**SPARC at FAIR: Quantum Dynamics in Extreme Electromagnetic Fields**

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Relativistic interactions with matter involving heavy high-Z ions provide a unique testing ground for our understanding of quantum electrodynamics and correlation in the non-perturbative regime as well as of elementary atomic processes mediated by ultrafast electromagnetic interactions. For this realm of physics, the future international accelerator Facility for Antiproton and Ion Research (FAIR) has key features that offer a range of novel challenging research opportunities [1]. The facility currently under construction will provide the highest intensities for relativistic beams of both stable and unstable heavy nuclei at high nuclear charge, in combination with the strongest possible electromagnetic fields, thus allowing to extend atomic spectroscopy virtually up to the limits of atomic matter. At the same time, experiments at relativistic beam energies are complemented by experiments at low beam energies (< 10 MeV/u) or even at rest but still at high charge state (see figure 1). This scenario is worldwide unique and will deliver high-accuracy data for bound state QED (avoiding Doppler shifts) as well as the determination of fundamental constants. In addition, atomic collisions can be studied in the non-perturbative, adiabatic regime, and even super-critical fields will get accessible.

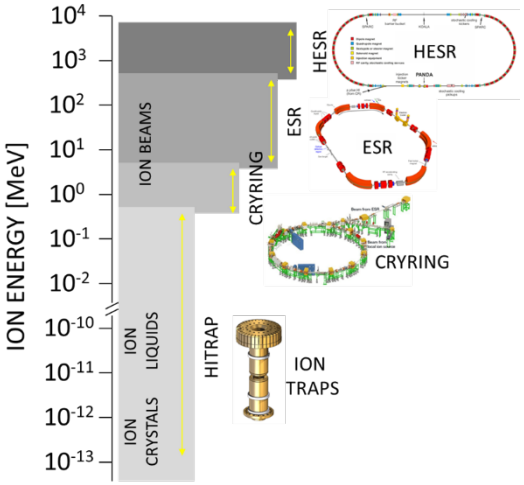


Figure: *Portfolio of storage and trapping facilities at FAIR*. Note, HITRAP, CRYRING, and ESR are already in operation or under commissioning.

In this talk, I will also review recent experimental results for atomic, quantum and fundamental research obtained at the already existing ion storage and trapping facilities. Examples include e.g. laser spectroscopy exploiting the large Doppler boost associated with relativistic ions as well as precision x-ray spectroscopy. Experiments at the border between atomic and nuclear physics will be addressed in addition with emphasis on rare nuclear decay modes only possible for nuclei at high atomic charge states.

[1] Th. Stöhlker *et al* 2015 *Nucl. Instr. Meth. Phys. Res. B* **365** 680-685

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