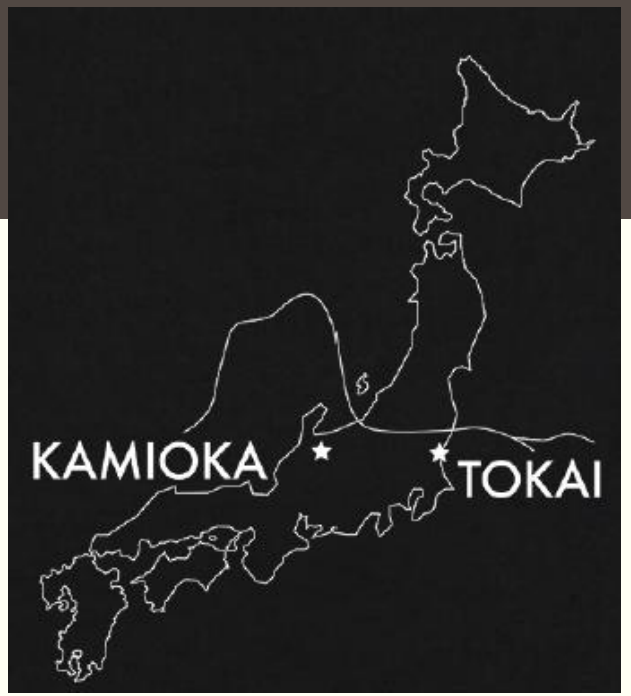


T2K, SK, HK: My personal Favorite 2019

Ka Ming Tsui

UNIVERSITY OF LIVERPOOL

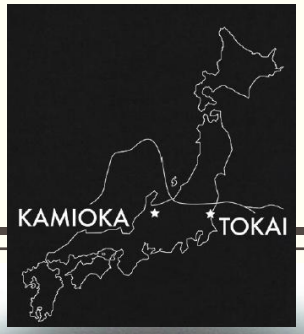
T2K SUPER SK Hyper-Kamiokande

Our group@Liverpool

- Graduate students
  - Francis Bench
  - Lauren Anthony
  - Gabriel Penn
  - Pruthvu Mehta
  - Jaiden Parlone (New)
- Post Docs
  - David Payne
  - Steve Dennis
  - ~~Adrian Pritchard~~
  - Ka Ming Tsui

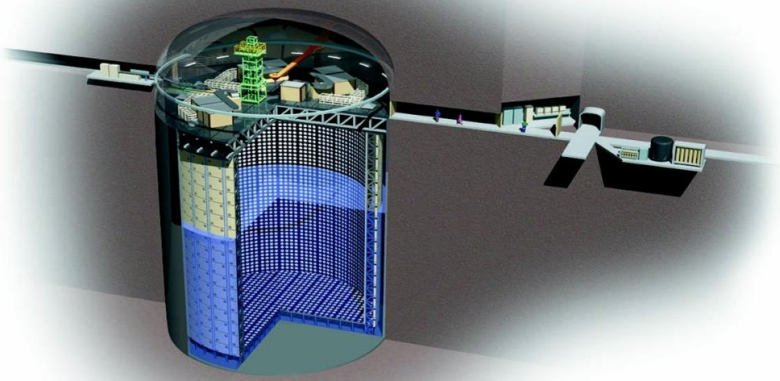
- Academics
  - Costas Andreopoulos
  - Neil McCauley
  - Christos Touramanis
  - Kostas Mavrorkoridis
  - Jon Coleman
- Support
  - Ashley Greenall
  - Sam Powel → HVCOMS
  - John Bland
  - Rob Fey
  - Steve Jones
  - Peter Sutcliffe
  - Karl Metelko

Super-Kamiokande (SK)

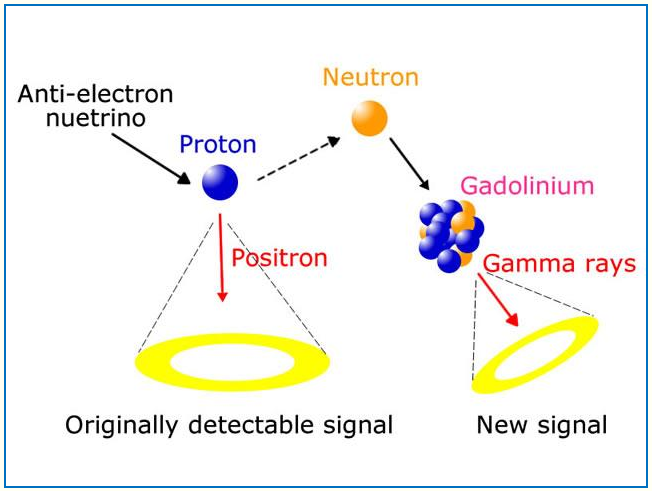


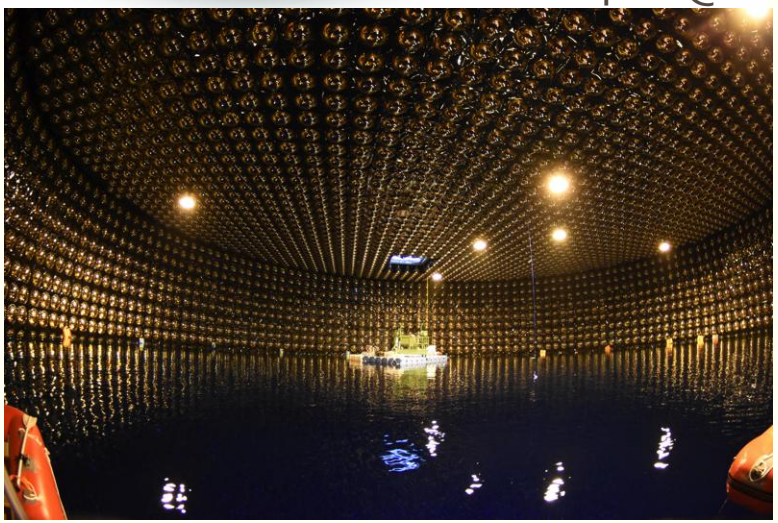
Nobel Prize 2015

- Solar neutrinos
- Atmospheric neutrinos
- Proton Decay
- Supernova (relic) neutrinos
- Gadolinium upgrade (2020)



Tank open@2018

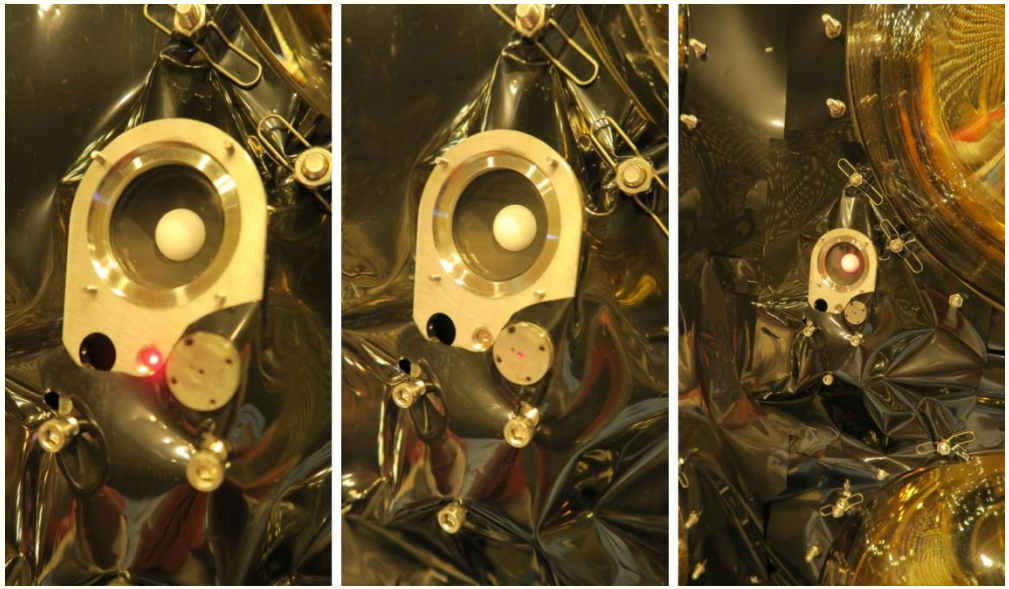




Liverpool calibration system

- **Installation work** completed in August 2018 and reported by Adrian last year X'mas
- **First signal** from the optics seen in November 2018
- **Commissioning** electronics in February-July 2019 with help from Super-K experts
- Integrated one of our optics with Super-K **automatic calibration system** for test run in August 2019. Success!
- Now Lauren is writing the **instrumentation paper**

- Injectors provide 3 different opening angles
- Calibrate various detector properties including optical properties of the water
- LED light source at 435nm from a dedicated UK electronics system

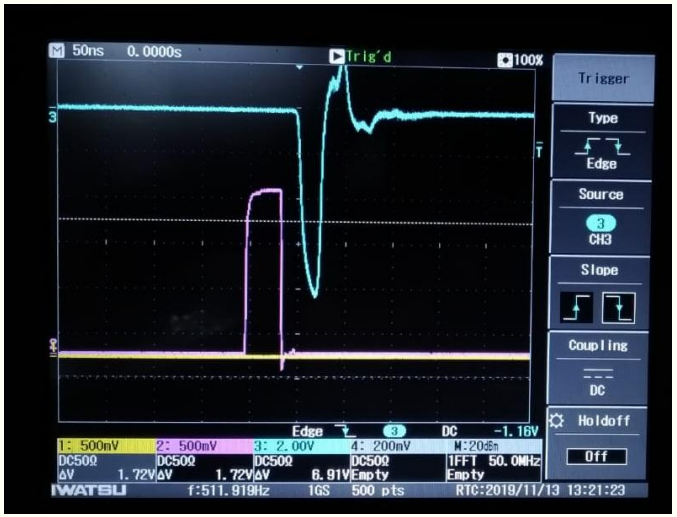


Commissioning of Electronics

- Completed in **July 2019** by Sam, Lauren, Neil and Adrian

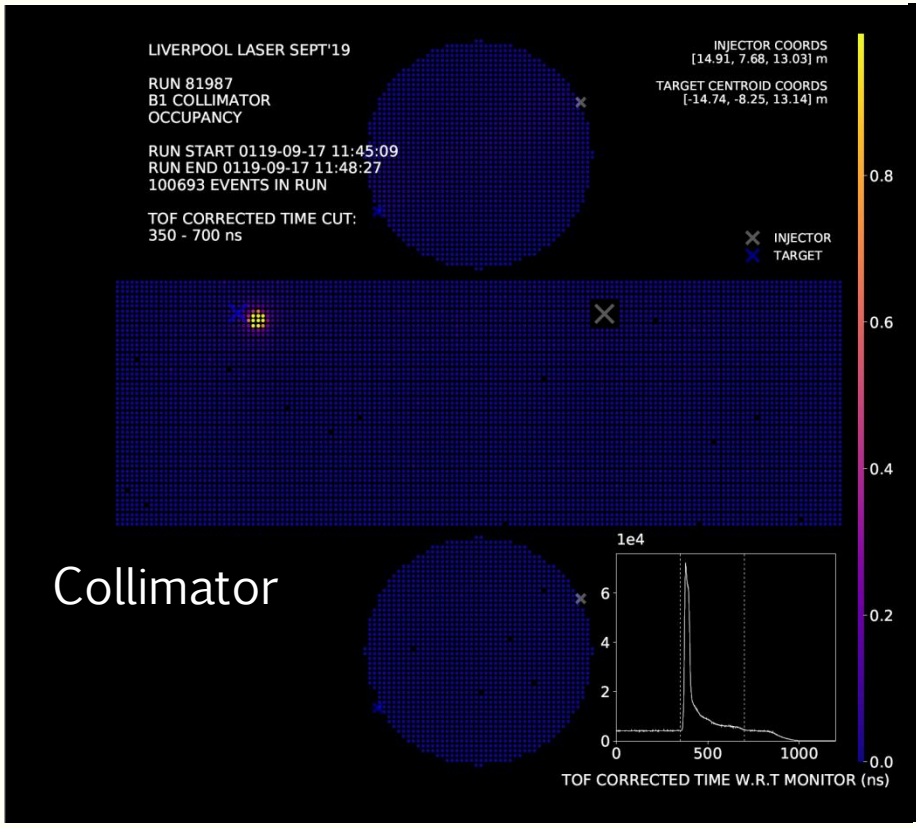
- Data taking is so easy that Neil can do it on his own!

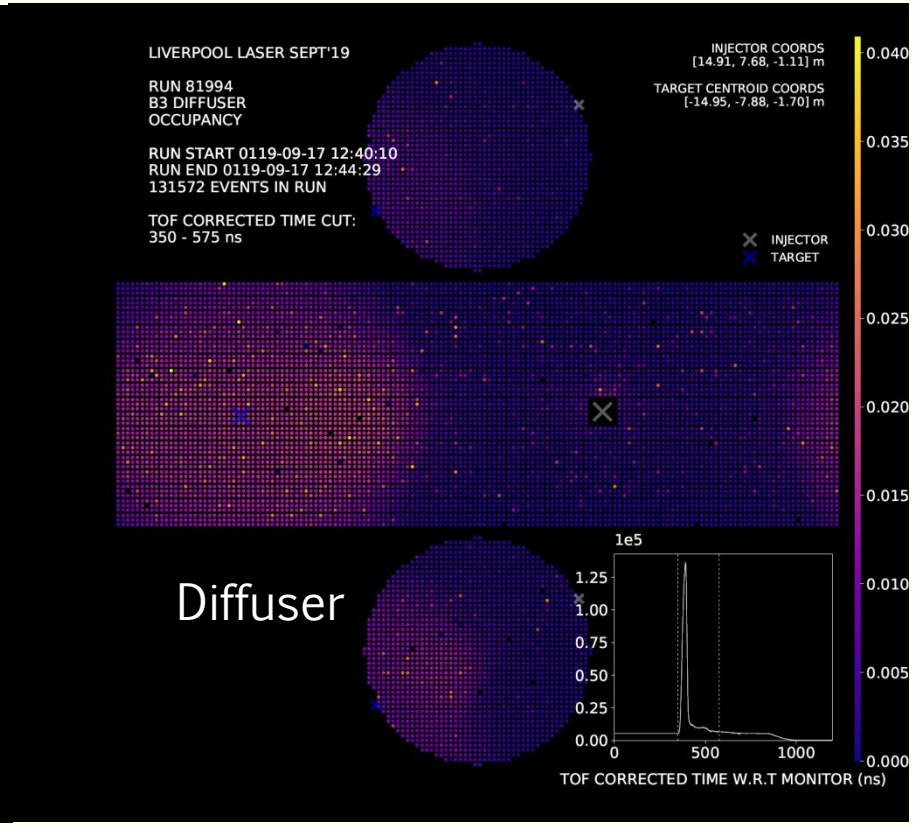
- Integrated electronics with Super-K trigger system and DAQ
- View of oscilloscope including LED input (pink) and PMT output (blue)
- System is set up for data taking which we have done over 3 periods in 2019



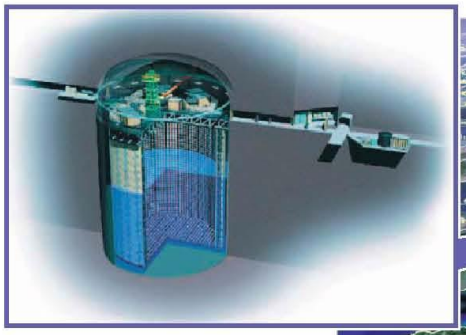
New calibration data from 2019

- Data processing & analysis collimator data (beam profiling and MC generation) for measuring water coefficients
- Working on integrating all optics into SK automated calibration system

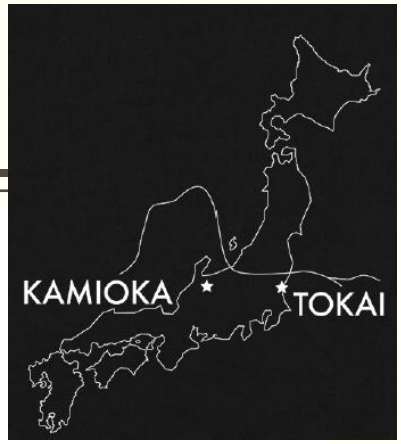




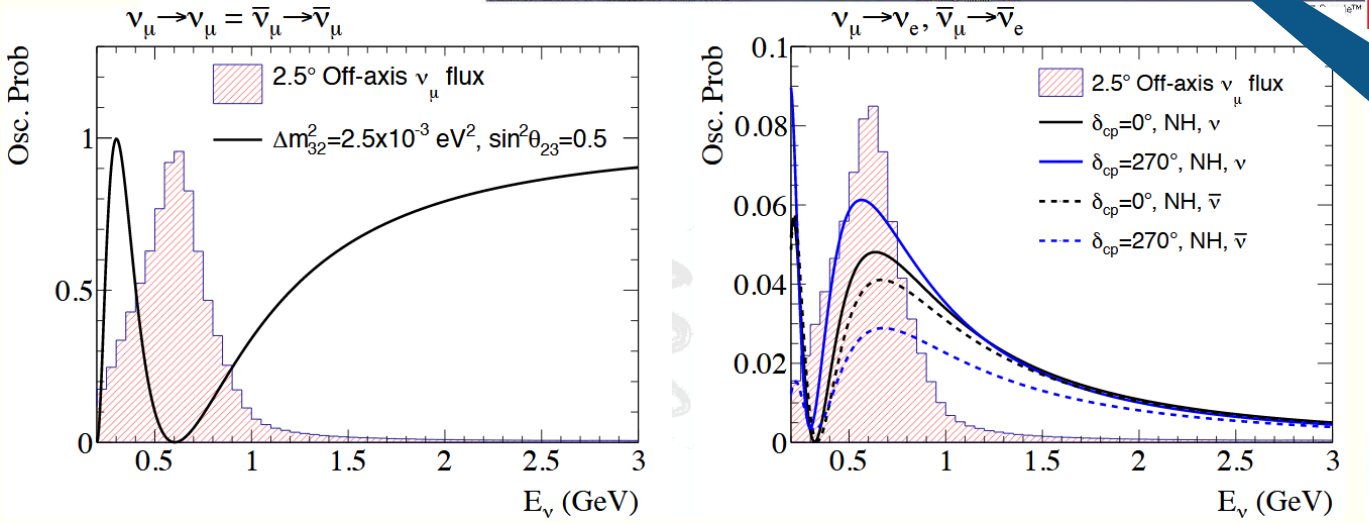
Tokai-to-Kamioka (T2K)

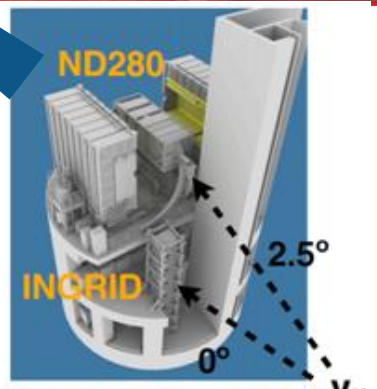


Super-Kamiokande
(ICRR, Univ. Tokyo)



J-PARC Main Ring
(KEK-JAEA, Tokai)

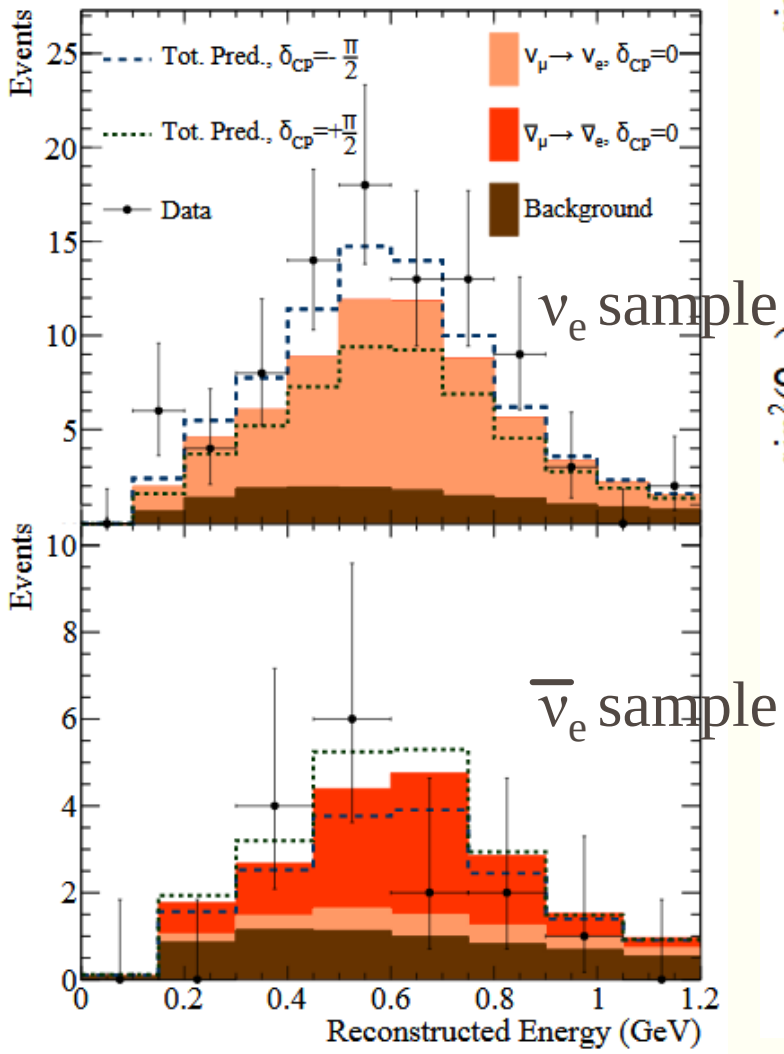


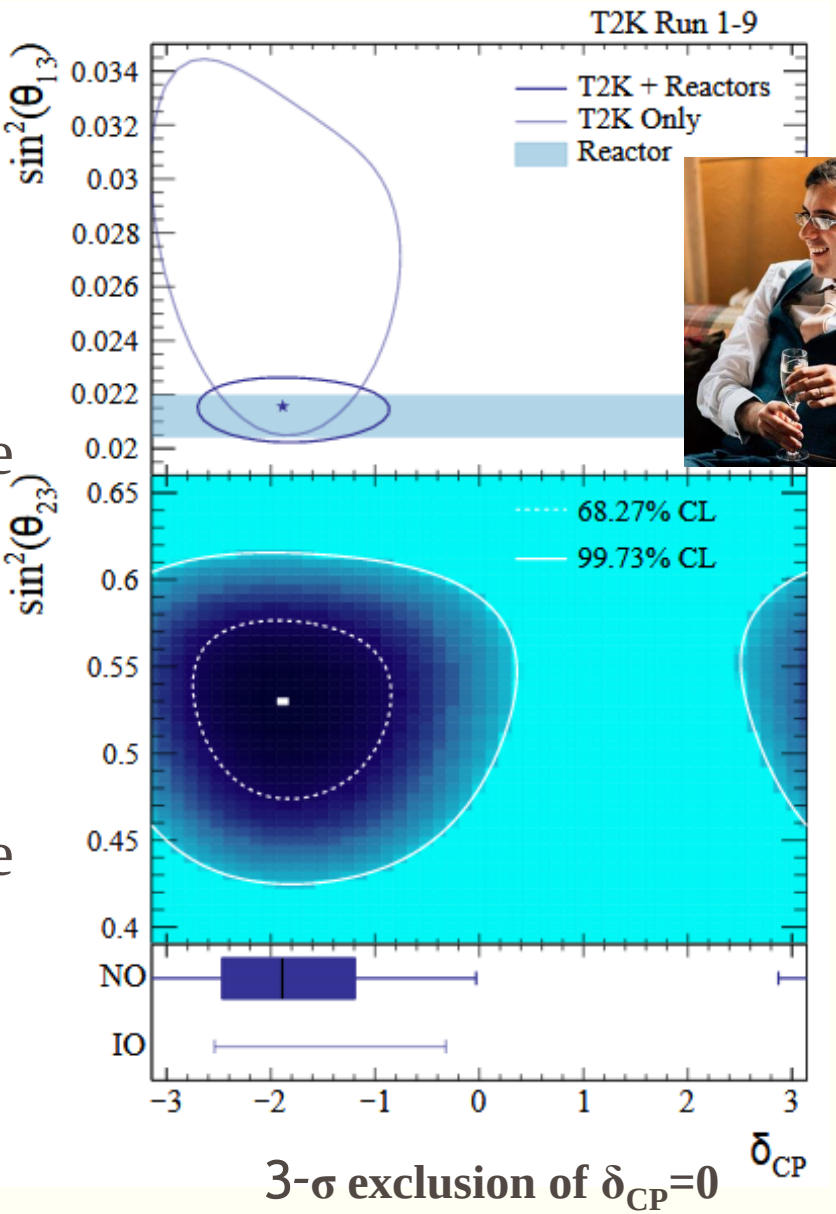


INGRID (on-axis) and
ND280 (off-axis)

Manuscript submitted to Nature (arXiv:1910.03887)

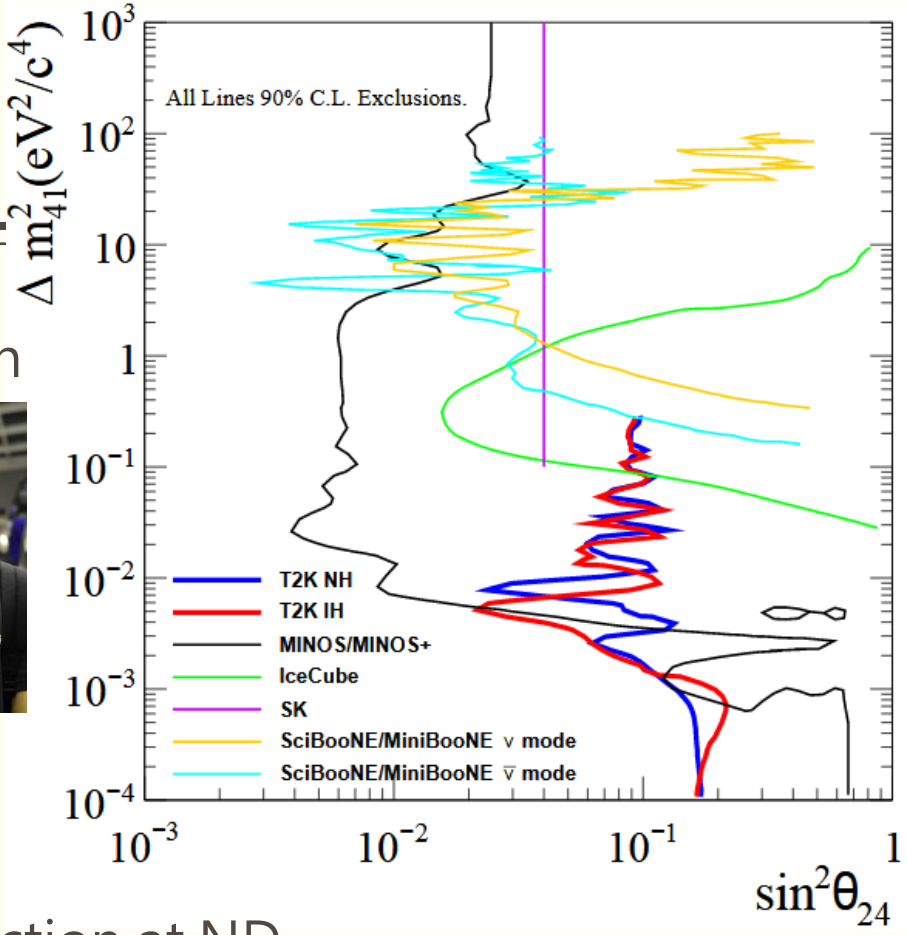
Oscillation Results





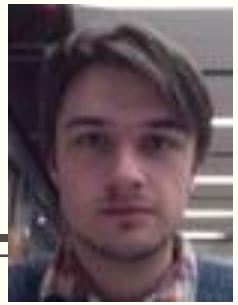
Non-oscillation Results

- Long baseline sterile neutrino search
  - Phys. Rev. D 99, 071103 (2019)

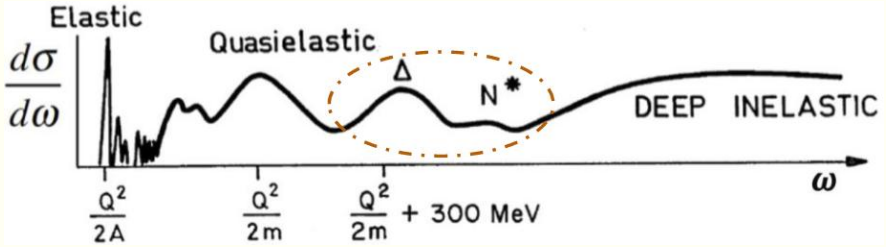


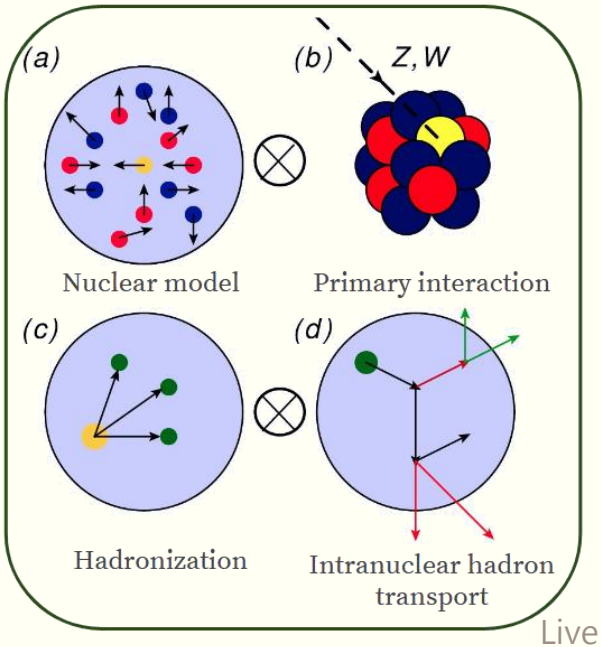
- Search for heavy neutrinos with ND
  - Phys. Rev. D 100, 052006 (2019)
- Search for NC induced single production at ND
  - J. Phys. G 46, 08LT01 (2019)
- First $\overline{\nu}_e$ cross-section from CC-0π in FGD1
  - To be submitted to JHEP
- Many cross-section papers coming out…

Cross-section work@Liverpool

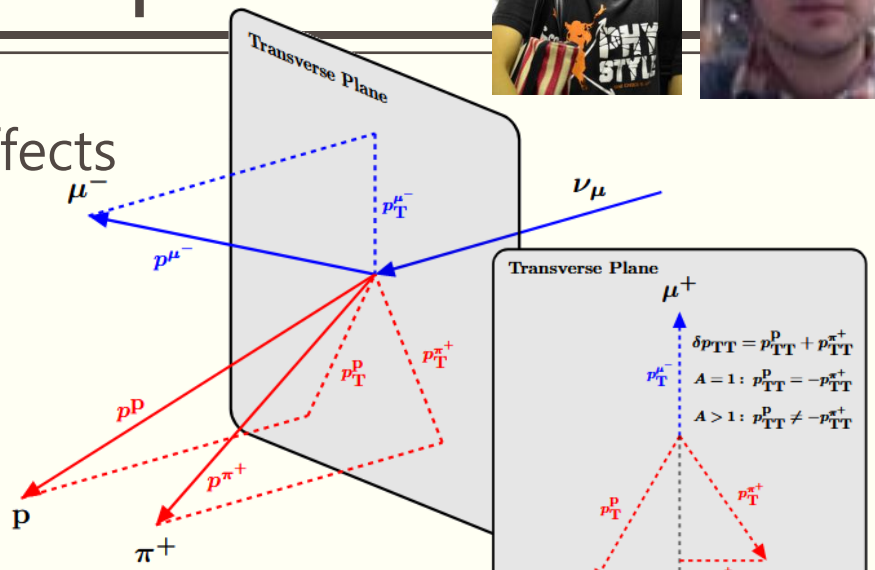


- CC-1π^+ measurement on nuclear effects
  - RES: $\nu_\mu + p \rightarrow \mu^- + \pi^+ + p$

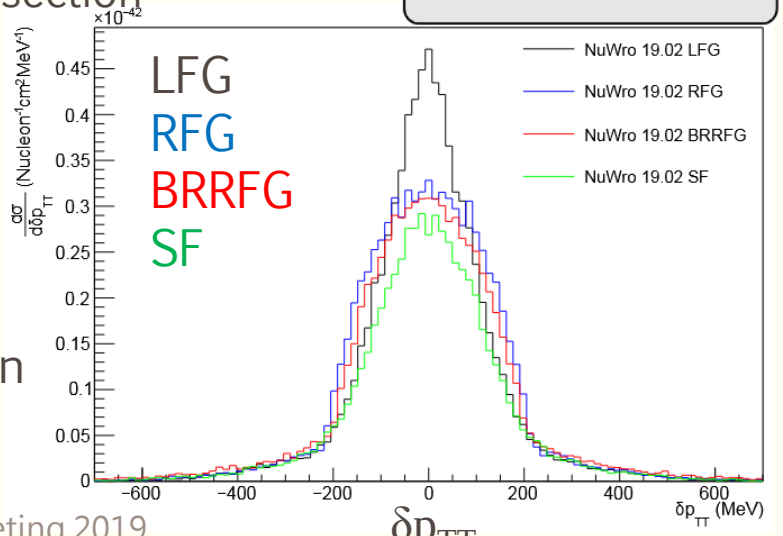




Model discrimination

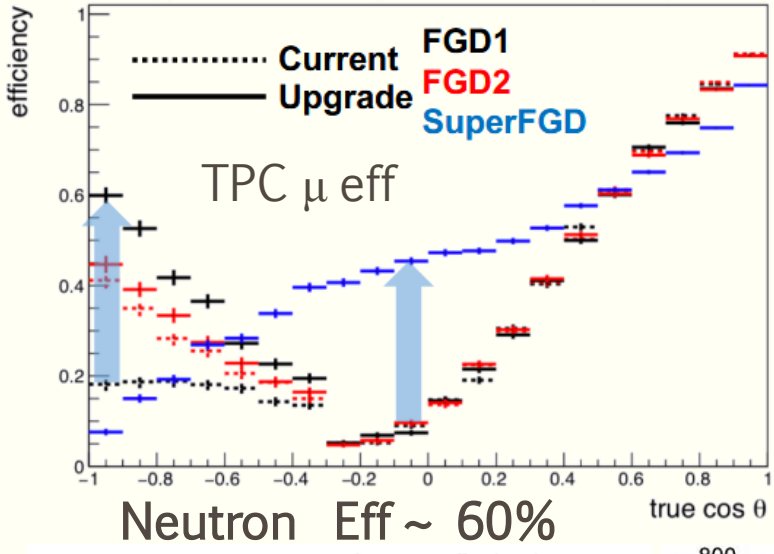


Cross-section

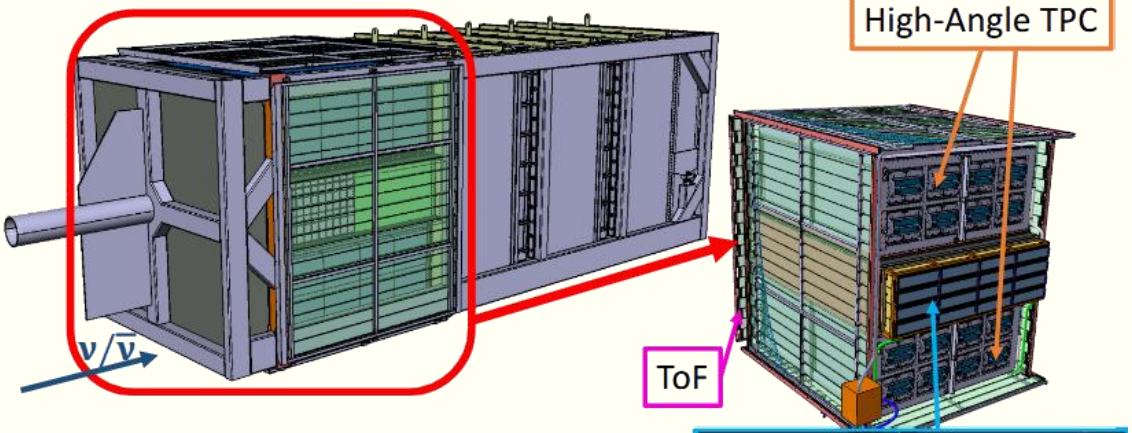


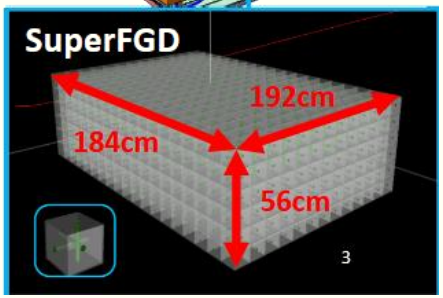
Looking forward

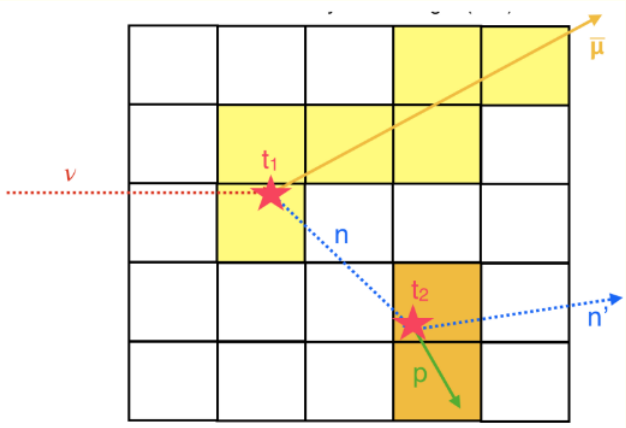
- (More powerful) Beam is back since 2018
- ND280 upgrade in <2yrs
- T2K-NOvA joint fit
- T2K-SK joint fit

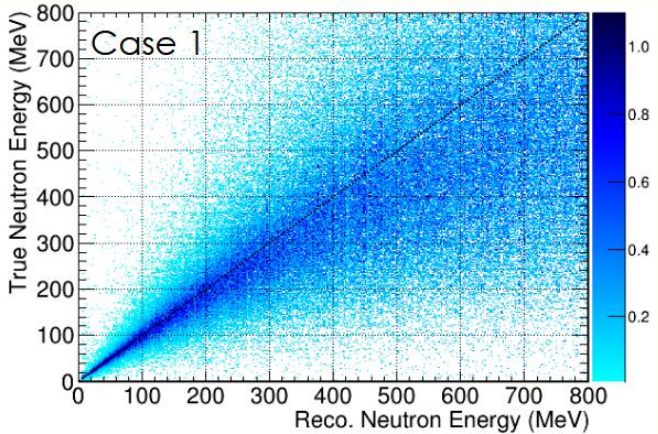


Neutron Eff ~ 60%

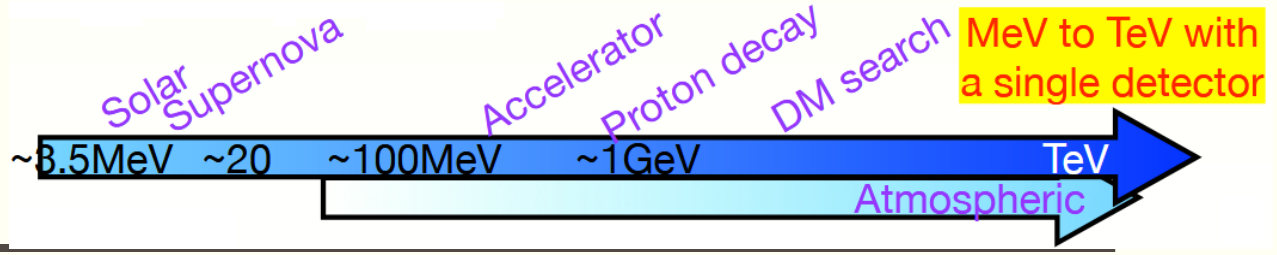




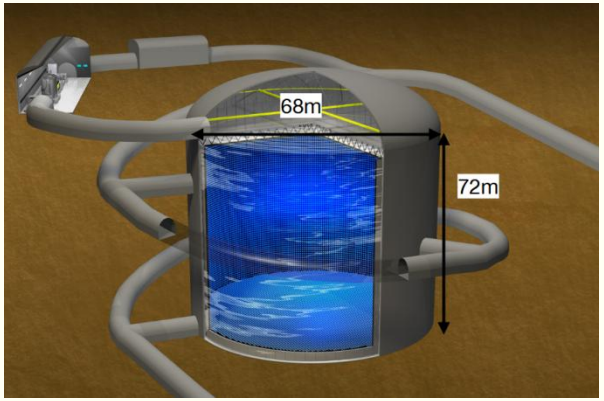




Hyper-K

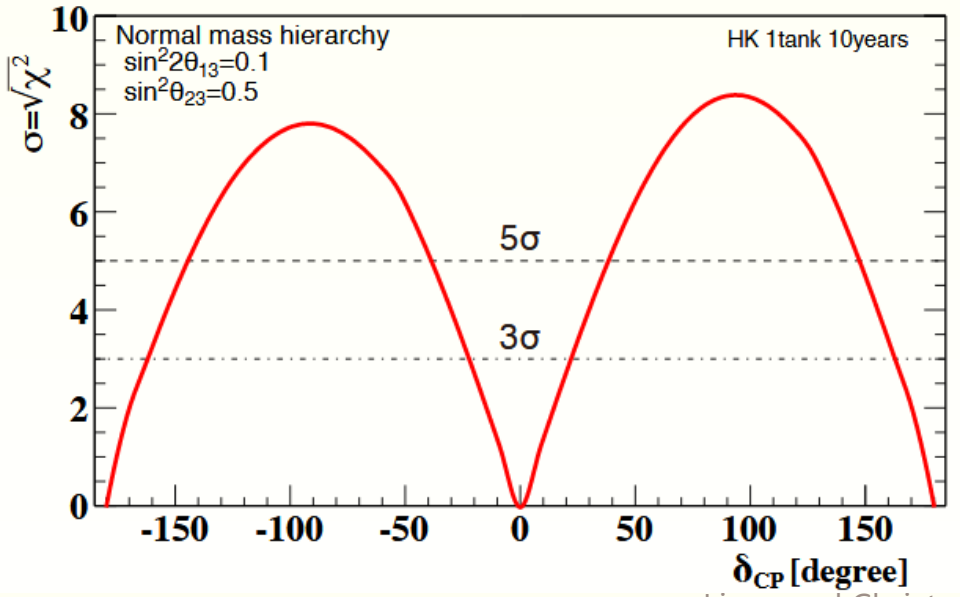


	Super-K	Hyper-K (1st tank)
Site (depth)	Mozumi (1000 m)	Tochibora (650m)
Number of ID PMTs	11,129	40,000
Photo-coverage	40%	40% (x2 sensitivity)
Mass/Fiducial Mass	50kton/22.5kton	260kton/188kton

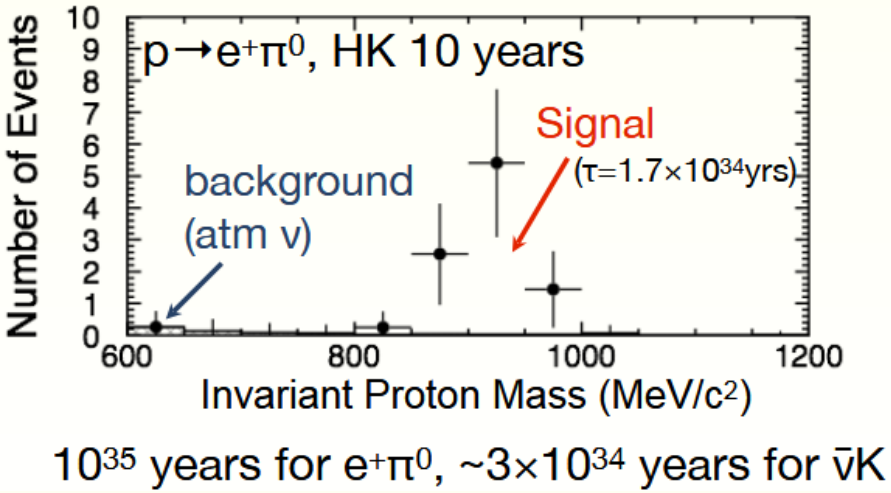


arXiv:1805.04163

- Beam neutrino



- Proton decay



10^{35} years for $e^+\pi^0$, ~3×10^{34} years for $\bar{\nu}K$

Hyper-Kamiokande

How to achieve?

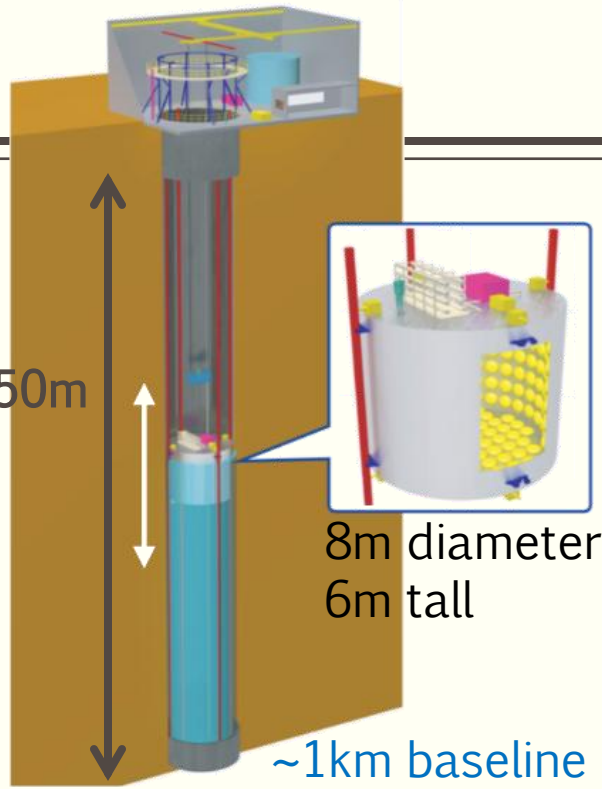
- 3% stat. errors in δ_{CP} measurement

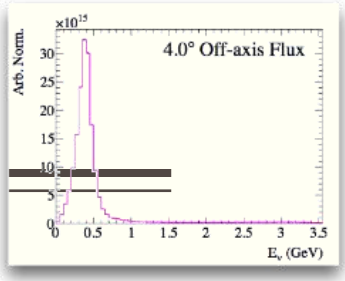
T2K, Neutrino 2018

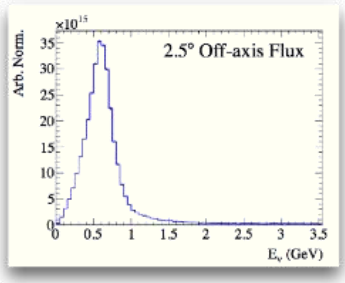
Error Source	% Error on neutrino/ antineutrino rate
Pion Interactions	1.58
Neutral Current Background	1.50
Electron (anti)neutrino cross section	3.03
Extrapolation from near detector	2.31
Removal Energy	3.74
Far Detector model	1.47
Total	5.87

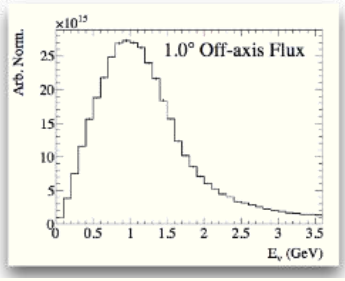
Sys. errors to reduce

Intermediate Water Cherenkov Detector

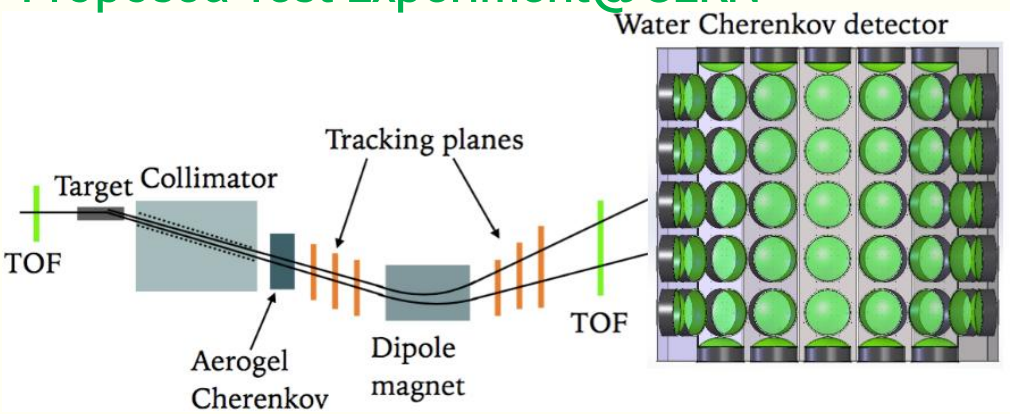






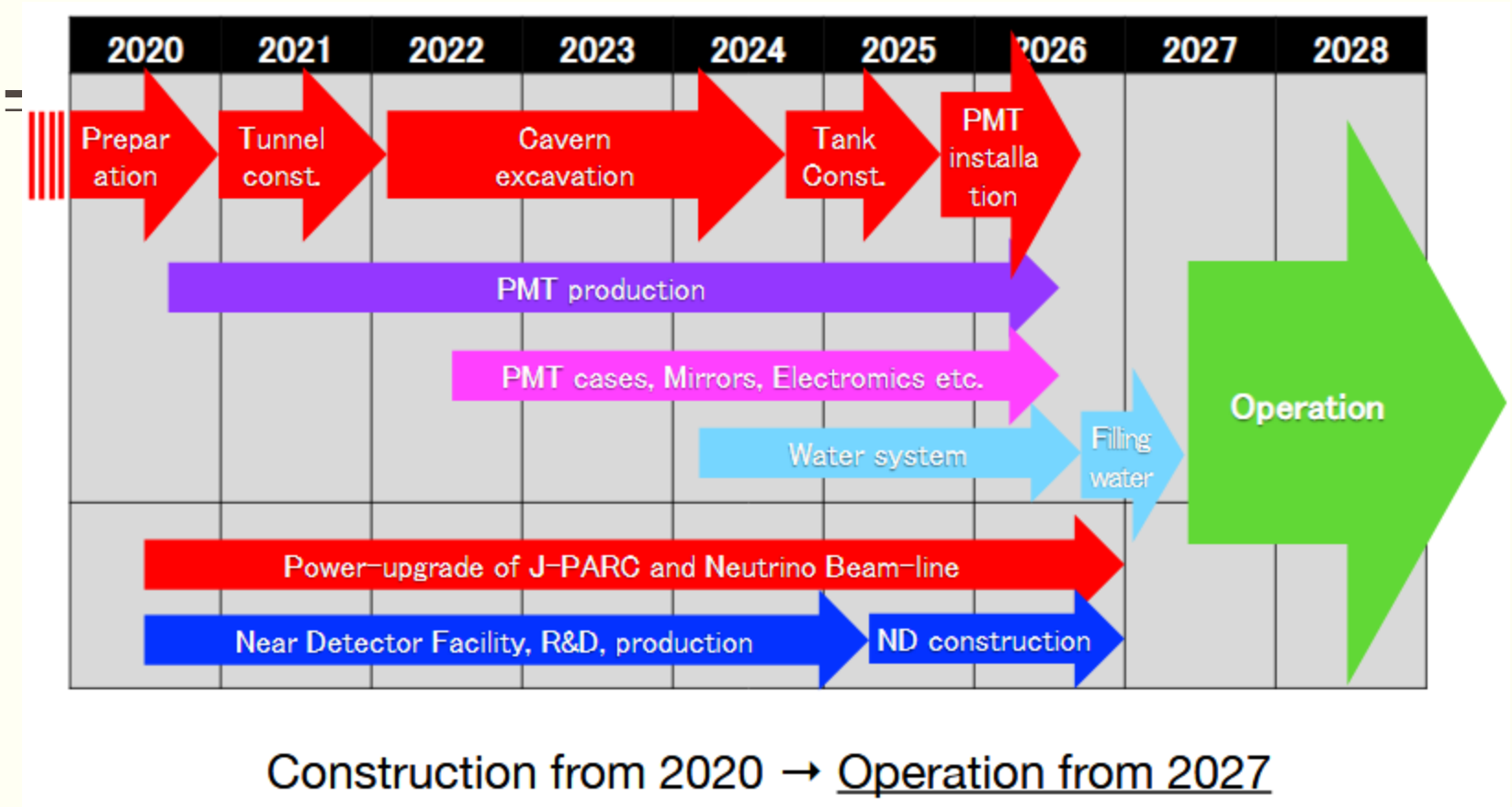


Proposed Test Experiment@CERN



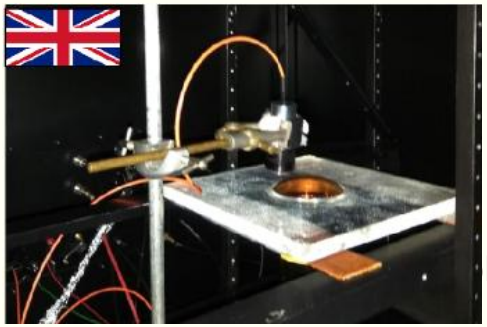
Hyper-Kamiokande

KamiokaNDE Nobel 2002 ➡ Super-K Nobel 2015 ➡ Hyper-K Nobel 20XX

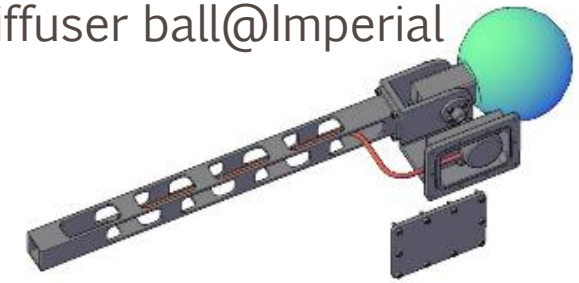


Construction from 2020 → Operation from 2027

- Liverpool/UK: calibration system



Diffuser ball@Imperial



Hyper-Kamiokande

KamiokaNDE Nobel 2002 → Super-K Nobel 2015 → Hyper-K Nobel 20XX

2020 2021 2022 2023 2024 2025 2026 2027 2028

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a natureresearch journal

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NEWS · 16 DECEMBER 2019 · CORRECTION 16 DECEMBER 2019

Japan will build the world's largest neutrino detector

Cabinet greenlights US$600-million Hyper-Kamiokande experiment, which scientists hope will bring revolutionary discoveries.

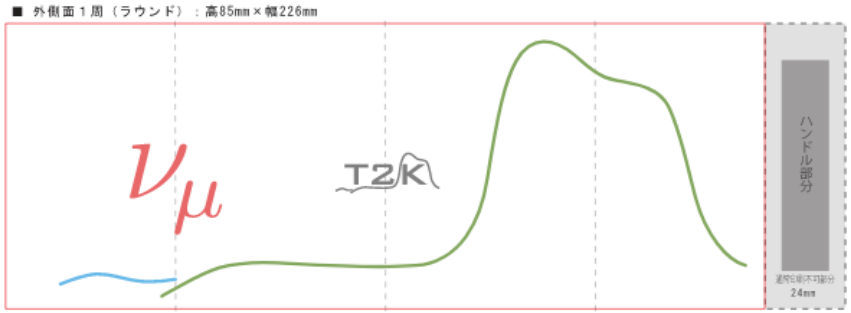
...the country's cabinet approved the first ¥3.5-billion (US$32-million) tranche towards construction as part of a supplementary budget for the current financial year... The budget will need to be approved by parliament; this is likely to happen next month

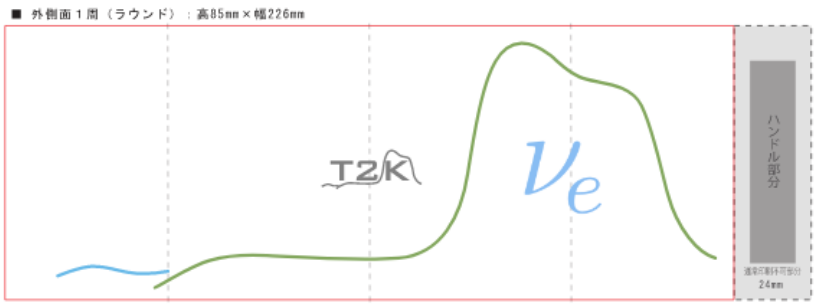
From our Japanese colleague:
Approval of the first year's budget in Japan means project approval and an intention to fund the future years in line with the project proposal.

T2K-merchandise (Advertisement 😘)

One realizable proposal (~¥1600/mug)

Design proposal by us T2K-Young reps

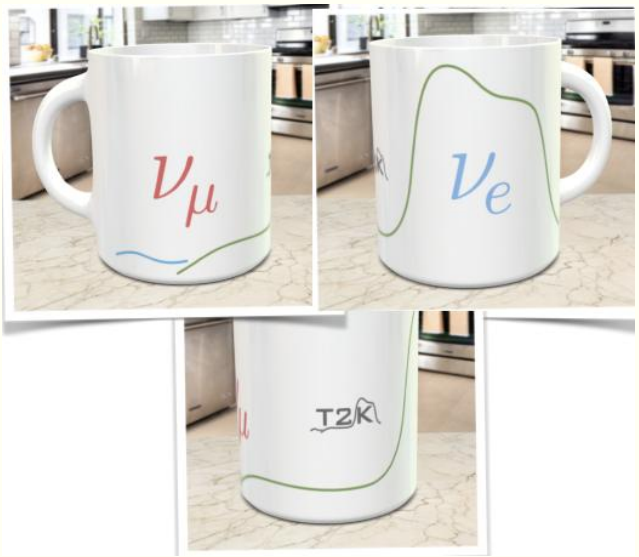




Cold

Will collect other design proposals from t2k-young, take pre-orders and sell at March 2020 meeting

Warm



#1

#2

Designs by Alex Goldsack

#1

[new! kids sizes]

#2


Merii
Kurisumasu !!
メリー クリスマス
JAPANLOVER.ME
T2K
TOKAI TO KAMIOKA