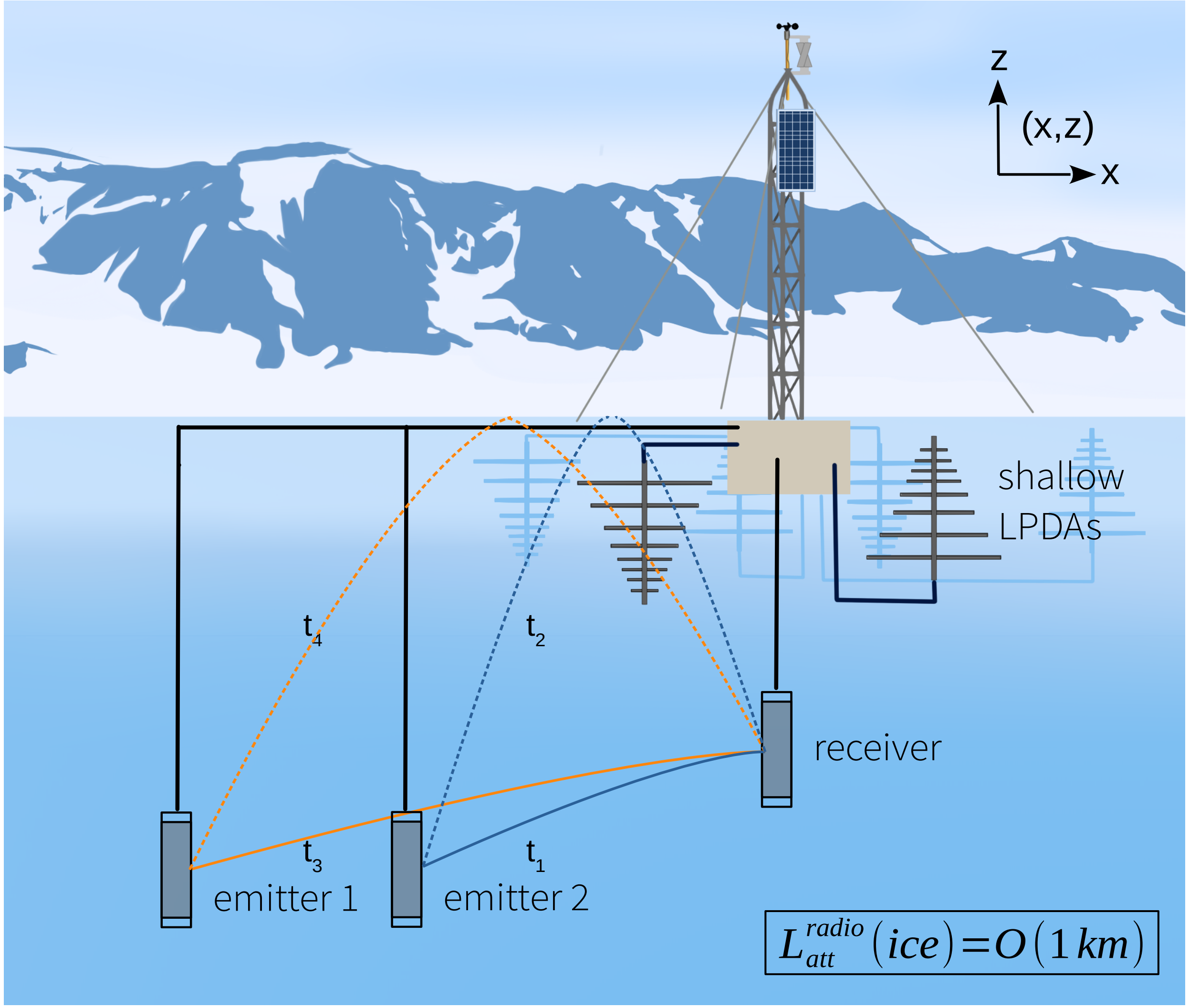
# Snow accumulation measurement

Credit: ARIANNA Collaboration,
Journal of Cosmology and Astroparticle Physics 11(2019)030

- In-situ measurement for one ARIANNA station at Ross Ice-Shelf
- Scatter for averaged traces ~1 mm (5 ps) to ~ 5mm (25 ps)
- Jumps in snow accumulation correlate to periods of high winds



# Extension to the measurement of the n(z) profile




Refractive index with depth:

$$n(z)=n_0-\Delta n\cdot\exp(-z/z_0)$$

1.78

Δn: change of refractive index

z0: characteristic length

- Reconstruct **h, Δn, $z_0$**
- 3 independent observables

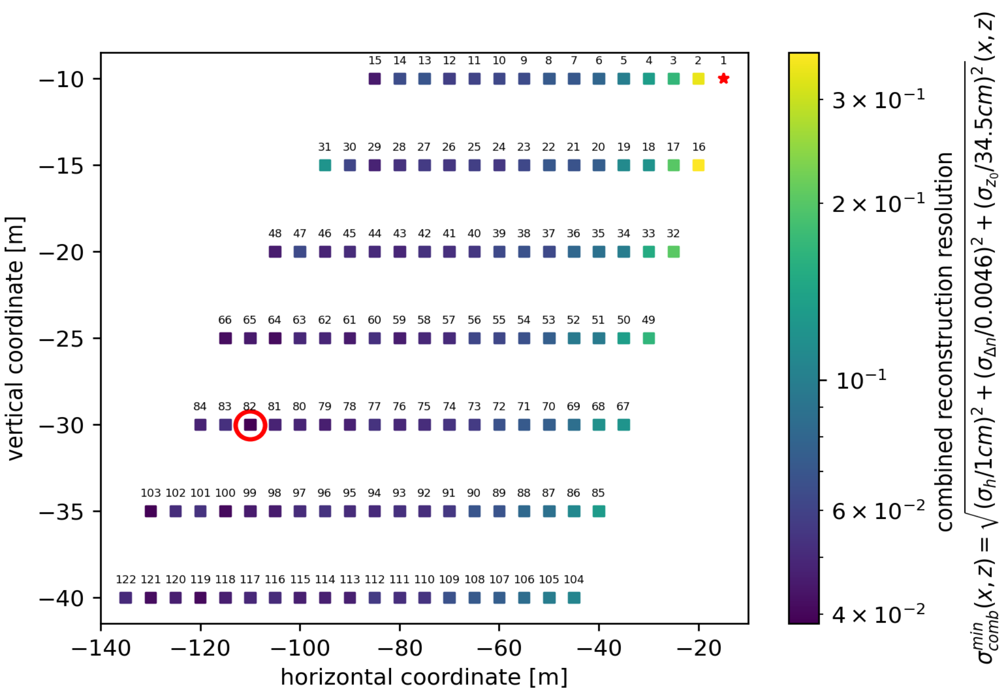
$\Delta t_{21}=t_2-t_1, \Delta t_{31}=t_3-t_1, \Delta t_{41}=t_4-t_1$

- Optimize emitter configuration

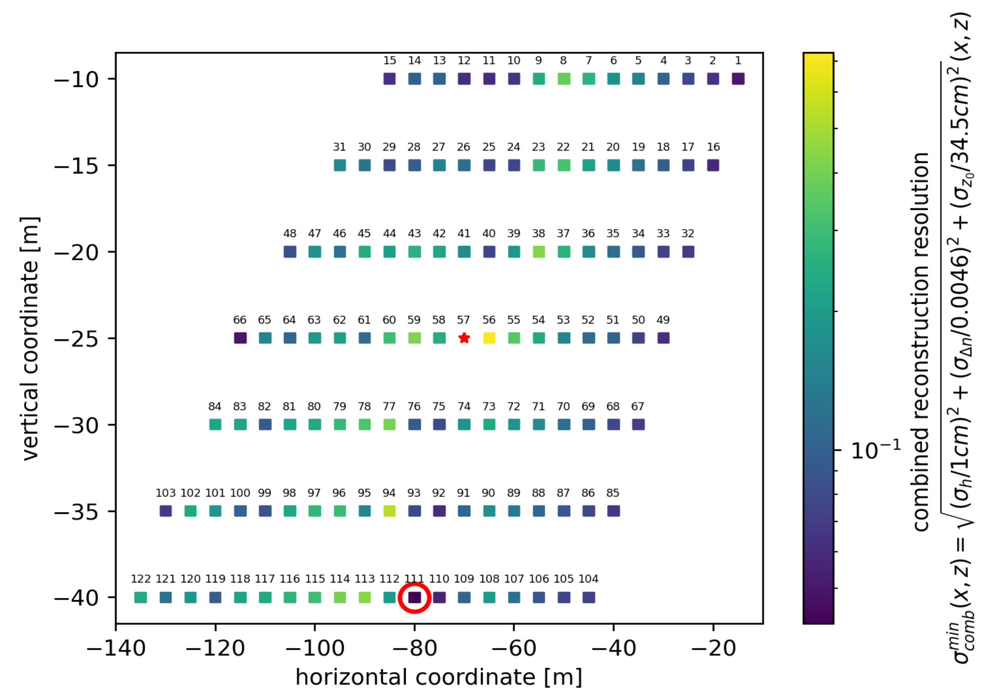
# Optimizing emitter position

- Simulate 10,000 measurements with event uncertainty of 0.2 ns
- Grid of possible conditions is constrained

for E1 @ (-15,-10) m, optimal E2 @ (-110,-30) m




for E1 @ (-70,-25) m, optimal E2 @ (-80,-40) m




$$\sigma_h \sim O(cm), \sigma_{z_0} \sim O(m) \Rightarrow \sigma_{comb} = \sqrt{(\sigma_h/1\,cm)^2 + (\sigma_{\Delta n}/0.0046)^2 + (\sigma_{z_0}/34.5\,cm)^2}$$

# Achievable precision

- Find configuration of emitters where **reconstruction resolution** and **correlation** between parameters is minimal:
- Reconstruction resolution independent of E1 position, E2 can always be placed so that combined resolution is good
  ↳ Correlation provides a clear minimum

**optimal configuration: E1**: [-115, -20] m, **E2**: [-30, -25] m
(per 100 events uncertainty)

| | | | |
|---|---|---|---|
| (relative) Reconstruction Resolution | $\sigma_h$=4 mm | $\sigma_{\Delta n}$=0.08% | $\sigma_{z0}$=0.12% |
| Correlation | $\rho_{h,\Delta n}$ = -4% | $\rho_{h,z0}$ = -3% | $\rho_{\Delta n,z0}$ = 15% |

# Systematic uncertainty

- A) Emitter deployment uncertainty in **x** of ±1 cm

  $\sigma(\Delta n)$ ~ 0.022%, $\sigma(z_0)$ ~ 0.004%

- B) Emitter deployment uncertainty in **z** of ±1 cm

  $\sigma(\Delta n)$ ~ 0.08%, $\sigma(z_0)$ ~ 0.09%

- C) Do we have a sensitivity to deviation from the exponential n(z) profile?

# Summary

- In-situ calibration device for snow accumulation measurement
- Extension to a two emitter calibration device
  - **$\sigma(h)$** = 4 mm
  - **$\sigma(\Delta n)$** = 0.08%
  - **$\sigma(z_0)$** = 0.12%
- Study of systematic uncertainties likely the dominating factor
- Impact of n(z) uncertainty on the ν-direction reconstruction

**Proposal:** Equip every station with at least one emitter and check variation in n(z) profile for a few stations equipped with the two emitter calibration system. Adapt layout if necessary.

# BACKUP SLIDES

# Details of snow accumulation analysis

Credit: ARIANNA Collaboration,
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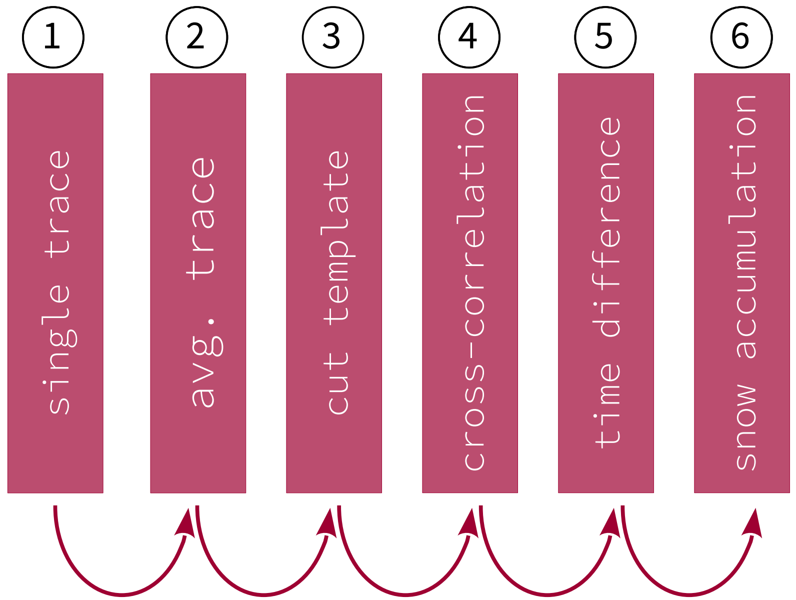
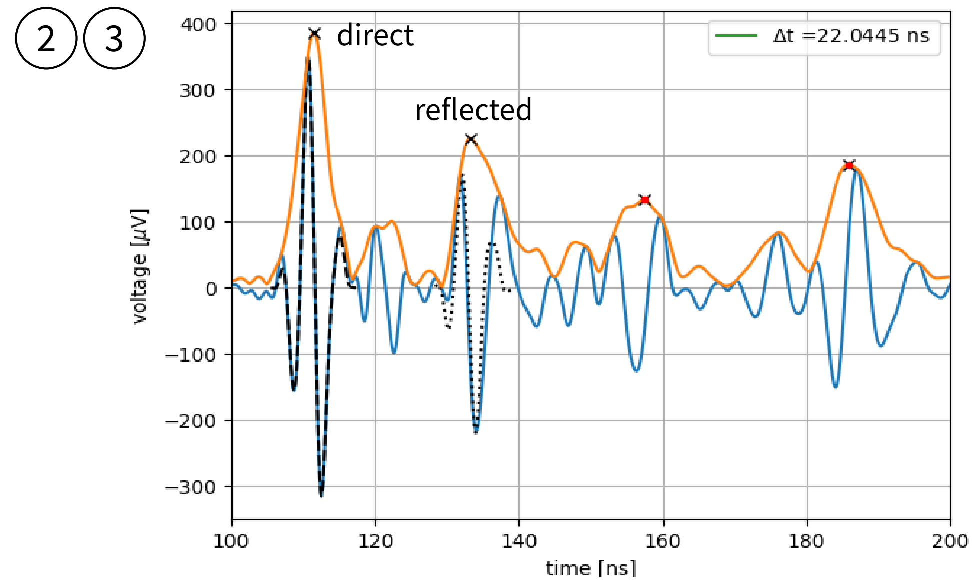
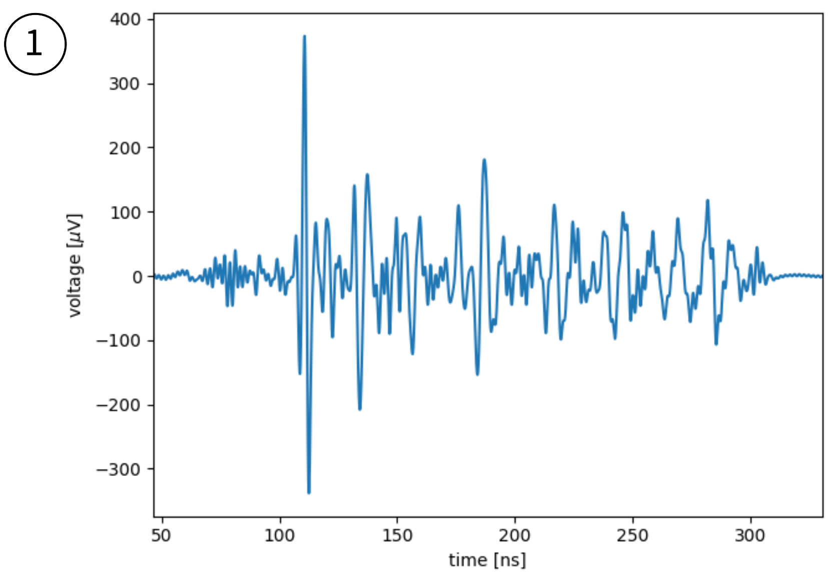
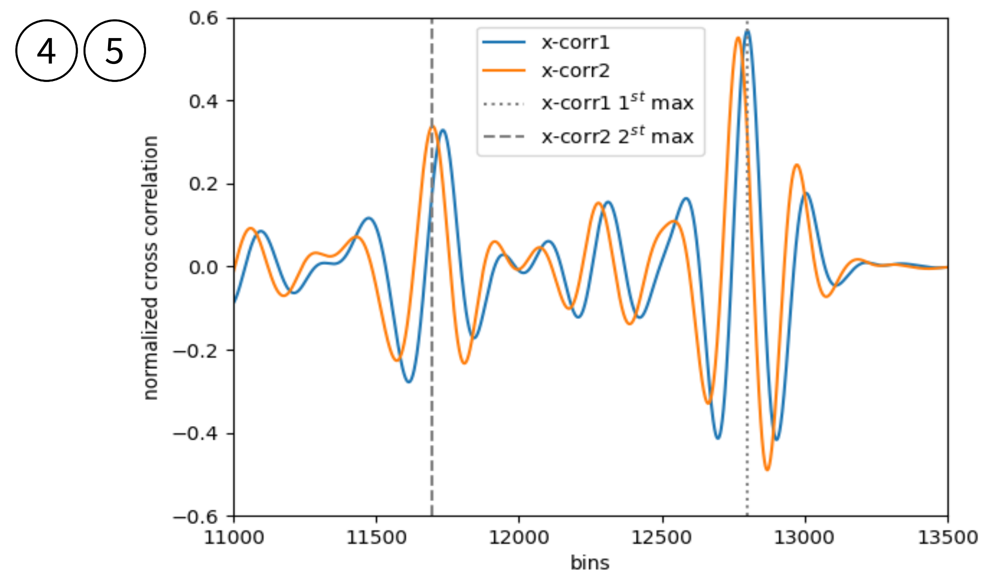


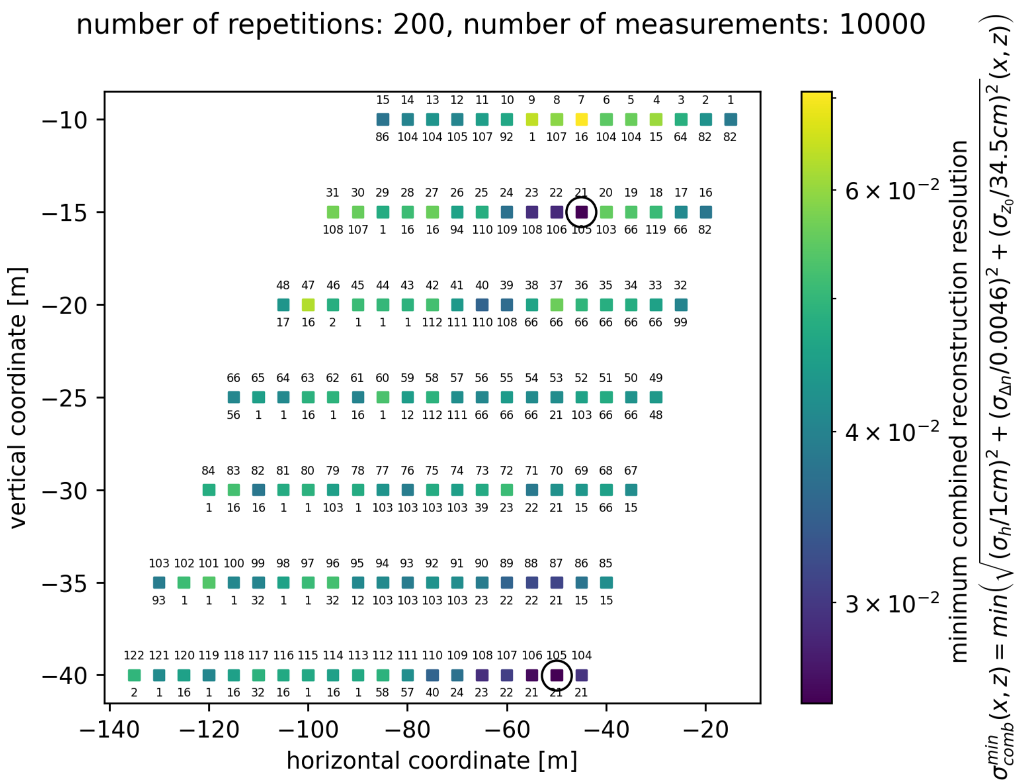



# Reconstruction Resolution and Correlation

## Reconstruction Resolution




## Correlation