What is the P5 report and what are the implications for Belle II@SuperKEKB ?

Tom Browder, (University of Hawai'i)

P5 = Particle Physics Project Prioritization Panel

After the decadal Snowmass community process with thousands of White Papers, the P5 decides on funding priorities in a couple of future funding scenarios.
They decide on a 10-year plan within a 20 year context. The P5 included panelists from Japan (new Director General Asai-san) and Europe. The chair was Hitoshi Murayama (UC Berkeley, U Tokyo).

Report at https://www.usparticlephysics.org/2023-p5-report/

Acknowledgements:
We thank the Belle II authors of the Snowmass White Papers
https://www.belle2.org/info/snowmass2021/

We also thank Jake Bennett, DG Yamauchi, Kodai Matsuoka (slides for the DG), Frank Zimmerman for talks at the P5, Yutaka Ushiroda for the translation of the MEXT review of the SuperKEKB/Belle II project. Many others helped in the P5 lobbying process.

Much younger and more diverse than the 2013 panel

The P5 panel

NATURE summary of P5

BIG BANG OBSERVATORY TOPS WISH LIST FOR BIG US PHYSICS PROJECTS

CMB-S4 (1 billion and South Pole infrastructure), DUNE (3.3 billion dollar neutrino project), DM G3

Report also supports projects of unprecedented scale to study dark matter, neutrinos and the Higgs boson.

By Davide Castelvecchi

The United States should fund proposed projects to drastically scale up its efforts in five areas of high-energy physics, an influential panel of scientists has concluded.

Topping the ranking is the Cosmic Microwave Background–Stage 4 project, or CMB-S4, which is envisioned as an array of 12 radio telescopes split between Chile's Atacama Desert and the South Pole. It is designed to look for indirect evidence of physical processes in the instants after the Big Bang – processes that have been mostly speculative so far.

The other four priorities are experiments to study the elementary particles called neutrinos, both coming from space and made in the laboratory; the largest-ever dark-matter detector; and strong US participation in a future overseas particle collider to study the Higgs boson.

An ad hoc group called the Particle Physics Project Prioritization Panel (P5) presented the recommendations on 7 December (see go.nature.com/41jzfrf). The committee, which is convened roughly once a decade, was charged with making recommendations for the two main US agencies that fund research in high-energy physics, the Department of Energy (DoE) and the National Science Foundation (NSF).

In addition to the five key recommendations, the report says that the United States should embark on a programme to demonstrate the feasibility of two completely new kinds of particle accelerator, after a surge of grass-roots enthusiasm in the particle-physics community.

New York Times summary of the P5 report

Particle Physicists Agree on a Road Map for the Next Decade

A "muon shot" aims to study the basic forces of the cosmos. But meager federal budgets could limit its ambitions.

Muon collider R&D endorsed with a *long-term* goal of a muon collider at FNAL

“Medium Size” and “Small” projects also discussed and endorsed.

Quite different from 2013

Part of Recommendation 1

In addition, we recommend continued support for the following ongoing experiments at the medium scale (project costs > $50M for DOE and > $4M for NSF), including completion of construction, operations, and research:

d. NOvA, SBN, and T2K (*elucidate the mysteries of neutrinos*, section 3.1).

e. DarkSide-20k, LZ, SuperCDMS, and XENONnT (determine the nature of dark matter, section 4.1).

f. DESI (*understand what drives cosmic evolution*, section 4.2).

g. Belle II, LHCb, and Mu2e (*pursue quantum imprints of new phenomena*, section 5.2).

The agencies should work closely with each major project to carefully manage the costs and schedule to ensure that the US program has a broad and balanced portfolio.

Recommendation 3: Create an improved balance between small-, medium-, and large-scale projects to open new scientific opportunities and maximize their results, enhance workforce development, promote creativity, and compete on the world stage.

In order to achieve this balance across all project sizes we recommend the following:

a. Implement a new small-project portfolio at DOE, Advancing Science and Technology through Agile Experiments (ASTAE), across science themes in particle physics with a competitive program and recurring funding opportunity announcements. This program should start with the construction of experiments from the Dark Matter New Initiatives (DMNI) by DOE-HEP (section 6.2).

b. Continue Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs as a critical component of the NSF research and project portfolio.

c. Support DESI-II for cosmic evolution, LHCb upgrade II and Belle II upgrade for quantum imprints, and US contributions to the global CTA Observatory for dark matter (sections 4.2, 5.2, and 4.1).

The Belle II recommendation includes contributions towards the SuperKEKB accelerator.

This is an important figure for Belle II@SuperKEKB

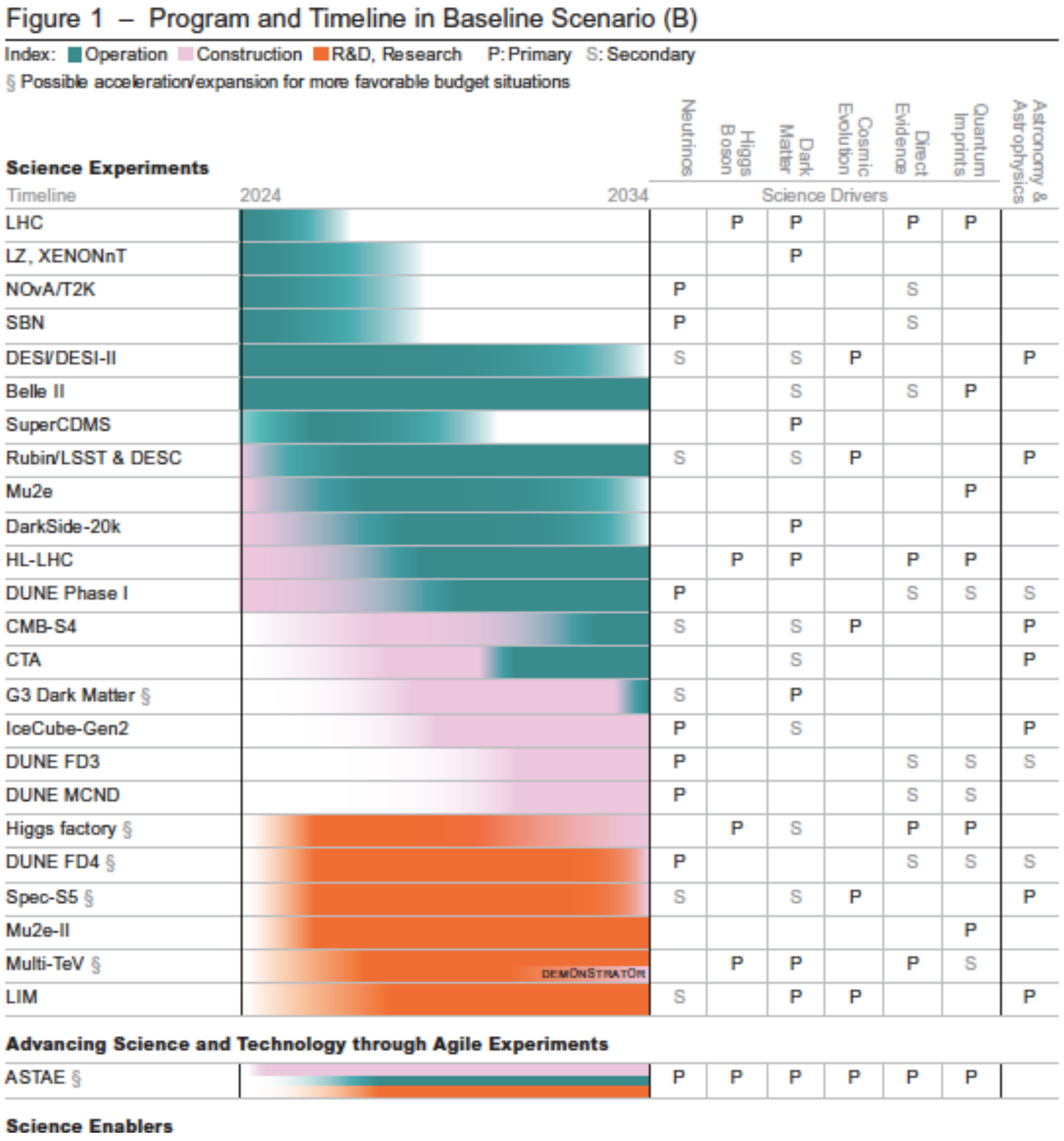


Figure 1 – Program and Timeline in Baseline Scenario (B)

Index: Operation Construction R&D, Research P: Primary S: Secondary

§ Possible acceleration/expansion for more favorable budget situations

Science Experiments

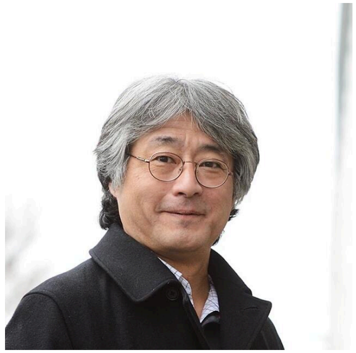
Experiment (Timeline 2024–2034)	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
LHC		P	P		P	P	
LZ, XENONnT			P				
NOvA/T2K	P				S		
SBN	P				S		
DESI/DESI-II	S		S	P			P
Belle II			S		S	P	
SuperCDMS			P				
Rubin/LSST & DESC	S		S	P			P
Mu2e						P	
DarkSide-20k			P				
HL-LHC		P	P		P	P	
DUNE Phase I	P				S	S	S
CMB-S4	S		S	P			P
CTA			S				P
G3 Dark Matter §	S		P				
IceCube-Gen2	P		S				P
DUNE FD3	P				S	S	S
DUNE MCND	P				S	S	
Higgs factory §		P	S		P	P	
DUNE FD4 §	P				S	S	S
Spec-S5 §	S		S	P			P
Mu2e-II						P	
Multi-TeV § (DEMONSTRATOR)		P	P		P	S	
LIM	S		P	P			P

Advancing Science and Technology through Agile Experiments

Experiment	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
ASTAE §	P	P	P	P	P	P	

Science Enablers

Extends to 2034, following the MEXT review.



Belle II now pursues "Quantum Imprints of New Phenomena", one of the five major science drivers.

The New P5 Science Drivers (2023)

2013

Science Questions and Science Drivers

The eleven groups of physics questions from Snowmass are shown in Appendix D, along with a reference to all the Snowmass documents. Based on this comprehensive work by the broad community, we have identified five compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years. These are the science Drivers:

- **Use the Higgs boson as a new tool for discovery**
- **Pursue the physics associated with neutrino mass**
- **Identify the new physics of dark matter**
- **Understand cosmic acceleration: dark energy and inflation**
- **Explore the unknown: new particles, interactions, and physical principles**

Decipher the Quantum Realm	Explore New Paradigms in Physics	Illuminate the Hidden Universe
Elucidate the Mysteries of Neutrinos	Search for Direct Evidence of New Particles	Determine the Nature of Dark Matter
Reveal the Secrets of the Higgs Boson	Pursue Quantum Imprints of New Phenomena	Understand What Drives Cosmic Evolution

→ *"Pursue Quantum Imprints of New Phenomena"*

Now in the first tier of HEP.

Given these open questions, we explore new paradigms that might yield transformational insights into our universe. There are two broad strategies to venture into the unknown:

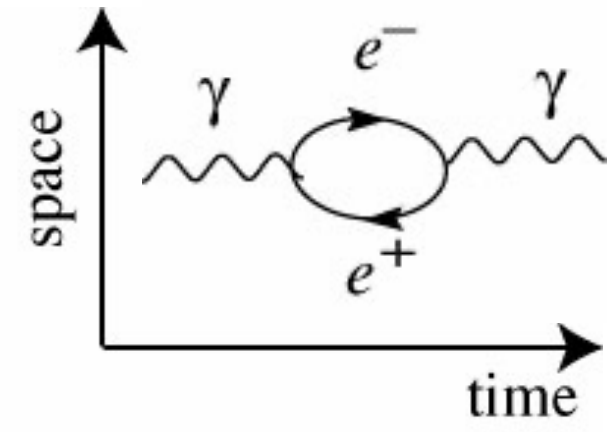
Search for Direct Evidence of New Particles. Experiments that seek direct evidence for new particles set the gold standard for discovery. Heavy particles can be produced at colliders with sufficiently high energies, while light but elusive particles can be produced at accelerator-based experiments with sufficiently high intensity. The discovery of new particles, or definitive evidence for their absence, would ignite major paradigmatic shifts and determine the direction of future research.

Pursue Quantum Imprints of New Phenomena. Even if new particles cannot be produced directly, they can still leave clues to their existence via quantum imprints on known particles. This is especially true if the new particles break a fundamental symmetry of the Standard Model. Many known particles were first detected indirectly through their quantum imprints, with followup direct experiments providing definitive evidence. This motivates continued investments in a broad search program for possible quantum imprints of new phenomena.

Ole Miss Q: Can you give an example of a particle discovered first by its quantum imprints ?

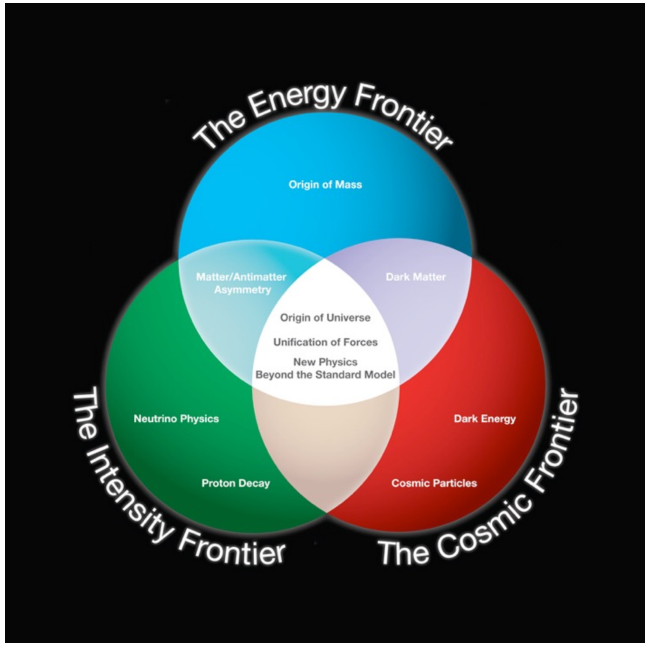
GIM mechanism: see slides by Jim Libby.

Quantum Mechanical (QM) Imprints versus Brute Force



Energy conservation ?

$$\Delta E \Delta t \geq \hbar / 2$$



Banking Analogy (may be easier to understand):
At the Heisenberg Quantum Mechanical bank, customers with no collateral may take out billion Euro loans if they return the full loan within a billionth of a second.

If a *beautiful but rare* customer takes out such huge loans very frequently, *the bank will take notice.*

N.B. Sometimes it is much better to have a large collateral and pay back the loan *directly* after a longer time.

Werner Heisenberg,
Physicist and QM banker

The physics of flavor is particularly sensitive to quantum imprints of particles that are not present in either the initial or the final state of interactions. The existence of three families of elementary particles of matter and their mass and mixing patterns are a key feature, and a puzzle, in the Standard Model. Rare quark flavor transitions have unparalleled sensitivity to the existence of new physics many orders of magnitude beyond the reach of direct searches in current and planned energy frontier accelerators.

For electrons, muons, and tau leptons, Standard Model mixing is so rare that any observation of a flavor-changing signal called Charged Lepton Flavor Violation in any current or planned experiment would be an important discovery and an unambiguous signature of new physics. Collider experiments can search for subtle effects that would be caused by particles with masses much too heavy to be produced directly.

A discovery made by any current or planned experiments would indicate specific directions in which to focus subsequent experiments to directly observe the underlying new physics, and potentially suggest the new energy scale to be probed. Progress necessitates clean theoretical predictions and high precision experiments with huge data samples and excellent control of systematic uncertainties. Theoretical and experimental progress go hand in hand, with advances in one side motivating further activity and progress in the other side, in a continuous synergistic interplay.

Currently a number of intriguing experimental deviations from theoretical Standard Model predictions have been observed. The most significant of these anomalies are related to g-2, the magnetic moment of the muon, which appears larger than anticipated; decays of the bottom quark to a strange quark and a pair of charged leptons, which may be less frequent than expected; and a possibility that bottom quark decays to tau leptons and muons do not have the same strength, pointing to possible Lepton Flavor Universality Violation. All of these anomalies might be resolved by improved experimental precision or theoretical predictions. They also might be the first signs of new discoveries.

Now in the first tier of HEP.

Ole Miss Q:
What is meant by lepton flavor universality ?

5.2.2 – Ongoing Projects: Mu2e, Belle II, LHCb, ATLAS, CMS

The largest experimental efforts of the US dedicated to indirect probes of new physics currently are the Mu2e charged Lepton Flavor Violation experiment, hosted by Fermilab, and the Belle II and LHCb programs, hosted by KEK in Japan and CERN, respectively. These programs will continue over the time frame of this report with alternating periods of data taking and upgrades (Recommendation 1). The other HL-LHC experiments also present many opportunities for indirect searches, as will experiments at future colliders.

Mu2e, which searches for the conversion of a muon captured by a nucleus into an electron with no emitted neutrinos, will extend our sensitivity to charged lepton flavor violation in this sector by a remarkable four orders of magnitude. Our access to new muon-electron-quark interactions will increase by an order of magnitude in energy scale, up to 10^4 TeV. Any observed signal at Mu2e would indicate new physics, and should be followed up by further experiments for its full characterization.

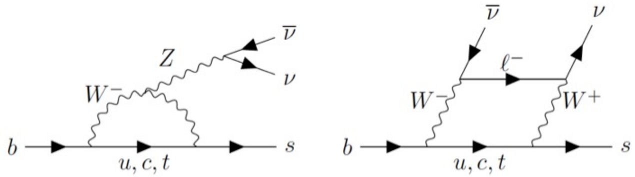
The Belle II and LHCb programs focus on decays of bottom and charm quarks, and of tau leptons. The clean, controlled environment of electron-positron collisions (for Belle II) and the extremely high rates and broad-spectrum production in proton-proton collisions (for LHCb) make the two experiments complementary in many ways. These experiments will further probe, with unprecedented precision, Standard Model predictions for quark behavior and lepton physics including leptoquark searches, flavor changing neutral currents, as well as conducting wide hidden sector searches. They will reduce the experimental uncertainties in the measurements in tension with the Standard Model by an order of magnitude or more, and introduce qualitatively new tests made possible by the extremely large number of particle decays available for study. The experiments will continue the established program of searches for potential new signs of unexpected matter-antimatter differences, and of performing measurements which overconstrain and challenge Standard Model parameters to search for inconsistencies between different processes.

Dark Sector at Belle II, Prof. Savino Longo

One new direction:

Feynman Diagrams and Model Building

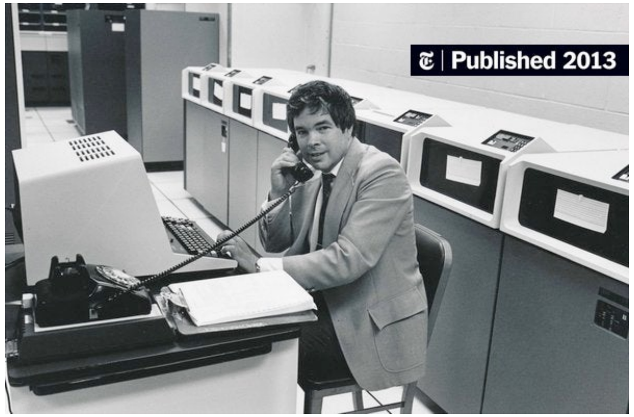
Feynman family and diagrams



(a) Penguin diagram (b) Box diagram

Paradigm shift

Effective Field Theory
→Wilson Coefficients



Ken Wilson ("Wilson coefficients")

$$C_7, C_9, C_{10}$$

Extract Wilson coefficients directly by fitting angular distributions in B→K* l+ l- or B→D* l ν

New Physics/BSM Couplings in b→s

The effective Hamiltonian for $b \to s$ transitions can be written as

$$\mathcal{H}_{\rm eff} = -\frac{4\,G_F}{\sqrt{2}} V_{tb} V_{ts}^* \frac{e^2}{16\pi^2} \sum_i (C_i O_i + C_i' O_i') + \text{h.c.}$$

and we consider NP effects in the following set of dimension-6 operators,

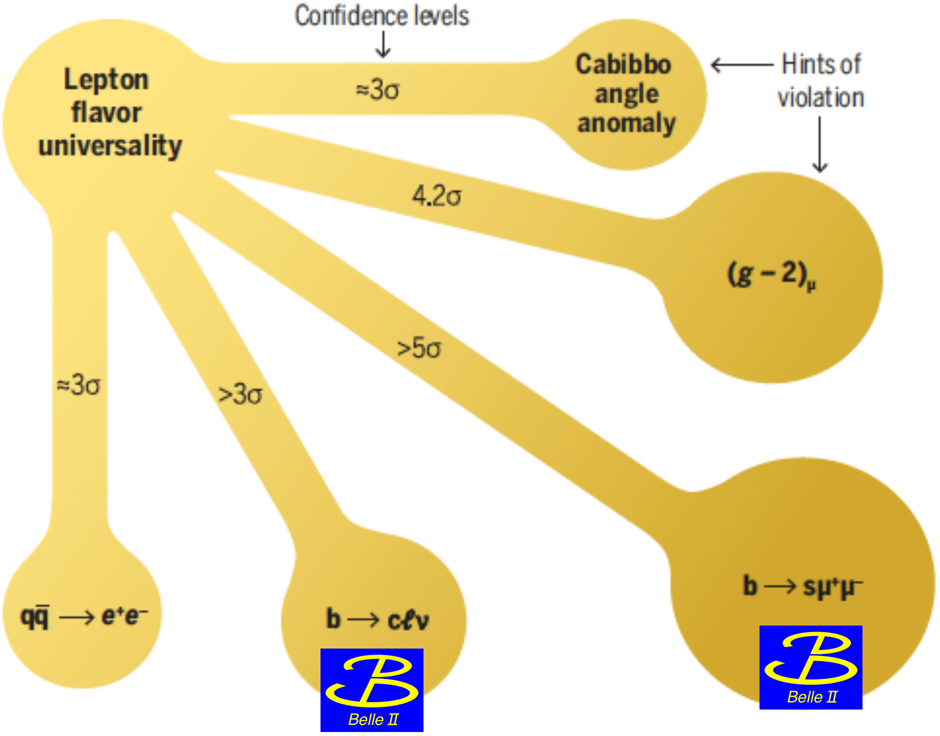
$$O_9 = (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \ell)\,, \qquad O_9' = (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \ell)\,,$$
$$O_{10} = (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)\,, \qquad O_{10}' = (\bar{s}\gamma_\mu P_R b)(\bar{\ell}\gamma^\mu \gamma_5 \ell)\,.$$

The primes are NP right-handed couplings.

The landscape of BSM hints in High Energy Physics ?

Possible violations of lepton flavor universality are getting harder to ignore

Shown are five hints for the violation of lepton flavor universality from existing experimental data, with the size of each circle and length of each arm reflecting the level of confidence for the experimental data to break away from standard model predictions.



From December 2021 SCIENCE magazine article by A. Crivellin and M. Hoferichter.

"Tsukuba, we may have a problem" (apologies to Apollo 13 again)

Is this real ? R_K went away after LHCb re-analysis. *Angular asymmetries persist.* What about B→K$^{(*)}$ $\nu\ \bar{\nu}$? (BSM hint ?)

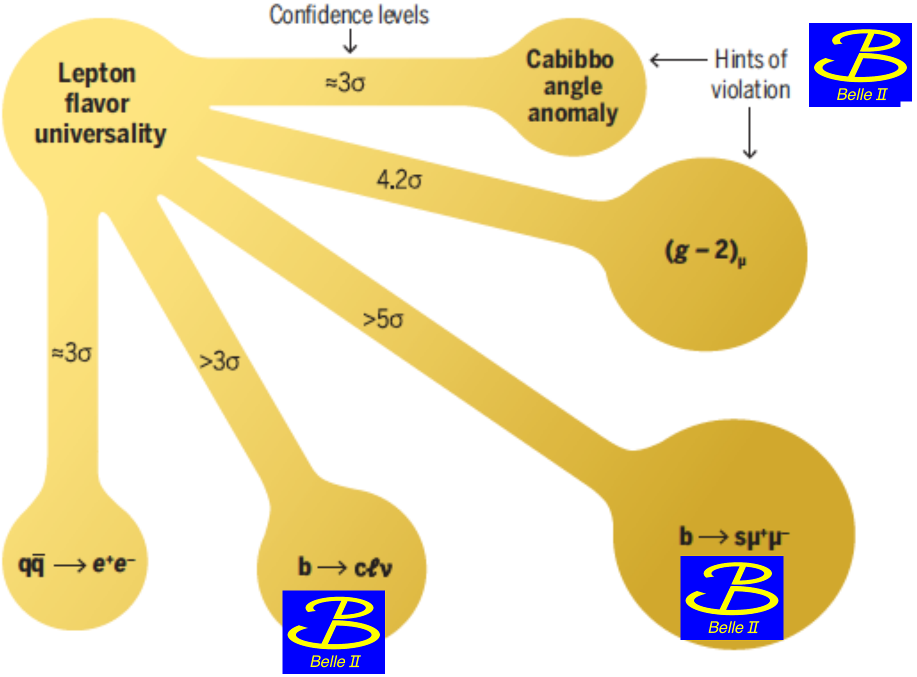
We must carry out the full program of measurements at Belle II to find out.

But wait there's more…..

Belle II can contribute to the resolution of the Cabibbo Angle Anomaly (CAA)

Possible violations of lepton flavor universality are getting harder to ignore

Shown are five hints for the violation of lepton flavor universality from existing experimental data, with the size of each circle and length of each arm reflecting the level of confidence for the experimental data to break away from standard model predictions.

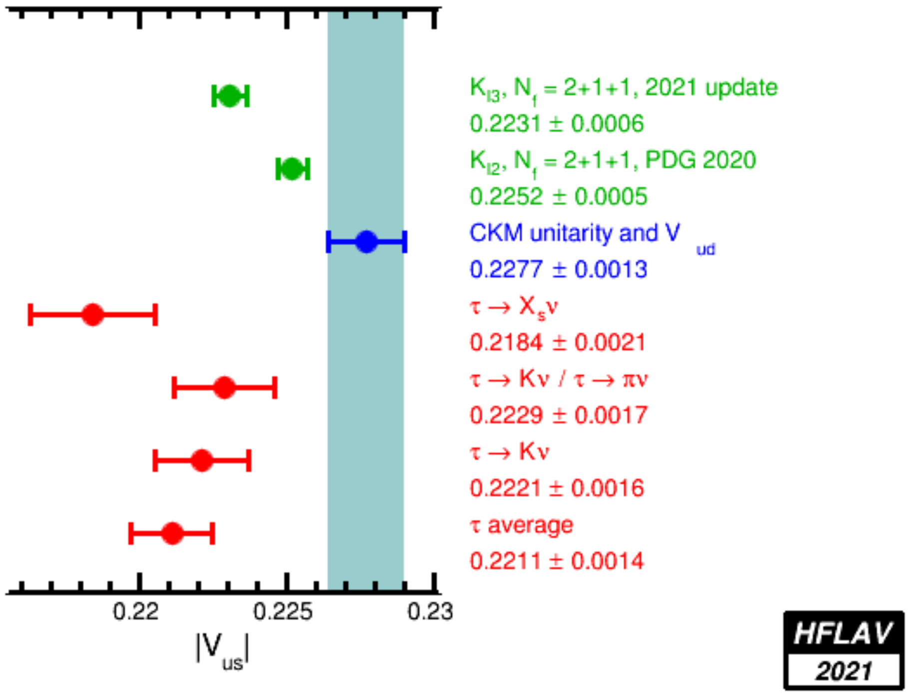


From December 2021 SCIENCE magazine article by A. Crivellin and M. Hoferichter.

A major supporting role of Belle II in the resolution of two more of the other HEP anomalies.

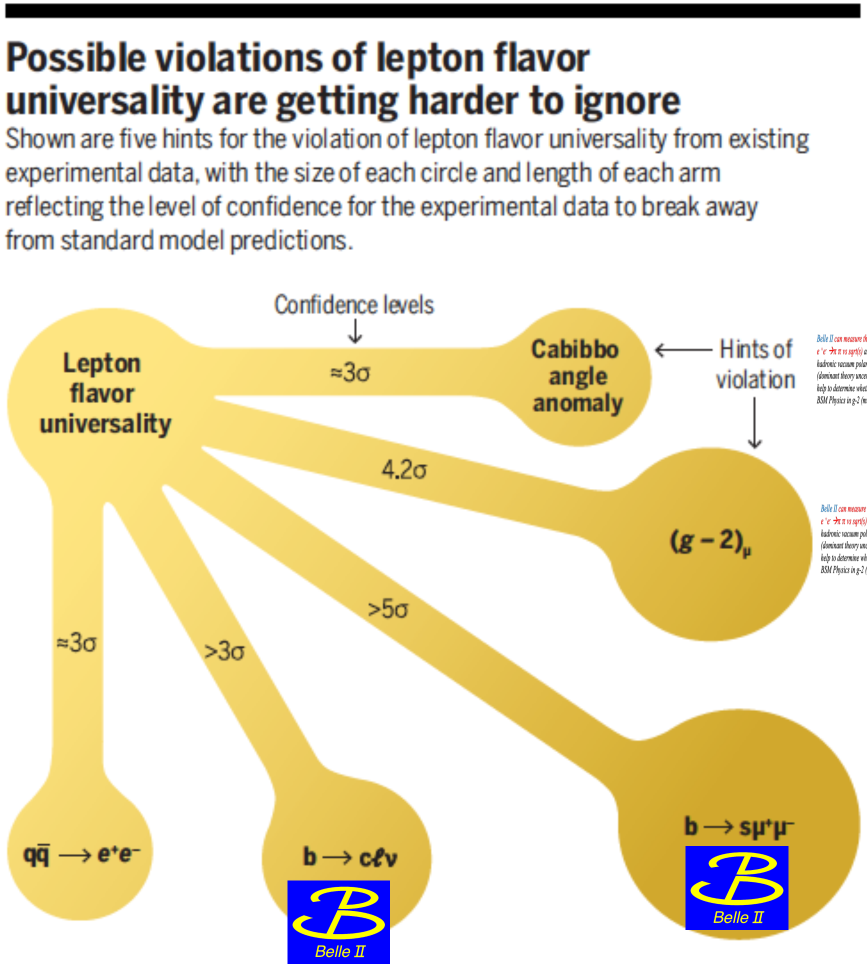
There is a ~3σ discrepancy between $|V_{us}|$ measured from tau and kaon semileptonic decays.

Belle II will measure $|V_{us}|$ in inclusive tau decays to high precision



The CAA could be another hint of lepton flavor universality violation

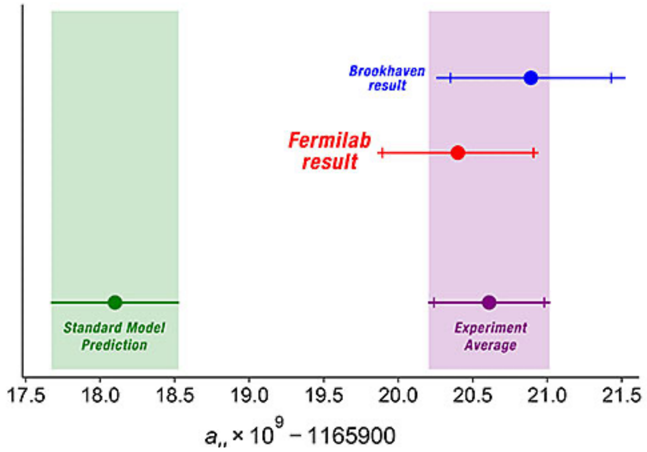
+But wait there's *still more.....*

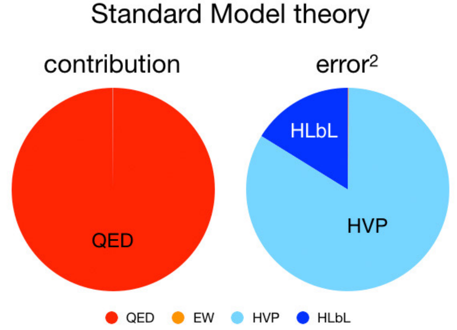


From December 2021 SCIENCE magazine article by A. Crivellin and M. Hoferichter.

A major supporting role of Belle II in the resolution of two more of the other major HEP anomalies.

Belle II can contribute to g-2

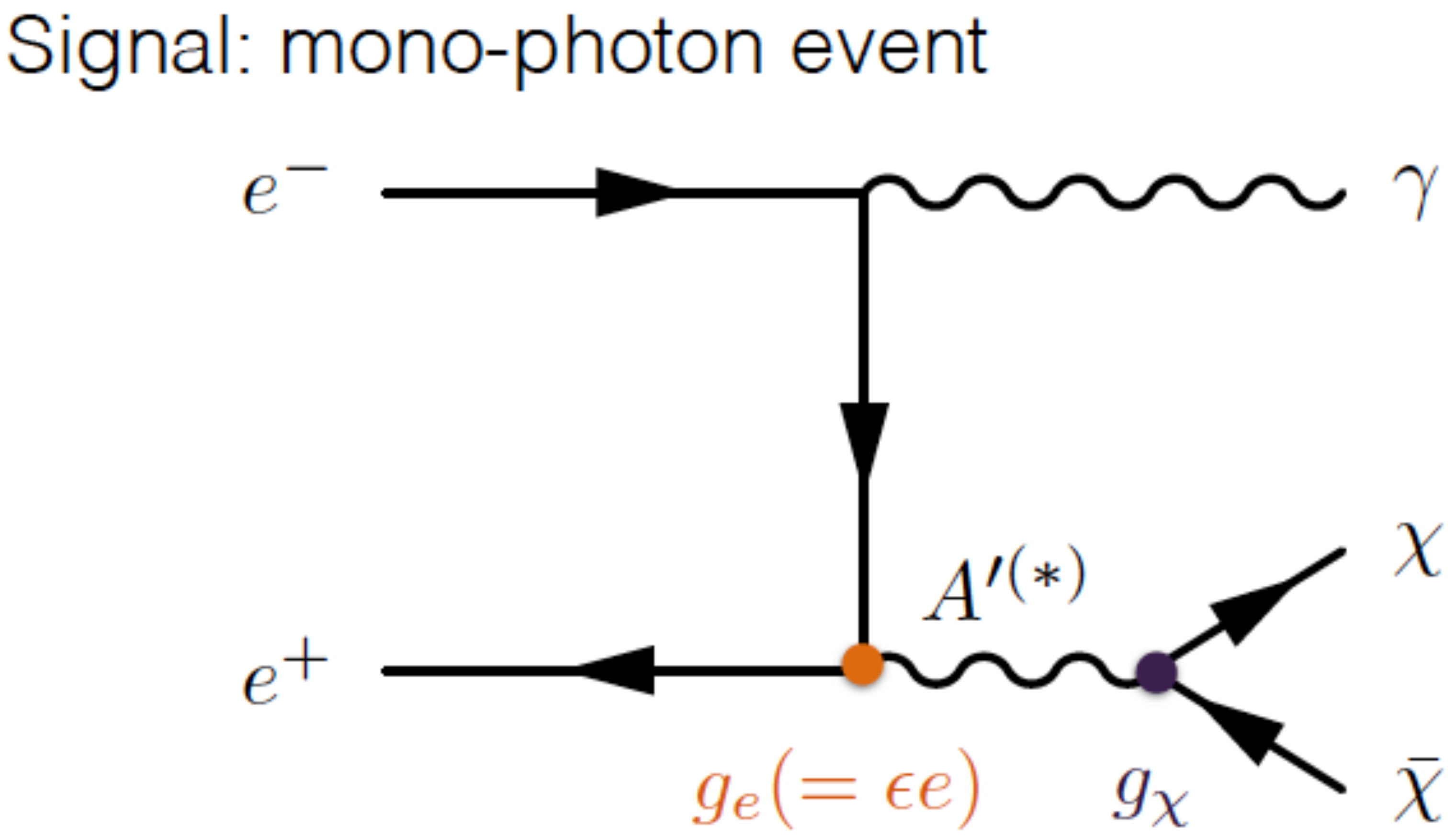




KLOE, BaBar and CMD-2 data disagree

Belle II can measure the cross-section for $e^+e^- \to \pi\,\pi$ vs sqrt(s) and reduce the hadronic vacuum polarization error in g-2 (dominant theory uncertainty). This could help to determine whether there really is BSM Physics in g-2 (muon).

Only in e+ e-:
"Light DM" (dark sector) sensitivity in $e^+e^- \to \gamma$+nothing



BTW Belle II already has 6 published PRLs on the dark sector.

This is hard. Requires a special new trigger that is being used for Belle II. QED backgrounds are large.

Excerpts from the P5 report

5.2.3 – New Initiatives: Belle II and LHCb upgrades

The upgraded Belle II experiment will record 25 times more data of electron-positron collisions by 2035 at the SuperKEKB accelerator at KEK in Japan. The facility produces world record luminosity using the most advanced nano-size beams. The unique environment of the SuperKEKB offers access to decays with multiple undetected particles in the final state, such as hadron and tau decays producing more than one neutrino. The experiment will also further constrain hadronic vacuum polarization which is important for the precise comparison of theoretical and experimental results on the muon g-2. Quark mixing parameters will be measured with ultimate precision (Recommendation 3c).

The US community has extensive experience with this science at the BaBar experiment at the SLAC National Accelerator Laboratory in the early 2000s, and has a lot to contribute to the operation of the detector and analyses of data.

To achieve such an unprecedentedly powerful beam, there are many challenges in the accelerator. A major technological challenge is producing a nanobeam, namely the ability to focus the beam down to the nanometer scale just before collisions. Another is to maintain a very high degree of vacuum in the beam pipe, as a small amount of residue gas can interact with the beam and cause problems. Finally the intense beams can also cause a high level of background at the collision point that needs to be mitigated. These technologies are important for all future electron-positron colliders and therefore it is crucial that the US is involved in their development for the future of the field.

LHCb after its second upgrade will produce huge B hadron samples and will reach unprecedented precision in a large number of observables in the 2035 to 2043 time period. The scientists in the LHCb collaboration will explore extremely rare flavor processes, including matter-antimatter asymmetries in the charm sector, and will also search for and study pentaquarks, hidden sector particles, anomalous B meson decays, and more. LHCb upgrade II will be a major project that opens a new era of precision in the rare phenomena explored by the experiment (Recommendation 3c).

The LHCb experiment, together with BaBar, Belle, and Belle II, have also produced a new type of matter composed of quarks. It has been known that most matter around us is either made of three quarks, such as protons and neutrons (collectively called baryons), or of a quark and an antiquark, such as pions and kaons (called mesons). However these experiments discovered a type of matter made of two quarks and two antiquarks (tetraquarks) or four quarks and an antiquark (pentaquarks). The study of these exotic particles helps us understand the forces that bind quarks together. Such novel states of matter are of strong interest not only in particle physics but also in nuclear physics, and might also exist at the interior of very dense stars such as neutron stars.

These experiments also produce large samples of tau particles. In addition to charged lepton flavor violation searches at Mu2e from muon decays, they can search for the same violation in tau decays, a complementary probe to quantum imprints of particles well beyond the reach of current collider experiments.

All experiments mentioned here are major international projects with small but important US contributions and demonstrate the good investment value of international engagements.

Ole Miss Q:
What is the major challenge for the accelerator ?

Ole Miss Q:
How can Belle II contribute to charged lepton flavor violation ?

For example, the FCC-ee circular collider is expected to produce a sample of bottom mesons twenty times larger than that of Belle II, enabling a strong indirect search program which will complement its Higgs boson and electroweak parameter measurements. That search program is unfeasible at LHCb-II or Belle II. Precision measurement of the top quark mass is an indirect measure of its interaction with the Higgs boson, which controls the quantum mechanical evolution of the Standard Model at high energies; a 350 GeV Higgs Factory stage will reduce the uncertainty in this crucial parameter by a factor of ten. Proposed 10 TeV-scale machines will probe even higher scales.

The decisions related to construction of an off-shore Higgs factory are anticipated to be made later this decade. The current designs of both FCC-ee and the ILC satisfy our scientific requirements. To secure a prominent role in a future Higgs factory project, the US should actively engage in feasibility and design studies (Recommendation 2c). Engagement with FCC-ee specifically should include design and modeling to advance the feasibility study, as well as R&D on superconducting radio frequency cavities designed for the ring and superconducting magnets designed for the interaction region. These efforts benefit from synergies in workforce development through participation in SuperKEKB and the Electron-Ion Collider.

See talk by Dr Oskar Hartbrich

Associate Director of OHEP, Gina Rameika

General response to recommendations 1, 2, and 3

- Recommendation 1 :
  - DOE fully supports this recommendation and puts it as the **highest priority** in planning our allocation of funding.
- Recommendation 2 :
  - DOE forwarded each of the projects listed in red on slide 7 to the Facilities sub-panel
  - These are all large undertakings and will comment on each one separately
- Recommendation 3 :
  - DOE will implement and execute a plan to address the ASTAE recommendation
  - DOE will NOT support scope towards the LHCb Upgrade II
  - DOE will continue to meet its on-going commitments to Belle-II; contributions towards SuperKEKB will be considered in the context of accelerator R&D toward e+e- luminosity improvements
  - DOE will work with the DESI Collaboration to carefully decide a scope, schedule and cost envelope for the DESI-II upgrade

Further comments from Brian Beckford at the DPF/PHENO meeting in Pittsburgh and by e-mail

Dr Brian Beckford, Program Manager for the Intensity Frontier.

Beckford, Brian via phys.hawaii.edu   Wed, May 29, 1:09 PM (6 days ago)

to Glen, Tom

Dear Prof. Browder,

- Belle II is a highest-priority project for DOE

    -*LBNF/DUBE is the highest priority for DOE HEP. Belle-II is a high priority for the Intensity Frontier research program.*

- we want to support Belle II until the end of its program

    – *Correct, HEP is a mission driven agency which includes building (project), operations, and analysis through completion of physics output.*

- we now also plan to support the machine upgrade.

    - We endorse and support the planned machine upgrades to achieve higher luminosity.

- if a detector upgrade is needed to exploit improvements on the machine side, we will therefore support it.

    -We plan to follow the P5 recommendations that include the Belle-II -upgrades as might be needed to take full advantage of the machine/accelerator upgrades, which has some coupled dependence in the machine upgrades being achieved.

Warmly,
Brian Beckford, Ph.D. [He/Him]

Program Manger- Intensity Frontier Research Program

What does the P5 report and the DOE response mean for Belle II@SuperKEKB ?

Seize the opportunity:

We are in the first tier of HEP priorities.

We can ask for a Belle II upgrade, do R&D on the upgrade, hire junior faculty etc.

We can ask for targeted contributions to SuperKEKB.

Examples:

Fermilab is proposing ”start-up funding” for collaborative Nb_3Sn magnet R&D for SuperKEKB within the US-Japan fund.

Later, they will request more significant DOE funding (not in the intensity frontier) for this important type of magnet R&D.

BNL will request a “beam-beam” postdoc from lab LDRD in fall 2024 (*delayed*).

Technical Work-Force Development was highlighted in the P5 report

Recruiting: We should draw research and technical personnel from both a national and international talent pool. Recruitment should address historic and ongoing patterns of underrepresentation in particle physics by engaging broadly in educational efforts and dissemination of scientific findings to the public. Pathways to cutting-edge research at the frontiers of our field should be expanded to reach a broader cross section of students. Strategic academic partnerships connecting different types of academic and research institutions play an important role and continued support is recommended (Recommendation 5b). There should be a concerted effort on including institutions which reach historically underrepresented groups such as minority-serving and rural institutions.

Professional Development

Training: Given the technologically advanced skill sets needed to ensure a robust future for particle physics, we must have strong programs that pass knowledge from experts to new participants in the field. Imparting knowledge to the next generation is crucial to keeping our field at the forefront of AI/ML, quantum sensors, accelerators, and a host of other technologies needed for current and future research. Programs like the US Particle Accelerator School and the Theoretical Advanced Study Institute in Elementary Particle Physics (TASI) are essential ingredients in equipping the next generation with key skills and require sustained support (Recommendation 5b).

Professional Development and Hands-on Sessions.

Retaining: People are our most precious resource. Scientific advances rely upon the coordinated efforts of experimental and theoretical physicists, technicians, engineers, and administrative support staff. An infrastructure that facilitates individual participation in these efforts will allow us to meet the community's ethical standards, ensure good stewardship of human resources, and help retain talent. This infrastructure must ensure accessibility, including living wages and sufficient support for those with family and caregiver responsibilities (Recommendation 5b). Studies of the work climate of the field, informed by experts in sociology and organizational psychology, can allow us to identify barriers to participation and gauge our progress (Recommendation 5c).

First cell phone call from NYC to Bell Labs, NJ 1973
(2.5 lbs, 30 minute battery life, 10 hours to recharge)

Took Motorola *ten years* to commercialize, 1983.
First small cell phone, 1989, Motorola

First cell phone with text messages, 1992, Nokia
Smart phone precursors, IBM 1994 Personal Communicator.

First IPhone 2007.

"Don't stop thinking about tomorrow
Don't stop it'll soon be here".
-Fleetwood Mac, 1977

In 2018, we fought hard and managed to integrate 0.428 fb^{-1} for the whole spring run. Seemed pretty hopeless (KLM and trigger were not working). No vertex detector. DAQ was *crashing* all the time. Got a dark sector PRL paper from this tiny dataset.

By 2022, we integrated ~428 fb^{-1} and reached 2.5 fb^{-1}/day. Found first hints of B->K nu nubar but started having SBLs.

Need to reach ~5 fb^{-1}/day every day and then integrate steadily during long 6-7 month runs. (see Karim Trabelsi's talk) to reach 1 ab^{-1}/year level.

Last comment:

"Belle II needs more data !!!"

Apologies to Director Akira Kurosawa

Why ?To find out whether there are BSM couplings in the weak interaction

The futuristic nano-beam e+e- collider, SuperKEKB, is the key. We are at ~200nm vertical beam height (and L x5 PEP-II). Need to go to 50 nm and build up beam currents.

Imaginary but realistic future dialogue

"But Captain Ohnishi, I can't squeeze β^*_y any further"

"Well, increase the beam currents"

"Sorry Captain, I can't push the linac any harder."

P5 Appendix:

Technical Work-Force Development was highlighted

Need more detector and accelerator R&D

Area Recommendation 6: Increase the budget for generic Detector R&D by at least $20 million per year in 2023 dollars. This should be supplemented by additional funds for the collider R&D program.

Area Recommendation 7: The detector R&D program should continue to leverage national initiatives such as QIS, microelectronics, and AI/ML.

Area Recommendation 8: Increase annual funding to the General Accelerator R&D program by $10M per year in 2023 dollars to ensure US leadership in key areas.

Area Recommendation 9: Support generic accelerator R&D with the construction of small scale test facilities. Initiate construction of larger test facilities based on project review, and informed by the collider R&D program.

DEI

We must collaborate to do our science, which by necessity brings together people at various career stages and from a diverse set of backgrounds. Within these collaborations, ethical standards must be stated clearly and upheld in order for our community members, and our science, to thrive. Establishing and maintaining these standards includes setting professional expectations, reporting violations, and having a process to rectify violations. Such infrastructure should include ombudspersons, independent investigators in cases of egregious alleged violations, training for those in leadership positions, and training to encourage collaborators to create an environment in which people can thrive and scientific output can reach its potential. Laboratories and funding agencies are charged to support such infrastructure (Recommendation 5a).

Prof. Kay Kinoshita et al.

Appendix: Summary of Major Recommendations

Figure 1 – Program and Timeline in Baseline Scenario (B)

Index: Operation Construction R&D, Research P: Primary S: Secondary

§ Possible acceleration/expansion for more favorable budget situations

Science Experiments

Timeline 2024 – 2034

Science Experiments	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
LHC		P	P		P	P	
LZ, XENONnT			P				
NOvA/T2K	P				S		
SBN	P				S		
DESI/DESI-II	S		S	P			P
Belle II			S		S	P	
SuperCDMS			P				
Rubin/LSST & DESC	S		S	P			P
Mu2e						P	
DarkSide-20k			P				
HL-LHC		P	P		P	P	
DUNE Phase I	P				S	S	S

Science Drivers

For convenience, we gather here the full list of recommendations from the report, with the caveat that some meaning may be lost when taken out of context.

Recommendation 1: As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science.

We reaffirm the previous P5 recommendations on major initiatives:

a. HL-LHC (including ATLAS and CMS detectors, as well as Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe (reveal the secrets of the Higgs boson, section 3.2), to search for direct evidence for new particles (section 5.1), to pursue quantum imprints of new phenomena (section 5.2), and to determine the nature of dark matter (section 4.1).

b. The first phase of DUNE and PIP-II to determine the mass ordering among neutrinos, a fundamental property and a crucial input to cosmology and nuclear science (elucidate the mysteries of neutrinos, section 3.1).

c. The Vera C. Rubin Observatory to carry out the Legacy Survey of Space and Time (LSST), and the LSST Dark Energy Science Collaboration, to understand what drives cosmic evolution (section 4.2).

In addition, we recommend continued support for the following ongoing experiments at the medium scale (project costs > \$50M for DOE and > \$4M for NSF), including completion of construction, operations and research:

d. NOvA, SBN, and T2K (elucidate the mysteries of neutrinos, section 3.1).

e. DarkSide-20k, LZ, SuperCDMS, and XENONnT (determine the nature of dark matter, section 4.1).

f. DESI (understand what drives cosmic evolution, section 4.2).

g. Belle II, LHCb, and Mu2e (pursue quantum imprints of new phenomena, section 5.2).

Recommendation 3: Create an improved balance between small-, medium-, and large-scale projects to open new scientific opportunities and maximize their results, enhance workforce development, promote creativity, and compete on the world stage.

In order to achieve this balance across all project sizes we recommend the following:

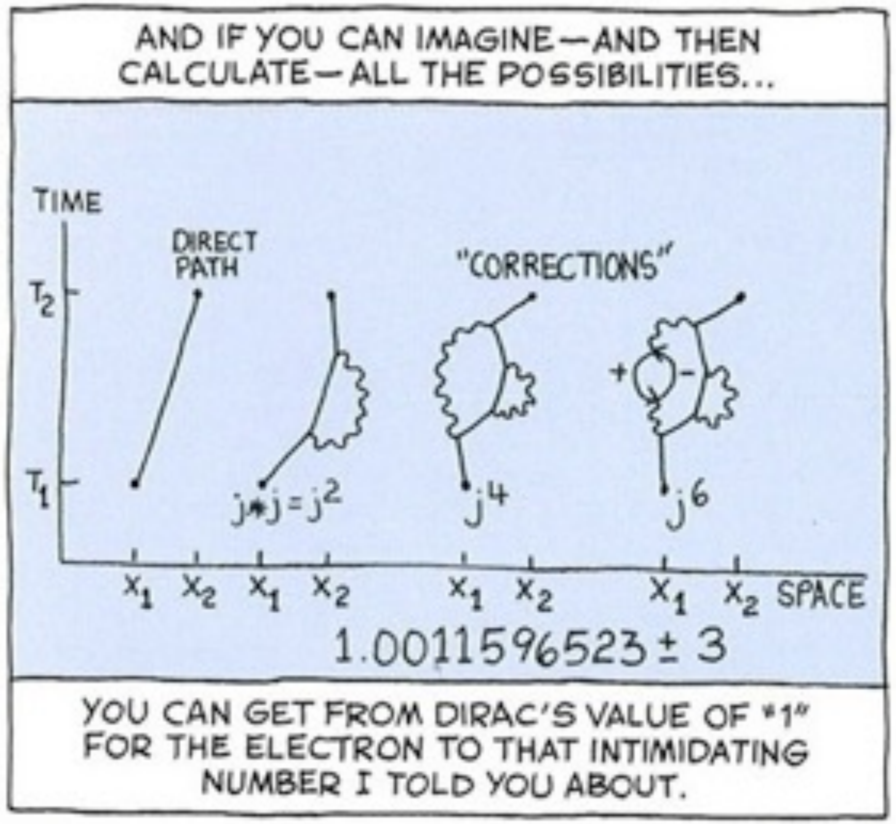
a. Implement a new small-project portfolio at DOE, Advancing Science and Technology through Agile Experiments (ASTAE), across science themes in particle physics with a competitive program and recurring funding opportunity announcements. This program should start with the construction of experiments from the Dark Matter New Initiatives (DMNI) by DOE-HEP (section 6.2).

b. Continue Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs as a critical component of the NSF research and project portfolio.

c. Support DESI-II for cosmic evolution, LHCb upgrade II and Belle II upgrade for quantum imprints, and US contributions to the global Cherenkov Telescope Array (CTA) Observatory for dark matter (sections 4.2, 5.2, and 4.1).

The Belle II recommendation includes contributions towards the Super-KEKB accelerator.

Feynman, Heisenberg and Virtual Particles



$$\Delta E \cdot \Delta t = \frac{h}{4\pi}$$

You can create and destroy a virtual massive heavy particle in the loop if you do it for a very short time

Not so long ago (before the pandemic)

The experimental control room in Tsukuba Hall B3 (Spring 2019)

This was scientific history in the making: SuperKEKB/Belle II joined DORIS/ARGUS, CESR/CLEO, and PEP-II/BaBar and KEKB/Belle