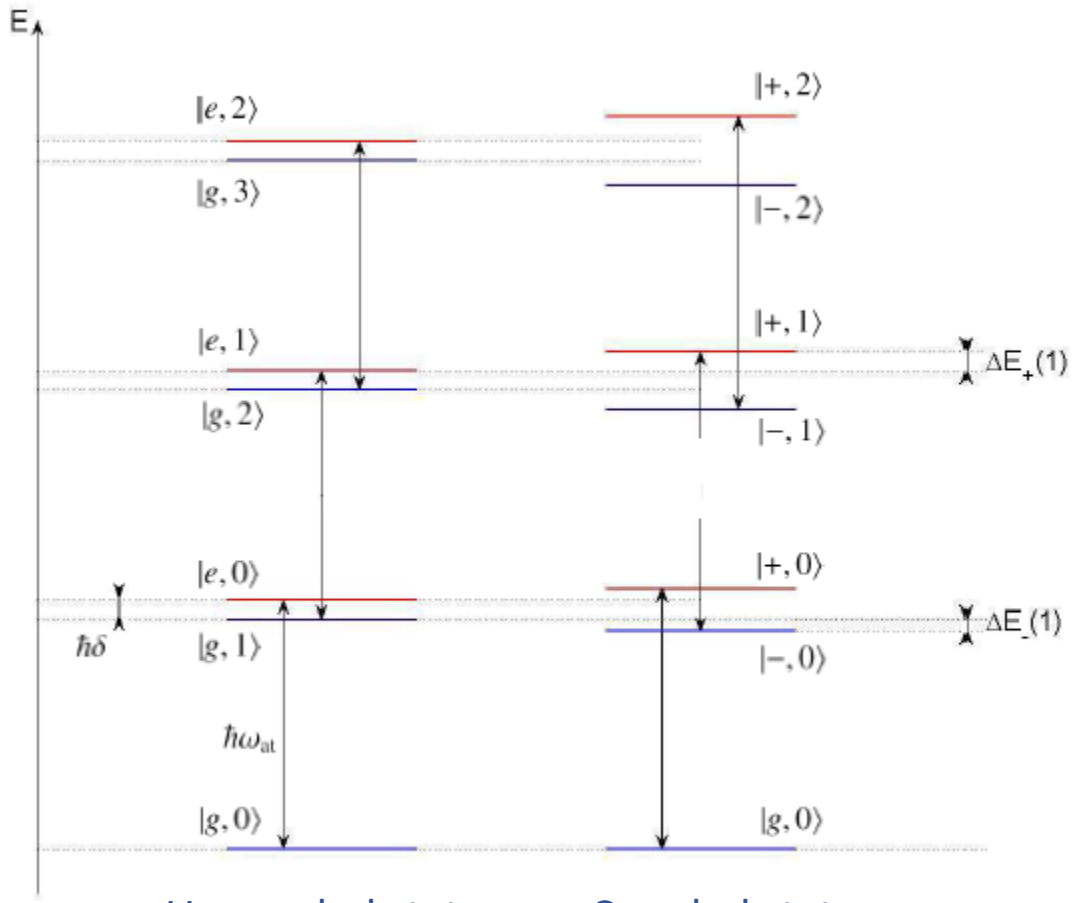
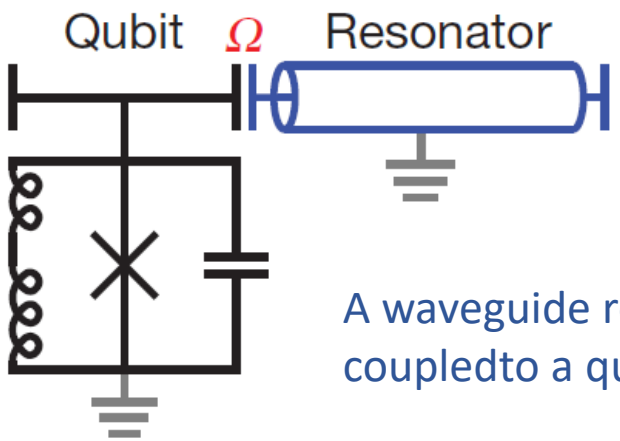
Energy levels in the detuned case

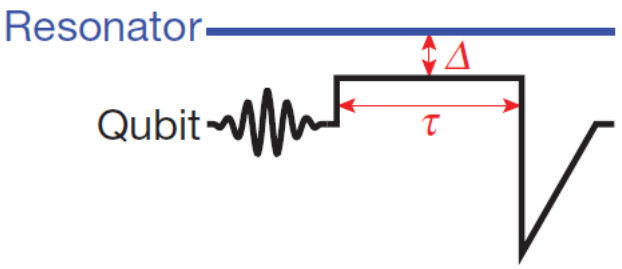


Uncoupled states Coupled states

Quantum Rabi oscillations in the detuned case

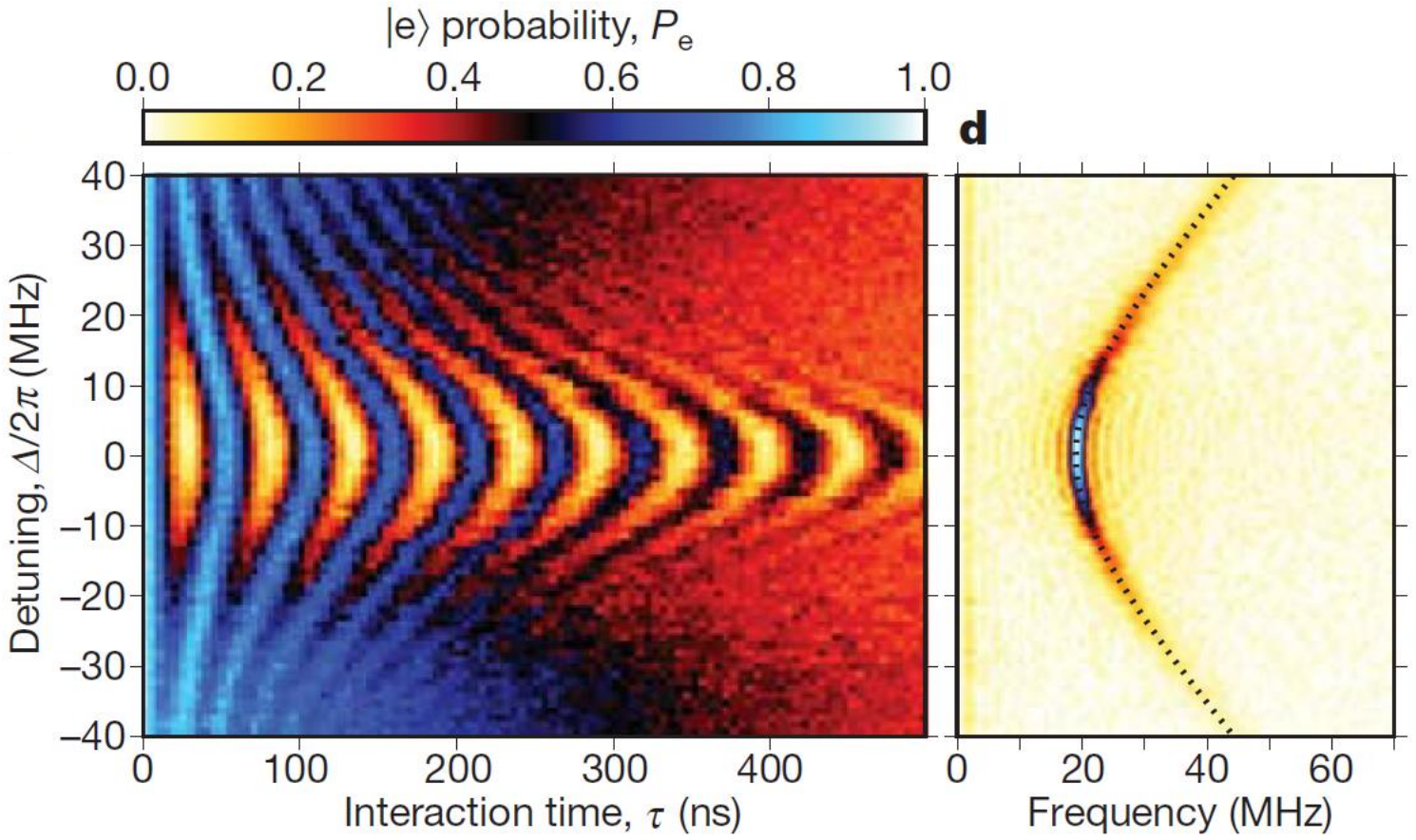


A waveguide resonator coupledto a qubit



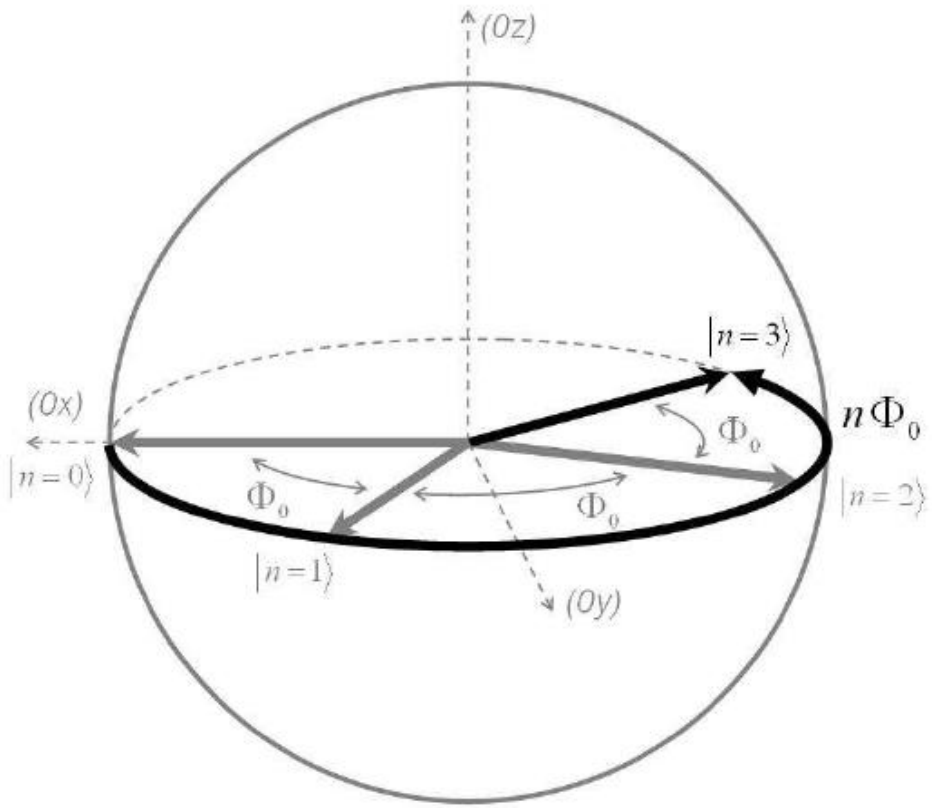
Rabi-swap pulse sequence

Experimental results

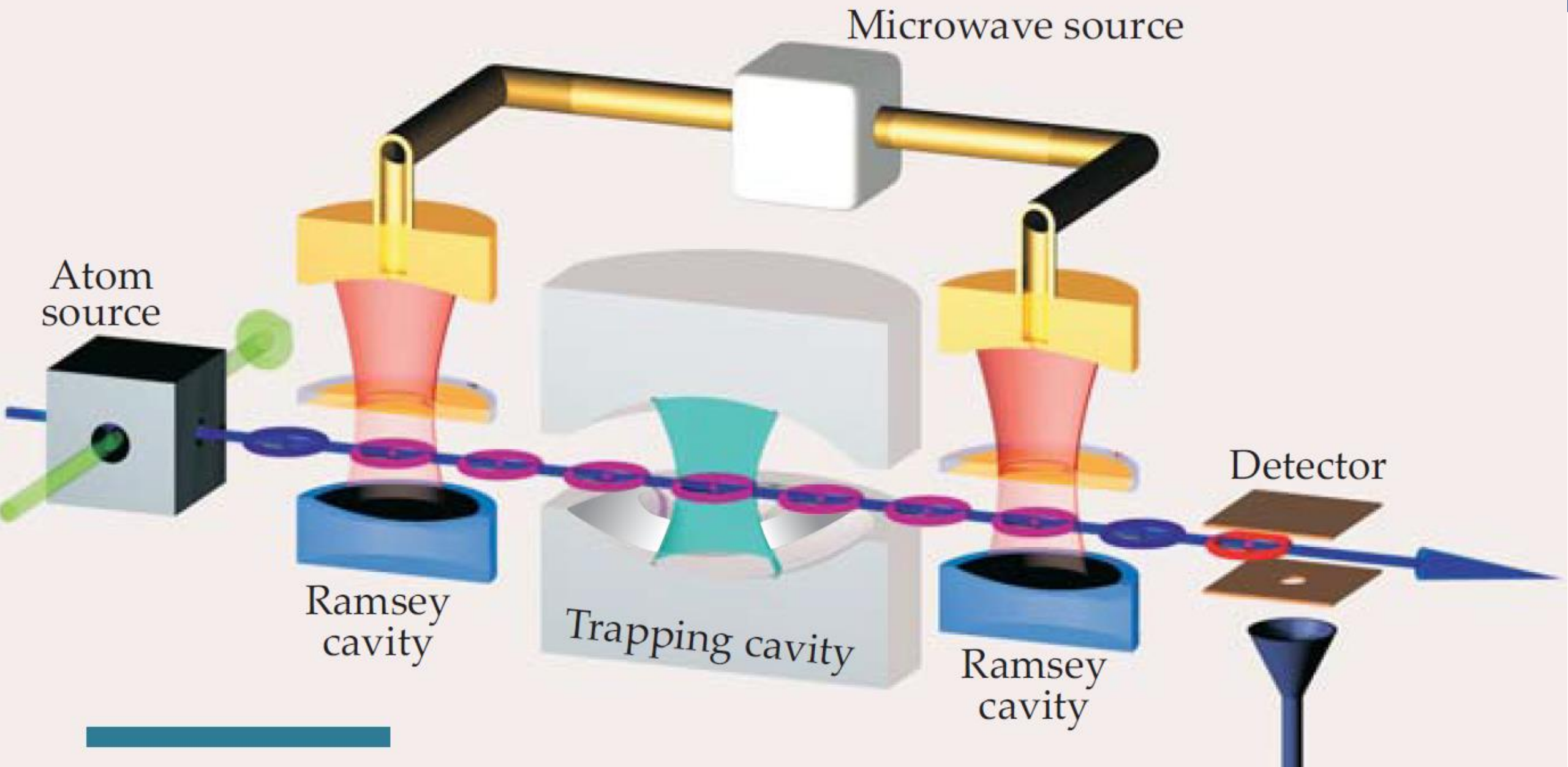


M. Hofheinz, … A. Cleland, *Synthesizing arbitrary quantum states in a superconducting resonator*, Nature 2009

Atomic phase-shift depends linearly on the photon number

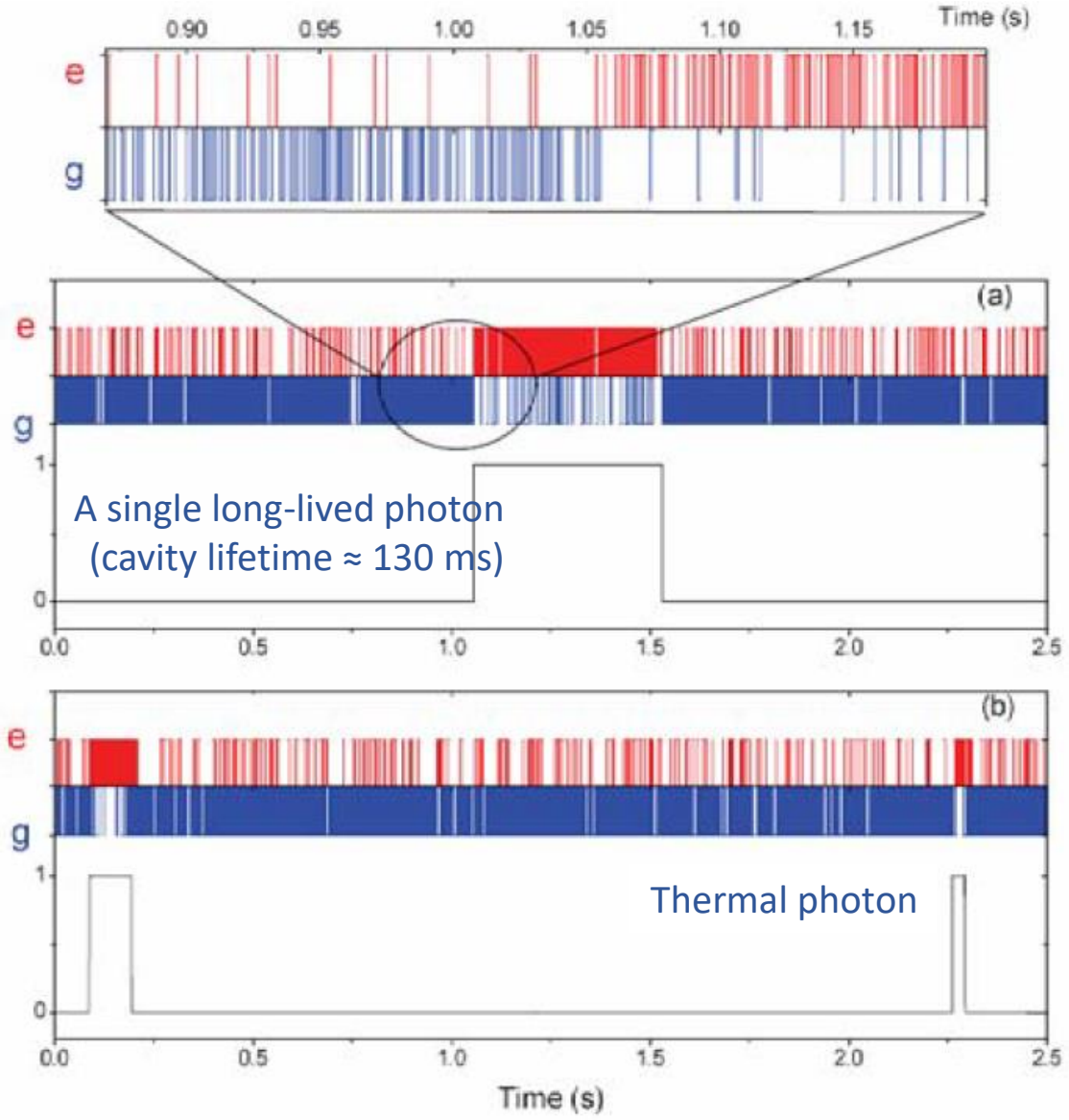


The experimental setup (2006)



Birth, life and death of a photon

Two individual trajectories



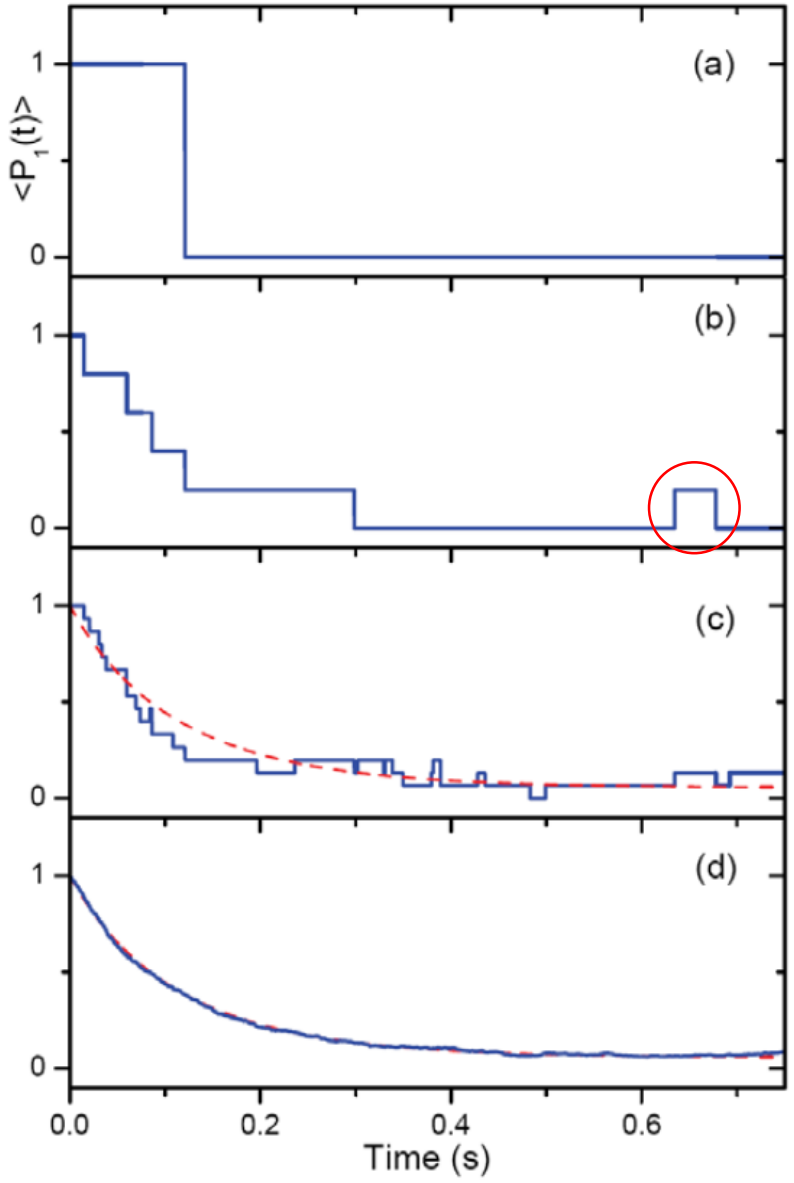
Short-term fluctuations due to measurement errors

Raw signal

Majority vote (8 atoms)

S. Gleyzes, … S. Haroche, *Quantum jumps of light recording the birth and death of a photon in a cavity*, Nature 2007

From quantum randomness to smooth ensemble average



1 experiment

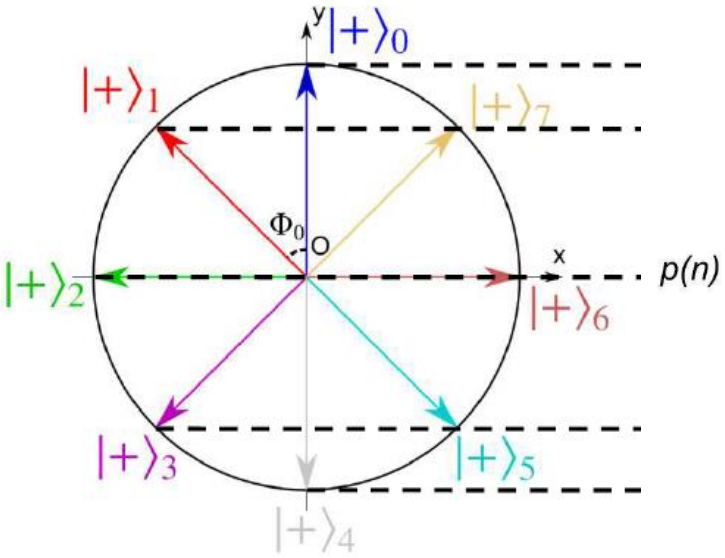
5 averages
thermal photon

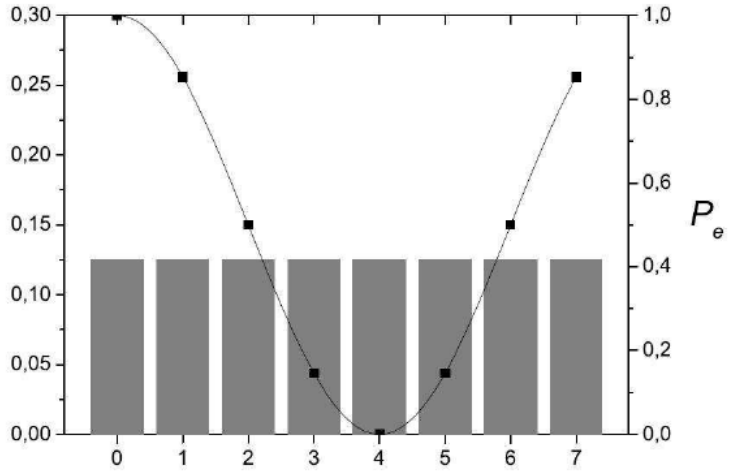
15 averages
exponential decay

904 averages
≈ 0.05 photon background

S. Gleyzes, … S. Haroche,
Quantum jumps of light recording the birth and death of a photon in a cavity, Nature 2007

Extension to more excited states: state estimation

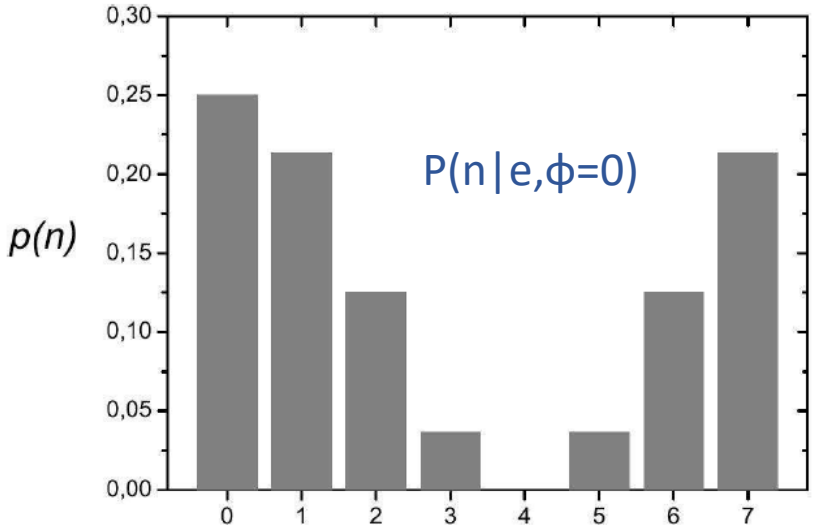


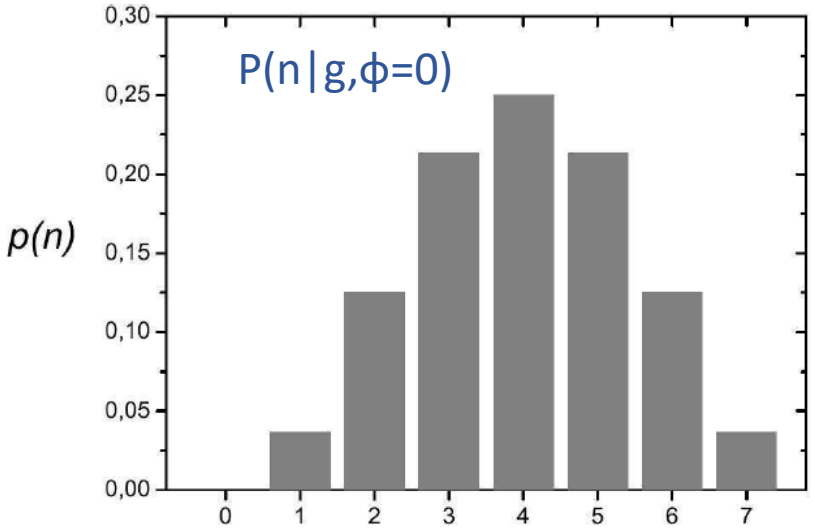


Initial distribution

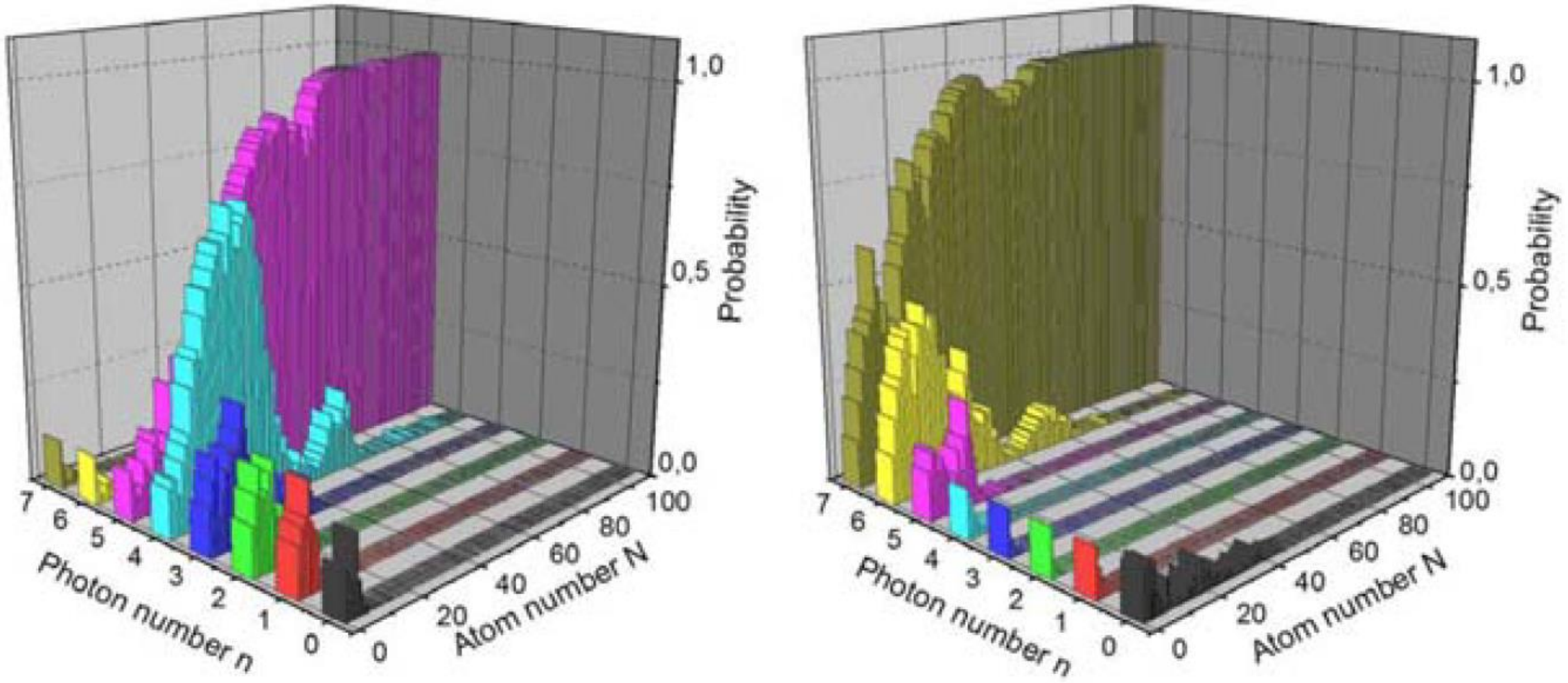
Probability P_e of a measurement in the excited state

Estimated distributions



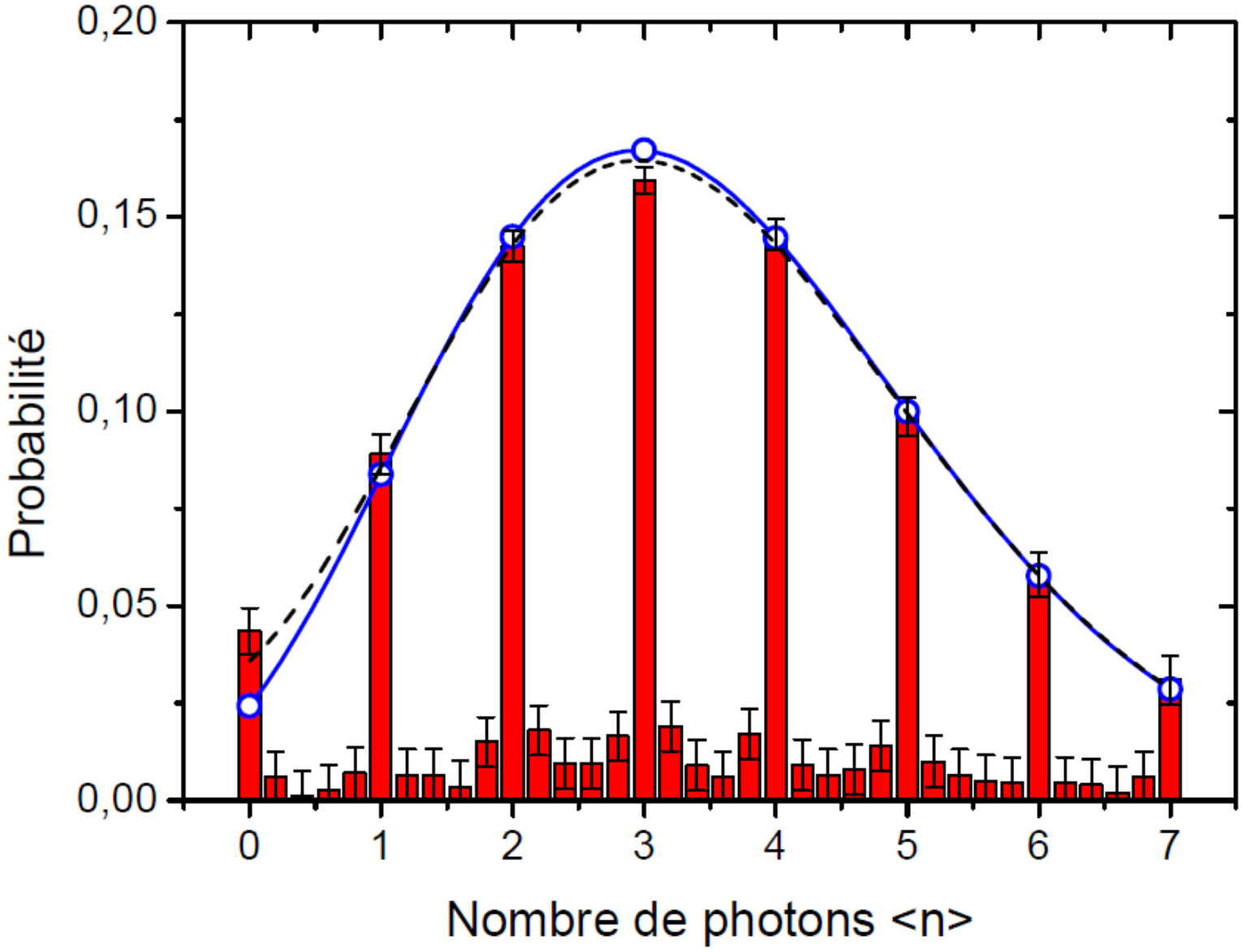


The field collapse into a number state: individual trajectories



C. Guerlin, … S. Haroche, *Progressive field-state collapse and quantum non-demolition photon counting*, Nature 2007 (6 months later)

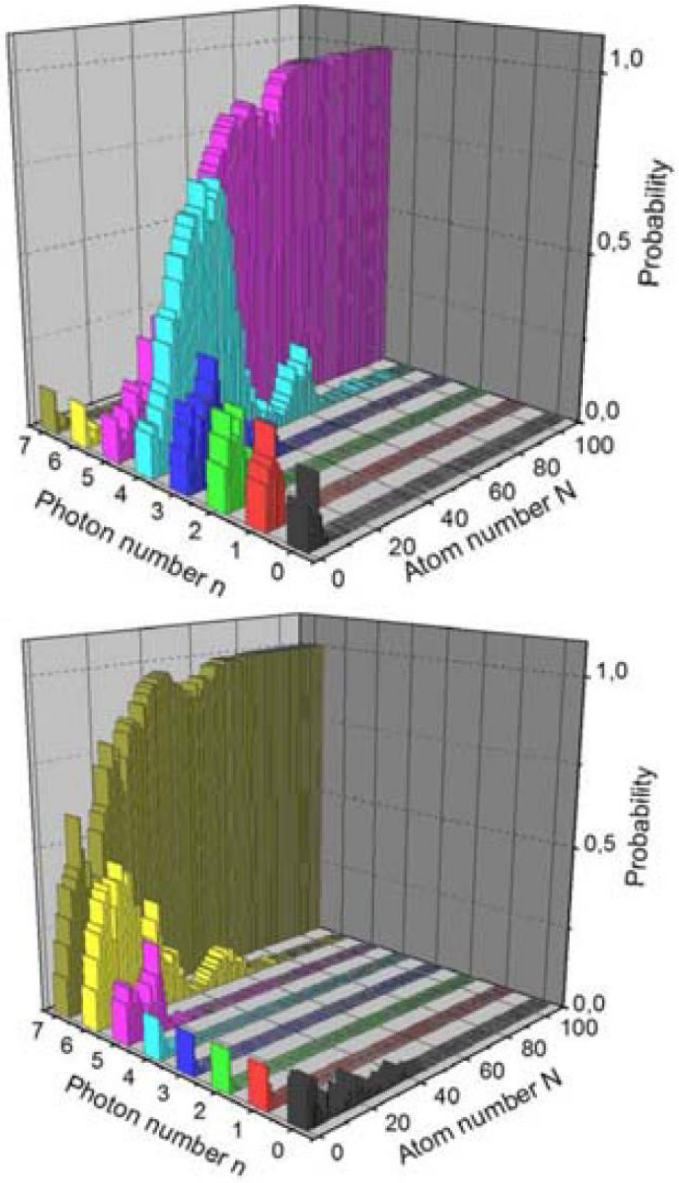
Number distribution of a coherent state



Excellent agreement
with Poissonian distribution
(+ n=8 correction)

C. Guerlin, … S. Haroche,
Progressive field-state collapse and quantum non-demolition photon counting,
Nature 2007 (6 months later)

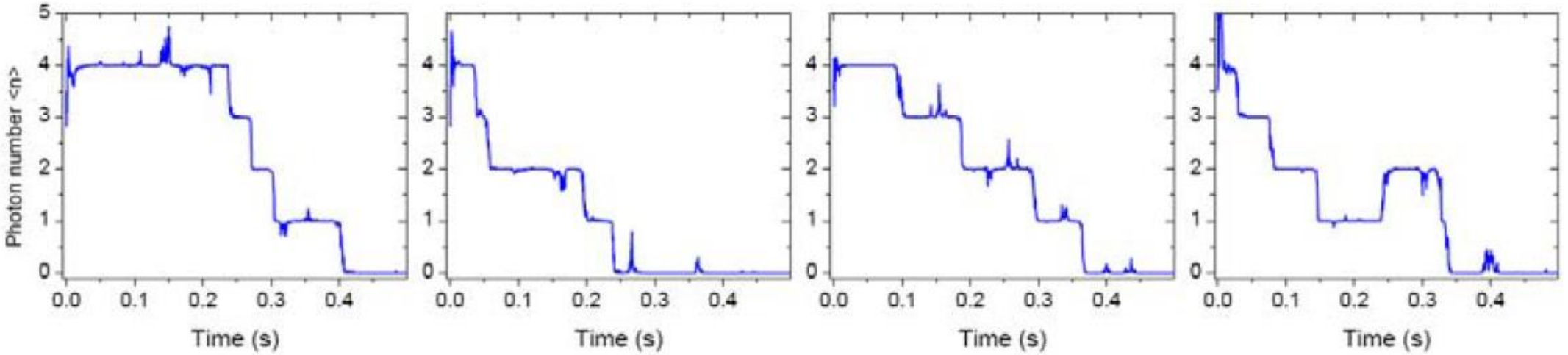
Subsequent time evolution: cavity damping

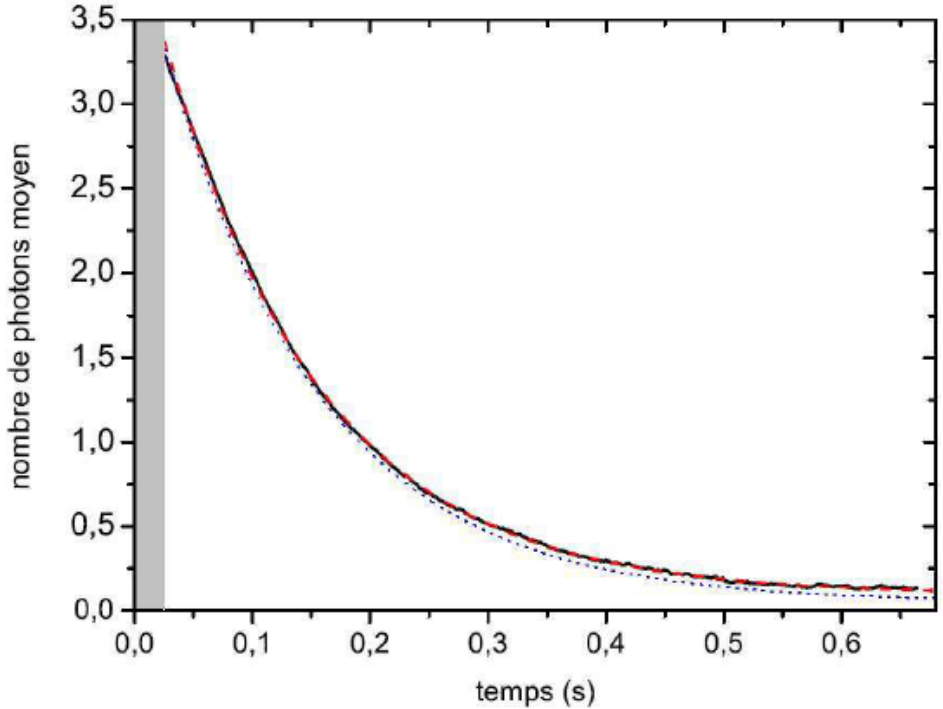


Quantum jumps
as photons leave the cavity
(same events as previous slide)

C. Guerlin, … S. Haroche,
Progressive field-state collapse and quantum non-demolition photon counting,
Nature 2007 (6 months later)

Subsequent time evolution: cavity damping

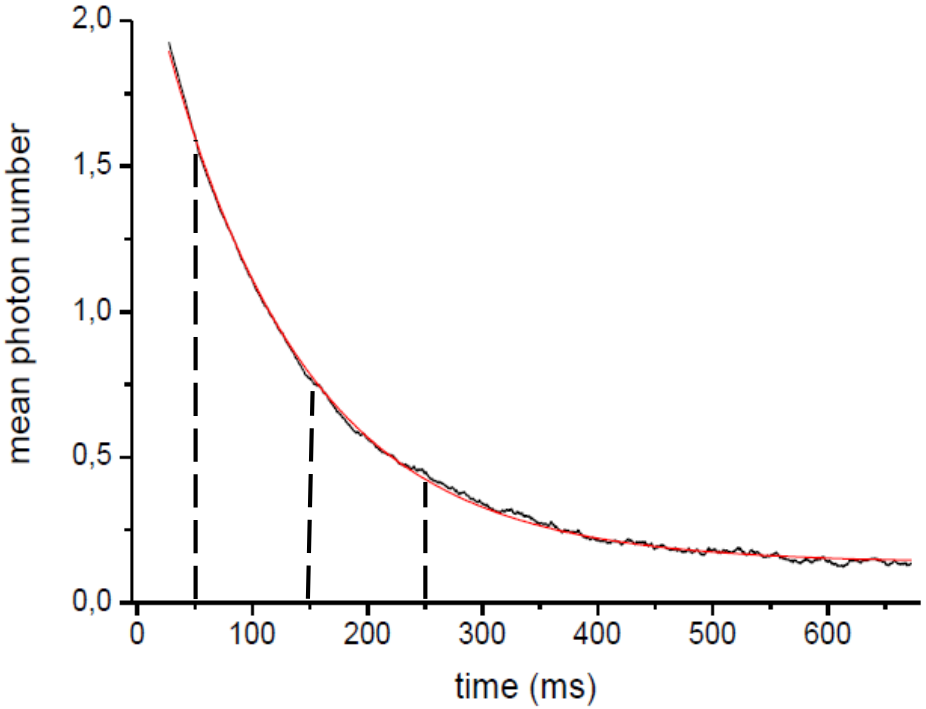




Averaging multiple trajectories
(which first converge to the same photon number)
yields an exponential decay curve
with similar damping time
and 0.05 photon background

C. Guerlin, … S. Haroche,
Progressive field-state collapse and quantum non-demolition photon counting,
Nature 2007 (6 months later)

Subsequent time evolution: cavity damping



From a different set of data
Different Photon number distributions (at different times)
can be measured (overaging over many different experiments)
+ fit with the Poissonian law of coherent states

A relaxing coherent state remains a coherent state