The NP and (hopefully) SM flavor puzzles at LHC

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Interplay of collider and flavour physics, general meeting

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Open Questions

The New Physics flavor puzzle

- Consider, for example

$\frac{z_{sd}}{\Lambda^2_{\rm NP}}(\overline{d_L}\gamma_\mu s_L)^2 + \frac{z_{cu}}{\Lambda^2_{\rm NP}}(\overline{c_L}\gamma_\mu u_L)^2$

- For $\Lambda_{\rm NP} \lesssim TeV$:

$$\begin{aligned} |z_{sd}| &\lesssim 9\times 10^{-7} \\ \mathcal{I}m(z_{sd}) &\lesssim 3\times 10^{-9} \\ |z_{cu}| &\lesssim 6\times 10^{-7} \\ \mathcal{I}m(z_{cu}) &\lesssim 1\times 10^{-7} \end{aligned}$$

$\Longrightarrow$ The flavor structure of NP@TeV must be highly non-generic

How? Why? = The NP flavor puzzle

The Supersymmetric flavor puzzle

$$\boxed{\frac{\Delta\tilde{m}^2_{ij}}{\tilde{m}^2} \times K_{ij} \ll 1}$$

Why? = The SUSY flavor puzzle

- Solutions:
  - Degeneracy: $\Delta\tilde{m}^2_{ij} \ll \tilde{m}^2$
  - Alignment: $K_{ij} \ll 1$
  - Gauge-mediation
  - Horizontal symmetries

Minimal Flavor Violation (MFV)

- Theoretical requirements:
  - NP fields have well-defined transformation properties under $G_{\text{flavor}}^{\text{quarks}} = SU(3)_Q \times SU(3)_U \times SU(3)_D$
  - The only spurions that break $G_{\text{flavor}}^{\text{quarks}}$ are $Y_u(3, \bar{3}, 1), \quad Y_d(3, 1, \bar{3})$

- Phenomenological predictions:
  - The third generation practically decoupled from the first two
  - Often 2+1 spectrum

The SM flavor puzzle

$$Y_t \sim 1, \quad Y_c \sim 10^{-2}, \quad Y_u \sim 10^{-5}$$
$$Y_b \sim 10^{-2}, \quad Y_s \sim 10^{-3}, \quad Y_d \sim 10^{-4}$$
$$Y_\tau \sim 10^{-2}, \quad Y_\mu \sim 10^{-3}, \quad Y_e \sim 10^{-6}$$
$$|V_{us}| \sim 0.2, \quad |V_{cb}| \sim 0.04, \quad |V_{ub}| \sim 0.004, \quad \delta_{\rm KM} \sim 1$$

- For comparison: $g_s \sim 1, \quad g \sim 0.6, \quad g' \sim 0.3, \quad \lambda \sim 1$
- The SM flavor parameters have structure: smallness and hierarchy
- Why? = The SM flavor puzzle

The Froggatt-Nielsen mechanism

- Approximate "horizontal" symmetry (e.g. $U(1)_H$)
- Small breaking parameter $\epsilon = \langle S_{-1} \rangle / \Lambda \ll 1$
- $\mathbf{10}(2,1,0), \quad \bar{\mathbf{5}}(0,0,0)$

$$\Downarrow$$

$$Y_t : Y_c : Y_u \sim 1 : \epsilon^2 : \epsilon^4$$
$$Y_b : Y_s : Y_d \sim 1 : \epsilon : \epsilon^2$$
$$Y_\tau : Y_\mu : Y_e \sim 1 : \epsilon : \epsilon^2$$
$$|V_{us}| \sim |V_{cb}| \sim \epsilon, \quad |V_{ub}| \sim \epsilon^2, \quad \delta_{\rm KM} \sim 1$$

$$+$$

$$m_3 : m_2 : m_1 \sim 1 : 1 : 1$$
$$|U_{e2}| \sim 1, \quad |U_{\mu 3}| \sim 1, \quad |U_{e3}| \sim 1$$

What will we learn?

New flavor parameters

- If ATLAS/CMS observe new particles that couple to the SM quarks and leptons...
- ... then there are new flavor parameters that can, in principle, be measured:
  - The spectrum
  - The flavor decomposition (BR's)
- We will surely make progress on the NP flavor puzzle
- We may make progress on the SM flavor puzzle

Testing MFV

- If ATLAS/CMS observe a new particle that decays to both third generation (t, b) and light generation (not t, b) quarks:

$\Longrightarrow$ MFV will be excluded

- Concrete example: $B' \to q + (W \text{ or } Z \text{ or } H)$

Grossman, Nir, Thaler, Volansky, Zupan, arXiv:0706.1845

- Can we nevertheless measure the $\mathcal{O}(V_{ti})$ mixing effects?

$\Longrightarrow$ If so, strong support to MFV

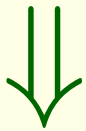
- Concrete example: $\widetilde{t} \to c\chi_1^0$

Hiller, Nir, arXiv:0802.0916

Solving the SUSY flavor puzzle

Imagine that sleptons are observed at ATLAS/CMS and...

- The slepton mass splitting is measured
- The slepton flavor decomposition is determined



- We will understand the supersymmetric mechanism of flavor suppression
- We will probably understand the mediation mechanism and determine its scale

Feng, Lester, Nir, Shadmi, arXiv:0712.0674

Hiller, Hochberg, Nir, arXiv:0812.0511

Feng, French, Galon, Lester, Nir, Sanford, Shadmi, Yu, work in progress

Solving the SM flavor puzzle?

Perhaps, if the NP flavor structure is determined by the same physics that generates smallness and hierarchy in the SM Yukawa

- Imagine: ATLAS/CMS discover supersymmetry
- Gauge mediation dominates
- Gravity mediation non-negligible
- $\Longrightarrow \quad \tilde{M}^2 = \tilde{m}^2(\mathbf{1} + r_{\text{gravity/gauge}} X)$
- Mixing determined by X, no matter how small r is
- It is plausible that X is determined by the FN mechanism
- Measure mixing $\Longrightarrow$ Test FN

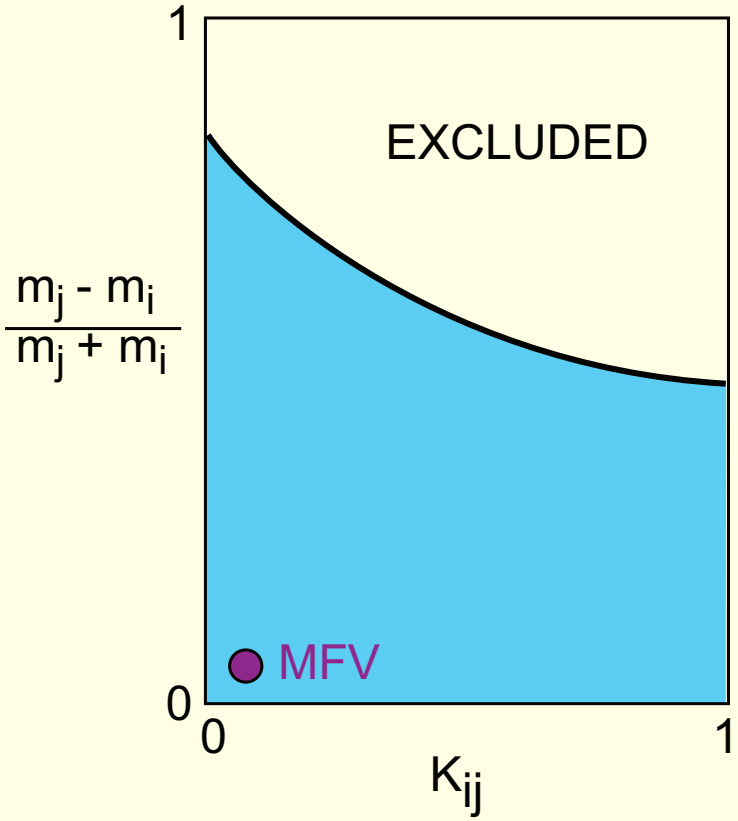
Feng, Lester, Nir, Shadmi, arXiv:0712.0674

Conclusions

ATLAS/CMS and flavor factories give complementary information

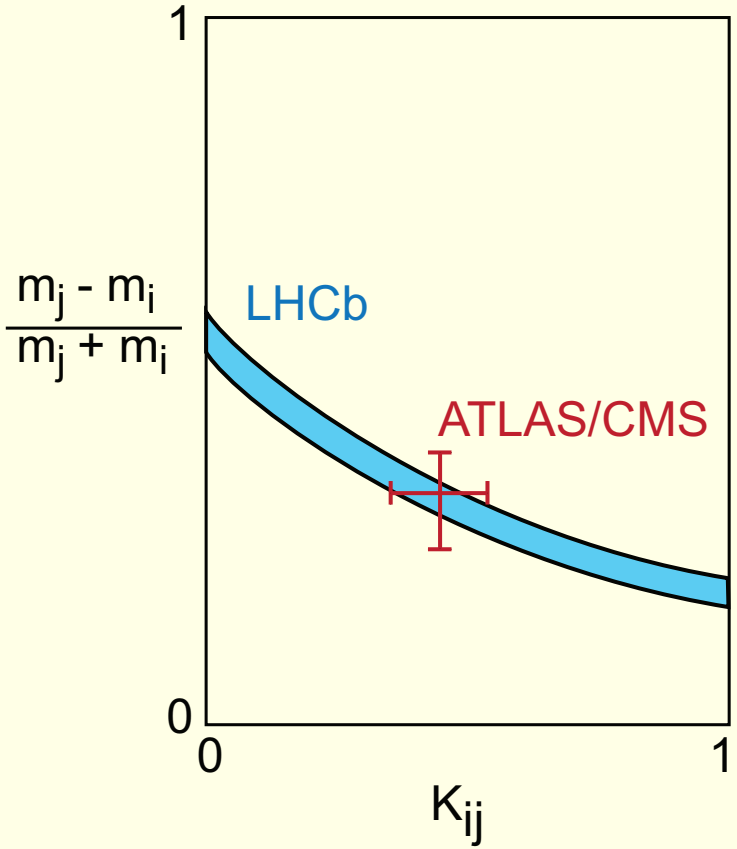
- In the absence of NP at ATLAS/CMS, flavor factories will be crucial to find $\Lambda_{\rm NP}$
- The NP flavor puzzle is likely to be understood
- With supersymmetry: The SM flavor puzzle may be solved
- Flavor can probe physics at $\Lambda_{\rm NP} \gg \Lambda_{\rm LHC}$

The SUSY flavor plane



Flavor Factories

MFV



FF+ATLAS/CMS

Non-MFV