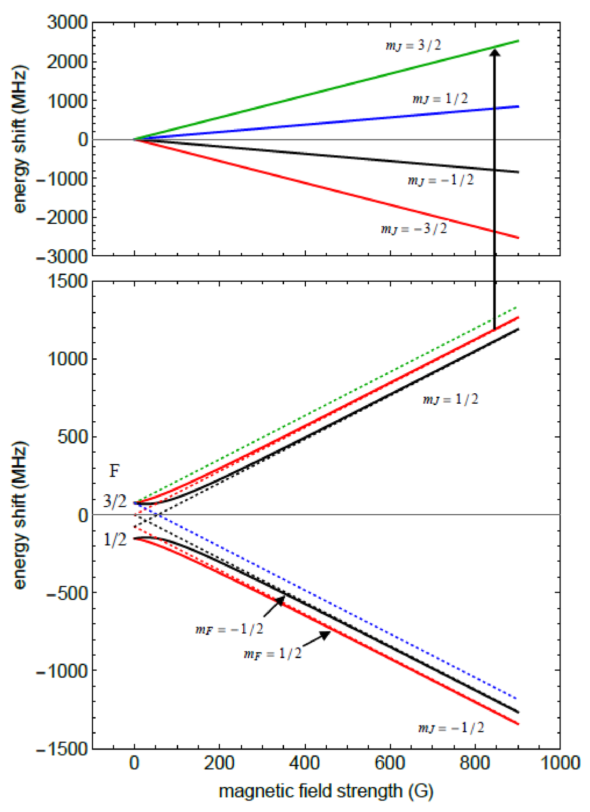
Simulation of an atomic beam under magneto-optical influence

Andreas C. Wieltsch[1], Jan Haack[1], Stefan Schmidt[1], Marcel Willig[1] and Randolf Pohl[1]

[1]Johannes Gutenberg – Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA+, Mainz, Germany

Simulation software for laser spectroscopy experiments

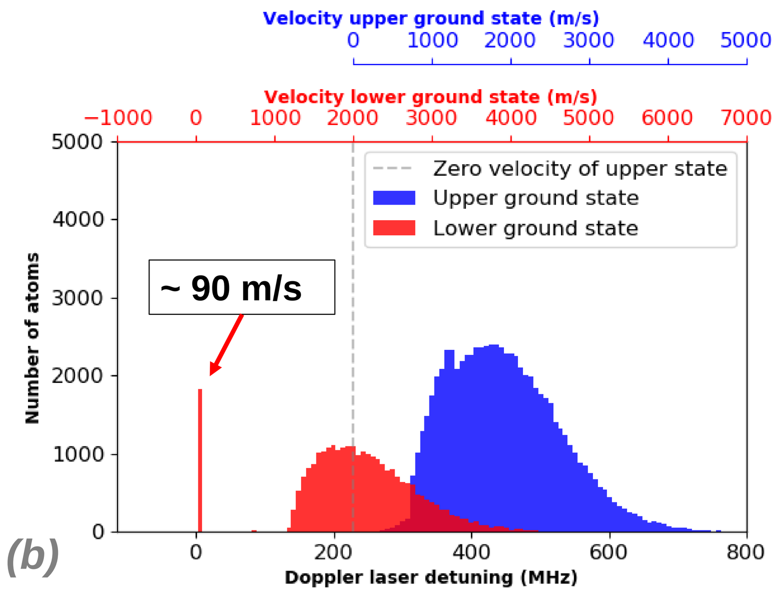


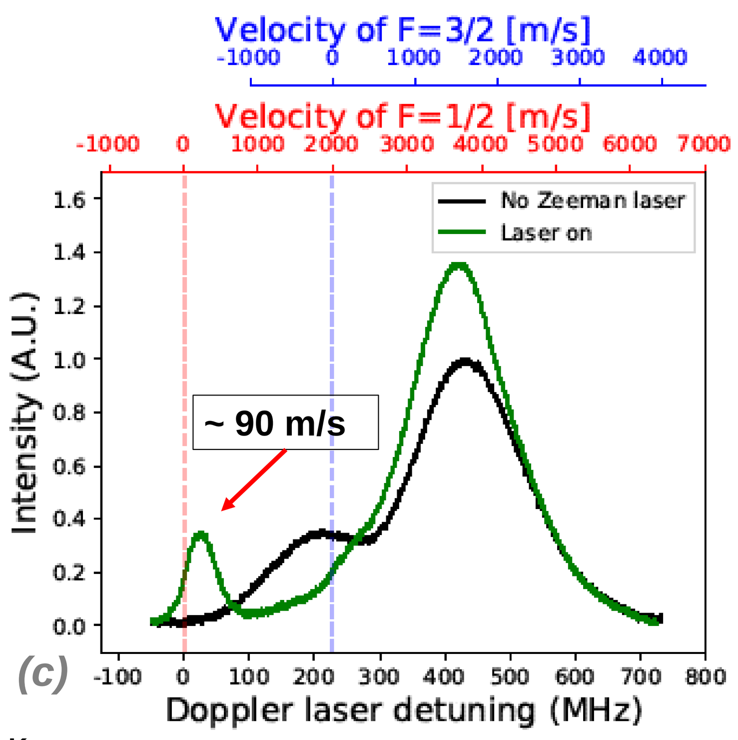
Motivation: To provide a simulation package…

- for all alkali atoms based on a generic implementation.
- that takes into account more than two energy levels of an atomic system.
- that gives deeper insights into the behaviour of the experiment.

Case study and benchmark testing – Lithium experiment:

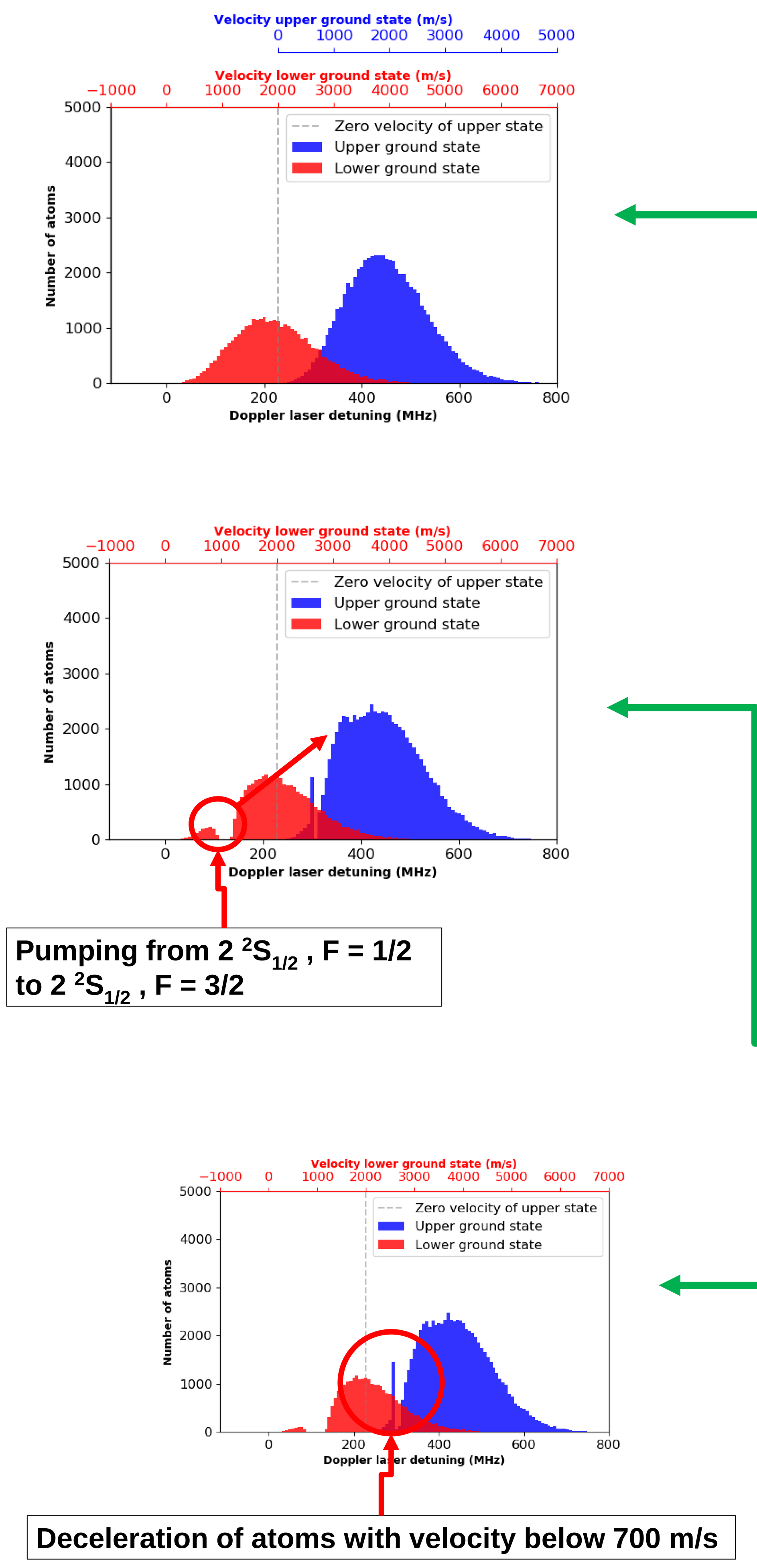
- Six energy levels (a) due to Zeeman effect with transitions depending on the polarisation of the laser light.
- Figure (b) and (c): Simulation results vs. experimental data.

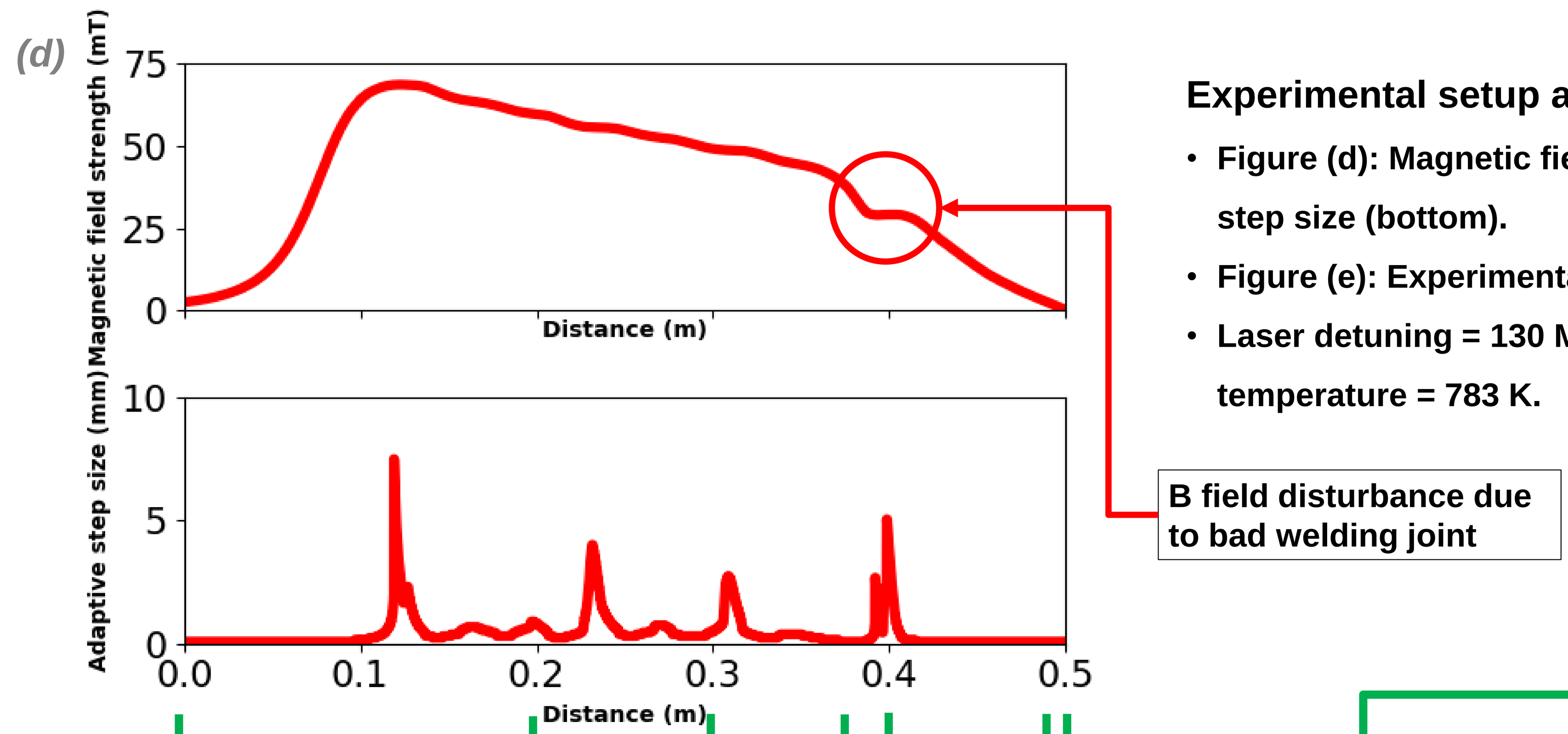




Laser detuning = 130 MHz, particle number = 100000, S = 5, T = 783 K.

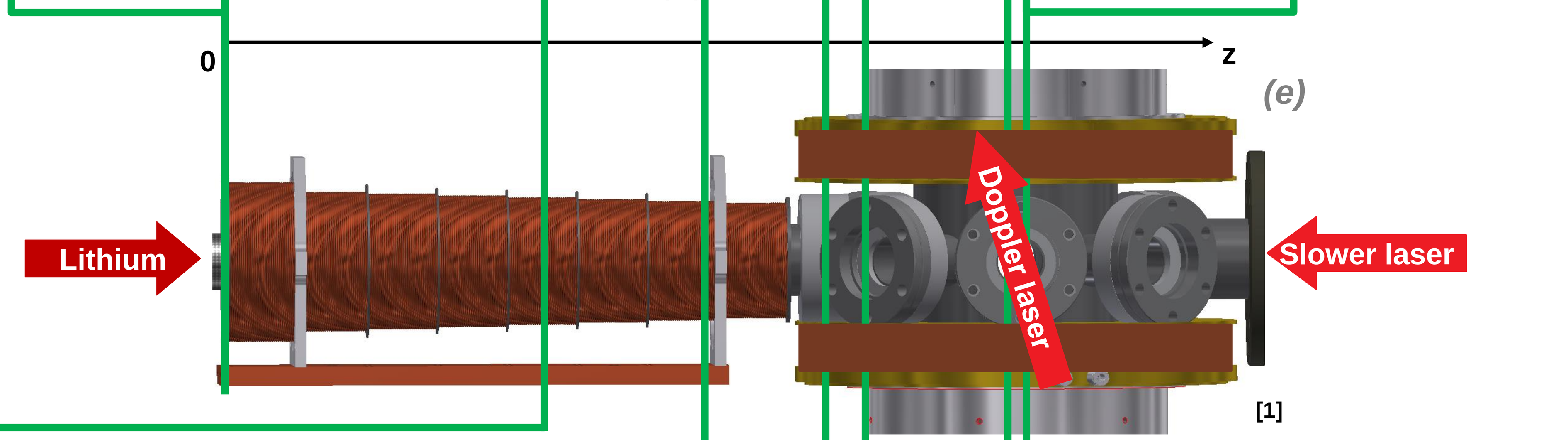
Velocity distributions at different locations in the experiment

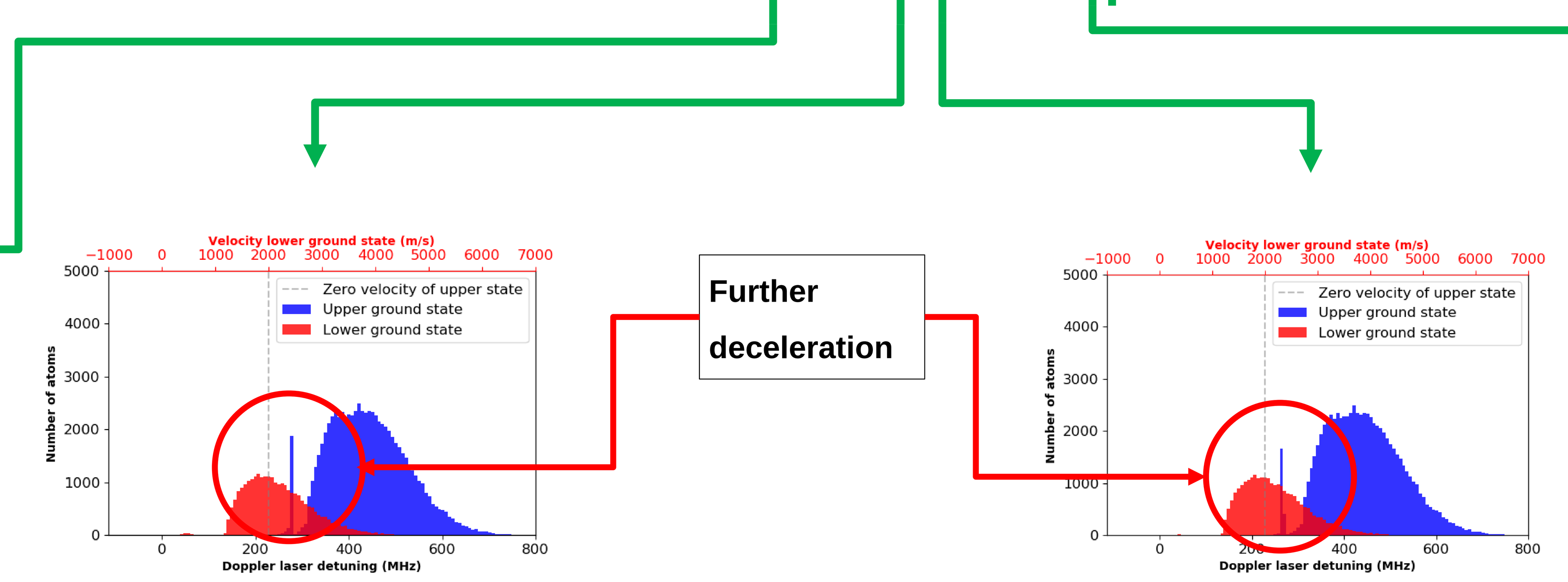


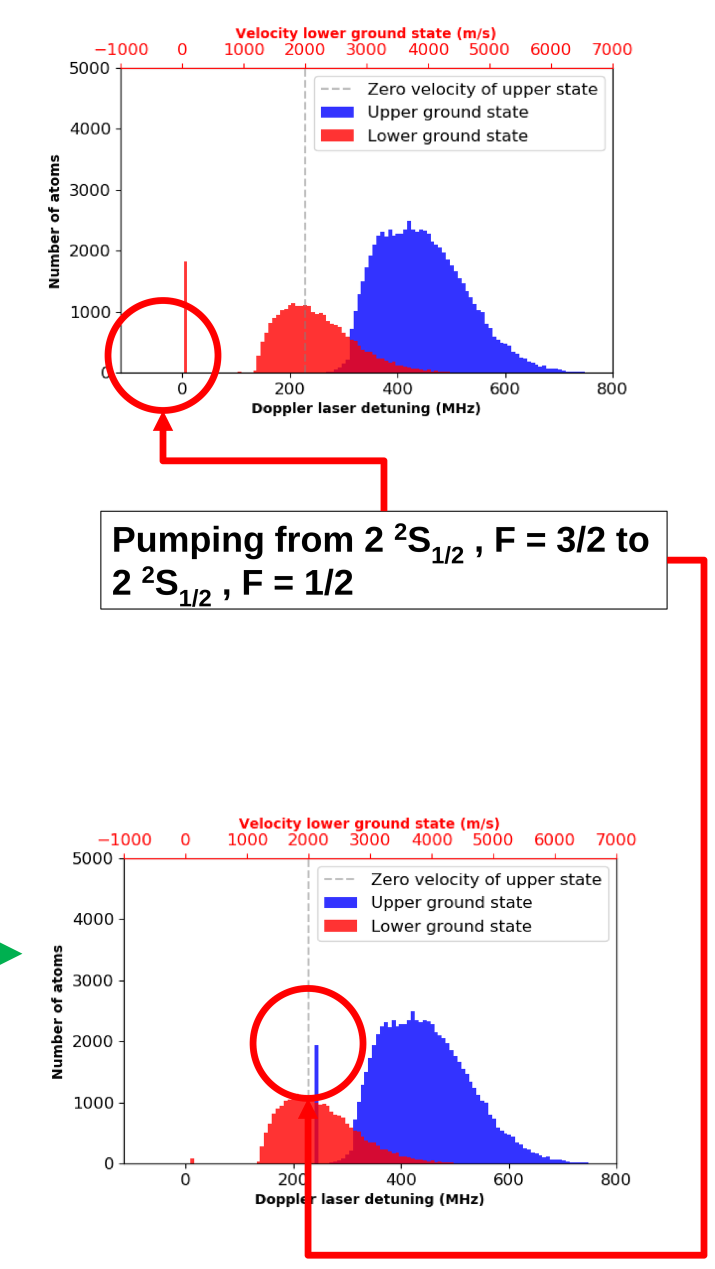


Experimental setup and magnetic field

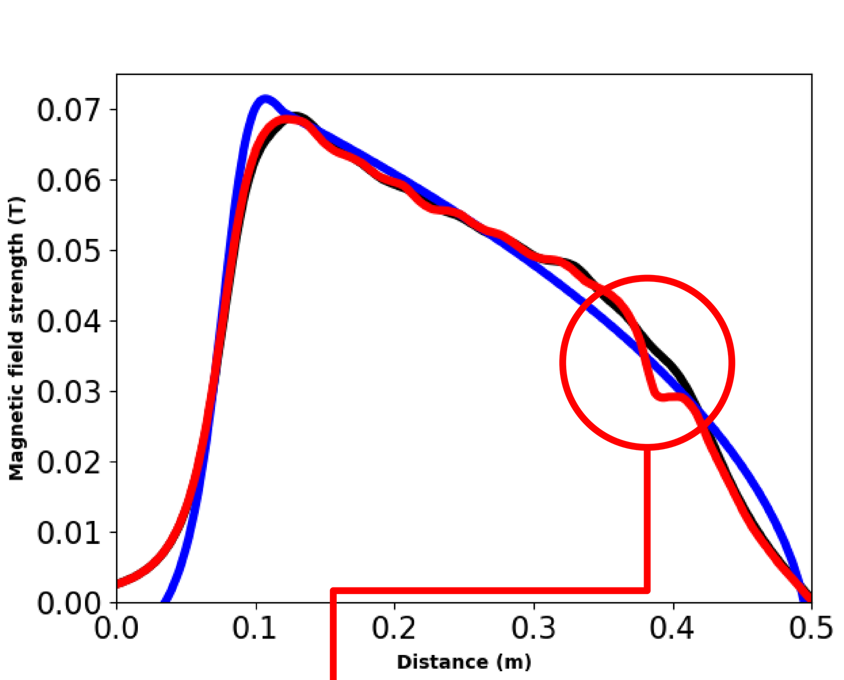
- Figure (d): Magnetic field of the Li experiment (top) and adaptive step size (bottom).
- Figure (e): Experimental setup.
- Laser detuning = 130 MHz, particle number = 100000, saturation = 5, temperature = 783 K.

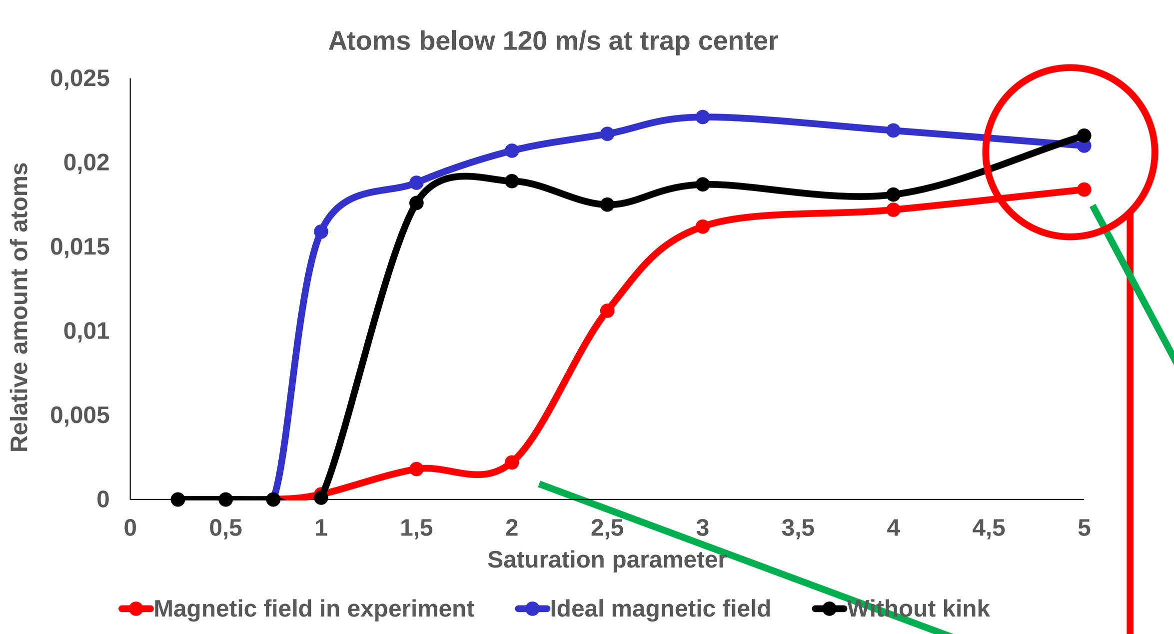


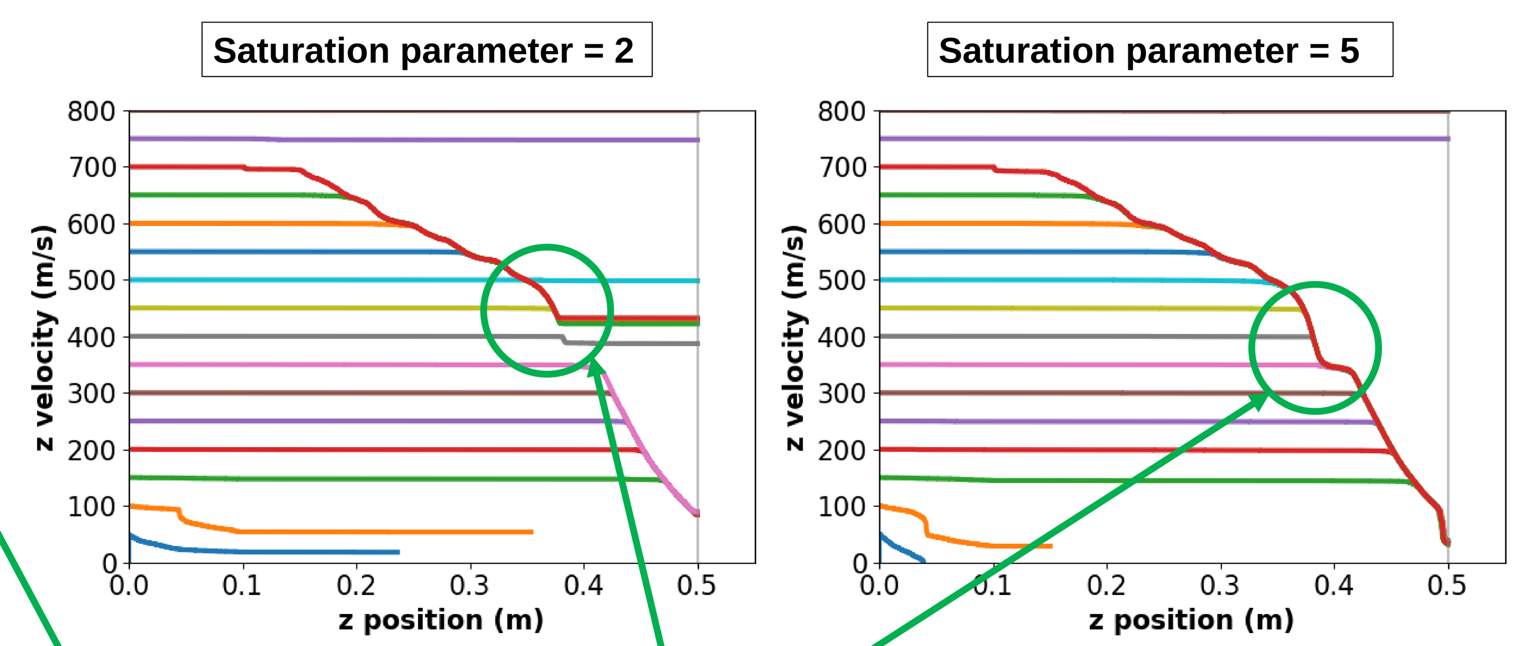




Modification of magnetic field configuration







- Kink leads to lower number of atoms which are slow enough to be catched in the MOT.
- Modifications can lead to increase of catchable atoms of nearly 20%.

- Increasing saturation parameter from S = 2 to S = 5.
- Less atoms fall out of resonance at the kink of the magnetic field in the experiment.

Formulas in the simulation

$$f(v) = \frac{1}{2}\left(\frac{m}{2k_BT}\right)^2 v^3 e^{-mv^2/2k_BT}$$

$$p(\Delta) = \frac{\Gamma^2\frac{s}{2}}{4\Delta^2+\Gamma^2(1+s)}$$

$$\Delta E(B) = -\mu_B B\left(g_J^g m_J^g - g_J^e m_J^e\right)$$

[2]

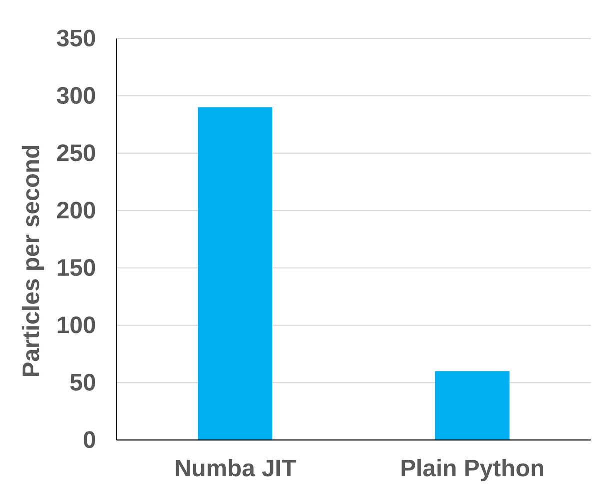
Get the digital poster!

Runtime behaviour

Simulation speed up:

- Just-in-time compiler Numba for Python.
- Adaptive step size in magnetic field.

Leads to a simulation of nearly one million particles per hour.



References

[1] T. Kohlert, A Magneto-Optical Trap for Lithium Atoms, Master's Thesis, Munich, 2016.
[2] C. J. Foot, Atomic Physics, Oxford University Press, Oxford, 2005.

Outlook

- Parallelize code.
- Simulation of magnetic guide for T-REX.
- Improve user experience.