NSAC Subcommittee Report

Implementing the 2007 Long Range Plan

Robert E. Tribble

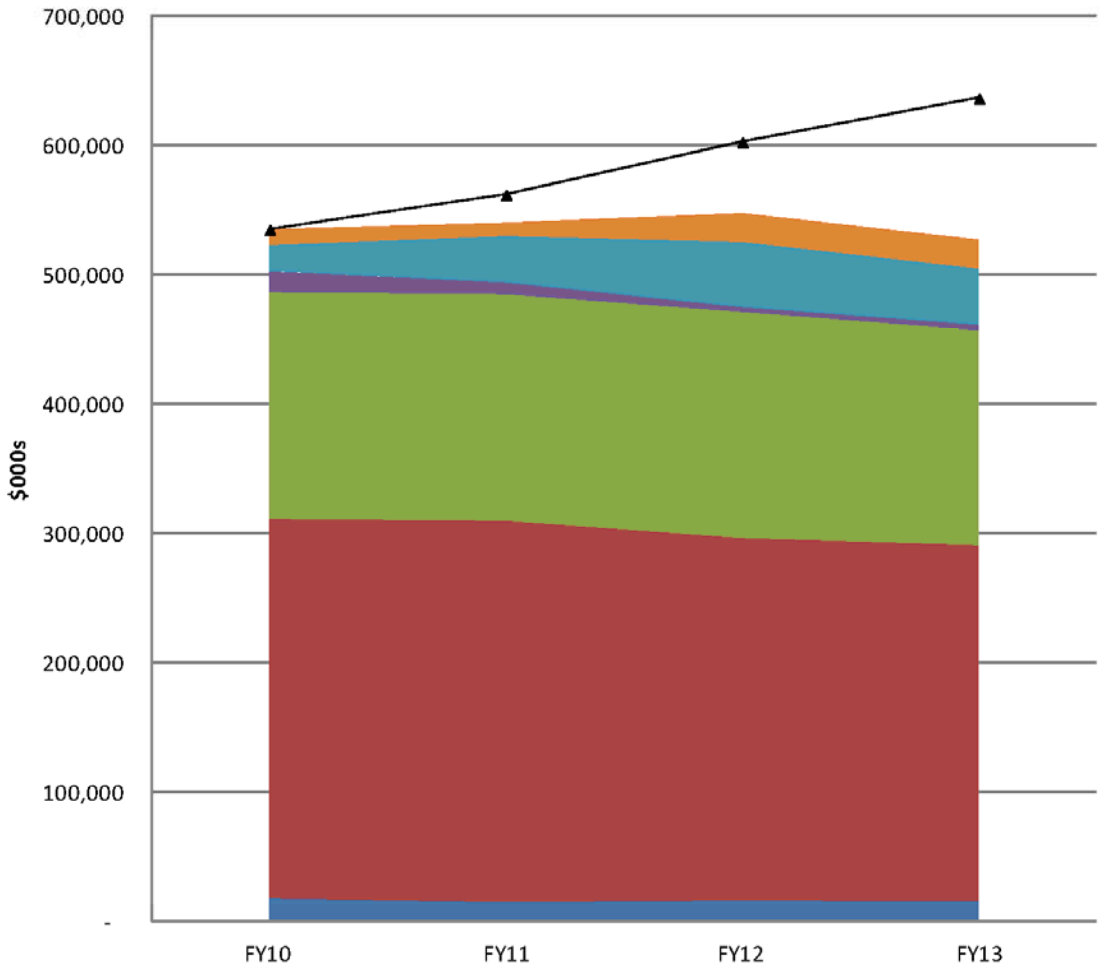
Texas A&M University

January 28, 2013

TEXAS A&M UNIVERSITY

The Budget Problem

Office of Nuclear Physics FY 2013 Congressional Request



This chart reflects the enacted FY 2010-FY 2012 appropriations and the FY 2013 Congressional Request for the Nuclear Physics program.

- FRIB
- 12 GeV Upgrade
- MIEs/Other Projects
- Research
- Facility Operations
- Other
- ~ LRP implementation

The black line represents estimated funding needed to implement the majority of elements of the NSAC 2007 Long Range Plan (LRP).

U.S. Department of Energy
and the
National Science Foundation

April 5, 2012

Dr. Donald Geesaman
Chair
DOE/NSF Nuclear Science Advisory Committee
Argonne National Laboratory
9800 South Cass Avenue,
Argonne, Illinois 60439

Dear Dr. Geesaman:

In 2007 the Department of Energy (DOE)/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) completed work on a Long Range Plan for nuclear science for the decade. This plan provided a roadmap for the development of new and existing facilities to maintain U.S. leadership in nuclear science, including completion of the 12 GeV CEBAF Upgrade at Jefferson Lab, and construction of the Facility for Rare Isotope Beams (FRIB). The plan also recommended a targeted program of experiments on fundamental symmetries and a luminosity upgrade to determine the properties of a new state of matter discovered at the Relativistic Heavy Ion Collider. The NSAC identified the need to maintain funding above the FY 2007 constant-effort level to effectively utilize the nuclear science program's facilities, mount strong university and theory programs, and develop new research capabilities.

DOE and NSF are making significant progress toward achieving the vision of the 2007 Long Range Plan for Nuclear Science. However, DOE and NSF now seek your advice to continue the vision in the Plan so that the recommendations can move forward in light of projected constrained budgets.

We seek advice from NSAC on implementing the priorities and recommendations of the 2007 Long Range Plan in light of projected budgetary constraints and for guidance on developing a plan to implement the highest priority science in the context of likely available funding and world-wide capabilities. We request that NSAC examine the existing research capabilities and scientific efforts, assess their role and potential for scientific advancements, and advise the two agencies regarding the time and resources needed to achieve the planned programs. Your report should describe how to optimize the overall nuclear science program over the next five years (FY 2014-2018), under at least the following funding scenarios for the nuclear science budgets at the two agencies: (1) flat funding at the FY 2013 request level, and (2) modest increases over the next five years.

Based on the priorities and opportunities identified and recommended in the 2007 Long Range Plan, the report should discuss what scientific opportunities will be addressed, and what existing and future facilities and instrumentation capabilities would be needed by the Federal nuclear science program to mount a productive, forefront program for each of the funding scenarios.

NSAC should submit the report by January 2013. We are aware that this is a difficult task. However, the involvement and input of the research community is essential to inform the Department's decisions regarding the strategy for implementing a world-leading U.S. Nuclear Physics program in times of fiscal constraint.

Sincerely,

W. F. Brinkman
Director
Office of Science

Edward Seidel
Assistant Director
Directorate for Mathematical
and Physical Sciences

Report Appendix

Charge from NSAC to the subcommittee

Donald F. Geesaman
Distinguished Argonne Fellow
1-630-252-4059 phone
1-630-252-3903 fax
geesaman@anl.gov

Physics Division
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 203
Argonne, IL 60439-4845

May 1, 2012

Prof. Robert Tribble
Cyclotron Institute
Department of Physics and Astronomy
4242 Texas A & M University
College Station, TX 77843-4242

Dear Bob,

As you know William Brinkman, Director of the Office of Science at DOE, and Edward Seidel, Associate Director for the Directorate of Mathematical and Physical Sciences at the NSF, have charged NSAC to provide advice on implementing the priorities and recommendations of the 2007 NSAC Long Range Plan in light of projected budgetary constraints and for guidance on developing a plan to implement the highest priority science in the context of likely available funding and world-wide capabilities.

The charge, of which you have a copy, asks that the report should describe how to optimize the overall nuclear science program over the next five years (FY2014-2018) under at least two budget scenarios: (1) flat funding at the FY2013 request level and (2) modest increases over the next five years.

I am writing to formally ask you to serve as the Chair of an NSAC subcommittee to consider this charge and report back to NSAC. The work of this subcommittee is of utmost importance for the future of nuclear science, both for the U.S. and the international science community. Based on the priorities and opportunities identified and recommended in the 2007 Long Range Plan, the report should discuss what scientific opportunities will be addressed and what existing and future facilities and instrumentation capabilities would be needed to mount a productive forefront program for each of the funding scenarios. It should also present what opportunities would be lost in each scenario. These opportunities should include the impact on education and training of the workforce in nuclear science.

The time scale of the charge requires NSAC to submit its report by January 2013. Therefore I must ask your subcommittee to submit its report to NSAC by 7 January 2013. I realize this is a heavy responsibility. I and our whole community will, once more, owe you an enormous debt of gratitude.

Sincerely yours,

Donald F. Geesaman

Report Appendix

Subcommittee Membership

Joseph Carlson – LANL

Brad Filippone – Caltech

Stuart Freedman* – UCB & LBL

Haiyan Gao – Duke

Donald Geesaman – ANL (ex officio)

Barbara Jacak - SUNYSB

Peter Jacobs - LBL

David Kaplan – UW and INT

Kirby Kemper – FSU

Krishna Kumar – U Mass

Naomi Makins – U Illinois

Curtis Meyer – CMU

Jamie Nagle – CU

Witold Nazarewicz – UT & ORNL

Krishna Rajagopol – MIT

Michael Ramsey-Musolf – U Wisc

Lee Sobotka – Wash U

Robert Tribble (chair) – TAMU

Michael Wiescher – ND

John Wilkerson – UNC

Adam Burrows – Princeton

George Crabtree – ANL

*Deceased

Report Appendix

[Posted on subcommittee website: http://cyclotron.tamu.edu/nsac-subcommittee-2012/]

TEXAS A&M UNIVERSITY

Subcommittee Activities

- Meeting in DC – May, 2012
  - organization meeting

Subcommittee May Meeting

May 15, 2012

Meeting schedule:

08:00 – 0:830 – Welcome and introductions – Don G., Robert T. and subcommittee members

08:30 – 0:915 – Mission, Vision, and Research – T. Hallman

09:15 – 10:05 – Facilities and Initiative – J. Gillo

10:05 am – 10:30 – Break

10:30 am – 11:15 – NSF Program and Budget – B. Keister

11:15 – 15:00 – Subcommittee Discussion

Outcomes: (1) outlined program for second meeting
(2) created questions to guide presentations
(3) discussed report structure
(4) after discussion, added way to post comments on website (http://cyclotron.tamu.edu/nsac-subcommittee-2012/)

Subcommittee Activities

- Meeting in DC – May, 2012
  - organization meeting
- Meeting in DC – September, 2012
  - overview of program (pointed questions)

Subcommittee September Meeting

Friday, September 7

RHI

08:00 – 08:45 – W. Zajc, RHI Overview

08:45 – 09:00 – S. Aronson, BNL Strategy

09:00 – 09:45 – S. Vigdor, RHIC Plans

09:45 – 10:15 – U. Wiedemann, Theoretical Issues and LHC Perspective

10:15 – 10:30 – Coffee Break

10:30 – 11:00 – P. Sorenson, Soft Probes

11:00 – 11:30 – Y. Akiba, Hard Probes

11:30 – 11:45 – S. Vigdor, Wrap Up

11:45 – 12:30 – Executive Session with RHIC management

Subcommittee September Meeting

Friday, September 7

Fundamental Symmetries and Neutrinos

13:30 – 14:15 – Fundamental Symmetries overview – M. Ramsey-Musolf

14:15 – 15:00 – Neutrinos overview – H. Robertson

15:00 – 15:20 – JLab Parity experiments – K. Paschke

15:20 – 15:40 – EDM overview – B. Filippone

15:40 – 16:10 – Other FS experiments – D. Hertzog

16:10 – 16:40 – $\beta\beta$-decay overview – S. Freedman

16:40 – 17:15 – Neutrino experiments – K. Heeger

17:15 – 18:00 – Executive Session with questions to focus on FS&N

Subcommittee September Meeting

Saturday, September 8

Medium Energy Physics

08:00 – 08:45 – R. Holt, MEP overview

08:45 – 09:05 – R. Ent, JLab Recent Accomplishments

09:05 – 09:35 – R. McKeown, JLab Future Science Program

09:35 – 09:55 – J. Dudek, Meson Spectroscopy and GlueX

09:55 – 10:15 – M. Guidal, Nucleon Imaging

10:15 – 10:30 – Coffee Break

10:30 – 10:50 – C. Rode, 12 GeV Project Status

10:50 – 11:10 – A. Hutton, Accelerator Science

11:10 – 11:30 – A. Lung, Budget Impacts

11:30 – 11:45 – H. Montgomery, Summary and Outlook

11:45 – 12:30 – Executive Session with JLab management

Subcommittee September Meeting

Saturday, September 8

Low Energy – FRIB/NSCL

13:30 – 14:15 – David Dean, LE (NS&NA) overview

14:15 – 14:35 – K. Gelbke, FRIB Laboratory Overview

14:35 – 15:00 – T. Glasmacher, FRIB Project

15:00 – 15:15 – A. Gade, FRIB Science – Nuclear Structure and Reactions

15:15 – 15:30 – H. Schatz, FRIB Science – Nuclear Astrophysics

15:30 – 15:40 – Z. Lu, FRIB Science – Fundamental Symmetries

15:40 – 15:50 – G. Bollen, FRIB Science – Applications of Isotopes

15:50 – 16:05 – Discussion of FRIB Science

16:05 – 16:20 – Break

16:20 – 16:35 – B. Sherrill, Uniqueness of FRIB

16:35 – 16:50 – D. Leitner, NSCL Capabilities and Operations

16:50 – 17:15 – P. Mantica, NSCL Science Program and Results

17:15 – 18:00 – Executive Session with FRIB management

Subcommittee September Meeting

Sunday, September 9

Low Energy, Nuclear Astrophysics, Theory, and Computation

08:00 – 08:30 – ATLAS – G. Savard

08:30 – 09:15 – ARUNA – I. Wiedenhoever

09:15 – 10:00 – Nuclear Astrophysics (interface to NP) – A. Burrows, M. Wiescher

10:00 – 10:45 – Nuclear Theory – D. Kaplan

10:45 – 11:15 – Computational Physics – M. Savage

11:15 – 16:00 – Closed Executive Session and lunch

Subcommittee Activities

- Meeting in DC – May, 2012
  - organization meeting
- Meeting in DC – September, 2012
  - overview of program (pointed questions)
- Town Meetings at the Fall DNP Meeting
- Meeting in Newark – Nov/Dec, 2012
  - develop findings and recommendations

Subcommittee Resolution Meeting

Friday, November 30

08:00 – 08:45 LE/FRIB
08:45 – 09:30 Discussion
09:30 – 10:00 Break
10:00 – 10:45 Medium Energy/JLab
10:45 – 11:30 Discussion
11:30 – 11:00 Lunch
13:00 – 13:45 FS&N
13:45 – 14:30 Discussion
14:30 – 15:00 Break
15:00 – 15:45 RHI/RHIC
15:45 – 16:30 Discussion
16:30 – 16:45 break
16:45 – 17:30 Spreadsheet budgets
17:30 – 18:00 Workforce
18:00 – 18:30 Discussion

Subcommittee Resolution Meeting

Saturday, December 1

08:00 – 08:30 Theory
08:30 – 09:00 Discussion
09:00 – 09:30 Applications
09:30 – 10:00 Discussion
10:00 – 10:30 break
10:30 – 12:00 – discussion I: subcommittee recommendations, changes from LRP, research vs operations and construction, etc.
12:00 – 13:30 lunch
13:30 – 15:30 – discussion II: continuation of I, budget scenarios
15:30 – 16:00 break
16:30 – 18:30 budget discussion III: scenarios and conclusions
18:30 – 19:00 – homework assignments made

By the end of the day on Saturday

Subcommittee Resolution Meeting

Sunday, December 2

08:00 – 09:00 – review of decisions
09:00 – 12:00 – developing the wording of conclusions, recommendations, and content of closure statements
12:00 – 13:00 lunch
13:00 – 16:00 finish wording of conclusions and recommendations, review final report schedule

Subcommittee Activities

- Meeting in DC – May, 2012
  - organization meeting
- Meeting in DC – September, 2012
  - overview of program (pointed questions)
- Meeting in Newark – Nov/Dec, 2012
  - develop findings
- MANY emails

Report Structure

- Executive Summary
- Introduction (includes 2007 LRP recommendations)
- Nuclear Science—A Forward Look**

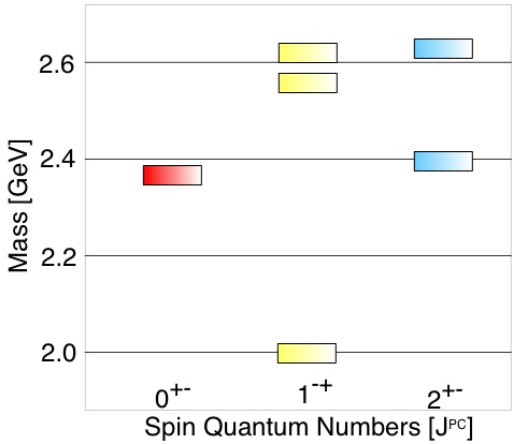
  Hadronic Physics; Science of Quark-Gluon Plasma; Nuclear Structure, Reactions, and Nuclear Astrophysics; Fundamental Symmetries and Neutrinos; Nuclear Theory, and Computational Nuclear Physics
- Facilities

  U.S.: Present and Future Large Facilities; Low-Energy Facilities; Underground Facilities; Large International Facilities: Europe, Asia, Others, Major Facilities in the Planning Stage
- Applications (focus on new applications)
- Nuclear Science Workforce
- Budget Options and the Future Program
- Appendices

Hadronic Physics

- Excitations of the gluon field - GLUEX

Lattice QCD Calculations of particles from gluonic excitations



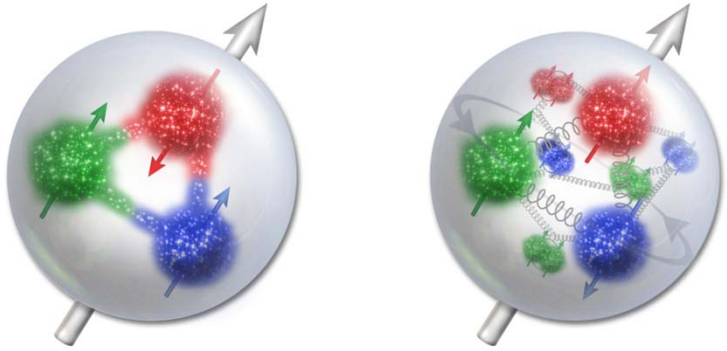
Hadronic Physics

- Excitations of the gluon field – GLUEX
- Generalized Parton Distributions and Transverse Momentum Dependent Distributions
  - A tomographic view of the proton
- Proton Spin
  - gluon and antiquark contributions from RHIC
  - orbital motion contributions from CEBAF

Hadronic Physics

- Proton Spin
  - gluon and antiquark contributions from RHIC
  - orbital motion contributions from CEBAF

Old view of spin on left, new understanding of spin on right



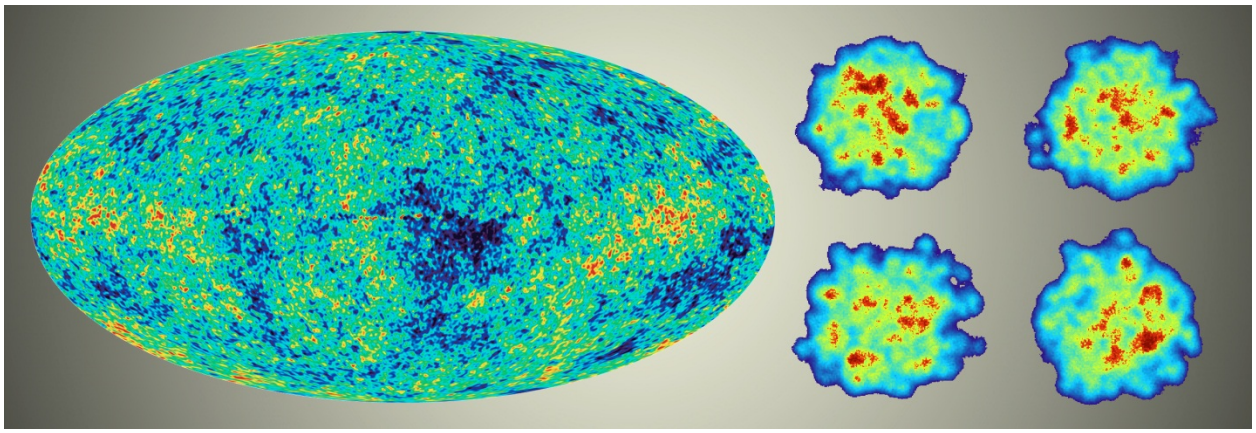
Hadronic Physics

- Excitations of the gluon field – GLUEX
- Generalized Parton Distributions and Transverse Momentum Dependent Distributions
  - A tomographic view of the proton
- Proton Spin
  - gluon and antiquark contributions from RHIC
  - orbital motion contributions from CEBAF
- Nuclei from QCD
  - nature of the short-range interaction
  - QCD inspired forces for nuclei

The Science of Quark-Gluon Plasma

- The role of quantum fluctuations in QGP

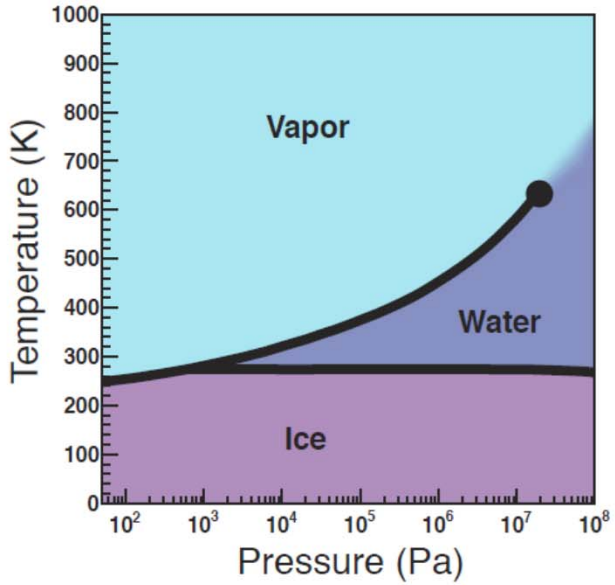
Simulations of heavy-ion collisions show variations in temperature compared to the temperature fluctuations in the early universe from WMAP.

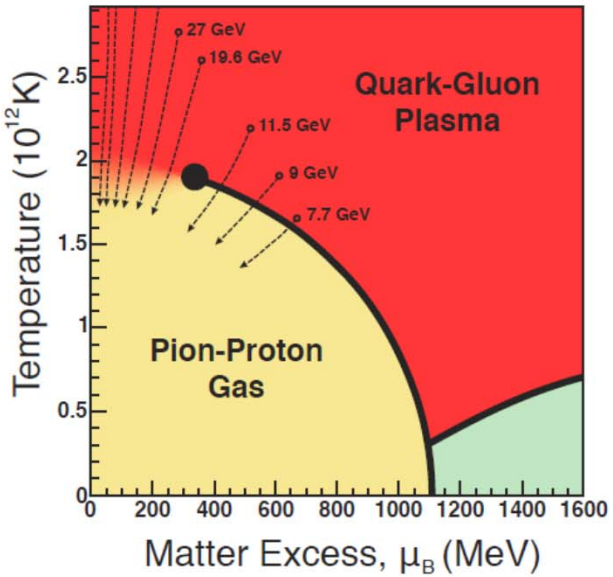


The Science of Quark-Gluon Plasma

- The role of quantum fluctuations in QGP
- Mapping phase diagram of nuclear matter
  - nature of the phase transition
  - is there a critical point

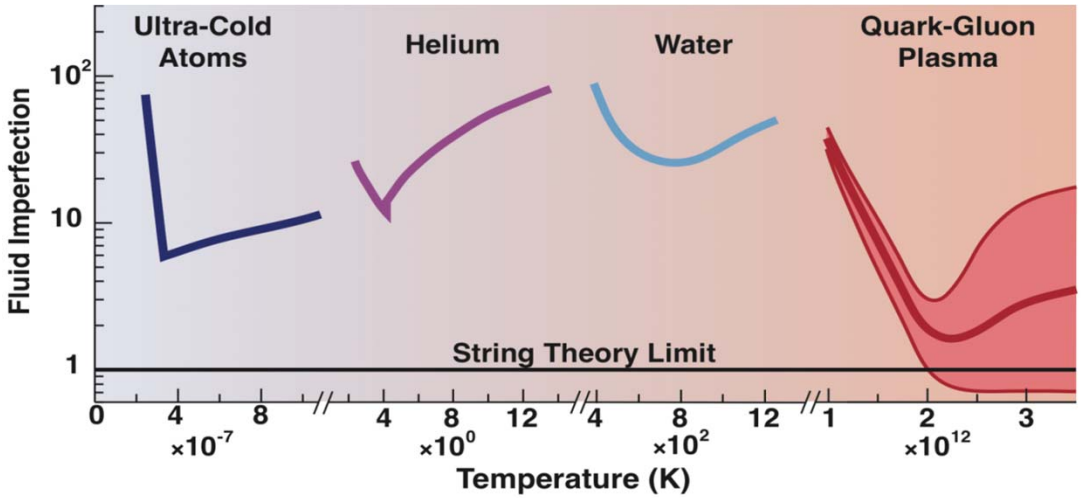
By studying QGP at lower energies, become sensitive to different chemical potentials (μ_B)





The Science of Quark-Gluon Plasma

- The role of quantum fluctuations in QGP
- Mapping phase diagram of nuclear matter
  - nature of the phase transition
  - is there a critical point
- Parity violating domains in QGP
- How perfect is the 'perfect liquid' QGP



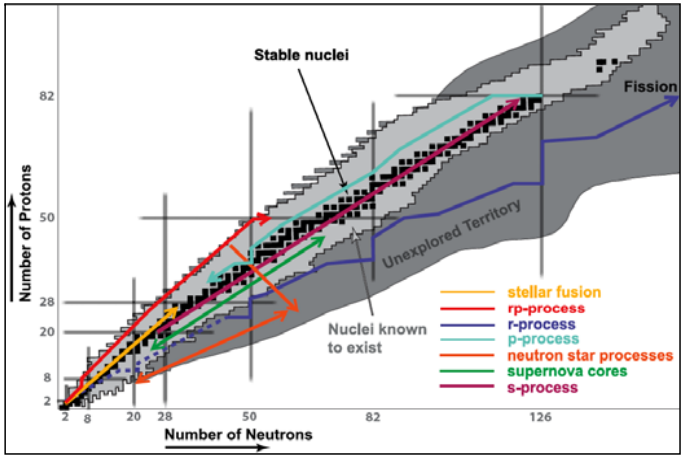
Imperfection index – the lower it is, the less internal friction occurs as liquid flows

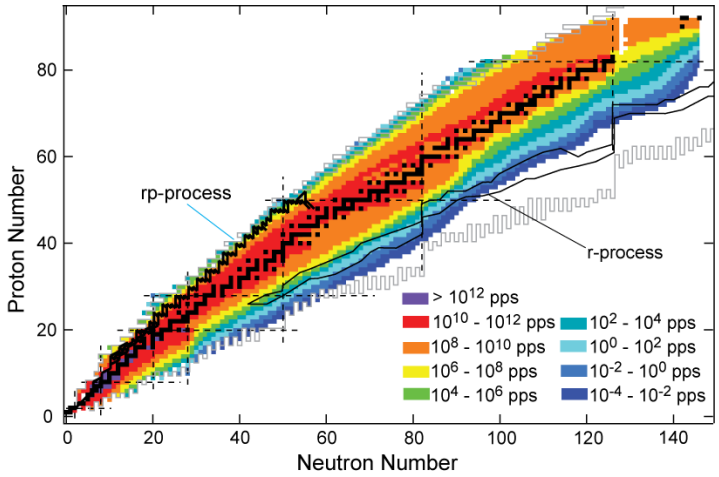
The Science of Quark-Gluon Plasma

- The role of quantum fluctuations in QGP
- Mapping phase diagram of nuclear matter
  - nature of the phase transition
  - is there a critical point
- Parity violating domains in QGP
- How perfect is the ‘perfect liquid’ QGP
  - control over geometry producing QGP with addition of EBIS and new injector
  - lack of quasi-particle formation
  - measurements of heavy quarks may provide best determination of liquid perfection

Nuclear Structure, Reactions, and Nuclear Astrophysics

- Origin and evolution of atoms and nuclei

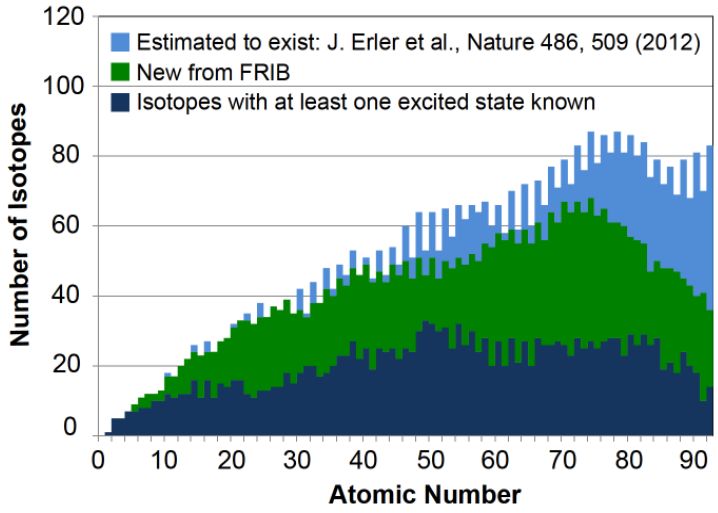




Many nucleosynthesis processes contribute to the origin and evolution of nuclei in the cosmos. FRIB can produce many of the nuclei that nature produces. The yield of many of the FRIB products will be sufficient to study reaction rates and determine masses and β decay half lives.

Nuclear Structure, Reactions, and Nuclear Astrophysics

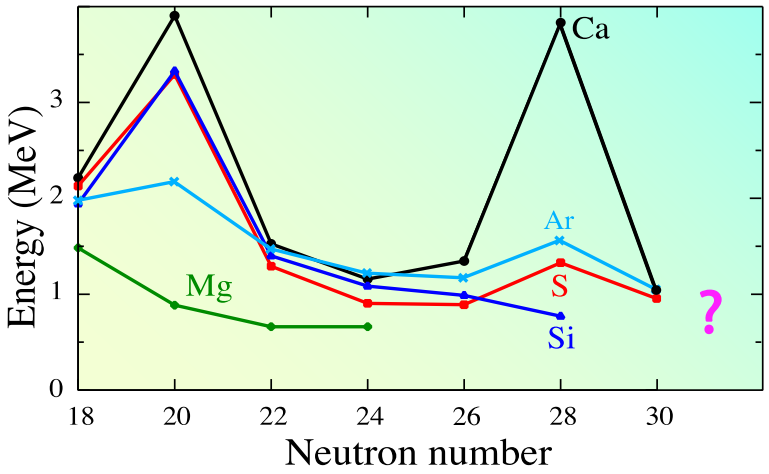
- Origin and evolution of atoms and nuclei
- Limits of proton and neutron stability



Estimates of the isotopes that exist in nature, those that have been studied, and those that can be produced with FRIB.

Nuclear Structure, Reactions, and Nuclear Astrophysics

- Origin and evolution of atoms and nuclei
- Limits of proton and neutron stability
- Complexity from simplicity – the nuclear many body problem and shell structure



As the neutron to proton ratio changes, the shell structure of nuclear isotopes evolves. Understanding and predicting these changes one of the challenges in the field.

Nuclear Structure, Reactions, and Nuclear Astrophysics

- Origin and evolution of atoms and nuclei
- Limits of proton and neutron stability
- Complexity from simplicity – the nuclear many body problem and shell structure
- Neutron-rich matter and the connection to neutron stars
- Tests of fundamental symmetries via traps
  - β-ν correlations
  - atomic EDMs

Fundamental Symmetries and Neutrinos

- Program of studies summarized in table

Electric Dipole Moment Searches • *Origin of Matter* • *New Forces* Exp'ts: nEDM	**Neutrinoless Double β-decay Searches** • *Nature of the Neutrino* • *Origin of Matter* Exp'ts: CUORE, EXO, MAJORANA → Tonne
Electron & Muon Properties & Interactions • *New Forces* • *New subatomic particles* Exp'ts: MOLLER, SoLID, Muon g-2	**Radioactive Decays & Other Tests** • *New Forces* • *Neutrino mass* Exp'ts: KATRIN, Nab

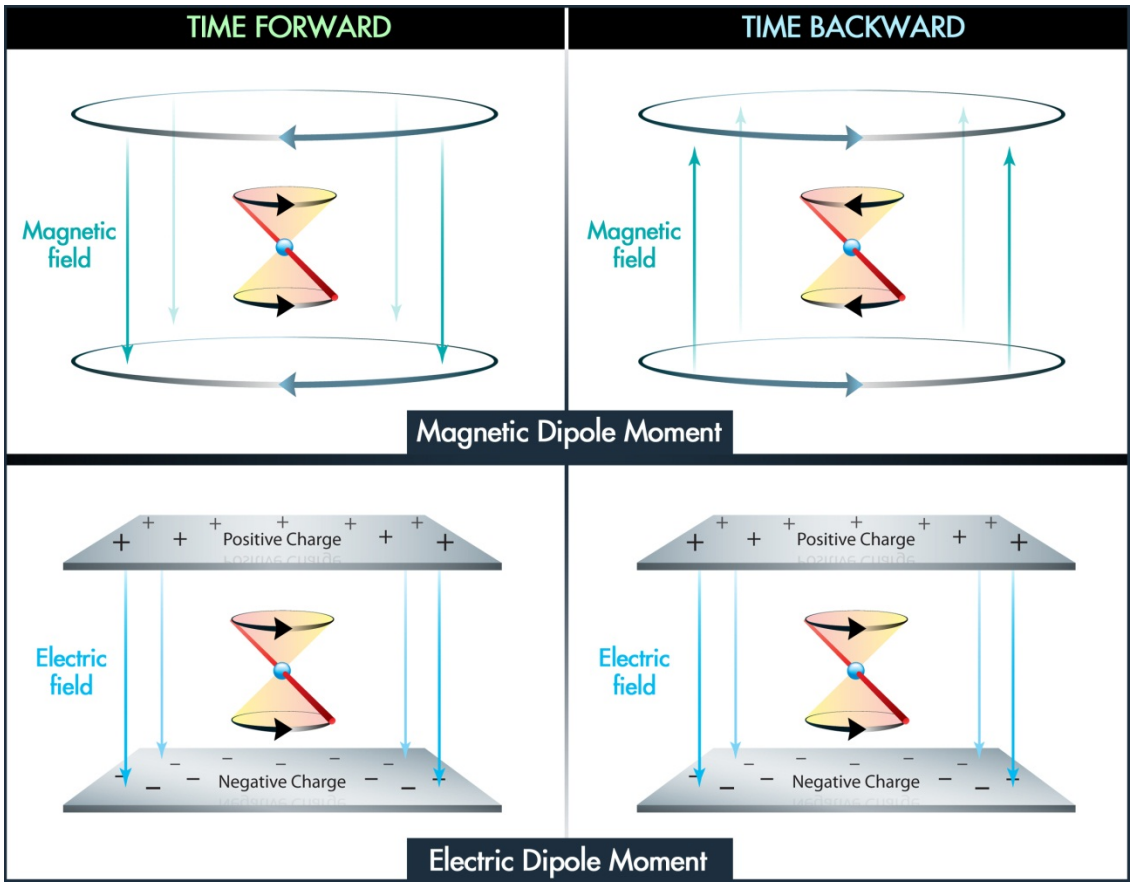
Fundamental Symmetries and Neutrinos

- Program of studies summarized in table

Electric Dipole Moment Searches

- *Origin of Matter*
- *New Forces*

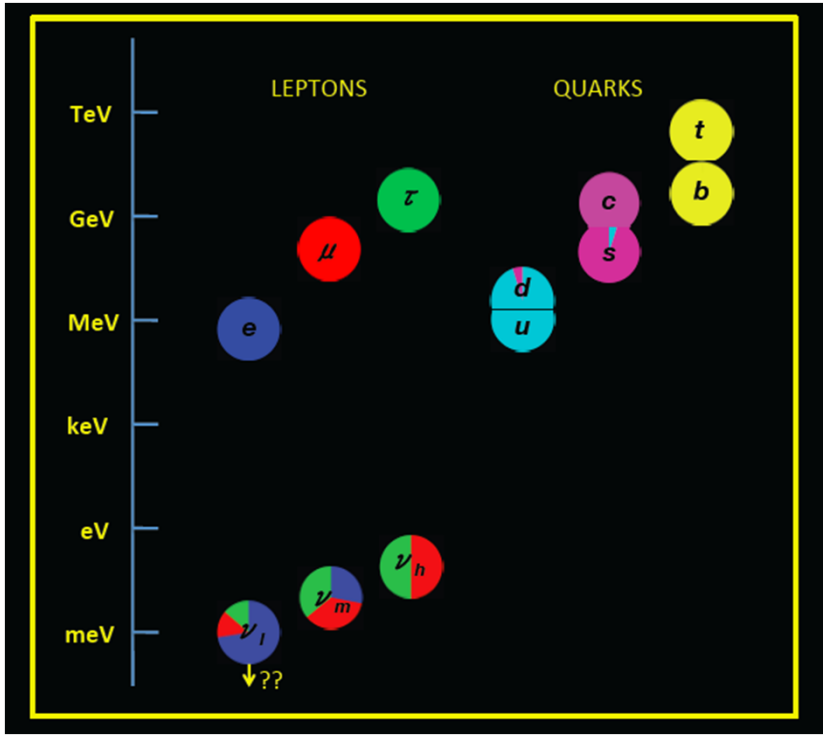
Exp'ts: nEDM



Magnetic dipole moment obeys time reversal symmetry whereas EDM does not

Fundamental Symmetries and Neutrinos

- Program of studies summarized in table



Neutrinoless Double β-decay Searches

- *Nature of the Neutrino*
- *Origin of Matter*

Exp'ts: CUORE, EXO, MAJORANA → Tonne

Radioactive Decays & Other Tests

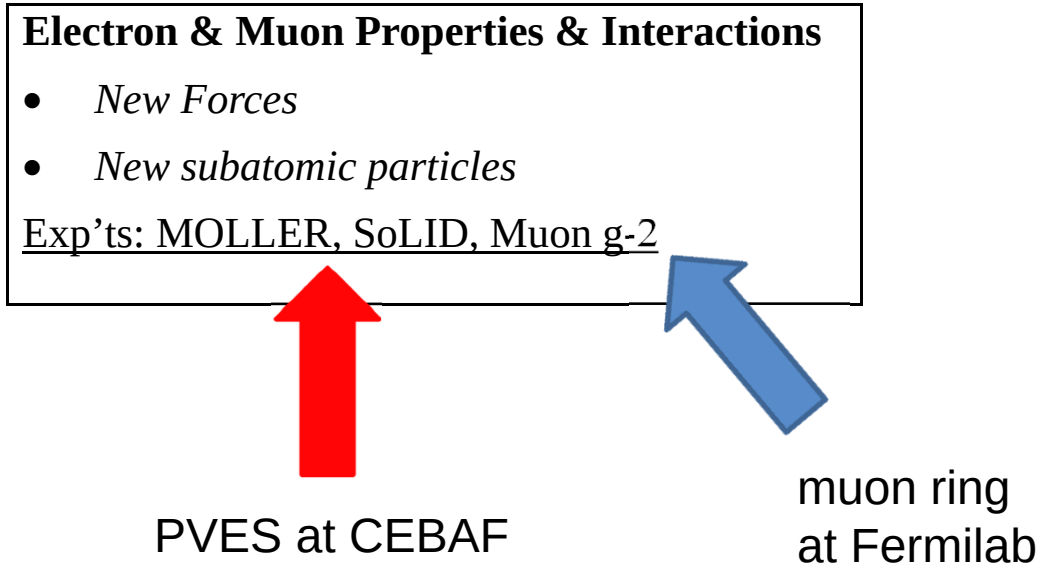
- *New Forces*
- *Neutrino mass*

Exp'ts: KATRIN, Nab

The neutrino mass state is a mixture of flavor states. Understanding the details and implications of this and determining the mass scale are key to future studies in neutrino physics.

Fundamental Symmetries and Neutrinos

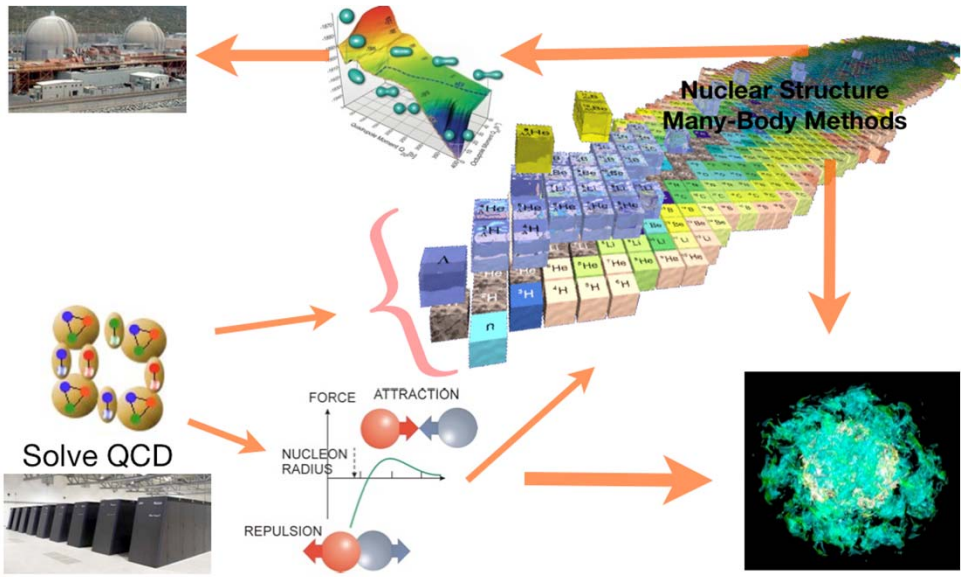
- Program of studies summarized in table



Nuclear Theory and Computational Nuclear Physics

- Impacts all areas of the nuclear science program
- Examples given of the interactions
- Computation plays a major role in effort

Theory addresses the nuclear interaction from Lattice QCD and ties it to structure, super-novae and astrophysical en-viroments, and applications



Developing the science case

- Subcommittee members working primarily in the different science areas were asked to be the primary authors for the science sections
- Readers from other areas were assigned to critique the work
- Required subcommittee members to look in detail at a broad range of the science that makes up the field

Subcommittee Finding

"The subcommittee is ***unanimous*** in reaffirming the LRP vision for the field. Each of the recommendations is supported by an extremely compelling science case. If any one part is excised, it will be a significant loss to the U.S. in terms of scientific accomplishments, scientific leadership, development of important new applications, and education of a technically skilled workforce to support homeland security and economic development."

Budget Options

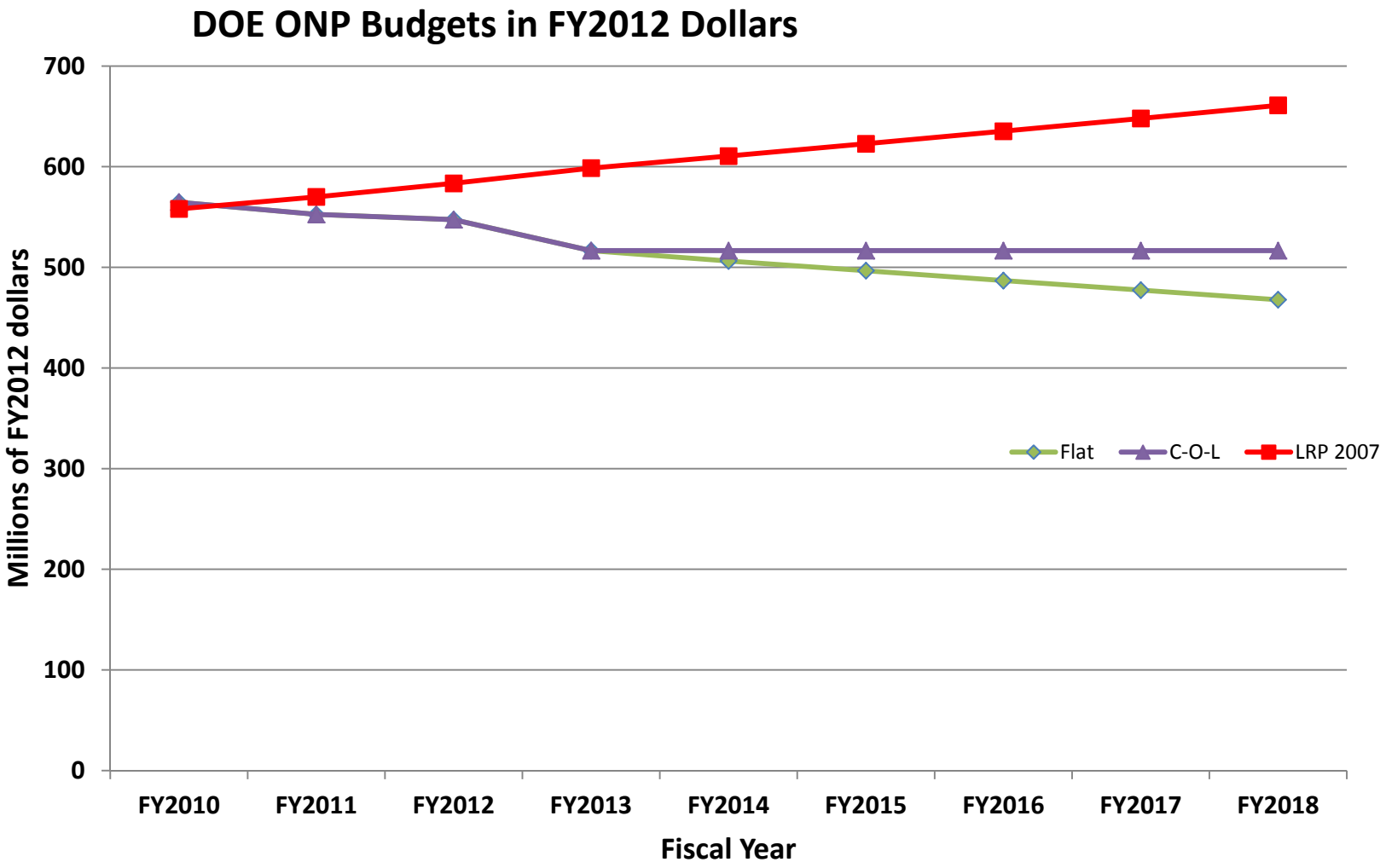
Starting with President's FY2013 request, three options considered:

- Flat-flat funding
- Cost of Living
- Modest Growth

For comparison:

- Used LRP line adjusted for inflation

Budget Options – I



Budget Options – I

Flat-Flat budgets:

- Cannot run CEBAF, RHIC, and build FRIB
- Three options – No CEBAF, No FRIB, No RHIC
- Running at CEBAF and RHIC would be at reduced levels and continue to drop (No FRIB)
- Running either RHIC or CEBAF and building FRIB would be possible but very tight
- In any of the three options, difficult to recover losses in research funding from cuts in FY2012 and FY2103
- Lose another 2-3% per year to inflation
- Very little funding for new initiatives

Budget Options – I

Cost of Living budgets starting with FY2013:

- Cannot run CEBAF, RHIC, and build FRIB
- Running at CEBAF and RHIC would still be at reduced levels (No FRIB)
- Running one of the two and building FRIB would be possible but tight
- In any of the three options, still difficult to recover losses in research funding from cuts in FY2012 and FY2103
- Little funding for new initiatives

No Growth Budgets

What is lost:

- A major facility that supports or will support more than 1/4 of the nuclear science workforce
- A significant drop in Ph.D. production (minimal beam time)
- Many discoveries that will not be made

Further fallout:

- Negative incentive for universities to replace retirements in the field

No CEBAF

What is lost:

- Investments made to upgrade to12 GeV
- No studies of the excited gluon field (GLUEX)
- No three-dimensional tomography of the proton
- No understanding of the orbital motion of the valence quarks and their contribution to the proton spin
- No correlation measurements to probe the short-range nuclear force
- No determination of neutron distributions in heavy nuclei
- No experiments to probe physics beyond the Standard Model of fundamental interactions
- Likely closure of Jefferson Lab with:
  - loss of a cutting-edge accelerator technology group
  - loss of a world class theory effort
  - loss of infrastructure support for the free electron laser

No FRIB

What is lost:

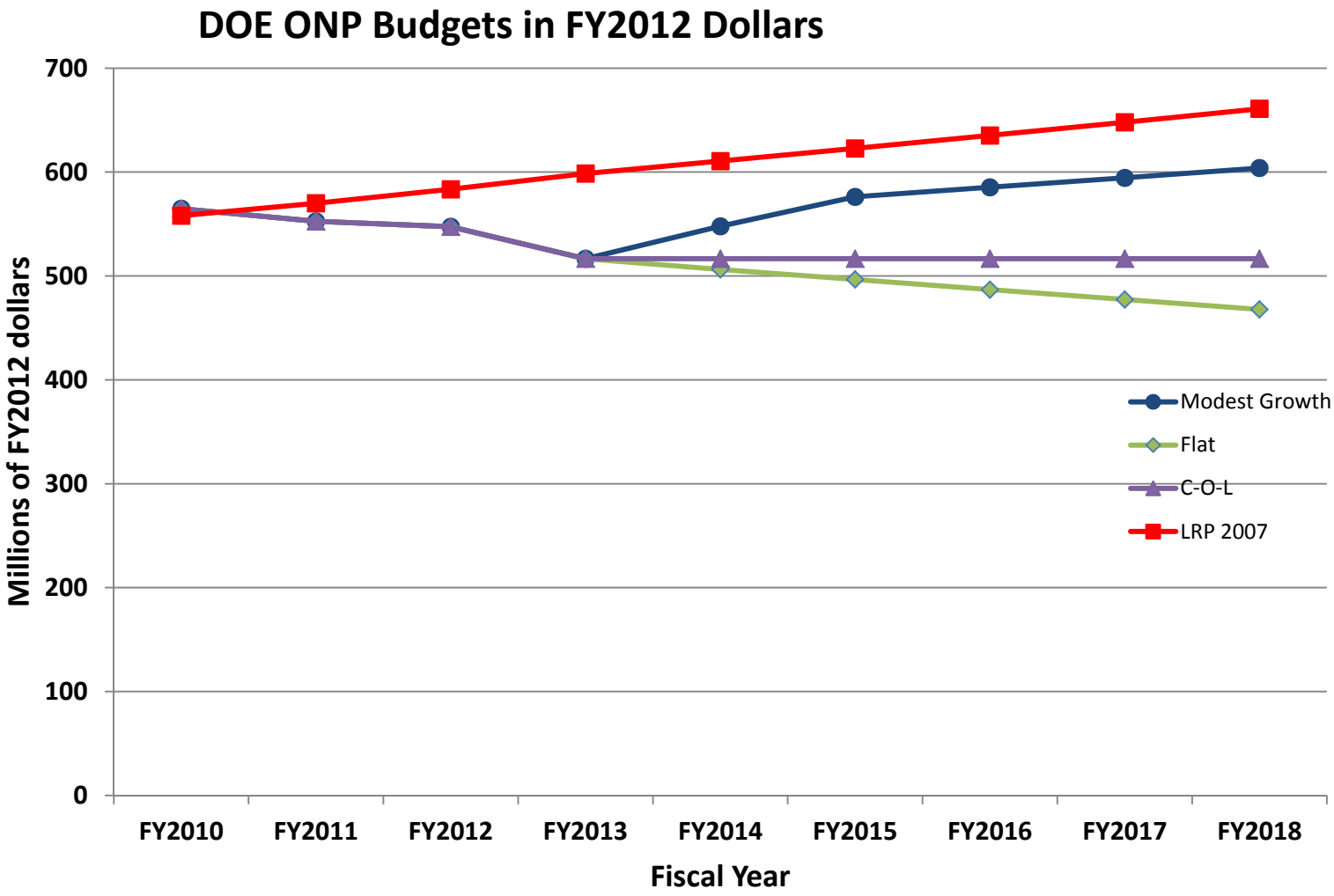
- Investments made by DOE and MSU toward construction
- No critical capabilities for exploring fundamental processes underlying stellar explosions and x-ray bursts
- No studies of extremely neutron rich matter and understanding the origin of the heaviest nuclei in nature
- No knowledge of the neutron drip line at higher Z
- No studies to elucidate the basic processes of fission and fusion
- Lack of key experimental clues to develop a comprehensive theory of all nuclei
- Loss of new applications to medicine, environmental protection, reactor design, waste destruction, stockpile stewardship, and nuclear forensics
- Likely closure of the NSCL

No RHIC

What is lost:

- Investments made for intensity and detector upgrades
- No further examination of critical regions of phase diagram of quark-gluon plasma; in particular, no low energy beam scan to search for the critical point
- No comprehensive understanding of most perfect liquid
- No studies of quantum fluctuations in QGP that probe dynamical processes similar to matter-antimatter asymmetry in the universe
- No jet physics that serves as a microscopic probe to resolve quark-gluon plasma constituents
- No further measurements of gluon and anti-quark contributions to proton spin
- Possible loss of: world-class accelerator division; NASA space radiation program; medical isotope production

Budget Options – II



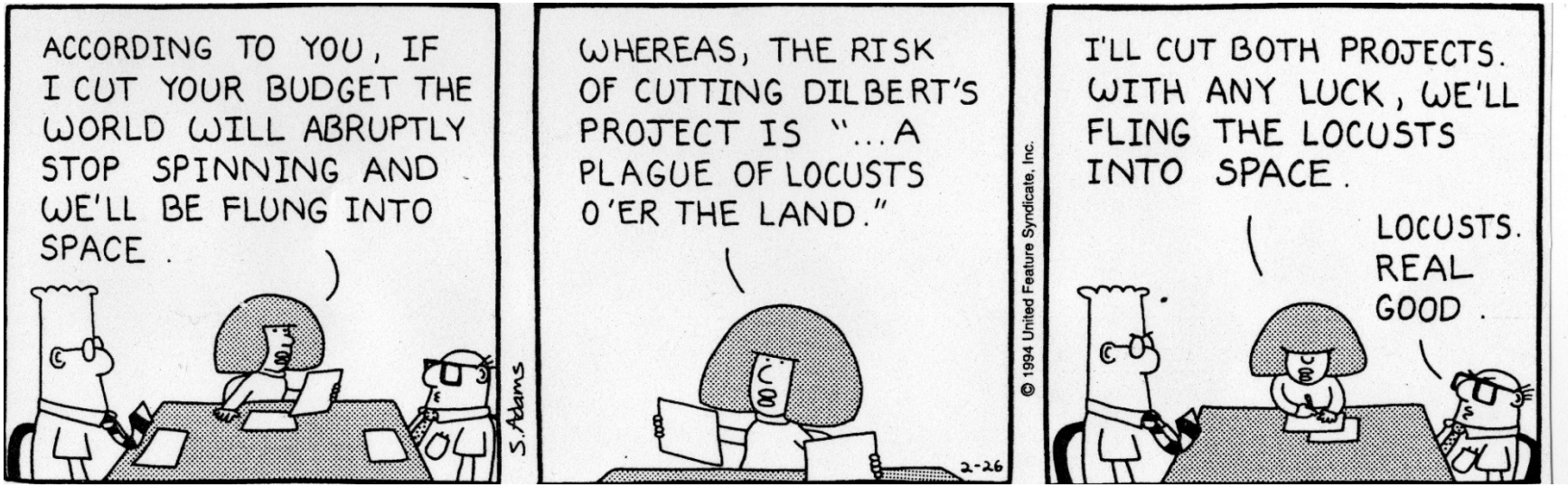
Budget Options – II

Modest growth (1.6% over COL) budgets:

- Can run CEBAF and RHIC at reduced levels, and build FRIB
- Research budgets remain tight
- Rather small amount of funding for new initiatives during FRIB construction

the subcommittee was unanimous in endorsing the modest growth budget scenario as the minimum level of support that is needed to maintain a viable long-term U.S. nuclear science program that encompasses the vision of the LRP

Subcommittee No Growth Budget **Deliberations** Summarized Below



No Growth Budgets

"In light of the substantial commitment that has been made to upgrade CEBAF, under all budget scenarios the subcommittee recommends completing the upgrade and capitalizing on the science that it enables.

If a decision were made to force the U.S. nuclear science community to downsize through budgets that provide no growth over the next four years, a choice would have to be made that would fundamentally change the direction of what remained of the field."

No Growth Budgets

See report for direct quote on subcommittee response to the no growth budget option for FRIB and RHIC.

Conclusions - I

"With no growth in the budget in the next four years, nuclear science must relinquish a major part of its program. If we close RHIC now, we cede *all* collider leadership, not just the high-energy frontier, to CERN and we lose the scientific discoveries that are enabled by the recent intensity and detector upgrades at RHIC. If we terminate FRIB construction, future leadership in the cornerstone area of nuclear structure and nuclear astrophysics will be ceded to Europe and Asia."

Conclusions - II

"There are alternate paths to the two no-growth scenarios. The budget profile laid out in the 2007 Long Range Plan defines what is needed for a vibrant U.S. program in nuclear science. This report presents a modest growth budget option for the near term that falls well short of the LRP profile and requires significant sacrifices be made relative to the LRP vision. But the modest growth budget will allow the U.S. to preserve the tools that enable our science . . ."

***Personal* Comments**

- There would be no ‘winners’ and ‘losers’ if we have no growth budgets through FY2018
- It would be a disaster for U.S. nuclear science – a clear short term problem that would likely be the start of a longer term decline of the field as a whole
- We ***must*** work together to do our best to keep it from happening