RARE DECAYS AT TLEP

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- Introduction & general considerations
- Rare decays & FCNC Z couplings
    - Leptonic flavour
    - Hadronic flavour
- Conclusions and Outlook

INTRODUCTION

- LEP history tells us that TLEP has a very good chance to contribute strongly to the experimental progress in rare decays
- This talk is by no means a review or a systematic study of rare decays @TLEP; my aim is to pose a few questions and trigger some discussion...

GENERAL CONSIDERATIONS

- TLEP will produce:
  - ~3 10^{10} τ, vs 3 10^{10} @ τ-c and 7 10^{10} @ Belle II
  - ~ 2 10^{11} b & c quarks, vs 2 10^{10} c @ τ-c and 10^{11} c and 8 10^{10} B @ Belle II

  so it could compete with Belle II or τ-c in B, c and τ decays: detailed studies needed

- TLEP could do better than LHCb on a few B_s decays: A_{SL}^s, $B_s \to \gamma\gamma$, ...

RARE DECAYS & Z FCNC: LFV

- LEP limits on $Z \to l_i l_j$: (based on 4 10^6 Z decays)

- $BR(Z \to \mu e) < 1.7\ 10^{-6}$
- $BR(Z \to \tau e) < 9.8\ 10^{-6}$
- $BR(Z \to \tau \mu) < 1.2\ 10^{-5}$

- How much can we improve these bounds with 10^{12} Z's?

- How do these bounds compare with indirect ones from LFV μ and τ decays?

LFV II

- Write FC Z Lagrangian as

$$L_{FC}=g_Z\ \bar{l}_i \gamma^\mu (U^L_{ij} P_L + U^R_{ij} P_R)\ l_j\ Z_\mu + h.c.$$

- $BR(Z\to l_i^+ l_j^-) \sim 8\ (|U^L_{ij}|^2+|U^R_{ij}|^2)\ \Gamma_l/\Gamma \sim$

$$0.3\ (|U^L_{ij}|^2+|U^R_{ij}|^2)$$

- $BR(l_i^-\to l_j^- l_k^+ l_k^-) \sim 0.3\ (2+\delta_{jk})\ (|U^L_{ij}|^2+|U^R_{ij}|^2)$ * $BR(l_i^-\to l_j^- \nu_i \nu_j)$

- $BR(Z\to l_i^+ l_j^-) < BR(l_i^-\to l_j^- l_k^+ l_k^-)/BR(l_i\to l_j \nu_i \nu_j)/(2+\delta_{jk})$

See e.g. Brignole&Rossi

LFV III

- Current and future bounds on LFV μ and τ decays:
  - $BR(\mu \to eee) < 10^{-12}$
  - $BR(\tau \to \mu\mu\mu) < 2\ 10^{-8}\ (10^{-9})$
  - $BR(\tau \to eee) < 3\ 10^{-8}\ (10^{-9})$
- These bounds imply:
  - $BR(Z \to \mu e) < 3\ 10^{-13}$
  - $BR(Z \to \tau\mu) < 4\ 10^{-8}\ (2\ 10^{-9})$
  - $BR(Z \to \tau e) < 6\ 10^{-8}\ (2\ 10^{-9})$
- Measuring $BR(Z \to \tau e)$ & $BR(Z \to \tau\mu)$ better than 10^{-9} would overcome future bounds on LFV decays

RARE DECAYS & Z FCNC: DOWN-TYPE QUARKS

- From $K_L \to \mu\mu$ one gets $|U_{ds}| < \sim 10^{-5}$

  $\Rightarrow$ $BR(Z \to ds) <\sim 10^{-11}$ Buras & L.S.

- From present expts in B physics one gets

  $|U_{bs}| <\sim 4\ 10^{-4}$ and $|U_{bd}| <\sim 10^{-4}$ Buras et al.

  $\Rightarrow$ $BR(Z \to bd) <\sim 10^{-9}$, $BR(Z \to bs) <\sim 2\ 10^{-8}$

- How far can TLEP go? How will b id perform? Need detailed studies

RARE DECAYS & Z FCNC: UP-TYPE QUARKS

- From D mixing one gets $|U_{uc}| <\sim 2\ 10^{-3}$

  $\Rightarrow$ $BR(Z \rightarrow cu) <\sim 5\ 10^{-7}$ UTfit

- How far can TLEP go? How will c id perform? Need detailed studies

RARE DECAYS & Z FCNC BEYOND THE Z POLE

- At energies larger than the Z pole, other FCNC Z form factors ($q^2 \gamma_\mu$, $\sigma_{\mu\nu} q^\nu$) become important in ($e^+e^- \to f_i f_j$), while FCNC decays are mainly sensitive to the γ_μ form factor:
- The impact of running @ higher energies should be studied in detail

	Top decay	Single top
$t \to uZ(\gamma_\mu)$	3.6×10^{-5}	8.0×10^{-5}
$t \to uZ(\sigma_{\mu\nu})$	3.6×10^{-5}	2.3×10^{-5}
$t \to u\gamma$	1.2×10^{-5}	3.1×10^{-6}
$t \to ug$	–	2.5×10^{-6}
$t \to uH$	5.8×10^{-5}	5.1×10^{-4}

	Top decay	Single top
$t \to cZ(\gamma_\mu)$	3.6×10^{-5}	3.9×10^{-4}
$t \to cZ(\sigma_{\mu\nu})$	3.6×10^{-5}	1.4×10^{-4}
$t \to c\gamma$	1.2×10^{-5}	2.8×10^{-5}
$t \to cg$	–	1.6×10^{-5}
$t \to cH$	5.8×10^{-5}	2.6×10^{-3}

Table 4: $3\,\sigma$ discovery limits for top FCN interactions at LHC, for an integrated luminosity of 100 fb^{-1}. The limits are expressed in terms of top decay branching ratios.

Aguilar-Saavedra, hep-ph/0409342

	500 GeV	800 GeV
$t \to qZ(\gamma_\mu)$	1.9×10^{-4}	1.9×10^{-4}
$t \to qZ(\sigma_{\mu\nu})$	1.8×10^{-5}	7.2×10^{-6}
$t \to q\gamma$	1.0×10^{-5}	3.8×10^{-6}

Table 6: $3\,\sigma$ discovery limits for top FCN interactions in single top production at TESLA, for CM energies of 500 and 800 GeV, with respective luminosities of 345 fb^{-1} and 534 fb^{-1}. The limits are expressed in terms of top decay branching ratios.

CONCLUSIONS & OUTLOOK

- The physics potential of TLEP on rare decays seems very promising
- Detailed studies needed on a broad range of topics:
  - rare τ, D, B and B_s decays: sensitivities and comparison with LHCb, Belle-II, τ-c
  - FC leptonic Z decays: sensitivities
  - FC hadronic Z decays: b and c id, sensitivities

CONCLUSIONS & OUTLOOK II

- Studies also needed for top FCNC interactions:
  - sensitivities to $t\to cZ$, $t\to c\gamma$, $t\to uZ$, $t\to u\gamma$ and comparison with LHC
  - sensitivities to single top production through FCNC Z and γ plus NP boxes
- Plenty of interesting topics to be studied and discussed!