LBNL Activities in Support of Intense Muon Beam R&D

Michael S. Zisman
Center for Beam Physics
Accelerator & Fusion Research Division
Lawrence Berkeley National Laboratory

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OUTLINE

- Background of LBNL involvement
- Areas of expertise
- Community participation (muon-related)
- Accomplishments
  - MuCool
  - MICE
  - related areas
- Summary

BACKGROUND OF LBNL INVOLVEMENT (1)

- LBNL staff involved in "MC" → "NFMCC" since its formation in late 90s
  - participated in first MC feasibility study
    - and four NF feasibility studies (leadership role in 3)
- LBNL one of three NFMCC "sponsoring Labs"
  - provided NFMCC Spokesperson in 1999-2002
    - associate spokesperson otherwise
  - provide NFMCC Project Manager 2000-present
  - provide typically three members of Executive Board and two members of Technical Board

BACKGROUND OF LBNL INVOLVEMENT (2)

- LBNL traditionally a leader in developing new initiatives of importance to HEP
  - 300 BeV synchrotron → FNAL
  - PEP
  - SSC (Ref. Design; CDG)...not a happy ending
  - PEP-II (developed concept; built and commissioned); highest lumi U.S. collider to date
- Muon accelerators a logical next step in evolution of HEP accelerator capabilities
  - physics potential is immense (Geer's talk)

AREAS OF EXPERTISE (1)

- LBNL brings much to the table regarding development of new HEP facilities
  - beam dynamics
    - lattice design and nonlinear optimization
    - impedance-driven instabilities and collective effects (beam-beam; e-cloud; space charge)
    - cooling theory

AREAS OF EXPERTISE (2)

- technical areas
  - RF cavity design and LLRF controls
  - beam instrumentation
  - magnet design (conventional, permanent, and superconducting)
  - vacuum systems

EXAMPLES OF EXPERTISE (1)

- Beam dynamics
  - lattice design
    - PEP-II LER, ALS, ILC Damping Ring
    - developed design tools, FMA (Robin/Steier)
  - impedance driven instabilities
    - Vlasov code (Venturini)
  - collective effects
    - TRS (b-b; Tennyson/Furman), POSINST (Furman), WARP-POSINST (Vay/Furman)
  - cooling theory
    - ECALC9 added to ICOOL (Penn)
  - have access to AMAC group staff and tools

EXAMPLES OF EXPERTISE (2)

- Technical areas
  - RF cavity design (805 and 201 MHz)
    - both MuCool cavities provided by LBNL
  - beam instrumentation
    - transverse and longitudinal feedback systems; LHC luminosity monitor
  - magnet design
    - SC solenoids for MuCool, MICE
    - world's highest-field accelerator dipole (Nb_3Sn)
  - vacuum systems
    - ALS, PEP-II LER, ILC-DR wiggler chamber, CESR-TA

COMMUNITY PARTICIPATION (1)

- Organized NuFact00 (Wurtele/Chattopadhyay)
- Co-organized various NuFact accelerator design working groups (Zisman, Li)
- Project Manager for NFMCC R&D (MZ)
  - also member of MCCC
- MuCool RF Physicist (Li)
- Led or co-led technical designs for
  - NF FS-2, NF FS-2a (APS study), ISS AWG (MZ)
- Member, IDS-NF Steering Group (MZ)

COMMUNITY PARTICIPATION (2)

- MICE activities
  - Deputy Spokesperson (MZ)
  - level 2 manager for cooling channel (MZ)
    - served as operations manager (MOM) twice
  - level 3 manager for RFCC module (Li)
  - Deputy Technical Coordinator (Virostek)

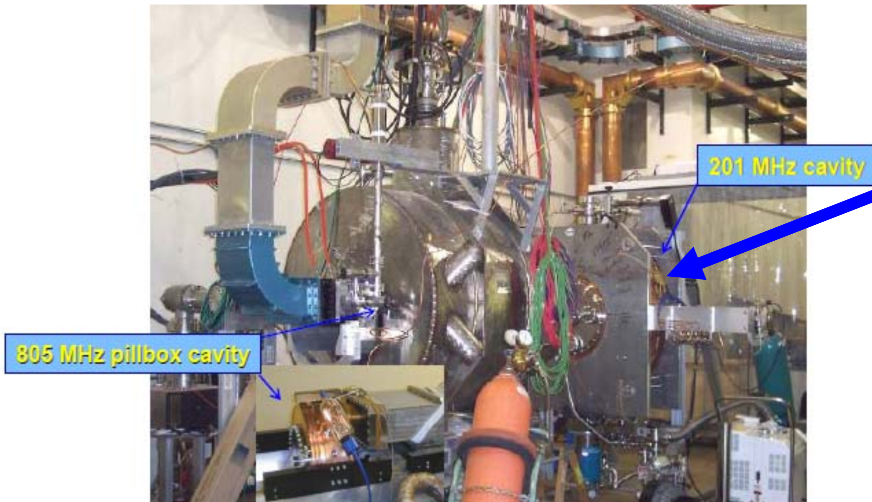
LBNL is involved in major muon-related R&D activities worldwide

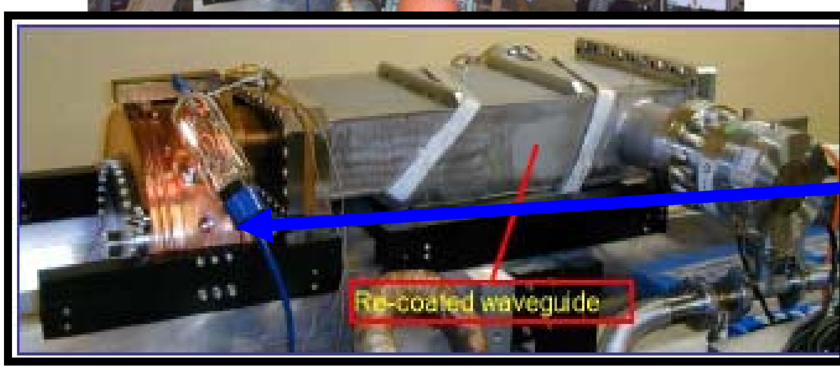
ACCOMPLISHMENTS-MuCool (1)

- Delivered 5 T two-coil solenoid (Green)
  - operates in both solenoid and gradient modes
    - workhorse for testing 805 MHz RF cavity in B field
- Delivered 805 MHz pillbox cavity (Li, Rimmer)
  - operated at 40 MV/m without field
- Delivered 201 MHz cavity (Li, Virostek)
  - MICE prototype; operated at 19 MV/m without field (limited by power source)
- Developed and delivered Be windows for both cavities (Li, Virostek)

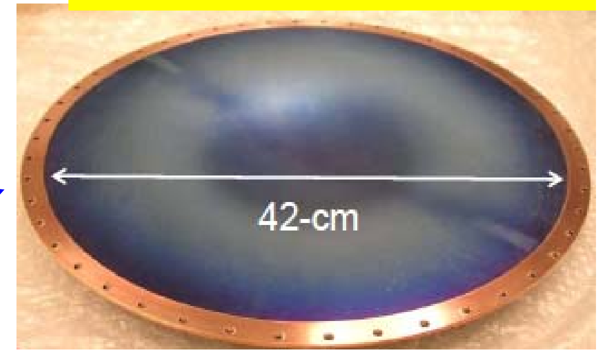
ACCOMPLISHMENTS-MuCool (2)

- LBNL-provided hardware at Fermilab MTA

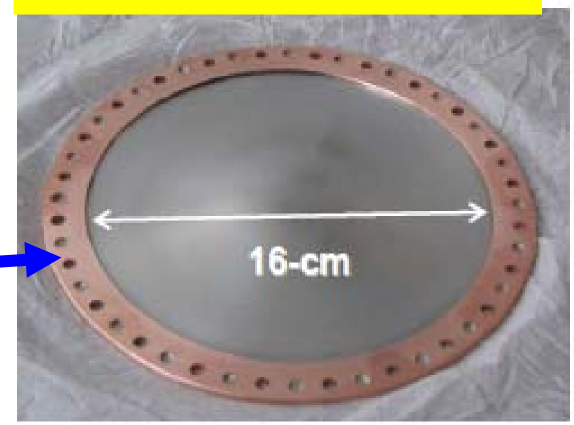




201 MHz Be window

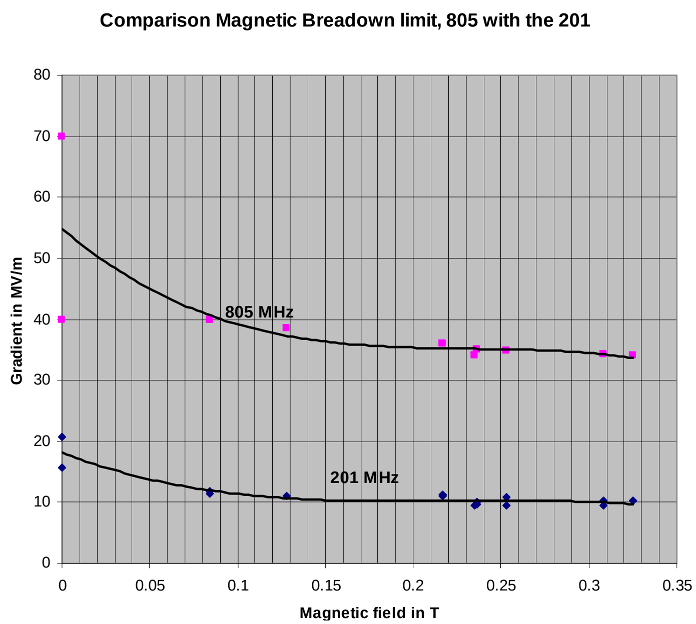


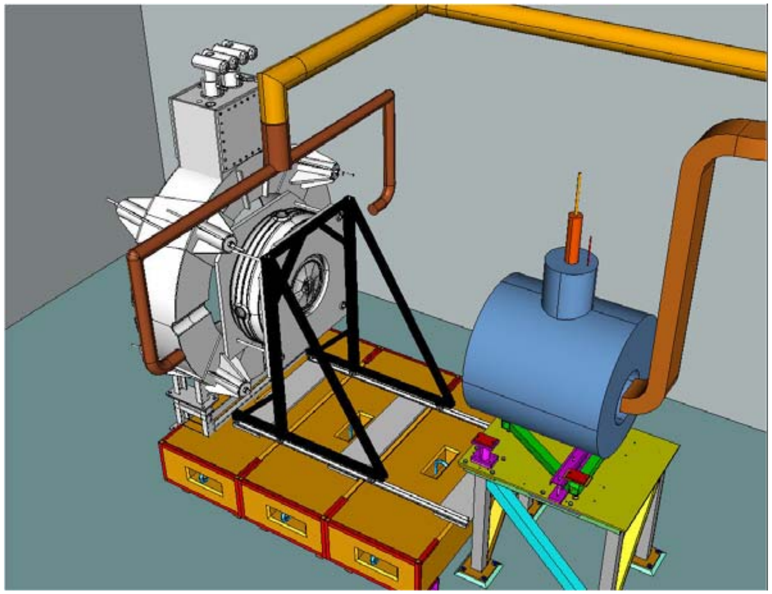
805 MHz Be window



ACCOMPLISHMENTS-MuCool (3)

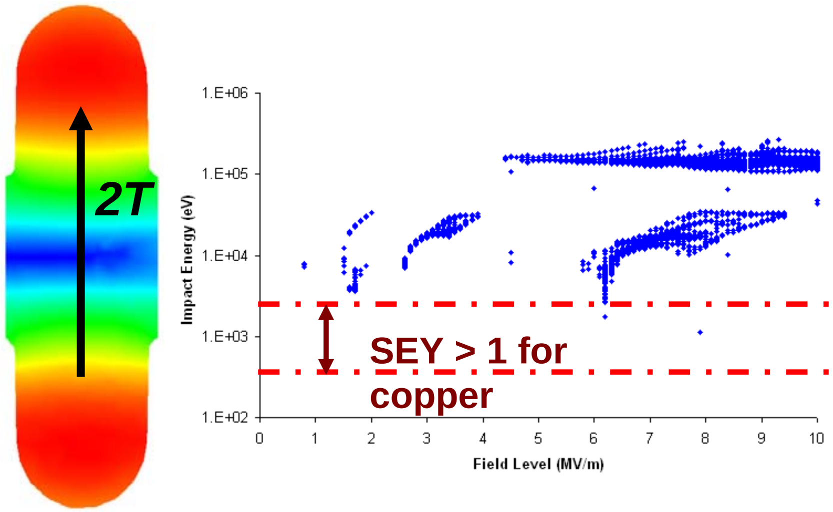
- Big issue is degradation of gradient in presence of strong B field
  - need to study with coupling coil
    - plan for providing and installing coil in MTA in place

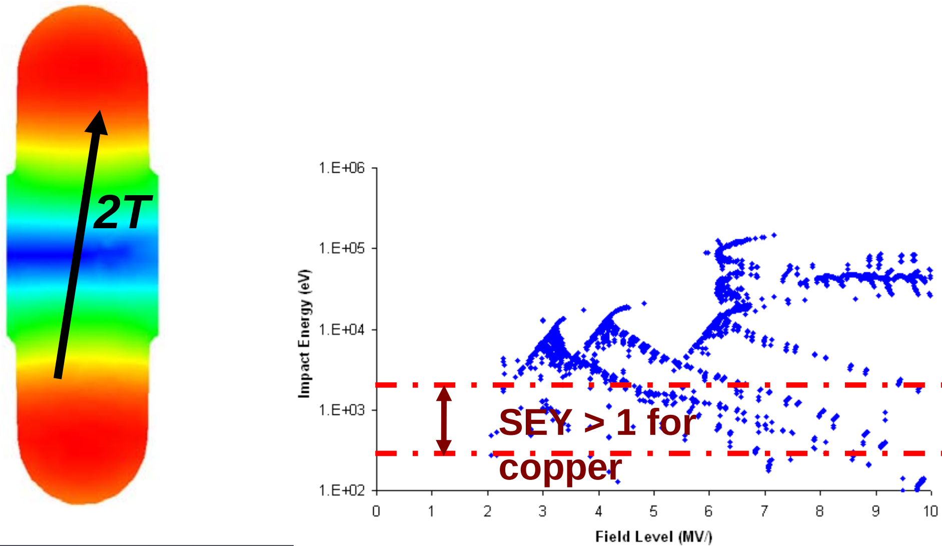




ACCOMPLISHMENTS-MuCool (4)

- Working with SLAC (Ko *et al.*) to assess multipactor effects in RF cavities
  - look at "magnetic insulation" effect of field parallel to windows with MP3
    - even 10° offset leads to multipactor





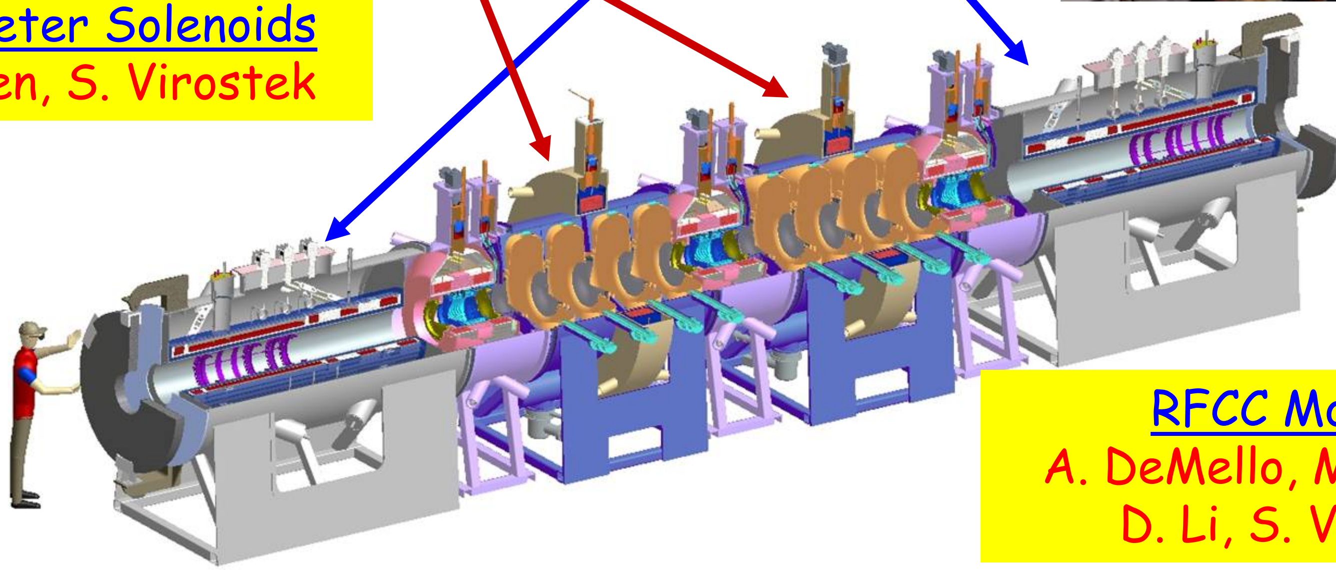
ACCOMPLISHMENTS-MICE (1)

- Muon Ionization Cooling Experiment (MICE)
  - international; ~130 scientists and engineers
    - hosted at RAL; uses secondary pion beam from ISIS
      - parasitic operation that cannot interfere with ISIS mission
  - goals (expect to complete in 2011)
    - design, engineer, and build a section of cooling channel capable of giving the desired performance for a NF
    - place this apparatus in a muon beam and measure its performance in a variety of modes of operation and beam conditions
    - show that design tools (simulation codes) agree with experiment

ACCOMPLISHMENTS-MICE (2)

- LBNL responsible for fabrication and delivery of
  - 2 spectrometer solenoids
  - 2 RFCC modules

Spectrometer Solenoids
M. A. Green, S. Virostek



RFCC Modules
A. DeMello, M. A. Green
D. Li, S. Virostek

ACCOMPLISHMENTS-MICE (3)

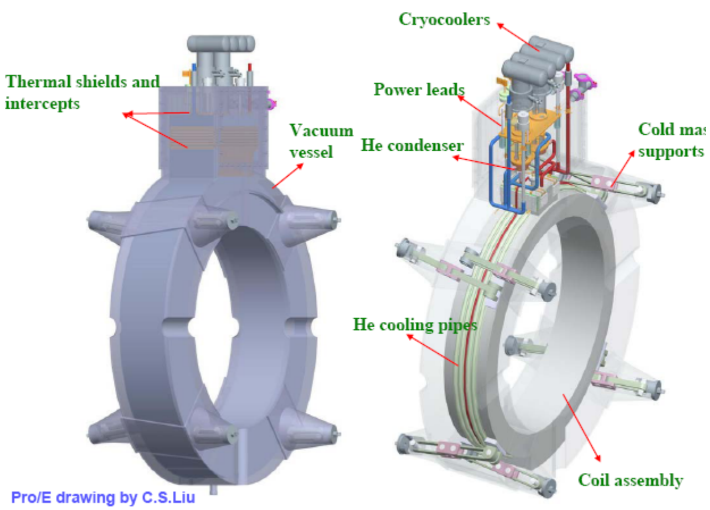
- Spectrometer solenoids are well along in the fabrication process at vendor
  - will measure first one at FNAL early next year

Magnet 1 assembled but needs modification

Magnet 2 ready for assembly

ACCOMPLISHMENTS-MICE (4)

- RFCC module extensively reviewed by MICE
  - coupling coil work (in collaboration with ICST Harbin) is already under way
    - test coils wound; progress to be reviewed Dec. 6-8



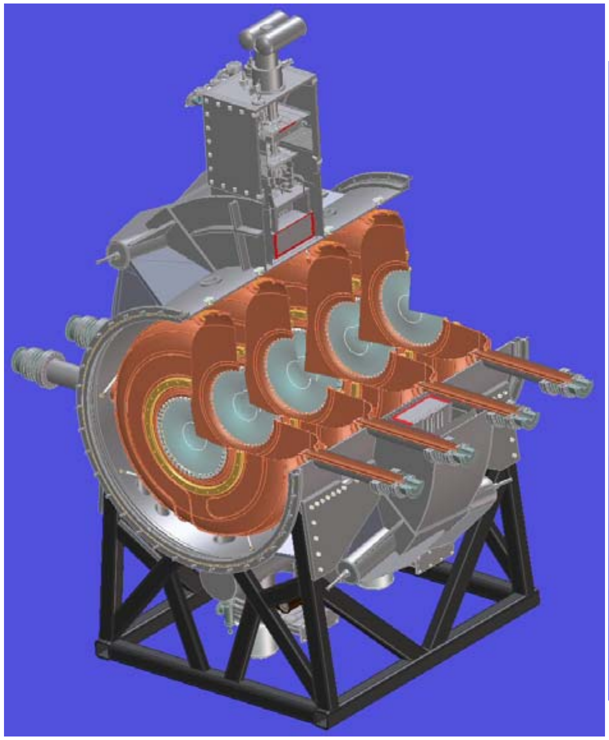
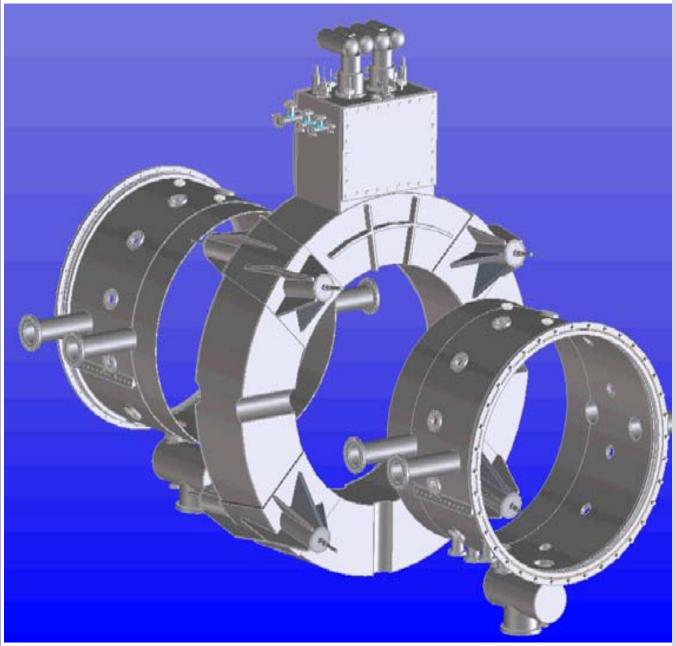
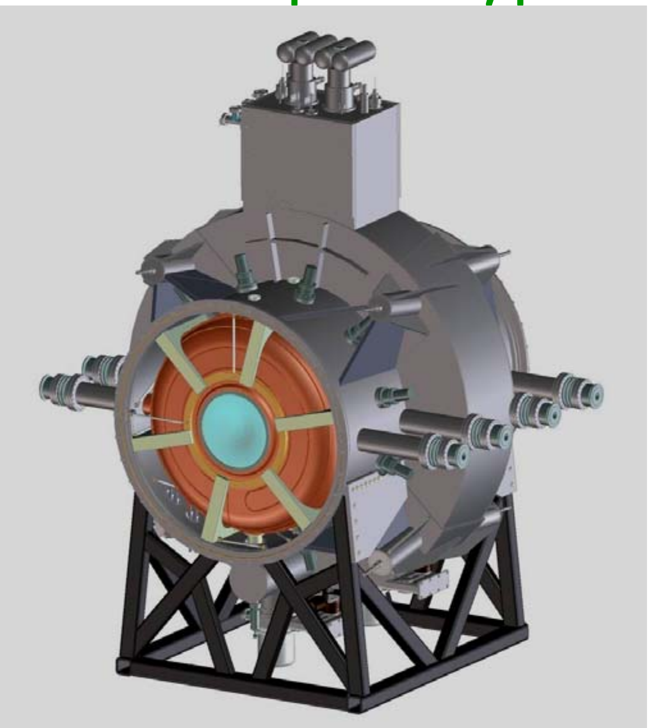
Pro/E drawing by C.S.Liu

Basic Magnet Parameters

	Small coil	Large Coil	Coupling Coil
Coil Length (mm)	285	72	285
Coil Inner Radius (mm)	175	750	750
Coil Thickness (mm)	25.5	102.5	102.5
Number of Layers	20	96	96
No. Turns per Layer	166	42	166
Magnet J (A mm-2)*	95.9	114.6	114.6
Magnet Current (A)*	210	210	210
Magnet Self Inductance (H)	3.143	50.813	592.680
Peak Induction in Coil (T)	2.334	3.925	7.427
Magnet Stored Energy (KJ)	69.30	1120.43	13068.59
4.2 K Temp. Margin (K)	3.448	2.690	0.792
Length of conductors per coil (km)	3.916	20.299	80.228

ACCOMPLISHMENTS-MICE (5)

- RF cavity design approved for fabrication
  - writing vendor spec in preparation for bid
    - fabrication techniques based on successful prototype

MUON-RELATED ACCOMPLISHMENTS (1)

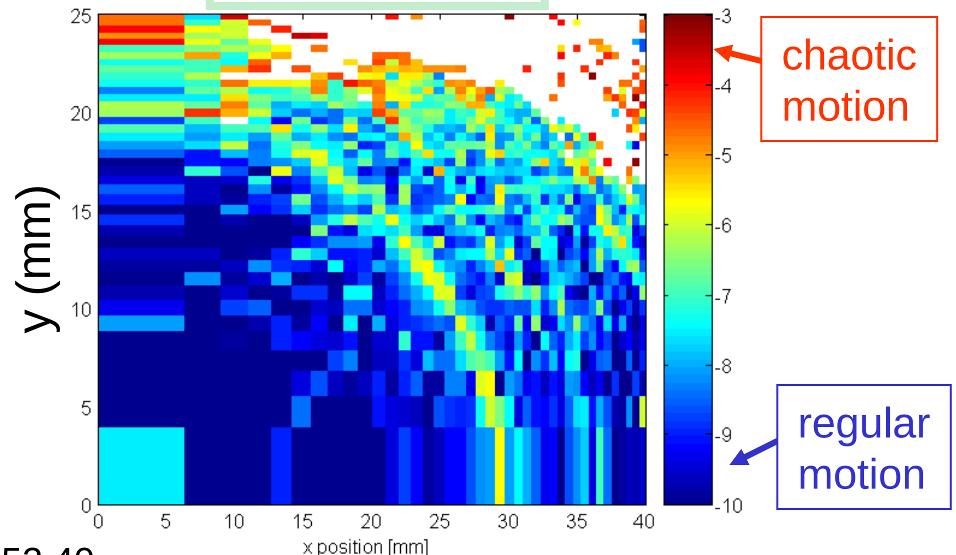
- Participated in initial b-b assessments (Furman, 1996-99)
  - did simulations based on 9th order Taylor maps
    - COSY map from W. Wan; lattice from C. Johnstone
  - modest beam blowup for 1000 turns, $N=2\times10^{12}$
    - increased blowup for higher N
  - hourglass effect an issue for $\sigma_z \geq \beta^*$
  - IP offset must be $\leq 0.7\sigma_z$
  - provided Sec. 8.6 of MC feasibility
    - and several LBNL reports

MUON-RELATED ACCOMPLISHMENTS (2)

- LBNL has experience applying modern tools to lattice design
  - studied ILC DR with FMA (Reichel)

Presence of harmful resonances led to retuning lattice

e+ at injection



ν_x=52.40
ν_y=49.31

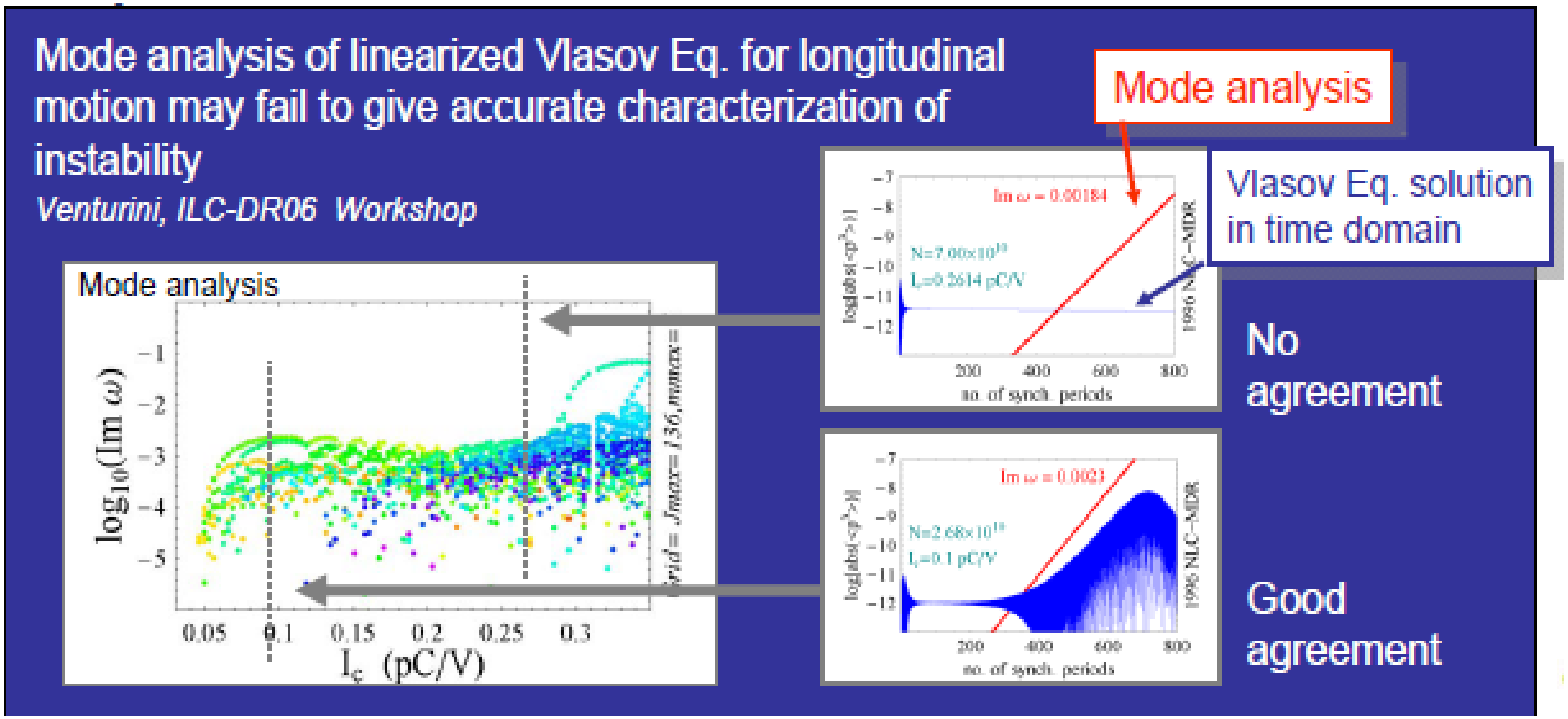
MUON-RELATED ACCOMPLISHMENTS (2)

- Developed LLRF board for SNS (Doolittle, Ratti)
  - applied to synchronization in several light source projects (SSRF, Fermi FEL, LCLS)
    - test results encouraging
      - 2.5 bits rms wideband noise and clock jitter < 0.5 ps rms

- In collaboration with SNS
- 4 14-bit 80 MS/s digitizers
- 2 14-bit DACs
- Xilinx Spartan-3 FPGA
- USB interface

MUON-RELATED ACCOMPLISHMENTS (4)

- Single-bunch instabilities
  - use time-domain Vlasov solver (Venturini)



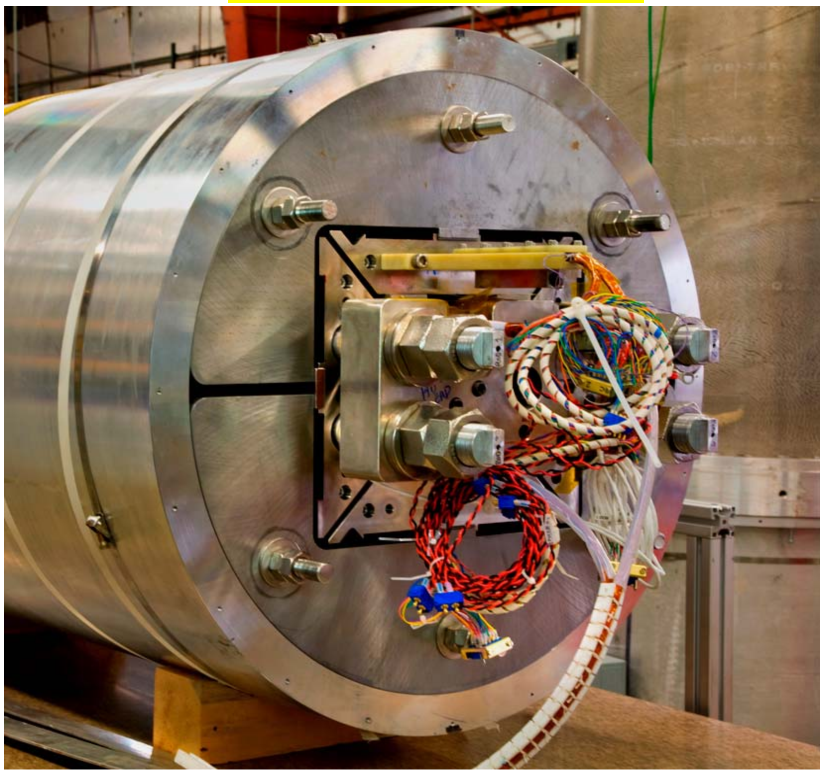
MUON-RELATED ACCOMPLISHMENTS (5)

- Magnet development
  - LBNL's Superconducting Magnet Group is world leader in advanced accelerator magnets (magnets and materials)
    - Nb_3Sn conductor development program management
    - record-breaking dipoles up to 16 T
    - HTS W&R technology for fields beyond 18 T
  - group attracts and trains talented students and postdocs
  - works effectively in collaborations, e.g., LARP
- Magnets are a cost driver for MC or NF

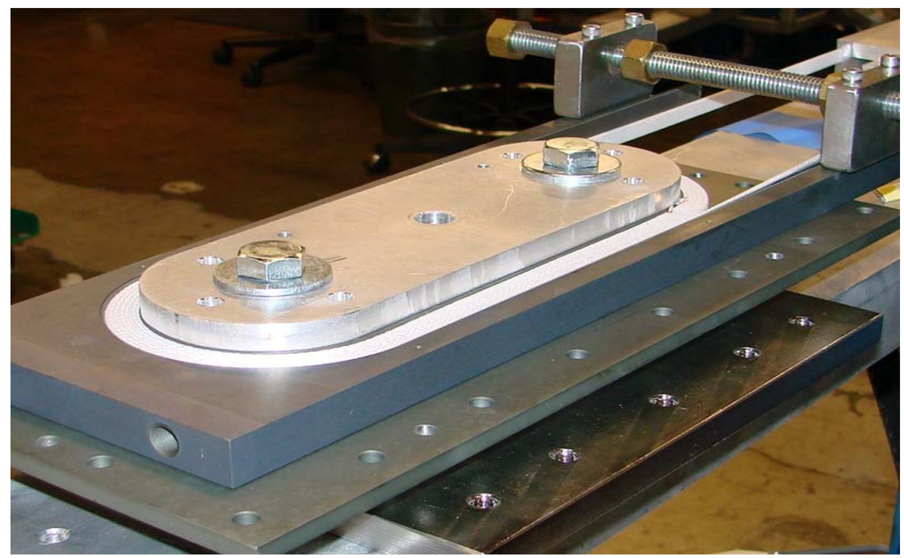
MUON-RELATED ACCOMPLISHMENTS (6)

- Magnet development (cont'd)

HD2 magnet

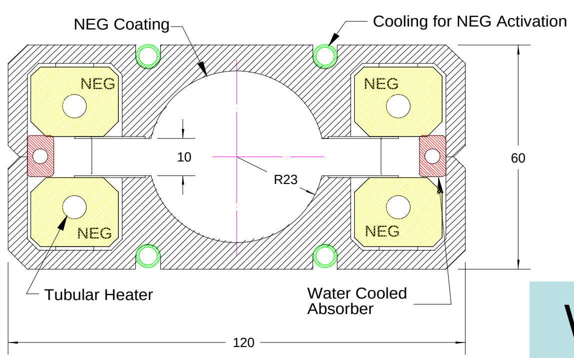


Bi-2212 HTS coil winding

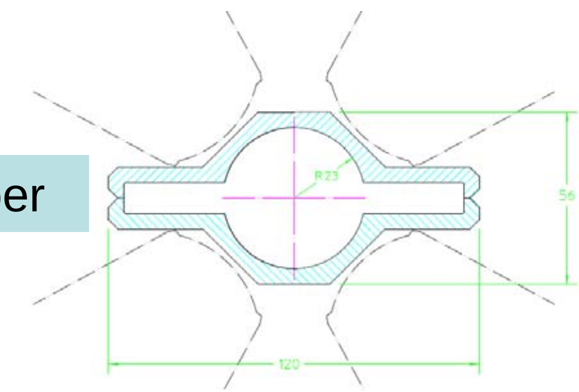


MUON-RELATED ACCOMPLISHMENTS (7)

- Vacuum systems
  - developed novel systems for ALS and PEP-II LER (Marks, Plate)
    - optimize pumping, minimize impedance and e-cloud effects
    - applying lessons to ILC-DR wiggler chamber design
      - and CESR-TA test chambers also



Wiggler chamber



Wiggler quadrupole chamber

SUMMARY

- LBNL has long history of developing frontier HEP accelerator facilities
  - we would like to continue playing such a role for a muon-based facility (Corlett talk)
    - important opportunity for HEP to explore fully
  - 2013 time frame expected to be significant for worldwide HEP planning
- Muon accelerators are very challenging but have large scientific payoff
  - we have skills to address critical technical areas