

"Fundamentals of Rydberg Atoms and
Molecules »
Workshop "YEA" (Young Excited Atomix)



Part II

Properties and dynamics of a cold sample of Rydberg atoms

Pierre Pillet

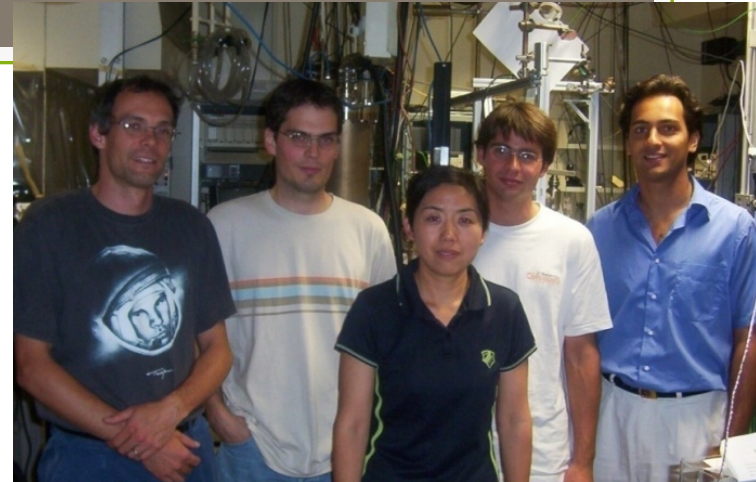
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COHERENCE School
and YEA meeting

Pisa, 20 – 22 September 2012

Cold Rydberg atoms / Ultracold plasmas

Paul Huillery
Yoann Bruneau
Thibault Vogt
Matthieu Viteau
Amodsen Chotia
Joshua H. Gurian
Jianming Zhao
Andrea Fioretti
Patrick Cheinet
Daniel Comparat
Pierre Pillet



Collaborations:

On few-body effects with Phil F. Gould, Univ of Connecticut and Jianming Zhao, Univ of Shanxi

On dipole blockade with the group of Ennio Arimondo, Univ of Pisa

On ultracold plasmas with Thomas F. Gallagher, Univ of Virginia and Ducan Tate, Colby College

On collective excitation of a pair of atoms in the dipole blockade regime with Philippe Grangier, Antoine Browaeys et al., Institut d'Optique



Interference, interaction and entanglement

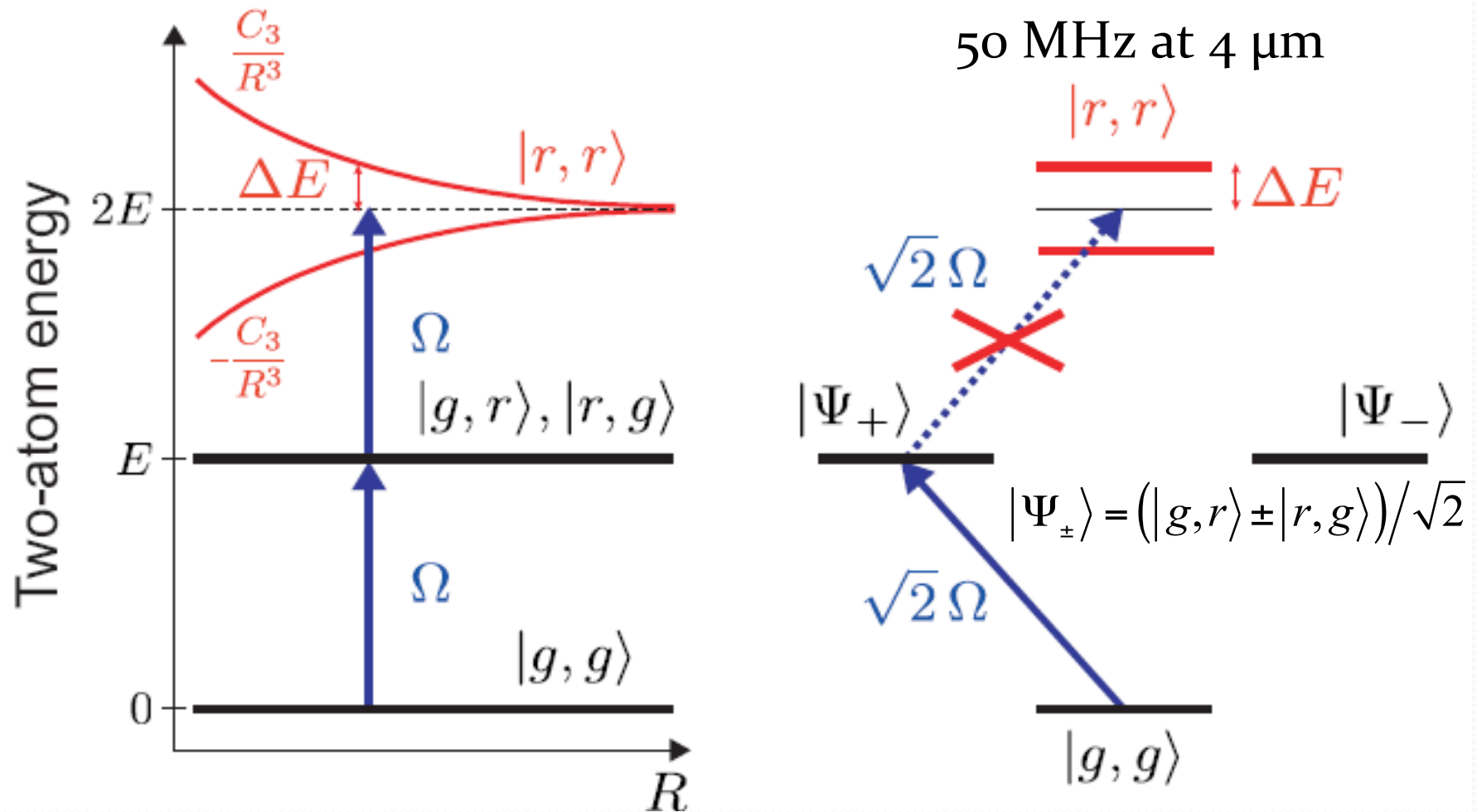
Collective excitation of a pair of atoms individually trapped in regime of blockade

Cooperativity and dipole-dipole interaction

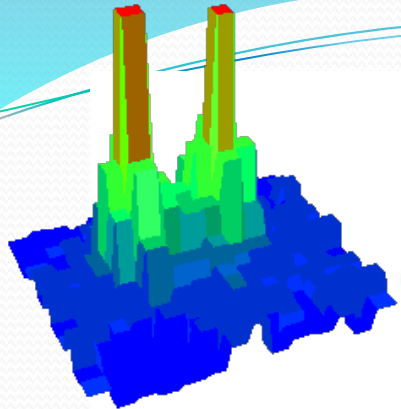
Collaboration with LCF – LAC

Alpha Gaëtan *et al*, Nature Physics 5, 115 (2009).

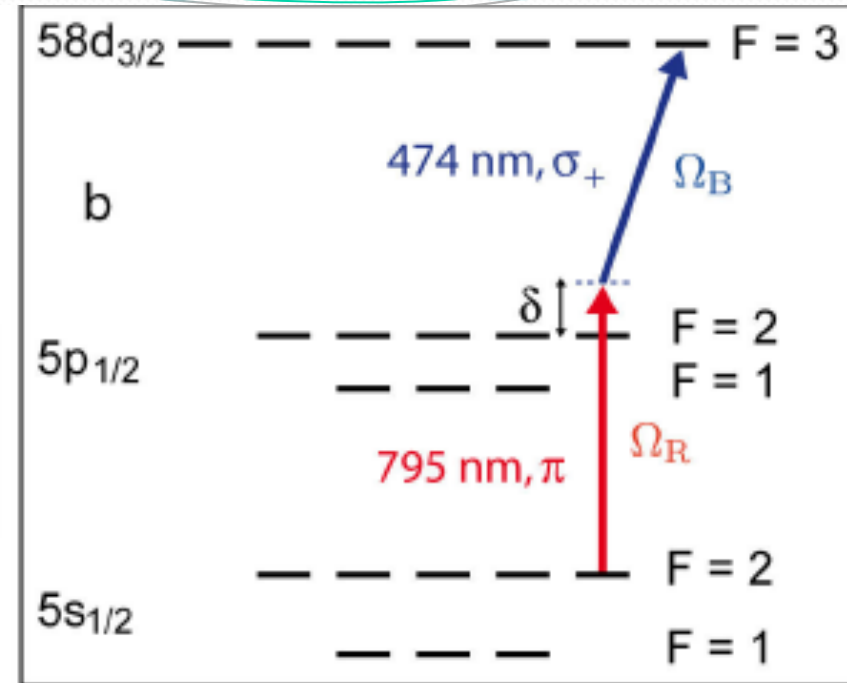
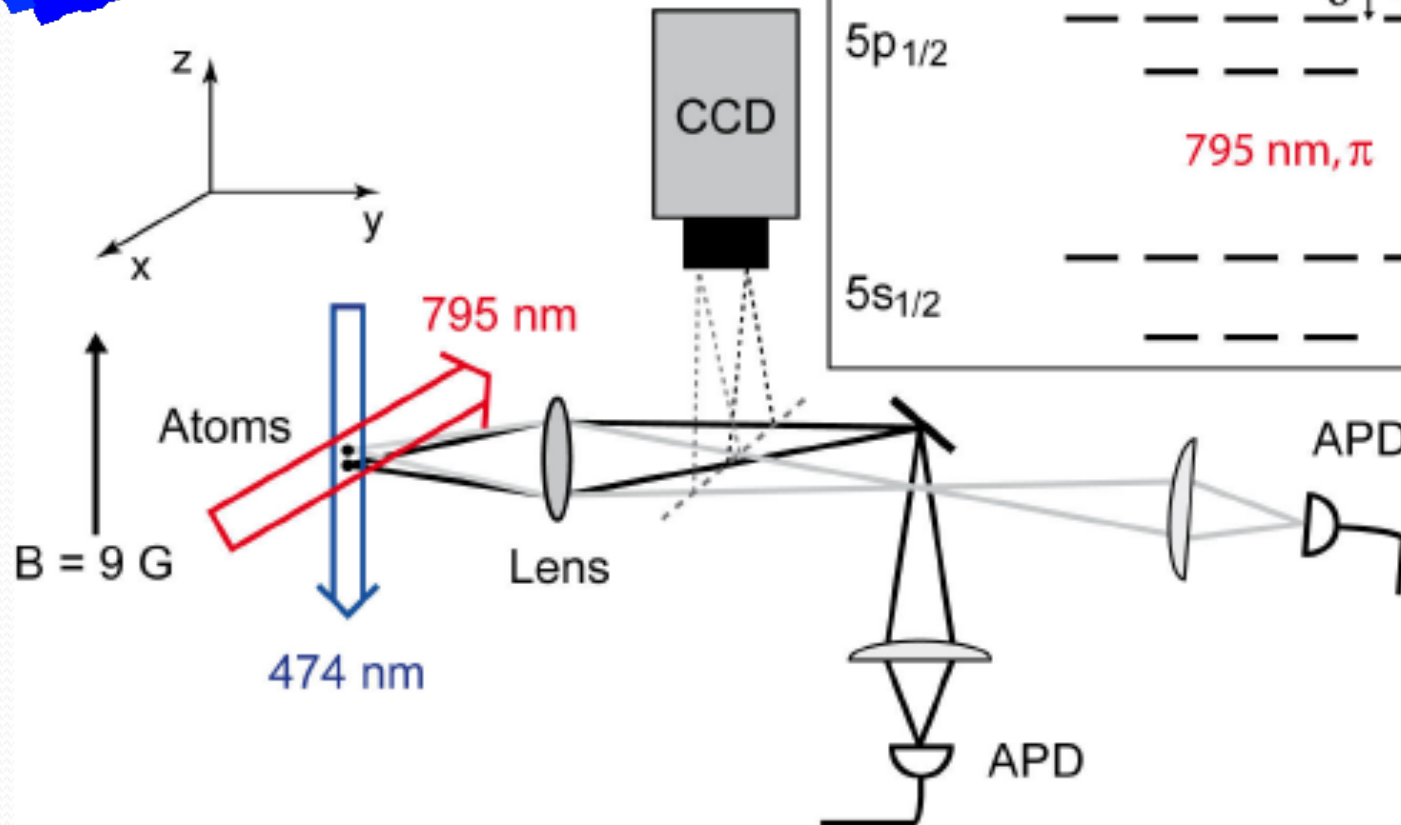
Rb : Förster resonance ($58d_{3/2}, 58d_{3/2}$) and ($60p_{1/2}, 56f_{5/2}$)
 Application for the realization of scalable quantum gates



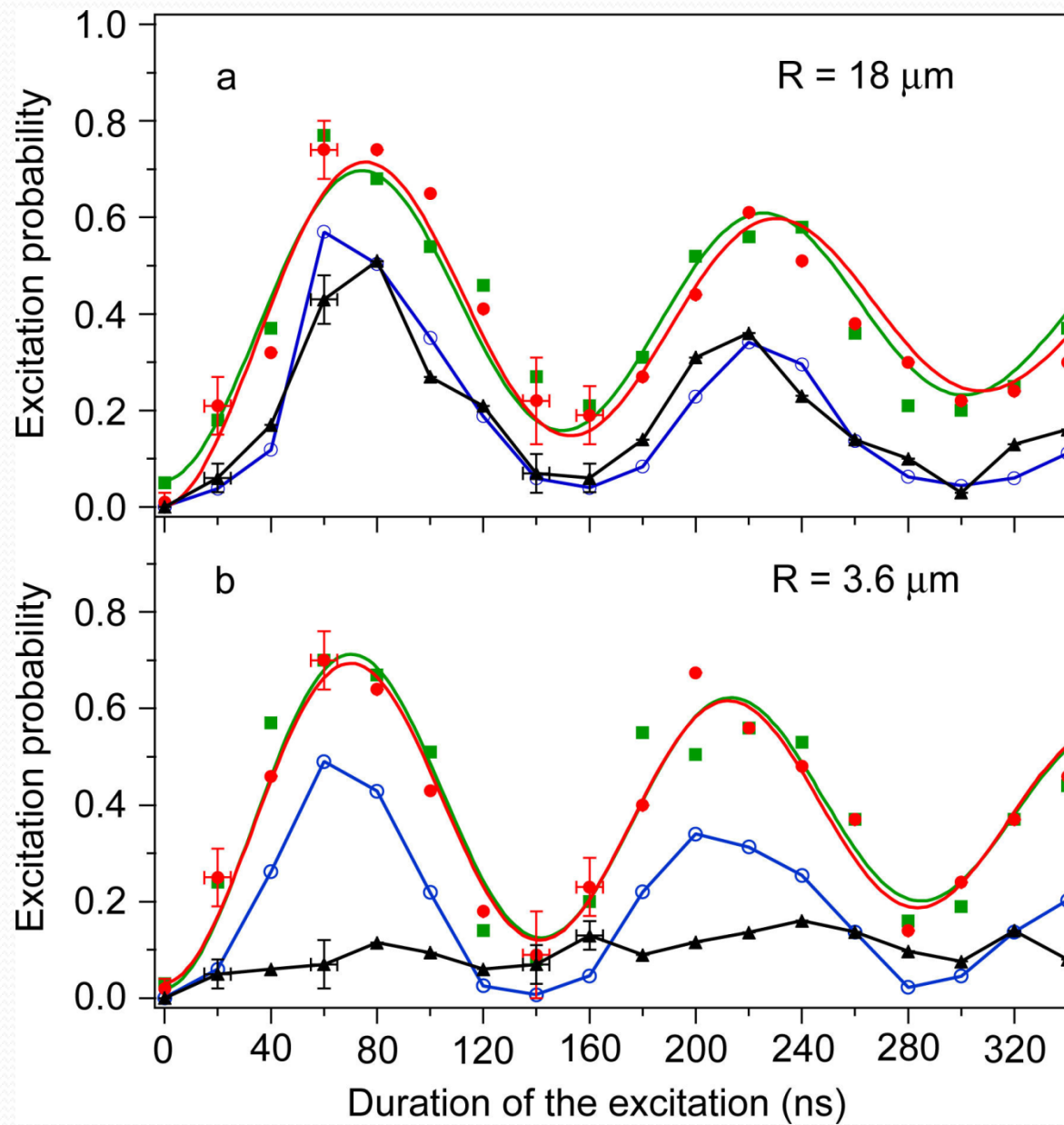
Conditionnal excitation or collective excitation
 of two individually trapped atoms



Experiment
 P. Grangier and
 A. Browaeys
 LCF - IOGS
 Palaiseau



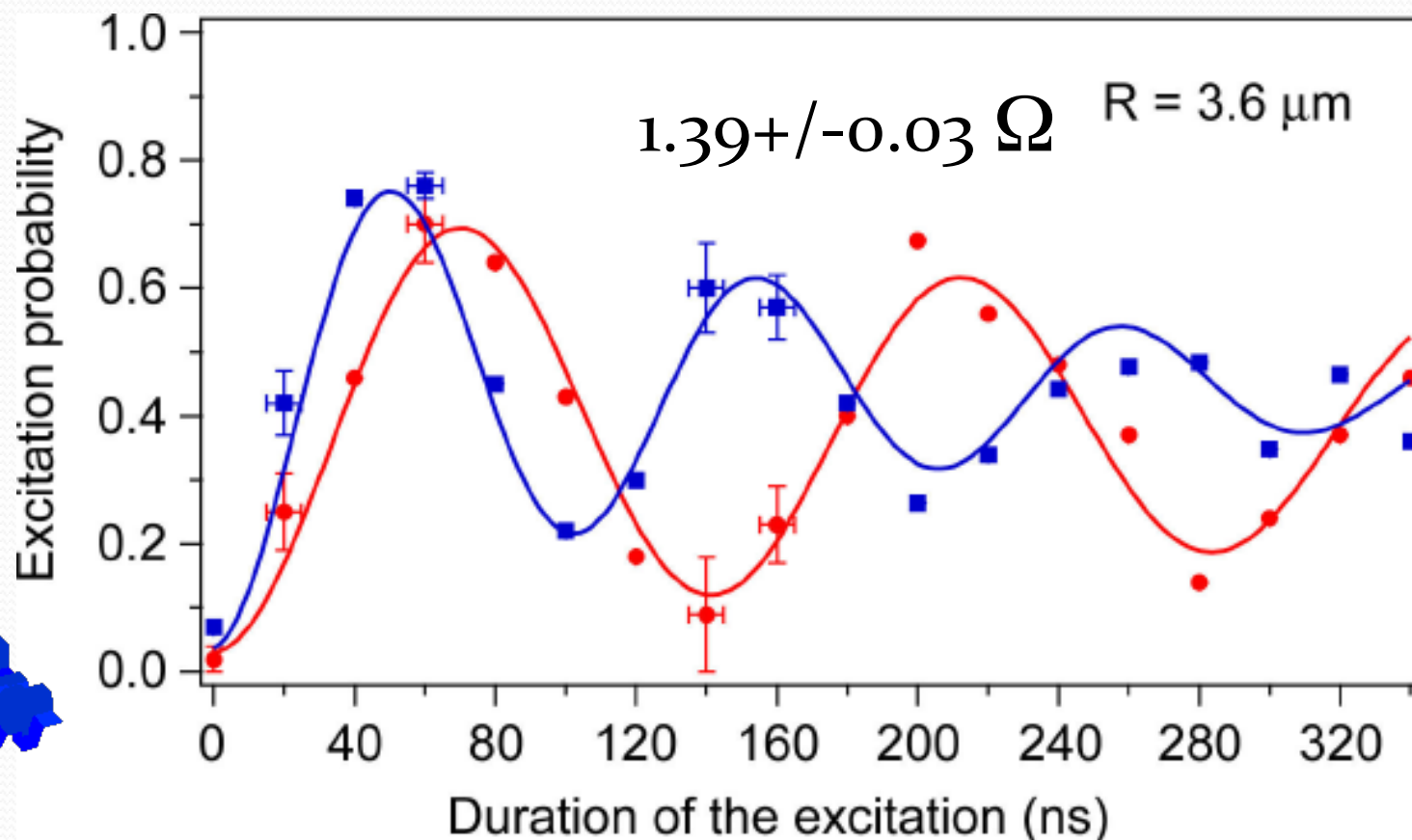
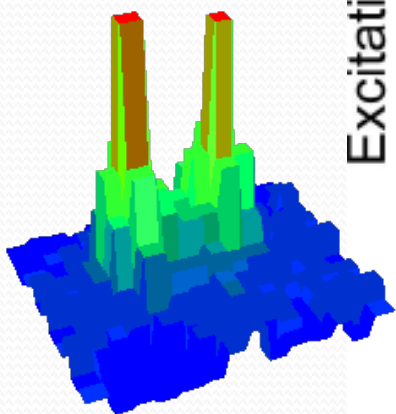
Conditionnal excitation



Collective excitation: Alpha Gaëtan, Yevhen Miroshnychenko, Tatjana Wilk, Amodsen Chotia, Matthieu Viteau, Daniel Comparat, Pierre Pillet, Antoine Browaeys and Philippe Grangier

Nature Physics 5 115 (2009)

LCFIO
IOGS
Palaiseau



Dipole-dipole interactions and interatomic forces

Attractive or repulsive forces

The way to control these forces

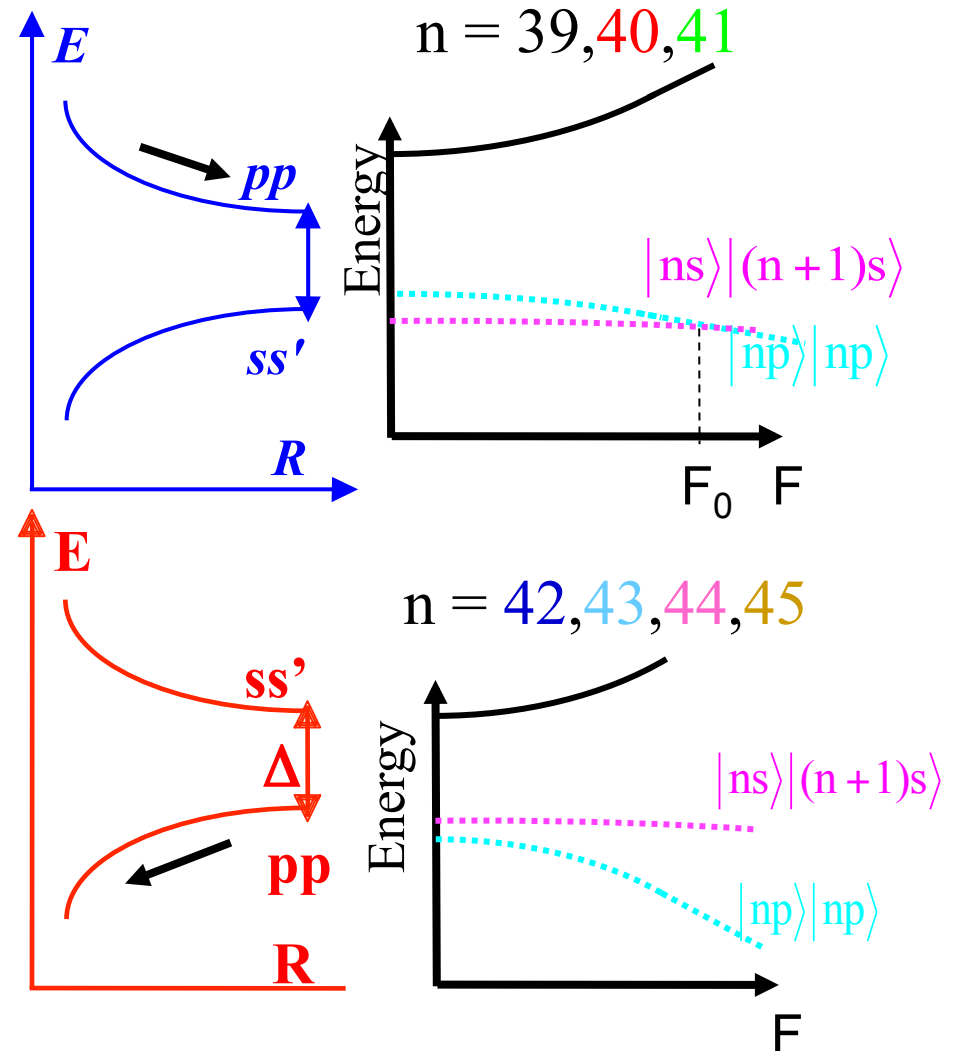
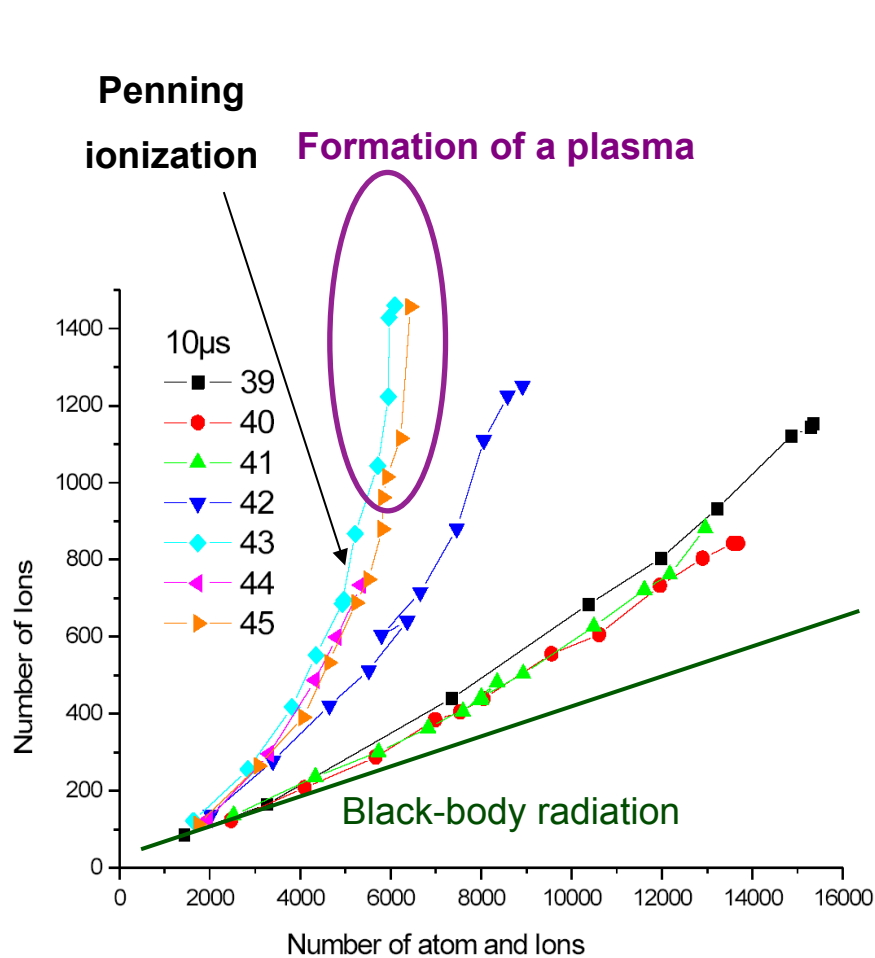
Limit of the frozen Rydberg gas picture

Penning ionization: $nl + nl \rightarrow n'l' + \text{ion} + e$ ($n' < n$)

Frontier with ultracold plasmas

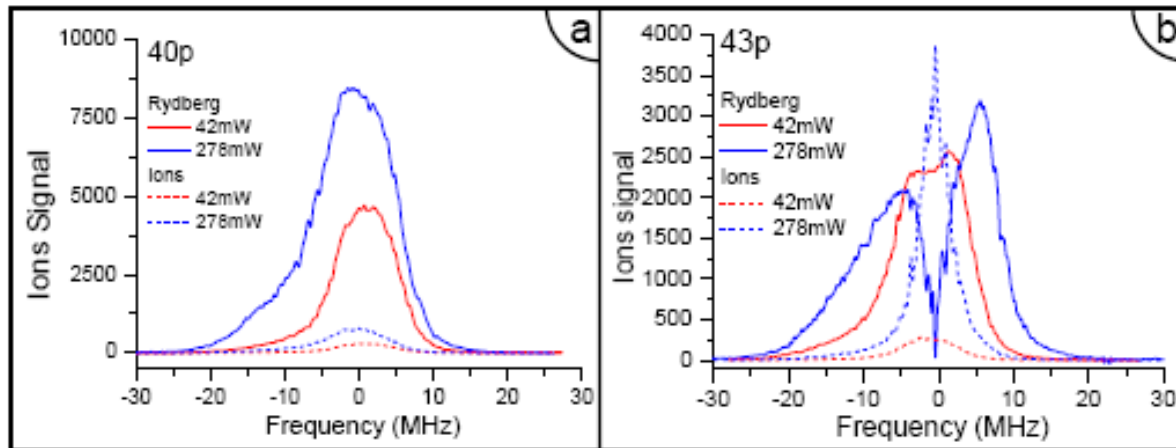
Dipole-dipole collisions (after $10\mu\text{s}$)

- Excitation of $np_{3/2}$ at zero field ($F = 0\text{V/cm}$)
van der Waals or second order dipole-dipole coupling

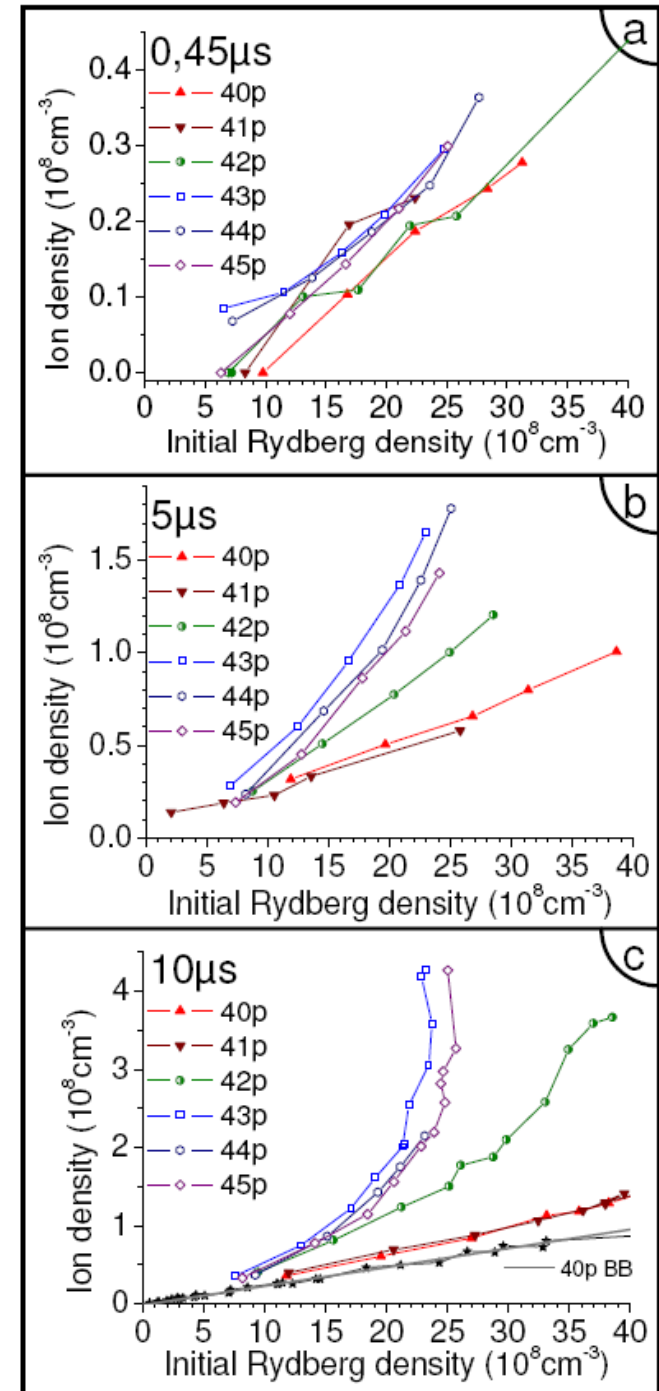


From 40p to 43p: Spectacular change in the behavior of the Rydberg gas

Viteau et al. PRA **78** 040704(R) (2008)



For 43p: The pairs of close atoms collide to form an ion space charge which can trap the electrons, leading to avalanche ionization up to the formation of an ultracold plasma



Dynamics of the dipole blockade of the excitation

In collaboration with the group of Ennio Arimondo at the
University of Pisa

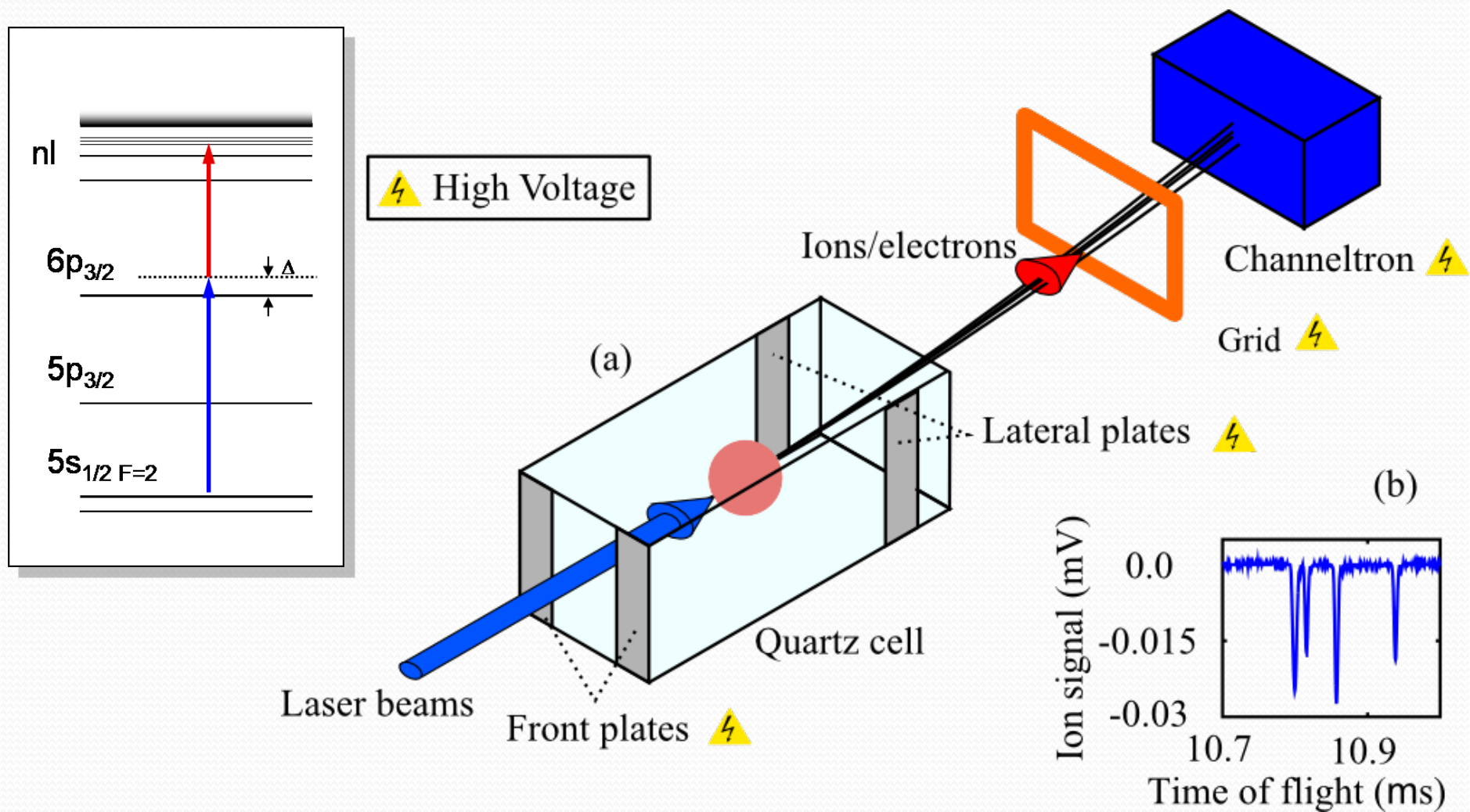
P. Huillery, M. Viteau, M.G. Bason, N. Malossi, D. Ciampani, O.
Morsh, E. Arimondo, D. Comparat, P. Pillet, PRL 109, 053002 (2012)

Cooperativity and dipole-dipole interactions

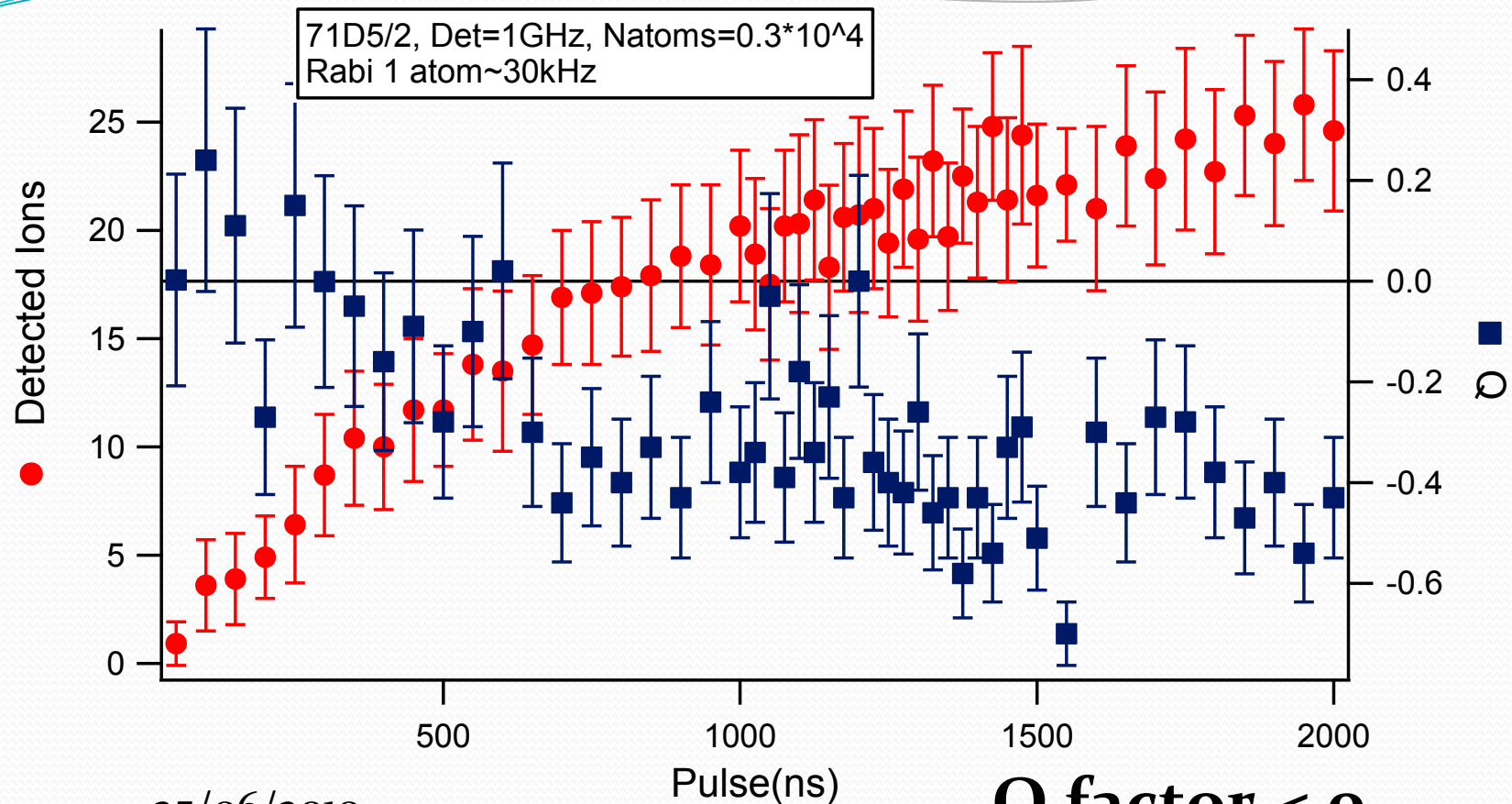
Correlated ensembles

Coherence and decoherence

Experiment in Pisa



PISA - experiments : excitation of Rb $71d_{5/2}$



25/06/2010

$71d_{5/2}$

Density $\approx 1.2 \cdot 10^{10}$ at.cm⁻³

atoms $\approx 8 \cdot 10^3$

Rabi 1 atom ≈ 45 kHz

Q factor < 0

Sub-Poissonian distribution

Correlated events

$$Q = \frac{\langle j^2 \rangle - \langle j \rangle^2}{\langle j \rangle} - 1$$