Upgrade of Virgo Adv. & scientific exploitation; Towards ET telescope

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Context

Gravitation wave interferometers have opened a new window to study some of the our department traditional topics, for example:

- Search for Dark matter (PBH as DM, DM around black holes)
- Developing the cosmology model (solving the Hubble constant value tension, Gravitation Waves from inflation),
- Compact objects (Galactic and extragalactic CR accelerators)

Context

CIEMAT Basic research department has built a (beyond) multimessenger approach to these problems:

- Astroparticle division
  - Cosmology group (Dark matter, Dark energy, inflation)
  - Cosmic rays group (Compact objects, Dark matter)
  - Gamma rays group (Compact objects, Dark matter)
- Physics division
  - Neutrinos group (Compact objects)
  - Dark matter group (Dark matter)
  - Accelerator physics group (Dark matter)

Context

CIEMAT recognizes that staying at the front of these field requires to open a gravitational waves research line.

This is aligned with the interest of the Ministry into ET, expressed directly to the members of our department.

In consequence CIEMAT recently became member of ET and of the Virgo experiment

Context: Virgo Adv+

Virgo proposed us to participate in computing, science and 4 hardware activities.

We decided to only keep science, computing and 2 hardware activities to maximize the return vs costs, and to adapt it to our group expertise and size.

Goals of the project

Long term:

Collaborate in the preparatory phase of the Einstein Telescope and in the construction.

Train and consolidate a team of scientist and engineers to exploit the future facility.

Short and medium term:

Exploit current instruments towards studying the topics of interest of the Department using the new window.

Participate in the evolution of current instruments and in the development of the technologies for ET.

Coordination

Currently this project is not coordinated, although coordination with other groups happens in practice within the collaborations.

First contacts with IFAE (Mario Martinez) and UAM (Juan Garcia Bellido) already happened, essentially regarding collaboration but not coordination.

We need to understand running projects timelines, but will not happen for current call.

Personnel

- Team
  - Carlos Delgado (IP): Management, Analysis, Hardware coordination
  - Pablo Garcia (IP): Management, Analysis, Computing
  - Two engineers

- Collaborators from other CIEMAT groups
  - Scientific Computing Division
  - PIC
  - Physics division IA expert
  - Astroparticle physics division
  - CIEMAT’s technology department: scientific instrumentation division, Workshops, Vacuum

Current project structure

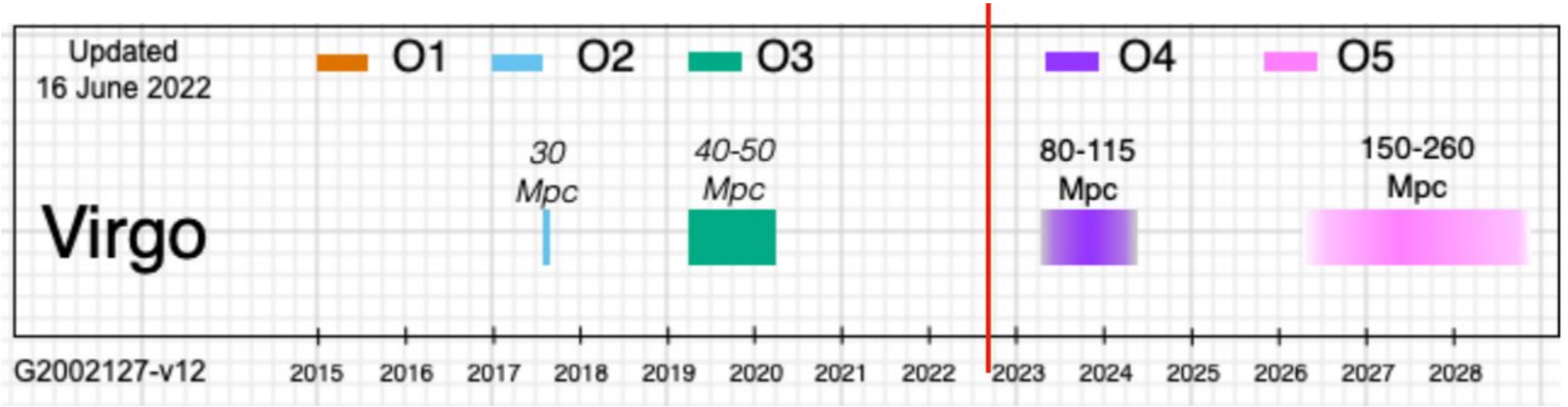
- WP.1 Advance Virgo
  - WP.1.1 Development of hardware for O5
    - WP.1.1.1 Design, production and AIT of mechanics for the ring heater of the injection mode cleaner
    - WP.1.1.2 Design, production and AIT of a scattered light mitigation baffle for the laser at the output port
  - WP1.2. Computing: deployment and maintenance of the low latency computing server for O4
  - WP.1.3 Analysis and physics exploitation
    - WP.1.3.1 Development of Explainable IA analysis tools
    - WP.1.3.2 Templateless search (SN and other compact objects)
    - WP.1.3.3 Physics analysis (Measurement of Hubble constant, Stochastic Background,CW)
  - WP1.4 Services & Management
    - WP.1.4.1 Outreach
    - WP.1.4.2 Participation in data taking
    - WP.1.4.3 Participation in collaboration meetings
- WP.2 Einstein telescope:
  - WP.2.1Development of the computing model
  - WP.2.2 Development of the vacuum system (together with CERN)

Budget

Package	k€
WP.1 Advance Virgo	
WP.1.1 Development of Hardware	
Hiring a Technician	112.5
Raw material for materias, coating and mesurement services, and tooling for CIEMAT workshop	100
Travels to attend meetings (27 trips x person x years) and integration at Virgo site	50
WP.1.2 Computing: deployment and maintenance of the low latency computing server for O4	
Server cost	30
Maintenance and personnel costs	20
WP.1.3 Analysis and physics exploitation	
Hiring a postdoc	125
Trips (9 trips person tyeras)	10
Student	
WP.1.4 Services & Management	
Collaboration meetings (30 trips x person x years)	30
Collaboration common services cost	20
WP.2 Einstein Telescope	
Collaboration meetings (20 trips x person xyears)	20

Calendar

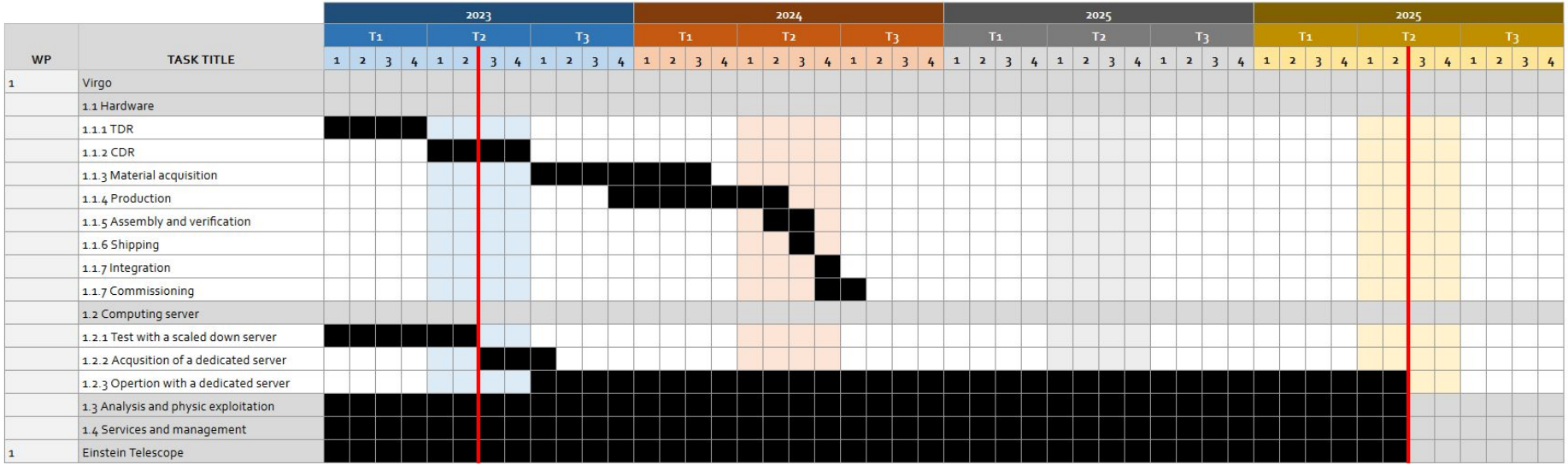
Window of opportunity: aligned with O4 run and preparation of O5 Virgo one:



More details at: https://observing.docs.ligo.org/plan/

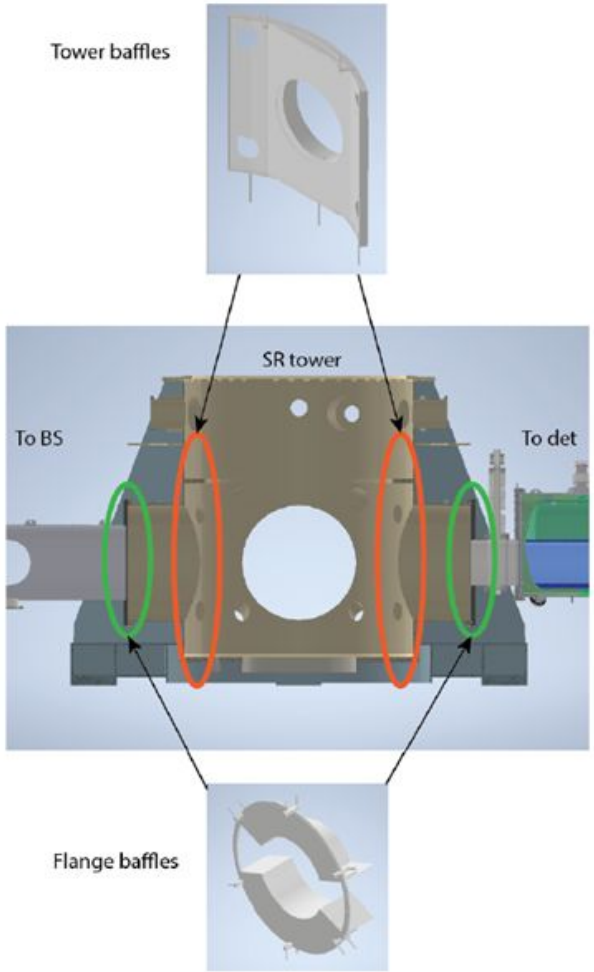
(15 June 2022 update; next update by 15 September 2022)

Schedule


2023
2024
2025
2025
T1 T2 T3
WP
TASK TITLE
1 2 3 4
1 Virgo
1.1 Hardware
1.1.1 TDR
1.1.2 CDR
1.1.3 Material acquisition
1.1.4 Production
1.1.5 Assembly and verification
1.1.6 Shipping
1.1.7 Integration
1.1.7 Commissioning
1.2 Computing server
1.2.1 Test with a scaled down server
1.2.2 Acqusition of a dedicated server
1.2.3 Opertion with a dedicated server
1.3 Analysis and physic exploitation
1.4 Services and management
1 Einstein Telescope

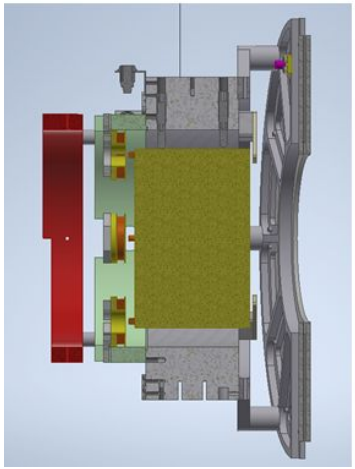
Scattered light mitigation

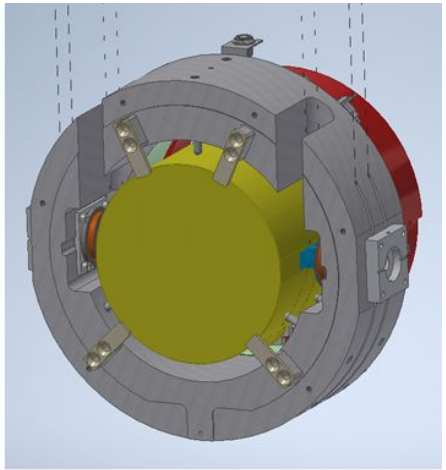
- Light scattered from the output optics towards the vacuum chamber and then scattered back into the main beam
- Recombine with the main beam and produces spurious signals
  - Sensitivity to environmental noise
    - » Acoustic noise
    - » Seismic noise
- Solution: protect the vacuum chambers walls with baffles absorbing the scattered light
  - Polished metal sheets with anti-reflection treatment



Mode cleaner mechanics

- Input mode cleaner: 300 m optical cavity
- Goal: control the radius of curvature of the end mirror
- Integrate a ring heater in the mirror suspension (payload)
- Work to be done: modify the mirror payload





Computing in Virgo for O4

Initial commitment (under discussion): hosting of a customized computing cluster dedicated to running low latency pipelines:

- Computing requirements: 2 VMs and one HTCondor cluster:
  - Two VMs for online data transfer/data distribution: 24 CPU,
  - HTCondor farm: 240 CPU.
- Low-latency data transfer installation of software packages on shared disk areas visible on the whole cluster (via CVMFS).
- Storage requirements: a few TB visible to all nodes of the cluster via NFS.
- Budget: 4 servers are required, around 30 k€. Maintenance and personnel costs: 20 k€ in 3 years.

Meeting with experts of Virgo this week to understand the details: timescale, funding, maintenance effort, scalability, availability level of the service, and other technical details.

Opportunistic Grid resources for GW

PIC Joined the LIGO/VIRGO Grid in Summer 2019.

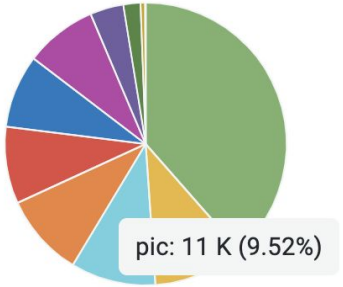
Site integration was fast and easy. Thanks to using same sw stack as other experiments (LHC, DUNE …)

No major issues have been experienced.

- CPU and GPU access through HTCondor
- CVMFS mounted in the WNs:
  - /cvmfs/ligo.osgstorage.org/
  - /cvmfs/ligo-containers.opensciencegrid.org
  - /cvmfs/oasis.opensciencegrid.org
- StashCache deployed on K8s (OSG repo) for Virgo/Ligo
  - 3.2 TB - 88% occupancy
  - running xrootd v5.1.1

PIC GW opportunistic Grid resources

GPU Wall Hours by Facility

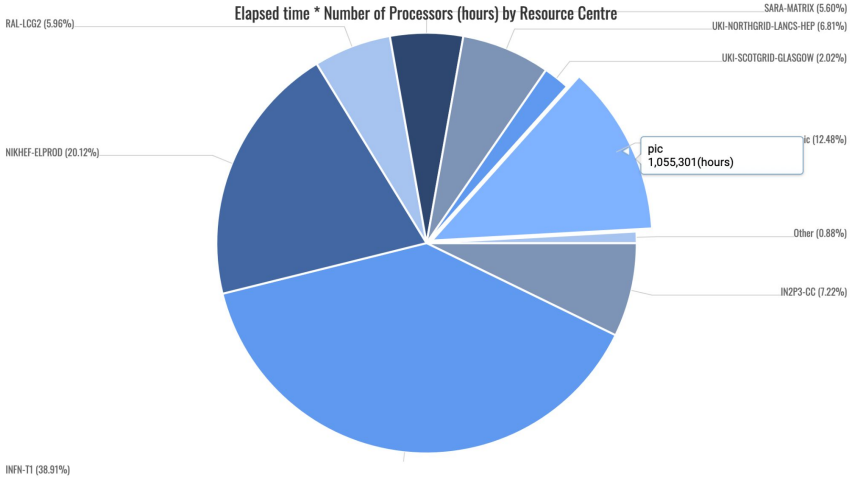


	total
LIGO-CIT-CE	46 K
Crane	13 K
ComputeCanada-Cedar	12 K
pic	11 K
Georgia_Tech_PACE_CE_2	11 K
LSU-QB2-CE1	10 K
ND_CAMLGPU	10 K
LIGO-WA-CE	5 K

Last 12 months contribution:

~9.5% of GPU *(OSG/LIGO accounting portal)*

~12.5% of CPU *(EGI accounting portal)*



Science

- Virgo's physics programme is very broad.
- We are interested in
  - Developing Artificial Explainable Intelligence (IAX) tools to study phenomena whose signals are less singular than those of black hole and neutron star mergers, such as supernova explosions and other compact objects.
  - Measurement of the Hubble parameter and studies of stochastic backgrounds associated with phenomena, which may be of cosmological or astrophysical origin, in the latter case produced by a superposition of unresolved sources.
- Virgo (as well as LIGO and KAGRA) will start the 4^{th} observing run (O4) in March, so it will be a particularly interesting time to participate in the analysis of the new data.

THE END