Le groupe ν*eutrinos* du LLR

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Stephen Dolan (T2K) & Sonia El Hedri (Super-K)

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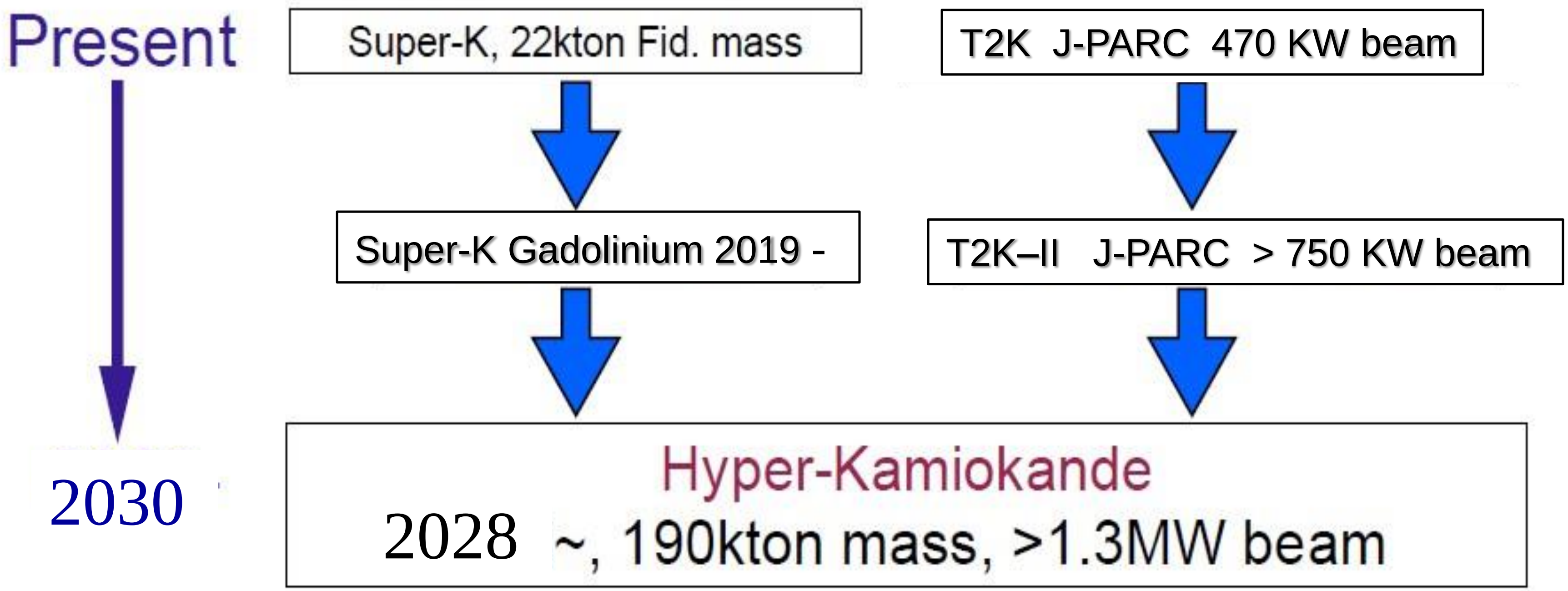
Alain Bonnemaison et Oscar Ferreira. Frank Gastaldi et Frederic Magniette

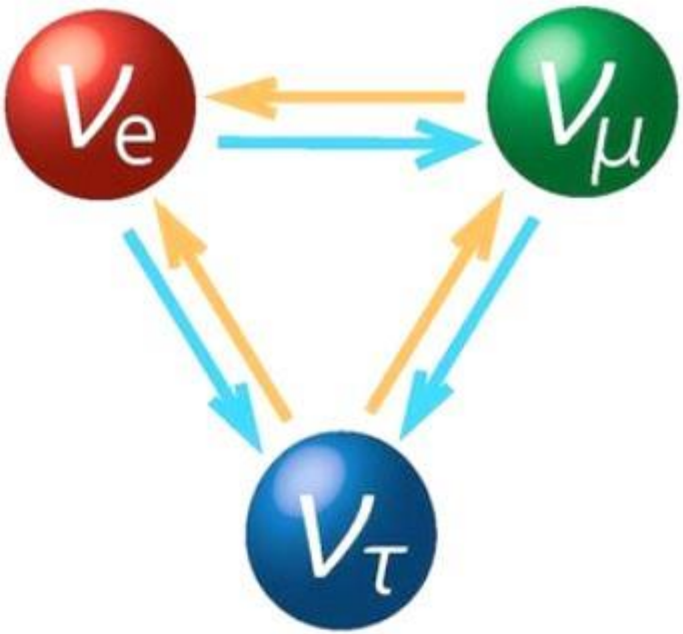
1. Nos expériences en cours
2. Les upgrades T2K II
3. Le projet Hyper-Kamiokande



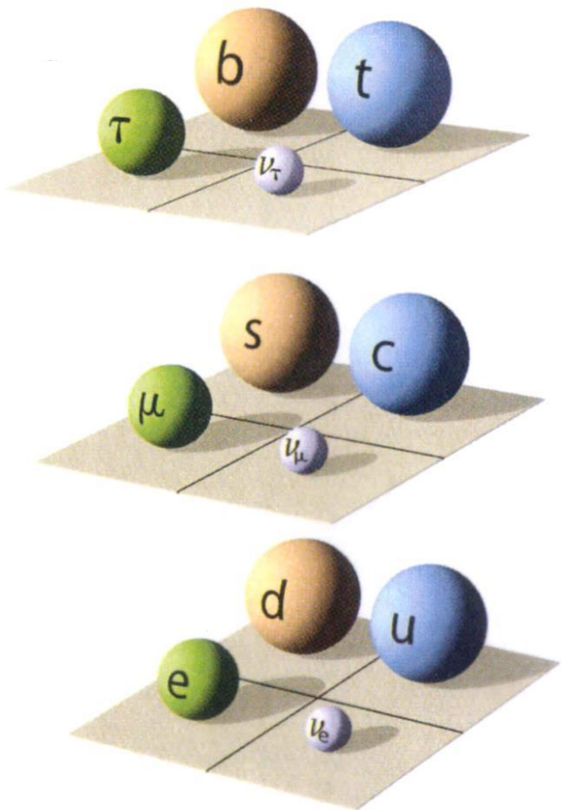
Une stratégie de groupe exceptionnelle pour un potentiel de découvertes hors du commun

Nos expériences en cours

Physique des oscillations



Matrices de mélanges



T2K

Super-Kamiokande
スーパーカミオカンデ

Réduction progressive des incertitudes pour les leptons

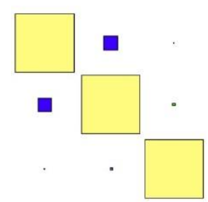
$$\begin{bmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{bmatrix} = \begin{bmatrix}U_{e1} & U_{e2} & U_{e3}\\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3}\\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3}\end{bmatrix}\begin{bmatrix}\nu_1\\ \nu_2\\ \nu_3\end{bmatrix}$$

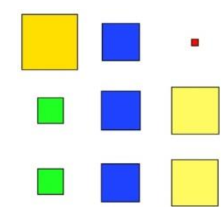
Quark "Mixing"

mixing parameters	best fit	3σ range
θ^q_{23}	2.36°	2.25° - 2.48°
θ^q_{12}	12.88°	12.75° - 13.01°
θ^q_{13}	0.21°	0.17° - 0.25°

Lepton "Mixing"

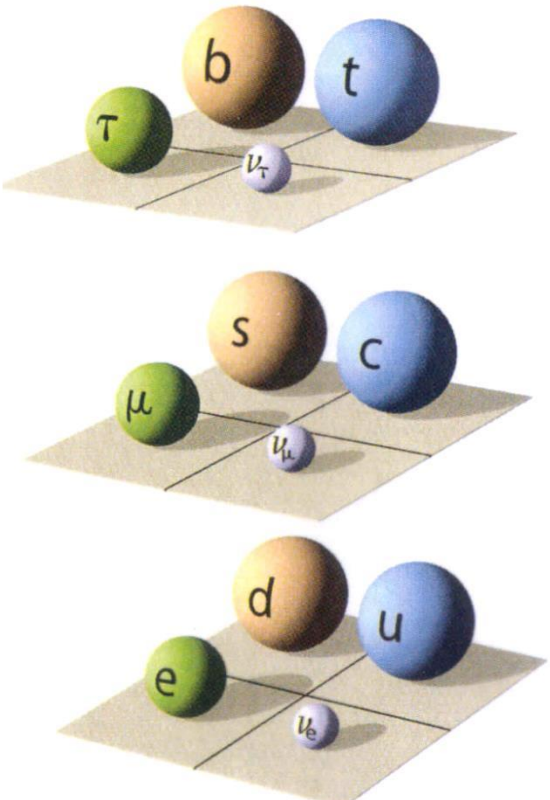
mixing parameters	best fit	3σ range
θ^e_{23}	45°	35.5° - 53.5°
θ^e_{12}	34°	31.5° - 37.6°
θ^e_{13}	9°	8.5-9.5°

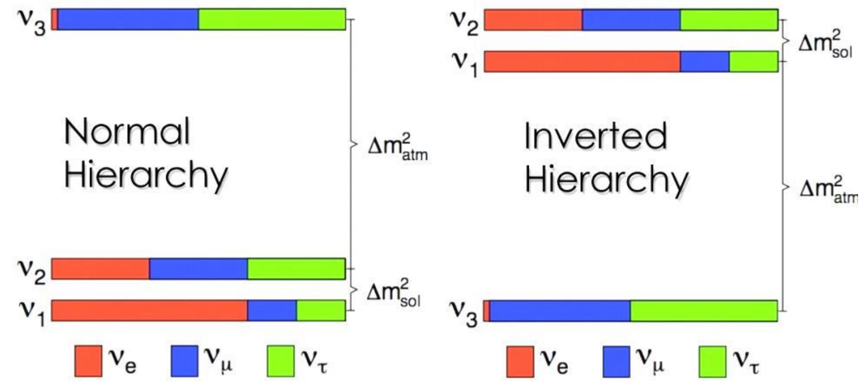




$$\begin{bmatrix}d'\\ s'\\ b'\end{bmatrix} = \begin{bmatrix}V_{ud} & V_{us} & V_{ub}\\ V_{cd} & V_{cs} & V_{cb}\\ V_{td} & V_{ts} & V_{tb}\end{bmatrix}\begin{bmatrix}d\\ s\\ b\end{bmatrix}$$

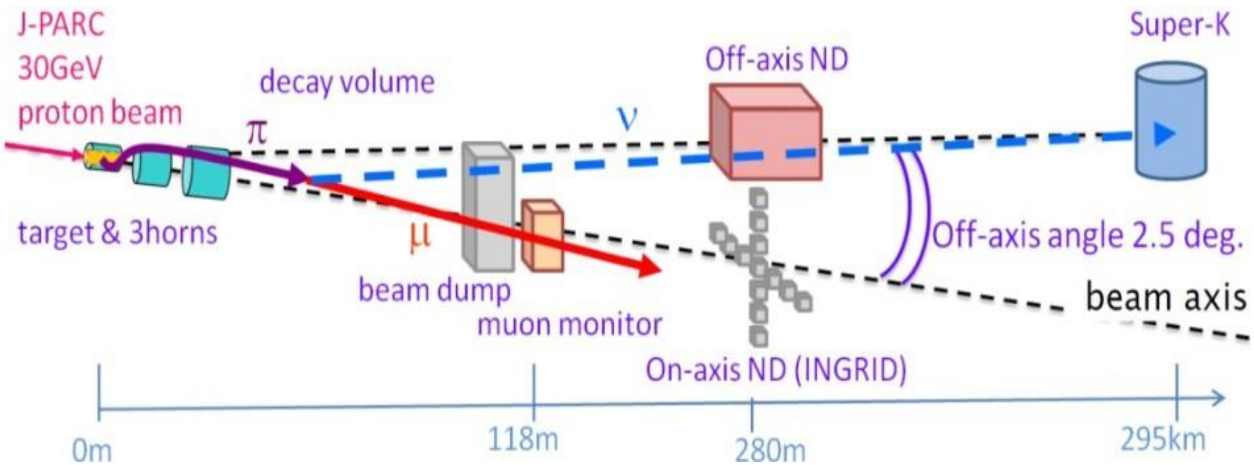
Les oscillations des neutrinos

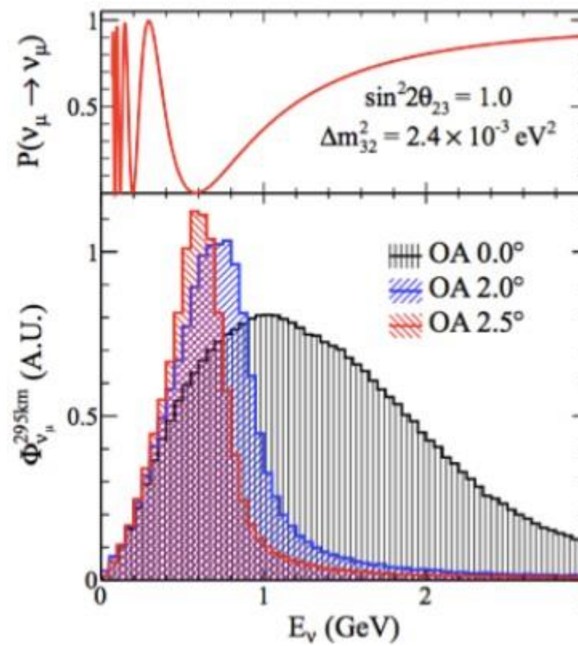




T2K

$$P(\nu_\mu \to \nu_e) = 4C_{13}^2 S_{13}^2 S_{23}^2 \sin^2\frac{\Delta m_{31}^2 L}{4E} \times \left(1 + \frac{2a}{\Delta m_{31}^2}\left(1 - 2S_{13}^2\right)\right)$$
$$+8C_{13}^2 S_{12} S_{13} S_{23} (C_{12} C_{23} \cos\delta - S_{12} S_{13} S_{23}) \cos\frac{\Delta m_{32}^2 L}{4E} \sin\frac{\Delta m_{31}^2 L}{4E} \sin\frac{\Delta m_{21}^2 L}{4E}$$
$$-8C_{13}^2 C_{12} C_{23} S_{12} S_{13} S_{23} \sin\delta \sin\frac{\Delta m_{32}^2 L}{4E} \sin\frac{\Delta m_{31}^2 L}{4E} \sin\frac{\Delta m_{21}^2 L}{4E}$$
$$+4S_{12}^2 C_{13}^2 \left\{C_{12}^2 C_{23}^2 + S_{12}^2 S_{23}^2 S_{13}^2 - 2C_{12} C_{23} S_{12} S_{23} S_{13} \cos\delta\right\} \sin^2\frac{\Delta m_{21}^2 L}{4E}$$
$$-8C_{13}^2 S_{13}^2 S_{23}^2 \cos\frac{\Delta m_{32}^2 L}{4E} \sin\frac{\Delta m_{31}^2 L}{4E} \frac{aL}{4E} \left(1 - 2S_{13}^2\right)$$





Faisceaux de neutrinos muons

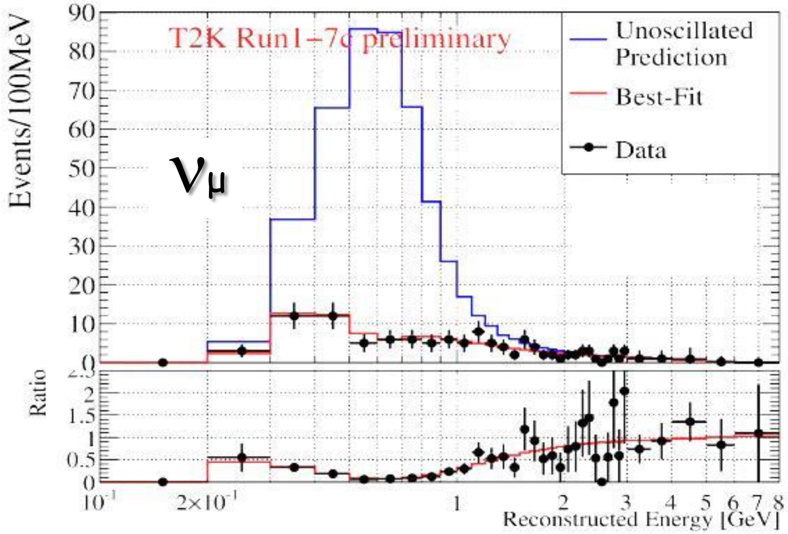
2016 DATA

Oscillation results

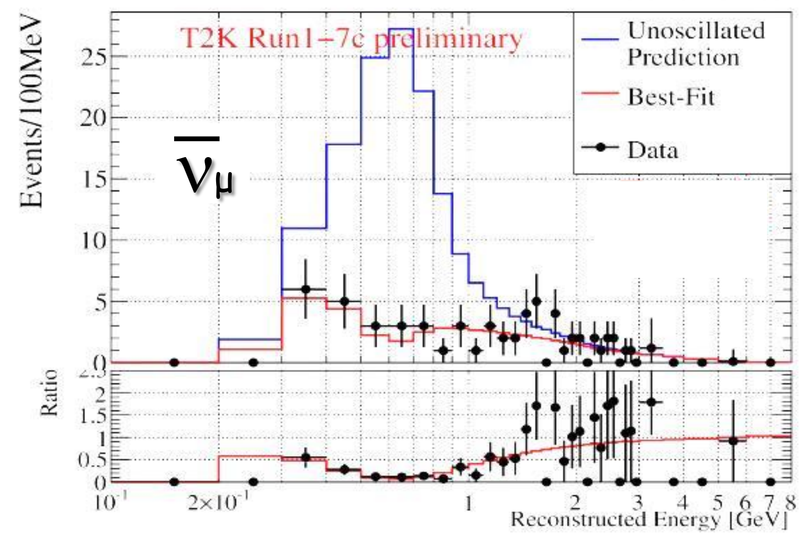
T2K

Disappearance

125 events

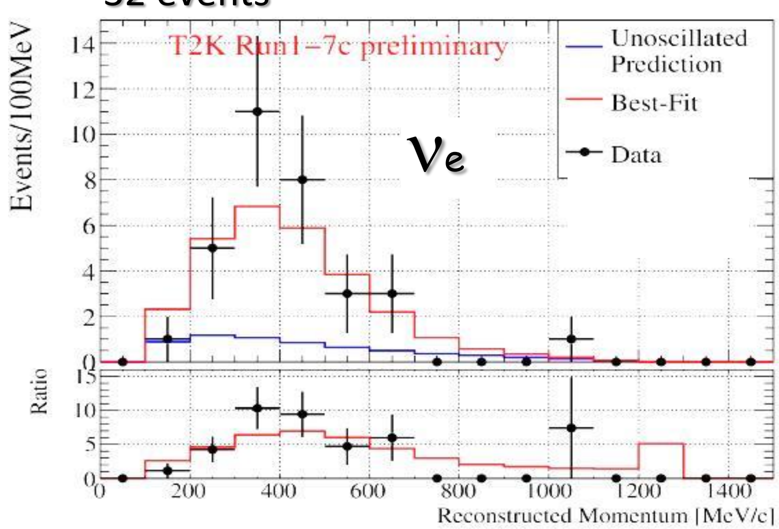


66 events

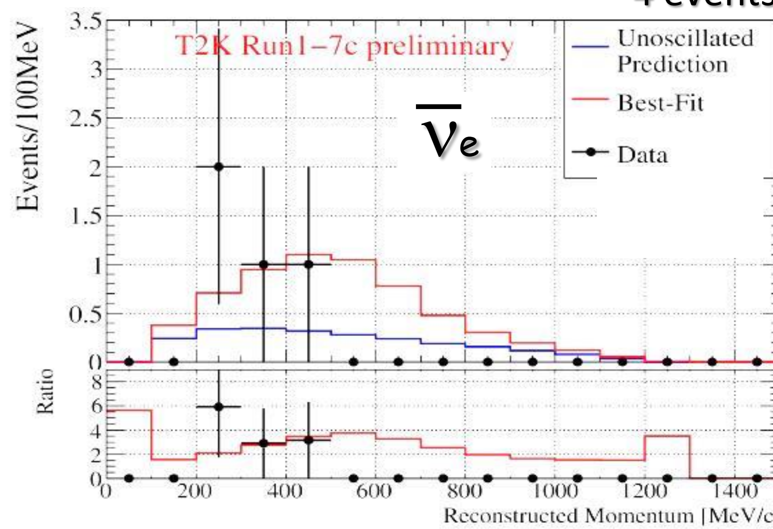


Appearance

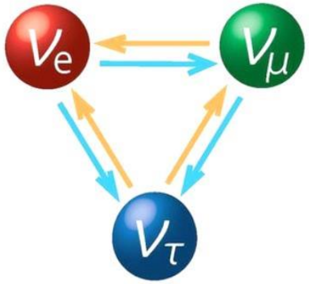
32 events



4 events



Oscillation results



T2K

Neutrino2016

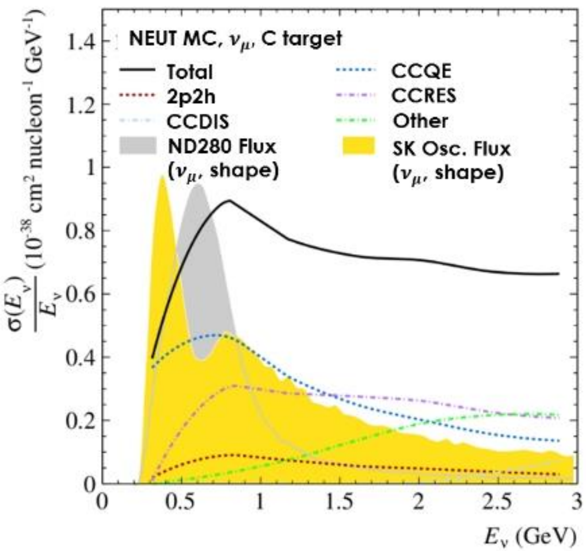
	OBS.	EXP. (NH, $\sin^2\Theta_{23}$=0.528, NH)			
		$\delta_{CP}=-\pi/2$	$\delta_{CP}=0$	$\delta_{CP}=+\pi/2$	$\delta_{CP}=\pi$
ν_μ	125	127.9	127.6	127.8	128.1
ν_e	32	27.0	22.7	18.5	22.7
$\bar{\nu}_\mu$	66	64.4	64.3	64.4	64.6
$\bar{\nu}_e$	4	6.0	6.9	7.7	6.8

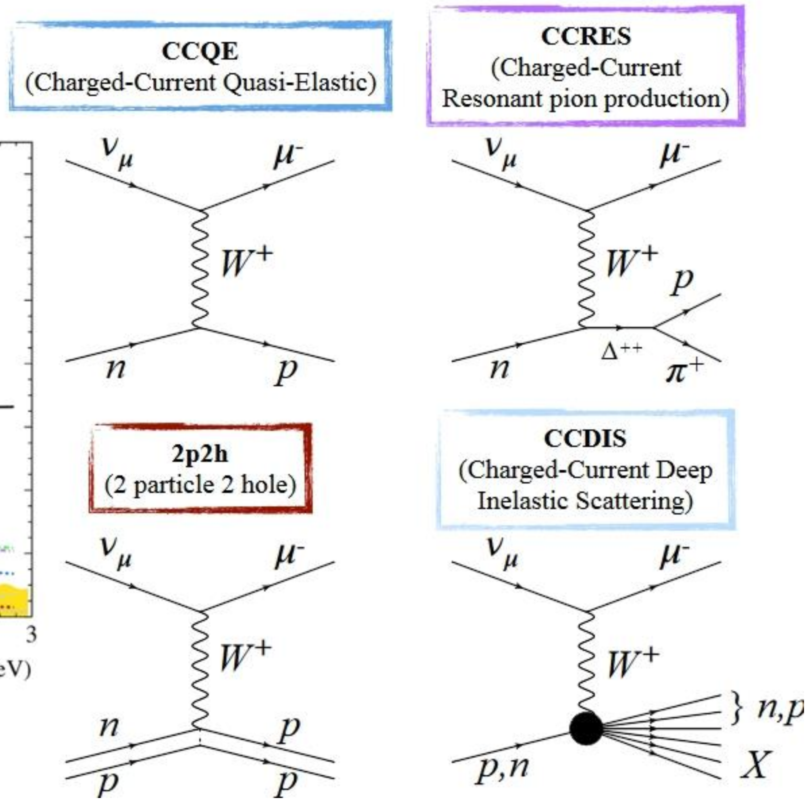
SAMPLE	2016	2018
ν_μ	125	243
ν_eQE	32	75
$\nu_e 1\pi$	N/A	15
$\bar{\nu}_\mu$	66	102
$\bar{\nu}_e$	4	9

Neutrino2018

SAMPLE	PREDICTED				OBSERVED
	$\delta_{CP}=-\pi/2$	$\delta_{CP}=0$	$\delta_{CP}=+\pi/2$	$\delta_{CP}=\pi$	
FHC 1Rμ	268.5	268.2	268.5	268.9	243
FHC 1Re 0 decay-e	73.8	61.6	50.0	62.2	75
FHC 1Re 1 decay-e	6.9	6.0	4.9	5.8	15
RHC 1Rμ	95.5	95.3	95.5	95.8	102
RHC 1Re 0 decay-e	11.8	13.4	14.9	13.2	9

Nos expériences en cours
Mesures des sections efficaces à basse énergie





- Phys.Rev. D87 (2013) no.9, 092003, "Measurement of the inclusive ν_μ charged current cross section on carbon in the near detector of the T2K experiment"
- Phys.Rev. D90 (2014) no.7, 072012, "Measurement of the neutrino-oxygen neutral-current interaction cross section by observing nuclear de-excitation γ rays"
- Phys.Rev.Lett. 113 (2014) no.24, 241803, "Measurement of the Inclusive Electron Neutrino Charged Current Cross Section on Carbon with the T2K Near Detector"
- Phys.Rev. D90 (2014) no.5, 052010, "Measurement of the inclusive ν_μ charged current cross section on iron and hydrocarbon in the T2K on-axis neutrino beam"
- Phys.Rev. D92 (2015) no.11, 112003, "Measurement of the ν_μ charged-current quasi-elastic cross section with ND280 detector at T2K"
- Phys.Rev. D91 (2015) no.11, 112002, "Measurement of the ν_μ charged current quasi-elastic cross-section on carbon with the T2K on-axis neutrino beam"
- Phys.Rev. D93 (2016) no.7, 072002, "Measurement of the muon neutrino inclusive charged-current cross section in the energy range of 1-3 GeV with the T2K INGRID detector"
- Phys.Rev. D93 (2016) no.11, 112012, "Measurement of double-differential muon neutrino charged-current interactions on C_8H_8 without pions in the final state using the T2K off-axis beam"
- Phys.Rev. D95 (2017) no.1, 012010, "First measurement of the muon neutrino charged current single pion production cross section on water with the T2K Near Detector"
- Phys.Rev.Lett. 117 (2016) no.19, 192501, "Measurement of Coherent π^+ Production in Low Energy Neutrino-Carbon Scattering"
- Phys.Rev.D96 052001 (2017), "Measurement of $\bar{\nu}_\mu$ and ν_μ charged current inclusive cross sections and their ratio with the T2K off-axis near detector"

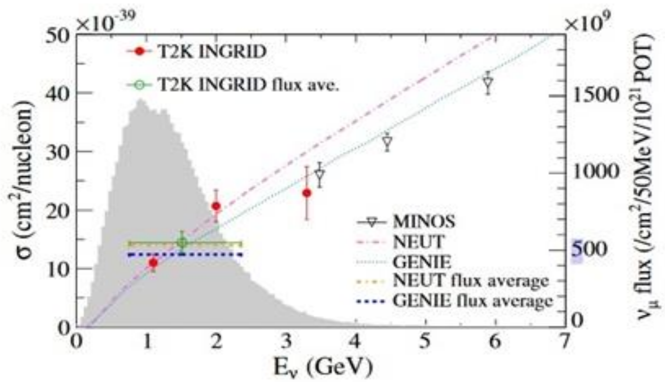
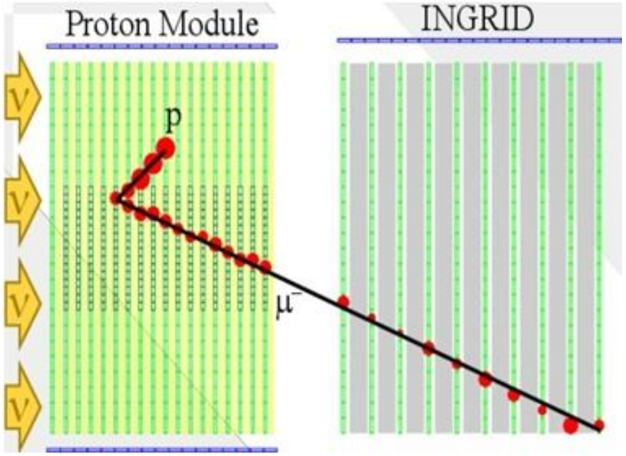


FIG. 27. Results of the ν_μ CC inclusive cross section on Fe. The energy-dependent cross section measured by the MINOS near detector [1] and the flux-averaged cross section fro are shown with the NEUT (v.5.1.4.2) and GENIE dictions. The T2K on-axis ν_μ flux is shown in INGRID flux-averaged cross-section measuremen are consistent with one another.



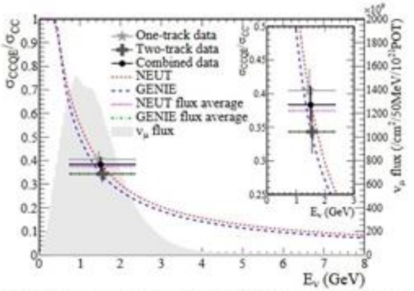


Figure 8.24: The cross section ratio of CCQE to total CC interaction.

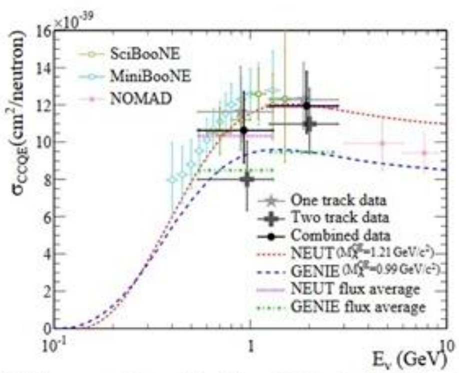
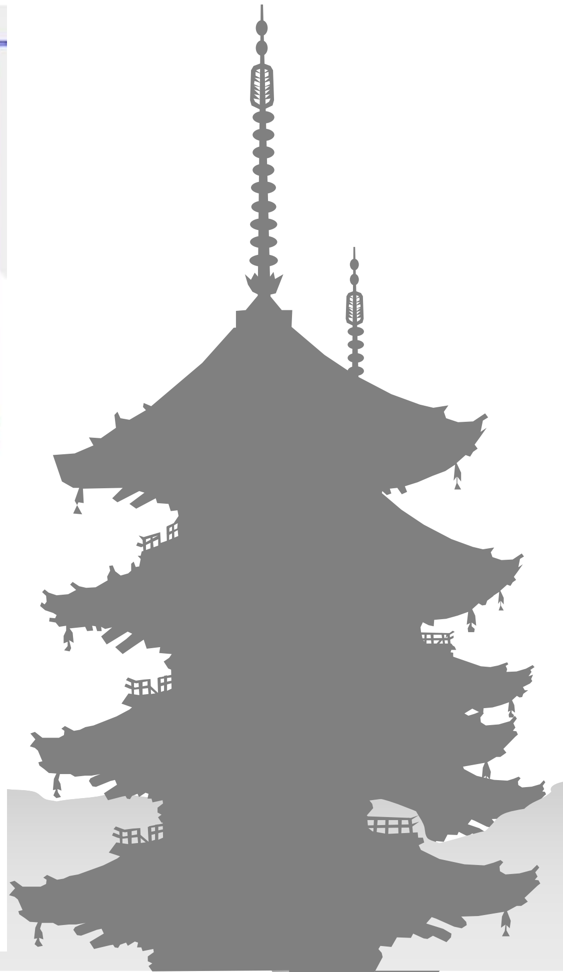
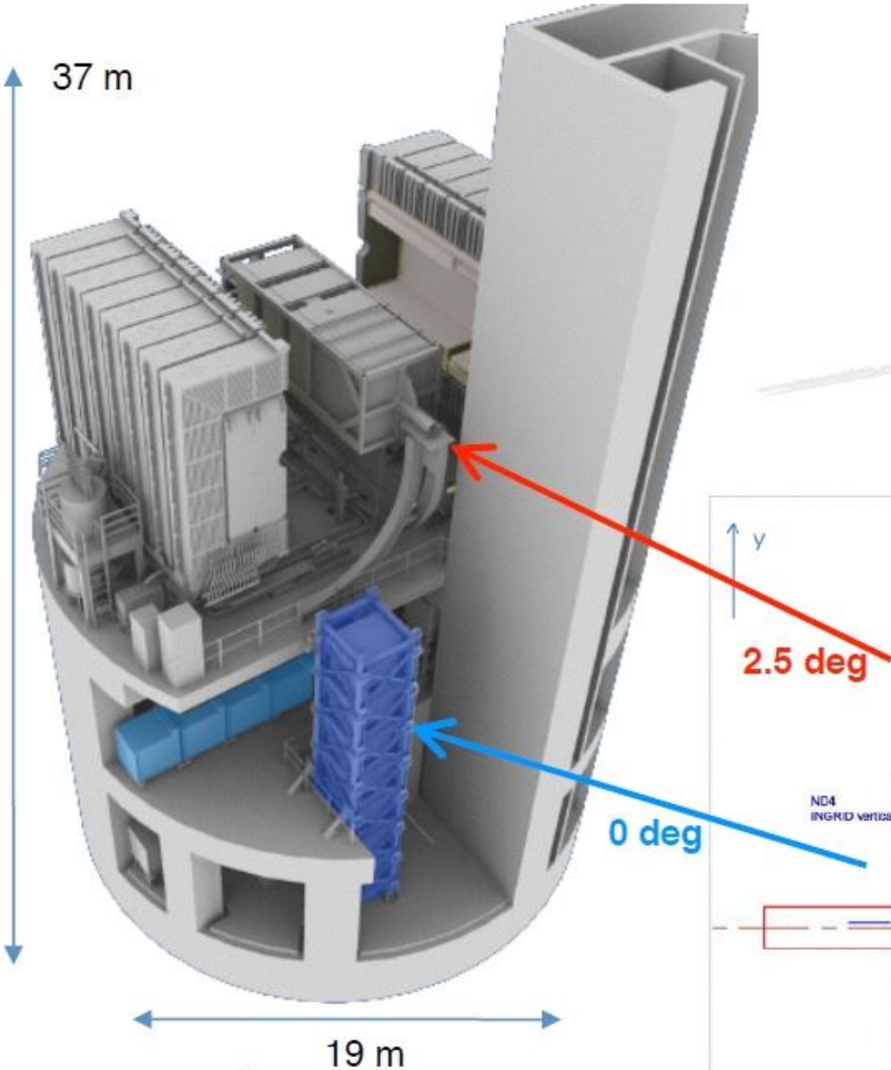
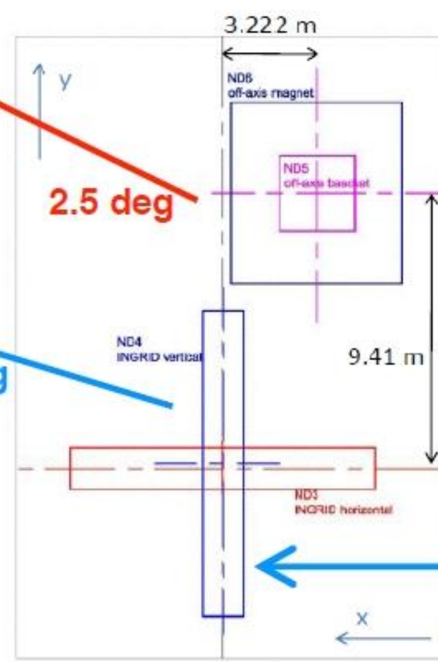


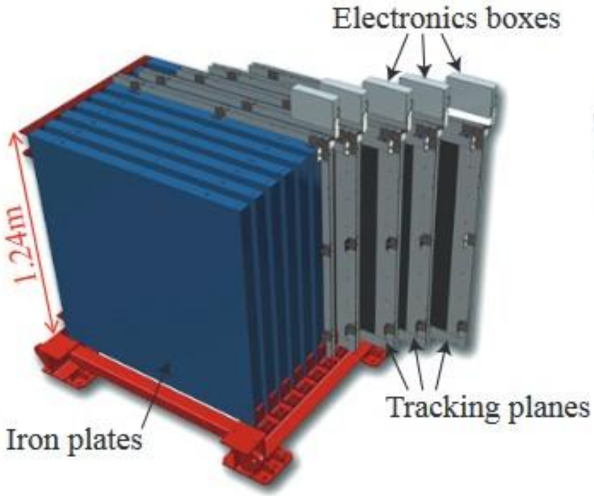
Figure 8.18: The CCQE cross section result with predictions by NEUT and GENIE. Our data point is placed at the flux mean energy. The vertical error bar represents the total (statistical and systematic) uncertainty, and the horizontal bar represents 68% of the flux at each side of the mean energy. The SciBooNE, MiniBooNE and NOMAD results are also plotted [212, 220, 285].

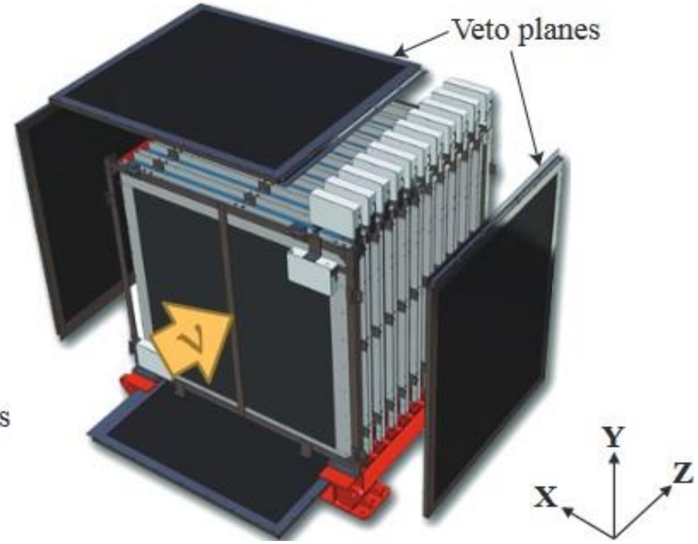


T2K Near Detector pit houses both the off-axis (ND280) and on-axis (INGRID) detectors









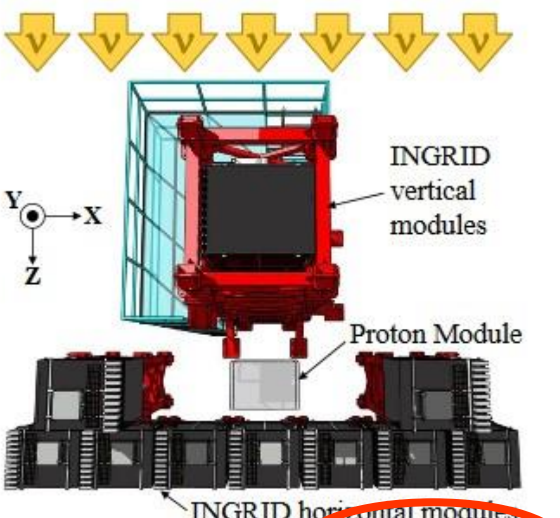


Figure 3.5: Position of the Proton Module viewed from above.

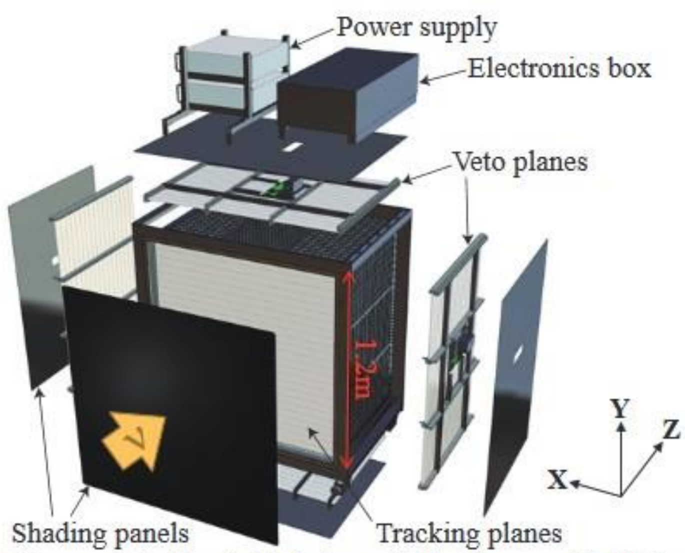


Figure 3.6: Exploded view of the Proton Module. See Appendix A for more details of the design.

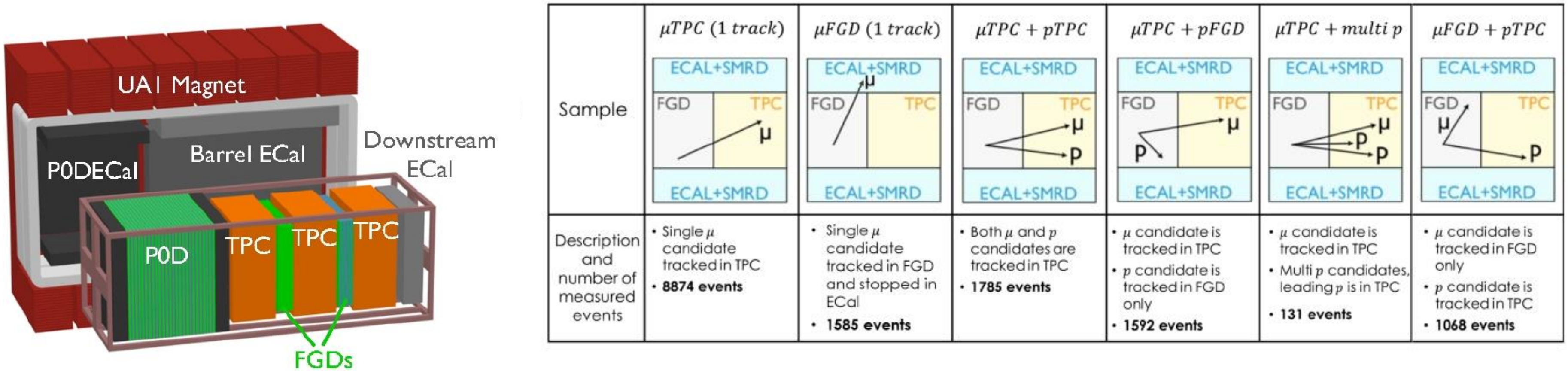


Figure 3: A schematic view of ND280

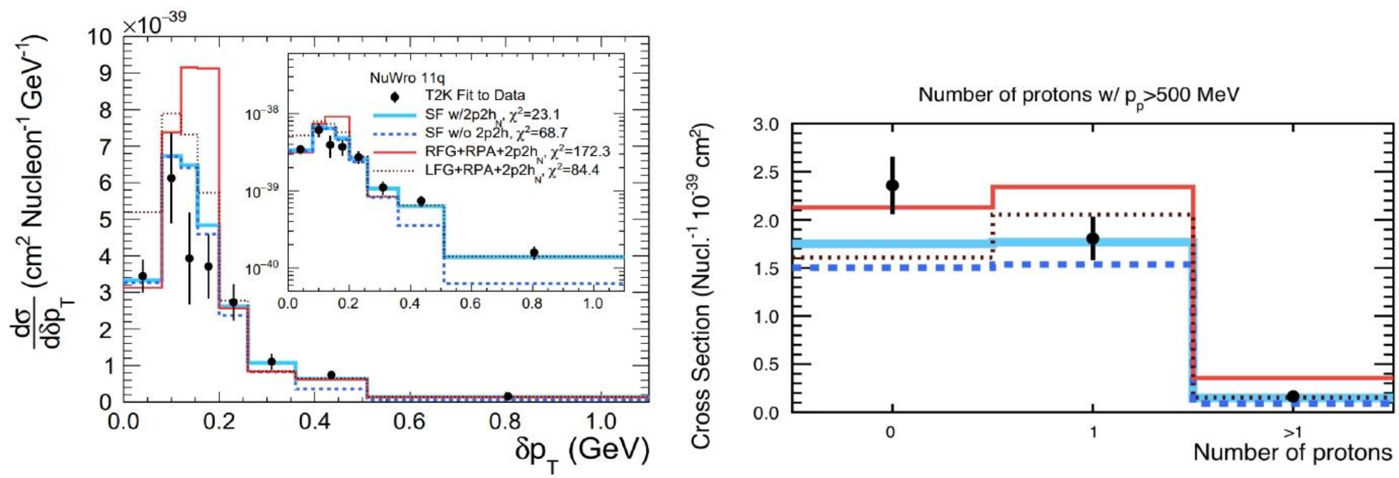
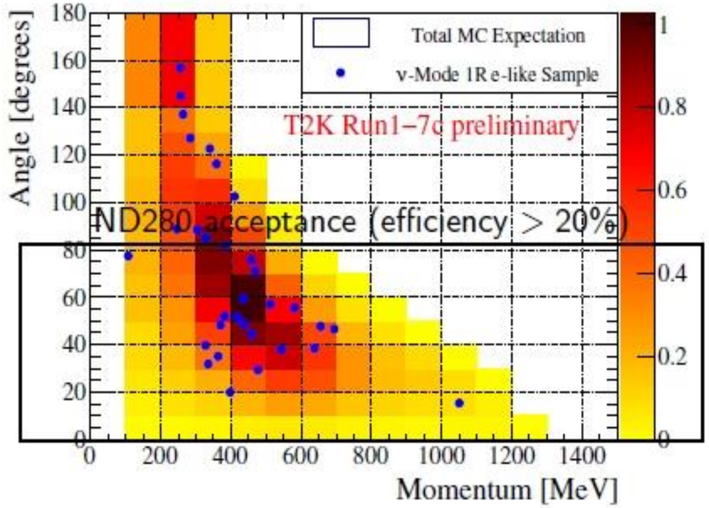


Figure 12: Left: the ND280 cross-section measurement of the momentum imbalance between the outgoing lepton and highest momentum proton (δp_T) compared to a variety of different nuclear models (SF, RFG+RPA, LFG+RPA) with and without a 2p2h contributon. The bulk of the distribution can be seen to be sensitive to the former whilst the tail show sensitivity to the latter. The inlay shows the same plot on a logorithmic scale. Right: cross section as a function of the number of protons compared to different neutrino generators: NEUT [40, 41] (red), NuWRO [42] without 2p2h (dotted blue), NuWRO SF+2p2h (light blues), NuWRO LFG+2p2h (dotted brown).

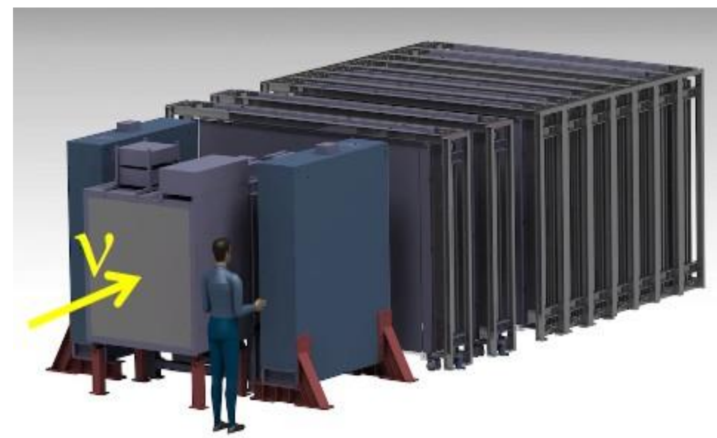
WAGASCI

Towards systematics reduction



- Need a measurements with :
  1. Similar target nucleus as SK : independent of cross section models
  2. 4π acceptance as SK for lepton kinematics : efficiency corrections not needed
  3. High granularity to identify interaction final states (track low momenta hadrons) : improve energy reconstruction

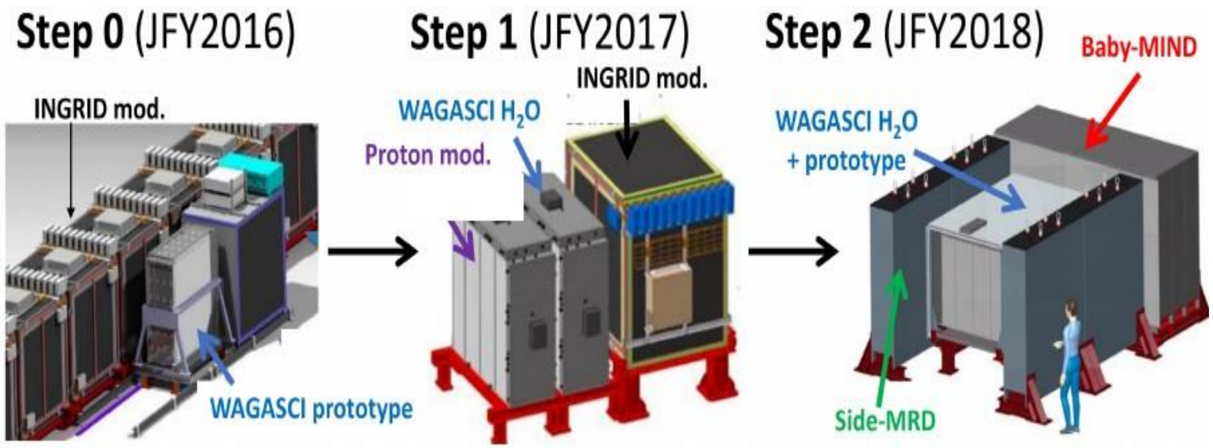
⇒ goal of the WAGASCI detector (and of ND280 upgrades! not discussed here)

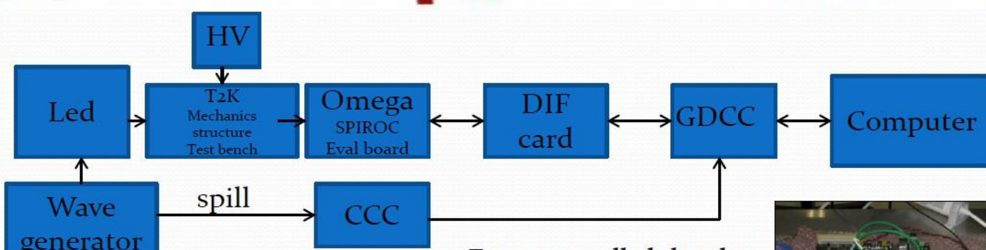


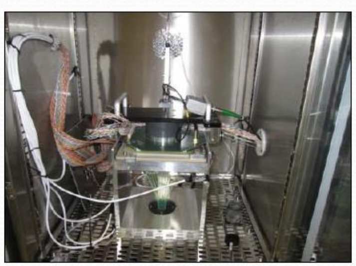
50 K€ de l'X

Contributions du LLR

Conception mécanique (A. Bonnemaison & O. Ferrreira)
Conception et production de la DAQ (F. Gastaldi & F. Magniette)



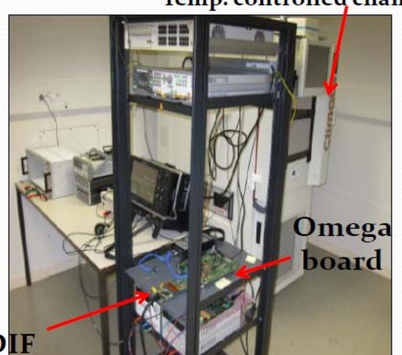




Zone where we introduce the mechanic structure

Boxes are put in temperature controlled chamber
Nota : for the test: just used for the light isolation

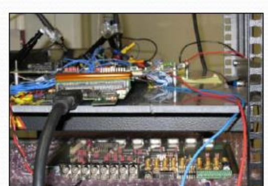
Temp. controlled chamber



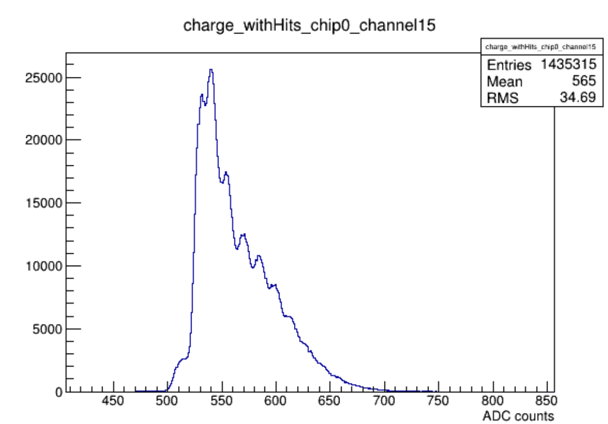
Omega board

DIF board

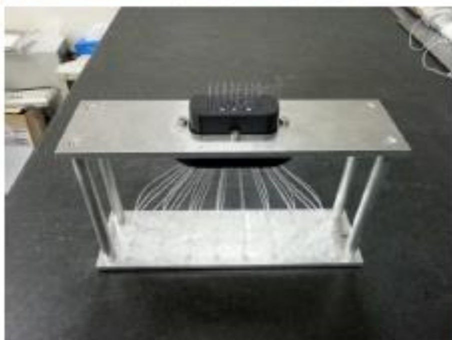
GDCC board

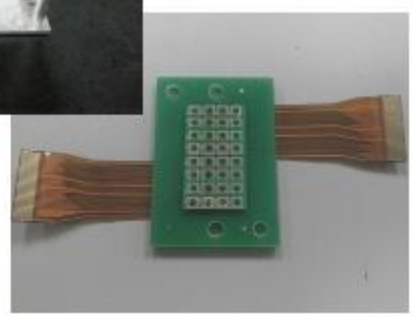


CCC board



WAGASCI



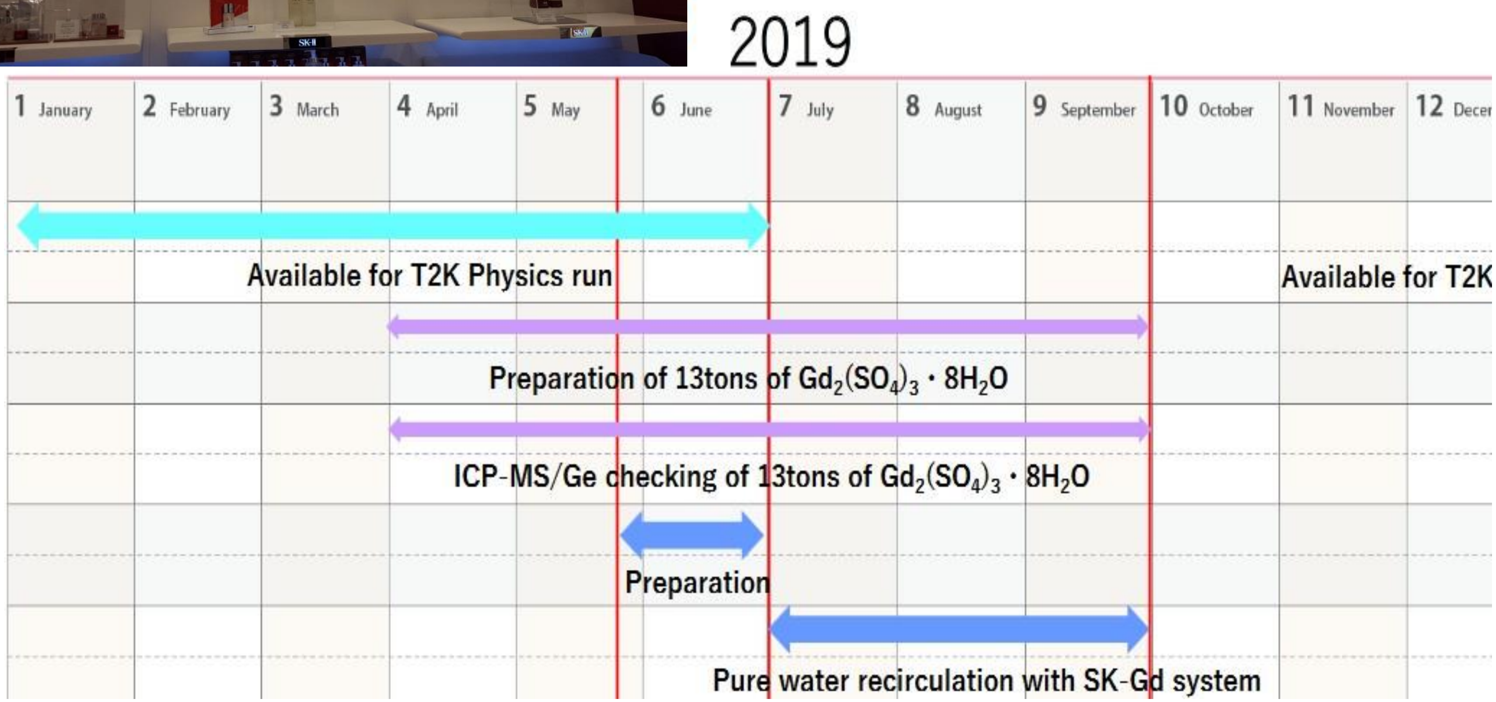


Nos expériences en cours

Astronomie neutrinos avec Super-Kamiokande

Nos expériences en cours

Astronomie neutrinos avec Super-Kamiokande



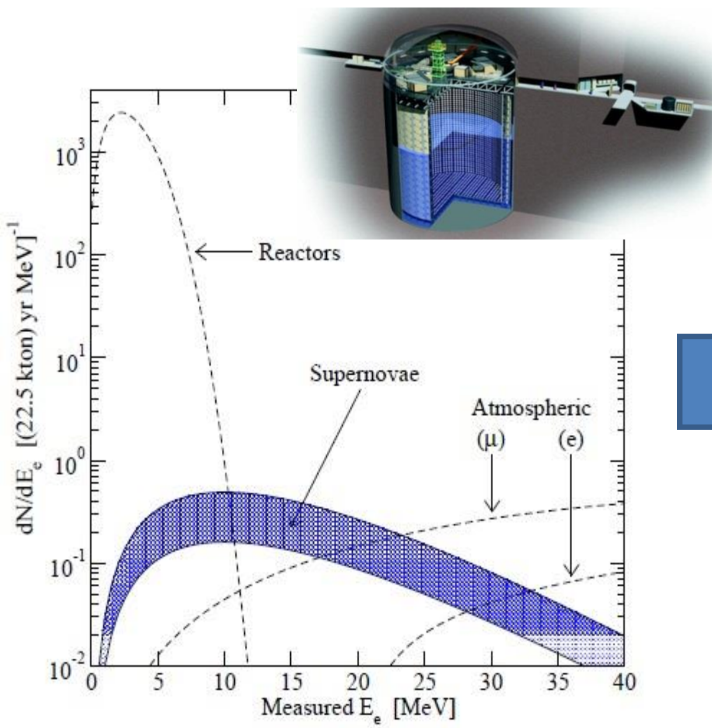
140 K€ de l'X

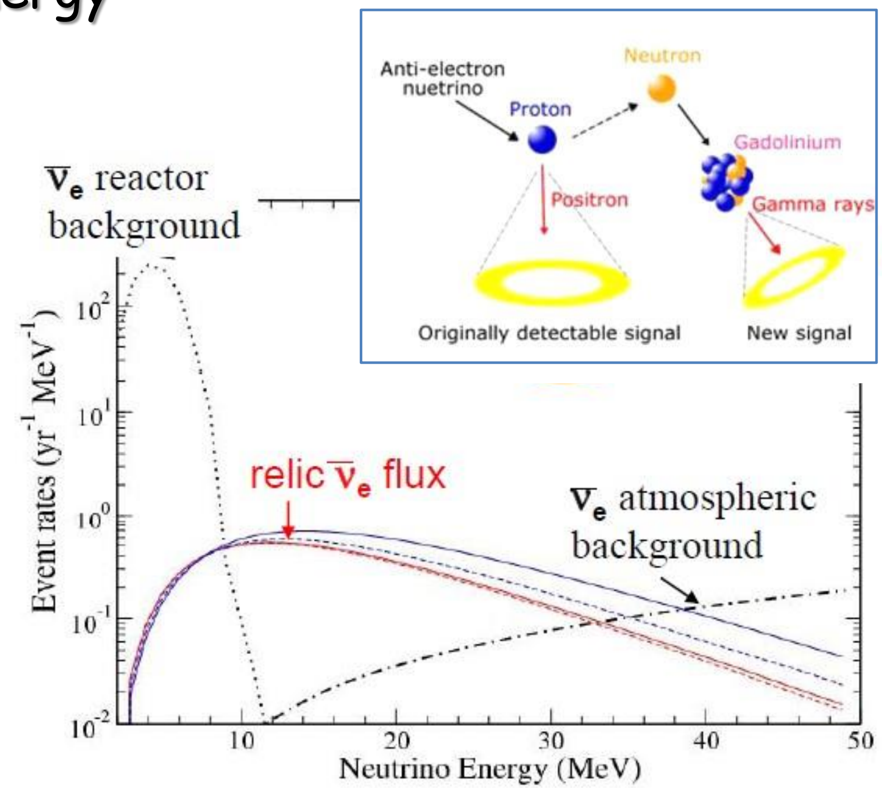
Upgrade for the Super-Kamiokande experiment

LLR group is the only French group in SK (since November 2016)

The goal of the upcoming upgrade is to improve neutron tagging for :

- anti electron-neutrino high efficiency detection
- background reduction at low energy





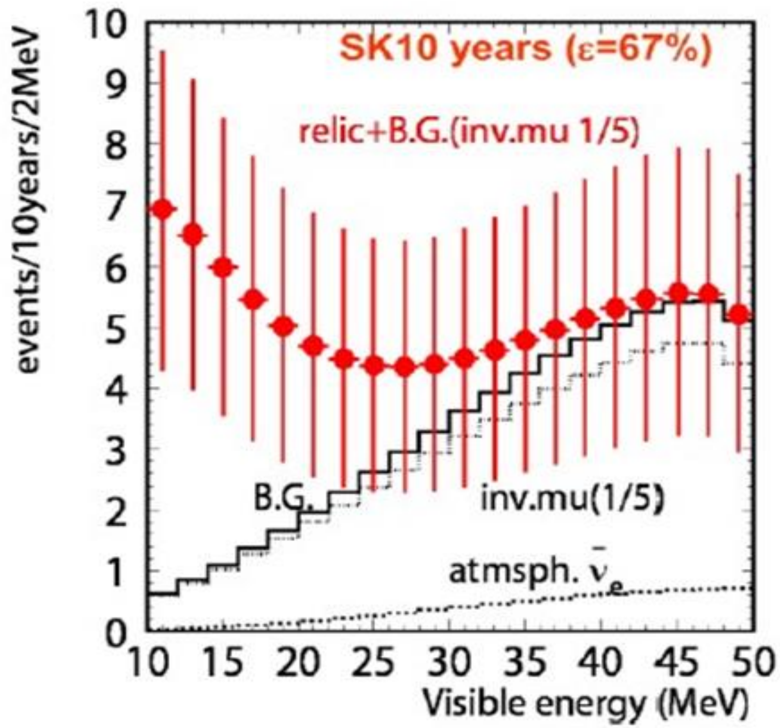
Neutrino Astronomy

Supernova relic neutrinos

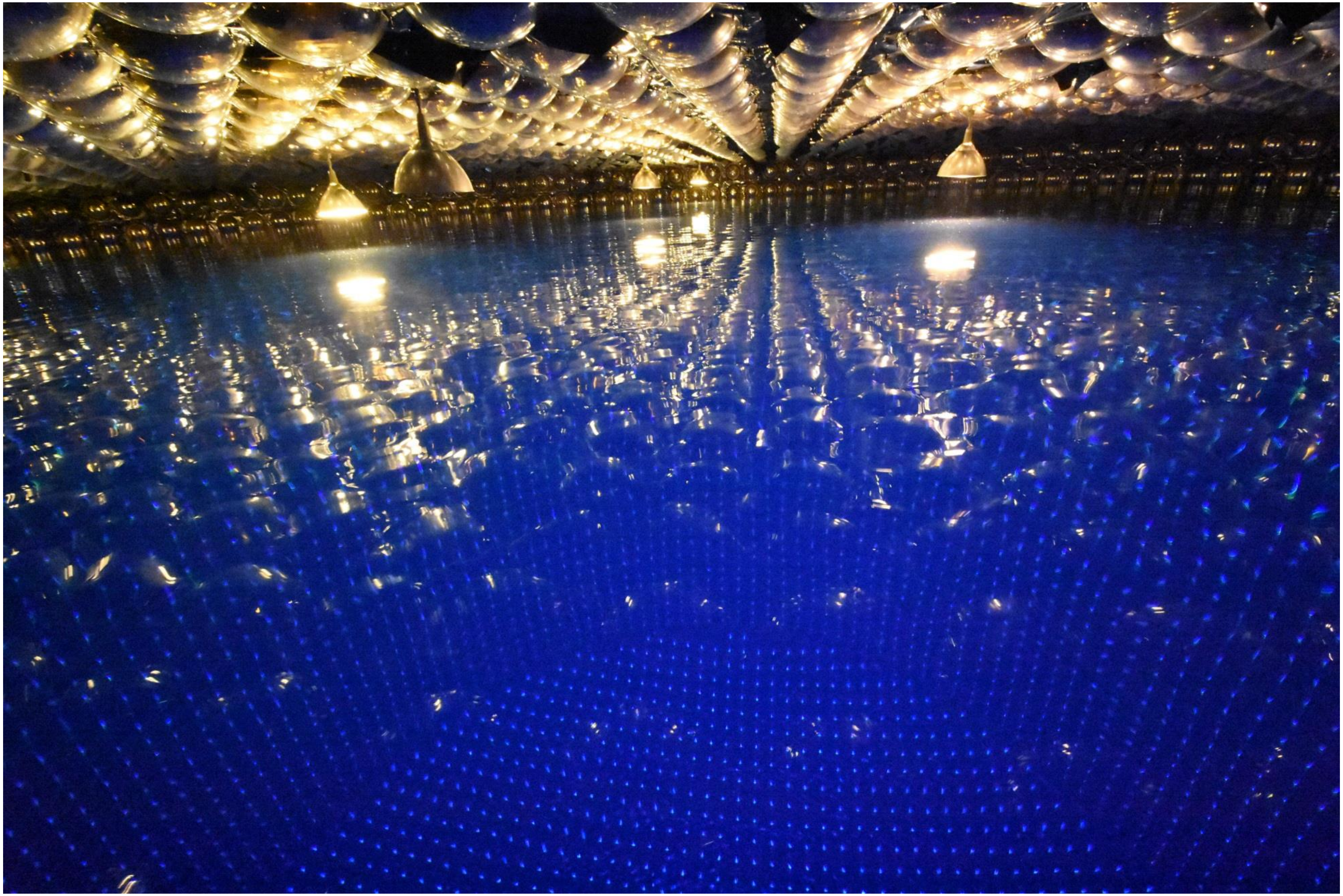
Diffuse Supernova Neutrino Background (DSNB)

Accumulation since the beginning of the Universe of past Supernova burst

Super-Kamiokande is expected to discover DSNB

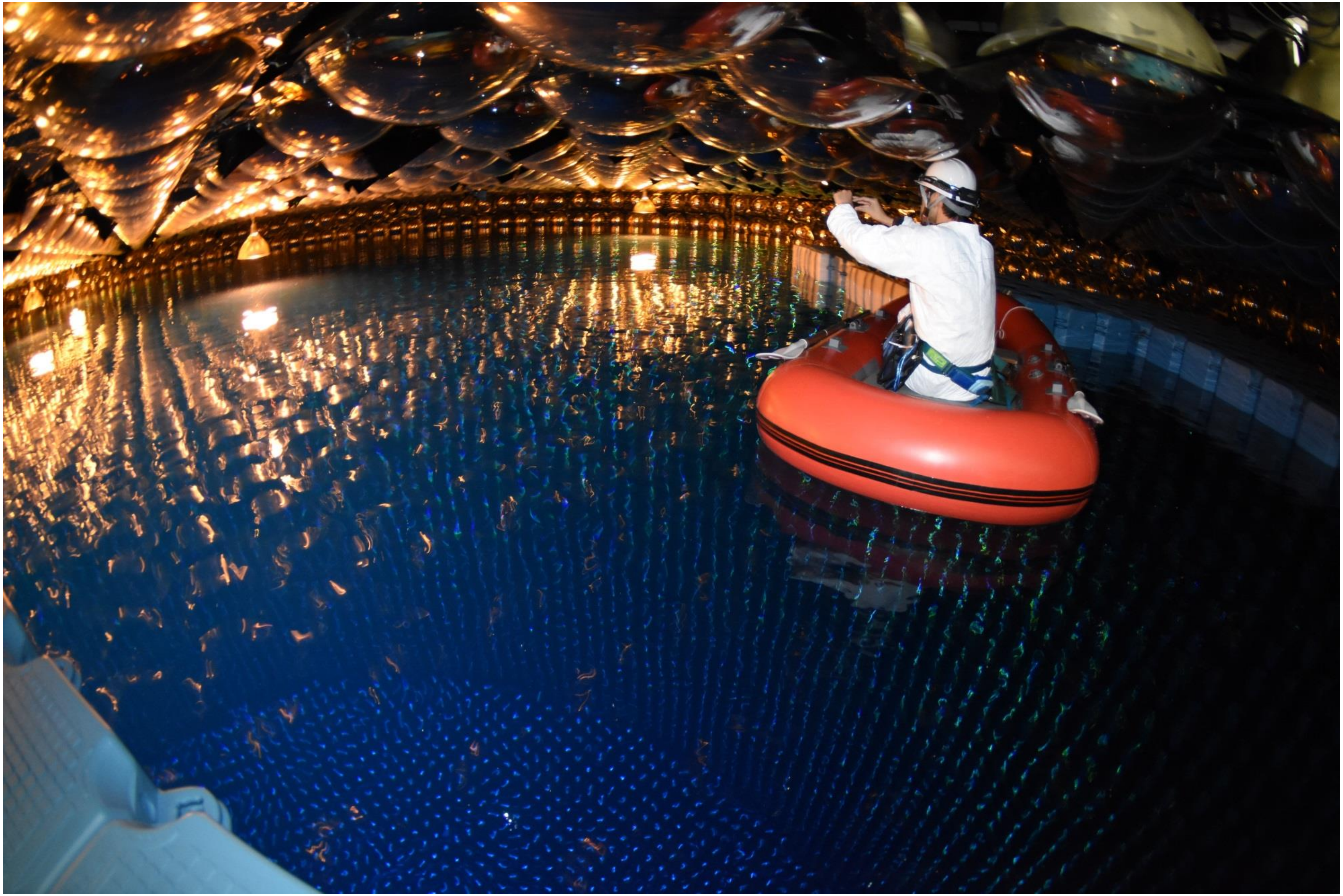


Nos expériences en cours
Astronomie neutrinos avec Super-Kamiokande



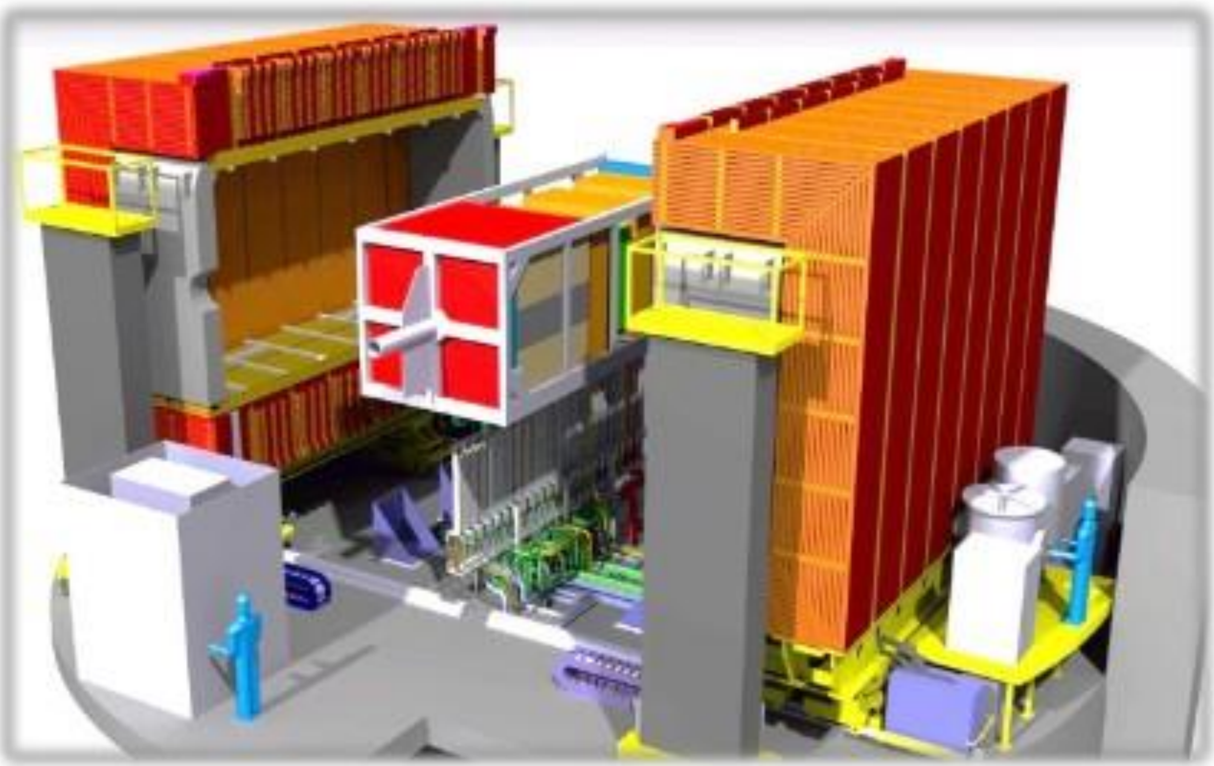
1. Nos expériences en cours

Astronomie neutrinos avec Super-Kamiokande



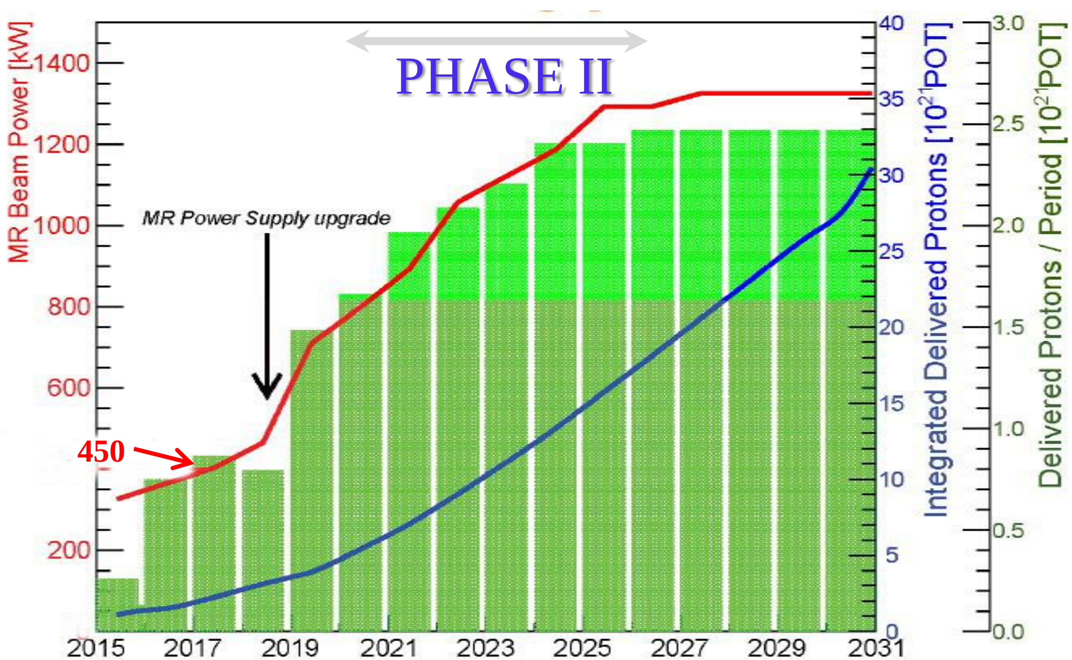
1. Nos expériences en cours

2. Les upgrades T2K II



JPARC and Near Detectors

Beam Upgrades (MR power supply, upgrade MR RF, …)



Step by step

- Decrease bunch intervals from 2.48 sec to 1.3 sec, then 1.16 sec
- Increase protons/bunch from 2.7 10^{14} to 3.2 10^{14}
- Increase horn current form 250 kA to 320 kA

Proposal for T2K phase II @ 1.3 MW (funded)

Increase total delivered protons from 7.8×10^{21} to 20.0×10^{21}

Systematic errors for oscillation analysis

Estimations and simulations will be based
on *T2K and SK studies with real data*

ν-mode ν_e candidates (T2K)

Source of uncertainty	$\delta N_{SK}/N_{SK}$
SKDet+FSI+SI	3.48%
SKDet only	2.28%
FSI+SI only	2.63%
Flux	3.67%
2p-2h (corr)	3.90%
2p-2h bar (corr)	0.05%
NC other (uncorr)	0.15%
NC 1gamma (uncorr)	1.47%
XSec nue/numu (uncorr)	2.61%
XSec Tot (corr)	4.26%
XSec Tot	5.21%
Flux+XSec (ND280 constrained)	2.90%
Flux+XSec (All)	4.17%
Flux+XSec+SKDet+FSI+SI	5.45%
Flux+XSec+SKDet+FSI+SI (pre-fit)	12.1%
Oscillations	4.20%
All	6.91%
All (pre-fit)	12.6%

$\overline{\nu}$-mode $\overline{\nu}_e$ candidates (T2K)

Source of uncertainty	$\delta N_{SK}/N_{SK}$
SKDet+FSI+SI	3.95%
SKDet only	3.11%
FSI+SI only	2.43%
Flux	3.84%
2p-2h (corr)	3.04%
2p-2h bar (corr)	2.36%
NC other (uncorr)	0.33%
NC 1gamma (uncorr)	2.95%
XSec nue/numu (uncorr)	1.46%
XSec Tot (corr)	4.46%
XSec Tot	5.55%
Flux+XSec (ND280 constrained)	3.20%
Flux+XSec	4.60%
Flux+XSec+SKDet+FSI+SI	6.28%
Flux+XSec+SKDet+FSI+SI (pre-fit)	13.5%
Oscillations	4.00%
All	7.38%
All (pre-fit)	14.1%

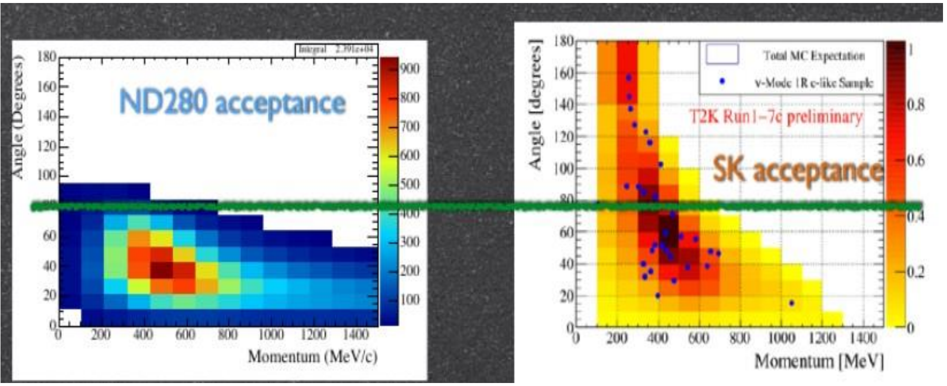
Goal

Reduction from ~ 6-7% in T2K to ~ 3-4% in T2K II and T2HK
for the expected number of events.

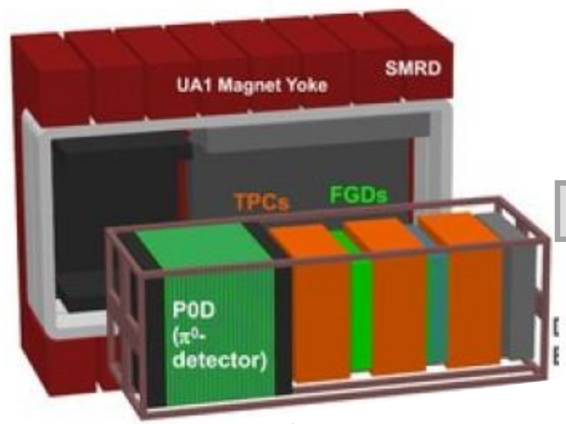
Beam flux, XSections, HK Detector, New Near Detectors.

Beam flux and Xsections

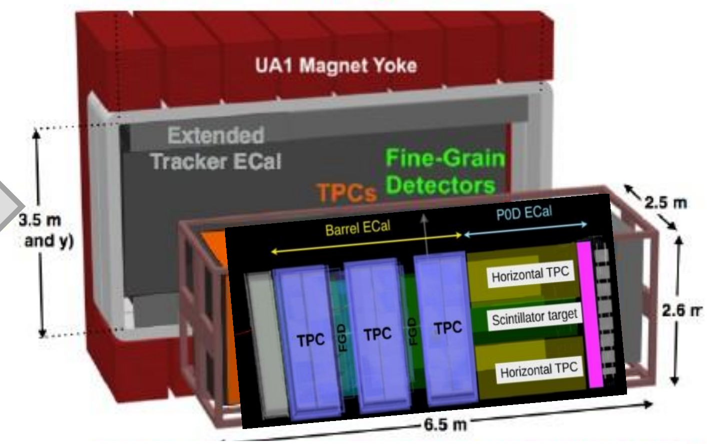
for T2K-II



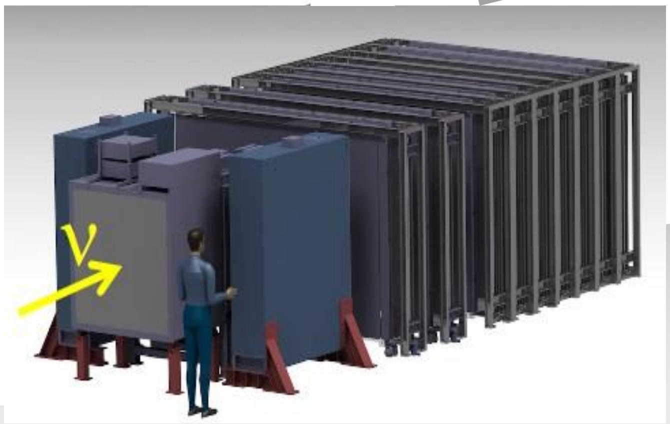
ND280 (NOW)



ND280 (Upgrade)



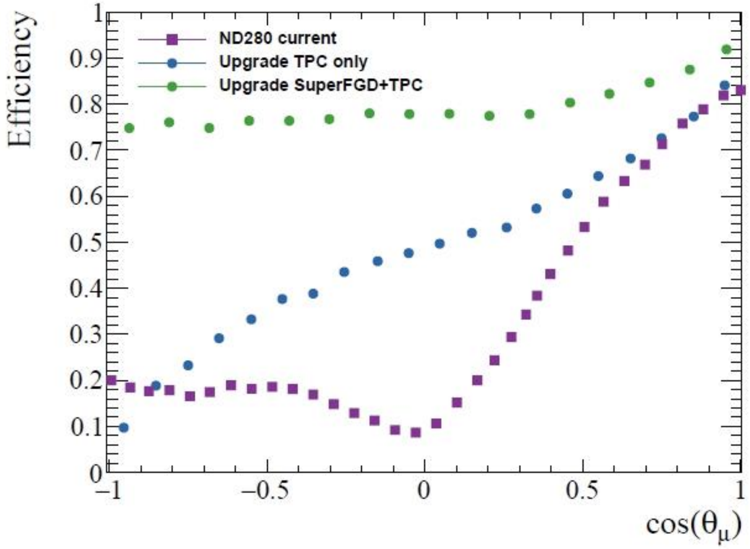
WAGASCI

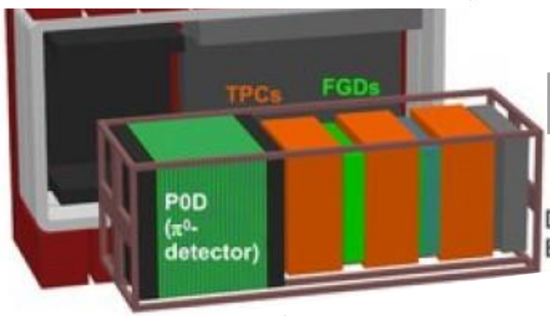


a) Sections efficaces neutrinos dans l'eau
b) Améliorations de l'identification des neutrinos électrons à basse énergie
c) Détections à grand angle des muons
d) Détections des protons de faible énergie.

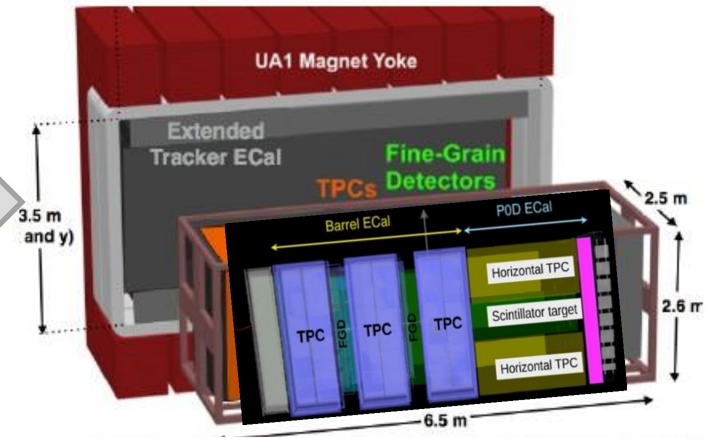
Beam flux and Xsections

for T2K-II

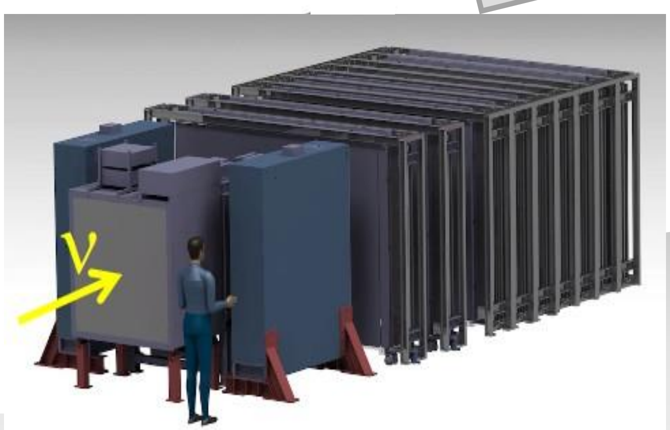




ND280 (Upgrade)



WAGASCI

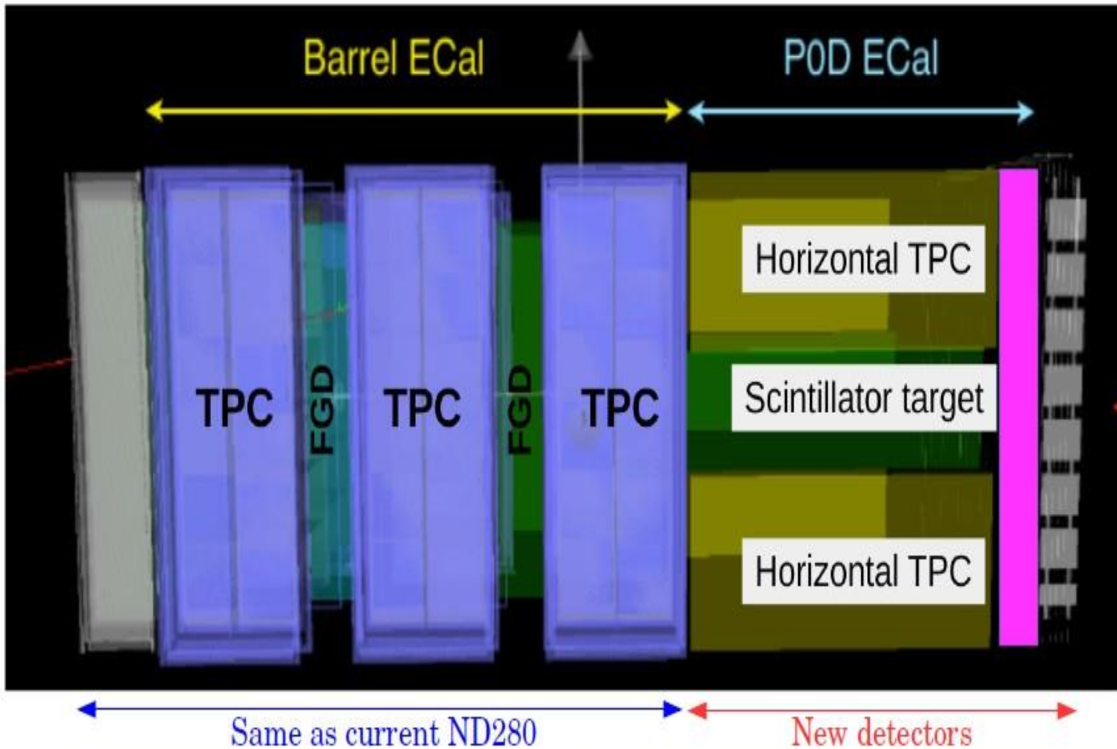


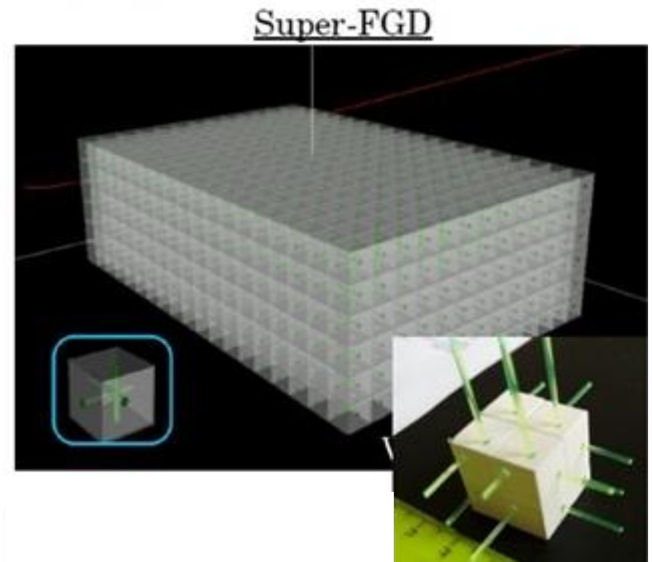
a) Sections efficaces neutrinos dans l'eau
b) Améliorations de l'identification des neutrinos électrons à basse énergie
c) Détections à grand angle des muons
d) Détections des protons de faible énergie.

ND280 upgrades @ +2.5°

Proposal for the ND280 upgrade

Benjamin Quilain 1





1. Existing two FGD targets : H_2O + CH ~ 1.8 T each

2. One new fully active plastic target embedded in 4π tracker ~ 1.5 T

Maximal acceptance coverage

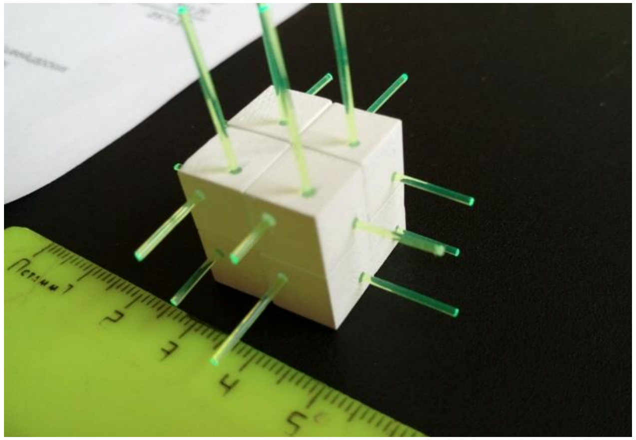
3. Use 3 ND280 TPC + build 2 new TPCs & support structure
→ particle momenta can be measured in all direction (SK 4π angular acceptance)

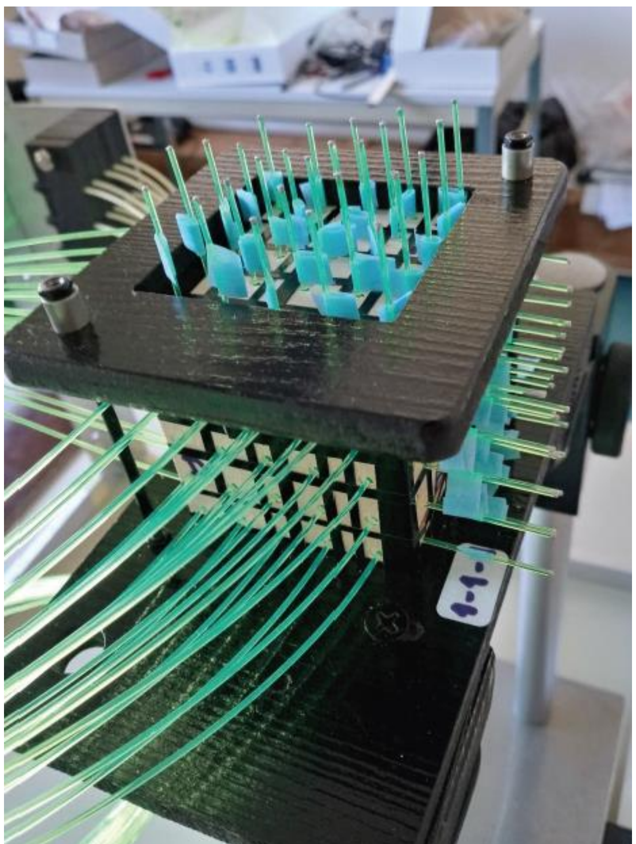
IN2P3 contributions to the Japanese neutrino program: T2K, T2K-II, Super-K and Hyper-K

LLR and LPNHE neutrino groups

Prepared for the IN2P3 Scientific Council – June 2018

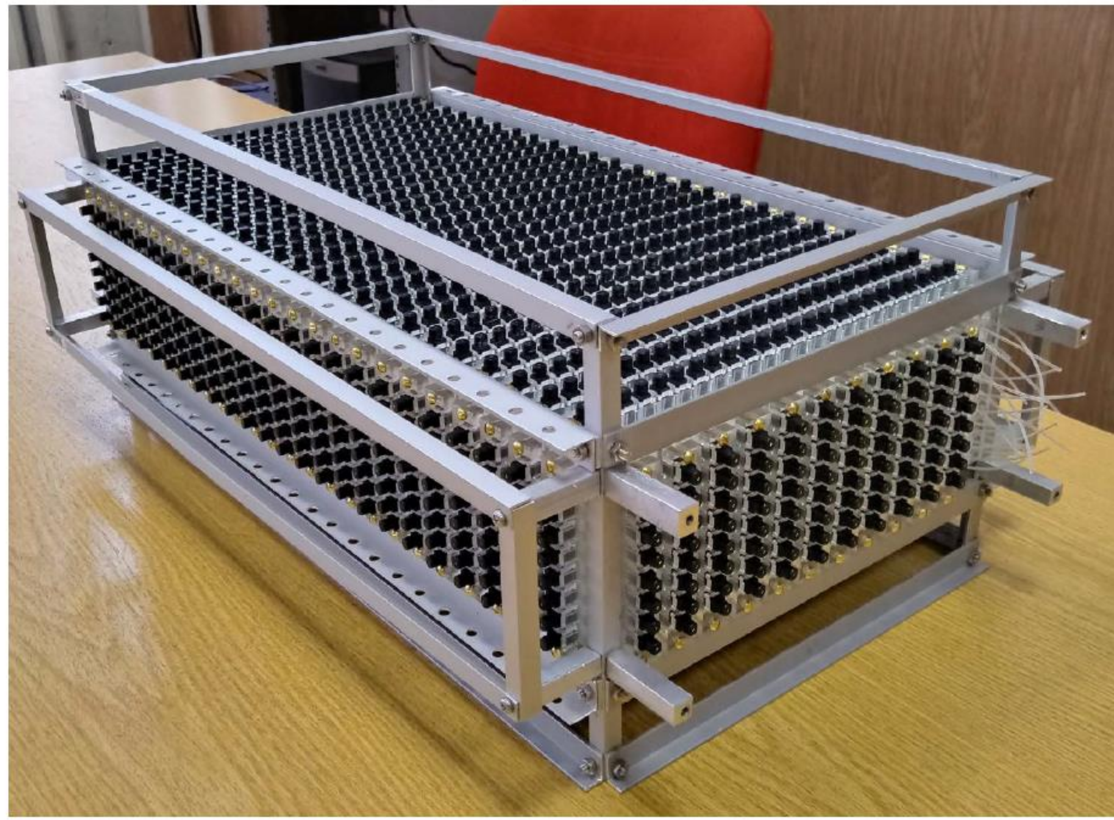
Contents





Contribution technique du LLR électronique de lecture du SFGD

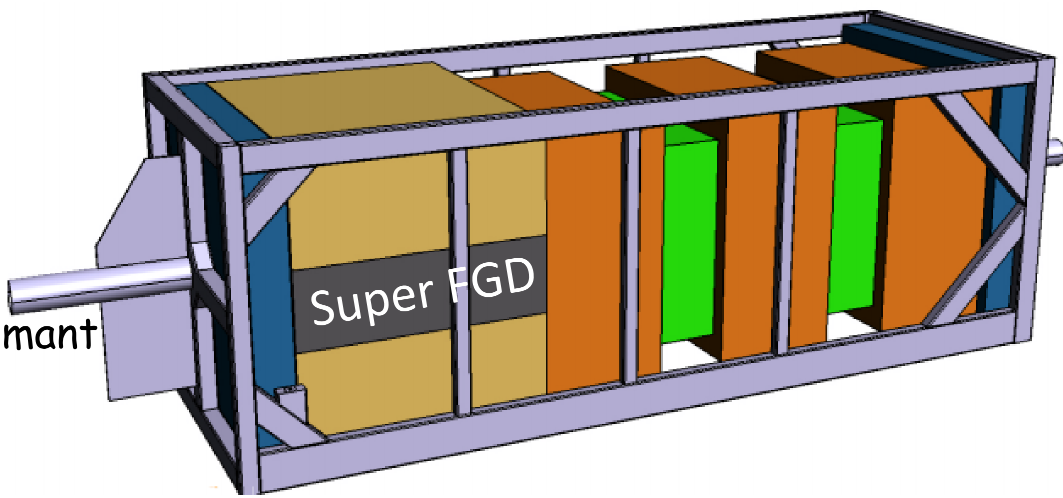
Complete SuperFGD prototype at INR

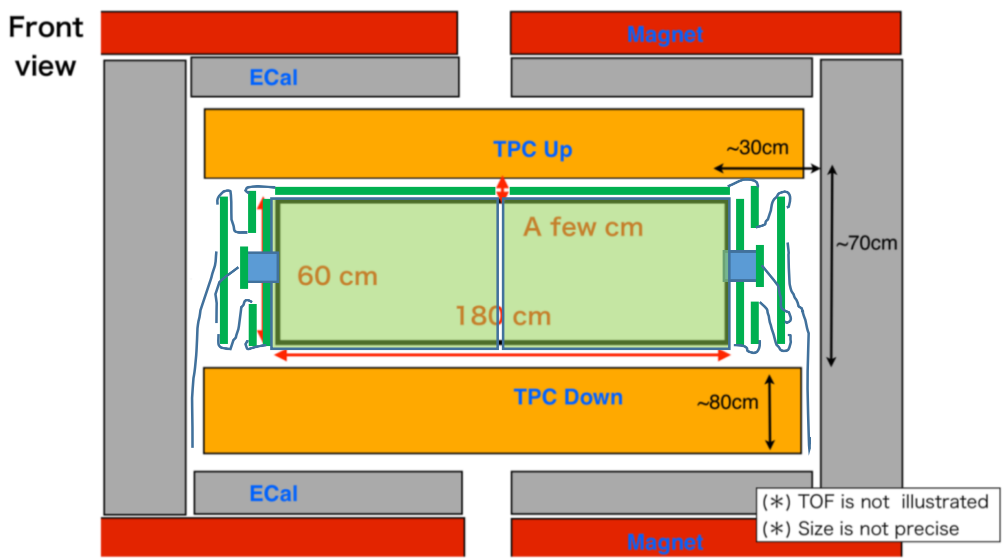


Arrived at CERN 4th June

Contraintes

- Dimensions : ~ 200 x 180 x 60 cm^3 ~ 2 m^3
  - De 60 000 à 90 000 canaux selon géométrie exacte (quadrants)
- Bilan matière aussi petit que possible entre SFGD et TPC
  - et sur le trajet du faisceau
  - Pas de lecture dessous
- Plus de place sur les côtés
  - Front-end chips sur toutes les faces sauf dessous
  - DIFs sur les côtés, GDCC hors aimant

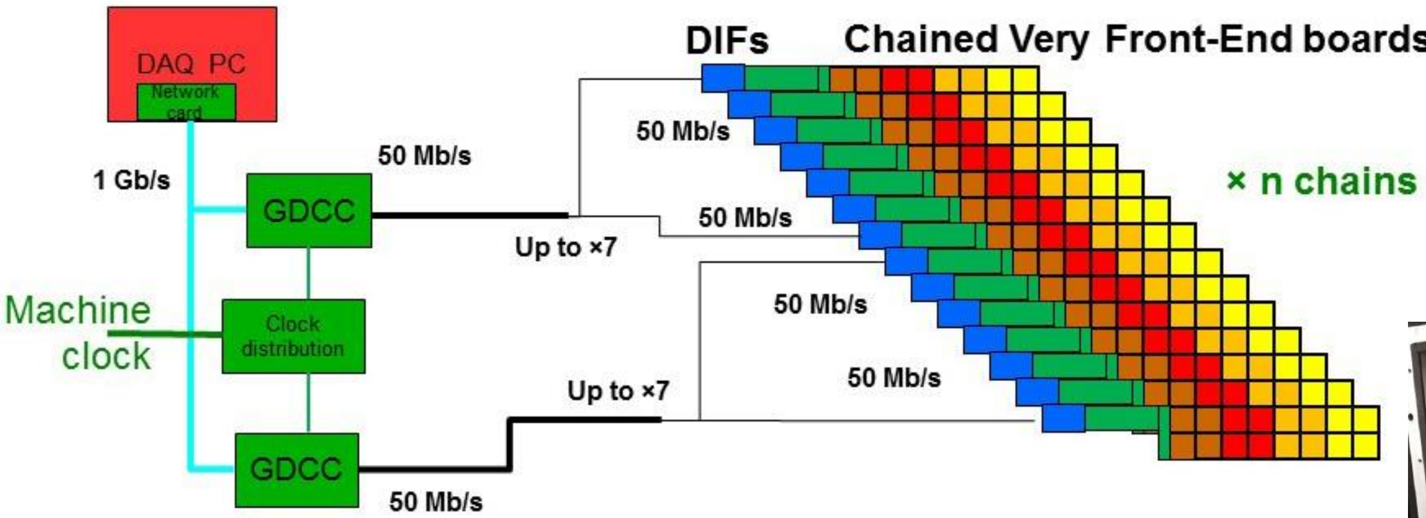


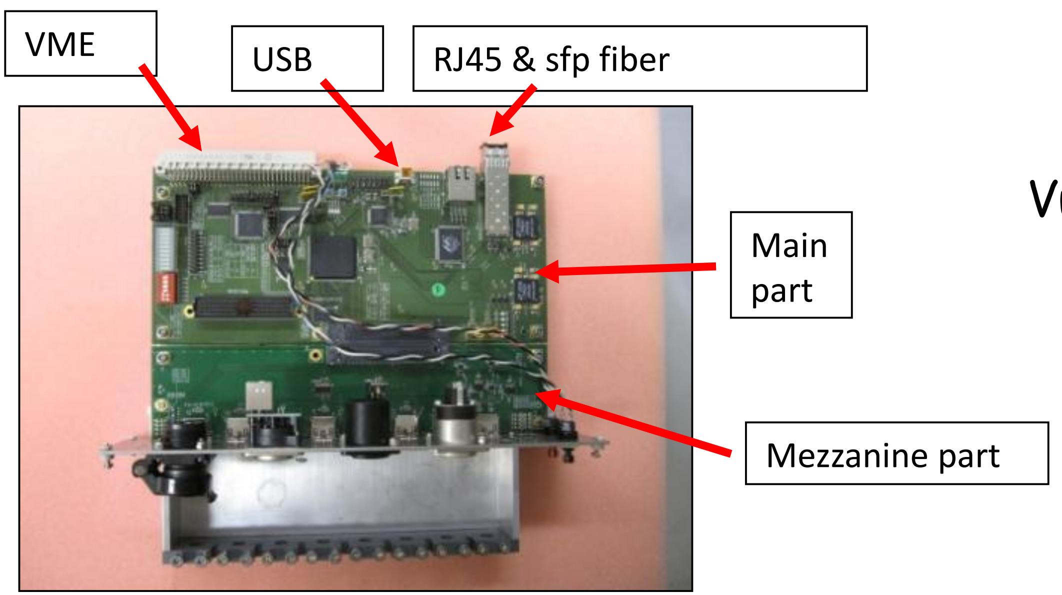


- Intégration mécanique non prise en charge actuellement

Schéma de principe de la DAQ proposée

Développée pour CALICE/ILC et déjà adaptée dans T2K pour WAGASCI

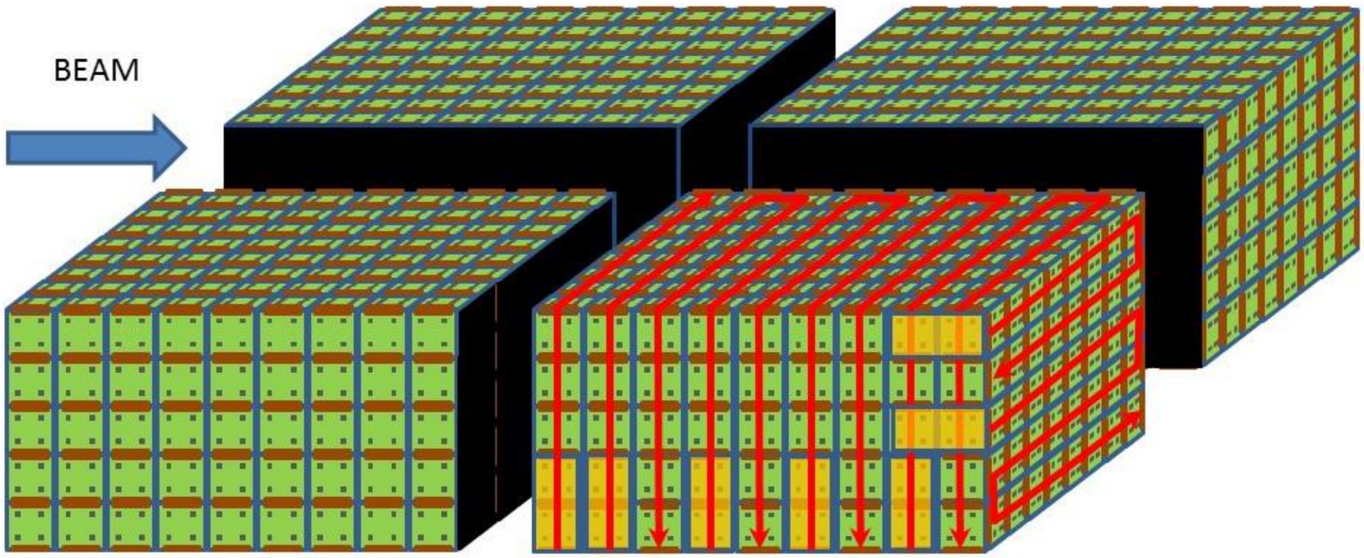




Carte GDCC

Vue d'un module WAGASCI

Implémentation



- Environ 1700 à 2500 SPIROC2E (Omega) front end chips
  - ADC 12 bits, TDC ~300 ps
- Environ 400 à 600 cartes front-end
- 7 cartes DIF + 1 GDCC par quadrant
- Total de 700 W de dissipation / 8m^2
- **Coût approximatif : 600 k€**

CS IN2P3 28 juin

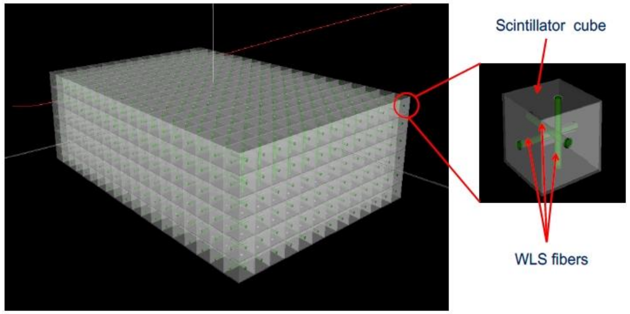
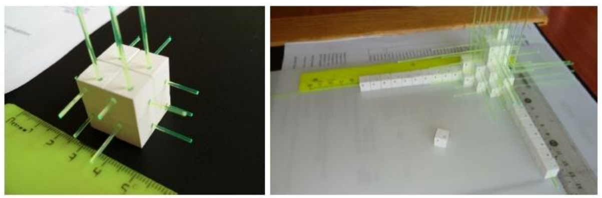


Figure 21: Schematic of the super-FGD structure.



Project	Cost
T2K-II TPCs	200 k€
T2K-II Super–FGD	600 k€
NA61++	15 k€(per year)
Hyper–K R&D	40 k€

Estimated resources needed for the projects described in this document.

The request for NA61++ would allow the LPNHE group to continue its participation in the NA61 physics program, with the goal of reducing uncertainties on the neutrino fluxes for T2K-II and future LBL experiments (DUNE and Hyper-Kamiokande).

Concerning the ND280 upgrade, the estimated cost of the project to develop and construct the new Front-End-Cards for the horizontal TPCs within the ND280 upgrade project is about 200 k€. This include also the mechanics and cooling system of the Front-End electronics.

If the LLR option for the Super–FGD electronics is choosen by the collaboration, the total cost of the project is estimated to 600 k€.

Finally for the proposed R&D project for Hyper-Kamiokande the LLR and LPNHE groups will need $\sim$40 k€ to start buying components and producing cards for prototype activities. An evaluation of the full costs of the project for the Hyper-Kamiokande experiment is not done within this proposal.

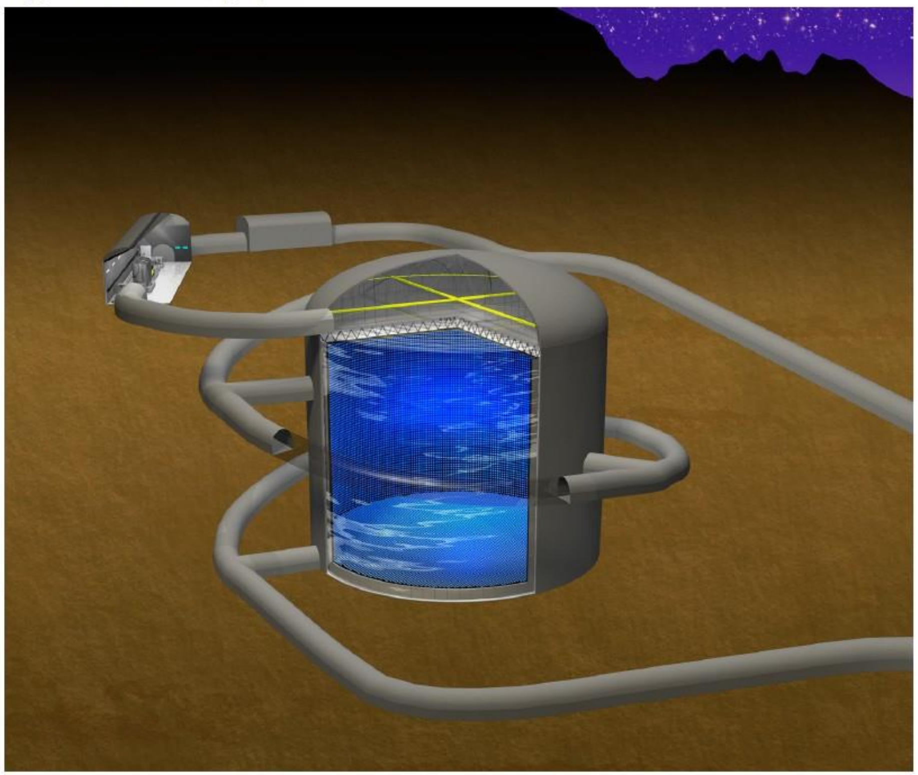
If the LLR option for the Super–FGD electronics is choosen by the collaboration, a full time electronics research engineer position will be necessary during three years to adapt the CALICE electronics to the new detector configuration. This person will then develop the electronics for the Hyper-Kamiokande experiment that has been detailed in the previous section. Thus, a permanent position would be preferable. In addition, if it appears that a contribution from LLR is needed for the mechanical structure of the Super–FGD detector, a two years mechanics research engineer position would be required.

1. Nos expériences en cours

2. Les upgrades T2K-II

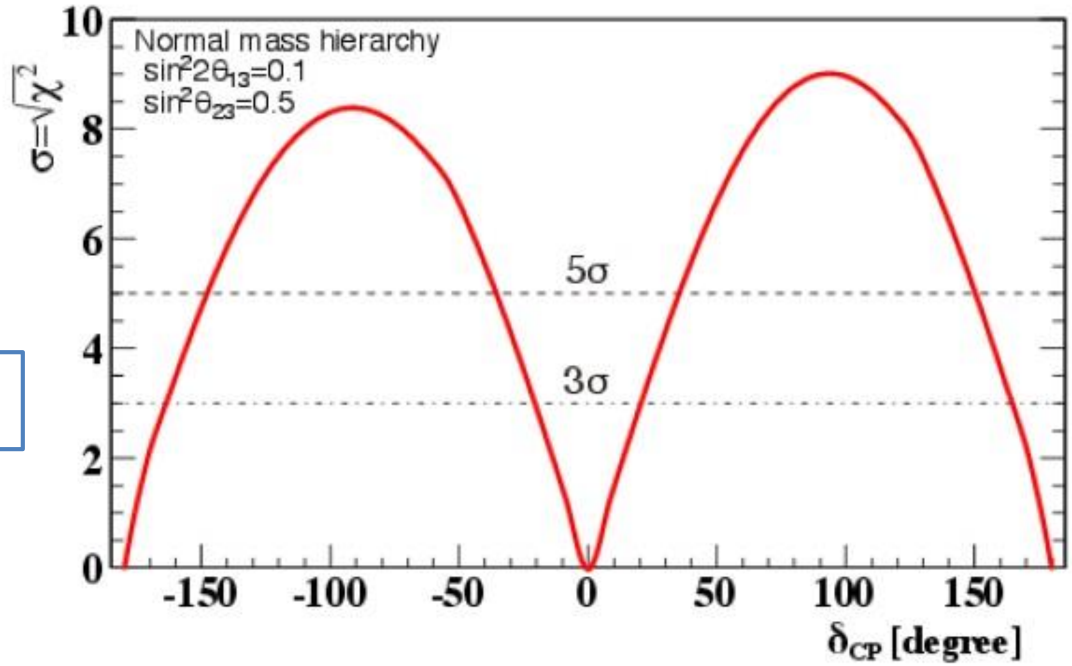
3. Le projet Hyper-Kamiokande

Hyper-Kamiokande project

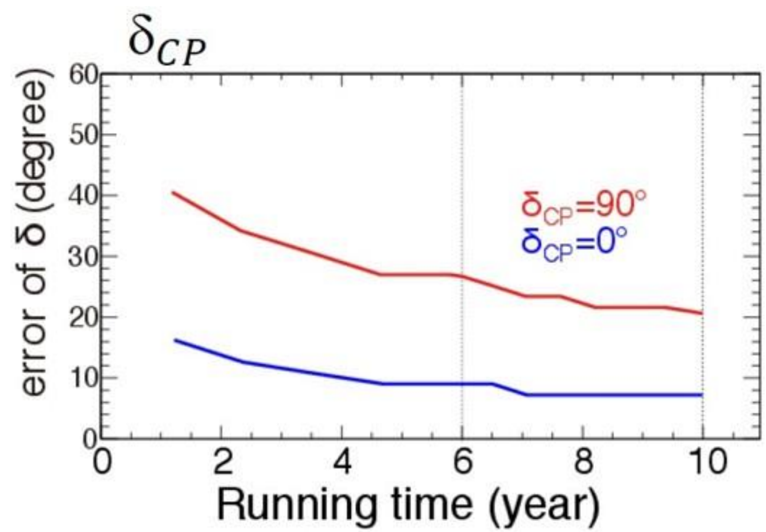


Hyper-Kamiokande

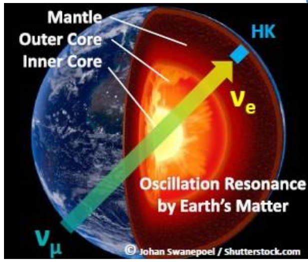
CPV studies



- Exclusion of $\sin\delta_{CP}=0$
  - 8σ for δ=-90°
  - 80% coverage of δ parameter space for CPV discovery w/ >3σ
- δ_{CP} precision measurement
  - 20° for δ=-90°
  - 7° for δ=0°

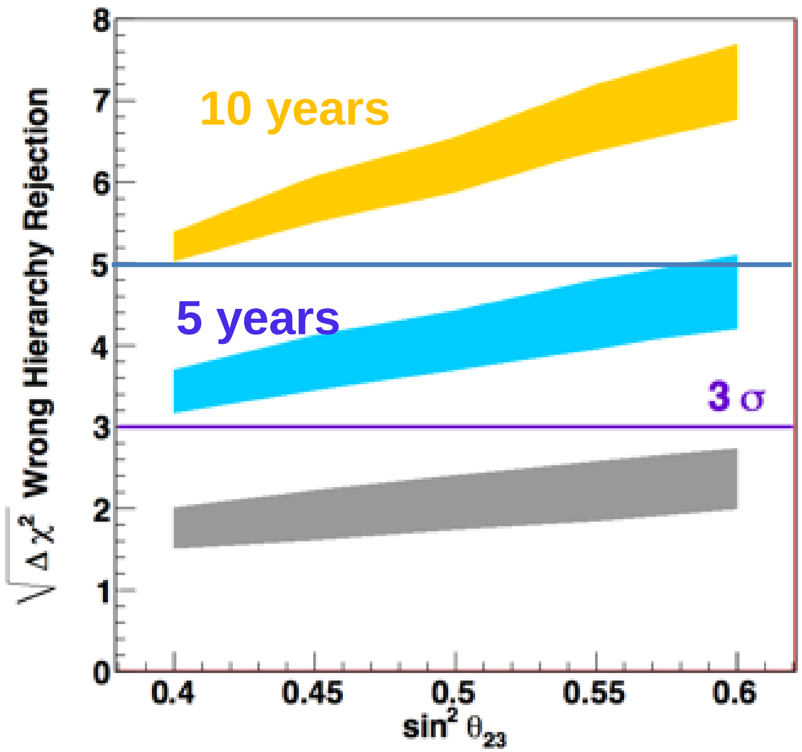


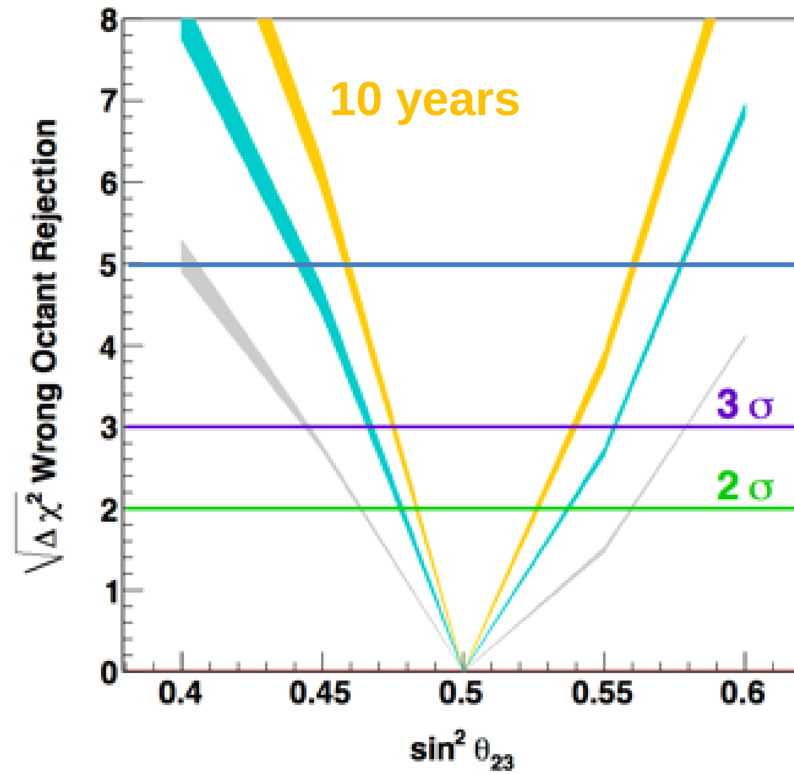
Physics performance for oscillation parameter measurements



JPARC Beam + Atmospheric neutrinos

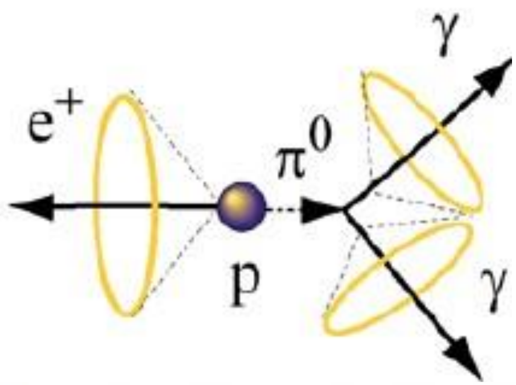
Normal Hierarchy

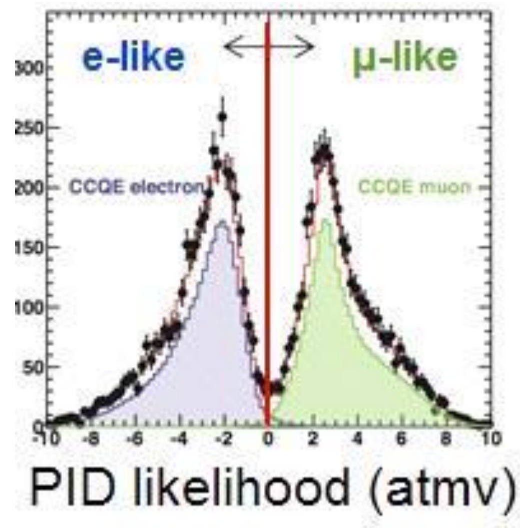




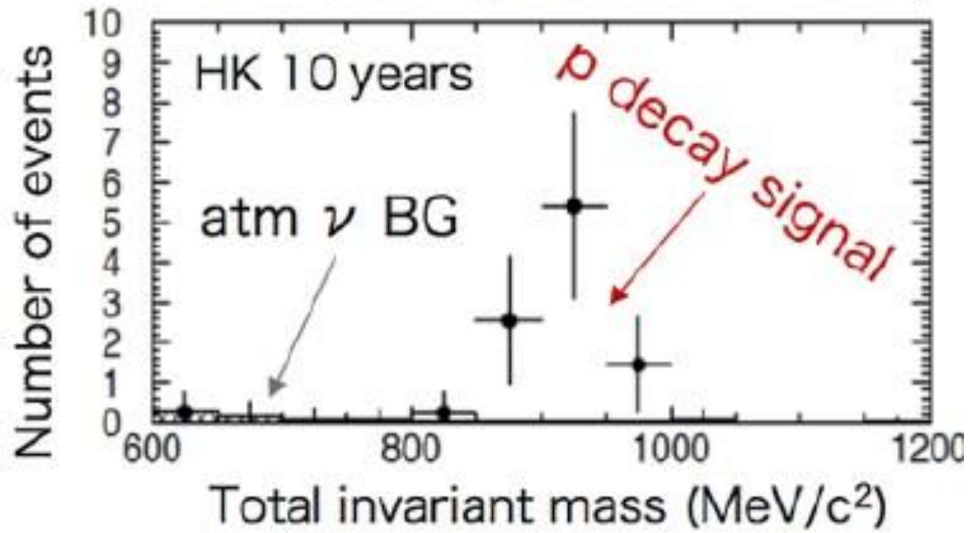
M.H. determination ~ 5σ. Good performance for octant determination

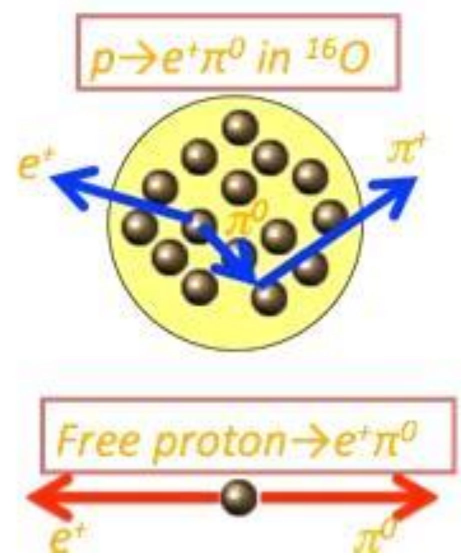
Proton Decay Sensitivity





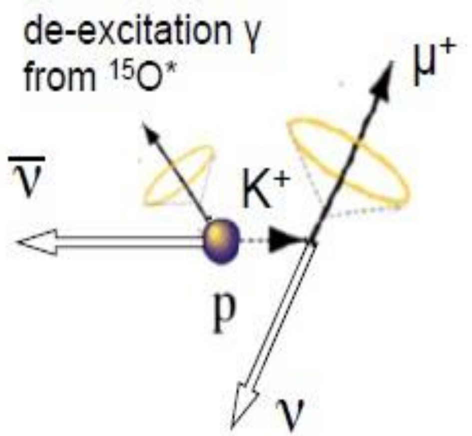
Invariant mass assuming τ/Br = 1.7×10^{34} years (SK 90% C.L. limit)





- Great potential for discovery

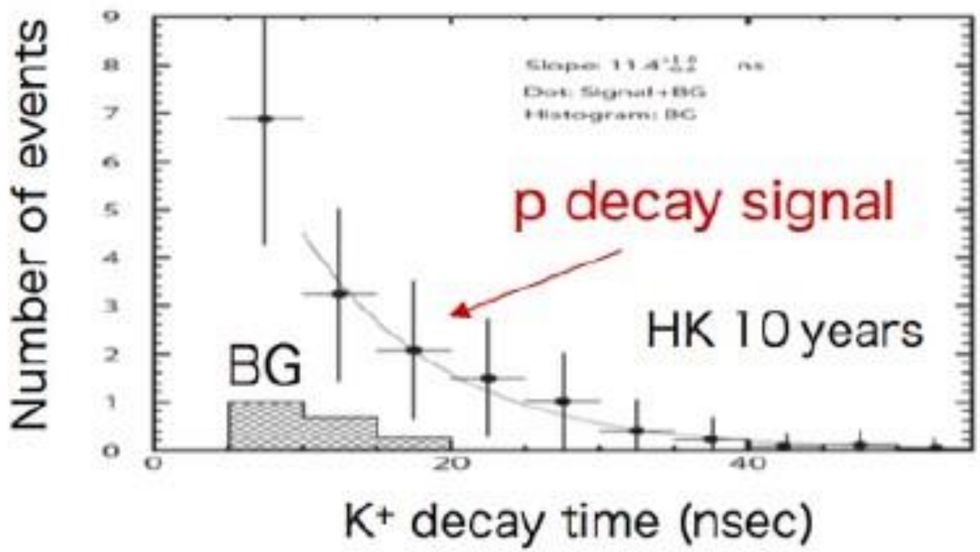
Proton Decay Sensitivity



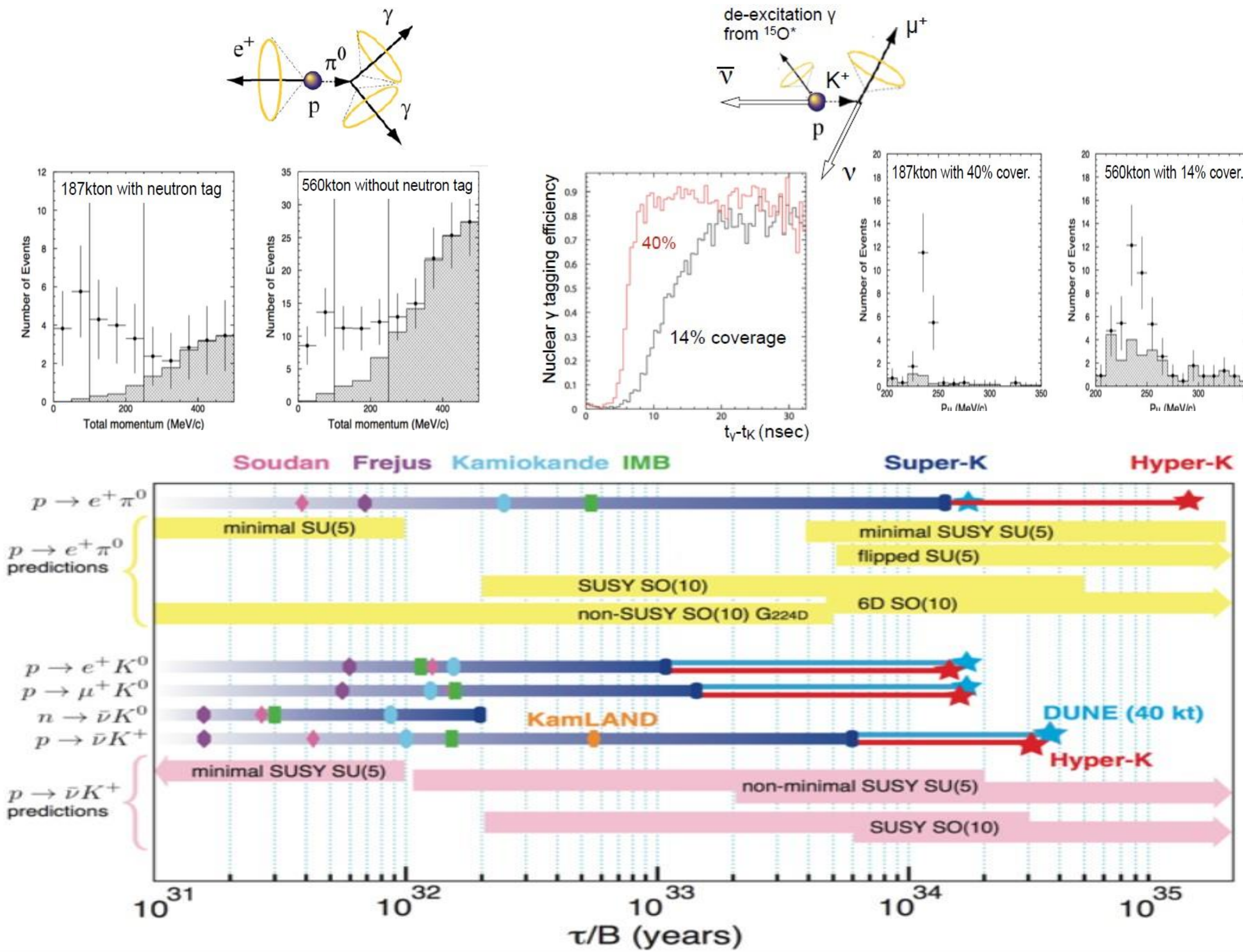
K^+ identification by decay products

$K^+ \rightarrow \mu^+ \nu$ (64%)	236 MeV/c μ^+ + decay e^+ de-excitation γ from $^{16}O^*$ (6 MeV)
$K^+ \rightarrow \pi^+ \pi^0$ (21%)	205 MeV/c π^+ + π^0 back-to-back

K^+ decay time assuming τ/Br =
6.6×10^{33} years (SK 90% C.L. limit)



- Great potential for discovery



e+
π0
γ
γ
p
de-excitation γ
from 15O*
μ+
ν̄
K+
p
ν
187kton with neutron tag
560kton without neutron tag
Number of Events
Total momentum (MeV/c)
Nuclear γ tagging efficiency
40%
14% coverage
tγ-tK (nsec)
187kton with 40% cover.
560kton with 14% cover.
Soudan
Frejus
Kamiokande
IMB
Super-K
Hyper-K
p → e+π0
p → e+π0 predictions
minimal SU(5)
minimal SUSY SU(5)
flipped SU(5)
SUSY SO(10)
6D SO(10)
non-SUSY SO(10) G224D
p → e+K0
p → μ+K0
n → ν̄K0
p → ν̄K+
KamLAND
DUNE (40 kt)
Hyper-K
p → ν̄K+ predictions
minimal SUSY SU(5)
non-minimal SUSY SU(5)
SUSY SO(10)
τ/B (years)

Neutrino Astronomy

Hyper-Kamiokande

Super-Kamiokande

Kamiokande

11 observed events

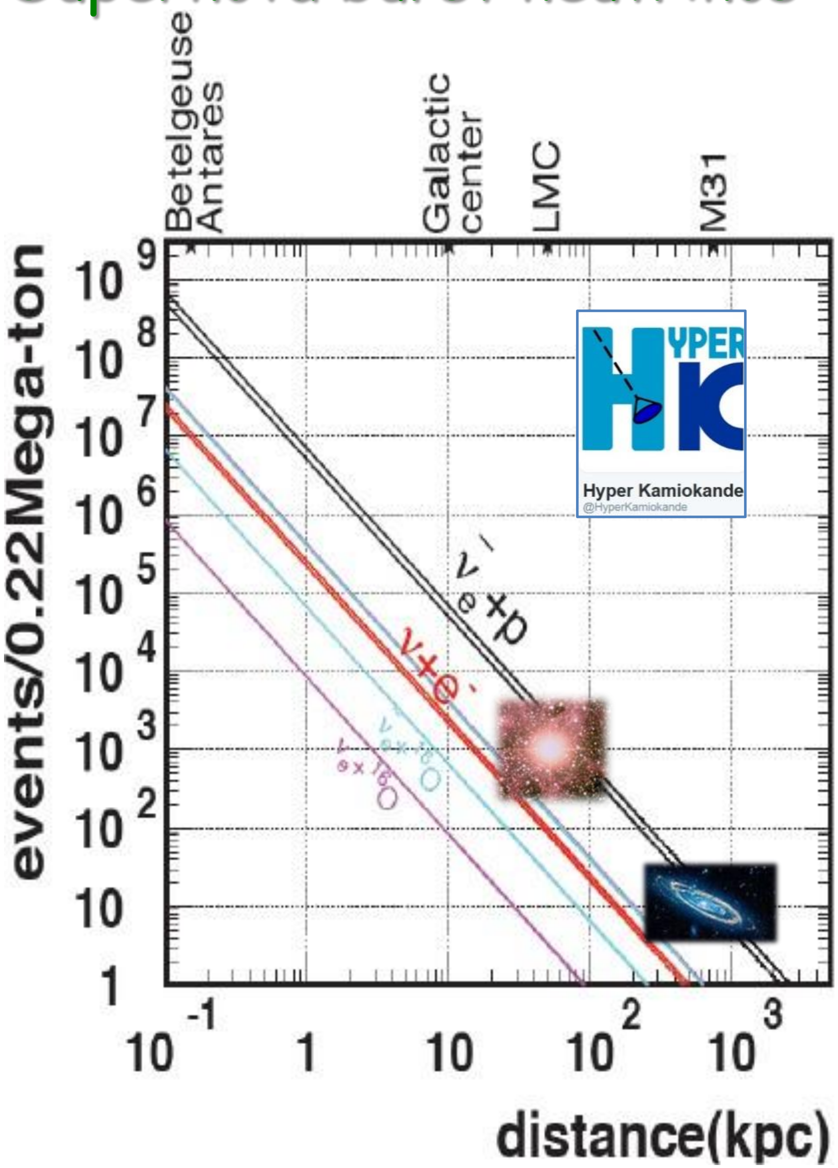
~ 250 events

~ 3000 events

Much more events … in addition to reduced background

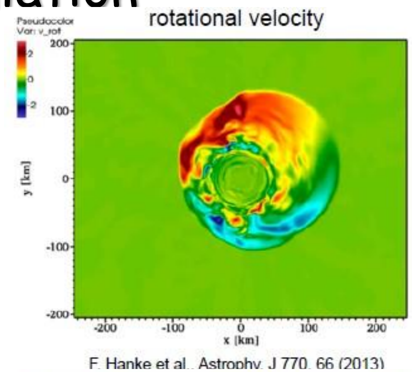
Hyper-Kamiokande

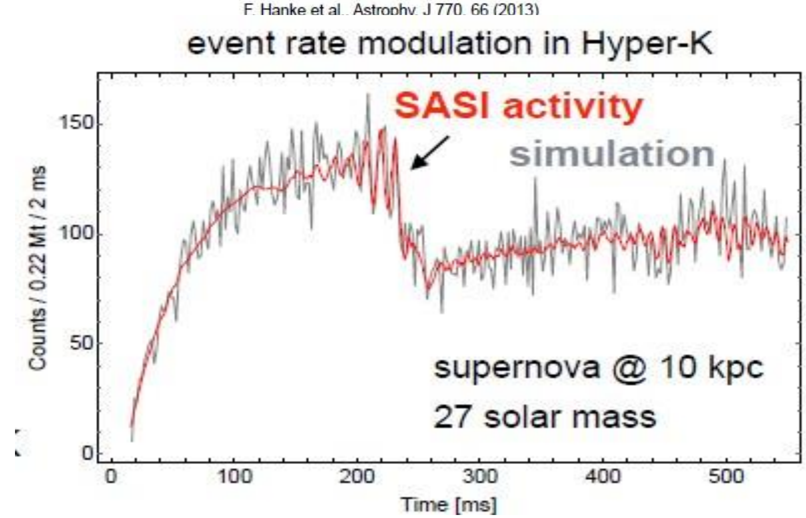
Supernova burst neutrinos



- HK can extend the supernova search distance to extra-galaxy such as Andromeda

- HK will test the supernova neutrino flux modulation





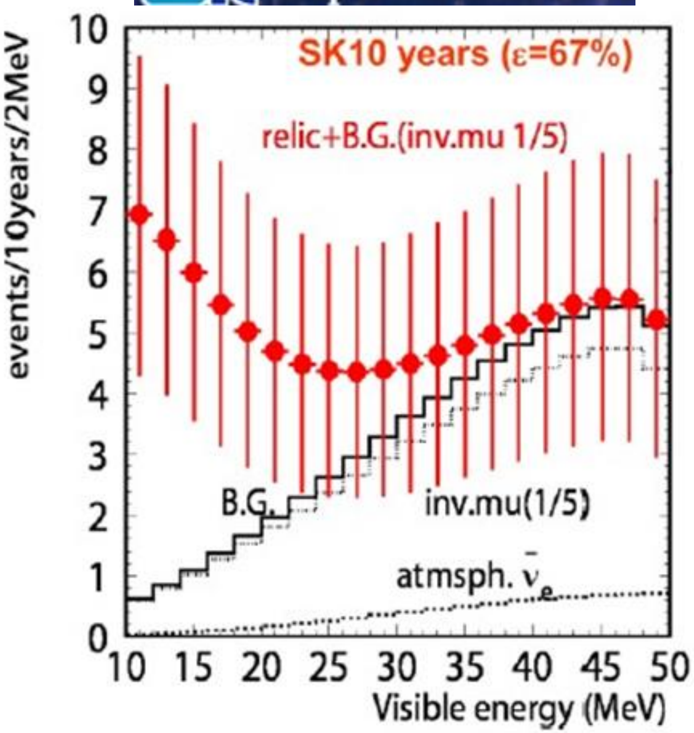
Neutrino Astronomy

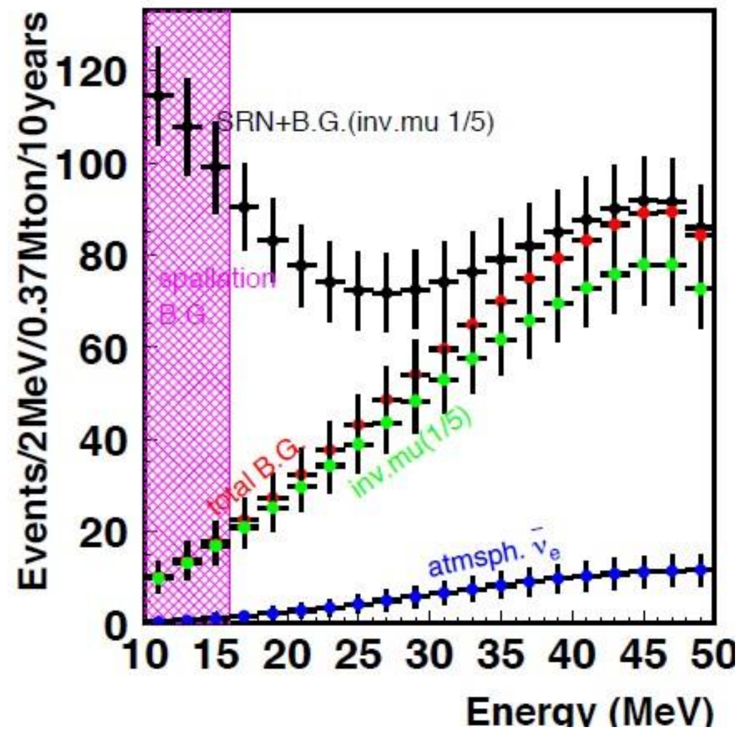
Supernova relic neutrinos

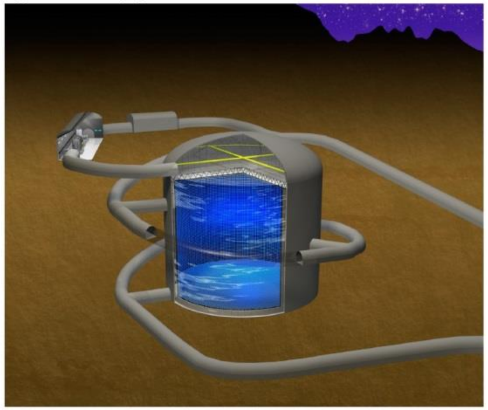
Diffuse Supernova Neutrino Background (DSNB)

Accumulation since the beginning of the Universe of past Supernova burst

Super-Kamiokande is expected to discover DSNB





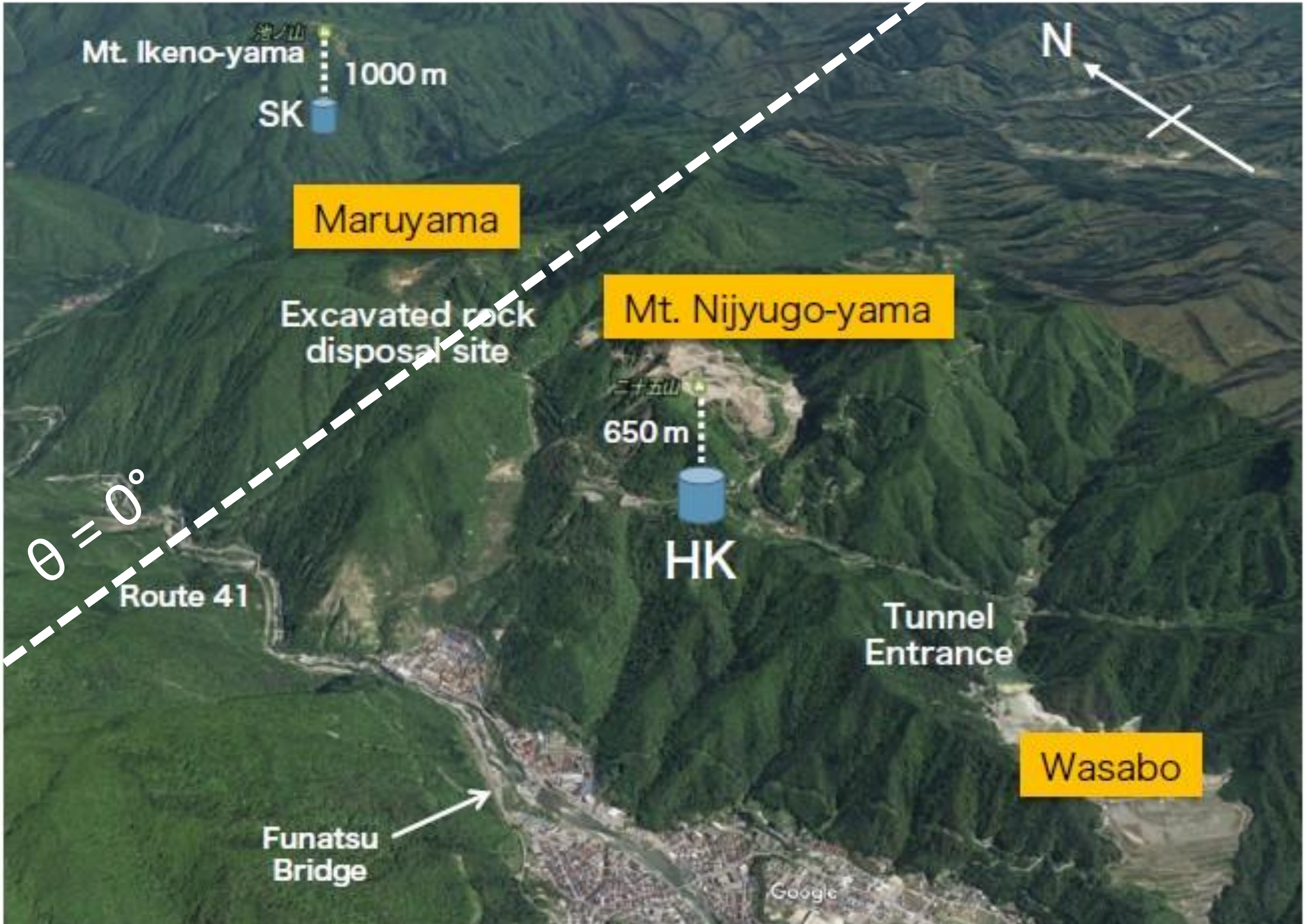


Toward construction start

- MEXT lists the HK in its Roadmap2017
  - FY2018 budget includes 10 million JPY which can be used for Hyper-K
  - Next is approval for starting construction

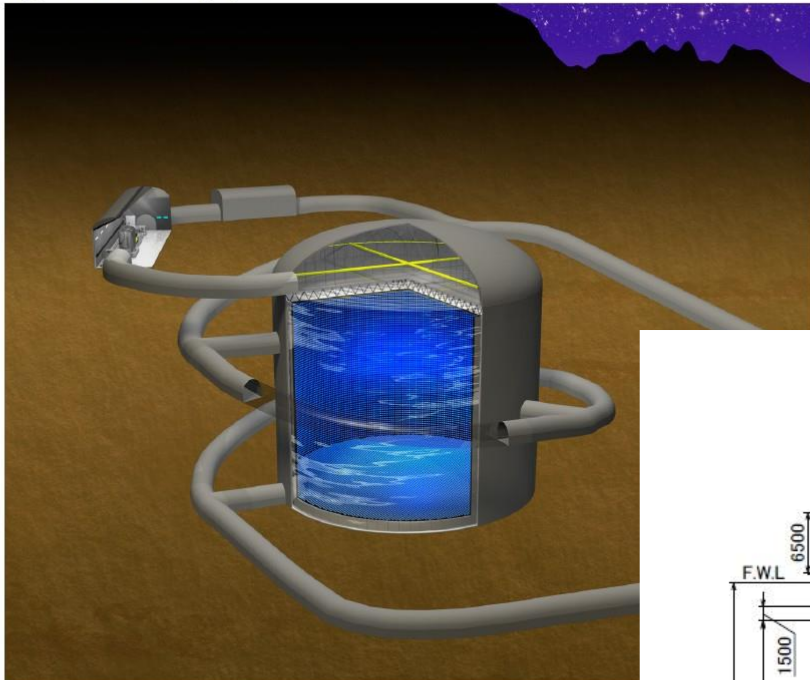
- UTokyo is making all efforts to get funded with strong leadership of the president Gonokami.
  - Hyper-K is requested to MEXT as a top priority project
  - UTokyo launched “Next Next-Generation Neutrino Science Organization”

- External Advisory Committee urges the proto-collaboration to make a **design** and **organization** for construction start



Kamioka town

Hyper-Kamiokande project



Hyper-K Detector

	Super-K	Hyper-K (1st tank)
Site	Mozumi	Tochibora
Number of ID PMTs	**11,129**	**40,000**
Photo-coverage	40%	40% (**×2 sensitivity**)
Mass / Fiducial Mass	50 kton / **22.5 kton**	260 kton / **187 kton**

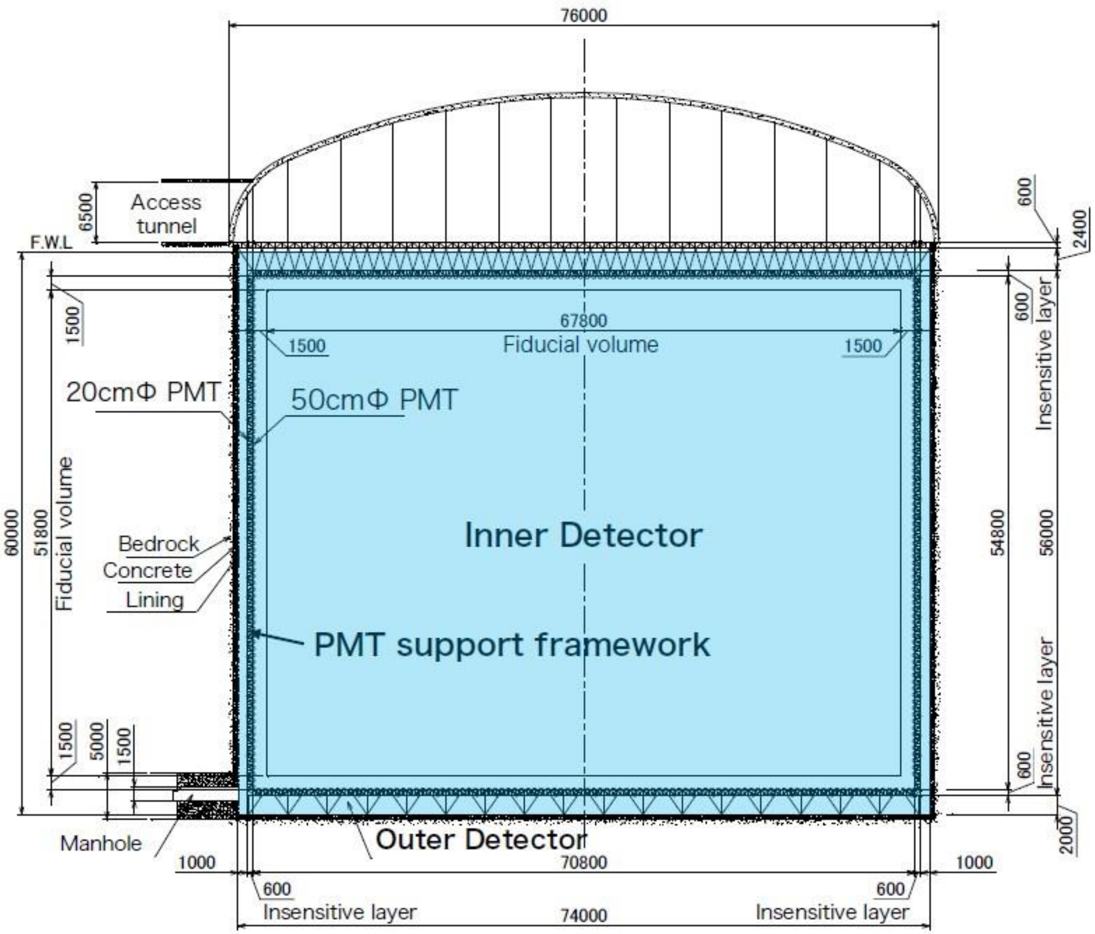
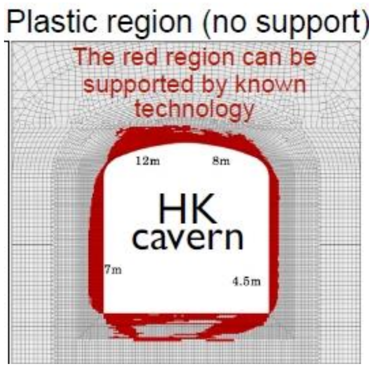


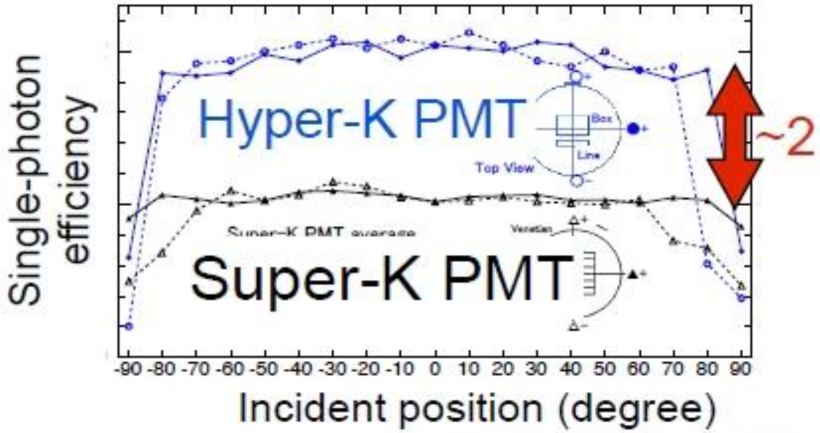
Figure 1: Schematic view of the Hyper-Kamiokande detector

Sensitivity goals were maintained for HK oscillations physics



HK photosensors R&D

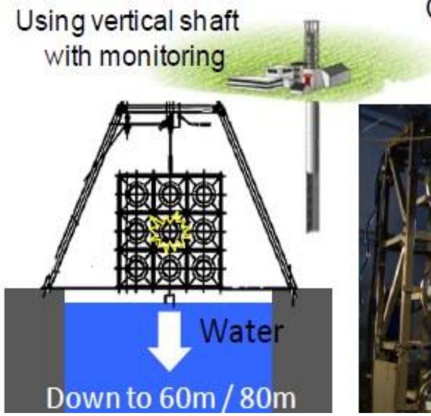
- sensitivity: 2 x SK
- Time resolution: 1/2 x SK
- Pressure: 2 x SK



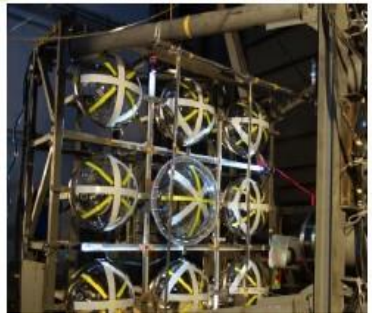
- ~140 new PMTs will be installed in Super-K this summer
  - Performance check w/ Cherenkov light, for years
- Continuous effort for improvements
  - Noise reduction, Cover design, Light concentrator under study

Validation test of cover at Kamisunagawa in 60 m / 80 m water

Using vertical shaft with monitoring



Confirmed with artificial implosion at central PMT



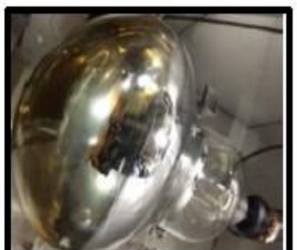
Prototype of cover to stop chain implosion

15 mm acrylic

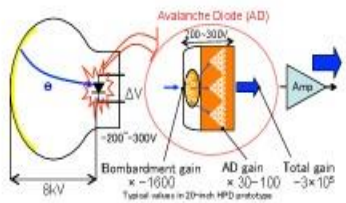
Stainless steel (3 mm)

- No damage for all tests
  - 3 times w/cover (2 with surrounding PMTs)
  - OK for 60 m (HK), and for 80 m also

Hybrid Photo Detectors (HPDs)

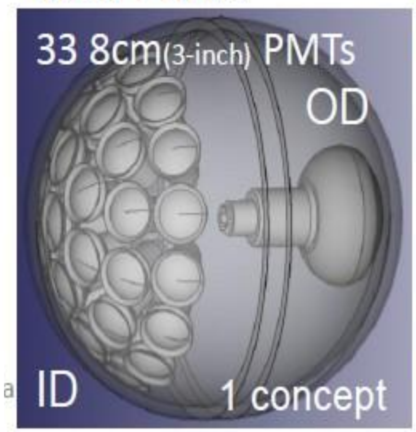


50cm HQE HPD w/ 20mm ϕ AD



Under viability study

Multi-PMTs



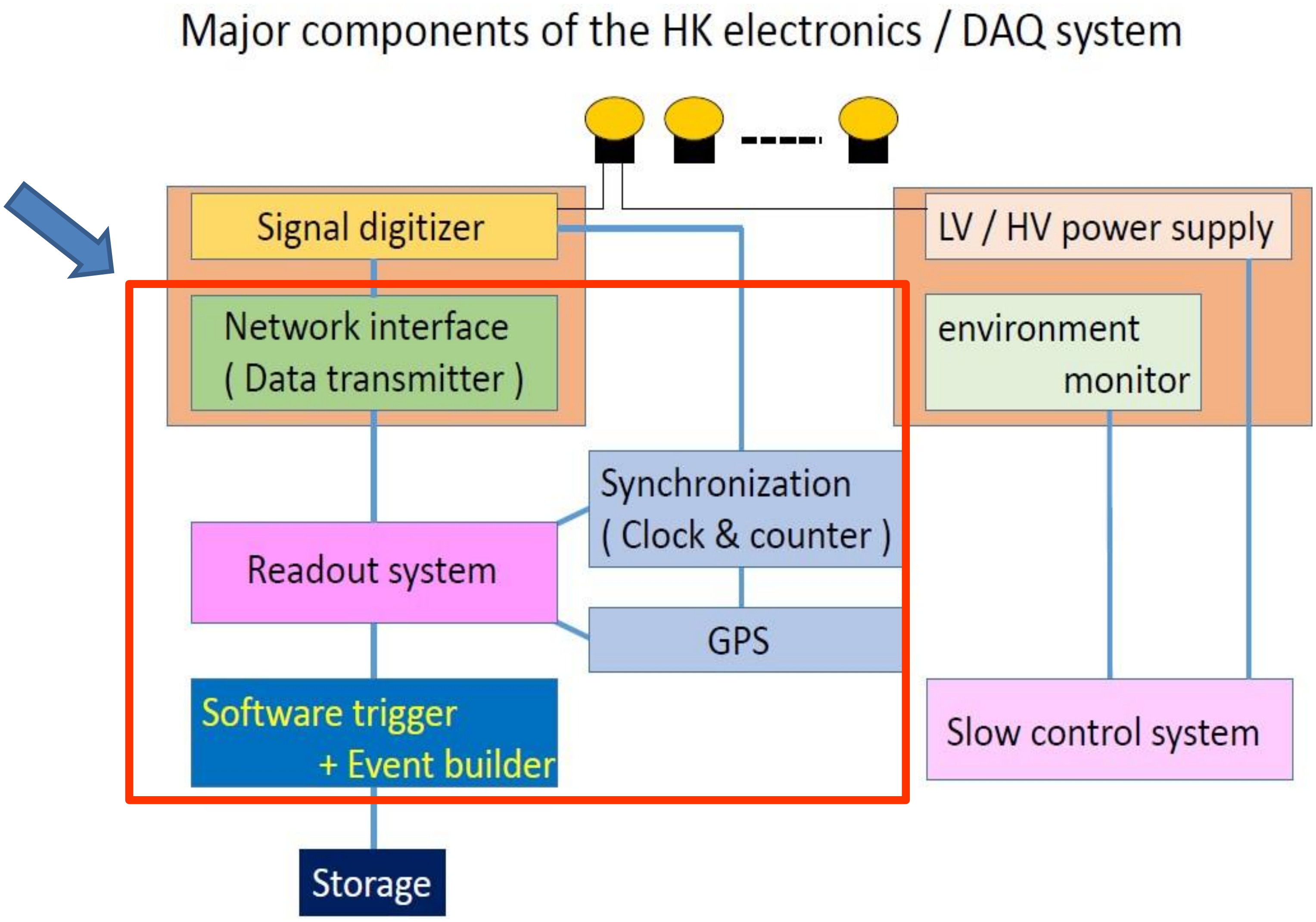
Working concept from KM3NeT but:

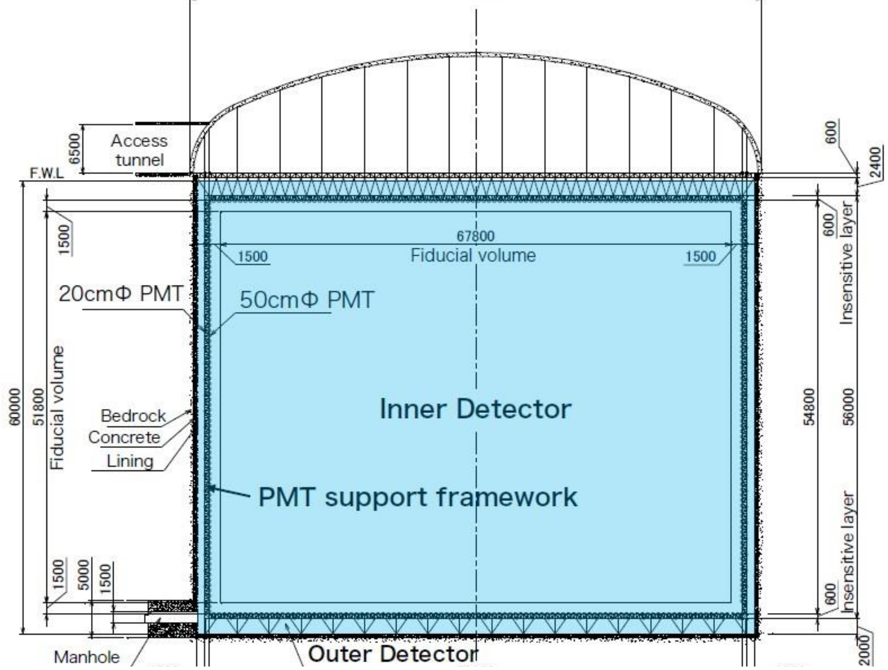
- peripheral ID/OD
- lower pressure tolerance required.
- ultrapure water.

International contribut.

- Worldwide studies for new photo sensors detectors (JUNO, IceCube, KM3NET, …)
- Foreseen collaborative efforts of HK with other experiments

Possible contribution du LLR (+ LPNHE)



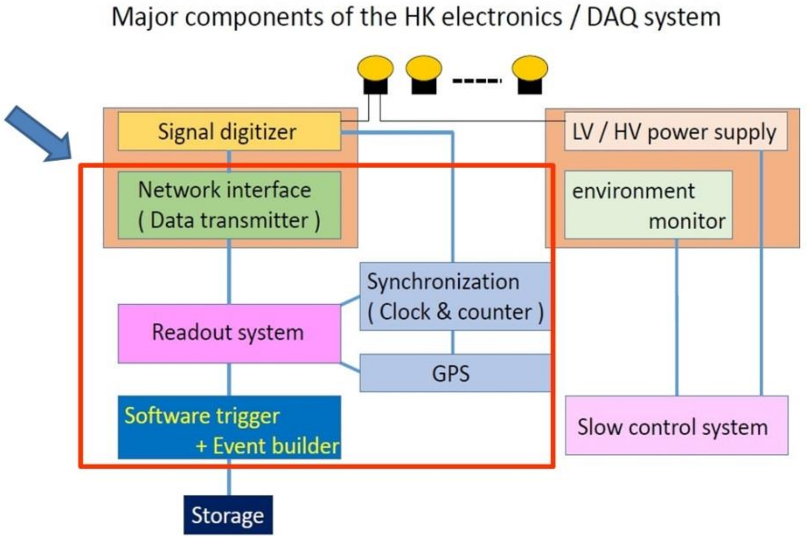


If we locate the front-end electronics modules on the top of the detector, it is necessary to run the cable from the PMT to the roof and the detector structure has to support the weight of the cables, **which is expected to be 800 tons.**

Thus, it would be possible to simplify the detector structure if we can reduce the weight of the cables. Also, the maximum length of the cable is ~ 30% longer than in the SK case. This not only reduces the signal amplitude, but also degrades the quality of the signal – the leading edge is smoothed out due to higher attenuation of the cable in the high frequency region.

Therefore, we plan to place the modules with **the front-end electronics** and power supplies for the photo-sensors **in the water**, close to the photo-sensors.

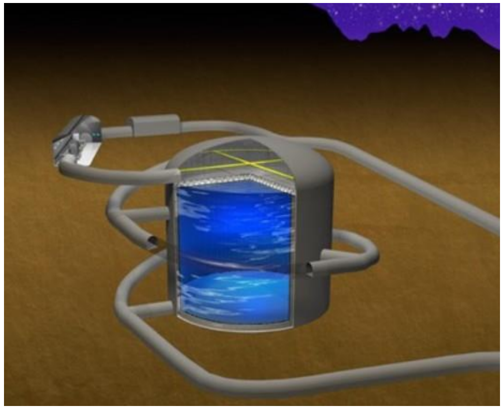
Possible contribution du LLR (+ LPNHE)



Synchronization of the timing of each TDC or FADC is crucial for precise measurement of the timing of photon arrival. In Hyper-Kamiokande, timing resolution of the photo-sensor is expected to be largely improved. Therefore, we have to be careful with the synchronization of the modules . The design should minimize the clock jitter, so that the timing resolution of the whole system is as good as possible. We are planning to distribute the common system clock and the reference counter to all the modules.

Regarding the **communication** block, on order to reduce the amount of cables, we are planning to connect the modules in a mesh topology, with each module connected to its neighbors. Only the top modules would be connected to the readout computers. Each module will have several communication ports, so that a single point of failure would be avoided. In case of failure of one of the modules, the data would simply be re-routed to one of the neighbors, thus ensuring that communication path will be secured. It is expected to have the following functionalities:

- receive the commands from the DAQ system and control the digitizer,
- return the status of the request from the DAQ system,
- receive the data from digitizer, keep them in the local DRAM buffer, and transmit to the DAQ system,
- receive the commands from the slow control/monitor system and control or monitor the slow control
- return the status of the request from the slow control/monitor system.



Spring 2020	*Final design review of the system*
Autumn 2020	*Start the design of the system based on the design review*
Autumn 2021	*Start bidding procedure*
Autumn 2022	*Start mass production*
Autumn 2023	*Start final system test*
Autumn 2024	*Complete mass production*
Autumn 2025	*Complete system test and get ready for install*

Project	Cost
T2K-II TPCs	200 k€
T2K-II Super–FGD	600 k€
NA61++	15 k€(per year)
Hyper–K R&D	40 k€

Table 3: Estimated resources needed for the projects described in this document.

The request for NA61++ would allow the LPNHE group to continue its participation in the NA61 physics program, with the goal of reducing uncertainties on the neutrino fluxes for T2K-II and future LBL experiments (DUNE and Hyper-Kamiokande).

Concerning the ND280 upgrade, the estimated cost of the project to develop and construct the new Front-End-Cards for the horizontal TPCs within the ND280 upgrade project is about 200 k€. This include also the mechanics and cooling system of the Front-End electronics.

If the LLR option for the Super–FGD electronics is choosen by the collaboration, the total cost of the project is estimated to 600 k€.

Finally for the proposed R&D project for Hyper-Kamiokande the LLR and LPNHE groups will need ~40 k€ to start buying components and producing cards for prototype activities. An evaluation of the full costs of the project for the Hyper-Kamiokande experiment is not done within this proposal.

If the LLR option for the Super–FGD electronics is choosen by the collaboration, a full time electronics research engineer position will be necessary during three years to adapt the CALICE electronics to the new detector configuration. This person will then develop the electronics for the Hyper-Kamiokande experiment that has been detailed in the previous section. Thus, a permanent position would be preferable. In addition, if it appears that a contribution from LLR is needed for the mechanical structure of the Super–FGD detector, a two years mechanics research engineer position would be required.

Le groupe νeutrinos du LLR **Prochaine décennie**

- Un potentiel <u>unique</u> de découvertes « top niveau »
- Nous sommes le seul groupe français de la collaboration Super-K. Forte implication du groupe dans l'upgrade en cours.
- Proposition de participation technique aux upgrades T2K II
- Hyper-K en voie d'obtenir ses premiers financements pour un début de construction. Projet de participation à l'électronique large PMT

<u>Notre demande au CS du LLR (& CS IN2P3)</u>

1) **Reconnaissance et soutien pour notre programme scientifique**
2) **Soutien financier et technique (ingénieur) pour l'upgrade SFGD**
3) **Encouragement pour nous impliquer rapidement dans l'électronique R&D Large PMT de H-K**