XIII Einstein Telescope Symposium - Cagliari

Massimo Carpinelli
EGO Director

11-05-2023

Virgo and EGO the first 30 years

A.Giazotto

A. Brillet

- **1993-1994** CNRS and INFN approve VIRGO
- **1997** Construction starts near Pisa
- **2000 Foundation of EGO (CNRS, INFN)**
- **2003 Inauguration of Virgo** **(+10y)**
- **2004-2006** Commissioning of Virgo
- **2006 Nikhef joins EGO as an Observer**
- **2007** Start of Virgo science runs
- **2007** LIGO-Virgo “a single machine”

Inauguration Virgo 2003

Virgo and EGO the first 30 years

- **2009 EGO Council approves AdVirgo** (+16y)
- **2010's** Polish, Hungarian and Spanish groups join AdVirgo
- **2017 First Virgo-LIGO detection** (+24y)
- 2019 Declared Historical milestone by IEEE
- 2020 EGO Council approves AdVirgo+ (+27y)
- **2021 Nikhef enters EGO as a full member**
- **2021 Virgo (+LIGO) recognised as a IEEE Historical Milestone**

A.Giazotto

A. Brillet

Inauguration Virgo 2003

EGO today

- 63 Employees not changed significantly
- Virgo members x3 since 2017
- 5 Departments:
  - Interferometer Technology
  - Vacuum and Mechanics
  - Information Technology
  - General Infrastructure
  - Administration
- European Projects, Outreach and communication, etc

New since 2023

EGO Scientific Group is part of the VIRGO Collaboration

The European Gravitational Observatory (EGO)

- EGO is a consortium, with members CNRS and INFN, with the goal of promoting research in the field of gravitation in Europe.
  - Nikhef/Netherlands joined in 2021
- Objectives:
  - *Construction, maintenance operation and upgrade of the Virgo interferometer*
  - Maintenance, operation and upgrade of the site infrastructures including a computing center
  - Representation of the consortium at the regional, national, European and global level
  - Promotion of interdisciplinary studies
  - Promotion of R&D (mostly environmental noise and photonic science)

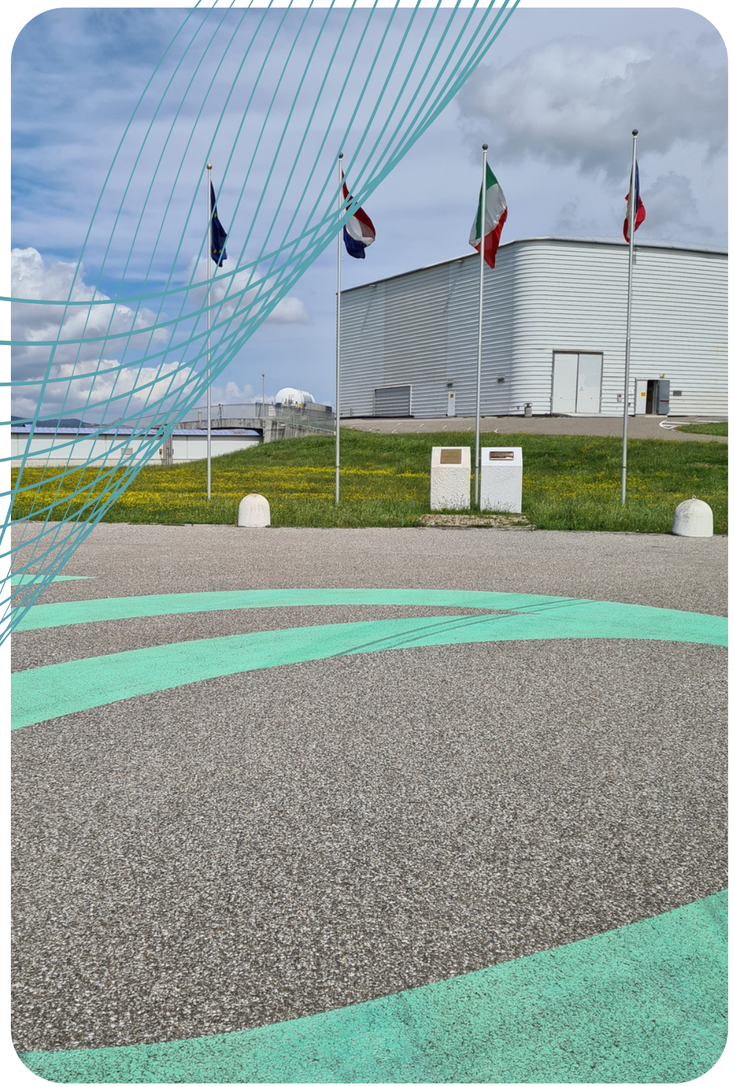
Virgo

Virgo is a European collaboration with **849** Members, representing **143** Institutions in **15** different countries.

- APC Paris
- ARTEMIS Nice
- EGO Cascina
- IFAE
- INFN Firenze-Urbino
- INFN Genova
- INFN Napoli
- INFN Perugia
- INFN Pisa
- INFN Roma La Sapienza
- INFN Roma Tor Vergata
- INFN Trento-Padova
- LAL Orsay – ESPCI Paris
- LAPP Annecy
- LKB Paris
- LMA Lyon
- Nikhef Amsterdam
- POLGRAW(Poland)
- RADBOUD Uni. Nijmegen
- RMKI Budapest
- UCLouvain
- ULiège
- Univ. of Barcelona
- Univ. of Valencia
- University of Jena
- University of Thessaloniki
- ...

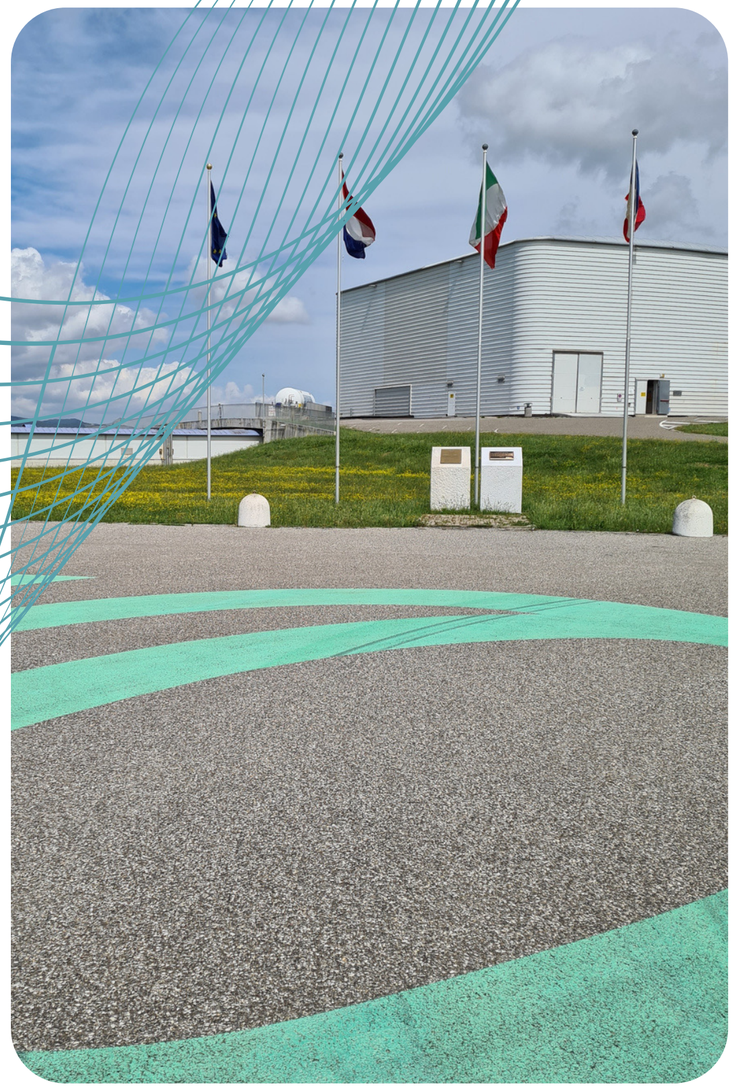
Virgo Collaboration has tripled since 2017

EGO VIRGO



Common Funds – EGO Members

- Clear indication given by the EGO Council: financial participation to the M&O of the Virgo detector is mandatory
- Virgo Members affiliated with the EGO Founding or Associate Members participate to the M&O by the annual contribution of the respective Institutions.
- EGO Members are CNRS,INFN, NWO-I
- EGO is eagerly open to new Associate Members



Common Funds – non-EGO Members

- Institutions that are not EGO Members have financial obligations proportionate to the number of members that qualify as Virgo authors.
- The contribution for non-EGO Members is set at 8 kEuro per author, excluding Master Degree and PhD students
- Preferentially in cash, unless an in-kind contribution valuable to EGO could be identified and approved by the EGO Director after consultation with the Virgo spokesperson.

TABELLA CUBATURE

Zona Volume Edificabile [m³] con provvedimento Regione Toscana n. 2186 del 23-04-2004		Volume Edificato [m³] dal 2004 ad oggi		Volume Edificabile [m³]	
ZONA	[m³]	ZONA	[m³]	ZONA	[m³]
Area Centrale	27196	Area Centrale	11322	Area Centrale	15874
Capannone di Montaggio Braccio Nord	6345	Capannone di Montaggio Braccio Nord	2809	Capannone di Montaggio Braccio Nord	3536
Edificio Terminale Braccio Nord	2064	Edificio Terminale Braccio Nord	0	Edificio Terminale Braccio Nord	2064
Capannone di Montaggio Braccio Ovest	12704	Capannone di Montaggio Braccio Ovest	0	Capannone di Montaggio Braccio Ovest	12704
Edificio Terminale Braccio Ovest	2064	Edificio Terminale Braccio Ovest	0	Edificio Terminale Braccio Ovest	2064
TOTALE	50375	TOTALE	14131	TOTALE	36244

Area Centrale

Capannone di Montaggio Braccio Ovest

Edificio Terminale Braccio Ovest

Edificio Terminale Braccio Nord

Capannone di Montaggio Braccio Nord

SCOLMATORE DELL'ARNO

Edifici Progetto VIRGO realizzati ante 2004

Aree edificabili come da provvedimento Regione Toscana 2186 del 23-04-2004

Edifici realizzati dal 2004 ad oggi

ZONE DI NUOVA EDIFICAZIONE E SISTEMAZIONE URBANISTICA DELL'AREA

PLANIMETRIA GENERALE

ARCH. FEDERICO CAMBO

ECO CONSULTING INGEGNERIA S.r.l.

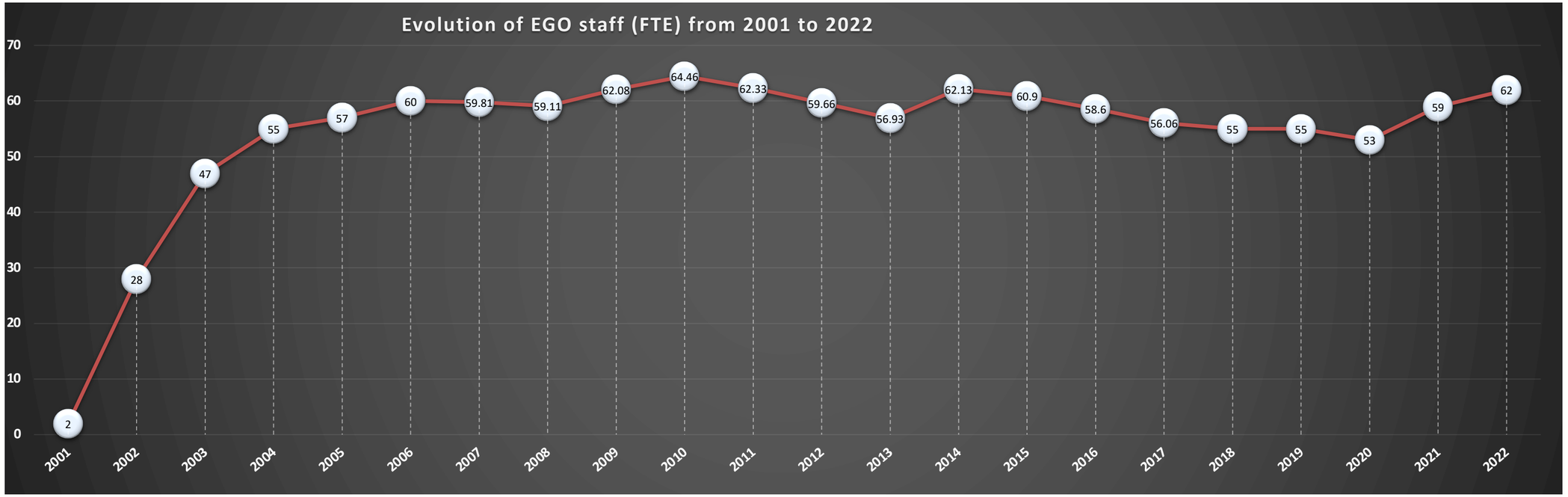
All. 1.1

ZONE DI NUOVA EDIFICAZIONE E SISTEMAZIONE URBANISTICA DELL'AREA

VIRGO Planimetria Generale

Art.01 sovrapposo allo stato attuale

EGO Staff


Evolution of EGO staff (FTE) from 2001 to 2022
70
60
50
40
30
20
10
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2
28
47
55
57
60
59.81
59.11
62.08
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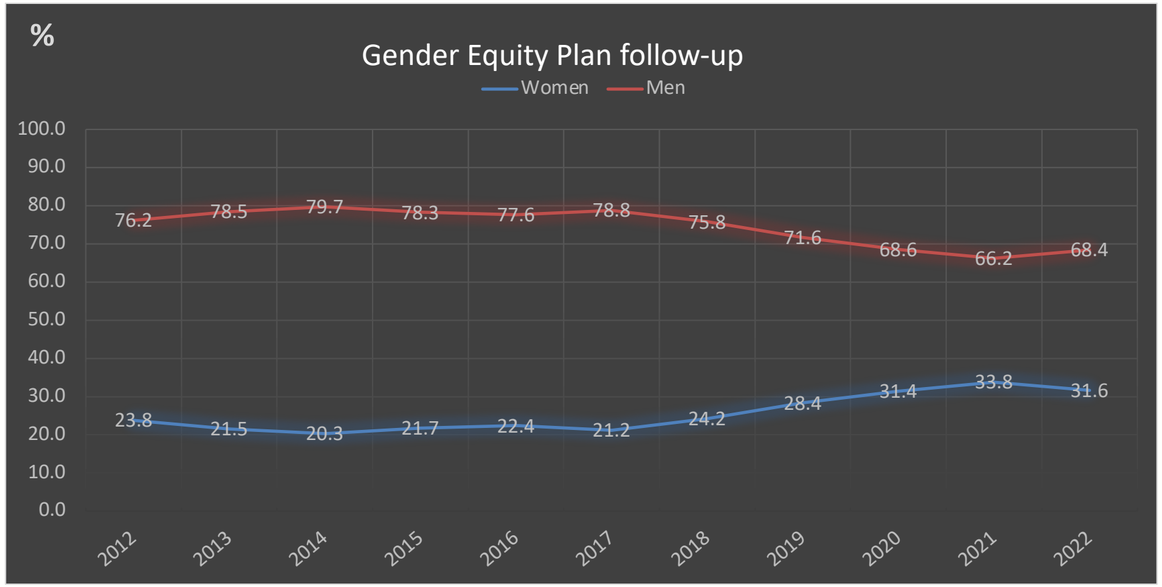
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Gender Equity Plan follow-up
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78.5
79.7
78.3
77.6
78.8
75.8
71.6
68.6
66.2
68.4
23.8
21.5
20.3
21.7
22.4
21.2
24.2
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31.4
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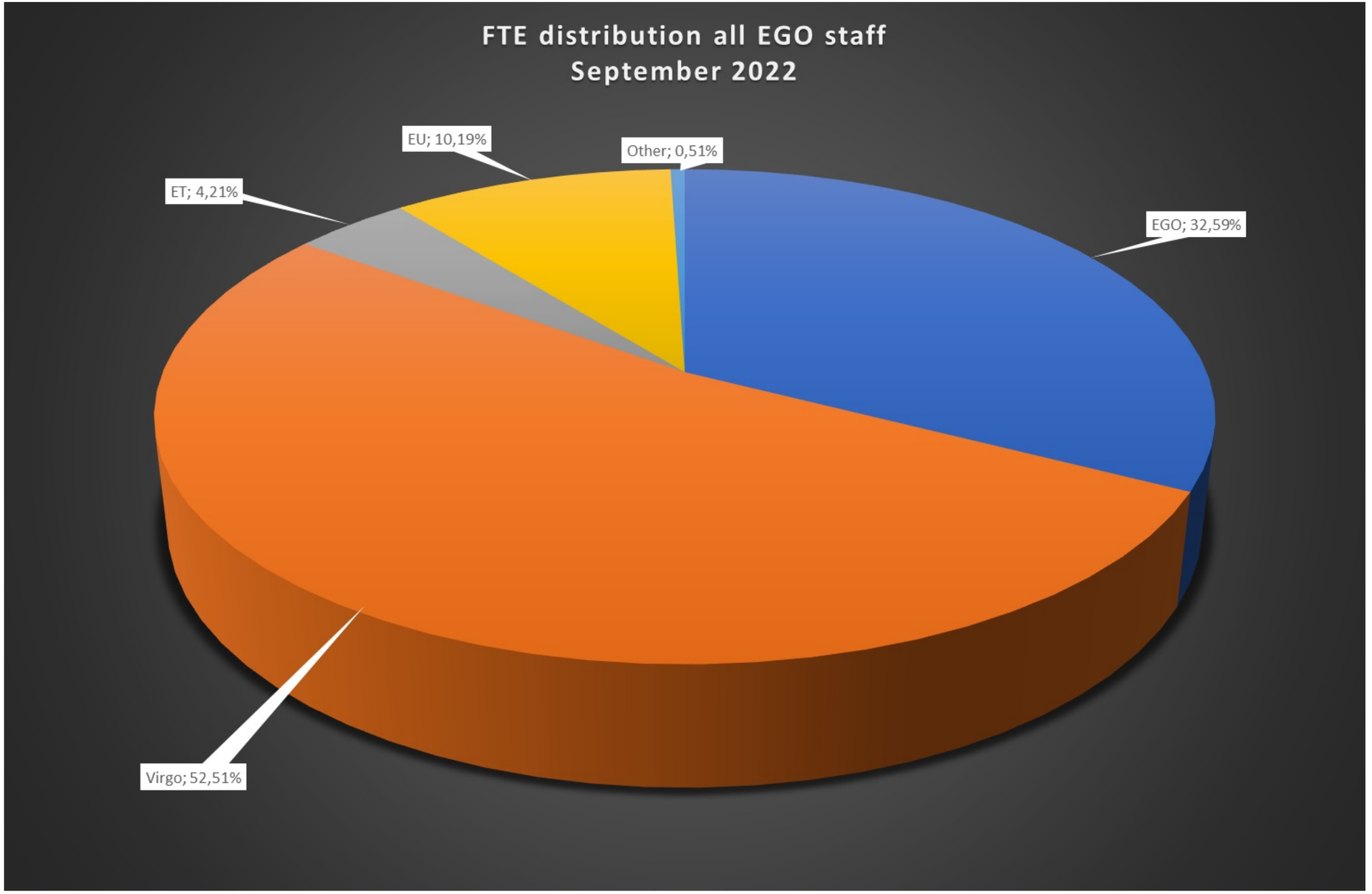
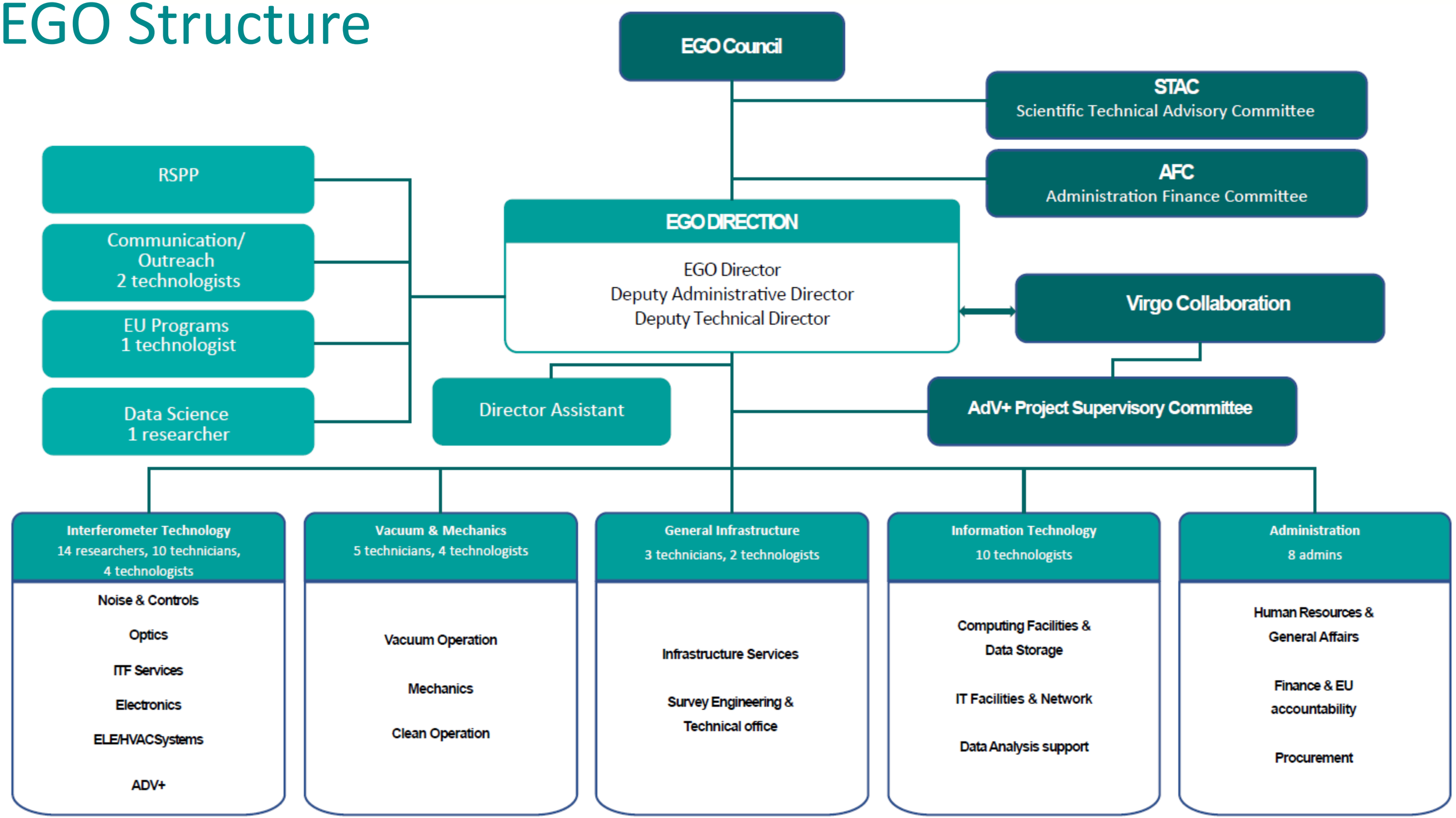
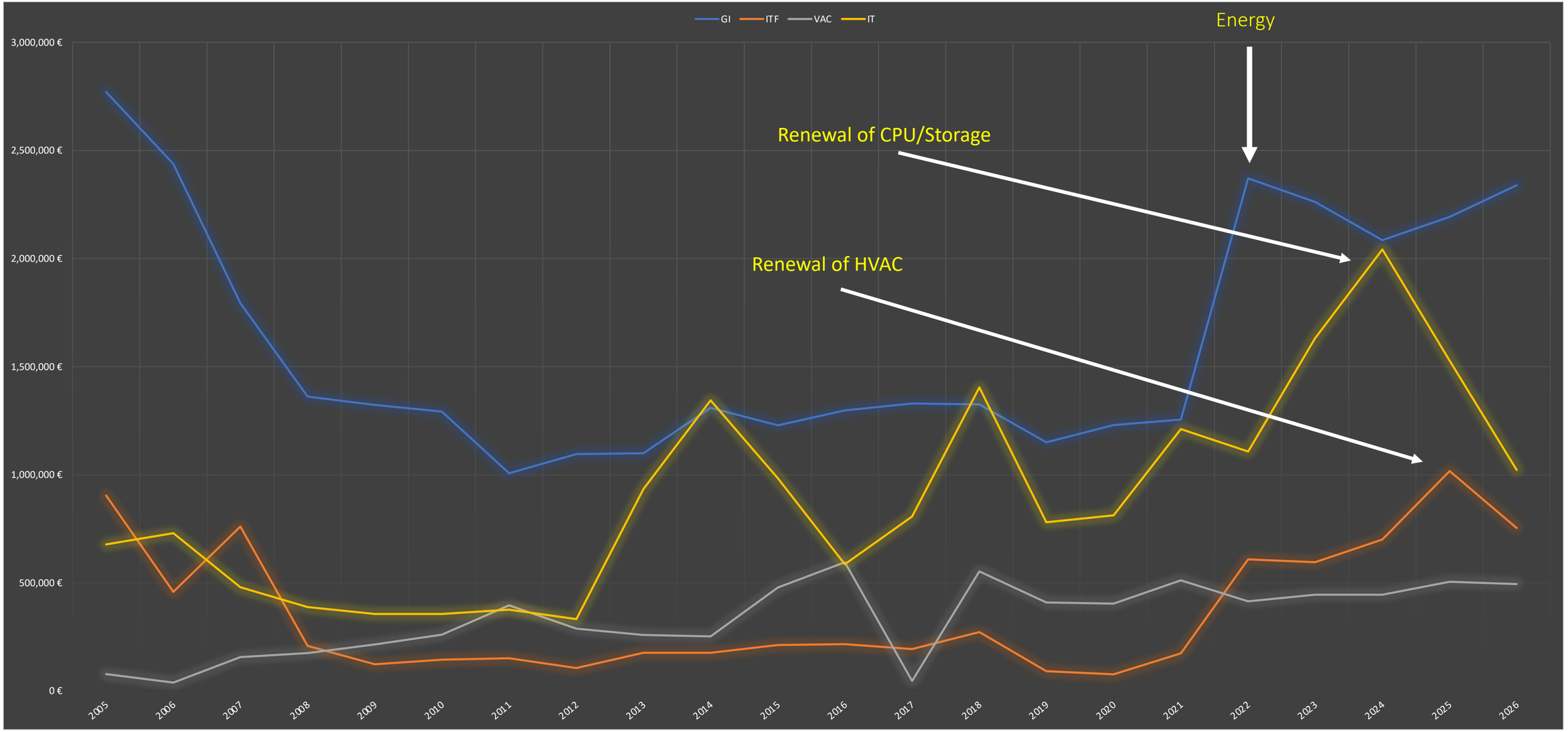
2022


FTE distribution all EGO staff
September 2022
EU; 10,19%
Other; 0,51%
ET; 4,21%
EGO; 32,59%
Virgo; 52,51%

EGO Structure



Budget per technical department



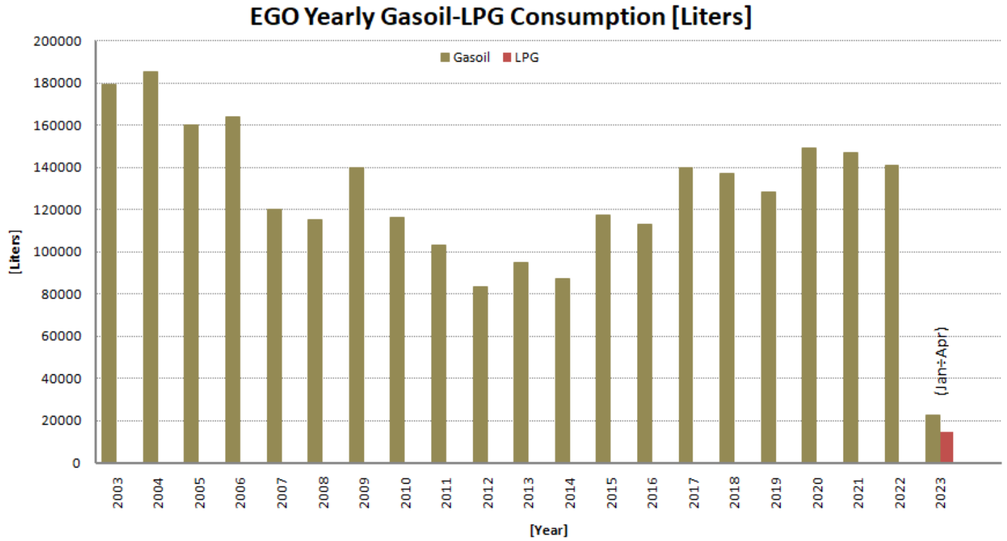
Energy Consumption

EGO power yearly contracts since 2005

Year	Cost k€ (1)	Cons. MWh	U.P. €/MWh	Year	Cost k€ (1)	Cons. MWh	U.P. €/MWh
2005	338	2 766	122.20	2015	475	2 592	183.39
2006	411	2 900	141.75	2016	487	2 711	179.77
2007	448	2 894	154.79	2017	448	2 817	159.20
2008	474	3 205	147.74	2018	472	2 883	163.73
2009	472	3 213	146.92	2019	523	2 819	185.34
2010	485	3 226	150.35	2020	489	2 886	169.60
2011	483	3 040	158.91	2021	745	3 086	241.32
2012	459	2 499	183.81	2022	1 450	3 245	446.78
2013	492	2 507	196.22	2023 (*)	223	678	328.75
2014	470	2 351	199.87				

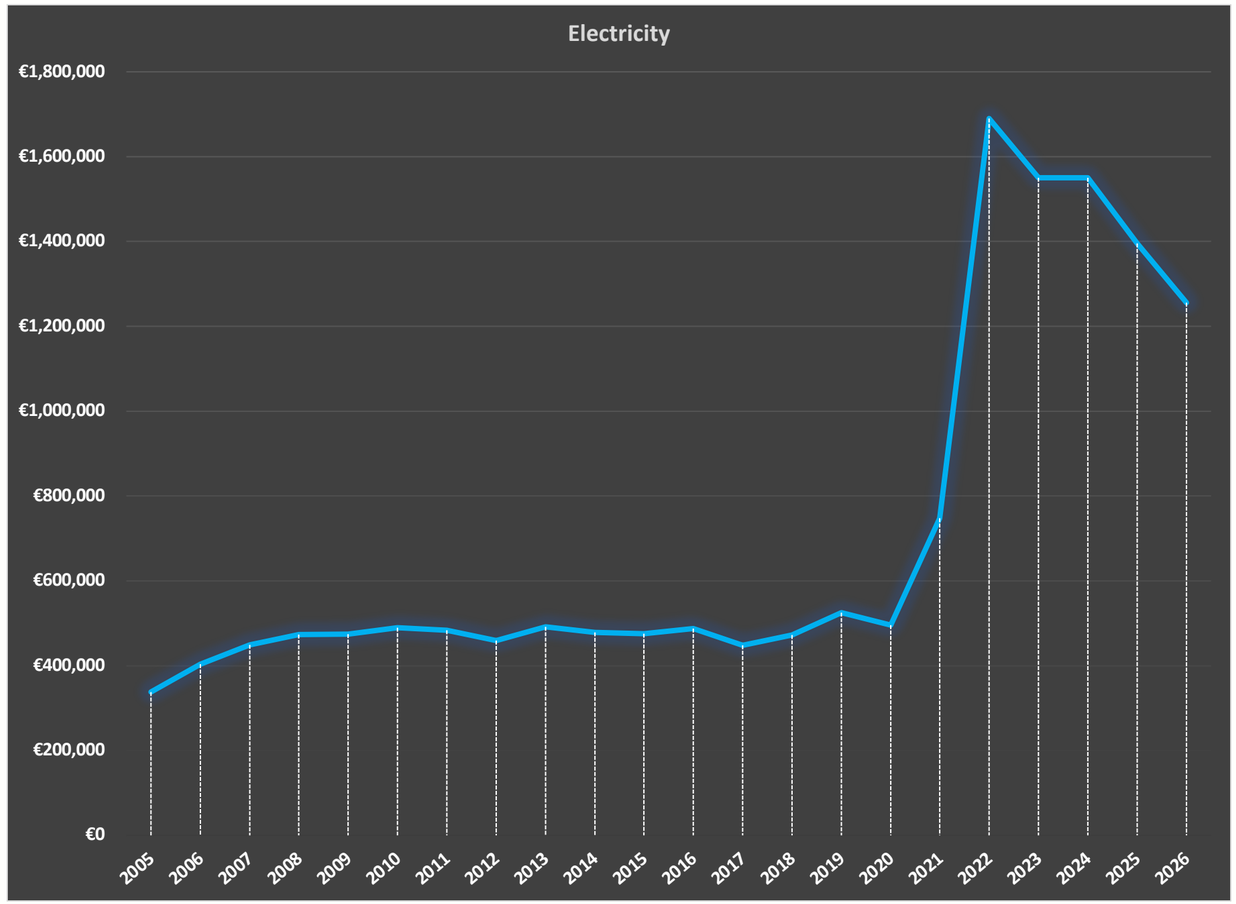
(1) VAT and charges included

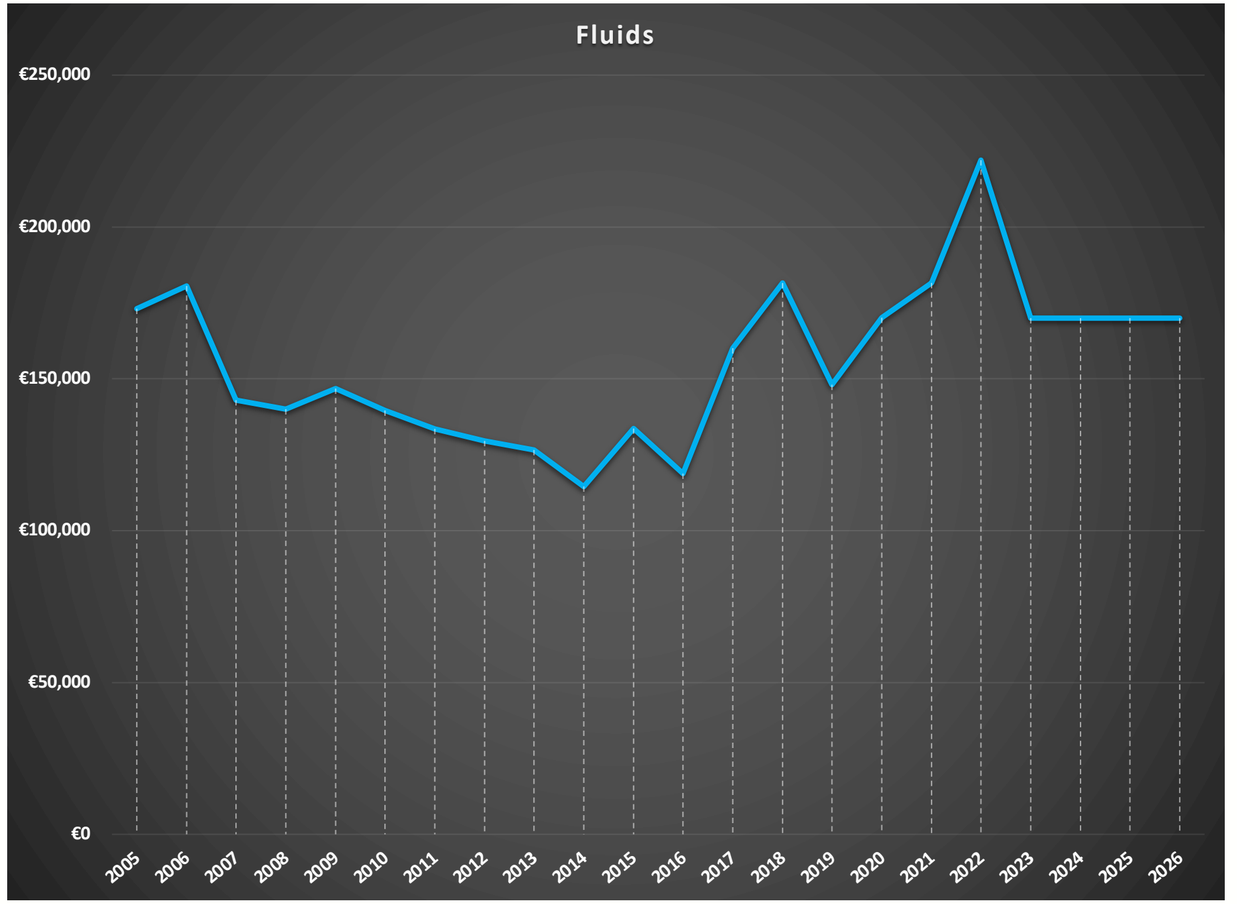
(*) period: 3 months Jan÷Mar 2023



Great increase in costs in 2021 and 2022 (over 3x)

Energy Consumption

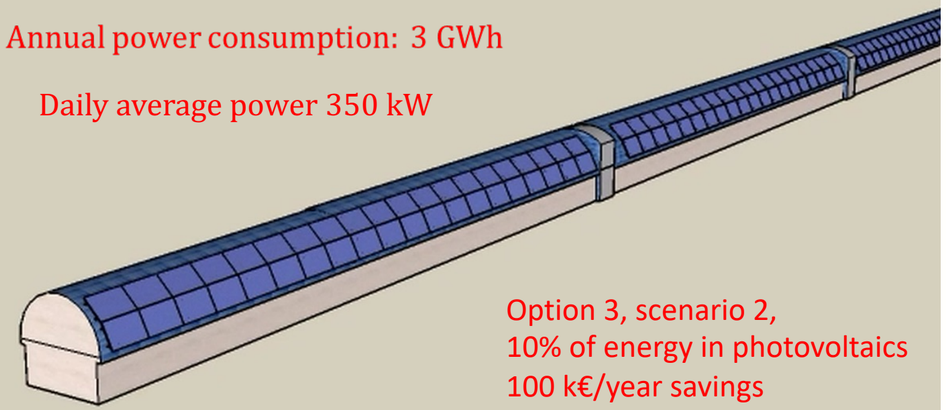




Energy Future Strategy

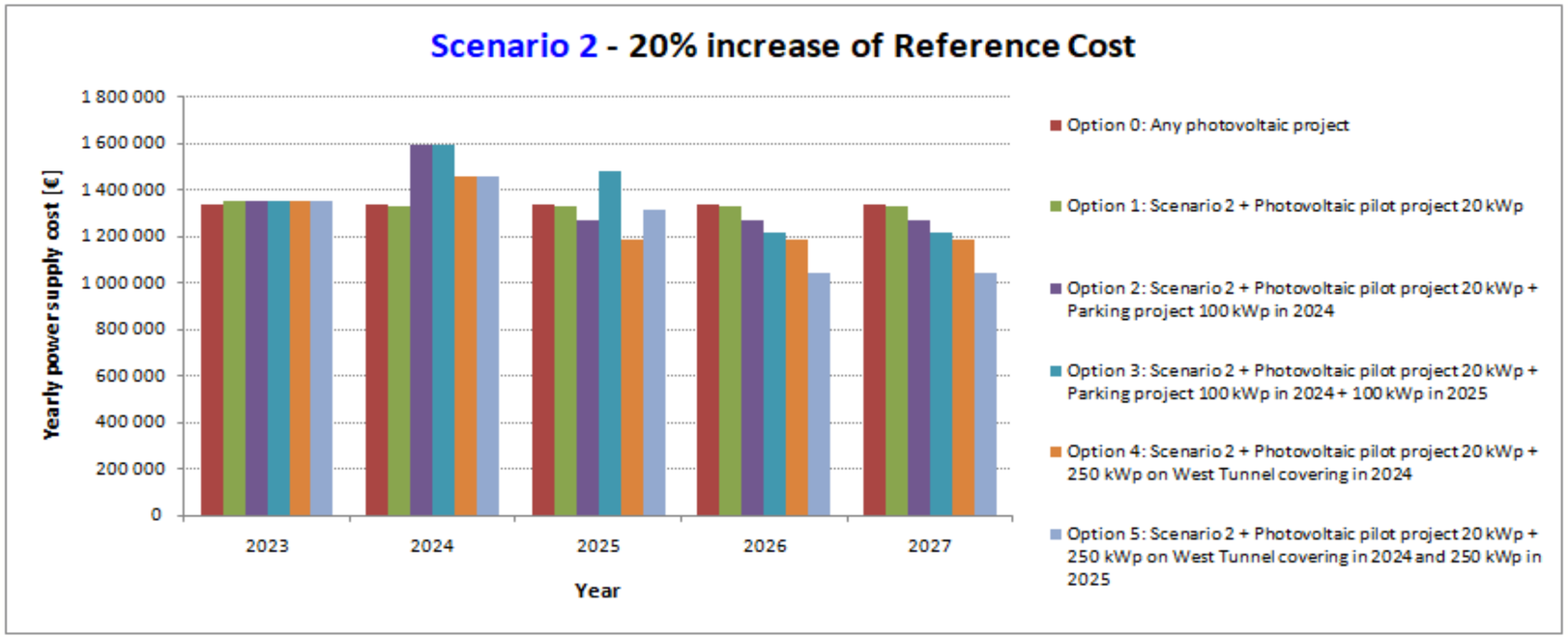
Annual power consumption: 3 GWh

Daily average power 350 kW



Option 3, scenario 2,
10% of energy in photovoltaics
100 k€/year savings

Energy saving project, at minimal pace, despite demand by funding members (CNRS) for a specific renewable energy strategy



EGO VIRGO

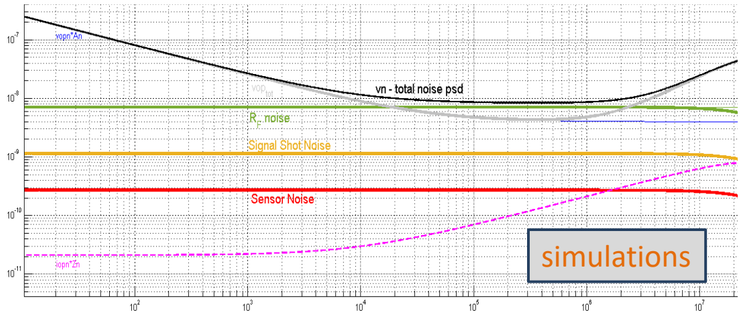
On site Expertise and R&D

EGO Electronics Group Team

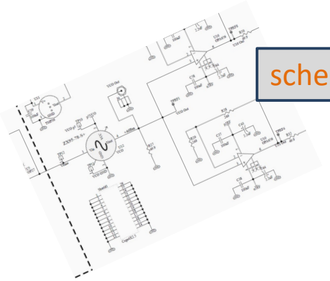
Double Role

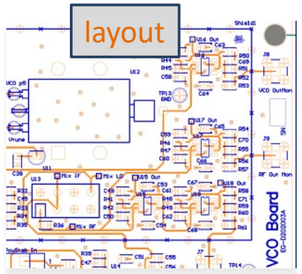
- On-Site System Integration (Standards, Systems Engineering) and Infrastructure Monitoring Support
- Design, Construction, Commissioning of AdV and AdV+ Systems Electronics
  - very low-noise and RF custom electronics design, construction, integration, and commissioning for sensors, servo systems, units, chassis, and racks whose ultimate performance have to be limited by fundamental noise sources (thermal, shot noise)
    - DC and RF photodiode and quadrant frontend electronics
    - custom RF Electro-optic modulator
    - cavity lock, multiple actuators servo electronics
    - Residual Amplitude Modulation Stabilization servo electronics
  - design, construction, verification and validation tests of subsystems and components (optoelectronics, mechanics, electronics, and electro-optics)
  - experience in electrical engineering for observatory class systems (EMC, grounding, and shielding)
  - Systems architecture design and engineering (integration with supporting infrastructure)
    - Injection System, Auxiliary Laser System and contribution to many others

EGO Electronics Group Team



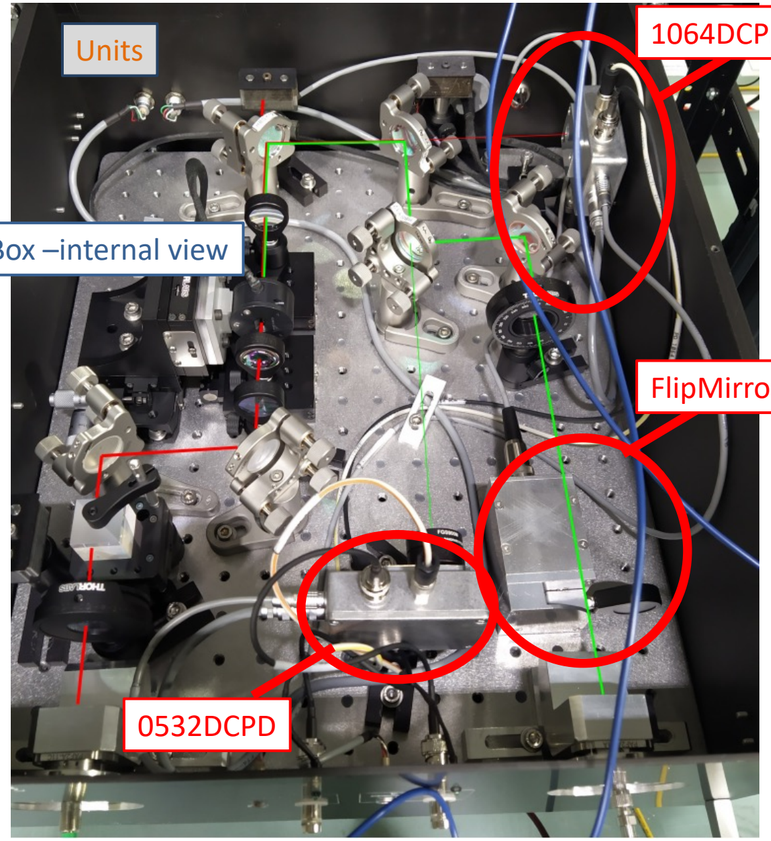

Racks

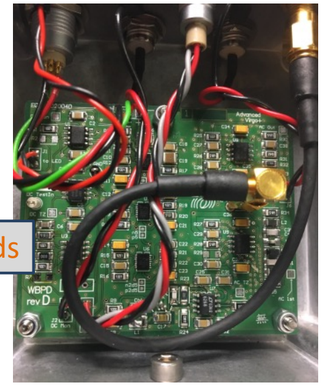

schematics



layout

Chassis




boards

EGO Environmental Studies Group

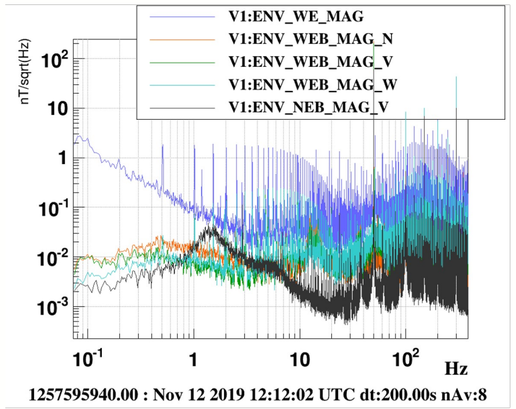
Site and interferometer infrastructure noise

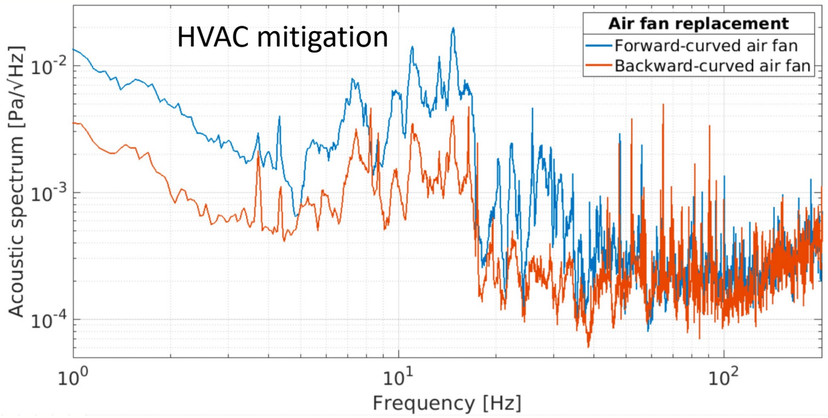
Characterizing noise sources, paths, influences on Virgo and implementing mitigation solutions

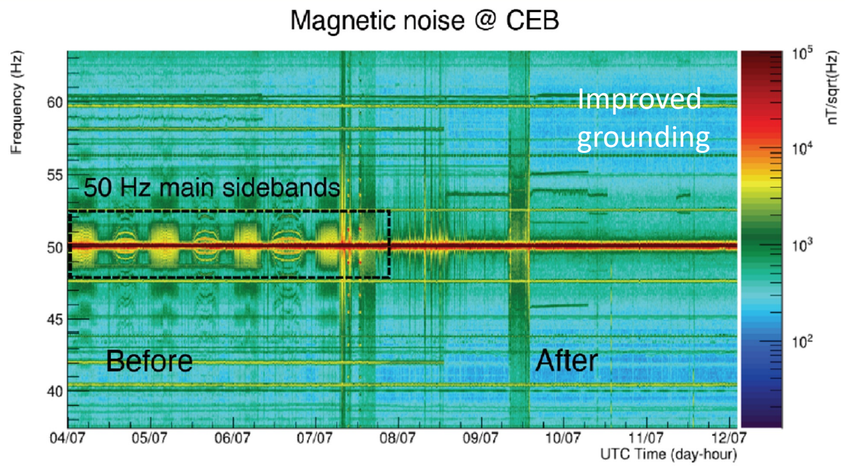
Examples:

- HVAC systems (MC Tringali's poster)
- Power distribution (I Fiori's talk)
- Vacuum system equipments
- Electronics and electro-mechanical devices

Implementation of comprehensive and extensive sensor networks for infrastructure noise monitoring







EGO Environmental Studies Group

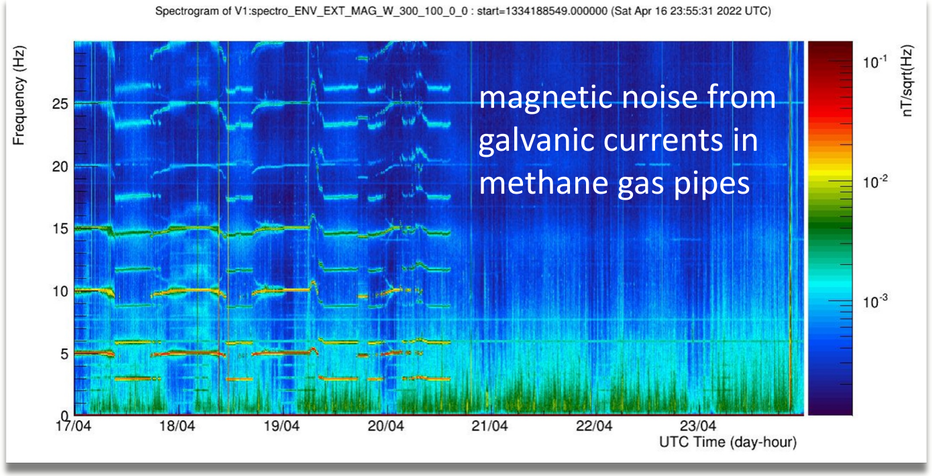
Anthropogenic noise

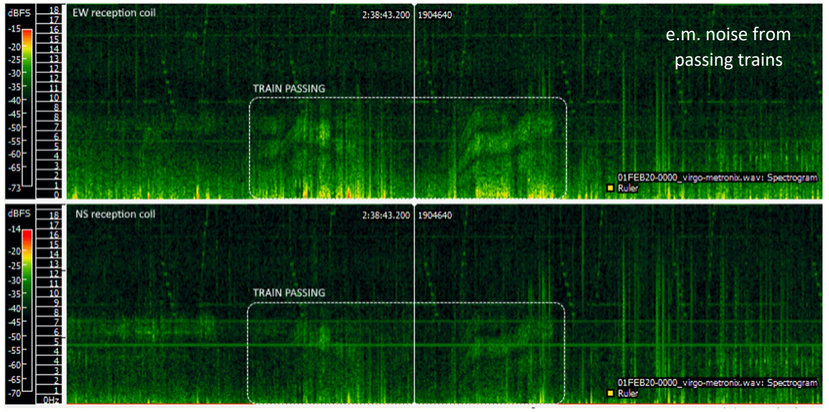
Examples of studied sources in the EGO site surroundings:

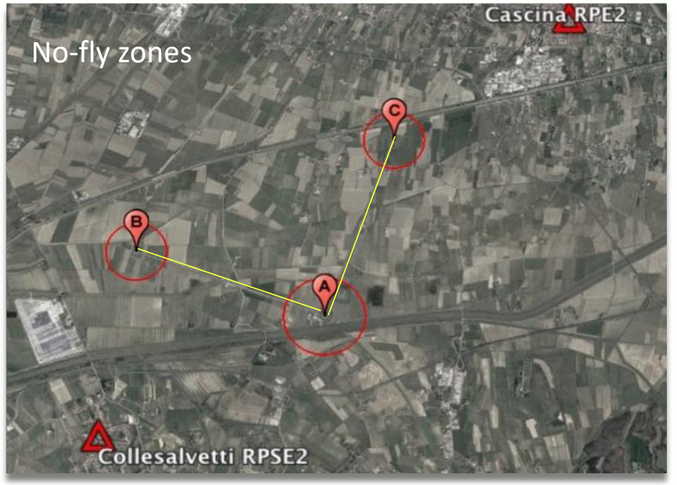
- Trains (F.Paoletti's talk)
- Methane gas pipes
- Wind farms

Site noise preservation:

Agreement with Provincia di Pisa (noise limits for new installations) and with Aeronautica militare (no-fly zones over Virgo)







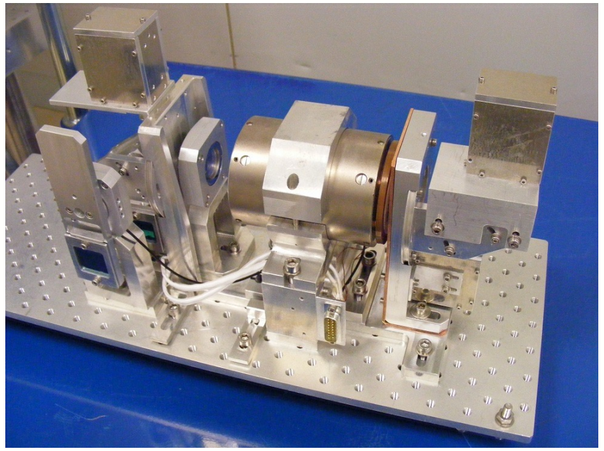
EGO Optics Group

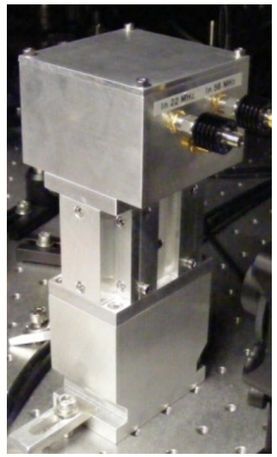
❑Problem: some optical components for Virgo not available off-shelf

➢ In-house development of large aperture, high-power, low-losses, UHV compatible devices such as:

Electro-Optic Modulator

Faraday Isolator





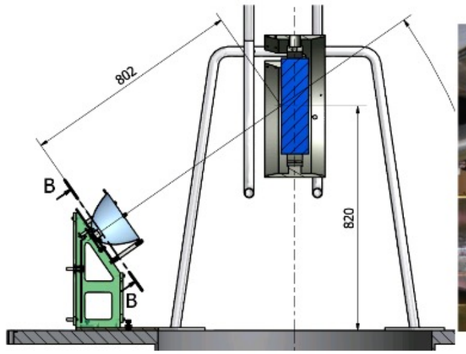
Development of low losses Faraday isolator (losses<1%) and High Power EOM (200W) widely used in Virgo

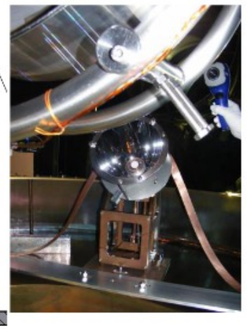
O. Palashov, et al. High-vacuum compatible high-power Faraday isolators for gravitational-wave interferometers, JOSA B, Vol. 29, Issue 7, pp. 1784-1792 (2012).

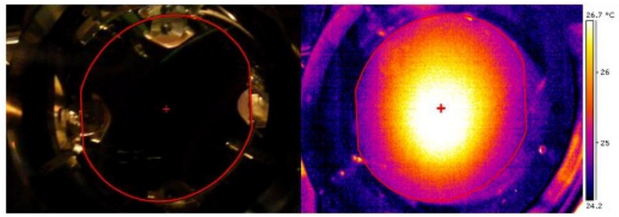
❑ Problem: Virgo+ needed RoC actuator for end mirrors to equalize the arms and escape some spurious resonances of higher-order modes

➢ In-house development of new thermal actuator: the Central Heating Radius of Curvature Correction (CHRoCC)

➢ *Also used for Advanced Virgo Plus!*







Development of Central Heating Radius of Curvature Correction device (CHRoCC)

T Accadia *et al,* Central heating radius of curvature correction (CHRoCC) for use in large scale gravitational wave interferometers 2013 *Class. Quantum Grav.* 30 055017

EGO Optics Group

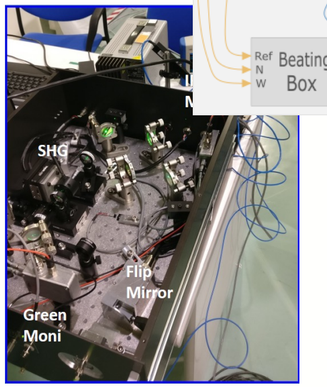
❑ Problem: equip Advanced Virgo with new baffles for stray light control suited to new geometry and *on a tight budget*

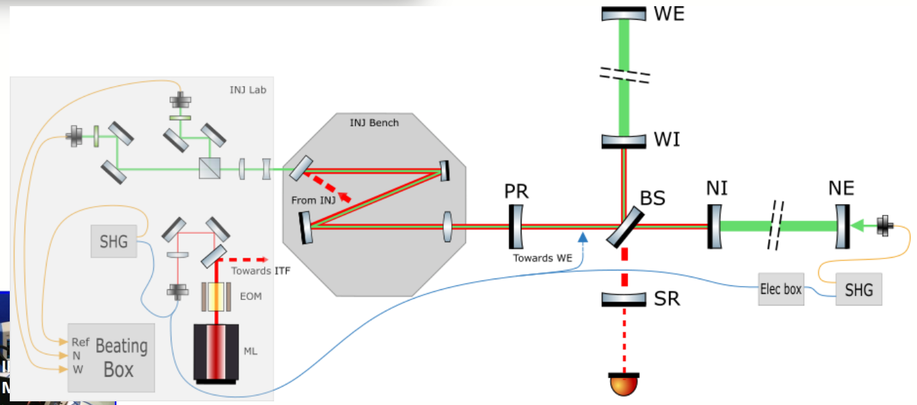
➢ In-house development of efficient and cost-effective anti-reflective coating on metallic surface

Development of Anti reflective coatings directly on metallic baffles for stray light trapping

❑ Problem: provide AdV+ with auxiliary laser systems to lock the arms away from main laser resonance

➢ In-house development of second harmonic sources locked in phase with main laser





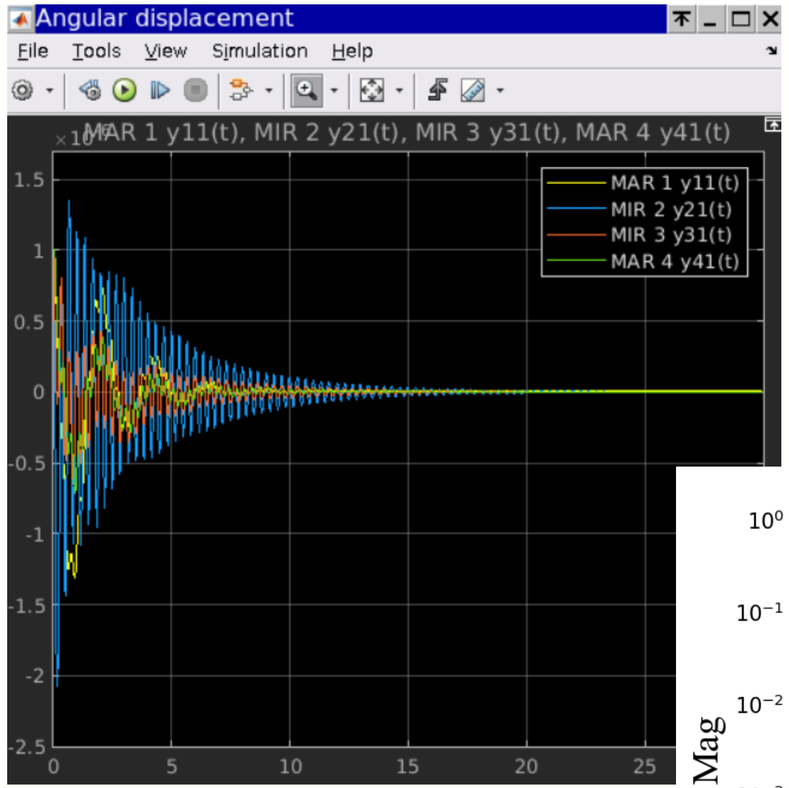
De Rossi C, et al. Development of a Frequency Tunable Green Laser Source for Advanced Virgo+ Gravitational Waves Detector.
Galaxies. 2020; 8(4):87. https://doi.org/10.3390/galaxies8040087

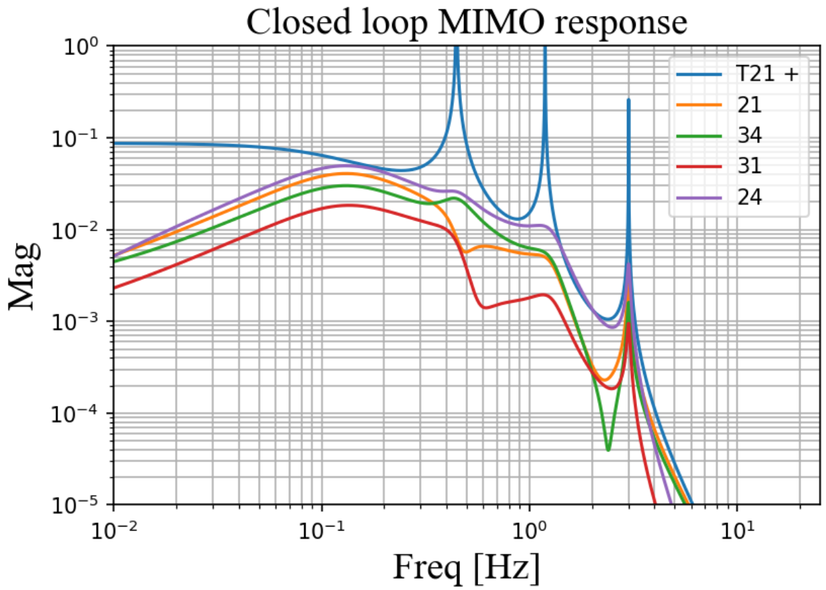
Take home message: keeping a *resident team* of fully committed instrument scientists has often been a game changing asset

EGO VIRGO

EGO Control Group

- The EGO control group leads the Interferometer Sensing and Control subsystem (starting from 2015 Advanced Virgo experiment).
- Coordination of the design for the Advanced Virgo+ Phase II experiment
- Strong contribution on the suspension control (since initial Virgo)
- Involvment in the Auxiliary Laser System for Advanced Virgo +)

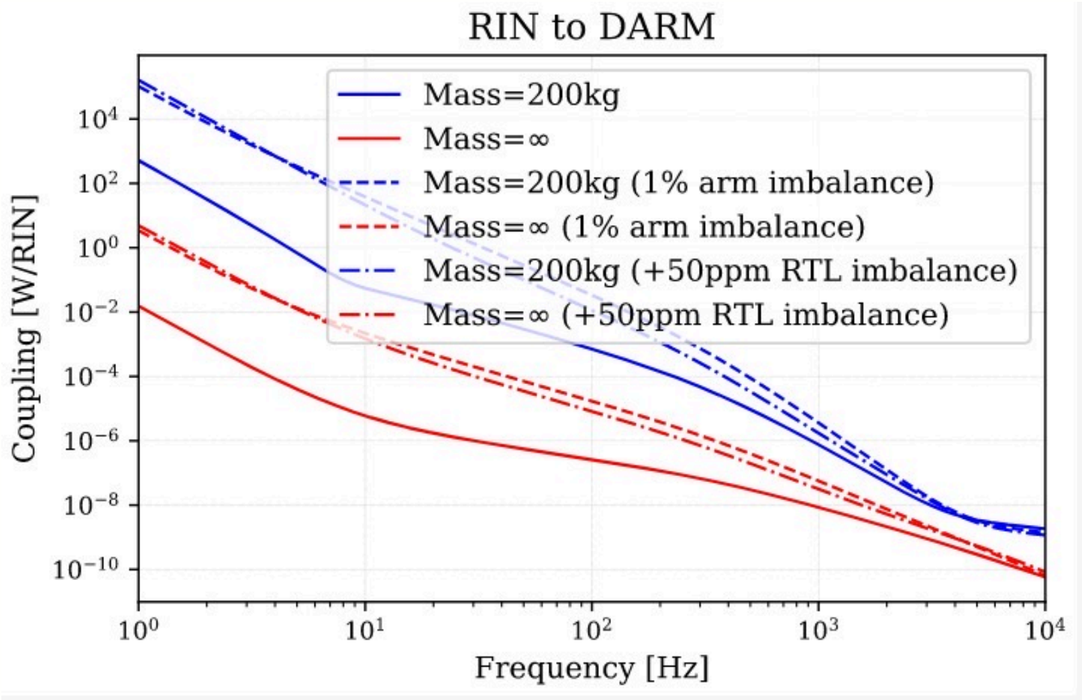


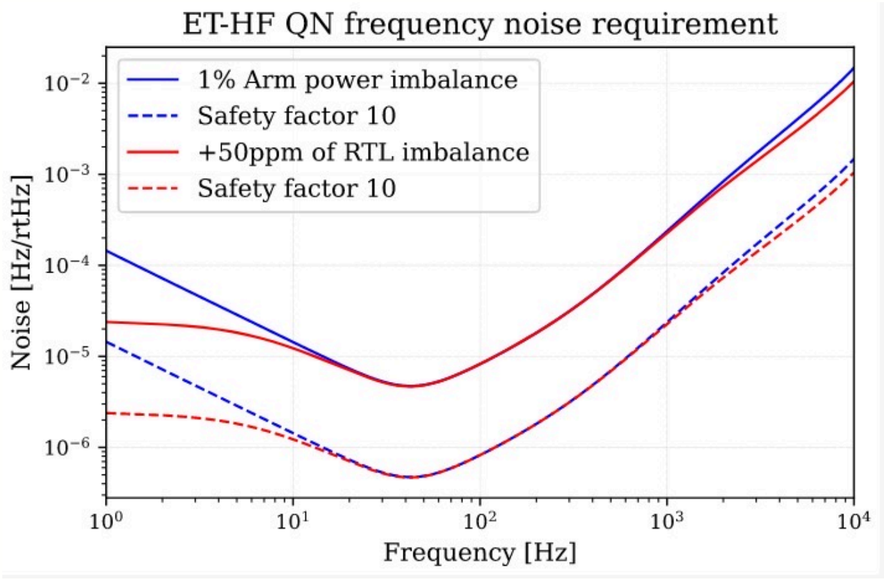


EGO Control Group

❑Moreover the EGO control group is already contributing to ET:

- Co-chairing of "Optical design and sensing and control LF“ package
- Co-chairing of "Inter platform noise suppression" package





EGO System Engineering/Online Computing

AdV+ System Engineering

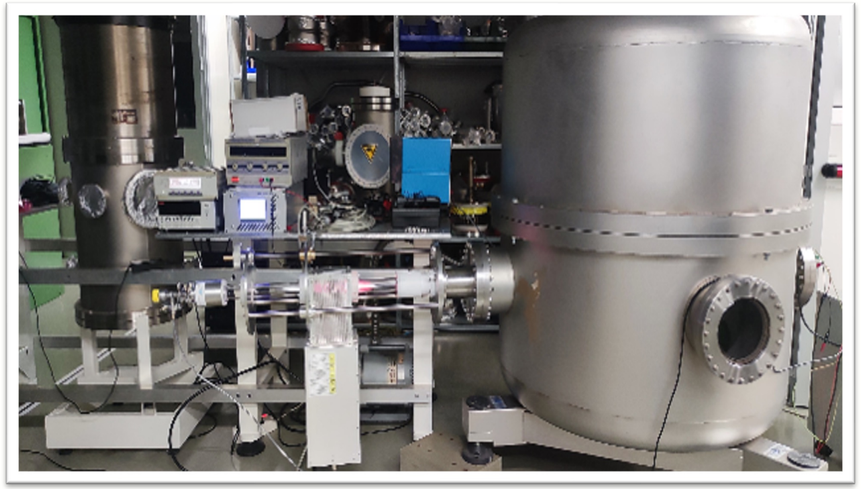
- Finalizing the remaining AdV+ Phase II Design Reviews (DR) based on deliverables organization.
- Initiated the Phase II Production Readiness Reviews (PRR) related to all mayor procurements that are ready to start
- Validation/Reception Reviews (VRR)
  - templates and procedures have been updated to make it as light as possible but still effective. Main outcome in the form of a simple and predefined checklist worksheet covering the integration relevant points
  - VRR management added into the automation procedures developed for DR and PRR
- The introduced automation procedures to support the reviews workflow are proving effective in the managements of the associated hundreds of mails, documents and follow up actions.

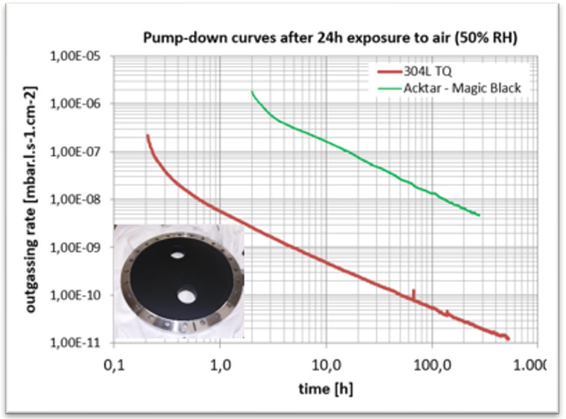
Computing

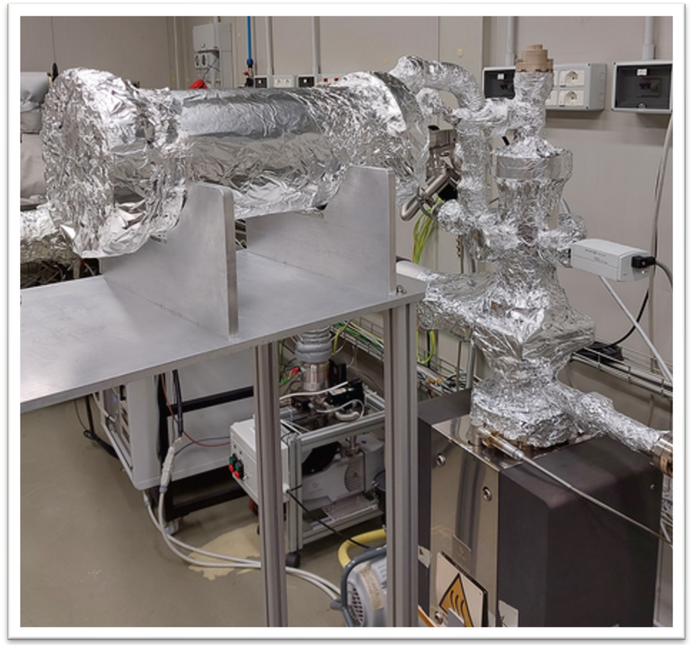
- In the role of Data Processing Infrastructure (DPI) manager focused on ER15/O4 readiness, with current status highlight:
  - Low latency data distribution
    - Up and running in production mode using jointly developed lldd library.
  - Raw data transfer
    - data are flowing into the dedicated ER15 directories at CNAF and CCIN2P3. The transfer is being used to tune the transfer procedure and asses performances.
  - Bulk data distribution
    - Setup completed for the Louvain origin following the naming convention defined into the "Final O4 Plan for IGWN OSDF/CVMFS Origins". Aggregated 2000 sec h(t) data (aka online files) are flowing from Cascina to Louvain using Rucio

EGO Vacuum Group

- MISSION = Study and improve Virgo Vacuum
- UHV laboratory
  Outgassing measurements of new materials
- Collaboration with Virgo teams for new phenomenologies
  Charging effects mitigation, Dust particles migration, Contamination issues,...

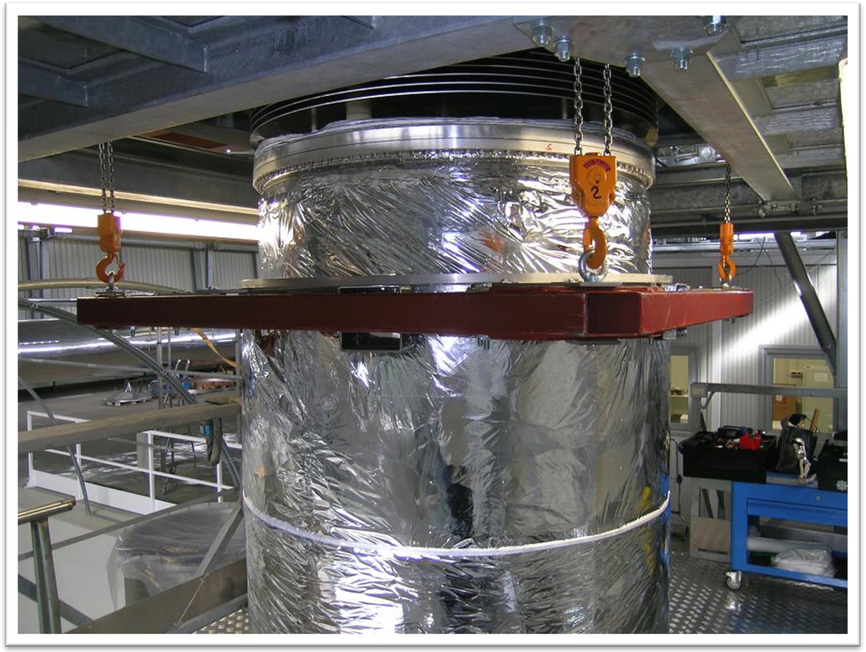






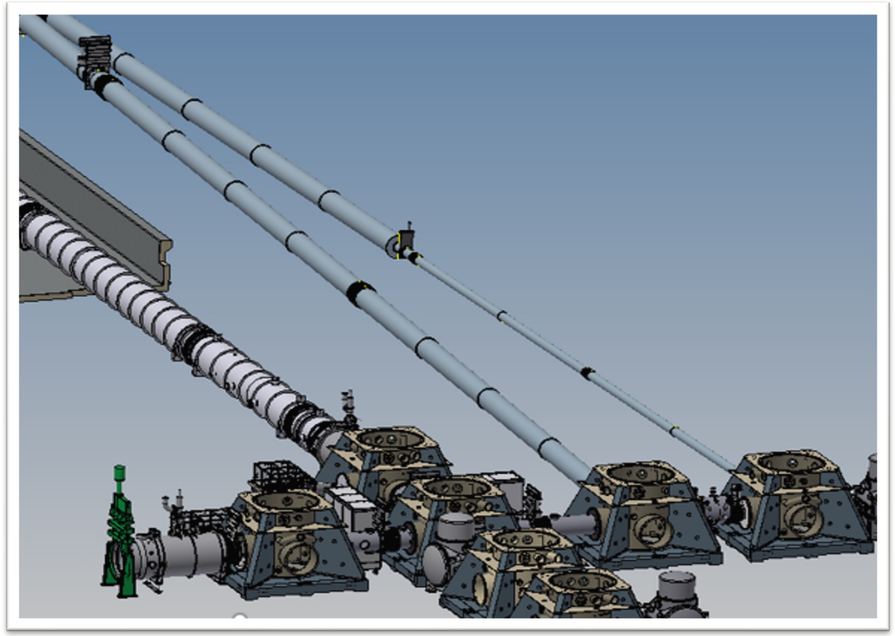
EGO Vacuum Group

Large test chambers



10K Cryostat (under revamping)

Design of Vacuum and in-Vacuum systems



Impact on society, relationships with local communities and institutions

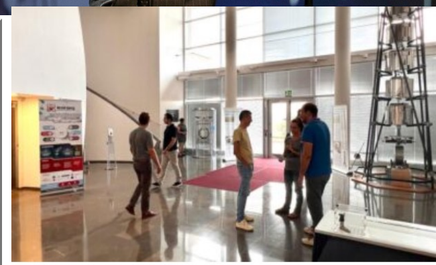
Strengthening relations with academic institutions

- Several agreements with local (Pisa area), national and international institutions
- Funding of PhD fellows, Thesis
- Proposal to start a Fellow program (Junior and Senior) that may include teaching activities

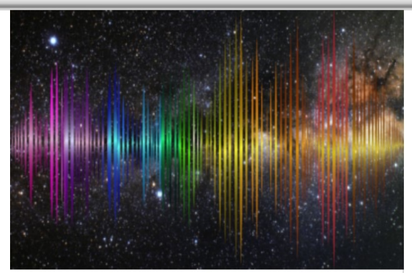
A program of visits on site...

- Guided tours have restarted in March 2022 after a long stop due to COVID-19
- Presently we get about 10.000 visitors a year, 15% come from abroad, most of them are high school students or younger
- Remote tours continue to be organized connecting with people all over the world in many languages

Over 15 events and institutional visits in the last 12 months

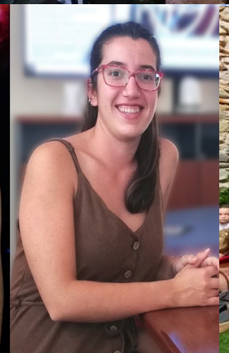


A TWO DAYS WORKSHOP AT EGO FOR FOSTERING CITIZENS ROLE IN FUNDAMENTAL SCIENCE



"THE SOUND OF THE UNIVERSE" AT GENOA SCIENCE FESTIVAL

"LE DONNE E I PAESAGGI DELL'ASTRONOMIA", AT PISA BOOK FESTIVAL 2021

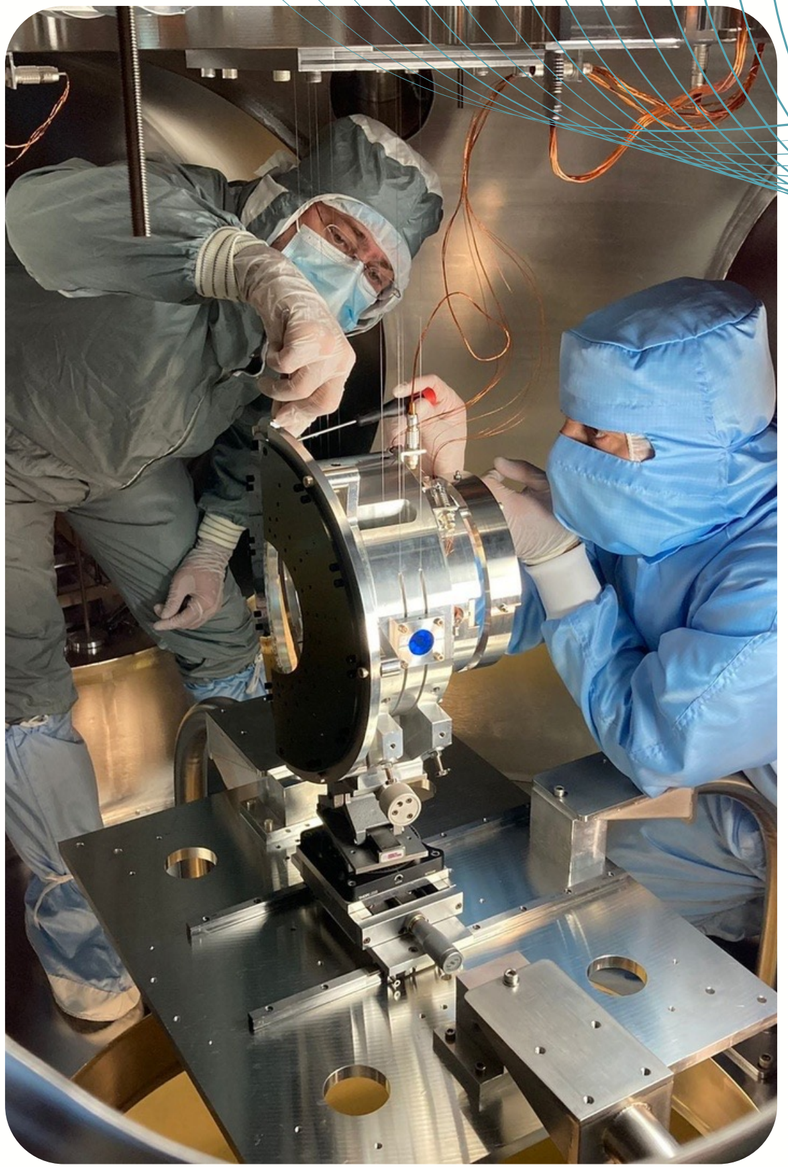


Targeting different audiences and communities

- Over 15 local and national events organized during 2022
- Participation to exhibitions and science festivals both in Italy and Europe, with exhibits and installations
- This activity supports in a crucial way the institutional networking at the local/regional level
- Citizen Science programs (Reinforce, GWitchHunters)

Visiting programs, exchanges and more…

- The improvement of the pandemic situation and the upcoming runs will bring more people on site
- It is important to broaden the international role of EGO for the European GW community
- Visiting programs and exchanges will be organized



Increasing the appeal of EGO to scientific visitors

- 2023 first year post pandemic
- Smooth access to the EGO laboratories for VIRGO and all LVK scientists
- A user office will be created

Thank you for your attention!