



# Division of Physics Perspective

Saul Gonzalez  
Division Director

Division of Physics  
National Science Foundation

AAAC Meeting - September 20, 2024

# Preliminaries

- Today:
  - Context
  - Our perspectives on recent advisory committee reports
  - Brief status of Astrophysics in the Physics Division
- Division changes
  - Jean Cottam Allen: Deputy Division Director → (Acting) Director, Office of Polar Programs (GEO) since February 2024
  - Michael Cavagnero: Program Director → (Acting) Deputy Division Director
  - Saul Gonzalez: Division Director since December 2023
- Scope of Astrophysics in PHY: dark matter, non-accelerator neutrinos, underground low-background science, cosmic rays, gamma rays, nuclear, plasma
  - Camillo Mariani, Helio Takai, William Wester: Program Directors (Experiment)
  - Keith Dienes: Program Director (Theory)
- Gravitational Physics Program
  - Pedro Marronetti: Program Director (Experiment and Theory)



# Context: Astrophysics at the NSF Division of Physics

- Primarily funds individual investigators, postdocs, and students at U.S. universities and engineers, computing professionals, and technicians to develop new or maintain existing facilities
- Also includes center and institutes, such as PFC, AI Institute, ...
- Covers Experimental, Observational, Theoretical, Computational techniques
- Has strong links to the Astronomy Division, Office of Polar Programs, DOE
- Is part of a Division that supports many other areas in Physics such as Nuclear Physics, Plasma Physics, Atomic Molecular and Optical Physics, Gravitational Physics, Physics of Living Systems, and Quantum Information Science

How do we set priorities? Community-driven in the context of Physics, MPS, and NSF priorities



# Community Input to MPS and the Division of Physics

Gravitational  
Physics

Laser  
Technology

Particle  
Physics

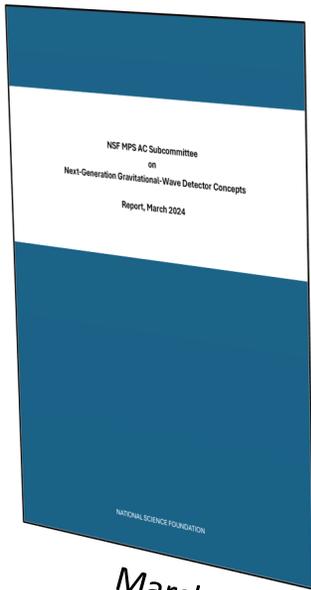
Nuclear  
Physics

Physics of  
Living Systems

Astronomy  
Astrophysics

Plasma  
Physics

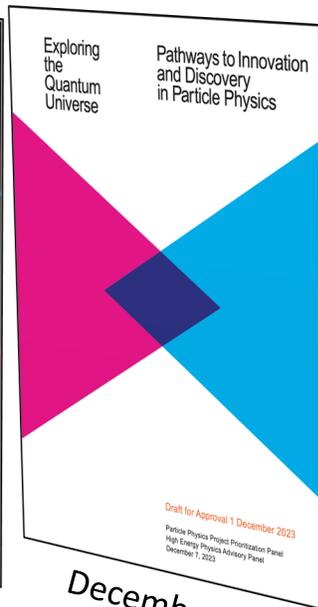
AMO  
Physics



March 2024



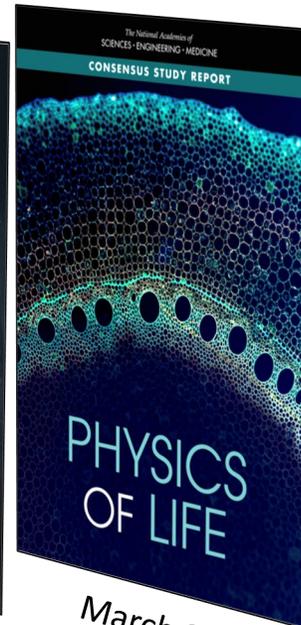
January 2024



December 2023



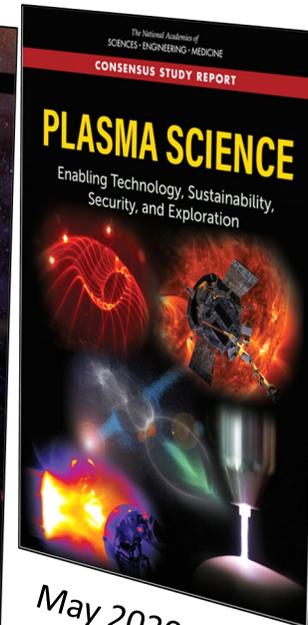
October 2023



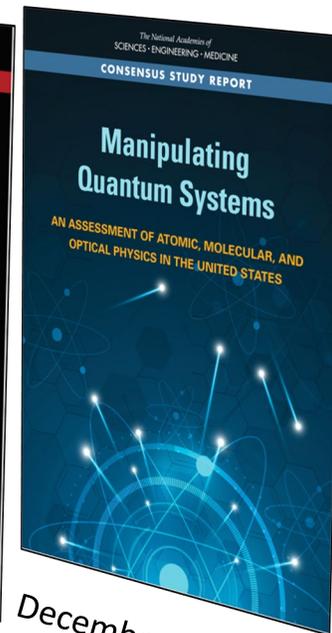
March 2022



November 2021



May 2020



December 2019

**Next: NASEM EPP2024, “Elementary Particle Physics: Progress and Promise”**



# Physics and MPS Project Prioritization

- As the science disciplines push their respective frontiers, the aspiration for research facilities exceeds what budgets can accommodate
- There is thus a need to prioritize across disciplines
- Over a year ago, we charged our MPS Advisory Committee to develop a framework for prioritization.
- Recommendations fall in 3 categories:
  - Science & Technical need and impact
  - Readiness to Proceed
  - Alignment to Broader Missions

**2<sup>nd</sup> Report from the MPS AC Subcommittee  
on  
MPS Facilities and Major Research Infrastructure  
December 2023**

<p><b>Jill Pipher (co-chair)</b> Vice President for Research Elisha Benjamin Andrews Professor of Mathematics Brown University</p>	<p><b>Roger Falcone (co-chair)</b> Professor of the Graduate School Professor of Physics University of California, Berkeley</p>	
<p><b>Patricia M. Dehmer</b> Deputy Director for Science Programs Department of Energy (retired)</p>	<p><b>Jerry Blazey</b> Vice President for Research and Innovation Partnerships Northern Illinois University</p>	
<p><b>Tabbatha Dobbins</b> VP for Research &amp; Dean of the Graduate School, Professor, Department of Physics &amp; Astronomy Rowan University</p>	<p><b>Andrew J. Millis</b> Co-Director, Center for Computational Quantum Physics, The Flatiron Institute, &amp; Professor of Physics, Columbia University</p>	
<p><b>Marc Kastner</b> Professor Emeritus Massachusetts Institute of Technology</p>	<p><b>Juan de Pablo</b> Executive Vice President for Science, Innovation, National Laboratories and Global Initiatives University of Chicago</p>	
<p><b>Markus Kissler-Patig</b> Head of Science and Operations European Space Astronomy Center (ESAC) European Space Agency, Madrid, Spain</p>	<p><b>Cornelia C. Lang</b> Associate Dean for Undergraduate Education Professor of Physics and Astronomy University of Iowa</p>	
<b>NSF MPS Staff</b>		
<p><b>Saul Gonzalez</b> Senior Advisor</p>	<p><b>R. Chris Smith</b> Senior Advisor for Facilities</p>	<p><b>Nelyan Lopez Perez</b> Executive Secretary/Facilities</p>

**AC Subcommittee on  
Facilities and Major Research  
Infrastructure**

**Report, December 2023**



# P5 Recommendation 1

**P5:** *As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science.*

a) through g): *HL-LHC, DUNE, Vera C Rubin, IceCube, DarkSide-20k, LHCb...*

**NSF perspective:** Yes, absolutely. Let's complete ongoing projects and extract as much science as we can from existing or soon-to-start facilities

**IceCube Upgrade**



Image Credit: IceCube Upgrade

**Vera C. Rubin**



**DarkSide-20k**



The DarkSide-20k experiment (arxiv.org)

**LHCb**



Image Credit: CERN



# P5 Recommendation 2

**P5:** *Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future. [in priority order:]*

*a) CMB-S4, which looks back at the earliest moments of the universe to probe physics at the highest energy scales. It is critical to install telescopes at and observe from both the South Pole and Chile sites to achieve the science goals*

## **NSF perspective:**

- NSF is prioritizing Antarctic infrastructure recapitalization projects, which are necessary to maintain the viability and safe operation of that important resource for future science projects.
- NSF has decided not to move CMB-S4 forward to the Design Stage at this time. Therefore, recommendation 2a) cannot be currently implemented.
- We are working with DOE and will work with the community to explore possible options for CMB science that do not depend on the Antarctic infrastructure.



## P5 Recommendation 2 (continued)

**P5:** *Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future. [in priority order:]*

*e) IceCube-Gen2 for study of neutrino properties using non-beam neutrinos complementary to DUNE and for indirect detection of dark matter covering higher mass ranges using neutrinos as a tool*

### **NSF perspective:**

- There is currently no defined timescale for IceCube-Gen2, although we know that Antarctic infrastructure needs provides an important constraint.
- Currently, we are focused on completing the ongoing IceCube upgrade. Results from that upgrade will inform any future plans for IceCube-Gen2



# P5 Recommendation 3

**P5:** *Create an improved balance between small-, medium-, and large-scale projects to open new scientific opportunities and maximize their results, enhance workforce development, promote creativity, and compete on the world stage.*

*b) Continue Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs as a critical component of the NSF research and project portfolio.*

## NSF perspective:

- We agree. The FY 2025 President's Budget Request for NSF includes requests for MRI, MSRI-1, and MSRI-2. The Division has benefitted from these programs.
- Latest MSRI-1 Solicitation: [NSF 24-598](#)



Photo Credits: University of Michigan



## P5 Recommendation 3 (continued)

**P5:** *Create an improved balance between small-, medium-, and large-scale projects to open new scientific opportunities and maximize their results, enhance workforce development, promote creativity, and compete on the world stage.*

*c) Support DESI-II for cosmic evolution, LHCb upgrade II and Belle II upgrade for quantum imprints, and US contributions to the global CTA Observatory for dark matter.*

### **NSF perspective:**

c) We acknowledge this recommendation (LHCb, CTA). Working with the respective communities, we will consider their plans in the context of budgets and priorities.



# LIGO Status



LIGO-Virgo-KAGRA 4<sup>th</sup> observational run (O4) is split into:

**O4a:** May 24, 2023, to January 16, 2024

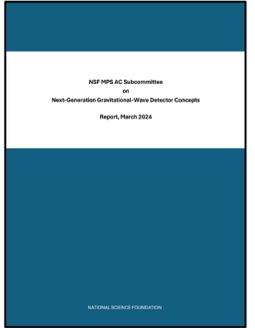
**O4b:** April 10, 2024, to June 9, 2025

For a total of 21 months of observing time.

As of Sept 10, 2024, **128 new GW events have been detected during O4.** The total number of LIGO detections is 218.



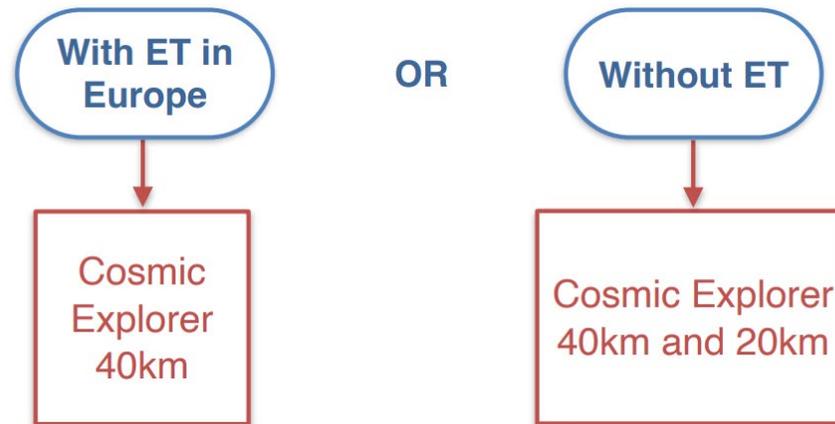
# A next-generation GW observatory in the U.S.



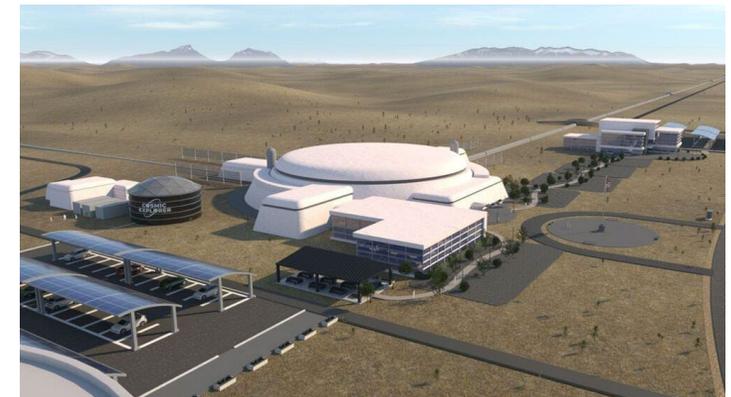
In 2023, MPS convened a review panel to study the landscape of next-generation GW observatories in the U.S. In March 2024, the panel (or MPS AC sub-committee) recommended potential candidate configurations for such observatories as MREFC projects. Recommendations:

ET = Einstein Telescope ([et-gw.eu](http://et-gw.eu)), a 3<sup>rd</sup> gen GW detector concept in Europe

The full report can be found at [www.nsf.gov/mps/phy/nggw.jsp](http://www.nsf.gov/mps/phy/nggw.jsp)



CE 40km concept



Credit: A. Nguyen, V. Kitchen, E. Anaya (CSU - Fullerton)



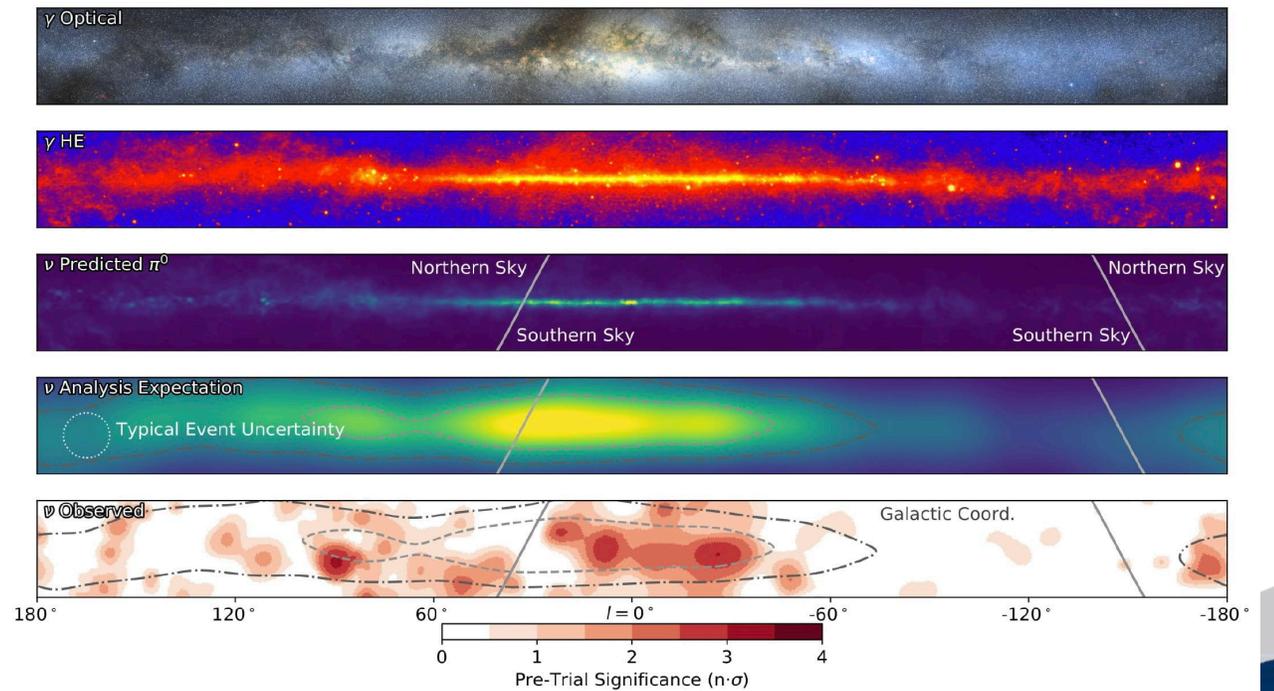
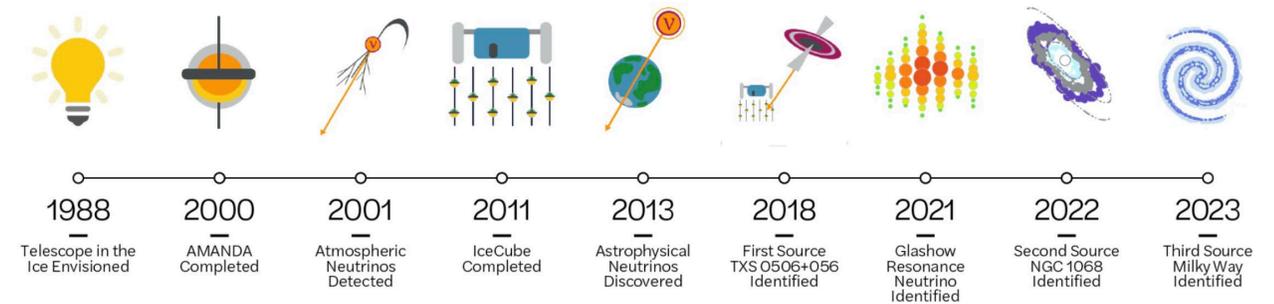
# IceCube Neutrino Observatory

Recent IceCube discoveries/observations show the benefits of better calibrations, better sensitivity, more data, and improved analyses techniques such as incorporating AI/ML.

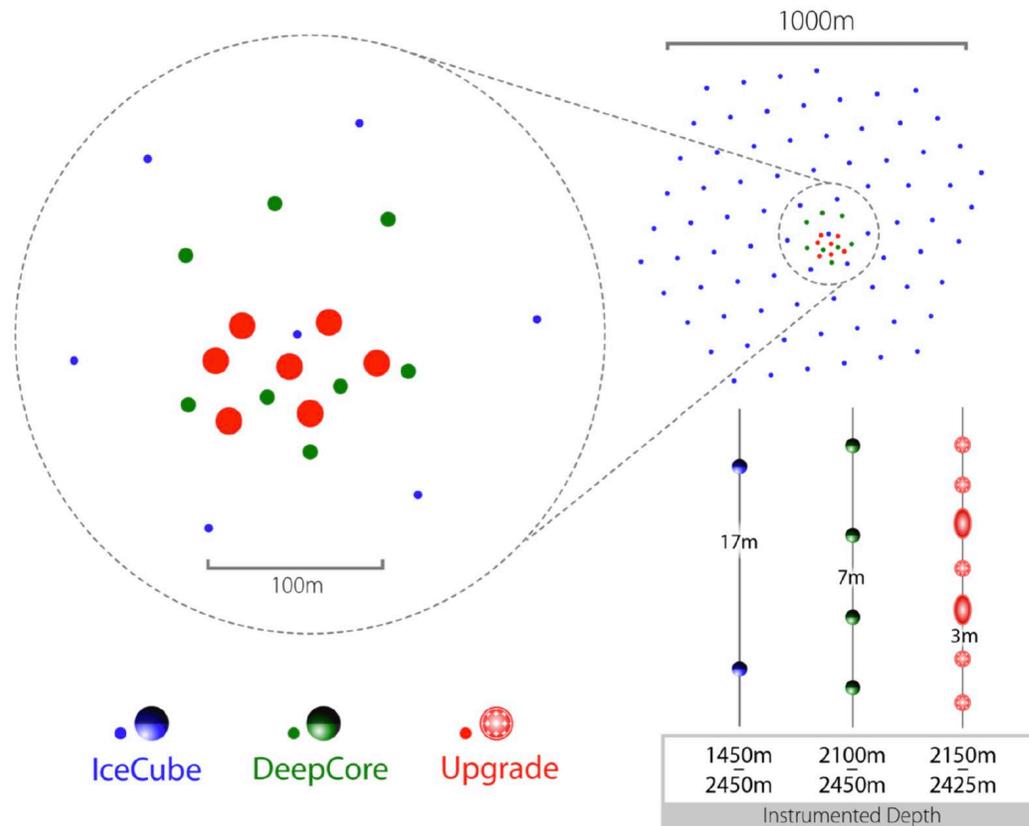
The Milky Way observed in neutrinos consistent with expectations from other messengers (2023).

NSF CAREER scientist at Drexel, Naoko Kurahashi Neilson, along with German collaborators were key to this result.

*MPS/PHY + GEO/OPP partnership*

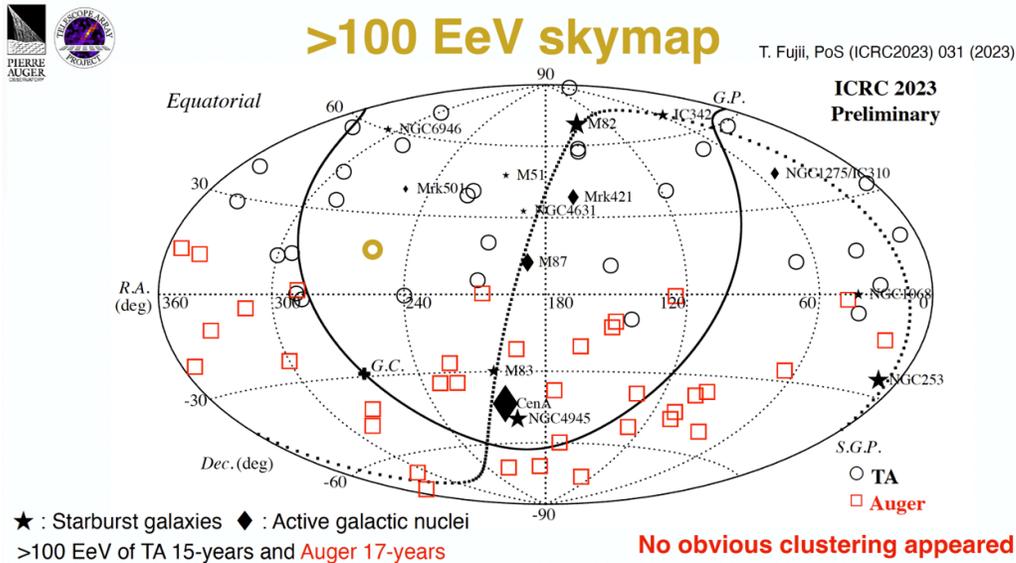


# IceCube Upgrade (ongoing)



- **Scope:**
  - Seven new in-fill strings, densely instrumented
  - Target mass: 2 Mt.
- **Objective:**
  - Precision measurement of atmospheric neutrino oscillations, mass hierarchy
  - Improved calibration
  - Technology development
- **Ongoing construction:**
  - Scheduled completion 2025/2026

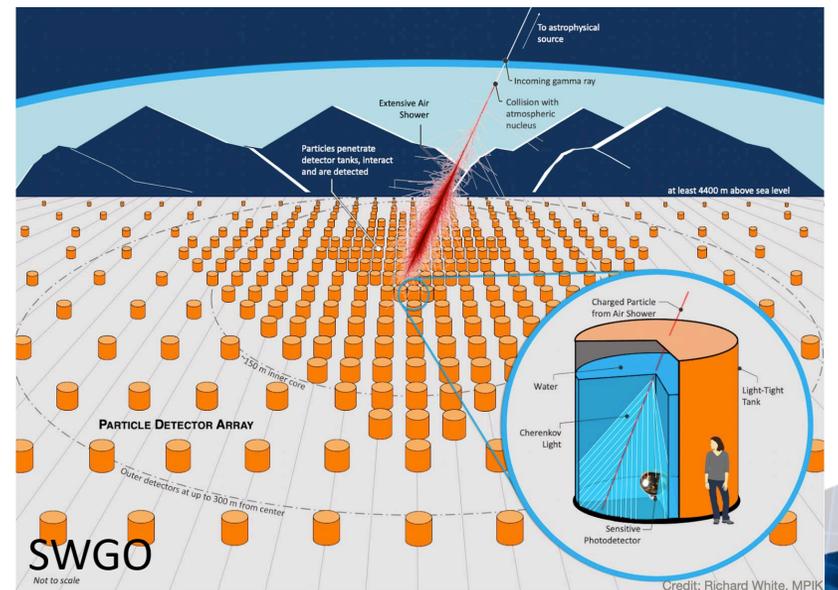
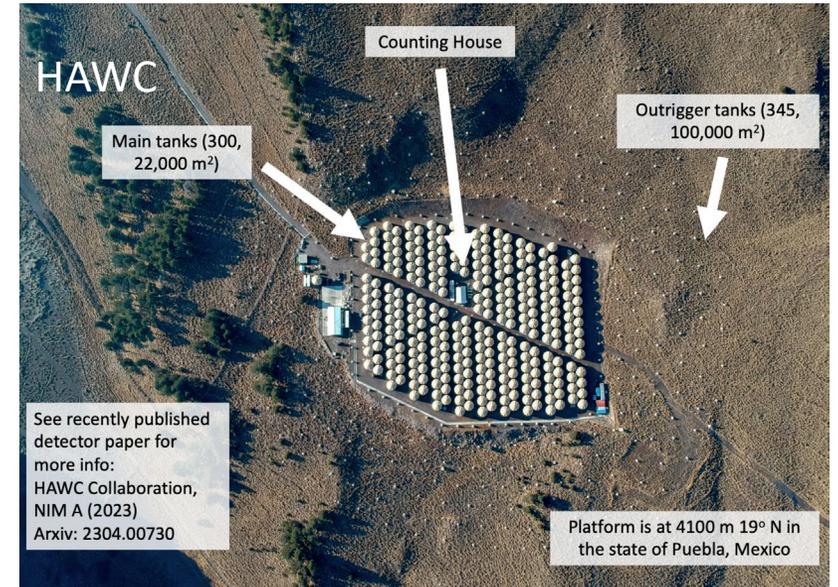
# Particle Astrophysics: Ultra High Energy Cosmic Rays



- **Pierre Auger:** data taking through 2025 (AugerPrime)
- **Telescope array:** finishing ~20 years of data collection. One remaining year of NSF funded data-taking operations including new array stations.
- **IceCube with IceTOP and IceACT** (moderate energies)  
IceCube has surface optical modules (IceTOP) and Air Cherenkov Telescopes (ACTs) to study cosmic rays including in coincidence with any signals in the in-ice optical modules.

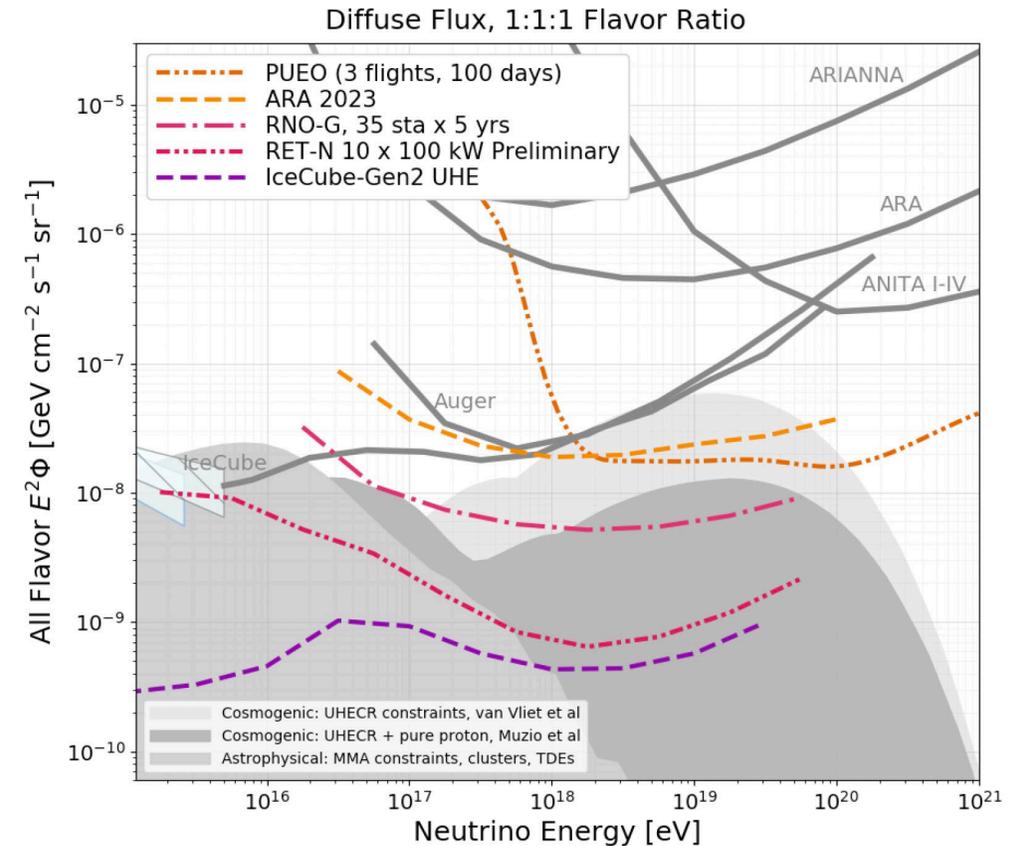
# Particle Astrophysics: Gamma Rays

- Wide-Field Water Cherenkov Telescopes
  - HAWC – High Altitude Water Cherenkov Experiment
    - Recent expansion of outrigger stations and improved reconstruction analysis continue to make HAWC relevant
    - Recent LHASSO brightest gamma ray burst in 2022 suggests continued investment in wide field gamma ray observations
  - SWGO – Southern Wide-Field Gamma Ray Observatory
    - International project with strong US presence
    - NSF support for finishing R&D towards construction
    - Recent site selection in August 2024 (Atacama, Chile)
- Imaging Air Cherenkov Telescopes
  - VERITAS – operating since 2007
  - CTA – future international project; already 1 400 scientists, 25 countries, and 200 institutes



# Particle Astrophysics: Ultra High Energy Neutrinos / other physics

- Large instrumented water detectors
  - Support for US researchers in under water neutrino detectors (including for future P-ONE project off of coast of British Columbia)
  - Surprising single UHE event observed with KM3NeT presented at Neutrino 2024 this summer
  - Competition in China with a future TRIDENT project
  - Super-K / Hyper-K (Japan)
- Radio through the Askaryan Effect
  - ARA (5 stations at South Pole) and ARIANNA (2011-2020)
  - RNO-G Eight of 35 stations deployed
  - IceCube Gen2 proposes 500 km<sup>2</sup> radio array



# Laboratory Plasma & Nuclear Astrophysics

- Laboratory astrophysics is key to advance Astronomy & Astrophysics, as recognized in the AAAC Laboratory Astrophysics Task Force report
- PHY supports many lab astro efforts, particularly in its plasma and nuclear physics programs, with direct relevance to multi-messenger and high energy astrophysics.
  - These are often conducted using laser- and beam-driven laboratory facilities supported by NSF and/or DOE
  - NSF and the Division of Physics have invested in design, construction, and operation of two high-power laser facilities that will enable laboratory astrophysics studies

**NSF ZEUS Laser Facility**  
Zettawatt-Equivalent Ultrashort pulse laser System at the University of Michigan

**About**  
Once completed, the ZEUS laser system will be the highest-power laser system in the US and will be among the highest-power lasers worldwide for the next decade.  
[Learn more >](#)

**Research**  
ZEUS allows exploration of fundamental yet unanswered questions regarding non-linear quantum electrodynamics in relativistic plasmas, including quantum radiation reaction and electron-positron pair production mechanisms.  
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**Facility Access**  
ZEUS is an NSF sponsored user facility, offering external users experimental access to advance science frontiers and enable discovery.  
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**NSF OPAL**  
A next-generation laser facility dedicated to the study of ultra-high-intensity laser-matter interactions.

**Particle Acceleration and Advanced Light Sources** →

**High-Field Physics and Quantum Electrodynamics** →

**Laboratory Astrophysics and Planetary Physics** →

**Laser-Driven Nuclear Physics** →



# Conclusion

- Community input provides us with an opportunity map for NSF PHY—and like in all maps, there are some destinations that are more difficult to reach than others
- But there are still many places to discover
- We must maximally exploit existing and new facilities
- In particle physics, there is a shift in the center of gravity to cosmo/astro techniques. We heard that message and are thinking about how to leverage existing PHY & NSF equities to address these scientific opportunities.
- There are budgetary constraints and technically-limited infrastructure constraints, so need to be realistic about what can be done when and where, and consider alternative platforms
- We are excited about the future of PHY contributions to astrophysics!



