The impact of rare K decays in New Physics searches

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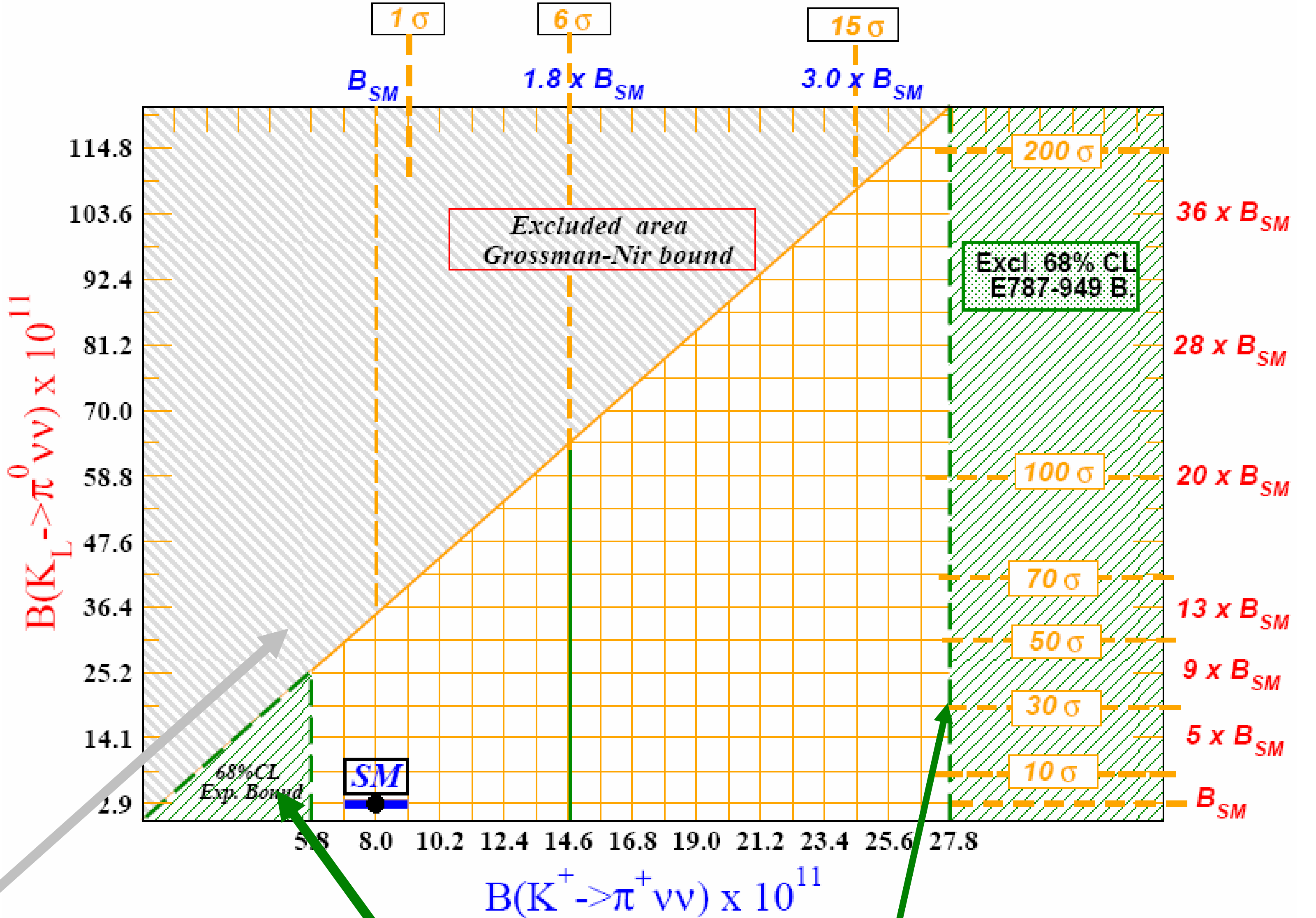
Golden Modes	Standard Model	Experiment	
$K^+ \to \pi^+ \nu\bar{\nu}$	$8.0^{+1.1}_{-1.1} \times 10^{-11}$	$14.7^{+13.0}_{-8.9} \times 10^{-11}$	E787 E949
$K_L \to \pi^0 \nu\bar{\nu}$	$2.9^{+0.4}_{-0.4} \times 10^{-11}$	$< 2.9 \times 10^{-7}$	E391a
$K_L \to \pi^0 e^+ e^-$	$3.7^{+1.1}_{-0.9} \times 10^{-11}$	$< 2.8 \times 10^{-10}$	KTeV
$K_L \to \pi^0 \mu^+ \mu^-$	$1.5^{+0.3}_{-0.3} \times 10^{-11}$	$< 3.8 \times 10^{-10}$	KTeV

CKM 2006 - December 12-16, 2006 - Nagoya

2006

$K_L \to \pi\nu\nu \div K^+ \to \pi\nu\nu$: uncertainties at 15% due to present CKM accuracy



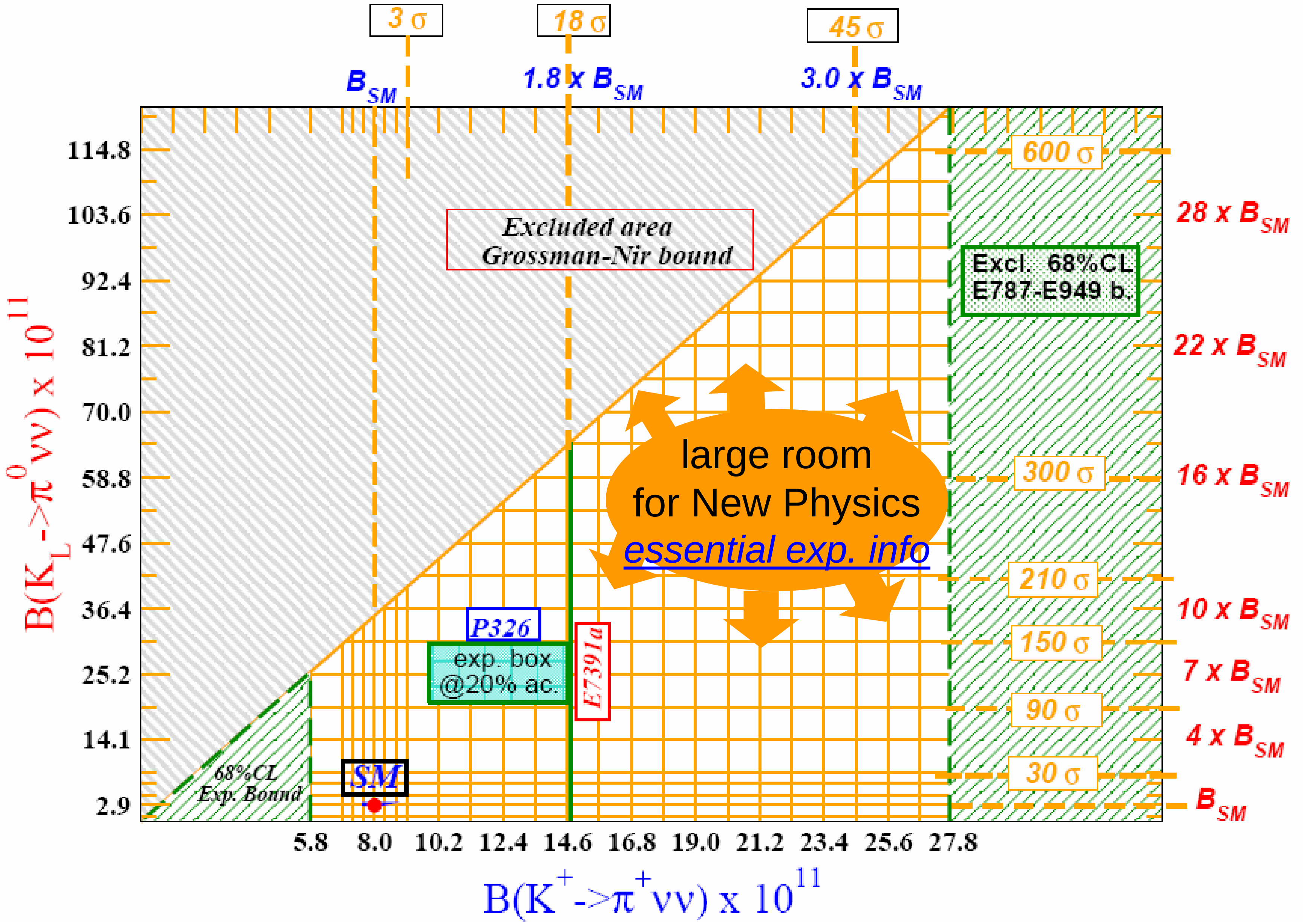
$B(K^+ \to \pi^+ \nu\bar{\nu}) = 14.7^{+13.0}_{-8.9} \times 10^{-11}$ [E787-E949]

$B(K_L \to \pi^0 \nu\bar{\nu}) \leq 4.4 B(K^+ \to \pi^+ \nu\bar{\nu})$ [Grosmann - Nir Bound]

2010

at 5% uncertainties with CKM updates from Babar/Belle/LHCb

$K_L \to \pi^0 \nu\nu$ – $K^+ \to \pi^+ \nu\nu$: high-precision discovery lens!



large unexplored room in principle, but

1 *is it still possible to expect deviations, despite constraints from the large amount of processes compatible with the Standard Model?*

reminder

- ✓ tree-level processes → disfavoured for *NP* searches, normally $(M_W/\Lambda)^2 \leq 1\%$
  (*Mind at special cases*, *Paride's talk*)
- ✓ FCNC loop processes → suitable for *NP*, *only* measured *$\Delta B=2$, $\Delta S=2$ and $\Delta B=1$ transitions*
- ✓ K rare decays → $s \to d$ coupling and highest CKM suppression → like ε'/ε
  very clean → like $\sin 2\beta$

2 *in any case, LHC will saturate the room left, won't it?*

- ➢ ATLAS-CMS → new particles at the TeV scale by flavour conserving channels
  complementarity information @TeV
- ➢ LHCb at work → $B_s \to \mu\mu$ and $B_d \to \mu\mu$, information on $b \to s/b \to d$ couplings

$K \to \pi\nu\nu$ & $K \to \pi\ell\ell$ *can give some surprise, with small effects in B and EWPT*

Moreover, clean probe to higher scale $\Lambda_{flav} \sim 100$ *TeV*

Let's not forget "The definitive answer is from experiments"

G. Galileo

Two classes of "*Beyond SM*" scenarios:

1. Minimal Flavour Violation:

flavour breaking induced only by SM Yukawa couplings, Y_U & $Y_{D.}$

(*Y: Wilson coefficient at* Λ_{flav}»1 TeV)

• *SM hierarchy of FV couplings:*

$(s\to d)_{MFV} = O(\lambda^5)\times[\ \mathrm{SM} + \text{new d.o.f}\ ]$

• Specific realisations in *SUSY, UED, LH, EFT*

• Small deviations in specific models:

$B(K_L\to\pi^0\nu\nu) \leq O(20\%\text{-}30\%)$

• In specific models, stringent correlations can rise with either B physics ($B\to\ell\ell$, $B\to X\ell\ell$, $B\to X\nu\nu$) or EWPT ($\Delta\rho$)

2. New sources of Flavour Symmetry breaking arising at the TeV scale

• $s\to d$ new couplings no longer $O(\lambda^5)$ suppressed

$(s\to d)_{BMFV} = O(\lambda^5)\times \mathrm{SM} + O(1)\times(\text{new d.o.f})$

• *Many proposed models already killed from present data (B, K, EWPT & DM)*

• *One order of magnitude enhancement still possible in MSSM and LHT* → Cecilia & Buras

$B(K_L\to\pi^0\nu\nu) \leq 5\,10^{-10}$

in reach of E391a upgrade

Pattern*:* effects on $B(K_L\to\pi^0\nu\nu) > B(K^+\to\pi^+\nu\nu) > B(K_L\to\pi^0\ell\ell)$

Peculiarity: $K_L\to\pi^0\mu\mu - K_L\to\pi^0 ee$ correlation

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Minimal Flavour Violation $\to$ U(3)^{5}EFT at TeV

D'Ambrosio,Giudice,Isidori,Strumia (02)

$$\mathcal{L}_{eff} = \mathcal{L}_{gauge}(A_i,Q_i,H) + \underbrace{\bar{Q}_L Y_D D_R H + \bar{Q}_L Y_U U_R H_c} + \sum_i \frac{c_i^6 \cdot O_i^6}{\Lambda_{flav}^2} + \dots$$

$U(3)^5$ flavour group

Y_D & Y_U regulate flavour violation: $\cancel{U(3)^5}$

$\mathcal{L}_{SM}$

new d.o.f @ TeV

$O^6 \to$ functions of SM fields and Y_D-Y_U spurions, made invariant of $U(3)^5 \equiv SU(3)^5 \otimes B \otimes L \otimes CP$.

- $c^6 \to$ universal and real coef.

see Grinstein's talk

Minimal Flavour Violation → U(3)^{5}EFT at TeV

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K-rare decays

13 operators

$$\left.\begin{array}{l} c_1^6\left(\overline{Q}_L Y_U Y_U^+ \gamma_\mu Q_L\right)\left(H^+ D_\mu H\right) + c_2^6\left(\overline{Q}_L Y_U Y_U^+ \vec{\tau}\gamma_\mu Q_L\right)\left(H^+ \vec{\tau} D_\mu H\right) \\ c_3^6\left(\overline{Q}_L Y_U Y_U^+ \gamma_\mu Q_L\right)\left(\overline{L}_L \gamma_\mu L_L\right) + c_4^6\left(\overline{Q}_L Y_U Y_U^+ \vec{\tau}\gamma_\mu Q_L\right)\left(\overline{L}_L \gamma_\mu \vec{\tau} L_L\right) \\ c_5^6\left(\overline{D}_R Y_D Y_U Y_U^+ \sigma_{\mu\nu} Q_L\right) F^{\mu\nu} + c_6^6\left(\overline{Q}_L Y_U Y_U^+ \gamma_\mu Q_L\right)\left(\overline{Q}_L Y_U Y_U^+ \gamma_\mu Q_L\right) \end{array}\right\} \rightarrow \begin{array}{l} \boxed{V_{ts}^* V_{td} X\left(\overline{s}_L \gamma_\mu d_L\right)\left(\overline{\nu}\gamma_\mu^L \nu\right)} + V_{ts}^* V_{td} K_{V/A}\left(\overline{s}_L \gamma_\mu d_L\right)\left(\overline{l}l\right)_{V/A} \\ V_{tb}^* V_{ts} K_{V/A}\left(\overline{b}_L \gamma_\mu s_L\right)\left(\overline{l}l\right)_{V/A} + V_{tb}^* V_{td} K_{V/A}\left(\overline{b}_L \gamma_\mu d_L\right)\left(\overline{l}l\right)_{V/A} \\ V_{tb}^* V_{ts} m_b C_7\left(\overline{b}_R \sigma_{\mu\nu} s_L\right) F^{\mu\nu} + V_{ts}^* V_{td} B\left(\overline{s}_L \gamma_\mu d_L\right)\left(\overline{s}_L \gamma_\mu d_L\right) \end{array}$$

...

$$\left(Y_U Y_U^+\right)_{ij} \propto V_{ti}^* V_{tj} m_t^2 / m_W^2$$

D'Ambrosio, Giudice, Isidori, Strumia (02)

K-rare decays

$$\boxed{K \to \pi\nu\overline{\nu}}, K \to \pi^0 \ell\overline{\ell}, \varepsilon_K$$

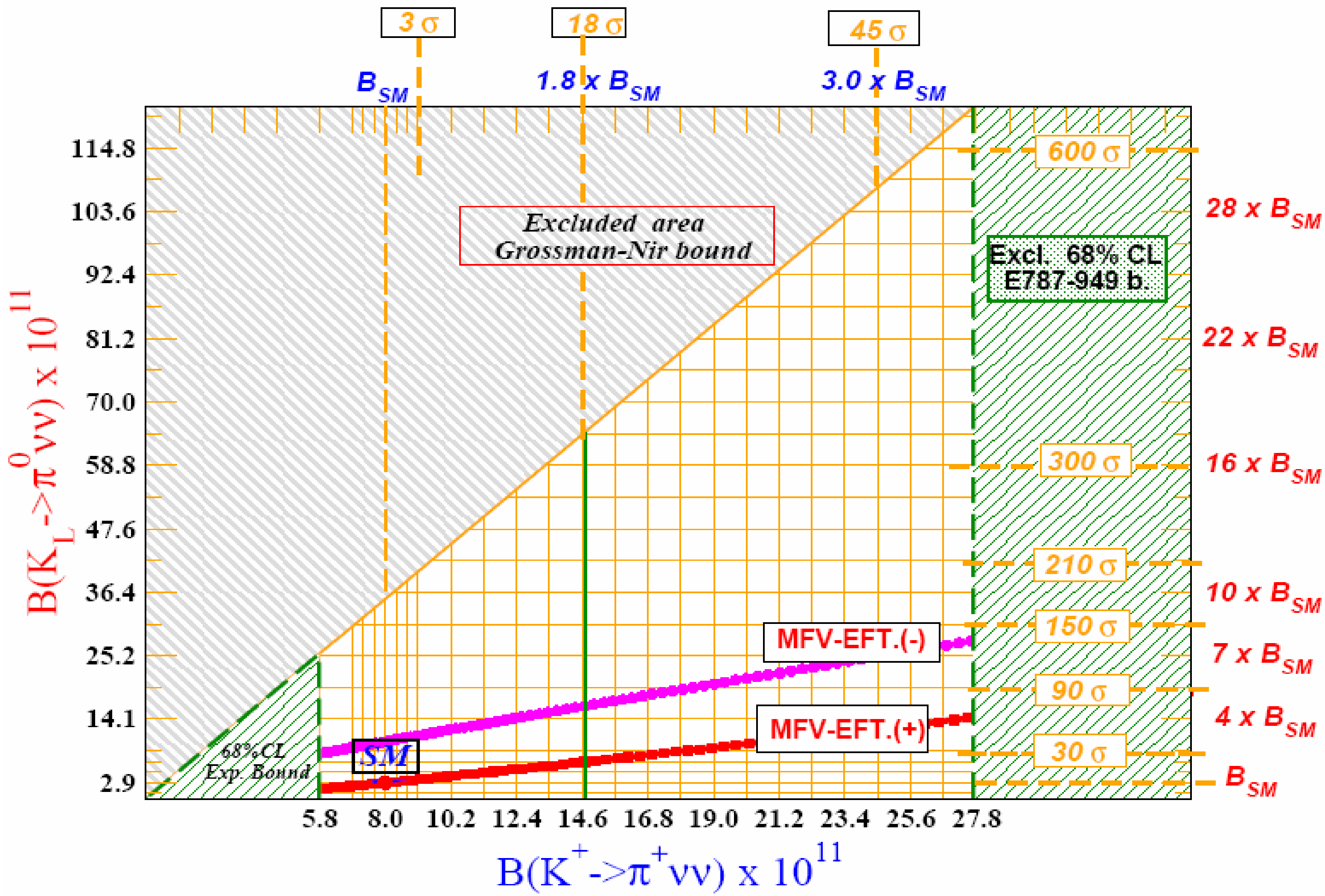
$$B \to X_{s/d} \ell\overline{\ell}, B \to X_{s/d}\gamma$$

1. CKM suppression ($O(\lambda^5)$) still on;
2. the X coefficient unbounded from B processes or ε_K

$$\frac{B(K_L \to \pi^0 \nu\overline{\nu})}{B(K^+ \to \pi^+ \nu\overline{\nu})} \propto \frac{\left|V_{ts}^* V_{td} X\right|^2 \sin\beta_{SM}^2}{\left|V_{ts}^* V_{td} X\right|^2 \left[1 + \varepsilon_c \mathrm{sign} X\right]} \simeq \left.\frac{B(K_L \to \pi^0 \nu\overline{\nu})}{B(K^+ \to \pi^+ \nu\overline{\nu})}\right\|_{SM} \times \left[1 + \varepsilon_c \mathrm{sign} X\right]$$

MFV
model
independent ap.

$$\left.\frac{B(K_L\to\pi^0\nu\bar\nu)}{B(K^+\to\pi^+\nu\bar\nu)}\right\|_{MFV} = \left.\frac{B(K_L\to\pi^0\nu\bar\nu)}{B(K^+\to\pi^+\nu\bar\nu)}\right\|_{SM} \times\left[1+\varepsilon_c\,\mathrm{sign}X\right]$$



MFV enhancement: $B(K_L\to\pi^0\nu\nu) \le 4.6\, B^{SM}$ $B(K^+\to\pi^+\nu\nu)/B(K_L\to\pi^0\nu\nu)$ ~SM

MFV- Specific Scenarios

In a given model implementation, *X* bounded trough *EWPT* & *B* data.
Deviations from SM can get smaller

1. MFV- Phenomenological Model (CMFV)

- *only Standard Model operators*

Buras,Gambino,Gorbahn,Jäger,Silvestrni (00)

- *box and g-peng. d.o.f frozen to their SM value*

Bobeth,Bona,Buras,Ewerth,Pierini,Silvetrini,Weiler (05)

$$\left.\begin{array}{l} B(B\to X_s\gamma)\cong\left|C_7^{eff}\right|^2 \\ B(B\to X_s\ell\bar{\ell})\to Y,Z,E,C_7^{eff} \end{array}\right\} \xrightarrow[\text{Model d.}]{E=0} \begin{pmatrix} Y \\ Z \end{pmatrix} \xrightarrow[\text{Model d.}]{Y\cong X} \left\{\begin{array}{l} B(K\to\pi\nu\bar{\nu})\to X \\ B(K\to\pi\ell\bar{\ell})\to Y,Z,E \end{array}\right.$$

X -> constrained by *B* processes

$$Y = X + \cancel{B^{ll} - B^{\nu\nu}}$$

$$Z = X + \frac{1}{4}\left(D_\gamma - 4B^{\nu\nu}\right)$$

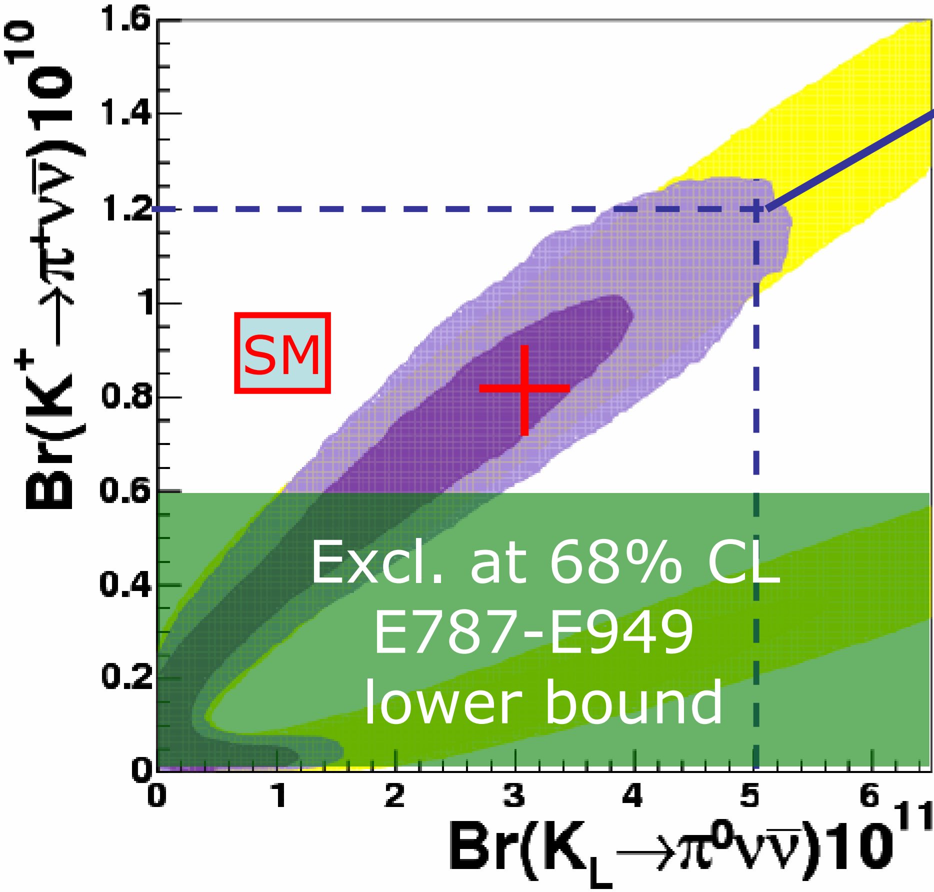
gauge invariant

s.d. couplings

Analysis on MFV-Phenomenological Model

X≅Y and E≅0

Bobeth,Bona,Buras,Ewerth,Pierini,Silvetrini,Weiler (05)



at 95% CL

O(20-50%) enhancement

$B(K_L \to \pi^0 \nu\nu) \leq 1.6\, B^{SM}$

$B(K^+ \to \pi^+ \nu\nu) / B(K_L \to \pi^0 \nu\nu)$ ~SM

MFV-EFT: X free

D'Ambrosio,Giudice,Isidori,Strumia (02)

$$\left.\frac{B(K_L \to \pi^0 \nu\bar{\nu})}{B(K^+ \to \pi^+ \nu\bar{\nu})}\right\|_{MFV} = \left.\frac{B(K_L \to \pi^0 \nu\bar{\nu})}{B(K^+ \to \pi^+ \nu\bar{\nu})}\right\|_{SM} \times \left[1 + \varepsilon_c \mathrm{sign} X\right]$$

Outcome:

MFV + Exp. Evidence of K⁺ excludes small vanishing K_L *BR*

MFV- Specific Scenarios

In a given model implementation, *X* bounded trough *EWPT*, *B & K* data.
Deviations from SM can get smaller

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2. MFV+SUSY- *Msugra-like*

D'Ambrosio,Giudice,Isidori,Strumia (02)

a) SUSY→

- spectrum:SM+4Higgs+SUSY partners
- dark matter candidate
- stabilization of Higgs sector

b) MFV→

- *scalar soft breaking terms proportional to SM Yukawa couplings*

$$\boxed{M_{\tilde u}^2=\underbrace{\begin{pmatrix}\left(m_U^2\right)_{LL} & \left(m_U^2\right)_{RL}\\ \left(m_U^2\right)_{RL}^{\dagger} & \left(m_U^2\right)_{RR}\end{pmatrix}}_{6x6}}$$

$$\left(m_U^2\right)_{RL}=\left(a_4^*-\mu\cot\beta\right)M_u$$

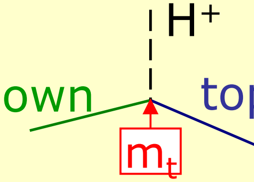
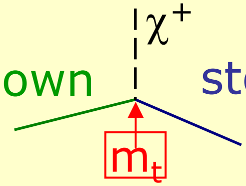
$$\left(m_U^2\right)_{LL}\propto a_1^2 1\ldots$$

$$\left(m_U^2\right)_{RR}\propto a_2^2 1\ldots$$

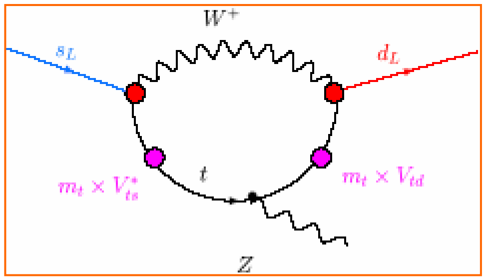
H & χ ***interactions*** **ruled by CKM** (super CKM basis)

Analysis on MFV-MSSM (R-parity)

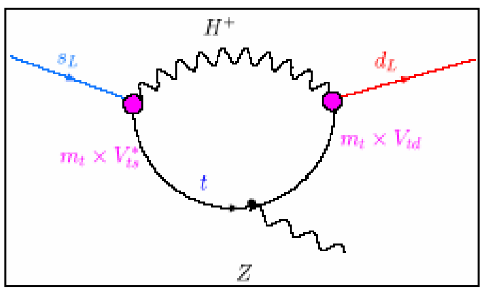
Isidori,F.M,Paradisi,Trine,Smith (06)

Largest effects by down  top and down  stop_R, since enhanced by the large top mass

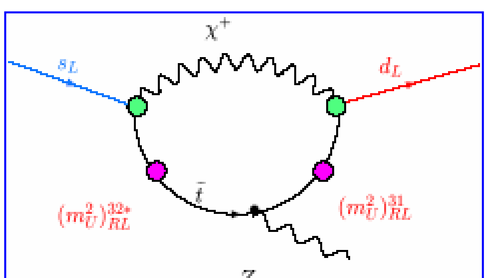
Nir,Worah(98)/Buras,Romanino,Silvestrini(98)/Colangelo,Isidori(98)



$$W^+ \propto V_{ts}^* V_{td} \times \frac{m_t^2}{M_W^2}$$



$$H^+ \propto V_{ts}^* V_{td} \times \frac{m_t^2}{M_W^2} \cot\beta^2 \frac{m_t^2}{M_H^2}$$



$$\chi^+ \propto V_{ts}^* V_{td} \frac{m_t^2}{M_W^2} \frac{M_W^2 \left| a_4^* - \mu \cot\beta \right|}{M_{\tilde{t}}^2 M_{\chi^+}^2}$$

+perm.+boxes

no FV via gluino/neutralino

- *common CKM factor*
- enhancements due to *flavour conserving* parameters: $\Leftrightarrow$ LHC
  1. small $\tan\beta \rightarrow 2$
  2. light spectrum;
     stop$\rightarrow$ 150 GeV
     chargino$\rightarrow$ 150 GeV
     charged Higgs$\rightarrow$ 300 GeV
  3. large a_4 ;maximal effects for sign(μ)=–sign(a_4)
- *the largest correlation from* $\Delta\rho$

Buras,Gambino,Gorbahn,Jager,Silvestrini (00)

- *Upper limits*

  $B(K_L \rightarrow \pi^0 \nu\nu) \leq 1.25\, B^{SM}$

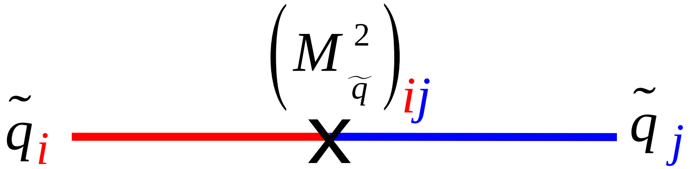
Isidori,F.M,Paradisi,Trine,Smith (06)

Two classes of "*Beyond SM*" scenarios:

2. New sources of Flavour Symmetry breaking arising at the TeV scale

MSSM: generic insertions

120 parameters free! MAMMA MIA!



and ... 27 new Flavour Changing couplings along the squark lines.

What can we ever learn from K-rare?

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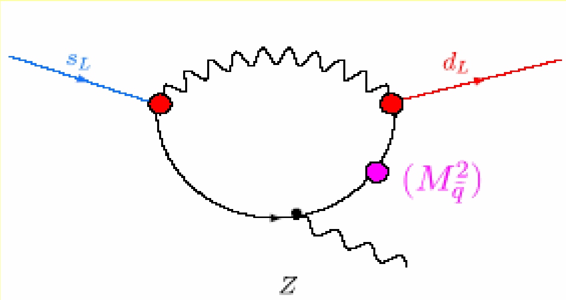


New FCNC transitions by

gluino, neutralino and chargino

$\propto \alpha_s \left(M^2_{\tilde{d}}\right)_{ij}$ $\quad$ $\cancel{\propto \alpha_w \left(M^2_{\tilde{d}}\right)_{ij}}$ $\quad$ $\propto \alpha_w \left(M^2_{\tilde{u}}\right)_{ij}$

The interplay between $SU(2)_L \otimes U(1)$ and Flavour symmetry prevents strong headaches:

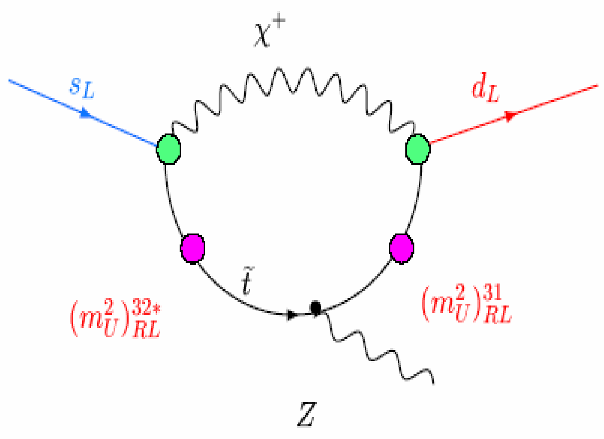
1. $SU(2)_L$-conserving insertions, $M_{LL/RR} \rightarrow q^2/m^2_Z$ suppressed
2. LR mass insertions $\rightarrow$ propto to quark masses $\rightarrow$ $\left(m^2_U\right)^{3j}_{RL} = m_t \left(A^U - \mu \cot\beta\right)^{3j}$

$\Rightarrow$ gluino diagrams negligible;

contrary to ε_K, $b \rightarrow s\gamma$, ΔM_{B_d}, CPV in B decays

$\Rightarrow$ <u>appreciable sensitivity only</u> to χ-up-squark diagrams by 1 effective coupling

$$\rightarrow \left(m^2_U\right)^{32*}_{RL} \cdot \left(m^2_U\right)^{31}_{RL}$$



Nir,Worah(98)/Buras,Romanino,Silvestrini(98)/Colangelo,Isidori(98)

What can we ever learn from K-rare? a lot

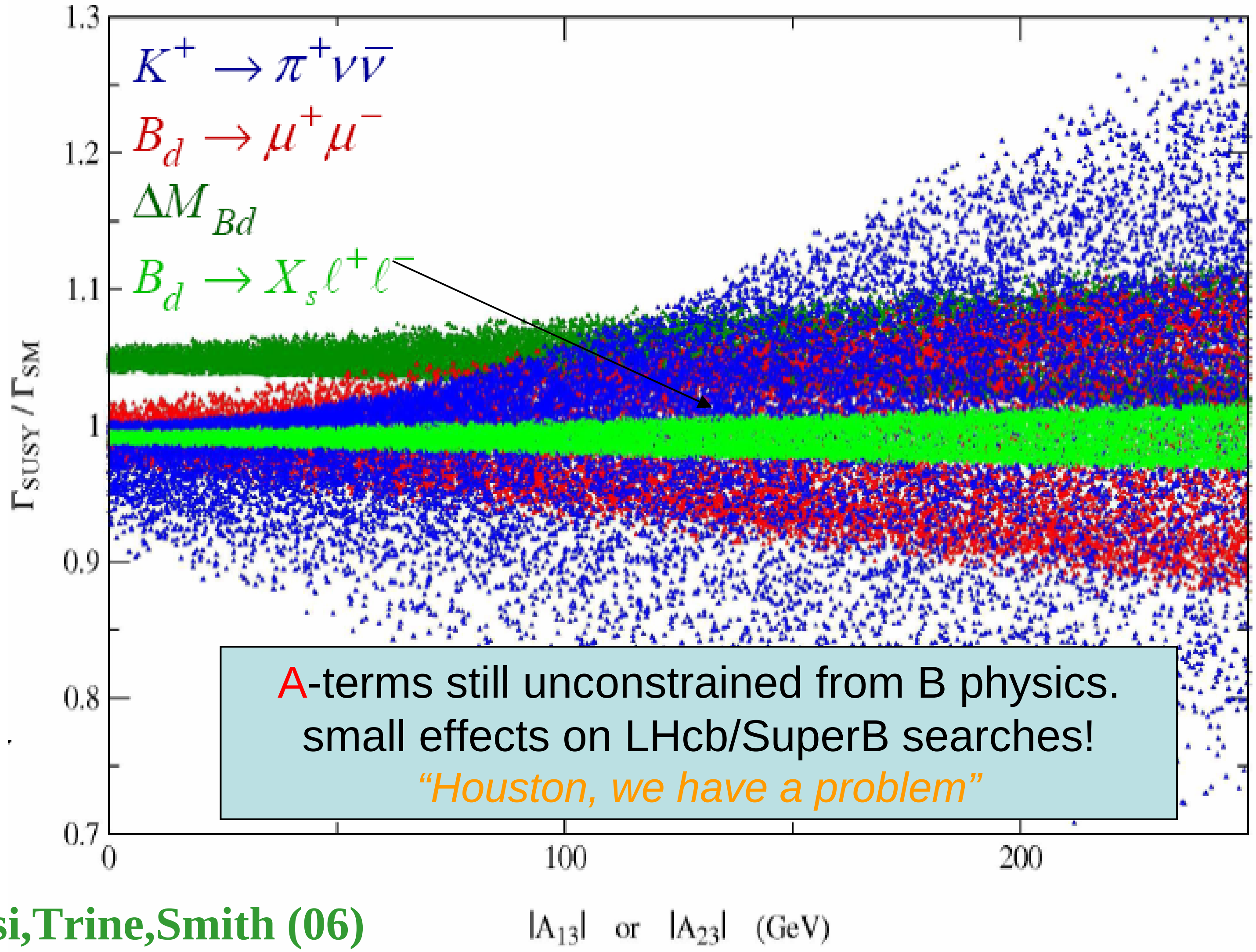
$K \to \pi\nu\nu$ are the *best probe* of the flavour structure of the A^U terms ($\propto M_t$)

$$\left(m_U^2\right)_{RL}^{ij} = M_u\left(A^U - \mu\cot\beta\right)^{ij}$$

$|\mathbf{A}_{13}^U|, |\mathbf{A}_{23}^U| \leq A_0\lambda,$
$A_0 = 1$ TeV
Phases left free.

LHC - spectrum

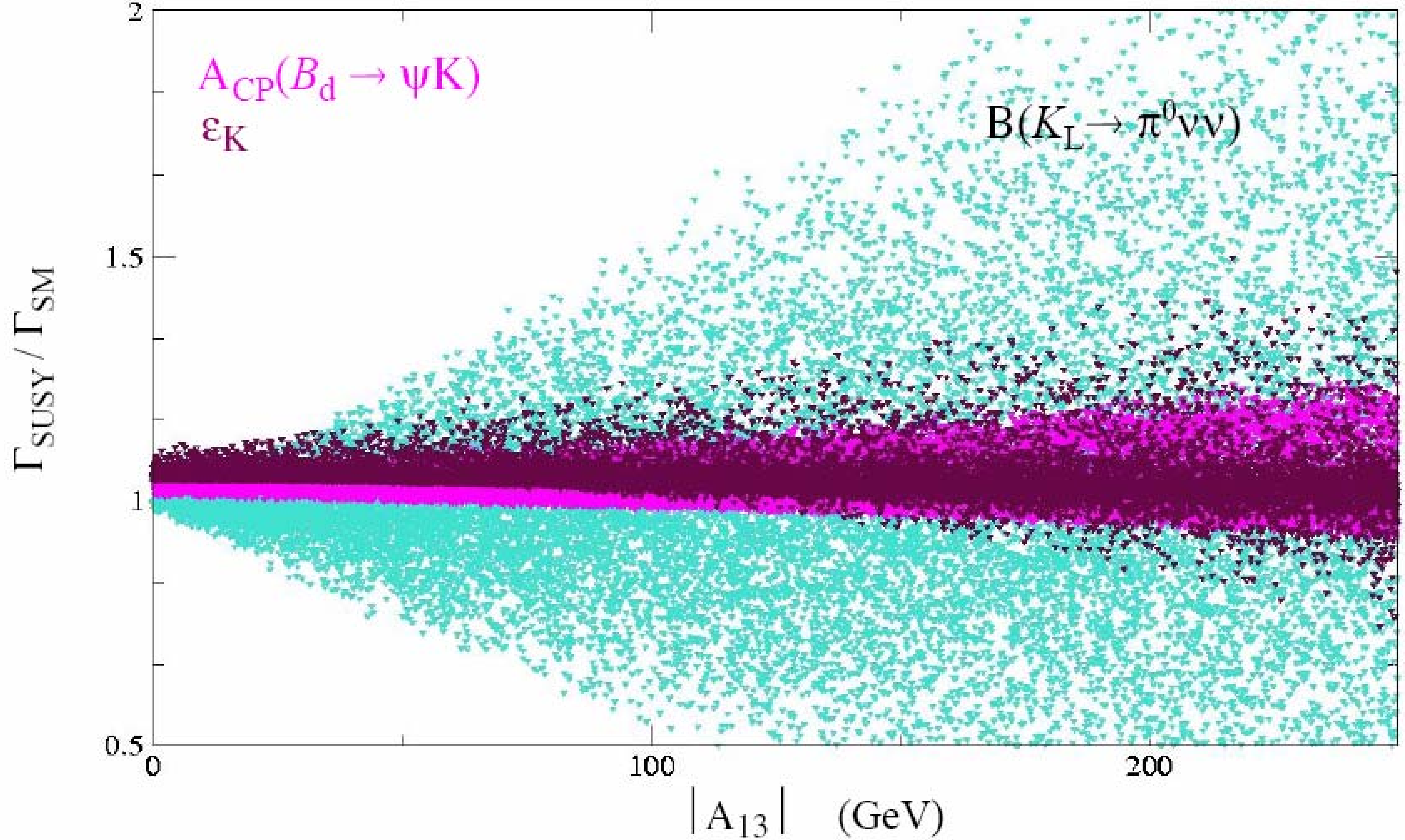
$\tan\beta = 2 - 4$
$\mu = 500 \pm 10$ GeV
$M_2 = 300 \pm 10$ GeV
$m_{u_R} = 600 \pm 20$ GeV
$m_{q_L} = 800 \pm 20$ GeV
$others: 2$ TeV



A-terms still unconstrained from B physics.
small effects on LHCb/SuperB searches!
"Houston, we have a problem"

Isidori, F.M, Paradisi, Trine, Smith (06)

CPV observables at comparison: large room left due to the A^U terms



small impact on ε_K & $\sin\beta$, complementarity to LHCb/SuperB

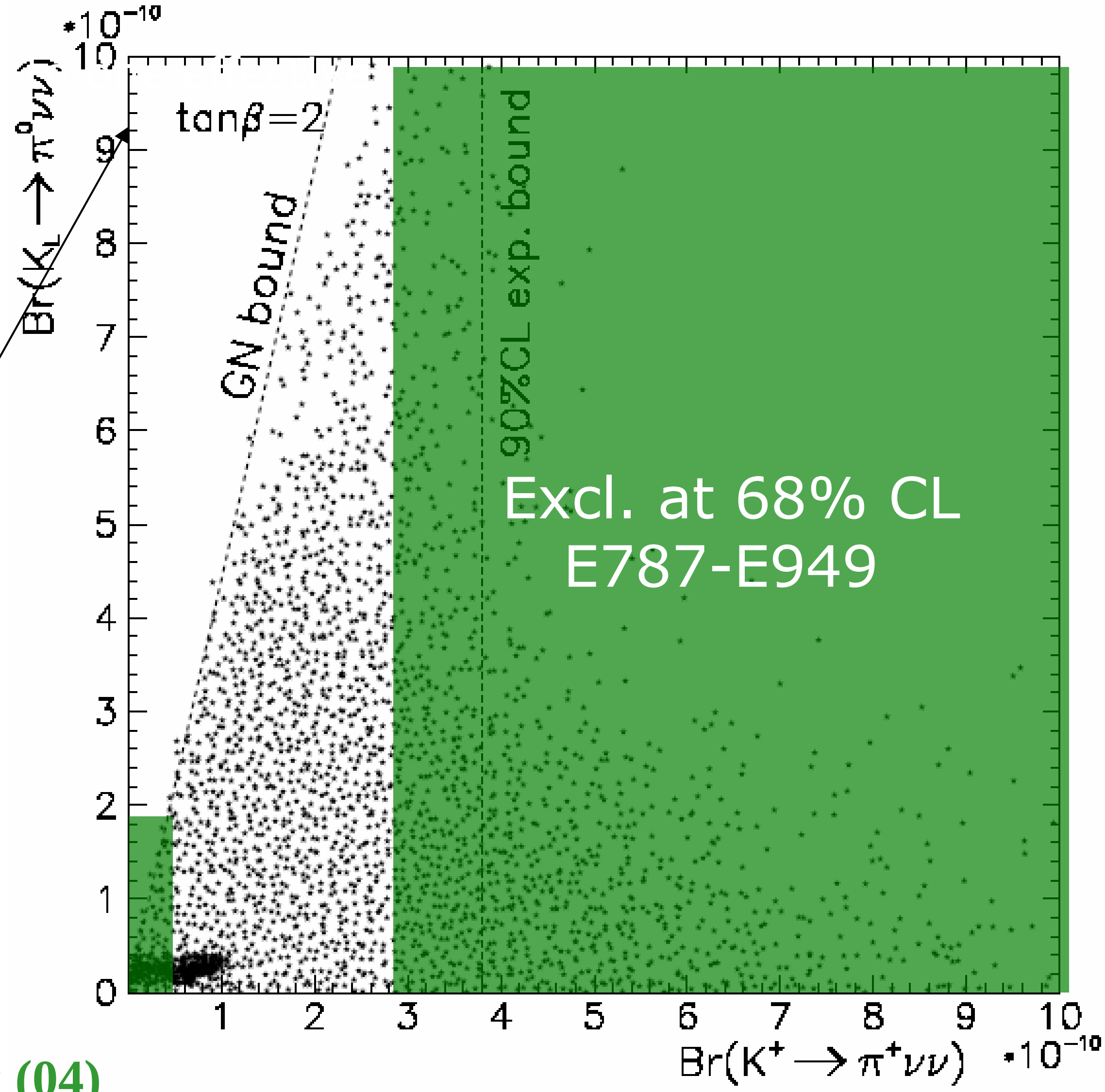
Isidori,F.M,Paradisi,Trine,Smith (06)

How sizable are these effects? big

including all the present constraints from ε_K, ΔM_K, $b \to s\gamma$, ...

<u>Grossman-Nir bound is saturated</u>

$B(K_L \to \pi^0 \nu\nu) \sim 30\ B^{SM}$



Buras,Ewerth,Jäger,Rosiek (04)

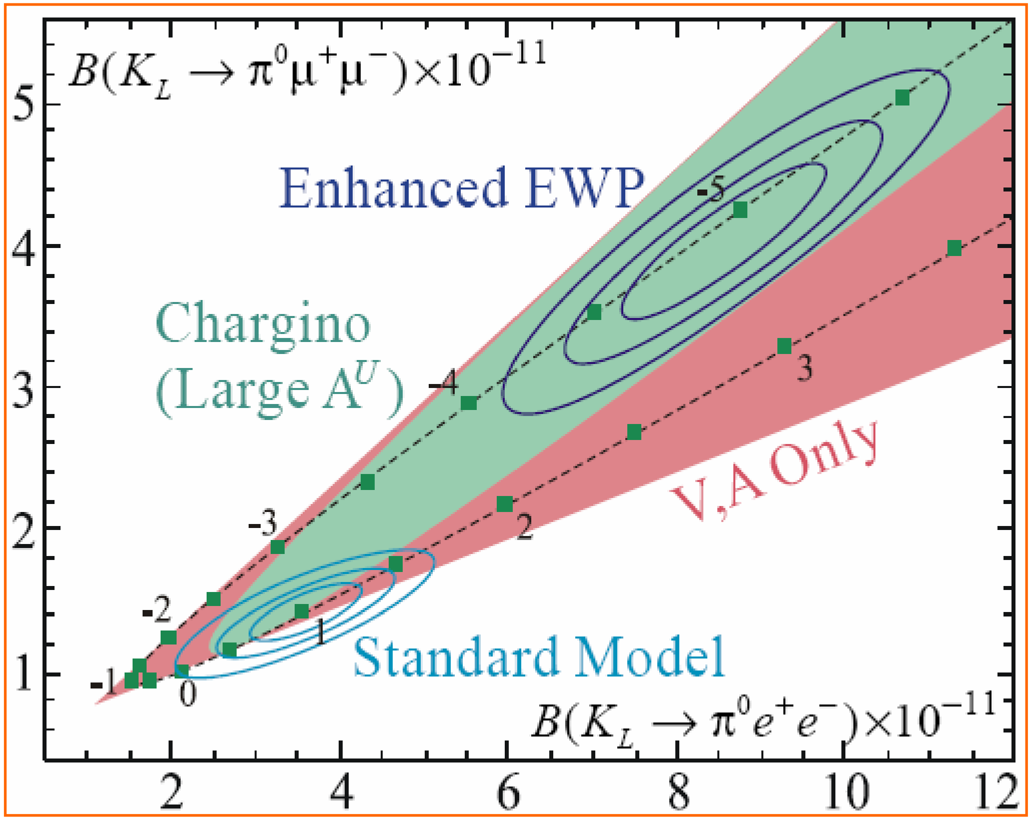
$K_L \to \pi^0 \mu\mu$ – $K_L \to \pi^0 ee$ correlation

special opportunity to *New Physics* Searches

$K_L \to \pi^0 \mu\mu$ – $K_L \to \pi^0 ee$ correlation

1. alike to $K \to \pi\nu\nu$ → χs by γ & Z peng.; *visible effects* on current-current operators

$$H_{eff}^{BSM}(s \to d) = X(\bar{s}\gamma_\mu d)(\bar{\nu}\gamma_L^\mu \nu)$$
$$+ y_{7V}(\bar{s}\gamma_\mu d)(\bar{\ell}\gamma^\mu \ell) + y_{7A}(\bar{s}\gamma_\mu d)(\bar{\ell}\gamma_L^\mu \gamma_5 \ell)$$



Smith@BEACH06/F.M, Trine, Smith (06);

Bounds for general vector and axial vector FCNC operators (i.e. arbitrary y_{7A}, y_{7V}):

$$0.1\cdot 10^{-11} + 0.24 B(\pi^0 e^+ e^-) \le B(\pi^0\mu^+\mu^-) \le 0.6\cdot 10^{-11} + 0.58 B(\pi^0 e^+ e^-)$$

F.M,Trine,Smith (06);

$K_L\to\pi^0\mu\mu$ – $K_L\to\pi^0 ee$ correlation

1. alike to $K\to\pi\nu\nu$ → χs by γ & Z peng.; *visible effects* on current-current operators

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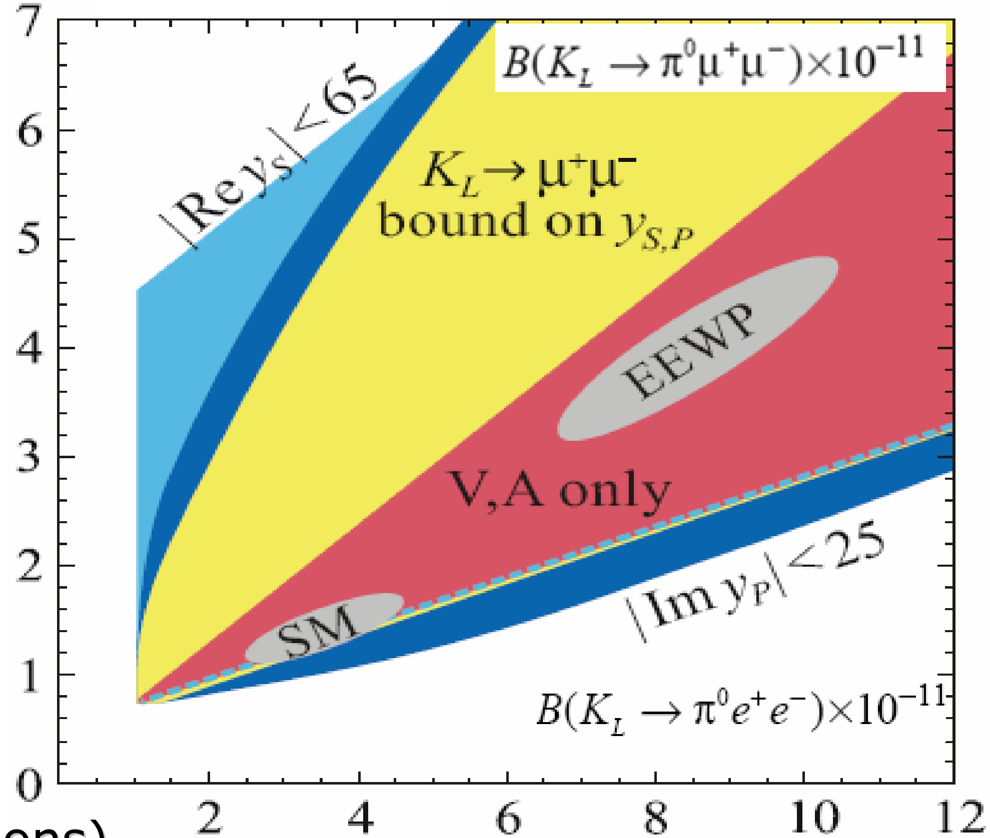


F.M, Trine, Smith (06)

2. contrary to $K\to\pi\nu\nu$ → sensitive to helicity-suppressed operators

$$+\,y_S(\bar{s}d)(\bar{\ell}\ell) + y_P(\bar{s}d)(\bar{\ell}\gamma_5\ell)$$

→ H^0 penguins at large *tanβ*
(as $B\to\mu\mu$, but different mass insertions)
copiare papers

$$y_{S,P} \sim (M_W^2/M_A^2)\tan^3\beta\,(1+0.01\tan\beta\,\mathrm{sign}\,\mu)^{-2}\left(\left(\delta_{LL}^D\right)_{12} + 18\left(\delta_{RR}^D\right)_{13}\left(\delta_{LL}^D\right)_{32}\right)$$

Retico, Isidori (02)/Buras,Chankowaki,Rosiek,Slawianowska(02)/ Foster ,Okumura,Roszkowski (05)

Conclusions

Combining all present th. and exp. information , large deviations on $K\to\pi\nu\nu$ & $K\to\pi\ell\ell$ are still possible

E787-E949
ex-0403034
ex-0403036

GN Bound
ph-9701313

MFV:

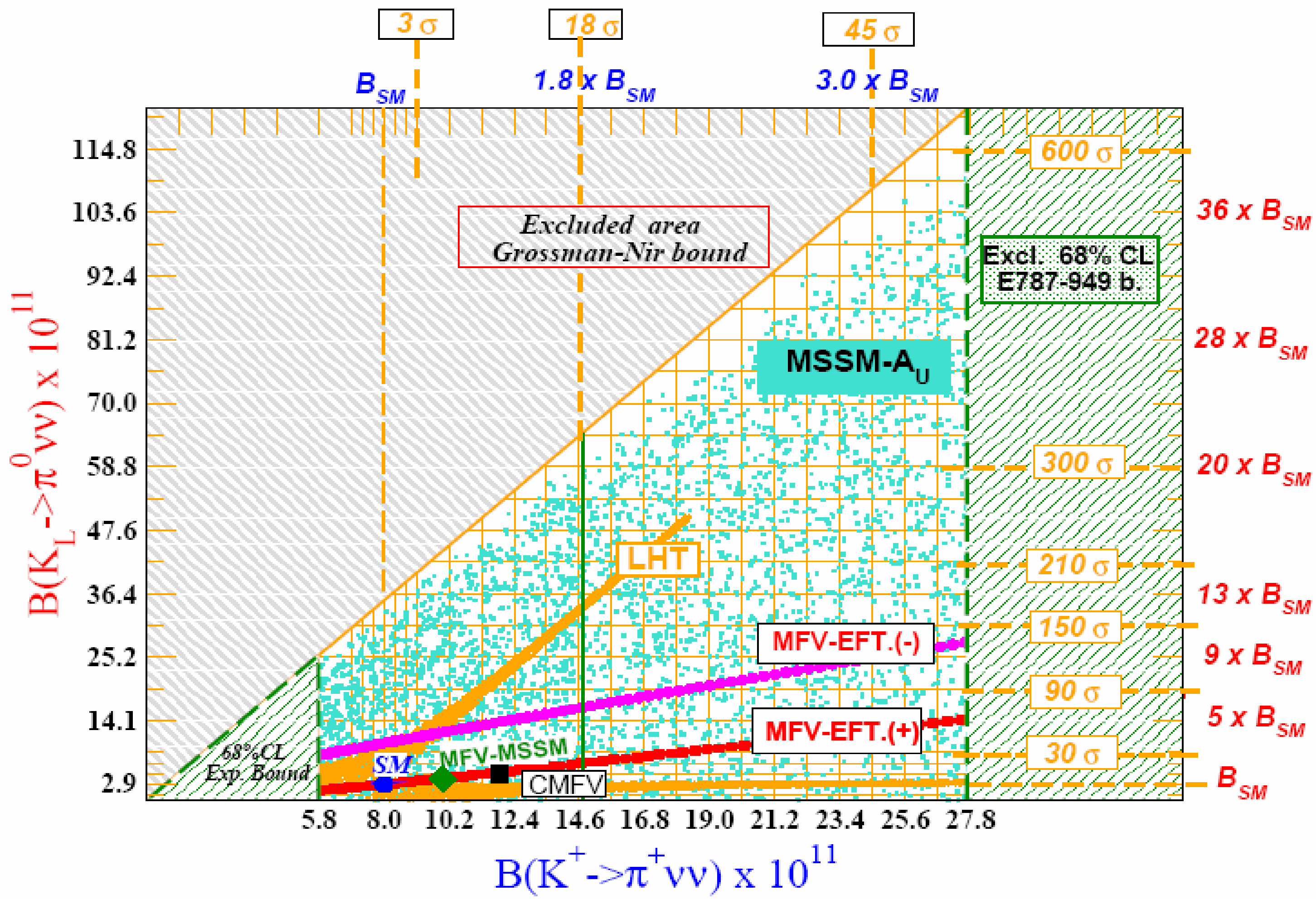
- D'Ambrosio *et al.* ph-0207036
- Buras *et al.* ph-0505110

MSSM:

- Buras *et al.* ph-0408142.
- Isidori *et al*. ph-0604074.
- Mescia *et al.* ph-0606081

LHT:

- Blanke *et al*. ph-0604074



K-rare decays $\Rightarrow$ *large not covered parameter space!*

- complementarity to Atlas/CMS searches $\Rightarrow$ new particles
- supplementarity to LHcb/SuperB activities $\Rightarrow$ gluinos

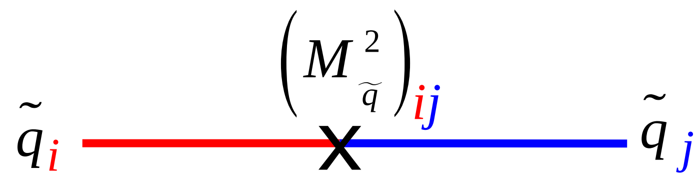
BACKUP

MSSM: SUSY model at low-energy

- particle content: SM+4Higgs+SUSY partners $\boxed{\Leftrightarrow \text{LHC task}}$
- R-parity conservation$\rightarrow$ dark matter candidate
- SUSY softly broken$\rightarrow$ trilinear scalar couplings, squark/slepton and chargino, masses

$$\mathcal{L}_{soft} = \underbrace{A_{ijk}\phi_i\phi_j\phi_k + \phi M_s^2 \phi}\, + \chi M_\chi^{2x2} \chi$$

$$M_{\tilde q}^2 = \underbrace{\begin{pmatrix} \left(m_Q^2\right)_{LL} & \left(m_{U/D}^2\right)_{RL} \\ \left(m_{U/D}^2\right)_{RL}^\dagger & \left(m_{U/D}^2\right)_{RR} \end{pmatrix}}_{6x6}$$



new source of flavour violation

27 FC mass insertions free.

MFV-Phenomenological Model

Buras, Gambino, Gorbahn, Jäger, Silvestrni (00)

- flavor and CP violation is entirely governed by the CKM matrix
- the only relevant operators are those already present in the SM

$$\mathrm{A(Decay)} = \sum B_i \eta^i_{\mathrm{QCD}} V^i_{\mathrm{CKM}} F_i(v), \qquad F_i(v) = F^i_{\mathrm{SM}} + F^i_{\mathrm{New}}$$

- *"stronger"* correlations between *K* & *B* decays, *module to neglect* $\boxed{\textit{box contr.}}$ & $\boxed{\textit{poorly constrained } \gamma \textit{ couplings}}$ → $\boxed{X \cong Y \text{ and } E=0}$

Bobeth, Bona, Buras, Ewerth, Pierini, Silvetrini, Weiler (05)

$\boxed{K^0 - \bar{K}^0\text{-mixing } (\varepsilon_K)}$	$S(v)$
$\boxed{B^0_{d,s} - \bar{B}^0_{d,s}\text{-mixing } (\Delta M_{s,d})}$	$S(v)$
$K \to \pi \nu \bar{\nu}$	$\boxed{X(v)}$
$K_{\mathrm{L}} \to \pi^0 l^+ l^-$	$\boxed{Y(v),\ Z(v),\ E(v)}$
$\boxed{B \to X_s \gamma}$	$\boxed{D'(v),\ E'(v)}$ fixed
$B \to X_s l^+ l^-$ $0.04 < q^2(\mathrm{GeV}) < 1,\ 1 < q^2(\mathrm{GeV}) < 6$ $14.4 < q^2(\mathrm{GeV}) < 25$	$\boxed{Y(v),\ Z(v),\ E(v)}$ $D'(v),\ E'(v)$

$$X(v) = C(v) + B^{\nu\bar{\nu}}(v)$$
$$Y(v) = C(v) + B^{l\bar{l}}(v)$$
$$Z(v) = C(v) + \tfrac{1}{4} D(v)$$

weakly constrained within present exp. accuracy

measured | free parameters | frozen to SM

$X \cong Y$ and $E=0$

$K_L\to\pi^0\mu\mu$ – $K_L\to\pi^0 ee$ correlation

1. like $K\to\pi\nu\nu \to \chi$s by γ & Z peng.; *visible effects* on current-current operators

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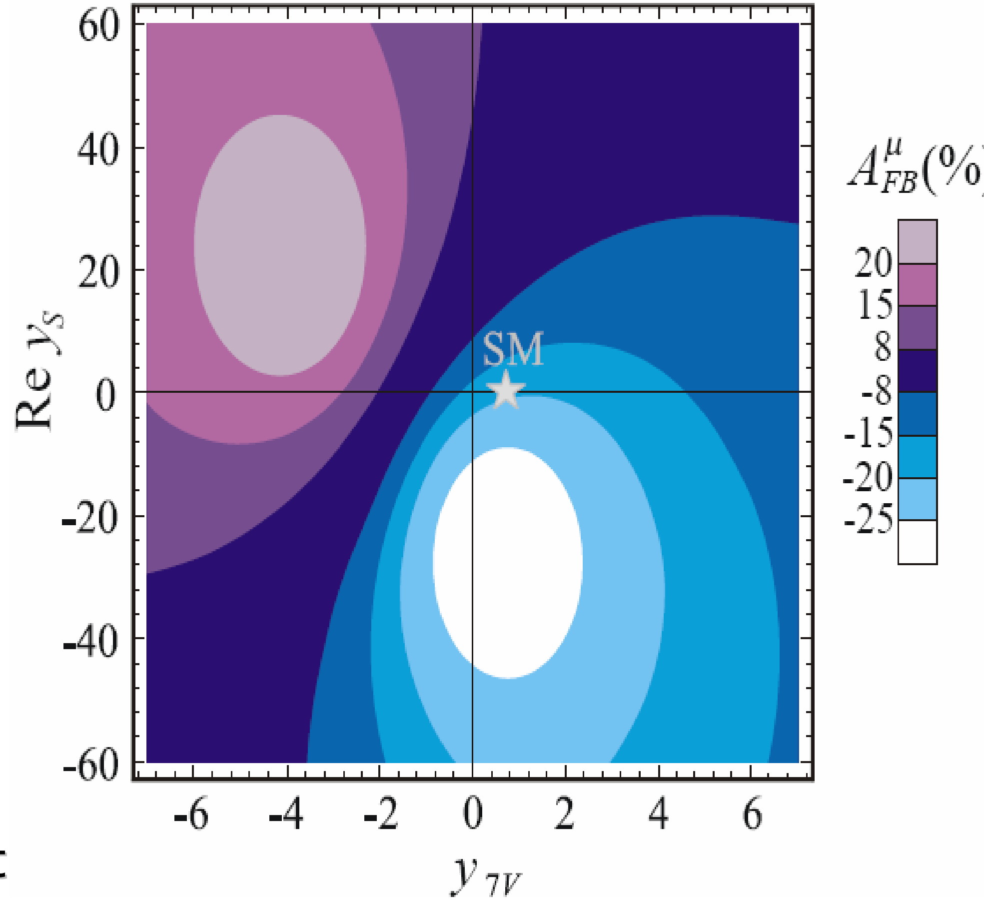

→ H^0 penguins at large *tanβ*
(*as B*→μμ, but different mass insert

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Retico, Isidori (02)/Buras,Chankowaki,Rosiek,Slawianowska(02)/ Foster ,Okumura,Roszkowski (05)

FCNC asymmetries and branching ratios within a th. err ≤ 15%

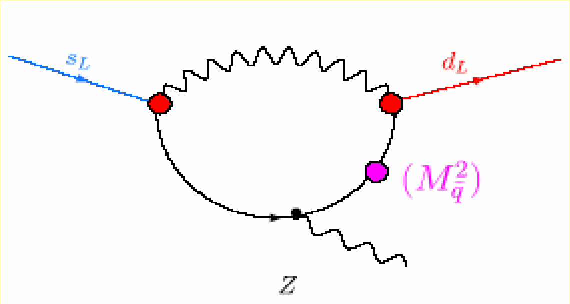
$K \to \pi\nu\nu$ peculiarities: highest CKM suppression and $\Delta S=1$ coupling → like ε'/ε
very clean → like *sin2β*

		QCD M. E.	ΔF=2 b.	ΔF=1 b.	g-pen.	γ–pen.	Z-pen	H-pen.
b→s $\mathcal{O}(\lambda^2)$ small	ΔM_s	$1 + 4\,B_i$	$\bar b\Gamma s\,\bar b\Gamma s$					
	$B_d \to X_s\,\gamma$	OPE			$\bar b\sigma^{\mu\nu}G_{\mu\nu}s$	$\bar b\sigma^{\mu\nu}F_{\mu\nu}s$		
	$B_d \to X_s\,\ell\ell$	OPE			⊗	⊗	$\bar b\Gamma s\,\bar\ell\Gamma\,\ell$	
	$B_s \to \ell\ell$	f_B					⊗	$\bar b\Gamma s\,\bar\ell\Gamma\,\ell$
	$A_{CP}(B_s \to \psi\phi)$ ☆	-	⊗					
	$A_{CP}(B_d \to \phi K)$	-		⊗	⊗			
b→d $\mathcal{O}(\lambda^3)$	ΔM_d	$1 + 4\,B_i$	$\bar b\Gamma d\,\bar b\Gamma d$					
	$B_d \to X_d\,\gamma$	OPE			$\bar b\sigma^{\mu\nu}G_{\mu\nu}d$	$\bar b\sigma^{\mu\nu}F_{\mu\nu}d$		
	$B_d \to \ell\ell$	f_B			⊗		$\bar b\Gamma d\,\bar\ell\Gamma\,\ell$	$\bar b\Gamma d\,\bar\ell\Gamma\,\ell$
	$A_{CP}(B_d \to \psi K_S)$ ☆	-	⊗					
s→d $\mathcal{O}(\lambda^5)$ tiny	ε_K	$1 + 4\,B_K$	$\bar s\Gamma d\,\bar s\Gamma d$					
	$K_L \to \pi^0\nu\nu$ ☆	known					$\bar s\Gamma d\,\bar\nu\Gamma\,\nu$	
	$K^+ \to \pi^+\nu\nu$ ☆	Known					$\bar s\Gamma d\,\bar\nu\Gamma\,\nu$	
	$K_L \to \pi^0\,\ell\ell$	$+ B_T$				$\bar s\sigma^{\mu\nu}F_{\mu\nu}d$	$\bar s\Gamma d\,\bar\ell\Gamma\,\ell$	$\bar s\Gamma d\,\bar\ell\Gamma\,\ell$

measured

☆ *≤ 5% Th err.*

What can we ever learn from K-rare?



New FCNC transitions by

gluino, neutralino and chargino

$\propto \alpha_s \left(M^2_{\tilde{d}}\right)_{ij}$ $\cancel{\propto \alpha_w \left(M^2_{\tilde{d}}\right)_{ij}}$ $\propto \alpha_w \left(M^2_{\tilde{u}}\right)_{ij}$

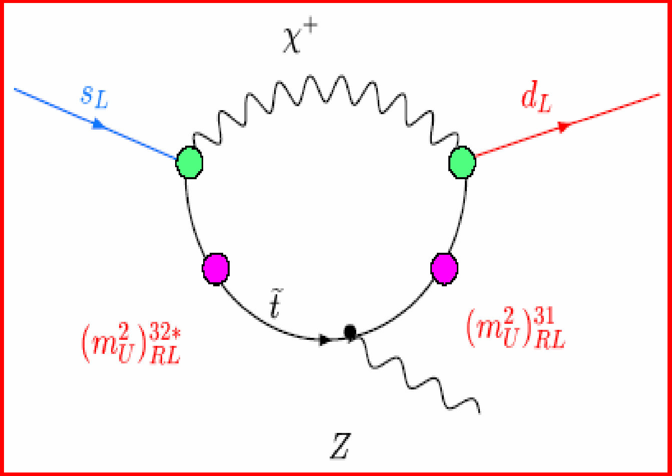
The interplay between $SU(2)_L \otimes U(1)$ and Flavour symmetry prevents strong headaches.

1. gluino diagrams negligible$\rightarrow$ reduced sensitivity to LL/RR $SU(2)_L$-conserving insertion and LR suppressed by down quark masses $\boxed{\left(m^2_{\tilde{d}}\right)^{ij}_{RL} = M_D \left(A^D - \mu \cot\beta\right)^{ij}}$

contrary to ε_K, $b \rightarrow s\gamma$, ΔM_{B_d}, CPV in B decays

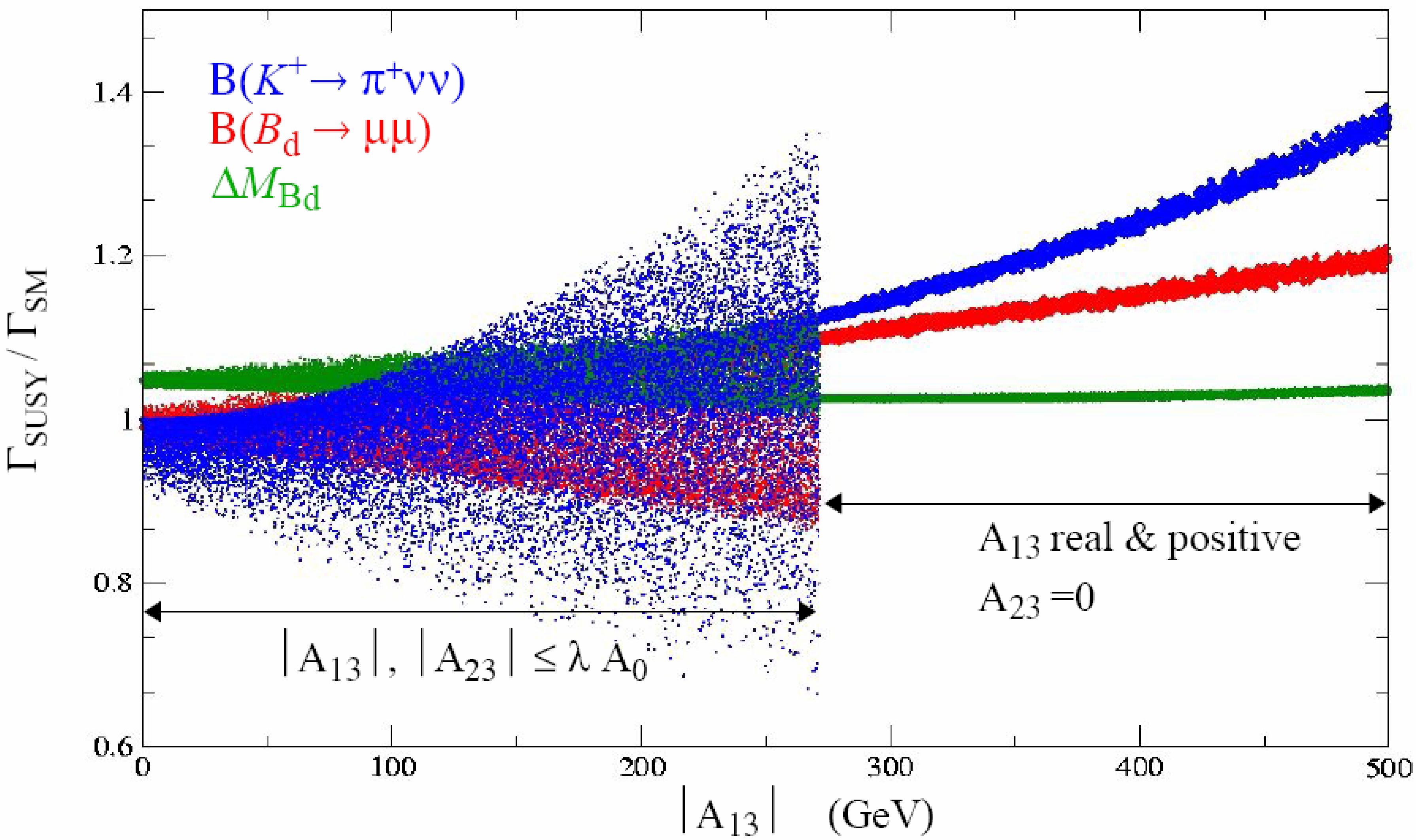
2. <u>appreciable sensitivity only,</u> to χ-up-squark diagrams by 1 effective coupling

$$\boxed{\rightarrow \left(m^2_U\right)^{32*}_{RL} \bullet \left(m^2_U\right)^{31}_{RL}}$$

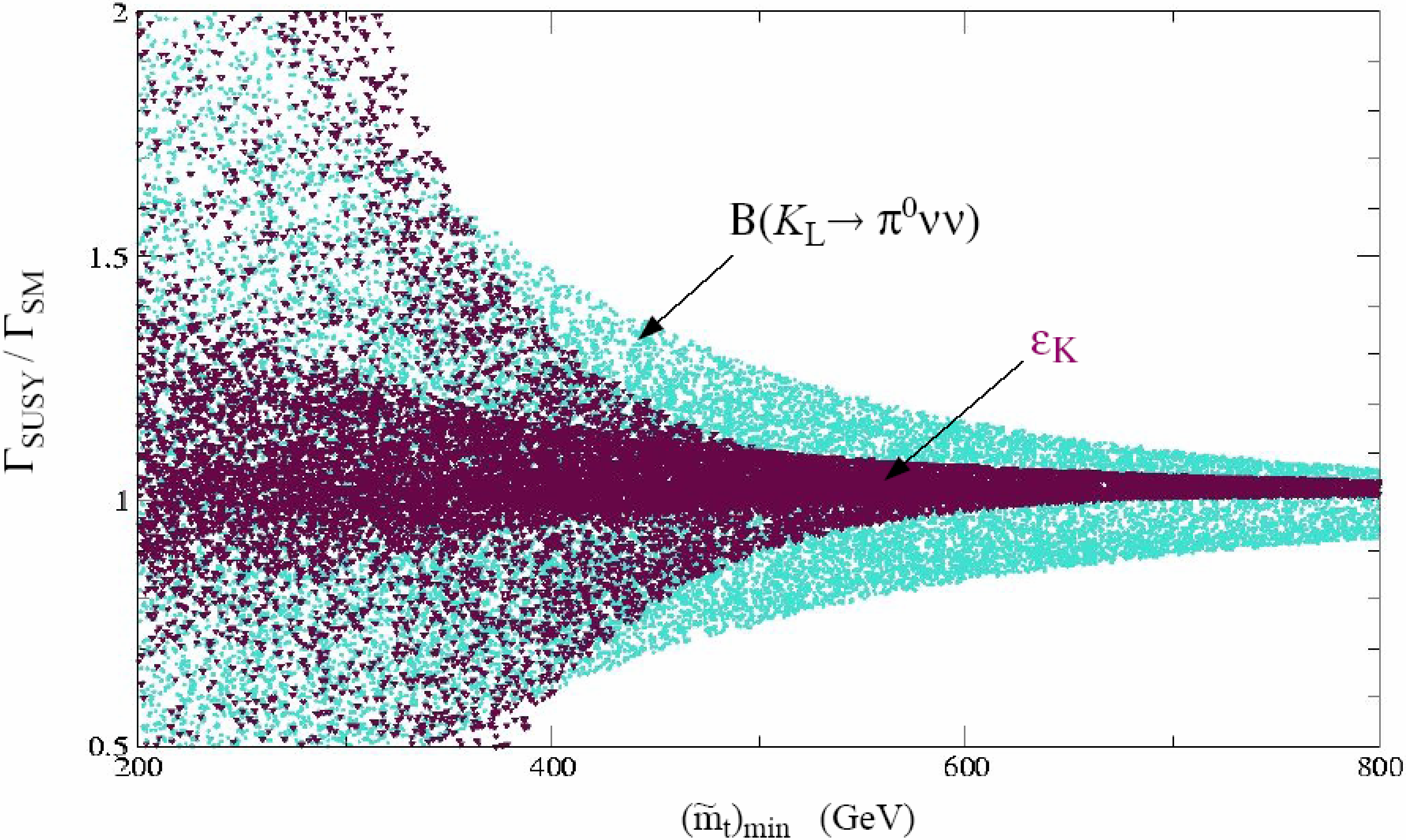


Nir,Worah(98)/Buras,Romanino,Silvestrini(98)/Colangelo,Isidori(98)

The single MIA (mass insert. approx.) is bad approximation for $K \to \pi\nu\nu$, even in presence of a single flavour-violating coupling ⇒ dominance of the double-MIA [Colangelo & G.I. '98]



Slower decoupling of penguins ($K \to \pi\nu\nu$) with respect to boxes ($\Delta F=2$)



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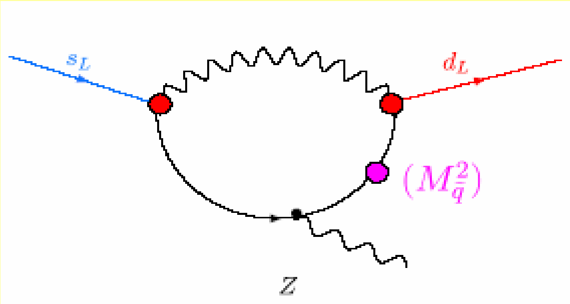

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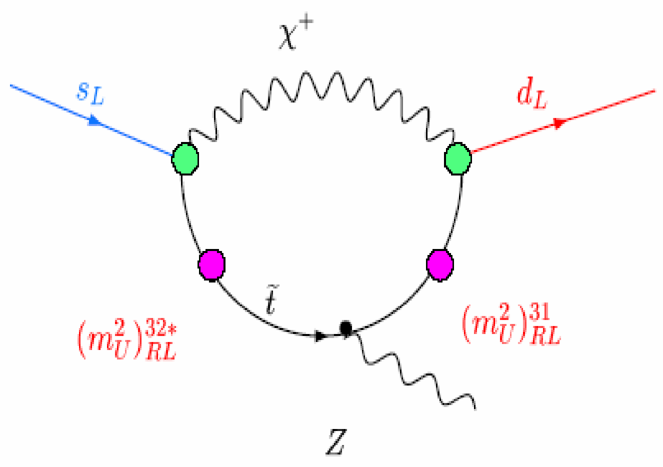

Nir,Worah(98)/Buras,Romanino,Silvestrini(98)/Colangelo,Isidori(98)