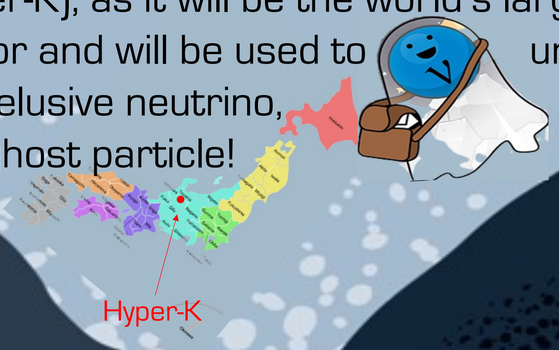
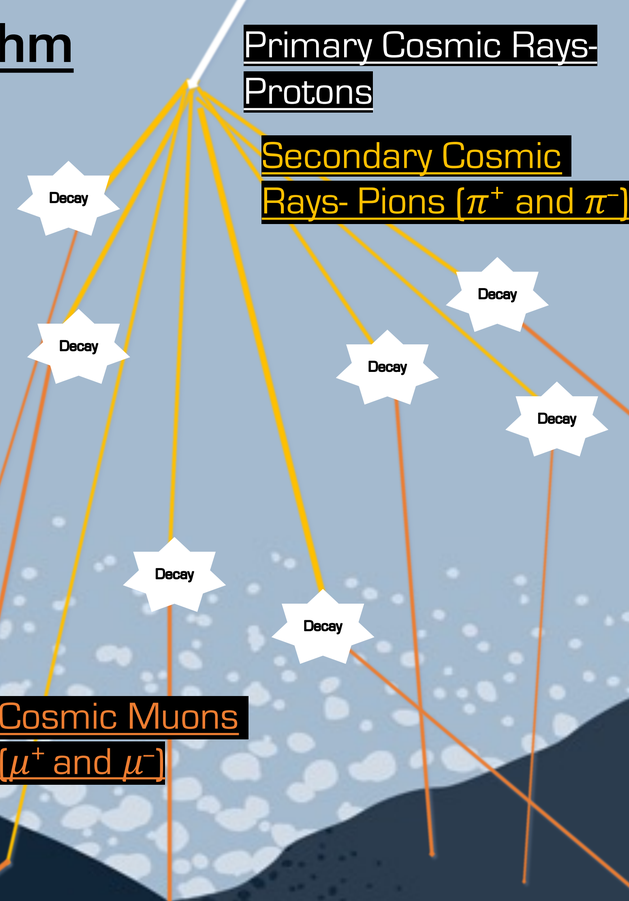
An approach to the Hyper-Kamiokande Outer Detector Clustering Algorithm for Cosmic Muons

Hyper Kamiokande (Hyper-K) is a large underground particle detector, in Gifu Prefecture, Japan. It expands upon the successes of Super Kamiokande (Super-K), as it will be the world's largest water Cherenkov detector and will be used to uncover the secrets of the elusive neutrino, a.k.a. the ghost particle!

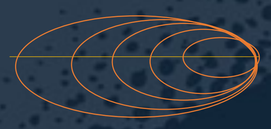


Hyper-K will be approximately 650m below the surface!

Primary cosmic rays (mainly protons) interact with the upper atmosphere to produce secondary cosmic rays, which decay into muons.



(1) The Main Physics of Hyper-K - Charged particles can travel faster than light in water. This creates a flash of light, akin to a sonic boom with sound! This flash of light is detected using Photomultiplier Tubes (PMTs) which act like reverse cameras, converting light into electric signals.



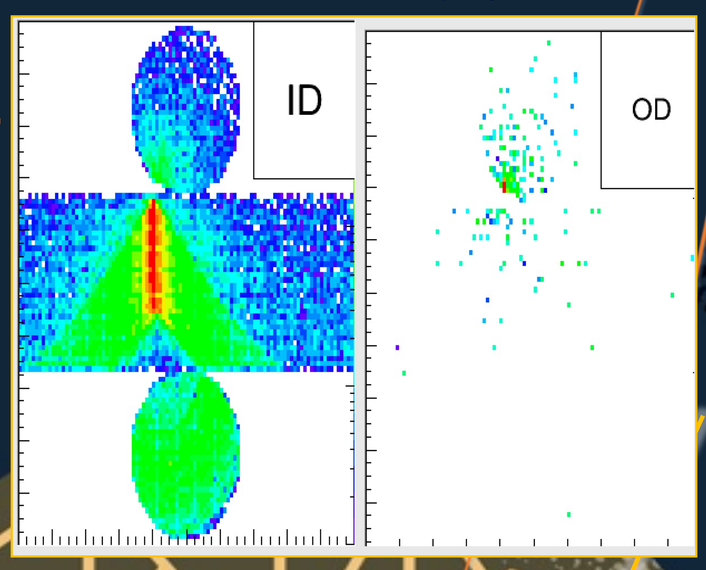
- Rings of Cherenkov photons
- Faster than light charged particle


Rings from a Super-K Event!

An OD PMT!

(2) The Hyper-K Outer Detector- Hyper-K is a giant cylindrical tank of water. It is comprised of an inner detector (ID), and an outer detector (OD). The role of the OD is to veto cosmic muons, which are the main source of noise in Hyper-K. The Cherenkov photons are reflected by Tyvek sheets, and their wavelengths are shifted into a detectable range by Wavelength Shifting Plates. They then hit the OD PMTs just like the ID PMTs, as can be seen in the ID and OD Event Display plot.

ID and OD Event Display!

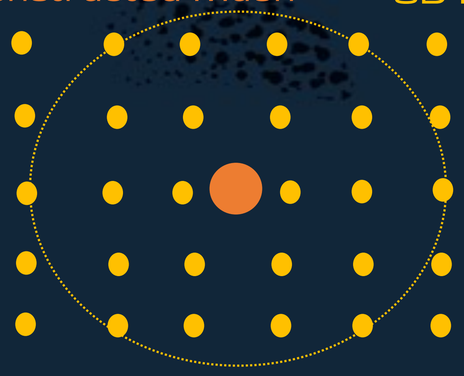


(3) Centre of Mass Clustering Method- Using the event display, the OD cluster that we want can be seen. I have employed a Centre of Mass Clustering to get the cosmic muons' positions. I take the average positions of all the OD PMTs which are triggered by a certain muon event. This will end up being somewhere in the middle of Hyper-K, therefore I project that through the center of the detector, onto the OD surface.

This support structure more clearly shows that the OD is its own, distinct, optically isolated volume, with outward facing PMTs

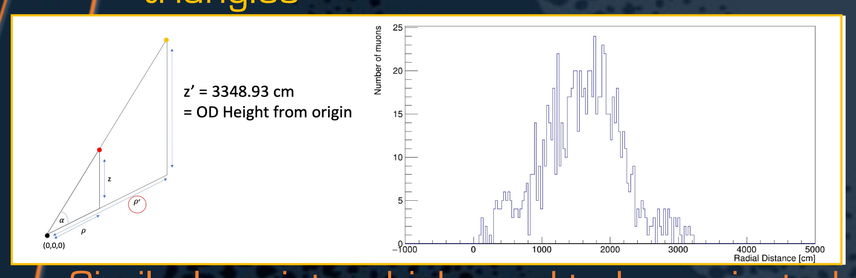
(5) Clustering around the muons- Calculate the distance to each OD PMT, then do a spherical cut-off

Reconstructed Muon OD PMT

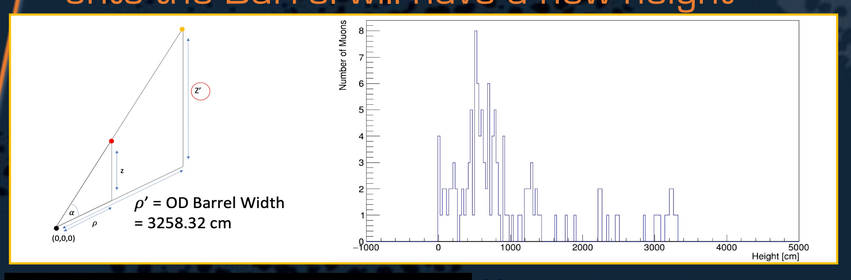


(6) Preliminary Results- If there are more than a certain number of hits within this cluster, then noise can be ruled out, and the event is a cosmic muon which can be vetoed!

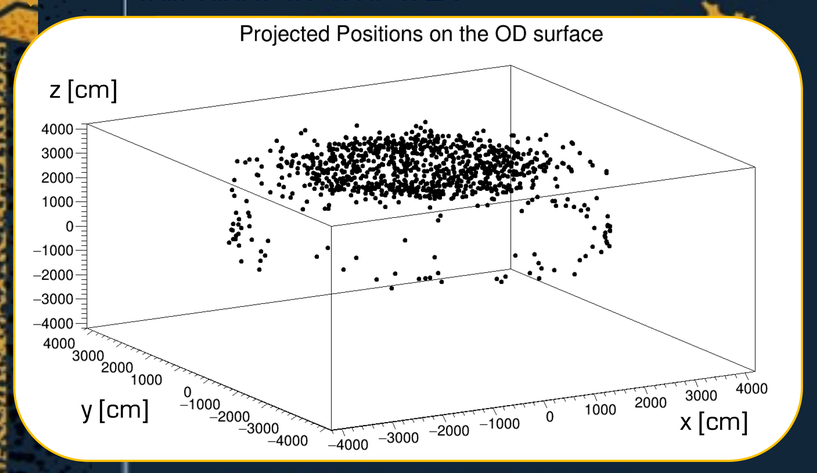
Points which need to be projected onto the Top will have a new radial position which can be calculated using similar triangles



Similarly, points which need to be projected onto the Barrel will have a new height



(4) OD Projection Method- If one imagines two cones inside the detector, as shown inside the image of Hyper-K, any muon which is reconstructed inside the top (bottom) cone is projected onto the OD top (bottom) cap. Anything outside of these cones is projected onto the OD barrel. The plot below shows the reconstructed positions which are all on the surface of the OD!



This preliminary plot shows the reconstructed positions for 1000 incoming vertical cosmic muons, which come from a circular plane above the detector, and have an energy of 10 GeV

- The Hyper-K OD is planned to be ~67m in height
- Hyper-K is 84 times larger than Super-K, and has a fiducial volume of 187kton
- It is planned that the OD will contain between 8,000 and 10,000 PMTs! My simulations have used 10,000

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