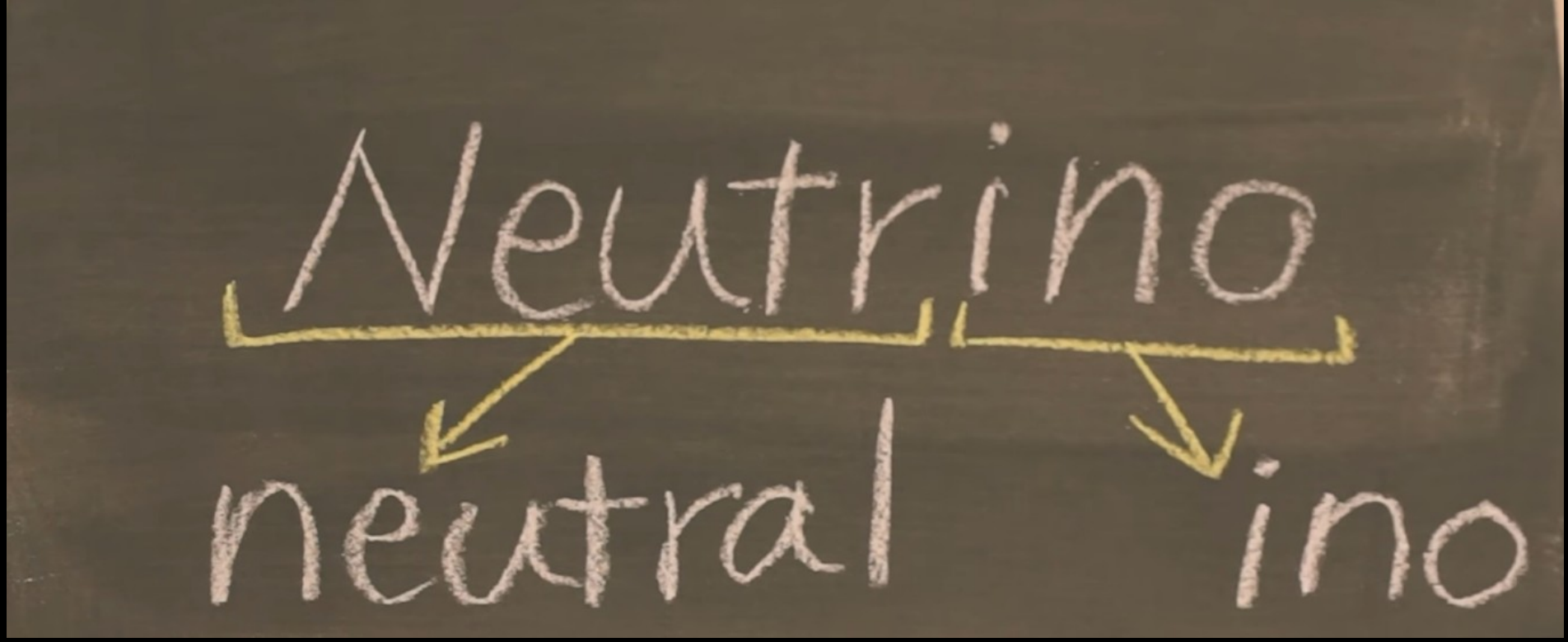
The study of **neutrinos** with accelerator based experiments : the saga of the **Tokai To Kamioka experiment (T2K)**

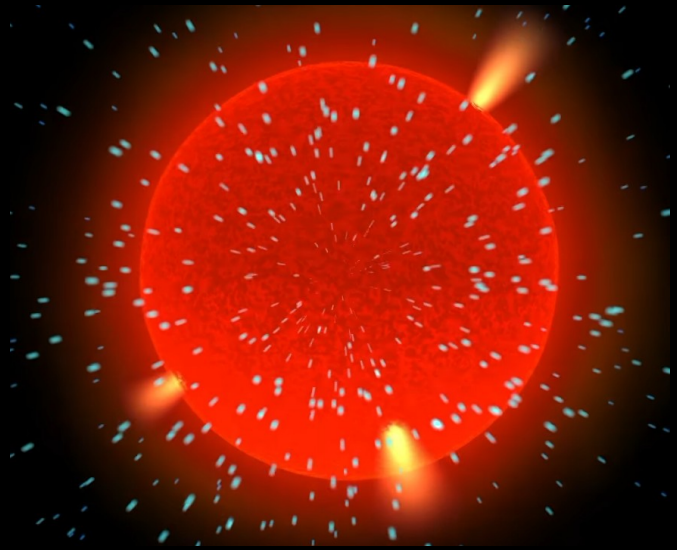


中性微子


Several hundreds trillions of ν pass
through our body each second !
→ very elusive particles!

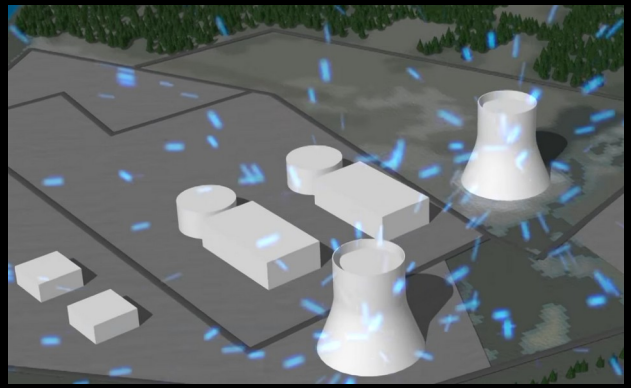
Main neutrino sources

From stars (including the Sun)



From interactions of cosmic rays in the atmosphere

From nuclear reactors

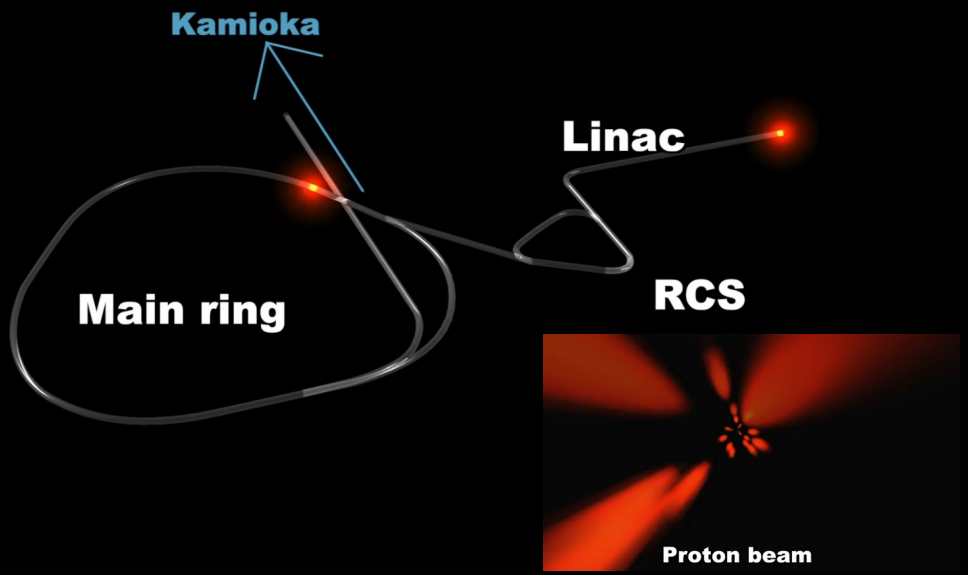


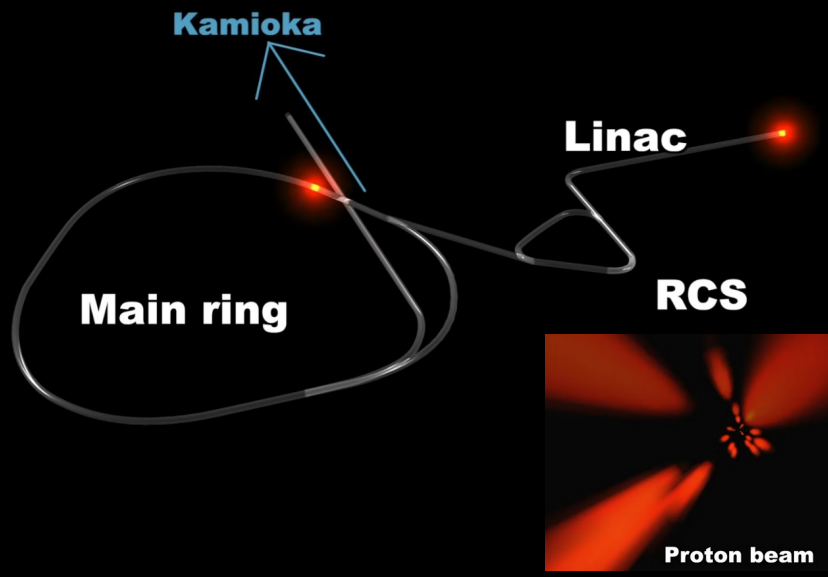
Accelerator neutrinos : to control and manipulate the source following our needs


Kamioka
Tokai
KEK
Kamioka
Super Kamiokande
297 km
Tokai
J-PARC
KEK


Kamioka
Super Kamiokande
Tokai
J-PARC
KEK
J-PARC
The Japan Proton Accelerator Research Complex


A beam of man-made muon neutrinos


Kamioka
Linac
Main ring
RCS
Proton beam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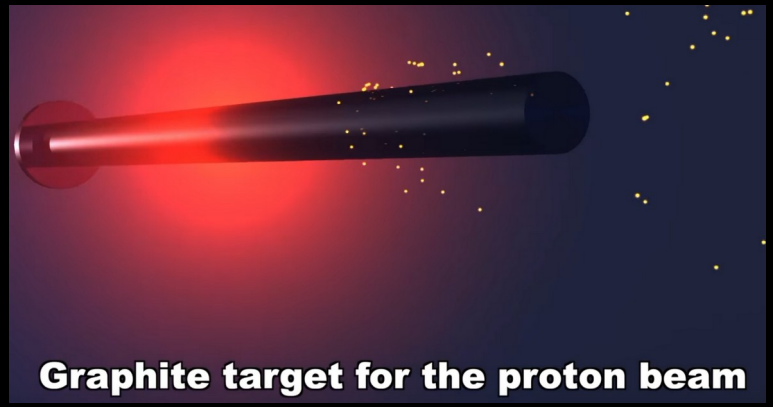
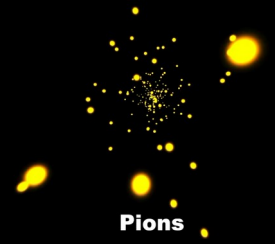
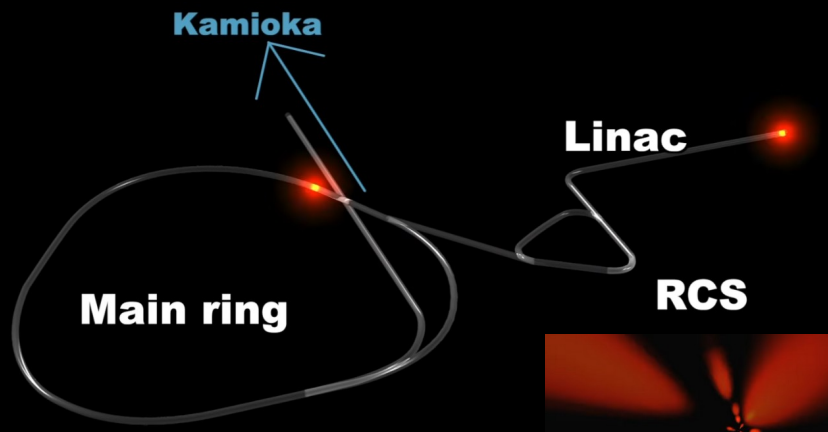

Graphite target for the proton beam


Pions


Kamioka
Linac
Main ring
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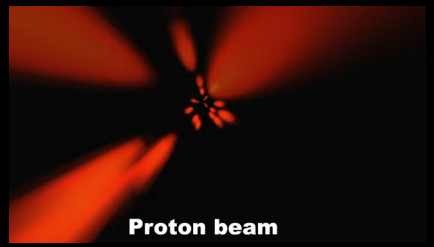
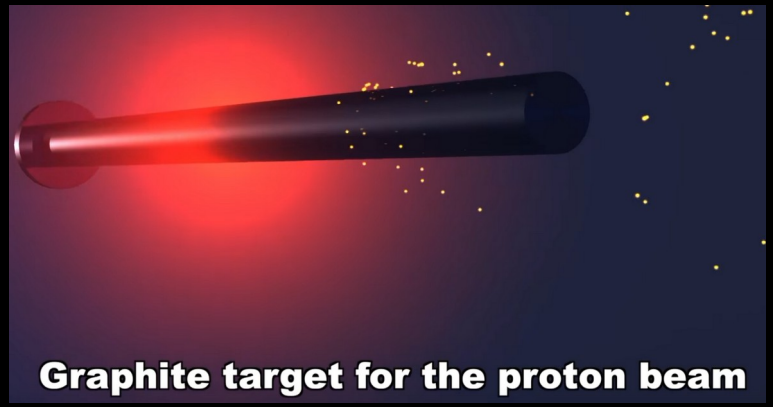
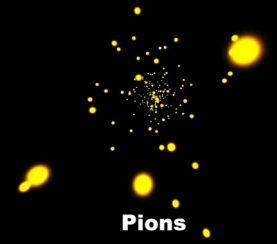
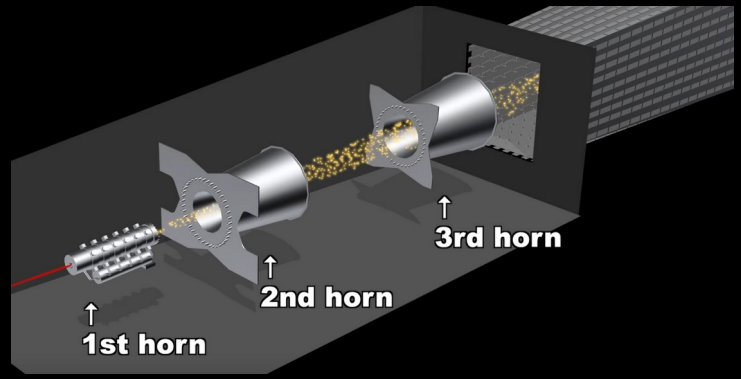
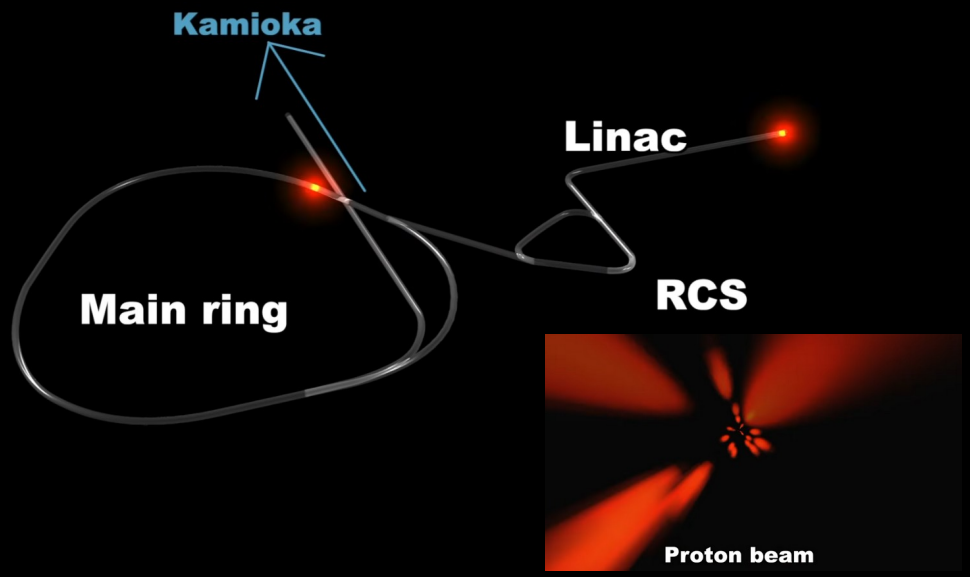
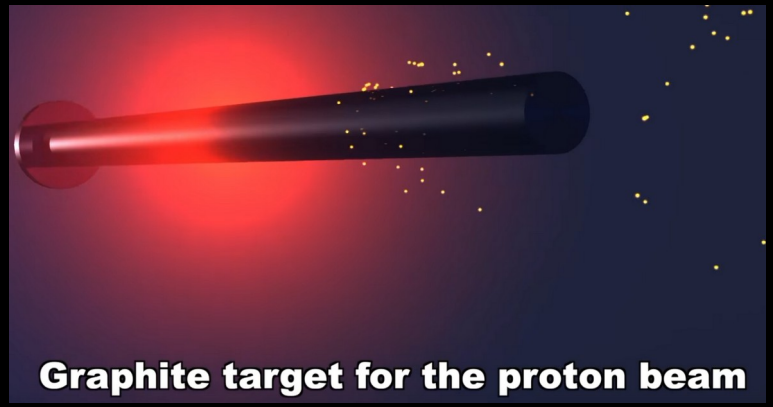

Proton beam


Graphite target for the proton beam


Pions


3rd horn
2nd horn
1st horn


Kamioka
Linac
Main ring
RCS
Proton beam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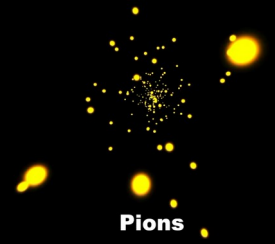
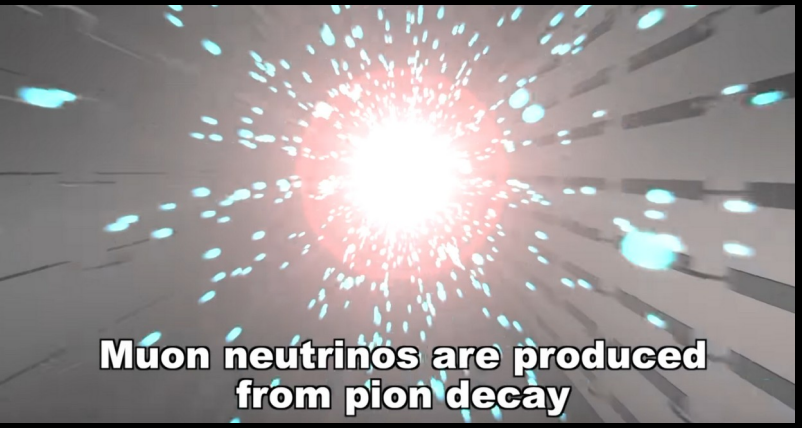
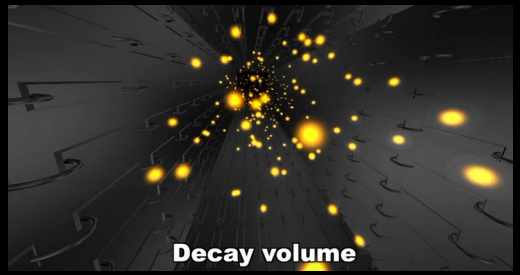
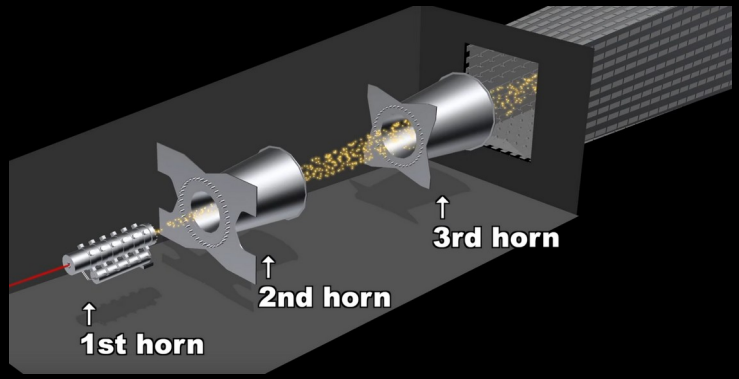
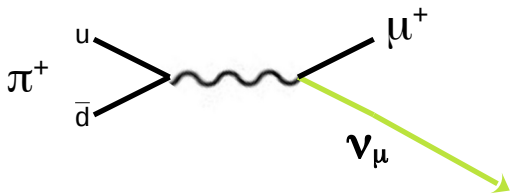

Pions

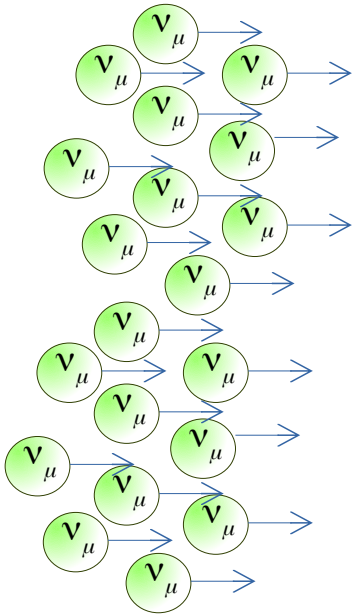

Muon neutrinos are produced
from pion decay


Decay volume

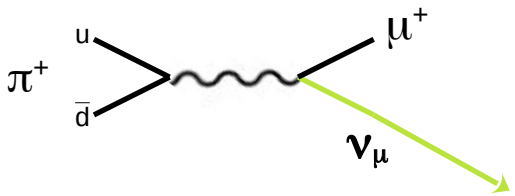

1st horn
2nd horn
3rd horn

Accelerator



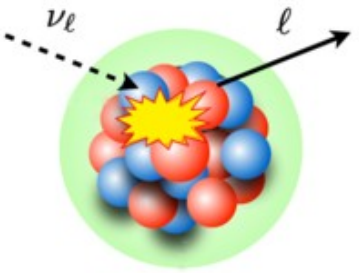


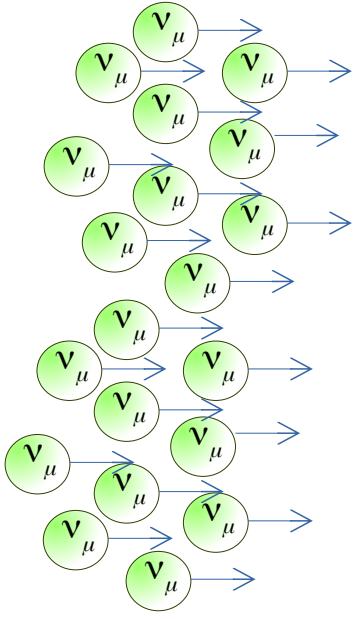
Accelerator

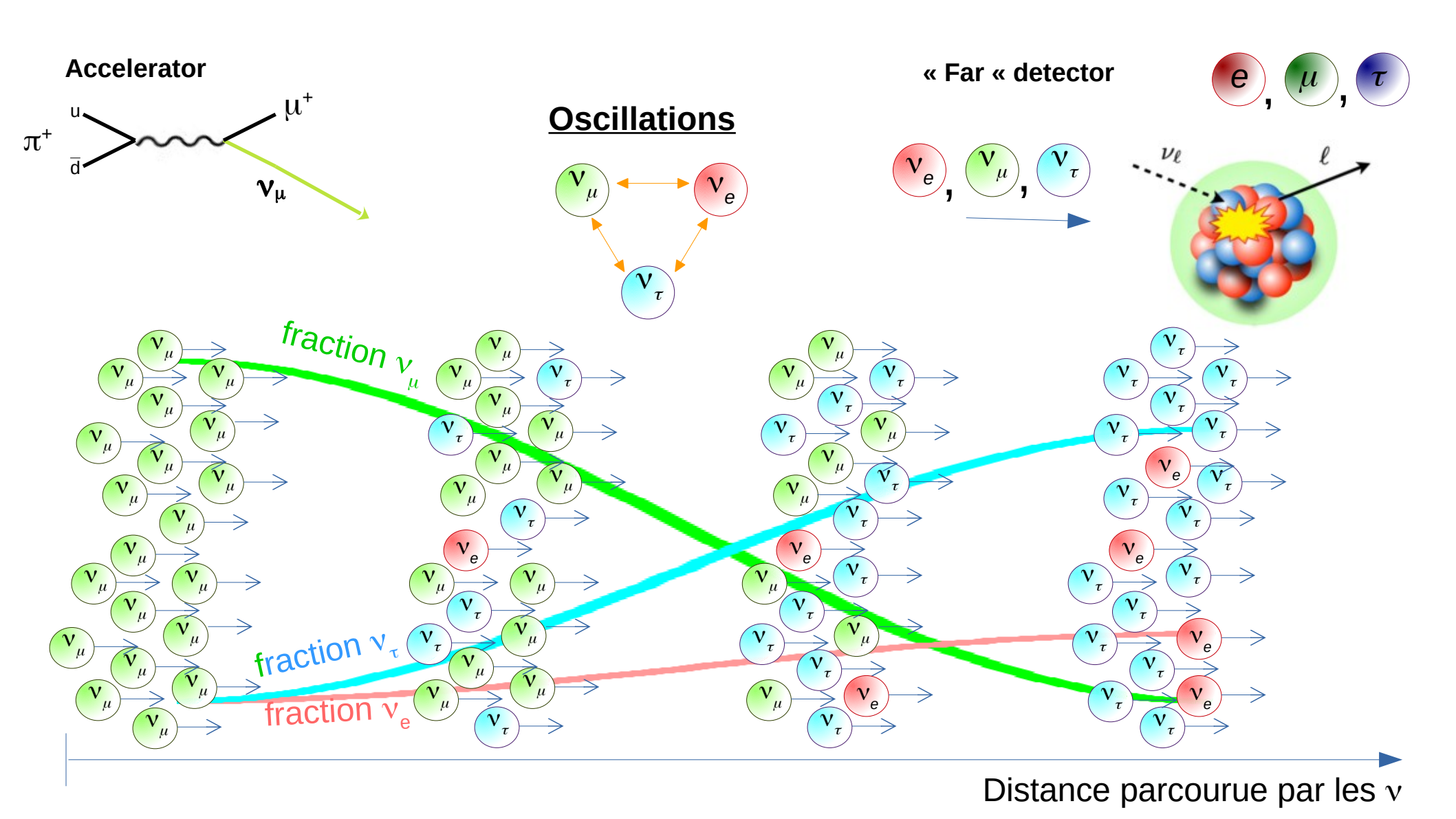


Hundreds of kilometers

« Far « detector



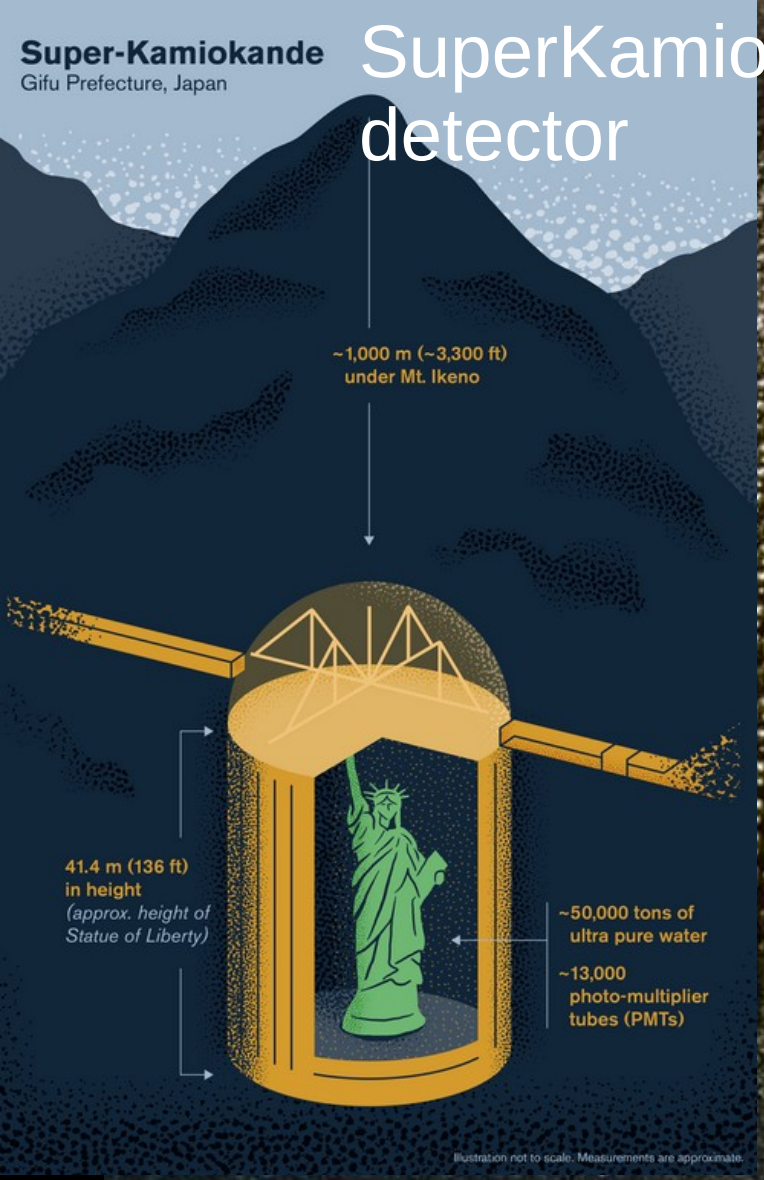


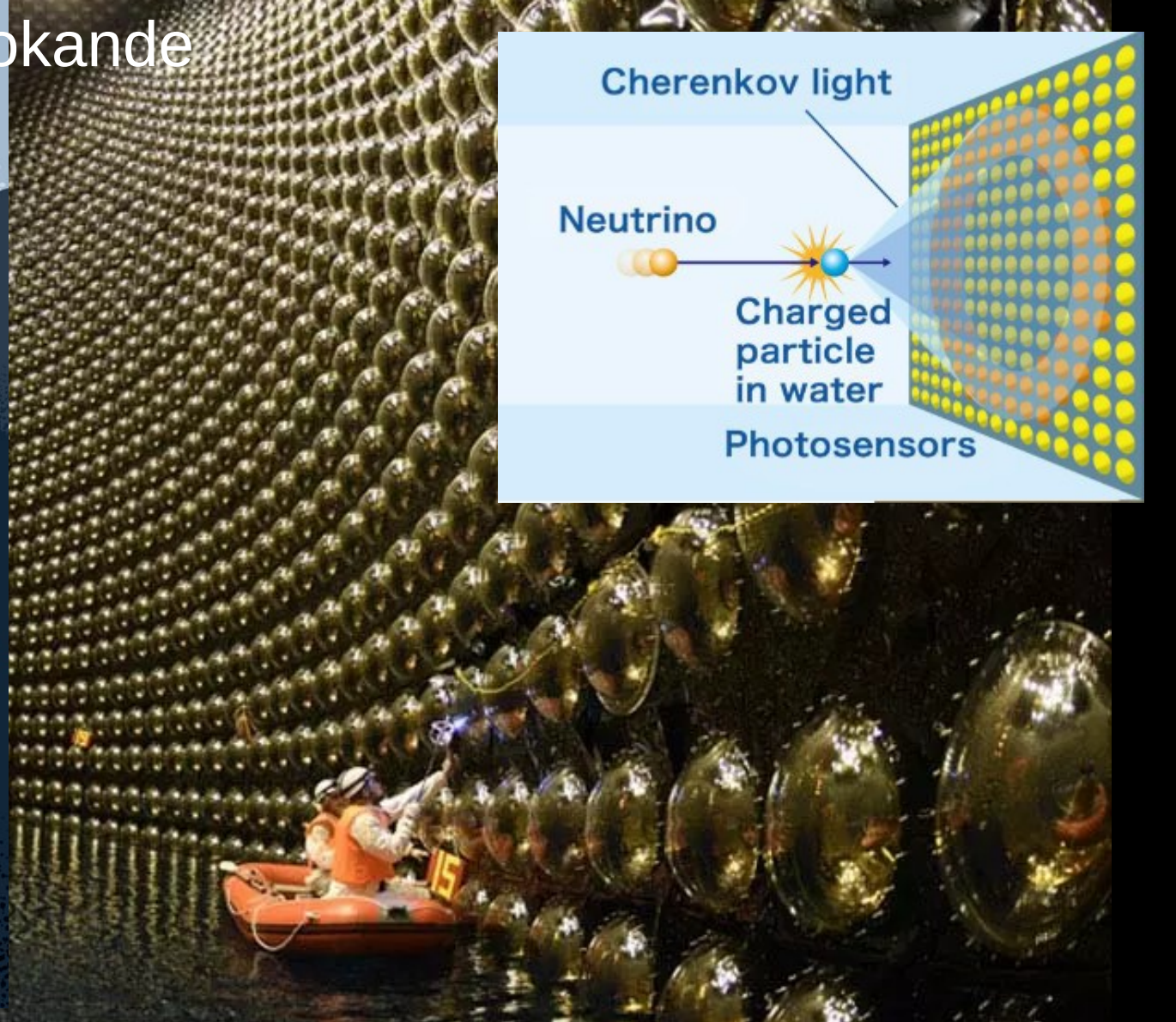

Accelerator
u
$\bar{d}$
π^+
μ^+
ν_μ
Oscillations
ν_μ
ν_e
ν_τ
« Far « detector
e, μ, τ
ν_e, ν_μ, ν_τ
ν_ℓ
ℓ
fraction ν_μ
fraction ν_τ
fraction ν_e
Distance parcourue par les ν


Kamioka
Super Kamiokande
Tokai
J-PARC
KEK
Kamioka Mine


SuperKamiokande
detector

SuperKamiokande detector





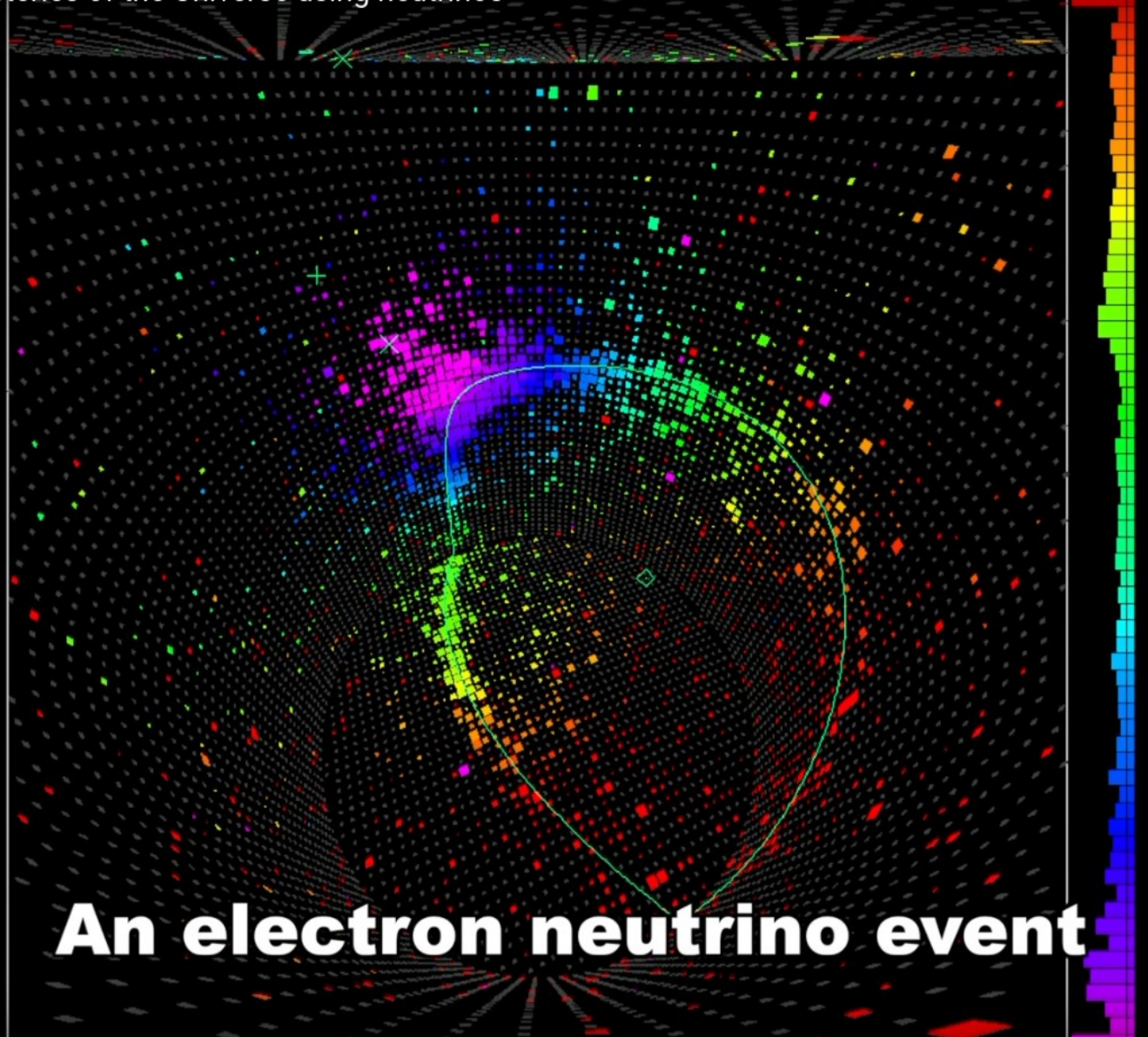
Enormous amount of ν_μ produced by accelerator

→

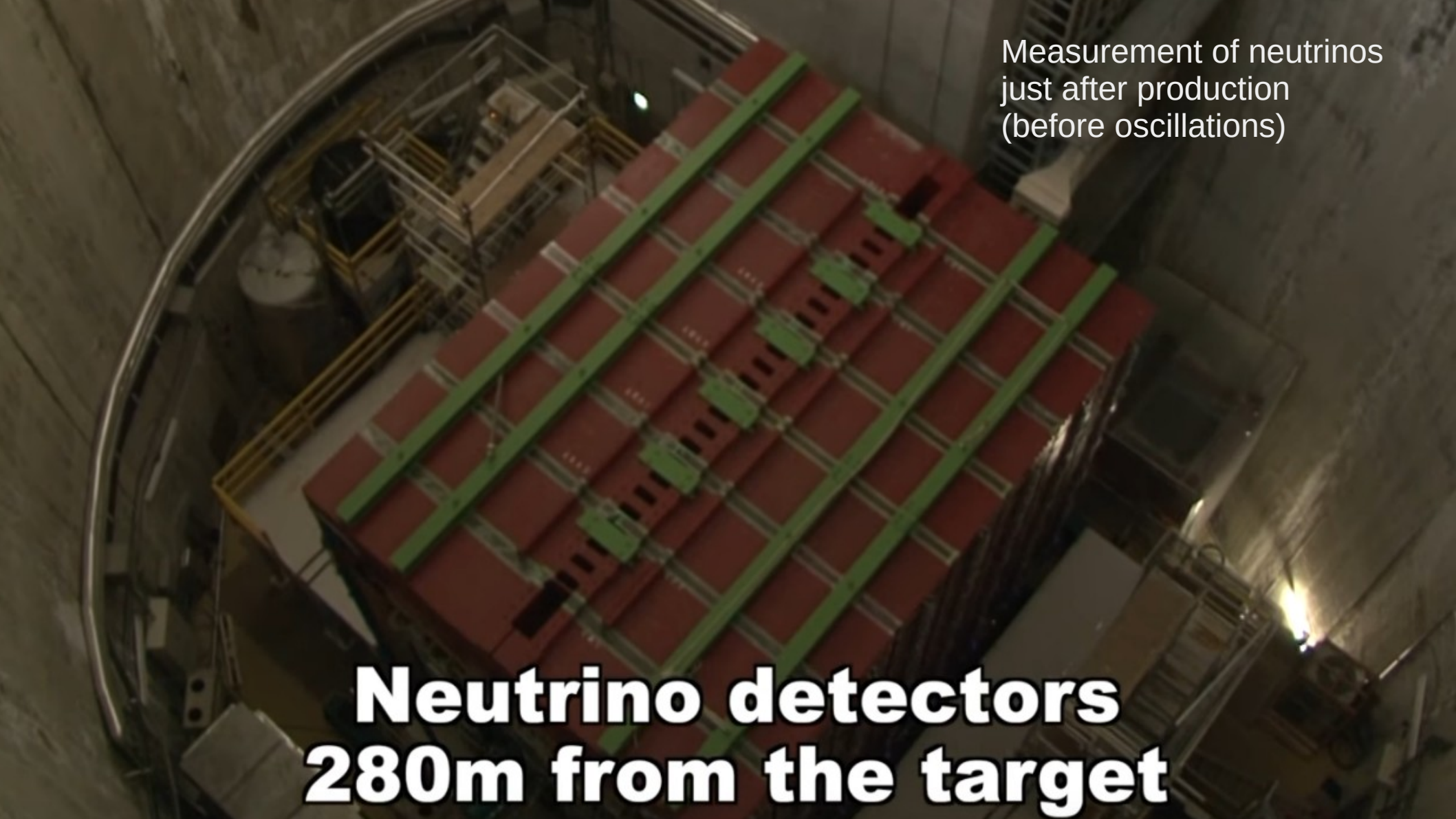
few of them per day interacts in SuperKamiokande

→

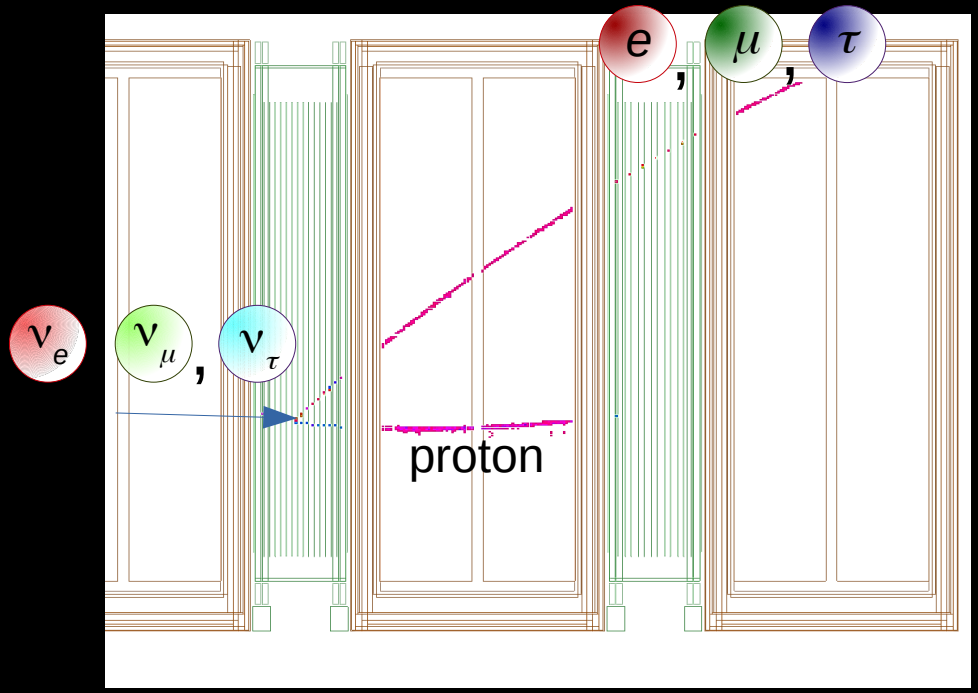
even fewer oscillated into electron neutrinos !




~570 members, 78 Institutes, 14 countries (incl. CERN)

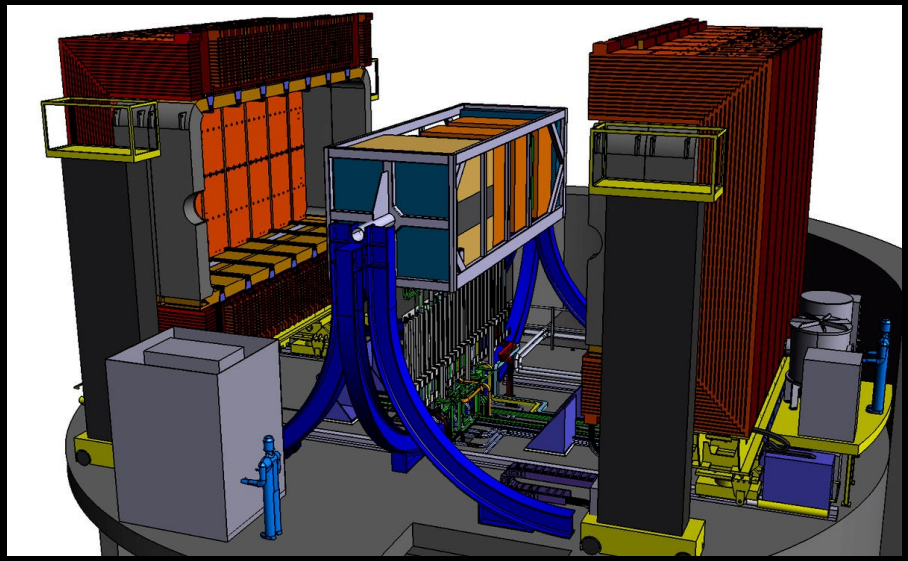

Measurement of neutrinos
just after production
(before oscillations)
Neutrino detectors
280m from the target

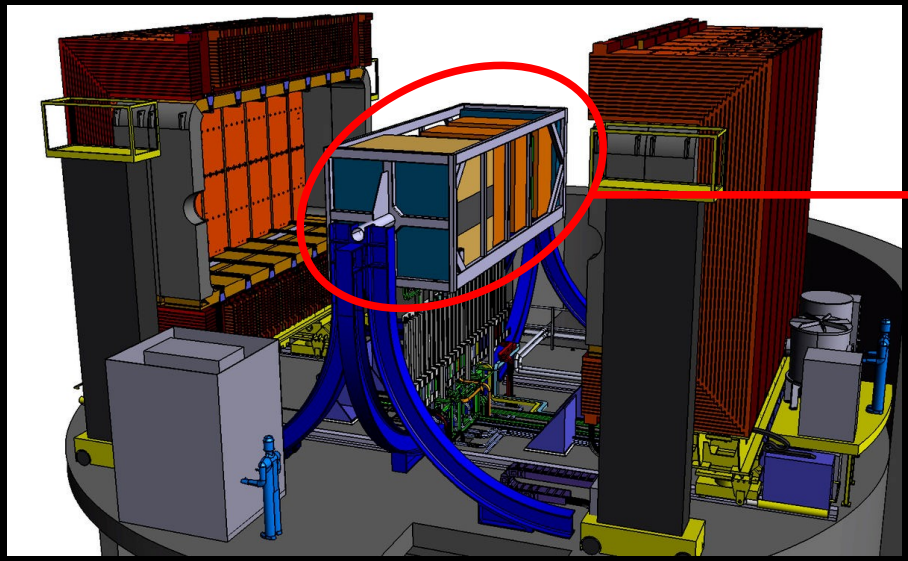
‘Near’ detector

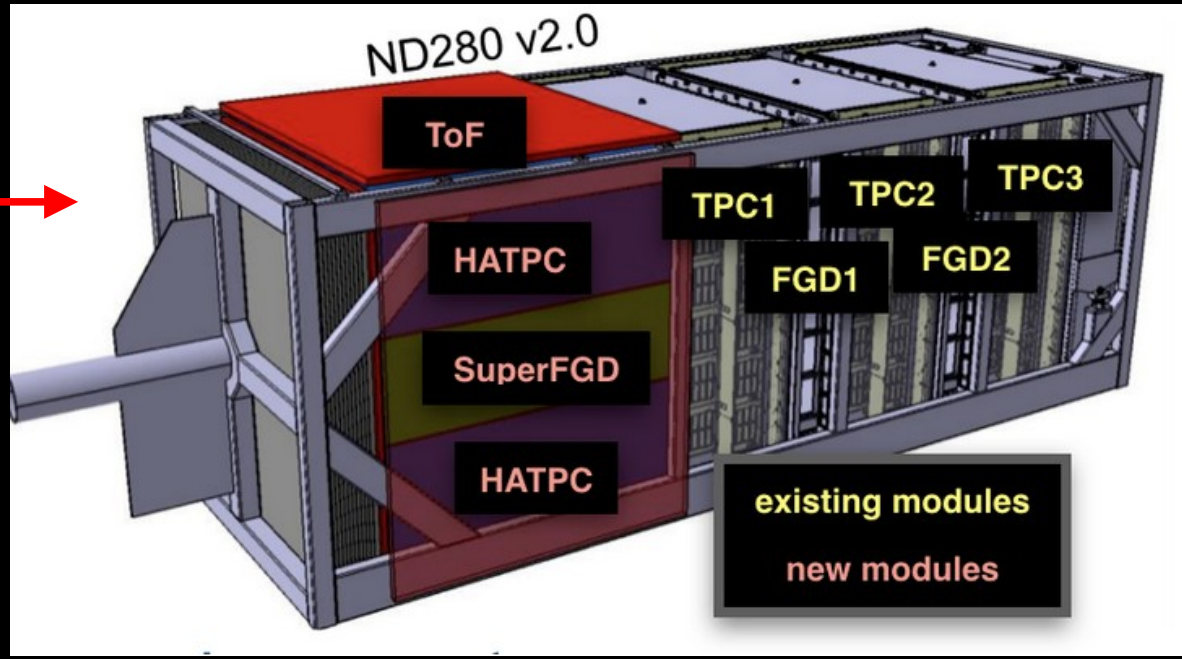


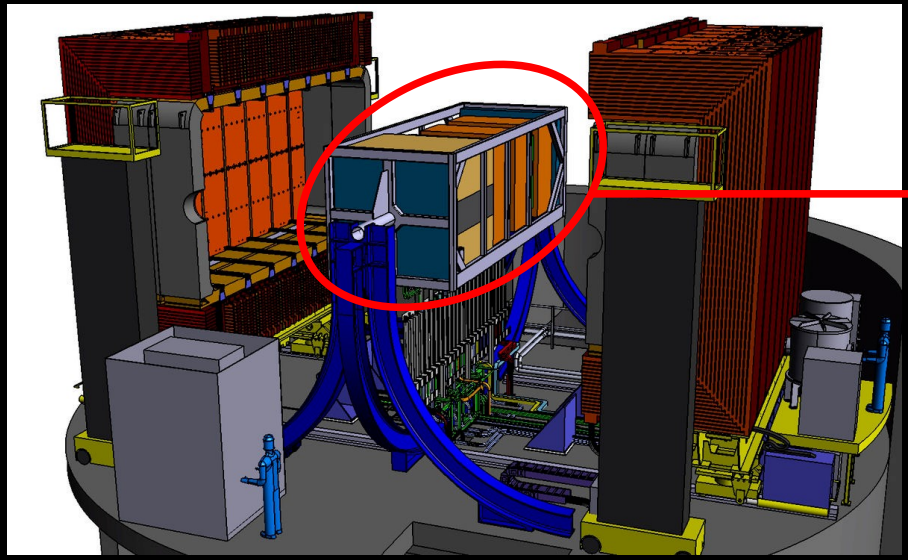
To measure how many neutrinos are produced by the accelerator (‘flux’) ...

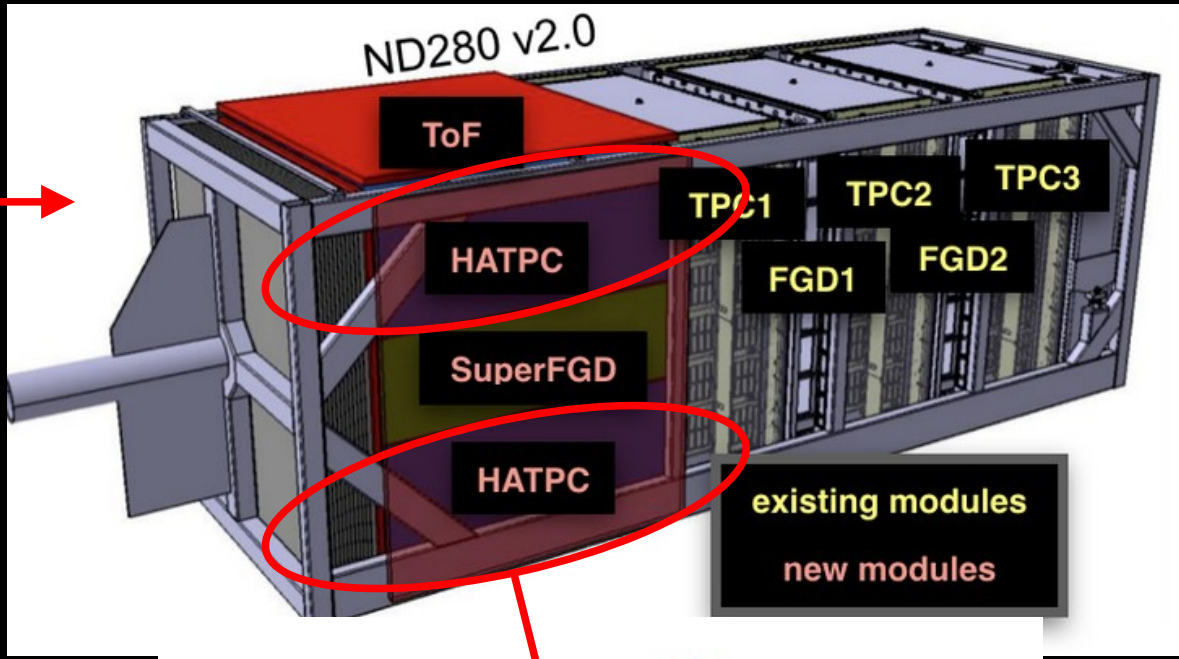
… and what is the probability that neutrinos interact with the matter of our detectors (‘cross-section’)

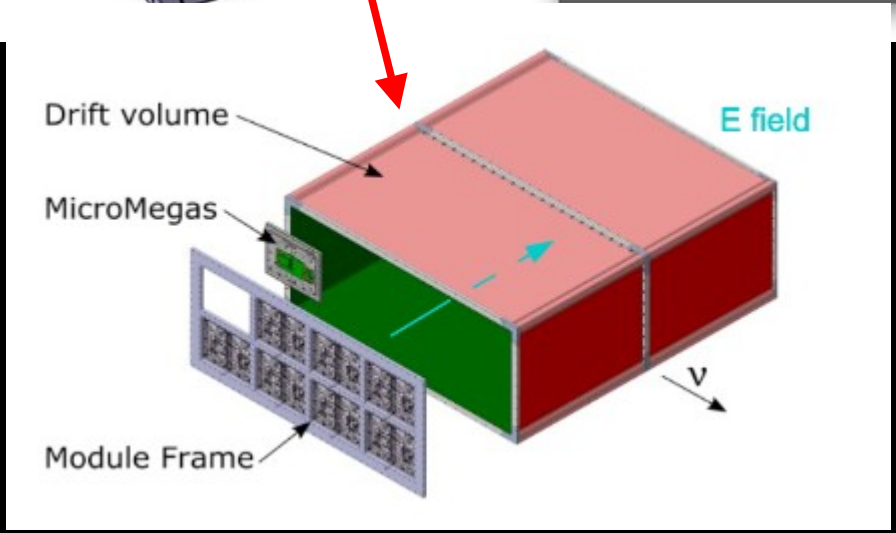


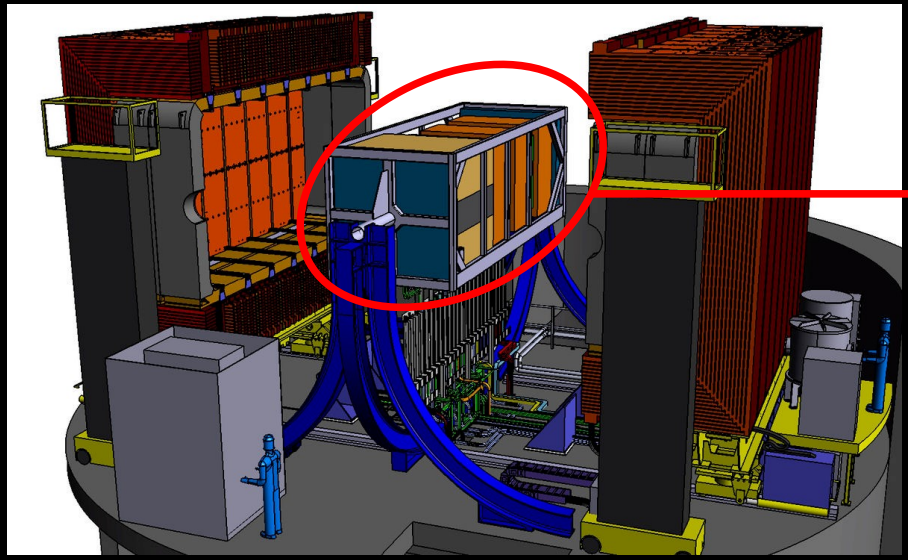


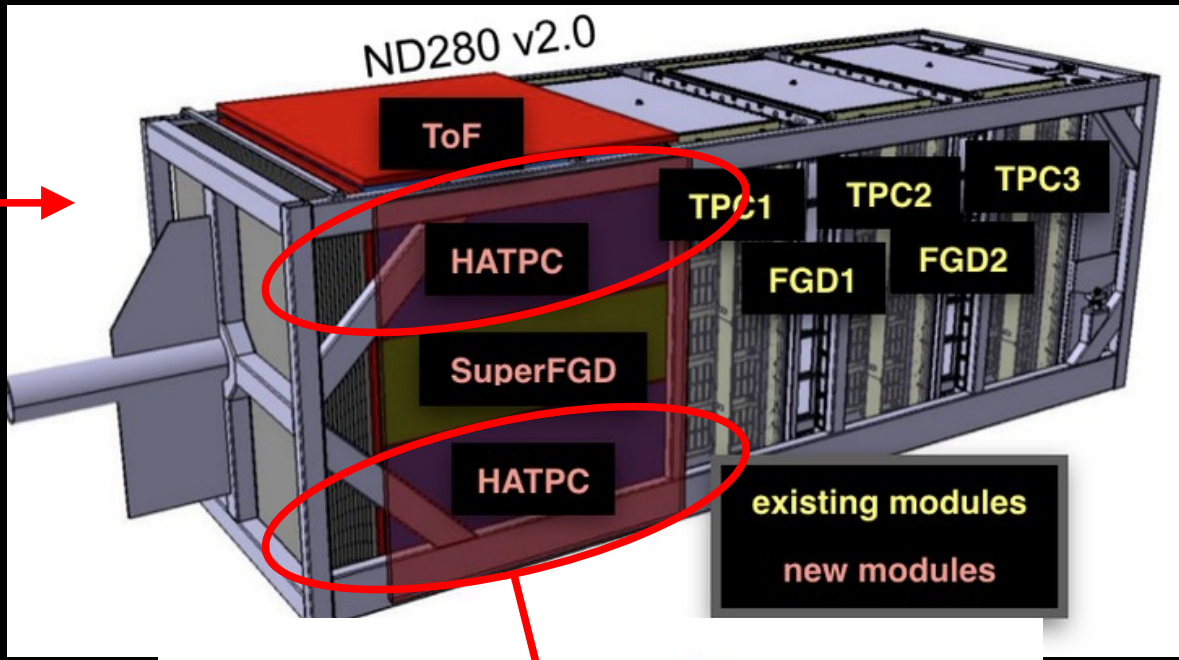

ND280 v2.0
ToF
TPC1
TPC2
TPC3
HATPC
FGD1
FGD2
SuperFGD
HATPC
existing modules
new modules

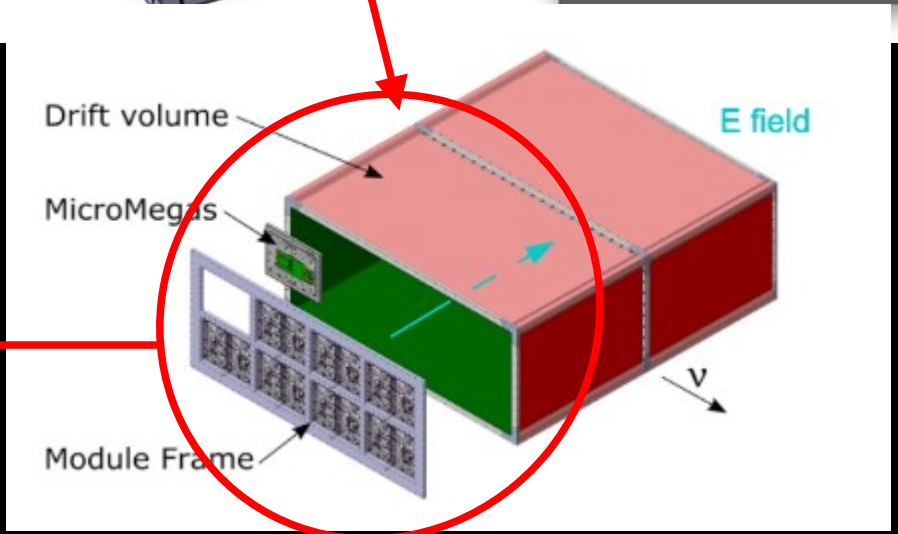


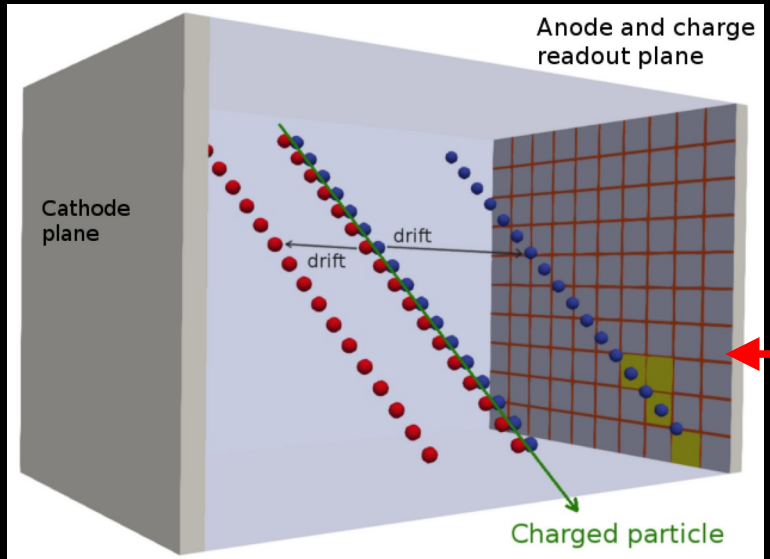

ND280 v2.0
ToF
TPC1
TPC2
TPC3
HATPC
FGD1
FGD2
SuperFGD
HATPC
existing modules
new modules

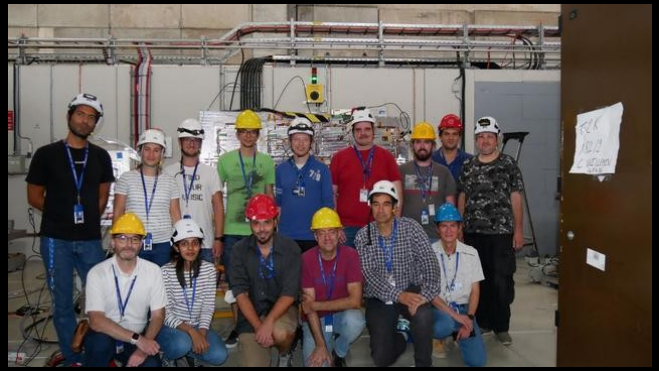

Drift volume
E field
MicroMegas
ν
Module Frame




ND280 v2.0
ToF
TPC1
TPC2
TPC3
HATPC
FGD1
FGD2
SuperFGD
HATPC
existing modules
new modules

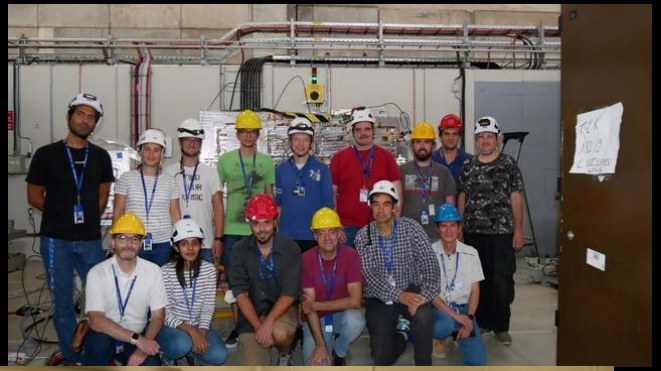

Drift volume
E field
MicroMegas
ν
Module Frame

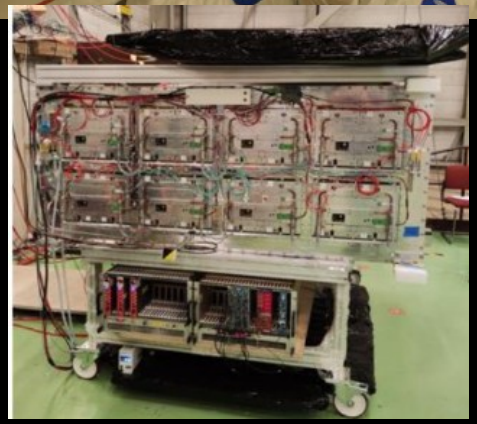

Anode and charge readout plane
Cathode plane
drift
drift
Charged particle



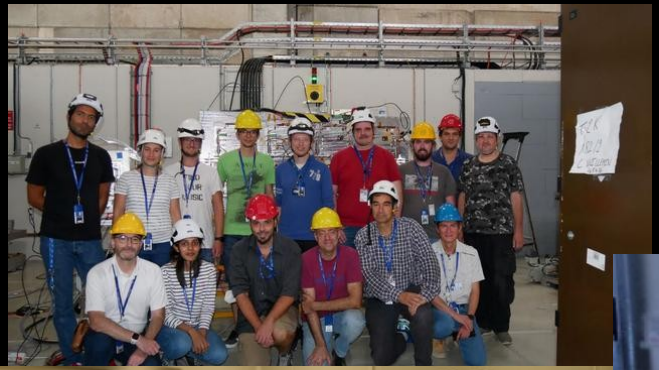
Prototypes and test beams
→ final design

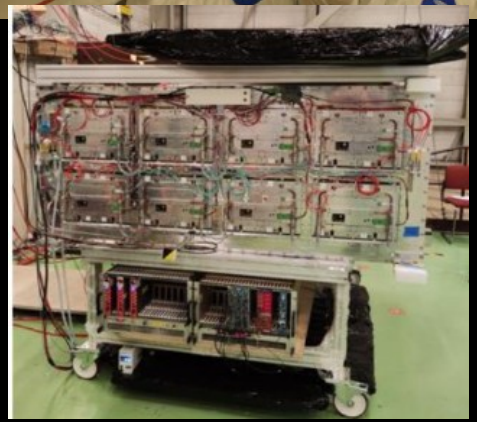
Prototypes and test beams
→ final design
→ production and assembly, tests at CERN



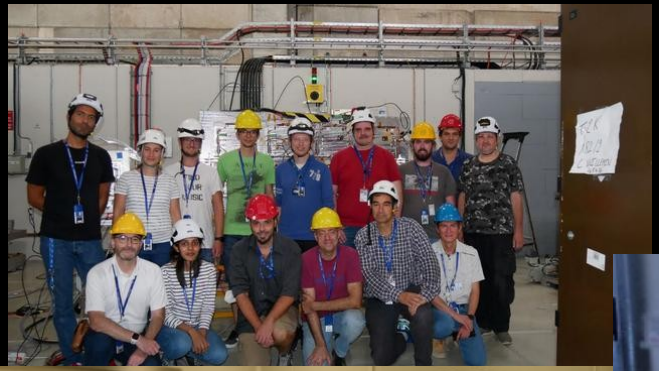


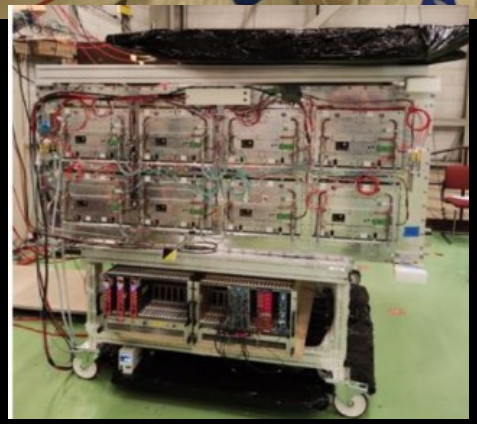
Prototypes and test beams
→ final design
→ production and assembly at CERN
→ shipping to Japan by flight

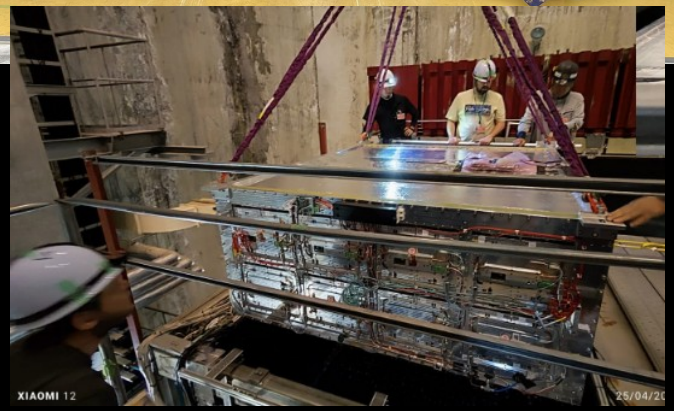


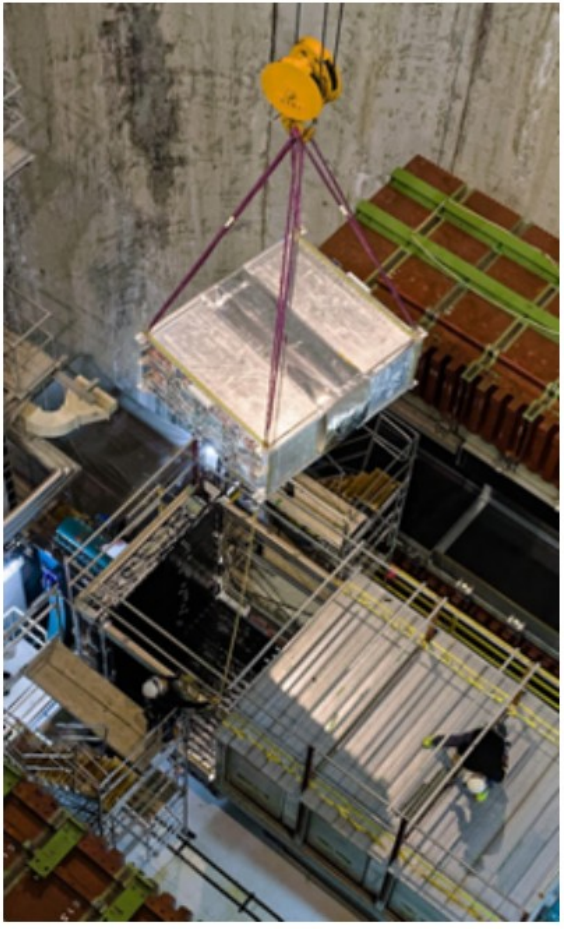


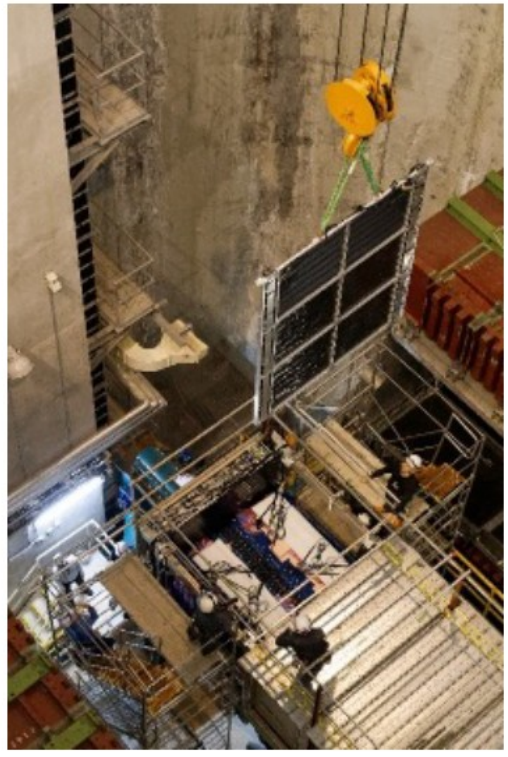
Prototypes and test beams
→ final design
→ production and assembly at CERN
→ shipping to Japan by flight
→ installation
→ first data !!

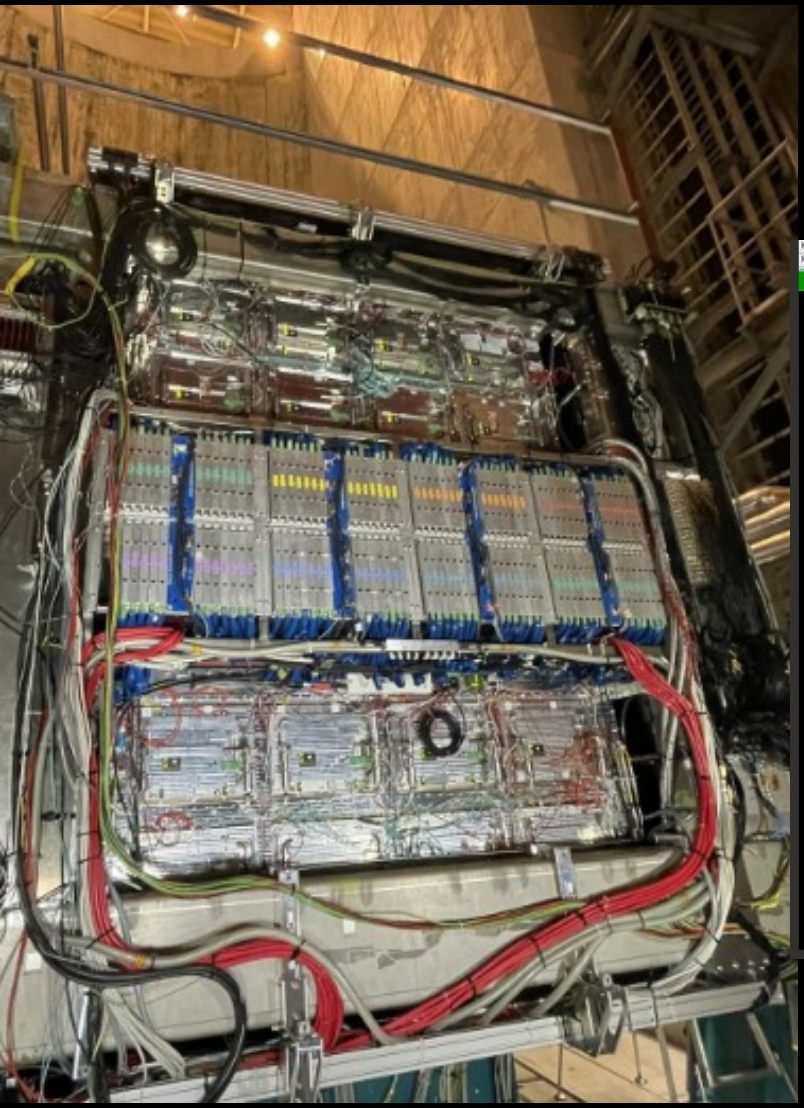




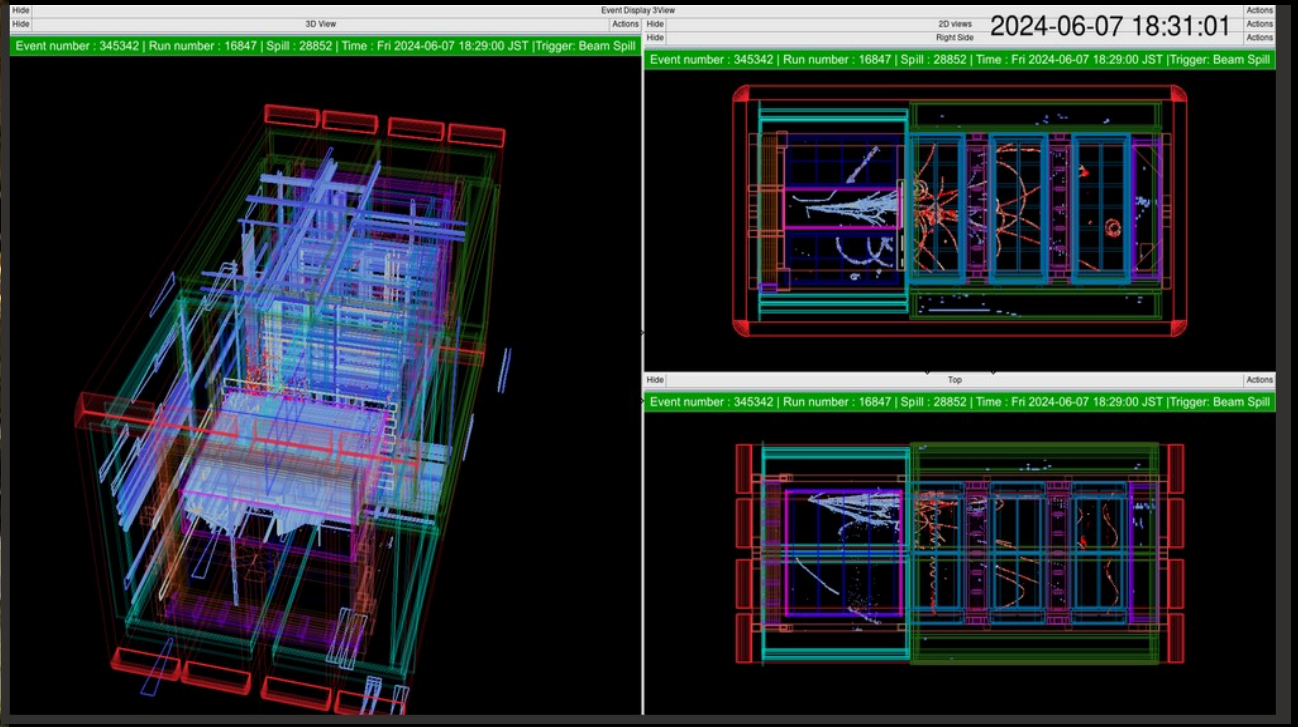






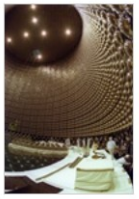


First neutrino event with upgraded near detector !



Prix 2012 de la Recherche,

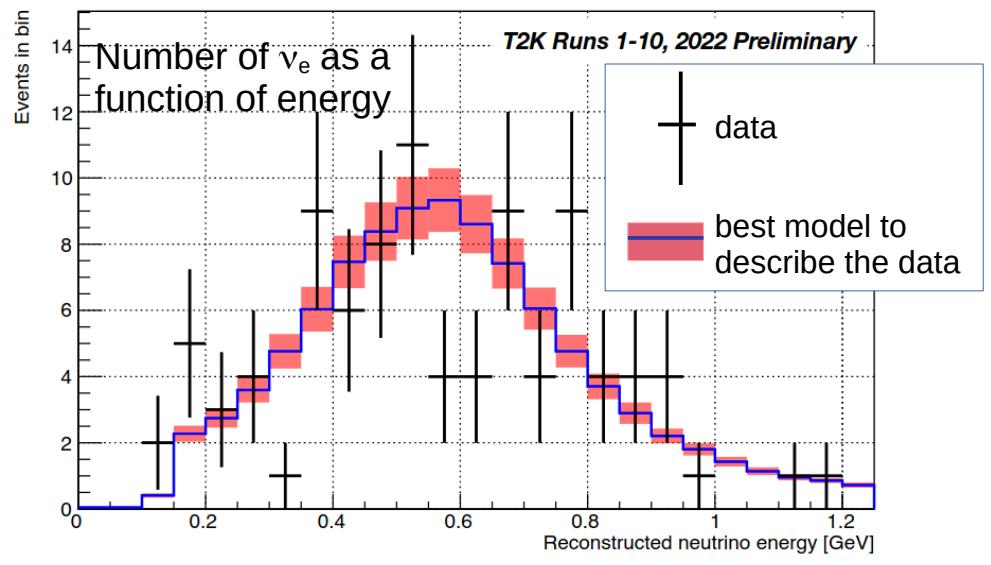
Breakthrough Prize 2016



New Evidence for Flavor-Switching Neutrinos

by Gregory Mone

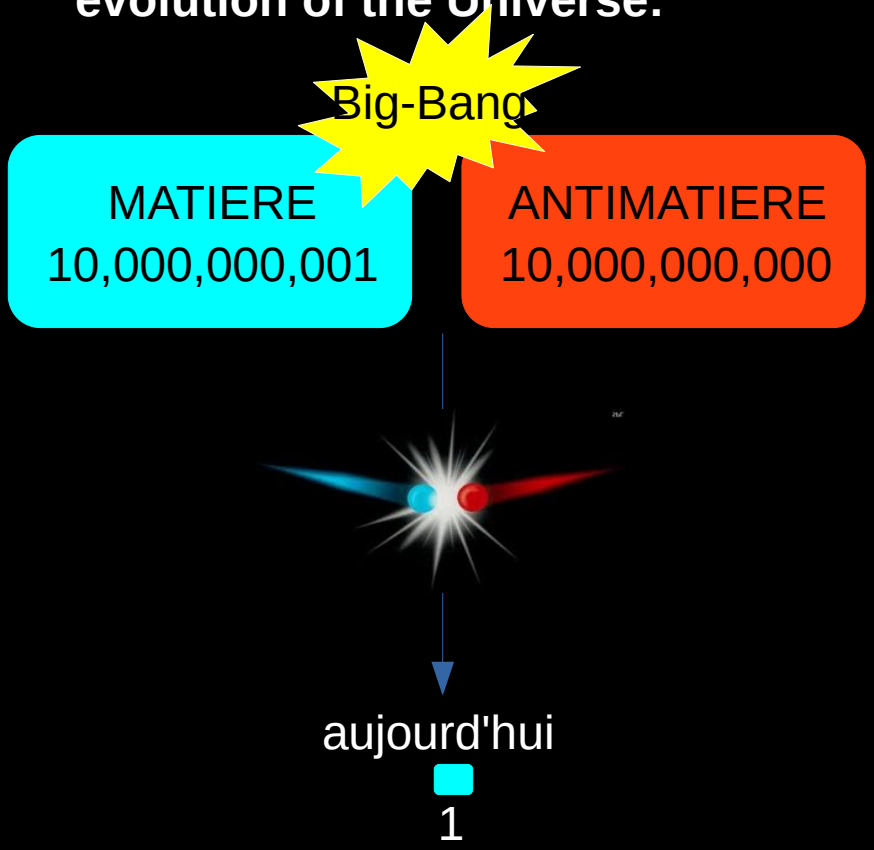
An accelerator experiment confirms that neutrinos can mysteriously morph from one type to another.



- **Neutrinos play a major rôle in the evolution of the Universe:**

In paricular neutrinos could be responsible of the
matter/antimatter asymmetry if
neutrino oscillation different than antineutrino oscillation

- **Neutrinos play a major rôle in the evolution of the Universe:**

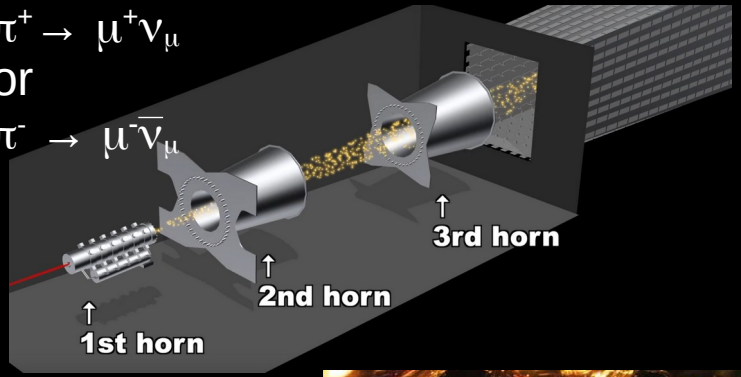


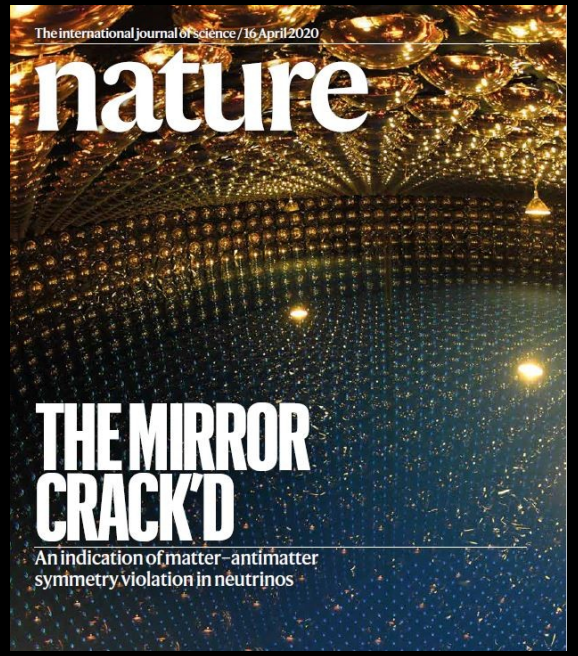
T2K can produce beam of ν_μ or $\bar{\nu}_\mu$ by focusing

$\pi^+ \rightarrow \mu^+\nu_\mu$

or

$\pi^- \rightarrow \mu^-\bar{\nu}_\mu$





In paricular neutrinos could be responsible of the **matter/antimatter asymmetry if neutrino oscillation different than antineutrino oscillation**