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A HIGH-LUMINOSITY $e^+ e^-$ COLLIDER FOR PRECISION EXPERIMENTS AT THE GeV SCALE

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Abstract

This document, prepared for the European Call FP7-INFRASTRUCTURES-2011-1, describes the proposal for a design study for a high-luminosity ($10^{33}cm^{-2}s^{-1}$) electron-positron (e^+e^-*, in the following*) collider with a variable center of mass energy in the range from about 0.6 GeV to about 3 GeV.

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A High-Luminosity e+ e- Collider for
Precision Experiments at the GeV scale

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DAΦNE-VE

Collaborative Project

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Graziano Venanzoni

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1. Scientific and/or technical quality, relevant to the topics addressed by the call

1.1 *Concept and objectives*

1.1.1 Leading ideas

We propose a design study for a high-luminosity ($10^{33}cm^{-2}s^{-1}$) electron-positron (e^+e^-*, in the following*) collider with variable center of mass energy in the range from about 0.6 GeV to about 3 GeV. This machine, named DAΦNE-VE will be an ideal tool, unique in Europe, for precision tests of the Standard Model (*SM, in the following*) in lepton-quark interactions at low energies, a region which is still poorly known both from experimental and theoretical point of view.

The high statistics provided by this machine, more than 100 times larger than that collected by any previous collider in this energy range, will allow a precise measurement of the hadronic cross sections, with accuracy up to one order of magnitude better than the existing measurements in the energy region between 1 and 3 GeV. This energy region currently represents the bottleneck for improving the accuracy of the SM prediction of the anomalous magnetic moment (g−2) of the muon, which is one of the very few observables where a significant deviation from the SM is observed. There are plans for new experiments at FNAL and J-PARC to improve the accuracy of the measurement of (g−2) of the muon by a factor of four or even more. While currently the SM prediction and the measured value of (g-2) have comparable accuracies, the planned experiments will require comparable improvements of the theoretical prediction as well. The knowledge of the hadronic cross sections with 1% accuracy will dramatically improve the SM prediction of (g-2), and with it the sensitivity to contributions from physics beyond the SM (BSM*, in the following*). This will help significantly to discriminate between different BSM models in the case that new physics will be found at the Large Hadron Collider (LHC) at CERN.

DAΦNE-VE will have also a strong impact on the determination of the effective fine-structure constant at the scale of the Z boson mass, α_{em} (M_Z^0), which is a key ingredient in the so-called electroweak precision fits of the SM, which provide indirect tests of the SM through higher-order effects, complementary to direct searches at the LHC. For further progress, a reduction of the error of α_{em} (M_Z^0) is mandatory and will be crucial for the physics program at future high-energy lepton colliders like the International Linear Collider.

Therefore, DAΦNE-VE will complement high-energy experiments at the LHC and future linear colliders through its ability to improve the determination of precision observables of the SM, like, e.g., (g-2) of the muon, which are, through quantum effects, sensitive to possible BSM physics at high scales of the order of hundred GeV or TeV.

In addition, an important motivation for DAΦNE-VE is the possibility for extensive studies of two-photon physics processes which would allow precise measurements of the transition form factors of scalar-, pseudoscalar- and axial-mesons (with the potential to improve the hadronic light-by-light scattering contributions to (g-2) of the muon); the spectroscopy of light meson and baryon states; precise tests of the conserved vector current (CVC) hypothesis which relates e^+e^- annihilation into isovector hadronic states with corresponding hadronic decays of the τ lepton; and searches for exotics or hypothetical light vector bosons weakly coupled to SM particles.

On the technological side the scope of the proposal is to make sure that Europe remains at the frontier of electron-positron collider and detector development for this energy range. The Frascati laboratory (Rome, Italy) had a leading role in the development of electron - positron Colliders, which started with ADA, a storage ring built in Frascati in 1960 where e^+e^- collisions have been proved to be feasible for the first time. ADA paved the way to a more ambitious project for a collider, named ADONE, working at a center of mass energy of ~3 GeV and providing a luminosity $\sim 3\cdot 10^{29}$ $cm^{-2}s^{-1}$. ADONE has been in operation until 1993, and five years later the new accelerator complex DAΦNE was ready for commissioning.

DAΦNE is a new generation Φ-factory (1.02 GeV c.m.), designed and realized by the Accelerator Division of the LNF, and meant to provide high Φ meson rates, in sequence, to three different experiments.
DAΦNE recently has been upgraded in order to implement an innovative collision scheme based on a large crossing angle, small beam sizes at the crossing point and compensation of beam-beam interactions by means of sextupole pairs creating a Crab-Waist configuration in the interaction region. Experimental tests of the novel scheme exhibited an increase in the peak luminosity of the collider to $\sim 4.5 \cdot 10^{32} cm^{-2} s^{-1}$, i.e. by a factor of three with respect to the original configuration. However, as DAΦNE's injection system and the interaction region are based on permanent magnet quadrupoles, the new configuration allows only a minimal variation (+/- 2%) around the nominal energy, and with a progressive luminosity reduction up to a factor two. For this reason, the DAΦNE-VE design study will require significant efforts and a new technological approach to achieve an unprecedented high luminosity in a wide beam energy range.
These aspects will put and Europe at the frontier of the research and development in the field of low energy electron-positron colliders.

The high luminosity of DAΦNE-VE and the precision measurements expected to be performed in this energy range require significant improvements in the technology for the detector construction. Frascati and many of the laboratories which are involved in the present proposal have a long standing tradition in this field, witnessed by the many detectors constructed and operated all over the world by these groups. However, the problems to be solved in this design study represent a real challenge and will require solutions at the forefront of the present technologies, with potential positive fall-outs also on the European industries involved in the sector.

The precise determination of the hadronic cross sections (with increased accuracy to better than 1%) requires excellent control of higher-order radiative corrections (RCs) and the non-perturbative contributions to the running of α (i.e., the hadronic vacuum polarization).
Similarly, the anticipated use of gamma-gamma(*) induced processes to better constrain the modelling of the hadronic light-by-light scattering contributions to (g-2) is a challenging issue, both theoretically and experimentally, and needs to be explored in detail.

Studies on these topics are on the borderline between experiment, software tools and theory, and are, at present, carried out by fragmented groups scattered mainly around Europe. The proposed design study will provide the ideal framework to organize the required efforts to push the frontier of RCs and to improve or develop Monte Carlo generators for collider energies below 3 GeV. Like in the era of precision measurements at LEP1 at CERN, synergies between the participating groups will play an important role to achieve the needed breakthroughs.

Scientific and technical objectives of the design study

Figure 1 shows an up-to-date compilation of the ratio of the electron-positron annihilation cross section into hadrons to that of electron-positron annihilation into a muon pair (the so called R value), as measured by different experiments in the energy region below 10 GeV/c^2. Practically all electron–positron colliders contributed to the global data set on the hadronic cross section in this range. The value of R extracted from the experimental data is then widely used for various QCD tests, including the determination of quark masses and the strong coupling, as well as for the calculation of dispersion integrals. At high energies and away from resonances, the experimentally determined values of R are in good agreement with the predictions based on perturbative QCD, confirming, in particular, the hypothesis of three colour degrees of freedom for quarks. On the other hand, for the low-energy region the direct R measurement at experiments with energy scan is necessary. The matching between the two

regions is performed at energies of a few GeV, where both approaches for the determination of *R* are in fair agreement.
While below 1 GeV the fractional accuracy is better than 1%, there is a significant drop of accuracy when going up to 3 GeV, where a large number of different hadronic channels in the final state are presented. In this region the error on each hadronic final state is between 6-15%.

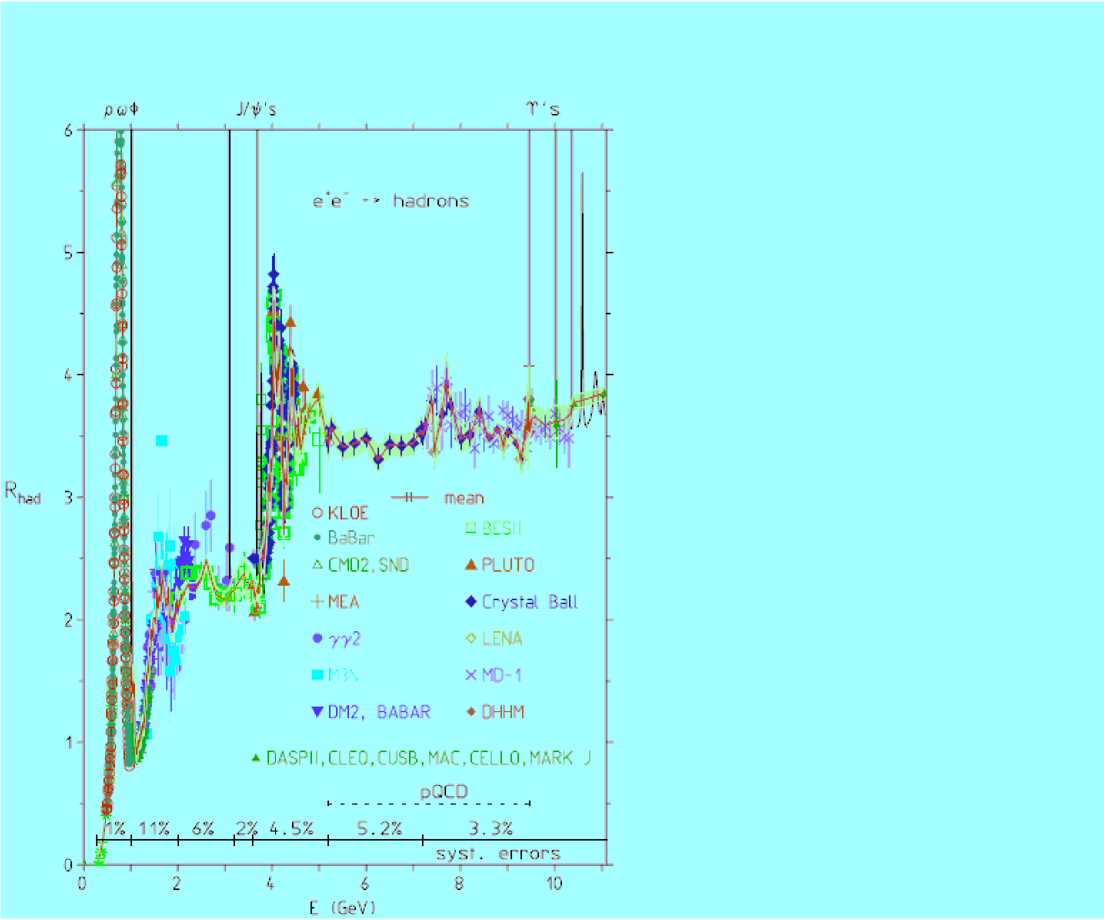


Figure 1- Compilation of the ratio of the hadronic cross section to the cross section for muon pair production by different experiments in the region below 10 GeV/c^2. For each energy the overall systematic error is indicated in the lower part of the figure.

The reasons for this lack of accuracy are well known:

- The low luminosity of the existing machines, which resulted in large statistical fluctuations of the data;
- The limited acceptance of the detectors and the difficulty in particle identification and separation for multi-hadron final states, which contributed to large systematic errors:
- The limited sophistication of the analysis tools and the treatment of radiative corrections, which introduced theoretical errors in the interpretation of the data.

All these effects were limiting the overall accuracy to well above 1%. Therefore a facility aiming at a significant reduction of the error on the measurements must address all these limitations.

The first target of this Design Study is the conceptual design of a machine which allows reaching a luminosity of 10^{33}cm^{-2} sec^{-1} in the center of mass energy range 0.6 GeV ÷ 3.0 GeV. This is expected to be attained by:

- A new injection system allowing on-energy injection in the colliding rings;
- An interaction region based on superconducting magnets and including the Crab-Waist collision scheme;

- A flexible ring lattice, studying and proposing innovative solutions for all those aspects affecting the beam dynamics, i.e. radio-frequency, feedback systems, ring impedance, cures to keep beam instabilities induced by ion and electron clouds under control;
- Developing tools for the simulation and optimization of the behaviour of beam-beam interactions.

The second target is to identify the best strategy to detect the physics final states of interest with high efficiency. This can be achieved either by a proper modification of the existing KLOE detector which is taking data at DAΦNE since the year 2000, or by a totally new detector design in which features not present in KLOE could be implemented.

Finally, **the third target** of this Design Study is the detailed exploration of the physics scenario and scrutiny of analysis issues which could limit the feasibility or precision of the envisaged measurements. This includes both the determination of clear benchmarks for machine and detector, and the delivery of improved theoretical calculations and Monte Carlo generators.

All these intermediate targets must converge to the main objective of this Design Study: the conceptual design of a **High-Luminosity e^+e^- machine for precision experiments at the GeV scale**, with the specifications of the machine and infrastructure characteristics and the description of the requirements of the main detector components.

1.2 *Progress beyond the state-of-the-art*

1.2.1. State of the art

The systematic comparison of Standard Model (SM) predictions with precise experimental data served, in the last decades, as an invaluable tool to test this theory at the quantum level. It has also provided stringent constraints on "new physics" scenarios. The (so far) remarkable agreement between the measurements of the electroweak observables and their SM predictions is a striking experimental confirmation of the theory, even if there are a few observables where the agreement is not so satisfactory. On the other hand, the Higgs boson has not yet been observed, and there are clear phenomenological facts (dark matter, matter-antimatter asymmetry in the universe) as well as strong theoretical arguments hinting at the presence of physics beyond the SM. The LHC, or a future e^+e^- International Linear Collider (ILC), will hopefully answer many questions. However, their discovery potential may be substantially improved if combined with more precise low energy tests of the SM. In the last years the improved precision reached in the measurement of e^+e^- annihilation cross sections in the energy range below a few GeV has led to a substantial reduction in the uncertainty of the hadronic contribution to (g-2) of the muon and α_{em} (M_Z^0). The main improvements have been achieved in the region below 5 GeV: between 2 and 5 GeV (where the data are now closer to the prediction of perturbative QCD), the BESII collaboration (Beijing) reduced the error to about 7% (before it was 15%); between 1 and 4.5 GeV BaBar at Stanford measured various final states with more than two hadrons with a systematic accuracy between 5% and 15%. Below 1 GeV, the CMD-2 and SND collaborations at Novosibirsk, KLOE at Frascati and BaBar measured the pion form factor in the energy range around the ρ peak with a systematic error of about 1%. The CMD-2 and SND collaborations and BESII were performing the hadronic cross section measurements in the traditional way, i.e., by varying the e^+e^- beam energies. KLOE, BaBar and more recently Belle used the method of radiative return (Initial State Radiation of photons, *ISR in the following*) which, while running at a fixed energy, allowed to measure cross sections in the whole energy region from threshold to the collider energy.
However, despite this recent progress, the energy range between 1 and 3 GeV is still poorly

known, with an average fractional uncertainty of the total cross section of about 10% only. This limits the improvement of the calculation of the hadronic contributions to (g-2) of the muon and α_{em} (M_Z^0), and thus the accuracy of the SM predictions of these quantities.

An unprecedentedly large data sample of hadronic events, together with the broad possibilities provided by a modern general-purpose detector, will also allow detailed measurements of the exclusive channels of e^+e^- annihilation and their intermediate mechanisms. Good knowledge of exclusive cross sections will help to establish the spectroscopy of low-lying vector mesons (excitations of the ρ, ω and ϕ mesons) and open the way to a better understanding of the interactions between light quarks (u,d,s) and the construction of theoretical models of strong interactions. It will also give the possibility of a systematic search for exotic states like hybrids and glueballs. As a by-product, various intermediate mechanisms of e^+e^- annihilation will be a copious source of information on standard light-quark mesons with different sets of quantum numbers, including various K* mesons.

1.2.2. Comparison with current and future approved e^+e^- machines

Table 1 shows a list of existing and future approved e^+e^- machines running at energies below (or of the order of) 10 GeV. As can be seen, DAΦNE-VE will provide by far the largest statistics in the energy region below 3 GeV, with enormous impact on several physics topics.

Machine	**Energy Range (GeV)**	**Luminosity (cm^{-2} s^{-1})**	**Main Goals**	**Starting data taking**
DAΦNE-VE (Frascati)	Thr. < √s < 3	$L = 10^{33}$	σ_{HAD}, γγ, FF, spectroscopy, searches	>2016
VEPP-2000 (Novosibirsk)	Thr. < √s < 2	$L = 10^{31}$-10^{32}	σ_{HAD}, FF, spectroscopy	2010
BEPC (Beijing)	2.2 < √s < 4.2	$L=10^{33}$ @ ψ(3770) L_{eq}~10^{31} below 3GeV	σ_{HAD}, FF, spectroscopy	2010
CESR-c (Cornell)	3 < √s < 4	L ~$3 \cdot 10^{31}$	σ_{HAD}	Data taking stopped, analysis in progress
PEP-II (Stanford)	Thr. < √s < 5	L_{eq}~10^{31}	σ_{HAD}, FF, γγ, spectroscopy, searches	Data taking stopped, analysis in progress
KEKB (Tsukuba)	Thr. < √s < 5	L_{eq}~10^{31}	σ_{HAD}, FF, γγ, spectroscopy, searches	Data taking stopped, analysis in progress
Super KEKB (Tsukuba)	Thr. < √s < 5	L_{eq}~10^{32}	σ_{HAD}, FF, γγ, spectroscopy, searches	>2014

Table 1 shows a list of existing and approved future e^+e^- machines producing data at energies below 5 GeV; σ_{HAD} ="Measurement of hadronic cross section"; FF= "Measurement of form factors"; γγ = "Two photon physics". L_{eq} is the equivalent luminosity with ISR in the energy region considered.

1.2.2. Physics with DAΦNE-VE

DAΦNE-VE will represent a precision tool to test the SM at an unprecedented level of accuracy and to search for unexpected physics BSM.

Precision test of the Standard Model via the muon (g-2): The SM determination of the anomalous magnetic moment of the muon is presently limited by the evaluation of the hadronic vacuum polarisation effects, which cannot be computed perturbatively at low energies.
DAΦNE-VE can improve the accuracy of the leading-order hadronic contribution of the muon anomaly to about $2 \cdot 10^{-10}$. This would represent a two-fold reduction of the present uncertainty, necessary to match the increased precision of the proposed muon (g-2) experiments at FNAL and J-PARC, and to firmly establish (or further constrain) *new physics* effects. In addition, as discussed below, there is great potential to better constrain the determination of the so-called hadronic light-by-light contributions to (g-2) through measurements of photon-photon processes.

Precision test of the SM via the effective fine-structure constant at the scale M_Z^0: Precision tests of the Standard Model require the appropriate inclusion of higher-order effects and the knowledge of the input parameters to the best possible accuracy. One of the basic input parameters is the fine-structure constant α, determined from the anomalous magnetic moment of the electron with an impressive accuracy of 0.37 parts per billion (ppb), relying on the validity of perturbative QED. However, physics at non-zero squared momentum transfer q^2 is actually described by the effective electromagnetic coupling, the `running' α_{em} (q^2), rather than by the low-energy constant α itself. The evolution of the fine-structure constant from the Thomson limit to higher energies involves low-energy non-perturbative hadronic effects, which spoil the precision.
The effective electromagnetic coupling at the scale of the Z boson, α_{em} (M_Z^0), is a key ingredient in the global electroweak fits of the SM. Its uncertainty affects the indirect determination of the Higgs mass already at present, and the limitations will become more severe as other parameters (like the top quark mass) are determined ever more precisely. As measurements of the effective electroweak mixing angle at a future linear collider may improve its precision by one order of magnitude, a much better accuracy of α_{em} (M_Z^0) is required. By providing hadronic cross section measurements with a total fractional accuracy of 1% up to 3 GeV, DAΦNE-VE will match this request.

Photon-photon physics: The two-photon (*γγ in the following*) physics program (i.e., the study of the process $e^+e^- \rightarrow e^+e^- \gamma^*\gamma^* \rightarrow e^+e^-$ X) will benefit from the energy upgrade of DAΦNE, not only because of the larger γγ flux, but also from the opening of channels not available at the Φ peak.
For example, studying the process of two-photon production of two pions (X = ππ) can significantly contribute to the solution of various open questions in low-energy hadron physics. This process is a clean probe to investigate the nature of the scalar resonances. The nature of the isoscalar scalars seen in ππ scattering below 1.6 GeV, namely the f_0 (600) or σ, f_0 (980), f_0 (1370) and f_0 (1510) mesons, is still controversial. Various models have been proposed in which some of these states are qbar-q, some qbar-qbar-q-q, sometimes one is a Kbar-K molecule, and one a glueball, but definitive statements cannot be drawn. Their two photon couplings will help unravelling this enigma.
Single pseudoscalar (X= π^0, η or η') production is also accessible and would improve the determination of the two-photon decay widths of these mesons, relevant for the measurement of the pseudoscalar mixing angle ϕ_P, and the measurement of the valence gluon content in the η' wave function. Moreover, the study of the same processes gives access to the transition form factors $F_{X\gamma^*\gamma^*}$ (M_X^2, Q_1^2, Q_2^2) at spacelike photon momentum transfer, which is relevant for the hadronic light-by-light (LbL) scattering contributions to (g-2) of the muon.
Experimental investigations of these form factors have been done so far only in the range 1 $\mathrm{GeV}^2 < Q^2 < 40\ \mathrm{GeV}^2$. The region of very low Q^2 (less than 0.5 GeV^2, the more important for the LbL contributions to (g-2)), is devoid of experimental data and is only accessible at DAΦNE. By increasing the energy of the machine, new higher-mass states will become

accessible: pseudoscalars (like the η'), scalars (like the f_0) and axial-vector (like the a_1) mesons. A measurement of all these meson transitions form factors will be of fundamental importance to reduce the uncertainties that currently affect the estimates of the hadronic LbL scattering.

Light mesons, spectroscopy and baryon form factors: One goal of DAΦNE-VE is to provide data for solving the hardest problem of the strong interactions – the origin of QCD confinement and, in particular, the role of the lightest scalar and the eta and eta' mesons. This region of QCD is intractable by perturbative calculations due to the large value of the strong coupling constant. For the lowest energies, a successful approach is through an effective field theory based on the approximate chiral symmetry. Europe leads the developments in this field – Chiral Perturbation Theory (ChPT): here the first successful one-loop calculations were performed (Gasser and Leutwyler 1984). There are three world leading theory centres: Bern, Bonn and Lund are devoted to ChPT calculations. The crucial part of the progress in this field is to extend the theory tools to higher energies, where vector and scalar resonances start to contribute. The questions concerning the structure of the scalar resonances are unsettled, and vector mesons influence radiative processes due to their direct coupling to real and virtual photons.
On the theory side, effective field theories have been proposed where pseudoscalar and vector mesons are treated as active degrees of freedom. However, the way to a satisfactory theory is long and, in particular, will require a proper power counting and one-loop calculations. These efforts will ultimately lead to a more profound understanding of the low-energy degrees of freedom of QCD around 1 GeV and below.
On the experimental side, light meson studies are carried out at well established European accelerator research facilities: COSY (Jülich), DAΦNE (Frascati), ELSA (Bonn), GSI (Darmstadt) and MAMI (Mainz). However, in the near future most of the focus of most facilities will shift to higher energies, with new experiments at FAIR and possibly at a SuperB factory. Physics of light mesons is included in the plans for these facilities only as a by-product. This is in contrast with world trends with the new dedicated facilities like J-PARC and energy upgraded JLAB. Our consortium represents physicists interested in pursuing low-energy studies and keeping Europe at the frontier of understanding of low-energy QCD.

Searches for physics beyond the SM: Low energy, high luminosity electron-positron colliders are an ideal tool to search for hypothetical U vector bosons weakly coupled to SM particles. These bosons are predicted in extensions of the SM, which have recently appeared in the literature as a consequence of intriguing and, as yet not completely explained, astrophysical observations. In fact, KLOE, BaBar and BES-III have already started measurements in the field. There are several possible signatures to look at, such as $e^+e^- \to e^+e^- \gamma$, $e^+e^- \to \mu^+\mu^- \gamma$, $e^+e^- \to E_{missing}+\gamma$, $e^+e^- \to E_{missing}+e^+e^-$, or events with four or six leptons in the final state. A careful analysis of such reactions in the region of interest for this proposal would complement the above mentioned searches, particularly in the case of the channels with missing energy or multilepton jets. The cross sections for these processes are expected to be of the order of 10-100 fb, thus one could expect to observe a few hundred events at DAΦNE-VE.

1.3 *S/T methodology and associated work plan*

1.3.1 Work plan strategy description

The activities of this design study are grouped in three scientific working packages (WP1-WP3) and one management working package (WP4).
Each scientific working package (WP) starts by analysing the status of the current technologies, before continuing with activities related to the requests posed to the WP by

DAΦNE-VE. All the Working Packages must converge towards the realization of the conceptual design of the **High-Luminosity e^+e^- machine for precision experiments at the GeV scale**, with particular attention to the machine and infrastructure characteristics, the requirements of the main detector components, the description of the physics issues and the cost evaluation.

1.3.2 WP1 strategy description: Machine Design

The proposed WP is aiming at verifying the feasibility of an electron-positron collider working at variable center of mass energy in the range 0.6 GeV ÷ 3.0 GeV, and providing a luminosity spanning from 10^{32} to 10^{33} $cm^{-2}s^{-1}$, allowing the experiment to perform precision tests of the SM. Research in the field of high energy physics requires large and expensive infrastructures demanding long time for design and construction. For this reason there is a general tendency around the world to re-use existing facilities as much as possible, as has been the case for several colliders: BEPC2 in China, VEPP-2000 in Russia and Super KEKB in Japan. The basic approach of this design study consists in re-using the infrastructure of the DAΦNE accelerator complex in Frascati as much as possible. The relevance of the design study is assured by considering state-of-the-art technologies, by the involvement of several leading European and international institutions and by the experience of the scientists working on DAΦNE.

Recently a new collision scheme has been proposed, implemented and tested at DAΦNE, resulting in an increase of the luminosity by a factor of three. This new configuration, called Crab-Waist, has been widely recognized as a major advance in the field of beam-beam interactions at lepton colliders.

DAΦNE is an electron-positron collider working at the c.m. energy of the Φ resonance (1.02 GeV) and producing a high rate of K mesons. The collider complex consists of two independent rings where two interaction regions can be housed and used in sequence. The injection system includes a full energy linear accelerator, a damping/accumulator ring and transfer lines. Since 2001 DAΦNE has been delivering luminosity to three different experiments investigating physics aspects related to CP violation, Λ-hypernuclei formation and decay, and kaonic atom spectroscopy. The peak and total integrated luminosity achieved have been $\sim 4.5 \cdot 10^{32}$ $cm^{-2}s^{-1}$ and ~ 7 fb^{-1}, respectively.

This proposal aims at studying several design options and finding the most suitable solutions to define a variable energy collider which takes into account the most recent advances in the field of particle accelerators, and at developing, when necessary, innovative solutions. In the following the most relevant design issues will be discussed.

Collider lattice: Our idea is to adopt a compact double ring collider with one interaction region where multi-bunches flat beams collide under a rather large horizontal angle (~0.05 rad), made possible by the compensation mechanism of the synchrobetatron resonances provided by the Crab-Waist configuration successfully tested at DAΦNE. A large horizontal collision angle allows to separate the vacuum chamber of the two rings very close to the interaction point, and thus to avoid parasitic crossings which would introduce severe limitations to the beam-beam behaviour and to the maximum achievable luminosity.

The ring lattice needs to be flexible from the optics point of view in order to allow a wide range of variability for the betatron functions, emittance, and momentum compaction and to guarantee suitable dynamic aperture and lifetime.

The bending magnets in the arc must be compatible with operation at different energies. A first evaluation suggests that a normal conducting option is feasible; however the dipole parameters and the technological solutions for its realization will have to be studied in detail. The two rings must include wigglers to provide damping for operation at low energy, and to tune the beam emittance. The wiggler design will profit from the experience acquired at DAΦNE in minimizing the non-linear terms arising from the interplay between the beam trajectory oscillation and the roll-off of the magnetic field in the poles.

Interaction region: Integrating the high luminosity Crab-Waist collision scheme with the detector introduces several challenges in terms of Interaction Region layout and optics, beam acceptance and betatron coupling correction. The detector efficiency poses tight limitations to the maximum space available for the accelerator components around the interaction point. The interaction region has to meet the different requirements coming from operation at different energies and with different values of the detector magnetic field. For this reason it is necessary to study a low–beta section based on superconducting quadrupoles including skew and correction coils to provide betatron coupling and beam trajectory correction, respectively. Superconductive technology will be considered also in the design of the anti-solenoids necessary to cancel the field integral of the detector.
The design of the interaction region must include purpose developed screens to shield the background hitting the experimental apparatus. Their design must be compatible with the vacuum chamber layout and the impedance budget of the rings.

Beam-beam effects: Simulations of beam-beam interactions should indicate which ultimate luminosity can be achieved in the upgraded DAΦNE at different energies and help to optimize the collider performance in terms of lifetime and luminosity in realistic operational conditions. For this purpose, we plan:

- To perform a series of numerical simulations of beam-beam collisions, taking into account all kinds of nonlinear lattice elements such as wigglers, sextupoles, octupoles etc.;
- To develop a fast numerical code capable to simulate a self-consistent beam size evolution of both colliding beams ("quasi strong-strong approach").

Dynamic aperture: Dynamic aperture (area of particle's stable motion) and energy acceptance are of crucial importance for beam quality and beam lifetime in an accelerator. These are defined by nonlinear machine optics, working point choice and crosstalk between beam-beam effects and lattice nonlinearities. Thus, a careful numerical modelling of the particles' motion in the 6D phase space is necessary in order to optimize the collider performance in the whole energy range. This task is particularly important for the DAΦNE upgrade based on the CW concept with strong nonlinear CW sextupoles installed in the interaction region.

RF system: The RF system of the rings will provide turn-by-turn restoration of the energy lost by the beam due to synchrotron radiation and parasitic interaction with the vacuum chamber elements, as well as beam longitudinal focusing.
The RF power request will be defined by the machine parameters at the maximum nominal energy and is expected to exceed 100 kW. The maximum accelerating voltage and the required number of cavities will also depend on the high energy machine specifications. On the contrary, system stability and low-level control will be more critical at low energy, where the radiation damping is weaker and a high beam current is necessary (in the range of several amperes) to maintain the collider luminosity at the required values.
The RF system design study is intended to define the RF frequency, number and type of RF cavities (including special parts such as input couplers and tuners), number, type and rating of the RF power sources, specifications and structure design of the low-level RF control, how much hardware of the existing infrastructure can be re-used and which performance can be expected. The system has to be designed to cope with machine requirements all over the proposed operational energy range.
Regarding the injection system, the RF system for the energy ramping synchrotron option has to be studied and designed, at a frequency lower than the collider rings one to optimize the synchrotron acceptance. Also, a study involving the accumulator RF system has to be carried out to investigate the feasibility of a different injection option, based on post acceleration in a C-band linac of the beam extracted from the accumulator ring.

Impedances and instabilities: Parasitic beam interaction with the surrounding vacuum chamber can result in several harmful effects: destroying beam instabilities, both single- and multibunch, excessive overheating of vacuum chamber components, damage of collider diagnostics etc. In order to avoid these phenomena, all the new vacuum chamber components will be designed taking care of beam coupling impedance minimization and suppression of parasitic higher order modes. Particular attention will be given to study and tests of mitigation techniques for the electron cloud instability suppression that is considered most severe in the present DAΦNE operating conditions.

Bunch-by-bunch feedback systems: Performances of last generation's lepton colliders in terms of luminosity strongly depend on the maximum achievable beam currents and, in turn, on the bunch-by-bunch feedback systems used to damp both synchrotron and betatron instabilities. During the last years, continuous research and development has pointed out several critical aspects limiting feedback effectiveness and have sustained continuous efforts for new upgrades. The very fast technological advance of the electronic components has also given the opportunity to make more compact and powerful digital feedback systems. At the same time, feedback systems have proved to be a powerful diagnostic tool to investigate several aspects related to the instability formation and build up. In a program wishing to study lepton colliders with a large energy range, it is necessary to evaluate carefully the bunch-by-bunch feedback design in the framework of a complex scenario including different optics layouts and radio frequency setups, as well as flexible energy range and injection system schemes.

Injection system: The present injection system of DAΦNE consists of an S-band Linac delivering up to 0.80 GeV electrons and 0.55 GeV positrons, an Accumulator/Damping ring where multiple pulses of particles are injected, stored, damped and extracted with strongly improved beam quality, and a rather complicate system of Transfer Lines to transport the beams from the Accumulator to the Main Rings at the full operation energy of 0.51 GeV, coping with the structure of the existing buildings designed for ADONE.
Operation below 0.51 GeV poses no problems, because the system can operate at any energy smaller than the present one. In order to provide beams in the Main Rings up to 1.5 GeV, the design study will examine three different options and compare advantages and drawbacks in terms of system complexity, operational reliability and cost:

1) Inject and store the beams from the Accumulator at 510 MeV and then ramp the whole magnetic structure of the Main Rings up to the desired energy. In this case the beams must be dumped at any injection to perform a complete magnetic cycle, thus making "top-up" injection unfeasible.

2) Build a 1 GeV Linac to be inserted between the Accumulator and the Main Rings to accelerate the particles up to the desired operation energy. Due to the limits set by the geometry of the existing buildings a large energy gain per unit length is required, suggesting the use of C-band technology, which is becoming a mature option and has been adopted in various projects mainly in the field of Free Electron Laser Linacs. A bunch compression scheme, either embedded in the accumulator ring or placed just after the accumulator extraction as a matching section, has to be studied to confine the bunches in the C-band accelerating crest region to limit the beam energy spread growth during acceleration. Special parts necessary to interconnect the C-band klystrons to the accelerating structures, such as waveguides, bendings, directional couplers, vacuum windows, are neither cheap nor abundant on the market. In order to widen their availability and to reduce the costs, an effort has been put in the design and in instructing producers.

3) Build a slowly cycling 1.5 GeV Synchrotron (≈ 1 Hz) where the particles are stored with multiple pulses at 0.51 GeV, or lower, as in the present Accumulator, and then ramped up to the desired energy and injected into the Main Rings. The Synchrotron can be housed in the

centre of the DAΦNE hall, thus avoiding the complex lattice of the present system of Transfer Lines.

The last two options will imply a relevant modification of the Transfer Lines system.

Vacuum system: The design study of the DAΦNE-VE vacuum system will address issues concerning the following items:

- Vacuum chamber design for the interaction region compatible with the detector and the collider requirements.
- Design of new vacuum chamber for the ring arcs suitable to cope with the higher synchrotron radiation power emission.
- Techniques to cope with the power load and the gas load due to heavy synchrotron radiation emitted by the beams.
- Thin film deposition techniques to reduce the vacuum chamber wall secondary electron yield to reduce the positron beam instabilities arising from e-cloud build up.

Precision measurement of the beam energy: The measurement of *R* quantity (see Fig. 1) requires the knowledge of the energy of the beams circulating in the collider with an accuracy of 50 - 100 keV. A well established technique to perform a precise measurement of the energy of an electron beam is based on the Compton backscattering (CBS) of laser photons against the electron beam. In the case of head-on collisions between the laser photon (energy ω_L) and the electron ($\gamma = E_e/m_e$), the photon scattered in the forward direction, i.e. along the direction of the incoming electron, has the highest possible energy (approximately equal to $4\gamma^2\omega_L$), and the Compton spectrum shows a sharp cut-off edge at this energy.
A typical experimental apparatus consists, essentially, of a CO_2 laser (w_0 = 0.117 eV, $\Delta w_0/w_0 = 10^{-7}$), and a high-purity germanium detector (HPGe) for measuring the energy spectrum of the backscattered photons. For an electron beam energy in the range of [0.5, 1.5] GeV, the CO_2 line results in a backscattered photon energy between 0.5 MeV and about 4.0 MeV. In this energy region the available HPGe detectors have a good efficiency.
The measurement procedures consists in the acquisition of a statistically significant (of order of 10^6 counts) Compton spectrum, and in fitting its edge with a suitable function. For a one hour acquisition run a statistical accuracy in the determination of the beam energy of about 70 - 100 keV can be obtained.
In principle, it is possible to increase this accuracy by measuring the energy of the scattered electron. This has been done at the GRAAL beam at ESRF in Grenoble, a Compton backscatted photon beam with maximum energy of 1.5 GeV. At GRAAL the determination of the gamma-ray energy is achieved by tagging the scattered electrons that, having energy less than the nominal one, are separated from the primary beam by the machine optics (bending magnets and quadrupoles) following the laser-beam interaction region. The measurement of the displacement of these electrons from the equilibrium orbit allows to determine the energy of the electron, and thus, of the photon. In this case the accuracy of the determination of the beam energy is fixed by the accuracy which can be reached in the position measurement. At GRAAL, where the tagging detector is a silicon μstrip, accuracy at the level of 10 keV was achieved.
The final result of the design study consists in elaborating the most suitable, innovative and economical solution for the injection system, the collider ring lattice, the interaction region and the beam-energy measurement, as well as in defining a list of collider parameters compatible with the luminosity requirements. The work progress will be documented by technical reports, and the coordination among partners from different countries will be organized in dedicated workshops.

1.3.3 WP2 strategy description: Detector Design

Although the design and construction of particle detectors for colliders operating at the energy

of interest rests on a long standing and well consolidated tradition, the very stringent precision requirements for the proposed measurements pose a number of unprecedented challenges in the field.
The ideal detector must be capable of minimizing acceptance losses for both charged and neutral particles while being able to correctly determine their multiplicity. It must also measure the total energy and momentum of the events with the maximum possible precision. Particle identification is a crucial issue, since some of the key physics goals of the project heavily depend on the precise determination of the nature of the final state particles, particularly in the case of charged pions, muons and kaons. Finally, since high luminosity implies high physics event rates as well as high machine backgrounds, trigger and data acquisition issues will play a fundamental role for the success of the project.
The KLOE detector, which has been in successful operation since 2000 at DAΦNE, can be considered as the ideal starting point for our studies. Its main merits are a high tracking capability and a fully hermetic calorimetry with exceptional timing performance. The detector is optimized for the observation of the rarest decays of neutral kaons, which are copiously produced at the Φ resonance peak. However, since for this proposal the relevant events are very different in many respects (particles multiplicities, topologies, spectra, etc.) compared to the above mentioned ones, it is clear that deep modifications to KLOE's detection strategy are required.
These considerations naturally drive the organization of the WP into subgroups, each one specific for the solution of the above mentioned issues. We therefore envisage the following sub working packages:

Charged particle tracking: A magnetic spectrometer is undoubtedly the best possible instrument to observe charged particles and to measure their momenta. However, there are several different options on how to build such a device, ranging from conventional drift chambers, like the one operated in KLOE, to fast time projection chambers, or to the recently developed cylindrical GEMs. The geometrical dimensions, the gas mixture composition and the readout technique are among the parameters to be studied and optimized. The KLOE drift chamber has been developed and built with the main purpose of maximizing the observation of long-lived particles, resulting in its large dimensions. However, most of the physics events of interest for DAΦNE-VE are produced at the interaction point, which suggests the usage of more compact detectors, thus permitting the insertion of new types of detectors which are useful for particle identification purposes, as will be discussed below. It would also be interesting to determine whether the usage of a silicon vertex detector would be advantageous. In KLOE this technique has not been exploited, since it would have required very large and hence very expensive detectors due to the peculiar dimensions of its interaction region. However, in our case, the dimensions of the interaction region are expected to be smaller, thus making the choice of silicon devices very attractive.

Calorimetry: As specified above, the KLOE lead-scintillating fiber calorimeter has particularly relevant timing capabilities, a choice imposed by the need for the precise reconstruction of neutral decay vertices of long-lived kaons. On the other hand, its energy as well as its position resolution is far from exceptional. In our case, however, the situation could be converse, although timing could still play a role for the purpose of particle identification based on time of flight techniques. The main requirements for the electromagnetic calorimeter are fine granularity and timing for photon counting. In the studies of pseudoscalar meson decays, precise energy information will be used for tagging. In this case, calorimeters built using scintillating crystals may represent an interesting alternative.

Particle identification: At the typical energies of the proposed machine, particle identification is a very challenging issue. In particular, following the experience from KLOE, separation between pions and muons is a very difficult task, especially for particle momenta below a few hundred MeV/c. In KLOE this problem is also enhanced by the calorimeter's rather coarse granularity, which renders the pion/muon separation based on their different

ranges a difficult task. Techniques to increase this granularity will therefore be studied in this subWP. As specified above, it is also possible to conceive time-of-flight systems inserted anywhere between the tracking device and the calorimeter.
For the study of nucleon form factors the capability to detect neutrons and anti-neutrons will be required. In this respect, the above mentioned increase in the readout granularity of the calorimeter can be of great help.

Trigger and data acquisition: High luminosity translates into high event rates and, most likely, into a high level of various types of machine backgrounds. For these reasons, a fast trigger system, capable of maximizing the efficiency on physics signals while keeping backgrounds at a reasonable level, must be carefully studied, and also a strategy for the data acquisition (DAQ) to cope with high data flows is mandatory.

Data managing and storage: Computer data reconstruction rates, in high energy physics, have a significant dependence on the energy of the events. In particular, low energy (GeV) events are characterized by a small number of components compared to high energy (TeV) events, which require the extraction of the relevant physical data from very complex topologies. In a low energy physics environment, the physical circumstance builds against the increasing power of modern computers with typically hundreds of very fast CPUs. In practice, when dealing with relatively low energy events, the computer reconstruction times are very short (of the order of a few milliseconds) and a single modern computer can process concurrently hundreds of input data streams (each data stream producing dozens of files) with a total of thousands of output streamed files. For any large scale production, when using several computers together, disk I/O activity cannot scale efficiently since disk areas are not able to hide the unavoidable I/O latencies. An interesting opportunity to remove these scaling limitations is the adoption of concurrent data processing, where one exploits the possibility to allocate several cores to process a single raw data stream, thus increasing the processing speed (as events are independent and can be processed concurrently). In this case also the total amount of concurrently opened data streams is significantly reduced.

Detector's Engineering and Integration: In all existing machines, strategies to maximize the luminosity rest on the usage of properly designed focusing systems very close to the interaction region. This poses severe constraints to the detector's design and dimensions, which must be carefully studied. A further objective of this subgroup must also be to understand how much of the existing construction facilities of the laboratory could be used and how much must be built ex novo.

The **main objectives** of the working group are:

(i) Definition of the response of the present KLOE detector to the main physics events expected at DAΦNE-VE. This includes both a study of the detection efficiency for the events of physics interest, and a study of the response to machine induced backgrounds. Data managing and storage with the presently existing facilities will also be studied.

(ii) Study of possible subdetectors, alternative to the existing ones for all main detection fields: tracking, vertexing, calorimetry, particle identification, DAQ. The goal of this study is to determine the best possible subdetector for each of these issues. Some prototyping effort and laboratory measurements are envisaged to reinforce and certify the results obtained by the simulation work.

(iii) Define the best possible final detector, i.e. the one which maximizes the precision on the main physics channels of interest, while keeping construction difficulties and costs at the lowest possible level. This work will include also a study of the integration of this detector in the machine layout.

1.3.4 WP3 strategy description: Physics studies

The aim of WP3 is to explore and help maximise the potential of the machine and detector design w.r.t. the planned physics programme. As discussed in detail in sections 1.1 and 1.2, the main motivation for DAΦNE-VE comes from the requirement to improve the prediction of the hadronic contributions to (g-2) of the muon and to the running of $\alpha_{em}(q^2)$, and from the desire to better understand the low-energy hadronic sector in a region presently not probed with sufficient precision.
The relevant physics program covered in the framework of the proposal and studied within WP3 can therefore be grouped into the five topics:

1. **Energy scan through the whole energy range of DAΦNE-VE** to determine the hadronic cross sections for all accessible hadronic final states, including high multiplicities and also the inclusive hadronic cross section.

2. **Measurements similar to the energy scan, but using the complementary method of radiative return,** where by using initial state radiation of photons a whole spectrum can be measured at single center of mass energy of the machine.

3. **Gamma Gamma physics:** Study of meson production (e.g. π^0, η, η') through real and virtual photons. From this class of processes information can be revealed on form-factors of the pseudoscalar resonances. This is required to improve the prediction of the so-called light-by-light scattering contributions to (g-2), which heavily relies on the modelling of these form-factors. Studies of gamma gamma production of scalar resonances will help to unravel the nature of these mesons.

4. **Form factors of mesons and baryons in production and decay.** The high luminosity and variable energy of DAΦNE-VE will allow measuring the properties of both flavoured and unflavoured hadrons which are so far not well accessible. Specific issues are e.g. the form factors of the neutron and neutral kaons, or pair production of ρ mesons. These studies will help to develop and test models of the low-energy hadronic interactions (like chiral perturbation theory) and to constrain model parameters and parameterisations.

5. **Searches for and study of "exotics", within and beyond the Standard Model.** This includes the search for possible four-quark bound states or the search for hypothetical, weakly coupled light bosons as predicted in specific extensions of the Standard Model.

In alignment with these topics WP3 consists of five working groups, WP3.1-5, `Energy Scan', `Radiative Return', `Gamma Gamma', `Form Factors' and `Searches'. Clearly, there is overlap of the sub-fields and also of the five working groups and individual researchers involved. This will naturally result in a close interconnection of the sub-groups working on different physics topics, and boost new collaborations. To encourage such collaboration and to achieve the objectives of WP3, regular meetings of all five sub-groups of WP3 are planned.

The **main objectives**, for which the work will be organised, are:

(i) Perform studies of the physics program to define pivotal benchmark parameters which significantly influence the machine and detector design already at an early stage.

(ii) Perform advanced studies of the planned physics topics and quantify the impact of the envisaged analyses. This includes:
- identify the most important measurements and their reach, for example w.r.t. improvements in g-2 and $\alpha_{em}(M_Z^0)$, for given machine and detector design options;

- study the status of theoretical calculations and software tools (Monte Carlo generators, computer codes for radiative corrections etc.) which will be required for future studies based on data from DAΦNE-VE.

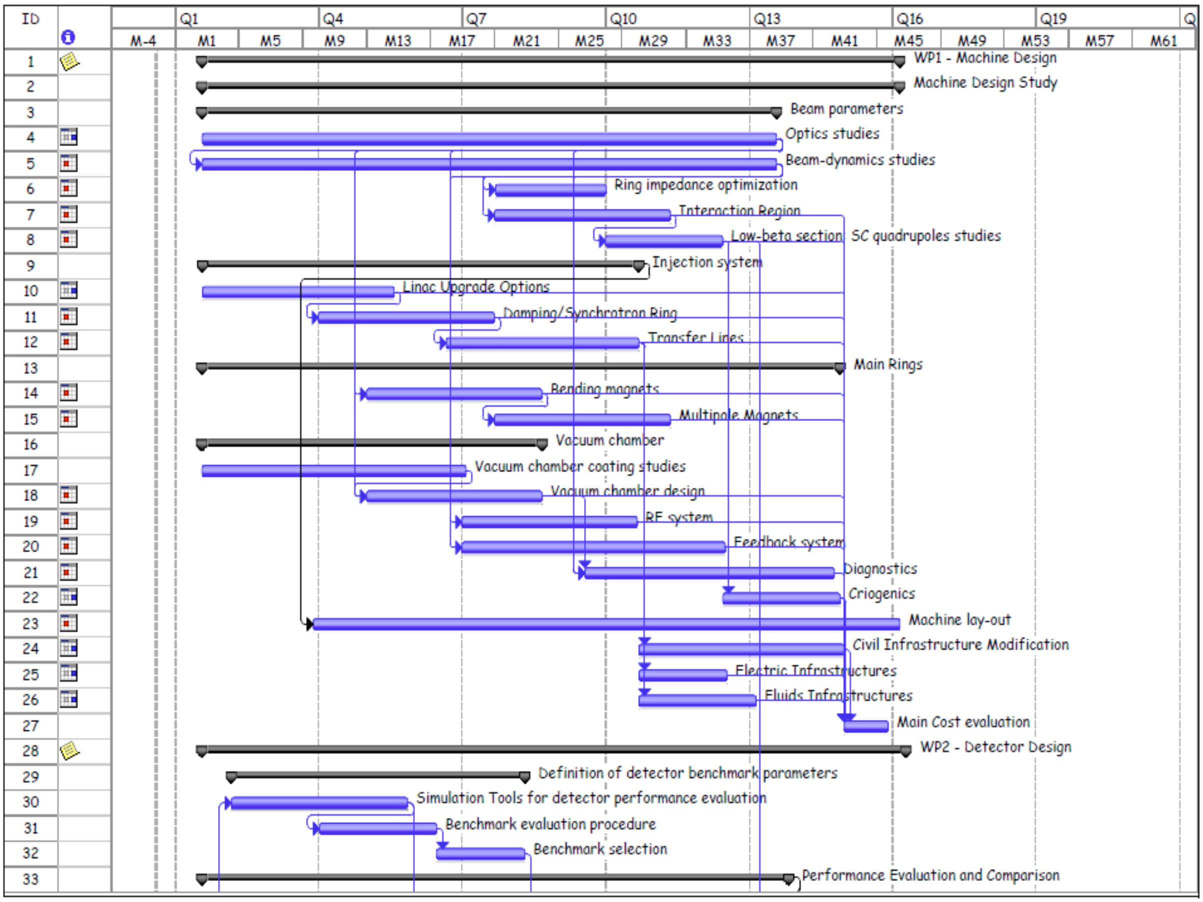
(iii) Kick-start and, if feasible, organise and carry out activities resulting in the delivery of the required improved tools and theoretical calculations as scrutinized in (ii).

(iv) Interact with WP1-2 and provide feedback for the machine and detector design. This is crucial to guarantee that designs can deliver within benchmarks. Possible issues are e.g. the angular coverage of the detector or the possibility for enhanced forward instrumentation.

Objectives (i), (ii) and (iii) are (loosely) ordered with respect to time, whereas (iv), the interaction with WP1-2, must happen from the start and throughout the project.

1.3.5 WP4 strategy description: Management

The strategy adopted in the WP4 is described in Section 2.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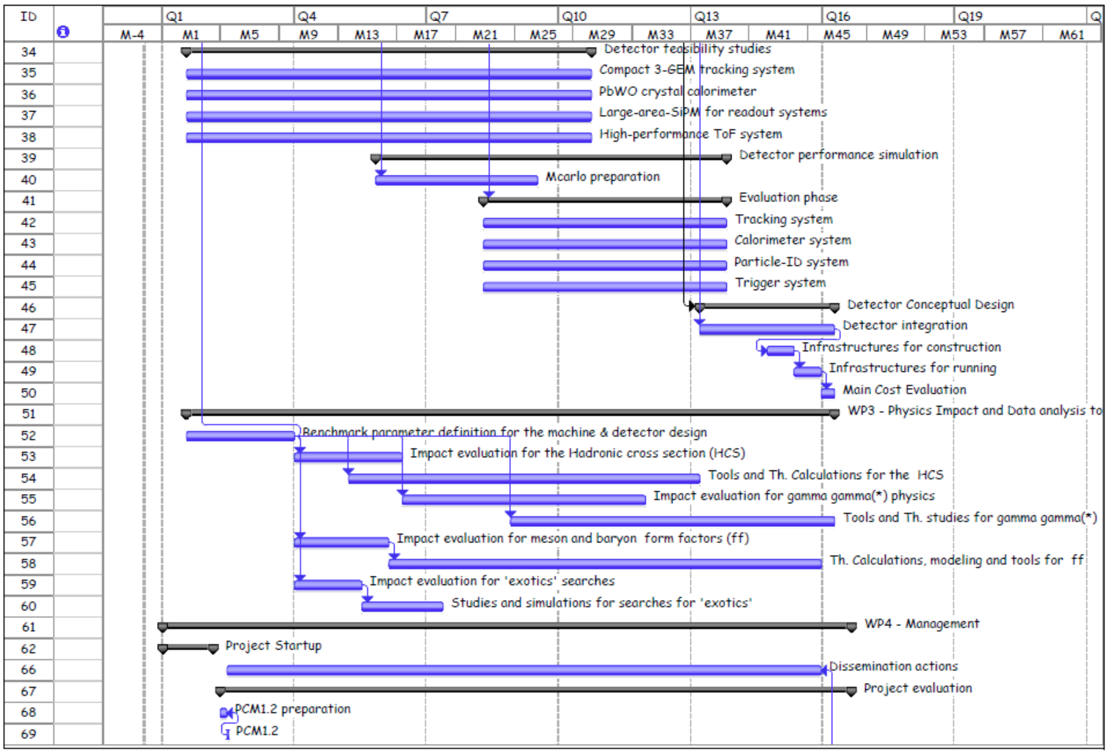
WP1 - Machine Design
Machine Design Study
Beam parameters
Optics studies
Beam-dynamics studies
Ring impedance optimization
Interaction Region
Low-beta section
SC quadrupoles studies
Injection system
Linac Upgrade Options
Damping/Synchrotron Ring
Transfer Lines
Main Rings
Bending magnets
Multipole Magnets
Vacuum chamber
Vacuum chamber coating studies
Vacuum chamber design
RF system
Feedback system
Diagnostics
Criogenics
Machine lay-out
Civil Infrastructure Modification
Electric Infrastructures
Fluids Infrastructures
Main Cost evaluation
WP2 - Detector Design
Definition of detector benchmark parameters
Simulation Tools for detector performance evaluation
Benchmark evaluation procedure
Benchmark selection
Performance Evaluation and Comparison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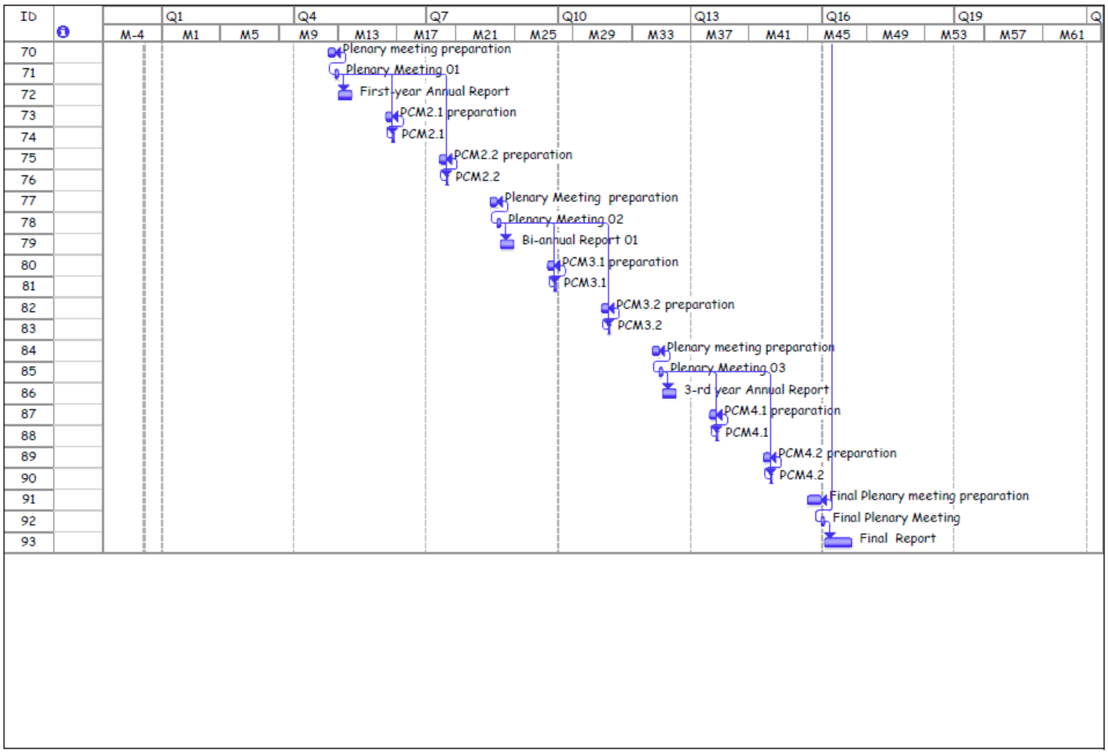
34 Detector feasibility studies
35 Compact 3-GEM tracking system
36 PbWO crystal calorimeter
37 Large-area-SiPM for readout systems
38 High-performance ToF system
39 Detector performance simulation
40 Mcarlo preparation
41 Evaluation phase
42 Tracking system
43 Calorimeter system
44 Particle-ID system
45 Trigger system
46 Detector Conceptual Design
47 Detector integration
48 Infrastructures for construction
49 Infrastructures for running
50 Main Cost Evaluation
51 WP3 - Physics Impact and Data analysis to
52 Benchmark parameter definition for the machine & detector design
53 Impact evaluation for the Hadronic cross section (HCS)
54 Tools and Th. Calculations for the HCS
55 Impact evaluation for gamma gamma(*) physics
56 Tools and Th. studies for gamma gamma(*)
57 Impact evaluation for meson and baryon form factors (ff)
58 Th. Calculations, modeling and tools for ff
59 Impact evaluation for 'exotics' searches
60 Studies and simulations for searches for 'exotics'
61 WP4 - Management
62 Project Startup
66 Dissemination actions
67 Project evaluation
68 PCM1.2 preparation
69 PCM1.2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70 Plenary meeting preparation
71 Plenary Meeting 01
72 First-year Annual Report
73 PCM2.1 preparation
74 PCM2.1
75 PCM2.2 preparation
76 PCM2.2
77 Plenary Meeting preparation
78 Plenary Meeting 02
79 Bi-annual Report 01
80 PCM3.1 preparation
81 PCM3.1
82 PCM3.2 preparation
83 PCM3.2
84 Plenary meeting preparation
85 Plenary Meeting 03
86 3-rd year Annual Report
87 PCM4.1 preparation
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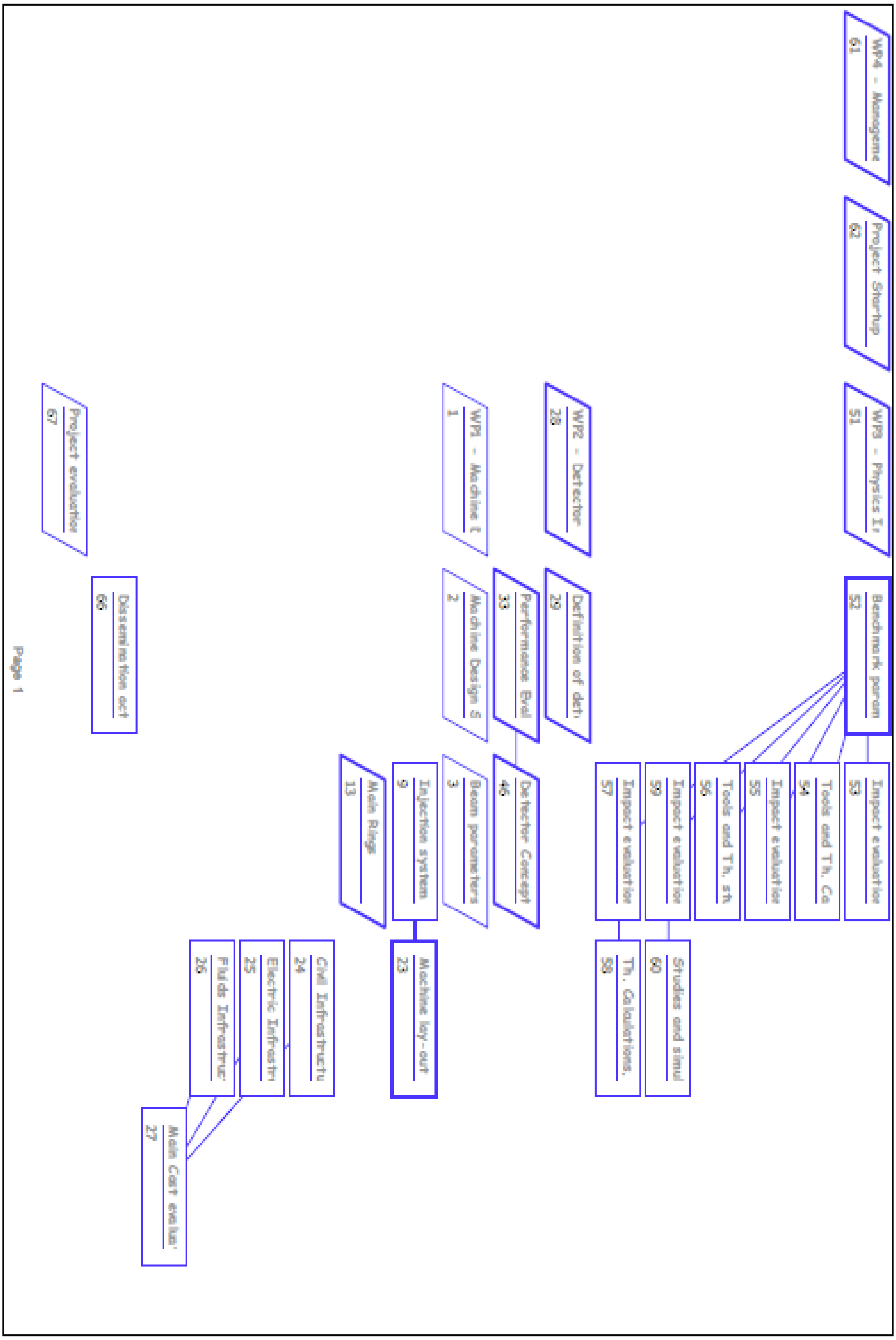
89 PCM4.2 preparation
90 PCM4.2
91 Final Plenary meeting preparation
92 Final Plenary Meeting
93 Final Report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WP1 - Machine I
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Main Rings
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Machine lay-out
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Page 1

Table 1.3 a: Work package list

Work Package no.	Work Package title	Type of activity	Lead Participant no.	Lead Participant short name	Person months	Start month	End month
WP 1	Design study for a variable energy lepton collider	RTD	1	INFN	223	1	48
WP 2	Detector design	RTD	2	UU	196	1	48
WP 3	Physics studies and software tools for DAΦNE-VE	RTD	4	UNILIV	194	1	48
WP 4	Management	MGT	1	INFN	116	1	48
				TOTAL	729		

Table 1.3 b : Deliverable list

Del. no.	Deliverable name	WP no.	Nature	Dissemination level	Delivery date
1.1	Annual Report	WP1	R	PU	12
2.1	Annual Report	WP2	R	PU	12
3.1	Annual Report	WP3	R	PU	12
1.2	Annual Report	WP1	R	PU	24
2.2	Annual Report	WP2	R	PU	24
3.2	Annual Report	WP3	R	PU	24
1.3	Annual Report	WP1	R	PU	36
2.3	Annual Report	WP2	R	PU	36
3.3	Annual Report	WP3	R	PU	36
1.4	Final Report	WP1	R	PU	48
2.4	Final Report	WP2	R	PU	48
3.4	Final Report	WP3	R	PU	48
4.4	Final Report with CDR	WP4	R	PU	48

Table 1.3 c: List of milestones

Milestone number	Milestone name	Work packages involved	Expected date	Means of verification
WP1.1	Machine Design Study.	WP1	M45	Report
WP1.2	Beam Parameters	WP1	M38	Report
WP1.3	Optics Studies	WP1	M38	Report
WP1.4	Beam Dynamics Studies	WP1	M38	Report
WP1.5	Ring Impedance Optimization	WP1	M27	Report
WP1.6	Interaction Region	WP1	M31	Report
WP1.7	Low-beta section: SC quadrupoles studies	WP1	M35	Report
WP1.8	Injection System	WP1	M29	Report
WP1.9	Linac Upgrade option	WP1	M15	Report
WP1.10	Damping/Synchrotron ring	WP1	M20	Report
WP1.11	Transfer Lines	WP1	M29	Report
WP1.12	Main Rings	WP1	M42	Report
WP1.13	Bending Magnets	WP1	M22	Report
WP1.14	Multipole Magnets	WP1	M30	Report
WP1.15	Vacuum Chamber	WP1	M23	Report
WP1.16	Vacuum Chamber coating studies	WP1	M18	Report
WP1.17	Vacuum Chamber design	WP1	M22	Report
WP1.18	RF system	WP1	M28	Report
WP1.19	Feedback Systems	WP1	M34	Report
WP1.20	Diagnostics	WP1	M40	Report
WP1.21	Cryogenics	WP1	M41	Report
WP1.22	Machine Layout	WP1	M45	Report
WP1.23	Civil Infrastructure	WP1	M40	Report
WP1.24	Electric Infrastructure	WP1	M33	Report
WP1.25	Fluids Infrastructure	WP1	M36	Report

WP1.26	Main cost evaluation	WP1	M45	Report
WP2.1	Definition of detector benchmark parameters	WP2	M22	Report
WP2.2	Simulation Tools for detector performance evaluation	WP2	M13	Internal note
WP2.3	Benchmark evaluation procedure	WP2	M17	Report
WP2.4	Benchmark selection	WP2	M21	Report
WP2.5	Performance evaluation and comparison	WP2	M40	Report
WP2.6	Detector feasibility studies	WP2	M29	Report
WP2.7	Compact 3-GEM tracking system	WP2	M29	Report
WP2.8	PbWO crystal calorimeter	WP2	M29	Report
WP2.9	Large-area-SiPM for readout system	WP2	M29	Report
WP2.10	High-performance ToF system	WP2	M29	Report
WP2.11	Detector performance simulation	WP2	M38	Report
WP2.12	MonteCarlo preparation	WP2	M24	Report
WP2.13	Evaluation phase	WP2	M38	Report
WP2.14	Tracking system	WP2	M38	Report
WP2.15	Calorimeter system	WP2	M38	Report
WP2.16	Particle-ID-system	WP2	M38	Report
WP2.17	Trigger system	WP2	M38	Report
WP2.18	Detector conceptual design	WP2	M45	Report
WP2.19	Detector integration	WP2	M45	Report
WP2.20	Infrastructures for construction	WP2	M41	Report
WP2.21	Infrastructures for running	WP2	M43	Report
WP2.22	Main Cost evaluation	WP2	M45	Report
WP3.1	Benchmark parameter definition for the machine & detector design.	WP3	M10	Report
WP3.2	Impact evaluation for hadronic cross sections (HCS) from energy scan &	WP3	M18	Report

	ISR			
WP3.3	Tools and theory calculations for energy scan & ISR based processes	WP3	M38	Report; MC comparison and validation
WP3.4	Impact evaluation for gamma gamma(*) physics	WP3	M34	Report
WP3.5	Tools and theoretical studies for gamma gamma(*) processes	WP3	M46	Report; MC validation
WP3.6	Impact evaluation for meson and baryon form factor measurements	WP3	M16	Report
WP3.7	Theoretical calculation, modelling and tools for form factors	WP3	M46	Report
WP3.8	Impact evaluation for `exotics' searches	WP3	M14	Report
WP3.9	Studies and simulations for searches for `exotics'	WP3	M20	Report

Table 1.3 d:

<table>
<tr><td>Work package number</td><td>WP1</td><td colspan="4">Start date</td><td colspan="2">M2</td></tr>
<tr><td>Work package title</td><td colspan="7">Design study for a variable energy lepton collider</td></tr>
<tr><td>Activity Type</td><td colspan="7">R&D</td></tr>
<tr><td>Participant number</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>Participant short name</td><td>INFN</td><td>UU</td><td>UJ</td><td>UNILIV</td><td>MAINZ</td><td>CSIC</td><td>BINP</td></tr>
<tr><td>Person-month per participant:</td><td>70</td><td>8</td><td>0</td><td>48</td><td>5</td><td>0</td><td>92</td></tr>
<tr><td colspan="8">Objective: the proposed Working Package is aimed at verifying the feasibility of an electron-positron collider working at variable center of mass energy in the range 0.6 GeV ÷ 3.0 GeV, and providing a luminosity of 10^{33} cm^{-2}s^{-1} .</td></tr>
<tr><td colspan="8">Description of work and role of participant
The design study will be aimed at studying several options and at finding the more suitable solutions in order to define a proposal for a variable energy collider designed taking into account the more recent advances in the particle accelerator field, developing when necessary innovative solutions and reusing as much as possible the infrastructure of the DAΦNE accelerator complex in Frascati.
The objective is expected to be attained by:
- A new injection system allowing on-energy injection in the colliding rings;
- An interaction region based on superconducting magnets and including the Crab-Waist collision scheme;
- A flexible ring lattice;
- Studying and proposing innovative solutions for all those aspects affecting the beam dynamics: radio-frequency, feedback systems, ring impedance, cures to keep under control beam instability induced by ion and by electron cloud;
- Developing tools for beam-beam behaviour simulation and optimization
- Precise measurement of beam energy.</td></tr>
<tr><td colspan="8">Deliverables: Annual Reports (12, 24, 36), Final Report (48)</td></tr>
</table>

Work package number	WP2	Start date			M2		
Work package title	Detector Design						
Activity Type	RTD						
Participant number	1	2	3	4	5	6	7
Participant short name	INFN	UU	UJ	UNIL IV	MAINZ	CSIC	BINP
Person-month per participant:	27	24	94	0	14	0	37
Objectives: Definition of the detection capabilities requirements, evaluation of the design driven by the physics goals. Preparation of the conceptual design.							
Description of work and role of participants: Analysis of the applicability of the KLOE detector, for the proposed experimental programme (LNF+UU+UJ). Preparation of fast simulation programme to define detector configuration (UU). Studies of applicability of the GEM technology (LNF) and PWO calorimeter for the new detector (UU). Study detectors state-of-the-art detector concepts such as CMD-3, Panda (BINP, UU). Detailed studies of detector subsystems: charged particle tracking, calorimetry with focus on photon and neutron reconstruction, particle identification, frontend electronics, trigger, data acquisition system and data management and storage. The last year of the project will be focused on the preparation of the report containing the conceptual design of the detector. The conceptual design will combine results of all studies in the final report.							
Deliverables: Annual Reports (12, 24, 36), Final Report (48)							

Work package number	WP3	Start date				M2	
Work package title	Physics studies and software tools for DAΦNE-VE						
Activity Type	RTD						
Participant number	1	2	3	4	5	6	7
Participant short name	INFN	UU	UJ	UNILIV	MAINZ	CSIC	BINP
Person-month per participant:	11	8	40	29	38	37	31

Objectives: Definition of benchmark parameters for machine and detector design. Following this, performance of detailed studies of the physics programme to quantify the impact of various design options and to improve the theoretical understanding; refinement/creation of required software tools for simulations.

Description of work and role of participants:
The initial task of WP3 is to review the physics scenario and to define benchmark parameters for the machine and detector design. Following this, the rich physics programme will be scrutinized, and its impact, depending on the design parameters, will be quantified. This includes: detailed theoretical studies in the specified sub-fields; dedicated calculations of higher-order radiative corrections and also within effective theories describing low energy hadronic interactions; improvements or creation of relevant software tools (Monte Carlos).
As outlined in the WP3 strategy description, there will be five working groups, WP3.1-5, corresponding to the five sub-fields:
1.) Hadronic cross section measurements via energy scan and its impact on (g-2) of the muon and the effective QED coupling.
2.) Measurements via the alternative method of Radiative Return (using Initial State Radiation of photons).
3.) Study of photon-photon physics, especially the production of pseudoscalar resonances in order to better constrain the hadronic light-by-light scattering contributions to (g-2).
4.) Form factor measurements for a wide range of mesons and baryons, largely not possible with existing facilities.
5.) Search for `exotic' particles, both within and beyond the SM.
For WP3.1 and 2, a variety of hadronic final states will be assessed simultaneously, though the analysis methods are very different and complementary to each other.
A further work topic is the determination of the strong coupling α_s from the hadron to muon cross section ratio R, and to scrutinize the relation between hadronic tau decays and the corresponding hadron production in electron-positron annihilation.
WP3.4 covers a rich field of research: form factors of the neutron, proton and Lambda, but also, e.g., Kaons. At DAΦNE-VE, through its high luminosity, many channels will be accessible, and form factors may be measured for space- and time-like momentum transfer. The modelling of the structure of light scalar mesons would benefit tremendously from the envisaged detailed measurements of hadron production and decays and will be studied within WP3.4.
Work on Monte Carlos is particularly important for the rather new method of Radiative Return and for photon-photon processes. Codes for ISR-production of two pions as well as higher-multiplicity final states will be improved or created.
There is also need to refine routines for the hadronic vacuum polarization (which is needed for all processes) and for Bhabha scattering and muon pair production used to monitor the luminosity, which will be part of WP3.

Individual researchers from all participants will contribute to WP3 as outlined in the participants' descriptions, providing a very wide and far-reaching expertise.

Deliverables: Annual Reports (12, 24, 36), Final Report (48)

<table>
<tr><td>Work package number</td><td>WP4</td><td colspan="4">Start date</td><td colspan="2">M1</td></tr>
<tr><td>Work package title</td><td colspan="7">Management</td></tr>
<tr><td>Activity Type</td><td colspan="7">MGT</td></tr>
<tr><td>Participant number</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>Participant short name</td><td>INFN</td><td>UU</td><td>UJ</td><td>UNILIV</td><td>MAINZ</td><td>CSIC</td><td>BINP</td></tr>
<tr><td>Person-month per participant:</td><td>54</td><td>32</td><td>12</td><td>0</td><td>5</td><td>8</td><td>5</td></tr>
<tr><td colspan="8">Objectives: Monitoring of the communication among WPs. Evaluation of the progress in the WP S/T tasks. Coordination of the Administrative activities. Secretary support to the Project Coordinator.</td></tr>
<tr><td colspan="8">Description of work and role of participants:
The task of the working package 4 is the administration of the project. The initial action is the setup of the governing bodies. Every 4 months the Project Council meets to verify the status of the S/T tasks and every year reports to the Institution Board the project progress. An important task of the WP4 is the dissemination of the results to the scientific community. The WP activities are better described in the 2.1 section.</td></tr>
<tr><td colspan="8">Deliverables: Annual Reports (12, 24, 36), Final Report with CDR (48)</td></tr>
</table>

Table 1.3 e: Summary of staff effort

Participant no. / short name	WP1	WP2	WP3	WP4	Total person months
Part. 1 - INFN	**70**	27	11	**54**	162
Part. 2 - UU	8	**24**	8	32	72
Part. 3 - UJ	0	94	40	12	146
Part. 4 - UNILIV	48	0	**29**	0	77
Part. 5 - MAINZ	5	14	38	5	62
Part. 6 - CSIC	0	0	37	8	45
Part. 7 - BINP	92	37	31	5	165
Total	223	196	194	116	729

2. Implementation

2.1 *Management structure and procedures*

2.1.1 The management strategy

The management strategy is based i) on the monitoring of the communication among WPs and ii) on the evaluation of the progress in the WP S/T tasks.
The circulation of information on the status of the WP tasks is considered essential for the overall project since the achievements and new ideas in one sector have the potentiality to clarify the objectives and stimulate the research on other issues.
The scheduling of the WPs is regularly reviewed to determine whether the objectives have been reached or the plans need revision to meet changed circumstances related to both, the internal organization, and the general evolution in the fields of interest.

2.1.2 The management structure

The project coordinator is responsible:

i) for the relationship with the European Commission and

ii) For the distribution of resources among the working groups of the project. He is also responsible of the administrative procedures needed to accomplish each task, for which he is supported by the secretary service. He leads the Management WP (WP 4).

The WP coordinators are responsible for the planning and the fulfilment of the S/T objectives of each WP. They take care of the communication among WPs and provide the annual and bi-annual report on the achievements of the WPs.
Depending on the complexity of the activity, the WPs are led by one or two coordinators. The principal investigators for each task of the WPs are in charge for the fulfilment of the milestones of the activity and for preparing the status report at the WP meetings. They contribute to the annual and bi-annual status reports edited by the WP coordinator.
The scientific secretaries are in charge for the meeting organization and for the publication on the WEB of the related documentation.
The secretary service supports the project coordinator in the administrative procedure and in the collection of the documentation of the project.

2.1.3 The Governing bodies

2.1.3.1 The Project Council

The Project Council is the executive body of the project. It is chaired by the Project Coordinator and composed by the WP coordinators and the scientific secretaries.
The Project Council decides on the implementation of the management strategies to attain the S/T objectives. It regularly reviews the activity related to each task, publicize the result of the scrutiny, and takes proper initiatives for the project progress.
It prepares the annual and bi-annual global reports of the Project.
It decides motivated changes in the project planning when needed, and takes care of all of the consequent actions. Among possible changes, it decides about the extension of the project with the inclusion of new tasks.
The Project Council is competent for the attribution of the resources to the WP tasks, for the monitoring of the cost profile and for the budgetary re-assessments, when needed.
The Council proposes to the Institution Board, among other issues, the admission of new contractors and the motivated exclusion of institutions from the Consortium.

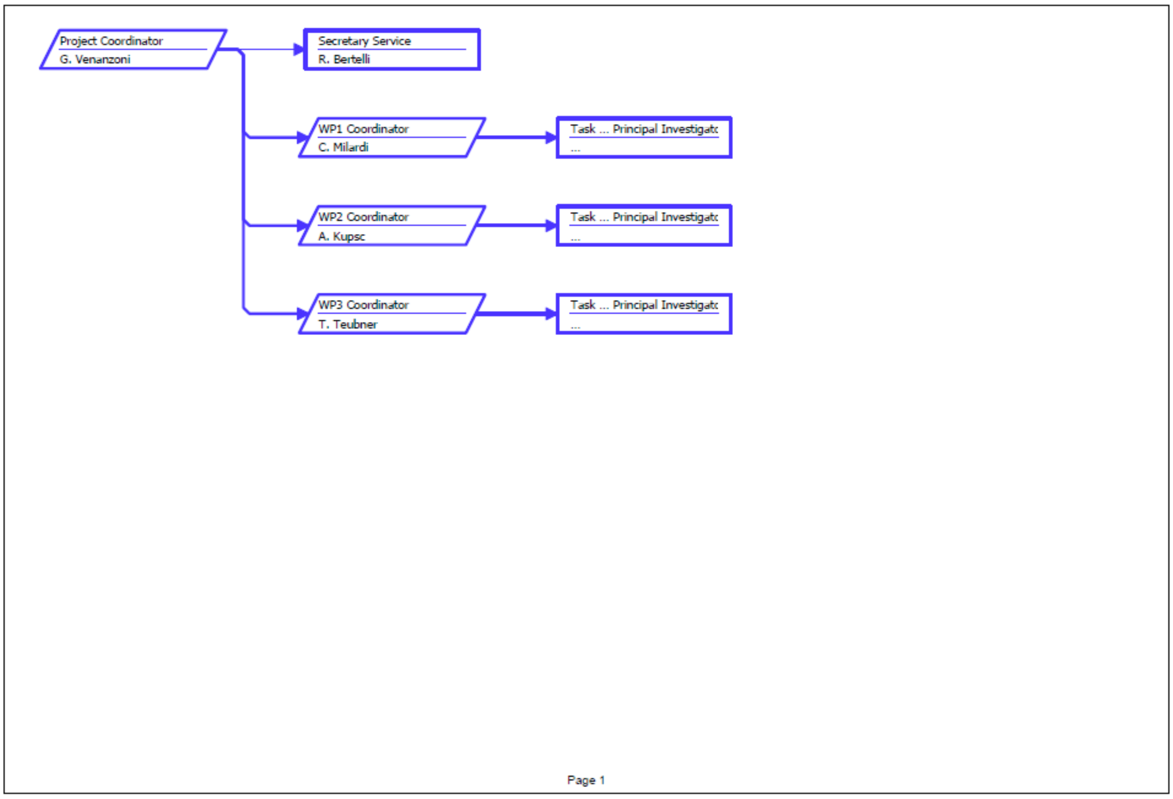
2.1.3.2 The Institution Board

The Institution Board endorses the Consortium Agreement. The Board is chaired by the Project Coordinator and composed by the representatives of the institutions participating to the Project. Each institution participates with one delegate to the Institution Board.
The details on the Institution Board are described in Sect. 2.3, devoted to the Consortium implementation.

2.1.4 The management procedures

The Project Council meets every four months. The scientific secretary is in charge for calling the meetings and preparing the agenda while the opinion of the Project and the WP Coordinators have been obtained. The scientific secretary is also in charge for preparing and posting on the WEB the meeting documentation.
The WP coordinators organize every three months a WP meeting to verify the activity progress. To insure a wide participation and to be effective in the communication of the results the remote connection via audio-conference will be customarily guaranteed.
Once per year a plenary meeting with the status report of the WPs is organised by the Project Coordinator supported by the secretary service. The plenary meetings constitute the occasions to meet the worldwide community interested to the Project or active in the S/T fields of interest.
Proper actions to publicize the plenary meetings, including the invitation to contribute on the assessment of crucial issues to S/T experts, are decided in advance by the Project Council.
The documentation, available on the WEB, is referenced in the annual and bi-annual Project reports.
The Institution Board, called by the Project Coordinator, is customary held in occasion of the plenary meetings. The secretary service supports the Coordinator in the organization of the meetings and takes care of the related documentation. More details on the procedures can be found in the Consortium section, Sect. 2.3.

In Fig. 3 the management diagram is reported.



2.2 *Individual participants*

2.2.1 Istituto Nazionale di Fisica Nucleare (INFN)

Frascati National Laboratories (LNF) is the biggest INFN research structure dedicated to nuclear and subnuclear physics studies with charged particle accelerators. LNF has a long tradition in design, construction and operation of electron-positron accelerators and colliders. The main LNF infrastructure is the DAΦNE accelerator complex consisting of a linear accelerator, an intermediate damping/accumulator ring and two intersecting main rings. DAΦNE is the electron-positron collider that works at the energy of Φ-resonance at 1.02 GeV c.m. ("Φ-factory"). Since 2000 it has been delivering luminosity for several physics experiments: KLOE, FINUDA, DEAR and SIDDHARTA. A wide spectrum of experiments is also being carried out at the DAΦNE beam test facility (BTF), a dedicated beam line providing electron and positron beams in the energy range 25-725 MeV with intensities varying from a single electron to 100 mA in short pulses from 1 to 10 nsec. 3 separate beam lines are used in DAΦNE for synchrotron radiation studies extracting photons from wiggler and dipole magnets. Recently SPARC linear accelerator has been successfully commissioned at Frascati. This 150 MeV electron accelerator with a photo injector provides high brightness beams to drive several FEL experiments as well as tests of new acceleration techniques. The LNF Accelerator Division participates in numerous international accelerator projects and collaborations such as ILC, CLIC, CTF3, SuperB, CNAO etc. Scientific activities of LNF cover many fields of research: high energy physics, nuclear physics, astrophysics, theoretical physics, technological research, synchrotron radiation. Frascati physicists participate in experiments at CERN, SLAC, FNAL, DESY, TJNAF, LNGS, VIRGO and other Italian and international laboratories. INFN has also a long standing history of detector development, giving a significant contribution to the successful operation of most of the particle physics experiments in the world (ALICE, ATLAS, BaBar, CDF, CMS, KLOE, LHCb, NA62, etc.).

The INFN specific roles in the working packages:
WP1 leading role in the design studies of the whole machine including the evaluation of the cost and the analysis of its realization and the required infrastructures
WP2 contribution to the detector studies, in respect to tracking, particle-identification detector, calorimeter, trigger, software and DAQ.
WP3 contribution to the whole physics and software programme.
WP4 leading role in the management scheme and collaboration to develop the coordination strategy of the project

Contributing Staff members:
Several INFN operative units will participate to this project. To respect the one page limit we list here the main contributors to this project (the full list will be given in the last page):
Danilo Babusci, detector, physics
Giovanni Bencivenni, detector
Monica Bertani, detector, physics
Caterina Bloise, detector, physics
Fabio Bossi, detector, physics
Alessandro Drago, accelerator
Alessandro Gallo, accelerator
Gino Isidori, physics
Catia Milardi, accelerator
Stefano Miscetti, detector, physics
Marco Mirazita, detector, physics
Dario Moricciani, detector, physics
Claudio Sanelli, accelerator
Paolo Santangelo, detector, physics
Graziano Venanzoni, detector, physics

2.2.2 Uppsala University, Department of Physics and Astronomy (UU)

Uppsala University is a comprehensive university with nine faculties, about 40,000 students, and ca. 5,500 employees. The university has ca. 550 full professors, ca. 20% of them are women. Some 4,200 undergraduate degrees and about 300 doctorates are conferred every year. The annual turnover of Uppsala University is ca. MSEK 4,500; nearly 70% goes to research and postgraduate education. About 50% of the research budget is funded from external sources. The Uppsala groups at the Department of Physics and Astronomy has been very actively involved in experiments at CERN, Uppsala-TSL and Jülich. Physicists and engineers from hadron physics group and from the Center for Accelerator and Instrument (CAI) Development group are interested in the participation in the project. The main scientific interests of the hadron group are investigations of the lightest neutral mesons. We play the leading role in EU project coordinating physicists working in this field (Work Package 5 *PrimeNet* of the FP7 HadronPhysics2 project). Our group constituted the core team responsible for preparation of a large acceptance WASA detector for studies of π^0 and η meson decays. The WASA detector has been build for experiments at CELSIUS light ion storage ring in Uppsala. Since 2006 the detector is located in FZ Julich (Germany) at COSY storage ring where we continue to play the leading role. The group is now also involved in PANDA and KLOE2 experiments. The specific expertise covers many aspects of scintillating crystal electromagnetic calorimeters, including radiation damage studies, electronic signal digitization, readout systems and data analysis. WASA detector central part was designed in close collaboration with BINP CMD-2 experiment physicists and the novel concept of internal target – *pellet target* was originally developed in Uppsala. Frontend electronics for many detector components *e.g*: trigger boards, discriminators and Charge–to–Digit converters were developed in house and *e.g*. Charge–to–Digit converter VME board was recently commercialized by Wiener. There is also interest from theory group in the physics of light vector mesons and the extensions of Chiral Perturbation Theory to higher energies. The CAI personnel have background from accelerator physics and diagnostics for the CELSIUS storage ring and also in build-up of superconducting magnets for WASA and Atlas detectors. The present projects include participation in Two-beam Test Stand (TBTS), part of the CLIC Test Facility CTF3 and engineering support for the design and construction of components for the laser heater of the European X-ray Free-Electron Laser project in Hamburg, Germany. The group has close collaboration with Scanditronix Magnet AB and with Lund synchrotron radiation facility MAX-lab and the leading role in European Coordination for Accelerator Research & Development (EuCARD) project.

The UU specific roles in the working packages:
WP1 contribution to magnet design, consultant role and contacts with industry (Scanditronix Magnet AB), detector-collider interface, accelerator background studies
WP2 leading role in the design studies and simulations and in particular contribution to the electromagnetic calorimeter, tracker and to the readout electronics design
WP3 contribution to specification and feasibility of the light meson decay programme

Contributing Staff members:
Hans Calen, detector design
Kjell Fransson, electronics, detector design
Volker Ziemann, accelerator
Roger Ruber, accelerator
Marek Jacewicz, accelerator, detector design
Tord Johansson, physics, detector design
Magnus Wolke, physics, detector design
Andrzej Kupsc, physics, detector design, simulation
Christoph Redmer, simulations
Pawel Marciniewski, electronics
Stefan Leupold, physics issues

2.2.3 Jagiellonian University, Faculty of Physics, Astronomy and Applied Computer Science (UJ)

The expertise of the Jagiellonian University research group includes design, construction and assembling of multi-modular scintillator, semiconductor and gaseous detectors. The group comprises experts in (i) elaboration of calibration methods and reconstruction algorithms for particle identification, (ii) development and maintaining of data analysis and simulation programs for particle and nuclear physics experiments, (iii) performing of data analysis and simulations of experiments based on the Monte-Carlo methods and advanced statistical inferences. The detector systems (drift chambers, neutral particle detectors, scintillator hodoscopes) designed and build in the Physics Institute of the Jagiellonian University are successfully used in laboratories such as example: GSI, COSY, KVI and PSI. Over the past several years, the group has built for example: Large drift chambers for the COSY-11 and BIG KARL experiments at the cooler synchrotron COSY-Juelich in Germany, proportional chambers for monitoring the beam of COSY, central drift chamber for the SAPHIR experiment at ELSA synchrotron in Bonn, shower detectors for the HADES experiment in GSI-Darmstadt, wire chambers for experiments devoted to studies of fundamental symmetries in decays of muons and neutrons conducted at the Paul Scherrer Institute in Villigen (Switzerland). The achievements of physicists from the Physics Institute of the Jagiellonian University is very much acknowledged and recognized among the foreign researchers. This is manifested e.g. by the fact that the present spokespersons of many international research groups e.g. nTRV (PSI), HADES (GSI), COSY-11 (FZ-Juelich), PISA (FZ-Juelich), Few-Body Programme (KVI) are coordinated by the physicists from the Jagiellonian University. Since many years the group form the Jagiellonian University has carried out experiments at COSY and at DAFNE in close collaborations with partners from
Institute of Nuclear Physics of Polish Academy of Science, Cracow, Poland,
Soltan Institute for Nuclear Studies, Warsaw, Poland,
Institute of Physics, University of Silesia, Katowice, Poland,
And on the theory sides these groups collaborates with
Akhiezer Institute for Theoretical Physics of the National Academy of Sciences of Ukraine.
Many of the above mentioned detectors systems have been build together.
For this project the above listed institutions and the Jagiellonian University will constitute a group which in addition to the expertise in experimental physics will include experts on theory, Monte Carlo generators and grid computing. The members of the group are main co-authors of many Monte Carlo generators which are of great importance for the realisation of this project. On the theoretical side the experience of the group includes calculation of higher order radiative corrections to continuum processes and modelling of hadronic form factors and tests of the isospin symmetry in e^+e^- annihilation and lepton tau decays.
It is important to stress that the Jagiellonian University together with all listed partner institutions is since many years actively involved in the KLOE-2 experiment carried out at the DAFNE collider.

The UJ specific roles in the working packages:
WP2 contribution in the design studies and simulations
WP3 contribution to specification of physics programme, development of Monte Carlo event generators

Contributing Staff members: the full list of staff members will be reported in the last page of the proposal. To respect the one page limit we list here one contributor for each institute:
Pawel Moskal (physics, detector design, simulations)
Zbigniew Was (theory, Monte Carlo simulations)
Henryk Czyz (theory, Monte Carlo simulations)
Wojciech Wislicki (physics, computing, detector design, simulations)
Sergiy Ivashyn (theory, Monte Carlo simulations)

2.2.4 The University of Liverpool (UNILIV)

The University of Liverpool is one of the UK's top 20 research-led universities. It has 21,000 students pursuing over 400 programmes in 54 subject areas. The Particle Physics Group in the Department of Physics is one of the largest such groups in the UK, with over 50 staff members. The group has access to exceptional facilities including the Liverpool Semiconductor Detector Centre, large scale, high performance computing, and the Cockcroft Institute for Accelerator Science and Technology. The Particle Physics Group and the Cockcroft Institute both have strong collaborative links with other universities and research organisations around the world. Recent successes at the Cockcroft Institute include demonstration of the first European free electron laser driven by an energy-recovery linac. The theoretical physics group is part of the Department of Mathematical Sciences and has 10 permanent staff members. Their expertise ranges from String Theory and Supersymmetry to QCD, multi-loop calculations and phenomenology, with strong links between the theory and experimental group.

The UNILIV specific roles in the working packages:

WP1: develop optics and lattice design for different sets of parameter specifications (energy, luminosity, etc.);
Consider options for modifications to the magnets and layout, where necessary and appropriate;
Investigate a range of beam dynamics issues, including dynamic aperture, collective instabilities, and beam-beam effects, and characterise the overall machine performance for the selected configuration options.
WP3: coordinate the activities of WP3, including the organisation of the planned two annual meetings of the working group;
Conduct detailed studies of the impact of measurements of various hadronic channels on the improvements of g-2 of the muon and the effective electromagnetic coupling;
Provide and maintain improved routines for the vacuum polarisation to be used in physics analyses and MC codes;
Perform theoretical calculations to constrain the light-by-light contributions to g-2 by exploiting existing and anticipated form factor measurements and expected results from lattice QCD simulations.

Contributing Staff members:

Kai Hock, Lecturer in Accelerator Science in the Department of Physics
Andrzej Wolski, Reader in Accelerator Science in the Department of Physics
Thomas Teubner, Senior Lecturer in Theor.Physics in the Dept. of Math.Sciences.

2.2.5 Johannes Gutenberg University Mainz, Institute for Nuclear Physics (MAINZ)

The Institute for Nuclear Physics of the University of Mainz has a long-standing expertise in the design, construction and operation of large scale electron accelerators and detector setups. The Mainz Microtron MAMI consists of the actual accelerator and three major experimental installations:

- The A1 experiment uses three high-resolution spectrometers for electron scattering measurements; in addition the KAOS detector is capable of measuring kaons with high resolution and efficiency.
- The A2 setup is installed at a tagged photon beam facility and consists of the SLAC Crystal Ball detector and the TAPS calorimeter in forward direction.
- The A4 experiment has been designed for the measurement of tiny asymmetries in electron-nucleon scattering, which allow the extraction of strangeness electromagnetic form factors as well as the electroweak Weinberg mixing angle at small Q^2.

The MAMI accelerator consists of two sources for unpolarised and polarised electrons, followed by an injection linac, three consecutive race-track-microtrons and a harmonic double sided microtron for beam energies up to 1604 MeV. The final accelerator stage, named MAMI C, is operational since 2007. Researchers of the Institute for Nuclear Physics have also been working at electron-positron-annihilation experiments, such as KLOE at DAΦNE and BABAR at PEP-II (SLAC). Most recently, the Institute has joined the Beijing tau-charm factory experiment BES-III. The physics interests of Mainz researchers are measurements in the field of hadron physics and the investigation of their impact on precision quantities, such as the anomalous magnetic moment of the muon and the running fine structure constant. The expertise in electron scattering experiments in the time-like regime as well as the expertise in e^+e^- physics allow a complementary view to hadrons. The theory group of the Institute studies the strong interaction at low and medium energies. The activities focus on the theoretical interpretation of the experiments at MAMI and at other accelerator facilities. Beside analytical methods like effective field theories and dispersion theory numerical simulations of Quantum Chromodynamics on the lattice are applied. Two theory groups are collaborating with Mainz: University of Karlsruhe and DESY-Zeuthen. The Karlsruhe group is well-known in the field of high-precision radiative corrections calculations for particle physics applications (i.e. PHOKHARA Monte-Carlo generator has been developed at Karlsruhe). The theory Group of DESY Zeuthen has a long-standing expertise in perturbative quantum field theory and its applications to accelerator physics at different energy scales and within different theoretical frameworks. A variety of open source programs useful or even necessary for data analysis have been created for applications at e.g. HERA, LEP, LHC, and also of course at meson factories.
Prague is also well known for calculation in phenomenology of hadron physics.

The MAINZ specific roles in the working packages:
WP1 beam polarization studies and beam polarimetry
WP2 R&D, design studies and simulations
WP3 ISR physics, Energy Scan of R, gamma-gamma physics, timelike nucleon FFs, Lattice QCD, effective field theories

Contributing Staff members:
Kurt Aulenbacher (accel. exptl.)
Achim Denig (exptl.)
Frank Maas (exptl.)
Sebastian Baunack (exptl.)
Harvey Meyer (lattice QCD theory)
Marc Vanderhaeghen (theory)
Hartmut Wittig (lattice QCD theory)
Tord Riemann (theory) - DESY
Johannes Blümlein (theory) - DESY

Johannes Kühn (theory) - KARLSRUHE

2.2.6 Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC)

The Instituto de Física Corpuscular (IFIC) is a joint research centre of the Spanish Research Council (CSIC) and the University of Valencia. The main aim of IFIC is the study of the fundamental forces and the building blocks of matter in the Universe, in both their theoretical and experimental aspects. This structure provides an excellent atmosphere for scientific cooperation between both fields.

The main research activities of the IFIC´s team are focussed on the application of perturbative methods in Quantum Field Theory and Effective Field Theories to collider phenomenology and flavour physics. Dr. G. Rodrigo is one of the main authors of the NLO Monte Carlo event generator PHOKHARA, which simulates with high precision radiative return events at flavour factories. He is currently the coordinator of LHCPhenoNet, an Initial Training Network of the FP7. Prof. A. Pich has been coordinating the FLAVIAnet European Network on flavour, and will coordinate a new proposal in the next call.

The Institut de Physique Nucleaire d'Orsay belongs to the French Centre National de la Recherche Scientifique, Institut National de Physique Nucleaire et de Physique des Particules (CNRS/IN2P3). More than 100 researchers work mainly in the domain of Hadronic and Nuclear Physics. The three participants from IPN group are involved in phenomenology in hadronic and intermediate physics. They are members of the PANDA collaboration, where they initiated a program on the measurements of form factors in the time-like region. Their main research expertise is the calculation of cross sections and polarization observables for elementary reactions of annihilation and scattering.

The results, mostly analytical, are given in a form suitable for simulation programs and for the interpretation of the experimental data.

Hangzhou Normal University, close to Shanghai, is growing rapidly. Many young scientists who have abroad experiences are employed there. Their main research fields are particle and astroparticle physics. The main research interests of Dr. Qingjun Xu are radiative corrections in decays, especially in hadronic processes at low energy, and in Supersymmetric models at high energy. Currently, she is a member of the BESIII collaboration. She has contributed to the PHOTOS Monte Carlo event generator, which simulates QED radiative corrections in decays of particles and resonances. She has also implemented new physics models in the MC@NLO event generator.

The CSIC specific roles in the working packages:

WP3: Higher order radiative corrections in energy scan and radiative return.
Gamma gamma (and gamma gamma*) physics.
Form factors of mesons and baryons in production and decay.
Searches for and study of `exotics', within and beyond the Standard Model.

Staff members who will be undertaking the work

Germán Rodrigo (IFIC Valencia)
Antonio Pich (IFIC Valencia)
Jorge Portolés (IFIC Valencia)
Olga Shekhovtsova (IFIC Valencia)
Egle Tomasi-Gustafsson (IPNO Orsay)
Saro Ong (IPNO Orsay)
Alaa Dbeyssi (IPNO Orsay)
Qingjun Xu (Hangzhou Normal University)

2.2.7 Budker Institute of Nuclear Physics of SB RUS (BINP)

Budker Institute of Nuclear Physics (BINP) in Novosibirsk, with its personnel of 2,800 people, is the largest Institute of the Russian Academy of Science. It is the place where the world-first e^+e^- collider started taking data for physics in 1965 after ADA in Frascati realized first e^+e^- collisions and proved the feasibility of the method. Since 1965 various e^+e^- colliders were designed and constructed at BINP:

VEPP-2 (3 detectors running up to the maximum c.m. energy of 1.34 GeV), VEPP-2M (6 detectors, up to 1.4 GeV), VEPP-4 (2 detectors, up to 11 GeV). Two e^+e^- colliders are now running at BINP: VEPP-4M (KEDR detector, 1.8-8 GeV) and VEPP-2000 (CMD-3 and SND detectors, 0.36-2 GeV). BINP has large experience in high-precision measurements of the exclusive and total cross sections of e^+e^- annihilation into hadrons, studies of spectroscopy of vector mesons, calculations of the hadronic contributions to muon g-2 and running fine-structure constant. Physicists of BINP participate in various international collaborations – BABAR at SLAC, Belle at KEK, ATLAS and LHCb at CERN. They also have large experience in design and construction of various detectors, in particular, calorimeters on base of scintillation crystals (NaI, CsI, and BGO) and liquid noble gases (Kr and Xe), various Cherenkov detectors including aerogel counters, micropattern gas detectors as well as tracking devices of different types. BINP has a large accelerator department with experts in various fields of accelerator science and technology including design and construction of colliders and synchrotron radiation facilities, superconducting magnets, development of methods of beam diagnostics and precise beam energy measurement, e.g., resonance depolarization providing unique accuracy in determination of masses of various particles and meson resonances, as well as production and handling of beam polarization. Accelerator experts of BINP have developed and realized a method of electron cooling now successfully used in many accelerator centres in the world.

The members of the group from the Joint Institute of Nuclear Research (JI) in Dubna are well-known experts in the calculations of various higher-order effects including radiative corrections to cross sections of e^+e^- annihilation and muon g-2.

The BINP specific roles in the working packages:

WP1 contribution to collider design and simulation, consultant role and contacts with industry, accelerator background

WP2 leading role in the detector design studies and simulations

WP3 contribution to specifications of the measurements of the exclusive and total cross sections, program of light meson decay studies

Contributing Staff members:

A. Bogomyagkov, collider design, energy measurement
S. Eidelman, physics, data analysis,
G. Fedotovich, physics, detector design,
E. Levichev, collider design,
P. Lukin, physics, detector simulation,
I. Okunev, collider design,
P. Piminov, collider design,
D. Shatilov, collider design,
B. Shwartz, physics, detector design,
S. Sinyatkin, collider design,
P. Voblyi, collider design,
Yu. Bystritsky, physics, (DUBNA)
V.Bytev, physics, (DUBNA)
E.Kuraev, physics, (DUBNA)

2.3 *Consortium as a whole*

The consortium of participant institutions will allow through each participant characteristics to reach the objectives stated in each Working Package.

The governing body of the Consortium will be taken by the Institution Board which is chaired by the Project Coordinator and composed by the representatives of the institutions participating to the Project. Each institution participates with one delegate to the Institution Board.

2.4 *Resources to be committed*

The main investment in this project is manpower needed to prepare a conceptual design of the accelerator and the detector. Most of the physicists interested in the DAΦNE-VE program have also duties related to other active projects like participation in the existing experiments. Therefore they are able to commit only small fraction of FTE to the project. For the success of the DAΦNE-VE there is a need for a core team focused on the task. We aim to achieve this by hiring a group of highly qualified post-docs.

3 Impact

3.1 *Expected impacts listed in the work programme*

Objectives of the Project

The project is devoted to the conceptual design of a new European facility for high luminosity electron-positron accelerator for precise studies of interactions between the elementary building blocks of matter: leptons and light quarks. This field of research explores high intensity and high precision frontiers in searches of new fundamental laws of physics and attracts a large number of scientists from all over the world.

Expected Impact on Existing Research Infrastructures

The proposed physics program is complementary both to the proposed European SuperB factory and to Facility for Antiproton and Ion Research (FAIR) in Darmstadt (Germany).
It will complement also high-energy experiments at LHC and future linear colliders because various SM observables like, e.g., muon g-2 are, through higher-order effects, sensitive to possible BSM effect at hundred GeV and TeV scale.
The project will improve the performance of the European Research Infrastructures, and will help to maintain their leading role worldwide. It will provide advanced instrumentation, and concentrate high-level expertise.
The experimental activities in the field of lepton colliders and detectors will improve the European Research Infrastructures consolidating their leading role worldwide, will promote advancement in instrumentation, and will maintain high-level expertise in the local institutions

Expected Impact on Existing and Proposed Colliders

The DAΦNE-VE design will require developments beyond the present status of the art, paving the way for possible new conceptual approaches. The impact of the achievements attained on low energy colliders on more challenging projects is clearly underlined by the DAΦNE experience. In fact the Crab-Waist collision scheme, originally proposed and tested at DAΦNE is the main design concept for new project aimed at building SuperB factories and it has been also taken into consideration for upgrade of one of the LHC interaction regions.

Expected Impact on European Industry

Collaboration with industrial partners will enable to extend range of products and therefore increase their competitiveness. Since the industrial partners are also involved in build-up of accelerators for medical applications this would lead ultimately also to improvement of life quality in Europe. This is illustrated by the proposed collaboration with Scanditronix Magnet AB. Their range of products includes at present a wide range of conventional magnets. Participation in the project will introduce them to the design of superconducting magnets.

European Approach

The roots of this collaborative project come from two other FP7 EC projects HadronPhysics2 and EuCAR. The project is illustration of fostering cooperation between European groups involved in electron and hadron machines. The opportunities for synergies come for example in detector design work package where experience and latest developments for modern fixed target experiments (PANDA) will be used.

Impact on Partnership between Non-European and European Institutes

The project includes close collaboration between the LNF and Novosibirsk groups the two world leading centres for low energy, high luminosity electron-positron colliders. The contribution of the Novosibirsk group will add to the European expertise in both accelerator and the detector design.

Monitoring the Achievement of the Impact

The indicators to determine whether the impacts were achieved will be content and quality of the project deliverables – design specification and the conceptual design of the new infrastructure for hadron physics and the use and development the innovative technologies. A clear indication of the success will be the prepared design study reports and the community response to the presentation of the project by of members of the Consortium at international workshops and conferences. In many cases, the groups involved are among the leading experts worldwide. The success will be recognized immediately by the international community. The conceptual design report will be used for presenting the project to the financial agencies. The results of the studies will be presented to the community and could be used in new projects.

3.2 *Dissemination and/or exploitation of project results, and management of intellectual property*

The project will have own web site with public and internal pages. On the public pages there will be listed physics goals of DAΦNE-VE and planned events. In particular we would encourage experts and all interested physicists in participation in open meetings where the physics case and feasibility will be discussed. The project status and the results will be presented on particle and nuclear physics conferences. The final report will be published electronically as an open access document.

3.2.1 Management of intellectual property

The principles for dissemination, access and use of knowledge generated through the project will fully comply with the *Rules for participation in FP7 and for dissemination of research results*. Results from work carried out under the project shall be the property of the participant carrying out. Where several participants have jointly carried out work generating Foreground, they shall have joint ownership. The final report for the conceptual design will be signed by all participants.

4 Ethics Issues

	Research on Human Embryo/ Foetus	YES	NO
*	Does the proposed research involve human Embryos?		x
*	Does the proposed research involve human Foetal Tissues/ Cells?		x
*	Does the proposed research involve human Embryonic Stem Cells (hESCs)?		x
*	Does the proposed research on human Embryonic Stem Cells involve cells in culture?		x
*	Does the proposed research on Human Embryonic Stem Cells involve the derivation of cells from Embryos?		x

	Research on Humans	YES	NO
*	Does the proposed research involve children?		x
*	Does the proposed research involve patients?		x
*	Does the proposed research involve persons not able to give consent?		x
*	Does the proposed research involve adult healthy volunteers?		x
	Does the proposed research involve Human genetic material?		x
	Does the proposed research involve Human biological samples?		x
	Does the proposed research involve Human data collection?		x

	Privacy	YES	NO
	Does the proposed research involve processing of genetic information or personal data (e.g. health, sexual lifestyle, and ethnicity, and political opinion, religious or philosophical conviction)?		x
	Does the proposed research involve tracking the location or observation of people?		x

	Research on Animals	YES	NO
	Does the proposed research involve research on animals?		x
	Are those animals transgenic small laboratory animals?		x
	Are those animals transgenic farm animals?		x
*	Are those animals non-human primates?		x
	Are those animals cloned farm animals?		x

	Research Involving Developing Countries	YES	NO
	Does the proposed research involve the use of local resources (genetic, animal, plant, etc)?		**x**
	Is the proposed research of benefit to local communities (e.g. capacity building, access to healthcare, education, etc)?		x

	Dual Use	YES	NO
	Research having direct military use		x
	Research having the potential for terrorist abuse		x

Other Ethical Issues	YES	NO
Are there **OTHER** activities that may raise **Ethical Issues**?		x

If **YES** please specify:

ANNEX 1

Here below we report the full list of the scientists who expressed interest in this project

Michelangelo AMBROSIO, INFN
Danilo BABUSCI, INFN
Giovanni BENCIVENNI, INFN
Monica BERTANI, INFN
Caterina BLOISE, INFN
Fabio BOSSI, INFN
Paolo BRANCHINI, INFN
Paolo CIAMBRONE, INFN
Alberto CLOZZA, INFN
Riccardo DE SANGRO, INFN
Alessandro DRAGO, INFN
Giulietto FELICI, INFN
Fabio G. FORTUGNO, INFN
Alessandro GALLO, INFN
E. GRAZIANI, INFN
Gino ISIDORI, INFN
Catia MILARDI, INFN
Stefano MISCETTI, INFN
Marco MIRAZITA, INFN
Dario MORICCIANI, INFN
Massimo PASSERA, INFN
Antonio PASSERI, INFN
Miro PREGER, INFN
Pantaleo RAIMONDI, INFN
Claudio SANELLI, INFN
Paolo SANTANGELO, INFN
Bruno SPATARO, INFN
Sandro TOMASSINI, INFN
Graziano VENANZONI, INFN
Mikhail ZOBOV, INFN

Hans CALEN, UPPSALA
Kjell FRANSSON, UPPSALA
Andrzej KUPSC, UPPSALA
Marek JACEWICZ UPPSALA
Tord JOHANSSON, UPPSALA
Stefan LEUPOLD, UPPSALA
Pawel MARCINIEWSKI, UPPSALA
Christoph REDMER, UPPSALA
Roger RUBER, UPPSALA
Magnus WOLKE, UPPSALA
Volker ZIEMANN, UPPSALA

Eryk CZERWINSKI, Uniwersytet Jagiellonsi
Jacek GOLAK, Uniwersytet Jagiellonsi
Andrzej HECZKO, Uniwersytet Jagiellonsi
Marcin KAJETANOWICZ, Uniwersytet Jagiellonsi
Janusz KONARSKI, Uniwersytet Jagiellonsi
Konrad LOJEK, Uniwersytet Jagiellonsi

Wojciech MIGDAL, Uniwersytet Jagiellonsi
Pawel MOSKAL, Uniwersytet Jagiellonsi
Witold PRZYGODA, Uniwersytet Jagiellonsi
Zbigniew RUDY, Uniwersytet Jagiellonsi
Piotr SALABURA, Uniwersytet Jagiellonsi
Roman SKIBINSKI, Uniwersytet Jagiellonsi
Jerzy SMYRSKI, Uniwersytet Jagiellonsi
Agnieszka WACH, Uniwersytet Jagiellonsi
Aleksandra WRONSKA, Uniwersytet Jagiellonsi

Bronislaw CZECH, INPP, Cracow, Poland
Stanislaw KLICZEWSKI, INPP, Cracow, Poland
Adam KOZELA, INPP, Cracow, Poland
Pawel KULESSA, INPP, Cracow, Poland
Krzysztof PYSZ, INPP, Cracow, Poland
Regina SIUDAK, INPP, Cracow, Poland
Antoni SZCZUREK, INPP, Cracow, Poland
Zbigniew WAS INPP, Cracow, Poland

Henryk CZYZ, University of Silesia, Katowice, Poland
Janusz GLUZA, University of Silesia, Katowice, Poland
Michal GUNIA, University of Silesia, Katowice, Poland

Anna KOWALEWSKA, A. Soltan Institute for Nuclear Studies, Warsaw, Poland
Rafal MOZDZONEK, A. Soltan Institute for Nuclear Studies, Warsaw, Poland
Wojciech WISLICKI, A. Soltan Institute for Nuclear Studies, Warsaw, Poland

Sergiy IVASHYN, Akhiezer Institute for Theoretical Physics, Ukraine

Kai HOCK, University of Liverpool
Thomas TEUBNER, University of Liverpool
Andrzej WOLSKI, University of Liverpool

German RODRIGO, Agencia Estatal Consejo Superior De Investigaciones Cientificas
Toni PICH, Agencia Estatal Consejo Superior De Investigaciones Cientificas
Jorge PORTOLES, Agencia Estatal Consejo Superior De Investigaciones Cientificas

Alaa DBEYSSI, IPNO, Orsay
Egle TOMASI, IPNO, Orsay
Saro OMG, IPNO, Orsay

Qingjun XU, Hangzhou Normal University

Kurt AULENBACHER, MAINZ
Sebastian BAUNACK, MAINZ
Achim DENIG, MAINZ
Frank MAAS, MAINZ
Harvey MEYER, MAINZ
Marc VANDERHAEGHEN, MAINZ
Hartmut WITTIG, MAINZ

Joahnnes BLUEMLEIN, DESY
Tord RIEMANN, DESY

Francisco CAMPANARIO, KARLSRUHE

Johann KUEHN, KARLSRUHE

Karol KAMPF, PRAHA
Marian KOLESAR, PRAHA
Jiri NOVOTNY, PRAHA
Martin ZDRAHAL, PRAHA

A.BOGOMYAGKOV, BINP
S.EIDELMAN, BINP
G.FEDOTOVICH, BINP
E. LEVICHEV, BINP
P.LUKIN, BINP
I.OKUNEV, BINP
P.PIMINOV, BINP
D.SHATILOV, BINP
B. SHWARTZ, BINP
S.SINYATKIN, BINP
P.VOBLYI, BINP

Yury BYSTRITSKIY, DUBNA
V. BYTEV, DUBNA
E. A. KURAEV, DUBNA