Discussion session:
A theoretical perspective on lepton flavour physics at the TeV scale within
i) SUSY models
ii) extra dimension models

Motivation

In the most popular neutrino mass models there are new particles with masses much larger than the electroweak scale that couple to the Higgs bosons. Then, they generate large corrections to the Higgs boson mass; for instance in see-saw models

$$\delta m_H^2 \sim \frac{h_\nu^2 M^2}{16\pi^2}\,, \qquad M \gg m_H$$

Strong and definite hierarchy problem (h_ν and M are definite couplings and masses). It calls for a solution in a wider scheme that solves the hierarchy problem:

- SUSY
- Extra dimensions and little Higgs models
- ...

SUSY

- S. Khalil has shown us that, even with massless neutrinos, SUSY has LFV because the off-diagonal terms of slepton mass matrices. These lead to processes like $\mu \to e\gamma$ which provide stringent constraints on SUSY parameters.
He has also shown that see-saw parameters induce further contributions to LFV which are difficult to disentangle from pure SUSY contributions.
Finally he has discussed LFV in SUSY models with TeV scale seesaw as in a SUSY B-L extension of the SM. In both cases LFV is tiny.

- A. Teixeira has shown that, in mSUGRA see-saw, $B(\mu \to e\gamma)$ is very sensitive to θ_{13} and that there can be strong correlations $B(\mu \to e\gamma) - m_{N_3}$ and $B(\mu \to e\gamma) - B(\tau \to \mu\gamma)$.
- S. Lavignac has reviewed the main features of supersymmetric neutrino mass models with broken R-parity. Some scenarios (bilinear R-parity breaking) can accommodate easily the observed masses and mixings and are very predictive

$$\frac{\mathrm{BR}\left(\tilde{\chi}_1^0 \to \mu^\pm W^\mp\right)}{\mathrm{BR}\left(\tilde{\chi}_1^0 \to \tau^\pm W^\mp\right)} \simeq \frac{\mathrm{BR}\left(\tilde{\chi}_1^0 \to \mu^\pm \bar{q}q'\right)}{\mathrm{BR}\left(\tilde{\chi}_1^0 \to \tau^\pm \bar{q}q'\right)} \simeq \tan^2\theta_{23}$$

but have negligible LFV in the charged lepton sector.

Extra dims

- F. del Aguila has reviewed how to build a model of lepton masses from a warped dimension (and a custodial symmetry). The observed hierarchy of lepton masses is due to the different zero mode localization, the charged current mixing to the A_4 symmetry and the vev structure which is given by the UV-IR boundary conditions. He has also emphsized that multilepton signals allow for discovery as well as for discrimination among different models with new physics in the lepton sector at the TeV scale.
- J.M. Frère has told us how to obtain three generations of fermions from a model in 6 dimensions with a background scalar field providing a vortex in the 2 extra dimensions if the winding number happens to be $n = 3$. Predictive scheme for fermion masses. Can accommodate Dirac neutrino masses and large mixings.

Questions

- How does the generation of neutrino masses and flavour mixing at the TeV scale fit into the wider perspective of particle physics models?
  - See-saw models at high scales have strong and definite hierarchy problems. They call for embedding in a wider perspective that solves the hierarchy problem. This embedding has been achieved in susy models, in extra-dimension models and in little Higgs models.
  - If there are no right-handed neutrinos neutrino masses require new fields that carry lepton number and new interactions that do not conserve it. Many ad hoc models have been be designed to achieve it. SUSY without R-parity contains these two ingredients for free. Predictive models of neutrino masses have been constructed along these lines.

- Are there any generic features? What can we learn about flavour in the lepton sector?
  - Generically the embedding of neutrino mass models in wider structures that solve the hierarchy problem requires the existence of new particles that induce LFV processes like $\mu \to e\gamma$, $\tau \to \mu\gamma$, $\tau \to e\gamma$,$\mu \to 3e$, μ–e conversion in nuclei, etc. However, the precise predictions seem to depend on the details of the models.
  - Some models give sharp predictions for correlations among LFV observables and/or neutrino mass parameters; in principle one can discrimite among models.

Dirac or Majorana neutrinos?

- In SUSY Majorana neutrinos seem more natural. After all gauginos are Majorana fields.
- Extra dimensions seem to prefer Dirac neutrinos:
  - In 5 dims fermions are vector-like.
  - One can easily justify small Yukawa couplings (small overlap of wave functions, large volumes of extra dims...).
  - Extra-dimension models are not renormalizable; they are effective theories valid only upto a few orders of magnitude above the scale set by the lightest KK modes. Difficult to accommodate a see-saw scale much larger than the scale of validity of the models.