WP9

ET Sustainable Development Strategy

N. Arnaud, R.Galler, Hauzinger, S.Katsanevas, M.Marsella, A.Paoli

Objectives

1. Minimize the global carbon footprint of the Einstein Telescope (ET)
2. Evaluate landscape, environmental and societal impact and how to implement valorization and mitigation actions
3. Contribute to Sustainable goals (enforce a strong multidisciplinary approach by addressing other science-based targets for natural hazards and climate change mitigation)

Topics to be discussed

- Carbon Footprint
- Current measurements, Virgo, LVK, Astrophysicsl Infrastructures
- Future cases e.g. computing in ET
- Other domains e.g CERN
- WP7-WP9
- Contributions to climate monitoring
- Planning and Deliverables
- Planned workshops in Europe, Us/Asia

Task 9.1 ET Carbon footprint assessment and mitigation (CNRS, EGO, INFN)

Sub-task 9.1.1 ET carbon budget. The first sub-task is an accurate evaluation of the ET carbon footprint during both its construction and initial operation stages. All power consumptions of the infrastructure will be considered (instruments, service plants, computing facilities) as well as those linked to the transportations (commuting, supplies, travels) by analysing all the scientific scenarios envisioned. The study will be based on simulations and projections using literature standards, plus some critical revision of the existing studies for the current ground-based gravitational-wave detectors: the two LIGO instruments (USA), Virgo at EGO (Italy) and KAGRA (Japan, underground). Surveys made by large research infrastructures like CERN and SKA will be used as well, both for their methodology and as inspiration for our actions for ET.

Sub-task 9.1.2 ET Energy consumption optimization. The goals of this sub-task are twofold. First, to enforce a responsible energy consumption policy by

1. increasing the efficiency of all devices;
2. reducing the ET global need for energy thanks to an optimized design of the most energy-consuming areas;
3. recovering as much emitted energy as possible (e.g. heat from cooling systems) to reuse it.

Second, to ensure a responsible production for the consumed energy, whether it be produced on site (e.g., by arrays of solar panels) or provided by external suppliers.

Such optimization will be done separately for the three main elements of the on-site infrastructure – underground constructions, surface buildings and the local computing center – that all have different requirements to fulfil and challenges to meet. Joint work with other work packages (WP6, WP7, WP8) will be necessary to complete this sub-task.

2nd sustainable HEP workshop (5 – 7 Sept 2022):
https://indico.cern.ch/event/1160140/

1st sustainable HEP workshop (June 2021):
https://indico.cern.ch/event/1004432/

Peter Millington (he/him), on behalf of everyone working towards this document
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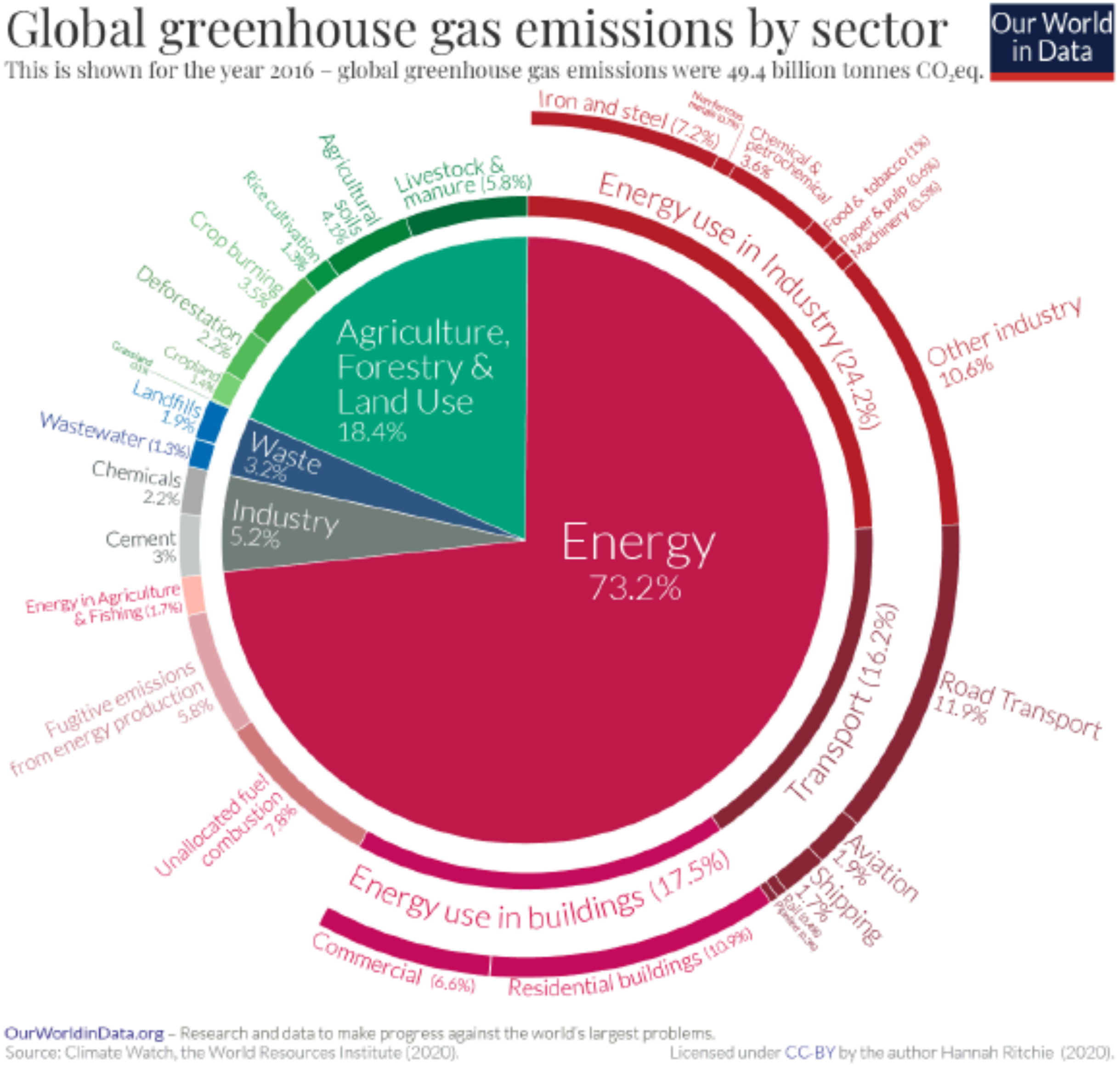
ICHEP2022, 9 July 2022

Please get involved!

- Conferences
- Canteens

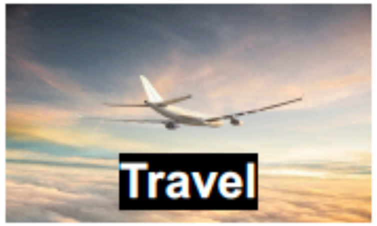
- Consumables
- Computing

- Usage
- Source
- Facilities

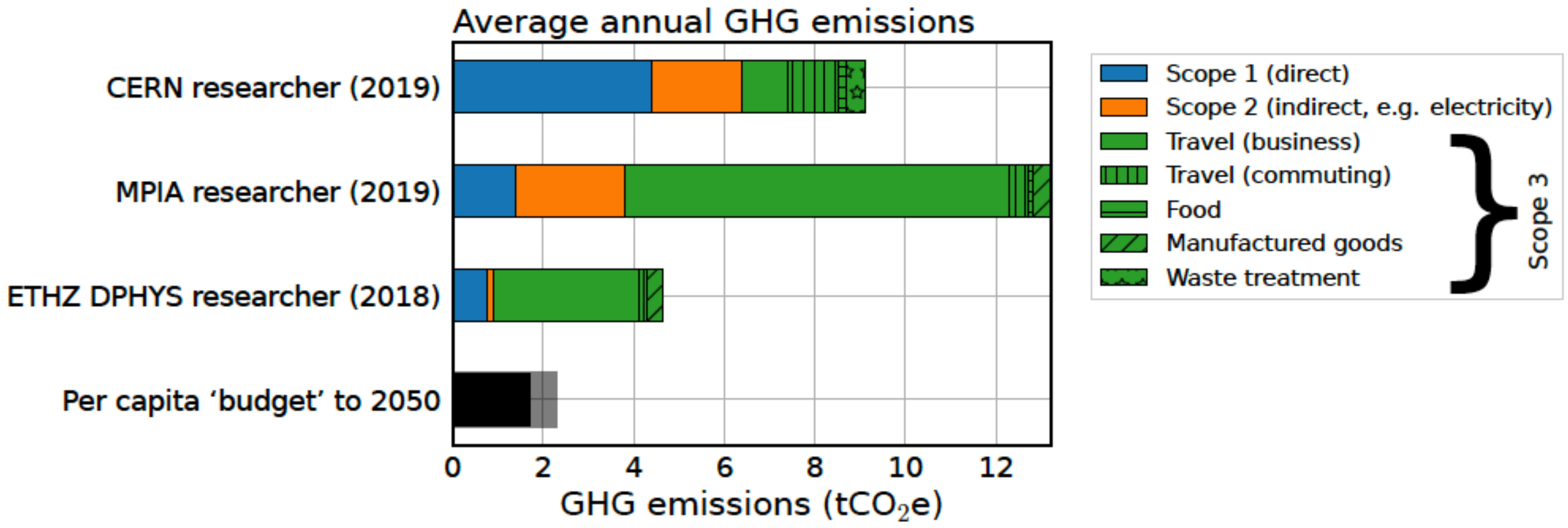


- Experimental infrastructure

- Analysis
- Simulation
- Communication



- Conferences
- Collaboration



CERN Scope 3 data excludes procurement, ETHZ Scope 3 data is incomplete. Total emissions are assigned to individual researcher as follows: each individual emissions category was divided by the nominal number of users for that resource, be it total number of employees, or researchers, or users (CERN). This is distinct from the procedure in [Jahnke et al. 2020], where all emissions were equally distributed amongst researchers only. Data from: CERN [CERN 2019, 2020, 2021], MPIA [Ivanova et al. 2017, Jahnke et al. 2020] and ETH [Beisert et al. 10].

Figure from the white paper, see https://sustainable-hecap.github.io/.

Please get involved!

References

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Snowmass 2021

Striving towards Environmental Sustainability in High Energy Physics, Cosmology and Astroparticle Physics (HECAP)

Disclaimer

This is a working draft of the white paper *Striving towards Environmental Sustainability in High Energy Physics, Cosmology and Astroparticle Physics.*

We need your help to complete it.

We welcome new contributors, new contributions, and constructive feedback on this document. Please get in touch with us via the online platform at: https://sustainable-hecap.github.io/.

Thank you.

The climate crisis and the degradation of the world's ecosystems require humanity to take immediate action. Given this, the High Energy Physics, Cosmology and Astroparticle Physics (HECAP) communities have a responsibility to limit the negative environmental impacts of their research. This document represents a community-wide step towards identifying these impacts, proposing positive changes that individuals, groups and institutions can make, and highlighting the associated opportunities for improving social justice.

This must only be the beginning.

Version: Draft, July 2022

Please read this document in electronic format where possible and refrain from printing it unless absolutely necessary. Thank you.

Preprint number
March 16, 2022

Sustainability Considerations for Accelerator and Collider Facilities

Thomas Roser[a] on behalf of the ICFA Panel for Sustainable Accelerators and Colliders

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ABSTRACT

As the next generation of large accelerator-based facilities are being considered at the Snowmass 2021 study high priority has to be given to environmental sustainability including energy consumption, natural resource use and the environmental impact of effluents. Typically, increased performance – higher beam energies and intensities – of proposed new facilities have come with increased electric power consumption. In the following we discuss the most important areas of development for the sustainability of accelerator-based research infrastructures in three categories - technologies, concepts and general aspects. To achieve the goal of increased performance with reduced energy consumption a focused R&D effort is required with the same or even higher priority as the traditional performance-related R&D. Such a recommendation was included in the recent European Strategy for Particle Physics Accelerator R&D Roadmap [1].

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Estimate of the carbon footprint of astronomical research infrastructures

Jürgen Knödlseder ✉, Sylvie Brau-Nogué, Mickael Coriat, Philippe Garnier, Annie Hughes, Pierrick Martin and Luigi Tibaldo

The carbon footprint of astronomical research is an increasingly topical issue with first estimates of research institute and national community footprints having recently been published. As these assessments have typically excluded the contribution of astronomical research infrastructures, we complement these studies by providing an estimate of the contribution of astronomical space missions and ground-based observatories using greenhouse gas emission factors that relates cost and payload mass to carbon footprint. We find that worldwide active astronomical research infrastructures currently have a carbon footprint of 20.3 ± 3.3 $MtCO_2$ equivalent (CO_2e) and an annual emission of 1,169 ± 249 $ktCO_2e\,yr^{-1}$ corresponding to a footprint of 36.6 ± 14.0 tCO_2e per year per astronomer. Compared with contributions from other aspects of astronomy research activity, our results suggest that research infrastructures make the single largest contribution to the carbon footprint of an astronomer. We discuss the limitations and uncertainties of our method and explore measures that can bring greenhouse gas emissions from astronomical research infrastructures towards a sustainable level.

Table 1 | Adopted emission factors

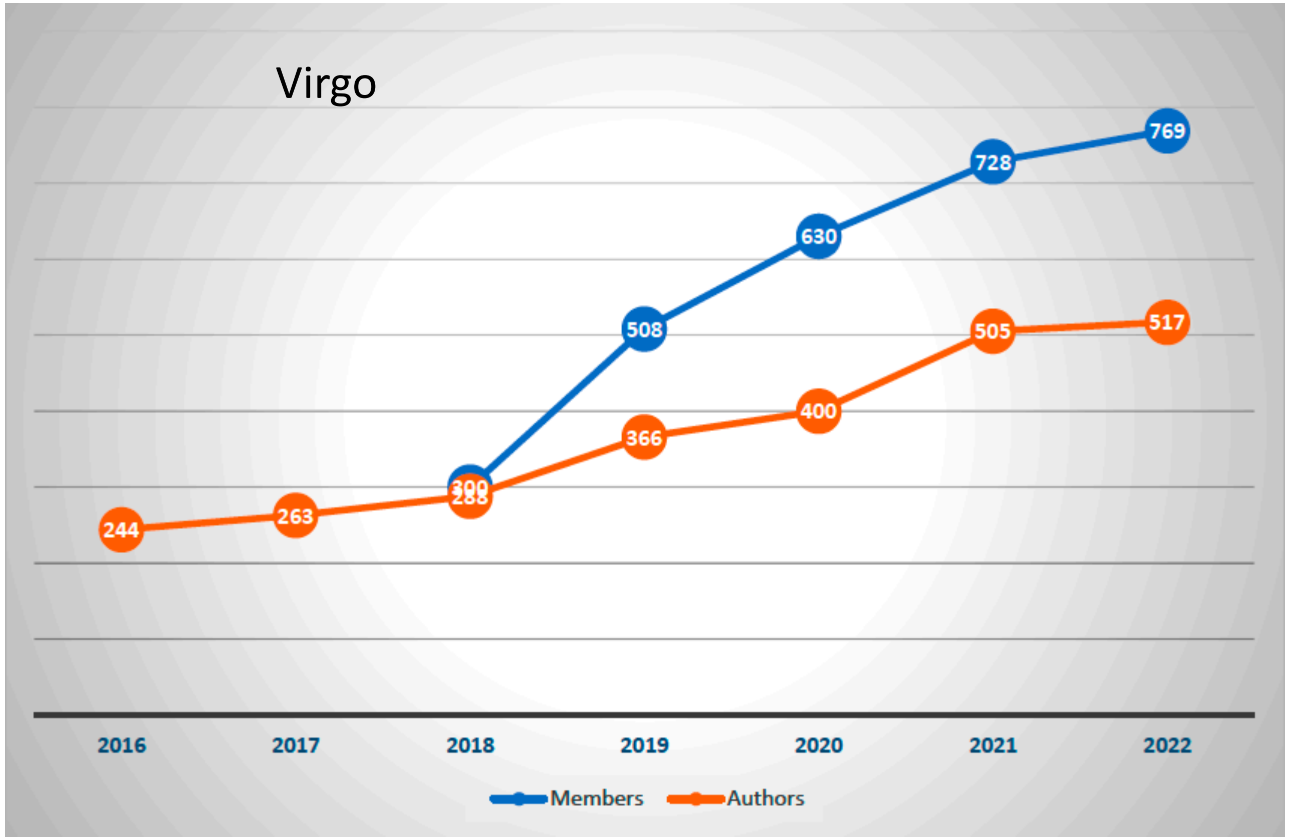
Activity	Emission factor
Space missions (per payload launch mass)	50 $tCO_2e\,kg^{-1}$
Space missions (per mission full cost)	140 $tCO_2e\,M€^{-1}$
Ground-based observatory construction	240 $tCO_2e\,M€^{-1}$
Ground-based operations	250 $tCO_2e\,M€^{-1}$

Table 3 | Order-of-magnitude estimates of the carbon footprint of some selected ground-based astronomical observatories or telescopes, ordered by decreasing footprint over the lifetime of the infrastructure

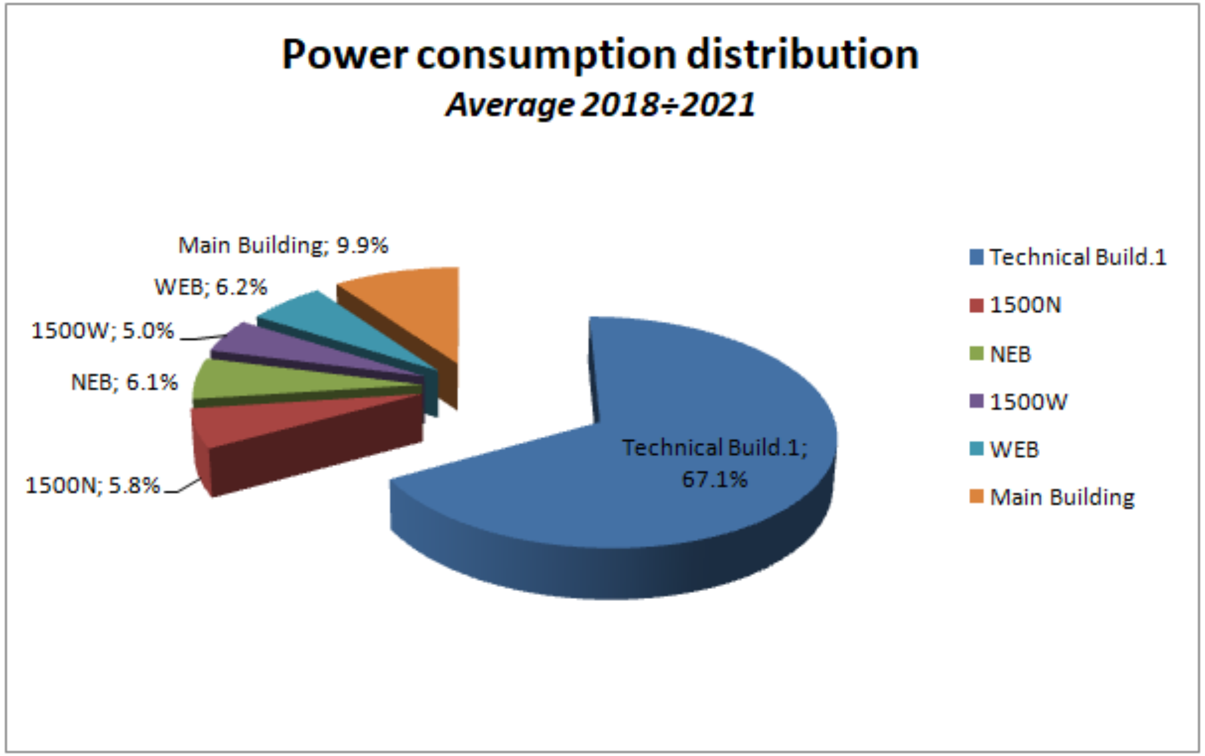
Observatory[a]	Lifetime[b] (yr)	Papers	Authors	Footprint				Carbon intensity	
				Construction (tCO_2e)	Operation ($tCO_2e\,yr^{-1}$)	Lifetime (tCO_2e)	Annual ($tCO_2e\,yr^{-1}$)	(tCO_2e per paper)	(tCO_2e per author)
VLT (Paranal)	21	17,235	26,442	332,280	9,875	539,655	25,698	31	20
ALMA	9	7,460	18,610	299,576	26,196	535,340	56,154	72	29
SOFIA	9	662	3,586	263,544	22,375	464,919	48,729	702	130
AAT	46	4,297	10,848	29,728	3,824	205,610	4,470	48	19
VLA	40	26,918	28,206	82,817	2,400	178,826	4,471	7	6
VLBA	27	4,995	12,427	31,608	3,874	136,194	5,044	27	11
IRAM	30	6,744	12,095	12,240	3,750	124,740	4,158	18	10
Gemini-South	20	1,735	9,949	32,280	3,250	97,280	4,864	56	10
CFHT	41	8,400	16,228	20,414	1,575	84,989	2,073	10	5
ESO 3.6 m (La Silla)	43	3,774	8,515	23,815	1,298	79,608	1,851	21	9
GBT	19	2,554	9,905	28,812	2,436	75,088	3,952	29	8
LOFAR	8	2,205	10,304	48,000	2,291	66,326	7,091	30	6
JCMT	33	4,726	9,145	9,192	1,364	54,194	1,642	11	6
ATCA	32	4,108	12,537	22,863	873	50,787	1,587	12	4
H.E.S.S.	17	4,577	12,889	11,848	2,193	49,126	2,890	11	4
MeerKAT	2	335	2,750	30,624	3,190	37,004	6,252	110	13
GTC	11	1,059	6,445	29,880		29,880	2,716	28	5
NRO	38	1,776	3,739	12,233	378	26,609	700	15	7
LMT	6	213	1,912	18,504	786	23,221	2,637	109	12
MLSO	55	385	932		306	16,817	306	44	18
APEX	15	2,244	8,097	4,800	675	14,925	995	7	2
SMA	17	1,585	5,312	14,354		14,354	844	9	3
EHT	11	606	2,079	12,580	–[c]	12,580	1,144	21	6
Noto Radio Observatory	32	108	1,490		378	12,096	378	112	8
2 m TBL	40	435	1,392	1,435	250	11,435	286	26	8
2.16 m (Xinglong Station)	46	235	651	1,750	182	10,137	220	43	16
1.93 m OHP	62	394	2,056	1,309	136	9,763	157	25	5
KMTNet	5	169	4,191	4,193	437	6,377	856	38	2
THEMIS	21	142	307		275	5,775	275	41	19
2.4 m LiJiang (YAO)	12	149	688	2,297	239	5,168	431	35	8
2 m HCT	19	276	1,259	1,454	151	4,331	228	16	3
1.5 m Tillinghast (FLWO)	51	652	2,514	683	71	4,312	85	7	2
1.5 m (OAN-SPM)	50	253	1,258	683	71	4,241	85	17	3
1.8 m (BOAO)	24	262	892	1,093	114	3,827	159	15	4
1 m (Pic-du-Midi)	57	29	345	240	25	1,665	29	57	5
1.3 m Warsaw (OGLE)	23	4,210	9,470	472	49	1,604	70	0.4	0.2
C2PU	6	31	1,982	480	50	780	98	25	0.4
TAROT	22	206	5,602	216	23	711	32	3	0.1
1 m NOWT	7	17	118	240	25	415	49	24	4

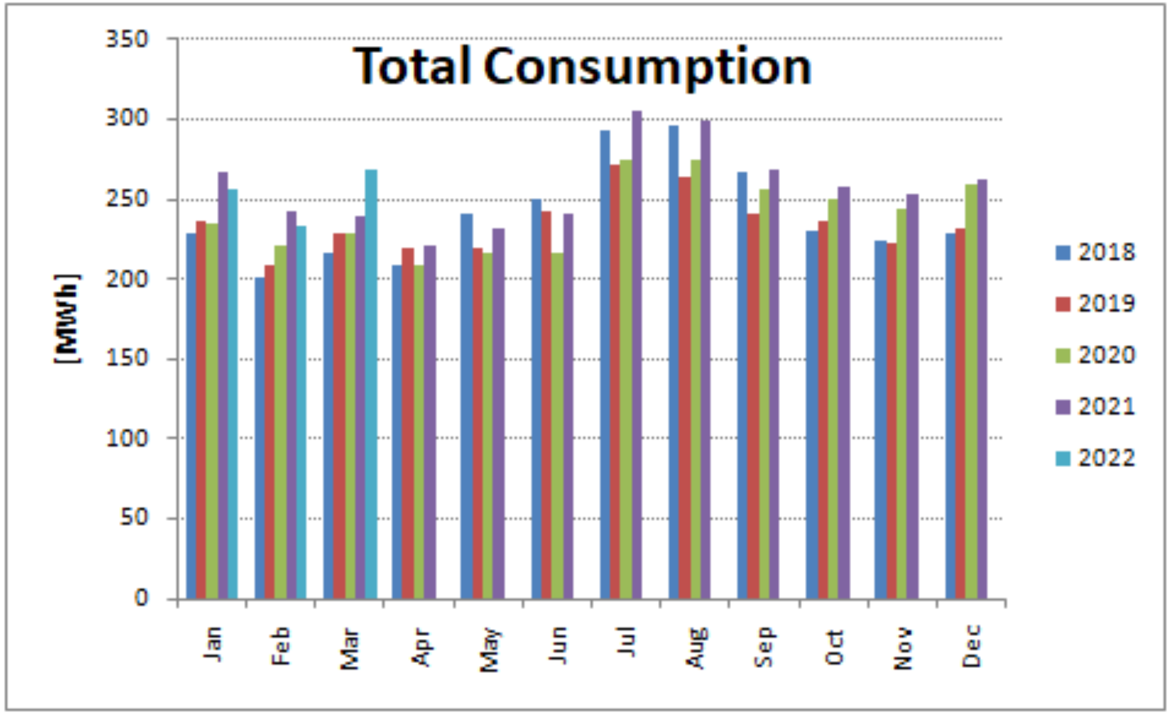
Table 4 | Extrapolated carbon footprint of all active astronomical research infrastructures in the world

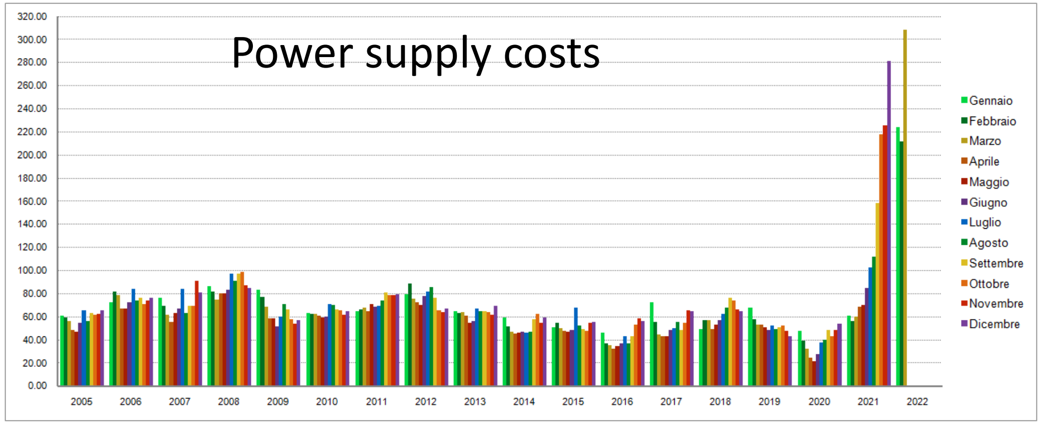
Category	Research infrastructures[a]		Carbon footprint of selected research infrastructures[b]		Carbon footprint of all research infrastructures[c]	
	Selected	Worldwide	Life cycle ($ktCO_2e$)	Annual ($ktCO_2e\,yr^{-1}$)	Life cycle ($ktCO_2e$)	Annual ($ktCO_2e\,yr^{-1}$)
Space missions (mass based)						
Solar	3	3	282 ± 147	23 ± 13	282 ± 166	23 ± 16
Plasma	7	13	553 ± 219	31 ± 12	1,029 ± 375	58 ± 20
Planetary	6	21	703 ± 256	65 ± 25	2,461 ± 546	226 ± 54
Astro	12	18	1,759 ± 586	99 ± 28	2,636 ± 955	149 ± 43
Sum			3,298 ± 692	217 ± 78	6,409 ± 1,174	455 ± 74
Space missions (cost based)						
Solar	3	3	510 ± 241	39 ± 19	510 ± 247	39 ± 20
Plasma	4	13	402 ± 175	30 ± 14	1,306 ± 352	96 ± 30
Planetary	6	21	886 ± 351	83 ± 34	3,100 ± 798	289 ± 80
Astro	12	18	2,339 ± 1,033	114 ± 41	3,526 ± 1,816	172 ± 68
Sum			4,137 ± 1,131	265 ± 58	8,442 ± 2,030	596 ± 111
Ground-based observatories						
OIR (≥3 m)	9	37	1,037 ± 478	42 ± 21	4,263 ± 665	171 ± 27
OIR (others)	19	~1,000	65 ± 17	3 ± 1	3,409 ± 163	147 ± 6
Radio	6	74	206 ± 81	10 ± 4	2,540 ± 345	127 ± 18
Radio arrays	9	27	1,156 ± 481	87 ± 46	3,465 ± 1,140	260 ± 115
Others	4	4	537 ± 374	52 ± 39	538 ± 499	52 ± 53
Sum			3,001 ± 779	194 ± 64	14,214 ± 1,461	757 ± 131

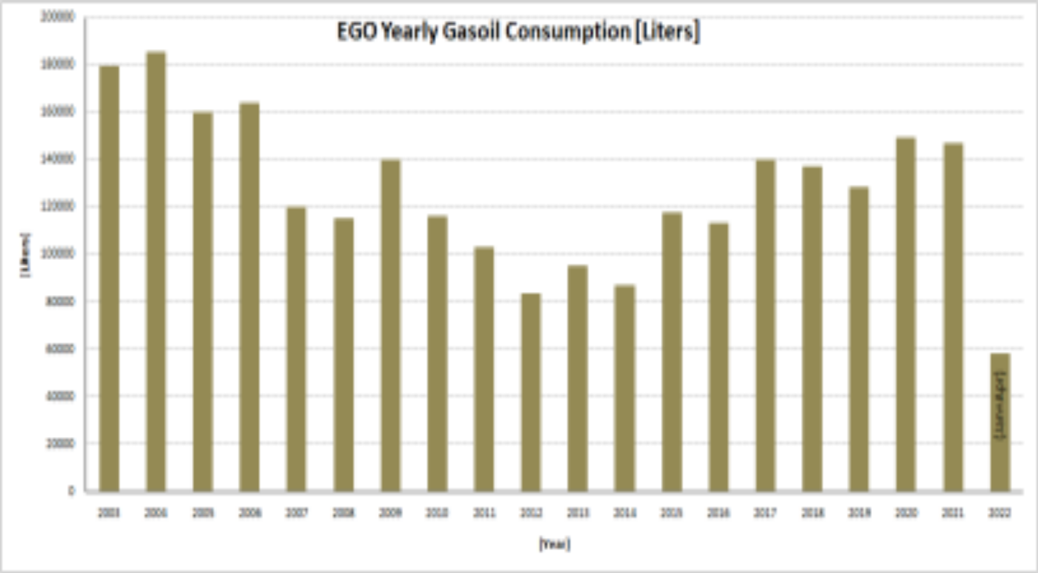


Operation Budget: 10 M€
Included above
Travel : 0,6 M€
Computing 0,3 M€
ELectricity/liquids 1,5 M€


Power consumption distribution
Average 2018÷2021
Main Building; 9.9%
WEB; 6.2%
1500W; 5.0%
NEB; 6.1%
1500N; 5.8%
Technical Build.1; 67.1%
Technical Build.1
1500N
NEB
1500W
WEB
Main Building

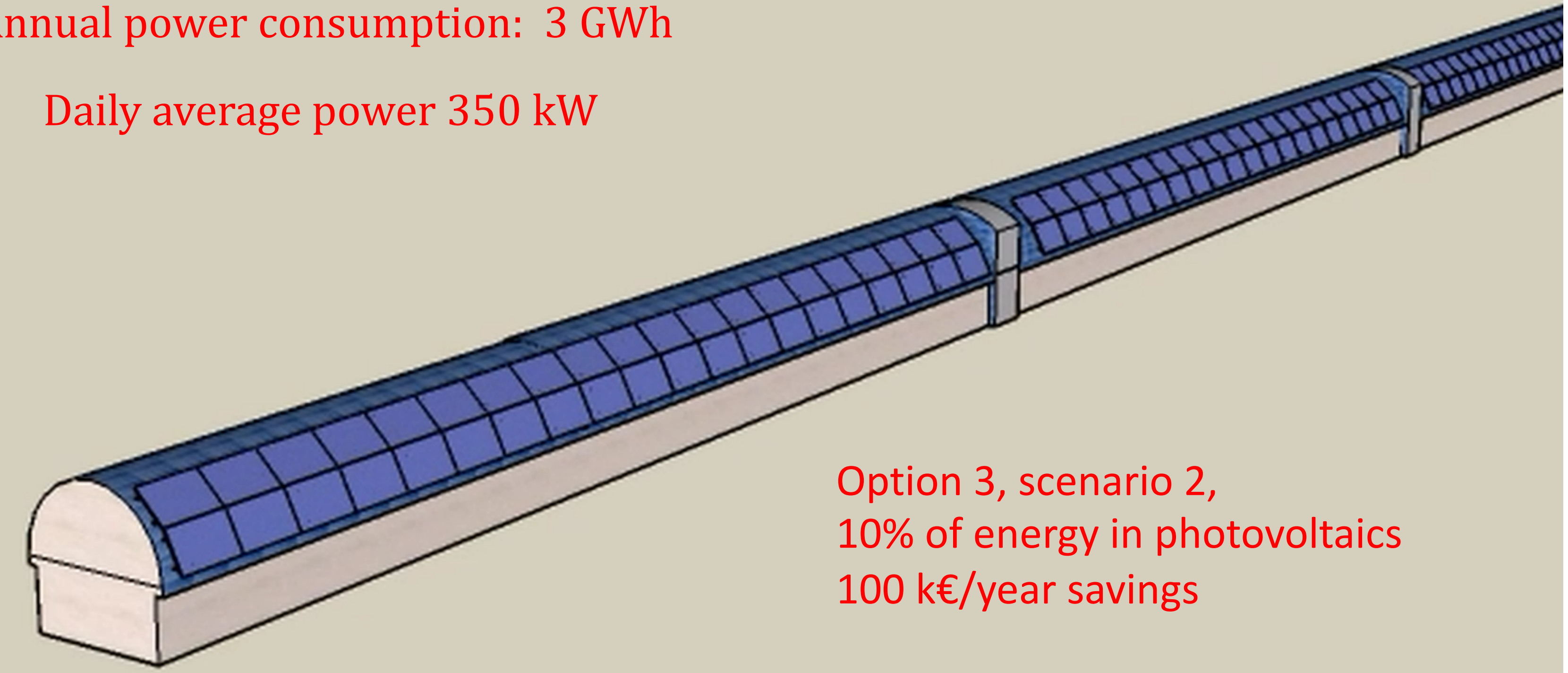

Total Consumption
[MWh]
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2018
2019
2020
2021
2022


Power supply costs
320.00
300.00
280.00
260.00
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Gennaio
Febbraio
Marzo
Aprile
Maggio
Giugno
Luglio
Agosto
Settembre
Ottobre
Novembre
Dicembre


EGO Yearly Gasoil Consumption [Liters]

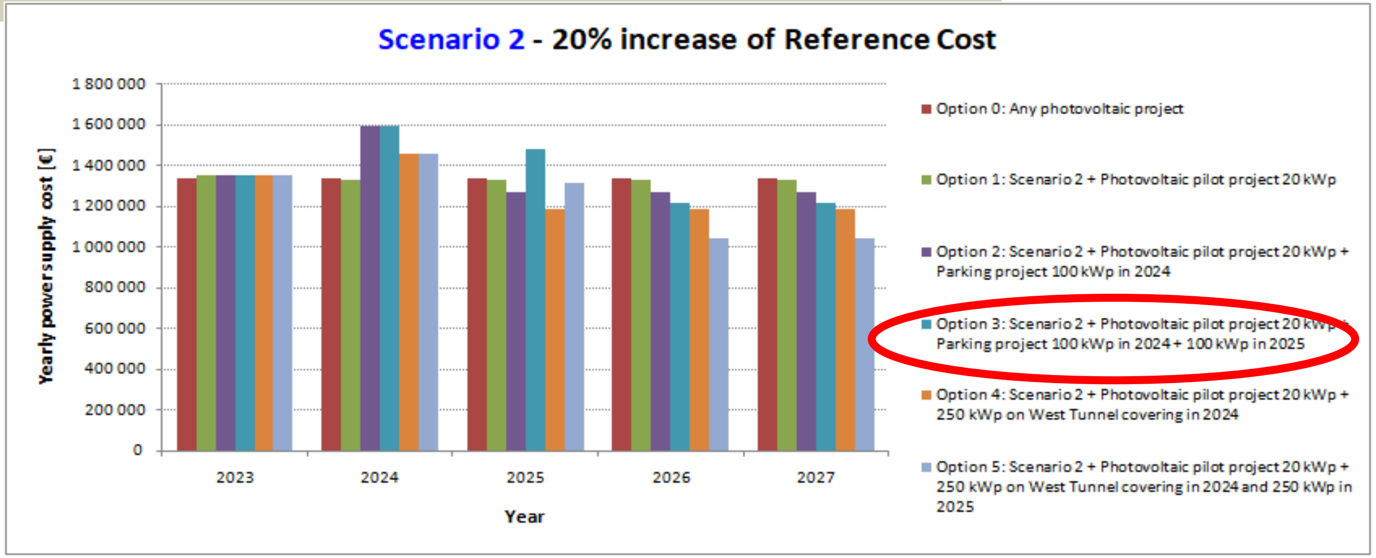
Annual power consumption: 3 GWh

Daily average power 350 kW



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

A. Paoli



LVK Sustainability commitee

- Gijs Nelemans
- David Shoemaker
- Szabi Marka
- Stefan Hil
- Mario Martinez
- Luca Baiotti
- Stefan Hild
- Irene Fiori
- Quynh Lan Nguyen
- Steven Penn

WP9.1 Carbon footprint (including computing and transportation)

- **We start our study with a comparison with the existing footprint of the current 2nd Generation detectors., based on a study done 2 years ago.**
- **SWP9.1.1 Power.**
  - Total power usage: LLO reports that they use on average 800 kW. This leads to a rough yearly number of kWh of 800*24*365 of 5,088,000 kWh -- 5GWh.
  - For LHO: we average 700,000kWh per month. A good estimate for the year is 8,4 GWh. A very nice fact: the power for LHO is mostly renewables.
  - Virgo:average power consumption of the EGO site is 320 kW annual energy consumption of the EGO site is between 2.4 to 3.2 GWh/year. In 2019 it has been 2.7 GWh.
  - KAGRA: Power (kWh) consumption at KAGRA site.2,2 MWh.
  - LHO is >50% higher power usage than LLO. Surprising? ➔ Weather
  - Summary power usage: LHO: 8.4 GWh (100% renewables!), LLO: 5 GWh, Virgo: 2.7 GWh, KAGRA: 2.2 GWh Total is 18.3 GWh. subtracting LHO (green!), end up with 10 GWh.
  - Using 1 kg CO_2/kWH, get total power carbon footprint: 1e7 kg of CO_2. ~1000 tons of CO_2

WP9.1 Carbon footprint (including computing and transportation)

- **WP9.1.2 Computing. LIGO**: O3 computing cycles, 500 million CPU core hours, over roughly 18–24 months Baseline computing estimate: 250 million CPU core hours per year. Power/computing comes from ~10 different sources. Caltech. Milwaukee. XSEDE. etc. Assume average carbon footprint for US power. **Virgo** (not known yet). **Kagra**: The total computing cycles of KAGRA's dedicated clusters, assuming a duty cycle of 80% for each system. The total number is approximately 550k computing cycles/day (≈ 16M computing cycles/month). Combined computing is ~700M CPU core hours per year Supposing that 10 CPU core hours requires 0.52 kWh. So 700M CPU core hours requires 364 MWh each year.
- Using 1 kg CO_2/kWH, get total power carbon footprint ~400 tons of CO_2

WP9.1 Carbon footprint (including computing and transportation)

- **WP9.1.3 Travel:** Start with 2 main meetings? Start with LVK specific ones. ask LVK labs business office to give data on trips. At some point need to do poll. Also contact previous two LVK meetings. 3 Virgo weeks per year. Start google doc/sheet to collect information. Some scientific meetings are almost completely "our" community. Start with actual LVK collaboration activities (because we can influence). Exemples: Sonoma meeting: Asia (Japan, australia): 300, US: 200 Europe: 112, S. America (mostly Brazil): 12. .Using this calculator, it's 1.3 tons of CO2 from CDG to SFO. Sonoma meeting generated roughly: 200 tons of CO2. Glasgow meeting: Using the participant country breakdown for the Glasgow LVC meeting in 2016: one calculates ~120 tons CO2
- Kagra:They have lists of participants of KAGRA members to LVK related conferences and in principle could estimate the total number of km traveled, maybe separating planes and other means of transport. But we better have a common way of doing this. How do we want to estimate the impact of travel? 24th KAGRA face-to-face meeting (University of Tokyo., December 2019) Participants: 110 ~ 54 tons CO2, 5th The KAGRA International Workshop (KIW), Perugia - Italy, 2019 ~123 tons CO2; ù
- Two annual international LVK conferences, plus assorted workshops: ~400 tons CO2

WP9.1 Carbon footprint (including computing and transportation)

- **Bottom Line**
- **Power at sites: 1000 tons CO2 per year,**
- **Travel: 400 tons CO2 per year**
- **Computing: 400 tons CO2 per year**

- The group will study the use of photovoltaic and geothermal energy.
- Ideas to be studied
  - Photovoltaic, underwater storage of power,
  - Reuse dissipated energy from computing center
  - Reuse dissipated energy from vacuum and cryogenic installations ?
  - Efficient internet / wifi distribution?
  - Organize passive house buildings, green car shuttle,
  - Videoconferences instead of travels? how much we gain , find the numbers
  - Reduce travels

Computing Model for ET

ASPERA meeting on Computing in Astroparticle Physics, Barcelona May 30-31 2011

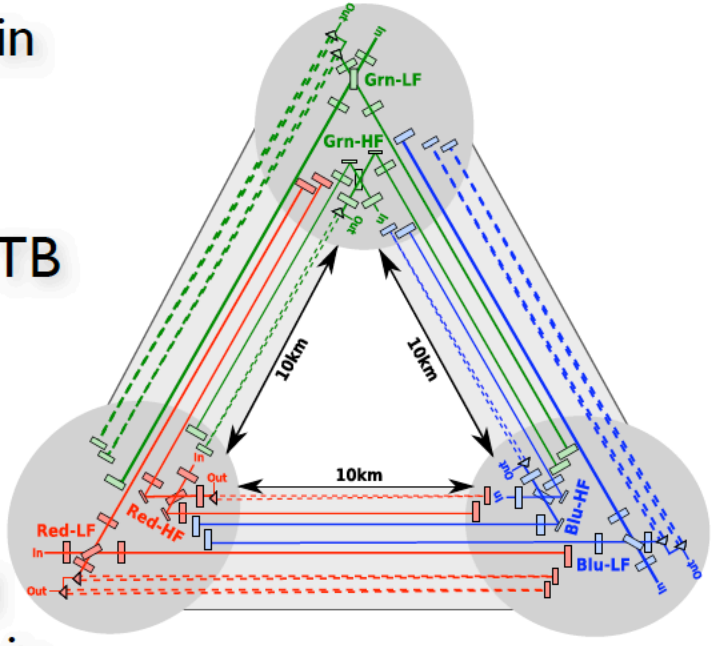
B.S. Sathyaprakash

School of Physics and Astronomy, Cardiff University, UK

on behalf of the Einstein Telescope Design Study Team

Einstein Telescope: An Observatory

- Six interferometers in a triangular array
- Timeline: 2025+
- Data rates of ~ 100 TB per year from the observatory
  - data handling is not a great challenge
- Data processing and science exploitation is the challenge



Searching for binary inspirals in ET

- Inspirals are traditionally searched using matched filtering
- Whitened data is filtered through a bank of templates that are copies of the expected signal
  - The search space and algorithm is already limited due computational requirements
  - The full parameter space is 17-dimensional
  - A coincidence search is carried out instead of a coherent search although the latter has a great potential to strengthen the searches

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Cost of Matched Filtering

To search for one day's worth of data

		GPU C2050	WLCG	Tianhe-1A	Low-cost
Power (TFlops)		0.25	2000	2567	100
# of Params	# of Templates	Computational Time			
2	10^{9}	128 d	24 m	18 m	7 h
4	10^{13}	> 1 y	182 d	128 d	9 y
6	10^{18}	> 1 y	> 1 y	> 1 y	> 1 y

New Computing Paradigms

- Conventional computing paradigms for detecting binary inspirals simply won't work
  - Signal lengths are far too long - need to break up the data set as in CW case
  - Number of overlapping signals means focus should be on those that are brightest
- At several events every minute the signal rate is far too high for post-processing pipelines
  - Current follow-up analyses take ~ days per event
  - E.g., posterior distribution of parameters is essential for delivering the science but takes too much time

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Multi-messenger Astronomy

- A subset of events (50%) might be followed up in radio, X-ray, gamma-ray, etc
  - Processing power is required for not just GW data
  - Need to process EM observations
- Current set up and that envisaged for advanced detectors still work with semi-automated set ups for EM follow-ups
  - Must have fully automated data pipelines
  - Automated alerts, observation and analysis

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ET EINSTEIN TELESCOPE

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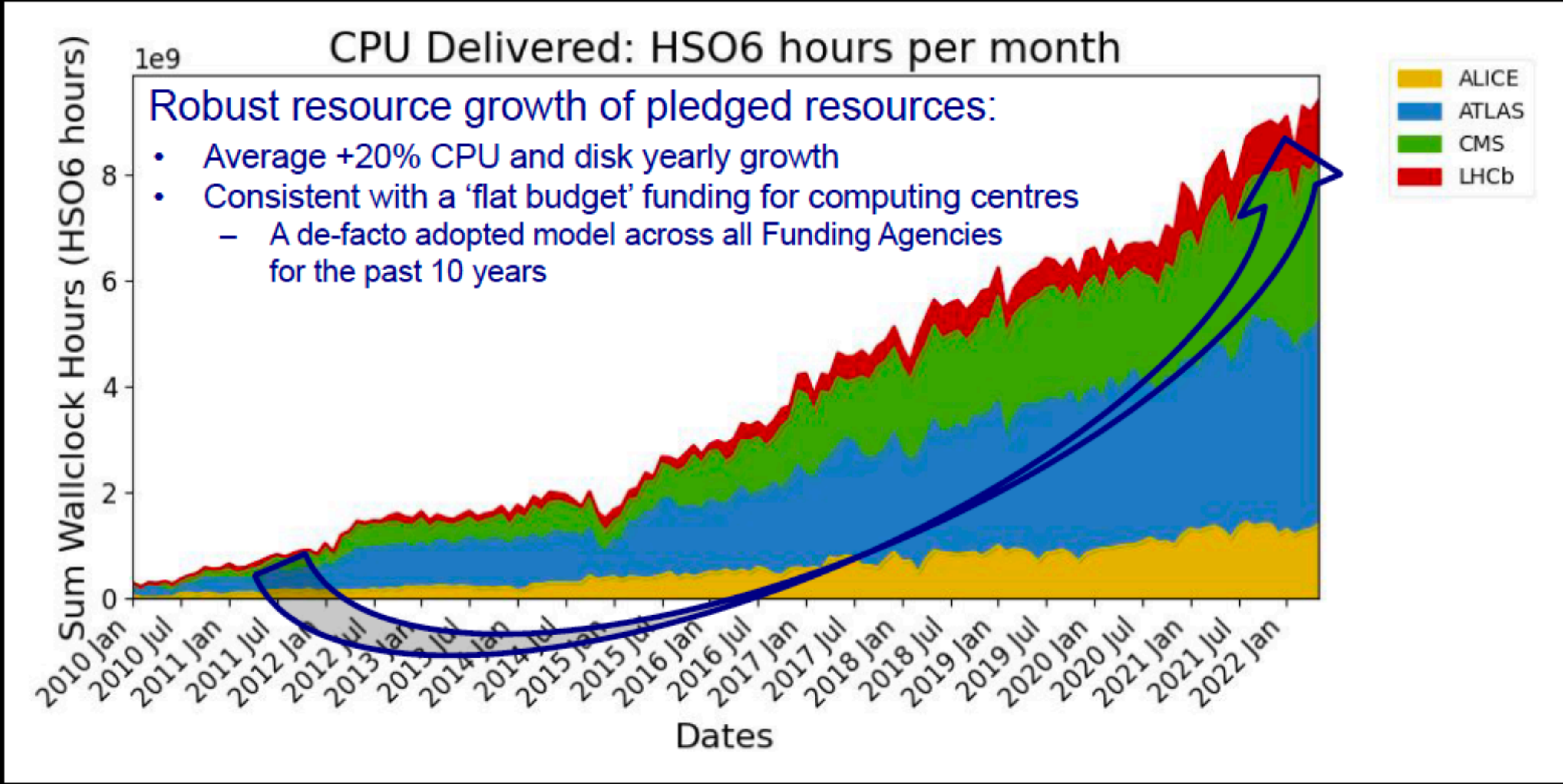
A new model for data processing

- Current data analysis of most GW data is centrally controlled
  - A software library that is contributed and maintained by the collaboration as a whole
- This is not a good model in the ET era
  - It might be impossible to centrally process all the data and keep up also with progress in algorithms, theory, models, etc.
- Computation and analysis should perhaps be decentralize
  - End users apply for "observatory time" and they get a week's worth of data or a month's worth
  - They could have the ownership for a set period (say six months), after which the data will be made public
- The decentralized models might help distribute the load

Summary

- Raw data rates in ET are not expected to be too different from advanced detectors
  - Each site might host a number (~10) interferometers but even so the data rate might not be a big issue
- ET will be a signal-dominated detector
  - 1 event per week in advanced detectors translates to millions per year in ET
  - Data products could overwhelm the raw data rate
- A new model for data products might be needed
  - ET could see a variety of different signals and we need a way to store all the information associated with them
  - Need to develop a new formats/structures/databases, to store data products

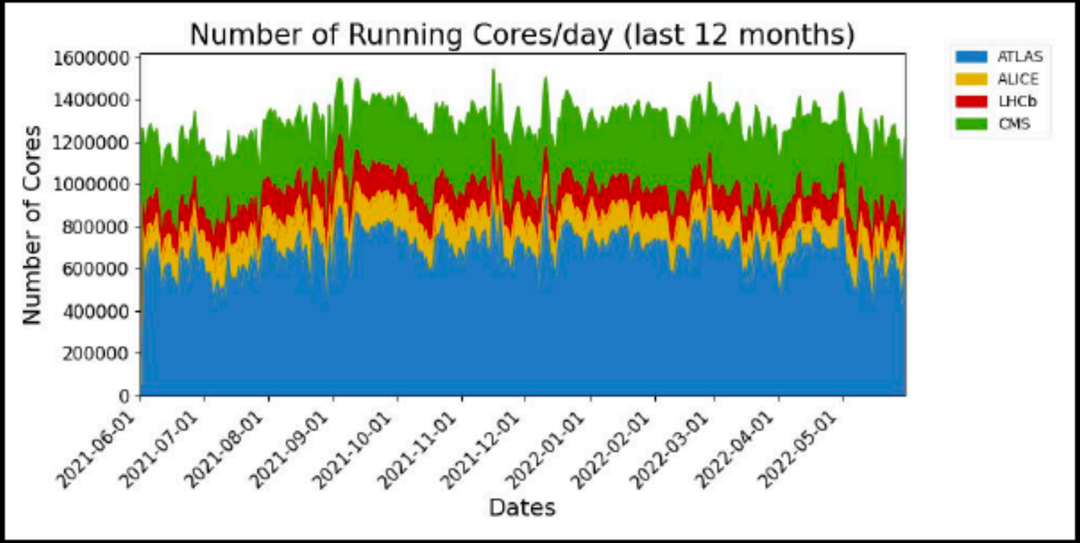
WLCG resource evolution



WLCG
Worldwide LHC Computing Grid

Scale of LHC computing needs today

- CPU: > 1 million cores fully occupied (pledges+opportunistic resources)
- Firmly in the Exabyte-scale data:
  - 2022 pledges for all LHC exp's: 0.8 EB disk and 1.2 EB tape
  - Data ingestion tens of EB/year



WLCG
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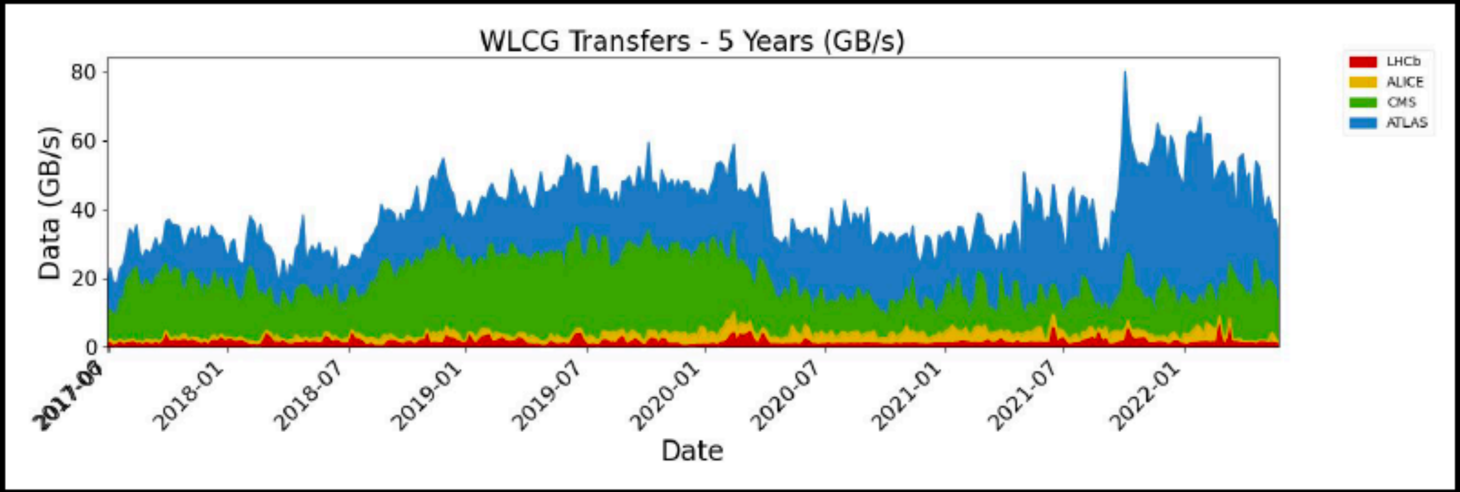
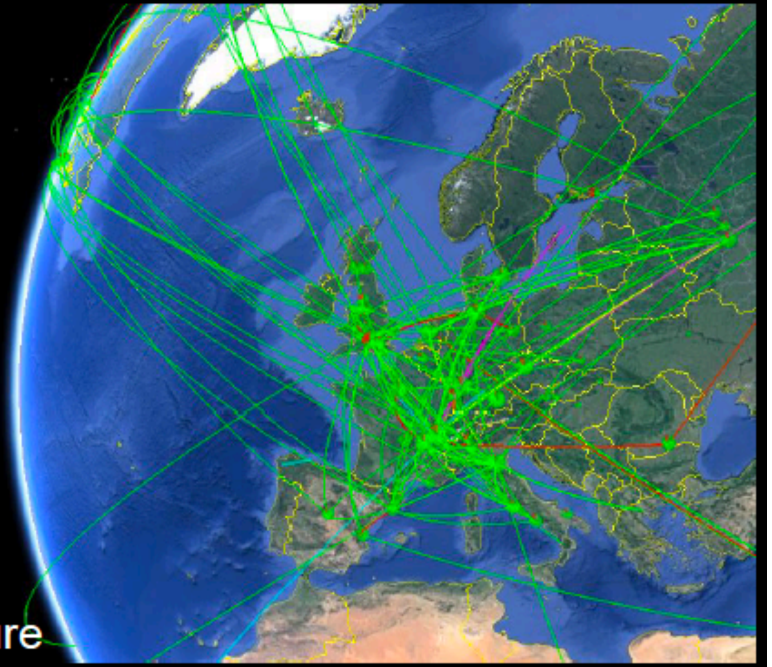


WLCG
Worldwide LHC Computing Grid



- Networking:
  - LHCOPN >1 Tbps from Tier 0 to 14 Tier1's
  - LHCOne overlay of 10-100 Gbps networks to connect
    - Tier 1 – Tier 2 – Tier 3
  - Other HEP experiments share a part of this infrastructure
    - Belle II, Dune, Pierre Auger, NovA, XENON, JUNO
  - Other sciences will use much of the same computing infrastructure

D. Fazzini, Friday
R. Münzer, Friday

A big challenge in data handling

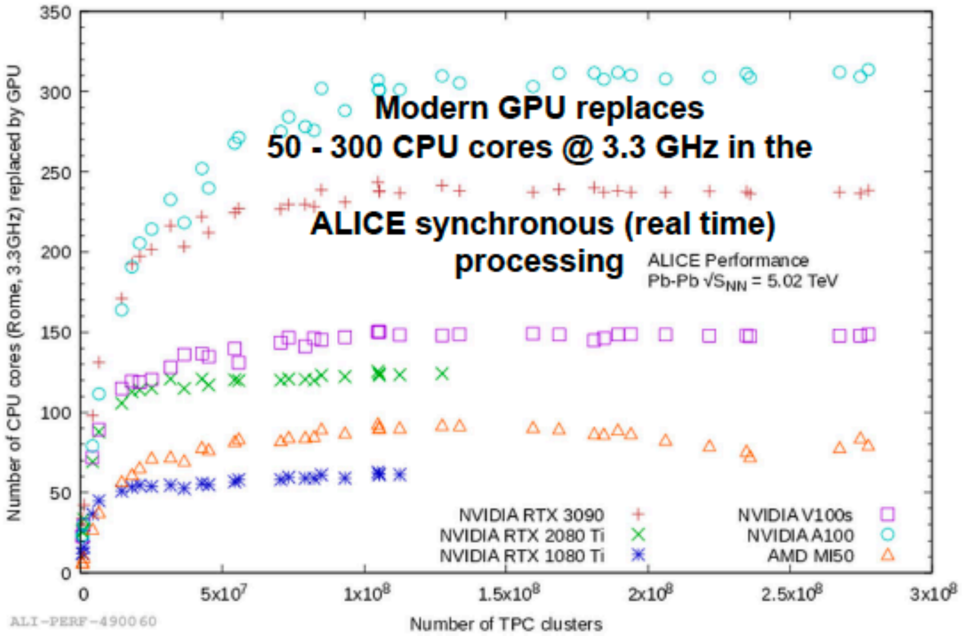
- Projections assume constant funding every year for LHC computing
- Technology improvements will bring ~20% more resources every year
  i.e. computing increases by factor 5 in 10 years ("flat budget" scenario)
- ALICE @ Run 3 and 4: 100x more recorded collisions
- Need to gain factor 20 (disk and CPU) through smarter strategy and algorithms maintaining (or better improving) the physics performance
- Similar challenge for LHCb: 30x increase in throughput from the upgraded detector (10x physics event rate x factor 3 increase in average event size due to larger pile-up)
- Keep data volumes under control: aggressive compression (ALICE), selective persistence (LHCb), optimized data formats
- Simulation and reconstruction optimization (see next talk!)

Courtesy of LHCb collaboration

C.Bozzi, Software e computing in LHCb: la sfida di Run3 (e oltre) (seminar @ CNAF 2021)
S.Piano, The ALICE O² computing model for Run 3 and 4 (seminar @ CNAF 2021)

Heterogeneous architectures

- Heterogeneous architectures: complementing CPU capacity with accelerators (e.g. GPUs)
  - GPUs offer more theoretical FLOPS in a compact package
  - Lower cost than CPUs per theoretical FLOPS
- Playing a fundamental role in Run 3 already, in most online systems. Non exhaustive examples:
- **ALICE:** Speed up from GPU usage + from algorithmic improvements + tuning on CPUs
  - porting of asynchronous (offline) reconstruction code to GPUs well advanced thanks to common online-offline framework
- **LHCb:** exploitation of heterogeneous architectures, thanks to Allen framework:
  - for partial reconstruction in Run 3 (HLT1)
- **CMS:** Patatrack Pixel Reco + ECAL and HCAL:
  - 30% of the online Run 3 reconstruction is offloaded to GPUs



D.Rohr, Usage of GPUs in ALICE Online and Offline processing during LHC Run 3 (vCHEP 2021)

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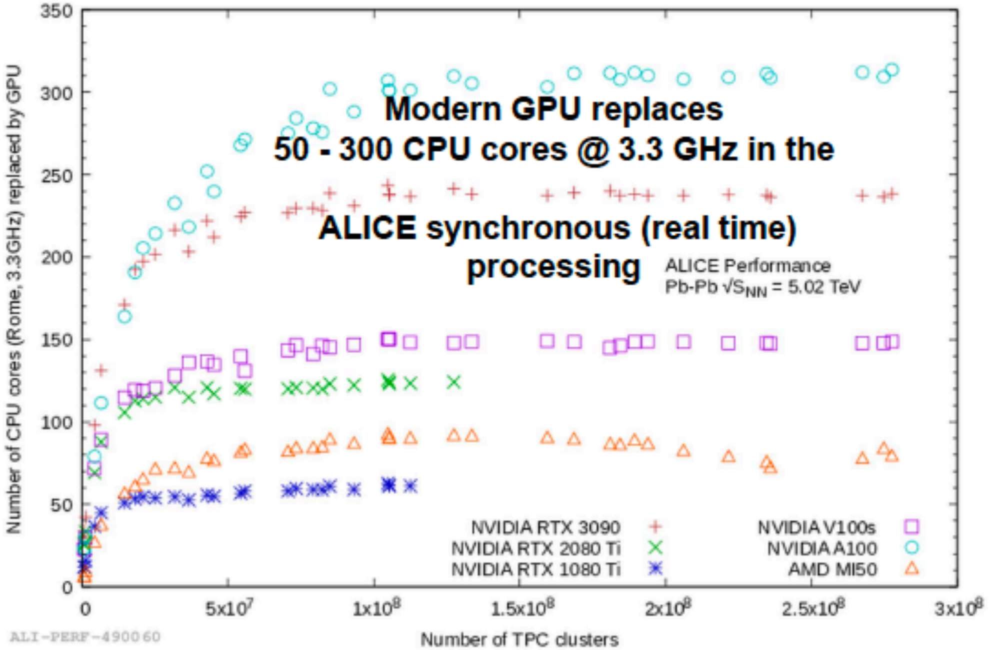
- **ALICE:**
  - Without GPU 1800 Event Processing Nodes:
    - 2 CPUs x 32 cores per EPN (115 kcores)
  - With GPU 250 Event Processing Nodes
    - 2 CPUs x 32 cores + 8 GPUs per EPN
  - GPU based solution strong impact on hardware and operating cost savings



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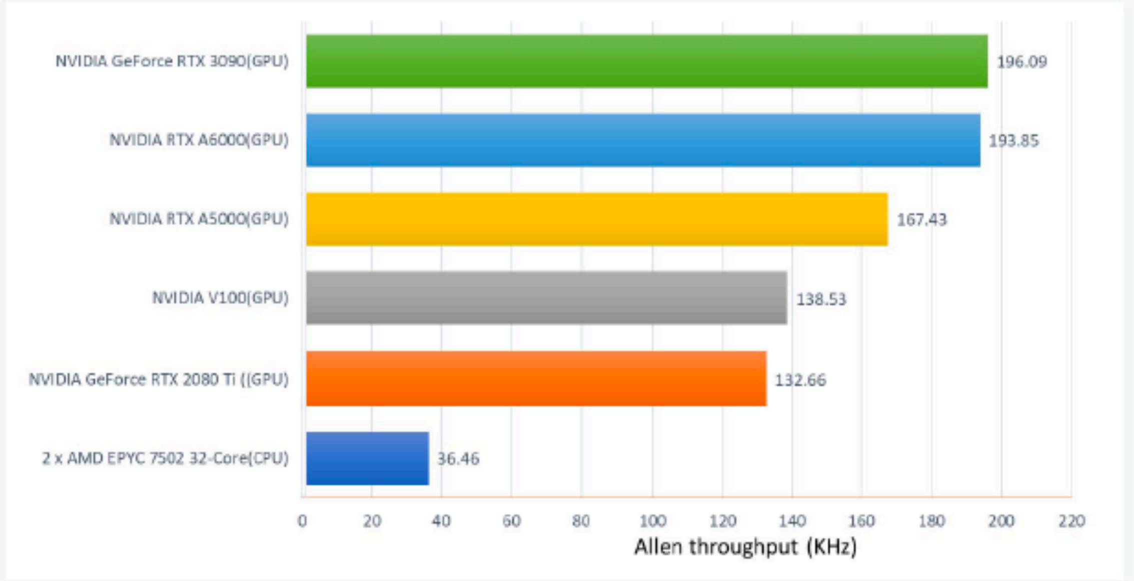
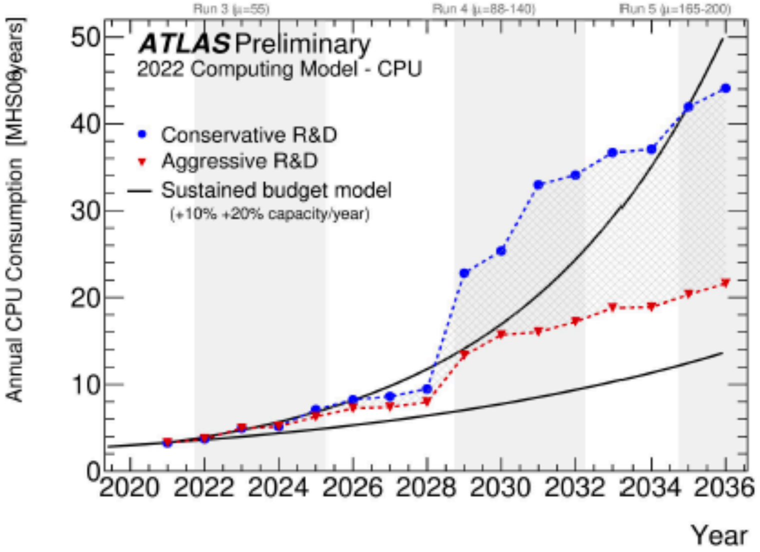
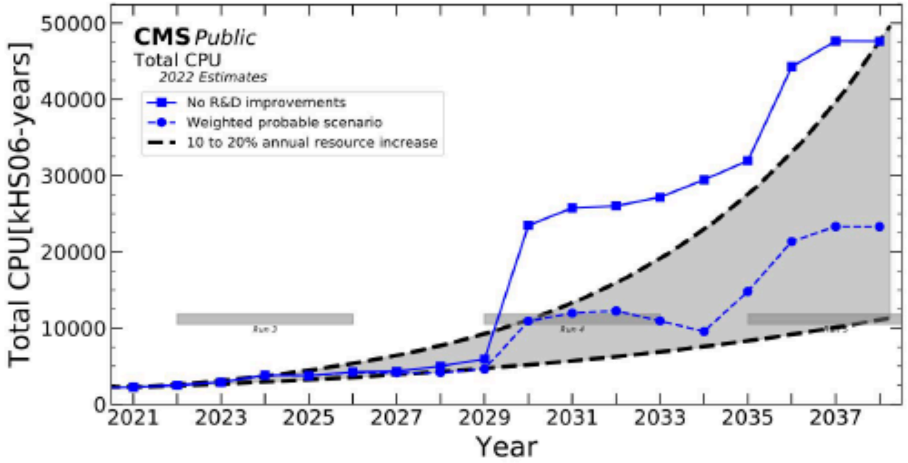
- **LHCb:**
  - Full detector read-out at 40 MHz (visible: 30MHz)
  - HLT1 running on GPUs on ~170 EB servers:
    - Cost savings: less EB servers and no need for high-speed network from EB to HLT2 farm
  - GPU: more opportunities for future performance gain



LHCb-FIGURE-2022-010

Expected CPU needs for HL-LHC

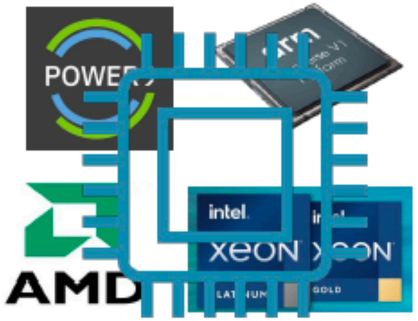




- The gap between available and needed resources can be filled up, assuming the main R&D activities are successful. There are still large uncertainties
- Investing in person power now is crucial to ensure we will be ready for HL-LHC
- Investing in hardware must be done in close cooperation with the R&Ds

ATLAS Collaboration, Computing and Software - Public Results
CMS Collaboration, Offline and Computing Public Results

Heterogeneous Computing



GPUs:	Generators with GPUs:	FPGA:
Several talks on ML,DL,(G)NN,AI	A. Valassi, Friday	M. Lorusso, Friday
F. Legger, Saturday	E. Bothman, Saturday	K. Tadome, Friday

- Today we use opportunistically some types of computing system, in particular HPC systems, and HLT
- In future, this heterogeneity will expand; we must be able to make use of all types: Non-x86 architectures, GPUs, HPCs, clouds, HLT farms, FPGA?
- Requires:
  - Common provisioning mechanisms, transparent to users
  - Facilities able to control access (cost), efficient use
- HPC storage is transient, cloud storage is still prohibitively expensive:
  - Must be able to deliver data to them when they are in active use
  - Data delivery will become crucial!

WP7-WP9 (Mauro Morandin Rob van der Meer)

EINSTEIN TELESCOPE

In Task 7.2 we will perform:

* Risk analysis on maturity of technologies and industry capabilities needed in the C&O phase;
* Mapping of engagement initiatives already in place in partner countries, both for ET and other RIs;
* Address gaps from Risk analysis and extend activities into an engagement plan for national and international activities. [MS in M10];
* Execute this plan and report on activities at the end of the project [D in M42];

We do not have an active sustainability component in our plans, but we might consider sustainability as one of our gaps and integrate it in our engagement plan. On general technologies we suggested to WP6 to exchange information on the items below. We could use this list as starting point for our discussion on information exchange.

WP7-WP9 (Mauro Morandin Rob van der Meer)

For interaction with WP9 we foresee information you might want to receive from WP7:

* list of maturity of technologies;
* list of industry standards and capabilities;
* Gap analysis on maturity and capabilities;
* industry Engagement plan for national and international activities;
* updates on industry engagement activities;

o Q: Do you foresee a preferred timeline for exchange of such information?
o e.g., at what moment in the technical design timeline is input needed about industry capabilities ?

We foresee to request/receive from WP9 to WP7

* WP7.2: List of (necessary) technologies for risk analysis on maturity and industry capabilities.

o Q: At what moment can we learn from the technical design what your requests to industry are?

* List of industry contacts found by WP6 activities.
* Requests for industry contacts, necessary for WP6 activities.
* WP7.1 Innovation plan: We could use you input on possible innovation activities
* WP7.3 IP: We could use your input on possible IP sensitive developments.

Task 9.2 Landscape, environmental and societal impact (INFN, EGO, CNRS, Austria)

EINSTEIN TELESCOPE

Sub-task 9.2.1: Assessing and minimizing the ET impact on its environment. This sub-task will study

1. how to optimize the surface transportation network and design an underground transportation system for personnel and materials, by identifying the paths, the types of users, the vehicles needed, and also by considering the highest safety standards;
2. the planning and management issues related to the definition of critical areas (safety and environmental) and to the necessary investigations to obtain the associated risk assessments;
3. the impact of different scenarios for the design of the underground structures (tunnels, shafts and caverns) to minimize interference with external surface infrastructure networks, urban and natural areas;
4. the development of layout concepts for the foreseen surface infrastructures taking into account technical requirements, environmental constraints and connection with existing infrastructure and service plants;
5. the development of integrated processes for environmental assessment evaluation in agreement with local regulations;
6. the study of the impact on biodiversity and on the hydrologic cycle;
7. finally, a global approach for non-hazardous and hazardous waste management and recycling both during the construction and operation phases.

Sub-task 9.2.2 Environmental management approach.

This subtask, inspired by relevant CERN actions, will study the organization to manage environmental issues. As part of its Environmental Protection Strategy, ET may launch

1. an *ET Environmental Protection Steering Board* to identify and prioritize environmental areas to be addressed and to propose programs of action, and
2. an *ET Energy Management Panel* to monitor the ET energy consumption and identify measures to improve efficiency and promote energy re-use.

These actions will be developed in the framework of the environmental protection regulations of the ET hosting and member states.

Task 9.3 Contribution to sustainable goals (EGO, INFN, CNRS) ET will extend its sensibility down to the Hz range. It will be necessary to deploy surface and underground distributed or mobile monitoring networks to measure

1. low frequency seismic activity and other vibrations (e.g., sea waves),
2. electromagnetic noise and atmospheric pressure variations that may have an impact on GW measurements.

Through these monitoring systems developed for the ET noise mitigation strategy other studies in geosciences and atmospheric sciences can be supported also developing specific machine and deep learning techniques for data analysis. Consequently, ET can become an interdisciplinary and technological hub open to a variety of collaborations with geoscientists, electromagnetic and data science expert and contribute to the studies on natural hazards and climate changes.

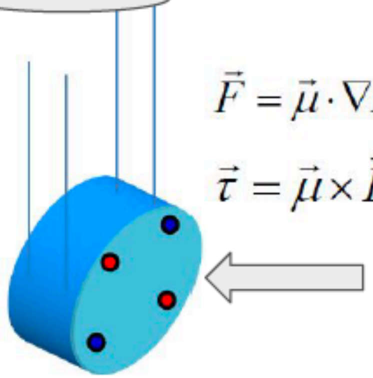
Participate with our sensor networks to Climate monitoring

Temperature and Energy	Atmospheric Composition	Ocean and Water	Cryosphere
Surface Temperature	Atmospheric CO_2	Ocean Acidification	Glaciers
Ocean Heat		Sea Level	Arctic and Antarctic Sea Ice Extent

Environmental influences

Magnetic fields

Force on magnetic actuators

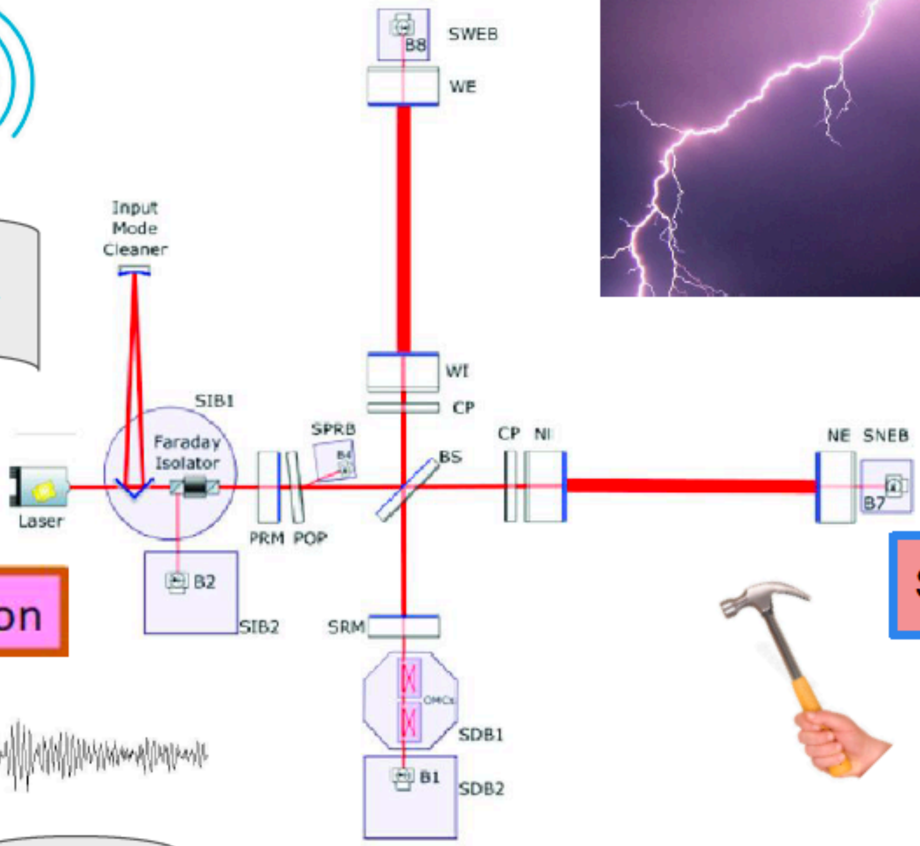


$$\vec{F} = \vec{\mu} \cdot \nabla \vec{B}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

Radio waves (6MHz, 8MHz, 56MHz)

Couple with RF laser modulation used for angular and longitudinal controls



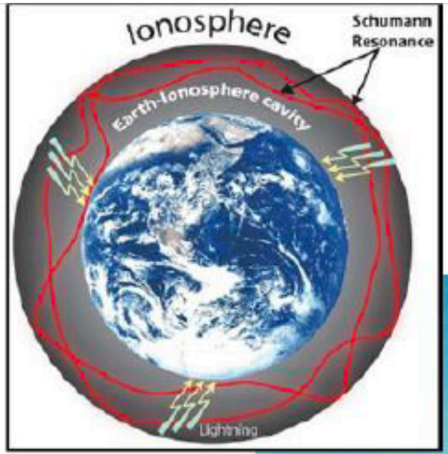
Slow ground motion

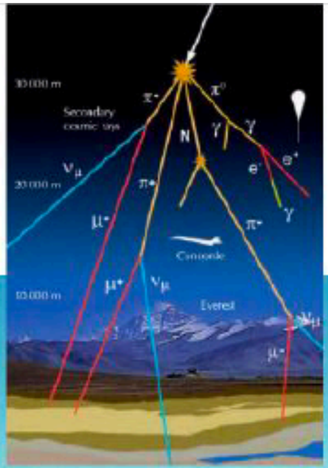
Excite mechanical modes of mirrors and optical benches suspensions

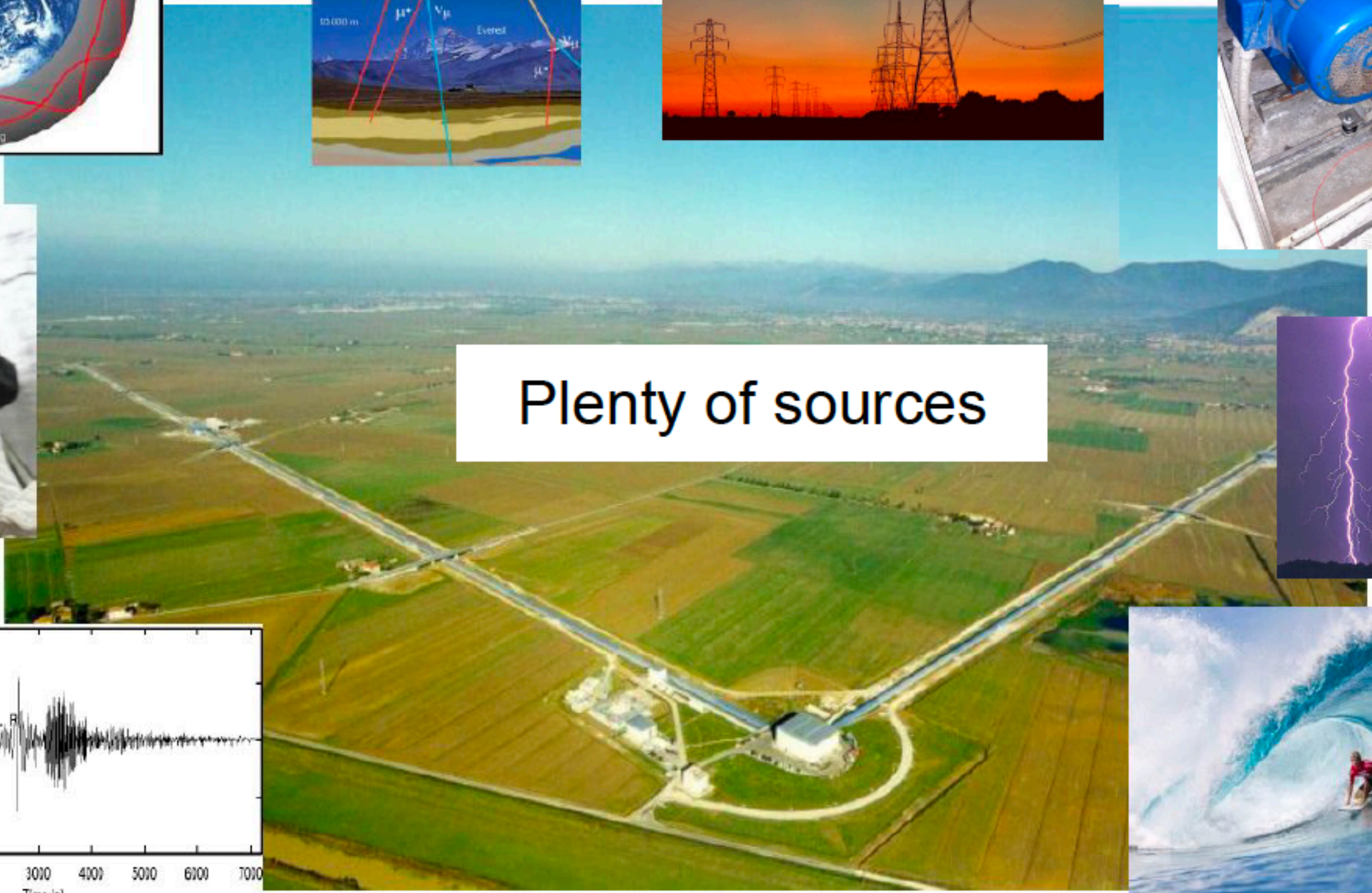
Sounds and Vibrations

Imprint phase noise on scattered light beams

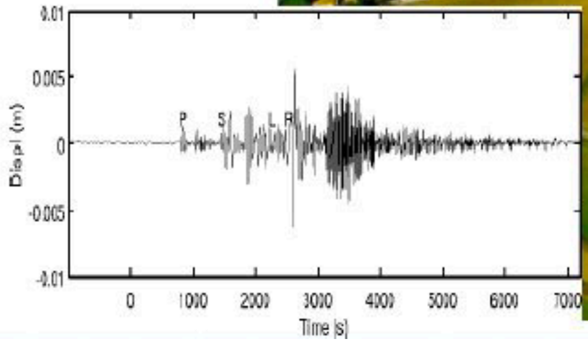
Excite vibrations of vacuum chambers, in-air optical benches







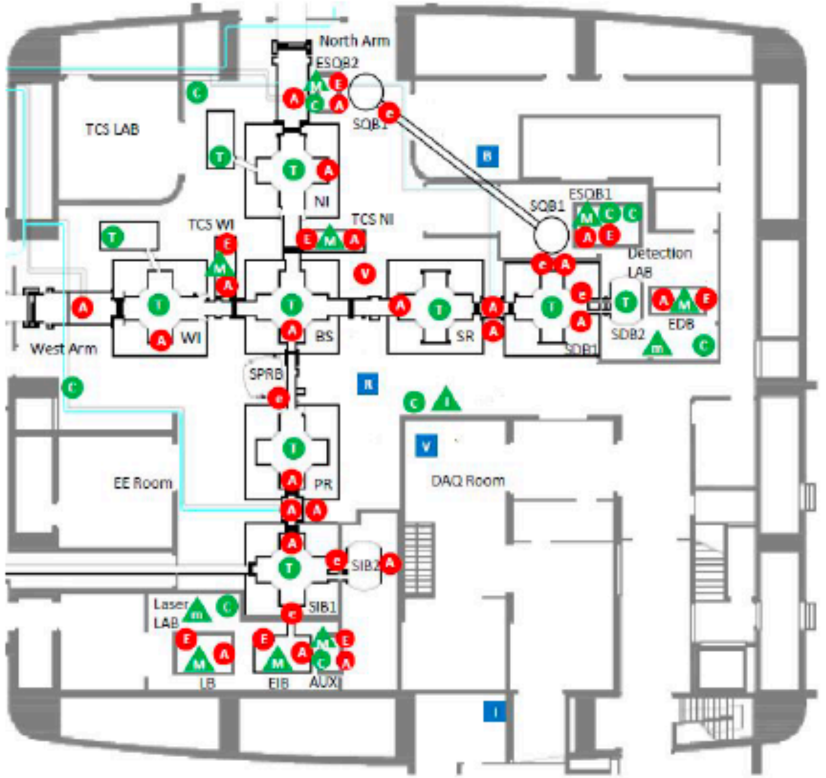
Plenty of sources



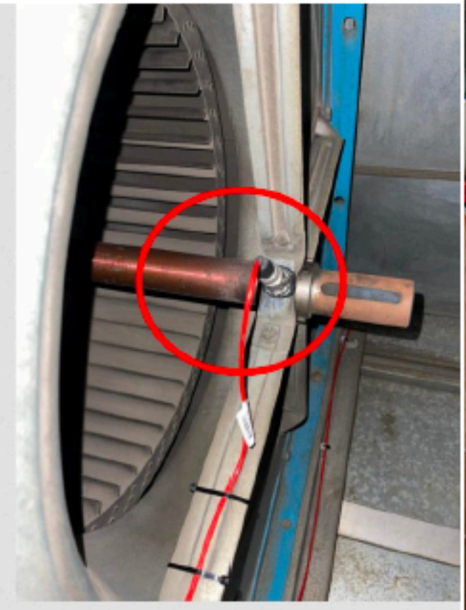
Extensive monitoring

- Probes close to the interferometer: ~600 (accelerometers, microphones, magnetometers, RF antennae, power grid monitors, temperature, humidity, pressure, etc.)
- External monitors: magnetic fields, wind, lightnings, seism, cosmic muons

ENV sensors
CEB



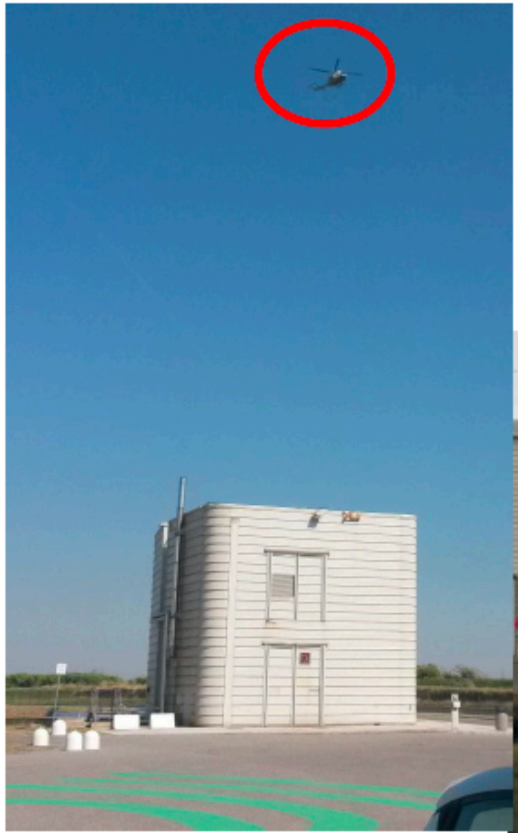
Diaphane Detector at EGO



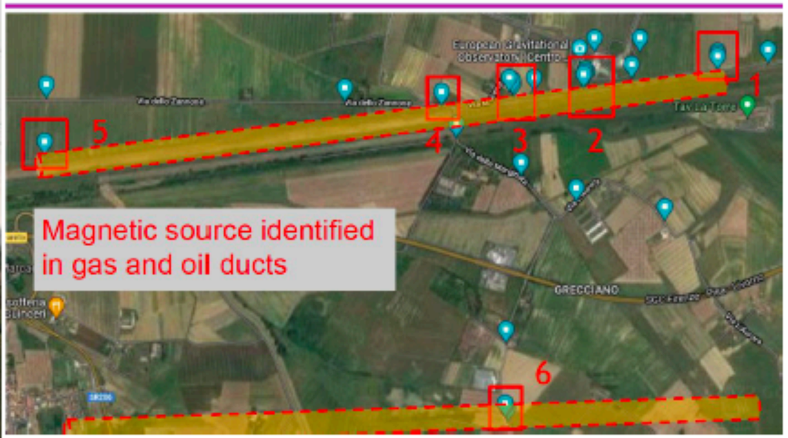
ACC-3 on fan pulley left bearing

Noise from human activities

- Study anthropic sources in the EGO surroundings and influences on the Virgo detector
- Preserve the noise climate of the EGO site: agreement signed with the local administration authorities (Province of Pisa)



Mysterious Magnetic Noise



Planning

- Year 1: bibliography + survey of existing practice and plans in the scientific community at large; collecting data from existing GW facilities; discussion with other WPs and the relevant divisions of the ET collaboration to get a better idea on what is planned.
- Year 2: first draft of the plan (including rules and long-term goals); discussion with ET; discussion with existing GW facilities to see what could be tested/implemented.
- Year 3: iterations of the plan
- Year 4: completion.

Deliverables (brief description and month of delivery)

Deliverable 9.1.1 An assessment of the CO_2 footprint linked to construction/operation stage of the infrastructure, computing facilities and transportation and supplies for personnel.

Deliverable 9.1.2 A report on the strategy for minimization of the CO_2 emission

Deliverable 9.2.1 A report on the environmental impact of ET RI on the landscape and on the effect of surrounding urban areas.

Deliverable 9.2.2 A roadmap for establishing the organization and the mandate for an ET management boards on sustainability and environmental protection

Deliverable 9.3.1 A report on the contribution of the ET measurements on climate change studies, low latency alert and on the technologies to develop to enforce this activity .

Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (in months)
9.1.	ET Sustainable Development Implementation Strategy	WP9	CNRS	Report	PU	18
9.2.	ET Environmental impact assessment and mitigation strategy	WP9	INFN	Report	PU	24
9.3	ET CO_2 footprint ET assessment and mitigation strategy	WP9	EGO	Report	PU	36

Organize 3 workshops
Internal to the community and the last evening open to the public
in the context of the UN International Year of Basic Sciences for Sustainable Development 2022

LVK event

- LVK I Europe , When ? November ? EGO or Paris (UN headquarters)
- LVK II , US (March 2023 , Northwestern)
- LVK III Asia, (September 2023, Toyama)

Tentative Agenda

- Estimate Carbon footprint of
  - LIGO, Virgo, KAGRA, Projections of ET, Projections of CE
  - reports, discussions with
    - Astronomical Research infrastructures J. Knodleseder et al. (Arxiv 2201.06748), https://labos1point5.org/
    - Particle Physics Community
  - Expand: energy for operation, communication and travelling needs, computing
- Keynote speakers on green technologies for energy production and climate monitoring, Part I
- GW low frequency sensor networks as monitors of the environment and natural catastrophes
  - LIGO, Virgo, KAGRA, ET, CE
  - Synergies with underground labs
- Keynote speakers on green technologies for energy production and climate monitoring, Part II
- Closing: Global coordination (IGWIN ?, Multimessenger ?) on BSSD