

# The Japanese Neutrino Program and Spain



## Kamiokande, ~ 1983 → 1996

- search for proton decay
- first  $\nu$  astronomy, SN1987A



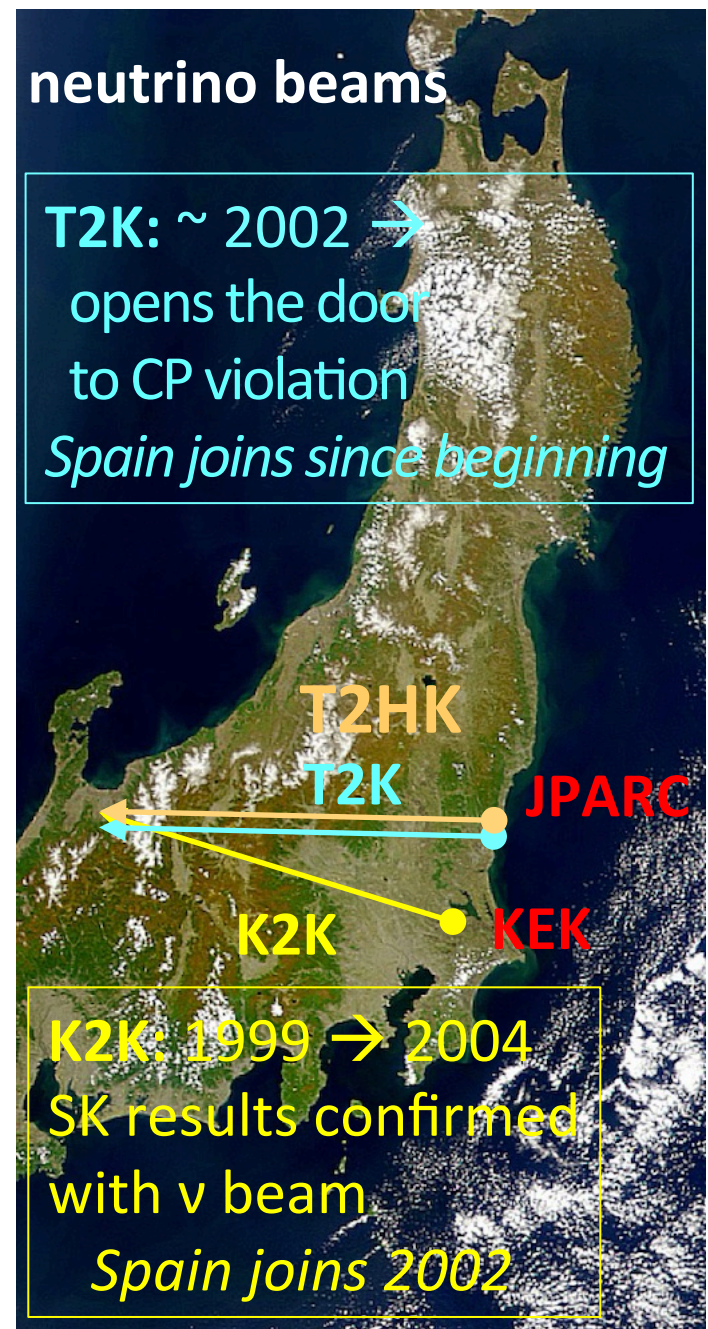
## Super-Kamiokande, ~1996 →

- $\nu$ s are massive,
- search for p- decay
- search for SN relic neutrino **SuperK-Gd**  
*Spanish group joins in 2008*

## ○ **next: Hyper-Kamiokande, ~ 2026 →**

- Origin of  $\nu$  mass, matter anti-matter asymmetry
- $\nu$  astrophysics and cosmology: Supernovae, DSNB, other sources
- proton decay, Grand Unification  
*Spanish group since beginning*

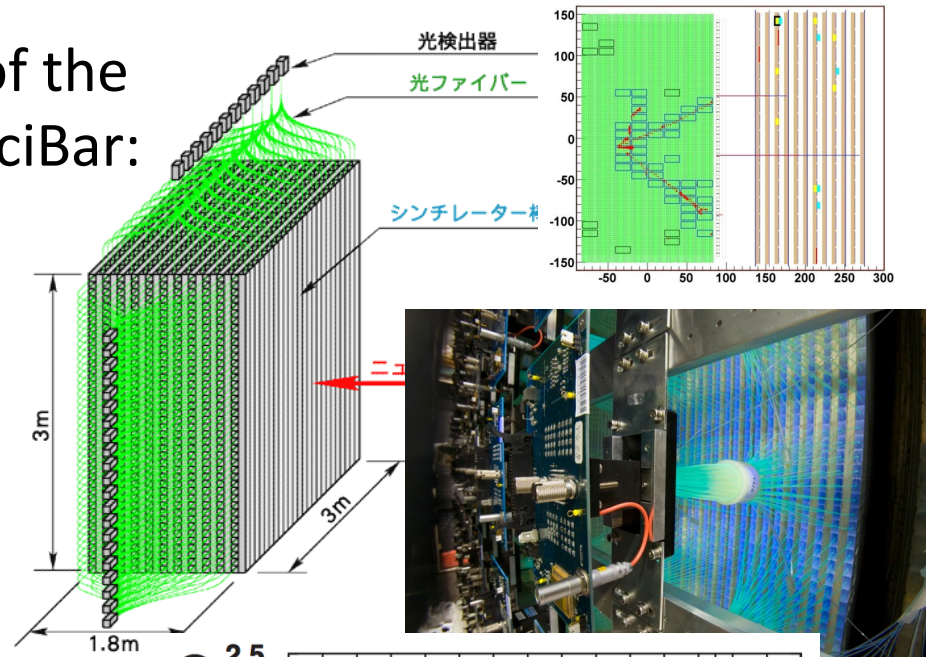
2018/10/10, La Palma  
L. Labarga, U.A.M.



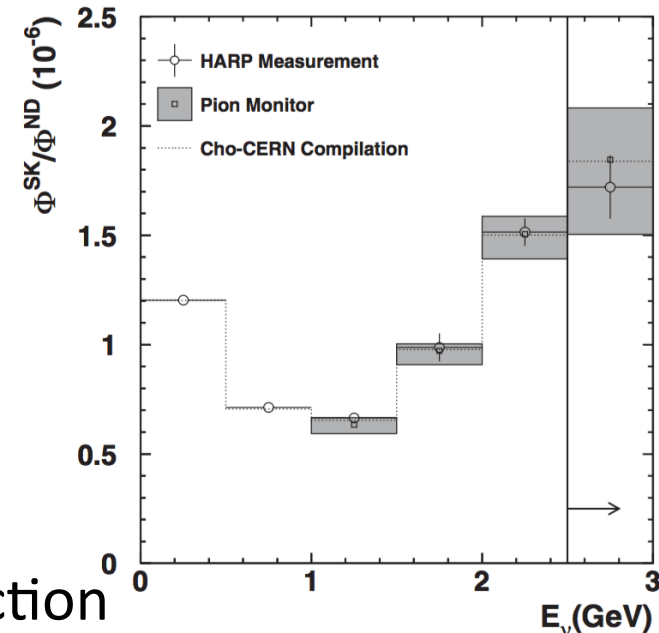
Spain joined K2K in 2002:



- IFAE: installation, commissioning of the near detector scintillator tracker SciBar:
  - Full reconstruction software
  - External veto equipment
  - Data analysis concentrated on neutrino-nucleus interactions



- IFIC: analysis of the HARP hadron production experiment data (CERN)
  - used the K2K replica target
  - computed the far/near extrapolation ratio using that data
  - → significant reduction of errors

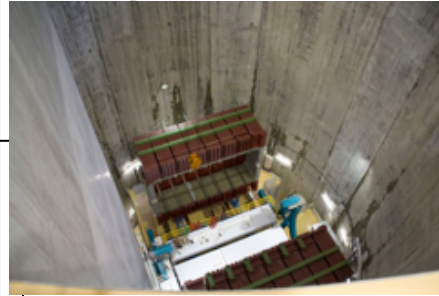
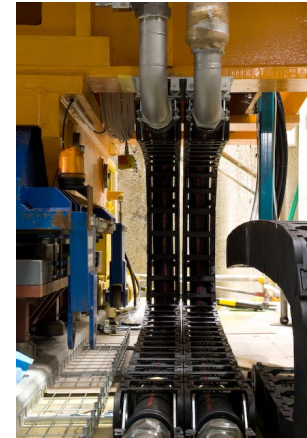


- Helped to Super-Kamiokande reconstruction

# Spain in

since 2002:    
+ since 2016: 

ND280 : Magnet  
Slow Control  
Cooling manifolds  
Magnet coordination.



ND280: TPC  
Detector Design  
MM calibration & procurement  
DAQ, Reconstruction software



Oscillation analysis  
Sterile oscillations  
Software development

Neutrino cross-sections  
Neutrino electrons.  
Calibration



group members have been co-conveners of several ND280 working groups (calibration, software and analysis)



Breakthrough prize on  
Fundamental Physics 2016



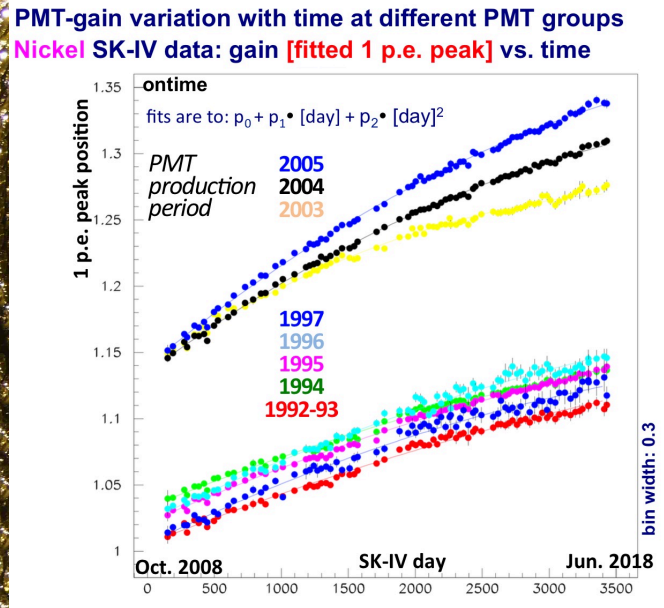
IP is member of the T2K EC since 2013  
IP was EU leader in the ND280 design group.

# Spain & Super-Kamiokande: since 2008

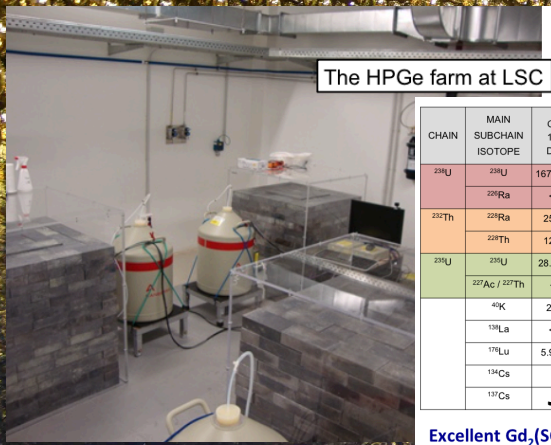
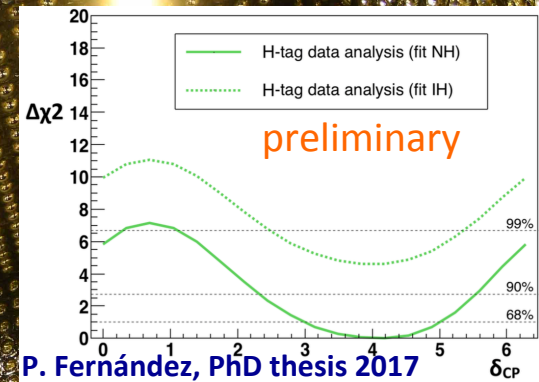
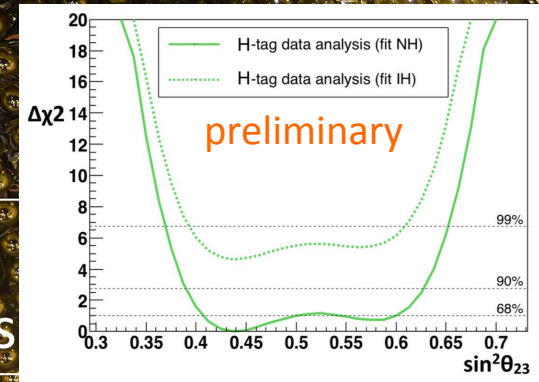
funding mostly from EU, UAM, Japan



calibrations,  
detector evolution, etc.



neutron-tag in  
oscillation analyses



## Radio-purity campaign at LSC for SuperK-Gd

CHAIN	MAIN SUBCHAIN ISOTOPE	GOX-1510-D-001	GSF-1701-D-003	GSF-1705-D-001	GSF-1711-D-171111B	GSF-1711-D-171111A	GSF-1703-A-702142	GSF-1703-B-(RGD-OSF-005)	GOX-1603-B-237	GOX-1603-B-239	GOX-1603-B-236	GSF-1604-B-1	GSF-1611-B-003	GSF-1703-B-(RGD-OSF-005)	GSF-1703-B-(RGD-OSF-005)b	GSF-1707-B-007	GSF-1604-C-160303	GSF-1707-B-007	GSF-1710-C-170901	GSF-1710-C-170902	GSF-1710-C-170903
<sup>238</sup> U	<sup>238</sup> U	1672 ± 122	< 45	< 11	< 52	< 168	< 13	< 13	< 68	< 130	< 36	< 25	< 13	< 10	< 19	< 10	< 20	< 10	< 9.7	< 12	< 11
	<sup>226</sup> Ra	< 2.8	0.4 ± 0.2	4.3 ± 0.6	< 1.1	2.0 ± 1.4	0.7 ± 0.4	< 0.34	< 0.9	< 1.0	< 1.4	< 0.6	< 0.3	< 0.31	< 0.54	< 0.18	< 0.64	< 0.18	< 0.21	< 0.21	< 0.21
<sup>232</sup> Th	<sup>232</sup> Th	259 ± 6	28.5 ± 1.1	12.2 ± 1.0	300 ± 7	778 ± 39	< 0.39	< 0.39	< 2.7	< 2.3	< 1.4	< 0.7	< 0.3	< 0.30	< 0.74	< 0.21	< 0.67	< 0.21	< 0.24	< 0.26	< 0.30
	<sup>228</sup> Th	124 ± 3	6.3 ± 0.5	2.5 ± 0.4	31 ± 2	70 ± 3	1.7 ± 0.4	< 0.28	< 2.5	< 1.4	< 0.8	0.9 ± 0.3	< 0.4	< 0.33	< 0.43	< 0.26	0.5 ± 0.2	< 0.26	< 0.28	< 0.31	< 0.30
<sup>235</sup> U	<sup>235</sup> U	28.7 ± 1.5	< 1.5	< 1.0	< 3	< 4	< 1.3	< 0.77	< 1.6	< 0.8	< 1.0	< 3.1	< 0.6	< 0.69	< 0.82	< 0.3	< 0.7	< 0.3	< 0.35	< 0.41	< 0.42
	<sup>227</sup> Ac / <sup>227</sup> Th	< 14	< 5.5	3.4 ± 1.4	31 ± 5	46 ± 9	< 3.1	< 2.3	< 4.3	-	-	< 6.1	< 1.9	< 1.8	< 2.0	< 1.2	< 2.3	< 1.2	< 1.7	< 1.4	< 1.6
<sup>176</sup> Lu	<sup>176</sup> Lu	21 ± 6	< 1.0	< 1.8	27 ± 3	57 ± 4	< 8.2	< 3.2	< 4.6	< 5.3	< 3.4	< 2.1	< 1.8	< 1.5	< 2.5	< 0.9	< 1.6	< 0.9	< 0.8	< 1.0	< 0.7
	<sup>139</sup> La	< 3.2	< 0.25	< 0.36	< 2.4	< 2.4	< 0.29	< 0.29	< 0.6	< 0.7	< 0.7	< 0.5	< 0.3	< 0.29	< 0.31	< 0.20	< 0.3	< 0.20	< 0.09	< 0.05	< 0.14
	<sup>176</sup> Lu	5.9 ± 0.4	26.5 ± 0.8	6.1 ± 0.4	< 1.2	4.3 ± 0.6	2.6 ± 0.3	< 0.29	< 0.8	< 0.7	< 1.6	0.4 ± 0.3	0.4 ± 0.1	< 0.46	< 0.41	0.4 ± 0.1	< 0.4	0.8 ± 0.1	0.13 ± 0.03	0.11 ± 0.04	< 0.14
	<sup>134</sup> Cs	-	-	-	-	-	-	-	< 0.24	< 0.4	< 0.23	< 0.24	< 0.09	< 0.09	-	< 0.06	< 0.1	< 0.06	< 0.08	< 0.06	< 0.07
<sup>137</sup> Cs	-	-	-	-	-	-	-	< 0.3	< 0.34	< 0.30	< 0.24	< 0.16	< 0.12	-	< 0.12	< 0.1	< 0.12	< 0.13	< 0.10	< 0.11	

J. Pérez, PhD thesis 2017

Excellent Gd<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> achieved, within specifications within experimental limits; Now preparing for mass production screening.

Name of Samples analyzed [MATerial-date-Company-lot]  
\*GSF: Gd<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>, GOX: Gd<sub>2</sub>O<sub>3</sub>

# Spain in Hyper-Kamiokande



funding from EU, UAM, Japan

- Relatively large UAM contribution to project proposal just approved
- UAM working on simpler / cheaper approach to anti-implosion covers for the ~40000 PMT
- Already V1, V2 designed, prototypes made in Spain; tested in Spain and Japan



Hydrostatic pressure tests of V1 at Kamioka



V1



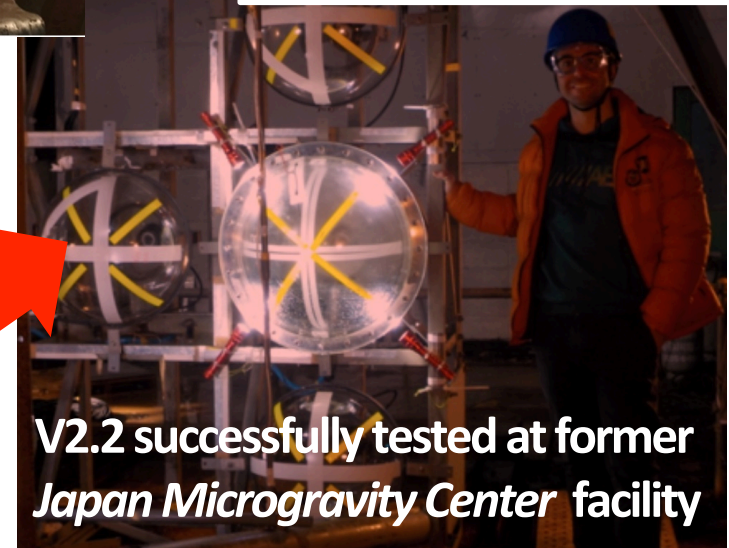
V2.2



Hydrostatic pressure tests at Spain for V2



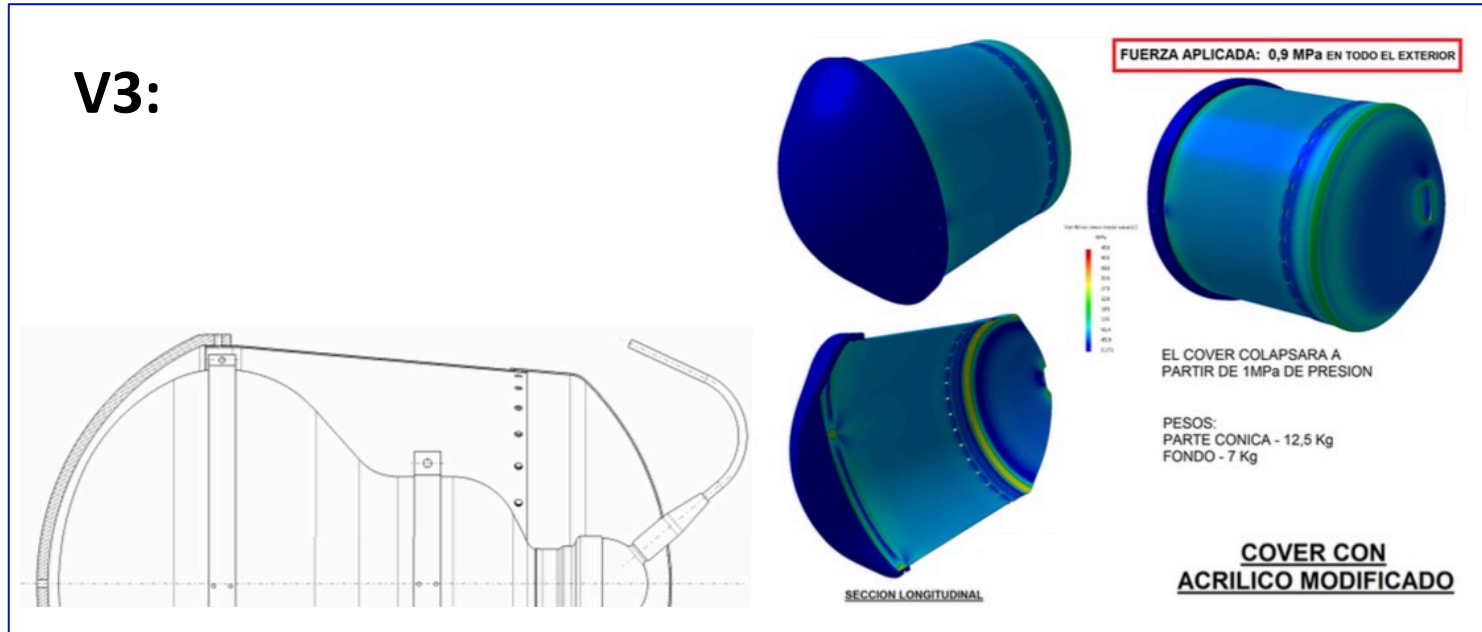
V2.0



V2.2 successfully tested at former Japan Microgravity Center facility

# Potential Action Items Spain

- short-medium term:
  - ✓ to continue our R&D on low cost PMT cover



- ✓ radio-purity screening campaigns at the Canfranc Underground Laboratory (large experience with SK-Gd)
- ✓ R&D on attachment system PMT-Cover-Structure (more manpower/money need)
- mass production; in all cases is **XY000** items (maximum ~40000):
  - ✓ anti-implosion cover for PMT
  - ✓ ancillary mechanical parts for PMT-Cover-Structure
  - ✓ DAQ etc. electronic boards (for the time being only production)

# Additional Materials

## Spain in K2K and T2K

- The ministry has directly financed the Japanese program through IFAE and IFIC:
  - IFAE : 1800000 Euros in 16 years (almost all invested in the Japanese program).
  - IFIC: 1200000 euros inverted in the Japanese program
- Other sources of finance has been the European Community through Jennifer program with 100000 euros (IFAE).
- IFAE has produced 7 PhD (+ 4 in preparation), 7 master thesis, 6 master degrees and 6 secondary school science masters. 7 post-docs have been trained at IFAE neutrino during this period.
- IFIC has produced 5 PhD thesis in K2K and T2K and has trained 5 post docs in those experiments

## Key people

- IFAE: E. Fernández (IP K2K), F. Sánchez Nieto (IP T2K)
- IFIC: J.J. Gómez Cadenas (IP K2K), A. Cervera Villanueva (IP T2K)
- UAM: L. Labarga