Project B4: Field Theoretic Aspects of New Physics

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1. Mission
2. Status quo
3. First physics results
1. Mission

- **Rule:** Mixing and instability of elementary particles concur in nature
- **Status of field theory treatment:**
  - Renormalization of CKM matrix for stable quarks satisfying UV finiteness, gauge independence, unitarity and flavour democracy
  - Renormalization of masses and wave functions of unstable particles without mixing satisfying gauge independence (pole scheme)
- **Mission for SFB:** Construct pole scheme of mixing renormalization for unstable particles that unifies both aspects in a physically consistent and mathematically rigorous way
- **Methods:** higher-order perturbation theory in $R_\xi$ gauge, $S$-matrix theory, BRST symmetry, Nielsen identities, modern computer algebra
- **Milestones:**
  - $t \to b l^+ \nu_l$ in the SM as starting point: proper treatment of imaginary parts due CKM matrix and absorptive parts
Incorporation of (Majorana) neutrinos: required by experimental evidence for flavour oscillations and finite masses in neutrino sector

Incorporation of bosons: mixing of unstable sfermions in MSSM scenarios

Generalization to all orders: proof on the basis of BRST symmetry exploiting Nielsen identities

Applications to new-physics scenarios: reliable predictions for most important production and decay processes of heavy neutrinos and sfermions at LHC and ILC

Networking with other projects:

- B3: neutrinos in the SM
- B6: strong interactions and new physics at the LHC
- B2: supersymmetry at the LHC
- A3: high-energy limit of QCD
- C3: leptogenesis
3. Status quo

- **People:**
  - University: Simon Albino (since June 2006), Bernd Kniehl, Gustav Kramer
  - Guests: Alberto Sirlin (MPI Munich, August 2006)
  - SFB Positions: Malgorzata Awramik (from July 2006 through September 2007 lended out to Project B1; see her talk)
  - GK Positions: 1 PhD student searched for

- **Papers:**
3. First physics results

- **Goal**: Find renormalization prescription for CKM matrix with properties:
  - on-shell scheme
  - UV finiteness
  - unitarity
  - gauge independence
  - absence of singularities for mass-degenerate quarks
  - no shift in $V_{ud}$
  - simplicity

- **Literature**: All starts from mass basis of quark fields.
• Idea:

- separate external-leg mixing corrections,

\[
\Delta M_{ii'}^{\text{leg}} = \bar{u}_i(p) \Sigma_{ii'}(\phi) \frac{1}{\bar{\psi} - m_{ii'}},
\]

into gauge-independent self-mass and gauge-dependent wave-function renormalization contributions

- adjust non-diagonal mass counterterm matrices,

\[
-\bar{\psi}_R \left( m - \delta m^{(-)} \right) \psi_L - \bar{\psi}_L \left( m - \delta m^{(+)} \right) \psi_R,
\]

to cancel all the divergent self-mass contributions, and also their finite parts subject
to constraints imposed by the hermiticity of the mass matrices,

$$\delta m^{(+)} = \delta m^{(-)\dagger}$$

- diagonalize complete mass matrix by biunitary transformation,

$$\psi_{L,R} = U_{L,R} \hat{\psi}_{L,R},$$

$$U_{L,R} = 1 + i h_{L,R},$$

$$i(h_{L,R})_{ii'} = \frac{m_i \delta m_{ii'}^{(\mp)} + \delta m_{ii'}^{(\pm)} m_{i'}}{m_i^2 - m_{i'}^2} \quad (i \neq i')$$

- CKM counterterm matrix:

$$\delta V = i \left( h_L^U V - V h_L^D \right)$$