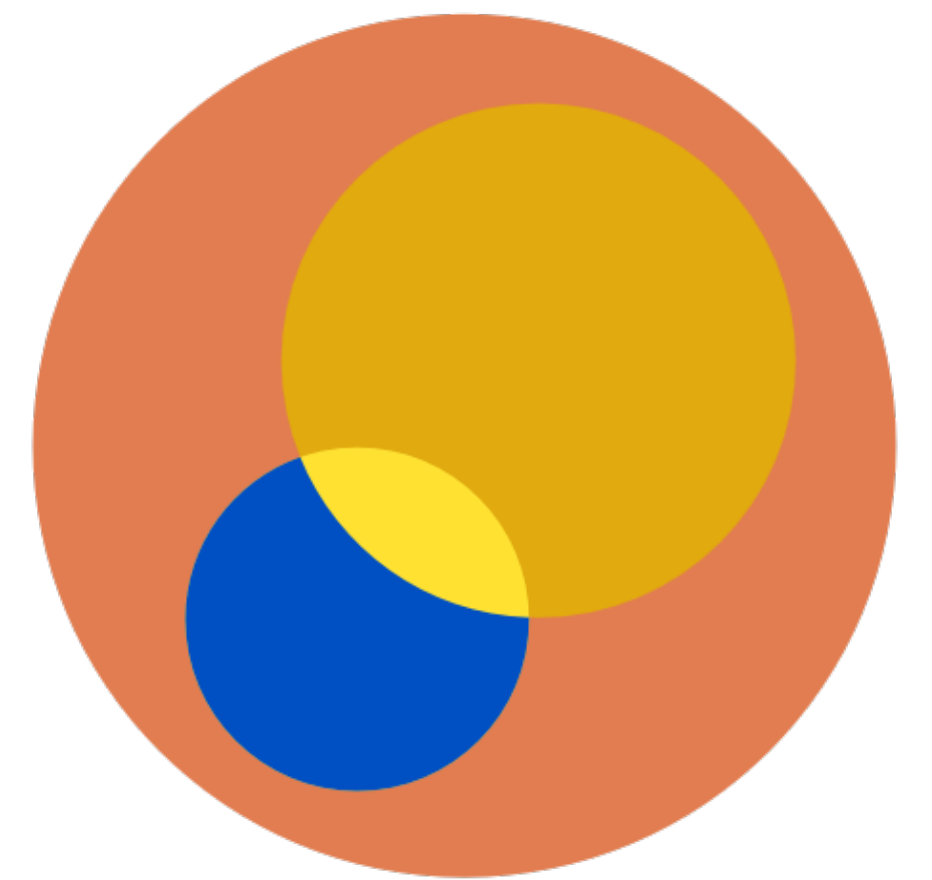


# US Muon Collider Collaboration

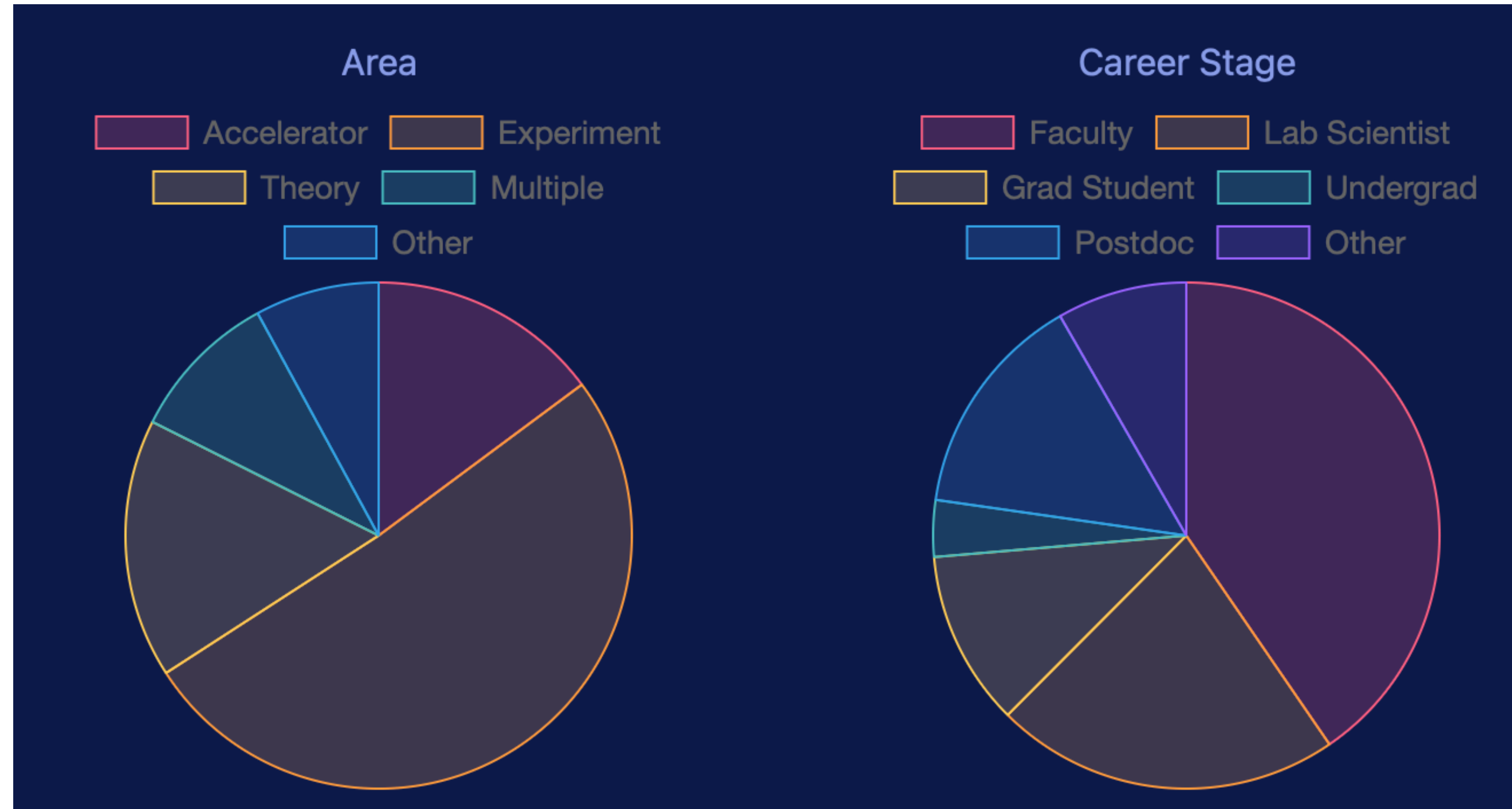
**Patrick Meade**

CN Yang Institute for Theoretical Physics  
Stony Brook University  
on behalf of the USMCC collaboration



**USMCC**

# Who are we? A broad *grassroots* organization

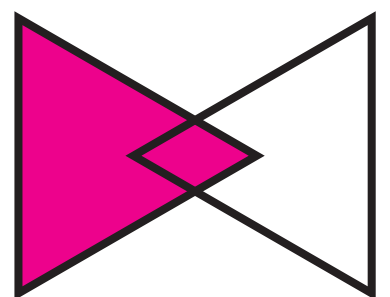
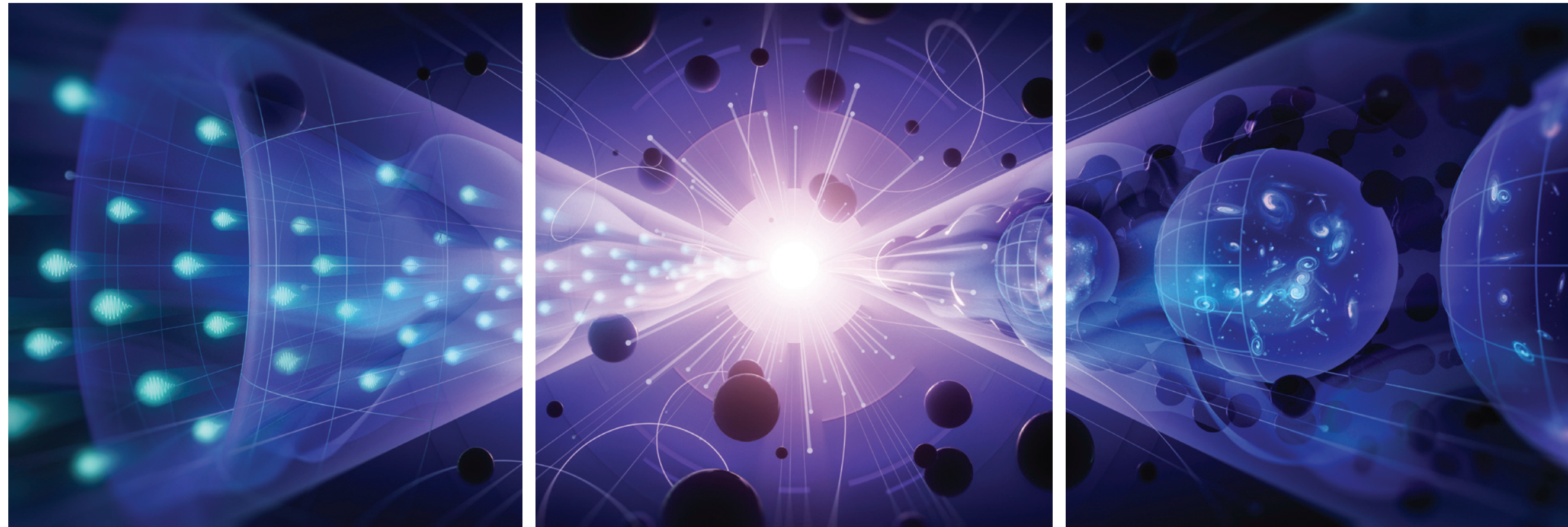


- Almost 300 members
- Approximately 1/3 **Early Career**
- Mix of accelerator, experimental and theoretical physicists

**Big tent for  
Big physics potential**

**MUON  
COLLIDER**  
<https://www.muoncollider.us/>

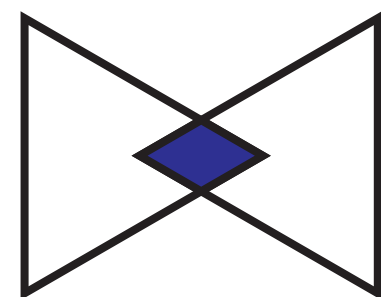
# Working collaboratively (and incrementally) *towards* a shared muon collider facility *vision*



Decipher  
the  
Quantum  
Realm

Elucidate the Mysteries  
of Neutrinos

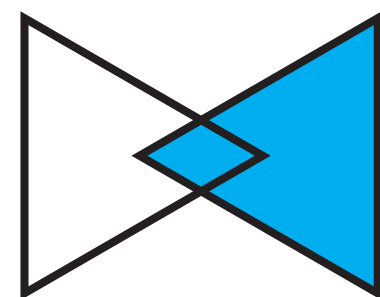
Reveal the Secrets of  
the Higgs Boson



Explore  
New  
Paradigms  
in Physics

Search for Direct Evidence  
of New Particles

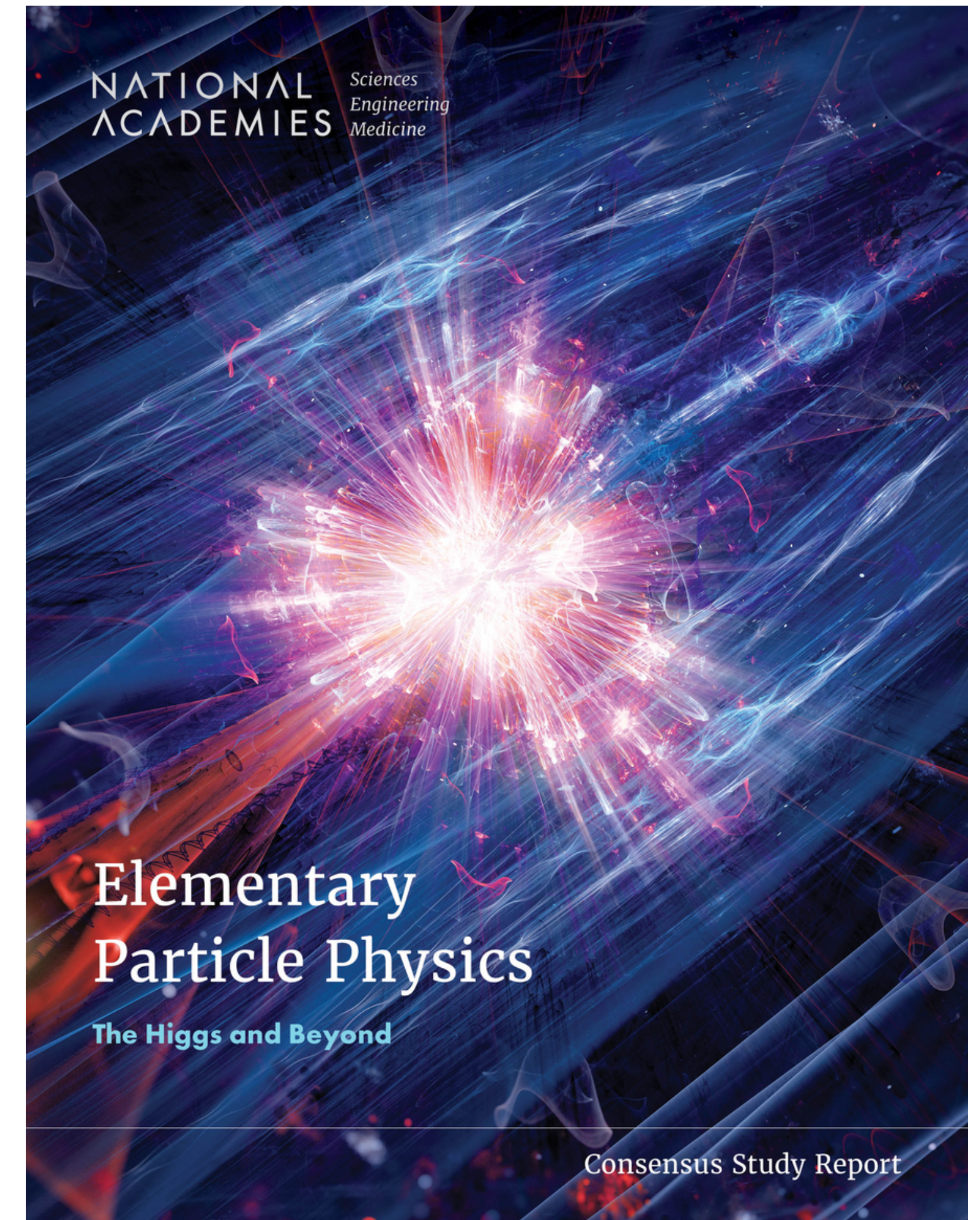
Pursue Quantum Imprints  
of New Phenomena



Illuminate  
the  
Hidden  
Universe

Determine the Nature  
of Dark Matter

Understand What Drives  
Cosmic Evolution



**As this is a community meeting and I only have 12+3 minutes... I'll give you a biased sampling of updates, with the hope to generate further DPF(DNP) community engagement!**

# Why colliders, when we have so many types of potential experiments?



- Quantum Field Theory implies **colliders are the modern microscope**
- Many of our deepest questions *require* colliders
- Fortunately we have the technology to advance in certain directions by e.g. looking for *quantum imprints* on the Higgs and Electroweak sector
- P5 recommendation 2 - offshore Higgs Factory - see Valentina Cairo's great FCC-ee talk from earlier

**Snowmass + P5 gave us an even grander vision, because certain questions *require* us to probe nature at even shorter distances!**



**P5 community vision - 10 TeV pCM**

# P5 vision - 10 TeV pCM



- P5 vision reflected a need to ***reach beyond currently available technology***
- **Multiple** potential technological R&D paths were encouraged by P5 to reach “10 TeV pCM”
- This is a reflection of ensuring humanity ***gets*** to shorter distances rather than an exact energy threshold
- **10 TeV pCM colliders *aren't* all the same physics wise\***

\*but they can be complementary!

# Why are so many people excited by a potential Muon Collider facility?



- The **physics** it enables at the highest energy
- The **physics opportunities** along the journey to get there
- The **technological challenges** it presents and potential payoffs, we *are* miracle workers every day, but we must **earn** any support through careful planning
- An opportunity for a long-term unifying vision of **US leadership across *many* frontiers** potentially building on **existing infrastructure**

**What are the most pressing physics questions  
that a *muon collider* addresses best?**



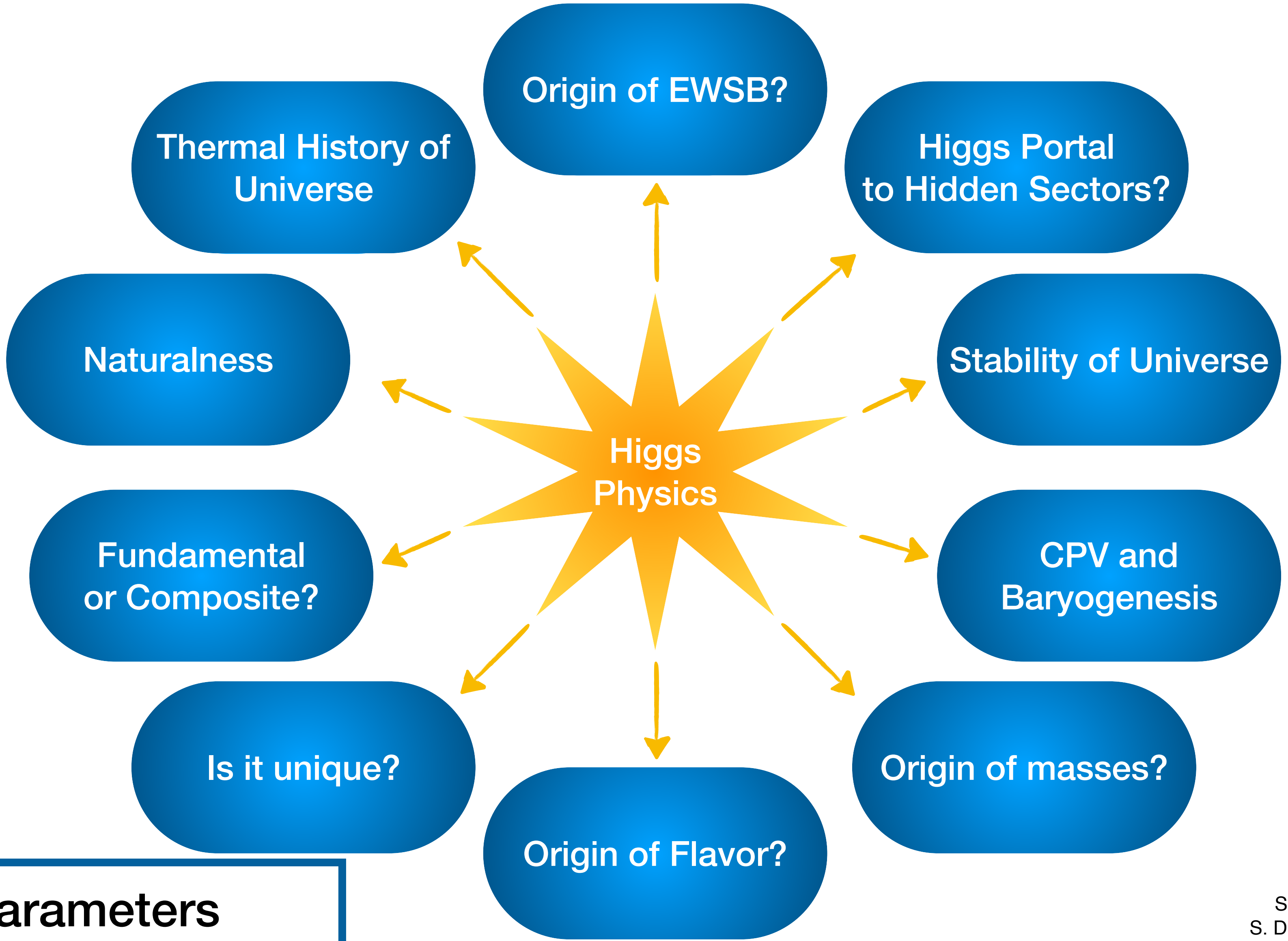
**Why are we here?**

**Where did we come from?**

**Where are we going?**

**The LHC has given us more questions than answers!**

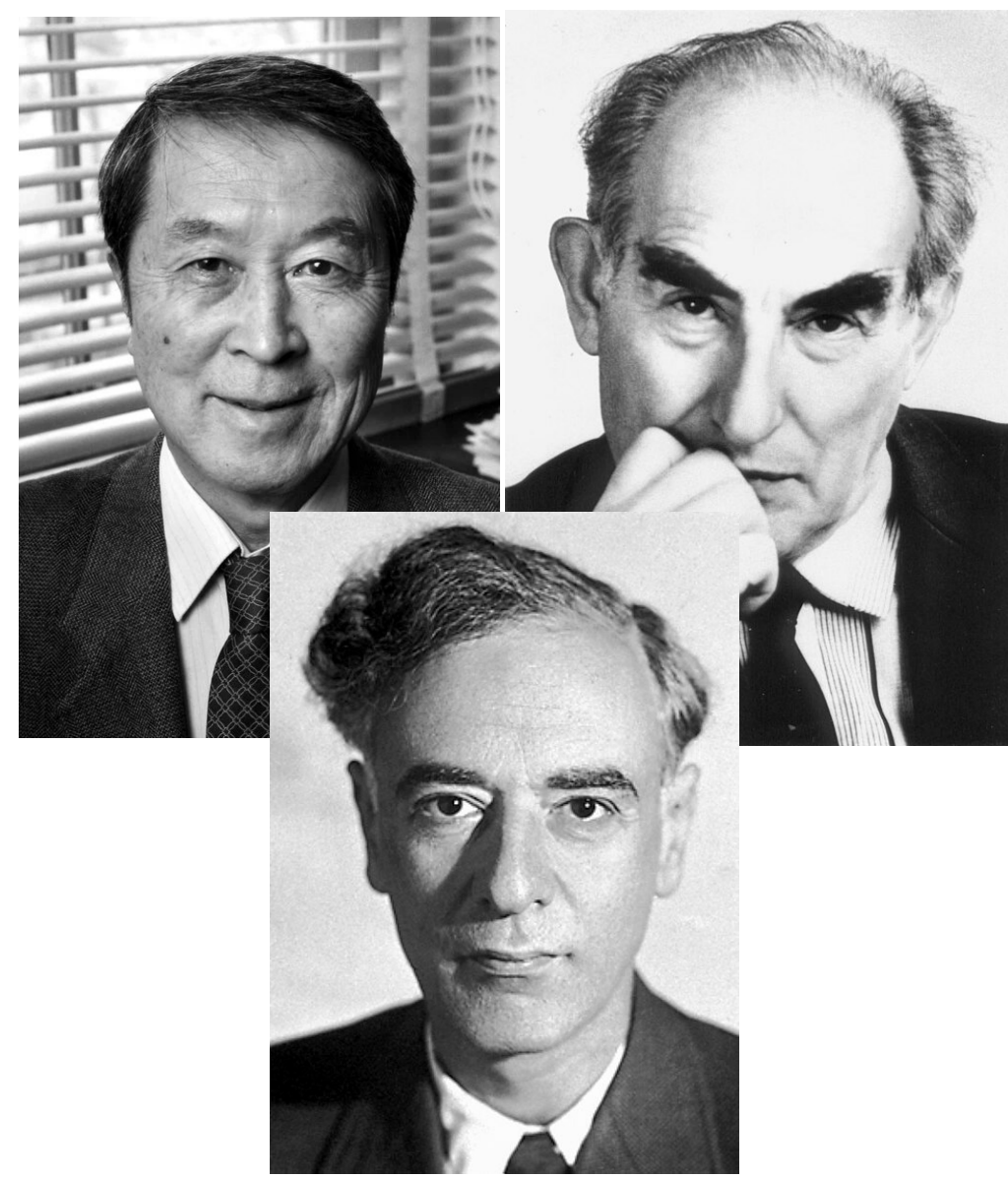
# The Higgs is *central to so much*, but *answers so little*



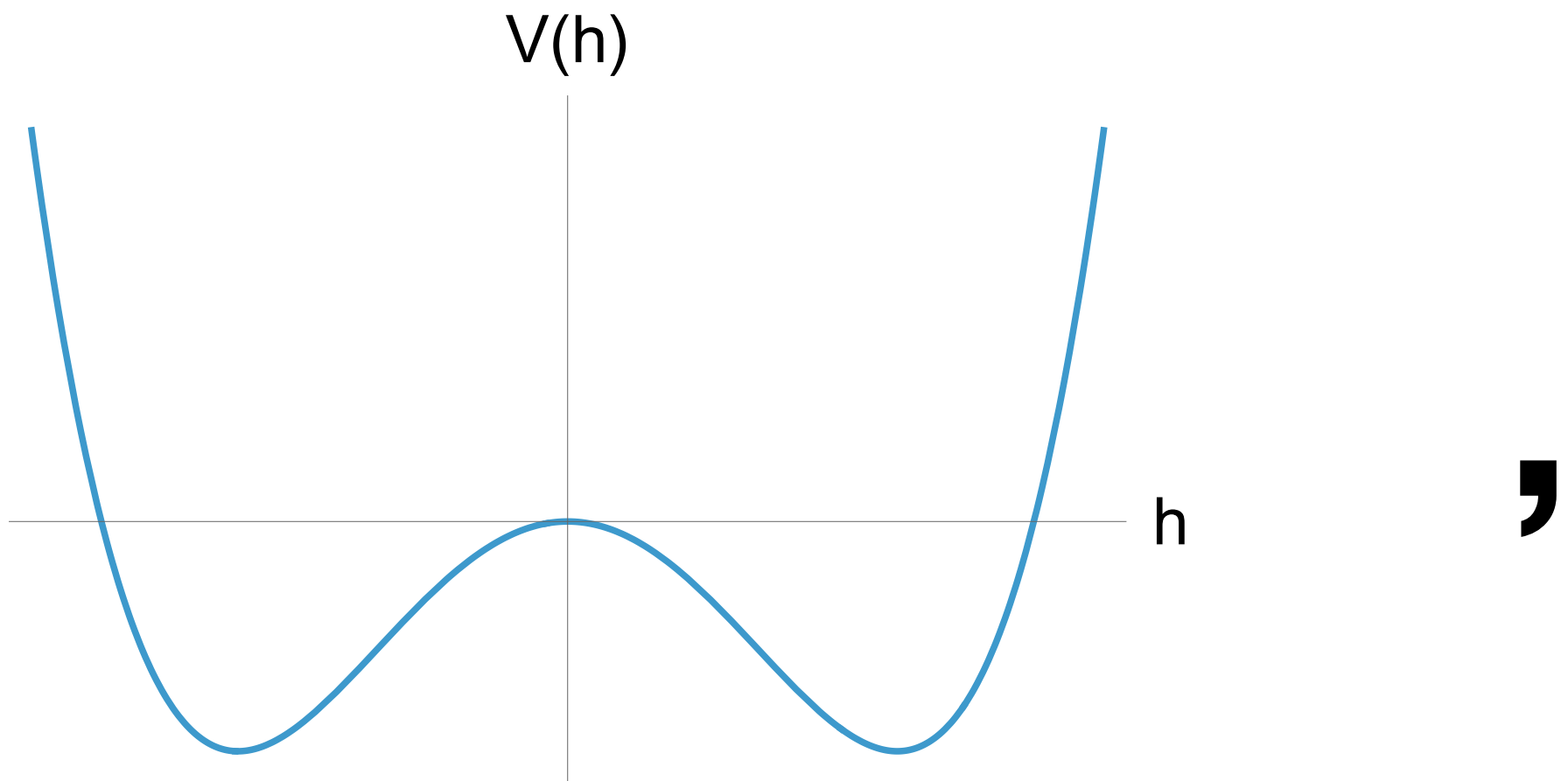
**15/19**  
SM parameters  
due to Higgs

**22/26** SM parameters  
w/ $\nu$  mass or new EWSB source

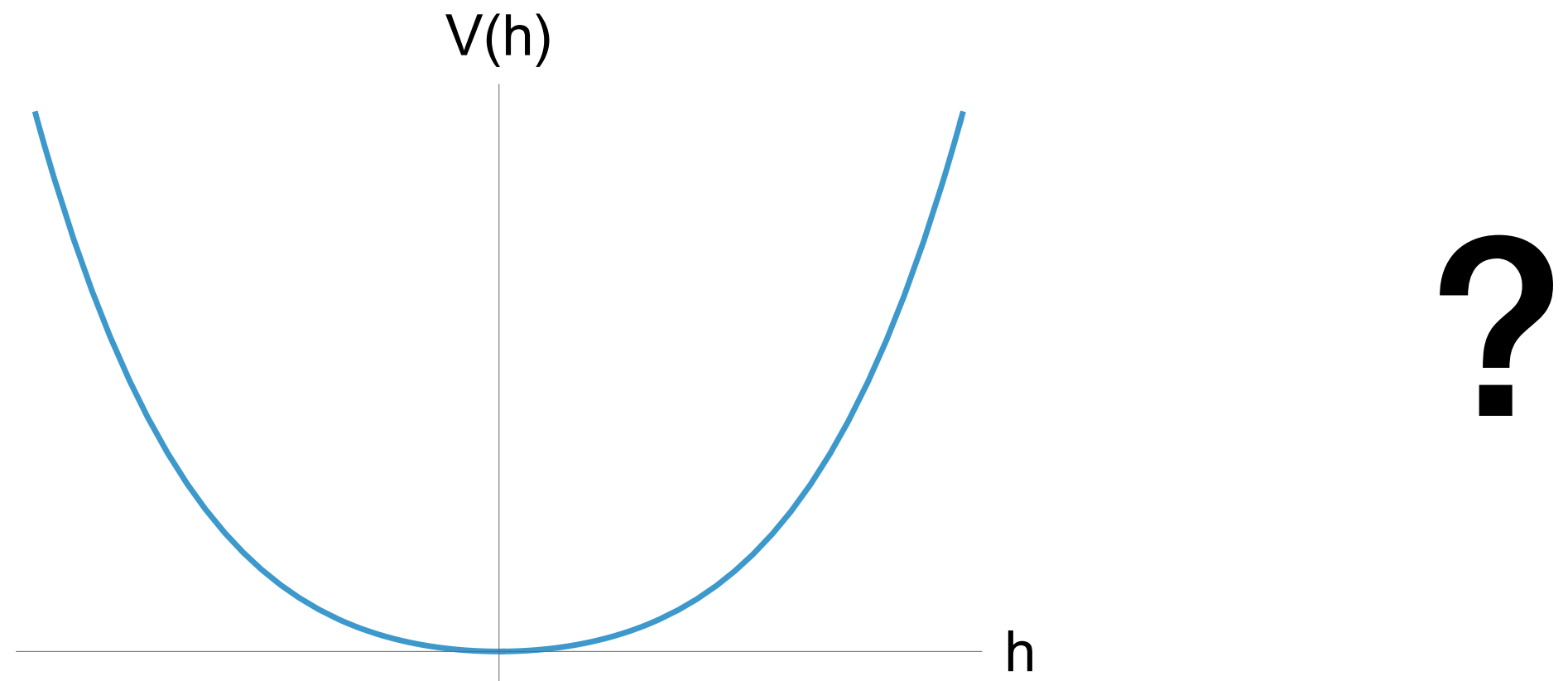
# Spontaneous Symmetry Breaking and *our* place in the universe



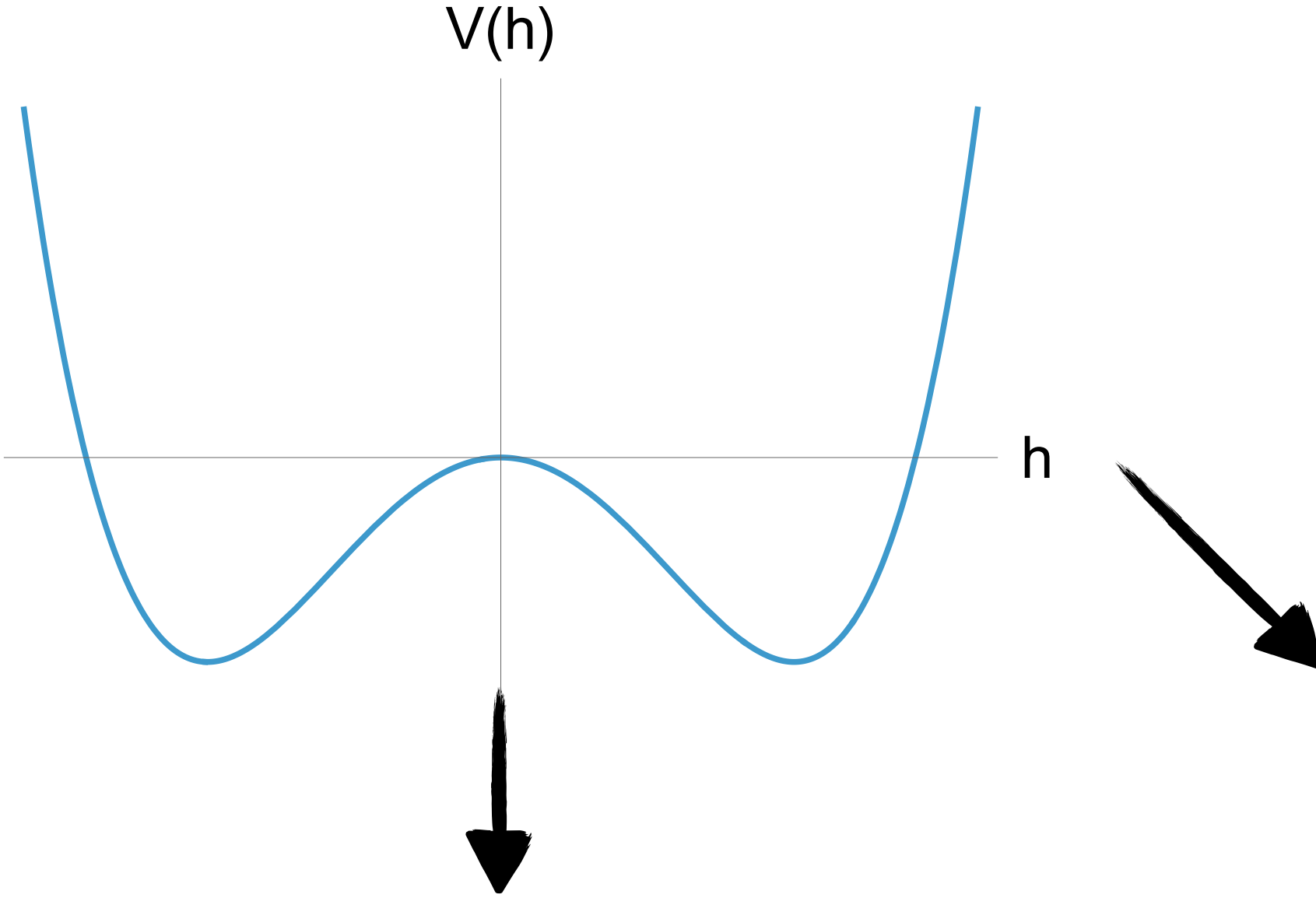
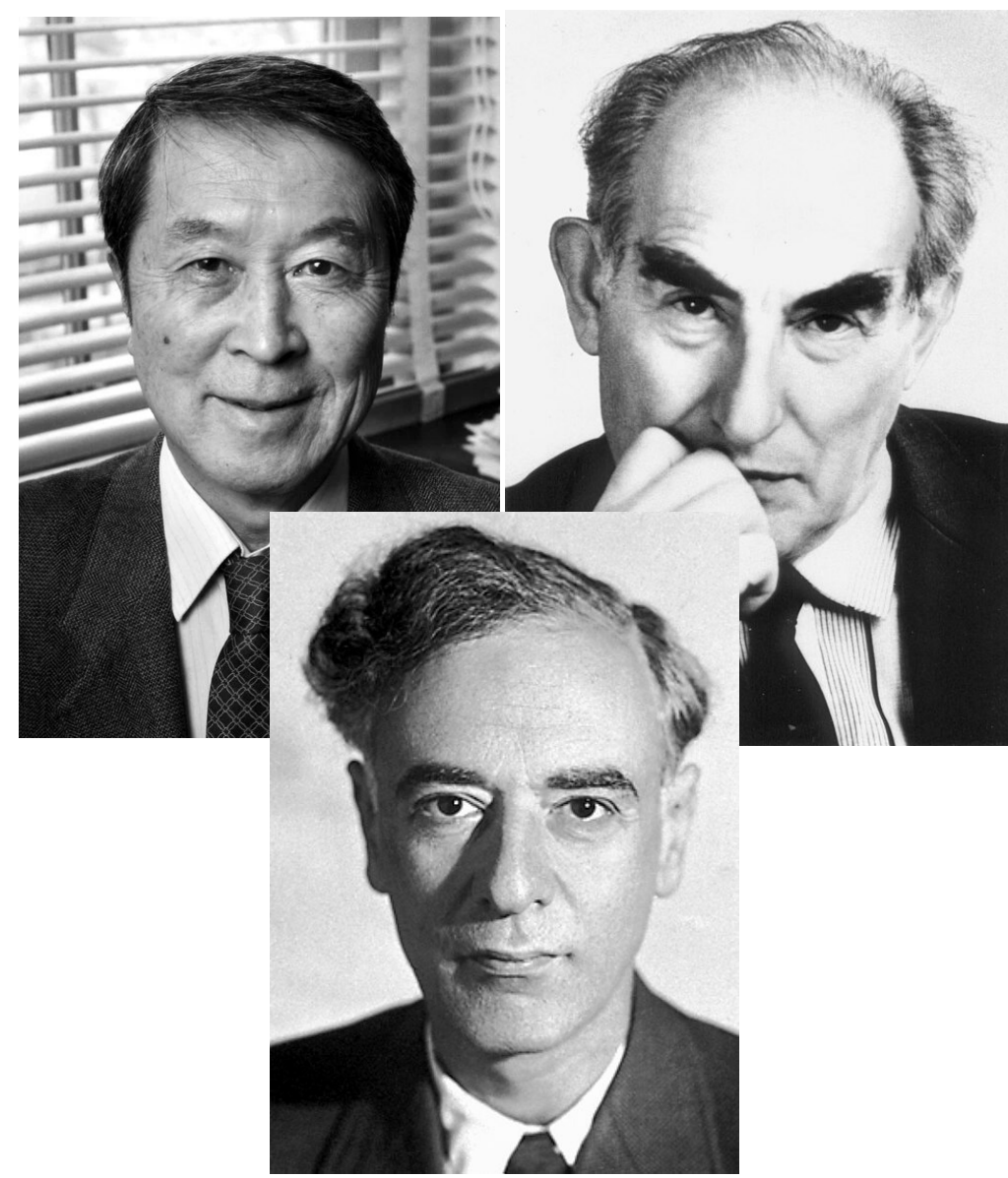
Why



not



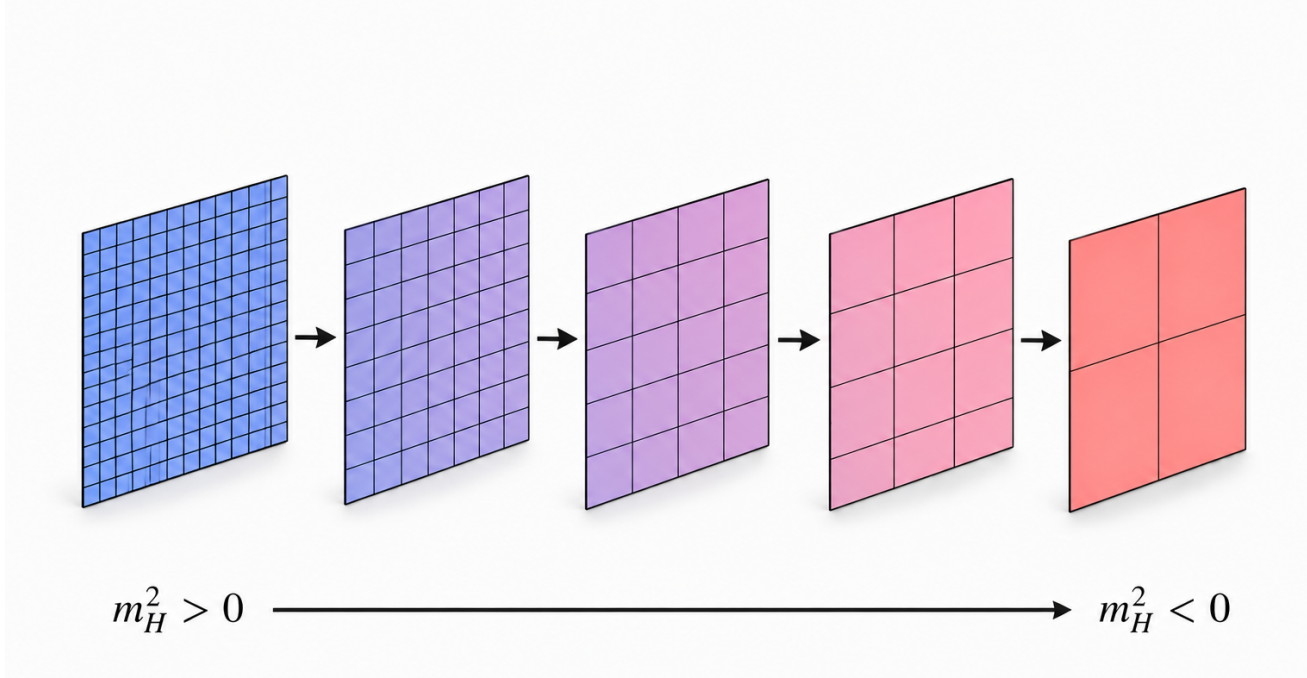
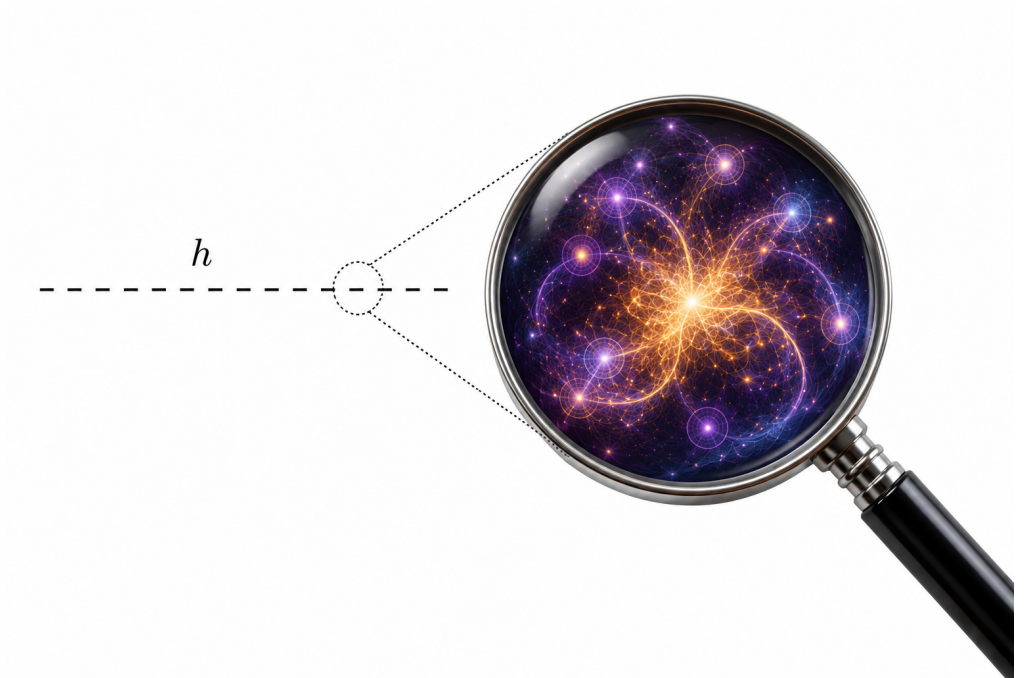
# Spontaneous Symmetry Breaking and *our* place in the universe



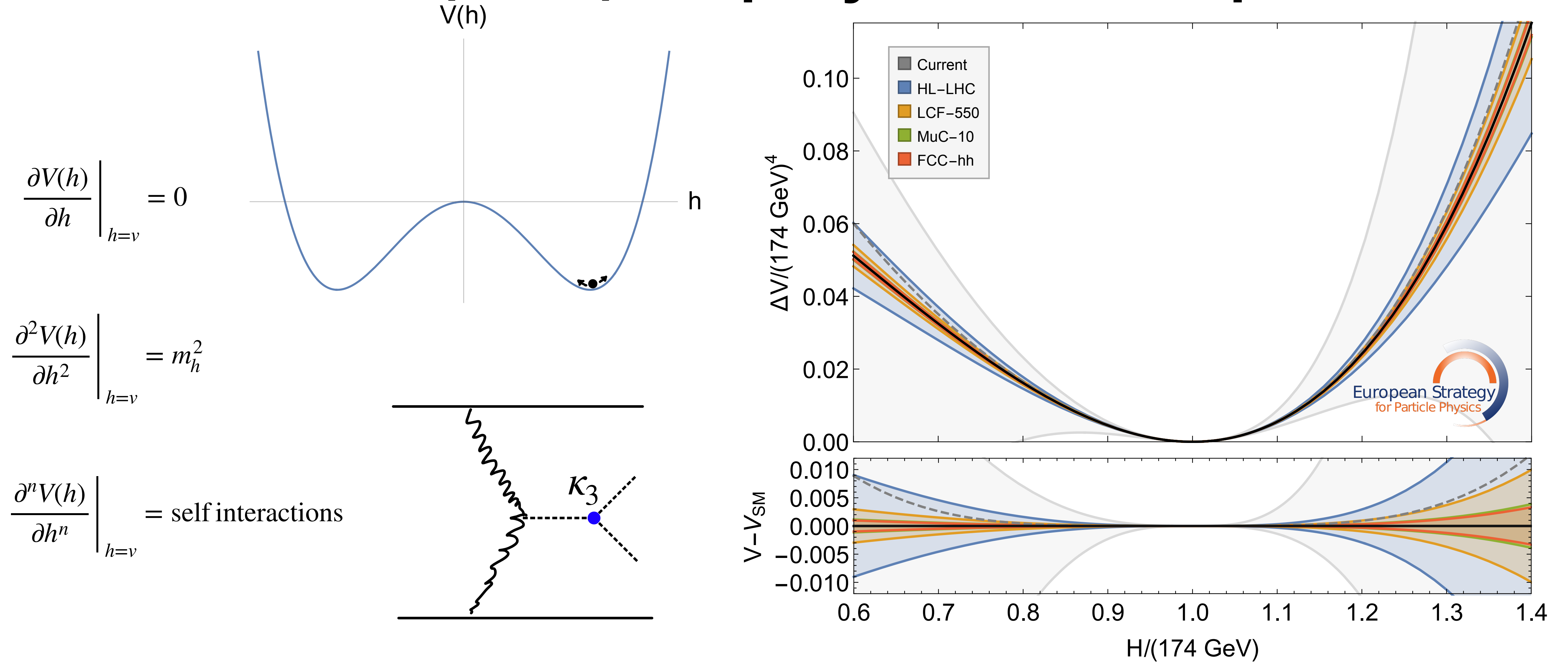
Underlying dynamics  
***Composite Higgs***

Radiative Symmetry Breaking

...

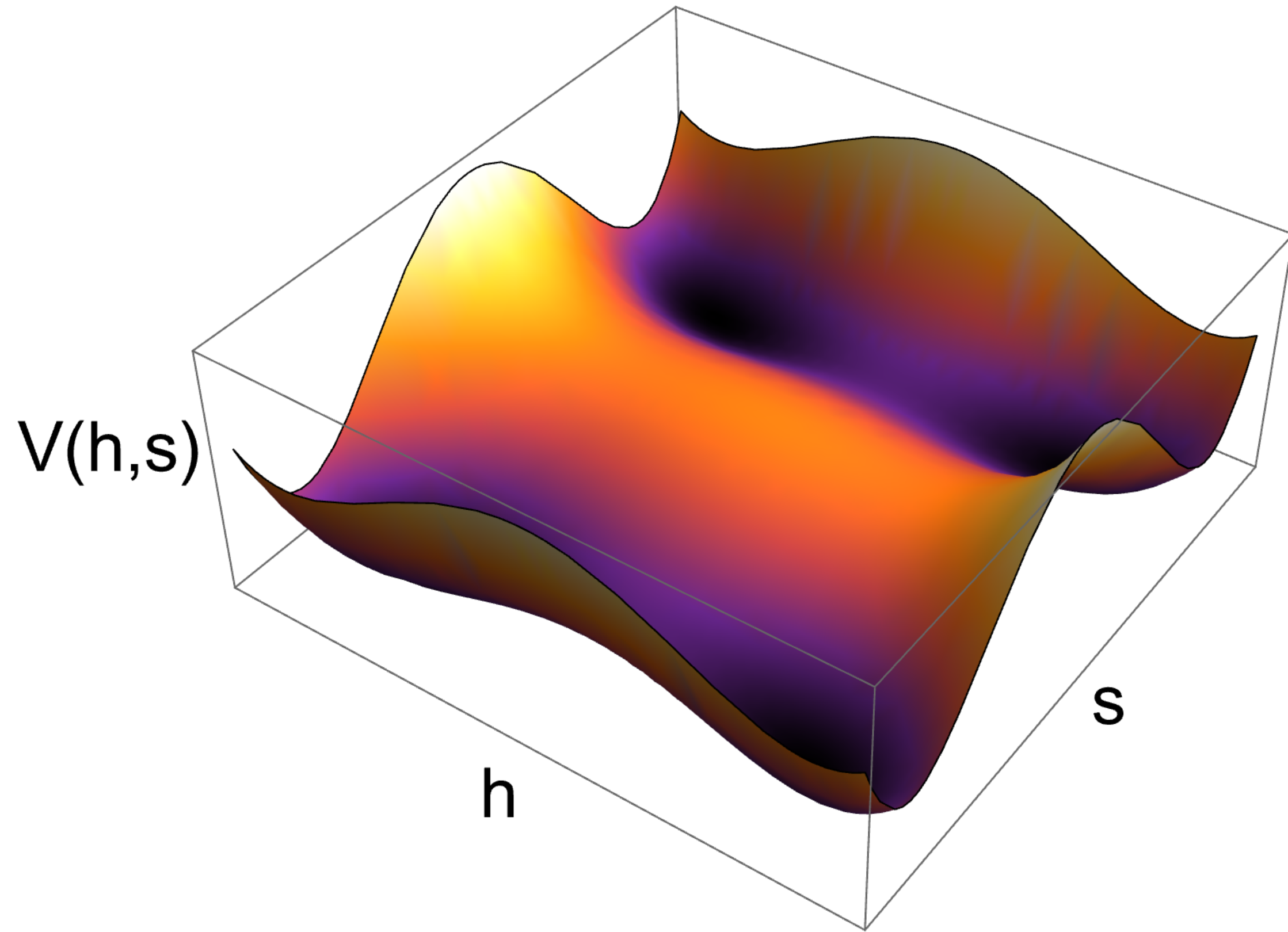


# We often (*over*)simplify this for exposition

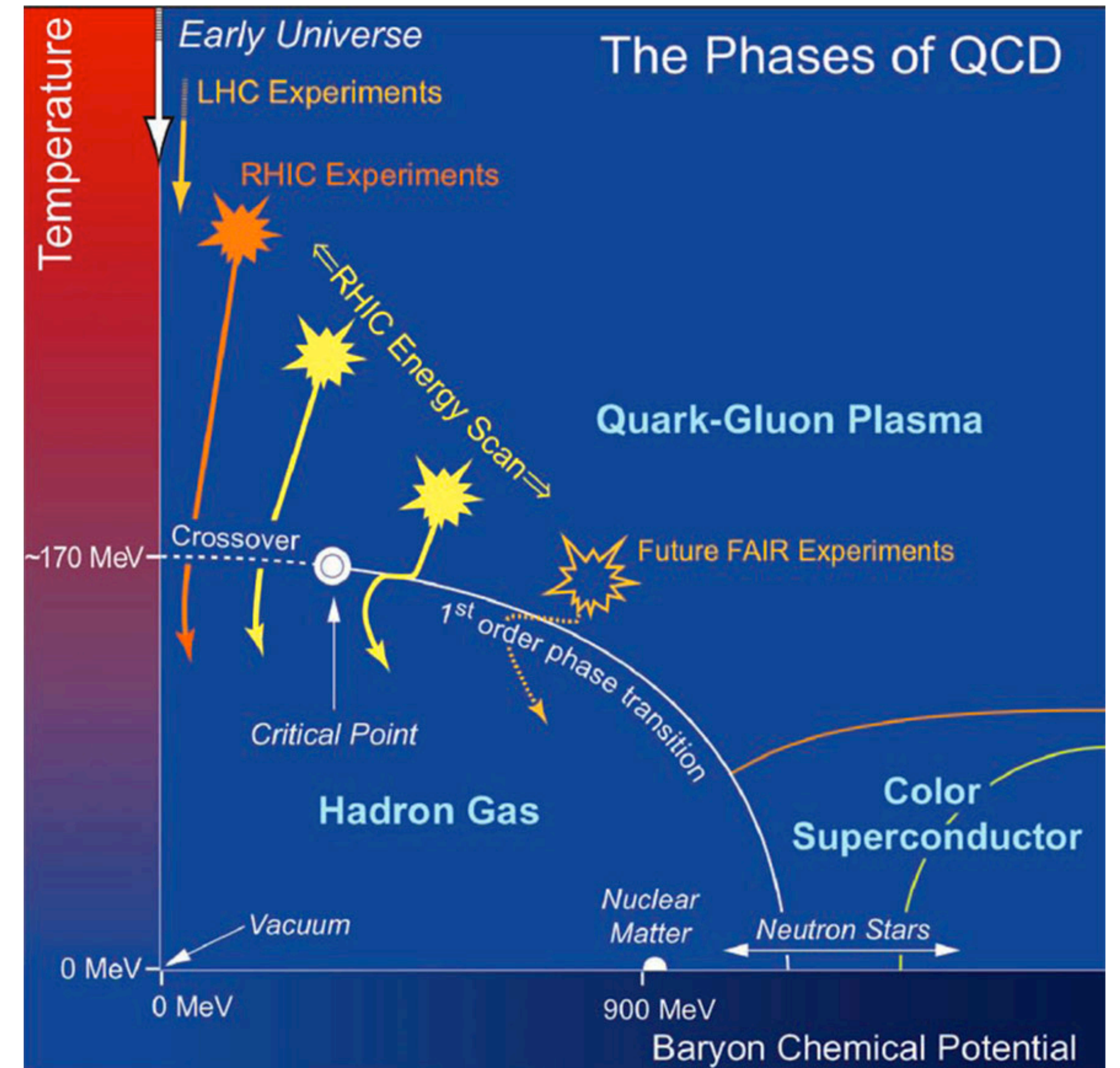


It makes it easy to understand why *energy* matters, however, exploring/measuring the vacuum of our universe is *more than*  $\kappa_3$

# ***Any deviation in a SM parameter must have an origin***



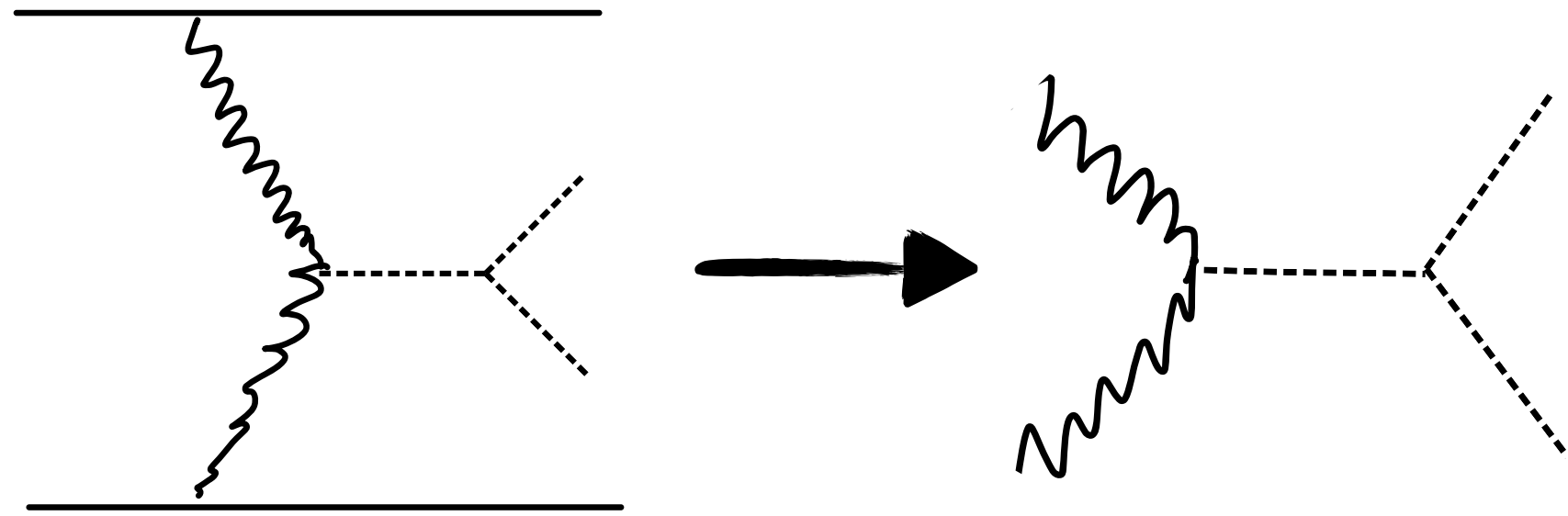
***A more complex vacuum***



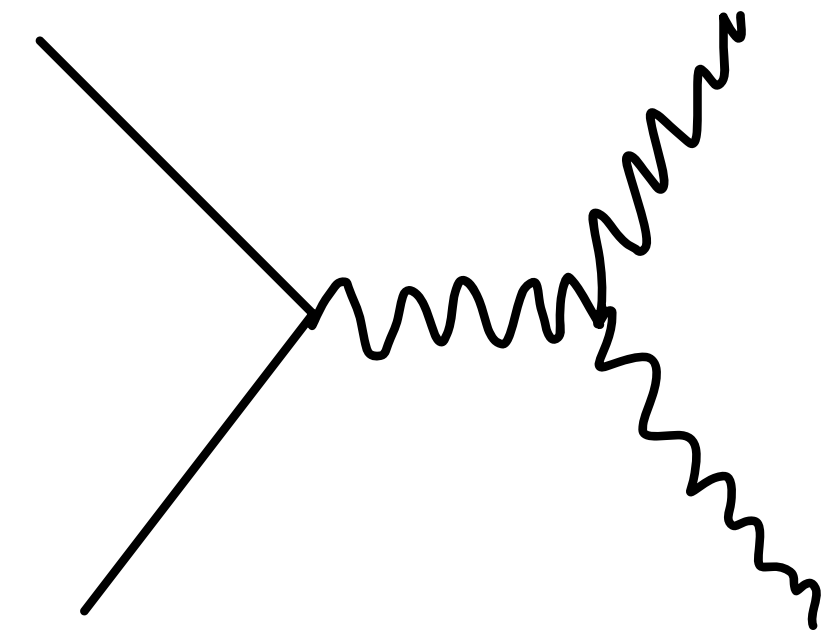
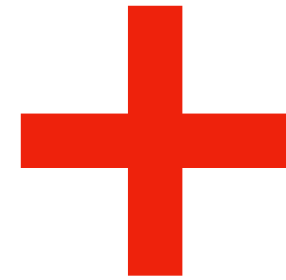
(STAR whitepaper)

We'd like to understand the ***EW phase diagram*** analogously to the ***QCD phase diagram***

# *Why is a Muon Collider well matched to these fundamental questions?*



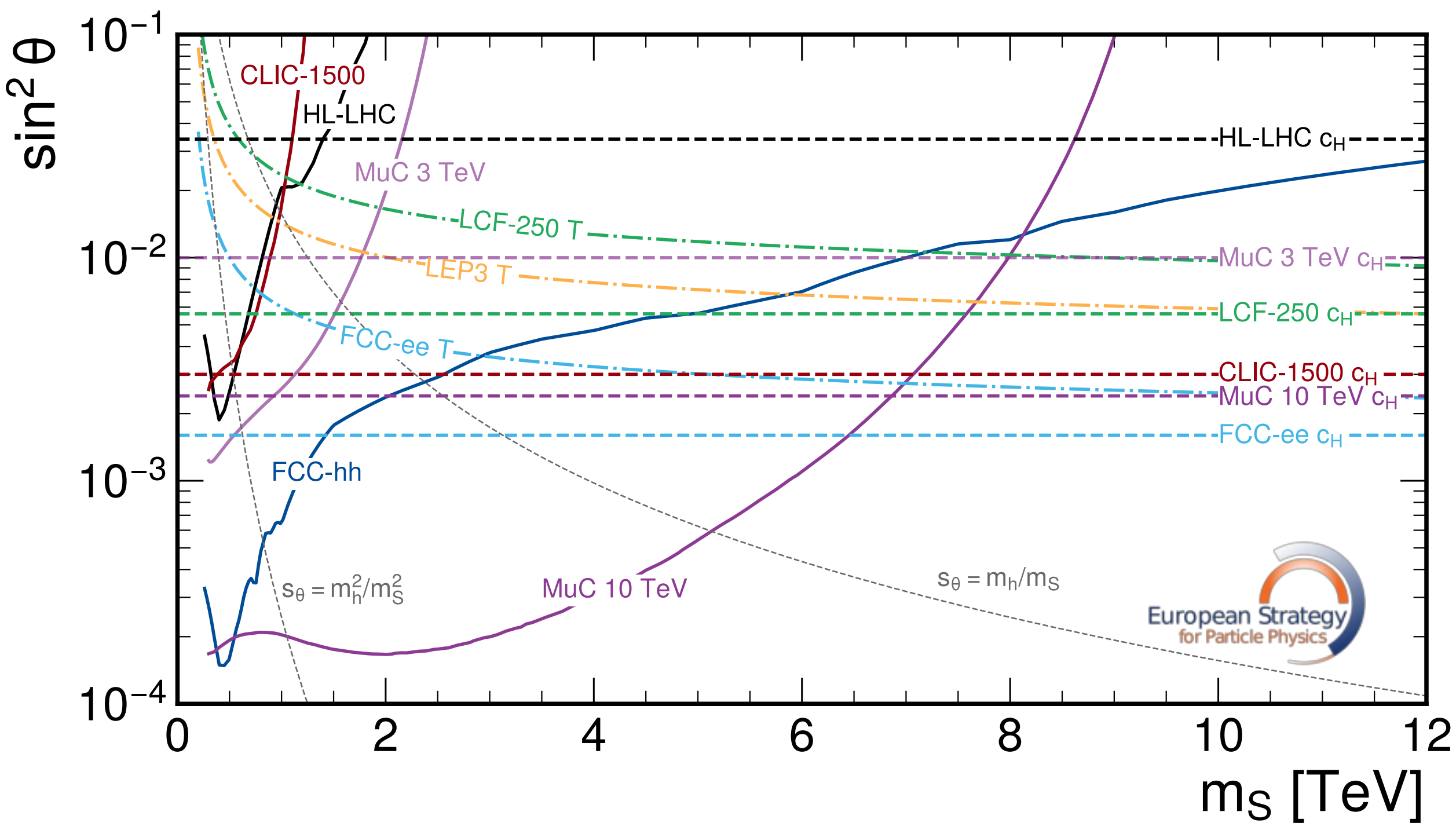
EW boson collider  
with large cross sections



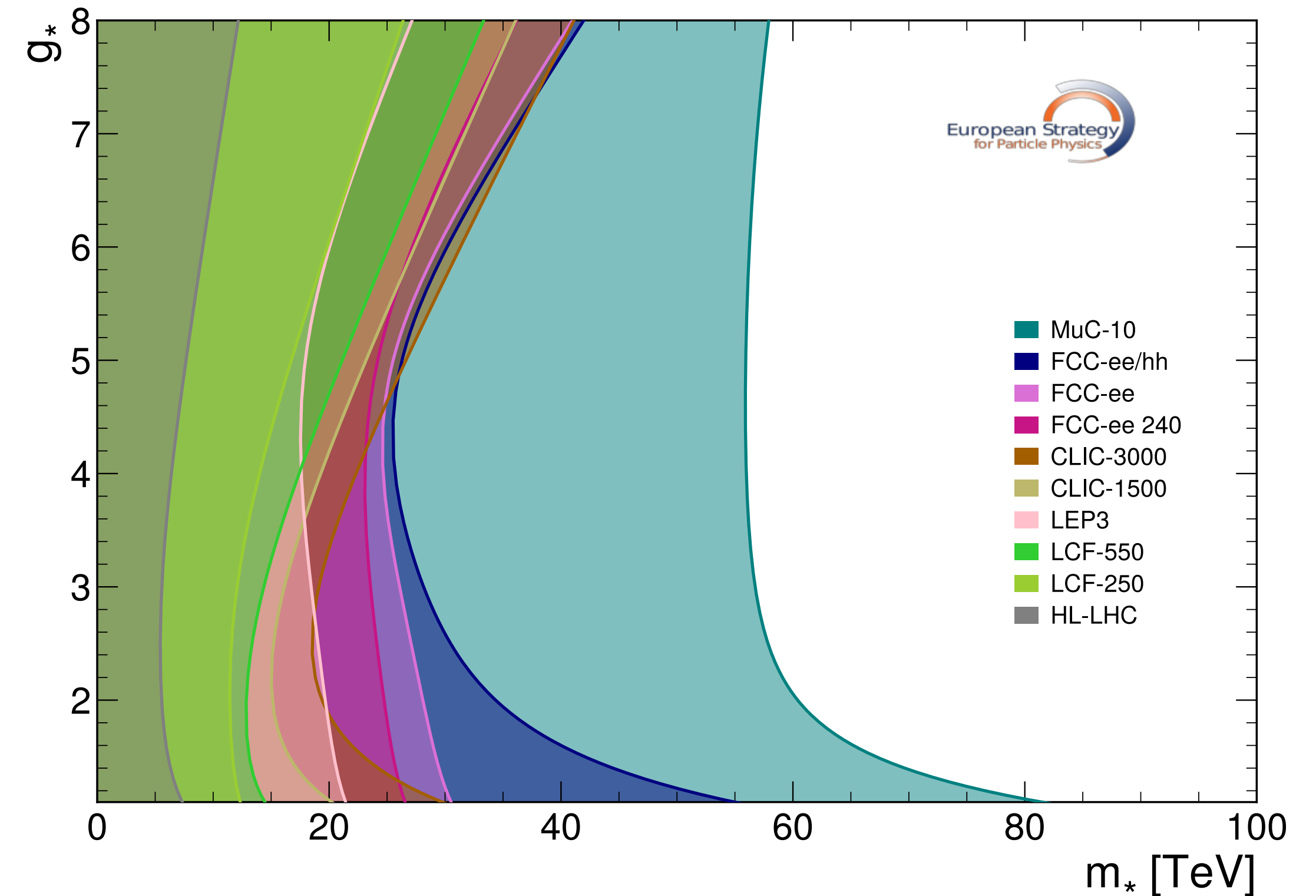
Highest Energy w/sufficient  
lumi and small backgrounds

**Energy + Precision and large dynamic  $\sqrt{\hat{s}}$  range**

# Energy + precision *generically* unlocks the EW phase diagram



Exciting a more complex vacuum



Composite Higgs imprints  $\gg 10$  TeV

# What is a muon collider?

***A second generation Higgs Factory to map the EW phase diagram, reach the epoch of “EW restoration”, and continue to explore the constellation of Higgs-related questions***

**(Also a much broader physics program but no time to highlight now)**

# Muon collider vision



- There are clear *physics goals* and opportunities to further develop them
- However muon beam R&D  $\neq$  a commitment to build a collider
- Limited direct DOE funding *near term* is not the worst thing for now, technical planning is still required before even imagining to increase the TRLs beyond 1-3 and build our “road”
- **AI**-driven design offers incredible opportunities for a Muon Collider
- Many opportunities for grassroots DPF/DNP involvement



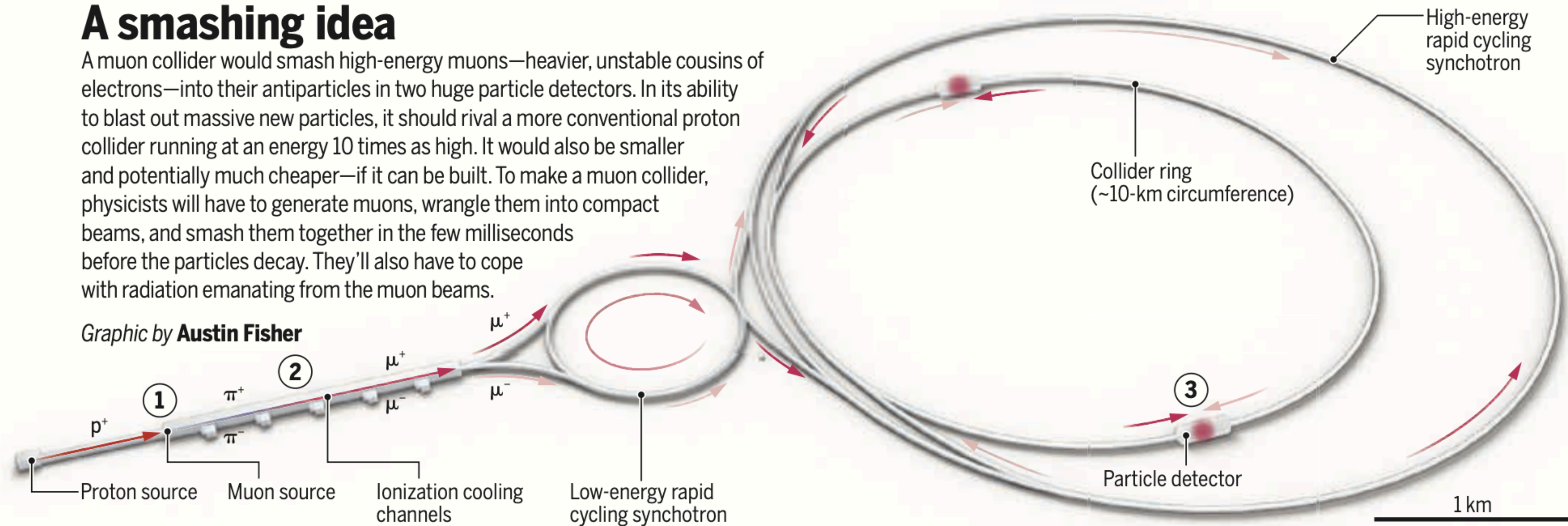
***Eventually*** one has to build things to go from TRL 1-3's to TRL 4-6's and have a better idea how to get there, but ***even then*** it's not muon collider or bust!

# A muon collider reaches the *Energy Frontier* via the *Intensity Frontier*

## A smashing idea

A muon collider would smash high-energy muons—heavier, unstable cousins of electrons—into their antiparticles in two huge particle detectors. In its ability to blast out massive new particles, it should rival a more conventional proton collider running at an energy 10 times as high. It would also be smaller and potentially much cheaper—if it can be built. To make a muon collider, physicists will have to generate muons, wrangle them into compact beams, and smash them together in the few milliseconds before the particles decay. They'll also have to cope with radiation emanating from the muon beams.

Graphic by Austin Fisher



Inherently there will be exquisite sources of *protons*, *muons*, and *neutrinos* that are intertwined!

# Muon collider R&D offers unparalleled synergies across HEP/NP with both off-shoots *AND* off-ramps



***If* a collider ultimately isn't feasible as currently envisioned, muon beam R&D never goes to waste given all the physics opportunities**

**What we need now is support to further advance the vision in the community/planning that could turn into more targeted R&D support when/if the opportunity arises!**

**Growing the next generation accelerator workforce such that HEPNP *has* opportunities in the future**



# National Lab Accelerator Study Group for a Muon Collider

## Purpose and Scope

- Identify the **key accelerator challenges** for a **10 TeV Muon Collider**
- Define the **necessary R&D steps**
- Estimate **timeframes for major R&D areas**
- Evaluate and build on existing **U.S. and IMCC plans**
- Identify **gaps, overlaps, and coordination issues**:
- Strong focus on:
  - **U.S. national lab collaboration**
  - **Alignment with international efforts**
- Goal: ensure **high-impact, complementary U.S. contributions**

The study is about **prioritizing and organizing the critical R&D needed now**—not designing the collider itself—so future planning can be grounded in realistic technical progress.

## Membership

Argonne: Philippe Piot

Berkeley: Jean-Luc Vay, Chad Mitchel

Brookhaven: Steve Peggs

Fermi: Steve Gourlay (Chair)

JLab: Robert Rimmer

Los Alamos: Steve Russel

Oak Ridge: Fulvia Pilat

SLAC: Emilio Nanni

Scientific Secretary, Diktys Stratakis, Fermi

**Held 17 Seminars on systems and technologies – report writing in progress – aiming for July 31<sup>th</sup>**

Where does our *current* support come from?  
**Also** predominantly grassroots given current (and future) budget constraints!



Individual PIs w/Private foundations/NSF/DOE awards,  
LDRDs, generic R&D that could apply, University seed  
funding/startups, fractions of base grants, + **150K FY26 DOE**

# CU CATALYST

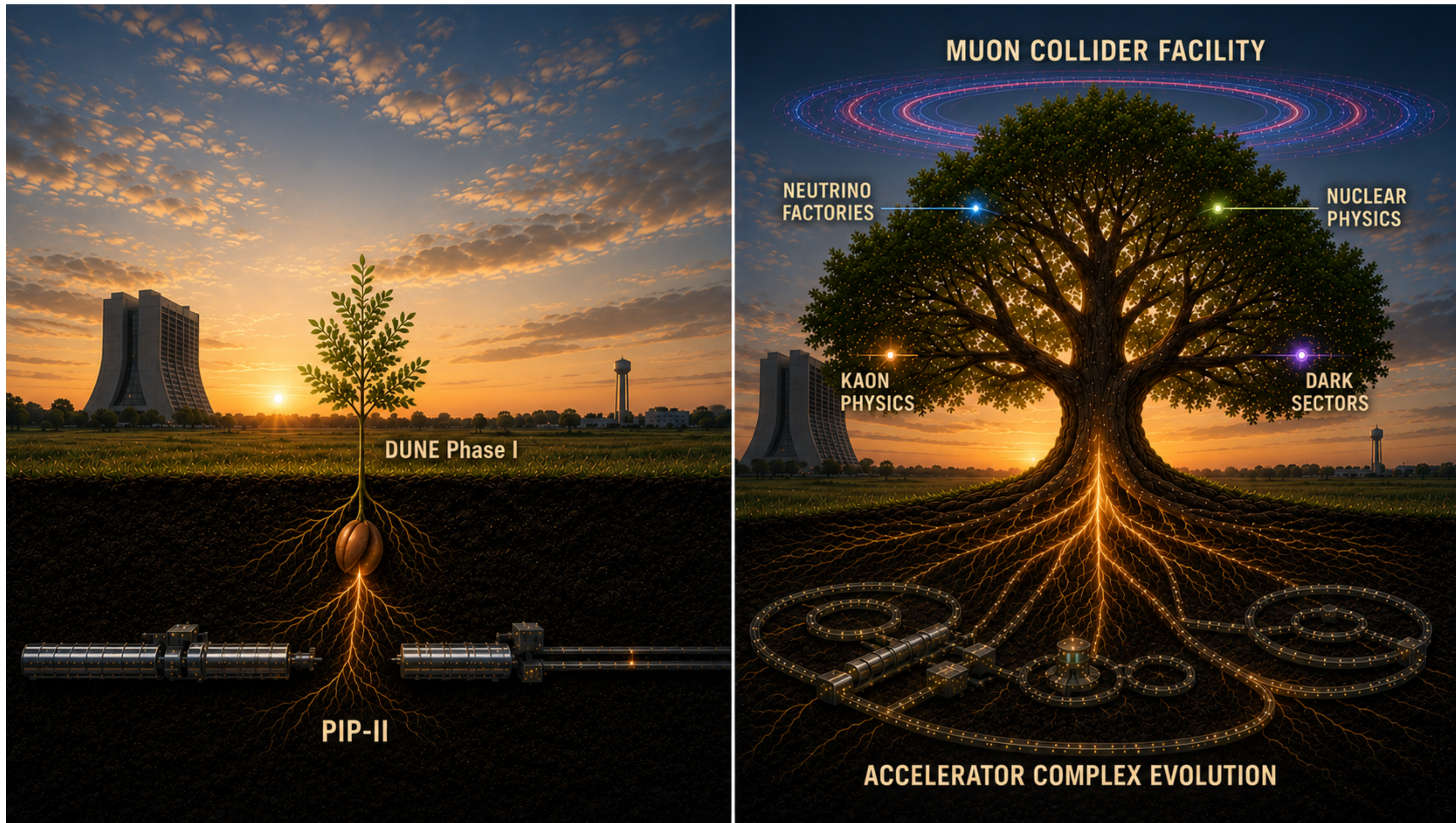
*A summer research program to support graduate students pursuing research related to muon collider accelerator R&D at U.S. national laboratories*



**10 students matched this year across BNL, Fermilab, LBNL, ORNL, and SLAC**

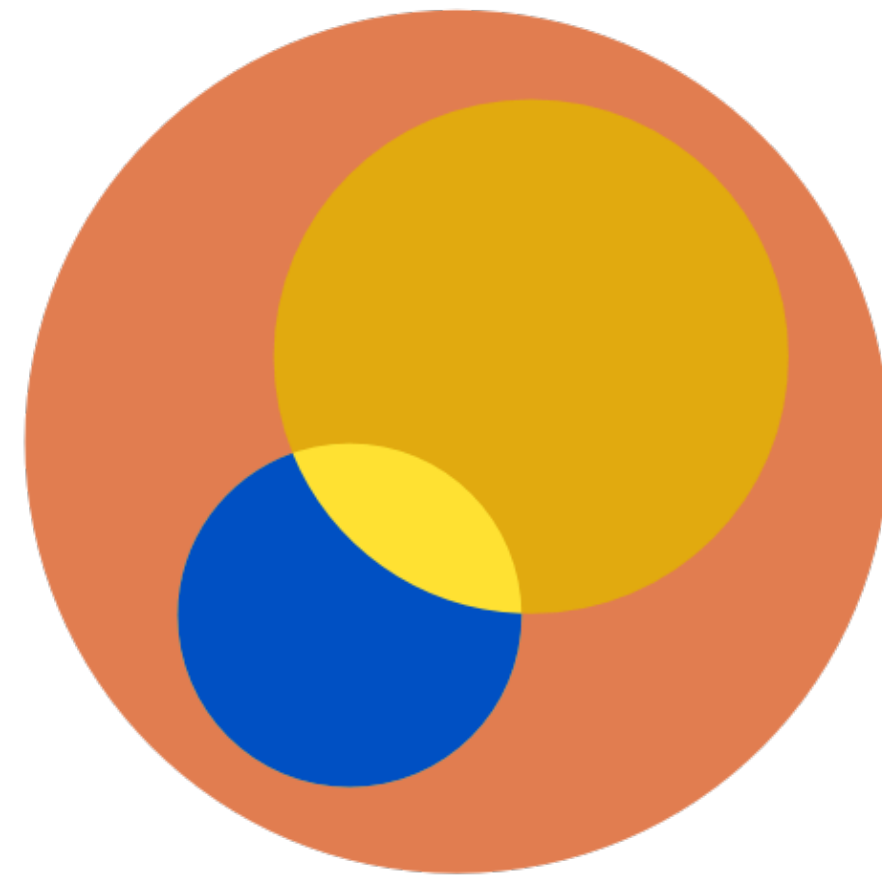
**The challenges of the muon collider help *inspire* a next generation that also will ensure the expertise for our near future with DUNE and EIC as well as this long term vision**

Last but not least, this vision doesn't represent an orthogonal direction for US HEPNP, it's a *possible evolution* that can substantially *unite our field for decades of science*



Serit arbores quae alteri saeculo prosint

**Thank you for your time, and if you have any questions please contact us!**



**USMCC**

**More information at [www.muoncollider.us](http://www.muoncollider.us) and upcoming meetings  
IMCC (CERN) June, AI4muC (Virtual) July, USMCC (SLAC) December**