Tokai to Kamioka long-baseline neutrino oscillation

New TPC for the ND280 detector in T2K experiment

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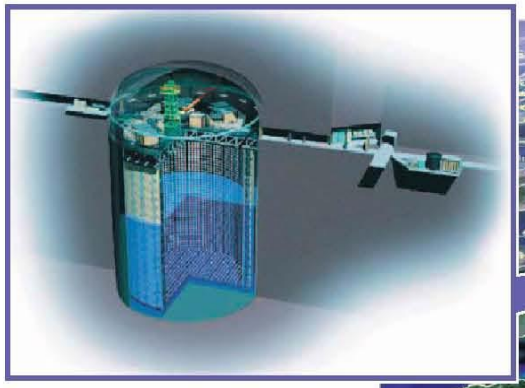
Outline

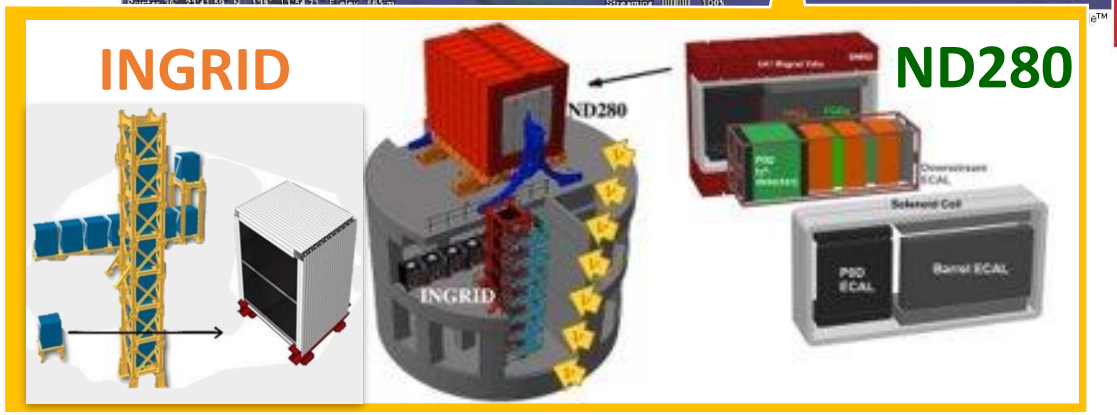
- T2K: an experiment to study the neutrino oscillations
- T2K detectors upgrade
  - New HA-TPC
  - Test on prototype

Tokai to Kamioka long-baseline neutrino oscillation



Super-Kamiokande
(ICRR, Univ. Tokyo)

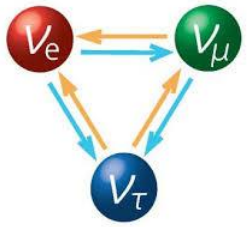
J-PARC Main Ring
(KEK-JAEA, Tokai)



NEUTRINOS
produced at **J-PARC** accelerator
and **detected** by:

- Near Detector (**ND280**+**INGRID**)
- T2K far detector (**Super-Kamiokande**)

From ν-oscillation study to leptonic CP violation observation



$$\begin{pmatrix} |\nu_e\rangle \\ |\nu_\mu\rangle \\ |\nu_\tau\rangle \end{pmatrix} = U_{PMNS} \begin{pmatrix} |\nu_1\rangle \\ |\nu_2\rangle \\ |\nu_3\rangle \end{pmatrix}$$

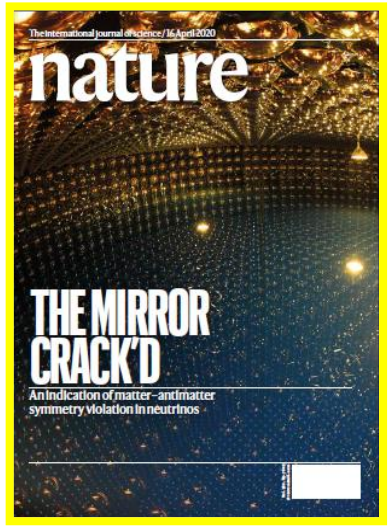
FLAVOR EINGENSTATES — MASS EINGENSTATES

First observation of the oscillation: $\nu_\mu \rightarrow \nu_e$ with a significance of 7.3σ

[K. Abe et al., Phys Rev Lett 112 (2014) 061802.]

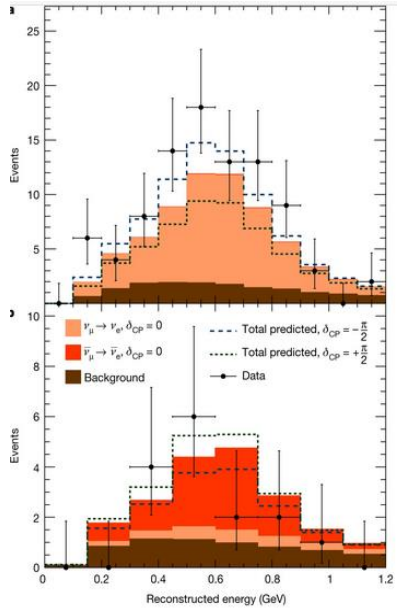
The study of **neutrino and anti-neutrino oscillations** under the same conditions shed light on **matter anti-matter asymmetry** in the universe.

ν_e flux / ν_μ flux => accessible observation of **LEPTONIC CP VIOLATION.**



"Our results indicate **CP violation in leptons** and our method enables sensitive searches for matter–antimatter asymmetry in neutrino oscillations using accelerator-produced neutrino beams."

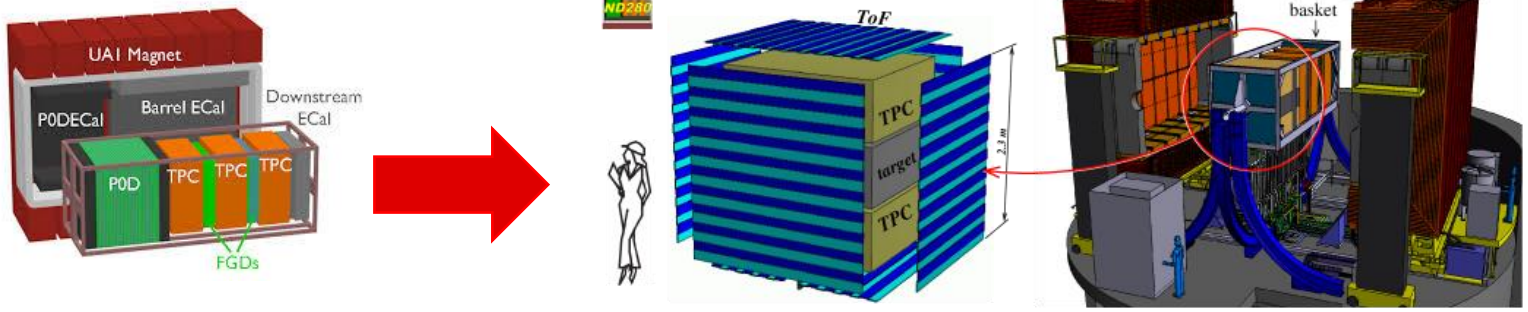
	1e0de ν-mode	1e0de $\bar{\nu}$-mode	1e1de ν-mode
$\nu_\mu \rightarrow \nu_e$	59.0	3.0	5.4
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	0.4	7.5	0.0
Background	13.8	6.4	1.5
Total predicted	73.2	16.9	6.9
Systematic uncertainty	8.8%	7.1%	18.4%
Data	75	15	15



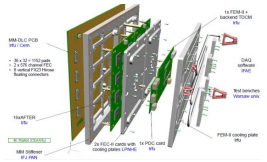
[K. Abe et al. (T2K Collaboration), Nature 580 (2020) 339-344]

Upgrade to get a better sensitivity (3σ)

- **Deliverable maximum neutrino beam** (POT events up to 20×10^{21})
- **NEAR DETECTOR (ND280)** better handling of systematic errors: ~3% for the systematic uncertainties affecting the CP violation measurement
  [A. Blondel et al T2K Collaboration, "The T2K-ND280 upgrade proposal", CERN-SPSC-2018-001; SPSC-P-357]
- **Super-kamiokande** (water doped with Gd)

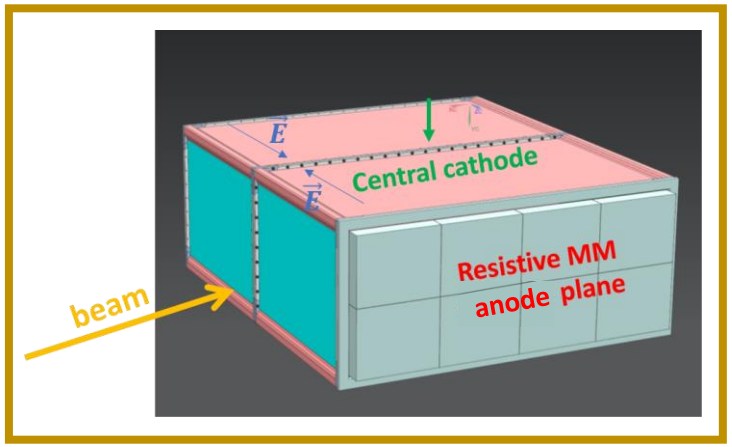


- high granularity SuperFGD (Active Target)
- 2 horizontal TPCs with thin field cage
- Resistive Micromegas (innovative gas amplifiers)



Innovative feature of ND280 → **Efficient measurement** of charged particles **in an unknown kinematic region**.

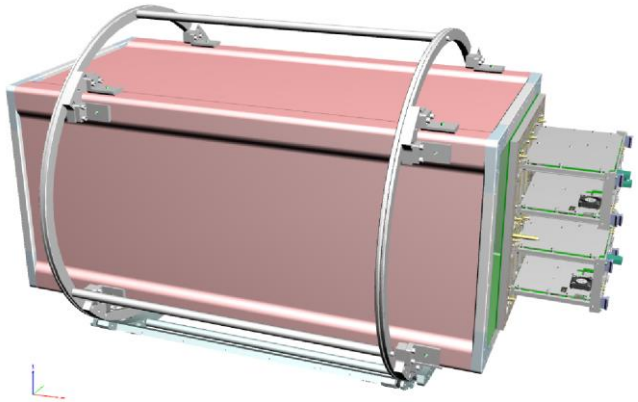
Magnetic field → **increases** the T2K **sensitivity to the matter anti-matter asymmetry**

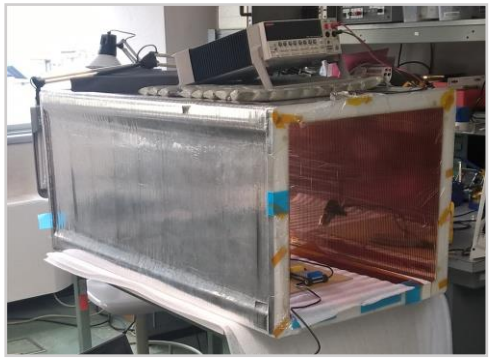


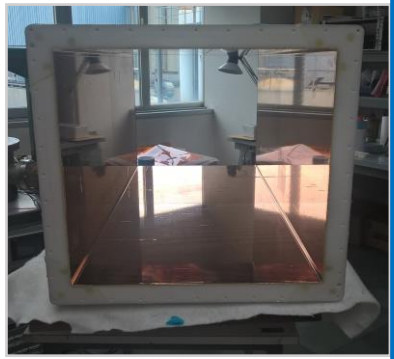
To keep $\frac{\Delta E_\perp}{E_\parallel} \leq 10^{-4}$ confined at < 1.5 cm from FC walls, the TPC cage requirements are:

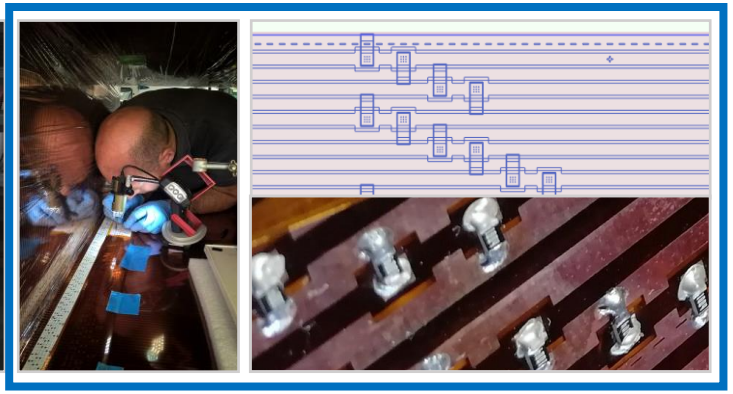
- Cathode flatness better than 0.1 mm
- Micromegas detector flatness better than 0.2 mm
- Cathode/Anode planes parallel to within 0.2 mm
- Field Cage walls flatness better than 0.3mm
- Voltage divider resistors matched within rms ~ 0.1%

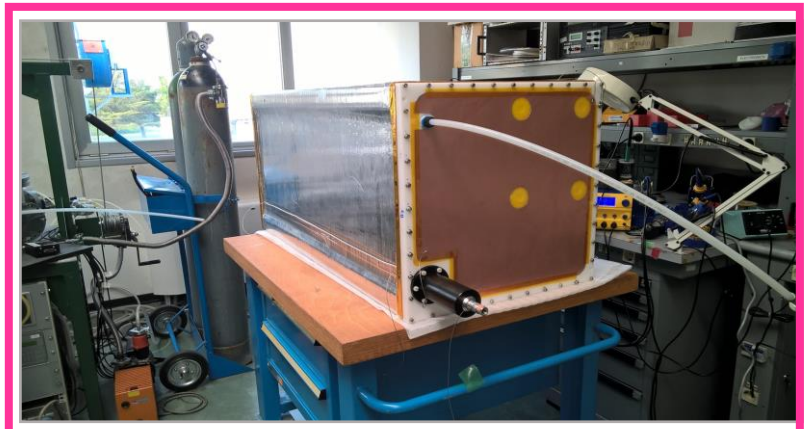
ND280 Upgrade: HA-TPC – 1st FC prototype at LNL









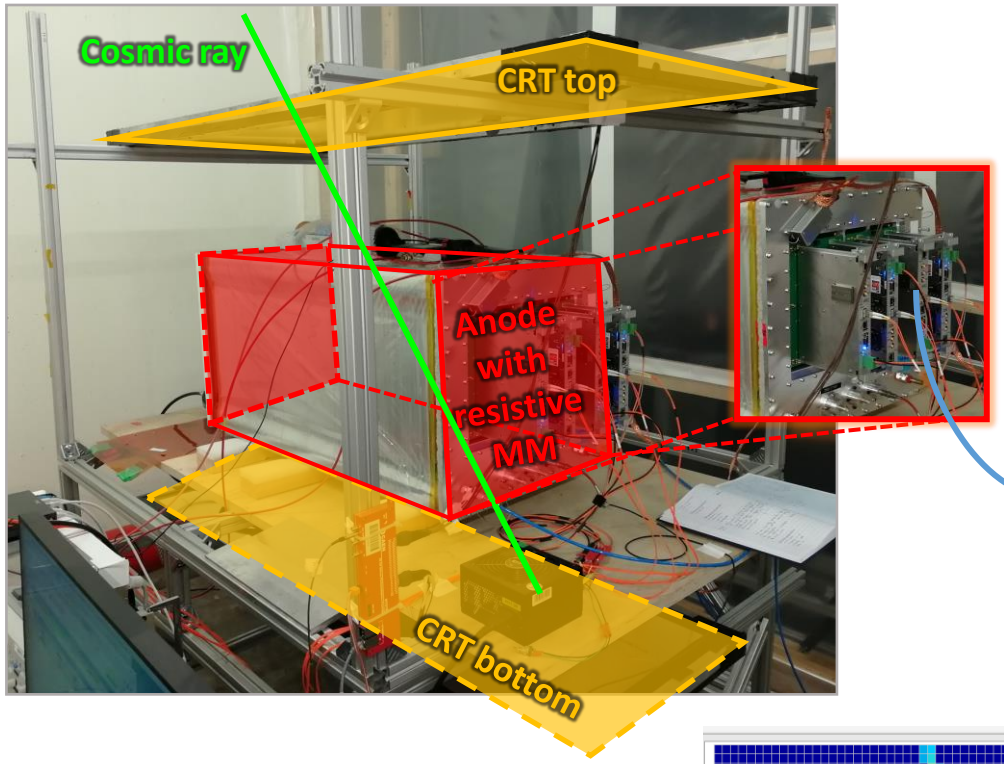


Field Cage

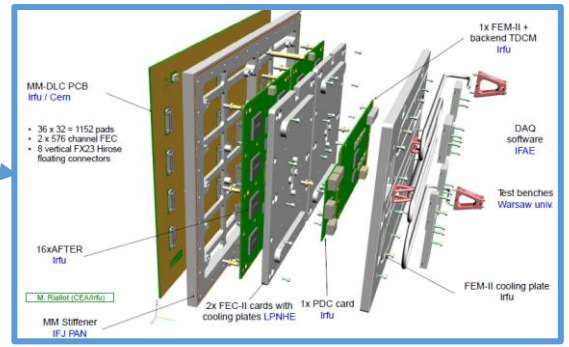
- produced by NEXUS
- assembled & tested at LNL:
  Resistors are soldered and tested;
  Cathode plane is mounted;
  Gas system is assembled, and **gas tightness** id tested.

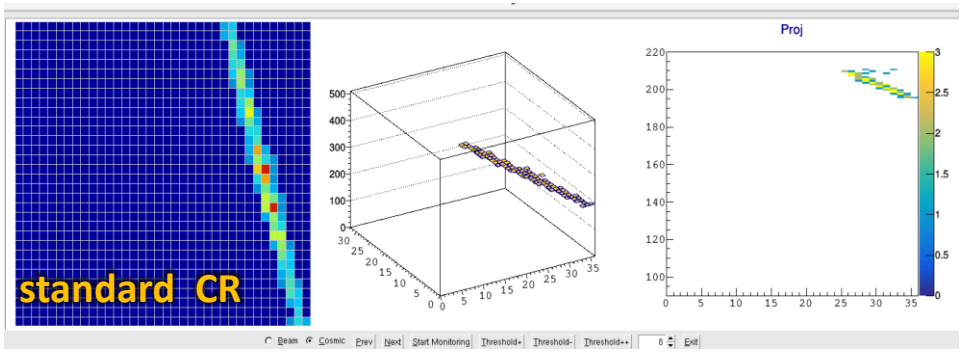
Now **the prototype is testing at CERN with Cosmic Rays**

1st TPC prototype: CR test at CERN



Resistive MM
made at Saclay





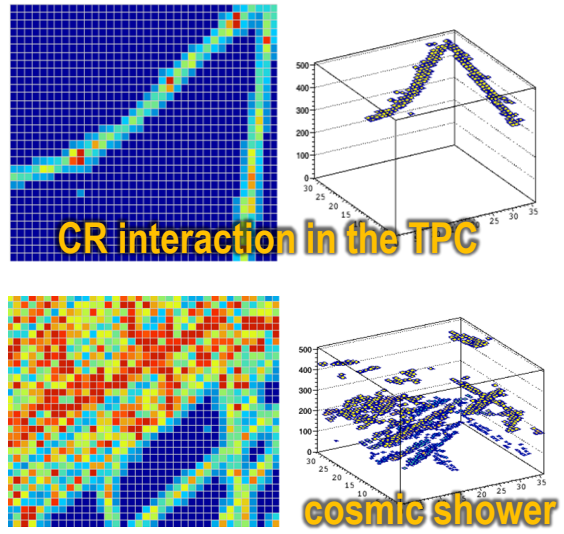
HV cathode tests → stable up to -18kV

Gas tightness:

- T2K gas mixture {Ar:CF_4:iC_4H_{10} (95:3:2)} flux = 50l/h
- O_2 contamin < 35ppm
- Water dewp T = -25°C

Reference experimental test conditions

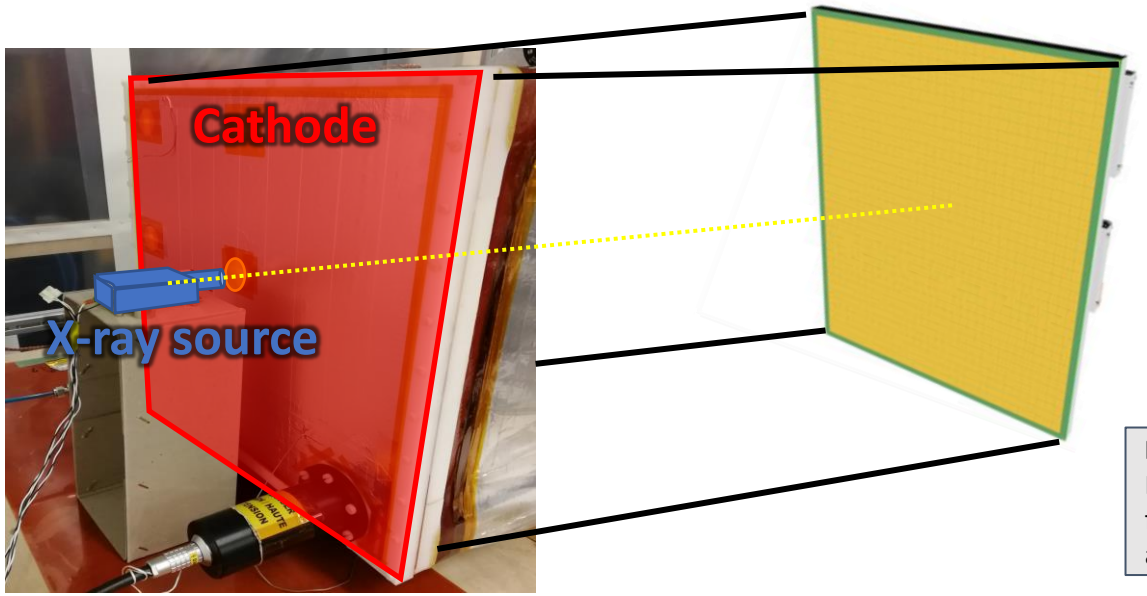
- sampling frequency 25MHz
- **trigger** = combination of signals from: CRT; small scintillator PMT; pulser.



TPC tested with Cosmic Rays:

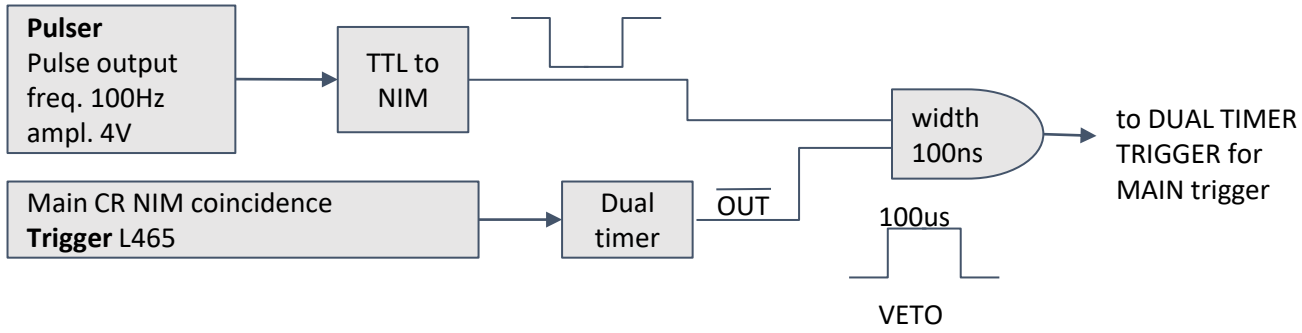
- tracks at edges;
- tracks at small theta angle;
- scan DLC voltage;
- scan shaping time;
- scan +HV applied to 2nd strip at anode (mesh plane is located at 4th strip)
- triggering on spikes of divider current (AC pick-up)

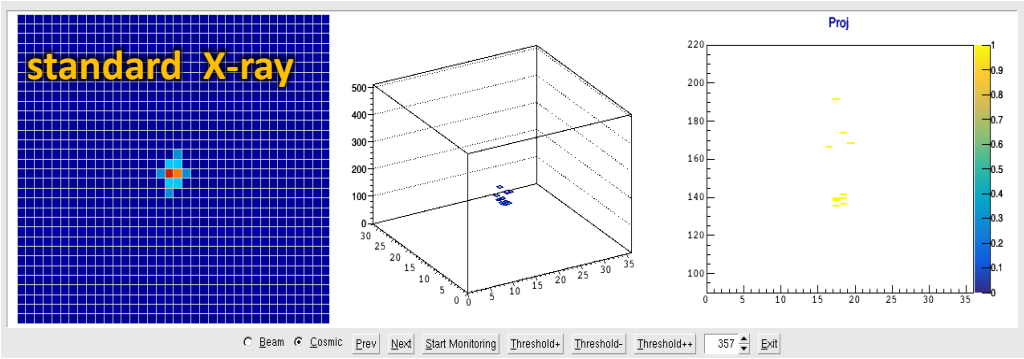
1st TPC prototype: test with X-rays source



- source = cool-X pyroelectric generator (Cu peaks + broad spectrum 1-10 keV)

- trigger:





Next Steps

1st prototype tests led to fix the issues and to optimize the construction and assembling procedure;

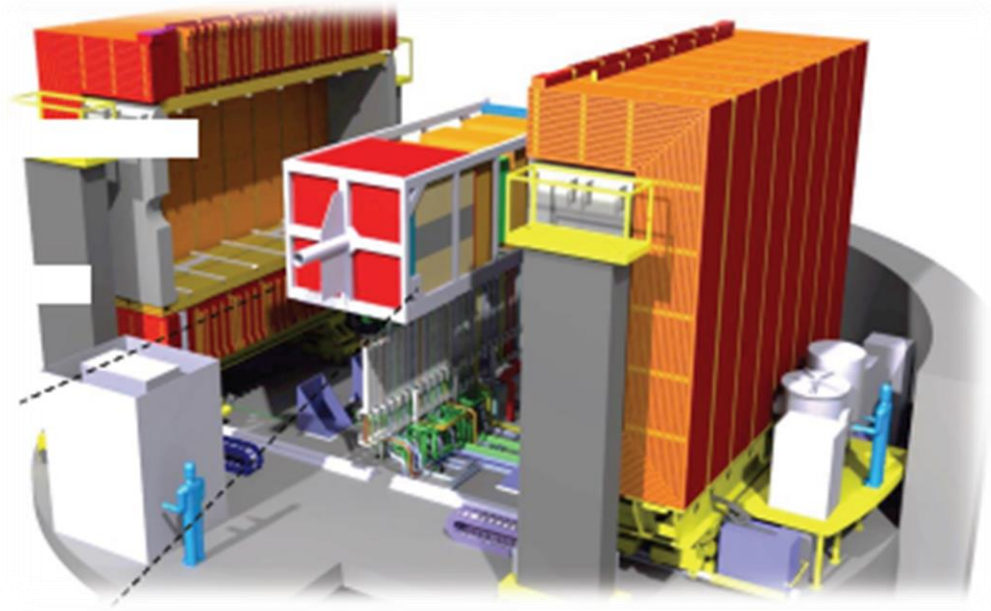
will be tested with e-beam at DESY (October 2020)

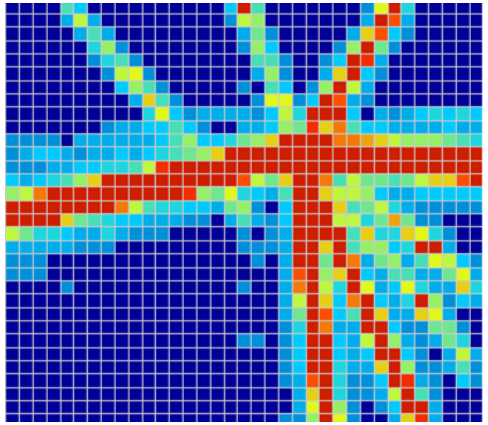
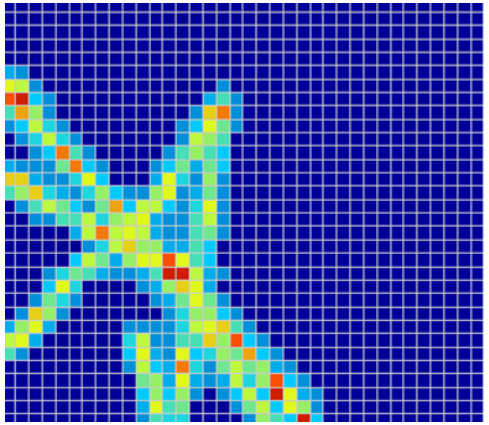
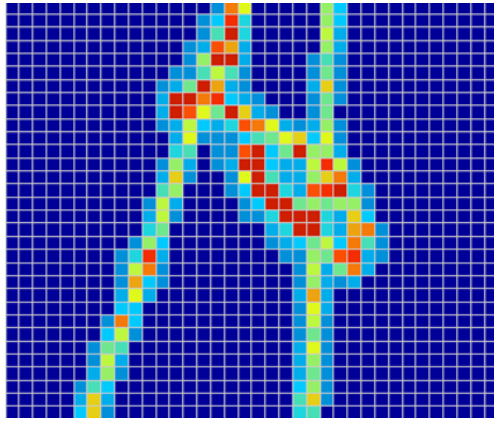
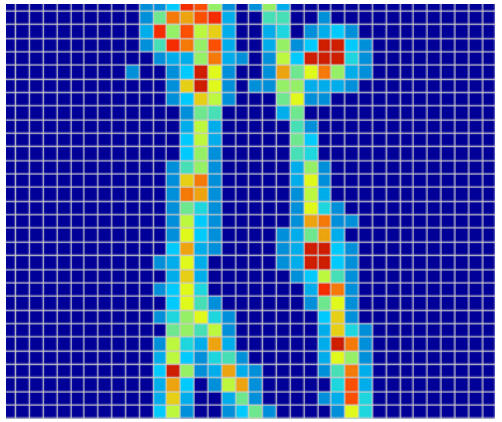
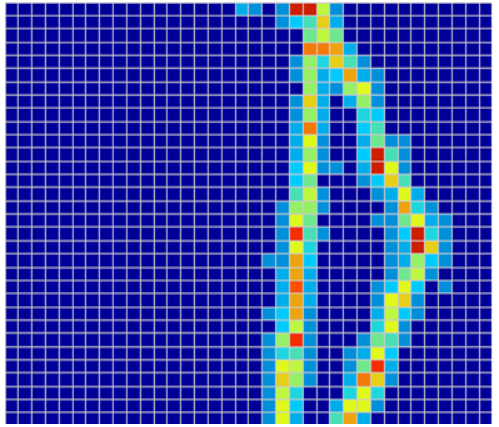
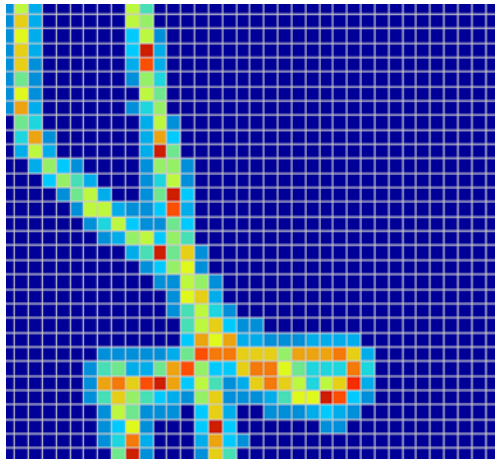
2nd prototype is under construction (ready in November 2020)

HA-TPC → start production early 2021

→ assembly in ND280 at Tokai (2022)

End of 2022 → start new measurements of ν-oscillation



Thank you for the attention!