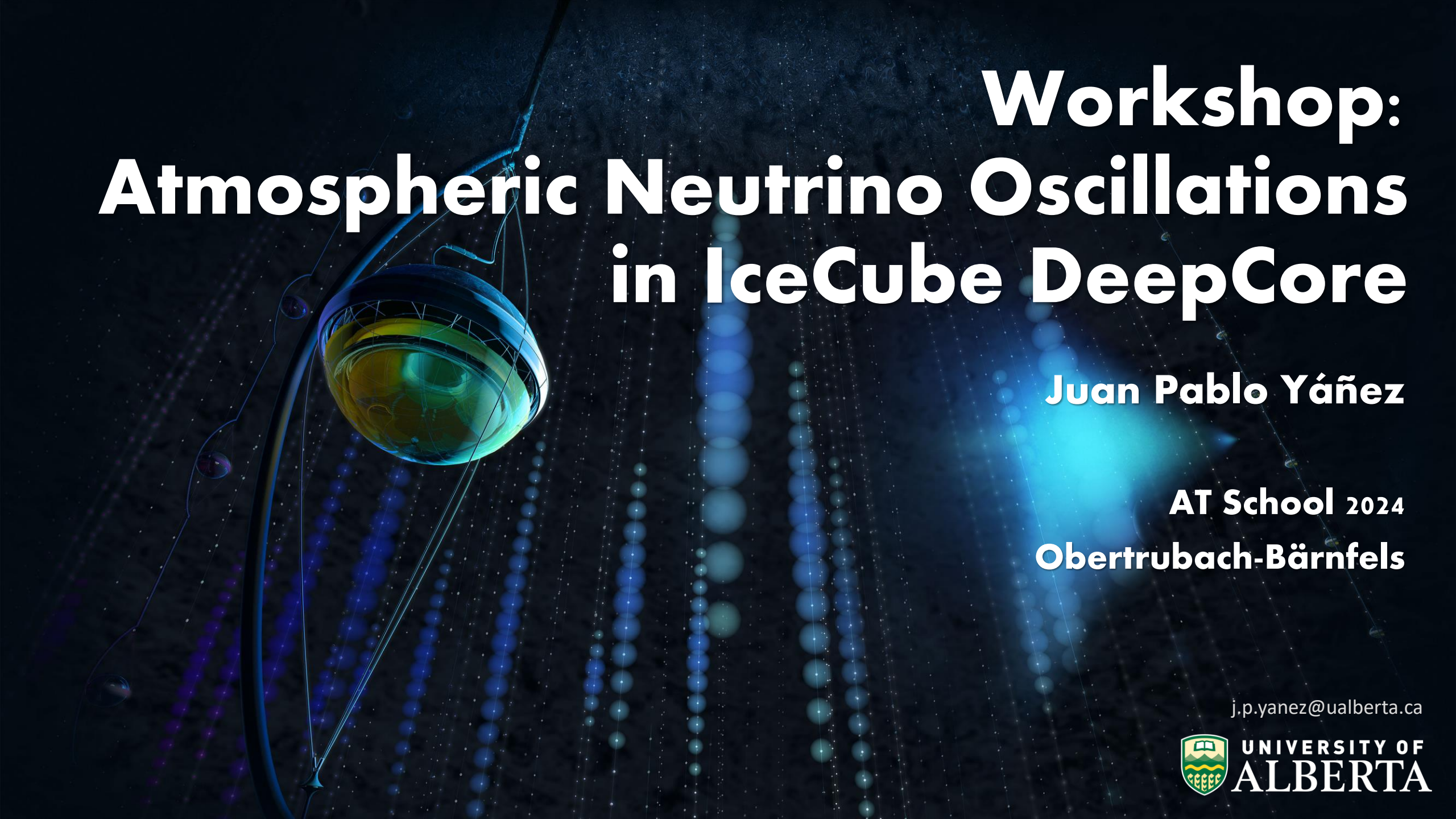

Workshop: Atmospheric Neutrino Oscillations in IceCube DeepCore

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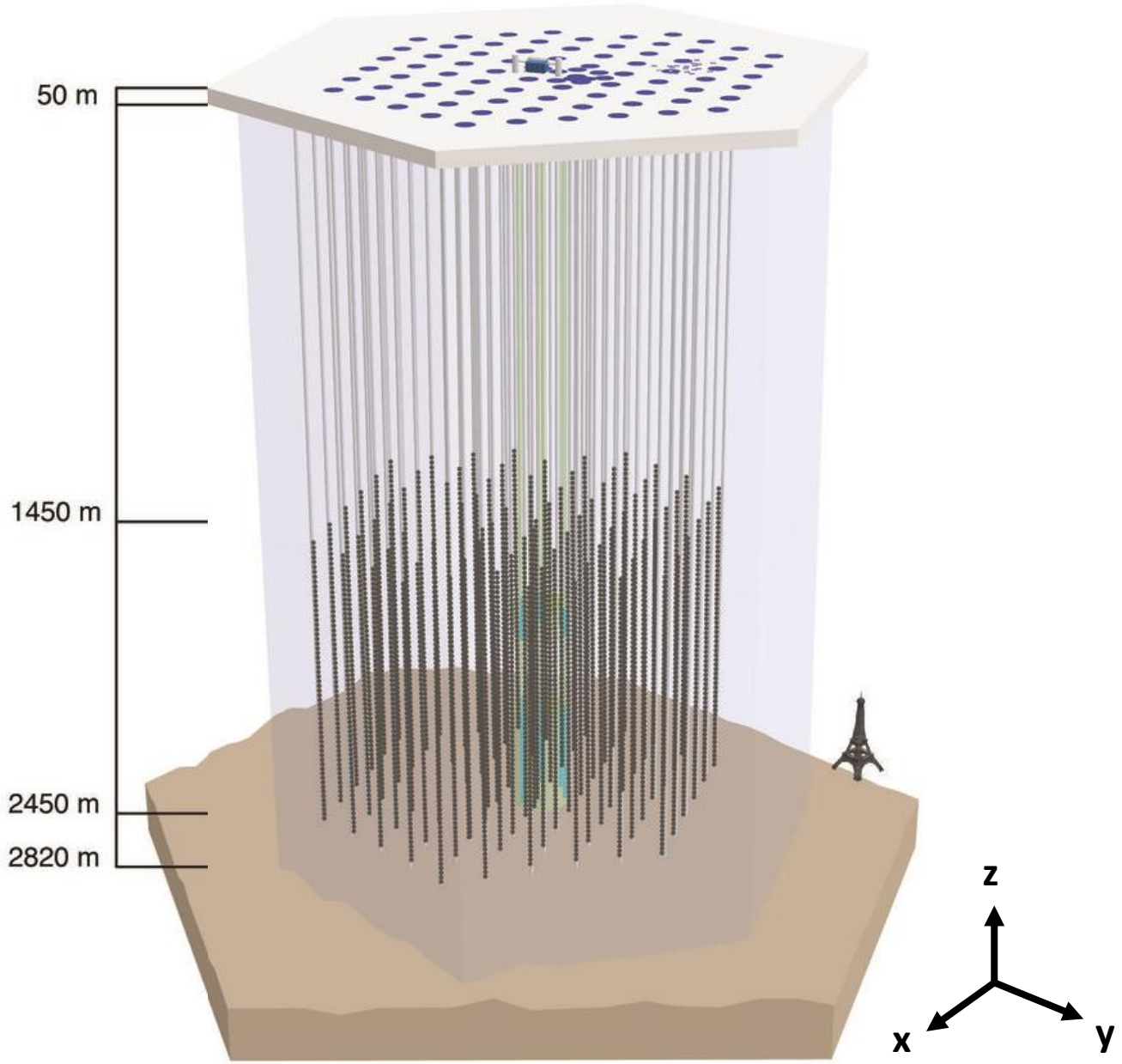
AT School 2024

Obertrubach-Bärnfels

IceCube **ν** detector

- Ice **Cherenkov ν** detector
- 1.5 – 2.5 km under ice
- 5,160 DOMs on 86 strings
- 1 km^3 volume
- High energy array spacing
  - Δz=17m
  - $\Delta(x, y)$=125m
- LE extension: DeepCore
  - Δz=7m
  - $\Delta(x, y)$=40-70m



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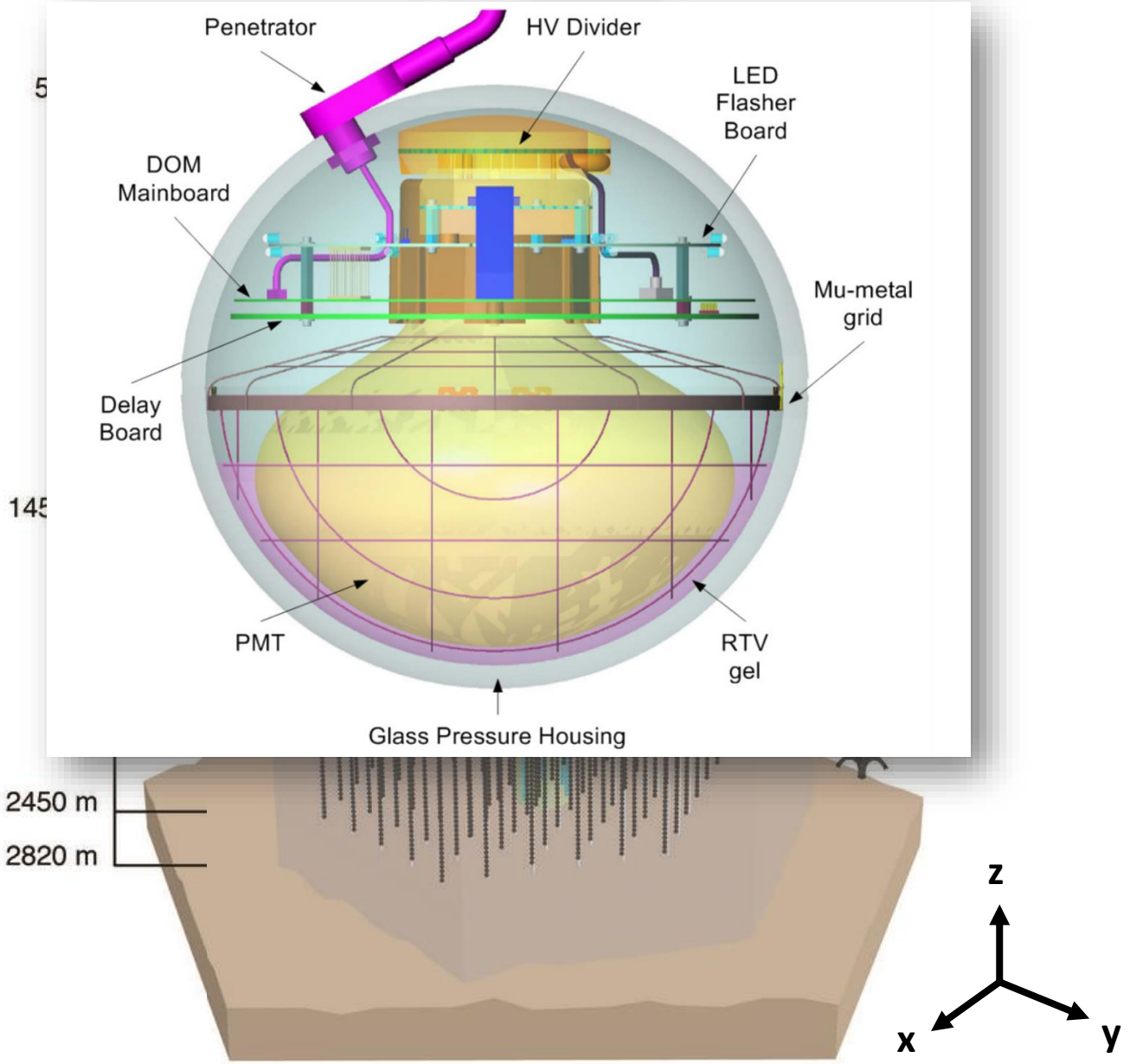

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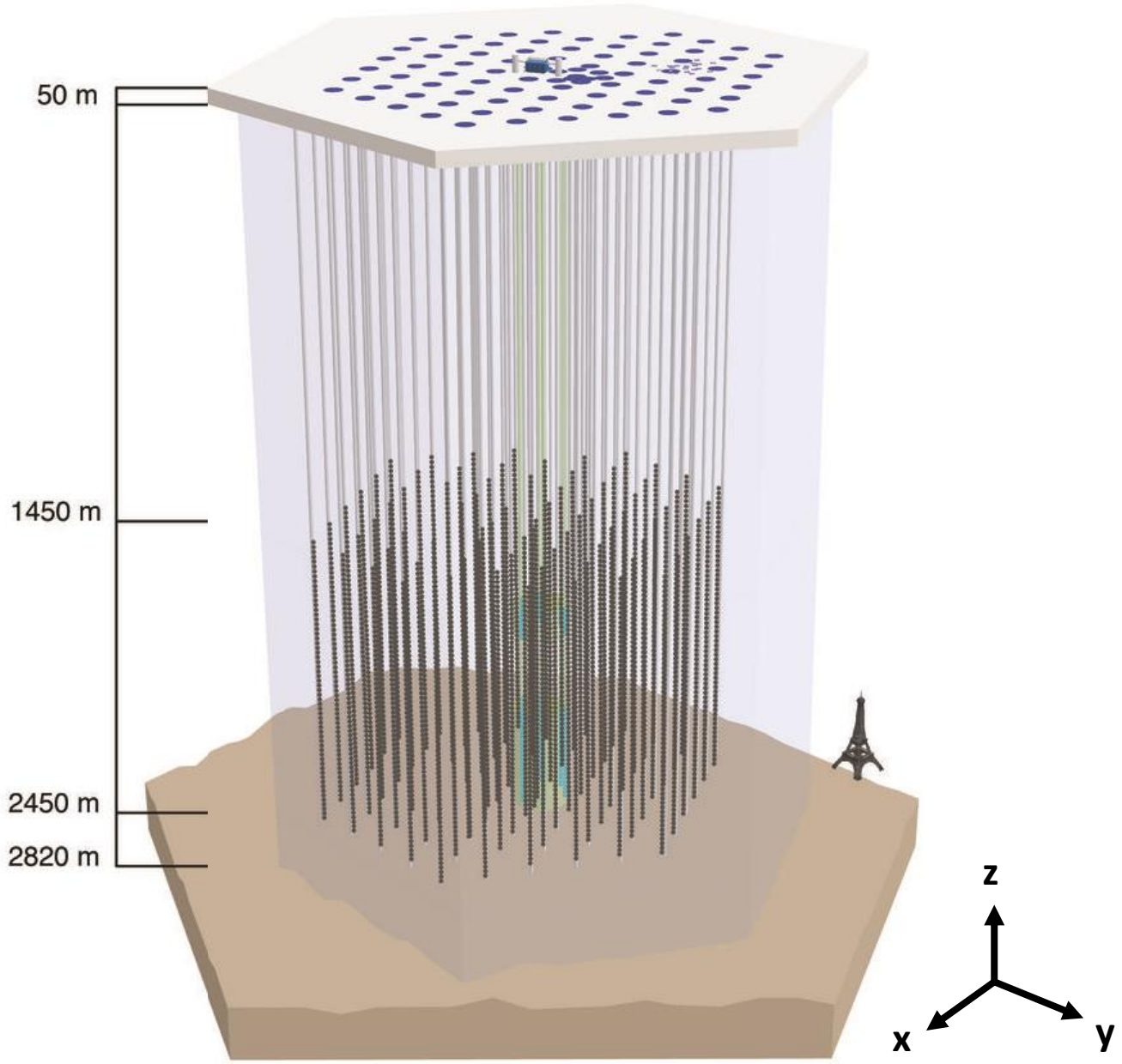

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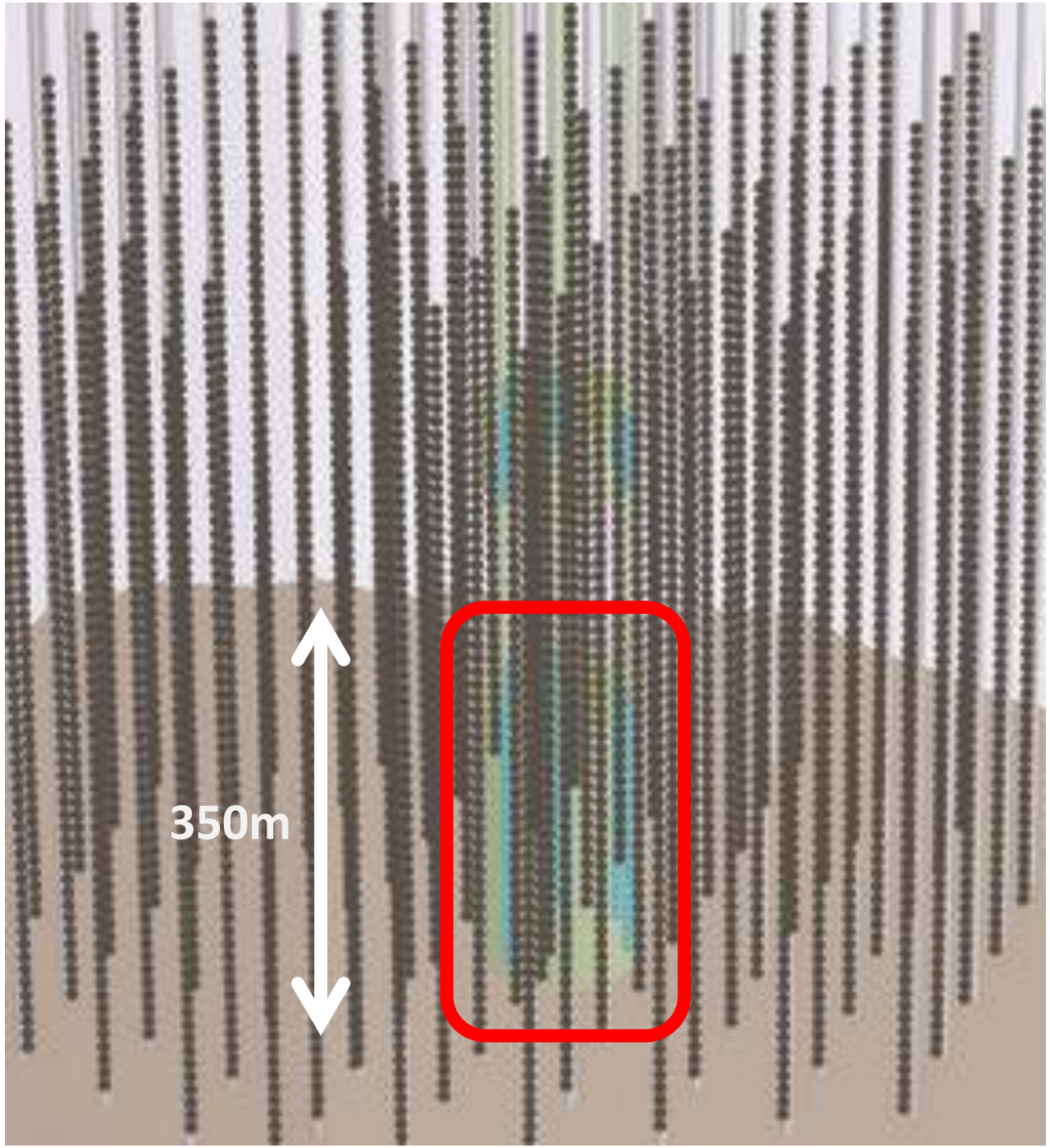
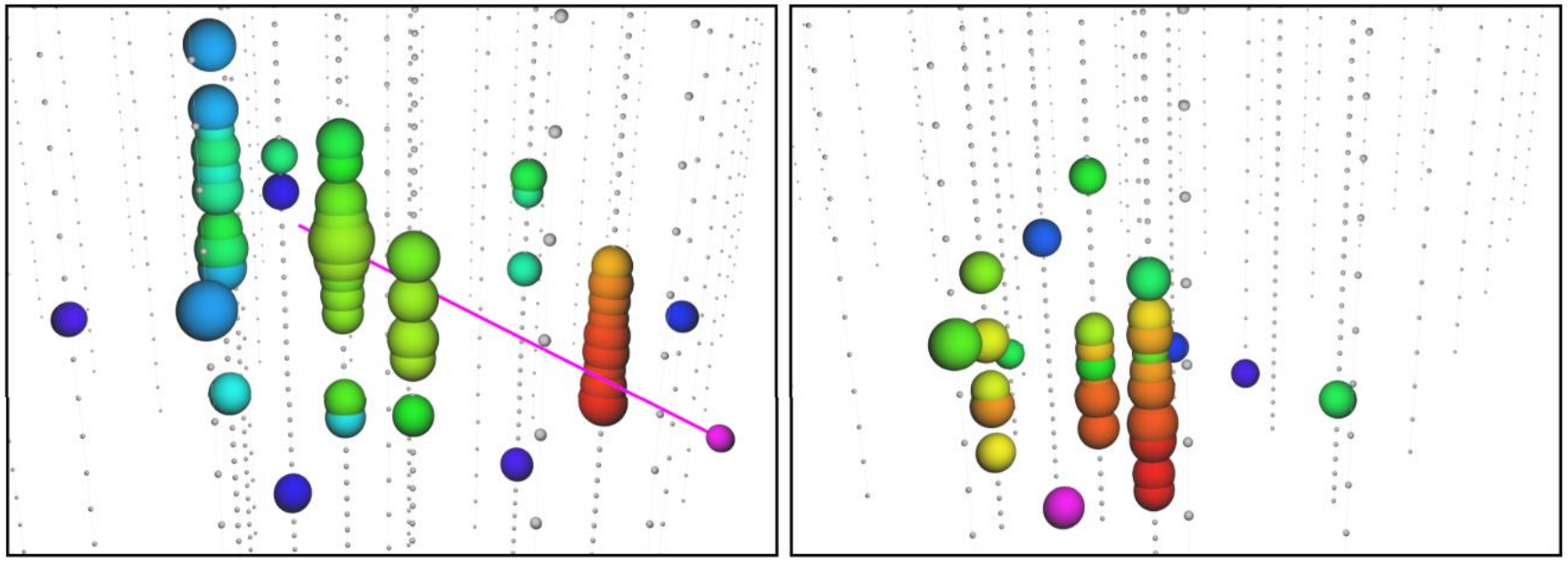


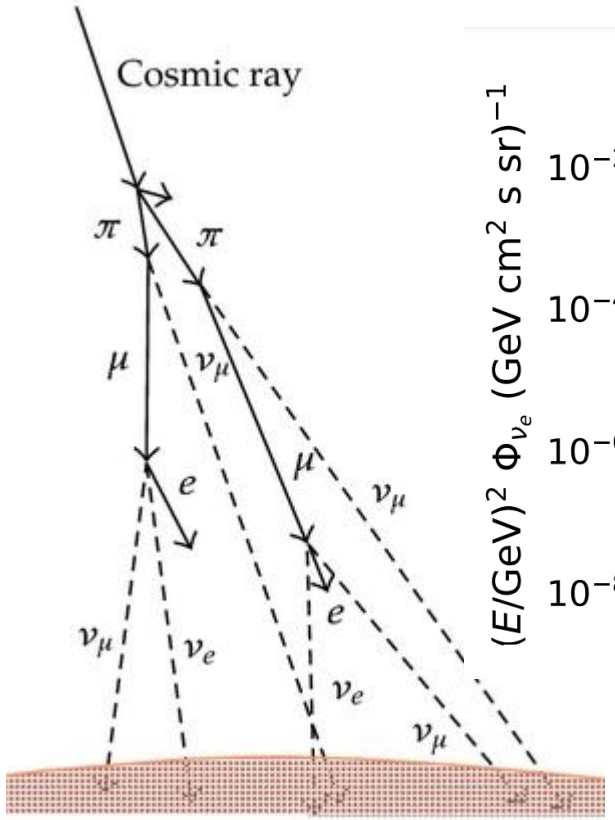
The DeepCore **data**

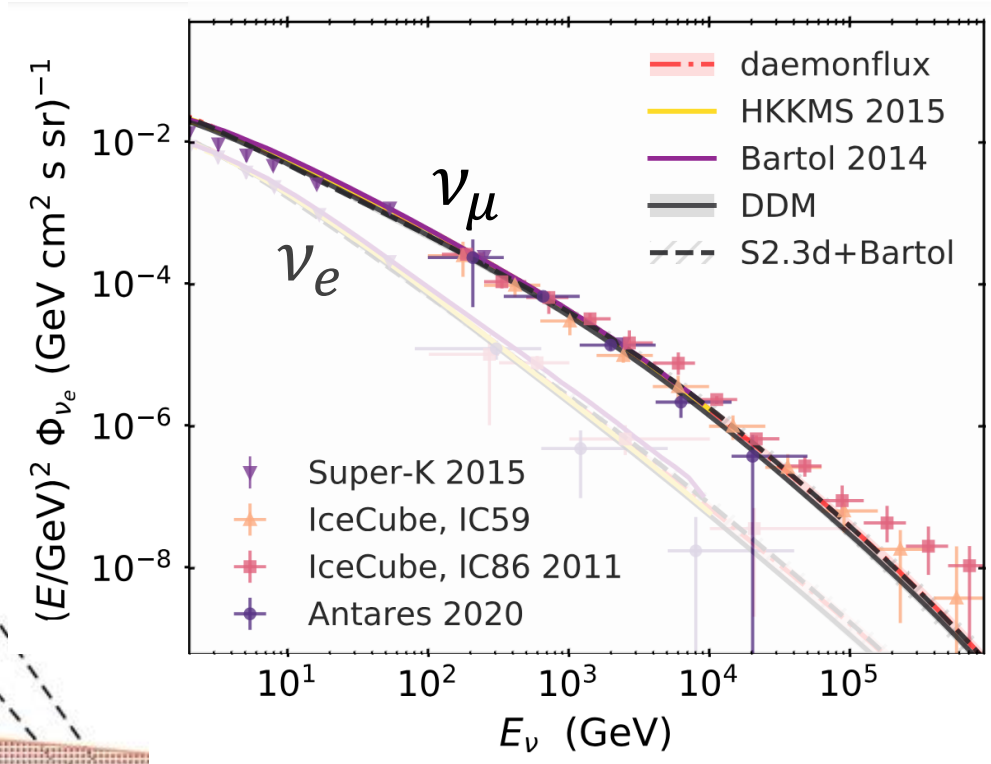
- Use all/most events starting in the DeepCore region
  - Strong atm. μ background suppression – still, some will remain
  - Mostly contained – energy estimator is reasonable
  - Information from interaction available: topology → flavor



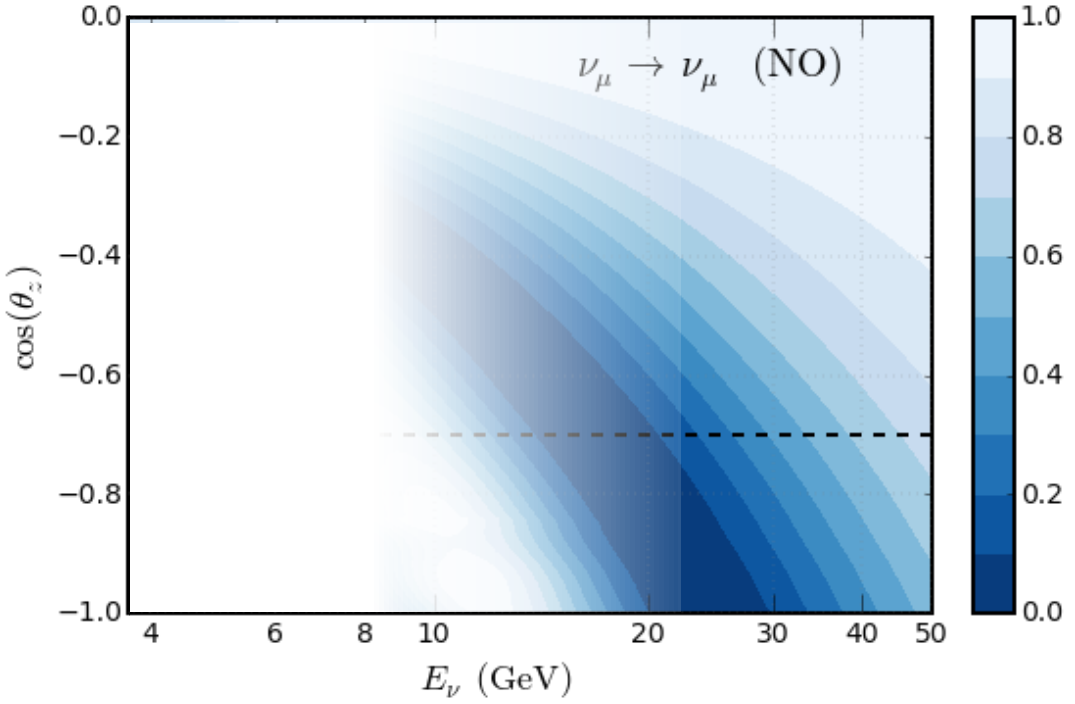
Color indicates time (red=early, blue=late). Sphere size is proportional to number of photons observed.

Measurements of neutrino oscillations (DeepCore)

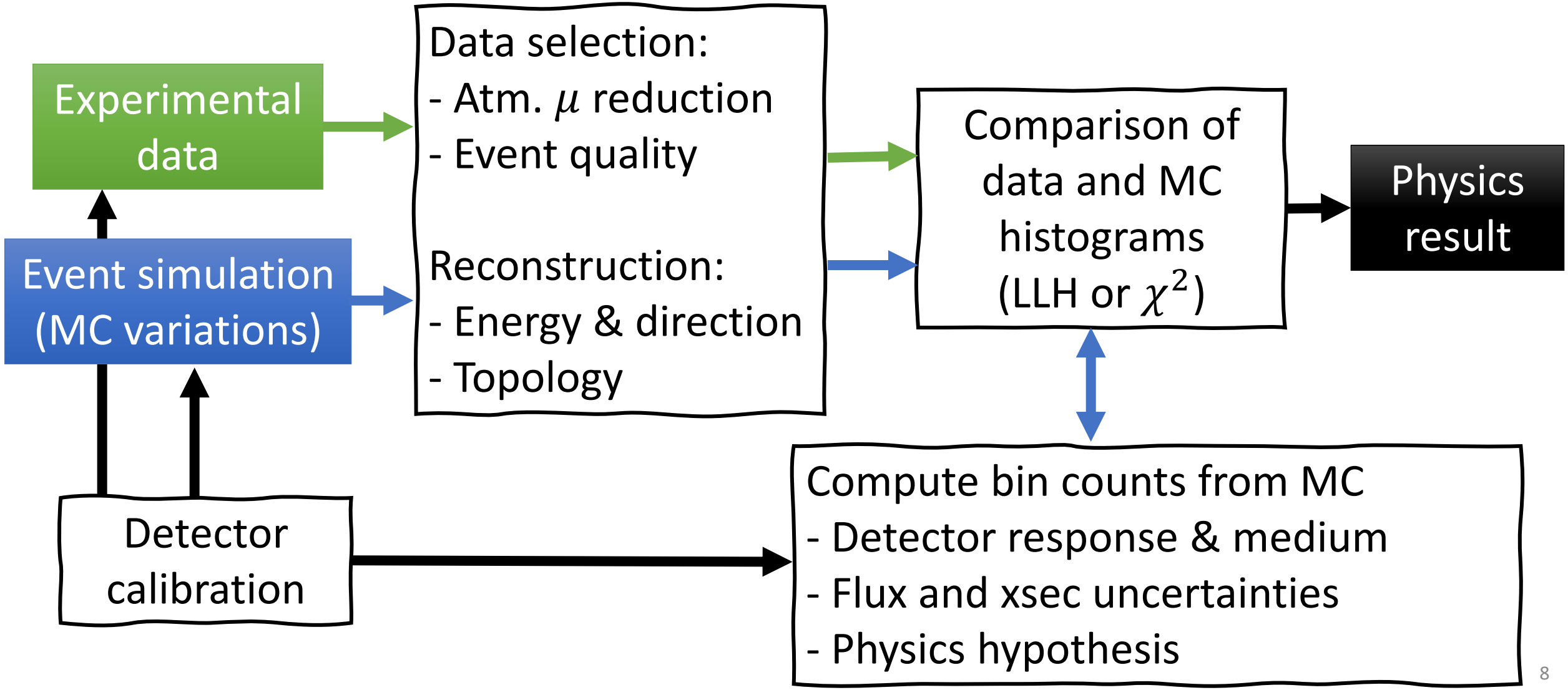




$$P\nu_\mu \rightarrow \nu_\mu \simeq 1 - \sin^2 2\theta_{23}\ \sin^2\left(\frac{\Delta m^2_{32}}{4E} L\right)$$



Analysis **strategy** for oscillations



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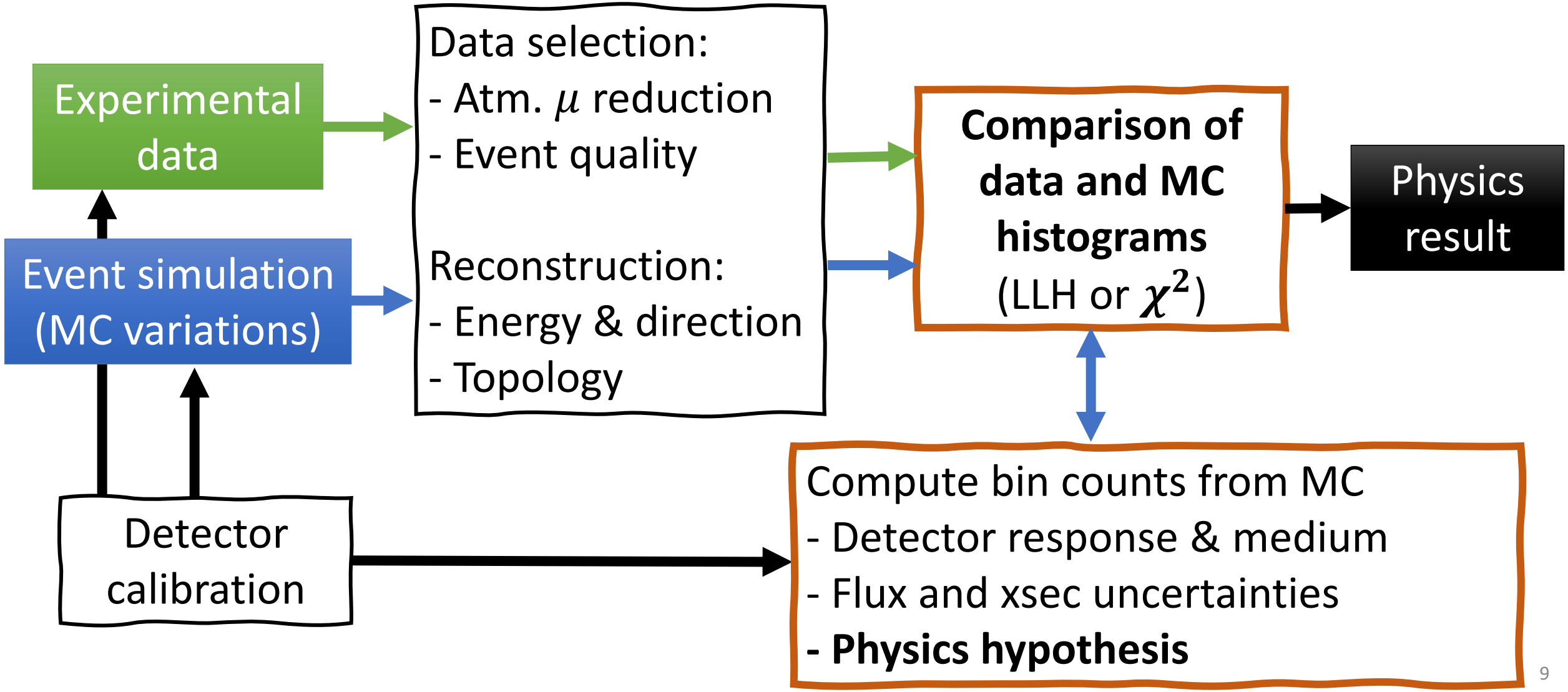

What are we doing today?

Explore the data release for IceCube's 2018 result - PRL 120, 071801 (2018)

- Load the data, look at the "observables" that IceCube uses
- Understand what signature is expected from oscillations
- Learn how you compute an "oscillated flux of neutrinos"
- Test the impact of oscillations on atmospheric neutrinos
- Extract the oscillation parameters using the simplified 2-flavor formula

$$P_{\nu_\mu \to \nu_\tau} \simeq \sin^2 2\theta_{23} \ \sin^2\left(\frac{\Delta m^2_{32}}{4E} L\right) = A \ \sin^2\left(1.267 \ \frac{\Delta m^2_{32}}{\mathrm{eV}^2} \ \frac{L/\mathrm{km}}{E/\mathrm{GeV}}\right)$$

Links and tools

- Coding in Google Colaboratory
  - Link to the folder with code and data
  - Open the code and copy to your own google drive
  - Download dragon_data.pkl and upload to your own google drive
- Follow the code, think about the questions, propose answers
- Fill in the gaps (write the missing code)
- Run the fit