USQCD - The Origin Story

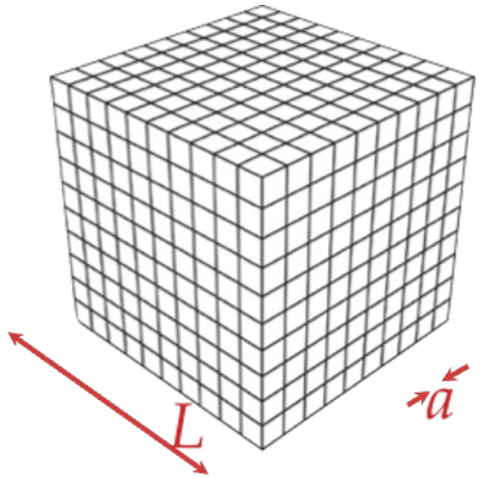
Robert Edwards (JLab)

USQCD Collaboration
Scientific Program Committee (& Chair): 2008 - 2014
Executive Committee: 2015 - present
Deputy Spokesman: 2018 - 2021
Spokesperson: 2021 - 2024

LBNL: July 29, 2025

Why? - circa 1990

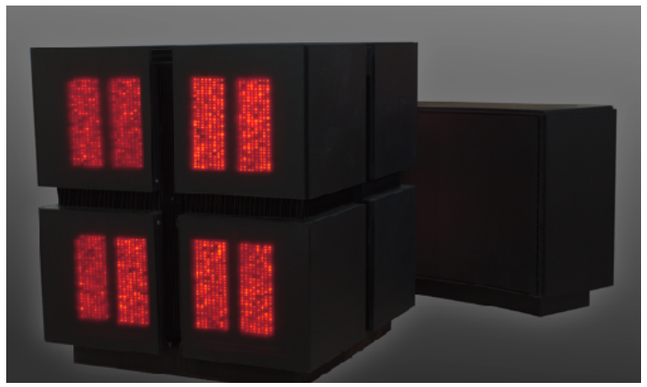
Not enough computing resources!



Columbia U - Fermi256 (1989)

Supercomputer Computations Research Institute (SCRI) - Florida State U

- Thinking Machines CM-2 (1990)

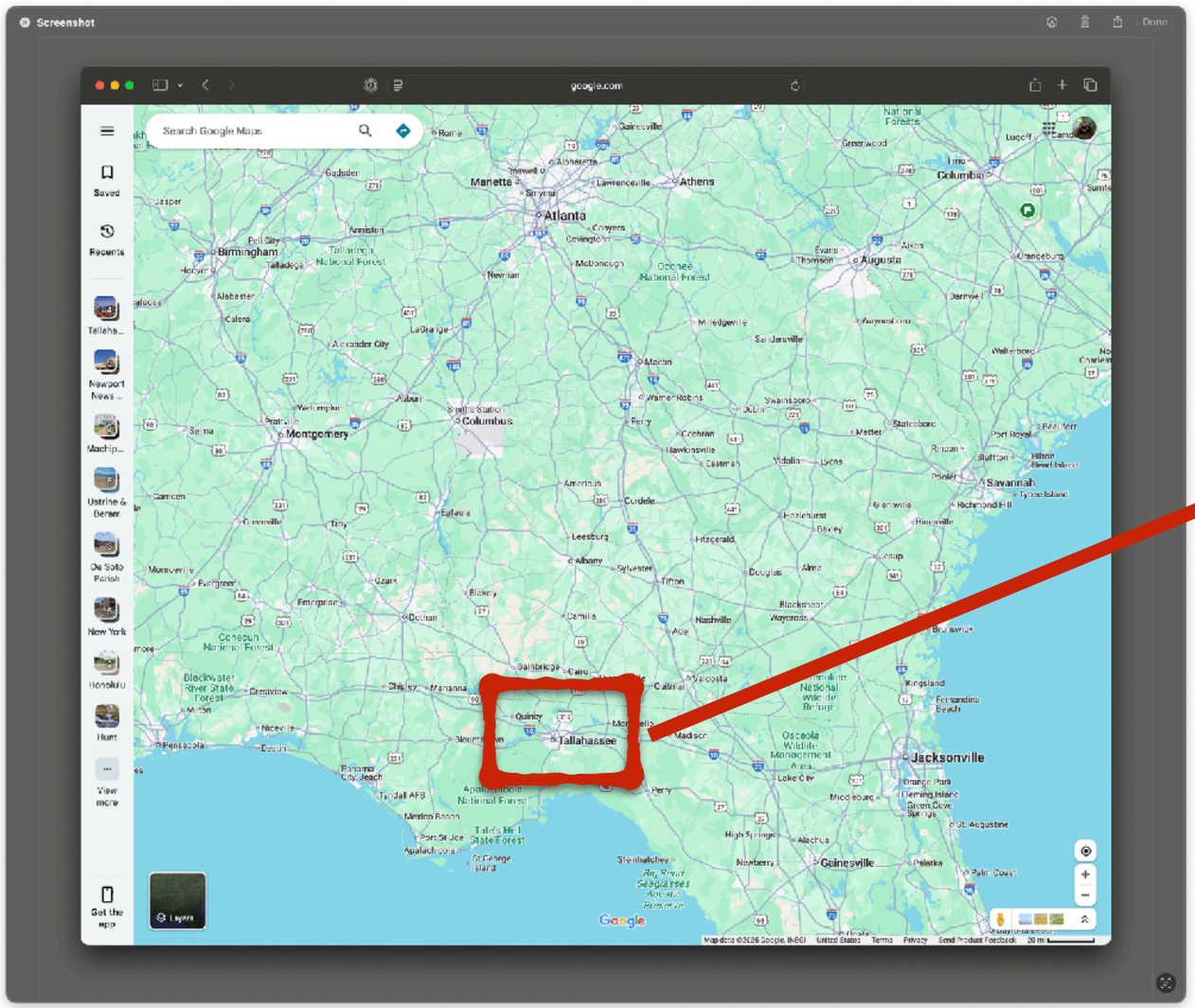


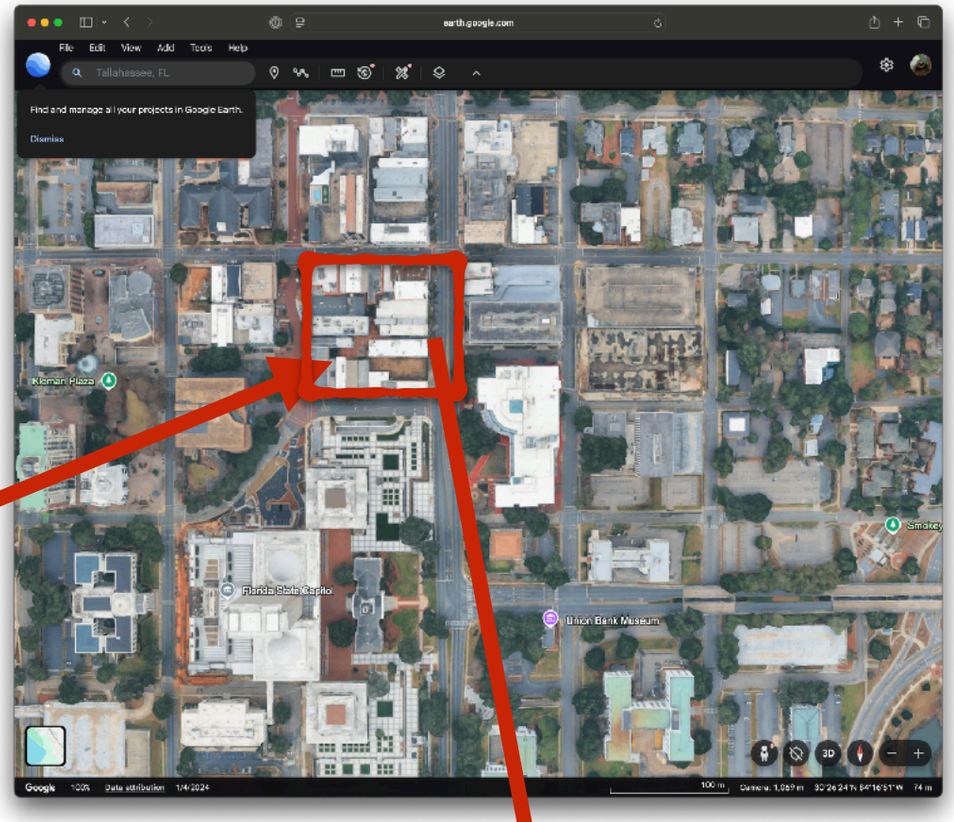
Other systems

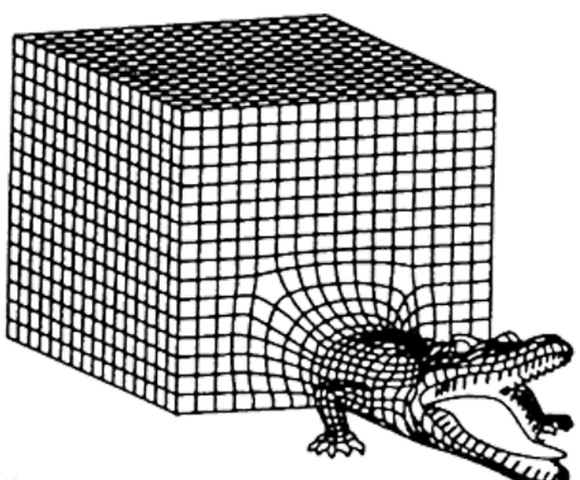
- Cray & Hitachi - expensive!
- APE, QCDPAX, GF11

Need MUCH more

Where? Lattice 1990 @ Tallahassee







Jefferson Lab

Birth of QCD Teraflop Project

Meeting at Angelo's Restaurant

Formed an organizational structure

- Richard Brower
- Norman Christ
- Anthony Kennedy
- Claudio Rebbi
- ....

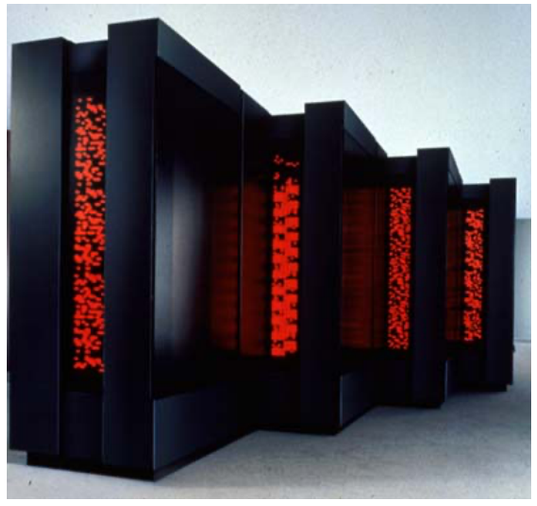
Members:

The present members of the QCD Teraflop Collaboration are Sinya Aoki, Bernd Berg, Claude Bernard, Gyan Bhanot, Khalil Bitar, Richard Brower, Frank R. Brown, Norman Christ, Carleton DeTar, Robert Edwards, Steve Gottlieb, Herbert Hamber, Urs Heller, Anthony Kennedy, Greg Kilcup, John Kogut, Andreas Kronfeld, I-Hsiu Lee, Robert Mawhinney, Michael Ogilvie, Shigemi Ohta, Don Petcher, Jean Potvin, Claudio Rebbi, Pietro Rossi, Sergio Sanielevici, Junko Shigemitsu, Donald Sinclair, Robert Shrock, Amarjit Soni.

QCD Teraflop Project - 1990s

First idea & proposal to predecessor of ASCR

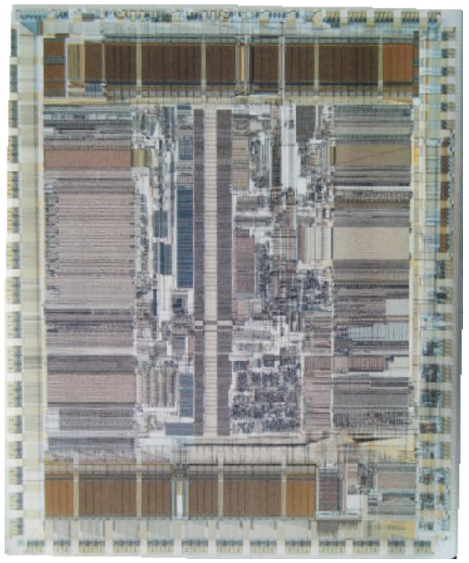
- The (future) Thinking-Machines CM-5



Second idea

- Modified CM-5 with direct complex math ops

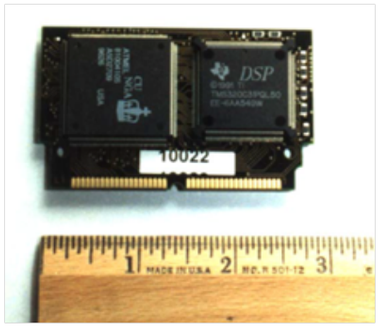
Third idea - early version of DEC Alpha



Lots of fishing, but no bites

The Dark Times

1990s - no industry support - build it ourselves!



QCDSP (QCD on a TI Digital Signal Processor)

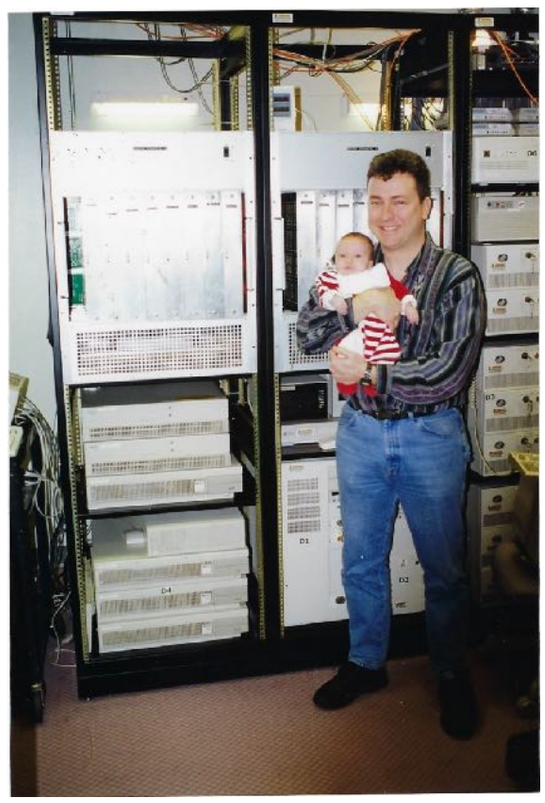
Columbia U, Riken/Brookhaven, SCRI - QCDSP

- 1998 - QCDSP @ at three sites

Columbia

Riken/BNL

SCRI



Gordon Bell Prize - 1998

2000 revolution - US DOE initiative - SciDAC

Japanese Whole Earth Simulator caused a wake-up call in US

USQCD formed in response - founded 2000

USQCD US Lattice Quantum Chromodynamics

- BTW, needed a brand name update - QCD **Teraflop** - no longer appropriate

https://www.usqcd.org/index.html

DOE Scientific Discovery Through Advanced Computing

Scientific Discovery through Advanced Computing

2001 SciDAC (version 1)

https://www.scidac.gov/

Birth of USQCD - 2000

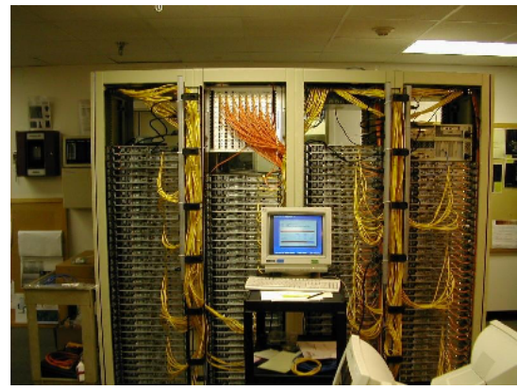
First meeting at BNL - centered on response to SciDAC

Origin of USQCD - JLab joins!

- Support for QCDOC - built at RBRC and Edinburgh
- And first clusters for JLab and FNAL
- Developed new software stack

QCDOC

JLab 2002

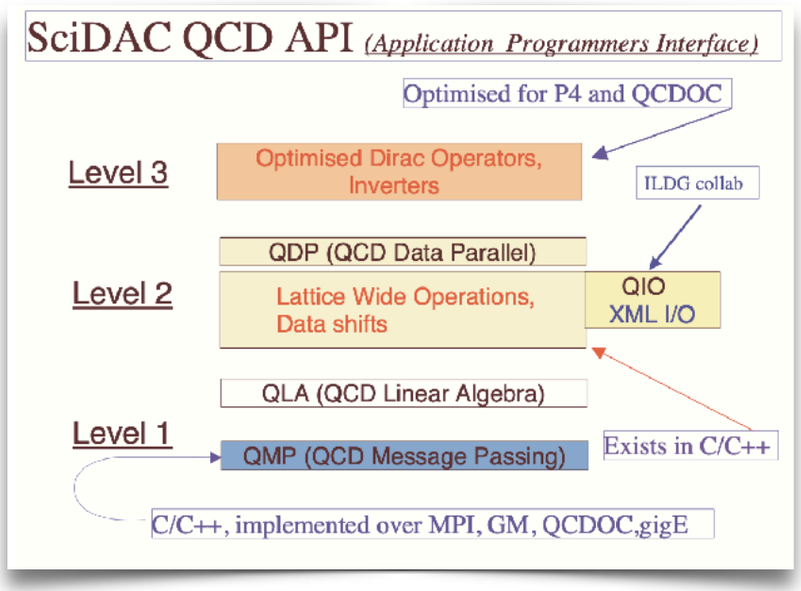


National Computational Infrastructure for Lattice Gauge Theory: Final Report

2006

Lattice QCD Executive Committee

R. Brower, (Boston U.) N. Christ (Columbia U.), M. Creutz (BNL),
P. Mackenzie (Fermilab), J. Negele (MIT), C. Rebbi (Boston U.),
D. Richards (JLab), S. Sharpe (U. Washington), and R. Sugar (UCSB)



Site	Cluster	Processor	Network
JLab	2m	Xeon (single)	Myrinet
JLab	3g	Xeon (single)	3D GigE
JLab	4g	Xeon (single)	5D GigE
JLab	6n	Pentium (dual core)	Infiniband
FNAL	w	Xeon (dual)	Myrinet
FNAL	qcd	Xeon (dual)	Myrinet
FNAL	pion	Pentium (single)	Infiniband

Table 1: Prototype production clusters built under SciDAC-1.

USQCD organization

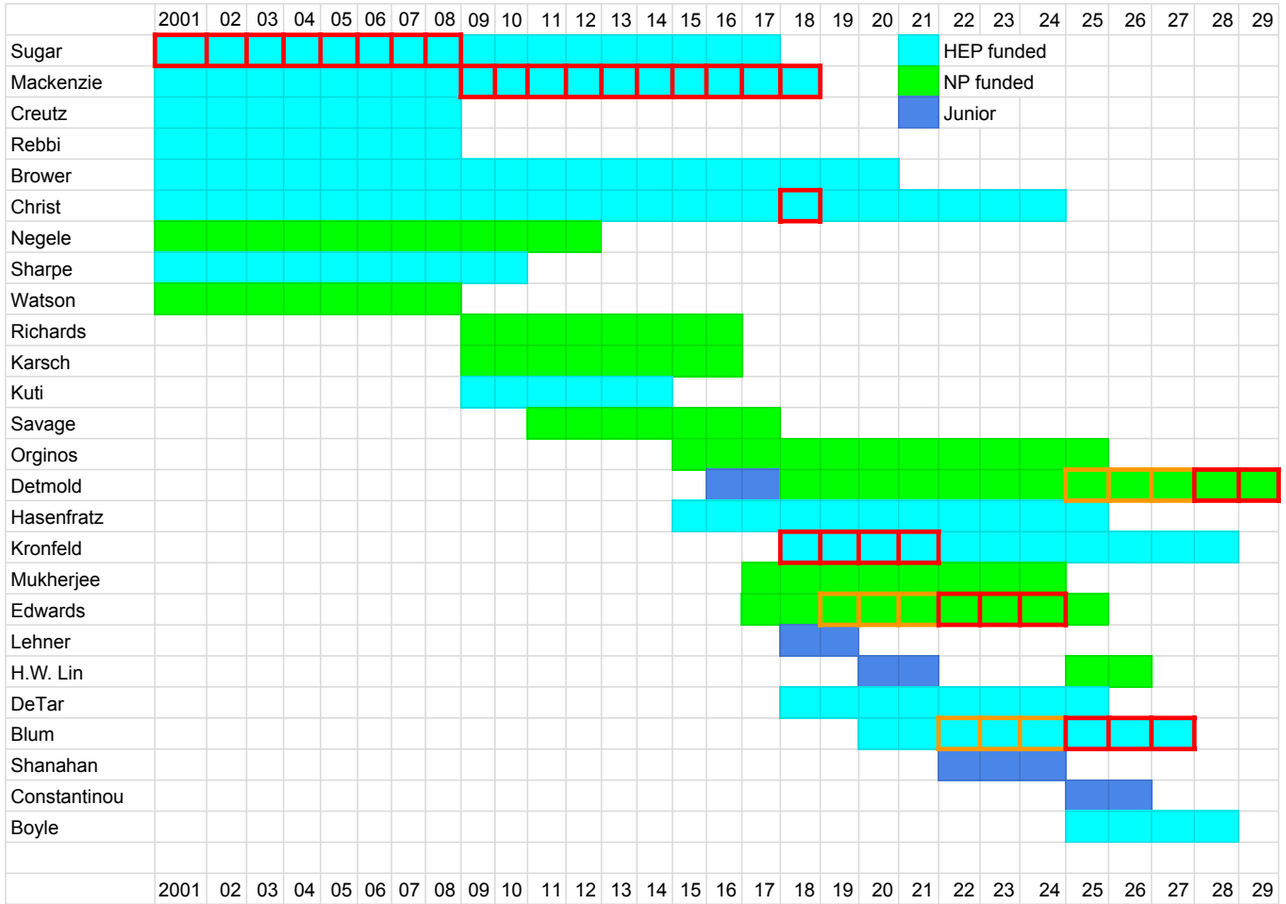
Executive Committee (EC)

- Leads/manages the collaboration
- 192 current members
- Organize community interactions

Scientific Program Committee (SPC)

- Recommends allocations of USQCD resources

Science Advisory Board



USQCD organization

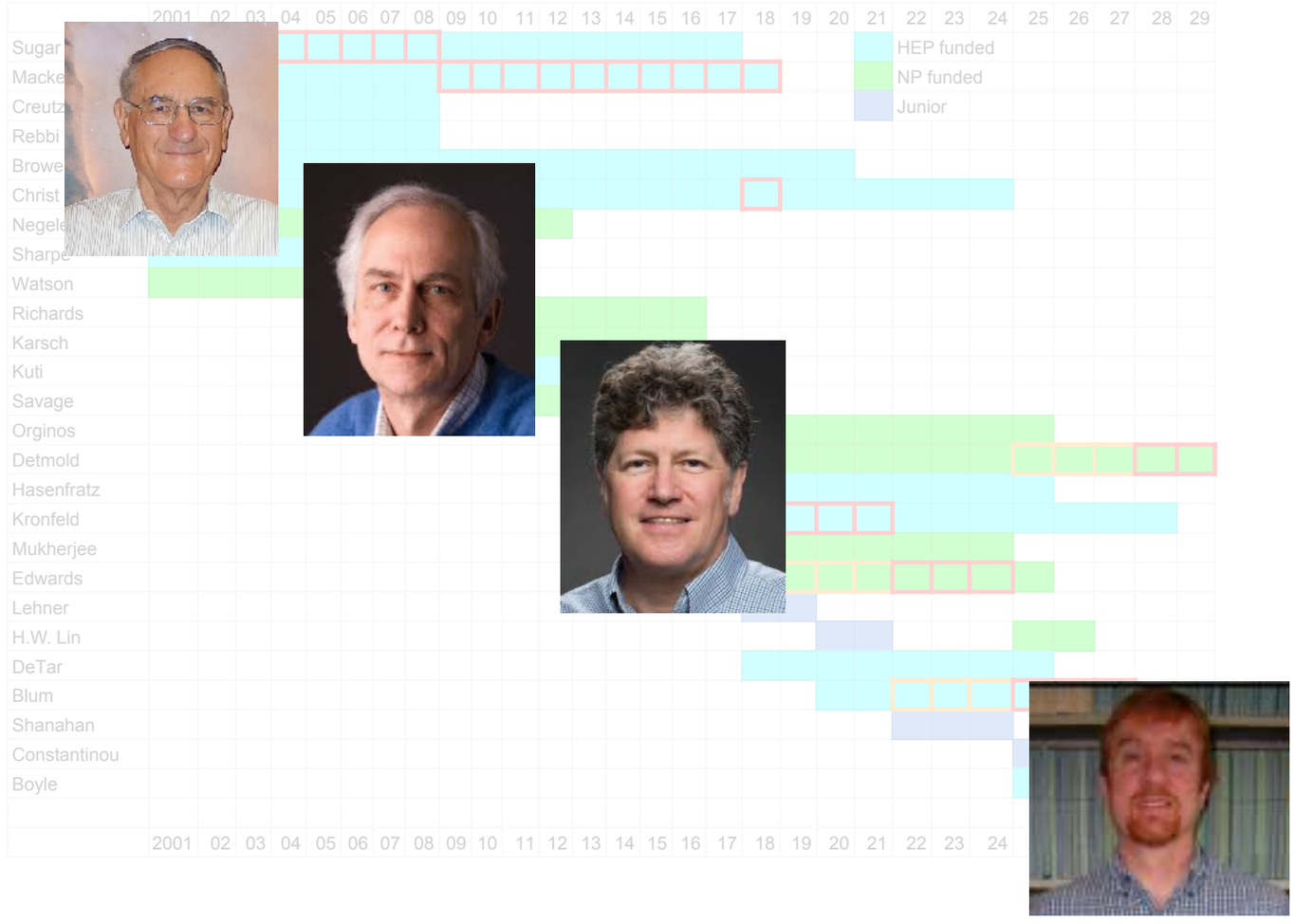
Executive Committee (EC)

- Leads/manages the collaboration

Scientific Pro C)

- Recommen CD resources

Science Advisory Board



USQCD organization

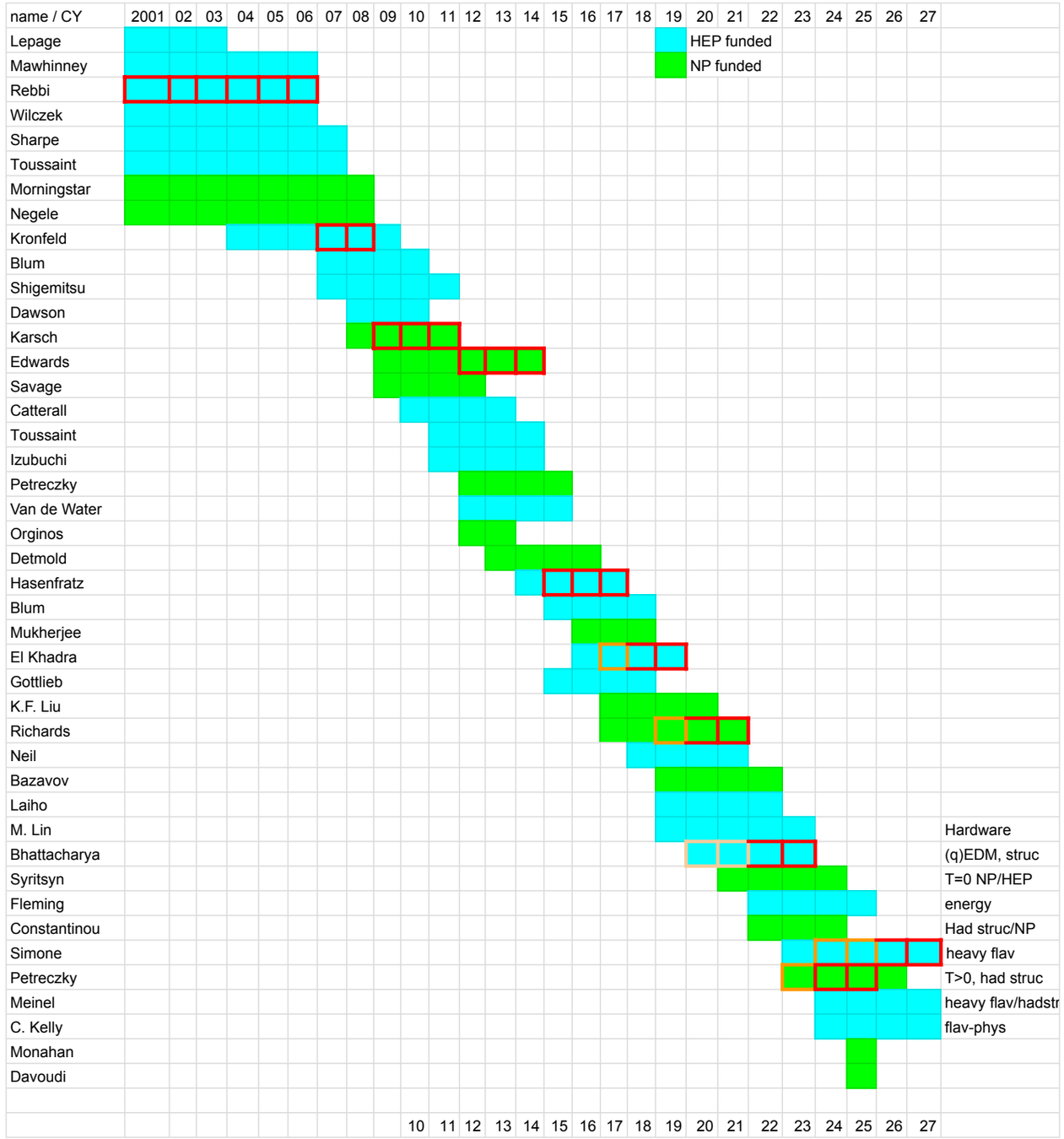
Executive Committee (EC)

- Leads/manages the collaboration

Scientific Program Committee (SPC)

- Recommends allocations of USQCD resources
- ~30 proposals per year

Science Advisory Board



USQCD organization

Executive Committee (EC)

- Leads/manages the collaboration

Scientific Program Committee (SPC)

- Recommends allocations of USQCD resources
- ~30 proposals per year

Science Advisory Board

USQCD organization

Executive Committee (EC)

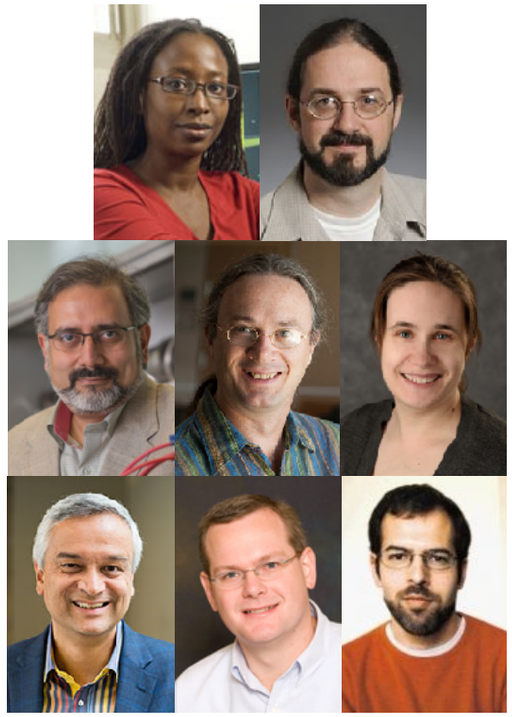
- Leads/manages the collaboration

Scientific Program Committee (SPC)

- Recommends allocations of USQCD resources

Science Advisory Board

- HEP & NP theory & expt.



Community engagement

White papers outlining connection of LQCD, science & expt.

DOE HEP & NP long range planning activities

Community engagement

White papers outlining connection of LQCD, science & expt.

DOE HEP & NP long range planning activities

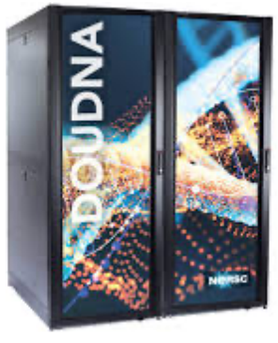
Final writing committee - 2023

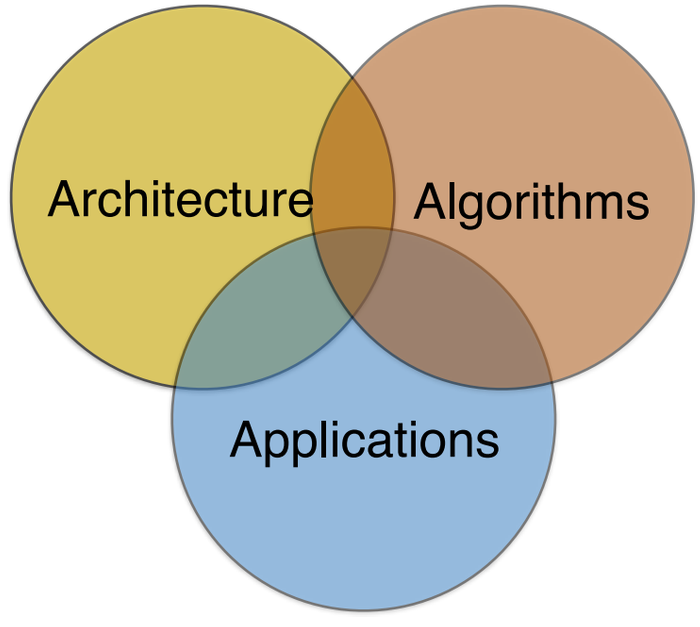
P5 - C. Monahan

NSAC - J. Dudek

USQCD & LQCD software development

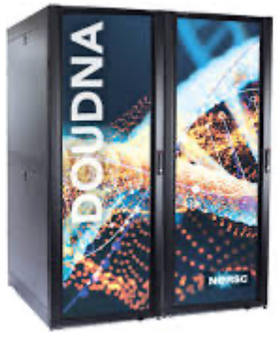
Software efforts: efficiently utilize national resources leveraged with local/commodity resources

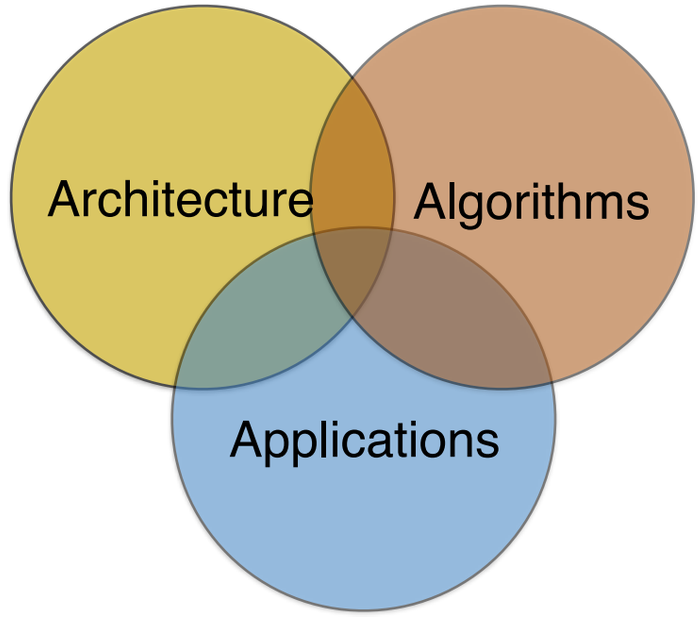




USQCD & LQCD software development

Software efforts: efficiently utilize national resources leveraged with local/commodity resources





DOE Office of Science - software development grants:

Partners: ASCR: Advanced Scientific Computing Research | HEP: High Energy Physics | NP: Nuclear Physics

2001 - 2012: ASCR/HEP/NP: Scientific Discovery through Advance Computing: 1 & 2
2013 - 2017: HEP + ASCR SciDAC-3
2013 - 2017: NP + ASCR SciDAC-3
2016 - 2023: Exascale Computing Project (ECP)
2017 - 2022: NP + ASCR SciDAC-4
2023 - 2027: HEP + ASCR SciDAC-5 (P. Boyle, PI)
2023 - 2027: NP + ASCR SciDAC-5 (R. Edwards, PI)

USQCD & LQCD software development

Software efforts: efficiently utilize national resources leveraged with local/commodity resources

NVIDIA GPU-s

JLab 2009

GTX 285

2016 - 2023: Exascale Computing Project (ECP)
2017 - 2022: NP + ASCR SciDAC-4
2023 - 2027: HEP + ASCR SciDAC-5 (P. Boyle, PI)
2023 - 2027: NP + ASCR SciDAC-5 (R. Edwards, PI)

USQCD & LQCD software development

Software efforts: efficiently utilize national resources leveraged with local/commodity resources

NVIDIA GPU-s

JLab 2009

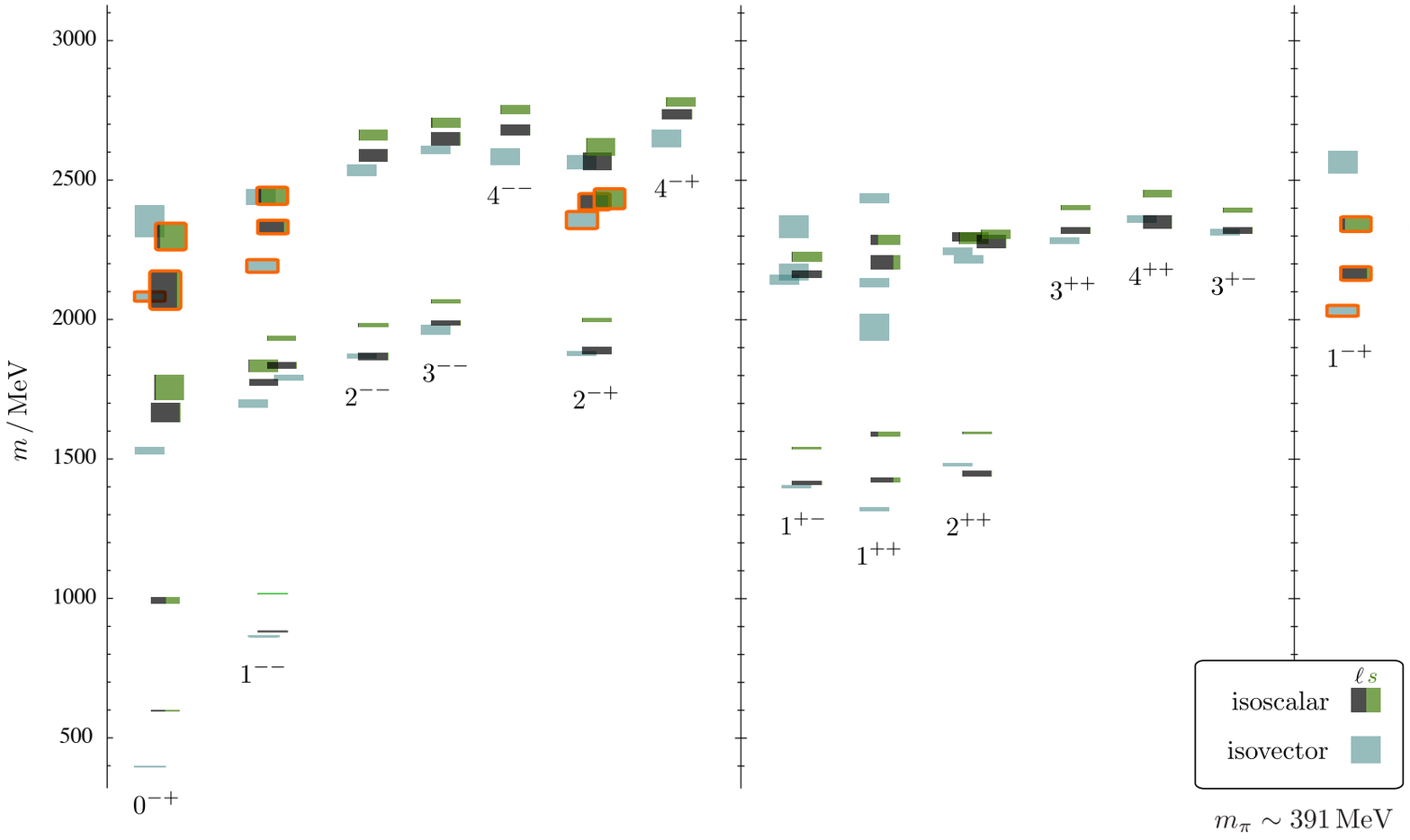
GTX 285

Revolution continues today

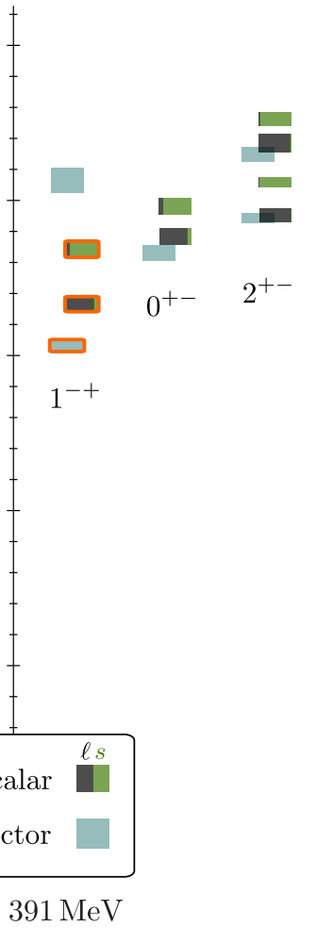
Lattice QCD & the excited hadron spectrum

LQCD SciDAC project has pioneered novel techniques in lattice QCD

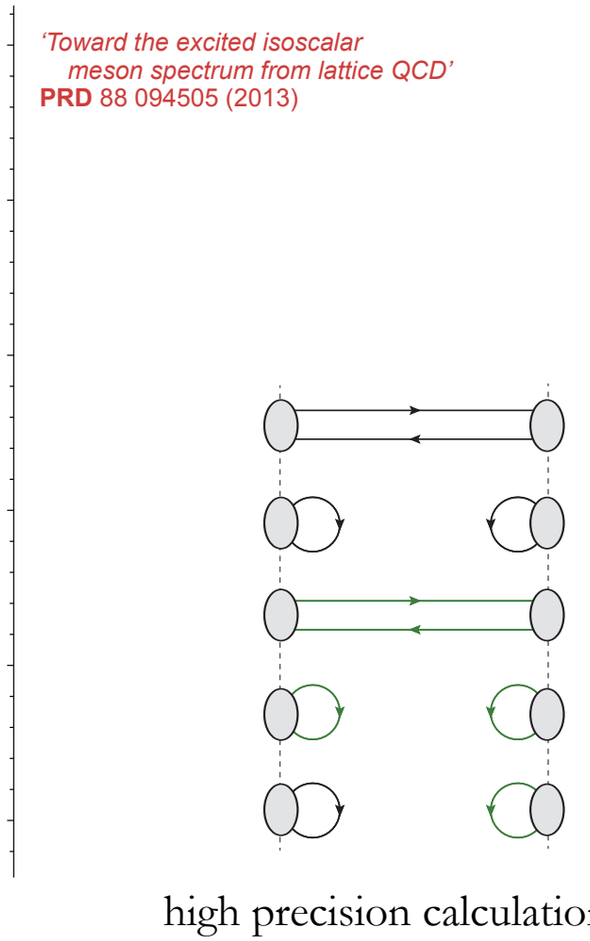
Light quark meson + “exotics” & “hybrids” spectrum



Exotics



‘Toward the excited isoscalar meson spectrum from lattice QCD’
PRD 88 094505 (2013)

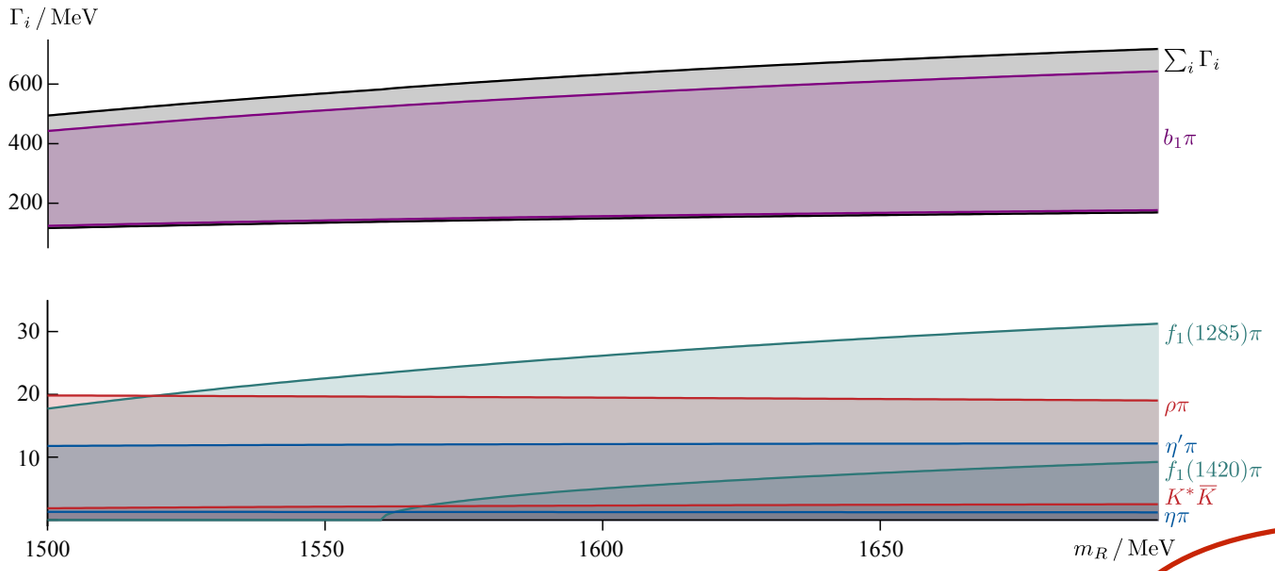


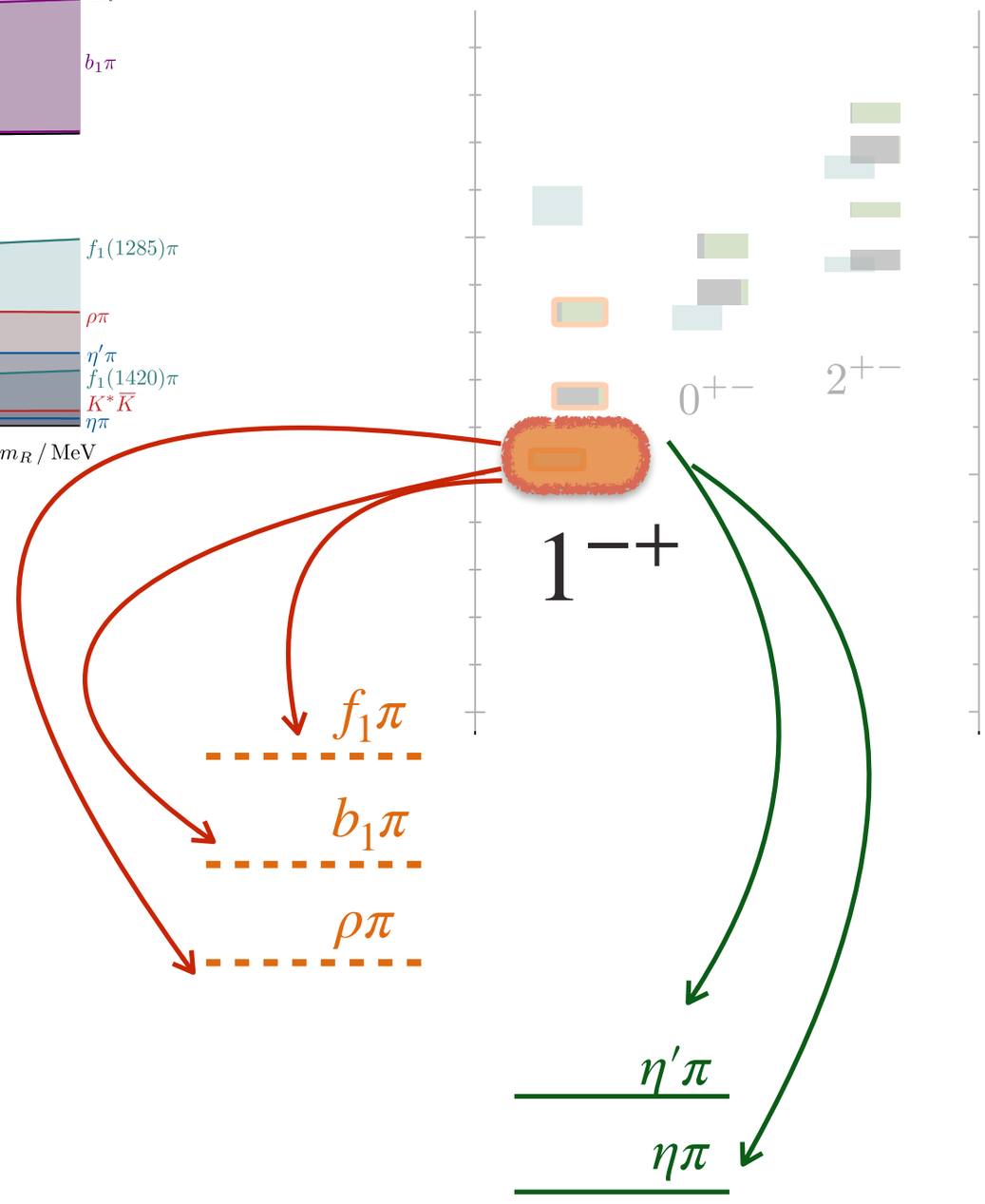
high precision calculation of **disconnected diagrams**

Clear indication of **hybrid mesons**

Exotic mesons - two-body decays

First determination of full branching fractions for an exotic meson from QCD

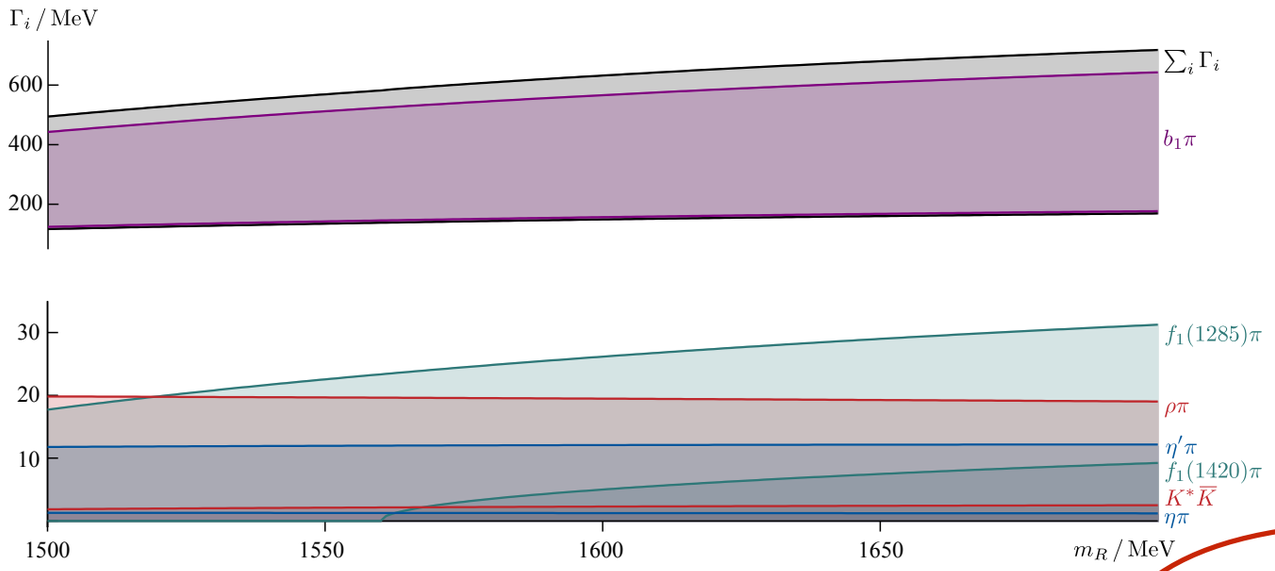


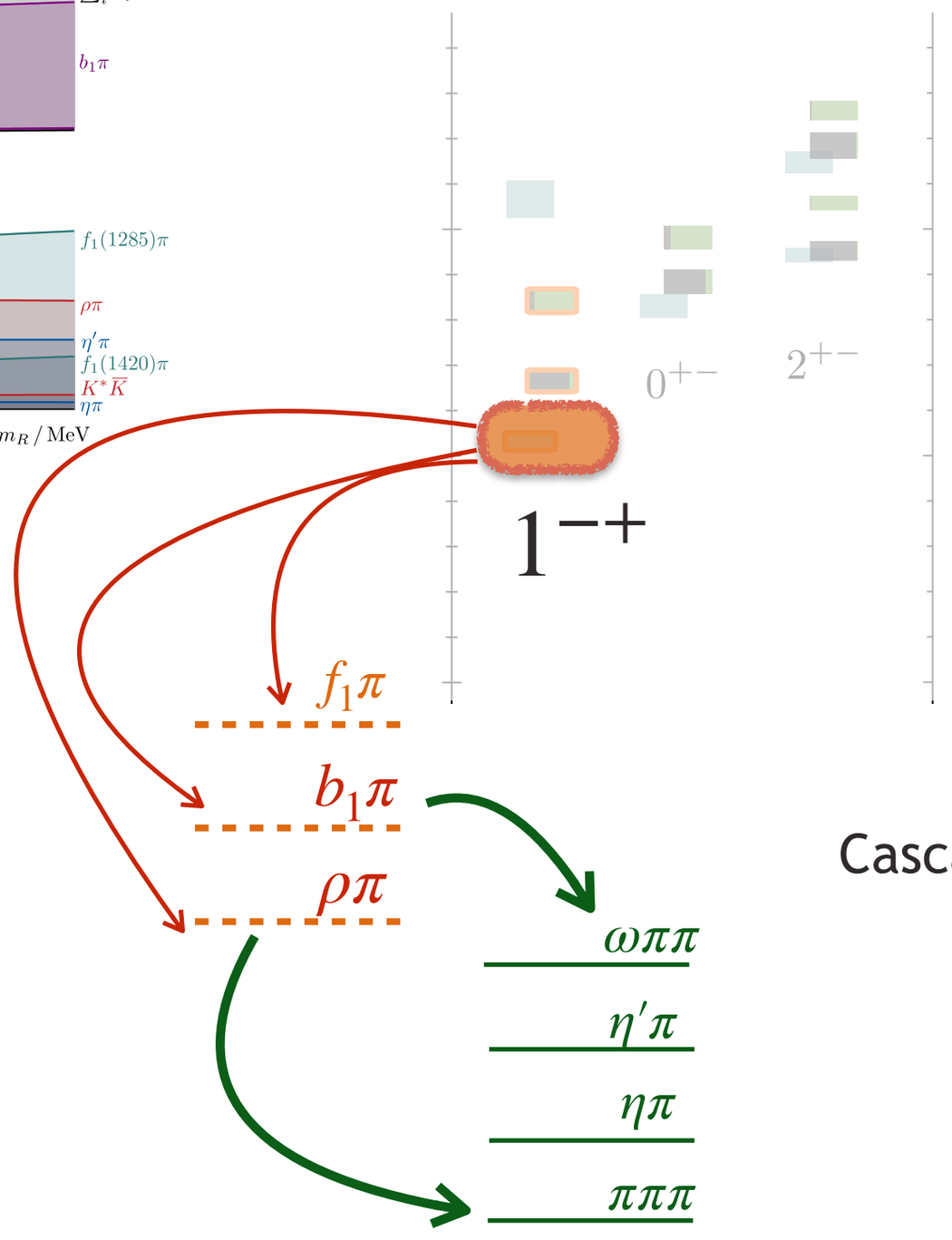


Used by GlueX

Need for three-body formalism

Decreasing pion mass, decreasing thresholds, more unstable states





Cascading decays

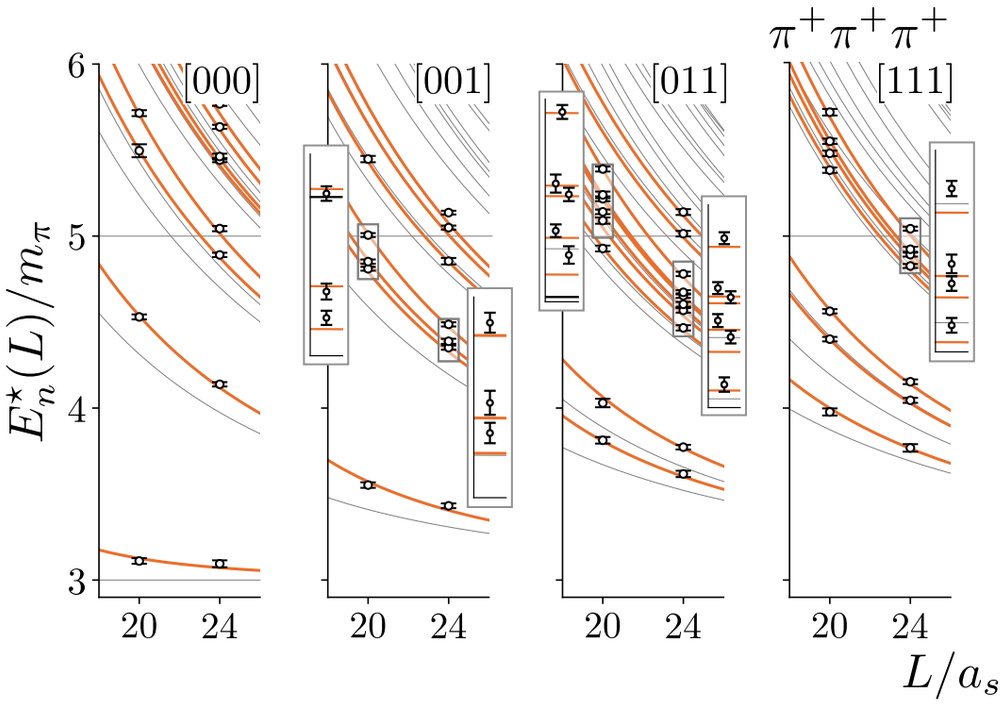
First forays into 3-body decays

More complicated formalism

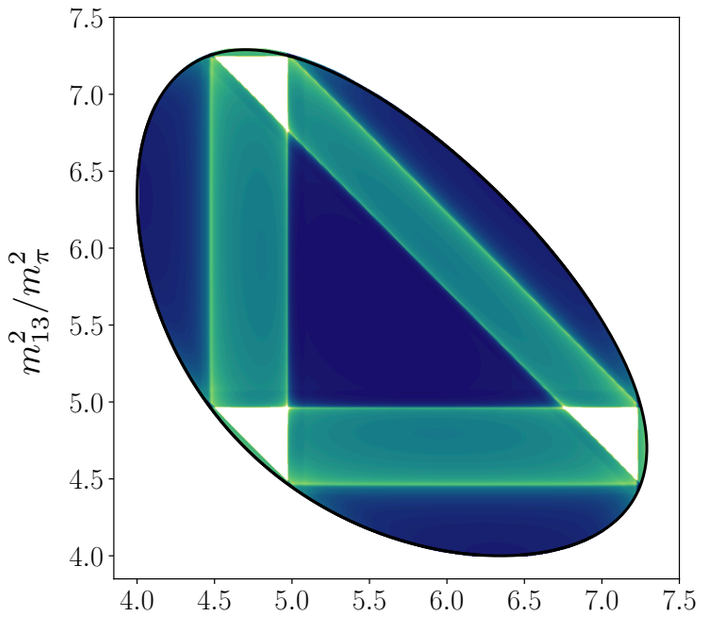
First calculations of full 3-body scattering amplitudes

Using USQCD resources and SciDAC developed algorithms & software

Finite-volume energy levels



3-body amplitudes

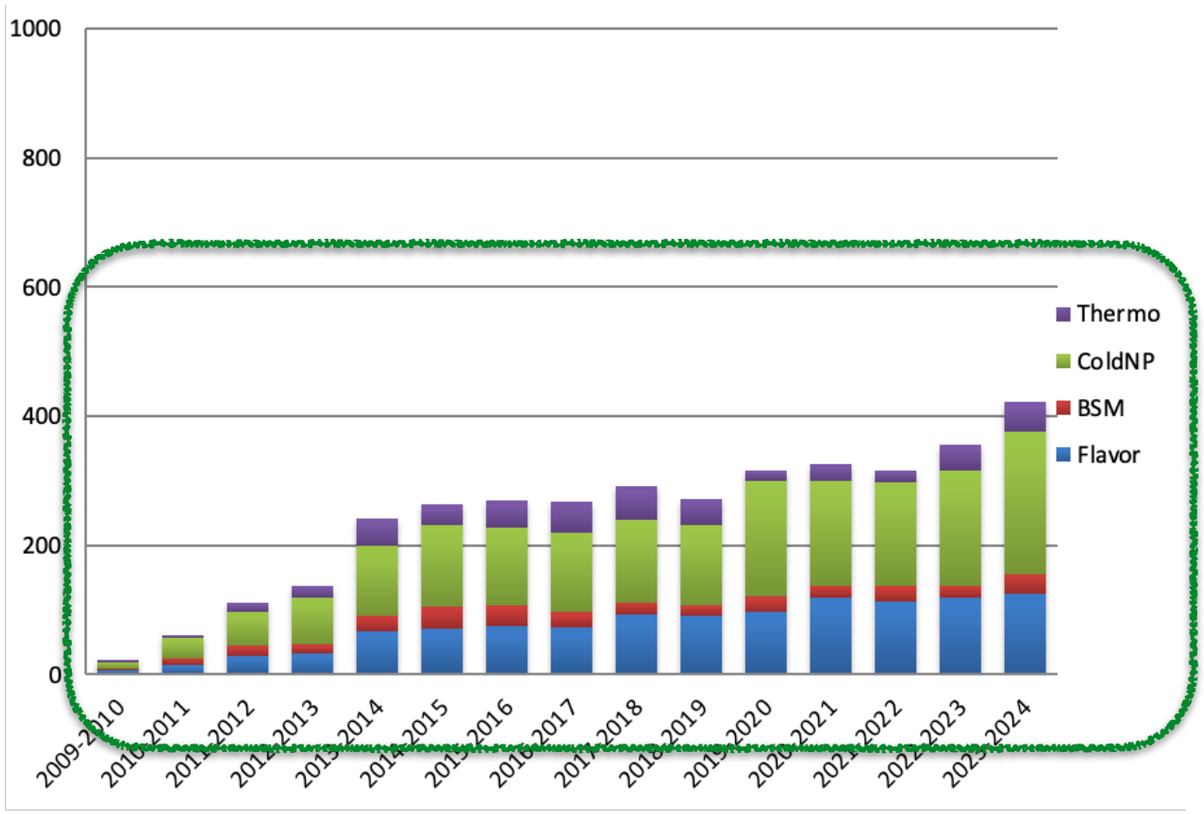


HADRON SPECTRUM: PRL 123
EDITOR'S SUGGESTION

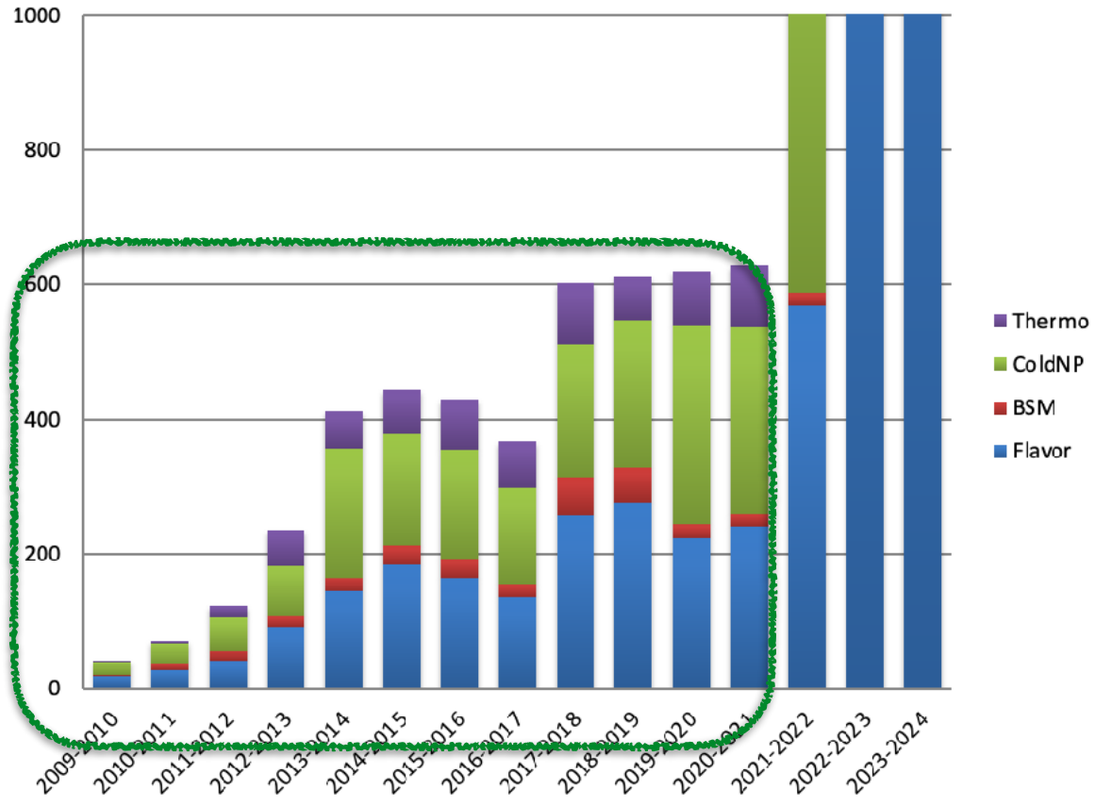
LQCD & leadership resources

Total by Field (in TFlop/s-year)

USQCD hardware



USQCD+Leadership



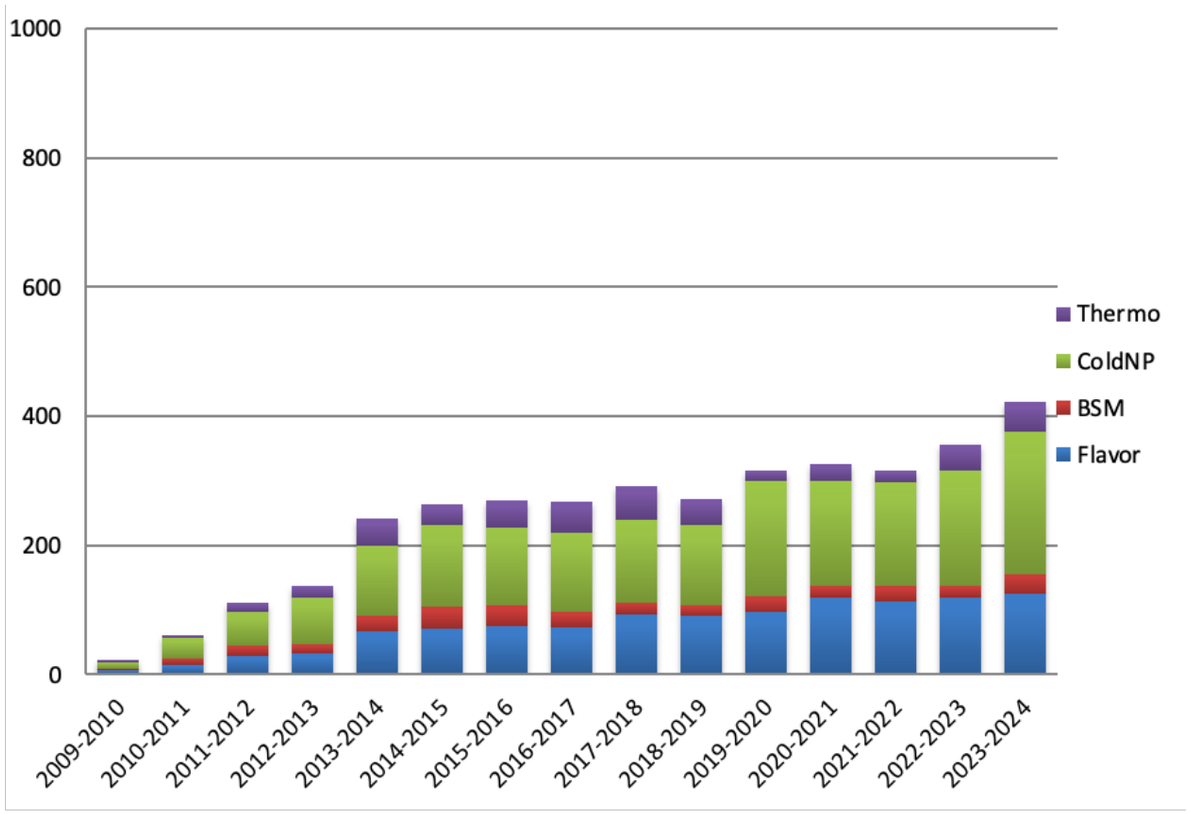
USQCD about half of total amount before NERSC+Exascale turned on by 2023

USQCD essential leverage of leadership resources → greater productivity

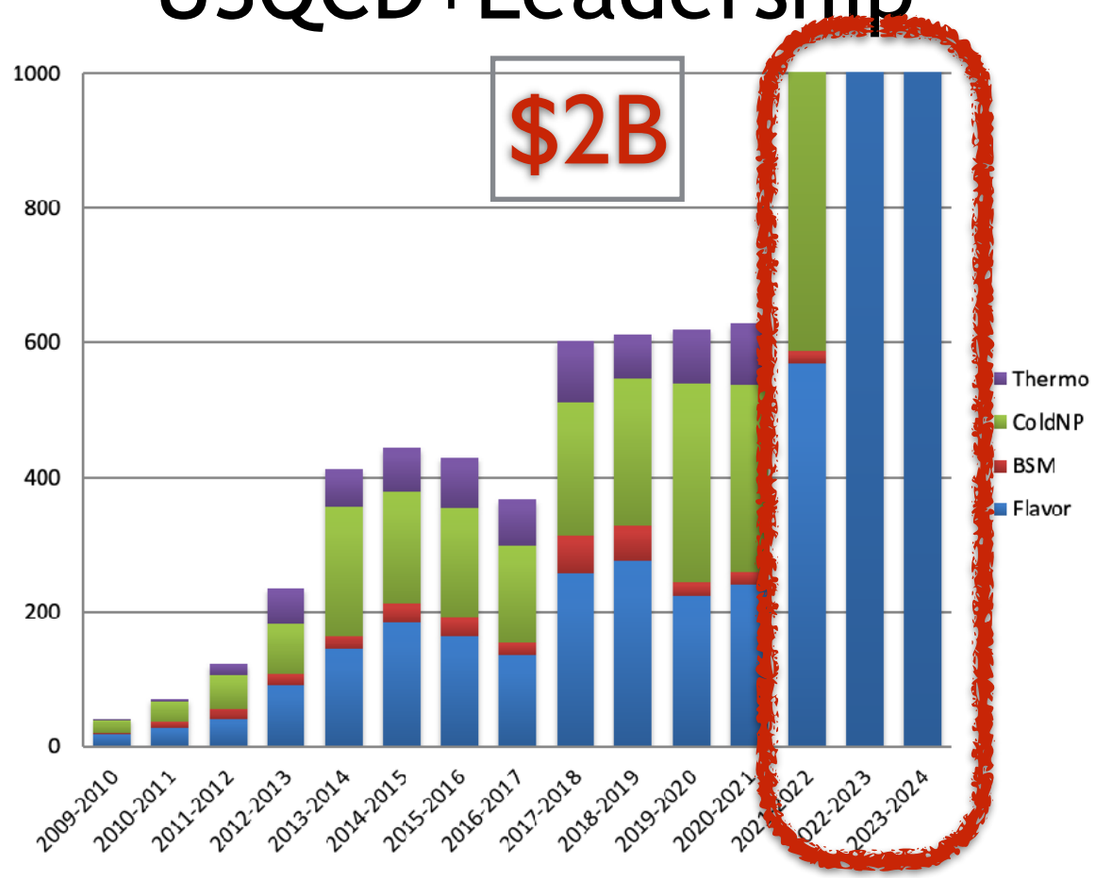
LQCD & leadership resources

Total by Field (in TFlop/s-year)

USQCD hardware



USQCD+Leadership

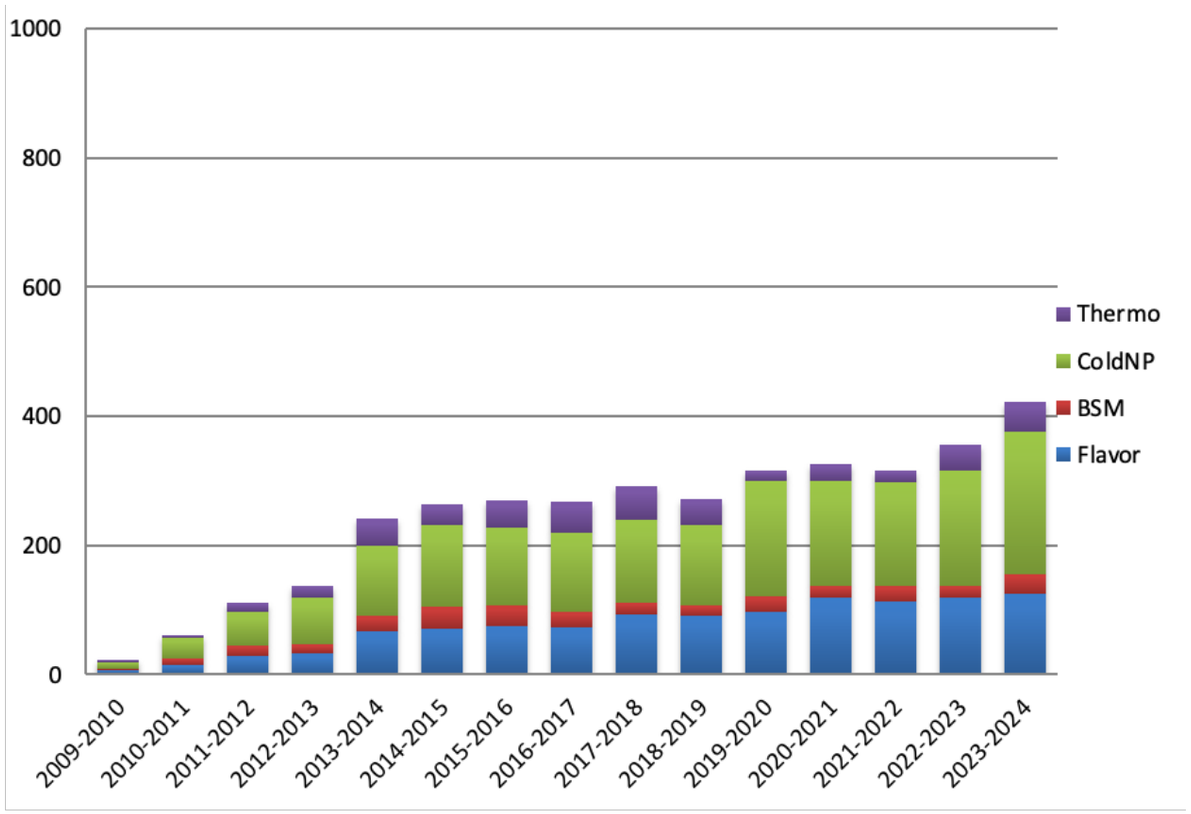


Large investment by DOE into leadership computing facilities

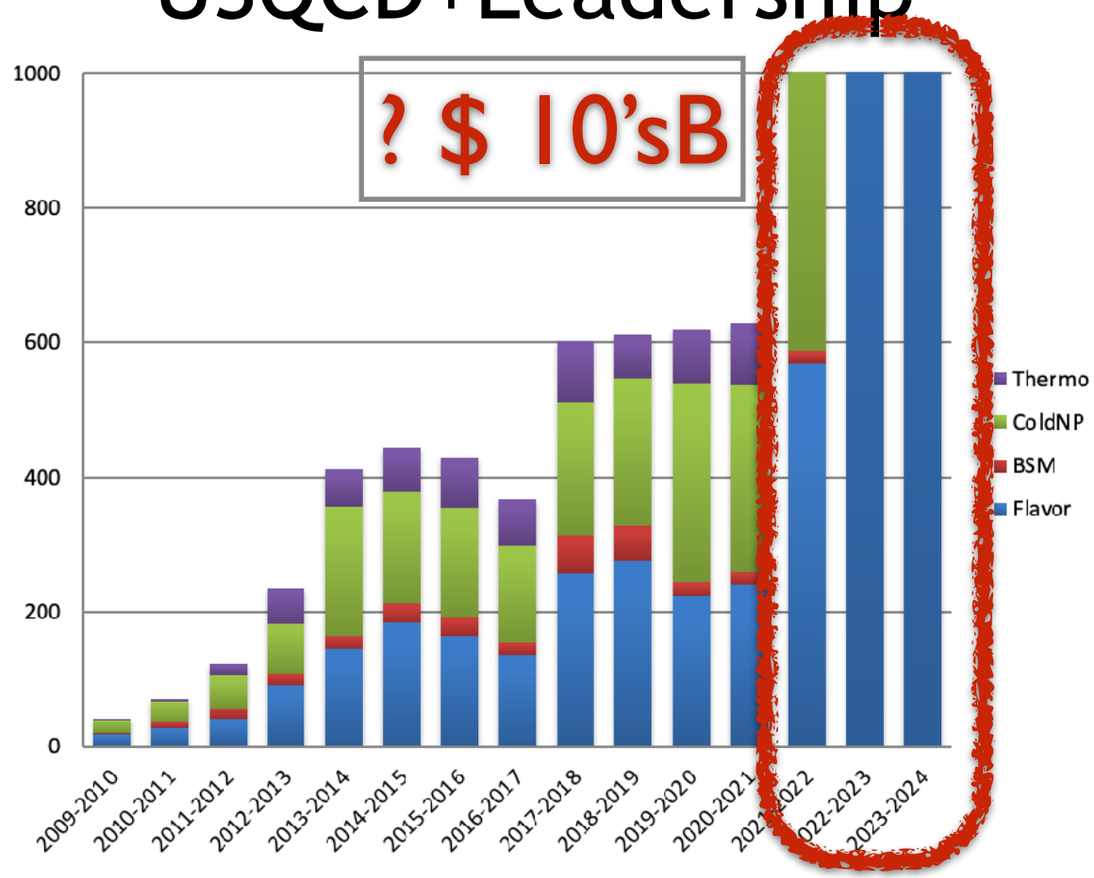
LQCD & leadership resources

Total by Field (in TFlop/s-year)

USQCD hardware



USQCD+Leadership

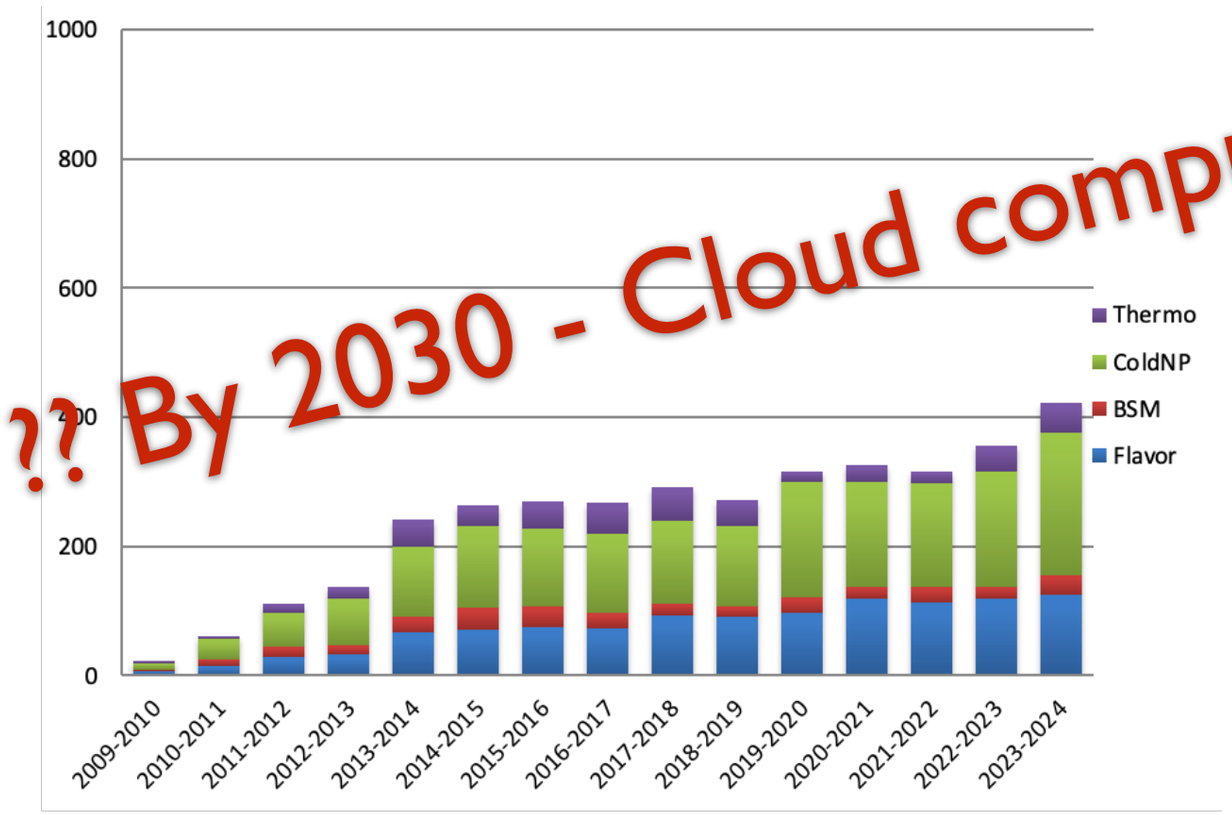


Is the future the cloud for universities & even labs?

LQCD & leadership resources

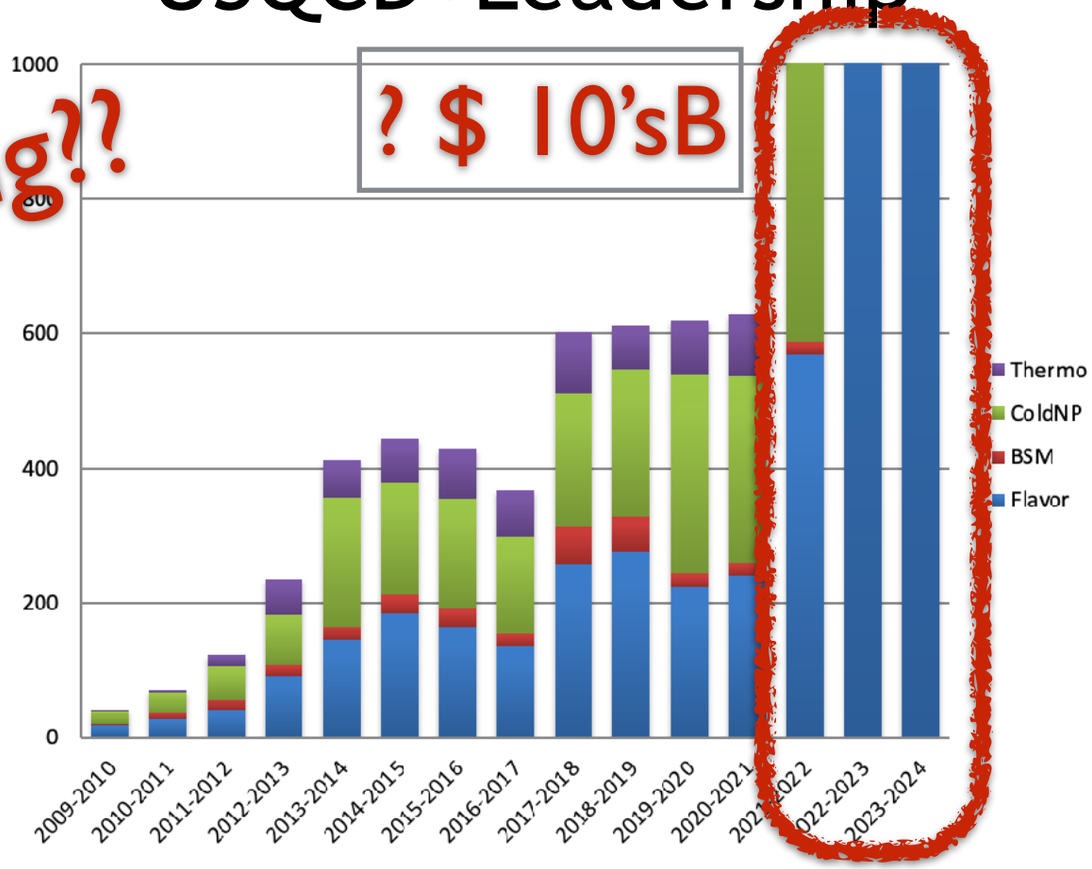
Total by Field (in TFlop/s-year)

USQCD hardware



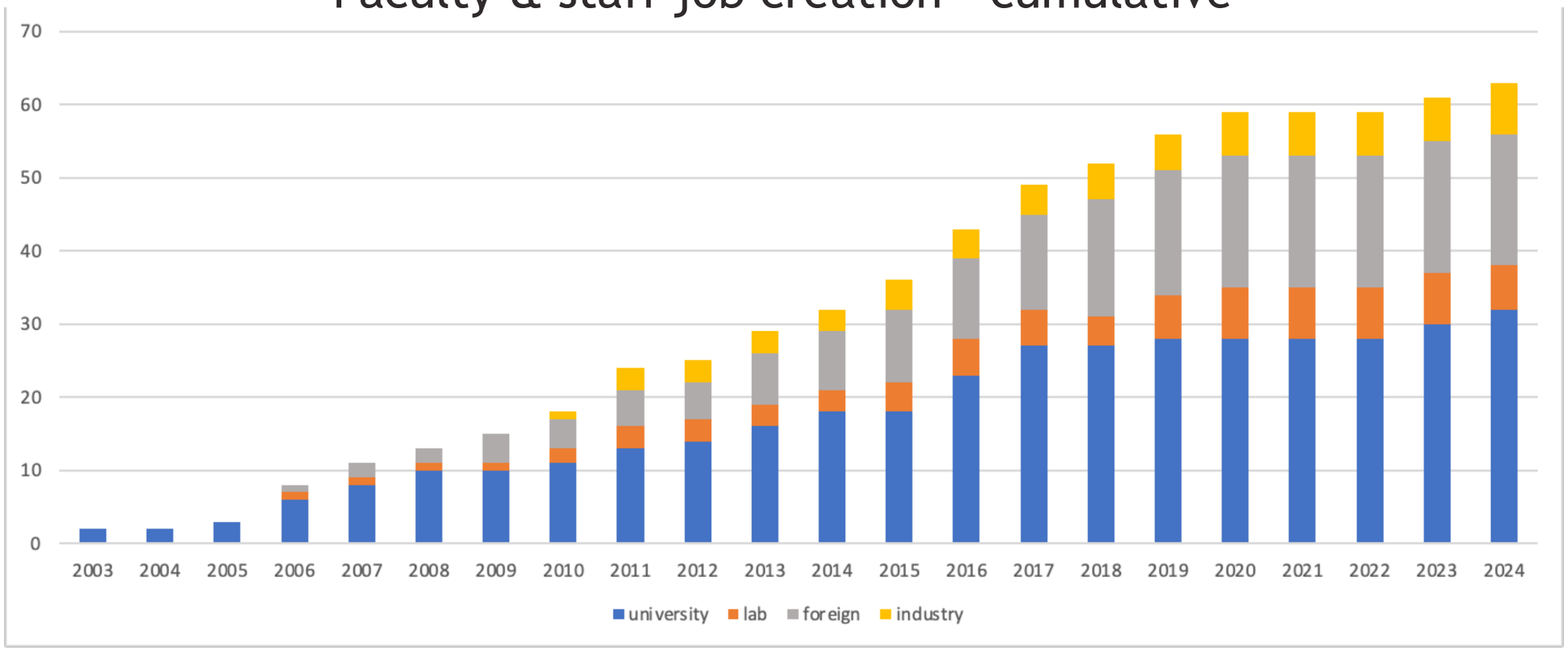
?? By 2030 - Cloud computing??

USQCD+Leadership



Is the future the cloud for universities & even labs?

Workforce & education



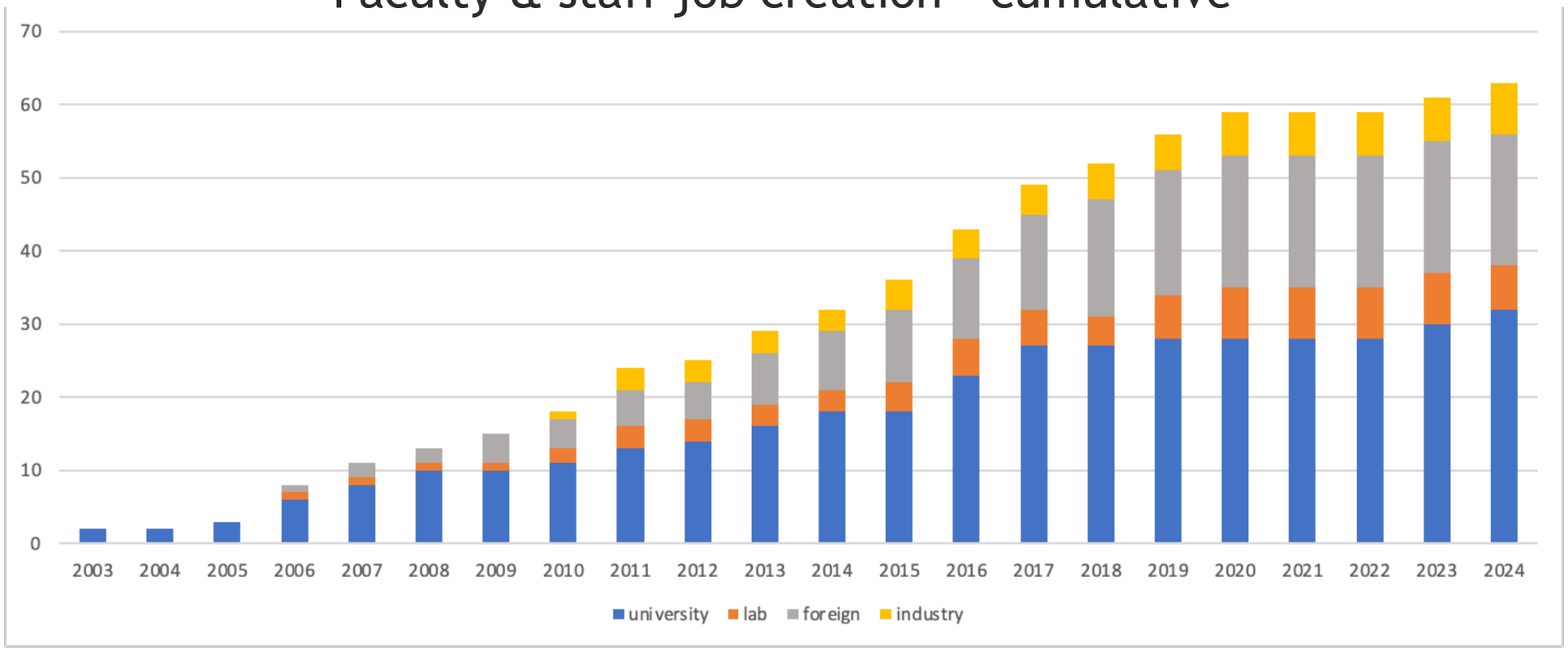
Good job creation over the years

10+ DOE/NSF Early Career awards

Job drivers: joint/bridge positions with JLab, FRIB, LBNL, and RIKEN-BNL Research Center

> 130 graduate students graduated since 2003

Workforce & education



Good job creation over the years

10+ DOE/NSF Early Career awards

Job drivers: joint/bridge positions with JLab, FRIB, LBNL, and RIKEN-BNL Research Center

> 130 graduate students graduated since 2003

Very much threatened