# 35th MEETING OF THE LNF SCIENTIFIC COMMITTEE FINDINGS AND RECOMMENDATIONS



The primary focus of the 35th meeting was the status and near future of the upgraded DAΦNE collider and the experimental program that will exploit the higher luminosities expected from the upgrade.

The Committee also completed its first broad review of the LNF external program, by hearing overviews of particle, astroparticle and nuclear physics work at the LNF, by the representatives in the three respective National Scientific Committees, CSN-1, CSN-2 and CSN-3.

Two presentations highlighted the increasing importance of FEL research at the Lab. An expert from this field, J. Rossbach, took part in the 35th meeting and will join the Committee.

## 1 DAΦNE AND ITS EXPERIMENTS: STATUS AND PLANS

Three collaborations (AMADEUS; FINUDA, KLOE) wish to take data at the upgraded collider, after the end of SIDDHARTHA data taking. Two of them have presented detector roll-in proposals. The Committee expects to make specific recommendations about these initiatives and their interplay as the first results of the luminosity upgrade program become available, around the time of its 36th meeting, on 21 and 22 May 2008.

### 1.1 DAΦNE UPGRADE

The end of the last DAΦNE run for the FINUDA experiment followed shortly after the last Committee meeting; therefore only progress with the DAΦNE upgrade installation for the SIDDHARTA run and plans for the next year were discussed at this meeting.

Both interaction regions in DAΦNE have been rebuilt and a number of new hardware items have been installed or modified. The benefits of the new injection kickers are clear. It is worth noting that some of the changes amount to simplifications. The Accelerator Department is to be congratulated for carrying out this work efficiently and completing it on time. Our visit to the machine hall confirmed the impression of a rejuvenated machine ready to enter a new phase of operation.

There were rather few problems in the installation. A polarity error in the manufacture of the outer (smaller) quadrupoles of the low-beta doublet necessitated some machining and repositioning of permanent magnet elements. The resulting non-uniform longitudinal gradient profile and field quality have been measured and are considered acceptable in the Accelerator Department.

Commissioning of the new collision scheme will proceed in stages, starting with the crab-waist sextupoles switched off; a gain in luminosity is expected from the large crossing angle alone. The sextupoles will be gradually excited and any undesired secondary effects compensated. Among these the closed-orbit at the sextupoles will need special attention; we learned that high precision, remotely movable supports may be available from SLAC and suggest considering their installation as soon as feasible.

Simulations indicate that the optimum luminosity conditions occur with the crab-waist sextupole strength at 60-80% of the value required by the analytical crab-waist compensation criterion. The present installation provides less than half this strength. However it was stated that the necessary hardware was on hand to upgrade the power supplies, or replace the sextupoles by larger ones, when required. The Committee expects that this will be necessary.

Weak-strong beam-beam simulations have been used to scan the tune diagram and confirm the luminosity gain by exciting the crab-waist sextupoles. New strong-strong beam-beam simulations also predict a luminosity gain and have not given any indications of coherent beam-beam or “flip-flop” phenomena so far. However these simulations are very time-consuming and it has not been possible to investigate many possible operating conditions (coherent instability can be expected in bands of tune that widen as the beam-beam strength parameters are increased).

There are very plausible indications that the positron current limit in DAΦNE was due to RF losses heating one of the vacuum bellows that has now been replaced with a new simplified design. This may yield an increase in positron current but a similar limit may soon be encountered at one of the remaining bellows of the old type.

The scheme of colliding beams with large Piwinski angle and crab-waist compensation has attracted great interest and much hinges upon the demonstration of its potential to yield an integrated luminosity of ~5 $fb^{-1}$/year from DAΦNE. We reiterate our previous recommendation that the commissioning must be undertaken systematically, in stages with clear, pre-defined objectives, and with due time given to analysis and understanding of the new mode of operation.

Following the SIDDHARTHA run, a further series of upgrades is envisaged for operation from autumn 2008. Some of these, such as the cryoplant upgrade and abort kickers are clearly necessary. It may turn out to be necessary to replace the remaining bellows of the old type with new design for the reason mentioned above. The independent injection transfer lines should provide a substantial gain in integrated luminosity in a straightforward way. Finally, the reshaping of the wiggler poles should improve beam lifetime and save a substantial quantity of energy.

Operational experience will clarify the value of work on the bellows and wiggler poles. Together with resource allocation and planning for the next shutdown, this will allow a final prioritization of the list of upgrade items.

Unlike SIDDHARTHA, future experiments will superimpose an experimental solenoid on the new interaction region and require a strategy for betatron coupling compensation. The plan is to tilt the inner low-beta quadrupole to a fixed, pre-calculated angle. However this angle depends on the solenoid field. It should be clarified whether the experiment will require any changes of the field and, if so, what the implications would be.

### 1.2 FINUDA

The FINUDA Collaboration has collected the expected integrated luminosity of ~1 $fb^{-1}$. We acknowledge the effort made by the FINUDA Collaboration on both calibration and analysis in order to present preliminary results using the entire data set. The calibration and alignment are already in good shape and FINUDA is not far from obtaining its ultimate momentum resolution.

The results on hypernuclei are already interesting and the Committee is eager to see corrected spectra. On the DBKS side, the analysis of Λp final states with an acceptance increased with respect to the published analysis and with different targets provides new input for understanding this physics. The Committee would like to know the uncertainty on the acceptance. We also acknowledge the rapid preliminary results on Λt associated production and we are waiting for the outcome of a detailed analysis.

A few days before the meeting, the Committee received a letter from FINUDA expressing the intention to take additional data at DAΦNE in fall 2008, in order to benefit from the period before the start of JPARC.

In order to discuss this in depth, the Committee, asked FINUDA for a written proposal addressing the following points:

- the physics case(s) for a new run, in particular compared to the results already obtained;
- the impact of the FINUDA results, with and without more data, *vis-à-vis* international competition;
- the integrated luminosity needed in order for a new run to have significant impact;
- the apparatus and DAQ modifications needed to run in the new interaction region and with higher luminosity.

While remarking that further progress on data analysis, together with theoretical help, would strengthen the case for more data, the Committee suggested that the new proposal should be received by Feb. 15, 2008. (These points were made in a letter sent by the SC chair to Vincenzo Lucherini, FINUDA spokesperson, a few days after the 35th meeting).

### 1.3 SIDDHARTA

The Committee continues to be impressed by the progress reported and the technical achievements made in preparations for the SIDDHARTA experiment. The kaon trigger, which will also be used to monitor the luminosity, is ready to be installed at the SIDDHARTA interaction interface. The testing of 230 $cm^2$ SDDs has been completed. All hardware is in hand with the exception of the HV/LV supplies, which will arrive in December 2007.

The work schedule foreseen is as follows. The first measurements with a kaon trigger and a small subset of the SDDs (12 $cm^2$) can begin by mid January 2008. Phase 1 of the experiment with the full SDD setup can follow in March 2008, aiming at a much-improved signal-to-background ratio.

The simulations performed by the group convincingly suggest that the energy shift and width in kaonic hydrogen can be measured with a precision of a few eV. For kaonic deuterium, the expected accuracy for the energy shift and width is several tens of eV. The deuterium measurement is the very first of its kind and is crucial in order to have a complete determination of the kaon-nucleon scattering lengths in both isospin channels. These precision results are of great significance for setting constraints on the theory of low-energy kaon-nucleon interactions, which in turn have a strong impact on discussions concerning the extrapolation of these interactions into the sub-threshold range potentially relevant for quasi-bound antikaon-nuclear clusters.

The luminosity requirements are 100 $pb^{-1}$ for setup and tuning, 400 $pb^{-1}$ for the precision measurement of kaonic hydrogen and 600 $pb^{-1}$ for the first measurement of kaonic deuterium. Options for the further future include high-statistics measurements of kaonic $^3$He and $^4$He and other light kaonic atoms.

The Committee again congratulates the SIDDHARTA group again for their highly professional performance. A two-page progress report and a presentation are expected at the next meeting of the Committee.

## 1.4 KLOE AND KLOE-2

A major topic at previous meetings was the issue of manpower, and in particular, the challenge of both pursuing the KLOE analysis and preparing the upgraded experiment in spite of a risk of personnel on time-limited contracts moving to careers elsewhere. The situation does not look critical at this time. As is the case everywhere, there are areas where more effort is needed, and analysis topics where new PhD students would be welcome. Nevertheless, in general the situation does not look problematic.

The Committee acknowledges the beautiful work by KLOE on precision physics in the flavour sector, and in particular notes the following.

- The previous studies and the upcoming publications on semileptonic ($K_L \rightarrow \pi e \nu \gamma$ and $K_L \rightarrow \pi \mu \nu$) kaon decays lead to a competitive determination of $V_{us}$.
- The upcoming paper on the $K^+$ lifetime is definitely a major improvement in our knowledge of all charged kaon properties and consequently of $V_{us}$; the Committee congratulates KLOE for this result.
- The publication of the paper determining the branching ratio $K^+ \rightarrow \pi^+\pi^0(\gamma)$ is very welcome by the scientific community. The upcoming finalization of the papers determining the branching ratios and slopes for $\eta \rightarrow 3\pi$ decays may lead to an improved understanding of quark masses.
- KLOE is also congratulated for finalizing the studies that use the full data sample: $BR(K_S \rightarrow \gamma\gamma)$, $BR(K_S \rightarrow e^+e^-)$, $BR(K_{e2})/BR(K_{\mu 2})$ and $K_S$-$K_L$ interferometry. In particular, $BR(K_S \rightarrow \gamma\gamma)$ is a crucial test of chiral perturbation theory, which accurately probes the theory at a quantum level and offers the possibility of determining higher order contributions.
- New physics tests have been performed by measuring accurately the ratio $BR(K_{e2})/BR(K_{\mu 2})$.
- Very precise measurements of $\eta$ and $K^0$ masses, through very clever procedures, have been submitted for publication.

We also acknowledge the publication of the paper on the gluonium content in $\eta$ - $\eta'$ decays.

The high level of the physics contributions by the KLOE collaboration is also shown by their work within the FlaviaNet EU network for the determination of relevant kaon decay parameters (BRs, $V_{ud}$ and $V_{us}$, lifetimes).

The KLOE collaboration expects that two more years will be needed to complete the analysis of the data taken up to the end of 2005.

In time for discussion at the meeting, the collaboration submitted a proposal for the roll-in of the detector. The proposed two-phase procedure makes sense and the work is proceeding well.

The first phase, labelled step 0, is a minimal upgrade to allow KLOE to make full use of high-luminosity conditions by the end of 2008. For step 0, the plans are to insert the new interaction region, to install the new DAQ hardware components, to produce a minimal set of spare components for the front-end electronics, to upgrade the Computing System, and to install the external pair of $\gamma\gamma$-taggers. The most critical issue is the DAQ, and in particular the new CPUs. The needed resources are reserved and conditioned on the performance of DAΦNE. The Committee should be informed by the next meeting about the outlook for the step-0 DAQ capacity. For step 0, the Committee also needs to be informed about the work needed for a new beam pipe and the related modifications to the detector.

The Committee expects to make a recommendation regarding step 0 at its next meeting. Contacts between the KLOE representatives and its referees are foreseen a few weeks before that date.

The second phase, labelled step 1, is planned for fall 2009. The step-1 plans call for a new inner tracker, forward $\gamma$-vetos (CCAL) and new calorimeters (QCAL) around the forward quadrupoles, new readout for the electromagnetic calorimeter, internal pair of $\gamma\gamma$-taggers, and possible further upgrades of the computing and the front-end electronics.

The Committee learned for the first time about the ongoing R&D for the forward calorimeters, the CCAL and QCAL. This work looks promising and results are expected for the next Committee meeting.

A critical issue is the material in the inner tracker. The Committee stresses the importance of closely monitoring the material budget as tracker design, engineering and construction proceeds.

A detailed mechanical design for the central region is important at an early stage; this is necessary in order to fully understand the expected KLOE-2 performance and the constraints with regards to the possible cohabitation between KLOE-2 and the proposed AMADEUS program. The Committee encourages KLOE to explore this collaborative scenario.

KLOE-2 is an ambitious experiment that will produce a large part of the physics expected from the upgraded accelerator. It is important for its success that it is seen as a priority program for the laboratory.

### 1.5 THE AMADEUS PROPOSAL

The pre-AMADEUS feasibility study, examining $K^-$ $^4$He data taken by KLOE (one *per mille* of the $K^-$ stopped in the KLOE chamber) has been remarkably successful. The analysis up to this point includes very precise Λ selection and detection of Λp and Λd pairs based on 400 $pb^{-1}$ of integrated luminosity.

The capability for analyzing Λp and Λd final states in a broad kinematical range with high acceptance is convincingly demonstrated. There is the additional option of identifying and analyzing the accompanying neutrons in order to fully control the kinematics, a condition which is mandatory for drawing conclusions about the existence (or non-existence) of quasi-bound kaon-nuclear clusters. So far, only one fifth of the integrated luminosity has been analyzed; hence further results can be expected. The Committee would like to see, in its next meeting, a presentation of further results on the physics potential of the AMADEUS project.

AMADEUS proposes to operate in two phases.

In phase 1 (beginning by the end of 2009 after phase 0 of KLOE-2) a first, low-mass $^3$He/$^4$He cryogenic target and trigger system would be inserted into the interaction region. The aim would be to measure complete sets of final states involving kaonic di- and tri-baryon systems, primarily in order to clarify the possible existence of quasi-bound antikaon-nuclear clusters, but also, at the same time, to provide a precision data set for low-energy kaon-nuclear physics at a new level of quality.

The detector-related items (including the beam pipe, slow controls, DAQ, software and hardware) are being developed in contact with KLOE and DAΦNE. Tests of scintillating fibers and APDs for the trigger are ongoing at the SMI in Vienna. A Monte Carlo simulation has been presented, based on the assumption of an optimistic "strong binding" scenario for antikaon-nuclear clusters with small width. The group is urged to perform such simulations also for (potentially more realistic) "weak binding" scenarios for comparison.

The integrated luminosity required for the entire first phase program would be 3.5 to 4 $fb^{-1}$.

A second phase is proposed to take place after 2010, with a new cryogenic target and tracking system. In this phase, the collected integrated luminosity would be much higher, 10-20 $fb^{-1}$. The physics program would be extensive, including systematic spectroscopy of a broad range of antikaon-nuclear systems.

The Committee is favorably impressed by the potential of the AMADEUS proposal, which has already been demonstrated in part by the feasibility study with part of the KLOE data and by the studies of the neutron detection efficiency of the KLOE calorimeter.

Before it can make any recommendations, the Committee thinks that the AMADEUS collaboration should further address the following issues.

- Cohabitation with KLOE-2: A collaborative scenario should be further explored.
- Timing: In the proposed two-phase scenario – with the second phase taking place after a substantial KLOE-2 run – the time between the two phases may be quite long.

Furthermore, every change of beam pipe and beam pipe detectors involves technical risks. The two-phase scenario needs further justification.

The Committee would also like to have more information on the human and technical resources that will be contributed by the large international collaboration signing the AMADEUS proposal.

The Committee assigned referees to the proposal (F. Linde, M. Cavalli-Sforza) and expects to receive further information on the project's progress a few weeks before its next meeting.

# 2 THE EXTERNAL PROGRAM: STATUS

The activities in the larger CERN-related experiments (ATLAS, CMS, LHCb, OPERA) were reviewed in the 34th meeting. Therefore the Committee focussed on the other components of the LNF external activities.

## 2.1 PARTICLE PHYSICS (CSN-1)

Particle physics activities under the supervision of CSN-1 are typically at the energy or luminosity frontier; they account for about 1/3 of the Research Division's personnel.

The presentation offered a clear view of this sector, highlighting the distribution of efforts. Of the 75 FTEs (physicists + engineers) contributing to CSN-1 research, about 77% are in KLOE or one of the three large LHC collaborations. The rest work on BABAR (7.5 FTE), CDF II (4.6 FTE), P326 (3.2 FTE) and P-ILC (2.0 FTE).

The two US-based experiments, BABAR and CDF, will end in the near future, thus posing a question of redirection of efforts within the Lab. This issue is expected to come up again in future SC meetings.

The prospects for enhanced computing facilities – essentially a Tier-2 level centre – appear to have improved since the last meeting.

## 2.2 ASTROPARTICLE PHYSICS (CSN-2)

Astroparticle physics at LNF is pursued both in large experiments and in smaller collaborations, which often involve state-of-the-art technologies and sophisticated and successful detectors.

Among the latter, the laboratory has had a very visible role in the search for gravitational waves with cryogenic detectors (reviewed at the 32nd meeting of the Committee), and has a strong program in experiments in space such as LARES (on the Lense-Thirring effect) and the recently launched cosmic-ray satellite PAMELA.

In addition, CSN-2 activities include experiments with neutrino beams. An update of the status of OPERA confirmed that emulsion brick production will be completed in mid-2008.

## 2.3 NUCLEAR PHYSICS (CSN-3)

Activities under the umbrella of CSN-3 span atomic physics, nuclear physics and hadron structure. These activities are represented at LNF by eight groups, of which two work at DAΦNE (FINUDA and SIDDHARTA), while the others have been working at HERA (HERMES), JLAB (CLAS–AIACE group), and ESRF (GRAAL, on photoproduction). One group has a large involvement in building the EM calorimeter for ALICE at the LHC, while another one prepares for PANDA at FAIR. A small experiment uses the low-background environment of LNGS to look for atomic transitions forbidden by the Pauli exclusion principle.

From this rapid review of the external laboratory activities, the Committee gained the impression of a vital if somewhat fragmented research environment. As pointed out by the open-session speakers, several of the national spokespersons of the external activities, which typically involve several Italian institutions, are from LNF.

## 3. FEL AND RELATED RESEARCH AT LNF

In the open session, two presentations were given on this rapidly growing sector of LNF activities: one on the status and plans of SPARC, a 530 nm FEL currently being commissioned; and one on the plans for SPARX, an X-ray FEL that will be built on the grounds of Roma 2 at Tor Vergata.

### 3.1 SPARC

An excellent team has been formed around the SPARC project, and world-class results have already been obtained in generating an electron beam with ultra-small emittance and in the experimental verification of the predicted beam dynamics behaviour. The further experimental programme is exciting, and it addresses many of the most relevant issues.

While all the activities are of worldwide interest, the relevance of the respective sub-tasks in view of the SPARX project is different. In case of conflict of resources, the LNF management may wish to decide whether SPARC is considered a stand-alone scientific enterprise with its own agenda, or rather a pilot project for the preparation of SPARX. In the latter case, the following priority order would be recommended.

1. Minimum electron beam emittance and its preservation through compression
2. FEL seeding, High Gain Harmonic Generation
3. FLAME plasma wakefield acceleration
4. Compton backscattering.

It is emphasized that this is not a priority list in terms of general scientific relevance or originality but refers to the SPARX project.

Although the SPARC hardware is to a large extent already built, it will require continuous support and some priority within the Lab. Due to the novelty and research character of the installation, it is likely that the need to complement SPARC with new measurement devices will arise from the operation of SPARC, for example, devices for improved control in the time domain with femtosecond resolution.

The output of SPARC could be significantly increased by encouraging the growth of a pilot user group that would perform research at an attractive wavelength accessible by SPARC, for example, at approximately 100 nm. Such a wavelength might be accessible through a higher FEL harmonic or by harmonic seeding. As a result, an on-site FEL user culture would grow, which in turn would train the SPARC team in responding to user needs when operating the FEL. Both aspects would be most beneficial in view of SPARX.

### 3.2 SPARX

For further planning, it is important that the Technical Design Report (TDR) now under preparation be completed soon. Based on this, a detailed resource planning step must follow. Generally speaking, it should be clear that SPARX will have to be built mainly by people already present in the Lab, complemented by their collaborators. In terms of the capacities of the Lab this does not look unrealistic, but it will require clear definitions of priorities.

SPARX may need the strong involvement of many of the persons currently working in particle or nuclear physics activities. This is mainly for two reasons: first, on the world market there are not enough accelerator experts to be hired; and second, a team formed from scratch would need too much time before rising to the challenge of building SPARX. On the other hand, the SPARC team would certainly represent a suitable nucleus for building up the SPARX team.

In view of the construction of SPARX and its operation, there are two expert teams that should be built up within the Lab:

1. A photon diagnostics group, capable of characterizing the FEL photon beam, in close collaboration with the accelerator people, and to build the photon beam lines transferring the photon beam from the FEL undulator to the various user stations.

2. A laser group ("classical" lasers) to design and operate the considerable number of lasers needed to operate the accelerator. According to present-day understanding, only a system entirely based on lasers will be capable of controlling the timing and beam parameters of an XFEL at the level of few femtoseconds. Of course, this expertise will also be needed immediately by future FEL users (timing, pump-probe experiments).

The approach involving a 1 pC/1 fs electron bunch with 0.05 mrad mm normalized emittance, mentioned in the open session, needs more detailed investigation in order to be a credible option for SPARX. In particular, technology issues would have to be addressed: how can such a beam be verified and controlled? How can one measure such small charges and emittances? What are the RF phase stability requirements and how can they be met?

At a more general level, in view of the importance of the FEL line of work but also of its interaction with other activities of the Accelerator Division, a presentation by the Lab management explaining the plans for the various projects and the allocation of lab resources for the next 3-5 years would be welcome. This presentation should preferably be given within a closed session of the Committee.