



Astroparticle Physics European Consortium

Astroparticle Physics in Poland

**Celebratory Event
in the frame of the APPEC General Assembly
Warsaw, June 2023**

Andreas Haungs | KIT – Institute for Astroparticle Physics

Warsaw, Poland | 29/6/2023



Agenda

THURSDAY, 29 JUNE

09:30 → 13:30 **Celebratory Event: Astroparticle Physics In Poland**

09:30

Come together

10:00

Welcome and Introduction to APPEC

Speaker: Andreas Haungs



10:20

Astroparticle Physics In Poland

Speaker: Leszek Roszkowski



ASTROCENT

10:40

Speak from Ministry (funding opportunities / strategy...)

Speaker: TBA



gov.pl

Ministry of Science
and Higher Education

11:00

Copernican Academy

Speaker: Leszek Roszkowski



11:20

The German Center for Astrophysics (DZA) In Lusatia (Łużyce)

Speaker: Christian Stegmann (DESY)



11:40

Open / panel discussion

Speaker: all speakers

12:00

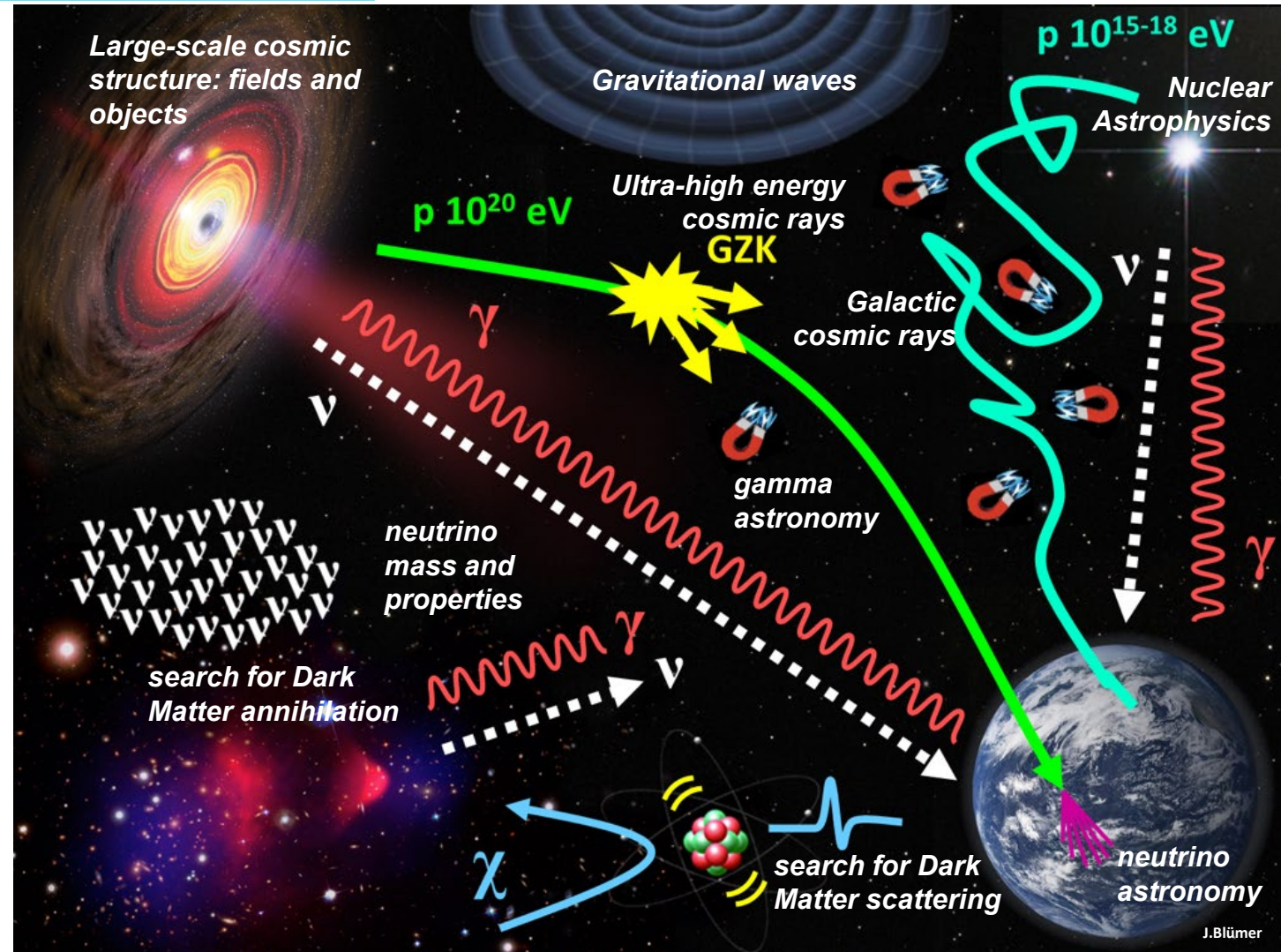
Reception / Lunch



Astroparticle Physics

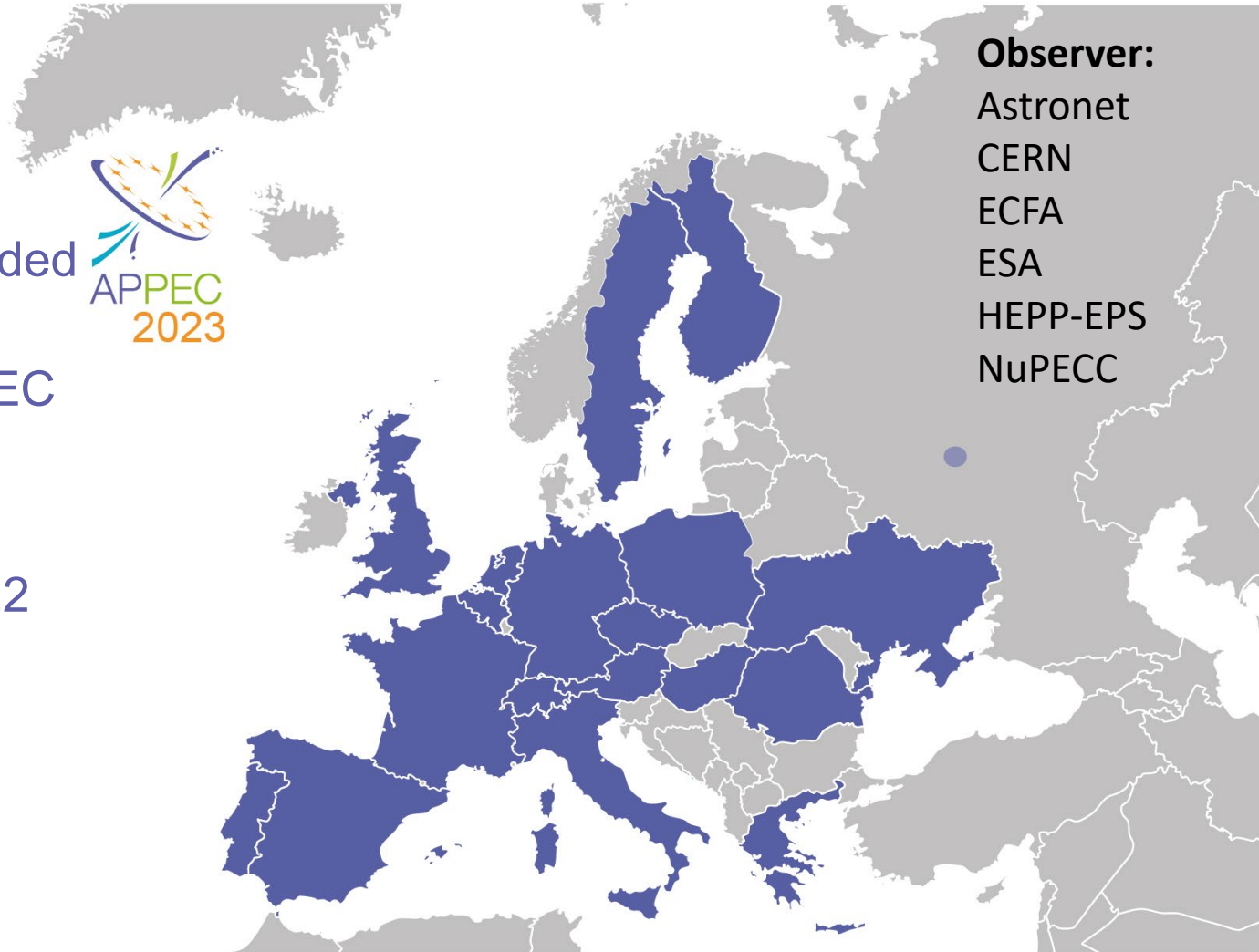
Astroparticle Physics is a branch of fundamental science embedded in environment and society!

Understanding the Multi-Messenger and the Dark Universe



AstroParticle Physics European Consortium

- an international coordinating structure, founded in 2012
- Based on MoUs by all partners and an APPEC Common Fund with c. 70k€/year
- a budget of c. 70k€/year
- 18 (+1 suspended) member countries with 22 funding agencies
- 3 bodies:
 - General Assembly with Observers
 - Scientific Advisory Committee;
 - Joint Secretary



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

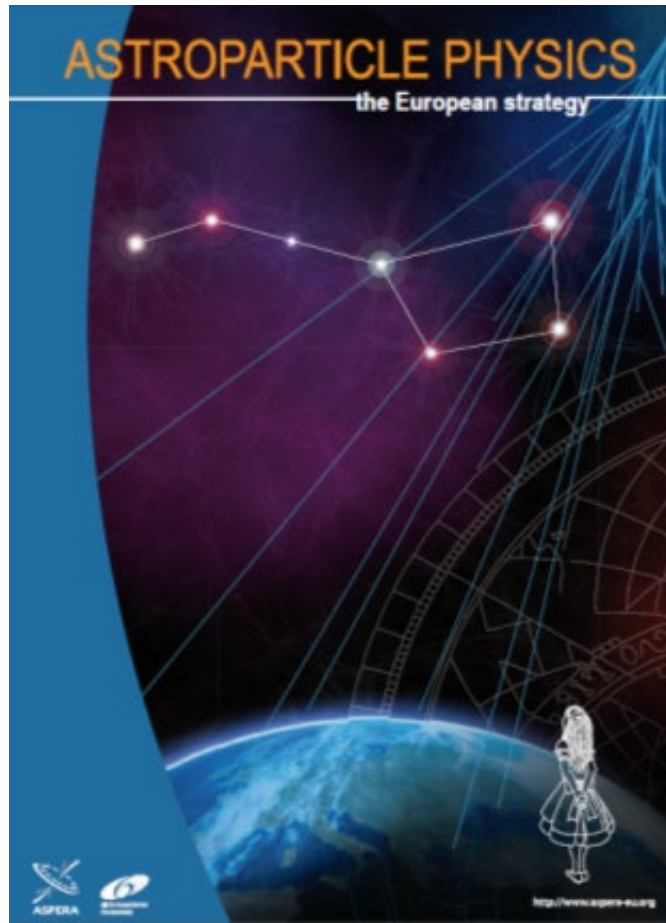
APPEC is

- **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**

APPEC Roadmaps

<https://www.appec.org/roadmap>

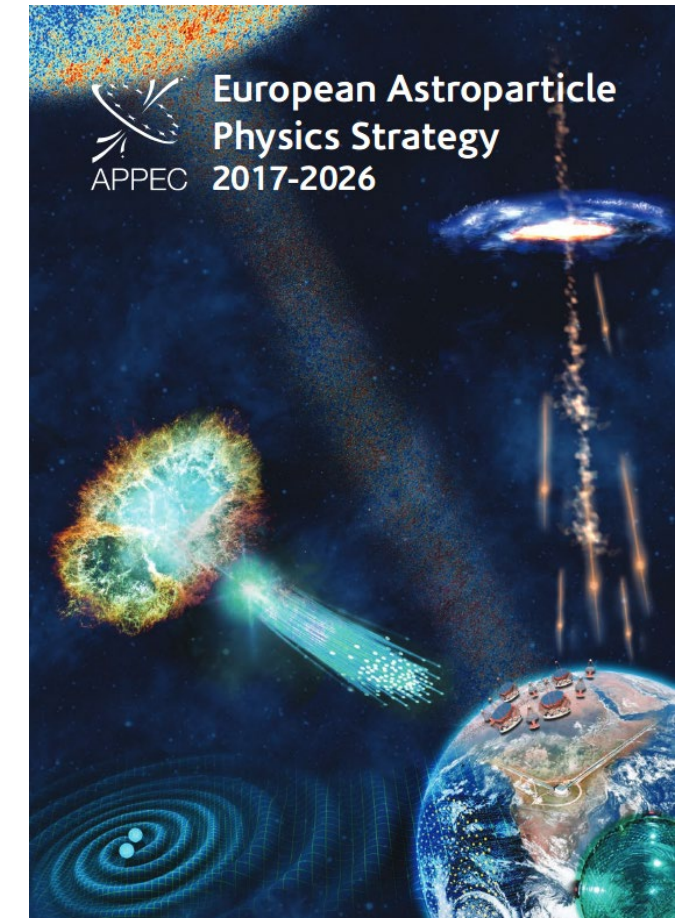
2008



2011



2017



APPEC Roadmap 2017-2026

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

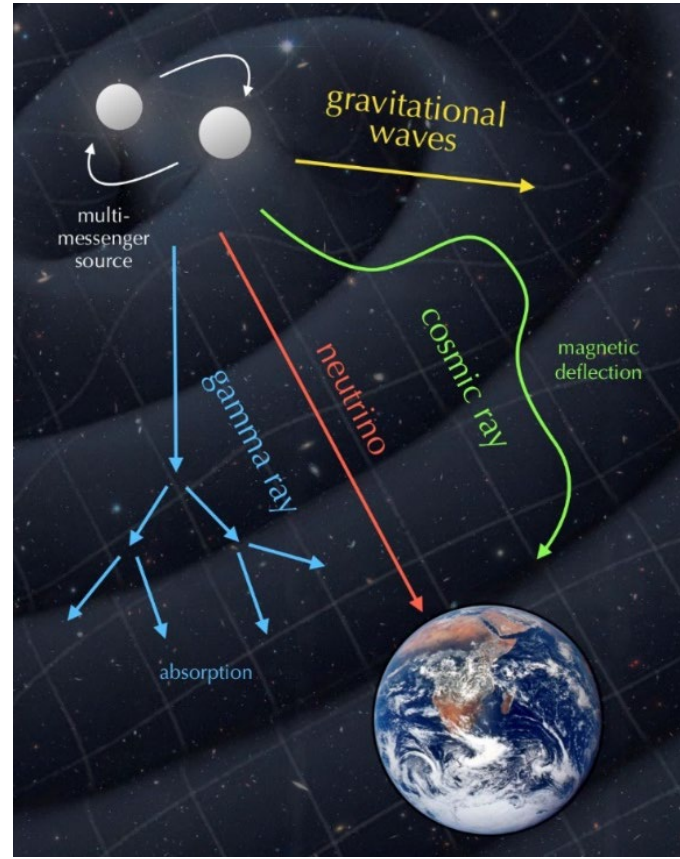
Societal topics

- Gender balance
- Education
- Outreach
- Open Science
- Citizen Science
- Ecological impact
- Connection to industry
- Neighboring fields
- European Commission
- Interdisciplinary opportunities

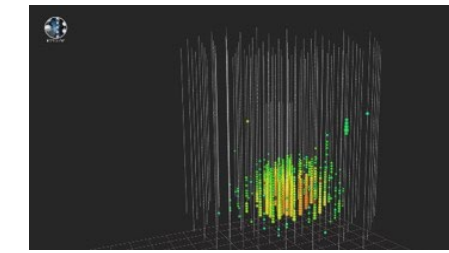
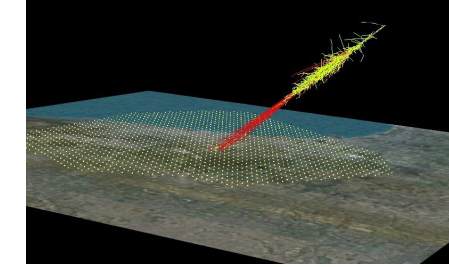


Multi-Messenger Universe

- 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..... preferably in real-time!



... plus all astronomy

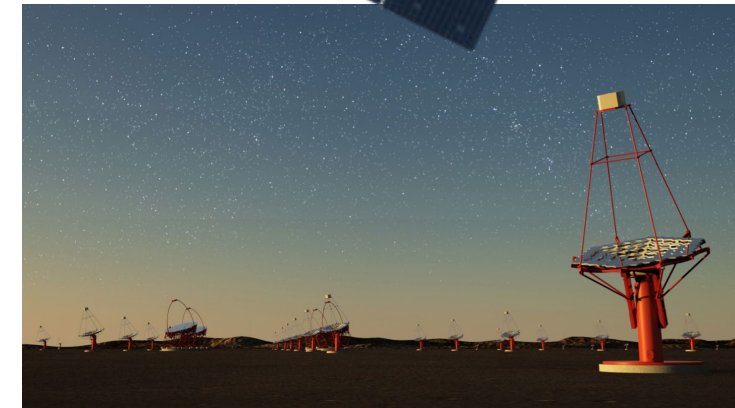


High-Energy Gamma Rays

- Covers large energy range with different observatories
- Satellites (Fermi, AMEGO (launch 2029), ASTROGAM)
- 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



H.E.S.S.



MAGIC



LHAASO

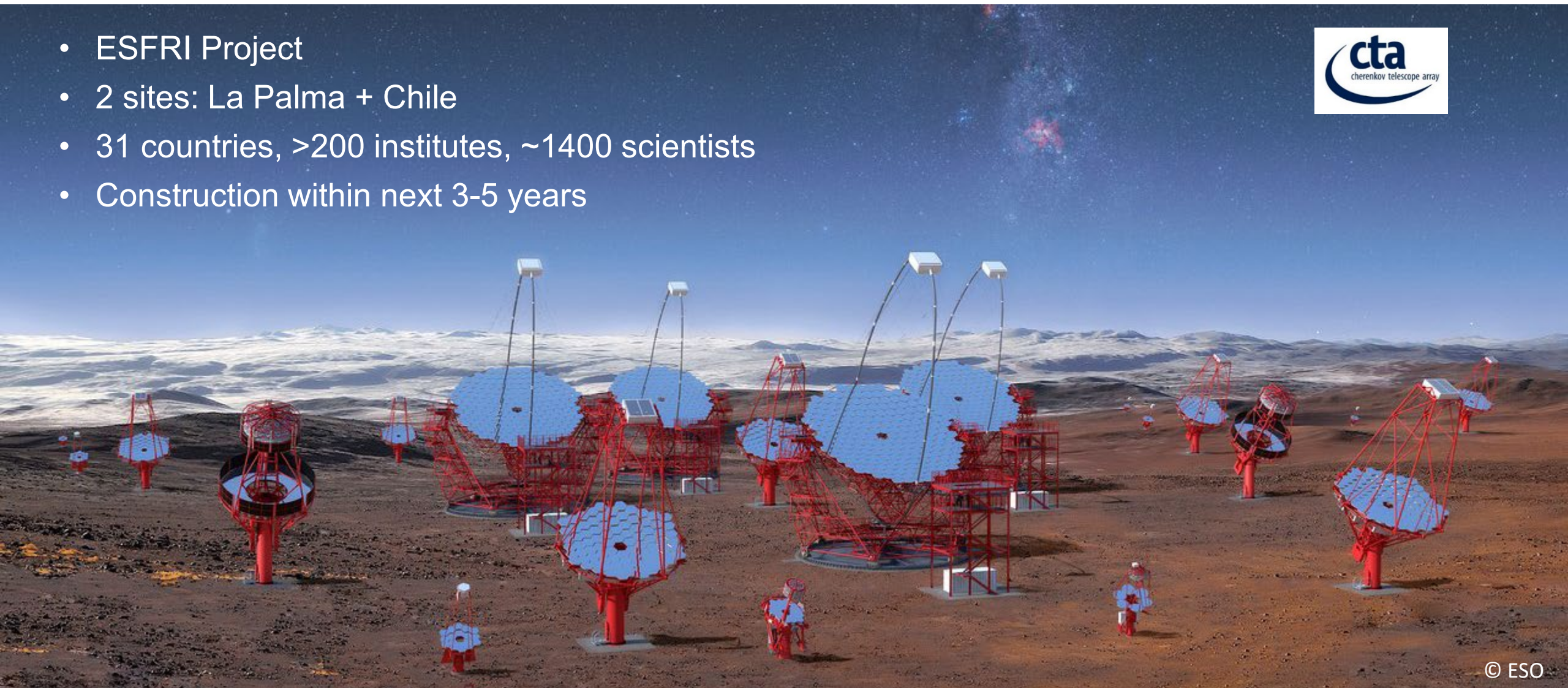


HAWC



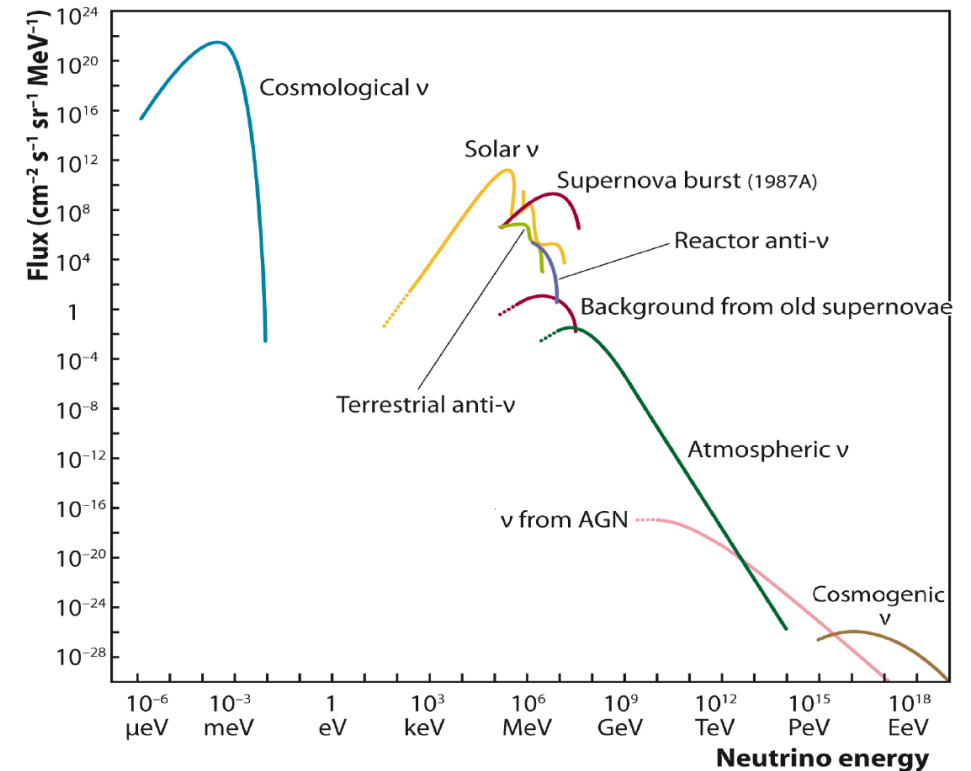
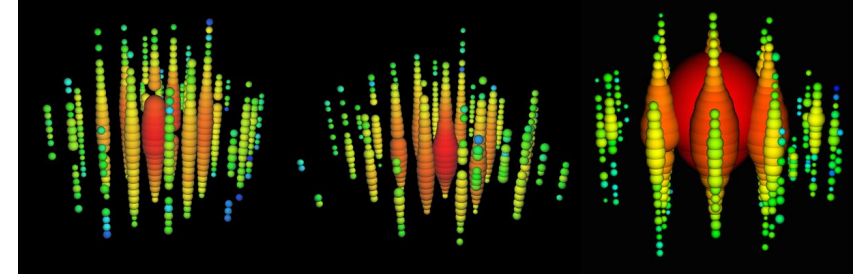
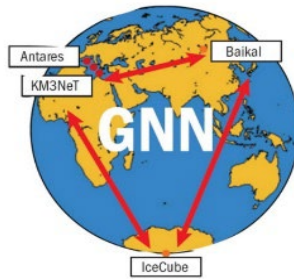
Cherenkov Telescope Array – CTA

- ESFRI Project
- 2 sites: La Palma + Chile
- 31 countries, >200 institutes, ~1400 scientists
- Construction within 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 \rightarrow IceCube-Gen2
 - Antares \rightarrow 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](#)



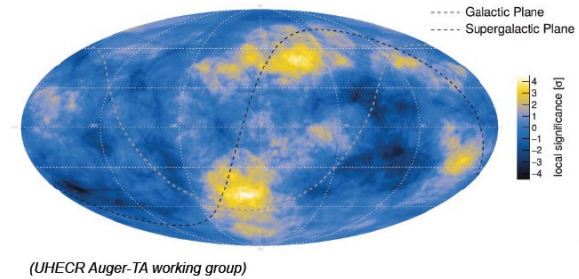
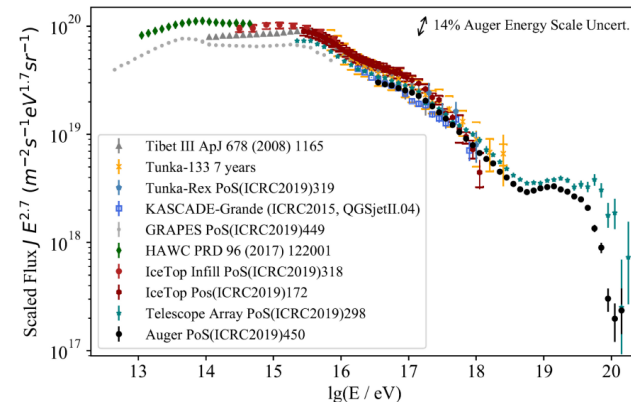
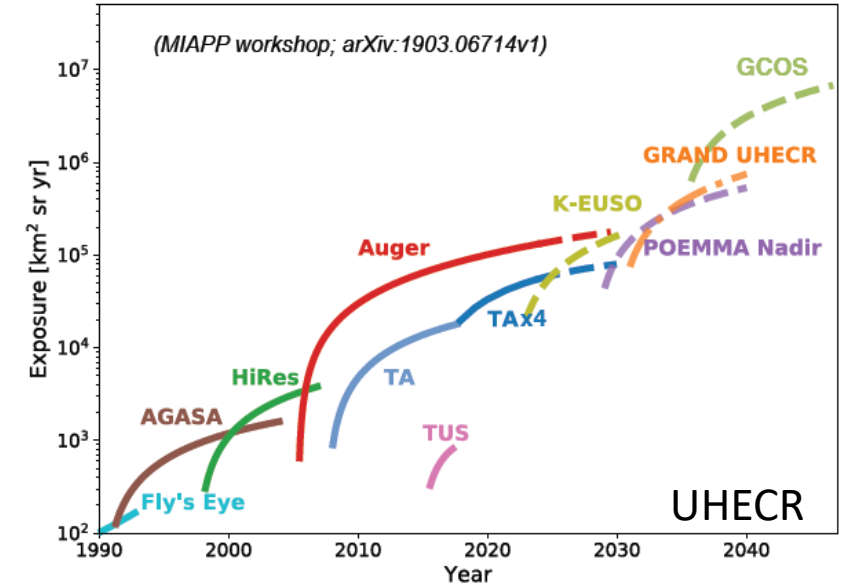
Cubic Kilometre Neutrino Telescope – KM3NeT

- ESFRI project
- ARCA (high-energy ν astronomy, Italian site)
Installation started, completed 2026
- ORCA (low-energy ν physics, French site)
Installation started, completed 2024
- 15 countries, >250 scientists



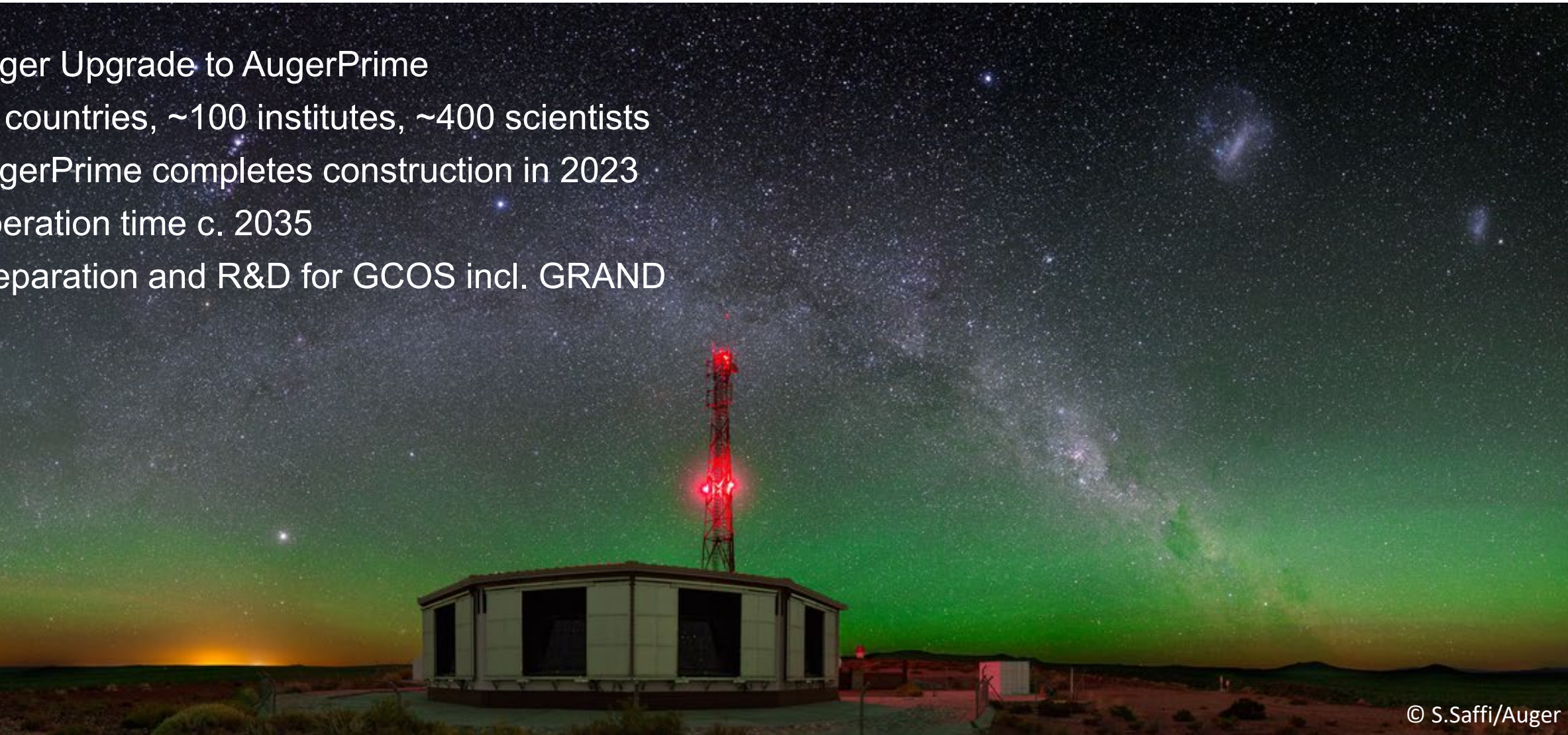
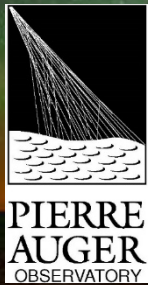
High-Energy Cosmic Rays

- 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)



Pierre Auger Observatory

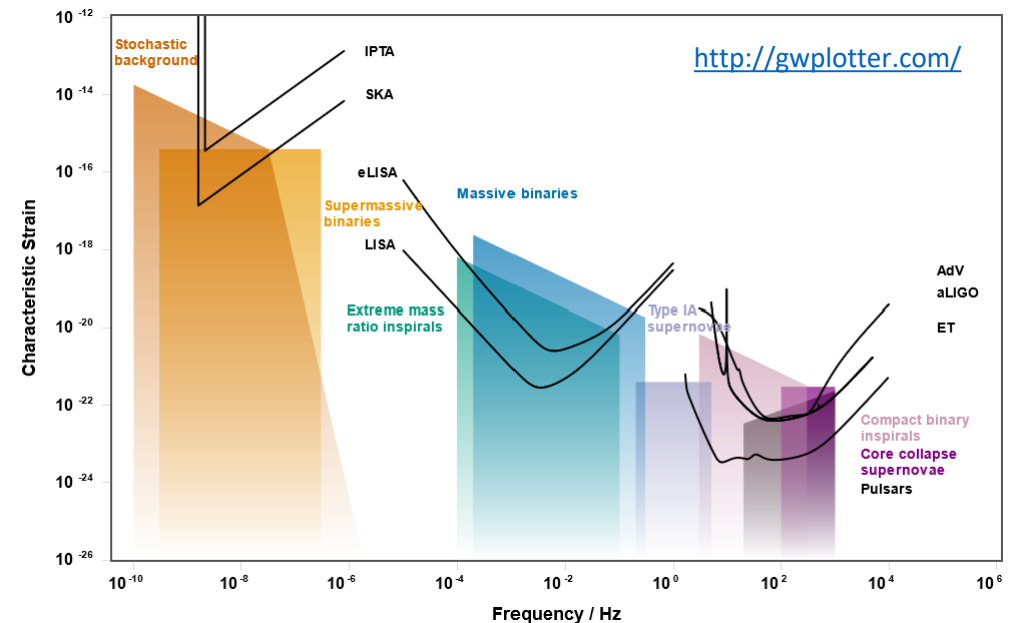
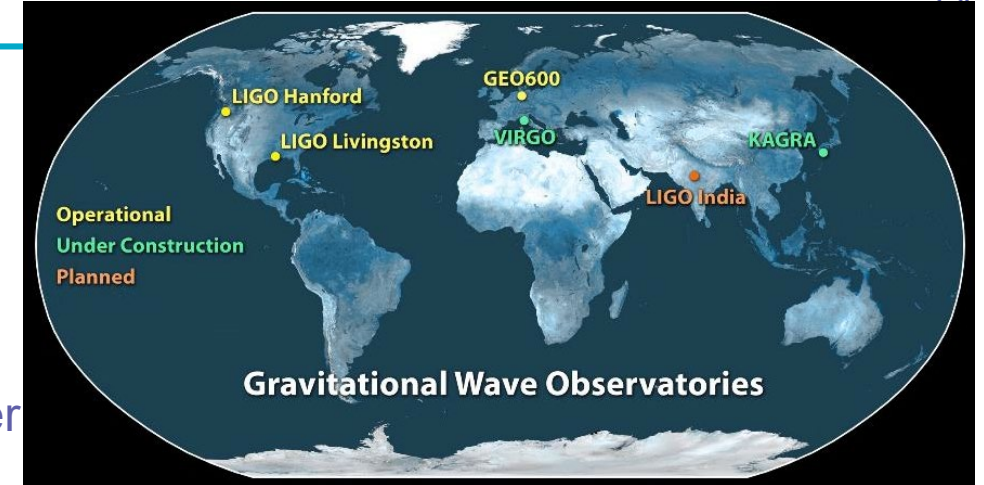
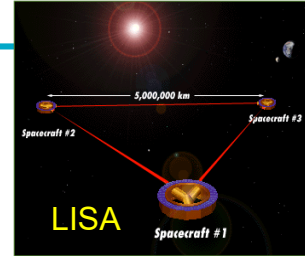
- Auger Upgrade to AugerPrime
- 18 countries, ~100 institutes, ~400 scientists
- AugerPrime completes construction in 2023
- Operation time c. 2035
- Preparation and R&D for GCOS incl. GRAND



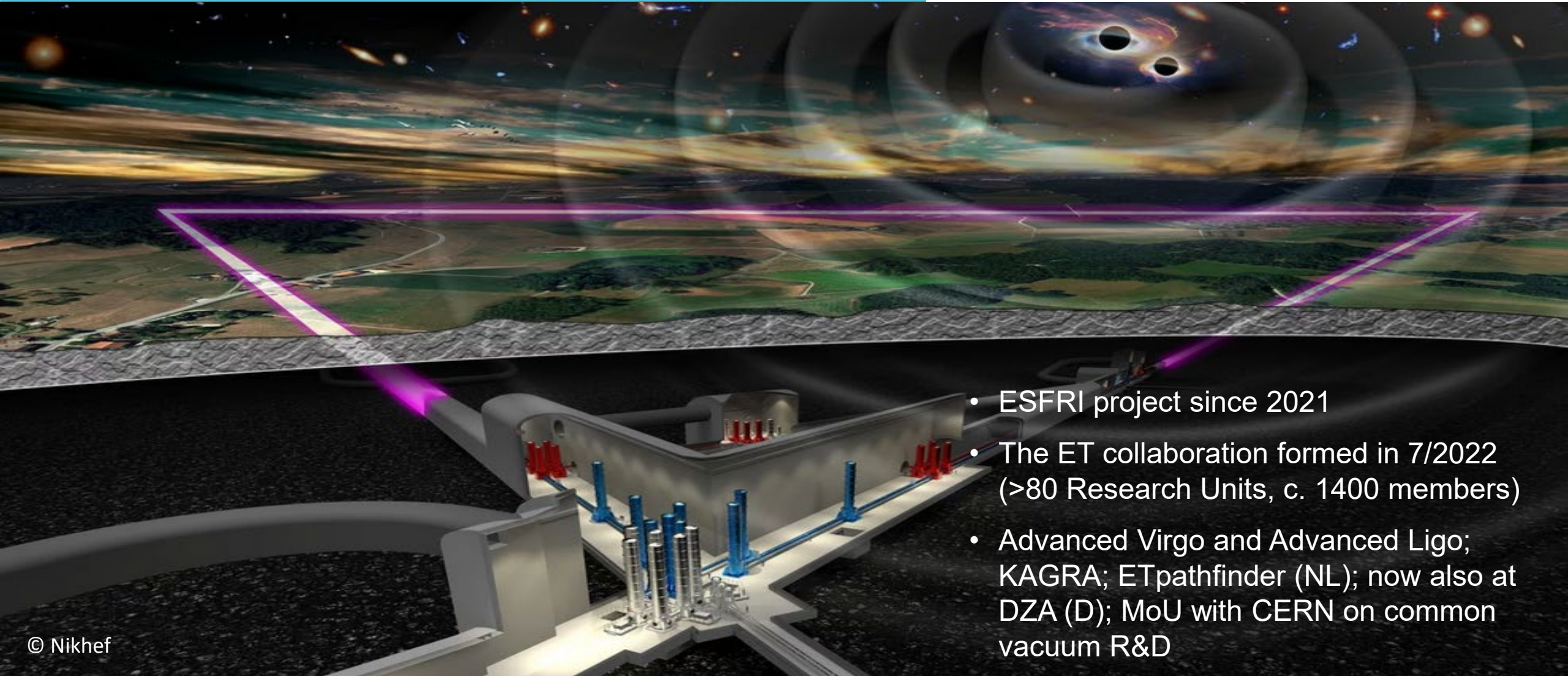
© S.Saffi/Auger

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, Cosmic Explorer
 - 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



- ESFRI project since 2021
- The ET collaboration formed in 7/2022 (>80 Research Units, c. 1400 members)
- Advanced Virgo and Advanced Ligo; KAGRA; ETpathfinder (NL); now also at DZA (D); MoU with CERN on common vacuum R&D

© Nikhef

The Dark Universe

- Experiments (often) require sophisticated Deep Underground Laboratories (DULs)
- R&D and prototyping also require DULs
- Community-overarching, synergetic research possible
- Needs long-term commitments for operation of Underground Labs.

➔ Structured Coordination of European Underground Activities and Infrastructures

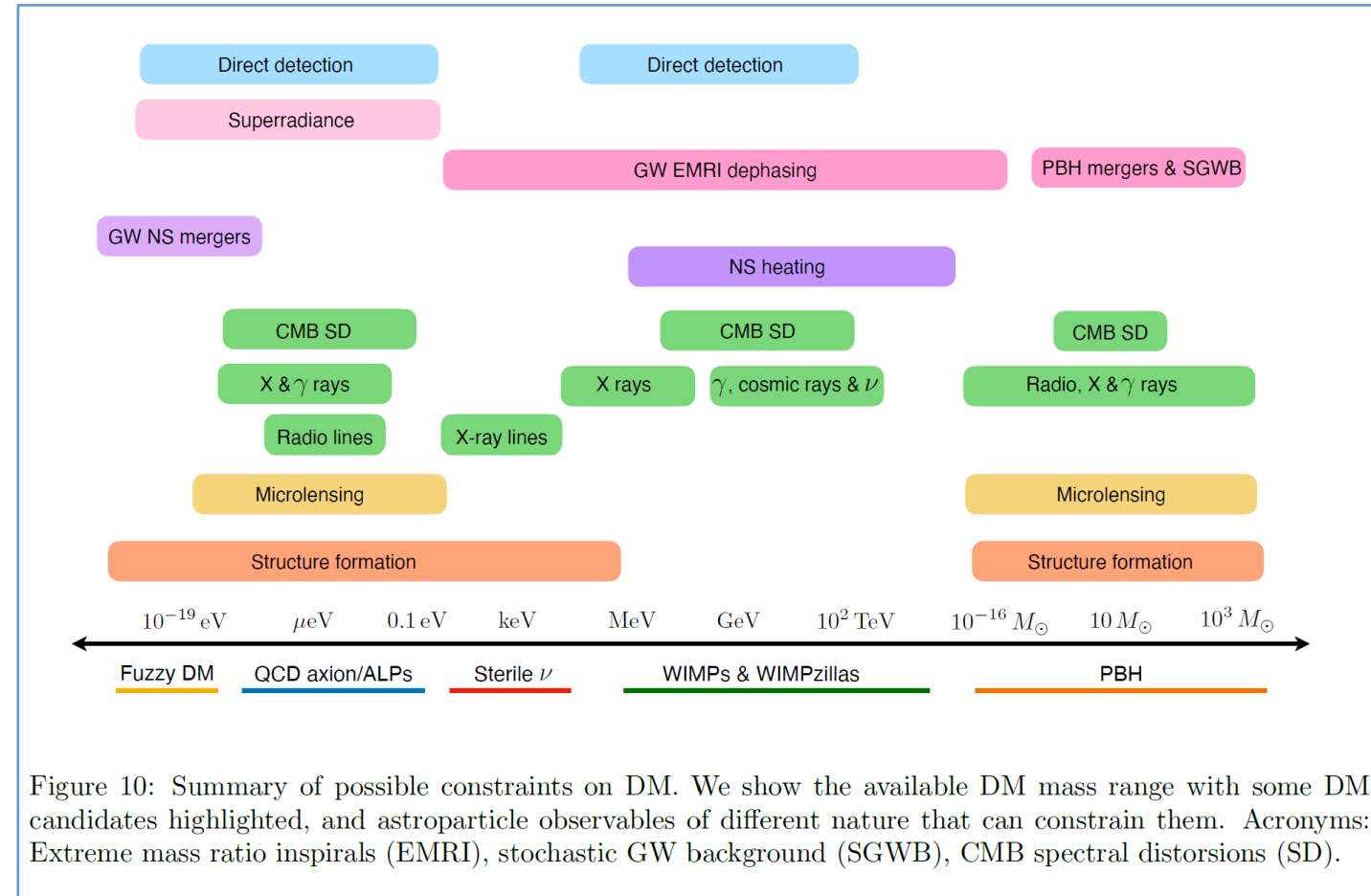


Recommendation in APPEC roadmap:

APPEC encourages the European Underground Laboratories involved in astroparticle physics to establish a Virtual Coordination Office that establishes robust cooperation in key services and support for experiments, coordinates future investments in deep underground infrastructures and establishes a trans-national access policy

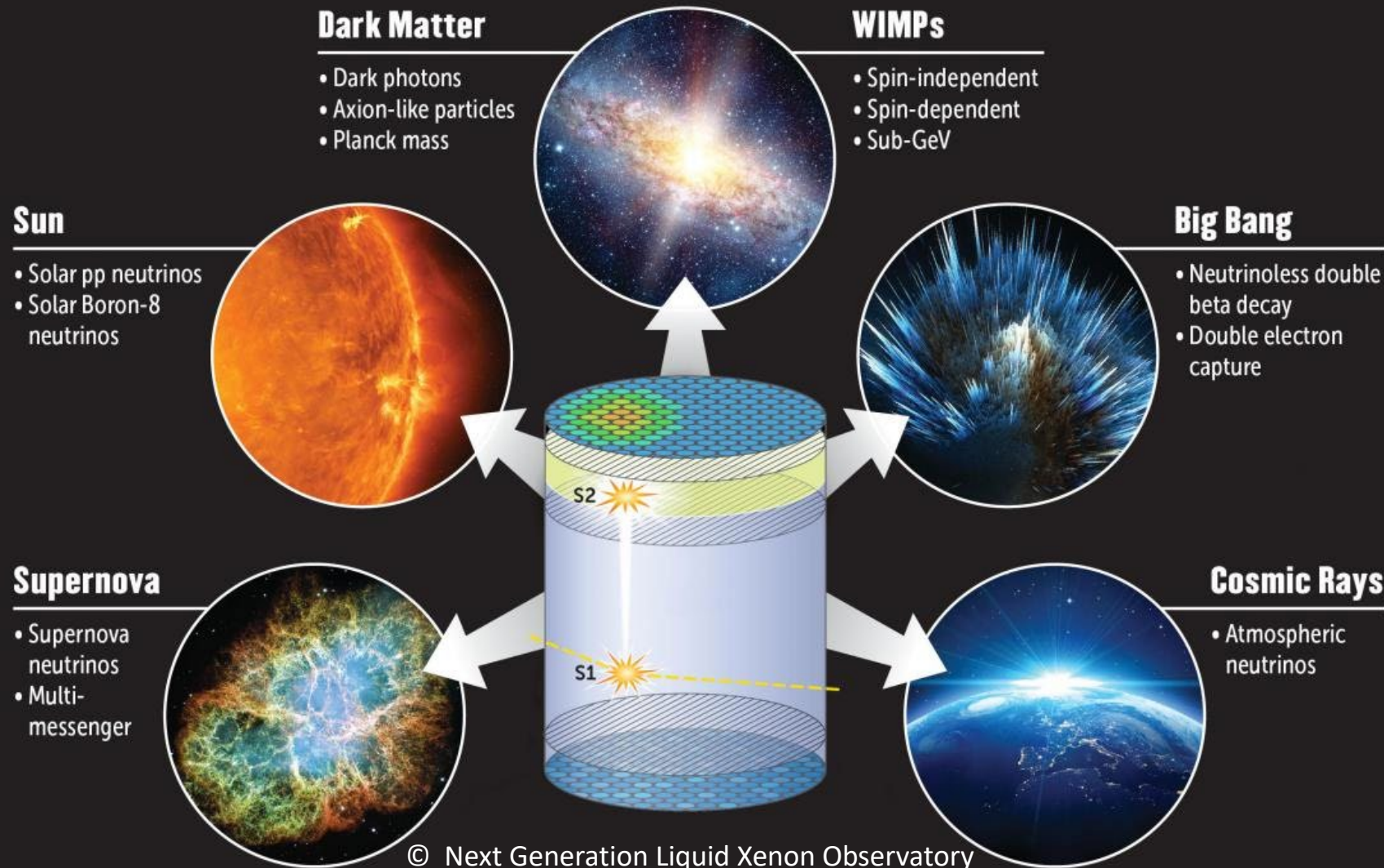
Dark Matter

- 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



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

Dark Matter WIMP search with liquid Xenon

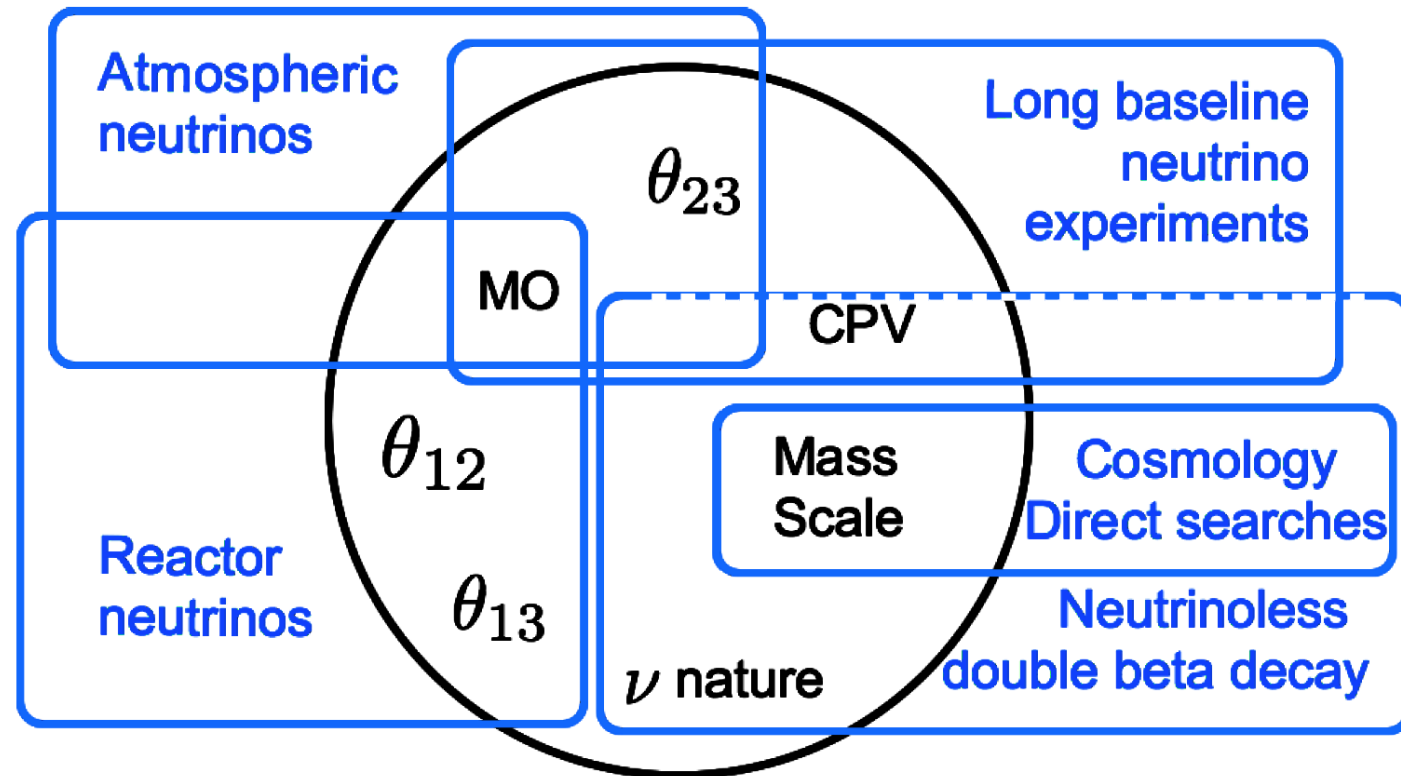


- APPEC recommends to realize worldwide at least one xenon (50t) and one argon (300t) experiment
- XENON/DARWIN and LUX-ZEPLIN → **XLZD**
- collaborations have signed a common MoU [arxiv.org/2203.02309](https://arxiv.org/abs/2203.02309) (141 institutes, ~600 authors)
- **Needs (European) infrastructures 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 is the first hot “dark” particle and has a role in various stages of the Universe
- APPEC’s RI flagship is next generation neutrinoless double beta decay experiment
- Needs (European) infrastructures for Underground Science

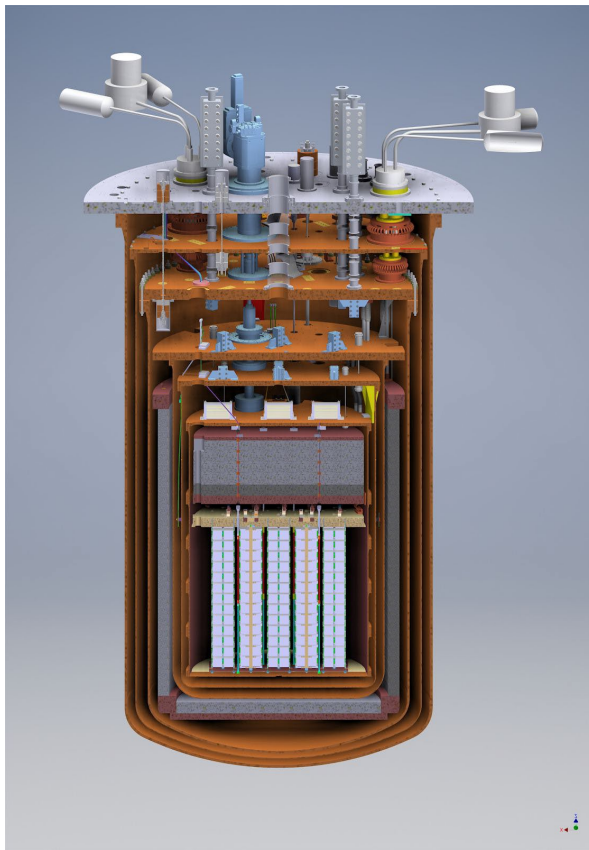
Science has large overlap with neighboring fields



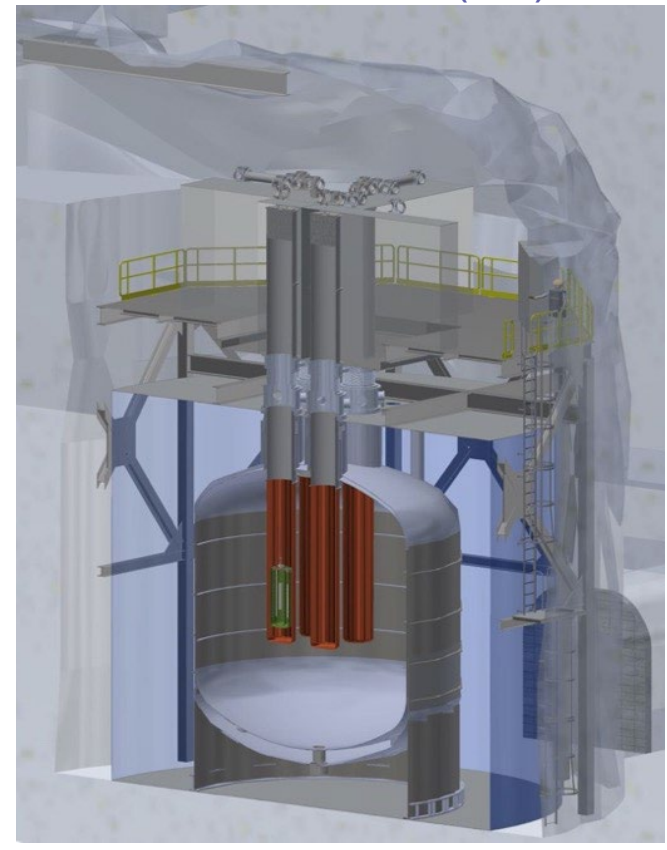
© APPEC SAC

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

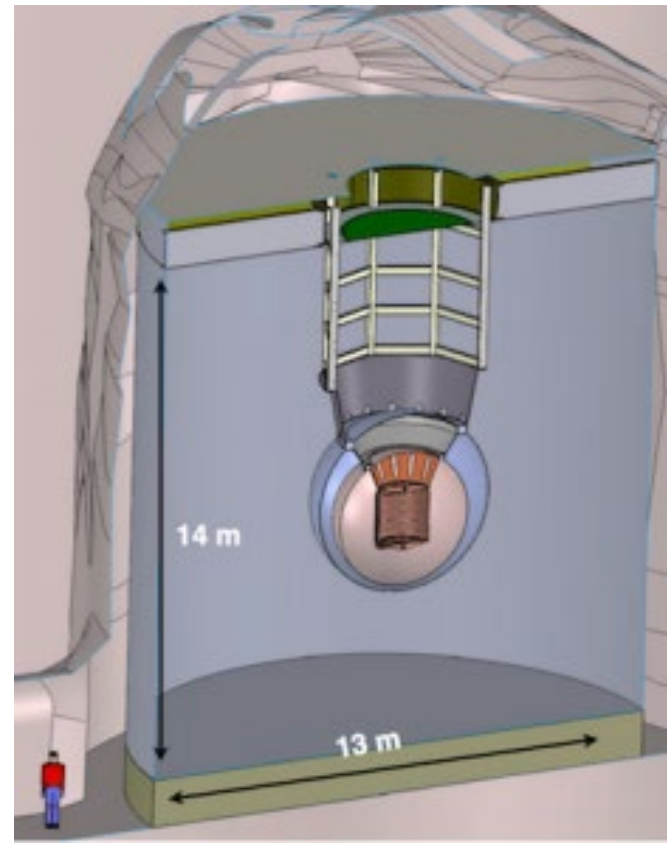
CUPID (100 Mo)



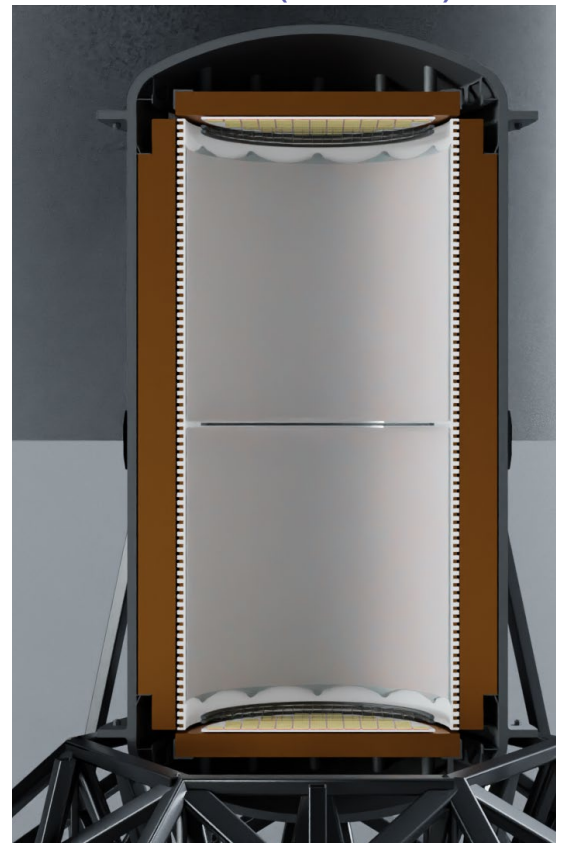
LEGEND-1000 (Ge)



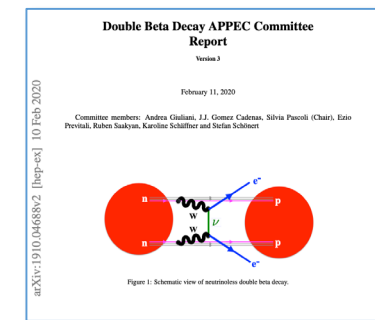
nEXO (136 Xe)



NEXT (136 Xe)



Neutrinoless Double Beta Decay



Strategy (Status 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
- $0\nu\beta\beta$ 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...

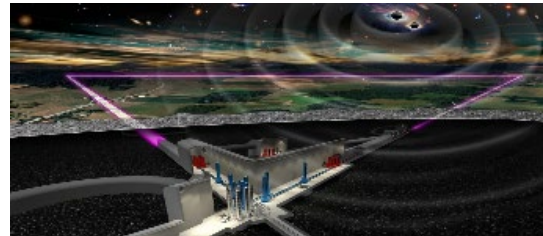
[construction KM3NeT 2020-2026; IceCube-Gen2]



ESFRI



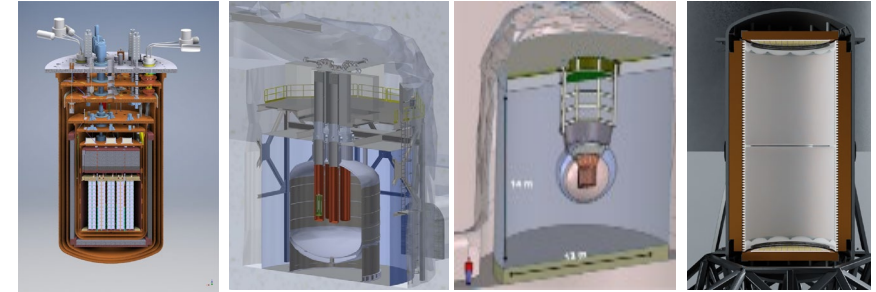
HE Neutrinos



ESFRI

[construction Einstein Telescope 2026-]

Gravitational Waves



[construction LEGEND-1000 / nEXO 2023- ; ...]

Neutrino Properties

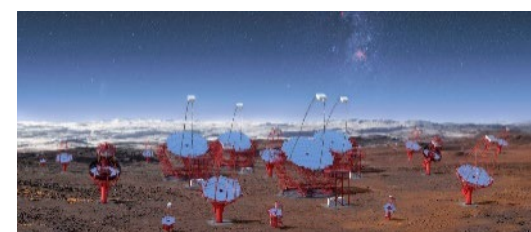


[construction AugerPrime 2019-2023]



HE Cosmic Rays

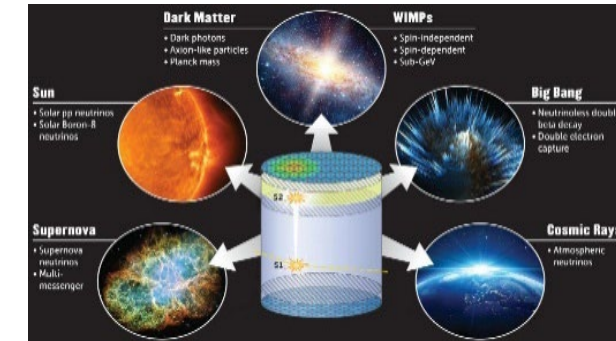
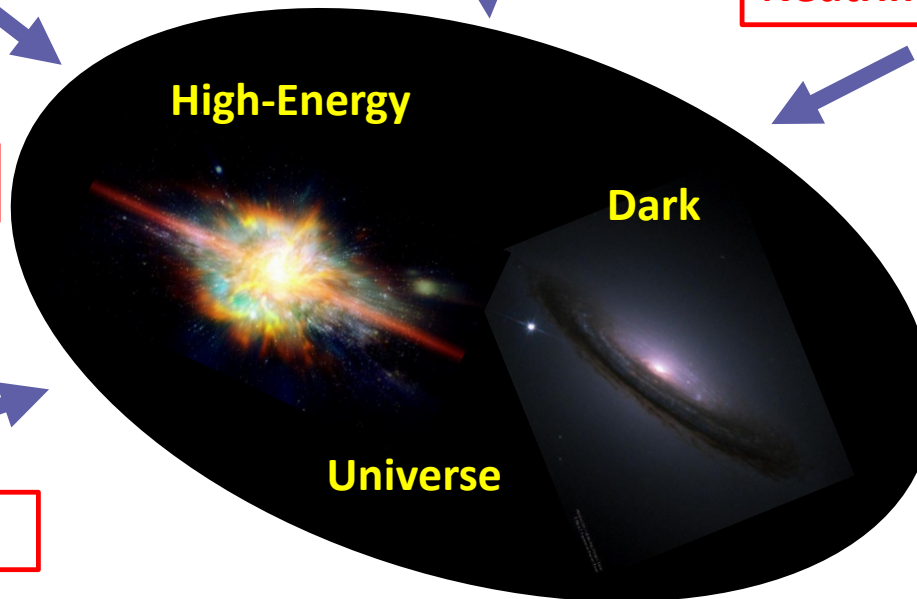
[construction CTA 2021-]



ESFRI



HE Gamma Rays



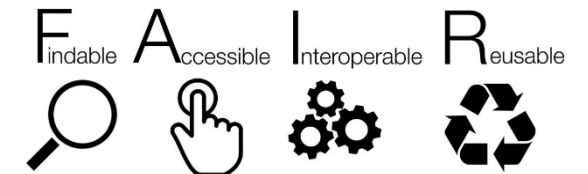
[construction DARWIN 2024- ; XLZD, ARGO, ...]



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
- Horizon Europe
 - European and global collaboration and coordination, e.g. INFRA-SERV-2023



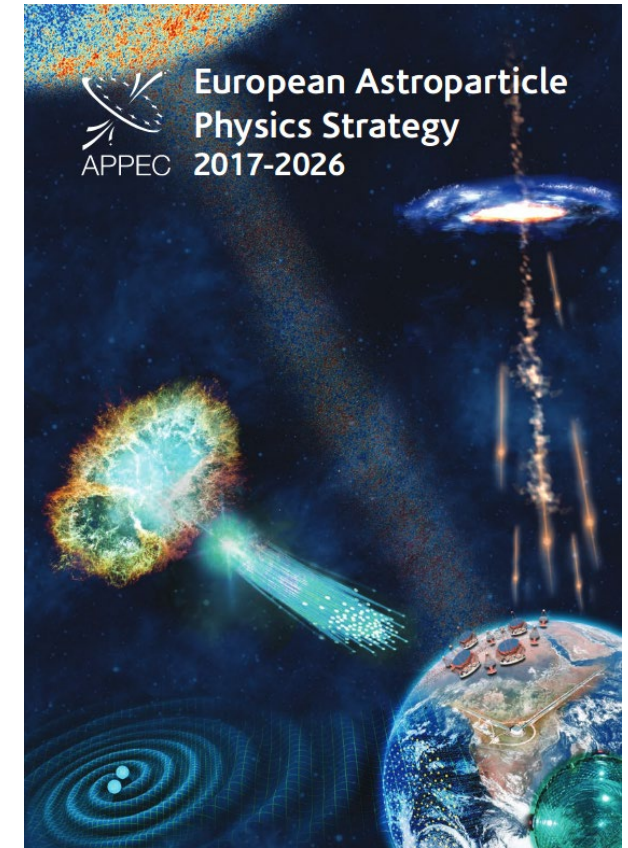
Summary



- Astroparticle Physics is a booming and blooming field
- Going to understand the fundamental law of Nature
- Operates large-scale research infrastructures
- Plenty of opportunities for young scientists

APPEC:

- Publication of a resource-aware Roadmap Update in 2023
- 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!