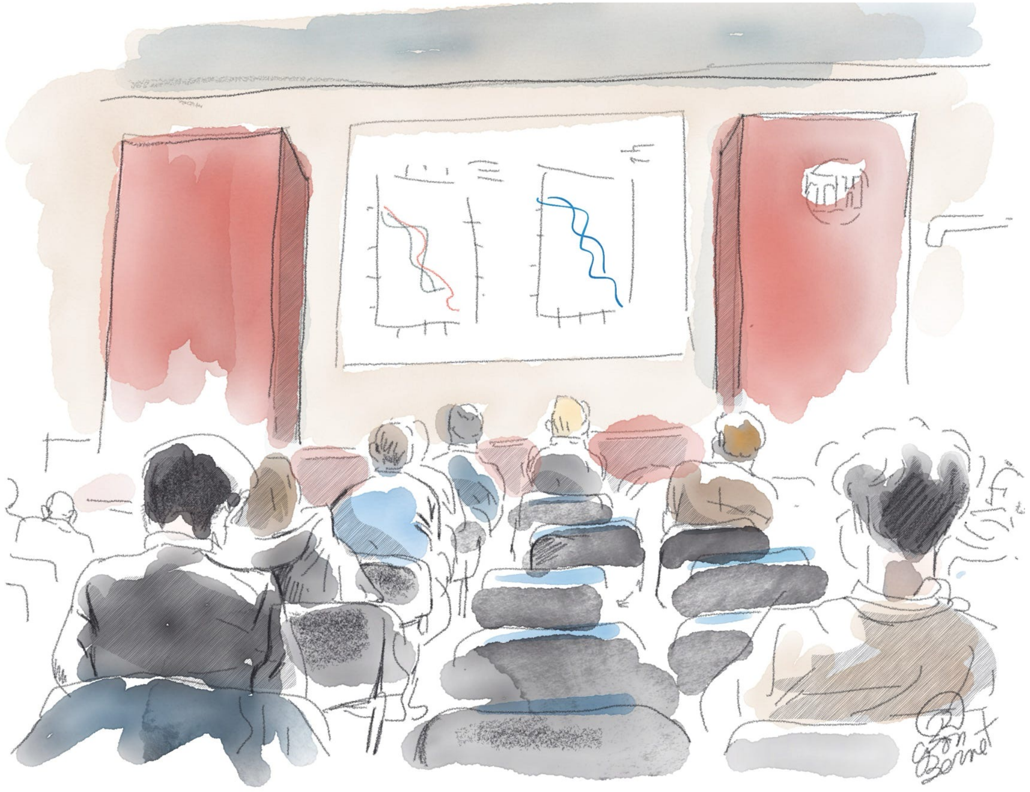
Moriond 2025 - Theory Summary

Electroweak Interactions & Unified Theories



Laura Reina

Florida State University and

INFN, University of Rome "La Sapienza"

March 30, 2025

FSU | DEPARTMENT OF PHYSICS

SAPIENZA UNIVERSITÀ DI ROMA

U.S. DEPARTMENT OF ENERGY

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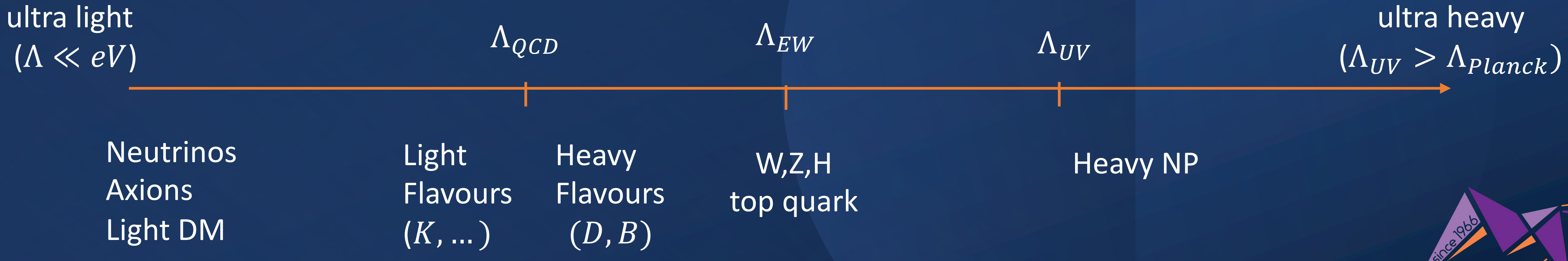


A unique time in particle physics

- A **wealth of high-quality data** now available from a **broad spectrum of experiments and observations.**
- **Powerful new ideas** are **boosting the accuracy of both theoretical and experimental results.**

- **Major decisions for future projects are being made** (**Snowmass/P5**, **European Strategy**) based on current results and technologies, future projections, and theoretical guidance.

~ 80 experimental talks!

	SUNDAY 23/03	MONDAY24/03	TUESDAY25/03	WEDNESDAY26/03	THURSDAY27/03	FRIDAY28/03	SATURDAY29/03	SUNDAY30/03
8:30		C. Marin Benito	S. Stefkova	A. Menegolli	D. Litim	M. Schmaltz	A. Nigamova	
		S. Wang	G. Karathanasis	S. Urrea-González	S. Addepalli	A. Droster	M. Valli	J. Albrecht
		S. Trifinopoulos	R. Manfredi	G. Milton	M. Nardecchia	D. Kaplan	A. Taliercio	
		L. Ecklund	M.L. Piscopo	F. Jörg	C. Pena	D. Leppla Weber	A. Trautner	
		S. Robertson	G. Ruggiero	C. Englert	J. Zupan	V. Domcke	C. Vico	L. Reina
		coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	
		M. Reboud	C. Hill	J. Kamenik	P. Ecker	C. Yèche	R. Wang	
		T. Martinov	J. Kleykamp	C. Pollard	A. Ibarra	M. Drewes	M. Stange	
		X. Pan	D. Henaff	A. Teixeira	S. Eriksen	A. Chou	G. Boldrini	
		A, Juettner	T. Tashiro	C. Wang	G. Perez	M. Mühlleitner	D. Camarero	Bu
12:00		Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	
15:00	Registration							
17:00	|	P. Gironella	N. Ackerman	I. Neutelings	D. Redigolo	R. Hayes	E. Manca	
	|	R. Puthumanaillam	I. Esteban	K. Kowalska	C. De Dominicis	R. Chatterjee	T. Robens	
		M. Escudero	T. Lasserre	M. Montella	A. Ray	V. Miralles	F. Fabbri	
	|	A. Scarabotto	P. Decowski	J, Lizana	L. Di Luzio	T. Lenz	D. Pinna	
	|	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	
	|	V. S. Vobbilisettyi	V. D'Andrea	B. Donmg	R. Durrer	H. Yin	B. Fuks	
		YSF I M. Hartmann, G. Gaudino, A. Bansal, C. Lemettais, D. Suelmann. L. Paolucci	YSF II H. Birch, E. Lavaut, J.P. Pinheiro, N. Bhuiyan, M.I. Dias Astros, C. Girard-Carilho, R. Faure, A. Langella	YSF III A. Ruggiero, S. Lomte, M. Kuschick, F. Esser	G. Yu	Moriond discussion	E. Watton	
					E. Fernandez Martinez		YSF IV Z. Wolls, D. Minh Hoang. H. Tiblom, E. Muhammad, D. Marckx	
19:30	Cocktail							
			Dinner	Dinner	Dinner	Conference dinner	Dinner	
							SUMM	

Impressive breadth and quality of experimental results

SESSIONS

- Flavour
- Neutrino
- BSM
- Dark Matter
- Cosmology
- Dark Matter, Axions and Cosmology
- Brout-Englert-Higgs Boson
- Standart Model

B-factories, LHCb, (ATLAS/CMS)
Towards higher luminosities.
Probing flavour dynamics in the quark sector.

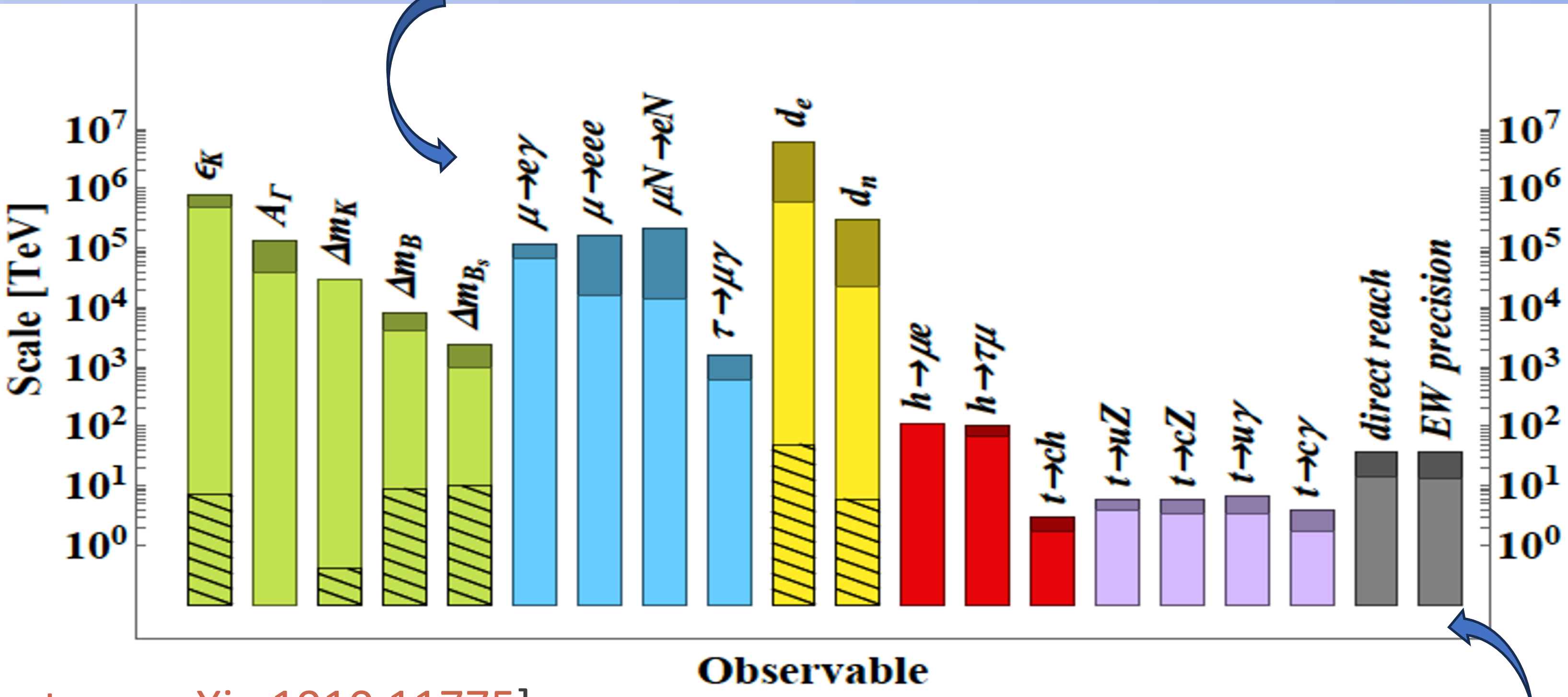
Neutrino experiments,
DUNE on the horizon.
Probing new physics and lepton flavour dynamics.

Dark-matter experiments,
Cosmological observations.

ATLAS and CMS main program,
Towards the HL-LHC upgrade.
Probing new physics with energy and unprecedented precision .

Complementarity in bounding new physics

Flavour- and low-energy observables can be more sensitive to the scale of new physics, but they may not be able to unambiguously test it.



See talks by Ana Texeira, Jure Zupan, and flavor-physics talks

[European Strategy, arXiv:1910.11775]

High-energy collider have less sensitivity but can test the compatibility of new physics over a uniquely broad spectrum of measurements.

~ 80 experimental talks
~ 30 theory talks

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2:00								

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- Standart Model
- …ntists Forum

Impressive breadth and quality of experimental results

The role of theory is challenging

- Unambiguously confirm the realm of validity of known theories (Standard Model)
- Identify its failures and use them as hints of new physics
- Constantly explore new ideas and promote future explorations
- Identify and interpret new phenomena

The Standard Model

Strengths and Weaknesses

- Our current knowledge of particle physics is based on the **Standard Model (SM)** which has been **confirmed by discoveries and precision measurements** to correctly describe particle physics at the EW scale with great accuracy.
- The **strength and success of the SM** at the EW scale allows us to **identify its failures and weaknesses.**
- They become a **unique handle to explore physics beyond the SM (BSM).**

SM strength: consistency at the quantum level

For M_W we combine:

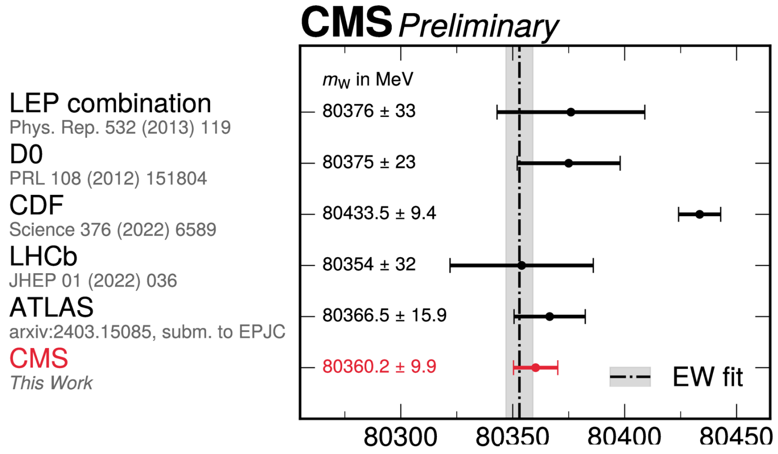
- ❑ All LEP 2 measurements
- ❑ Previous Tevatron average
- ❑ ATLAS and LHCb early measurements
- ❑ CDF [M_W=(80.4335±0.0094) GeV]
- ❑ ATLAS [M_W=(80.3665±0.016) GeV]
- ❑ CMS [M_W=(80.3602±0.010) GeV]

M_W = 80.366 ± 0.0080 GeV (without CDF)
80.356 ± 0.0045 GeV (from fit)

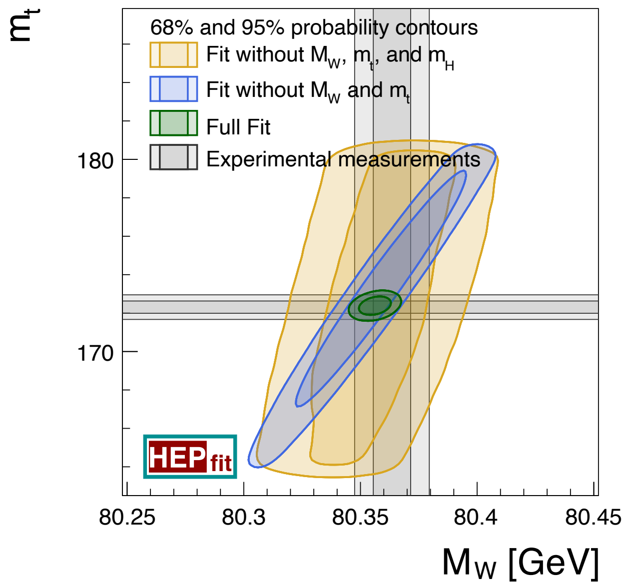
For m_t we combine:

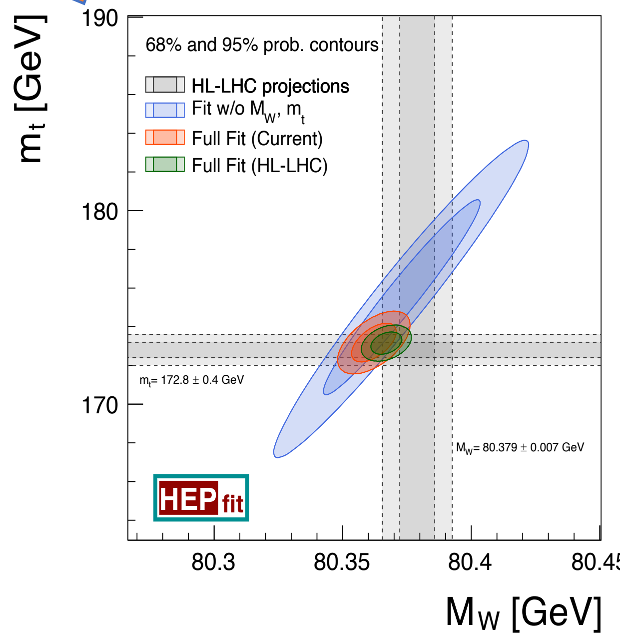
- ❑ 2016 Tevatron combination
- ❑ ATLAS Run 1 and early Run2 results
- ❑ CMS Run 1 and early Run 2 results
- ❑ CMS l+j [m_t=(171.77±0.38) GeV]
- ❑ CMS l+j boosted [m_t=(173.06±0.83) GeV]
- ❑ ATLAS l+j boosted [mt=172.95±0.53) GeV

m_t = 172.31 ± 0.32 GeV
172.38 ± 0.31 GeV (from fit)



With HL precision





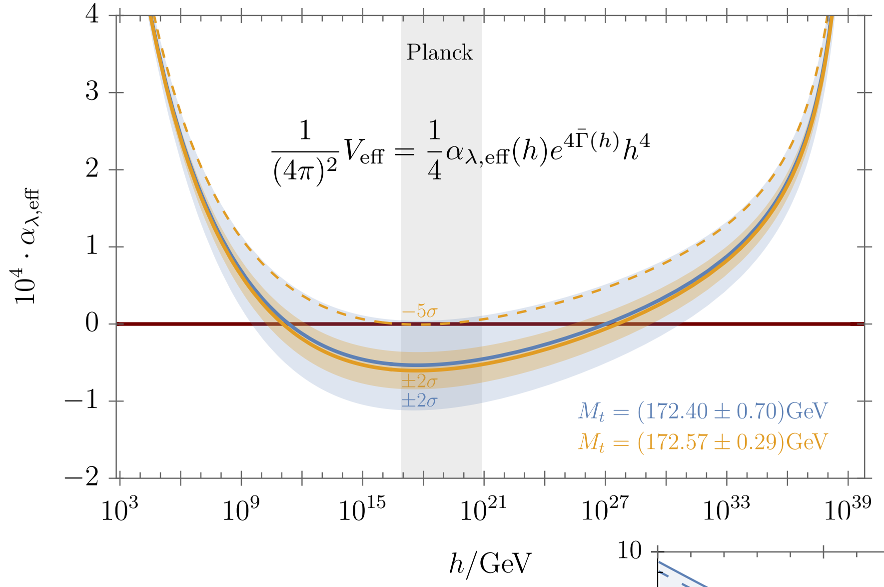
J. de Blas et al. 2204.04204, **updated**

J. de Blas et al. 1902.04070
HL/HE-LHC Report

See talk by Daniel Litim

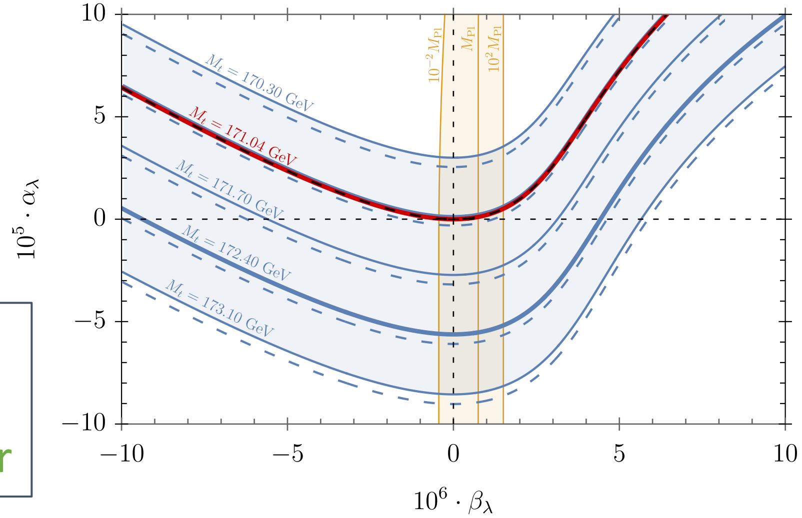
SM vacuum stability revisited

Can we ascertain or refute vacuum stability at the 5σ level?

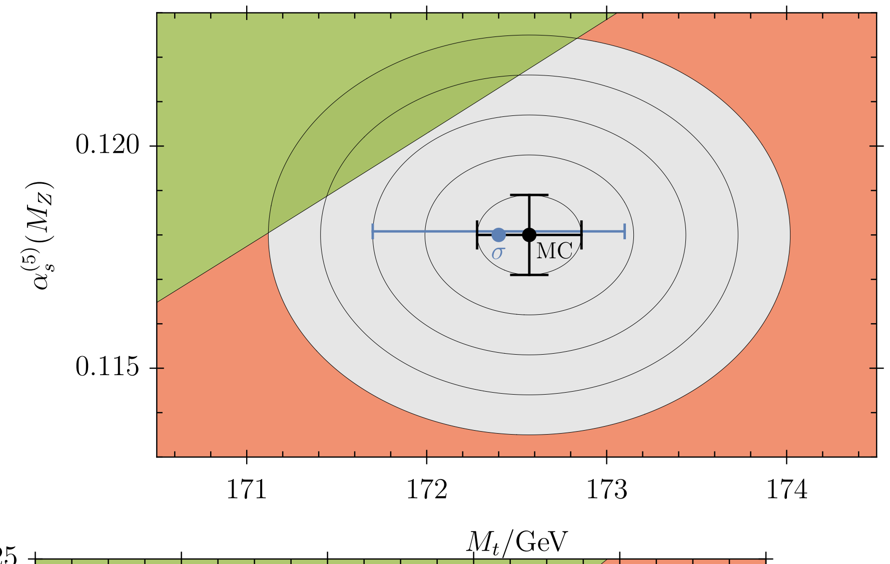


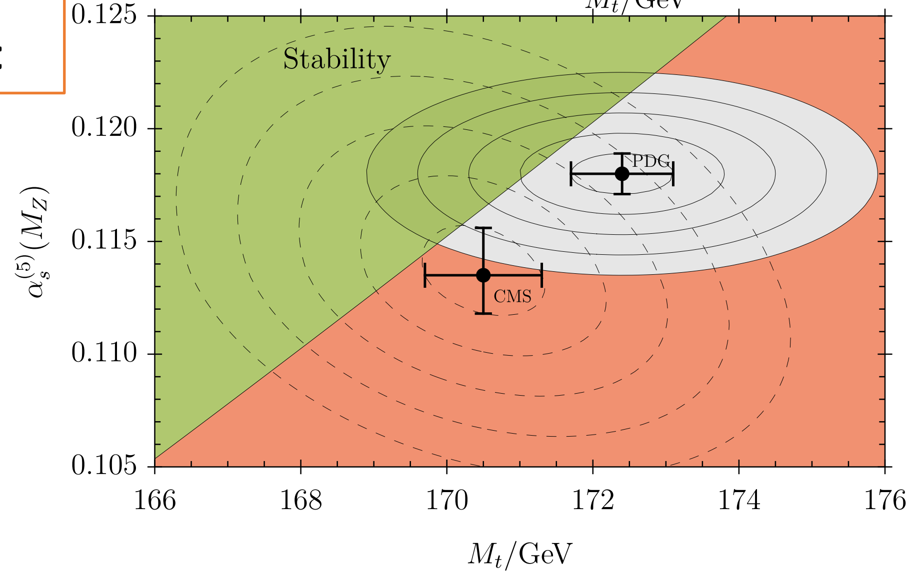
Uncertainty dominated by central values and errors for **top-quark mass** and **strong coupling constant**

Stability is dominated by RG running



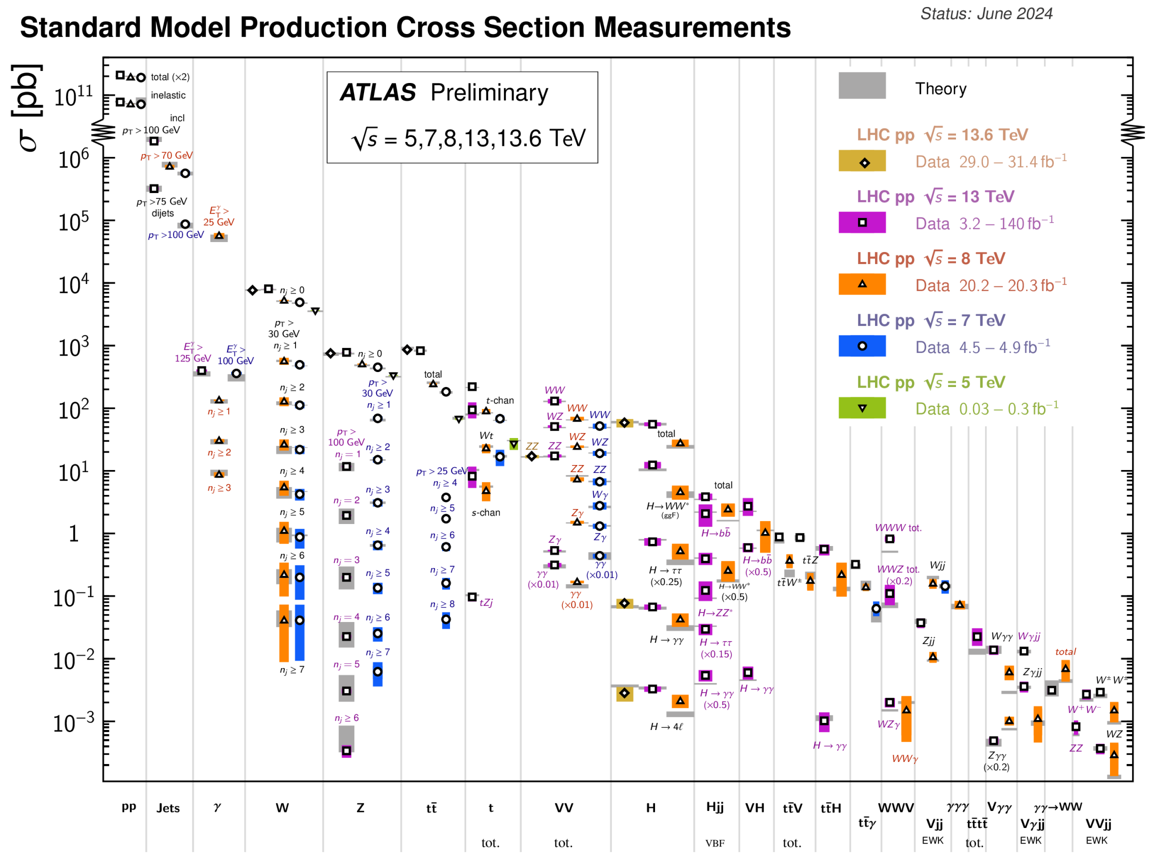
On quantum criticality and custodial naturalness,
See talk by Andreas Trautner

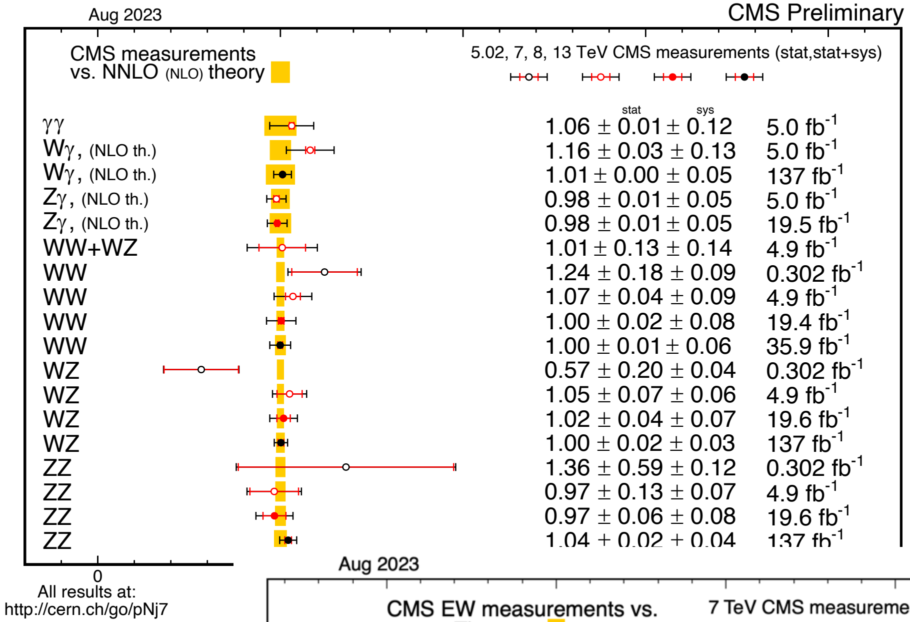


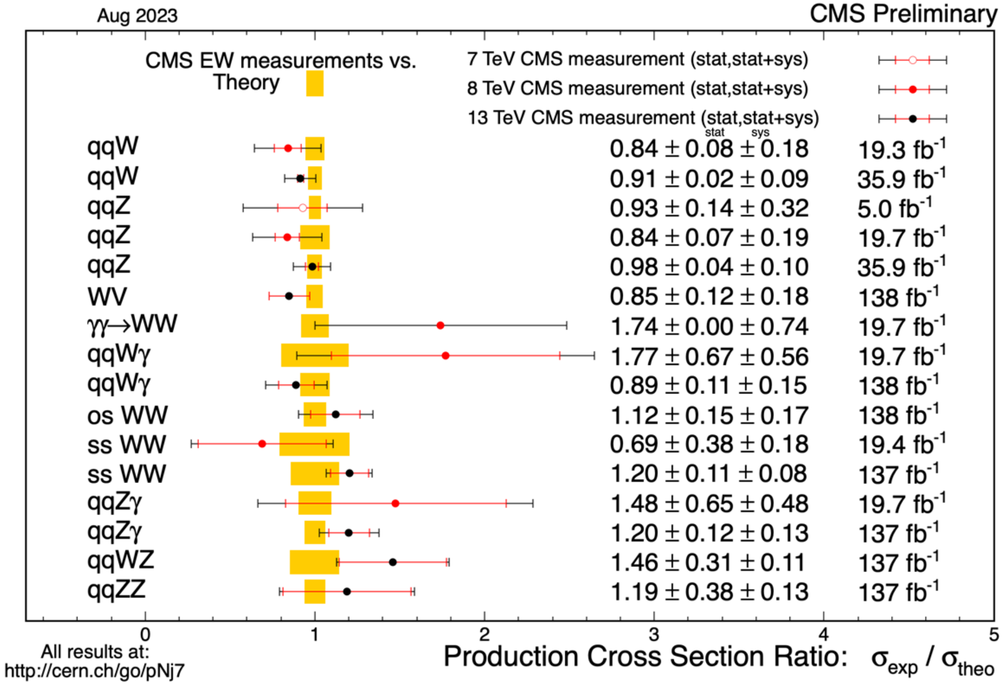


CMS, 1904:05237:
Combined fit of M_t and α_s: effect of **correlations**

SM strength: broad consistency with all LHC measurements





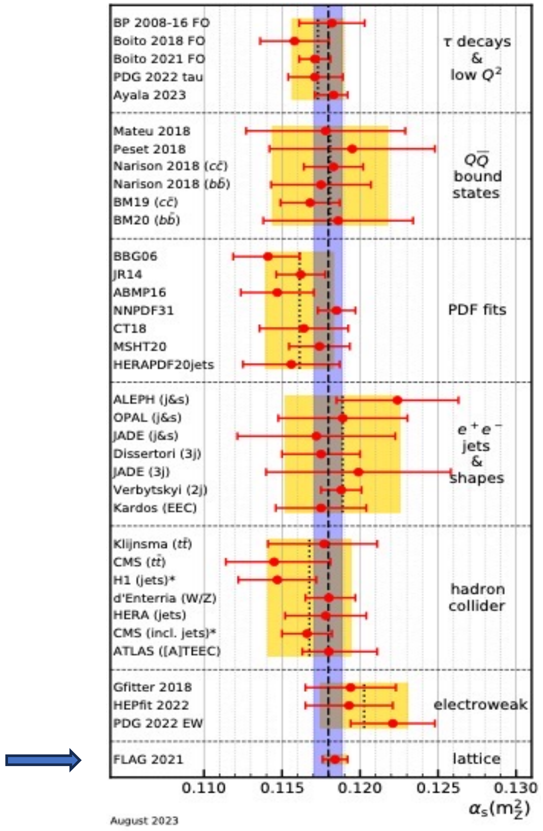


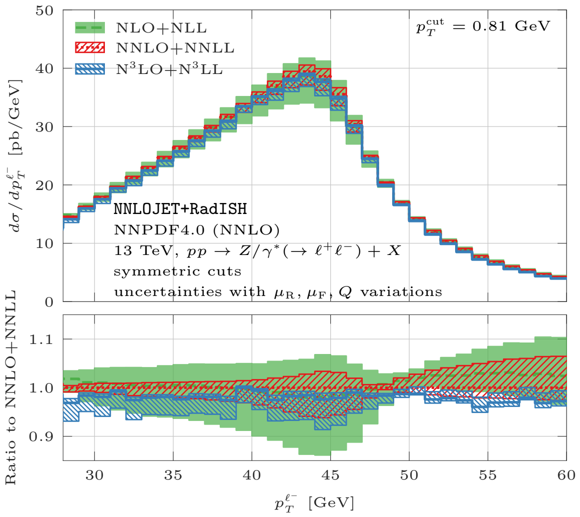
Within experimental and theoretical errors
that often already reach percent level

SM: still work in progress

Often referred to as “*theoretical systematics*”: ubiquitous in all talks we have listened to.

Parametric Uncertainties:
High precision which will continuously improve

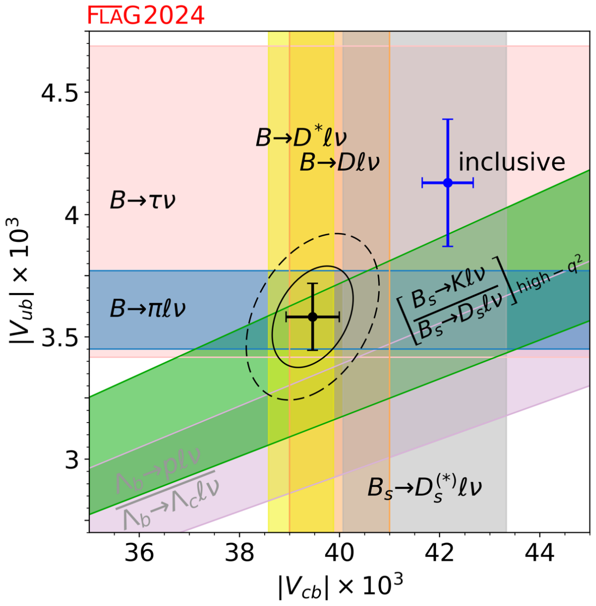




Short-distance QCD+EW:
Impressive progress

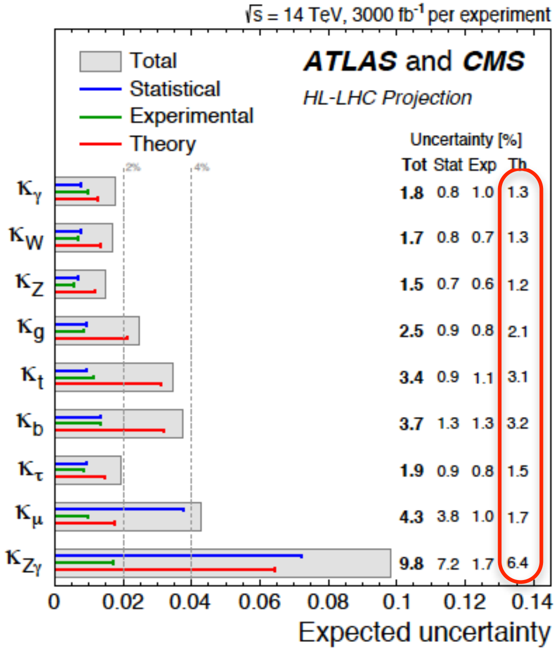
Moriond QCD

Long-distance QCD effects (PDF, hadronization, hadronic matrix elements, …)



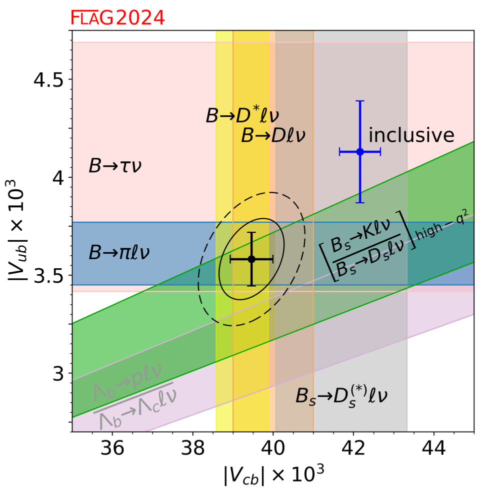
Moriond EW

Impact of:
QCD infrastructure,
Theoretical framework,
Observables (definition of), …



Controlling hadronic matrix elements in rare b decays

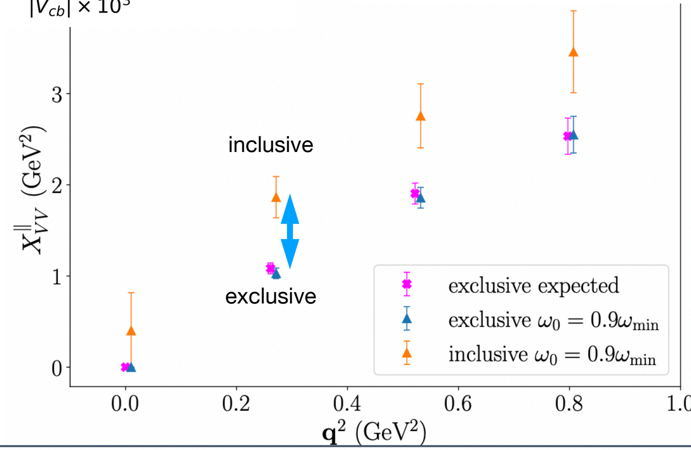
See talk by Andreas Jüttner



CKM puzzle (V_{cb} anomaly):
lattice+experiment
working on a fully comprehensive analysis of both and $B(s)$ and $D(s)$ inclusive decays

$$\langle D_s | V_\mu | B_s \rangle = f_+(q^2)(p_{B_s} + p_{D_s})_\mu + f_-(q^2)(p_{B_s} - p_{D_s})_\mu$$

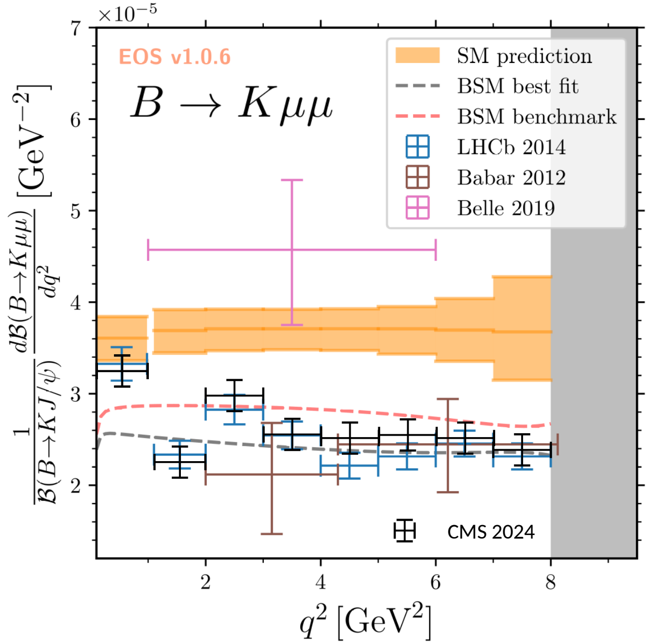
$$\bar{X}^{\parallel}_{VV} \to \frac{M_{B_s}}{E_{D_s}} \mathbf{q}^2 |f_+(q^2)|^2$$



D-mesons: CP-violation in charm decays,
Highly sensitive to new physics

See talk by Maria Laura Piscopo

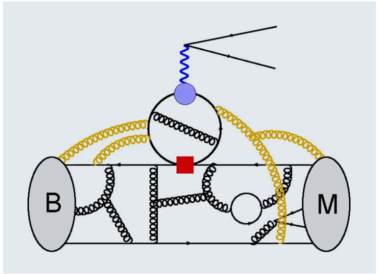
See talk by Méril Reboud



LHCb and CMS measure b FCNC with **unprecedented precision**

Large tensions observed

Theory affected by large uncertainties from **non-local form factors**, dominated by **charm loops**



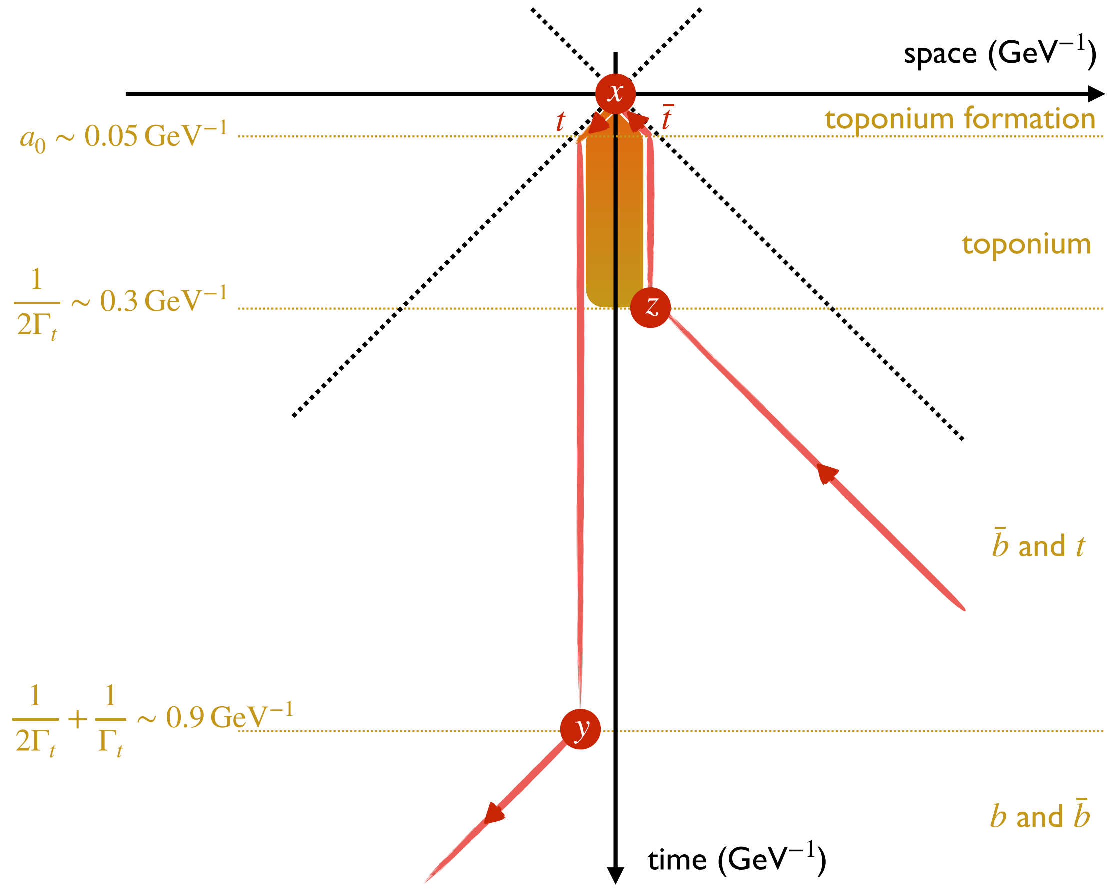
Theoretical uncertainty could mimic new physics.

Recent **progress on lattice QCD and analytic constraints** allow for large numerical analyses.

Top-antitop production near threshold

Toponium physics at the LHC

See talk by Benjamin Fuks



Probe of the QCD potential

- Toponium effects
- Currently not included in MC simulations

Top-antitop production near threshold

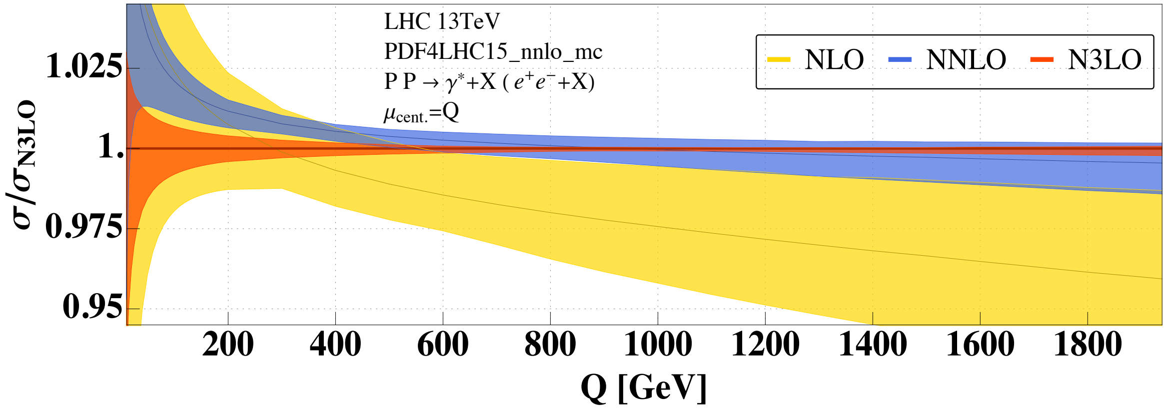
- Emergence of a toponium system at a scale of 0.05 GeV^{-1}
- Decay at a time scale of ~ 0.3 GeV^{-1}
- Occurs well before hadronisation at 5 GeV^{-1}

Possible impact on top-quark mass measurement

Reaching percent-level precision for (HL)-LHC physics

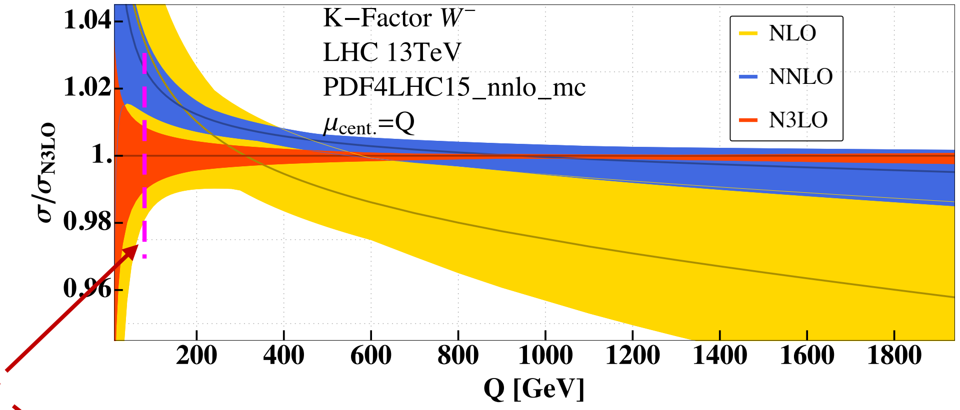
A prototype example: Drell-Yan production – what higher-orders can tell

NC-DY

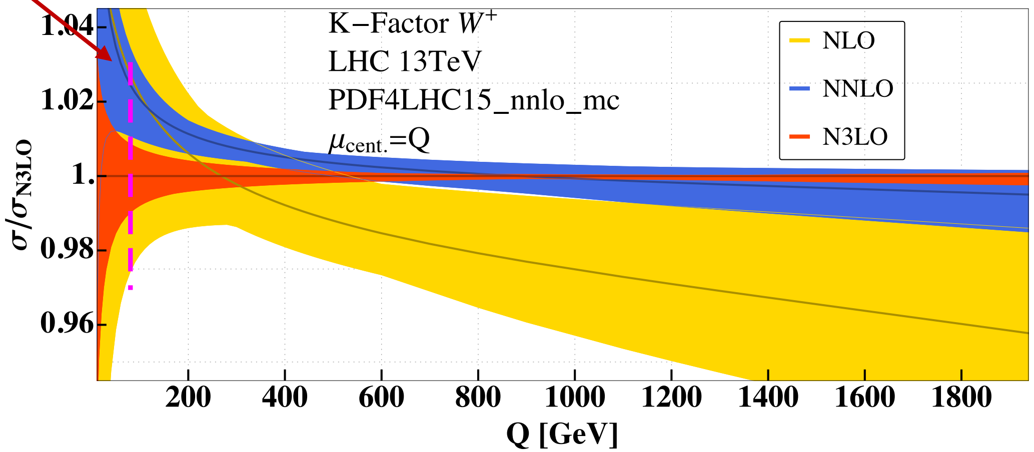


Duhr, Dulat, Mistlberger, 2001.07717

CC-DY



M_W



- Scale dependence: non-uniform behavior in all Q-regions
- Important input for PDFs (not yet included)
- **Region around Q~M_W: reconsider how to estimate theoretical uncertainty from scale variation**

Duhr, Dulat, Mistlberger, 2007.13313

Recall : **need 0.1% accuracy in template distributions in order to achieve ΔM_W~10 MeV**

SM – weakness

Apart from not explaining nor including

- The nature of **dark matter** and dark energy
- The origin of the **baryon asymmetry** of the universe
- The origin of **neutrino** masses
- **Gravity** as a quantum theory

All these themes have been at the core of this week's program!

They all come together at Moriond EW (neutrinos, BSM, DM, axions, cosmology)

The scalar sector of the SM itself leaves lots of questions unexplained and mainly fails to explain the origin of the EW scale itself

- Why the form of the **SM scalar potential**? $V(\phi) = \mu^2\phi^\dagger\phi + \lambda(\phi^\dagger\phi)^2$ $(\mu^2 < 0)$?
- Why a *light* **Higgs-boson mass** $(M_H \sim \Lambda_{EW})$. $M_H^2 = -2\mu^2$ $\rightarrow +O(\Lambda_{UV}{}^2)$?
- Why the hierarchy of **Yukawa couplings** (fermion masses)? Why this **new force**? $y_{ij} \rightarrow \frac{m_f}{v}\delta_{ij}$?

  Origin of quark/lepton flavor dynamics

- **Why one scalar**? **Elementary**? **Composite**?

$$L_{Yuk} = y_{ij}\bar{\psi}_L^i\phi\psi_R^j + h.c.$$

Exploring models beyond the SM

- BSM models **targeting SM failures and weaknesses**
  - Flavor hierarchies (CKM, PMNS, …)
  - Baryon Asymmetry of the Universe
  - Dark Matter

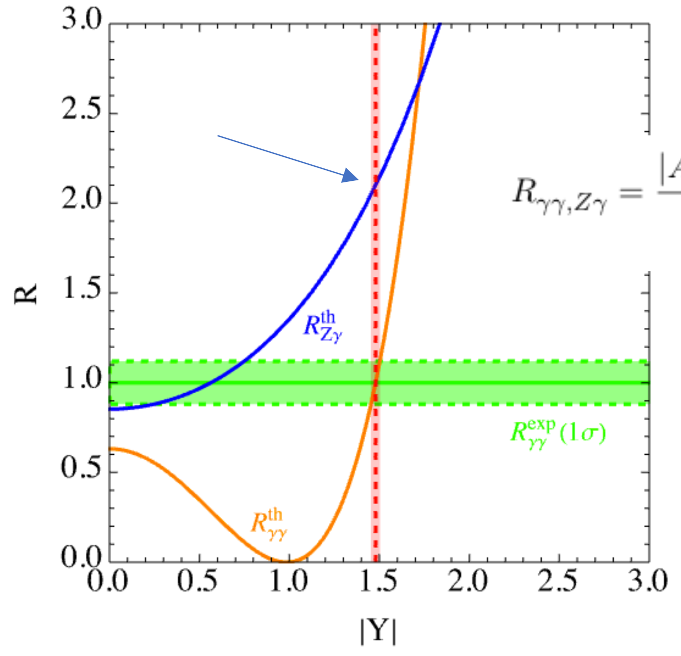
- BSM models **exploring unchartered regions**
  - Very light/weakly coupled (axions, DM, …)
  - Very heavy (beyond LHC bounds)

Light weakly-interacting particles

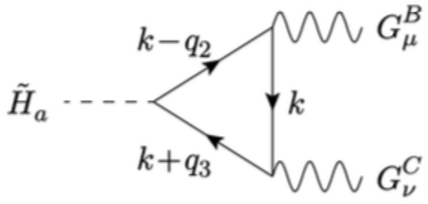
Could still have evaded detection so far

See talk by Marco Nardecchia

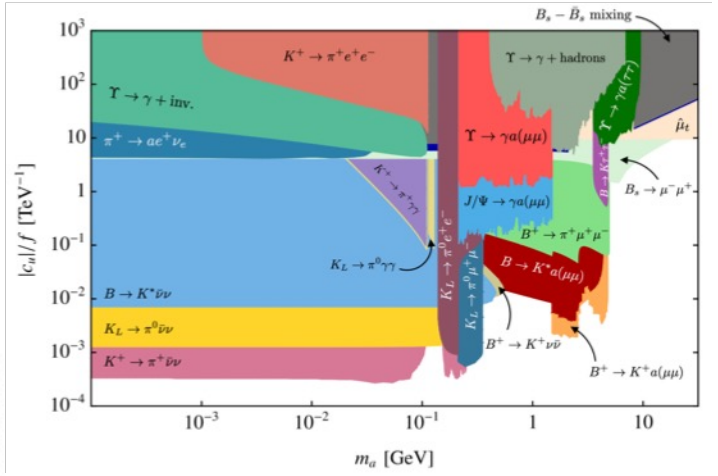
Models with **light vectors** accompanied by *anomalons*,
heavy chiral leptons which directly affect $H\gamma\gamma$ and $HZ\gamma$ couplings

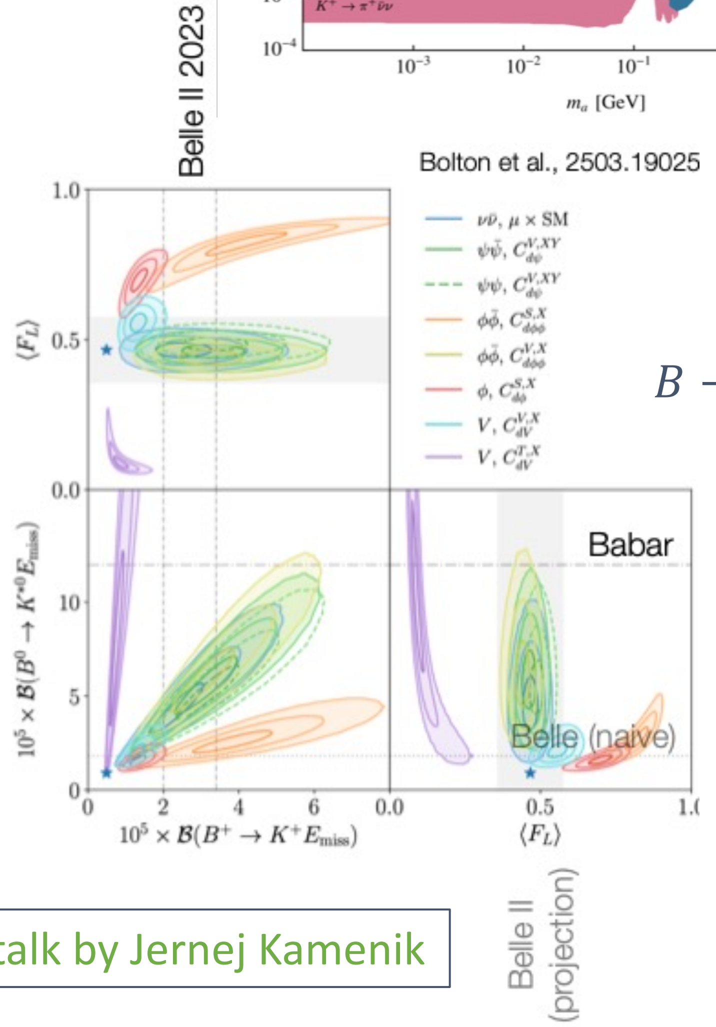


$$R_{\gamma\gamma,Z\gamma} = \frac{|A^{SM}_{\gamma\gamma,Z\gamma} + A^{BSM}_{\gamma\gamma,Z\gamma}|^2}{|A^{SM}_{\gamma\gamma,Z\gamma}|^2}$$



[ATLAS+CMS 2023: $R_{Z\gamma} = 2.2 \pm 0.7$]



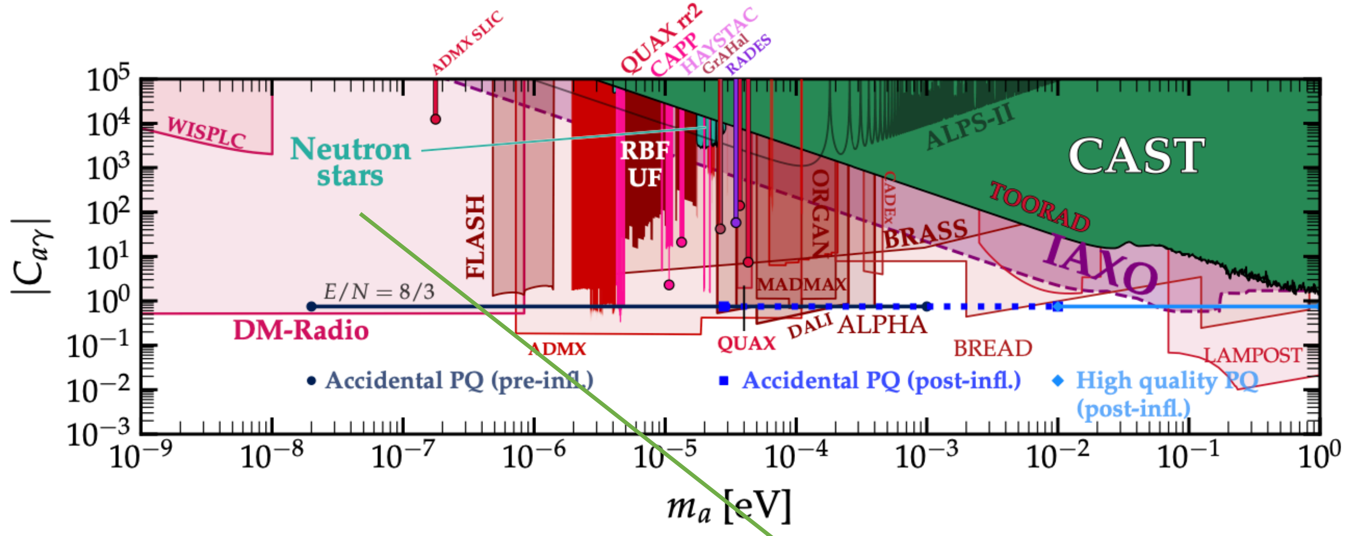


$B \to K^* + E_{miss}$,

See talk by Jernej Kamenik

Dark Matter/Axions

Phenomenological study of
Accidental SO(10) and Pati-Salam axions



See talk by Anupam Ray

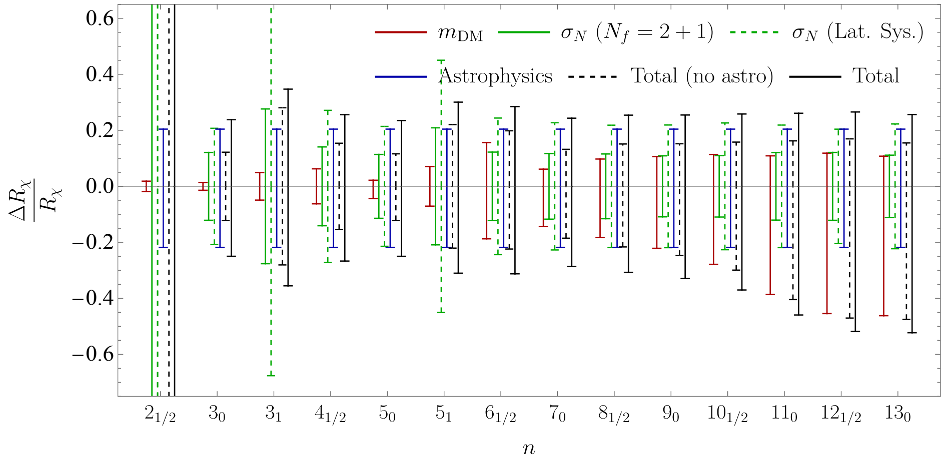
A proper PQ theory should:

- realize the PQ as an accidental symmetry
- protect the U(1)PQ against UV sources of PQ breaking (PQ-quality problem)

See talk by Luca Di Luzio

Is DM electroweak?

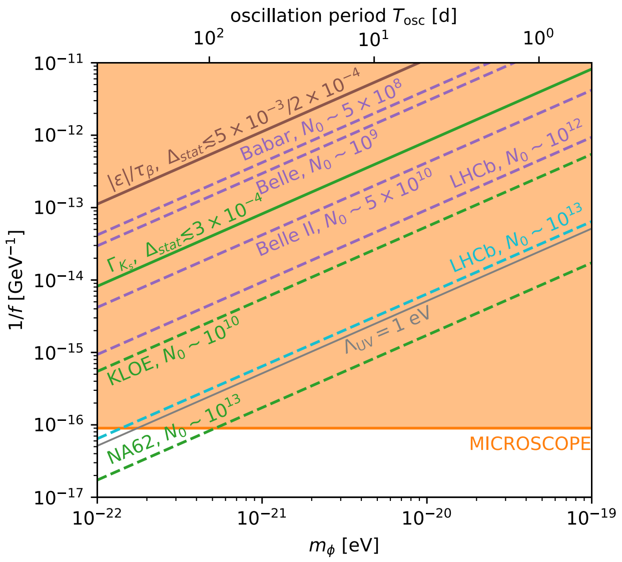
Comprehensive review of *EW DM survivors* pointing to **needed theoretical improvements**

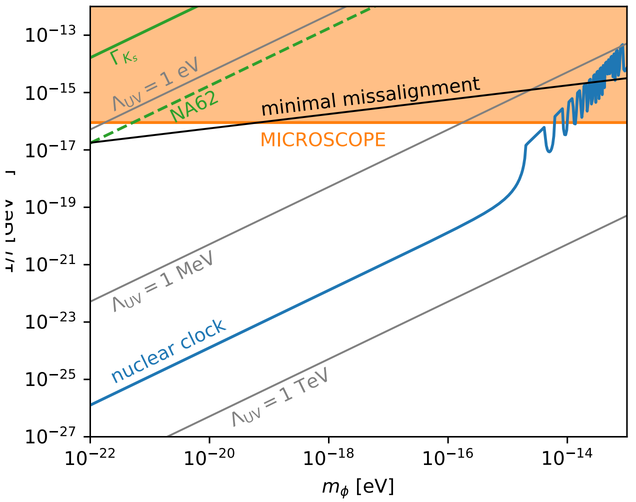


See talk by Diego Redigolo

DM with implications for Baryogenesis
See talks by Alejandro Ibarra and Miguel Escudero Abenza

Dark Matter/Axions





See talk by Gilad Perez

Nelson-Barr ultra-light DM

Non-QCD axion DM solving the strong CP problem

New type of pheno

- Time dependent CKM angles
- Probed by B-factories and nuclear clocks

Food for thought:

Shadow Matter (and Charge)

See talk by David E. Kaplan

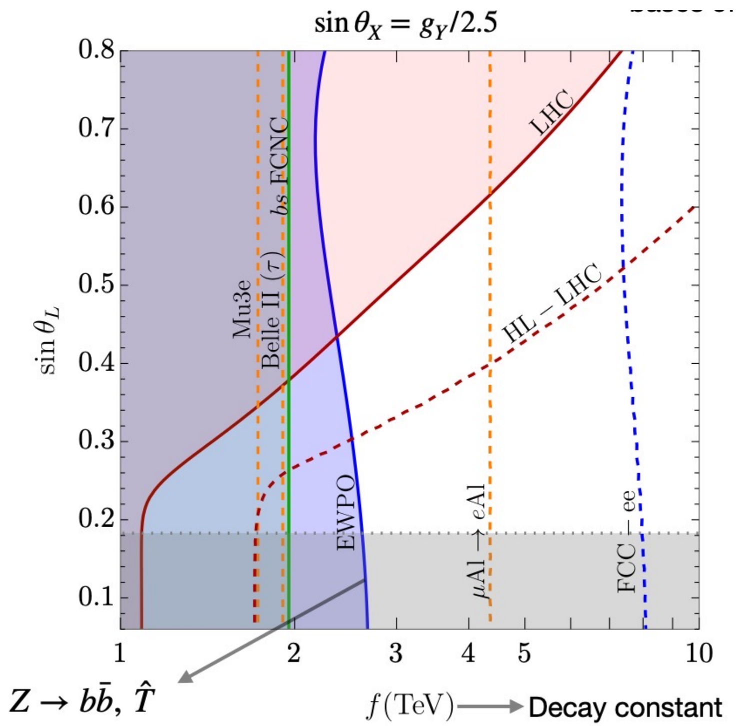
- Loosening constraints of GR allows for source terms that could explain why we think there is dark matter
- New source terms for EM produce a charged component of the fake dark matter. could affect the CMB, BBN, galactic dynamics, and direct detection. Challenging pheno (plasma dynamics)
- If Shadow Matter is most or all of dark matter, it is in conflict with inflation. Worth exploring new ideas for initial conditions.

CKM hierarchy vs PMNS anarchy

Pati-Salam + flavor deconstruction inspired + partial compositeness

See talk by Javier Lizana

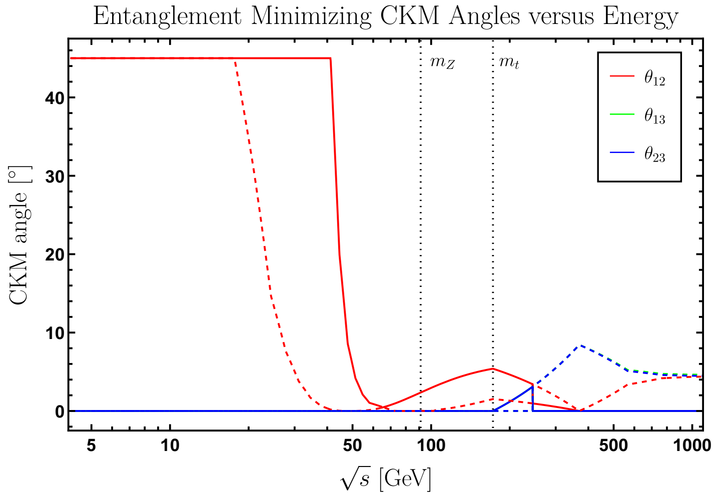
- Generate CKM/PMNS patterns
- Composite Higgs
- Testable at present/future experiments



See talk by Sokratis Trifinopoulos

Flavor pattern from quantum entanglement?

$$\mathcal{E}(\mathcal{S}_f) \equiv \overline{E\left(\mathcal{S}_f\,|i\rangle_u \otimes |j\rangle_d\right)} \qquad (ud \to ud)$$



$$\mathcal{E}_{\min}(\mathcal{S}_f) \equiv \min\left(\mathcal{E}_{ud}, \mathcal{E}_{u\bar{d}}\right)$$

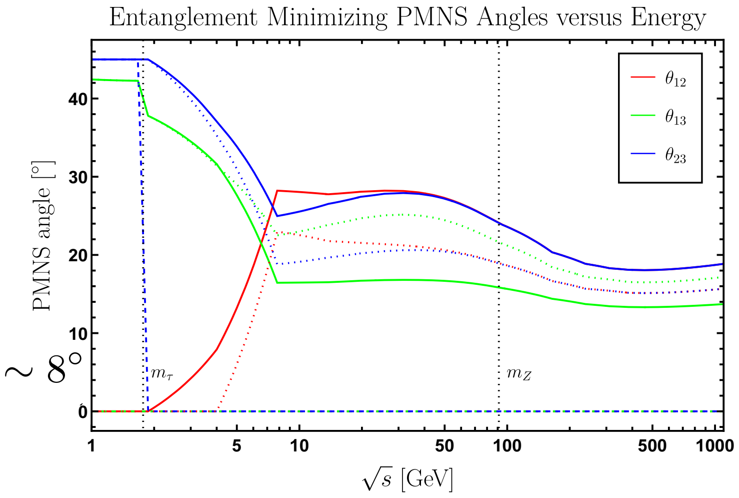
$$\theta^{\min}_{\mathrm{CKM},12} \sim 6^\circ, \quad \theta^{\min}_{\mathrm{CKM},23} \sim \theta^{\min}_{\mathrm{CKM},13} \approx 0$$

$$\theta^{\exp}_{\mathrm{CKM},12} \sim 13^\circ, \quad \theta^{\exp}_{\mathrm{CKM},23} \sim 2^\circ, \quad \theta^{\exp}_{\mathrm{CKM},13} \sim 0.2^\circ$$

$$\theta^{\mathrm{NO,min}}_{\mathrm{PMNS},12} \sim \theta^{\mathrm{NO,min}}_{\mathrm{PMNS},23} = 29^\circ, \quad \theta^{\mathrm{NO,min}}_{\mathrm{PMNS},13} = 16^\circ$$

$$\theta^{\mathrm{IO,min}}_{\mathrm{PMNS},12} \sim \theta^{\mathrm{IO,min}}_{\mathrm{PMNS},23} = 21^\circ, \quad \theta^{\mathrm{IO,min}}_{\mathrm{PMNS},13} = 25^\circ$$

$$\theta^{\exp}_{\mathrm{PMNS},12} \sim 33^\circ, \quad \theta^{\exp}_{\mathrm{PMNS},23} \sim 48^\circ, \quad \theta^{\exp}_{\mathrm{PMNS},13} \sim 8^\circ$$



Extended scalar sectors

For a more general overview:
see talk by Tania Robens

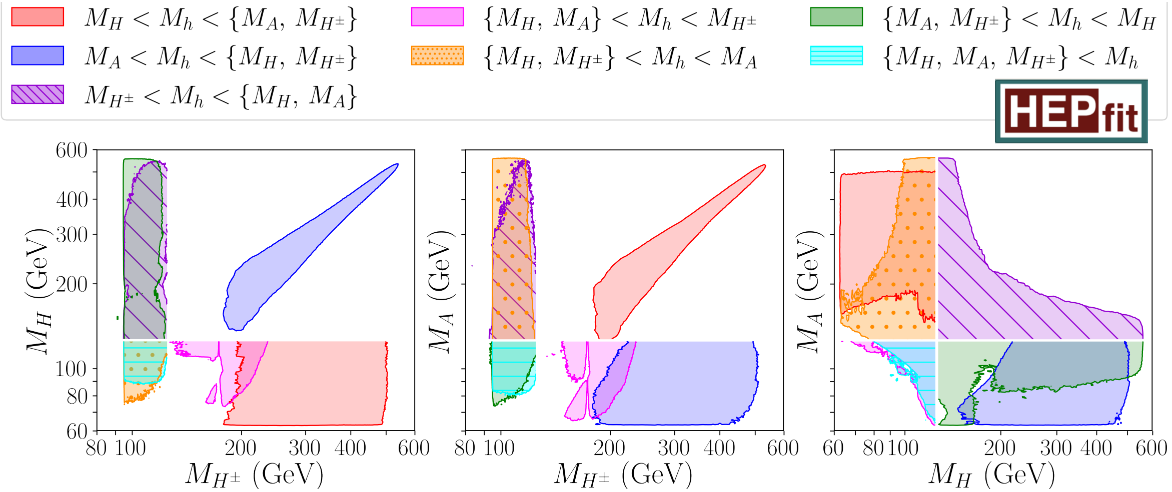
Aligned 2HDM

$$Y_{u,d,l} = \zeta_{u,d,l} M_{u,d,l}$$

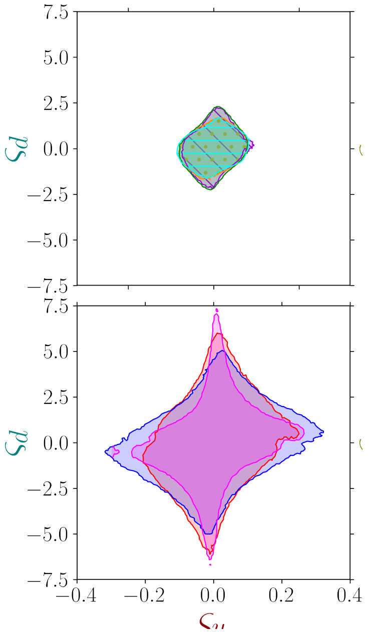
Global fit of EW, Higgs, top, flavor

See talk by Victor Miralles

Masses



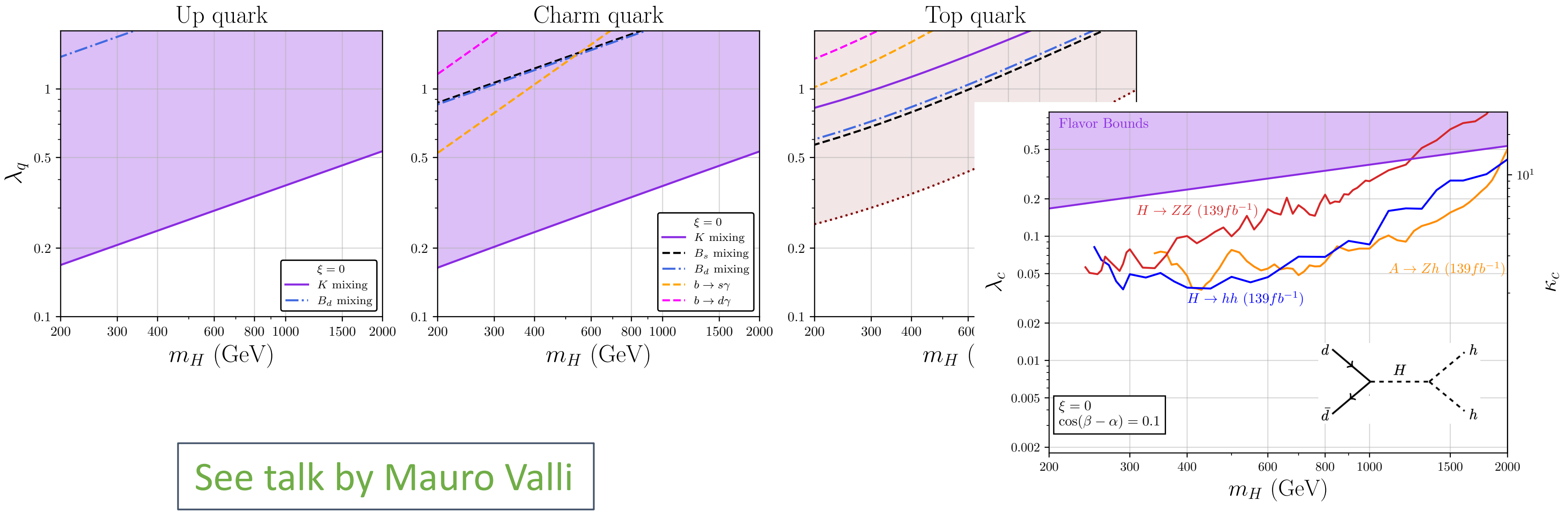
Yukawa couplings



S(ponstaneous)FV 2HDM

$$\mathcal{Y}_1^u = y^u = \text{diag}(y_u, y_c, y_t)$$
$$\mathcal{Y}_2^u = \lambda^u = \text{diag}(\lambda_u, \lambda_c, \lambda_t)$$

$$\mathcal{Y}_1^d = V y^d \qquad \mathcal{Y}_1^\ell = y^\ell$$
$$\mathcal{Y}_2^d = \xi\, V y^d \qquad \mathcal{Y}_2^\ell = \xi^\ell y^\ell$$



See talk by Mauro Valli

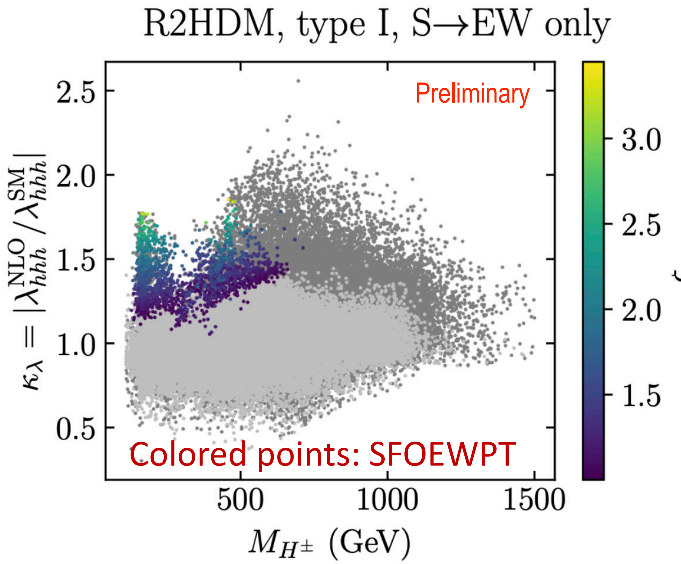
$T = 0 \rightarrow T > 0$

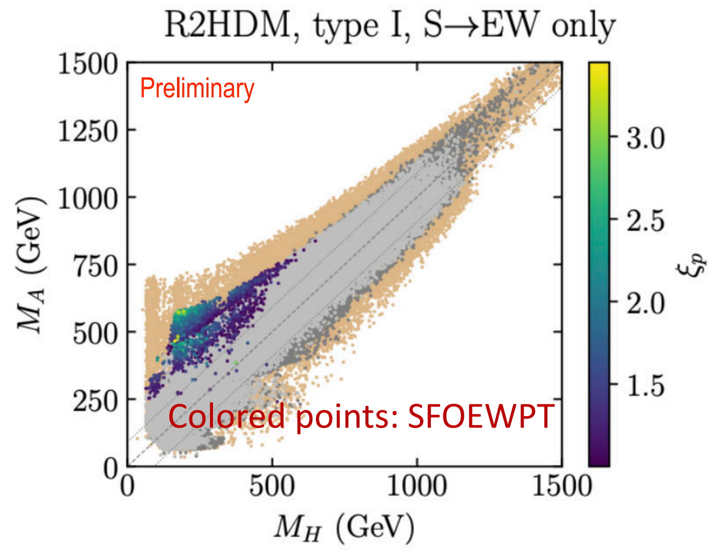
See talk by Margarete Mühlleitner

Study the **vacuum history** and the **possibility of a strong 1st order EW phase transition** (condition for EW baryogenesis)

Phenomenological implications:

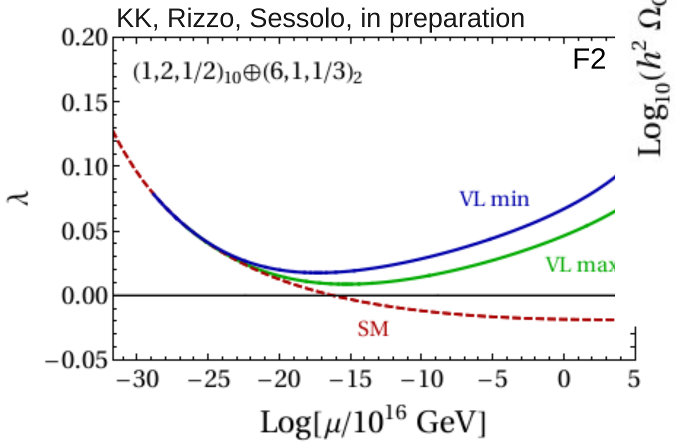
- Enhanced trilinear Higgs couplings
- Detectable Gravitational Waves

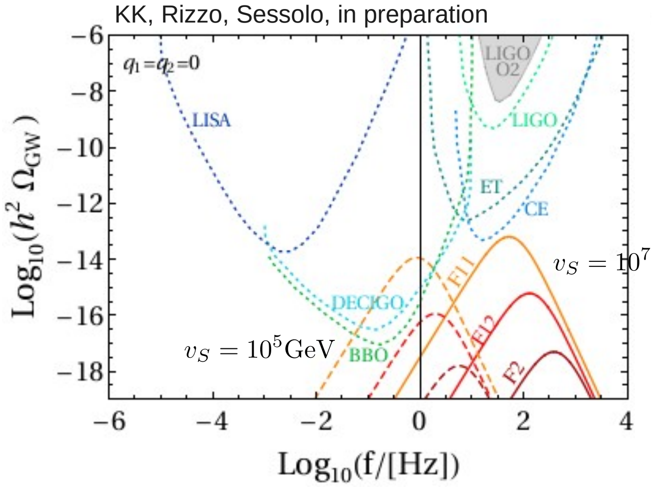




F_x → different PGU models

Similar study for BSM theories with vector-like fermions (assuming SU(5) perturbative conditions at GUT scale)





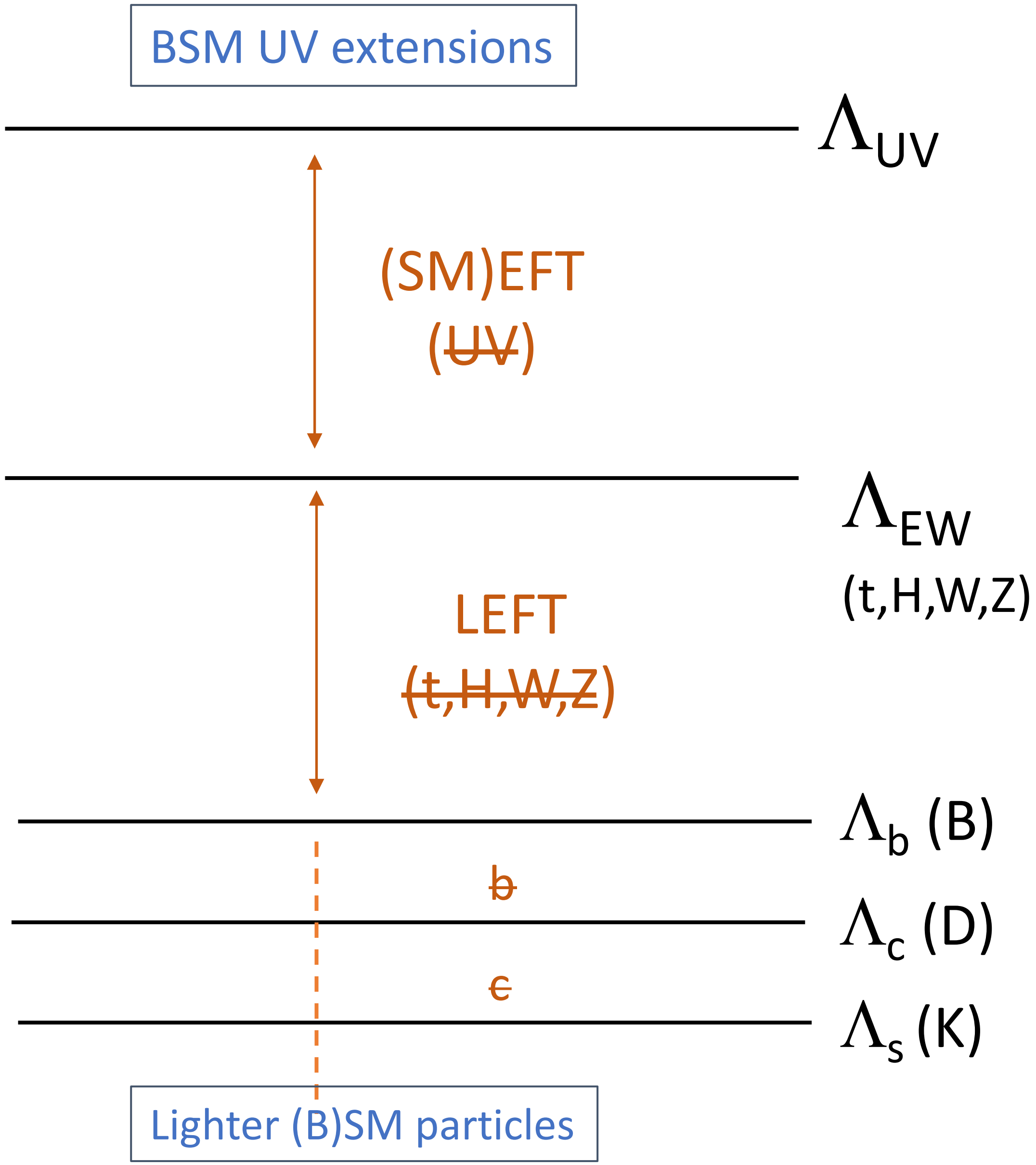
See talk by Kamila Kowalska

Interpreting new physics

- Within the more **general framework** of **effective field theories**
  - SM Effective Field Theory
  - Low Energy Effective Field Theory (Flavor)
  - Effective theory for $\mu \to e$ conversion

- Matching to UV models

Connecting far apart scales: the EFT picture



Heavy physics decouples and leaves effective contact interactions of dim > 4

RGE

EFT operators in terms of SM fields

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum_{i,d} \frac{C_{i,d}^{SMEFT}}{\Lambda^{d-4}} O_{i,d}^{SMEFT}$$

RGE

WC depend on m_t, M_W, M_Z, M_H, …M_X

$$\mathcal{L}_{LEFT} = \mathcal{L}_{QED+QCD} + \sum_{i,d} \frac{C_{i,d}^{LEFT}}{\Lambda_{EW}^{d-4}} O_{i,d}^{LEFT}$$

Calculate physical processes at each scale and derive constraints on the UV theory

Beyond EW fits – Higgs, top, flavour observables

Connecting far apart scales naturally lends itself to the EFT framework

Λ_{UV}

$C_{i,d}^{SMEFT}(\Lambda_{UV})$ (from matching to UV theory)

SMEFT
(~~UV~~)

Will be constrained by the global fit together with SM parameters

Evolved to $C_{i,d}^{SMEFT}(\Lambda_{EW})$

Based on 1-loop SMEFT anomalous dimension

Jenkins, Manohar, and Trott, 1308.2627, 1310.4838,1312.2014

Λ_{EW}
(t,H,W,Z)

All fit observables are calculated in terms of $C_{i,d}^{SMEFT}(\Lambda_{EW})$

LEFT
(~~t,H,W,Z~~)

Match to LEFT operators to calculate flavour observables

Jenkins, Manohar, Stoffer, 1709.04486, 1711.05270

Λ_b (B)

Λ_c (D)

Λ_s (K)

So far only LO RGE evolution can be consistently implemented, NLO RGE evolution requires 2-loop anomalous dimension.

SMEFT Global Fits

Constraining new physics through the spectrum of LHC and b-factory measurements

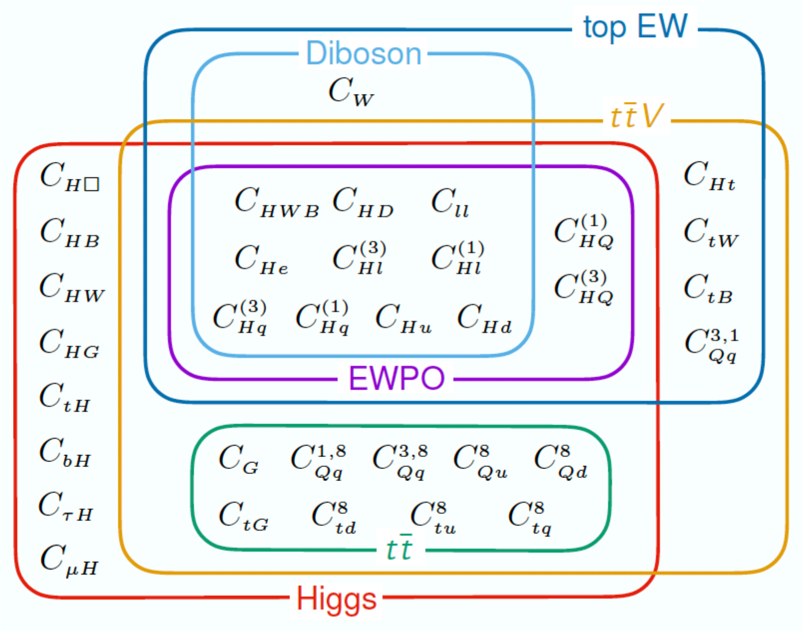
- Higgs boson observables
  - Production and decay rates
  - Simplified Template Cross Sections (STXS)

See ATLAS and CMS talks

- Top quark observables
  - $pp \to t\bar{t}, t\bar{t}Z, t\bar{t}W, t\bar{t}\gamma, tZq, t\gamma q, tW, \ldots$

- Drell-Yan, Di-boson measurements
  - $pp \to W, Z \to f_i \bar{f}_j$
  - $pp \to WZ, WW, ZZ, Z\gamma$

- Flavor observables
  - ΔF=2: $\Delta M B_{d,s}$, $D^0 - \bar{D}^0$, ε_K
  - Leptonic decays: $B_{d,s} \to \mu^+\mu^-$, $B \to \tau\nu$, $D \to \tau\nu$, $K \to \mu\nu$, $\pi \to \mu\nu$
  - Semi-leptonic decays: $B \to D^{(*)} l\nu$, $K \to \pi\nu\bar{\nu}$, $B \to K\nu\bar{\nu}$, $B, K \to \pi l\nu$
  - Radiative B decays ($B \to X_{s,d}\gamma$)



See Belle and LHCb talks

SMEFT: beyond SM coupling rescaling

Framework: Extend SM Lagrangian by effective interactions (SMEFT)

$$\mathcal{L}_{\text{SM}}^{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{d>4} \frac{1}{\Lambda^{d-4}} \mathcal{L}_d = \mathcal{L}_{\text{SM}} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \cdots$$

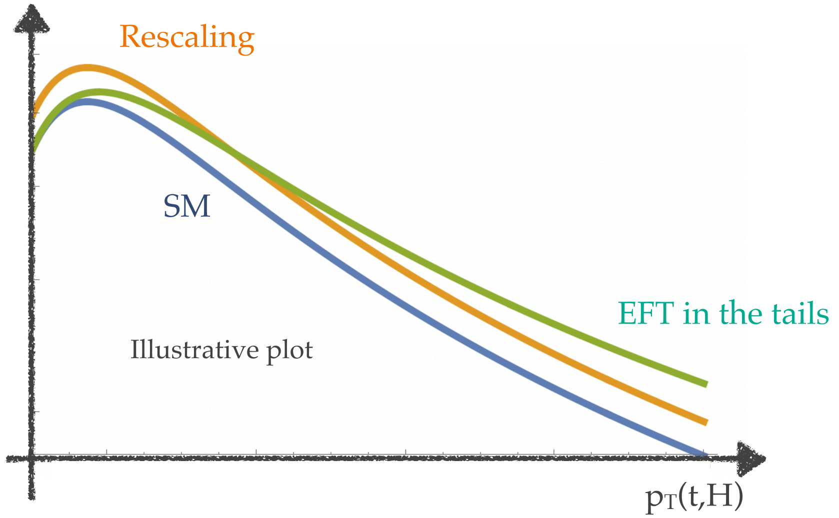
$$\mathcal{L}_d = \sum_i C_i^{(d)} \mathcal{O}_i^{(d)}, \quad \left[\mathcal{O}_i^{(d)}\right] = d$$

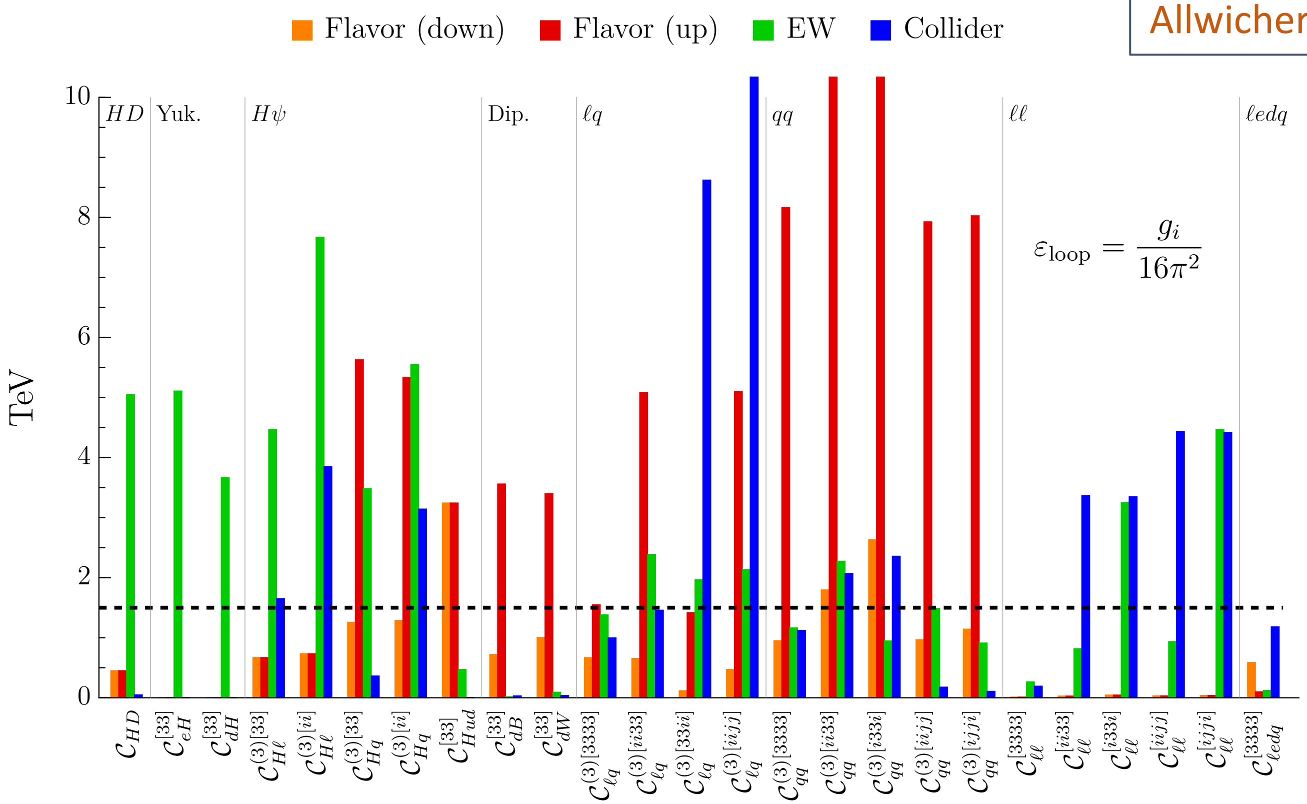
Under the assumption that new physics leaves at scales $\Lambda > \sqrt{s}$

Built of SM fields and respecting the SM gauge symmetry.

Expansion in $(v, E)/\Lambda$: **affects all SM observables** at both low and high energy

- **SM masses and couplings** → **rescaling**
- **Shapes of distributions** → more visible in **tails of distributions**

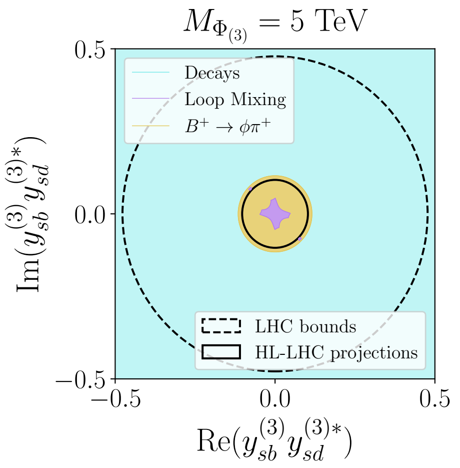




Allwicher, Cornella, Isidori, Stefanek: 2311.00020

Flavour assumption: U(2)^5 scenario
4q-operators drastically constrained by flavour observables, put strong bound on new physics scale when added to a global fit

This can be mapped to specific UV models



Can be instructive to have a class of models in mind

See talk by Christoph Englert

Scalar diquarks → probe composite scenarios

$$\mathcal{L}_{(6)} = -y^{(6)}_{ij}\,\Phi^{(ab)}_{(6)}\, d^{Ta}_{Ri} C d^{b}_{Rj} + \text{h.c.},$$

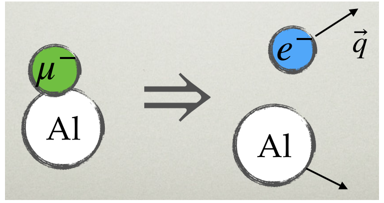
$$\mathcal{L}_{(3)} = -y^{(3)}_{ij}\,\Phi^{a}_{(3)}\, \epsilon_{abc}\, d^{Tb}_{Ri} C d^{c}_{Rj} + \text{h.c.}$$

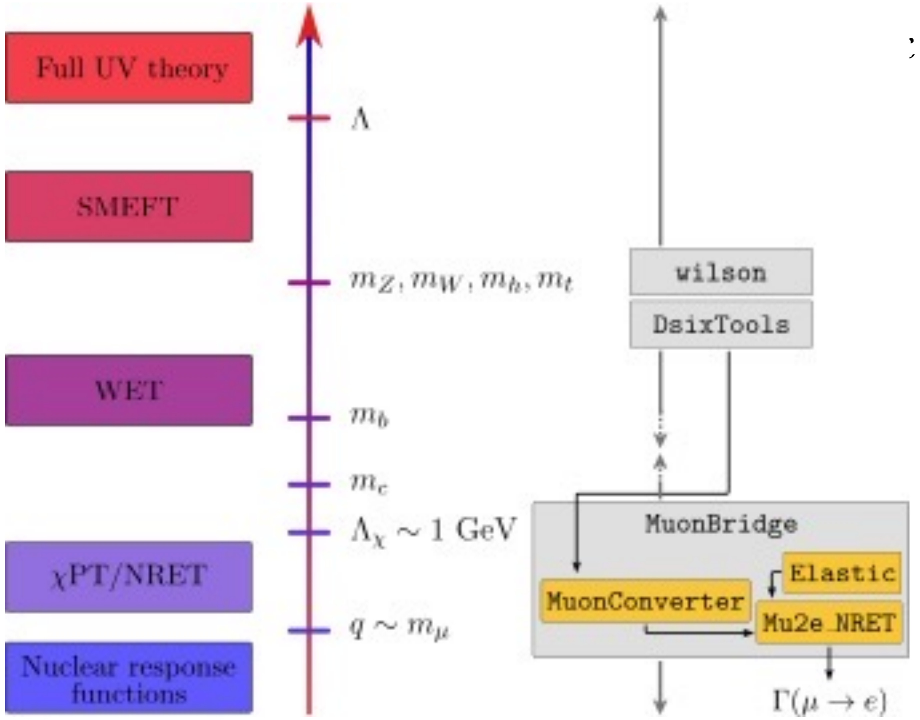
State	Spin	SM charges	Tree-level generated operators
$\Phi_{(3)}$	0	$(\mathbf{3},\mathbf{1})_{2/3}$	O_{dd}
$\Phi_{(6)}$	0	$(\bar{\mathbf{6}},\mathbf{1})_{2/3}$	O_{dd}

$$O_{dd} = (\bar{d}^i_R \gamma^\mu d^j_R)(\bar{d}^k_R \gamma_\mu d^l_R)$$

Effective theory for $\mu \to e$ conversion

See talk by Jure Zupan





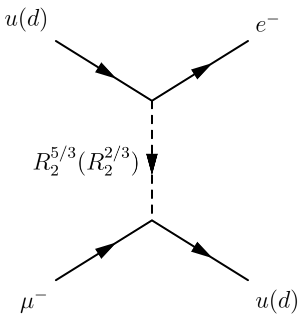
$$\supset -y^{RL}_{2\,ij}\,\bar{u}^i_R R^a_2 \epsilon^{ab} L^{j,b}_L + y^{LR}_{2\,ij}\,\bar{e}^i_R R^{a\,*}_2 Q^{j,a}_L + \text{h.c.},$$

$$C^{12ii}_{\ell u} = -\frac{1}{2m^2_{\rm LQ}} y^{RL}_{2\,i2} y^{RL*}_{2\,i1},$$

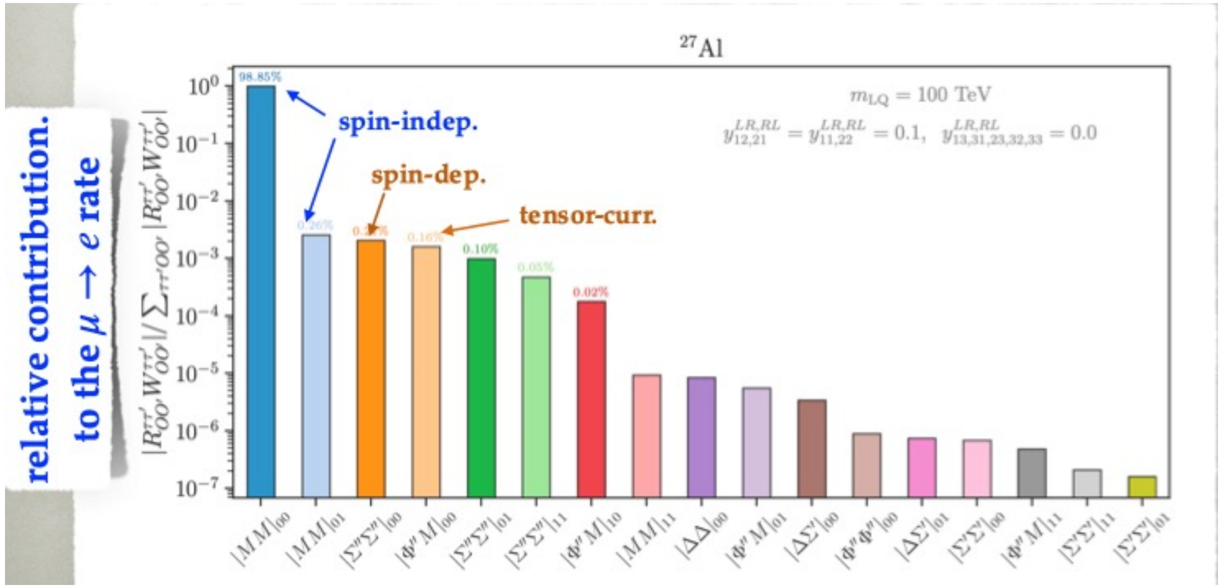
$$C^{ii12}_{qe} = -\frac{1}{2m^2_{\rm LQ}} y^{LR*}_{2\,2i} y^{LR}_{2\,1i},$$

$$C^{(1),12ii}_{\ell equ} = 2C^{(3),12ii}_{\ell equ} = -\frac{1}{2m^2_{\rm LQ}} y^{LR*}_{2\,2i} y^{RL*}_{2\,i1},$$

$$C^{(1),21ii}_{\ell equ} = 2C^{(3),21ii}_{\ell equ} = -\frac{1}{2m^2_{\rm LQ}} y^{LR}_{2\,i2} y^{RL}_{2\,1i},$$



Example: Leptoquark Model



Probing heavy new physics in $\mu \to e$ conversion

Overview talks

We had some very nice **overview talks**:

- Global Analysis of neutrino data (Ivan Esteban)
- Large Scale Structures Observations (Ruth Durrer)
- Connecting to cosmic inflation (Marco Drewes)
- H0 tension (Martin Schmaltz)
- Gravitational Waves: present and future (Valerie Domcke)

Thank you!

- **To the organizers and the staff** who has hosted us during this remarkable week.
- **To all the speakers** who have reported about so many different exciting results and ideas.
- **To all our colleagues** who have contributed to the work we have heard about.