Searches for permanent electric dipole moments in Radium isotopes

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Experiments Committee for experiments with HIE-ISOLDE

Searches for permanent electric dipole moments in Radium Isotopes

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Abstract

Permanent electric dipole moments are uniquely sensitive to sources of T and P violation in fundamental interactions. In particular radium isotopes offer the largest intrinsic sensitivity. We want to explore the prospects for utilizing the high intense beams from HIE-ISOLDE to boost the statistical sensitivity of search for EDMs in atomic radium.

Physics Case

Fundamental symmetries are at the core of the Standard Model of the electroweak interactions. They can be tested at low energies in atomic physics precision measurements complementary to high energies which are available at accelerators such as LHC. Our group is active in the field of low energy tests of Parity (P) and time reversal (T) symmetries. Of particular interest are searches for permanent electric dipole moments (EDM). Any observation of a non-zero EDM would require CP violation beyond the Standard Model. Time reversal and parity violating permanent electric dipole moments are strongly enhanced in neutral radium due to its nuclear and atomic structure [1]. Experimental activities have started at Argonne National Lab, Il, USA [2] and at the KVI, Groningen, NL [3].
The experiment requires large numbers of laser cooled and trapped atoms. We have developed a novel and efficient laser cooling and trapping scheme suited for heavy alkaline earth metals [4]. This is currently implemented for the efficient collection of radium from a thermal source into a magneto optical trap. The dependance on the nuclear structure of the isotopes is the focus of a HIE-ISOLDE LOI on octupole collectivity in odd-mass Rn, Fr and Ra isotopes [5].

The design of the EDM experiment requires frequent access to radium isotopes for debugging of the apparatus and studies of systematics. The dedicated TRIμP facility at KVI, where sufficient beam time is available, offers an ideal environment for the development of the experimental techniques, which

include the radium atom source, the optical trapping and cooling and the measurement of the electric dipole moment in a controlled magnetic and electric filed. The final sensitivity of the experiment will depend on the intensity of radium beams and the availability of several isotopes in order to quantify nuclear and atomic structure effects in P and T violating processes. The large range of different isotopes, in particular neutron rich isotopes, and the high yields make HIE-ISOLDE an ideal place for such activities.
With this letter of intent we want to explore the possibilities to use HIE-ISOLDE radium beams to provide the best limit on nuclear permanent electric dipole moments.

Experimental setup

The setup to slow an atomic beam of radium and trap it in a magneto optical trap (MOT) and the EDM measurement is being developed at the TRIμP facility at KVI. The interface to radium ion beams from HIE-ISOLDE is shown in Fig. 1. The conversion to an atomic beam will utilize an accumulation cell which can be heated to 900 K in order to create an effusive atomic beam. This design decouples the time structure of the HIE-ISOLDE beams from the experiment. The accumulation time should not be longer than the isotope lifetime. This permits different operation modes for the short lived isotope (^{213}Ra) and longer lived isotopes (e.g. ^{225}Ra). Isotopes with lifetimes of several days can be accumulated for some amount of time and slowly extracted from the effusive atomic beam. In the latter case the Ra-EDM experiment is decoupled from the operation cycle of HIE-ISOLDE.

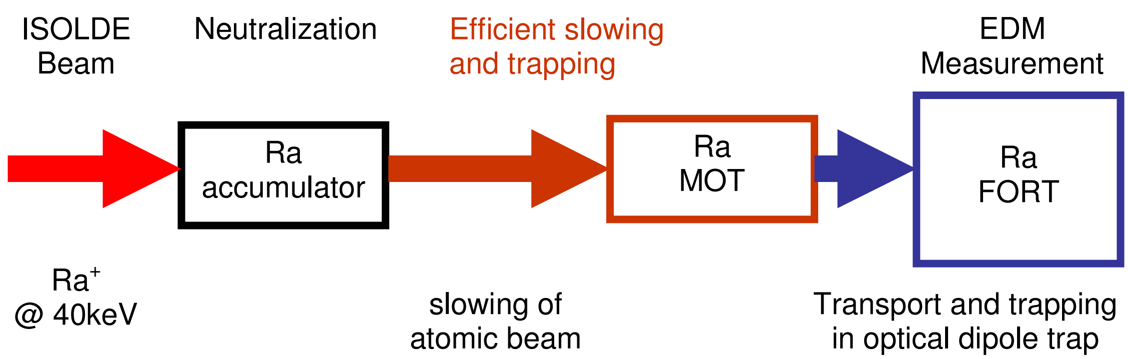

Figure 1: Schematics of the experimental setup. The interface between ISOLDE and the Ra-EDM experiment is a radium accumulator to convert the keV ion beam into a thermal atomic beam. This atomic beam is slowed by light forces and the atoms are trapped in a magneto optical trap (MOT). The cold and trapped atoms are further held in the focus of an intense laser beam (Far Off Resonant Trap, FORT). The distance from the accumulator to the MOT is 1 m. The floor space of the experiment is 10 m^2 and an additional 15 m^2 for a laser table.

Beam requirements

The experiment can be done with different isotopes which have a lifetime of more than several seconds. Of particular interest are ^{213}Ra and ^{225}Ra which both have a nuclear spin I=1/2. A low energy ion beam (40-60keV) will be converted into a low divergence atomic beam. The experiment itself does not depend on the time structure of the beam.
The contamination level of the beam is of minor importance for the experiment because of the high isotope selectivity of laser cooling and trapping but can be relevant in view of accumulated activity.

Safety aspects

The experiment requires a shielded environment because of the use of laser. The accumulated activity during a run depends on the isotope and the contaminations in the primary beam. The limits need to be evaluated.

References

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