Accelerator Science and Technology and Accelerator Stewardship at Fermilab

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Argonne-UofChicago-Fermilab Collaboration meeting
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U.S. DEPARTMENT OF ENERGY

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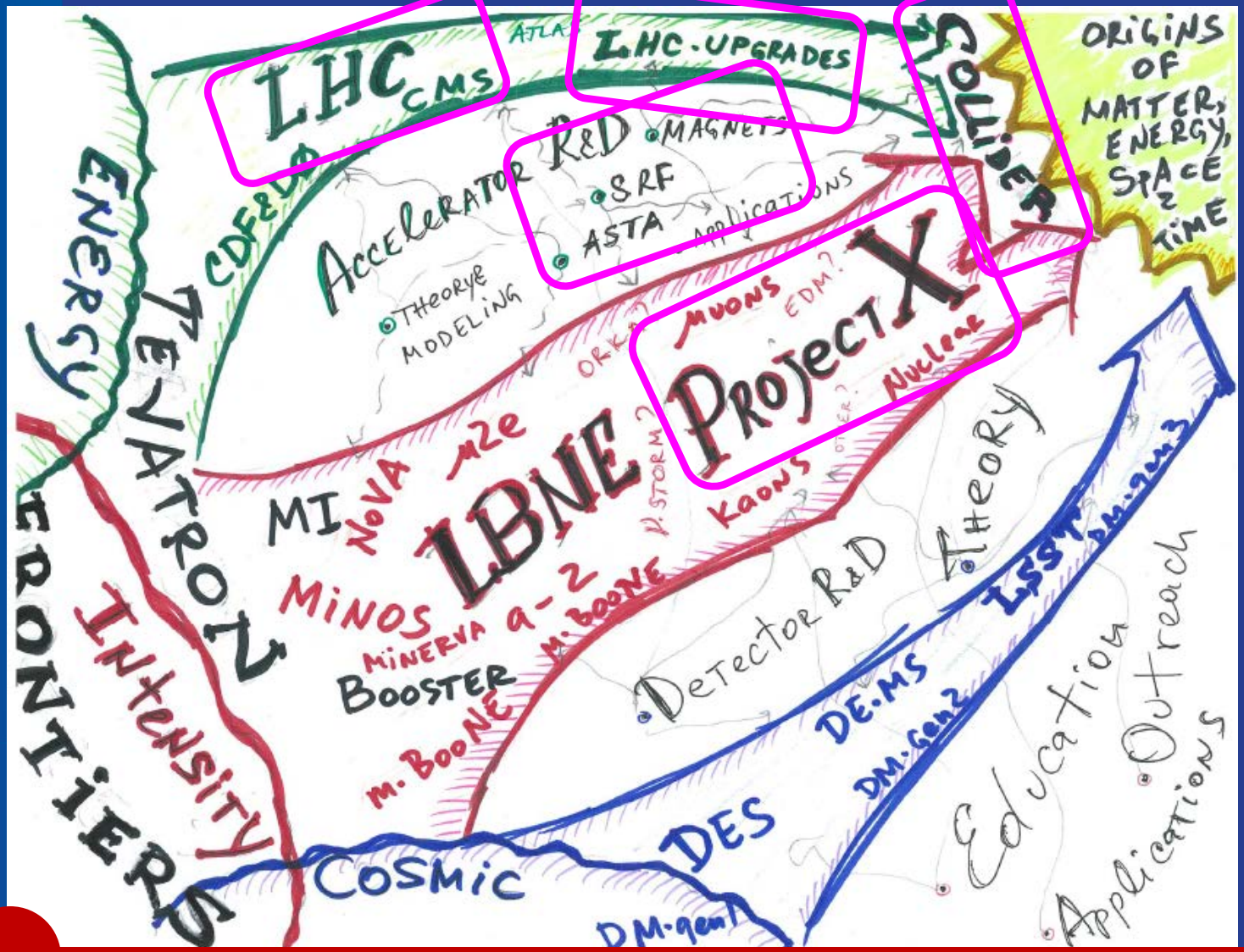
High Energy Physics in the US: Directions

Caveat: this is an outline, "The Plan" to be revealed by Snowmass and P5



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Project X

Linchpin of the Laboratory's (and US HEP) Future

- **More protons than ever anywhere**
  - 1 MW at 1 GeV
  - 3 MW at 3 GeV
  - 0.2-4 MW at 8 GeV
  - >2MW at 120 GeV
- **Many (dozens) of experiments**
- **Direct connection to Muon Collider**

Towards Project X

Needs Accelerator Science and Technology

- **SRF Program:**
  - Develop SRF cavities and cryomodules for Project X
    - Develop PXIE (to mitigate PrX technical risks)
    - Fabricate and test first articles of cavities and cryomodules to mitigate the cost/schedule risk
  - Develop related SRF infrastructure and technology
  - U.S. Industrialization to permit Project construction
- **General Accel. R&D Program:**
  - Accelerator physics issues intensity frontier machines
    - Beam dynamics, losses, targetry, etc

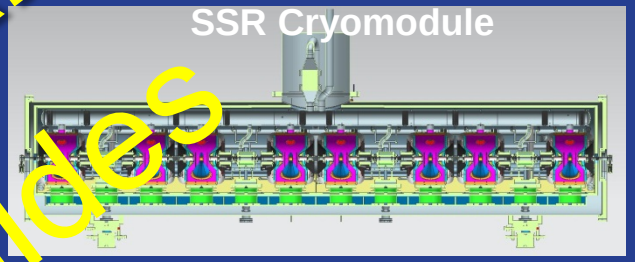
Superconducting RF Program

- Goals
  - Develop β<1 SRF cavities and cryomodules to form technological basis for Project-X
  - Scientific understanding of SRF surfaces leading to improved Q_0, gradient, and manufacturing yield
- Major activities and highlights
  - 325 MHz Single-spoke resonators and CMs
  - 650 MHz elliptical cavities and CMs
  - Support and nurture India Collaboration
  - Exploration of game-changing cavity processing for higher Q, eco-friendly processing approaches
- Plans
  - Support SRF for Project-X and Project-X Injector Expt.(HWR/SSR)
  - Continue materials work with aim of reducing cost

Active Role of Argonne

see Rod's slides

Single spoke resonator 325 MHz β=0.22



SSR Cryomodule

Single-cell 650 MHz β=0.9

Mirror-like finish from Centrifugal Barrel Polishing

LHC and LHC-Upgrades

Flagship Energy Frontier facility for the next 20+yrs

- **Improved performance at ~14 TeV**
  - x5 Luminosity upgrade via tighter focusing and more beam
  - Luminosity leveling via “crab-cavities”
  - (Old) Injector Complex upgrades
- **(Potential) energy upgrade**
  - x2.5-3 with HTS magnets?
- **Direct connection to Muon Collider**

Towards LHC *L* & *E*-upgrades

Needs Accelerator Science and Technology

- **LHC Accelerator Research Program:**
  - Nb3Sn magnets for final focusing
  - R&D on beam dynamics and crab cavities
  - Being transformed into “Construction project ~2023”
- **SC Magnet Program**
  - New SC materials (Nb3Sn and HTS)
  - Novel designs for Very High Field magnets
- **General Acc. R&D Program:**
  - Beam dynamics, collimation, simulations, beam studies

Superconducting Magnet and Materials Program

- Goals
  - Develop advanced SC "Accelerator Quality" magnets based on Nb_3Sn technology
  - Understand and develop next generation superconducting materials, emphasizing use in accelerator applications.
- Major activities and highlights
  - 11T Dipole Development for LHC Upgrades
    - First short-turn-around (1.5 years from "paper" to test) Nb3Sn dipole achieved 10.4 T at 1.9 K (78% SS)
  - SC Materials
    - Breakthrough (w/ collaboration) hyper-baric process cures Bi-2212 bubbles
- Plans:
  - Support for LARP, 11T development and handoff to CERN, HTS for future machines

2m Nb_3Sn long dipole

DOE Pulse

Science and Technology Highlights from the DOE National Laboratories

Number 381 | February 4, 2013

The birth of a very-high-field superconductor

Fermilab scientist Tengming Shen and his collaborators have discovered how to make better superconducting wires for magnets.

The strong magnetic fields of an MRI scanner or a particle accelerator are generated efficiently by electromagnets that have superconducting wire in their coils. A group of scientists has discovered how to make better wires using a promising material known as Bi-2212. With this discovery comes the possibility of creating magnetic fields in excess of 30 Tesla, three to four times higher than those generated by present accelerator magnet technology.

Bi-2212 (Bi2Sr2CaCu2Ox) is one of the copper-oxide high-temperature superconductors discovered 27 years ago. Since then, attention has focused on the use of such HTS materials in electric power transmission and other electrical applications not related to high-field magnets. In those applications, Bi-2212 loses out to other HTS materials.

Yet scientists had recognized for a long time the potential of Bi-2212 for use in superconducting magnet coils. When cooled with liquid helium, many HTS materials, including Bi-2212, can conduct large electric currents without resistance even in the presence of huge magnetic fields. But so far scientists only have managed to turn three of these HTS materials into the long wires that are necessary to make coils. Among these materials, Bi-2212 stands out as the only HTS that can be fabricated as a round wire. This makes Bi-2212 a perfect candidate for winding cables and coils without significantly changing present magnet technology.

Future Colliders

"Beyond LHC"

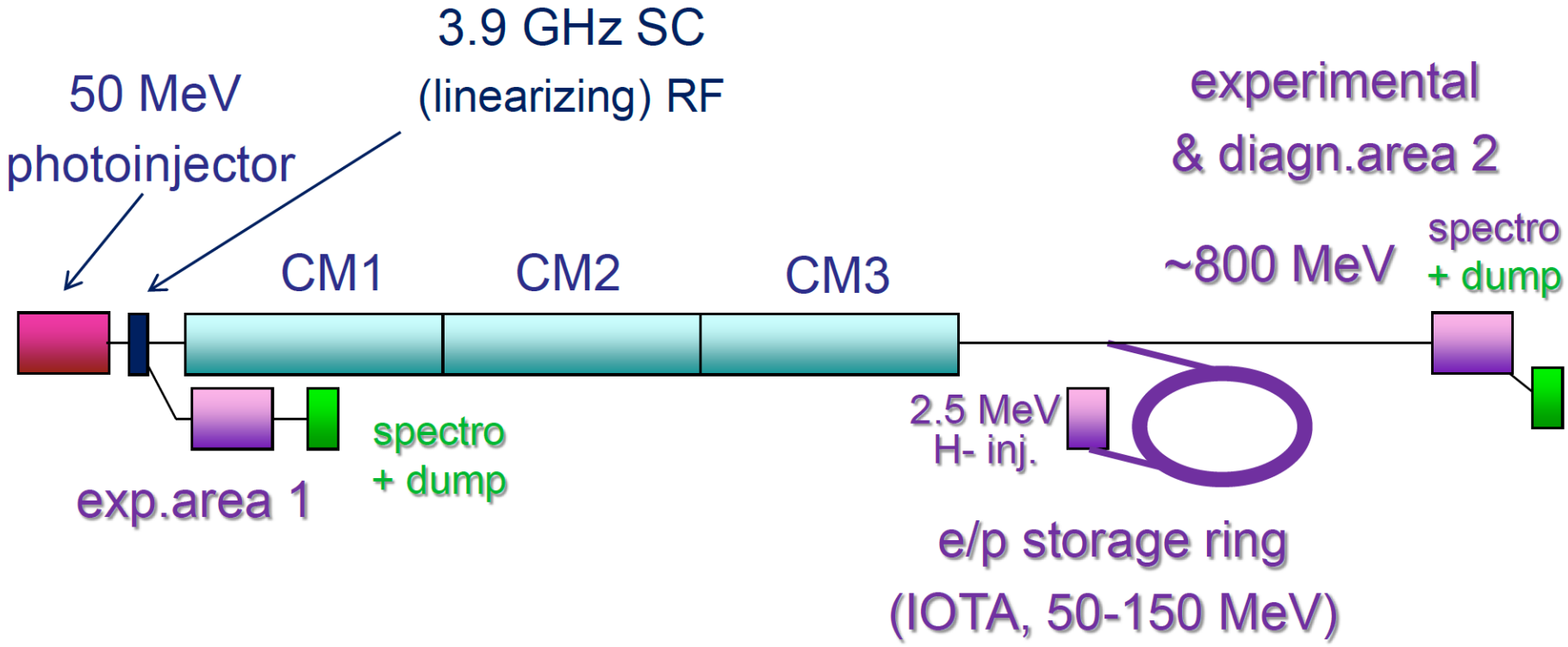
- **Must be relevant and affordable:**
  - x10 "more ***Physics***" (events or energy)
  - Cost <10 B$... Length <10km, Power <100 MW (wall plug)
- **VERY FEW OPTIONS ! :**
  - Higgs Factories (cost)
  - Muon Collider (feasibility - ***L*** & cost)
  - Others –not feasible so far →need R&D

Towards Future Colliders

Need Long-term Accelerator R&D

- **Muon Accelerator Program (MAP):**
  - Muon ionization cooling experiments
  - Technical feasibility of key components (RF, magnets, etc)
  - Design and Cost range (in ~6 years)
- **General Acc. R&D Program:**
  - Beam experiments, advanced schemes, simulations, etc
  - ASTA Users Facility (incl. ANL, U.Chicago, and many others)
- **Accelerator Education Programs:**
  - US Particle Accelerator School
  - Lee Teng Internship (with Argonne), PhD program, PARTI

ASTA (Schematically)



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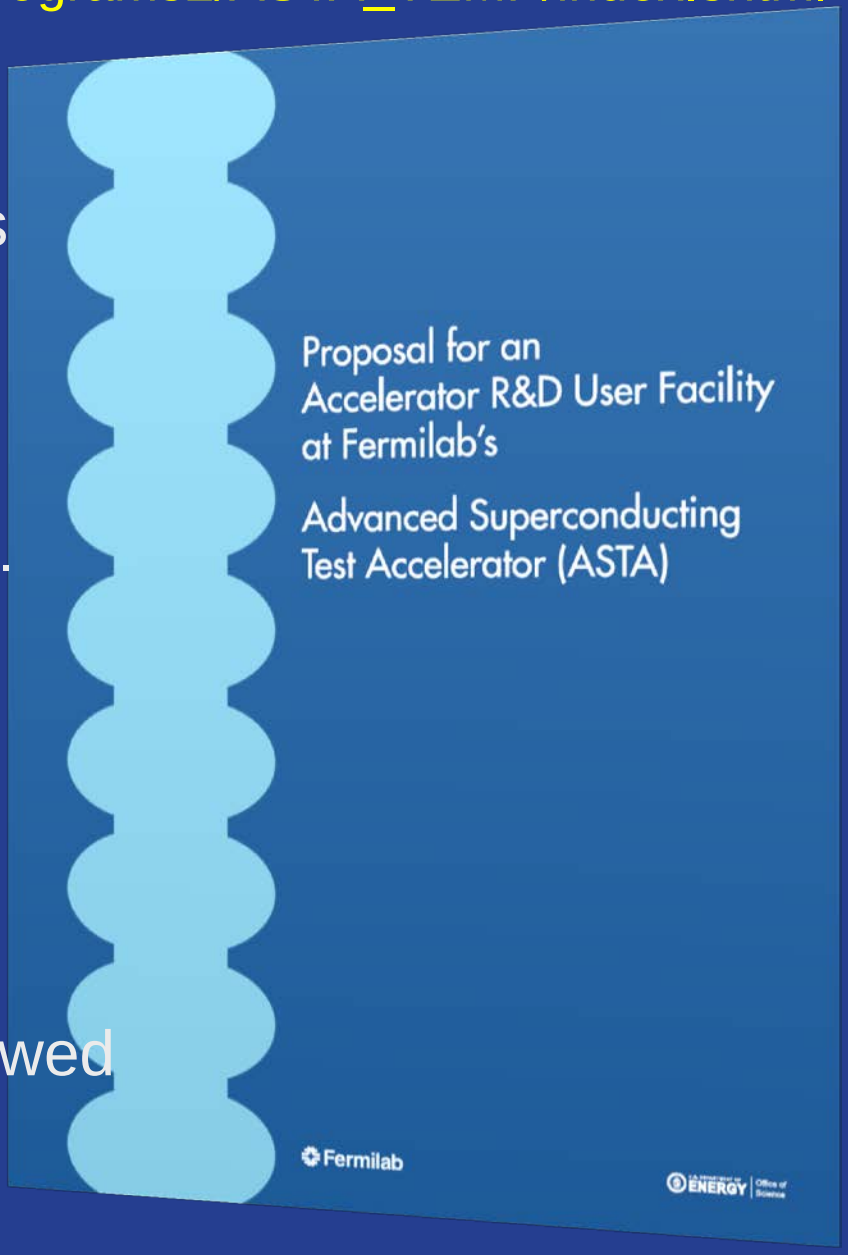
ASTA

http://apc.fnal.gov/programs2/ASTA_TEMP/index.shtml

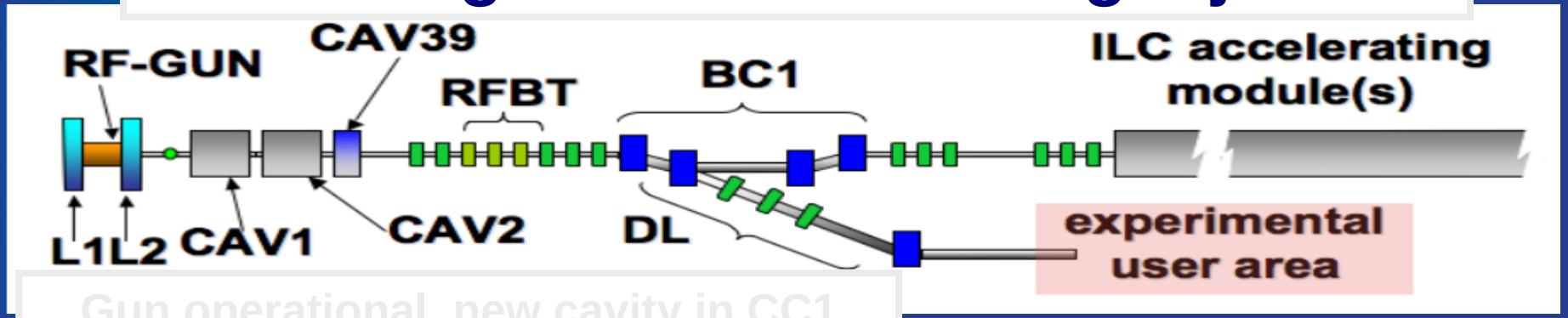
- 60 co-authors from 13 institutions
  - Including Argonne and U Chicago
- 24 proposals and growing
  - R&D towards Energy Frontier accel.
  - R&D towards Intensty Frontier accel.
  - SC RF technology with beams
  - Novel Radiation Sources
  - Stewardship and Applications
- Argonne (DEEX, DWA, etc)
- UChi (students at IOTA, other)
- Proposal to DOE in Feb'13, reviewed Mar'13, NSF interest Apr'13
- Users/PAC mtg July 23-24, 2013



ASTA Accelerator R&D User's Facility

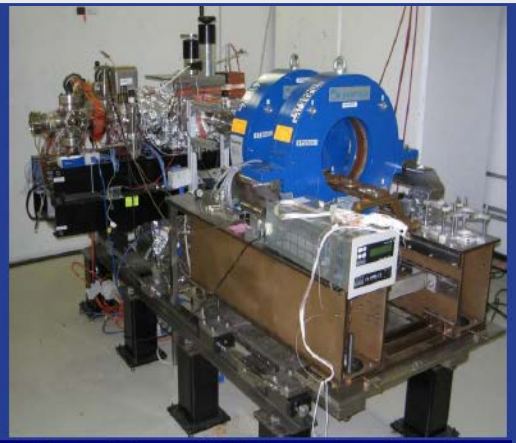
50 MeV Injector & CM2 in 2013, 300 MeV e- in 2014

Installing & commissioning injector

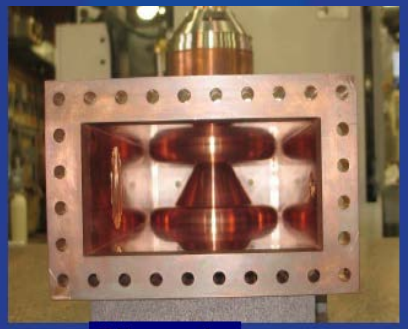


Gun operational, new cavity in CC1

gun cavity



Solenoids and PC transfer chamber



RF coupler

HEQ

LED

High Energy Beam Dump Core

The ASTA Team

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Mike Church
Commissioning & Operations

J. Leibfritz
Installation & Engineering

Philippe Piot
Physics

Sergei Nagaitsev
IOTA

Peter Garbincius
Program Office

- **Program Advisory Committee:** G. Dugan (chair), M. Blaskiewicz (BNL), J.Byrd (LBNL), R. Palmer(MAP), G. Hoffstaetter (Cornell), A.Zholents (ANL)
- The 1st ASTA User's meeting and first PAC meeting July 23-24, 2013

ASTA: Accelerator Science Potential

ASTA will be a gem of the US National Accelerator R&D program, as it offers:

- A broad range in beam energies (50-800 MeV)
- High-repetition rate and the highest power beams available
- High beam quality and beam stability
- The brightest beams available
- Arbitrary emittance partition with repartition of phase space
- Linacs and ring, electrons and protons, lasers

ASTA is unique among accelerator R&D facilities

- It allows the broadest research program available at very reasonable cost:
  - Relevant to Project X, all intensity frontier accelerator s, LHC upgrades, future colliders and light sources, attracts dozens of University groups, etc

Three exp.areas are good for multiple experiments

  - With 50 MeV electrons, with 300-800 MeV electrons and SRF, with 50-150 MeV/c electrons and protons in IOTA ring

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