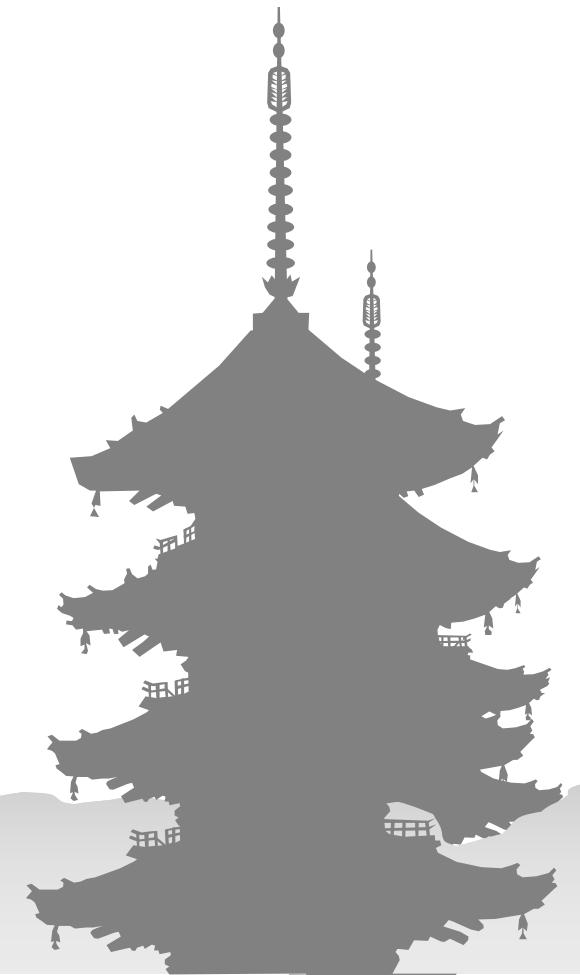


# De la symétrie matière - antimatière aux explosions de supernovas



# Le groupe “Neutrinos” du LLR

- ✿ 6 seniors

Margherita Buizza Avanzini (CR), Olivier Drapier (DR), Michel Gonin (DRCE), Thomas Mueller (CR),  
Pascal Paganini (DR) & Benjamin Quilain (CR)

- ✿ 2 Postdocs

- Sonia El Hedri

Astronomie neutrino, entre théorie et expérience

- Laura Bernard

Astronomie neutrino

- ✿ 3 Doctorants

- Alice Coffani

Super-K. Directeur de thèse: M. Gonin

Soutenance prévue en 2021

- Alberto Giampaolo

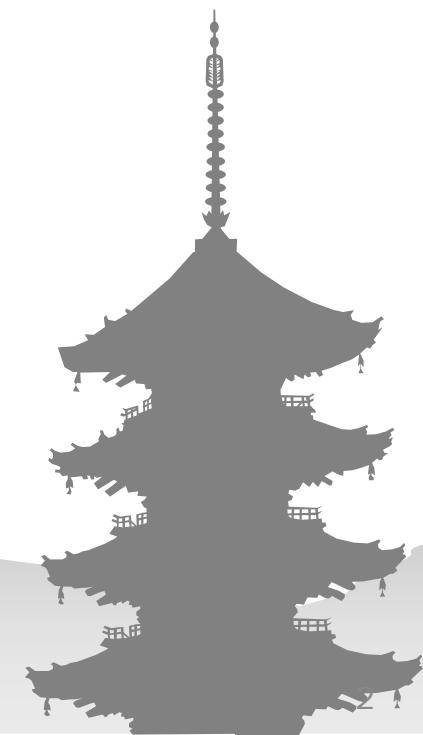
Super-K. Directeur de thèse: P. Paganini

Soutenance prévue en 2022

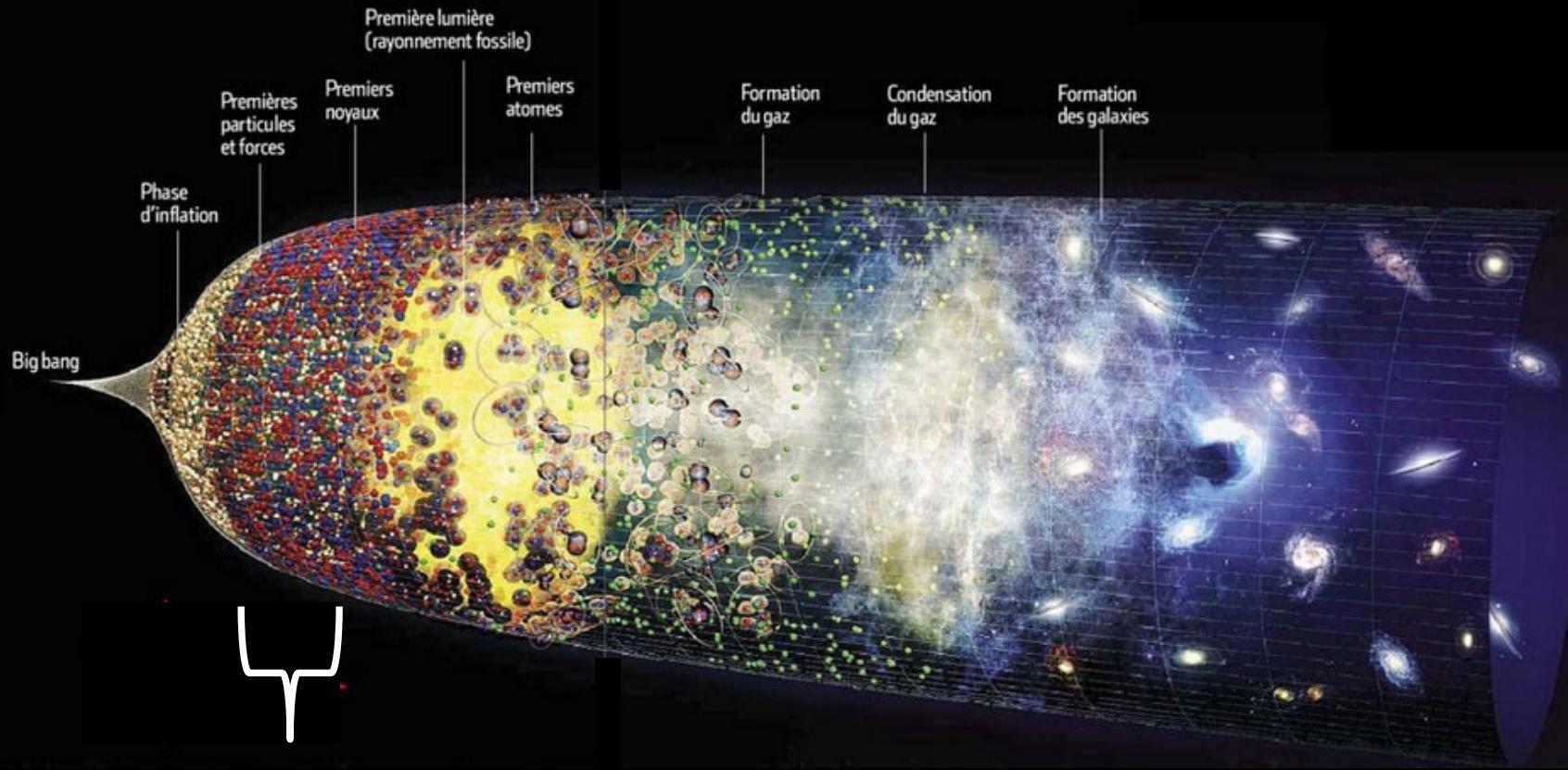
- Jaafar Chakrani

T2K. Directeur de thèse: M. Buizza Avanzini

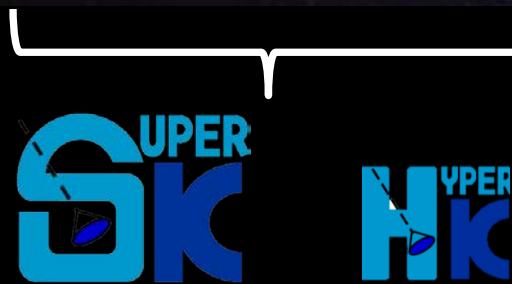
Soutenance prévue en 2023



# Nos activités de recherche

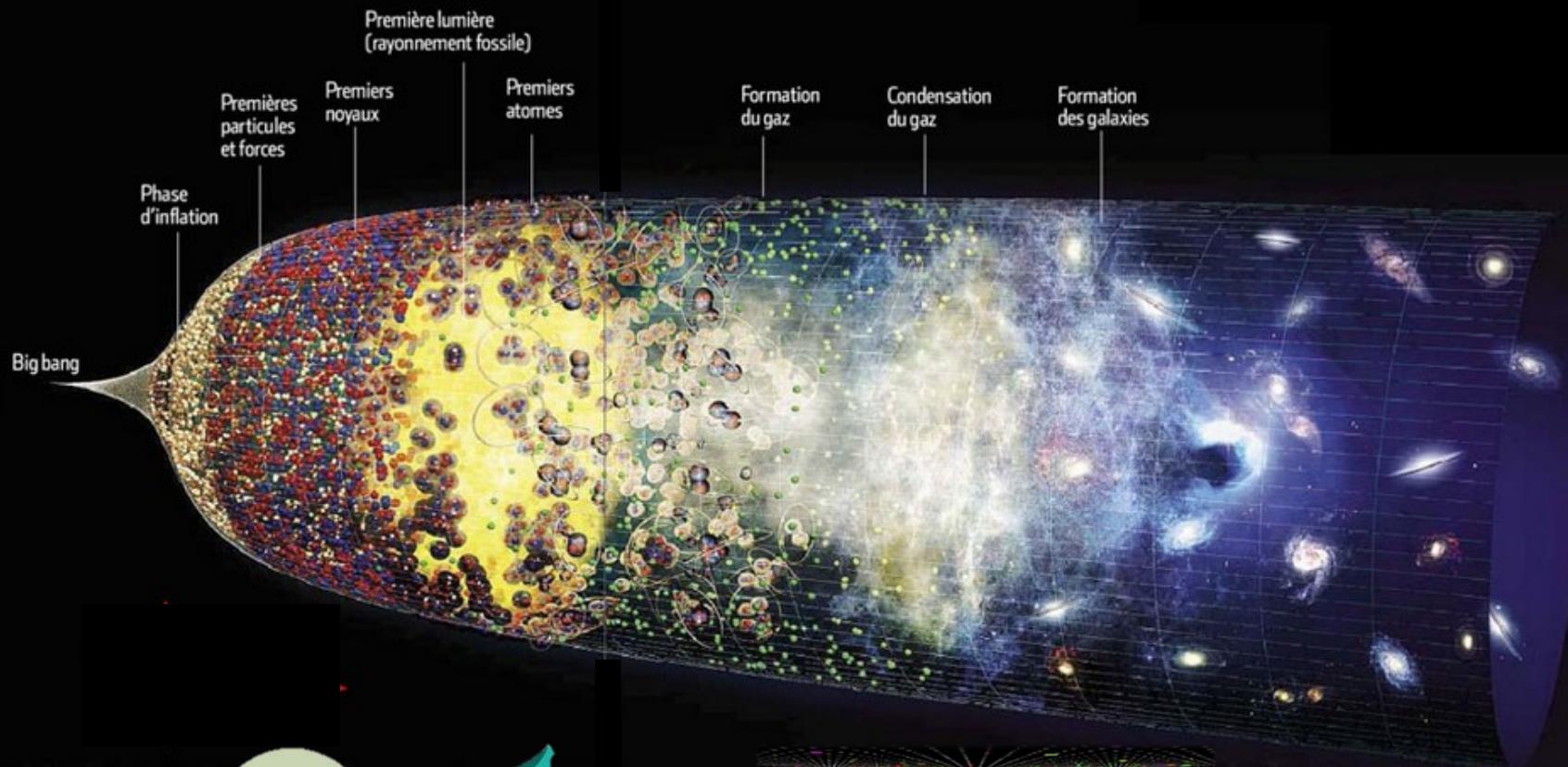


Asymétrie matière - antimatière

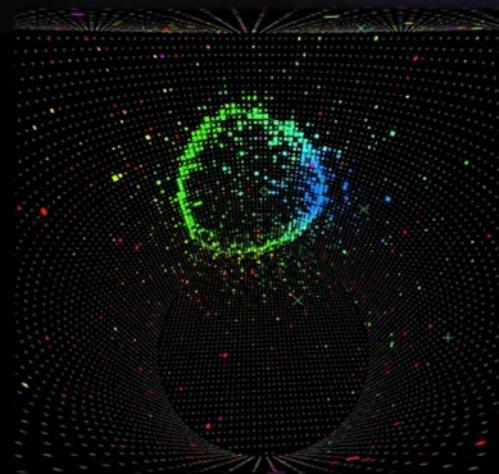


Explosions de Supernovas, formation de trous noirs & fusion d'étoiles à neutrons

# Nos activités de recherche



NEUTRINOS

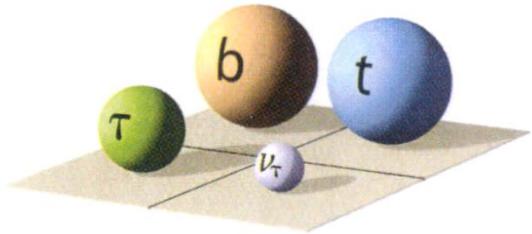


# NEUTRINOS

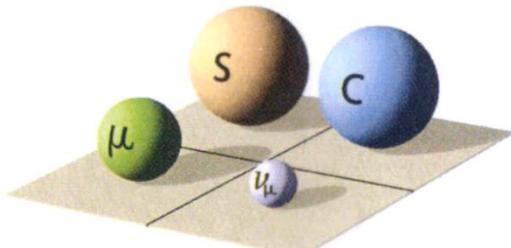


Some particular elementary particle

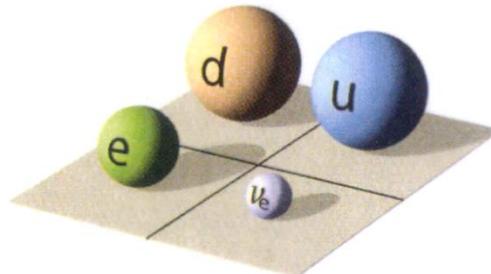
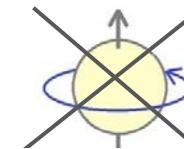
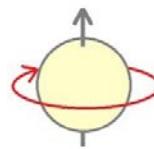
$\nu_e$   $\nu_\mu$   $\nu_\tau$



# Zero electric charge



# One state of helicity “left-handed”



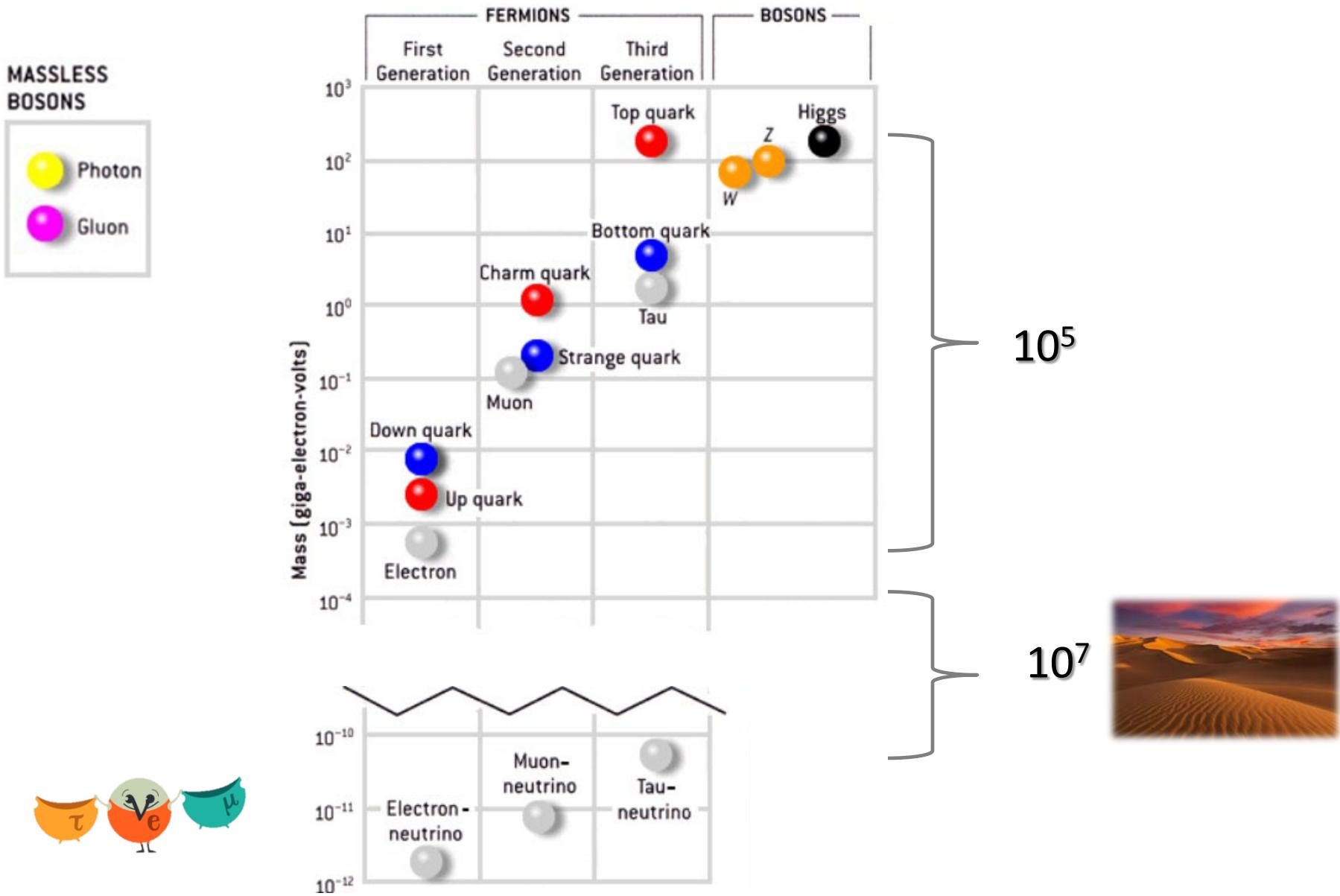
# Very small masses compared to masses of other fermions

fermions

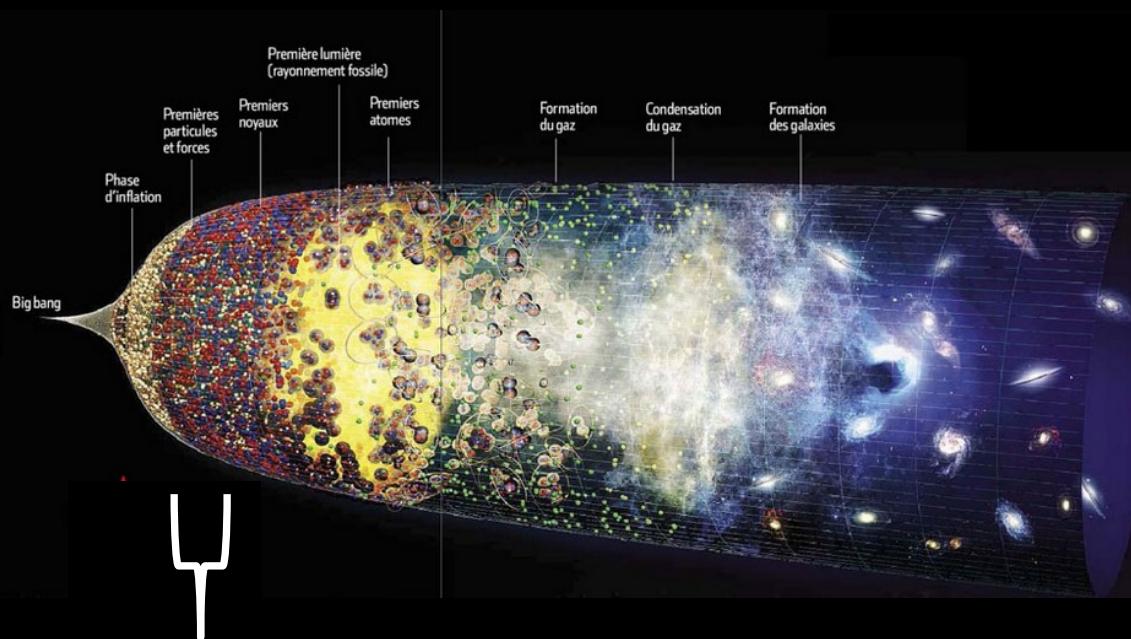
# Do not interact with matter and are very abundant on Earth and in our Universe

# Mass states  $\neq$  flavor states

# Mass Hierarchy of Elementary Particles



# Disappearance of antimatter at the very beginning of our Universe



## Possible explanation

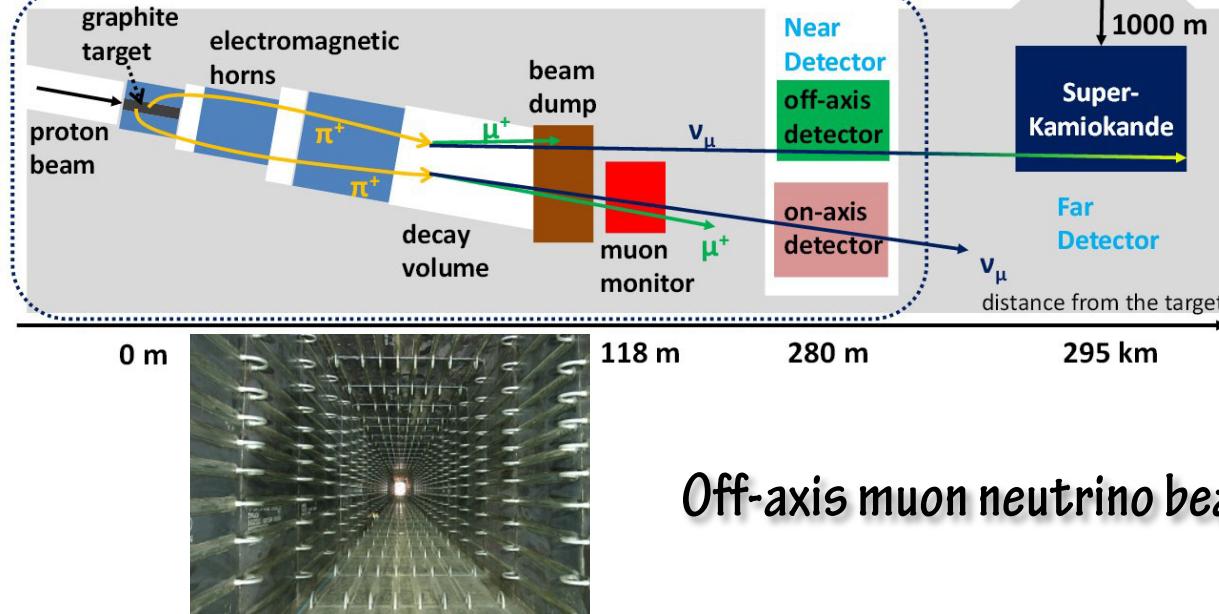
strong violation of matter-antimatter symmetry (CP) in the lepton sector



Not the case for quarks

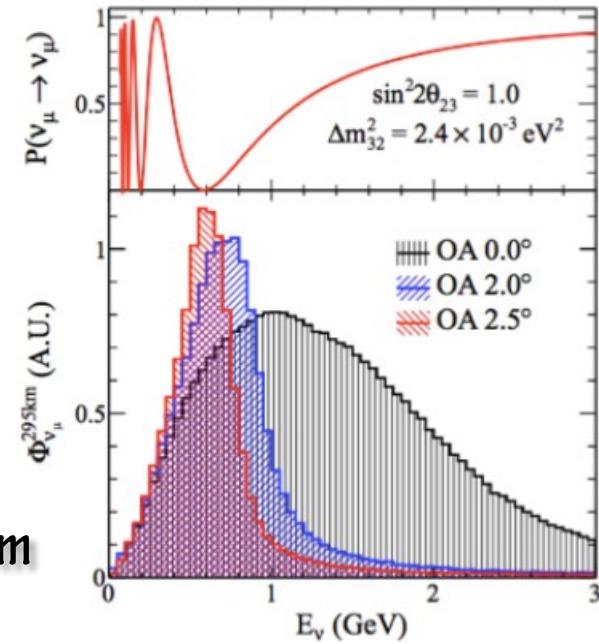


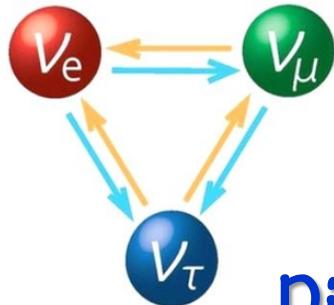
J-PARC Neutrino Facility



T2K

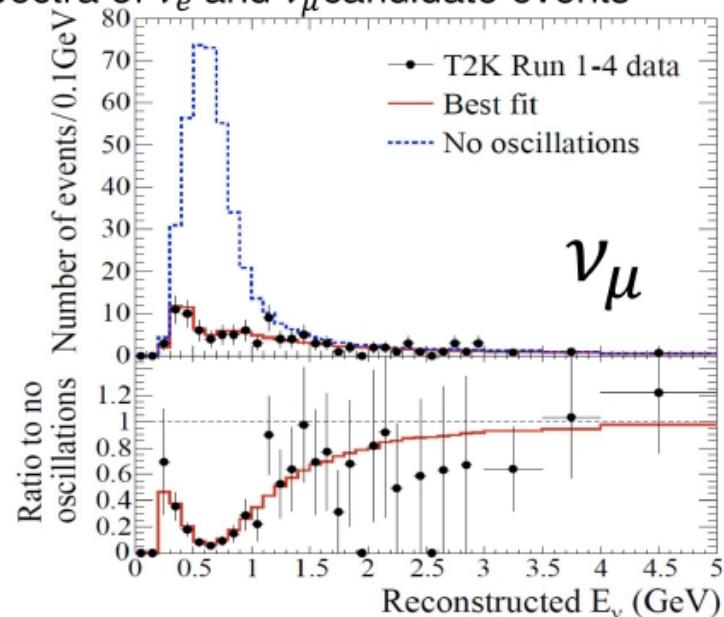
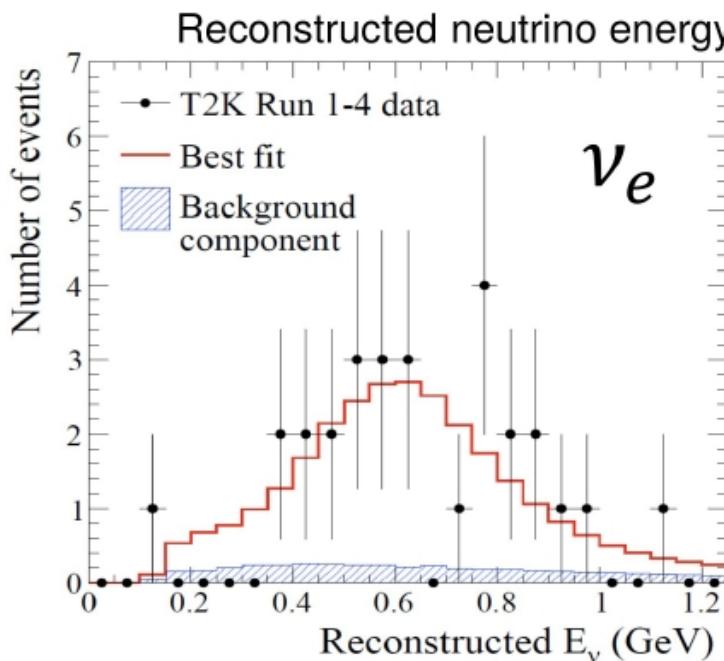
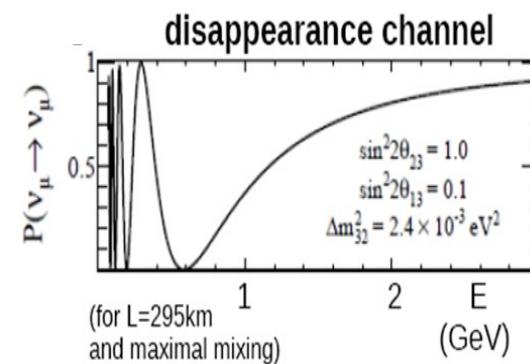
## Appearance of electron neutrinos Quantum flavor oscillations





## Discovery in 2013 of off flavor appearance

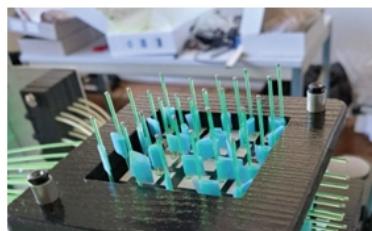
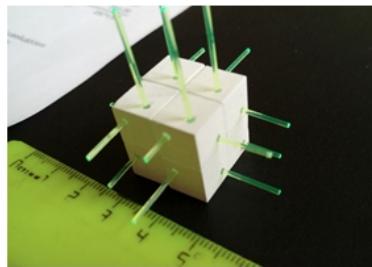
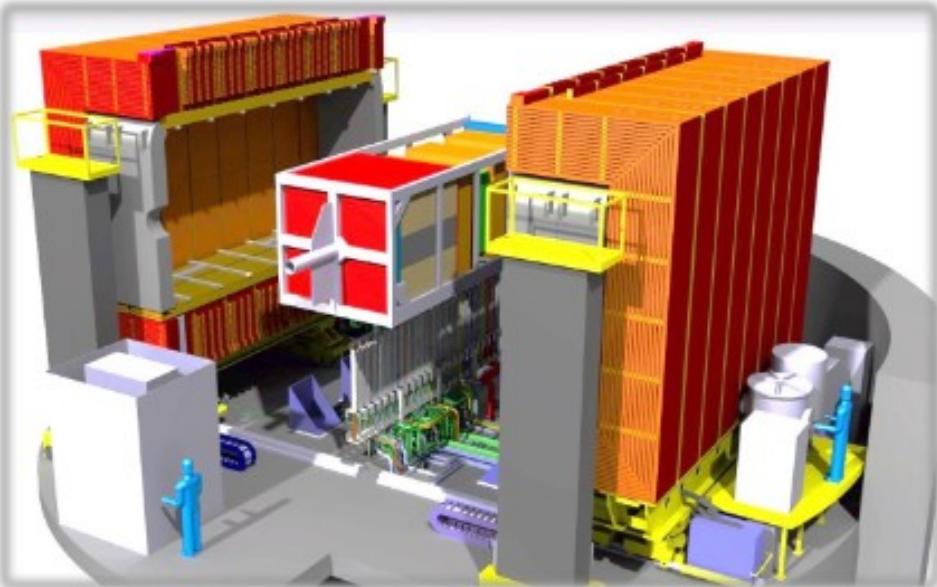
$$\nu_\mu \longrightarrow \nu_e$$



# Perspectives pour les 10 prochaines années



## UPGRADES



FE electronics of SFGD



Arrived at CERN 4<sup>th</sup> June

2019 - 2026

# Contributions techniques du LLR T2K

## WAGASCI (first T2K upgrade)

Goal: measurement of cross sections on carbon and water to reduce systematic errors for T2K and futures “long baseline experiments”

- Mechanical design
- Monte-Carlo physics studies
- Installation and commissioning in Japan
- Design et testing of the FE + DAQ electronics

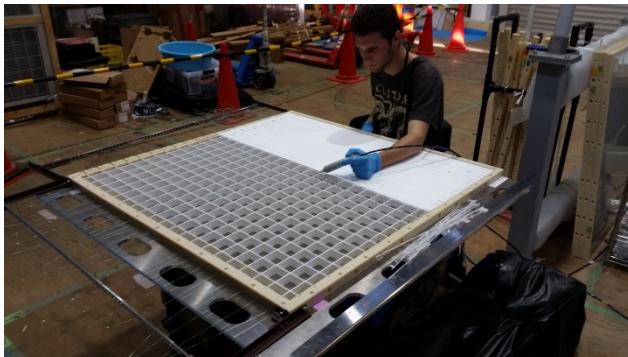
WAGASCI



electronics



Grid scintillators



bundles





Une « petite » expérience de physique des hautes énergies, environ 130 participants

# Neutrino Astronomy

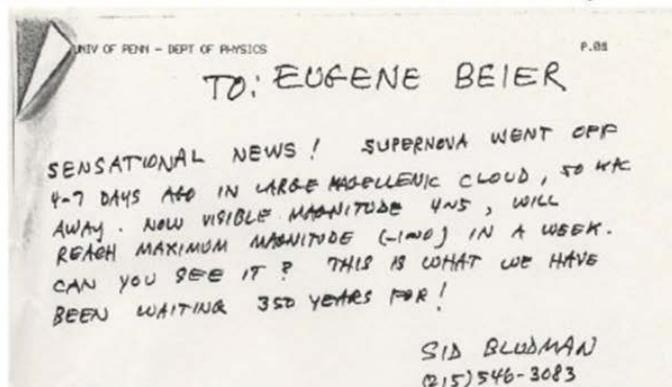
Explosion of the supernova SN 1987A

Nobel Prize 2002 (Kamiokande) for the detection of 11 neutrinos

99% of the energy  
emitted in form  
of neutrinos!

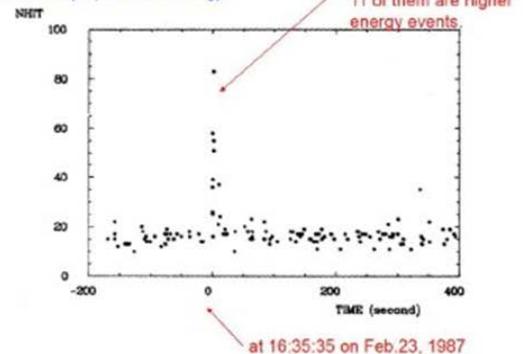


Feb. 25<sup>th</sup>, 1987: A fax was sent to Univ. of Tokyo

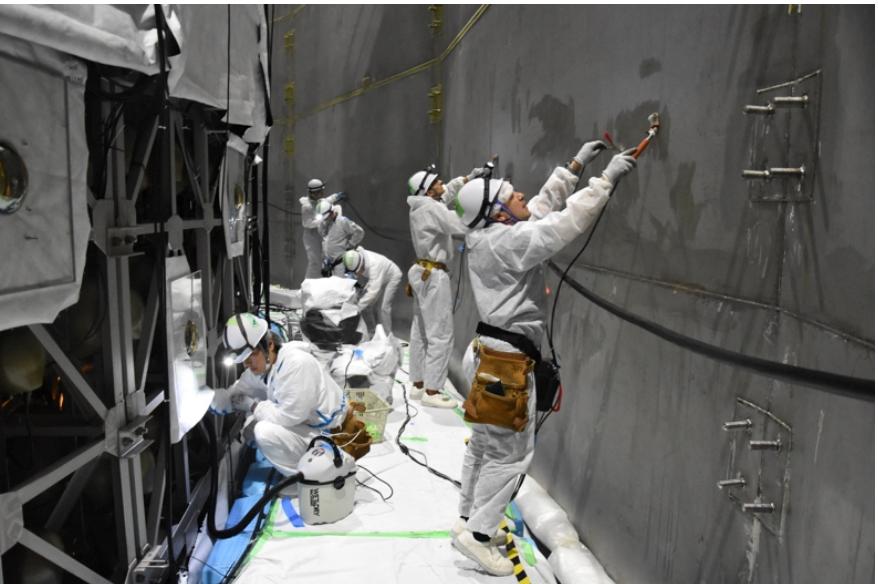
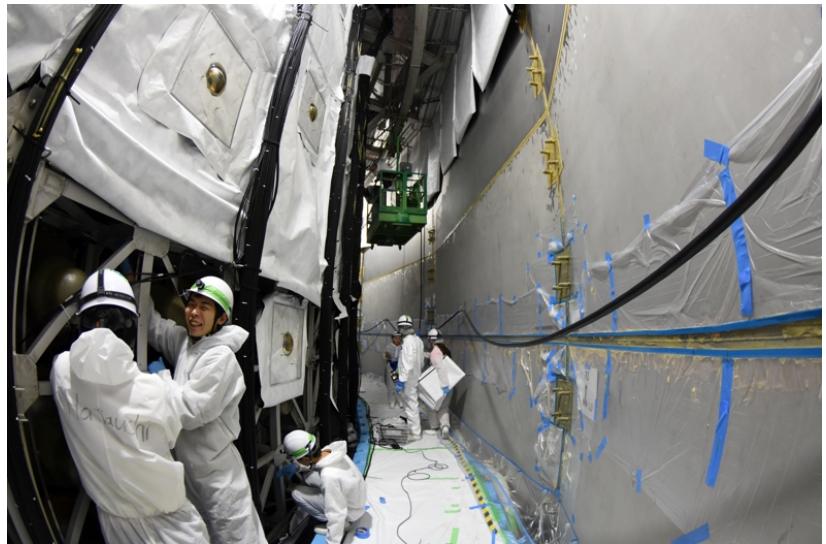


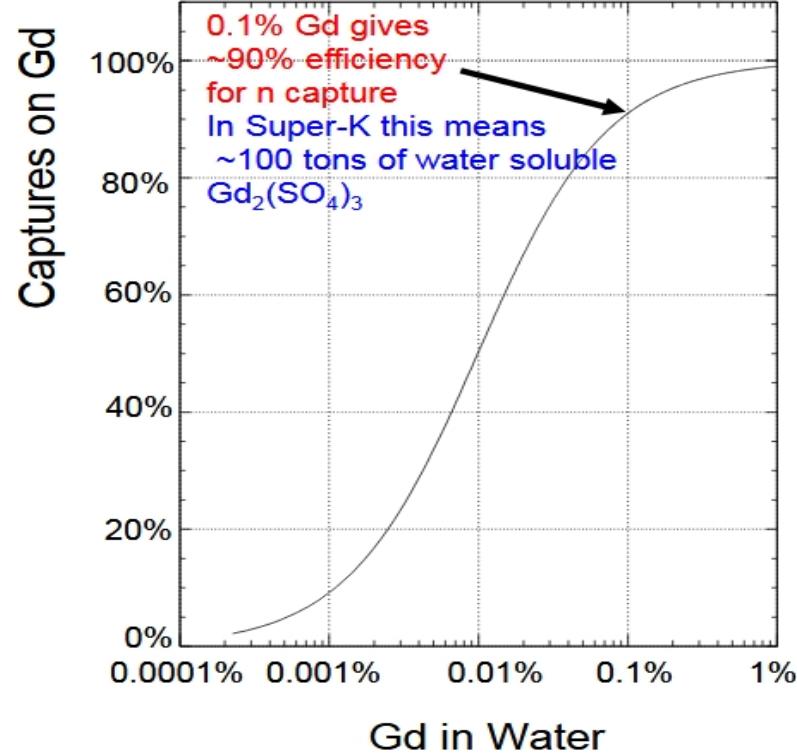
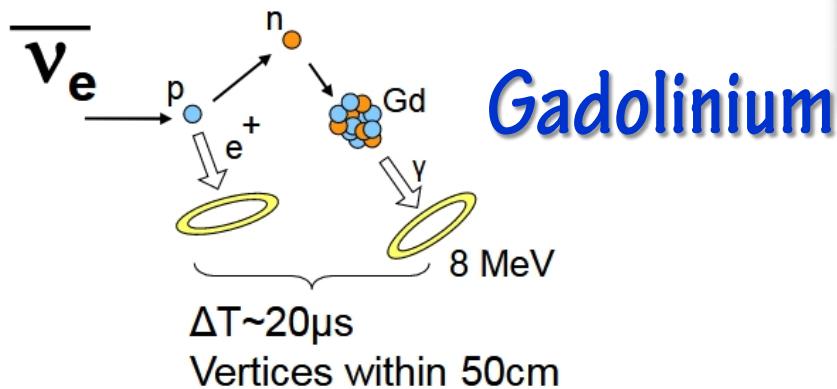
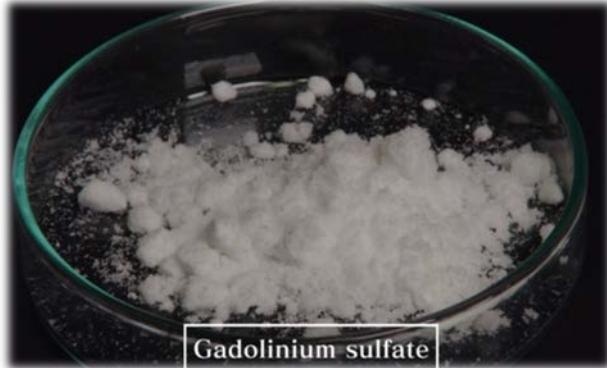
## NEUTRINO SIGNALS !

Number of hit PMTs for each event,  
which is almost proportional to energy



# Renovation et "upgrade" de la cuve Super-Kamiokande en 2018



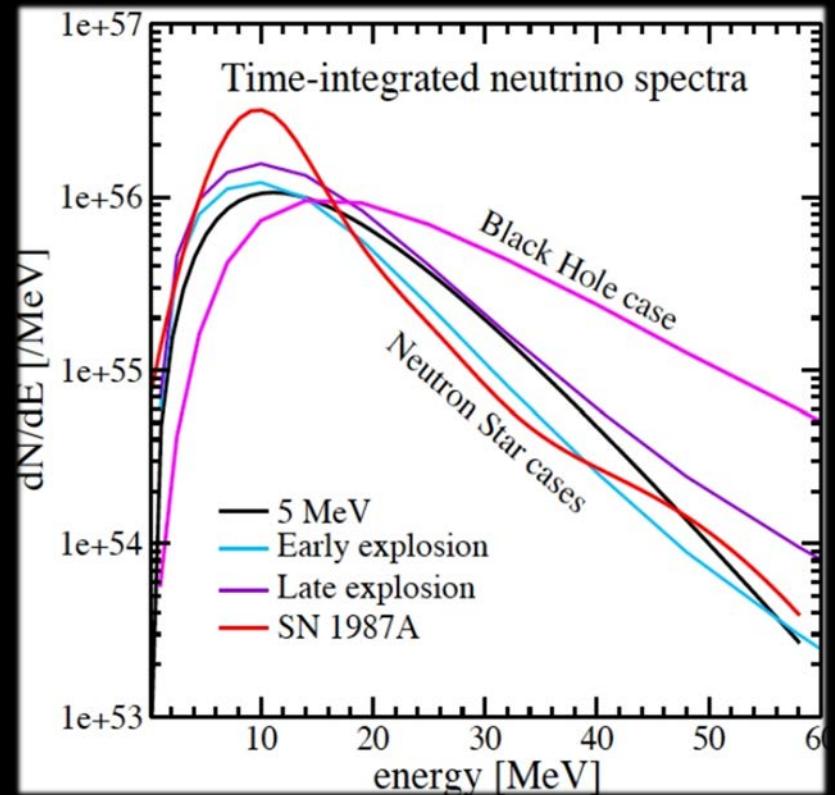


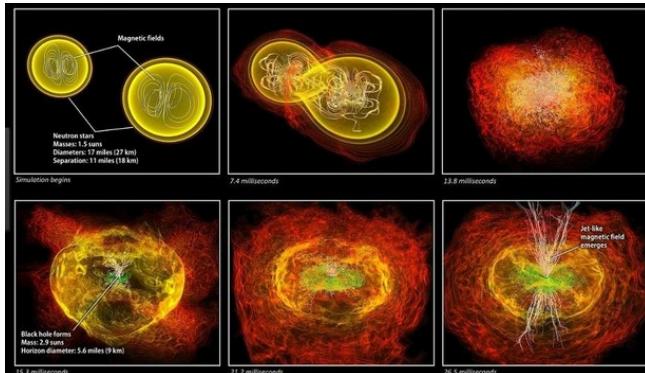
### Physics targets:

- (1) Supernova relic neutrino
- (2) Enhance directional signals for supernova burst
- (3) Reactor neutrinos
- (4) Proton decay background ID

# Neutrino Astronomy

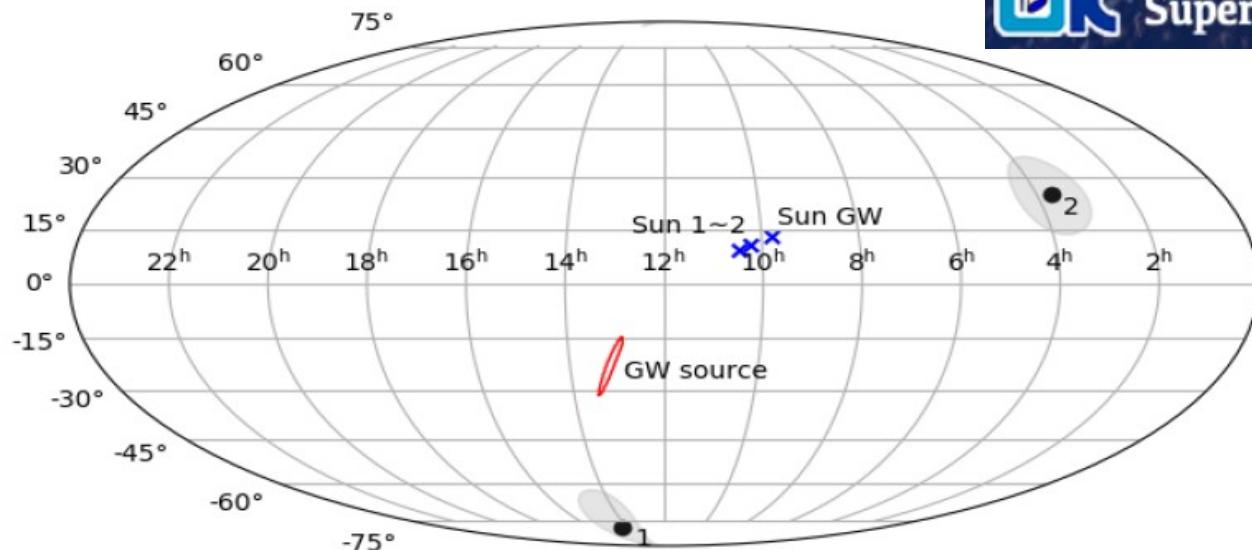
*Diffuse Supernovas Neutrinos  
Background emitted by the sum of all  
explosions of Supernovas*





## Une fusion de deux étoiles à neutrons Emission d'ondes gravitationnelles

2 events left in relic sample in 14days  
after GW170817



equatorial coordinate system

Points 1&2: R.A. and Dec of the 2 events

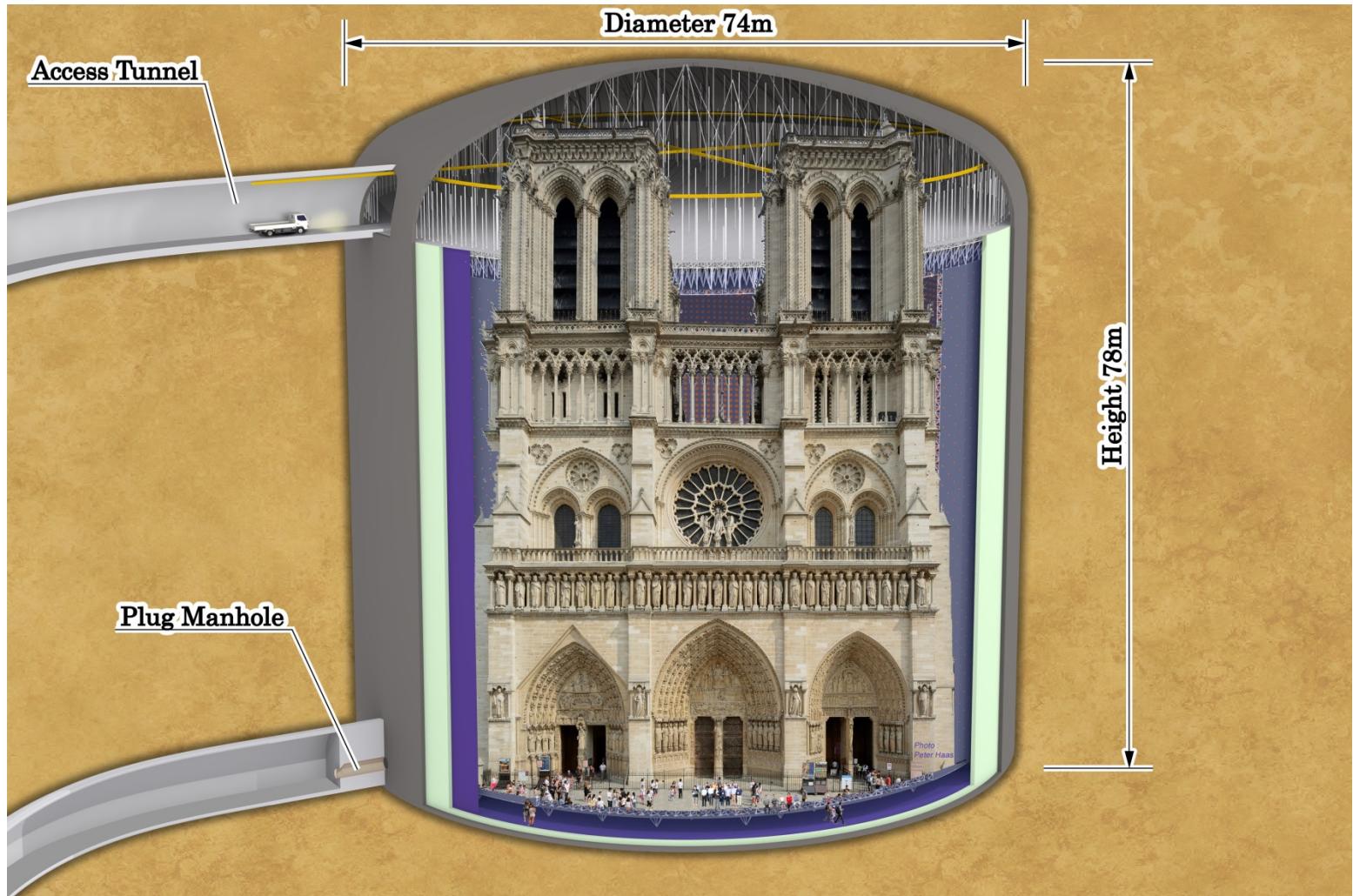
Shadow Area : angle solution

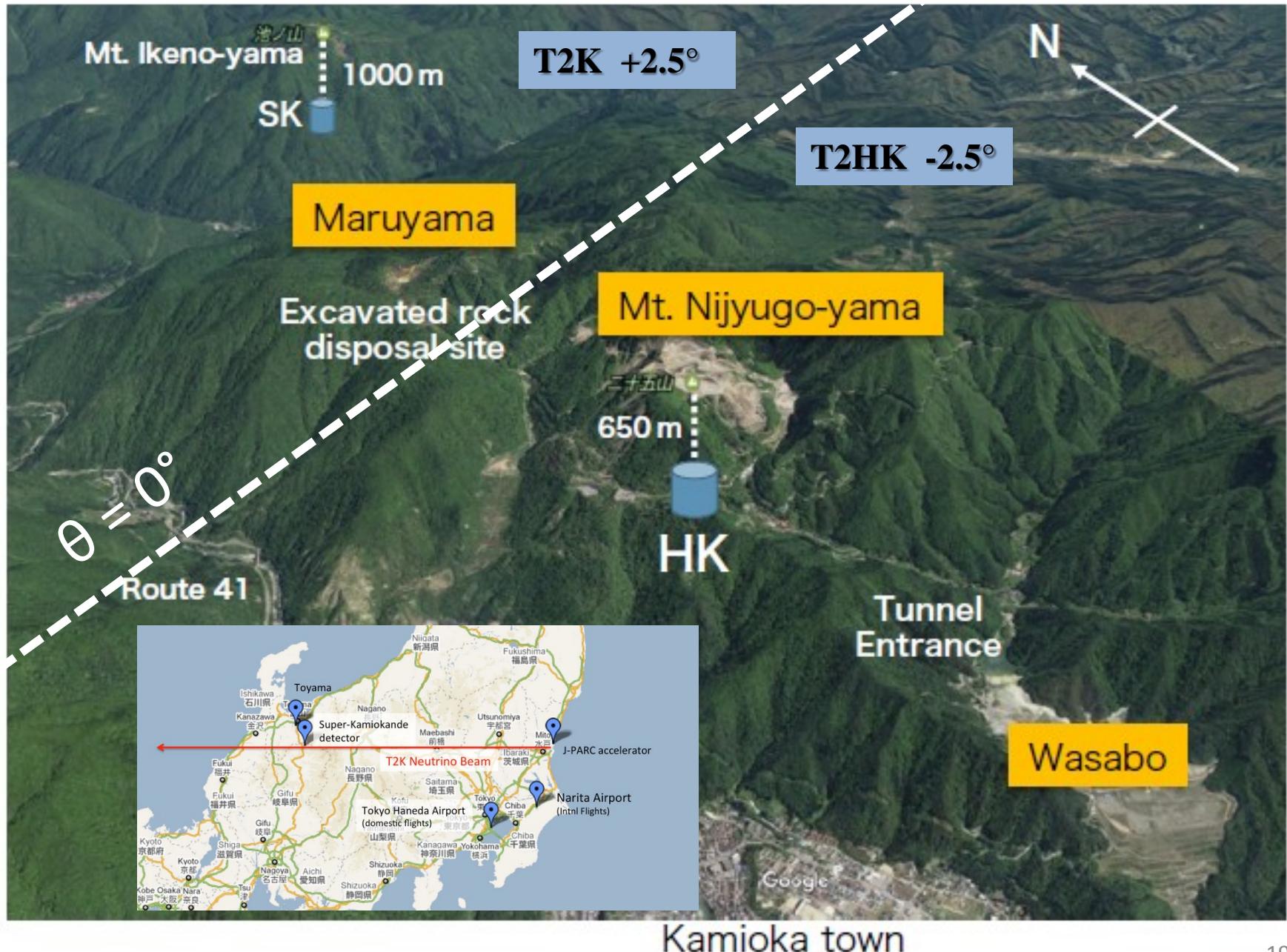
Both 2 events are far away from GW170817 source.

# Perspectives pour les 10 prochaines années



Construction 2020 – 2026





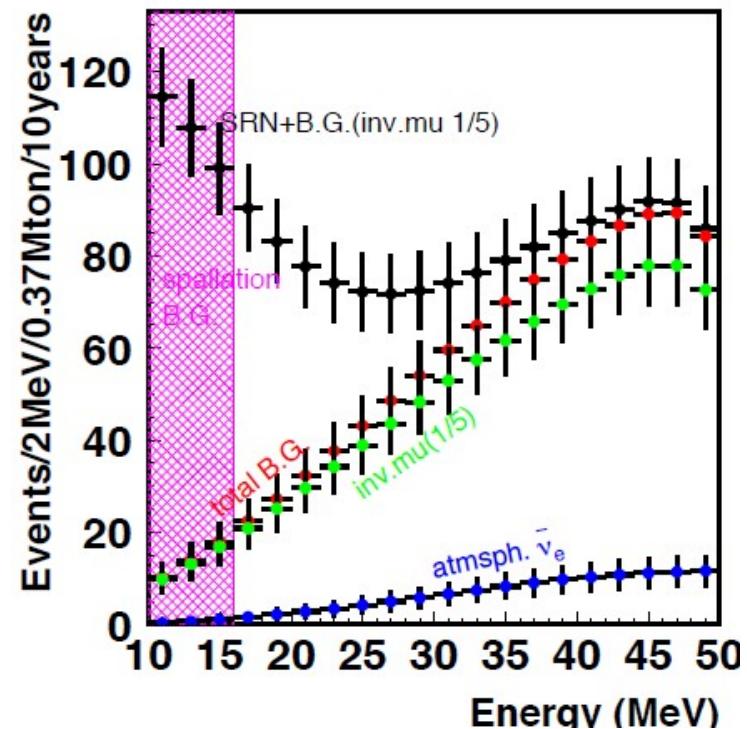
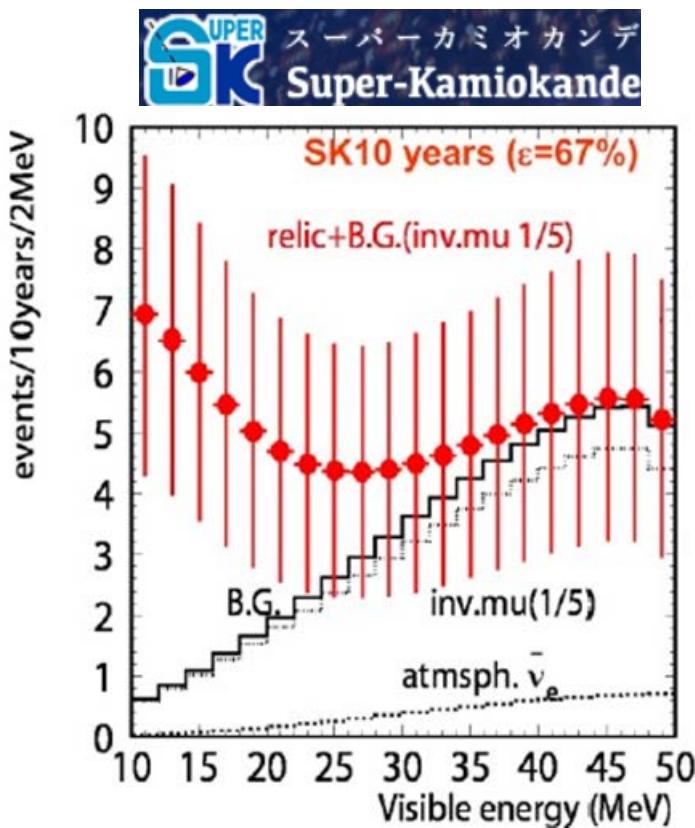
# Neutrino Astronomy

## 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



# Supernova burst neutrinos



Kamiokande



11 evts (1987)

Super-Kamiokande



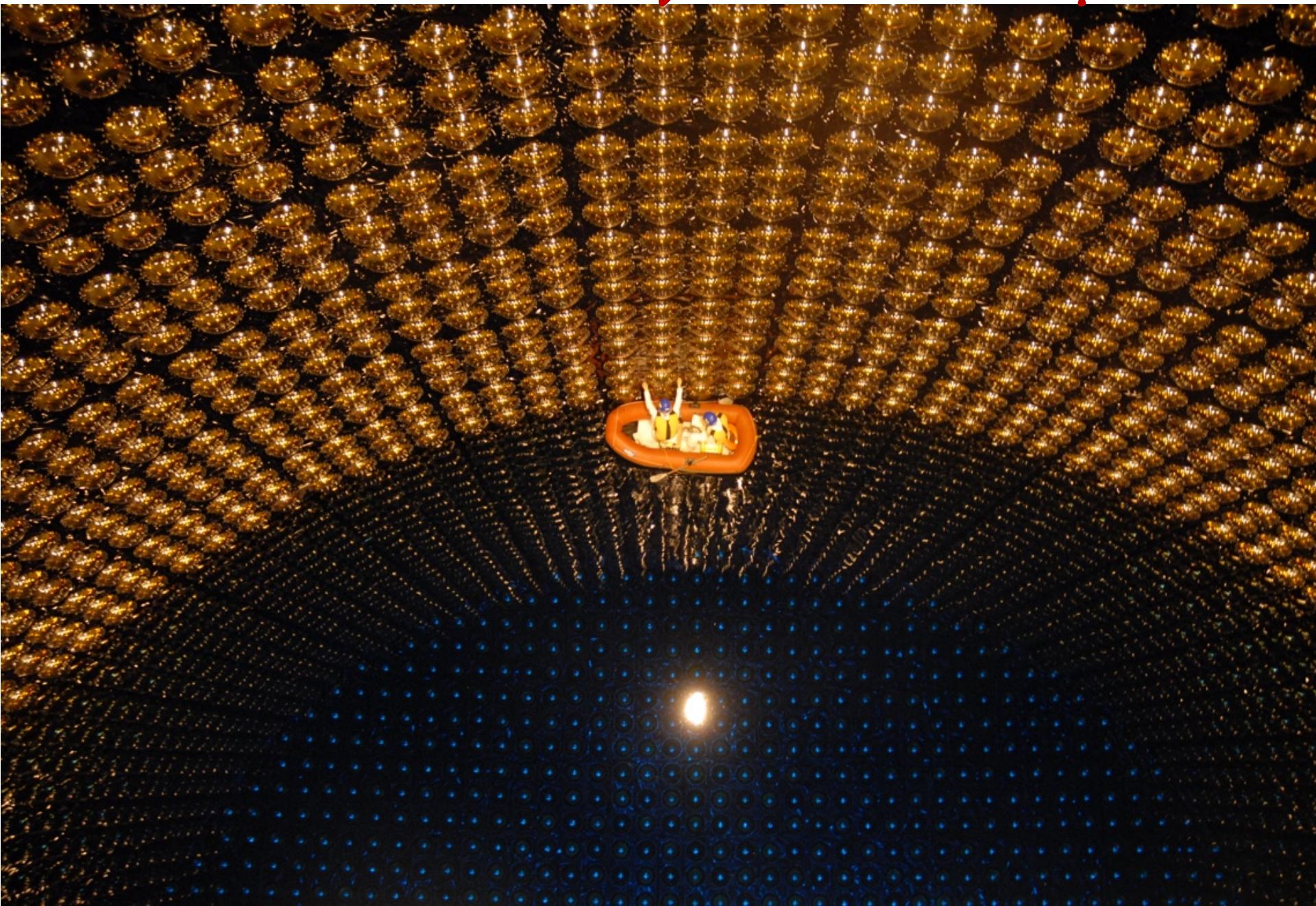
~ 250



~ 3000

~ 8000 events in Super-K for an explosion in the center of our galaxy  
An explosion expected every 40 years !

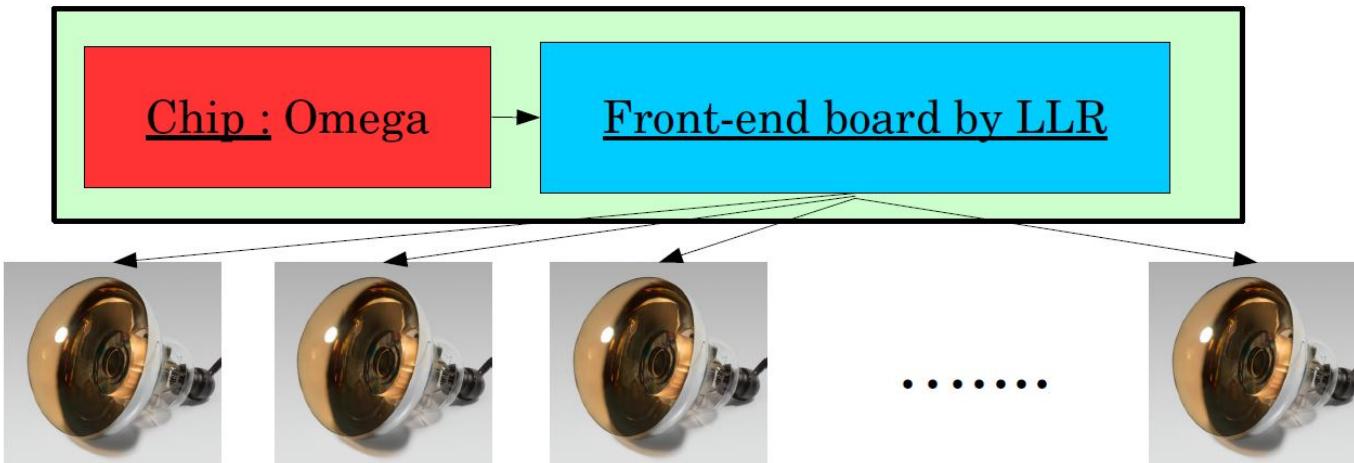
# Contributions techniques du LLR Hyper-K



# Contributions techniques du LLR Hyper-K

## Our proposal for Hyper-Kamiokande <sup>2</sup>

- Electronic expertise on Front-End development for  $\nu$ -detectors.
- Long-standing collaboration between  $\Omega$  and LLR engineers on various projects : WAGASCI, ND280-upgrade for T2K, CMS/HGCAL etc.
- Omega and LLR are physically on same site (Ecole polytechnique)  
→ Proposal : Develop the front-end electronics of the 20'' PMTs.



# De la symétrie matière - antimatière aux explosions de supernovas

Un programme de **physique** incroyable pour les dix prochaines années avec un potentiel extraordinaire de **découvertes** de premier plan,

Une opportunité de **visibilité** pour l'X à ne pas rater !

