Expedition Beyond the Standard Model:
Charting new territories in Particle Physics

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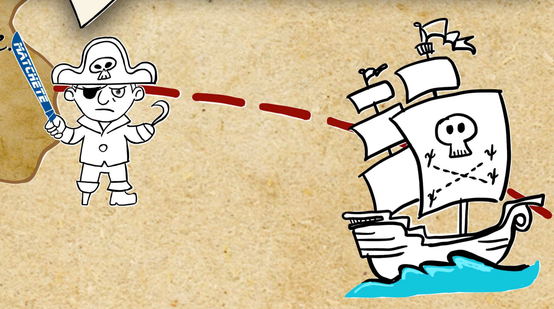
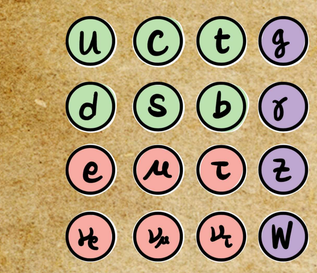
The starting point of our journey is the Standard Model, a mathematical model that specifies the fundamental interactions of the elementary constituents of matter, quarks and leptons.

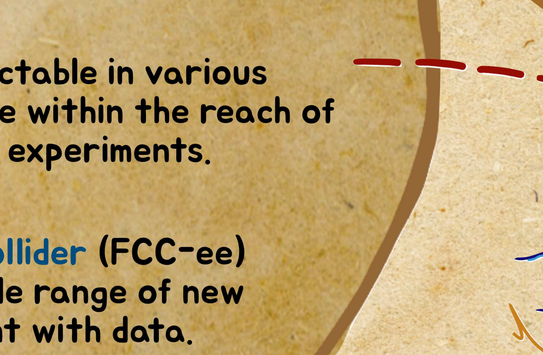
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\psi} \not{D} \psi + h.c. + \psi_i y_{ij} \psi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$

Ahoy! Be ready to leave the familiar shores of the SM, and navigate the turbulent seas of physics that lies beyond!





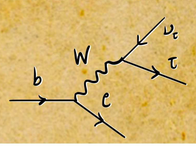
The unexplained problems of the SM (gravity, dark matter, neutrino masses, hierarchy problem, strong CP problem...) are the reasons to start our quest for new physics.



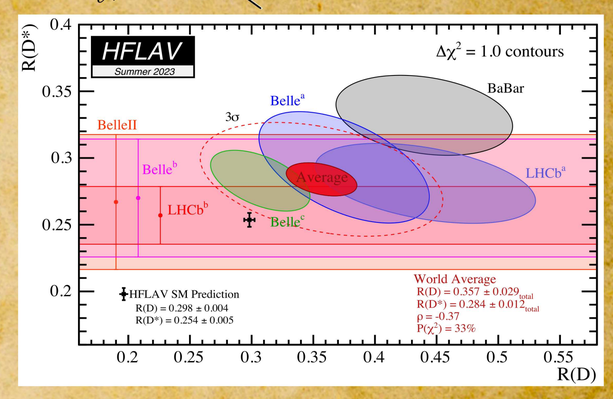
One big mystery is the mass hierarchy of fermions: what is the origin of the peculiar pattern of the masses of quarks and leptons?
Maybe this particular structure is a hint of how new physics should look like...

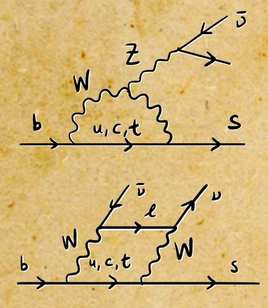
Also, some unexpected results have been observed in experiments related to the decays or interactions involving different quark flavors (the so-called anomalies):

- $R_{D^{(*)}} = \dfrac{\mathcal{B}(\bar{B} \to D^{(*)} \tau \bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^{(*)} \ell \bar{\nu}_\ell)}$

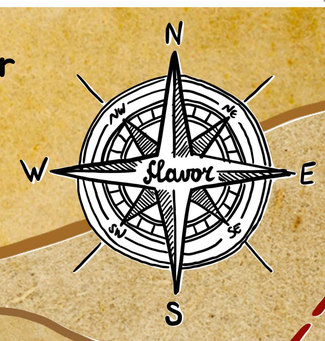


- $B \to K^{(*)} \bar{\mu} \mu$
- $B_s \to \phi \ell \bar{\ell}$
- $B \to K \bar{\nu} \nu$





We can use flavor as our guide to build extensions of the SM!



Our group also follows a top-down approach: we try to build ultraviolet models to address the unexplained phenomena.

In particular, we explore models where flavor hierarchies emerge from underlying flavor non-universal gauge structure (flavor deconstruction), and we look at the phenomenological implications of such models.

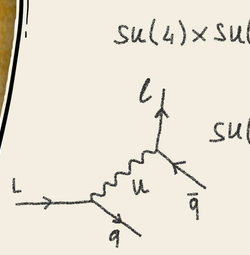
These models feature quark-lepton unification in the third family, and predict the existence of new particles, such as vector-like fermions, massive bosons, and leptoquarks.

These new degrees of freedom would be detectable in various observables, and their low-energy signatures are within the reach of the present generation of flavor-physics experiments.

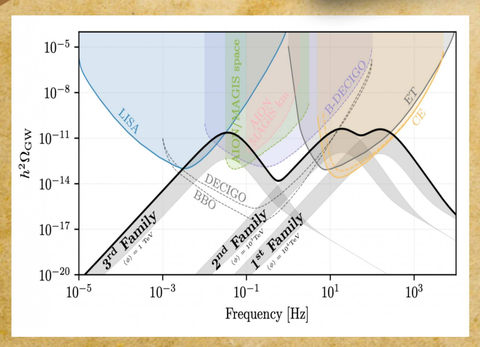
Furthermore, the proposed Future Circular Collider (FCC-ee) would be able to either confirm or refute a wide range of new physics models that are currently consistent with data.

One possible extension of the SM is the 4321 model:

$$SU(4) \times SU(3)' \times SU(2)_L \times U(1)' \downarrow SU(3)_c \times SU(2)_L \times U(1)_Y$$



Our exploration continues with gravitational waves! Indeed, signals of new physics could be imprinted in their spectrum.



As the Universe cools down after inflation, some high-energy model symmetries break spontaneously. Rapidly expanding bubbles are created, and colliding, they generate shock waves that perturb the spacetime metric.

Gravitational waves are then produced and their power spectrum can be detected by LISA.

One of the main tools of the BSM explorer is Effective Field Theories.

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \frac{1}{\Lambda^2} \sum_i C_i \mathcal{O}_i$$

Our group develops numerical and theoretical tools to simplify and automatize EFT computations.

HighPT

MATCHETE

We know there must be new physics out there waiting to be discovered!

Do you want to join our crew?

Jason Aebischer
Lukas Allwicher
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Sandro Maechler
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Gioacchino Piazza
Emanuelle Pinsard
Zachary Polonsky
Davide Racco
Arianna Tinari