

Report to NSAC

Subcommittee on
Fundamental Physics with Neutrons

September 13, 2003



Today

- Science and Facilities discussed - 5/30/03
- **Report provides details!**
- Synopsis – science issues and facilities
- Four Subcommittee Recommendations
 - present program
 - future initiatives
 - theory
- Budget Impact

Subcommittee

- David Hertzog
- Roy Holt
- June Matthews
- Mike Pendlebury*
- Michael Ramsey-Musolf
- Robert Tribble (chair)
- John Wilkerson
- Rick Casten (ex-officio)

The Charge

The recent NSAC Long-Range Plan identified and recommended pursuit of promising new initiatives in fundamental physics with neutrons. Further guidance is requested at this time in the implementation of this recommendation. It is important that the available resources are directed to optimize investments by NSF and DOE for a strong national research program in this scientific area for the coming decade.

The Report

Your report should **identify the most compelling scientific opportunities**, and the infrastructure and effort required to address them. Your assessment should be **placed in the context of scientific efforts and capabilities in the United States and elsewhere**. It should **establish priorities for these opportunities with constant level of effort at the FY 2004 DOE Nuclear Physics Congressional Request level**, and **recommend priorities for further investment with additional funds beyond this level**. In dealing with the proposed activities at the various funding levels, guidance regarding the appropriate mix of facility operations, research, investments in instrumentation and R&D to optimally exploit these opportunities should be provided.

Meetings

- Los Alamos National Laboratory
April 17 - 18
LANL program, PULSTAR and LENS
- Oak Ridge National Laboratory
April 23 - 24
SNS program, NIST program
- NSF headquarters – committee discussion
May 9

The Science

- **Standard Model** tests and new physics
 - CKM unitarity, L-R symmetry, Supersymmetry, ...
 - Time reversal invariance, CP violation
 - S/T interactions
- **Hadronic weak interaction** parameters
 - few nucleon system \Rightarrow excellent 'laboratory'
 - effective field theory approach to problem
 - applications to many body systems (double β decay)

Measurements

- Properties of the neutron
 - τ_n
 - electric dipole moment – EDM
 - decay correlation coefficients
- Hadronic weak interaction
 - parity violation in neutron capture and neutron spin rotation

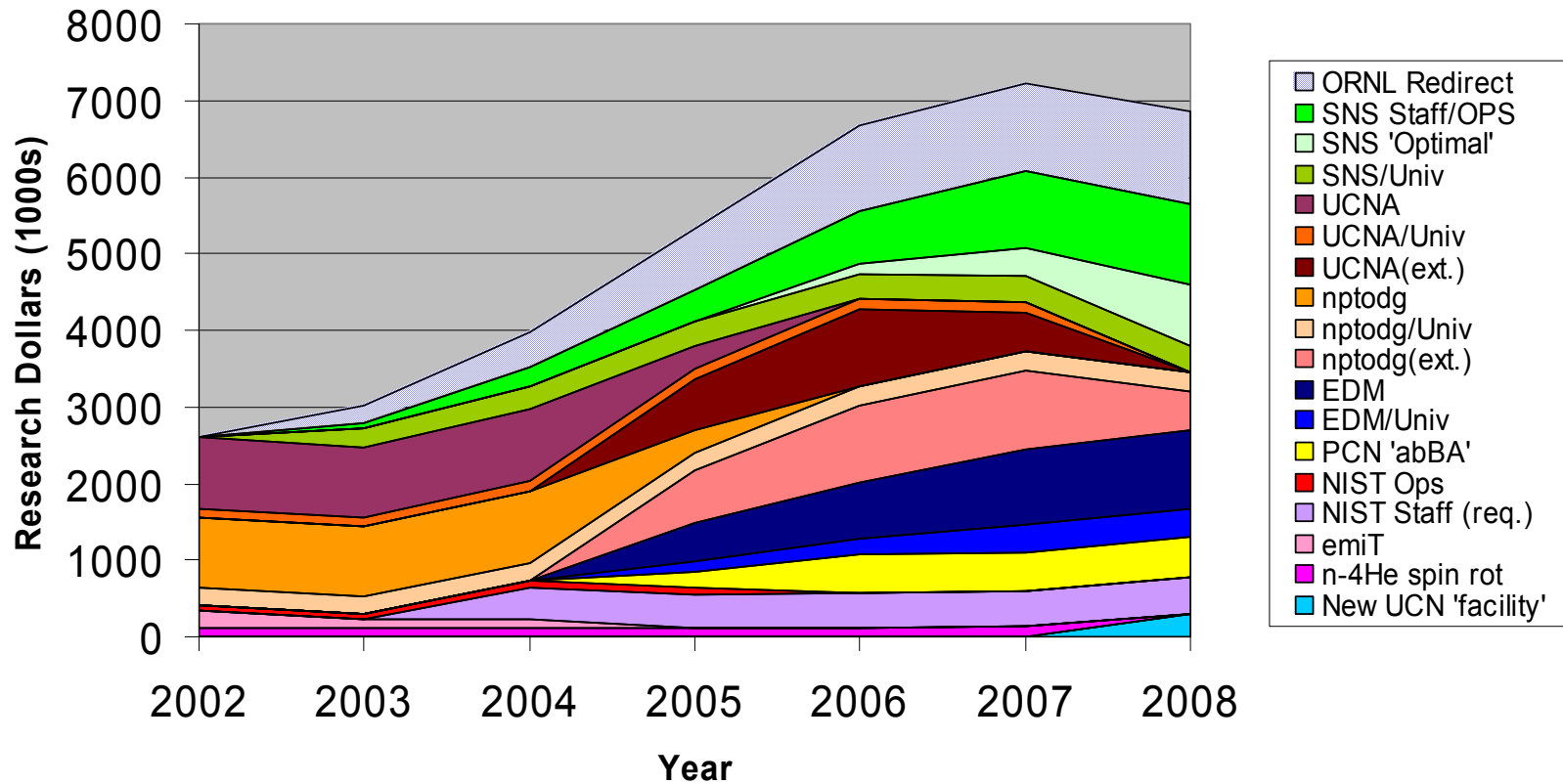
Science Summary

- Ongoing programs at LANL and NIST
 - $\vec{n} + p \rightarrow d + \gamma$, UCN-A, emiT, τ_n , n spin rotation, ...
- New proposals at LANL and NIST
 - EDM, correlation coefficients ($abBA$, a , b , $A+B$), PV, ...
- SNS program

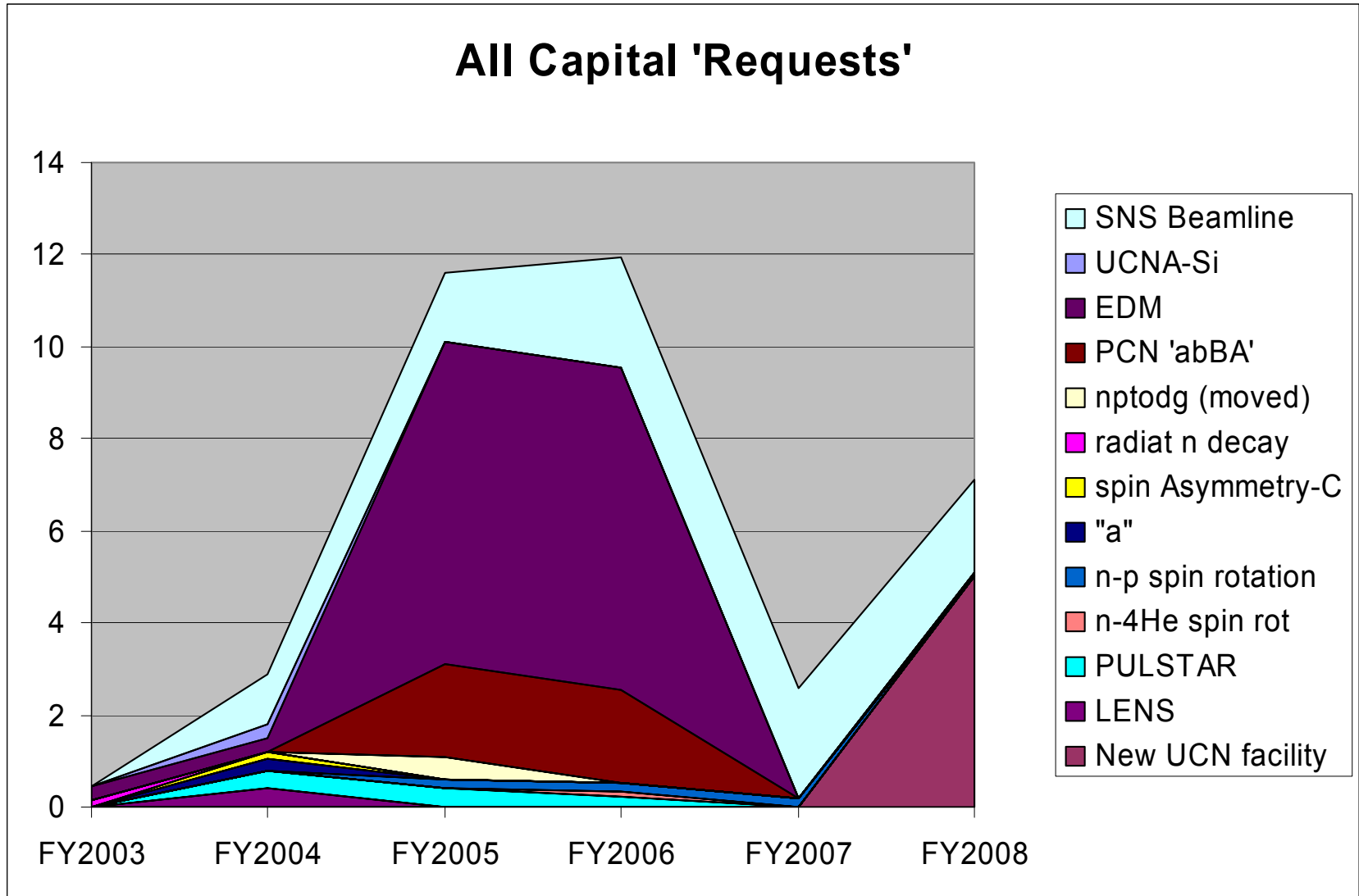
[Resources: DOE, NSF, Lab and University funding]

DOE Research 'Requests'

Required DOE Operations Funding



Capital Equipment Requests



The Problem

Positives:

- Excellent science program
- Cost effective with accelerator ops. paid by BES/NNSA

Negative:

Not enough resources - \$\$ - to carry out the proposed program!

The Choices

- **LANL/LANSCE** experiments
 - UCN-A (about to run) and extensions
 - $\vec{n} + p \rightarrow d + \gamma$ (about to run)
 - EDM (development - SNS)
 - abBA - correlation experiment (development - SNS)
- **NIST** experiments
 - τ_n
 - 'D' coefficient/emiT (nearly complete)
 - n spin rotation in liquid He (in progress)
 - 'a' coefficient (proposal/development)
 - proton asymmetry – 'A' + 'B' (proposal/development)
- **SNS** beam line and future program

Subcommittee Conclusions

- Four recommendations
- But must consider in context of budget scenarios.

Present Program

- The US has an active program in fundamental physics with neutrons using cold and ultracold neutrons at LANSCE and NIST where measurements of neutron β decay and hadronic parity violation are underway. It is important to successfully complete the commissioning of the two major experiments that are poised to begin operation at LANL. The subcommittee urges the groups in these experiments to focus their efforts on them. The subcommittee strongly recommends that the existing program at NIST continue.

EDM Experiment

- The EDM experiment has the highest discovery potential of all proposed experiments. The subcommittee strongly supports it. We encourage the collaboration to address the technical issues surrounding this experiment and recommend R&D funding be provided to accomplish this.

[**UCN** beam line needed at **SNS**]



SNS beam line

- We recommend the construction of the cold beam line at the SNS and the program of measurements in fundamental neutron science that it can support. We further recommend that provision be made for the construction of an ultracold neutron beam line.

{ORNL - support needed for beam line operations}

Theory Support

- ~6 FTE senior theorists in the US working on fundamental symmetries
- problems (just) in fundamental physics with neutrons that need (a lot of) work
 - hadronic contributions to radiative corrections in β decay
 - few-body parity-violating observables
 - connection between EDM and BAU
 - . . .

Theory Support

- Resources should be allocated or redirected to increase the size of the theoretical community associated with fundamental symmetries with effort directed to neutron physics. Such growth could occur through the creation of new senior theory positions at laboratories and at universities where there are strong experimental efforts, faculty bridge positions involving laboratories and universities, and post-doctoral positions in theory groups addressing issues relevant to the fundamental neutron physics program.

Reality Check – DOE Budgets

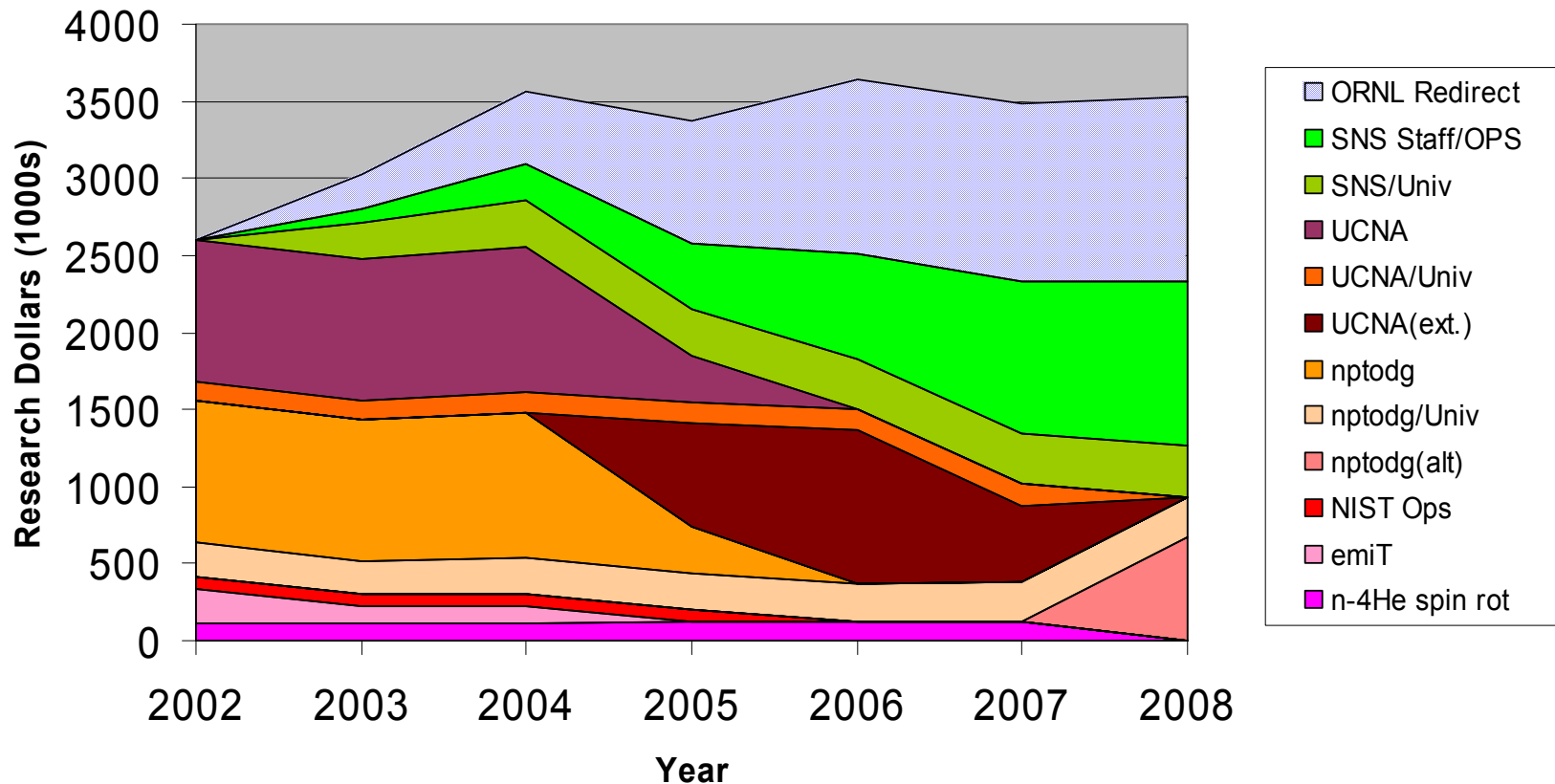
Funding *Scenario 1*

- Funding at base program level (~ \$2.5 M/yr for research and operations, \$2 M/yr for capital)

The EDM measurement is dropped. The SNS cold beam line is built over a time period dictated solely by the available funding. The current experimental program at LANL is significantly reduced. The subcommittee recommends, based on the near term physics impact and present experimental status, that priority be given to complete the UCN-A experiment and its follow up measurements. Consequently the neutron capture asymmetry experiment ($\bar{n} + p \rightarrow d + \gamma$) is delayed and becomes the first effort at the SNS. This would be followed by other hadronic PV measurements that would move from NIST. Money for new experiments at the SNS, e.g. new correlations experiments, or new hadronic PV experiments, is delayed with significant funding available only after beam line construction is completed.

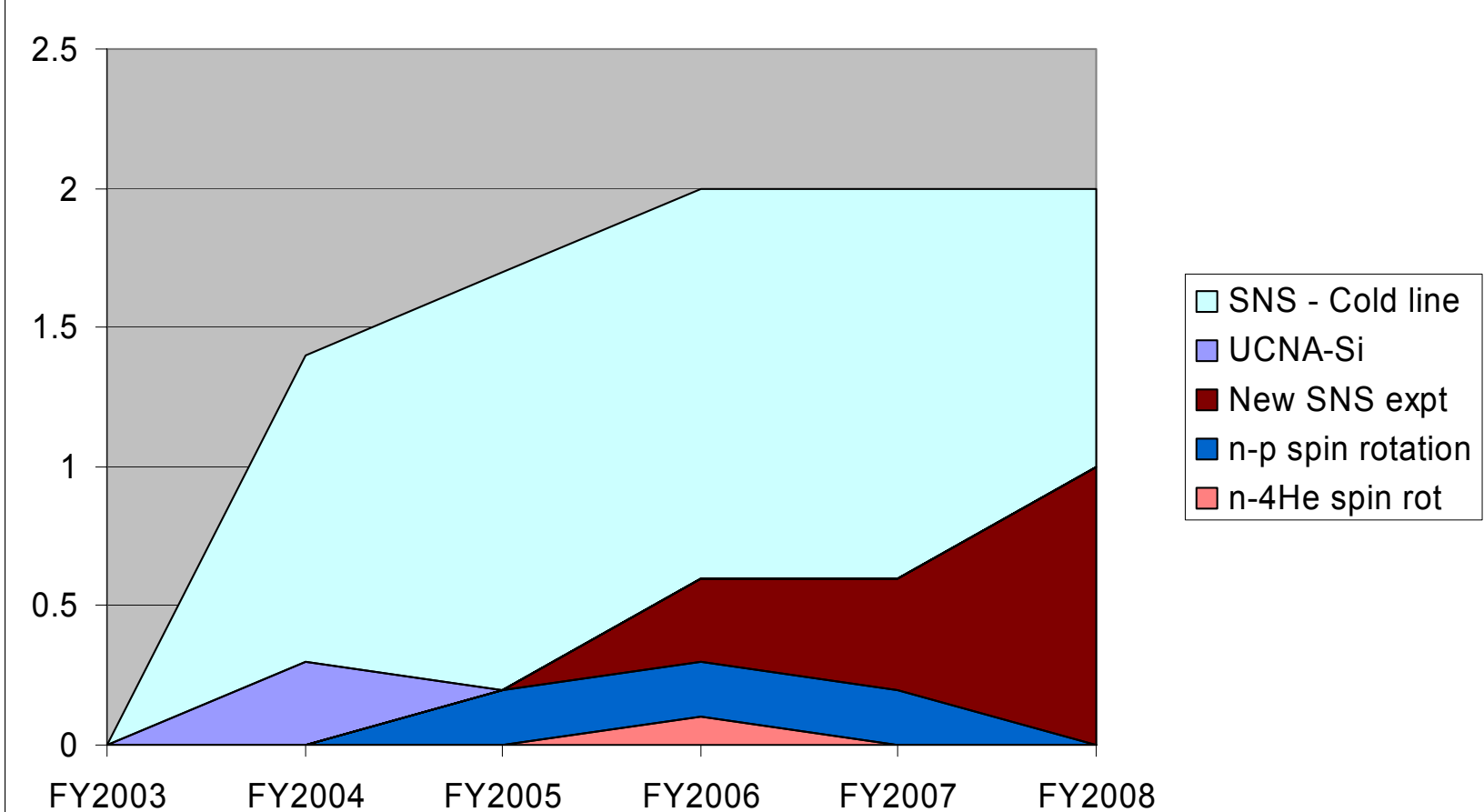
DOE Research

DOE BASE Program Operations



DOE Capital

DOE Base Program Capital



Reality Check – DOE Budgets

Funding *Scenario 2*

- Funding at base program level **and** additional funding for EDM experiment

This scenario would provide for the top priority experiment to be carried out. But the remaining program would have the same restrictions as shown in *scenario 1*. The staging of the EDM experiment with initial running at LANSCE followed by a move to the SNS, as presently proposed, would depend on the level of support available and the status of the beam line at LANSCE.

Reality Check – DOE Budgets

Funding *Scenario 3*

- Increase in base program level by 20% **but** no funding for EDM experiment

If either the R&D for the EDM experiment is not successful or monies for the project cannot be found, additional funding for the base program would provide much needed support allowing operations funding for the new SNS beam line to begin without severely impacting the existing program. This additional support would allow continued funding for the experiment at LANL without the delays imposed under *scenario 1*. Construction of the cold beam line at the SNS proceeds expeditiously. The NIST program continues and is provided with appropriate support to ensure efficient use of its facilities. This funding profile would provide sufficient manpower to carry out the full set of parity violation experiments that are needed to constrain the model parameters and to simultaneously begin developing a new generation decay correlation experiment.

Reality Check – DOE Budgets

Funding *Scenario 4*

- Increase in base program level by 20% **and** additional funding for EDM

This combines the positive features of scenarios 2 and 3. Here funds are available for the EDM experiment to evolve in two stages, as proposed. Initially, it is constructed and run at LANL (subject to a demonstrated adequate flux of neutrons). Assuming success, the UCN beam line at SNS is completed and the EDM measurement is moved to the SNS for stage 2.

Summary

- **First-rate** science program!
- **No** associated **NP** facility
(cost effective use of BES/NNSA facilities)
- Modest budget for entire effort
- Subcommittee urges expanding program!

One Change in Wording

(on page 6)

What is the character of the neutrino and what is the origin of its mass?

Neutrino oscillation experiments have clearly established the existence of a non-vanishing neutrino mass, and, therefore, the existence of right-handed neutrinos. Since right-handed neutrinos are “sterile” with respect to all the interactions of the minimal SM, the origin of the neutrino mass cannot be explained in this framework. At the same time, we do not know whether the neutrino is its own anti-particle, as suggested by many models for massive neutrinos. Both experimental and theoretical studies of hadronic parity violation are **[important]** **{essential}** to understand neutrinoless $\beta\beta$ decay so that the mysteries of the neutrino can be revealed.

{Thanks to A. Garcia!}

