

Introduction to the Introduction to Fusion Energy and Plasma Physics Course



PRINCETON
PLASMA PHYSICS
LABORATORY

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Head of the Science
Education Department

First, a bit about myself

- From Bogotá, Colombia
- Started studying physics at the National University of Colombia at Bogota.
- Transferred to University of Texas at Austin where I finished undergrad (HOOK'EM HORNS!)



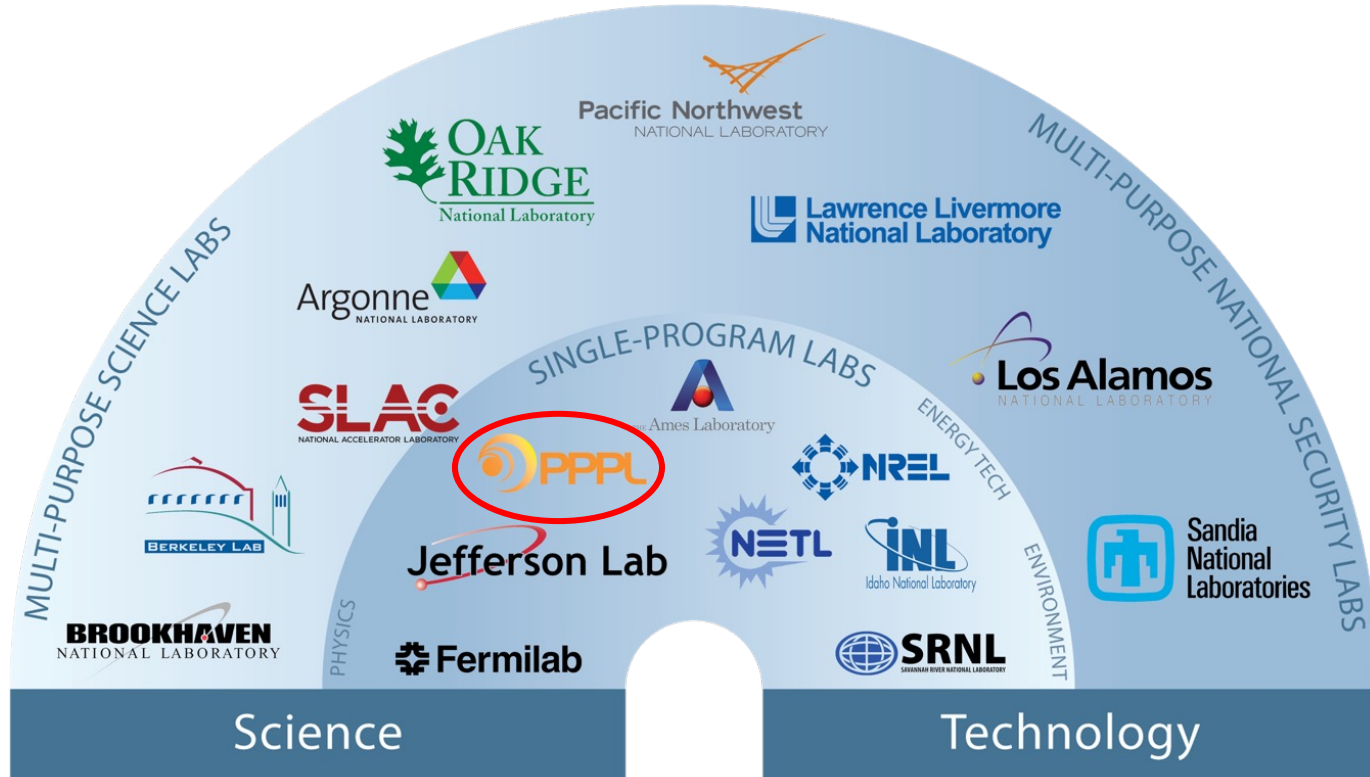
- Did my graduate work at MIT, in Boston on **fusion plasmas** (GO BEAVERS!)



- Now I'm at the Princeton Plasma Physics Lab (GO TIGERS!)



PPPL is one of 17 Department of Energy national laboratories





- ~600 employees
- 19 faculty (Princeton)
- ~22 post-docs
- ~40 grad students
- Operated by Princeton U.





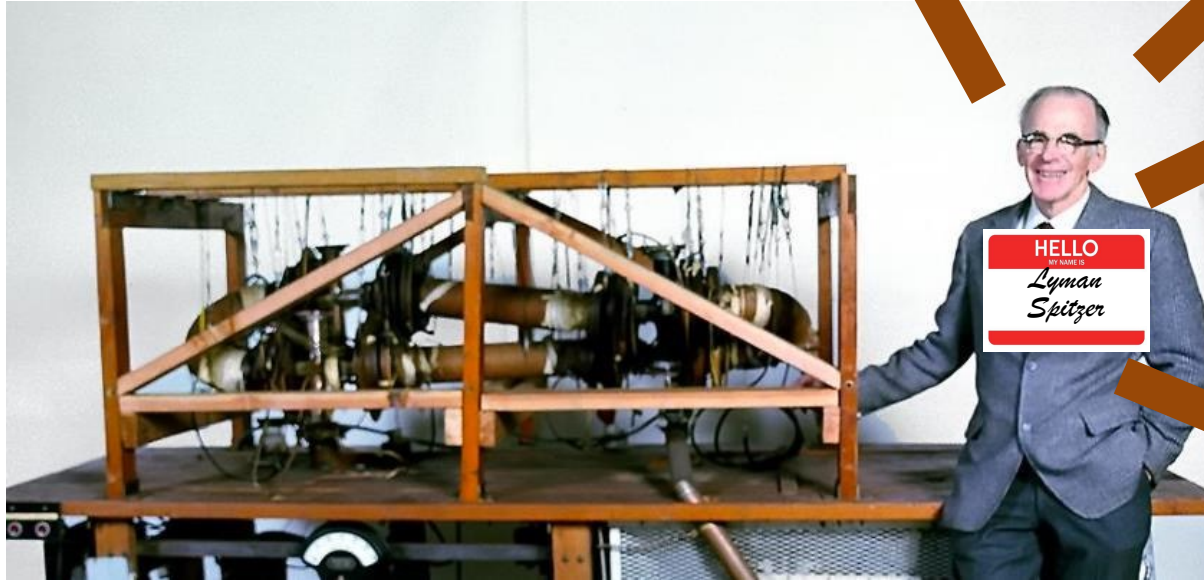
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Lyman Spitzer started PPPL (originally Project Matterhorn) in 1951...Birthplace of US fusion

Inventor of the Stellarator

Founder of the lab



Made countless advances in plasma physics (his name is everywhere)

Proposed telescopes in outer space (hence the Spitzer Space Telescope)

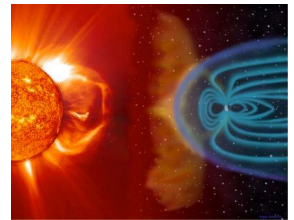
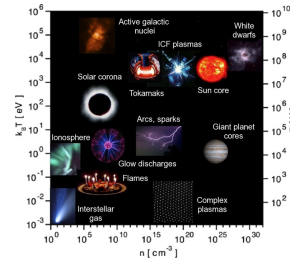
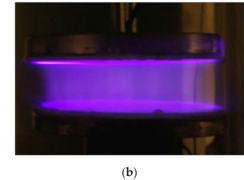
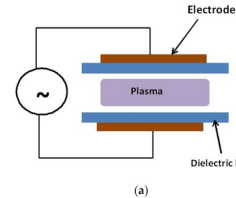
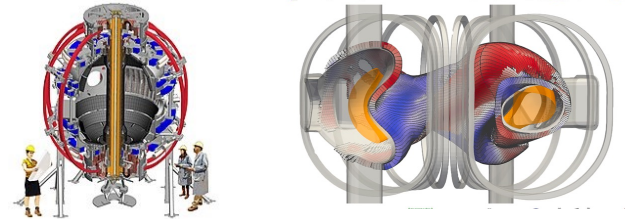
PPPL's mission goes beyond fusion

The Laboratory has three major missions:

1.Fusion: To develop the scientific knowledge and advanced engineering to enable fusion to power the U.S. and the world

2.Plasma Manufacturing: To advance the science of nanoscale fabrication for industries of the future

3.Frontiers of Plasmas: To further the scientific understanding of plasmas from nano- to astrophysical-scales



History of the Intro to Fusion/Plasma Course

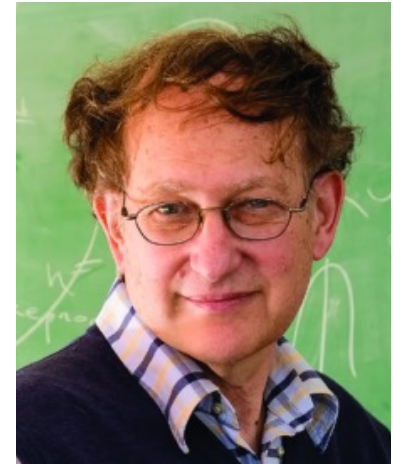
- Originally started in 1992 by Prof. Nat Fisch and former assistant director (and former congressman) Rush Holt, as part of the National Undergraduate Fellowship (NUF).



1994 NUF class



Rush Holt



Nat Fisch

Changes during the pandemic

- Fully Remote
- 2 weeks long, but 4.5 hours a day
- Shorter talks (50+10 minutes, vs. 90 minutes)
- Many more talks (27 speakers vs. 15 in the past)!
- Many more participants!
- Broader scope, covering the full spectrum of topics under the Fusion Energy Sciences and Plasma Physics umbrella

All lectures are free to watch and will be posted

- All lectures will be streamed via Zoom Webinar. No registration is needed.
- Enrollees, i.e. those who filled out the google form on the site and which we could fit, will have a Zoom-Brady-Bunch-Square, will get priority for questions, join the hallway discussions, and will join the networking events.
- Webinar participants can ask questions using the ask/chat feature.
- ALL written questions should be directed at the hosts and we will hold them for the Q/A portion.
- As has been done since 2015, the course lectures and the speaker videos will be posted on [the site](#).

We had way more submissions than we could handle!

- We were pleasantly surprised by the number and breadth of enrollment submissions (almost 1000)!
- Submissions included undergraduate students, grad students, postdocs, researchers, professors and general public.
- Because of technical limitations, we could only enroll ~ 300 participants so priority has been given to undergraduates conducting fusion/plasma research.

Y'all are all over the world!



Y'all are all over the world! Except Australia ☹️



A birds-eye view of the undergrads

Undergraduate enrollees are based in the US and in many other countries, including: Mexico, India, Nigeria, Colombia, UK, and many more!

Many enrollees are conducting internships/summer research.
Some of the programs are:

- Science Undergraduate Laboratory Internship Program (SULI) and Community College Internship (CCI), run by DOE.
- Students doing internships at their own colleges
- Private companies developing fusion
- Plasma and Fusion Undergraduate Research Opportunities (PFURO) program



2021 Intro course participants

WHAT TO EXPECT IN THE NEXT COUPLE OF WEEKS

Today (6/13) we'll begin with introductions

Eastern Time	Day 1 (6/13/22)
12:00 PM	Introduction to the Course <i>Dominguez</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Introduction to fusion <i>Hartwig</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Introduction to Plasmas I <i>Schaffner</i>
4:00 PM	Adjourn



- After this intro, Prof. Zach Hartwig (MIT) will present the promise and challenges of fusion energy



- Prof. David Schaffner (Bryn Mawr) will introduce plasmas and highlight the wide breadth of the field.




Tomorrow (6/14) we continue with Plasmas

Eastern Time	Day 2 (6/14/22)
12:00 PM	Introduction to Plasma Physics II <i>Williams</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Plasma Waves <i>Diem</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Stellarators <i>Hammond</i>
4:00 PM	Adjourn






- Prof. Jeremiah Williams (Wittenberg) will discuss different models for dealing with plasmas (single-particle/fluid)
- Prof. Steffi Diem (Wisconsin-Madison) will present the variety of waves in plasmas, and how they can be used in various plasma systems
- Dr. Ken Hammond (PPPL) will introduce the first of the magnetic fusion concepts, the stellarator.

On Wednesday (6/15) we will focus on magnetic and inertial fusion (with a turbulent detour)

Eastern Time	Day 3 (6/15/22)	
12:00 PM	Tokamaks <i>Wilks</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	Plasma Turbulence <i>Francisquez</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Inertial Confinemnt Fusion <i>Kraus</i>	
4:00 PM	Adjourn	

- Dr. Theresa Wilks (MIT) will present on the most widely studied magnetic fusion devices, the tokamak.
- Dr. Manaure Francisquez (PPPL) will discuss how turbulence arises in plasma systems and its physics
- Dr. Brian Kraus (PPPL) will focus on another approach to fusion, inertial confinement.

Thursday (6/16) we will concentrate on plasmas....in space!

Eastern Time	Day 4 (6/16/22)	
12:00 PM	Magnetic Reconnection <i>Egedal</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	Heliosphere Plasmas <i>Rivera</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Unlocking the Secrets of Van Allen Radiation Belts <i>Tu</i>	
4:00 PM	Networking Hour	
5:00 PM	Adjourn	

- Prof. Jan Egedal (Wisconsin) will discuss magnetic reconnection, ubiquitous in astrophysical plasmas
- Dr. Yeimy Rivera (Harvard Smithsonian CFA) will touch upon plasmas within the solar system.
- Prof. Weichao Tu (West Virginia) will relate basic plasma physics concepts to the plasmas of the Van Allen belts

Thursday (6/16) will also feature the first networking session

Eastern Time	Day 4 (6/16/22)
12:00 PM	Magnetic Reconnection <i>Egedal</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Heliosphere Plasmas <i>Rivera</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Unlocking the Secrets of Van Allen Radiation Belts <i>Tu</i>
4:00 PM	Networking Hour
5:00 PM	Adjourn

- Day 4 will also feature the first of two network sessions in which the group will be divided into groups of ~10-20 and will meet with current graduate students in the field. This is a space to ask questions about grad schools, the grad experience, the field, etc.

Friday (6/17) Princeton and PPPL will be observing Juneteenth – NO COURSE

- **Juneteenth is a holiday commemorating the emancipation of enslaved people in the US.**
- It commemorates the day in 1865 when enslaved people of Texas, then the most remote region of the Confederacy, finally learned slavery had been abolished.
- In observance of **Juneteenth**, Princeton U and PPPL will be closed on Friday, June 17th.
- We welcome you to take some time to learn about Juneteenth and about ongoing systemic racism in the US and in your own country.






Plaque in Galveston commemorating Juneteenth

| Saturday and Sunday, we rest



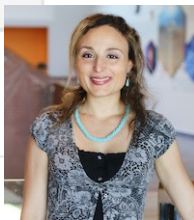
On Day 5 (6/20) we touch on astrophysical plasmas, fusion technology and alternative configurations

Eastern Time	Day 5 (6/20/22)	
12:00 PM	Astrophysical Plasmas <i>Kunz</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	High Temperature Superconductors <i>Salazar</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Alternative Configurations <i>Parke</i>	
4:00 PM	Adjourn	

- Prof. Matt Kunz (Princeton) will discuss plasmas at astrophysical scales and their unique qualities.
- Dr. Erica Salazar (CFS) will present high-temperature superconductors, the technological innovation that is revolutionizing fusion.
- Dr. Eli Parke (TAE) will present on the innovative alternative fusion approaches that haven't been discussed yet.

On Day 6 (6/21) we will quantify success towards fusion and tackle the physics at the edge

Eastern Time	Day 6 (6/21/22)
12:00 PM	Physics of Core-Edge <i>Casali</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Quantifying progress towards fusion energy gain: the Lawson criterion <i>Wurzel</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Plasma-surface interactions: Interplay between the plasma and solid wall components <i>Lasa</i>
4:00 PM	Adjourn



- Prof. Livia Casali (UTK) will begin discussing the way the core of the plasma relates to the edge physics and vice-versa
- Sam Wurzel (ARPA-E) will connect the fusion talks by introducing the Lawson criterion and how it can be generalized to various fusion approaches
- Dr. Ane Lasa (UTK) will focus on the physics interactions between the plasmas at the edge and the materials at the wall of the reactors.

Day 7 (6/22): Focus on Low-Temperature Plasmas

Eastern Time	Day 7 (6/22/22)
12:00 PM	Physics of Low-Temperature Plasmas <i>Simeni-Simeni</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Biomedical Plasmas <i>Stapelmann</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Industrial Plasma Applications <i>Shannon</i>
4:00 PM	Networking Hour
5:00 PM	Adjourn



- Day 8 will start with a broad overview of the physics of low-temperature plasmas given by Prof. Marien Simeni-Simeni (Minnesota).
- Prof. Katharina Stapelmann (NCSU) will present on how low-temperature plasmas can be used in biomedical applications.
- Prof. Steven Shannon (NCSU) will expand on the applications of low-temperature plasmas, by discussing their industrial uses.
- The day will conclude with the second networking session event.

Day 8 (6/23): Heat removal, neutronics and computation

Eastern Time	Day 8 (6/23/22)
12:00 PM	Heat Removal for First Wall Components <i>Carasik</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Neutronics in fusion devices <i>Nieto-Perez</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Computational Workshop <i>PlasmaPy team</i>
4:00 PM	Computational Workshop <i>PlasmaPy team</i>
5:00 PM	Adjourn

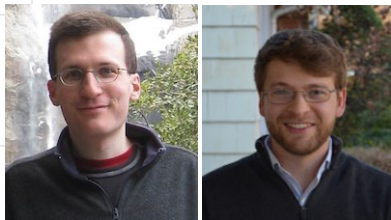


- Prof. Lane Carasik (Virginia Commonwealth U) will continue the edge issues discussed on day 6 by presenting on the challenges of removing the heat from the first wall
- Prof. Martin Nieto-Perez (Penn State) will continue on the fusion technological challenges by presenting on the issue of neutronics in fusion devices.

Day 8 (6/23): Computational workshop




Eastern Time	Day 8 (6/23/22)
11:30 AM	
12:00 PM	Heat Removal for First Wall Components <i>Carasik</i>
1:00 PM	Break/Hallway Discussion
1:30 PM	Neutronics in fusion devices <i>Nieto-Perez</i>
2:30 PM	Break/Hallway Discussion
3:00 PM	Computational Workshop <i>PlasmaPy team</i>
4:00 PM	Computational Workshop <i>PlasmaPy team</i>
5:00 PM	Adjourn

PlasmaPy



- The computational workshop will be a “hands-on” event organized by the PlasmaPy team, led by Dr. Nick Murphy and Dr. Peter Heuer.
- This workshop will require you to have the Anaconda Python environment installed in your computer.
- In order to ensure the time is spent on the content and not on the setup, we’ve put together [this document](#) laying out the steps for installation.

Day 9 (6/24): Computational methods + HEDP and closing

Eastern Time	Day 9 (6/24/22)	
12:00 PM	Computational Methods in Plasma Physics <i>Hakim</i>	
1:00 PM	Break/Hallway Discussion	
1:30 PM	Z-Pinches, Pulsed Power, and Fusion <i>Rocco</i>	
2:30 PM	Break/Hallway Discussion	
3:00 PM	Short-pulse driven relativistic plasmas <i>Albert</i>	
4:00 PM	Closing / Adjourn <i>Dominguez</i>	

- Dr. Ammar Hakim (PPPL) will follow the computational workshop with a discussion on computational methods used in plasma physics
- Dr. Sophia Rocco (LLNL) will switch topics to high-energy density plasmas (HEDP) to discuss various approaches in this field.
- To close the HEDP section (and the course) Dr. Félicie Albert (LLNL) will explore one extreme realm in plasma physics, relativistic plasmas.
- I will conclude with some closing remarks

We've started a Discord server for the incoming fusion/plasma community!



- Summer of 2020, we created a venue to let the participants of this course, and, in general, undergrads and grads just starting out in the road of fusion and plasma physics, talk to each other and learn about summer opportunities. Conversations continued beyond the summer.
- With the help of Nigel DaSilva and Louise Ferris, we've created and maintained a Discord server for this purpose. **Enrollees were all invited to join.**



Nigel DaSilva, 2020 PPPL SULI
Current Columbia
grad student



Louise Ferris, 2020 LANL SULI
Current UW-Madison
grad student

Continue the conversations with the speakers!

- Some speakers will be able to stick around after their talks to continue discussions. We will share a “Hallway Discussions” zoom link with enrollees. We will announce if speakers will be available and when.
- We will also have Discord channels for each topic to continue discussions and we’re inviting the speakers to join (we’ll also send them the questions that arise there).

APS-DPP abstract submissions



- The American Physical Society Division of Plasma Physics (APS-DPP) meeting is scheduled for the week of October 17-21 in Spokane, WA. The conference will be held as a hybrid in-person/remote event. Visit the [meeting website](#) for up to date information.
- As with every year, undergraduates are invited to present their research at a dedicated poster session. There were more than 100 undergraduate posters at the 2021 APS-DPP meeting!
- **All poster abstract submissions are due July 1st and can be submitted on the [meeting website](#)**
- Registration and APS membership is free for undergrads!

These are not normal times and we should
acknowledge this

- The reason the course is remote is because we are living during a pandemic.
- All talks are recorded and will be posted, so practice self-care. Take rests, sit out when you're exhausted, stretch, stay hydrated, etc.
- **YOUR HEALTH AND WELL BEING ARE THE PRIORITY!**

A healthy culture of diversity, equity and inclusion is needed for the future of fusion energy and plasma physics

- The US fusion energy and plasma physics community has a poor record on diversity, equity and inclusion, as evidenced by the few women and underrepresented minorities in the field as compared to other physics and engineering fields.
- Recent community-wide strategic plans have, for the first time, acknowledged these problems and put forth initial plans to address them. But an inclusive climate is the only way to start.

Code of conduct

Since this is a public forum we ask speakers and participants to:

- Make participation in our community a harassment-free experience for everyone
- Act in ways that contribute to an open, welcoming, diverse, inclusive, and healthy community
- We align with the [Contributor Covenant Code of Conduct](#)

Code of conduct: Unacceptable Behaviors

- The use of sexualized language or imagery, and sexual attention or advances of any kind
- Trolling, insulting or derogatory comments, and personal attacks
- Public or private harassment
- Other conduct which could reasonably be considered inappropriate in a professional setting

Code of conduct: Positive Behaviors

- Demonstrating empathy and kindness
- Being respectful of differing opinions and experiences
- Giving and gracefully accepting constructive feedback
- Accepting responsibility and apologizing to those affected by our mistakes, and learning from the experience

Code of conduct: Positive Behaviors

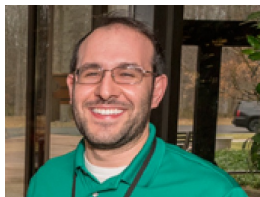
- Respect the pronouns of others
- Recognize that intent is not equal to impact
- **Self-Care is revolutionary!**

Thanks to the folks that make this happen

This course is a massive effort that requires many folks behind the scenes, both at PPPL and beyond. I'd like to especially thank:



Deedee
Ortiz



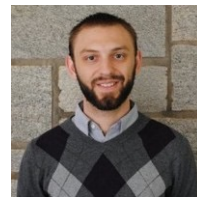
Harry
Tsamutalis Jr



Louise
Ferris



Britt
Albucker



Matt
Parsons



Anthony
Pizzo

Finally, of course, thanks to all of the speakers!



Dr. Felicie Albert
LLNL



Prof. Lane Carasik
Virginia Commonwealth U.



Prof. Livia Casali
UT Knoxville



Prof. Steffi Diem
UW Madison



Prof. Zach Hartwig
MIT-PSFC



Dr. Peter Heuer
Laboratory for Laser Energetics



Dr. Brian Kraus
PPPL



Prof. Matt Kunz
Princeton U



Prof. Jan Egedal
UW Madison



Dr. Manuere Francisquez
PPPL



Dr. Ammar Hakim
PPPL



Dr. Kenneth Hammond
PPPL



Dr. Ane Lasa Esquisabel
UT Knoxville



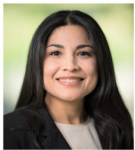
Dr. Nick Murphy
Harvard-Smithsonian CFA



Prof. Martin Nieto-Perez
Penn State U.



Dr. Eli Parke
TAE



Dr. Yeimy Rivera
Harvard-Smithsonian CFA



Dr. Sophia Rocco
LLNL



Dr. Erica Salazar
CFS



PlasmaPy Team



Prof. Weichao Tu
WV University



Dr. Theresa Wilks
MIT PSFC



Prof. Jeremiah Williams
Wittenberg U



Mr. Sam Wurzel
ARPA-E



Prof. David Schaffner
Bryn Mawr College



Prof. Steven Shannon
NC State University



Prof. Marien Simeni Simeni
University of Minnesota



Prof. Katharina Stapelmann
NC State University