Particle Physics at the NSF

DPF 2017
Fermilab
August 1, 2017

Saúl González
Transitions

- Major NSF leadership transition in Jan/Feb
- New Chief Operating Officer
- GEO AD started on June 1; ENG AD started on June 19.
- Fleming Crim returned to Wisconsin in January 2017; Jim Ulvestad is MPS Acting Assistant Director.
- Future Assistant Director has not yet been identified.
- AST Acting Division Director (Ralph Gaume)
We are moving this summer

August 1, 2017

25 mins to/from DCA

MPS, including Physics, is scheduled to move in 4 weeks

10 mins to/from DCA

2415 Eisenhower Avenue
Alexandria, VA 22314

4201 Wilson Boulevard
Arlington, VA 22230

No specific funding targets incorporated.

Supports NSF principles of merit review.

Language relating to NSF awards being in the national interest.

Language about facility oversight.

Instructions to Physical Sciences Subcommittee of the National Science and Technology Council relating to HEP: *policies, procedures, and plans in the physical sciences, including high-energy physics*
NSF’s 10 Big Ideas

**RESEARCH IDEAS**

- Harnessing Data for 21st Century Science and Engineering
- Work at the Human-Technology Frontier: Shaping the Future
- Windows on the Universe: The Era of Multi-messenger Astrophysics
- The Quantum Leap: Leading the Next Quantum Revolution
- Understanding the Rules of Life: Predicting Phenotype

**PROCESS IDEAS**

- Mid-scale Research Infrastructure
- NSF 2026
- Growing Convergence Research at NSF
- NSF INCLUDES: Enhancing STEM through Diversity and Inclusion
About one third of Physics Division funding is in Particle Physics or related programs.
### FY 2018 President's Budget Request

**National Science Foundation**

**Summary Table**

**FY 2018 Budget Request to Congress**

(Dollars in Millions)

<table>
<thead>
<tr>
<th>NSF by Account</th>
<th>FY 2016 Actual</th>
<th>FY 2017 Annualized CR</th>
<th>FY 2018 Request Amount</th>
<th>FY 2018 Request change over FY 2016 Actuals Percent</th>
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<tbody>
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<td>-</td>
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<td>GEO</td>
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<td>SBE</td>
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<td>315.74</td>
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<td>-</td>
<td>1.43</td>
<td>-</td>
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<tr>
<td>Research &amp; Related Activities</td>
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<td>Major Research Equipment &amp; Facilities Construction</td>
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<td><strong>Total, NSF</strong></td>
<td><strong>$7,493.86</strong></td>
<td><strong>$7,449.30</strong></td>
<td><strong>$6,652.89</strong></td>
<td><strong>-$840.98 -11.2%</strong></td>
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</tbody>
</table>

[https://www.nsf.gov/about/budget/fy2018/tables.jsp]
## MPS Funding

(Dollars in Millions)

<table>
<thead>
<tr>
<th>Division</th>
<th>FY 2016 Actual</th>
<th>FY 2017 (TBD)</th>
<th>FY 2018 Request</th>
<th>Change Over FY 2016 Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomical Sciences (AST)</td>
<td>$246.63</td>
<td>-</td>
<td>$221.15</td>
<td>-$25.48</td>
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<tr>
<td>Chemistry (CHE)</td>
<td>246.52</td>
<td>-</td>
<td>221.05</td>
<td>-25.47</td>
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<tr>
<td>Materials Research (DMR)</td>
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<td>-</td>
<td>282.87</td>
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<tr>
<td>Mathematical Sciences (DMS)</td>
<td>233.95</td>
<td>-</td>
<td>209.78</td>
<td>-24.17</td>
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<td>Physics (PHY)</td>
<td>276.91</td>
<td>-</td>
<td>253.30</td>
<td>-$23.61</td>
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<tr>
<td>Office of Multidisciplinary Activities (OMA)</td>
<td>34.89</td>
<td>-</td>
<td>31.28</td>
<td>-3.61</td>
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<tr>
<td>Total</td>
<td>$1,348.78</td>
<td>-</td>
<td>$1,219.43</td>
<td>-$129.35</td>
</tr>
</tbody>
</table>

Change Over FY 2016 Actual:

- **Astronomical Sciences (AST)**: -$25.48 (-10.3%)
- **Chemistry (CHE)**: -$25.47 (-10.3%)
- **Materials Research (DMR)**: -$27.01 (-8.7%)
- **Mathematical Sciences (DMS)**: -$24.17 (-10.3%)
- **Physics (PHY)**: -$23.61 (-8.5%)
- **Office of Multidisciplinary Activities (OMA)**: -$3.61 (-10.3%)
- **Total**: -$129.35 (-9.6%)
## FY 2018 PHY Budget Request

### PHY Funding

(Dollars in Millions)

<table>
<thead>
<tr>
<th></th>
<th>FY 2016 Actual</th>
<th>FY 2017 (TBD)</th>
<th>FY 2018 Request</th>
<th>Change Over FY 2016 Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Amount</td>
<td>Percent</td>
</tr>
<tr>
<td>Total</td>
<td>$276.91</td>
<td>-</td>
<td>$253.30</td>
<td>-$23.61</td>
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<td>Research</td>
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<td>5.00</td>
<td>5.00</td>
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<td>Education</td>
<td>5.40</td>
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<td>Infrastructure</td>
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<td>IceCube</td>
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<td>Large Hadron Collider (LHC)</td>
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<tr>
<td>Laser Interferometer Gravitational Wave Observatory (LIGO)</td>
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<td>Nat'l Superconducting Cyclotron Lab. (NSCL)</td>
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<td>Pre-construction planning:</td>
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<td>6.30</td>
<td>6.30</td>
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<tr>
<td>High-Luminosity LHC Upgrade Planning</td>
<td>-</td>
<td>-</td>
<td>6.30</td>
<td>6.30</td>
</tr>
</tbody>
</table>
FY 2018 PHY Budget Request (2)

MPS Subactivity Funding
(Dollars in Millions)

PHY Division Funding History
($M)

FY18 PBR

August 1, 2017
DPF 2017
• Support early career
  • CAREER request relatively stable. Targeted REU reductions if undergraduate students could be supported through national facilities and normal research awards. 8,000 graduate students to be supported through research awards.

• Protect the core; cross disciplinary programs
  • Major research facilities are “core” to MPS.
  • Retained flexibility to fund the best science by rolling some cross-disciplinary programs into core programs.

• Strategic and prioritized reductions within directorates
  • Emphasized funding of highest priority facilities; reductions proposed for some facilities in transition.
  • Reduced mid-scale and instrumentation; support individual investigators.
  • Prioritized low-level investments leading to “Big Ideas”.
  • Roll back “accretions” (things scaled up since 2008)
Elementary Particle Physics

EXPERIMENT

Jim Shank, Randy Ruchti, Saul Gonzalez
Snapshot: FY 2016 EPP

Total Funding = $19.4 million

Includes: eEDM, Belle II, E&O, Einstein, Tevatron legacy, etc.
EPP Funding History

EPP Total Funding by Fiscal Year

ARRA

$35,000,000

$30,000,000

$25,000,000

$20,000,000

$15,000,000

$10,000,000

$5,000,000

$0


August 1, 2017
EPP Highlight: LHCb

Recent physics highlights:

• **Observation of exotic-like particles (Tetraquarks)**
  - $B^+$ meson decays into $J/\psi$, $\varphi$ and $K^+$ mesons.
  - The plot shows the $J/\psi$, $\varphi$ mass spectrum which can only be fit with the inclusion of the four exotic particles at 4140, 4274, 4500 and 4700 MeV. See [https://arxiv.org/abs/1606.07898](https://arxiv.org/abs/1606.07898)

• **Ongoing Lepton Universality test probes physics beyond the Standard Model**
EPP Highlight: CMS Phase 1 Upgrade

• Phase 1 upgrade goal: enhance pixel detector to maintain high efficiency at $L=2 \times 10^{34}\text{cm}^2/\text{sec}$ and $\eta < 2.5$.

• Part of NSF scope: replaced the three end-cap disks during the 2016 LHC shutdown (FPIX)

• Verification of operation after resumed LHC operation

FPIX Occupancies in Collisions
Particle Astrophysics

EXPERIMENT

Jean Cottam, Jim Whitmore
PA Program Scope -- Supported Projects

- Direct Dark Matter Detection – WIMP and non-WIMP experiments
  - SuperCDMS at SNOLAB, XENON100/1T, LUX, DArkSide-50, PICO, DRIFT, DM-Ice, SABRE, DAMIC, HAYSTAC (ADMX-HF), ALPS2 and Light mass DM experiments

- Indirect Dark Matter Detection
  - VERITAS, HAWC, IceCube

- Cosmic Ray, Gamma Ray, and UHE Neutrino Observatories
  - IceCube, VERITAS, HAWC, Auger, Telescope Array, CTA, ARA, ARIANNA

- Cosmic Microwave Background
  - SPT and BICEP

- Neutrino Properties
  - Double Chooz, Project 8, IceCube, IsoDAR, CHANDLER

- Solar, SuperNova and Geo-Neutrinos
  - Borexino, SNEWS

- Detector R&D
  - NaI/CsI, LiSc/QuDots
PA Program Funding FY2002-2016

ARRA

Funding per program (SM)

Fiscal Year

FY02  FY03  FY04  FY05  FY06  FY07  FY08  FY09  FY10  FY11  FY12  FY13  FY14  FY15  FY16

DarkMatter  UHECR-GR  Neutrino  Other  UadGrd R&D  Total
A comparison of the unfolded spectrum with theoretical predictions for a purely atmospheric flux shows good compatibility up to energies of $E \sim 126\text{TeV}$. For energies above $126\text{TeV}$, however, a flattening of the spectrum is observed, consistent with an astrophysical contribution to the overall spectrum of muon neutrinos. [arXiv:1705.07780v1 (May 22, 2017)]

Using CC events:
- **Conventional** = from $\pi/K$ decays
- **Prompt** = from charm decays
34.2 live days of data acquired between November 2016 and January 2017. They achieved the lowest electronic recoil background in a dark matter detector. The experiment resumed operation shortly after the January 18, 2017 earthquake and continues to record data. [arXiv:1705.06655v2 May 23, 2017]
As WIMPs remain elusive, there is a growing interest in alternatives:

**Purple** indicates FY2017 awards

- **ADMX-HF**: 20 to 100 μeV
- **Opt. levitating spheres**: 0.1 meV to 1 eV
- **IsoDAR**: 0.3 eV to 1 keV
- **M1 trans ^57Fe**: 2 meV to 5 keV
- **DAMIC**: 1.2 to 30 eV; 1 to 10 GeV
- **SuperCDMS**: 0.3 to 10 GeV
- **DArkSide-50**: > 10 GeV
- **XENON-100/1T**: > 10 GeV
- **SABRE**: 30 to 100 GeV
- **COSINE-100**: 30 to 100 GeV

Axions “Theory?” 50 to 1500 μeV

- GNOME: 1 feV to 0.1 neV
- GPS.DM: 10 feV to 0.1 neV
- ABRACADABRA: 10 feV to 0.1 μeV
- ALPS-IIC: 1 neV to 10 meV
- ARIADNE: 10 μeV to 10 meV

Hi LQCD: Borsanyi et al., Nature 539, 69 (Nov 2016)
Elementary Particle Physics
THEORY

Astrophysics and Cosmology
THEORY

Keith Dienes
A vibrant, intellectually diverse Theory program is vital to the success of the entire Particle Physics mission. We capitalize on the talents and creativity of the Theory community by supporting the best, most cutting-edge investigator-driven research in two programs:

- Theoretical High-Energy Physics
- Theoretical Particle Astrophysics and Cosmology

These two theory programs interface regularly with many other programs at NSF (EPP, PA, Gravity Theory, Nuclear Theory, Astronomy, Materials Research, Mathematical Sciences, etc.) We also coordinate, as needed, with DOE.

Approximately 110 separate active grants supporting ~180 PIs; ~30 large university groups.

Supporting individuals, RUI's, and special facilities or initiatives (Aspen Center for Physics, TASI summer school, LHC Theory Initiative, etc.)
Theory Trends

• FY15-17: three-year absorption of string-theoretic portion of former Mathematical Physics program. Now nearly complete.

• FY16: NSF renews Aspen Center for Physics grant for next five years, expands support and scope into Atomic Physics

• Numbers of proposals received is currently twice what it was only 3-4 years ago.

• Increasing numbers of RUI proposals, particularly in FY17.

• One major challenge affecting Theory is the entrance of non-traditional (private philanthropic) funding sources. NSF has developed new procedures for evaluating overlapping sources of funding and introducing such evaluations into the proposal review process. (See NSF 17-561)

<table>
<thead>
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<th></th>
<th>FY 2015</th>
<th>FY 2016</th>
<th>FY 2017</th>
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<td>$13.7 million</td>
<td>$13.2 million</td>
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<td>26</td>
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<tr>
<td>CAREER</td>
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<td>1</td>
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</table>
Accelerator Science

EXPERIMENT AND THEORY

Vyacheslav (Slava) Lukin, Jim Shank
The Accelerator Science program supports and fosters research that exploits the educational and discovery potential of basic accelerator physics research at academic institutions. A key goal of the program is to seed and develop research efforts in fundamental accelerator science at colleges and universities that will enable transformational discoveries in this crosscutting academic discipline. In particular, this program seeks to support research with the potential to disrupt existing paradigms and advance accelerator science at a fundamental level…

This program aims to provide the foundation in knowledge and workforce upon which major advances in accelerator-driven technologies will be based. An important component of the program is the support and training of the next generation of accelerator scientists, including students, postdoctoral researchers, and junior faculty, who will lead innovations in the field and will form the backbone of the nation's highly trained accelerator workforce…. Priority will be given to those proposals that enable the discovery science supported by the MPS Division of Physics and do not augment ongoing work supported by other agencies.

NSF Accelerator Science Program started in 2014
Funding History

- FY14: $9.56M
- FY15: $9.31M
- FY16: $9.03M
- FY17: $5.1M
- FY18: Unknown

Success Rate
- FY14: 40%
- FY15: 35%
- FY16: 30%
- FY17: Unknown

Projects Considered vs. Projects Funded

<table>
<thead>
<tr>
<th>Country - State/Territory</th>
<th>Award Amount</th>
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</thead>
<tbody>
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<tr>
<td>US - California</td>
<td>$6,484,135</td>
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<tr>
<td>US - Illinois</td>
<td>$2,791,941</td>
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<tr>
<td>US - Michigan</td>
<td>$2,112,162</td>
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<tr>
<td>US - Nebraska</td>
<td>$1,749,998</td>
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</table>
Exploring the Limits in Ultrafast High Brightness Electron Beam Generation
PI: Pietro Musumeci, UCLA

Optical (left) and electron (right) image of the nanofabricated UCLA target. The actual letter size in the target is 100 micron. The image on the right is the first single shot ps-time resolved transmission electron microscopy image using a MeV energy electron beam. (D. Cesar et al. PRL, 117, 024801, 2016)

Tomographic Visualization of Electron-Beam-Driven Plasma Wakefield Accelerators
PI: Michael Downer, UT Austin

Visualization of electron-driven plasma wakefield accelerators (Experiment E224)

Structures generated by intense GeV electron bunches at SLAC/FACET.
The Accelerator Science program has not seen a large number of proposals that would fit well under the Program Description.

We have decided not to hold a regular Accelerator Science competition in FY18: recently released NSF PHY Investigator-Initiated Research Projects solicitation 17-561 does not contain a due date for the Accelerator Science program.

The program will consider proposals submitted to NSF-wide solicitations such as CAREER – we maintain the desire “to seed and develop research efforts in fundamental accelerator science at colleges and universities.”

The program intends to be able to entertain supplement requests for graduate student support from PI’s whose current awards expire in FY18.
Facilities and Scientific Infrastructure

Mark Coles, Jean Cottam, Saul Gonzalez, Bogdan Mihaila, Jim Shank, Randy Ruchti, Jim Whitmore
High Luminosity LHC Planning

- Conceptual Design (approved initiation Nov 2015)
- Preliminary Design (approved initiation August 2016)
  - “pre-PDR” snapshot review of ATLAS and CMS plans (April 2017)
  - Preliminary Design Reviews in December/17-January/18
- CERN’s LHC schedule → ATLAS, CMS schedules → HL LHC in 2020 NSF MREFC budget request

We are here

Conceptual Design Phase
- Conceptual Design Review (CDR)
- MREFC Panel Review
- OD Approval for Advancement to Preliminary Design

Preliminary Design Phase
- Preliminary Design Review (PDR)
- MREFC Panel Review
- Director’s Review Board (DRB) Review
- Director’s approval for Advancement
- Board approval for inclusion in MREFC Budget Request

Final Design Phase
- Final Design Review (FDR)
- MREFC Panel Review
- DRB Review
- Director’s approval for Advancement to Construction
- Board approval for the Director to obligate construction funds

Project Definition Established
- Cost, Scope, Schedule, Plans, Risks & Contingency
## Instrumentation at the NSF

<table>
<thead>
<tr>
<th>Project Cost (approx. in $million)</th>
<th>Funding Source</th>
<th>R&amp;D/Planning</th>
<th>Acquisition / Construction</th>
<th>Operations</th>
<th>Scope of Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 0 to 1.0</td>
<td></td>
<td>EPP or PA</td>
<td>EPP or PA</td>
<td>EPP or PA</td>
<td>Program (within EPP or PA)</td>
</tr>
<tr>
<td>0.2 from 5.7</td>
<td>n/a</td>
<td>MRI (70%); University (30%)</td>
<td>n/a</td>
<td>PHY (&lt;1.0)</td>
<td>NSF (&gt;1.0)</td>
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<tr>
<td>4.0 from 15</td>
<td>EPP or PA</td>
<td>PHY Research</td>
<td>EPP or PA</td>
<td>PHY</td>
<td>NSF</td>
</tr>
<tr>
<td>130 (MPS)</td>
<td>EPP or PA</td>
<td>MREFC</td>
<td>EPP or PA</td>
<td>NSF</td>
<td></td>
</tr>
</tbody>
</table>

- "midscale" (10-15)% of TPC
- Now $70 million across NSF
- (10-15)% of TPC per year
Computing

• We issued a Software Institute Conceptualization award: “Conceptualization of an S2I2 Software Institute for High Energy Physics” Award 1558216 (Elmer, Princeton) / 1558233 (Sokoloff, Cincinnati) / 1558233 (Neubauer, UIUC)

• Sponsors community workshops and conceptual work to take advantage of the significant data and computing requirements of the Large Hadron Collider as a science driver for next generation high-performance software and sustainability developments. Working together with the HEP Software Foundation to produce a Community White Paper.

• Next meeting: 23-26 Aug, 2017 – S2I2-HEP Workshop (Seattle)

• This effort will inform the future of computing and various software development needs for the HL-LHC era

• We are partnering with NSF’s Office of Advanced Cyberinfrastructure

• Working with ATLAS, CMS, and OSG to minimize disruption to U.S. LHC
Outlook

• Particle Physics at the NSF moves forward mindful of the P5 recommendations and aligned to the post-P5 MPS Advisory Committee recommendations

• PHY and the EPP program are committed—to the best of our ability—to the success of the HL LHC. This requires
  • Significant additional research contributions to planning activities
  • Additional reductions to EPP beyond nominal budget envelope
  • Essential to keep the LHC program viable beyond 2025
  • Close coupling between Research and Upgrade programs an issue

• But we are also committed to a diverse scientific portfolio that advances multiple frontiers

• FY18 President’s Budget will require a re-baselining of Research Programs
ADDITIONAL SLIDES
Other Items

- Workshop on “Table-top experiments with Skyscraper reach” (Aug 9-11, MIT): “…to bring together a diverse set of scientists from the particle physics, nuclear physics, and AMO communities to discuss new ideas for small-scale experiments that can search for new physics beyond the Standard Model

- CPAD 2017, University of New Mexico, October 12-14

- NSF Physics Division Solicitation (Investigator-initiated Research Projects) 17-561 Deadlines:
  - October 25, 2017 (EPP-experiment, PA-experiment)
  - December 7, 2017 (EPP-Theory, PA & Cosmology-Theory)
Particle Astrophysics Proposals (FY02-17)

Number of PA Proposals (UG+CP)

Fiscal Year

("Neutrino" includes $0\nu\beta\beta$ for <2015)
• CBB’s goal is to increase the intensity ("brightness") of beams of charged particles by two orders of magnitude while decreasing the cost of key accelerator technologies.

• CBB will promote significant advances in scientific disciplines ranging from physics to chemistry to biology by enhancing the capabilities of the accelerators essential to research in these fields.

• It will conduct collaborative research with national laboratories and companies, leveraging their diverse expertise, and will transfer technology to them.

• It will help integrate the research into instruments that advance the frontiers of knowledge in life sciences, materials science, condensed matter physics, particle physics, and nuclear physics.
Major Research Instrumentation (MRI)

• Up to $4 million from NSF for development or acquisition proposals
• Cost-sharing at the level of 30% of the total project cost is required for Ph.D.-granting institutions and non-degree-granting organizations. Cost-sharing is not required for non-Ph.D. granting institutions.
• Submission limit - Three (3) per organization: If three proposals are submitted, at least one of the proposals must be for instrument development.
• Merit Review - At the time of submission, PI’s are asked to identify an NSF division(s) to review proposal. NSF reserves the right to place proposals in the appropriate division(s) for review.
• Very competitive and supported mostly with non-PHY funding
• EPP and PA communities have leveraged many $million over the years
• MRI solicitation is evolving
Midscale Instrumentation

- Design and Construction or Acquisition of Instrumentation
- ~ $4M < TPC < ~ $15M; PHY funding over multiple years
- Currently 6 Midscale projects (see PHY Solicitation 17-561)

**ATLAS**
- Lead: SUNY-Stony Brook

**CMS**
- Lead: U. Nebraska/Catholic
- **HCAL**
  - Longitudinal Granularity
  - Timing Info
- **FPIX**
  - 2→3 disks
  - Less mass
- **L1 Trigger**
  - (Muon, Calorimeter)
  - Faster, Smarter Algos

**LHCb**
- NSF funded U.S. contribution, Upstream Tracker
- Leads: Syracuse, Cincinnati, MIT, UMd
Update: Major Research Equipment & Facilities Construction

~$130 million threshold (MPS) → $70 million

National Science Foundation
Office of the Director
Arlington, VA 22230

Notice No. 138

November 30, 2016

IMPORTANT NOTICE TO
PRESIDENTS OF UNIVERSITIES AND COLLEGES
AND HEADS OF OTHER NATIONAL SCIENCE FOUNDATION
GRANTEE ORGANIZATIONS

SUBJECT: Revision of the Major Research Equipment and Facilities Construction (MREFC) Eligibility Threshold.

Following open discussion at the National Science Board meeting on November 8th and 9th, NSF has established the Total Project Cost (TPC) eligibility threshold for potential inclusion in the Major Research Equipment and Facilities Construction (MREFC) account at $70M. This adjustment responds to emergent scientific research opportunities and addresses the gap that previously existed between smaller instrumentation and major facility projects. Further details on MREFC account eligibility will be included in the FY 2017 revision of NSF’s Large Facilities Manual which will be published in December and made available on the Large Facilities Office website (https://www.nsf.gov/bfa/lfo/index.jsp). The scientific community should incorporate this change in their long range portfolio planning and prioritization efforts.

France A. Córdova
Director

August 1, 2017  DPF 2017