



Characterization of the upgraded J-PARC neutrino beam for T2K-II and HK experiments

Romain Gaïor on behalf of the NU_09 project
2026/05/19

LPNHE
PARIS

I L **^** N C E

Context of NU_09:

Motivation:

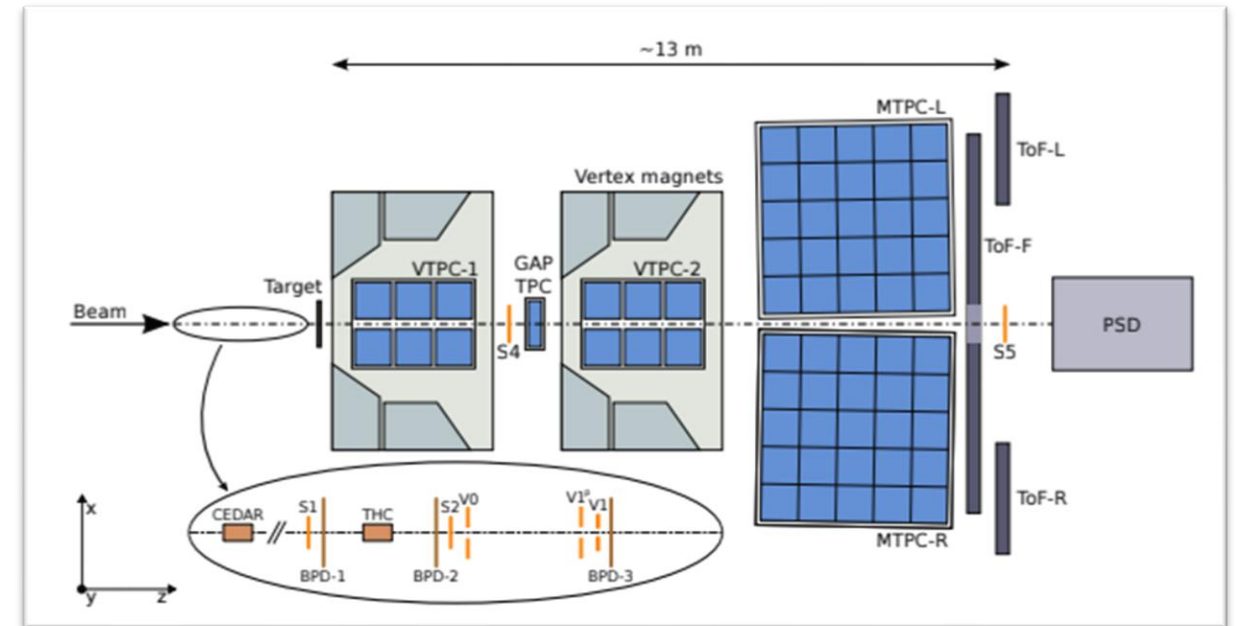
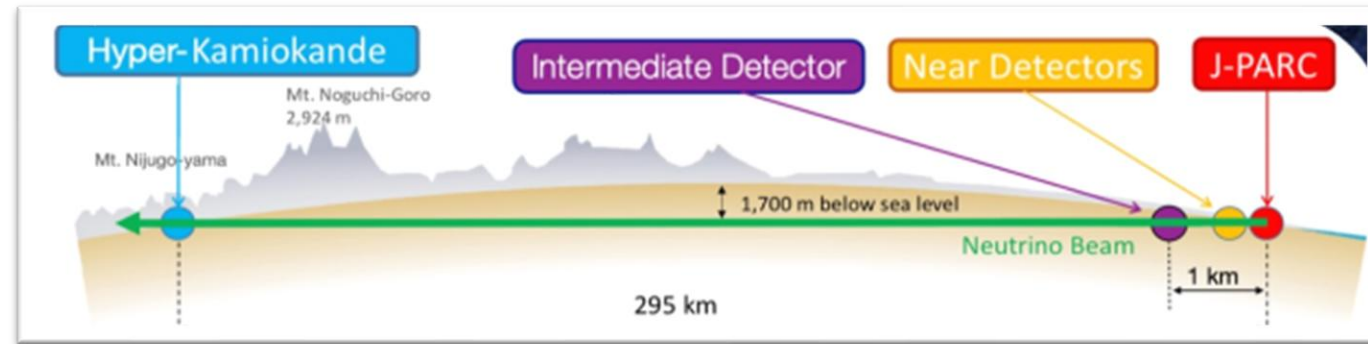
- ν oscillation with long baseline
- Broad ν physics program
- Search for CP violation

Tools

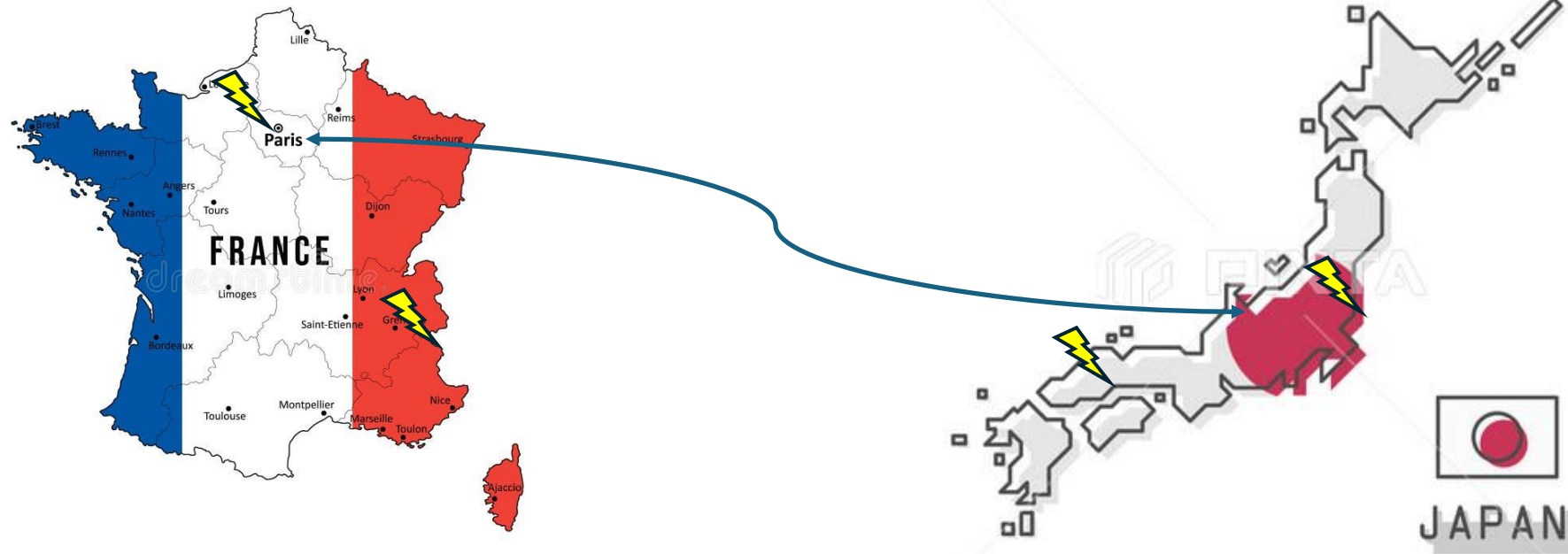
- T2(H)K
 - Beam from JPARC
 - Near Detector
 - Far Detector (Super / Hyper Kamiokande)
- NA61/SHINE
 - CERN based experiment to study the beam condition of T2K

Goal specific to NU-09:

- Improve the beam condition
- Characterize the beam
- Prepare future



France-Japan collaboration



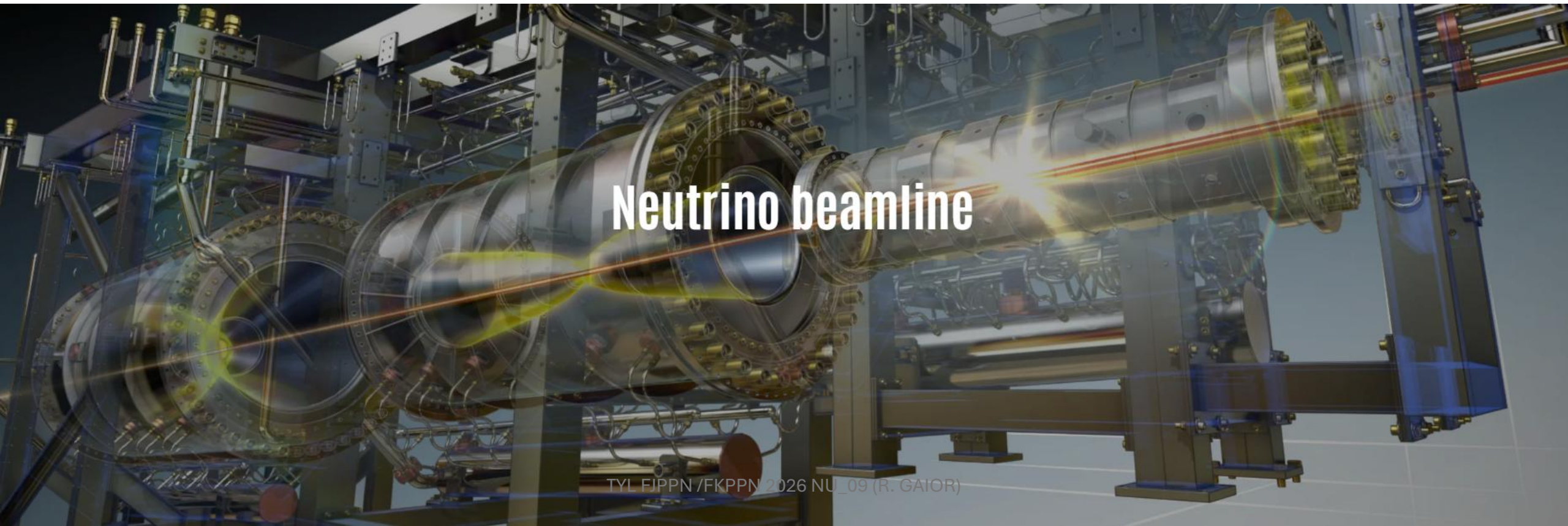
LPNHE / CERN

- Boris POPOV
- Claudio GIGANTI
- Romain GAIOR
- Mathieu GUIGUE
- Lorenzo RESTREPO
- Maria Adriana SABIA
- Stefano RUSSO
- Vincent VOISIN
- Claire DALMAZZONE

KEK / Okayama

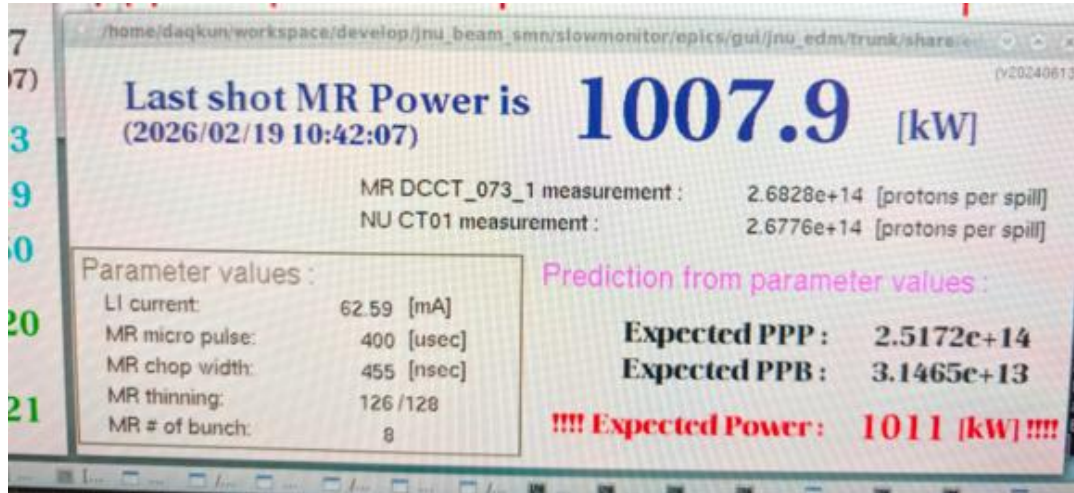
- Ken SAKASHITA
- Yoshikazu NAGAI
- Yota HINO
- Megan FRIEND
- Yusuke KOSHIO
- Ayana ASAI
- Yuki SHIRAISHI
- Takeshi NAKADAIRA
- Sakiko NISHIMORI

Beam operation and characterization at JPARC

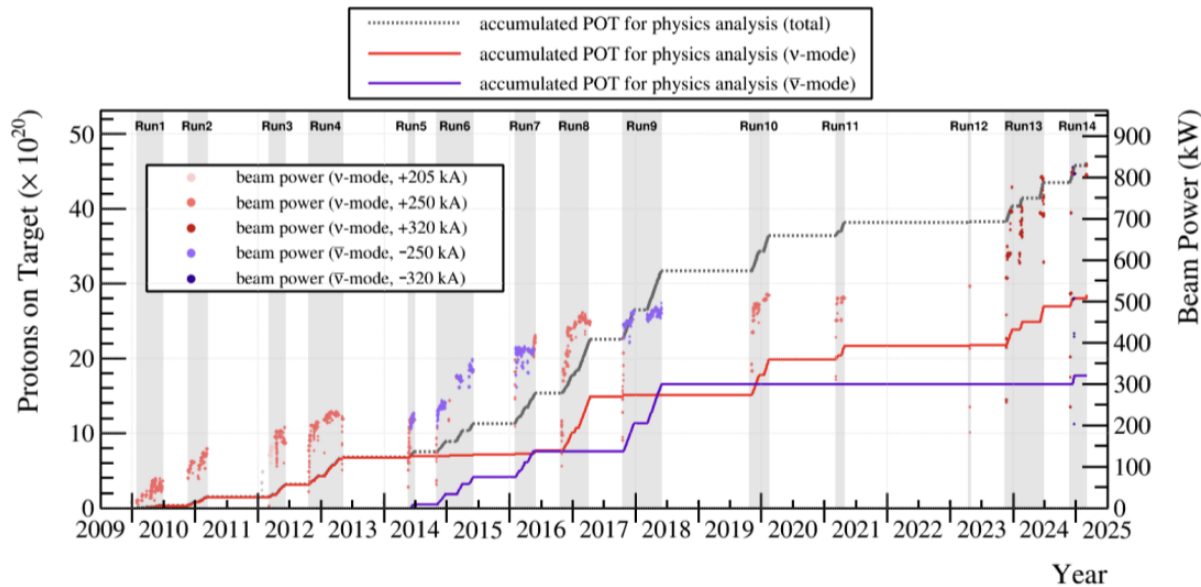


Neutrino beamline

Beam Operation at JPARC



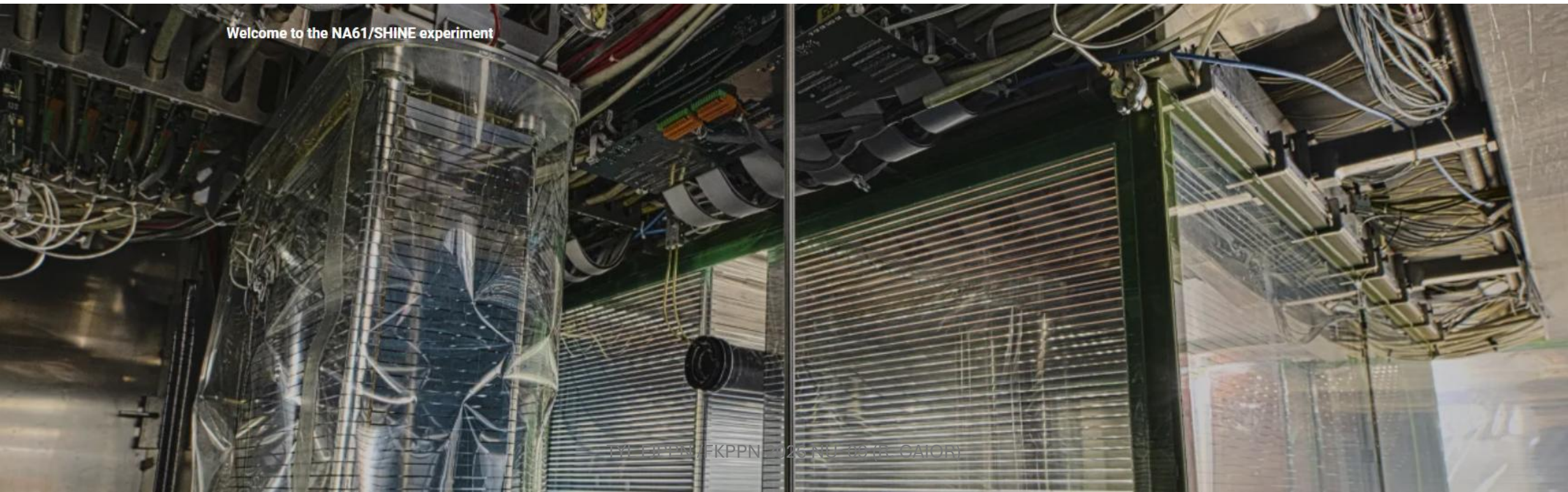
- Upgrade of JPARC MR
Cycle time from 2.8s/spill to 1.3s/spill
- Operation of the magnetic horn at 320kA
(instead of 250kA)
- Dedication of JPARC team



- ✓ 1MW beam ! On track to reach 1.3MW in 2028
- ✓ 3.69×10^{21} P.O.T. as of March 2025
- ✓ Make all possible effort to restart the beam in June 2026

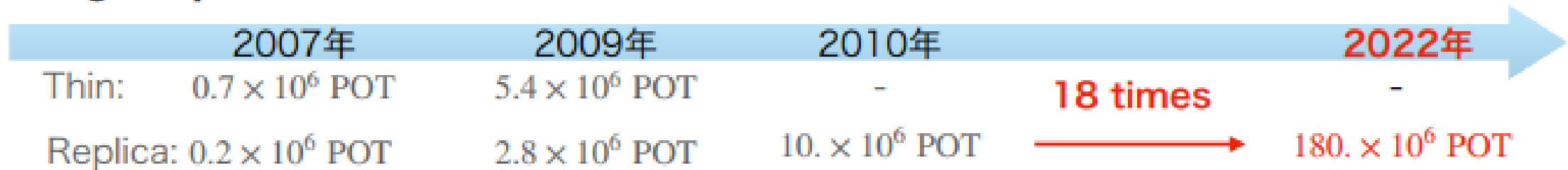
Beam Characterization

ν flux estimation with NA61/SHINE



History of the data-taking for T2K

C target + proton@31 GeV/c run



<Thin target> (in use: 2009 data set)

NA61



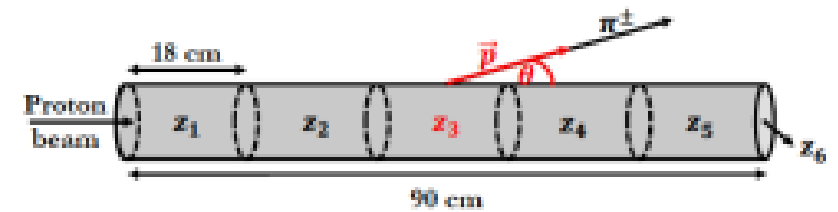
T2K



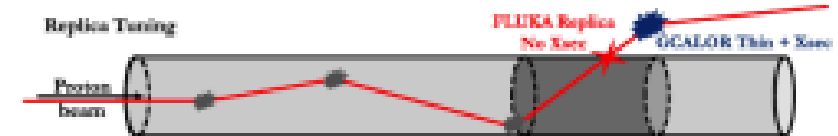
- Target length: 2 cm
- Measured value: $d^2\sigma/dpd\theta$
- The double differential production cross section is measured from the primary interactions.

<T2K replica target> (in use: 2010 data set)

NA61

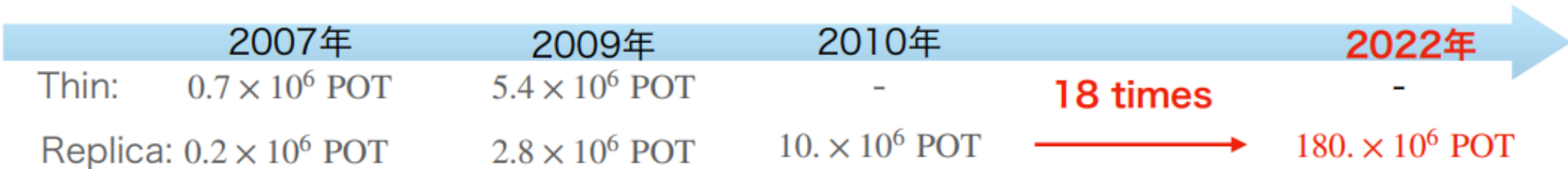


T2K

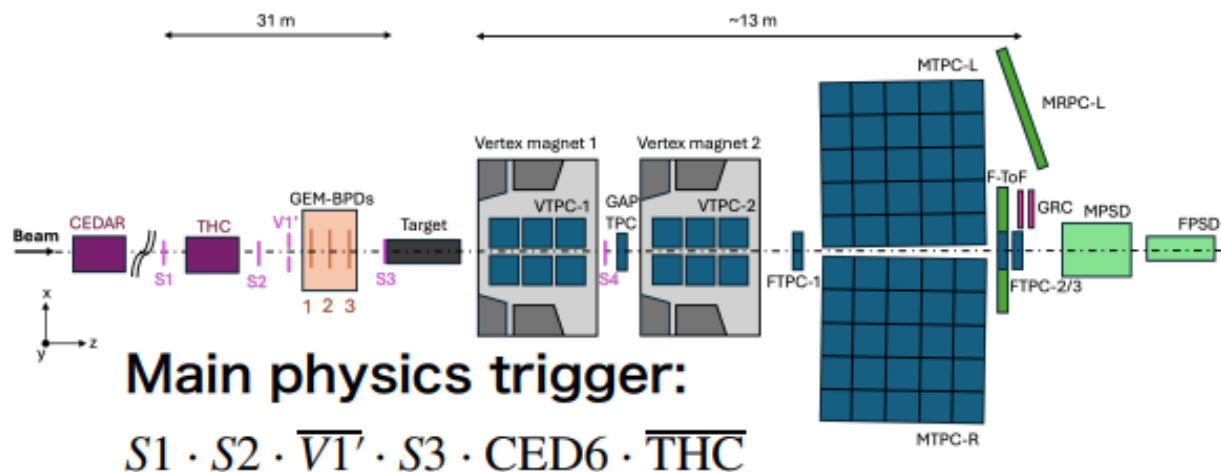
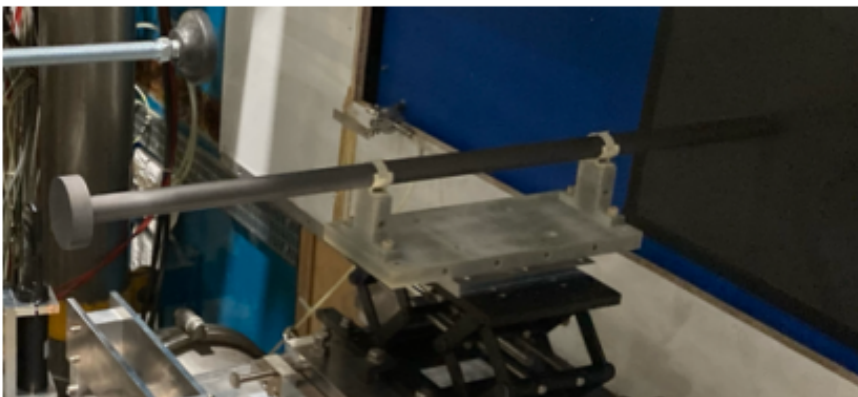


- Target length: 90 cm (the same as T2K)
- Measured value: $d^3N/dzdpd\theta$
- The hadron yields at the target surface are measured, and they can be used for the yield tuning directly.

T2K replica target + proton@31 GeV/c run (2022)



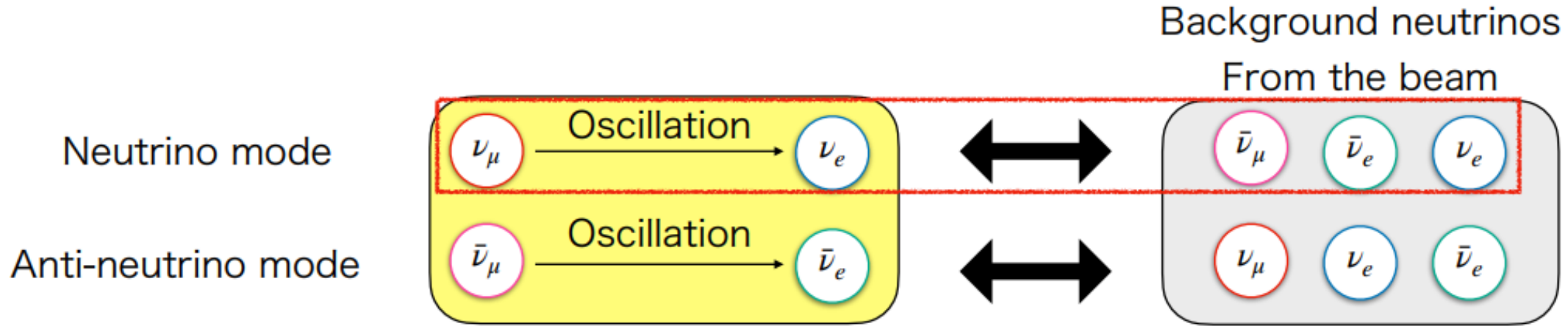
T2K replica target



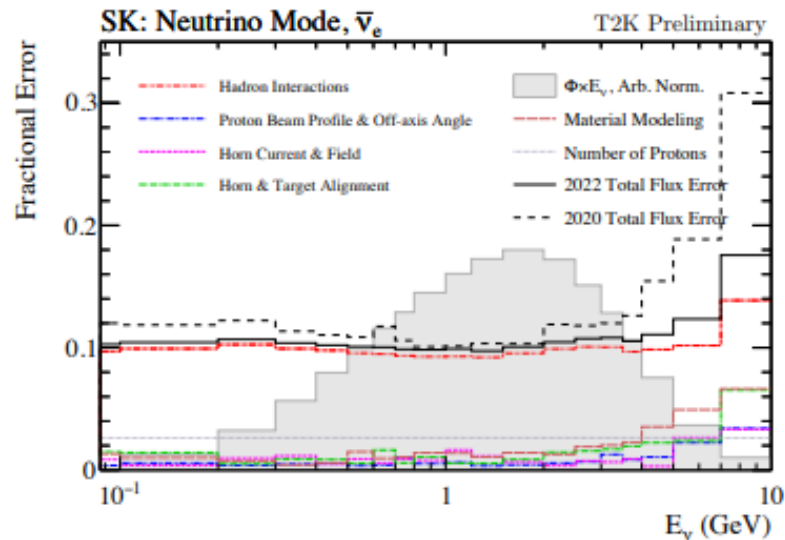
Particle	Thin (2 cm)	Replica (90 cm)	Plan with 2022 dataset
π^+/π^-	✓ (2009)	✓ (2010)	
K^+/K^-	✓ (2009)	△ (not enough)	Measurement of the high energy charged kaons
P	✓ (2009)	✓ (2010)	
K_S^0	✓ (2009)	✗	First measurements using a T2K replica target
Λ	✓ (2009)	✗	

- NA61/SHINE measures the differential production yield for each momentum and angle of K_S^0 .
- The results are input to a T2K beam simulation to estimate K_L^0 production at T2K.
- The analysis in NA61/SHINE is performed by reconstructing the trajectory for the process of $K_S^0 \rightarrow \pi^+ + \pi^-$.

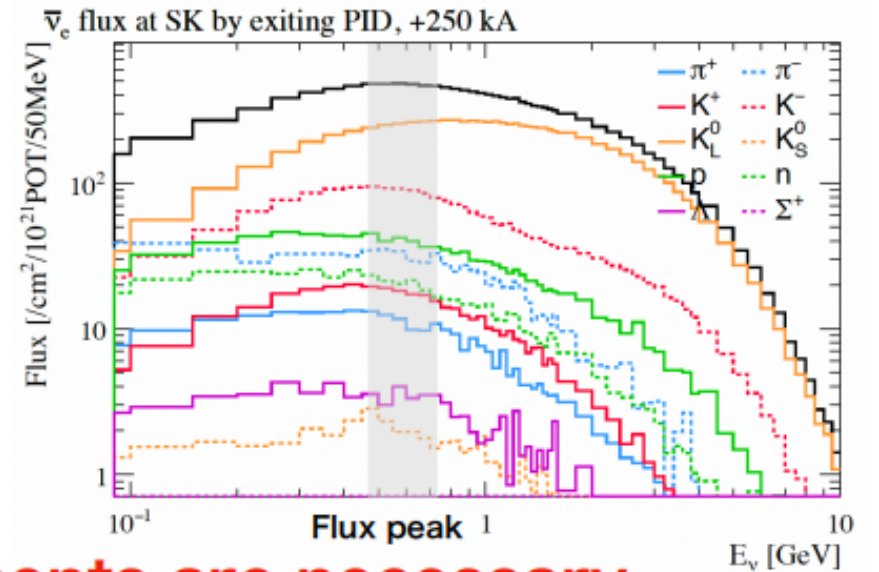
The motivation of K_S^0 measurement (1)



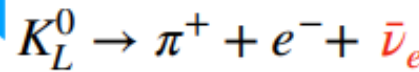
$\bar{\nu}_e$ flux uncertainties at SK



$\langle \bar{\nu}_e \text{ flux by type of parent particle (Neutrino mode) \rangle$



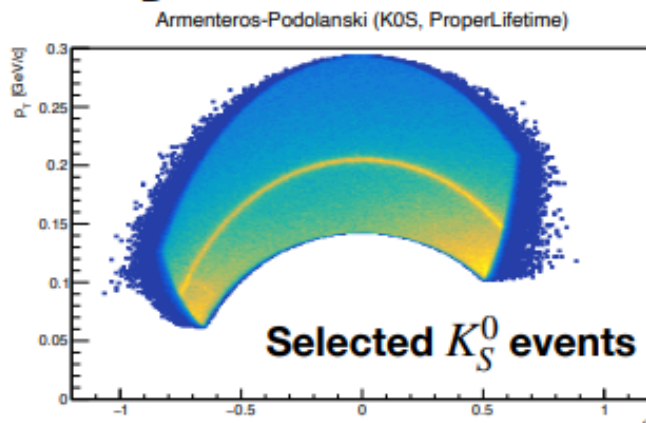
Main component



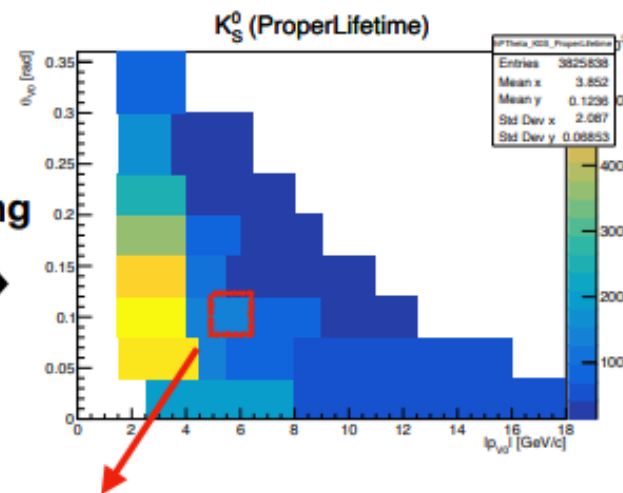
Additional NA61/SHINE measurements are necessary.

K_S^0 analysis status

- The data analysis is currently under review within the NA61 collaboration, and results will be published soon.



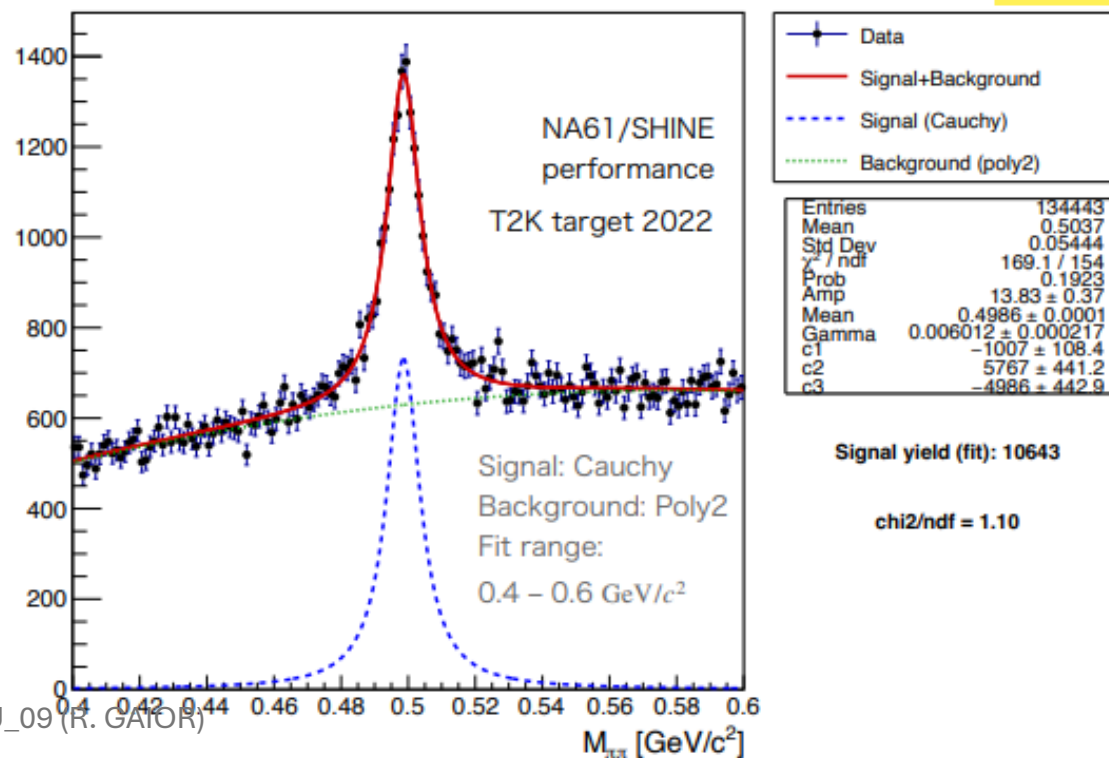
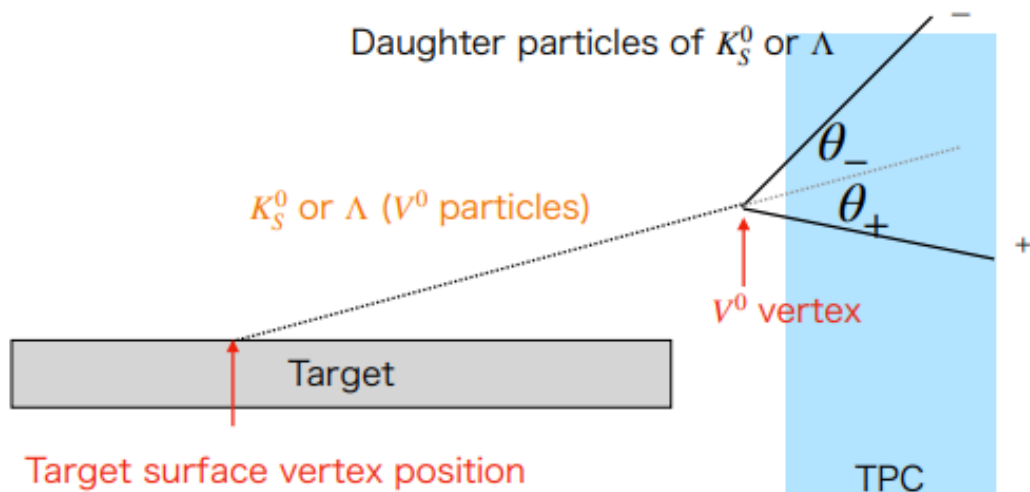
Binning



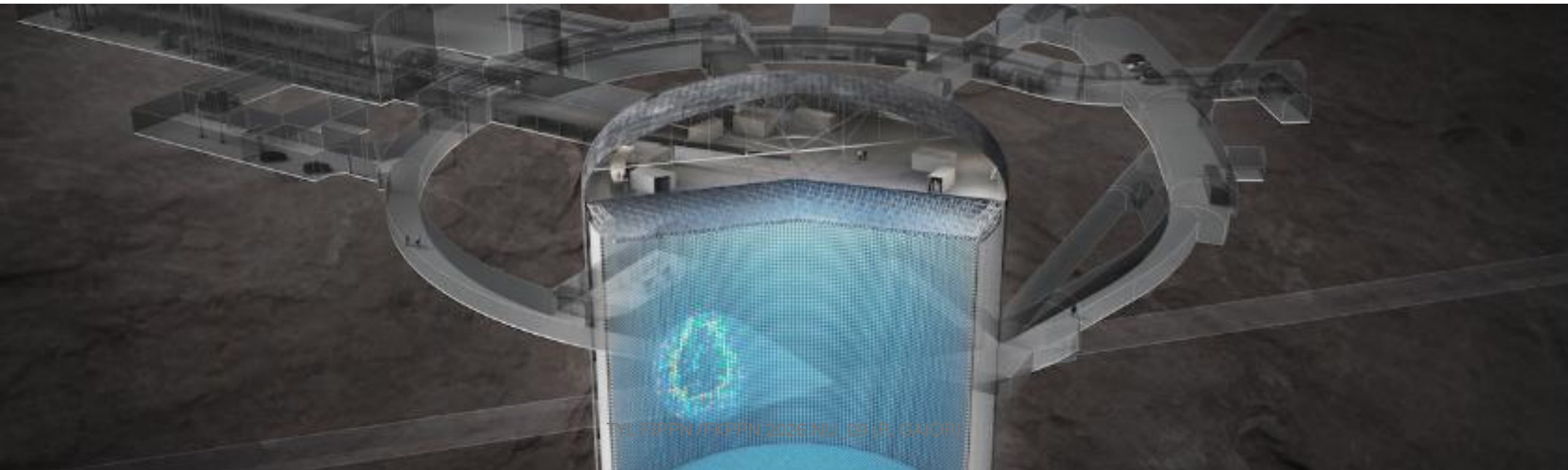
K_S^0 invariant mass (ProperLifetime, $0.080 < t < 0.120$, $5.000 < p < 6.500$)

Data

- Invariant mass fits are performed well for each kinematic bin.




Hyper Kamiokande: Sensitivity studies Timing system development



Sensitivity studies



See the award winner talk !
(Monday 18/05)



 **Hyper-Kamiokande**

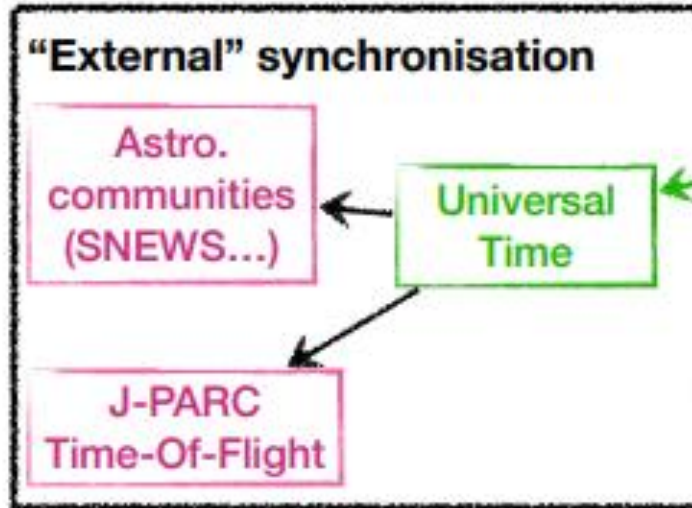
**Sensitivity studies for neutrino oscillation
parameters measurement and time
synchronisation system for the
Hyper-Kamiokande experiment**

Claire Dalmazzone

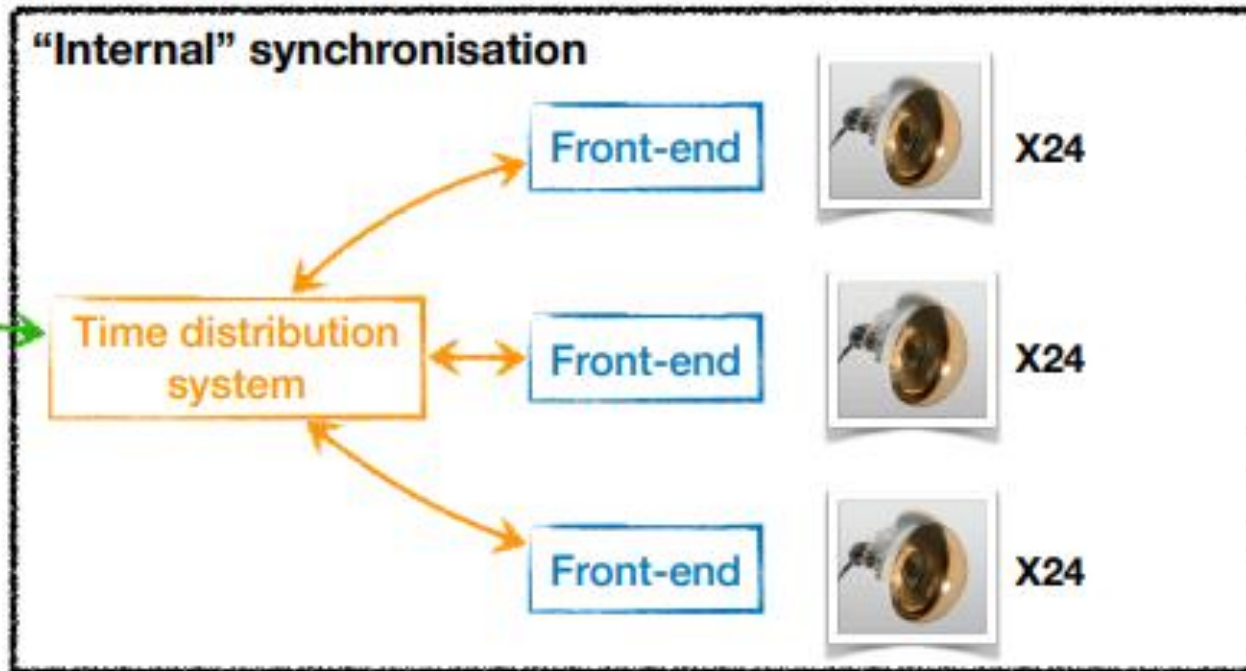
TYL/FJPPN Young Investigation Award Ceremony, Monday May 18th

Timing system development for HK

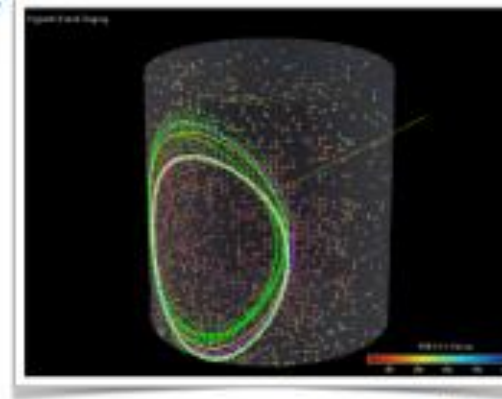


Correlation with external experiments
(J-PARC Time-Of-Flight, Supernovae...)
→ event time-tagging < 100 ns using GNSS receivers

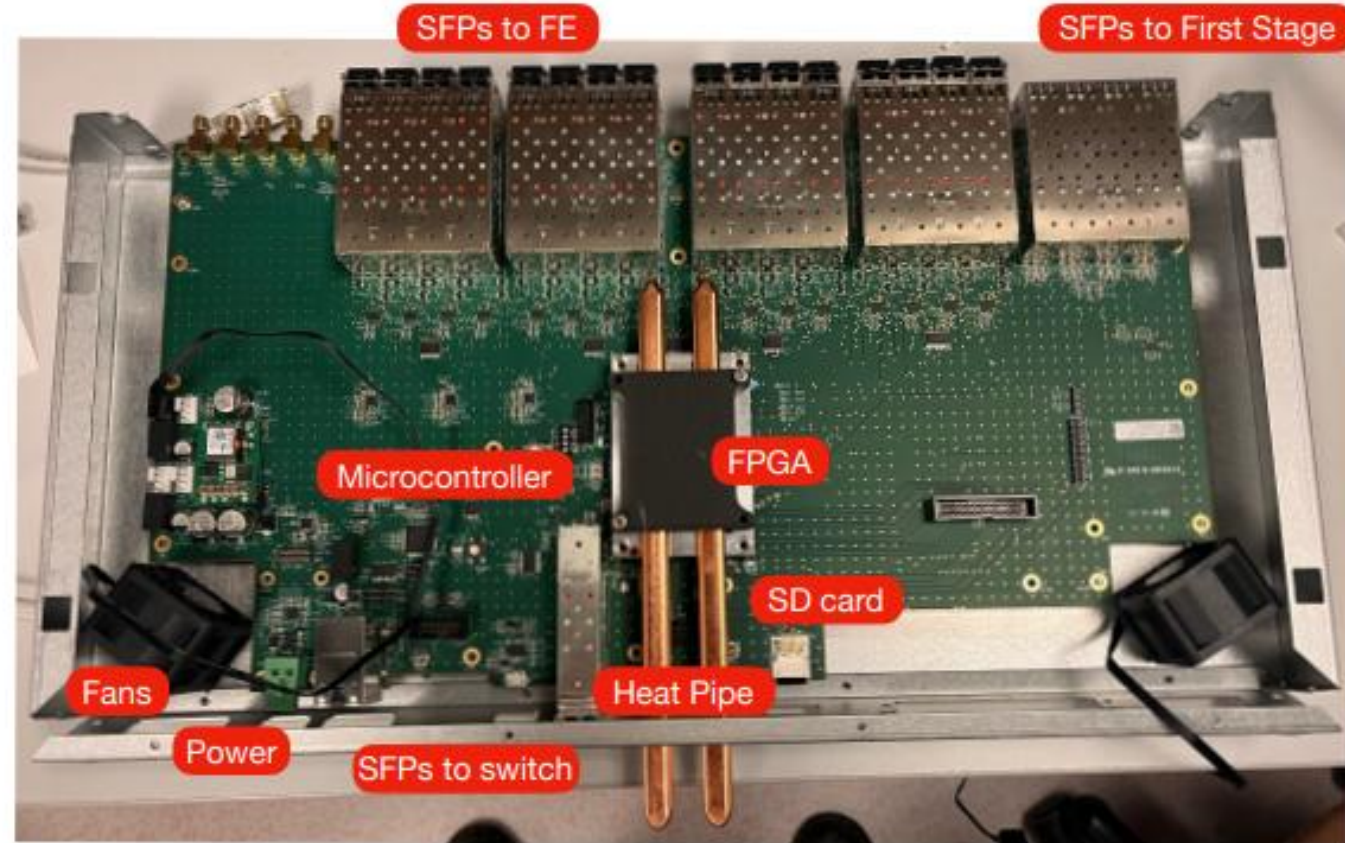
Local reference
(atomic clock)



Rings reconstruction by coincidence
→ time difference between PMTs
< 100 ps
→ constant skew after reset



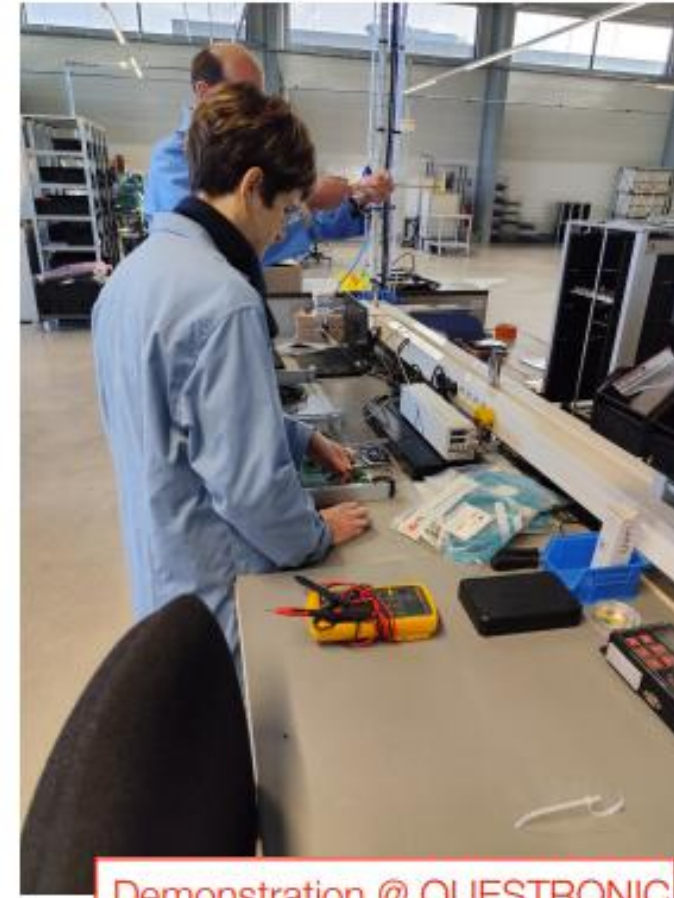
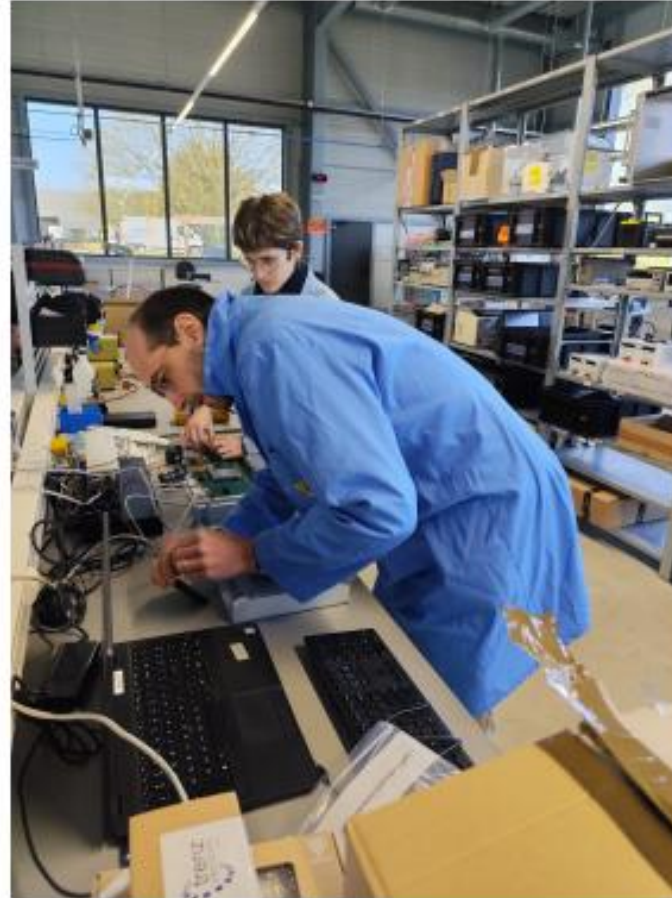
- The TDM board is designed to:
 - Receive master clock and distribute it with jitter at the endpoint $<$ requirement
 - Guarantee a constant channel to channel phase difference over each reset and power up compensating the differences introduced by different cable lengths
 - Guarantee a bidirectional data bandwidth $>$ 100 Mbps
 - Communicate to the DAQ system to exchange slow control data.
 - Redundant optical fiber link to each FE to be activated by a software command



- Main element : a Xilinx XCZU9EG Zynq ultrascale+ SoC FPGA
 - FPGA comes pre-assembled on a electronics board hosting main power supply section, a double data rate (DDR) memory for the processor etc... no complex routing on the board
 - Link between the TDM and the system-on-module with 4 high-speed connectors with 160 pins each

Integration: assembly procedure

- Assembly and testing procedure ready to be handled to external company (OUESTRONIC)
 - Goal: screening of faulty components and bad solderings
 - Procedure:
 - Physical installation: populated board fixed on a dedicated support, external components are mounted (mezzanine module, SFPs, SD card and cables)
 - Automatic tests: board switched on, ID info collected and network configured. Board parameters checked (voltages, current, temperature). Bit error rate measurement is done on all links.
 - Physical disassembly: the operator checks that data is collected and removes the SD card.



Demonstration @ OUESTRONIC

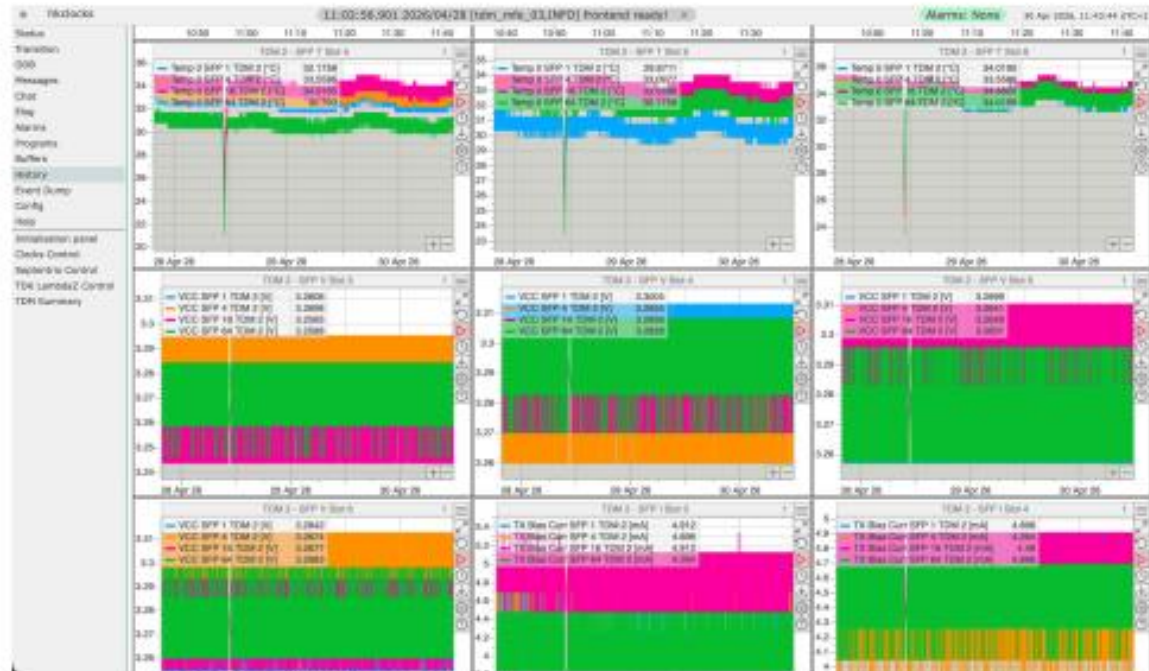
- At the end of the tests, the TDM is either ready to be used or declared faulty
- A report is posted on the github page of the tests.

TYL FJPPN /FKPPN 2026 NU_09 (R. GAIOR)

Slide from M.A. Sabia

Integration

- Fully equipped rack to mimic the configuration at Hyper-K
- 4 latest version TDMs up and running
- One TDK Lambda power supply
- One switch
- External fans for additional ventilation (exploits the heat pipe)
- Slow control via MIDAS to monitor temperature, voltages etc.



TYL FJPPN /FKPPN 2026 NU_09 (R. GAIOR)

Slide from M.A. Sabia



Time Distribution Modules

Switch

Power Supply TDK Lambda

Voltage Splitter



Installation at JPARC

- Needs synchronization between the beam and far detector
 - Similar timing generation and distribution system needed at JPARC
 - Dedicated link between JPARC timing and TDM
- Antenna support designed at LPNHE
- Just shipped and Installed at JPARC
- Planned test (06/2026): integration of TDM board with the JPARC beam timing system

GNSS Antenna installed at JPARC Neutrino building



Conclusion

- NU_09 project focused on the oscillation studies with T2(H)K:
 - Beam characterization (JPARC) and calibration (NA61/SHINE)
 - Development of timing system for HK
 - Sensitivity studies for HK
- Exciting time for the project:
 - NA61/SHINE:
 - Finalise and publish the K0s analysis
 - Measure the P and K yield → reduce flux uncertainties
 - T2K Beam:
 - Publish the use of target replica for the flux prediction and systematics reduction
 - Timing system:
 - Production in 2026
 - Integration and installation site in 2027