

BNL Overview and Future Directions

**Presented to
DOE HEP Annual Program Review**

**by
Thomas B.W. Kirk
Associate Laboratory Director
HENP**

**Upton, NY
April 22, 2004**

Presentation Structure of the Review

| | | | |
|---|--|--|---|
| <p>Overview</p> <p>T. Kirk Future Vision, QCDOC, VLBv, CAP, Safety, Budgets, etc.</p> | <p>Physics Dept.</p> <p>S. Aronson Research Programs, Budgets etc.</p> | <p>ATLAS Constr. & Research</p> <p>H. Gordon</p> | <p>LHC Accel. Proj. & Adv. Accel. R&D</p> <p>M. Harrison LHC Project, Accel. R&D, ATF, etc.</p> |
| <p>Instr. Div.</p> <p>V. Radeka</p> | <p>Experiment</p> <p>D0 Exp. – A. Patwa LSST – S. Aronson E949 Exp. – S. Kettell U.S. ATLAS Constr. – D. Lissauer U.S. ATLAS Computing – S. Rajagopalan MECO - W. Molzon KOPIO - D. Bryman VLBv Exp - W. Marciano</p> | <p>Accelerator</p> <p>ATF – I. Ben-Zvi μ Collider – R. Palmer SC Magnet R&D – M. Harrison AGS Upgrades and v Super Beam - T. Roser</p> | <p>Theory</p> <p>Overview – S. Dawson Lattice QCD – M. Creutz LHC Phys. – F. Paige Muon (g-2) - W. Morse</p> |

Plan of the Overview Talk

- Introductory Comments
- Capabilities and Facilities for HEP
- Future Vision
- QCDOC Supercomputer
- Neutrino Physics - VLB Neutrinos in a Super Beam
- Center for Accelerator Physics
- **Safety**
- HEP Priorities
- Budgets and Waste Management

BNL Achievements in HENP



2002 Nobelist
Raymond Davis Jr.

- BNL has established a long time record of important scientific advances in particle and nuclear physics, including *5 Nobels*
- Laboratory accelerators have served a worldwide user community since 1953 when the Cosmotron first began running
- Current C-AD user facilities, RHIC, AGS, NSRL, ATF, Tandems and BLIP have more than *1400 users from 23 countries*; RHIC dominates this with ~ 1000 ; about half are U.S. nationals
- Muon ($g-2$) will shortly publish an important new result for both positive and negative muons; physics beyond the SM is hinted at by the best theory calculations
- In recent years, the AGS has yielded important results in rare kaon physics; E949 just released a key new CP-violation result
- BNL research groups rank among the best in the world in HEP & NP theory & experiment as well as in accelerator, magnet and instrumentation sciences



PRL, 28 January 2002

Brookhaven National Laboratory High Energy Physics Program

Mission Statement:

“Perform frontier research in theoretical and experimental high energy physics; build, maintain and operate state of the art user facilities for high energy physics; perform research and development work in accelerator science, experimental detector design and computing for HEP; carry out construction projects in the HEP area as assigned.”

In support of this mission, the Laboratory operates accelerator facilities (**AGS*** and ATF) for HEP users and carries out an in-house program of research in theoretical and experimental high energy physics plus accelerator science and BNL collaborates in the D0 experiment at FNAL. BNL is the Host Laboratory for the US ATLAS Detector Project & Research Program and operates the ATLAS Tier-1 Computing Center. The work of the HEP Program is supported through the expertise of BNL’s Instrumentation Division, a Lab-wide instrumentation development organization reporting to the ALD-HENP.

Direction of the HEP Program:

The Associate Laboratory Director of High Energy and Nuclear Physics directs this program. The work of the HEP program is carried out in the Physics and Collider-Accelerator Departments and in the Superconducting Magnet and Instrumentation Divisions.

*** The AGS was “terminated” by DOE in their FY 2003 and subsequent BNL Budgets.**

Elements of the BNL HEP Program

The following elements comprise the HEP Program*:

- **Performance of a world class, in-house program of basic research in theoretical and experimental particle physics**
 - experimental groups engaged in forefront efforts at AGS, ATLAS, D0 and MINOS
 - theory group with broad capability and productive links to nuclear physics
 - close collaboration with RIKEN BNL Research Center on mutual topics
- **Operation, upgrade and R&D involving forefront user facilities**
 - **AGS** (highest intensity proton synchrotron in the world) - **not-funded in FY03-05**
 - US ATLAS Construction and Computing Projects (BNL is the Host Laboratory)
 - US LHC Accelerator Project (incl. R&D in LHC machine and accelerator phys.)
 - Tier-1 computing center for support of the US ATLAS research program
 - **U.S. ATLAS Research Program Host Laboratory** and **Physics Analysis Center**
- **Performance of a leading R&D role in the development of advanced accelerator and particle detector concepts plus provision of computing support for HEP**
 - ATF (a unique user facility for novel accelerator physics experiments)
 - R&D on advanced accelerator concepts (muon collider/storage ring, **FFAG** & **LC**)
 - development of novel particle detectors (with Instrumentation Division)

*Many of these areas of expertise provide benefit to programs outside DOE-HEP

Current HEP Programs with BNL Involvement

The following HEP programs are currently active at BNL:

- **BNL in-house research in Experimental and Theoretical Physics**
 - 3 HEP analysis efforts using data from HEP experiments at **AGS** and **D0**
 - 1 HEP design/construction/computing effort for LHC **ATLAS** Detector
 - 3 design/prototyping R&D efforts for planned AGS Exps., **KOPIO** & **MECO*** + **LSST**
 - 1 design/construction/physics effort for the **MINOS** Experiment
 - HEP Theory is active on topics of current particle physics interest
 - productive physics interactions with the Riken BNL Research Center (**RBRC**)
 - this program is annually reviewed by DOE plus a BSA Visiting Committee
- **BNL participation in the CERN LHC Construction Project & Research Program**
 - Host Laboratory and Project Office for the **US ATLAS Detector Project**
 - ATLAS Detector subsystem lead role (LAr EM Calorimeter and Muon System)
 - Host Laboratory for US ATLAS Computing Project & Tier-1 Computing Center
 - contributions to LHC physics analysis and accelerator science efforts
 - Host Lab for **ATLAS Research Program** (Comp., Maint. & Ops. + Upgrade R&D)
 - **US LHC Accelerator Project** - SC dipole prod. at BNL + test all LHC SC cable
 - **LHC Accel. Research Program** - accel. phys. + superconducting magnet R&D
 - **ATLAS Physics Analysis Center** will serve the U.S. ATLAS research community

* KOPIO and MECO are the two experiments in the NSF RSVP MRE-FC Project at BNL

Current HEP Programs with BNL Involvement

- **BNL participation in the MINOS and D0 Programs at Fermilab**
 - major contributors, D0 off-line physics analysis (top/bottom, W/Z, SUSY/higgs)
 - on-line and off-line D0 computer program upgrades and maintenance
 - operation of the D0 Forward Preshower (FPS) Detector
 - Milind Diwan leads the BNL contributions to the MINOS Experiment
- **Accelerator and Detector R&D Program**
 - Accelerator Test Facility (BNL's unique user facility for accelerator science exps.)
 - muon collider/storage ring R&D studies (with FNAL, LBNL and university groups)
 - superconducting magnet R&D, for **LARP & LC** needs, is performed in the SMD
 - development and testing of novel particle detectors (with BNL Instr. Div.)
 - conceptual studies for the **Very Long Baseline Neutrino Experiment** and the related 1-2 MW Upgrade of the AGS accelerator to an intense, wide-band **Super Neutrino Beam** for a future DOE facility under the Office of Science plan
- **AGS Fixed Target Program has been "terminated" by DOE for FY 2003 - FY 2005**
 - this represents a serious loss of quality & diversity in the U.S. HEP Program
 - the E949 Collaboration has a proposal in to NSF for running in FY06

* KOPIO and MECO are new AGS experiments in the RSVP Project for NSF's MREFC program; NSF proposed project funding to Congress for an FY05 Construction Start; R&D work is ongoing.

Recent HEP Physics Highlights

- **Sally Dawson** began serving as Chair of the DPF in January 2004
- **Muon (g-2)** has a new result adding μ^- data to the earlier μ^+ ; a hint of non-SM Physics
- **E787/E949** saw a 3rd $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay; the central value remains 2 x SM prediction
- **US ATLAS Detector Proj.** on-budget, on-schedule and responsive; U.S. Host Lab is BNL
- **US ATLAS Computing Proj.** successfully underway but remains under-funded in FY03,04
- **LHC Accel. Proj.** at BNL on-budget on-schedule, LHC dipole production & cable testing
- **RSVP - NSF MRE-FC Project** in R&D phase; construction project expects FY05 start
- **DOE OHEP** plans to fund an 8 Tflops (peak) QCDOC Supercomputer at BNL
- a **Super Neutrino Beam** was included in the Office of Science “Facilities for the future of Science – a Twenty-Year Outlook”; this is an enabling facility for the Very Long Baseline Neutrino Experiment that expects to determine all the oscillation parameters in one exp.
- BNL has joined the **LSST** collaboration, an exciting experimental cosmology project to determine the nature of dark energy in the universe using a ground-based telescope system
- DOE conducted a ‘Lehman’ Review in January 2004 of the **RSVP Impact** on operations of the RHIC accelerator complex; a net positive impact was reported

BNL Vision in High Energy Physics

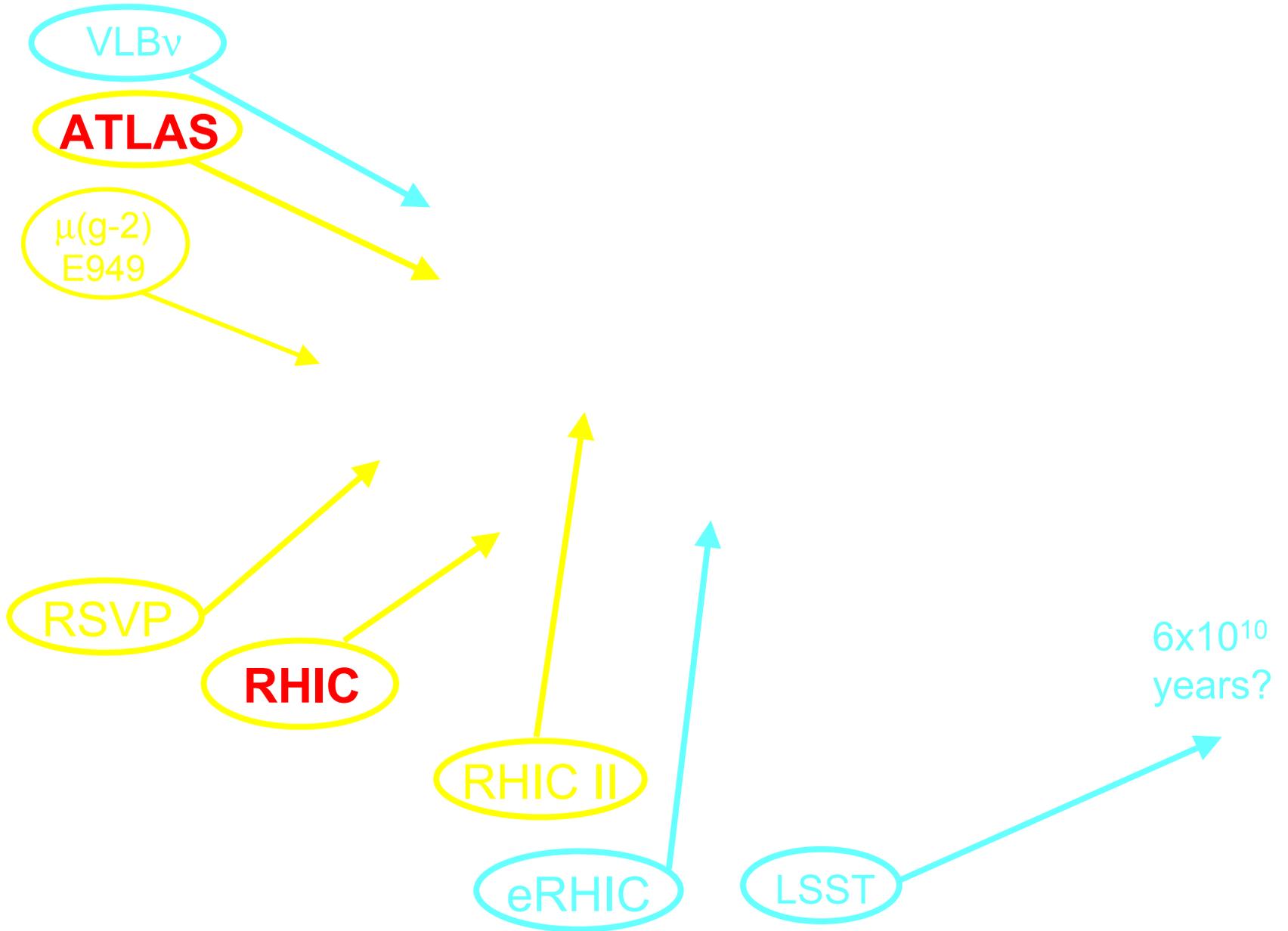
Office of Science Goal 4: “Explore Fundamental Interactions of Energy, Matter, Time and Space”

- **Our Science Vision is driven by study of the fundamental aspects of nature**
 - Standard Model (**SM**) **CP-violation** parameters, ρ and η are measured in rare kaon decays
 - comparison of CP-violation in the kaon and B-meson systems test the **SM quark sector**
 - **CP-violation in the neutrino sector** may be more fundamental and drive the quark sector
 - **soft QCD** processes in particle physics will be calculable by **lattice gauge theory**
- **ATLAS, RSVP, VLB ν and QCDOC provide unique tools for realizing our vision**
 - **LHC ATLAS** will explore the central questions of particle physics starting in this decade
 - **KOPIO** and **MECO** will provide world-leading advances in fundamental particle physics
 - **E949** at AGS complements KOPIO to completely determine ρ and η in the SM
 - a **Super Neutrino Beam** for the **VLB ν Experiment** measures all ν oscillation parameters
 - **lattice gauge theory** computations will be strongly advanced by **QCDOC** supercomputers
- **Collaborative Research Groups at BNL and User Institutions empower science**
 - worldwide users with BNL have built a *strong experimental community* to perform research
 - BNL has backed the AGS and LHC experiments with a *strong particle theory effort*
 - *lattice gauge theory research* efforts on HEP topics are progressing at BNL and RBRC
 - BNL is building collaborations in *accelerator R&D* with LHC, MIT Bates and AEI

BNL Activities to Reach our Goals

- **BNL engages in diverse planning activities**
 - we believe *BNL aligns well* with DOE's 2004 "**Office of Science – Strategic Plan**"
 - BNL physicists participate in **HEP Planning** activities and workshops (Snowmass etc.)
 - BNL presented facility concepts at the HEPAP Future Facilities Workshop at Philadelphia
 - a continuing 2004 series of *neutrino oscillations workshops* is co-sponsored by BNL
 - *workshops on many LHC physics topics* have been held at BNL over the years
 - advice and counsel on long range planning for HEP has been provided by the **BNL PAC**
- **BNL competes in advocacy forums for future facilities in Particle Physics**
 - BNL's Super Neutrino Beam earned a top-ranking from the HEPAP Future Facilities Panel
 - the **Super Neutrino Beam** is included in the "**Facilities for the Future of Science**" Plan
 - the lattice gauge power of **QCDOC** competed successfully with a 'clusters' approach
- **BNL conducts a forward-looking program of accelerator/detector R&D**
 - BNL accelerator scientists are pursuing *continuous improvement of the AGS intensity*
 - design is maturing at AGS for upgrade path to *1 MW and 2MW neutrino beams*
 - advanced concepts for an *image-plane camera array* for LSST are under study at BNL
 - ATLAS collaborators pursue *advanced detector concepts* for the LHC luminosity upgrade

- BNL Roles



“Connecting Quarks with the Cosmos”*

(*BNL HENP Vision for Future Facilities Development*)

1. What is Dark Matter? – ATLAS Experiment & Upgrade
2. What is the nature of the Dark Energy? – LSSST Collaboration
3. How did the Universe Begin?
4. Did Einstein have the Last Word on Gravity?
5. What are the masses of the neutrinos and how have they shaped the Evolution of the Universe? – MINOS; VLB Neutrino Experiment & Super Beam
6. How do Cosmic Accelerators work and what are they accelerating?
7. Are Protons Unstable? – UNO Experiment Collaboration
8. What are the New States of Matter at exceedingly High Density and Temperature? – RHIC, RHICII & eRHIC Collider and Experiments; QCDOC
9. Are there additional Space-Time Dimensions? – ATLAS Experiment & Upgrade
10. How were the elements from Iron to Uranium made?
11. Is a new theory of Matter and Light needed at Highest Energies? RSVP.

Approved &
Funded Projects
Underlined

* “Connecting Quarks with the Cosmos”, National Research Council of the National Academies, 2003

Lattice Gauge Physics & QCDOC Supercomputer

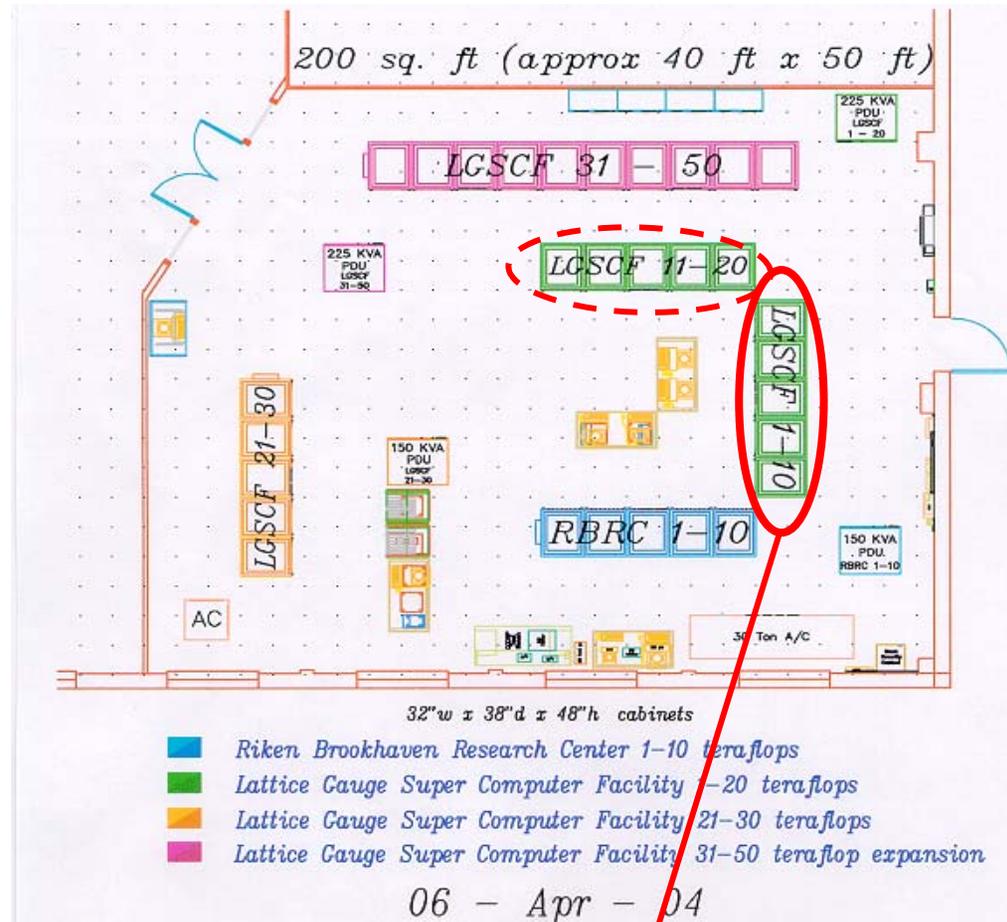
- the U.S. **Lattice Gauge Theory** (LGT) community, via its U.S. Executive Committee, submitted a proposal in 2001 to DOE 's **SciDAC Program** to pursue an aggressive strategy of developing and using dedicated supercomputers to advance the computational capabilities of LGT in particle and nuclear physics
- Columbia University and the IBM Corp. are now engaged in production of a massively-parallel supercomputer chip, **QCDOC**, to be used in two **10 Tflops (peak) supercomputers**, ideal for LGT calculations, for the RBRC and the UK that will begin operating at BNL by October 2004
- DOE's Office of HEP is planning funding to add a 3rd **8 Tflops (peak) QCDOC** at BNL for lattice gauge theory; this machine will be used by the entire *U.S.* LGT community
- we hope for further development of lattice gauge physics supercomputing capability at BNL in future years with both OHEP and ONP support

Lattice Gauge Supercomputing at BNL

- QCDOC 128-node prototype now operating with LGP codes
- 10 Tflops RBRC & UKQCD machines will be running at BNL by October 2004
- DOE HEP plans to fund a 8 Tflops QCDOC at BNL

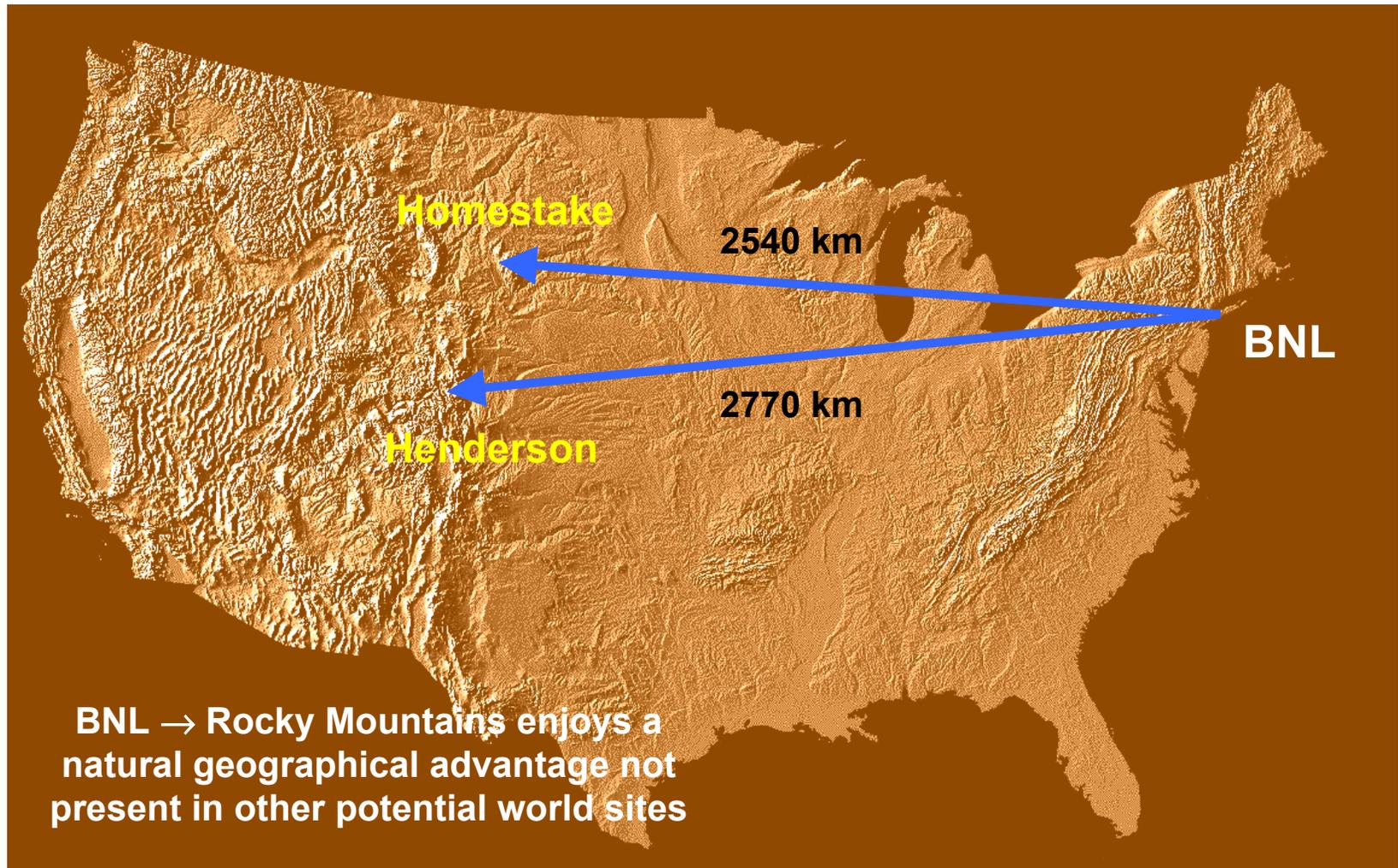


QCDOC daughter board



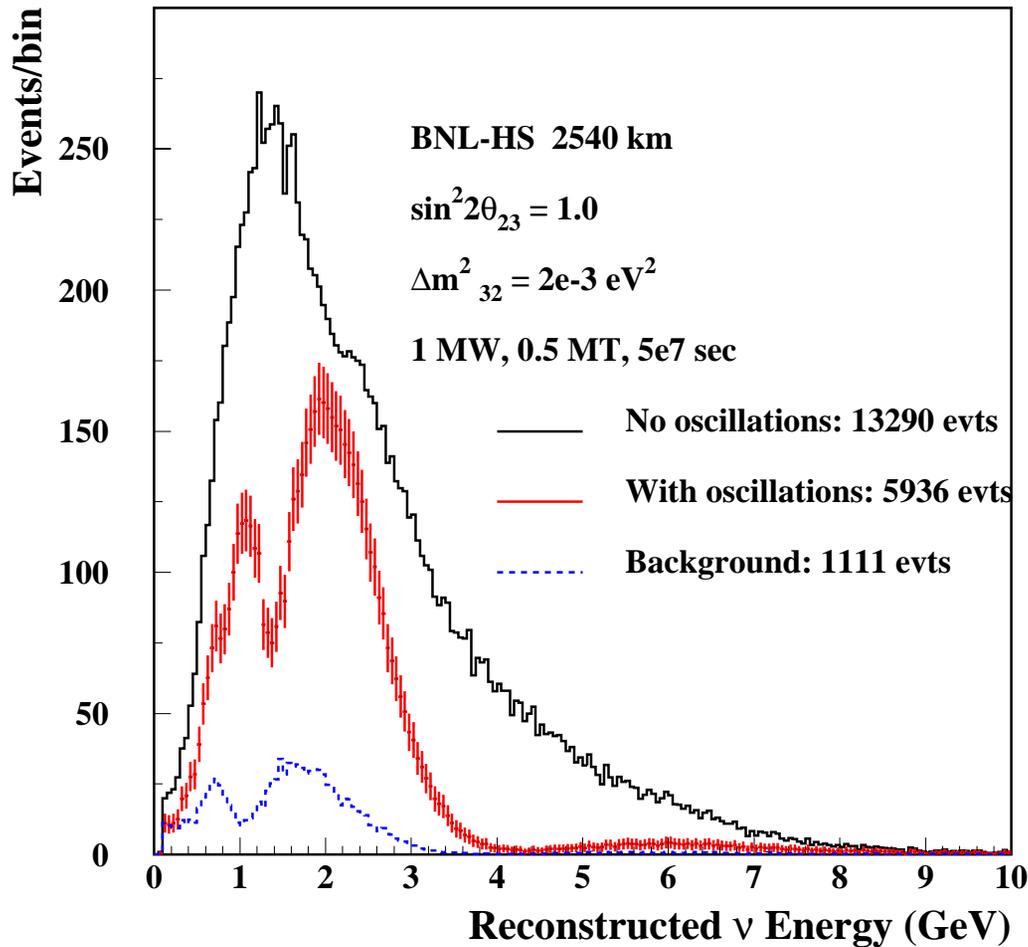
**8 Tflops (peak)
QCDOC module**

BNL → Rocky Mountains Super Neutrino Beam



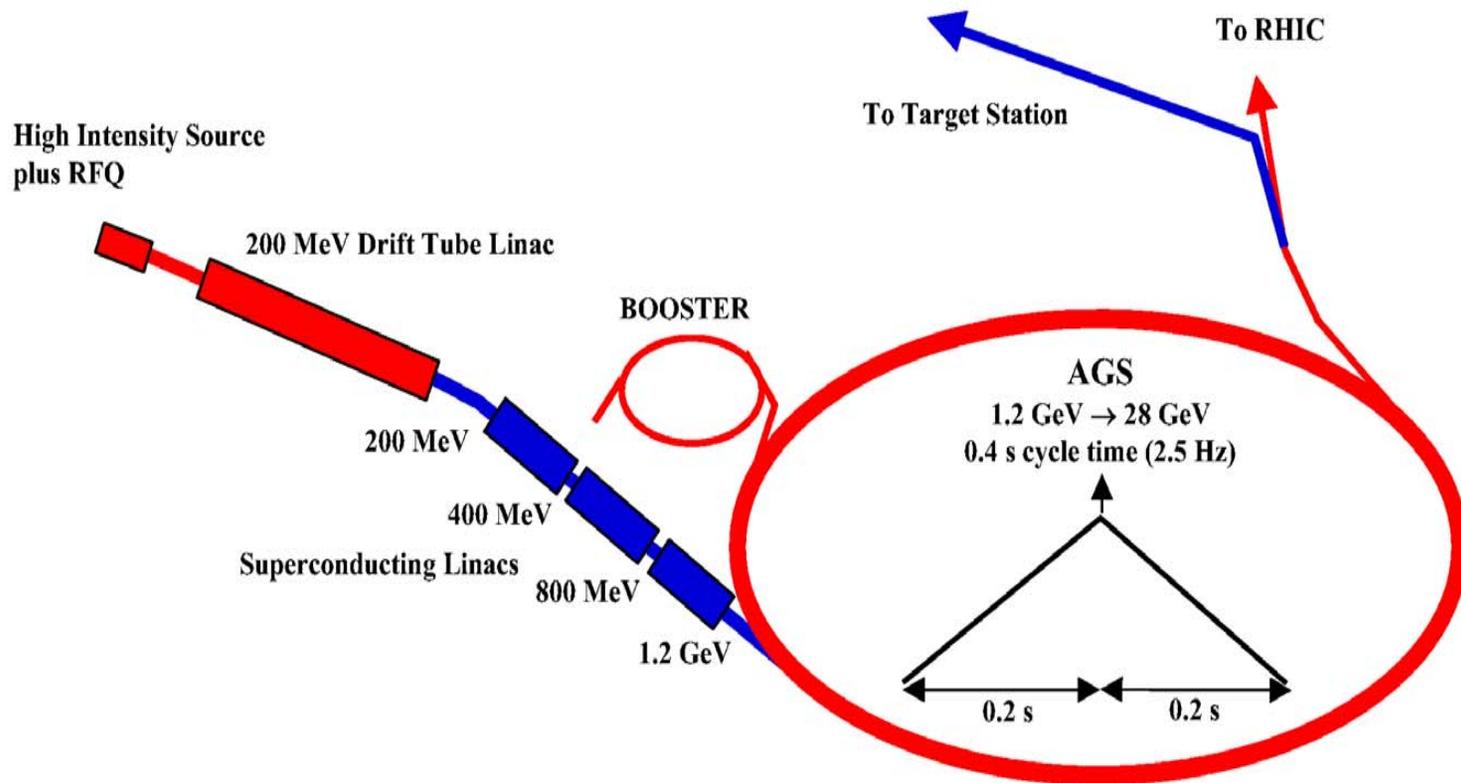
Very Long Baseline Neutrino Experiment

ν_μ DISAPPEARANCE



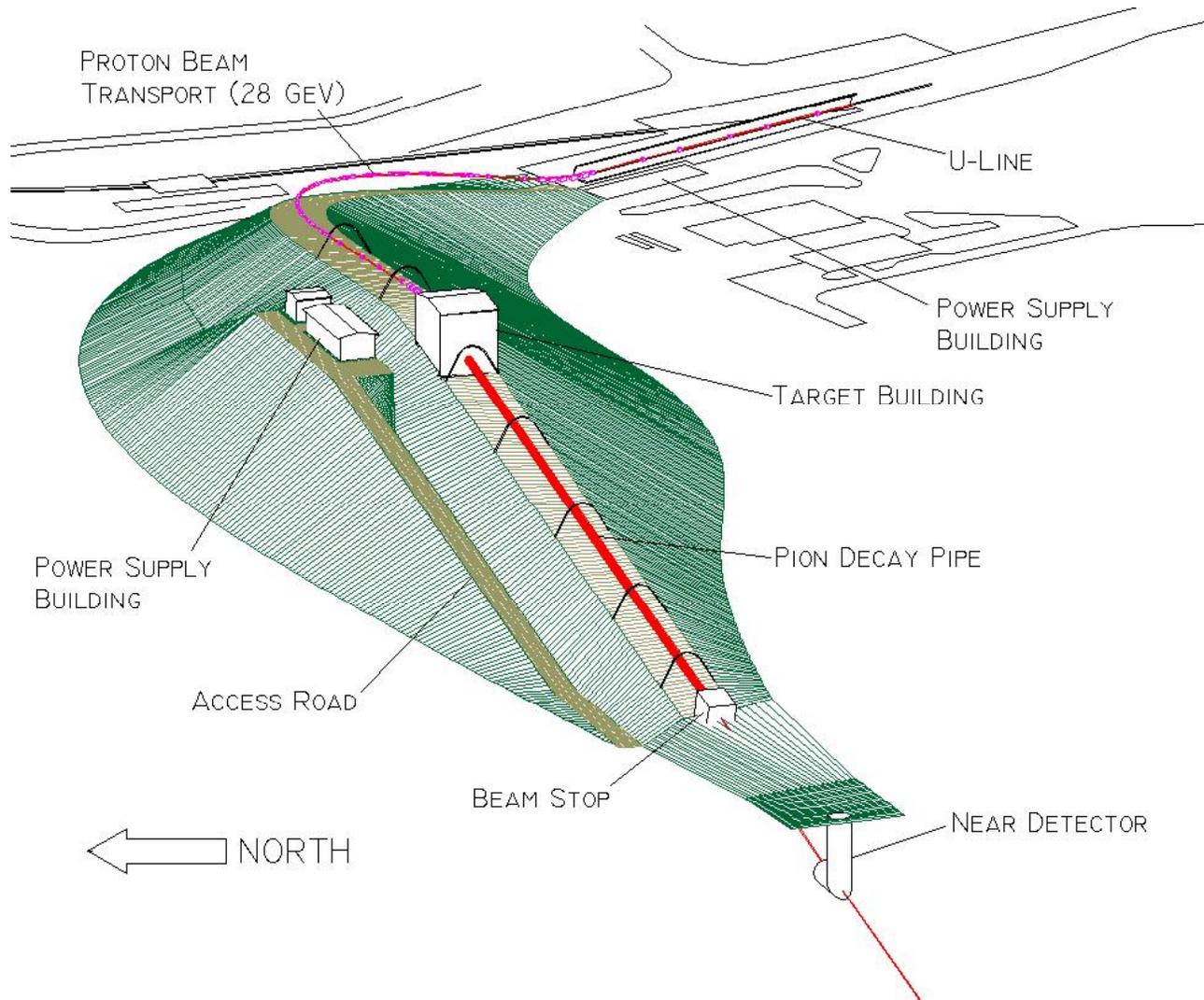
- neutrino oscillations result from the factor $\sin^2(\Delta m_{32}^2 L / 4E)$ modulating the ν flux for each flavor (here ν_μ disappearance)
- the oscillation period is directly proportional to distance and inversely proportional to energy
- with a *very long baseline* actual oscillations are seen in the data as a function of energy
- the multiple-node structure of the very long baseline allows the Δm_{32}^2 to be precisely measured by a *wavelength* rather than an amplitude (reducing systematic errors)

1-2 MW Super Neutrino Beam at AGS



- BNL will complete in June 2004, a Conceptual Design in preparation for a proposal to DOE to upgrade the AGS to 1-2 MW target power and construct the wide-band **Super Neutrino Beam** as listed in the DOE's "Facilities for the Future of Science" plan of November 2003

3-D Super Neutrino Beam Perspective



Center for Accelerator Physics - CAP

Mission Statement:

“The Center for Accelerator Physics serves as a forum for the discussion of Current topics in accelerator science that are of interest and potential value To BNL programs that utilize accelerator technology. All accelerator scientists At BNL are members of the Center and are encouraged to participate fully.”

Current Status and Activities:

- W.T. Weng is the present CAP head; *all* BNL accel. physicists are members
- organization of the Brookhaven Accelerator Forum
(lab-wide monthly lecture series on Frontier Accelerator R&D topics)
- coordination of the Neutrino Working Group
(AGS upgrade to 1 MW proton beam + wide-band neutrino beam)
- co-sponsor of the Targetry Material Testing US/Japan Collaboration Program
- participation in the US Superconducting Module Test Facility (SMTF)
Collaboration
- participation in the US Muon Collider Study Collaboration

Center for Accelerator Physics - CAP

Speakers in the BNL CAP Lecture Series in FY2004:

“Accelerator R&D for X-ray Free Electron Lasers”, S. Krinsky, April 2004

“Theory and Design of Fixed Field Alternating Gradient Accelerators”,
S. Berg, March 2004

“High-Power Targetry”, H. Kirk, February 2004

“Rare Isotope Accelerator (RIA) Project - - Design Options and Status”,
R. York, January 2004

“Practical Optical Stochastic Cooling for RHIC, V. Yakimenko,
December 2003

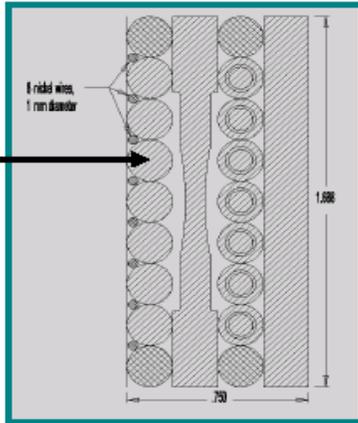
“The Spallation Neutron Source Accelerator Complex: Design, Status,
and Issues”, J. Wei, November 2003

“A Taste of Science to Come at NSLS-II”, S. Dierker, September 2003

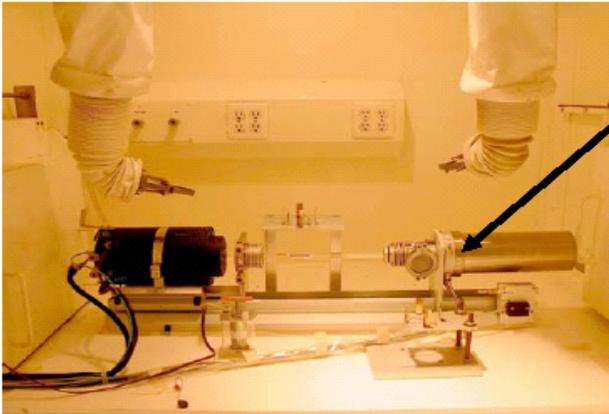
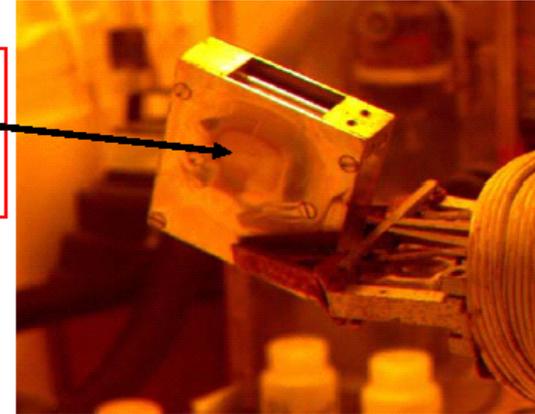
Center for Accelerator Physics - CAP

Super-invar Irradiation at BNL

The cylindrical samples of super-invar.

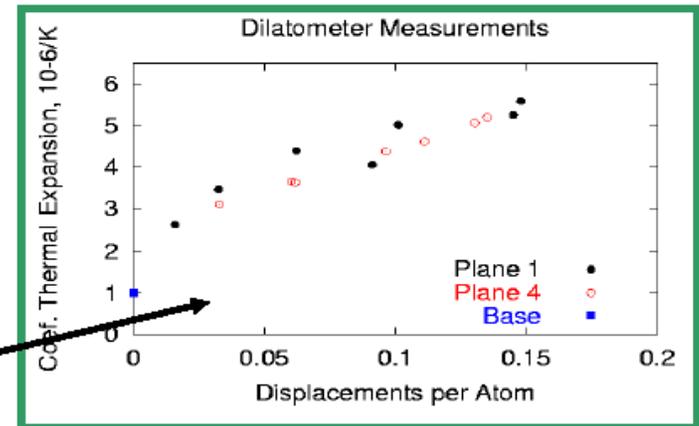


The target basket after irradiation



Dilatometer in Hot cell

Results of coefficient of thermal expansion measurements



Safety

Safety at BNL is paramount and must be addressed successfully *before* all other Laboratory operating priorities. We note here some aspects of improving safety that relate to the HENP directorate:

- ESH and Quality ALD, Jim Tarpinian said: **“No one comes to work in the morning expecting to be injured.”** We cannot say it better...
- BNL’s injury rate is above the DOE Laboratory average and *must* be improved; Director Praveen Chaudhari has engaged us all to this end
- C-AD, Physics, SMD and Instrumentation are fully dedicated to this goal
- T. Kirk prescribed **weekly** safety updates in **all HENP work units** to keep our personnel alert and refreshed on safety topics; this policy has been operational since September 2003
- HENP has an improving safety record in C-AD and no lost workday injuries for over 600 days in Physics, Instrumentation and SMD

BNL Priorities in High Energy Physics

The BNL *Future Facility priorities* in High Energy Physics are:

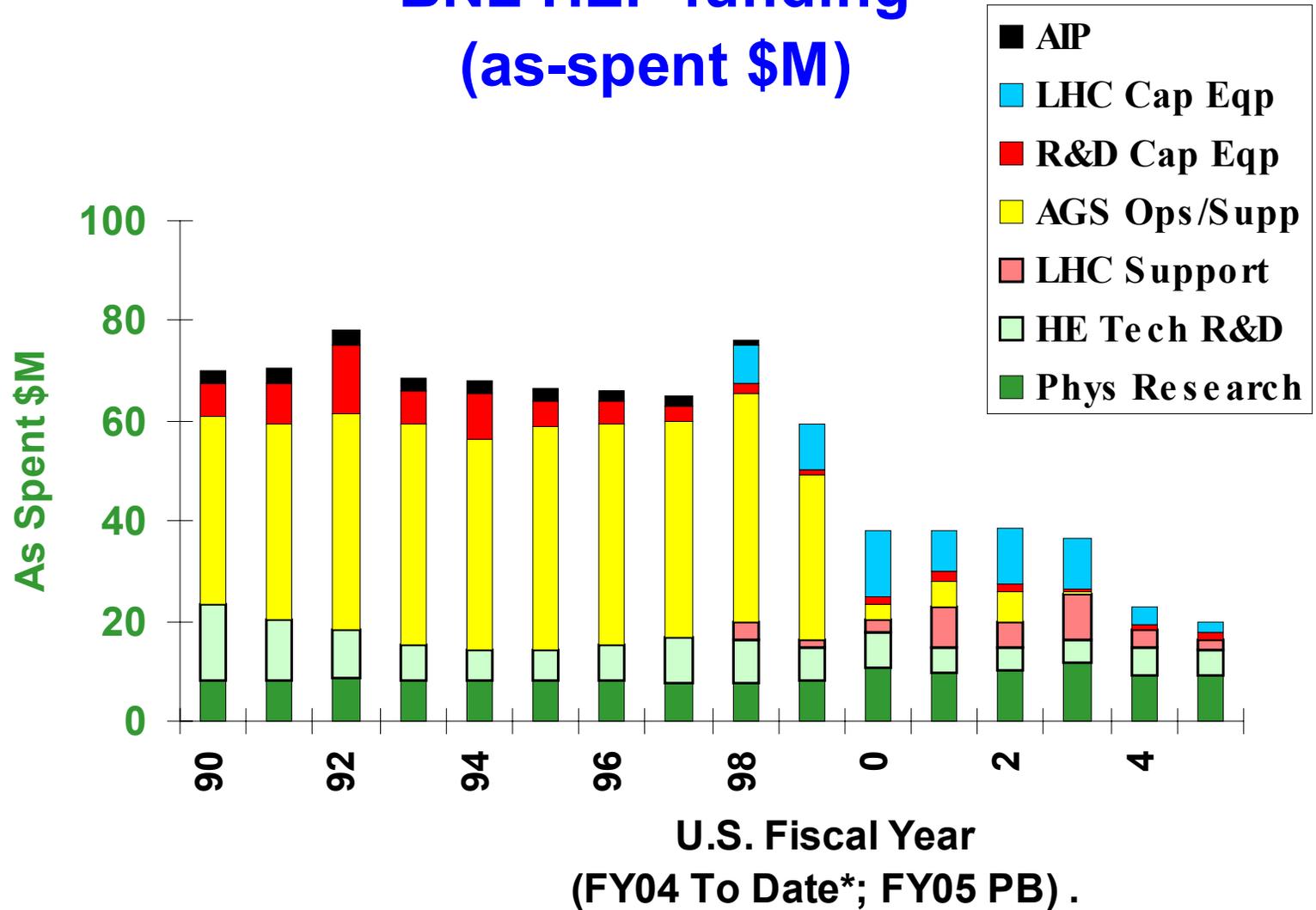
1. A *BNL Physics Analysis Center* for U.S. Participation in ATLAS Research
2. Approval and start of the *RSVP construction project* in FY 2005
3. Approval and start of the *LSST project* as early as FY 2008
4. Approval and start of the *VLB Super Neutrino Beam project*

We will return to these in the Summary and Outlook tomorrow

HEP Budgets and Waste Management

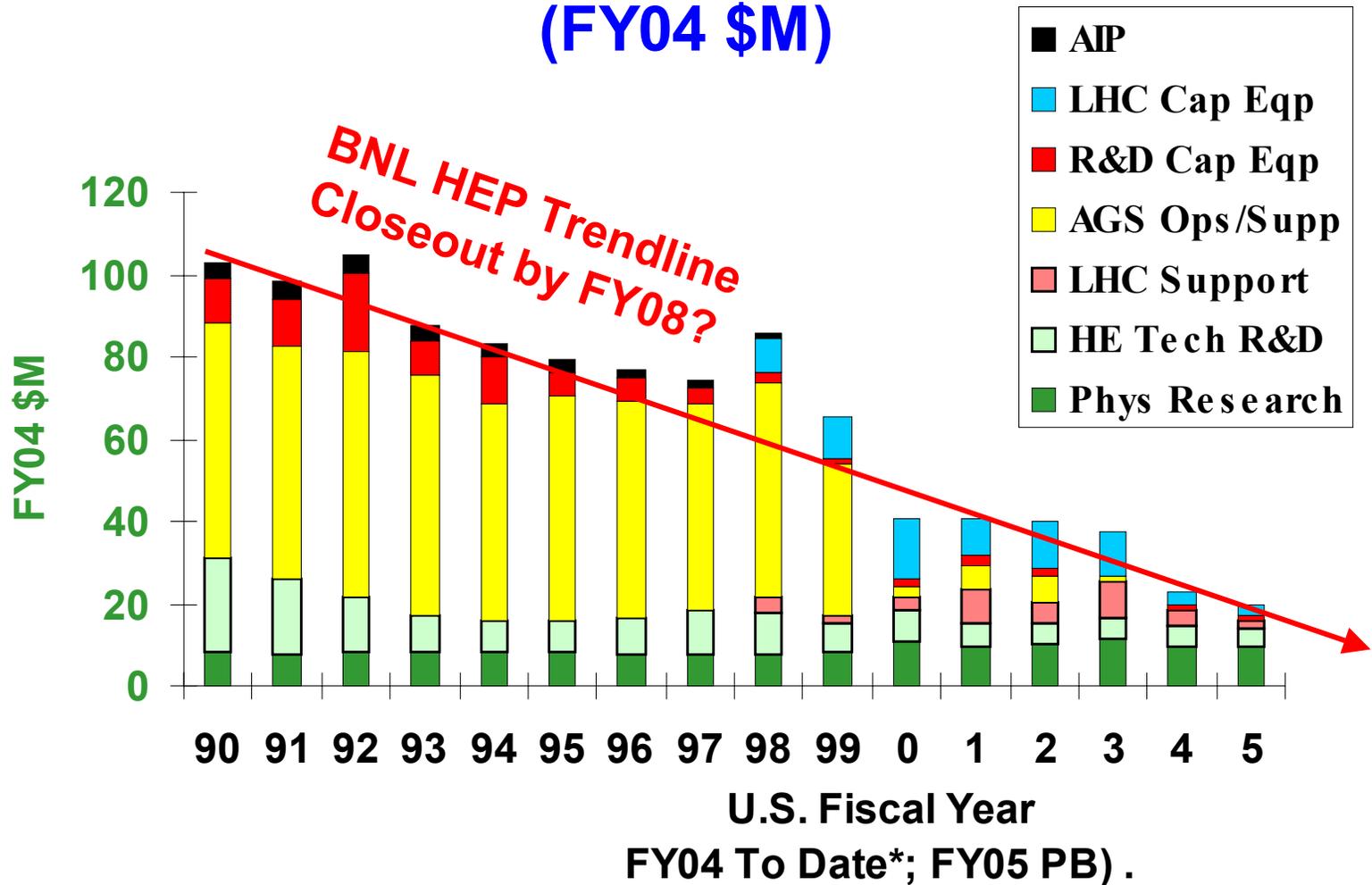
- Budget Issues – much the same as reported at last year’s review
 - BNL continues to endure three budget issues that impede and limit our program:
 1. **money** - **base operating funding** continues to fall in FY03, FY04 and FY05 PB
 2. **money** – DOE/NSF is under-funding support for the **LHC research program**
 3. **money** - AGS has been “terminated” for HEP in spite of DOE promises
 - a balanced HEP U.S. program needs *multiple key experiments* in operation
 - SLAC has 2 exps. that are providing excellent results: **BaBar** and **E-158**
 - Fermilab has 3 exps. that lag expectations: **CDF**, **D0** and **Mini-Boone**
 - AGS has 2 important exps. that could add value: **E-949** and **Muon (g-2)**
 - BNL’s important contributions to the U.S. HEP program are at risk if our funding slide cannot be mitigated; Robin Staffin correctly observed recently “Don’t tell me you’re going to squeeze a bit everywhere!” – BNL is out of places to squeeze...
- Waste Management continues at BNL for remaining HEP waste at AGS; productive discussions continue with the OHEP

BNL HEP funding (as-spent \$M)



* FY04 funding per x/03 Fin. Plan

BNL HEP Funding (FY04 \$M)



* FY04 funding per x/03 Fin. Plan

HEP Budgets at BNL & Revised Request by B&R

| Budget Category (Ops + Equip) | FY03 Actual (\$M) | FY04 ¹ Actual (\$M) | FY05P ² P. Bud (\$M) |
|--|-------------------------|--------------------------------------|---------------------------------------|
| KA 11 01, 02 (Research) | | | |
| Phys Research | 8.72 | 7.00 | 6.84 |
| ATLAS R&D/Constr. Ops. | 7.72 | 2.75 | 1.70 |
| LHC Accel. R&D/Constr. Ops. | 1.03 | 1.13 | 0.55 |
| AGS Facil. Ops. & Waste Mgmt | 0.76 | 0.00 | 0.00 |
| LHC Cap Eqp. | 10.10 | 3.20 | 2.37 |
| KA 14 01 01, 03 (Theory /SciDAC) | 2.78 | 2.27 | 2.43 |
| KA 15 01, 02 (Accel. R&D) | | | |
| Accel. Test Facil. (ATF) | 1.97 | 1.98 | 2.05 |
| Genl. Accel, + Det. R&D | 1.92 | 1.87 | 1.80 |
| Linear Coll + Muon R&D | 1.05 | 1.21 | 0.96 |
| KA 11, 15 (non-LHC Cap Eqp) | 0.50 | 1.19 | 1.19 |
| Total HEP Funding | 36.55 | 22.60 | 19.89 |
| AGS Weeks (SEB/FEB) | 0+0 | 0+0 | 0+0 |

¹ March 2004 DOE Fin. Plan, w/o Waste Mgmt.

² FY 2005 President's Budget

BNL Impacts of FY04-05 Budgets

- BNL scientific staff in the Physics Department was reduced by **2 FTEs** in FY04 and estimates **6 FTEs** in FY05 under the current planning budgets; BNL will not be able to fulfill its approved HEP program commitments in these years
Experimental research efforts that will continue at reduced strength:
ATLAS, D0, RSVP, MINOS, E949 analysis and VLBv planning
Experimental research efforts that have been *curtailed*:
CKM, g-2, EDM, AGS experiment data runs
Experimental research efforts that *cannot be started*:
LSST and Linear Collider Detector & Physics
- BNL's plans to advance U.S. ATLAS Computing & Research Programs and the LHC Accelerator Research work will be severely impeded under FY04, 05 DOE budget guidance; ***this inhibits a U.S. leadership role in ATLAS physics and potentially important BNL contributions to Linear Collider R&D***
- The Muon Collider/Storage Ring R&D Collaboration program has been cut in half relative to FY01 and appears to be flat in future years
High-Power Target R&D runs at AGS are on-hold

BNL Impacts of FY04-05 Budgets (Cont.)

- **AGS will not run, either in FY03 or in FY04:**
 - E949 will not make the planned advance in the measurement of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, as approved by DOE in August 1999
 - E962, Muon (g-2), will not be able to reduce the statistical error to the level of the systematic error

these are losses at the frontier of particle physics!
- **BNL's proposal to contribute value to the Linear Collider with Final Focus quadrupole design and spatial stabilization R&D is under-supported**