University of DØ

P5 for Students & Postdocs (and everyone else)

Outline:

- The physics & "drivers"
- Funding landscape & scenarios
- Getting it to fit
- Large, medium, small-ticket items
- Timelines
- Directions & choices

Rick Van Kooten
Indiana University
13 June 2014
Fermilab

The Report

Building for Discovery

Strategic Plan for U.S. Particle Physics in the Global Context

Report of the Particle Physics Project Prioritization Panel (P5)

http://usparticlephysics.org/p5/

Provide “an updated strategic plan for the U.S. that can be executed over a ten-year timescale, in the context of a twenty-year global vision for the field.”

Panel Members

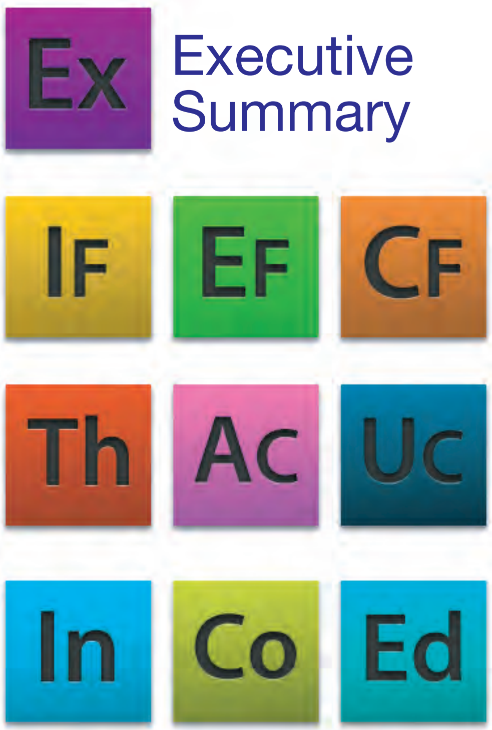
Hiroaki Aihara (Tokyo)
Martin Breidenbach (SLAC)
Bob Cousins (UCLA)
André de Gouvêa (Northwestern)
Marcel Demarteau (ANL)
Scott Dodelson (FNAL/Chicago)
Jonathan Feng (UCI)
Bonnie Fleming (Yale)
Fabiola Gianotti (CERN)
Francis Halzen (Wisconsin)
JoAnne Hewett (SLAC)
Andy Lankford (UCI)

Wim Leemans (LBNL)
Joe Lykken (FNAL)
Dan McKinsey (Yale)
Lia Merminga (TRIUMF)
Toshinori Mori (Tokyo)
Tatsuya Nakada (Lausanne)
Steve Peggs (BNL)
Saul Perlmutter (Berkeley)
Kevin Pitts (Illinois)
Steve Ritz (UCSC, chair)
Kate Scholberg (Duke)
Rick van Kooten (Indiana)
Mark Wise (Caltech)

Physics Inputs

Strong unanimous opinions that these must be the primary drivers for vision

"Snowmass": year-long community exercise
(see Dmitri D.'s U. of DØ slides),
physics *capabilities* of different projects compared (enjoyable!)



Executive Summary

Snowmass Reports

Intensity Frontier
Energy Frontier
Cosmic Frontier

Theory
Accelerator Capabilities
Underground Lab Capab.

Instrumentation
Computing
Education & Outreach

Physics Drivers

Strong unanimous opinions that these must be the primary drivers for vision

Identify the new physics of dark matter

Use the Higgs boson as a new tool for discovery

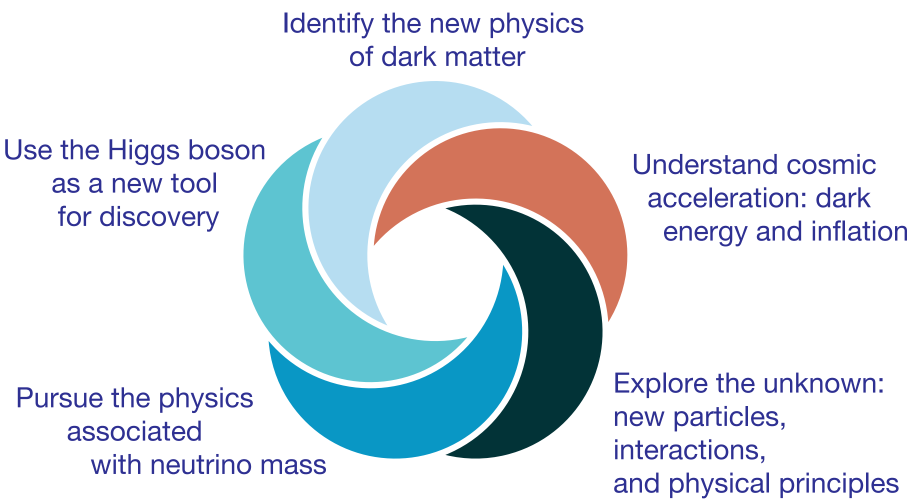
Understand cosmic acceleration: dark energy and inflation

Pursue the physics associated with neutrino mass

Explore the unknown: new particles, interactions, and physical principles

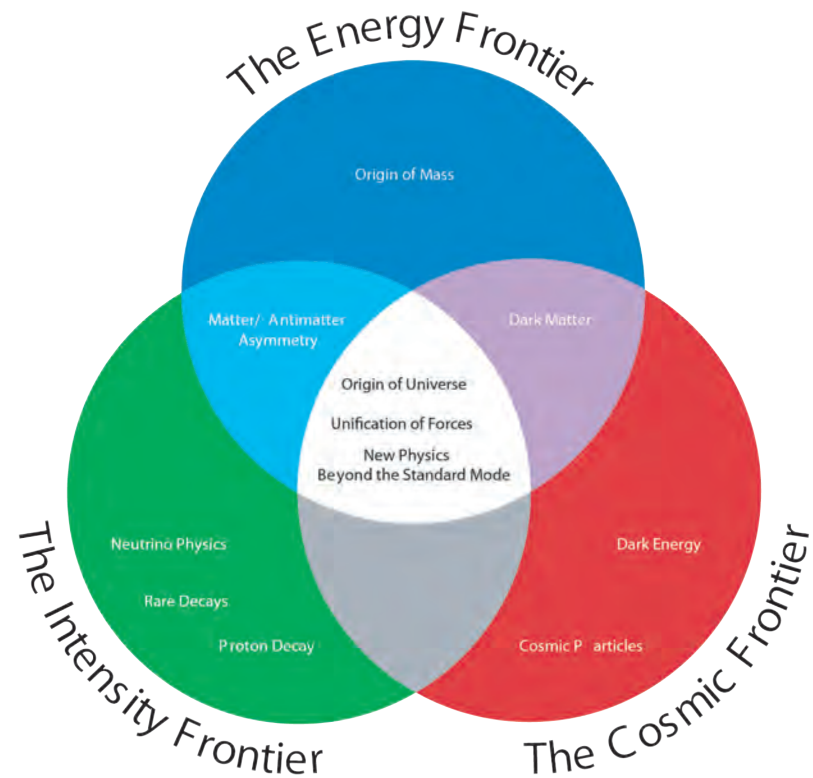
Entwined

Physics Drivers

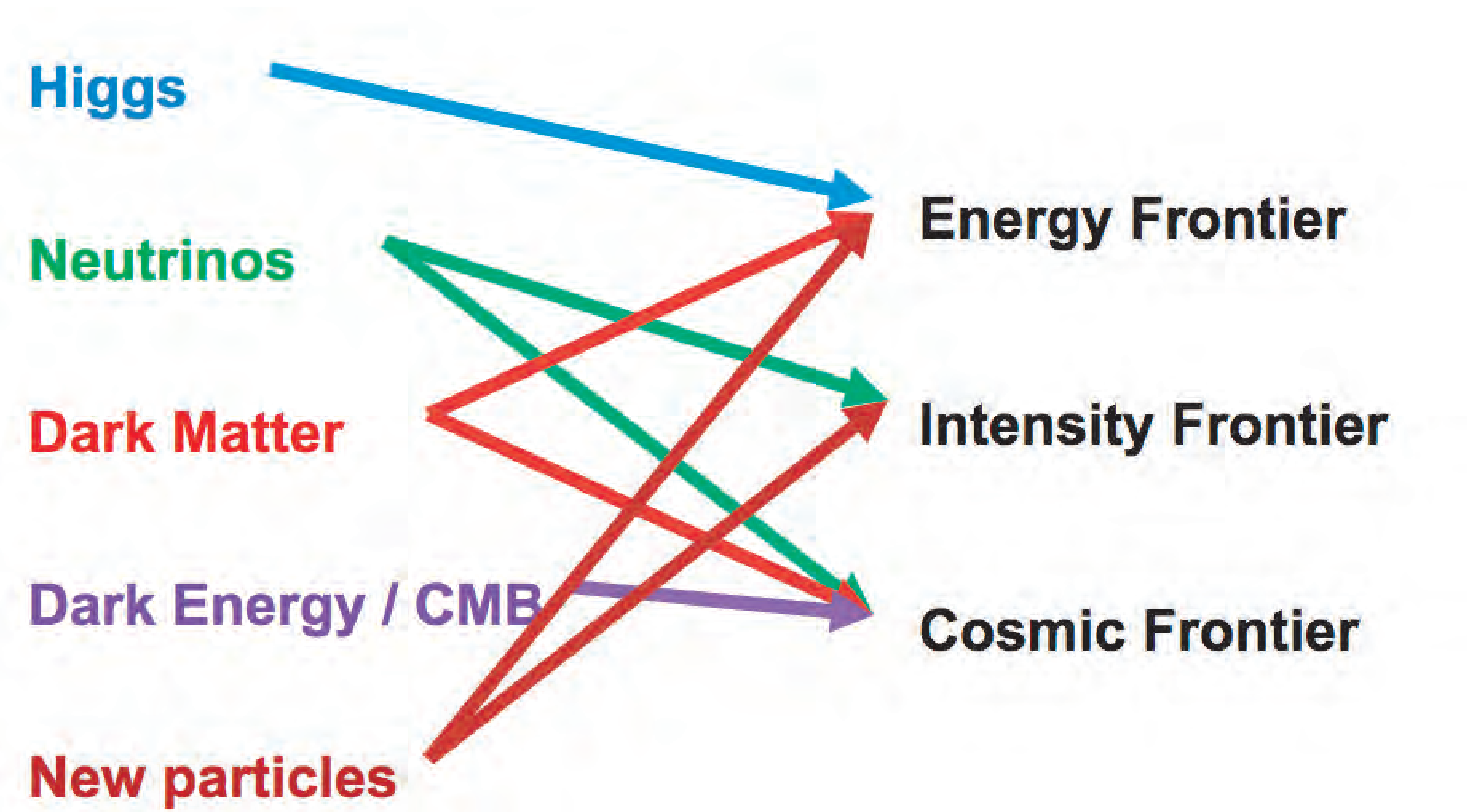


Entwined

Consider these as techniques to get at the physics

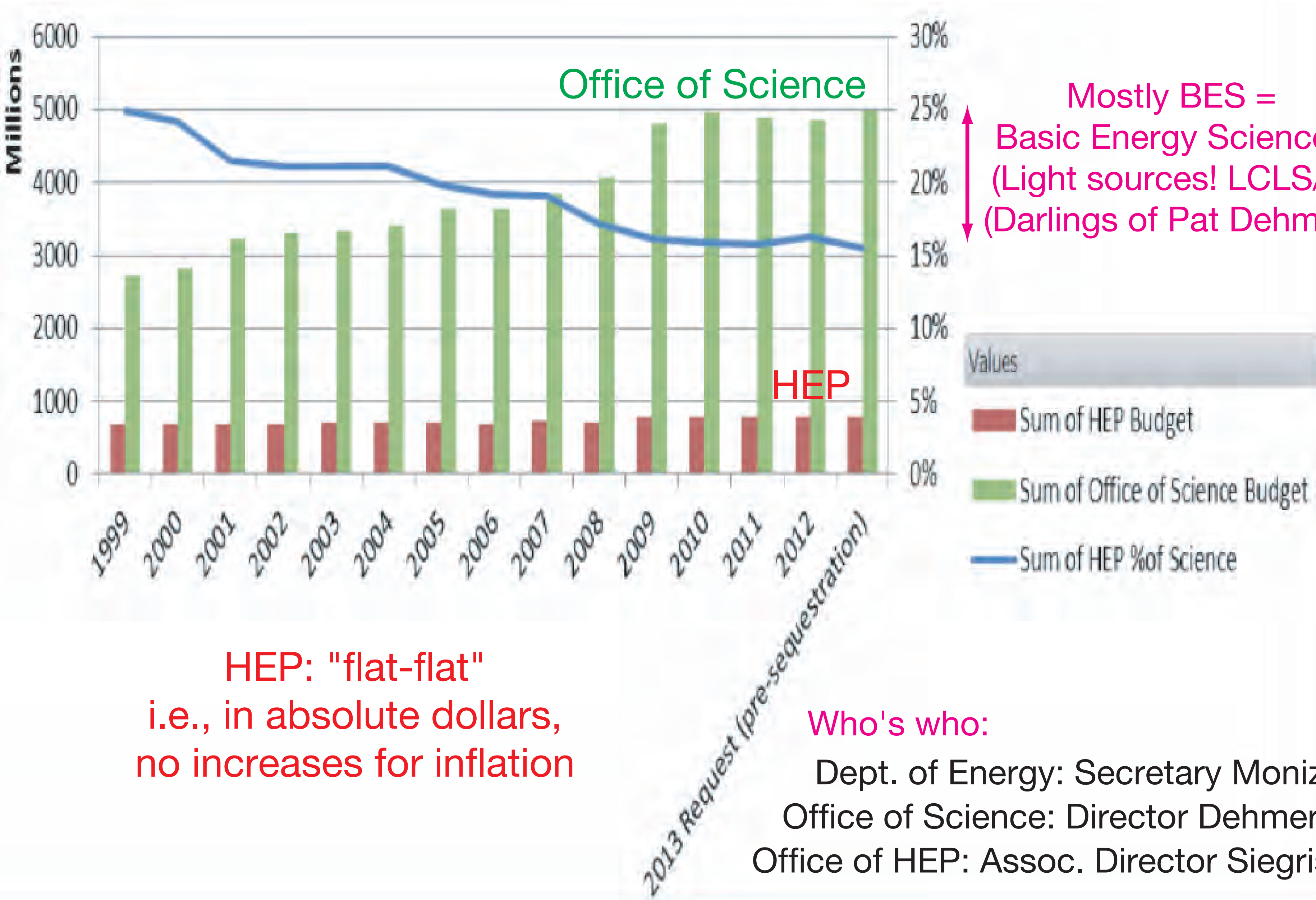


Physics Drivers



Courtesy Jim Siegrist

Budget Landscape

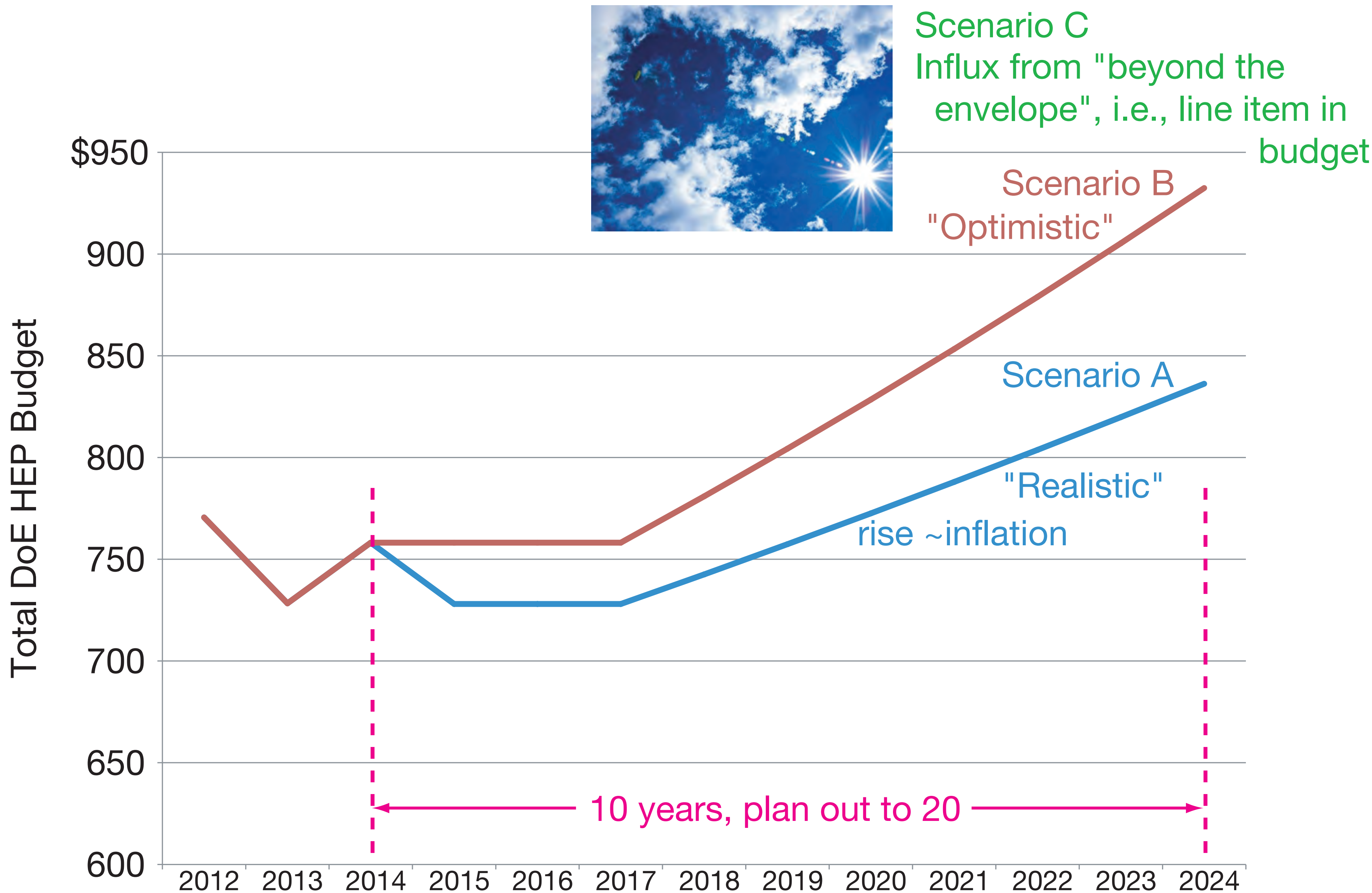


Mostly BES =
Basic Energy Sciences
(Light sources! LCLS/II)
(Darlings of Pat Dehmer)

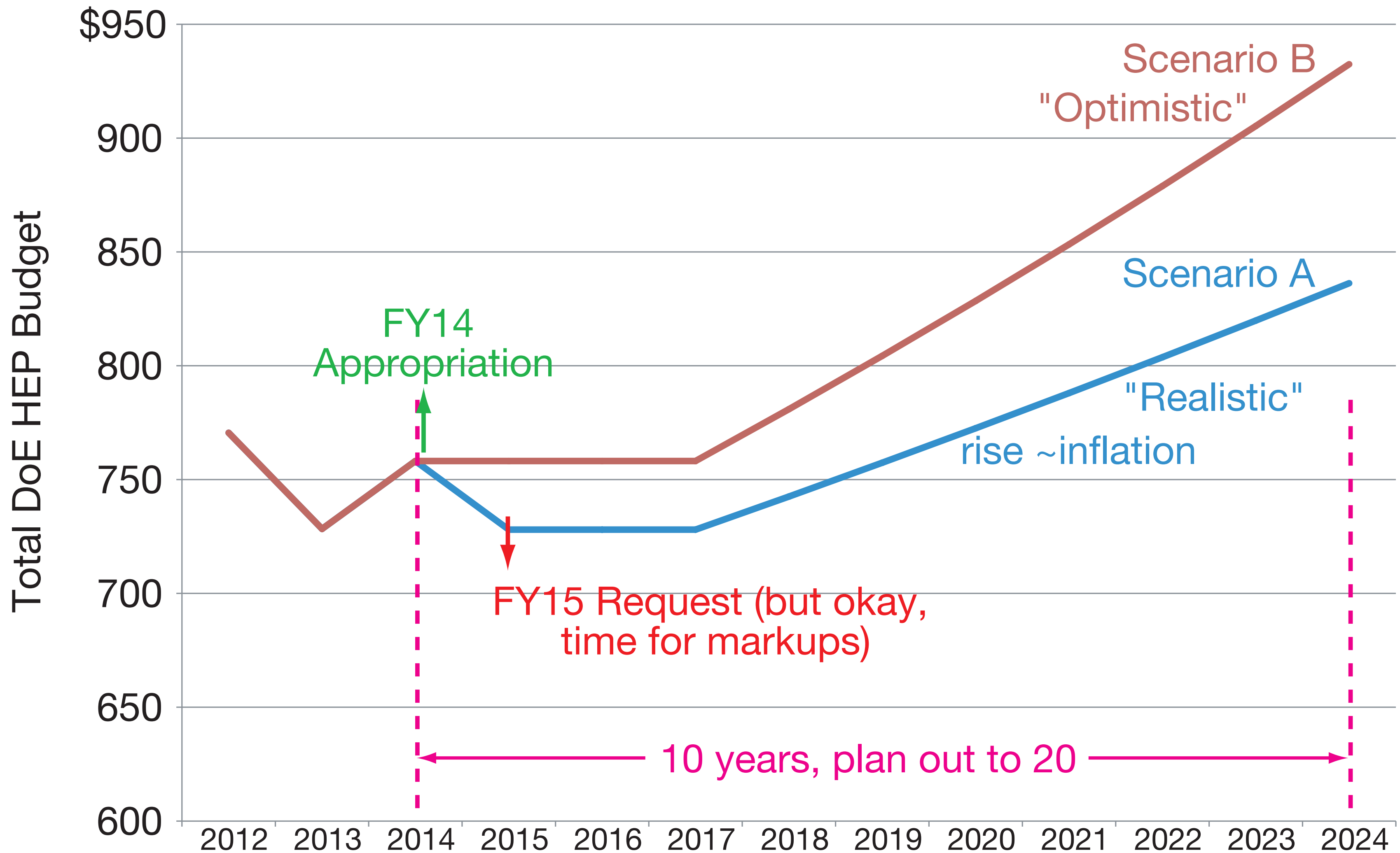
HEP: "flat-flat"
i.e., in absolute dollars,
no increases for inflation

Who's who:

Dept. of Energy: Secretary Moniz
Office of Science: Director Dehmer
Office of HEP: Assoc. Director Siegrist

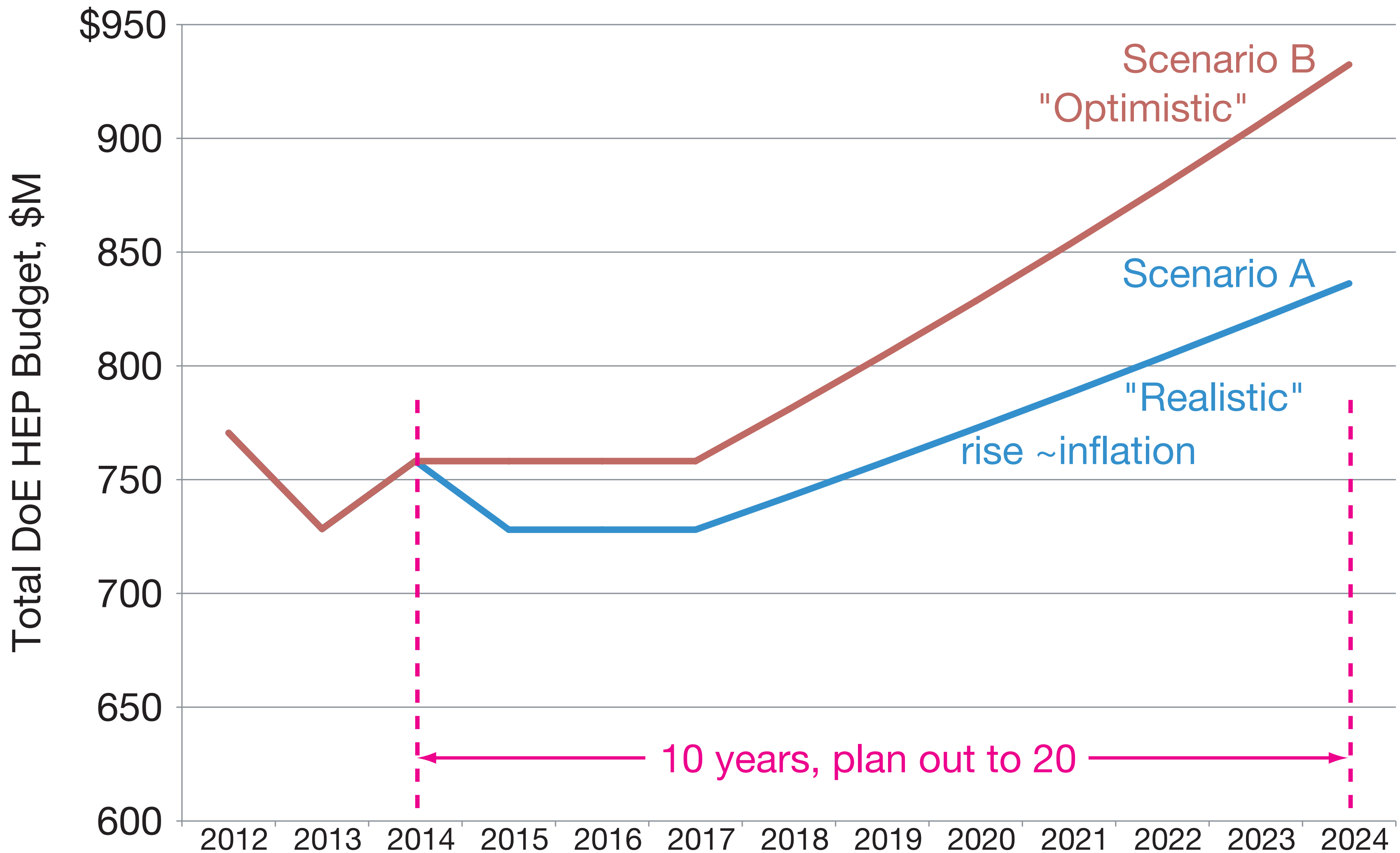


Scenario C
Influx from "beyond the envelope", i.e., line item in budget
Scenario B
"Optimistic"
Scenario A
"Realistic"
rise ~inflation
10 years, plan out to 20
Total DoE HEP Budget
$950
900
850
800
750
700
650
600
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024



- at any given time, it is tough to even know which scenario we are in!

- Hey, this seems like quite a bit from which to build projects!



- ...but: "Research" (university group's, your salaries, travel...) ~45%

(e.g., 2014/15) "Facilities" (mostly this place, FNAL [hidden stuff]) ~35%

Projects, $150M/yr ~20%

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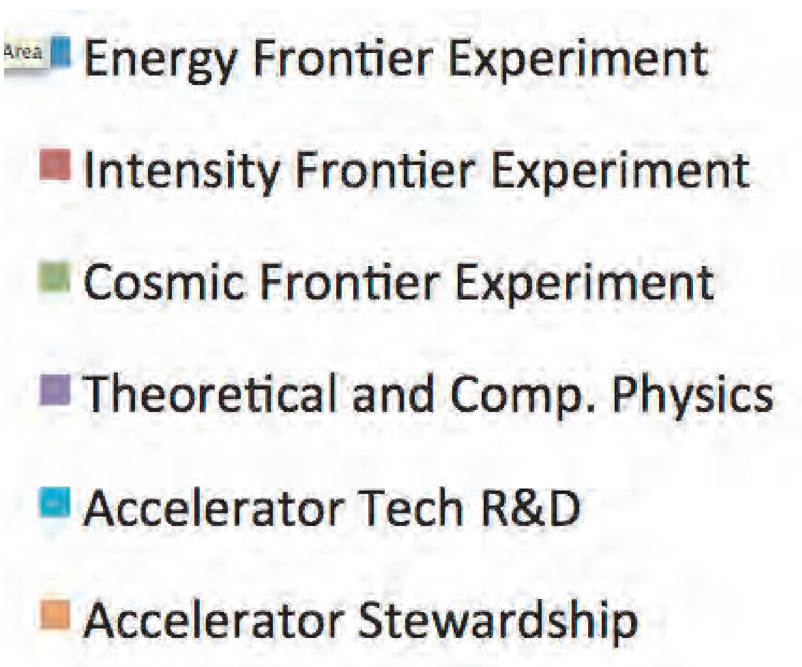
(e.g., 2014/15) "Facilities" (mostly this place, FNAL [hidden stuff]) ~35%

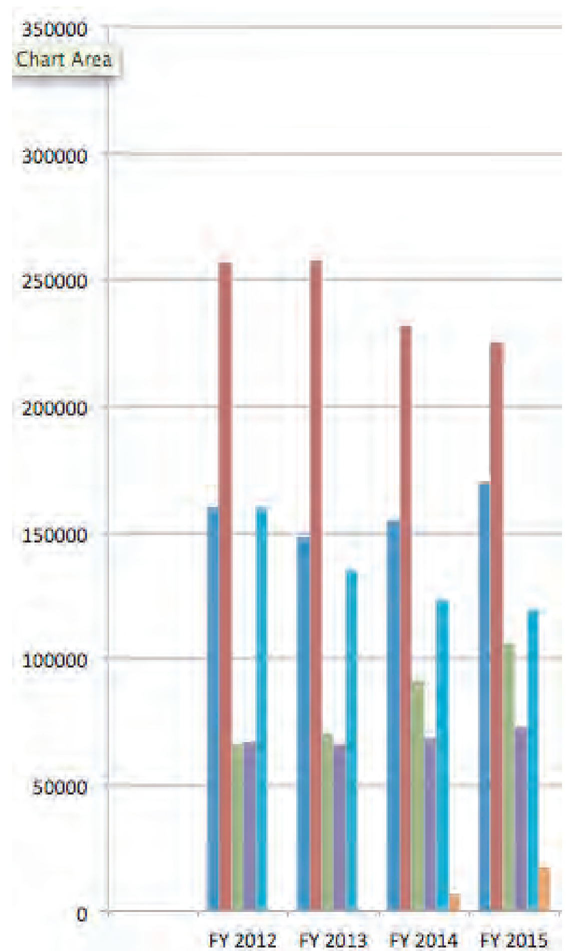
Projects, \$150M/yr ~20%

- After much discussion: increase/keep "Projects" in 20–25% range

Make sure that "Research" >40%

- How currently allocated:





What about the NSF?

Brings critical amounts!

(in M$)	FY 2008 Actuals	FY 2009 Actuals	FY 2009 ARRA	FY 2010 Actuals	FY 2011 Actuals	FY 2012 Actuals	FY 2013 Actuals	FY 2014 Estimate
EPP Research	20.5	18.8	14	25.8	25	24.7	21.8	18.6
LHC Ops	18	18		18	18	18	18	17.4
LHC Upgrades (Midscale)								5.9
CESR	13.7	8.5	1.3					
APPI	4	2.2		3	4.1	11.9	4.5	
Accel Research								In Prog
PA Research	15.8	15.9	15.3	17.9	9.7	11.5	12	11.9
IceCube Ops	1.5	2.2		2.2	3.5	3.5	3.5	3.5
DUSEL Planning	2	22		28.9	10.2			
Underground R&D	5	4	5.6	4.6	6	11	3.9	0.4
Underground Physics					8.4	6.3	6.8	6.8
THY (EPP/Astro/Cosmo)	11.7	12	6.8	13.2	14.1	13.6	12.1	12.1
Physics Frontier Centers	6.3	5.9		5.9	6	6	6	6
Total Particle Physics	98.5	109.5	43	119.5	105	106.5	88.5	82.6
Total Physics Division	285	275.5	102.1	307.8	280.3	277.4	247.4	260
% of Physics Division	34.6%	39.7%	42.1%	38.8%	37.5%	38.4%	35.8%	31.8%
Allied Funding	7.2	4.9	0.5	12.7	12.3	24.7	20.8	In Prog
Effective Total	105.7	114.4	43.5	132.2	117.3	131.2	109.3	In Prog

University groups

Total ~$100M/yr

What about the NSF?

- *"So how much can we realistically count on for xxxx?"*

"We are proposal-driven..." Hence more inherent uncertainty than DoE!

MRI – Major Research Instrumentation
- Physics Division Competition – up to $1M
- MPS Directorate Competition – up to $4M
- Requires 30% match from participating institutions

e.g., silicon wafers/equipment

Midscale Funding
- Funding level variable
- Resources from Division(s) and Directorate(s)

MREFC – Major Research Equipment and Facilities Construction
- Funding request exceeds 10% of Directorate Budget
- Competition is NSF-wide

e.g., LIGO, adv. LIGO, LSST

We are assuming these for a certain level of funding

The Process

- Meetings/Town Halls for community input
- Essentially all projects considered for Snowmass presented to P5 (enjoyable & educational!)

  Total cost: ~$6.6B!

- All projects asked to provide cost profiles, timelines, contingency, personnel/FTE with time

  Different levels of maturity from full CD-x to "notional", so vetted and scrubbed – uncertainties

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- **Monster spreadsheet:** scenario inputs, costs per year (included as an option a DoE-authored initial strawman)
- scale factors (□-factors), time shifts (□t), stretch-outs (□_n)
- get it all to fit, including focused alternatives; individual, small teams, panel as a whole; physics & budgeting

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New terms: "just mu-it", "to be mu'ed", "mu-ify"; "chump change"

The "Gorillas"

LBNE: Long Baseline Neutrino Experiment

- Neutrino beam from Fermilab, near detector, far detector at Sanford Underground Research Facility (SURF) in South Dakota
- See Stefan S.-R.'s excellent User's Mtg. talk
  LBNE Science Book: arXiv:1307.7335v3
  http://lbne.fnal.gov/

- CP violation in lepton sector
- Mass hierarchy
- Test three-flavor paradigm
  (c.f. quarks and CKM)

- Nucleon decay
- Supernovae neutrinos

For world-wide physics knowledge and progress, need a world-class long-baseline. So large scale: can we afford more than one globally?

The "Gorillas"

LBNE

- The "Brinkman Cap":
  thou shall not spend total >$1B of DoE funds on any one project
- CD-1 of LBNE, de-scoped $867M
  (700 kW beam, 10 kton LAr on *surface* at SURF)

- Snowmass conclusion: this results in inadequate physics
  Also lose some capabilities outright if on surface
- To "do it right" (and also to attract international partners!) requires more mass underground at higher beam power, but would cost ~$1.5B (violates the cap, do the math of remainder)
- Yes, many alternatives w/o LBNE were seriously considered.

The "Gorillas"

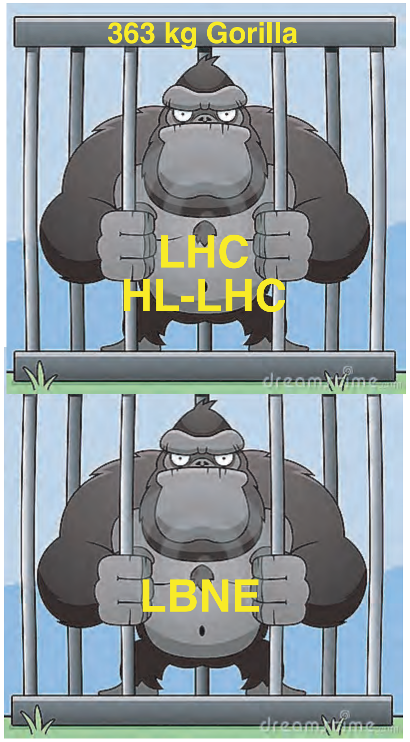
LHC & HL-LHC (Upgrades)

- Phase 1 upgrades (for 300 fb^{-1})
- Phase 2 upgrades for high-luminosity run (3000 fb^{-1})
- Total level of support required of U.S. to continue participation formulaic and by negotiation

- Physics motivation clearly motivated (confirmed at Snowmass), resulting in highest priority
- But expensive! Phase 1 detectors: ~$65M (+ machine)
  Phase 2 detectors: ~$500M
  Phase 2 machine: ~$225M
- Time constraints on funding of detector upgrades driven by CERN schedule of LHC and machine upgrades

The "Gorillas"

Doubling up...



- With default plans, the ~peaks of their spending profiles approximately line up
- Need to be moved apart in time

Optimize world-wide progress on neutrino physics

Particle physics is global. To address the most pressing scientific questions and maintain its status as a global leader, the U.S. must both host a unique, world-class facility and be a partner on the highest priority facilities hosted elsewhere.

Neutrinos

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text.* LBNF is the highest-priority large project in its timeframe.

Reformulate the long-baseline neutrino program as an internationally designed, coordinated, and funded program with Fermilab as host.

*1.2 MW proton beam, 40 kton (fiducial) LAr *underground* detector (more than current CD-1 planned project)

Neutrinos

Recommendation 14: Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.

Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.

LHC

Recommendation 10: Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.

To meet budget constraints, physics needs, and readiness criteria, large projects are ordered by peak construction time: the Mu2e experiment, the high-luminosity LHC upgrades, and LBNF.

Mu2e (FNAL Intensity Frontier, $\mu \longrightarrow e$ conversion in target)
Total project cost now $250M(!)

ILC

International Linear Collider ($e^+ e^-$)

The interest expressed in Japan in hosting the International Linear Collider (ILC) is an exciting development.

Participation by the U.S. in project construction depends on a number of important factors, some of which are beyond the scope of P5 and some of which depend on budget Scenarios.

As the physics case is extremely strong, all Scenarios include ILC support at some level through a decision point within the next 5 years.

Detector and accelerator R&D (~$40M)

What being bandied about to proceed?
U.S. provides ~$1B of $10B total project cost

Waaay, outside the envelope – political decision

"Grand Bargain"?

Requires genuine coordination between U.S., Europe, Asia

Europe

LHC, HL-LHC at CERN

Neutrinos: Laguna/LBNO?

Far future: TLEP/"VLHC"?

Asia

Japan: ILC

Japan: Neutrinos, HyperK?

China: e^+e^- circular at 240 GeV?

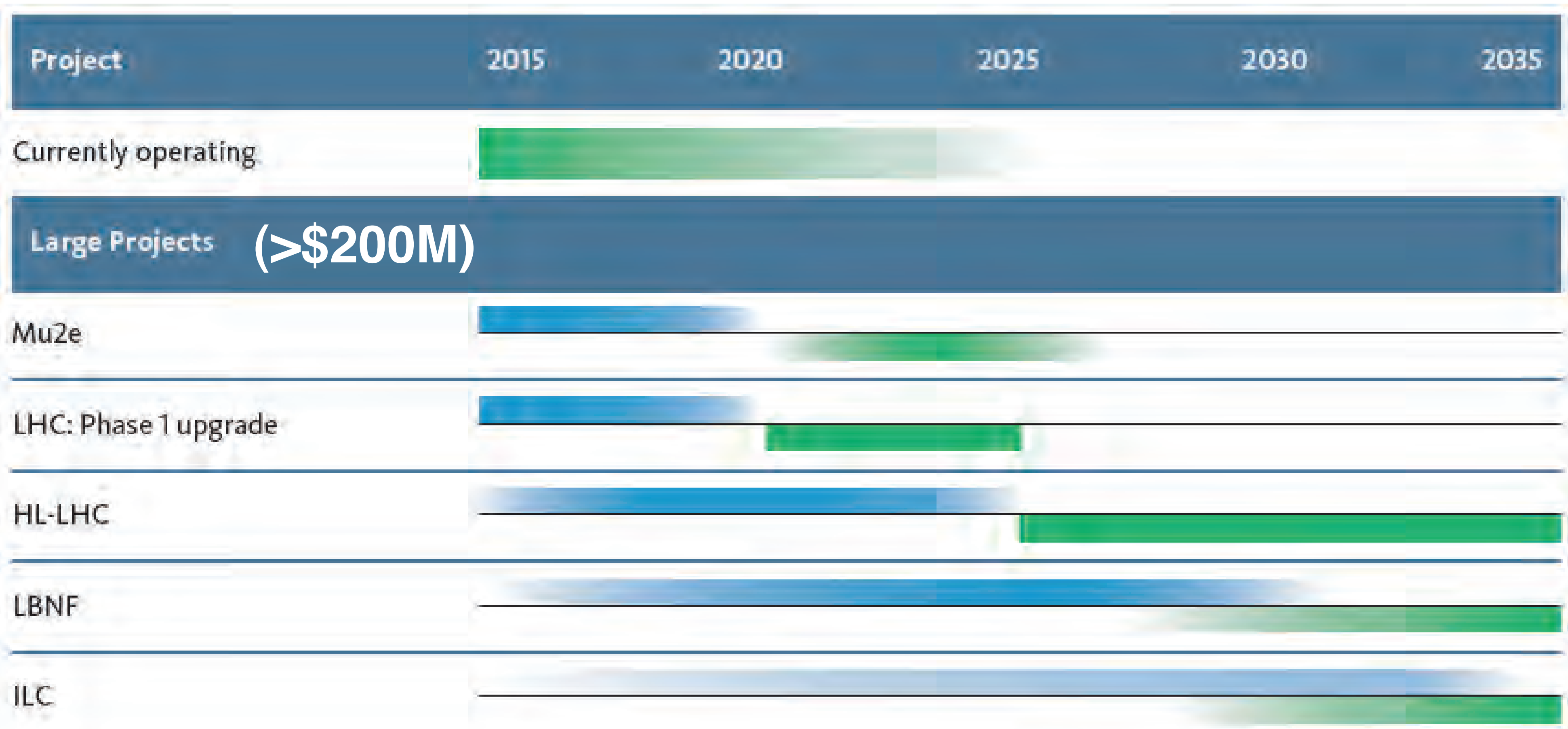
U.S.

Reformulated LBNF

Remain big part of LHC

Each region hosting a major facility?

Timeline



Project
2015
2020
2025
2030
2035
Currently operating
Large Projects
(>$200M)
Mu2e
LHC: Phase 1 upgrade
HL-LHC
LBNF
ILC

Scenarios

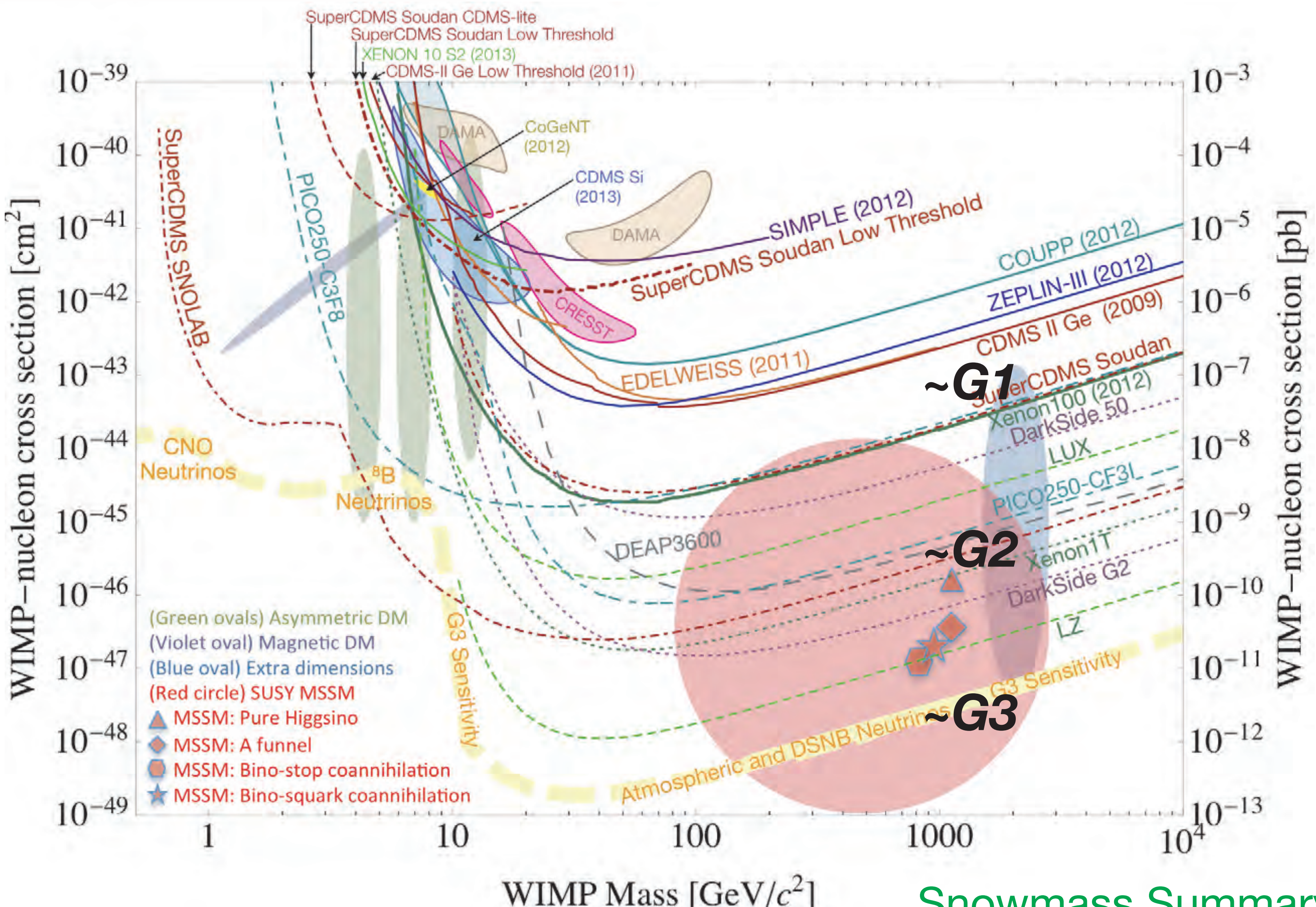
Project/Activity	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown	Technique (Frontier)
	Scenarios			Science Drivers					
Large Projects									
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y						I
HL-LHC	Y	Y	Y						E
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced						I,C
ILC	R&D only	R&D, possibly small hardware contributions. See text.	Y						E
NuSTORM	N	N	N						I
RADAR	N	N	N						I

NuSTORM = simplest implementation of neutrino factor,
short baseline, $370M

RADAR = R&D Liquid Argon detector at NOvA, $170M

Dark Matter

Gn = nth generation of detector



Snowmass Summary
arXiv:1310.837

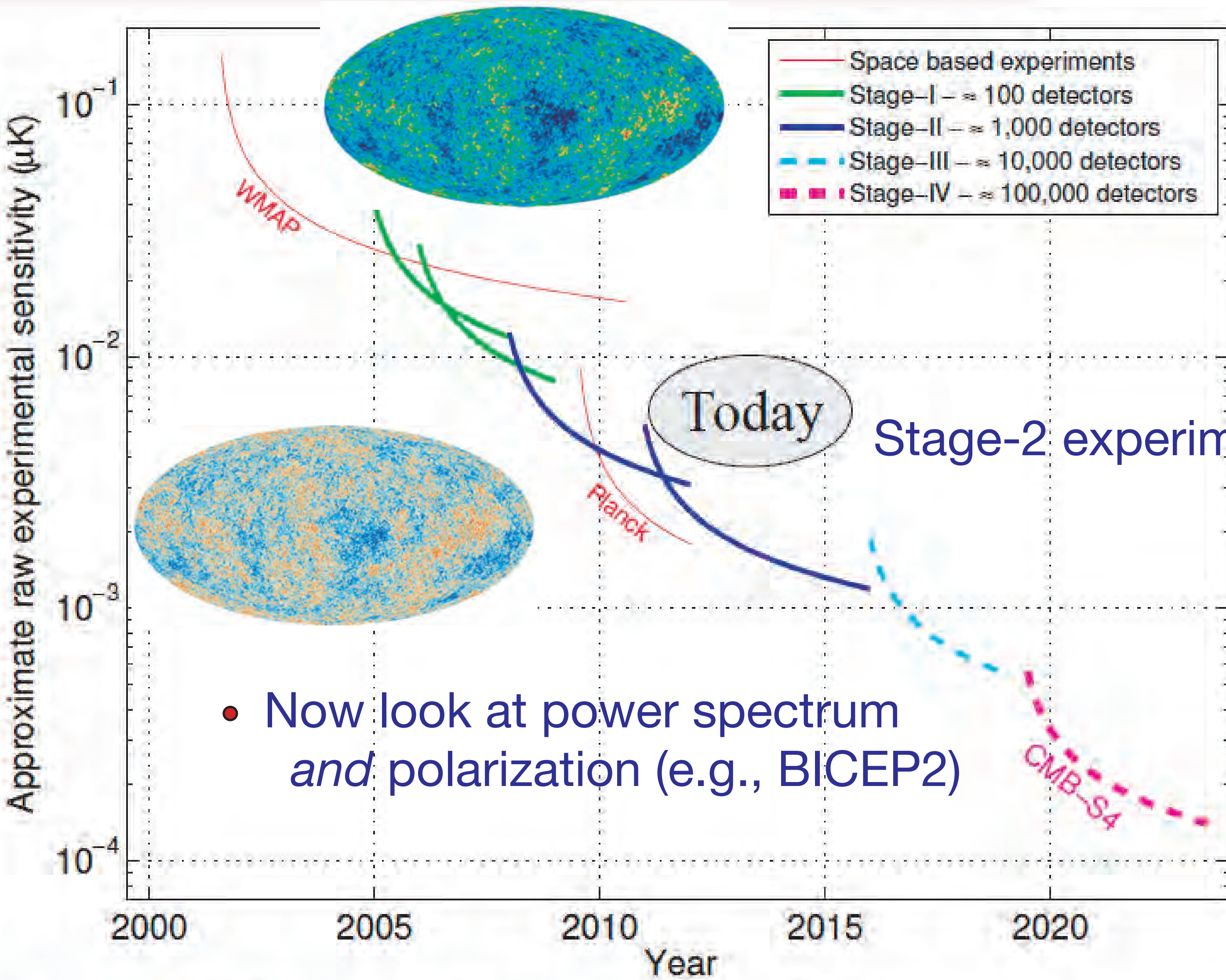
Dark Matter

- Currently operating: 1st generation or "G1"
- Larger mass, 2nd generation or "G2", several experiments
  Joint DoE/NSF solicitation, being "downselected" by another panel
- x5 – 10 more mass, 3rd generation of "G3", hitting neutrino backgs.

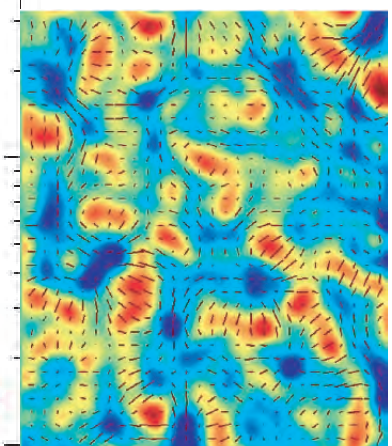
Recommendation 19: Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in the text. Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity. ~$75M

Recommendation 20: Support one or more third-generation (G3) direct detection experiments, guided by the results of the preceding searches. Seek a globally complementary program and increased international partnership in G3 experiments.

Cosmic Microwave Background



Stage-2 experiments



- Now look at power spectrum *and* polarization (e.g., BICEP2)

Snowmass: CF5 Neutrinos Document
arxiv:1309.5383

Cosmic Microwave Background

Fundamental physics:

- Did inflation happen? What physics drove inflation?
  - *Unique probe of ~10^{16} GeV physics!*
- Is there any "Dark" Radiation, from unknown relativistic particles? (e.g., sterile neutrinos)
- $\sum m_\nu > 0$ sum of the neutrino masses impacts growth of large scale structure, i.e., the matter power spectrum $\sum m_\nu \approx 16\,\mathrm{meV}$

Recommendation 18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multiagency support.

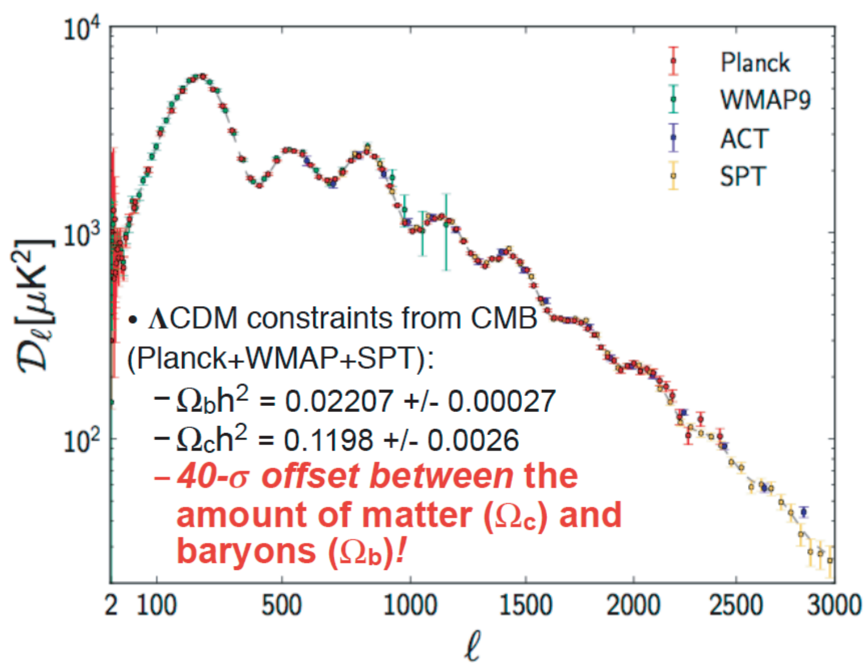
i.e., add DoE funding to NSF funding (to deal with scale)

"Bang for your buck": e.g., CMB-S4 project cost ~$90M

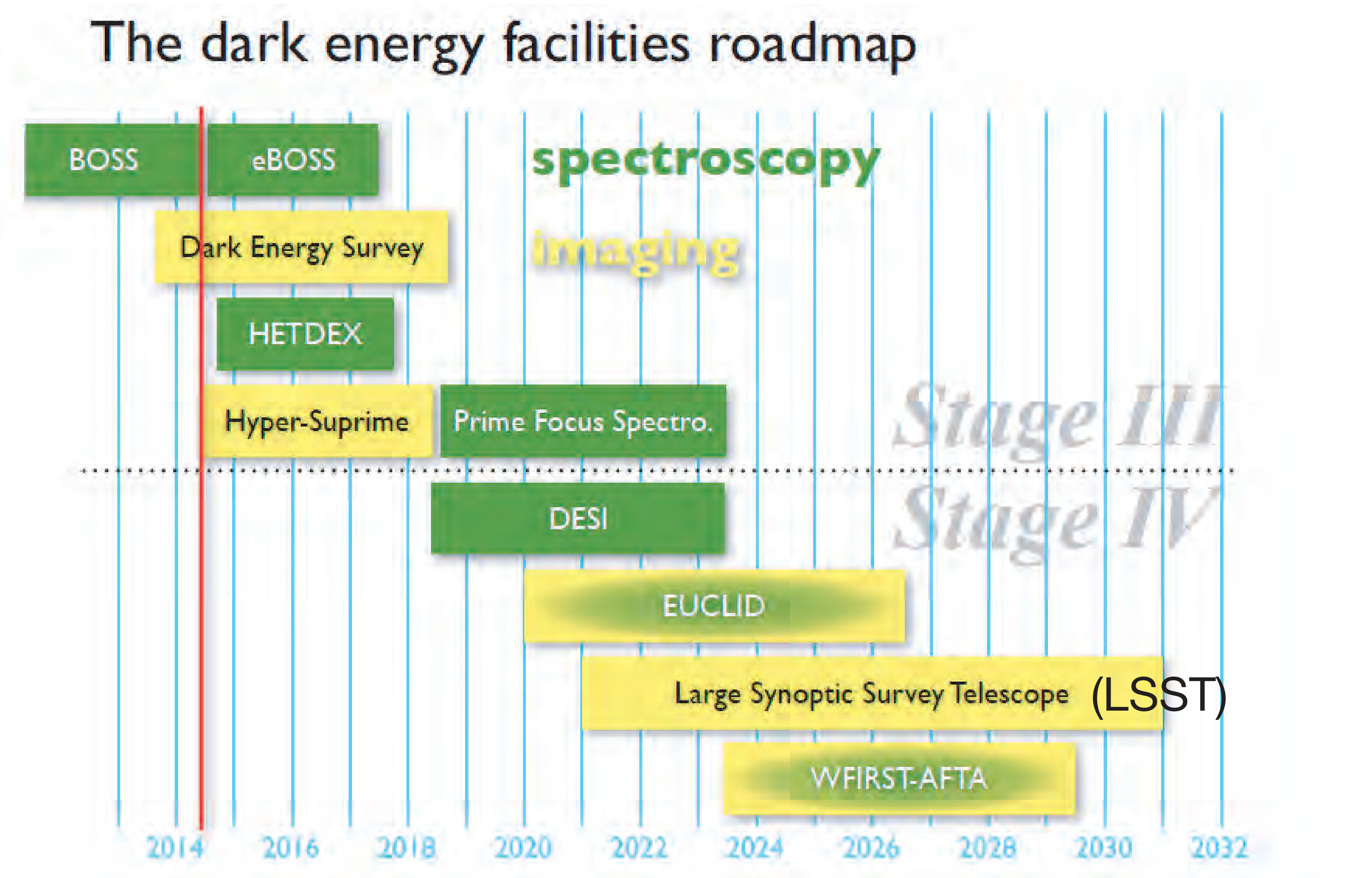
Dark Energy

- What is the source of the accelerated expansion of the universe?
  - Cosmological constant ($w = -1$)?
  - New long-range repulsive force?
  - Modification of gravity?
  - Other ideas?

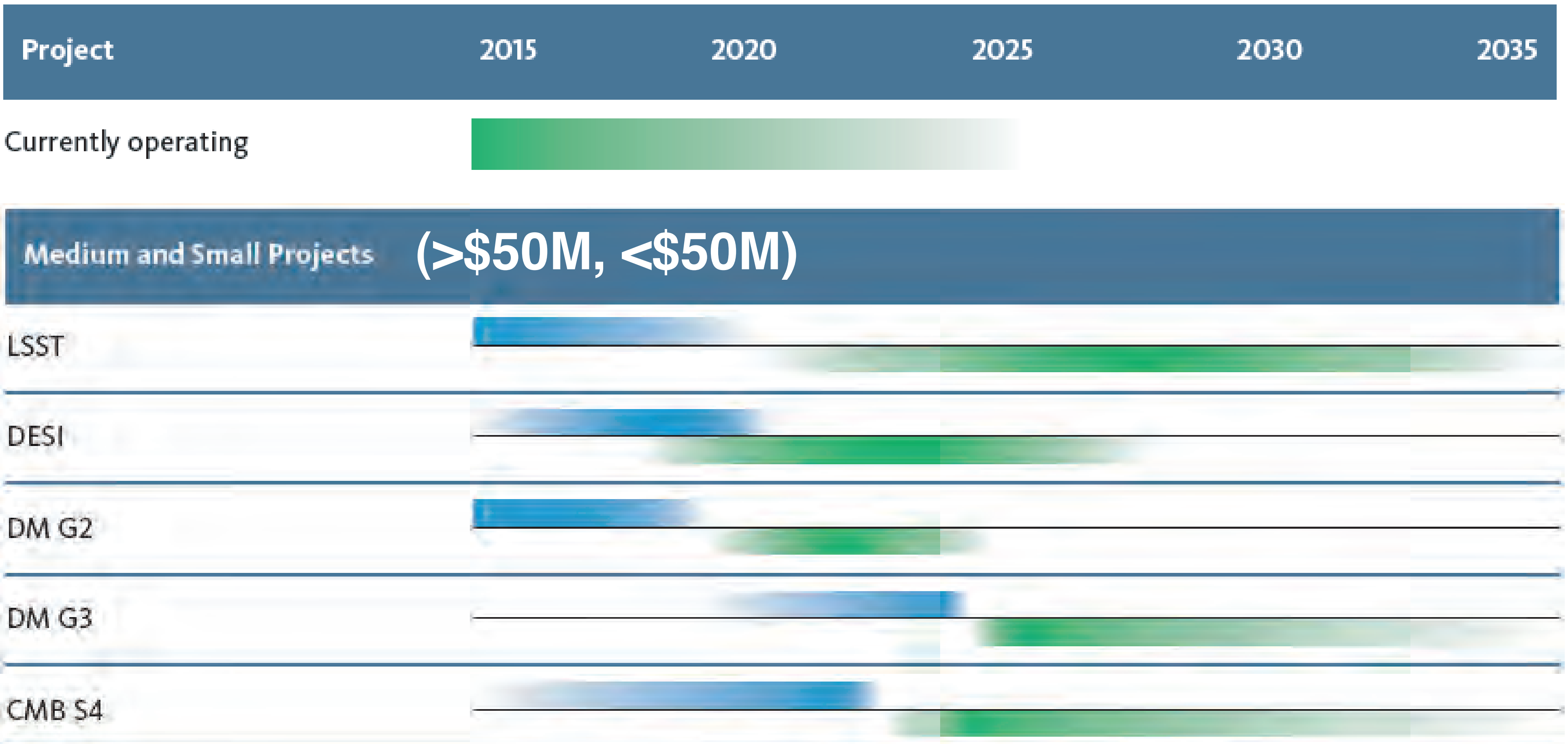
- Clustering of structure/galaxies; distance scales (red shift), Baryon Acoustic Oscillations (BAO):



Dark Energy


The dark energy facilities roadmap
BOSS
eBOSS
spectroscopy
Dark Energy Survey
imaging
HETDEX
Hyper-Suprime
Prime Focus Spectro.
Stage III
Stage IV
DESI
EUCLID
Large Synoptic Survey Telescope (LSST)
WFIRST-AFTA
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032

Timeline



Project
2015
2020
2025
2030
2035
Currently operating
Medium and Small Projects
(>$50M, <$50M)
LSST
DESI
DM G2
DM G3
CMB S4

Scenarios

Project/Activity	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matt	Cosm. Ac	The Unkno	Technique (F
Medium Projects									
LSST	Y	Y	Y						C
DM G2	Y	Y	Y						C
Small Projects Portfolio	Y	Y	Y						All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced						E,I
CMB-S4	Y	Y	Y						C
DM G3	Y, reduced	Y	Y						C
PINGU (with IceCube)	Further development of concept encouraged								C
ORKA $(K^+ \to \pi^+ \nu \bar{\nu})$	N	N	N						I
MAP (Muon Collider R&D)	N	N	N						E,I
CHIPS (Water Cherenk. ~NOvA)	N	N	N						I
LAr1	N	N	N						I
Additional Small Projects (beyond the Small Projects Portfolio above)									
DESI	N	Y	Y						C
Short Baseline Neutrino Portfolio	Y	Y	Y						I

Scenarios

Project/Activity	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matt	Cosm. Ac	The Unkno	Technique (F
Medium Projects									
LSST	Y	Y	Y						C
DM G2	Y	Y	Y						C
Small Projects Portfolio	Y	Y	Y						All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced						E,I
MAP (Muon Collider R&D)	N	N	N						E,I
CHIPS (Water Cherenk. ~NOvA)	N	N	N						I
LAr1	N	N	N						I
Additional Small Projects (beyond the Small Projects Portfolio above)									
DESI	N	Y	Y						C
Short Baseline Neutrino Portfolio	Y	Y	Y						I

Re-align accelerator R&D to focus on the latest assessment of our long-term needs, moving away from muon accelerator activities and towards capabilities that could dramatically improve the cost effectiveness of future accelerators

Limited, prioritized and time-ordered list of experiments, with pieces covering small, medium and large investment scales to produce results continuously throughout a twenty-year timeframe.

Identify the new physics of dark matter (DM-G2, DM-G3)

Use the Higgs boson as a new tool for discovery (LHC, ILC)

Understand cosmic acceleration: dark energy and inflation (e.g., LSST, DESI, CMB-S4)

Pursue the physics associated with neutrino mass (Fermilab neutrino program, LBNF)

Explore the unknown: new particles, interactions, and physical principles (Mu2e, g–2, all)

"Actionable" and exciting!