Flavor Benchmarks

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1. The general idea(s)

Benchmarks: (are not a new idea . . .)

a set of parameter points in a (your favorite) model (beyond the SM)

- **Tool for BSM searches** at colliders (past, present, future)
  → often it is not feasible to scan over all parameters

- Map out the **characteristics** of the parameter space

- Take into account **all(?) possibilities**

- Ensure **compatibility** with all(?) current bounds
  - searches for new particles
  - (low-energy) flavor bounds
  - (low-energy) electroweak precision bounds
  - cold dark matter
  - . . .
Benchmarks can be used to:

- Study the performance of different detectors
- Study the performance of different experiments
- Perform very detailed studies
- Analyzing the complementarity of different experiments
- Work out synergy effects of different experiments

Prime example from the past: SPS (Snowmass points and slopes) (especially SPS 1a)

[hep-ph/0202233]
**External constraints?**

If a benchmark is designed to **test one sector** of a specific model

⇒ should constraints from other sectors be taken into account?

⇒ could they be easily avoided?

If a benchmark is designed to **test collider phenomenology**

then little changes that do not affect the collider phenomenology can easily avoid:

– bounds from cold dark matter
– bounds on \((g - 2)_\mu\)
– \(b\) physics constraints

**Our idea here:**

Study **collider phenomenology** in (SUSY) models that are compatible with

– direct **experimental** searches
– **flavor physics** constraints
– **precision observables** constraints
Our idea here:
Study collider phenomenology in (SUSY) models that are compatible with
– direct experimental searches
– flavor physics constraints
– precision observables constraints

My personal wishes:
Find/use points as described above (in the (N)MFV MSSM) . . .
that show interesting phenomenology in low- and high-energy experiments
⇒ study the complementarity of the low/high-energy experiments
⇒ study the synergy of the low/high-energy experiments
i.e. combine results from all sources to pin down the (N)MFV MSSM
. . . but this seems to be very difficult
2. Different approaches

After some discussions we agreed on a two-step process:

1. **Identify “interesting” points (“benchmarks”)** for experimental analysis at ATLAS and CMS.
   "interesting" means points in the parameter space that are "favored" by available flavor and high-energy data.

2. **Provide the tools** (to a master tool) so that everyone (especially the experimentalists from ATLAS and CMS) can check potentially "interesting" points (for joint (experiment + theory) analyses).

And eventually (3.):
**Perform the analysis** to investigate the collider reach and phenomenology in the “interesting/favored” points.
The broad idea how to proceed with the first step:

a) Identify the models we want to investigate.

b) Collect suggestions for the point(s) in each model.
   (The points could also be connected to a model line, showing the variation of flavor effects.)

c) Test these points, i.e. everyone (of us) should check a point against existing experimental data.

d) Identify among the "surviving" points the ones that show the potentially most interesting phenomenology.
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d) **Identify** among the "surviving" points the ones that show the potentially most interesting phenomenology.

Sounds good . . .

. . . reality looked a bit different
One approach (with ATLAS):

1. Start with SPS 1a

2. **Check consistency** with *b* physics observables
   tool: evaluate flavor physics obs. ($B, K, B_s$) in “near MFV models”
   (more by the end of the year . . .)
   check Higgs and precision observables with FeynHiggs

3. Not fully consistent? $\Rightarrow$ add (small?) flavor violation

   Fully consistent? $\Rightarrow$ add as much is allowed without violating constraints

4. $\Rightarrow$ check for new effects in high-energy analyses (ATLAS)

**Status?**
Ask Luca and/or Giacomo! ;-)
Another approach (with CMS):

1. Choose model: MFV MSSM
   later (hopefully) also NMFV MSSM

2. **Find points** that are in perfect **agreement with** $b$ **physics** observables

3. **Check** against other observables (**electroweak precision, masses**)
   ⇒ build a **master tool for checks**
   (second step of the two-step process)

4. ⇒ **check for effects in high-energy analyses** (**CMS**)

**Status?**
See the next chapter of this talk
See the next talk by Michael Schmitt (UFL)
3. One approach in more detail

Step 1:

Model of our choice: MFV MSSM
possible extension at a later stage: NMFV MSSM

Starting point: hep-ph/0605012 [Gino Isidori, Paride Paradisi]

General feature: large $\tan \beta$, large $M_{\text{SUSY}}$

These points:
- pass all current $b$ physics bounds
- pass all current SUSY collider searches
- should be checked for the Higgs sector constraints
- should be checked for electroweak precision observables

⇒ may sound trivial, but wait for NMFV MSSM!

⇒ currently under study in CMS (see next talk)
Overview about the SUSY parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>“Best” value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tan \beta$</td>
<td>30 – 50</td>
<td>40</td>
</tr>
<tr>
<td>$M_A$ [GeV]</td>
<td>300 – 1000</td>
<td>300, 500, 800, 1000</td>
</tr>
<tr>
<td>$\mu$ [GeV]</td>
<td>500 – 1000</td>
<td>500, 1000</td>
</tr>
<tr>
<td>$M_{\tilde{q}}$ [GeV]</td>
<td>$&gt; 1000$</td>
<td>1000, 2000</td>
</tr>
<tr>
<td>$M_{\tilde{t}}$</td>
<td>$1/2 \ M_{\tilde{q}}$</td>
<td></td>
</tr>
<tr>
<td>$M_{\tilde{g}}$</td>
<td>$M_{\tilde{q}}$</td>
<td></td>
</tr>
<tr>
<td>$M_2$ [GeV]</td>
<td></td>
<td>300, 500</td>
</tr>
<tr>
<td>$M_1$</td>
<td>$1/2 \ M_2$</td>
<td></td>
</tr>
</tbody>
</table>
Step 2: the master tool

⇒ a code that calls the special codes evaluating all observables

1. code: $b$ physics
   
   based on hep-ph/0605012 [G. Isidori, P. Paradisi]
   
   → used by the CMS experimentalists

2. code: Higgs and precision observables
   
   → FeynHiggs [T. Hahn, S.H., W. Hollik, G. Weiglein]
   
   → not yet included(?)

3. code: other/complementary observables
   
   → anybody interested?

⇒ Let’s see how this works out . . .
4. Conclusions

- **Benchmarks** are an essential tool for collider studies

- **Our idea here:** study collider phenomenology in (SUSY) models:
  - agreement with direct experimental searches
  - agreement with flavor physics constraints
  - agreement with precision observables constraints

- **Two step process:**
  - identify such points
  - combine tools to a master tool (especially for experimentalists)

- **One approach:** SPS 1a (ATLAS)

- **Second approach (CMS):**
  - model: MFV MSSM (later: NMFV MSSM)
  - to fulfill $b$ physics: large $\tan \beta$, large $M_{\text{SUSY}}$, ...
  - to check Higgs, precision observables
  \[ \Rightarrow \] currently under study in CMS