

Theoretical perspectives



Michael Ratz



August 19 2022



supported by

Vietnam Flavour Physics Conference 2022

Disclaimers

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Outline

Some apologies



- ☞ Not a comprehensive summary nor a traditional summary talk
- 👉 Some statements are oversimplified
- ☞ A very nice perspective has already been anticipated ↗ Nazila Mahmoudi's wonderful slides
- 👉 Many issues have already been addressed in our daily discussion sessions
- 👉 Some illustrations recreated (i.e. stolen) from ↗ Vincenzo Cirigliano's Snowmass talk
- 👉 The purpose of provocative statements is to provoke discussions (and not fist fights!)

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- 😊 That is, the whole talk is going to be an experiment

Why study flavor?

(... my personal take)

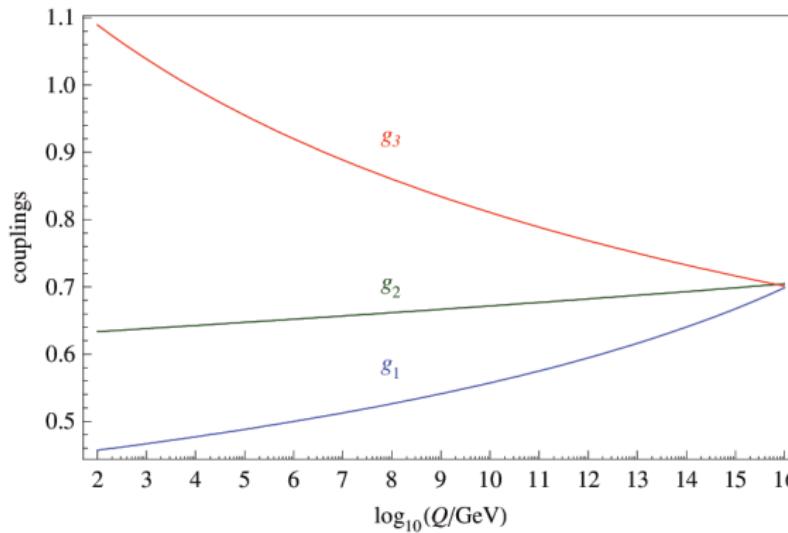
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- 3 gauge couplings

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if neutrino masses are Majorana

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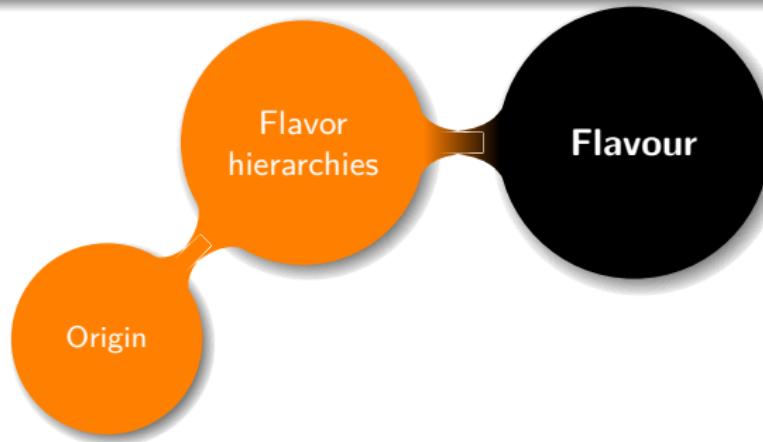
☞ Situation qualitatively a bit reminiscent of nuclear physics before QCD

☞ (How) can make sense of all these parameters?

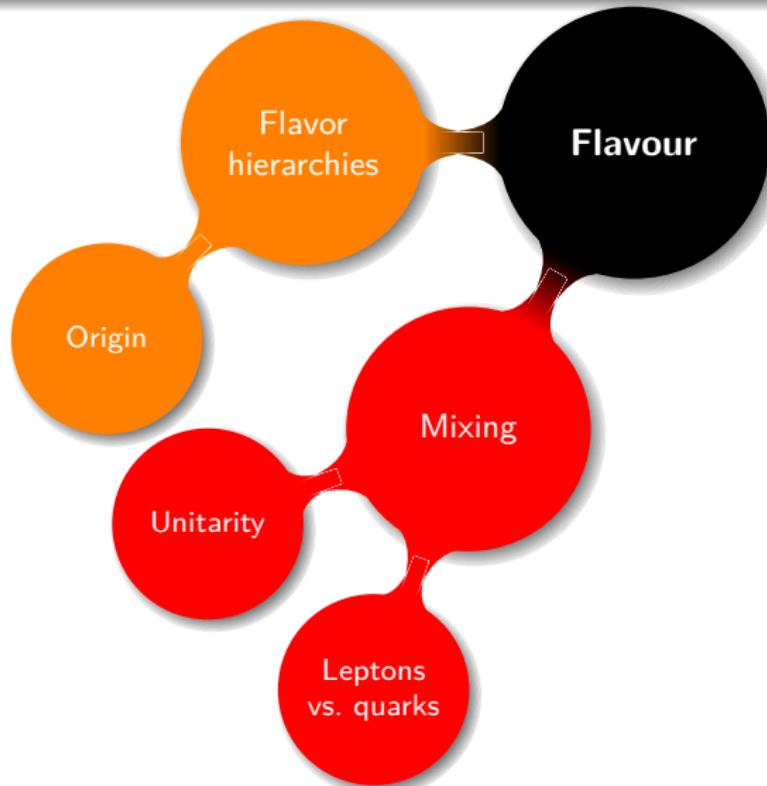
(A biased selection of) Big questions



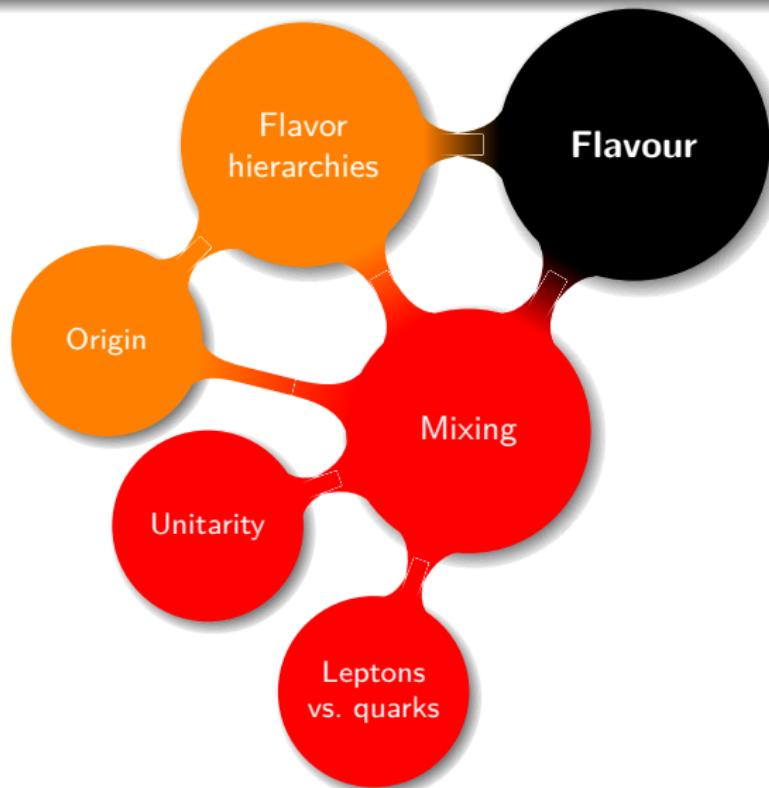
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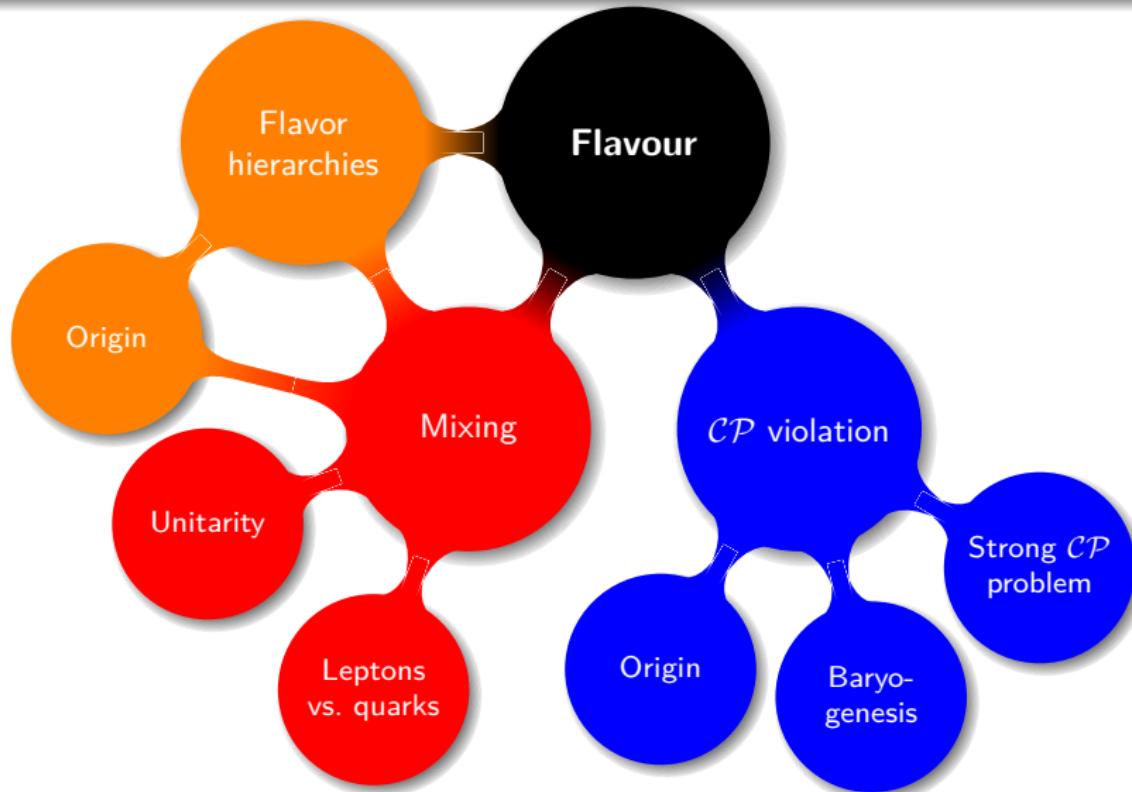
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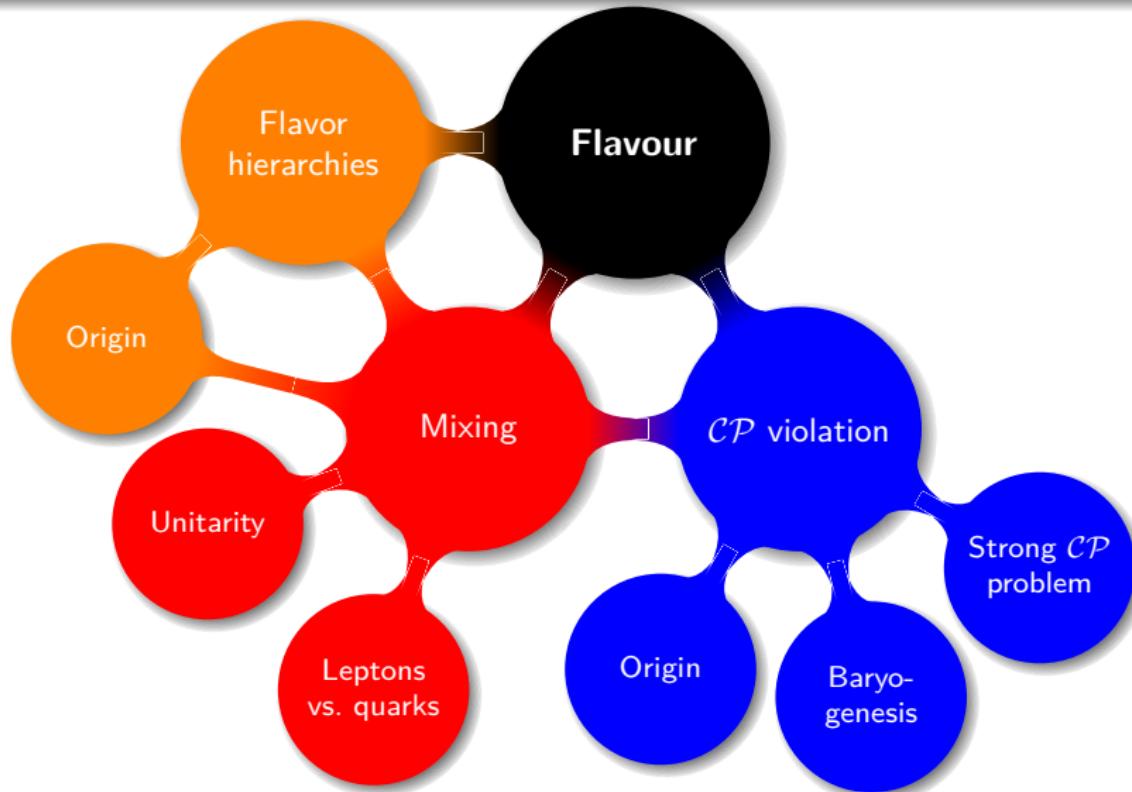
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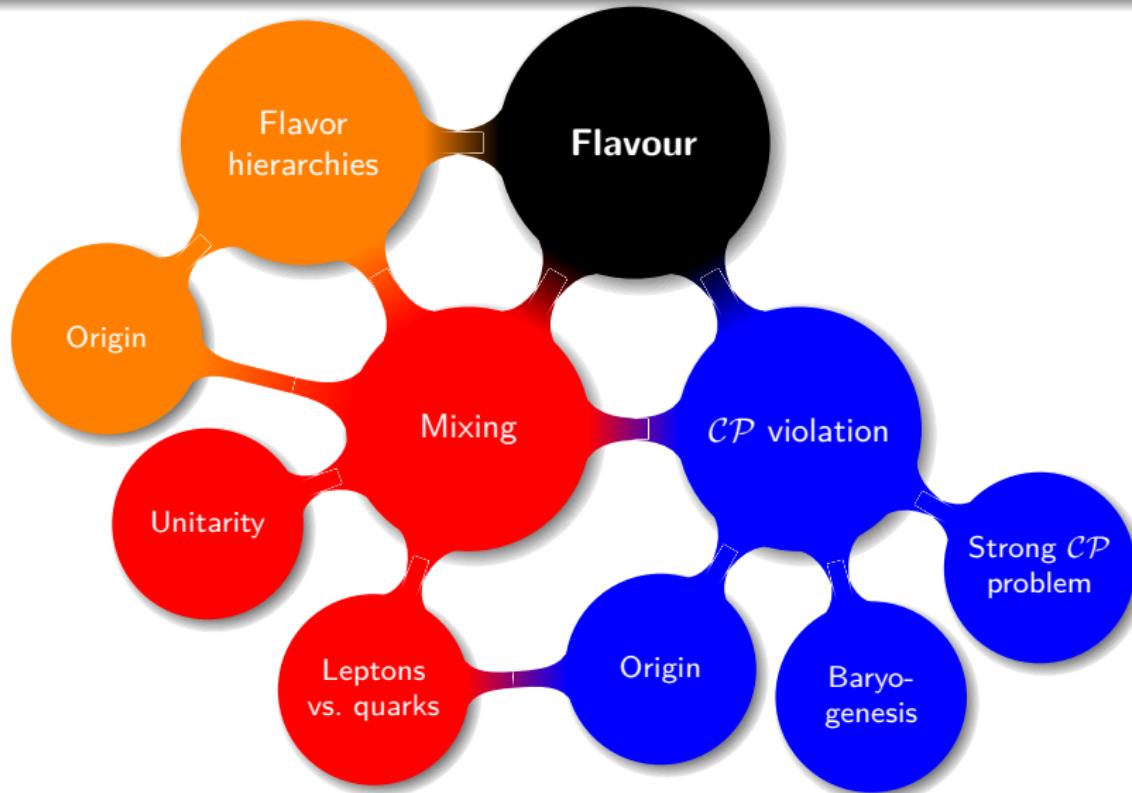
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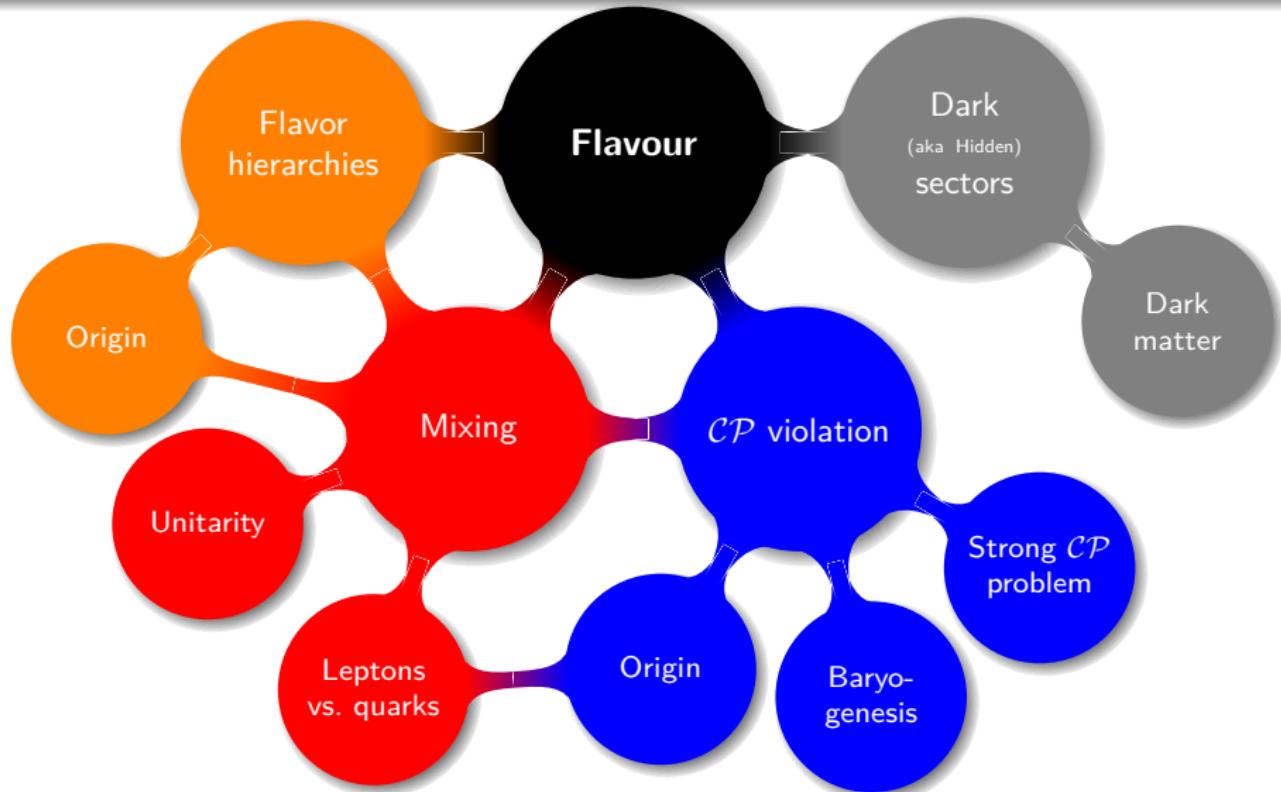
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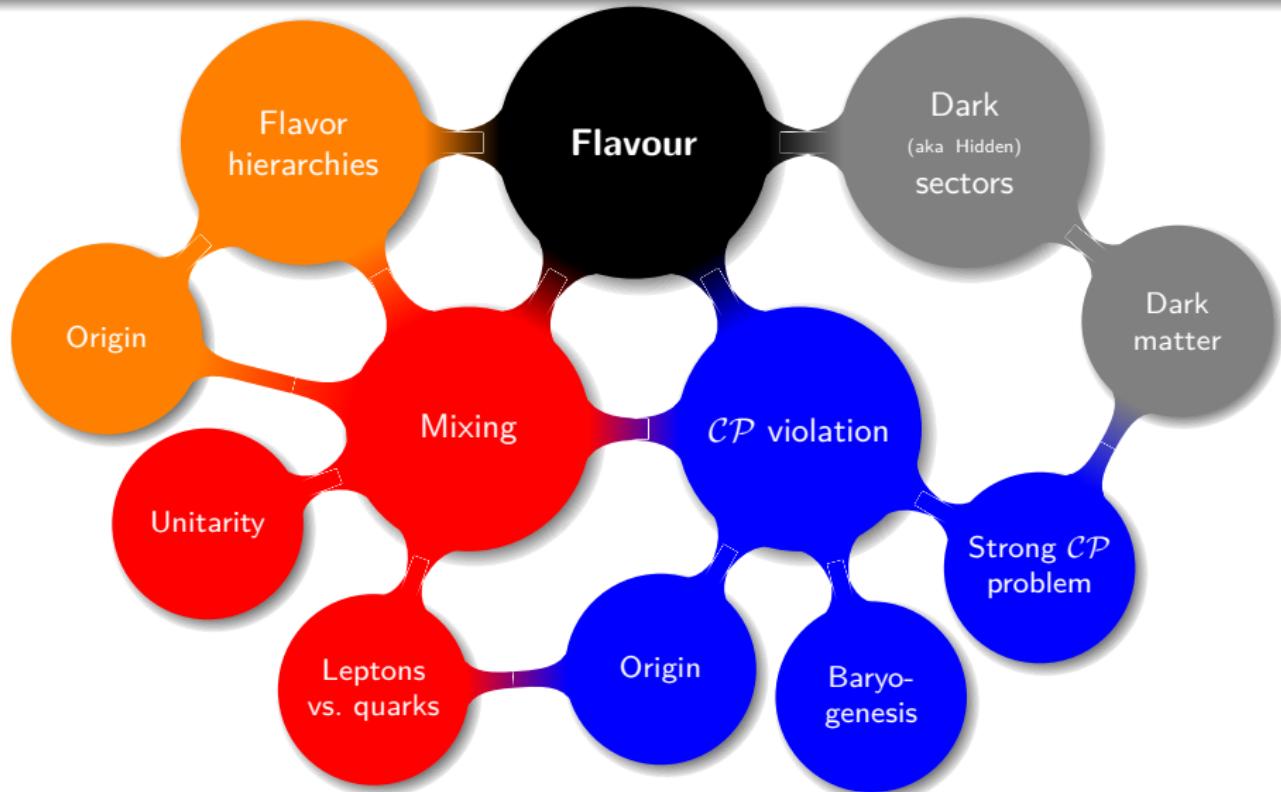
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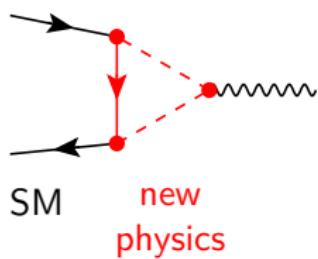
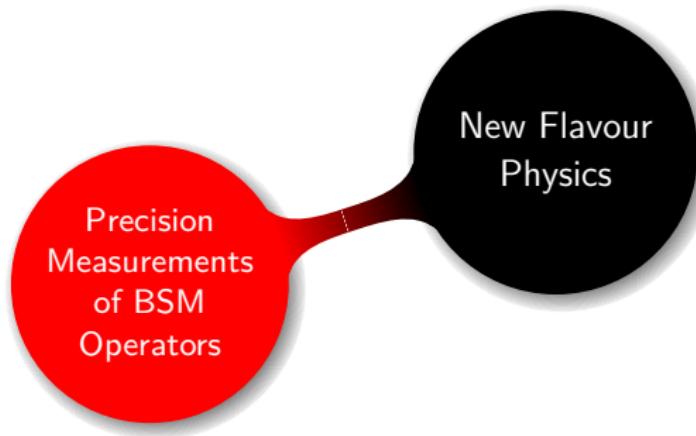
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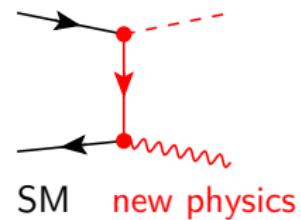
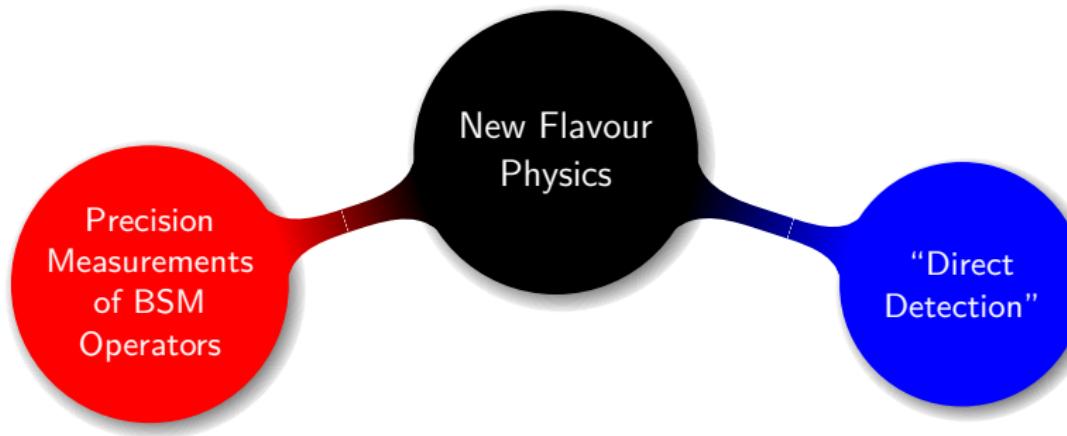
Standard ways of testing theories of flavor



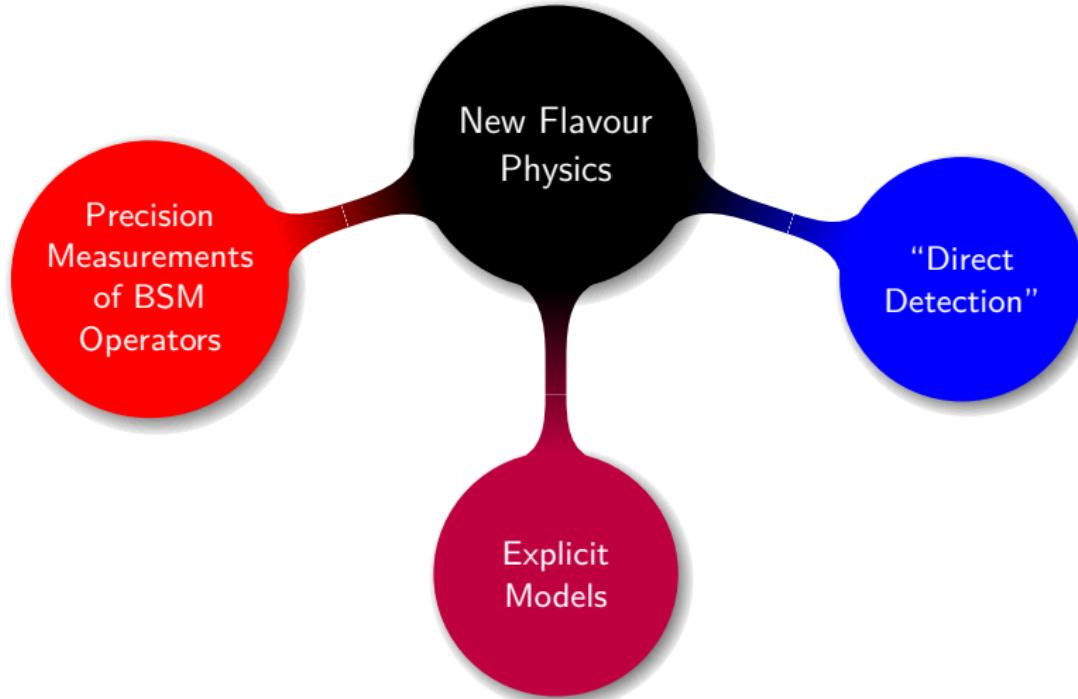
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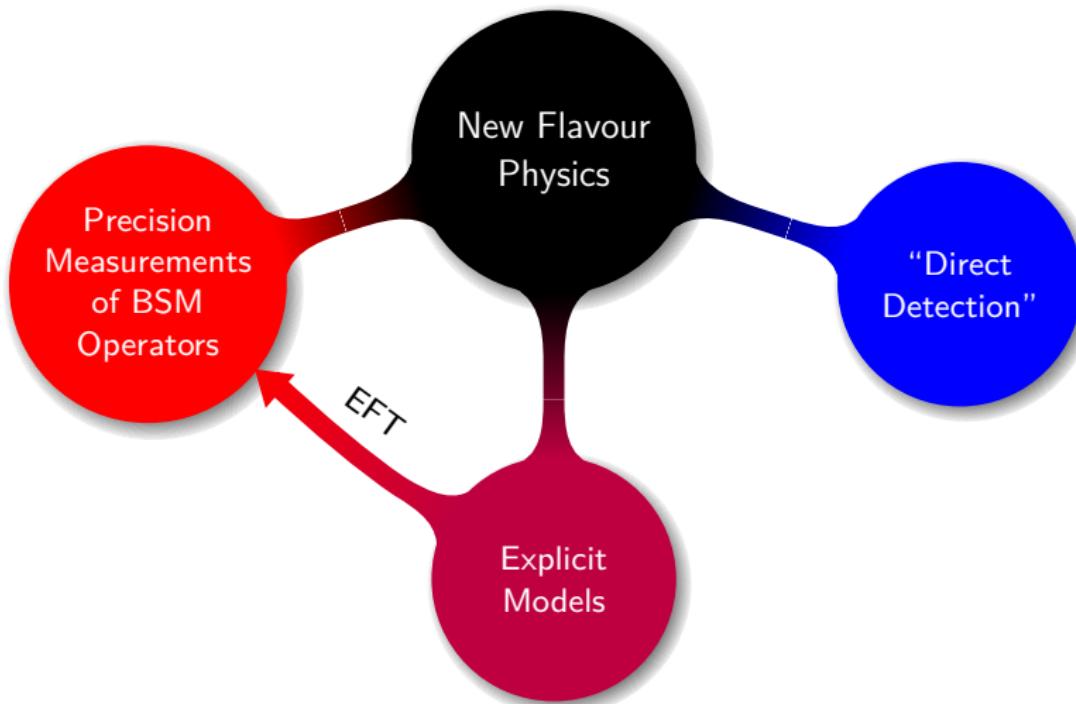
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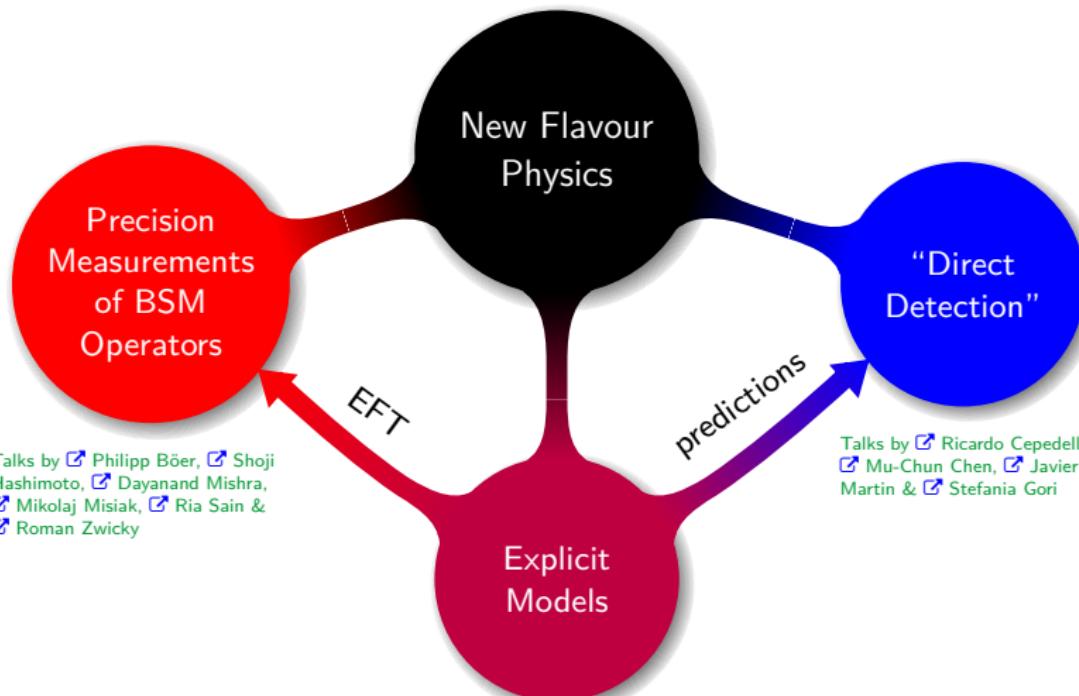
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Challenges

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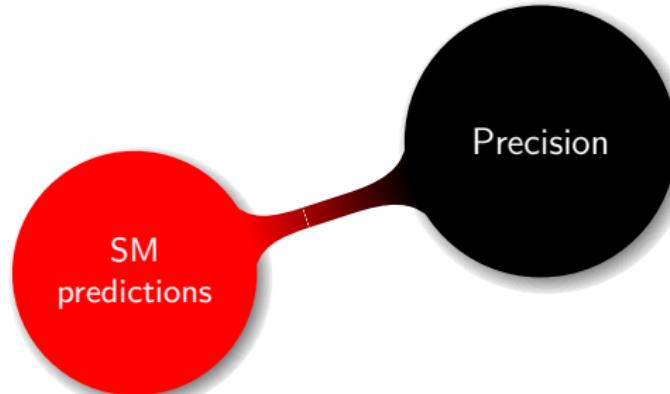
Opportunities

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Challenge # 1: Precision

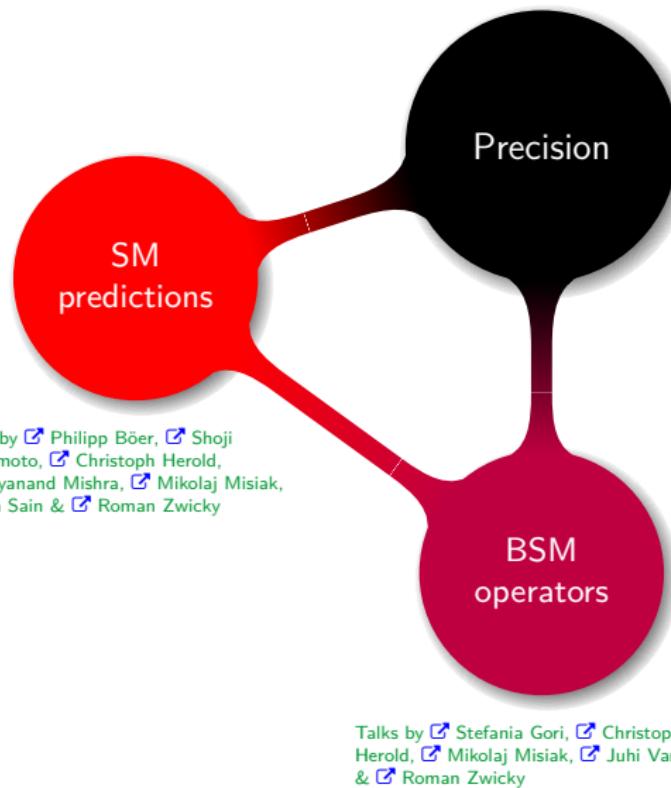


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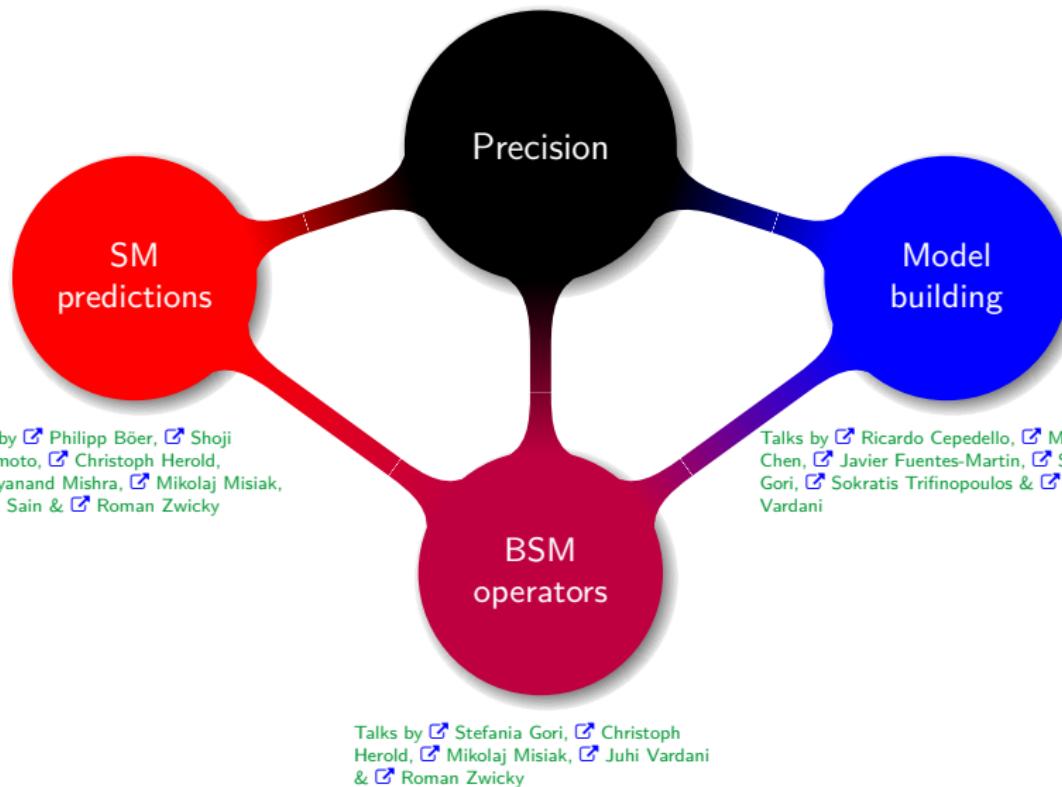


Talks by Philipp Böer, Shoji Hashimoto, Christoph Herold, Dayanand Mishra, Mikolaj Misiak, Ria Sain & Roman Zwicky

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Progress in precision computations

👉 Better control of QED effects

Talks by [Philip Böer](#), [Dayanand Mishra](#) & [Roman Zwicky](#)

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- ➡ In flavor model building some statements are more robust than others

Talks by [Ricardo Cepedello](#), [Mu-Chun Chen](#), [Javier Fuentes-Martin](#) & [MR](#)

Challenge # 1: Precision vs. convenience



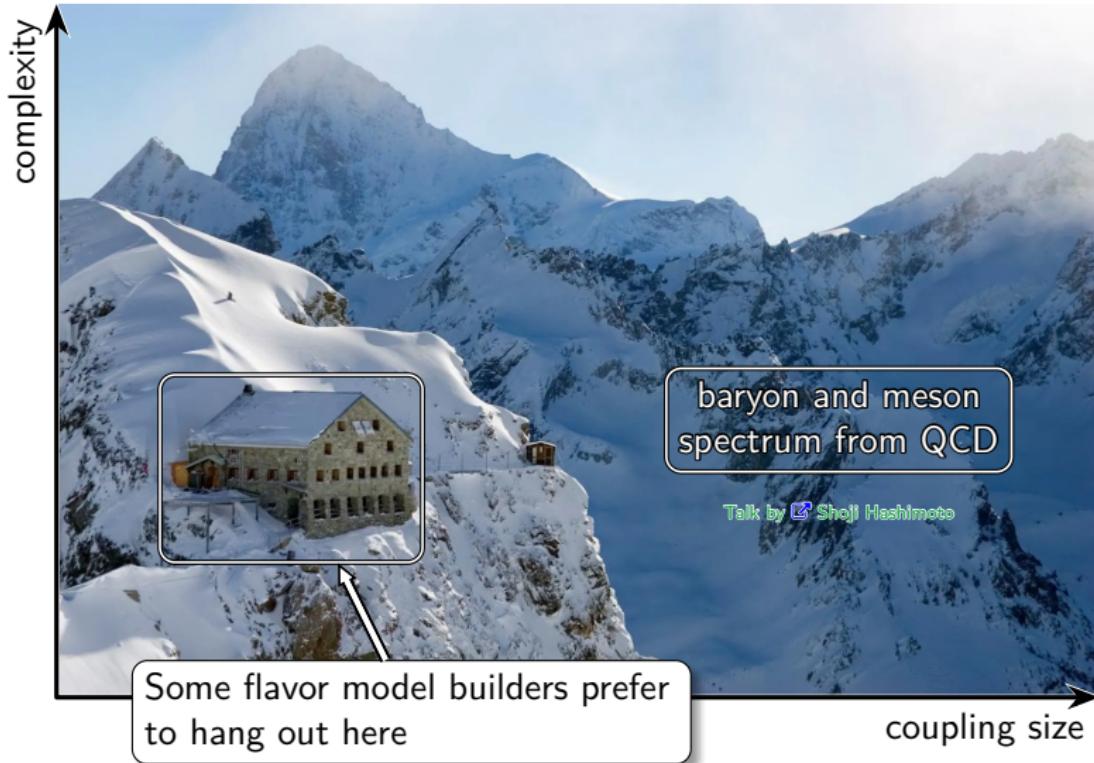
<https://www.redbull.com/int-en/10-mountain-huts-that-look-like-really-precarious>

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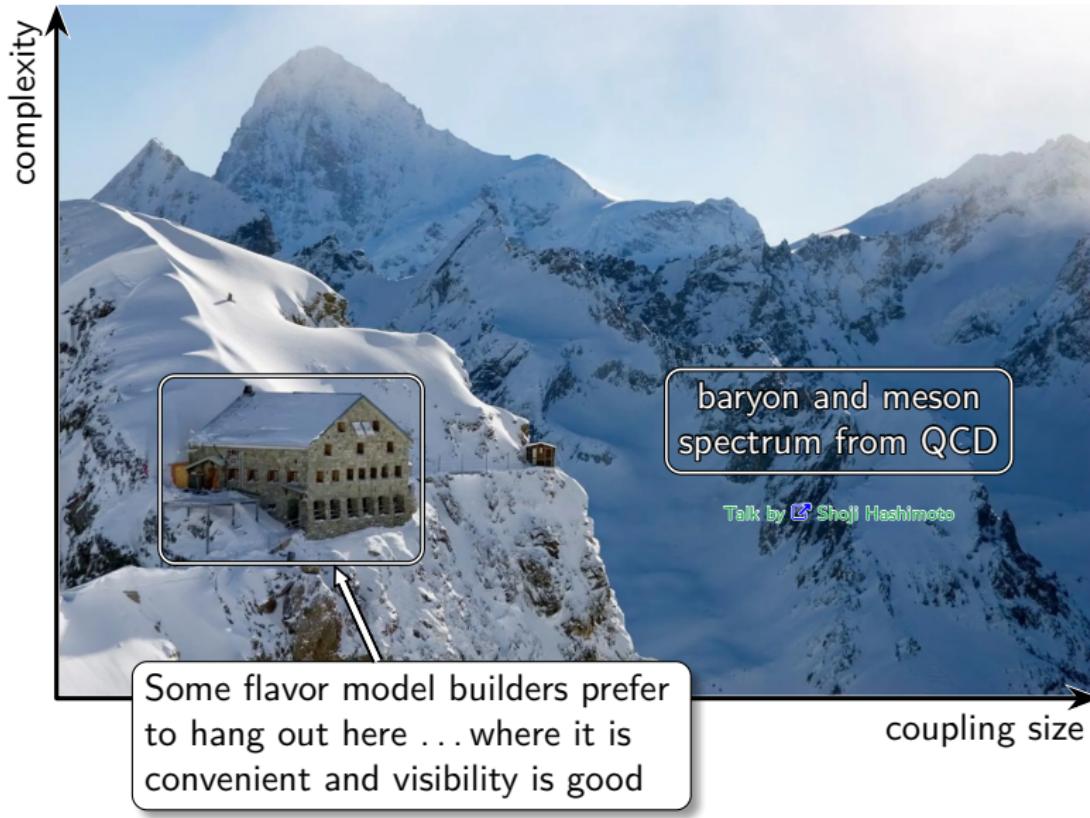
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Challenge # 2: Scales

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- ☞ Absence of large FCNCs, the longevity of the proton and the smallness of the neutrino mass scale may suggest that the scale of certain kinds of new physics is rather high

$$\tau_p \sim \frac{m_p^5}{M_X^4} \gtrsim 10^{34} \text{ years} \quad \curvearrowright M_X \gtrsim 10^{15} \text{ GeV}$$

$$m_\nu^{\text{naive see-saw}} = \frac{v_{\text{EW}}^2}{M_{\text{see-saw}}} \lesssim 0.1 \text{ eV} \quad \curvearrowright M_{\text{see-saw}} \gtrsim 10^{14} \text{ GeV}$$

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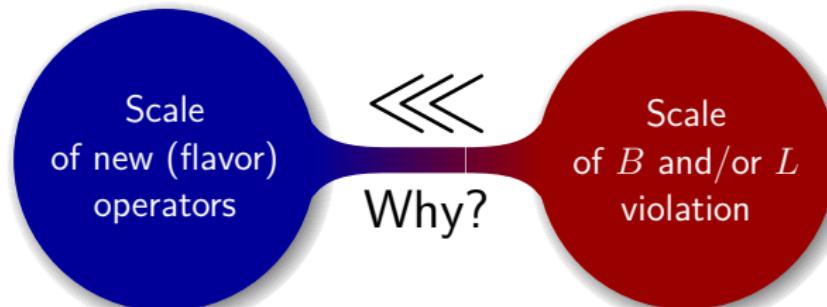
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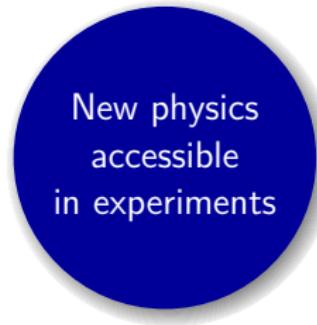
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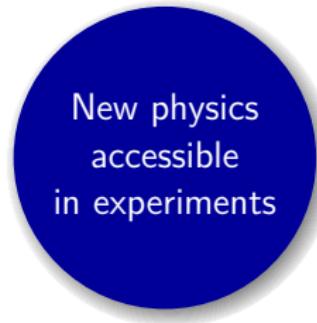
Challenge # 2: Scales (continued)

M_{np} vs. $M_{\mathcal{B}}$

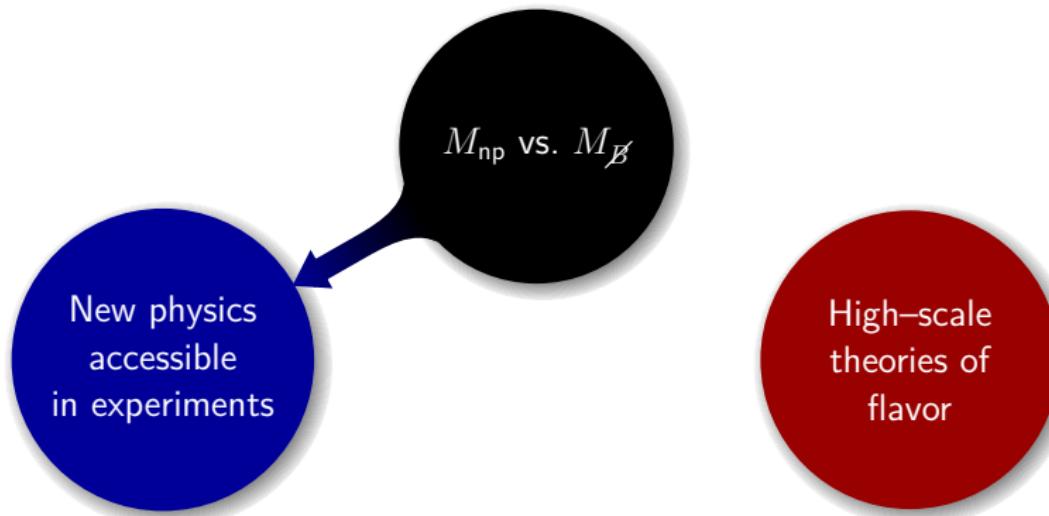
Challenge # 2: Scales (continued)



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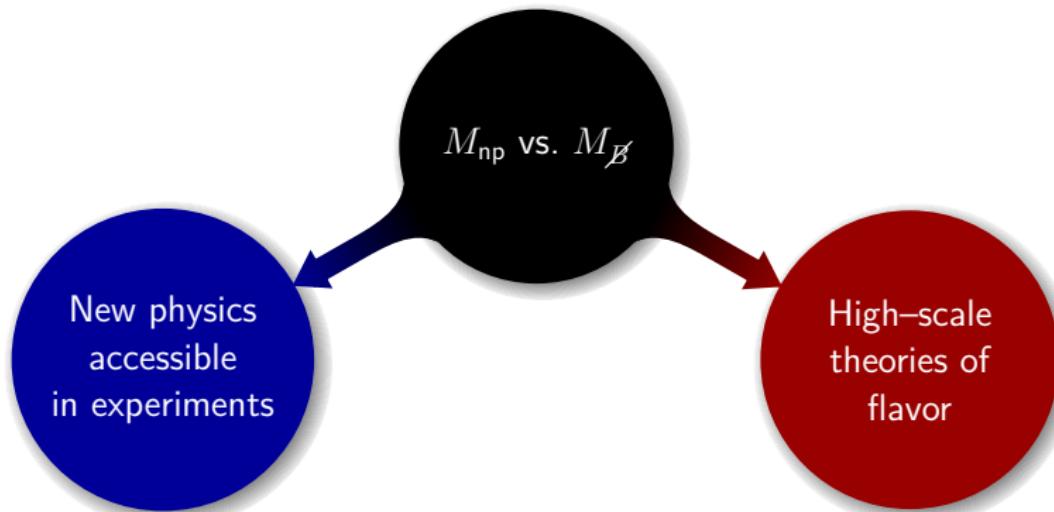


Challenge # 2: Scales (continued)



- need (consistent) symmetries to tame (or forbid) offending operators
- relations between operators?

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- need (consistent) symmetries to tame (or forbid) offending operators
- relations between operators?
- hard to test directly
- unequivocal/precise predictions?

Challenge # 3: Abundance and flexibility of models

Talks by [Mu-Chun Chen](#), [Javier Fuentes-Martin](#), [Stefania Gori](#), [MR](#) & [Sokratis Trifinopoulos](#)

- ☞ Observation can apparently be accommodated by numerous models
 - How do we know which one (if any) is the correct one?
 - Are the only worthwhile models those which can be fully explored in the not-too-distant future?

Challenge # 3: Abundance and flexibility of models

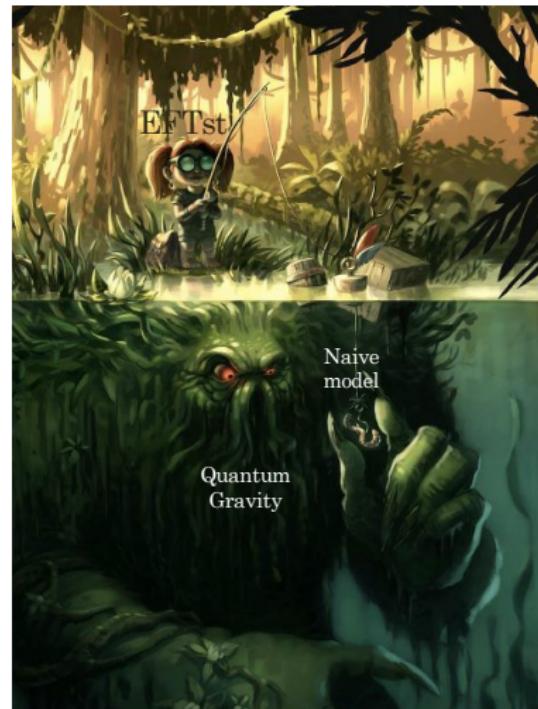
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- ☞ Observation can apparently be accommodated by numerous models
- ☞ Flexibility of some models
 - E.g. models that predicted $\theta_{13} = 0$ could be “upgraded” to accommodate a realistic θ_{13} after it has been measured
 - When do we call predictions unequivocal?

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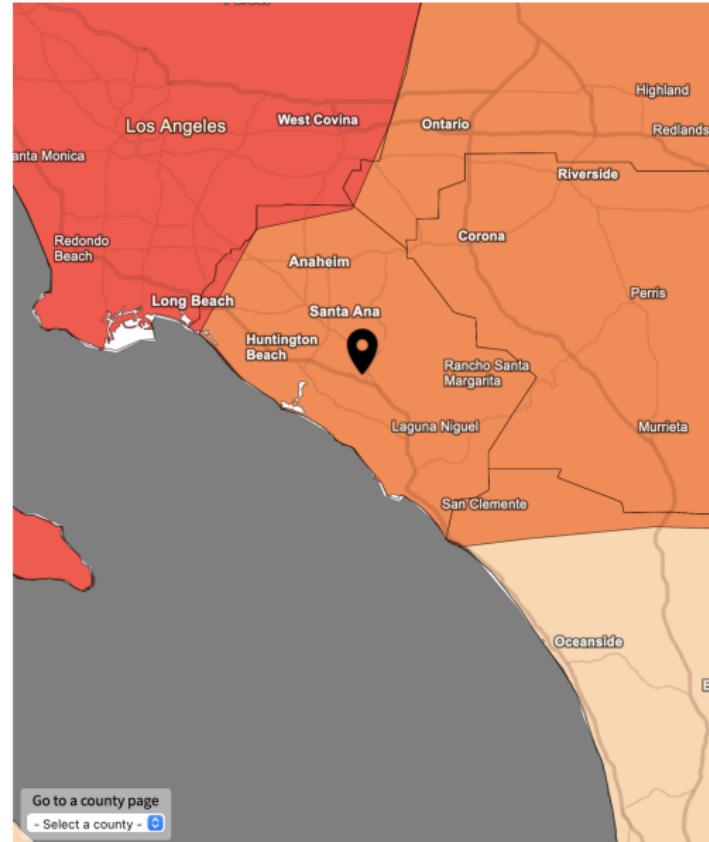
- ☞ Observation can apparently be accommodated by numerous models
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- ☞ What are the appropriate theoretical constraints?
 - We all know that continuous gauge symmetries need to be anomaly-free but what about discrete and/or global symmetries?
 - What are reasonable restrictions on the representation content?
 - Should we take string theory and/or swampland constraints seriously?



https://workshops.ift.uam-csic.es/uploads/poster/congreso_299.pdf

Can't really comment on swampland, though 😊

D0 - Abnormally Dry	100.00% of Orange County (D0-D4)
<ul style="list-style-type: none"> Soil is dry; irrigation delivery begins early Dryland crop germination is stunted Active fire season begins 	
D1 - Moderate Drought	100.00% of Orange County (D1-D4)
<ul style="list-style-type: none"> Dryland pasture growth is stunted; producers give supplemental feed to cattle Landscaping and gardens need irrigation earlier; wildlife patterns begin to change Stock ponds and creeks are lower than usual 	
D2 - Severe Drought	100.00% of Orange County (D2-D4)
<ul style="list-style-type: none"> Grazing land is inadequate Fire season is longer, with high burn intensity, dry fuels, and large fire spatial extent Trees are stressed; plants increase reproductive mechanisms; wildlife diseases increase 	
D3 - Extreme Drought	4.31% of Orange County (D3-D4)
<ul style="list-style-type: none"> Livestock need expensive supplemental feed; cattle and horses are sold; little pasture remains; fruit trees bud early; producers begin irrigating in the winter Fire season lasts year-round; fires occur in typically wet parts of state; burn bans are implemented Water is inadequate for agriculture, wildlife, and urban needs; reservoirs are extremely low; hydropower is restricted 	
D4 - Exceptional Drought	0.00% of Orange County (D4)
<ul style="list-style-type: none"> Fields are left fallow; orchards are removed; vegetable yields are low; honey harvest is small Fire season is very costly; number of fires and area burned are extensive Fish rescue and relocation begins; pine beetle infestation occurs; forest mortality is high; wetlands dry up; survival of native plants and animals is low; fewer wildflowers bloom; wildlife death is widespread; algae blooms appear 	



Organizing principles

Abelian flavor symmetries

 Froggatt & Nielsen [1979];...

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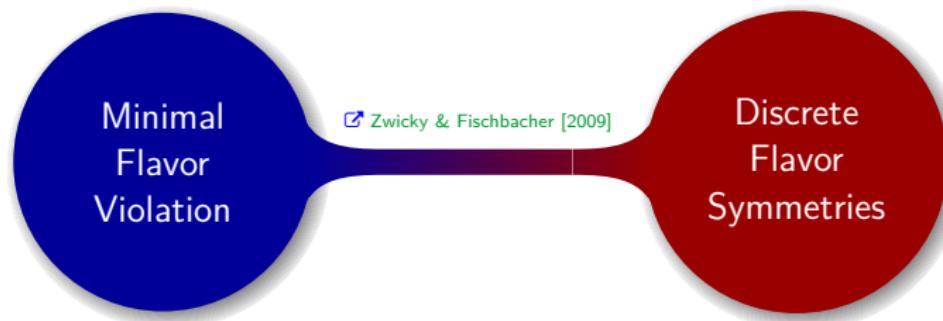
Benefits of consistent organizing principles

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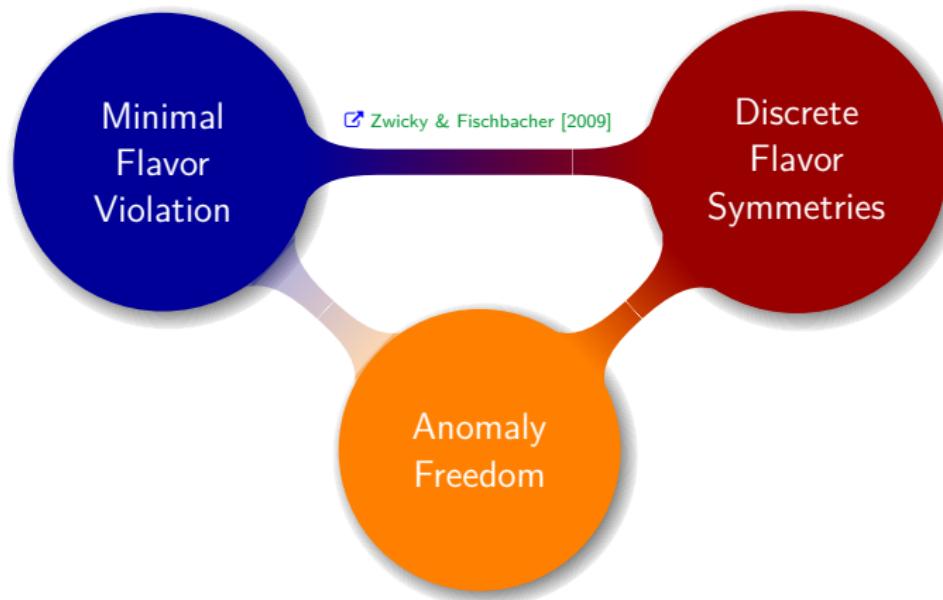
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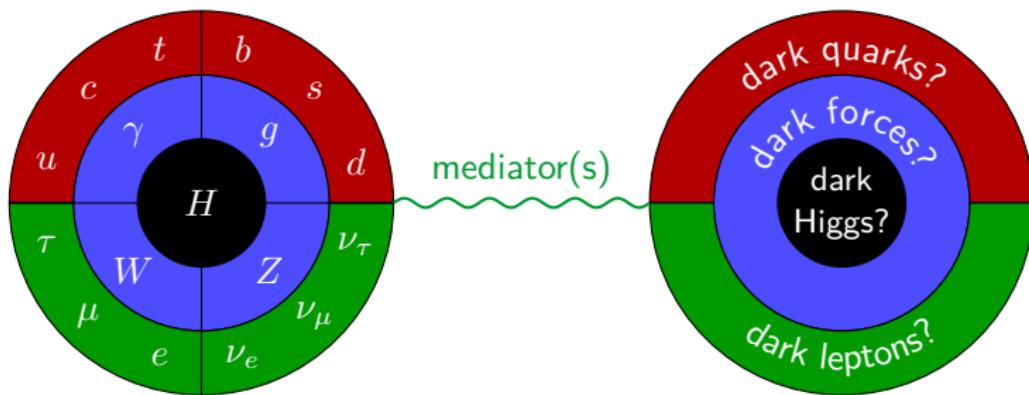
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- ☞ Expectation to find deviations from minimal flavor violation

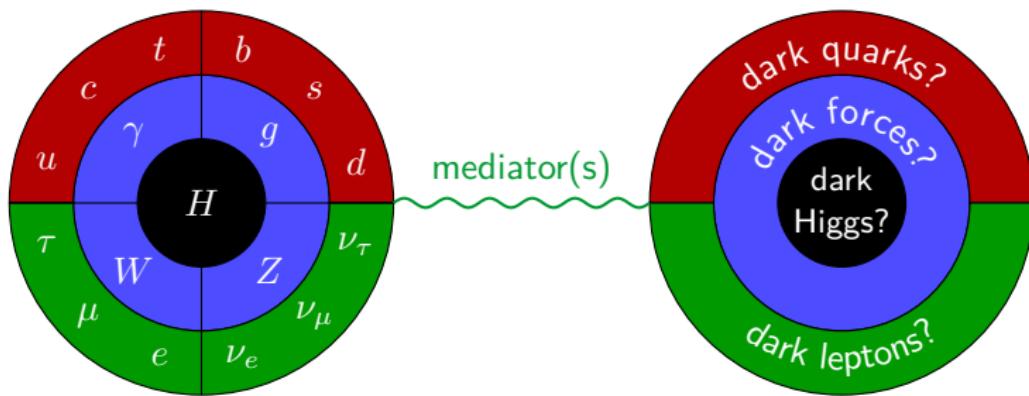
The dark side of the Force Flavour

Talk by  Stefania Gori



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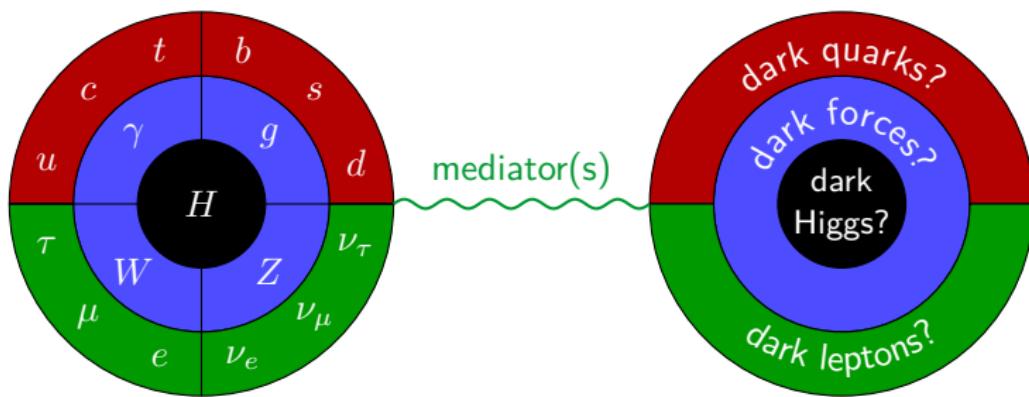


- Interesting relation between flavor symmetries and dark matter stability

Talk by Ricardo Cepedello

The dark side of the Force Flavour

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- Dark sectors (previously known as hidden sectors) have become popular because they may be testable in the foreseeable future (and not because of the oxymorons like "light dark sector" or "dark photon" 😊)

Conversation with Stefania Gori and Albert de Roeck

Challenge # 4: Cosmology of light dark sectors

☞ These sectors become more testable if the extra fields are

- light
- coupled to the SM

... which may also make them relevant for flavor

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-  Lillard, MR, Tait & Trojanowski [2018]

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... yet this also entails opportunities of going beyond standard cosmologies

e.g.  Chen & Takhistov [2019]

Summary

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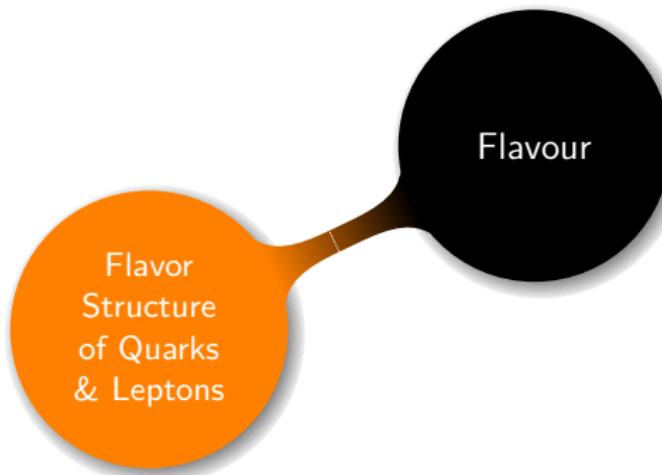
Outlook

Main insight(s)

flavour \neq flavor

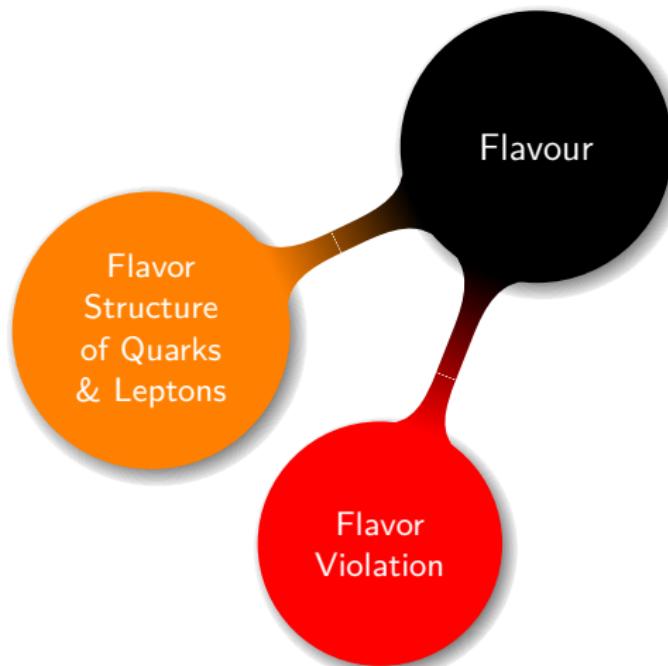
Main insight(s)

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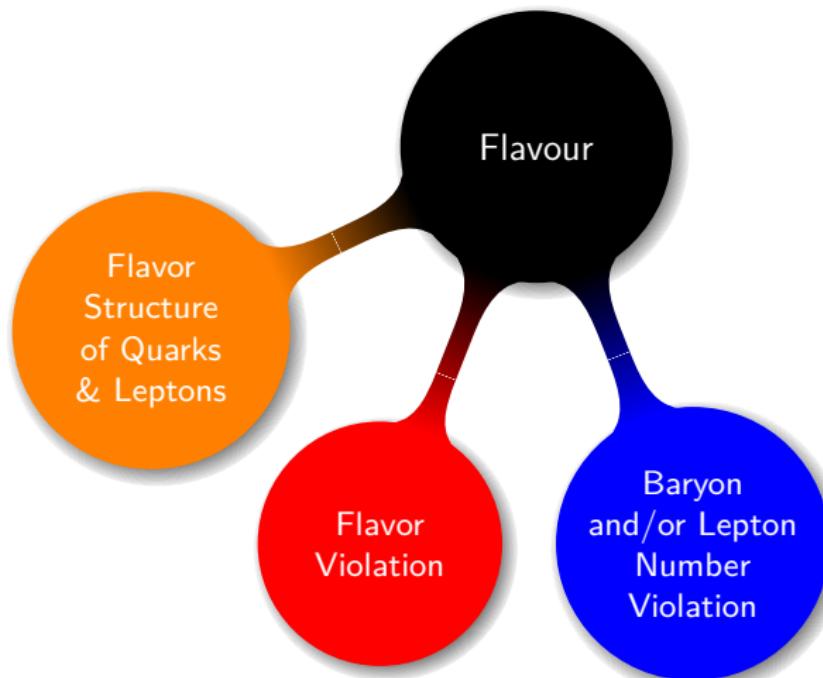
Main insight(s)

$\text{flavour} \neq \text{flavor}$



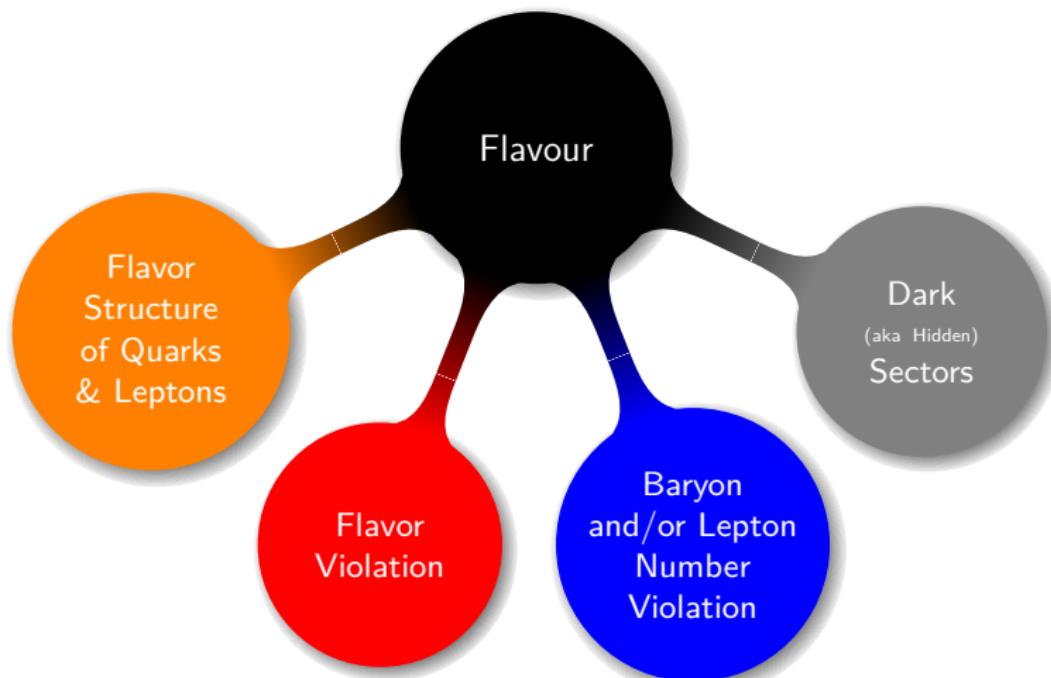
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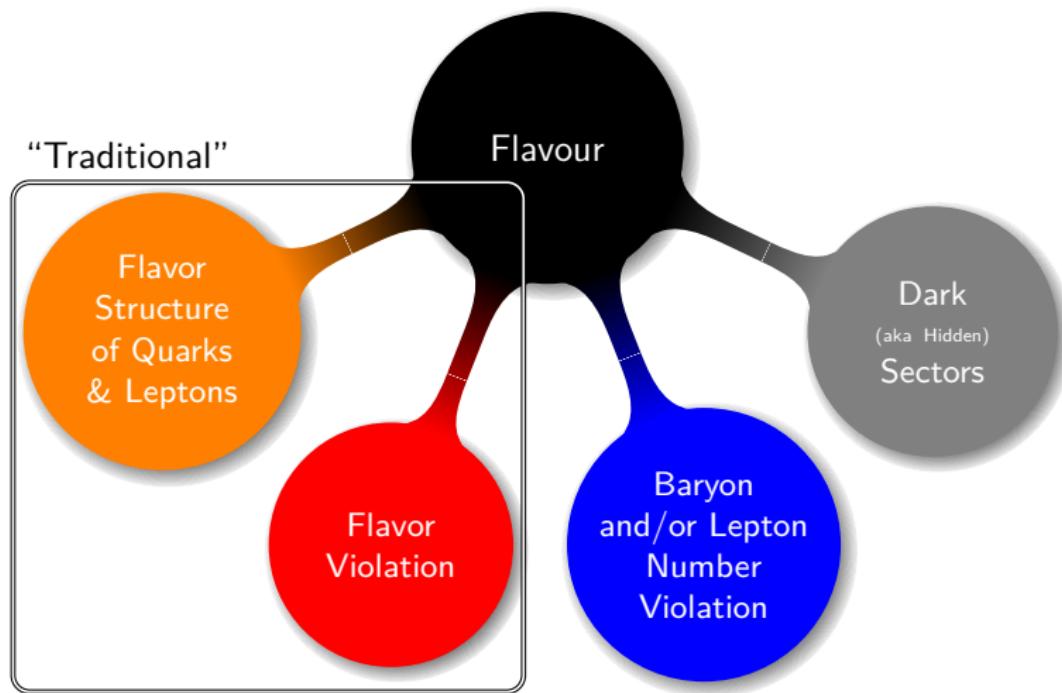
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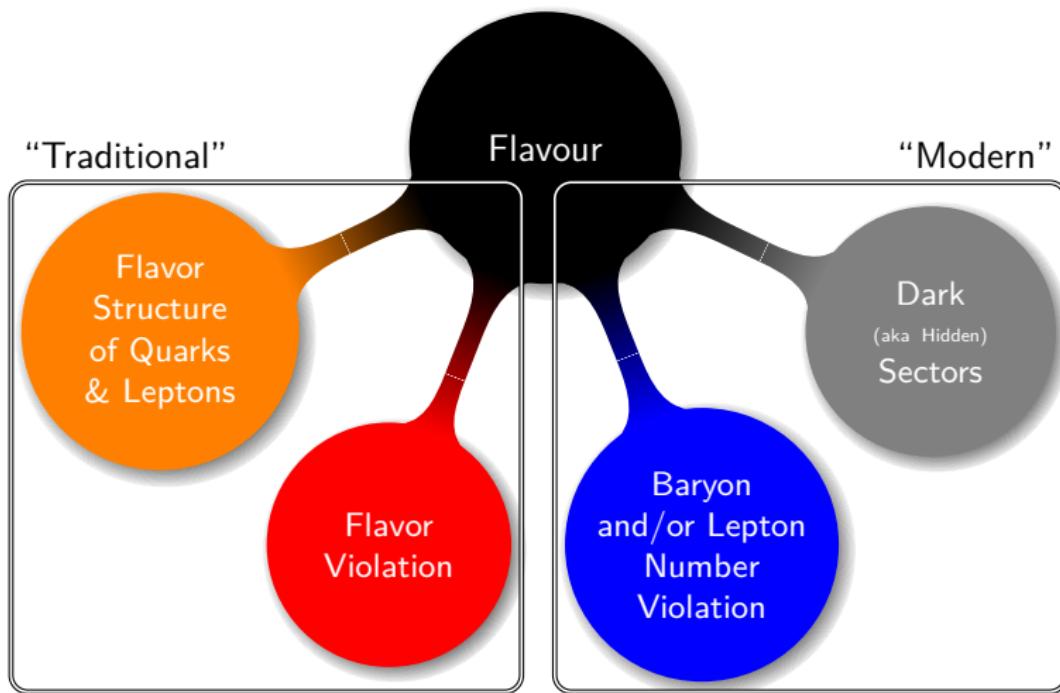
Main insight(s)

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Main insight(s)

flavour \neq flavor



Outlook



- ☞ More meetings of this kind
- ☞ Open discussion of challenges and opportunities

Further talking points

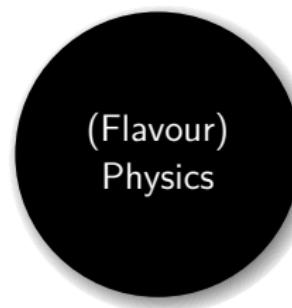
- ☞ Does the discovery of Majorana neutrinos prove leptogenesis?
- ☞ Is there a model-independent relation between δ_{CP} and the baryon asymmetry of the universe?
- ☞ Sum rules or some rules?
- ☞ Is the possibility that DM is just one single particle ruled out (or disfavored)?

Flavor physics: theory & experiment

 **BIG THANKS** to the organizers for bringing together experimentalists and theorists!

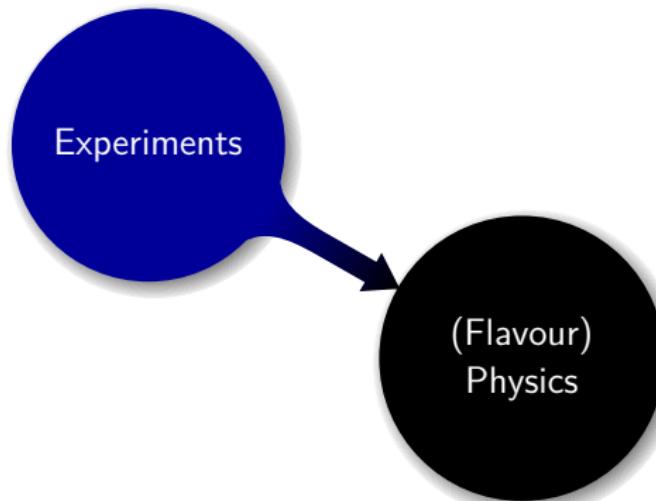
Flavor physics: theory & experiment

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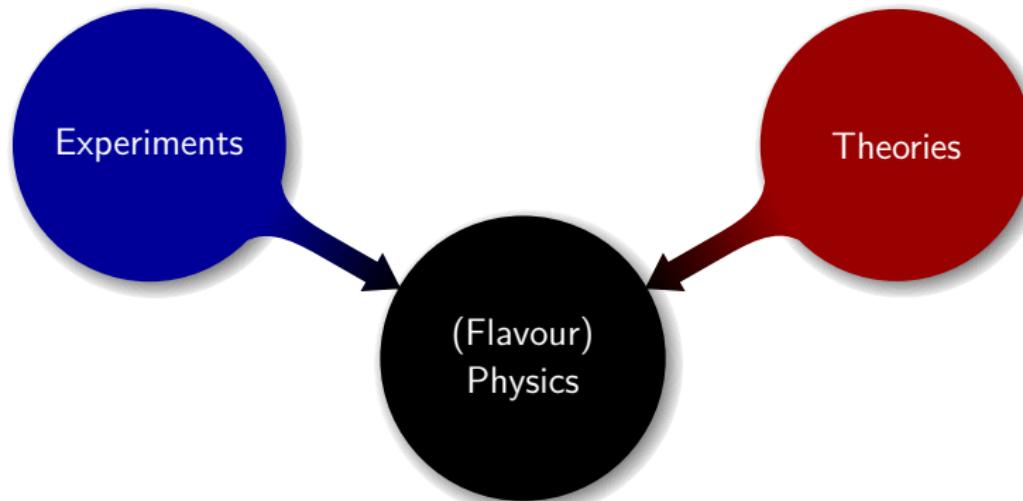
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Flavor physics: theory & experiment

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