Atoms and photons

Chapter 4

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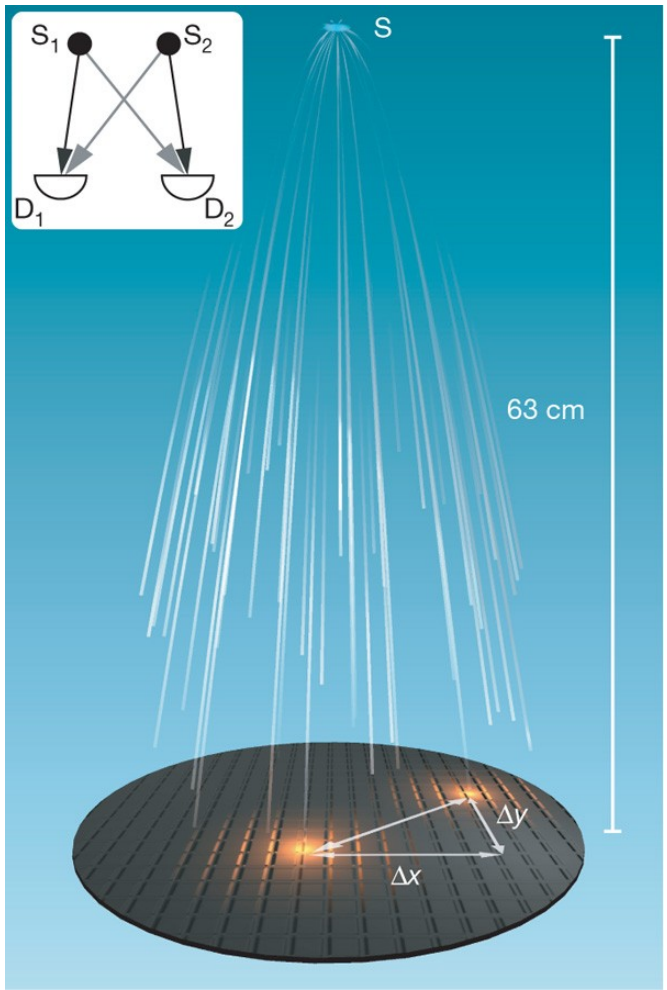
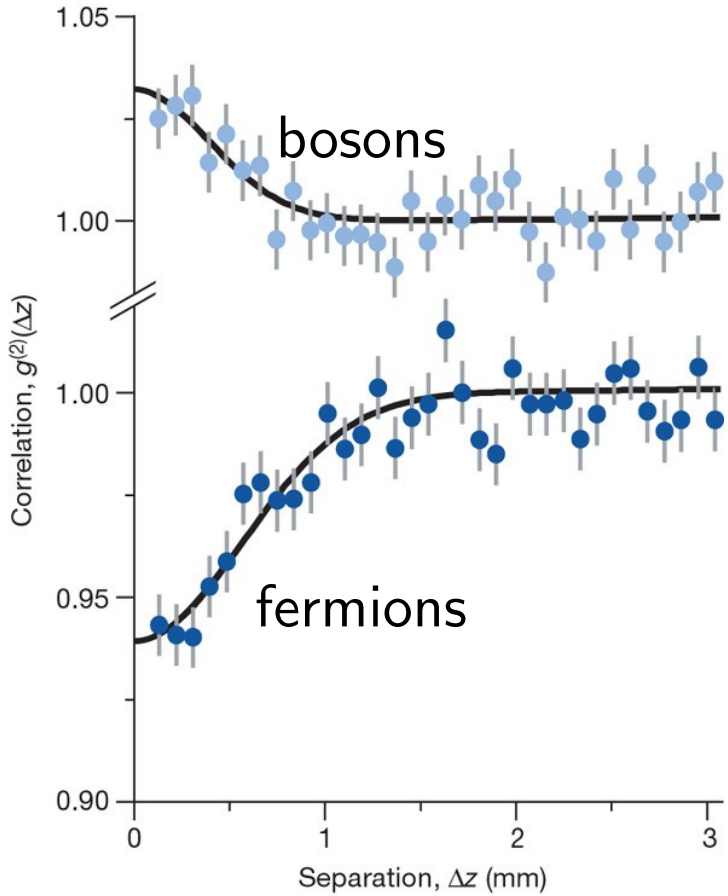
December 13, 2022

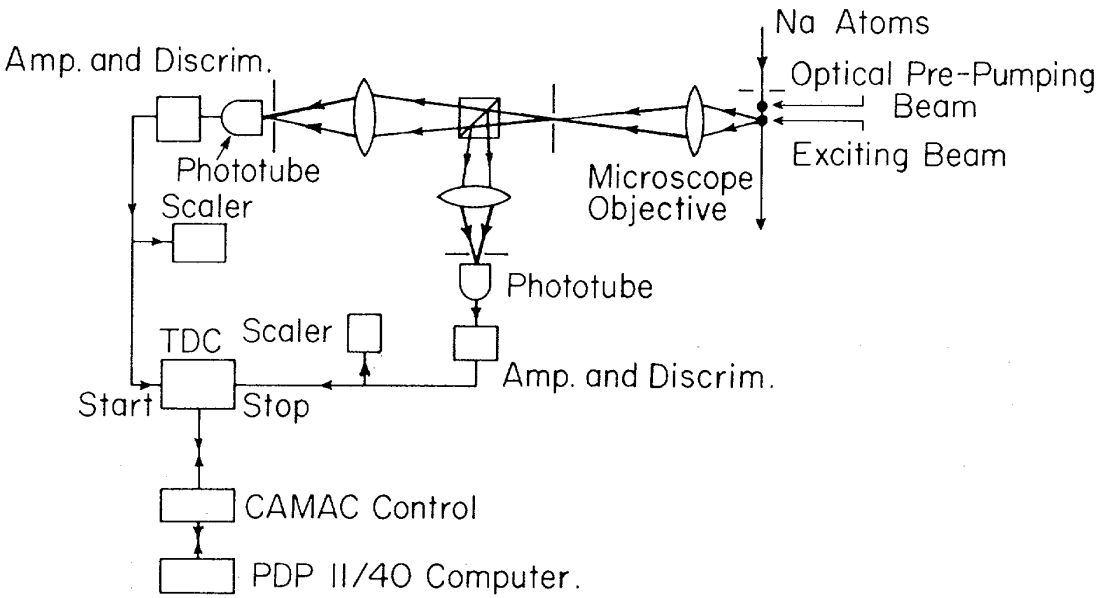
Hanbury Brown and Twiss experiments with atoms



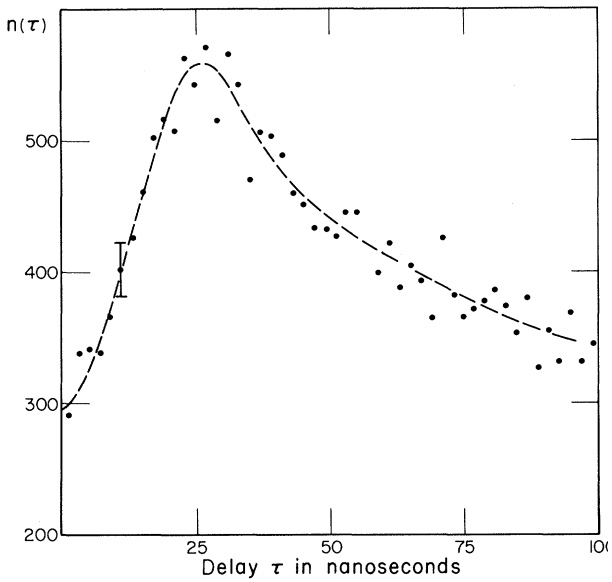


Jeltes et al., Nature **445**, 402 (2007)

Antibunching for a single emitter



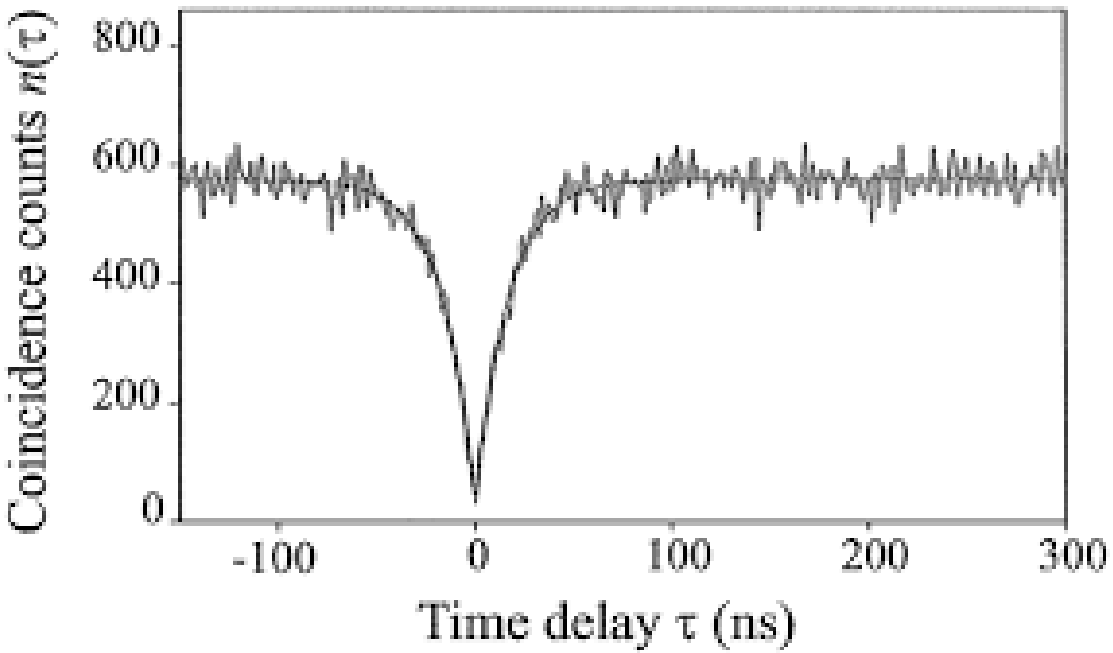
experimental setup

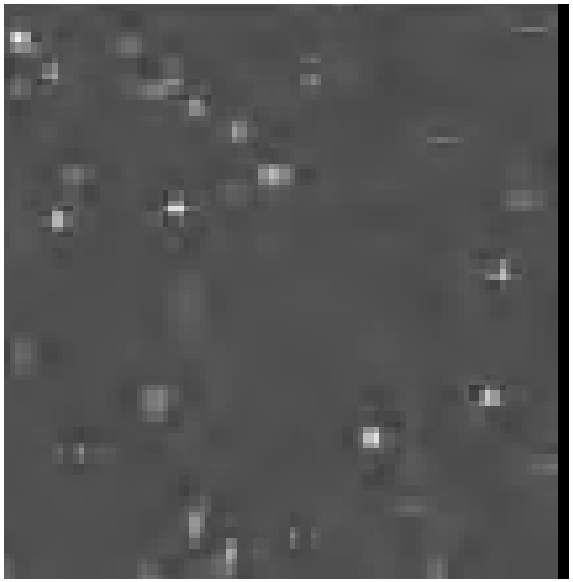


correlation signal vs τ

H. J. Kimble, M. Dagenais, and L. Mandel, Phys. Rev. Lett. **39**, 691 (1977)

Antibunching for a single emitter





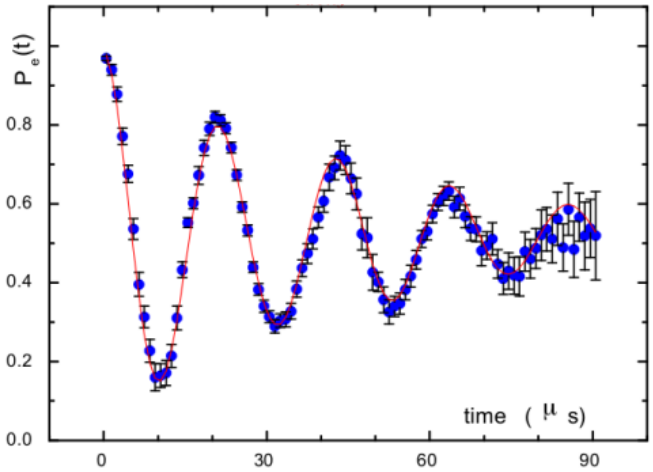
semiconductor nanocrystals

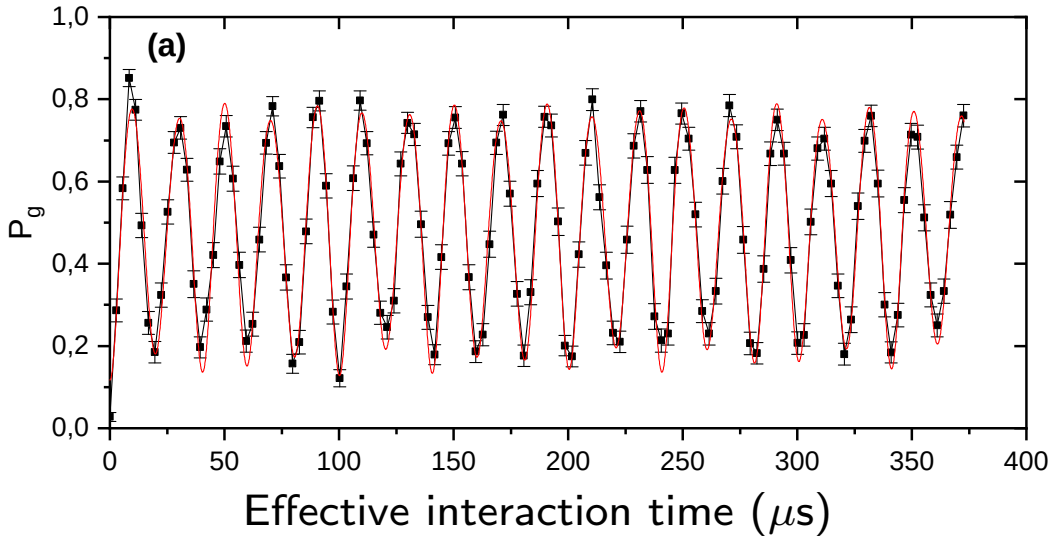
G. Messin, J. P. Hermier, E. Giacobino, P. Desbiolles, and M. Dahan, Optics Letters **26**, 1891 (2001)

Evolution in vacuum

$|\psi(t=0)\rangle = |e,0\rangle$

Evolution of the population P_e:



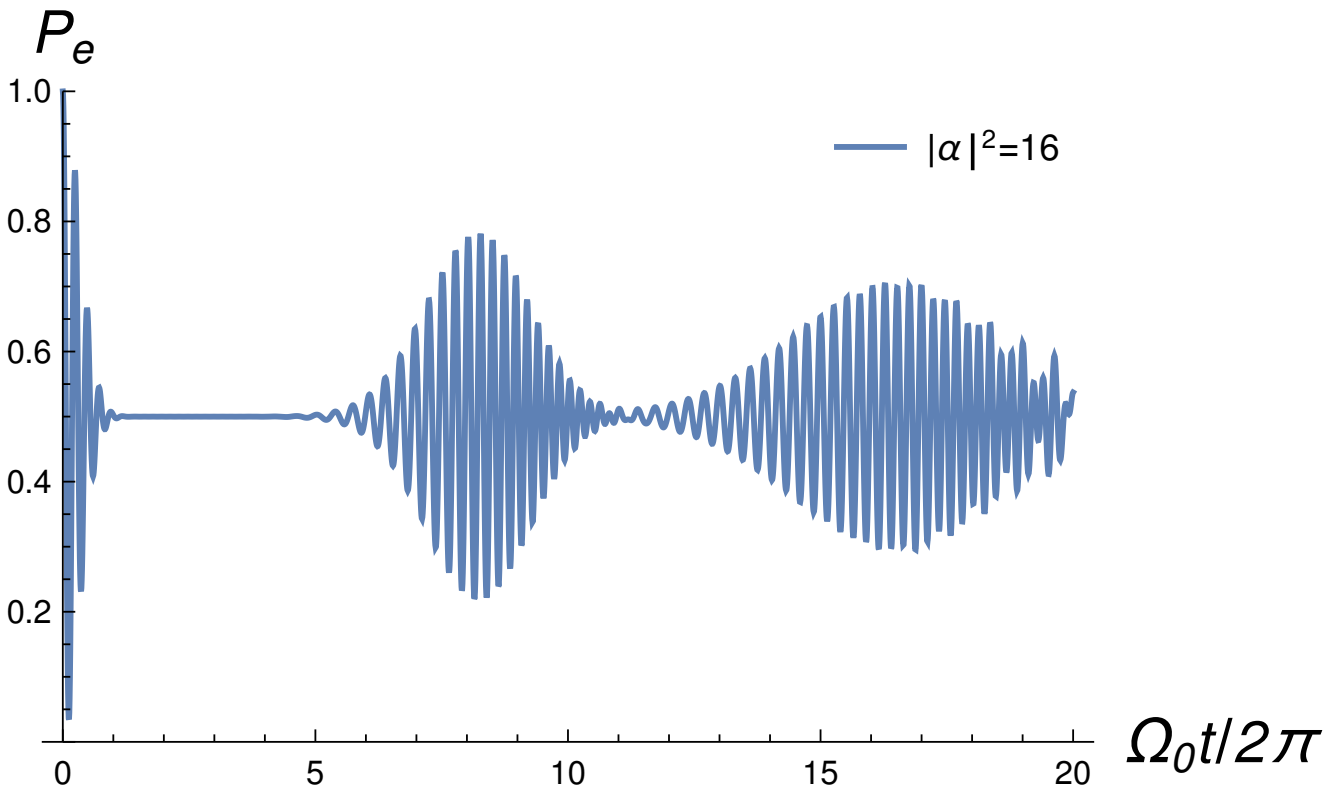


Brune et al., PRL 1996 / Assemat et al., PRL 2019

Evolution in a coherent state

$|\psi(t=0)\rangle = |e,\alpha\rangle$

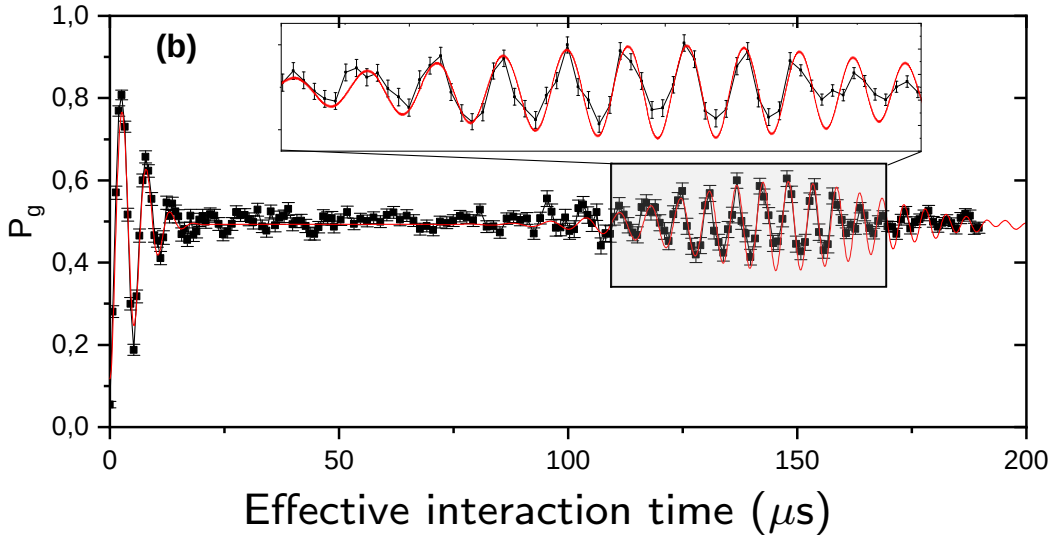
Evolution of the population P_e:



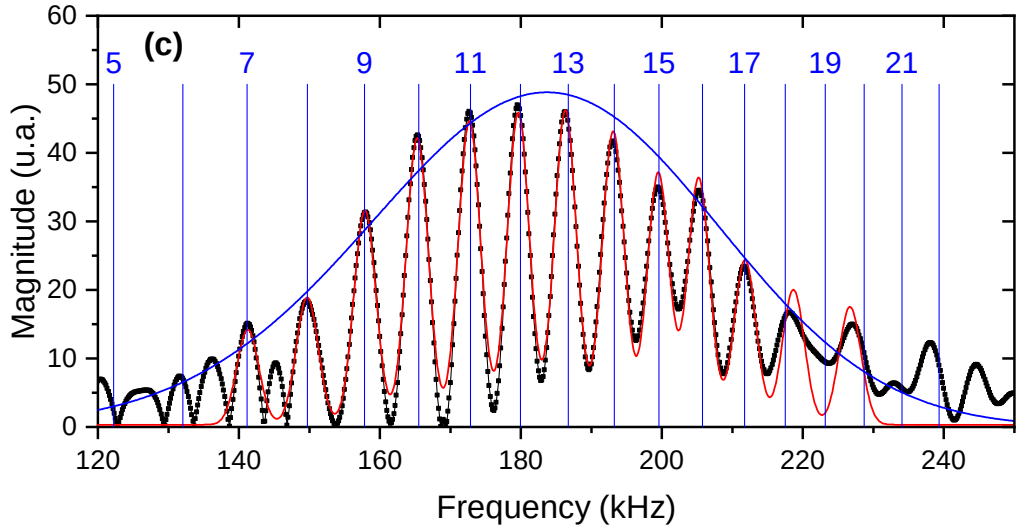
Evolution in a coherent state – recent experiment

Rabi oscillations in a small microwave field in a cavity.

Evolution of the population P_e



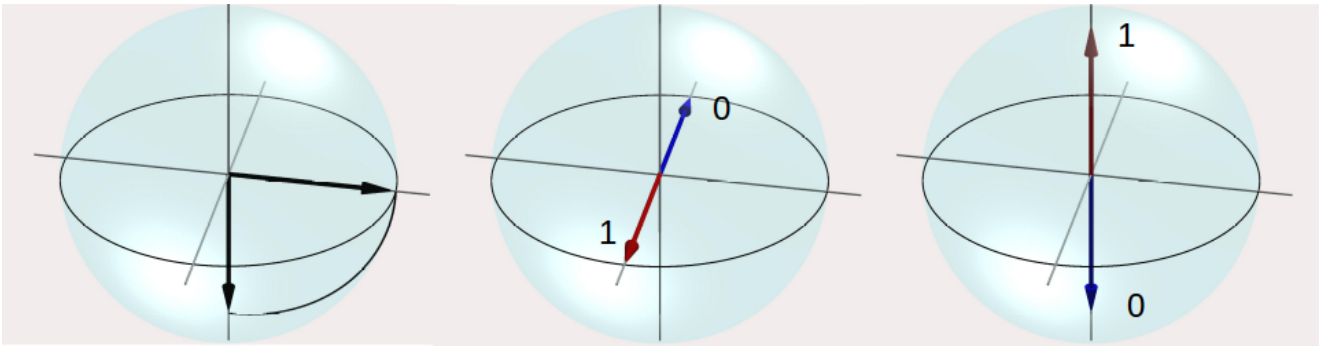
Fourier transform of the signal

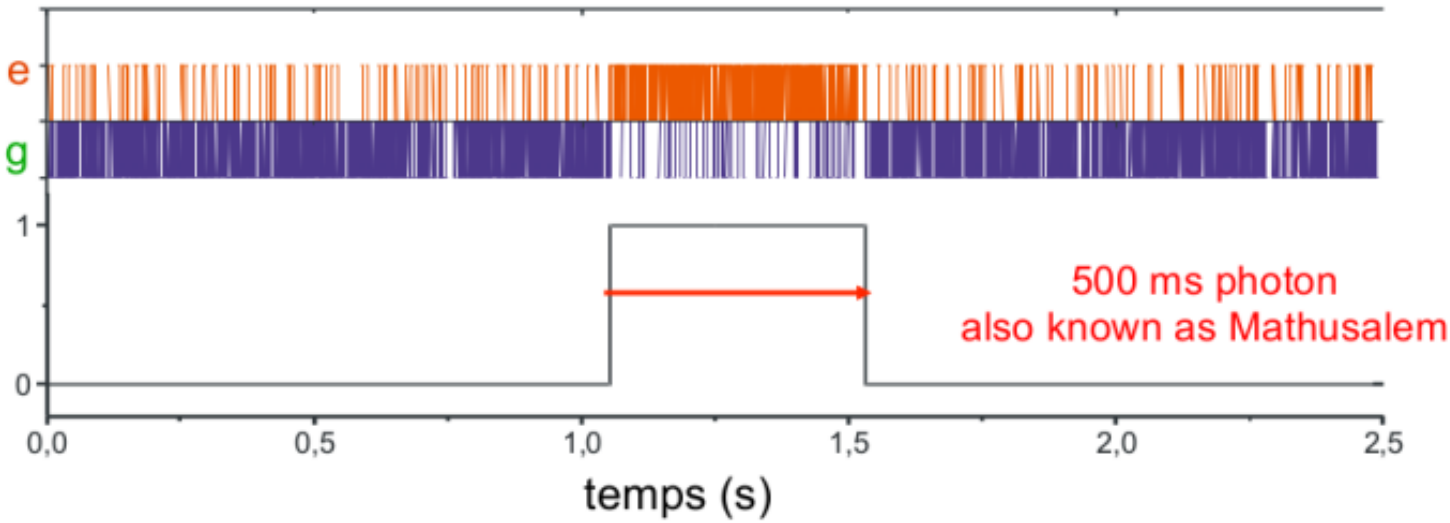


Assemat et al., PRL **123**, 143605 (2019).

QND measurement of a photon

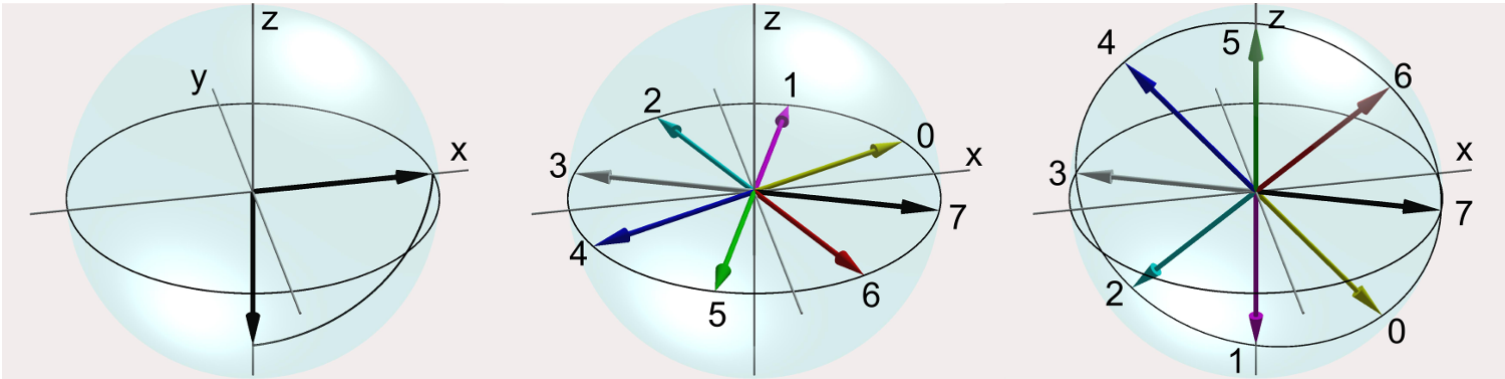
The dephasing allows to detect the presence of a photon in the cavity.





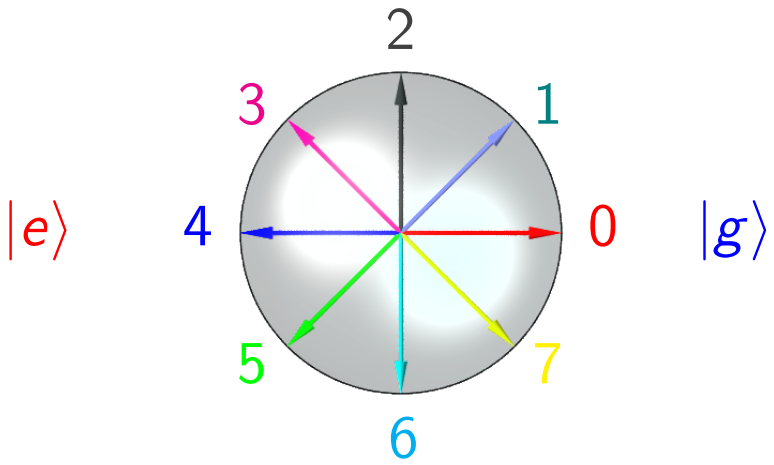
Generalization to n photons

Dephasing: $\Delta\varphi = t \times (2n+1)\Omega_1^2/4\Delta$
Choose Δ such that the dephasing is $n\pi/4$ (+ offset). The detection will give partial information on the photon number up to $n = 7$.

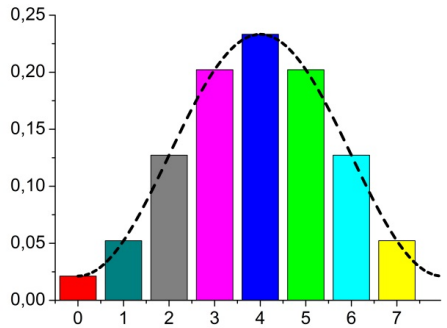


Generalization to n photons

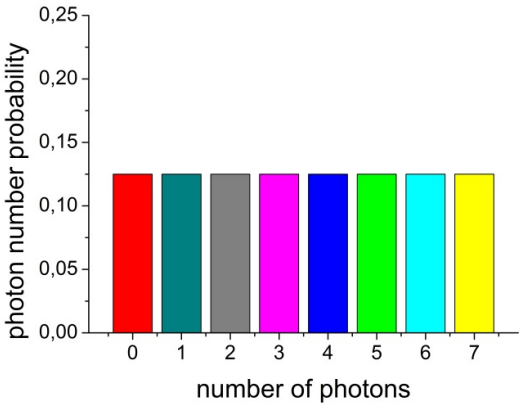
Example: detect a field state with $n \leq 7$



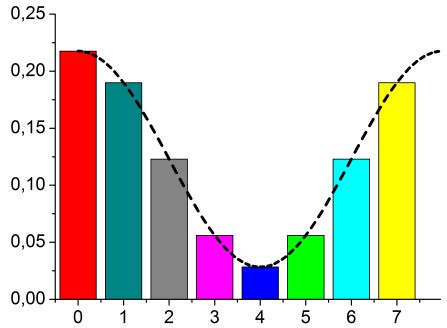
$P(n)$ after detection in $|e\rangle$:



initial flat $P(n)$:

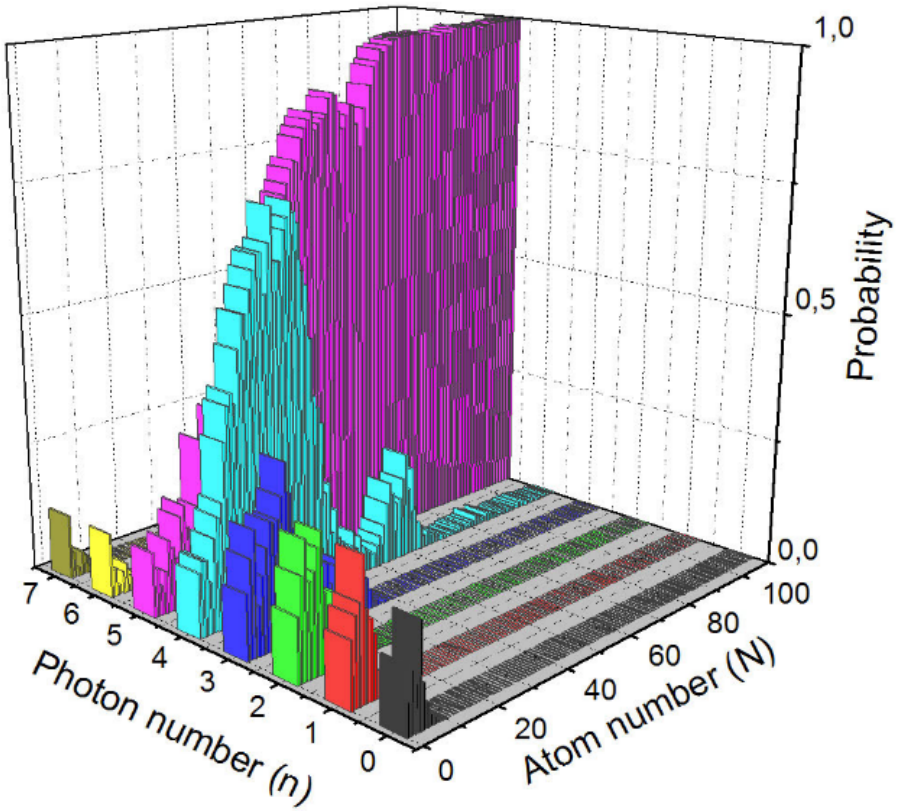


$P(n)$ after detection in $|g\rangle$:



Collapse to a photon number state

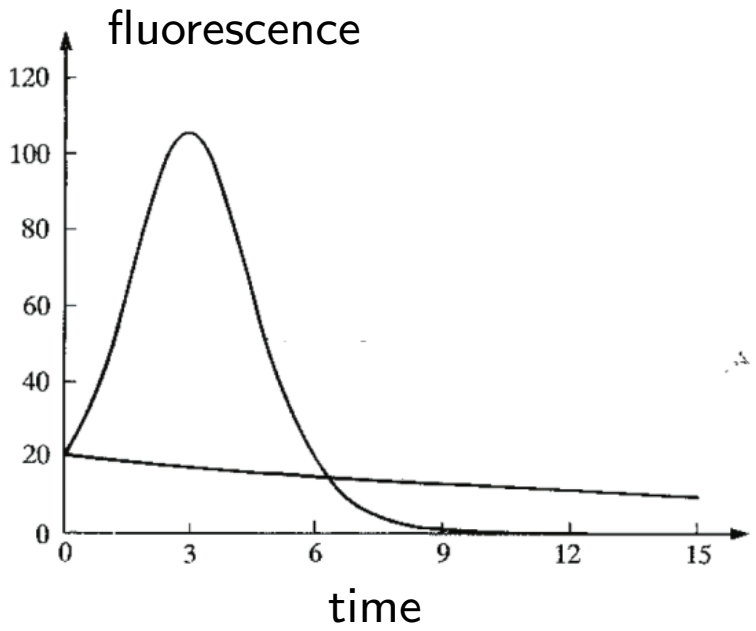
Evolution of $P(n)$ while detecting 110 atoms in a single sequence:



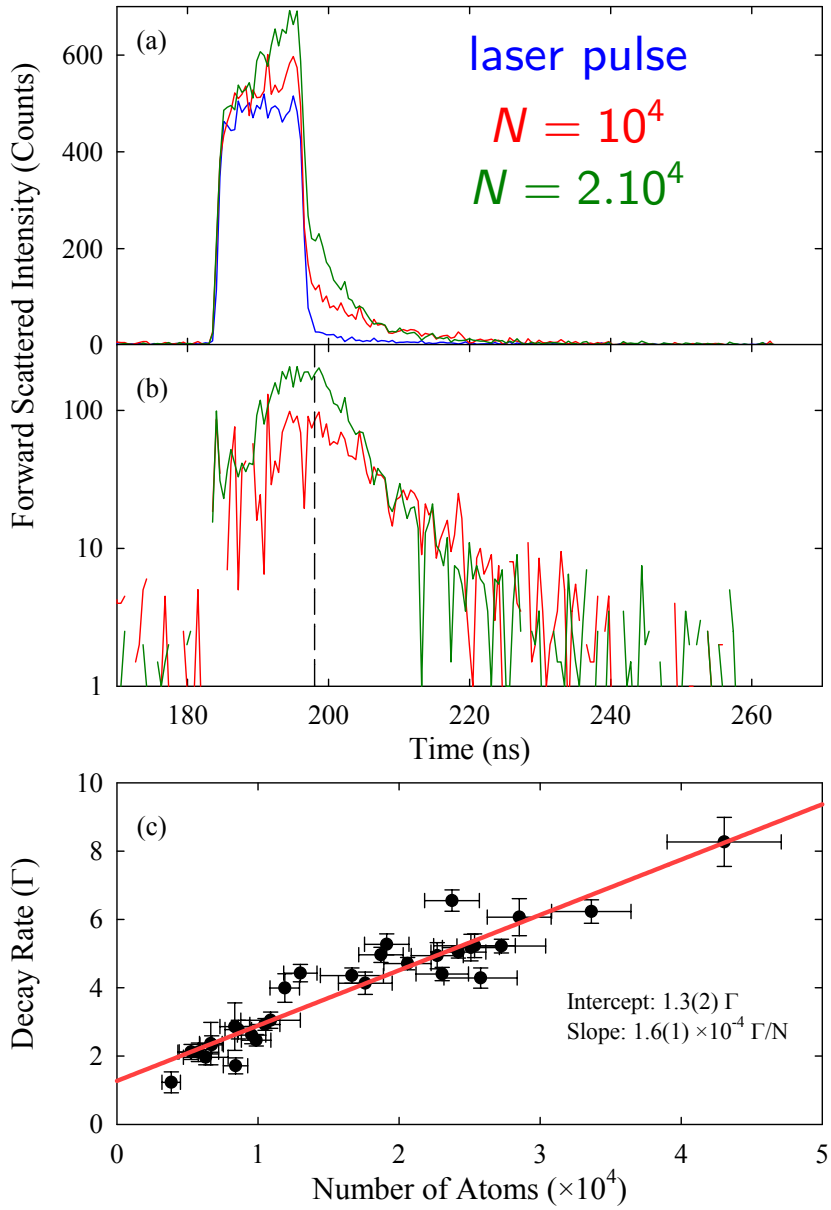
- Initial coherent field with 3.7 photons
- Initial inferred distribution flat (no information) but final result independent of initial choice
- Progressive collapse of the field state vector during information acquisition

Superradiance of N emitters

Theory: from Claude Fabre's lecture notes

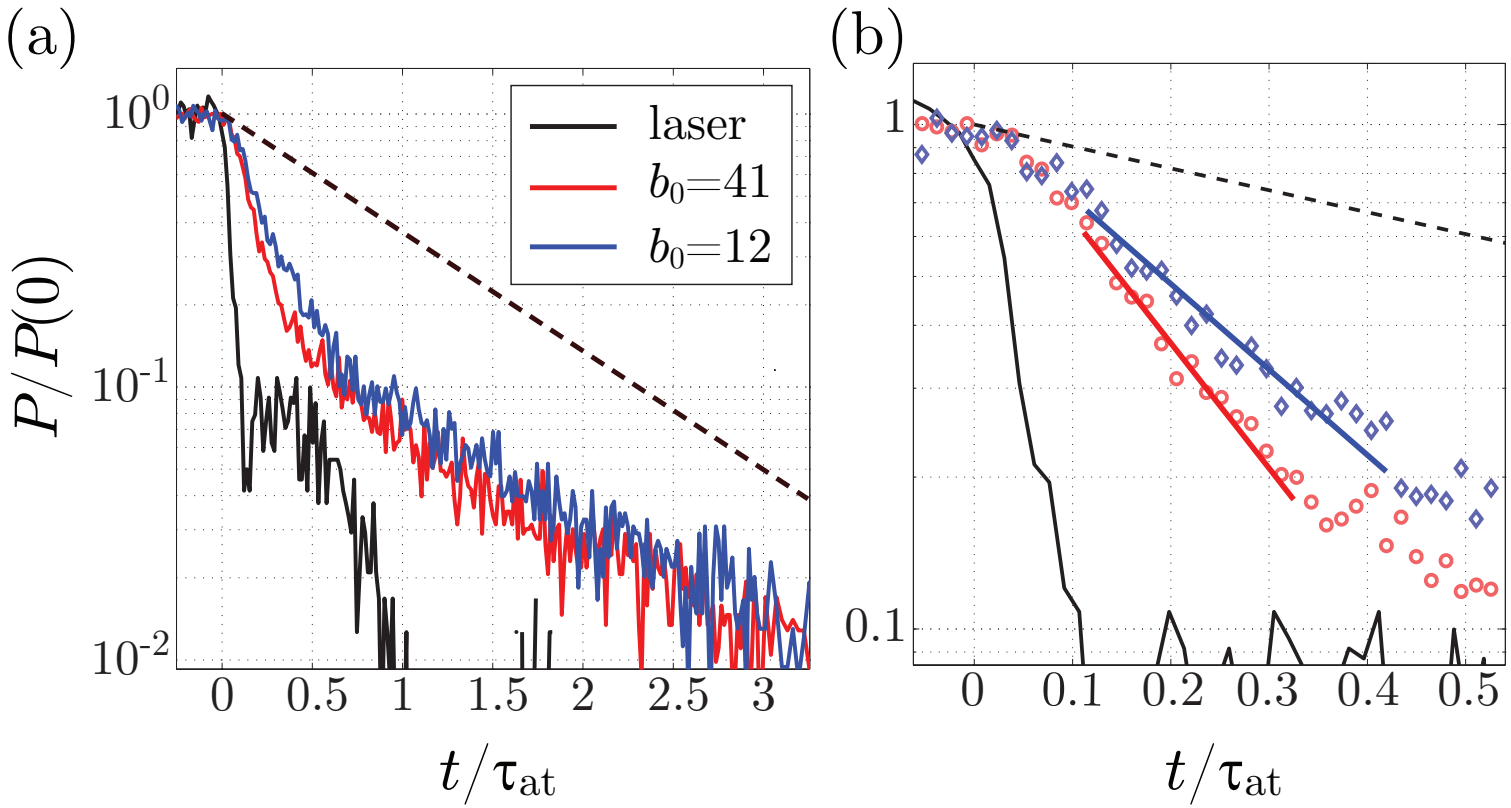


Experiment, forward scattering: S. J. Roof, K. J. Kemp, M. D. Havey and I. M. Sokolov, Phys. Rev. Lett. **117**, 073003 (2016)



Superradiance of N emitters

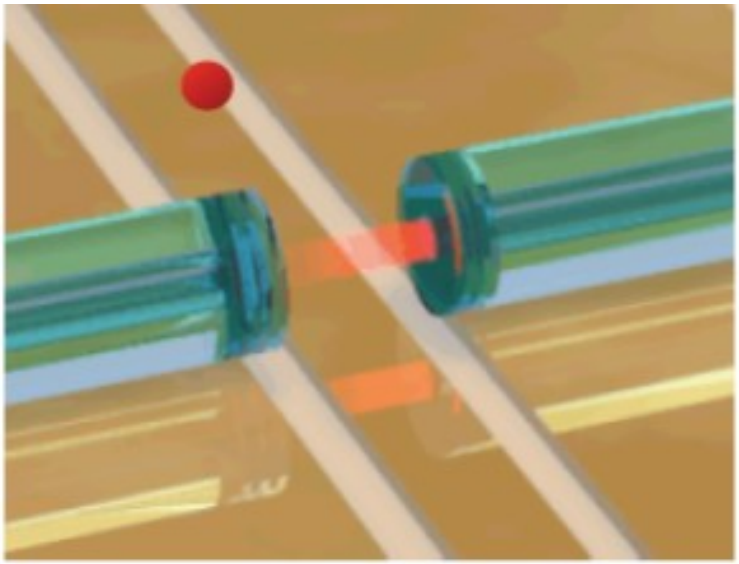
Experiment, transverse scattering: radiation faster by a factor 3-5.

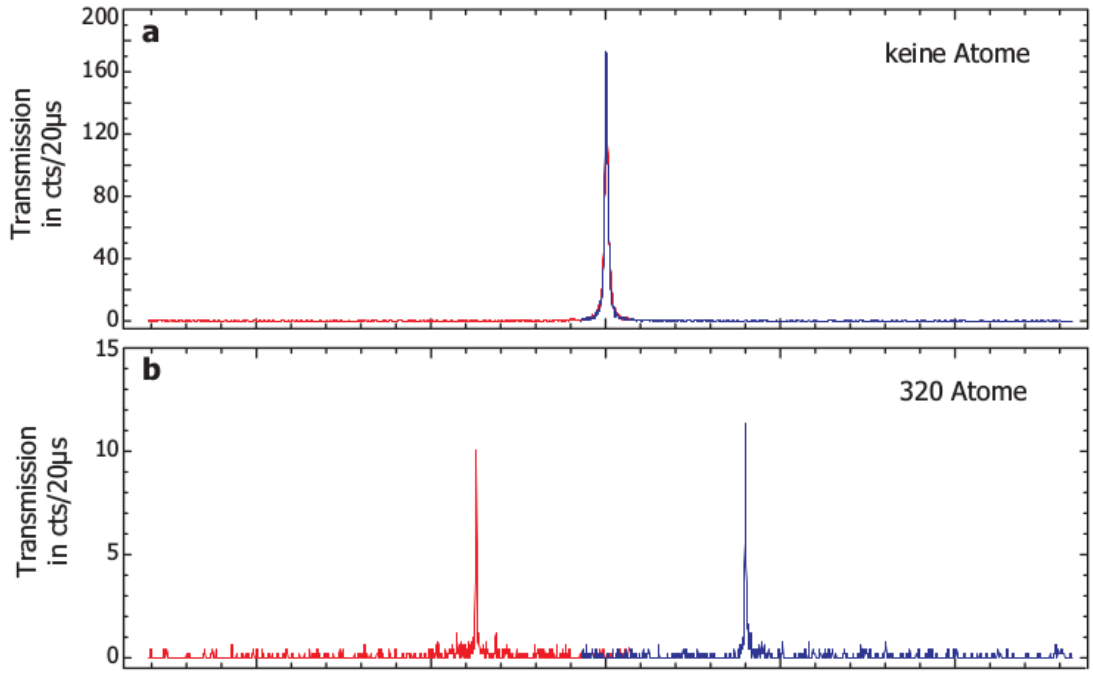


M. O. Araújo, I. Krešić, R. Kaiser, and W. Guerin, Phys. Rev. Lett. **117**, 073002 (2016).

Cavity QED with N atoms

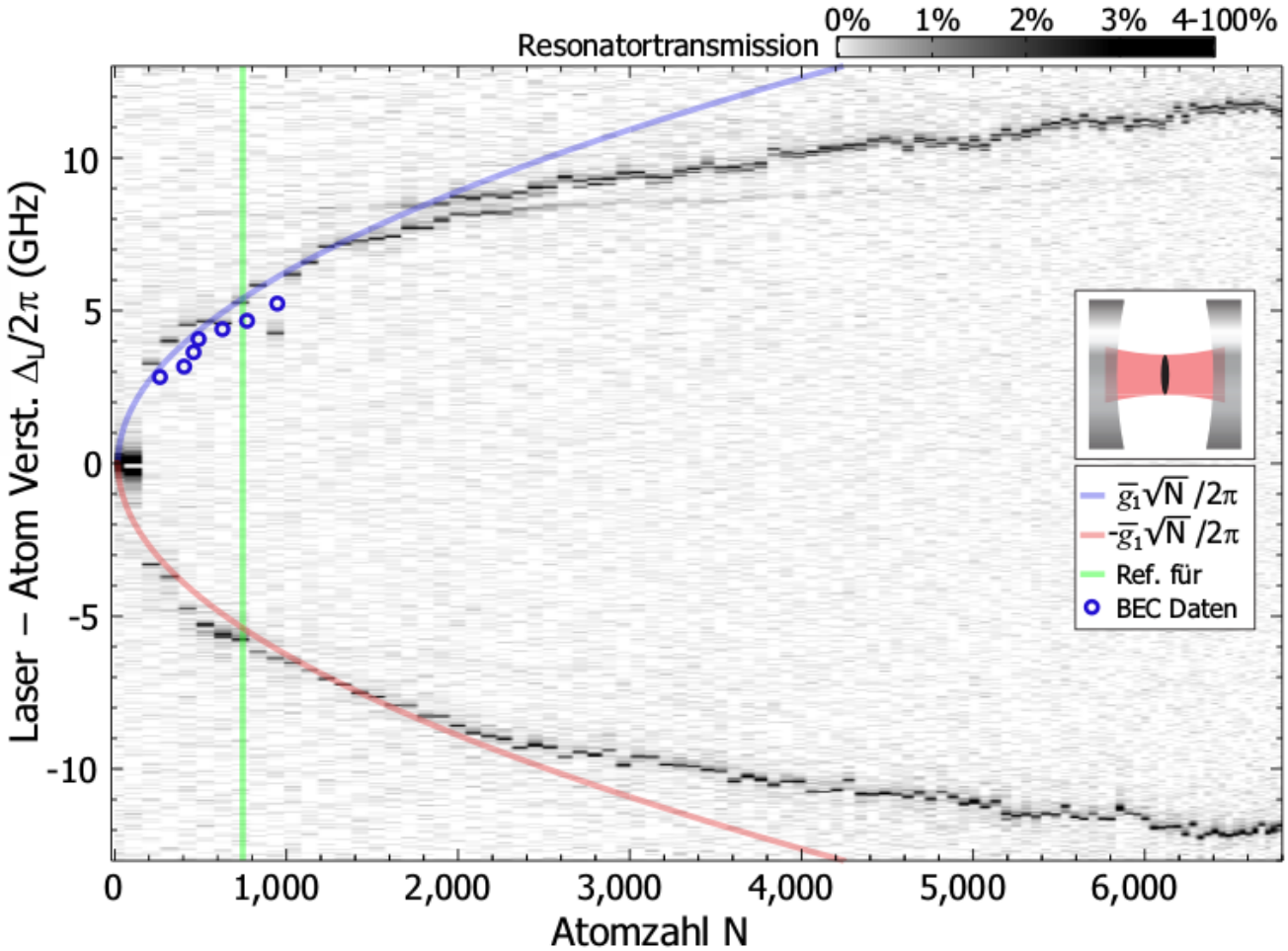
Experiments of the Jakob Reichel's group: cold atoms in a fiber based microcavity on an atom chip. Splitting $\propto$ coupling $\propto \sqrt{N}$





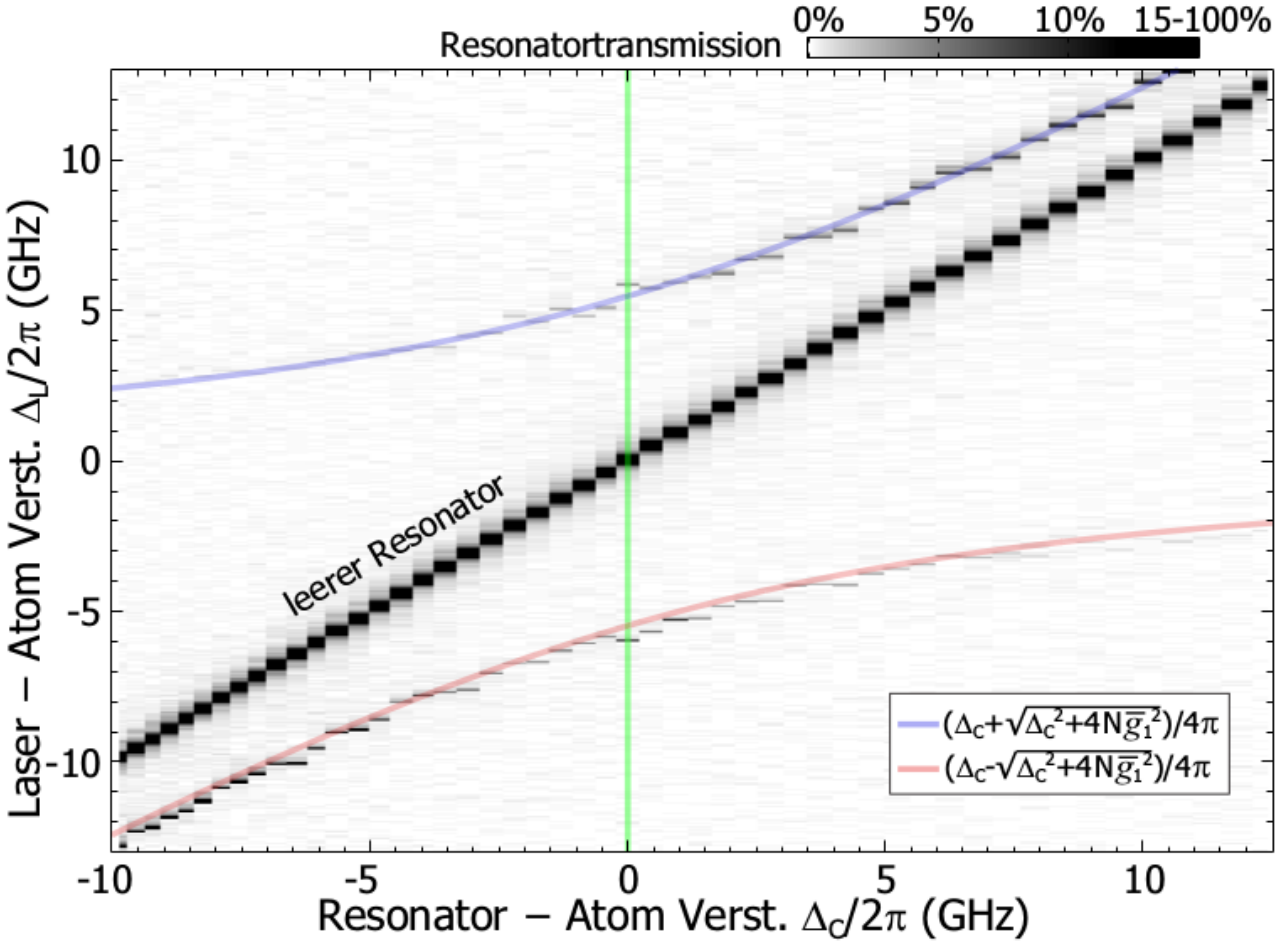
Cavity QED with N atoms

Transmission spectrum with $\Delta_c = 0$ and variable N. Splitting $\propto$ coupling $\propto \sqrt{N}$



Cavity QED with N atoms

Transmission spectrum with $N = 750$ and variable Δ_c



Detection of single atoms with the cavity

Cavity on resonance $\Delta_c = 0$