U.S. DEPARTMENT OF ENERGY | Office of Science

General Accelerator R&D Program

L.K. Len, J. Boger, E. Colby, K. Marken, M. Zisman

Office of High Energy Physics

U. S. Department of Energy

Office of Science

PI Meeting-Rockville

June 16, 2014

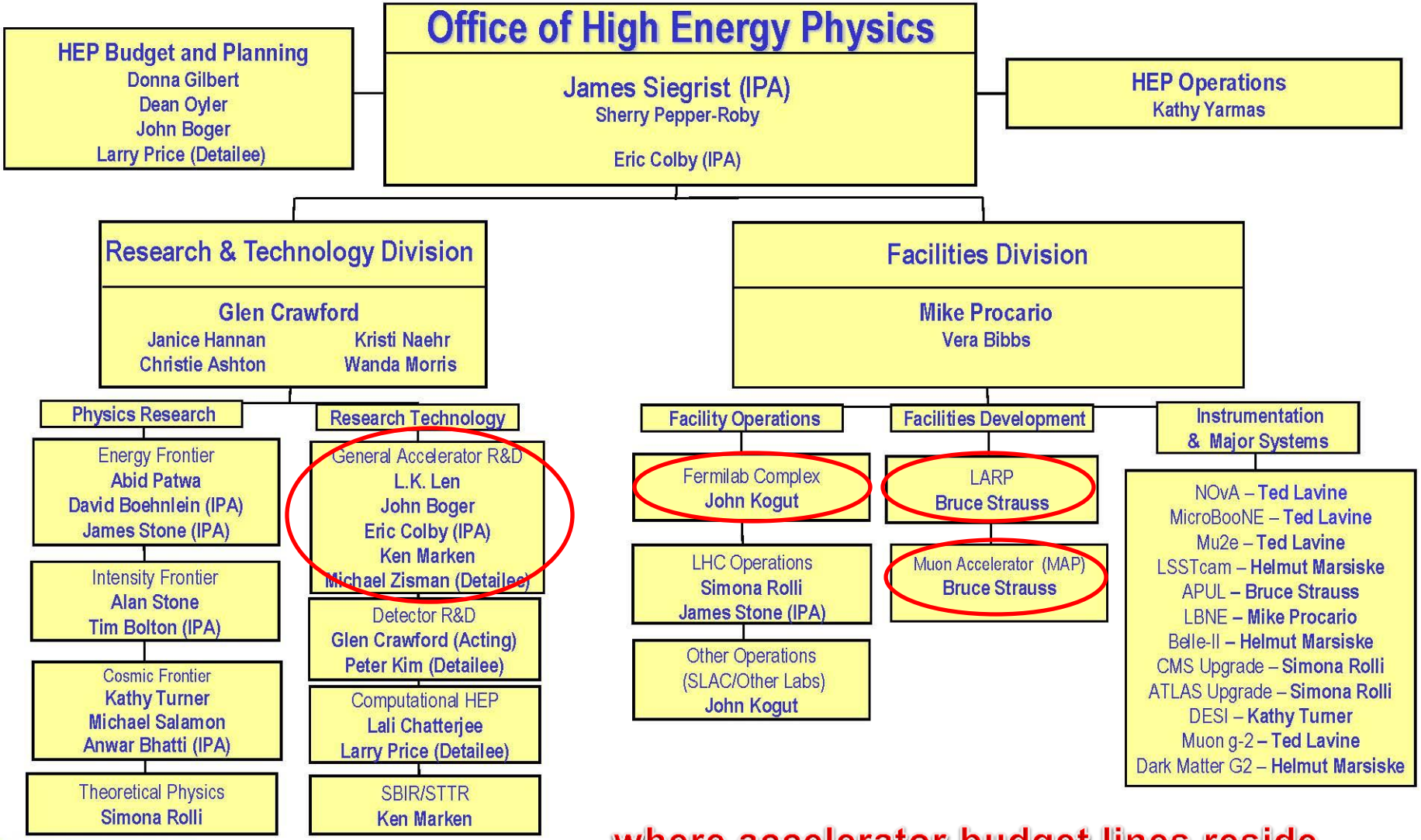
Introduction

- Accelerator R&D Efforts within SC Program
- Areas with support from different SC Programs
- Funding distribution across different thrust areas
- Funding distribution among labs and universities
- Some highlights and recent accomplishments
- Program status and evolution
- Summary

Program Mission and Goals

- Support **world-leading research** in the physics of particle beams and accelerator research and development
  - Necessary for advancement of a broad range of scientific disciplines: HEP, NP, photon and neutron science
- Three major categories:
  - **Long-term, proposal-driven research** on the fundamental science underlying particle accelerators and beams to enable breakthroughs in size, cost, beam intensity, beam energy, and control
  - **Mid-term, facility-inspired R&D** focused on specific concepts or technologies to demonstrate feasibility and engineering readiness
  - **Near- to mid-term directed R&D** for specific facilities or technologies in support of DOE projects (sometimes captured in project TPC)

HEP Organization chart



where accelerator budget lines reside

SC Accelerator R & D

Total FY13 SC Program Investment = $135M

Programs	Mid-term (facility-driven) R&D	Long-term (accel. science-driven) R&D	Directed R&D Campaign†	Total
ASCR*	0.5*	-	-	0.5*
BES	8.4	-	-	8.4
HEP	42.7	42.1	32.7	117.5
NP	9.1	-	-	9.1
Total	60.2	42.2	32.7	135.5

*ASCR number is from FY11

†Directed R&D includes LARP and MAP

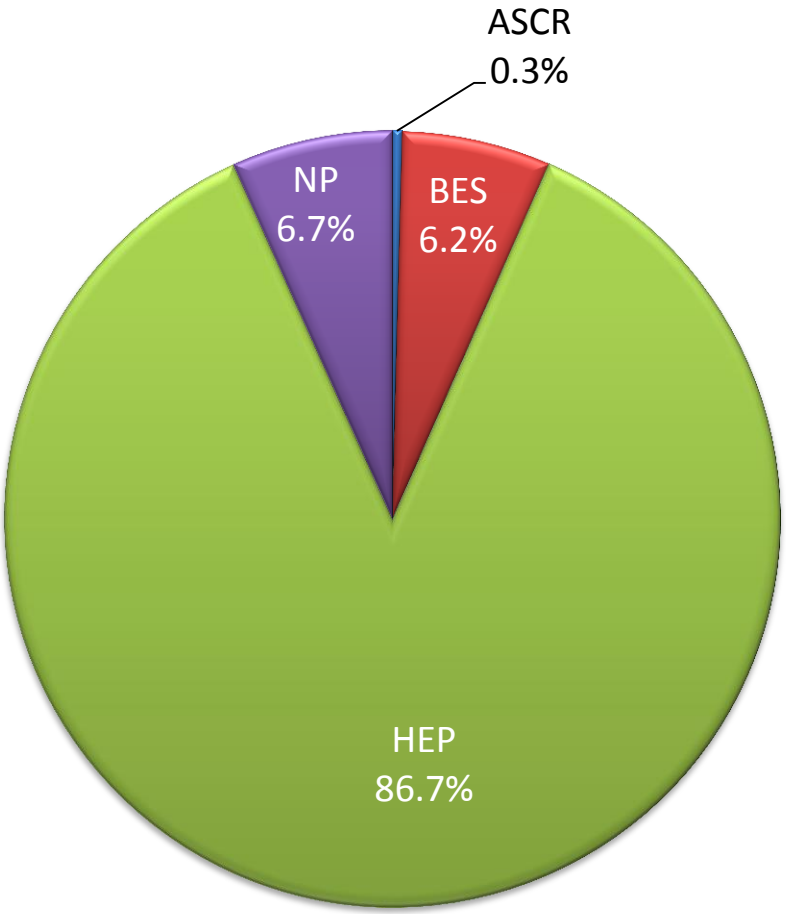
Accelerator R & D – By Program

DOE SC Programs supporting accelerator R&D:

- Office of Advanced Scientific Computing Research
- Office of Basic Energy Sciences
- Office of High Energy Physics
- Office of Nuclear Physics

Majority of SC R&D effort is coordinated by HEP

By SC Program - Mid and Long Term



SC Accelerator R&D Coverage

- **Complementary R&D**
  - Several research areas are support by multiple Programs
  - R&D activities complement each Program
  - Each Program focuses mainly on programmatic needs

- **Fundamental and Long Term R&D**
  - Long term R&D such as novel accelerator concepts is undertaken by the HEP program
  - Fundamental accelerator research and technology development also resides in the HEP program, e.g., high power RF sources, superconducting materials for magnets and SRF cavities.

SC Accelerator R & D Inventory

SC Program Participation by institutions and thrusts

Thrust / Inst.	Beam Physics	Beam Instr/ctl	New concept	NC struct & RF src	Particle sources	SC magnet	SC RF
ANL	⊙ ⊙	⊙	●	⊙	⊙		⊙
BNL	⊙ ⊙	⊙ ●	●	⊙	⊙ ⊙	⊙	●
FNAL	●					●	● ⊙
JLAB	⊙	⊙					●
LBNL	⊙ ⊙ ●	⊙	●		●	●	
PPPL	⊙						
SLAC	⊙ ● ●	⊙ ⊙	●	●			
UNIV.	⊙ ● ⊙	⊙	●	●	⊙ ⊙ ⊙	●	●

Key: 100<⊙<300; 300<⦿<1,000; ●>1,000 (FY13 $k) Color code: ■ASCR; ■BES ; ■HEP ; ■NP

HEP General Accelerator R&D Thrust Areas

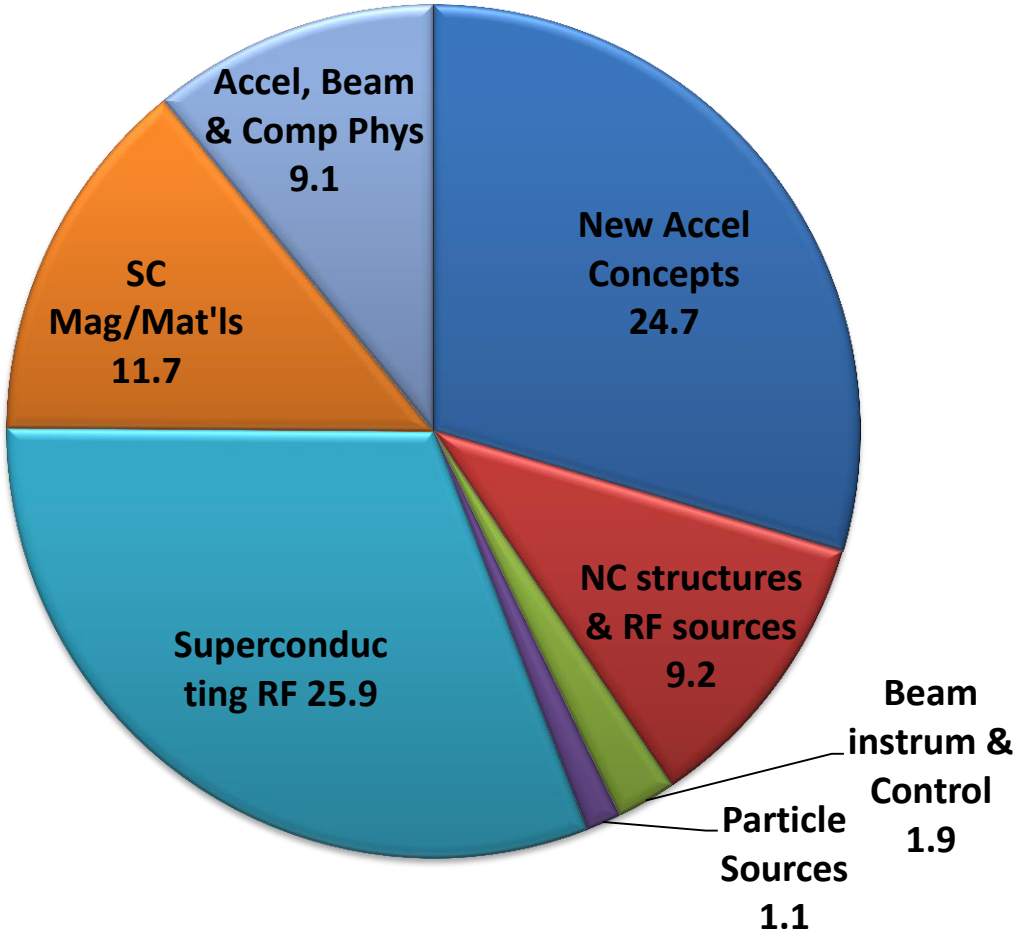
7 Core GARD Thrust Areas

- New Accelerator Concepts
- Accelerator, Beam and Computational Physics
- Particle Sources
- Beam instrumentation and Control
- NC structures & RF Sources
- Superconducting RF
- Superconducting Magnets

+ Directed R&D $32.7M
(for LARP, MAP, PX)

+ Other $1.5M
(for LC, workshops)

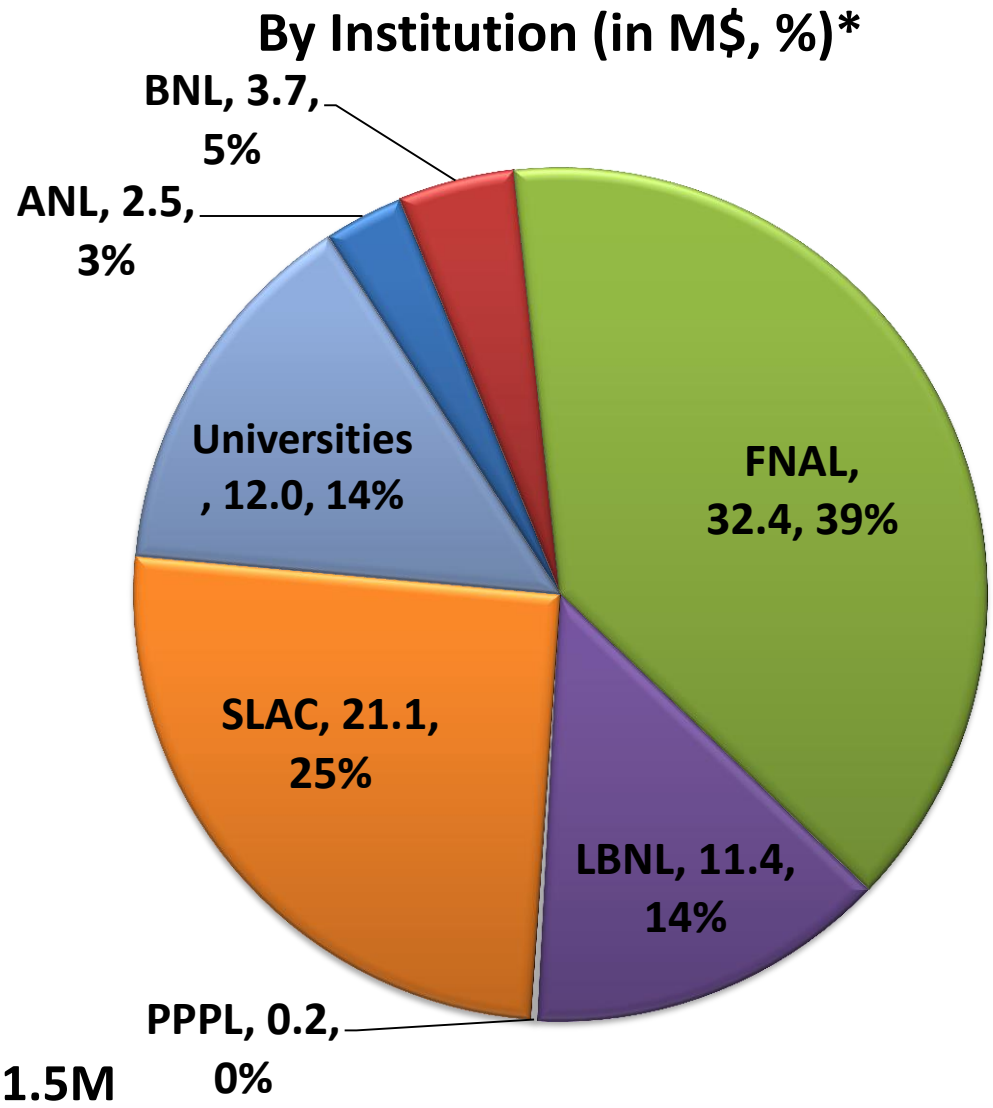
FY 2013 By GARD Thrust Areas (in M$)



GARD by Institutions

GARD supported research institutions (FY 2013):

- Argonne National Lab
- Brookhaven National Lab
- Fermi Nat'l Accel Lab
- Lawrence Berkeley Nat'l Lab
- Princeton Plasma Phys Lab
- SLAC Nat'l Accel Lab
- 42 University grants



* Plus other $1.5M

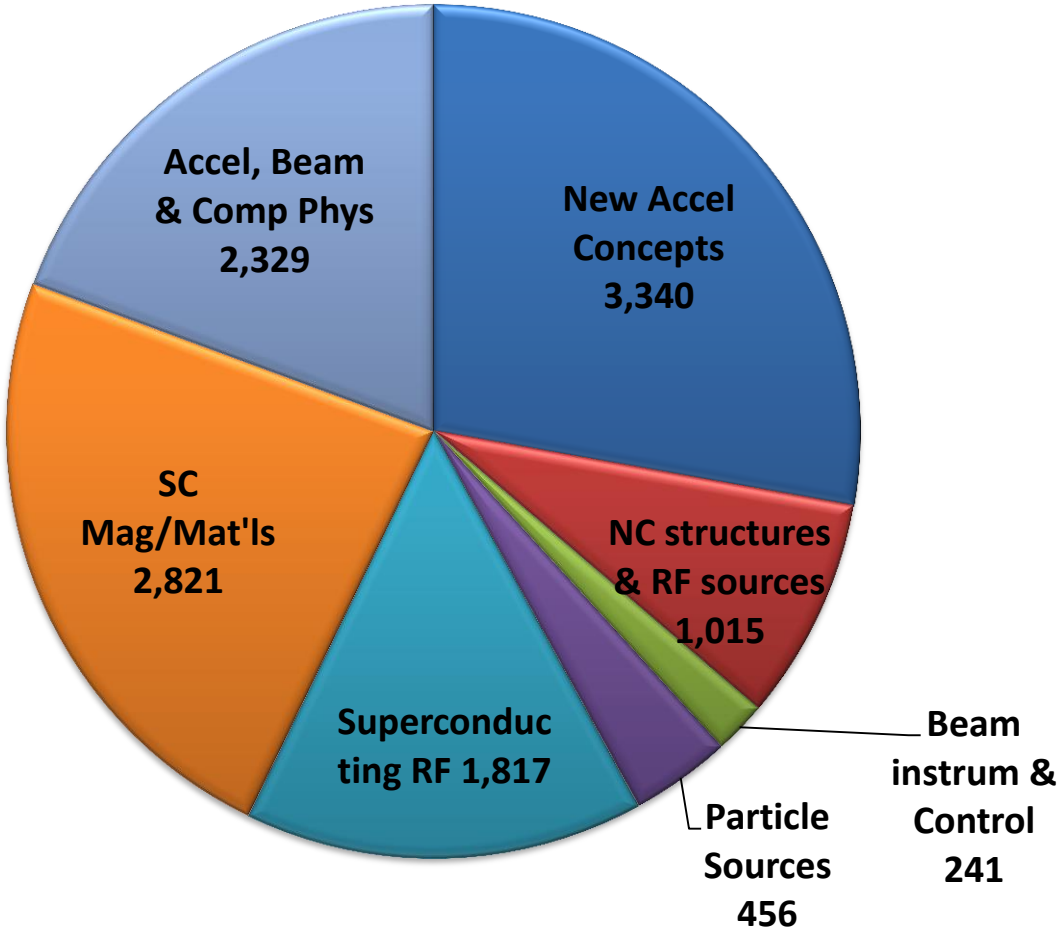
GARD at University by Thrust Areas

Same 7 Core GARD Thrust Areas for Universities:

- New Accelerator Concepts
- Accelerator, Beam and Computational Physics
- Particle Sources
- Beam instrumentation and Control
- NC structures & RF Sources
- Superconducting RF
- Superconducting Magnets

Average Grant Size ~ $300K

University By Thrust Areas (in k$)

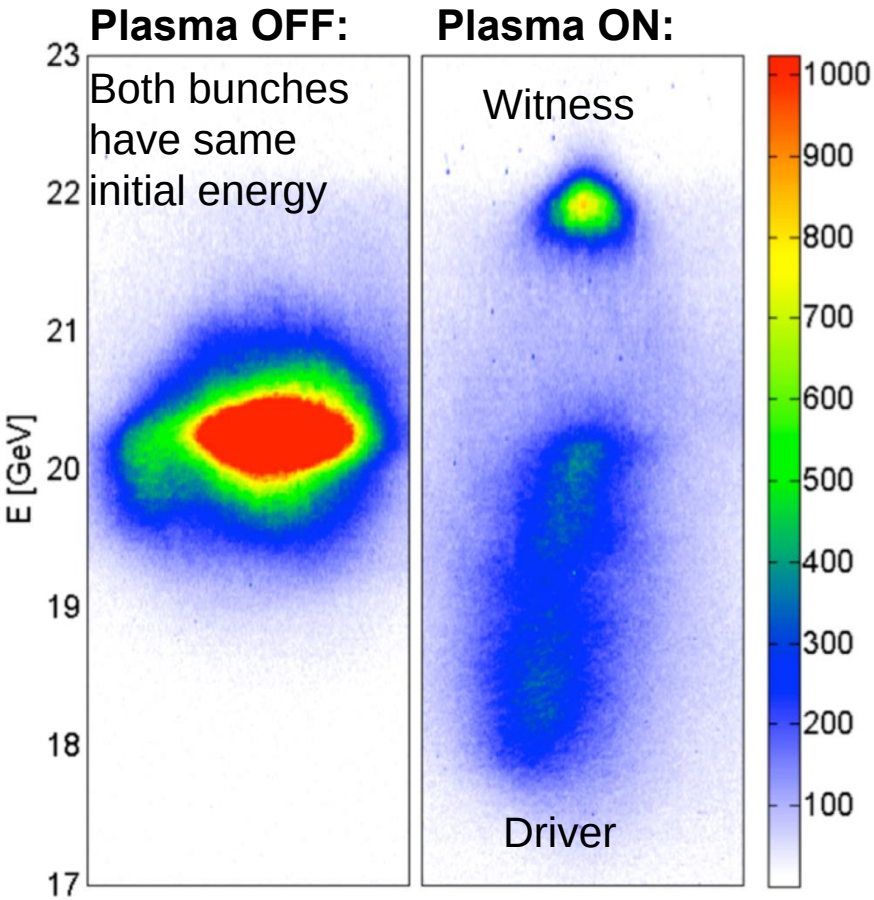


Highlights—Novel Acceleration Concepts

Two Flagship Plasma Acceleration Facilities:

- **BELLA (LBNL) – Laser-driven**
- **FACET (SLAC) – beam-driven are both operating**

Recent Accomplishment —FACET



FACET data from SLAC

High quality e- beams in a 6 GeV/m acceleration field

- New FACET facility demonstrates first acceleration of a witness bunch in beam driven plasma wakefield
- Accelerating Field 6 GeV/m, which is 300x that of the SLAC linac
- Important step towards meter scale high-energy plasma based accelerator

Impact

New technology with potential for far lower accelerator size and cost

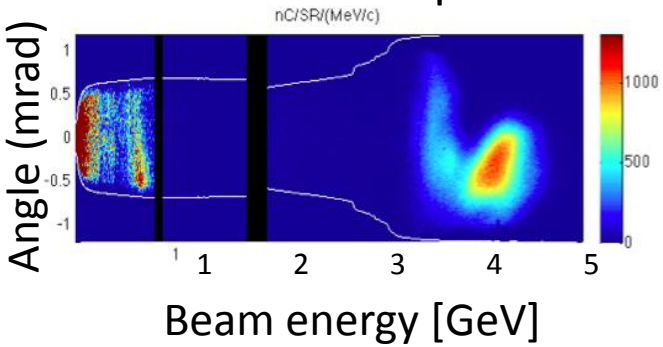
Recent Accomplishment —BELLA

BELLA: 4.25 GeV beams from 9 cm plasma channel with 390 TW laser pulses

- With conventional technology this energy requires a 200 m long accelerator, a downsizing factor of 10,000
- Present investment in Laser Plasma Acceleration has potential to achieve ~10 GeV energy level in future experiments
- New BELLA facility commissions world-record petawatt laser for LPA science (>1 PW at 1 Hz)

9 cm long capillary discharge

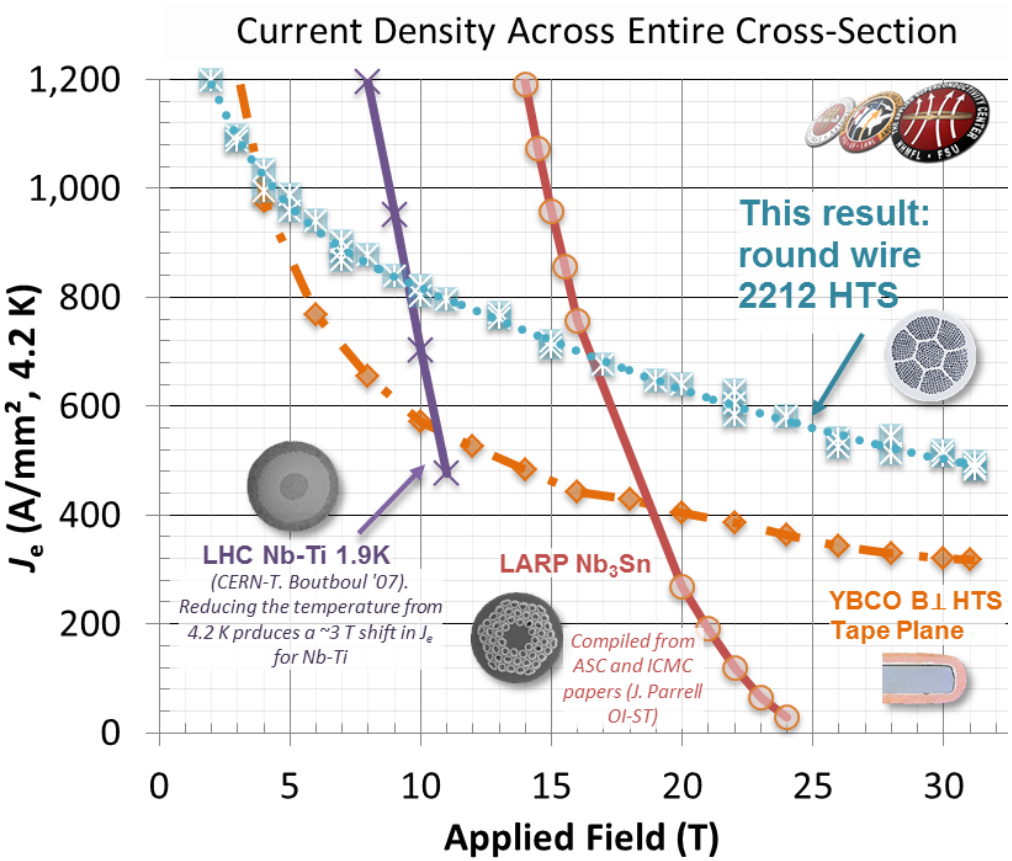
Electron beam spectrum



Impact

New technology with potential for far lower accelerator size and cost

Highlights—Superconducting Materials



Achieved record current in HTS: 500 A/mm² at 30 T, 4.2 K in $Bi_2Sr_2CaCu_2O$

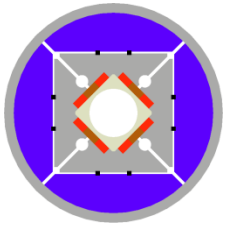
- Existing state-of-the art conductors (Nb_3Sn for LARP) sustain this performance only to 18 T
- LHC Nb-Ti conductors sustain this performance only to 11 T
- This practical HTS magnet material is an isotropic round wire which can be cabled on existing machines
- Competing HTS materials are anisotropic tapes and not easily made into magnet cables

Impact

This level of current density could technically enable magnetic field levels that double existing particle collision energies

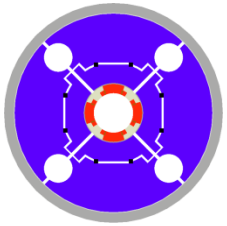
Highlights—Superconducting Magnets

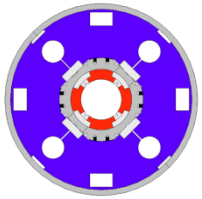
Subscale Quadrupole SQ
0.3 m long
110 mm bore

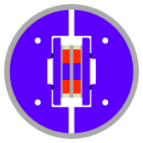


LBNL Subscale Magnet SM
0.3 m long
No bore

Technology Quadrupole TQS - TQC
1 m long
90 mm bore

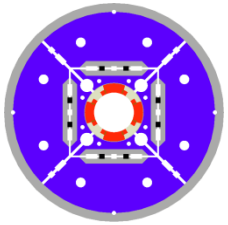




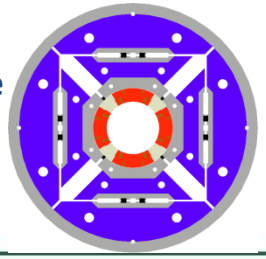


Long Racetrack LRS
3.6 m long
No bore

Long Quadrupole LQS
3.7 m long
90 mm bore

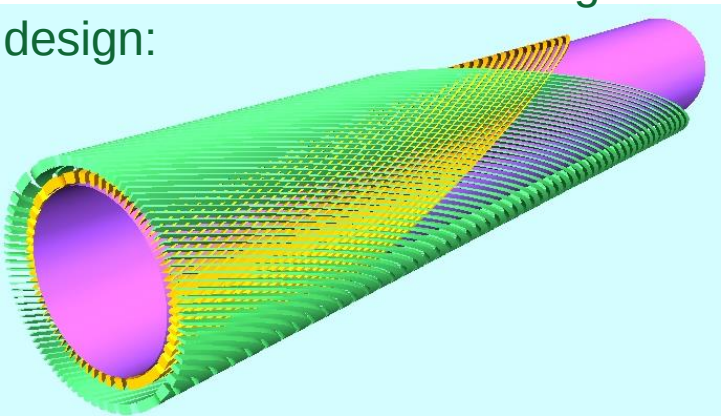


High Field Quadrupole
1 m long
120 mm bore

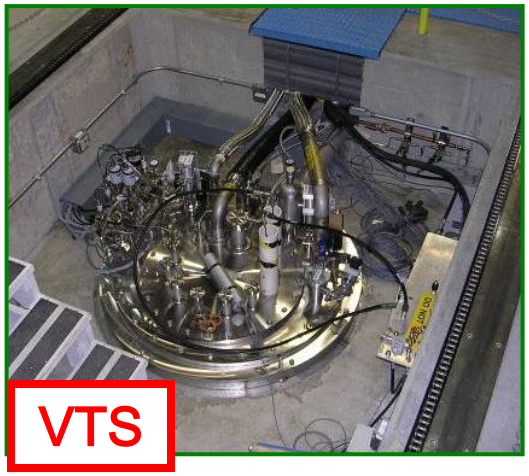


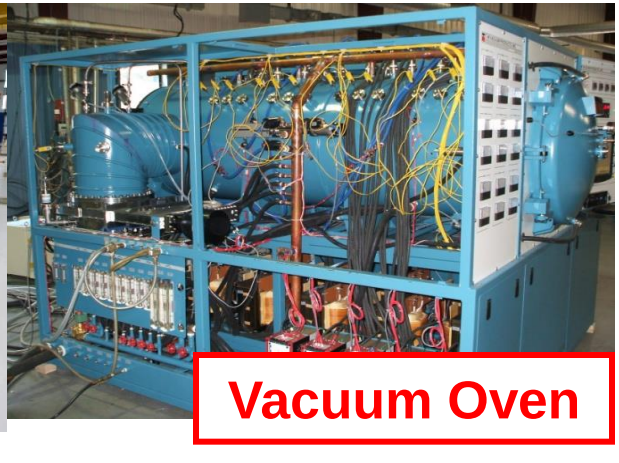
Significant progress made towards building magnets for future LHC upgrades

Continue to innovate in magnet design:



Highlights—SRF Technology

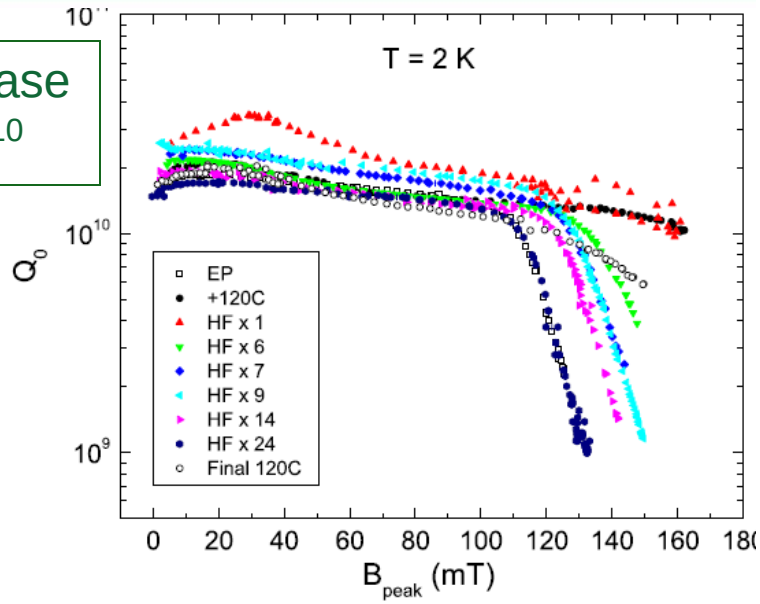


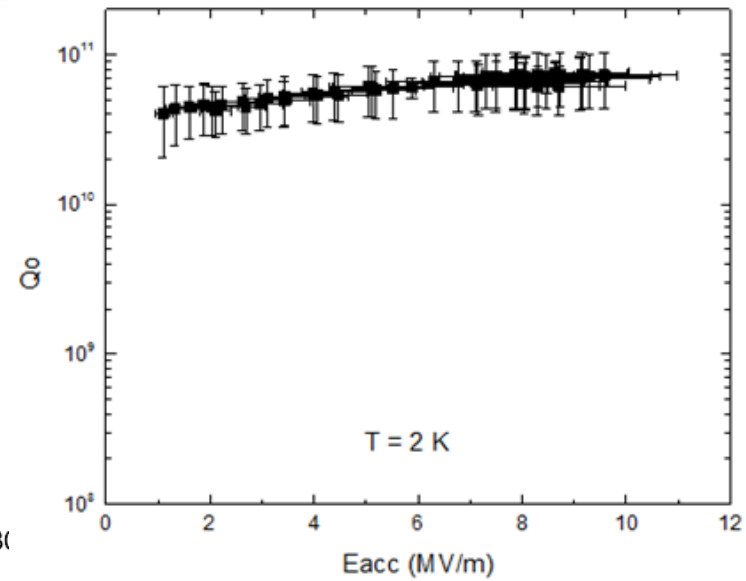


World class infrastructures at DOE Labs with complementary capability and capacity. (Examples shown are from Fermilab.)

Highlights—SRF Technology

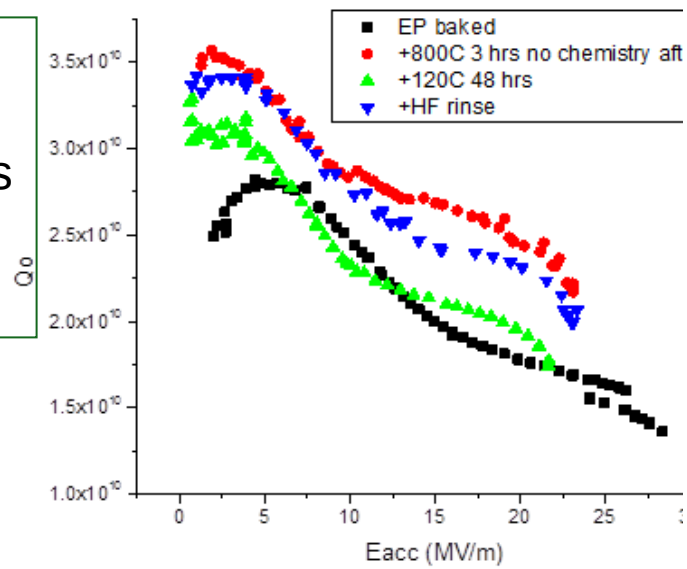
New ideas increase Q value to 7 x10^{10}

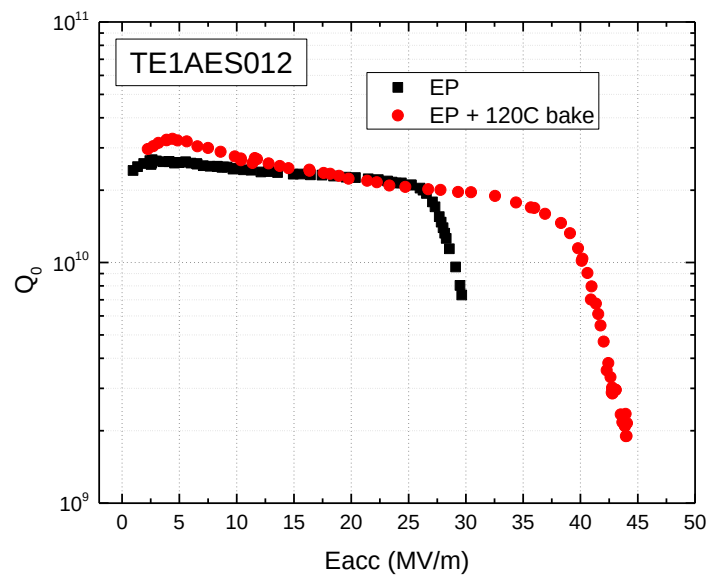




Simplification of cavity process:

– Annealing permits removal of other processing steps



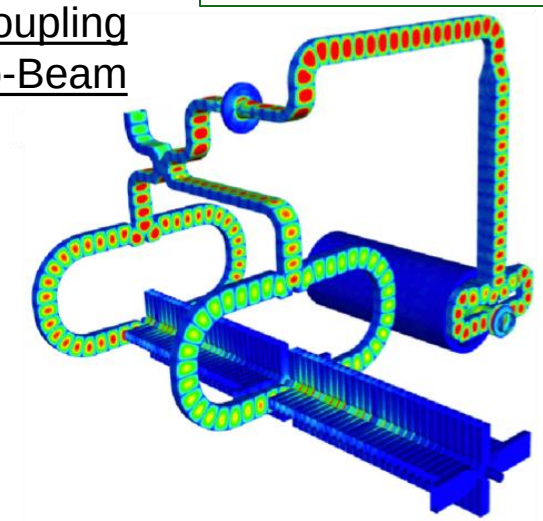


Highlights—Accelerator/Beam Physics

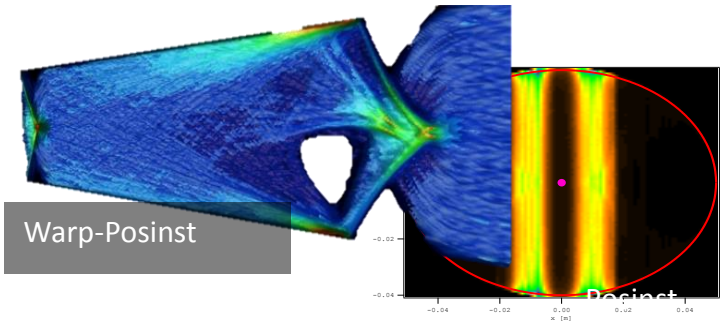
Powerful simulation codes running on supercomputers

Wakefield coupling in CLIC Two-Beam Structure

ACE3P

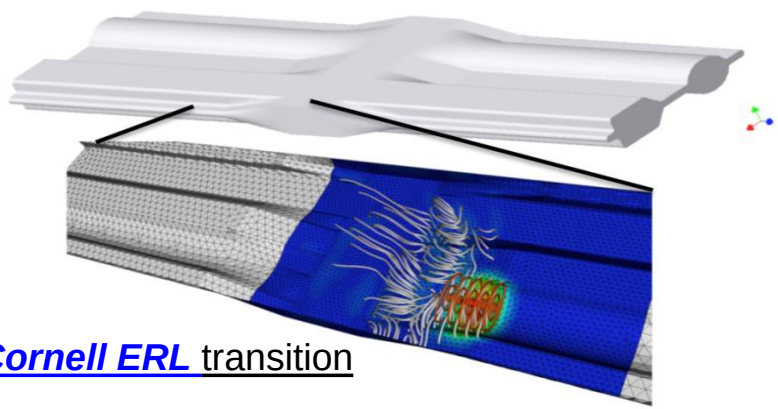


Electron cloud effects



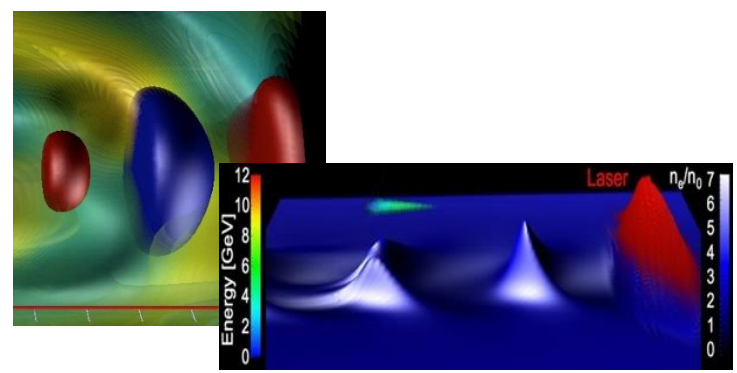
SPS

Moving window technique for short-range wakefield calculation



Cornell ERL transition

Laser plasma acceleration

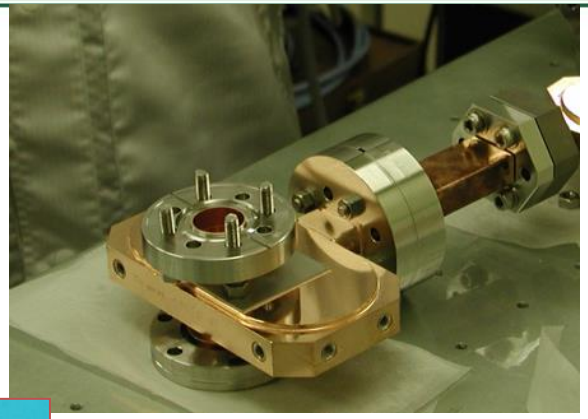


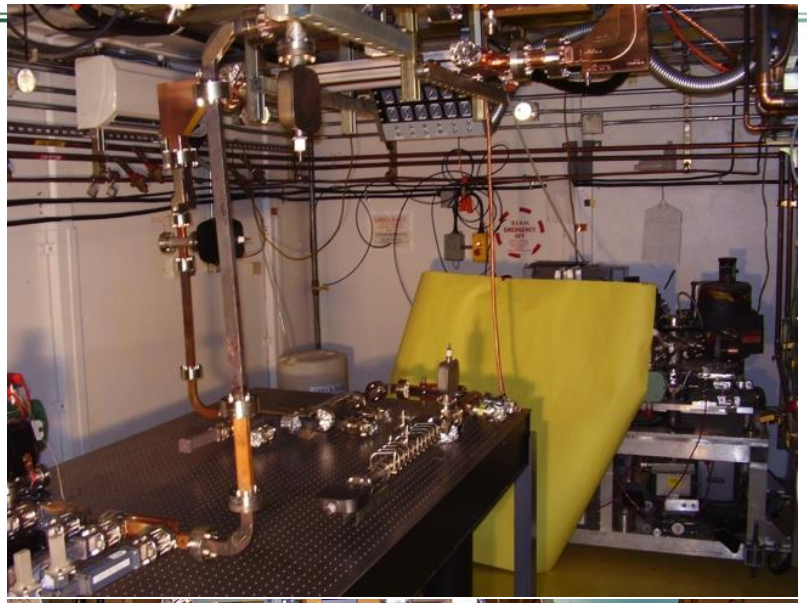
BELLA

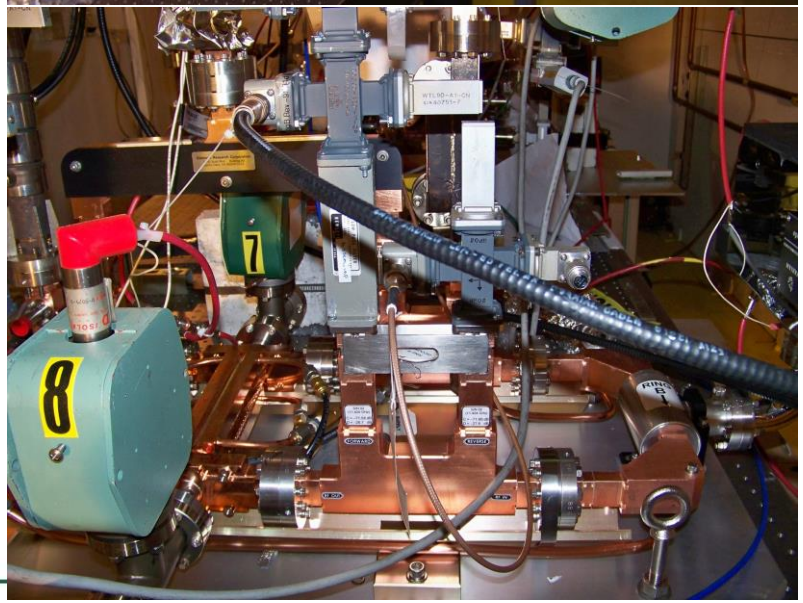
Warp

Highlights—NC RF High Gradient Structures

Comprehensive High Power RF Test Facility







Recent Results—High Gradient Research

Some research accomplishments:

- **Increased attainable gradients in accelerator structures by factor of ~3, from 65 MV/m to above 170 MV/m**
- **Surface preparation was not the key to achieving high gradients (srf-type cleaning affected only processing time, not gradient)**
- **Resonant ring testing produced the same result as driving with a klystron (Impedance match did not affect breakdown rates)**
- **Discovered the roles of surface magnetic fields on breakdown rates (already making an impact in design of high power rf structures)**
- **Better understanding of frequency scaling**
- **New understanding of material properties has led to new use of alloys for high gradient structures**

Program Status and Evolution

HEPAP Accelerator R&D Subpanel:

- **Formed to review the HEP Accelerator R&D Program in the context of the scientific priorities established by P5**
  - **Preliminary report November 2014**
  - **Final report March 2015**
- **Members**

Barletta, Bill
Ben-Zvi, Ilan
Breidenbach, Martin (Co-chair)
Bruning, Oliver
Carlsten, Bruce
Dixon, Roger
Gourlay, Steve
Hartill, Don (Co-chair)
Hoffstaetter, Georg
Huang, Zhirong (BES observer)
Koseki, Tadashi
Krafft, Geoff (NP observer)
Lankford, Andy
Merminga, Lia
Rosenzweig, Jamie
Syphers, Mike
Tschirhart, Bob
Yoshida, Rik
Young-Kee Kim

Program Status and Evolution

- Subpanel will consider
  - National goals
  - Current effort
  - Impediments to reaching goals
  - Training needs
  - Program balance
- Stewardship <u>not</u> included in subpanel charge
  - But, they can comment on potential synergies or conflicts

Program status and evolution

Accelerator R&D Stewardship:

- Some research efforts with broad applications within the current HEP long term R&D portfolio are being redirected into the new Accelerator Stewardship Program *[Colby, next talk]*

Accelerator Test Facilities:

- Three laboratory proposals were received and reviewed
  - Accelerator Test Facility II @ BNL
  - Advanced Superconducting Test Accelerator @ FNAL
  - Facility for Advanced Accelerator Experimental Tests II (FACET-II) @ SLAC

Summary

- Accelerator R&D is supported by multiple Programs within the Office of Science
- HEP supports the majority of accelerator R&D in SC, especially in the long term accelerator science
- Accelerator R&D supports many world-leading research programs at national labs and universities
- The HEPAP Accelerator R&D Subpanel will provide input to HEP to align its accelerator R&D program portfolio with updated national program needs