U.S. DEPARTMENT OF ENERGY | Office of Science

Update from the Office of High Energy Physics

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Introduction

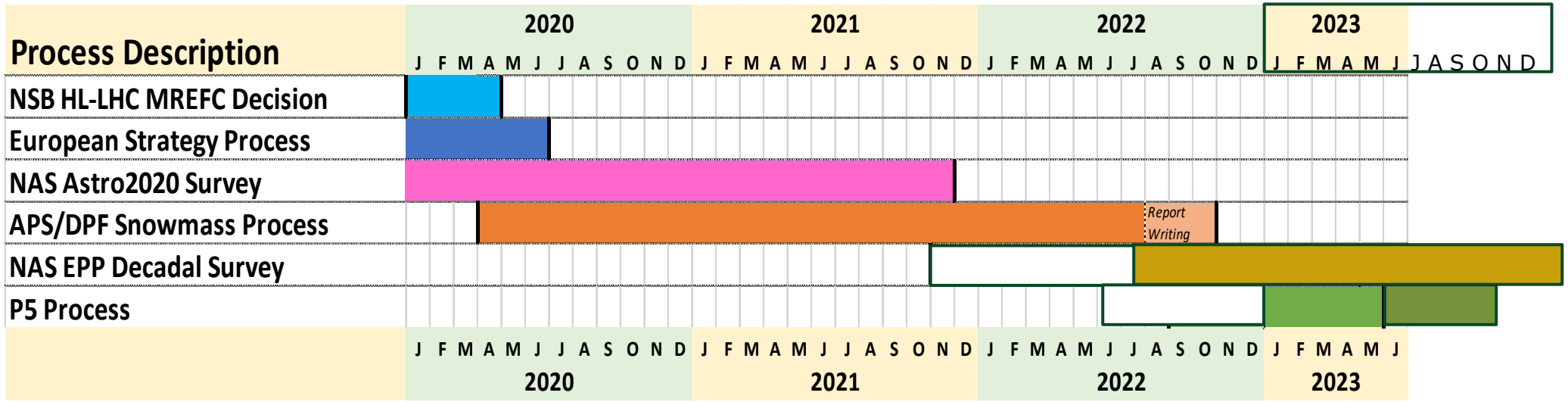
- I am new to this role in the Department of Energy, Office of Science (SC), Office of High Energy Physics (OHEP); started on November 7
- Prior to this role, I have been 40 years as a research scientist at Fermilab
  - Early work on hyperons
  - Since 1993 work has been on neutrinos, most recently, DUNE
- Since April 2022, OHEP has been led by Dr. Harriet Kung, assisted by the entire team – my thanks to all of them for keeping the office progressing and welcoming me
- Any errors or misunderstandings in my remarks today, are entirely mine…

OHEP and NAS EPP2024

HEP community-wide "Snowmass" study process organized by the American Physical Society (APS) Division of Particles and Fields (DPF) & Division of Particles and Beams held July 2022. https://snowmass21.org/start

- Identify science questions & directions & options to address these for the coming decade.

National Academy of Sciences (NAS) Elementary Particle Physics (EPP) Decadal Survey will complement the upcoming P5 process.



EPP2024 Charge Elements

1. Identify the **fundamental questions** in particle physics that could motivate research in the **next decade and beyond**, irrespective of the tools and techniques to address them.

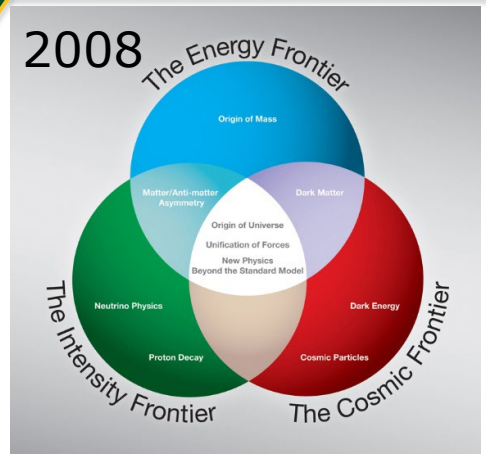
2. Distinguish which of these questions could be addressed with available experimental and theoretical tools in the coming decade and which could require new techniques or approaches.

3. Suggest technical research areas that could provide particle physics with new tools needed to enable new techniques and approaches.

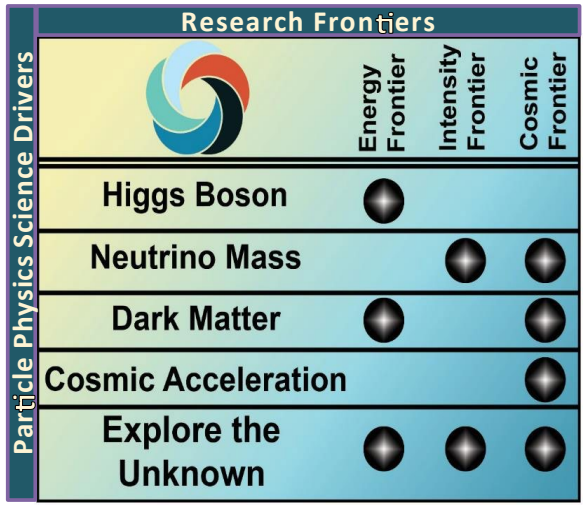
4. Suggest different ways of thinking and alternative approaches from other areas of science that could be incorporated into and benefit the overall particle physics enterprise.

Expanding Frontiers

2008



2014



Snowmass 2021

- Energy Frontier
- Neutrino Physics Frontier
- Rare Processes and Precision
- Cosmic Frontier
- Theory Frontier
- Accelerator Frontier
- Computational Frontier
- Underground Facilities
- Community Engagement

Considerations in the new P5 charge

- 2014 P5 plan laid out a decadal roadmap; we are now approaching the end of the initial timeframe of that plan (see next slide)
- We now want an updated strategic plan for a 10-yr timeframe (FY2024-FY33), in the context of a 20-yr vision
- We need to reassess the importance of the 2014 science drivers; are they as compelling as before; is the science case for on-going construction projects as strong as it was??
  - *These can be very hard questions*
- Is the particle physics portfolio balanced with small, medium and large projects?

Additional considerations in the charge

Remember HEP is a global field

Support decisions to retain US leadership as a global partner

Preserve essential roles of Universities and National Labs

Assess science case for on-going projects

Assess infrastructure upgrades that create new science capabilities

Remember costs of R&D, commissioning, and operations for future projects

Remember that a balanced core research budget is paramount to producing science from current projects and developing ideas for new ones

Remember that a diverse workforce results in improved science

Address synergies with broad national initiatives

Timeframes

- Past : What have we decided, started and need to finish or continue
- Present : What are we doing right now? What challenges are we facing?
  - Aftermath of a pandemic
  - Global unrest and aggression
    - These have led to supply chain issues and inflation
  - Recognition/acknowledgement of climate issues in the community

Timeframes (con't)

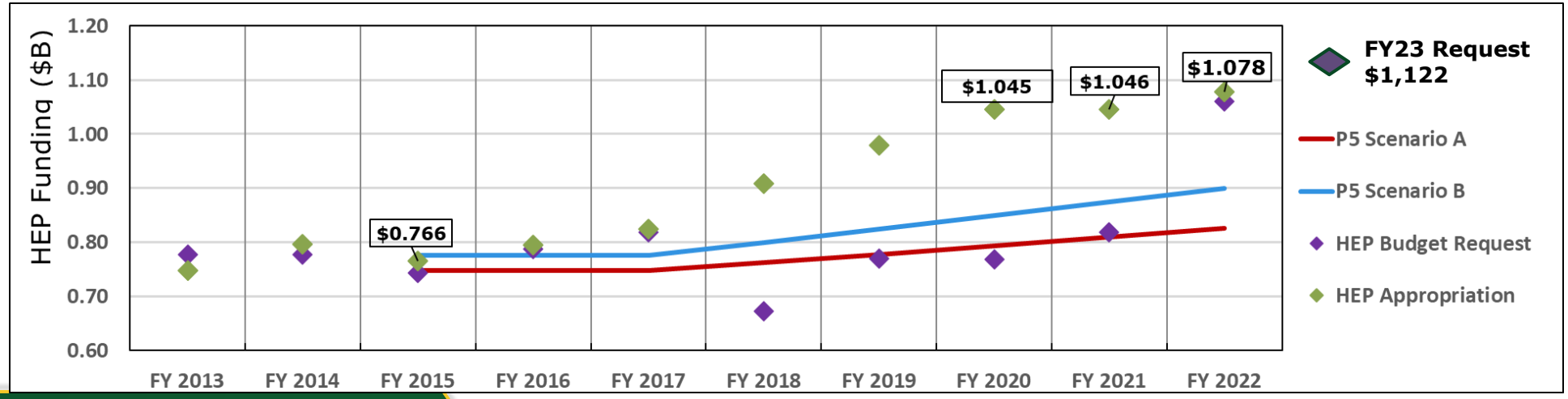
- Near future (2023 – 203?)
  - P5 process should influence
  - Budget outlook is important (and possibly predictable)
- Longer term future (2030+)
  - EPP2024 has the opportunity to shape
  - EPP2024 needs to work with P5 to agree on the groundwork which will enable the longer term future

What have we accomplished and what have we learned?

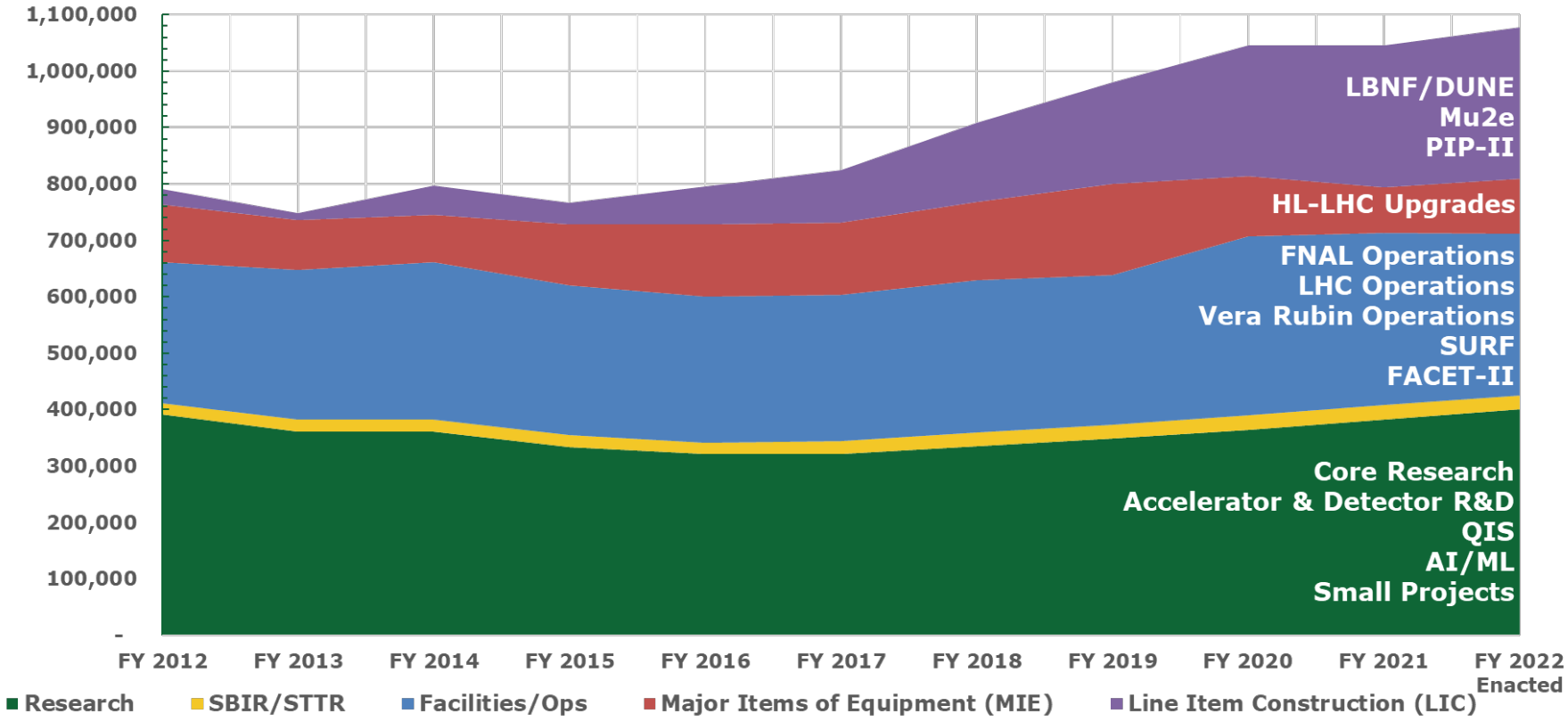
- A lot has been accomplished since 2014 P5
- We can evaluate how much, and how much is left to do
- Importantly, what have we learned, what questions have we answered, what questions remain – be honest!
- Have we answered any of our BIG questions?
- Have new questions emerged?

Perspective on budgets

- HEP is continuing to carry out the 2014 P5 Strategic Plan
- The Projects selected for this P5 strategic plan offer significant leaps in addressing the HEP science goals identified by P5 and other strategic planning studies
- This plan was well received by Congress and the budget in the years 2015 onward reflects this support



Budget growth has enabled the 2014 P5 projects



FY 2023 SC President's Budget Request
(Dollars in thousands)

	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2022 Enacted		FY 2023 Request vs FY 2021 Enacted	
Advanced Scientific Computing Research (ASCR)	1,015,000	1,035,000	1,068,741	33,741	3.26%	53,741	5.29%
Basic Energy Sciences (BES)	2,245,000	2,308,000	2,420,439	112,439	4.87%	175,439	7.81%
Biological and Environmental Research (BER)	753,000	815,000	903,685	88,685	10.88%	150,685	20.01%
Fusion Energy Sciences Research (FES)	672,000	713,000	723,222	10,222	1.43%	51,222	7.62%
High Energy Physics (HEP)	1,046,000	1,078,000	1,122,020	44,020	4.08%	76,020	7.27%
Nuclear Physics (NP)	713,000	728,000	739,196	11,196	1.54%	26,196	3.67%
Isotope R&D and Production (IRP)	...	82,000	97,451	15,451	18.84%	97,451	...
Accelerator R&D and Production (ARP)	...	18,000	27,436	9,436	52.42%	27,436	...
Workforce Development for Teachers and Scientists (WDTS)	29,000	35,000	41,300	6,300	18.00%	12,300	42.41%
Science Laboratories Infrastructure (SLI)	240,000	291,000	255,000	-36,000	-12.37%	15,000	6.25%
Safeguards and Security (S&S)	121,000	170,000	189,510	19,510	11.48%	68,510	56.62%
Program Direction (PD)	192,000	202,000	211,211	9,211	4.56%	19,211	10.01%
Office of Science	**7,026,000**	**7,475,000**	**7,799,211**	**324,211**	**4.34%**	**773,211**	**11.00%**

Inflation Recovery Act (IRA) and HEP

- Inflation recovery act passed just before end of FY2022
- OHEP received significant funding to aid projects to get back on track from effects of Covid, inflation etc.
- Total of $303.7M
  - HL LHC
  - PIP-II
  - LBNF/DUNE
  - CMB-S4
  - ACORN
  - Mu2e project

HL-LHC Projects

- The HL-LHC Accelerator Upgrade Project completes funding in FY 2023 thanks to the IRA.
  - The project will be rebaselined due to COVID from $242M to $266M.
  - Most work is conducted at the national laboratories, which were shutdown for months and then had COVID restrictions on occupancy affecting productivity
  - This project can speed up due to IRA funds and deliver the components to CERN as soon as they are built.
- The HL-LHC CMS and ATLAS projects also benefit from IRA funding.
  - The schedule for these projects is limited by the opportunity to install the components during the next long shutdown at CERN (2026-2028)
  - Both projects are planning to baselined in FY 2023
  - Plan to continue funding through FY 2027

HL-LHC ATLAS guidance IRA	Prior Years	FY 2021	FY 2022	FY 2023	IRA	FY 2024	FY 2025	FY 2026	FY 2027	Total
TPC	**68,515**	**16,000**	**20,000**	**12,500**	**32,785**	**16,200**	**16,200**	**12,800**	**5,000**	**200,000**
TEC	52,000	16,000	20,000	12,500	32,785	16,200	16,200	7,800	-	**173,485**
OPC	16,515	-	-	-		-	-	5,000	5,000	**26,515**
HL-LHC CMS guidance IRA	**Prior Years**	**FY 2021**	**FY 2022**	**FY 2023**	**IRA**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**	**Total**
TPC	**64,988**	**13,500**	**20,000**	**12,500**	**34,600**	**19,500**	**17,412**	**12,500**	**5,000**	**200,000**
TEC	34,738	13,500	20,000	12,500	34,600	19,500	16,212	7,500	-	**158,550**
OPC	30,250	-	-	-		-	1,200	5,000	5,000	**41,450**

Other HEP Projects

- Fermilab PIP II Project received $10M of IRA funding. Outyear funding will be reduced by $10M.
- Mu2e will be rebaselined using IRA funds ($36M). No funding is requested in FY 2024.
  - The rebaseline review has been completed and ESAAB approval is planned for December.
- There is FY 2024 guidance for CMB-S4. This along with IRA funding of $12M will allow the project to reach CD-1 in FY 2024.
  - The South Pole station is critical to DOE's plans for CMB S4 since the measurements that inform us about Inflation Theory are best done at the South Pole.
  - This year, NSF informed us that the infrastructure at South Pole Station is inadequate to support CMB-S4.
  - To move beyond CD-1, a plan is needed to fit into South Pole infrastructure. This requires the NSF to participate deeply in the planning.
- FY 2024 Guidance includes funding for ACORN, the accelerator control network upgrade for Fermilab.
  - There is also $12.6M of IRA funding, which should support the project to reach CD-1 in FY 2024.

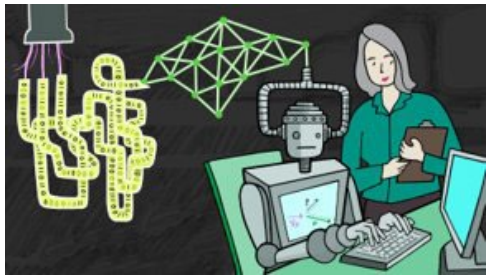
Research Initiatives

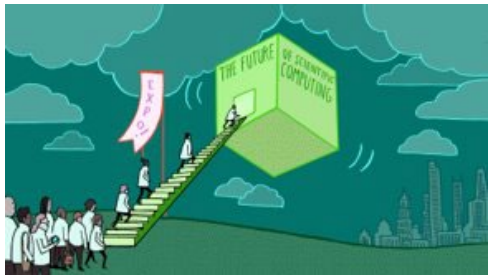
(B/A in thousands)

	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2022 Enacted		FY 2023 Request vs FY 2021 Enacted	
New Research Initiatives							
SC Energy Earthshot	...	...	204,250	204,250	...	204,250	...
Funding for Accelerated, Inclusive Research (FAIR)	...	...	35,508	35,508	...	35,508	...
Accelerate Innovations in Emerging Technologies	...	...	40,051	40,051	...	40,051	...
Ongoing Research Initiatives							
Climate and Clean Energy *(includes funding scored to other initiatives)*	2,472,842	2,716,570	3,009,849	293,278	10.80%	537,007	21.72%
Reaching a New Energy Sciences Workforce (RENEW)	...	30,000	60,000	30,000	100.00%	60,000	...
Fundamental Science to Transform Advanced Manufacturing	...	25,353	27,000	1,647	6.50%	27,000	...
Biopreparedness Research Virtual Environment (BRaVE)	...	21,756	51,756	30,000	137.89%	51,756	...
Urban Integrated Field Laboratory	...	17,000	22,000	5,000	29.41%	22,000	...
National Virtual Climate Laboratory (NVCL)	...	3,000	3,000	...	...	3,000	...
Climate Resilience Centers	...	5,000	5,000	...	...	5,000	...
Microelectronics	30,182	47,701	47,701	...	...	17,519	58.04%
Critical Materials/Minerals	17,000	25,000	25,000	...	...	8,000	47.06%
Quantum Information Science	270,391	293,075	293,426	351	0.12%	23,035	8.52%
Artificial Intelligence and Machine Learning	124,354	129,837	169,000	39,163	30.16%	44,646	35.90%
Exascale Computing	479,945	445,000	268,000	-177,000	-39.78%	-211,945	-44.16%
Revolutionizing Polymers Upcycling	14,500	14,500	14,500	...	...	...	...
Accelerator Science and Technology Initiative	11,411	34,725	28,872	-5,853	-16.86%	17,461	153.02%
Advanced Computing *(formerly Integrated Computational & Data Infrastructure)*	11,974	34,657	37,661	3,004	8.67%	25,687	214.52%
Total, Research Initiatives	**3,432,599**	**3,843,174**	**4,342,574**	**499,399**	**12.99%**	**909,975**	**26.51%**

HEP Research Initiatives

- QIS, AI/ML, Microelectronics, Advanced Computing, Accelerator Science and Technology, and ACCELERATE
- Quantum Information Science co-develops quantum information, theory, and technology with core research activities.
  - to more strongly focus and integrate efforts that align with HEP strengths in quantum sensors and theory
- AI/ML effort is highly embedded in core HEP research and accelerator technology, with a new thrust in proposal-driven, cross-cutting R&D. The balance between leveraging AI/ML tools for HEP science and using HEP data to drive AI/ML development will be reassessed.





New initiatives in research funding

HEP budget (in $K)	FY20 Enacted	FY21 Enacted	FY22 Enacted	FY23 Request
Artificial Intelligence & Machine Learning (AI/ML)	15.0	33.5	35.8	40.0
Integrated Computational & Data Infrastructure (renamed to Advanced Computing in FY23 Request)			4.1	5.1
Microelectronics		5.0	7.0	7
Quantum Information Science (QIS)	23.5	20.1	26.6	25.6
Quantum Center	15.0	25.0	25.0	25
Reaching a New Energy Sciences Workforce (RENEW)	0.0	0.0	4.0	8
Accelerate Innovations in Emerging Technologies				4
Accelerator Science and Technology Initiative (ASTI)	0	6.3	17.4	10
Funding for Accelerated, Inclusive Research (FAIR)				2

Some news from COSMIC Frontier

- DESI, LZ continue operations
- Rubin Observatory construction → commissioning; ops planning
- CMB-S4 planning continues

Dark Energy Spectroscopic Instrument (DESI) Experiment

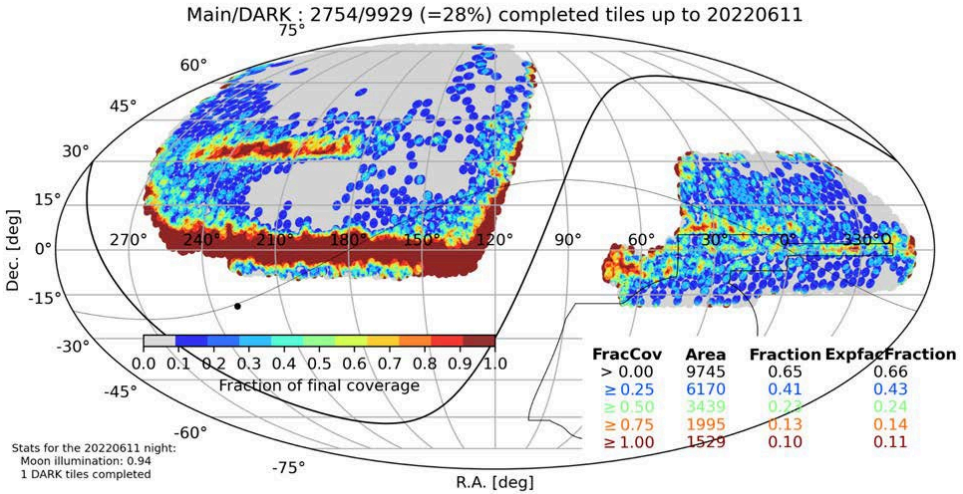
DOE's DESI started its 2nd year of operations in May.

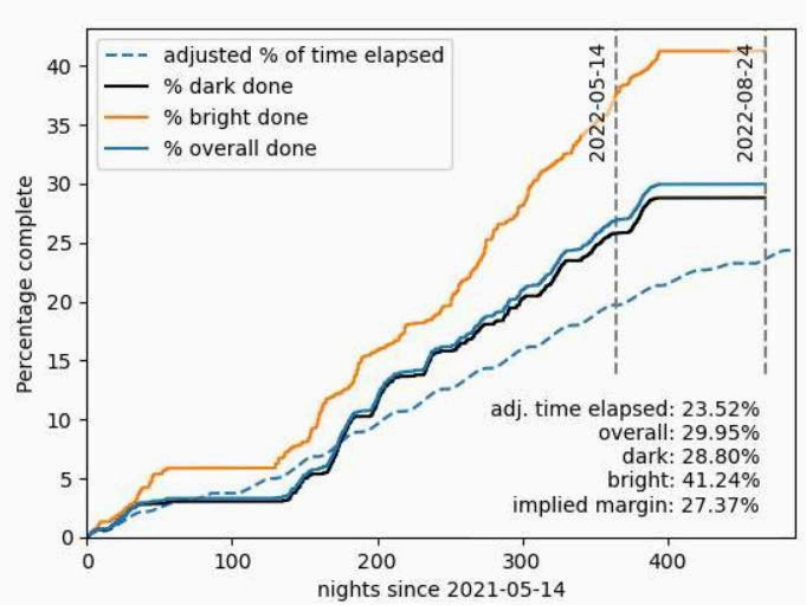
- World's premier multi-object spectrograph w/5,000 fibers, positioned robotically

First **Stage IV dark energy;** Will measure spectra of > 40 million galaxies

DOE/LBNL Project: Instrumentation, Data Management System, & Upgrades of NSF's Kitt Peak Mayall telescope (including MOSAIC camera).
Operations: DOE provides full support for NSF's Mayall telescope.

Through mid-June 2022 -- DESI was running ahead of project schedule
Successful data-taking: ~ 18 Million extra-galactic redshifts recorded (more than all other surveys combined)





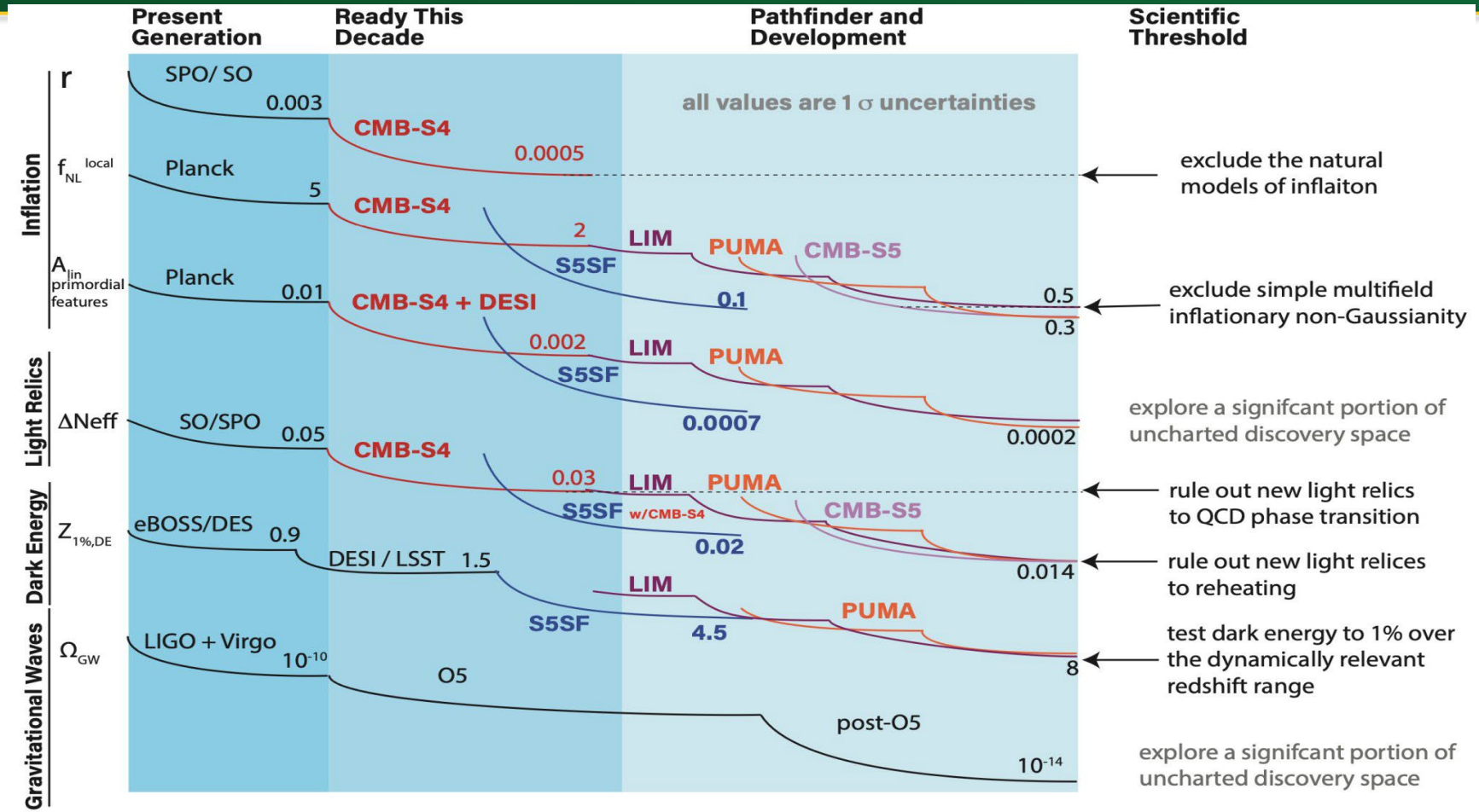
DESI - status

Mid-June: Fire went through Kitt Peak
DESI operations were shut down on June 14 when fire was on the way; brush cleared; all instrumentation and telescope secured.

NEWS ➔ DESI is back on-sky as of Sept. 16
- still assessing any degradation in performance

Thank you to fire fighters
and the other agencies that protected the site and are now carrying out recovery services.
There's still a ways to go:
…no internet, generator power, problems with the roads, etc.

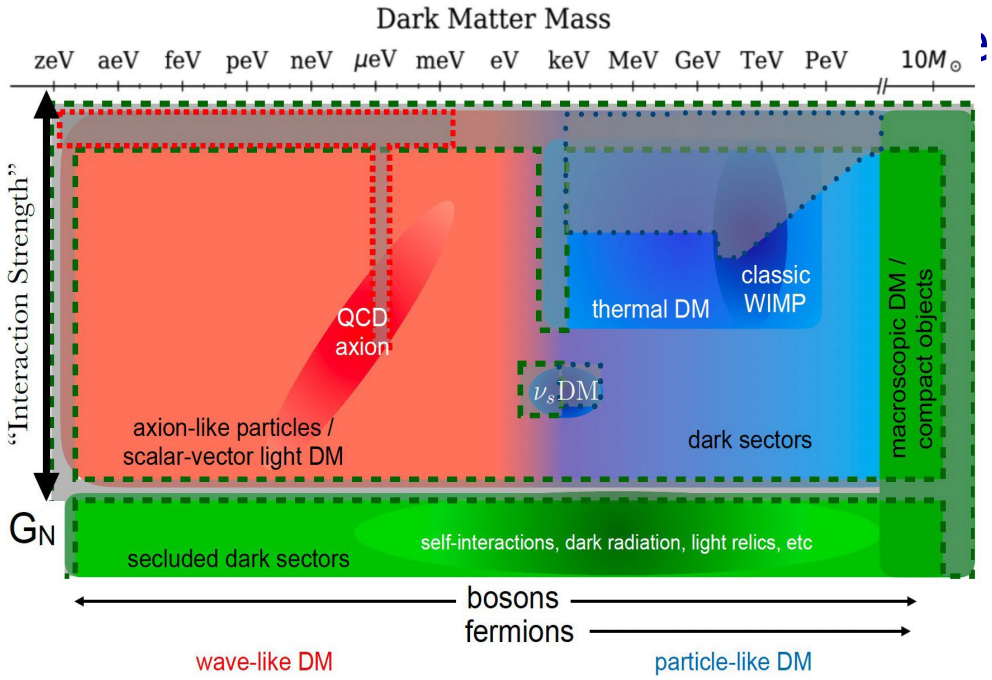
Snowmass Cosmic Frontier Summary - Cosmology
Search Wide, Aim High



Near term: DESI survey; complete Rubin & LSST; construct CMB-S4
Longer term roadmap to a future Stage V Spectroscopic Facility, and small projects & pathfinders toward new opportunities such as gravitational waves, 21cm,and Line-Intensity Mapping.

Dark Matter – summary from Snowmass

- **Delve deep, search wide**
- **→ leave no stone unturned**
  - range of direct searches for WIMPs interacting with targets on Earth
  - indirect searches for annihilation products

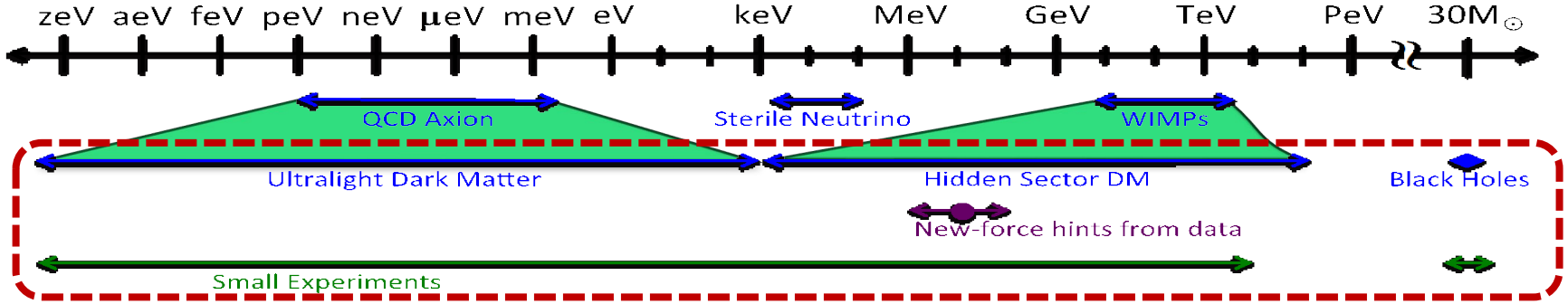


Next 10 years, including future Gen-3 direct searches for WIMPs and axions, combined with future indirect observatories, a program of smaller scale searches, and key inputs from cosmic probes, results in broad coverage.

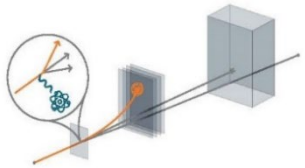
Dark Matter New Initiatives (DMNI) for small projects

2014 P5 recommended the search for Dark Matter particles as a high priority & also that the program should include small projects

- Recent theoretical advances and development of new technologies opened new avenues to explore dark matter

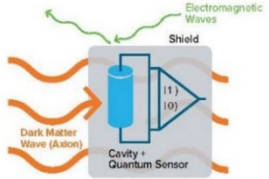


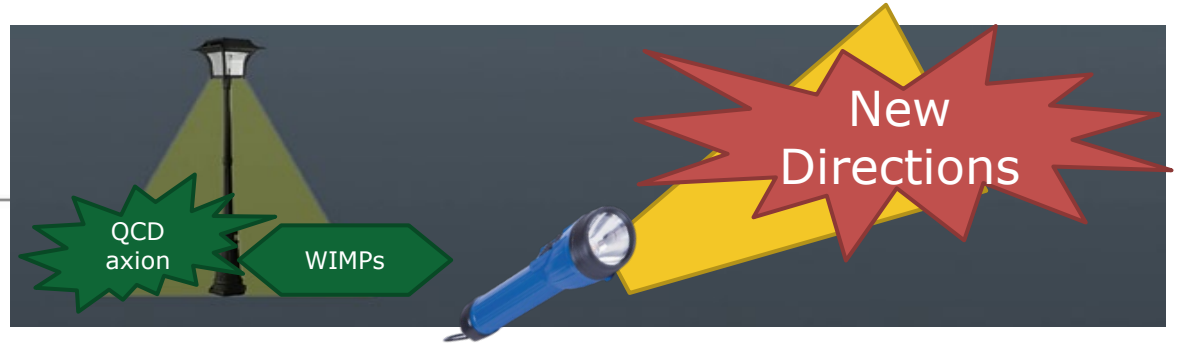
PRD 1
Create and Detect DM at Accelerators.



PRD 2
Detect Galactic DM Underground.

PRD 3
Detect Wave DM in the Laboratory





- **2017** Community Workshop, https://arxiv.org/abs/1707.04591
- **2018-2019**: Basic Research Needs (BRN) study developed 3 Primary Research Directions (PRD) https://science.energy.gov/hep/community-resources/reports/

CMB-S4

- 2 large aperture (6m) in **Chile;** Deep & wide N_{eff} & Legacy Survey ~60% of sky

<u>Project plan sent to Astro2020</u>

21 telescopes, in 2 aperture scales, at 2 sites:

- 1 large (5m), 18 small (0.5m) at **South Pole;** Ultra-deep survey ≥ 3% of sky + delensing

Total 500,000 cryogenic sensors, superconducting readout; scale up of over x10 from all stage 3.

CMB-S4 timeline to date

2014 HEPAP/P5 strategic plan recommended CMB-S4 as a joint DOE/NSF project
2016-2017 AAAC subpanel: CMB-S4 Concept Definition Taskforce study
2019 – DOE approved CD-0

- **2019-2020** – Plan to Astro2020
- 2 large aperture (6m) in **Chile;** Deep & wide N_{eff} & Legacy Survey ~60% of sky
- 1 large (5m), 18 small (0.5m) at **South Pole;** Ultra-deep survey ≥ 3% of sky + delensing
- Total 500,000 cryogenic sensors, superconducting readout; scale up > x10 from all stage 3.
- **FY2021** - Congress approved DOE **Major Item of Equipment "project start"**

2020 – LBNL chosen as DOE's lead lab
FY2021 - Congress approved DOE **Major Item of Equipment "project start"**

- **Nov. 2021** - **Astro2020 recommended DOE/NSF partnership** on CMB-S4
- **July 2022** – new Project Director on board -- Jim Strait

FY2023 – focus on development of updated concept that aligns with infrastructure availability at the South Pole and carries out the science goals as planned.

In conclusion

- It's an exciting time in particle physics
- We are executing the strategic plan laid out in 2014
  - We have operation of large and small experiments, i.e. DESI, LZ, NOvA, ICARUS, ATLAS, CMS, ….
  - We have many projects under construction (PIP-II, LBNF/DUNE, HL LHC, LSST, mu2e, ..)
  - We have some important experiments in the planning stages, i.e. CMB-S4
- We have received significant funding support from the SC allocation of the IRA; this puts major projects back on track following delays incurred from covid and affects of inflation
- We have just completed a completed a Community Summer study which will provide input into a new P5 panel
- We have launched a new National Academy Study, EPP2024, to assess where we are with answering our most important questions and looking at promising directions for the future of particle physics

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