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# *Report of Project Manager*

**Michael S. Zisman**

*CENTER FOR BEAM PHYSICS*

*Muon Collaboration Project Manager*

MUTAC Review-BNL

April 28-29, 2004

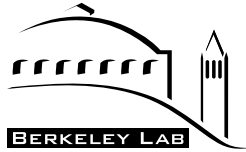


# Outline

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- Introduction
- FY03 accounting
- FY03 R&D accomplishments
- FY04 budget
- FY04 plans
- Summary and outlook



# Introduction

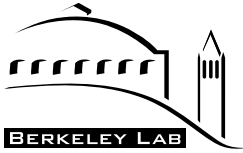


- In FY03, the **MC** budget was halved
  - \$2.809M—\$1.429M

Year	DOE-base (\$M)	DOE- <b>MC</b> (\$M)	TOTAL (\$M)
FY00	3.3	4.7	8.0
FY01	3.0	3.2	6.2
FY02	3.0	2.8	5.8
FY03	2.2	1.4	3.6
<b>FY04</b>	<b>2.2</b>	<b>1.4</b>	<b>3.6</b>
<b>FY05<sup>a)</sup></b>	<b>2.2</b>	<b>1.4</b>	<b>3.6</b>

<sup>a)</sup> Present DOE guidance.

- We had anticipated restoration to FY02 level in FY04
  - no such luck!
- By juggling projects across fiscal year boundaries and careful prioritization, we have continued to make progress
  - this was recognized by MUTAC and MCOG last year



# Introduction



- Hardware development continues as major focus of FY04 activity
- Simulation effort aimed at ring coolers made good progress last year
  - appears more relevant for Muon Collider than Neutrino Factory
  - FFAG work also making good progress
- Effort toward **MICE** proposal is coming to fruition
  - now **have scientific approval** from RAL
    - but still **no real funding**
- Here I will cover:
  - **FY03 accounting and R&D accomplishments**
  - **FY04 budget and plans**





## FY03 Accounting



- FY03 budget finalized by Spokespersons and PM in November
- FY03 budget was tight (\$1.429M → \$1.403M)
- Supplemental funding request submitted in May, 2002
  - and subsequently ignored
- Simulations and Theory group reconstituted by Spokespersons in FY03
  - led by R. Raja, with lieutenants for various subgroups
  - now led by R. Fernow
- Another “initiative” requiring resources: International Muon Ionization Cooling Experiment
  - investment in our future, but non-trivial to accommodate
  - presently requires mostly “effort” (base program funds)
    - this is changing as engineering is becoming necessary



# FY03 Accounting



- FY03 **MC** budget (approved by MCOG):

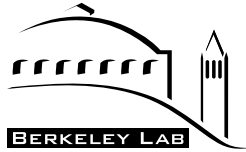
Institution	COOLING	TARGETRY	COLLIDER	EFFORT <sup>a</sup>	RESERVE <sup>b</sup>	TOTAL (\$K)
BNL		300				300
FNAL	400					400
LBNL	204				26 <sup>c</sup>	320
ANL				144		144
IIT				75		75
Mississippi				50		50
Princeton		50				50
UCB			5			5
UCLA	25		50			75
UCR			90			90
ORNL						0
JLab				10		10
<b>TOTAL (\$K)</b>	<b>629</b>	<b>350</b>	<b>145</b>	<b>279</b>	<b>26</b>	<b>1429</b>

<sup>a</sup>Includes beam simulation and diagnostics effort.

<sup>b</sup>Modest project reserve used to account for uncertainties in R&D activity costs.

<sup>c</sup>Eventually lost due to "recision" by DOE late in the year.

- Also: salary support from BNL, FNAL, LBNL; support from NSF (mainly Cornell) of ≈ \$1M; and support from ICAR (≈ 12 FTE)



## FY03 Accounting



- Supplemental request submitted to DOE in May, 2002 (priority order)
  - priorities decided in discussions at Shelter Island
    - no response from DOE

<u>Item</u>	<u>Request (\$K)</u>
0) AGS operation	50
1) 201 MHz RF cavity fabrication	350
2) Targetry magnet fabrication	400
3) Cooling simulation effort	200
4) 805 MHz RF cavity R&D	100
5) LH <sub>2</sub> absorber fabrication	100
6) Target studies	50
7) Solenoid coil design	150
8) Target simulations	50
<b>TOTAL</b>	<b>1450</b>



## FY03 Accounting



- Main goals for FY03
  - engineer target test magnet
  - continue development of MUCOOL Test Area (MTA) at FNAL
  - continue high-power tests of 805 MHz cavity
  - continue 201-MHz SCRF development (NSF supported)
  - continue with  $\text{LH}_2$  absorber development (includes ICAR support)
  - begin fabrication of 201-MHz NCRF cavity
  - submit technical proposal for MICE
  - continue exploring and optimizing cooling ring and FFAG performance
- Aspirations modest this year due to severe budget shortfall



# FY03 Accounting



- Before funds were distributed, each institution provided milestones agreed upon by PM
  - milestones (example below) reflect budget allocations for each institution, including base program funds

## FNAL [Geer]

### Milestone

Complete pillbox cavity tests with copper windows  
 Install Be windows in pillbox cavity and begin testing  
 Complete initial analysis of pillbox cavity results with copper windows  
 Report surface analysis of copper windows  
 Complete first tests of Be windows in pillbox cavity  
 Complete report on analysis of RF tests  
 Complete design of 805 MHz grid structure  
 Sign contract for MUCOOL Test Area Phase-II construction  
 Begin MTA site mobilization  
 Beneficial occupancy of MTA  
 Organize emittance exchange workshop  
 Implement ring cooler with realistic fields in GEANT  
 Match RF phase rotation channel to cooling channel

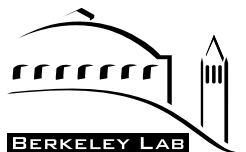
<u>Date</u>	<u>Deliverable</u>
Dec-02	Inspection
Dec-02	Inspection
Jan-03	Presentation
Apr-03	MC note prepared
Apr-03	Inspection
Apr-03	MC note prepared
Jun-03	MC note prepared
Dec-02	Signed contract
Jan-03	Inspection
Dec-03	Inspection
Nov-02	Workshop
May-03	Presentation
May-03	Presentation

## ANL [Norem]

### Milestone

Study conditioning and dark currents with Be RF windows  
 Continue optimization of dark currents and x-rays for MICE and MUCOOL  
 Organize workshop on surface effects and breakdown in RF cavities  
 Preliminary evaluation of RF breakdown mechanisms  
 Complete experimental setup to study RF breakdown effects  
 Perform (with IIT and NIU) experiment on e-beam generated turbulence in water with schlieren system

<u>Date</u>	<u>Deliverable</u>
May-03	MC report prepared
Sep-03	MC report prepared
Apr-03	Inspection
May-03	PAC03 paper prepared
Sep-03	Inspection
Jun-03	MC report prepared



# FY03 Accounting



- Summary of FY03 spending is shown below

Institution	Collaboration		Base Program	Overall	Contact
	Committed (\$K)	Uncommitted (\$K)	Committed (\$K)	Total (\$K)	
ANL	144	0	144	288	J. Norem
BNL	164	316	1054	1218	H. Kirk
FNAL [1]	1205	155	700	1905	S. Geer
LBNL [2]	248	376	282	531	M. Zisman
Princeton U.	50	0	195	245	K. McDonald
UC-Berkeley	30	16	23	53	J. Wurtele
UCLA	75	0	71	146	D. Cline
Mississippi	50	12	17	67	D. Summers
IIT	75	0	0	75	D. Kaplan
Jlab	10	0	0	10	A. Bogacz
Cornell + NSF Contracts [3]	1049	1886	0	1049	D. Hartill
<b>TOTALS [4]</b>	<b>2052</b>	<b>876</b>	<b>2487</b>	<b>4538</b>	
	<i>3100</i>	<i>2762</i>		<i>5587</i>	
<b>NOTES:</b>					
[1] Includes \$380K of GPP funds from FY01 and \$580K of GPP funds from FY02 committed in FY03.					
[2] Includes \$174K in uncommitted Project Reserve funds maintained by LBNL.					
[3] Includes carryover from previous years.					
[4] DOE totals in Roman type; <i>additional NSF funding shown in italics.</i>					



# FY03 Accounting



- Accounting summary made for each institution

Institution: Brookhaven National Laboratory

Task	Muon Collaboration Funds			Laboratory Funds		
	Effort (\$K)	M&S (\$K)	Sum (\$K)	Effort (\$K)	M&S (\$K)	Sum (\$K)
<u>Targetry Studies</u>						
AGS Operations						
Targets		\$ 52.0	\$ 52.0			
Magnetic Systems		\$ 70.0	\$ 70.0			
<u>Physics Salaries</u>						
Targetry				\$ 127.0		\$ 127.0
Cooling/Acceleration Simulations	\$ 42.0		\$ 42.0	\$ 827.0		\$ 827.0
Acceleration						\$ -
Storage Ring						\$ -
<u>Administration and Travel</u>					\$ 100.0	\$ 100.0
<b>SUBTOTALS</b>	<b>\$ 42.0</b>	<b>\$ 122.0</b>		<b>\$ 954.0</b>	<b>\$ 100.0</b>	
<b>TOTALS</b>			<b>\$ 164.0</b>			<b>\$ 1,054.0</b>

Uncommitted	Muon Collaboration Funds		
	Effort (\$K)	M&S (\$K)	Sum (\$K)
Carryover [1]		\$ 316.00	\$ 316.00
<b>SUBTOTALS</b>	<b>\$ -</b>	<b>\$ 316.00</b>	
<b>TOTALS</b>			<b>\$ 316.00</b>

NOTES:

[1] Includes \$180K carryover from FY02.



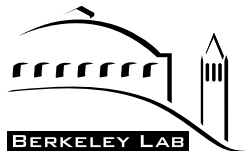
## FY03 Accounting

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- **Along with list of accomplishments**
  - Developed engineering design and cost estimate for 15-T targetry test solenoid
  - Developed continuous-flow Hg jet at 2 m/s
  - Measured properties of Super-Invar and inconel samples after irradiation
  - Continued design and simulation studies of conventional-magnet (dipole, quadrupole) cooling rings
  - Carried out simulation studies for solenoid-based ring cooler
  - Continued evaluation of alternative FFAG accelerators
  - Added time-of-flight capability into G4MICE package
  - Simulated baseline and alternative configurations for MICE





# FY03 Accounting



- Scorecard of milestones also prepared at the end of the year

## FNAL [Geer]

### Milestone

Complete pillbox cavity tests with copper windows  
 Install Be windows in pillbox cavity and begin testing  
 Complete initial analysis of pillbox cavity results with copper windows  
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 Complete first tests of Be windows in pillbox cavity  
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 Sign contract for MUCOOL Test Area Phase-II construction  
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 Beneficial occupancy of MTA  
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 Implement ring cooler with realistic fields in GEANT  
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<u>Date</u>	<u>Deliverable</u>	<u>Status</u>
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Jan-03	Presentation	Complete
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Jun-03	MC note prepared	In progress
Dec-02	Signed contract	Complete
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<u>Date</u>	<u>Deliverable</u>	<u>Status</u>
May-03	MC report prepared	Complete
Sep-03	MC report prepared	In progress
Apr-03	Inspection	Complete
May-03	PAC03 paper prepared	Complete
Sep-03	Inspection	Late
Jun-03	MC report prepared	Complete

- Complete summary report given to MCOG and DOE each year
  - available in your handout



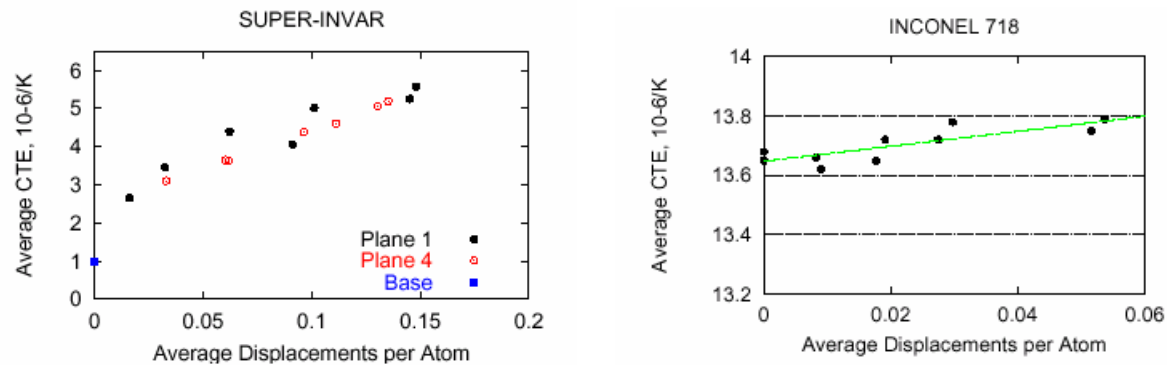
## FY03 R&D Accomplishments

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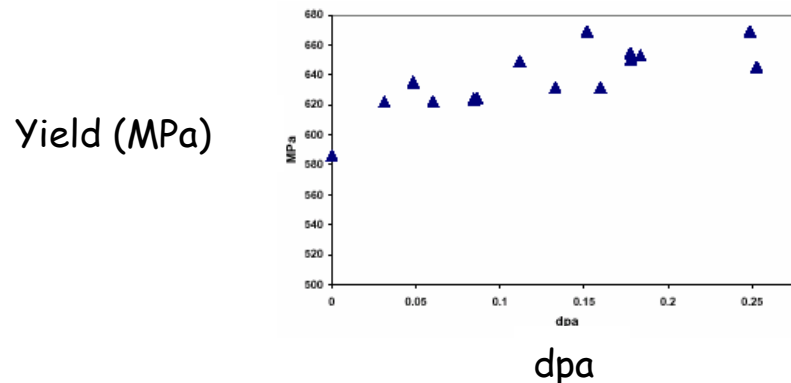


- R&D progress being made on all fronts:
  - Targetry (**McDonald, Samulyak, Kirk**)
  - Cooling (**Bross, Li, Torun, Errede, Cummings, Ishimoto, Johnson**)
  - Acceleration (**Berg**)
  - Simulations (**Fernow, Palmer**)
- Overview presented here; details to follow

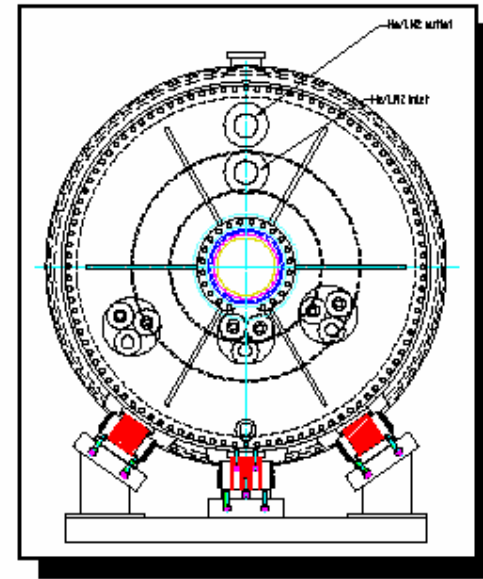
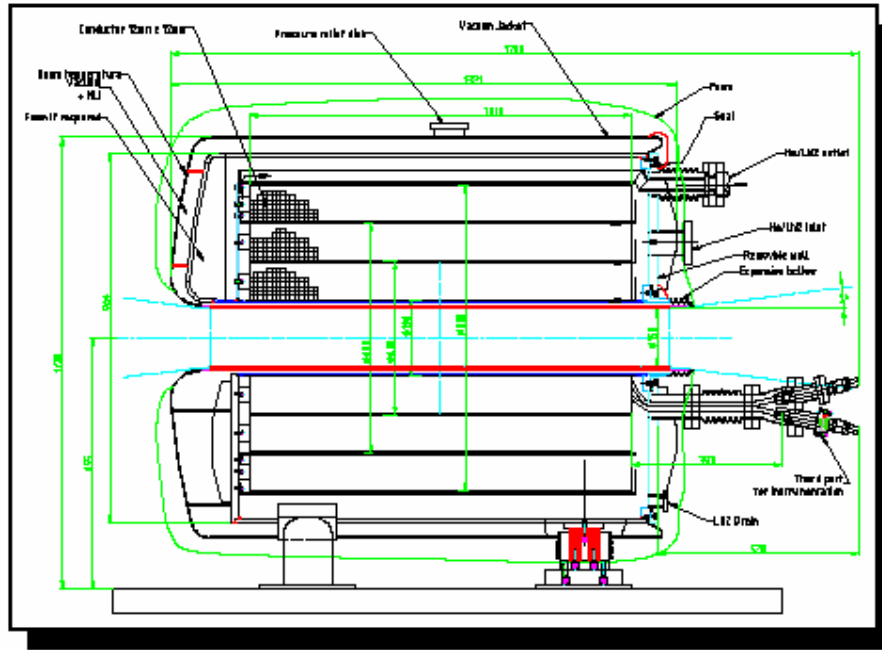
- Radiation testing of candidate solid-target materials (Super-Invar and Inconel) carried out at BNL with 200 MeV p beam
  - looked at both CTE and tensile strength changes
    - big changes in Super-Invar CTE with dose, less with Inconel



- yield strength increases but material gets more brittle



- Contract awarded for 5-15 T magnet fabrication (for E951 at BNL?)



Stage	Field (T)	Power (MW)	Coolant	Temperature (K)
1	5	0.6	N <sub>2</sub>	84
2	10	2.2	N <sub>2</sub>	74
3	15	2.2	H <sub>2</sub>	30
<b>3a</b>	<b>15</b>	<b>4.5</b>	<b>N<sub>2</sub></b>	<b>70</b>

- looking seriously into using battery power (suggested originally by **Summers**)



Battery and charger (12 V, 1400 A)

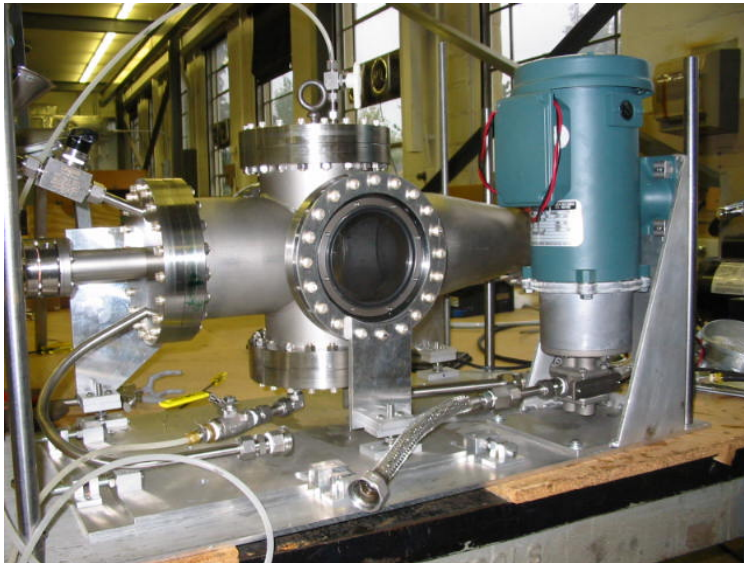


Mechanical switch for 4.4 MW

- if power supply fails, we call AAA!



- Developed a 2.5 m/s continuous Hg jet system for E951 at Princeton
  - never used with beam due to elimination of AGS HEP running
  - Wood's metal (heated) version was started but put on hold for now

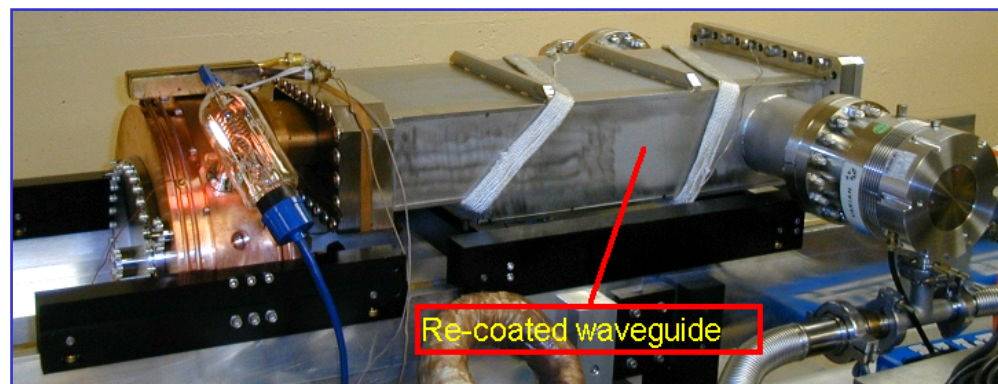
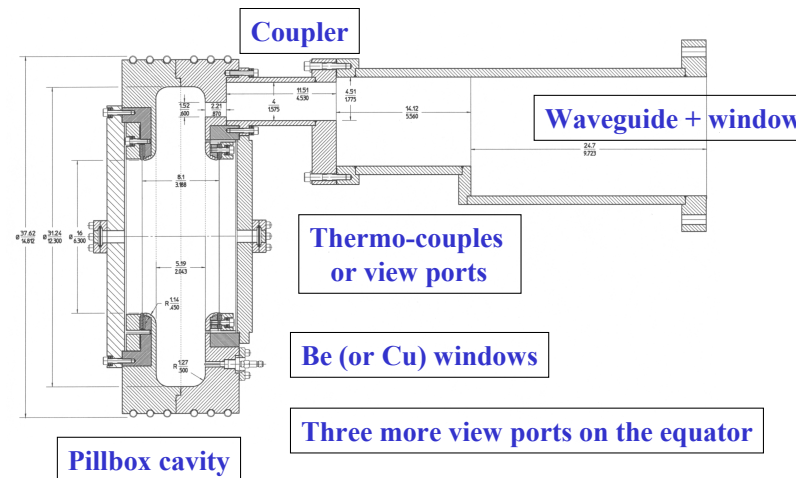


Test apparatus

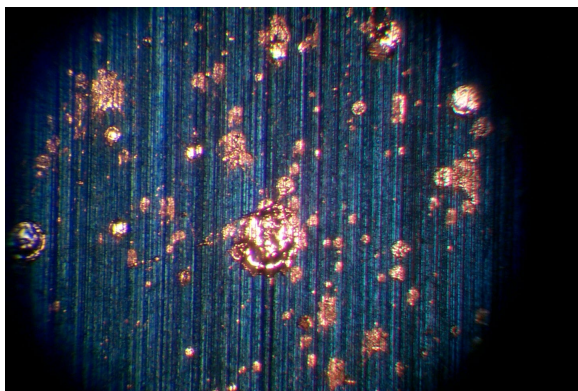


Mercury jet...on a good day

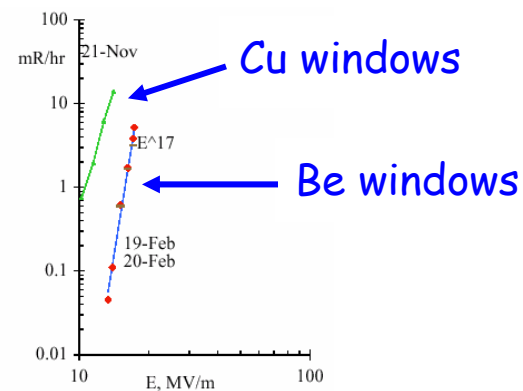
- Present tests use **pillbox cavity** with replaceable windows (or grids) (**Li**)
  - cavity fits in bore of Lab G solenoid



- Pillbox cavity reached **40 MV/m** in Lab G **with no solenoid field**
  - **with solenoid** performance worse (18 MV/m), **radiation levels higher**
- With TiN-coated Be windows no conditioning problems seen without magnetic field
  - ⇒ parallel plate geometry does not cause big problems
- Found **no damage to Be surface**, but sputtered Cu is present
  - suggests need to focus more on copper body than on windows
- Backgrounds lower with Be than Cu



Be windows with sputtered copper





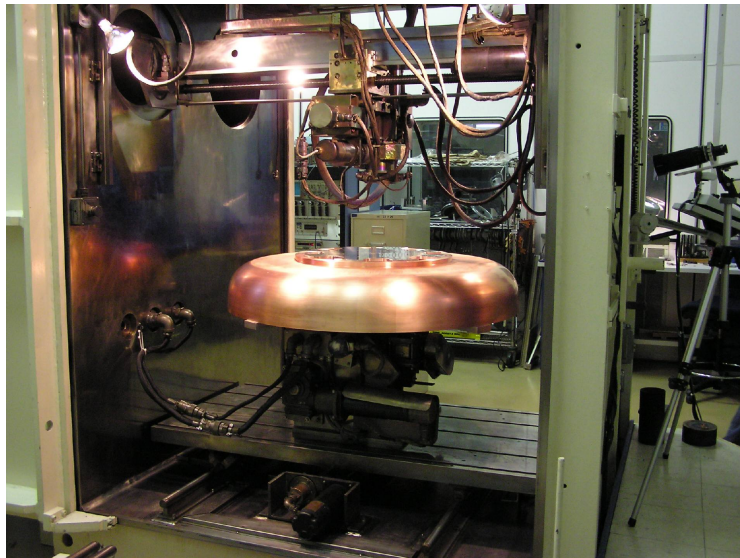


## FY03 R&D Accomplishments

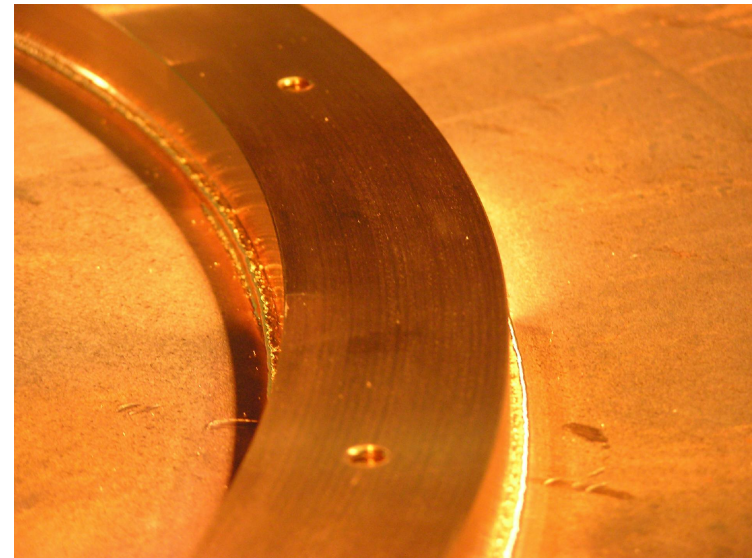


- Workshop on high-gradient rf limitations was held at ANL, October 7-9, 2003
  - URL: <http://www.mice.iit.edu/rfworkshop/>

- 201 MHz rf cavity under construction (Li, Virostek, Rimmer)
  - completion in about 1 year
    - Jlab and U-Miss collaborating on cavity fabrication

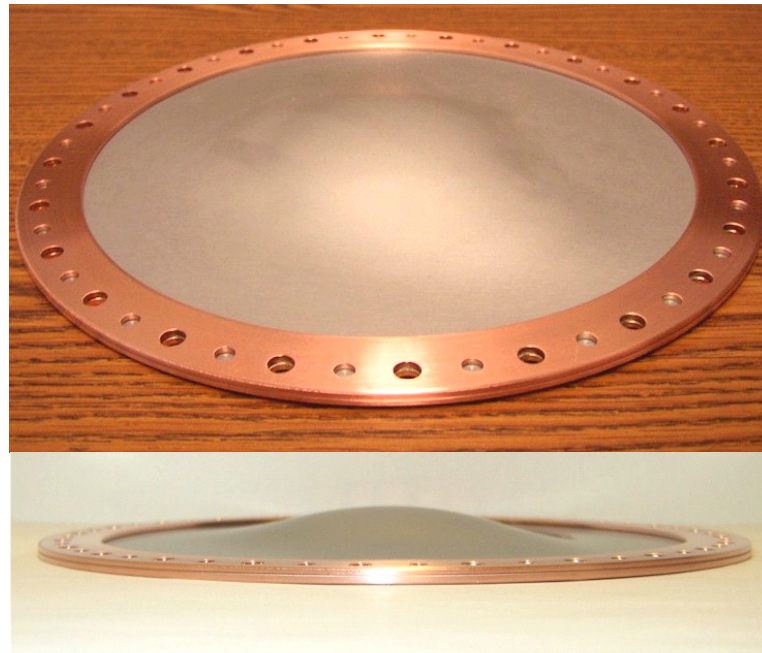


Setup for welding stiffener ring

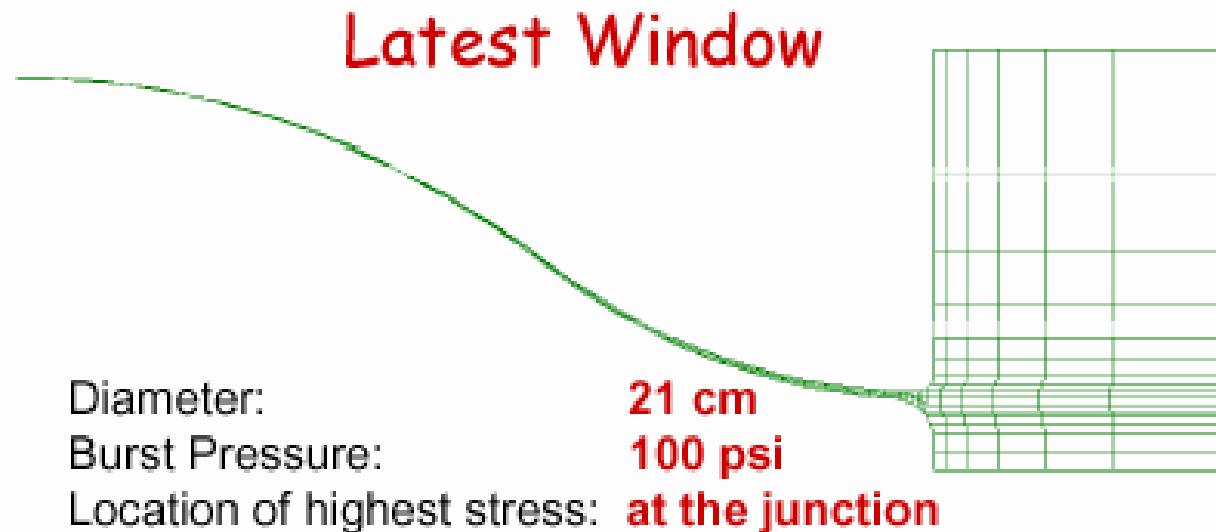


After e-beam weld to half-shell

- Ideal cavity termination would be perfectly conducting and transparent to muon beam, and would not affect cavity frequency
  - we now propose **pre-curved windows** that bow predictably
    - with proper design, stresses remain quite low as the foil heats
- **Ordered shaped Be foils from Brush-Wellman** to test at 805 MHz



- Absorber group has developed strong, thin windows (**Cummings, Kaplan**)
  - windows as thin as 125  $\mu\text{m}$  machined from solid Al (**Summers**)
  - new stronger ( $\Rightarrow$ thinner) design (**Lau**) to be built and tested next



- none built last year, but fabrication of first window done now
  - will destruction-test a series of windows to certify design

## FY03 R&D Accomplishments

- To test hardware, built **MUCOOL Test Area** at Fermilab (**Popovic**)
  - absorber, solenoid, and 201 MHz rf cavity will be integrated here

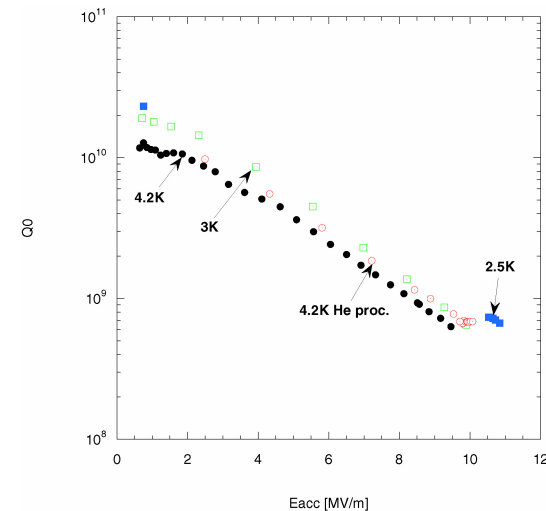


Completed MTA (as seen by Project Manager)



Completed MTA (as seen by Lab Director)

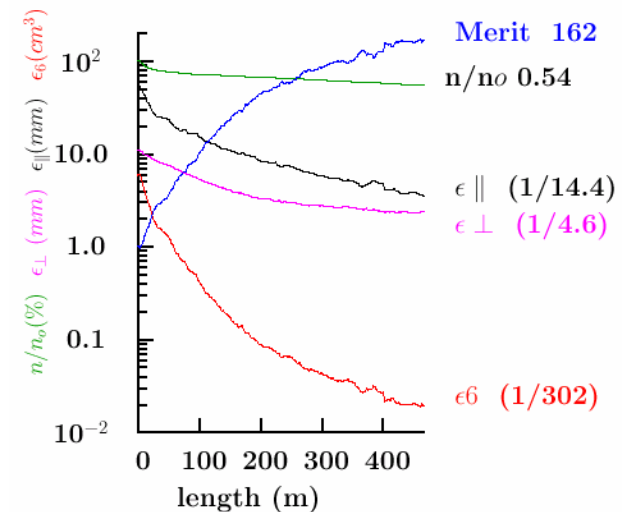
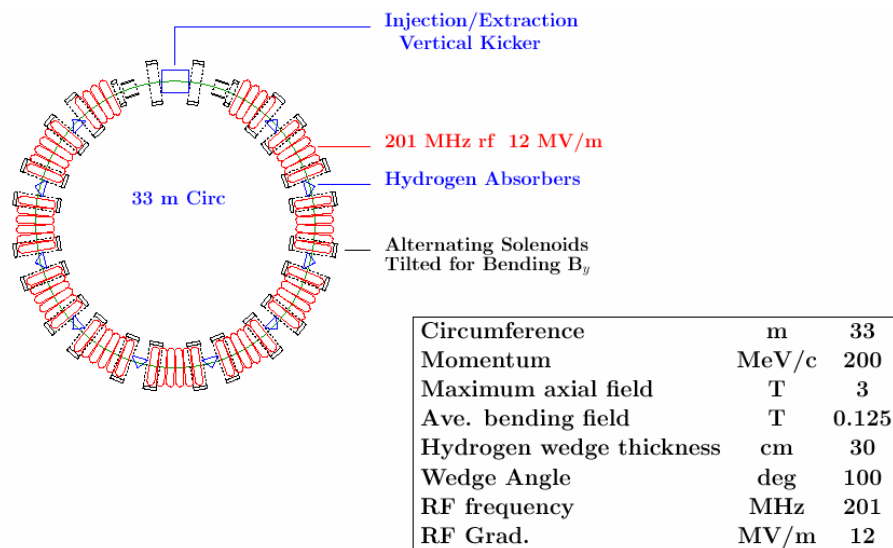
- Work on 201 MHz scrf cavity for the acceleration system made good progress (**Hartill, Padamsee; NSF**)
  - reached 11 MV/m after re-cleaning cavity
    - low-power  $Q_0 = 2 \times 10^{10}$  (at 2.5 K)
  - now trying to understand  $Q$  slope in terms of impurities and Nb coating properties
    - cavity being recoated at CERN





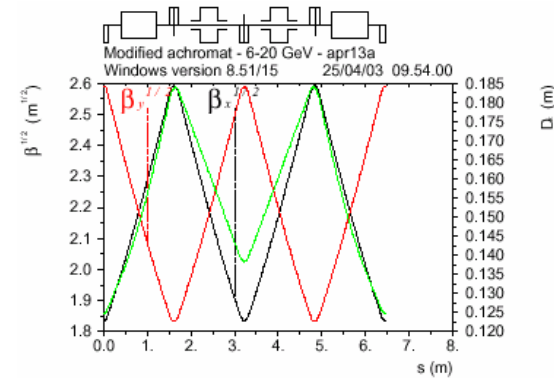
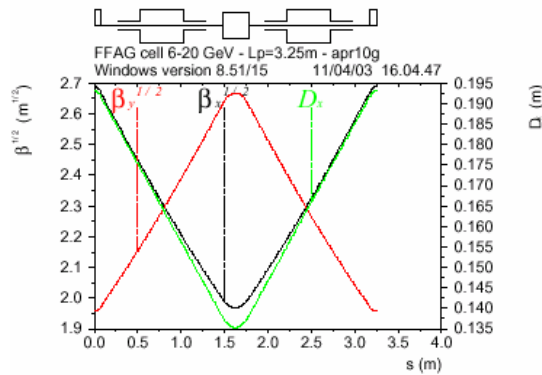
## • Simulations

- significant effort on emittance exchange
- ring coolers (**Balbekov, Palmer**) important due to potentially significant cost reduction (for Muon Collider)
  - 6D cooling looks promising; injection is an issue



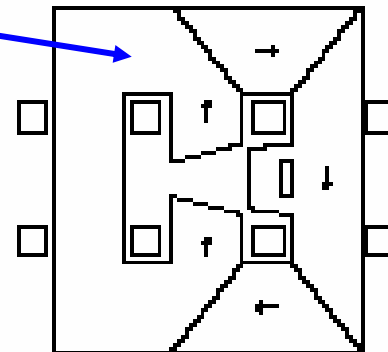
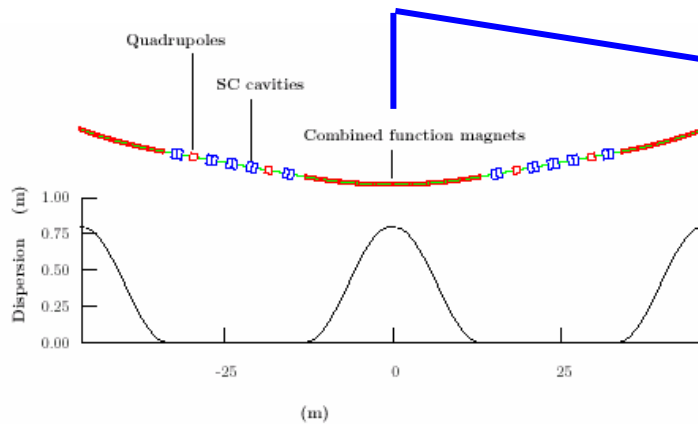
- dipole rings also being explored; some configurations look promising

- Looking at alternative acceleration schemes
  - RLA with FFAG arcs (**Berg, Johnstone, Keil, Sessler, Trbojevic**)



- very rapid cycling booster (**Summers**)

Grain-oriented Si steel



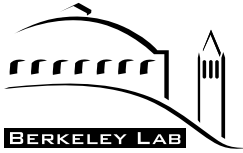




## FY03 R&D Accomplishments



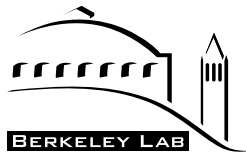
- discussion of building an electron model of FFAG has started
  - would need to identify funding and host institution
    - proposed for U.S.-Japan funds; TRIUMF as host?
  - hard to see how to pry this out of existing budgets



## FY04 Budget



- Prepared initial budget for FY04 based on present budget guidance
  - Tech Board met three times to discuss it
  - original guidance was (sadly) accurate
- Given so many uncertainties, we have chosen to maintain a reasonable reserve despite the low funding
  - money for this was available due to the failure to hire a simulations post-doc last year
- A small amount of funding will be transferred to BNL for offsetting travel expenses of consultants
  - this allows me to off-load some of the administrative work to Kathy Tuohy
- MCOG approved budget in February
- Budgetary goal is to maintain university programs while making some progress on key fabrication activities



# FY04 Budget



• **FY04 MC budget (only DOE-MC funds)<sup>†</sup>**

Institution	COOLING	TARGETRY	ACCEL./ COLLIDER	EFFORT <sup>a</sup>	RESERVE	TOTAL (\$K)
BNL		275	10			285
FNAL	400					400
LBNL	100				104	204
ANL				144		144
IIT				77		77
Mississippi	50					50
Princeton		50				50
UCB	5					5
UCLA	25		50			75
UC-Riverside						0
ORNL						0
Jlab	110					110
<b>TOTAL (\$K)</b>	<b>690</b>	<b>325</b>	<b>60</b>	<b>221</b>	<b>104</b>	<b>1400</b>

<sup>a</sup>Includes beam simulation and diagnostics effort.

**<sup>†</sup>Also: salary support from BNL, FNAL, LBNL; support from NSF (mainly Cornell) of \$1M; and support from ICAR (≈ 12 FTE)**



## FY04 Budget



- Supplemental request submitted to DOE in September, 2003 (priority order)
  - priorities decided in discussions between Spokespersons and PM
    - no response from DOE...again!

<u>Item</u>	<u>Request (\$K)</u>
1) 201 MHz RF testing	400
2) LH <sub>2</sub> absorber test capability	460
3) Targetry magnet fabrication	400
4) Coupling coil design and construction	300
<b>TOTAL</b>	<b>1560</b>



## FY04 Plans



- **Targetry**
  - complete fabrication of 15 T magnet and begin power supply
- **Cooling**
  - complete fabrication of 201 MHz high-gradient cavity (17 MV/m)
  - test convection-cooled LH<sub>2</sub> absorber with all safety aspects
- **Acceleration**
  - continue effort to increase 201 MHz SCRF cavity gradient
- **Simulations**
  - develop cost-optimized front-end for APS Study
  - continue design work on FFAG-based systems
- **MICE**
  - continue to seek funding

- Equatorial weld completed
  - a “cavity” at last!





## Summary and Outlook



- The past year was productive for the **MC**
  - fabrication of **Targetry test magnet** started
  - **NCRF cavity** tests made progress (at 805 MHz)
  - **201 MHz NCRF cavity** fabrication launched
  - approaches to study **cooling rings** and **FFAG rings** developed
  - improved **absorber window design** developed
  - **SCRF cavity** testing reached 11 MV/m
- **MICE** gaining momentum
  - scientific approval from RAL; U.S. **funding proposal** under review
- Strong **MUTAC** and **MCOG** endorsements of R&D accomplishments and plans will hopefully help our budget eventually
  - *the **MC** is certainly continuing to hold up its end of the bargain!*