APPEC

Astroparticle Physics European Consortium

Strategy in Astroparticle Physics

A European View

Andreas Haungs | KIT – Institute for Astroparticle Physics

JENA Symposium | Madrid | 3-6 May 2022

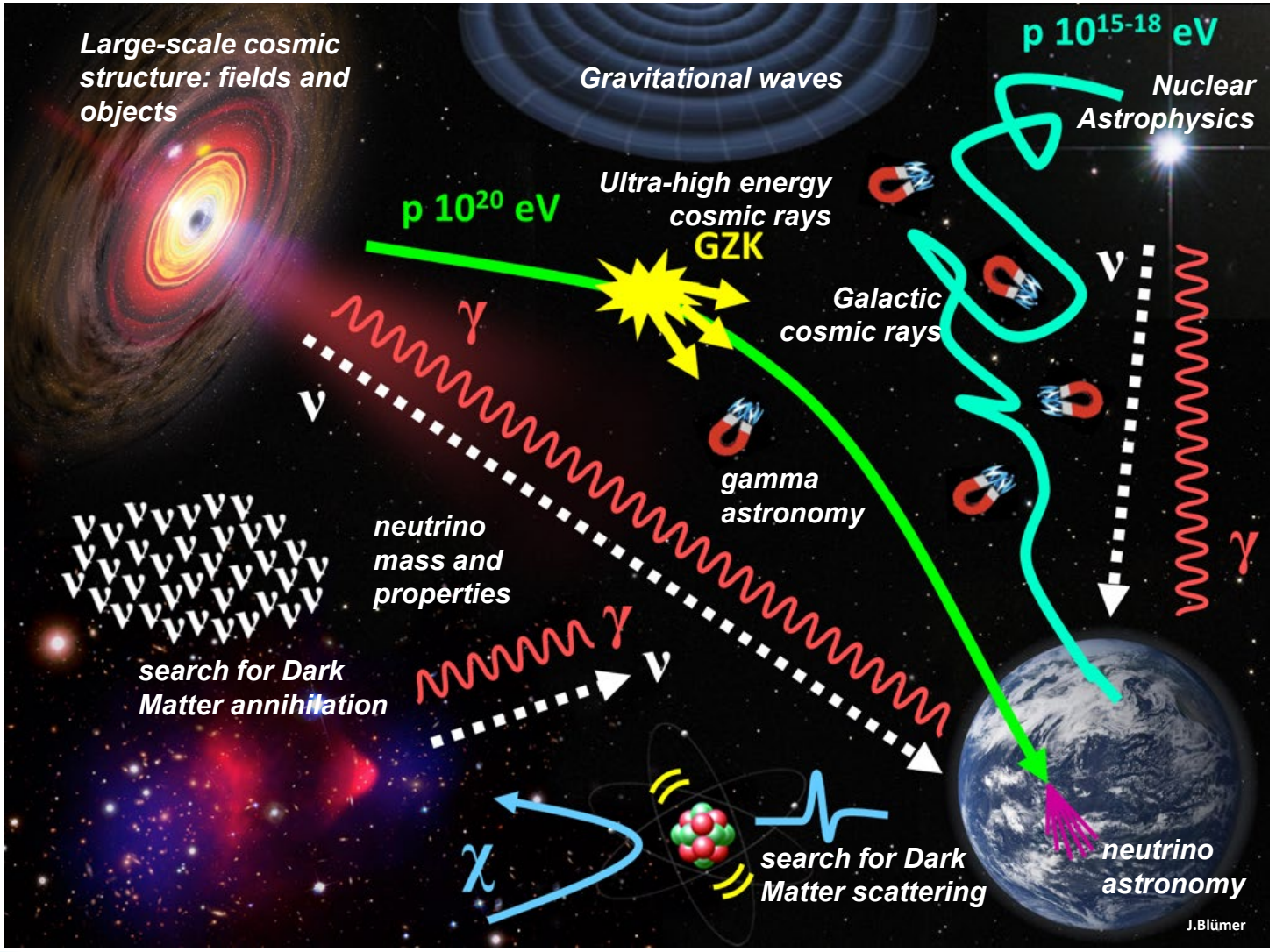
KIT Karlsruhe Institute of Technology

Astroparticle Physics

Understanding the Multi-Messenger and the Dark Universe

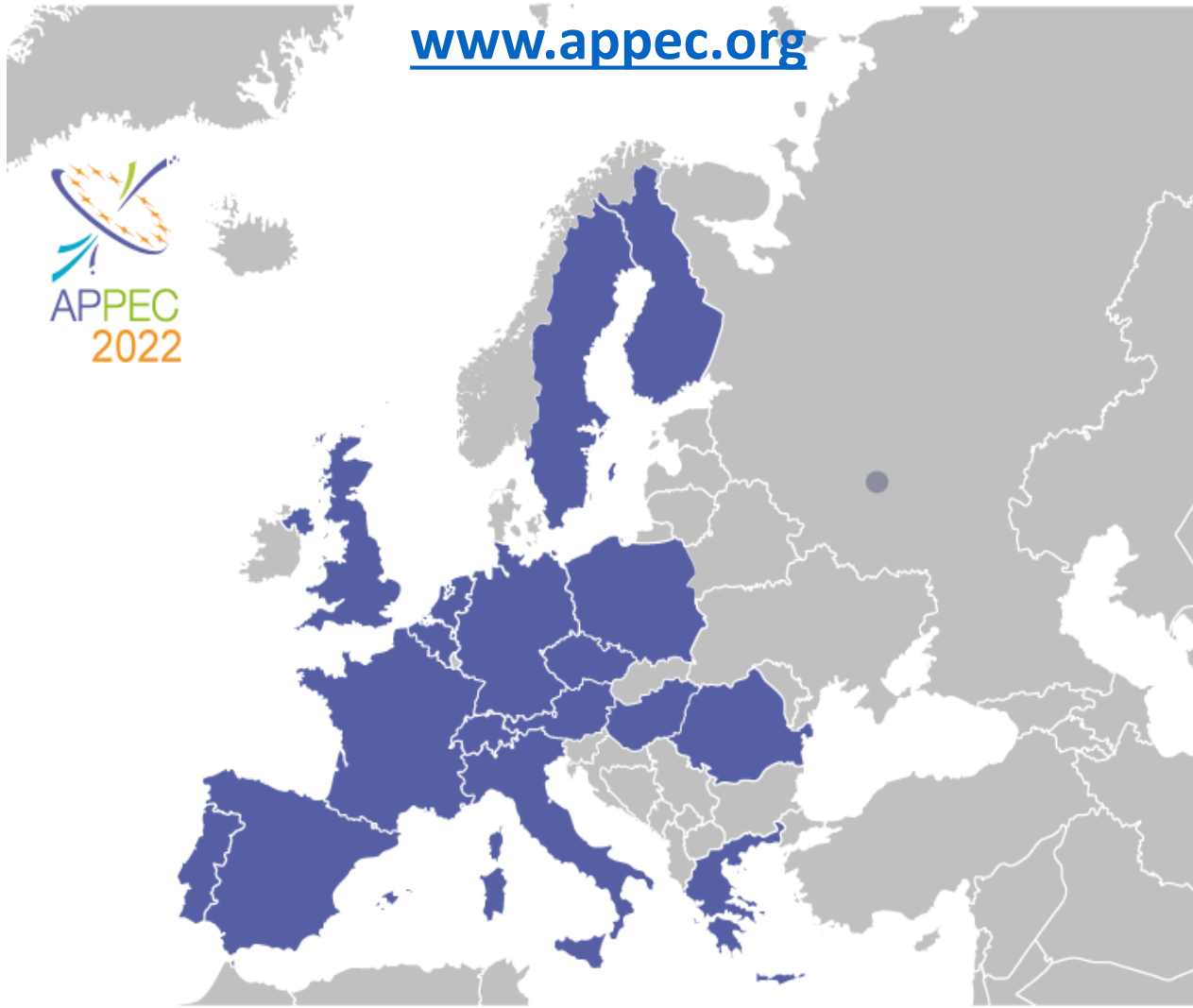
Astroparticle Physics is a branch of fundamental science embedded in environment and society!

Wikipedia:
While it may be difficult to decide on a standard 'textbook' description of the field of astroparticle physics, the field can be characterized by the topics of research that are actively being pursued.



APPEC

- Is the **A**stro**P**article **P**hysics **E**uropean **C**onsortium
- An international coordinating structure
- Founded in 2012
- Is based on
  - a Memorandum of Understanding (MoU)
  - a Financial Agreement with DESY (host of the APPEC Common Fund) by all partners
- Has at the moment
  - 17 (+1 suspended) member countries, 21 funding agencies, and 6 observers
  - a budget of 70k€/year

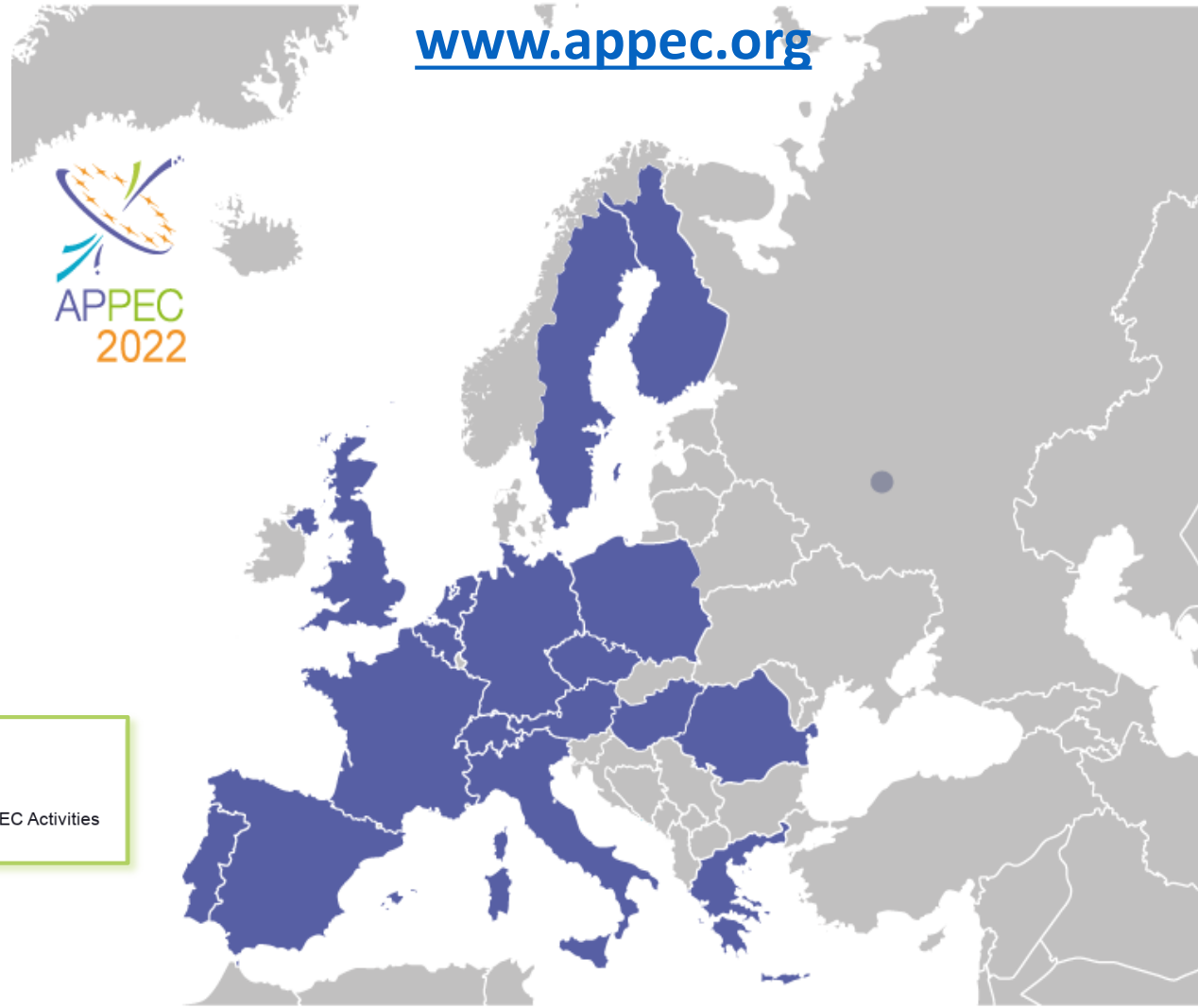


APPEC bodies

- General Assembly
  - Strategic, decision making and supervisory body
  - Representatives of funding agencies
  - Chair: Andreas Haungs (KIT);
  - Vice-Chair: Antoine Kouchner (APC)
- **Scientific Advisory Committee**
  - Advisory body
  - Chair: Sijbrand de Jong (Nijmegen);
  - Vice-Chair: Silvia Pascoli (Bologna)
- **Joint Secretariat (distributed office)**
  - Executive body chaired by the General Secretary
  - General Secretary: Katharina Henjes-Kunst (DESY)
- Observer
  - CERN (Joachim Mnich)
  - ECFA (Karl Jakobs)
  - NuPECC (Marek Lewitowicz)
  - Astronet (Colin Vincent)
  - ESO (Andy Williams)
  - EPS-HEPP (Ramon Miquel)

JENAA
Joint ECFA-NuPECC-APPEC Activities

www.appec.org

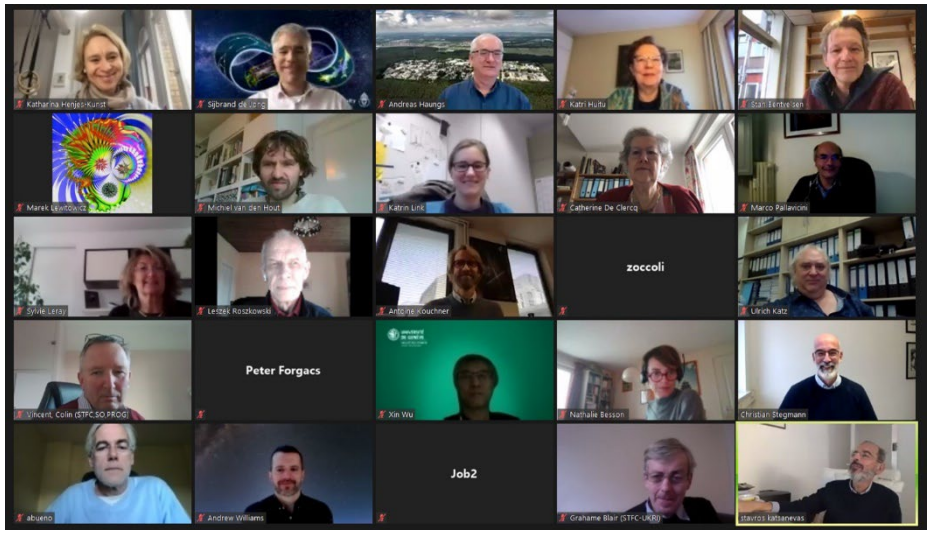


APPEC tasks

Guarantee Coordination of European Astroparticle Physics in Europe between funding agencies and visibility at Ministry level through:

- Structured scientific advising (SAC, dedicated panels to specific challenges)
- Development and update of roadmaps based on scientific strategies and financial considerations
- Establish relations with other bodies in companion fields
- Initiate activities within Horizon Europe
- Express collective views on APP in international fora
- Organise Town meetings
- Support relevant meetings/schools of the community
- Organize TechFora and Open Calls
- Engagement with society (Outreach, Education,...)
- Contribute to Working Groups (R&D panel, Individual Recognition, Early Scientist career, Science WGs) and Organisations (EuCAPT...) and JENA

to support the Astroparticle Physics community



GA: since 2020 online-meetings, only

APPEC Strategy Process

APPEC is

- Helping in coordination of large-scale RI
- Helping in transition of mid-scale experiments to large-scale RI
- Helping in support of small-scale and R&D experiments

Disclaimer:

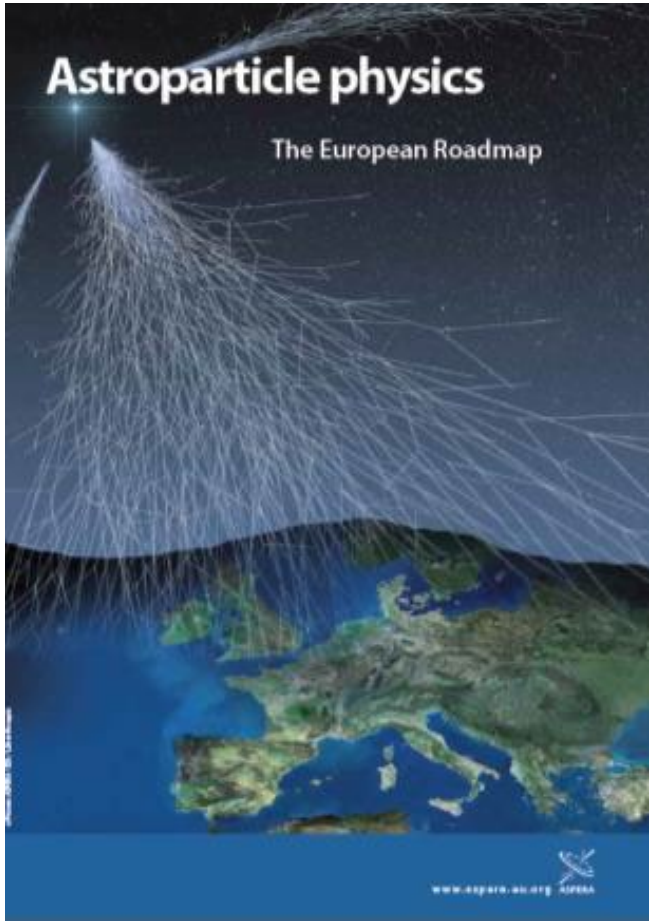
- I am not covering everything
- I will focus on main considerations from point of view of APPEC
- I will focus on future flagship experiments or facilities whose main contribution lies in the field of astroparticle physics
- Not all figures are fully referenced, but all are publicly available (thanks to all)

APPEC Roadmaps

https://www.appec.org/roadmap

2008

2011



2017

APPEC scientific topics

- High-energy gamma rays
- High-energy neutrinos
- High-energy cosmic rays
- Gravitational waves
- Dark Matter
- Neutrino mass and nature
- Neutrino mixing and mass ordering
- Cosmic microwave background
- Dark Energy
- Astroparticle theory
- Detector R&D
- Computing and data policies
- Unique infrastructures

APPEC organisational & societal issues

Organisational:

- European Commission
- European and global collaboration and coordination
- Astronomy and particle physics communities
- Interdisciplinary opportunities

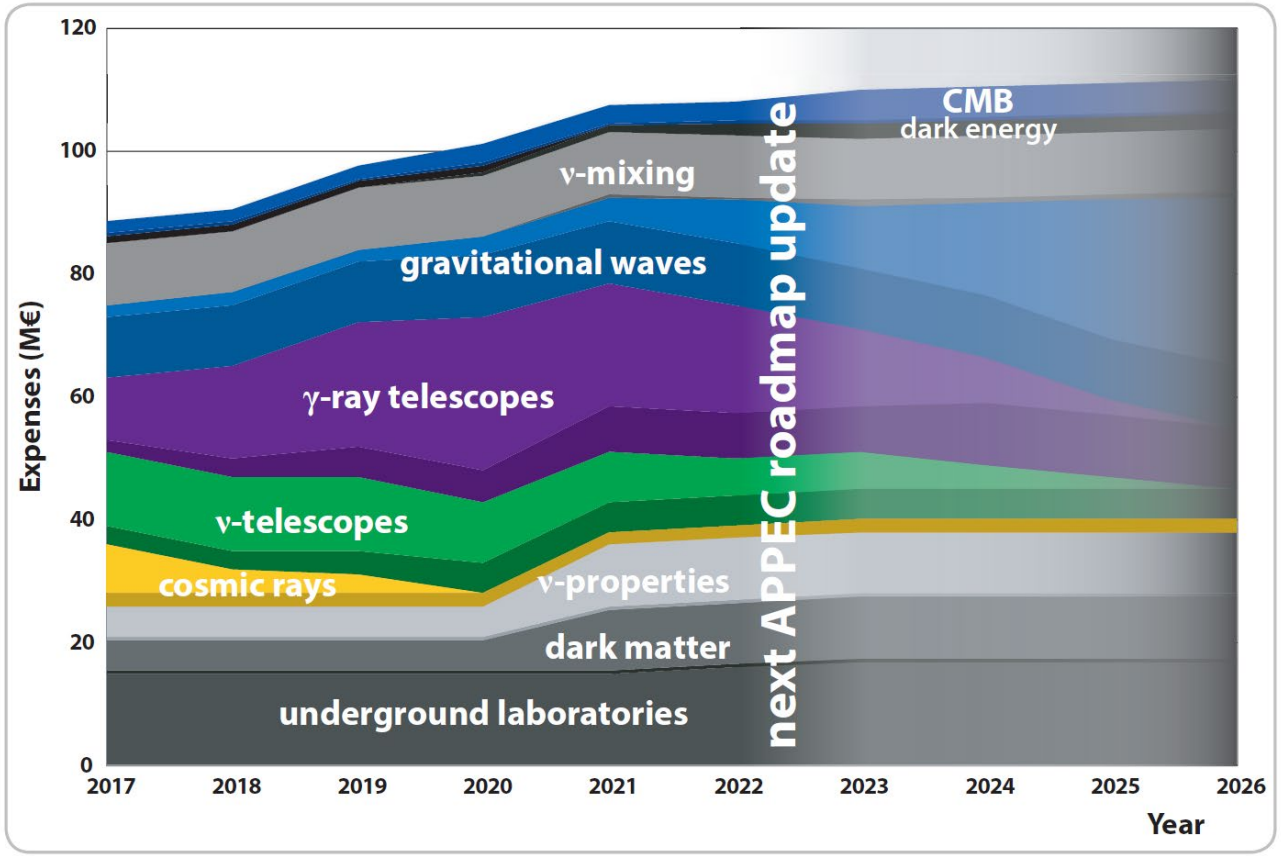
Societal:

- Gender balance
- Education and outreach
- Open Science and Citizen Science
- Ecological impact and Industry

JENAS-2022

2nd Joint ECFA-NuPECC-APPEC Symposium

Midterm Evaluation of the Roadmap



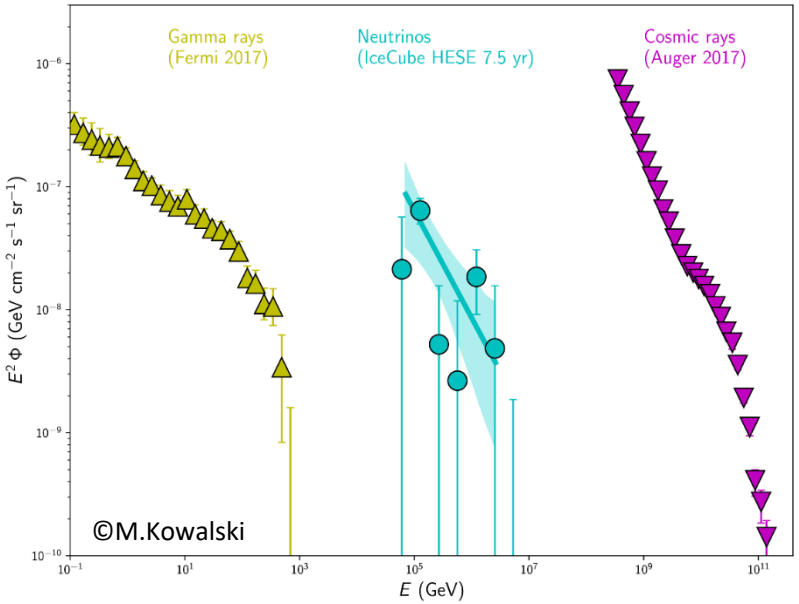
From Roadmap 2017: Projected annual capital investment

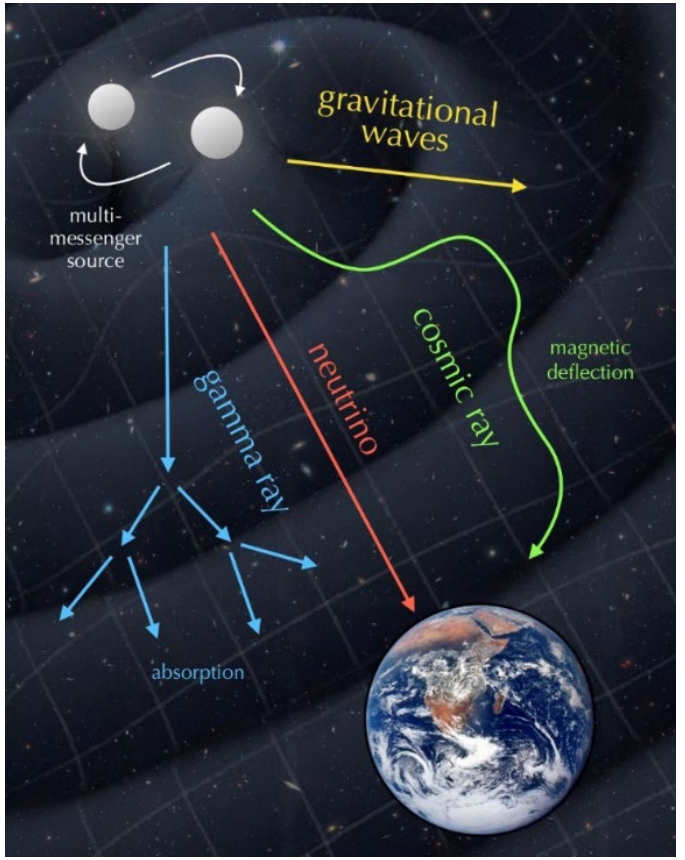
- A resource aware roadmap

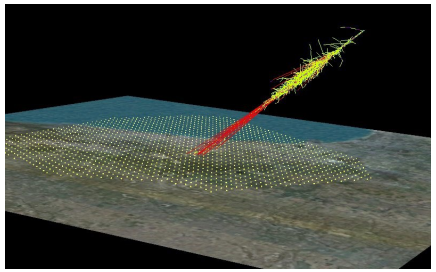
  (darker colors also show M&O of RI)
- Midterm Evaluation: Preparation of roadmap update
  - Direct Dark Matter working group
  - Double Beta Decay APPEC Sub-Committee
  - Multi-Messenger Discussion Workshop
- Goals
  - Identify new developments and new topics
  - Update recommendations
  - Update time and cost line
- Timeline
  - Provide information to the communities (2021)
  - Discussion at the Town Meeting 9+10/6/2022 (Berlin) https://indico.desy.de/event/25372/

Multi-Messenger Astroparticle Physics

- Required to understand the sources of cosmic rays and the physics processes in the high-energy Universe
- Needs long-term operational observatories
- And a sophisticated Big Data management: Big Data Analytics; Research Data Management; Data Curation; Open Data

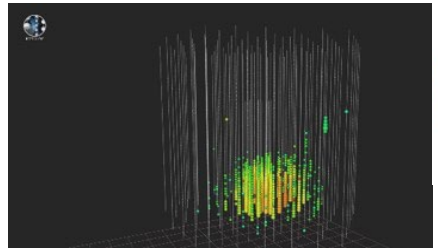






PIERRE AUGER OBSERVATORY

cta cherenkov telescope array



KM3NeT

IceCube

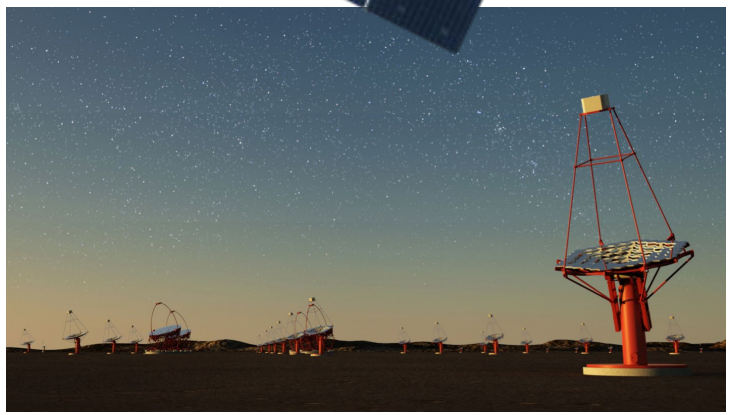
LIGO VIRGO

High-Energy Gamma Rays

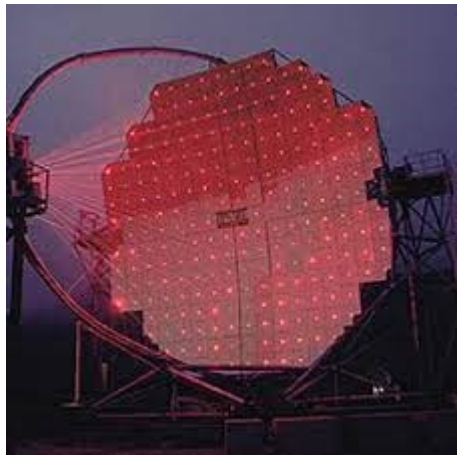

FERMI

- Covers large energy range with different observatories
- Satellites (Fermi, AMEGO (launch 2029))
- Imaging Air Cherenkov Telescopes (H.E.S.S., Veritas, MAGIC)
- Ground-based arrays (GRAPES, TAIGA, HAWC, LHAASO, SWGO)
- Main future project within APPEC: CTA (ESFRI)

VERITAS



MAGIC

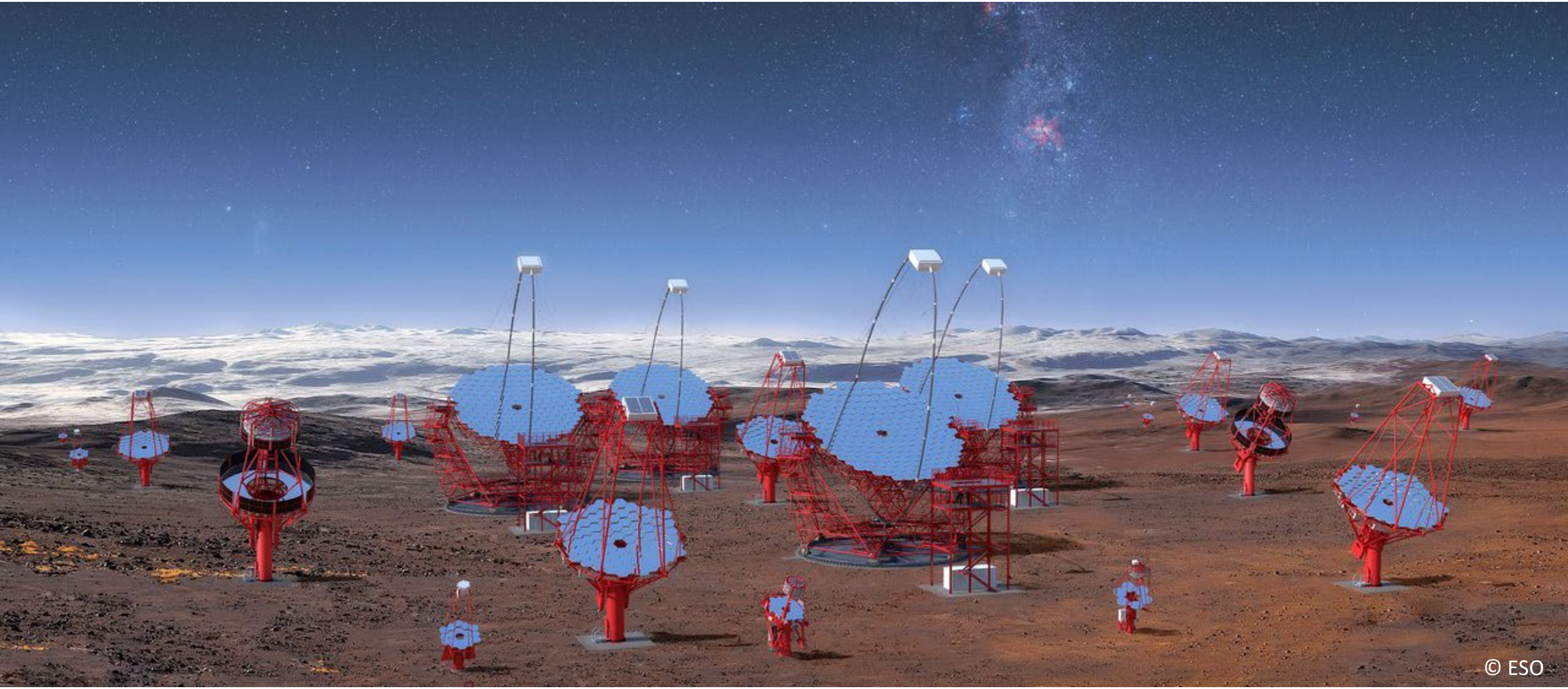


H.E.S.S.

LHAASO

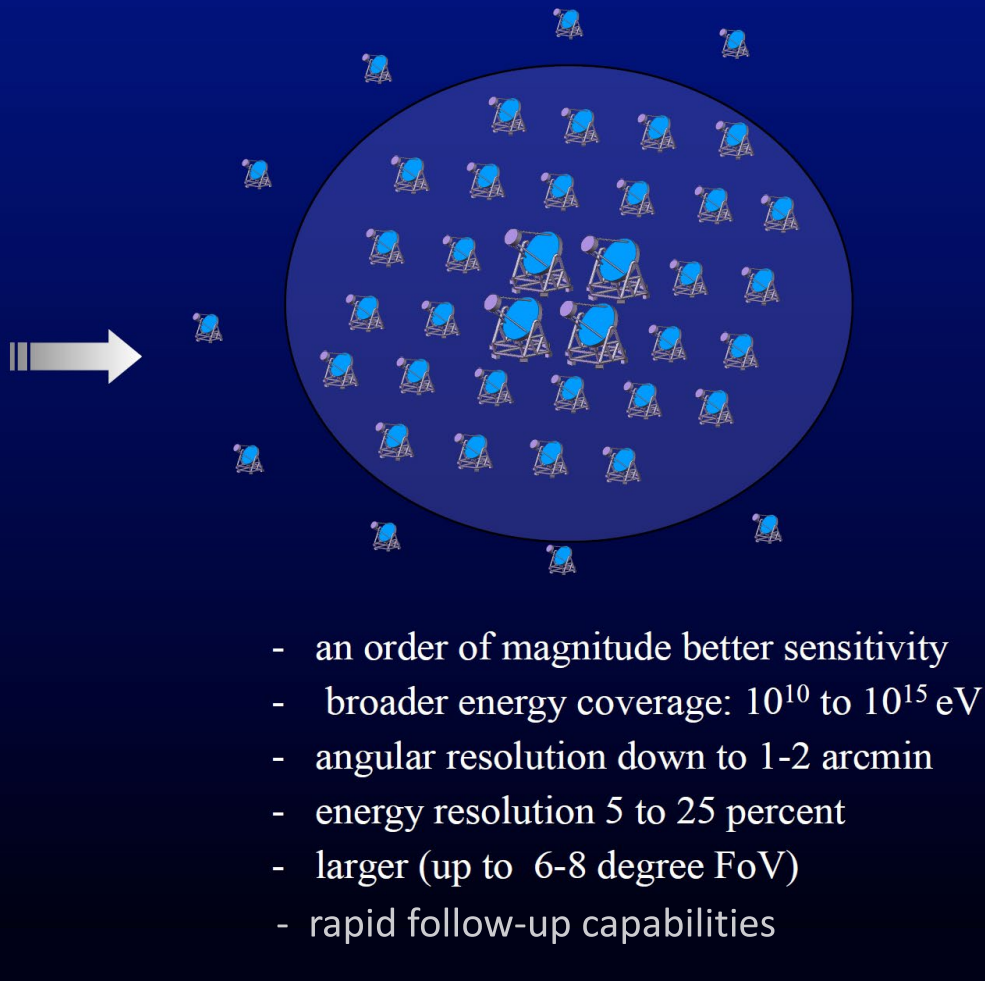
HAWC

Cherenkov Telescope Array – CTA



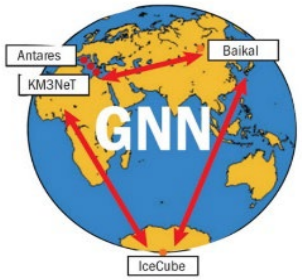
High-Energy Gamma Rays

- ESFRI Project
- Open, proposal-driven observatory
- 3 telescope types: LST, MST, SST
- 2 sites: La Palma + Chile
- Governance: ERIC (established 2022)
- 31 countries, >200 institutes, ~1400 scientists
- Construction next 3-5 years

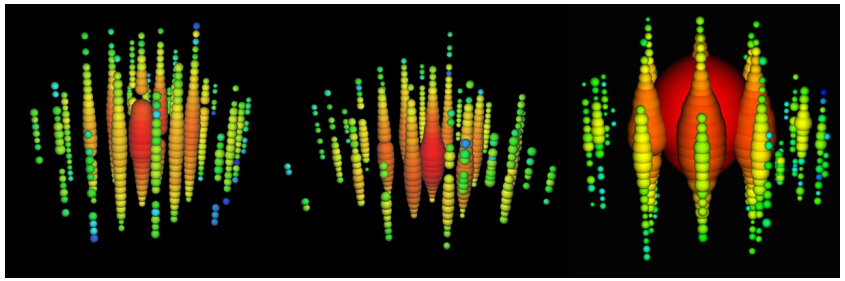


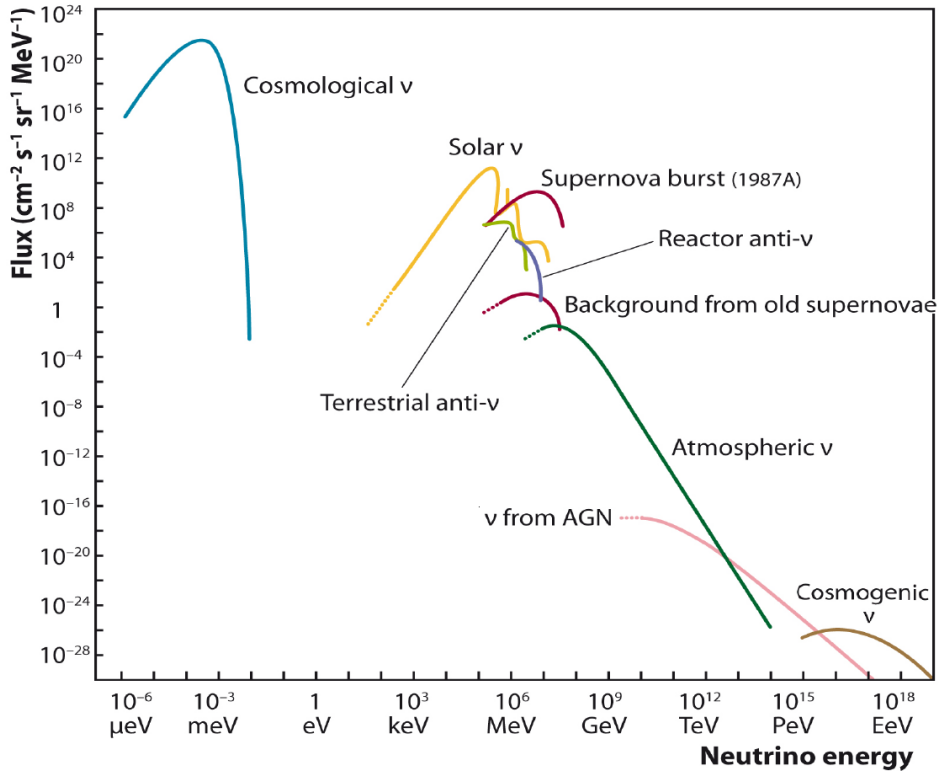
High-Energy Neutrino Astronomy

- IceCube opened in 2013 the new window of >100 TeV neutrino astronomy
- Several experiments are now organized in the Global Neutrino Network GNN:
  - IceCube ➔ IceCube-Gen2
  - Antares ➔ KM3NeT
  - Baikal-GVD

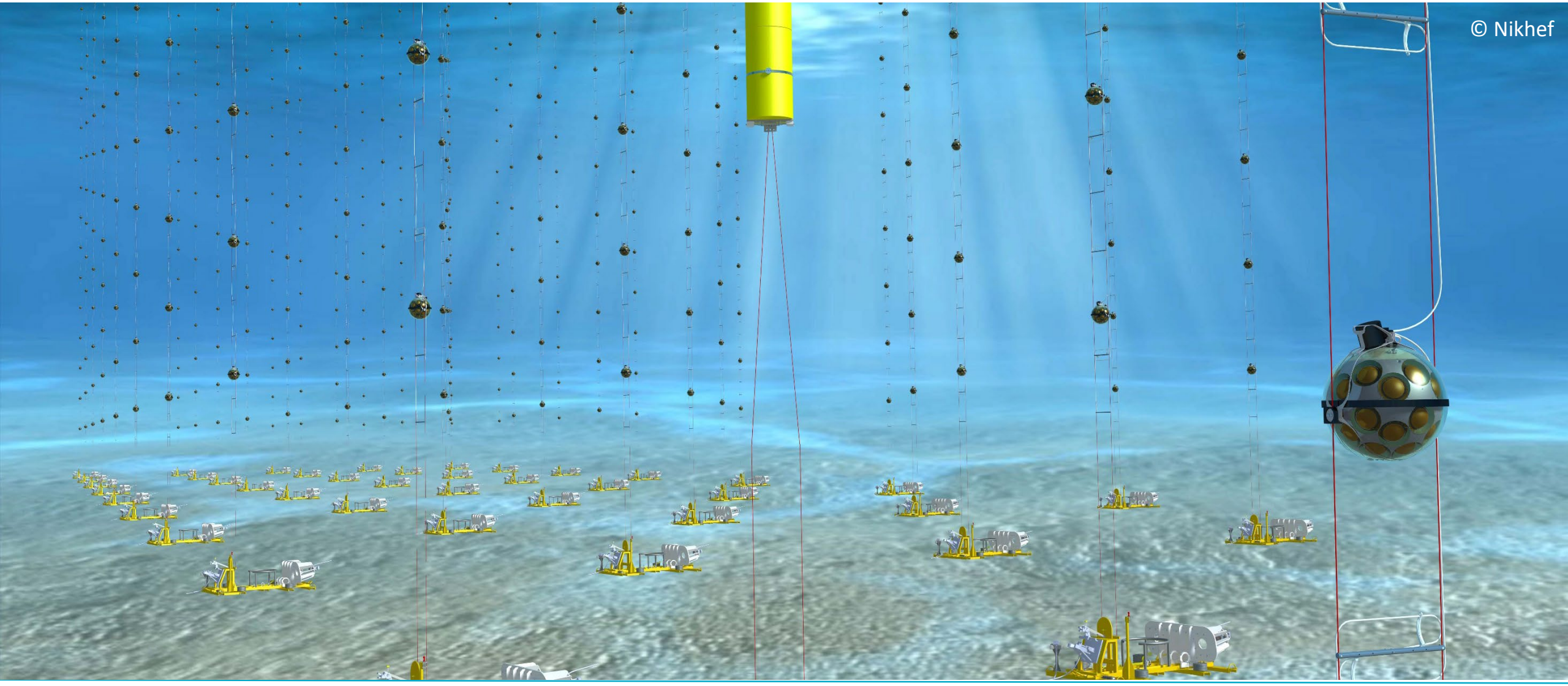


- R&D phase (in particular for cosmogenic Neutrinos): P-ONE, RNO-G, POEMMA, ANITA, GRAND, …
- European flagship (ESFRI): KM3NeT
- Strong partner of US lead IceCube-Gen2





Cubic Kilometre Neutrino Telescope – KM3NeT

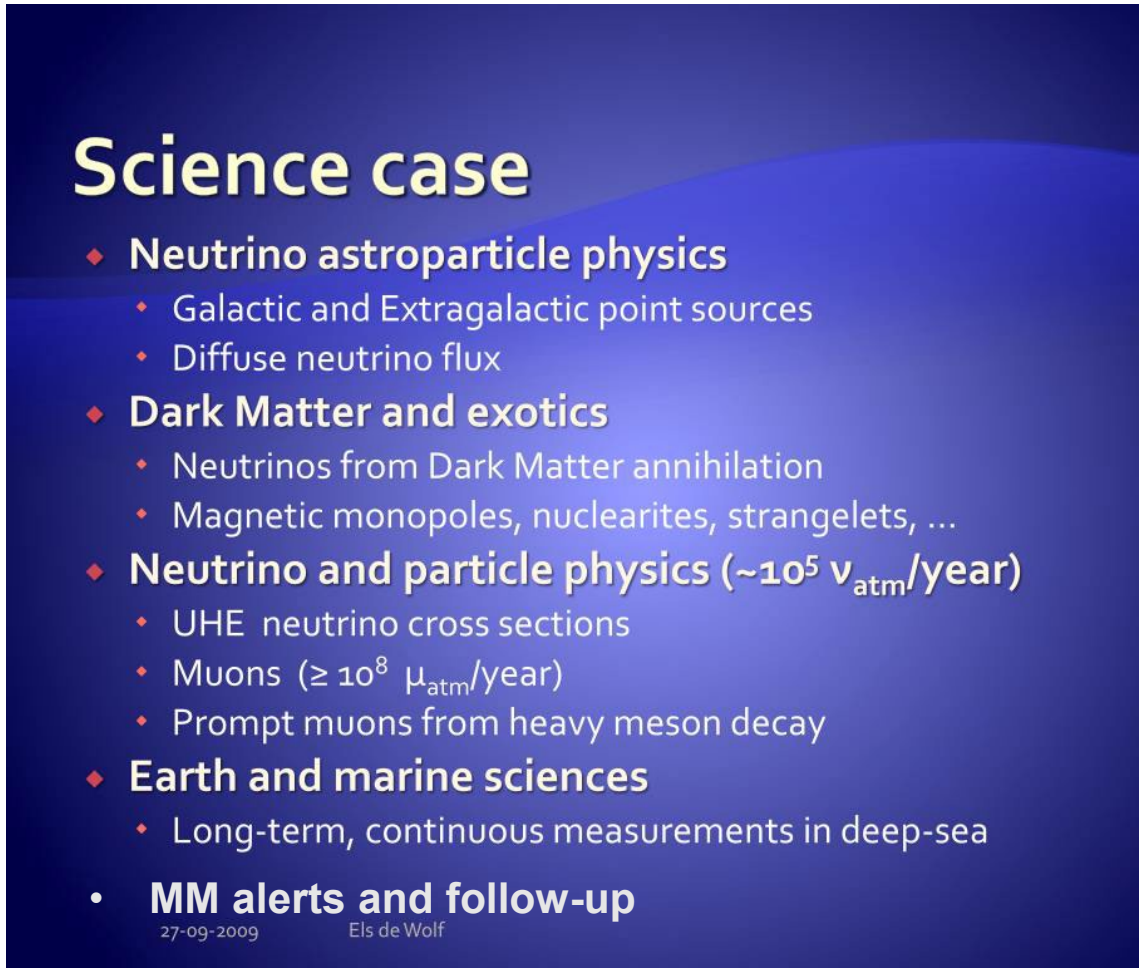


High-Energy Neutrino Astronomy

- ESFRI project
- KM3NeT = ARCA + ORCA
- Discovery and subsequent observation of neutrino sources
- Determination of mass ordering of neutrinos
- ARCA (high-energy neutrino astronomy, Italian site)

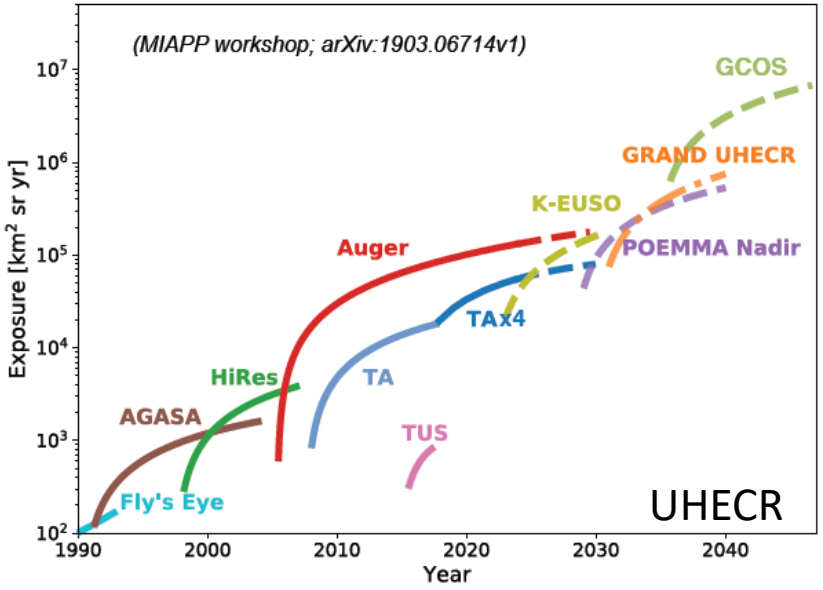
  Installation started, completed 2026
- ORCA (low-energy neutrino physics, French site)

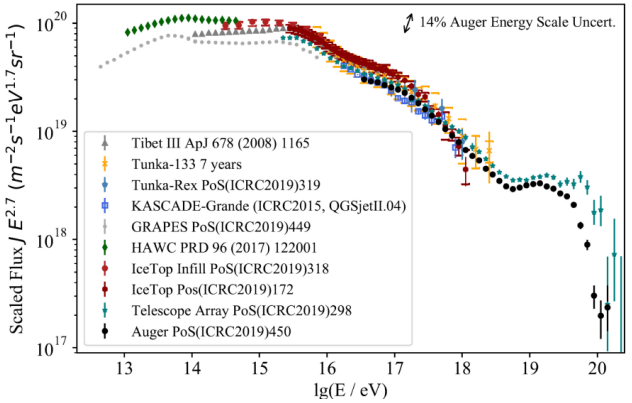
  Installation started, completed 2024
- 15 countries, >250 scientists

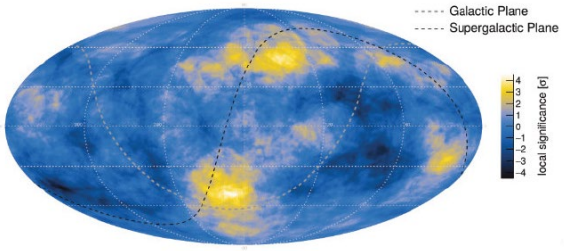


High-Energy Cosmic Rays

- Accuracy of measurements in all energy ranges increased dramatically in last 2 decades, but still:
  - Transition energy range ?
  - Hadronic Interaction models ?
  - Composition and Anisotropies at all energies?
  - Suppression mechanism?
- Pierre Auger Observatory is major experiment
- Highest energies: extensions to TAx4, AugerPrime
- At lower energy (LHAASO, IceCube-Gen2)
- Plus future projects: POEMMA, GRAND, GCOS (global, cost effective, sustainable, experiments)





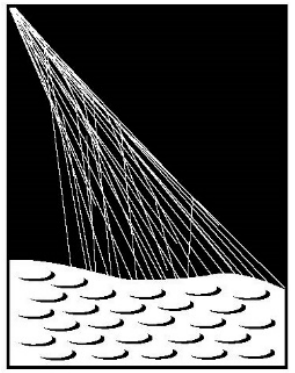


(UHECR Auger-TA working group)

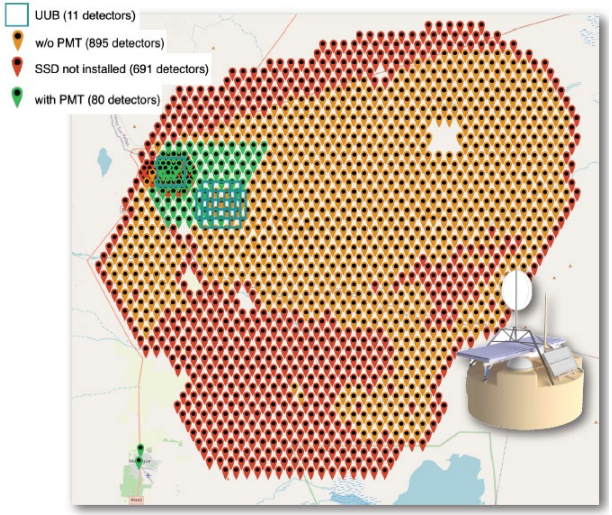
Pierre Auger Observatory

High-Energy Cosmic Rays

- Auger Upgrade to AugerPrime
- High statistics and accuracy required for determining energy spectrum, composition, anisotropy over a large energy range
- Combining data of the various projects (UHECR working groups!)
- 18 countries, ~100 institutes, ~400 scientists
- AugerPrime completes construction in 2023
- Operation time >2030
- Preparation and R&D for GCOS incl. GRAND

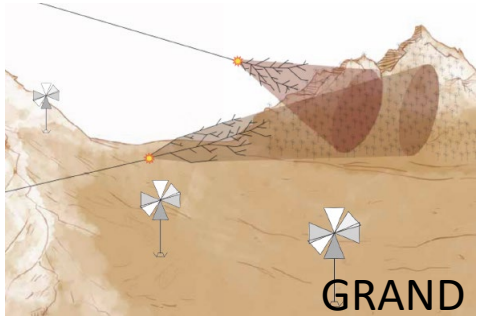


PIERRE AUGER OBSERVATORY



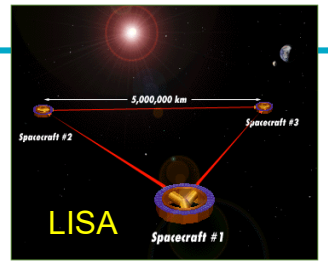
Ongoing upgrade AugerPrime (scintillators and radio antennas)

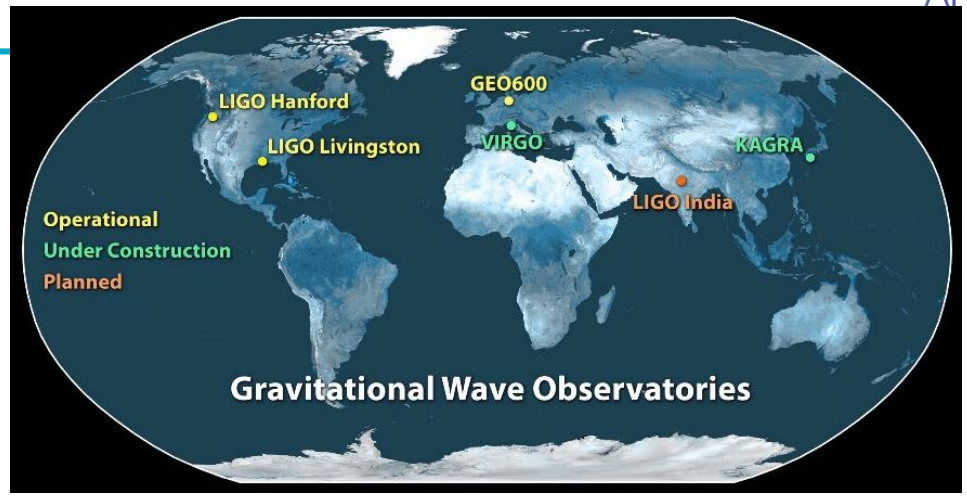
(AugerPrime design report 1604.03637)

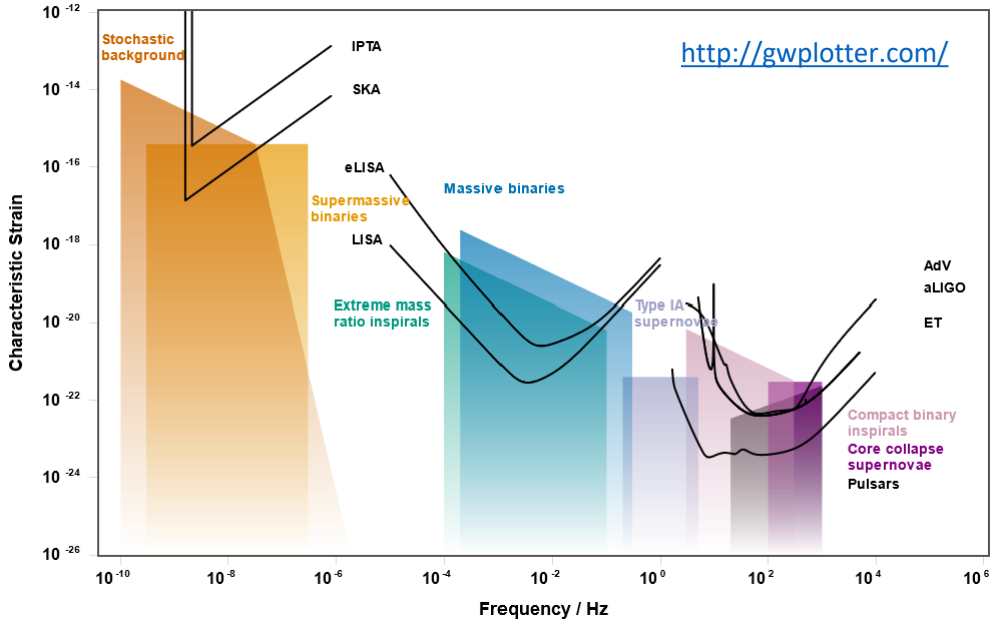


Gravitational Waves

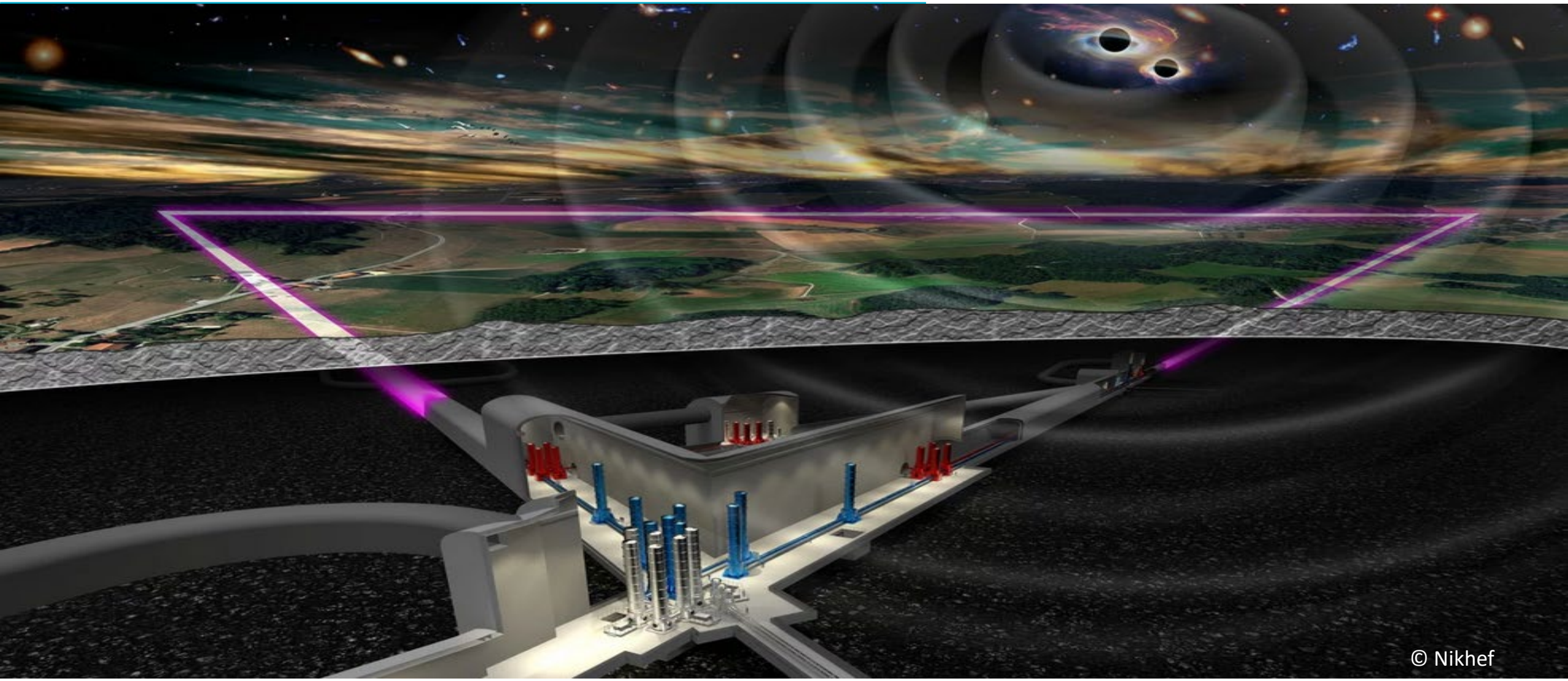
- 2015: First direct detection by LIGO / Virgo
- 2022+: Data taking with aLIGO and aVirgo
  - Volume of visible space increases by a factor 50
- 2030+: 3rd Generation: The Einstein Telescope
  - Volume of visible space increases by a factor 1000
- GWIC + GWAC (worldwide collaboration)
  - GWIC Gravitational Wave International Committee https://gwic.ligo.org
  - GWAC Gravitational Waves Agencies Correspondents
- Gravitational Waves Ground-Space complementarity
  - Einstein Telescope; Cosmic Explorer
  - LISA; e-LISA
  - Pulsar Timing Arrays; IPTA; SKA







Einstein Telescope - ET

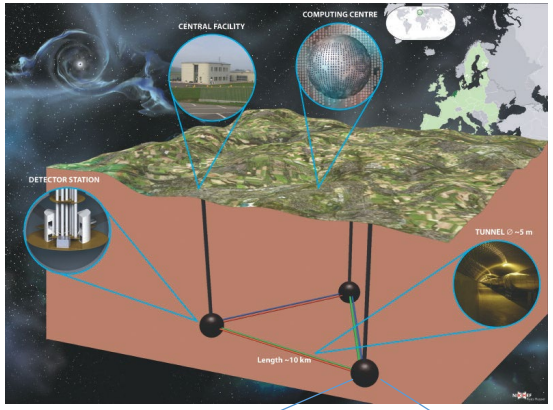


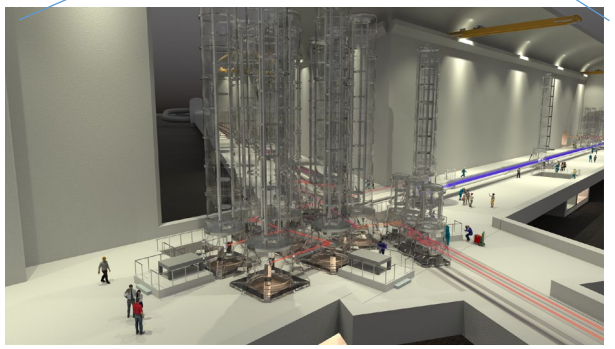
Gravitational Wave Detection

- Science (very interdisciplinary)
  - Formation of Black Holes at the center of galaxies?
  - Is General Relativity (GR) right or do we need new physics?
  - Is Dark Energy the cosmological constant?
  - Understanding the dynamics of ultra dense matter!
- Status
  - Due to the 3G science case, the interest in ET in Europe is rapidly growing.
  - The ET symposium in December 2020 had 710 participants!
- ESFRI
  - The ESFRI roadmap proposal (I, NL, B, E, Pl) was successful;
  - The ESFRI roadmap was updated in June 2021
- Organisation
  - The organizational structure of the project and the collaboration has evolved
  - Boards have been formed:
    Instrument science, Observational science, Site characterisation, E-Infrastructure.
  - The Instrument science board is the most advanced and is fully operational
- R&D
  - Advanced Virgo and Advanced Ligo; KAGRA; ETpathfinder (NL); may be DZA (D)

ET EINSTEIN TELESCOPE

http://www.et-gw.eu





Dark Matter

- Topic has large overlap with neighboring fields
- Direct Detection of Dark Matter APPEC SAC Subcommittee Report:
  - https://www.appec.org/documents
  - arXiv: https://arxiv.org/abs/2104.07634
- Recommendations:
  - Priority of Dark Matter Search
  - Diversified Approach Needed
  - Direct search for WIMPs down to neutrino floor (DARWIN, ARGO)
  - Coordinated detector R&D
  - European Infrastructure for Underground Science
  - Studying of the axion/ALPs mass range
  - Continuation of diverse theoretical activity

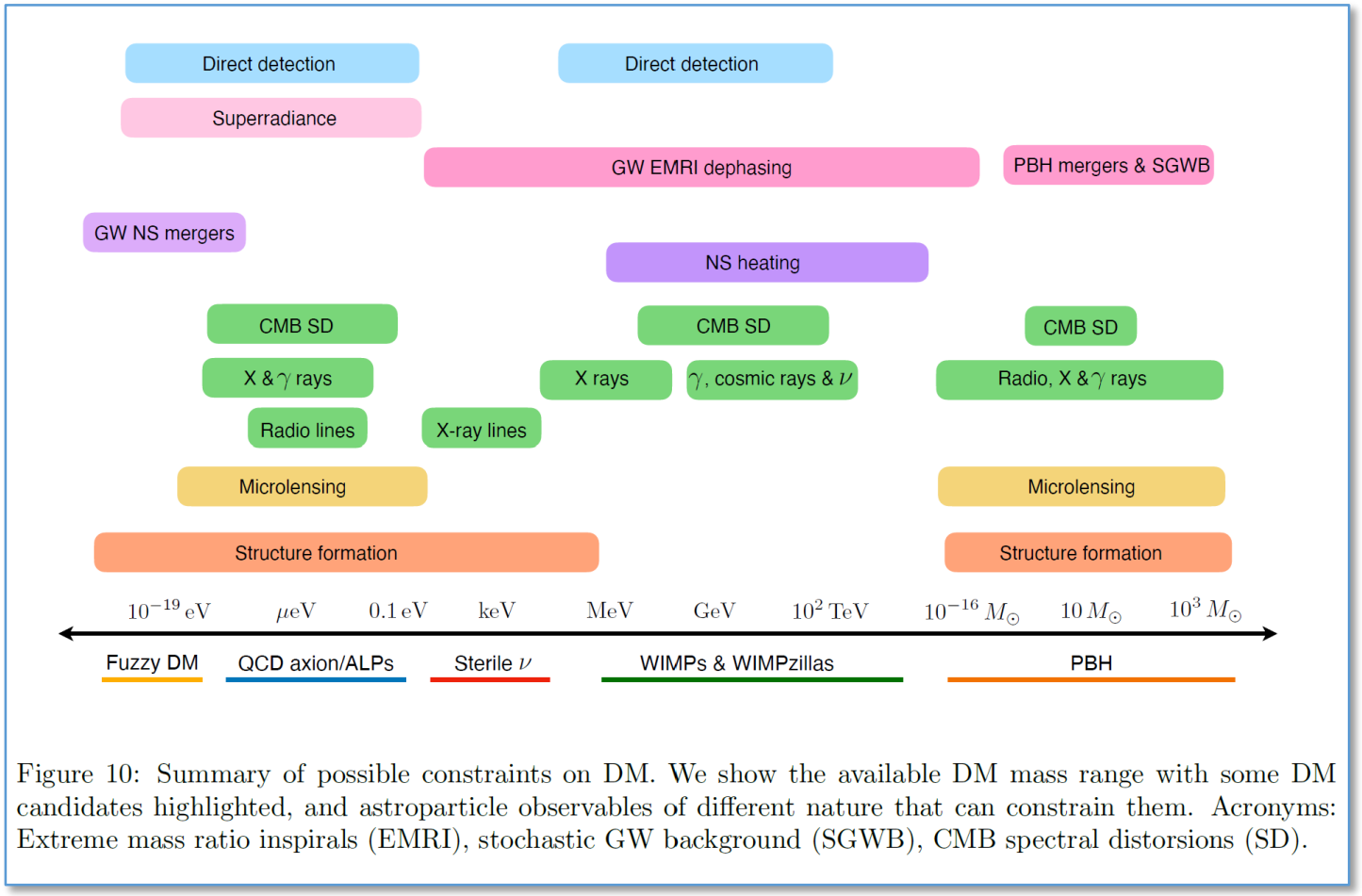
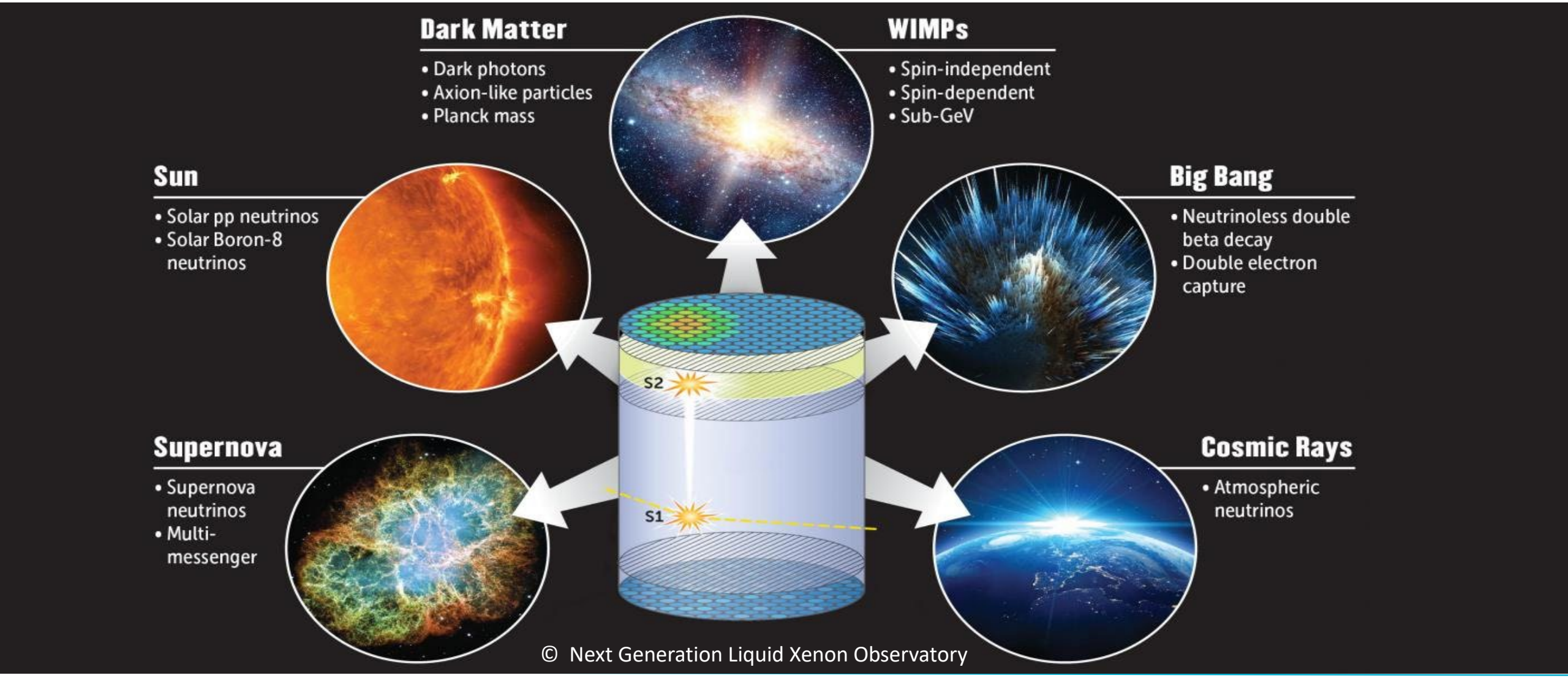


Figure 10: Summary of possible constraints on DM. We show the available DM mass range with some DM candidates highlighted, and astroparticle observables of different nature that can constrain them. Acronyms: Extreme mass ratio inspirals (EMRI), stochastic GW background (SGWB), CMB spectral distorsions (SD).

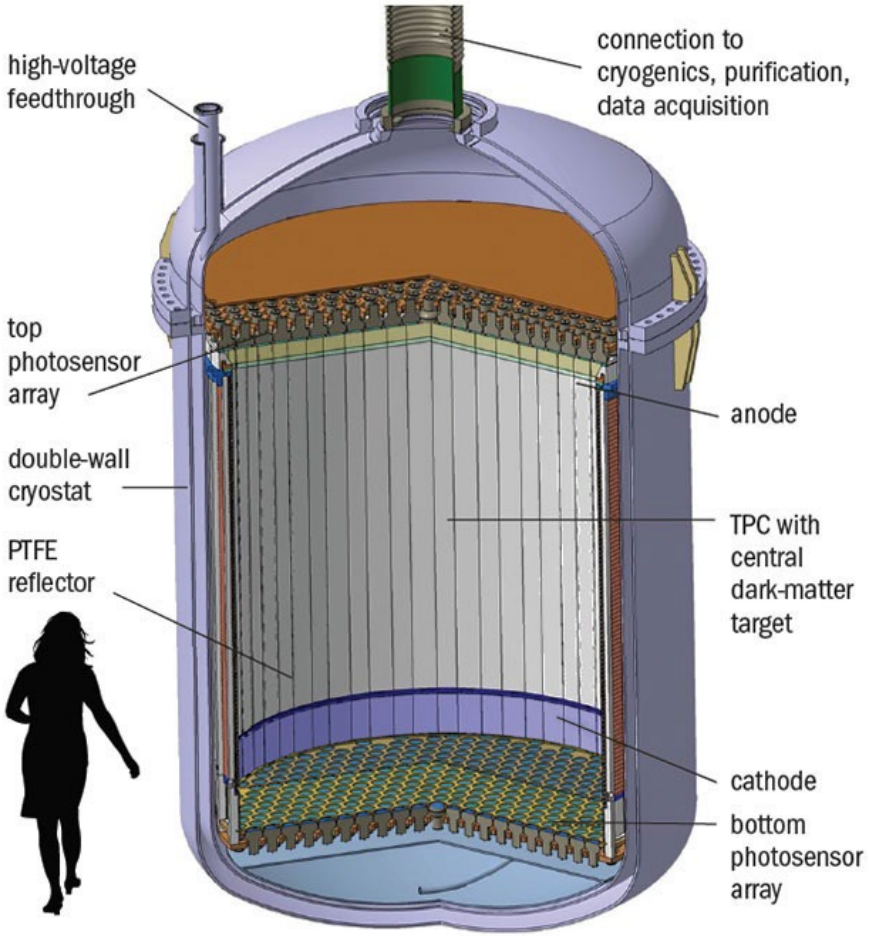
EuCAPT White Paper https://arxiv.org/abs/2110.10074

dark matter wimp search with liquid xenon - DARWIN



Dark Matter - WIMP

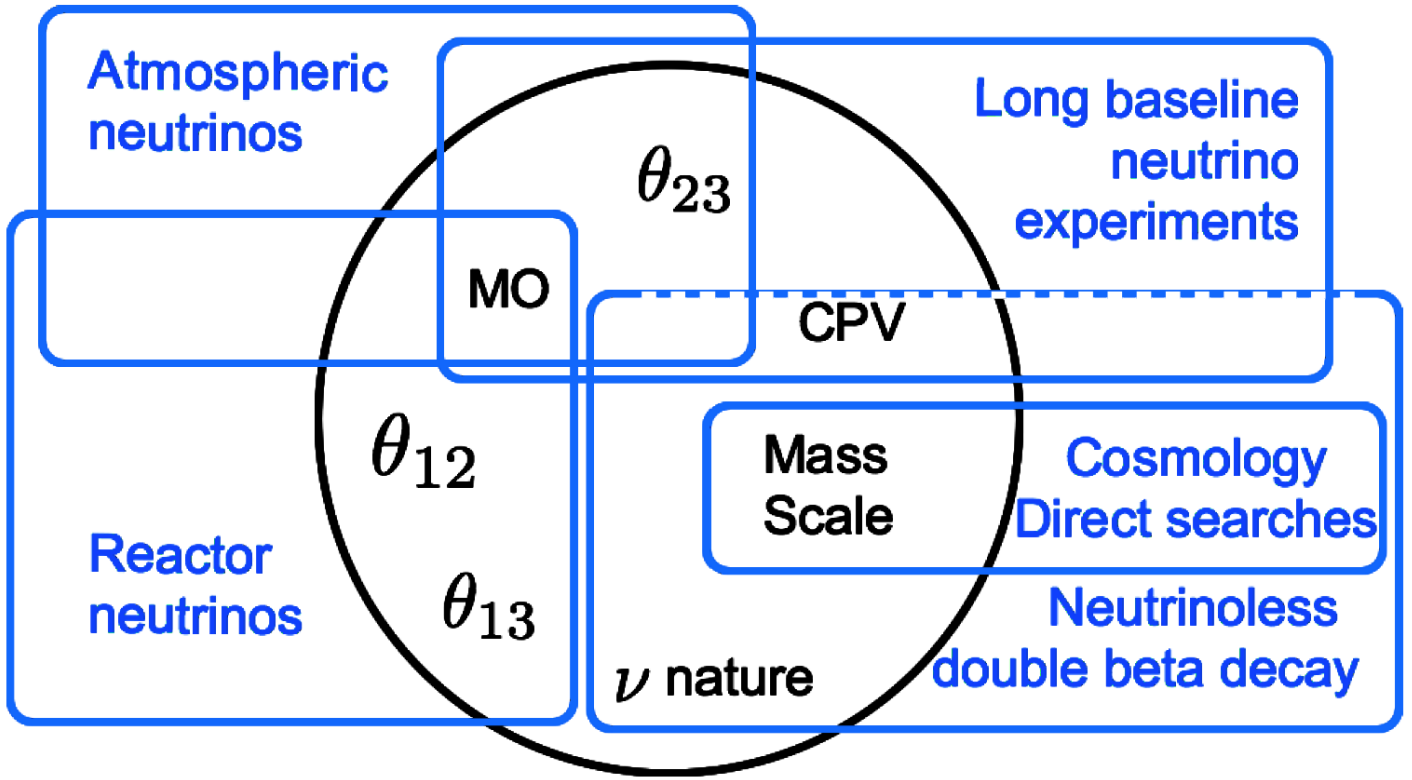
- APPEC recommends to realize worldwide at least one xenon (50t) and one argon (300t) experiment
- DARWIN is currently the European flagship experiment for WIMP search
- In addition, ongoing detector R&D has to be pursued
- XENON/DARWIN and LUX-ZEPLIN collaborations have signed a common MoU https://arxiv.org/abs/2203.02309 (141 institutes, ~600 authors)
- Needs (European) infrastructures for Underground Science



Neutrino Properties

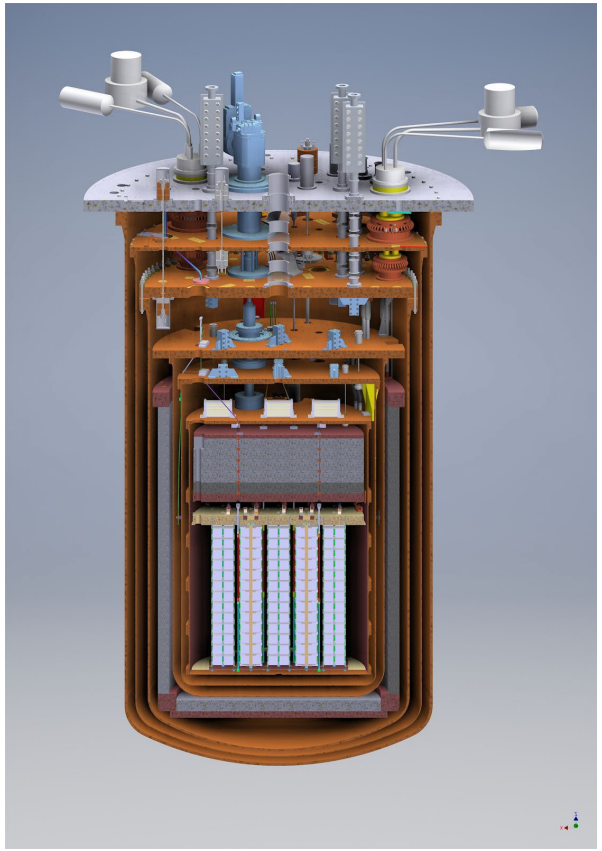
- ν CP-violation is still unknown and may give hints to matter-antimatter asymmetry
- ν–mixing is very different from CKM
- ν–nature undetermined (Majorana)
- ν mass ordering not yet determined
- ν masses << mSM particles gives access to higher mass scales (See-Saw)
- ν is the first hot “dark” particle and has a role in various stages of the Universe
- Needs (European) infrastructures for Underground Science

Science has large overlap with neighboring fields

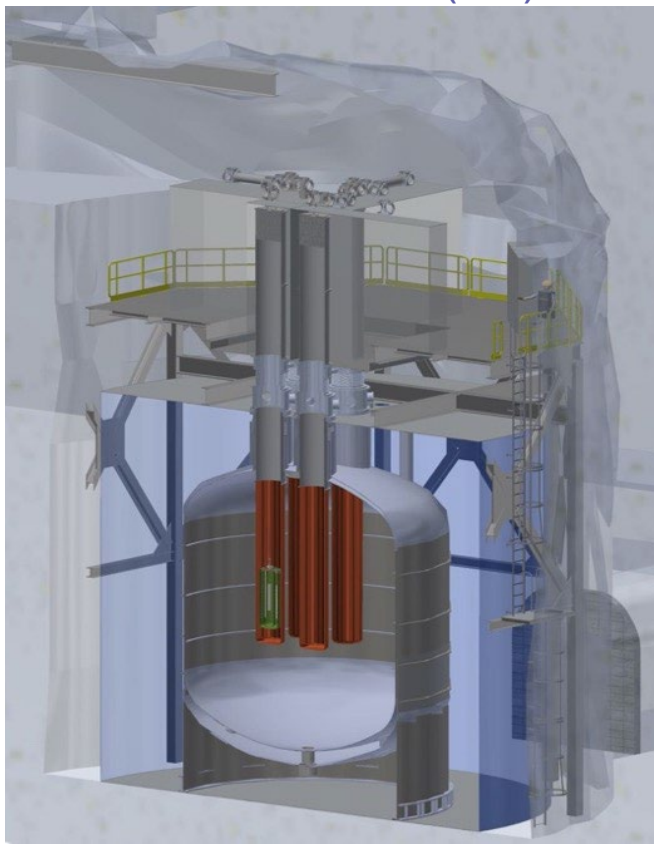


$0\nu\beta\beta$ decay: towards ton-scale experiment

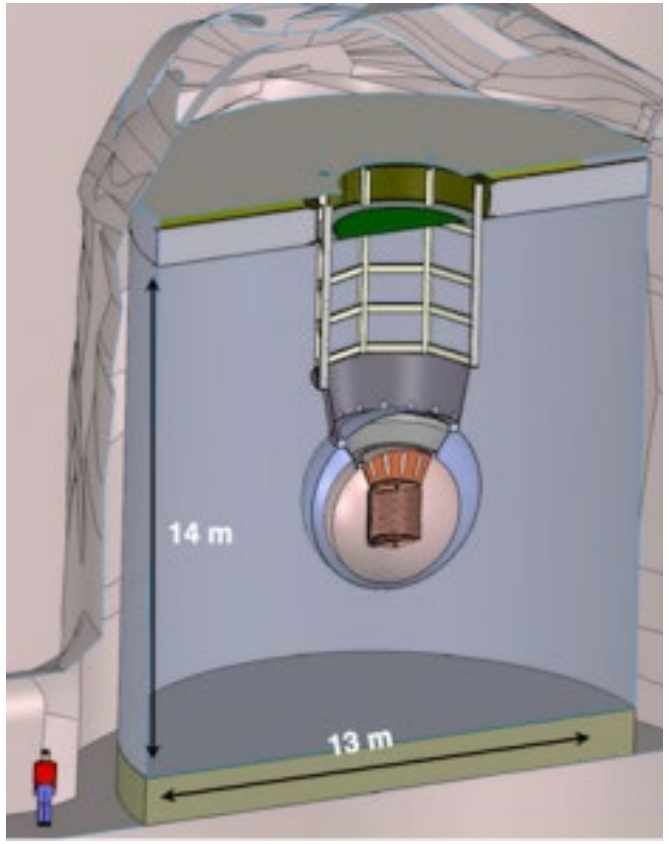
CUPID (100 Mo)



LEGEND-1000 (Ge)

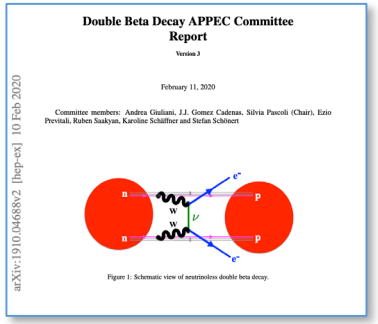


nEXO (136 Xe)



NEXT (136 Xe)

Neutrinoless Double Beta Decay


Double Beta Decay APPEC Committee Report

Version 3

February 11, 2020

Committee members: Andrea Giuliani, J.J. Gomez Cadenas, Silvia Pascoli (Chair), Ezio Previtali, Ruben Saakyan, Karoline Schäffner and Stefan Schönert

arXiv:1910.04688v2 [hep-ex] 10 Feb 2020

Figure 1: Schematic view of neutrinoless double beta decay.

Strategy (Status early 2022):

- Double Beta Decay APPEC Sub-Committee gave advise on the European (and global) program
- It provides an assessment of the current and future scientific opportunities in double beta decay over the next 10 year period
- Close coordination of APPEC with DOE nuclear physics and aligned with Snowmass process
- Spring 2021: DOE portfolio review on Neutrinoless Double Beta Decay Experiments
- 0vßß European-North American Summit at Gran Sasso, Italy, 29/9 -1/10/2021
  - https://agenda.infn.it/event/27143/ Presentation of Underground labs, Experiments, R&D, …
  - Closed session: 19 representatives of funding agencies and director of underground labs
  - Outcome : (i) Neutrinoless Double Beta Decay should have high priority

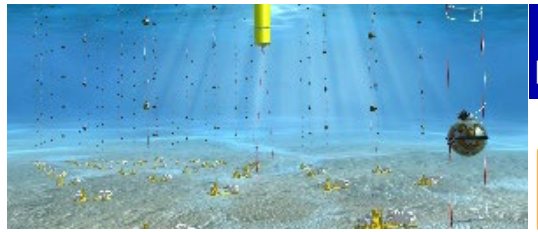
    (ii) funding agencies in Europe and North America should build a network

    (iii) if possible LEGEND and nEXO should be funded, one in Europe, one in North America

APPEC Flagship Research Infrastructures

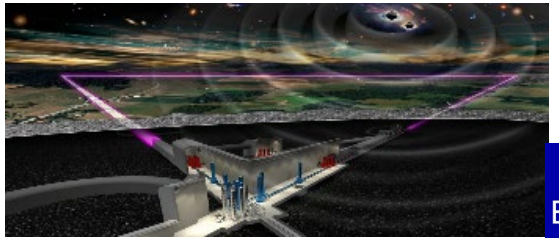
This is not a closed, but dynamic list…

[construction KM3NeT 2020-2026]



ESFRI

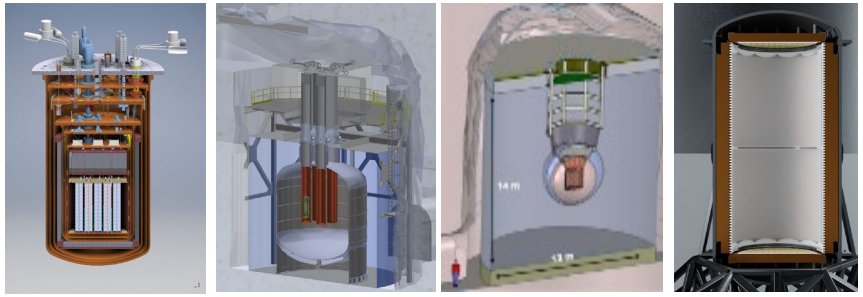
HE Neutrinos



ESFRI

[construction ET 2026-

Gravitational Waves

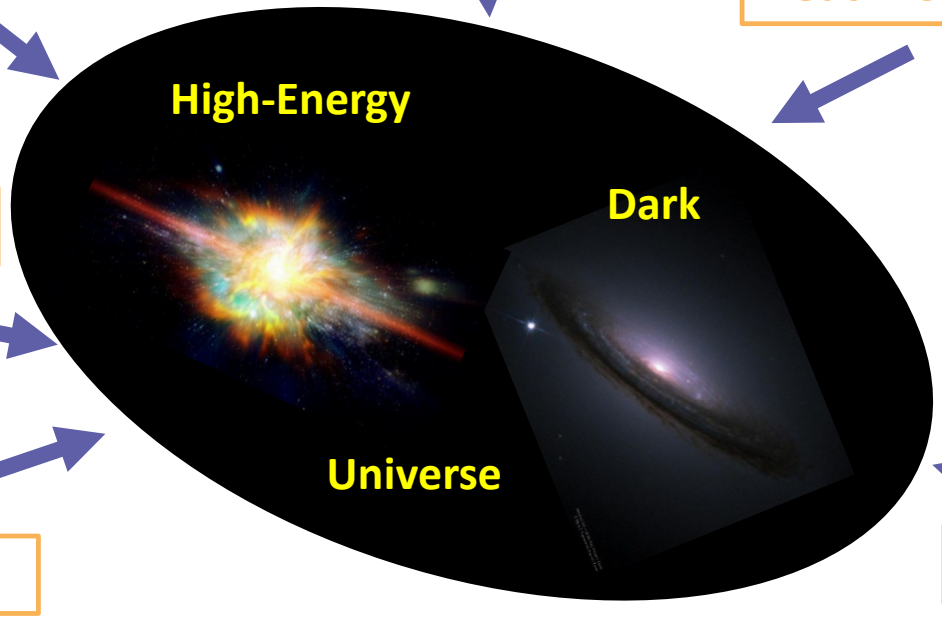


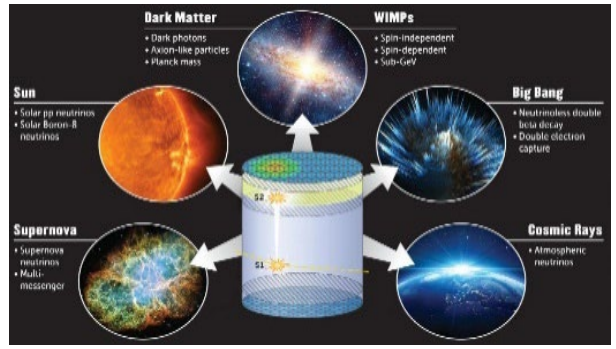
[construction LEGEND-1000 2023-

Neutrino Properties

[construction AugerPrime 2019-2023]

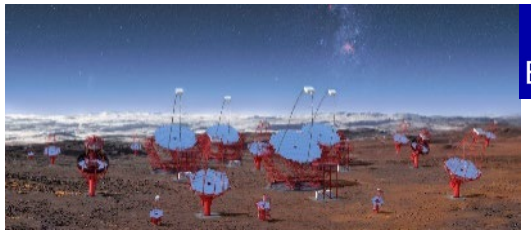
HE Cosmic Rays





[construction DARWIN 2024-

[construction CTA 2021-



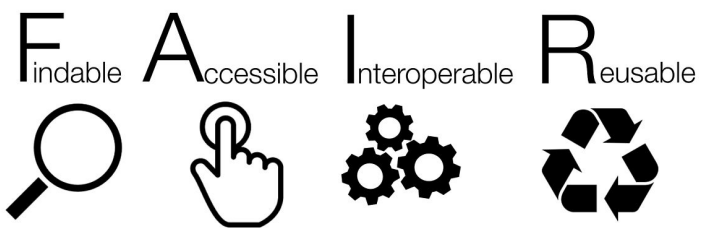
ESFRI

HE Gamma rays

Dark Matter

Overarching Topics in the Roadmap

- Ecological Impact
  - ..of satellites, observatories, infrastructures, travel…
  - ..provide spin-offs for other research areas
- Societal Impact
  - Survey and fostering of impact on society
- Open Science and Human Talent Management
  - Outreach and education
  - Open Data and Citizen Science ESCAPE https://projectescape.eu/
- Computing
- European Centre for Astroparticle Physics Theory EuCAPT
  - https://www.eucapt.org/
- Underground and Large-scale Infrastructures
  - Coordination of European Underground Labs



Strategy Connections

In the APPEC strategy process there are stong connections to

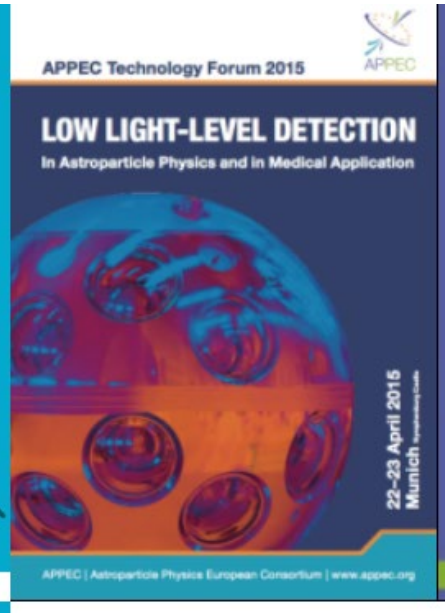
- ECFA: EPPSU and corresponding roadmaps
- NuPECC: Nuclear Physics Long Range Plans
- Astronet
- Snowmass2021
- Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020)
- National communities

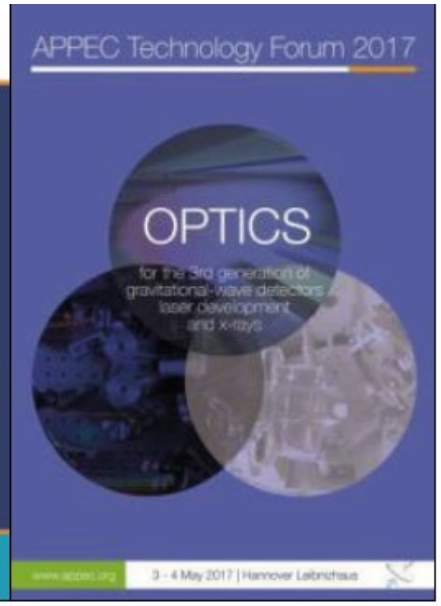
APPEC and EU Framework Programs

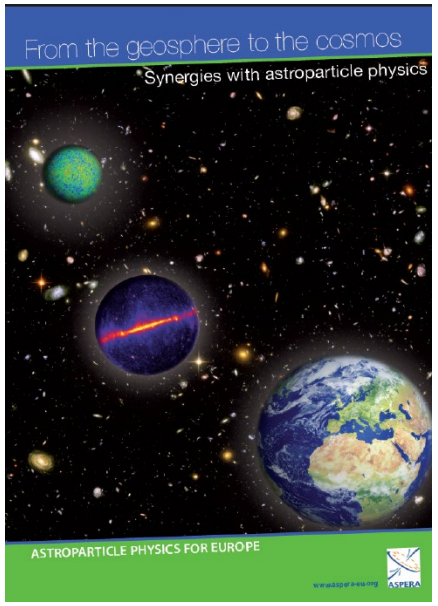
- APPEC was created in 2001 coordination instrument of the European agencies funding Astroparticle Physics
- Boost by EU funding of the ERANET ASPERA, for 6 years (2006-2012)
- launch of successful community driven EU proposals (ILIAS-I3 and ET-DS)
- Cooperation with ESCAPE, member of advisory board
- Participation in current calls (e.g. INFRA-TECH, APOGEIA, M2TECH)
- For ***Horizon Europe*** Work Programme 2023-2024:
  - ***INFRA-SERV: In 2023, the scientific domains called under this topic are: … Astronomy and Astroparticle physics***

APPEC Technology Platform

APPEC is also a platform for discussion and collaboration with other organisations and industry. It fosters also R&D projects.







Ultimate Low Light-Level Sensor Development

SENSE

FET-OPEN exchange
https://www.sense-pro.org

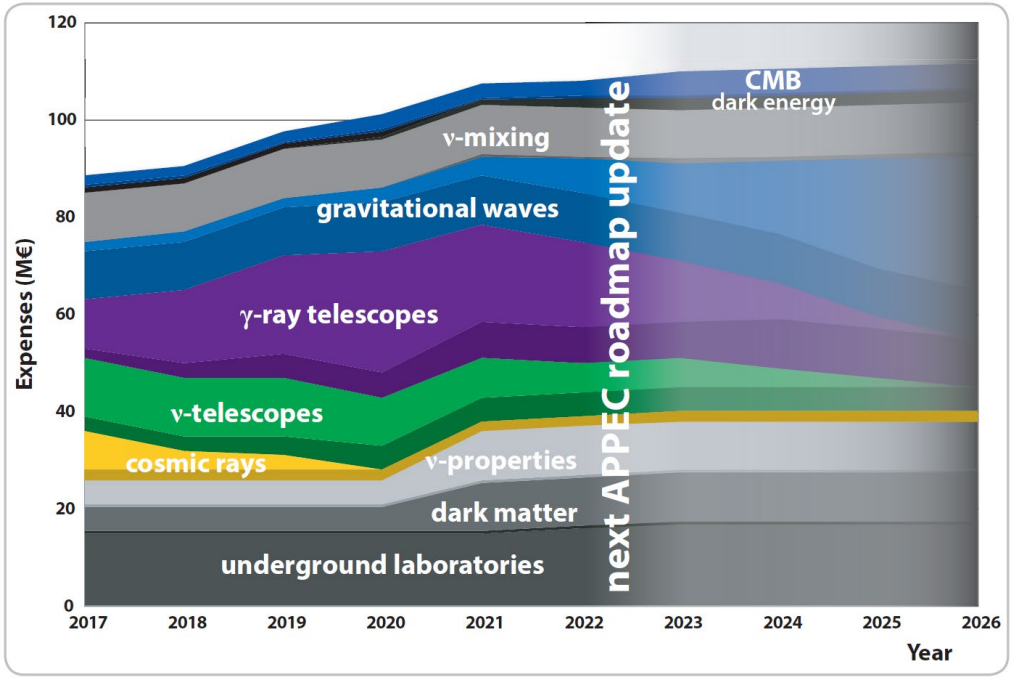
Next Tech Forum foreseen to be held in Prague (20-21/09/2022) focusing on „*Robotics and operation of detectors in harsh environment*" **https://indico.utef.cvut.cz/event/20/**

Midterm Evaluation of the Roadmap

- Diverse program with request to realize large infrastructures
- Balanced plans for investments
- General shift in schedule due to slow realizations
- Prize tags needs to be cross-checked / updated
- Societal and environmental impact as well as economic and ecological footprint and sustainability are becoming more and more important
- Is Astroparticle Physics too expensive?

  Compared to what?

  I believe that about €100 million/year from Europe for such extensive research is cost-effective.



APPEC TOWN MEETING BERLIN 2022

Invitation to the APPEC Town Meeting: 9–10 June 2022, Berlin
https://indico.desy.de/event/25372/

Summary

APPEC

- Astroparticle Physics is a booming and blooming field
- In search of the wonders of the cosmos
- Going to understand the fundamental law of Nature
- Plenty of opportunities for young scientists

APPEC:

- Town Meeting (midterm evaluation of Roadmap) in 2022
- Coordination of European Astroparticle Physics strategy…
- …in cooperation with neighboring fields
- APPEC Newsletter: https://www.appec.org/latest-news/newsletters

…and further foster and coordinate the European Astroparticle Physics!