

# DUNE ND-SAND

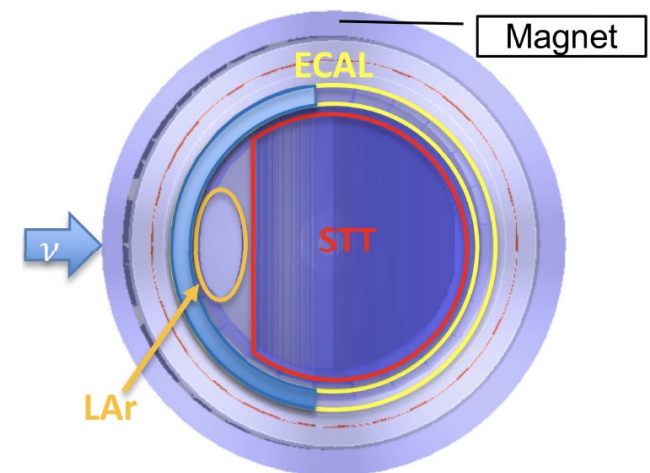
(Luca Stanco)

- Introduction
- Technical advancements
  - KLOE-to-SAND
  - STT developments
  - GRAIN
- SAND Physics & Software
- Conclusions

STT FV mass:  
4.7 t CH<sub>2</sub>  
557 kg C

GRAIN mass:  
1 t LAr

Front ECAL mass:  
22.8 t Pb



SAND, a multipurpose detector with highly performant ECAL, light-targeted tracker, LAr target, all of them in a magnetic field

SAND will probably be one of the best detector ever placed in a near site of a neutrino beam.

Is it worth for DUNE? A three-fold yes:

1. Plenty of neutrino measurements (xs, fluxes, systematics)
2. Beam monitoring
3. In-kind international contribution

Building it from scratch would not be reasonable due to the corresponding requests in terms of money and personnel.

It has a two-fold added value for DUNE:

1. Complementarities to the other specific detectors
2. Bit the unknown unknowns that could (much probably) be encountered.

# DUNE-SAND Consortium

After the choice for the tracker, we underwent a formal database investigation

- 112 collaborators from 24 Institutions from Italy, US, India
- There are additional collaborators and Institutions currently active (in the STT) but not yet formally included

An annex to the DUNE MoU with a detailed list of deliverables and sharing of responsibilities between DUNE-SAND Consortium, DUNE Project and Fermilab is in preparation.

*Excerpt from the Annex to the Multi-Institutional MoU for DUNE (Draft)*

The SAND Consortium is responsible for the delivery, installation and commissioning of the SAND detector at Fermilab's DUNE ND facility.

This Annex describes the planned design and construction, and integration and installation of SAND. SAND detector components are provided as in kind contributions of SAND Consortium collaborating institutions. The INFN contribution is regulated by the high level *Implementing Arrangement between the Department of Energy of the United States of America and the Ministry of Universities and Research of the Italian Republic for cooperation in the areas of High Energy, Astroparticle and Nuclear Physics concerning Neutrino Physics Research - Addendum 2: Deep Underground Neutrino Experiment Program*. According to this Arrangement, INFN is responsible for delivering and re-assembling the KLOE superconducting magnet, the yoke, the KLOE electromagnetic calorimeter, all appropriately refurbished and instrumented for operation as parts of SAND. INFN is also responsible for the development, construction of the GRAIN sub-detector. Sharing of responsibilities, within the Consortium, for the development, construction, delivery and re-assembly of the STT sub-detector are under definition. (...)

*Excerpt from the Annex to the Multi-Institutional MoU for DUNE (Draft)**(Cont.)**(...)*

Activities following the delivery of detector components at Fermilab such as, pre-assembly and testing at the Fermilab site, installation and integration at the DUNE-ND facility as well as activities preceding the delivery, aiming at the qualification of components for acceptance for operation at the Fermilab site are conducted in cooperation between SAND Consortium and Fermilab/DOE personnel. Fermilab is expected to provide infrastructures and onsite support for post-shipping tests and pre-assembly activities taking place at the Fermilab site, before installation at the DUNE-ND facility. DUNE-US project is expected to provide the infrastructures and onsite support required for installation and commissioning of the SAND detector at the DUNE-ND facility, including the cryogenic equipment for the delivery of helium and nitrogen as required for the commissioning and operation of the SAND magnet and of the GRAIN sub-detector. (...)

# Technical Working Groups

- Collection of individuals/Institutions interest (January 2022)
- Identification of preliminary chairs (February 2022)
- Formal request to organize the WG (March 2022)

## Activities / Sub-systems

## Initial chair(s)

**1) Magnet and Yoke**

*G. Delle Monache*

**2) ECAL**

*D. Domenici, A. Di Domenico*

**3) STT**

*G. Sirri, S. Di Falco, R. Petti*

**4) GRAIN**

*A. Montanari, L. Di Noto*

**5) DAQ/Trigger & Timing/Slow Controls**

*M. Pozzato, S. Di Domizio,  
C. Mariani*

# Contributions

- SAND Consortium provides the detector components, expertise and resources for testing, assembling, installation, commissioning
- DUNE-US/Fermilab is proposed to provide logistics, technical support and engineering for the pre-assembly activities, pre-shipping and post-shipping acceptance tests, occurring outside the DUNE-ND complex prior to installation
- DUNE-US/Fermilab is proposed to provide cryogenics for detector operation, logistic, technical support and engineering oversight for the installation activities in the DUNE-ND complex

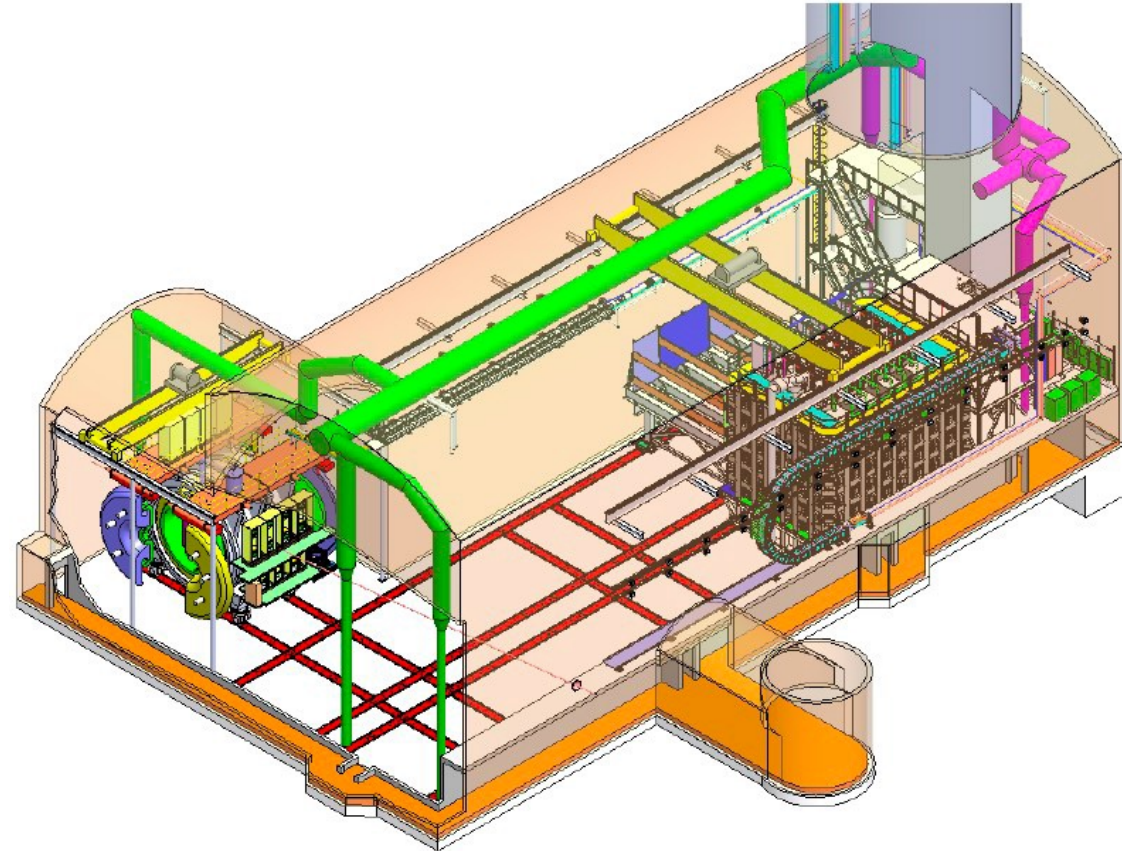


## DUNE Phase I:

ND-LAr (movable)

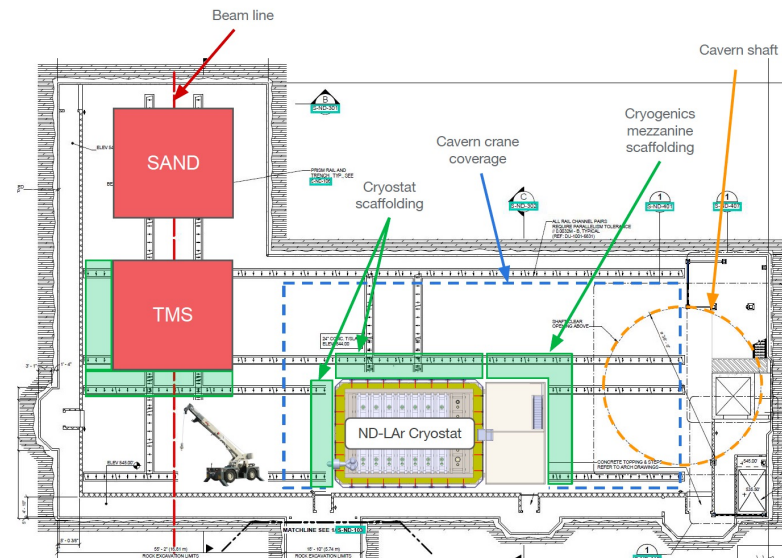
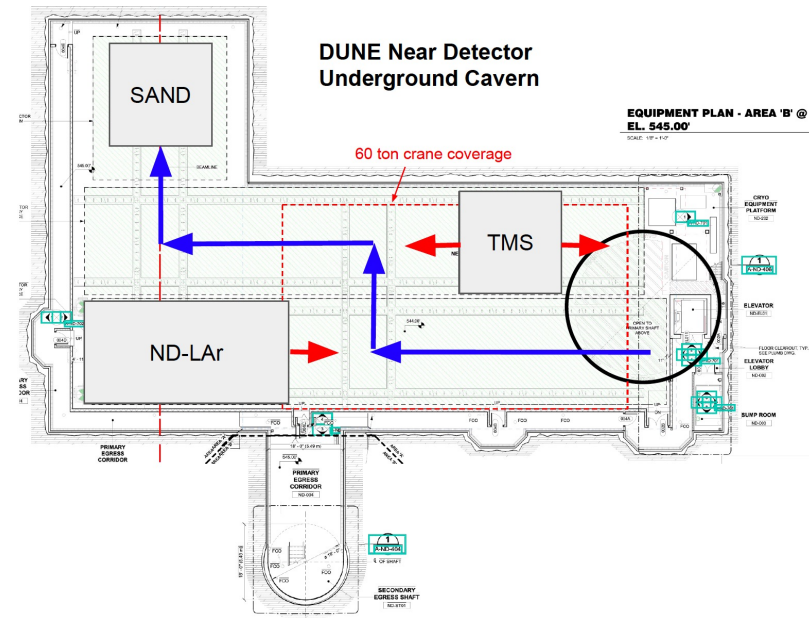
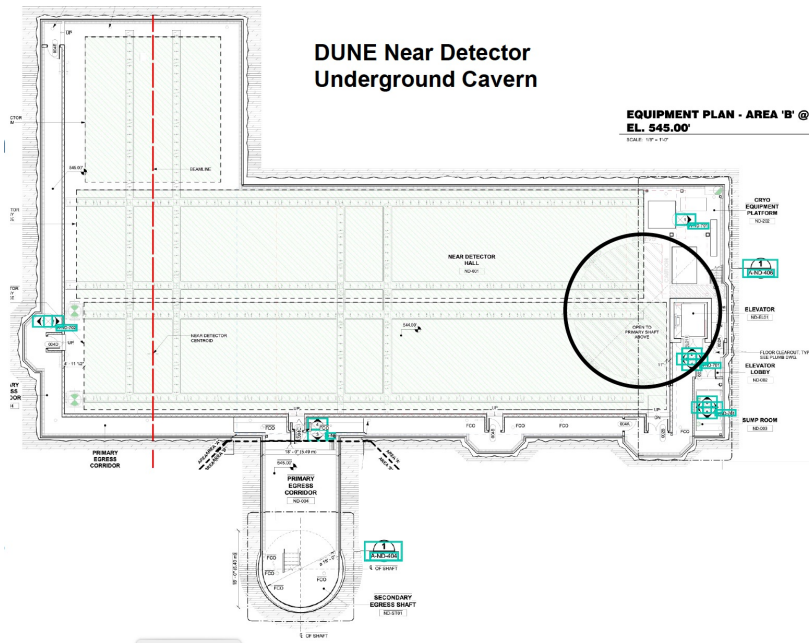
TMS (movable)

SAND (on-axis)



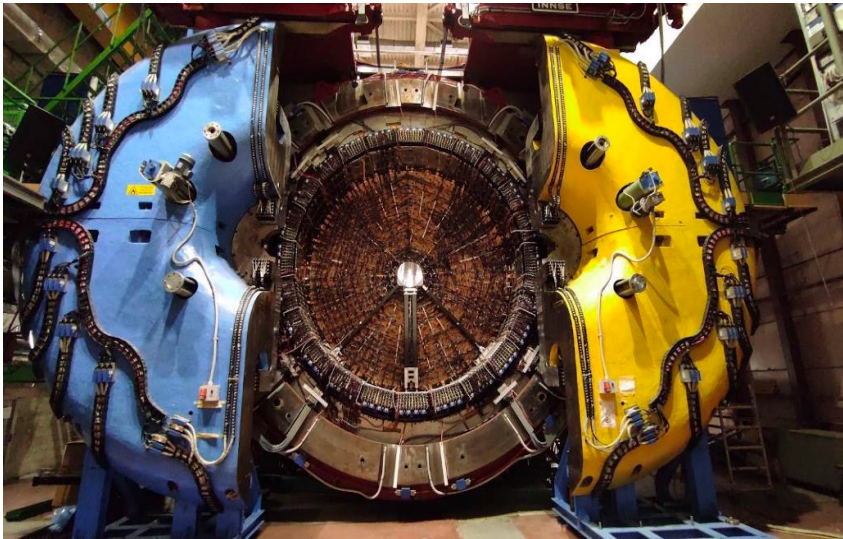
In one of the defined assembling sequence, SAND should be placed first in the alcove. A lot of flexibility for the assembly policy...





SAND will agree on any sequence it should be decided upon. In any case, our planning is consistent with starting installation as soon as beneficial occupancy will be given

# ECAL and Magnet status: from KLOE to SAND

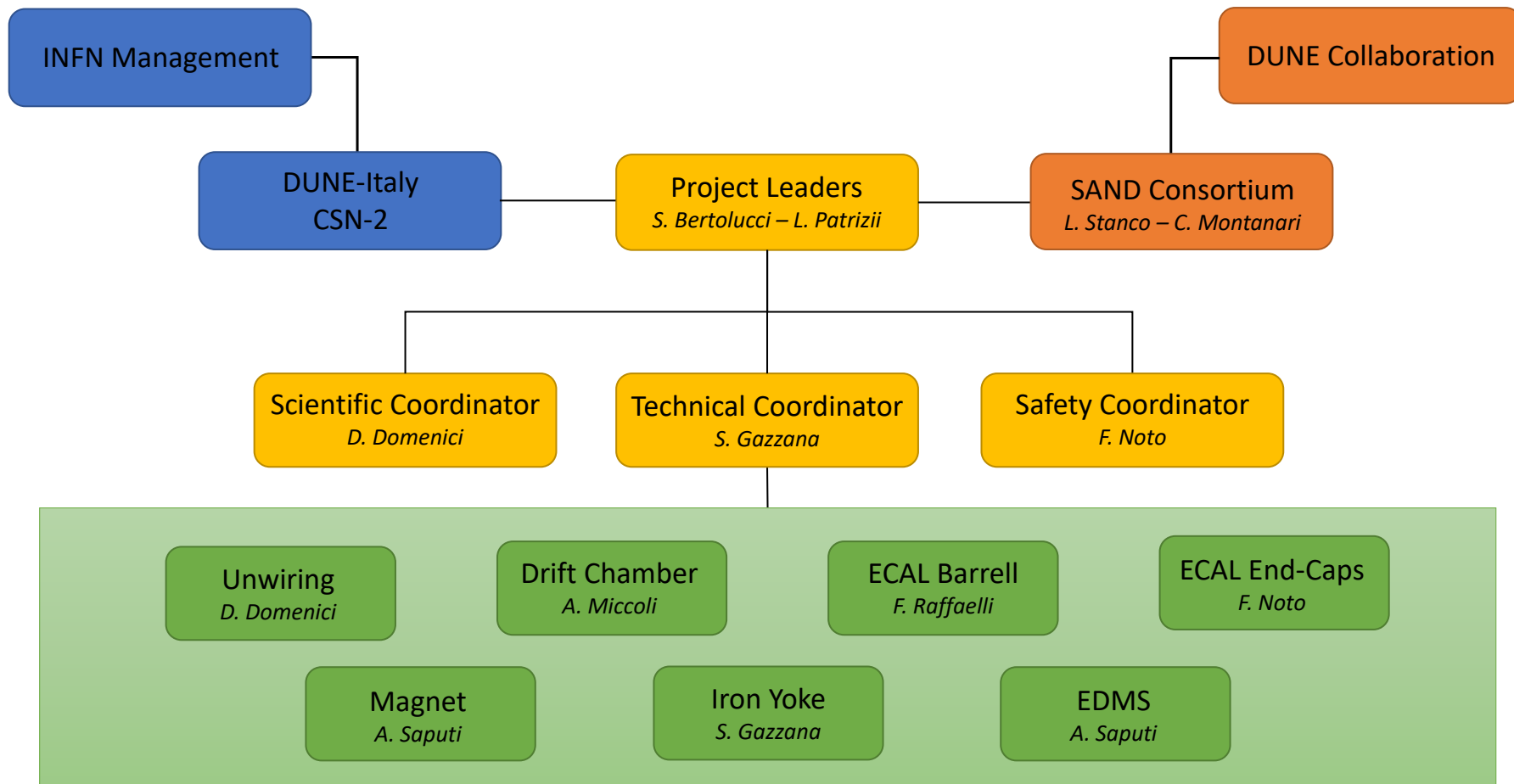


## List of operations:

1. survey, revision and design of mechanical tools
2. unplugging and cables removal
3. extraction of KLOE Drift Chamber
4. extraction of ECAL barrel modules
5. dismounting of ECAL endcaps
6. extraction of coil
7. dismounting of iron yoke

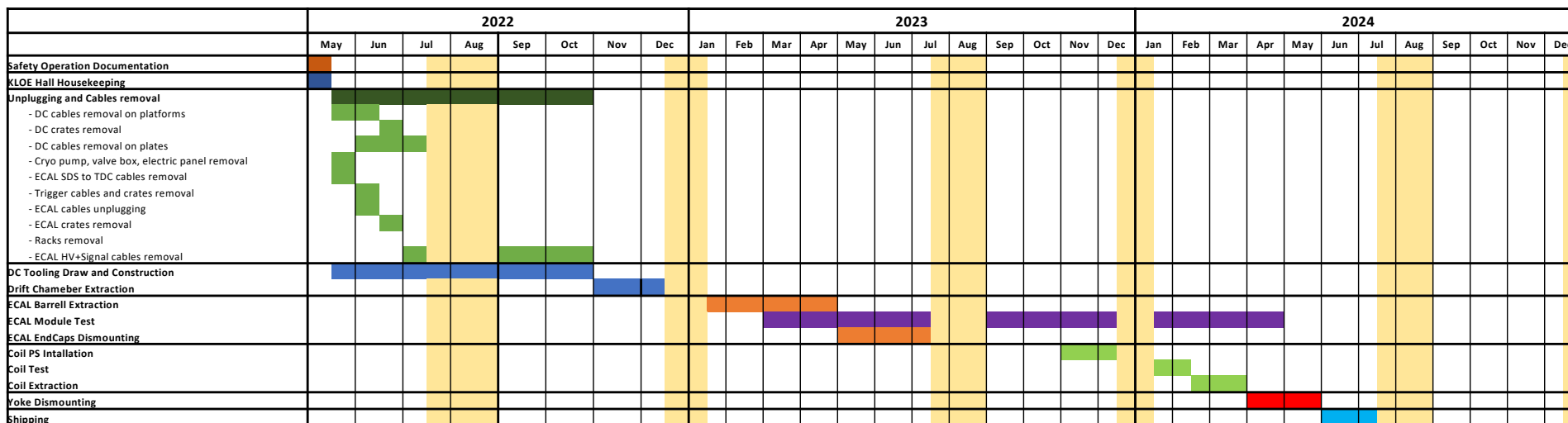
# KLOE-to-SAND

## KLOE-TO SAND Project OBS



# KLOE-to-SAND project

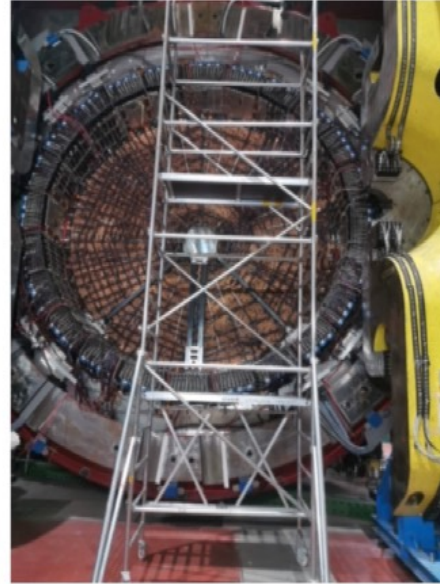
## Foreseen schedule



we are here



# Operations begun



Installation of scaffolding for un-cabling

Cleanup and removal of non re-usable instrumentation



# Start of the Operations

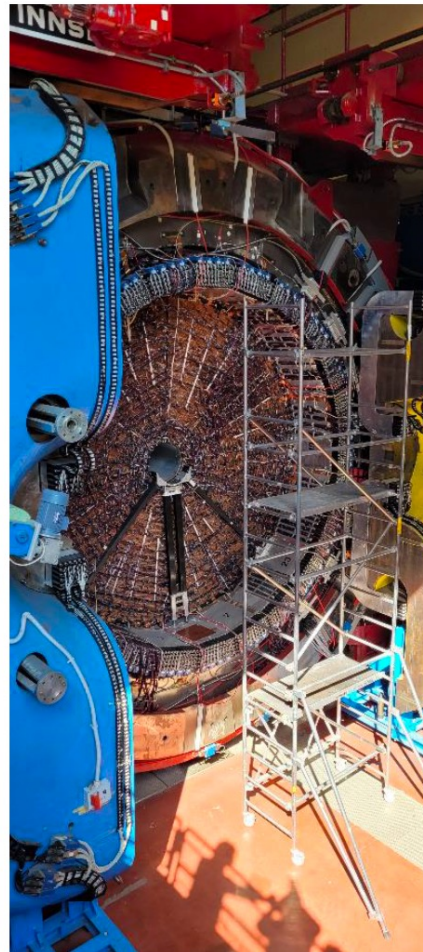
After several meetings and interactions with LNF Director and LNF Safety Head the dismantling procedures to be applied according to laws and regulations have been formally endorsed.

The first operations for preparation and cleaning of the area started on May 9th



Removal of not reusable instrumentation

17 May 2022 - DUNE CM



Mount of the scaffold

A. Di Domenico - D. Domenici

on Wednesday 12 the Barrell Extraction Tool left LNF for the company in Tuscany due to totally revamp it

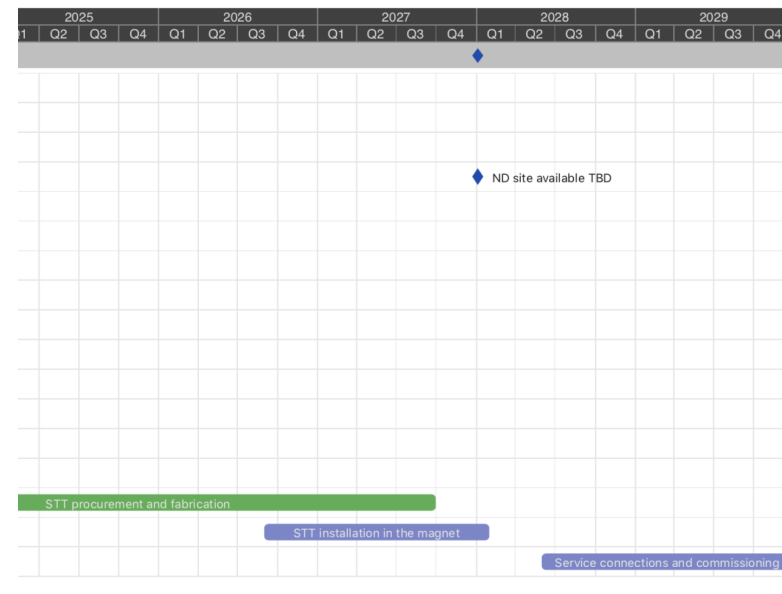


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# STT activities and schedule

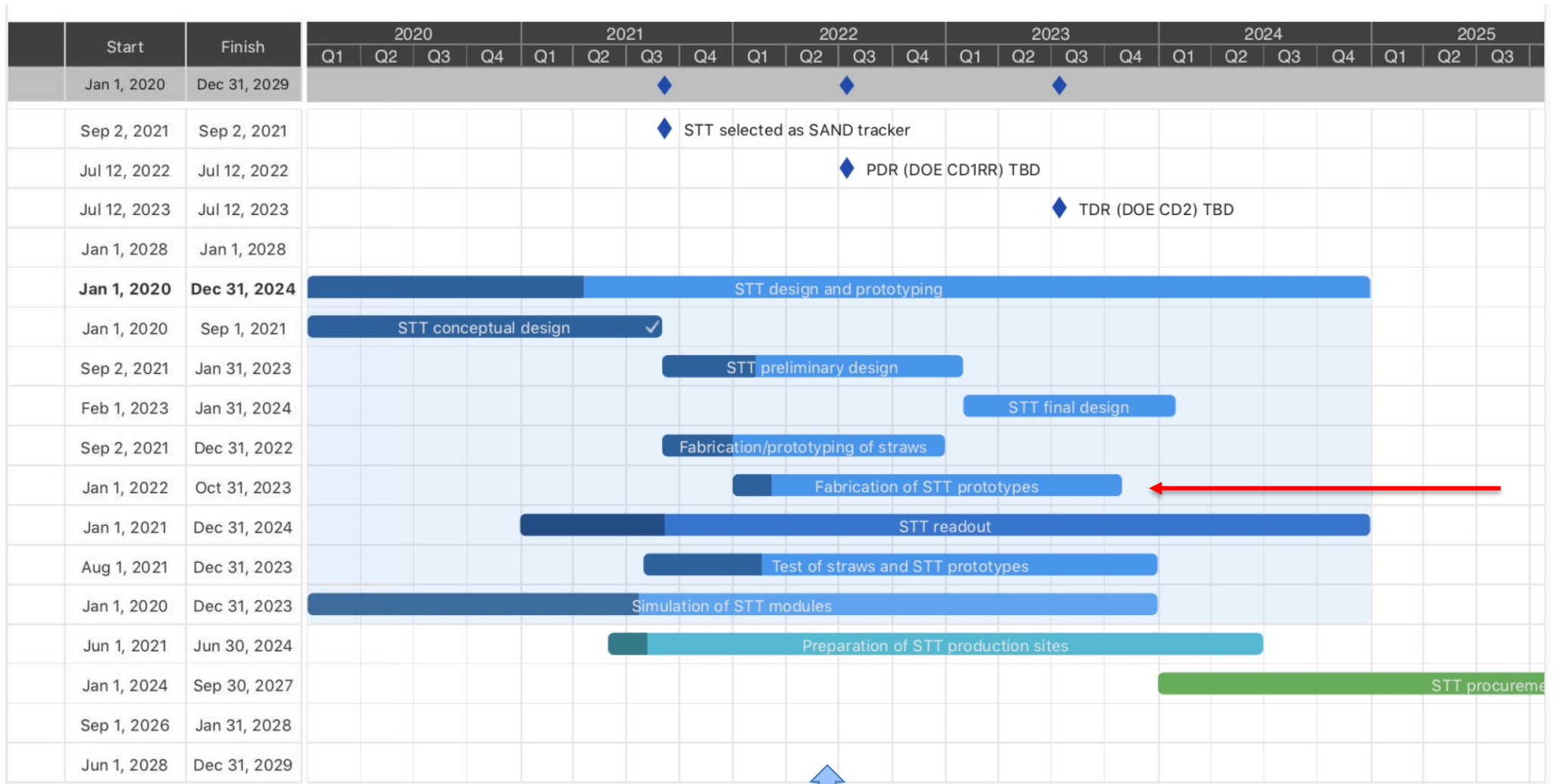
- Defined scope of activities required for the completion and installation of the STT.
- Foreseen schedule and related deliverables:
  - Identified main tasks and timeline (to be revised following inputs/developments);
  - Uncertainties on availability of ND site and current situation (covid19, conflict, supplies, etc.).

*Driven by the current DUNE schedule*





and backward



we are here

# Test beam at CERN (April-June)

V. Maleev (PNPI)

Start with minimal setup:

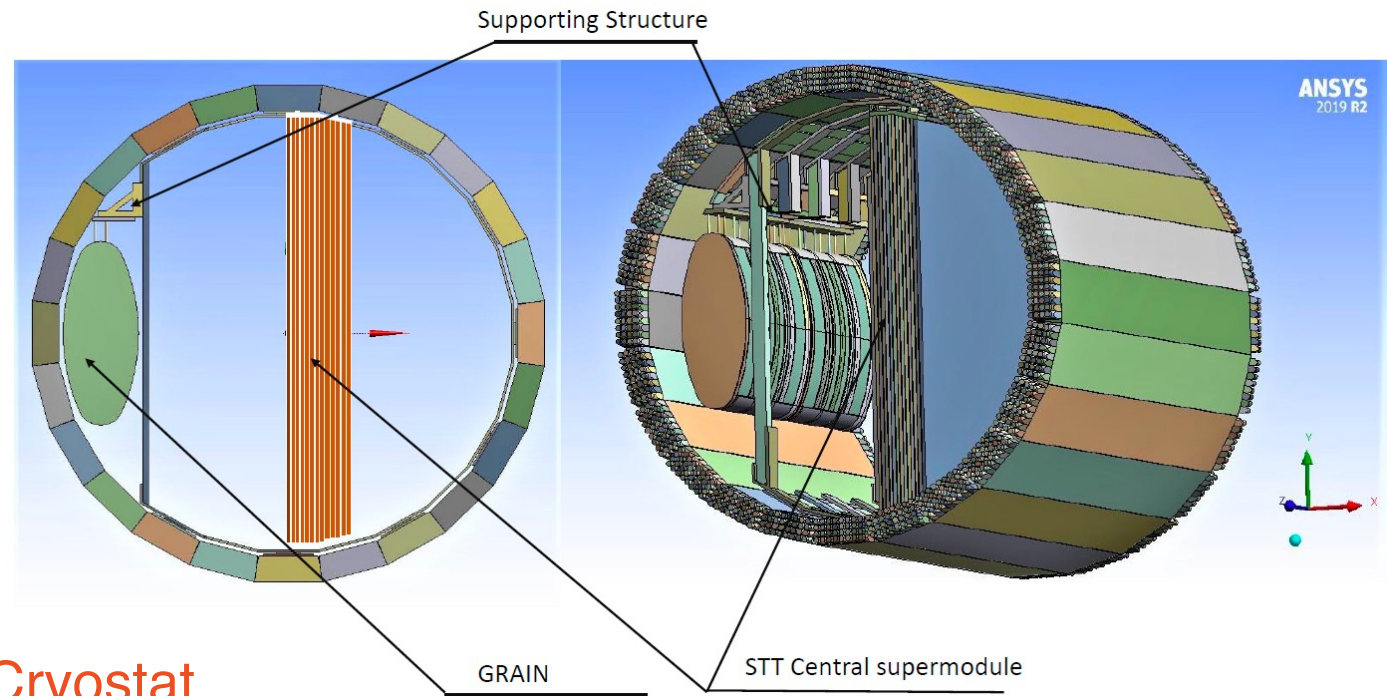
- One plane of 6 mm straws equipped with mu2e boards (one VMM3 chip)
- Scintillator for trigger
- 3 MM tracker with APV readout

Test beam schedule:

- 25 April – 3 May parasitic
- 18 May – 24 May main user
- 25 May – 8 June parasitic

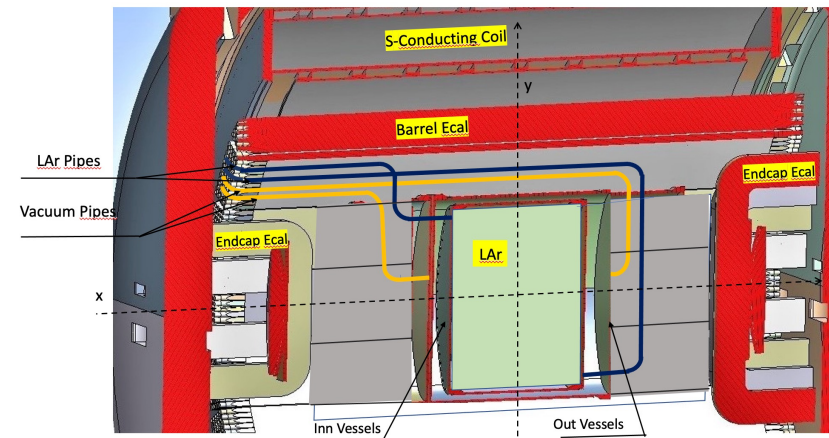


# GRAIN



Working on:

- Mechanics of the Cryostat
- Detectors and Optics for VUV
  - Scintillation lighto Coded Aperture masks (Hadamard)
  - Lens for VUV
- Cryogenic readout electronics and Detector demonstrator
- Tests in Argon cryostat(Artic)



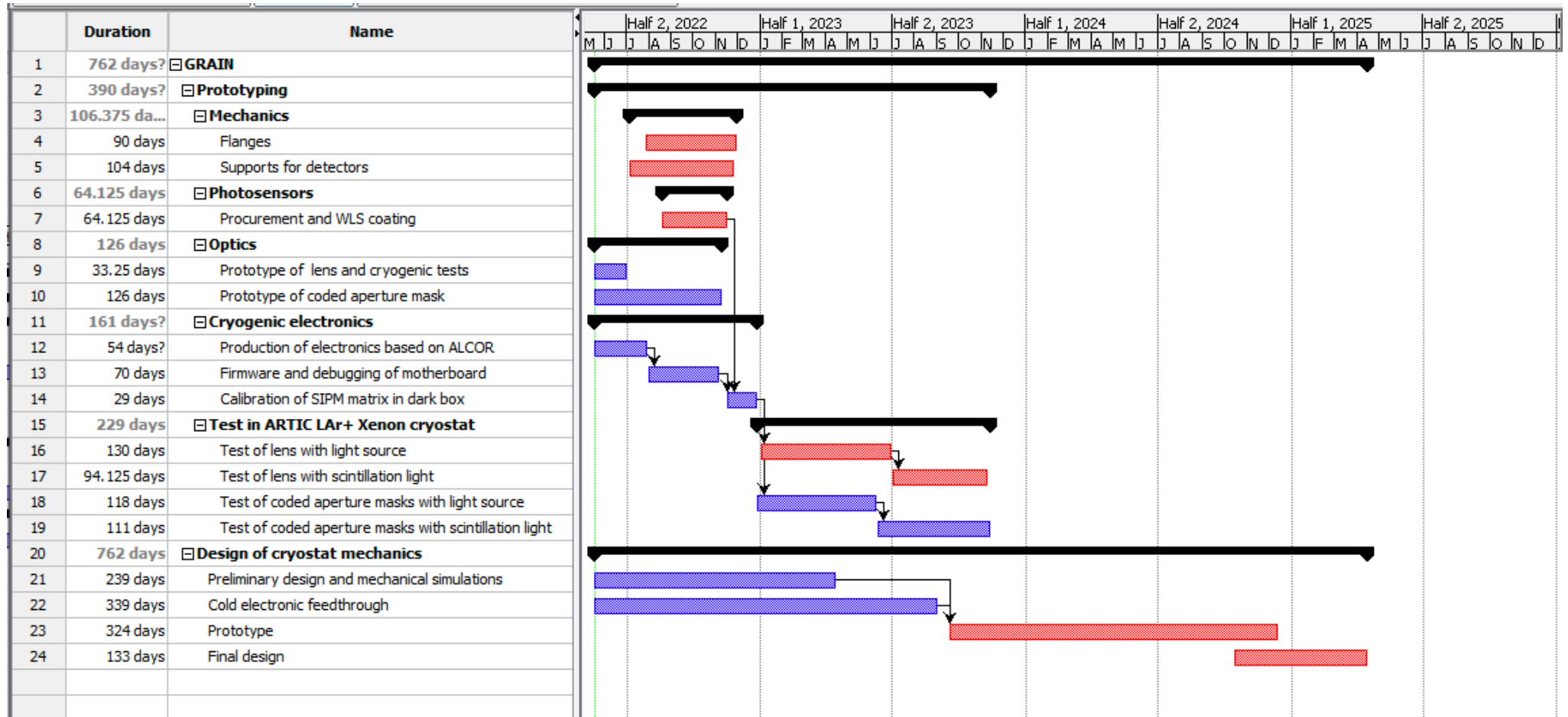
# GRAIN Review

- GRAIN (**GR**anular **Ar**gon for **I**nteraction of **N**eutrinos) concept aims at obtaining relevant information on nuclear effects by comparing topologies of neutrino scattering events off Argon, Carbon and Hydrogen, within the same detector, immersed in a uniform magnetic field.
- Identification of  $\nu$ -Ar interactions is achieved by imaging a (1 ton) LAr volume through the fast component of the LAr scintillation light. Tracks exiting the LAr volume are then reconstructed by the STT and ECAL detectors.
- Two technologies are being explored for the production of images from LAr scintillation light: one based on Hadamard masks and the other using concentration lenses. In both cases the optical sensors are SiPM readout by high density ASICs, specifically designed to operate at LAr temperature.
- An internal DUNE review was conducted, in February 23rd and 24th, to verify the maturity of GRAIN concept, in particular the physic potentials, the level of integration with other SAND and DUNE-ND detectors and, to a lesser extent, its technological implementation.
- **Committee report can be found at: <https://indico.fnal.gov/event/53099/>**

*We are grateful to the DUNE Internal Review, process and members*



# Timeline



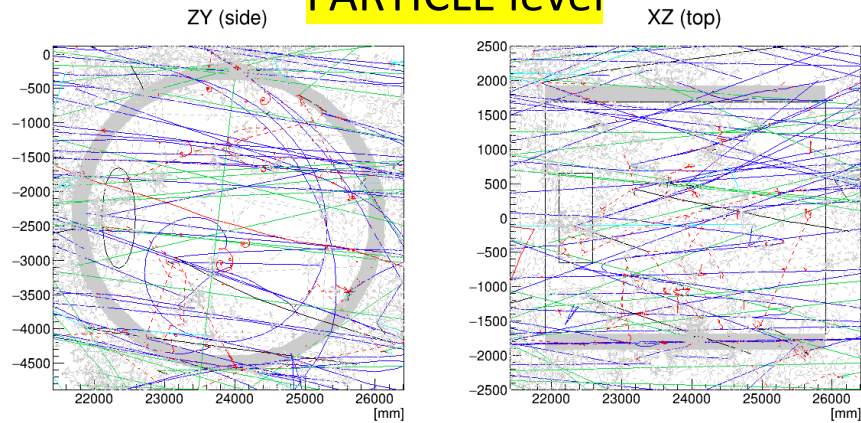
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# First set of high level milestones

- Design review of Yoke + Magnet + ECAL and of related installation procedures: **April 2023**
- • Preliminary design review of STT: **November 2023**
- Preliminary design review of GRAIN: **April 2024**

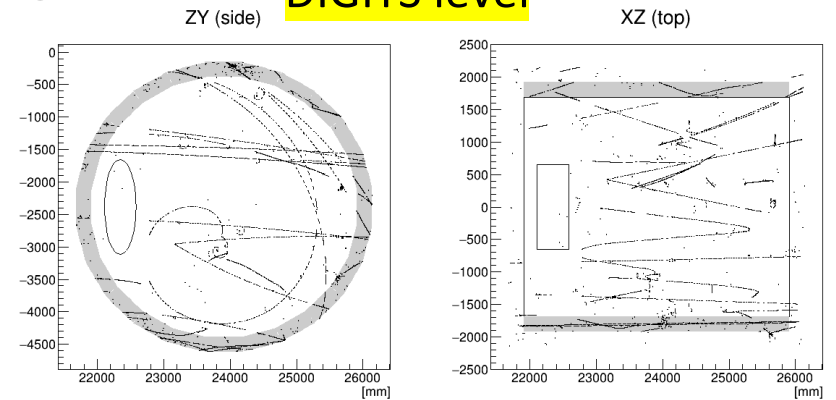
# Events in an entire spill

**PARTICLE level**

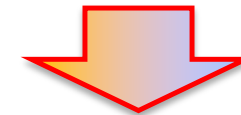


(not time-gated)

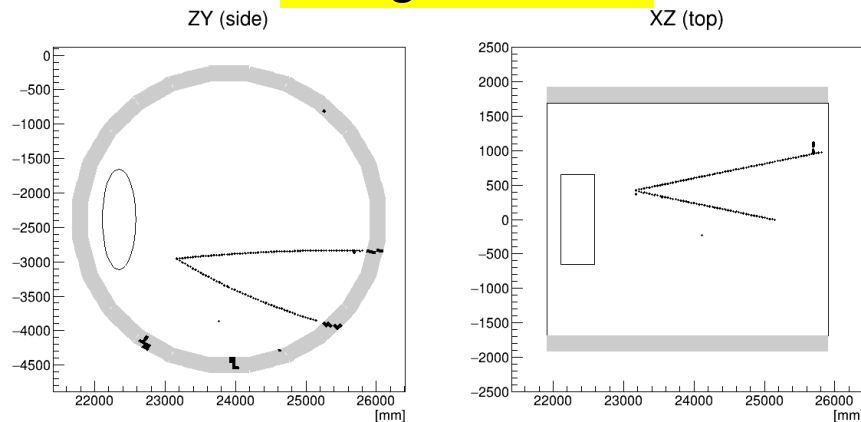
**DIGITS level**



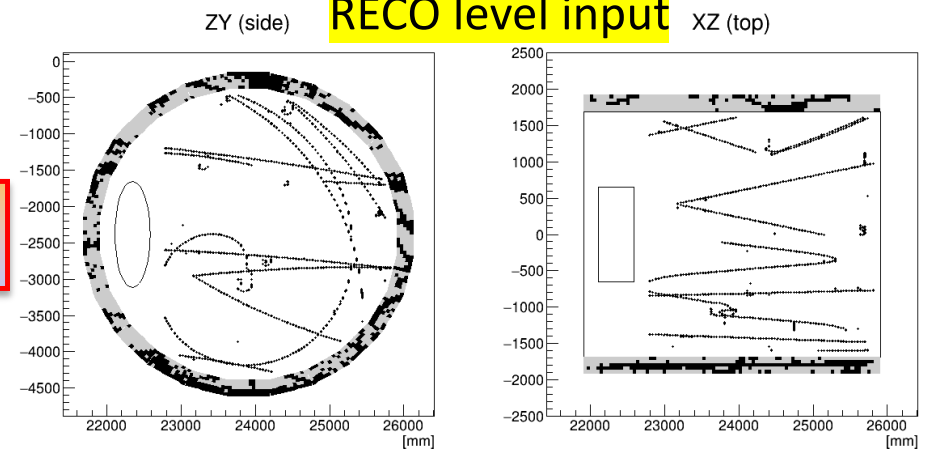
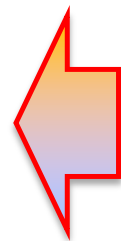
SAND + TMS + NDLAR (no rock-muon)



**time-gated 100 ns**



**RECO level input**



## Event identified



# STT+ECAL performances

**Momentum scale uncertainty:**  $\Delta p < 0.2\%$

calibration from  $K_s^0 \rightarrow \pi^+ \pi^-$  in STT volume (340 000 in FHC in 5 years)

**Reconstruction efficiency:**

- Protons: ~ **65%** for C interactions ~ **94%** for H interactions  
calibration from  $\Lambda^0 \rightarrow p \pi^-$  in STT volume (500,000 in FHC in 5 years)
- Neutrons: ~**74%** for C interactions ~ **82%** for H interactions
- $\pi^0$  from  $\gamma$  conversions (at least one) (~ **49%**)  
within the STT volume + ECAL clusters
- wrong charge identification: muons **0.8%**, electrons **1.2%** (from circular fit)

**Particle identification:**

- p/ $\pi$ /K with dE/dx, range, time-of-flight with ECAL, and ECAL energy depositions
- Electron with Transition Radiation and dE/dx in STT + ECAL energy and topology

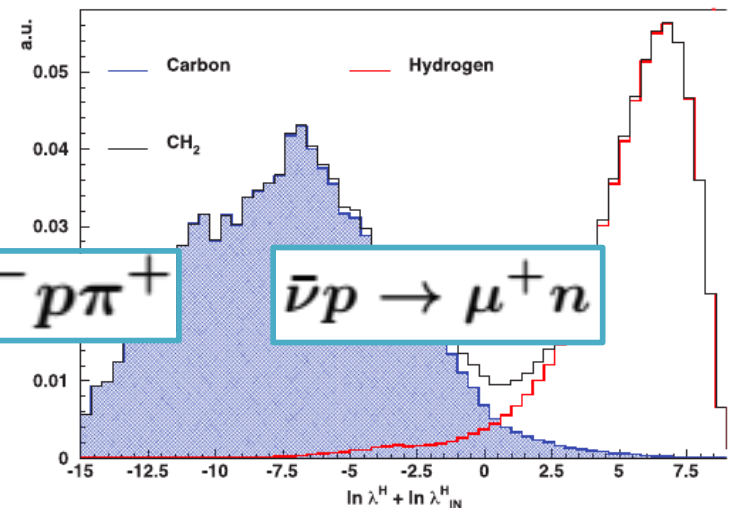
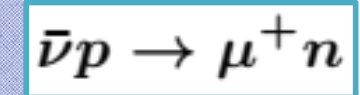
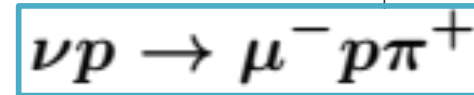
# SAND potentials

- Interactions on CH<sub>2</sub> :

- for low-nu analysis,
- for  $\nu + e$  on-axis flux measurement  $< 2\%$  ← ND-LAr+ TMS
- Ratio  $\nu_e / \nu_\mu$  and  $\bar{\nu}_e / \bar{\nu}_\mu$  vs E
- Ratio  $\nu_e / \nu_\mu$  vs E from coherent  $\pi^- / \pi^+$

- Interactions on H (after selection):

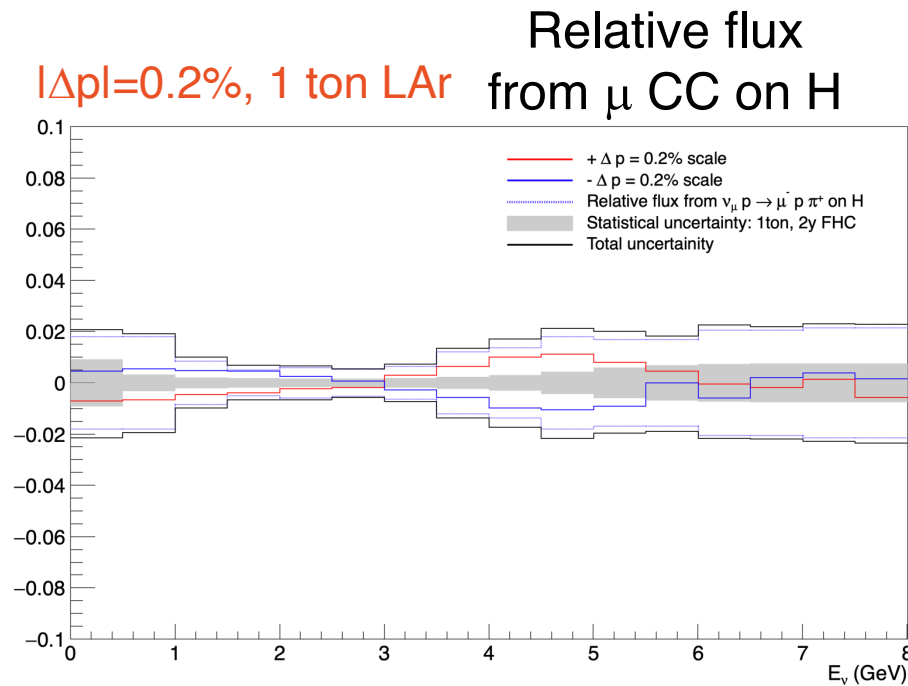
- for neutrino flux measurement
- for cross section measurement on H (model tuning)



- Interactions on Ar

- for inclusive/exclusive CC sample with a magnetic spectrometer ← ND-LAr+ TMS
- for cross-section constraints / tuning nuclear model
- by a comparison with hydrogen interactions

# Example of SAND systematics using GRAIN+STT



With a 2y FHC 1.2 MW exposure uncertainties dominated by systematics even for relatively small Ar target in SAND ( $\sim 1$  ton)

# Conclusions

- ✓ The SAND organization is well advanced.
- ✓ Base detector configuration is (most than) available and defined with optimizations in progress:
  - ✓ Disassembly of KLOE in Italy started
  - ✓ Robust R&D program underway for STT and GRAIN
- ✓ Financial resources and manpower are almost completely identified. Our plan is coherent with the first day of ND-hall allowance to start installation
- ✓ The physics potentials and complementarities are huge
- ✓ The SAND configuration allows for a full integration into DUNE-ND complex

# Richieste Finanziarie Padova

Gruppo Pd : 3 Ricercatori – 1.5 FTE

Capitolo	Descrizione	Parziali (k€)		Totale (k€)	
		Richieste	SJ	Richieste	SJ
missioni	Per meeting di Collaborazione (2 persone)	8.00	0.00	33.5	0
	Per supervisione SAND, sia a FNAL che a Frascati, incluso progetto STT	12.00	0.00		
	Per smontaggio KLOE a Frascati (tecnico elettronico), 2 m.u. (1.5 Kâ- x 9)	13.50	0.00		

# BACKUP

# STT WG

- Working Group: its activities are related to the design and construction of the STT for SAND, with the final goals assigned being the completion of the detector installation and its readiness for operation.

*new mailing list DUNE-ND-SAND-STT*

- Prototyping activities:
  - Production of straws with ultrasonic welding technology:  
5m (JINR) and 1.1m (GTU) long straws with 20  $\mu\text{m}$  walls for tests and mockup prototypes. External diameter: 4.90  $\pm$  0.05 mm
  - Measurements of straw deformations and tension under pressure (GTU):  
elongation, wall tension, diameter variation and deformations vs. internal pressure
  - Gluing and pressure tests of 4 XXYY layer assembly (JINR) (up to 5 bar absolute)
  - Preparation for small mockup assembly with plexiglass frame (Hamburg, JINR, UofSC), to be assembled at JINR
  - Tests of VMM3a chips and testbeam exposure of small XX+YY prototype with VMM3a readout at CERN (Oct.-Nov. 2021).  
New test-beam exposure at CERN: May 22
  - Preparation for the 1.2m  $\times$  0.8m STT prototype with C-composite frame (JINR, GTU, IIT Guwahati, Panjab, Duke, INFN, Hamburg, UofSC).  
Summer 2022?