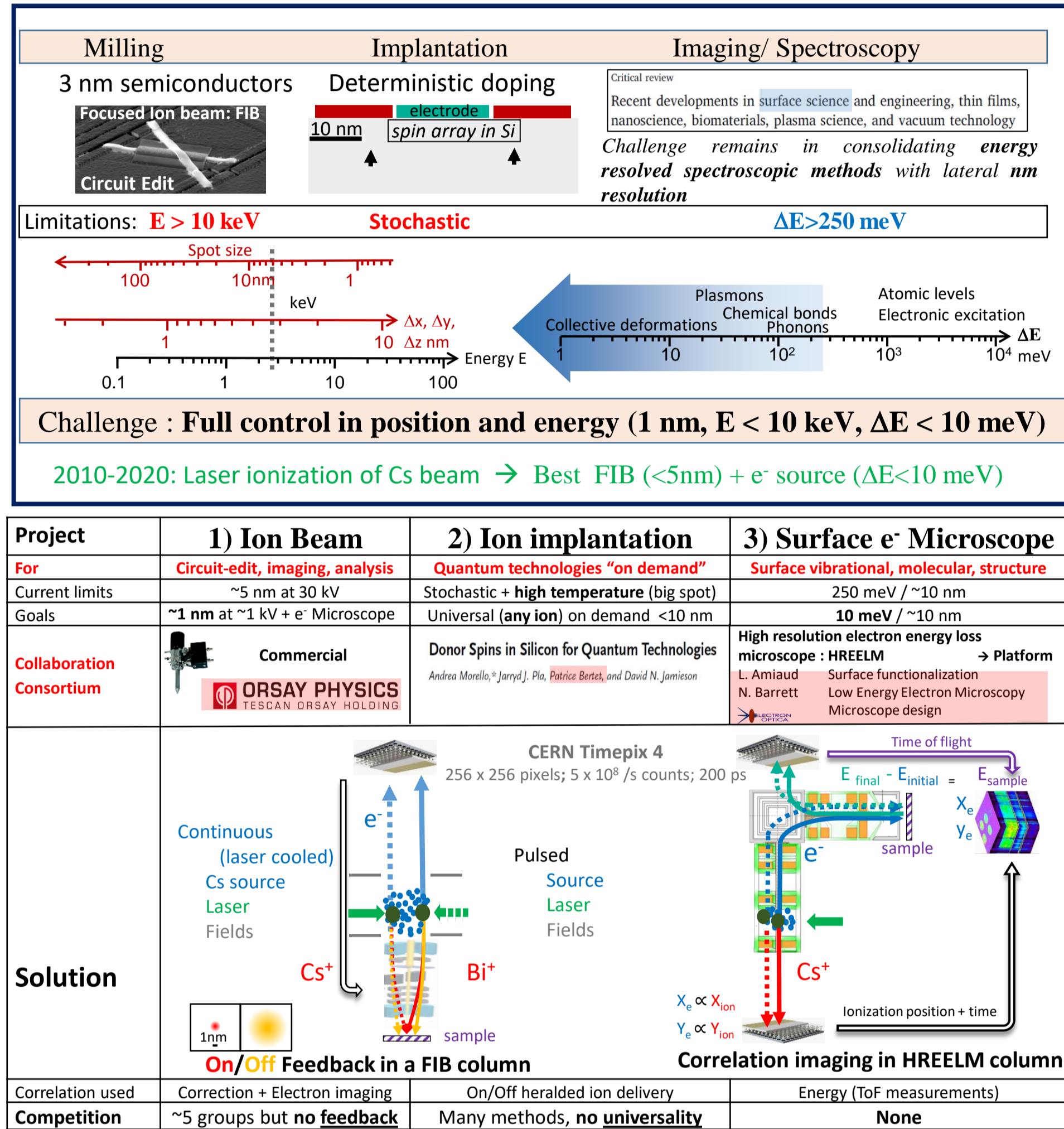


Introduction

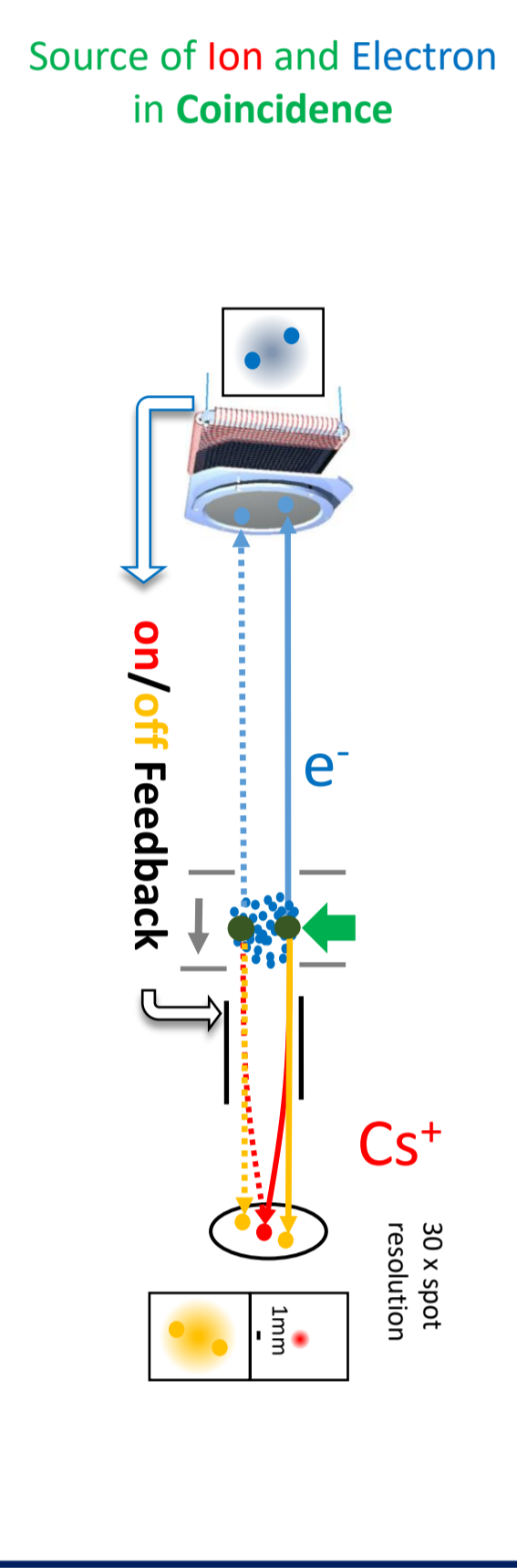
Electron and ion beams have become indispensable tools in surface and materials science. Unlike standard sources, laser ionization of a neutral atomic species allows to produce both ions and electrons. Moreover, **coincident ion/electron detection provides correlated information on both particles that can be used to improve beam properties**, such as deterministic creation of charged particles and correction of their trajectories in real time. We will develop three innovative prototypes:

- A focused ion beam using feedback control to perform (sub-)nm scale semiconductor circuit editing in collaboration with Orsay Physics company.
- A deterministic source of (potentially) any type of ion for controlled implantation at the nm scale for on-demand doping of quantum devices.
- A high resolution electron energy loss microscope to perform both imaging and vibrational spectroscopy for surface analysis in collaboration with ISMO and CEA.

Nanoscience needs new diagnostics and tools: ion + electron

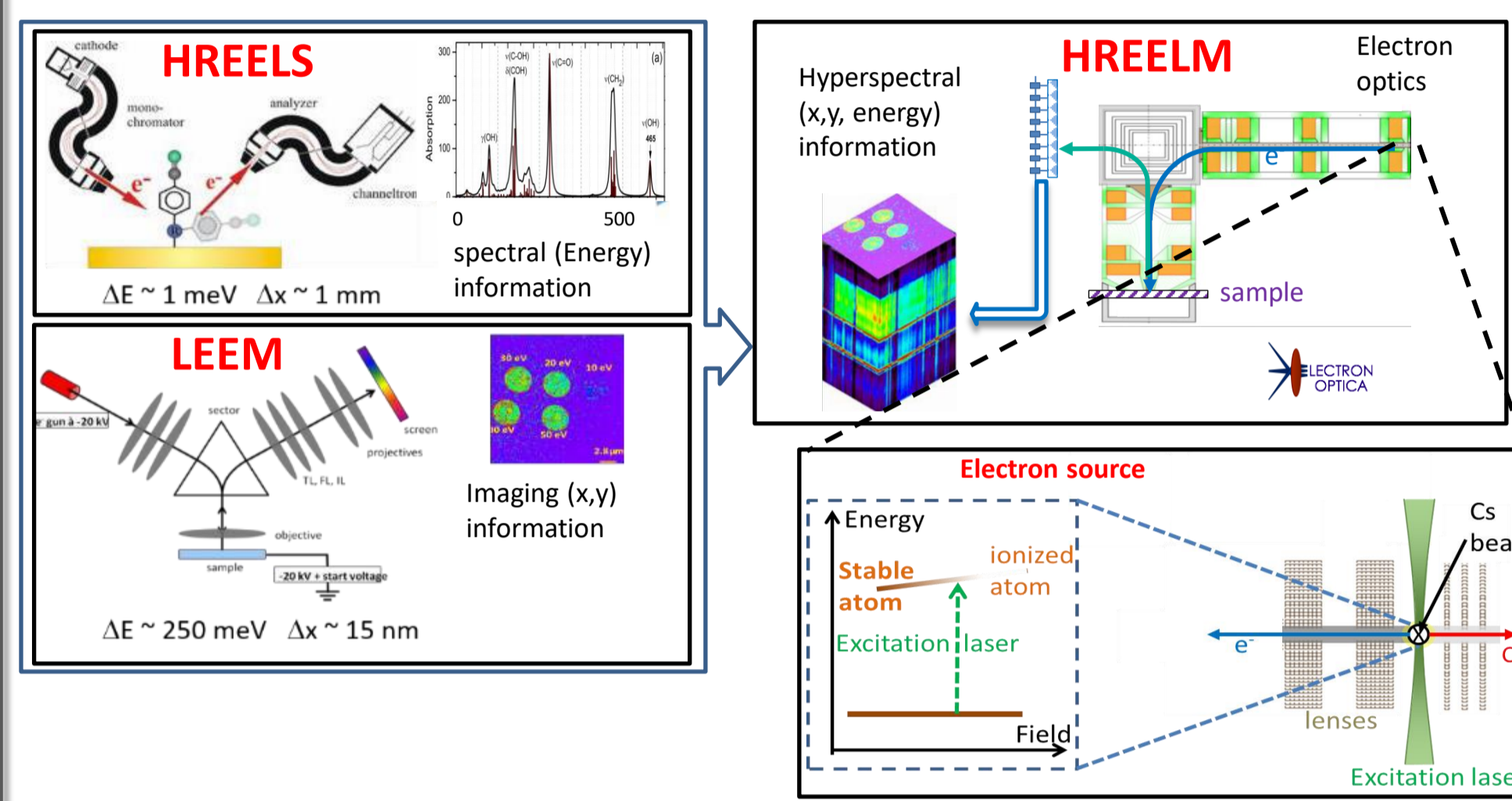


Innovation: Use both ion/electron + one by one control



High Resolution Electron Energy Loss Microscope (HREELM)

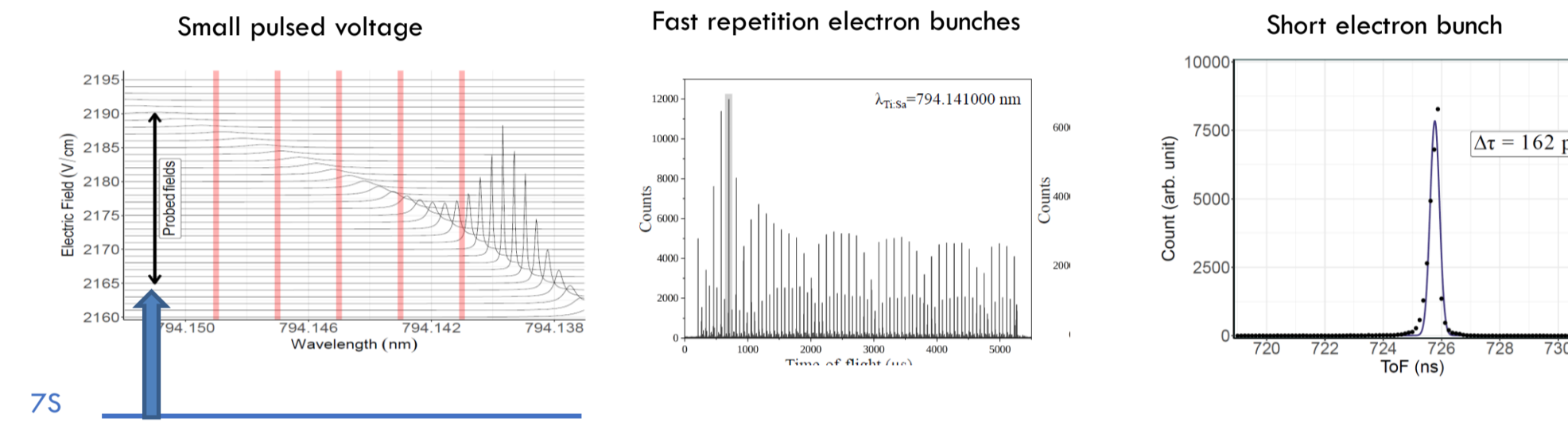
Column design (principle)



Collaborations:
Lionel Amiaud (ISMO)
Nick Barrett (CEA/SPEC)
Marie Géléoc (CEA/LIDYL)
Vincent Schoepff (CEA/LIST)

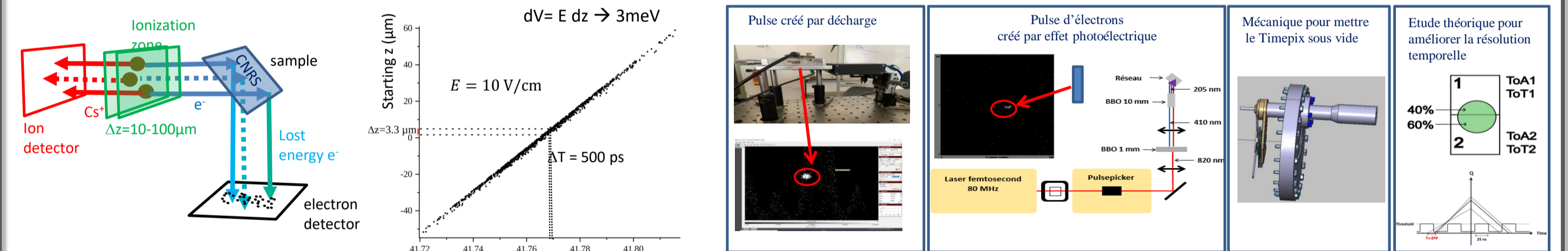
- High spatial and energy resolution
- Phonon dispersion mapping
- Nano-Functionalization (~20 nm)

Electron source study (continuous and pulsed): patent WO/2021/224079



160 ps electron pulse
10meV in pulsed mode
100pA in continuous mode

Future: use of Timepix 80-500 Mhit/s



Using knowledge of the initial electron position

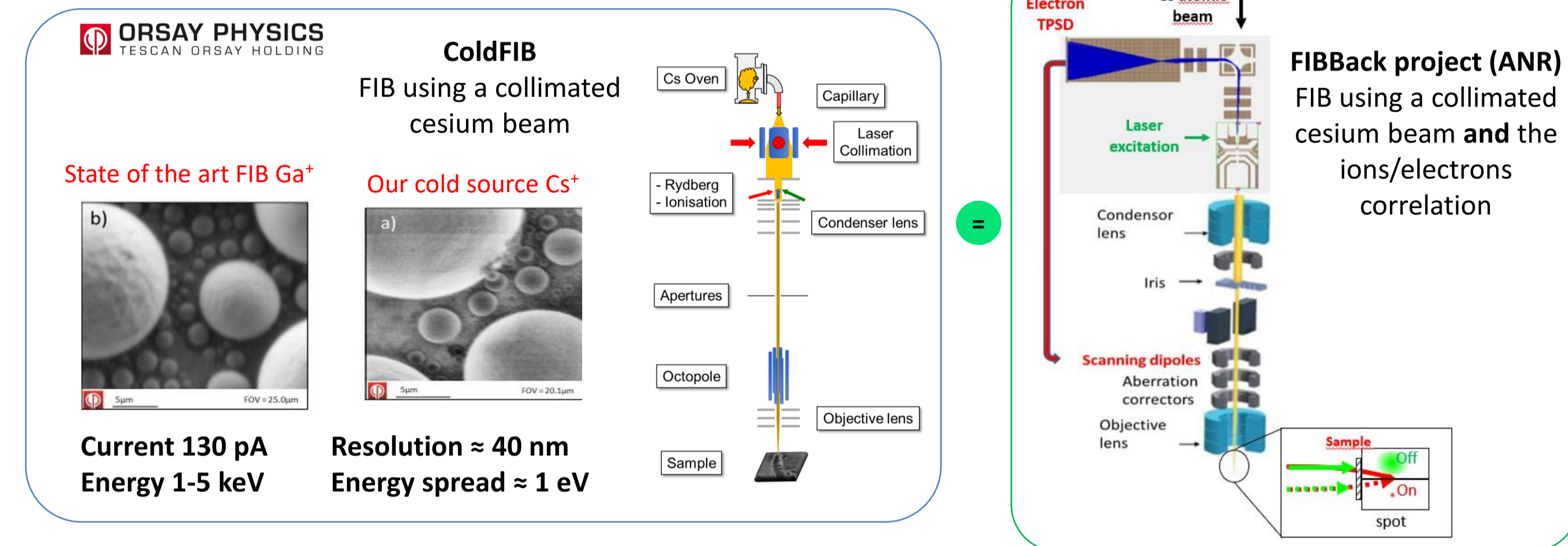
Nanometer focused ion beam (FIB) at low energy

Principle

Current focused ion beams (FIB) reach a resolution limit of a few nanometers for high-energy ions (5nm for 30kV). The challenge here is to achieve sub-nanometer resolution with low-energy ions.

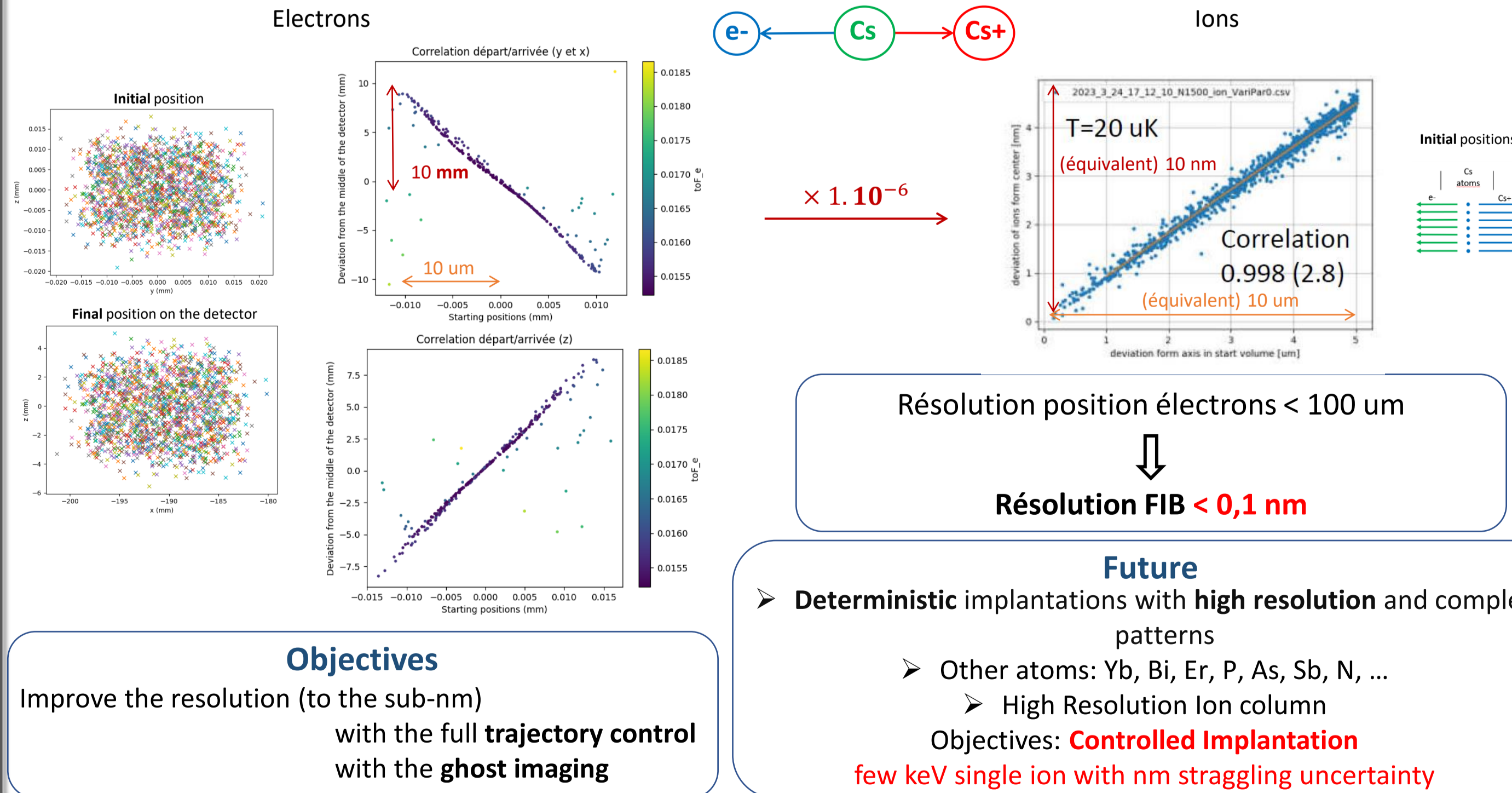
Source d'Ions et d'Electrons Correlés
Trajectories control
Deterministic source
Ghost imaging

Collaborations:
Matthieu Vitteau (Orsay Physics)
Martin Schmidt (LuMIn)
Colin Lopez (LuMIn)
Muquans,
AzurLight Systems

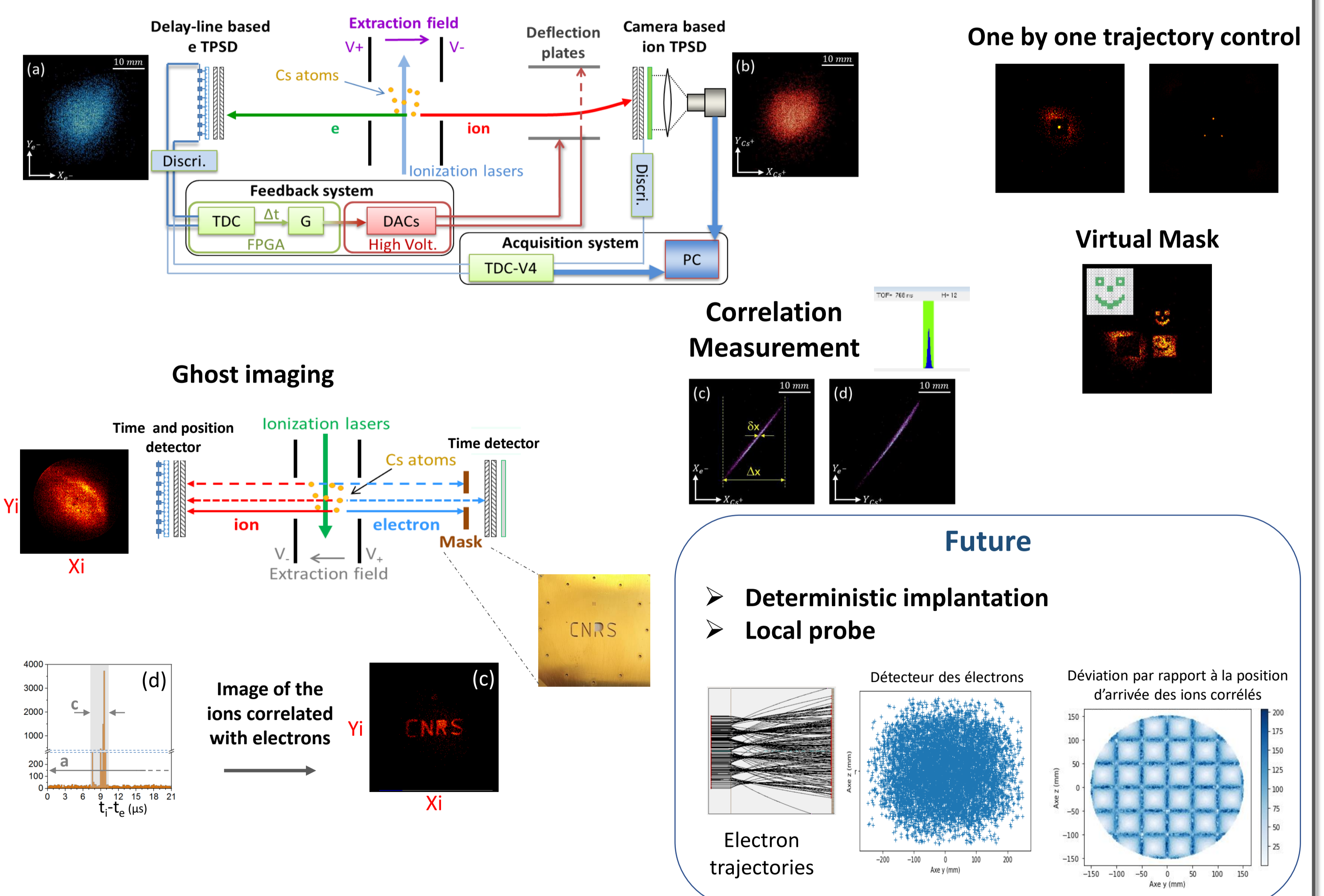


Results

Simulations of correlations between initial and final positions



SIEC (Source of Ions and Electrons in Coincidence)



- High repetition rate sub ns-electron pulses from Resonant Pulsed Rydberg Field Ionization; R. Hahn, D. Comparat, arXiv:2308.15333 (2023)
- High-resolution MCP-TimePix3 imaging/timing detector for antimatter physics; L Glöggler, R Caravita, M Auzins, B Bergmann, RS Brusa, P Burian,...; Measurement Science and Technology 33 (11), 115105 (2022)
- Comparative analysis of recirculating and collimating cesium ovens; R Hahn, T Battard, O Boucher, YJ Picard, H Lignier, D Comparat; Review of Scientific Instruments 93 (4), 043302 (2022)
- Efficient 2D molasses cooling of a cesium beam using a blue detuned top-hat beam; M Reveillard, M Viteau, G Santarelli, B Battelier, G Guiraud, N Traynor, ...; The European Physical Journal D 76 (2), 1-7 (2022)
- Cesium Rydberg-state ionization study by three-dimensional ion-electron correlation: Toward a monochromatic electron source; R. Hahn, A. Trimeche, C. Lopez, D. Comparat, and Y. J. Picard; Phys. Rev. A 103, 042821 (2021)
- Ion and electron ghost imaging; A Trimeche, C Lopez, D Comparat, YJ Picard; Physical Review Research 2 (4), 043295 (2020)
- Narrow-band pulsed electron source based on near-threshold photoionization of Cs in a magneto-optical trap; O Fedchenko, S Chernov, G Schönhense, R Hahn, D Comparat; Physical Review A 101 (1), 013424 (2020)
- Design for a high resolution electron energy loss microscope; M Mankos, K Shadman, R Hahn, YJ Picard, D Comparat, O Fedchenko, ...; Ultramicroscopy 207, 112848 (2019)
- Real-time trajectory control of deterministically produced ions; C Lopez, A Trimeche, D Comparat, YJ Picard; Physical Review Applied 11 (6), 064049 (2019)
- Watt-level narrow-linewidth fibered laser source at 852 nm for FIB application; L Antoni-Micollier, M Viteau, B Battelier, B Cadier, D Comparat, ...; Optics Letters 43 (16), 3937-3940 (2018)
- Coldfib - the new fib source from laser cooled atoms; M Reveillard, M Viteau, A Houel, D Comparat; Microscopy and Microanalysis 24 (S1), 804-805 (2018)