



Istituto Nazionale di Fisica Nucleare  
Laboratori Nazionali di Frascati



# Laboratori Nazionali di Frascati Research Division

P.Gianotti

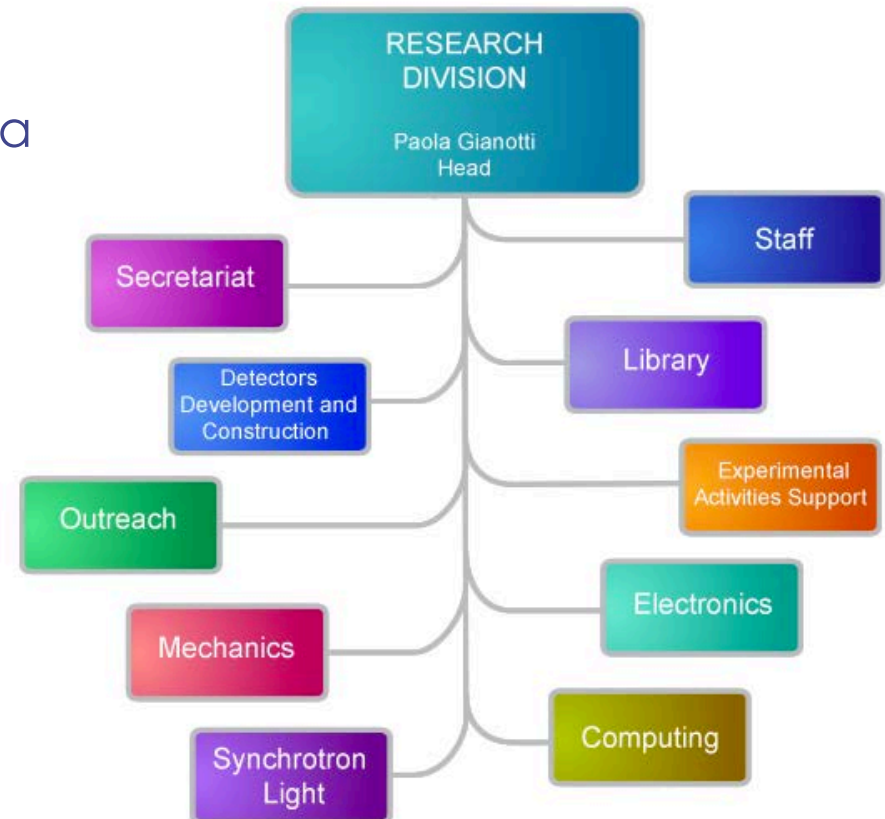
# Organization

The **Research Division** of the LNF carries out scientific activity in the field of **particle physics, astroparticle physics, nuclear physics, theoretical physics,** and **technological research**, according to the provisions of the five INFN National Commissions.

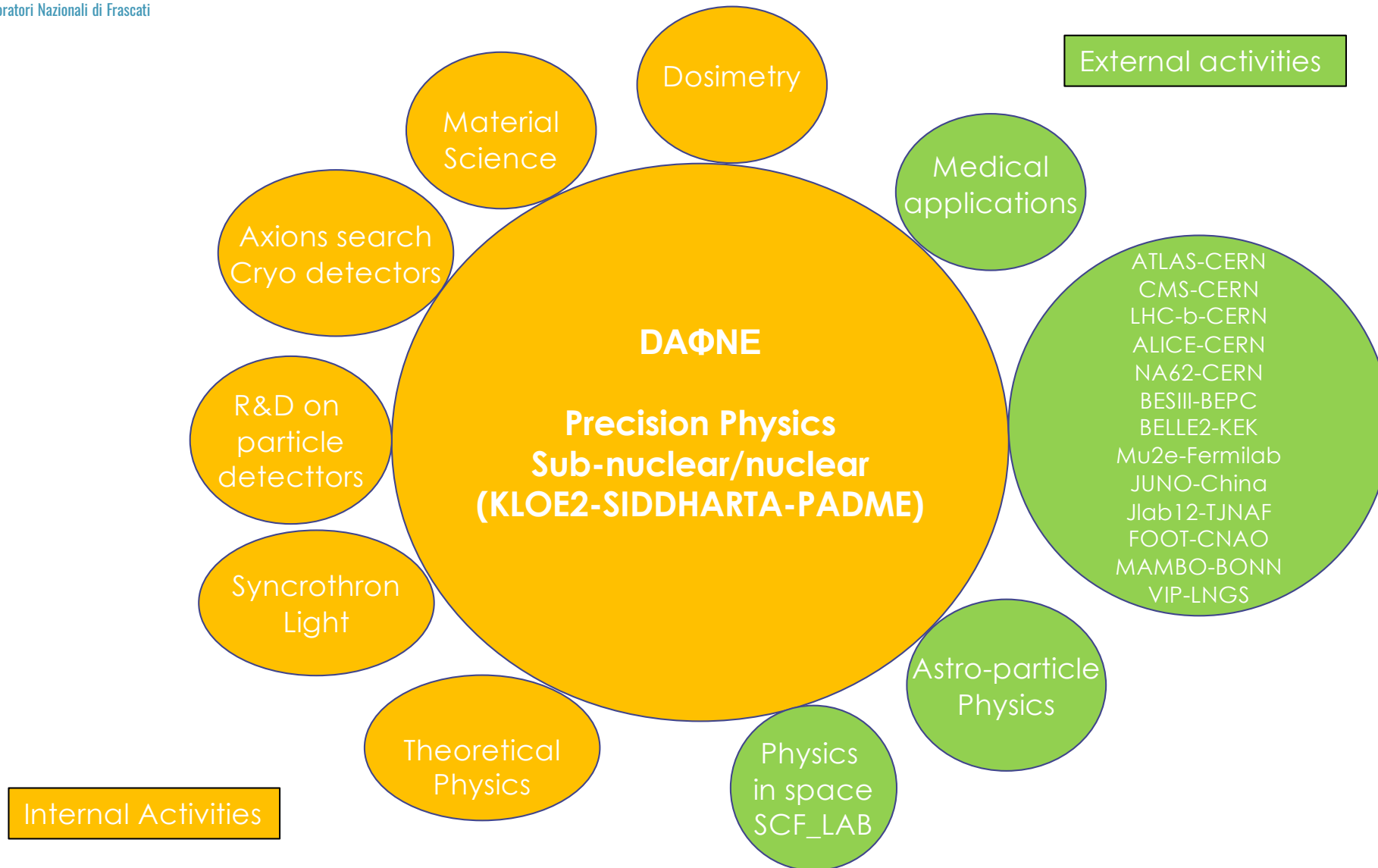
Around 200 people (employees, fellows and associates) work in the division with a percentage of researchers and technologists of 70%.

The division includes:

- 5 services (Mechanics, Electronics, Computing, Synchrotron Light, Outreach);
- 2 technical units;
- a documentation and library office;
- a secretariat office.

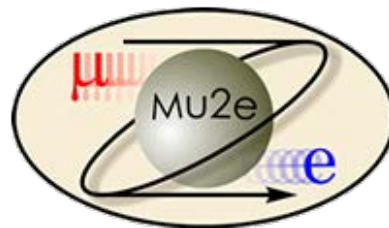


# Activities



# Particle Physics research

- Higgs boson;
- CP violation;
- Flavour physics;
- CKM matrix parameter study;
- QCD study;
- Rare decays;
- Dark matter.



Overall 71 people involved (52.1 FTE)



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# Nuclear Physics

- Structure and dynamics of hadrons;
- Hadron spectroscopy;
- Quark-Gluon-Plasma;
- Nuclear astrophysics and interdisciplinary research.



**ALICE**



**VIP**



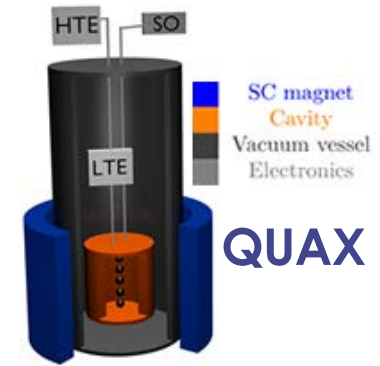
**KAONNIS**



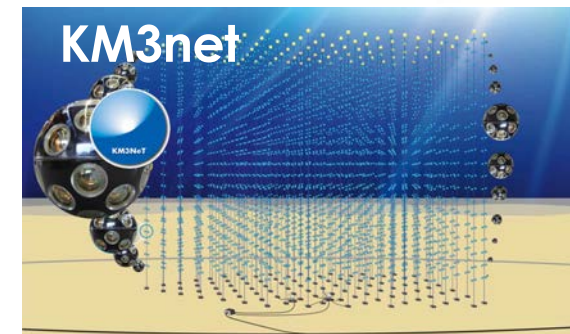
**Overall 42 people involved (32.25 FTE)**

# Astroparticle research

- Neutrino Physics;
- Dark matter search;
- Flavour physics;
- Universe radiation;
- Relativity.



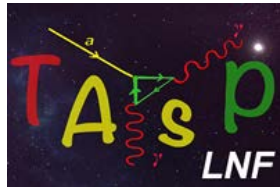
**Overall 24 people involved (15 FTE)**





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# Theoretical Physics



**TAsP**

(Theoretical Astroparticle Physics)



**ENP**

(Exploring New Physics)

**NEMESYS**

**LNF**

**NEMESYS**

(Non equilibrium dynamics models and excited state properties of low-dimensional systems)

**Overall 10 people involved (9 FTE)**



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# Technological research

LNF are engaged in numerous projects involving the use of fundamental research tools and techniques in other interdisciplinary fields.

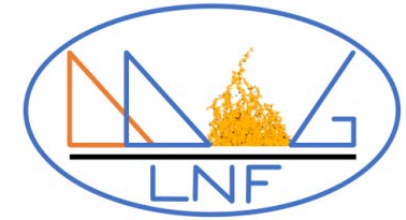
- Particle detectors;
- Particle accelerators;
- Electronics and software development;
- Interdisciplinary applications of INFN cutting-edge techniques.

**Overall 86 people involved (37.8 FTE)**

| Line | Experiment  | Sec participating   | PI                      |
|------|-------------|---------------------|-------------------------|
| in   | ANET        | TO LNF PV TS        | M. Costa                |
| ac   | ARYA        | LNF* NA RM          | <b>R. Cimino</b>        |
| in   | ENTER_BNCT  | PV LNF LNL TO       | S. Altieri              |
| in   | GLARE_X     | LNF* GSGC TIFPA     | <b>G. Delle Monache</b> |
| ac   | LEMAACC     | LNF                 | <b>O. Blanco Garcia</b> |
| ac   | NUCLEAAR    | LNF* RM             | <b>A. Marcelli</b>      |
| in   | OLAGS       | GE FI PI LNF        | F. Sorrentino           |
| in   | RESOLVE     | TO LNF LNL          | F. Picollo              |
| ri   | SIMP        | LNF* PI SA TIFPA    | <b>C. Gatti</b>         |
| ac   | SINGULARITY | LNF                 | <b>S. Pioli</b>         |
| ac   | SL_COMB2FEL | LNF LE MI NA RM RM2 | <b>E. Chiadroni</b>     |
| ac   | SL_EXIN     | MI LNF RM           | A. Rossi                |
| ac   | TERA        | RM LNF NA TO        | S. Lupi                 |
| ac   | TUAREG      | LNF RM              | <b>D. Alesini</b>       |

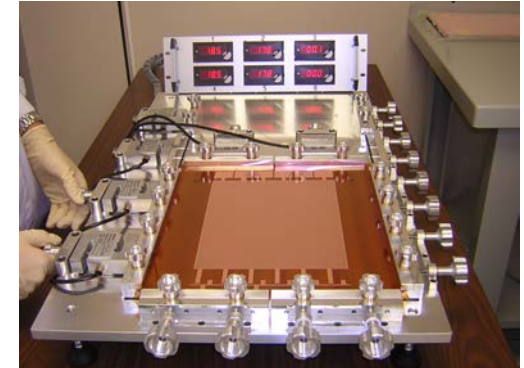


# Novel Gaseous Detectors

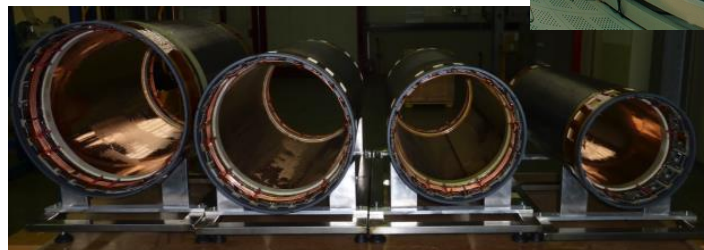
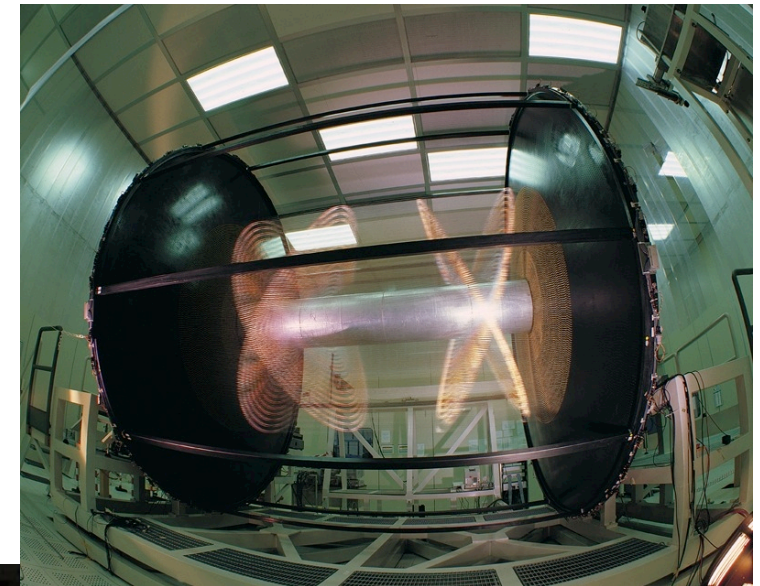


LNF has a long tradition of R&D, design and manufacturing of gaseous detectors:

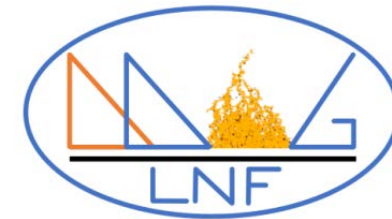
- wire tubes operated in proportional or streamer mode (1985 -1990);
- RPC with glass electrodes (1991-1994);
- large drift chamber (1995 -1997);
- Micro-Pattern-Gaseous-Detector (MPGDs – since 2000) for large high energy physics experiments.



- planar GEMs for fast muon triggering for LHCb;
- the first low mass **full Cylindrical** and dead-zone-free GEM (CGEM) detector as Inner Tracker for the KLOE2;
- R&D on novel MPGD with the introduction of the innovative  $\mu$ -RWELL gaseous detector;
- The  $\mu$ -RWELL is object of several applications in HEP (LHCb, CepC, FCC-ee) as well as thermal neutron detection (EU project - uRANIA-Attract );
- The first Cylindrical  $\mu$ -RWELL will be built in the next 2-3 years in the framework of the EU project CREMLIN-plus;
- Development ongoing for FCCee and CepC IDEA detector.

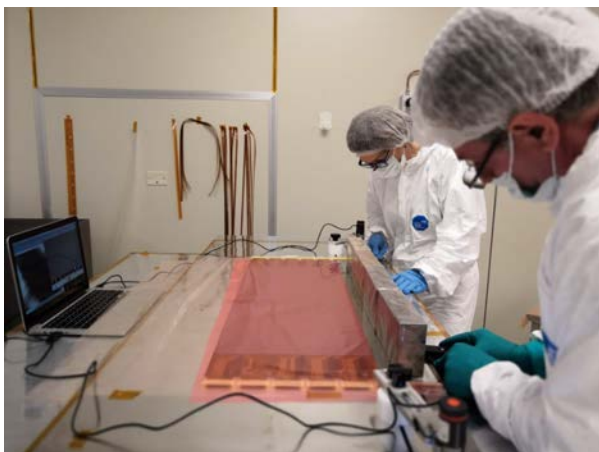


# Vertex gaseous detectors



- Precision cuts of anodes and GEM foils;
- Planar gluing: Anodes, GEM, Cathodes;
- Cylindrical gluing of Gem, Anode and Cathode
- Insertion of the 5 cylinders with the Vertical Insertion Machine (VIM) and sealing
- Final sealings;

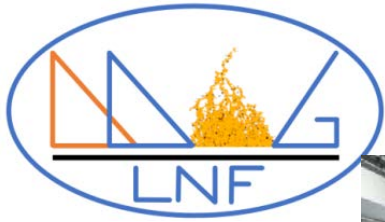
BES III



L3 of CGEM-IT  
construction just  
finished @LNF

L1 and L2 at IHEP  
since December  
'19 taking cosmic  
data





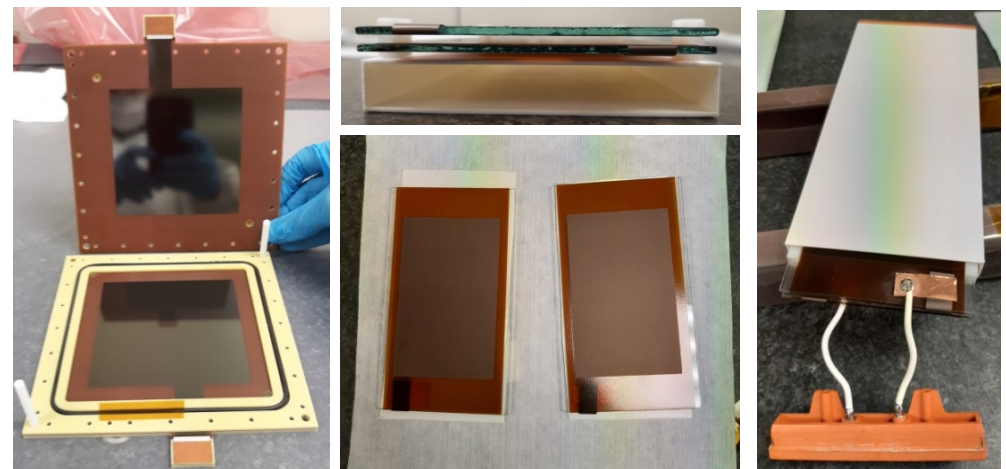
## A new Lab, new ideas...



In Bd. 8 a 20 sqm Lab devoted to this activity

A completely different concept from the one used in traditional RPCs, based on volume resistivity electrodes (phenolic resin or glass) not easily modulated.

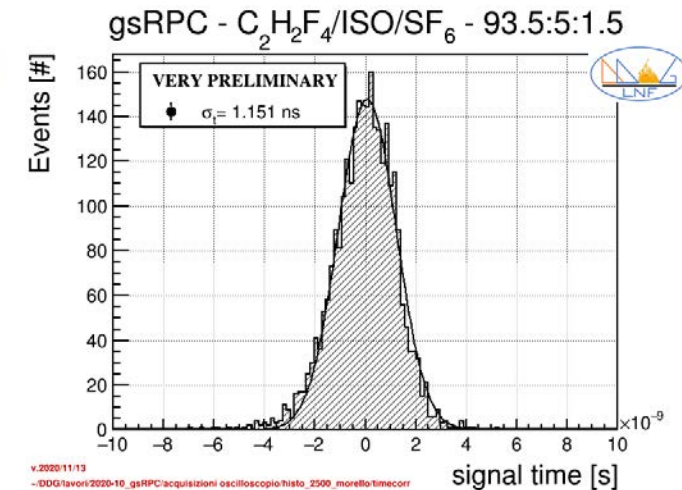
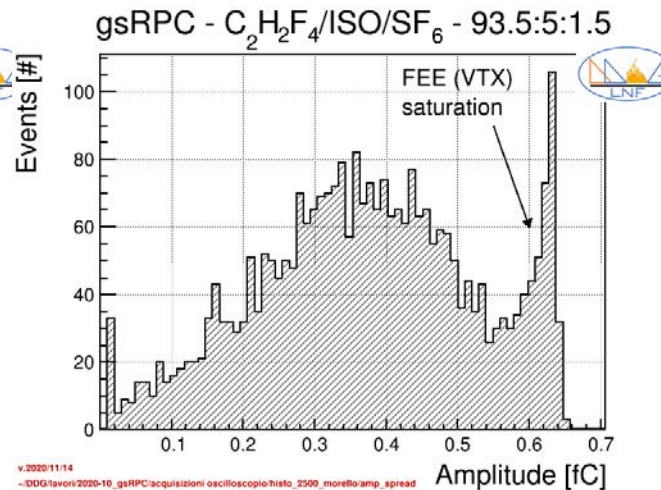
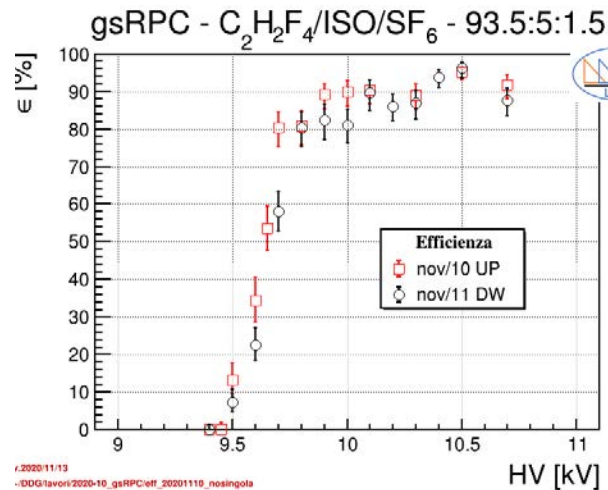
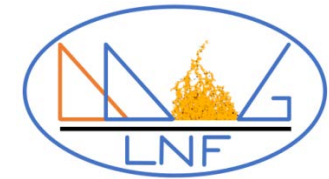
The idea → surface resistivity electrodes made with industrial technique of DLC deposition on flexible or semi-rigid supports. The surface resistivity of the DLC can be modulated over a wide range:  $100 \text{ k}\Omega/\text{sq} \div 10 \text{ G}\Omega/\text{sq}$ .



Brevetto in Italia N. 102020000002359

INFN – Istituto Nazionale di Fisica Nucleare "ELETTRODO PIANO A RESISTIVITÀ SUPERFICIALE MODULABILE E RIVELATORI BASATI SU DI ESSO."

# gsRPC: first results

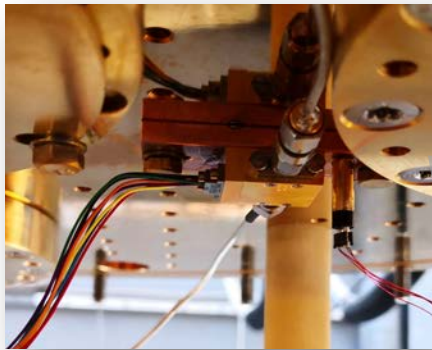


- Long efficiency plateau: > 1kV. Maybe longer but ... very large signals: > 600mV (fC)
- NO INSTABILITY and/or continuous current
- Good time resolution: After subtraction of scintillator trigger contribution compatible with  $\sigma_t \sim 875 \text{ ps}$

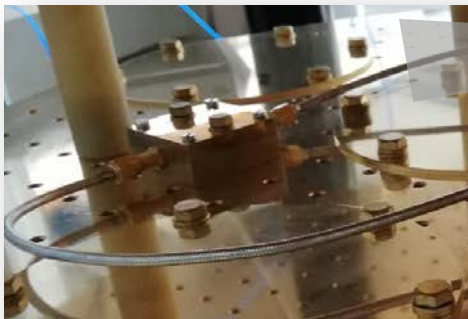


<http://coldlab.lnf.infn.it>

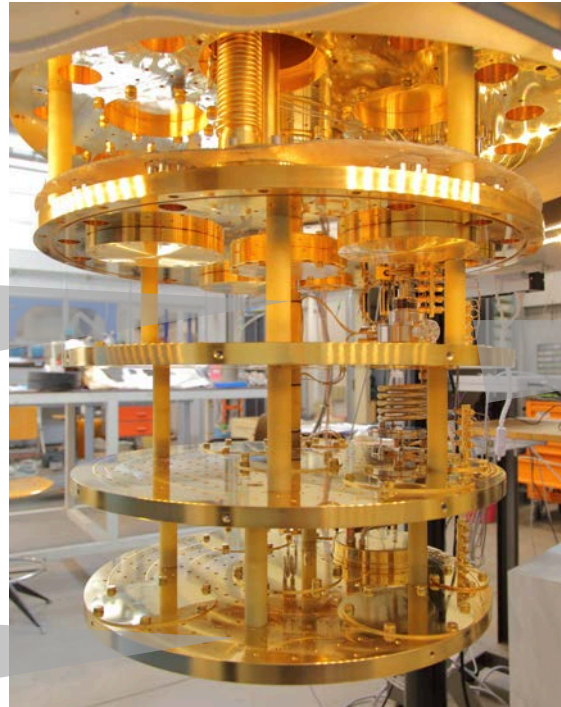
# COLD Lab



HEMT (6-20 GHz) 4K amplifier



Sample holder for SC chip at 10 mK for single photon device



4 RF lines installed from 300 K to MixCh

| Leiden CF-CS-110-1000              |   |
|------------------------------------|---|
| Cryo free Sumitomo PT              | 1.5 W at 4.2 K                                  |
| Cooldown time (with LN)            | 3 days  |
| Base temperature (measured)        | 8 mK  |
| Cooling power at 100 mK (measured) | 450 mW (up to 700 mW with a new pumping system) |



VNA 20 GHz  
WFG 20GHz  
SA 20 GHz

FET LNA 8-12 GHz and IQ-mixer (10-12 GHz)



Room T ampli & DAQ

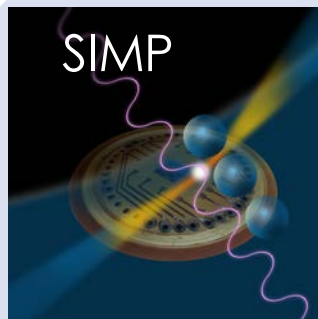




# Developing new tools

The idea is to use Quantum technologies to improve detectors

## Single microwave photon detectors



### Units

LNF (Resp Naz)

INFN Pi

INFN Sa

TIFPA-FBK

CNR Nano  
NEST

CNR IFN

INRIM

## DART WARS

### Units

MIB (Resp Naz)

LNF

INFN Sa

TIFPA-FBK

INFN Lecce

IBS-CAPP

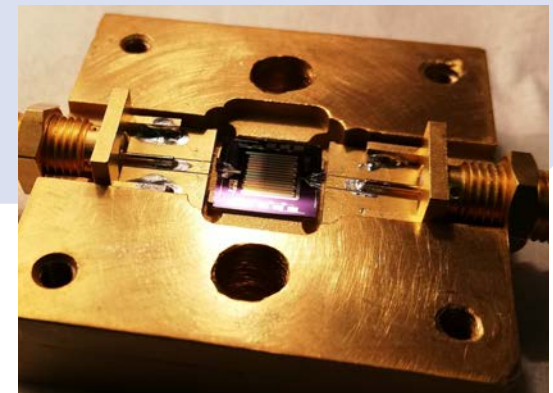
INRIM

## Detector Array Readout with Travelling Wave Amplifiers

TWJPA: under measurement at LNF

Its a chip fabricated at INRiM, composed of **900 consecutive cells containing each an RF SQUID.**

Unnder test now at LNF and at IBS-CAPP





<http://coldlab.lnf.infn.it>

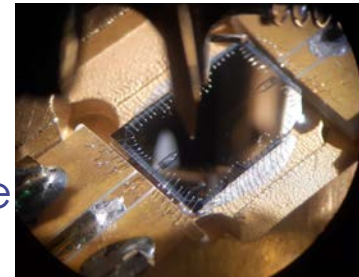
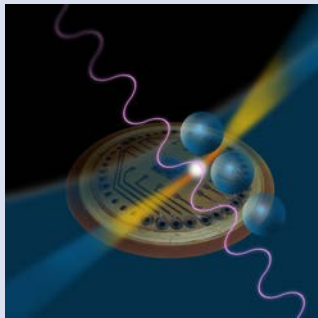
# Development of new tools

## Development of single microwave photon detectors

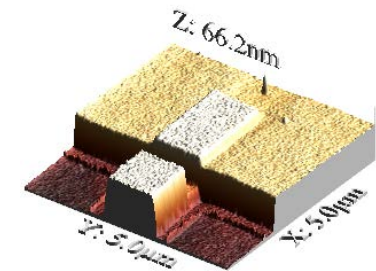
1. Josephson junctions (JJ) fully characterized at LNF in a dilution refrigerator

2. RF test of Al transmission line

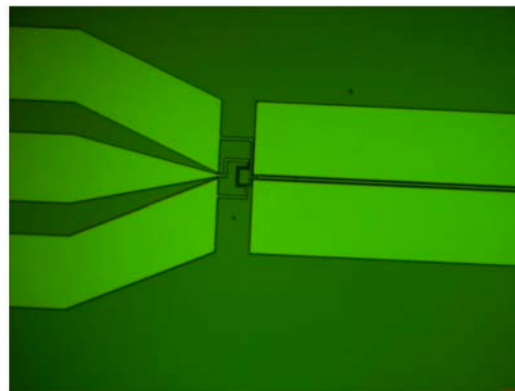
3. Fabrication of first photon counter based on JJ ongoing



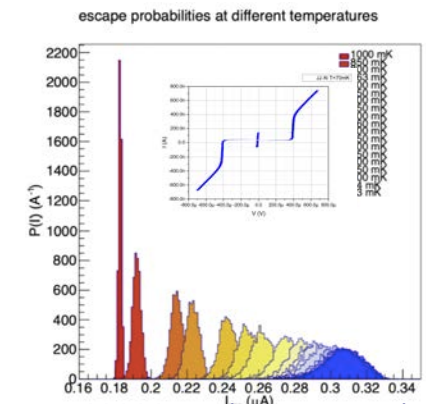
Chip with Al transmission line bonded on the sample holder



AFM Image of a JJ fabricated at CNR-IFN



Photon detector composed of a transmission line terminated with a tunable JJ (DC Squid)



JJ I-V and measured escape currents

### Units

LNF (Resp Naz)

INFN Pi

INFN Sa

TIFPA-FBK

CNR Nano  
NEST

CNR IFN

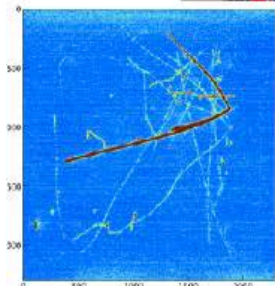
INRIM

# CYGNO/INITIUM

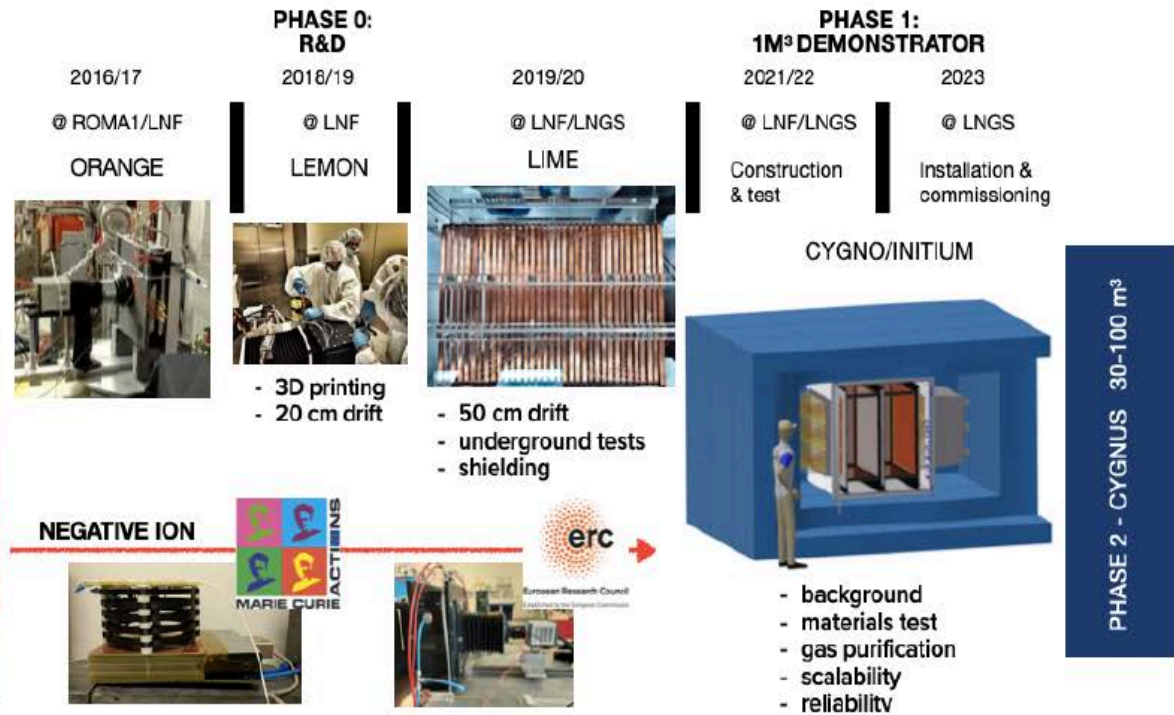
The CYGNO project aims to develop a large TPC with optical readout for high precision tracking of low energy O(keV) nuclear recoils.

*INFN (LNF, RM1, RM3, Dip di Ing. Chimica), GSSI, Centro Fermi  
University of Sheffield, University of New Mexico, University of  
Hawaii, University of UFJF Brasil*

## 1 m<sup>3</sup> demonstrator for directional dark matter search and solar neutrino physics

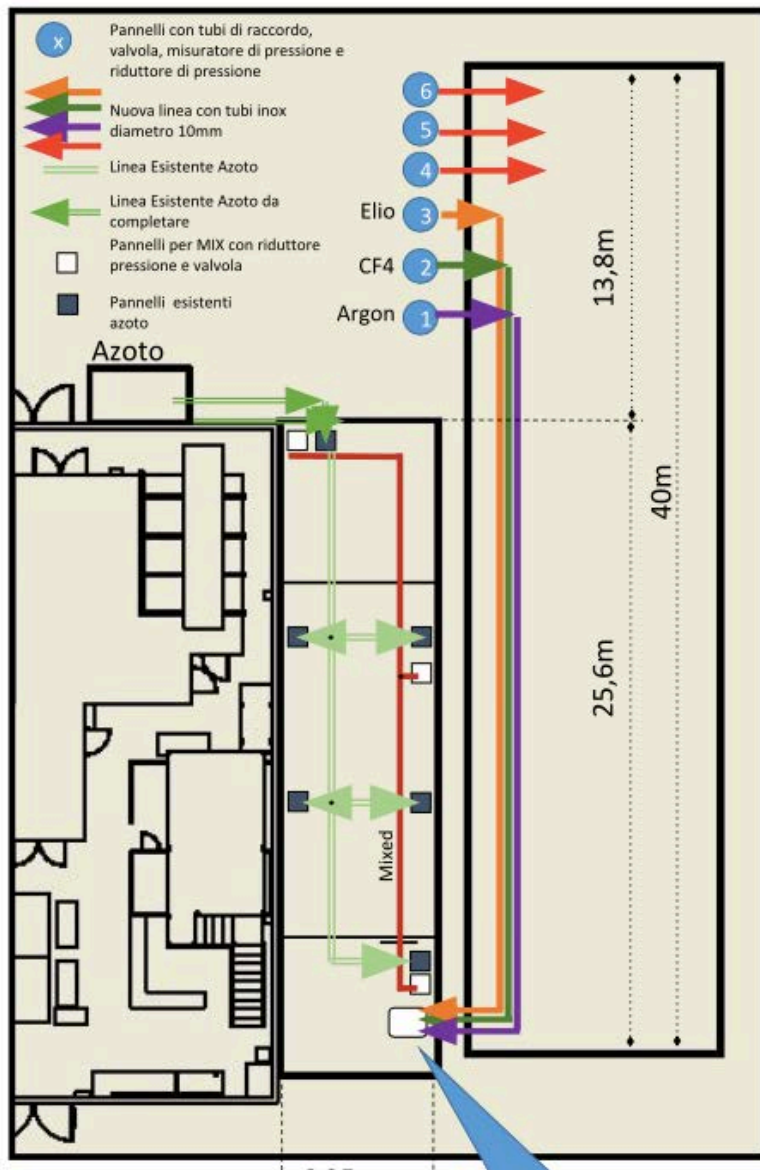


LIME first events



COVID output: arXiv:2007.00608, arXiv:2005.12272, arXiv:2004.10493  
+ 2 other papers under internal review before submission





A dedicated lab in Bd. 48 and 28 has been settled.

# LHC detector upgrade

The LHC is in Long Shutdown 2:

- upgrading the LHC experiments;
- finalising the LHC Injector upgrade;
- preparing the High-Luminosity LHC which will be the major particle physics programme during the second half of the decade and beyond.

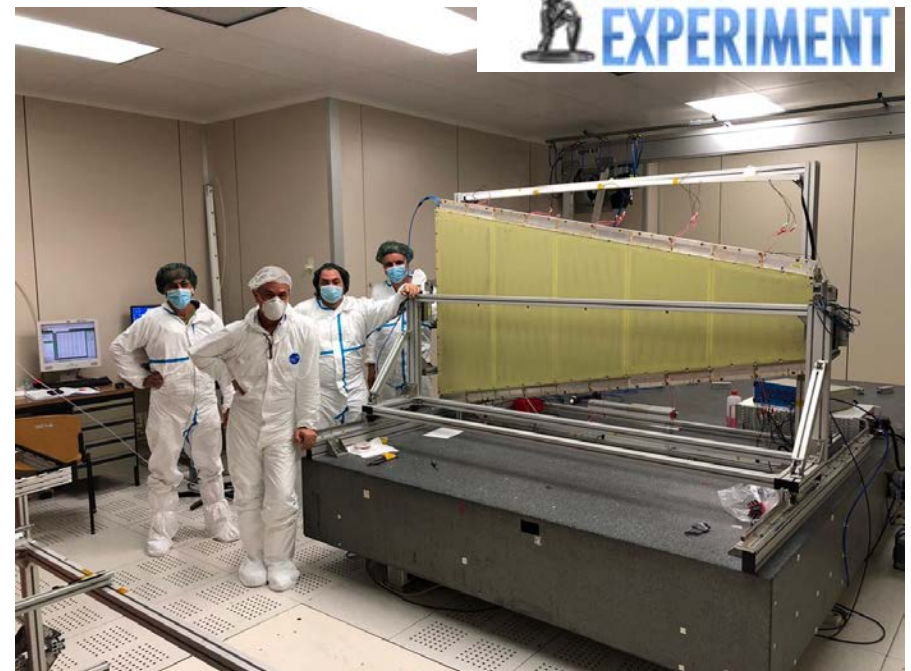


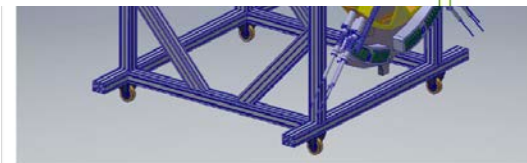
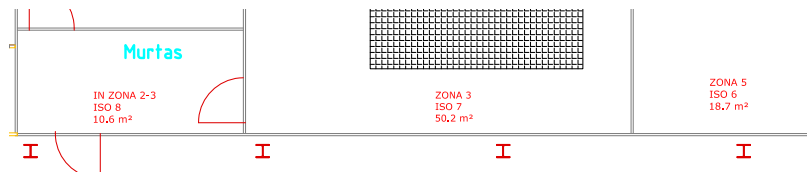
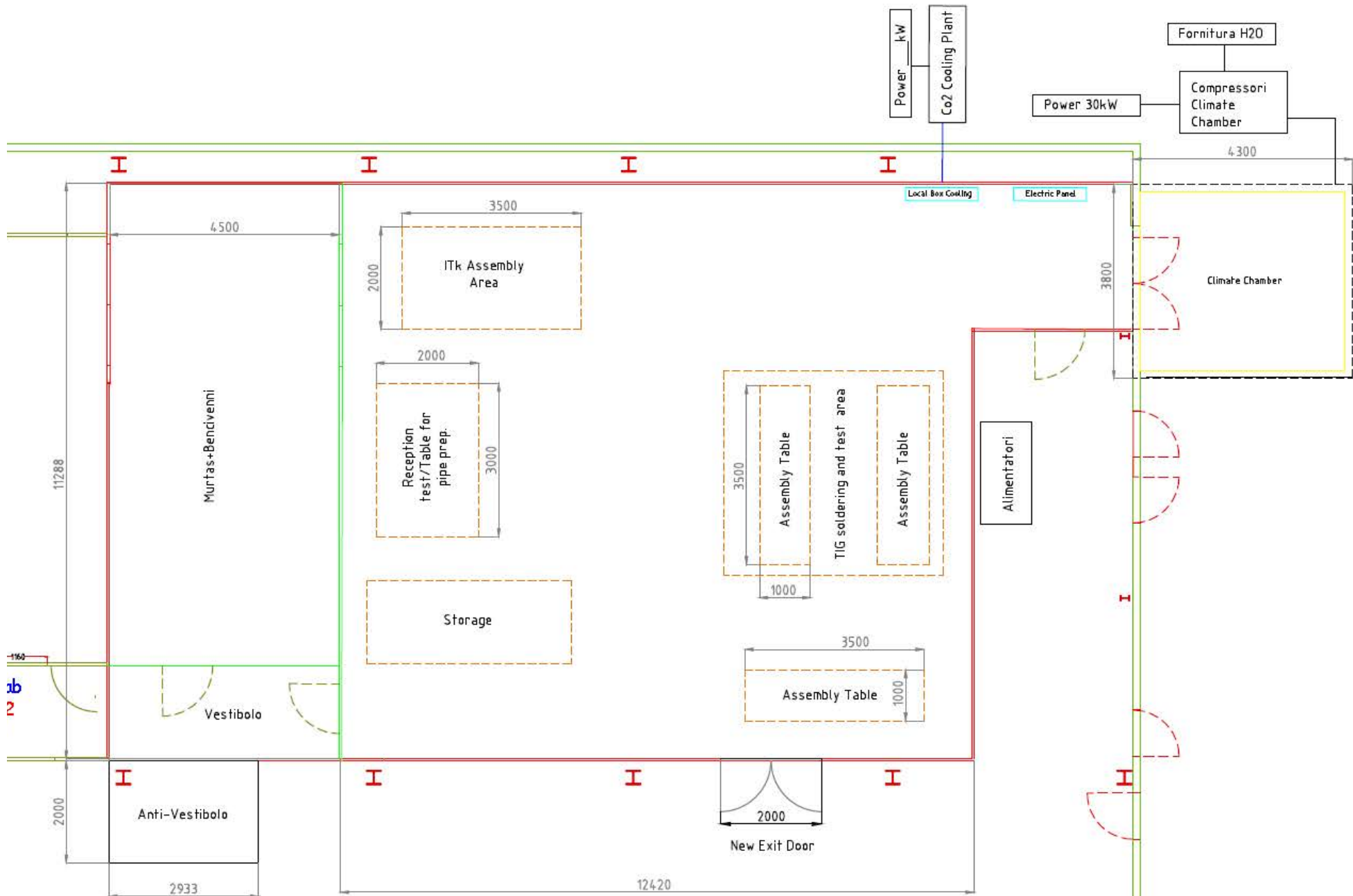
**ATLAS, CMS, ALICE and LHCb are working to improve detector capabilities for Run3.**

## ATLAS NSW

- MicroMegas chambers have been **chosen for the ATLAS upgrade of the forward Muon Spectrometer for their excellent performance in tracking particles (res.~100  $\mu\text{m}$ , eff.~95%) up to high fluxes.**
- The construction of such large area detectors has shown some challenges which required studies and special procedures
- **Main issues have been solved**
- **LNF has produced 32 fully validated SM1 chambers.**

**Support to France, Germany and Russia.  
Russian chambers will be reworked at  
CERN by LNF personnel.**



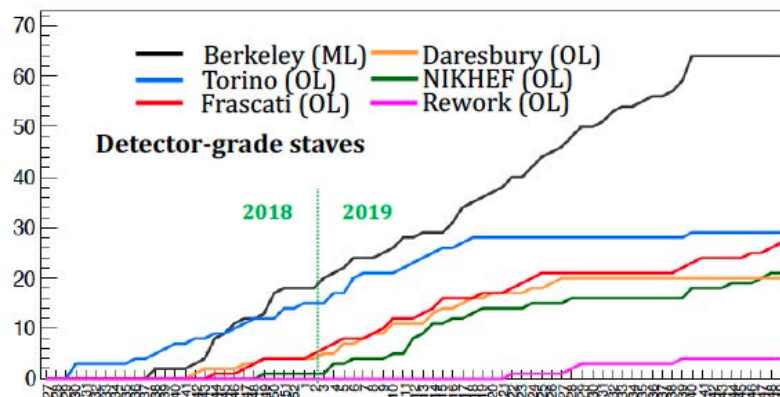
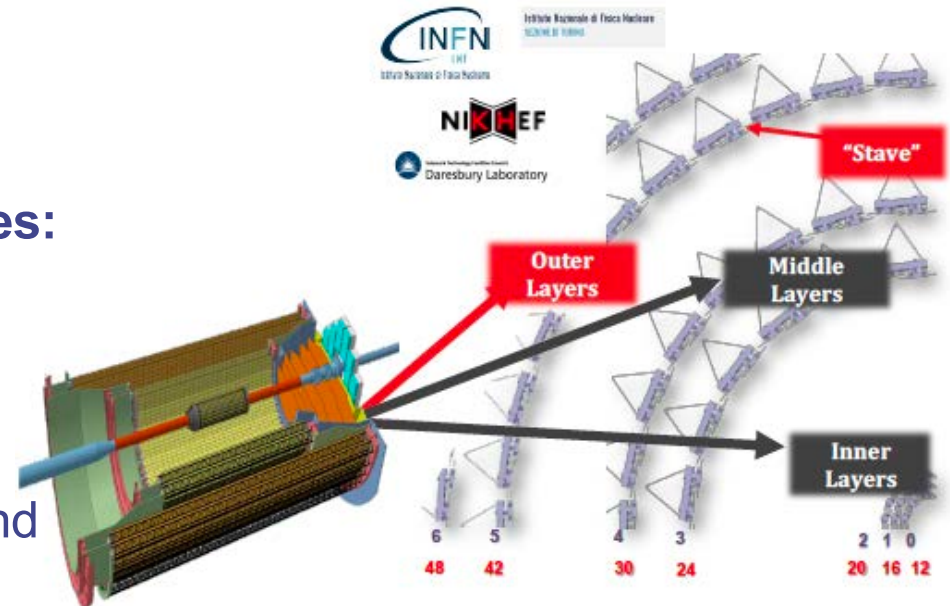


# ALICE ITS

Production at LNF from Feb 2018 to June 2019.

The LNF group also contributed to the development and debug of the procedures:

- Debug of the readout system
- Development of wire bond repairs using conductive glues
- Development of mechanical procedures and tooling to rework finished staves



Work done in the Clean-Room Bd. 27.  
A new CMM bought for this purpose.

## CMS and LHCb

LNF CMS group is responsible for the **construction of GEM chambers** for the muon upgrade. 14 Chamber have been already realized and installed (GE1) a second bunch of 53 (GE2) is ongoing.

At LHCb the main upgrade regards the Trigger System that has to reach the capability of digesting luminosity of  $2 \times 10^{33} \text{cm}^{-2} \text{s}^{-1}$ .

**The new Muon System off-detector electronics (nODE) has been redesigned to be compliant with the 40 MHz readout of the detector by the LNF electronic team (LNF-SEA).**

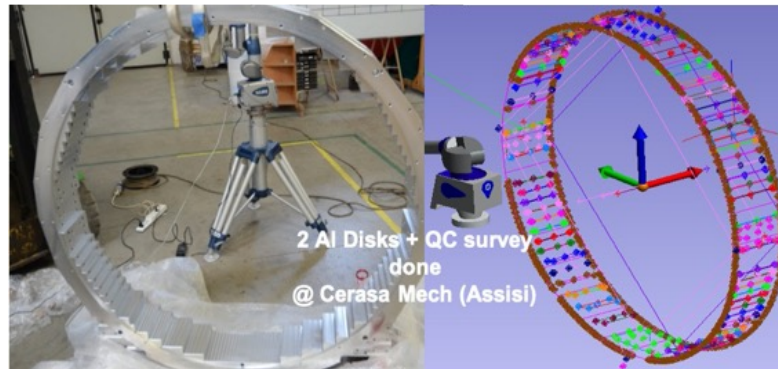
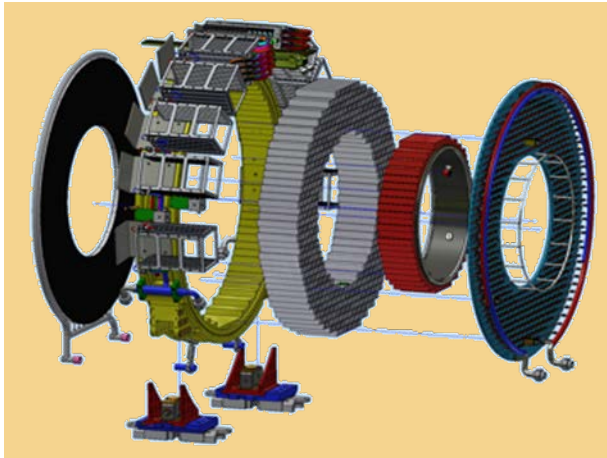
**Matteo Palutan is the new LHCb deputy spokesperson (since Summer 2020).**

LNF LHCb is also responsible for the SMOG2 project: the first internal fixed gas target at the LHC installed in summer 2020.

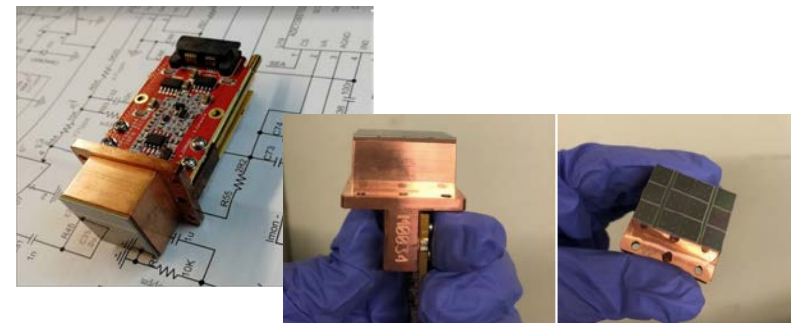
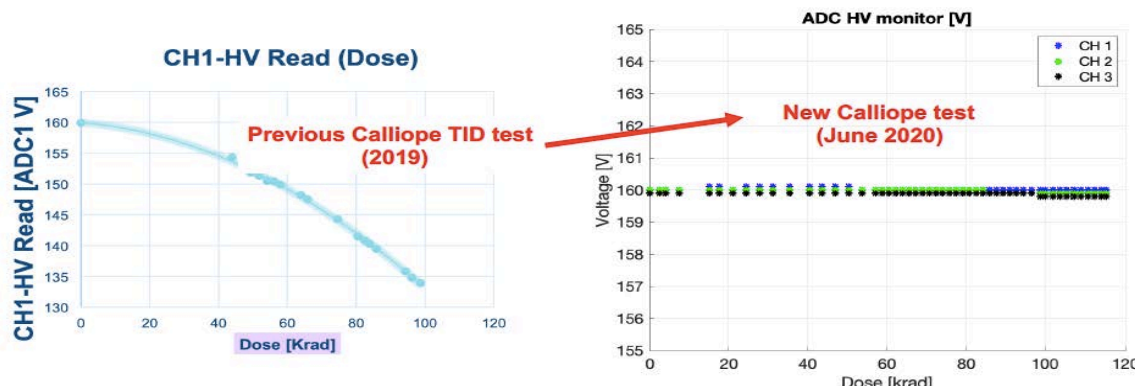


# MU2e

- Ecal construction under LNF coordination



- **FEE developed at SEA, LNF.** Long series of radiation hardness tests with ionizing dose, neutrons/protons. Latest version rad-hard up to 100 krad,  $10^{12}$  n/cm<sup>2</sup> → FEE production started: **80 boards already at LNF, completion expected for end of 2020**
- SiPM gluing on holders +FEE assembly under way at LNF → **work moved from FNAL to LNF due to COVID-19 pandemics**



# aMUSE (advanced Muon Campus in US and Europe Contribution)

Simona Giovannella is the International Coordinator of the aMUSE consortium.

The Project coordinates the activities of about 80 researchers from 12 European research institutes and industries participating to the search for New Physics in the muon sector and to the design of a new generation muon accelerators in high-profile US laboratories (Fermilab, BNL, SLAC).





# Neutrino Cosmic Ray Tagger

the Short Baseline Neutrino (SBN) experiment at Fermilab consists of shallow depth TPCs – few meters under-ground.

To mitigate cosmic muon induced background, SBn near and far detectors are surrounded by external **Cosmic Ray Tagger systems**.

The construction and testing of the top CRT of the ICARUS-T600 was carried out at the LNF



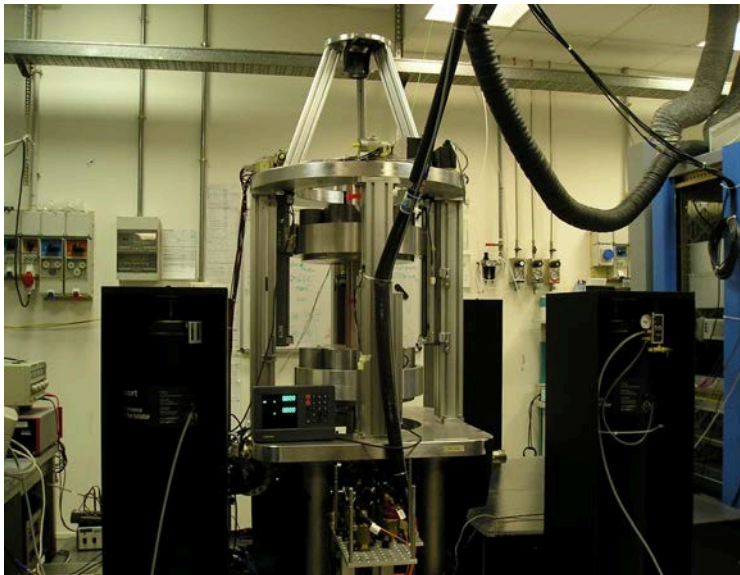
40 people, from the INFN sections of Bologna, Genova, Lecce, LNF, LNS, Milano, Milano Bicocca, Padova, and from CERN, contributed by weekly shifts to the **construction and testing of the 125 modules.**

# Measuring the Gravitational Constant MEGANTE project

The precise determination of the gravitational constant  $G$  remains a challenging endeavour.

**MEGANTE** will address this issue by carrying out precision  $G$  determinations making use of original experimental strategies based on quantum sensors.

Unprecedented accuracy levels will be achieved using **cold atoms in free-fall** to probe the gravitational field, surpassing thus the state-of-art measurements based on torsion balance and simple pendulum.

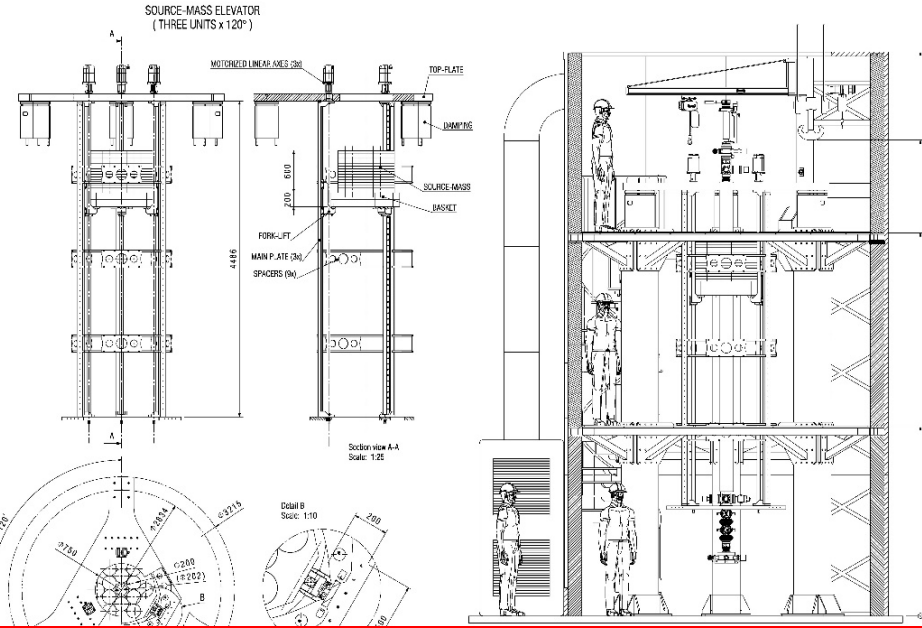
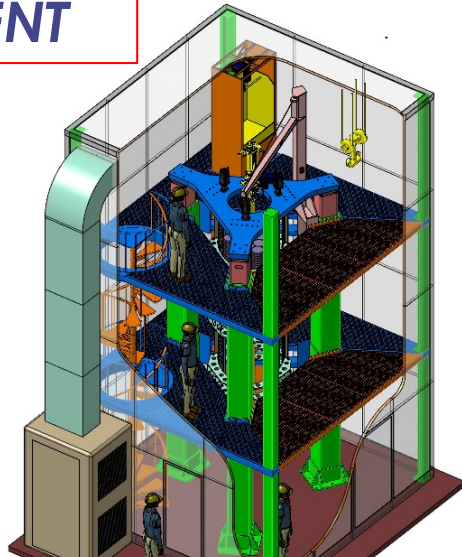
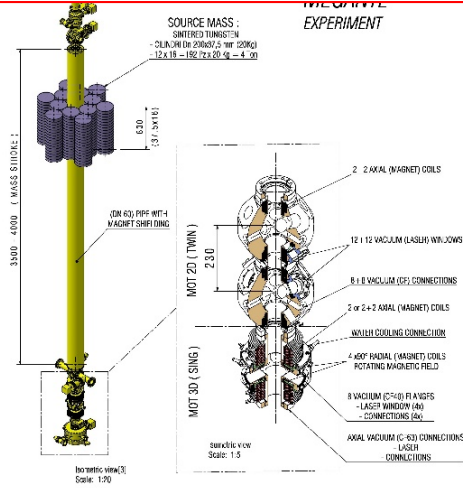


MAGIA detector

\*G. Lamporesi, A. Bertoldi, A. Cecchetti, B. Dulach, M. Fattori, A. Malengo, S. Pettoruso, M. Prevedelli, G.M. Tino, *Source Masses and Positioning System for an Accurate Measurement of  $G$* , *Rev. Scient. Instr.* **78**, 075109 (2007)

ERC-2018-STG - ERC Starting Grant  
Gabriele Rosi - Firenze

# MEGANTE EXPERIMENT



## COMPONENTISTICA BOSCH-REXROTH PER MOVIMENTAZIONE

|  | COSTO            | QU | TOTALE           |           |
|--|------------------|----|------------------|-----------|
| <b>MECCANICA</b>                               |                  |    |                  |           |
| R151057990 VITE A SFERE CON CHIOCCIOLA         | 3,559.61         | 3  | 10,678.83        | SENZA IMS |
| R168500010 ROTAIA SFERE IMS* IMS2A-KSA         | 7,190.74         | 3  | 21,572.22        | -3,971.22 |
| R168100010 PATTINO SFERE IMS* IMS2A-KWD        | 2,059.65         | 3  | 6,178.95         | -5,728.56 |
| R159123030 SUPPORTO RITTO SEB-F-A 30           | 1,658.82         | 3  | 4,976.46         |           |
| R159163520 SUPPORTO RITTO SEB-L-S 35           | 384.00           | 3  | 1,152.00         |           |
| R165131220 PATTINO SFERE CS KWD-035-FNS-C1-P-1 | 150.13           | 3  | 450.39           |           |
| <b>TOTALE</b>                                  | <b>45,008.85</b> |    | <b>-9,699.78</b> |           |

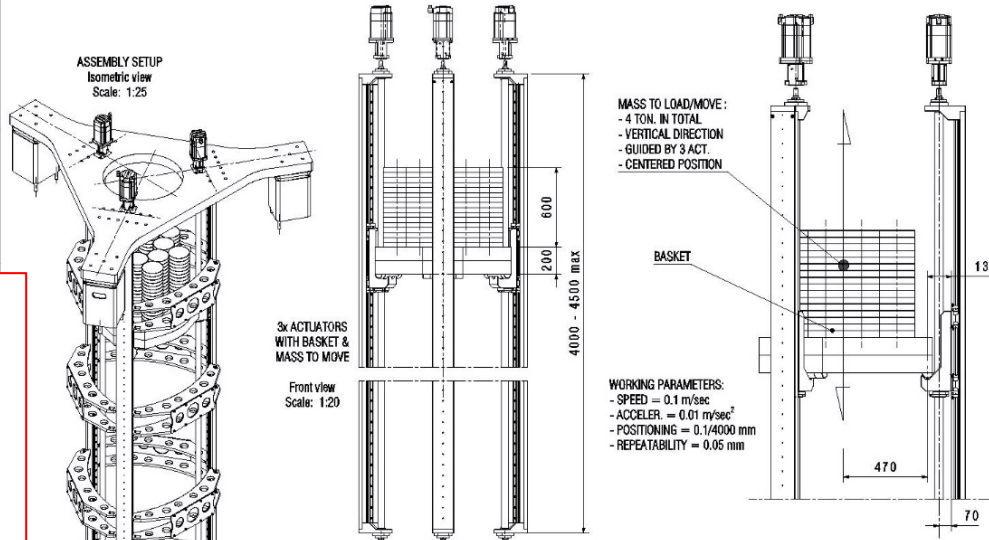
<https://www.youtube.com/watch?v=WOLICfmmKVI> \*

## AZIONAMENTO

|   | COSTO    | QU | TOTALE   |
|---|----------|----|----------|
| R911382896 MS2N07-D0BHN-CMSG2-NNNNN-NN (MOTORE)             | 3,076.04 | 1  | 3,076.04 |
| R911295324 HMS01.1N-W0036-A-07-NNNN (INVERTER)              | 1,296.12 | 1  | 1,296.12 |
| R911340358 CSH02.1B-CC-EC-ET-L3-NN-NN-FW (UNITA' CONTROLLO) | 1,910.40 | 1  | 1,910.40 |
| R911347115 FWA-INDRV*-MPC-20VRS-D5-1-ALL-ML (SOFTWARE)      | 1,000.05 | 1  | 1,000.05 |
| R911336255 PFM04.1-512-NW                                   | 126.54   | 1  | 126.54   |
| R911317797 RKB0013/00.25                                    | 22.98    | 1  | 22.98    |
| R911306620 HAS01.1-050-072-MN                               | 34.41    | 1  | 34.41    |
| R911306330 HAS02.1-001-NNN-NN                               | 46.69    | 1  | 46.69    |

| UNITA MASTER (1x)                        | UNITA SLAVE (2x)                         | POWER SUPPLY                            |
|--|--|---|
| R911372089 RH2-022DBB-NN-010,0 (CABLES)  | R911382896 MS2N07-D0BHN-CMSG2-NNNNN      | R911297460 HNV01.1R-W0018-A-07-NNNN (P) |
| R911382896 MS2N07-D0BHN-CMSG2-NNNNN      | R911295324 HMS01.1N-W0036-A-07-NNNN (I)  | R911382794 HNF01.2D-F240-R0026-A-480-NN |
| R911295324 HMS01.1N-W0036-A-07-NNNN (I)  | R911339883 CSB02.1A-ET-EC-NN-L3-NN-NN-FW | R911306584 HNL01.1R-0980-C0026-A-480-NN |
| R911339883 CSB02.1A-ET-EC-NN-L3-NN-NN-FW | R911347115 FWA-INDRV*-MPB-20VRS-D5-1-SF  | R911306630 HAS01.1-175-NNN-MN           |
| R911347115 FWA-INDRV*-MPB-20VRS-D5-1-SF  | R91130280 FWS-INDRV*-MP*. **VRS-NN-PR0   | R911347042 SWA-IWORKS-MLD-14VRS-D0-DV0  |
| R91130280 FWS-INDRV*-MP*. **VRS-NN-PR0   | R911306330 HAS02.1-001-NNN-NN            | R911389200 RKB0021/003,0                |
| R911306330 HAS02.1-001-NNN-NN            | R911372089 RH2-022DBB-NN-010,0 (CABLES)  |   |
| R911372089 RH2-022DBB-NN-010,0 (CABLES)  |  |   |

**FIRST DIMENSIONING OF VERTICAL DRIVE SETUP IN COLLABORATION WITH BOSCH-REXROTH & COST ESTIMATE OF STANDARD COMPONENTS: 73 K€ +IVA**



| PRIM | DRAWING                         | MATERIAL                      | DENOMINATION                     | WEB          |
|------|---------------------------------|-------------------------------|----------------------------------|--------------|
|      | General tolerance ISO 2768-mK-E |                               | Geometrical tolerance ISO 8015-E | Roughness IS |
|      | INFN                            | FRASCATI NATIONAL LAB S.P.A.S | SIZE A3                          |              |
|      |                                 |                               | DATE: 26/02/2019                 | C.C.         |
|      |                                 |                               | SCALE: 1:20                      |              |
|      |                                 |                               | 1/1                              |              |
|      |                                 |                               |                                  | LNf-XXXX     |

**MEGANTE EXPERIMENT**  
MASS SOURCE POSITIONING  
3x ACT. GROUP (WORK CONDITION SCHEME)

Cesidio.Capoccia@Inf.infn.it

# Beamlines @ DAΦNE

## Building 12

### OPEN to USERS

- 1) SINBAD - IR beamline (1.24 meV - 1.24 eV)
- 2) DXR1 - Soft X-ray beamline (900-3000 eV)
- 3) DXR2 - UV-VIS beamline (2-10 eV)

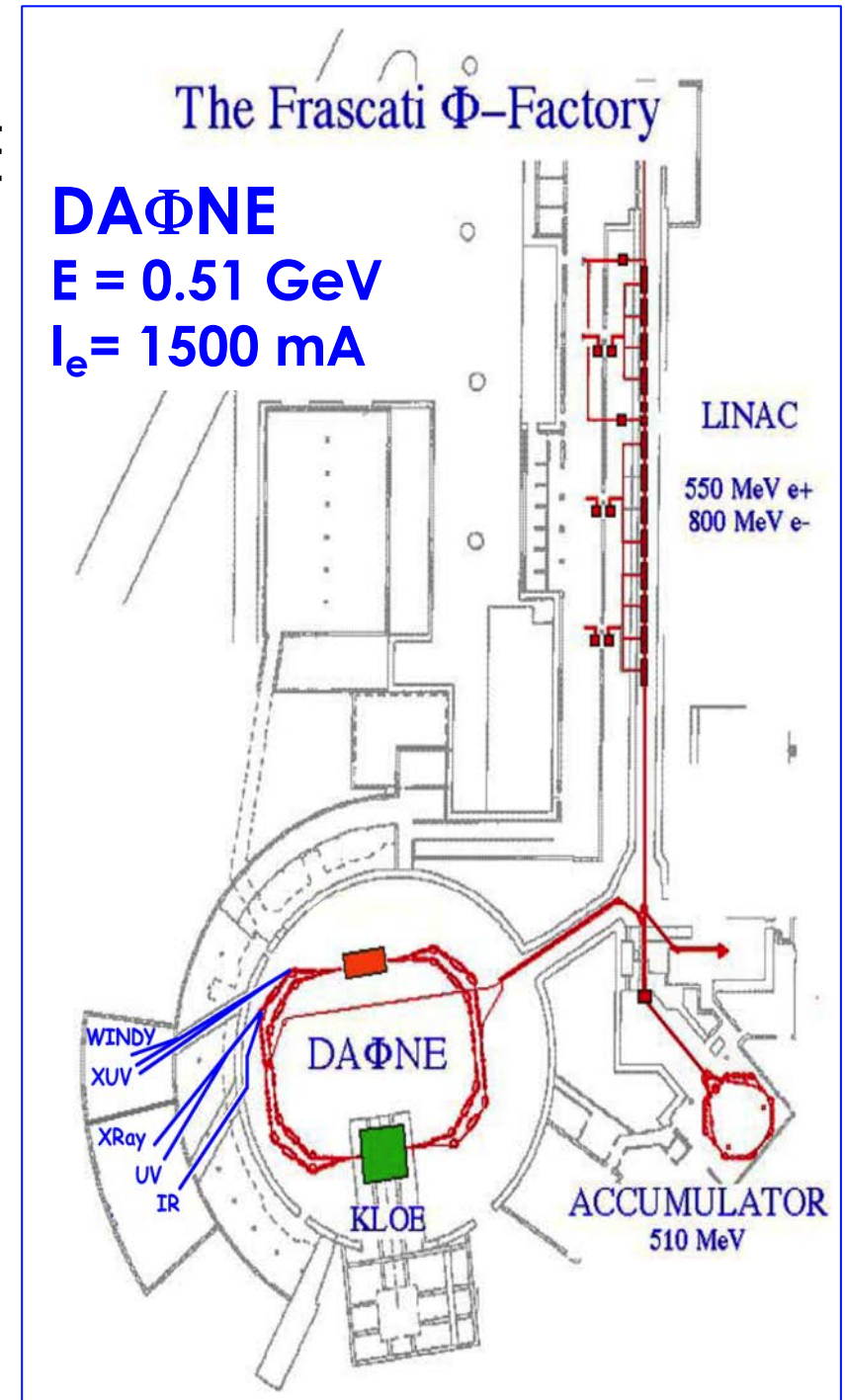
## Building 13

### XUV beamlines UNDER COMMISSIONING

- 4) XUV1 - Low Energy Beamline (30-200 eV)
- 5) XUV2 - High Energy Beamline (60-1000 eV)

### UNDER Construction

- 6) New XUV2 Branch White Line - CERN WINDY



# DAFNE-Light Activity

The activity at DAFNE-Light restarted in May 2020 with **in-house measurements and works for third parties, online schools on cultural heritage and with users by the end of June 2020** initially only **Italian** but in September also the **first external user** coming from Cyprus and related to the EU **CALIPSOplus (2018-2021)** project for **Transnational Access to SR beamlines**.

**Italian Users:** between the end of June and beginning of October about **7 proposals** related to studies in the field of **cultural heritage, material science** and **environment** received beamtime at the **SINBAD IR beamline** some including also the use of the **SEM-EDS microscope**.

## Proposals that receive beamtime

### Material Science

**Molla2:** Extra framework molecules in lazurite: a combined XAS/FTIR study (**Roma Tre**)

**MIOP:** Mid-IR Oxide Plasmonics (**Sapienza, Rome**)

### Environmental Studies

**FAST:** Multi-analytical approach to determine element and spectral variation and distribution in Pteris seedlings exposed to arsenic (**Sapienza, Rome**)

### Cultural Heritage

**CulturalFTIR:** Application of FTIR Technique to Cultural Heritage (**CNR - Sapienza**)

### CHNET:

FTIR and Raman studies on ancient manuscripts (**Sapienza, Rome**)

Analysis of paintings of Antonello Da Messina (**ICR - Istituto Centrale per il Restauro**)

### Work for third parties:

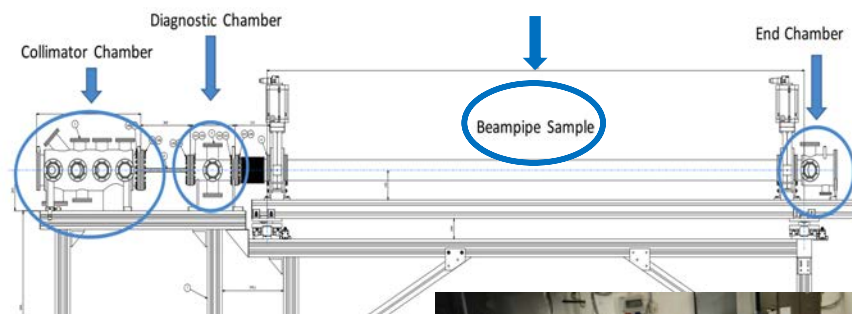
FTIR, Raman and SEM-EDS studies on fragments of ancient rock paintings (**Alfa restauri**)

# Beamline WINDY (CERN-INFN)

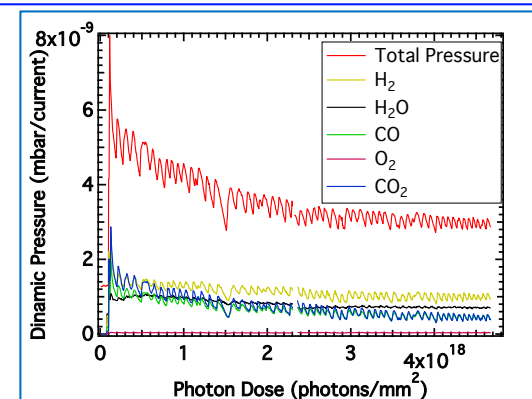


WINDY - Construction of a dedicated white light beamline for synchrotron radiation-based material studies in the framework of the High Luminosity LHC and Future Circular Colliders.

Synchrotron radiation-based material studies to achieve information on surface reflectivity, photon and photo-induced desorption yield, secondary electron emission, chemical modifications etc. on **small samples** using the existing **XUV beamlines and conventional sources** and on real long beampipes using the WINDY beamline.



Schematic view of the WINDY beamline setup



Some preliminary results achieved with the DAFNE XUV synchrotron radiation on small samples :  
**Gas desorption during photon irradiation.**

Studies are on going on surfaces of small samples using the XUV experimental chambers and conventional sources waiting for the SR beam.



Istituto Nazionale di Fisica Nucleare  
Laboratori Nazionali di Frascati

# Outreach

Since 20 years the outreach service of the Research Division in promoting the spreading of the scientific and technological culture with **educational programs**, addressed to students, teachers and general audiences of every age, from Italy and abroad.



Insights and education about the INFN-LNF research are offered thanks to the organization of **guided tours** and **open days, stages for students, refresher courses for teachers, seminars** and **divulcation events**.

Due to the pandemic the activity now is completely online, but the service is more active than ever!





Istituto Nazionale di Fisica Nucleare  
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# Main 2020 events

## [INSPIRE 2020 – International School on modern PhYsics and REsearch](#) [\(online edition\)](#)

30 Mar. - 3 Apr.

## [Researchers @Home](#)

A series webinars on modern physics subjects addressed to high school students. From Apr. to Jul. every week.

## [Summer School 2020 – online](#)

15 -19 Jun.

webinars to orient high school students towards university choice and STEM

## [Un Tuffo nel Mistero – Colloqui in rete](#)

From Sep. every 15 days a webinar on scientific subject for general public

## [Incontri di Fisica 2020](#)

4 - 6 Nov.

the 20<sup>th</sup> edition of refreshment course of Modern Physics for high school teachers, now also opened to scientific journalists.



## Summary

**LNF Research Division  
is alive and kicking**

Thanks to all colleagues that work professionally in the Research Division