Stony Brook University

CASE
CENTER FOR ACCELERATOR SCIENCE AND EDUCATION

The Role of Test Facilities in Beam Physics Research

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Argonne NATIONAL LABORATORY

BERKELEY LAB

SLAC NATIONAL ACCELERATOR LABORATORY

Brookhaven National Laboratory

Fermilab

U.S. DEPARTMENT OF ENERGY | Office of Science

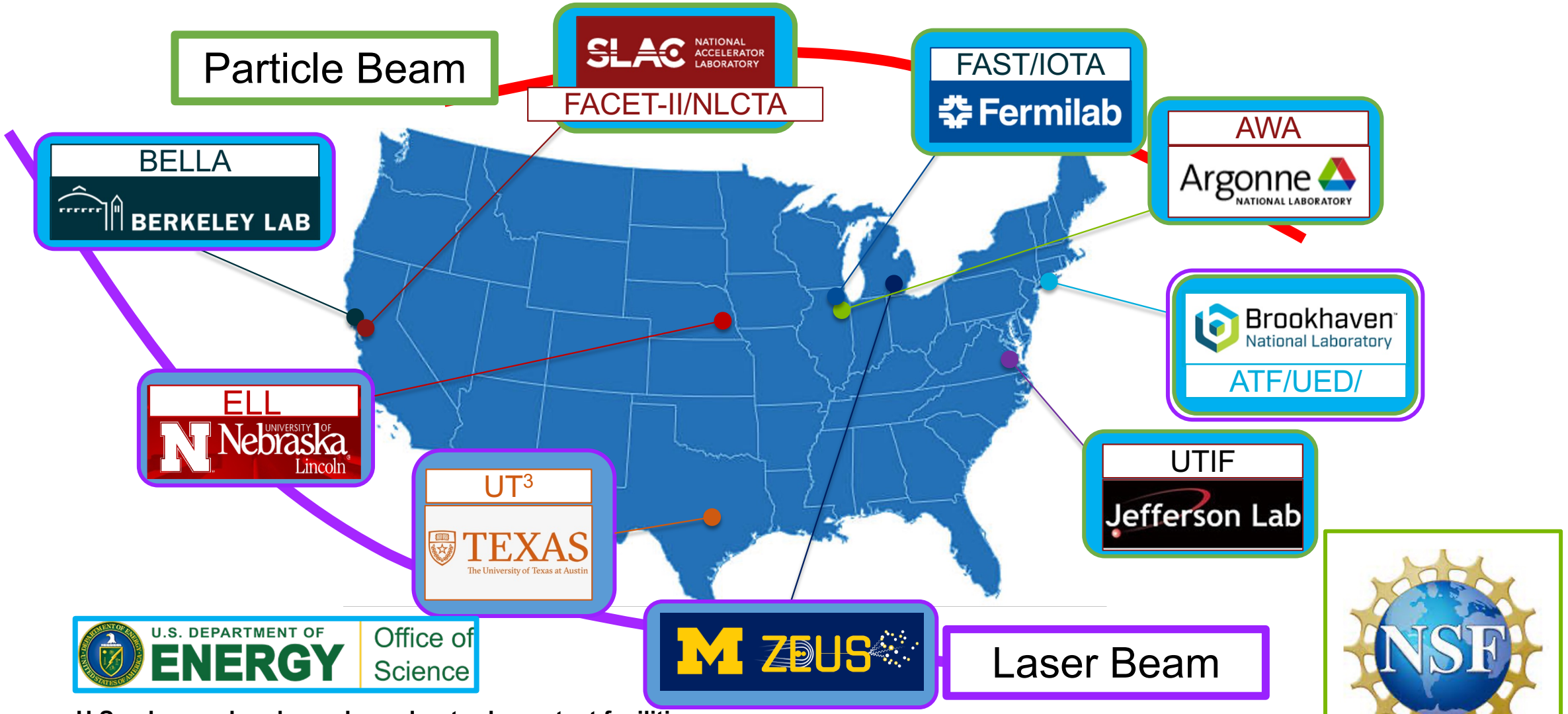
NSF

Jefferson Lab

Synthesis

- Beam test facilities have a critical role in facilitating high-impact research
- They provide unique training opportunities through direct instruction and research mentorship
- Introducing BeamNetUS: a network of national-lab beam test facilities aiming to broaden the participation in beam-based research
- The network aims to provide a centralized mechanism for access to the unique and distributed strengths of the beam test facilities

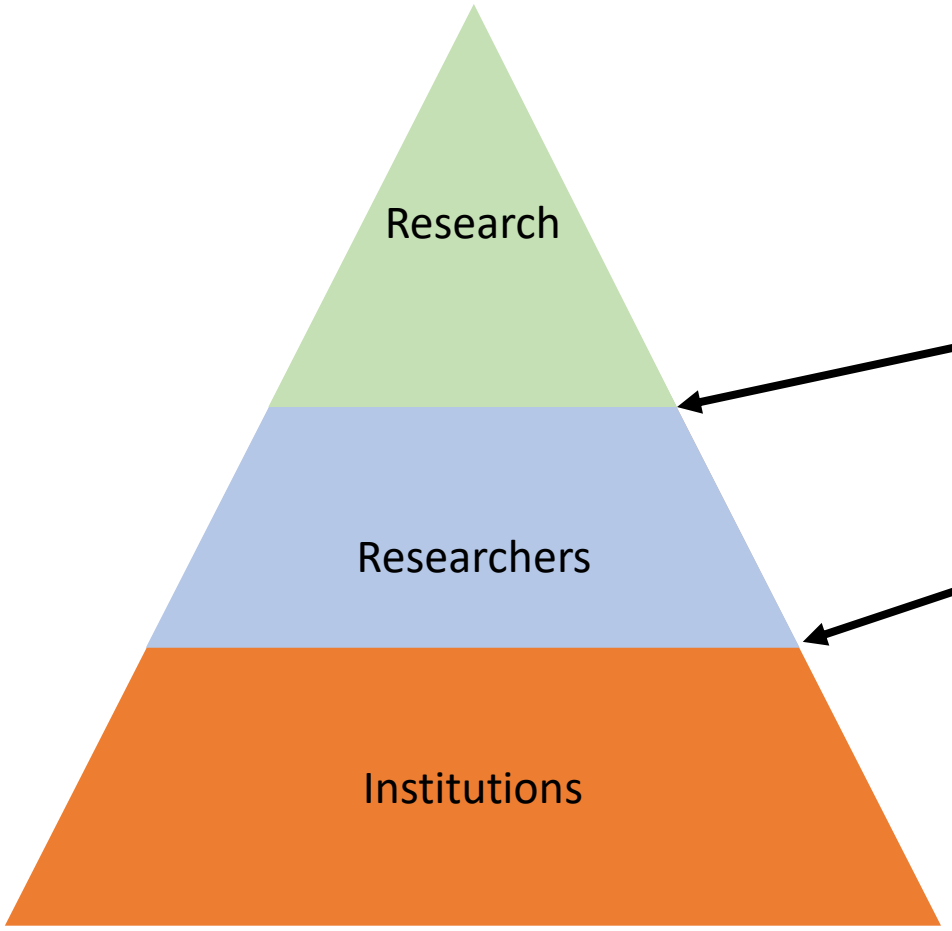
U.S. Advanced and Novel Accelerator Beam Test Facilities



U.S. advanced and novel accelerator beam test facilities
[C. Clarke et al 2022 JINST 17 T05009, https://iopscience.iop.org/article/10.1088/1748-0221/17/05/T05009]

National Laboratories **Universities**

R&D Ecosystem



Beam test facilities are engaged in the supporting layers of the pyramid

- Enabling access to research
  - – Provide state of the art facilities to enable high-impact research
- Training ground for institutions
  - – Facilitate research training for new researchers
  - – USPAS and university courses, professional courses
  - – DOE SULI, SCGSR, RENEW, FAIR
  - – NSF REU

Mission of Test Facilities

1. Providing experimental test beds to carry out basic research in advanced accelerators and beam physics

2. Developing the S&T needed to enable the next generation of science facilities and accelerator applications

3. Educating and training future scientists and engineers

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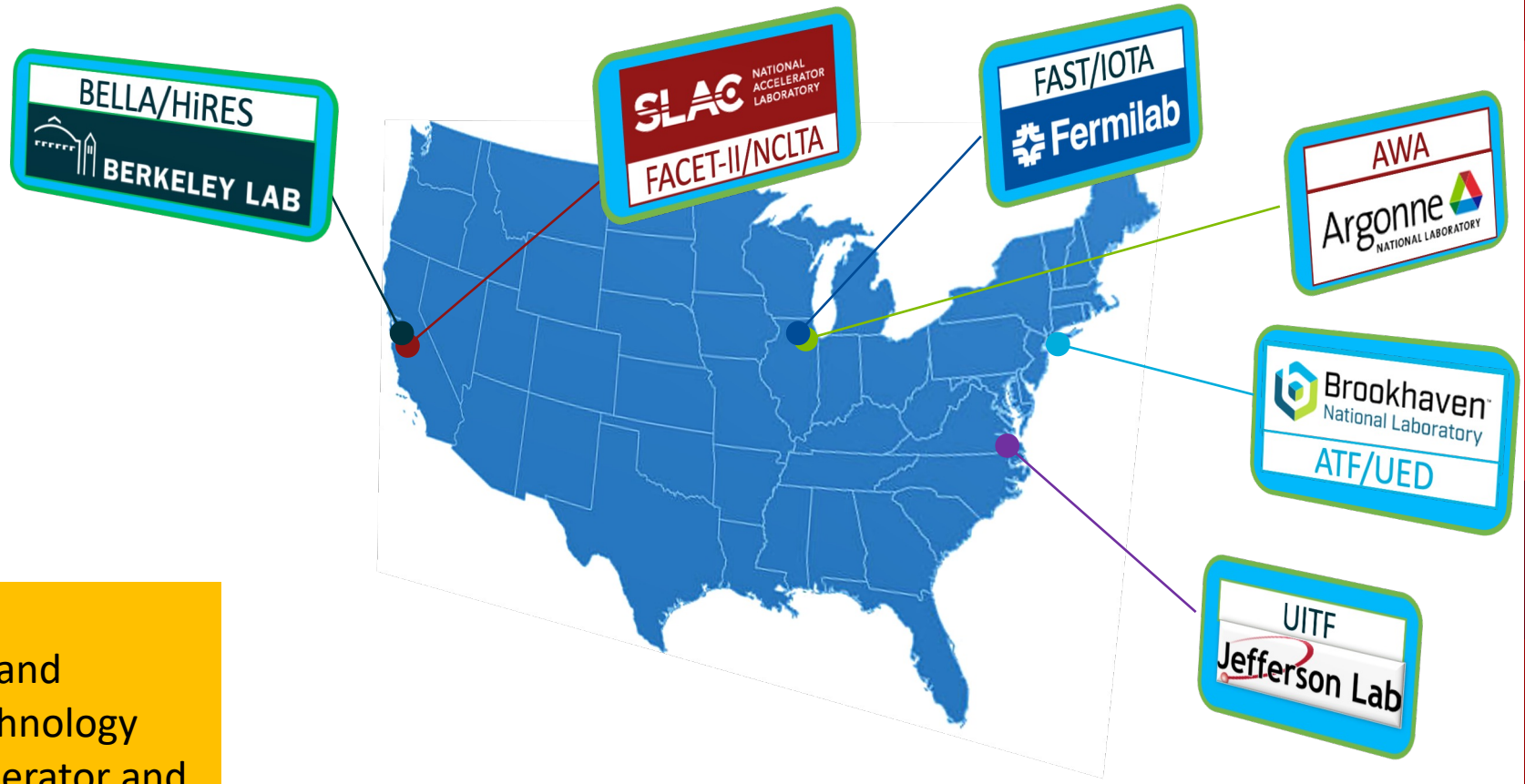
BeamNetUS

A network of National Lab facilities aiming to run a program specially targeting new collaborations for user-driven research



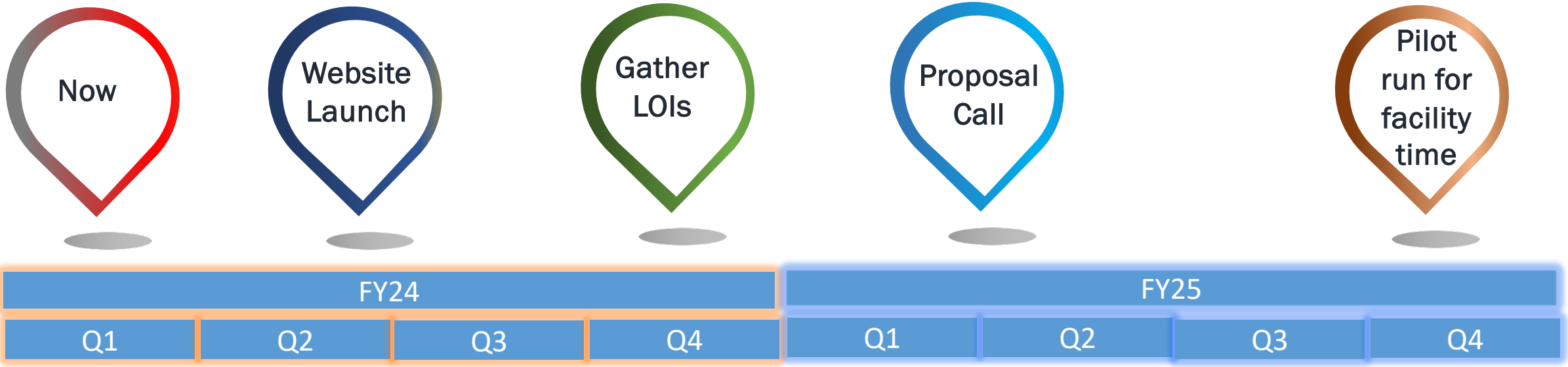
United in a common mission

- Advance accelerator research and applications of accelerator technology
- Provide access to unique accelerator and accelerator component resources
- Foster collaboration to exchange ideas, skills and resources

Implementation Timeline

BeamNetUS

- **Facilities at 6 National Labs** will form the initial network for the pilot year
  - Argonne (AWA), Berkeley (BELLA, HiRes), Brookhaven (ATF, UED), Fermilab (FAST/IOTA), Jefferson Lab (UITF), SLAC (FACET-II, NLCTA)



Coordinate efforts at conferences, workshops and meetings to inspire new engagements
& work to streamline and document processes

Pilot year for competitive beam time awards
~ 3 weeks at each laboratory/facility by end 2025

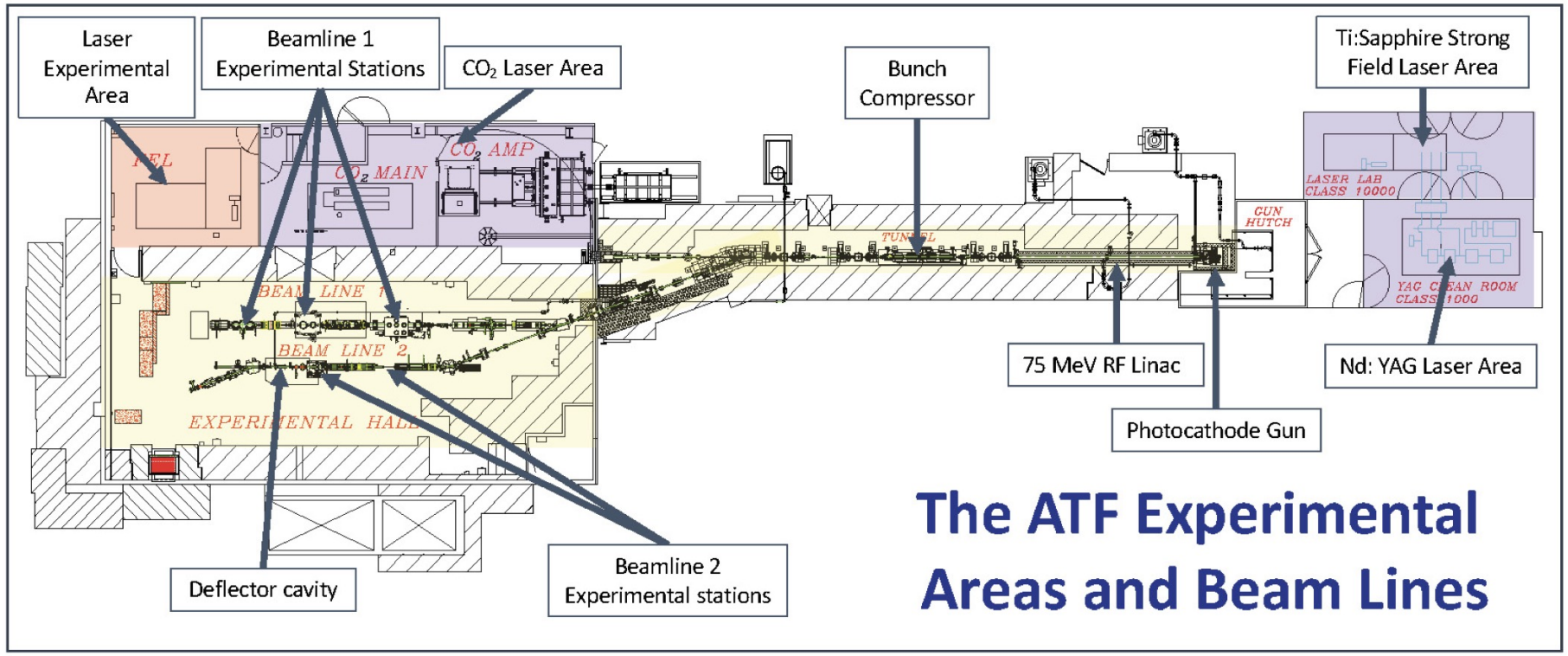
A Unique Set of Distributed Capabilities

- Electron, positron and proton sources
- Electron energies ranging from a few MeV to 10 GeV
- 100 TW class laser sources
- High power RF sources for testing
- Advanced particle and radiation diagnostics
- A mix of user facilities and mission-driven facilities

Overview of Individual Facilities

Accelerator Test Facility

Brookhaven National Laboratory



Beams

- 5 TW, 2 ps, CO_2 laser
- 75 MeV, <1ps, nC linac beam (single bunch and multi-bunch)
- TW NIR Sources

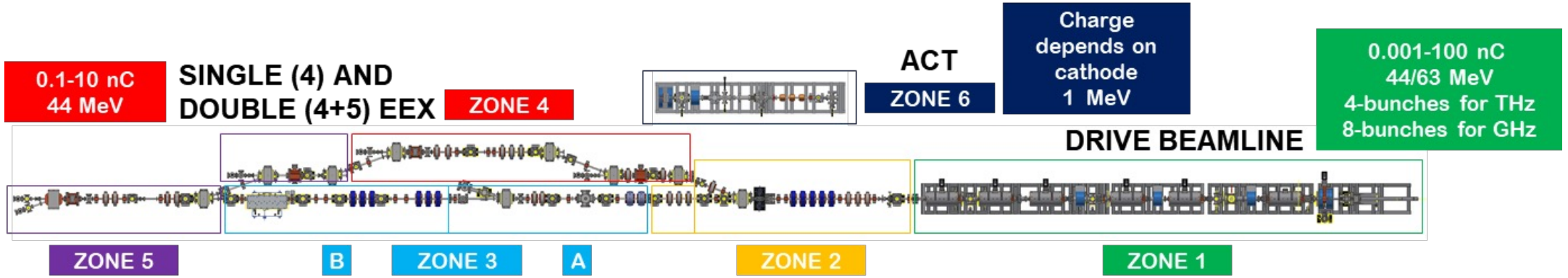
Research Focus

- Particle and photon source development
- Wakefield acceleration
- Inverse Compton scattering
- Laser-driven plasma ion acceleration

Mode of Operation

- National User Facility
- DOE Accelerator Stewardship

Argonne Wakefield Accelerator



ZONE 6 (ACT)

- 1 MeV flexible beamline
- Mostly used for cathode tests
- Main diagnostics:
  YAG, ICT, or any other installed diagnostics

ZONE 4 & 5

- ~1 m space is available for experiment.
- Special beams such as longitudinally shaped beam can be provided.
- Main diagnostics:
  YAG, slit/quad scan, ICT, TDC, spectrometer

ZONE 3b

- Flexible beamline, dedicated for re-build
- Main diagnostics:
  YAG, quad scan, ICT, or any other installed diagnostics

ZONE 3a

- Fixed beamline with a device test area
- Mostly used for SWFA exp
- 11.7 GHz 400 MW PETs available
- Main diagnostics:
  YAG, quad scan, ICT, spectrometer

ZONE 1 & 2

- Fixed beamline
- Main diagnostics:
  YAG, slit/quad scan, spectrometer, ICT
- Suitable for small footprint experiment

Beams

- Beamline #1: 1 pC-100 nC, 44/63 MeV
- Beamline #2: 1 pC-50 nC, 15 MeV
- Beamline #3: 1 MeV cathode R&D
- 1-16 bunch trains for GHz-THz
- Tunable bunch length (<10 nC)
- Tunable longitudinal profile (<10 nC)

Research Focus

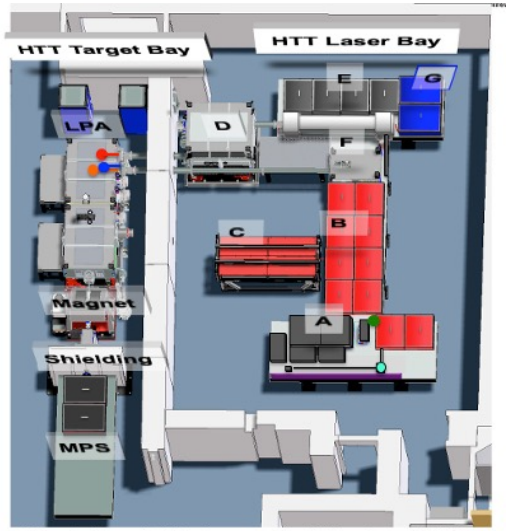
- High gradient acceleration (SWFA & PWFA)
- Advanced beam manipulation & control
- High-brightness electron source
- Beam-based radiation sources

Mode of Operation

- Mission based and Collaborative Experiments

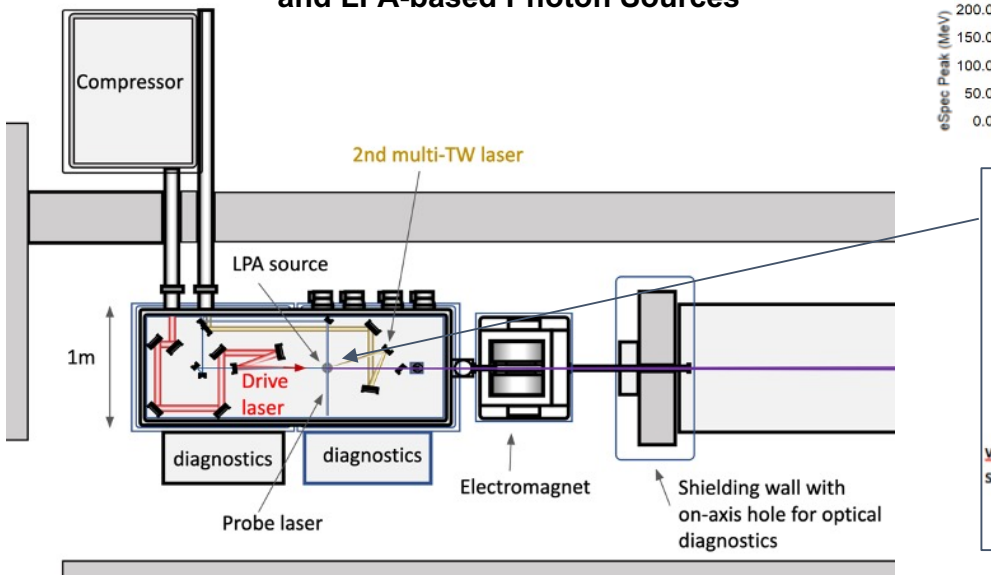
Hundred Terawatt Thomson (HTT)

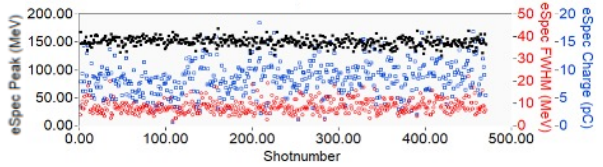
Dual Laser Beam Hundred Terawatt Thomson (HTT) System

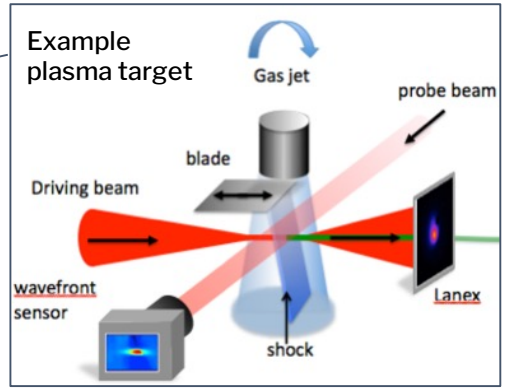


A. Frontend laser **B.** Drive laser amplifier **C.** Pump laser (GAIA) **D.** Drive laser compressor **E.** Completed scatter laser amplifier **F.** Scatter compressor **G.** Probe compressor

Target Bay: Laser Plasma Accelerator (LPA) and LPA-based Photon Sources







Beams

- Drive beam - 2J, 40 fs
- Multi-TW beam (0.5 J, 40 fs)
- Fs laser probes (2 mJ 40 fs)

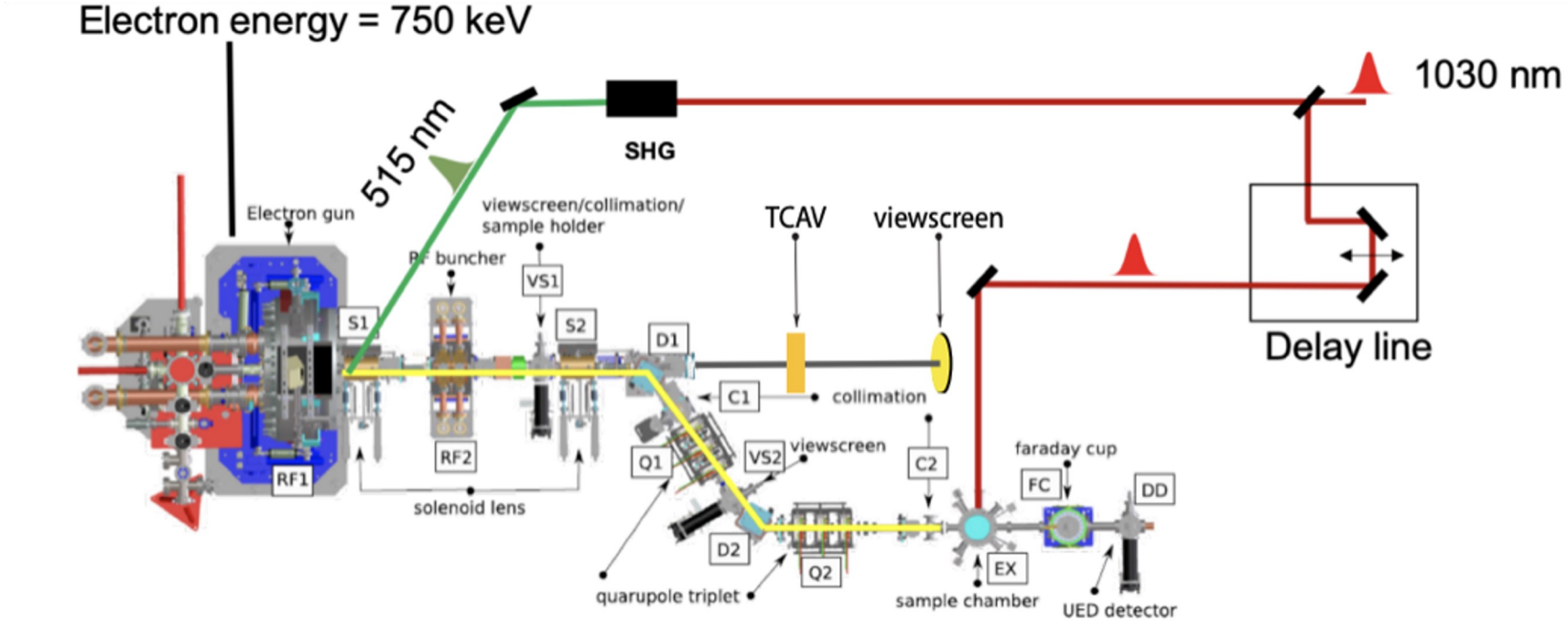
Research Focus

- Colliding pulse for e-beam injection in a laser wakefield
- Radiography of laser wakefield structures
- Thomson scattering for noninvasive e-beam energy measurement

Mode of Operation

- Mission based and Collaborative Experiments

High Repetition-rate Electron Scattering apparatus (HiRES)



Beams

- Electron beam (energy ~ 750 keV temporal resolution 300 fs, up to 1 MHz)
- Pump laser

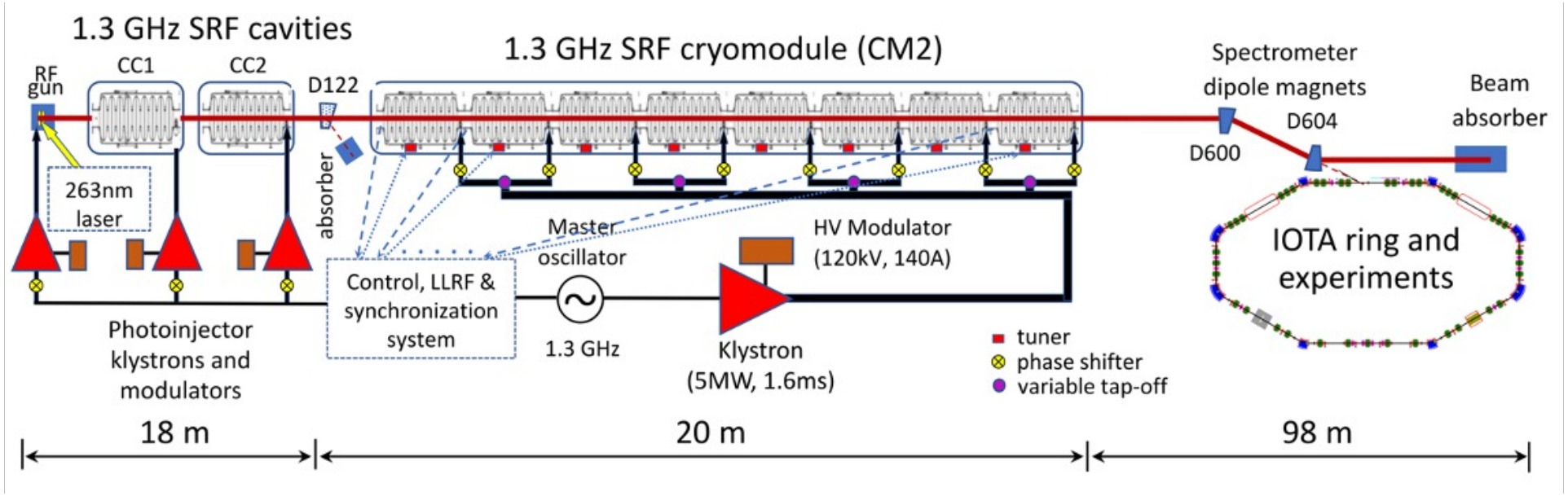
Research Focus

- Photocathode development
- Beam diagnostics, controls and instrumentation
- Ultrafast electron diffraction experiment

Mode of Operation

- Mission based and Collaborative Experiments

Fermilab Accelerator Science and Technology (FAST)



Beams

- Two injector linacs (e^- & p^+)
- 50-150 MeV/c

Research Focus

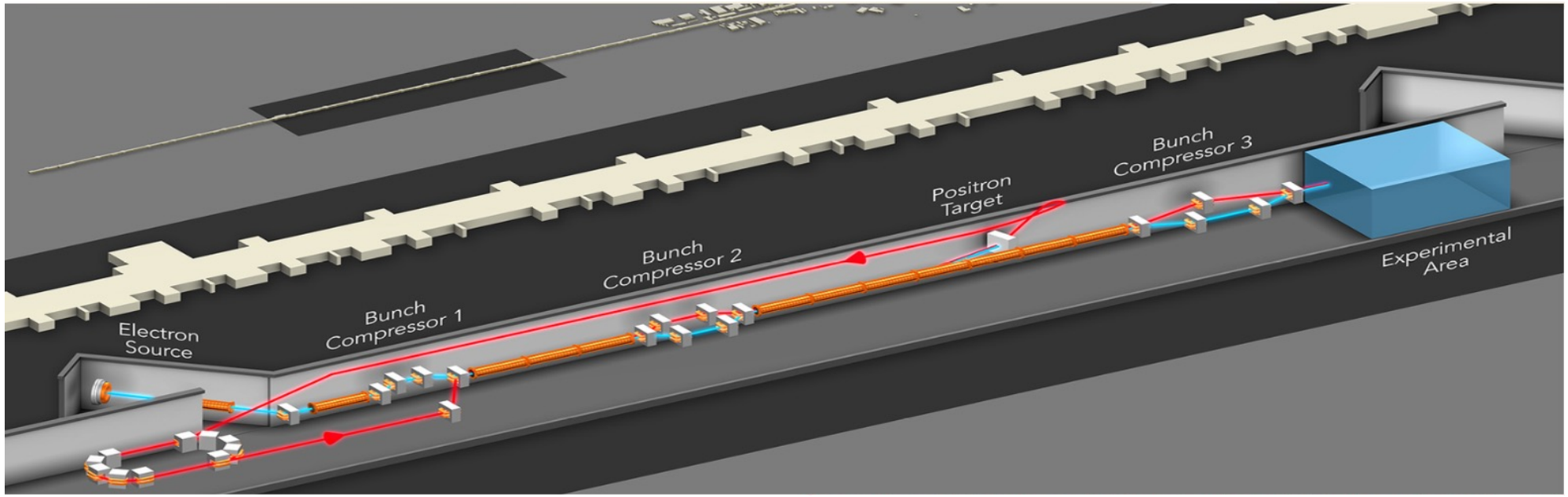
- Suppression of coherent beam instabilities
- Mitigation of space charge effects
- Advanced beam cooling

Mode of Operation

- Mission based and Collaborative Experiments
- 1–3 concurrent experiments

FACET II

FACET·II
Facility for Advanced Accelerator Experimental Tests
SLAC NATIONAL ACCELERATOR LABORATORY



Beams

- e^+/e^- beams* 10 GeV, nC, single bunch (compressed to 15 μm^3) or two bunch
- 10 TW Ti:Sapphire

Research Focus

50% PWFA research

- 10 GeV plasma stage
- Plasma-based photocathode
- High brightness γ source

50% Other research of high-intensity electron beams with lasers, plasmas and solids.

Mode of Operation

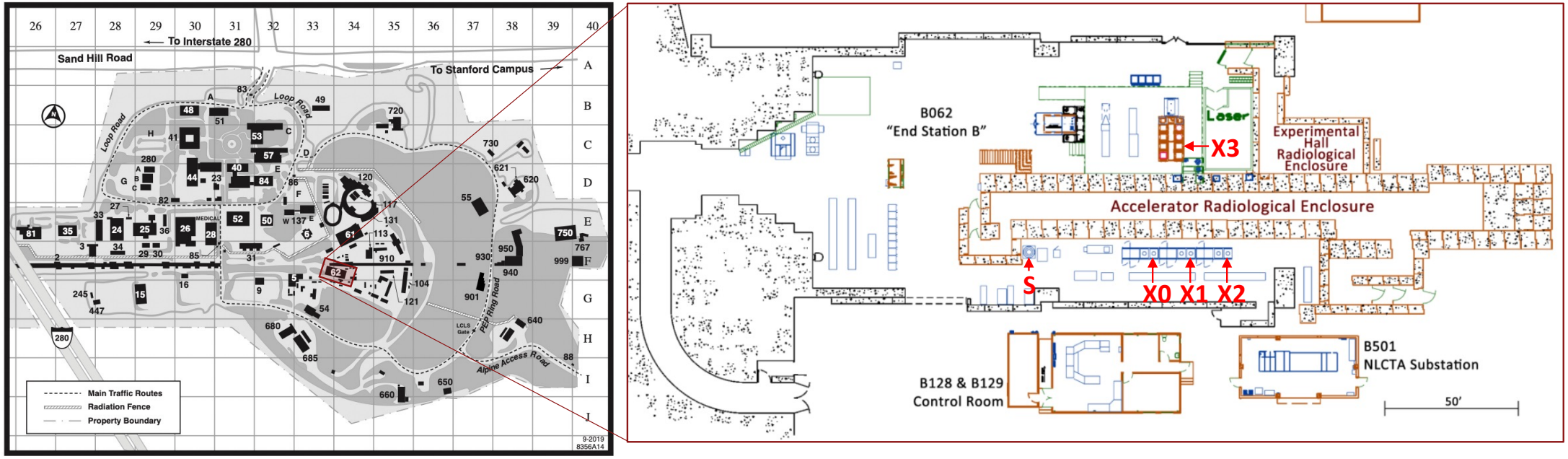
National User Facility

DOE HEP

* e^+ planned

Next Linear Collider Test Accelerator (NLCTA)

Five RF sources available to supply power to test areas



Beams

- X-band Test Accelerator (XTA), a stand-alone high-power X-band beamline

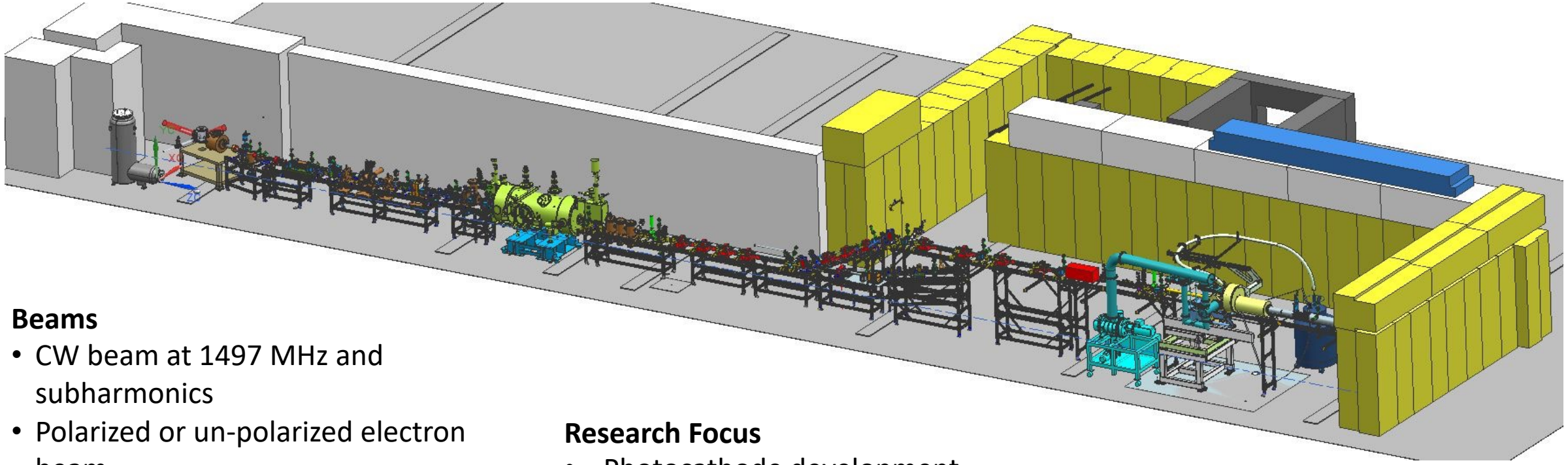
Research Focus

- Development of an X-band Linear Collider for future High Energy Physics Research
- New accelerator designs
- Compact accelerator applications in medicine, industry, and national security

Mode of Operation

- User Facility
- Multiple concurrent experiments

JLab – Upgraded Injector Test Facility



Beams

- CW beam at 1497 MHz and subharmonics
- Polarized or un-polarized electron beam
- Milliampere beam at keV,
- 100 nA avg. current at MeV limited by available shielding,
- 10 uA at MeV energy with modest augmentation of shielding
- 100 uA with dedicated local shielding

Research Focus

- Photocathode development
- Beam diagnostics, controls and instrumentation
- Polarized targets
- Fast kicker studies for EIC
- Waste-water irradiation for PFAS elimination

Mode of Operation

- Mission based and Collaborative Experiments

Mission of Test Facilities

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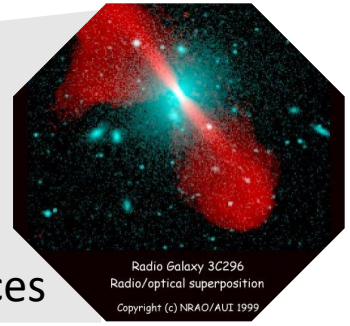
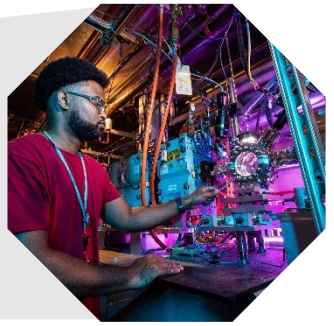
Enabling Next-Generation of Research

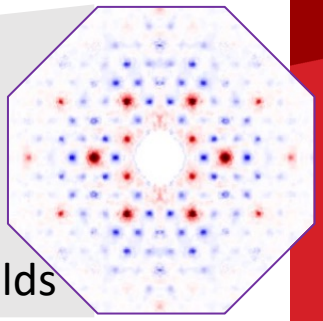
Plasma physics, astrophysics, particle acceleration, and particle and light sources



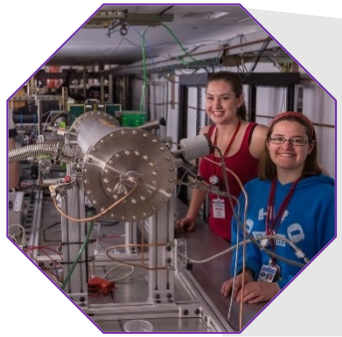
Beam physics, controls and diagnostics for conventional and advanced accelerators



Material science – Ultra fast electron diffraction of materials, materials in extreme fields



Radiofrequency Sources & structures: normal, super-conducting and novel



Nuclear physics, polarized beams of low current, polarimetry, particle detectors

Radiation enclosures and electron beam irradiation

- The facilities across the 6 participating laboratories provide complementary capabilities enabling research in multiple areas

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Graduate Education

Facilities participate directly in graduate education

U.S. Particle Accelerator School
Education in Beam Physics and Accelerator Technology

Offered twice a year
A dozen courses a session
Several hundred students

Brookhaven National Laboratory

Stony Brook graduate course
Hands-on experience with accelerator components

Advance Accelerator Laboratory course for City University of New York (CUNY) students

DOE Accelerator Traineeship Program

6-12 students per year per program
Certificate & special-degrees conferred
Graduate (and undergraduate) training

Virginia Innovative Traineeships in Accelerators (VITA)

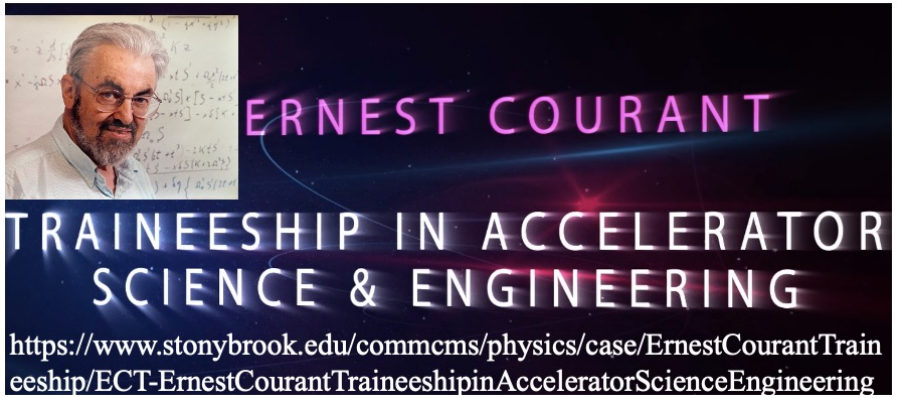
Norfolk State University
Old Dominion University
Hampton University — The Standard of Excellence

Chicagoland Accelerator Science Traineeship Program

Northern Illinois University
Illinois Tech

Accelerator Science and Engineering Traineeship (ASET)

Michigan State University



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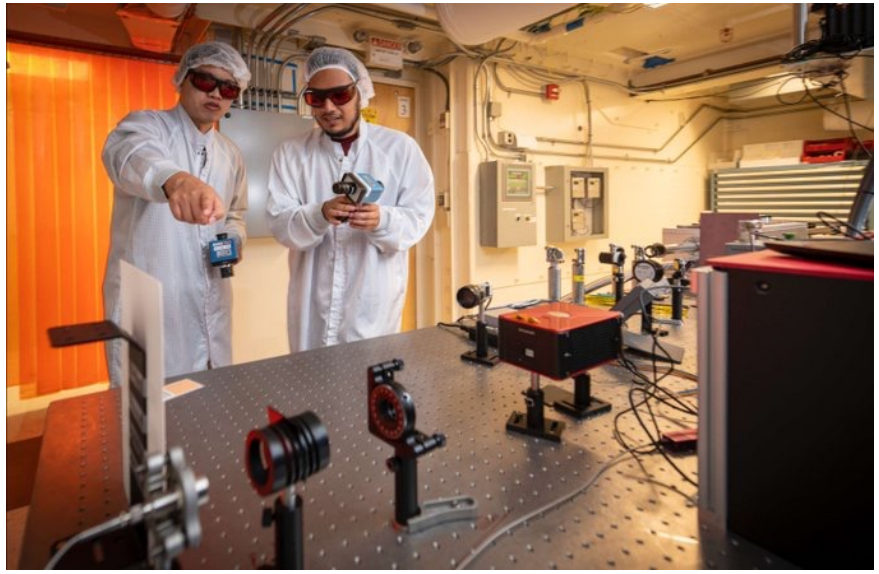
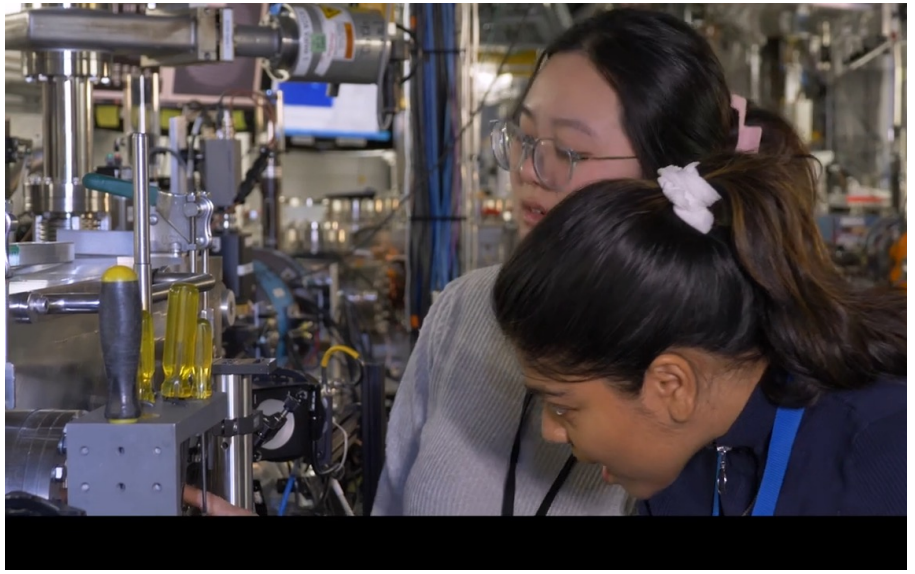
Training Ground for Next Generation Researchers

- Host SULI students and similar (NSF REU, RENEW, FAIR)
- Collaborate with academic institutions by mentoring SCGSR students and co-advising graduate thesis projects

FACET-II summer undergrads 2023



Bryan Alamillo (right) from California State University Channel Islands (CSUCI) under the NNSA MSIIP Internship Program (BELLA).



Stony Brook University graduate students co-advised by adjunct faculty at ATF

Summary

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