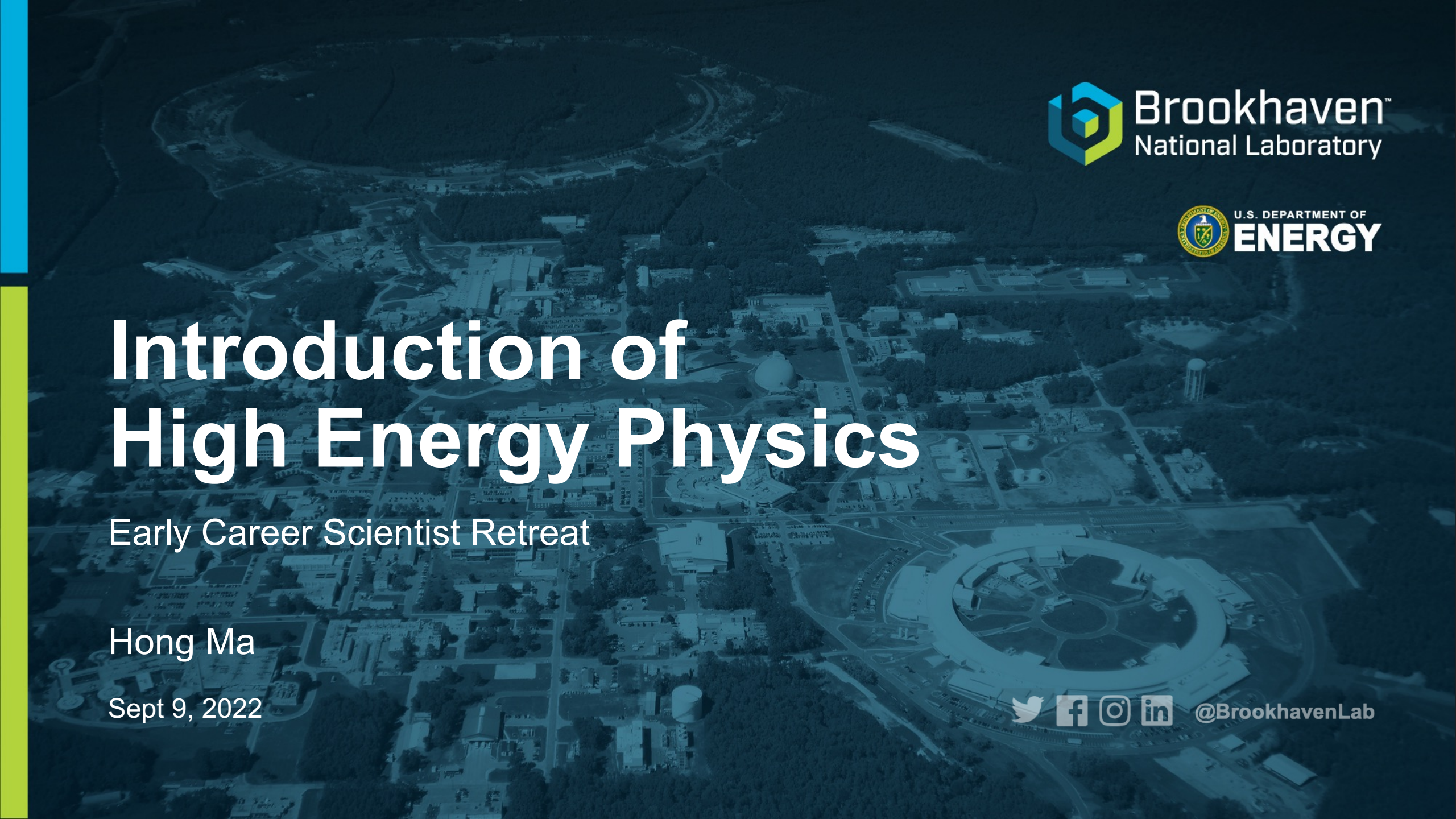


Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Introduction of High Energy Physics

Early Career Scientist Retreat

Hong Ma

Sept 9, 2022

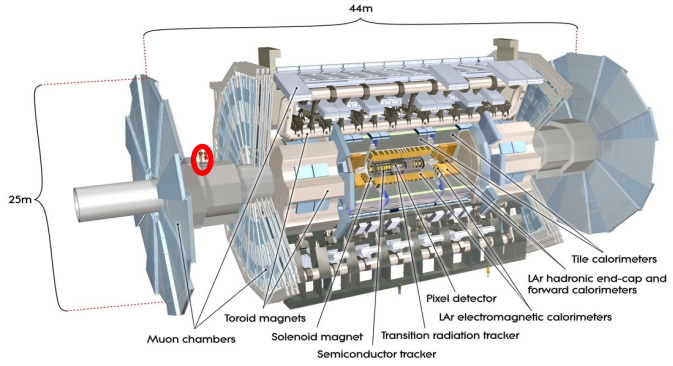
@BrookhavenLab

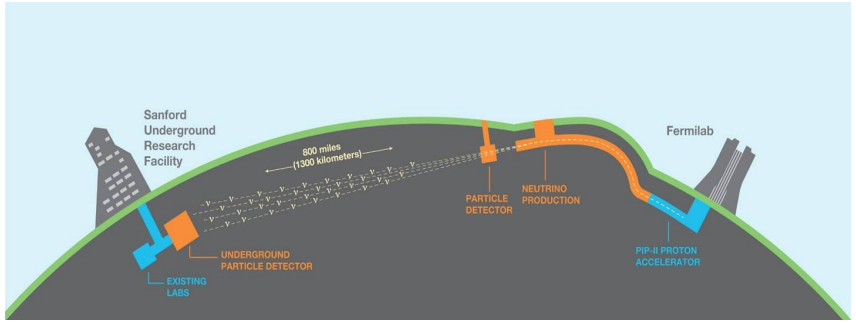
Science Drivers for High Energy Physics

US HEP community, through P5 in 2014, identified 5 science drivers

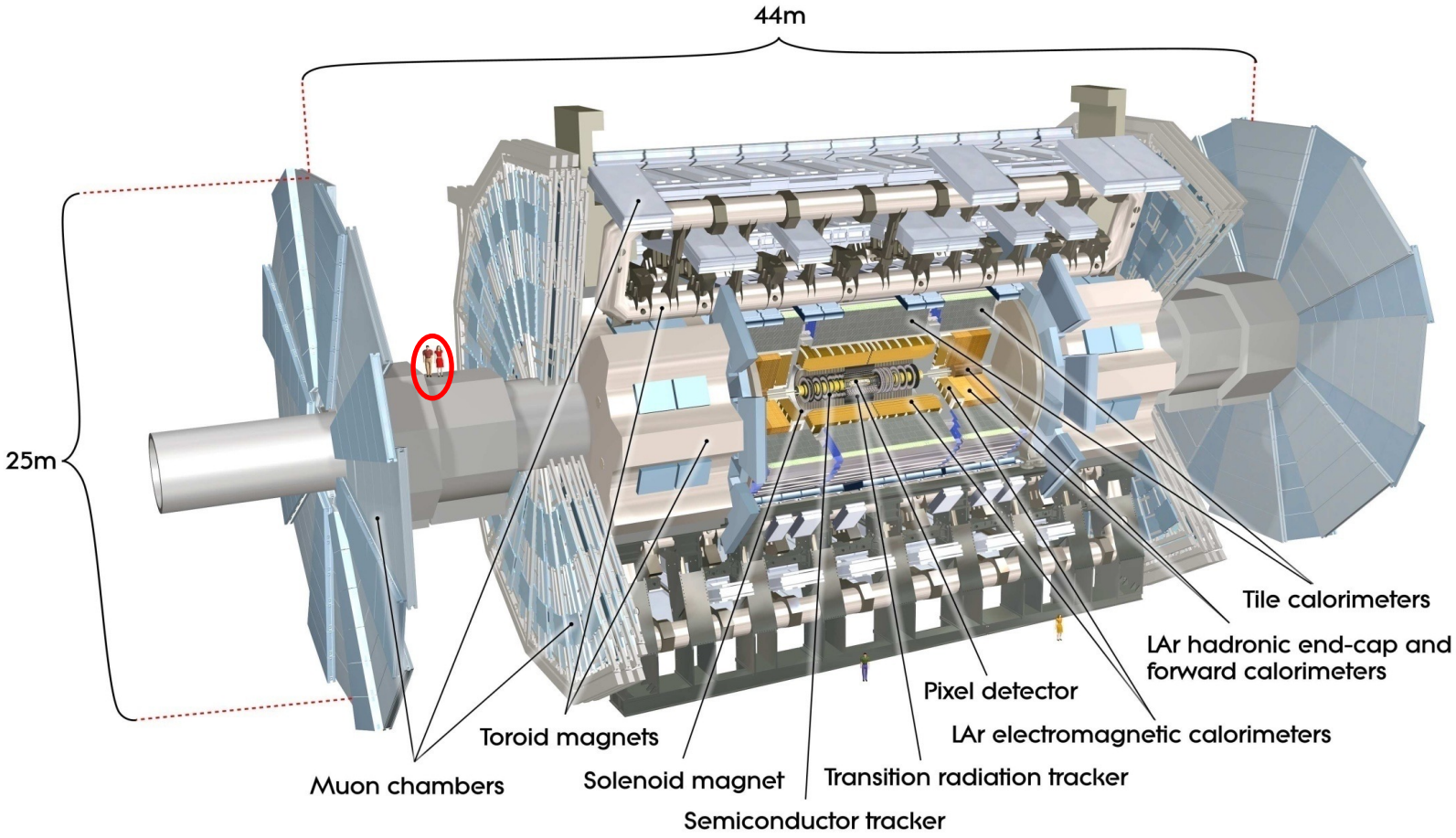
- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles.

BNL HEP program is well aligned with the scientific goal of the field.





The ATLAS and the LHC



- Highest energy collider
  - Studies of all known elementary particles
  - Search for new phenomena
- Strong projects, operations, research programs
  - Well integrated
- BNL is leading US participation in the ATLAS experiment
  - US ATLAS Operations program
  - Tier 1 computing center
  - HL-LHC Upgrade project
- LHC/HL-LHC will continue for ~20 years

BNL scientists are active in studying the Higgs boson and electroweak symmetry breaking (EWSB) as well as beyond the Standard Model (BSM) physics to address these drivers.

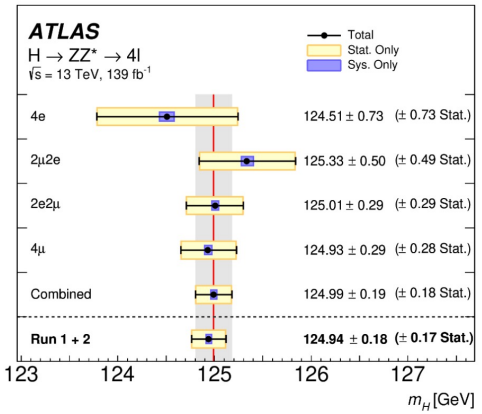
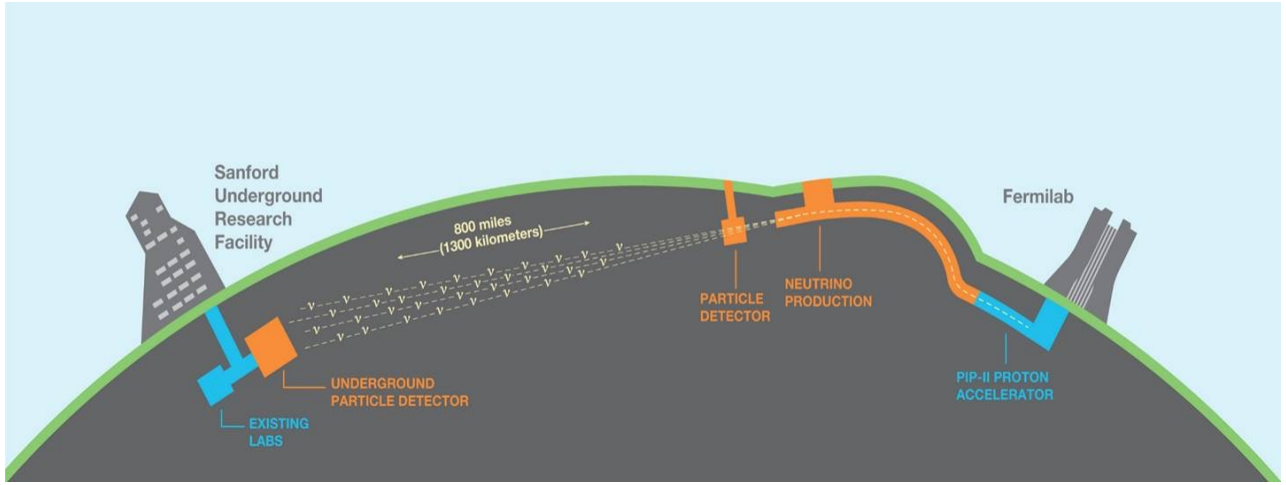
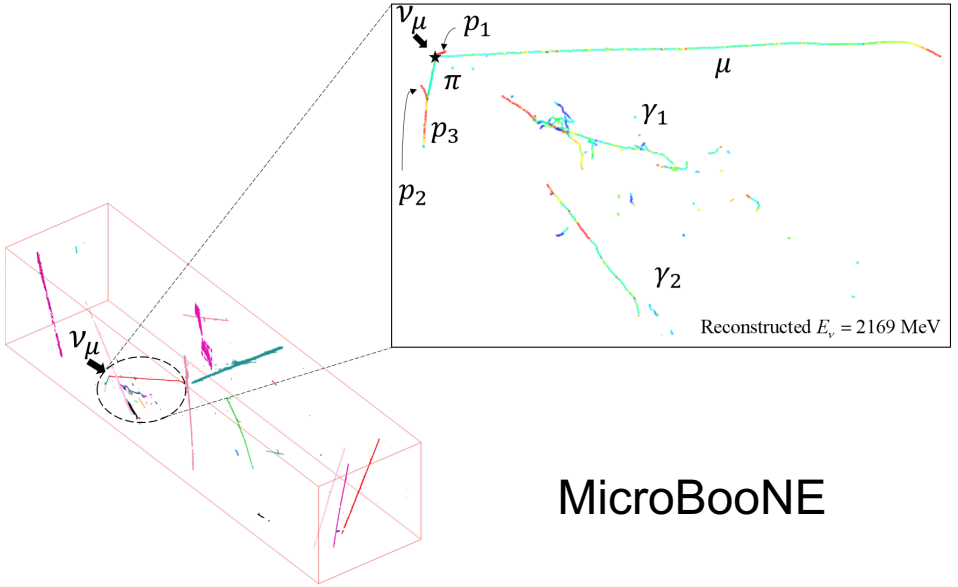


Figure 1. The Higgs Boson mass measurement in the H→ZZ→4ℓ channel using the full dataset.

DUNE and Short Baseline Neutrino Program at Fermilab

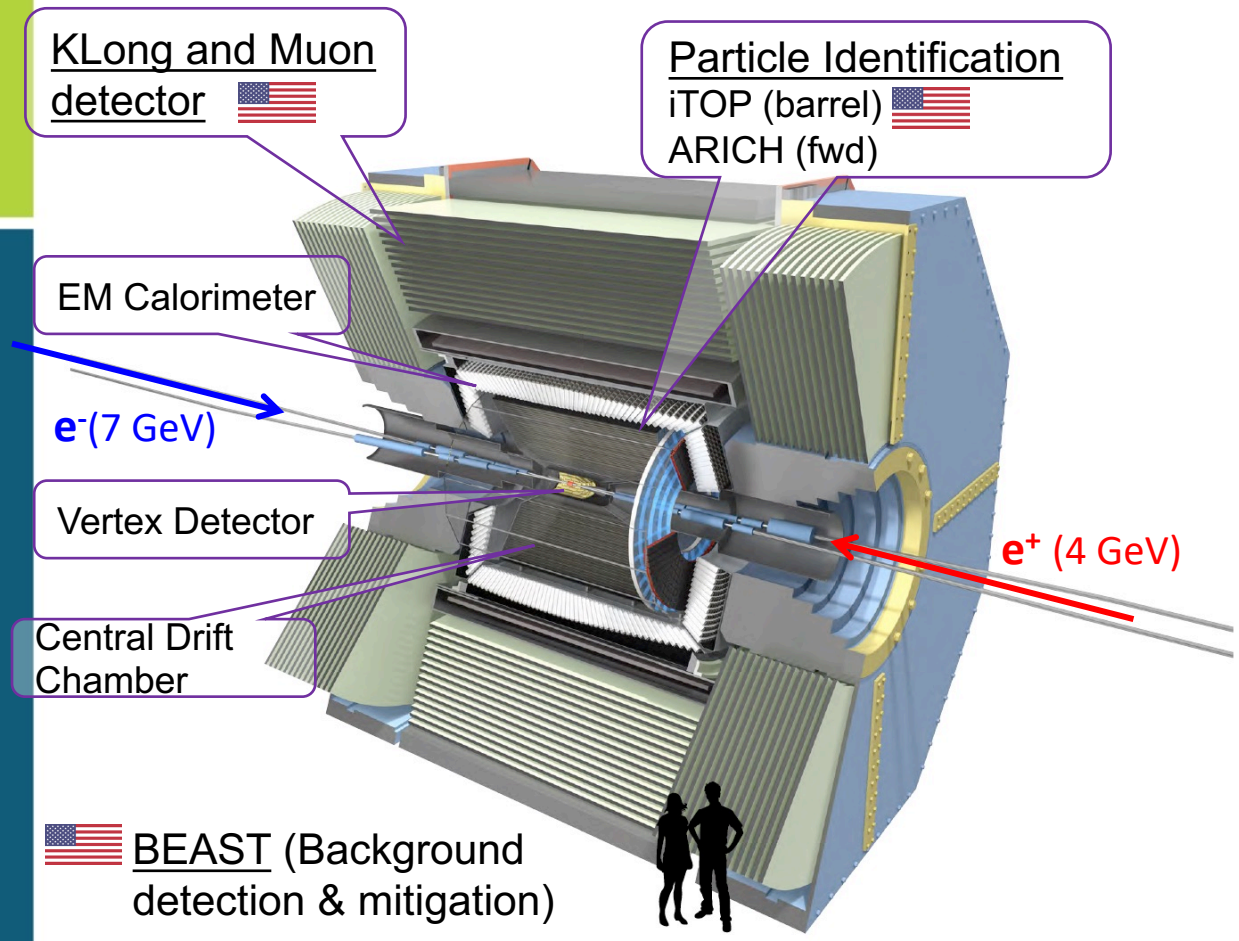




MicroBooNE

- Studies of the neutrinos – the most elusive elementary particle
- Contributing to construction of experiments, operations, performance and science
- Short baseline program timeline is ~10 years
- DUNE will start in late 2020's and run for ~20 years

Belle II Program



BEAST (Background detection & mitigation)

Computing: Tier1 site, raw data archive and prompt calibration center at BNL. Conditions database service and data management on the worldwide computing grid.

- Experiment at KEK laboratory in Japan
  - Largest samples of heavy quark states to understand their behavior and properties
- BNL is leading US Operations program
  - software and computing
- Strong participant in physics studies
- Expected to run till early 2030's

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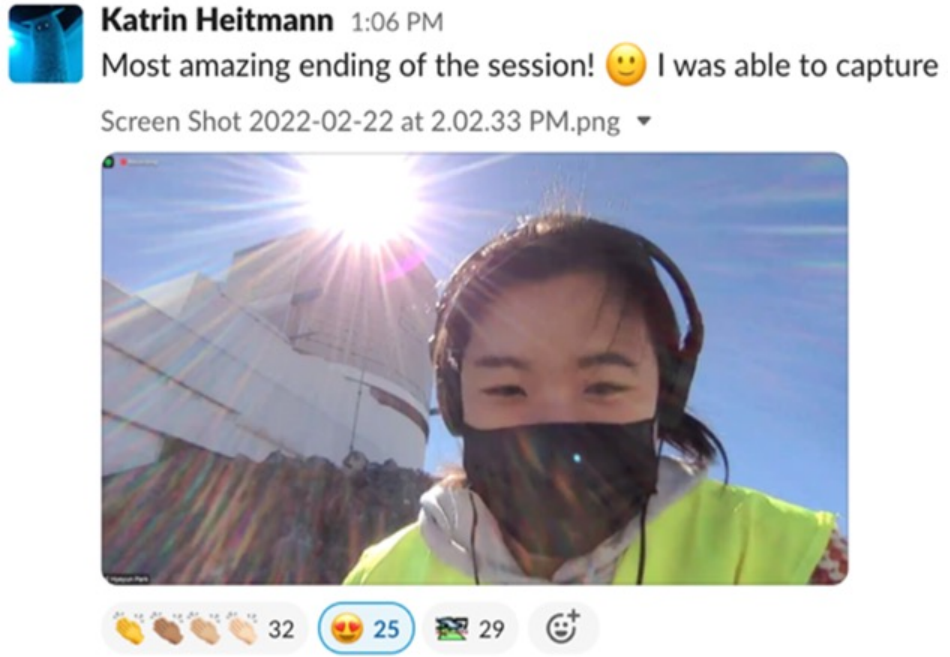
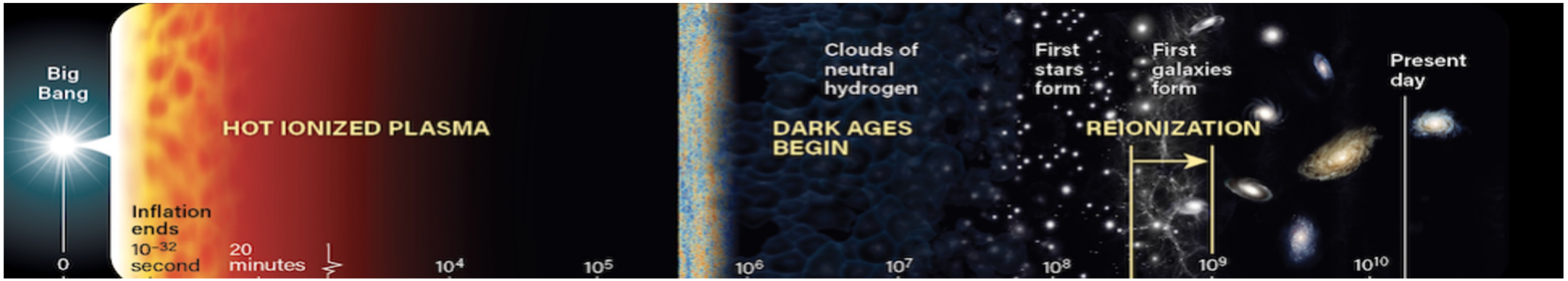
Astrophysics Program

- Most recent HEP program at BNL
- Started with Rubin/LSST
  - Understanding dark energy and dark matter
  - Camera construction, operations, science
  - ~10 years of data collection

LuSEE-Night program

- Most recent Astrophysics program at BNL
- Construction, operations, science
- Potential for studies of yet un-explored time period of the universe

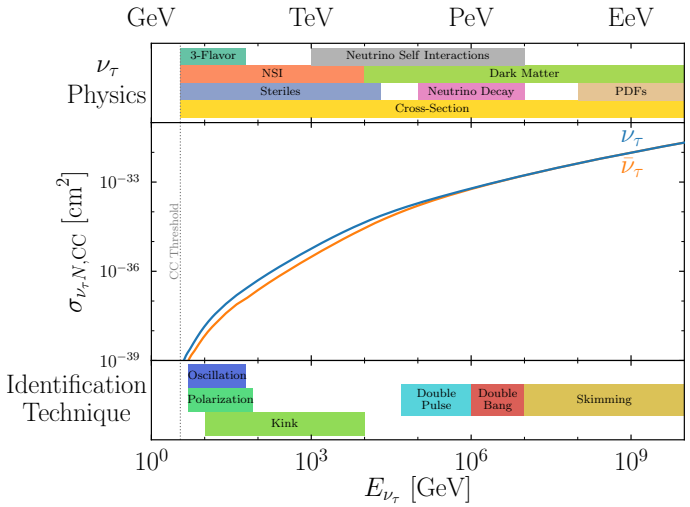




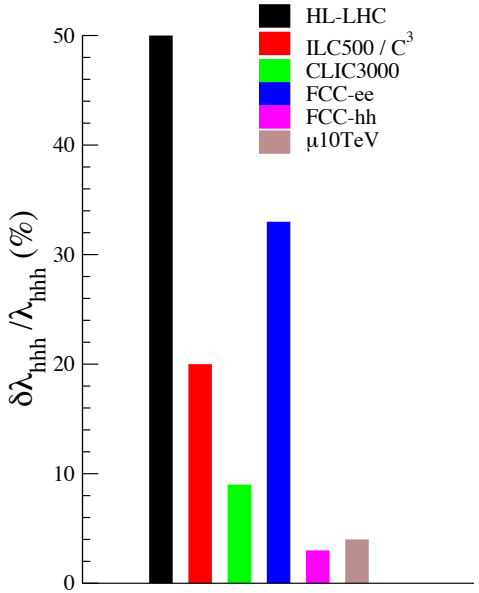
Particle Physics Theory

Strong efforts in precision calculations, neutrino physics, lattice gauge theory, BSM/cosmology

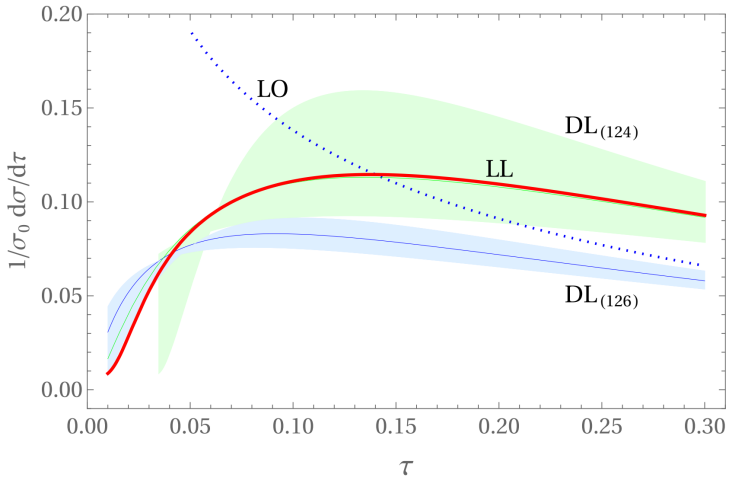
τ neutrino studies



Projections for measurements of hhh coupling



Thrust at the next-to-leading power
Relevant for jet production in e^+e^-



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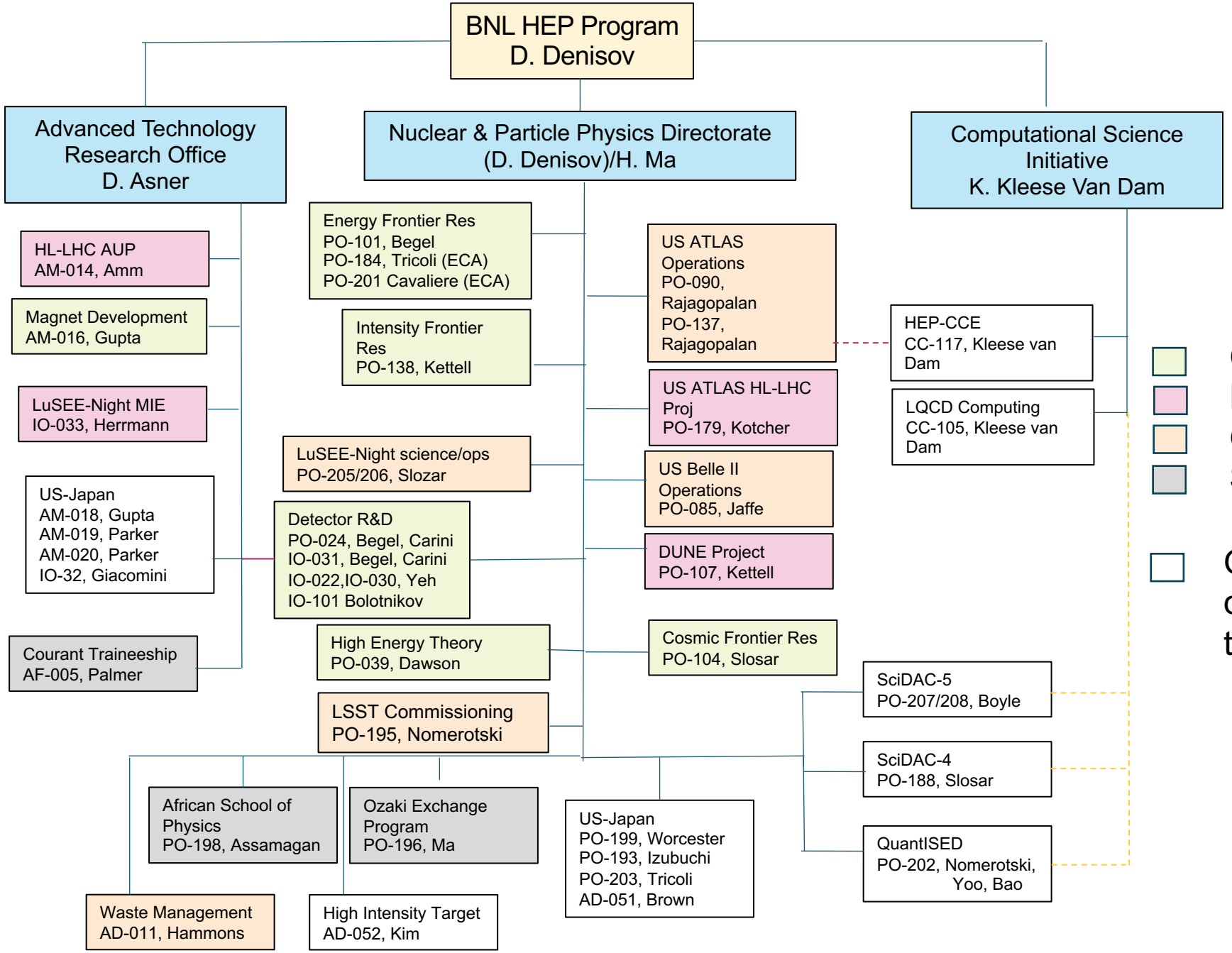
BNL High Energy Physics Program Organization



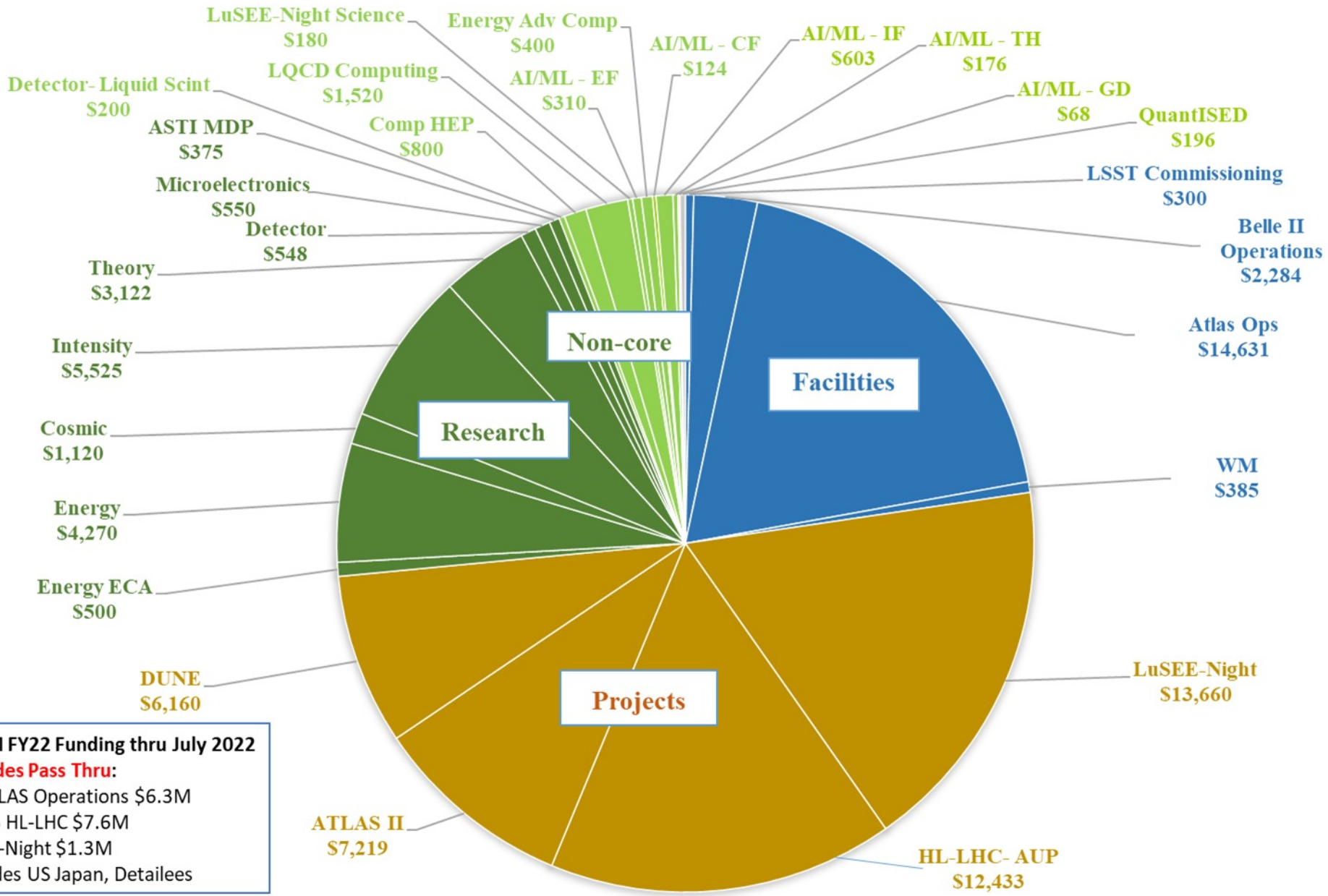
Core Research Projects
Operations
Student Prgms

Other proposal driven limited term programs

PO: Physics Dept
AM: Magnet Div
AD: Collider-Acc Dept
IO: Instrumentation Div
CC: Computational Science Initiative
AF: Acc Test Fac

HEP FY 22 BNL FUNDING*

In Thousands $



* 78M FY22 Funding thru July 2022
Excludes Pass Thru:
US ATLAS Operations $6.3M
ATLAS HL-LHC $7.6M
LuSEE-Night $1.3M
Excludes US Japan, Detailees

Early Career Awards

6 HEP ECAs, in all three frontiers and theory

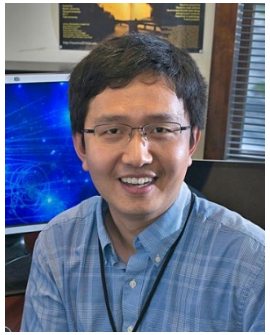
They are now leaders of their generation

Being able to attract and grow young talent is crucial to the future of the HEP program

FY 2011

Anže Slosar
Cosmic Frontier

FY 2014



Xin Qian
Intensity Frontier

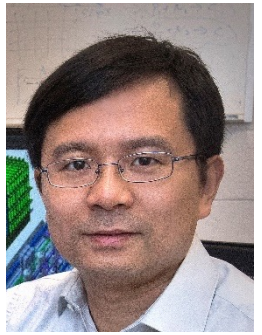
FY 2016

Christoph Lehner
Theory

FY 2017

Alessandro Tricoli
Energy Frontier

FY 2017



Chao Zhang
Intensity Frontier

FY 2019

Viviana Cavaliere
Energy Frontier

Planning for and Investing in the Future

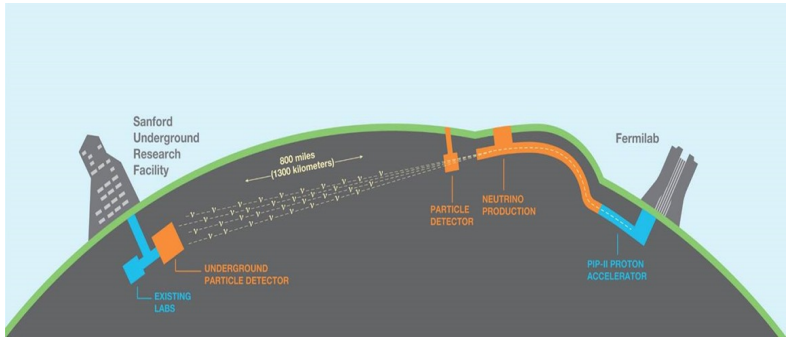
- Active participation in the community planning processes
  - 2020 Update to the European Strategy of Particle Physics
  - NAS: Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020)
  - NAS: Elementary Particle Physics: Progress and Promise (2022-2024)
  - Snowmass(2020-2022) and P5 (2023)
- Developing science cases and detector technology
  - LDRD provides support for exploratory R&D, PD for developing programs

Type	PI	TITLE	FY 2022	FY 2023
LDRD	V. Cavaliere	Real-time Particle Tracking	141500	
LDRD	E. Brost…	Real-time image classification using machine learning.	200000	200000
LDRD	A. Nomerotski	1 ps timing to probe time-energy entanglement of Photons …	200000	200000
LDRD	M. Diwan	Very high energy neutrino fluxes & events from LHC & HL-LHC		200000
LDRD	V. Tishchenko	R&D for PIONEER: Next generation Rare Pion Decay Experiment		200000
LDRD	O. Huang	Data Popularity, Placement Optimization & Storage		200000
PD	E. Lancon	DUNE Computing	130000	??
PD	A. Slosar	LuSee at Night	199000	??

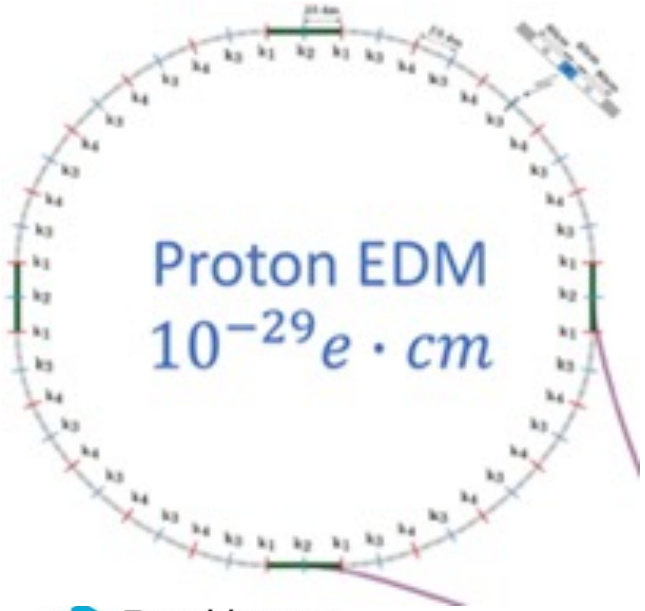
Snowmass and P5

- Snowmass Community Planning Exercise has energized the field
- We need new facilities and experiments which are exciting/competitive and affordable
  - Over 130 white papers submitted by BNL scientists to Snowmass
  - BNL is involved in all frontiers' activities – supporting field's diversity
- Participating in P5 committee nominations and plan to cooperate/host P5 meetings
- New P5 report is expected in 2023.

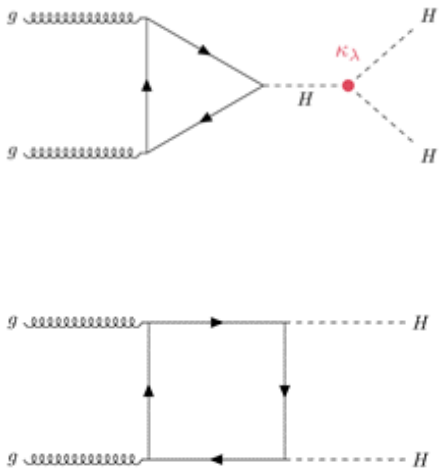
DUNE Phase II



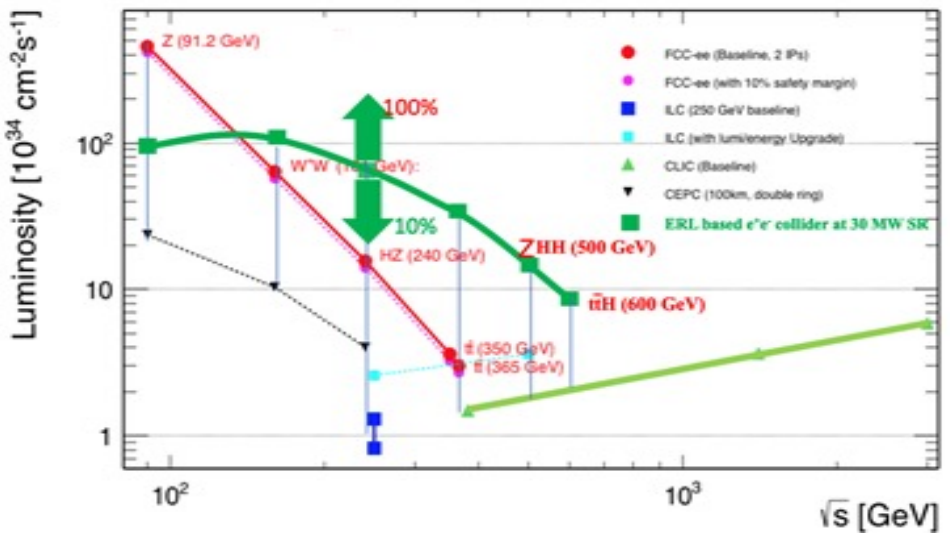
Proton EDM ring in AGS tunnel



di-Higgs studies



Higgs Factory



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Conclusions

- BNL HEP program is leading in a wide range of programs
  - Well know and trusted in US and international communities
  - Established funding and excellent potential for growth
- Diverse portfolio of well aligned activities
  - Construction, operations and research activities
  - R&D efforts for the future
- Positioned well to attract future initiatives
  - Including strong participation in Snowmass and soon P5
- Excellent opportunities for early career scientists
  - Be bold, be innovative, be ambitious
  - The future is yours