Bose-Einstein condensation of metastable He

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EPS-12 August 2002

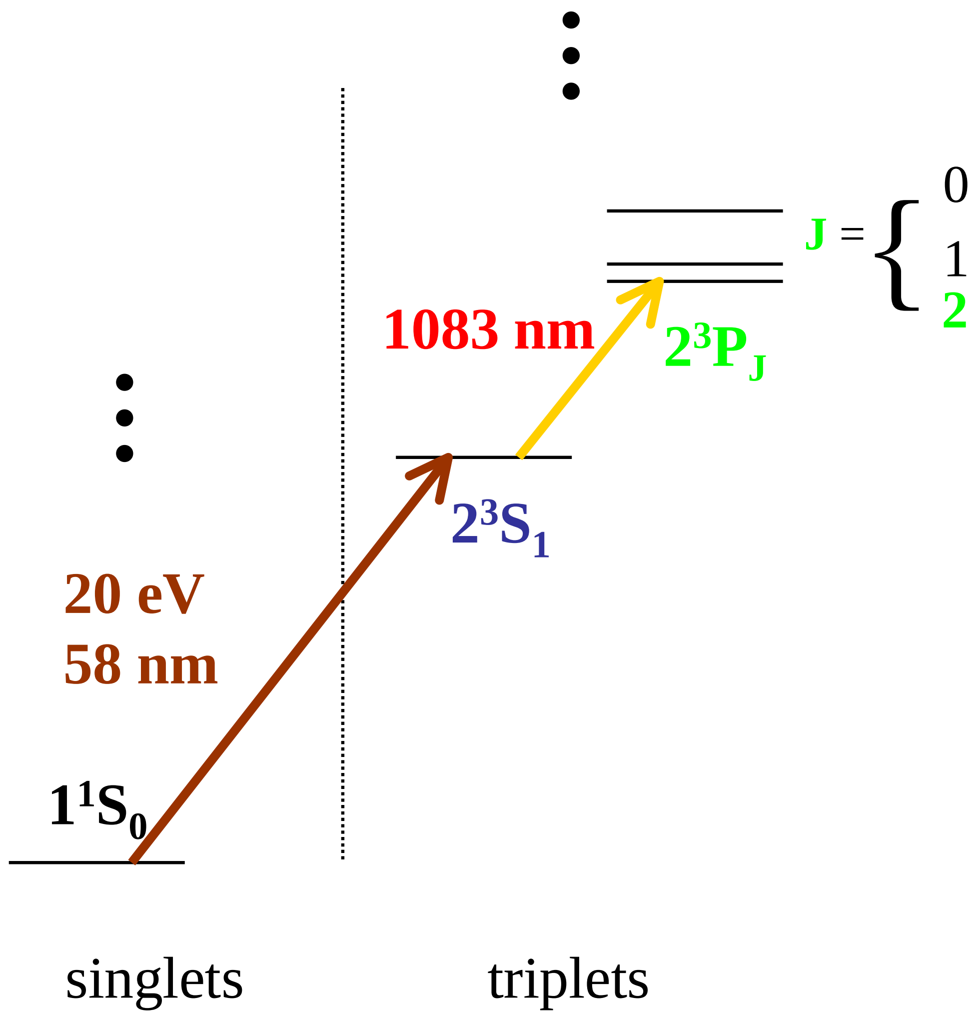
the helium atom

lifetimes:

$2^3S_1 \rightarrow 1^1S_0$: ~ 9000 s

$2^3P_2 \rightarrow 2^3S_1$: ~ 100 ns

$2^3P_2 \rightarrow 1^1S_0$: ~ 2 s



Why He*?

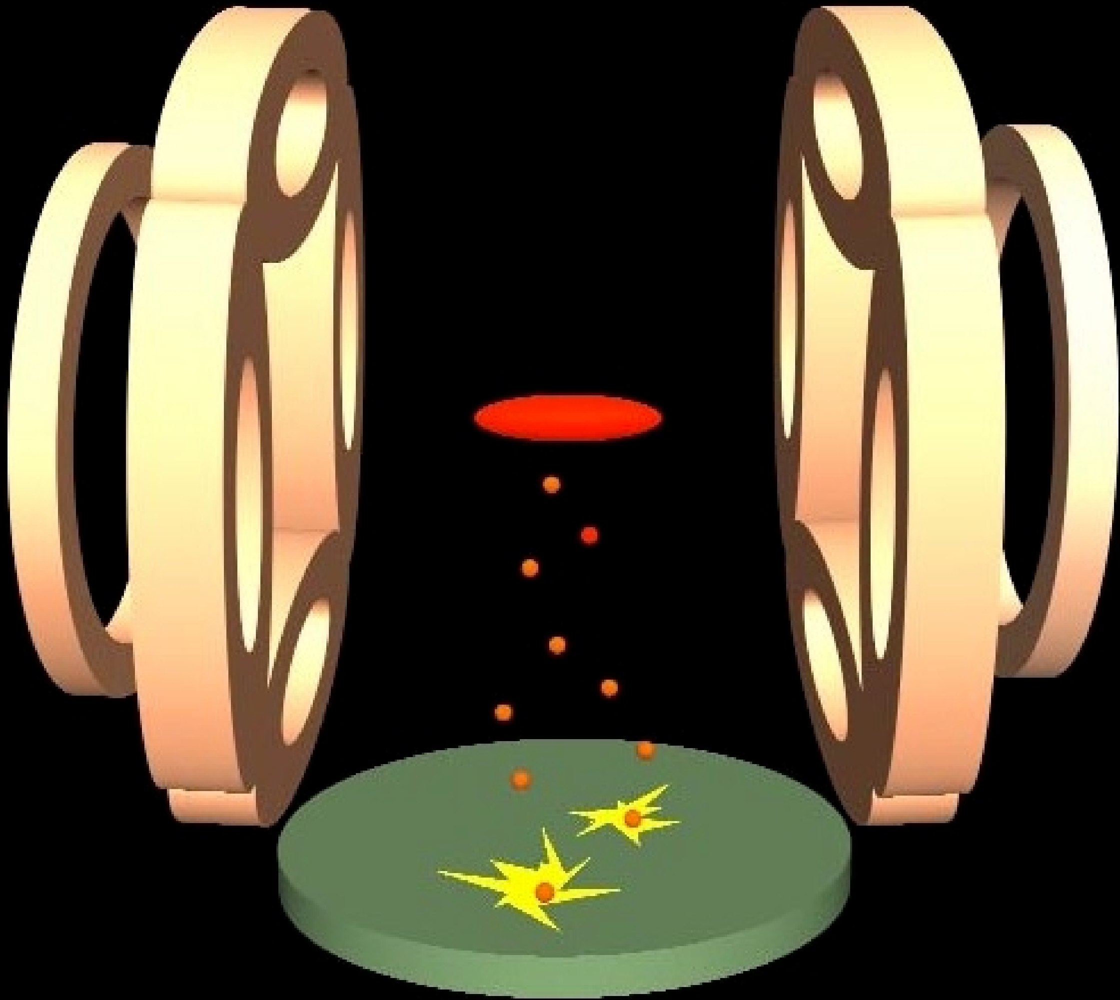
- If laser cooling of He* is a good idea, so is evaporative cooling.
- metastability: detection…
- Penning ionization

	He^*	$+$	He^*	$\rightarrow$	He	$+$	He^+	$+$	e^-
s	1		1		0		1/2		1/2
s_{tot}		0,1,**2**					0,1		

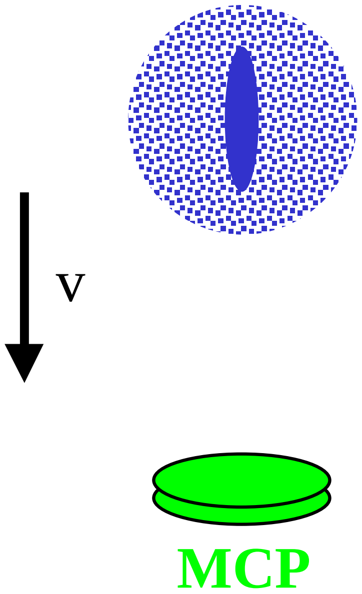
Strong suppression of ionization (Amsterdam)

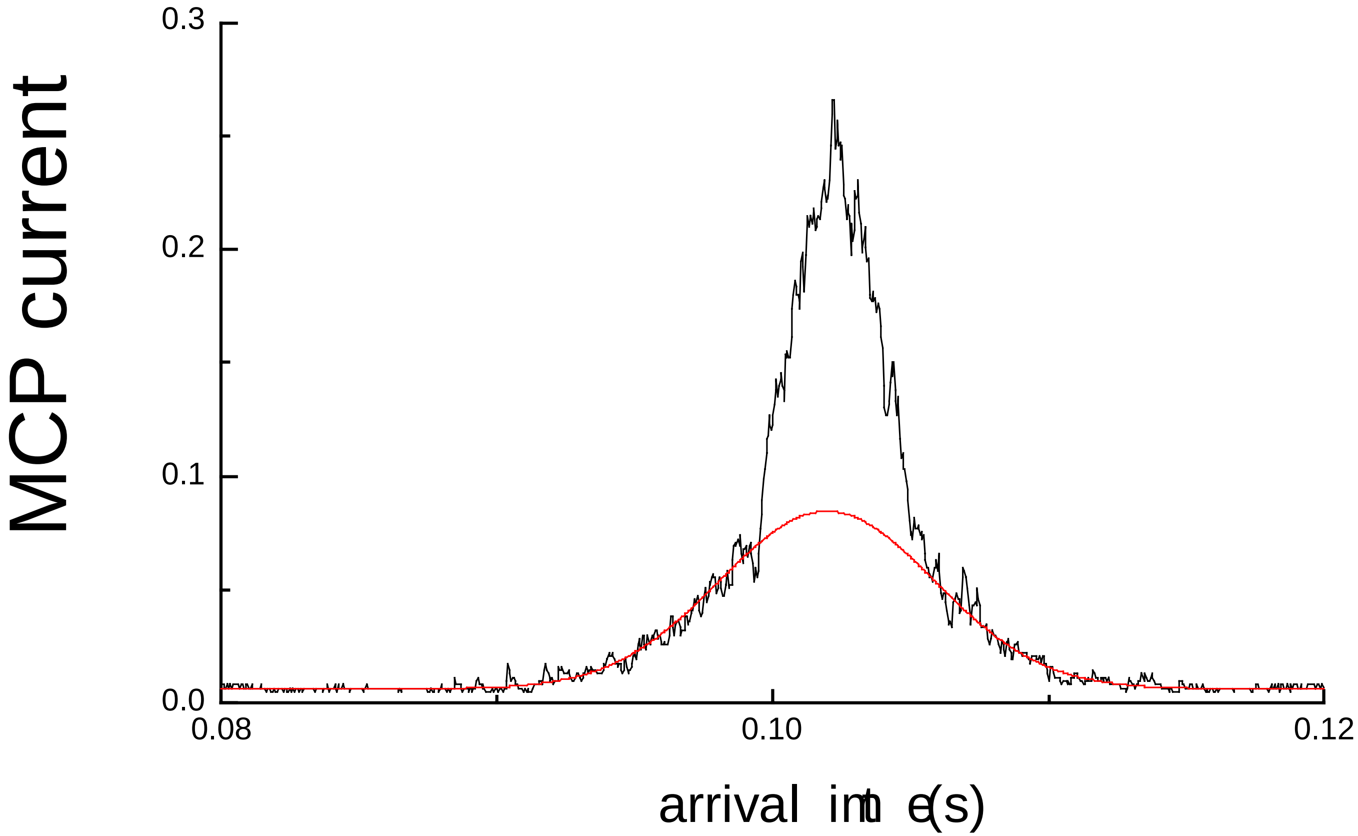
Expts: Amsterdam, Utrecht, Canberra, Paris, Orsay

Apparatus



At the BEC transition





we measure N, T, μ

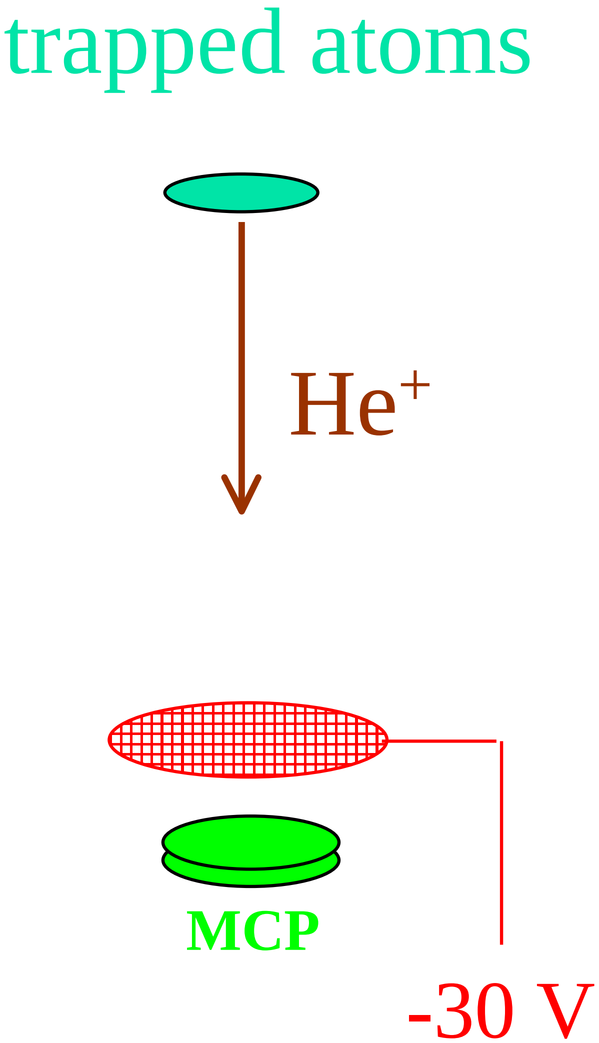
Summary

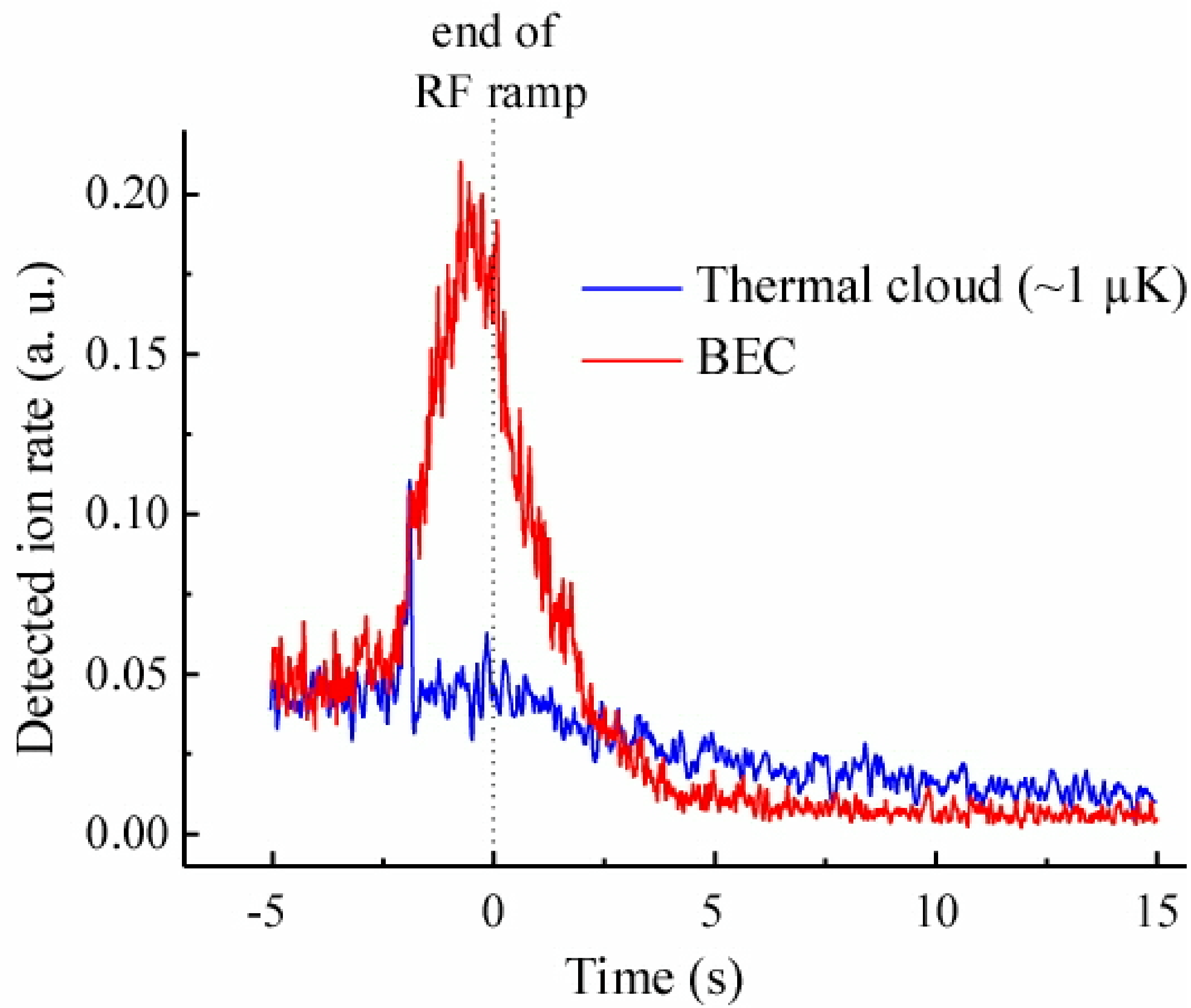
- $N_0 \sim 10^5$, $n_0 \sim 10^{13}$ cm^{-3}
- scattering length

  $a = 18 \pm 8$ nm
- Thomas-Fermi parameter: $\chi = N_0\, a/\sigma \sim 10^3$
- collision rate at T_C: $\gamma = n\sigma v \sim 10^3$–$10^4$ s^{-1}
  - hydrodynamic regime
- quantum depletion $\sqrt{(na^3)} \sim 0.01$

  Science, 292, 461 (2001), PRL 68, 3459 (2001)

Observation of ions





loss and ionization rate

$$\frac{dN}{dt} = -\beta \int n^2 dV - L \int n^3 dV$$

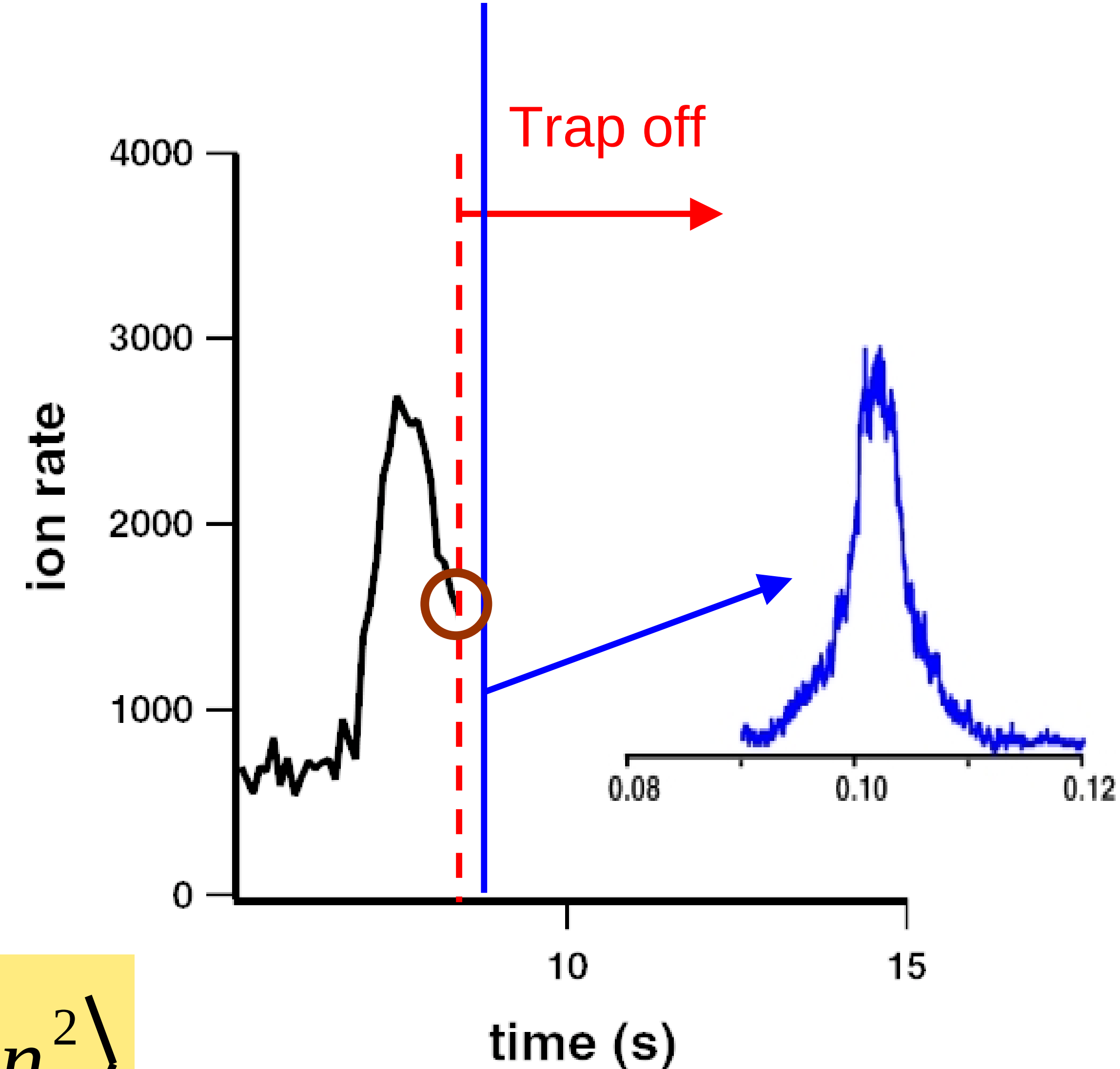
$$N = f(t; \beta, L)$$

$$\frac{dI}{dt} = \frac{\beta}{2} \int n^2 dV + \frac{L}{3} \int n^3 dV$$

$$\Gamma = \frac{1}{N}\frac{dI}{dt} = \tilde{\beta}\langle n \rangle + \tilde{L}\langle n^2 \rangle$$

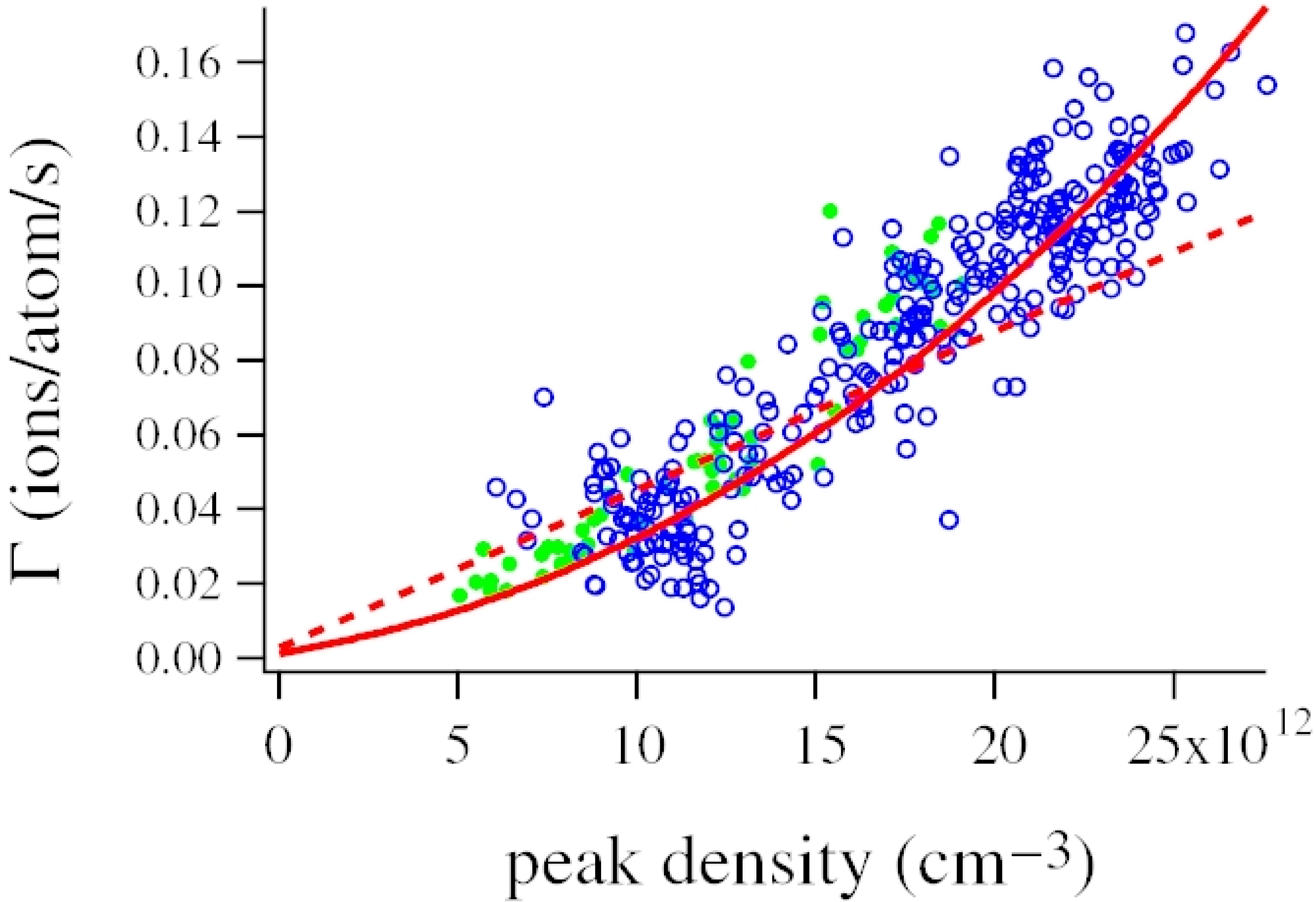
Analysis of ion signal

- lifetime: difficult to analyse
- we can measure ***dI/dt***
- and measure $N, T, \mu \Rightarrow \langle n \rangle$ best for a "pure" BEC



$$\Gamma = \frac{1}{N}\frac{dI}{dt} = \beta\langle n \rangle + L\langle n^2 \rangle$$

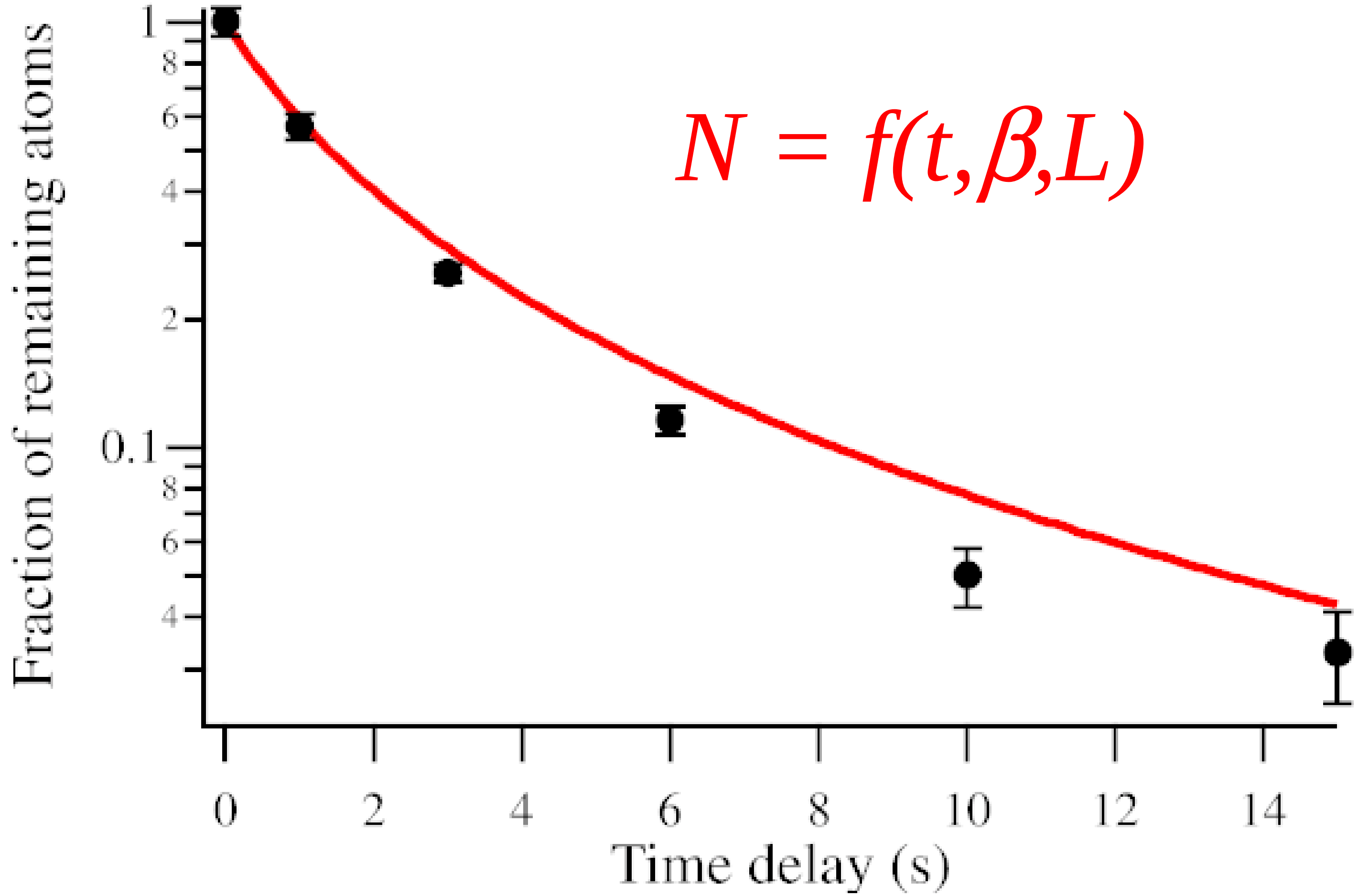
ion rate vs density (quasi-pure BEC)



decay of the number of atoms

- Independent of the ion detection

- Ionization accounts for most of the loss



$$N = f(t,\beta,L)$$

O. Sirjean et al. cond-mat/0208108

conclusions

- Calibration of N and I is difficult. We use a to get N_0.
- 2 body ionization rate coeff: 3×10^{-14} cm^{3}s^{-1}
- 3 body ionization is important 8×10^{-27} cm^{6}s^{-1}
- Statistical factors (2! or 3!) are important, but:

$$\Gamma_{3-\mathrm{body}}^{\mathrm{BEC}} = \frac{1}{3!}\left[1+\frac{64}{\sqrt{\pi}}\sqrt{n_0 a^3}\right] L n_0^2$$

Kagan, Svistunov, Shlyapnikov, **50% correction**
JETP Lett. 42, 209 (1985)

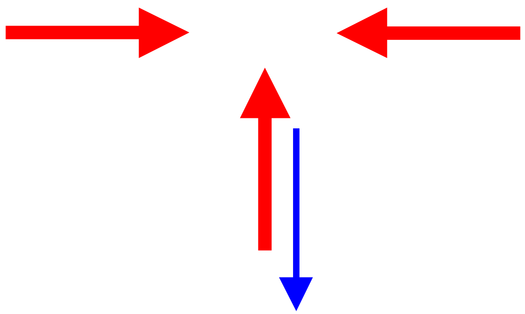
- We need the same for a thermal cloud
- and a better measurement of a.

making correlated atom pairs

Four wave mixing

NIST: Science 398, 218 (1999)

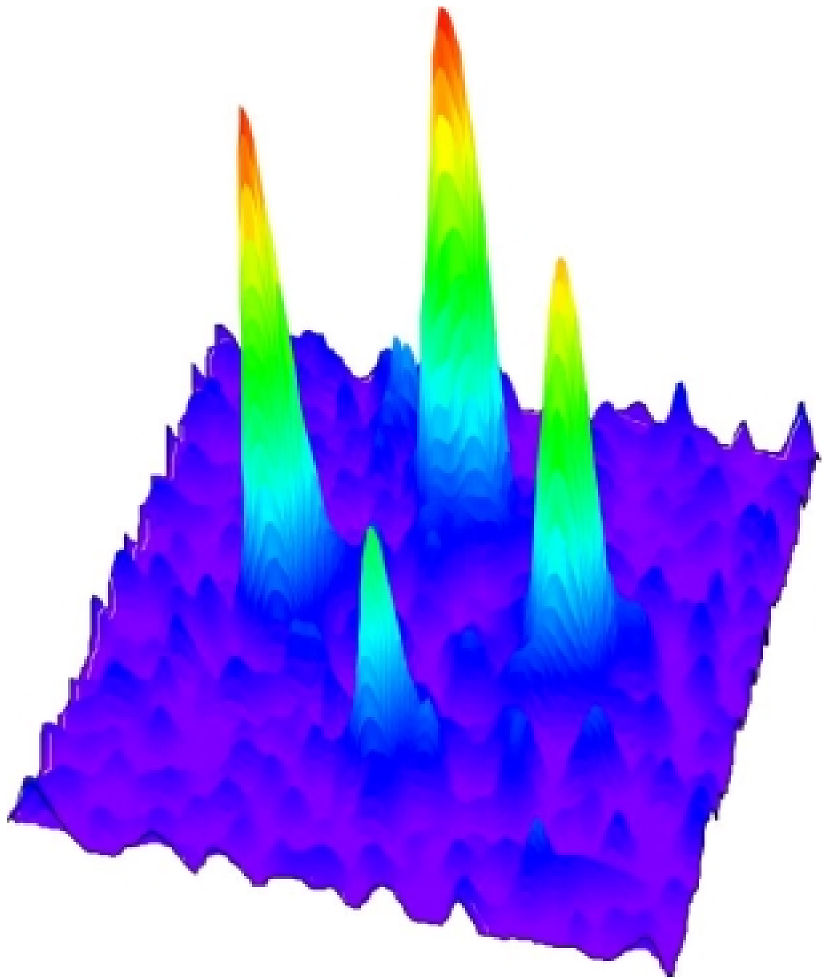
MIT: cond-mat/0203286 (2002)



Atoms (photons) created in entangled pairs

PRL 85, 3987 (2000)

PRL 85, 3991 (2000)

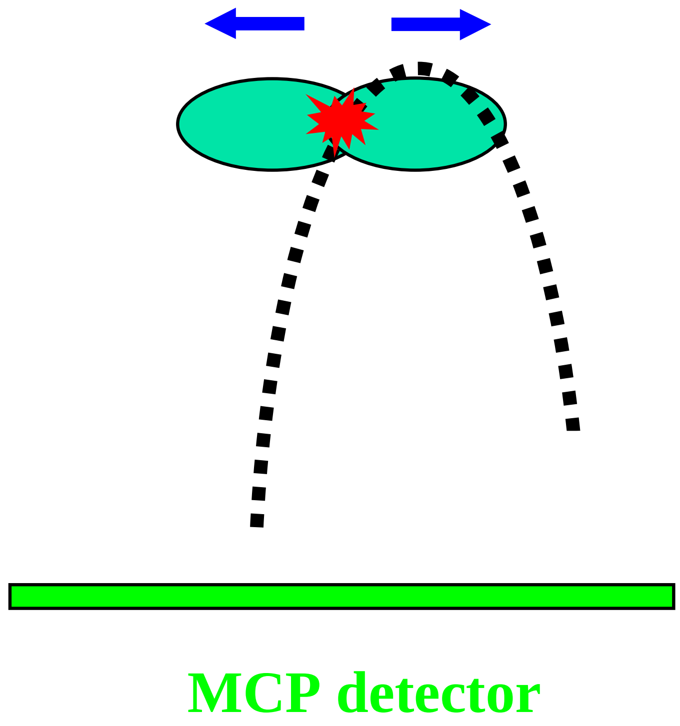


Data from NIST 1999

detecting the pairs

- Spontaneous 4 wave mixing ("perfect correlations")

- Raman pulses create colliding, untrapped condensates (other ways?)
- Spatial correlations become temporal correlations
- |0> + |0> collisions: Inelastic rate !



Thank you

- groupe 'hélium':

  O. Sirjean, S. Seidelin, J.Gomes, R. Hoppeler

  D. Boiron, A.Aspect, C.W.

  G. Shlyapnikov

- groupe d'optique atomique

  G. Delannoy, Y. Lecoq, F. Gerbier, R. Simon, J. Estève, C. Aussibal, M. Fauquembergue, S. Rangwala, J. Thywissen, D. Stevens, V. Savalli, P. Bouyer, N. Westbrook, I. Bouchoule

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