Electroweak physics at low energy

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Recent experimental results on the muon $(g-2)$ and τ-lepton decays including search for lepton flavour violation are discussed.

1 Introduction

In the last three decades the Standard Model (SM) was successfully used to describe variety of physical phenomena in the wide energy range from atomic transitions to the hundreds GeV scale. On the other hand, the word "model" in the title reflects the common feeling that some more fundamental theory can be hidden behind SM. At present many experiments are aimed to search for the SM boundaries. In this report the present status and recent results on muon anomalous magnetic moment and τ-lepton decays are considered.

2 Muon $(g-2)$ and R measurements

As it is well known, the magnetic moment of a particle with the charge e is:

$$\overrightarrow{\mu} = g\frac{e}{2m}\overrightarrow{s}, \quad a = (g-2)/2.$$

In Dirac theory for pointlike particles the gyromagnetic factor $g = 2$. However, higher-order QED effects (or new physics) can change it, $g \neq 2$. QED calculations of a provide a slightly (by 10^{-3}) higher value. A deviation of the experimental measurements from the theoretical calculations would be an evidence of the new physics.

2.1 Muon $(g-2)$ – experiment and theory

At present the a_μ value is measured with a $5 \cdot 10^{-7}$ relative accuracy [1]:

$$a_\mu = (11659208.0 \pm 6.3) \cdot 10^{-10}.$$

It should be noted that the value of anomalous magnetic moment for electron, a_e is measured with a $4.9 \cdot 10^{-10}$ relative accuracy. However, a_μ is much more sensitive to new physics effects: in most of the models the gain is proportional to $(m_\mu/m_e)^2 = 4.3 \cdot 10^4$.

Usually, the a_μ value is considered as a sum:

$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{had},$$

where a_μ^{QED} – the QED contribution; a_μ^{EW} – the electroweak contribution; a_μ^{had} – the contribution of the vacuum polarization by hadrons. At present, terms up to α^3 are known analytically, a recent more accurate numerical calculation of the α^4 terms and the leading $\log\alpha^5$ terms was done in [2, 3]. From the latest value of a_e [4, 5] $1/\alpha = 137.035999710(96)$,

$$a_\mu^{QED} = (116584718.09 \pm 0.14 \pm 0.08) \cdot 10^{-11}.$$

The errors are due to higher-order terms, $O(\alpha^5)$ and precision of the α.

The electroweak contributions were calculated in the two-loop approximation [6] to be $(15.4 \pm 0.1 \pm 0.2) \cdot 10^{-10}$. The quoted errors are due to hadronic loops which were not taken into account, ambiguity in the Higgs-boson mass, precision of the t-quark mass and higher order effects. A contribution corresponding to the light-by-light scattering diagrams was calculated in [7] as $(10.5 \pm 2.6) \cdot 10^{-10}$.

The hadronic contribution in the leading order, a_μ^{had}, is given by the expression:

$$a_\mu^{had} = (\frac{\alpha m_\mu}{3\pi})^2 \int_{4m_\pi^2}^{\infty} ds \frac{R(s)\hat{K}(s)}{s^2},$$

$$R(S) = \frac{\sigma(e^+e^- \to hadrons)}{\sigma(e^+e^- \to \mu^+\mu^-)}, \quad \sigma(e^+e^- \to \mu^+\mu^-) = \frac{85.86\,\mathrm{nb}}{s\,[\mathrm{GeV}^2]}.$$

$\hat{K}(s)$ grows from 0.63 at $s = 4m_\pi^2$ to 1 at $s \to \infty$. The factor $1/s^2$ emphasizes the role of low energies, particularly important is the reaction $e^+e^- \to \pi^+\pi^-$ with a large cross section below 1 GeV. The results of the calculations in comparison with the experiment are presented in Table 1 [8].

Contribution	$a_\mu, 10^{-10}$
Experiment	11659208.0 ± 6.3
QED	11658471.8 ± 0.016
Electroweak	$15.4 \pm 0.1 \pm 0.2$
Hadronic	693.1 ± 5.6
Theory, total	11659180.3 ± 5.6
Exp. - Theory	$27.7 \pm 8.4(3.3\sigma)$

Table 1: a_μ – experiment and theory

The calculations of a_μ^{had}, given in this Table, used the data on hadronic cross sections obtained in the direct measurements, mostly at the VEPP-2M collider.

2.2 Direct R measurements in e^+e^- annihilation

According to QCD, the quantity R is expressed as:

$$R_{QCD} = R^{(0)} \left[1 + \frac{\alpha_s}{\pi} + C_2 \left(\frac{\alpha_s}{\pi}\right)^2 + C_3 \left(\frac{\alpha_s}{\pi}\right)^3 + ... \right], R^{(0)} = 3 \sum e_q^2,$$

where α_s is a strong coupling constant, e_q are quark charges, $C_2 = 1.411$, $C_3 = -12.8$.

Why is R Measurement Interesting?

- The experimental data on R provide tests of perturbative QCD as well as QCD sum rules, give information about quark masses and values of the quark and gluon condensates. Higher order QCD corrections depend on Λ_{QCD} and $\alpha_s(s)$.
- Precise knowledge of R values is necessary to derive the hadronic corrections to various fundamental parameters like the running fine structure constant - $\alpha(M_{Z^2})$ as well as mentioned above anomalous magnetic moment of the muon.

Depending on the problem, different energy ranges are important. In the energy range below 2 GeV the total hadronic cross section is obtained as a sum of the exclusive cross sections. For more than 25 years, VEPP-2M collider was the main supplier of the precise data on the hadronic cross section in the energy range below 2 GeV [9]. The results on the hadronic cross section

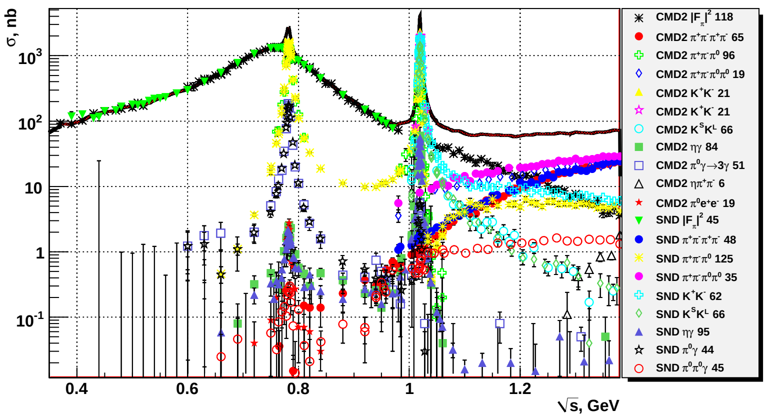

Figure 1: Overview of the results from the VEPP-2M e^+e^- collider.

obtained in the experiments at the VEPP-2M collider are shown in Fig. 1.

2.3 R measurement by ISR

In the last years a lot of new data were obtained at B- and ϕ-factories, at the BaBar, Belle and KLOE detectors, using initial state radiation (ISR) processes [10]. The idea of this approach is illustrated by the diagram shown in Fig. 2. After emission of hard photon e^+e^- pair can acquire

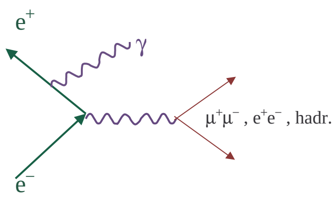

Figure 2: Diagram of the processes with initial state radiation.

any center-of-mass energy below the energy of the experiment. That means that one can study the processes of e^+e^- annihilation in the entire range from the threshold to the experiment energy.

The BaBar collaboration has measured cross sections of many processes like $e^+e^- \to 3\pi, 4\pi, 6\pi, p\overline{p}$ and other [11, 12, 13] while Belle obtained valuable data on $D\overline{D}$ production [14].

Recently BaBar presented the results on the pion formfactor [15, 16]. A measurement of the cross section of the process $e^+e^- \to \pi^+\pi^-(\gamma)$ was performed in the energy range from threshold up to 3 GeV using 232 fb^{-1} of data collected with the BABAR detector at the center-of-mass energies near 10.6 GeV. For the normalization and cross-check the process $e^+e^- \to \mu^+\mu^-(\gamma)$ was used. The results of this study is presented in Fig. 3.

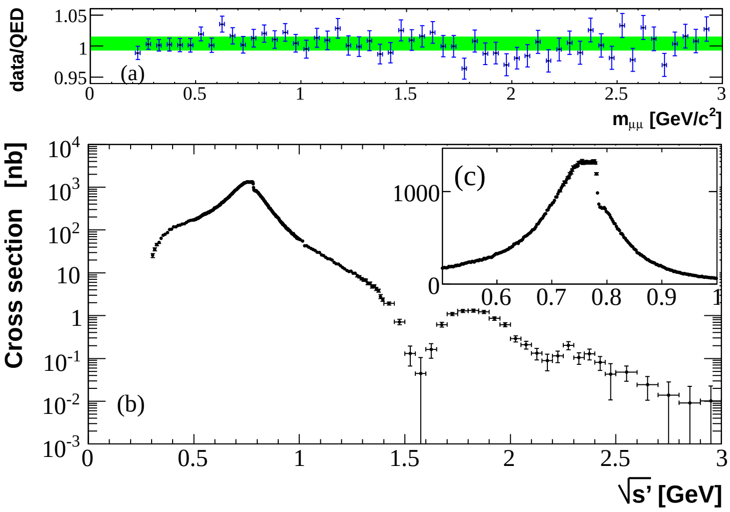

Figure 3: BaBar results on the study of the $e^+e^- \to \pi^+\pi^-$ process using ISR. The ratio of the measured $\mu^+\mu^-$ spectrum to QED calculation is shown in the upper plot.

The ratio of the measured $\mu^+\mu^-(\gamma)$ cross section to that calculated by QED is shown in upper part of the Figure. The average ratio is

$$\frac{\sigma^{exp}_{\mu\mu\gamma}}{\sigma^{NLOQED}_{\mu\mu\gamma}} = 1 + (4.0 \pm 2.0 \pm 5.5 \pm 9.4) \times 10^{-3},$$

where the first error is statistical, the second and third are systematic from the analysis and luminosity determination, respectively. Relative systematic uncertainties of the $\pi\pi\gamma$ cross section do not exceed 1% in the range from 0.4 to 1.3 GeV and increase to about 1.4% near $\pi\pi$ threshold. Obtained data were used to calculate the contribution to a_μ from $\pi^+\pi^-$ threshold to 1.8 GeV. This value, $(514.1 \pm 2.2 \pm 3.1) \times 10^{-10}$ is considerably higher than that based on all previous e^+e^- data: $(503.5 \pm 3.5) \times 10^{-10}$.

A comparison of the BaBar results with CMD-2 and KLOE data are presented in Fig. 4. The BaBar and CMD-2 data are in relatively good agreement while the former considerably differ from the results of KLOE.

KLOE is another experiment studying pion electromagnetic form factor via ISR. This experiment [17] has been conducted at DAPHNE e^+e^- collider near $\sqrt{s} = 1.019$ GeV center-of-mass

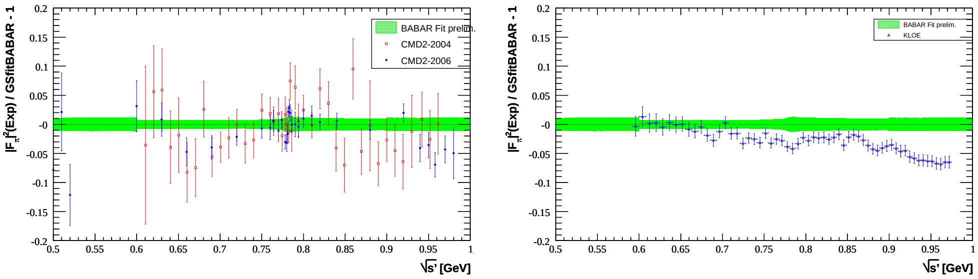

Figure 4: Ratio of the pion form factor squred values, $|F_\pi|^2$, measured by CMD-2 (left figure) and KLOE (right figure) to the BaBar fit. The bands correspond to systematic uncertainties.

with $L_{peak} = 1.3 \times 10^{32}\,\text{cm}^{-2}\text{s}^{-1}$. Results obtained by this experiment [18] are shown in Fig. 5. The systematic uncertainty shown in Fig. 5 by the grey band is approximately 1%. The com-

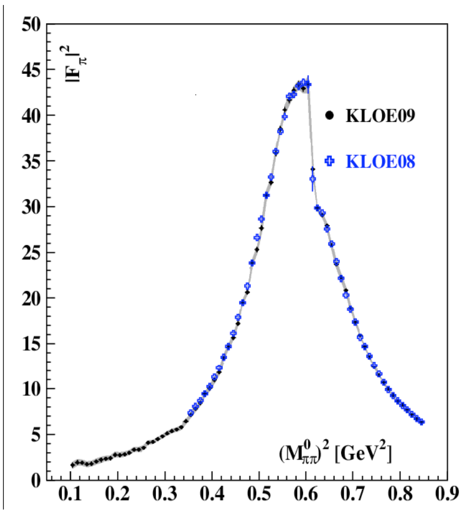

Figure 5: Results of the KLOE experiment.

parison of the KLOE results with CMD-2 and SND data is shown in Fig. 6.

The value of a_μ was calculated by KLOE using two sets of the results in the s range (0.35 – 0.85) GeV^2):
KLOE 08 (small angles): $a_\mu = (379.6 \pm 0.4(\text{stat.}) \pm 2.4(\text{sys.}) \pm 2.2(\text{theo.})) \times 10^{-10}$
KLOE 09 (large angles): $a_\mu = (376.6 \pm 0.9(\text{stat.}) \pm 2.4(\text{sys.}) \pm 2.1(\text{theo.})) \times 10^{-10}$

The value of a_μ obtained by KLOE can be compared with CMD-2 and SND results when the integration is performed over the same range, $0.397 < s < 0.918$ GeV^2:
KLOE 08 (small angles) $a_\mu = (356.7 \pm 0.4(\text{stat.}) \pm 3.1(\text{sys.})) \times 10^{-10}$;
CMD-2 $a_\mu = (361.5 \pm 1.7(\text{stat.}) \pm 2.9(\text{sys.})) \times 10^{-10}$;
SND $a_\mu = (361.0 \pm 2.0(\text{stat.}) \pm 4.7(\text{sys.})) \times 10^{-10}$.

Finally, KLOE strengthens the discrepancy 3.4 σ between the SM prediction and the BNL measurements.

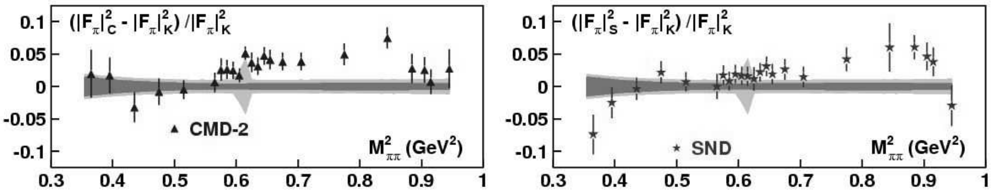

Figure 6: Comparison of the KLOE results with CMD-2 and SND data. The grey band shows the systematic uncertainty in the KLOE data.

3 Search for LFV in τ-lepton decays

Charged lepton flavour violation (LFV) would be a very clear manifestation of the new physics since in the Standard Model the lepton flavour violation decays are extremely small. Searches for $\mu - e$ LFV are performed in $\mu - e$ conversion and $\mu^- \to e^-\gamma$ decay [19] ($B < 1.2 \times 10^{-11}$), as well as in $\mu^- \to e^-e^-e^+$ decay [20] ($B < 1.0 \times 10^{-12}$).

Many models consider extensions of the Standard Model with enhanced LFV. Particularly popular are SUSY models, e.g. MSSM extension of SM, also discussed SUGRA, GUT, Higgs, little Higgs. The predicted $B(\tau \to \mu^-\gamma)$ reaches $10^{-8} - 10^{-7}$.

In the last years main contributions on tau decays study came from two B-factories. Both detectors, Belle [21] and BaBar [22], are forward/backward asymmetric detectors with high vertex resolution, magnetic spectrometry, excellent calorimetry and sophisticated particle ID ability. Total luminosity collected by both detectors is about 1.5 ab^{-1}, which corresponds to about 1 400 000 000 $\tau^+\tau^-$ events.

At Belle and BaBar 44 different LFV modes were searched for. The most stringent limit is $B(\tau \to \mu^+e^-e^-) < 1.5 \times 10^{-8}$ [23]. The sensitivity for different modes is limited by background suppression or statistics. The following results from Belle can be considered as examples:

- $\tau \to \mu^-\gamma, e\gamma$ [24]. The data sample included 535 fb^{-1} of integrated luminosity was used to the analysis. After event selection the number of events in the 2σ signal region was 10 (5) for $\mu\gamma$ ($e\gamma$) decays in agreement with the background expectation. This provides the upper limits $Br(\tau \to \mu^-\gamma) < 4.5 \times 10^{-8}$ and $Br(\tau \to e^-\gamma) < 1.2 \times 10^{-7}$ at 90% C.L. The sensitivity in this case is limited by the remaining background from $e^+e^- \to \tau^+\tau^-\gamma$ process.

- $\tau \to e/\mu(\eta, \eta\prime, \pi^0)$ [25]. The data sample included 401 fb^{-1} of integrated luminocity. One event was found in the signal region in agreement with expectation (0.–0.6 for different decay modes). The obtained upper limits are: $Br(\tau \to \mu\eta, \mu\eta\prime, \mu\pi^0) < (6.5 - 13) \times 10^{-8}$ $Br(\tau \to e\eta, e\eta\prime, e\pi^0) < (8.0 - 16) \times 10^{-8}$ at 90% C.L. In this case the sensitivity is clearly limited by the statistics.

In general, the improvement in upper limits on the LFV decays achieved by studies at the B-factories is ~ 100 compared to CLEO.

4 Hadronic τ-lepton decays

Main motivations to study tau hadronic decays:

- τ-lepton decays provide an excellent laboratory to study hadron physics up to 1.8 GeV. The main attractive feature is a clean initial state and low multiplicity of final hadrons decreasing combinatorial background and final state interaction effects.
- Tests of CVC and evaluation of the a_μ from spectral functions.
- Search for CP violation effects in the hadronic decays in hope to find new physics.
- Improvement of the limits on the τ-neutrino mass.

4.1 $\tau^- \to \pi^-\pi^0\nu_\tau$ decay and CVC

$\tau^- \to \pi^-\pi^0\nu_\tau$ decay has the largest branching fraction. The important feature is that the produced pions are in the vector state which means that their invariant mass distribution can be related to the cross section of the process $e^+e^- \to \pi^+\pi^-$ via CVC:

$$\frac{1}{N}\frac{dN_{\pi\pi}}{ds} = \frac{6\pi|V_{ud}|^2 S_{EW}}{m_\tau^2} \cdot \frac{B_e}{B_{\pi\pi}}\left[\left(1-\frac{s}{m_\tau^2}\right)^2\left(1+\frac{2s}{m_\tau^2}\right)\right]\nu^{\pi\pi}(s), \quad \nu^{\pi\pi}(s) = \frac{\beta_\pi^3(s)}{12\pi}|F_\pi|^2.$$

However, certain corrections to the Spectral Functions are needed [26]:
$S_{EW} = 1.0233 \pm 0.0006$
Real photons, loops; FSR;
$m_{\pi^\pm} \neq m_{\pi^0}$ – (phase space, Γ_ρ);
$m_{\rho^\pm} \neq m_{\rho^0}$;
$\rho - \omega$- interference;
Radiative decays ($\pi\pi\gamma$ amd other); $m_u \neq m_d$; and possible 2d class currents.

Recently the Belle collaboration presented the results of a study of the mentioned process based on 5.6×10^6 $\tau^- \to \pi^-\pi^0\nu_\tau$ decays (72.2 fb^{-1}) [27]. The measured value of the branching fraction is: $Br_{2\pi} = (25.24 \pm 0.01(\text{stat.}) \pm 0.39(\text{sys.}))\%$. Systematics is dominated by the uncertainty of the π^0 efficiency and the background from other τ decays.

The quoted value is in good agreement with the previous measurements as well as with the PDG average [28] but it is considerably higher than that calculated via CVC using e^+e^- data. It should be noted that the branching from all groups is systematically higher than the CVC prediction, $< Br_{2\pi} > -Br_{CVC} = (0.92 \pm 0.21)\%$ or 4.5σ from 0. The discrepancy is a 3.6% effect, about twice the SU(2) correction.

The $\pi^+\pi^0$ spectral function evaluated in the Belle analysis is shown in Fig. 7 in comparison with the results of the previous ALEPH and CLEO experiments [29]. The systematic error varies from 0.7% at the ρ-meson mass to about 11% at the right end of the spectrum.

The contribution to a_μ, calculated with the Belle data, $a_\mu = (523.5 \pm 1.5(\text{exp.}) \pm 2.6(\text{br.}) \pm 2.5(\text{isospin})) \times 10^{-10}$, is in good agreement with the previous calculation based on combined ALEPH, CLEO and OPAL data [30]. It should be noted that the recent work [31] revisiting isospin corrections gave a lower value for a_μ in good agreement with the last BaBar results.

4.2 Search for the second class currents

The idea to separate hadronic currents in weak interactions to the first and second classes with different isospin properties was introduced by S.Weinberg [32]. The properties of the First Class Currents (FCC) and the Second Class Current (SCC) are defined as: FCC – $PG(-1)^J = +1$

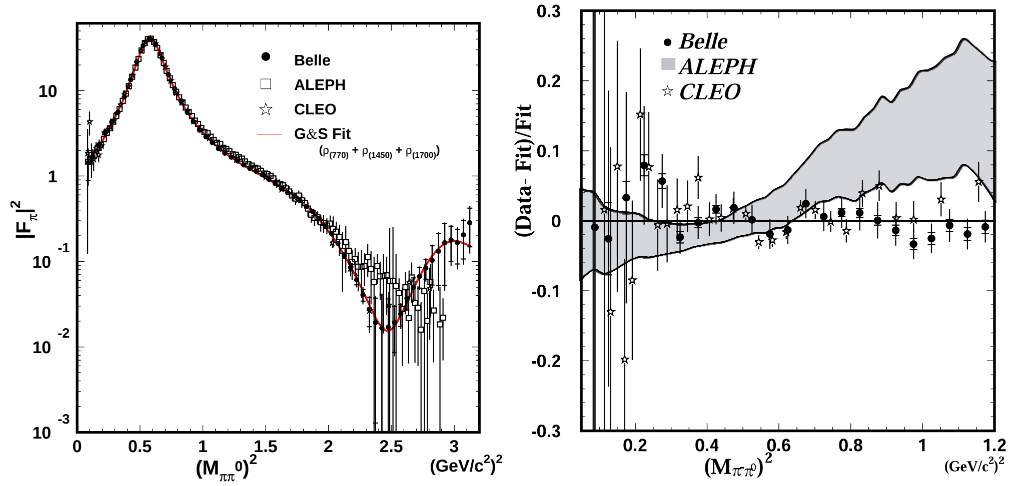

Figure 7: $|F_\pi|^2$ obtained by the Belle from the $\tau^- \to \pi^-\pi^0\nu_\tau$ decay study in comparison with previous experiments (left plot). Detail comparison at the ρ-meson region is shown in the right plot. The grey band indicates the systematic umcertainties of the ALEPH data.

and SCC – $PG(-1)^J = -1$, where P is a parity, G – G-parity and J – spin of the hadronic system.

In SM the SCC should be suppressed by the difference of the light quark masses: $m_u - m_d$. In case of the perfect $SU(2)$ symmetry only FCC exists. Up to now no SCC were found in experiment.

The decay $\tau^- \to \eta\pi^-\nu_\tau$ has $JPG = 0^{+-}$. The theoretical prediction of its branching fraction is at the level: $B(\tau \to \eta\pi\nu_\tau) \sim 10^{-6} \div 10^{-5}$. Large background from $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ decay with $B = (1.77 \pm 0.24) \times 10^{-3}$ is one of the problems in a search of SCC decay.

Recently a search for this decay was performed at Belle experiment [33]. A studied sample contained 6.2×10^8 τ pairs. Each event had to include $\tau \to \eta\pi + \nu_\tau$, $\eta \to \pi^+\pi^-\pi^0$ decay at the signal side while the tag side was required to be a leptonic τ decay – $\tau^- \to l^-\nu_l\nu_\tau + n\gamma$. An additional condition on invariant mass of four pions at the final state, $M(4\pi) < 1.2$ GeV was applied.

After background subtraction the number of signal events was found to be $N_{sig} = 190.9 \pm 68.6$ which corresponds to the $Br(\tau \to \eta\pi + \nu_\tau) = (4.4 \pm 1.6 \pm 0.8) \times 10^{-5}$ and to the upper limit $Br(\tau^- \to \eta\pi^-\nu_\tau) < 7.3 \times 10^{-5}$ at 90%CL. The obtained limit improved the previous results [34] by a factor of about 2.

In the same analysis the upper limit to the $\tau^- \to \eta\prime\pi^-\nu_\tau$ was set: $Br(\tau^- \to \eta\prime\pi^-\nu_\tau) < 4.6 \times 10^{-6}$ at 90%CL.

The BaBar experiment has also presented the results on the searches for $\tau^- \to \eta\prime\pi^-\nu_\tau$: $B(\tau^- \to \eta\prime(958)\pi^-\nu_\tau) < 7.2 \times 10^{-6}$ at 90% confidence level [35]. The other decay including SCC effects, which was studied recently by the BaBar, is $\tau^- \to \omega\pi^-\nu_\tau$. The hadronic current of this decay can contain both vector (FCC) and axial-vector (SCC) components. On the base of the integrated luminosity of 347 fb^{-1} (319 million $\tau^+\tau^-$-pairs) BaBar evaluated an upper limit for the ratio: $N(\omega\pi, vector)/N(\omega\pi, non-vector) < 0.69\%$ at 90% C.L. and 0.85% at 95%

CL [36], which is about 10 times better than the previous results of CLEO [37] and ALEPH [38]

4.3 V_{us} evaluation from τ hadronic decays

A precise measurement of the τ-lepton branching fractions provides a basis for the determination of the V_{us} element of the CKM matrix [39]. The following relations are used for this:

$$R_\tau = \frac{\Gamma(\tau \to h\nu_\tau)}{\Gamma(\tau \to e\overline{\nu}_e\nu)} = R_s + R_{ns}, \quad |V_{us}|^2 = \frac{R_s}{R_{ns}/|V_{ud}|^2 - \delta R_\tau},$$

where R_s and R_{ns} are the ratios containing strange and non-strange final states respectively. The branching fractions and invariant mass distributions are the experimental input to determine $|V_{us}|$ while V_{ud} is well measured from superallowed beta decays. The δR_τ is determined from Finite Energy Sum Rules and is relatively small, so that even a large relative error can allow a precise measurement of $|V_{us}|$. The $|V_{us}|$ value obtained in [40], where the latest results on hadronic τ-decays from Belle and BaBar were included, is in the range from 0.2160 to 0.2190 depending on the parameters in FESR calculations. The experimental uncertainty is about 0.0030. $0.2144 \pm 0.0030 \pm 0.0017$ Thus, this value is about $2-3\sigma$ smaller than the quantity derived from the unitarity condition, 0.2262 ± 0.0011, obtained with $|V_{ud}| = 0.97408 \pm 0.00026$ as determined in [41].

An independent determination of $|V_{us}|$ is possible via the ratio

$$\frac{\Gamma(\tau \to K\nu_\tau)}{\Gamma(\tau \to \pi\nu_\tau)}.$$

Such a study was recently made by BaBar [43] which measured the $B(\tau \to K\nu)/B(\tau \to \pi\nu)$ ratio. Then, taking the ratio $f_K/f_\pi = 1.189 \pm 0.007$ from Lattice QCD [42] and $|V_{ud}| = 0.97408 \pm 0.00026$ from superallowed beta decays they obtained the value 0.2255 ± 0.0023 in a good agreement with the unitarity prediction.

5 Lepton universality and τ-lepton mass measurement

In the Standard Model all lepton decays are governed by the same weak constant:

$$G_F = \frac{g^2}{4\sqrt(2)M_W^2}, \quad g = g_e = g_\mu = g_\tau,$$

where G_F is Fermi constant. According to the present knowledge $g_e = g_\mu$ within at least 0.2% while the difference $g_\mu - g_\tau$ is less than 2%. Tests of the g_l equality were performed in W decays (ALEPH, DELPHY, L3 and OPAL), τ decays (ALEPH, DELPHY, L3, OPAL and CLEO), kaon decays (KLOE) and pion decays (TRIUMPH and PSI).

To test the g_τ/g_μ ratio the precise value of τ mass is important. Recently, new results on that came from KEDR, Belle and BaBar experiments.

In the KEDR experiment [44], which was performed at the VEPP-4M collider at BINP, the τ-lepton mass was derived from the measurements of $e^+e^- \to \tau^+\tau^-$ cross section near threshold [45]. The key problem for this approach is the precise energy determination. Two independent methods were used in this experiment. One of them was resonant depolarization method which provided the accuracy of the energy determination of about 10 keV. The other one used Compton backscattering of the laser photons by the beam in the collider and determined the energy with the accuracy 50-70 keV. The τ mass value determined in this experiment is presented in Table 3.

In the Belle and BaBar experiments the τ mass values were determined by the fit of the pseudomass distribution of the hadronic decays. The pseudomass is defined by the formulae:

$$M_\tau^2 = (E_h+E_\nu)^2-(\overrightarrow{p}_h+\overrightarrow{p}_\nu)^2 = M_h^2+2(E_\tau-E_h)(E_h-p_h\cos(\theta)) \geq M_p^2 = M_h^2+2(E_\tau-E_h)(E_h-p_h).$$

The results of the BaBar and Belle experiments, based on 389 and 370 million $\tau^+\tau^-$ pairs respectively [46, 47] are presented in the Table 3.

These measurements can be used to determine the difference between masses of the positive and negative τ leptons and test CPT theorem. The results are presented in the Table 2

Experiment	OPAL, 2000	Belle, 2007	BaBar, 2008
$N_{\tau^+\tau^-}, 10^6$	0.16	370	389
$\Delta m/m_\tau, 10^{-4}$	0.0 ± 18.0	0.3 ± 1.5	-3.5 ± 1.3
$\Delta m/m_\tau, 10^{-4}$, 90% CL	< 30.0	< 2.8	$-5.6 < \Delta m/m_\tau < -1.4$

Table 2: Experimental values of the $\Delta m = m_{\tau^+} - m_{\tau^-}$

6 Perspectives and conclusion

In the next 3-5, or even more years intensive analysis of about a 1.5 ab^{-1} data sample harvested by both B-factories will continue that providing new interesting results. New results from KLOE, BES-III and KEDR are expected as well.

Talking about future we can also hope that two new proposals for muon $(g-2)$ measurements intended for FNAL [48] and JPARC [49] will be accepted and start experiments. These two projects aim to improve the $(g-2)$ accuracy by a factor 3-4.

At present the VEPP-2000 e^+e^-storage ring at BINP is at the commissioning stage. Experiments at this collider with two detectors, CMD-3 and SND, in the energy range up to 2 GeV should provide new accurate data on the hadronic cross sections. The expected accuracy is 2-3 times better than the present one [?].

Rich information on the tau lepton properties will be obtained if, at least, one of the Super B-factory projects [50, 51] is accepted. The design luminosity of $8 \div 20 \times 10^{35}$ and upgraded detector have to provide improvement 10-100 times in a sensitivity.

In the last decade many new precise results were obtained in the considered class of experiments at low energies. We can see in some cases discrepancies with the calculations based on the SM at the level of 3 standard deviation. These can be hardly taken as the indications of a NP, however, we have to apply additional efforts to clarify these phenomena.

Hopefully, in the next 5-10 years we will receive new rich information on the these field of physics from new experiments and advanced theoretical approaches .

Group	m_τ, MeV
BES, 1996	$1776.96^{+0.18+0.25}_{-021-0.17}$
PDG, 2006	$1776.99^{+0.29}_{-0.26}$
KEDR, 2007	$1776.81^{+0.25}_{-0.23} \pm 0.15$
Belle, 2007	$1776.61 \pm 0.13 \pm 0.35$
PDG, 2008	1776.83 ± 0.18
KEDR, 2008	$1776.68^{+0.17}_{-0.19} \pm 0.15$
BaBar, 2008	$1776.68 \pm 0.12 \pm 0.41$

Table 3: Measurements of τ-lepton mass

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Discussion

Eckard Elsen (DESY): Could you comment on the discrepancy in R from $\pi^+\pi^-\gamma$?
Answer: The experiments with such a high accuracy are quite complicated. On the other hand, theoretical calculations which are used to obtain the experimental results, like radiation corrections calculations, are very complicated as well. So, at present, we cannot say where the source of these discrepancies can be. In short words - I have no answer to your question, but it is clear that more work is needed to reach an understanding.