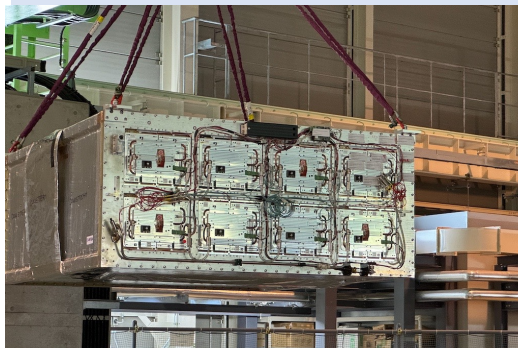


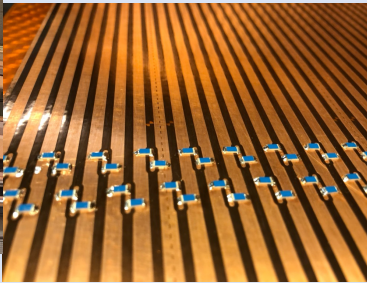
# Hyper-K (T2K/SK) in CSN1

Resp. Locale  
E. Radicioni

"Hyper-K" e' essenzialmente una sigla contenitore che include le attivita' di fisica del neutrino in Giappone subentra alla storica sigla T2K/CSN2 (2007-2024)

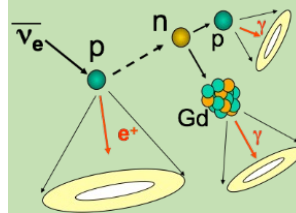
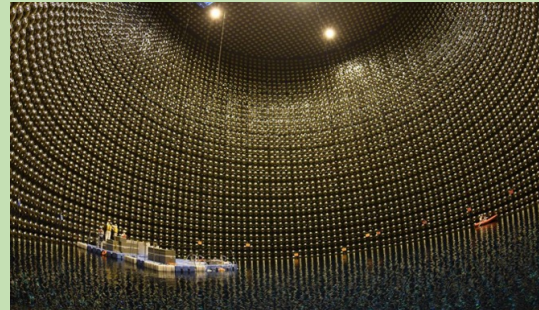


T2K

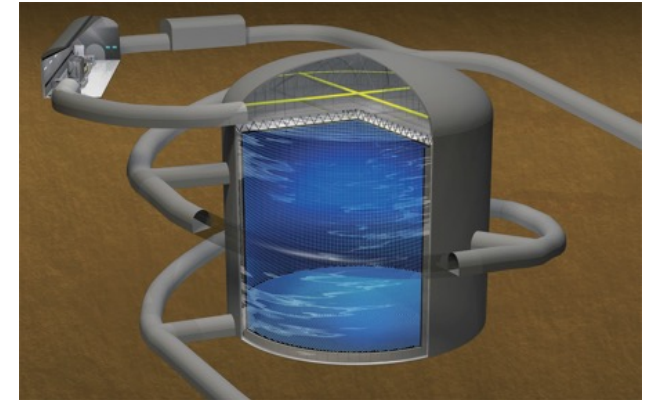


- Realizzazione di 2 nuove TPC (Test al CERN, Installate in Giappone 2023/2024, Commissioning 2024 )
- Installazione , Commissioning e integrazione del nuovo Gas System a JPARC
- Data Taking + Analisi

SK



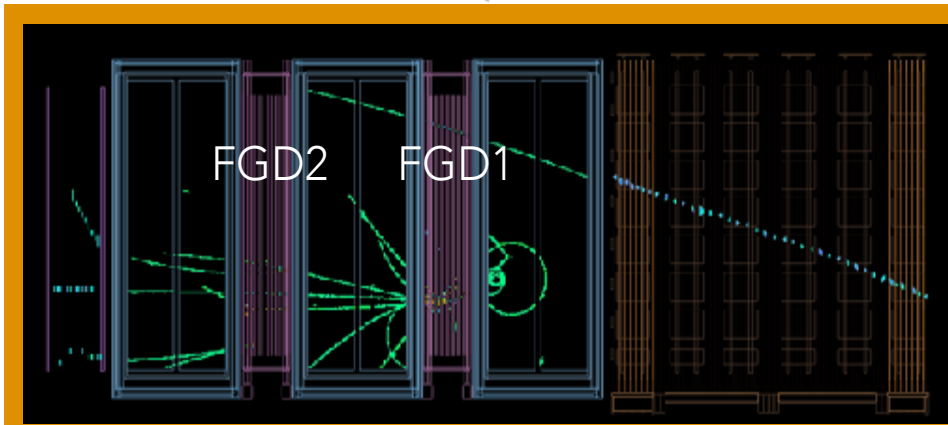
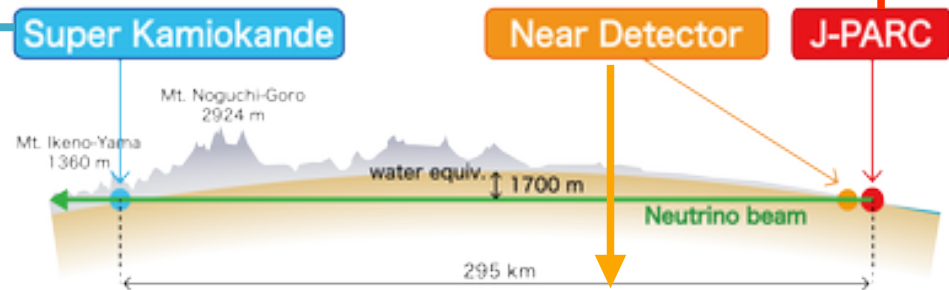
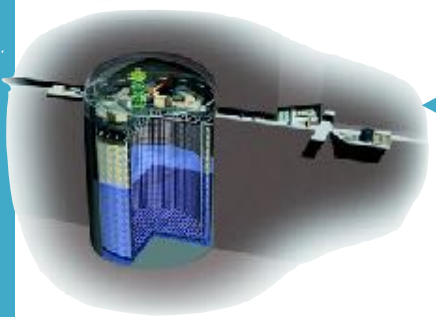
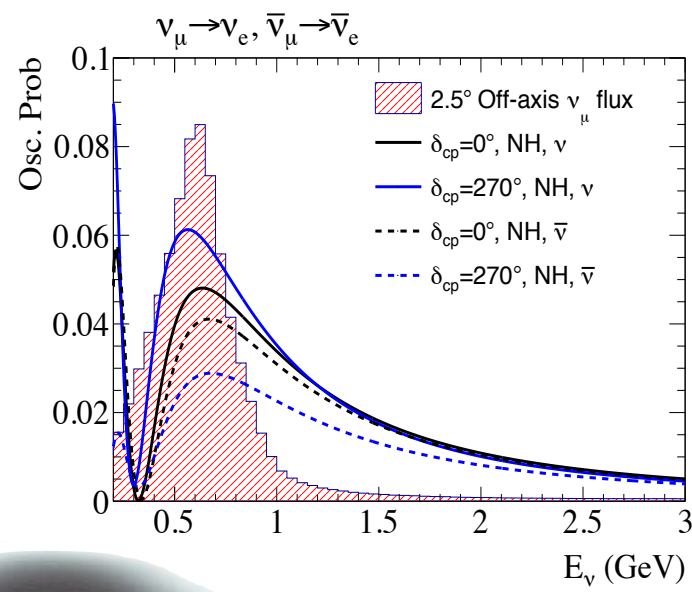
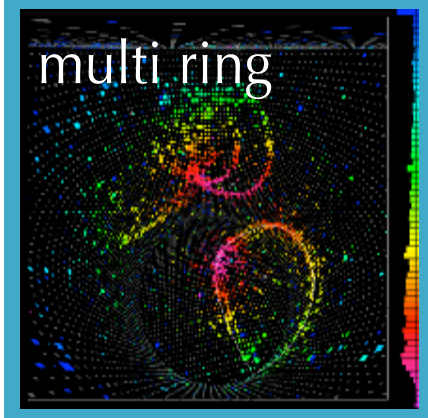
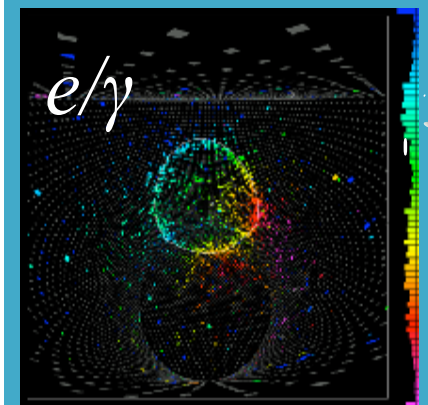
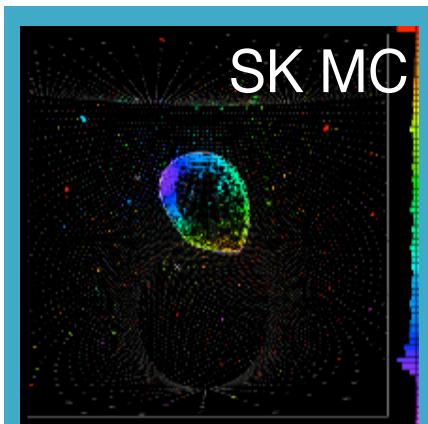
Dissolvimento Gadolinio  
Data Taking + Analisi



Hyper-K : Approvato Settembre 2022

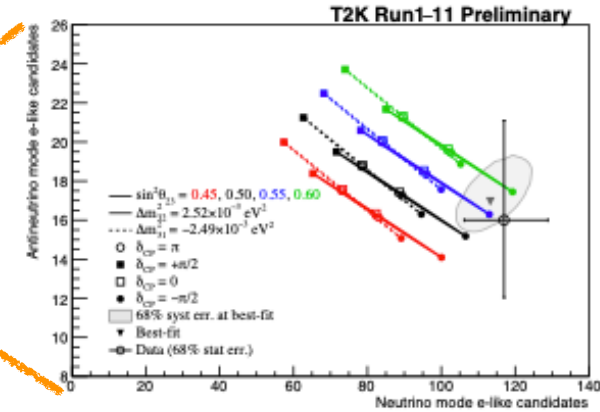
Construction phase

# The T2K experiment @JPARC in a "Nutshell"

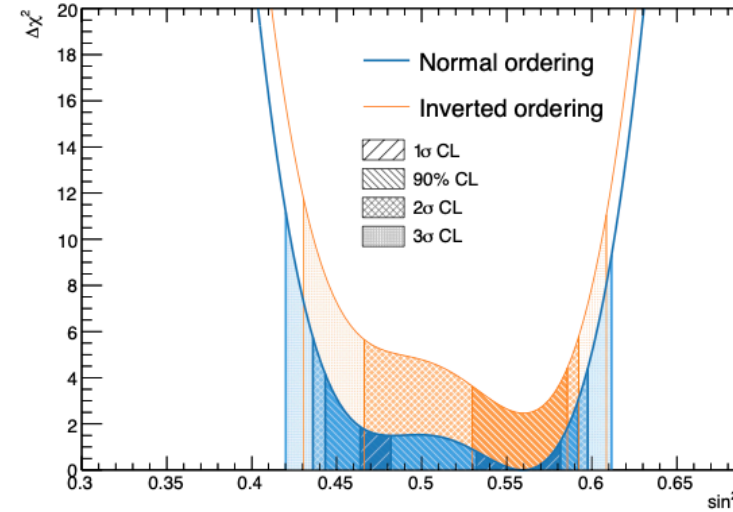
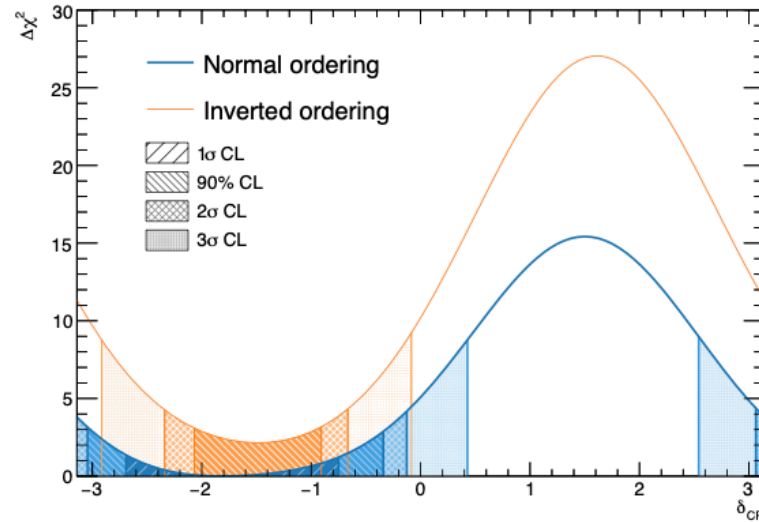


# T2K highlights (from Neutrino 2024)

|                              | $\delta_{CP} = -\pi/2$ | $\delta_{CP} = 0$ | $\delta_{CP} = \pi/2$ | $\delta_{CP} = \pi$ | $\delta_{CP} = -2.08362$ | Data |
|------------------------------|------------------------|-------------------|-----------------------|---------------------|--------------------------|------|
| FHC 1R $\mu$                 | 417.175                | 416.263           | 417.13                | 418.176             | 419.535                  | 357  |
| RHC 1R $\mu$                 | 146.65                 | 146.278           | 146.653               | 147.053             | 146.979                  | 137  |
| FHC 1Re                      | 113.168                | 95.4898           | 78.3118               | 95.99               | 112.053                  | 102  |
| RHC 1Re                      | 17.6271                | 20.0327           | 22.1536               | 19.7481             | 18.0458                  | 16   |
| FHC 1R $\nu_e$ CC1 $\pi^+$   | 10.0463                | 8.78564           | 7.15618               | 8.41697             | 9.89284                  | 15   |
| FHC MR $\nu_\mu$ CC1 $\pi^+$ | 123.889                | 123.349           | 123.863               | 124.411             | 123.318                  | 140  |

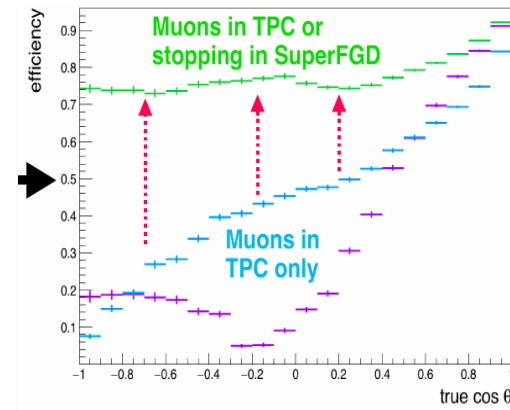
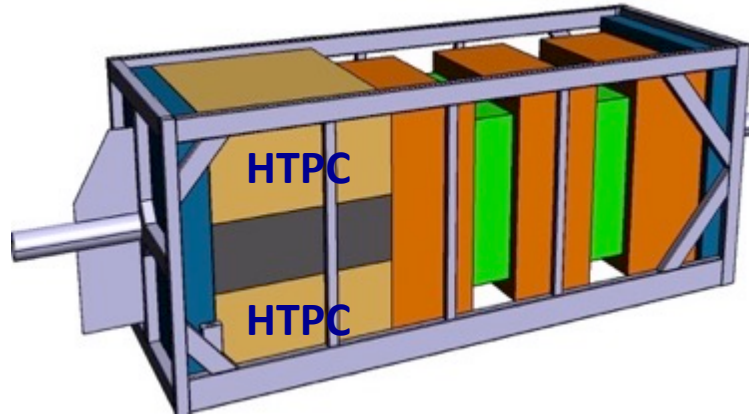


- Preference for  $\delta_{CP} \sim -\pi/2$  but CP conserving values are within the  $2\sigma$  interval
- Slight preference for normal ordering
- Best-fit in the upper octant for  $\theta_{23}$



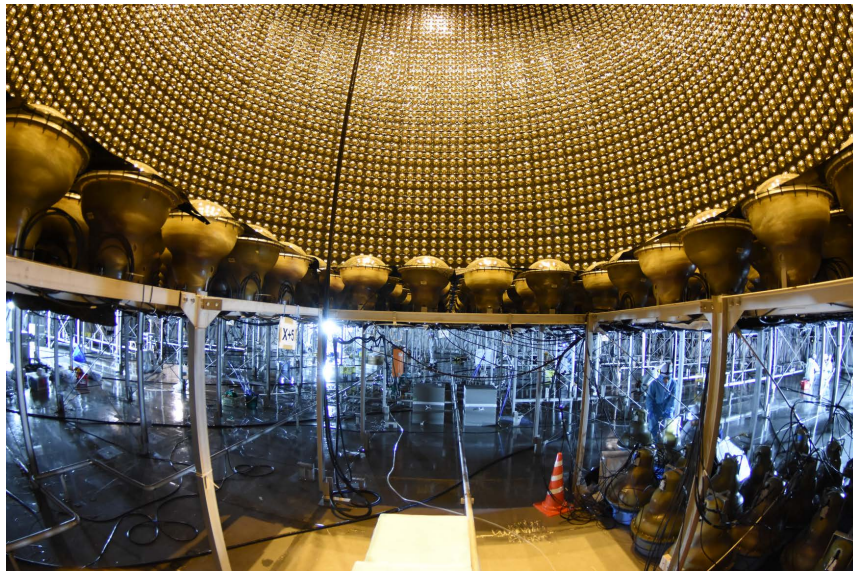
# ND280/SK Upgrades (T2K-II): come misurare $\delta_{CP}$ a 3 sigma aspettando la prossima generazione di esperimenti

- Two new High-Angle TPCs (HTPC)
- A highly segmented Scintillator Detector (Super-FGD)
- TOF planes all around
- Increasing the useful target mass from 2.2 to 4.3 tons



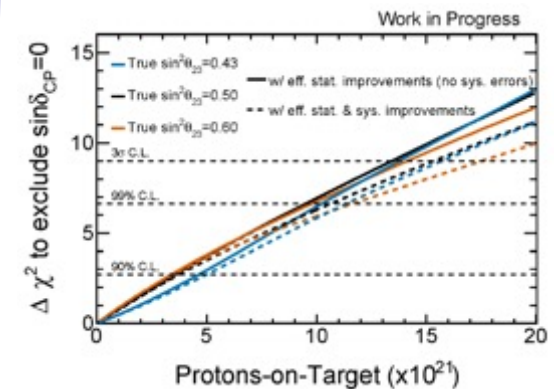
- Approvato dall'SPSC (CERN) e dal PAC (Japan) nel 2020
- L'INFN e' responsabile delle nuove HTPC attualmente in fase di commissioning a JPARC (2021-2024)

## SK Open Tank 2018-2019



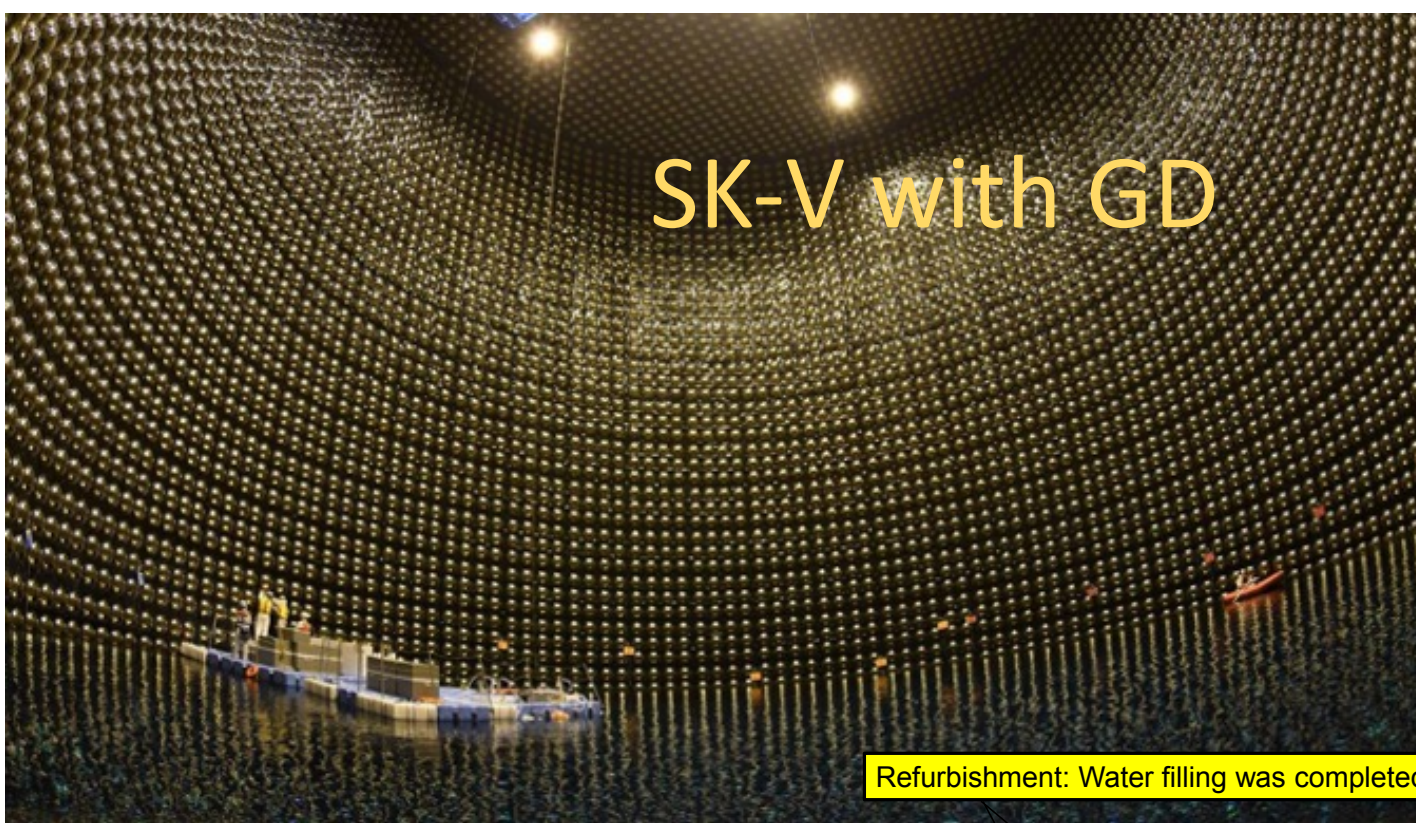
- In poco piu' di 6 mesi, SK e' stato svuotato, riparato e rimesso in funzione
- L'INFN ha contribuito finanziariamente e con personale all'operazione
- Dopo e' iniziata la diluizione del GD. Attualmente siamo in presa dati

## T2K-II Goal: $\delta_{CP}$ at $3\sigma$



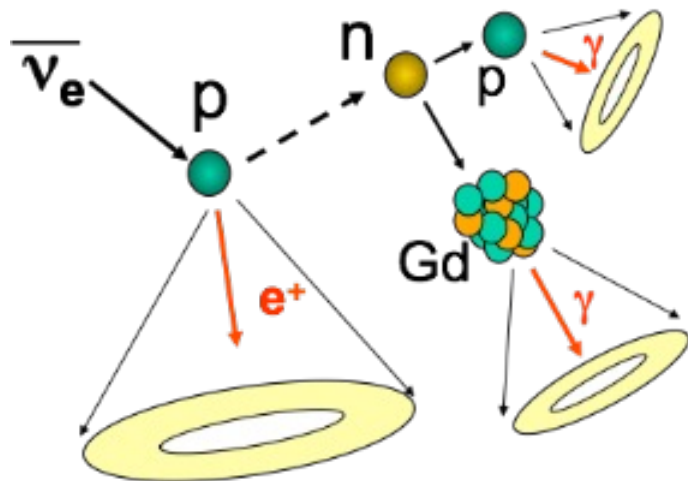
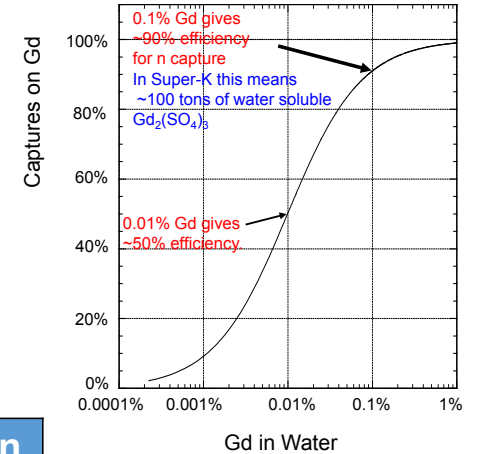
# SK upgrade

## SK-V with GD



Refurbishment: Water filling was completed in January 2019.

Aumentata la sensibilita' all'osservazione delle SN permettendo di distinguere neutrino da anti-neutrino. Importante anche per l'osservazione degli anti-neutrino del fascio di JPARC

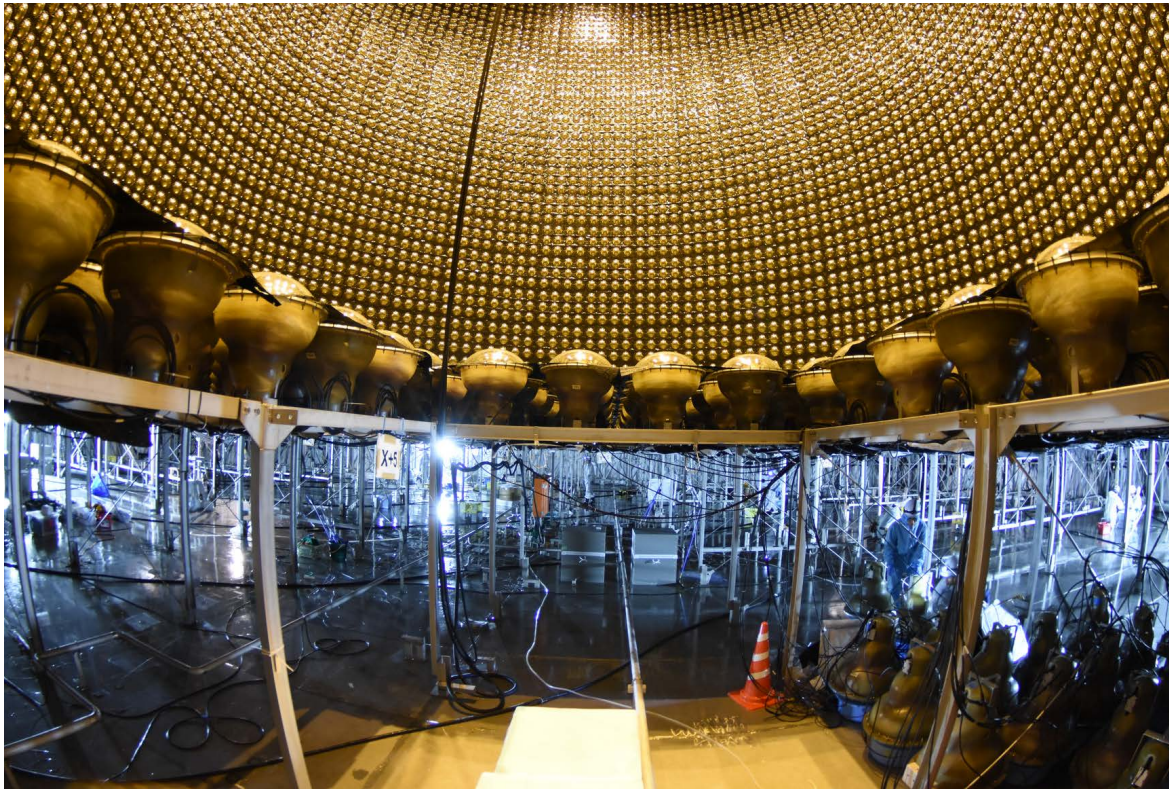
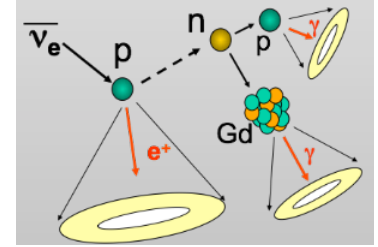


| 2018 | 2019           | 2020  | 202X  | 202X+n |
|------|----------------|---|---|--------|
| work | Pure water Run | T <sub>1</sub> : 10ton Gd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub><br>0.01%Gd run<br>~50% n cap. eff. | T <sub>2</sub> : 100 tonGd <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub><br>0.1%Gd run<br>~90% n cap. eff. |        |

Plan to start 0.01% Gd run in early 2020.  
(Adjusting schedule with T2K)

# Super-kamiokande

- Oltre ad essere utilizzato come Far detector di T2K, Super-kamiokande e' il piu' grande osservatorio al mondo di neutrini atmosferici e solari.
- Negli ultimi due anni anche grazie alla diluizione del Gadolinio sono stati pubblicati piu' di 30 nuovi articoli su PRD/PRL



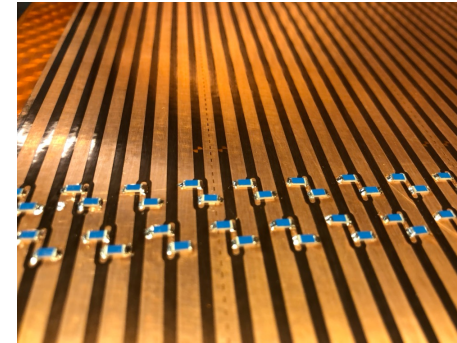
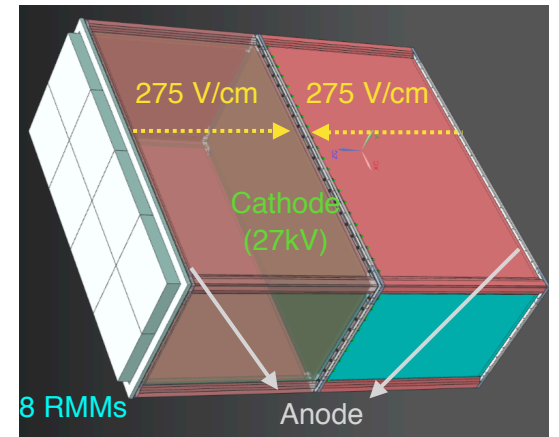
- Search for astrophysical electron antineutrinos in **Super-Kamiokande** with 0.01wt% gadolinium-loaded water
- Measurement of the cosmogenic neutron yield in **Super-Kamiokande** with gadolinium loaded water
- Searching for neutrinos from solar flares across solar cycles 23 and 24 with the **Super-Kamiokande** detector
- Search for Cosmic-Ray Boosted Sub-GeV Dark Matter Using Recoil Protons at **Super-Kamiokande**
- Search for proton decay via  $p \rightarrow \mu + K$  in 0.37 megaton-years exposure of **Super-Kamiokande**
- Diffuse supernova neutrino background search at **Super-Kamiokande**
- Testing Non-Standard Interactions Between Solar Neutrinos and Quarks with **Super-Kamiokande**
- First gadolinium loading to **Super-Kamiokande**
- Follow-up of GWTC-2 gravitational wave events with neutrinos from the **Super-Kamiokande** detector
- Etc. etc.

V. Berardi, contatto Gruppo italiano

# T2K-Upgrade

L'INFN di Bari ha contribuito in modo rilevante al disegno e alla realizzazione delle 2 nuove grandi TPC con lettura a MicroMegas.

- In particolare sono di responsabilità di Bari:
  - La realizzazione delle Field Cages (sottili di tipo innovativo) e l'integrazione delle TPC (con PD)
  - L'installazione, messa in funzione e commissioning del nuovo sistema del gas realizzato al CERN che servirà le vecchie e le nuove TPC (5 in totale): (E. Radicioni)
  - Il nuovo programma di ricostruzione dello ND280 (Close Detector di T2K) (L. Magaletti)
- Sono stati realizzati a Bari negli ultimi 3 anni
  - Il disegno dei piani di strips della Field Cage
  - Il disegno e la realizzazione del MOLD della field Cage
  - Il disegno e la realizzazione dei tavoli di allineamento per l'assemblaggio di precisione



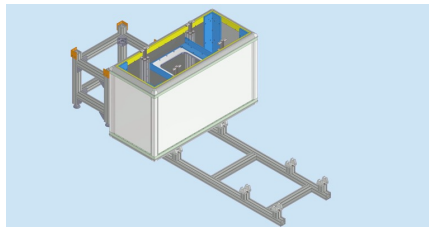
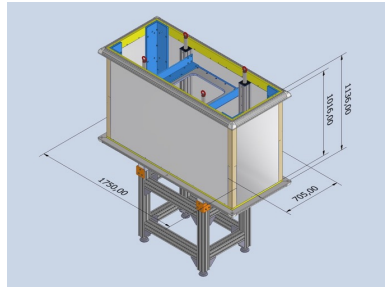
Mirror Strips



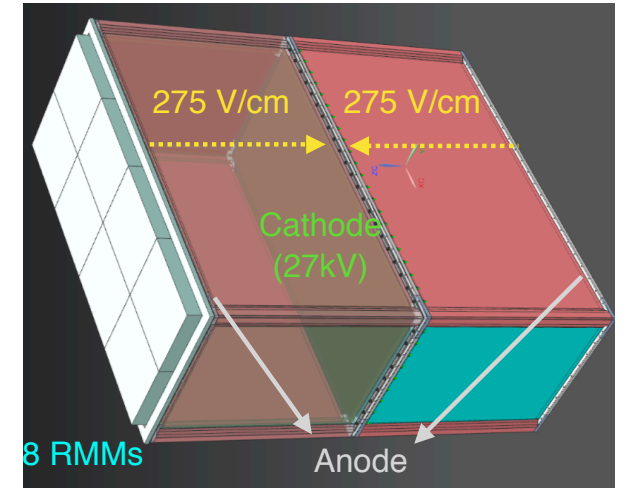
Nuovi tavoli di allineamento pronti per essere inviati al CERN

# T2K Upgrade (NP07) Preparazione e Test beams 2018-2021

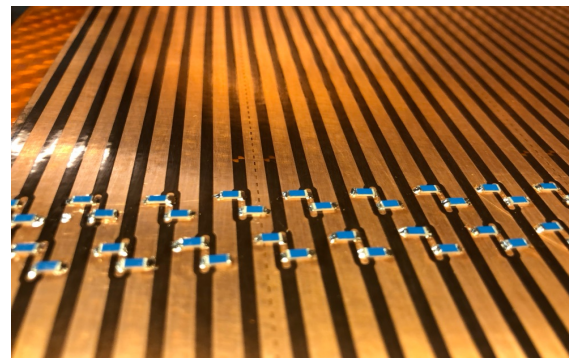
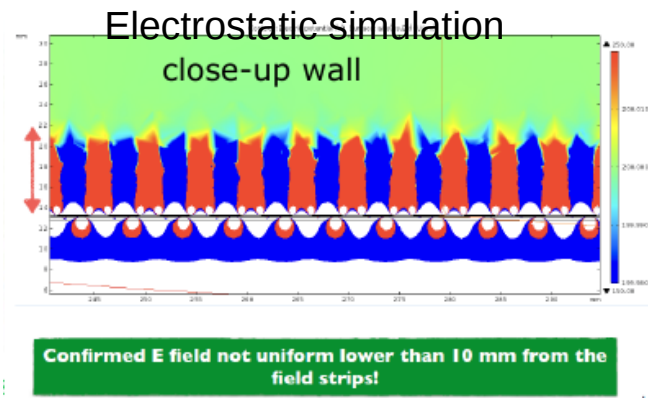
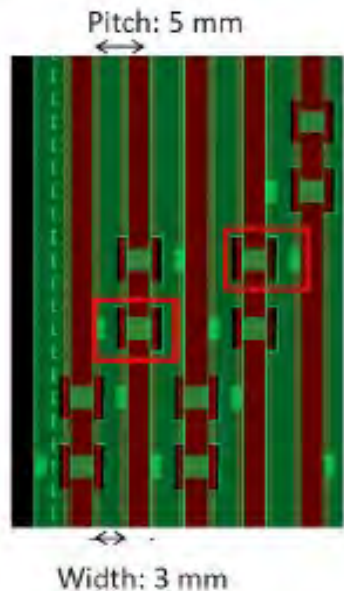
## Design e realizzazione del MOLD



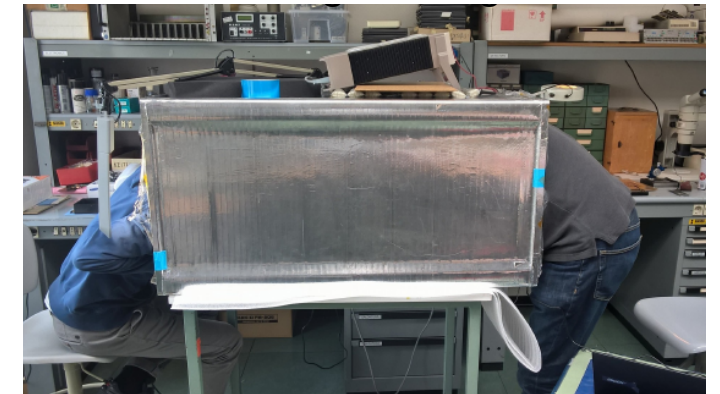
M. Franco , S. Martiradonna, N. Lacalamita, V. Valentino, C. Pastore e M. Mongelli



Field Cage: Responsabilita' INFN



Simulazione (COMSOL) e realizzazione dei piani di strips



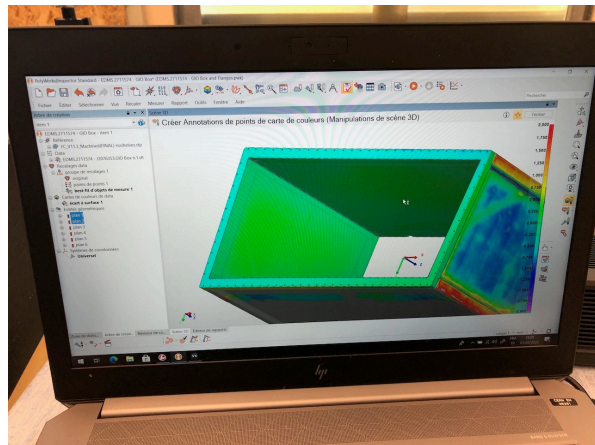
Prototipo 0.5x0.5x1 m<sup>3</sup>



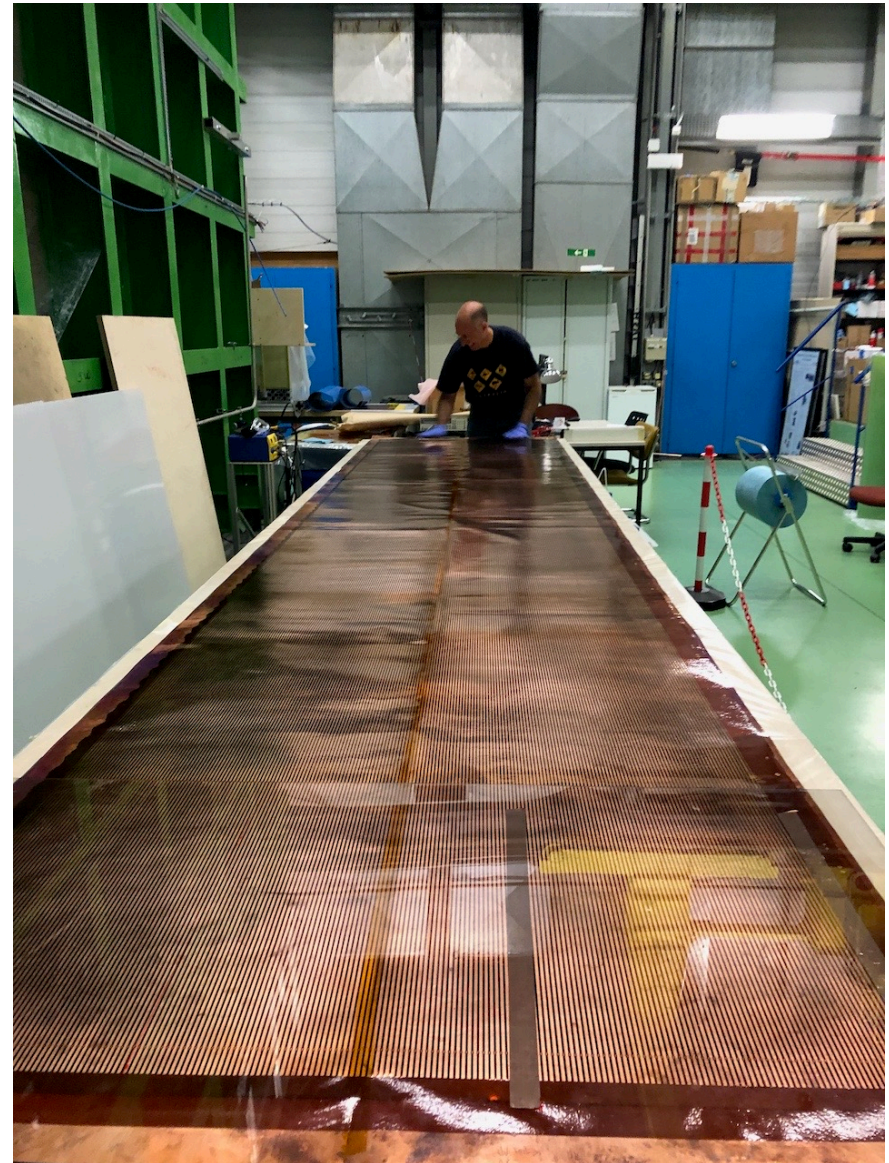
# T2K Upgrade (NP07) attivita' al 182 del CERN (2021-2024)



Test HV

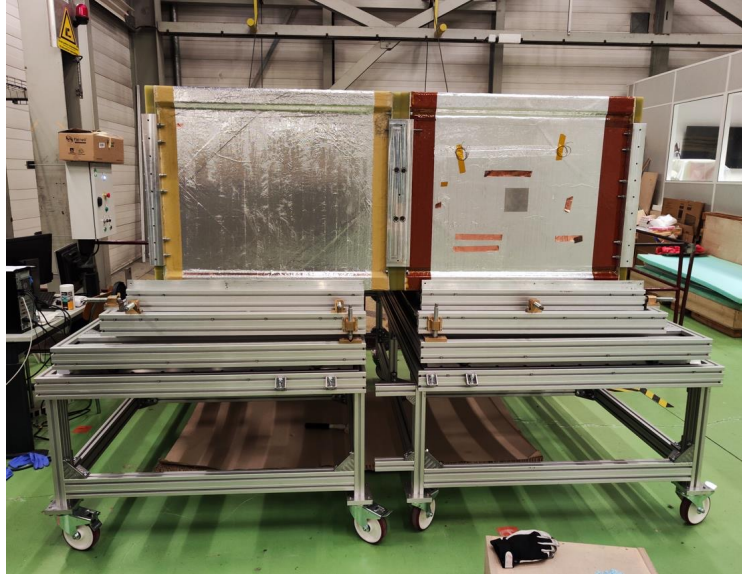


Metrologia



Test delle strips

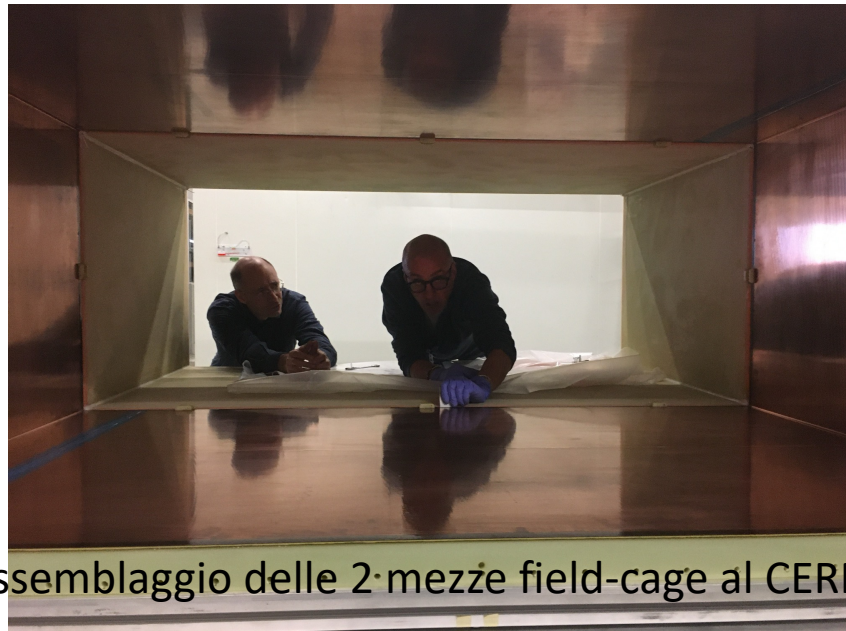
# T2K Upgrade (NP07) attivita' al 182 (2021-2024)



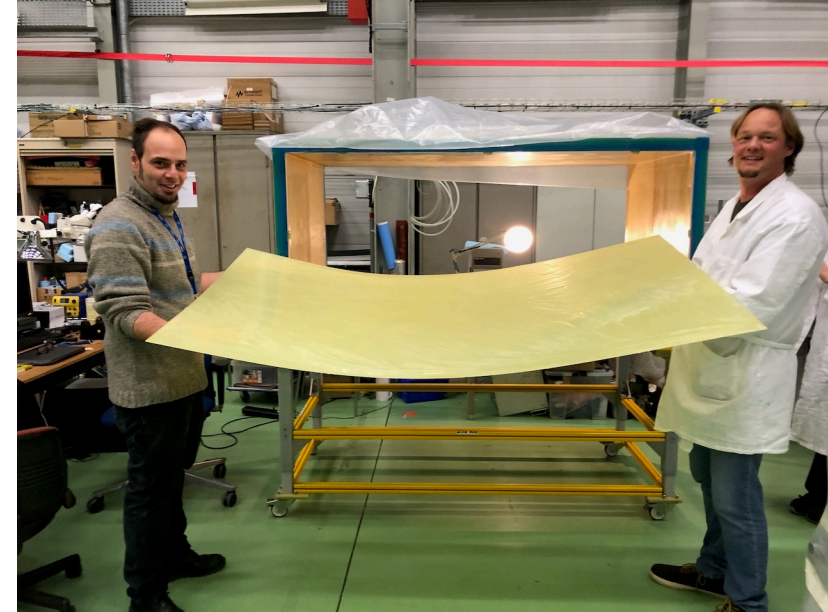
Tavoli di allineamento (ogni field-cage e' composta da 2 elementi 1mx2m)



Installazione MM in clean room

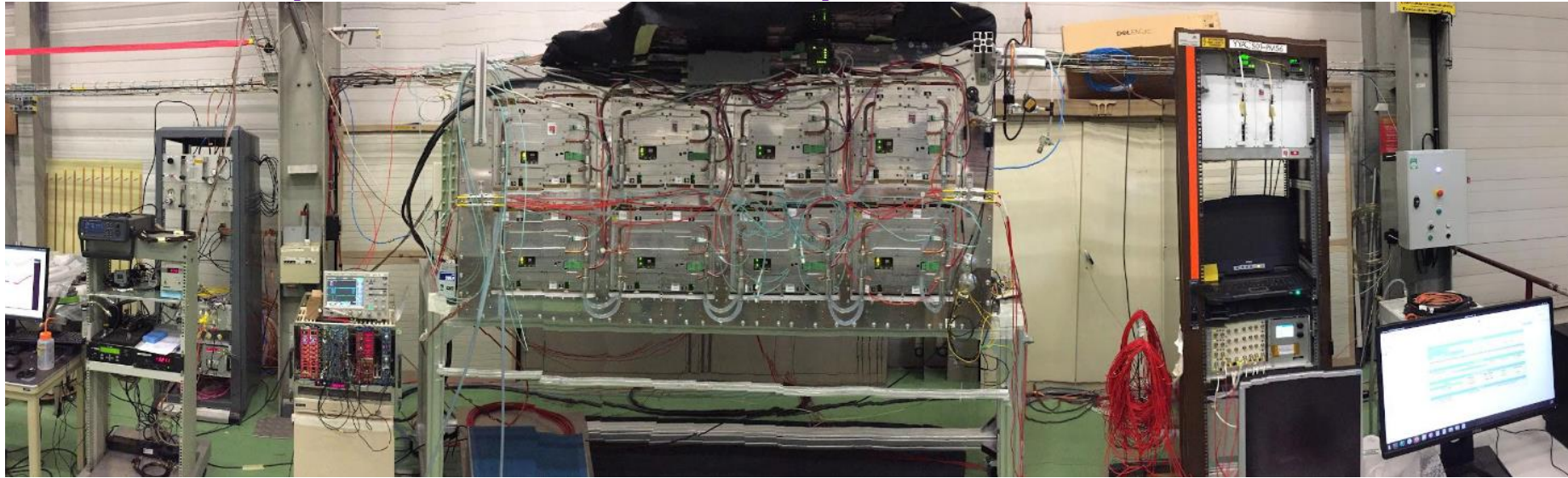


Assemblaggio delle 2-mezze field-cage al CERN

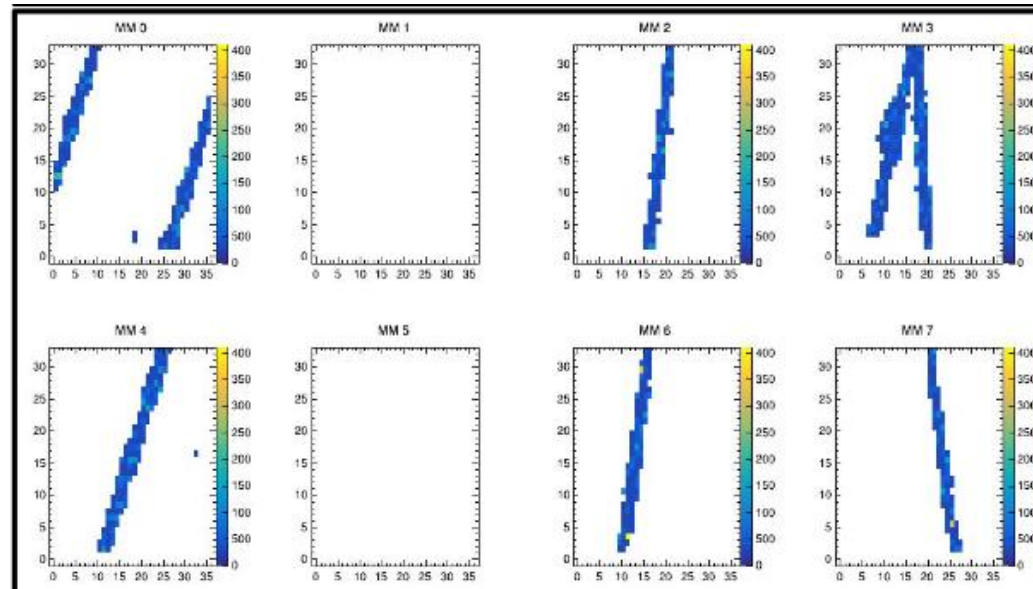


Test di incollaggio

# T2K Upgrade (NP07) - primavera 2023



Test con raggi cosmici della prima TPC di T2K al bld 182  
(foto presa dal CERN Bulletin giugno 2023)



Raggi cosmici : prime traccie

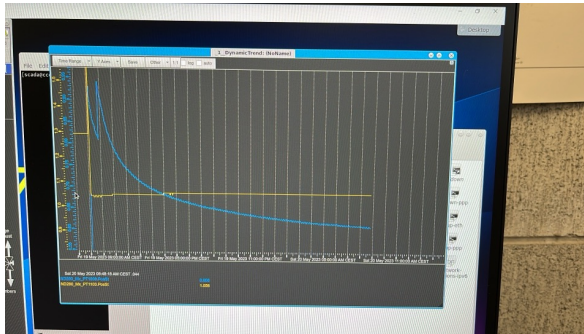
# T2K Upgrade : Gas System (aprile 2023 -> 2024 )



Arrivo a JPARC (giappone)



Trasporto e posizionamento di buffer e rack, nella mixing room e nel pit



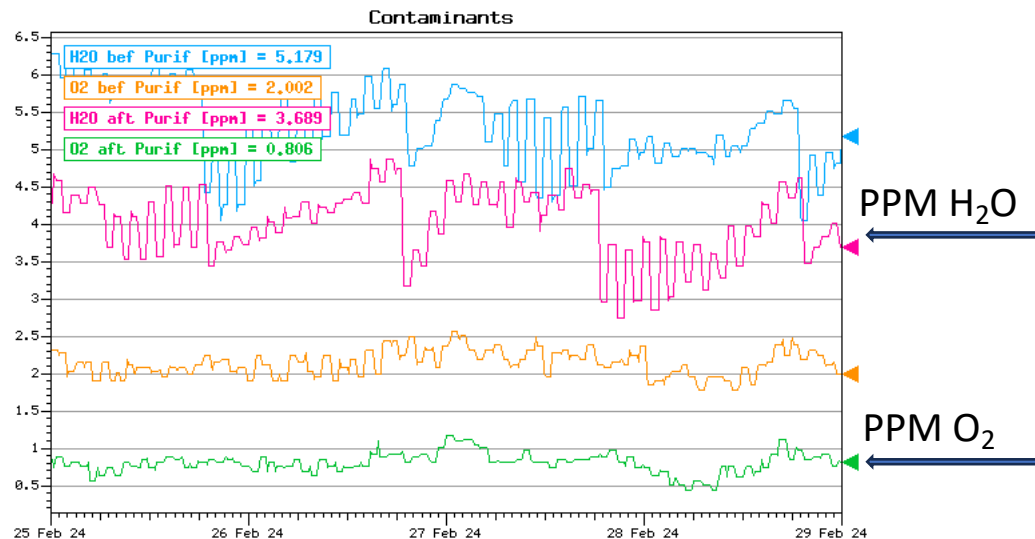
Test generali , installazione software e ricercar di fughe, sensoristica



Il Sistema e' ora complete e funzionante ma il commissioning continua ....

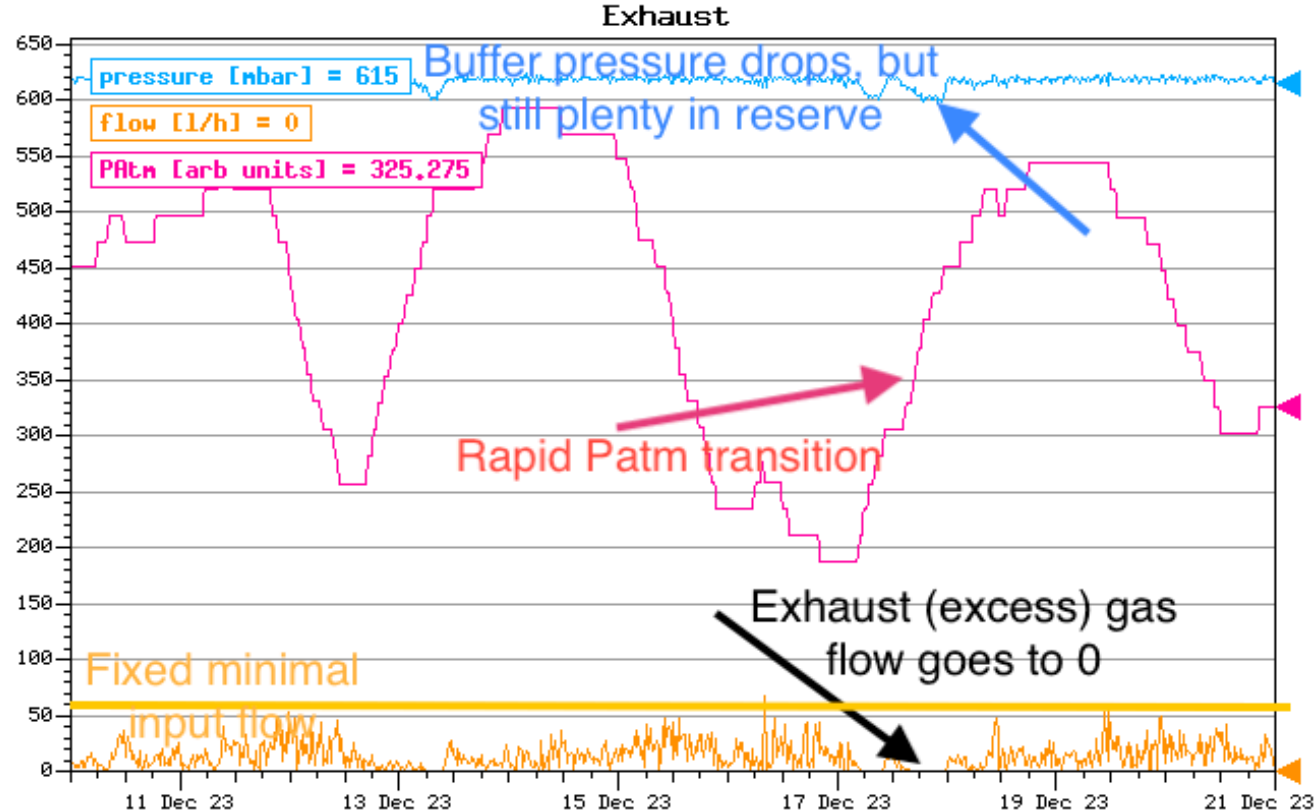
# Gas System commissioning and first operations

- Connected the new HA-TPC to the Ar standby system
- Connection and test of interlocks and safety sensors
- Started up the mixer with the active gas
- Tested recirculation and purification
- Provided active gas to the first HA-TPC
- Interface of the Gas System with the experiment's DCS to provide calibration data (thanks to software support from IFAE)
- Full start-up with HA-TPC-bottom + 3 V-TPCs by mid-November
- Running until end of 2023
- Second commissioning run in February 2024, achieving record gas purity (< 1ppm O<sub>2</sub> in gas distributed to TPCs)
- Gas consumption (and rejection in the atmosphere) reduced to 1/3 w.r.t. the past system, still subject to further optimization



Now: connection and commissioning with the second new TPC

# Gas loss



- Meaning: found a way to make the system behave differently w.r.t. the previous one
- There is no more any need to use brute force (large fresh gas input) to accommodate a rapid increase in Atm pressure (typical in the typhoon season)
- → reduced gas consumption

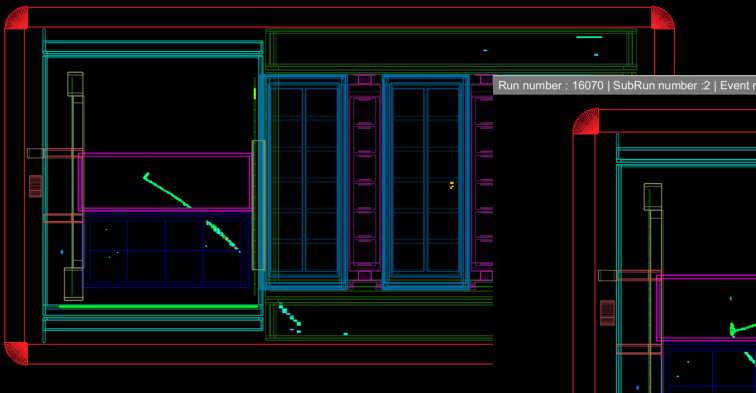
- Way open to fully optimize the gas consumption (and minimize manual work for changing gas cylinders) and reduce CF4 use (and release in the air)
  - Modify the analysis modules to return the analysis flow to the buffer (instead of to exhaust)
  - Add RGA to monitor N2 poisoning → towards (close to) 100% recirculation

# Upgrade : JPARC installazione della prima TPC (8-Settembre 2023)

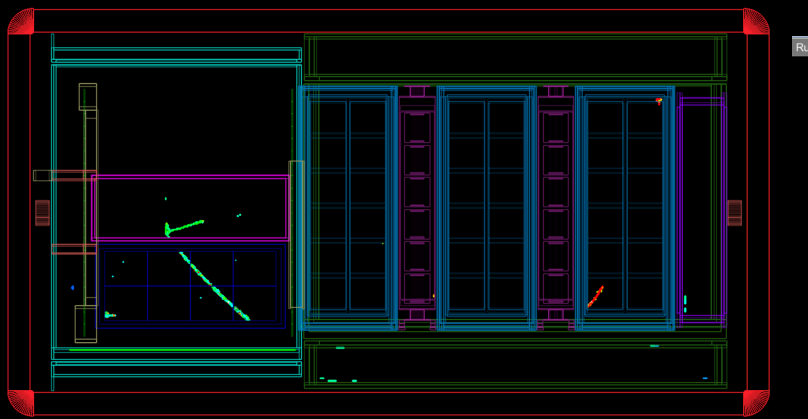


# First neutrino interactions (Dec 2023)

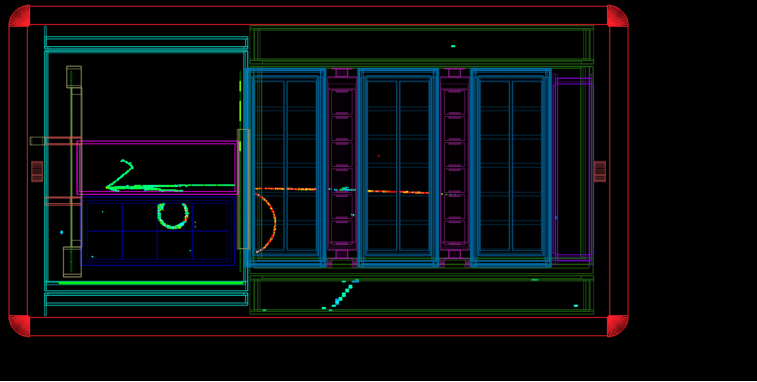
Run number : 16070 | SubRun number : 2 | Event number : 57918 | Spill : 57538 | Time : Wed 2023-12-20 22:12:15 JST | Partition : 61 | Trigger: Beam Spill



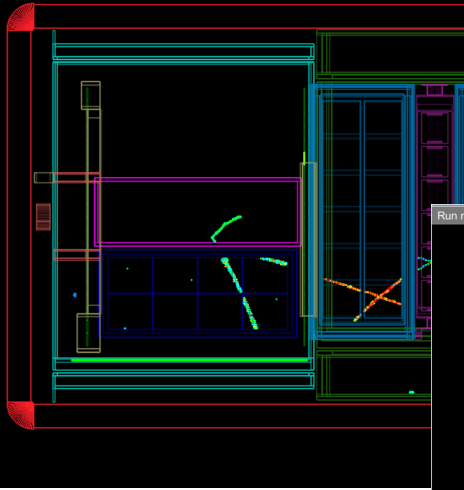
Run number : 16070 | SubRun number : 2 | Event number : 63089 | Spill : 58072 | Time : Wed 2023-12-20 22:24:20 JST | Partition : 61 | Trigger: Beam Spill



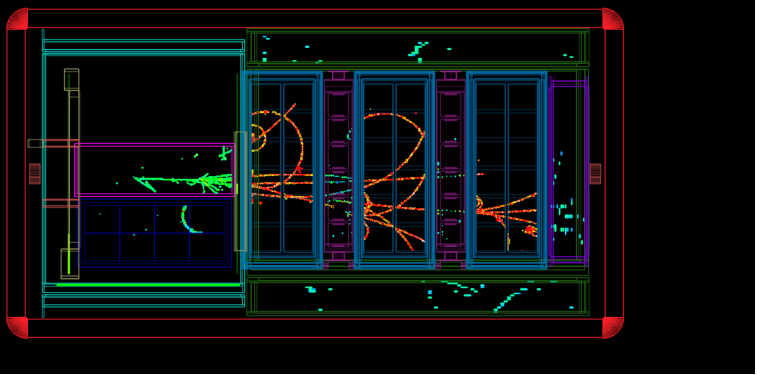
Run number : 16070 | SubRun number : 11 | Event number : 259310 | Spill : 9421 | Time : Thu 2023-12-21 06:00:10 JST | Partition : 61 | Trigger: Beam Spill



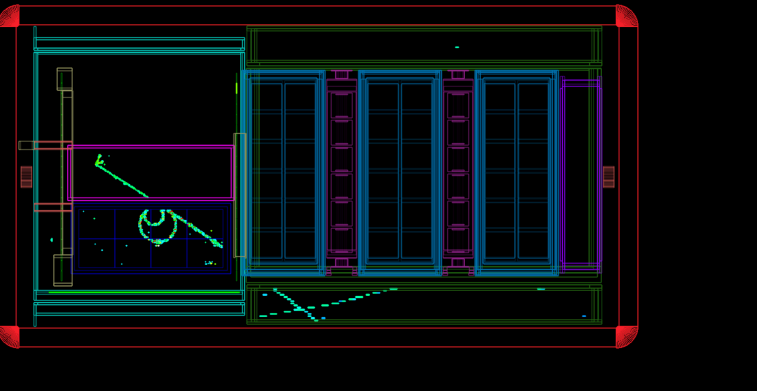
Run number : 16070 | SubRun number : 7 | Event number : 167539 | Spill : 2124 | Time : Thu 2023-



Run number : 16070 | SubRun number : 7 | Event number : 169035 | Spill : 2272 | Time : Thu 2023-12-21 02:30:36 JST | Partition : 61 | Trigger: Beam Spill

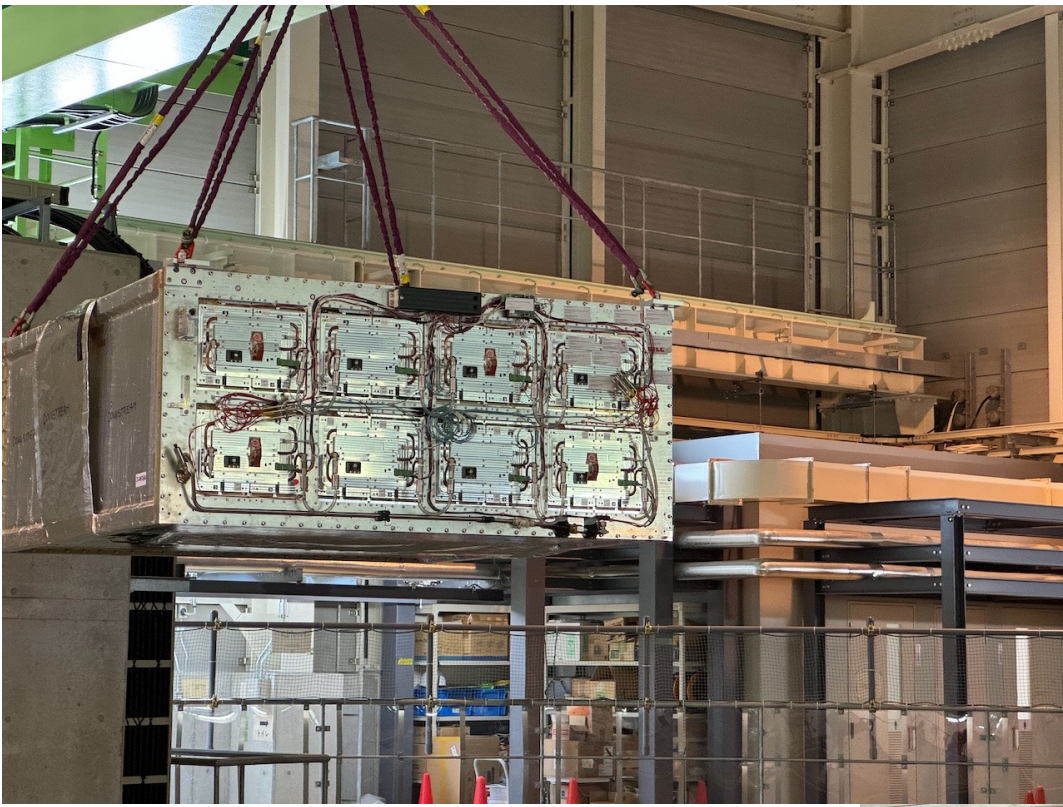


Run number : 16120 | SubRun number : 0 | Event number : 12772 | Spill : 12345 | Time : Sun 2023-12-24 17:28:50 JST | Partition : 61 | Trigger: Beam Spill

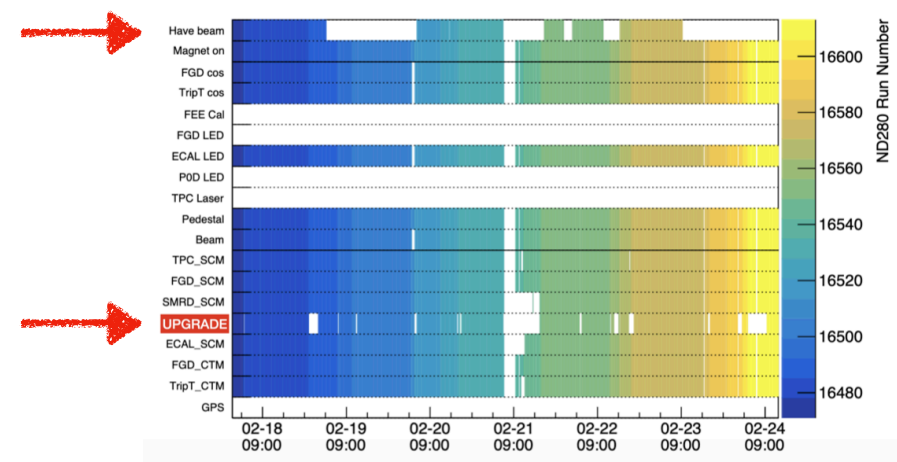
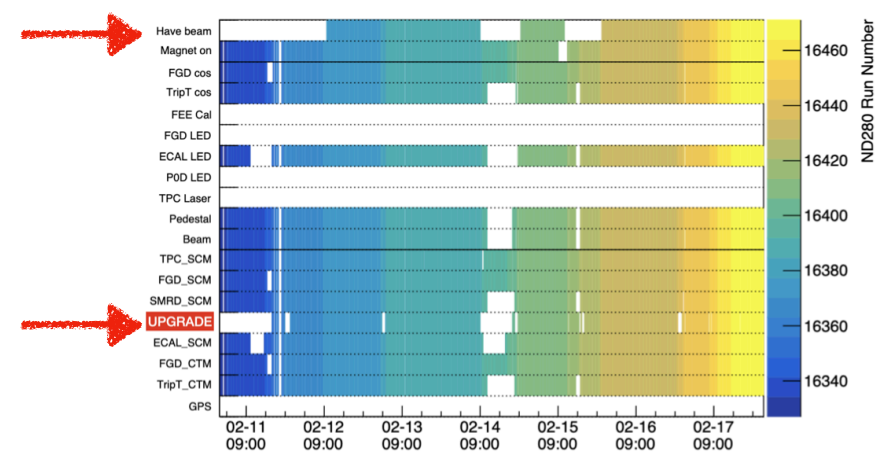
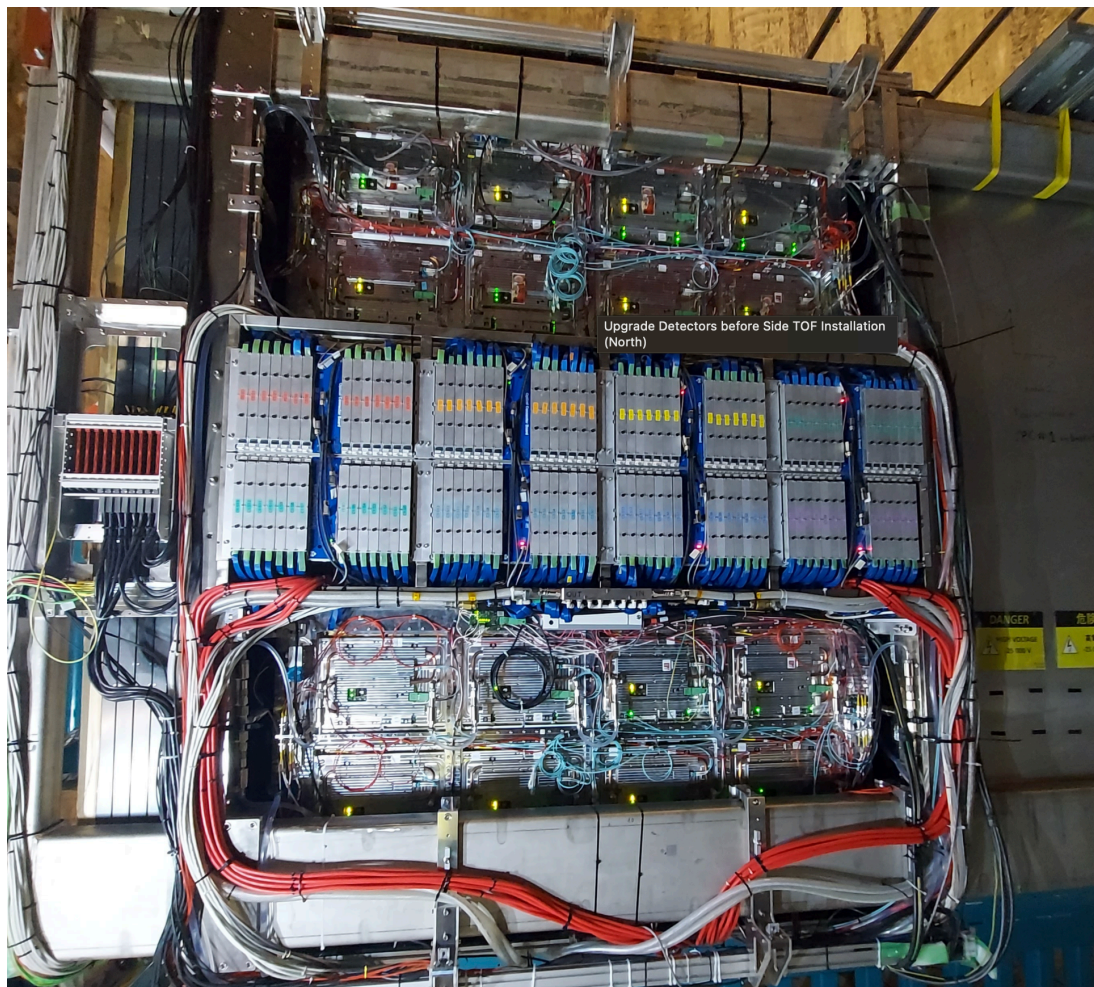




# Upgrade : JPARC installazione della seconda TPC (25 Aprile 2024)



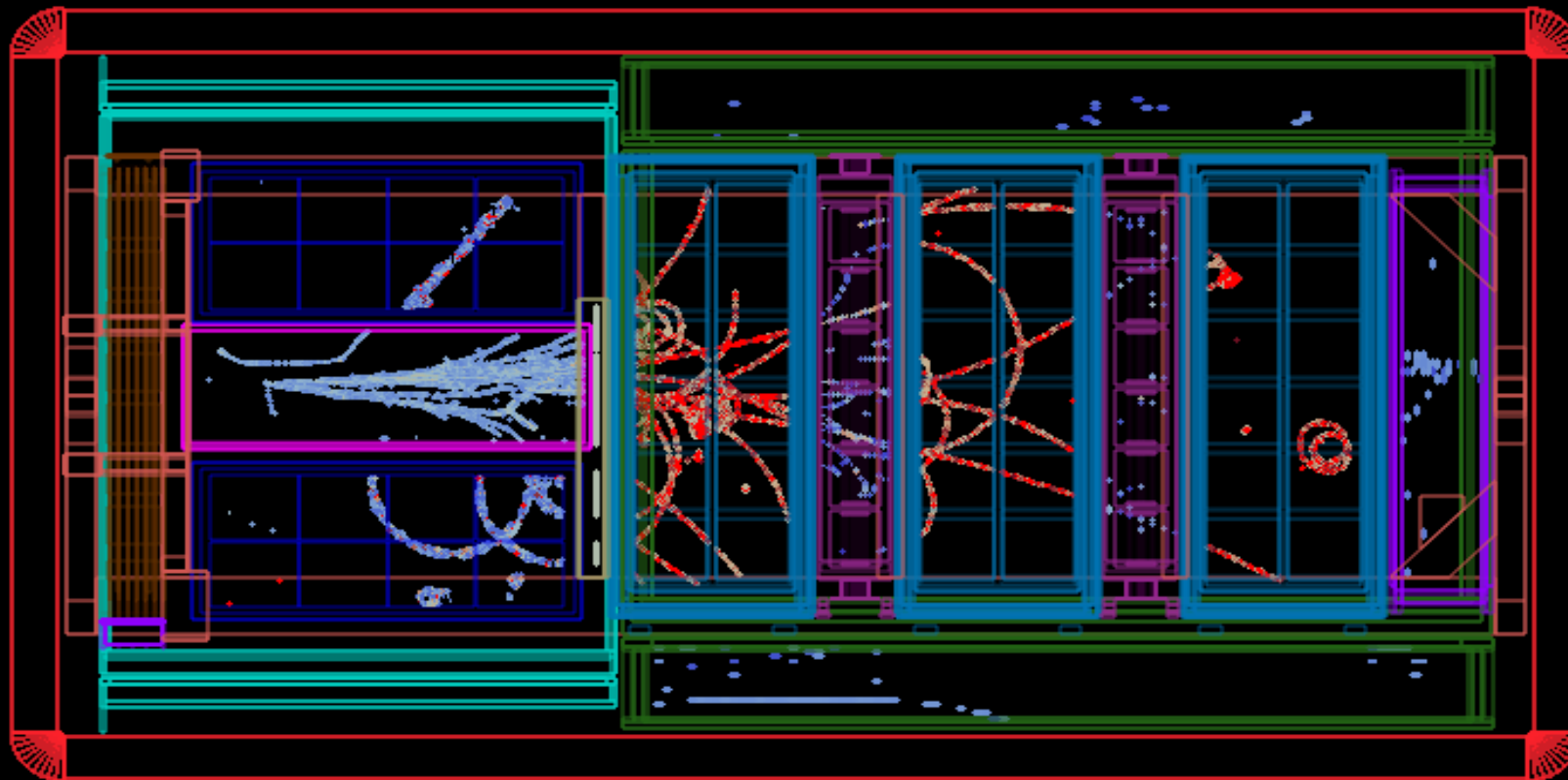
# Detectors installed and taking data

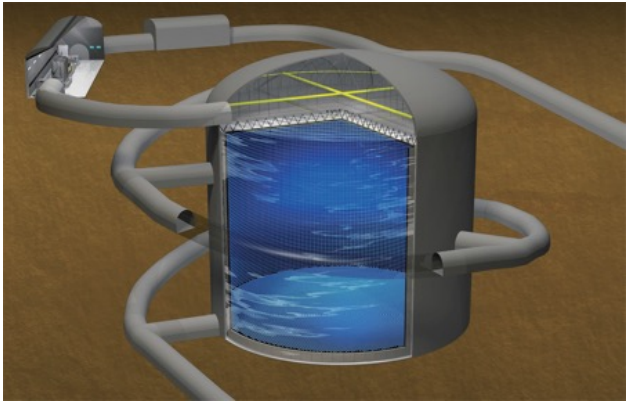


# T2K-Upgrade finalmente in presa dati

|         |  |            |                     |         |
|---------|--|------------|---------------------|---------|
| y 3View |  | 2D views   | 2024-06-07 18:31:01 | Actions |
| Hide    |  | Right Side |                     | Actions |
| Hide    |  |            |                     | Actions |

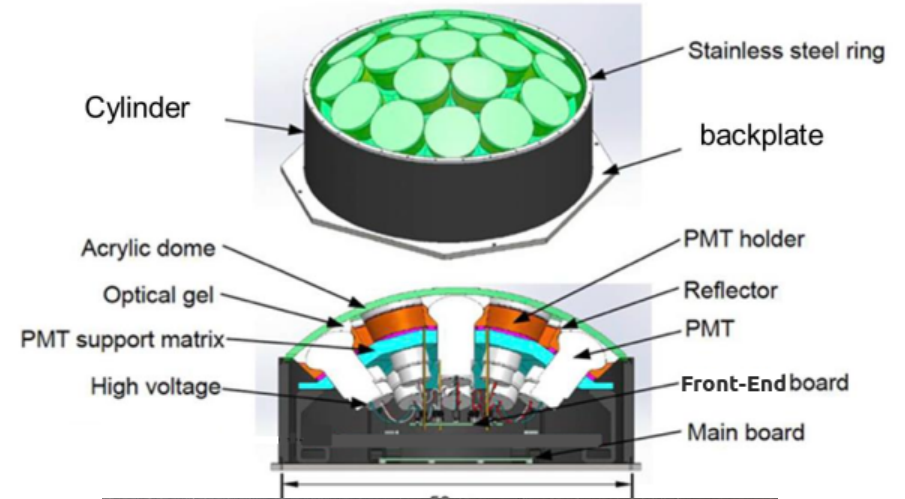
Event number : 345342 | Run number : 16847 | Spill : 28852 | Time : Fri 2024-06-07 18:29:00 JST | Trigger: Beam Spill





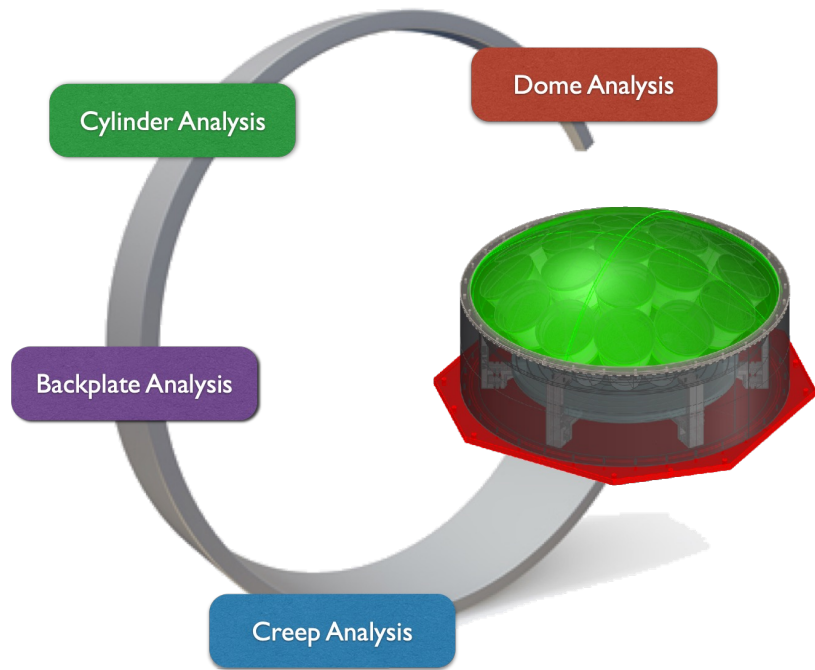
# Hyper-K 2025

- Completamento della fase di design del mPMT
- Il disegno e il test di buona parte della meccanica è stato fatto a Bari, stiamo attualmente nella fase finale di ottimizzazione
- Bari è responsabile di questa parte verso la collaborazione (R. Spina)
- Realizzazione di 5 mPMT in configurazione finale (Pre-production) da installare in WTCE per test al CERN (con Na)

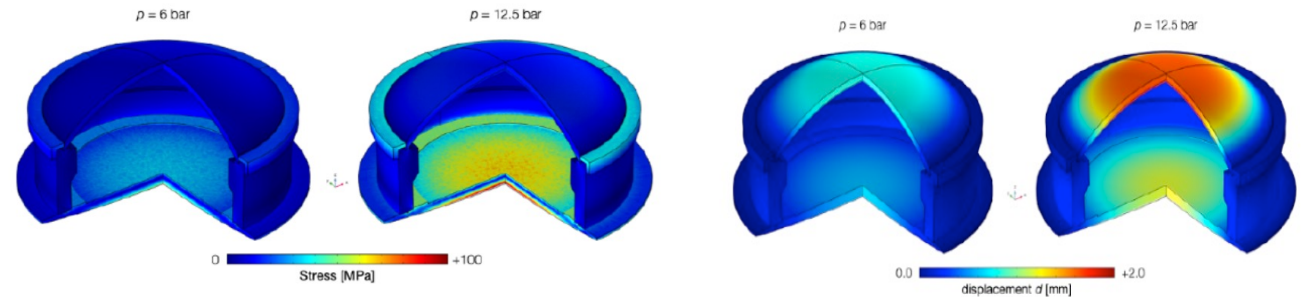


Prototipo di mPMT realizzato dall'INFN

# Simulation Studies



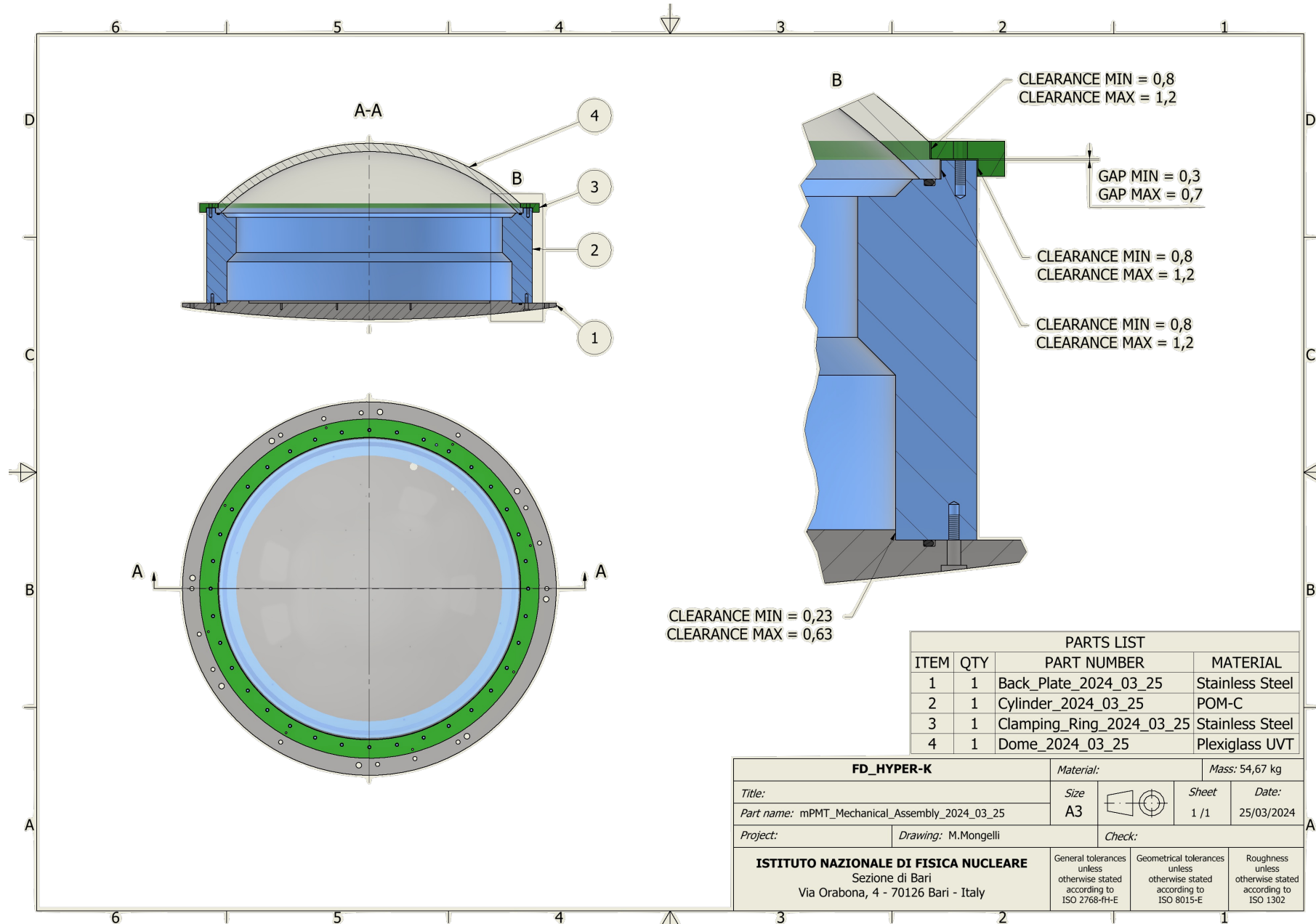
## Simulation: assembly



Stress was concentrated at the dome's borders, which could lead to high deformation, resulting in cracks and failure of the hydrostatic pressure test.

The clamp ring design avoids shortcomings, constituting the full end plate. The stress was uniformly distributed along and across the dome height, remaining within the elastic limits. The maximum stresses developed on the machinery with a pressure of 12.5 bar were within the specified yield stress limits of 600 bar. No critical deformation is observed even at 12 bar (operating pressure of HK is about 7 bar).

# Design



Contributo fondamentale del CAD meccanico di Bari: M.Mongelli

# Calcolo : Tecniche di "machine learning" applicate alla ricostruzione di eventi in Water Cherenkov detectors

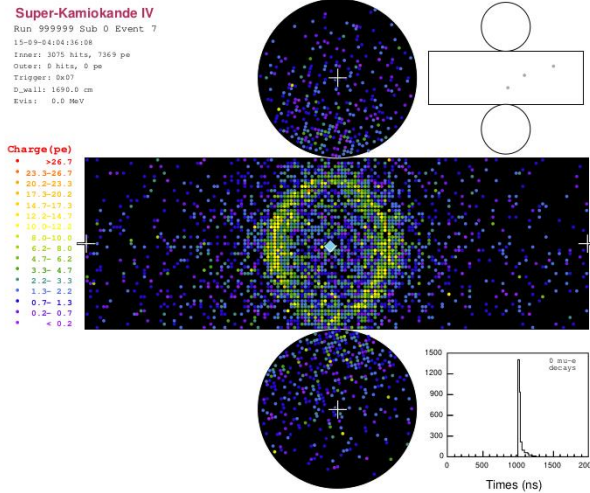


Application of Machine Learning techniques to improve event reconstruction in Super-Kamiokande

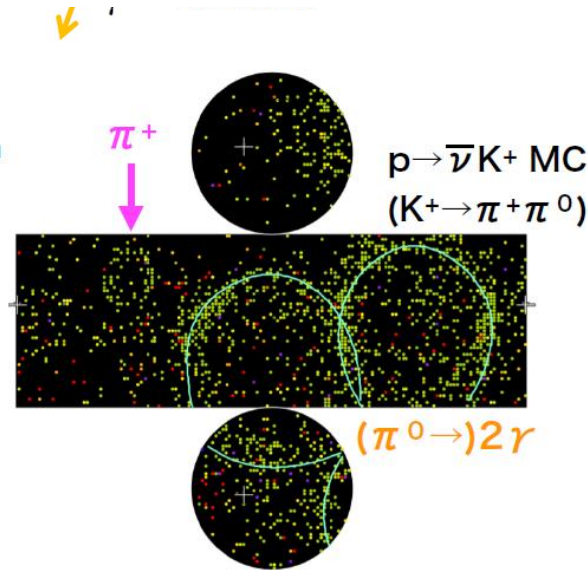
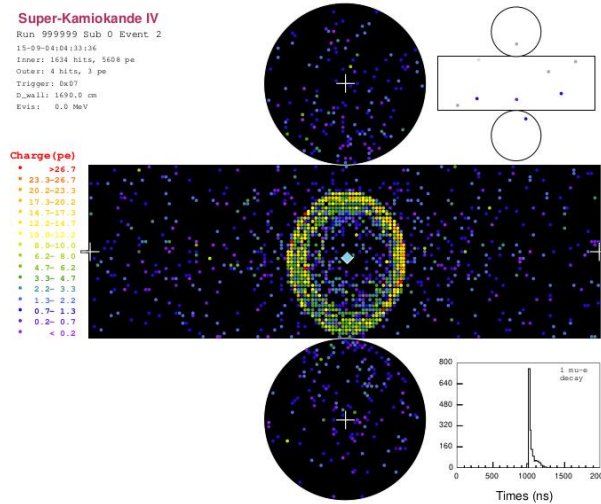
Neutrino Physics and Machine Learning 2024  
27 Jun. 2024

Nicola Fulvio Calabria  
Politecnico and INFN Bari

## Showering (e-like)



## Non showering (muon-like)



N. F. Calabria, E. Amato, N. Amoroso, R. Bellotti, A. Monaco

# Sommario attivita' Hyper-K 2025

- **Super-Kamiokande (SK-GD)**
  - data taking+ Analisi
- **T2K/Upgrade ND280**
  - Completamento costruzione Field-cage "spare" e test beam al CERN (NP07)
  - Parziale smontaggio area sperimentale al 182 del CERN
  - Presa dati e completamento commissioning a JPARC (Japan) (TPC+Gas system)
  - Attivita' di Analisi e sviluppo nuovi programmi di ricostruzione del N280
- **Hyper-K** (costruzione caverna in corso)
  - prototipi e pre-produzioni mPMT
  - test prototipi mPMT (CERN+Napoli)
  - Sviluppo algoritmi basati su tecniche di machine learning
  - Test fotosensori a Kamioka (Japan)
- **DRD1/WP8 (AidaInnova)**
  - Realizzazione di un prototipo di grandi dimensioni di TPC ad alta pressione e readout ottico (=>sinergico con RD\_MUCOL)

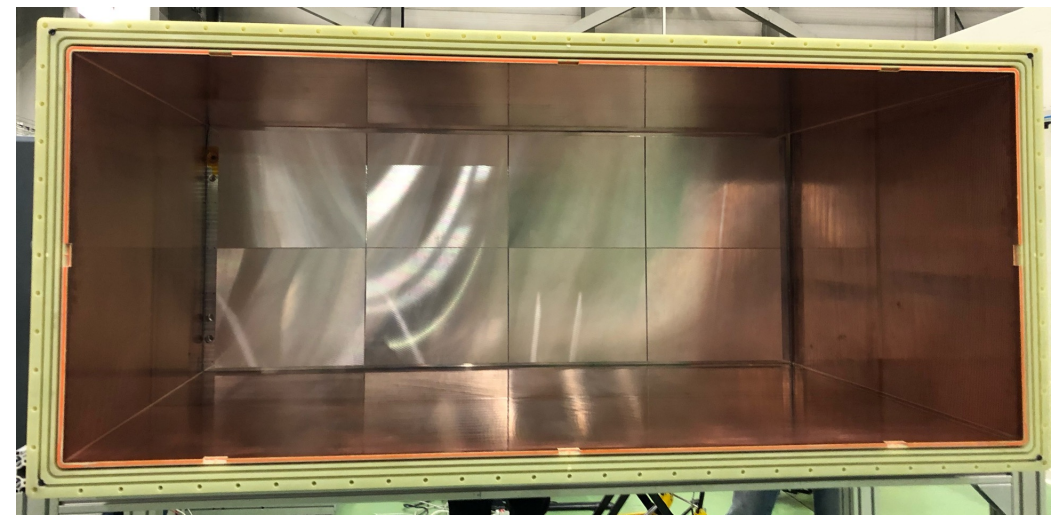
## Responsabilita' istituzionali

Hyper-K IB Chairman (E. Radicioni), Hyper-K Pub-board Chairman (M.G. Catanesi),  
Contatto Italiano Super-Kamiokande (V. Berardi)

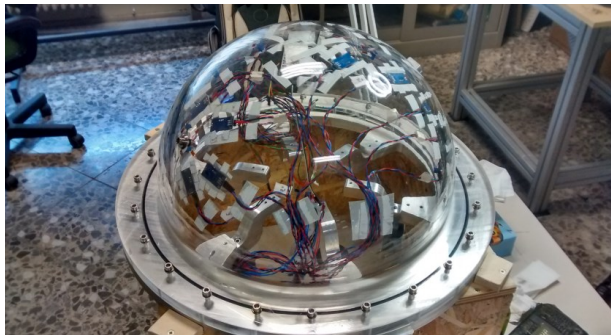


## Attività' che richiedono servizi di sezione:

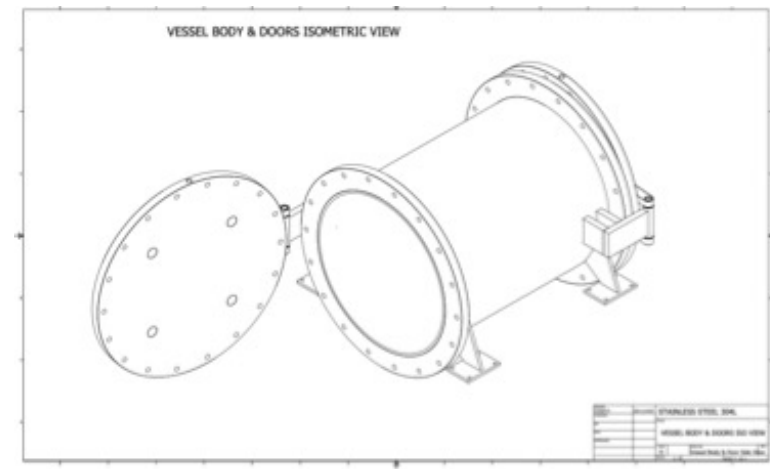
- Assemblaggi , montaggi e test TPC spare al CERN (NP07)
- Realizzazione prototipo TPC con lettura ottica ed alta pressione (laboratorio Bari):  
(AIDAINNOVA, DRD1 WP4,WP8 sinergiche con Hyper-K e RD\_MUCOL)
- Sviluppo prototipi mPMT per HyperK



assemblaggio TPC al CERN



Test covers sviluppati a Bari



Vessel TPC alta pressione

# Richieste Servizi (discusse con I responsabili)

- **Progettazione Meccanica => 3,5 m.u.**
  - Progettazione Field Cage nel lab di AIDAInnova/DRD1 W8(1,5 m.u.)
  - Ottimizzazione design meccanica mPMT (Hyper-K) (1 m.u)
- **Officina meccanica => 2,5 m.u. + 10 giorni di missione**
  - 10 giorni di missione per assemblaggio TPC spare al CERN
  - Realizzazione Field Cage nel lab di AIDAInnova/DRD1 W8 (1,5 m.u.)
  - Completamento Tavoli, supporti e gas system (1,0 m.u.)
- **Servizi Elettronica => 0,5 m.u**
  - Cavi , connessioni HV etc.

# Hyper-K/FTE (Resp. Locale E. Radicioni)

|                           | Qualifica         | FTE (%)          | note                     |
|---------------------------|-------------------|------------------|--------------------------|
| Amoroso Nicola            | Prof. Associato   | 30               |                          |
| Bellotti Roberto          | Prof. Ordinario   | 20               |                          |
| Berardi Vincenzo          | Prof. Associato   | 100              |                          |
| Cafagna Francesco Saverio | Primo Ricercatore | 10               |                          |
| Calabria Fulvio Nicola    | RTDA              | 20               |                          |
| Catanesi Maria Gabriella  | Ass. Senior       | *                | *                        |
| Magaletti Lorenzo         | Prof. Associato   | 80               |                          |
| Amato Emanuele            | Dottorando        | 50               |                          |
| Pastore Cosimo            | Primo Tecnologo   | 10               | 5% AidaInnova            |
| Radicioni Emilio          | Primo Ricercatore | 80               |                          |
| Spina Roberto             | Prof. Ordinario   | 70               |                          |
| Tangaro Sabina            | Prof. Associato   | 20               |                          |
| Assegnista (bando aperto) | Assegnista senior | (100)            | Inizio contratto 1/11/24 |
| <b>Totale</b>             |                   | <b>4,9 (5,9)</b> |                          |

Le percentuali includono quelli delle sigle affini, alcune percentuali sono ancora da limare