Pair creation and annihilation with atoms and channeling nuclei

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We theoretically investigate different processes connected with pair production and annihilation in atoms and highly charged ions. These fundamental features include nuclear excitation by resonant positron annihilation (NERPA) and the electron-positron pair creation in heavy ion channeling.

In the annihilation of a positron with a bound atomic electron, the virtual photon created may excite the atomic nucleus. We put forward this effect as a spectroscopic tool for an energy-selective excitation of nuclear transitions [1]. This scheme can efficiently populate nuclear levels of arbitrary multipolarities in the MeV regime, including giant resonances and monopole transitions. NERPA constitutes a way to excite nuclei which is alternative to photo- and Coulomb excitation. It has an attractive combination of advantages of both methods: the resonant character of the excitation and a significant cross section regardless of the multipolarity. Furthermore, in certain cases, it has higher cross sections than the conventionally used Coulomb excitation and it can even occur with high probability when the latter is energetically forbidden. The resonant character of nuclear excitation by positron annihilation opens a way to investigate the structure of broad nuclear resonances. For instance, it allows to efficiently excite certain energy regions of a Giant Resonance (GR) in heavy nuclei. For certain GR, our predicted NERPA resonance strengths are 8 orders of magnitude higher than the largest NERPA resonance strengths investigated so far.

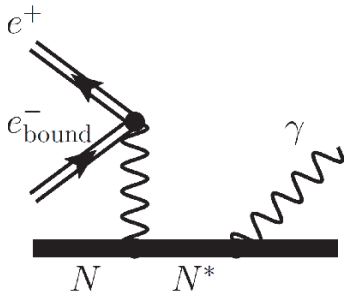

Figure 1: *Lowest-order Feynman diagram for NERPA followed by γ-emission.*

The time-reversed process, i.e. bound-free electron-positron pair production is a channel of monochromatic positron creation in nucleus-nucleus collisions. We suggest an alternative way to investigate this phenomenon by channeling of accelerated ions through a crystal. This scheme increases the pair production rate coherently and thus enhances the investigation of nuclear pair conversion [2]. It also allows to depopulate nuclei in metastable states, and convert the nuclear energy stored to electron-positron pairs. Pair creation by channeling ions can be also regarded as an extension of resonant coherent excitation of highly charged ions to higher frequencies and higher ion velocities, which has been investigated at the GSI before [3]. This novel channel of pair creation can be examined at the upcoming FAIR facility (see e.g. [3] and references therein) in the near future.

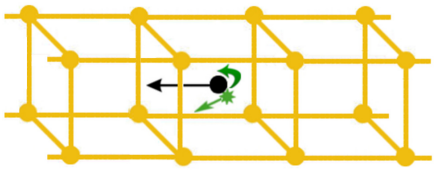

Figure 2: *Schematic view of electron-positron pair creation in heavy ion channeling.*

References

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[2] N. A. Belov, Z. Harman, submitted (2014); arXiv:1411.5711
[3] Y. Nakano *et al.* Phys. Rev. A **87** 060501 (2013)