NSF Report: Division of Physics Particle Physics

Jim Shank*

National Science Foundation

Division of Physics

HEPAP Meeting

Dec. 3, 2020

* Saul Gonzales, Jim Whitmore, Keith Dienes

NSF Particle Physics Programs & Funding Opportunities

- Transitions in Physics Division (PHY)
- Status of EPP/PA/THY Programs
- Funding Opportunities
- Status of Artificial Intelligence solicitation

Division of Physics – Individual Investigator Programs

Atomic, Molecular, & Optical Physics
Experiment: John Gillaspy; Kevin Jones
Theory: Robert Forrey

Plasma Physics
Slava Lukin

Elementary Particle Physics
Experiment: Jim Shank; Saul Gonzalez
Theory: Keith Dienes

Particle Astrophysics
Experiment: Jim Whitmore; Nigel Sharp
Theory (+cosmology): Keith Dienes

Gravitational Physics + LIGO research
Pedro Marronetti

Nuclear Physics
Experiment: Allena Opper; Jim Thomas
Theory: Bogdan Mihaila

Physics of Living Systems
Krastan Blagoev

Quantum Information Science
(Alex Cronin); Julio Gea-Banacloche

Notable transitions:
- Edmundo Garcia-Solis
- Jim Shank is back at NSF

Physics at the Information Frontier
Bogdan Mihaila

Integrative Activities in Physics
(REU Sites, MRI, CAREER, BP) (Edmundo Garcia-Solis)

Physics Frontiers Centers
Jim Shank

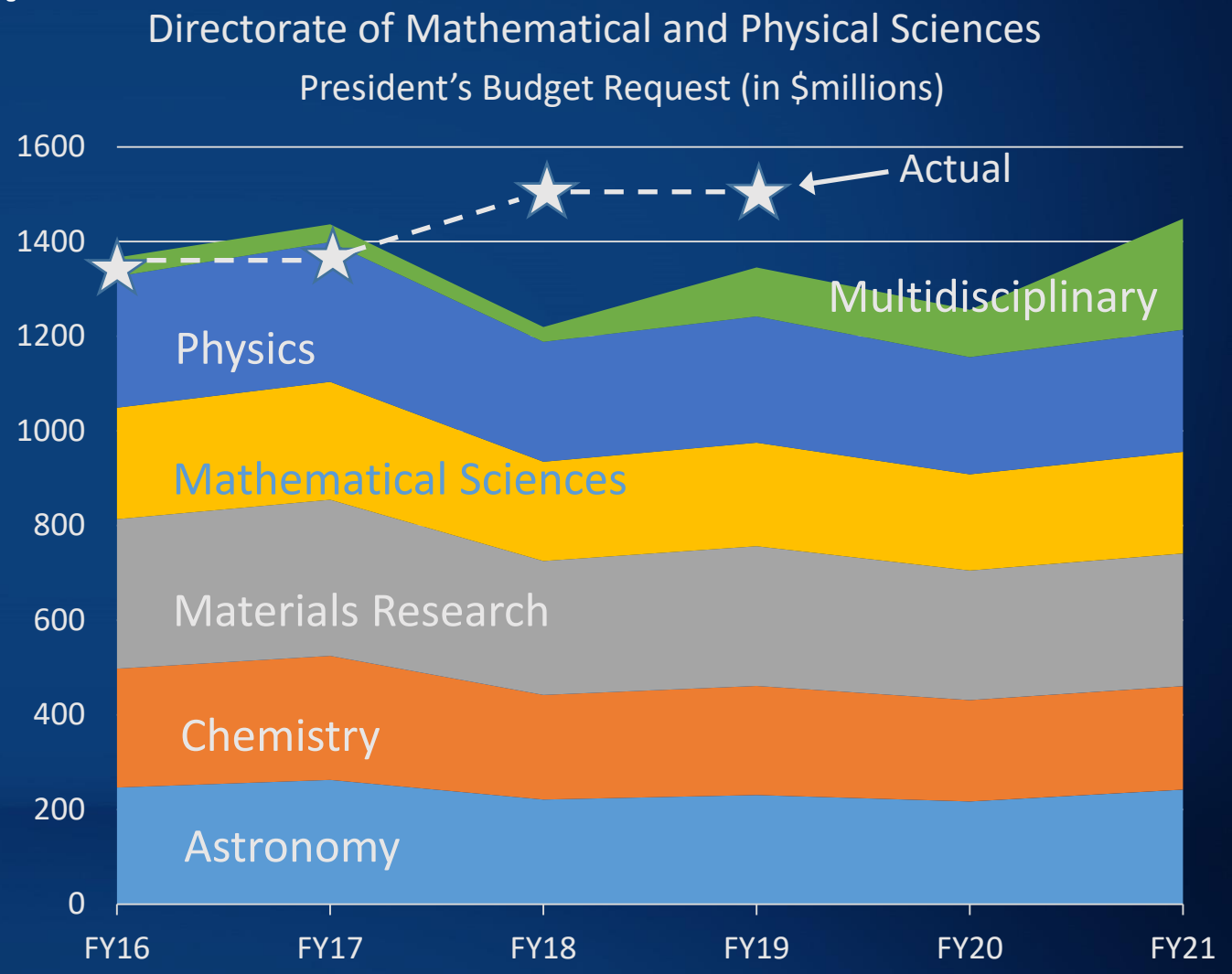
Personnel Actions in PHY

- For PA (Particle Astrophysics):
- Jim Whitmore, Program Director for the PA – Underground Physics and IceCube Research subprograms will be retiring in the March-April 2021 timeframe.
- If you, or anyone you know, might be interested in an IPA “rotator” position for this program, please contact one of us, with a letter and CV, and refer to the following DCL:

https://beta.nsf.gov/careers/openings/mps/phy/phy-19-001

Physics Funding at NSF

- PHY FY21 Request is 9.6% *below* FY19 Actual
- Particle physics funding is ~1/3 of Physics budget
- Increasing importance of NSF multidisciplinary "Big Ideas"
- Overall, FY20 enacted is ~3% *above* FY19 Actual for NSF



Particle Physics Research Programs

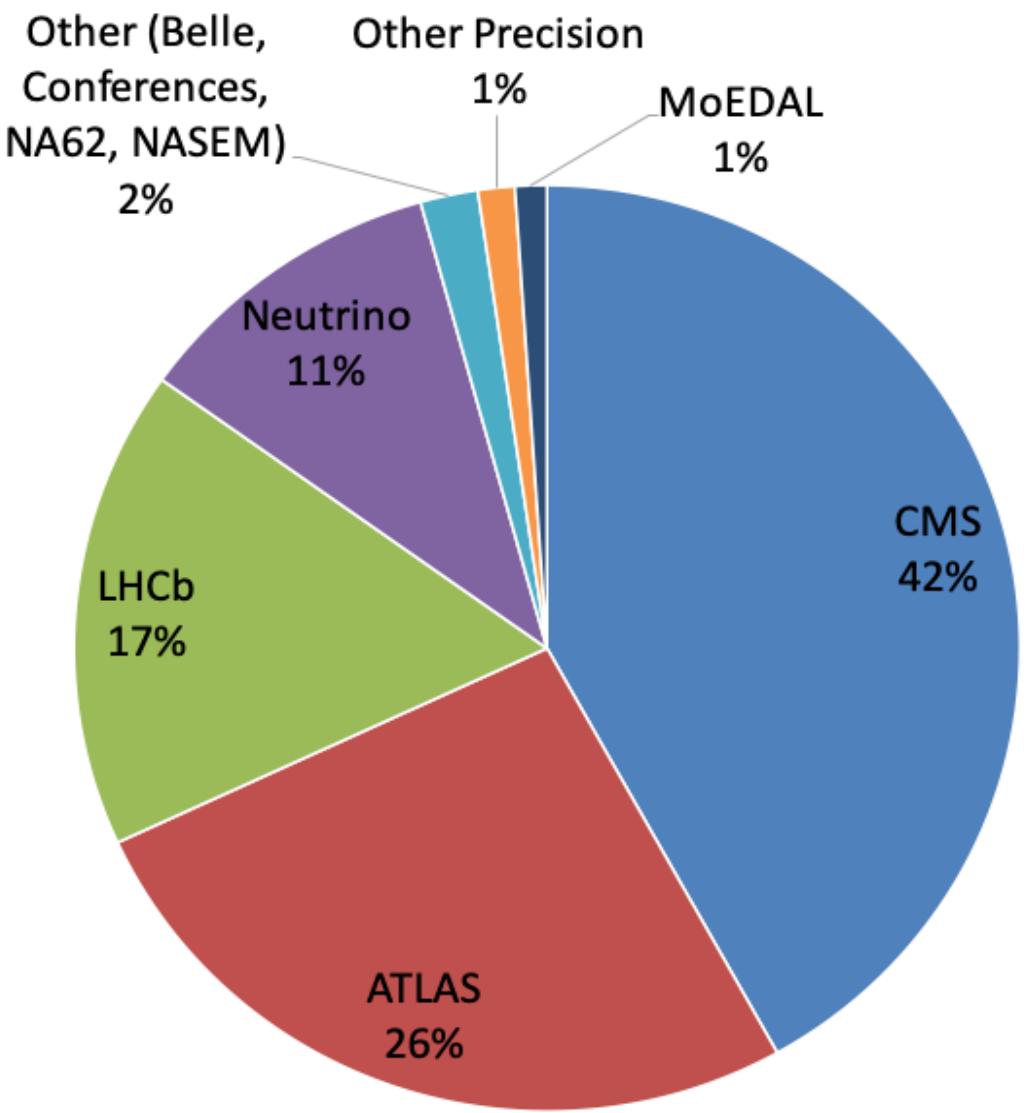
Experimental EPP Program

- Elementary Particle Physics (EPP) Program, which primarily supports particle physics at accelerators and advances in detector development.
- Range of program coverage:
  - High Energy Physics (ATLAS, CMS,…)
  - Precision Experiments (Neutrinos, LHCb, Rare-K, EDMs, …), LHCb M&O
  - Tools for Particle Physics (Artificial Intelligence, Instrumentation,…)

Program Directors: S. Gonzalez, J. Shank

EPP Program	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Funding (in $k)	$19,913	$19,183	$19,133	$20,522	$17,325
Awards issued	19	12	7	18	15
CAREER awards	1	2	1	1	0

EPP FY 20 Funding distribution



Decadal Survey of EPP
National Academies of Sciences

- At request of DOE and NSF
- The study will assess the progress and developments in EPP over the past decade and explore promising new directions for the period 2022-2032.
- It will also discuss the international landscape for EPP and leading roles that the United States can play in this field in the future.
- The study will identify, articulate, and prioritize the scientific opportunities in elementary particle physics
- It will evaluate the recent past and future directions of the entire field by members of the broader scientific community.

Experimental Particle Astrophysics Programs

- Underground Physics (PA): This area supports university research that generally locates experiments in low background environments:
  - IceCube Science Program
  - Underground experiments, reactor neutrinos
  - Neutrino mass measurements
  - Searches for the direct detection of Dark Matter
- Cosmic Phenomena (PA): This area supports university research that uses astrophysical sources and particle physics techniques to study fundamental physics:
  - Astrophysical sources of cosmic rays, gamma rays, neutrinos

Program Directors: J. Whitmore, N. Sharp

Particle Astrophysics	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Funding (in $k)	$19,665	$18,253	$18,142	$18,717	$16,632
Awards issued	26	16	17	25	18
CAREER awards	2	3	1	1	1

PHY Highlight: Observation of CNO Solar Neutrinos (1)

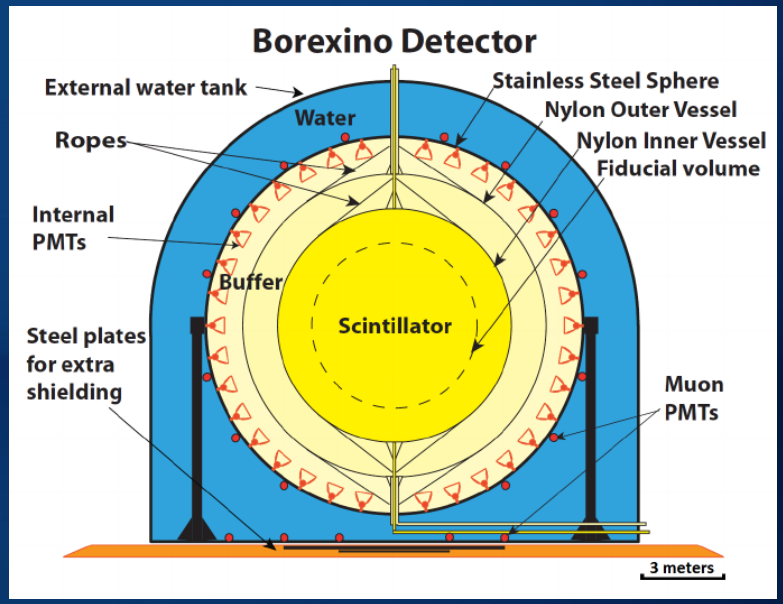
Stars are fueled by the fusion of hydrogen into helium via two well understood processes:

- the proton–proton (**pp**) chain and
- the carbon–nitrogen–oxygen (**CNO**) cycle.

Neutrinos that are emitted by such processes in the solar core are the only direct probe of the deep interior of the Sun.

The relative importance of these two mechanisms depends mostly on stellar mass and on the abundance of elements in the core that are heavier than helium (the '**metallicity**').
A complete spectroscopic study of neutrinos from the **pp** chain, which produces about 99% of the solar energy, has been performed previously.

In ***Nature*** (last week, Nov. 25, 2020), ***Borexino*** reports the first direct observation of **CNO** neutrinos. These data were obtained using the highly radiopure, large-volume, liquid-scintillator detector located underground at Gran Sasso (LNGS):



Observation of CNO Solar Neutrinos (2)

Their findings quantify the relative contribution of **CNO fusion** in the Sun to be of **the order of 1%;** (however, in massive stars, this is the ***dominant*** process of energy production).

In conclusion,

- ***The absence of a CNO solar neutrino signal is excluded with a significance of 5.0σ.***
- ***This is the first and only direct evidence for CNO neutrinos.***

This result paves the way for a solution to the long-standing '***solar metallicity problem***':

i.e., the discrepancy between

- *the physical properties predicted by solar models from spectroscopy (the low-metallicity SSM), and*
- *those inferred from helioseismology, which favors a higher metal content (the high-metallicity SSM).*

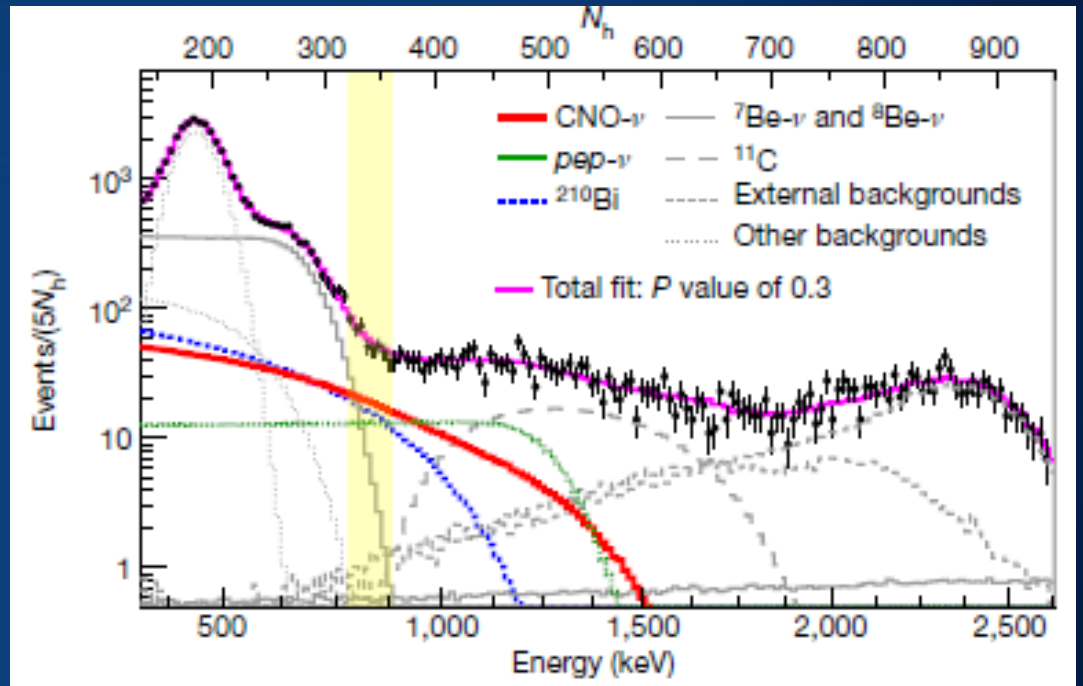


Fig. 2 | Spectral fit of the Borexino data. Distribution of the electron recoil energy scattered by solar neutrinos in the Borexino detector (black points) and corresponding spectral fit (magenta). CNO-neutrinos, ^{210}Bi and *pep*-neutrinos are highlighted in solid red, dashed blue and dotted green, respectively, and all other components are in grey. The energy estimator N_h represents the number of photoelectrons detected by photomultipliers, normalized to 2,000 live channels. The yellow band represents the region with the largest signal-to-background ratio for CNO-neutrinos.

Theory Program for Particle Physics

- Particle Theory is essential to the success of the entire Particle Physics mission. We support cutting-edge investigator-driven research in two programs:
  - Theoretical High-Energy Physics
  - Theoretical Particle Astrophysics and Cosmology
- Regular interactions with EPP, PA, Gravity Theory, Nuclear Theory, Astronomy, Materials Research, Mathematical Sciences, etc.
- Supporting individuals, RUI's, and special facilities or initiatives (Aspen Center for Physics, TASI summer school, LHC Theory Initiative, etc.)
- Trend: Dramatic increase in number of proposals—factor of two in last 5 years, +20% last year

Program Director: K. Dienes

Theory Programs	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Funding (in $k)	$13,751	$13,232	$13,388	$13,427	$12,029
Awards issued	28	30	26	32	23
CAREER awards	2	1	2	1	1

Funding Opportunities

NSF Proposal Preparation for FY2021

- All NSF proposals must conform to the NSF Proposal & Award and Procedures Guide:
  - Current submissions must follow PAPPG (NSF20001)
  - https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf20001
  - Questions can be referred to cognizant program directors.
- Proposals to other directorates – please refer to the NSF website: www.nsf.gov
- Intellectual Merit and Broader Impacts - All proposals to NSF PHY *must* address these two NSF Merit Criteria.

Physics Solicitation NSF 20-580

Programmatic Information and Deadlines for FY20

https://www.nsf.gov/pubs/2020/nsf20580/nsf20580.htm

Experiment: Elementary Particle Physics

Proposal Deadline: Dec 1, 2020

Program Directors: Saul Gonzalez, Jim Shank

Experiment: Particle Astrophysics

Proposal Deadline: Dec 1, 2020

Program Directors: Jim Whitmore

Theory: Elementary Particle Physics, Particle Astrophysics/Cosmology

Proposal Deadline: Dec 8, 2020

Program Director: Keith Dienes

New EPP program description for FY2021

https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505433:

"The Experimental Particle Physics (EPP) program explores the fundamental building blocks of matter and their forces by probing, directly or indirectly, particle interactions in a laboratory setting. Major focus areas include direct observation of new phenomena at the highest achievable energies and indirect discovery via precision measurements of known processes. The program provides support for university research at high energy accelerator facilities, development of novel instrumentation and analysis paradigms, and techniques that provide alternate pathways to discovery of new physics beyond the Standard Model.

The EPP program is organized in the following subareas (Program Elements):

- High Energy Particle Physics (1221): This area supports university research focused primarily on direct discovery using the highest achievable energies. It includes research support for the ATLAS and CMS experiments at the Large Hadron Collider and studies of discovery reach at current and future collider facilities.
- Precision Particle Physics (156Y): This area supports university research focused on precision measurements of known and often rare processes to discover or constrain deviations from Standard Model expectations. It includes research support for experiments at accelerator facilities, such as the LHCb experiment and neutrino experiments, and non-accelerator experiments using AMO or other techniques.
- Tools for Particle Physics (157Y): This area supports university research efforts to significantly improve or transform current particle physics experimental techniques. It includes early concept research into new particle detection technologies and development of novel data collection, processing, and analysis capabilities. Advances in this area are expected from connections to other domains such as AMO, QIS, and AI."

Other opportunities for Particle Physics

- Research at Undergraduate Institutions and Research Opportunity Awards
  - NSF 14-579 Deadlines same as EPP, PA and THY proposals
- AGEP/GRS
  - For current MPS awards: support additional graduate students
  - MPS Dear Colleague Letter: NSF20-083
  - Solicitation NSF 16-552
- Faculty Early Career Development Program (CAREER)
  - Solicitation NSF 20-525
  - Deadline for 2021 has passed, proposals still being reviewed
  - More information at: FAQs, Webinar, more…

National Artificial Intelligence (AI) Research Institutes (NSF 20-503)

- Artificial Intelligence (AI) has advanced tremendously and today promises personalized healthcare; enhanced national security; improved transportation; and more effective education, to name just a few benefits. Increased computing power, the availability of large datasets and streaming data, and algorithmic advances in machine learning (ML) have made it possible for AI development to create new sectors of the economy and revitalize industries. Continued advancement, enabled by sustained federal investment and channeled toward issues of national importance, holds the potential for further economic impact and quality-of-life improvements.
- This program solicitation describes two tracks:
- Planning track. Submissions to the **Planning** track are encouraged in any areas of foundational and use-inspired research appropriate to NSF and its partner organizations.
- Institute tracks. Submissions to the **Institute** track must have a principal focus in one or more of the following themes
  - Theme 1: Trustworthy AI
  - Theme 2: Foundations of Machine Learning
  - Theme 3: AI-Driven Innovation in Agriculture and the Food System
  - Theme 4: AI-Augmented Learning
  - Theme 5: AI for Accelerating Molecular Synthesis and Manufacturing
  - Theme 6: AI for Discovery in Physics

Program Directors: S. Gonzalez, J. Shank, N. Sharp

National Artificial Intelligence (AI) Research Institutes (NSF 20-503)

- Artificial Intelligence (AI) has advanced [illegible] healthcare: enhance[illegible]
- New solicitation: NSF 20-604 (Less involvement with MPS this year)
  - New Themes :
    1. **Human-AI Interaction and Collaboration**
    2. **AI Institute for Advances in Optimization**
    3. **AI and Advanced Cyberinfrastructure**
    4. **Advances in AI and Computer and Network Systems**
    5. **AI Institute in Dynamic Systems**
    6. **AI-Augmented Learning**
    7. **AI to Advance Biology**
    8. **AI-Driven Innovation in Agriculture and the Food System**
- **Deadline : December 4, 2020 !**
- **Webinar:** https://www.nsf.gov/events/event_summ.jsp?cntn_id=301175&org=CISE

Program Directors: S. Gonzalez, J. Shank, N. Sharp

NSF Particle Physics Centers and Institutes

Institute for Research and Innovation in Software for High Energy Physics

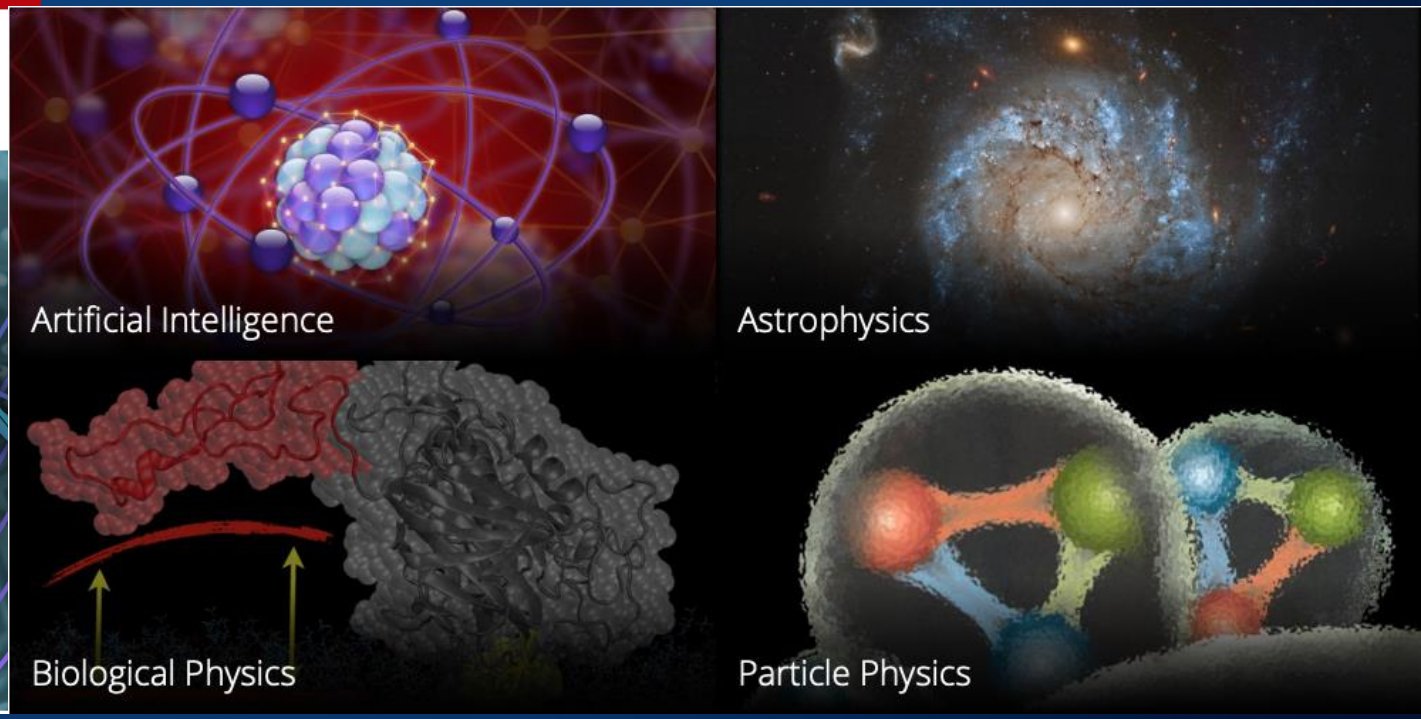
Center for Bright Beams Science and Technology Center

Network for Neutrinos, Nuclear Astrophysics, and Symmetries (N3AS) (Physics Frontier Center) NEW

NEW Institute for Artificial Intelligence and Fundamental Interactions

NSF AI Planning Institute

- Carnegie Melon University. PI: Scott Dodelson
- Two year award



The NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI)

"eye-phi"

Advance physics knowledge — from the smallest building blocks of nature to the largest structures in the universe — and galvanize AI research innovation

Physics

Theory

Physics Experiment

AI Foundations

Build strong multidisciplinary collaborations

Advocacy for shared solutions across subfields

Training, education & outreach at Physics/AI intersection

Cultivate early-career talent (e.g. IAIFI Fellows)

Foster connections to physics facilities and industry


The New York Times

By Dennis Overbye Nov. 23, 2020

Can a Computer Devise a Theory of Everything?

See Jesse Thaler's IAIFI talk tomorrow

Research Infrastructure

Research Infrastructure Opportunities

	Project Cost (approx. in $million)		Funding Source		
Solicitation	**From**	**To**	**R&D/Planning**	**Operations**	**Scope of Competition**
Individual program	**0**	**~1.0**	**EPP or PA**	**EPP or PA**	**Program (within EPP or PA)**
MRI (70%); University (30%)	**~0.2**	**5.7**	**n/a**	**n/a**	**PHY (<1.0) NSF (>1.0)**
Midscale RI-1	**0.6-6.0**	**20**	**EPP or PA or Midscale RI-1**	**EPP or PA**	**NSF**
Midscale RI-2	**20**	**70** Now 100	**EPP or PA or Midscale RI-1**	**EPP or PA**	**NSF**
MREFC	**70**	**--**	**EPP or PA**	**EPP or PA**	**NSF**

First Awards in FY19 →

Three awards recently →

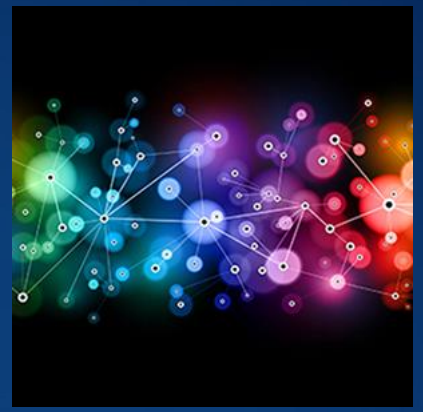
Mid-Scale Research Infrastructure

- Webinar from Nov. 2020: weblink
- Mid-Scale RI-1 Solicitation: 21-505
- Preliminary Proposal Deadline Date: January 7, 2021
- **Full Proposal Deadline Date:** April 23, 2021 (By Invitation Only)
- Mid-Scale RI-1 Implementation projects Total cost: $6M - $20M
- Mid-Scale RI-1 Design projects Total cost: $600k - $20M
- Mid-Scale RI-2 Solicitation: 21-537 (check link!)
- Letter of Intent Deadline Date: **Feb.**3, 2021 , Prelim proposal: Mar. 5, Full: Sept. 20, 2021
- Mid-Scale RI-2 Projects Total cost: $20M - $100M
- Consult the Major Facilities Guide NSF 19-068

NSF's 10 Big Ideas…

https://www.nsf.gov/news/special_reports/big_ideas/

- Future of Work
- Growing Convergence Research
- Harnessing the Data Revolution
- Mid-scale Research Infrastructure
- Navigating the Arctic
- NSF2026
- NSF INCLUDES
- Quantum Leap
- Understanding the Rules of Life
- Windows on the Universe



NSF/PHY: Summary/Comments

- The recent fiscal years have been challenging, but the Physics is compelling.
- We are working to understand and mitigate the full impact of the pandemic
- NSF-wide priorities offer opportunities to add value to the field.
  - Midscale Programs (NSF wide and PHY specific)
  - Windows on the Universe
  - AI Institutes
- We continue to work on Programmatic Balance
  - Demographic and Geographic
  - Larger Scale and Smaller Scale Programs
- The HL LHC MREFC is underway
- We look forward with great interest to the Snowmass process