Interplay of Flavor Physic And High Q^2 Physics:

Tools & Benchmarks

Sven Heinemeyer, IFCA (Santander)

CERN, 06/2008

1. Introduction
2. Tools
3. Benchmarks
4. SuperB activities
5. Conclusions

1. Introduction

Workshop (2006/2007):
“Flavour in the Era of the LHC”

working groups:
1.) Collider aspects of flavour physics at high Q^2
2.) B, D and K decays
3.) Flavour physics of lepton and dipole moments

$\longrightarrow$ working groups 1 and 2 had dedicated tools subgroups

Topics of tools subgroup of working group 2:
– get an overview about existing tools
– develop ideas for integration of different tools
– facilitate the interplay of high Q^2 and low-energy B-physics
– . . .

Continuation:

Working Group on the Interplay Between Collider and Flavour Physics

⇒ dedicated "Working group" on Tools

Contact persons:

Uli Haisch	Frederic Ronga	SH
		

Continuation:

Working Group on the Interplay Between Collider and Flavour Physics

$\Rightarrow$ dedicated "Working group" on Tools

Main topics:

– continue to collect tools

– continue to integrate B-physics and low/high energy codes

– explore model independent approaches (see Uli's talk later)

– . . .

Status?

On the importance of the interplay of high Q^2 and low-energy B-physics:

Q: How to determine the Lagrangian that describes the world?

On the importance of the interplay of high Q^2 and low-energy B-physics:

Q: How to determine the Lagrangian that describes the world?

A: Measure as much as possible

1. Direct discoveries/measurements (masses, mixing angles, . . .)
2. Electroweak precision observables (M_W, m_t, . . .)
3. Flavor-related observables (B, D, K physics, . . .)
4. Astro-physical observables (CDM density, . . .)
5. . . .

On the importance of the interplay of high Q^2 and low-energy B-physics:

Q: How to determine the Lagrangian that describes the world?

A: Measure as much as possible

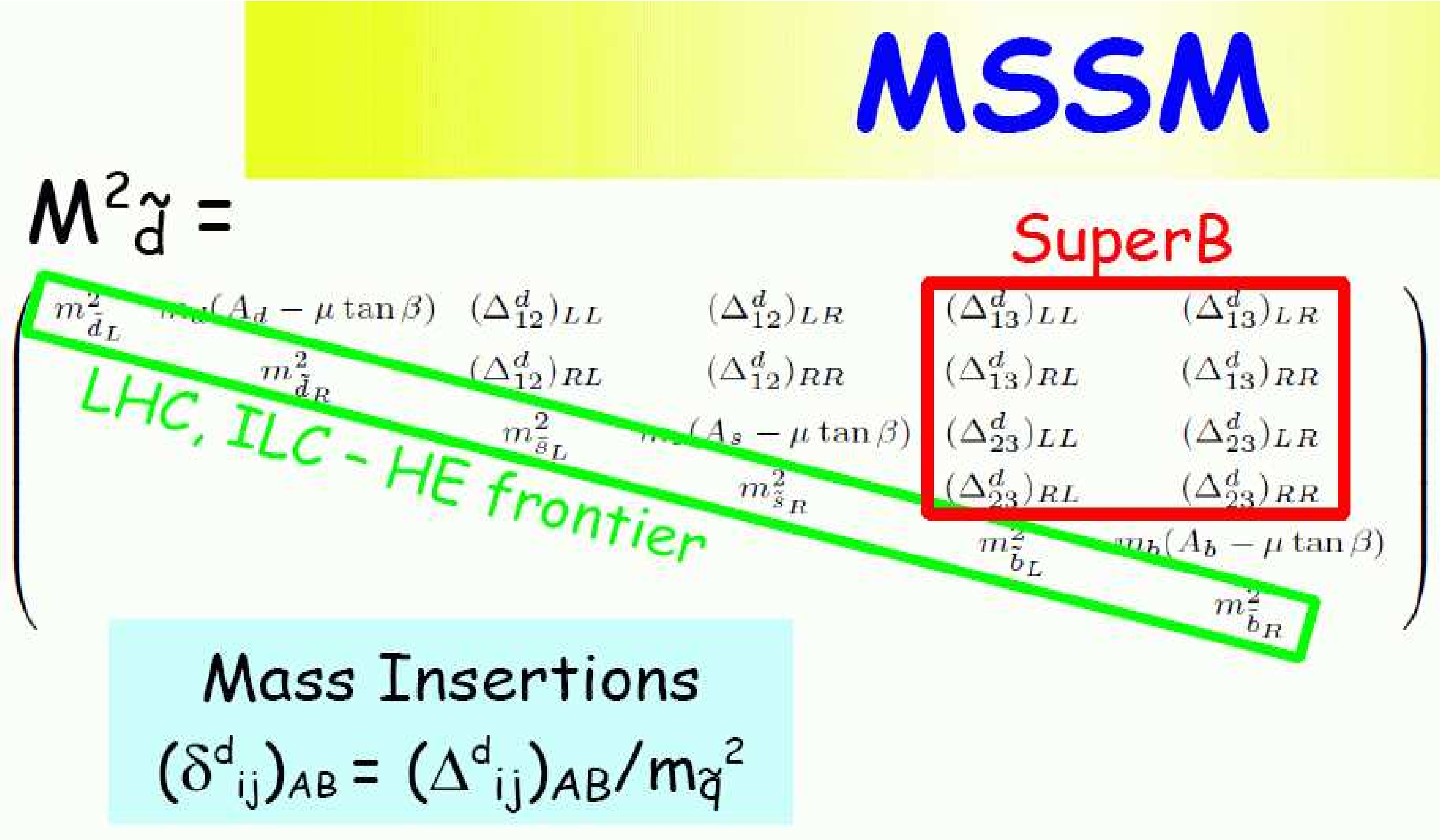
1. Direct discoveries/measurements (masses, mixing angles, . . .)
2. Electroweak precision observables (M_W, m_t, . . .)
3. Flavor-related observables (B, D, K physics, . . .)
4. Astro-physical observables (CDM density, . . .)
5. . . .

$\Rightarrow$ Interplay of the various observables/measurements ?
$\Rightarrow$ combination of tools
$\Rightarrow$ combination of benchmarks

Example: NMFV MSSM

("my" NMFV: non-zero off-diagonal entries at low energies)

[*taken from M. Ciuchini '07*]



2. Tools

Some history from the first LHC/Flavor workshop:

idea: let's do the tools of WG1 and WG2 together

⇒ substantial differences showed up

WG1: (quoting from our email exchange :-)
– more ATLAS/CMS oriented
– tools more relevant for (many) experimentalists
– examples: Pythia, Sherpa, Photos, . . .

WG2:
– more theory/theorists oriented tools?
– more low-energy codes to map out parameter space?
– more single/special purpose codes?
(notice the question marks!)

Real differences?
Indeed: Pythia, Herwig, Sherpa, . . . not in our focus

Status of "Flavor related tools":

still based on old WG2 activities. . .

Starting point to get an overview (and re-sent recently):

email to all WG1/WG2 participants, asking for

- What does your tool/code do?
  In which model?
  What is the input?
  What is the output?
  (In case of SUSY: is it SLHA(2) compatible?)
- Are there published results obtained with this tool/code?
  Did you present it already during this workshop course?
  If not, are you interested in a presentation?
- Is the tool/code public?
  (Does even a manual exist?)
- What does the tool/code not do, i.e. what are its limitations?
- What are your future plans?

⇒ Only 13+X+Y answers . . .

⇒ Only 13+X+Y answers . . .

(leave out what is not (planned to be) public)

However/at least:

As you will see: some variety:

– codes for low-energy observables
– codes for high-energy observables
– codes for the calculation of amplitudes
– codes for connecting the GUT and the (flavor)experimental scale
– codes to pass parameters/results from one code to another
– codes for UT/CKM fits (X)
– codes to facilitate the interplay (Y)

And this is what there is:

(ordered roughly thematically)

Code # 1:

Name: no name [*Silvestrini*]

Description: $K\bar{K}$ mixing, $B_{(s)}\bar{B}_{(s)}$ mixing, $b \to s\gamma$, $b \to s\, l^+ l^-$ in NMFV MSSM

Availability: planned

Code # 2:

Name: no name [*Isidori, Paradisi*]

Description: low-energy flavor observables in the MFV MSSM

Availability: planned/partially public

Code # 3:

Name: no name [*Bobeth, Ewerth, Haisch*]

Description: rare B and K decays in/beyond SM

Availability: planned

Code # 4:

Name: no name [*Chankowski, Jäger, Rosiek*]

Description: FCNC observables in MSSM

Availability: planned

Code # 5:

Name: no name [*Bozzi, Fuks, Klasen*]

Description: squark/gluino production at LO for NMFV MSSM

Availability: planned

Code # 6:

Name: FCHDECAY [*Bejar, Guasch*]

Description: FCNC Higgs decays in NMFV MSSM

Availability: yes (web page)

Code # 7:

Name: FeynHiggs [*Hahn, SH, Hollik, Rzehak, Weiglein*]

Description: Higgs/EWPO phenomenology in the (N)MFV (complex) MSSM

Availability: yes (manual, web page, $\oplus$ on-line version)

Code # 8:

Name: no name [*Bejar, Guasch*]

Description: FC Higgs/top decays in 2HDM I/II

Availability: planned

Code # 9:

Name: FeynArts/FormCalc [*Hahn*]

Description: (arbitrary) one-loop corrections in (N)MFV MSSM

Availability: yes (manual, web page)

Code # 10:

Name: SLHALib2 [*Hahn*]

Description: read/write SLHA2 data, i.e. NMFV/RPV/CPV MSSM, NMSSM

Availability: yes (manual, web page)

→ more on SLHA2 later

Code # 11:
Name: Spheno [*Porod*]
Description: evaluates NMFV MSSM parameters from GUT scale input
Availability: yes (manual, web page)

Code # 12:
Name: SoftSUSY [*Allanach*]
Description: evaluates NMFV MSSM parameters from GUT scale input
Availability: yes (manual, web page)

Code # 13:
Name: MicrOMEGAs [*Belanger, Boudjema, Pukhov, Semenov*]
Description: CDM density, some B-physics observables in MFV MSSM
Availability: yes (manual, web page)

Still true:
Would be nice if the "planned availability" codes would really become available, including manual, web page etc.

Code # 13+X, X=1:

Name: UTfit

Description: Unitarity Triangle fits (Bayesian), in SM and beyond

Availability: yes (web page)

Code # 13+X, X=2:

Name: CKMFitter

Description: CKM fits (Frequentist), (mostly) in SM

Availability: yes (web page)

⇒ all codes including short description are included in our write-up for the LHC/Flavor workshop

Code # 13+X, X=1:

Name: UTfit

Description: Unitarity Triangle fits (Bayesian), in SM and beyond

Availability: yes (web page)

Code # 13+X, X=2:

Name: CKMFitter

Description: CKM fits (Frequentist), (mostly) in SM

Availability: yes (web page)

⇒ all codes including short description are included in our write-up for the LHC/Flavor workshop

Code # 13+X+Y:

Description: combination of various tools (⇒ interplay!)

⇒ see below

Recent updates/additions for flavor related tools (I):

NEW: Code # 2:

Name: no name [*Isidori, Paradisi*]

Description: low-energy flavor observables in the MFV MSSM

Now included: BR($b \to s\gamma$), ΔM_{B_s}, BR($B_s \to \mu^+\mu^-$), BR($B_u \to \tau\nu_\tau$), BR($B_s \to X_s\ell\ell$), BR($K \to \tau\nu_\tau$), Δm_K, BR($K \to \pi\nu\nu$), BR($B_d \to \ell\ell$)

NEW: XSusy [*Bozzi, Fuks, Herrmann, Klasen*]

Description: masses, production cross sections, BR in NMFV MSSM

Availability: partially (partial SLHA2 compatibility)

Recent updates/additions for flavor related tools (II):

NEW: SuperIso [*Mahmoudi*]
Description: isospin asymmetries in the MFV MSSM
Availability: yes

NEW: SuperBSG [*Degrassi, Gambino, Slavich*]
Description: BR($b \to s\gamma$) in the MFV MSSM (highest precision)
Availability: yes

Anything else? Please talk to me (now?)!

Other codes (I):

not mentioned so far, since no flavor related models/observables are used/calculated

However: still relevant for interplay

Name: DarkSUSY [*Gondolo et al.*]
Description: CDM, σ_χ for direct DM detection
Availability: yes (manual, web page)

Name: Isajet/Isasusy [*Baer, Paige, Protopopescu, Tata*]
Description: MFV MSSM parameters from GUT scale input
Availability: yes (manual, web page)

Name: Suspect [*Djouadi, Kneur, Moultaka*]
Description: MFV MSSM parameters from GUT scale input
Availability: yes (manual, web page

Other codes (II):

not mentioned so far, since no flavor related models/observables are used/calculated

However: still relevant for interplay

Name: FeynWZ/SUSYPope [*SH, Hollik, Weber, Weiglein*]

Description: electroweak precision observables in the MFV (complex) MSSM

Availability: planned/partially public

Recent overview about SUSY related tools:

[*B. Allanach, hep-ph/0805.2088*]

Tools on the market:

– codes for B, K physics observables
– codes for low-energy (ew) observables
– codes for high-energy observables
– codes for the calculation of amplitudes
– codes for connecting the GUT and the (flavor)experimental scale
– codes to pass parameters/results from one code to another
– codes for UT/CKM fits

General questions:

– What is still missing? Are all relevant fields covered?
– How can it be ensured that code/calculation is useful for others?
– Can experimentalists make use of them?
– What are the wishes of the experimentalists?
– Interaction between theory and experiment?

Concerning the interplay issue:

One code/tool is good!

Many codes/tools are better!

Q: How can one connect different tools such that

– input/output is compatible

– (combination of) tools can be used by non-experts

(non-expert = non-author of the code)

$\Rightarrow$ mostly in the hands of the authors . . .

A: Two obvious possibilities (maybe more?):

1) Interface code that handles input/output $\rightarrow$ SLHA2

2) "Über-code" that interfaces various single codes

$\rightarrow$ two examples: MasterCode and GFitter

A few words on SLHA2: ⇒ MSSM (+ extensions) only!

[*P. Skands et al. '03 - '07*]

SLHA(2) = Collection of rules to unambiguously define input/output

– interface for MSSM (+ extensions) tools (new models ⇔ priv. defs.)
– ASCII format
– Block structure for different parameters/observables
– parameters defined via Lagrangian
– observables defined via "agreement"

Spectrum generators → cross section/decay packages → event generators

+ : IT WORKS!
– : only if implemented by the authors of the code
– : "only" for MSSM + extensions

NEW: inclusion of NMFV/RPV/CPV in the MSSM + NMSSM:
SLHA → SLHA2

I/O made easy via SLHALib2 [*T. Hahn '06*]
C++ classes [*P. Skands '07*]
read/write SLHA2 data, i.e. NMFV/RPV/CPV MSSM, NMSSM

“Über-code” that interfaces various single codes

→ two examples: MasterCode and GFitter

MasterCode:

→ combination of other existing MSSM codes

→ including B-physics code short summary ⇒

→ Frederic Ronga’s presentation

GFitter:

→ new programming of observables in various sectors (mostly SM)

→ B-physics observables for 2HDM

→ Henning Flächer’s presentation

The "MasterCode"

⇒ collaborative effort of theorists and experimentalists

[*Buchmüller, Cavanaugh, De Roeck, Ellis, Flächer, SH, Isidori, Olive, Paradisi, Ronga, Weiglein*]

Über-code for the combination of different tools:

– tools are included as subroutines

– compatibility ensured by collaboration of authors of "MasterCode" and authors of "sub tools"

– one "MasterCode" for one model . . .

⇒ evaluate observables of one parameter point consistently with various tools

Example: flavor observables and high p_T observables can be combined

⇒ MAIN POINT of the 2. LHC/Flavor workshop and this Focus Week!

Status of the "MasterCode":

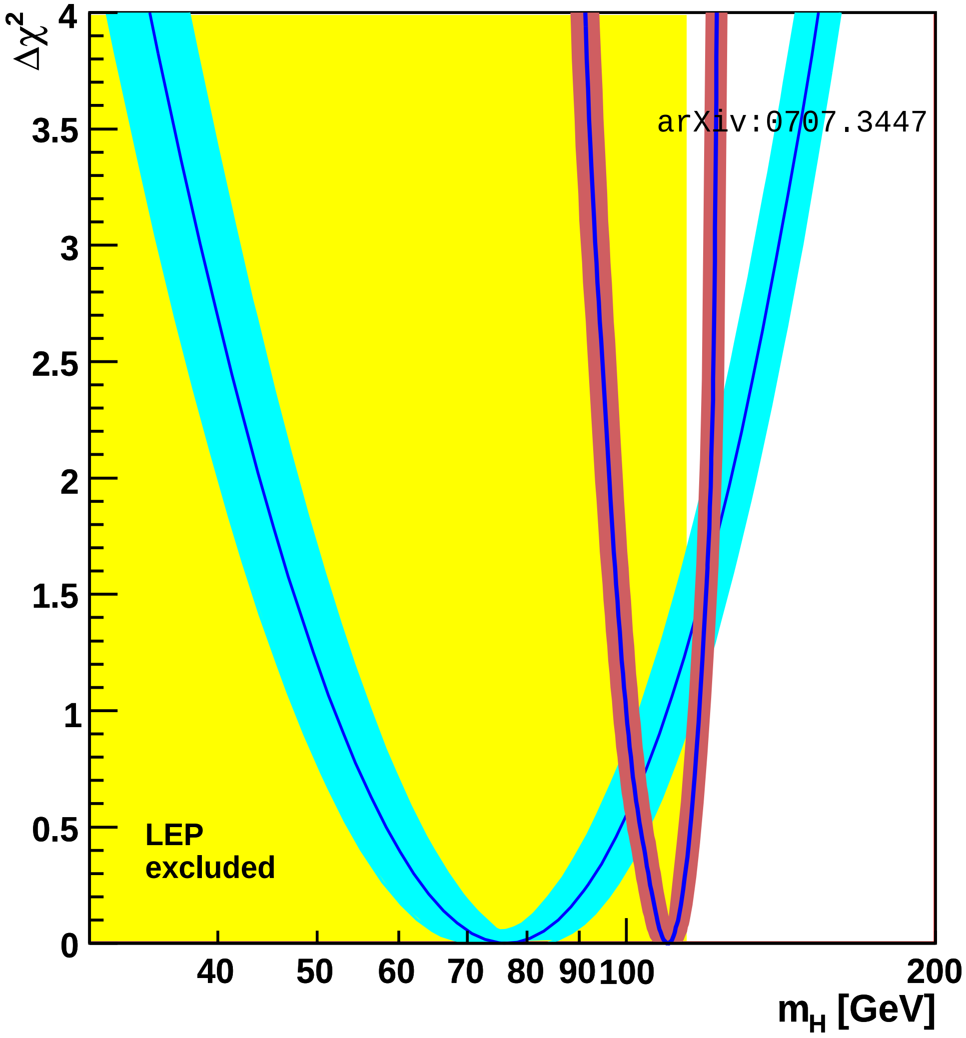
- one model: (MFV) MSSM
- tools included:
  - code # 2: B-physics observables [*Isidori, Paradisi*]
  - more B-physics observables [*SuperIso*]
  - code # 7: Higgs related observables, $(g-2)_\mu$ [*FeynHiggs*]
  - Electroweak precision observables [*FeynWZ/SUSYPope*]
  - Dark Matter observables [*MicrOMEGAs, DarkSUSY*]
  - for GUT scale models: RGE running [*SoftSUSY, Suspect*]
- added: χ^2 analysis code
  (→ similar directions as SFitter, Fittino)
- planned: inclusion of more tools
  inclusion of more models

Use of the "MasterCode":

Now:

- χ^2 fits in the CMSSM using today's data
- χ^2 fits in other constrained models (work in progress)
- χ^2 fits also including anticipated future data

  $\Rightarrow$ SuperB activities
- more details by Oliver



Future: Test (future) data with various tools

Discussion?

A: Two obvious possibilities (maybe more?):

1) Interface code that handles input/output → SLHA2

Enough for flavor?
Flavor specific extension?
More model independent approach?
→ Uli's/Gudrun's discussion trigger
How to get people converge? (SLHA was a HUGE effort!)
. . . ?

2) "Über-code" that interfaces various single codes

Wanted/accepted?
How to include more tools?
How to include updates of tools?
. . . ?

3) . . . ?

3. Benchmarks

...are not a new idea ...

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

- Required for BSM searches at colliders (past, present, future)
  $\longrightarrow$ 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

My main wish:

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

My main wish:

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

– direct experimental searches
– flavor physics constraints
– precision observables constraints

Special(?) approach for SUSY:

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

⇒ study the complementarity of the low/high-energy experiments

⇒ study the synergy of the low/high-energy experiments

Three approaches/results:

1. Take the good old SPS points
   some of them have been studied in quite detail
   → evaluate LHC measurements
   ⇒ investigate what B-physics can add ⇒ SuperB activities

2. Take a GUT based model with flavor violation
   → fit to current data
   → fit to anticipated LHC data
   ⇒ investigate what B-physics can add (in the future)
   not realized yet . . . possible models?

3. Define benchmark scenarios (in GUT based models)
   → investigate compatibility with all constraints
   ⇒ investigate what B-physics can add (in the future)
   ⇒ realized in NUHM

Impact and prospects of BPO in NUHM benchmarks

[J. Ellis, S.H., K. Olive, A.M. Weber, G. Weiglein '07][J. Ellis, T. Hahn, S.H., K. Olive, G. Weiglein '07]

NUHM: (Non-universal Higgs mass model)

> $\Rightarrow$ besides the CMSSM parameters ($m_{1/2}$, m_0, A_0, $\tan\beta$)
>
> M_A and μ

Assumption:

no unification of scalar fermion and scalar Higgs parameters
at the GUT scale

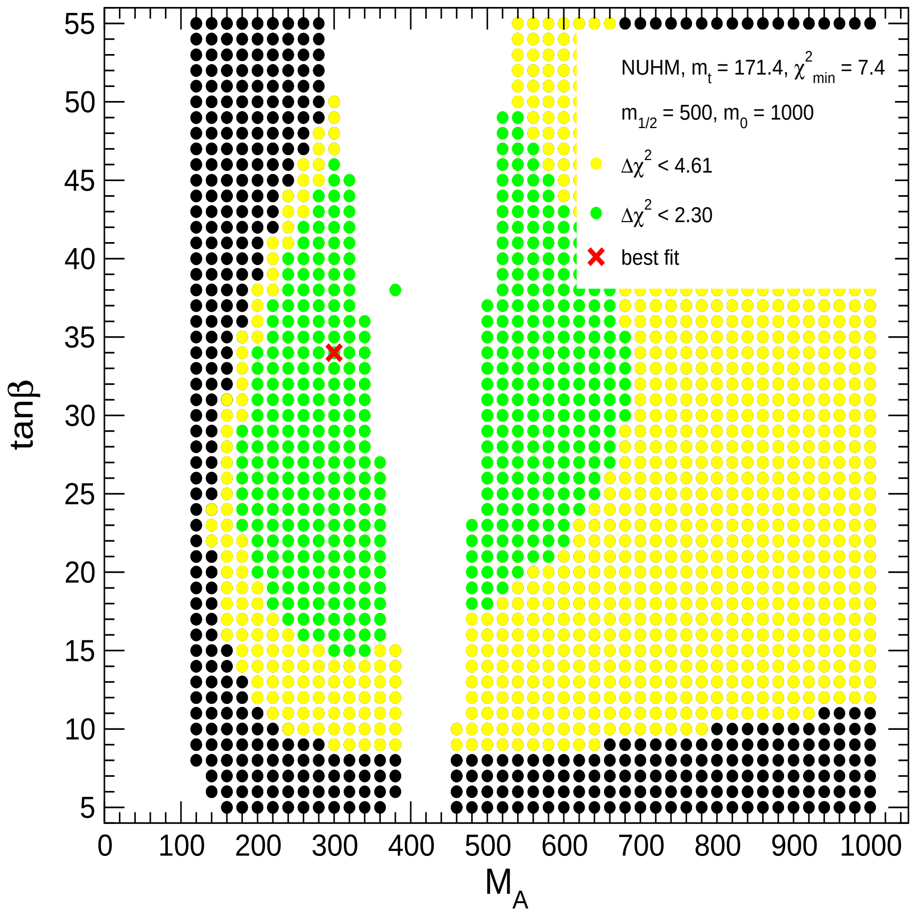
$\Rightarrow$ effectively M_A and μ free parameters at the EW scale

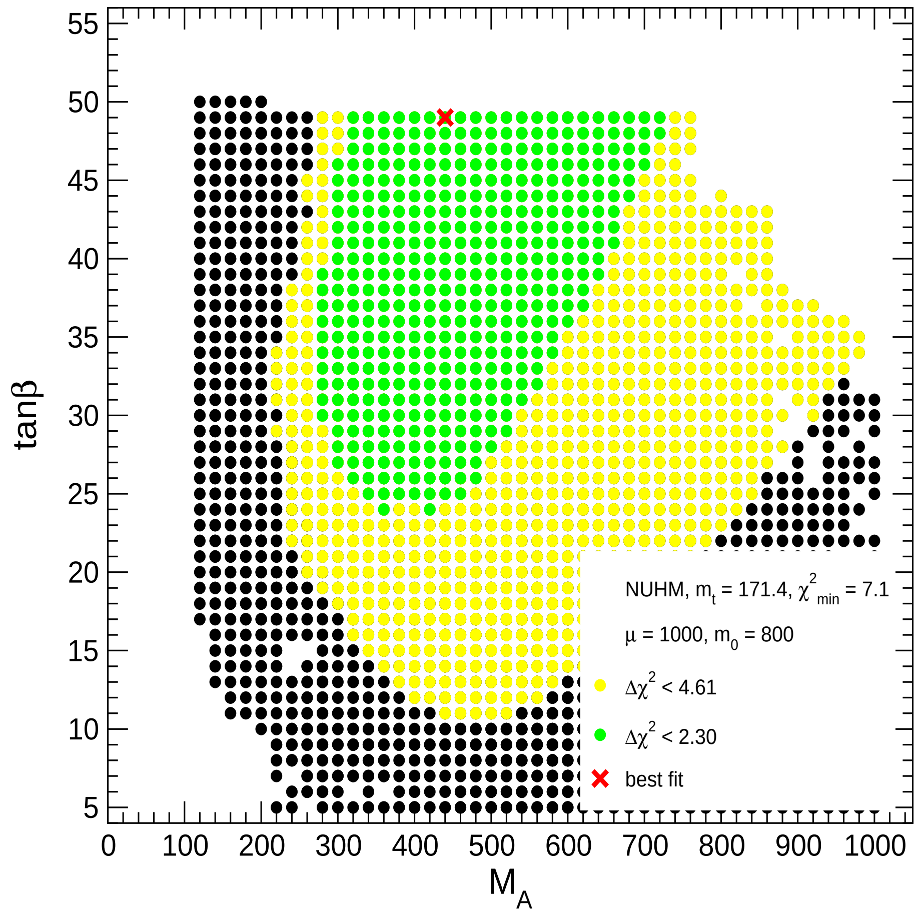
$\Rightarrow$ particle spectra from renormalization group running to weak scale

Lightest SUSY particle (LSP) is the lightest neutralino

$\Rightarrow$ possible: M_A–$\tan\beta$ planes in agreement with CDM :-)

Example: NUHM planes 2,3

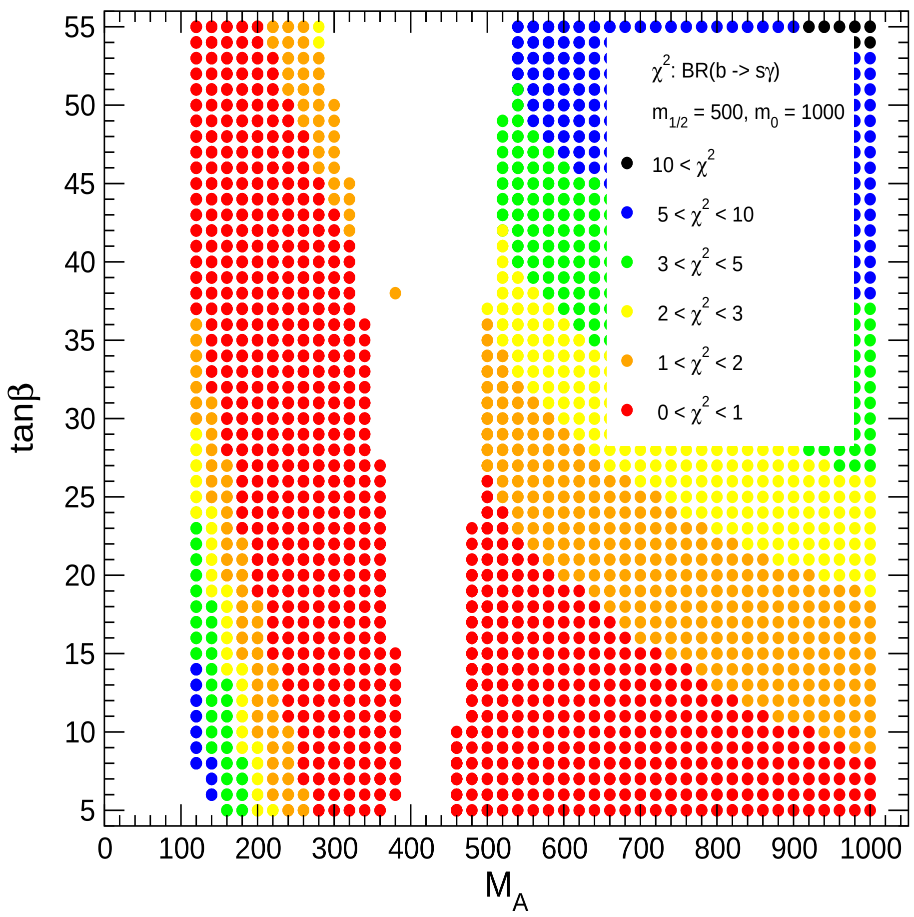




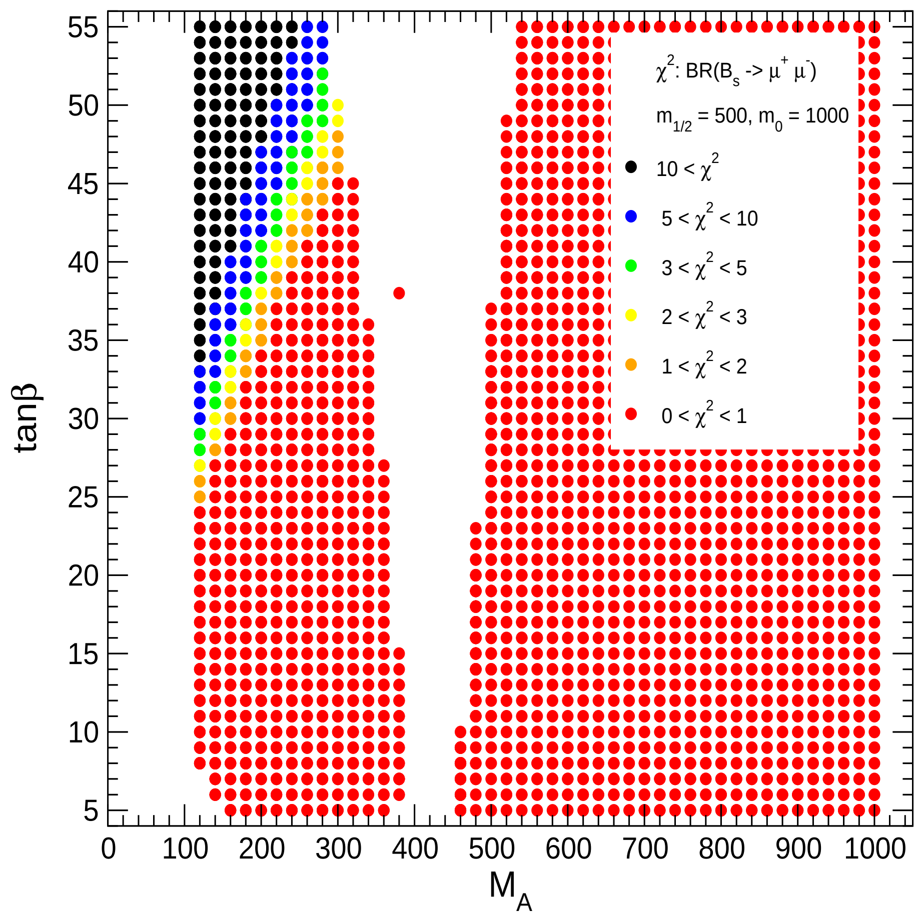
$\Rightarrow$ good χ^2 (M_W, $\sin^2\theta_{\rm eff}$, Γ_Z, M_h, $(g-2)_\mu$, BR($b \to s\gamma$) and other BPO)
$\Rightarrow$ larger regions o.k.

Impact of BPO on plane 2:

$\mathrm{BR}(b \to s\gamma)$



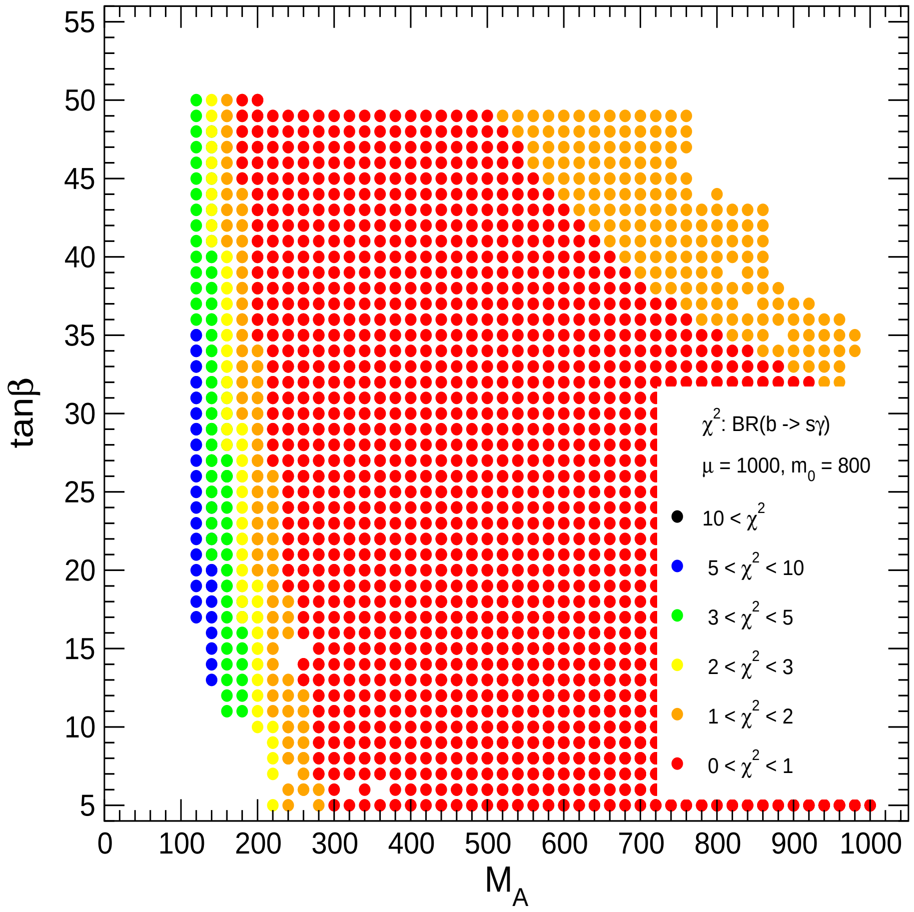
$\mathrm{BR}(B_s \to \mu^+\mu^-)$



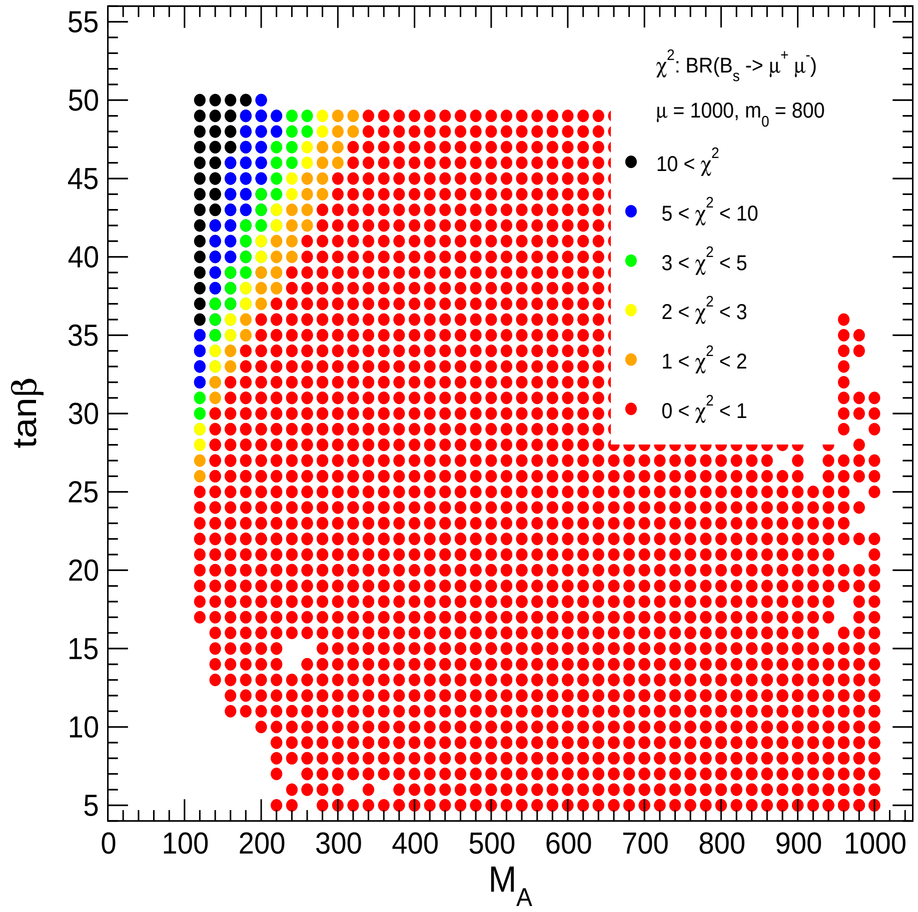
$\Rightarrow$ so far mostly "mild" impact

Impact of BPO on plane 3:

$\mathrm{BR}(b \to s\gamma)$

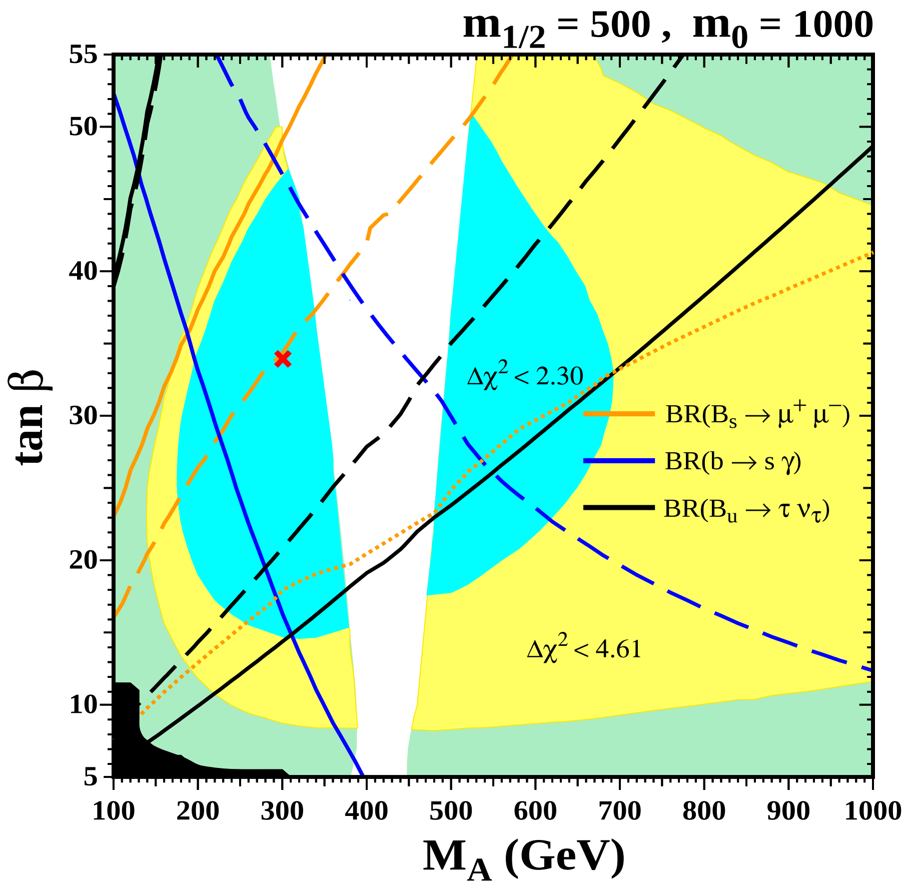


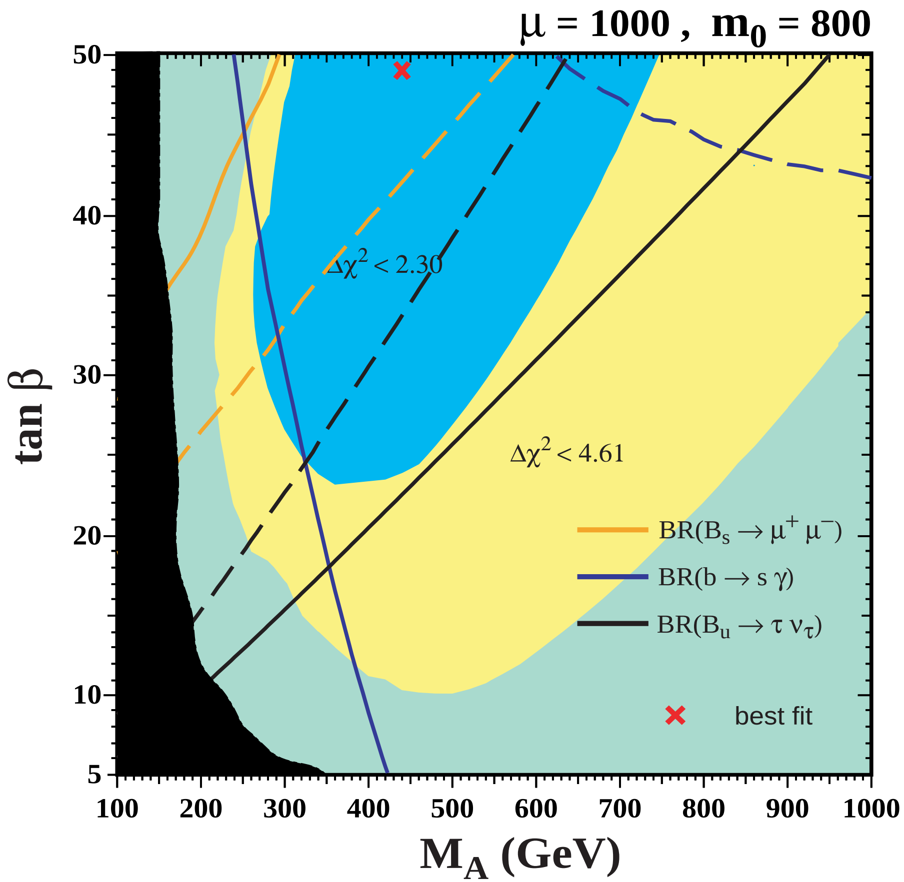
$\mathrm{BR}(B_s \to \mu^+\mu^-)$



⇒ so far mostly "mild" impact

Future prospects:



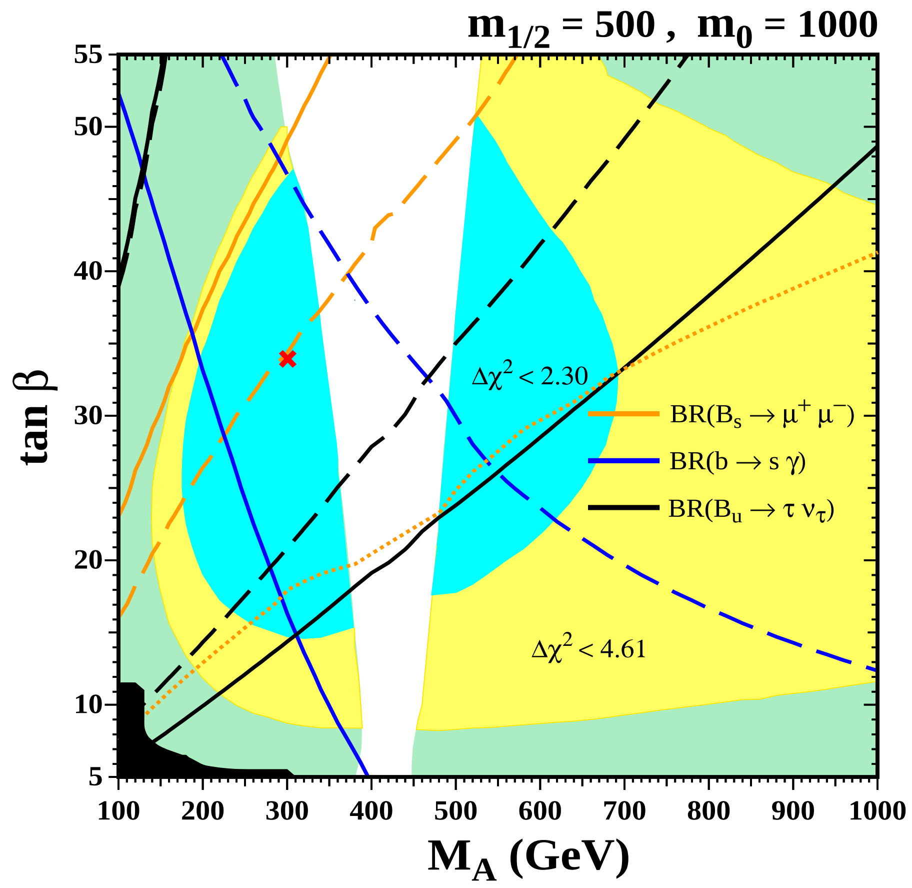


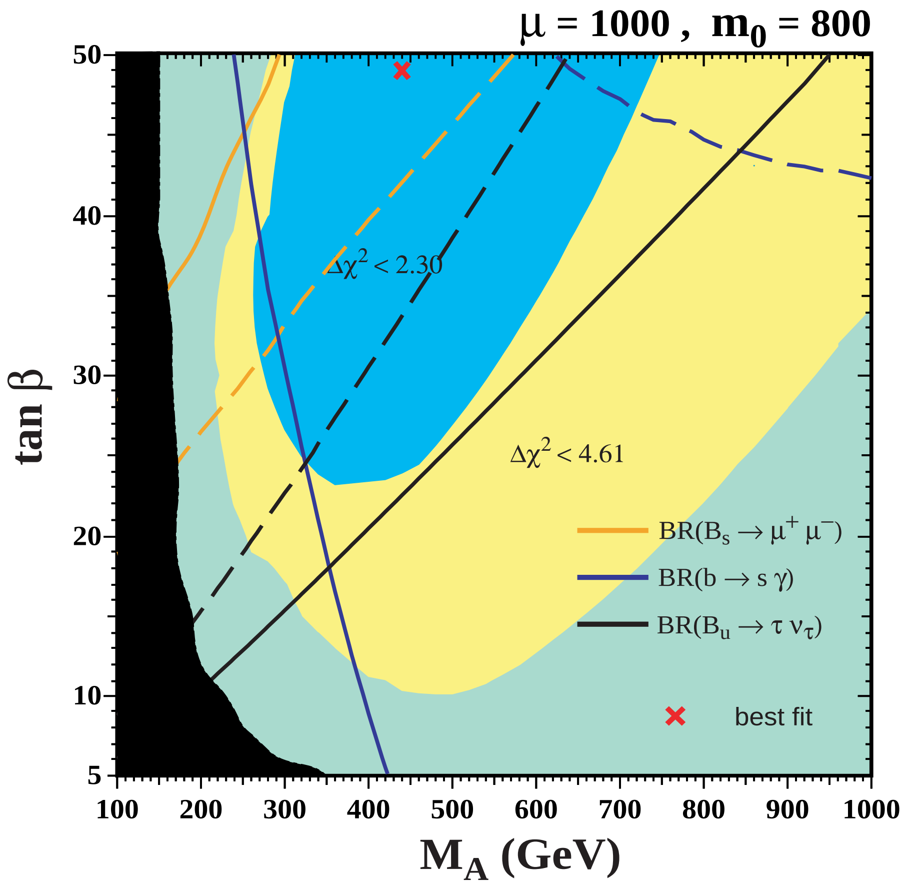
$\mathrm{BR}(B_s \to \mu^+\mu^-) = 1.0(0.2) \times 10^{-7}$ [, LHCb]

$\mathrm{BR}(b \to s\gamma) = 4.0(3.0) \times 10^{-4}$

$\mathrm{BR}(B_u \to \tau\nu_\tau) = 0.9(0.7)$

Future prospects:





$\Rightarrow$ Improvement in precision for BPO is needed!
Improvement in precision for BPO will help a lot!

4. SuperB activities

→ work done in the framework of the latest SuperB workshop, application of the MasterCode

[*special thanks to Frederic Ronga – who did most of the work!*]

Main idea:

Assumptions:

– LHC has collected 300 fb^{-1}
– CMSSM is a good description of observed data
– no (clear) sign of NMFV at the LHC
– data favors a certain SPS point

Impact of SuperB?

– Predictions for flavor observables?
– Can these predictions be constrained by SuperB?
– Can SuperB restrict the NMFV parameters?

Assumption (I): SPS1a realized ("typical" CMSSM scenario)

LHC friendly (light) spectrum

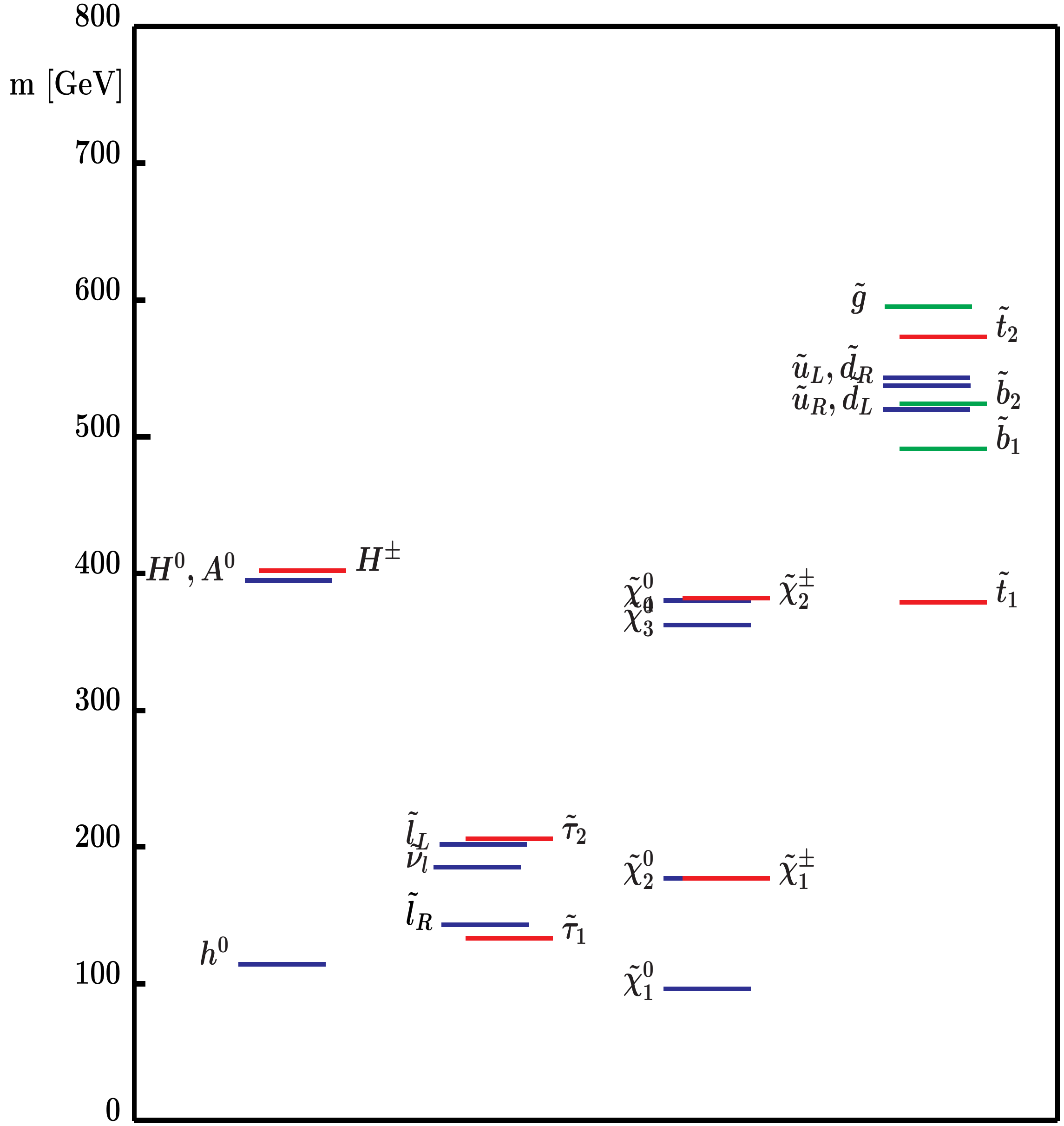
cascades possible:
$\tilde{q}_L \to \tilde{\chi}_2^0 q \to \tilde{l}_R \ell q \to \tilde{\chi}_1^0 \ell\ell q$

edge measurements:

$$(m^2_{\ell\ell})^{\rm edge} = \frac{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}_R}}$$

$$(m^2_{q\ell\ell})^{\rm edge} = \frac{(m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}_2^0})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}_R}}$$

$$(m^2_{q\ell})^{\rm edge}_{\rm min} = \frac{(m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}_2^0})(m^2_{\tilde{l}_R} - m^2_{\tilde{l}_R})}{m^2_{\tilde{l}_R}}$$



Assumption (I): SPS1a realized (“typical” CMSSM scenario)

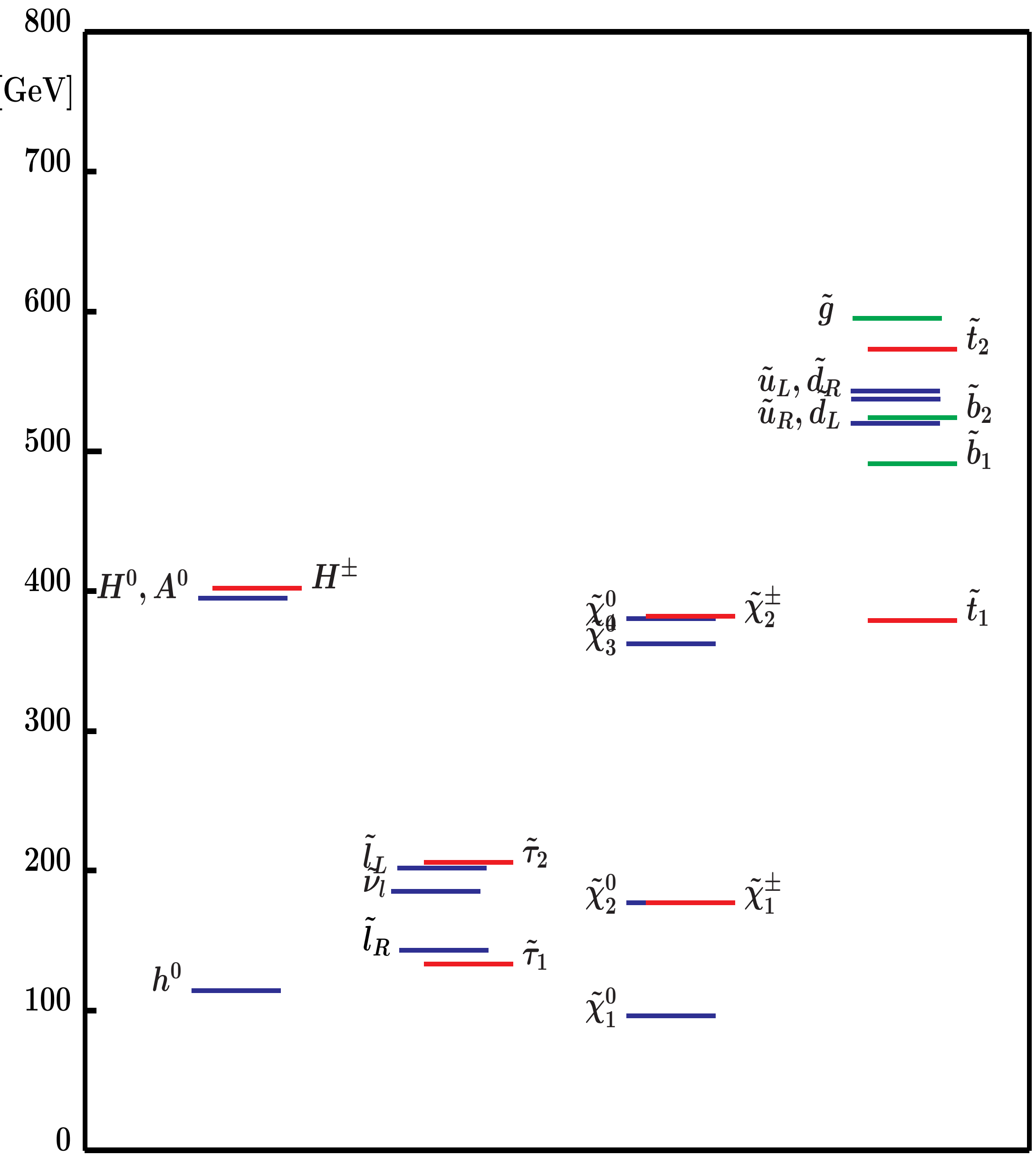
Results based on 300 fb^{-1} (2014)

Edge measurements:

$$(m_{\ell\ell})^{\text{edge}} = 58.9 \pm 0.1 \text{ GeV}$$
$$(m_{q\ell\ell})^{\text{edge}} = 451.1 \pm 4.5 \text{ GeV}$$
$$(m_{q\ell})^{\text{edge}}_{\text{min}} = 317.5 \pm 3.1 \text{ GeV}$$

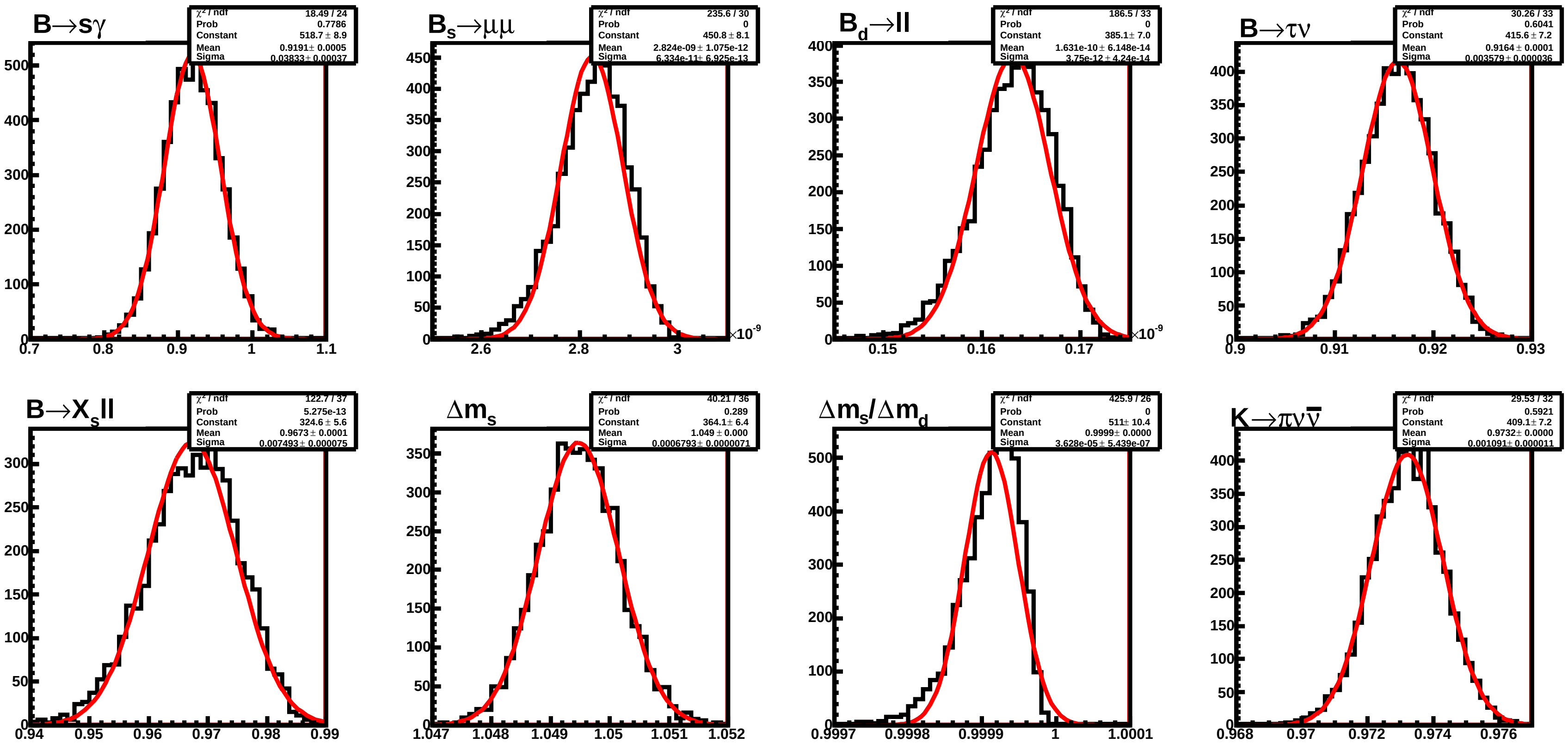
Combination with all other constraints:

$$m_{1/2} = 250.0 \pm 1.1 \text{ GeV}$$
$$m_0 = 100.0 \pm 1.5 \text{ GeV}$$
$$A_0 = 100 \pm 30 \text{ GeV}$$
$$\tan\beta = 9.8 \pm 1.2$$



⇒ Strong impact of LHC constraints on (SPS1a) flavor sector:

Toy MC analysis for flavor observables:



⇒ consistent prediction of flavor observables

$\Rightarrow$ Strong impact of LHC constraints on (SPS1a) flavor sector:

$\Rightarrow$ consistent prediction of flavor observables

no CKM uncertainties included $\Rightarrow$ errors only from fit!

theory errors: $\sim$ 3% $(K_L \to \pi^0 \nu\bar{\nu})$ ... $\sim$ 25% (ΔM_{B_s})

$$\begin{aligned}
\mathcal{R}(b \to s\gamma) &= 0.919 \pm 0.038 \\
\mathcal{R}(B_u \to \tau\nu_\tau) &= 0.968 \pm 0.007 \\
\mathcal{R}(B_s \to X_s \ell^+ \ell^-) &= 0.916 \pm 0.004 \\
\mathcal{R}(B \to K\nu\bar{\nu}) &= 0.967 \pm 0.001 \\
\mathrm{BR}(B_s \to \mu^+\mu^-) &= (2.824 \pm 0.063) \times 10^{-9} \\
\mathrm{BR}(B_d \to \mu^+\mu^-) &= (1.631 \pm 0.038) \times 10^{-10} \\
\mathcal{R}(\Delta M_{B_s}) &= 1.050 \pm 0.001 \\
\mathcal{R}(K_L \to \pi^0 \nu\bar{\nu}) &= 0.973 \pm 0.001
\end{aligned}$$

⇒ Strong impact of LHC constraints on (SPS1a) flavor sector:

⇒ consistent prediction of flavor observables

no CKM uncertainties included ⇒ errors only from fit!

theory errors: $\sim 3\%$ ($K_L \to \pi^0 \nu\bar{\nu}$) . . . $\sim 25\%$ (ΔM_{B_s})

$$\begin{aligned}
\mathcal{R}(b \to s\gamma) &= 0.919 \pm 0.038 \\
\mathcal{R}(B_u \to \tau\nu_\tau) &= 0.968 \pm 0.007 \\
\mathcal{R}(B_s \to X_s \ell^+\ell^-) &= 0.916 \pm 0.004 \\
\mathcal{R}(B \to K\nu\bar{\nu}) &= 0.967 \pm 0.001 \\
\mathrm{BR}(B_s \to \mu^+\mu^-) &= (2.824 \pm 0.063) \times 10^{-9} \\
\mathrm{BR}(B_d \to \mu^+\mu^-) &= (1.631 \pm 0.038) \times 10^{-10} \\
\mathcal{R}(\Delta M_{B_s}) &= 1.050 \pm 0.001 \\
\mathcal{R}(K_L \to \pi^0\nu\bar{\nu}) &= 0.973 \pm 0.001
\end{aligned}$$

⇒ SuperB could not see deviations if SPS1a (MFV) is realized

⇒ any deviation would prove NMFV!

Assumption (II): SPS5 realized (CMSSM scenario with light $\tilde{t}$)

still LHC friendly (light $\tilde{t}$)

cascades possible:

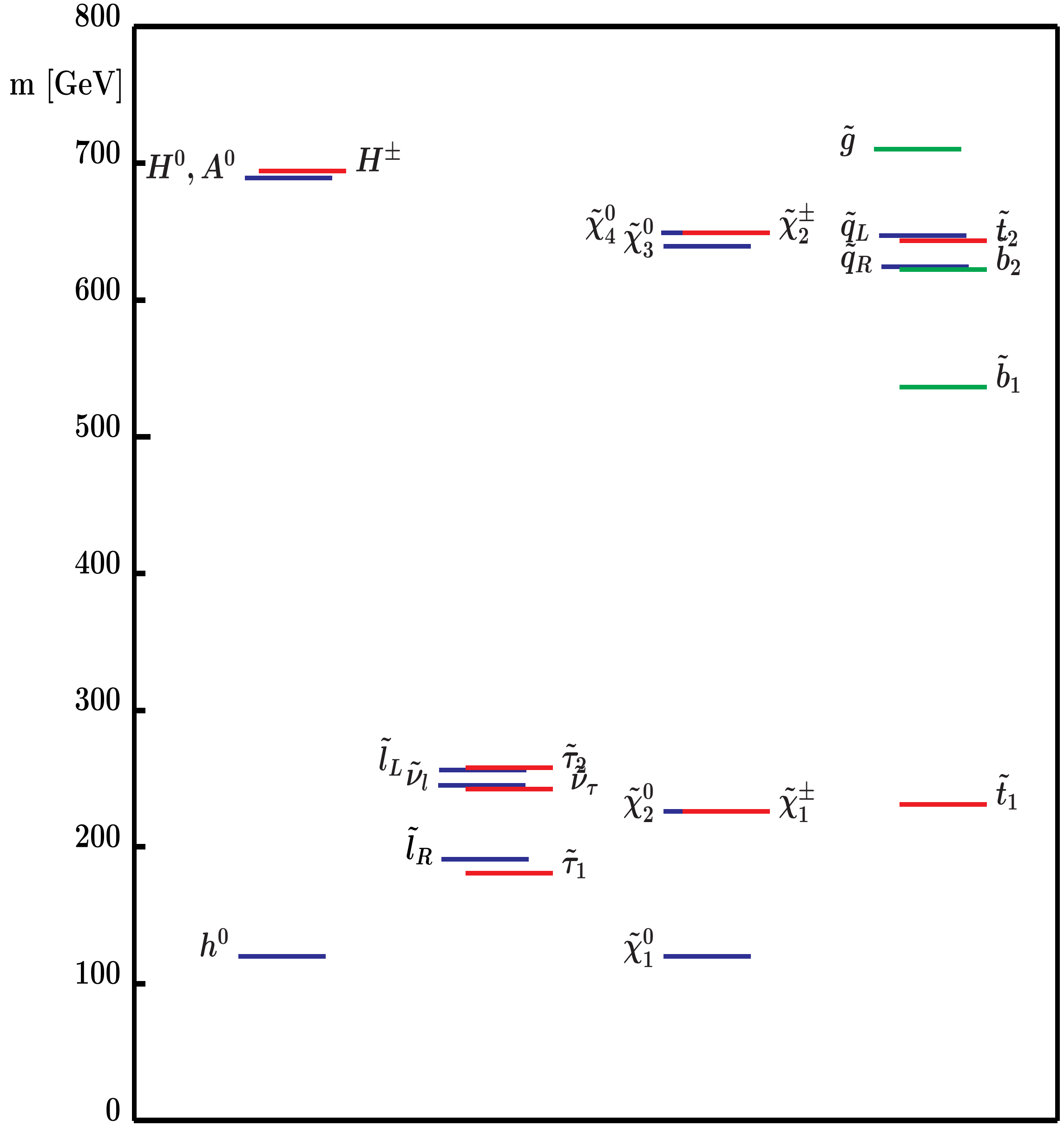
$\tilde{q}_L \to \tilde{\chi}_2^0 q \to \tilde{l}_R \ell q \to \tilde{\chi}_1^0 \ell\ell q$

edge measurements:

$$(m^2_{\ell\ell})^{\text{edge}} = \frac{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}_R}}$$

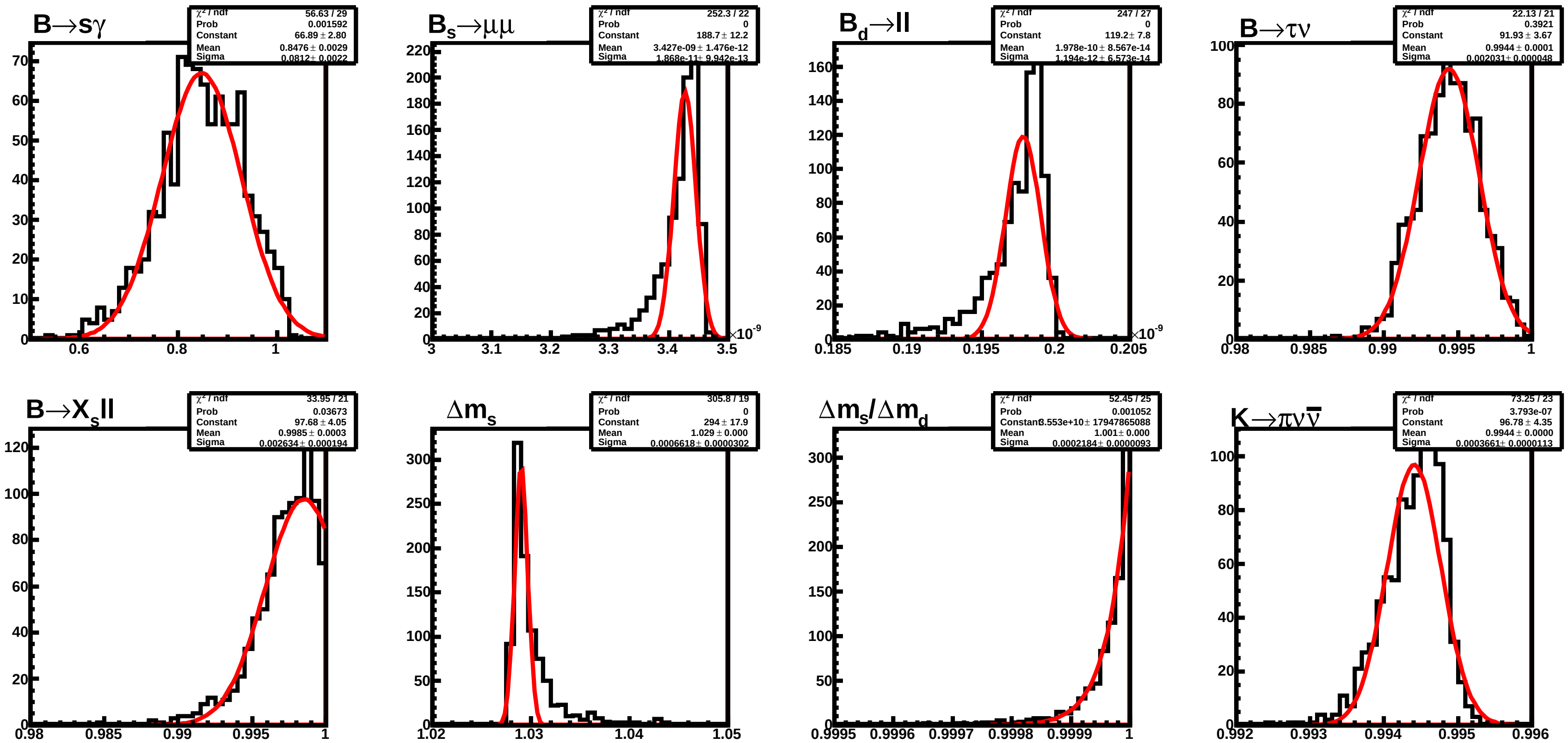
$$(m^2_{q\ell\ell})^{\text{edge}} = \frac{(m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}_2^0})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}_R}}$$

$$(m^2_{q\ell})^{\text{edge}}_{\text{min}} = \frac{(m^2_{\tilde{q}_L} - m^2_{\tilde{\chi}_2^0})(m^2_{\tilde{l}_R} - m^2_{\tilde{l}_R})}{m^2_{\tilde{l}_R}}$$



⇒ Strong impact of LHC constraints on (SPS5) flavor sector:

Toy MC analysis for flavor observables:



⇒ relatively consistent prediction of flavor observables

⇒ Strong impact of LHC constraints on (SPS5) flavor sector:

⇒ relatively consistent prediction of flavor observables

no CKM uncertainties included ⇒ errors only from fit!

theory errors: $\sim 3\%$ ($K_L \to \pi^0 \nu\bar{\nu}$) ... $\sim 25\%$ (ΔM_{B_s})

$$\begin{aligned}
\mathcal{R}(b \to s\gamma) &= 0.848 \pm 0.081 \\
\mathcal{R}(B_u \to \tau\nu_\tau) &= 0.997 \pm 0.003 \\
\mathcal{R}(B_s \to X_s \ell^+ \ell^-) &= 0.995 \pm 0.002 \\
\mathcal{R}(B \to K\nu\bar{\nu}) &= 0.994 \pm 0.001 \\
\mathrm{BR}(B_s \to \mu^+\mu^-) &= (3.427 \pm 0.018) \times 10^{-9} \\
\mathrm{BR}(B_d \to \mu^+\mu^-) &= (1.979 \pm 0.012) \times 10^{-10} \\
\mathcal{R}(\Delta M_{B_s}) &= 1.029 \pm 0.001 \\
\mathcal{R}(K_L \to \pi^0 \nu\bar{\nu}) &= 0.994 \pm 0.001
\end{aligned}$$

⇒ Strong impact of LHC constraints on (SPS5) flavor sector:

⇒ relatively consistent prediction of flavor observables

no CKM uncertainties included ⇒ errors only from fit!

theory errors: $\sim 3\%$ ($K_L \to \pi^0 \nu\bar{\nu}$) . . . $\sim 25\%$ (ΔM_{B_s})

$$\begin{aligned}
\mathcal{R}(b \to s\gamma) &= 0.848 \pm 0.081 \\
\mathcal{R}(B_u \to \tau\nu_\tau) &= 0.997 \pm 0.003 \\
\mathcal{R}(B_s \to X_s \ell^+\ell^-) &= 0.995 \pm 0.002 \\
\mathcal{R}(B \to K\nu\bar{\nu}) &= 0.994 \pm 0.001 \\
\mathrm{BR}(B_s \to \mu^+\mu^-) &= (3.427 \pm 0.018) \times 10^{-9} \\
\mathrm{BR}(B_d \to \mu^+\mu^-) &= (1.979 \pm 0.012) \times 10^{-10} \\
\mathcal{R}(\Delta M_{B_s}) &= 1.029 \pm 0.001 \\
\mathcal{R}(K_L \to \pi^0\nu\bar{\nu}) &= 0.994 \pm 0.001
\end{aligned}$$

⇒ SuperB could not see deviations if SPS5 (MFV) is realized (exc. $b \to s\gamma$?)

⇒ any deviation would prove NMFV!

5. Conclusions

- Tools are an essential part of the interplay issue!
- codes for: low-energy observables
  high-energy observables
  the calculation of amplitudes
  connecting the GUT and the (flavor)experimental scale
  pass parameters/results from one code to another
  UT/CKM fits
  interplay: MasterCode! GFitter?
- Combination of codes:
  - SLHA(2) for (N)MFV/RPV/CPV MSSM, NMSSM $\Rightarrow$ flavor physics?
  - "MasterCode" (various sub-tools included, more is planned)
    $\Rightarrow \chi^2$ analysis performed in CMSSM, NUHM, . . .
- Benchmarks are needed to compare experiments/study interplay
  - SPS analysis $\Rightarrow$ SuperB activities
  - benchmark planes in agreement with all data $\to$ BPO impact
- Future: what is missing?
  how to proceed with combination?
  SLHA-type agreement for flavor physics?

LHC/Flavor workshop: dedicated tools activities

TOOLS 2008 at MPI in Munich, Germany:

Back-up

Q: Can YOU do phenomenology with these new benchmarks?

Q: Can YOU do phenomenology with these new benchmarks?

A: YES! Of course!

Q: Can YOU do phenomenology with these new benchmarks?

A: YES! Of course!

They are included in FeynHiggs

available at `www.feynhiggs.de`

You specify:
- number of the plane
- M_A and $\tan\beta$

You get:
- all low energy parameters
- Higgs masses and mixings
- all Higgs branching ratios
- all Higgs production cross sections
- further precision observables

New M_A–$\tan\beta$ planes:

Data accessed within FeynHiggs in terms of tables
with a grid for M_A and $\tan\beta$

MT	MSUSY	MA0	TB	AT	MUE	...
171.4	500	200	5	1000	761	...
171.4	500	210	5	1000	753	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮
171.4	500	200	6	1000	742	...
171.4	500	210	6	1000	735	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮

FeynHiggs interpolates between the four NWSE points in M_A and $\tan\beta$
FeynHiggs gives an error if $\{M_A, \tan\beta\}$ combination is not allowed

4 M_A–$\tan\beta$ planes can be downloaded from `www.feynhiggs.de`
Definition of new planes by the user is possible (respect table format)