WHERE WE ARE AND WHERE WE'RE GOING: A PERSONAL PERSPECTIVE

37th Rencontres de Blois on Particle Physics and Cosmology

Jonathan Feng, UC Irvine, 15 May 2026

PARTICLE PHYSICS AND COSMOLOGY

- This Blois conference is about "Particle Physics and Cosmology." This focus follows many previous Blois conferences, but it is not to be taken for granted!

- From my own perspective, as a young particle physicist, I grew up under a steady diet of collider physics (LEP, SLC, Tevatron, …) and SUSY.

- Then as a postdoc:

SUSY
PARTICLE PHYSICS

NEUTRALINO DM
(THE GATEWAY DRUG)

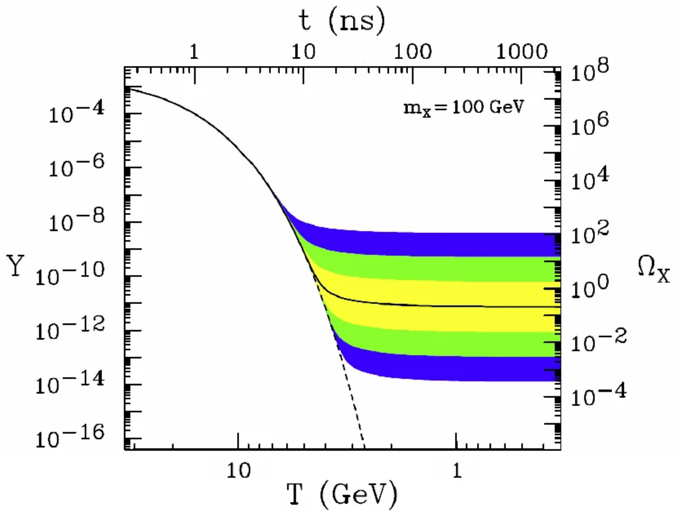
DARK MATTER
COSMOLOGY

- Following the pioneers, I became hooked on the synergy between probing the universe at the smallest and largest scales, and especially the remarkable fact that evidence from both pointed to the weak scale.

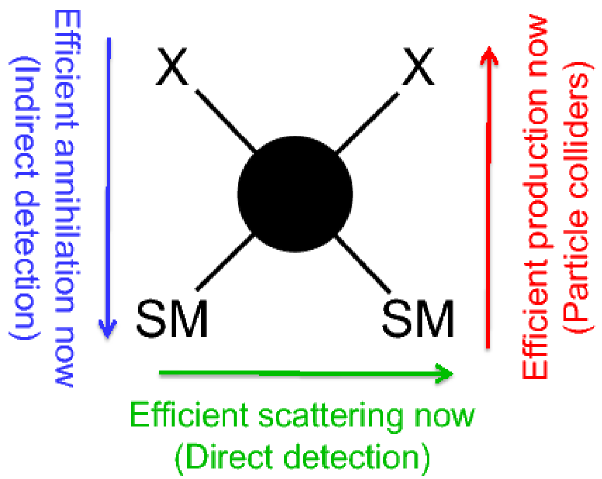
PARTICLE PHYSICS AND COSMOLOGY

- Unfortunately, this enthusiasm was not adequately shared by others. In the early 2000's, I tried to make the point in two ways:

THE WIMP MIRACLE



DARK MATTER COMPLEMENTARITY

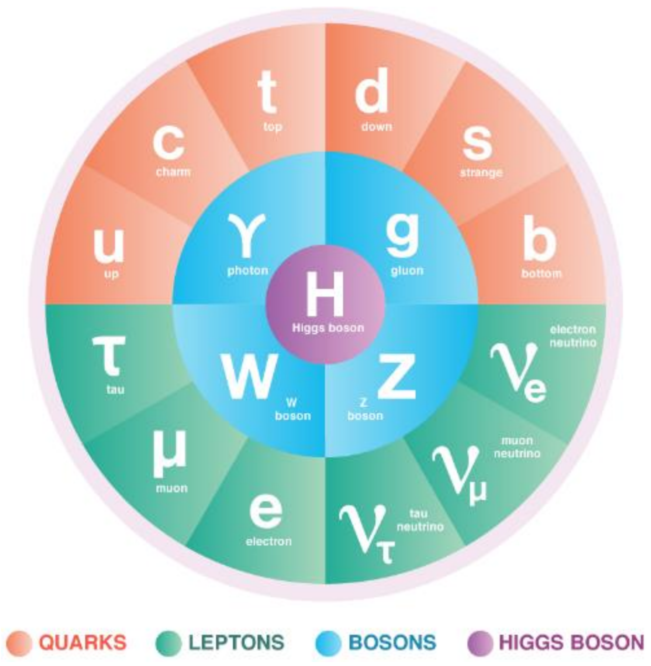


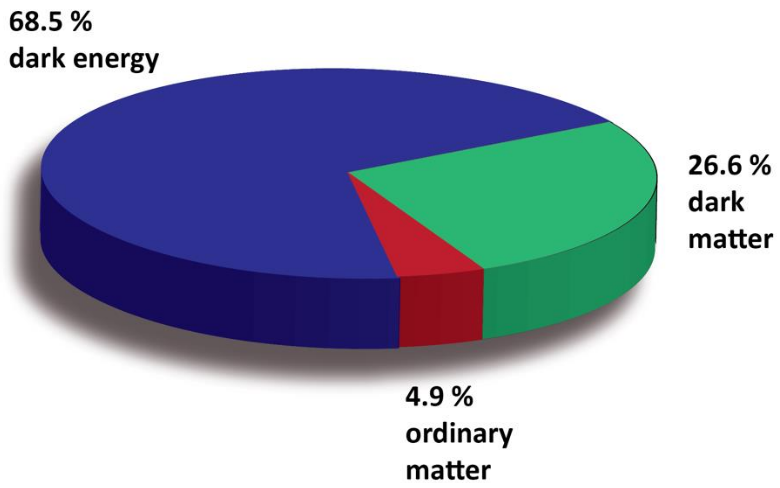
- These terms initially encountered resistance (including from the pioneers!).

- The Blois conferences have brought together researchers at the intersection of particle physics and cosmology for many years, and it has been a pleasure to take part in the meeting this week.

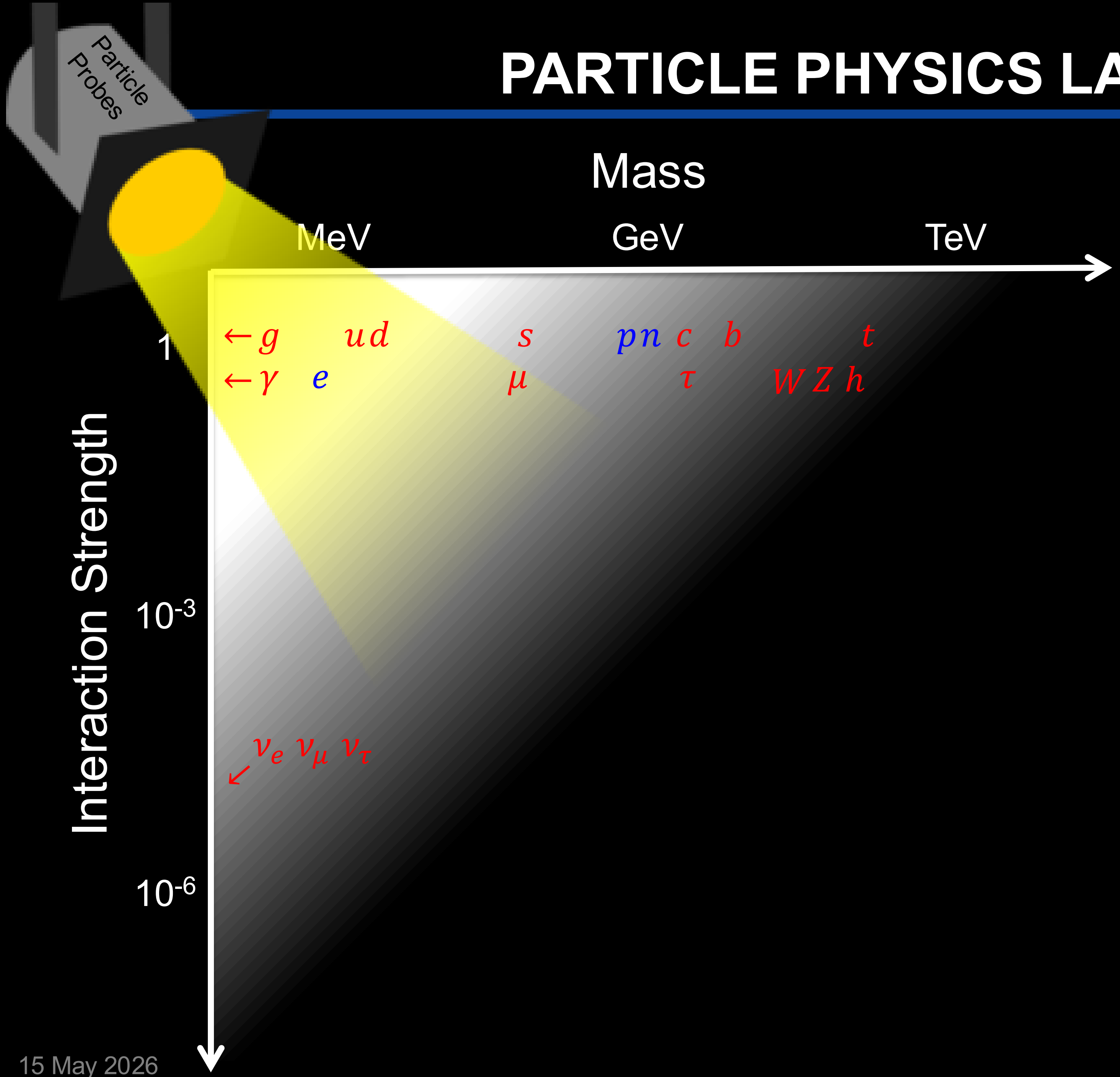
WHERE WE ARE

- The Standard Models of particle physics and cosmology are tremendous achievements of human thought.
- But they are not the last word, because many fundamental questions remain. For example:
  - "What" problems: neutrino masses, dark matter, baryo/leptogenesis, inflation…
  - "Why" problems: gauge hierarchy problem, strong CP problem, flavor problem, grand unification, cosmological constant problem, d=3+1 problem, …
- These questions imply that there is BSM physics, with (many) more particles left to discover.
- Many interesting avenues to pursue, as we have seen at this conference. What follows is a brief overview (with apologies to the many excellent parallel speakers, and for trying to fit square pegs into round holes).

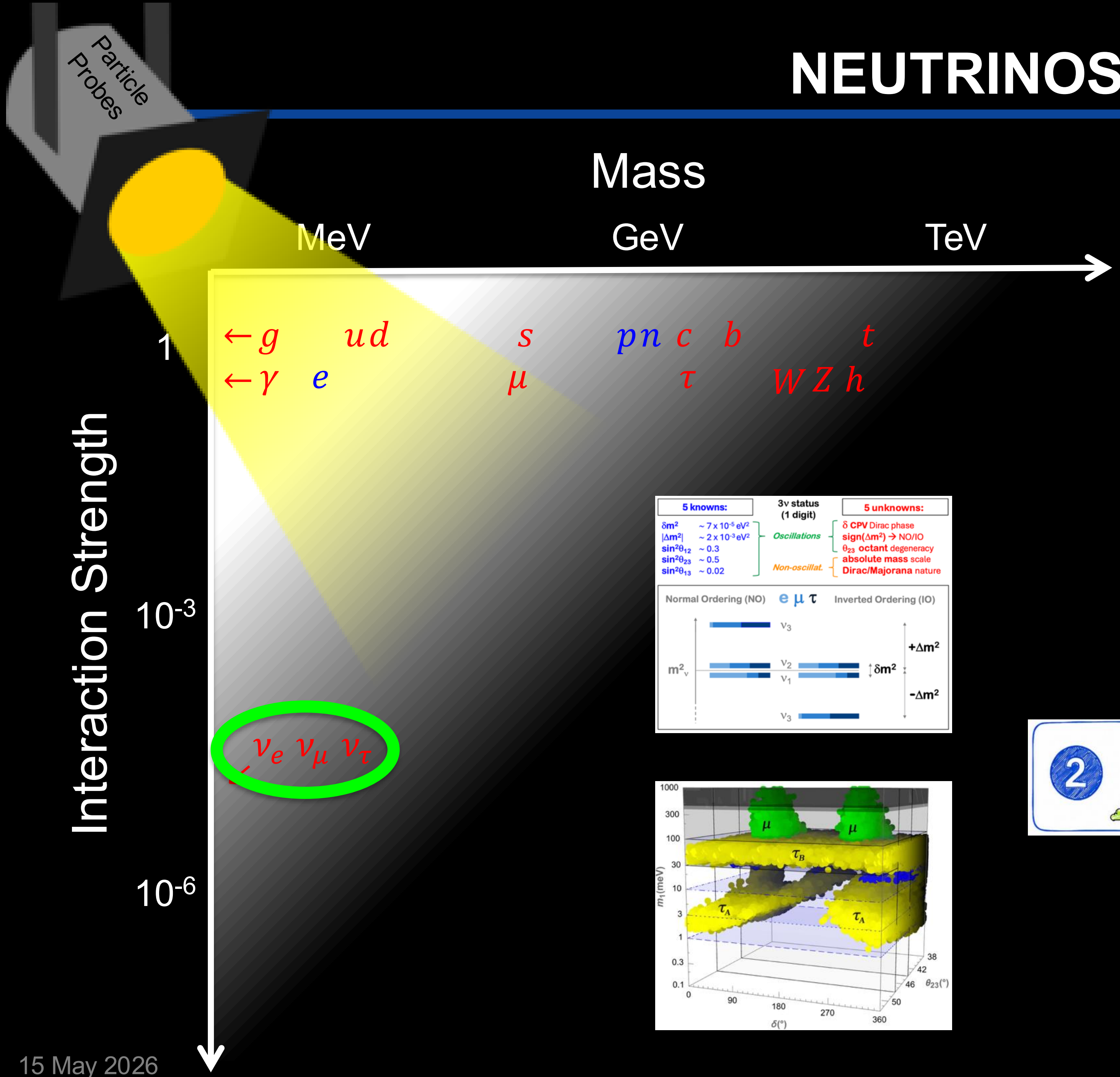




PARTICLE PHYSICS LANDSCAPE



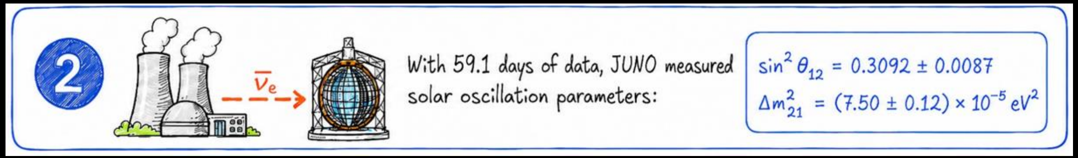
NEUTRINOS

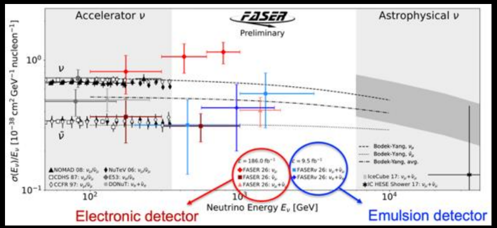


An obvious place to start: every time we detect a neutrino, we are seeing BSM physics!

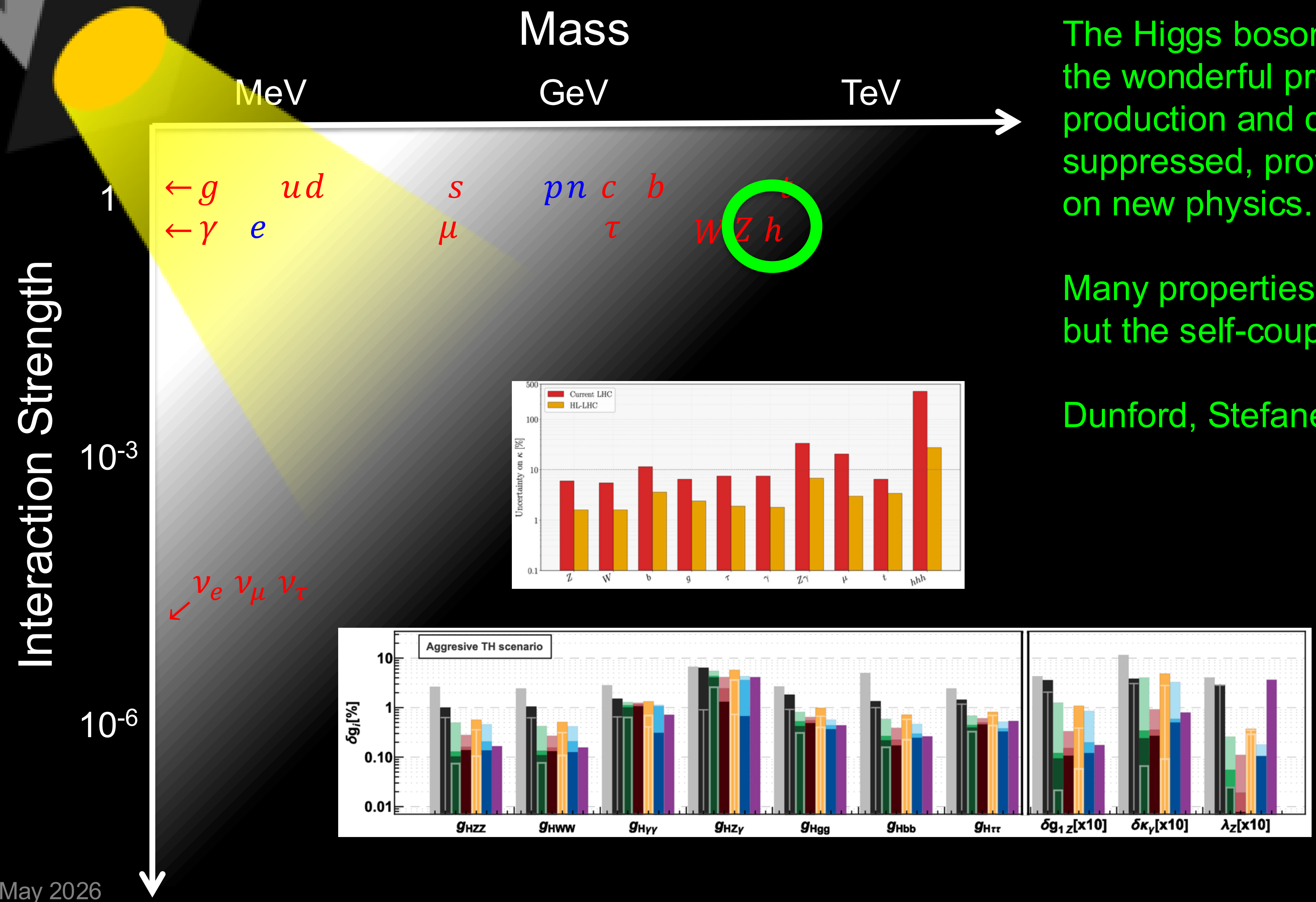
With JUNO, all mixing angles are now constrained, and with FASER and SND, many TeV neutrinos have been seen. An exciting area, with many outstanding questions: mass ordering, Dirac vs. Majorana, relevance for leptogenesis…

Ding, Sgalaberna, Lisi, di Bari





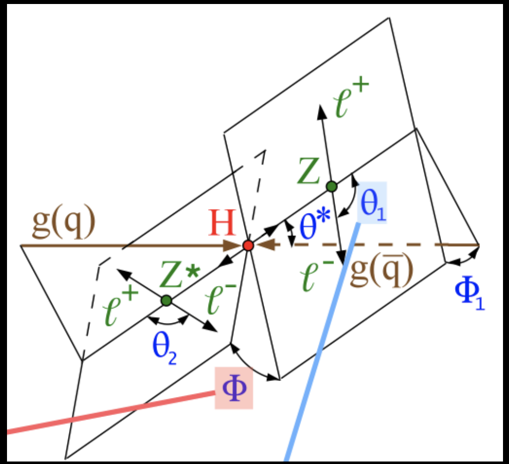
THE HIGGS BOSON



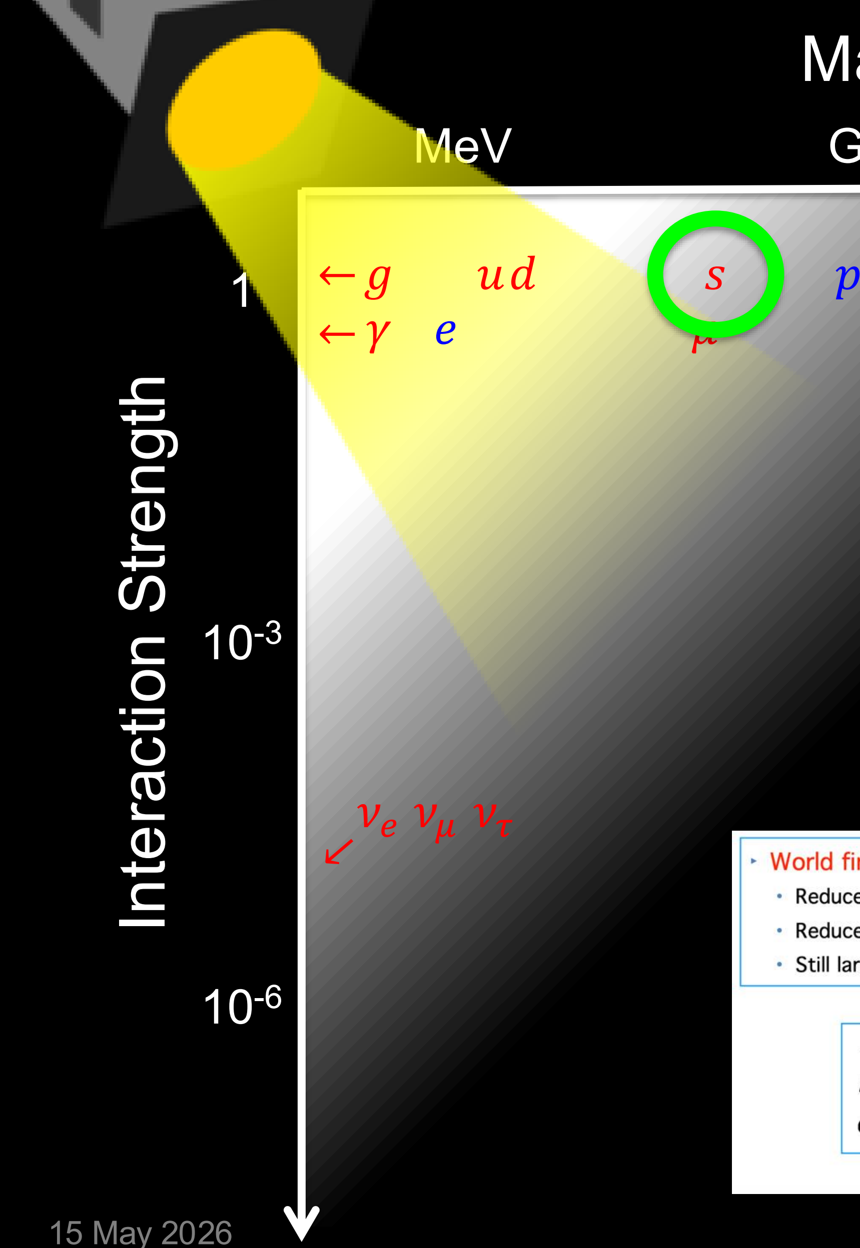
The Higgs boson is our newest toy. It has the wonderful property that all its production and decay modes are suppressed, providing sensitive windows on new physics.

Many properties already precisely known, but the self-coupling is far from measured.

Dunford, Stefanek, Frattari



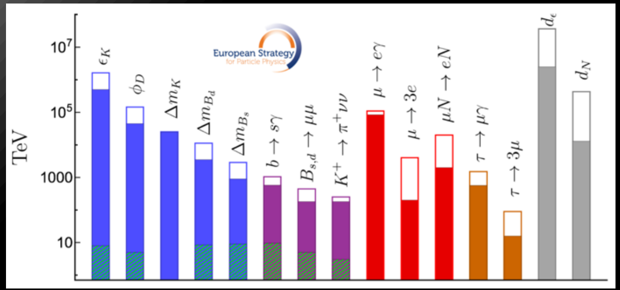
FLAVOR AND CP VIOLATION

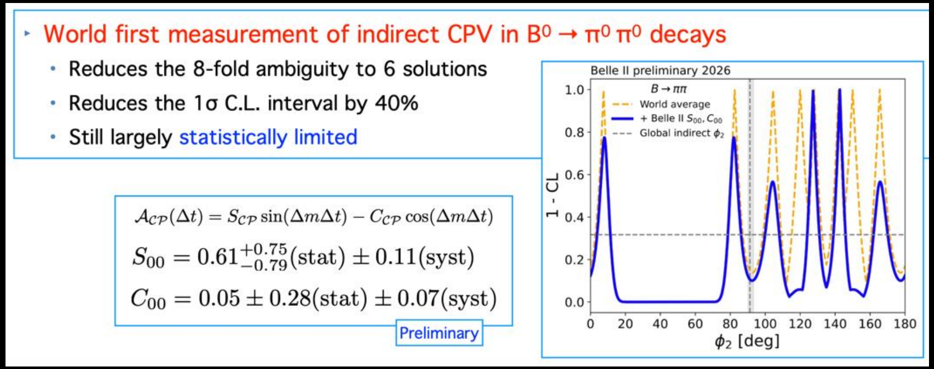


Low-energy precision measurements probe (extremely!) high mass scales through virtual effects.

Muon g-2 anomaly is gone, CERN has canceled its kaon program, but many K, D, B, τ probes remain.

Ripp-Baudot, Amhis, Fleischer

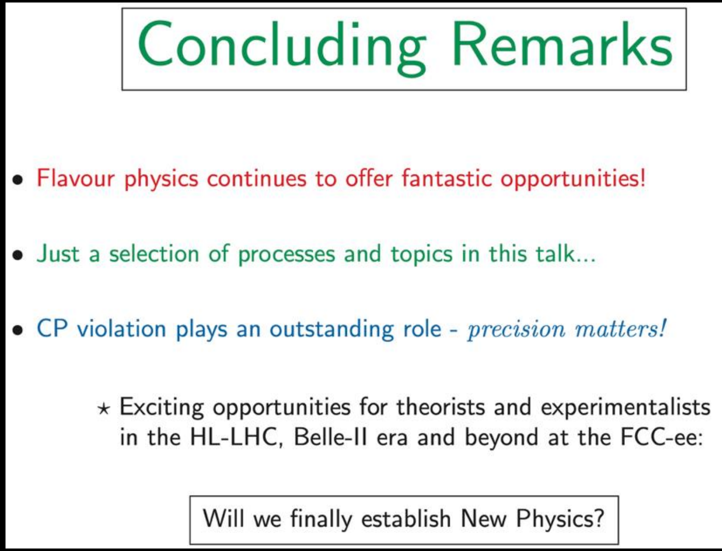




- World first measurement of indirect CPV in $B^0 \to \pi^0\pi^0$ decays
  - Reduces the 8-fold ambiguity to 6 solutions
  - Reduces the 1σ C.L. interval by 40%
  - Still largely statistically limited

$$\mathcal{A}_{CP}(\Delta t) = S_{CP}\sin(\Delta m \Delta t) - C_{CP}\cos(\Delta m \Delta t)$$
$$S_{00} = 0.61^{+0.75}_{-0.79}(\text{stat}) \pm 0.11(\text{syst})$$
$$C_{00} = 0.05 \pm 0.28(\text{stat}) \pm 0.07(\text{syst})$$

Preliminary



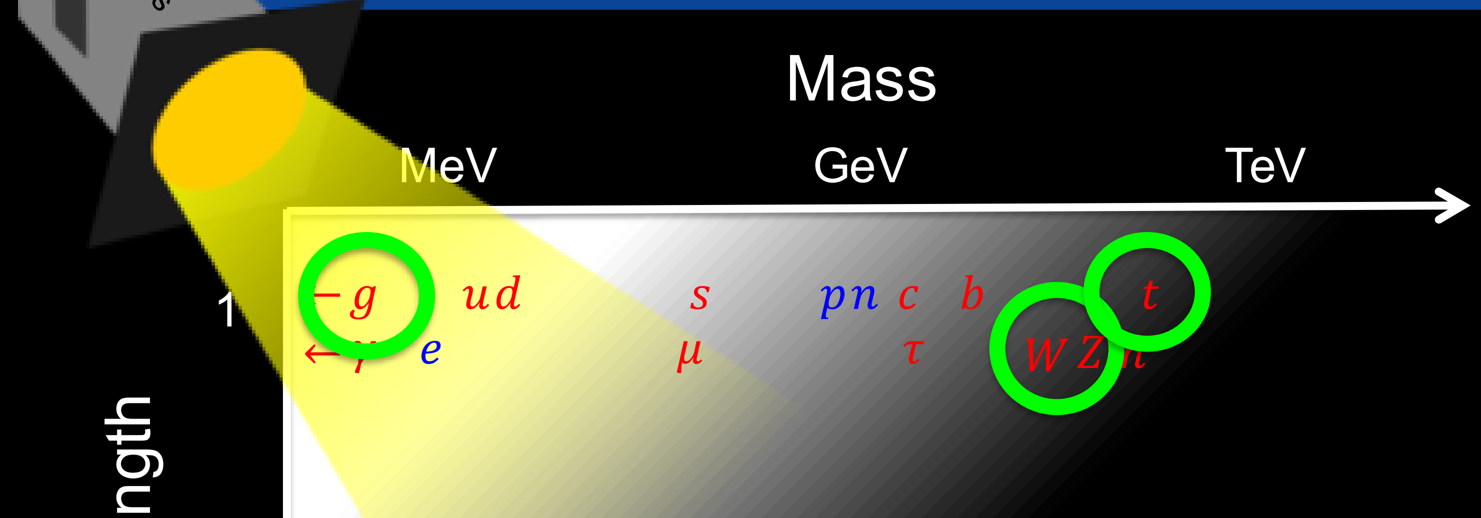
Concluding Remarks

- Flavour physics continues to offer fantastic opportunities!
- Just a selection of processes and topics in this talk...
- CP violation plays an outstanding role - *precision matters!*

⋆ Exciting opportunities for theorists and experimentalists in the HL-LHC, Belle-II era and beyond at the FCC-ee:

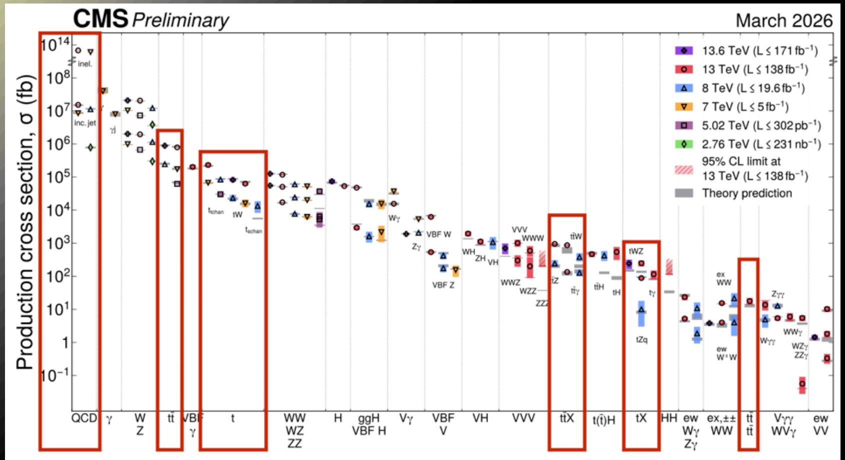
Will we finally establish New Physics?

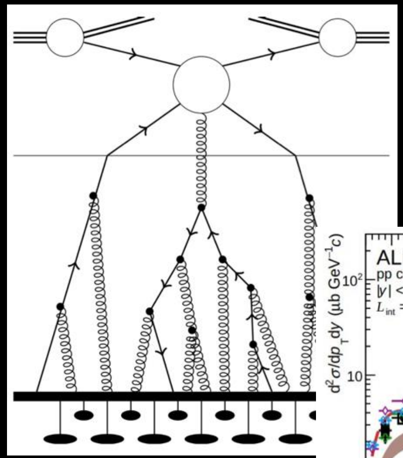
PRECISION EW AND QCD AT COLLIDERS

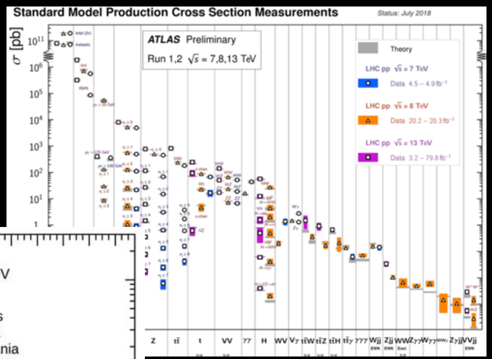


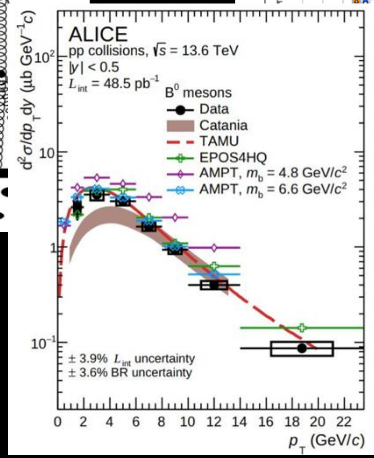
Precision at the theory/expt interface is crucial for (HL-)LHC to fulfill its potential: pdfs, higher-order parton cross sections, parton showering, hadronization, …

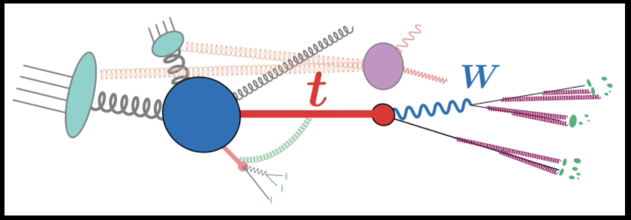
Chanon, Poncelet, Morodei, Faggin, Pathak



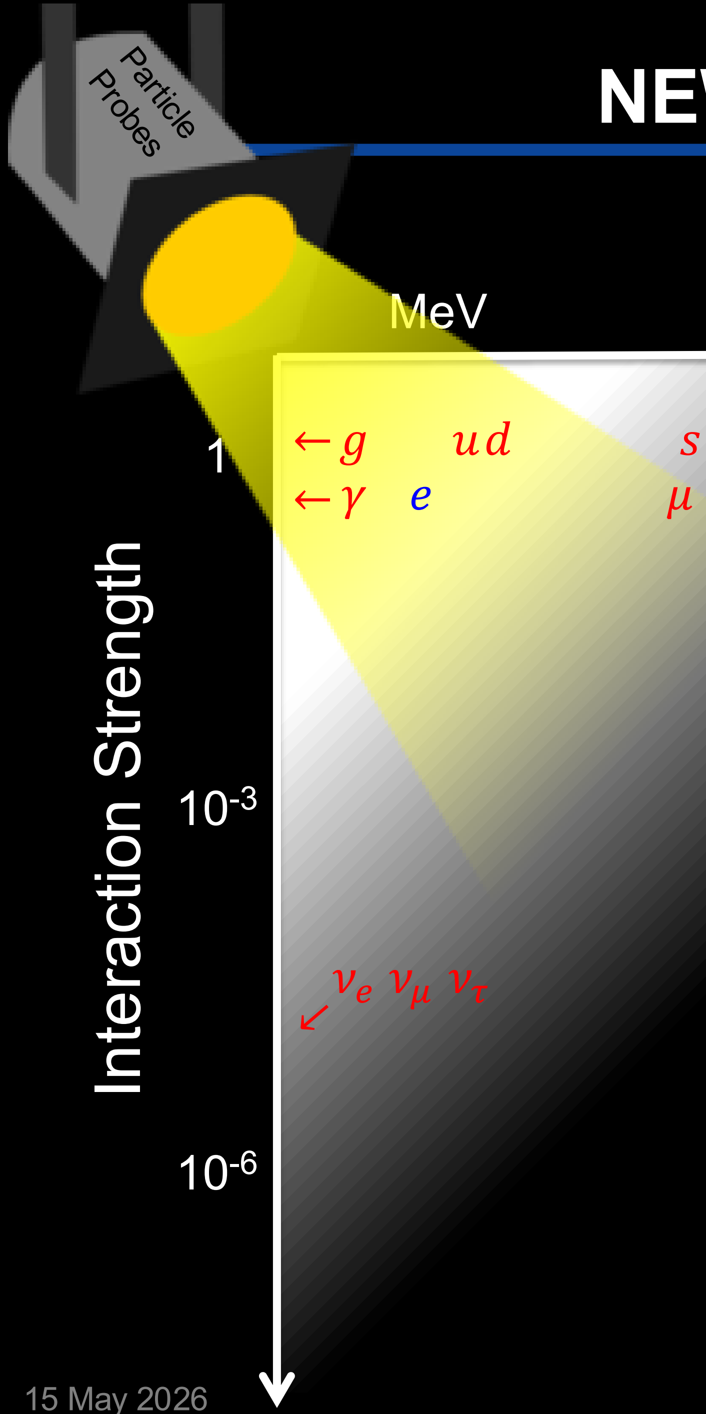








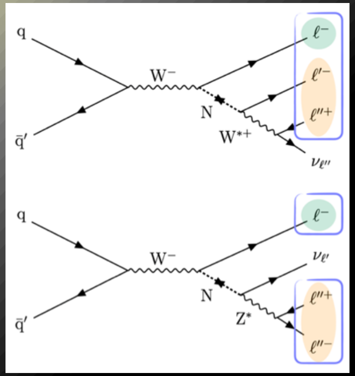
NEW TECHNIQUES FOR DISCOVERY

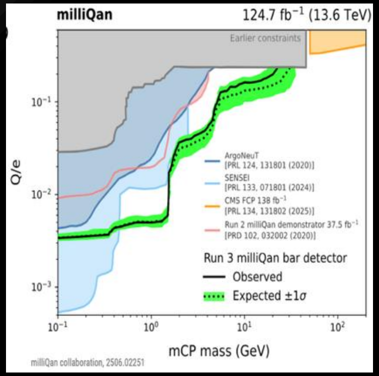


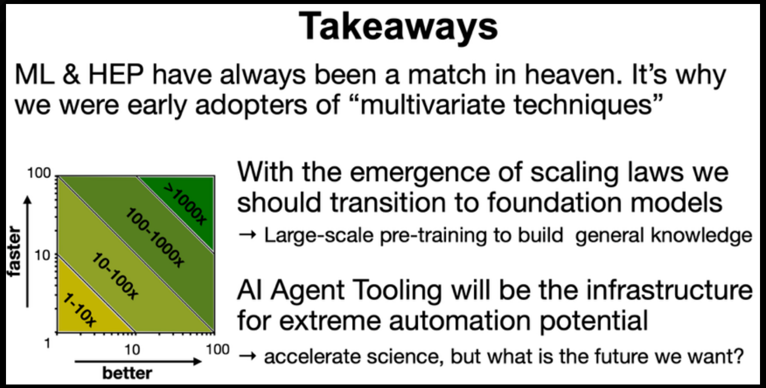
Are we missing something in the data?

AI/ML, new triggers, quantum sensors extend our sensitivity to new regimes.

Heinrich, Guedes, Tziaferi, Murgui Galvez





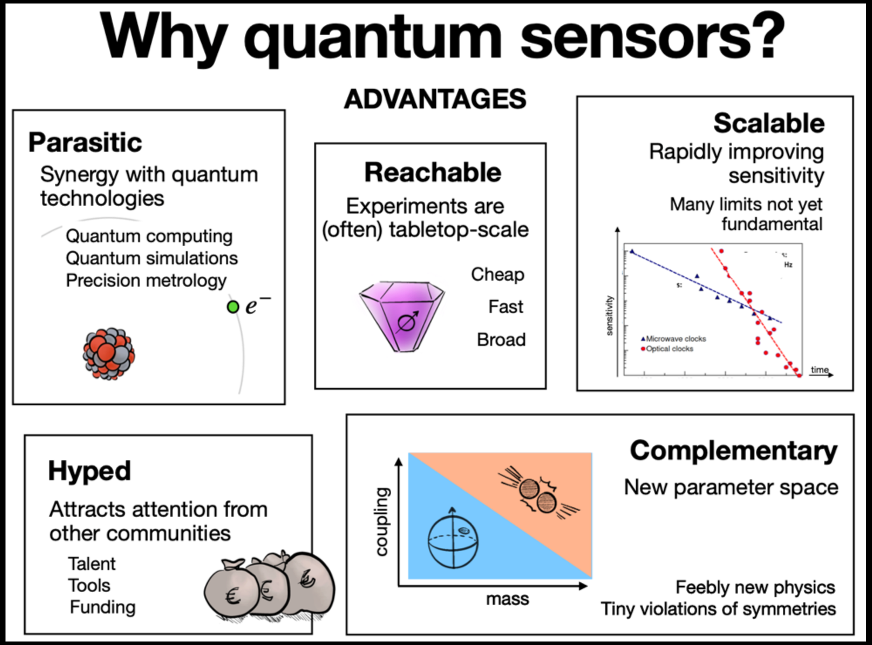


Takeaways

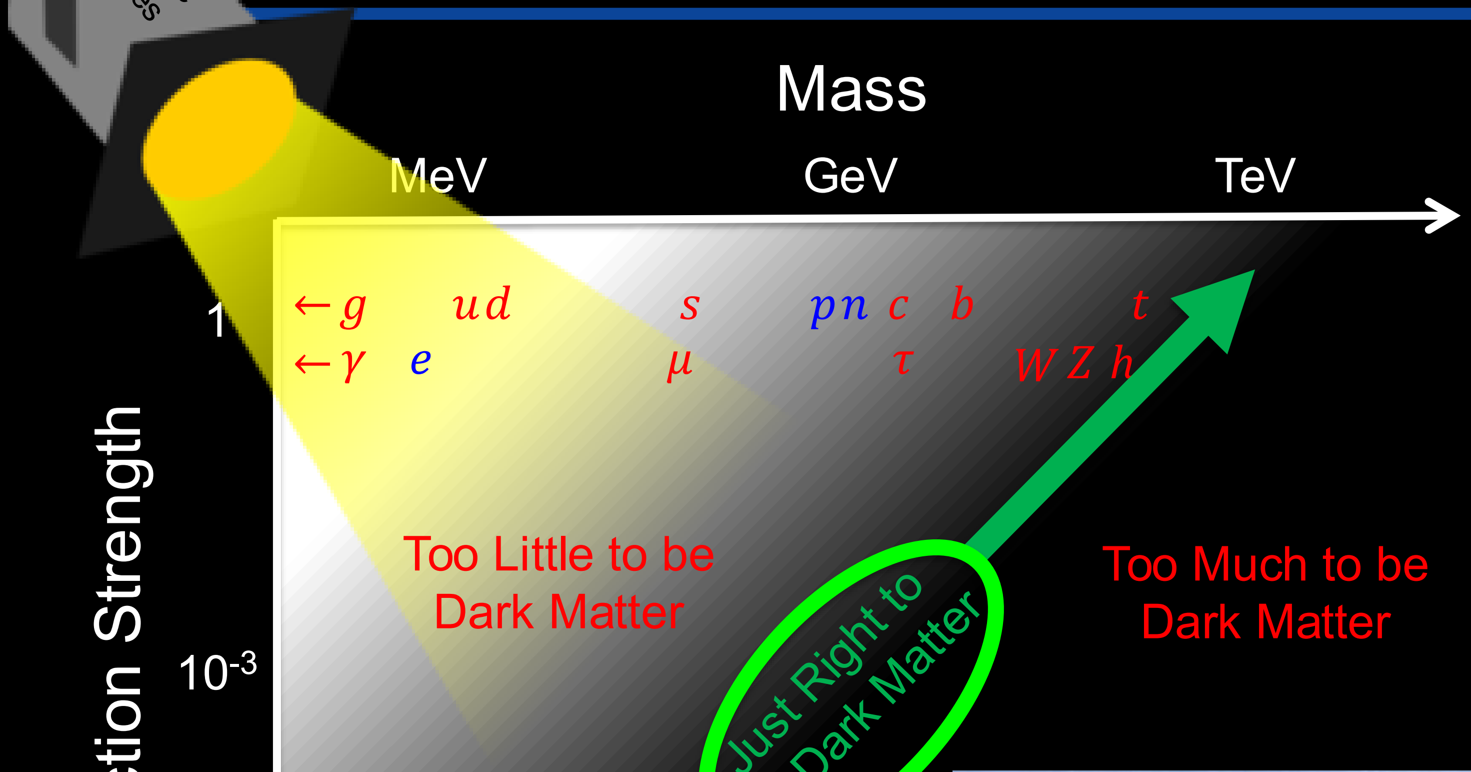
ML & HEP have always been a match in heaven. It's why we were early adopters of "multivariate techniques"

With the emergence of scaling laws we should transition to foundation models
→ Large-scale pre-training to build general knowledge

AI Agent Tooling will be the infrastructure for extreme automation potential
→ accelerate science, but what is the future we want?



DARK MATTER

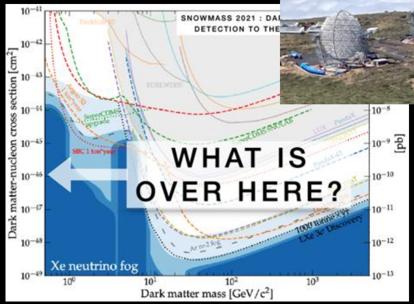


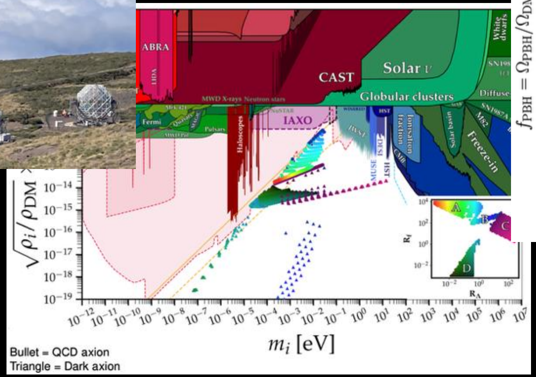
WIMP direct detection pushing to the neutrino fog and lower masses

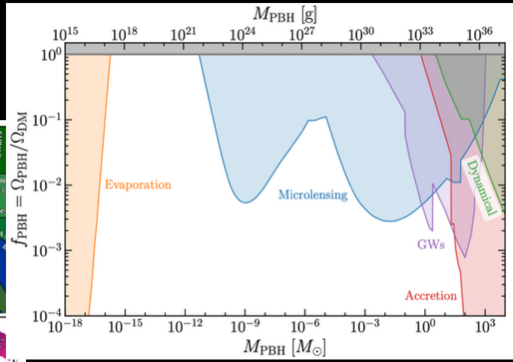
WIMP indirect searches probing very heavy DM at the thermal cross section

Axion, PBH searches of all kinds (Helen Quinn to me: The WIMP fad is over.)

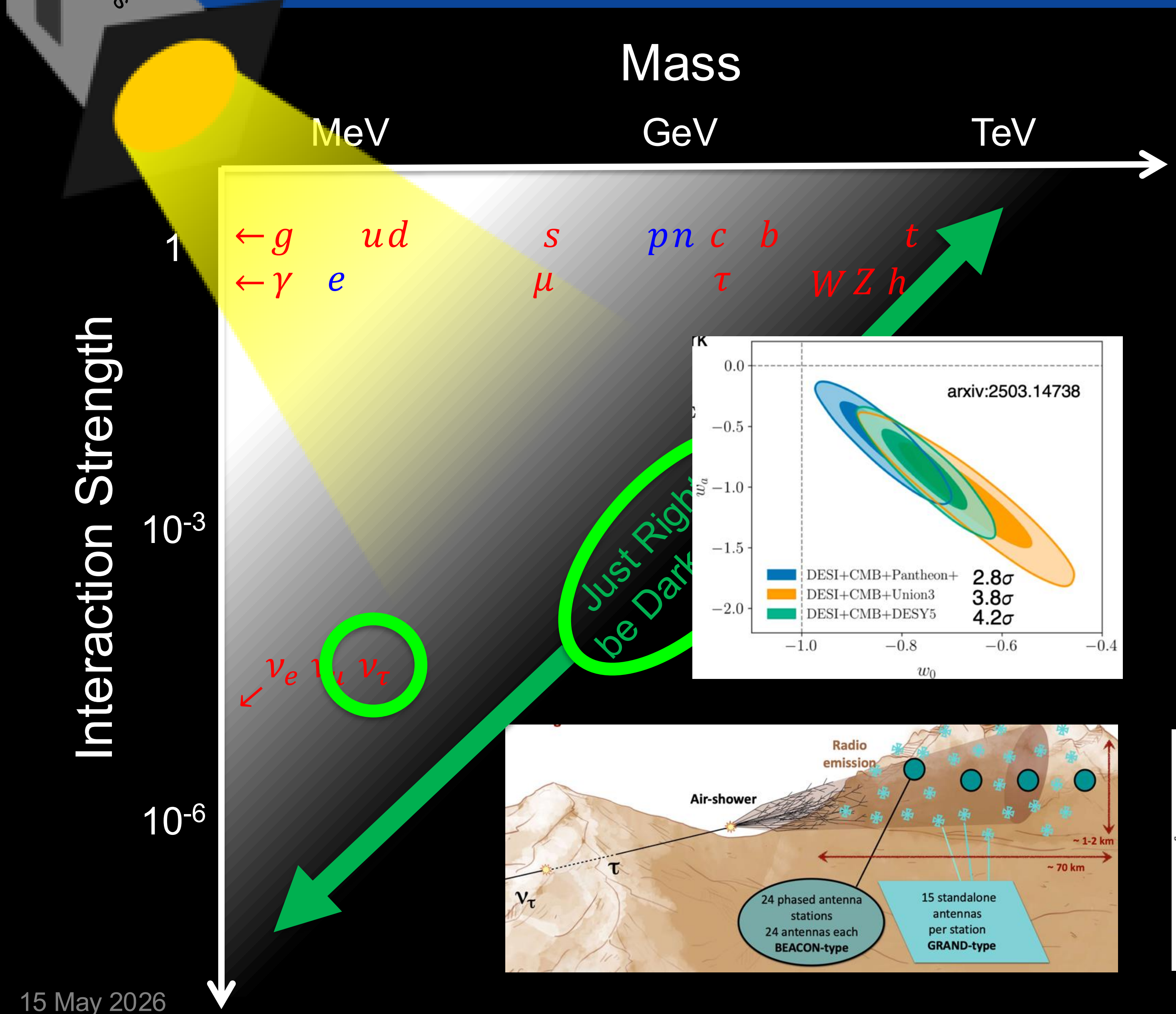
Ramos, Salemi, Plestid, Rogers, Manconi, Inada







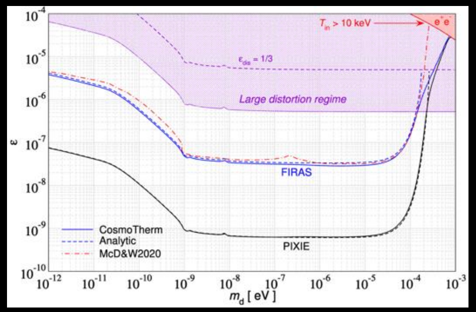
ASTROPARTICLE PHYSICS AND COSMOLOGY

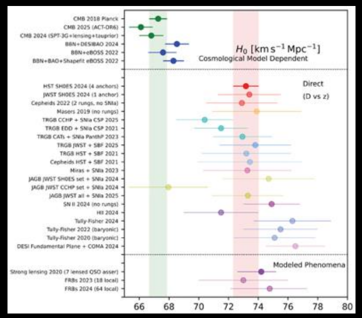


We are limited by collider energies, but can use the universe as the ultimate accelerator: UHE cosmic rays, UHE neutrinos, PeV photons, …

Cosmology also probes particles in ways unimaginable for particle physics experiments, including very massive oe very weakly interacting particles, stress tests ΛCDM, and sheds light on dark energy.

Armengaud, Kotera, Giacinti, Buson, Bohacova, Cyr, Calderon, Teixeria





WHERE WE’RE GOING

OUR FIELD HAS PHSD

- **PTSD: Post-Traumatic Stress Disorder.** A mental health condition triggered by experiencing or witnessing terrifying, life-threatening, or traumatic events.
- **PHSD: Post-Higgs Search Disorder.** A mental health condition triggered by experiencing or witnessing the discovery of the Higgs boson.
- To discover the Higgs boson, the world came together to build a truly monumental machine which produced a truly monumental discovery. We are still recovering. Two extreme reactions:
- **This is the greatest time in particle physics!** No, it is not. Please familiarize yourself with some of the history of our field (one of Steve Weinberg's Four Golden Lessons). We should stop over-selling, and simply accept that we are in a new era, with no guaranteed discoveries, but lots of interesting trails to follow.
- **Particle physics is dead!** No, it is not. We do not have a no-lose proposition like the Higgs boson, but this is not necessary to make revolutionary progress. Remember the muon: Who ordered that? We can be surprised, provided we keep our eyes and minds open.

PHSD'S IMPACT ON THE STRUCTURE OF OUR FIELD

- It is also undeniable that the Higgs discovery has had a huge impact on the structure of our field.

- Last year I had a medical problem that resulted in me being weak and bed-ridden for months. I read many books, including *Loonshots*, by Safi Bahcall. In it, he discusses how to catalyze breakthroughs. He also discusses conditions that stifle creativity and innovation:
  - The Napolean complex: leaders do something great, but then stick around too long and surround themselves with people who agree with them. Sphere of influence >> sphere of competence.
  - Silos: communities seal themselves off from others, removing cross-fertilization of ideas.
  - Stake vs. rank (I'd call it "The Rule of 150"): as organizations grow past 150 members, they stop innovating. People are more concerned with their rank within the organization than the overall health and mission of the organization.

- Do you recognize any of these problems in particle physics?

- Example: "Our entire community of thousands of people have signed on to this plan that maps out the future of our field until to 2060."
  - Lab particle physicists: Great!
  - University condensed matter physicists: Your field is dead. We'll put our FTEs elsewhere.

A FEW SUGGESTIONS

- How to fix this? There are no silver bullets: see the reports of P5 and NASEM in the US, and EPPSU in Europe. But just as a lack of a flagship project is an existential crisis for our labs, a lack of a diversity of smaller projects is an existential crisis for our field.

We can:

- In planning committees, include people who are more concerned with stake than rank, people who have been a voice in the wilderness, people who have started new things.

- Lower the barrier between theory and experiment. Value theorists (experimentalists) who really know some experiment (theory), and who can generate good ideas that can be tested realistically, quickly, and inexpensively.

- Fence off funding for smaller projects, which can be distributed quickly. The relative cost is small, and at the very least, we will train the next generation of physicists, give them leadership opportunities, and preserve their enthusiasm.

- Have small meetings (< 150 people), bringing together diverse expertise (no silos), with the freedom to challenge and question (no Napoleon).

In short, more meetings like Blois! To Christophe, Jacques, Van, Thao, and all the organizers,

THANK YOU!