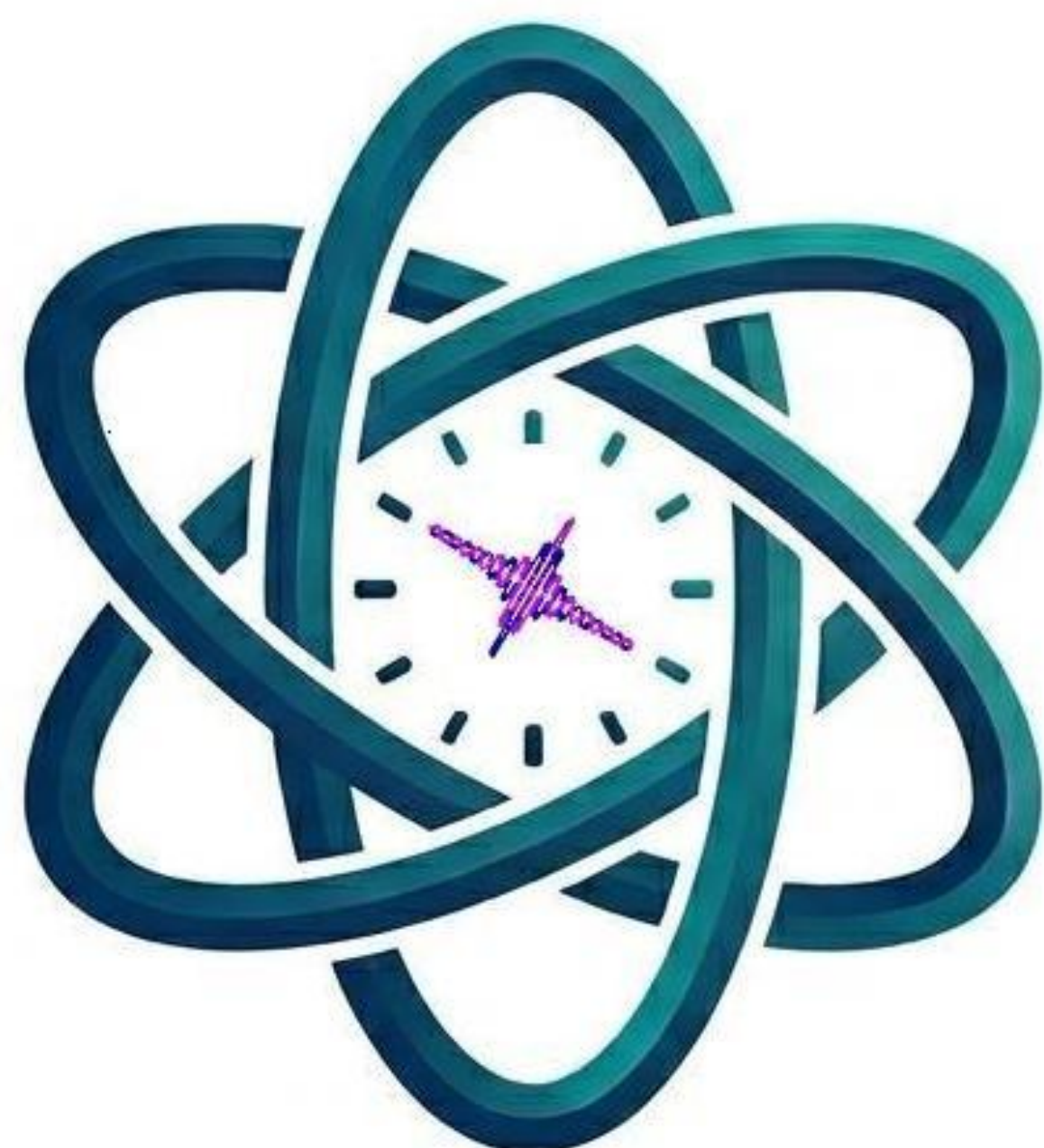


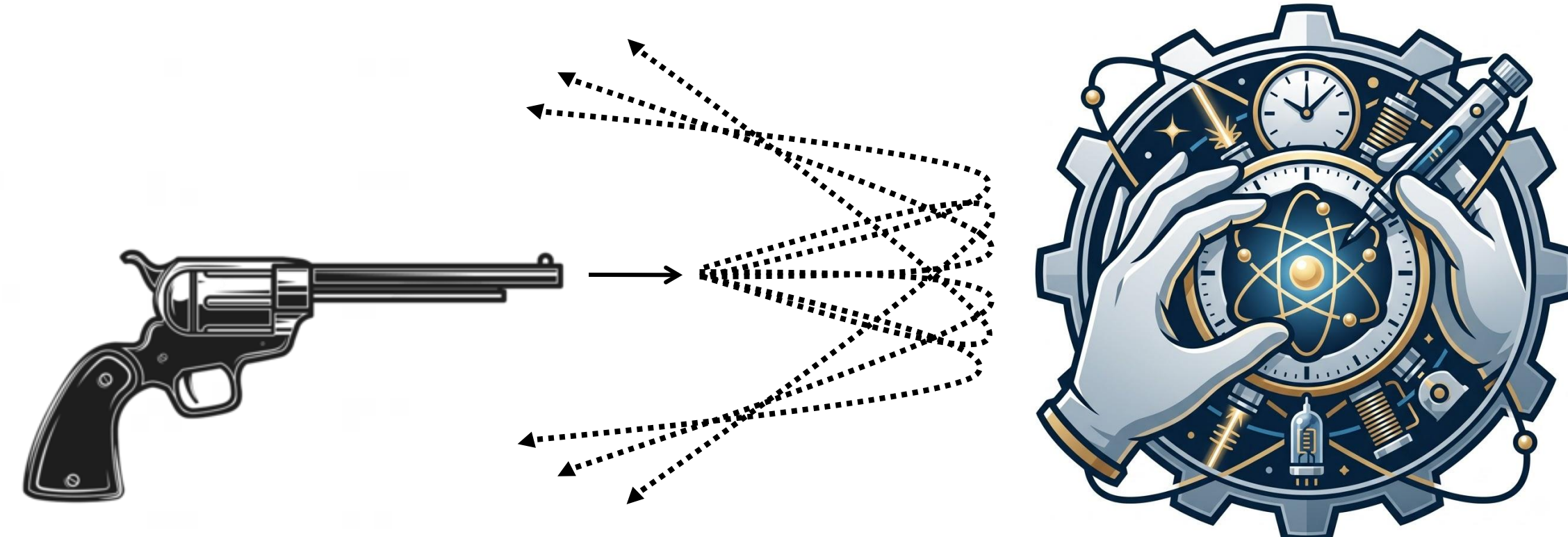


Co-funded by
the European Union



QUARCKS

QUANTUM ROBUST HYPER-CLOCKS AND ATOMIC SENSORS



Quantum engineering & optimal control
to shield interferences
against frequency shifts and decoherence



Ramsey Hahn Bloch Gell-Mann

QUARCKS aims to develop a new generation of highly robust optical clocks and atomic sensors that can operate with exceptional precision even in the presence of noise and real-world imperfections. Today's best atomic clocks already measure time with extraordinary accuracy, but their performance is still limited by two major challenges: disturbances from the environment and unwanted shifts caused by the laser light used to probe the atoms. These effects restrict how long the atoms can be observed and ultimately limit the stability and accuracy of optical clocks.

The project will address these limitations by combining advanced methods for controlling atoms with strategies that protect fragile quantum states from decoherence. QUARCKS will design new interrogation protocols based on time separated sequences of refocusing laser pulses that allow atoms to keep their quantum memory for longer, while also cancelling important sources

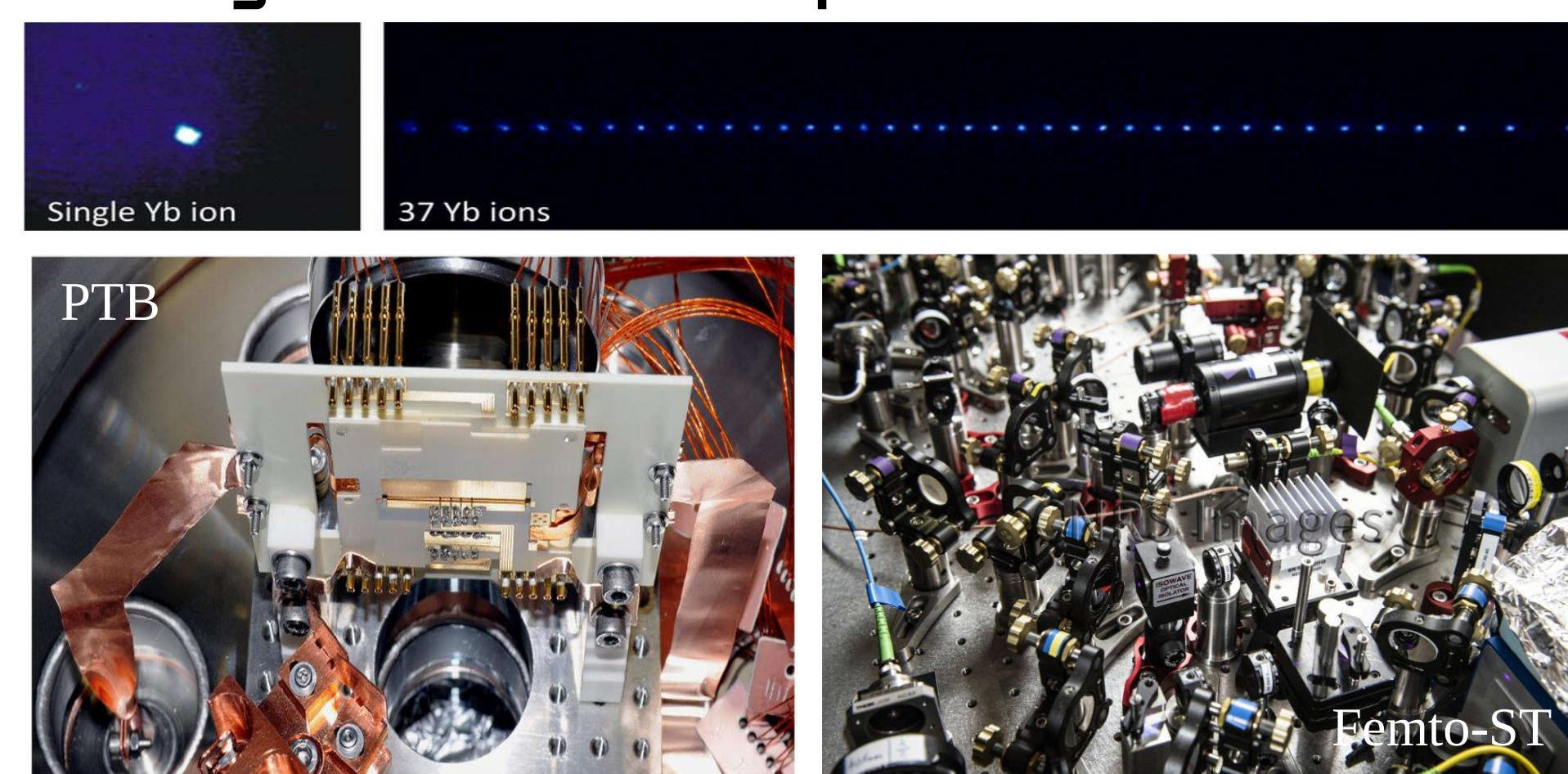
of errors. Such a dual protection is the core objective of the project. It will make clocks and sensors not only more accurate in ideal laboratory conditions, but also more reliable in practical, noisy environments for field applications. In addition, dynamical decoupling techniques will be introduced to reduce loss of contrast in harsh electromagnetic environments.

The project brings together leading expertise in high-performance optical clocks, trapped ions, atomic sensors, precision metrology, and quantum control. The consortium will first design and simulate the new protocols, then test them on advanced atomic-clock platforms, and finally explore their use in scalable systems such as multi-ion clocks, optical lattices, and atom interferometers. This step-by-step approach will ensure that the methods are not limited to one specific experiment, but can become a general tool for future fault-tolerant quantum technologies.

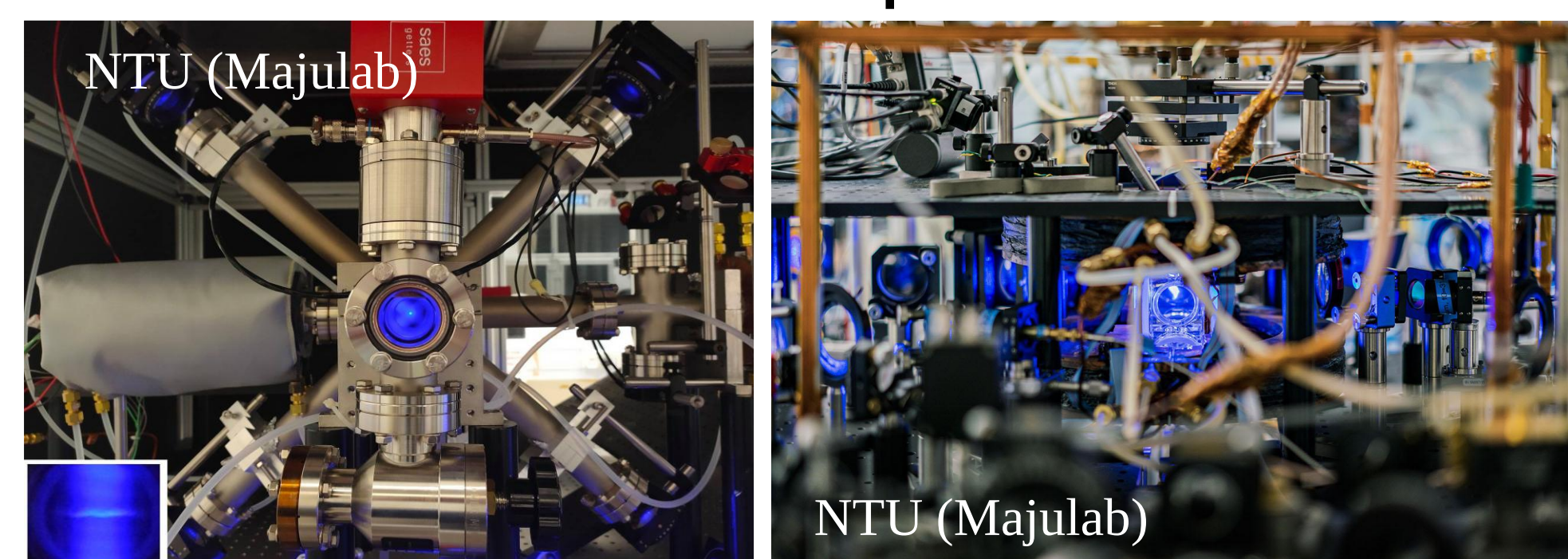
If successful, QUARCKS will contribute to clocks and sensors with improved stability, accuracy, and robustness. Such devices could support applications in geodesy, navigation, networked timekeeping, searches for dark matter, tests of fundamental physics, and future quantum sensing technologies.

Beyond its immediate scientific goals, the project will train young researchers, strengthen European leadership in quantum metrology, and provide open methods and data that can be used by the wider scientific and technological community. By making precision measurement more resilient and transferable, QUARCKS will help move quantum clocks and atomic sensors from highly controlled laboratories toward practical, field-deployable technologies with broad scientific and societal impact.

Single ion and multiple ion chain (Yb)

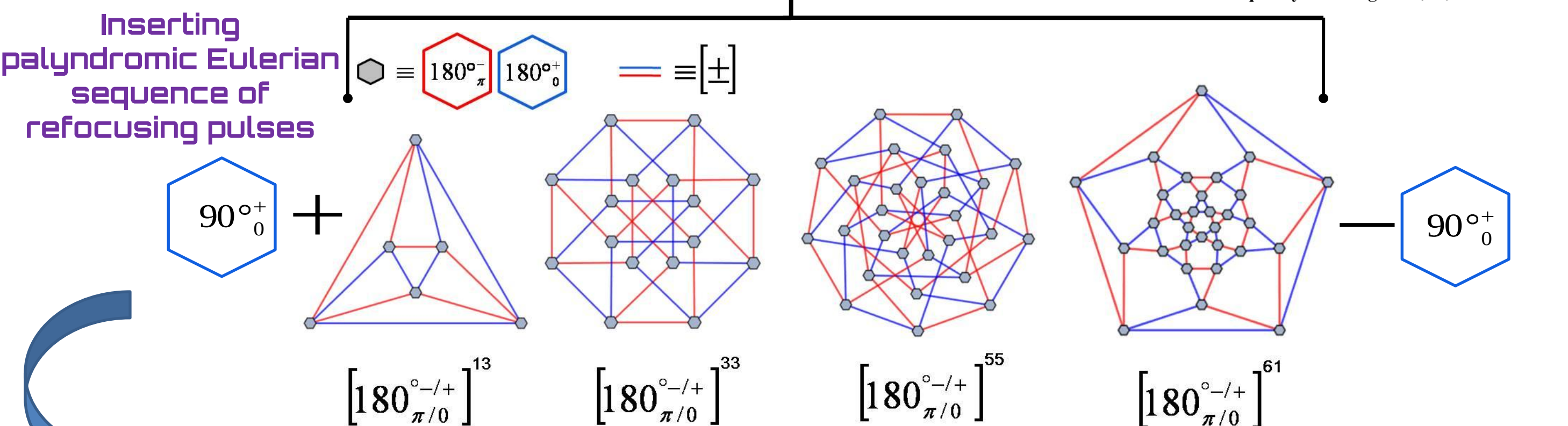
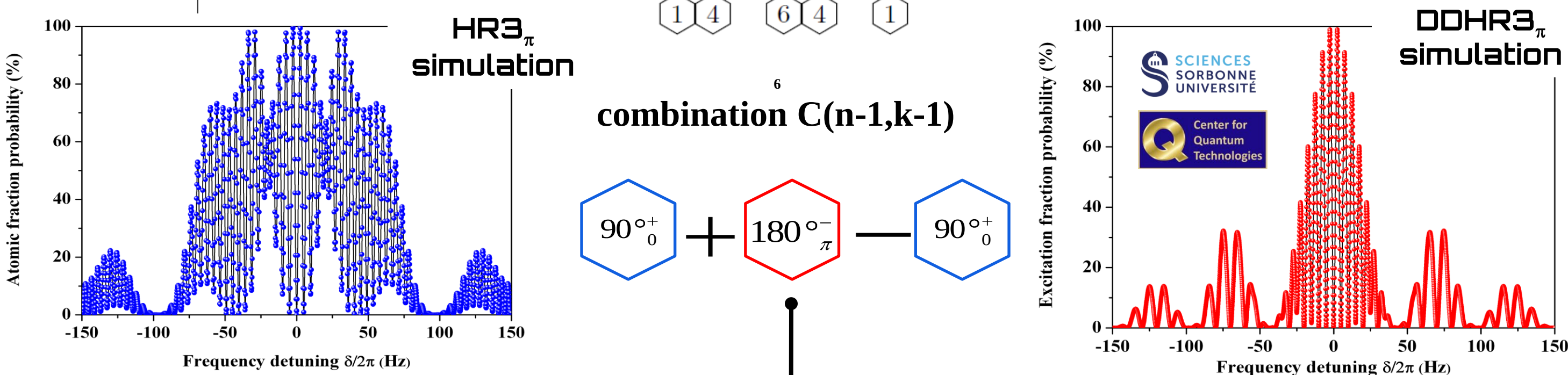
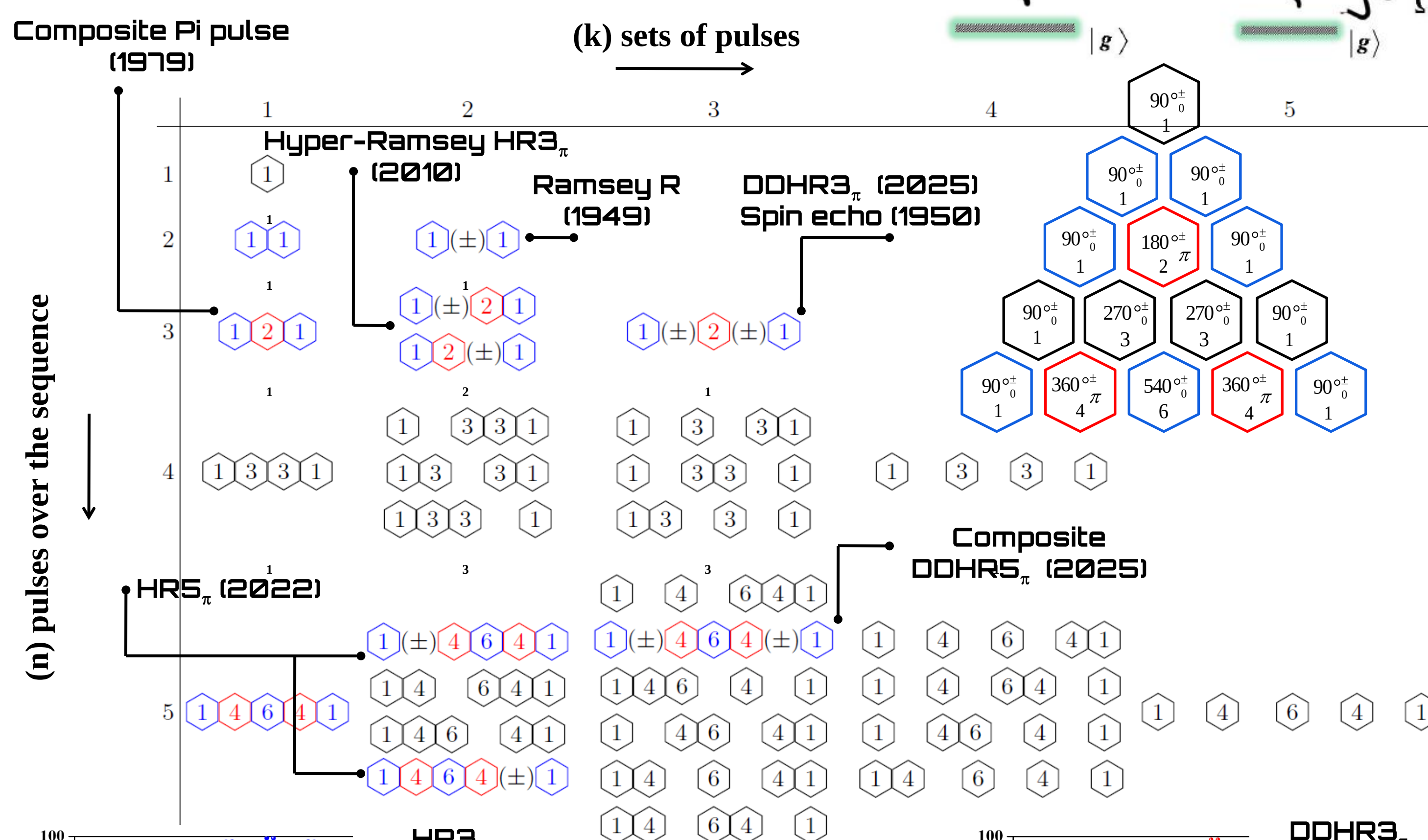


Neutral atoms into optical lattices (Sr)



Periodic table of composite pulse interrogation protocols

$$C(n-1, k-1) = \binom{n-1}{k-1} = \frac{(n-1)!}{(k-1)!(n-k)!}$$



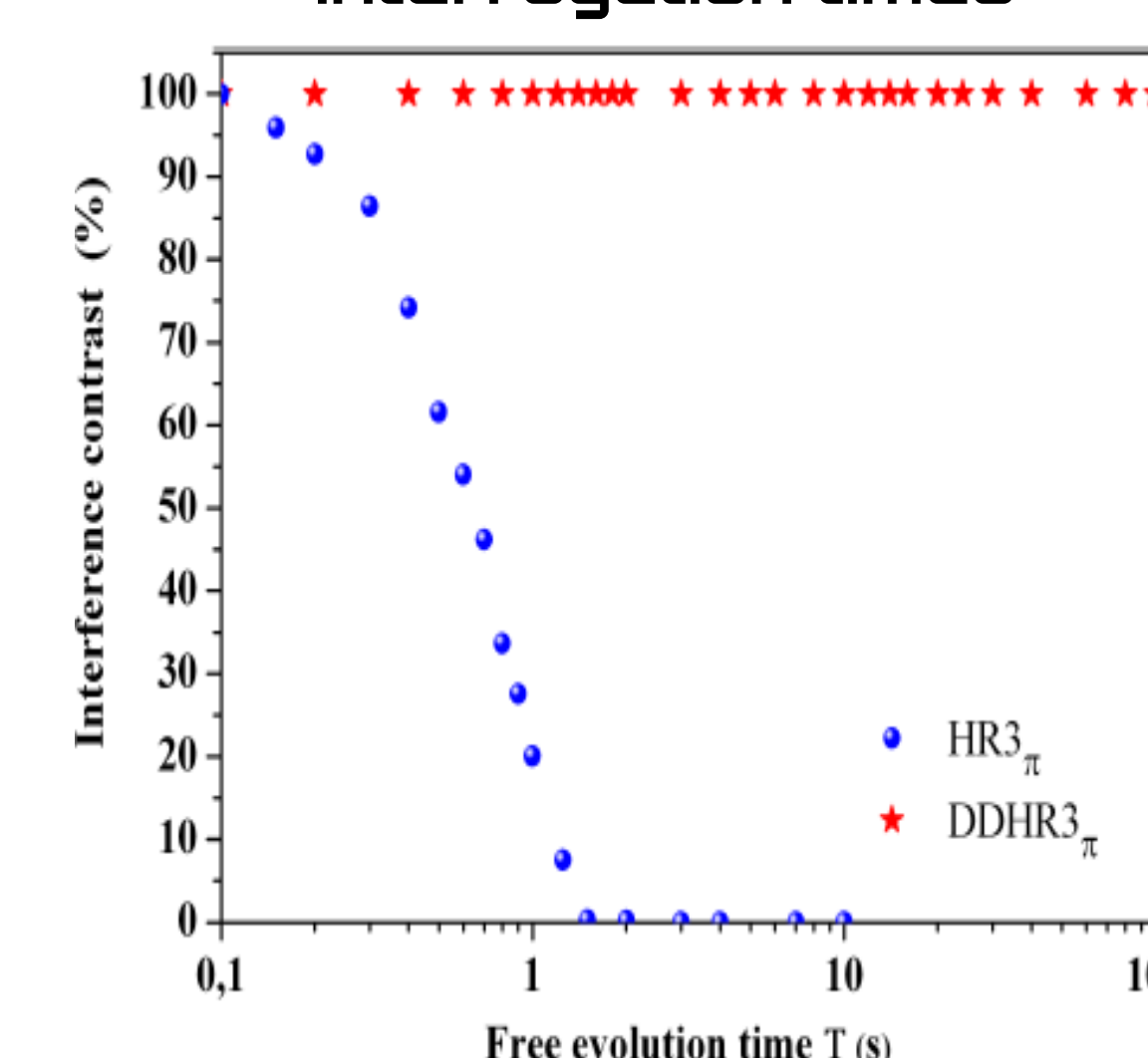
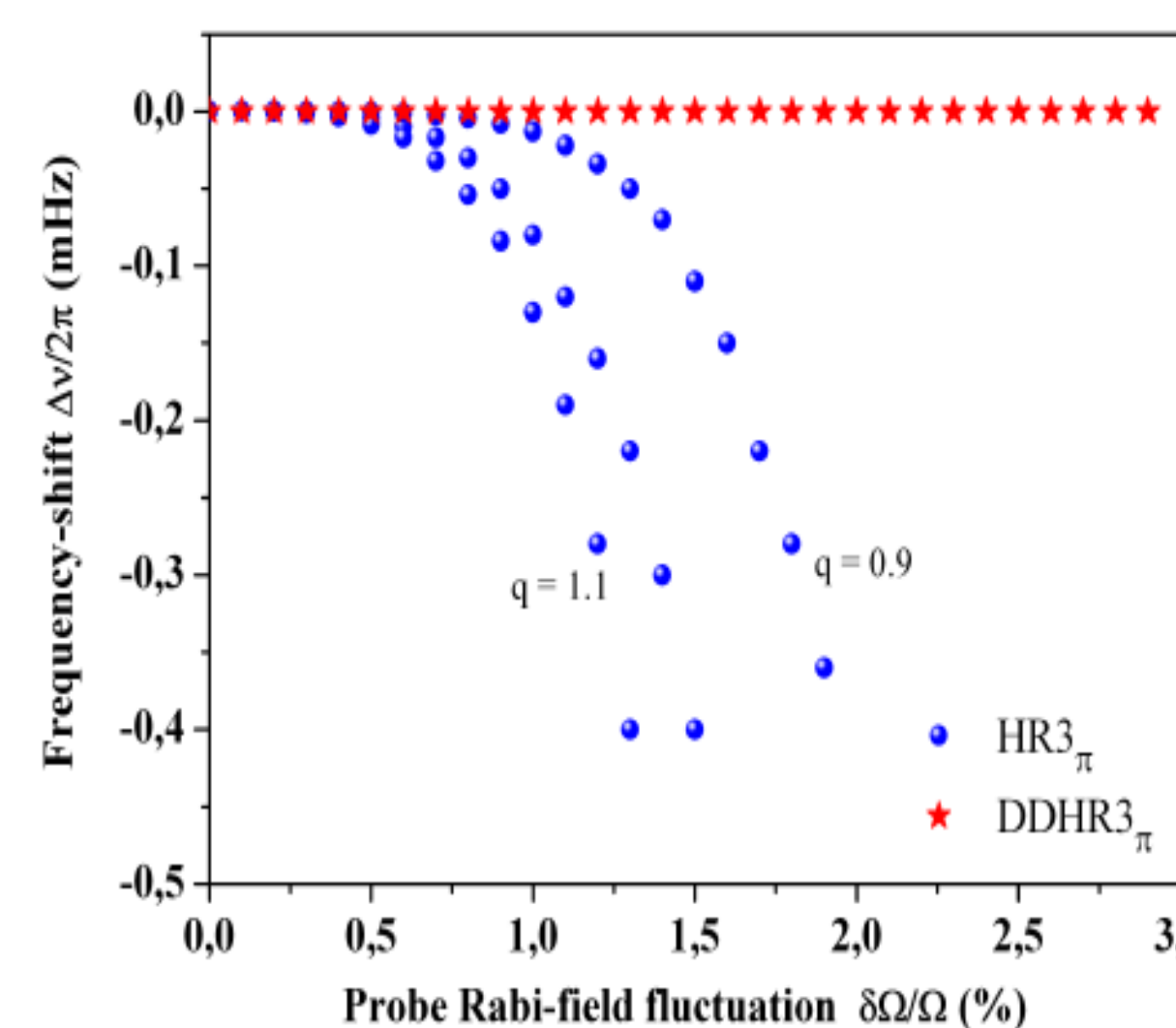
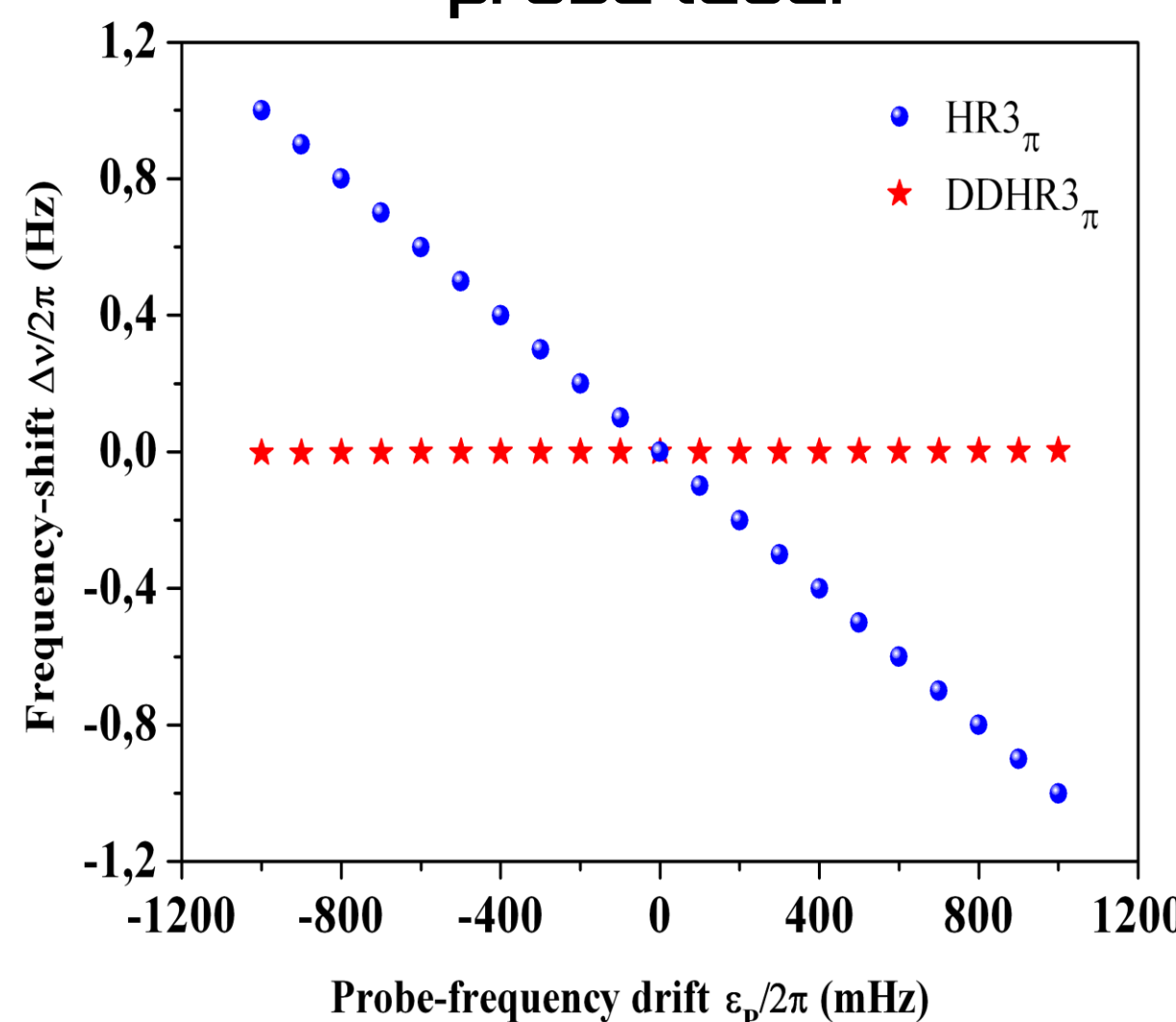
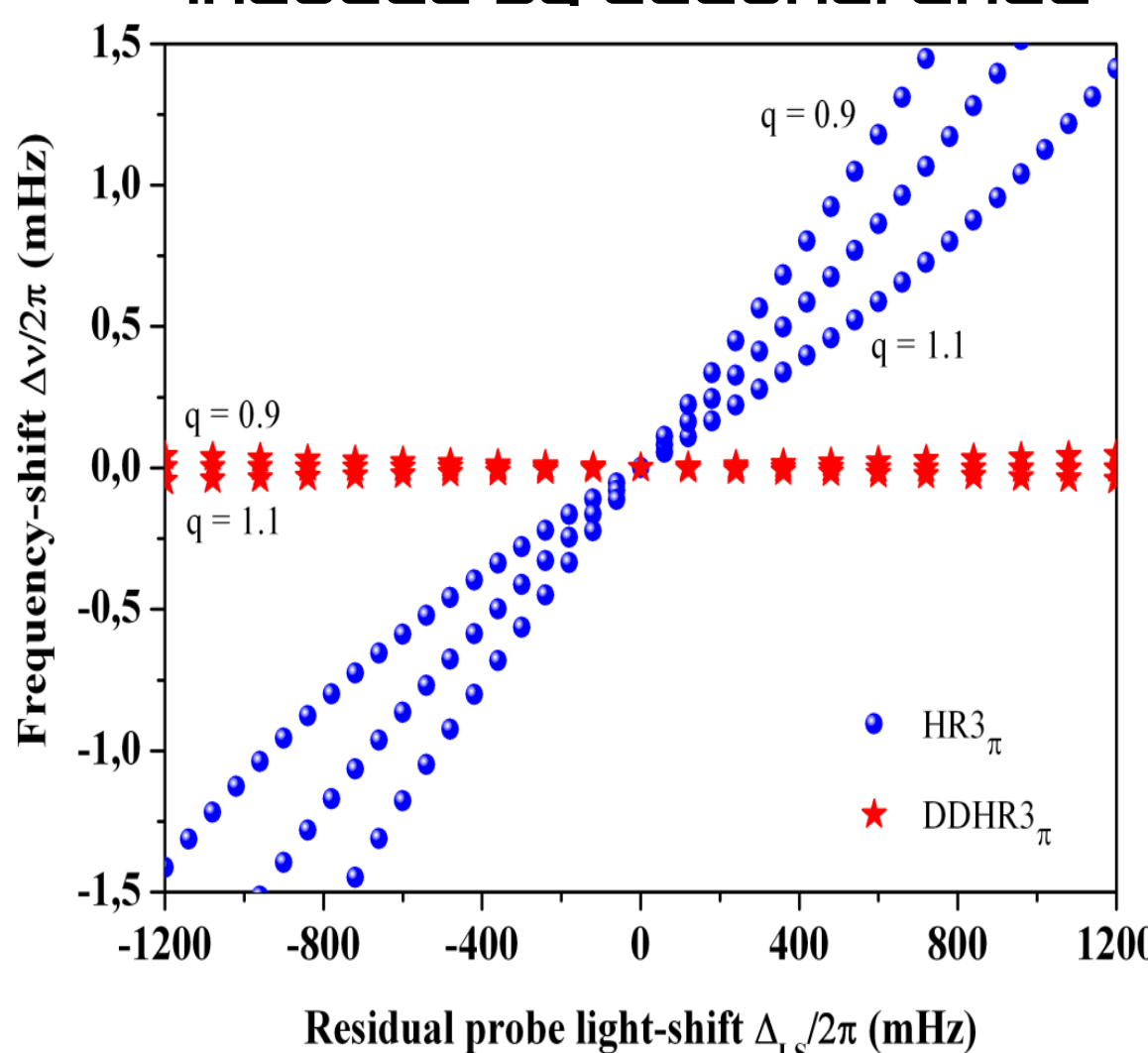
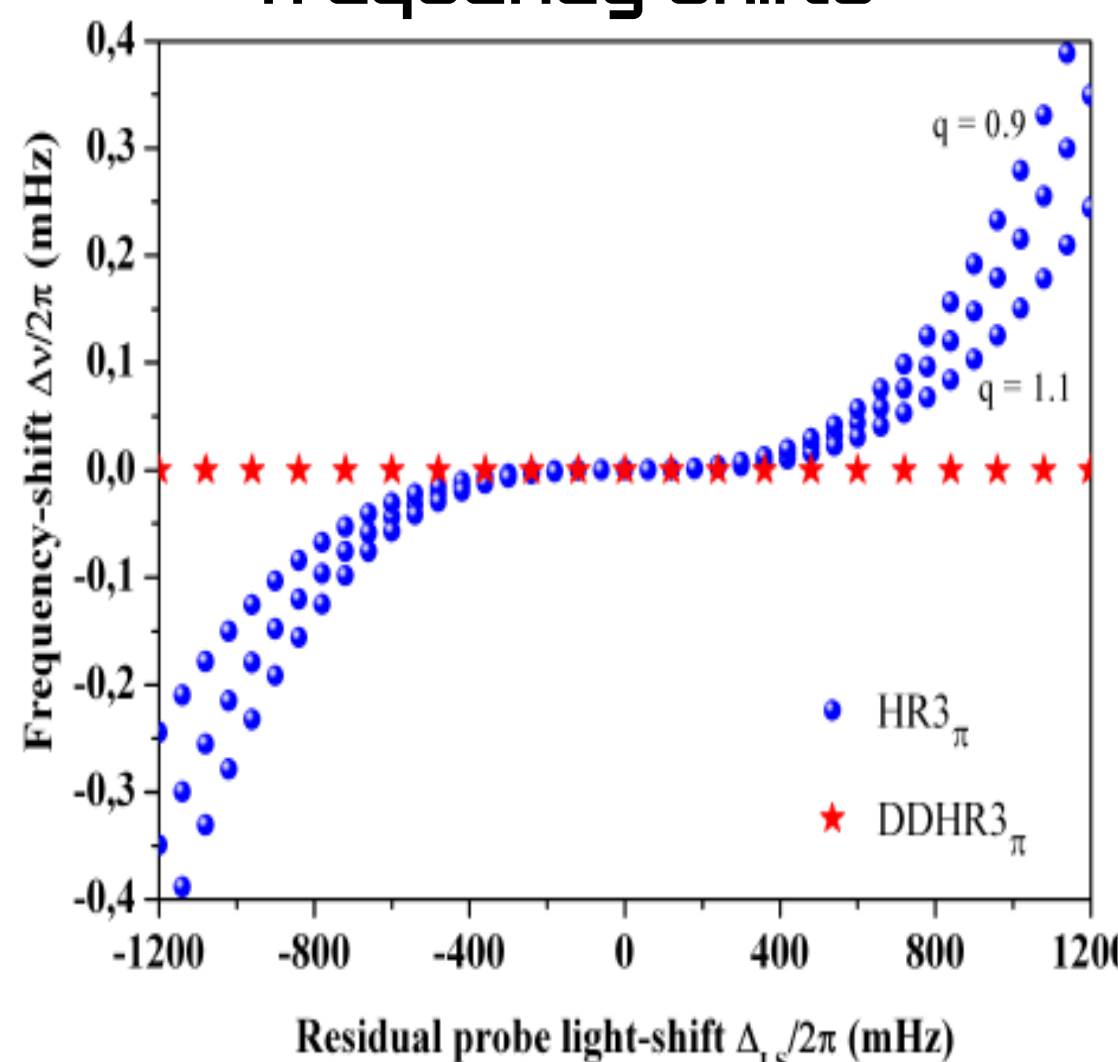
➤ Elimination of probe-induced frequency shifts

➤ Very low sensitivity to frequency shifts induced by decoherence

➤ Very low sensitivity to spectral drifts of the probe laser

➤ Elimination of the frequency shift induced by probe intensity fluctuation

➤ Preserving high interference contrast over longer interrogation times



Consortium

- Coordinator:
Thomas Zanon
De la Molécule aux Nano-objets: Réactivité, Interactions et Spectroscopies (FR)
- Clément Lacroûte
Institut Franche-Comte Electronique Mecanique Thermique Et Optique - Sciences Et Technologies (FR)
- Tanja Mehlstäubler
Physikalisch-Technische Bundesanstalt (DE)
- Ivo Mihov
Center for Quantum Technology, Faculty of Physics, Sofia University (BG)
- David Wilkowski
Centre for Quantum Technologies (SG)

Funding organisations



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Braunschweig und Berlin



→ Atomic interferometry platform & quantum computers



→ Yb clock platforms



→ Theory & simulation with quantum computers

→ Coordination & Simulation

→ Transportable Yb clock platform for field applications