

# **PHI PSI13 - International Workshop on e+e- collisions from Phi to Psi 2013**

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## **Book of Abstracts**



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**Monte Carlo and Radiative Corrections / 0****Final state Coulomb interaction and asymmetry of pair production close to threshold in  $e^+e^-$  annihilation.****Authors:** Alexander Milstein<sup>1</sup>; Vladimir Dmitriev<sup>1</sup><sup>1</sup> *Budker Institute of Nuclear Physics***Corresponding Author:** dmitriev@inp.nsk.su

We investigate a contribution of the  $d$  wave to the cross section of  $e^+e^-$  annihilation to the pair of charged leptons or nucleons close to threshold of the process.

In contrast to the point of view accepted in literature, due to the Coulomb final state interaction this contribution does not vanish even at zero relative velocity of produced particles. This results in the nonzero asymmetry in angular distribution at threshold. Though value of the asymmetry is small, observation of this effect is not hopeless.

**Summary:**

We have calculated the asymmetry in angular distribution of pair production in  $e^+e^-$  annihilation taking into account the Coulomb FSI. It is shown that the asymmetry does not vanish in the limit  $\beta \rightarrow 0$ . The origin of this anomaly is the singularity of the “dressed” Dirac form factors  $calF_1$  and  $calF_2$  at  $\beta \rightarrow 0$ , see Eq. (ref{calF2}).

The corresponding electromagnetic Sachs form factors  $G_E$  and  $G_M$  are not singular, but  $G_E \neq G_M$  at  $\beta \rightarrow 0$ . The effect is non-perturbative, since in this limit  $\alpha/\beta \gg 1$ . This very nonzero difference  $G_E - G_M$  at  $\beta \rightarrow 0$  provides nonzero asymmetry at threshold. Although the value of the asymmetry is small for electromagnetic Coulomb interaction ( $\sim \alpha^2/24$ ), the asymmetry for heavy quark pair production, where the Coulomb-like strong interaction must be considered, can be noticeable.

**Light Meson Spectroscopy / 1****To learn light scalars from semileptonic decays of heavy quarkonia****Author:** Nikolay Achasov<sup>1</sup><sup>1</sup> *Sobolev Institute of Mathematics***Corresponding Author:** achasov@math.nsc.ru

The mechanisms of light scalar meson production in the  $D_{s+} \rightarrow \bar{s} s e^+ \nu$  to  $[\sigma(600)+f_0(980)] e^+ \nu$  to  $\pi^+ \pi^- e^+ \nu$  decays are compared with the mechanisms of light pseudoscalar meson production in the  $D_{s+} \rightarrow \bar{s} s e^+ \nu$  to  $(\eta/\eta')$   $e^+ \nu$  decays. It is shown that the  $\bar{s} s$  to  $\sigma(600)$  transition is negligibly small in comparison with the  $\bar{s} s$  to  $f_0(980)$  one. As for the  $\bar{s} s$  to  $f_0(980)$  transition, its intensity makes near thirty percent from the intensity of the  $\bar{s} s$  to  $\eta_s$  ( $\eta_s = \bar{s} s$ ) transition. The  $D_{s+} \rightarrow \pi^+ \pi^- e^+ \nu$  decays support the previous conclusion about a dominant role of the four-quark components  $u\bar{d}u\bar{d}$  and  $s\bar{d}s\bar{d}$  in the  $\sigma(600)$  and  $f_0(980)$  mesons, respectively. The program of the light scalar investigation in the semileptonic decays of the  $D+(D^-)$ ,  $D_0(\bar{D}_0)$  and  $B+(B^-)$ ,  $B_0(\bar{B}_0)$  mesons is discussed.

**R-measurement (II) / 3**

## Pion form factor and reactions $e^+e^- \rightarrow \omega\pi^0$ and $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$ at energies up to 2 – 3 GeV in the many-channel approach.

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Using the field-theory-inspired expression for the pion electromagnetic form factor  $F_\pi$ , a good description of the data in the range  $-10 < s < 1 \text{ GeV}^2$  is obtained upon taking into account the pseudoscalar-pseudoscalar (PP) loops. When the vector-pseudoscalar (VP) and the axial vector-pseudoscalar (AP) loops are taken into account in addition to the PP ones, a good description of the BABAR data on the reaction  $e^+e^- \rightarrow \pi^+\pi^-$  is obtained at energies up to 3 GeV. The inclusion of the VP and AP loops demands the treatment of the reactions  $e^+e^- \rightarrow \omega\pi^0$  and  $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$ . This task is also made, with the SND data on the  $\omega\pi^0$  production and the BABAR data on the  $\pi^+\pi^-\pi^+\pi^-$  production, both in  $e^+e^-$  annihilation, upon taking into account  $\rho(770)$  and the heavier  $\rho(1450)$ ,  $\rho(1700)$ ,  $\rho(2100)$  resonances. The problems with inclusion of the VP and AP loops are pointed out and discussed.

### Measurement and Theoretical Evaluation of g-2 (III) / 4

## HLS Approach to the muon g-2 evaluation

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The HLS model supplemented with suitable SU(2)/SU(3) breaking schemes allows to build a phenomenological model which encompasses six e+e- annihilation channels ( $\pi^+\pi^-$ ,  $K^+K^-$ ,  $K^0\bar{K}^0$ ,  $\pi^0\gamma$ ,  $\eta\gamma$ ,  $\pi^+\pi^-\pi^0$ ), the dipion spectrum in the tau decay and a few more meson annihilation partial width information. One thus yields a simultaneous description of all these physics channels by means of quite successful global fits of all the corresponding data.

The fit results provide the six corresponding annihilation cross sections up to 1.05 GeV. This is used to determine accurately the leading order hadronic vacuum polarisation contribution up to the phi region. Supplementing this with additional information covering the physics channels falling outside the scope our model, one derives an improved estimate of the muon g-2. The data samples recently collected by KLOE play an important role in this improvement



**Measurement and Theoretical Evaluation of  $g-2$  (III) / 5**

## **Towards analytic four-loop corrections to the anomalous magnetic moment of leptons**

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The anomalous magnetic moments of the electron and muon have been measured to high accuracy. On the theory-side they are predicted including quantum corrections up to five loops. Whereas three-loop corrections are known analytically the four- and five-loop terms are only available in numerical form. In this talk first analytic four-loop results are presented. As a byproduct the fermionic contribution to the four-loop relation between the  $\overline{\text{MS}}$  and on-shell quark mass in QCD is obtained.

**Measurement and Theoretical Evaluation of  $g-2$  (I) / 8**

## **Virtual photon-photon scattering**

**Authors:** Gilberto Colangelo<sup>1</sup>; Martin Hoferichter<sup>1</sup>; Massimiliano Procura<sup>1</sup>; Peter Stoffer<sup>1</sup>

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We present a formalism for the scattering of two photons into a pion pair based on dispersion relations in combination with unitarity, chiral symmetry, and soft-photon constraints. In particular, we discuss the complications that arise due to the analyticity properties of the amplitude if both photons are off-shell, and argue that the dispersive framework can be extended to remain valid even in that case. Such a representation is crucial input for a reduction of model dependence in the light-by-light scattering contribution to the anomalous magnetic moment of the muon.

**Measurement and Theoretical Evaluation of  $g-2$  (I) / 9**

## **Unified dispersive approach to $\gamma^* \rightarrow \gamma \pi \pi$ and $\gamma \gamma \rightarrow \pi \pi$ at low energy**

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We discuss how to generalize the classic results on photon-photon scattering which combine dispersion theoretical constraints with chiral symmetry and soft photon theorems to the photon-photon\*( $q^2$ ) scattering amplitude into a pion pair. This generalisation requires a

specific treatment of resonance exchange diagrams. The constructed amplitude displays explicitly the dependence on pi-pi phase-shifts, pion electromagnetic form factors (being also sensitive to the omega-pi form factor puzzle) and pion polarizabilities. It is matched to the NLO ChPT amplitude near zero energies and compared to experimental measurements of  $e^+ e^- \rightarrow \gamma \pi^0 \pi^0$  by SND and CMD-2 below one GeV. Applications are made to the pions generalized polarizabilities, to the sigma meson (pole) electromagnetic form factor and to the gamma pi pi contribution to the HVP and the muon g-2.

## Tau-lepton Physics / 10

### Lattice Input on the $V_{us}$ from inclusive hadronic tau decay data

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**Co-authors:** Eoin Kerrane<sup>2</sup>; James Zanotti<sup>3</sup>; Luigi Del Debbio<sup>4</sup>; Nicholas Garron<sup>5</sup>; P. A. Boyle<sup>4</sup>; R.J. Hudspith<sup>4</sup>

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The determination of  $V_{us}$  via finite energy sum rule analyses of flavor-breaking combinations of non-strange and strange hadronic tau decay data yields values of  $V_{us} \sim 3 \sigma$  below both expectations based on 3-family unitarity and results obtained from analyses of  $\Gamma[K_{\ell 3}]$  and  $\Gamma[K_{\mu 2}]/\Gamma[\pi_{\mu 2}]$ . A key issue in understanding whether this low value represents new physics or just an underestimate of the uncertainties in the existing analyses is the very slow convergence of the leading  $D=2$  contribution to the OPE representation of the relevant flavor-breaking correlator difference. A sign of this slow convergence is the fact that switching from the ‘‘local scale’’ CIPT prescription to the ‘‘fixed scale’’ FOPT prescription for the relevant  $D=2$  contour integrals leads to results for  $V_{us}$  differing by an amount  $\sim 0.0020$  much larger than most total theory error estimates existing in the literature. Here we investigate the issue of which (if either) of the two prescriptions for the  $D=2$  series is more reliable by studying lattice data for the relevant correlator differences, obtained using RBC/UKQCD  $n_f=2+1$  domain wall fermion ensembles covering a range of light quark masses and lattice spacings. We then use the lessons learned from this comparison to improve and update two flavor-breaking sum rule determination of  $V_{us}$ .

#### Summary:

We describe a lattice investigation focussed on understanding how to best treat the very slowly converging  $D=2$  OPE series entering flavor-breaking correlator combinations relevant to the determination of  $V_{us}$  from hadronic tau decay data.

## Measurement and Theoretical Evaluation of g-2 (III) / 12

### Hadronic vacuum polarization contribution to g-2 from the lattice

**Author:** Maarten Golterman<sup>1</sup>

**Co-authors:** Christopher Aubin <sup>2</sup>; Kim Maltman <sup>3</sup>; Santiago Peris <sup>4</sup>; Thomas Blum <sup>5</sup>

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In this talk, I will discuss the status of lattice computations of the leading hadronic contribution to the muon anomalous magnetic moment. The focus will be on methods that can help making the lattice determination competitive with the value obtained from the e+e- cross section.

**Poster session / 13**

## **Combined analysis of BES and KEDR data on $\psi(3770)$**

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The available data on the D-D-bar cross section and the inclusive hadronic cross section in the  $\psi(3770)$  region by BABAR, BELLE, BES, CLEO and KEDR experiments were analyzed assuming that the systematic uncertainties in cross sections measured by different detectors are not correlated. The three theoretical models were employed for the data analysis. The first model implies that the D-D-bar production amplitude is the sum of the  $\psi(3700)$ ,  $\psi(2S)$  and smooth nonresonant contributions and that the resonant contributions have the Breit-Wigner shape with the commonly used assumption on the energy-dependent width. The  $\psi(3770)$  parameters obtained with are close to those recently published by the KEDR collaboration. Alternatively, the models suggested by N.N. Achasov and G.N. Shestakov and by G.-Y. Chen and Q. Zhao were used in the analysis of cross sections.

**Tau-lepton Physics / 15**

## **Low-energy constants and condensates from the V-A spectrum.**

**Author:** Santiago Peris<sup>1</sup>

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We present an analysis of the isospin-one V-A correlator based on our successful description of the OPAL V and A non-strange spectral data. We discuss the values obtained for the ChPT low-energy constants  $L_{10}$  and  $C_{87}$  as well as the dimension-six and eight condensates and compare them with those in the existing literature.

**Poster session / 16**

## **Analytic continuation of nucleon form factors in the time-like region.**

**Author:** Simone Moretti<sup>1</sup>

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Using the Skyrme model for nucleons we test the possibility of determining nucleon form factors in the time-like region by an analytic continuation of space-like form factors with particular attention to the behavior at the nucleon-antinucleon production threshold.

**Poster session / 17**

## **Study of $\psi(2s) \rightarrow \mu^+ \mu^-$ decay with KEDR detector**

**Author:** Andrey Sukharev<sup>1</sup>

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Since 2004 KEDR detector at VEPP-4M collider has taken several data sets in  $\psi(2s)$  region, acquiring total luminosity of about  $7 \text{ pb}^{-1}$ , which corresponds to more than  $3.5 \times 10^6 \psi(2s)$ .

There were 5 scans of the resonance allowing us to know the collider's energy spread and 5 runs where the data was taken at the  $\psi(2s)$  peak and slightly below it.

We report the value of

$$\Gamma_{ee} \times B_{\mu\mu} = 20.5 \pm 0.5 \pm 1.0 \text{ eV.}$$

No direct measurement of this quantity is listed in the PDG tables yet.

**Poster session / 18**

## **Determination of the magnetic dipole moment of the rho meson**

**Author:** Genaro Toledo Sanchez<sup>1</sup>

**Co-author:** David Garcia Gudino<sup>1</sup>

<sup>1</sup> UNAM**Corresponding Author:** toledo@fisica.unam.mx

We determine the magnetic dipole moment of the rho meson using preliminary data from the BaBar Collaboration for the  $e^+e^- \rightarrow \pi^+\pi^-2\pi^0$  process, in the center of mass energy range from 0.9 to 2.2 GeV. We describe the  $\gamma^* \rightarrow 4\pi$  vertex using a vector meson dominance model, including all intermediate resonance contributions. We find that  $\mu_\rho = 2.1 \pm 0.5 [e/2m_\rho]$ . In addition, we obtain the branching ratio  $BR(\rho^0 \rightarrow \pi^+\pi^-2\pi^0) = 1.7 \pm 0.6 \times 10^{-5}$ .

Poster session / 19

## The Measurement of the P BarP cross section with CMD-3 Detector at VEPP-2000

**Author:** Aleksandr Popov<sup>1</sup><sup>1</sup> Budker Institute Of Nuclear Physics (BINP)**Corresponding Author:** al.s.popov@inp.nsk.su

The preliminary results of the e+e->P bapP cross section with CMD-3 detector at electron-positron collider VEPP-2000 in the c.m. energy range 1.92 - 2.0 GeV will be presented. Analysis based on 4.5 inversed picobarns of integrated luminosity, collected in first physical run of new facility. The events selection procedure based on the information from Drift Chamber and Calorimeters allowed clean sample of P barP events. The obtained results are in a good agreement with the previous measurements.

Poster session / 20

## Radiative pi-gamma transitions of excited light-quark mesons in the covariant oscillator quark model

**Author:** Tomohito MAEDA<sup>1</sup>**Co-authors:** Kenji YAMADA <sup>1</sup>; Masuho ODA <sup>2</sup>; Shin ISHIDA <sup>1</sup><sup>1</sup> Nihon University<sup>2</sup> Kokushikan University**Corresponding Author:** maeda.tomohito@nihon-u.ac.jp

The COMPASS collaboration, as a part of their hadron spectroscopy program, will measure the radiative decay widths of the light-quark mesons via the Primakoff reactions. In this work we study the photon couplings of light qqbar states applying the covariant oscillator quark model and evaluate the rates for the transitions; {rho, b1(1235), a1(1260), a2(1320), pi2(1670), rho3(1690), rho(1700)} -> pi gamma, which can be measured in the experiments. Forthcoming results from the COMPASS will make these predictions to verify.

Poster session / 22

## Dispersion theory methods for transition form factors: from $\omega/\phi \rightarrow \pi^0\gamma^*$ to $e^+e^- \rightarrow \pi^0\gamma$

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Dispersion theoretical analyses of transition form factors are stepping stones to a model-independent determination of the light-by-light scattering contribution to  $(g-2)_\mu$ . We have performed such an analysis on the conversion decays of the lightest isoscalar vector mesons,  $\omega/\phi \rightarrow \pi^0 \ell^+ \ell^-$ . For that we resort to a dispersive analysis of the  $V \rightarrow 3\pi$  partial-wave amplitude and the precisely constrained pion vector form factor as main ingredients. Extending the framework for the vector decays to incorporate the intermediate  $e^+ e^- \rightarrow 3\pi$  we obtain a description of the  $\pi^0$  transition form factor measured in  $e^+ e^- \rightarrow \pi^0 \gamma$ .

**Gamma-gamma Physics / 23**

## The anomalous process $\gamma \pi \rightarrow \pi \pi$ and its impact on the $\pi^0$ transition form factor

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The process  $\gamma \pi \rightarrow \pi \pi$ , in the limit of vanishing photon and pion energies, is determined by the chiral anomaly. This reaction can be investigated experimentally using Primakoff reactions, as currently done at COMPASS. We derive a dispersive representation that allows to extract the chiral anomaly from cross-section measurements up to 1 GeV, where effects of the rho resonance are included model-independently via the pi-pi P-wave phase shift. We discuss how this amplitude serves as an important input to a dispersion-theoretical analysis of the  $\pi^0$  transition form factor, which in turn is a vital ingredient to the hadronic light-by-light contribution to the anomalous magnetic moment of the muon.

**Measurement and Theoretical Evaluation of  $g-2$  (I) / 24**

## The light-by-light contribution to the muon ( $g-2$ ) within nonlocal chiral quark model

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**Co-authors:** Alexander Dorokhov<sup>2</sup>; Alexey Zhevlakov<sup>3</sup>

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The light-by-light contribution to the anomalous magnetic moment of muon is calculated in the framework of the nonlocal chiral quark model. The contributions from pseudoscalar and scalar resonances and nonresonance contact terms are included. Full kinematic dependence of vertices with off-shell photons and mesons in intermediate states in the light-by-light scattering amplitude is taken into account. The limit of local quark model is discussed.

**Measurement and Theoretical Evaluation of g-2 (II) / 25**

## **Hadronic vacuum polarisation in g-2 and alpha\_QED**

**Author:** Thomas Teubner<sup>1</sup>

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The Standard Model prediction of the anomalous magnetic moment of the muon is reviewed with emphasis on the hadronic vacuum polarisation contributions. The current status of these corrections is described, different evaluations are compared and future prospects for further reducing the error are discussed. Also discussed are the hadronic contributions to the running of the QED coupling and their role for g-2.

**R-measurement (I) / 26**

## **Selected implications of an R-scan between 3GeV and 4.5GeV for charm physics**

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Precise determinations of the cross section between 3 GeV and 4.5GeV as planned in the near future at BESS III can provide an important input for an improved determination of the charmed quark mass. The necessary experimental and theoretical ingredients are presented. As a second topic the possibilities for direct resonant production of  $\chi_{c1}$  and  $\chi_{c2}$  in electron-positron annihilation at BESS III will be explored and possible backgrounds will be studied.

**Symmetries (I) / 27**

## **Lepton mixing under the lepton charge nonconservation, neutrino masses and oscillations and the "forbidden" decay $\mu^- \rightarrow e^- + \gamma$**

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The lepton-charge ( $L_e, L_\mu, L_\tau$ ) nonconserving interaction leads to the mixing of the electron, muon and tau neutrinos, which manifests itself in spatial oscillations of a neutrino beam, and also to the mixing of the electron, negative muon and tau lepton, which, in particular, may be the cause of the "forbidden" radiative decay of the negative muon into the electron and gamma quantum. Under the assumption

that the nondiagonal elements of the mass matrices for neutrinos and ordinary leptons, connected with the lepton charge nonconservation, are the same, and by performing the joint analysis of the experimental data on neutrino oscillations and experimental restriction for the probability of the decay  $\mu^- \rightarrow e^- + \gamma$  per unit time, the following estimate for the lower bound of neutrino mass has been obtained:  $m_{\nu} > 1.5 \text{ eV} / c^2$

**Symmetries (II) / 28**

## **New results in rare allowed muon and pion decays**

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Thanks to the simple underlying dynamics of pion and muon decays, small numbers of the available decay channels, and extremely well controlled radiative and loop corrections, these decays offer a uniquely sensitive means to explore details and limits of the underlying symmetries. For example the anomalously suppressed decay of the charged pion to the electron,  $\pi^+ \rightarrow e^+ \nu$  (labeled  $\pi_{e2}$ ), provided an early signal of the V-A Lorentz structure of the weak interaction. Today, the  $\pi_{e2}$  decay still offers the most sensitive test of lepton universality: the equality of the lepton couplings to the weak boson regardless of the lepton family (generation). Hence,  $\pi_{e2}$  decay is highly sensitive to non-(V-A) terms manifested through pseudoscalar contributions. Radiative decays of the muon,  $\mu^+ \rightarrow e^+ \nu \bar{\nu} \gamma$ , and pion,  $\pi^+ \rightarrow e^+ \nu \gamma$ , or  $\pi_{e2\gamma}$ , are sensitive in different ways to departures from the basic V-A dynamics of the weak interaction. Currently the experimental precision of all these processes lags significantly, i.e., by an order of magnitude or more, behind the precision of their theoretical description.

We report on new, unpublished results on the radiative decay of the muon (RMD) from a comprehensive program of precise measurements of the pion and muon rare decays at the Paul Scherrer Institute, Switzerland, the PIBETA and PEN experiments. Compared to previous experiments, our recently completed data analysis improves the uncertainty of the RMD branching ratio by a factor of almost 30, and that of the extracted value for the Michel parameter  $\bar{\eta}$  by a factor of 4. Both are in good agreement with the SM expectations.

We also update the current status of the data analyses of  $\pi_{e2}$  (implications on limits of lepton universality, as well as non-V - A extensions to the SM) and  $\pi_{e2\gamma}$  decays (pion form factors, additions to V - A interaction terms). This work is highly complementary to the Frascati kaon decay measurement program, with both providing key new information.

**Tau-lepton Physics / 29**

## **Alpha\_s from tau decays: perturbative expansion of spectral function moments**



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We will discuss recent developments in the QCD description of hadronic tau decays with emphasis in the perturbative contribution. Various moments of the hadronic spectral functions have been employed in the determination of the strong coupling  $\alpha_s$  from tau decays. We will analyse the behaviour of their perturbative series under different assumptions for the large-order corrections and for the renormalization group improvement of the series. Some moments commonly employed in  $\alpha_s$  analyses from tau decays should be avoided because of their perturbative instability. Finally, we will argue that some of the recent analyses do not employ an optimal strategy for an  $\alpha_s$  determination.

## Light Meson Spectroscopy (cont'd) / 31

### The puzzle of $\eta(1405)$ and $\eta(1475)$

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We raise the issue on the nature of the  $\eta(1405)$  and  $\eta(1475)$ . We will show that so far there is no strong evidence for their being individual states. In particular, there exists a so-called “triangle singularity” mechanism which will alter the lineshape and shift the mass of a state  $\eta(1440)$  in its decays into  $K\bar{K}\pi$ ,  $\eta\pi\pi$ , and  $3\pi$ .

## Flavour Physics (II) / 32

### Study of the rare decay $K^{+-} \rightarrow \pi^{+-} \gamma \gamma$ and high precision measurement of the form factors of the semileptonic decays $K^{+-} \rightarrow \pi^0 l^{+-} \nu$

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A sample of about 300  $K^{+-} \rightarrow \pi^{+-} \gamma \gamma$  rare decays with a background contamination below 10% has been collected by the NA48/2 and NA62 experiments at CERN during low intensity runs with minimum bias trigger configuration. The presented measurements of the decay spectrum and rate provide a crucial test of the Chiral Perturbation Theory (ChPT) describing weak low energy processes.

Semileptonic kaon decays offer the most precise determination of the CKM matrix element  $|V_{us}|$ . The experimental precision is however limited by the knowledge of the form factors of this decay, since these enter both the phase space integral and the detector acceptances.

The NA48/2 experiment presents new measurements of the form factors of the semileptonic decays of charged kaons, based on 4.3 million  $Ke3$  and 3.5 million  $K\mu3$  decays, both with negligible background. The result matches the precision of the current world average on the vector and scalar form factors and allows to significantly reduce the form factor uncertainty on  $|V_{us}|$ . In addition, the

comparison of both channels sets tight constraints on lepton flavor violation and other possible new physics.

## Flavour Physics (II) / 33

### Searches for rare and forbidden kaon decays at the NA62 experiment at CERN

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The decay  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  is highly suppressed in the Standard Model (SM), while its rate can be predicted with minimal theoretical uncertainty. The branching ratio for this decay is thus a sensitive probe of the flavor sector of the SM.; however, the smallness of this BR ( $8 \times 10^{-11}$ ) and challenging experimental signature make it very difficult to measure. The primary goal of the NA62 experiment at the CERN SPS is to measure  $BR(K^+ \rightarrow \pi^+ \nu \bar{\nu})$  with  $\sim 10\%$  precision. This will require the observation of  $10^{13}$   $K^+$  decays in the experiment's fiducial volume, as well as the use of high-performance systems for precision tracking, particle identification, and photon vetoing. These aspects of the experiment

will also allow NA62 to carry out a rich program of searches for lepton flavor and/or number violating  $K^+$  decays. Such searches can probe new physics scenarios involving, for example, heavy Majorana neutrinos or R-parity violating SUSY. Part of the experimental apparatus was commissioned during a technical run in 2012; installation continues and data taking is expected to begin in late 2014. The physics prospects and the status of the NA62 experiment will be reviewed.

## Measurement and Theoretical Evaluation of g-2 (II) / 34

### Progress on the new g-2 experiment at FNAL

## Measurement and Theoretical Evaluation of g-2 (II) / 35

### Status and prospects of the muon g-2 experiment at J\_PARC

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## Measurement and Theoretical Evaluation of g-2 (II) / 36

### Status of Standard Model calculation of lepton g-2

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## Heavy Meson Spectroscopy / 37

## **Charmonium-like spectroscopy and decays from BESIII**

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**Heavy Meson Spectroscopy / 38**

## **Parameters of Charmonium states from KEDR**

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**Heavy Meson Spectroscopy / 39**

## **Exotic spectroscopy at B\_Factories**

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**Heavy Meson Spectroscopy / 40**

## **Heavy quarks spectroscopy at LHCb**

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**Heavy Meson Spectroscopy / 41**

## **Theoretical status of exotic spectroscopy**

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## **Talk by PANDA - TBC**

**R-measurement (I) / 43**

## **Hadronic cross section measurement at CMD3**

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**R-measurement (I) / 44**

## **Hadronic cross section measurement at SND**

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**R-measurement (I) / 45**

## **Hadronic cross section at BaBar**

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**R-measurement (I) / 46**

## **Measurement of the hadronic cross section at KLOE/KLOE-2**

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**Symmetries (I) / 47**

## **MEG results and prospects**

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The field of Charged Lepton Flavor Violation (CLFV) is very interesting since it permits clear background-free observations of physics beyond the SM, with an extended reach with respect to LHC searches. The MEG experiment has been searching for the Standard-Model suppressed decay  $\mu \rightarrow e + \gamma$  with unprecedented sensitivity. Its last result is an upper limit on the  $\mu \rightarrow e\gamma$  Branching ratio of  $5.7 \times 10^{-13}$  and has still room for improving it thanks to its final 2013 run. To go further with the sensitivity an upgrade is being prepared in order to improve the experimental apparatus and reach the  $10^{-14}$  range. This will constraint several models proposed to extend the SM. Other experiments are searching for different CLFV processes and a more complete picture of the Flavor Physics will be available in the next years, leading to more detailed knowledge of beyond-SM physics.

**Symmetries (I) / 48**

## **Lepton Flavour Violation beyond the present limits**

**Symmetries (I) / 49**

## **Dark force searches in fixed target experiments**

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**Symmetries (I) / 50**

## **Recent KLOE results on the search for dark forces**

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**Gamma-gamma Physics / 51**

## **Gamma-gamma physics at KLOE/KLOE-2**

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**Gamma-gamma Physics / 52**

## **Gamma-gamma physics at BELLE**

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We report a high-statistics measurement of the differential cross section of the process  $\gamma\gamma \rightarrow K_s K_s$  with the Belle detector. We study spectroscopy of light-quark resonances and charmonia and test QCD models using the data. We summarize our systematic measurements of different processes of  $\gamma\gamma \rightarrow$  meson pair production based on the parameterization of the cross sections and comparison with QCD models. We report also on the measurement of the two-photon  $\pi^0$  transition form factor at Belle.

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## **$\eta/\pi^0$ $\gamma\gamma$ width at PRIMEX - TBC**

**Gamma-gamma Physics / 54**

## **Eta and eta\_prime transition form factors from rational approximations**

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**Monte Carlo and Radiative Corrections / 55**

## **Status of Monte Carlo generators for energy scan and radiative return**

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Monte Carlo and Radiative Corrections / 56

## **Status of Monte Carlo generators for gamma-gamma physics**

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Flavour Physics (I) / 57

## **Charm physics with D and Ds at BESIII**

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Flavour Physics (I) / 58

## **Charm mixing and decays at B-Factories**

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Flavour Physics (I) / 59

## **Charm: mining, CP violation and rare decays at LHCb**

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Flavour Physics (I) / 60

## **Charm physics at HERA**

Measurement and Theoretical Evaluation of  $g-2$  (III) / 61

## **The electroweak contributions to $(g-2)_\mu$ after the Higgs boson mass measurement**

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**Flavour Physics (II) / 62**

## **Recent results on BR(K $\rightarrow$ pi pi pi) at KLOE/KLOE-2**

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**Baryon Form Factors / 63**

## **Theoretical and experimental review**

**Baryon Form Factors / 64**

## **Results and perspectives on Baryon Form Factors from SND and CMD3**

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**Baryon Form Factors / 65**

## **BaBar results on Baryon form factors**

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**Baryon Form Factors / 66**

## **Baryon Form factors at BESIII**

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**Baryon Form Factors / 67**

## **Baryon form factors program at JLAB**

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## **Radiative corrections to form factors related processes: pbar+p $\rightarrow$ e+e-, e+e $\rightarrow$ pbar+p - TBC**

**R-measurement (II) / 69**

## **e+e- hadron production cross section at BELLE**

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A number of production cross sections for electron-positron annihilation to hadronic final states have been measured using the Belle data set. This is possible given that the Belle detector is a general purpose detector with a large solid angle coverage. The cross section measurements predominantly fall into two categories: cross sections at, or near, the machine operating energy, and cross sections over a range of energy bins produced via initial-state radiation. Cross section measurements can be used in the studying of hadron spectroscopy, as well as providing checks for the development of Quantum Chromodynamic models. The Belle data still provides the opportunity for the systematic measurement of low-energy, below 3 GeV, cross sections. These low-energy cross sections can be used in the calculation of the leading-order Hadronic Vacuum Polarization contributions to the muon anomalous magnetic moment and the running of alpha.

**R-measurement (II) / 70**

## **Hadronic cross section measurement at BESIII**

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**Machines and Detectors (I) / 72**

## **The IRIDE project**

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**Machines and Detectors (I) / 73**

## **Low-energy electron physics at MAMI**

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**Machines and Detectors (I) / 74**

## **Meson spectroscopy at JLAB at 12 GeV**

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**Symmetries (II) / 75**



## **Overview of CPT, T and Lorentz invariance tests at e+e- colliders**

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**Symmetries (II) / 76**

## **Search for CPT and Lorentz invariance violation in neutral kaons at KLOE/KLOE-2**

**Symmetries (II) / 77**

## **Status and prospects of the muonium experiment at J-Parc**

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**Symmetries (II) / 78**

## **Measurement of the ratio of charged kaon leptonic decay rates at NA62**

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A lepton universality test by measurement of the helicity suppressed ratio  $R_K$  of leptonic decay rates of the charged kaon has been performed by the NA62 experiment. A precision measurement of the ratio  $R_K$  of the rates of kaon leptonic decays  $K^{+-}$  to  $e^{+-} \nu$  and  $K^{+-}$  to  $\mu^{+-} \nu$  with the full minimum bias data sample collected with low intensity 75 GeV/c beam by the NA62 experiment at CERN in 2007-2008 is reported. The result, obtained by analyzing ~150,000 reconstructed  $K^{+-}$  to  $e^{+-} \nu$  candidates with 11% background contamination, has a record precision of 0.4% and is in agreement with the Standard Model expectation. The record accuracy of 0.4% constrains the parameter space of new physics models with extended Higgs sector, a fourth generation of quarks and leptons or sterile neutrinos.

**Tau-lepton Physics / 79**

## **Precision measurement of the tau mass at BESIII**

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**Tau-lepton Physics / 80**

## **Recent tau results from BELLE**

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**Tau-lepton Physics / 81**

## **Recent tau results from BaBar**

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**Light Meson Spectroscopy / 82**

## **Light meson spectroscopy at KLOE/KLOE-2**

**Light Meson Spectroscopy / 83**

## **Light meson spectroscopy and gamma-gamma physics at BESIII**

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**Light Meson Spectroscopy / 84**

## **Light meson studies with WASA-AT-COSY**

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Detailed experimental studies of the decays and interactions of light mesons, such as  $\pi^0$ ,  $\eta$  and  $\omega$ , are highly needed as precision tests for theoretical models. Such studies allow for extractions of parameters describing decay dynamics as well as transition form factors.

Experimental results in this area can also provide measurements of symmetry breaking processes, test the symmetries of the Standard Model and contribute to the search for physics beyond the Standard Model.

The WASA detector is one of the available experimental set-ups optimised for studying production and decays of light mesons. In contrast to the focus of this workshop, the mesons are produced through proton-proton or proton-deuteron collisions using a xed target in the WASA experiment.

This talk will highlight the contributions made and ongoing studies by the WASA-at-COSY collaboration in the eld of light meson interactions.

**Light Meson Spectroscopy / 85**

## **Meson photoproduction from the nucleon at CLAS**

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An extensive measurement programme of meson photoproduction from the nucleon has been obtained exploiting the CLAS detector in Hall-B of Jefferson Lab. The main aim of the programme is to provide high quality experimental data to constrain partial-wave analyses and reaction models used to determine the spectrum and properties of nucleon resonances. Obtaining accurate and detailed information on this spectrum would provide valuable insights regarding the dynamics and interactions of the nucleon's constituents. Theoretical predictions of the resonance spectrum can be obtained from a range of approaches including constituent quark models and more recently from Lattice QCD. Despite these exciting advances in theory the properties and even existence of many nucleon resonances are poorly established experimentally.

The programme of measurements at CLAS will provide new, quality data on single and multiple meson photoproduction from the nucleon to better constrain the extraction of the spectrum. The experiments utilised linearly and circularly polarised photon beams on longitudinally and transversely polarised nucleon targets. The centre-of-mass energy,  $W$ , of the data set is 1.2 - 2.25 GeV, covering a large fraction of the resonance region. The FROzen Spin Target (FROST) and polarised H-D target used in the experiments will be discussed. Preliminary results for a range of single- and double-polarisation observables in meson photoproduction will also be presented.

**Machines and Detectors (II) / 86**

## **Overview prospects at BINP**

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**Machines and Detectors (II) / 87**

## **Post BEPCII and the Supert Tau Charm Factory**

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**Machines and Detectors (II) / 88**

## **INFN tau-charm factory**

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**Machines and Detectors (II) / 89**

## **Status of SuperKEKb and BELLE II**

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**Heavy Meson Spectroscopy / 90**

## Doubly heavy exotics

Recent discoveries by Belle and BESIII of charged exotic quarkonium-like resonances provide fresh impetus for study of heavy exotic hadrons. In the limit  $N_c \rightarrow \infty$ ,  $M_Q \rightarrow \infty$ , the  $(\bar{Q} Q \bar{q} q')$  tetraquarks (TQ-s) are expected to be narrow and slightly below or above the  $(\bar{Q} q')$  and  $(Q \bar{q})$  two-meson threshold. The isoscalar TQ-s manifest themselves by decay to  $(\bar{Q} Q) \pi$  and  $(Q \bar{q}) \pi$ , and the  $\sim 30$  MeV heavier charged isotriplet TQ-s by decays into  $(\bar{Q} Q) \pi$ . The new data strongly suggest that the real world with  $N_c=3$ ,  $Q=c,b$  and  $q,q' = u,d$  is qualitatively described by the above limit. We discuss the relevant theoretical estimates and suggest new signatures for TQ-s in light of the recent discoveries. We also consider "baryon-like" states  $(Q Q' \bar{q} \bar{q}')$ , which if found will be direct evidence not just for near-threshold binding of two heavy mesons, but for genuine tetraquarks with novel color networks. We stress the importance of experimental search for doubly-heavy baryons in this context.

Poster session / 91

### Study of the process $e^+e^- \rightarrow K+K-\pi+\pi$ with the CMD-3 detector at VEPP-2000

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Poster session / 92

### Comparative study of the production of scalar and tensor mesons in $e^+e^-$ collisions

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The intensity of scalar  $a_0(980)$ ,  $f_0(980)$  and tensor  $a_2(1320)$ ,  $f_2(1270)$  mesons production at VEPP-2000 (BINP, Novosibirsk) and, possibly, the upgraded DAΦNE (Frascati, Italy) in the processes  $e^+e^- \rightarrow a_0(f_0, a_2, f_2)\gamma$  is calculated with the help of VDM and the kaon loop model (for scalar mesons case).

The processes  $e^+e^- \rightarrow a_2(f_2)\gamma$  have not been seen in the energy region 1.5 – 2.0 GeV. It turned out that at this energies  $\sigma(e^+e^- \rightarrow a_2(f_2)\gamma) \sim 10$  pb and  $\sigma(e^+e^- \rightarrow a_0(f_0)\gamma) \sim 0.1$  pb.

Photon angle distribution, the spin density matrices of  $a_2$  and  $f_2$  and the background situation will be reported also

Poster session / 93

### On the spin correlations of muons and tau leptons generated in the annihilation processes $e^+e^- \rightarrow \mu^+ \mu^-$ , $e^+e^- \rightarrow \tau^+ \tau^-$

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Using the technique of helicity amplitudes, the electromagnetic process  $e^+e^- \rightarrow \mu^+\mu^-$  is theoretically investigated in the onephoton approximation. The structure of the triplet states of the final  $\mu^+\mu^-$  system is analyzed. It is shown that in the case of unpolarized electron and positron the final muons are also unpolarized, but their spins are strongly correlated. Explicit expressions for the components of the correlation tensor of the final  $\mu^+\mu^-$  system are derived. The formula for the angular correlation at the decays of final muons  $\mu^+$  and  $\mu^-$ , produced in the process  $e^+e^- \rightarrow \mu^+\mu^-$  is obtained. It is demonstrated that spin correlations of muons in the process of electronpositron pair annihilation have the purely quantum character, since one of the Bell type incoherence inequalities for the correlation tensor components is always violated. The additional contribution of the weak interaction of lepton neutral currents through the virtual Z boson is considered it is established that, taking into account the weak interaction, the qualitative character of the muon spin correlations does not change. Analogous consideration can be wholly applied as well to the final tau leptons formed in the process  $e^+e^- \rightarrow \tau^+\tau^-$

**Poster session / 94**

## **Spin correlations of the final leptons in the two-photon processes $\gamma\gamma \rightarrow e^+e^-$ , $\mu^+\mu^-$ , $\tau^+\tau^-$**

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The spin structure of the two-photon process  $\gamma\gamma \rightarrow e^+e^-$  is theoretically investigated. It is shown that if the primary photons are unpolarized the final electron and positron are unpolarized as well but their spins are strongly correlated. Explicit expressions for the components of the correlation tensor of the final  $e^+e^-$  system are derived and the relative fractions of singlet and triplet states of the  $e^+e^-$  pair are found. It is demonstrated that in the process  $\gamma\gamma \rightarrow e^+e^-$  one of the incoherence inequalities of the Bell type for the correlation tensor components is always violated and thus spin correlations of the electron and positron in this process have the strongly pronounced quantum character. Analogous consideration can be wholly applied as well to the two-photon processes  $\gamma\gamma \rightarrow \mu^+\mu^-$  and  $\gamma\gamma \rightarrow \tau^+\tau^-$  which become possible at considerably higher energies

**Poster session / 95**

## **Status of the hadronic light-by-light scattering in the muon $g-2$**

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We give an update on the current status of the hadronic light-by-light scattering contribution to the muon  $g-2$ . We review recent work by various groups, list some of the open problems and give an outlook on how to better control the uncertainty of this contribution. This is necessary in

order to fully profit from planned future muon g-2 experiments to test the Standard Model.

Poster session / 96

## Precision measurement of the charged $K_{4(+-)}$ decay ( $K_{+-}$ to $\pi^+ \pi^- e^+ \nu$ ) and study of the charged $K_{4(00)}$ decay ( $K_{+-}$ to $\pi^0 \pi^0 e^+ \nu$ )

The NA48/2 collaboration has analyzed 1.13 million charged kaon decays  $K_{4(+-)}$  to  $\pi^+ \pi^- e^+ \nu$  leading to an improved determination of the Branching Fraction at percent level precision and detailed form factor studies.

The hadronic form factors in the S- and P-wave and their variation with energy are obtained concurrently with the phase difference between the S- and P-wave states of the  $\pi\pi$  system. The latter measurement allows a precise determination of  $a_0$  and  $a_2$ , the I=0 and I=2 S-wave  $\pi\pi$  scattering lengths. A combination of this result with another NA48/2 measurement, obtained in the study of  $K_{\pm} \rightarrow \pi^0 \pi^0 \pi^{\pm}$  decays, brings a further improved determination of  $a_0$  and the first precise experimental measurement of  $a_2$ . These measurements bring new inputs to low energy QCD calculations and are crucial tests of existing predictions from Chiral Perturbation Theory and lattice QCD calculations.

The NA48/2 collaboration has accumulated ~66000 semi-leptonic charged kaon decays  $K_{4(00)}$  to  $\pi^0 \pi^0 e^+ \nu$ , increasing the world available statistics by several orders of magnitude. Background contamination at the one percent level and very good  $\pi^0$  reconstruction allow the first accurate measurement of the Branching Fraction and decay Form Factor. The achieved precision makes possible the observation of small effects such as a deficit of events at low  $\pi^0 \pi^0$  invariant mass which can be explained by charge exchange rescattering in the  $\pi\pi$  system below the  $2 m(\pi^+)$  threshold. Future prospects include the observation of several ~1000 decays in similar muonic modes  $K_{\mu 4(00)}$  (never observed) and  $K_{\mu 4(+-)}$  (7 events observed). Such poorly known modes could be studied also in the forthcoming NA62 experiment currently under construction.

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## Weak radiative pion vertex in $\tau^+ \rightarrow \pi^- l^+ l^- \nu$ tau decay

We carry out a detailed study of the branching fractions and lepton pair invariant-mass spectrum of  $\tau^+ \rightarrow \pi^- l^+ l^- \nu$  decays ( $l=e, \mu$ ). In addition to the model-independent (QED) contributions, we include the structure-dependent (SD) terms, which encode information on the hadronization of QCD currents. The form factors describing the SD contributions are evaluated by supplementing Chiral Perturbation Theory with the inclusion of the lightest multiplet of spin-one resonances as active degrees of freedom. The Lagrangian couplings have been determined demanding the known QCD short-distance behaviour to the relevant Green functions and associated form factors in the limit where the number of colours goes to infinity. As a result, we predict  $BR(\tau^+ \rightarrow \pi^- \nu_e \tau^+ e^+ e^-) = (1.7^{+1.1}_{-0.3}) \times 10^{-5}$  and  $BR(\tau^+ \rightarrow \pi^- \nu_{\mu} \tau^+ \mu^+ \mu^-) = [0.03, 1.0] \times 10^{-5}$ . According to this, the first decay could be measured in the near future, which is not granted for the second one.

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## Impact of $\gamma$ -V-vertex corrections on the $V P \gamma$ transi-

## **tion form factors**

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