SUSY Flavour at LHC7

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We need to wait until we get some statistics...

Do you see the Higgs boson?

(Nope.

Huh. Well, then, until the theorists get back to us, wanna try hitting pigeons with the proton stream?

Already on it.

Cool! I just gave a helicopter cancer.
LHC 7 TeV Run

• Last year's luminosity expectations for December 2011: 1 fb\(^{-1}\)

• Big Question: What if we see some new physics signal? How can flavour help to tell if it is consistent with the MSSM?

• Objective: Analyze the region of the parameter space that LHC can probe.
  – If we get a signal, what can flavour physics tell us?
  – Can there be a flavour feedback to colliders?
Outline

- Models of Interest and LHC Reach
- Flavour Constraints
- Analysis of Specific Models
Models of Interest

- CMSSM
  Can give us a general idea of what we should expect. Useful as an initial benchmark.
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  *Well-motivated expansion that allows us to probe flavour in the lepton sector. Results are very model-dependent.*

Masiero, Vempati, Vives (hep-ph/0209303)
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- **CMSSM + $SU(3)_F$: RVV Model**
  
  *Example of a way of entangling all flavour-dependent observables. Results are heavily model-dependent.*

Ross, Velasco-Sevilla, Vives (hep-ph/0401064)
Collider Issues

- Main problem of analyzing the CMSSM is to estimate the LHC constraints and reach in a four-dimensional parameter space.
- Full collider simulation at each point in order to find out if it is ruled out or not?? Not feasible!
Collider Issues

Some results depend strongly only on $m_0$ and $M_{1/2}$!

- *Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions.* (1102.5290 [hep-ex])

- *Search for Supersymmetry in $pp$ Collisions at 7 TeV in Events with Jets and Missing Transverse Energy.* (1101.1628 [hep-ex])

It seems possible to do a scan on the CMSSM parameter space without doing a collider simulation.
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Scan shall use a modified version of SPheno 3.1.3

Porod (hep-ph/0301101)
Porod, Staub (1104.1573 [hep-ph])
Relevant Parameter Space for 2 fb$^{-1}$

ATLAS Collaboration (1102.5290 [hep-ex])

Baer, Barger, Lessa, Tata (1004.3594 [hep-ph])
Relevant Parameter Space for 2 fb$^{-1}$

\[ M_{\text{eff}} \approx 1.6 \times \min(m_{\tilde{g}}, m_{\tilde{q}}) \]

Feldman et al (1102.2548 [hep-ph])
Direct Search + Higgs Constraints
Flavour $3\sigma$ Constraints

$b \rightarrow s\gamma \quad (g - 2)_{\mu}$
Constraints

\( b \rightarrow s\gamma \)

\( (g - 2)_\mu \)

\( b \rightarrow s\gamma \)
The Role of $B_s \rightarrow \mu \mu$

- LHCb with 2 fb$^{-1}$
  - Exclusion of BR($B_s \rightarrow \mu \mu$) down to $4 \times 10^{-9}$, 95% C.L.
  - $3\sigma$ evidence of BR($B_s \rightarrow \mu \mu$) down to $5 \times 10^{-9}$.
  - $5\sigma$ discovery of BR($B_s \rightarrow \mu \mu$) down to $9 \times 10^{-9}$.

R. Lambert @ Moriond
The Role of $B_s \rightarrow \mu \mu$

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  - 5$\sigma$ discovery of BR($B_s \rightarrow \mu \mu$) down to 9x10$^{-9}$.

- CDF with 7 fb$^{-1}$
  - $BR(B_s \rightarrow \mu \mu) = (1.8 \pm 1) \times 10^{-8}$

CDF Collaboration (1107.2304 [hep-ex])
Exclusion due to $B_s \rightarrow \mu \mu$

$$\text{BR} (B_s \rightarrow \mu \mu) < 4 \times 10^{-9}$$
A Large $B_s \rightarrow \mu \mu$

\[ \text{BR}(B_s \rightarrow \mu\mu) > 5 \times 10^{-9} \]

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- $\text{BR}(B_s \rightarrow \mu \mu) > 5 \times 10^{-9}$
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$2\sigma$ Constraints

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2σ Constraints

\[ \text{BR} \left( B_s \rightarrow \mu \mu \right) > 4 \times 10^{-9} \]

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What about the Lepton Sector?

- First Assumption: \( Y_\nu \sim Y_u \)

Masiero, Vempati, Vives (hep-ph/0209303)
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- Mixings:
  - CKM-like
    \[
    Y_\nu = V_{CKM} Y_u^{\text{diag}}
    \]
  - PMNS-like
    \[
    Y_\nu = V_{PMNS} Y_u^{\text{diag}}
    \]

Masiero, Vempati, Vives (hep-ph/0209303)
Comparing CKM and PMNS

$\sin^2 2\theta_{13} = 0.04$

$m_{\nu_1} = 0.001 \text{ eV}$
Comparing CKM and PMNS

CKM-Mixing with large $Y_{\nu}$ cannot be probed by MEG

$\Delta a_{\mu}$

$\text{BR}(\mu \rightarrow e\gamma)$

$m_{\nu_1} = 0.001 \text{ eV}$

$\sin^2 2\theta_{13} = 0.04$
Comparing CKM and PMNS

PMNS Mixing
Small $B_s \rightarrow \mu\mu$

PMNS Mixing
Large $B_s \rightarrow \mu\mu$

PMNS-mixing with large $Y_\nu$ is mostly ruled out by MEGA, T2K and $(g-2)_\mu$

$m_{\nu_1} = 0.001 \text{ eV}$

$\sin^2 2\theta_{13} = 0.04$
RVV Models

- Flavour model based on SU(3) symmetry.
- Structure and phases in SUSY sector related to structure and phases in SM Yukawa sector.
- Capable of solving flavour tension in $\epsilon_K$, $\sin 2\beta$ and $\Delta m_B/\Delta m_{B_s}$.

Ross, Velasco-Sevilla, Vives (hep-ph/0401064)
Calibbi, JJP, Masiero, Park, Porod, Vives (0907.4069 [hep-ph])
RVV Models

- $\epsilon_K$ and $\sin 2\beta$ become a crucial source of constraints.
3\sigma constraints, solution of Flavour Tension + LFV reduce the parameter space considerably!
RVV Model and Leptons

Such a reduced parameter space allows to make very definite predictions.

For RVV to survive, MEG and eEDM experiments should give a positive signal soon!
Conclusions

Disclaimer: Upcoming conclusions should be valid for models with a CMSSM-like structure, i.e. universal $M_{1/2}$, $m_0$, $a_0$.

HANDLE WITH CARE
Conclusions

- Flavour and collider physics are complementary, as expected.
- If LHC gives a positive signal, flavour can give important hints in favour / against SUSY.
- $2\sigma$ constraints + $B_s \rightarrow \mu \mu$ separate CMSSM parameter space into two regions, which can be differentiated in a collider.
Conclusions

- SUSY SeeSaw models can be constrained by combination of LHC, T2K, $(g-2)_\mu$ and MEGA.
- Models with large $\nu$ Yukawas with PMNS mixing not in a good situation.
- Models with large $\nu$ Yukawas with CKM mixing should survive, but give no interesting signal.
Conclusions

- Low SUSY masses and flavour constraints push RVV flavour models into a particular region of the parameter space.
- Solution of flavour problem is still possible.
- MEG + eEDM experiments crucial for the model.
Ze Backoupé
Current LHC Constraints
Future Reach

No lepton channel:

[Graph showing the future reach for different mass ranges.]

Baer, Barger, Lessa, Tata (1004.3594 [hep-ph])
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2\sigma Constraints

\[ BR(B_s \rightarrow \mu\mu) > 4 \times 10^{-9} \]

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“Milder” Yukawas

\[ Y_\nu = \kappa_\nu V_{\text{PMNS}} Y^\text{diag}_u \]

\[ \kappa_\nu = 0.01 - 1 \]

\[ \sin^2 2\theta_{13} = 0.03 - 0.28 \]
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No hope for \( \tau \rightarrow \mu \gamma \) at SuperB
RVV Models Parameter Space

$3\sigma$ constraints, solution of Flavour Tension + LFV reduce the parameter space considerably!
RVV Models

- Very difficult to satisfy anomalous $S_{\psi\phi}$