Title of the Workshop:

Hadronic Atoms and Kaonic Nuclei

solved puzzles, open problems and future challenges in theory and experiment

Organizers: Catalina Curceanu (Petrascu) – LNF–INFN, Frascati (Italy)

Carlo Guaraldo – LNF-INFN, Frascati (Italy)

Paul Kienle – TU München (Germany)

Johann Marton – SMI, Vienna (Austria)

Wolfram Weise – TU München (Germany)

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Scientific Proposal:

Hadronic atoms and the kaonic nuclear states are extremely valuable tools for studying fundamental interactions and symmetries in a fairly direct way, complementing the high energy physics studies performed at LHC and elsewhere. Important information regarding the low-energy, non-perturbative, regime of QCD can be gained from these types of experiments, as will be shown later.

Since the pioneering days, decades ago, new technologies (in accelerators and detectors) were developed in order to perform precision experimental studies in order to clarify open issues (such as still existing discrepancies between experiment and theory in kaonic atoms or the quest for kaonic nuclear clusters) and to extract new hadronic atom data with unprecedented accuracy. One can say that the field is experiencing a happy coincidence in which the progress achieved in accelerator physics is paralleled by the advances in detector physics.

Since the very successful 2006 ECT* Workshop on *"Exotic hadronic atoms, deeply bound kaonic nuclear states and antihydrogen"* new results (e.g. precision data on the KHe-4 Balmer X-rays, high accuracy data on pionic hydrogen and deuterium) were found and new developments in experimental and theoretical research are under way. This workshop will bring together international experts in the research area of hadronic atoms and kaonic nuclear states, working on theory as well as on experiments, to discuss the present status, to develop new methods of analysis and to have the opportunity for brainstorming towards future studies.

Going more in detail into the physics motivations, the low-energy interactions of the lightest pseudoscalar mesons (pions and kaons) with nuclear systems are basically dictated by the spontaneous chiral symmetry breaking of QCD. Important information related to the mechanism of chiral symmetry breaking (spontaneous and explicit) can be obtained from the study of exotic hadronic atoms and from exploring the possible existence of bound antikaon-nuclear states, the latter being a very hot issue presently.

An exotic hadronic atom is formed whenever a hadron (pion, kaon, antiproton) from a beam enters a target, is stopped inside and replaces an orbiting electron. Such exotic atoms are usually formed in a highly excited state; a process of de-excitation through the respective atomic levels follows. The X-ray transitions to the lowest orbits (1s) are affected by the presence of the strong interaction between the nucleus and the hadron. This is translated into a shift of the 1s level with respect to the purely electromagnetic-based calculated value and by a limited lifetime (width) of the level. Extracting these quantities, via the measurement of the X-ray transitions, provides fundamental information on the low-energy hadron-hadron and hadron-nuclear interactions. Quantities such as pion-pion, pion-nucleon or kaon-nucleon scattering lengths turn out directly accessible by measuring properties of exotic atom. Further on, these quantities are important milestones to deal, in a unique way, with some important aspects of chiral symmetry breaking. Although the field of exotic atoms has a long history, it is very active, both from the experimental and from the theoretical point of view. On the experimental side, new "hadronic" beams became available recently (kaons at DAFNE) or will become available in 2009 (J-PARC facility), while new detectors with improved performance (better energy resolution, stability, efficiency, trigger capability) are starting to operate. On the theoretical side the field has advanced significantly through recent developments in chiral effective field theories and their applications to hadron-nuclear systems.

Experiments at PSI, DAΦNE, CERN, KEK are delivering yearly new results with steadily increasing precision, so that theoreticians can cope with items not accessible till very recently and realize important progress in the understanding of basic features of low-energy QCD.

The kaonic hydrogen was measured by the DEAR Collaboration (on DAΦNE) with an unprecedented precision, leading to a lively debate on the kaon-proton scattering length extraction procedure, and on the compatibility with existent kaon-nucleon scattering data. The SIDDHARTA experiment will perform in early 2009 an even more precise measurement and will complement it with the kaonic deuterium measurement; the results will be presented and discussed at the Workshop. Kaonic helium was measured at KEK recently (E570 experiment) – solving the "kaonic helium puzzle", while new experiments are planned at JPARC in the near future (E17) to measure kaonic Helium on 3He. The DIRAC Collaboration measured the pionium lifetime, which gives the |a0-a2| combination of scattering lengths for pion-pion scattering in a model-independent way; |a0-a2| was measured as well by NA48 in Ke4 decay; DIRAC is presently analyzing data from measurements performed in 2008 on kaonic pionium exotic atoms – the first time ever such measurements are being performed and which are going to be discussed at this Workshop. At PSI a series of successful pionic atoms measurements have been performed while at CERN antihydrogen studies are being continued.

Future experiments are already planned at existent and/or future machines (GSI, J-PARC, DAFNE-upgraded). The future of exotic hadronic atoms will reach new horizons – in precision and in dealing with new types of exotic atoms, never measured before, such as kaonic deuterium, or sigmonic atoms. A brainstorming in this direction will be organized during the Workshop, in order to push for the next generation experiments and motivate accelerator projects in this direction, and to discuss theoretical issues.

Another hot item to which this workshop is dedicated, deals with the recently studied "*Kbar -mediated bound nuclear systems"*, with first (contradictory) experimental indications being produced at KEK, LNF, BNL and GSI. It was originally suggested that in the few-body nuclear systems the (strongly attractive) isospin I=0 Kbar-N interaction can favor the formation of *discrete and narrow Kbar- nuclear bound states with large binding energy (100 MeV or even more)* , while contracting the nucleus thus producing a *cold dense nuclear system.* Recent theoretical works suggest, however, that such deeply bound kaonic nuclear states do not exist: antikaon-nuclear systems are only weakly bound and very short-lived. Different interpretations for the existing experimental results are given, based for example on the interaction of negative kaons with two or more nucleons. This topic has important consequences in astrophysics as well – in the physics of the neutron stars for example.

The presently available experimental results will be reviewed (KEK experiments. FINUDA at DAFNE, FOPI, BNL, OBELIX, Dubna experiments, DISTO at Saturne), together with a critical discussion of current theories/models. Future perspectives at J-PARC (E15, E17); GSI (upgrade of FOPI and HADES) and DAΦNE (AMADEUS experiment) will be discussed in the framework of an integrated strategy in which complementary facilities should bring together the various pieces of the puzzle.

Interconnections between the physics of bound kaonic nuclear systems and of the exotic atoms will be analyzed.

The workshop is intended to gather about 30-40 of the world-leading experimental and theoretical experts in the field, to perform a detailed exchange of information, to discuss the existent results and to contribute to the future of this field. Last but not least, the meeting will attract young scientists and students, providing a state-of-the-art overview of the field of hadronic atoms and kaonic nuclear states.

Outline of the program:

- Hadronic atoms – theory and phenomenology
- Cascade calculations for hadronic atoms transitions
- Meson-meson and meson-nucleon scattering status
- Lattice QCD calculations and low-energy effective theories
- Deeply bound meson-nuclear states: theoretical status
- Antiprotons as hadronic probes
- Experimental results:
    - DIRAC at CERN
    - DEAR and SIDDHARTA at DAFNE
    - Pionic atoms at PSI
    - Ke4 decay with NA48 at CERN
    - Deeply bound mesonic nuclear states:
    - E471 at KEK
    - E549 and E570 at KEK
    - FOPI at GSI
    - FINUDA at DAFNE
    - E 930 at BNL
    - OBELIX results
    - Dubna results
    - DISTO at Saturne

- Next-generation experiments
    - Experiments at GSI: upgrade of FOPI and HADES
    - Experiments at DAFNE-upgrade: AMADEUS and future plans; SIDDHARTA; FINUDA upgrade
    - E15and E17at J-PARC
    - Facility for low-energy antiproton and ion research: FLAIR at GSI

Prospects for outside funding: from INFN, SMI and FP7 HadronPhysics