

Science and  
Technology  
Facilities Council

# **HYPER-K AND ITS SIBLINGS**

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# The T2K/SuperK/HyperK Group

- We have a small but active group
- T2K and SuperK are both running experiments, while HyperK is being built to start in 2027/28



Anna



Federico



Tomislav



Sammy



George



Rebecca



Adam

- People also closely linked to our group are:

- Morgan Wasko and Luke Pickering - T2K
- PPD HK project managers Lisa and David
- RAL TD group (Chris Densham, Mike Fitton and co)



\* Menai has now finished her PhD and has moved onto a postdoc on HK



# The Physics Questions

\* Neutrinos oscillations are only confirmed sign of physics beyond the Standard Model.

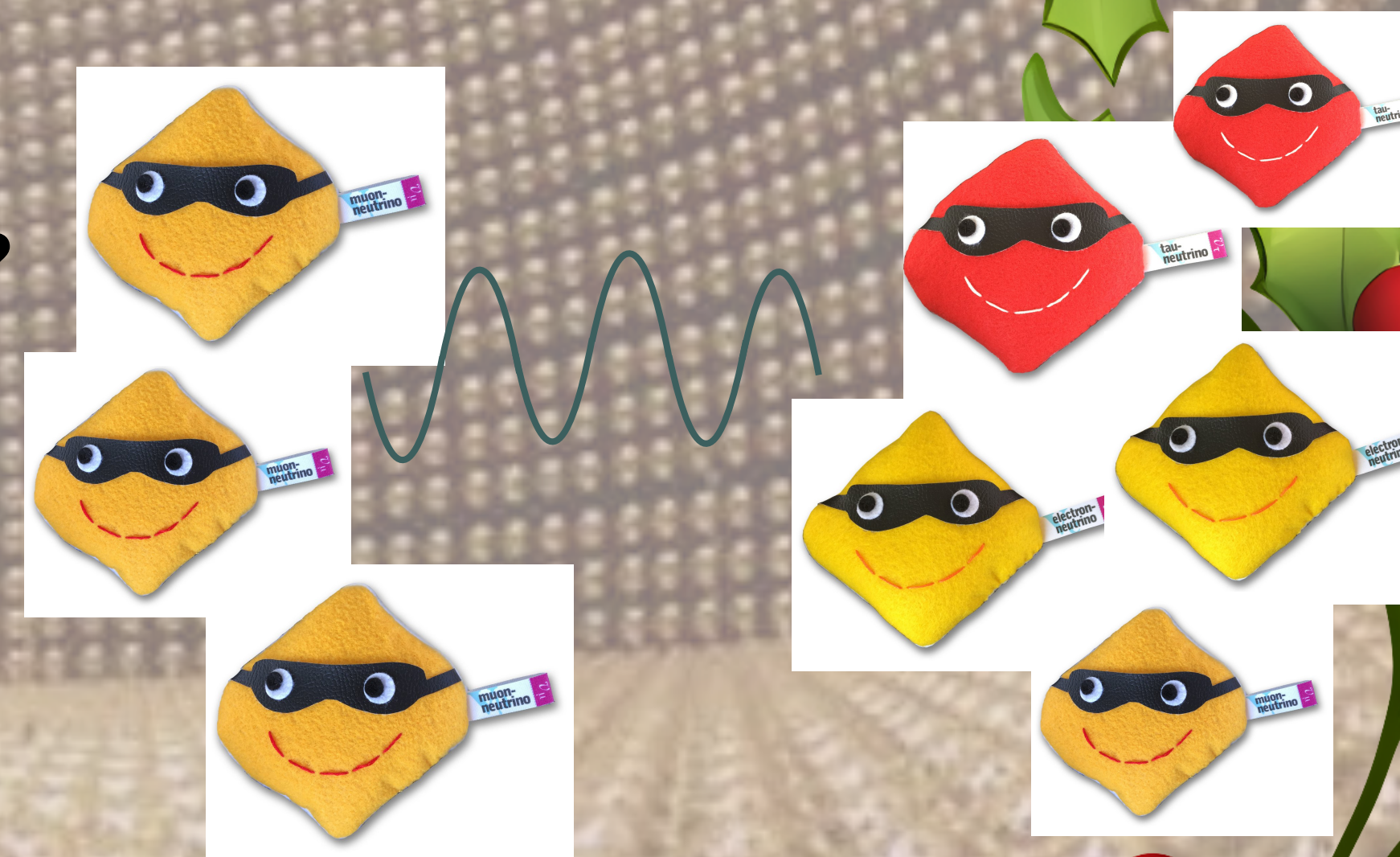
\* There are still outstanding fundamental neutrino questions:

\* The neutrino mass hierarchy (is  $\delta m_{32}^2$  positive or negative)?

\* Is the  $\theta_{23}$  mixing angle (between  $\mu$  and  $\tau$  neutrinos) maximal?

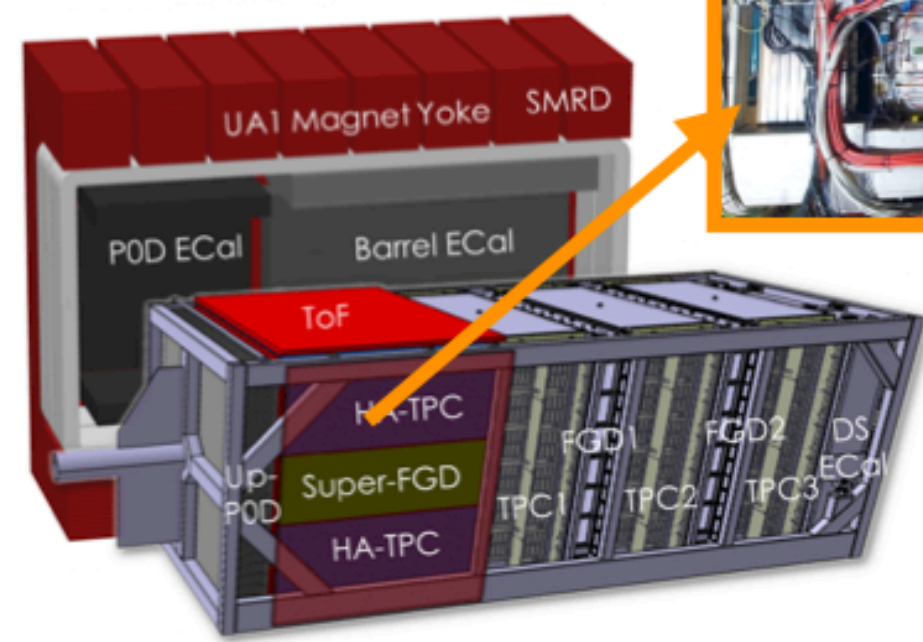
\* Is  $\delta_{CP}$  non-zero, i.e. is charge parity violated in the neutrino sector?

\* In addition, there are many other things we want to see, for example SuperNova neutrinos, dark matter neutrinos...

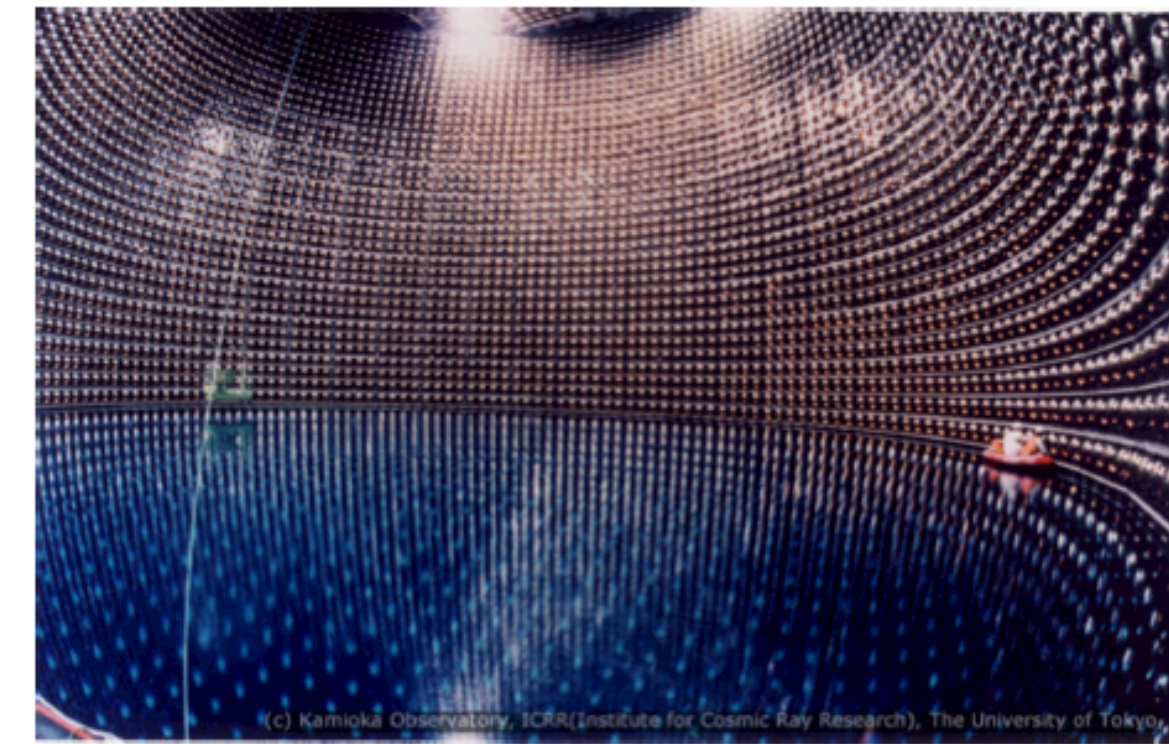


$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$





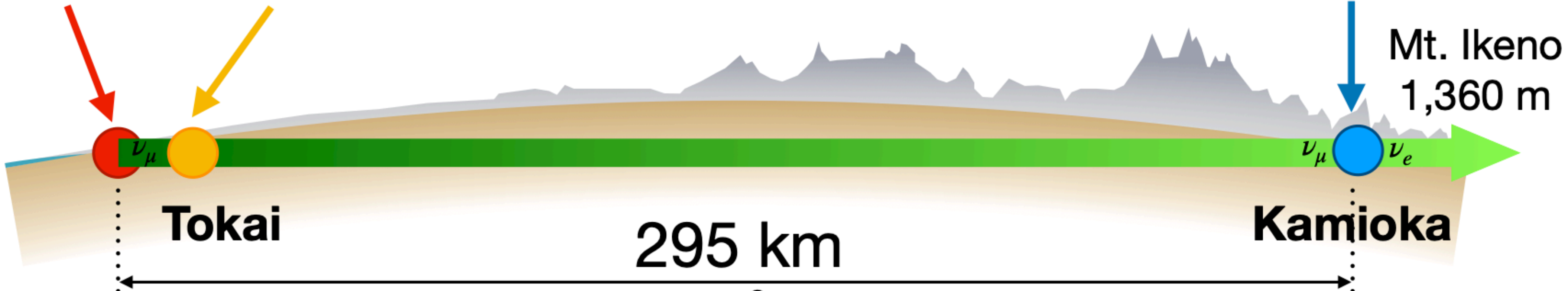
# T2K



J-PARC

ND280

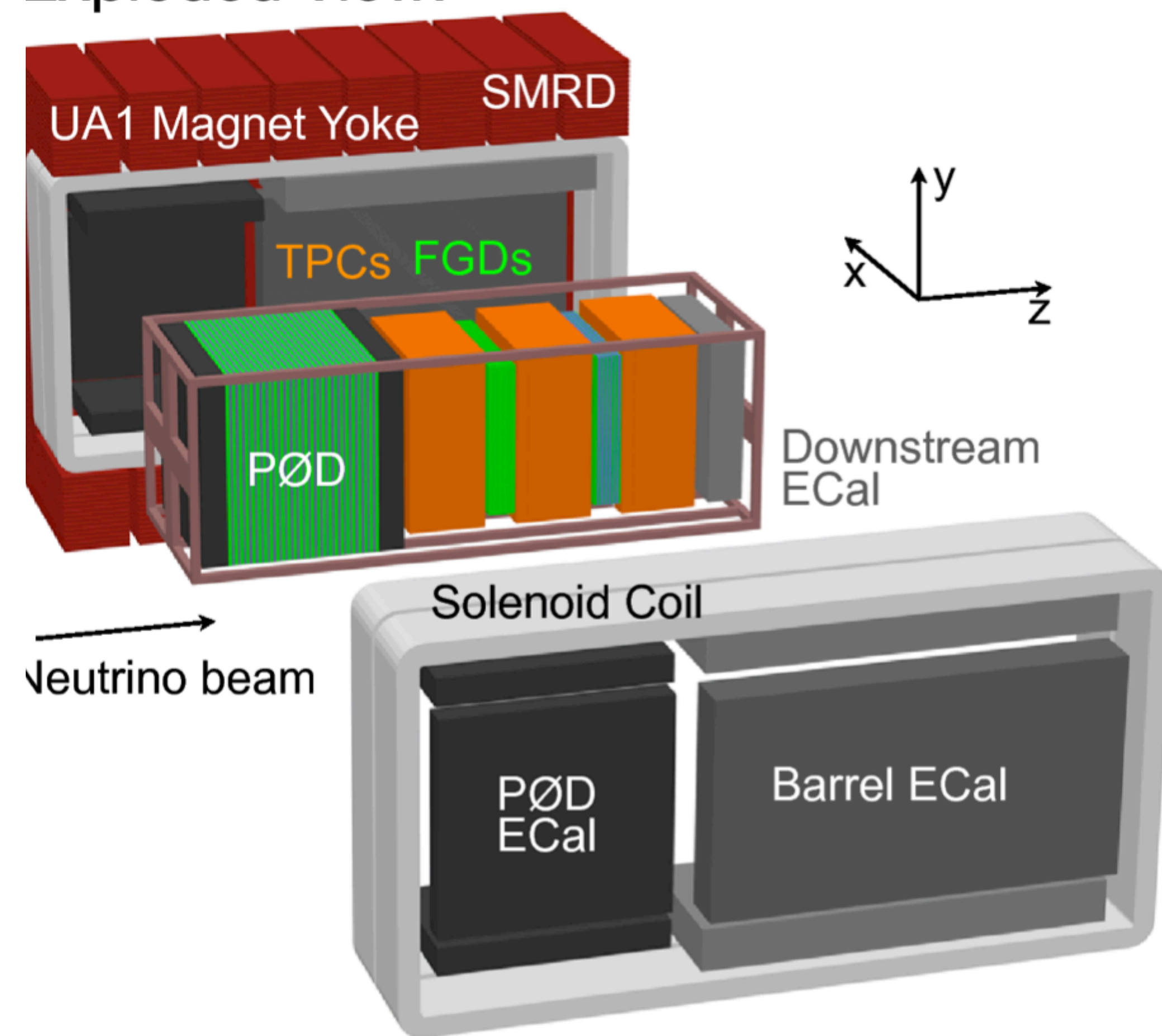
Super-Kamiokande







## ND280 Off-Axis Near Detector of T2K, Exploded View:

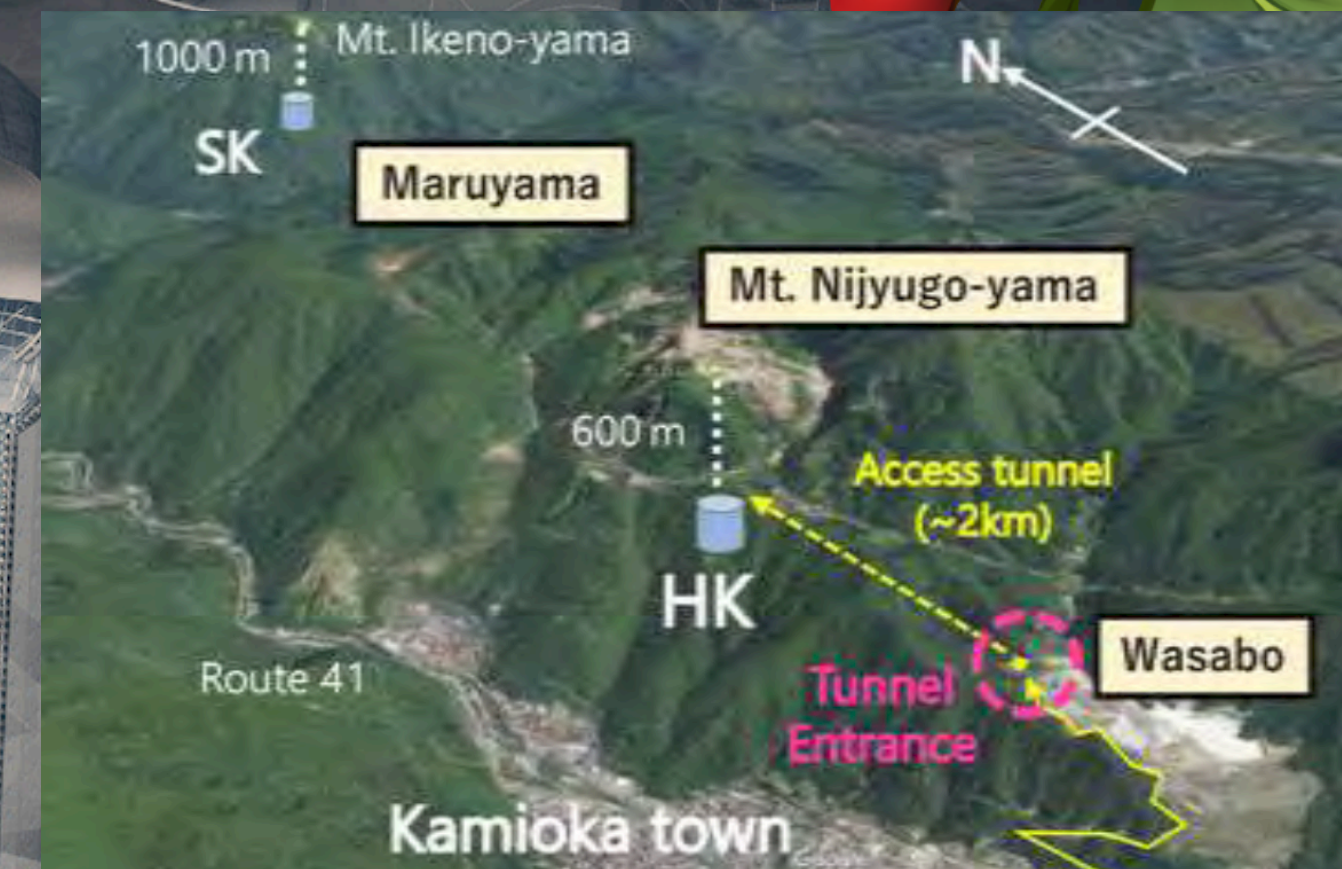


- \* ND280 DAQ Experts
- \* Managing of data back-up
- \* Cross-section analyses
- \* Event selections
- \* Beam systematics



# Hyper-Kamiokande

- Hyper-K is the next evolution of the existing Super-Kamiokande and T2K experiments
- It will be huge! Fiducial volume about 8 times bigger than the existing SuperK detector; its volume will be equivalent to about 80 olympic swimming pools!
- Huge cylindrical water Cherenkov detector, volume ~71m tall x 69m diameter, filled with ultra-pure water
- Detects Cherenkov light produced by particles interacting in the detector volume
- Using ND280 near detector, plus building new IWCD 1km from beam target





# A full program of science!

Neutrino beams



Dark matter neutrinos

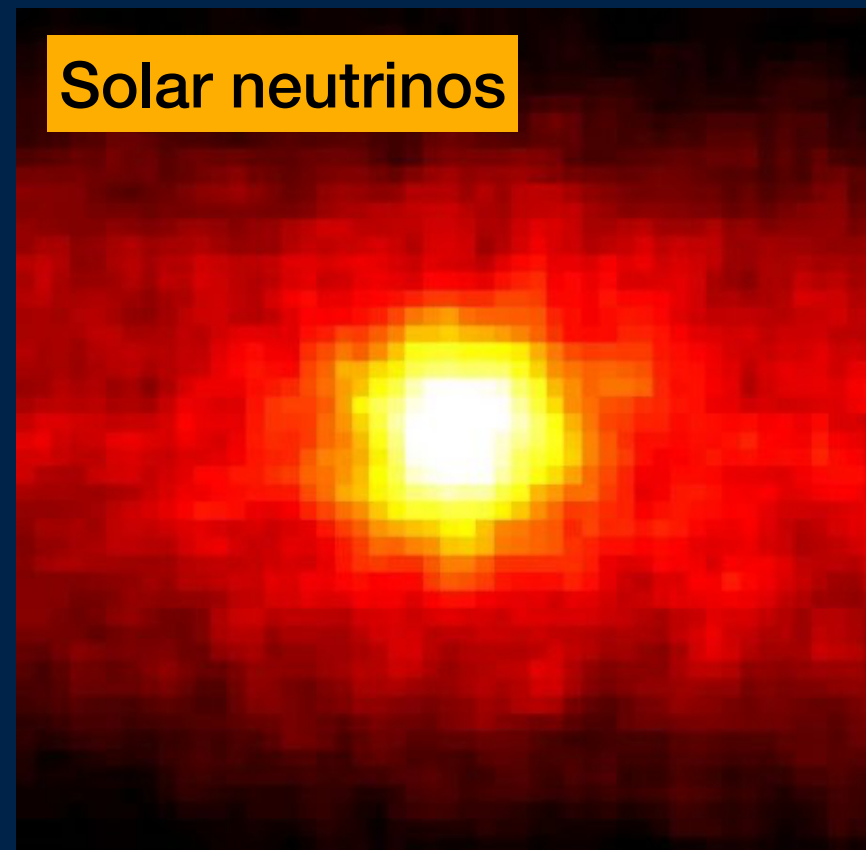


- Hyper-K will be more than just a high precision instrument for measuring the oscillation parameters we want to know
- It will be a multi-messenger neutrino observatories capable of measuring so many things!

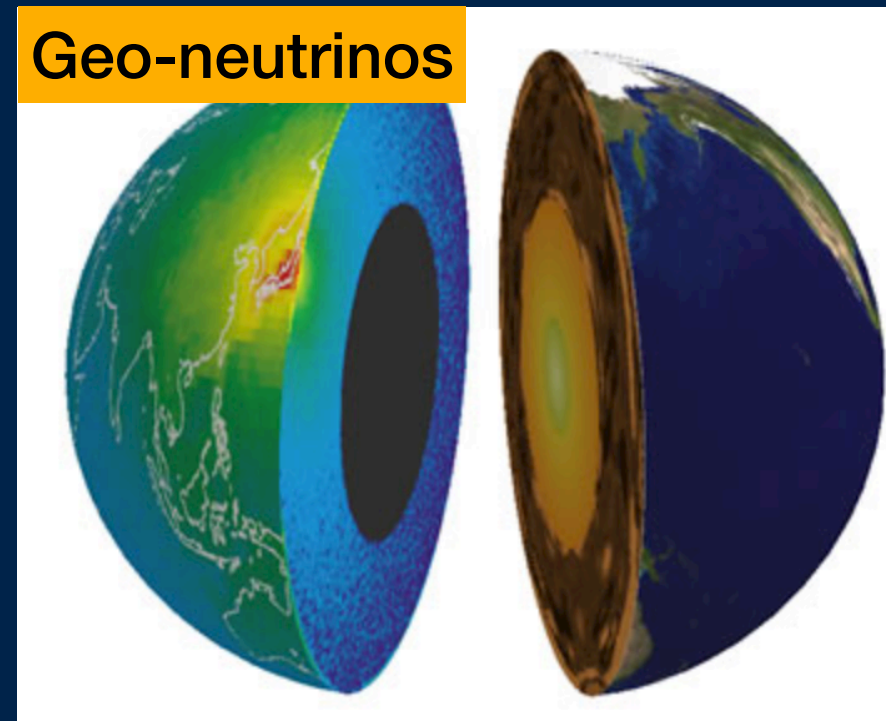
Supernova neutrinos



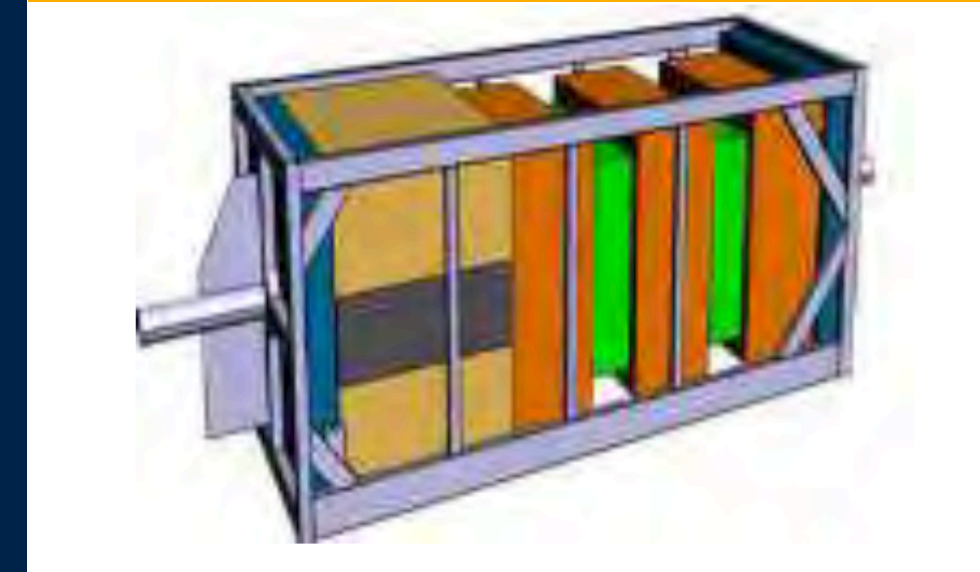
Solar neutrinos



Geo-neutrinos



Neutrino Cross-Sections



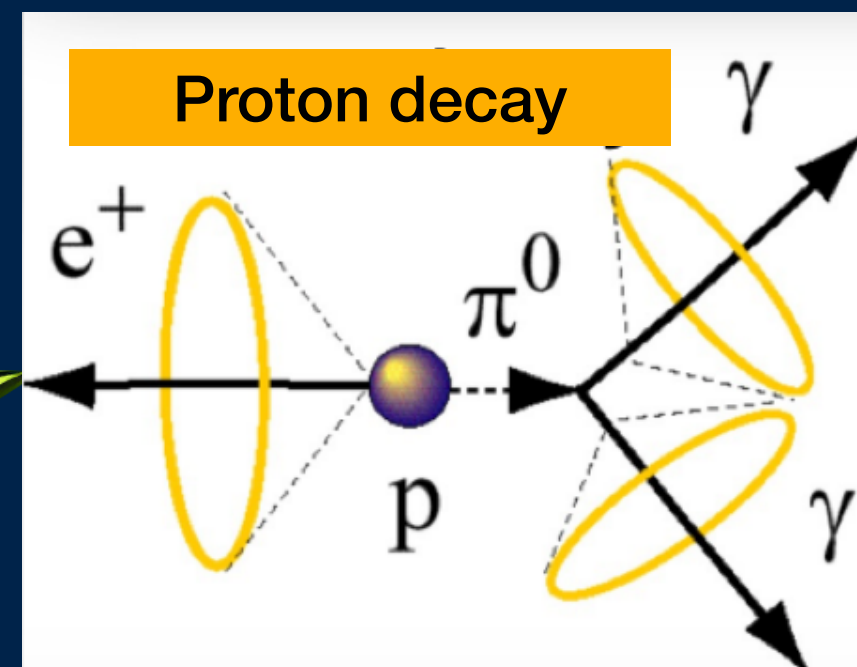
Exotic Physics

Unknown Physics?

Astrophysical neutrinos



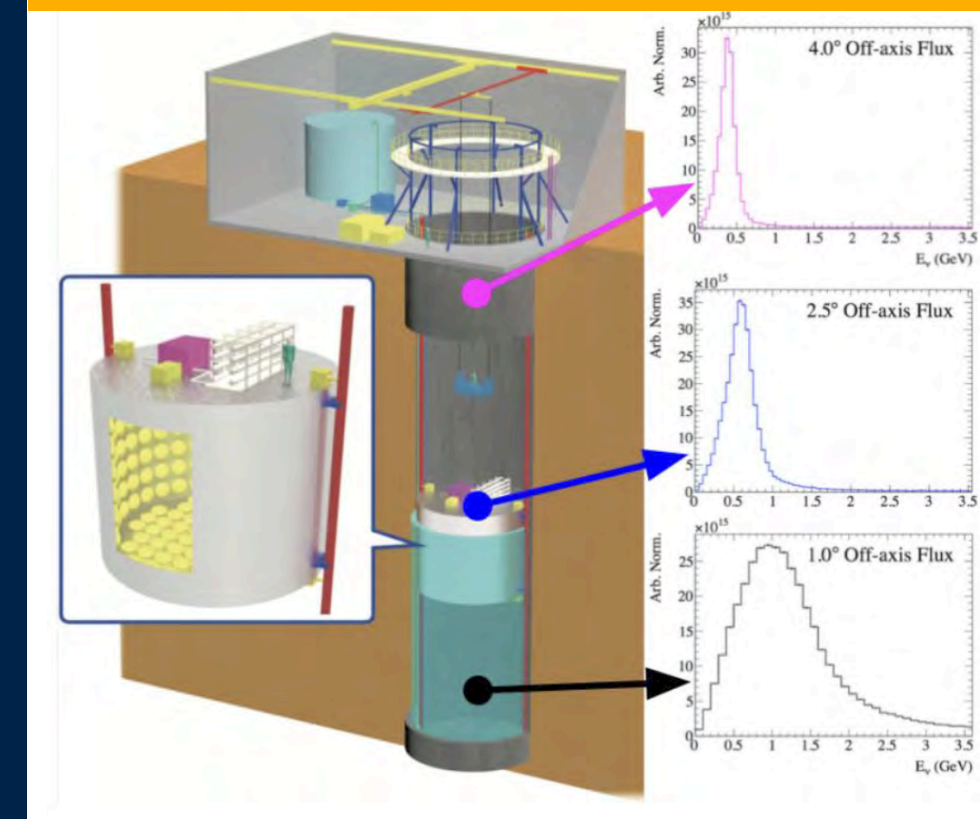
Proton decay



Atmospheric neutrinos



Neutrino Fluxes





# Hyper-Kamiokande at PPD

DAQ Triggers - both ID and OD

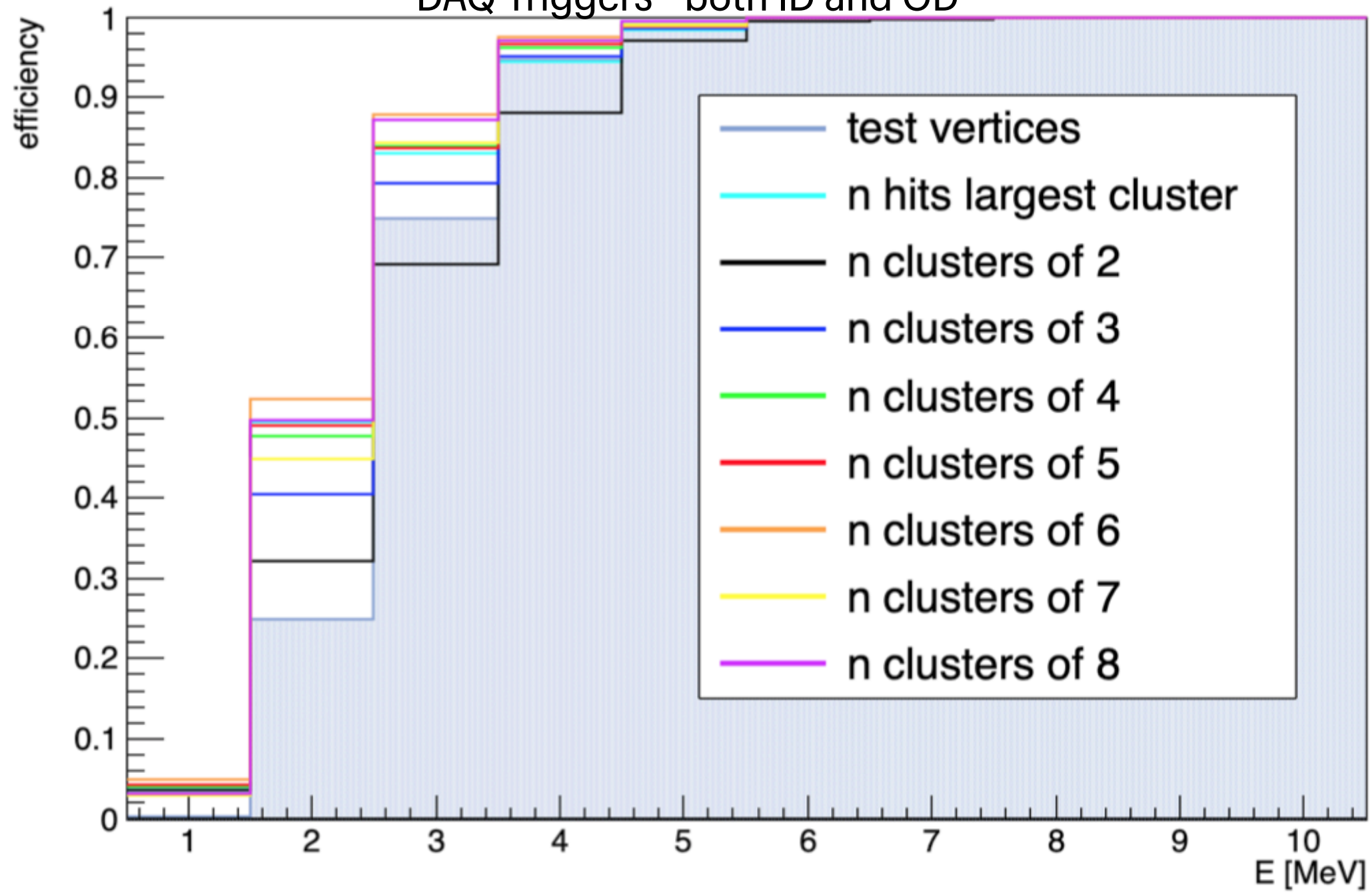
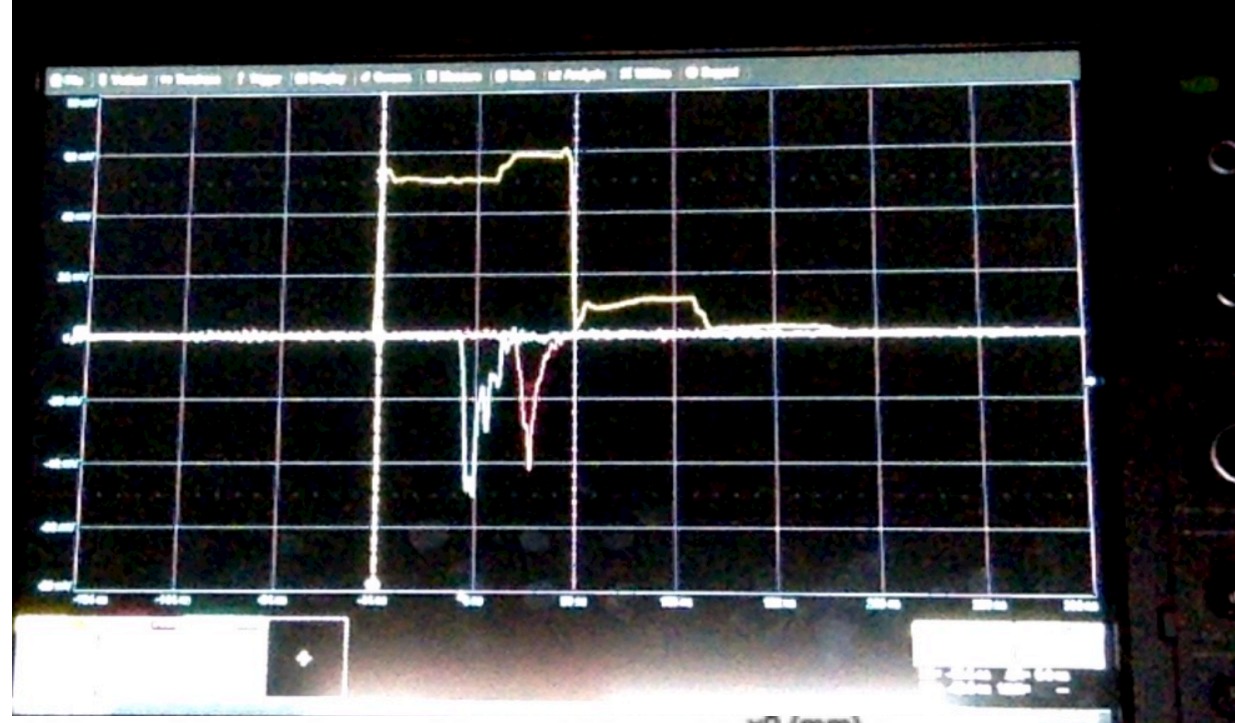


Photo-detection lab



Hyper-Kamiokande Mock Frame at RAL

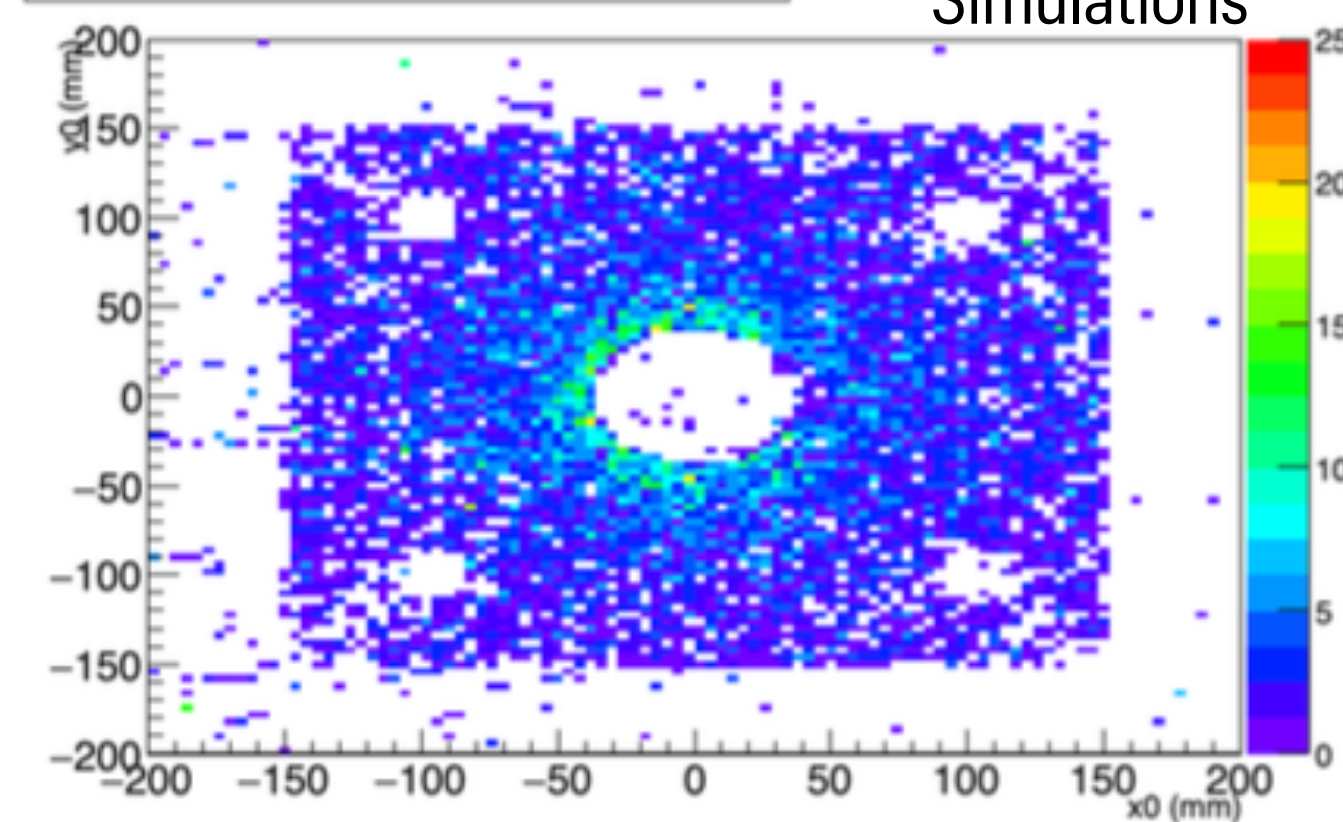


Outer detector testing of WLS plates and PMTs



25 mm holes @ 14 cm diagonal (X)

Simulations



Neutrino oscillation analysis...

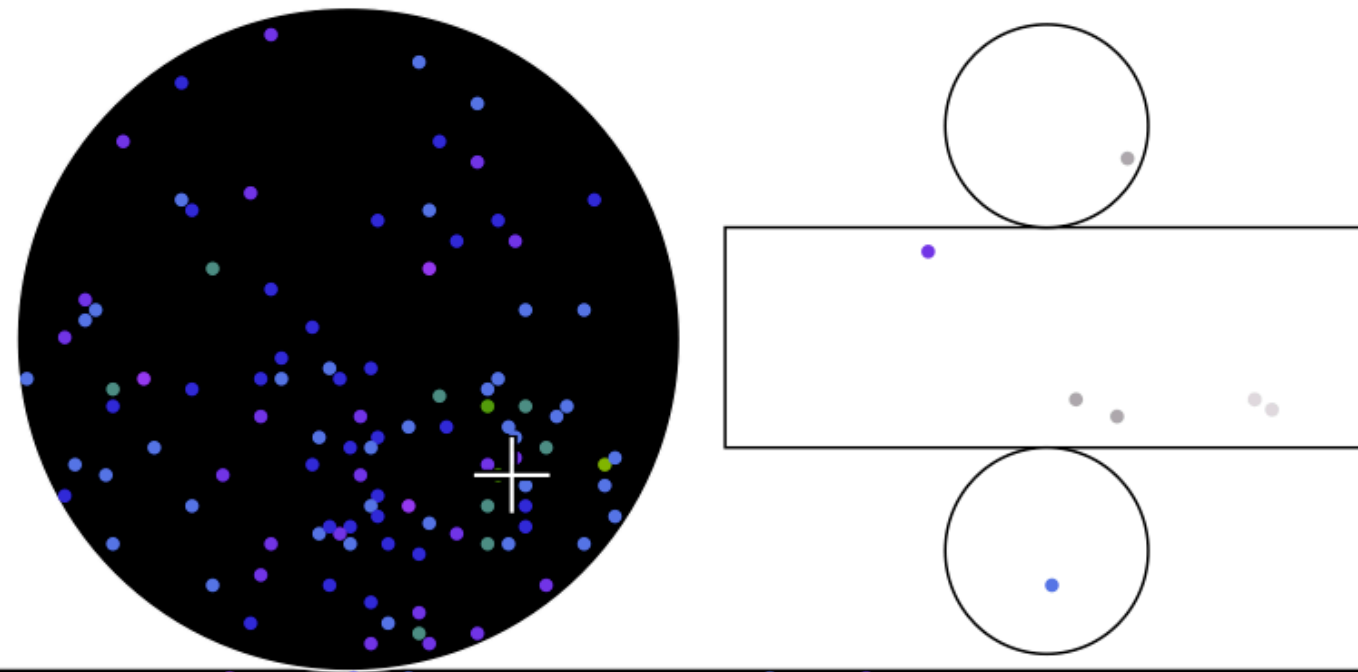
TD - Neutrino target



# Super-Kamiokande at PPD

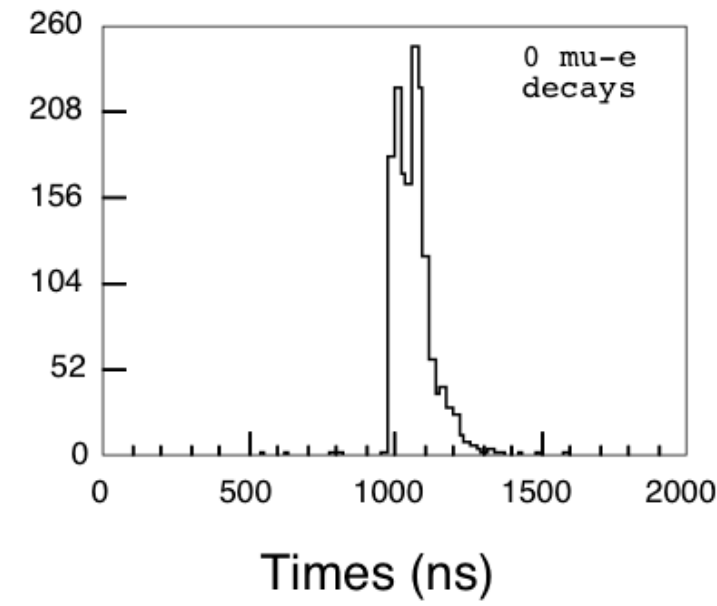
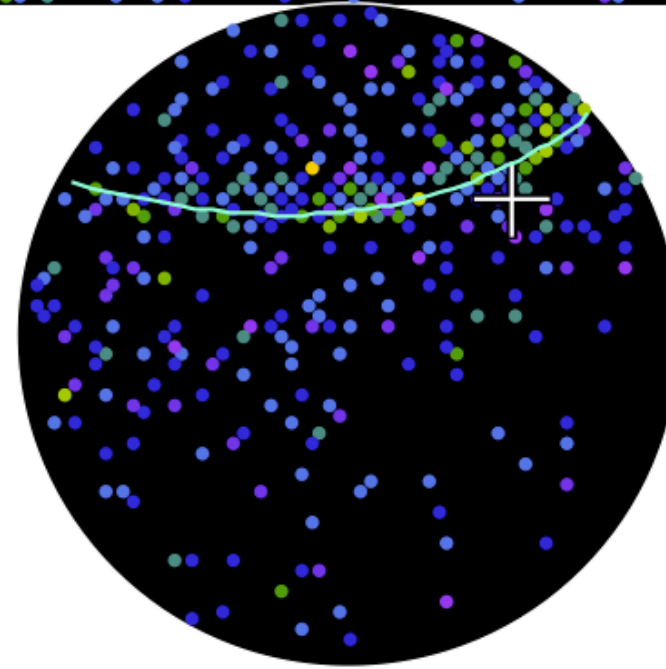
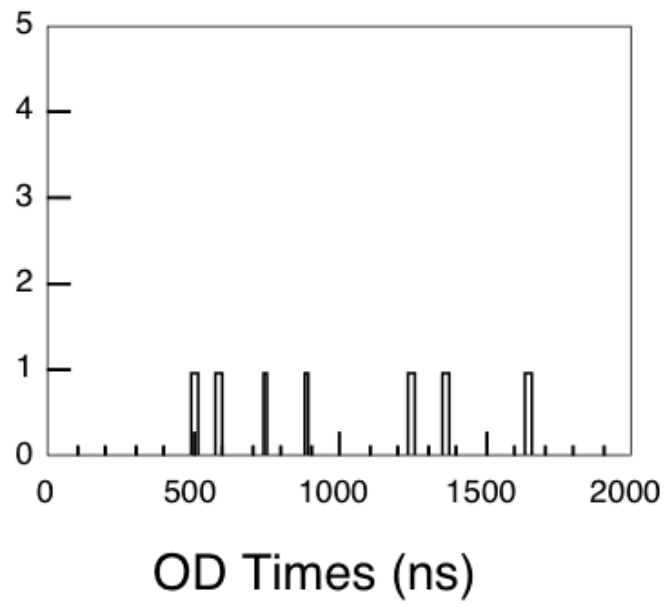
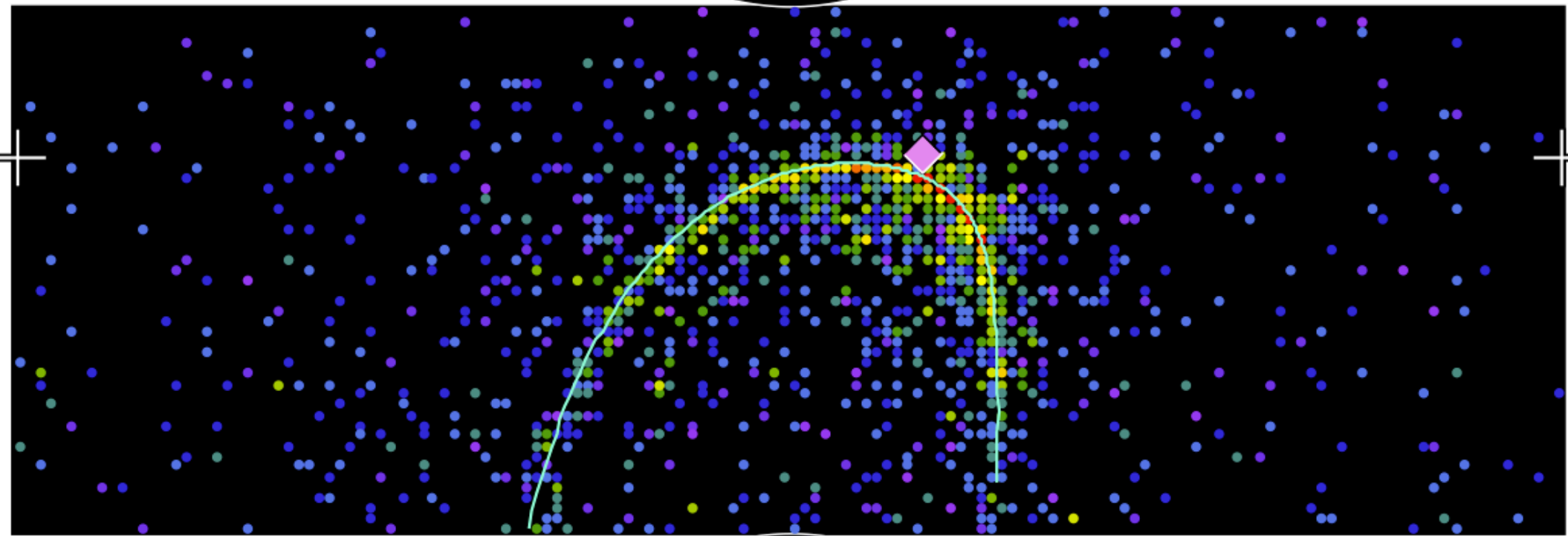
## Super-Kamiokande IV

T2K Beam Run 0 Spill 822275  
 Run 66778 Sub 585 Event 134229437  
 10-05-12:21:03:26  
 T2K beam dt = 1902.2 ns  
 Inner: 1600 hits, 3681 pe  
 Outer: 2 hits, 2 pe  
 Trigger: 0x80000007  
 D\_wall: 614.4 cm  
 e-like, p = 377.6 MeV/c

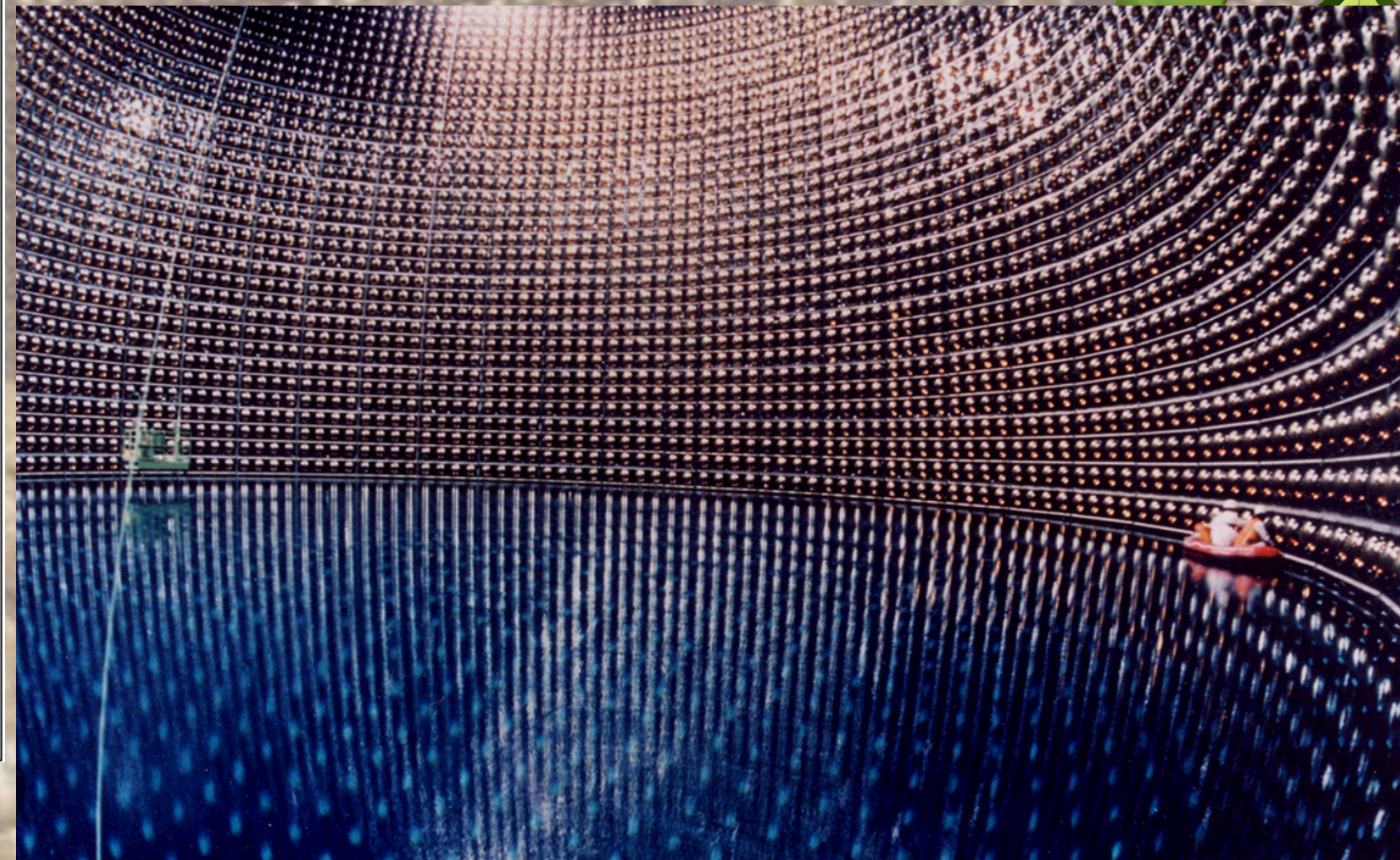
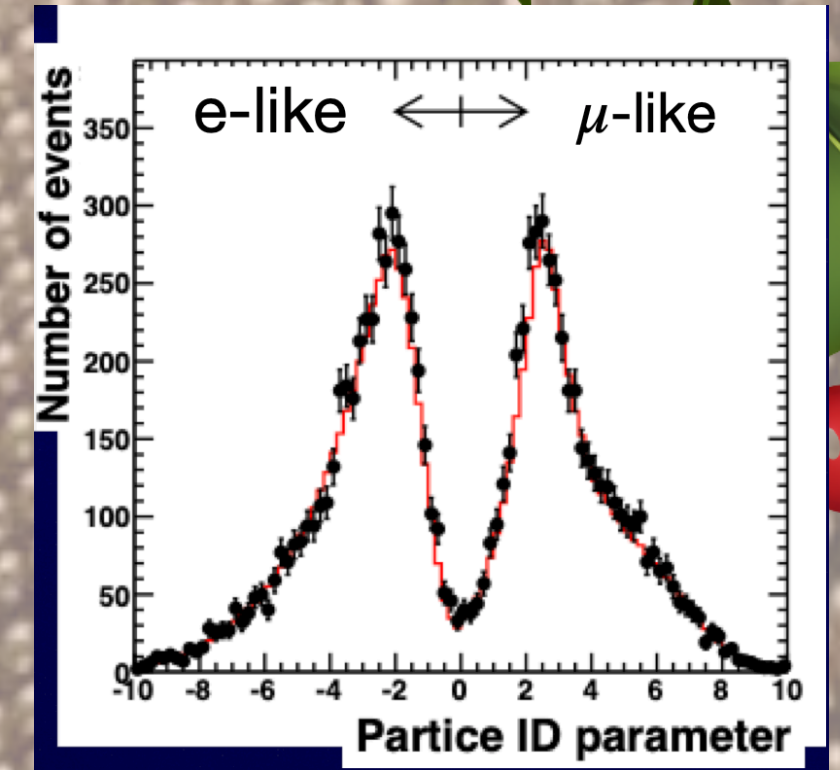


### Charge (pe)

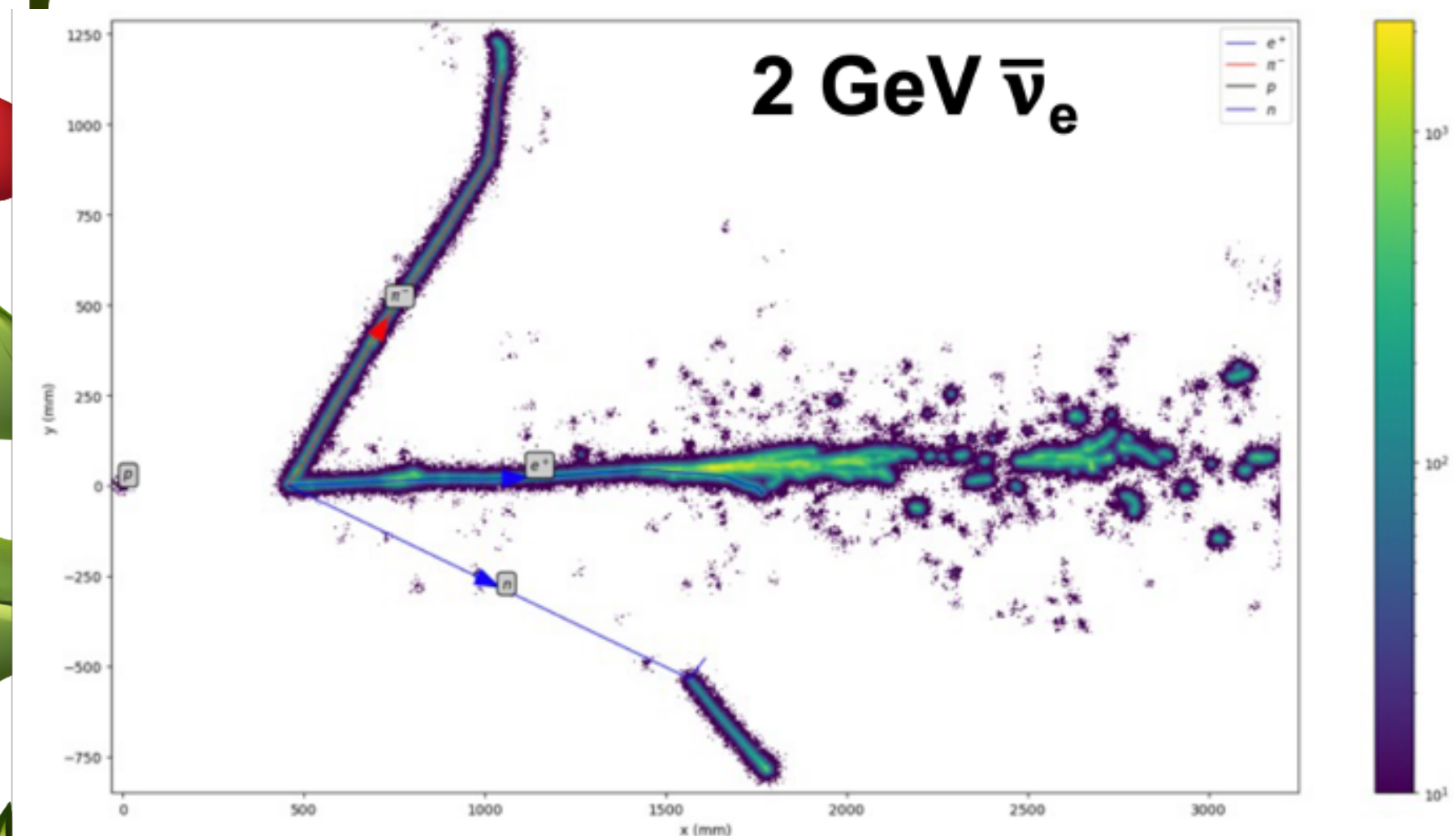
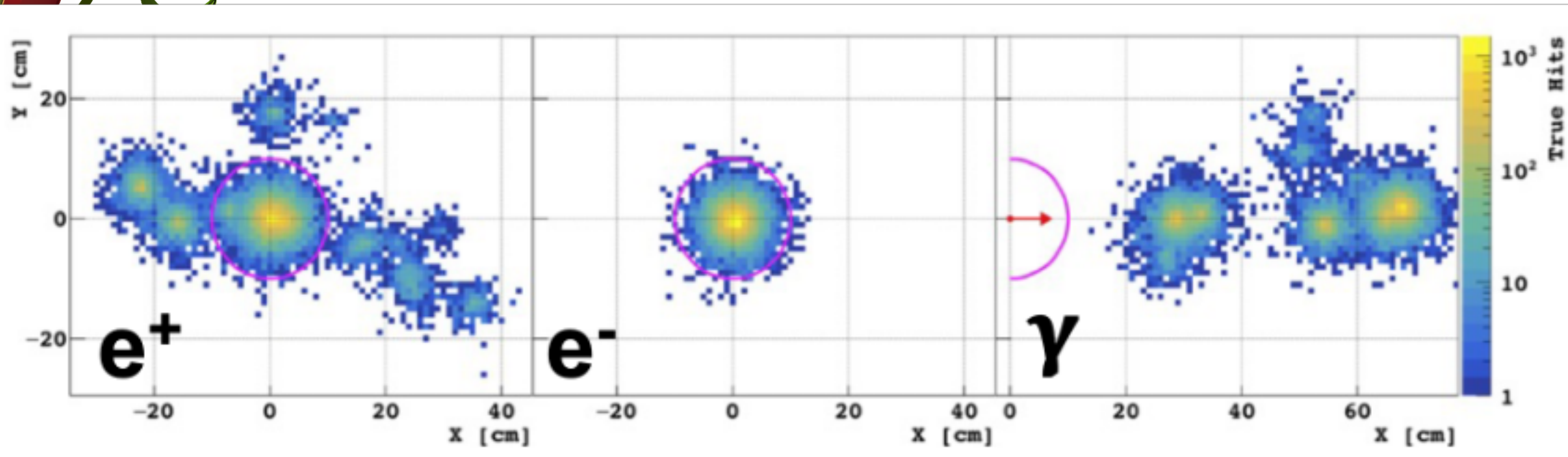
- >26.7
- 23.3-26.7
- 20.2-23.3
- 17.3-20.2
- 14.7-17.3
- 12.2-14.7
- 10.0-12.2
- 8.0-10.0
- 6.2- 8.0
- 4.7- 6.2
- 3.3- 4.7
- 2.2- 3.3
- 1.3- 2.2
- 0.7- 1.3
- 0.2- 0.7
- < 0.2



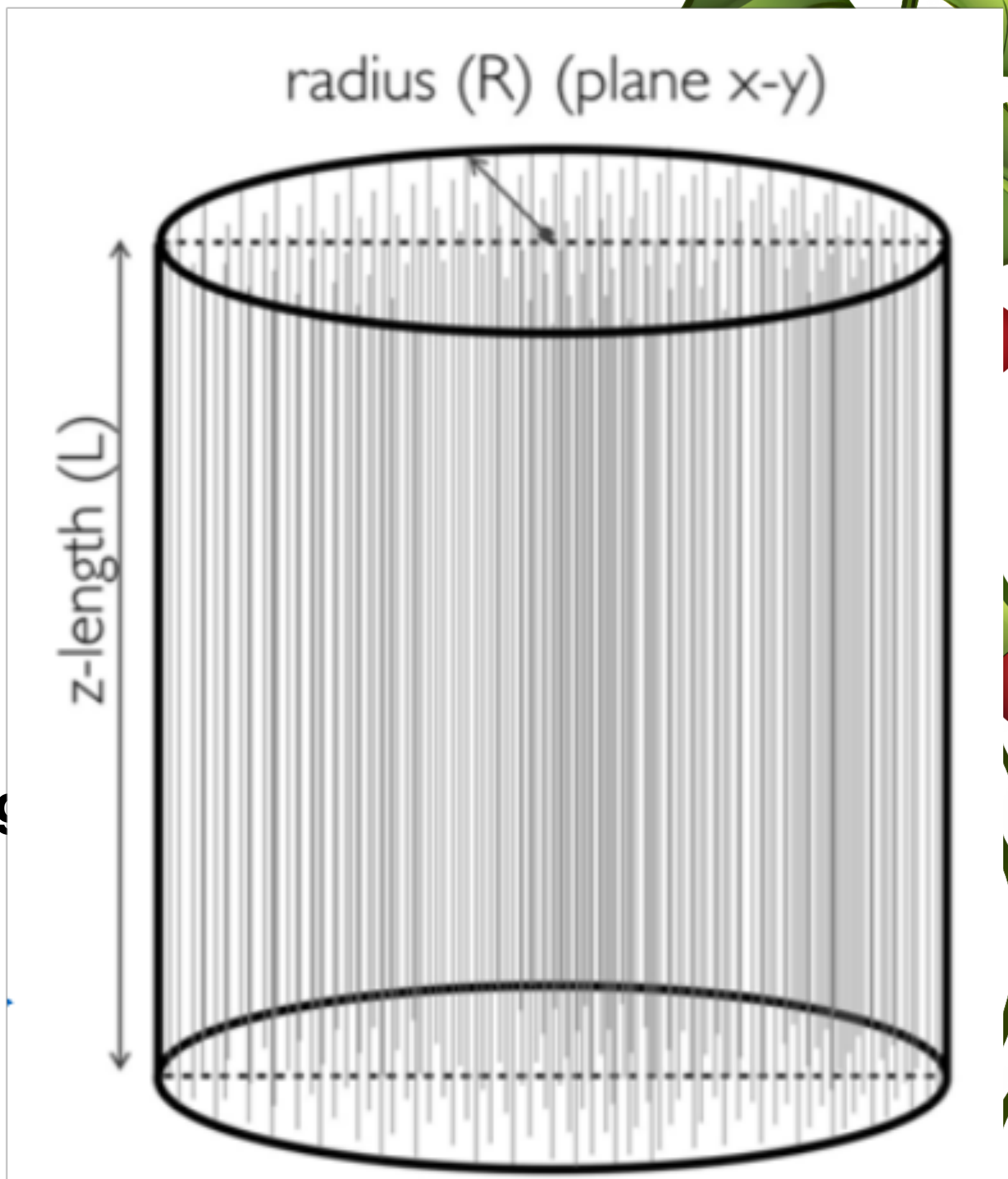
- \* Analysing new Gd loaded data
- \* Atmospheric Oscillation analysis
- \* Calibration
- \* Detector shifts



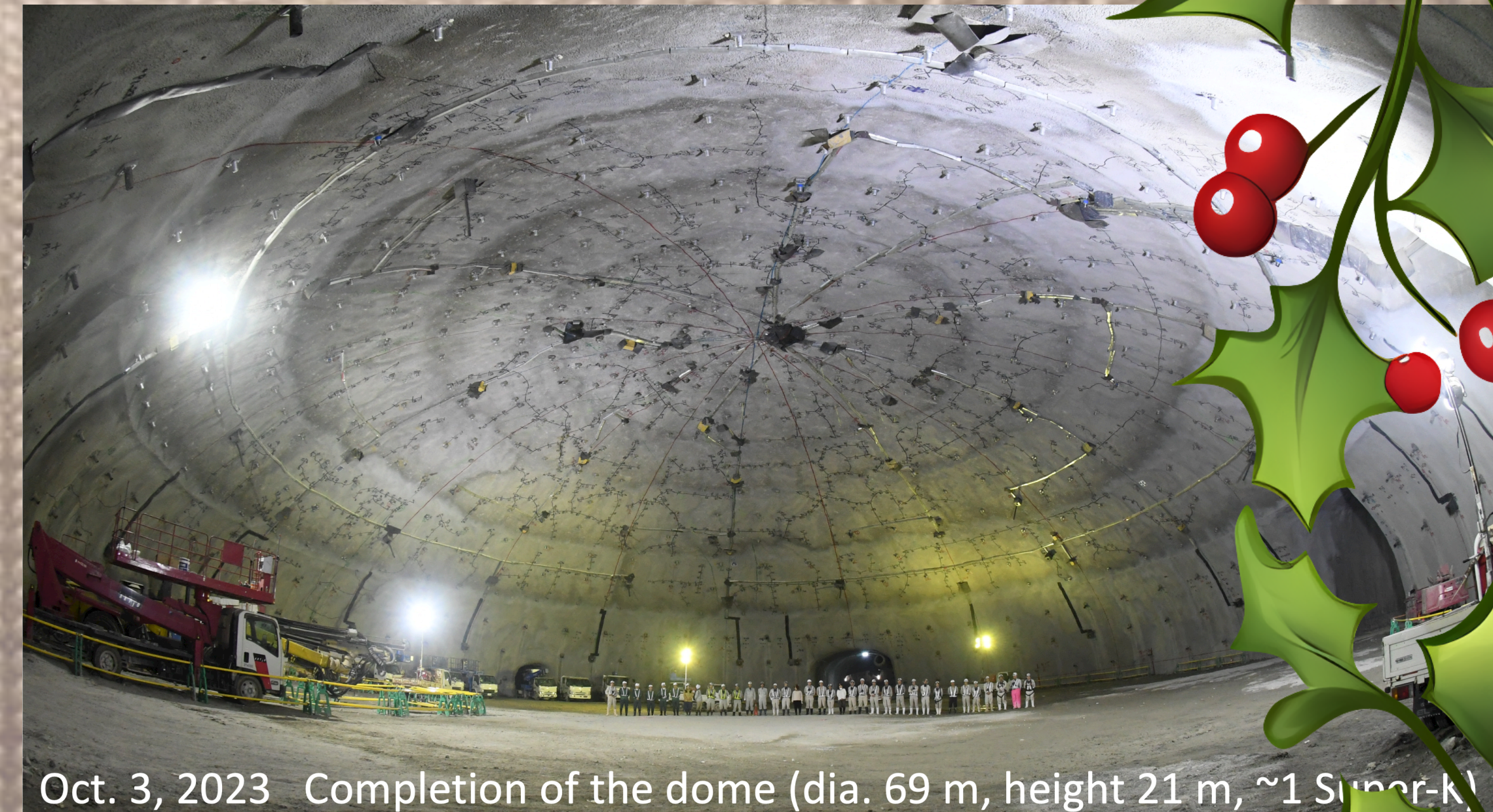




- \* Opaque Scintillator - light scattered locally and read out with wavelength shifting fibres - future detectors
- \* R&D - SiPM Readout and DAQ
- \* Detector design for CLOUD with TD







Oct. 3, 2023 Completion of the dome (dia. 69 m, height 21 m, ~1 Super-k)





