Synergies
- Yale Center for Astronomy and Astrophysics (YCAA)
- Yale Center for Research Computing (YCRC)
- Yale Quantum Institute (YQI)

Nuclear/Particle/Astrophysics

Faculty, PIs
16 faculty
4 adjunct/research faculty

Scientists, Staff, Students
12 research scientists
13 postdocs
43 graduate students
~120 total personnel

https://wlab.yale.edu
State-of-the-Art Facilities

https://wlab.yale.edu
New Tools for Discovery

Li scintillator detectors for reactor \( \nu \)

Coldest cubic meter of Universe to study \( 0\nu\beta\beta \)

Low-background NaI detectors for dark matter search at South Pole

Zero point motion close to zero K

Electron EDM searches

Axion searches

LAr TPC for \( \nu \)
Research in Maruyama Group

http://maruyama-lab.yale.edu

Research

- Physics Beyond the Standard Model of Particle Physics
- Neutrinos and Dark Matter
- direct detection dark matter experiment at Yale, South Pole and South Korea.
- Is DAMA really seeing dark matter?
- Neutrinoless double beta decay
- Are neutrinos their own anti-particles? Are they Majorana particles?
Why is the Universe made of matter and not anti-matter?

What are neutrinos?

What is dark matter?
Relativistic Heavy-Ions at Yale  
Caines-Harris Group  
Studying the Quark-Gluon Plasma - Nature’s Most Extreme Liquid

What makes the Quark Gluon Plasma Extreme?

- **Nature’s first liquid** - existed $10^{-6}$ second after the Big Bang
- **Most perfect liquid** - 10 times less viscous than water
- **Hottest Liquid** - $T \sim 10^{12}$ Kelvin - We hold a Guinness World record
- **Most vortical liquid** - spins 10 billion trillion times faster than powerful tornadoes
- **Smaller liquid** - evidence for QGP creation when only the size of a proton

All occurring in the most intense magnetic field ever created!

+ Improving our studies of the strong force and the role of gluons in matter at the Electron Ion Collider - New accelerator approved for construction at BNL
Relativistic Heavy-Ions at Yale
Caines-Harris Group

Studying the Quark-Gluon Plasma - Nature’s Most Extreme Liquid

- 2 Faculty - Helen Caines & John Harris
- 2 Adjunct Faculty - Jurgen Schukraft (CERN), Thomas Ullrich (BNL)
- 1 Research Scientist (Hardware R&D focus) - Nikolai Smirnov
- 4 Post Docs - Mesut Arslandok (ALICE), Fernando Flor (STAR), Laura Havener (ALICE), Raghav Kunnawalkam Elayavalli (STAR), Mike Sas (ALICE)
- 9 Graduate students - Caitie Beattie (ALICE), Hannah Bossi (ALICE), Evan Craft (ALICE), Tong Liu (STAR), Dan Nemes (STAR), Michael Oliver (ALICE), Youqi Song (STAR), Andrew Tamis (STAR), Sierra Weyhmiller (ALICE)
- Undergraduate students - usually over the summer

Hoping to recruit new students into either STAR, ALICE or the EIC
Will work on mixture of data analysis and hardware R&D
Based at Yale, travel to BNL and CERN as needed
Yale ATLAS Group

- Dark sector might be complex – containing its own (massive) U(1) gauge boson \(Z_d\)

\[
\text{Kinetic mixing parameter } \epsilon \\
(\text{controls coupling between } Z_d \text{ & SM})
\]

Baker, Weber, Pan, da Silva, ...

**Higgs boson decays to tau leptons, Dark sector searches with the Higgs, Lepton-flavor-violating Higgs searches, CP of the Higgs, quantum entanglement at the LHC...**
The Mu2e Experiment

Production Solenoid
Proton Beam
Transport Solenoid
Production Target
Detector Solenoid
Tracker
Calorimeter

Fermilab

1S Orbit
Lifetime = 864 ns

\[ E_e = m_e c^2 - (\text{B.E.})_{1S} - E_{\text{recoil}} = 104.96 \text{ MeV} \]

Mu2e

The Mu2e Experiment

Fermilab
Motivations for these models come from measurement hints or attempts to make progress with the standard model’s shortcomings...
Faculty
Bonnie Fleming

Post-Docs
Jay Hyun Jo
Domenico Franco
Kaicheng Li

We work on short baseline and long baseline neutrino physics and on Detector R&D. Will take new student next year!

Palamara and Cavanna are Adjunct Faculty. Antonio Ereditato is Visiting Faculty.

Ornella Palamara
Flavio Cavanna

London Cooper-Troendle
6th year

Lee Hagaman
3rd year

Angela White
1st year

Giacomo Scanavini
4th year
Short Baseline Neutrino Oscillation Program at Fermilab

Phase 1: MicroBooNE
Taking data now!

Phase 2: New Near Detector
Under Construction now, in part at Yale

Phase 3: ICARUS far detector

Neutrino Cross sections...
New physics?
Deep Underground Neutrino Experiment (DUNE)
Bonnie Fleming and Karsten Heeger

Neutrino and Anti-Neutrino beams created at DOE’s Fermi National Accelerator Laboratory in Chicago, and directed to the Sanford Underground Research Facility in South Dakota

Neutrinos and anti-neutrinos change (oscillate) as they travel – look for these differences...

Massive detectors a mile underground measure the neutrinos and anti-neutrinos
At Wright Lab: Build the planes that “see” the neutrinos interacting in the detector

Wright lab will be an far detector and near detector fabrication and assembly center for DUNE
Neutrinos and the Invisible Universe

Is there new physics beyond 3 neutrinos?

Are neutrinos their own antiparticles?

What is the absolute neutrino mass?

Synergies with groups of Maruyama and Fleming

heegerlab.yale.edu
Neutrinos and the Invisible Universe

Postdocs/Scientists

Pranava Surukuchi  Luis Saldana  James Nikkel  Penny Slocum

Graduate Students

Ben Foust  Samantha Pagan  Iris Ponce  Talia Weiss  Arina Telles

student distinctions: NSF fellowships, co-founder of Yale Physics Professional Development Organization; Poorvu teaching fellow
alumni: faculty, national labs, industry

heegerlab.yale.edu
Our group is developing technologies to search for new physics through precision searches for extremely rare or weakly coupled phenomena:

**Extremely rare events (EXO):** Searching for $0\nu\beta\beta$ with half-life sensitivity up to $10^{28}$ years (and beyond?) with large liquid Xe detectors:
- Are neutrinos Majorana fermions?
- Is lepton number conserved in nature?
- What is the origin of the matter/antimatter asymmetry?

**Extremely tiny forces (SIMPLE):** Developing levitated optomechanical force sensors to search for forces $< 10^{-21}$ N:
- Searching for deviations from Newton’s or Coulomb’s law a micron distances
- New techniques to detect dark matter scattering using quantum optomechanical sensors
- Tests of the neutrality of matter and searches for millicharged particles
- Mechanical detection (and spectroscopy) of single nuclear decays
Our group @ Wright Lab

http://campuspress.yale.edu/moorelab/

- We are looking for students to join us on both nEXO and SIMPLE
- These are small scale experiments, and graduate students play a major role in the design, construction, data taking, and analysis!

nEXO:
- Avinay (PD)
- Ako (GS)
- Sierra (GS)
- Glenn (GS)
- Barkotel (UG)

SIMPLE:
- Gadi (PD)
- Tom (PD)
- Ben (GS)
- Molly (GS)
- Jiaxiang (GS)
- Juan (UG)