

A Deep Dive Into The Neutrino Mass Ordering with KM3NeT

Jasmine Simms

Determining the neutrino mass ordering and oscillation parameters with KM3NeT/ORCA.

Aiello, S., Albert, A., Alves Garre, S. *et al.*

Eur. Phys. J. C **82**, 26 (2022)

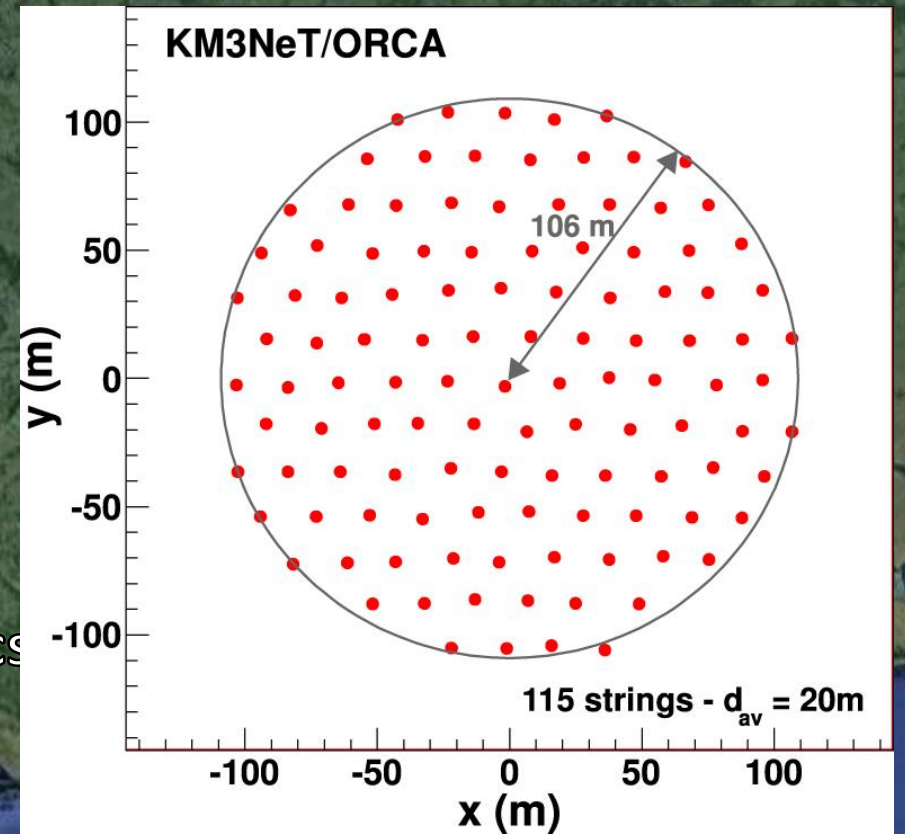
Fr- Oscillation Research with Cosmics
in the Abyss (ORCA)



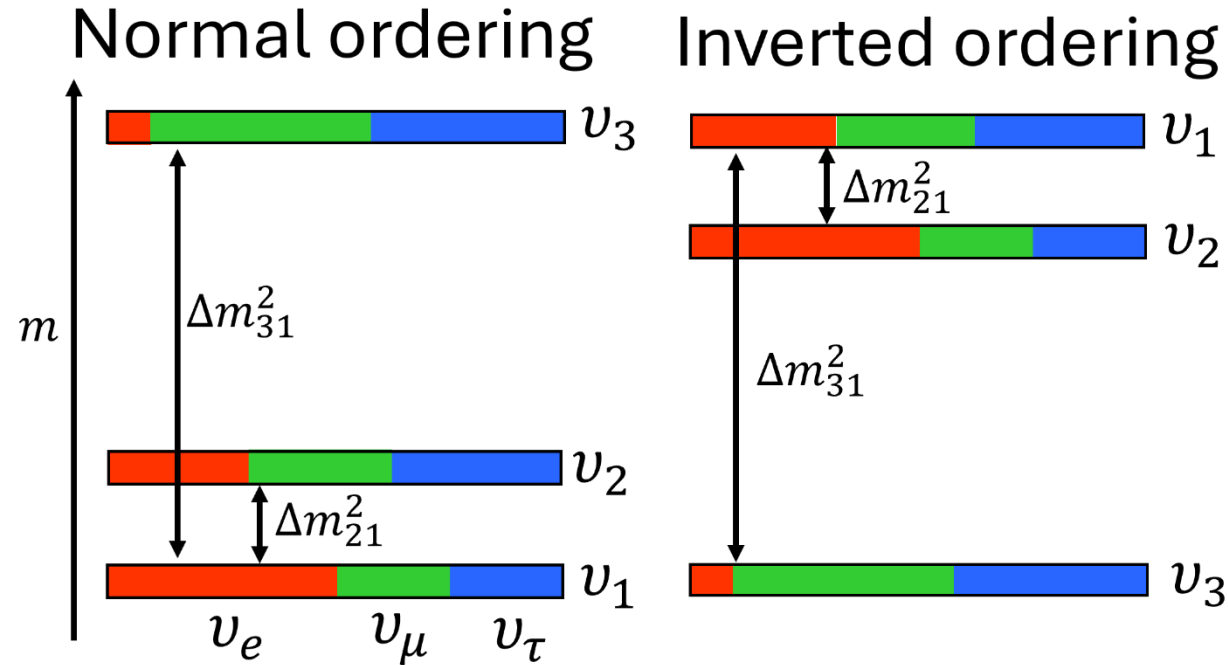
It- Astrophysical Research with Cosmics in
the Abyss (ARCA)



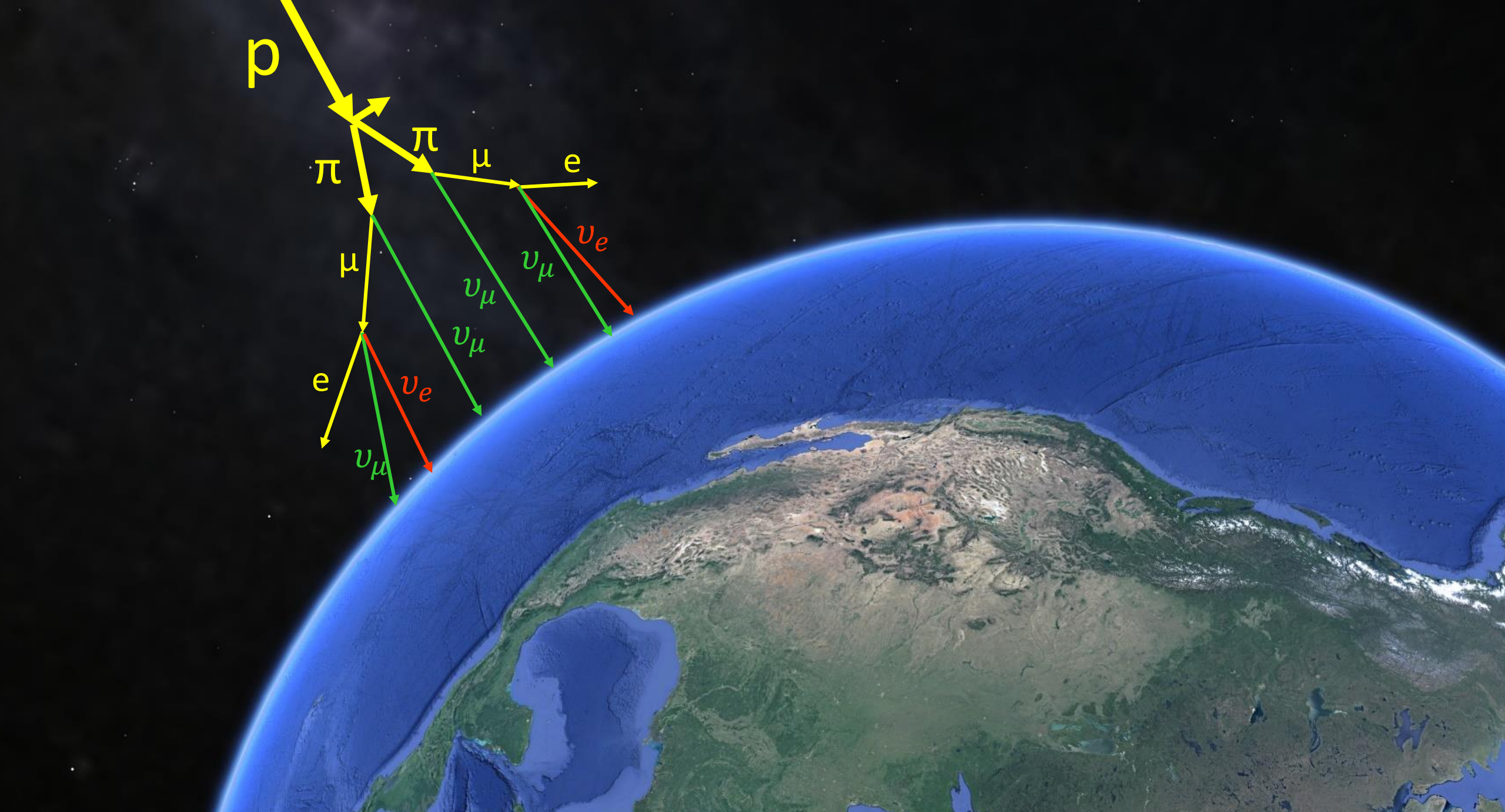
Gr- Validation and Qualification

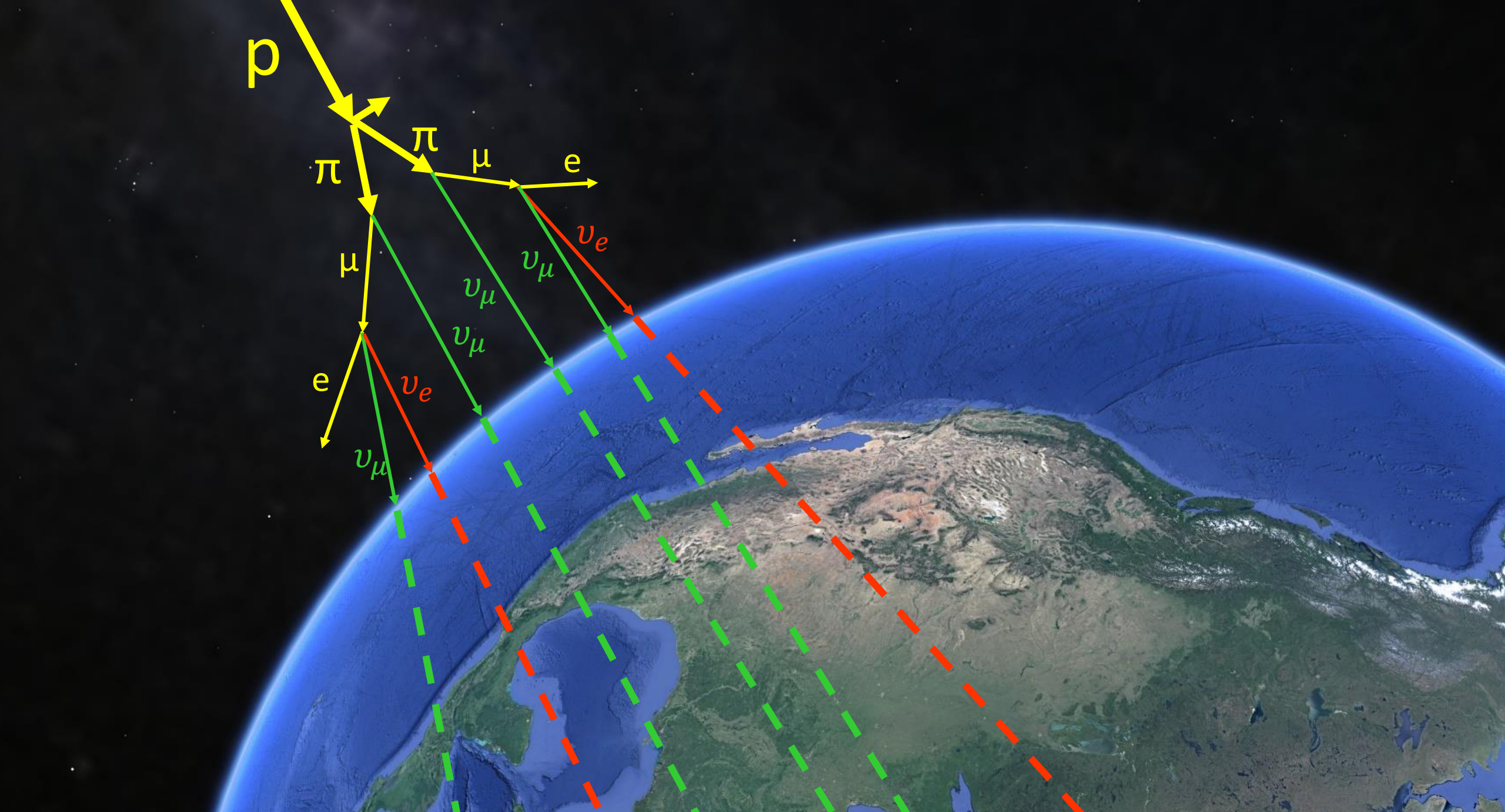


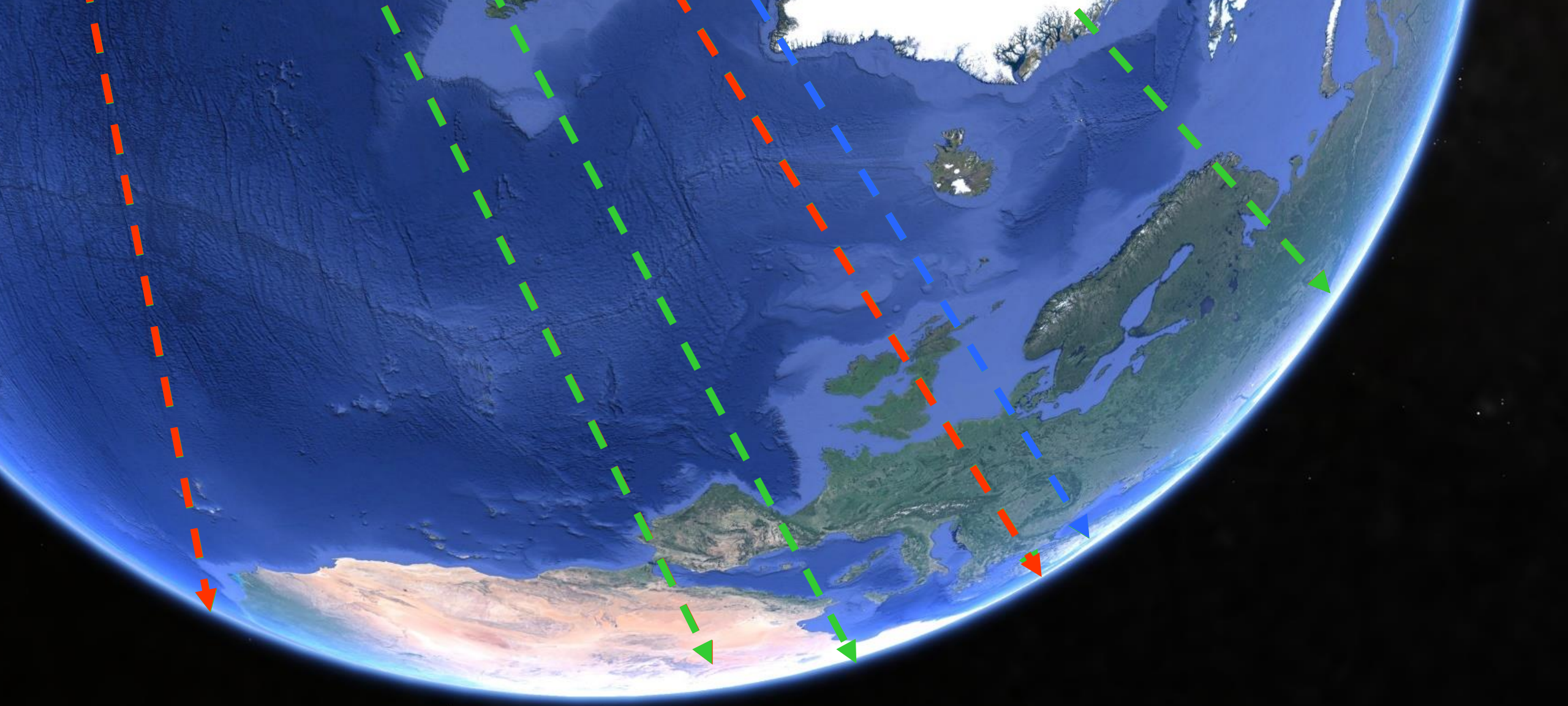
Neutrino Mass Ordering

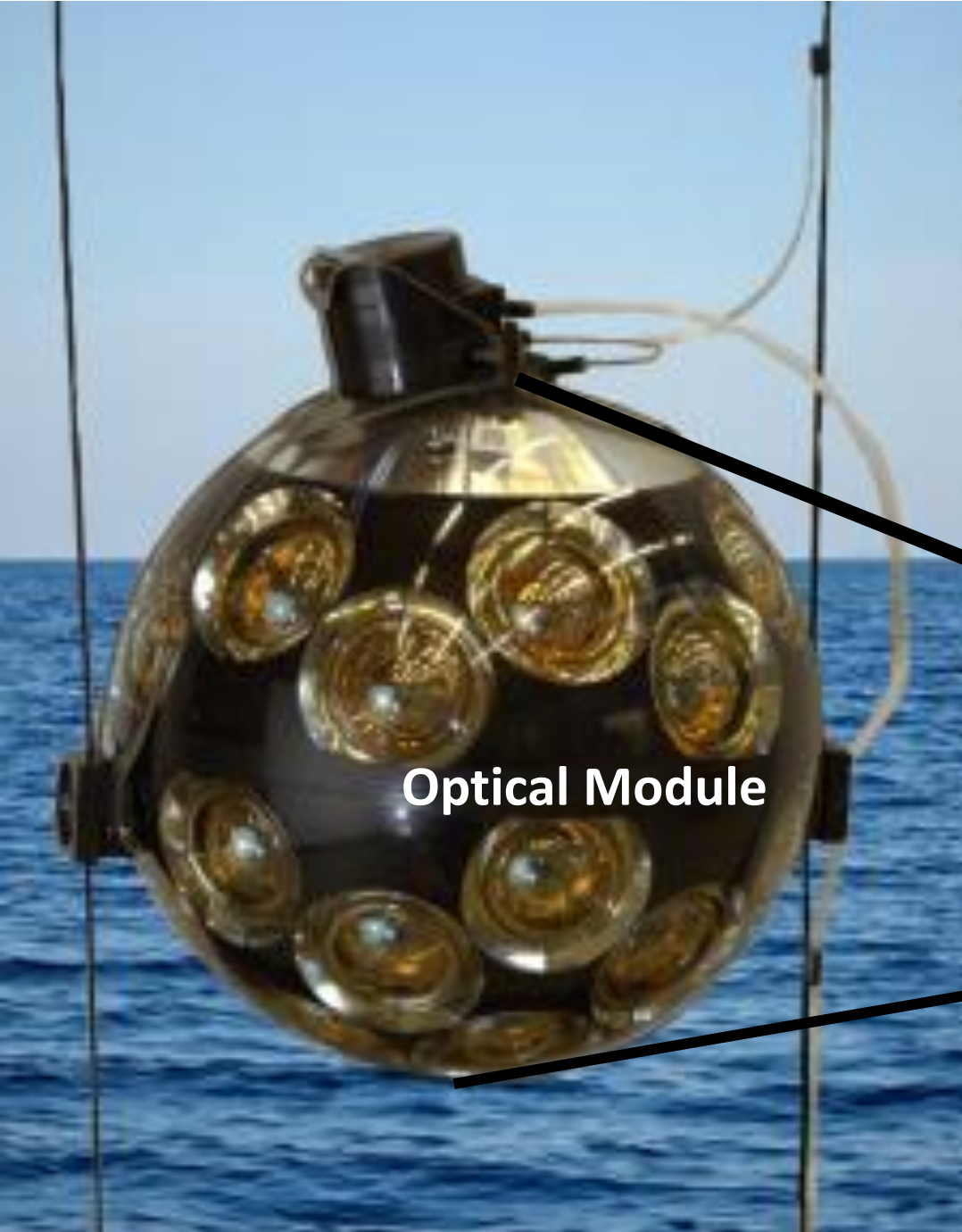


- Oscillations in vacuum gives sensitivity to Δm^2 , but not the mass ordering
- Matter induced modification to neutrino oscillations
- Normal ordering enhances $\nu_\mu \leftrightarrow \nu_e$ Inverted ordering enhances $\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e$





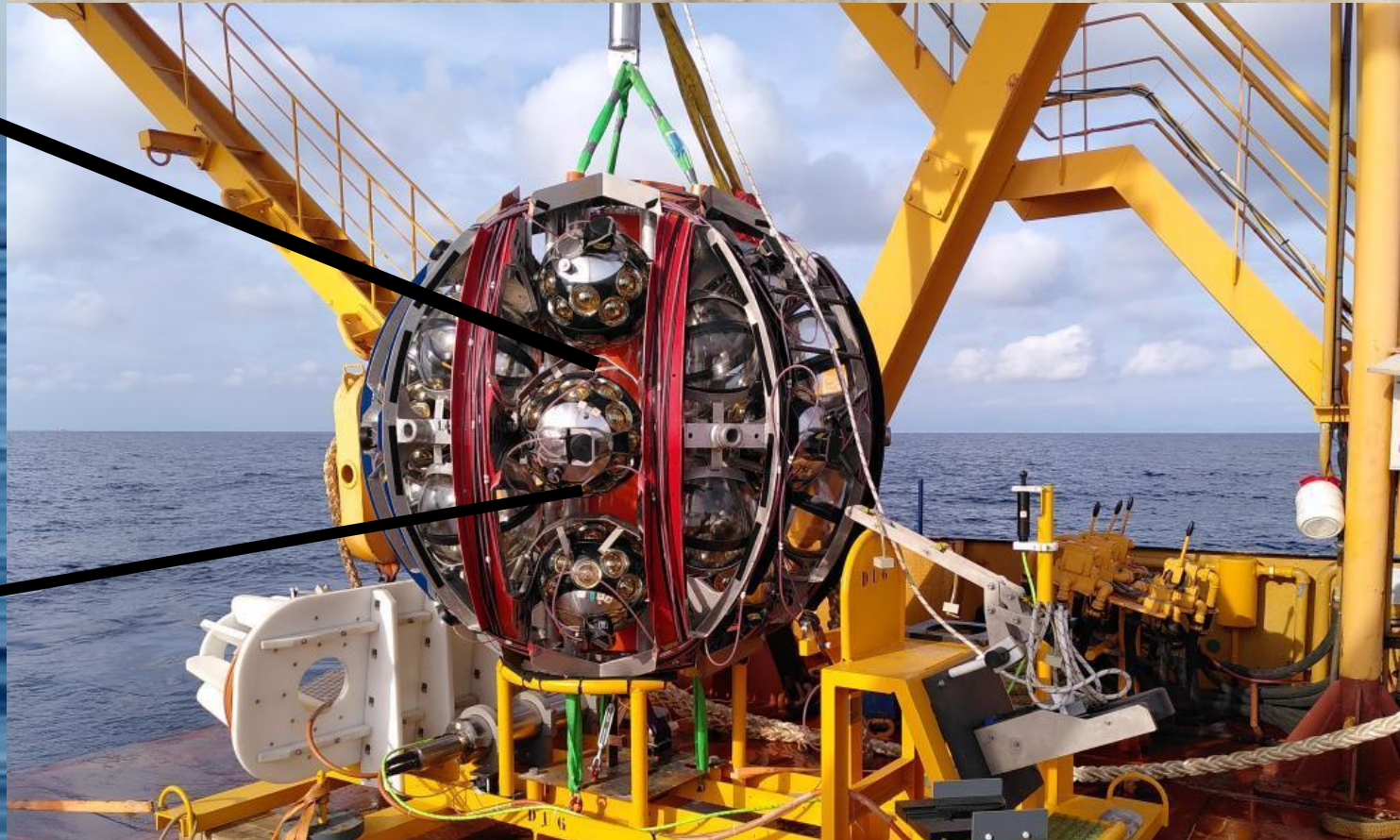


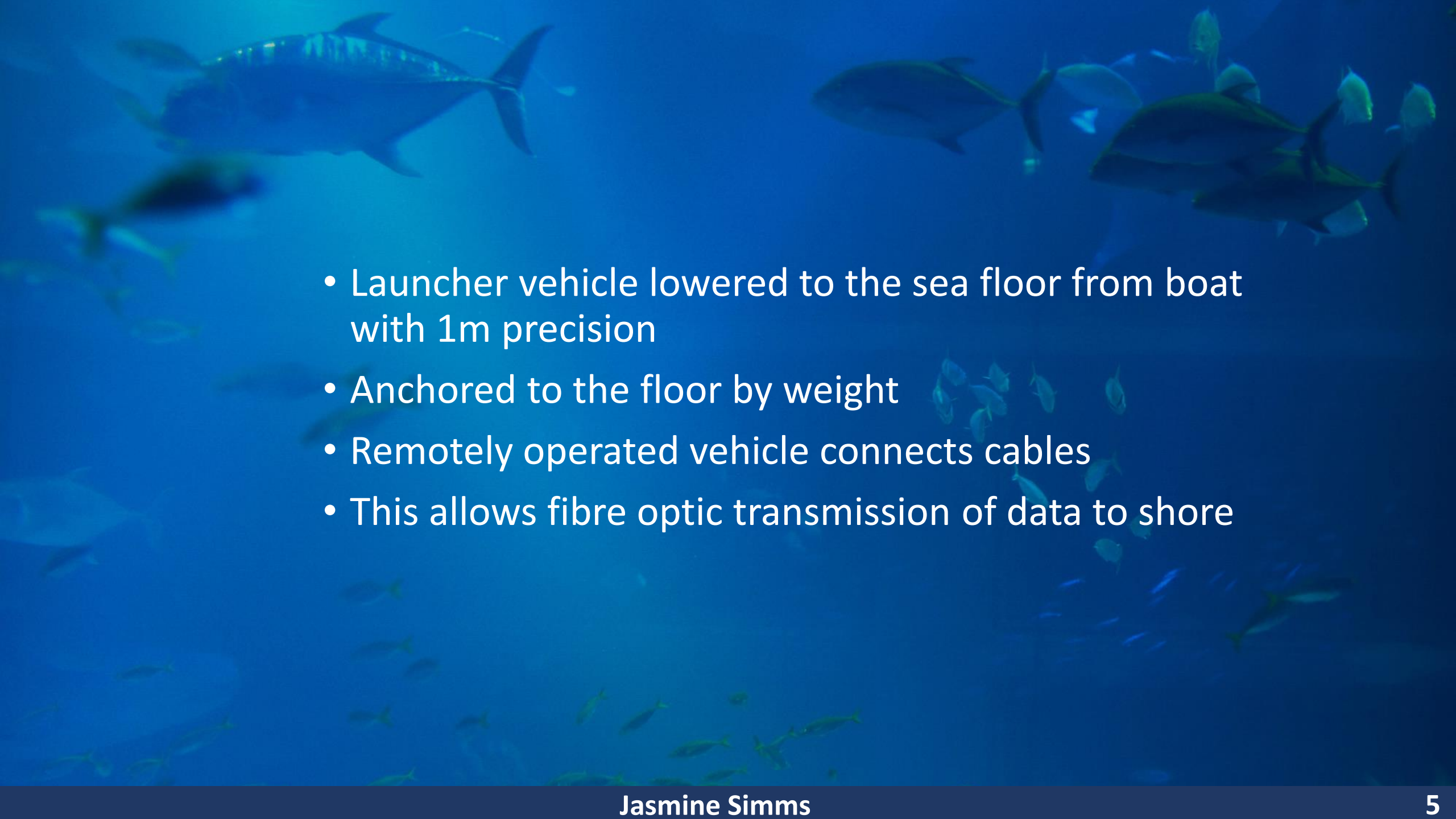


Optical Module

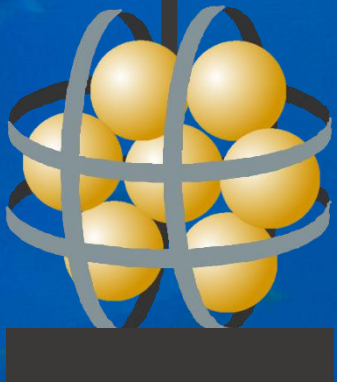


Launching Vehicles



- 
- An underwater scene with various fish swimming in clear blue water. The fish are silhouetted against the light, creating a serene and naturalistic background for the text.
- Launcher vehicle lowered to the sea floor from boat with 1m precision
 - Anchored to the floor by weight
 - Remotely operated vehicle connects cables
 - This allows fibre optic transmission of data to shore

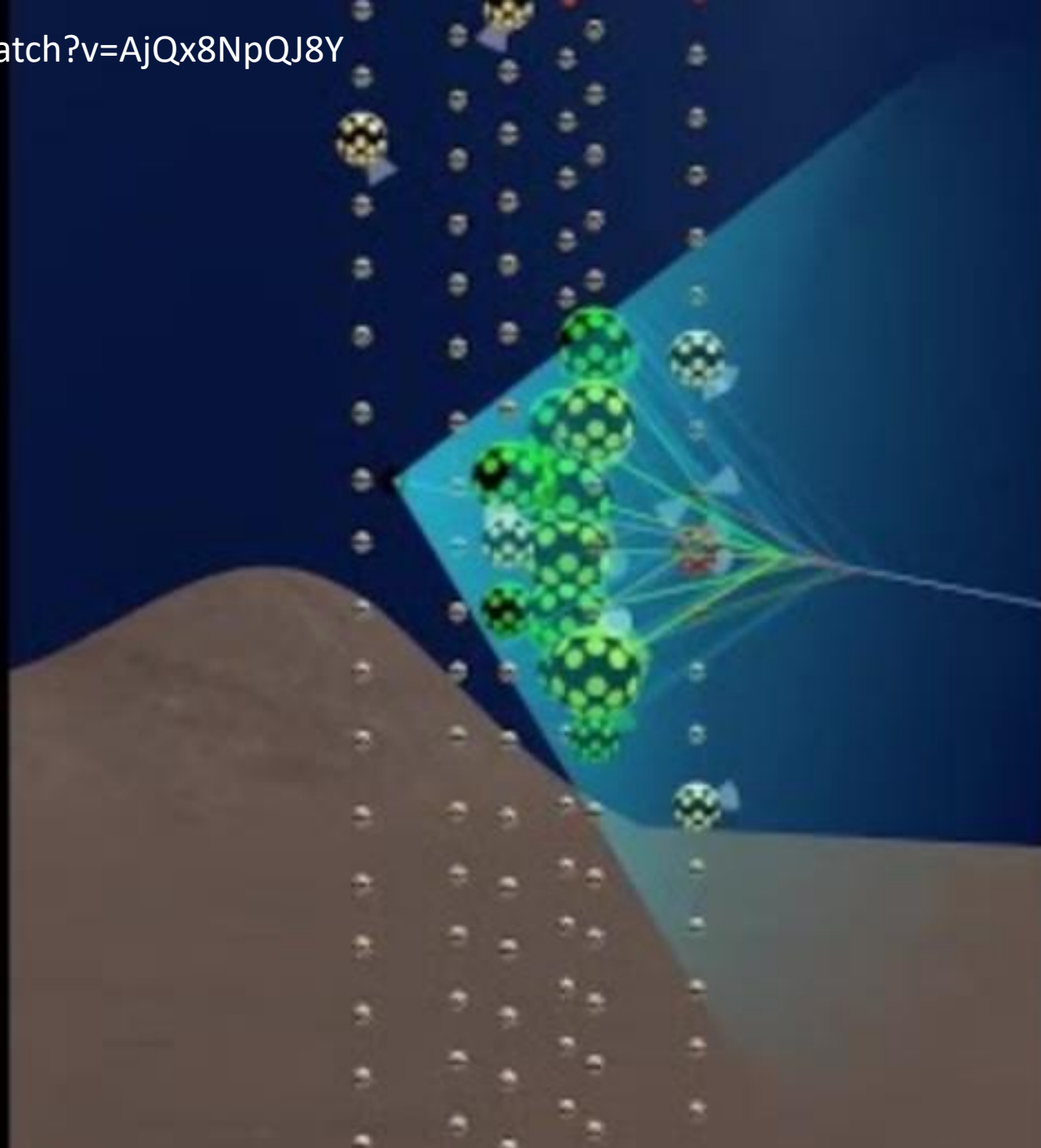
- A consistent and low cost platform for the fleet
- Anchored to the seabed by a weight
- Buoyant at the top of the detection unit keeps the unit upright
- This allows fibre optic transmission of data to shore
- Empty unit floats to surface to be reused





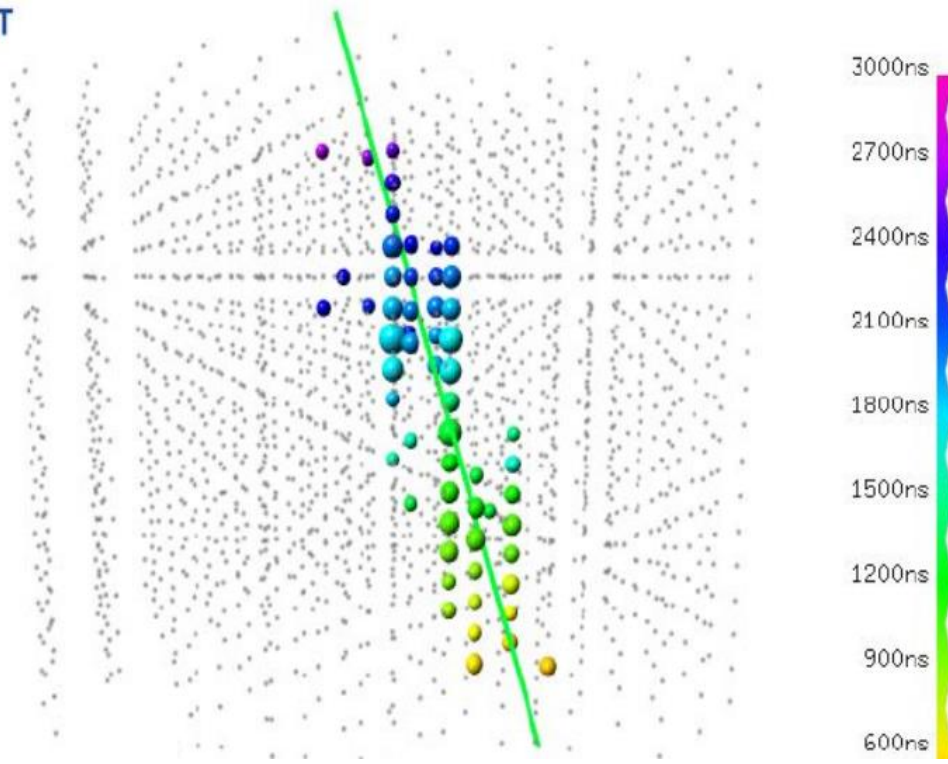
- Acoustic signal from the boat deploys the launcher vehicle
- Launcher vehicle floats to the surface while releasing the string of optical modules
- Buoyant at the top of the detection unit keeps the unit upright
- Empty unit floats to surface to be reused





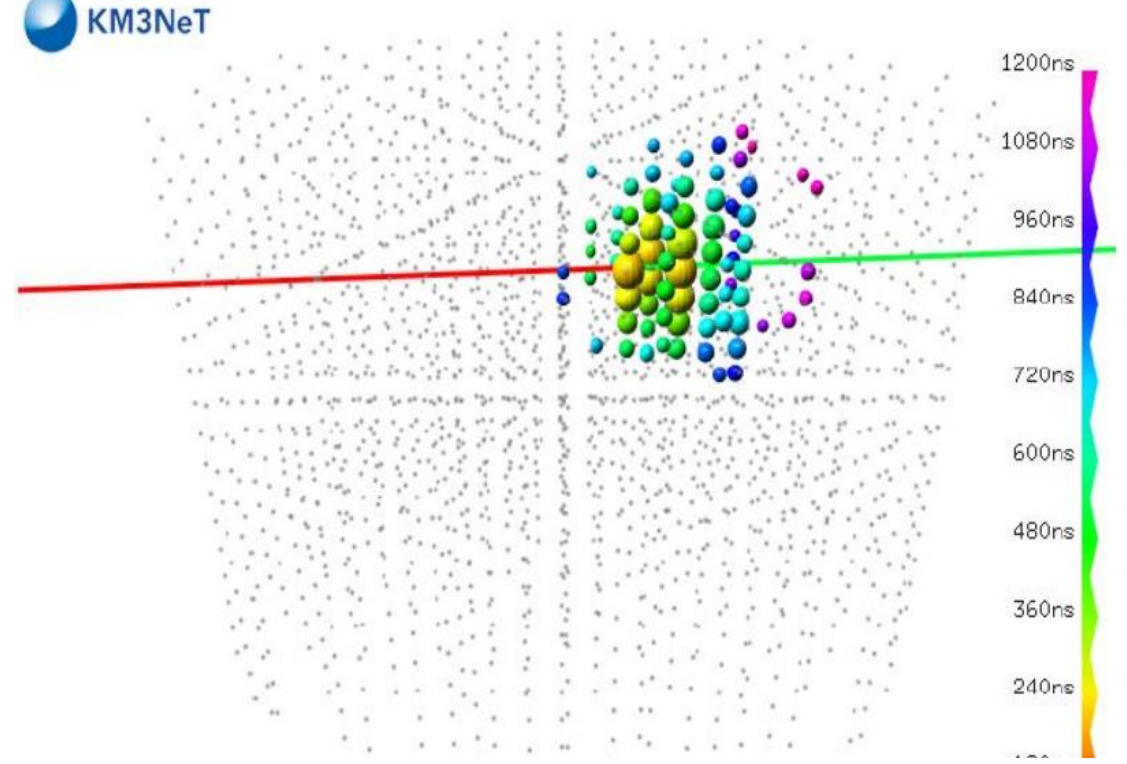
Particle Identification in ORCA

KM3NeT

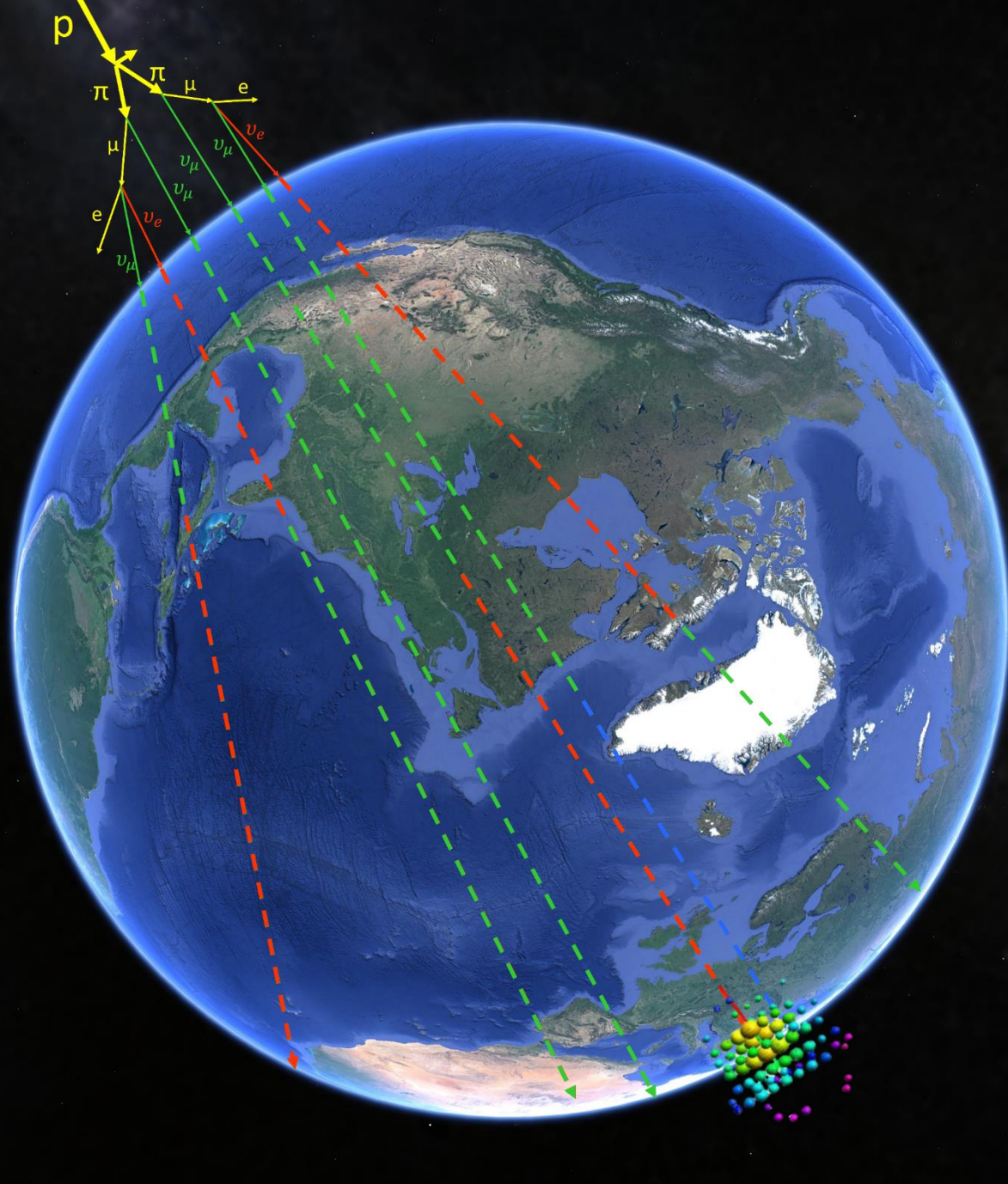


Track event: charged current ν_{μ}

KM3NeT

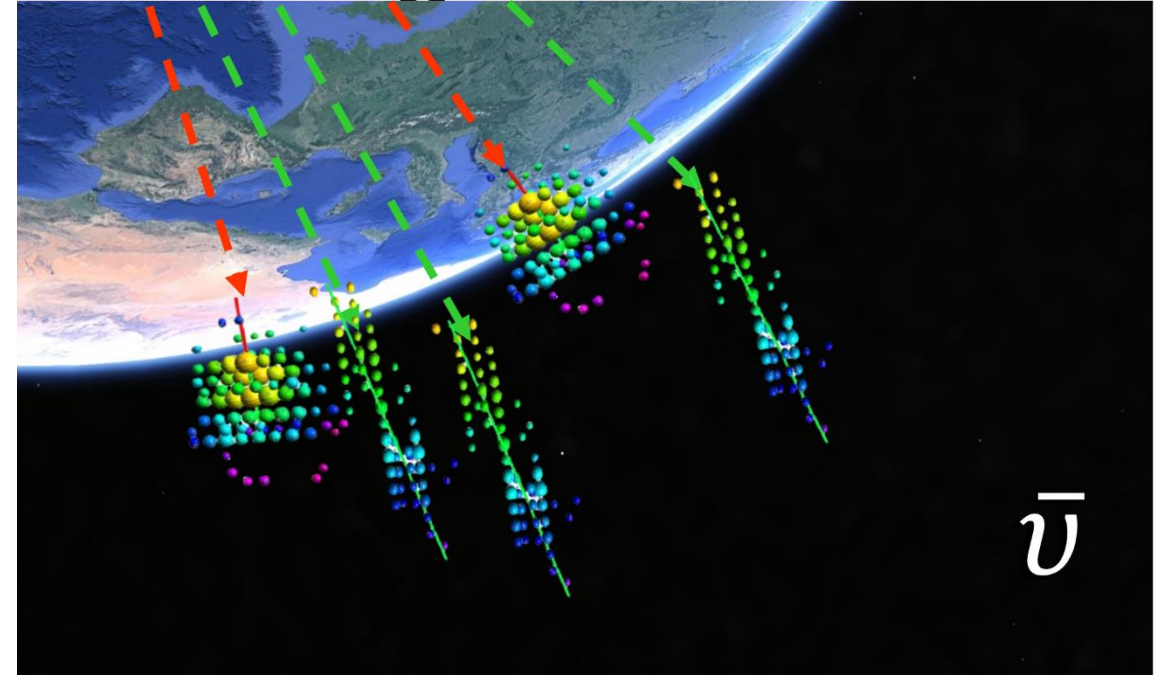
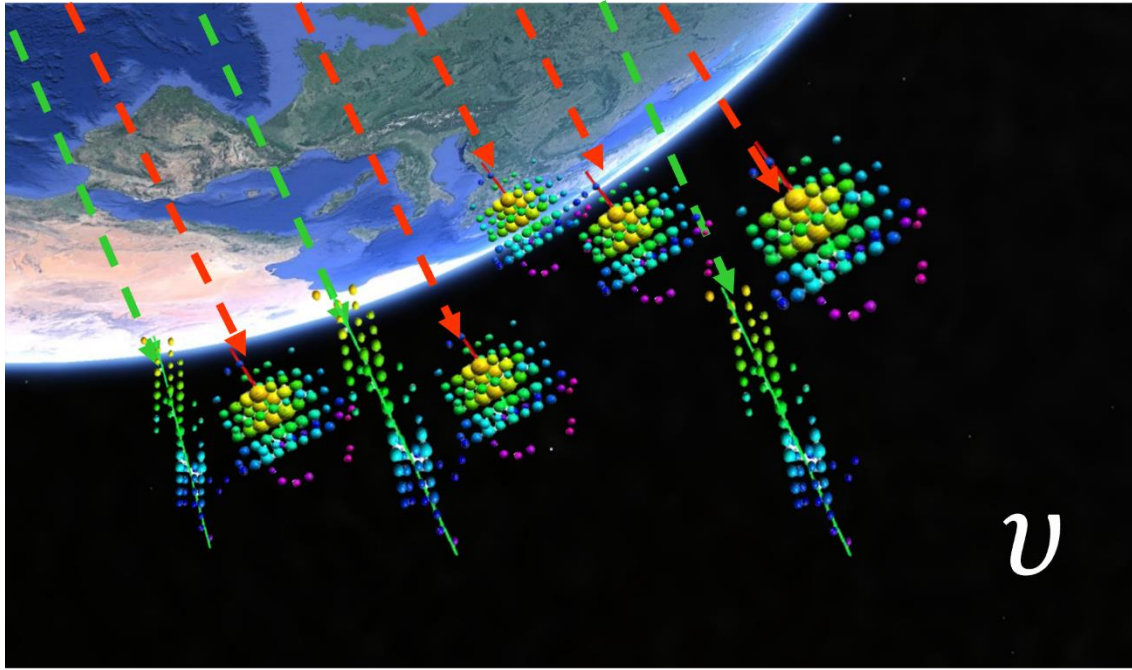


Shower event: charged current ν_e



- Atmospheric neutrinos created 2:1 $\mu:e$
- Oscillate including matter induced modification
- Detected by optical modules in ORCA
- Relative $\nu_\mu \leftrightarrow \nu_e$ to $\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e$ oscillations gives sensitivity to mass ordering
- The ν cross-section in ORCA is roughly twice that of $\bar{\nu}$

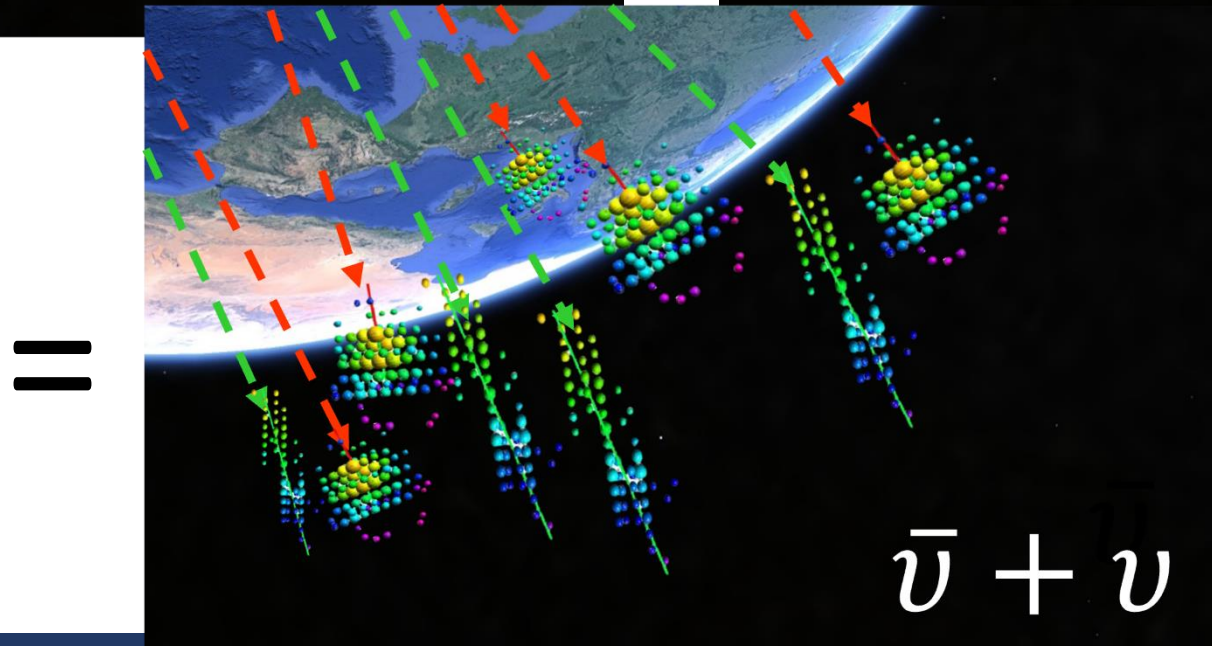
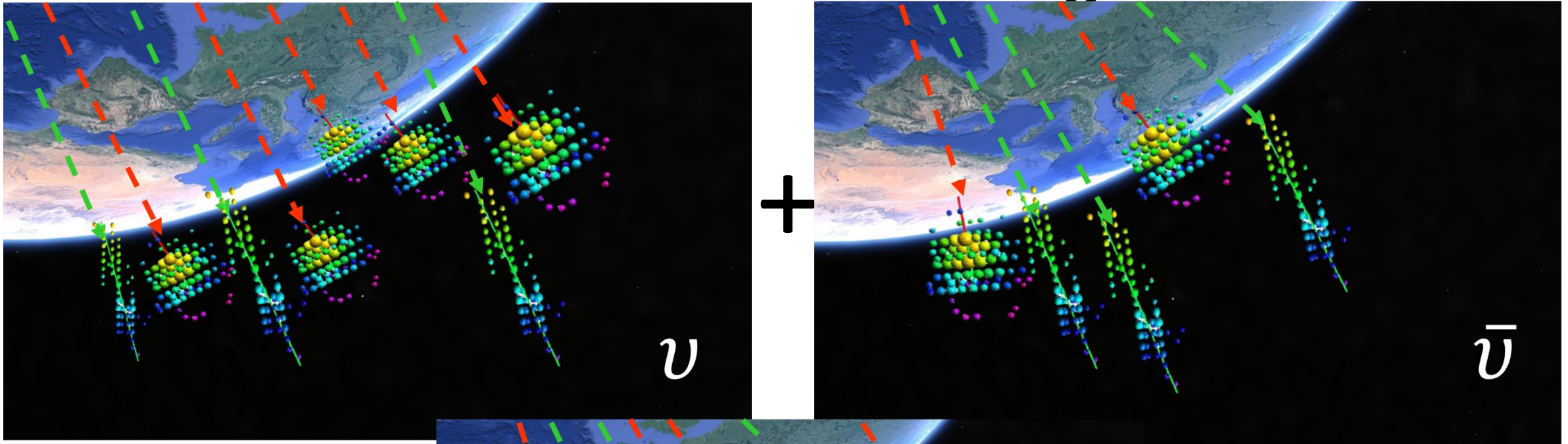
Normal Mass Ordering



- Enhanced $\nu_\mu \leftrightarrow \nu_e$
- Higher shower (ν_e) to track (ν_μ) ratio
- Higher cross section

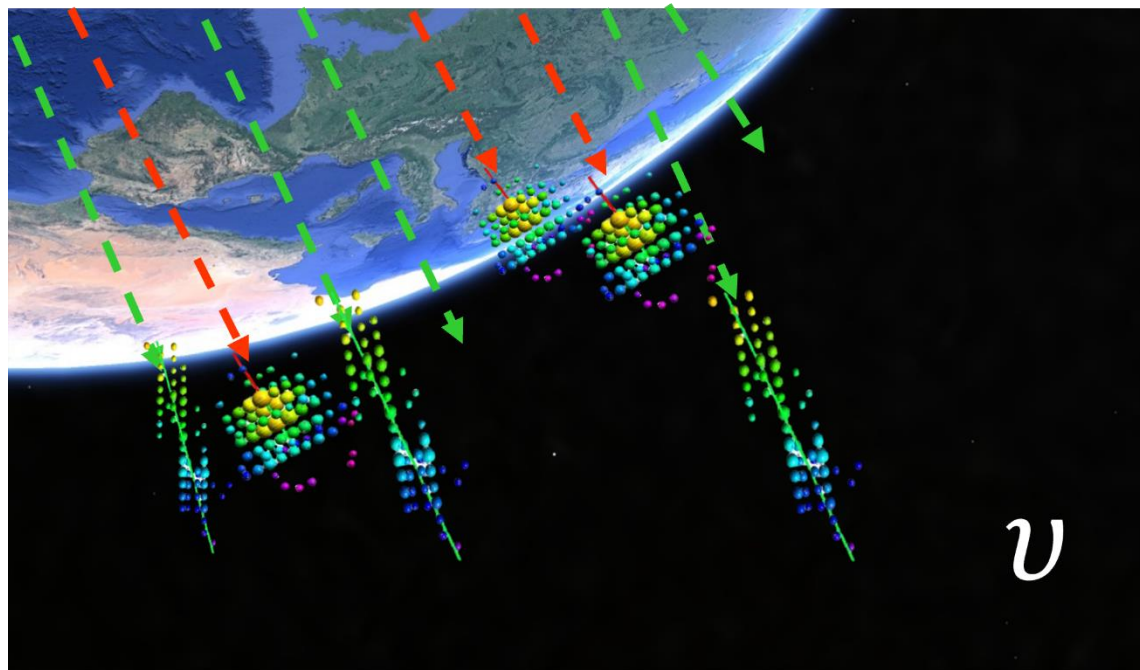
- No enhanced $\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e$
- Lower shower (ν_e) to track (ν_μ) ratio
- Lower cross section

Normal Mass Ordering

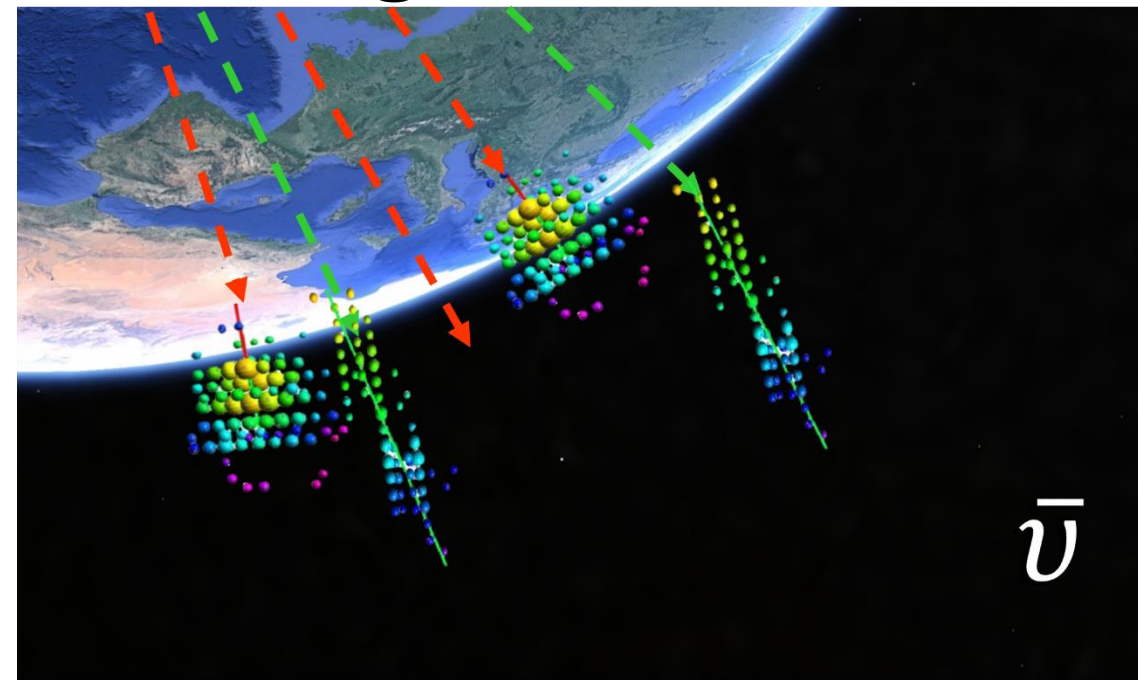


- Overall Higher shower (ν_e) to track (ν_μ) ratio

Inverted Mass Ordering

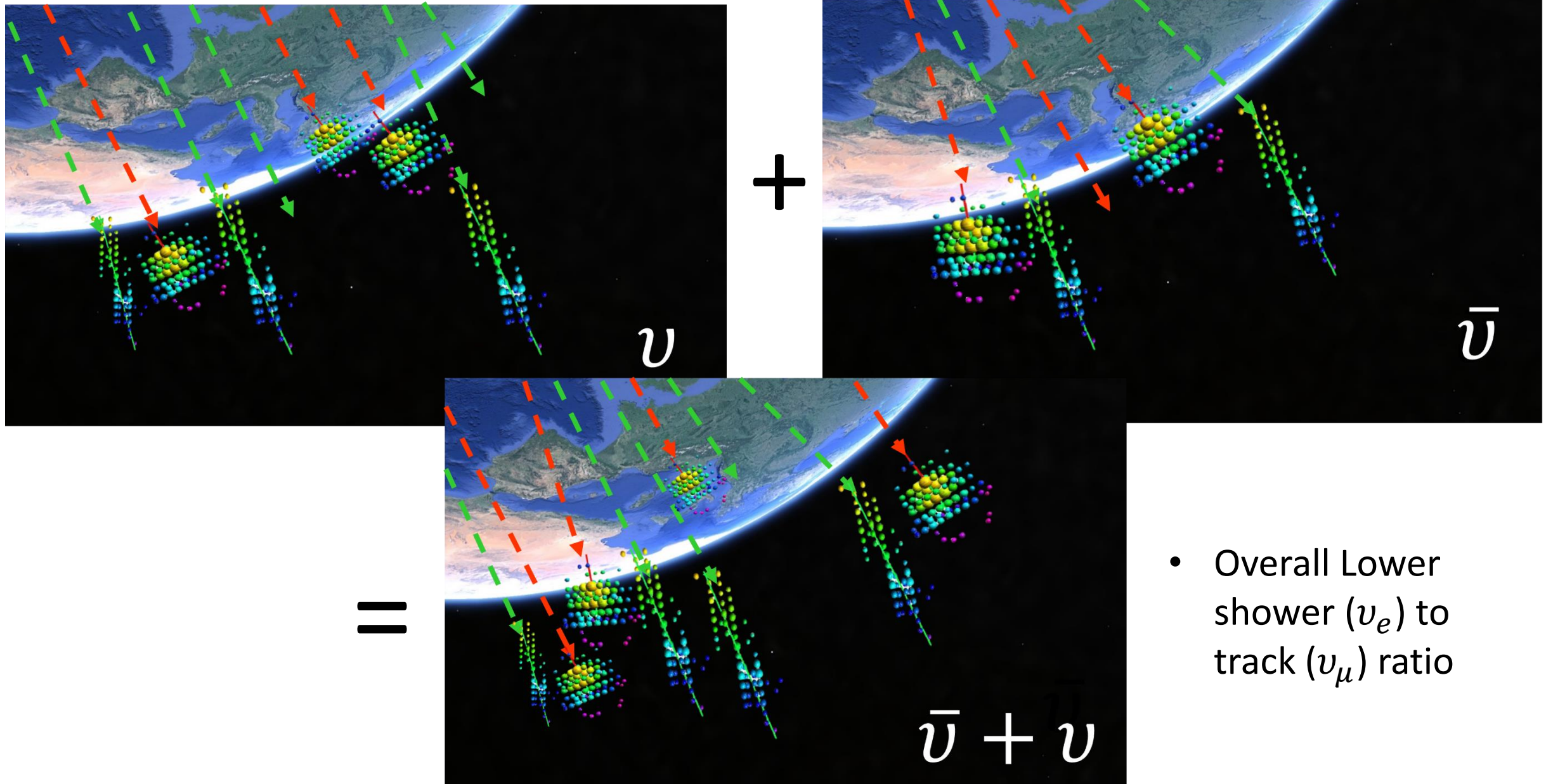


- No enhanced $\nu_\mu \leftrightarrow \nu_e$
- Lower shower (ν_e) to track (ν_μ) ratio
- Higher cross section



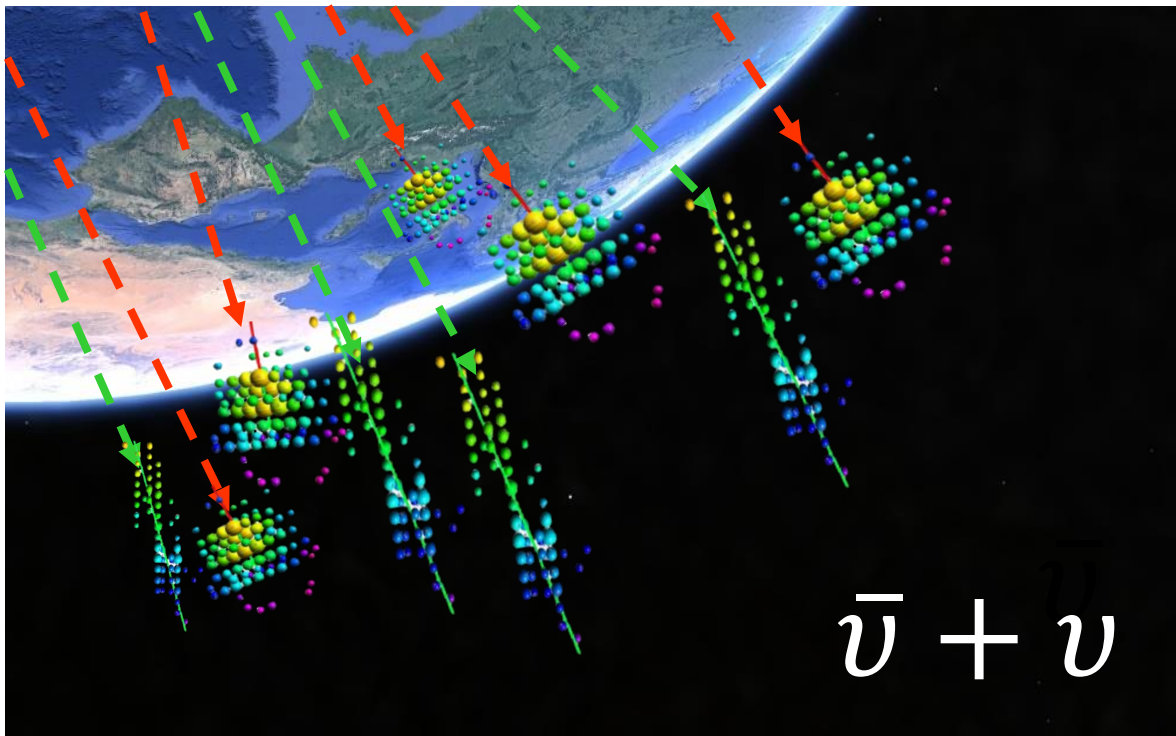
- Enhanced $\bar{\nu}_\mu \leftrightarrow \bar{\nu}_e$
- Higher shower (ν_e) to track (ν_μ) ratio
- Lower cross section

Inverted Mass Ordering



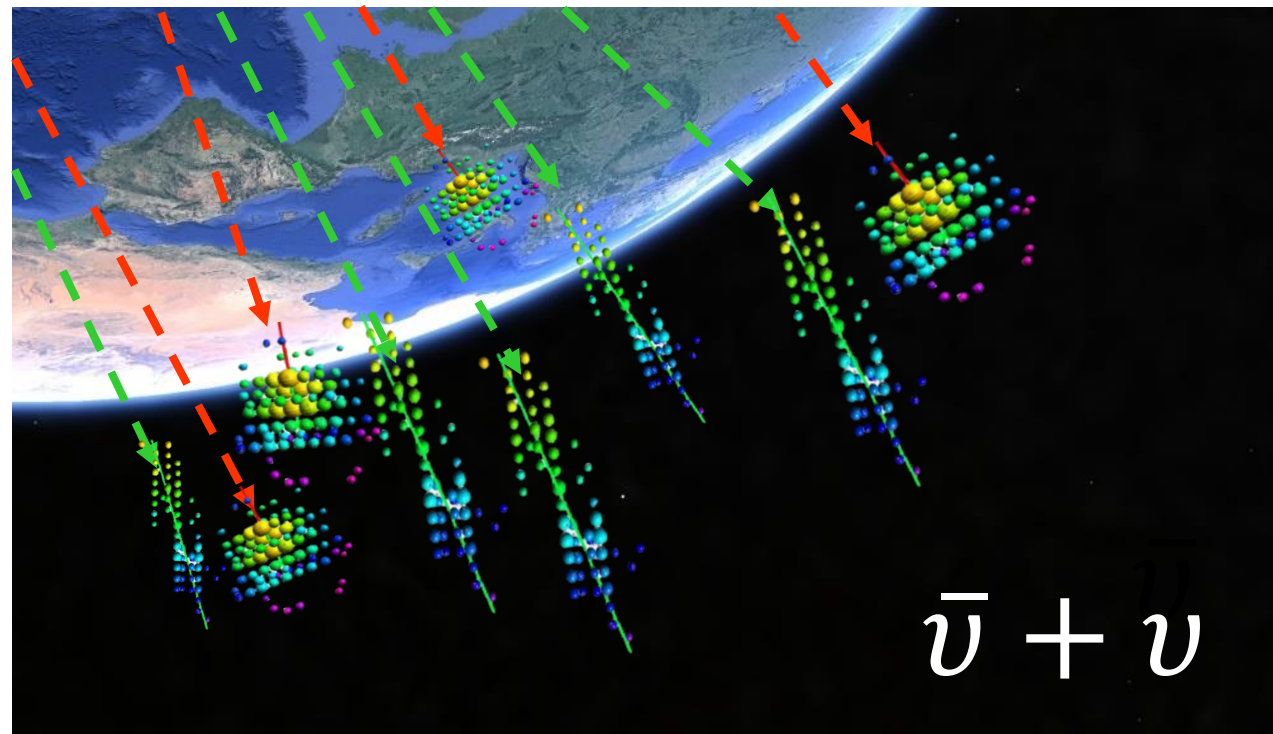
Comparison

Normal ordering



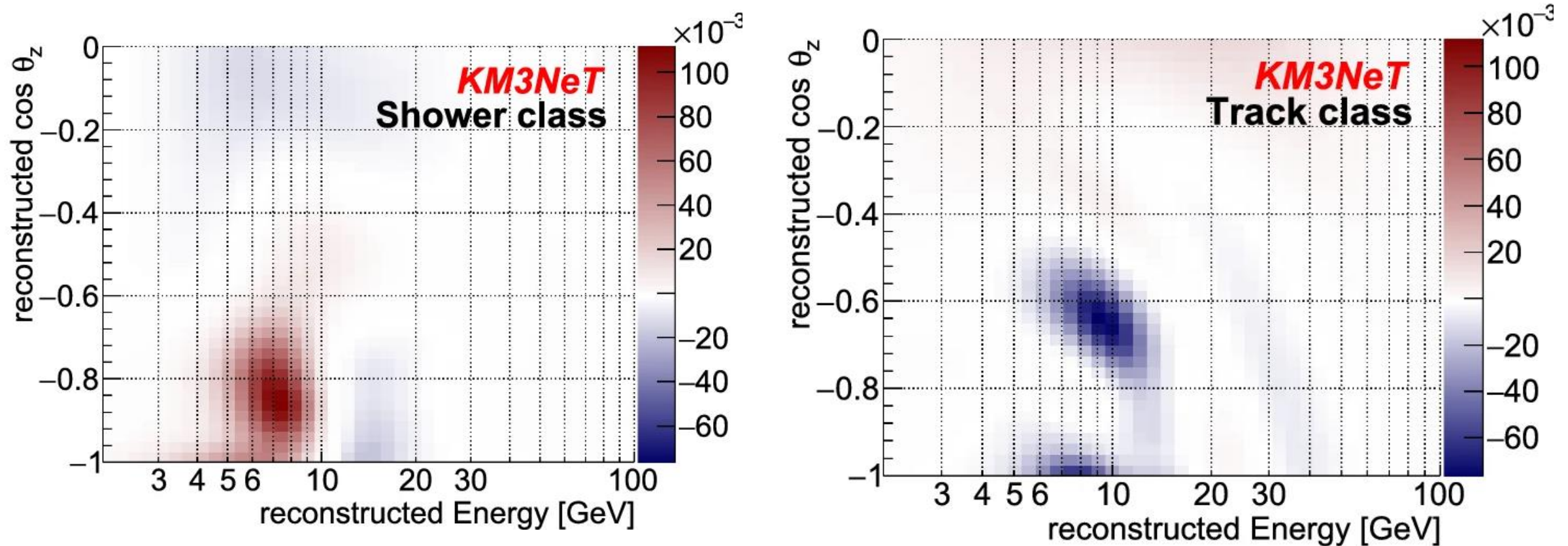
Higher shower (ν_e) to track (ν_μ) ratio

Inverted ordering



Lower shower (ν_e) to track (ν_μ) ratio

Difference in signal between the 2 orderings

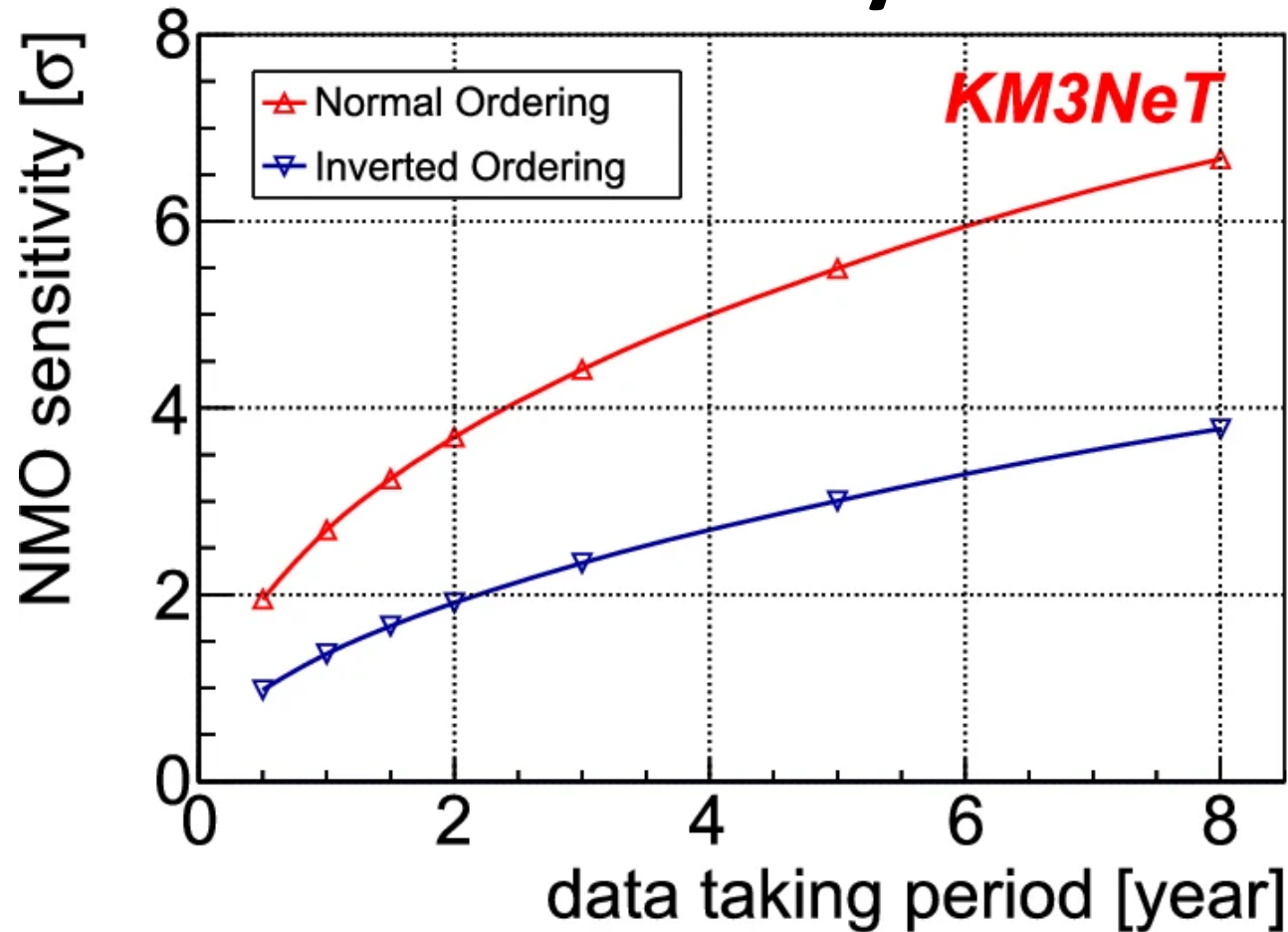


- Greater signal if normal ordering is correct
- Greater signal if inverted ordering is correct

Figure 8, Determining the neutrino mass ordering and oscillation parameters with KM3NeT/ORCA

Aiello, S., Albert, A., Alves Garre, S. et al. , *Eur. Phys. J. C* **82**, 26 (2022)

Sensitivity



The sensitivity of neutrino mass ordering after 3 years of data taking: 4.4σ if the true ordering is normal and 2.3σ if inverted

Figure 9, Determining the neutrino mass ordering and oscillation parameters with KM3NeT/ORCA

Aiello, S., Albert, A., Alves Garre, S. et al. , *Eur. Phys. J. C* **82**, 26 (2022)

Thank You

