# Midterm Review Report

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| RTN Network Title | : | EURIDICE |
| Network short title | : | European Investigations on DAΦNE and other International Collider Experiments using Effective Theories of Colours and Flavours from the Φ to the ϒ |
| Contract $N^o$. | : | ERBFMRXCT2002-0311 |
| Commencement date of contract | : | September 1st, 2002 |
| Duration of Contract (months) | : | 48 |
| Period covered by this report | : | September 1st, 2002 to December 31st, 2004 |

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| Name of co-ordinator | : | Giulia Pancheri |
| Organization | : | Istituto Nazionale di Fisica Nucleare, Frascati National Laboratories |
| Address | : | Via Enrico Fermi 40 |
| Telephone | : | +390694032885 |
| Telefax | : | +390694032427 |
| E-mail | : | pancheri@lnf.infn.it |


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| Network home page | : | http://www.lnf.infn.it/theory/rtn/ |

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| Location of the midterm review meeting | : | INFN-Frascati National Laboratory<br>Aula Touschek, Edificio Alte Energie<br>Via Enrico Fermi 40, Frascati |
| Date and timing of meeting | : | February 11th, 2005 14:30-19:30 |
| | : | February 12th, 2005 9:00-12:30 |

RTN NETWORK

# EURIDICE

European Investigations on DAΦNE and
other International Collider Experiments
using Effective Theories of Colours and Flavours
from the Φ to the ϒ

EU contract no.: ERBFMRXCT2002-0311

Midterm Report 09/2002 - 01/2005

## Contents

# 1 A - RESEARCH RESULTS

The EURIDICE project focuses on a precise determination of masses, coupling constants and order parameters in the Standard Model. The major theoretical and phenomenological objectives of EURIDICE, stated in Annex I of the contract, can be grouped into six main research projects, respectively:

1. **CP- violation and Cabibbo-Kobayashi-Maskawa (CKM) matrix**
2. **Chiral Perturbation Theory**
3. **Quark masses**
4. $\alpha_{em}(M_Z)$**, the anomalous magnetic moment of the leptons, and other electroweak parameters**
5. **Heavy flavour decays and Heavy Quark Effective Theory (HQET)**
6. **Strong Interaction limit of QCD**

Notice that, following progress in the field, the fourth of the above objectives has been enlarged to include precision determination of other Standard Model Parameters like the W-boson mass and the effective weak mixing angle.

In the sections to follow, the progress achieved towards attainment of these objectives during the first 28 months of operation will be discussed. During this period, remarkable progress was done by the experimental group KLOE, whose members in the network work in close collaboration with the theorists. A separate subsection has thus been devoted to describe the main scientific highlights obtained by the experimental group.

## 1.1 A1. Scientific Highlights

We now describe the main scientific highlights obtained by the network. These highlights have been grouped following the objectives stated in the work program,and are not in order of importance.

### CP- violation and Cabibbo-Kobayashi-Maskawa (CKM) matrix

C-, T- AND CPT-VIOLATING PARAMETERS

*To help clarify the origin of CP-violation:*

- A calculation of the standard model $|\Delta S| = 2$ matrix element relevant for indirect CP violation in the $K \to \pi\pi$ decay modes was done by the Marseille node using Neuberger's formulation of lattice fermions.

- Together with the experimental groups at BaBaR, BELLE and FOCUS, the UK node of the network is engaged in a comprehensive analysis of all $B$ to $D$ decays relevant to the determination of $CP$-violation parameters. With the huge statistics of the data provided by these experiments, this analysis programme will extend over several years with the aim of precision determination of both the CKM angle $\gamma$ and the parameters of all light mesons appearing in $D$ and $B$ decays.

- A sum rule of superconvergence type for parity violating (p.v.) amplitudes (p.v. analogue of Gerasimov-Drell-Hearn sum rule) in the frame of p.v. nucleon-meson effective interactions, was studied by the Warsaw node and found to be useful to limit the range of poorly known parameters. The asymmetries for the p.v.$\pi^0$ and $\pi^+$ production, measurable in future high intensity polarized photon beams experiments, were given.

RARE DECAYS

*CP violation and rare decays*:

- The theoretical analysis of the rare decays $K_L \to \pi^0 e^+ e^-$ and $K_L \to \pi^0 \mu^+ \mu^-$, performed by the LNF and Napoli groups (INFN node), marks the beginning of a new era in the study of such decays. For the first time, it has been possible to present firm theoretical predictions for the two branching ratios within the SM. The analysis demonstrates that these two modes are among the best probes to perform precision studies of short-distance flavour dynamics and CP violation in $\Delta S = 1$ transitions.

- The parameter $\epsilon'$ is a measure of direct CP violation in the $K^0 - \overline{K^0}$ system. For a meaningful interpretation of the measurements and comparison with the Standard Model, the first complete calculation of isospin breaking effects for $\epsilon'$ was performed by the Valencia and Vienna nodes showing destructive interference between three different sources of isospin violation.

- The CP conserving $K \to 3\pi$ decays have now been studied including all isospin breaking effects (Lund). This should allow better future predictions of CP violation in these processes beyond the isospin conserving approximation. A first step here was taken by the Valencia/Granada collaboration.

- The matrix elements of $\Delta I = 3/2$ transitions in $K \to \pi\pi$ were studied by the Valencia node within lattice QCD.

- The role of the charm flavour in the $\Delta I = 1/2$ rule of non-leptonic kaon decays was analyzed by the Valencia group within Chiral Perturbation Theory.

- The $K \to \pi\bar{\ell}\ell$ decay modes were considered by the Marseille node in a combined framework of chiral perturbation theory and large-$N_C$ QCD. For $K^+ \to \pi^+ e^+ e^-$, both the experimental decay rate and the leptonic invariant mass spectrum are well reproduced. The predicted branching ratio for $K_S \to \pi^0 e^+ e^-$ is, within errors, consistent with the recent experimental result from the NA48 collaboration. Predictions for the $K \to \pi\mu^+\mu^-$ modes were also obtained.

- A second possible solution to the weak mixing angle $\phi_d$ in the B-system ($2\beta$ in the SM) was explored by the Barcelona group and a new and useful method to determine the unitarity triangle has been identified. Moreover, this second solution seems to be preferred by some rare decays such as $K^+ \to \pi^+\nu\bar{\nu}$.

*Quantum mechanics and the neutral meson system*: QM

- Kaons are an ideal laboratory for studying quantum mechanics and possible alternatives. A collaboration including the Barcelona, Turin and Vienna nodes has explored the capabilities of the neutral kaon pairs copiously produced at Daphne to test basic issues of Quantum Mechanics. Experiments were suggested to test the ideas of quantum marking and quantum erasure. Interferometric duality and a quantitative formulation of complementarity were also investigated. The entangled kaon pairs have been found to be very useful in two cases: i) Bell inequality tests closing the usual loopholes and ii) quantum marking and quantum erasure phenomena.

*To improve the theoretical precision for the CKM matrix elements*: CKM MATRIX

- The past year has witnessed intense experimental activities in connection with the so-called unitarity problem of the CKM matrix. The systematic account of isospin breaking including electromagnetic corrections performed by members of the Network from Vienna and Valencia nodes, turned out to be crucial for solving the problem on the basis of new data.

- A new high-precision determination of the $K \to \pi$ form factor, relevant for the extraction of the CKM matrix element $V_{us}$ from $K_{\ell 3}$ decays, has been obtained by the LNF group (INFN node) in collaboration with external members from Rome universities. This analysis has been performed combining Lattice QCD and CHPT techniques: an innovative strategy which opens very interesting perspectives also in the longer term.

- The Lund-Barcelona collaboration has extended the ChPT calculation of $K_{\ell 3}$ decays to two-loop order and has shown that all needed parameters can be independently experimentally determined. This has removed one of the major blocks towards a higher precision from this decay.

- The determination of the CKM angle $\gamma$ through CP asymmetries in three-body $B$-decays was investigated for $B^- \to \pi^+\pi^-K^-$, $B^- \to K^+K^-K^-$, and $B^- \to \phi\phi K^-$ (with the $\phi\phi$ invariant mass below the charm threshold) by the Orsay group.

- A determination of $|V_{us}|$ from hadronic tau decays was done by the Valencia group.

**Chiral Perturbation Theory**

ChPT

- The Bern group has set up renormalization group equations for non renormalizable theories. These apply in particular to ChPT.
- The Bern group has finalized the evaluation of the spectra and decay widths of $\pi^{\pm}K^{\mp}, \pi^{+}\pi^{-}$ atoms and the decay width of $\pi^{-}p$ atom, and compared the result with potential models.
- The theoretical predictions of radiative $K_{e3}$ decays have been revisited in view of recent experimental results and ongoing measurements by a joint Bern-Trieste/INFN collaboration. Special emphasis has been given to the stability of the inner bremsstrahlung-dominated relative branching ratio vs. the $K_{e3}$ form factors, and on the separation of the structure dependent amplitude in differential distributions over the phase space.
- ChPT allows one to perform extrapolation to large volumes and small quark masses in lattice calculations through analytic methods. The group Bern-Zeuthen has taken up this issue and analyzed the behaviour of the pion mass in a finite volume
- The Barcelona and Lund nodes have performed a full two–loop calculation in three–flavour ChPT of the $\pi\pi$ and $\pi K$ scattering and the first two–loop calculation in partially quenched ChPT.
- Isospin violation is generically a small effect that can be enhanced in certain cases such as in $K \to 2\pi$ decays. A systematic treatment of such effects was performed by a joint Vienna-Valencia collaboration to obtain reliable values for the $\Delta I = 1/2$ ratio and for the amplitudes themselves.

*To determine effective low-energy couplings from first principles:*

Effective Coupling constants

- The Bern group has clarified the role of the scale dependence of Low Energy Couplings (LEC's) in case of electromagnetic interactions, in the framework of the linear sigma model.
- The Lund group including the young researcher has calculated the pseudoscalar masses to two-loop order in the partially quenched theory. A first work in a simplified mass case is finished and many more are in progress.
- The Lund-Granda group has constructed a systematic ladder resummation based hadronic model which will allow to analytically study the earlier numerical results. A general conflict between quark counting rules, QCD short distance constraints and saturation by a finite number of resonances was found also for a class of order parameters.
- The Valencia-Marseille-DESY Zeuthen nodes, studying the long-distance behavior of two-point functions of flavor non-singlet axial and vector currents in a finite volume, found that quenching has a dramatic effect on the vector correlator.

ChPT on the lattice

- Through finite-size scaling studies in lattice QCD, the parameters of the effective Chiral Lagrangian has been investigated through a joint collaboration between Bern and DESY-Zeuthen.

- The relation between a low energy hadronic scale and the fundamental QCD parameter $\Lambda_{\rm QCD}$ has been computed from first principles in $N_f = 2$ flavor QCD.

- QCD low-energy couplings from lattice QCD simulations in a finite volume with Ginsparg-Wilson fermions were determined by the Valencia group.

- The Valencia group performed a non-perturbative renormalisation of coupling constants on the lattice.

- The quark condensate and the pion decay constant in the chiral limit, as well as the chiral coupling $L_5$ were determined by the Marseille group from lattice simulations with Wilson-Ginsparg fermions, in a finite volume and in the quenched approximation. This study rests on analytical computations of non singlet axial and vector two point functions in sectors of fixed topology at next-to-leading order in the $\epsilon$-expansion of chiral perturbation theory

- The promising method of using large-$N_c$ approximations to interpolate between low and high energies was pursued for certain three-point functions by the Vienna and Valencia nodes. The matching procedure yields values for some of the low-energy constants of $O(p^6)$. Constraints on the spectrum of scalar resonances were also investigated with similar methods. RESONANCES

- The decay $\tau^- \to (\pi\pi\pi)^-\nu_\tau$ was studied by the Valencia group within the framework of the Resonance Effective Theory of QCD.

- The $\langle VVP\rangle$ and $\langle VAP\rangle$ Green Functions were studied phenomenologically by the Valencia group within the Resonance Chiral Theory.

- The Orsay group has derived a set of coupled equations of the Roy and Steiner type for the $S$- and $P$-waves of the $\pi K \to \pi K$ and $\pi\pi \to K\bar{K}$ amplitudes. From experimental data above 1 GeV, tight constraints on the two $\pi K$ $S$-waves scattering lenghts were obtained, and some $O(p^4)$ low-energy constants estimated.

- The Orsay group has obtained a set of sum rules for the electromagnetic chiral parameters which involve QCD four-point correlators. These sum rules were estimated through an effective Lagrangian for light resonances where QCD constraints were implemented, and implications for radiative corrections were considered.

*To investigate the order parameters of QCD*: ORDER PARAMETERS

- The Lund Barcelona collaboration has calculated $\pi\pi$ and $\pi K$ scattering to two-loop order. This allowed to determine the $N_f/N_c$ effect experimentally by comparing with the scattering lengths in both channels. The results were compatible with the large $N_c$ based expectations.

- The Orsay group has investigated the effect of vacuum fluctuations of $s\bar{s}$ pairs on three-flavour ChPT. This effect is described by the $O(p^4)$ low-energy constants $L_4$ and $L_6$, which are suppressed at large-$N_c$, violate the OZI rule and are poorly known. Large vacuum fluctuations would lead to significantly different patterns of chiral symmetry breaking in the two- and three-flavour chiral limits.

*Baryon ChPT and Hypernuclei:*

BARYON CHPT

- The Valencia and Barcelona nodes performed an analysis of the dynamical generation of baryonic resonances using unitary extensions of chiral perturbation theory and a new analysis of chiral meson dynamics in nuclear matter, obtaining valuable progress in hypernuclei studies and $\Lambda(1405)$ production in K–Nucleon interactions, which included

  - Development of the Kaplan-Savage-Wise Effective Field Theory for nucleon-nucleon interactions.
  - Study of the interaction between the meson and baryon octet.
  - Determination of the $\pi N$ scattering lengths through the study of pionic hydrogen and pionic deuteron.
  - Effects of $\phi(1020)$ in nucleus.

- Barcelona and Torino nodes have studied the influence of Final State Interactions on the characterization of the nonmesonic decay of $\Lambda$-hypernuclei from two-nucleon coincidence observables, providing a cleaner determination of $\Gamma_n/\Gamma_p$ than single-nucleon observables. The comparison of our results with preliminary KEK data has allowed us to extract a $\Gamma_n/\Gamma_p$ ratio much smaller than previous single-nucleon based values, and in agreement with most theoretical predictions at present.

- A comprehensive investigation was made of the nucleon form factors and the baryon magnetic moments in the constituent quark model with instant, point and front form kinematics by the Helsinki node. The study was extended to a quantitative assessment of the need for sea-quark configurations in the pion decays of the low-lying nucleon resonances.

- The Helsinki and Warsaw nodes have investigated the $\pi^0 - \eta$ mixing from recent Juelich /Wasa data on $pd \to \eta^3He, \pi^{-3}H \to^3 He\eta, pd \to \pi^+,^3 H$. These data, used to extract $\eta - 3He$ scattering length, indicate existence of $\eta^3He$ virtual state. An attempt was made to extract the $\eta - \pi^0$ mixing parameter.

- Warsaw and Helsinki analysis of coupled $\eta N, \pi N, \gamma N, \pi\pi N$ systems based on K matrix method and the recent data for $(\pi, \eta)$ reactions from Crystal Ball (Brookhaven) suggests a good chance to find eta-nucleon quasi-bound states in Wasa and GSI experiments.

- Professor Dalitz from Oxford, UK node, remains a world authority on all aspects of hypernuclear physics and is regularly consulted by theorists and experimentalists within the network.

**Quark masses**

QUARK MASSES

- The Valencia group obtained a new determination of the mass of the strange quark ($m_s$) from hadronic tau decays.

- From the available $\pi\pi$ data, the Orsay group derived a lower bound for the quark mass ratio $r = m_s/m > 14$ with 95% confidence level, keeping open the possibility of large vacuum fluctuations of $s\bar{s}$ pairs.

- A new strategy has been developed at DESY Zeuthen for a non-perturbative computation of the b-quark mass to leading order in $1/m$ in the Heavy Quark Effective Theory (HQET). The approach avoids the perturbative subtraction of power law divergencies, and the continuum limit may be taken.

**$\alpha_{em}(M_Z)$, the anomalous magnetic moment of leptons $(g-2)_l$ and other SM electroweak parameters**



*$(g-2)_\mu$ and multi-loop calculations:*

- INFN/Bologna and Warsaw/Katowice groups developed numerical methods, based on differential equations, to calculate multi-loop scalar integrals.

- The Bologna group (INFN node), in collaboration with the Karlsruhe and Warsaw nodes, has continued an intense activity about analytic and/or numeric evaluations of multi-loop amplitudes: i) two loop (and more) analytic calculations for Bhabha scattering and others QED quantities; ii) two loop analytic corrections to QCD quantities; iii) two loop precise numerical evaluations (even on thresholds) of a selfmass with arbitrary masses from differential equations.

*Precision determination of electroweak parameters:*

- Two major observables, the mass of the $W$ boson and the effective weak mixing angle $\sin^2\theta_{\rm eff}^{\rm lept}$, have been calculated at two-loops as a result of a collaboration between the DESY-Zeuthen and the Durham nodes. The results have substantial impact on the indirect determination of the Higgs boson mass. The contribution is large enough to compare with the effects of the recent shift in the measured top quark mass. The results have been used by the experimental groups to derive the most recent Higgs mass limits.

*The electroweak contribution:*

- The electroweak hadronic contribution to $(g-2)_\mu$ was improved in a joint Barcelona-Marseille analysis via the implementation of the current algebra Ward identities and the inclusion of the correct short-distance QCD behaviour of the relevant hadronic Green's function. New non–renormalization theorems for the non–anomalous sector were also proven.

*Hadronic Effects in electroweak precision observables*

- The DESY/Karlsruhe team made substantial progress in the investigation of low energy hadronic cross sections both experimentally (KLOE) and theoretically (PHOKHARA). The new KLOE result for the cross section $\sigma(e^+e^- \to \pi^+\pi^-)$ plays an important role in improving the calculation of hadronic effects in electroweak precision observables like $a_\mu$ and $\alpha_{\rm em}(M_Z)$.

- The collaboration between the DESY/Karlsruhe and Katowice group from the Warsaw node has developed theoretical concepts which allow to utilize the Radiative Return at KLOE, CLEO-C, BABAR and BELLE for a precise measurement of the pion form factor at low $Q^2$. The impact of the FSR contribution on the anomalous magnetic moment of the muon was evaluated.

- Common efforts of Zeuthen/Karlsruhe, Valencia and Warsaw/Katowice groups resulted in developing of the state-of-the-art Monte Carlo event generator PHOKHARA of processes $e^+e^- \to hadrons + photons$ and $e^+e^- \to \mu^+\mu^- + photons$. It has helped in KLOE $\sigma(e^+e^- \to \pi^+\pi^-)$ measurement via the radiative return method. It was shown also, that this method can be used at B-factories to measure separately nucleon form factors in time-like region.

- The Desy-Zeuthen node showed that isospin breaking effects due to the differences between masses and widths of the charged and neutral $\rho$ mesons indicate that $\tau$ - data cannot be used to improve the evaluation of the vacuum polarization effects without further input from theory.

- New precise data on the low energy $e^+e^-$ annihilation into hadrons from Novosibirsk were used by the Warsaw node to obtain bounds on the elasticity parameter and the difference between the phase of the pion form factor and that of the $\pi\pi$ scattering.

- A new analysis of the vector form factor of the pion at next-to-leading order in the $1/N_C$ expansion was performed by the Valencia group.

**Heavy-flavour decays and Heavy-Quark Effective Theory (HQET)**

- The extraction of charge and matter radial distributions for S-wave heavy-light mesons using lattice QCD in addition to the P-, D-, F-wave energies was done by the Helsinki node.

- The role of pion exchange in the two-pion decays of exited charmonia and bottomonia was investigated quantitatively. The isospin symmetry breaking decay $D_s^* \to D_s\pi^0$ was studied for extracting the coupling of $\eta-$mesons to strange and charm quarks.

- The nature of the newly discovered positive parity charmed mesons and that of the scalar resonance $f_0(980)$ have been investigated by the Bari/INFN group.

*D-decays* *D*-DECAYS

- It has been shown by the Marseille node that the introduction of a radial excitation of the $D$ or $D*$ mesons allows the large experimental value of the $g_{DD*\pi}$ constant from light cone sum rules to be reproduced.

*B-decays* *B*-MESONS

- The group Bern-Frascati has investigated the rare decay B $\to X_s l^+ l^-$ to NNLL precision for arbitrary dilepton invariant mass.
- The first of the three steps in the NNLO QCD calculation of the $B \to X_s\gamma$ decay rate was performed by Warsaw node taking into account different masses of the top quark ($m_t$) and the W-boson ($M_W$). The strength of the relevant flavour-changing interactions is determined at the electroweak scale to the $O(\alpha_s^2)$ accuracy.
- It was demonstrated by Warsaw node that the sign of the $b \to s\gamma$ amplitude can be determined from the current data on $b \to s l^+ l^-$. This has a large impact on parameters of extensions of Standard Model.

- Semileptonic $B$-decays in the heavy-quark limit of QCD were studied through Bjorken-like sum rules by the Orsay node. New results came from considerations of the non-forward amplitude and the systematic use of particular boundary conditions that allow to put bounds on derivatives of the Isgur-Wise function. These results were extended to include $1/M_B$ corrections.
- The Orsay group proved QCD factorisation at one loop for the radiative B-decays $B \to \gamma l \nu$, $B \to \gamma\gamma$ and $B \to \gamma l^+ l^-$, and large Sudakov logarithms were resummed in the framework of Soft Collinear Effective Theory. The radiative decays $B \to V\gamma$ (with $V$ a vector meson) were also shown to factorise at one loop.
- The Orsay group showed that nonfactorisable contributions to some two-body $B$-decays could be numerically significant, even though they are suppressed in the heavy-quark limit (charming penguin, final-state interactions). Experimental data on these decays support this conclusion.

**Strong Interaction limit of QCD**

*$\alpha_s$ in the infrared region :* $\alpha_s$

- The UK node has been engaged in solving the field equations of QCD in the strong coupling limit. Numerical studies of the Schwinger-Dyson equations have been pioneered in Durham. Current investigations focus on the behaviour of $\alpha_s$ in the infrared region and its relation to hadron dynamics.
- The INFN-LNF and Granada groups have investigate the impact of the infrared behaviour of $\alpha_s$ upon the energy behaviour of total cross-sections, showing the need for a singular, integrable, limit.
- The new 5 flavour LO and NLO global fits and parton parametrizations were constructed for a real photon by Warsaw and Granada nodes.

*Meson and baryon Spectroscopy beyond the naive Quark Model :*

- The properties of the Wilson loop in QCD for large contours were investigated by the Orsay group. The resulting covariant three-dimensional bound state equation for the quarkonium system was studied in the nonrelativistic and ultrarelativistic limits.
- In the light scalar meson sector the experimental evidence has been strengthened for the existence of the controversial $\kappa(800)$. This means that we could have a complete scalar nonet: $\sigma(600)$, $a_0(980)$, $f_0(980)$, and $\kappa(800)$. This possibility which was originally suggested by Jaffe was discussd by C. Amsler and N.A. Törnqvist in their recent Physics Reports review.
- The recently observed X(3872) charmonium state of Belle, BaBar and CDFII collaborations is likely to be one the deuteronlike $D\bar{D}^*$ states predicted by N.Törnqvist 10 years ago, just below the $D\bar{D}^*$ thresholds.
- The Barcelona node has studied the connection between the old known Linear Sigma Model and the low energy constants of ChPT. From the values of these latter constants, interesting constraints for the spectrum of the low mass scalar mesons are derived.

- The nature of the lightest scalar nonet was discussed by the Valencia and Vienna nodes.
- Radiative decays of the $\phi$ meson were studied by the Valencia node and compared with experimental data from KLOE (DAPHNE). Both $J/\psi$ and $\phi(1020)$ radiative decays were analyzed by the Valencia node in connection of the nature of $f_0(980)$ and $a_0(980)$ resonances. RADIATIVE DECAYS
- The UK node has led extensive studies of exotic hadrons during the first period of the network. The work of the node includes the first proposal that the newly discovered $D_s(2317)$ and $D_s(2460)$ are $DK$ and $DK^*$ bound states, now known as tetraquarks (hep-ph/0305025). The Oxford group has proposed that the X(3872) is a $1^{++}$ $D^0D^{*0}$ state at threshold (hep-ph/0309253), implying a large violation of isospin invariance in decays. This appears to be confirmed by the observation of $\psi\rho$ and $\psi\omega$ decays.
- A dynamical generation of baryonic resonances was obtained by the Valencia group.

*New baryons*

- The claimed pentaquark baryon has been investigated in a series of papers by the UK group at Oxford and reviewed in the summary talk by F.E. Close at Hadron03 (hep-ph/0311087). These studies have investigated the implications for the production of the sibling $\Sigma_5$ (hep-ph/04031159), the decays and selection rules for pentaquarks (hep-ph/0311258, 0401192), as well as the implications the existence of a narrow pentaquark baryon has for exotic mesons with strangeness +2 (hep-ph/0411160). These recent ideas have been developed building on the work of others in the EURIDICE network, viz. Vento *et al.*.
- Pentaquark states were analyzed by the Valencia group to determine spin and parity of $\Theta^+$, its origin as a K$\pi$N bound state and the existence of hypernuclei of $\Theta^+$.
- The Warsaw node has shown that level shift and widths in kaonic deuterium may constrain the subthreshold $K-N$ scattering amplitudes. That is an interesting region of $\Lambda(1405)$ resonance which may be a quark state and/or $KN$ quasibound state.
- The possibility for narrow strange pentaquarks in the quark model was investigated in the Helsinki group.

**Experimental progress of KLOE Collaboration.**

The Kloe experiment took data during year 2002 (about 300 $pb^{-1}$); in year 2003 there was a long machine shutdown for the installation and first data taking of the Finuda experiment. In year 2004 Kloe resumed the data taking in May and has collected up to the end of the year another 800 $pb^{-1}$; in this period the machine luminosity reached the 1.0 $10^{32}cm^{-2}sec^{-1}$ milestone with a record of 1.2 $10^{32}cm^{-2}sec^{-1}$ . The Kloe program foresees to continue data taking in 2005 to collect at least another $fb^{-1}$.

In the mean time the analysis criteria and tools have been refined and in particular great care has been given to the MonteCarlo program in order to simulate the detector

behaviour as accurately as possible, including also the effects of machine background. Up to now Kloe has published 10 physics papers and 2 more have been accepted and are in press. Preliminary results from new or updated analyses are being presented to international conferences.

The Kloe physics analysis is performed inside three working groups. In the following for each working groups the analysis items are described.

**1) $\phi$ decays.**

- Through the study of the dynamic of the decay $\phi \to \pi^+\pi^-\pi^0$ estimates of the masses and widths of the 3 states of charge of the $\rho$ meson have been obtained, together with a clear evidence of a direct term.

- Through the radiative decay $\phi \to \eta\gamma$ the rare and forbidden decays $\eta \to \pi^0\gamma\gamma$, $\eta \to \gamma\gamma\gamma$ and $\eta \to \pi^+\pi^-$ have been searched for. For all the three quoted decays the KLOE sensitivity improves the previous experiments. Moreoever a complete study of the dynamic of the less rare decays $\eta \to \pi^+\pi^-\pi^0$ and $\eta \to \pi^0\pi^0\pi^0$ is in progress.

- The decay $\phi \to \eta'\gamma$ has been observed in 2 different decay modes of the $\eta'$ and the branching ratio has been measured. From this measurement a new improved estimate of the pseudoscalar mixing angle has been obtained.

- A complete study of the radiative decay of the $\phi$ to the scalar mesons $f_0(980)$ and $a_0(980)$ is in progress involving the decays $f_0 \to \pi^+\pi^-$, $f_0 \to \pi^0\pi^0$ and $a_0 \to \eta\pi^0$. The data are compared with several models based on different approaches.

- With the method of the radiative return, the cross section of the process $e^+e^- \to \pi^+\pi^-$ has been obtained in the center of mass energy range $590 < \sqrt{s} < 980$ MeV. This, in turn, allows to get an estimate of the hadronic contribution to the muon anomaly $a_\mu$ with very good accuracy.

- From the energy scan done in the end of the 2002 data taking, measurements of the leptonic widths of the $\phi$, $\Gamma_{ee}$ and $\Gamma_{\mu\mu}$ have been performed. Moreoever the cross-section of the process $e^+e^- \to \omega\pi^0$ in the region around the $\phi$ resonance energy has been measured and the analysis is in progress to extract the $\phi \to \omega\pi^0$ branching ratio.

**2) CP and neutral kaon decays.**

- Using the decay $\phi \to K_S K_L$, high purity samples of tagged $K_S$ and $K_L$ are obtained. A complete study of the semileptonic decays of the neutral kaon is in progress. New improved values for the branching ratios of $K_S \to \pi e\nu$ and for the corresponding charge asimmetry have been obtained. The branching ratios of $K_L \to \pi e\nu$ and $K_L \to \pi\mu\nu$ have also been obtained together with a direct measurement of the $K_L$ lifetime. All these informations contribute in a very significant way in the determination of the CKM matrix element $V_{us}$ and in the assessment of the unitarity of the CKM matrix itself.

- The branching ratios of the other main $K_L$ decays, $K_L \to \pi^+\pi^-\pi^0$, $\pi^0\pi^0\pi^0$ and $\pi^+\pi^-$ are also determined.

- The high purity of the $K_S$ samples allows to extract the best present direct upper limit on the CP violating decay $K_S \to \pi^0\pi^0\pi^0$. Analysis is also in progress to study the rare decay $K_S \to \pi^+\pi^-\pi^0$.

- The most accurate measurement of the ratio $BR(K_S \to \pi^+\pi^-)/BR(K_S \to \pi^0\pi^0)$ has been measured using also the pure $K_S$ beam.

- The ratio of branching ratios $BR(K_L \to \gamma\gamma)/BR(K_L \to \pi^0\pi^0\pi^0)$ has also been measured with high accuracy.

- Evidence has been found of the interference pattern of the decay $\phi \to K_S K_L$ with both kaons decaying in $\pi^+\pi^-$. From the shape of the interference pattern the decoherence parameter is estimated.

**3) Charged kaon decays.**

- Using the copious decay $\phi \to K^+K^-$, the charged kaon decays $K^\pm \to \mu^\pm\nu$, $K^\pm \to \pi^\pm\pi^0$ $K^\pm \to \pi^\pm e\nu$ and $K^\pm \to \pi^\pm\mu^\pm\nu$ have been studied and the measurement of the branching ratios is in progress.

- The branching ratio of the decay $K^\pm \to \pi^\pm\pi^0\pi^0$ has been measured with high accuracy.

- A new measurement of the charged kaon lifetime is in progress.

### 1.2 A2. Joint Publications

In the following, we list the joint publications which have been completed by two or more nodes of our network. Whenever a young researcher is one of the co-authors of a paper, his/her name is underlined. We distinguish between papers published in refereed journals, papers published in Proceedings of Conferences, and we list, as the last, papers recently completed and posted in the international bulletin board at Los Alamos and submitted to a journal for publication. The published papers have been grouped in six major categories, most of which correspond to the research highlights described in the previous section.

We have refrained from listing the joint publications in order of importance: the only semi-objective way to do this is through use of the impact parameter index, but it is the opinion of many members of this network that it is often unfair to recent papers and sometimes it also fails to do proper justice.

*Published in refereed journals*

## CP Violation and Cabibbo-Kobayashi-Maskawa Matrix

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# 2 B - COMPARISON WITH THE PROJECT PROGRAM

## 2.1 B1. Research Objectives

All the research objectives described in the Contract and reproduced in the previous section, are still relevant and, in our opinion, achievable. In the subsection dedicated to the work plan, more details about the progress of the project, can be found.

## 2.2 B.2 Methodological Approach and Work Plan

There has been no change in the research method described in our Contract, which is based on the use of *Effective Theories of Colours and Flavours* applied to the study of elementary particle interactions through data collected by experiments in the low and intermediate energy region, like KLOE and DEAR at DAPHNE, WASA, NA48, DIRAC, BaBar, BELLE, CESR-C, FOCUS, SELEX, B-TeV, HERA-B, LHC-B. The theoretical methods used have included

- Chiral Perturbation Theory
- Large $N_c$- expansion
- Heavy Quark Effective Theory
- Exact Renormalization Group
- QED and Perturbative QCD
- Quantum Mechanics

### Breakdown of Tasks

The work plan of the EURIDICE network is structured in a number of tasks, grouped into three main groups. This structure is reproduced in the three tables which follow, where, together with a $\star$ to indicate the assigned tasks at the time of the Contract, we have included

- a $\surd$ to indicate the involvement of the groups during the first year of operation (see First Periodic Report),
- a $\bullet$ for the involvement during the second year of operation (see Second Periodic Report),
- a $\oplus$ for involvement at the time of this midterm report.

Notice that the last two columns in Table 2 have been more generally labelled to include items related to the given task. Thus, the column $\alpha_s$ *in the infrared* includes now also *Structure functions*, whereas *glueballs spectroscopy* includes the study of scalar mesons and the newly observed (but not yet fully confirmed) pentaquark state. From these tables one can see that most groups are actually performing the tasks as originally planned. Further updates and completions of tasks can be expected as the project moves toward completion.

Table 1: Task Assignments in theoretical developments in Effective Field Theories

| Team | Quark masses | ChPT 3 flav ours | Isospin breaking effects | Large $N_c$ QCD | $N_f/N_c$ dependence | Lattice QCD and and ChPT | HQET and LEET | EFT in Nuclear matter |
|---|---|---|---|---|---|---|---|---|
| INFN | | $\oplus$ | $\star$ | $\oplus$ | | $\oplus$ | $\star\surd\bullet\oplus$ | $\star\bullet\oplus$ |
| UVEG | $\star\surd\bullet\oplus$ | $\star\oplus$ | $\star\surd\bullet$ | $\star\surd\bullet\oplus$ | | $\star\bullet$ | $\star$ | $\star\surd$ |
| UAB | | $\star\surd\bullet$ | | $\star\surd\bullet$ | $\star\bullet$ | | | |
| CNRS DR12 | | $\star$ | $\star$ | $\star\bullet\oplus$ | | $\star\surd\bullet\oplus$ | $\star$ | |
| CNRS-IN2P3 | $\star\bullet$ | $\star\surd\bullet\oplus$ | $\star\bullet\oplus$ | $\star\oplus$ | $\star\ \surd$ | | $\star\ \surd\bullet\oplus$ | |
| DUR | $\bullet\oplus\ \star$ | | $\star$ | | | | | $\star\oplus$ |
| ULUND | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\bullet\oplus$ | $\star\surd\bullet\oplus$ | | $\star\surd\bullet\oplus$ | $\surd\bullet\oplus$ | |
| UHELS | $\star\bullet$ | $\star\bullet\oplus$ | $\star\bullet\oplus$ | $\surd\bullet\oplus$ | | $\surd$ | | |
| DESY Zeuthen | $\star\bullet\oplus$ | | $\star\bullet\oplus$ | | | $\star\surd\bullet\oplus$ | | |
| UNIBE | $\star\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet$ | $\star$ | | $\surd\bullet\oplus$ | $\star\bullet\oplus$ | |
| Vienna | $\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\surd\bullet\oplus$ | | | | |
| Warsaw | | $\star$ | $\star$ | | | | | |

Table 2: Task Assignments in theoretical estimates and modelling of precision measurements

| Team | CP CPT QM | CKM Matrix | Rare K-decays | Charm and Beauty decays | $(g-2)_\mu$ and $\alpha_{QED}$ | $\alpha_s$ in infrared and structure functions | glueballs scalars exotics and spectro scopy |
|---|---|---|---|---|---|---|---|
| INFN | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet$ | $\star\surd\bullet$ | $\bullet$ |
| UVEG | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star$ | $\star\surd\oplus$ | $\star\surd$ | | $\bullet\oplus$ |
| UAB | $\star\surd\bullet$ | $\star\bullet\ \surd$ | $\star\oplus$ | $\star\surd\bullet$ | $\surd\bullet$ | $\surd$ | $\bullet$ |
| CNRS DR12 | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd$ | $\star\surd\bullet\oplus$ | | $\bullet$ |
| CNRS-IN2P3 | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\oplus$ | $\star\surd\bullet\oplus$ | | | |
| DUR | | | | $\star\surd\bullet\oplus$ | $\star$ | $\star\bullet\oplus$ | $\star\surd\bullet\oplus$ |
| ULUND | $\star\surd\bullet\oplus$ | $\star\surd$ | $\star$ | $\star\surd\bullet\oplus$ | | | |
| UHELS | | | | $\star\surd\bullet\oplus$ | | | $\star\surd\bullet\oplus$ |
| DESY Zeuthen | | | | | $\star\surd\bullet$ | | |
| UNIBE | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet$ | $\star\surd\bullet\oplus$ | | |
| Vienna | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\bullet$ | | $\star$ | | |
| Warsaw | $\star\surd$ | $\surd$ | $\star$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\bullet\oplus$ | $\star$ |

Table 3: Task Assignments in studies for future or upcoming experiments

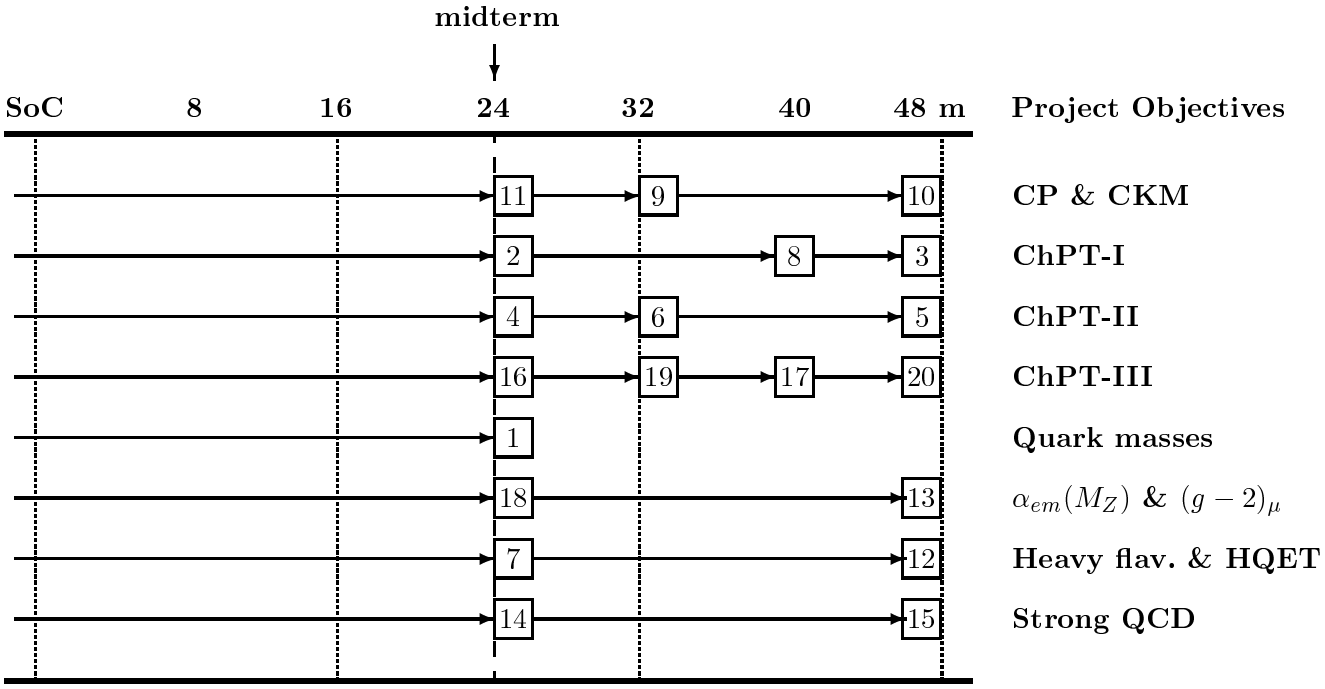
| Team | Hadronic atoms at DEAR and DIRAC | $\eta, \eta'$ at WASA and KLOE | MC and Rad.Corr. for $\sigma_{had}$ at KLOE and PEPII | $\tau$-Charm factories | Kaon-Nucleon scattering | Hyper nuclei from FINUDA |
|---|---|---|---|---|---|---|
| INFN | $\star$ | $\bullet\oplus$ | $\star\bullet\oplus$ | | $\star$ | $\star\bullet\oplus$ |
| UVEG | | | $\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | $\star\surd\oplus$ |
| UAB | | $\star\oplus$ | | $\star$ | $\star\bullet$ | $\star\surd\bullet$ |
| CNRS DR12 | $\star$ | $\star$ | | $\star$ | | |
| CNRS-IN2P3 | $\star\oplus$ | $\star$ | | $\star\oplus$ | | |
| DUR | | | | $\star\surd\bullet\oplus$ | $\star\bullet\oplus$ | $\star\surd\bullet\oplus$ |
| ULUND | $\surd$ | $\star\surd\oplus$ | | | | |
| UHELS | $\star\surd\bullet\oplus$ | $\star\surd\bullet\oplus$ | | $\star\bullet\oplus$ | | |
| DESY Zeuthen | | | $\star\surd\oplus$ | | | |
| UNIBE | $\star\surd\bullet\oplus$ | $\star$ | | | $\star\bullet$ | |
| Vienna | | | | $\star$ | | |
| Warsaw | $\star\bullet\oplus$ | $\star$ | $\star\surd\bullet\oplus$ | $\star$ | $\star\bullet\oplus$ | |

## 2.3 B.3 Schedules and Milestones

The EURIDICE project is a joint effort between experimentalists and theorists, aimed to extract informations in the low energy regime explored by the accelerator DAΦNE . As such, some of our milestones are necessarily connected to the progress of the experimental program and may not be completely in line with the original milestones. Such is the case for one particular item, the last one in the milestone table, since the data analysis of the FINUDA experiment is not yet available for theoretical work.

Concerning the other milestones, the general schedule of our work appears well in line with the predictions. To illustrate this, we reproduce the milestone table in our contract. At the right of this table, the objectives of the project are reproduced, while the numbers in the table refer to the specific tasks related to each objective. Status of accomplishment of the milestones is discussed in conjuction with the table in the next page.

**EURIDICE Schedule and Milestones**




**Legend**: SoC=Start of Contract, m=months

Here we list the tasks using different markings to indicate whether a given milestone has been reached or not. Complementary to the table, and to substantiate the status of progress in each task, we have included an Annex where a series of comments following the table are meant to support our assessment,via a bibliographic information.

As a final comment, concerning the milestone table, we point out that a theoretical project in fundamental physics is really never completed. There are always new features that appear when a given part of the puzzle has been solved. This is why we have refrained from indicating as *completed* many tasks, where work in continuing, although the initial endeavour had been fully undertaken

**Tasks**:

1 Quark masses $\odot$
2 ChPT with 3 flavours ($\star$)
3 Isospin breaking effects ($\bullet$)
4 Large-$N_c$ QCD $\odot$
5 $N_f/N_c$ dependence $\star$
6 Lattice QCD and ChPT ($\bullet$)
7 HQET and LEET $\star$
8 EFT in nuclear matter ($\bullet$)
9 CP, CPT and QM ($\bullet$)
10 CKM matrix ($\bullet$)
11 Rare $K$-decays $\odot$
12 Charm and Beauty decays ($\bullet$)
13 $(g-2)_\mu$ and $\alpha_{\rm QED}$ ($\bullet$)
14 $\alpha_s$ in the infrared region and structure functions $\odot$
15 Glueballs, scalars, exotics and spectroscopy ($\bullet$)
16 Hadronic atoms at DEAR and DIRAC $\star$
17 $\eta$ and $\eta'$ at WASA and KLOE ($\bullet$)
18 Monte-Carlo methods and radiative corrections for $\sigma_{\rm had}$ at KLOE and PEPII $\odot$
19 Kaon-Nucleon scattering ($\bullet$)
20 Hypernuclei at FINUDA ($\bullet$)

$\star$ completed,

($\star$) near completion,

($\bullet$) work in progress,

$\odot$ initial plan completed, new features under study

## 2.4 B.4 Research Effort of the participants

This network consists of 1 Coordinator and 11 participants, 10 of which from Member States and 1 from Switzerland. Some of the teams include researchers belonging to different institutions, as we specify in the following.

1. Istituto Nazionale di Fisica Nucleare [INFN-LNF] established in Italy which includes external team members from Sezione INFN di Roma1, Sezione INFN di Roma3, Sezione INFN di Napoli, Sezione INFN di Bari, Sezione INFN di Perugia, Sezione INFN di Bologna, Sezione INFN di Trieste, Sezione INFN di Torino.

2. University of Valencia [UVEG] established in Spain which includes external team members from University of Madrid

3. Universitat Autonoma de Barcelona [UAB] established in Spain which includes external team members from Universidad de Granada, Universitat de Barcelona, Universitat Politecnica de Catalunya

4. CNRS-CPT Luminy, Marseille [CNRS-DR12] established in France

5. CNRS - Institut National de Physique Nucleaire et de Physique des Particules [CNRS/IN2P3] established in France, which includes external team members from IPN- Orsay, LPT - Orsay, Ecole Polytechnique - Palaiseau, LPNHE - Paris.

6. Universiy of Durham [DUR] established in the United Kingdom which includes external team members from Oxford University, University of Manchester

7. University of Lund [ULUND] established in Sweden which includes external team members from University of Oslo, Norway

8. University of Helsinki [UHELS] established in Finland

9. DESY Zeuthen [DESY Zeuthen] established in Germany which includes external team members from University of Karslruhe

10. University of Bern [UNIBE] established in Switzerland which includes external team members from University of Zurich

11. Universitat Wien [UWIEN.ITP] established in Austria

12. Warsaw University [Warsaw] established in Poland which includes external team members from IPJ (Soltan Institute of Nuclear Studies), Warsaw and University of Silesia, Katowice

The network has two subnodes

- University of Oslo, Norway, as a subcontractor of University of Lund, Sweden
- University of Karslruhe, Germany, as a subcontractor of DESY Zeuthen, Germany

Table 4 illustrates the present involvement of scientists from different nodes in comparison with what was stated in Annex I of the Contract. As one can see, the original involvement is very similar to the present one. The main disagreement concerns the Bern

Table 4: EURIDICE Research Effort after 2 years of operation: Columns (c) and (d) include also the young researchers financed by the Contract

| Professional research effort on the network project | | | | | | | |
|---|---|---|---|---|---|---|---|
| $N.^o$ | Team | Young Researchers to be financed by the contract (person-months) (a) as in the contract, (b) as of 31/12/04 | | Total Researchers financed from all sources (person-months)/year (c) as in the contract, (d) as of 31/12/04 | | Researchers contributing to the project (number of individuals) (e) as in the contract, (f) as of 31/12/04 | |
| | | (a) | (b) | (c) | (d) | (e) | (f) |
| 1. | INFN | 48 | 30 | 155 | 183 | 30 | 30 |
| 2. | UVEG | 30 | 3 | 200 | 180 | 19 | 19 |
| 3. | UAB | 30 | 26 | 222 | 240 | 26 | 28 |
| 4. | CNRS DR12 | 24 | 15 | 80 | 94 | 12 | 12 |
| 5. | CNRS-IN2P3 | 24 | 3 | 66 | 66 | 12 | 12 |
| 6. | DUR | 48 | 16 | 60 | 76 | 10 | 11 |
| 7. | ULUND | 13 | 15 | 53 | 131 | 6 | 7 |
| 8. | UHELS | 13 | 13 | 58 | 55 | 8 | 8 |
| 9. | DESY Zeuthen | 24 | 14 | 122 | 136 | 13 | 18 |
| 10. | UNIBE | 24 | 23 | 226 | 132 | 13 | 15 |
| 11. | Vienna | 24 | 15 | 60 | 60 | 9 | 8 |
| 12. | Warsaw | 0 | | 67 | 52 | 11 | 8 |
| Totals | | 302 | 173 | 1369 | 1405 | 169 | 176 |

node, with 226 pm/year vs. actual 132 pm/year in colums (c) and (d). Notice that the involvement by the Bern node as stated in the contract contained a factual mistake, since it is impossible to have 226 months/year with 13 researchers. The actual numbers are as stated in the Table.

## 2.5 B.5 Cohesion with Less Favoured Regions

In our network, there is one group located in a less favoured region, Granada in Andalusia, and two nodes lovcated in less favoured regiona, namely UVEG, University of Valencia and DESY-Zeuthen, located in Brandenburg. All of these groups are extremely well integrated in the network.

For Granada, integration in the network is demonstrated by the many close links between Granada and the other nodes and subnodes, some of which presently include : GRANADA

- A long standing collaboration between G. Pancheri from Frascati and A. Grau from Granada, presently focussed on understanding the infrared behaviou of the strong coupling constant
- A collaboration between J. Prades from Granada and J. Bijnens from Lund which has made several major steps forward in understanding the value of both $\epsilon'$ and $\epsilon$ in the standard model.
- A collaboration between F. Cornet from Granada and the Warsaw group, concerning photon structure functions.

As for Valencia, its integration in the network is demonstrated by the very large number of joint publications and its central role in most of the project objectives. Then, for DESY Zeuthen, this node, together with its Karlsruhe subnode, is in charge of one of the major research objectives, the study of the muon anomaly. Researchers from these nodes collaborate both with Frascati as well as with members of the Warsaw and exchange frequent visits. Scientists from Karlsruhe are part of the experimental group KLOE working on extracting data from DAΦNE . DESY-ZEUTHEN

## 2.6 B.6 Network Organization and Management

### Coordination and communication strategy

- *Network organization and management :* The network has been organized following the guidelines described in the Work Program. Coordination and communications were based on the Team Committee constituted by the 12 scientists in charge, who exchanged frequent e-mails and telephone calls to discuss and plan both network meetings as well as the training programme. The state of the network could be regularly checked through the network web page, **http://www.lnf.infn.it/theory/rtn/** where announcement of meetings as well as available positions were posted.
- *Decision making :* The process followed along the work program, through operation of the Network Executive Committee, consisting of the 12 scientists in charge, implemented by representatives from the two subnodes, i.e. Karlsruhe (DESY-Zeuthen subnode) and Oslo (Lund subnode), by the representative from the Granada team, by the monitor of progress in B-physics, L. Oliver fom the Orsay node, and the Analysis Coordinator of the KLOE experiment, J. Lee Franzini from the LNF-INFN node. During the first 28 months of operation 6 meetings were held, namely

  1. Frascati, October 18th 2002, during the Start-off Collaboration meeting : the Executive Committee decided the dates for the call for young researcher training

positions and planned for the various meetings and workshops organized by the participants

2. Orsay, February 2003, during the Second Collaboration Meeting : the hiring for the year 2003 proposed by each node was approved.
3. Paris, December 5th 2003 : assessment of working group activities and preparation of next Collaboration Meeting were discussed.
4. Vienna, February 13th, 2004, during the third Collaboration Meeting: young researcher hiring for 2004 was approved, working groups progress and planning for the LNF Spring School and for other topical workshops were discussed
5. Frascati, November 20th 2004 : The Midterm Report, the Midterm Review Meeting and of the Collaboration Meeting were discussed and prepared.

- *Publications and dissemination of information :* The network results have been published in journals, and/or electronic bulletin boards, and/or presented at Conferences. The publication record of the network can be found from the network webpage, where the publications from each node have a dedicated space. In this space, accessing SPIRES, the link http://www.lnf.infn.it/theory/rtn/papers.htm lists in real time the publications by each member of each node of the network.

- *Presentation at International Conferences :* During the reporting period, network members have participated with presentations to the following International Conferences:

1. American Physical Society Meeting in Baltimore, USA, April 2003
2. Linear Collider School in Ambleside, UK, August 2003
3. Tenth International Conference on Hadron Spectroscopy, Aschaffenburg, Germany
4. Photon 2003 International Conference on the Structure and Interactions of the Photon, including the 15th International Workshop on Photon-Photon collisions, Frascati, Italy, April 2003
5. 10th High Energy Physics International Conference on QCD (Montpellier, 2-9 July 2003).
6. Hadron 03: 10th International Conference on Hadron Spectroscopy, Aschaffenburg, Germany, Aug-Sept. 2003
7. Chiral Dynamics 2003, Bonn, Germany, Sept. 2003
8. Beauty 2003, Carnegie Mellon, Pittsburg, USA, October 2003
9. 39 Rencontres de Moriond in La Thuile, 21-28 March 2004
10. Linear Collider World Study in Paris, April 2004
11. Meson04, Kraków, June 4-8, 2004.
12. DAΦNE 2004, 4th International Conference on Meson factories, June 2004
13. Lattice 2004 Conference at Fermilab, 21-26 June 2004
14. BEACH2004, 6th International Conference on Hyperons, Charm and Beauty Hadrons, Illinois Institute of Technology, june 27.-july 3., Chicago, 2004

15. QCD 2004 Conference in Montpellier, July 2004
16. XXXIV International Symposium on Multiparticle Dynamics, Sonoma County, California, USA, july 26th-August 1st, 2004
17. International Conference on High Energy Physics 2004, Beijing, August 2004
18. 19th European Few-Body Conference on Problems in Physics, Groningen, The Netherlands, 23-27 Aug 2004.
19. 10th International Symposium on Meson-Nucleon Physics and the Structure of the Nucleon, Beijing, China, August 29 - September 4, 2004
20. Baryons 04, Palaiseau, Oct. 2004
21. Effective Field Theories in Nuclear, Particle and Atomic Physics Bad Honnef/Germany, Dec. 13 - 17, 2004

**Network meetings**

As part of the training and networking program, three types of meetings were organized, namely

- Collaboration meetings,
- Topical workshops
- LNF Spring School.

All these meetings were advertized through the network webpage. They were often extended to external participants, and always included presentations by young researchers of the network attending the meeting. The list of such meetings follows :

1. Start-off Collaboration Meeting, Frascati, 18-20 October 2002.

   Organized by G. Pancheri, attended by about 50 participants from the network. No external experts were invited.

2. Second Collaboration Meeting, Orsay, 6-8 February 2003.

   Organized by J. Stern and attended by about 70 scientists, with external experts invited.

3. LNF Spring School Bruno Touschek, Frascati May 19-23rd 2003.

   Organized by G. Pancheri, attended by approximately 50 students, including some young researchers of the network already hired or to be soon hired, and young researcher from another RTN network, ESOP, which traditionally has held joint sessions with EURIDICE.

4. Workshop on Chiral Dynamics of Hadrons and Hadrons in a Medium, June 26-28th, 2003, Valencia, Spain.

   Organized by E. Oset from the Valencia node jointly with A. Ramos of Barcelona node, and attended by about 64 people with external experts.

5. Workshop on $e^+e^-$ in the $1 \div 2$ GeV range, September 10-13th, 2003, Alghero, Italy.

   Organized by INFN with network participation.

6. Workshop on Hadronic Cross-section at Low Energy, organized by G. Venanzoni from INFN-LNF and W. Kluge from the Karlsruhe subnode of the DESY-ZEUTHEN node, Pisa, Italy, October 8-10th, 2003.

7. Workshop on Hadronic Atoms, organized with the collaboration of the Bern node, Trento (Italy) 13-17 October 2003.

8. Third Collaboration Meeting, Vienna, Austria, 12-14 February 2004.

   Organized by G. Ecker , attended by 66 participants from the network.

9. LNF Spring School Bruno Touschek, Frascati May 17-21st 2004.

   Organized by G. Pancheri, attended by approximately 50 students, including young researchers of the network already hired or to be soon hired, and PhD students from Italian and European Universities from the network.

10. 4Th Conference on Physics at Meson Factories DA$\Phi$NE 2004, 7-11th June 2004, Frascati.

    Organized by Frascati INFN Laboratories with network collaboration. Attended by 150 participants, with young researchers from the network and external attendees.

11. Meeting of EURIDICE Spectroscopy Group, September 18-20th, 2004, in Barcelona.

    Organized by A. Bramon and R. Escribano, attended by 30 participants from the network and 10 participants from outside the network.

### 2.7 B.7 Connections to Industry

This is a network in theoretical particle physics with phenomenological applications. From this point of view, there are few connections to industry, except from the ones resulting from the work of the experimental group KLOE, some of whose members are part of the network. In general the close collaboration between experimentalists and theorists in our network already allows for a large and partly unique exchange between theoretical work and industry.

## 3 C - TRAINING

The training programme is proceeding well. Vacant positions were advertized through the Cordis page, through the network page, through electronic distribution of the advertisement to the CERN theoretical group mailing list and to individual node e-mail lists. All nodes have advertised the available positions.

### 3.1 C.1 Employment of Young Researchers

The training programme is proceeding well. In the following tables we illustrate the status of training of our network. In Table 5 we summarize the number of young researchers (in man-months) whose employment has so far been financed by the contract and compare it with the overall deliverable specified in the contract. In Table 6 we show the original training plan together with the hiring at the end of 28 months of operation and the presently committed positions, where pm indicates the length of the contract in person-months.

From the tables one can see that 57% of proposed training has already taken place with 90 % of the position committed.

Table 5: Training : Actual Person-months compared with Contract

| Participant | Young Researchers financed by contract 31-12-2004 (person-months) | | | Contract Deliverable of young researchers to be financed by the contract (person-months) | | |
|---|---|---|---|---|---|---|
| | Pre-doc | Post-doc | Total | Pre-doc | Post-doc | Total |
| **1. INFN-LNF** | 12 | 18 | 30 | 24 | 24 | 48 |
| **2. UVEG** | | 3 | 3 | | 30 | 30 |
| **3. UAB** | | 26 | 26 | | 30 | 30 |
| **4. CNRS-DR12** | | 15 | 15 | | 24 | 24 |
| **5. CNRS/IN2P3** | | 3 | 3 | | 24 | 24 |
| **6. DUR** | 14 | 2 | 16 | 24 | 24 | 48 |
| **7. ULUND** | | 15 | 15 | | 13 | 13 |
| **8. HELS** | | 13 | 13 | | 13 | 13 |
| **9. DESY Zeuthen** | | 14 | 14 | | 24 | 24 |
| **10. UNIBE** | | 23 | 23 | | 24 | 24 |
| **11. UWIEN** | | 15 | 15 | | 24 | 24 |
| Total | 26 | 147 | 173 | 48 | 254 | 302 |

Table 6: Status of Training Programme

| Participant | Contract deliverable to YR to be financed by the contract (person-months) | | | YR financed by the contract so far and in next period (person-months) | | | Committed to start or continue after 01/01/2005 (person-months) |
|---|---|---|---|---|---|---|---|
| | (a) | (b) | (a+b) | (c) | (d) | (c+d) | |
| 1.INFN-LNF | 24 | 24 | 48 | R. Unterdorfer 9 S. Tsatis 3 | C. Smith 15 S. Trine 3 | 30 | C. Smith 9 S.Trine 9 |
| 2.UVEG | | 30 | 30 | | J. Hirn 3 | 3 | J. Hirn 20 |
| 3.UAB | | 30 | 30 | | B. Hiesmayr 6 I. Scimemi 6 M. Verbeni 14 | 26 | M. Verbeni 6 |
| 4.CNRS-DR12 | | 24 | 24 | | S. Necco 15 | 15 | S. Necco 9 |
| 5.CNRS/IN2P3 | | 24 | 24 | | J.J. Sanz-Cillero 3 | 3 | J.J.Sanz-Cillero 20 |
| 6.DUR | 24 | 24 | 48 | J. Hirn 12 K. Benhaddou 2 | L. Edera 2 | 16 | L. Edera 10 |
| 7.ULUND | | 13 | 13 | | T. Lähde 15 | 15 | T. Lähde 9 |
| 8.UHELS | | 13 | 13 | | B. Julia-Diaz 13 | 13 | |
| 9.DESY Zeuthen | | 24 | 24 | | M. Czakon 14 | 14 | |
| 10.UNIBE | | 24 | 24 | | B.Kubis 23 | 23 | |
| 11.UWIEN.IT | | 24 | 24 | | R. Kaiser 15 | 15 | R. Kaiser 9 |
| TOTAL | 48 | 254 | 302 | 26 | 147 | 173 | 101 |

## 3.2 C.2 Training Program

### Integration into the research program

All the young researchers so far have been fully integrated in the research programme, some of them have already published their results in reeereed journals, most of them in the form of electronic preprints and the relative papers have been submitted for publication in the international journals.

### Training measures

The measures undertaken in the training program concerned both individual and common training. Common training was performed through attendance to the Spring School, paticipation and attendance to the Collaboration Meeting and partecipation to the topical Workshops dedicated to the research topic of interest for the young researcher. Individual training consisted in collaboration exchanges and secondments to other nodes to work on common projects. All these activities are listed in the individual nodes reports in the First and Second Annual Report.

EQUAL OPPORTUNITIES

The network has a good proportion of women in leading positions, since 4 out of the 17 members of the Executive Committee are women, namely the Coordinator, the scientist in charge of the Warsaw node, the scientist in charge of the Granada team and the KLOE experiment analysis coordinator. This increases the visibility of women in the field.

Among the 17 young researchers being trained so far, 5 of them are women, representing a proportion of 29%, higher what is usualy reported for the presence of women in the field of theoretical physics (according to INFN statistics of the year 2000, in Italy only 11% of the total number of theoretical particle physicists with permanent positions were women).

## 3.3 C.3 Factual Information on the Young Researchers

In the next Table 7, for each young researcher appointed with network funds, we show the following information: name, nationality, age at time of appointment, start and likely end date of appointment, category of researcher (post-doc, pre-doc mentioning if undertaking PhD studies) scientific speciality, place of work, country of work, and whether the researcher had previously worked or studied at another network partner.

Table 7: Factual Information on Young Researchers

| Name | Nationality | Age at appointment | Start of appointment | End of appointment | Post (PD) or pre-doc (ST) | Specialty | Place and Country of work | Previous exp. with network |
|---|---|---|---|---|---|---|---|---|
| Rene' Unterdorfer | Au | 26 | 1-09-03 | 31-05-04 | ST | P01 | LNF It | Student Vienna |
| Christopher Smith | Be | 29 | 1-10-03 | 30-9-05 | PD | P01 | LNF It | None |
| Stratos Tsatis | Gr | 26 | 1-05-04 | 28-2-01 | PhD ST | P01 | LNF It | Student USA |
| Stephanie Trine | Be | 27 | 1-10-04 | 31-10-05 | ST/PD | | LNF It | None |
| Johannes Hirn | Fr | 26 | 1-10-04 | 31-08-06 | PD | P01 | UVEG ES | Student Paris |
| Beatrix Hiesmayr | Au | 28 | 1-02-03 | 30-07-03 | PD | P01 | UAB Es | Student Vienna |
| Ignazio Scimemi | It | 34 | 1-10-03 | 31-03-04 | PD | P01 | UAB Es | PD Bern |
| Michela Verbeni | It | 33 | 1-11-03 | 31-06-05 | PD | P01 | Granada Es | PD Bern |
| Sylvia Necco | It | 29 | 1-10-03 | 30-09-05 | PD | P01 | CNRS-CPT Fr | None |
| Juan Jose Sanz-Cillero | Es | 28 | 1-10-04 | 31-08-06 | PD | P01 | CNRS-IN2P3 Fr | Student Valencia |
| Johannes Hirn | Fr | 25 | 1-10-03 | 30-09-04 | ST | P01 | Durham UK | Orsay Node |
| Kamel Benhaddou | Fr | 29 | 1-10-03 | 30-11-03 | PD | P01 | Durham UK | Student Durham |
| Laura Edera | It | 29 | 1-11-04 | 31-10-05 | PD | P01 | Durham UK | None |
| Timo Lähde | Fin | 26 | 1-10-03 | 30-09-05 | PD | P01 | Lund S | ST Helsinki |
| Bruno Julia-Diaz | Es | 27 | 1-06-03 | 30-06-04 | PD | P01 | Helsinki Fin | None |
| Michal Czakon | Pol | 29 | 1-10-03 | 30-11-04 | PD | P01 | DESY Zeuthen De | None |
| Bastian Kubis | De | 28 | 1-11-02 | 30-10-04 | PD | P01 | Bern Switz | None |
| Roland Kaiser | Swi | 31 | 1-10-03 | 30-09-05 | PD | P01 | Vienna | None |

# 4 D - Sketches of the Young Researchers

## 4.1 D.1

In the following, for each of the young researchers who will present their experience at the Mid-Term Review Meeting, a description of the young researchers scientific background, of his responsabilities in the network and of his experiences (positive and negative) to date, is presented. These sketches have been written by the young researchers themselves, and show their diverse backgrounds and experiences.

### Rene Unterdorfer : INFN-LNF Laboratori Nazionali di Frascati

SCIENTIFIC BACKGROUND

I was a Ph. D. student of Prof. Gerhard Ecker at University of Vienna (Austria) and I filled a pre-doc position at Laboratori Nazionali di Frascati. Between 1st of September 2003 and 31st of May 2004 I was paid by funds of the EURIDICE contract. Now I am a post-doc at Paul Scherrer Institut (Villigen, Switzerland).

My research field is theoretical elementary particle physics, especially chiral perturbation theory and its extension to the intermediate-energy region by including meson resonance exchange.

RESPONSABILITIES

Together with Dr. Gino Isidori (a scientist at Laboratori Nazionali di Frascati) I worked on the theoretical description of the decay $K_L$ into two muons. This decay can be decomposed into a long-distance contribution from the two-photon intermediate state and a short-distance part, which in the standard model arises due to weak gauge bosons. As the second part is sensitive to the presence of a virtual top quark, it can be used to extract information on the Cabibbo-Kobayashi-Maskawa matrix element $V_{td}$. Furthermore, it could be used to put constraints on possible new-physics phenomena. The results are published in the Journal of High Energy Physics (JHEP 0401, 009, 2004).

A second research project together with Dr. Christopher Smith (a young researcher at LNF) and Dr. Gino Isidori was the analysis of the decay $K_L \to \pi^0\mu^+\mu^-$ that contains three different parts of comparable size within the standard model. A long-distance CP-conserving contribution due to two-photon intermediate states, a long-distance indirect CP-violating part and a short-distance direct CP-violating term. In the most realistic scenarios it is the short-distance part that could receive possible new physics contributions. In order to be able to compare the theoretical decay rate with data of future experiments, an accurate knowledge also of the long-distance amplitude is necessary. An explicit two-loop calculation of the CP-conserving part has been performed. The existing amplitudes of the CP-violating contributions have been updated by use of the results of new precise measurements on the processes $K_S \to \pi^0\ell^+\ell^-$ and on the $K_L \to \pi^0\gamma\gamma$ diphoton spectrum. The theoretical predictions of the branching ratio of $K_L \to \pi^0\mu^+\mu^-$ for the standard model and for a new physics model have been presented in a publication (Eur. Phys. J. C36, 57-66, 2004).

My other responsibilities in the network were the cooperation in the organisation of conferences of young researchers meetings as a scientific secretary and giving talks.

PERSONAL EXPERIENCE

It was very beneficial for me to work together with other people in a big research centre like Laboratori Nazionali di Frascati and to use all the resources offered there. Being a member of the EURIDICE network makes it easy to have scientific exchange with scientists from other nodes. Apart from that, it was a nice experience to live in another country for a couple of month.

## Christopher Smith: INFN-LNF Laboratori Nazionali di Frascati

SCIENTIFIC BACKGROUND

I joined the network as a postdoc research fellow on the $1^{st}$ October 2003. Previously, I had experience in B physics, and in positronium/quarkonium physics, which was the subject of my Ph.D. (2002) done at Louvain University (Belgium).

RESPONSABILITIES

During my first year at Frascati, I have been mostly concerned by kaon physics, and more precisely rare semi-leptonic decays. The basic tools to deal with such processes are chiral perturbation theory, operator product expansion and eventually large $N_c$ expansion. These CP-violating modes serve as probes of the structure of the Standard Model. In general however, some pollution from long-distance CP-conserving contributions is expected. The purpose was to estimate these effects. For the $K_L \to \pi^0\mu^+\mu^-$ mode, it was found that the direct CP-violating contribution is enhanced compared to the electron mode, while control over its CP-conserving contribution was achieved through a study of the ratio $Br(K_L \to \pi^0\mu^+\mu^-)_{CPC}/Br(K_L \to \pi^0\gamma\gamma)$. In addition, it was shown by taking a specific New Physics model as an example that the set of decay rates $K_L \to \pi^0\mu^+\mu^-$, $K_L \to \pi^0 e^+e^-$ and $K_L \to \pi^0\nu\bar{\nu}$ is very promising to constrain, eventually signal and interestingly characterize the eluding new physics. This work was published in Eur.Phys.J. **C36**, 57 (2004). Analysis of other modes is currently under way.

PERSONAL EXPERIENCE

My experience with the network is highly positive. The working environment is excellent, as is the collaboration within the Frascati theory group. This has greatly facilitated my task of learning Kaon physics and its relevant theoretical tools. In addition, I was given several opportunities to present my works: at the Euridice Collaboration meeting (Feb. 04, Vienna), at the Kaon mini-workshop (May 04, CERN) and at Daphne 04 (June 04, Frascati). Also, I gave a review talk on rare K decays at my former institute (June 04, Louvain U.). Finally, living in Rome is a wonderful experience, and permits me to discover the Italian culture and language. vspace0.4cm

## Stéphanie Trine : INFN-LNF Laboratori Nazionali di Frascati

SCIENTIFIC BACKGROUND

I joined the Frascati theory group two months ago, on October 11, just after having completed my Ph.D. thesis "Strong and electromagnetic anomalies in weak meson decays" at the Université de Louvain (Louvain-la-Neuve, Belgium).

RESPONSABILITIES

My involvement in the Euridice network is thus very recent. My research interests, however, have always been quite close, which makes of my stay here a unique opportunity to both exploit former results and explore new areas of research. I already had the chance to discuss many interesting points (including dimension eight operators for hadronic and radiative kaon decays, an alternative estimation of the charm contribution to the $\eta$' decay constant, nonlinear representations of the trace and axial anomalous operators beyond the chiral limit and trace anomaly effects in $K \to \pi\pi$ decays) with one of the local staff members, Gino Isidori, who had kindly accepted to be a member of my Ph.D. thesis jury. These results were also presented as an internal seminar contribution, and several directions for future work were pointed out. A deeper analysis of some nonperturbative effects in radiative $K$ decays is now being finalized in collaboration with another member of the group, Christopher Smith. Of course, I hope to benefit from the intense scientific activity inside the Euridice network to tackle other problems and initiate other collaborations.

PERSONAL EXPERIENCE

There is no doubt my experience, though quite short, has been very positive. The warm

atmosphere here in Frascati added to the many opportunities for scientific communication provided by the network results in a really enjoyable and stimulating environment.

## Johannes Hirn: UVEG Universitat Val'encia

I have been participating in the activities of both the EURODAΦNE and the EURIDICE networks for the last four years, although on topics that are at the periphery of the main research themes. Therefore, in addition to the members of the network in each of the three nodes that I have been staying at, I also had the opportunity to start a collaboration with non-members.

I started my Ph.D. with Jan Stern in the Orsay node, where I was in 2000-2003, working on applications of the techniques of Effective Field Theories (EFTs) such as Chiral Perturbation Theory (ChPT) to a different range of phenomena and energies: Higgs-less electroweak symmetry breaking. We have been reorganizing and clarifying the rules and necessary framework for a systematic expansion, and also considering the question of anomalies in such EFTs. This has led to two publications. I presented this work on various occasions, including two EURIDICE Collaboration meetings.

By providing me with a one-year pre-doctoral stay period in Durham in 2003-2004, Michael Pennington gave me the opportunity of spending a full year in a foreign laboratory during my thesis. This allowed me not only to finish my thesis in a different and stimulating environment, but also to start fruitful discussions with a post-doc working in Durham, but unrelated to the network: Ver'onica Sanz. Our collaboration started on subjects related to Higgs-less electroweak symmetry breaking, such as extra-dimensions.

I started my post-doc in Valncia two months ago, extending this collaboration by applying such five-dimensional set-ups to describe hadronic resonances in the limit of quantum chromo-dynamics (QCD) with a large number of colors (large-$N_c$). The idea that such a connection exists comes from the so-called AdS/CFT correspondence, itself a spin-off of string theory. We were able to progress thanks to the collaboration of various researchers here in Valncia. On the extra-dimensional side, we are working with Nuria Rius and Arcadi Santamaria, both non-members and on the QCD/ChPT side, with Antonio Pich. I will report on this work in progress in a workshop on EFTs in December 2004 in Bad Honnef in Germany, as well as at the next EURIDICE Collaboration Meeting.

In parallel, I am also currently finalizing some work on lepton-number violation and the flavor problem with Jan Stern from the Orsay node. This should lead to our third publication on the subject of Higgs-less EFTs.

In addition to providing me with direct collaborators inside or outside the network, the environment of the various nodes has been very useful in generating contact with experts on the different fields that my work touches, even though they are outside the scope of the network. This includes help on cosmology and neutrinos as dark matter from Sergio Pastor from Valncia. Working on such a broad spectrum of subjects both during my thesis and now has only been possible thanks to these enriching contacts.

## Ignazio Scimemi : ECM-Facultat de Fisica, U. Barcelona

SCIENTIFIC BACKGROUND

For almost 6 months I have been staying here in Barcelona as a postdoc within the Euridice collaboration.
My activities cover the following topics: I studied the decay $K \to 3\pi$ within the framework of Chiral Perturbation Theory (ChPT). The calculation was motivated by the possibility of extracting the numerical value of an unknown matrix elements. In particular we studied CP violation phenomena in relation with new experiments at CERN (NA48) and Frascati.

RESPONSABILITIES

A second subject of my study here is SCET, Soft Collinear Effective Theory. This theory is particularly suitable for describing exclusive decays of B-mesons and also some properties of inclusive decays. We are now continuing a project on B$\to X_s\gamma$ which we think should provide a better evaluation of this observable in the Standard Model and so stronger constraint on New Physics.

PERSONAL EXPERIENCE

What concerns my experiences with the network, or more precisely the node in Barcelona, I have to say that I found an atmosphere of friendship. I found a lot of people with whom I can discuss questions on physics and who are interested in my work and I am enjoying my stay here very much.

## Michela Verbeni: Departamento de Fisica Teorica y del Cosmos, Universidad de Granada

SCIENTIFIC BACKGROUND

I joined the EURIDICE Network in September 2002, while I was a post-doc at the Institut für Theoretische Physik, Universität Bern. At that time my scientific background was mainly concerned with quantum field theory, in particular the axial anomaly issue. In Bern I started working on Chiral Perturbation Theory (ChPT) topics, in collaboration with Prof. J. Gasser (Institut für Theoretische Physik, Universität Bern), Dr. B. Kubis (Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn) and Prof. N. Paver (Dipartimento di Fisica Teorica, Università degli Studi di Trieste and INFN-Trieste). We have been working on the revisitation of radiative $K_{e3}$ decays within the framework of ChPT. The aim of this analysis was to review the ChPT predictions concerning, in particular, the process $K_L \to \pi^\mp e^\pm \nu_e \gamma$, motivated by recent experimental results and ongoing measurement. The results are now the subject of an article submitted to The European Physical Journal C (hep-ph/0412130). I presented this analysis at the conference "MESON 2004: 8th International Workshop on Meson Production, Properties and Interactions" (Cracow, Poland, June 2004) and wrote a proceeding (submitted to the International Journal of Modern Physics A). I continued to be part of the EURIDICE Network as a post-doc fellow at the "Departamento de Fisica Teorica y del Cosmos" of the Granada University. Here, while keeping on working on the radiative $K_{e3}$ decays, I started working in the framework of baryon ChPT. Thus I now have the possibility of extending my knowledge of effective field theories of low energy QCD. Presently I am collaborating with Prof. J. Prades (Universidad de Granada) and with Prof. J.A. Oller (Universidad de Murcia) on meson-baryon scatterings. We are working out the calculation of the strangeness changing meson-baryon amplitudes at order $q^2$, within the relativistic baryon ChPT. We are also re-deriving the complete $O(q^3)$ relativistic meson-baryon Lagrangian in chiral $SU(3)$.

RESPONSABILITIES

PERSONAL EXPERIENCE

Concerning my personal experience within the EURIDICE network, I have to say that it

has been definitely positive. In general it allowed me to increase and improve my scientific knowledge and to meet a number of valuable physicist of the Network. Regarding my present situation, I am really enjoying the collaboration with Profs. Prades and Oller, which is surely stimulating and fruitful. I find my staying in Granada very pleasant also from a personal point of view, since I am experiencing an atmosphere of friendship and help.

## Silvia Necco : CPT/CNRS Marseille

I started my activity within the EURIDICE Network in November 2003, with a postdoc position at CPT, Marseille.
Lattice gauge theories and lattice QCD are the main topic of my research. This framework provides a powerful tool to investigate non-perturbative properties of QCD and to determine low energy quantities from first principles.

For example, the determination of the parameters of the effective chiral Lagrangian is one of the possible applications. One of my recent activities in this direction concerns the investigation of lattice SU(3) gauge theories which suppress the change of the topological charge and keep the system in a given topological sector. The goal is to adopt these formulations in lattice QCD simulations in the so-called $\epsilon$ regime, where the quark mass goes to zero and the volume is kept finite. A feature of the $\epsilon$ regime is indeed that the QCD low energy constants can be extracted from correlation functions computed in a given topological sector. This work has been presented at the Lattice conference (22nd International Symposium on Lattice Field Theory, Batavia, Illinois, 21-26 Jun 2004, hep-lat/0409073) and a comprehensive article is in preparation.

Moreover I am studying quenched hadronic correlation functions on the lattice; in particular I am investigating to which extent we can reproduce on the lattice physics from hadronic scales up to the perturbative regime. This would be useful in order to check quark-hadron duality and narrow resonance models of QCD.

PERSONAL EXPERIENCE

My experience within the network is definitely positive: in the Marseille node I had the possibility to enlarge considerably my knowledges, especially on the phenomenological side, and I've found a very lively and stimulating atmosphere during the meetings and the Spring School in Frascati.

## Juan José Sanz Cillero : CNRS-IN2P3 Orsay-Paris

SCIENTIFIC BACKGROUND

I started working as a Euridice postdoctoral fellow in October 2004 at IPN-Orsay (CNRS-IN2P3 node). I spent the five previous years in the IFIC group (Valencia node), during my Ph. D. under the supervision of A. Pich. During that time, I studied the vector and scalar pion form factors, and the pion and kaon decay constants, in the framework of the Resonance Chiral Theory (R$\chi$T) and the $1/N_C$ expansion. I also worked with J. F. Donoghue (U. Massachusetts) to estimate chiral corrections to $B$-meson decays which are required to extrapolate lattice results.

RESPONSABILITIES

I am currently involved in several projects. 1) With members of the Orsay group, I analyse the scalar form-factors of pion and kaon within Chiral Perturbation Theory ($\chi$PT). Thanks

to dispersive methods and recent work on $\pi\pi$ and $\pi K$ Roy equations, these form factors can be reconstructed fairly accurately. They may provide valuable indications whether the patterns of chiral symmetry breaking differ significantly between the two- and three-flavour massless limits. 2) Pursuing the work started with A. Pich, we aim at constraining the structure of the R$\chi$T Lagrangian in the large-$N_C$, by investigating form factors of mesons (including light resonances) and two-point QCD correlators. Although the impact of the infinite series of resonances cannot be fully assessed, it is possible to get upper and lower bounds on the contributions to the correlators coming from the resonances.

Within the network, I attended two LNF spring schools in Frascati (2000 and 2001). I also gave a talk during the 3rd Euridice Collaboration Meeting in Vienna (2004). This gave me the opportunity to meet many people with whom to discuss my work and to start new collaborations. Finding people with similar scientific interests has been definitely essential for the success of my Ph. D. thesis and the development of my present projects.

PERSONAL EXPERIENCE

## Laura Edera : Durham University

I joined the EURIDICE Network in November 2004, starting a post-doctoral position at Durham University (U.K.), just after the conclusion of my Ph.D. thesis.

SCIENTIFIC BACKGROUND

My research interests lie in the Heavy Flavour sector and in particular my Ph.D. thesis dealt with the study of the Doubly and Singly Cabibbo suppressed decays of $D^+$ and $D_s^+$ to $K^+\pi^-\pi^+$, from the selection of the samples to the physical measurements of the branching ratios and the amplitude analysis. The amplitude analysis of the three-body final state by fitting Dalitz plots is a powerful tool for investigating effects of resonant substructure, interference patterns, and final-state-interactions. The high statistics of the data now available require a more general and robust formalism to be used, such as the *K-matrix* model, in order to study overlapping multi-channel resonances beyond the naive Breit-Wigner approximation, traditionally used in the charm sector. This formalism allows the known physics from the scattering data to be incorporated, while guaranteeing the two-body unitarity constraint and ensures a consistent description of heavy flavour decays.

RESPONSIBILITIES

I look forward to meeting the rest of collaboration members at the Midterm Review meeting.

PERSONAL EXPERIENCE

## Timo Lähde : Department of Theoretical Physics, Lund University

I am presently active, as of October 1, 2003, within the EURIDICE Collaboration as a postdoctoral research fellow at the Department of Theoretical Physics, Lund University, Sweden. My stay at Lund University is due to end in October 2005.

SCIENTIFIC BACKGROUND

My present research activities are centered on the calculation of properties of pseudoscalar mesons within NNLO Partially Quenched Chiral Perturbation Theory ($PQ\chi pt$). This project is being pursued in collaboration with Dr. Johan Bijnens (Lund U.). The main purpose of such calculations is to provide Lattice QCD researchers with NNLO expressions to be used in the chiral extrapolation of simulation results. Several lattice QCD collaborations have already reported detection of NNLO effects in the simulations of pseudoscalar meson masses and decay constants. In the long run, our calculations may also be used together with lattice data to fix the numerical values of the NNLO low-energy constants of

RESPONSABILITIES

QCD. Due to unexpected technical difficulties in the NNLO $PQ\chi pt$ calculations, the publication of first results was significantly delayed. However, at this time a short letter-type article has been accepted for publication by Phys.Rev.D, and two major research papers are under preparation and will most likely be submitted for publication before the end of January 2005 at the very latest. Thus the aforementioned technical difficulties are now considered solved. These papers mentioned contain analytical formulae for the NNLO contributions to the masses and decay constants of charged pseudoscalar mesons in $PQ\chi pt$. I have also given presentations of the $PQ\chi pt$ work at several conferences / workshops, and a number of seminars during 2004.
During my stay at Lund, I have also been able to pursue other research activities, notably the study of spectra and decays of heavy quarkonia, in collaboration with Prof. Dan-Olof Riska (Helsinki U.) and Prof. Franz Gross (College of William & Mary, Jefferson Lab). Due to the extraordinary effort required by the $PQ\chi pt$ calculations, little has been accomplished within this field during the last year. However, at least two major publications are planned for the year 2005. Furthermore, a description of the M1 transitions between $Q\bar{Q}$ states developed by myself in collaboration with Prof. Dan-Olof Riska (Helsinki U.) was recently found to be the most realistic one on the market in an experimental study, hep-ex/0411068, by the CLEO collaboration.

PERSONAL EXPERIENCE

On a personal level, I was offered a convenient apartment, a nice office and good computing facilities. All practical details were very well handled upon my arrival in Lund. On the other hand, the research efforts into $PQ\chi pt$ at Lund would have been greatly aided by the employment of an additional resercher at the postdoctoral level, besides myself. I have enjoyed the company of my colleagues at Lund University, although my own choice of workload has left me with rather limited free time.

## Michał Czakon: DESY Zeuthen

I was involved in the EURIDICE network from the 1st of October 2003 to the end of November 2004. During this time I was hosted by Prof. Fred Jegerlehner from the DESY Zeuthen node.

RESPONSABILITIES

My main research concentrated on the study of higher order corrections to precision observables necessary for the analysis of the data of the LEP and SLD colliders. The purpose was the indirect determination of the mass of the Higgs boson, which is one of the most fundamental parameters of the Standard Model. This goal has been reached with the implementation of the prediction of the W boson mass and effective weak mixing angle in the ZFitter program used by experimental collaborations to perform the fit of the Higgs boson mass.

My presence in Zeuthen allowed me also to broaden my scientific interests. In collaboration with scientists from Zeuthen, I started a calculation of the higher order corrections to Bhabha scattering, a process which is used in electron-positron colliders for luminosity callibration and is thus indispensable in any experiment of this type. I also performed a calculation of the QCD beta function, a parameter which is of fundamental importance as it shows that Quantum Chromodynamics fulfills the necessary requirements of a theory of strong interactions. My calculation confirmed the highest known term in the perturbative expansion of the beta function.

PERSONAL EXPERIENCE

A highlight of my stay at DESY , which made me leave the network in November 2004,

was the Sofja Kovalevskaja Award of the Alexander von Humbold Foundation, which I received that year. This prize will allow me to form my own research group during the next three years. It would have not been possible for me to get this award without the help and involvement of Prof. Jegerlehner.

AWARD

## Bastian Kubis[1] : Institut für Theoretische Physik, Universität Bern

I joined the EURIDICE network in November 2002 as a postdoc in the Institute of Theoretical Physics at the University of Bern. I had finished my PhD in October 2002, based on work done in the group of Prof. Ulf-G. Meißner in Jülich, Germany. My scientific background when joining the network therefore consisted of various aspects of Chiral Perturbation Theory mainly in the nucleon sector, but I had also performed calculations within the purely mesonic theory.

SCIENTIFIC BACKGROUND

The main project during my time as a EURIDICE postdoc was an in-depth study of the decay $K_L \to \pi^\mp e^\pm \nu_e \gamma$ [$K_{e3\gamma}$]. An important point for comparison with recent experimental results (KTeV, NA48) was to give a theoretical prediction for the rate relative to the non-radiative decay channel [$K_{e3}$], with particular emphasis on a reliable estimate of the theoretical uncertainty coming from all possible sources. Furthermore, we have studied structure dependent terms in Chiral Perturbation Theory, calculating contributions at next-to-leading order ($\mathcal{O}(p^6)$), and how these terms can be extracted from experiment via differential distributions. Also here, comparison with an existing experimental study (KTeV) was of paramount importance.

RESPONSABILITIES

I have had the opportunity to collaborate on this project with the scientist in charge of the Bern node, Prof. Jürg Gasser. Furthermore, this was a joint effort with Prof. Nello Paver (Trieste) and Dr. Michela Verbeni (postdoc in Bern up to September 2003, EURIDICE postdoc at the Granada node from October 2003 on). This work was published as a preprint (`hep-ph/0412130`) and submitted to Eur. Phys. J. C; a couple of publications with follow-ups and extensions of this article are in preparation. In addition, these results were presented, inter alia, at the Third EURIDICE Collaboration Meeting in Vienna (February 2004), at the Kaon Mini Workshop at CERN (May 2004), and at the International Heraeus Seminar on Effective Field Theories in Bad Honnef (December 2004).

The Institute of Theoretical Physics in Bern offers a very rich and international scientific environment, both of physicists working directly on network-related activities, and others from neighbouring subfields of theoretical physics. The institute is extremely active as far as seminars (both internal and with invited speakers) are concerned, and therefore a very rewarding place for young researchers. The vicinity to CERN, Geneva proved very fruitful as it allowed for close contact to the experimentalists of the NA48 experiment in the context of the research project sketched above.

PERSONAL EXPERIENCE

As for specific network activities, I have participated in the Second (Paris, February 2003) and Third (Vienna, February 2004) EURIDICE Collaboration Meetings as well as the LNF Spring School "Bruno Touschek" (Frascati, May 2004). I found these meetings very helpful in getting to know young researchers from other nodes, and in particular seeing these colleagues repeatedly helped to establish good personal contacts that in turn facilitate

fruitful scientific discussions. I shall certainly profit from these contacts and friendships in the coming years.

I have by now obtained a position outside the network, an assistant position (for 3+3 years, starting October 2004) at the University of Bonn. However I will keep close contact with various scientists in the network institutions and thereby continue to profit from the experience as a EURIDICE postdoc.

[1] *present address:* Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Nussallee 14-16, D-53115 Bonn, Germany

## Roland Kaiser: University of Vienna

SCIENTIFIC BACKGROUND

I did my PhD with Heiri Leutwyler at the University of Bern with the topic of anomalies and large $N_c$ in the context of chiral perturbation theory. I then was awarded a fellowship that allowed me a stay at the University of California at San Diego where I came into contact with heavy quark effective theory and nonrelativistic quantum field theory. I joined the particle physics group of the University of Vienna in October 2003.

RESPONSABILITIES

In collaboration with H. Leutwyler from Bern I was continuing research on a determination of the ratio of the strange to the mean up and down quark masses in the framework of chiral perturbation theory with a large number of colours. Due to the absence of the Kaplan–Manohar ambiguity in this setting, it is possible to express this ratio in terms of experimentally observable quantities. Our preliminary results imply a value close to the current algebra result $2m_s/(m_u + m_d) = 25.9$. During my stay in Vienna I also worked out the chiral corrections to the current algebra prediction for the topological susceptibility of QCD. For the observed values of the quark masses, our result implies a small correction to the leading order value. It also serves as an improved prediction to compare to results from full QCD simulations on the lattice. In that connection, it may help to determine the low energy constant $L_7$ from the lattice. Further, I got involved in a new project (together with G. Ecker, V. Cirigliano at Caltech and researchers from the Valencia node) with the goal to obtain estimates for the coupling constants that occur at order $p^6$ in the chiral expansion. The analysis relies on an approximation of QCD correlation functions by the contributions from the lowest lying resonances alone. For the procedure to lead to sensible results it is crucial that the approximation be compatible with the constraints that follow from QCD asymptotic behaviour. At order $p^4$, an analogous analysis has been remarkably successful, so that we are confident that the results from our investigation will also represent decent estimates. In particular, we are about to release a short publication concerned with the determination of the low energy coupling constants relevant for the extraction of $V_{us}$ from $K_{e3}$ decays.

PERSONAL EXPERIENCE

In Vienna, the working atmosphere is very friendly and stimulating and there is a close collaboration with the Valencia node which I was able to visit twice this year. I was also involved in the organization of the $3^{rd}$ EURIDICE collaboration meeting held in Vienna in February 2004. I was also able to present my work at the Large $N_c$ 2004 workshop in Trento, Italy.

# 5 E - NETWORK FINANCING

## 5.1 E.1

In Table 8 we compare the estimated expenditure as of December 31st, 2004 of each network partner with the allowable costs foreseen in the the contract. We also estimated a breakdown of the total expenditure of the network into the cost categories.

1. Personnel
2. Networking,
3. Overhead

Table 8: Assigned funds and funds spent as of Dec. 31st, 2004 in KEURO

| $N^o$ | 1 | $1_{now}$ | 2 | $2_{now}$ | 3 | $3_{now}$ | Tot | $Tot_{now}$ |
|---|---|---|---|---|---|---|---|---|
| INFN-LNF | 120,000 | 68,334 | 32,000 | 20,422 | 30,000 | 17,751 | 182,000 | 106,507 |
| UVEG | 90,000 | 6,958 | 18,340 | 13,939 | 21,660 | 4,179 | 130,000 | 25,079 |
| UAB | 75,000 | 61,287 | 33,333 | 20,398 | 21,667 | 14,177 | 130,000 | 95,862 |
| CNRS-DR12 | 88,400 | 51,462 | 19,600 | 12,571 | 22,000 | 12,063 | 130,000 | 76,097 |
| CNRS/IN2P3 | 88,400 | 12,800 | 19,600 | 9,413 | 21,000 | 1,790 | 129,000 | 24,003 |
| DUR | 122,180 | 22,469 | 15,320 | 5,250 | 27,500 | 4,915 | 165,000 | 32,634 |
| ULUND | 59,500 | 32,440 | 21,450 | 10,598 | 14,050 | 7,536 | 95,000 | 50,574 |
| UHELS | 49,491 | 44,899 | 11, 343 | 4,875 | 12,166 | 9,955 | 73,000 | 59,729 |
| DESY Zeuthen | 97,424 | 54,964 | 31,522 | 16,607 | 18,054 | 10,020 | 147,000 | 81,591 |
| UNIBE | | | | | | | | |
| UWIEN.IT | 96,000 | 57,806 | 20,000 | 7,089 | 23,000 | 12,978 | 139,000 | 77,873 |
| Warsaw | | | 25,000 | 13,092 | 5,000 | 2,618 | 30,000 | 15,710 |
| Total | 886,395 | 413,419 | 247,508 | 134,254 | 216,097 | 97,982 | 1 350,000 | 645,655 |

In Table 9 the percentage of money spent by each node in each category is shown. We notice that, on the average, the network has spent 48% of its totally assigned funds, and, in particular, 47% of the funds assigned to the training of young researchers. This reflects the fact that most training did not start until the second year of operation of the network and shows that the network is well on its way to deliver the proposed training.

Table 9: Assigned funds and percentage spent as of Dec. 31st, 2004 in KEURO

| $N^o$ | 1 | $1_{now}$ | 2 | $2_{now}$ | 3 | $3_{now}$ | Tot | $Tot_{now}$ |
|---|---|---|---|---|---|---|---|---|
| INFN-LNF | 120,000 | 57% | 32,000 | 64% | 30,000 | 59% | 182,000 | 59% |
| UVEG | 90,000 | 8% | 18,340 | 76% | 21,660 | 19% | 130,000 | 19% |
| UAB | 75,000 | 82% | 33,333 | 61% | 21,667 | 65% | 130,000 | 74% |
| CNRS-DR12 | 88,400 | 58% | 19,600 | 64% | 22,000 | 55% | 130,000 | 59% |
| CNRS/IN2P3 | 88,400 | 14% | 19,600 | 48% | 21,000 | 9% | 129,000 | 19% |
| DUR | 122,180 | 18% | 15,320 | 34% | 27,500 | 18% | 165,000 | 20% |
| ULUND | 59,500 | 55% | 21,450 | 49% | 14,050 | 54% | 95,000 | 53% |
| UHELS | 49,491 | 91% | 11, 343 | 43% | 12,166 | 82% | 73,000 | 82% |
| DESY Zeuthen | 97,424 | 56% | 31,522 | 53% | 18,054 | 56% | 147,000 | 56% |
| UNIBE | | | | | | | | |
| UWIEN.IT | 96,000 | 60% | 20,000 | 35% | 23,000 | 56% | 139,000 | 56% |
| Warsaw | | | 25,000 | 52% | 5,000 | 52% | 30,000 | 52% |
| Total | 886,395 | 47% | 247,508 | 54% | 216,097 | 45% | 1 350,000 | 48% |

## 6 Changes with respect to the Contract

There have been two minor changes in the financial division between categories, namely

1. In the INFN-LNF node, the total months of pre-doc training is now 12 pm rather than the originally planned 24. The missing 12 pm have been assigned to Stephanie Trine, who was hired at the end of her pre-doc training at University of Louvain. Dr. Trine is at her first post-doc position, and, for a variety of reasons, the salary was not an issue : she was happy to accept an offer of 12 month with a pre-doc salary. Permission was asked to and granted by the EU for this small change.

2. The Helsinki node was financed for 13 months of post doc salary (the amount was fixed by the Marie Curie fellowship). The node however, paid Bruno Julio-Diaz (the Helsink-postdoc) slightly less than the calculated value (because they were paying according to the local rules; Bruno had just finished his PhD when he arrived in Helsinki). Therefore, the node has a small amount of the training money left. The node requested permission from the EU to use this extra for networking. The request was granted.

# 7 ANNEX : Scientific Results in connection with Milestones

## 1 Quark masses

*Present status*

- The Bern group has revisited $\pi\pi$ scattering at low energy in the framework of ChPT and Roy equations. An understanding of this process at low energy allows one to draw conclusions about the quark condensate and therefore about the size of the quark masses.
- The Orsay group have shown that the latest data on $\pi\pi$ scattering yield the lower bound for the quark mass ratio $r = m_s/m > 14$ at 95% confidence level, even when potentially large fluctuations of $s\bar{s}$ pairs in three-flavour ChPT are allowed.
- A new non-perturbative method for computing the $b$-quark mass to leading order in $1/m$ in the Heavy Quark Effective Theory (HQET) on the lattice has been developed by the DESY-Zeuthen group. A preliminary result $m_b(4\text{GeV}) = 4.56(2)(7)$ GeV has been obtained in the quenched approximation.

*Relevant references include*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3. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab, *Determination of $m_s$ and $|V_{us}|$ from hadronic tau decays*, JHEP 0301 (2003) 060.
4. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab, *$V_{us}$ and $m_s$ from hadronic tau decays*, [hep-ph/0408044].
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6. J. Heitger and R. Sommer [ALPHA collaboration], *A strategy to compute the b quark mass with non-perturbative accuracy*, Nucl. Phys. B (Proc. Suppl.) **106** (2002) 358 [hep-lat/0110016].
7. F. Knechtli, M. Della Morte, J. Rolf, R. Sommer, I. Wetzorke and U. Wolff [ALPHA Collaboration], *Simulating the Schrödinger functional with two pseudo-fermions: Algorithmic study and the running mass*, Nucl. Phys. B (Proc. Suppl.) **129** (2004) 814 [hep-lat/0309074].


*Future prospects*

Extended Monte Carlo simulations are in progress by the DESY-Zeuthen group. A detailed investigation of the continuum limit has to be done. In principle, the idea may also be applied to the matching of composite operators or the computation of $1/m$ corrections in HQET.

## 2 ChPT with three flavours

*Present status*

- Joint work by Barcelona-Lund has lead to full two–loop computation of pion and kaon scattering and decays in three flavour ChPT.
- A study of $\mathcal{O}(p^6)$ chiral couplings from the scalar $\pi K$ form factor has been performed. Furthermore the high energy pion pion scattering and the precision of Chiral Perturbation Theory calculations have been analysed by the Valencia group.
- The full two-loop calculation in three-flavour ChPT of $K_{\ell 3}$, scalar form-factors, $\pi\pi$ and $\pi K$ scattering and the first two-loop calculation in partially quenched ChPT has been performed by the Lund group. It was found that the $\pi\pi$ and $\pi K$ scattering constraints implied no significant modification of the large-$N_c$ limit expectations.
- The Orsay group investigated the effect of vacuum fluctuations of $\bar{s}s$ pairs on three-flavour ChPT, which could suppress significantly $N_f = 3$ order parameters compared to their values in the $N_f = 2$ chiral limit.
- The Orsay group derived coupled equations of the Roy and Steiner type for the S- and P- waves of the $\pi K \to \pi K$ and $\pi\pi \to K\bar{K}$ amplitudes. From experimental data, the two S-wave $\pi K$ scattering lengths were significantly constrained, a large set of threshold and subthreshold expansion parameters was computed and some $O(p^4)$ chiral couplings were estimated.

*Relevant publications*


1. J. Bijnens and P. Talavera, *$K_{\ell 3}$ decays in Chiral Perturbation Theory*, Nucl. Phys. **B669** 341 (2003) [hep-ph/0303103].
2. J. Bijnens, P. Dhonte and P. Talavera, *$\pi K$ scattering in three flavour ChPT*, JHEP **0405** (2004) 036 [hep-ph/0404150].
3. J. Bijnens, P. Dhonte and P. Talavera, *$\pi\pi$ scattering in three flavour ChPT*, JHEP **0401** :050,2004. [hep-ph/0401039].
4. M. Jamin, J.A. Oller and A. Pich, *Order $p^6$ chiral couplings from the scalar $\pi K$ form factor*, JHEP 0402 (2004) 047.
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6. S. Descotes-Genon, L. Girlanda and J. Stern, *Chiral order and fluctuations in multi-flavour QCD*, Eur. Phys. J. C27 (2003) 115 [hep-ph/0207337]

## 3 Isospin breaking effects

*Present status*

- Isospin breaking corrections in $K \to \pi\pi$ and in the CP violating parameter $\varepsilon'$ were calculated to next-to-leading order in chiral perturbation theory by the Valencia and Vienna nodes.
- The Bern group has investigated the interplay between strong and electromagnetic interactions in the framework of the linear sigma model.
- Isospin breaking effects in the relation between the pion form factor as determined in $e^+e^-$ experiments and the corresponding quantity obtained after accounting for known isospin breaking effects by an isospin rotation from the $\tau$–decay have been analyzed by the DESY-Zeuthen group. A major part of the observed 10% discrepancy in the respective pion form factors may be explained by the isospin breaking due to the difference between masses and widths of the charged and neutral $\rho$ mesons.
- The full isospin breaking corrections to $K \to 3\pi$ have been calculated by the Lund group. This included the study of some effects in the rare decays $K \to 3\pi\gamma$ and recalculating the isospin breaking results in $K \to 2\pi$ decays.
- The recently observed $X(3872)$ charmonium state is likely to be one of the deuteronlike $D\bar{D}^*$ states predicted just below the $D\bar{D}^*$ thresholds by the Helsinki group. The isospin splittings between the charged and neutral $D$ and $D^*$ lead to a substantial isospin breaking of the $X(3872)$ state.

*Relevant references include*


1. S. Ghozzi and F. Jegerlehner, *Isospin violating effects in $e^+e^-$ vs. $\tau$ measurements of the pion form factor $|F_\pi|^2(s)$*, Phys. Lett. B **583** (2004) 222 [hep-ph/0310181].
2. J. Gasser, A. Rusetsky and I. Scimemi, Eur. Phys. J. C **32** (2003) 97 [hep-ph/0305260].
3. V. Cirigliano, A. Pich, G. Ecker and H. Neufeld, *Isospin violation in $\varepsilon'$*, Phys. Rev. Lett. **91** (2003) 162001.
4. V. Cirigliano, G. Ecker, H. Neufeld and A. Pich, *Isospin breaking in $K \to \pi\pi$ decays*, Eur. Phys. J. **C33** (2004) 369.
5. B. Ananthanarayan and B. Moussallam, *Four-point correlator constraints on electromagnetic chiral parameters and resonance effective Lagrangians*, JHEP 0406 (2004) 047 [hep-ph/0405206]
6. J. Bijnens and F. Borg, *Isospin breaking in $K \to 3\pi$ decays*, [hep-ph/0410333].


## 4 Large-$N_c$ QCD

- Several three-point Green functions of QCD currents and the hadronic decays of the tau lepton into three pseudoscalars were considered by the Valencia group. Large-$N_c$ methods were used to study Green functions at intermediate energies to interpolate between low and high energies by the Valencia and Vienna groups. The spectrum of scalar resonances was investigated.

- The vector form factor of the pion has been computed, for the first time, at next-to-leading order in the $1/N_C$ expansion within the consistent framework of Resonance Chiral Theory. The study involves the complex treatment of the divergences in this non-renormalizable theory.
- It was shown by the Lund-Granada group that a ladder resummation leads to a mesonic model with a constituent quark mass coming out naturally. Even for order parameters it may be impossible to satisfy all QCD short-distance constraints by saturation with a finite number of resonances.

*Relevant references include*


1. P.D. Ruiz-Femenia, A. Pich and J. Portolés, *Odd intrinsic parity processes within the resonance effective theory of QCD*, JHEP 0307 (2003) 003.
2. P.D. Ruiz-Femenia, A. Pich and J. Portolés, *Phenomenology of the $\langle VVP\rangle$ Green's function within the resonance chiral theory*, Nucl. Phys. Proc. Suppl. **133** (2004) 215.
3. J. Portolés and P.D. Ruiz-Femenia, *The hadronic cross-section in the resonance energy region*, Nucl. Phys. Proc. Suppl. **131** (2004) 170.
4. D. Gómez Dumm, A. Pich and J. Portolés, *$\tau \to \pi\pi\pi\nu_\tau$ decays in the resonance effective theory*, Phys. Rev. **D69** (2004) 073002.
5. D. Gómez Dumm, A. Pich and J. Portolés, *$\tau \to (\pi\pi\pi)\nu_\tau$ : Theory versus Experiment*, Nucl. Phys. Proc. Suppl. **133** (2004) 211.
6. V. Cirigliano, G. Ecker, H. Neufeld and A. Pich, *Meson resonances, large $N_C$ and chiral symmetry*, JHEP **0306**, 012 (2003).
7. V. Cirigliano, G. Ecker, M. Eidemüller, A. Pich and J. Portolés, *$\langle VAP\rangle$ Green function in the resonance region*, Phys. Lett. **B596** (2004) 96.
8. J. Portolés, *Hadronic decays of the tau lepton : Theoretical overview*, e-Print Archive: hep-ph/0411333.
9. J.J. Sanz-Cillero, *Rho meson properties*, [hep-ph/0310174].
10. I. Rosell, J.J. Sanz-Cillero and A. Pich, *Quantum loops in the resonance chiral theory: the vector form-factor*, JHEP 0408 (2004) 042.
11. A. Pich, *Mesons at Large-$N_C$*, AIP Conf. Proc. **660** (2003) 3.
12. J. Bijnens, E. Gamiz, E. Lipartia, J. Prades, *QCD short distance constraints and hadronic approximations*, JHEP **0304** (2003) 055 [hep-ph/0304222].


*Future prospects*

- A more complete set of three-point Green functions is being studied by the Valencia and Vienna groups. The contributions of resonances to the low-energy couplings of the $\mathcal{O}(p^6)$ chiral lagrangian is being computed. Finally, the analysis of tau decays will be extended to all channels with three pseudoscalars in the final state.

- A one-loop computation of the full Effective Action within the Resonance Chiral Theory is under way.

## 5 $N_f/N_c$ dependence

- The impact of $s\bar{s}$-pairs on chiral symmetry breaking has been studied by the Orsay group using a model of QCD with two ultralight quarks and $N_f - 2$ degenerate strange quarks. Increasing $N_f$ could lead to various patterns of chiral symmetry breaking and restoration in the $N_f$ chiral limit, without affecting much two-flavour order parameters.

- The Lund-Barcelona collaboration found that from comparing threshold parameters in $\pi\pi$ and $\pi K$ scattering using our two-loop ChPT results the present best fit was for $N_f/N_c$ effects to be of expected non-enhanced character.

*Relevant publications*

1. S. Descotes-Genon, L. Girlanda and J. Stern, *Chiral order and fluctuations in multi-flavour QCD*, Eur. Phys. J. C27 (2003) 115 [hep-ph/0207337]

## 6 Lattice QCD and ChPT

*Present status*

- The QCD low-energy couplings can be extracted from first principles from lattice QCD simulations in a finite volume and very close to the chiral limit. Some preliminary results have been obtained for the electroweak couplings involved in kaon decays. In particular, a strategy to clarify the relevance of the charm quark mass in explaining the $\Delta I = 1/2$ rule has been implemented.

- Lattice QCD results allow to extract low energy constants of the chiral Lagrangian by finite size scaling techniques. Problems with different formulations of dynamical chiral fermions have been analyzed and various difficulties have been pointed out by the DESY-Zeuthen group. An extensive analysis of the square rooting procedure of the staggered determinant in the context of the Schwinger model has been performed. The analysis supports square-rooting the staggered determinant to obtain dynamical ensembles with $N_f = 2$.

- The Bern-Zeuthen group has investigated finite size effects in lattice calculations, in the framework of ChPT.

- The determination of quark masses from lattice QCD requires the knowledge of the masses in ChPT to third order in the ChPT expansion. This has been done for the first simplest case by the Lund group.

- The extraction of charge and matter radial distributions for P-, D-, F- wave heavy-light mesons using lattice QCD and the interpretation of these results in terms of wave equations has been developed by the Helsinki group.

*Relevant references include*


1. P.H. Damgaard, M.C. Diamantini, P. Hernández, K. Jansen, *Finite size scaling of meson propagators*, Nucl. Phys. **B629** (2002) 445.

2. P.H. Damgaard, P. Hernández, K. Jansen, M. Laine and L. Lellouch, *Finite size scaling of vector and axial current correlators*, Nucl. Phys. **B656** (2003) 226.

3. P. Hernández and M. Laine, *Correlators of left charges and weak operators in finite volume chiral perturbation theory*, JHEP 0301 (2003) 063.

4. L. Giusti, P. Hernández, M. Laine, P. Weisz and H. Wittig, *Low-energy couplings of QCD from topological zero mode wave functions*, JHEP 0401 (2004) 003.

5. L. Giusti, P. Hernández, M. Laine, P. Weisz and H. Wittig, *Low-energy couplings of QCD from current correlators near the chiral limit*, JHEP 0404 (2004) 013.

6. L. Giusti, P. Hernández, M. Laine, P. Weisz and H. Wittig, *A strategy to study the role of the charm quark in explaining the* $\Delta I = 1/2$ *rule*, JHEP 0411 (2004) 016.

7. P. Hernández and M. Laine, *Charm mass dependence on the weak hamiltonian in chiral perturbation theory*, JHEP 0409 (2004) 018.

8. P. Hernández, K. Jansen, L. Lellouch and H. Wittig, *Scalar condensate and light quark masses from overlap fermions*, Nucl. Phys. Proc. Suppl. **106** (2002) 766.

9. P.H. Damgaard, M.C. Diamantini, P. Hernández and K. Jansen, *Finite volume meson propagators in quenched chiral perturbation theory*, Nucl. Phys. **B629** (2002) 445.

10. P. Hernández, *Ginsparg-Wilson fermions: practical aspects and applications*, Nucl. Phys. Proc. Suppl. **106** (2002) 80.

11. P.H. Damgaard, P. Hernández, K. Jansen, M. Laine and L. Lellouch, *Vector and axial-vector propagators in the epsilon regime of QCD*, Nucl. Phys. Proc. Suppl. **129** (2004) 754.

12. L. Giusti, P. Hernández, M. Laine, C. Pena, P. Weisz, J. Wennekers and H. Wittig, *Correlation functions at small quark masses with overlap fermions*, e-Print Archive: hep-lat/0409031.

13. D. Becirevic, Ph. Boucaud, V. Giménez, V. Lubicz and M. Papinutto, *B(K) from the lattice with Wilson fermions*, Eur. Phys. J. **C37** (2004) 315.

14. V. Gimenez, L. Giusti, S. Guerriero, V. Lubicz, G. Martinelli, S. Petrarca, J. Reyes, B. Taglienti, E. Trevigne, *Non-perturbative renormalization of lattice operators in coordinate space*, Phys. Lett. **B598** (2004) 227.

15. D. Becirevic, V. Gimenez, V. Lubicz, G. Martinelli, M. Papinutto and J. Reyes, *Renormalization constants of quark operators for the non-perturbatively improved Wilson action*, JHEP 0408 (2004) 022.

16. P. H. Damgaard, P. Hernandez, K. Jansen, M. Laine and L. Lellouch, *Finite-size scaling of vector and axial current correlators*, Nucl. Phys. B **656**, 226 (2003) [hep-lat/0211020].

17. V. Gimenez *et al.*, *Non-perturbative renormalization of lattice operators in coordinate space*, Phys. Lett. B **598**, 227 (2004) [hep-lat/0406019].

18. L. Giusti, P. Hernandez, M. Laine, P. Weisz and H. Wittig, *Low-energy couplings of QCD from topological zero-mode wave functions*, JHEP **0401**, 003 (2004) [hep-lat/0312012].

19. L. Giusti, P. Hernandez, M. Laine, P. Weisz and H. Wittig, *Low-energy couplings of QCD from current correlators near the chiral limit*, JHEP **0404**, 013 (2004) [hep-lat/0402002].

20. A.M. Green, J. Koponen and C. Michael, *P-wave radial distributions of a heavy-light meson on a lattice*, [hep-lat/0412002].

21. G. Colangelo and S. Dürr, *The pion mass in finite volume*, Eur. Phys. J. C **33** (2004) 543 [hep-lat/0311023].

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23. S. Dürr, C. Hölbling and U. Wenger, *Staggered eigenvalue mimicry*, Phys. Rev. D **70** (2004) 094502 [hep-lat/0406027].

24. G. Colangelo and C. Haefeli, *An asymptotic formula for the pion decay constant in a large volume*, Phys. Lett. B **590** (2004) 258 [hep-lat/0403025].

*Future prospects*

It is planned to carry over the methods developed by the Bern group to the $\pi N$ system.

## 7 HQET and LEET

*Present status*

- Semileptonic $B$-decays in the heavy-quark limit of QCD were studied through Bjorken-like sum rules. New results come from considerations of the non-forward amplitude and the systematic use of particular boundary conditions that allow to put bounds on derivatives of the Isgur-Wise function.

- QCD factorisation has been proved at one loop in the radiative B-decays $B \to \gamma l \nu$, $B \to \gamma\gamma$ and $B \to \gamma l^+ l^-$, and large Sudakov logarithms were resummed in the framework of Soft Collinear Effective Theory. The radiative decays $B \to V\gamma$ (with $V$ a vector meson) have also been shown to factorise at one loop.

- The Bern group has investigated the rare process $B \to X_d l^+ l^-$ at NNLL precision for the branching ratio, the CP-asymmetry and the forward-backward asymmetry.

*Relevant references include*


1. A. Le Yaouanc , L. Oliver and J.-C. Raynal, *Sum rules in the heavy quark limit of QCD*, Phys. Rev. D67, 114009 (2003) [hep-ph/0210233]

2. A. Le Yaouanc, L. Oliver and J.-C.Raynal, *Bounds on the derivatives of the Isgur-Wise function from sum rules in the heavy quark limit of QCD*, Phys. Lett B557 , 297, (2003) [hep-ph/0210231]

3. A. Le Yaouanc, L. Oliver and J.-C. Raynal, *Lower bounds on the curvature of the Isgur-Wise function*, Phys. Rev. D69, 094022 (2004) [hep-ph/0307197]

4. F. Jugeau, A. Le Yaouanc, L. Oliver and J.-C. Raynal, *Bounds on the derivatives of the Isgur-Wise function with a non-relativistic light quark*, [hep-ph/0405234]

5. F. Jugeau, A. Le Yaouanc, L. Oliver and J.-C. Raynal, *Subleading form factors at order* $1/m_Q$ *in terms of leading quantities using the non-forward amplitude* [hep-ph/0407176]

6. S. Descotes-Genon and C.T. Sachrajda, *Factorization, the light-cone distribution amplitude of the B-meson and the radiative decay* $B \to \gamma l \nu_l$, Nucl.Phys. B650 (2003) 356 [hep-ph/0209216]

7. S. Descotes-Genon and C.T. Sachrajda, *Universality of non perturbative QCD effects in radiative B-decays*, Phys. Lett. B557 (2003) 213 [hep-ph/0212162]

8. S. Descotes-Genon and C.T. Sachrajda, *Spectator interactions in* $B \to V\gamma$ *decays and QCD factorisation*, Nucl. Phys. B693 (2004) 103 [hep-ph/0403277] P. Ball, *QCD sum rules on the light-cone, factorisation and SCET*, [hep-ph/0308249].

9. H. M. Asatrian, K. Bieri, C. Greub and M. Walker, *Virtual- and bremsstrahlung corrections to* $b \to d$ *l+ l- in the standard model*, Phys. Rev. D **69**, 074007 (2004) [hep-ph/0312063].


*Future prospects*

The Bern group plans to investigate the processes $B \to X_s\gamma, X_s\gamma^*$ in connection with $m_c$-dependence, shape function, SUSY models at large $\tan\beta$.

## 8 EFT in nuclear matter

*Present status*

- The Valencia group continue with the development of a chiral effective theory in the nuclear medium by including short distance nucleon-nucleon interactions with a well defined power counting. We are also working on meson-baryon scattering from chiral perturbation theory working higher orders in the Unitarized ChPT effective field theory. An important step forward has been done by means of a thorough study which has allowed to determine the $\pi N$ scattering lengths from pionic hydrogen and pionic deuterium data. A systematic study has been carried out of the interaction of the meson octet with the baryon octet and a set of resonances have been found, some of them corresponding to resonances known and new resonances have been

predicted, among them a new resonance with the quantum numbers of the $\Lambda(1405)$, thus predicting that the peak attributed to the $\Lambda(1405)$ comes actually from two resonances. Different reactions have been suggested to disentangle these two states. In the subject of medium modifications of hadrons work has been done suggesting the use of the A dependence of the photonuclear cross section for $\phi$ photoproduction in order to learn about the modification of the $\phi$ width in the nuclear medium. The experiment has been done in Japan after our paper was published and it has led to the first experimental evidence of medium modifications of a vector meson. Finally we have also studied the two pion correlation function at finite temperature and the chiral restoration.

- The existence of hypernuclei with double-charm and double-beauty hyperons, stable against the strong decay, has been investigated by the Helsinki group as well as deuteronlike bound states of heavy flavour hyperons.

- A. Rusetsky, former EURODAPHNE postdoc (now in Bonn), has investigated, with methods developed during his stay in Bern, the behaviour of pions in nuclear matter.

*Relevant references include*


1. M. Doring, E. Oset and M.J. Vicente-Vacas, *S wave pion nucleon scattering length from $\pi N$, pionic hydrogen and deuteron data*, Phys. Rev. **C70** (2004) 045203.

2. D. Cabrera, L. Roca, E. Oset, H. Toki and M.J. Vicente-Vacas, *Mass dependence of inclusive nuclear $\phi$ photoproduction*, Nucl. Phys. **A733** (2004) 130.

3. D. Jido, J.A. Oller, E. Oset, A. Ramos and U.G. Meissner, *Chiral dynamics of the two $\Lambda(1405)$ states*, Nucl. Phys. **A725** (2003) 181.

4. J.A. Oller, *Finite width effects in $\phi$ radiative decays*, Nucl. Phys. **A714** (2003) 161.

5. J. A. Oller, *Nucleon-nucleon interactions from Effective Field Theory*, Nucl. Phys. **A725** (2003) 85.

6. A. Gómez Nicola, F.J. Llanes-Estrada, J.R. Pelaez, *Finite temperature pion vector form factors in chiral perturbation theory*, e-Print Archive: hep-ph/0405273.

7. B. Julia-Diaz and D.O. Riska, *Nuclei of double-charm hyperons*, [nucl-th/0405061].

8. F. Froemel, B. Julia-Diaz and D.O. Riska, *Bound states of heavy flavor hyperons*, [nucl-th/0410034].

9. L. Girlanda, A. Rusetsky and W. Weise, Annals Phys. **312**, 92 (2004) [hep-ph/0311128].


*Future prospects*

The Valencia group plan to extend on order higher the already performed work on the nucleon-nucleon effective theory, that is, up to $N^3 - LO$ so that we can improve present results and apply them to electroweak processes with nucleon and deuteron probes. We also plan to tackle problems in the baryon sector implementing full coupled channel calculations with the decuplet of baryons and octet of mesons, plus octets of pseudoscalar mesons and

vector mesons, plus the decay channels in octet of baryons and octet of mesons, which appear in D-waves. We shall also be looking at the modification of the NN interaction in the nuclear medium in the scalar isoscalar channel, and at the pion selfenergy in a nuclear medium, as a natural continuation of the work done in $\pi$-deuteron. New reactions producing the $\Lambda(1405)$ are been measured. We plan to study them theoretically in order to disentangle the presence of two resonances for the $\Lambda(1405)$.

## 9 CP, CPT and QM

*Present status*

- The Barcelona, Turin and Vienna nodes have explored the capabilities of the neutral kaon pairs copiously produced at Daphne to test basic issues of Quantum Mechanics in two cases: i) Bell inequality tests closing the usual loopholes and ii) quantum marking and quantum erasure phenomena.
- A theoretical update of the status of the CP-direct violating parameter $\varepsilon'/\varepsilon$ has been performed by the Valencia group.
- Sum rules of superconvergence type for parity violating amplitudes have been considered by the Warsaw group. The asymmetries for p.v. $\pi^0$ and $\pi^+$ production, measurable in future high-intensity polarized photon beam experiments, are given.

*Relevant publications*


1. A. Bramon, G. Garbarino and B. Hiesmayr, *Quantum marking and quantum erasure for neutral kaons,* Phys. Rev. Lett. 92, 020405 (2004).
2. A. Bramon, G. Garbarino and B. C. Hiesmayr, *Active and passive quantum erasers for neutral kaons,* Phys. Rev. A **69**, 062111 (2004).
3. A. Bramon, G. Garbarino and B. C. Hiesmayr, *Quantitative duality and neutral kaon interferometry in CPLEAR experiments,* Eur. Phys.J. C **32**, 377 (2003).
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7. R.A. Bertlmann, A. Bramon, G. Garbarino and B.C. Hiesmayr, *Violation of a Bell inequality in particle physics experimentally verified?*, Phys. Lett. **A332** (2004) 355.
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9. P. Ball, *The theory of CP-violation: In as much of a nutshell as will fit on 8 pages*, [hep-ph/0406326].

*Future prospects*

- Further improvements on tests of Bell inequalities with neutral kaons will be devised by the Barcelona group in order to close the two classical loopholes.
- An extension of the analysis by including higher-order electroweak corrections is planned by the Warsaw group.

## 10 CKM matrix

*Present status*

- For the determination of $V_{us}$ the two-loop corrections in the isospin limit have been calculated by the Lund group. All unknowns can be determined experimentally in related experiments. The effect of curvature in the form factors on the determination of $|V_{us}|$ was pointed out and later confirmed by the experiments.
- A Granada-Valencia collaboration has made progress in estimating $V_{us}$ from tau decays.
- The determination of CKM matrix elements through $CP$-asymmetries was investigated in several classes of $B$-decays by the Orsay group.
- Models of Higgsless electroweak symmetry breaking were built using the approach of effective field theory. Implications for the CKM matrix and Majorana neutrino masses were investigated.
- The first proper treatment of radiative corrections for $K_{e3}$ decays has been performed by a Valencia-Vienna group, allowing for the resolution of the unitarity problem of the CKM matrix on the basis of new measurements.
- A comprehensive summary of the field is given in the CERN Yellow report to which a number of nodes have contributed.

*Relevant publications*


1. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab, *Determination of $m_s$ and $|V_{us}|$ from hadronic tau decays*, JHEP 0301 (2003) 060.
2. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab. *$V_{us}$ and $m_s$ from hadronic tau decays*, [hep-ph/0408044]
3. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab, *Extraction of $m_s$ and $|V_{us}|$ from hadronic tau decays*, [hep-ph/0411278].
4. T. Hambye, S. Peris and E. de Rafael, *Delta(I) = 1/2 and epsilon'/epsilon in large-N(c) QCD*, JHEP **0305**, 027 (2003) [hep-ph/0305104].
5. L. Giusti, P. Hernandez, M. Laine, P. Weisz and H. Wittig, *A strategy to study the role of the charm quark in explaining the $\Delta I = 1/2$ rule*, JHEP **0411**, 016 (2004) [hep-lat/0407007].

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8. S. Fajfer, T.N. Pham and A. Prapotnik, *CP violation in the partial width asymmetries for $B \to \pi^+\pi^-K^-$ and $B \to K^+K^-K^-$ decays*, Phys.Rev.D70 (2004) 034033 [hep-ph/0405065]

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10. J. Hirn and J. Stern, *The role of spurions in Higgs-less electroweak effective theories*, Eur. Phys. J. C34 (2004) 447 [hep-ph/0401032]

11. J. Hirn and J. Stern, *Anomaly-matching and Higgs-less effective theories*, JHEP 0409 (2004) 058 [hep-ph/0403017]

12. V. Cirigliano, M. Knecht, H. Neufeld and H. Pichl, *The pionic beta decay in chiral perturbation theory*, Eur. Phys. J. **C27** (2003) 255.

13. V. Cirigliano, H. Neufeld and H. Pichl, *$K_{e3}$ decays and CKM unitarity*, Eur. Phys. J. **C35** (2004) 53.

14. M. Battaglia et al. (M. Misiak), The CKM matrix and the Unitarity Triangle, CERN Yellow Report CERN-2003-002, Geneva 2003, hep-ph/0304132.

*Future prospects*

- Isospin violation including radiative corrections in $K_{\mu 3}$ decays will be studied by the Vienna group.
- A detailed analysis by the Valencia group of the recent OPAL data, taking into account the experimental correlations of the measured moments, is under way.
- Other decay channels will be studied by the Orsay group to pin down features of the CKM matrix and/or detect inconsistencies related to new physics.
- Higgless models of electroweak symmetry breaking should be investigated at next-to-leading order, including phenomenological applications such as $WW$ scattering.

## 11 Rare $K$-decays

*Present status*

- Features of the rare kaon decay $K^+ \to \pi^+\nu\bar{\nu}$ have been found to be relevant in order to fix the parameters of the unitarity triangle by an INFN–Barcelona collaboration.

- The Granada-INFN-Bern group has investigated in great detail radiative $K_{e3}$ decays.

*Relevant publications*


1. R. Fleischer, G. Isidori and J. Matias, *Shedding light on the 'dark side' of $B - \bar{B}$ mixing through $B \to \pi^+\pi^-$, $K \to \pi\nu\bar{\nu}$ and $B \to \mu^+\mu^-$*, JHEP **0305**, 053 (2003)

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5. G. Isidori, C. Smith and R. Unterdorfer, *The rare decay $K_L \to \pi^0\mu^+\mu^-$ within the SM*, Eur. Phys. J. **C36** (2004) 57 [hep-ph/0404127].

6. G. Isidori and R. Unterdorfer, *On the short-distance constraints from $K_{L,S} \to \mu^+\mu^-$*, JHEP **0401** (2004) 009.

7. M. R. Pennington, *Light by light scattering at a low energy $e^+e^-$ collider or what to do while waiting for that rare kaon decay event*, eConf **C0309101** (2003) FRWP010 [hep-ph/0311299].


*Future prospects*

The Bern group will investigate charged kaon decays, the muon channel and $T$-odd effects in radiative decays.

## 12 Charm and Beauty decays

*Present status*

- A previously mentioned paper by the Granada/Barcelona-Valencia node has studied the suitability of tau–Charm factories to fix the strange quark mass. B–meson physics has been developed by another Barcelona group.

- QCD sum-rule estimates of $D * D\pi$ coupling, which differ signicantly from experiment, have been shown by the Orsay group to be in a better agreement once higher resonances were included.

- For various two-body $B$-decays, classes of power corrections to the factorisation approach were shown to be numerically significant, although suppressed in the heavy-quark limit.

- The Oslo subnode has worked on a heavy-light chiral quark model that has allowed to test for several nonfactorizable effects, especially studying some decays without a factorizable contribution.

- The state–of–art calculation of the $b \to s\gamma$ process is presented, with the first determination of the sign of the $b \to s\gamma$ amplitude. Three loop matching calculation has been completed by the Warsaw node.

- The Bern group has worked and is still working on various topics concerning heavy quark physics.

*Relevant publications*


1. E. Gamiz, M. Jamin, A. Pich, J. Prades and F. Schwab. *$V_{us}$ and $m_s$ from hadronic tau decays*, [hep-ph/0408044]

2. Joan Soto, *Model independent results for heavy quarkonium.* Invited brief review. Published in Mod.Phys.Lett.A19:1563-1576,2004 [hep-ph/0406104]

3. Xavier Garcia i Tormo and Joan Soto, *Soft, collinear and nonrelativistic modes in radiative decays of heavy quarkonium*, Phys.Rev.D69:114006,2004 [hep-ph/0401233] item D. Becirevic, J. Charles, A. Le Yaouanc, L. Oliver, O. Pène and J.-C. Raynal, *Possible explanation of the discrepancy of the light-cone QCD sum rule calculation of $g_{D*D\pi}$ coupling with experiment*, JHEP 0301 (2003) 009 [hep-ph/0212177]

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9. Paolo Gambino, Ulrich Haisch and Mikolaj Misiak, *Determining the sign of the $b \to s\gamma$ amplitude*, hep-ph/0410155.

10. Mikolaj Misiak and Matthias Steinhauser, *Three-loop matching for the dipole operators for $b \to s\gamma$ and $b \to sg$*, Nuclear Physics B 683 (2004) 277, hep-ph/0401041.

11. Mikolaj Misiak, *NNLO calculations of rare B decays*, Acta Physica Polonica B 34 (2003) 4397.

12. Mikolaj Misiak *Charm quark loops in $B \to X_s\gamma$*, Nuclear Physics B (Proc. Suppl.) 116 (2003) 279, Proc. of the RADCOR02 conference, Kloster Banz, Germany, September. 8–13, 2002.

13. P. Ball, *Weak decay form factors from QCD sum rules on the light-cone*, eConf **C0304052** (2003) WG101 [hep-ph/0306251].

14. P. Ball and R. Zwicky, *New results on $B \to \pi,\ K,\ \eta$ decay formfactors from light-cone sum rules*, [hep-ph/0406232].

15. P. Ball and R. Zwicky, *$B \to \pi,\ K,\ \eta$ decay formfactors from light-cone sum rules*, [hep-ph/0406261].

16. P. Ball and R. Zwicky, *$B_{d,s} \to \rho,\ \omega,\ K^*,\ \phi$ decay form factors from light-cone sum-rules revisited*, [hep-ph/0412079].

*Future prospects*

A comprehensive review on heavy quarkonium is being prepared.
Nonfactorisable contributions to two-body decays should be investigated further by the Orsay group in relation with experimental data in order to assess the limits of factorisation.

### 13 $(g-2)_\mu$, $\alpha_{\rm QED}$ and precision determination of other Standard Model parameters

*Present status*

- New precise data on the low energy e+e- annihilation into hadrons from Novosibirsk have been used by the Warsaw group to obtain bounds on the elasticity parameter and the difference between the phase of the pion form factor and that of the $\pi\pi$ scattering.

- The main emphasis at KLOE was on measuring the cross section $e^+e^- \to \gamma\gamma^* \to \pi^+\pi^-\gamma$ at the 1% level. The hadronic correction to the vacuum polarization for $a_\mu$ obtained in the interval $0.37 < Q^2 < 0.93\,GeV^2$ is $a_\mu^{\pi\pi} = (375.6 \pm 0.8_{stat} \pm 4.8_{syst.+theor.}) \cdot 10^{-10}$. The new measurement of $\sigma(e^+e^- \to \text{hadrons})$ from KLOE (Frascati 2004) is in rather good agreement with the corresponding CMD-2 (Novosibirsk 2003) result and allows for a reliable estimate of the contributions.

- The presently most accurate prediction for the $W$-boson mass in the Standard Model (SM) was obtained by combining the complete two-loop result with the known higher-order QCD and electroweak corrections. Their effect on the prediction of $M_W$ is estimated to be about 4 MeV for $M_H < 300$ GeV. Furthermore, a complete calculation of the contributions from closed fermion loops at the two-loop level of the electroweak interactions to the effective leptonic weak mixing angle, $\sin^2\theta_{\rm eff}^{\rm lept}$, has been performed. This quantity provides the most stringent bound on the mass $M_H$ of the as yet undiscovered Higgs boson. The size of the corrections with respect to known partial results translates into a shift of the predicted central value of $M_H$ by +19 GeV. The complete four-loops $\beta$-function in QCD has been recalculated providing the first cross check of original result. The master integrals for Bhabha scattering at two-loops including the mass effects have been calculated.

*Relevant publications*

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3. M. Knecht, S. Peris, M. Perrottet and E. de Rafael, *New nonrenormalization theorems for anomalous three point functions*, JHEP **0403**, 035 (2004) [hep-ph/0311100].

4. A. Aloisio *et al.* [KLOE Collaboration], *Measurement of* $\sigma(e^+e^- \to \pi^+\pi^-\gamma)$ *and extraction of* $\sigma(e^+e^- \to \pi^+\pi^-)$ *below 1 GeV with the KLOE detector*, Phys. Lett. **B** submitted, [hep-ex/0407048].

5. H. Czyż, A. Grzelińska, J. H. Kühn and G. Rodrigo, *The radiative return at* $\Phi$ *and B-factories: FSR at next-to-leading order*, Eur. Phys. J. C **33** (2004) 333 [hep-ph/0308312].

6. F. Jegerlehner, *Theoretical precision in estimates of the hadronic contributions to* $(g-2)_\mu$ *and* $\alpha_{\rm QED}(M_Z)$ International Conference on the Structure and Interactions of the Photon including the 15th International Workshop on Photon-Photon Collisions, LNF, April 7 - 11, 2003, Nucl. Phys. B (Proc. Suppl.) **126** (2004) 325, [hep-ph/0310234].

7. F. Jegerlehner, *The role of* $\sigma(e^+e^- \to$ hadrons$)$ *in precision tests of the standard model*, Workshop on Hadronic Cross Section at Low Energy SIGHAD03, Pisa, Oct. 8-10, 2003, Nucl. Phys. **B 131** (Proc. Suppl.) (2004) 213, [hep-ph/0312372].

8. M. Awramik, M. Czakon, A. Freitas and G. Weiglein, *Precise prediction for the W-boson mass in the standard model*, Phys. Rev. D **69** (2004) 053006

9. M. Awramik, M. Czakon, A. Freitas and G. Weiglein, *Complete two-loop electroweak fermionic corrections to* $\sin^2\theta^{\rm lept}_{\rm eff}$ *and indirect determination of the Higgs boson mass*, Phys. Rev. Lett. **93** (2004) 201805

10. M. Czakon, *The four-loop QCD beta-function and anomalous dimensions*, hep-ph/0411261.

11. M. Czakon, J. Gluza and T. Riemann, *Master integrals for massive two-loop Bhabha scattering in QED*, hep-ph/0412164.

*Future prospects*

Experimental programs by KLOE and BABAR continue with increasing precision. This as well as improved theoretical concepts for understanding the pion form factor and by improving on radiative corrections will allow further progress and thus more precise tests of the limits of the validity of the SM.

### 14 $\alpha_s$ in the infrared region and structure functions

*Present status*

- The energy dependence of the total hadronic cross-sections was shown to depend upon the behaviour of the strong coupling constant in the infrared region, through the soft gluon emission process described by the Bloch-Nordsieck resummation model.

- Hadronic interaction of photons is studied, taking into account the newest data for structure function for photon. The particular treatment of heavy quarks contributions has been presented by the Warsaw group.

*Relevant publications*


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2. U. Jezuita-Dabrowska, M. Krawczyk, How important are the longitudinal virtual photons in the semi-inclusive *ep* processes?, Acta Phys.Polon. B 34:3133-3153,2003

3. F. Cornet, P. Jankowski and M. Krawczyk, CJK-improved 5 flavour LO parton distributions in the real photon, Acta Phys. Polon. B **35**, 2215 (2004).

4. F. Cornet, P. Jankowski and M. Krawczyk, A new 5 flavour NLO analysis and parametrizations of parton distributions of the real photon, Phys. Rev. D **70**, 093004 (2004) [hep-ph/0404063].

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6. P. Ball and M. Boglione, *SU(3) breaking in K and K* distribution amplitudes*, Phys. Rev. D **68** (2003) 094006 [hep-ph/0307337].

7. A. Donnachie and P. V. Landshoff, *Evolution at small $x$*, Acta Phys. Polon. B **34** (2003) 2989 [hep-ph/0305171].

8. A. Donnachie and P. V. Landshoff, *Soft diffraction dissociation*, [hep-ph/0305246].

9. M. R. Pennington, *In the debris of hadron interactions lies the beauty of QCD* [hep-ph/0309228].

10. M. R. Pennington, *In the debris of hadron interactions lies the beauty of QCD (part II)*, eConf **C030614** (2003) 002 [hep-ph/0310186].

11. A. Donnachie and P. V. Landshoff, *Does the hard Pomeron obey Regge factorisation?*, Phys. Lett. B **595** (2004) 393 [hep-ph/0402081].

12. C. S. Fischer, F. Llanes-Estrada and R. Alkofer, *Dynamical mass generation in Landau gauge QCD*, [hep-ph/0407294].

13. M. R. Pennington, *QCD down under: Building bridges*, [hep-ph/0409156].

14. C. S. Fischer and R. Alkofer, *Dynamical chiral symmetry breaking in Landau gauge QCD*, [hep-ph/0411347].

15. R. Alkofer, W. Detmold, C. S. Fischer and P. Maris, *Analytic structure of the Landau gauge gluon propagator*, [hep-ph/0411367].

16. A. Donnachie, *Evidence for quark spin-flip in Pomeron exchange*, [hep-ph/0412085].

*Future prospects*

The application of the Bloch-Nordsieck technique to the QCD description of to tal cross-sections has indicates further possibilities in the study of how the so-called Regge behaviour can be related to infrared gluon emission.

**15 Glueballs, scalars, exotics and spectroscopy**

*Present status*

- The review "Mesons beyond the naive quark model" for Physics Reports has been published in collaboration with the Helsink group. This includes theoretical predictions and experimental observations on possible four-quark states, deuteronlike mesonic states, the light scalars, glueballs and hybrid mesons.

- Scalar mesons are still controversial. Some progress has been made from radiative decays of $\phi$ mesons as shown in the following papers. Data from Daphne are crucial. The spectrum of scalar mesons has been studied in the Large-$N_C$ limit of QCD. We have analysed the quark structure of light scalar mesons within the context of Unitarized Chiral Perturbation Theory. The study of $J/\Psi$ into VPP looking for the role played by the scalar mesons has given strength to the hypothesis that the light scalar mesons are dynamically generated from meson meson interaction. Finally the possibility that the $\Theta^+$ pentaquark could be a bound state of $K\pi N$ was investigated and it was found that it was unlikely to be so.

- A comprehensive investigation was made by the Helsinki group of the nucleon form factors and the baryon magnetic moments in the constituent quark model with instant, point and front form kinematics. The study was extended to a quantitative assessment of the need for sea-quark configurations in the pion decays of the low-lying nucleon resonances.

- The properties of the Wilson loop in QCD for large contours has been investigated by the Orsay group. The resulting covariant three-dimensional bound state equation for the quarkonium system was studied in the nonrelativistic and ultrarelativistic limits.

*Relevant publications*

1. C. Amsler and N.A. Törnqvist, *Mesons beyond the naive quark model*, Phys. Reports **389** (2004) 61.

2. S. Eidelman et al. (PDG including N.A. Törnqvist), *Review of particle physics*, Phys. Lett. **B592** (2004) 1.

3. A. Bramon, R. Escribano and J.L. Lucio Martinez, *Scalar meson dymamics in ChPT*, Phys.Rev.D69:074008,2004 [hep-ph/0312338].

4. R. Escribano, *Scalar meson exchange in $\phi \to \pi^0\pi^0\gamma$ decays.* Talk presented at Photon 2003: International Conference on the Structure and Interactions of the Photon and 15th International Workshop on Photon-Photon Collisions, Frascati, Italy, 7-11 Apr 2003. Published in Nucl.Phys.Proc.Suppl.126:204-209,2004 Also in *Frascati 2003, The structure and interactions of the photon* 204-209 [hep-ph/0307038].

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6. V. Cirigliano, G. Ecker, H. Neufeld and A. Pich, *Meson resonances, large-$N_C$ and chiral symmetry*, JHEP 0306 (2003) 012.

7. J.R. Pelaez, *On the nature of light scalar mesons from their Large-$N_C$ behaviour*, Phys. Rev. Lett. **92** (2004) 102001.

8. L. Roca, J.E. Palomar, E. Oset and H.C. Chiang, *Unitary chiral dynamics in $J/\Psi \to VPP$ decays and the role of scalar mesons*, Nucl. Phys. **A744** (2004) 127.

9. F.J. Llanes-Estrada, E. Oset and V. Mateu, *Is the $\Theta^+$ a $K\pi N$ bound state?*, Phys. Rev. **C69** (2004) 055203.

10. B. Julia-Diaz and D.O. Riska, *Baryon magnetic moments in relativistic quark models*, Nucl. Phys. **A739** (2004) 69.

11. B. Julia-Diaz, D.O. Riska and F. Coester, *Baryon form factors of relativistic constituent-quark models*, Phys. Refv. **C69** (2004) 035212.

12. B. Julia-Diaz, D.O. Riska and F. Coester, *Axial transition form factors and pion decay of baryon resonances*, Phys. Rev. **C70** (2004) 045204.

13. B. Julia-Diaz and D.O. Riska, *D-state configurations in the electromagnetic form factors of the nucleon and the $\Delta(1232)$ resonance*, [nucl.th/0411012].

14. Jun He, B. Julia-Diaz and Yu-bing Dong, *Electromagnetic form factors of pion and rho in the three forms of relativistic kinematics*, Phys. Lett. **B602** (2004) 212.

15. F. Jugeau and H. Sazdjian, *Bound state equation in the Wilson loop approach with minimal surfaces*, Nucl. Phys B670 (2003) 221 [hep-ph/0305021]

16. F. E. Close and Q. Zhao, *On baryon antibaryon coupling to two photons*, Phys. Lett. B **553** (2003) 211 [hep-ph/0210277].

17. F. E. Close, A. Donnachie and Y. S. Kalashnikova, *Radiative decays: A new flavor filter*, Phys. Rev. D **67** (2003) 074031 [hep-ph/0210293].

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19. F. E. Close and J. J. Dudek, *Electroweak production of hybrid mesons in a flux-tube simulation of lattice QCD*, Phys. Rev. Lett. **91** (2003) 142001 [hep-ph/0304243].

20. Q. Zhao and F. E. Close, *Locality of quark hadron duality and deviations from quark counting rules above resonance region*, Phys. Rev. Lett. **91** (2003) 022004 [hep-ph/0305017].

21. T. Barnes, F. E. Close and H. J. Lipkin, *Implications of a DK molecule at 2.32-GeV*, Phys. Rev. D **68** (2003) 054006 [hep-ph/0305025].

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26. F. E. Close and P. R. Page, *The $D^{*0}$ anti $D^0$ threshold resonance*, Phys. Lett. B **578** (2004) 119 [hep-ph/0309253].

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28. J. J. Dudek and F. E. Close, *The $J = 3/2$ $\Theta^*$ partner to the $\Theta(1540)$ baryon*, Phys. Lett. B **583** (2004) 278 [hep-ph/0311258].

29. F. E. Close and J. J. Dudek, *Pentaquark symmetries, selection rules and another potentially narrow state*, Phys. Lett. B **586** (2004) 75 [hep-ph/0401192].

30. F. E. Close and Q. Zhao, *A note on glueball hunting in the $e^+e^- \to J/\psi \to \phi f_0$*, Phys. Lett. B **586** (2004) 332 [hep-ph/0402090].

31. F. E. Close and Q. Zhao, *Photoproduction of $\Theta^+$ and other pentaquark states*, Phys. Lett. B **590** (2004) 176 [hep-ph/0403159].

32. Q. Zhao and F. E. Close, *On the experimental status of $\Theta^+$ and $\Sigma_5^+$ pentaquarks*, [hep-ph/0404075.

33. T. Barnes, F. E. Close, J. J. Dudek, S. Godfrey and E. S. Swanson, *Options for the SELEX state $D_{sJ}^+(2632)$*, Phys. Lett. B **600** (2004) 223 [hep-ph/0407120].

34. T. Burns, F. E. Close and J. J. Dudek, *Pentaquark implications for exotic mesons*, [hep-ph/0411160].

35. Q. Zhao and F. E. Close, *Restricted locality of quark-hadron duality in exclusive meson photoproduction reactions above the resonance region*, [hep-ph/0411257].

36. F. E. Close, *Hadron spectroscopy (theory): Diquarks, tetraquarks, pentaquarks and no quarks*, [hep-ph/0411396].

*Future prospects*

- Further and more accurate radiative decay data are needed. These will allow for future refinements of the models.
- The Wilson-line approach will be extended to other systems of interest for spectroscopy by the Orsay group.

## 16 Hadronic atoms at DEAR and DIRAC

*Present status*

- The Bern group has determined the decay widths and energy level shifts in $\pi^+\pi^-$, $\pi^-K^+$ and $\pi^-p$ atoms. Together with data on these atoms, presently investigated at CERN and PSI, one will be able to determine experimentally various hadronic scattering amplitudes at threshold.
- The analysis of pion-nucleon interaction is in progress by the Helsinki group with the aim to fix the pion-nucleon sigma-term and some of the low-energy constants in the baryon ChPT.

*Relevant publications*


1. J. Schweizer, *Spectra and decays of pi pi and pi K atoms*, Eur. Phys. J. C **36** (2004) 483 [arXiv:hep-ph/0405034]; P. Zemp, *Pionic hydrogen in QCD+QED: Decay width at NNLO*, Thesis University Bern, December 2004.
2. M.E. Sainio, *Pion-nucleon interaction and the strangeness content of the nucleon*, Eur. Phys. J. A (to appear).
3. P. Piirola and M.E. Sainio, *PWA of $\pi N$ scattering with fixed-t dispersion relations*, Int. J. Mod. Phys. A (to appear).
4. M.E. Sainio, *Pion-nucleon interaction and the sigma-term*, Int. J. Mod. Phys. A (to appear).


*Future prospects*

The only remaining calculations to be performed in the near future are the relevant formulae for the excited energy levels in pionic hydrogen.

## 17 $\eta$ and $\eta'$ at WASA and KLOE

*Present status*

- An analysis of various decay processes is performed using the two mixing angle description of the $\eta$-$\eta'$ system, incorporating the link to the gluonic sector through anomalies.
- The $\pi - \eta$ mixing has been investigated in few-body systems as well as the $\eta$-nucleon interaction close to threshold by the Helsinki group.

- A multi- channel analysis of $\eta - N$, $\pi - N$, $\gamma - N$ channels is made with the K matrix method by the Warsaw group. $\pi - \eta$ mixing close to the $\eta - He$ threshold was studied.

*Relevant publications*


1. R. Escribano and J.M. Frère, draft already available.
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4. A. M. Green and S. Wycech, On eta-pi mixing close to the eta-helium threshold, Phys. Rev. C **68**, 061601 (2003) [nucl-th/0308057]
5. A. M. Green and S. Wycech, Eta-nucleon scattering length and effective range uncertainties, [nucl-th/0411024], Phys. Rev.C, in press,
6. S. Wycech, The interest in kaonic deuterium atoms, [nucl-th/0408066]


*Future prospects*

States of KNNN system bound by 200 MeV were found at KEK. This might be a densely packed system of nine quarks or a more conventional system of K meson interacting with nucleons in a resonant way. The second line of research will be pursued by the Warsaw group.

## 18 Monte-Carlo methods and radiative corrections for $\sigma_{\rm had}$ at KLOE and PEPII

- Several improvements on the method of radiative return have been developed at the next-to-leading order and have been included in the PHOKHARA Monte Carlo generator.
- The state-of-the-art Monte Carlo event generator PHOKHARA of processes $e^+e^- \to hadrons + photons$ and $e^+e^- \to \mu^+\mu^- + photons$ was developed by the Warsaw group.
- Motivated by the ongoing experimental analysis of the KLOE Collaboration on the pion form factor and by related studies at B meson factories, hadronic cross section measurements by the radiative return method require further improvements by higher order corrections. Substantial progress has been achieved by the DESY-Zeuthen group in the development of the Monte Carlo program PHOKHARA. On the one hand additional hadronic modes were implemented in the program, on the other hand much effort was spent to push to precision to the permille level through the inclusion of more elaborated radiative corrections.

*Relevant references include*

1. H. Czyz, A. Grzelinska, J.H. Kuhn and G. Rodrigo, *The radiative return at $\Phi$ and B factories: FSR for muon pair production at next-to-leading order*, [hep-ph/0404078].

2. H. Czyz, A. Grzelinska, J.H. Kuhn and G. Rodrigo, *The radiative return at $\Phi$ and B factories at next-to-leading order*, Eur. Phys. J. **C33** (2004) 333.

3. H. Czyz, A. Grzelinska, J.H. Kuhn and G. Rodrigo, *The radiative return at $\Phi$ and B factories: small angle photon emission at next-to-leading order*, Eur. Phys. J. **C27** (2004) 563.

*New developments and future prospects*

- Radiative $\phi$ decays contributing to final state radiation of $e^+e^- \to \pi^+\pi^- + photons$ at DAPHNE will be important for new KLOE $\sigma(e^+e^- \to \pi^+\pi^-)$ measurement, which will use radiative return method with photons at large angles. At the same time charge asymmetries in the process $e^+e^- \to \pi^+\pi^- + photons$ can be used to study details of the radiative $\phi$-decay (which contributes also to point 15). Moreover narrow resonances and multi-hadron final states studies at B-factories via radiative return method are competitive to the scan methods and further Monte Carlo generator upgrades, to cover also that subjects, are highly desirable.

- In view of ongoing experimental activities and the importance for the future of precision physics ($\alpha_{\rm eff}(E)$, $(g-2)_\mu$, etc), the precision of Monte Carlo program PHOKHARA will be further developed by the DESY-Zeuthen group to include more complete two-loop radiative correction together with the appropriate real radiation.

## 19 Kaon-Nucleon scattering

*Present status*

- Valuable progress in hypernuclei studies and $\Lambda(1405)$ production in K–Nucleon interactions has been made by the Barcelona, Turin and Valencia nodes.

- The DEAR experiment has measured the $\bar{K}p$ energy level in the ground state. The theoretical status has been reviewed by one of the EURIDICE team at the recent DAFNE2004 conference.

*Relevant publications*

1. D. Jido, J.A. Oller, E. Oset, A. Ramos, U.G. Meissner, *Chiral dynamics of the two $\Lambda(1405)$ states*, Nucl. Phys. **A725**, 181 (2003) [nucl-th/0303062].

2. T. Hyodo, A. Hosaka, E. Oset, A. Ramos and M. J. Vicente Vacas, *Lambda(1405) production in the $\pi^- p \to K^0 \pi\Sigma$ reaction,* Phys. Rev. C **68**, 065203 (2003)

3. A. Ramos, E. Oset and C. Bennhold, *Low-lying J(P) = 1/2- resonances from chiral unitary dynamics,* Nucl. Phys. A **721**, 711 (2003).

4. J. Gasser, *Kaonic Atoms in QCD*, talk given at the international workshop *DAFNE2004: Physics at meson factories*, June 7-11, 2004, Frascati (It), to appear in the Proceeding.

5. J. Zmeskal, *First measurement of kaonic hydrogen and nitrogen X-ray spectra at DAFNE*, talk given at the international workshop *DAFNE2004: Physics at meson factories*, June 7-11, 2004, Frascati (It), to appear in the Proceedings.

*Future prospects*

It will be important to see whether the present discrepancy between theoretical predictions and measurements of the energy level can be resolved. A new effort in the evaluation of the threshold amplitude in the framework of effective field theory is needed, as well as a more precise experimental determination of the ground state property of pionic hydrogen.

### 20 Hypernuclei at FINUDA

*Present status*

Final State Interactions on the characterization of the nonmesonic decay of Λ-hypernuclei provide a cleaner determination of $\Gamma_n/\Gamma_p$. Many publications from the Barcelona–Turin collaboration have appeared.

*Some relevant publications*

1. G. Garbarino, A. Parreno and A. Ramos, *Non-mesonic weak decay of Lambda hypernuclei: A new determination of the Gamma(n)/Gamma(p) ratio,* [nucl-th/0312040].

2. G. Garbarino, A. Parreno and A. Ramos, *Towards a solution of the Gamma(n)/Gamma(p) puzzle in the non-mesonic weak decays of Λ–hypernuclei*, Phys.Rev. **C69** (2004) 054603. [nucl-th/0311071].

*Future prospects*

Studies along same lines are planned.