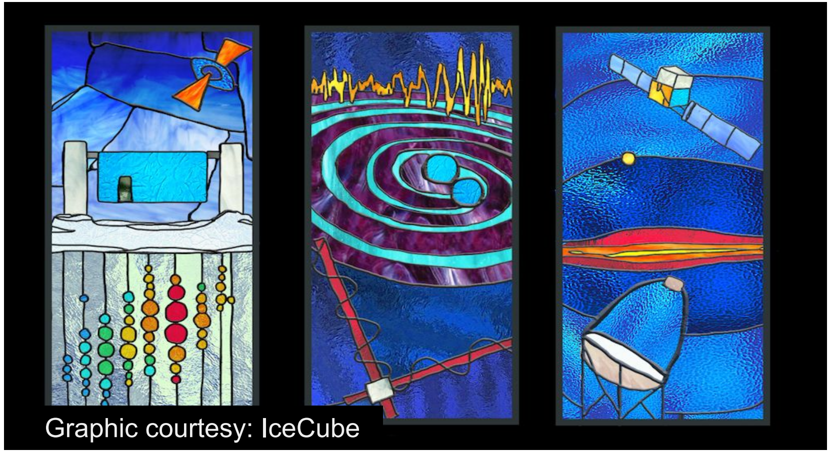
Cosmic Probes of Fundamental Physics: CF7

Using the windows on the universe to learn about fundamental particles and high energy physics

- **Science goals**: CF7 covers cosmic probes of fundamental physics topics beyond Dark Matter and Dark Energy using gravitational waves, cosmic rays, gamma rays, and neutrinos, as well as their combined studies to facilitate the multi-messenger science. It also covers various tests of ΛCDM using high and low redshift observations and the potential of standard candle/siren cosmology to address existing tensions in the data.

- **Conveners**:
  - Rana X Adhikari (Caltech)
  - Luis Anchordoqui (CUNY)
  - Ke Fang (UW-Madison)
  - B.S. Sathyaprakash (Penn State)
  - Kirsten Tollefson (MSU)
- Observers
  - Kristi Engel
  - Tiffany Lewis



Graphic courtesy: IceCube

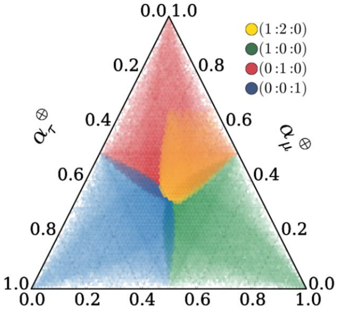
CF07: Solicited White Papers, 10 on arXiv, 2 more soon

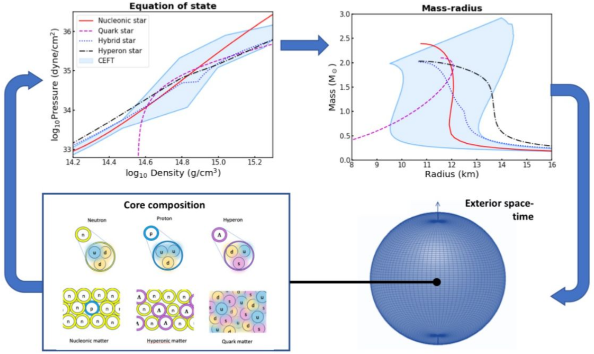
1. Advancing the Landscape of Multimessenger Science in the Next Decade [2203.10074]
2. Neutron-Star Equation-of-State (draft shared with conveners)
3. Fundamental Physics and Beyond the Standard Model [2203.06240]
4. Cosmology Intertwined: A Review of the Particle Physics, Astrophysics, and Cosmology Associated with the Cosmological Tensions and Anomalies [2203.06142]
5. Probing Dark Matter With Small-Scale Astrophysical Observations [2203.15954]
6. Detection of Early-Universe Gravitational Wave Signatures and Fundamental Physics [2203.07972]
7. The Future of Gamma-Ray Experiments in the MeV-EeV Range [2203.07360]
8. High Energy and Ultra-High Energy Neutrinos [2203.08096]
9. Future Gravitational-Wave Detector Facilities [2203.08228]
10. Ultra-High-Energy Cosmic Rays (draft shared with conveners)
11. The Forward Physics Facility at the High-Luminosity LHC [2203.05090]
12. Numerical relativity for next-generation gravitational-wave probes of fundamental physics [2203.08139]

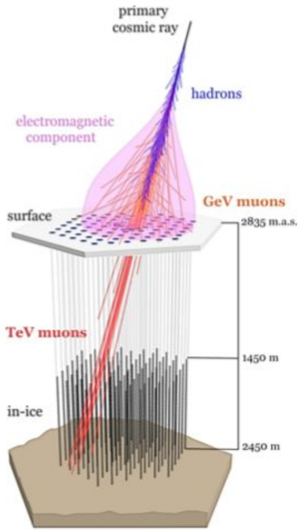
Related White Papers (incomplete at this time)

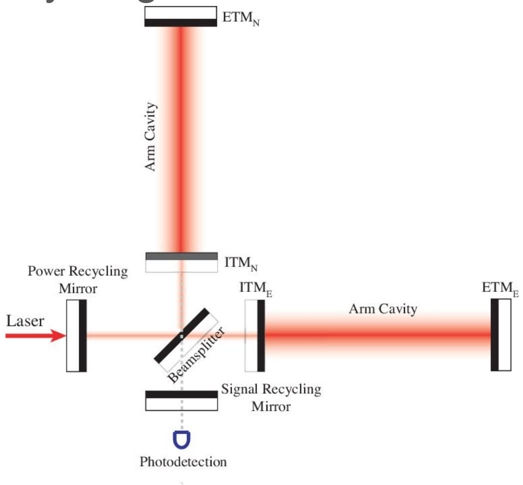
1. Axion physics [2203.08026]
2. Cosmology at the EF [2203.07629]
3. Inflation Theory and Observations [2203.08024]
4. Warped compactifications with GW predictions for LISA [2203.07533]
5. CMB-S4 whitepaper [2203.08024]
6. CMB measurements [2203.07638]
7. Physics of light relics [2203.07943]
8. UV constraints on IR Physics [2203.06805]
9. Synergies between dark matter searches and multiwavelength/multimessenger astrophysics [2203.06781]
10. Prompt neutrinos at the LHC [2203.07212]
11. Early universe model building [2203.06680]
12. Ultraheavy particle dark matter [2203.06508]
13. Dark matter physics from CMB-S4 experiment [2203.07064]
14. Astrophysical and cosmological probes of dark matter [2203.06380]
15. Searches for New Particles, Dark Matter, and Gravitational Waves with SRF Cavities [2203.12714]
16. Properties of Non-Minimal Dark Sectors [2203.17258]
17. Physics in a diverse world [2203.09485]

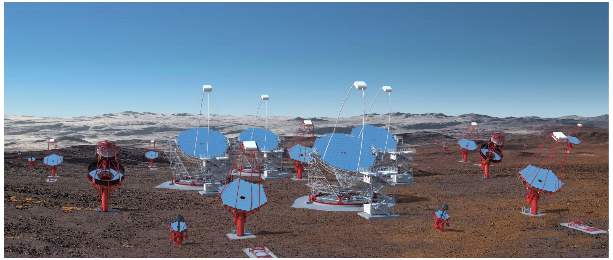
Draft outline: Goals, Context, Opportunities, Collaboration, Everything Else

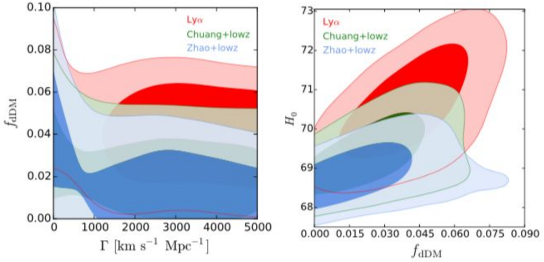


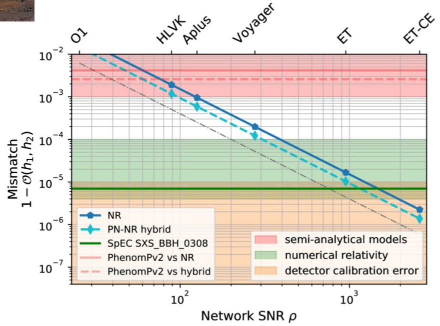


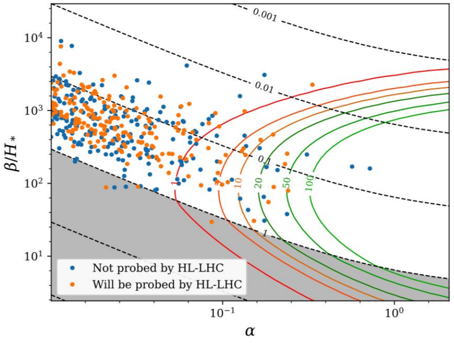


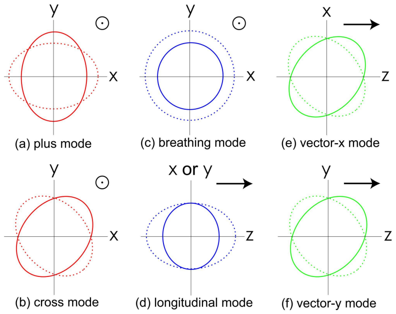












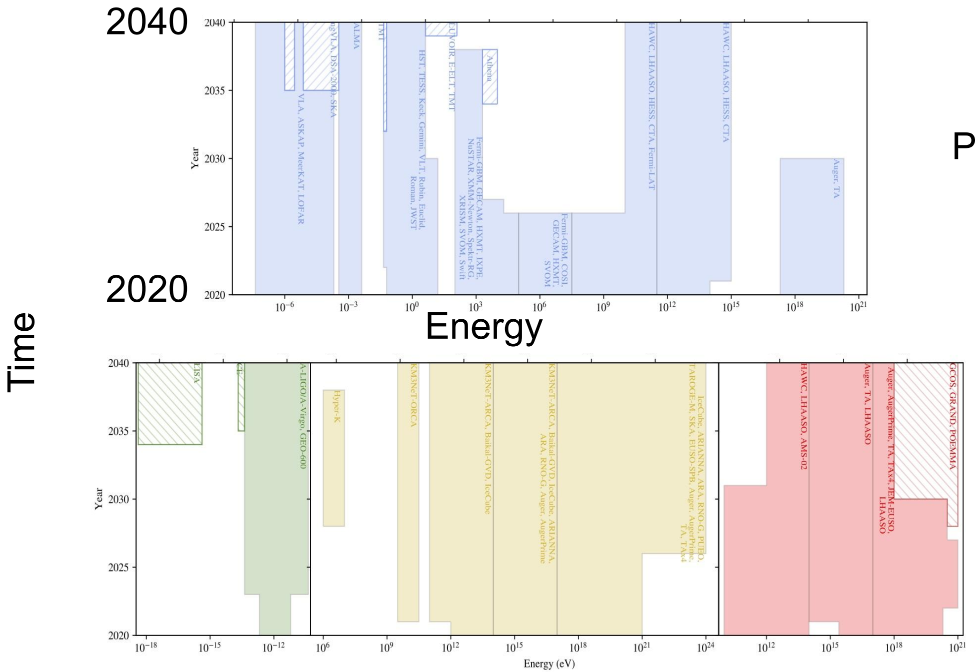
Goals

Planning for 2025-2035 with a view toward 2050 (comments welcome on each from any frontier)

- What are the important scientific questions in the CF7 topical group during this period?
- What enabling tools, technologies, or facilities studied by the CF7 topical group are needed to address the pressing scientific questions in particle physics during this period?
- How can we ensure that the US particle physics community is vibrant, inclusive, diverse, and capable of addressing the scientific questions identified, and of fulfilling our obligations to society during this period?

Context

What can be expected from ongoing, approved, or planned scientific, technical, or community programs in addressing the issues identified by the CF7 topical group?



Photons

GWs/Neutrinos/CRs

Opportunities

- What opportunities (identified by the CF7 topical group) are there for new scientific, technical, and community activities to create transformative change in particle physics, on what timescales could these occur, and what resources are required to realize these activities?

- What investments need to be made during 2025-2035 for the continuing scientific, technical, and community progress identified by the CF7 topical group in the decades beyond, on what timescales can these be implemented, and what resources would be required?

Collaboration

- What opportunities exist for cross-frontier, cross-disciplinary, or international collaboration and cooperation in the coming decade to enhance our ability to address the issues identified?
- How do these collaborations affect the timescales or resources needed for these activities?

ASCL Code Record

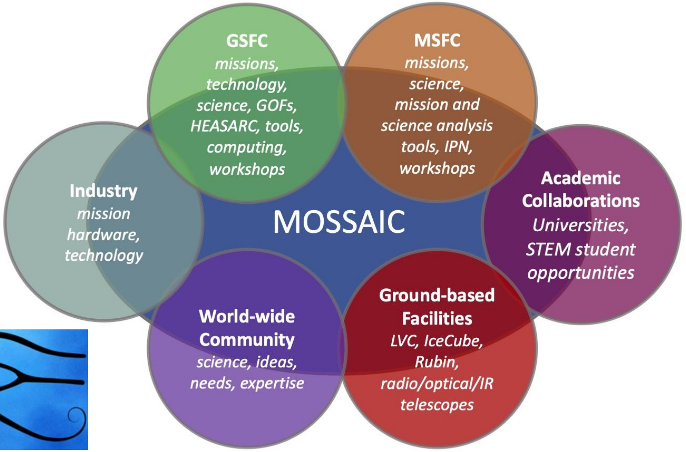
[ascl:1205.004] Turbospectrum: Code for spec
Plez, B.

Turbospectrum is a 1D LTE spectrum synthesis code which cover
lines, and uses the treatment of line broadening described by Ba

Code site: https://github.com/bertrandplez/Turbospectrun
Used in: https://ui.adsabs.harvard.edu/abs/1998A%26A.
https://ui.adsabs.harvard.edu/abs/2012A%26A.

Bibcode: 2012ascl.soft05004P

Preferred citation method:
https://ui.adsabs.harvard.edu/abs/2012ascl.soft05004P



Everything Else

- Are there other issues identified by the CF7 topical group that are not included in the responses to the questions above?

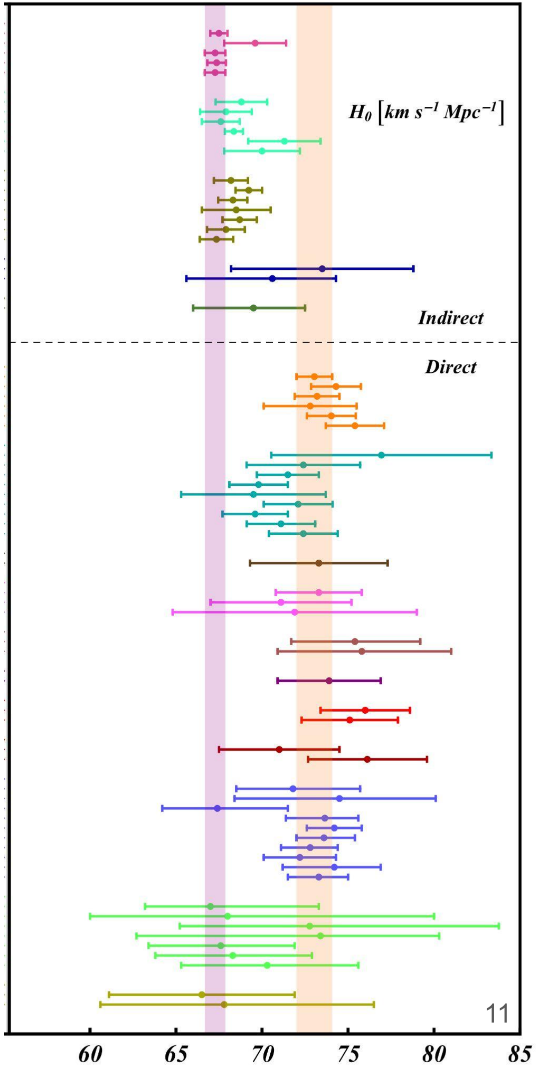
- In particular, are there adverse scientific, technical, or community impacts from the COVID-19 pandemic that still need to be addressed?

Goals

- Scientific Questions are grouped under five topics
  - History of the Universe and Cosmology
  - Cosmic Probes of Dark Matter
  - High Energy Physics with Cosmic Particles and Multimessengers
  - Particle Astrophysics
  - Architecture of Spacetime
- We will list questions identified in all the WPs under these heads
  - might require additional topics …
- Currently in the process of identifying
  - enabling tools, technologies, or facilities
  - address issues of diversity, equity and inclusion

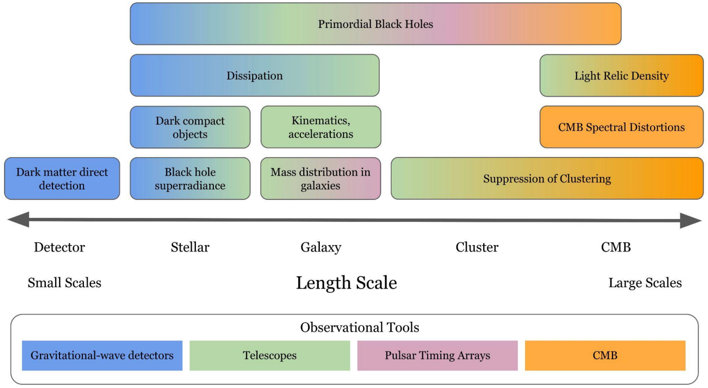
1. History of the Universe and Cosmology

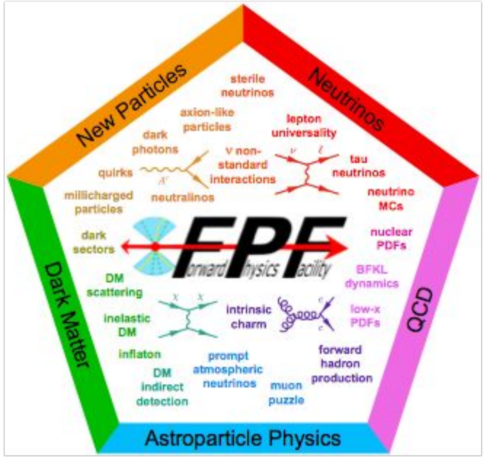
- Why is the Hubble constant measured with low redshift probes different from the value inferred with ΛCDM normalized the cosmic microwave background data?
- Is the Hubble tension a footprint of physics beyond the Standard Model?
- How did the inhomogeneity in the matter density of the early universe impact the evolution of matter distributions?
- What are the imprints of early universe phase transitions and inflation in the stochastic gravitational-wave backgrounds?
- What can ultra-high-energy cosmic rays and advances in constraint-based modelling of Grand Unified Theories tell us about the origin of the Universe?
- How can we exploit the wealth of information from multimessenger sources to map the cosmic expansion history up to high redshifts



2. Cosmic Probes of Dark Matter

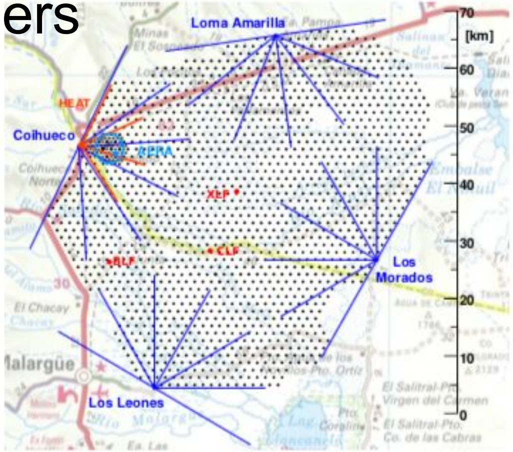
- Is there a portal connecting the dark and visible sectors?
- What fraction of dark matter is in primordial black holes and are there currently evaporating primordial black holes?
- Could the dark sector consist of a vast ensemble of particle species whose decay widths are balanced against their cosmological abundances?
- What is the impact of electroweak emission on the measurement of heavy dark matter candidates?
- What is the distribution of Dark Matter in galaxies and how did that distribution evolve?
- What are the gravitational-wave signatures of dilute dark matter distributions?

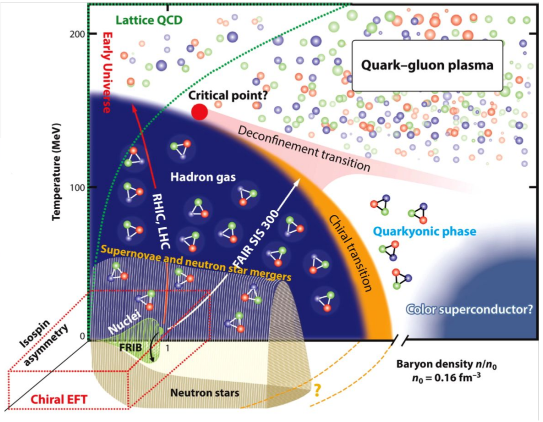


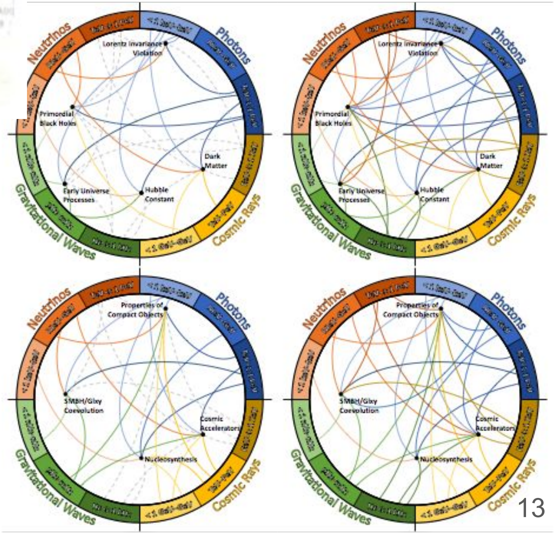


3. High Energy Physics with Cosmic Particles and Multimessengers

- What are the properties of particles (such as neutrino oscillations) and their interactions beyond the reach of terrestrial accelerators?
- Could an enhancement of strangeness production in hadronic collisions be the carrier of the observed muon deficit in air shower simulations when compared to ultra-high-energy cosmic ray data?
- Alternatively, do new particles and interactions exist at the highest energies?
- How does matter behave in the centers of neutron stars?
- What are the physical properties of matter at ultra-high density, large proton/neutron number asymmetry, and low temperature?
- Are there new fundamental symmetries?

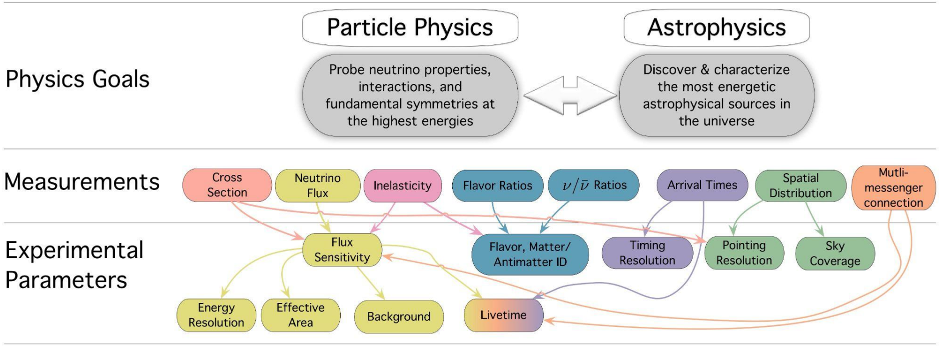


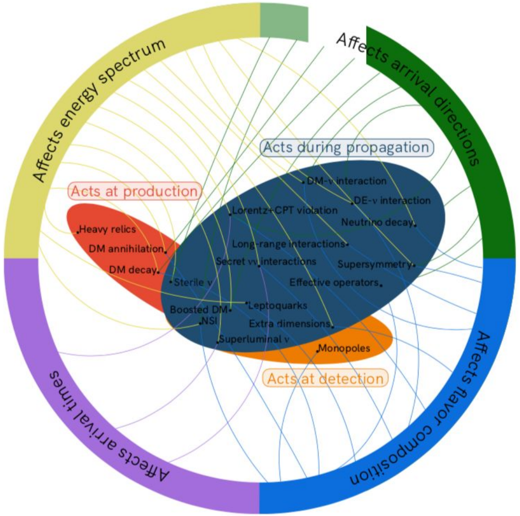


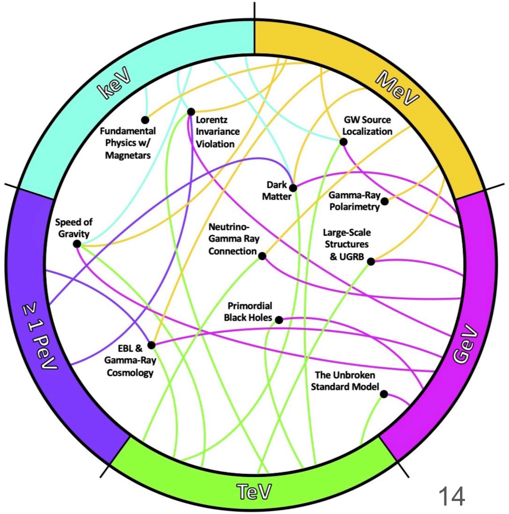


4. Particle Astrophysics

- What are the strength and structure of the Galactic and extragalactic magnetic fields?
- How are high-energy gamma-rays and neutrinos produced and cosmic rays accelerated in the cosmos?
- Where and how does nucleosynthesis occur in the Universe?
- What role do hadrons play in astrophysical jets?
- Does the QED domain (extreme magnetic fields) produce exotic particles or dark matter?

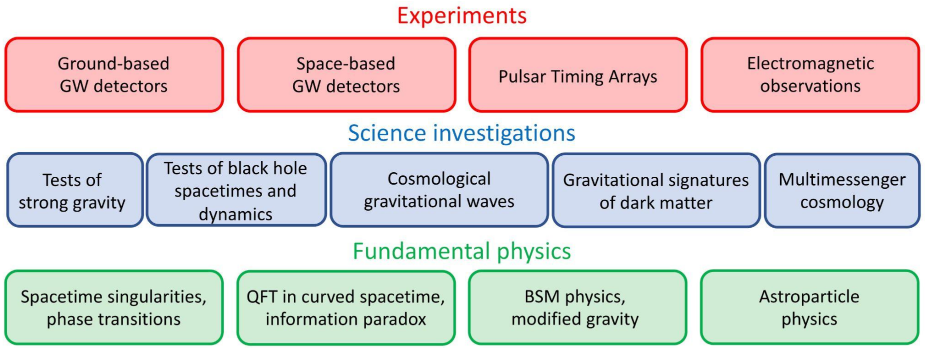


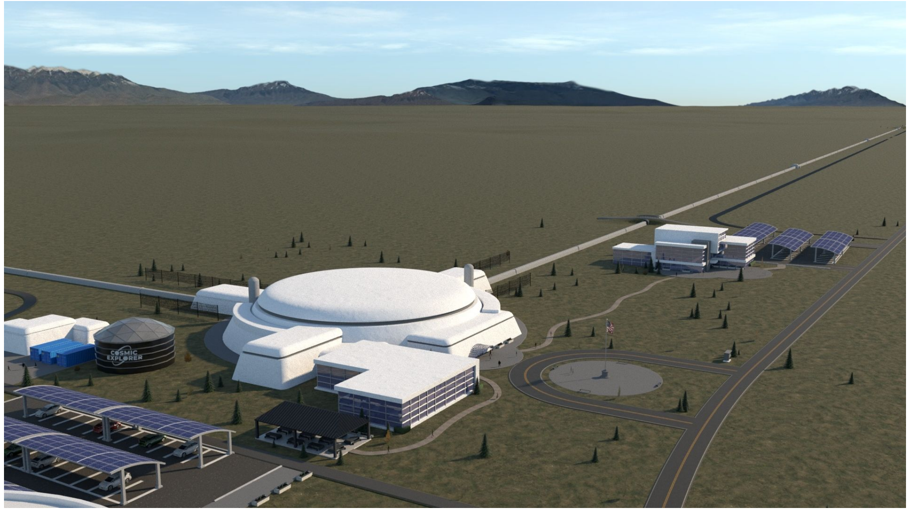




5. Architecture of Spacetime

- Is local Lorentz invariance a fundamental symmetry of nature, does the graviton have a mass, and what is the speed of gravity?
- What are the true degrees of freedom in gravitational-wave polarizations?
- What are the connections between astrophysical tests of GW production and propagation and laboratory tests of gravity?
- Is there a modification of general relativity that explains the origin of dark matter and dark energy?
- What can we learn about black hole dynamics from EM and GW tests of Einstein's theory?
- What are the nonsingular, horizonless alternatives to black holes?
- Is there a fundamental length scale of the Universe?





Conclusions

- Timeline
  - April: Conveners read the solicited (and all the relevant) WPs and draft the report
  - May 1: circulate draft report to the community
  - May 4: 1-3 pm, CF07 meeting to receive feedback from the community (it will also be possible to provide comments online)
  - May 26: revised report
  - May 31: Submit the first draft to CF
  - June: Further commenting period
- Planning the Workshop
  - July 17-26: Snowmass Summer Study Workshop
  - What’s the best way to organize the workshop to have the maximum impact?