BNL Overview and Future Directions

Presented to
DOE HEP Annual Program Review

by
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HENP

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Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN
NATIONAL LABORATORY

Presentation Structure of the Review

Plenary Session	T. Kirk Overview CAP, QCDOC & VLB Neutrino Exp. Budgets & W. Mgmt.	S. Aronson Physics Dept. Theory Experiments ATF	H. Gordon ATLAS
Parallel Sessions	Accelerator ATF – **I. Ben-Zvi** μ Collider – **R. Palmer** Superconducting Magnets - **M. Harrison** AGS Upgrades and ν Super Beam – **T. Roser**	Theory Overview - **W. Kilgore** Weak Matrix Elements - **A. Soni** Lattice QCD – **M. Creutz**	Experiment ATLAS Constr. - **H. Ma** ATLAS Computing – **S. Rajagopalan** D0 Exp. - **V. Jain** g-2 & MECO Exps. - **W. Morse** K^+ Exps. - **D. Bryman** ν Exp. - **W. Marciano**

Plan of the Overview Talk

- Introductory comments
- High Energy Physics at BNL - current program
- Center for Accelerator Physics
- Lattice Gauge Physics and QCDOC supercomputer
- Neutrino Physics - VLB Neutrinos in a Super Beam
- Future Directions in HEP

plus, sigh….

- Waste Management and HEP Budgets

High Policy to Guide our Thoughts
and give us hope…

Presidential Science Advisor and OSTP Director, John H. Marburger III, with his PCAST Co-Chair, Floyd Kvamme, transmitted with their full support, the following *Recommendation 1* of the "PCAST Panel on Federal Investment in Science and Technology and Its National Benefits" to President Bush on October 16, 2002:

"All evidence points to a need to improve funding levels for physical sciences and engineering. Continuation of present patterns will lead to an inability to sustain our nation's technical and scientific leadership. We recommend that beginning with the FY04 budget and carrying through the next four years, funding for physical sciences and engineering across the relevant agencies be adjusted upward to bring them collectively to parity with the life sciences."

We are still waiting to see a positive response on the Executive side but Congress is aware of this situation and has responded with substantially increased funding for the NSF in the FY 2002 and 2003 budgets. We hope the Office of Science is next…

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 FY 2004 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, D0 and ATLAS**
  - **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 FY03,04**
  - **US ATLAS Construction and Computing Projects (BNL is the Host Laboratory)**
  - **US LHC Accelerator Project (R&D in LHC machine and accelerator phys.)**
  - **Tier-1 computing center for support of the US ATLAS HEP program**

- **Performance of a leading R&D effort 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 & 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* plus *D0***
  - **1 HEP design/construction/computing effort for LHC *ATLAS* Detector**
  - **2 design/prototyping R&D efforts for planned AGS Exps., *KOPIO* & *MECO****
  - **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**

Current HEP Programs with BNL Involvement

- **BNL participation in the MINOS and D0 Programs at Fermilab**
  - **major contributors, D0 off-line phys. analysis (top, W, SUSY/higgs searches)**
  - **on-line and off-line D0 computer program upgrades and maintenance**
  - **operation of the D0 Forward Preshower (FPS) Detector**
  - **Jon Kotcher is the Run-2 Upgrade project manager for D0 Phase-2**
  - **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 MW Upgrade of the AGS accelerator for an intense, wide-band ν beam**

- **AGS Fixed Target Program is "terminated" by DOE in FY 2003 and 2004**
  - **this represents a serious loss of quality & diversity in the U.S. HEP Program**

* KOPIO and MECO are experiments in the RSVP Project in NSF's MRE Program; project funding is approved for FY06; R&D work is ongoing.

"Connecting Quarks with the Cosmos"*

(*BNL Involvement in 6 of the 11 topics*)

1. **What is Dark Matter? – *ATLAS Experiment***
2. **What is the nature of the Dark Energy? – *LSST 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? – *VLB Neutrino Exp. & 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 Collider and Experiments***
9. **Are there additional Space-Time Dimensions? – *ATLAS Experiment***
10. How were the elements from Iron to Uranium made?
11. Is a new theory of Matter and Light needed at the Highest Energies?

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

Recent HEP Physics Highlights

- **Ray Davis** received the 2002 **Nobel Prize in Physics** for the Homestake Solar Neutrino Exp.
- **Bill Willis** awarded the 2003 **Panofsky Prize** for important contributions to physics
- **Sally Dawson** moved up to **Chair-Elect of the DPF** in January 2003
- **US ATLAS Detector Proj.** on-budget, on-schedule and responsive; **U.S. Host Lab is BNL**
- **US ATLAS Computing Proj.** successfully **underway** but still under-funded in FY03,04
- **LHC Accel. Proj.** at BNL on-budget on-schedule, **LHC dipole production & cable testing**
- **'RSVP' MRE-FC Project** in R&D phase; **construction project starts in FY06** (maybe FY05?)
- DOE **FY 2004 President's Budget** identifies a **10 Tflops QCDOC Supercomputer at BNL**
- The **AGS Super Neutrino Beam** was presented to the HEPAP Future Facilities Committee in Pittsburgh on February 15, 2003; **measure the neutrino oscillation parameters** in a single experimental venue; the "P5+ Panel" rated this initiative "absolutely central to the field"
- Discussions have begun with **LSST** leaders about BNL collaboration in this key astro project

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)
- coordination of the Superconducting RF Working Group
- co-sponsor of the Targetry Workshop at BNL, September 8-12, 2003
- collaboration with SBU on a proposal for a "Center for Accelerator Science and Engineering", a PhD granting program co-sponsored by SBU and BNL

Center for Accelerator Physics - CAP

Speakers in the BNL CAP Lecture Series:

"The AGS Upgrade for 1.0 MW Super Neutrino Beam", T. Roser, September 2002

"Next Generation X-Ray Source and the NSLS Upgrade", J. Murphy, November 2002

"Supeconducting RF Accleration for the Coming Generation of Accelerators", H. Padamsee, December 2002

"The Performance and Challenges of RHIC", D. Trbojevic, January 2003

"Accelerator Physics for Muon-Collider/Neutrino FactorY", R. Palmer, February 2003

"The Applications and Challenges of High-Brightness Electron Beams", X.J. Wang, March 2003

"Design issues and Challenges for Linear Collider Damping Rings", A. Wolski, April 2003

Lattice Gauge Physics & QCDOC Supercomputer

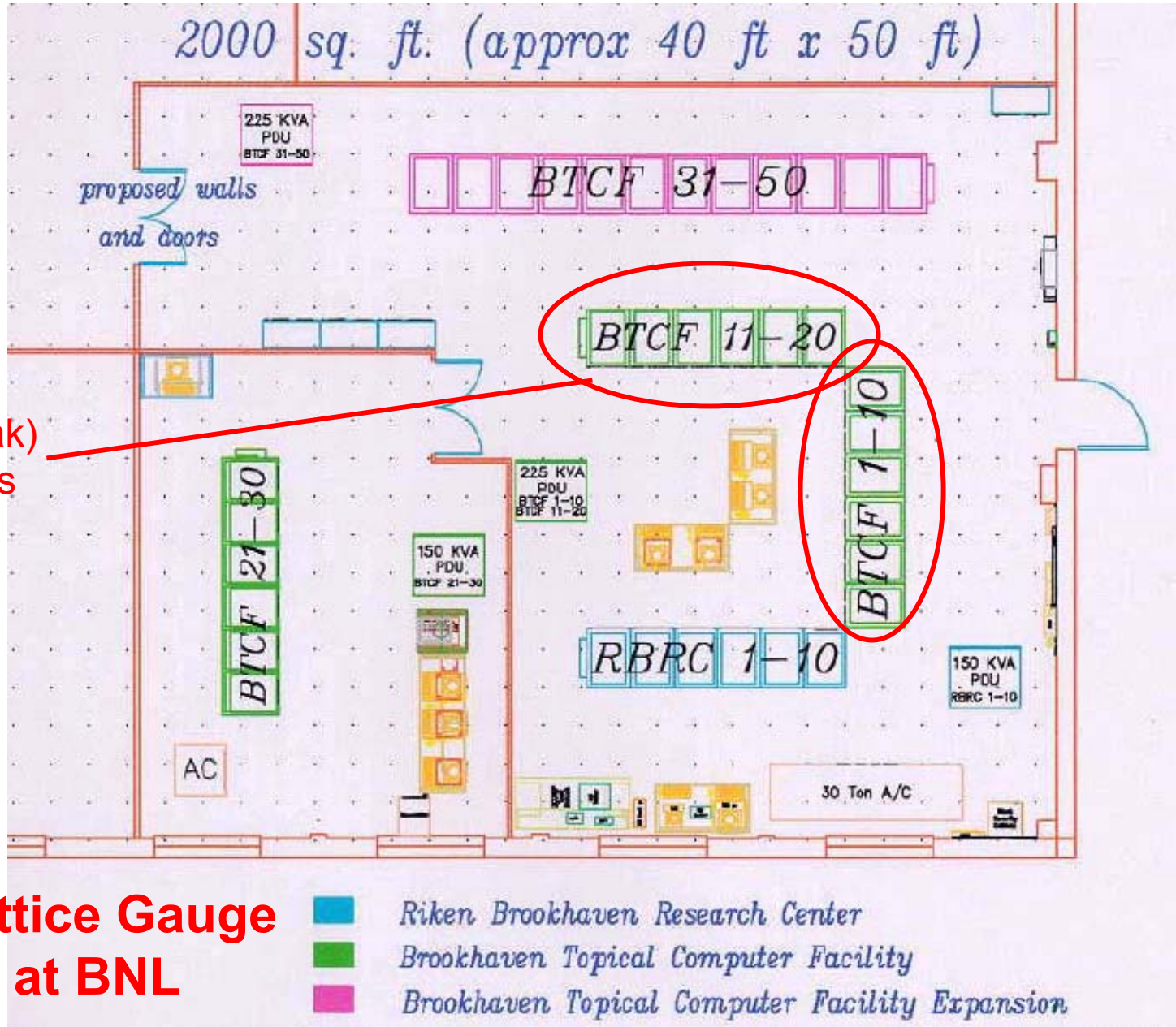
- the U.S. ***Lattice Gauge Theory*** (LGT) community, via its U.S. Executive Committee, submitted a proposal in 2001 to DOE 's ***SciDAC Program*** to pursue an aggressive strategy of developing and using dedicated supercomputers to advance the computational capabilities of LGT in particle and nuclear physics
- Columbia University, IBM Corp. and BNL are engaged in developing a new chip architecture, ***QCDOC***, and a massively-parallel supercomputer implementation of this computing chip design that will allow a ***10 Tflops supercomputer***, ideal for LGT calculations, to be built at BNL for $1/Mflop
- the Executive Committee and the Lab. will co-propose to DOE that the first dedicated "Topical Center" supercomputer for the LGT community be a 10 Tflops QCDOC machine at BNL, the ***BNL Lattice Gauge Center***
- the Riken BNL Research Center and the U.K. will each get a 5 Tflops QCDOC machine using funds already in hand; DOE paid for development of the QCDOC chip but DOE funding for the BNL LGC is not certain

Lattice Gauge HEP Physics Capabilities
(from Lattice Gauge Physics Proposal - 2003)

Measurement	CKM Matrix Elements	Hadronic Matrix Elements	Expt. Error	Current Lattice Error	Lattice Error 0.5 TF-yr	Lattice Error 10 TF-yr
ΔM_{Bd} ($\bar{B}B$ mixing)	$\lvert V_{td}\rvert^2$	$f^2_{Bd}B_d$	4%	35%	18%	9%
$\Delta M_{Bs}/\Delta M_{Bd}$	$\lvert V_{ts}/V_{td}\rvert^2$	$f^2_{Bs}B_s/f^2_{Bd}B_d$	Not yet measured	20%	5%	3%
ε ($\bar{K}K$ mixing)	ImV_{td}^2	B_K	2%	20%	10%	5%
$B \to (\rho\pi) l\nu$	$\lvert V_{ub}\rvert^2$	$\langle \rho\pi \lvert (V\text{-}A) \rvert B\rangle$	25%	Calc. in progress	15%	5-10%
	$\lvert V_{cb}\rvert^2$	$\lvert F_{B\to(D^*/D)l\nu}\rvert^2$	2%	Calc. in progress	6%	3%

Table 9: *Impact of lattice QCD on the determination of CKM matrix elements. In the table above, f_X is the leptonic decay amplitude for the indicated meson, and B_X is proportional to the matrix element of $\Delta S = 2$ or $\Delta B = 2$ four–quark operators. The last two columns show the improvements in lattice errors that we estimate would be obtained with computers sustaining 0.5 and 10 Tflops for one year.*

10 Tflops (peak)
LGC modules



Topical Lattice Gauge Center at BNL

VLB Neutrino Oscillations & AGS Upgrade

BNL plus other collaborators have developed a concept for making a complete set of measurements of the neutrino oscillation system parameters in a *"Very Long Baseline Neutrino Oscillations Experiment"*

This concept requires a beam from BNL's AGS machine, upgraded to provide a wide-band neutrino beam from a *1 MW target* aimed at a *0.5 MT Water Cerenkov Detector* (UNO would be our current choice), located in the Homestake Mine in Lead, South Dakota.

The VLB Neutrino Beam and the UNO Detector were presented to The "P5+ Committee" of HEPAP in separate but coordinated talks as part of the Orbach Future Facilities Initiative exercise in March 2003. Both presentations earned grades of *"absolutely central to the field"*, the highest grade identified by Dr. Orbach.

Since that time, a Collaboration has formed and is pursuing the design.

Physics Importance of Neutrino Oscillations

Complete measurement of the ***neutrino oscillation parameters*** is a physics goal of fundamental importance:

- neutrinos are fundamental particles whose full description in terms of mass and mixing parameters is basic to the progress of particle physics
- the mass scales among the neutrinos may help us understand the evolution of all particle masses down from the Planck scale
- if CP-violation is observed in the neutrino system, it will be quite large and may drive the much smaller CP-violation in the quark sector
- the early universe implications of large CP-violation in the neutrino sector might help explain the mass asymmetry in the present universe

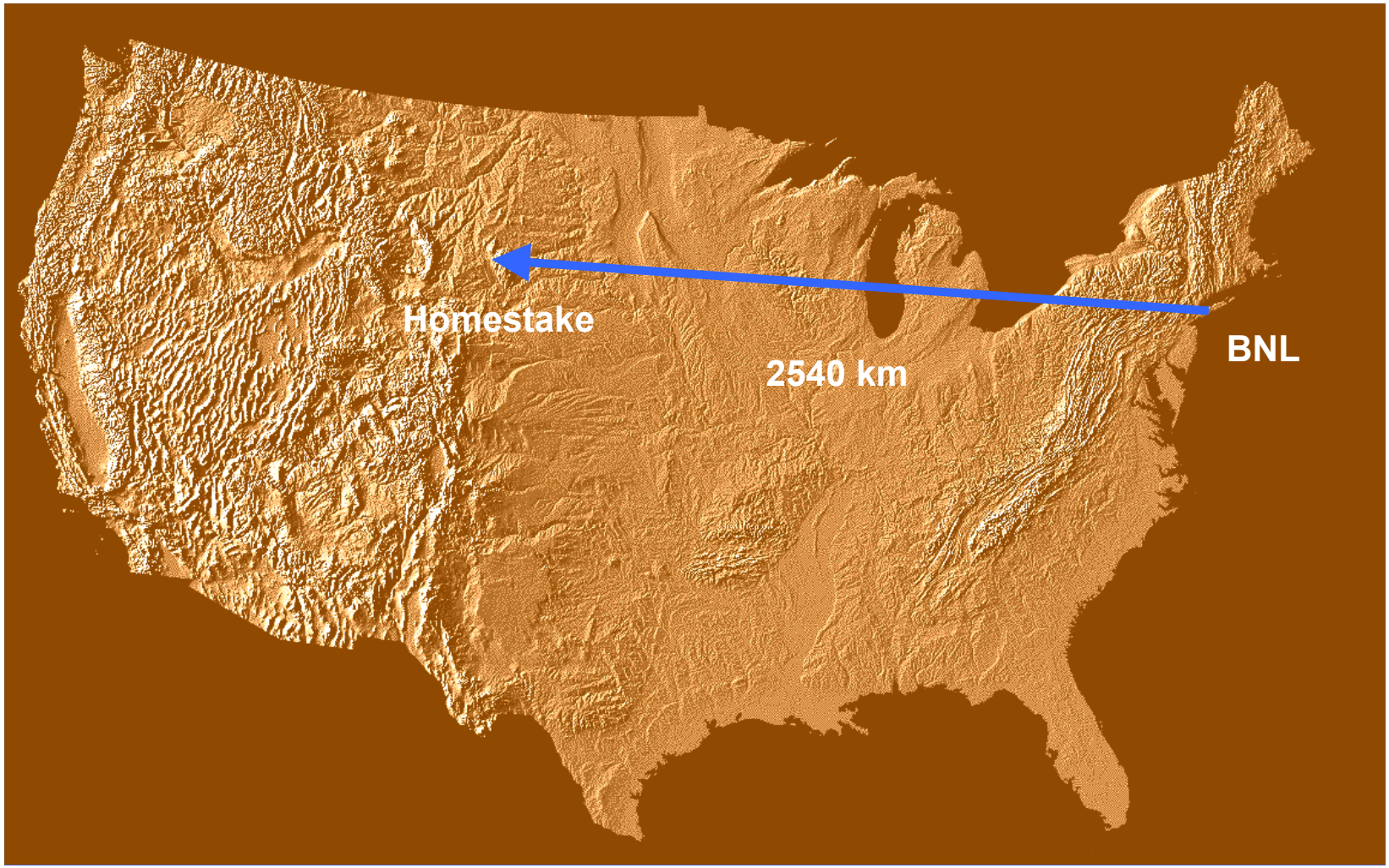
Physics Goals of the Very Long Baseline Neutrino Program

We introduce a plan to provide the following goals in a ***single facility***:

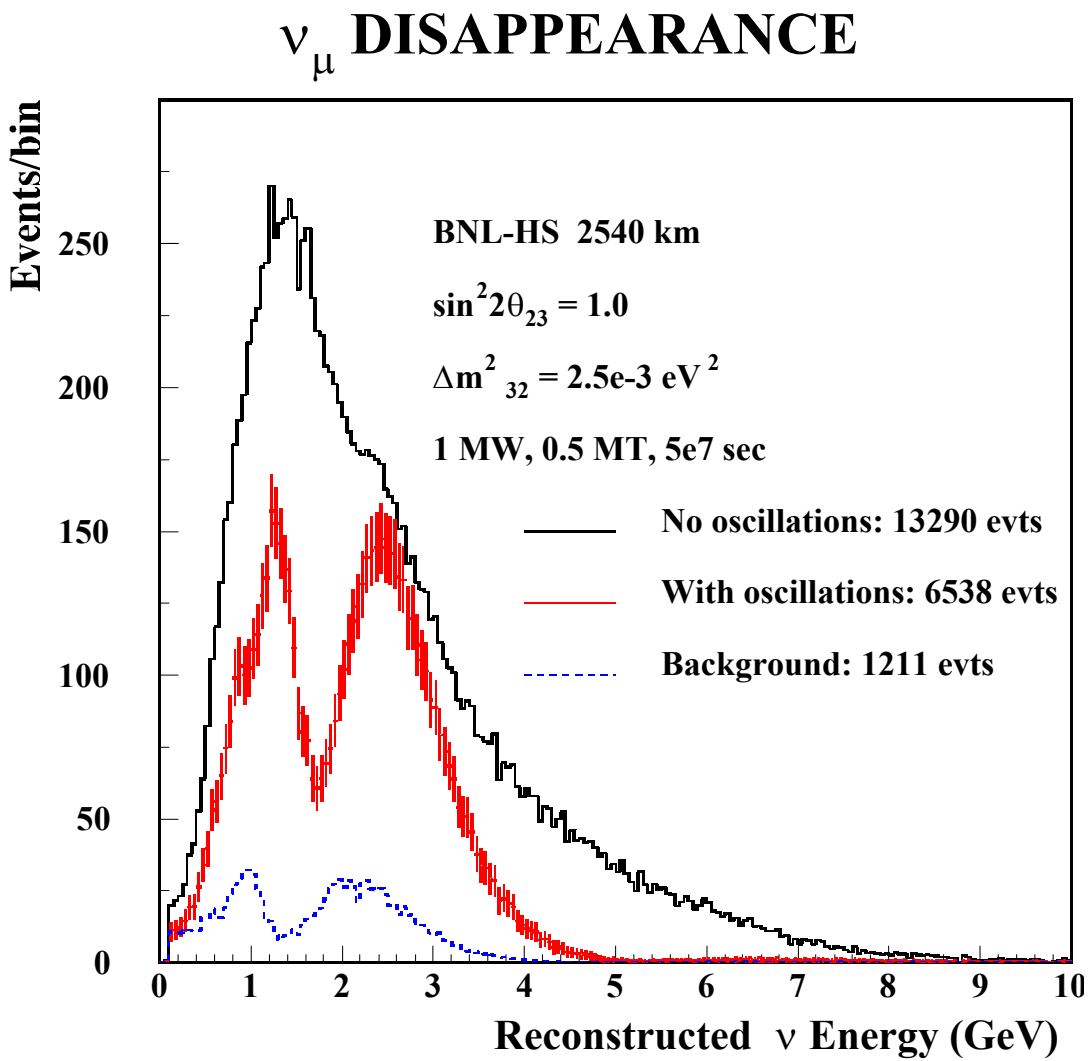
- precise determination of the oscillation parameters Δm_{32}^2 and $\sin^2 2\theta_{23}$
- detection of the oscillation of $\nu_\mu \rightarrow \nu_e$ and measurement of $\sin^2 2\theta_{13}$
- measurement of $\Delta m_{21}^2 \sin^2 2\theta_{12}$ in a $\nu_\mu \rightarrow \nu_e$ appearance mode, can be made if the value of θ_{13} is zero
- verification of matter enhancement and the sign of Δm_{32}^2
- determination of the CP-violation parameter δ_{CP} in the neutrino sector

The use of a *single neutrino super beam source* and *half-megaton neutrino detector* will optimize the efficiency and cost-effectiveness of a full program of neutrino measurements. If the value of $\sin^2 2\theta_{13}$ happens to be larger than ~0.01, then all the parameters, including CP-violation can be determined in the VLB program presented here.

BNL → Homestake Super Neutrino Beam

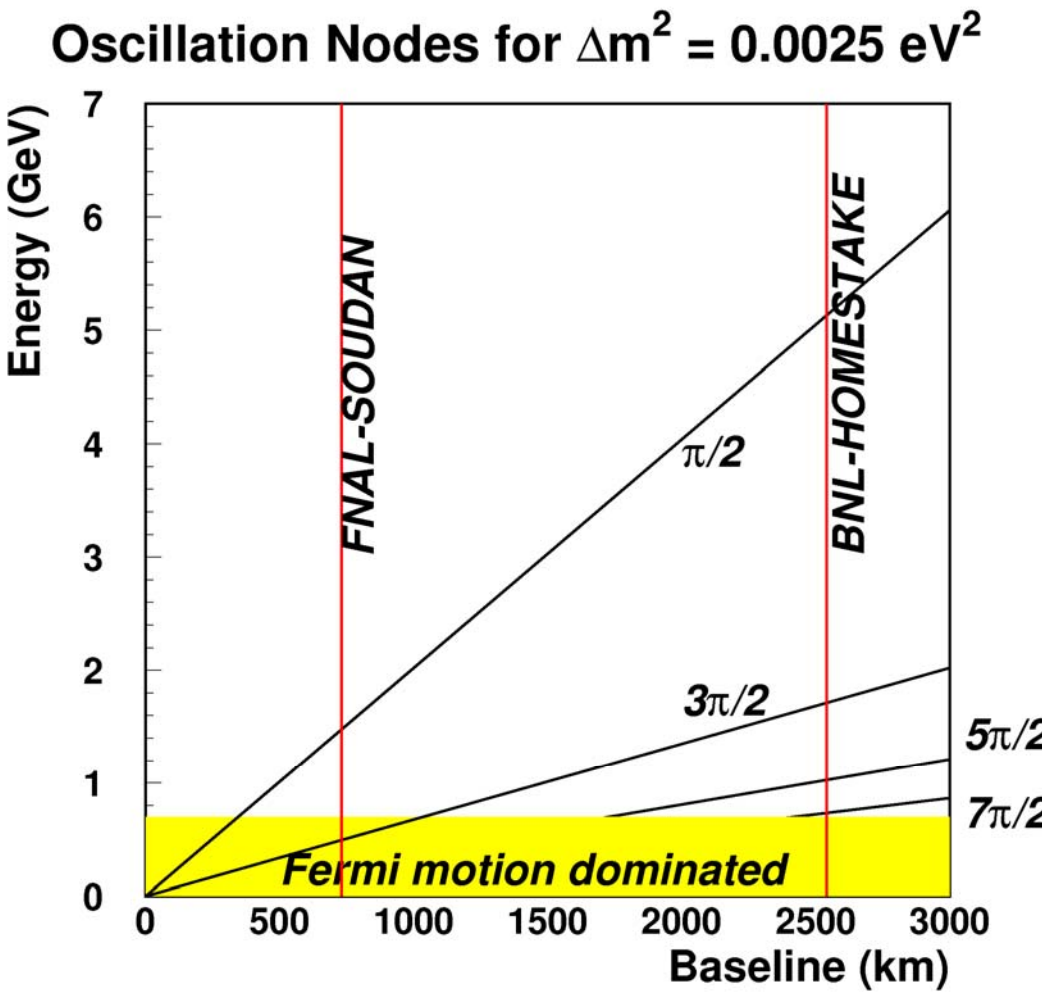


Advantages of a Very Long Baseline



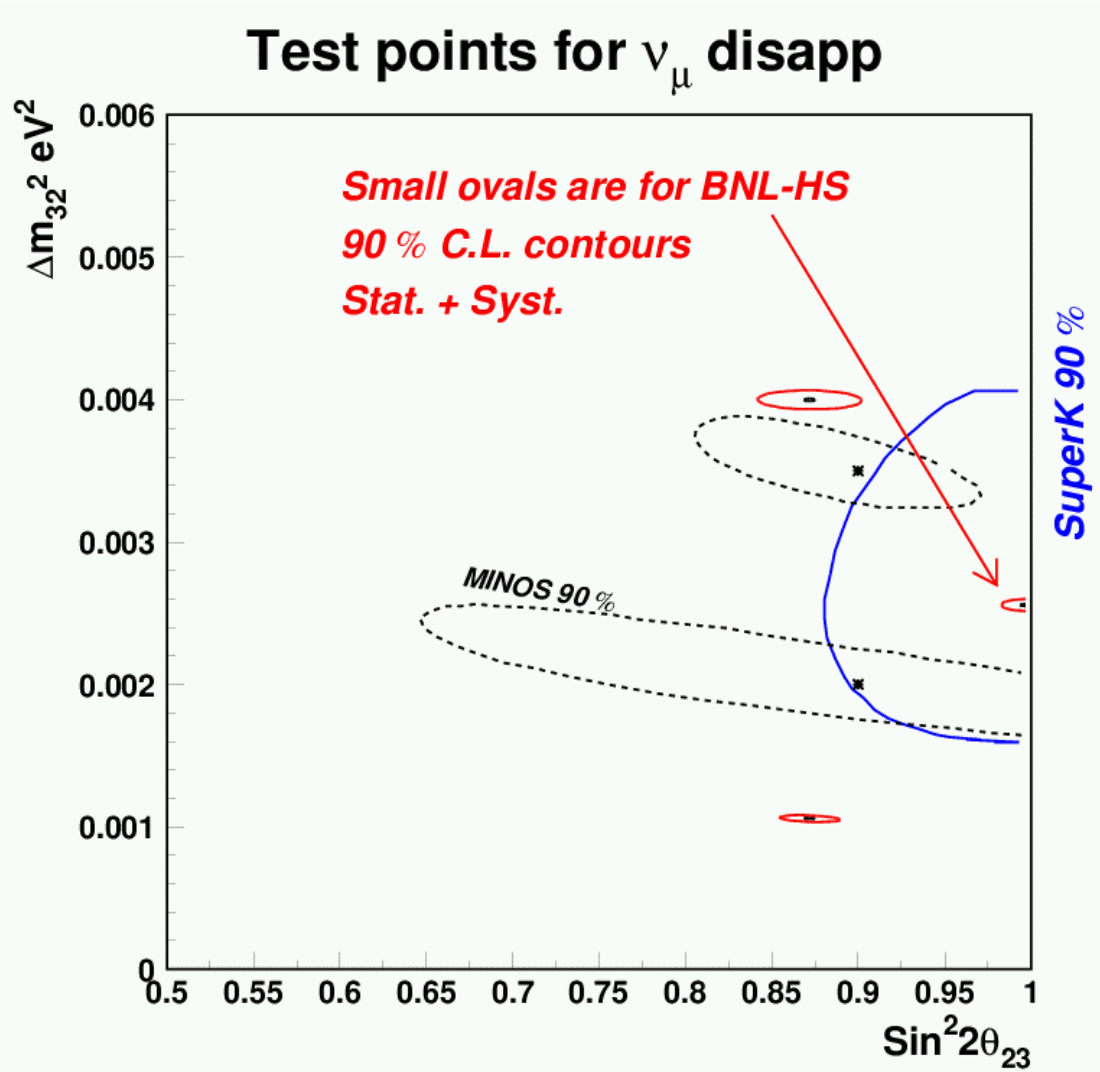
- neutrino oscillations result from the factor $\sin^2(\Delta m^2_{32} L / 4E)$ modulating the ν flux for each flavor (here ν_μ disappearance)
- the oscillation period is directly proportional to distance and inversely proportional to energy
- with a *very long baseline* actual oscillations are seen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

Baseline Length and Neutrino Energy



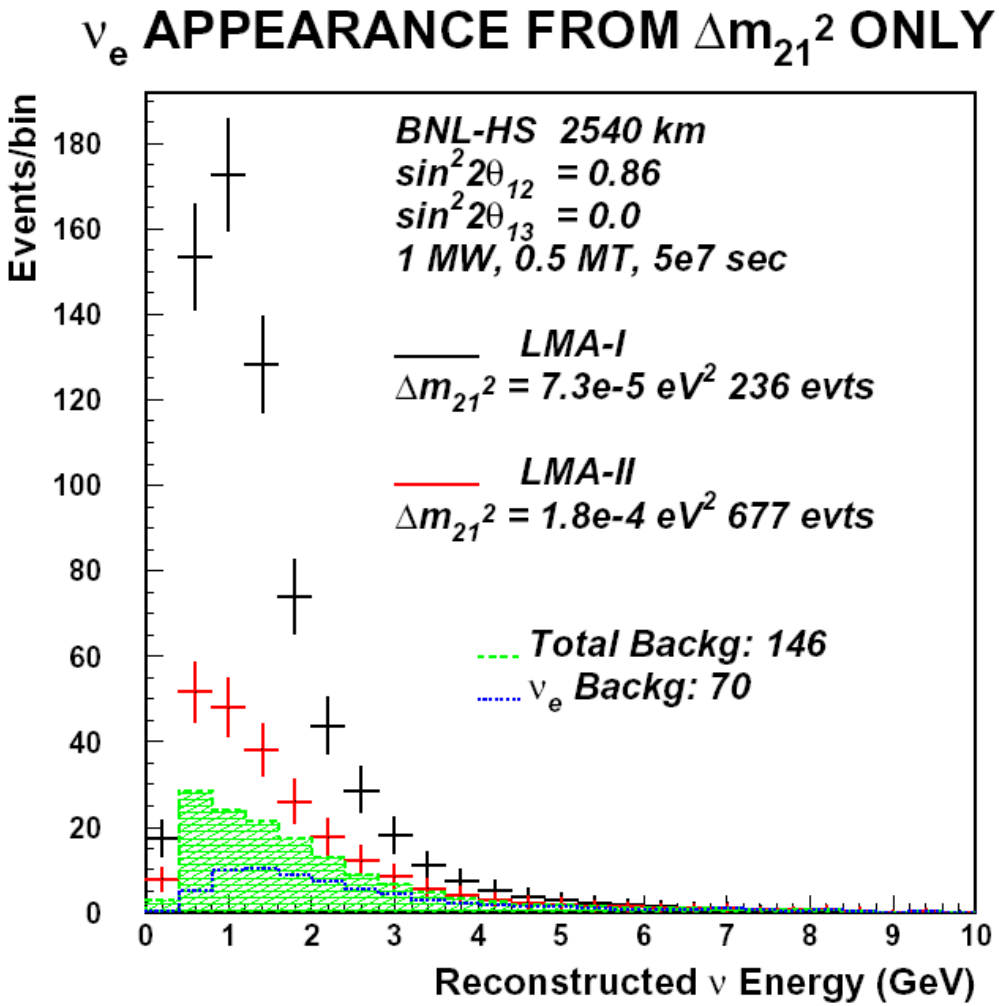
- for a fixed phase angle, e.g. $\pi/2$, the ratio of distance to energy is fixed (see sloped lines in Figure)
- the useful neutrino energy range in a beam derived from a proton production source is restricted:
  below ~1 GeV by *Fermi mom.* in the target nucleus
  above ~8 GeV by *inelastic ν interactions* background
- these conditions prescribe a needed baseline of greater than *2000 km* from source to detector
- by serendipity, the distance from BNL to the Homestake Mine in Lead, SD is 2540 km

VLB Application to Measurement of Δm_{32}^2



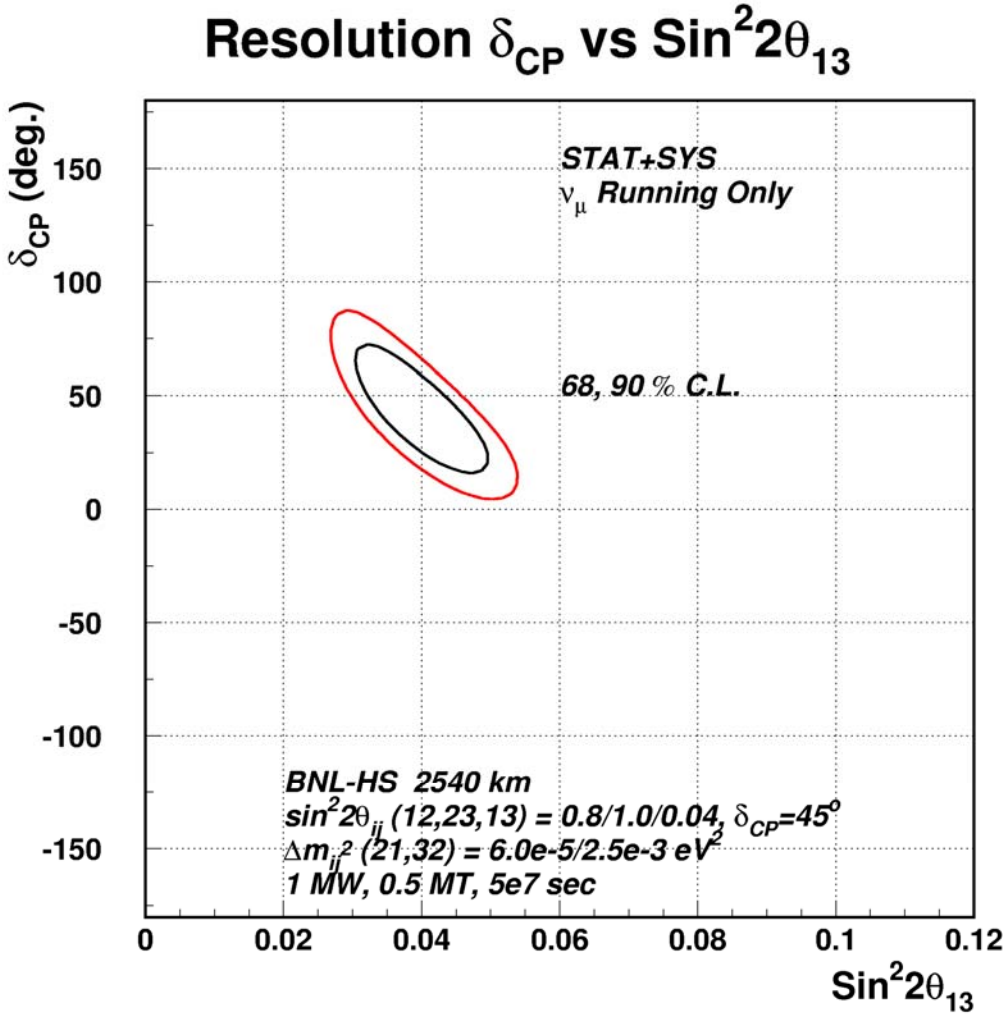
- the multiple node method of the VLB measurement is illustrated by comparing the BNL 5-year measurement precision with the present Kamiokande results and the projected MINOS 3-year measurement precision; all projected data include both statistical and systematic errors
- there is no other plan, worldwide, to employ the VLB method (a combination of target power and geographical circumstances limit other potential competitors)
- other planned experiments are can't achieve the VLB precision

ν_e Appearance Measurements (Cont.)



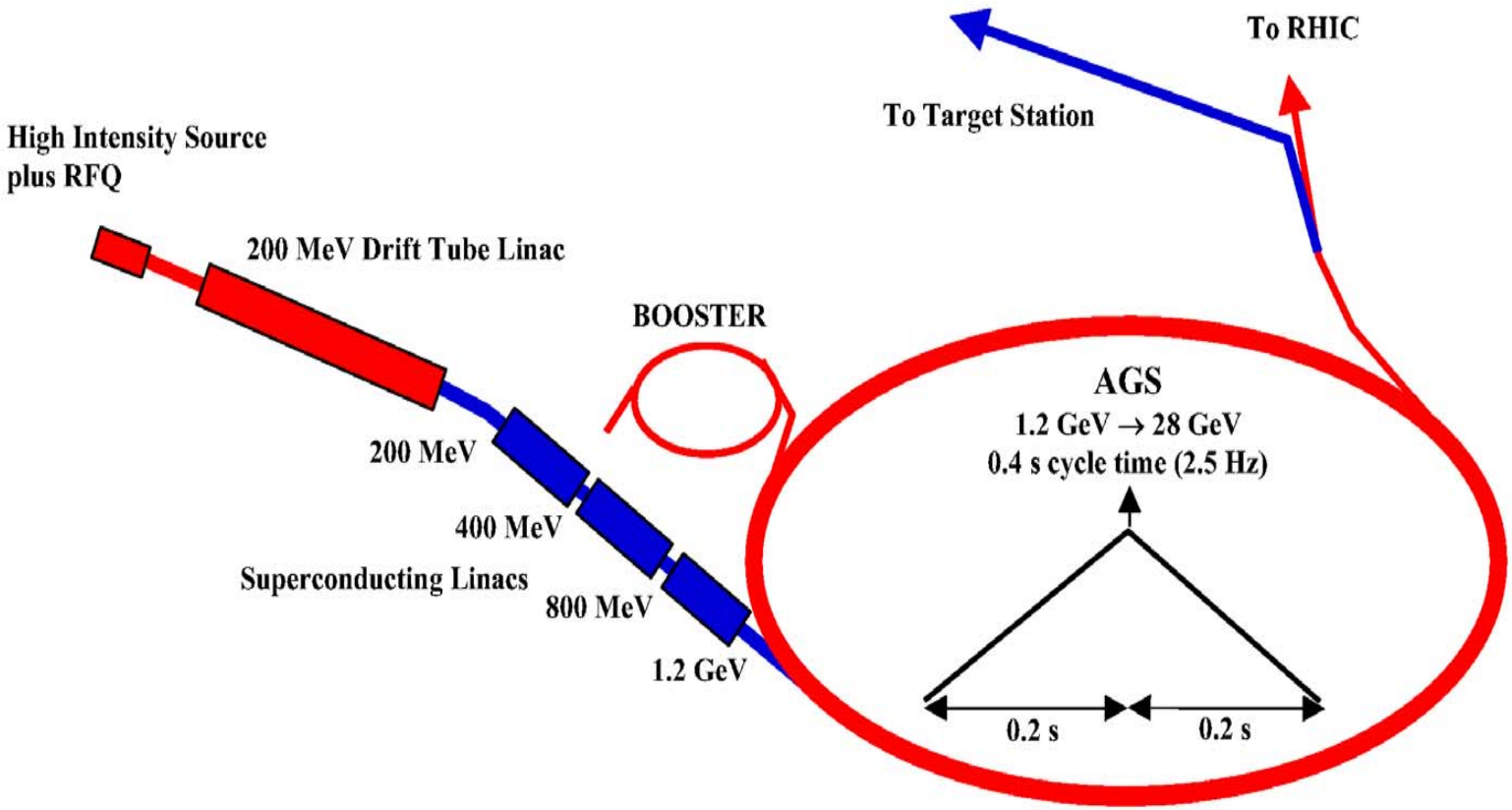
- even if $\sin^2 2\theta_{13} = 0$, the current best-fit value of $\Delta m_{21}^2 = 7.3 \times 10^{-5}$ induces a ν_e appearance signal
- the size of the ν_e appearance signal above background depends on the value of Δm_{21}^2; the figure left indicates the range of possible measured values for the ν_e yields above background for various assumptions of the final value of Δm_{21}^2

Mass-ordering and CP-violation Parameter δ_{CP}



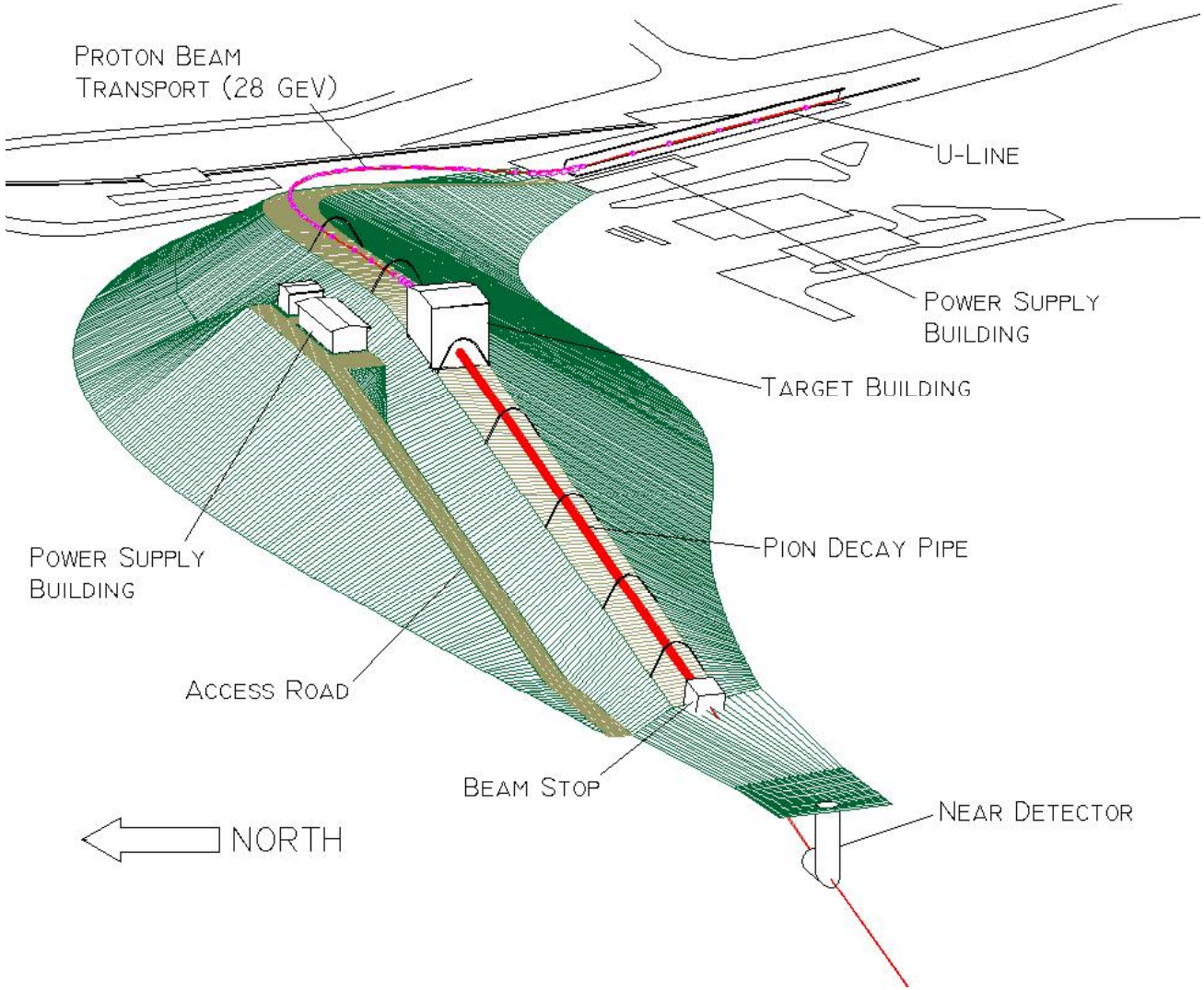
- the CP-violation parameter δ_{CP} can be measured in the VLB exp. And is relatively insensitive to the value of $\sin^2 2\theta_{13}$
- the mass-ordering of the neutrinos is determined in the VLB exp; $\nu_1 < \nu_2 < \nu_3$ is the natural order but $\nu_1 < \nu_3 < \nu_2$ is still possible experimentally; VLB determines this, using the effects of matter on the higher-energy neutrinos
- if $\sin^2 2\theta_{13}$ is smaller than 0.01, a muon neutrino factory could lower the sensitivity to as low as 10^{-4}

AGS Target Power Upgrade to 1 MW



- the *AGS Upgrade* to provide a source for the 1.0 MW Super Neutrino Beam will cost $265M FY03 (TEC) dollars

3-D Neutrino Super Beam Perspective



HEP Budgets and Waste Management

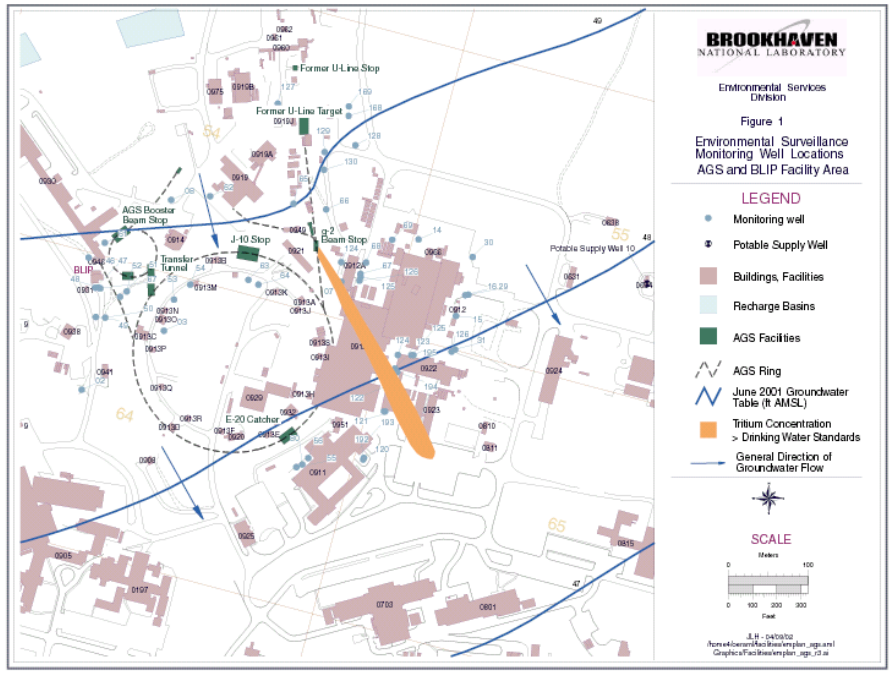
- Waste Management funding need continues at BNL for HEP topics

- Budget Issues

  - BNL has four budget issues that impede and limit our program:
    1. **money - base operating funding continues to fall in FY03 and FY04**
    2. **money - AGS has been "terminated" for HEP in spite of DOE promises**
    3. **money – new projects blessed by DOE-SC (like *QCDOC*) are still in doubt**
    4. **money - will DOE provide the needed level of support for LHC operations**

  - 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 are lagging expectations: ***CDF***, ***D0*** and ***Mini-Boone***
    AGS has 2 important exps. that should be added: ***E-949*** and ***Muon (g-2)***

Tritium Groundwater Contamination and Routine Monitoring Cost



FY	AGS	RHIC	Total
2000	$81,400	$22,700	$104,100
2001	$68,100	$13,500	$81,600
2002	$62,100	$10,000	$72,000

g-2 Plume Options (2003 $)

- No action
- 18-year monitoring, institutional controls ($1.4 M)
- 6-year monitoring, recharge and re-circulate ($1 M)
- 18-year monitoring, hot-spot contingency ($1.7 M)
- 32-year monitoring, HFBR remediation system ($1.8 M)

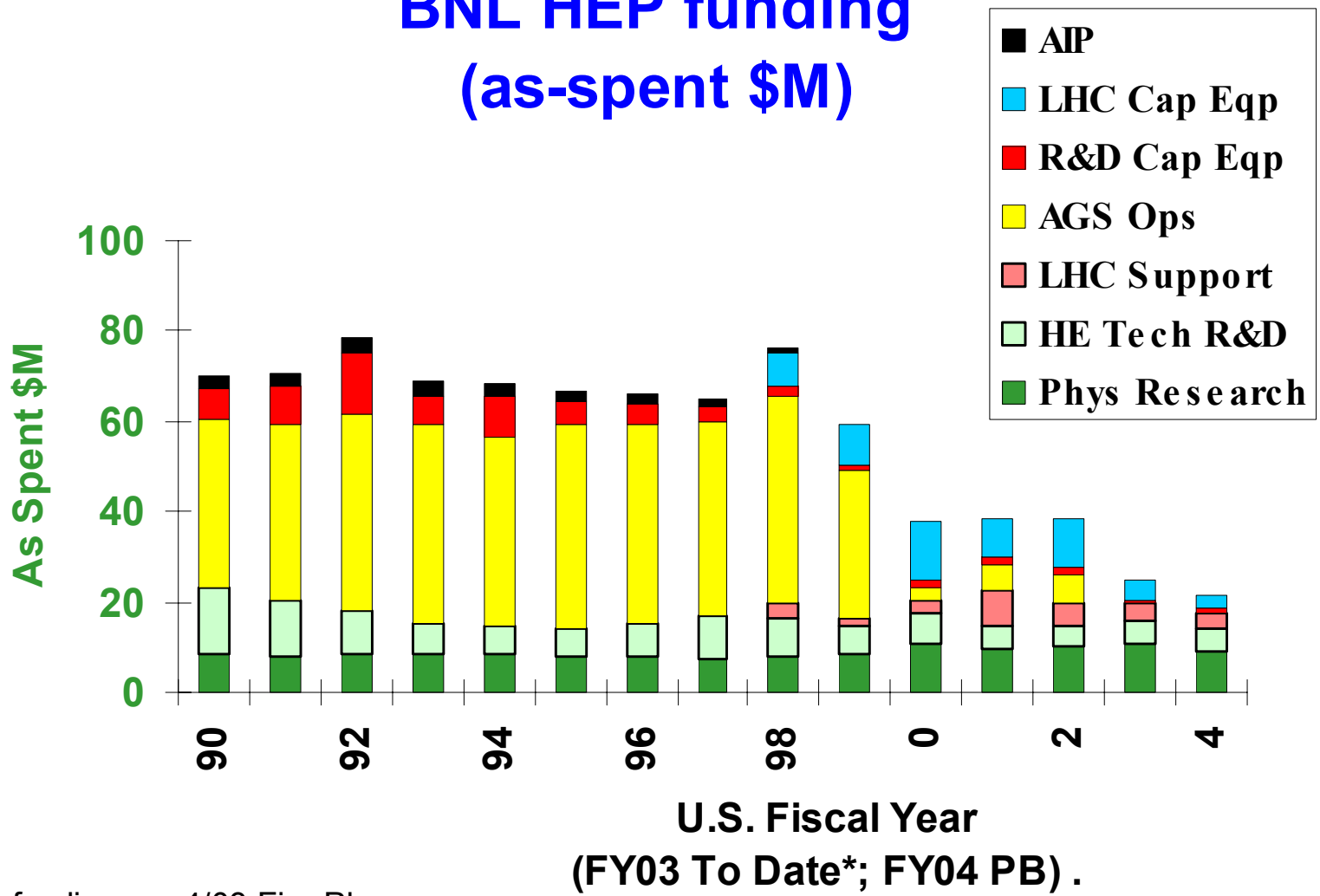
Choice of option is by DOE, with public and EPA input

Projected Rate of HEP Legacy Work

- Annual C-AD average is 3500 cu-ft of solid low-level radioactive waste
- This average is expected to continue due to large volume of residual waste from prior HEP operations
- HEP waste and groundwater monitoring cost is *$650,000 per year for at least 10 years**
- The cost to HEP is incremental

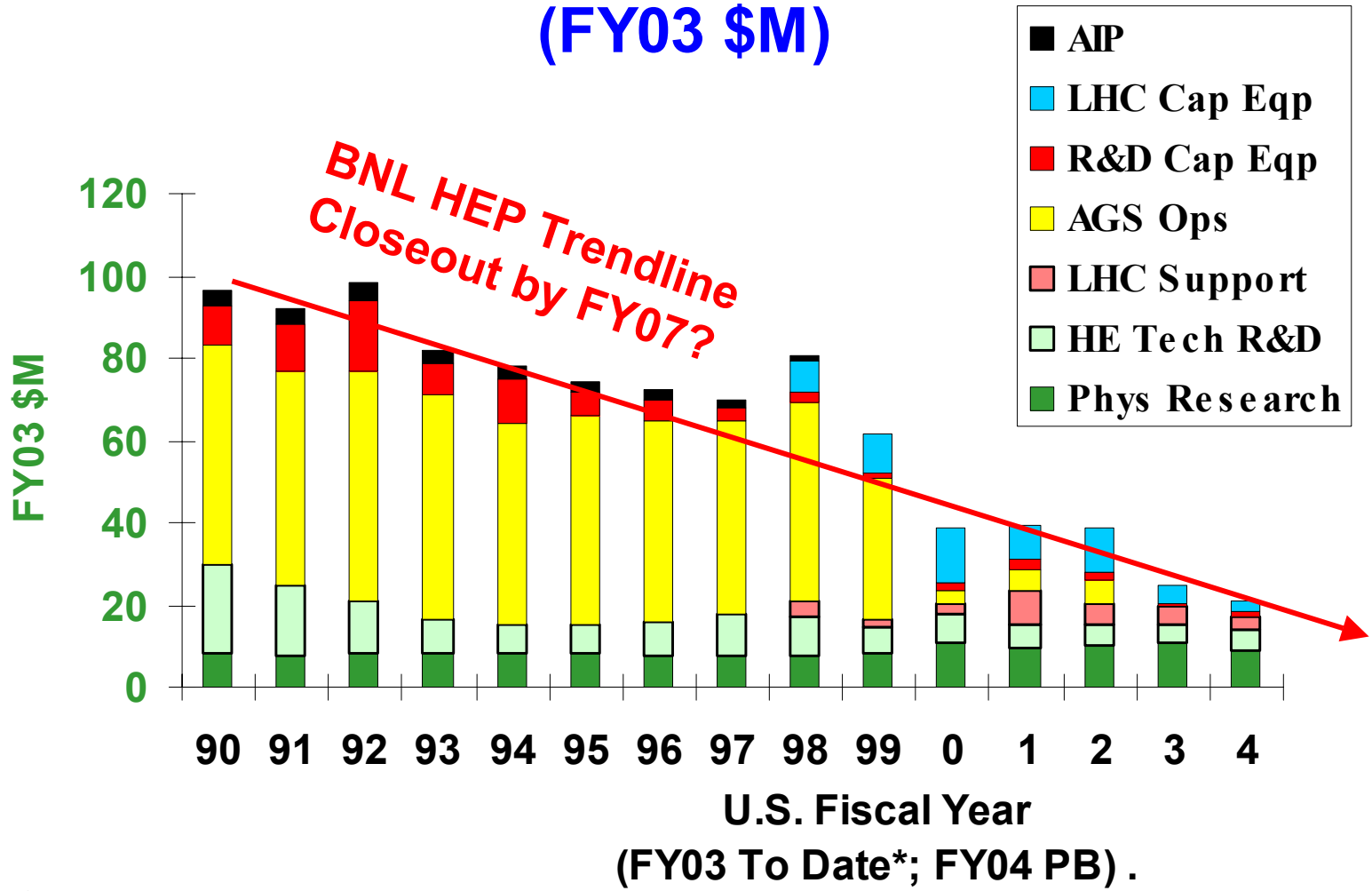
* This is the bottom line for HEP Waste Management at BNL and is going ahead in FY03.

BNL HEP funding (as-spent $M)



* FY03 funding per 4/03 Fin. Plan

BNL HEP Funding
(FY03 $M)



* FY03 funding per 1/03 Fin. Plan

HEP Budgets at BNL & Revised Request by B&R

Budget Category (Ops + Equip)	FY02 Actual ($M)	FY03[1] Actual ($M)	FY04P[2] P. Bud ($M)	FY04R[3] C. Rev ($M)
KA 11 01, 02 (Research)				
Phys Research	7.76	**8.30**[4]	**7.76**[4]	**9.16**
ATLAS R&D/Constr. Ops.	3.22	2.44	**1.30**	**5.60**
LHC Accel. R&D/Constr. Ops.	1.90	**1.60**	**1.90**	**2.10**
AGS Facil. Ops.	6.05	**0.00**	**0.00**	**8.30**
LHC Cap Eqp.	10.83	4.98	2.80	2.80
KA 14 01 01, 03 (Theory)	2.23	2.35	**2.43**	**2.83**
KA 15 01, 02 (Accel. R&D)				
Accel. Test Facil. (ATF)	1.68	1.83	**2.14**	**2.24**
Genl. Accel, + Det. R&D	1.66	1.82	**1.68**	**2.27**
Linear Coll + Muon R&D	1.55	**0.95**	**0.96**	**3.66**
KA 11, 15 (non-LHC Cap Eqp)	1.79	0.30[4]	0.19[4]	0.19
Total HEP Funding	38.67	24.57	21.16	**39.15**
AGS Weeks (SEB/FEB)	10+0	***0*+*0***	***0***+0	**25**+0

[2] January 2003 DOE Fin. Plan, w/o Waste Mgmt.

[3] BNL Contractor's Revised Request in FY05 Field Work Proposal

[2] FY 2004 President's Budget

[4] Trade-in Equip for Ops funding

BNL Impacts of FY03,04 Planning Budgets

- **BNL staff in the Physics Department will be reduced by 13 FTEs, in FY03 and 5 FTEs in FY04 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

  Experimental research efforts that will be curtailed:

  CKM, g-2, EDM, AGS experiment data runs

  Experimental research efforts that cannot be started:

  VLB Neutrino 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 FY03, 04 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 could be headed towards zero in future years**

  High-Power Target R&D runs at AGS on-hold

BNL Impacts of FY03 President's Budget (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 not supported in FY04**
- **What to do???**

"The breadth of the scientific problems we must attack requires, however, a diverse portfolio of experimental techniques." HEPAP Chair, Fred Gilman, to SC Director, Ray Orbach, in a March 10, 2003 letter reporting the outcome of the Office of Science Facilities Review