



# Advancing Physics with Neutrino Cross Sections and a Diverse Workforce

Mateus F. Carneiro (*he/they*)

Sep 19, 2024

 @BrookhavenLab

# Scientist/DEIA Liaison

- **Scientific Research**

- Conduct analysis of current neutrino experiments, including measurement of neutrino oscillations, **neutrino-argon cross section extraction**, or beyond standard model searches and to mentor students in these activities
- **Communicate and conduct presentations** in a wide community of students, physicists, engineers, and managers at meetings and conferences.
- Document research results and **publish papers** in scientific journals.

- **STEM DEIA Outreach**

- Take a leadership role in seeking funding **opportunities and writing proposals** to partially fund the departments DEI, education and outreach.
- **Develop and maintain the education and outreach programs** for visiting students
- Support research **collaboration with MSIs**
- Conduct detector simulation, event reconstruction, and physics sensitivity studies and to **mentor students** in these activities

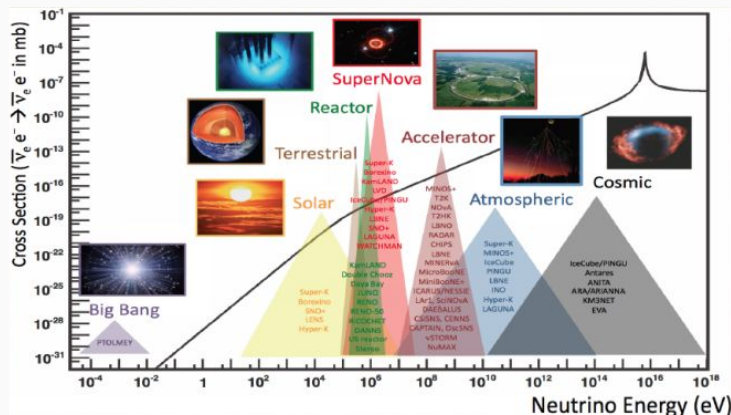
# Scientist/DEIA Liaison

- **Scientific Research**
  - Conduct analysis of current neutrino experiments, including measurement of neutrino oscillations, **neutrino-argon cross section extraction**, or beyond standard model searches and to mentor students in these activities
  - **Communicate and conduct presentations** in a wide community of students, physicists, engineers, and managers at meetings and conferences.
  - Document research results and **publish papers** in scientific journals.
- **STEM DEIA Outreach**
  - Take a leadership role in seeking funding **opportunities and writing proposals** to partially fund the departments DEI, education and outreach.
  - **Develop and maintain the education and outreach programs** for visiting students
  - Support research **collaboration with MSIs**
  - Conduct detector simulation, event reconstruction, and physics sensitivity studies and to **mentor students** in these activities

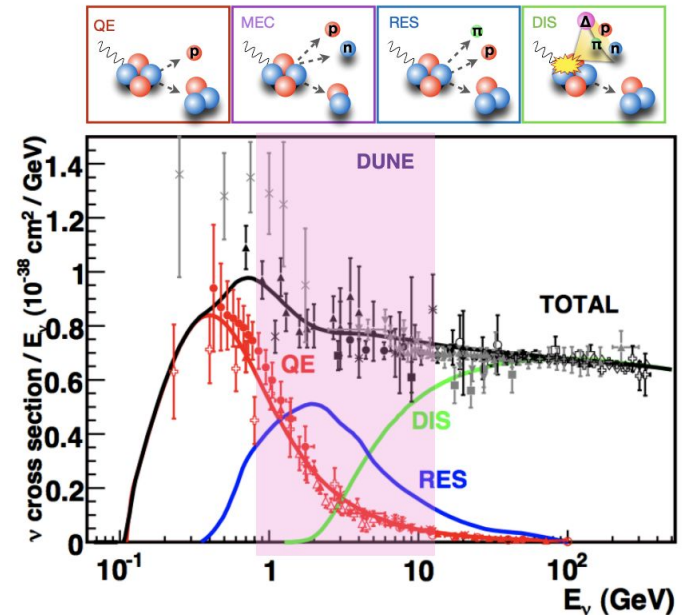
# Experimental Neutrino Physics Research

## Neutrino-Nucleus Cross section

Neutrinos have numerous sources covering a great range of energies. Knowledge of neutrino-nucleus scattering cross sections is crucial to the global neutrino physics program.



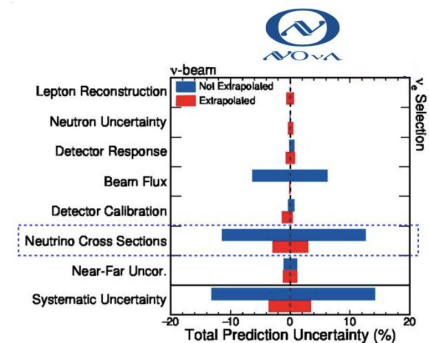
J.A. Formaggio and G.P. Zeller, Rev. Mod. Phys. 84 (2012)



Current oscillation experiments report large systematics uncertainties associated with neutrino-nucleus interaction models.

Nuclear models uncertainties hinder CP violation search

Error source	$\nu_e$ FHC	$\bar{\nu}_e$ RHC	$\nu_e / \bar{\nu}_e$ FHC/RHC
Flux and (ND unconstrained)	15.1	12.2	1.2
cross section (ND constrained)	3.2	3.1	2.7
SK detector	2.8	3.8	1.5
SK FSI + SI + PN	3.0	2.3	1.6
Nucleon removal energy	7.1	3.7	3.6
$\sigma(\nu_e)/\sigma(\bar{\nu}_e)$	2.6	1.5	3.0
NC1 $\gamma$	1.1	2.6	1.5
NC other	0.2	0.3	0.2
$\sin^2 \theta_{23}$ and $\Delta m_{21}^2$	0.5	0.3	2.0
$\sin^2 \theta_{13}$ PDG2018	2.6	2.4	1.1
All systematics	8.8	7.1	6.0



T2K, Phys. Rev. D 103, 112008 (2021)



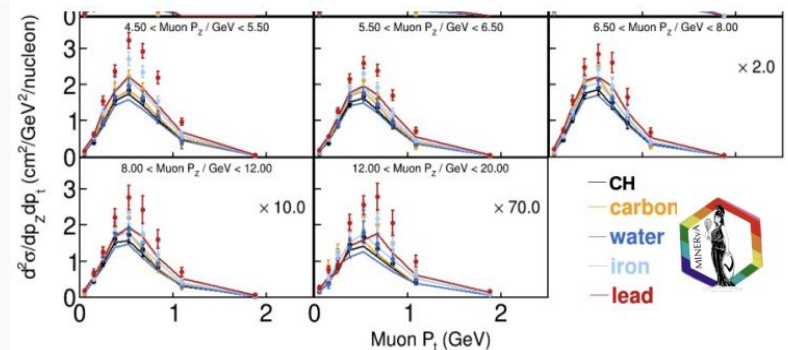
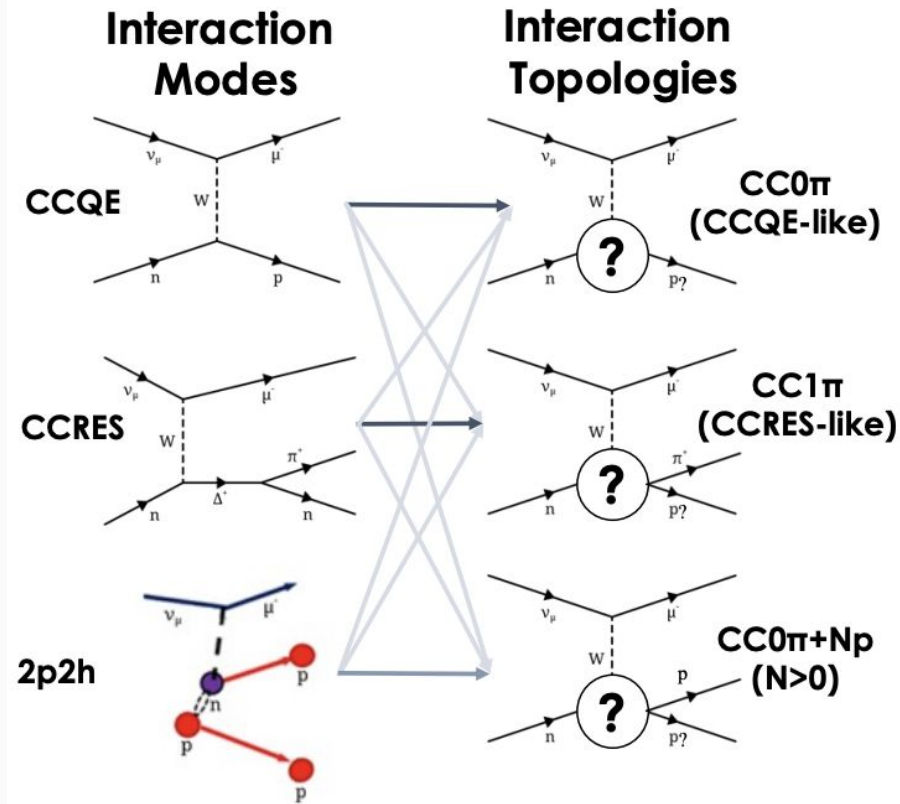
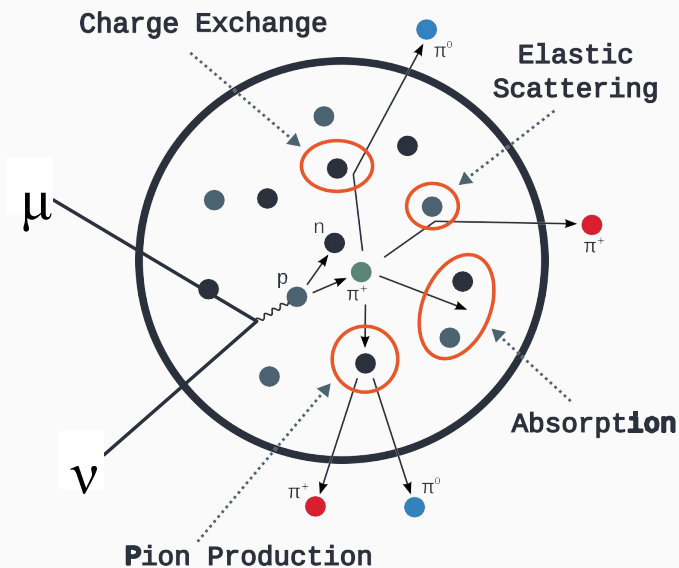
# Experimental Neutrino Physics Research

## Neutrino-Nucleus Cross section, what's so hard about it?

We somewhat understand interactions between neutrinos and single particles, but the nucleus environment is much more complex

The strong-interaction physics in play alters:

- final state particle compositions and kinematics
- determination of the incident neutrino energy,
- neutrino versus antineutrino scattering



# Experimental Neutrino Physics Research

Neutrino-Nucleus Cross section,  
where are we measuring it?

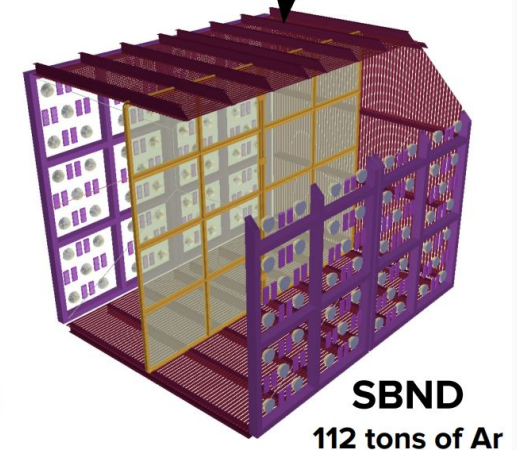
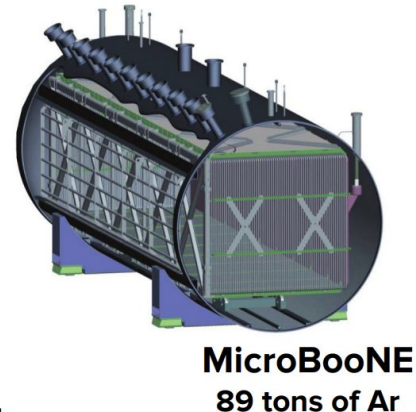
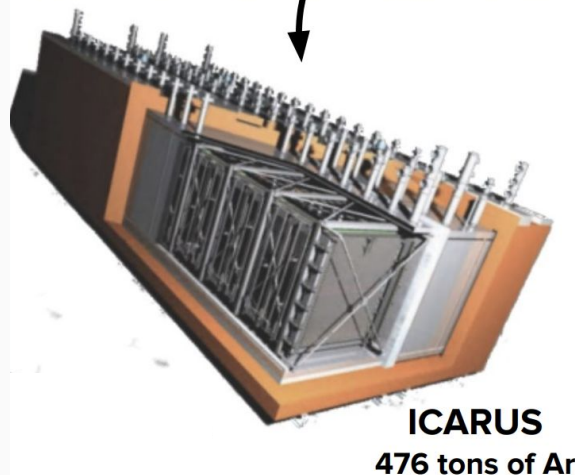
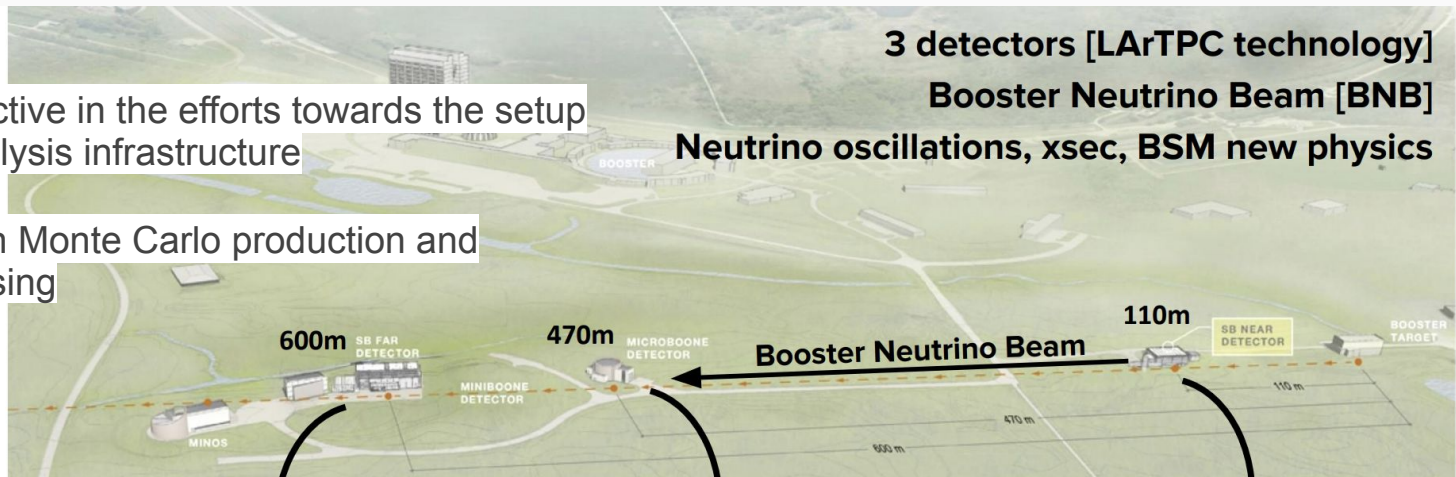
- I'm heavily active in the efforts towards the setup of a joint analysis infrastructure
- Leadership in Monte Carlo production and Data processing

## Short Baseline Neutrino Program (SBND)

3 detectors [LArTPC technology]

Booster Neutrino Beam [BNB]

Neutrino oscillations, xsec, BSM new physics

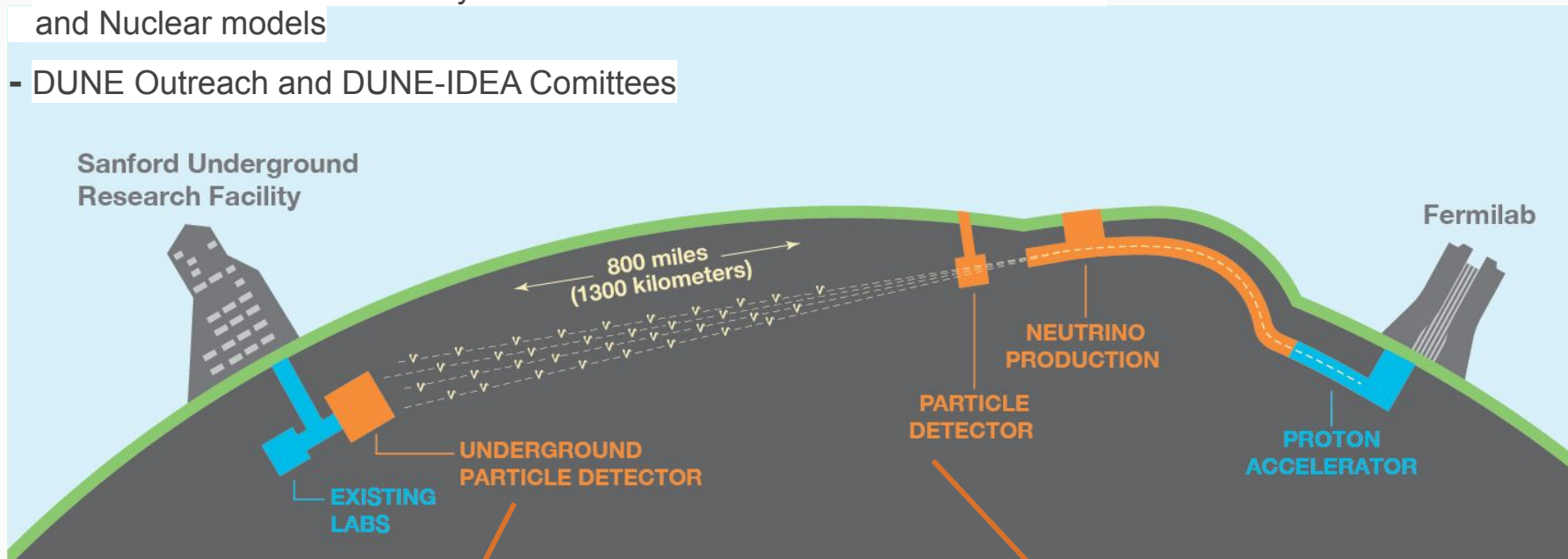


# Experimental Neutrino Physics Research

Neutrino-Nucleus Cross section,  
where are we measuring it?

## Deep Underground Neutrino Experiment (DUNE)

- Studies of detectors sensitivity to different neutrino cross-section channels and Nuclear models
- DUNE Outreach and DUNE-IDEA Committees



### Far Site

- 1300km from the proton source
- very large LAr TPCs (each 17 ktons)
- underground in South Dakota

### Near Site

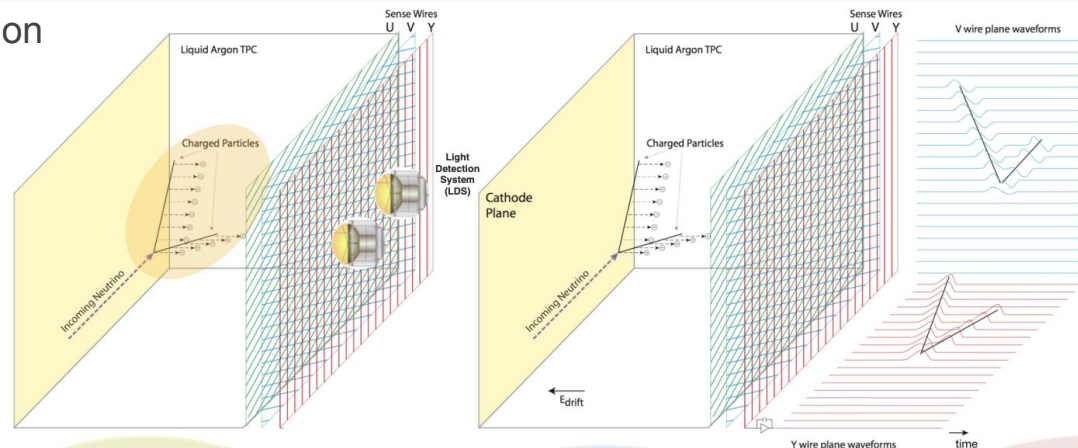
- 550m from proton source
- on-site at Fermilab
- both stationary & moveable detectors

# Experimental Neutrino Physics Research

Neutrino-Nucleus Cross section,  
how are we measuring it?

- 3D reconstruction with millimetric resolution
- Excellent particle identification with  $dE/dx$  information
- Low energy thresholds, subMeV to GeV

## Liquid Argon Time Projection Chamber (LArTPC)



Charged particles in LAr produce free ionization electrons and scintillation light

*m.i.p. at 500 V/cm: ~ 60,000 e/cm  
~ 50,000 photons/cm*

VUV photons propagate and are shifted into VIS photons

Ionization charge drifts in a uniform electric field towards the readout wire-planes

*Electron drift time ~ ms*

Scintillation light fast signals from LDSs give event timing

Digitized signals from the wires are collected [time of the wire pulses gives the drift coordinate of the track and amplitude gives the deposited charge]



# Scientist/DEIA Liaison

- **Scientific Research**

- Conduct analysis of current neutrino experiments, including measurement of neutrino oscillations, **neutrino-argon cross section extraction**, or beyond standard model searches and to mentor students in these activities
- **Communicate and conduct presentations** in a wide community of students, physicists, engineers, and managers at meetings and conferences.
- Document research results and **publish papers** in scientific journals.

- **STEM DEIA Outreach**

- Take a leadership role in seeking funding **opportunities and writing proposals** to partially fund the departments DEI, education and outreach.
- **Develop and maintain the education and outreach programs** for visiting students
- Support research **collaboration with MSIs**
- Conduct detector simulation, event reconstruction, and physics sensitivity studies and to **mentor students** in these activities

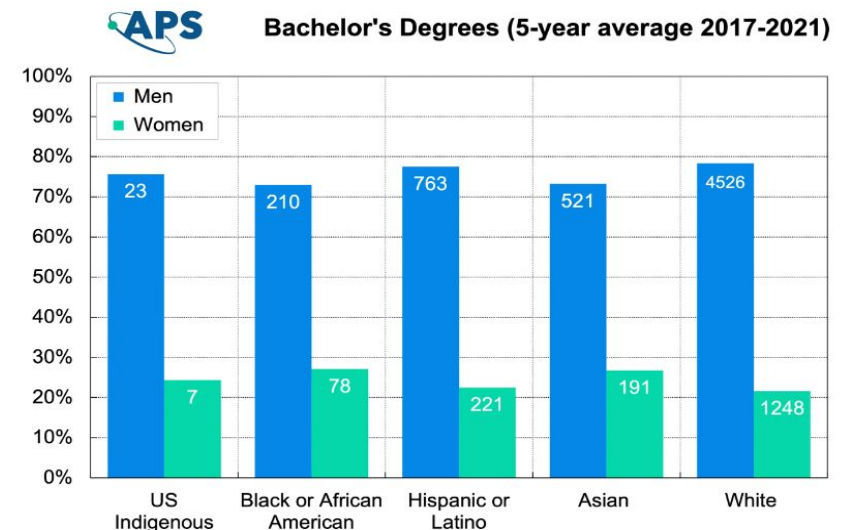
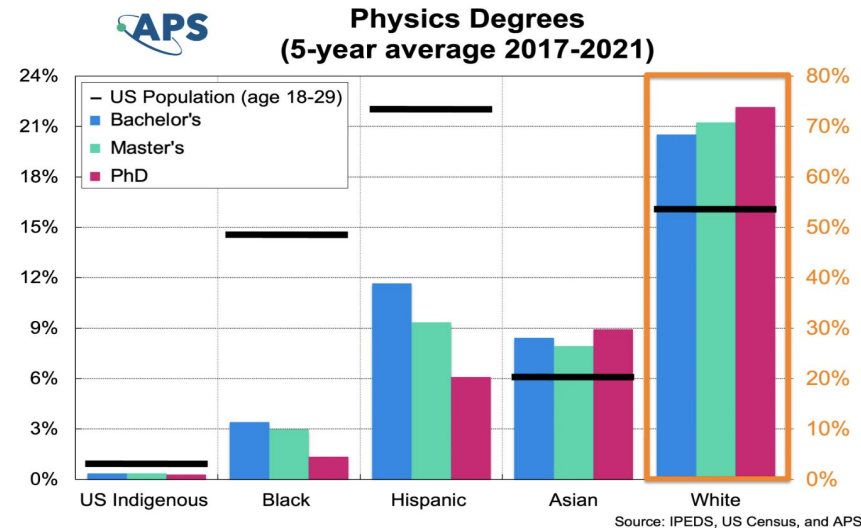
# STEM DEIA Outreach

Physics has a diversity issue that we need to address

Heavy focus on facilitation and management of DOE initiatives, mainly addressing the retention of Underrepresented Minority (URM) grad students

I also work with the Office of Education Programs (OEP), the DEI Office, and the NPP DEI Council on different efforts and opportunities for staff and visiting students

Students' projects? Candidates for our programs?  
Ideas for collaboration? Suggestions?  
Reach out! -> [mcarneiro@bnl.gov](mailto:mcarneiro@bnl.gov)



Students' projects? Candidates for our programs?  
Ideas for collaboration? Suggestions?  
Reach out! -> [mcarneiro@bnl.gov](mailto:mcarneiro@bnl.gov)

# STEM DEIA Outreach

## DOE DEIA efforts

### RENEW - Reaching a New Energy Sciences Workforce

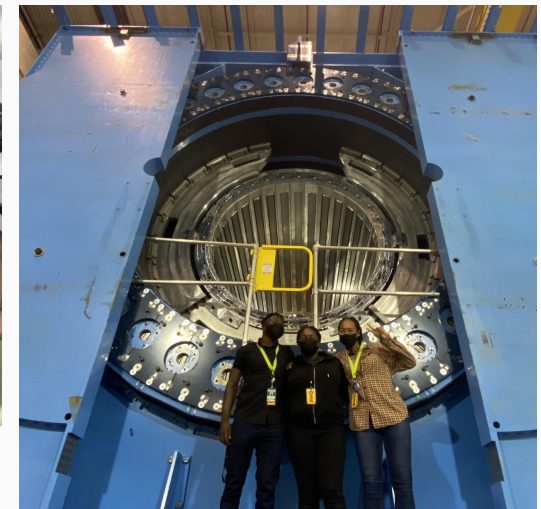
- Aims to build foundations for research at MSIs leveraging the structure available at National Labs
- 5+ BNL-HEP related projects funded in FY23
  - PREP-NPT as a model of recruit/train/retain
    - PREP-NP
    - PREP-HEP
    - LEAP-UP (SUNY Old Westbury)
  - Summer programs
    - NuSTEAM/NuPUMAS (Texas Physics Cohort)
    - Pathway Summer School (w/ OEP and Fermilab)
- Several new applications for the 2024 FOA!

### FAIR - Funding for Accelerated, Inclusive Research

- Builds faculty level research collaboration with MSIs

### PIER - Promoting Equitable and Inclusive Research

- SC requires that all project proposals include an appendix containing a PIER Plan that describes how applicants will promote DEIA in their project.



**Thank You**



# Backup

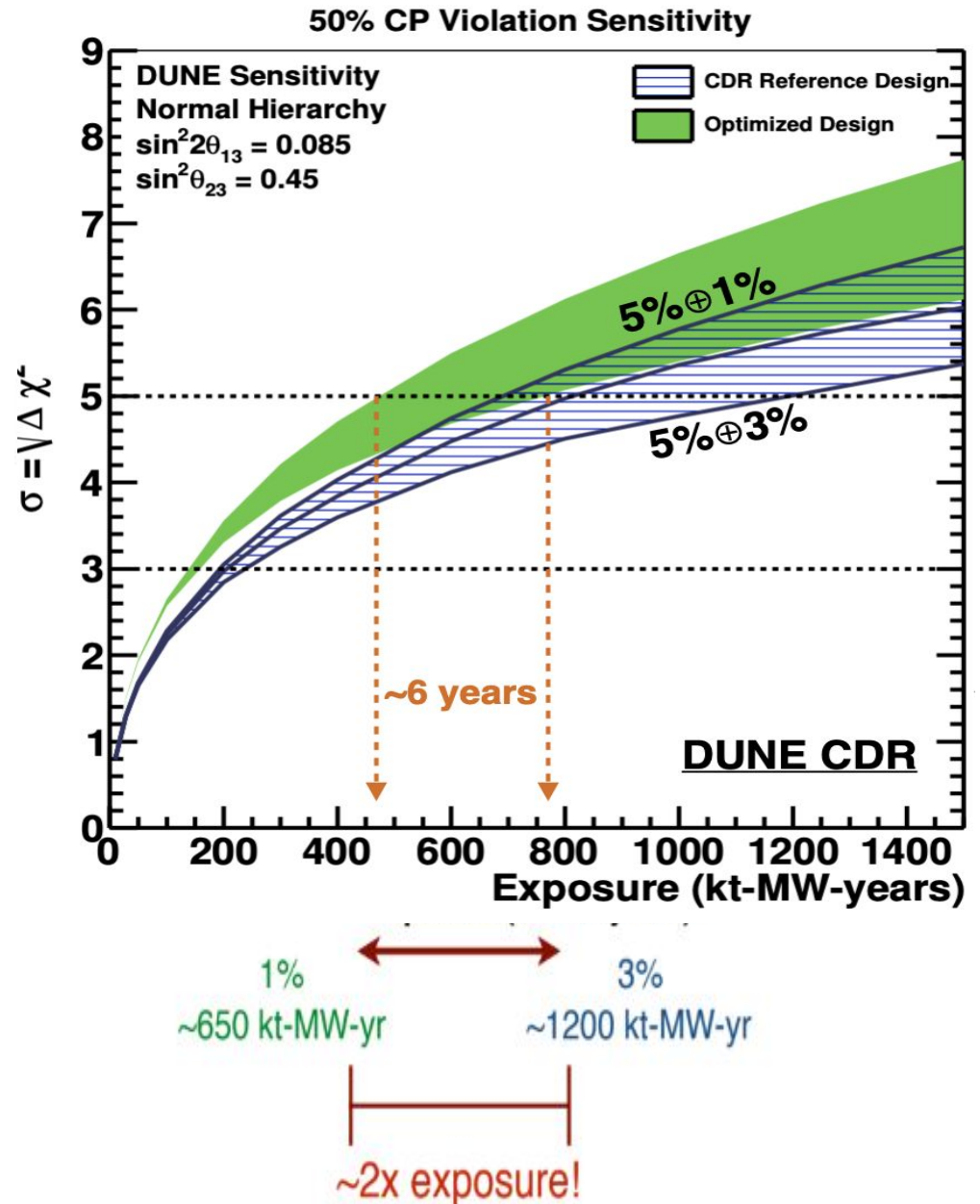
# We need to be ready for DUNE and Hyper-K!

We want precision neutrino oscillation measurements and **reducing systematics uncertainties is critical**

This includes neutrino **interaction cross sections**

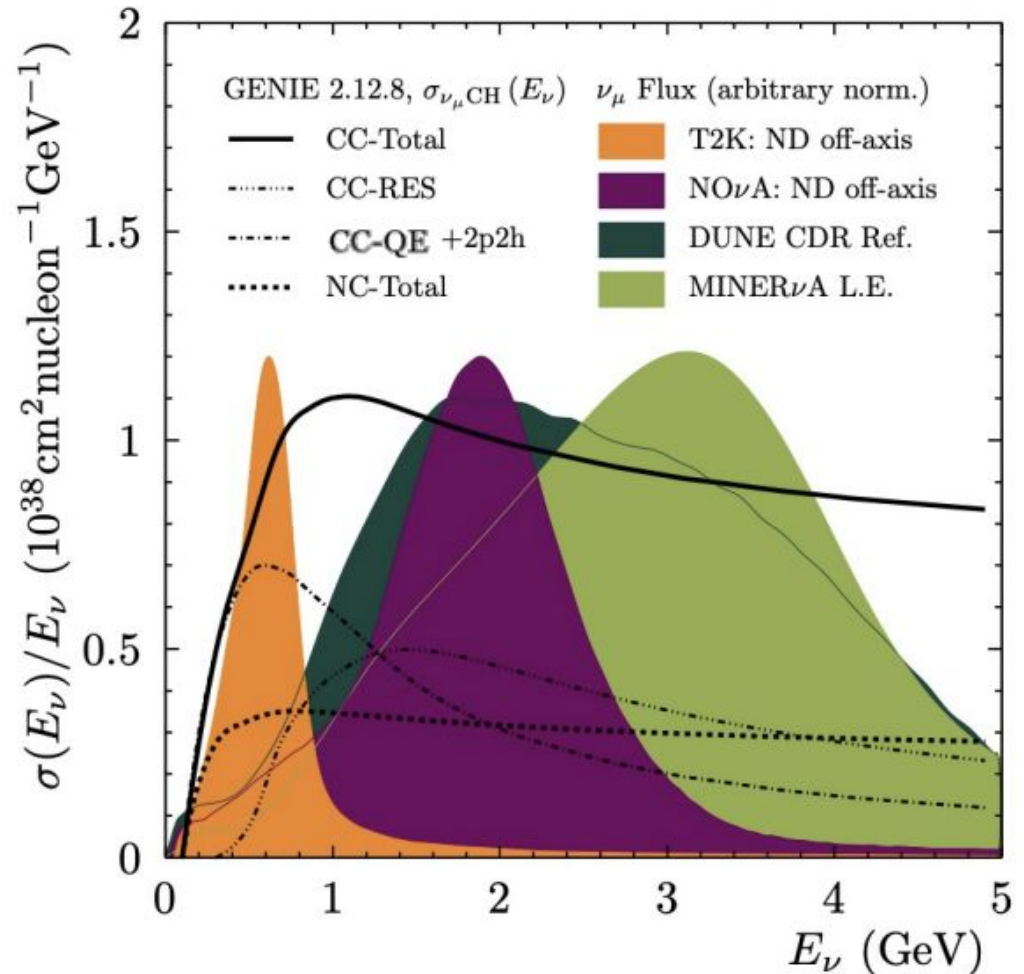
Oscillation experiments **rely on neutrino-nucleus interaction models** in neutrino event generators.

Need **better model** and high precision data



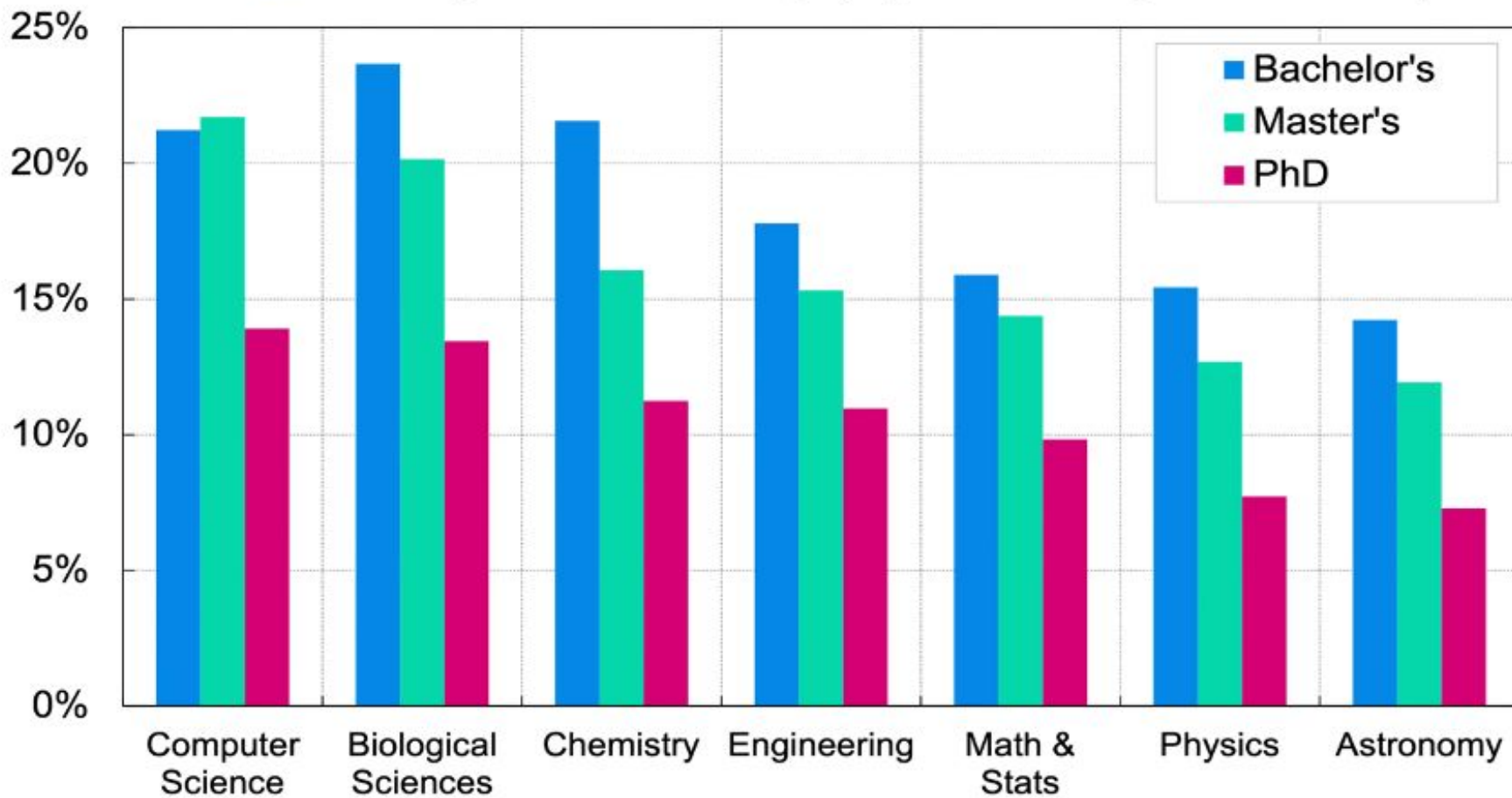
## Current experimental status

Different experiments cover different ranges of energy and different measurements complement each other using different technologies and materials





## Degrees to Individuals Marginalized by Race/Ethnicity (5-year average 2017-2021)



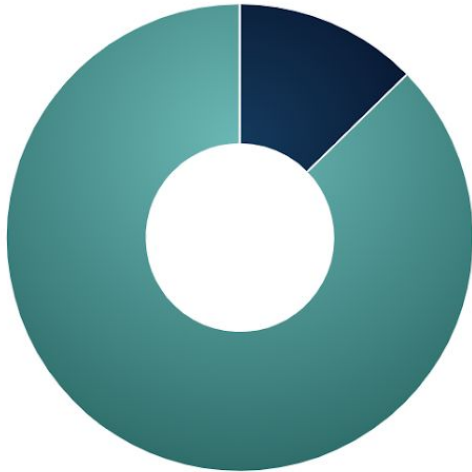
Source: IPEDS and APS

<https://www.aps.org/programs/education/statistics/>



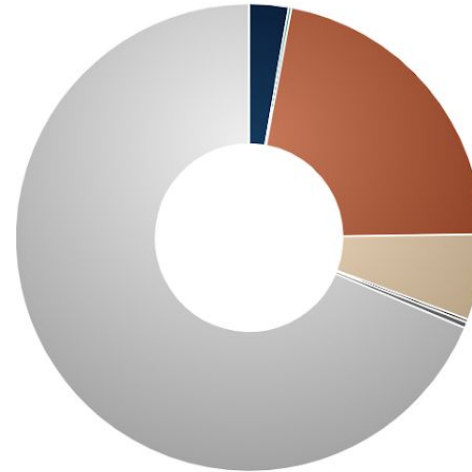
# Demographics in BNL - Technical Research Staff

Overall Gender



Gender		
	Women	12.69%
	Men	87.31%
	Did Not Provide	0%

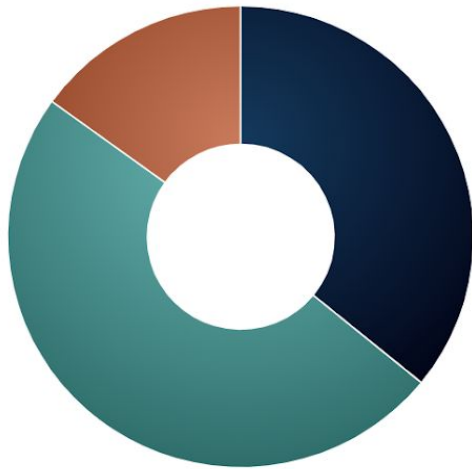
Overall Ethnicity



Ethnicity		
	African American/Black	2.72%
	American Indian or Alaska Native	0.2%
	Asian	21.85%
	Hispanic or Latino	5.94%
	Native Hawaiian or other Pacific Islander	0.2%
	Two or more Races/Ethnicity	0.4%
	White	68.68%
	Did Not Provide	0%

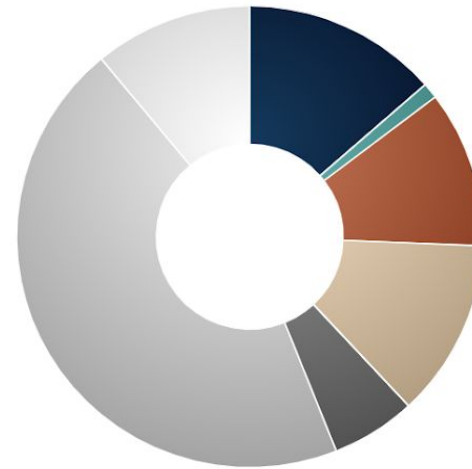
# Demographics in BNL - Undergrad students

Overall Gender



Gender		
	Women	35.9%
	Men	49.08%
	Did Not Provide	15.02%

Overall Ethnicity



Ethnicity		
	African American/Black	13.55%
	American Indian or Alaska Native	1.1%
	Asian	10.99%
	Hispanic or Latino	12.45%
	Native Hawaiian or other Pacific Islander	0%
	Two or more Races/Ethnicity	5.86%
	White	45.05%
	Did Not Provide	10.99%

# (some) BNL NPP efforts

## Office of Educational Programs

- Existing infrastructure and experience for students
  - Have successfully run SULI, CCI, HSRP, VFP, and other internships for decades
  - Provides organizational framework for bringing student fellows on-board
  - Provides training in giving scientific talks, writing reports and articles, professional behavior
  - Organizes talks, tours, and social activities
  - Student surveys already part of evaluation
- Longstanding relationship (network) to universities for recruiting
  - Key to recruiting students and finding those diamonds in the rough



## Workforce Development & Science Education

Preparing the next generation of scientists, engineers, technicians, and teachers utilizing the unique scientific tools and intellectual resources of Brookhaven National Laboratory



# (some) BNL NPP efforts

## DEI Office

- Collaboration w/ MSI's
  - MoUs (memorandum of understanding)
  - MSI Workshop
- Resources
  - Lab Diversity & Inclusion Plan (LDIP)
  - DEI Performance Appraisal Guidance
  - PIER Plan help
- Programs
  - Lab Connections
  - Gorman-Metz Scholarship
  - National Consortium for Graduate Degrees for Minorities
  - Professional Associates Program for Women and Minorities
  - Employment Opportunities for Individuals with Disabilities
  - African American Advancement Group Scholarship Program
  - Mow Shiah Lin Scholarship



Diversity



Equity



Inclusion



# (some) BNL NPP efforts



## African School of Fundamental and Applied Physics

- Graduate summer school every two years hosted by a different African country
- Workshop for high school teachers from the host country
- Outreach to high school learners from the host country
- International conference on fundamental physics and applications
- Continuous coaching and mentoring of students
- Forum to engage researchers, teachers, policy makers, and industry to discuss improvement for greater impact capacity development
- BNL International Engagements
  - Contributions to the ASP budget to support African students participation
  - Coverage for BNL staff lecturers in the organization, lecturing and mentoring of African students
  - Coverage for African students for 3-6 months visits for research at BNL

# BNL-MSI PREP-NPT as a model

Program for Research Excellence and Preparation via Nuclear Physics  
Traineeships – Mickey Chiu

- Pilot DOE Nuclear Physics Traineeship Program structured to address the lack of MSI students applying for grad school
  - We have solid summer programs, but the interaction and support of students ends with the season
    - Students/supervisors don't have time, resources, or structure to maintain a research program
  - Program includes financial support for full-time (40 hrs/wk) summer research @ BNL (equivalent to SULI)
  - Supports student research for 2 days per week during the Fall and Spring semesters (15 weeks each - \$15/hr)
  - Long term commitment (1-2 years) for all Fellows, through their final undergraduate years and into graduate school or other STEM career
  - Real research experience, conference presentations and publication!

# BNL-MSI PREP-NPT as a model

Results of the pilot:

- Scientific production
  - 10+ talks/posters presented or to be presented at APS DNP CEU 2022, NSBP, NAPAC 2022
  - 4 papers published or in pipeline to be published with student fellows as contributing author

**8/9 fellows are in or will be going to graduate school!**

