U.S. DEPARTMENT OF ENERGY | Office of Science

DOE HEP General Accelerator R&D

HEPAP Meeting
June 5, 2017

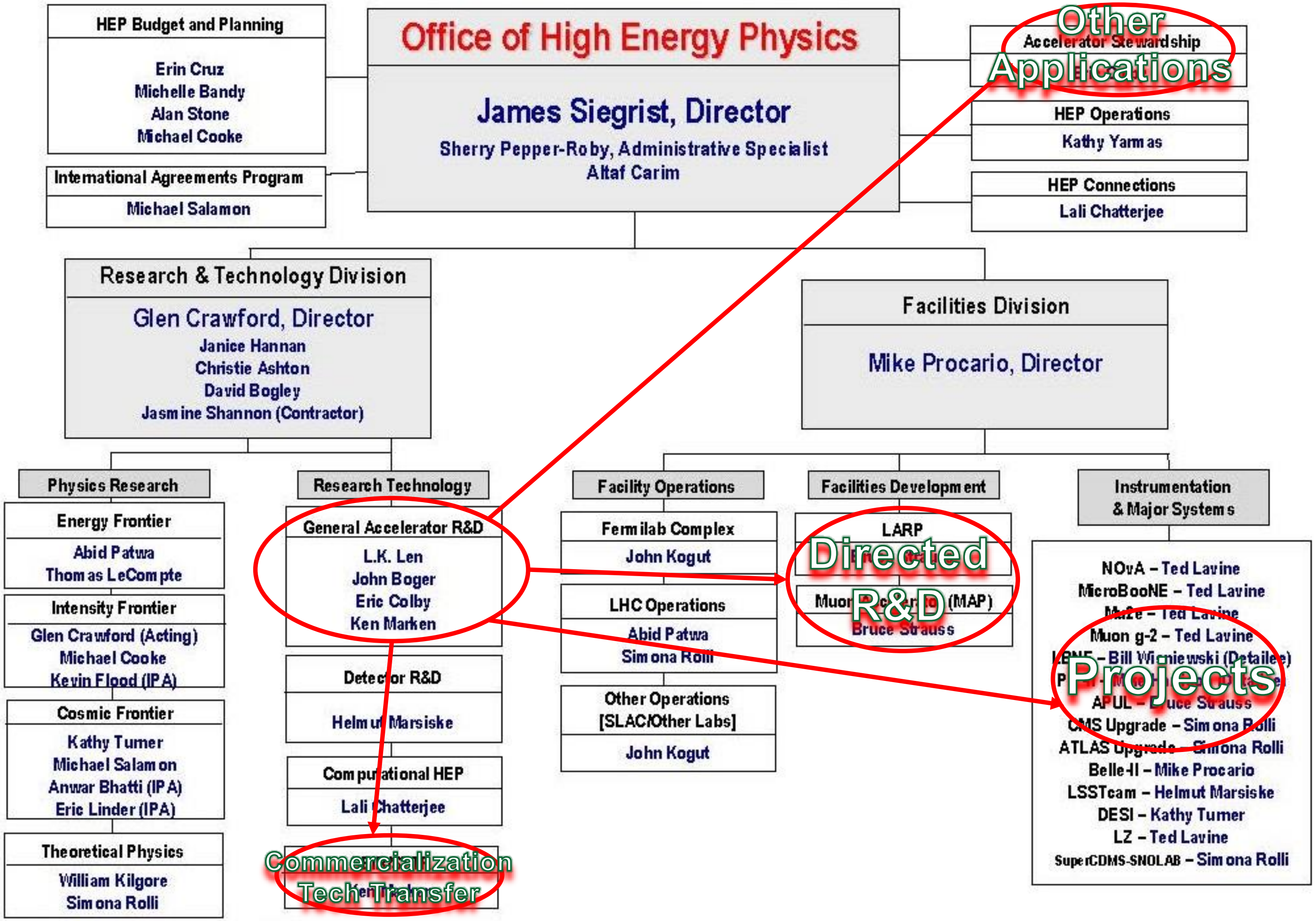
L.K. Len
Research and Technology Division

Office of High Energy Physics
Office of Science, U.S. Department of Energy

The HEP GARD Program

- **GARD supports accelerator science and technology R&D aimed at enabling HEP discovery science. It does so by developing new accelerator concepts, materials, designs and by pushing the performance limits, while acquiring and broadening the knowledge base of accelerator science.**
- **GARD funds medium and long term accelerator R&D primarily aimed at supporting the High Energy Physics mission. However, the long-term generic R&D may also benefit other applications—one can regard it as [small case] "accelerator stewardship".**
  - **Medium term accelerator R&D refers to work performed in the support of possible new facilities or of upgrades to existing ones. This applies to facilities that possess a reasonable conceptual idea for implementation.**
  - **Long-term accelerator R&D refers to the development of ideas and underlying technologies that could support facilities for which we do not currently have an integrated implementing concept**

GARD w.r.t. HEP Org Chart



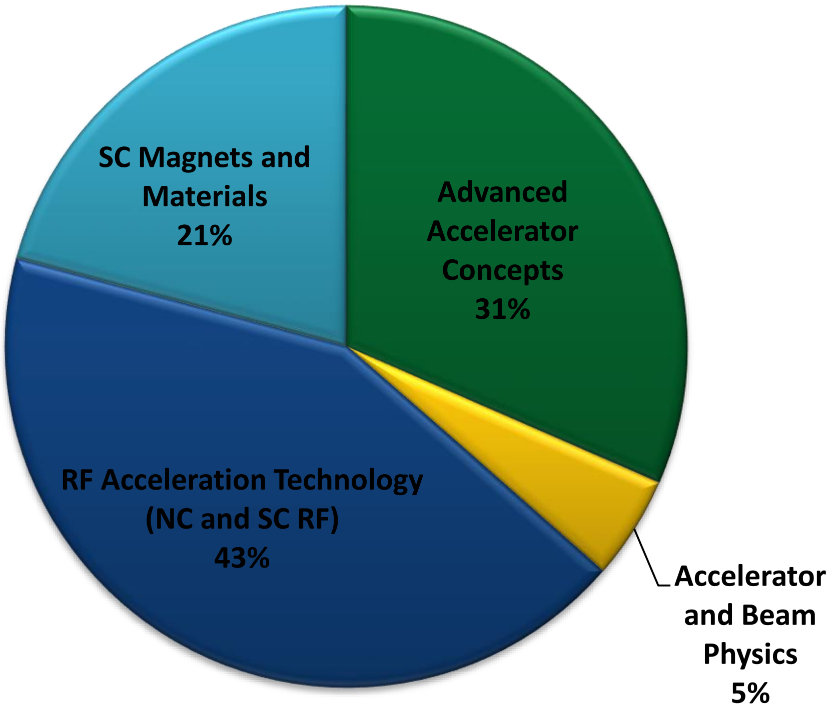
GARD Thrusts

- Supports 5 Research Thrusts:
  - Advanced Accelerator Concepts
  - Accelerator and Beam Physics
    - Expanded to include beam instrumentation and controls
  - Particle Sources and Targets
  - RF Acceleration Technology (NC and SC RF)
    - Includes RF sources, NCRF and SRF R&D
  - Superconducting Magnets and Materials

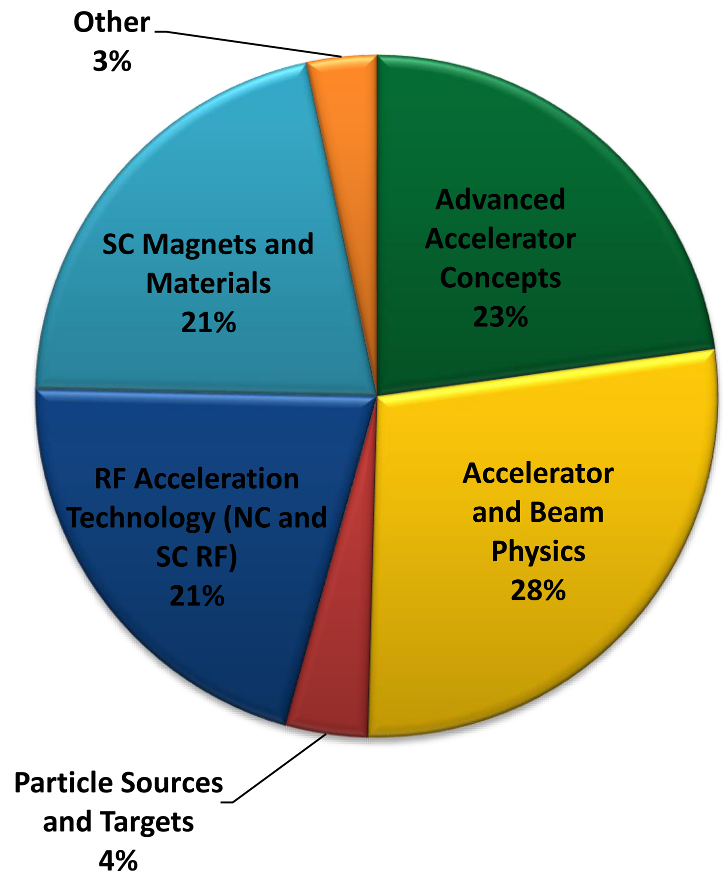
- Support research efforts at:
  - 7 DOE national labs
  - 30 university grants

FY 2016 GARD Research – % By Thrusts

GARD Facility Ops by Thrust ($27M)



GARD Research by Thrust ($44M)



P5 Report Strategy for GARD

- **In 2014—The P5 report recommended moving forward with a focused Advanced Technology R&D strategy:**
  - Play a leadership role in superconducting magnet technology focused on the dual goals of increasing performance and decreasing costs
  - Pursue accelerator R&D with a focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid-term and far-term accelerators

Accelerator R&D Subpanel

- **In 2015—Following P5, the Accelerator R&D Subpanel (charged to identify the most promising accelerator research areas to support the advancement of HEP) rolled out its report with 25 recommendations**
  - **provides prioritization advice to GARD on accelerator R&D towards the Next Steps [Medium-term] and Further Future [Long-term] accelerators**

	Intensity Frontier Accelerators	Hadron Colliders	e^+e^- Colliders
Current Efforts	PIP	LHC	
	PIP-II	HL-LHC	ILC
Next Steps	Multi-MW proton beam	Very high-energy *pp* collider	1 TeV class energy upgrade of ILC*
Further Future Goals	Neutrino factory*	Higher-energy upgrade	Multi-TeV collider*

****dependent on how physics unfolds***

ARDS Recommendations – AAC

- Advanced Acceleration Concepts
  - Support development of the most promising concepts toward far-term accelerators as envisioned by P5
    - [7] Vigorously pursue PWFA of positrons at FACET … preserve the momentum of PWFA research using other facilities.
    - [8] Support LWFA experiments on BELLA at the current level.
    - [9] Reduce funding for direct laser acceleration research activities.
    - [10] Convene the university and laboratory proponents of advanced acceleration concepts to develop R&D roadmaps
    - [C1b] Develop, construct, and operate a next-generation facility for PWFA research and development.

• Implemented • Implementing • In progress • Deferring

ARDS Recommendations – ABP

- Accelerator and Beam Physics
  - Maintain accelerator science core competence and support high intensity proton beam physics R&D
    - [2] Construct the IOTA ring, and conduct experimental studies of high-current beam dynamics in integrable non-linear focusing systems.
    - [3] Support a collaborative framework among laboratories and universities that assures sufficient support in beam simulations and in beam instrumentation to address beam and particle stability including strong space charge forces.
    - [14] Continue ABP R&D aimed at developing the accelerators defined in the Next Steps and the Further Future Goals.
    - [15] Ensure a healthy, broad program in accelerator research, allocate a fraction of the budget of the ABP thrust to pursue fundamental accelerator research outside of the specific goals.

• Implemented • Implementing • In progress • Deferring

ARDS Recommendations – PST

- Particle Sources and Targets
  - Develop plan to support high-power target for Intensity Frontier
    - [1] Fund generic high-power component R&D at a level necessary to carry out needed thermal shock studies and ionizing radiation damage studies on candidate materials that are not covered by project-directed research.

• Implemented • Implementing • In progress • Deferring

ARDS Recommendations – RF

- RF Acceleration Technology
  - Support high-efficient RF source development and high-gradient research
    - [4] Invest in SRF R&D in order to inform the selection of the acceleration technology for the multi-MW proton beam at Fermilab.
    - [6] Increase SRF R&D funding to significantly reduce the cost of a 1TeV-ILC. 80 MV/m accel gradients with new materials over 10 years.
    - [11] Continue research on high-efficiency power sources and high-gradient NCRF structures.
    - [12] Make NLCTA available for RF structure tests using its RF power and beam sources.
    - [13] Focus NCRF R&D on developing a multistage prototype based on high-gradient NCRF structures and high-eff RF sources to demonstrate the technology for a multi-TeV e+e- collider.

• Implemented • Implementing • In progress • Deferring

ARDS Recommendations – SCM

- **Superconducting Magnet and Materials**
  - **Support a balanced portfolio magnet and materials efforts; LTS and HTS conductors**

    [5a] Support accelerator design and simulation activities that guide and are informed by the SC magnet R&D program for a VHEPP collider.

    [5b] Form a U.S. HFM R&D collaboration that is coordinated with global design studies for a VHEPP collider. The over-arching goal is a large improvement in cost-performance.

    [5c] Aggressively pursue the development of Nb3Sn magnets suitable for use in a VHEPP collider.

    [5d] Establish and execute a HTS material and magnet development plan with appropriate milestones to demonstrate the feasibility of cost-effective accelerator magnets using HTS.

• **Implemented** • **Implementing** • **In progress** • **Deferring**

ARDS Recommendations – SCM

- Superconducting Magnet and Materials
  - Support a balanced portfolio magnet and materials efforts; LTS and HTS conductors

[5e] Engage industry and manufacturing engineering disciplines to explore techniques to both decrease the touch labor and increase the overall reliability of next-generation SC accelerator magnets.

[5f] Significantly increase funding for SCM R&D in order to support aggressive development of new conductor and magnet technologies.

[C1a] Ramp up SCM R&D, targeted primarily for a VHEPP collider, to permits a multi-faceted program to explore breakthroughs in parallel in magnet configurations, prototype fabrication, low-cost manufacturing and industrial scale-up of conductors. Increase HTS support to demonstrate the viability of accelerator-quality HTS magnets for a VHEPP collider.

• Implemented • Implementing • In progress • Deferring

ARDS Recommendations – General

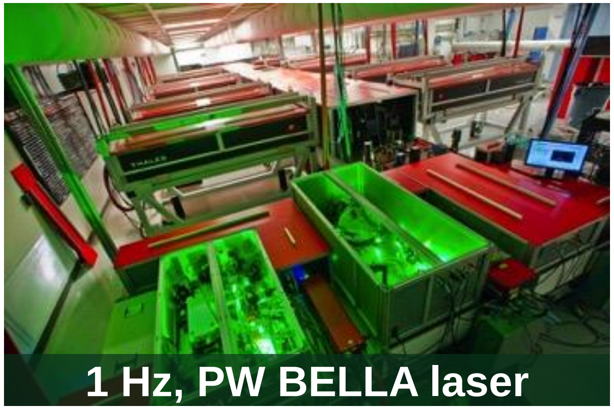
- **The GARD Program**
  - Current GARD budget is insufficient to satisfy the expectation of P5. Modest rise in base funding would open numerous critical R&D opportunities.
    - [B1] Increase base GARD funding modestly in order to open numerous critical R&D opportunities that do not fit in the current base, as well as to invigorate fundamental accelerator science research, and to step up development of the national accelerator workforce.

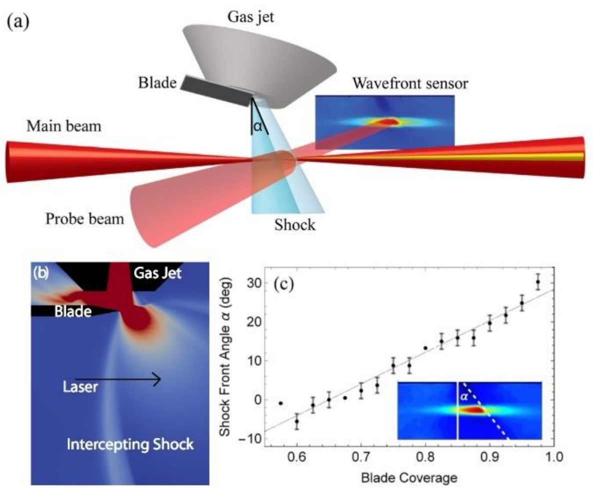
• Implemented • Implementing • In progress • Deferring

GARD Highlights

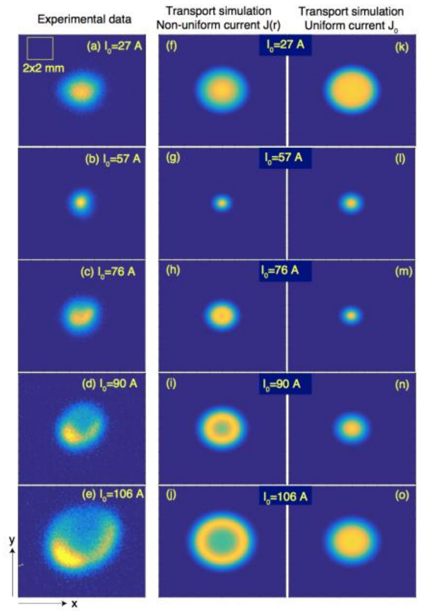
Advanced Accelerator Concepts – LWFA

- **BELLA Center at LBNL**
  - Most powerful 1Hz laser
  - Highest accelerated beam (4.25 GeV)
  - LPA staging at low energy
  - Tunable injection in a jet with a sharp shock

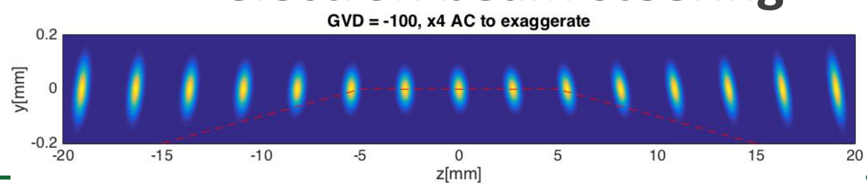




- Active plasma lens



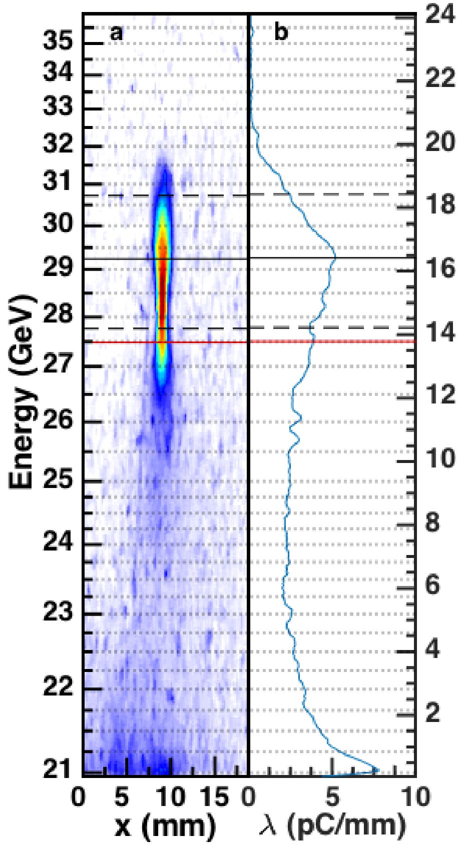
- Pulse front tilt and electron beam steering

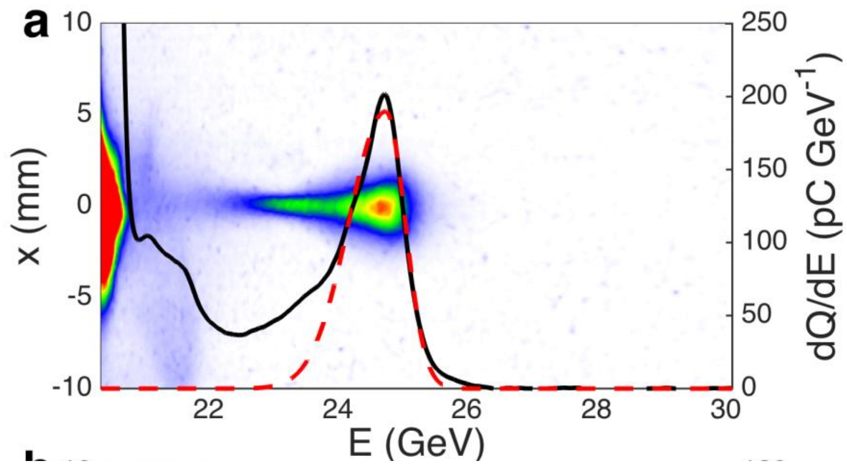


GARD Highlights

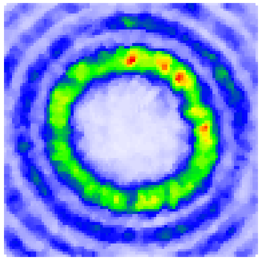
Advanced Accelerator Concepts – PWFA

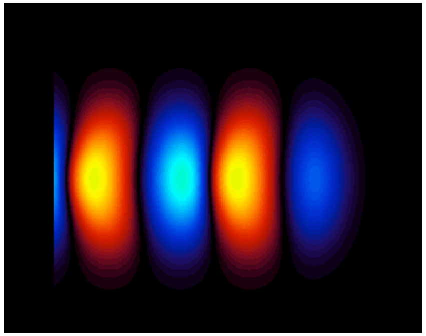
- **FACET at SLAC**
  - 9 GeV e-beam acceleration





  - Positron beam gain 4 GeV/1.3m
  - Hollow plasma channel for e+

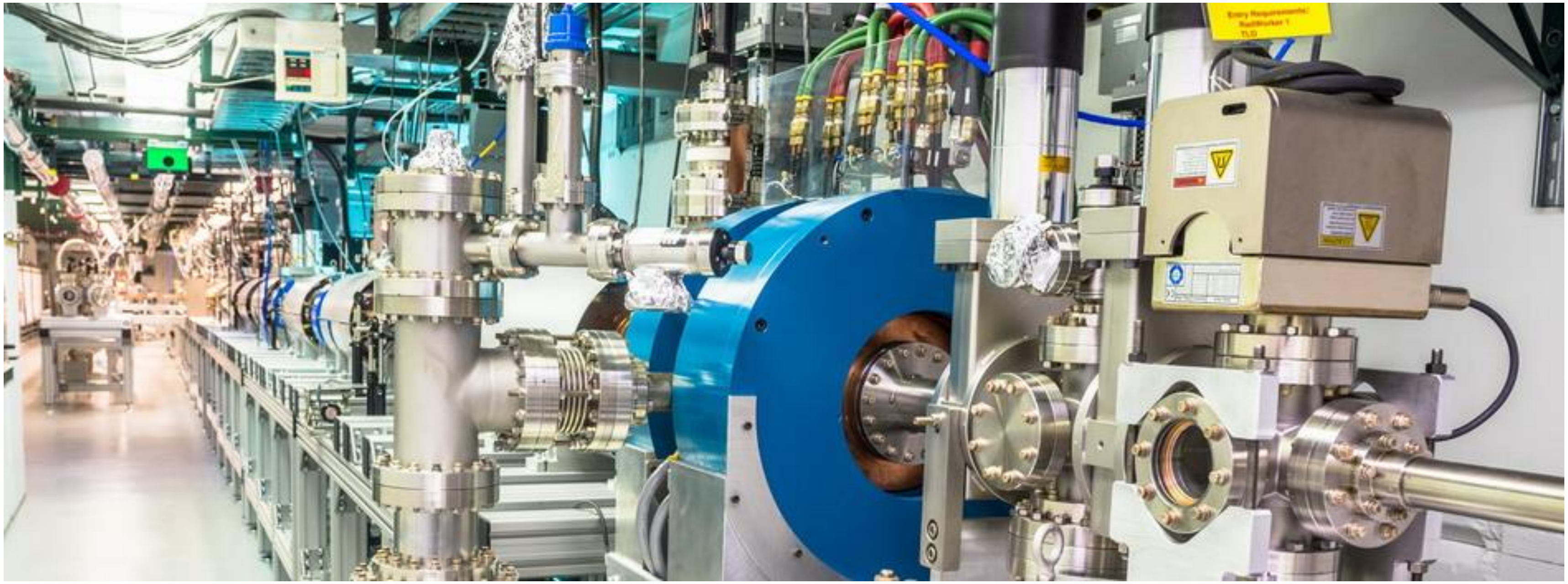




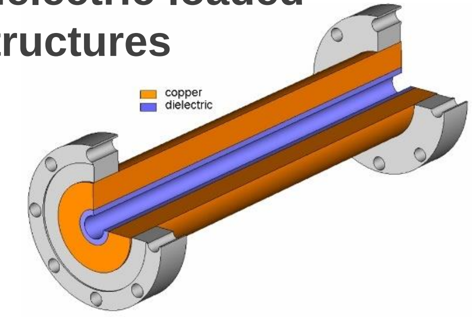
  - >1 GeV e+ acceleration in quasi-linear regime

GARD Highlights

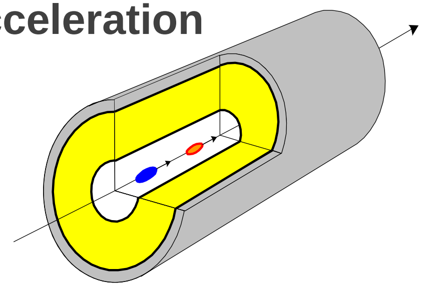
Advanced Accelerator Concepts – Argonne Wakefield Accelerator



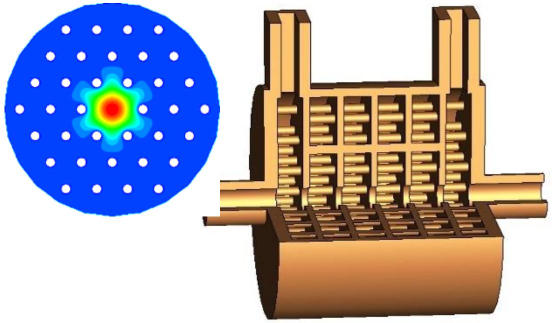
Dielectric loaded structures



Collinear wakefield acceleration



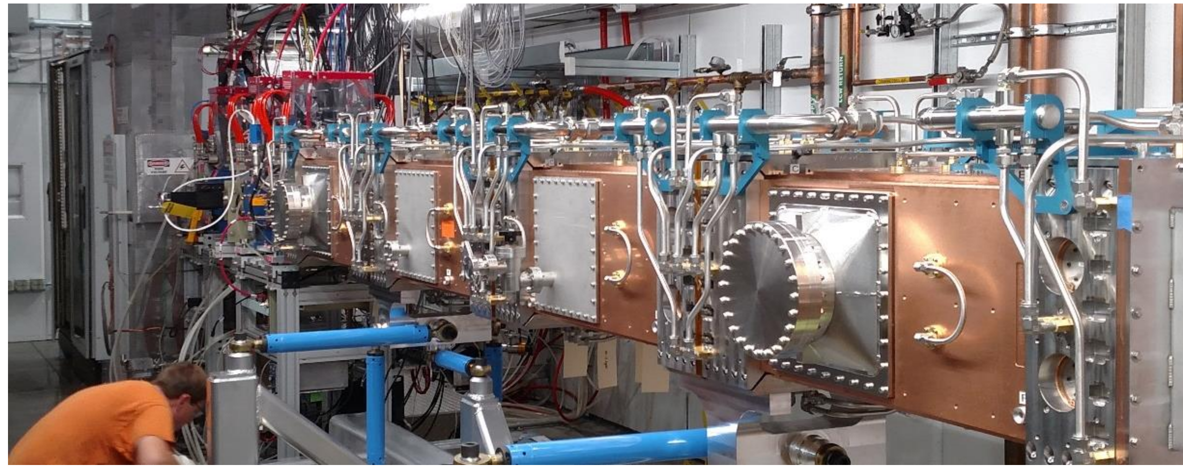
Photonic band gap structures

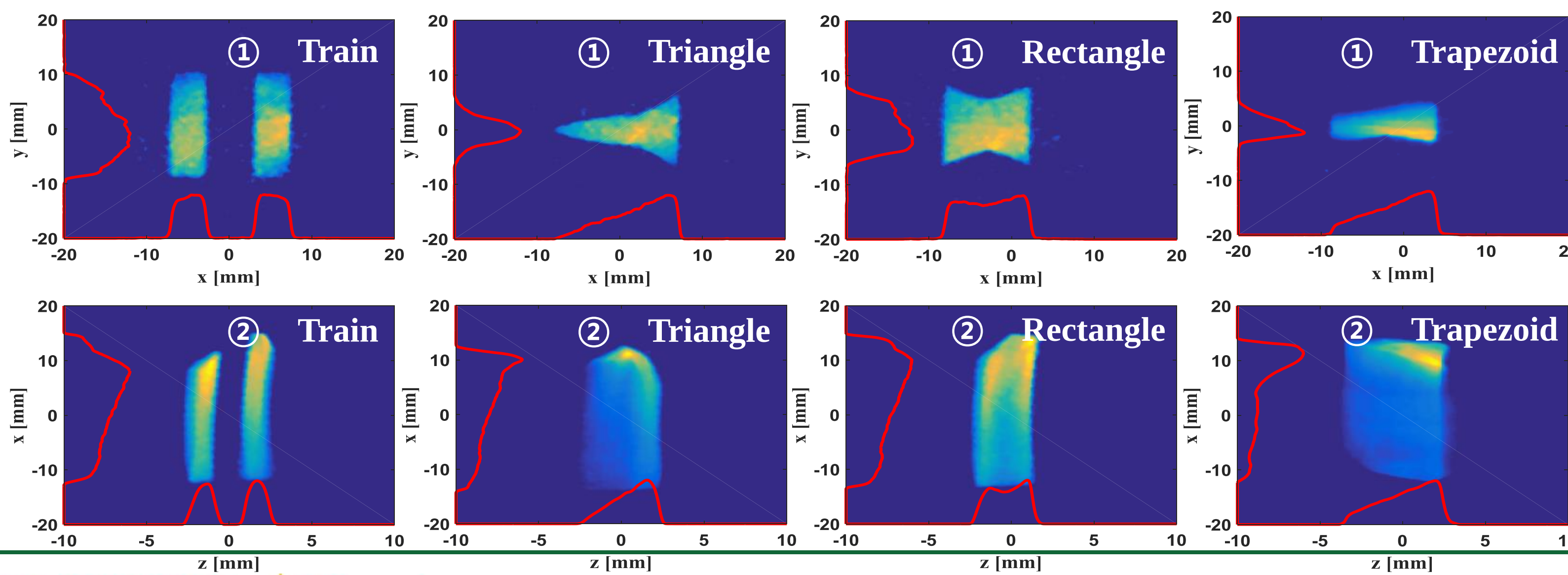


GARD Highlights

Accelerator and Beam Physics

- **RFQ accelerator—** fabricated by LBNL, installed at FNAL (~100% transmission; 1-10mA; 2.11 MeV ± 0.5%)
- **Beam phase space manipulation @AWA**





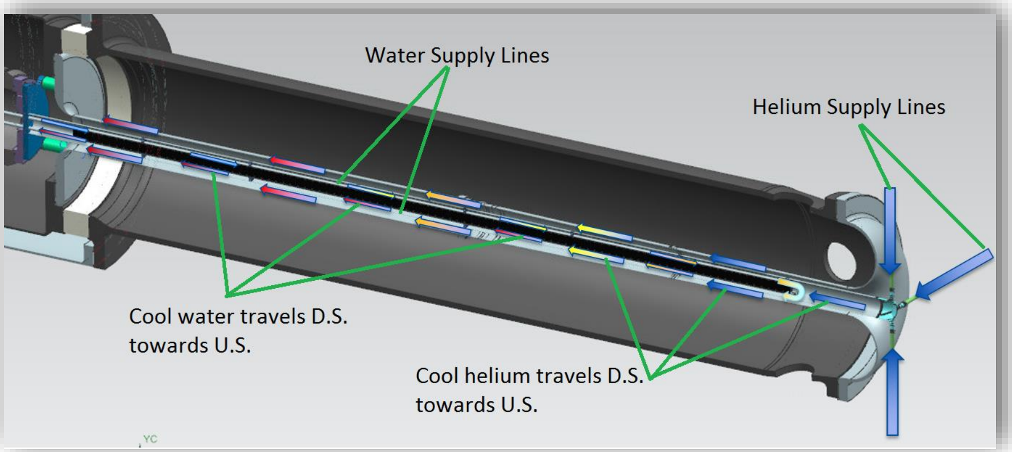
GARD Highlights

Particle Sources and Targets

- RaDIATE Collaboration (*Radiation Damage In Accelerator Target Environments*)

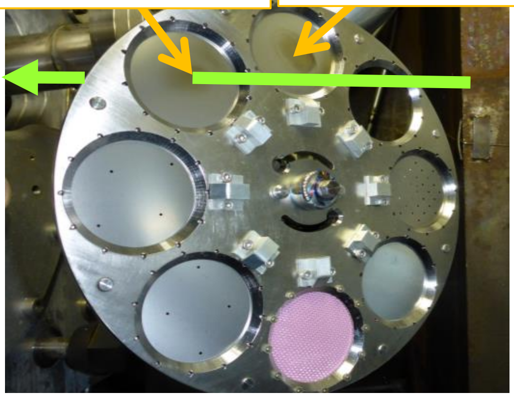
Fermilab · University of Oxford · Brookhaven National Laboratory · European Spallation Source · Argonne National Laboratory · Science & Technology Facilities Council · FRIB · Pacific Northwest National Laboratory · Oak Ridge National Laboratory · Los Alamos National Laboratory EST. 1943 · Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

- LBNF graphite target/Ti cooling tube



Ti-2: 5.22×10^{20} 0.42DPA(MARS)

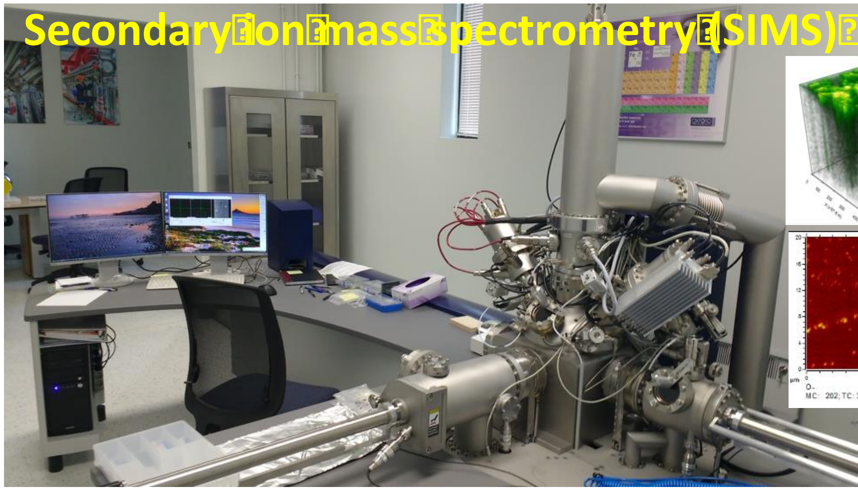
Ti-1: 1.42×10^{20} 0.17DPA

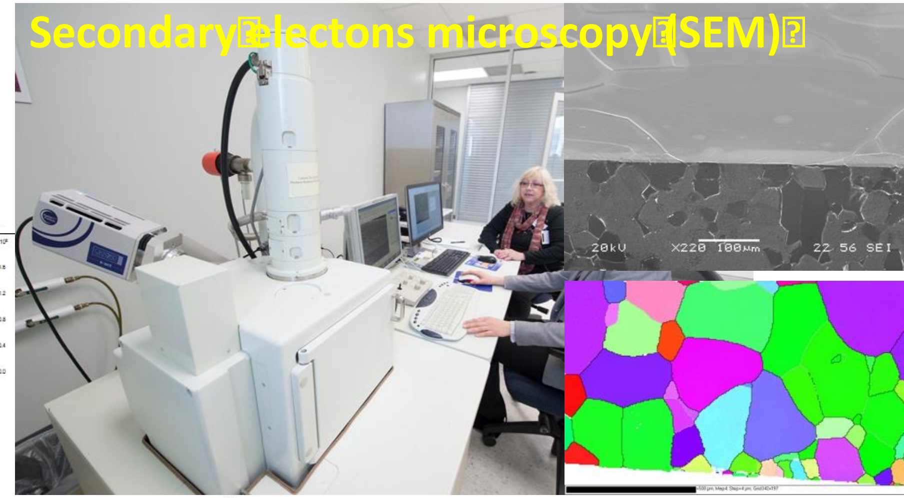


- Ti OTR foils

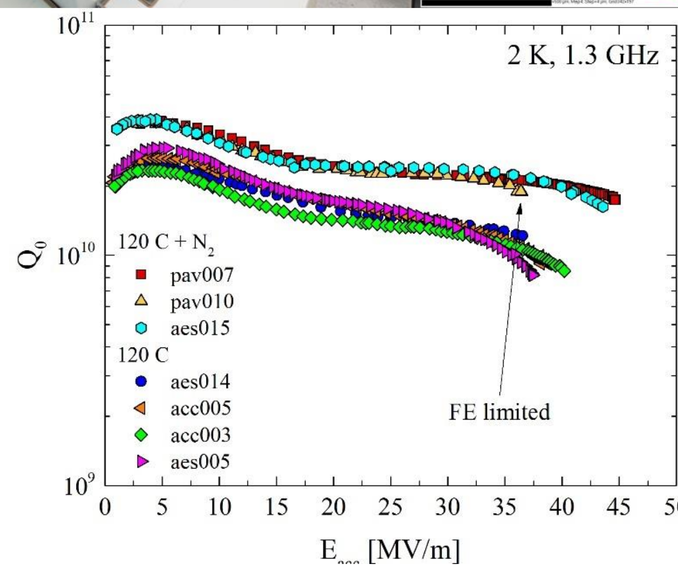
GARD Highlights

RF Acceleration Technology—SRF





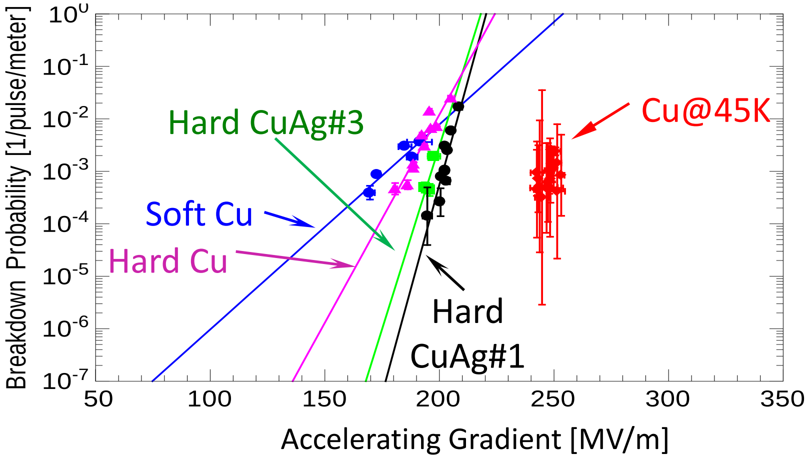
- State-of-the-art equipment @FNAL
- Nitrogen doping and better understanding of magnetic flux losses→SRF cavities with
  - High Q_0
  - High accelerating gradient
- Enable LCLS-II cryomodule to achieve world record Q_0

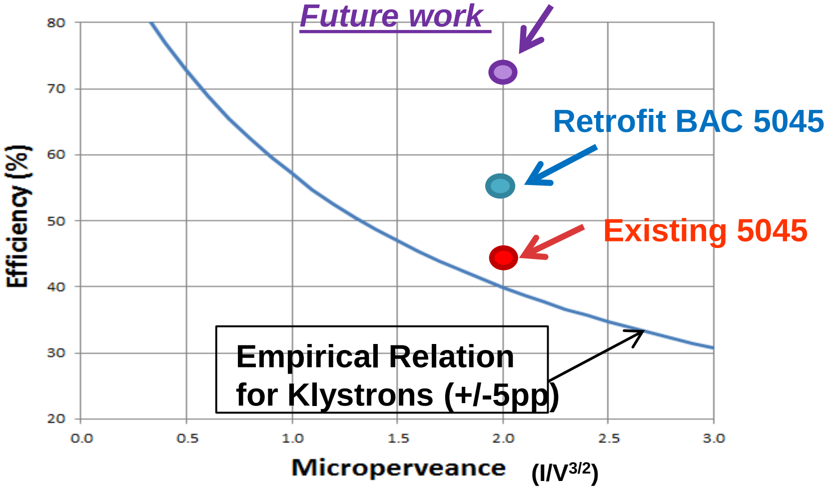


GARD Highlights

RF Acceleration Technology—NCRF

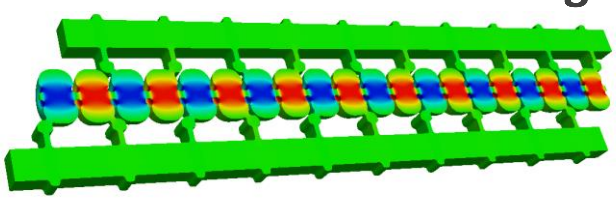
- Better understanding RF breakdown
  → dramatic increase in accel gradient



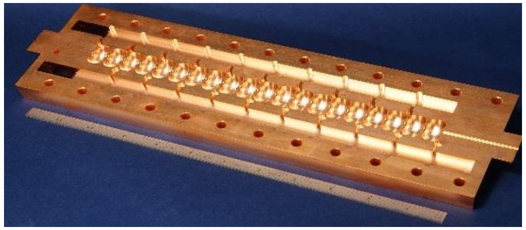


- High efficiency RF sources

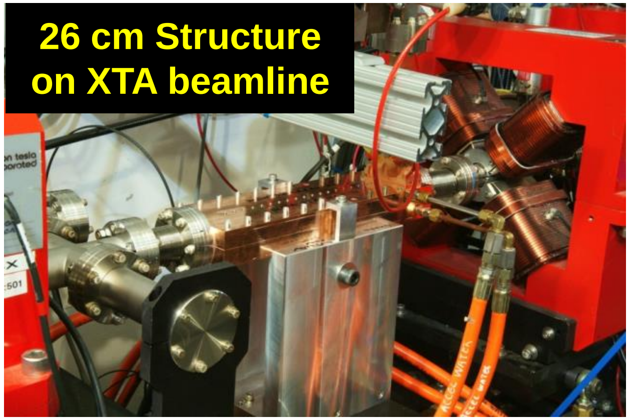
- Massively parallel computing tools enable virtual RF design



RF optimization and full structure modeling



Machined in two halves

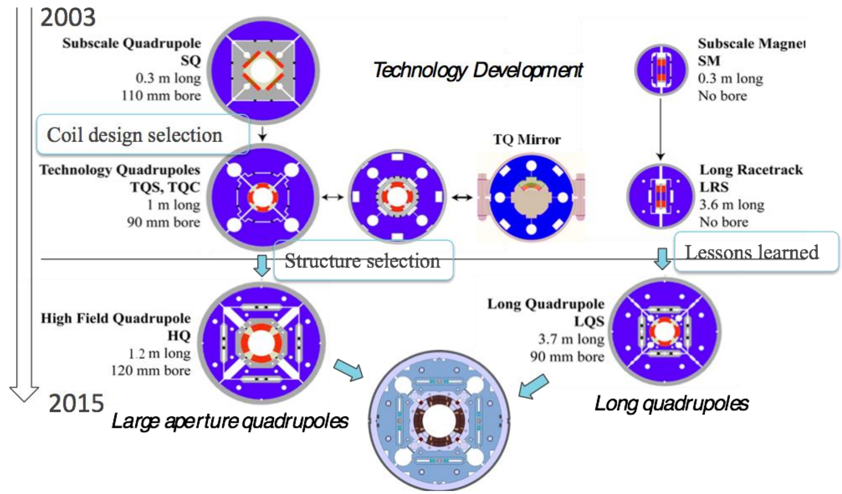


RF parameter calculation verified by measurement

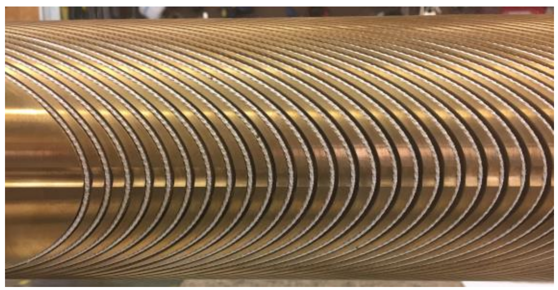
GARD Highlights

Superconducting Magnets and Materials

- GARD SC magnet and conductor development at BNL, FNAL, and LBNL
  → LHC upgrades.



- Explore new design—Canted Cosine Theta (CCT) at LBNL



- Develop HTS technology—
  - Round Bi2212 wire
  - REBCO tape and CORC cables

Image courtesy by J. Weiss and D. van der Laan, Advanced Conductor Technologies

Summary

- **The GARD Program**
  - supports a broad spectrum of R&D in Accelerator Science and Technology
  - supports many research efforts that are world-leading and continues to push their frontiers
  - is implementing the ARDS recommendations within its budget and programmatic constraints
  - is developing research roadmaps for each of its research thrusts