Working group report (WG8)

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Abstract

On the workshop of B2TIP from 28th to 29th, October, 2015, five speakers gave presentations, which covered charged lepton flavor violation, lepton flavor universality, and two–photon physics.

1 Higgs lepton flavour violation

(Talk: J. Zupan, University of Cincinnati, text: J. Hisano)

The LHC experiments are searching for the lepton–flavor violating decay modes of the Higgs boson, such as $h \to \mu\tau$. If the decay modes are discovered, what kind of new physics is expected? Searches for $\tau \to 3\mu$ give constraints on the lepton–flavor violating Higgs couplings $Y_{\mu\tau}$ and $Y_{\tau\mu}$. However, the current constraints are weaker than sensitivities of searches for the lepton–flavor violating Higgs decay modes at LHC. On the other hand, the constraints from searches for $\tau \to \mu\gamma$ are much involved since it is induced by loop diagrams. While the process is generated by two-loop or one-loop diagrams of the Higgs boson exchange, the constraints on $Y_{\mu\tau}$ are $Y_{\tau\mu}$ are still comparable to or weaker than the sensitivity at LHC. However, the effective lepton–flavor violating coupling should be proportional to a cubic term of the Higgs field if we write the effective operators in a $SU(2) \times U(1)$ symmetric way as $(\lambda'_{ij}/\Lambda^2)\bar{l}^i{}_L e^j_R H(H^\dagger H)$. This implies that $\tau \to \mu\gamma$ may be generated more directly so that it could give more stringent constraints on the models to predict the lepton–flavor violating Higgs decay. In fact, it is found that if the Higgs boson is the only a source of fermion mass, $\tau \to \mu\gamma$ is too large by four orders of magnitude [1]. In order to avoid this constraints, we have to assume that the discovered Higgs boson is not a part of the doublet Higgs boson for EWSB or that there are other EWSB sources. In this presentation, it is shown that, in the two-Higgs doublet models or technicolor models, the lepton–flavor violating Higgs decay accessible at the LHC may be predicted without conflict with $\tau \to \mu\gamma$.

References

[1] W. Altmannshofer, S. Gori, A. L. Kagan, L. Silvestrini and J. Zupan, arXiv:1507.07927 [hep-ph].

2 Lepton-flavour violation in SUSY models

(Talk: P. Paradisi, University of Padua, text: J. Hisano)

The origin of flavour is still, to a large extent, a mystery. Which is the organizing principle behind the observed pattern of fermion masses and mixing angles? Are there extra sources of flavour symmetry breaking beside the SM Yukawa couplings which are relevant at the TeV scale?

Important questions in view of ongoing/future experiments are following. What are the expected deviations from the SM predictions induced by TeV NP? Which observables are not limited by theoretical uncertainties? In which case we can expect a substantial improvement on the experimental side? What will the measurements teach us if deviations from the SM are [not] seen? The presenter's answers are following. The expected deviations from the SM predictions induced by NP at the TeV scale with generic flavor structure are already ruled out by many orders of magnitudes. On general grounds, we can expect any size of deviation below the current bounds. CLFV processes, leptonic EDMs and LFU observables do not suffer from theoretical limitations (clean th. observables). On the experimental side there are still excellent prospects of improvements in several clean channels especially in the leptonic sector: $\mu \to e\gamma$, $\mu N \to eN$, $\mu \to eee$, τ-LFV, EDMs, leptonic $(g-2)$ and also LFU processes. The the origin of the $(g-2)_\mu$ discrepancy can be understood testing new-physics effects in the electron $(g-2)_e$. This would require improved measurements of $(g-2)_e$ and more refined determinations of α in atomic-physics experiments.

Irrespectively of whether the LHC will discover or not new particles, flavor physics in the leptonic sector (especially cLFV, leptonic $(g-2)$, EDMs and LFU processes) will teach us a lot...

3 Lepton Universality

(Talk: M. Endo, University of Tokyo, text: J. Hisano)

Lepton–flavor universality, universality of EW charged current of leptons, is guaranteed by gauge symmetry in the SM. Thus, the lepton–flavor universality is a super-clean test of new physics, since the universality may be violated by new physics, such as low-scale seesaw models, introduction of vector-like lepton, or charged Higgs boson in multi-Higgs models.

The lepton–flavor universality in leptonic decay of tau gives constraints on charged Higgs boson. The current bounds on violation of the lepton–flavor universality are $g_\mu/g_e = 1.0018 \pm 0.0014$ and $g_\tau/g_e = 1.0029 \pm 0.0015$, while the charged Higgs boson predicts $g_\mu/g_e < 1$ and $g_\tau/g_e < 1$. Thus, the constraint on charged Higgs boson looks severe while it is also the central values of g_μ/g_e and g_τ/g_e.

Type-X two-Higgs doublet model is preferred by the muon $(g-2)$ anomaly. The lepton universality of tau decay is the a most powerful test of the model. It is easy to exclude the proffered regions if central value of $g_\mu/g_e > 1$. However, we need accuracy better than 0.1% if central value is the SM one (=1).

For the moment, Belle;2 has no experimental estimates for future prospects for the lepton–flavor universality. The accuracy of 0.05% would be achievable if the branching ratios and lifetime of tau are measured at better than 0.1%. g_μ/g_e may be measured with good accuracy while the improvement of accuracy of g_τ/g_e is difficult, since the later requires absolute values of branching ratios and lifetime.

4 QCD study of exclusive channels in $\gamma^*\gamma$ collisions : opportunities for Belle 2

(Talk and text: B. Pire, CPhT - Ecole Polytechnique / CNRS)

QCD collinear factorization [1] allows to describe two hadron (meson pair or baryon-antibaryon) production in single tag $\gamma^*(q)\gamma$ collisions at small or medium values of their invariant mass ($W^2 << Q^2 = -q^2$) in terms of generalized distribution amplitudes (GDAs). This partonic picture is different from the hadronic picture where one analyses data in terms of transition form factors. One then does not need to separate resonances from two meson background before extracting relevant information. The Q^2 scaling is the footprint of this factorized framework, and of the leading twist dominance at a measured value of Q^2. Extracting two π meson GDAs should already be feasible from recent data from Belle [2]. An impact picture exists [3] which allows through a Fourier transform from the meson transverse momentum to its transverse location, to probe details of the the 3-dimensional dynamics of hadronization of a $q\bar{q}$ pair into a pair of mesons.

The increased luminosity of Belle 2 should allow to access other two meson channels but also nucleon-antinucleon GDAs which are more interesting since they are intimately related to the generalized parton distributions (GPDs) of the nucleon which allow to access in this case the 3-dimensional structure of the proton through deep exclusive electroproduction (particularly at JLab). It is worth mentioning that these JLab electroproduction data indicate an early scaling behavior, which allows to expect an early scaling of $\gamma^*\gamma \to N\bar{N}$ exclusive reactions. Looking for exotics in these kinematics looks also much promising for Belle 2. Examples of tetraquarks [4] and hybrids as $J^{PC} = 1^{-+}$ mesons [5] have been studied. Distinctive signals are expected thanks to the interference effects naturally encoded in the factorized description with GDAs.

References

[1] D.Müller et al., Fortschr. Phys. **42** (1994) 101; M. Diehl, T. Gousset, B. Pire and O. Teryaev, Phys. Rev. Lett. **81**, 1782 (1998); M. Diehl, Phys. Rept. **388**, 41 (2003) and references therein.

[2] M. Diehl, T. Gousset and B. Pire, Phys. Rev. D **62**, 073014 (2000).

[3] B. Pire and L. Szymanowski, Phys. Lett. B **556** (2003) 129.

[4] I. V. Anikin, B. Pire and O. V. Teryaev, Phys. Lett. B **626**, 86 (2005)

[5] I. V. Anikin, B. Pire, L. Szymanowski, O. V. Teryaev and S. Wallon, Eur. Phys. J. C **47**, 71 (2006)

5 Two-photon physics, Belle to Belle 2

(Talk and text: S. Uehara, High Energy Accelerator Research Organization (KEK))

I have summarized analysis works for two-photon physics from the Belle experiment and have picked up several interesting subjects for the Belle 2 experiment from an experimental view. Thanks to high-luminosity B-factory machines, almost all fields of QCD and hadron physics can now be accessible with two-photon processes. Advantages of the two-photon collisions are in studies of test of perturbative QCD in exclusive hadron production, study of hadronization, measurement of the photon-hadron form factors, and meson spectroscopy including search of exotic hadrons.

In zero-tag mode, the high-energy region in $\gamma\gamma$ center-of-mass energy W is a statistics frontier for many processes. Exclusive meson-pair ($\pi\pi$, $K\bar{K}$ etc.) and baryon-pair ($p\bar{p}$, $\Lambda\bar{\Lambda}$ etc.) production processes are useful to test QCD predictions in $W = 3 - 4$ GeV region. Exploration of charmonium or XYZ particle production is another important theme in the same mass region, where we expect to accumulate event data including $D\bar{D}$ in the final state for spectroscopy of C-even states in the Belle 2 experiment.

Single-tag processes are also useful to test QCD and to search for exotic hadrons. With a high-statistics measurement, we can extend the measurements at Belle [1, 2] to the higher Q^2 regions. The processes have an advantage also in the low-W region near the mass threshold of produced hadrons, where the hadronic system can still have a sizable transverse momentum with respect to the e^+e^- beam axis.

Double-tag process comes into scope at the Belle 2 experiment. The measurement of $\pi\pi$ production is related to a calculation of hadronic light-by-light contribution to the muon $g-2$. Some authors suggest a test of QCD by the π^0 transition form factor at Q^2's of the similar size for the two virtual photons.

References

[1] S. Uehara, Y. Watanabe, H. Nakazawa, *et al.* (Belle Collaboration), Phys. Rev. D **86**, 092007 (2012).

[2] M. Masuda, S. Uehara, Y. Watanabe, H. Nakazawa, *et al.* (Belle Collaboration), arXiv:1508.06757[hep-ex] (2015), Submitted to Phys. Rev. D.