Physics with Herbi

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Herbi's 60th birthday Fest, Bonn, March 27th, 2023

Outline

- Rutherford Lab
- Bonn
- After Bonn till today

First meeting with Herbi

- I first met Herbi at SUSY'98 conference when I started my first post-doc position at Rutherford Appleton Laboratory (RAL) near Oxford. Herbi and Dick Roberts were my mentors.
- Herbi was the one who initiated the pre-SUSY concept in SUSY'98
- Herbi persuaded me to step forward and promote my work (by giving talks, team work etc)
- At RAL we were playing football every Monday!
- When I got injured in football Herbi took me to the hospital
- First project together: he asked Ben and me to derive the 2-loop RGEs in the R-parity violating MSSM

1st paper with Herbi

PHYSICAL REVIEW D, VOLUME 60, 056002

2-loop supersymmetric renormalization group equations including *R*-parity violation and aspects of unification

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We present the complete 2-loop renormalization group equations of superpotential parameters for the supersymmetric standard model including the full set of *R*-parity violating superpotential couplings. We use these equations to do a study of (a) gauge coupling unification, (b) bottom-tau unification, (c) the fixed-point structure of the top quark Yukawa coupling, and (d) two-loop bounds from perturbative unification. The value of $\alpha_S(M_Z)$ predicted from unification can be reduced by 5% with respect to the *R*-parity conserving case, bringing it to within 2σ of the observed value. Bottom-tau Yukawa unification becomes potentially valid for any value of $\tan\beta \sim 2-50$. The prediction of the top Yukawa coupling from the low $\tan\beta$ infrared quasi-fixed point can be lowered by up to 10%, raising $\tan\beta$ up to a maximum of 5 and relaxing experimental constraints upon the quasi-fixed scenario. For heavy scalar fermion masses $O(1\ \text{TeV})$ the limits on the higher family $\Delta L \neq 0$ operators from perturbative unification are competitive with the indirect laboratory bounds. We calculate the dependence of these bounds upon $\tan\beta$. [S0556-2821(99)04217-4]

2nd paper with Herbi

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Bounds on *R*-parity violating couplings at the weak scale and at the GUT scale

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We analyze bounds on trilinear *R*-parity violating couplings at the unification scale by renormalizing the weak scale bounds. We derive unification scale upper bounds upon the couplings which are broadly independent of the fermion mass texture assumed. The *R*-parity violating couplings are factors of 2–5 more severely bounded at the unification scale than at the electroweak scale. In the presence of quark mixing, a few of the bounds are orders of magnitude stronger than their weak scale counterparts due to new *R*-parity violating operators being induced in the renormalization between high and low scales. These induced bounds are fermion mass texture dependent. New bounds upon the weak scale couplings are obtained by the requirement of perturbativity between the weak and unification scales. A comprehensive set of the latest limits is included.
[S0556-2821(99)04819-5]

3rd paper with Herbi

Dipole moments of the electron, neutrino and neutron in the MSSM without R-parity symmetry

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JHEP05(2000)013

Abstract: We show that in the MSSM without R-parity symmetry there are *no* new contributions to electron and neutron electric dipole moments (EDMs) at one-loop induced by the R-parity violating Yukawa couplings. Non-zero EDMs for the electron and neutron first arise at the two-loop level. As an example we estimate the contribution of a two-loop graph which induces electron EDMs. On the other hand, we show that the (Majorana) neutrino electric and magnetic transition moments are non zero even at the one-loop level. Constraints on the R-parity violating couplings are derived from the existing bounds on the neutrino dipole moments.

4th paper with Herbi

A light bottom squark in the MSSM

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ABSTRACT: We study the compatibility of a light bottom squark $M_{\tilde{b}} < \mathcal{O}(10\,\text{GeV})$ in the unconstrained MSSM. We consider the one-loop radiative corrections which are large for a heavy gluino ($> \mathcal{O}(150\,\text{GeV})$). We then consider the renormalization group flow up to the Grand Unified scale. For most regions of the parameter space with a light sbottom we find directions in the scalar potential which are unbounded from below. Only a small window in gluino mass and $\tan\beta$ is consistent with all bounds. This is alleviated by a light gluino, which is however only marginally experimentally allowed.

KEYWORDS: Beyond Standard Model, Supersymmetric Standard Model.

JHEP06(2001)006

The last RAL-theory group photo (Summer 2000)

Left to right: Stefano Moretti, Cyril Hugonie, Herbi Dreiner, Sakis Dedes, Jay Watson, Mike Seymour, Robert Thorne, Richard Roberts, Frank Close, Peter Richardson, Roberto, Alberto.

Bonn

- In year 2000, Herbi was appointed professor in Bonn University. Hans-Peter kindly offered me a 2-year post-doc position there.
- Our collaboration in Bonn was fantastic!
- Herbi was always there to help!
- I even learned quite a few German by Heike (from Herbi I learned only the German swearwords. . . !)
- We also used to play football in Bonn too, but we also wrote three more papers...

5th paper with Herbi

PHYSICAL REVIEW D, VOLUME 65, 015001

Attempts at explaining the NuTeV observation of dimuon events

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The NuTeV Collaboration has observed an excess in their dimuon channel, possibly corresponding to a long-lived neutral particle with only weak interactions and which decays to muon pairs. We show that this cannot be explained by pair production of neutralinos in the target followed by their decay far downstream in the detector via a LLE R-parity violating operator, as suggested in the literature. In the parameter region allowed by the CERN e^+e^- collider LEP the event rate is far too small. We propose instead a new neutralino production method via B mesons, which can fully explain the observation. This is analogous to neutrino production via π mesons. This model can be completely tested and thus also possibly excluded with NOMAD data. If it is excluded, the NuTeV observation is most likely not due to physics beyond the standard model. Our model can also be tested at the current and future B factories. This opens up a new way of testing for a long-lived neutralino lightest supersymmetric particle at fixed-target experiments and thus the possibility of closing the gap between collider and cosmological tests of R-parity violation. We also discuss a possible explanation in terms of a neutral heavy lepton mixing with the standard model neutrinos. The flavor structure of the observation can be accounted for but the production rate is far too low.

6th paper with Herbi

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Correlation of $B_s \to \mu^+\mu^-$ and $(g-2)_\mu$ in Minimal Supergravity

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We analyze the decay mode $B_s \to \mu^+\mu^-$ in minimal supergravity (mSUGRA). We find that the recently measured excess in $(g-2)_\mu$, if interpreted within mSUGRA, is correlated with a substantial enhancement of the branching ratio $\mathcal{B}(B_s \to \mu^+\mu^-)$: if $(g-2)_\mu$ exceeds the standard model prediction by 4×10^{-9}, $\mathcal{B}(B_s \to \mu^+\mu^-)$ is larger by a factor of 10–100 and within reach of Run-II of the Tevatron. Thus the search for $B_s \to \mu^+\mu^-$ is a stringent test of the GUT scale relations of mSUGRA. An observation of $B_s \to \mu^+\mu^-$ at the Tevatron implies a mass of the lightest SUSY Higgs boson below 120 GeV. $B_s \to \mu^+\mu^-$ can also significantly probe SO(10) SUSY GUT models.

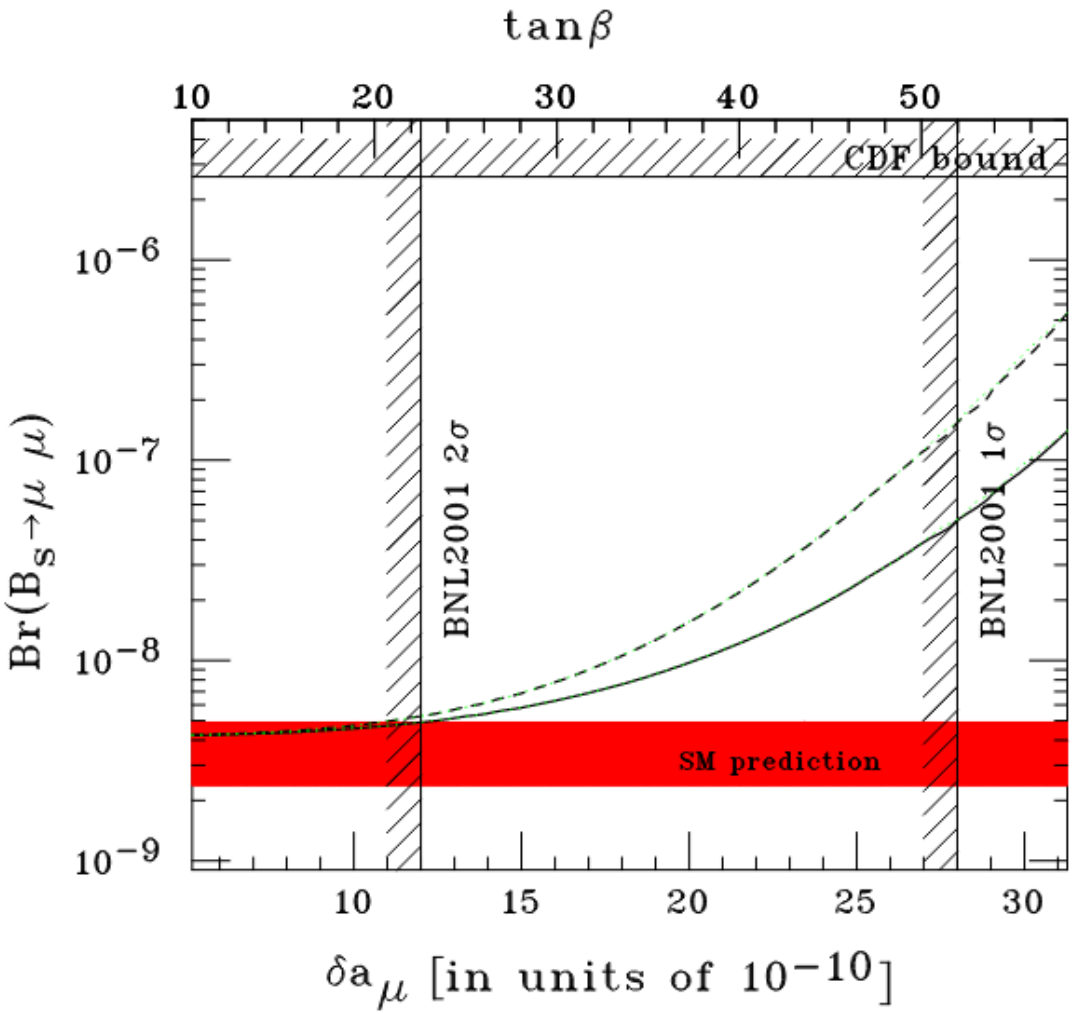

FIG. 1. $(\delta a_\mu)_{SUSY}$, versus $\mathcal{B}(B_s \to \mu^+\mu^-)$ for $\tan\beta$ (top) and $M_{1/2}$=450, $M_0 = 350, A_0 = 0, \mu > 0, m_t = 175$ GeV. Shown also, the SM prediction, the present bound by CDF [13], on $\mathcal{B}(B_s \to \mu^+\mu^-)$ as well as the present 1σ and 2σ bound on δa_μ from BNL [2]. We used $f_{B_s} = 230$ MeV.

7th paper with Herbi

PHYSICAL REVIEW D **69**, 115002 (2004)

R-parity violating minimal supergravity model

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We present the minimal supersymmetric standard model with general broken *R* parity, focusing on minimal supergravity (MSUGRA). We discuss the origins of lepton number violation in supersymmetry. We have computed the full set of coupled one-loop renormalization-group equations for the gauge couplings, the superpotential parameters, and for all the soft supersymmetry breaking parameters. We provide analytic formulas for the scalar potential minimization conditions which may be iterated to arbitrary precision. We compute the low-energy spectrum of the superparticles and the neutrinos as a function of the small set of parameters at the unification scale in the general basis. Specializing to MSUGRA, we use the neutrino masses to set new bounds on the *R*-parity violating couplings. These bounds are up to five orders of magnitude stricter than the previously existing ones. In addition, new bounds on the *R*-parity violating couplings are also derived demanding a nontachyonic sneutrino spectrum. We investigate the nature of the lightest supersymmetric particle and find extensive regions in parameter space where it is *not* the neutralino. This leads to a novel set of supersymmetric signatures, which we classify.

The wedding (Evia, 19th of October, 2002)

Yiota Kanti and Herbi Dreiner in our wedding

Today (Pre-SUSY 2022, Ioannina, Summer 2022)

From left to right: Sakis Dedes, Mark Goodsell, John Ellis, Herbi Dreiner, Carlo Angelantonj, Anastasios Petkou

Epilogue

Herbi offered to me his continuous support not only during my first steps in physics but for many years after, at different stages of my career.

The physics I discussed with Herbi was a lot more fun than the physics I had in mind to pursue when I came to RAL.

I am deeply grateful, Herbi, for all your support, friendship, and the love for the "physics of the real world" you inspired in me.

Happy 60th Birthday!