Dynamic systems

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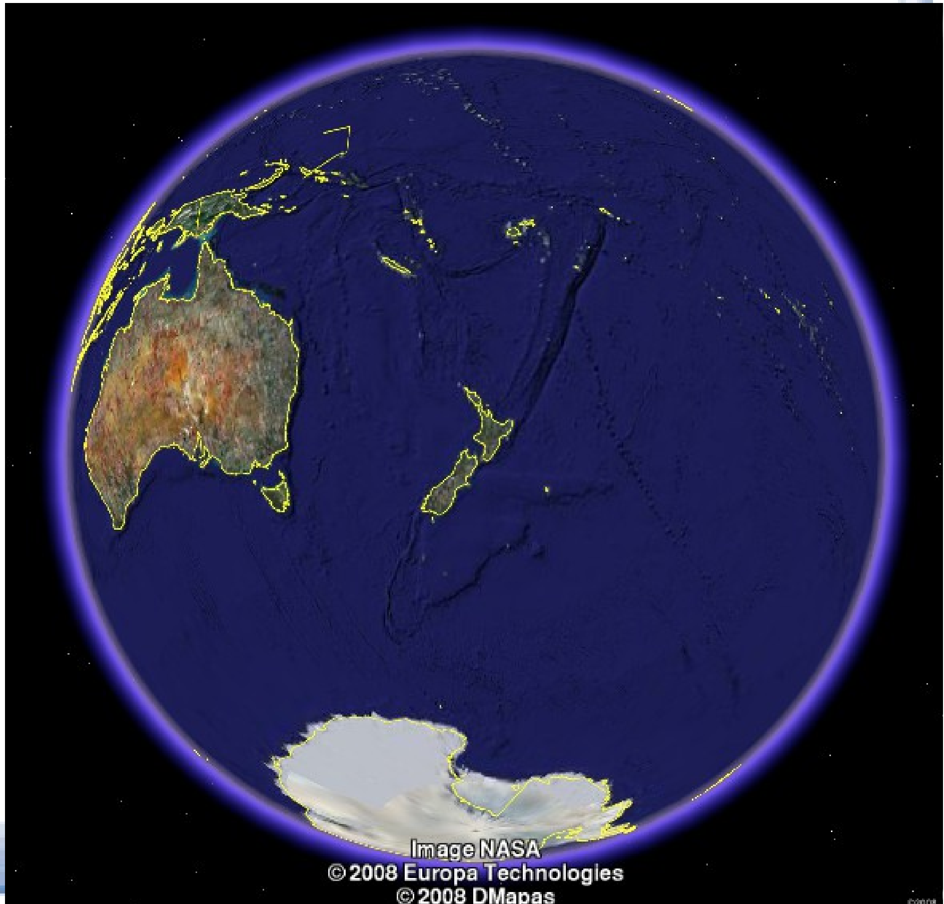
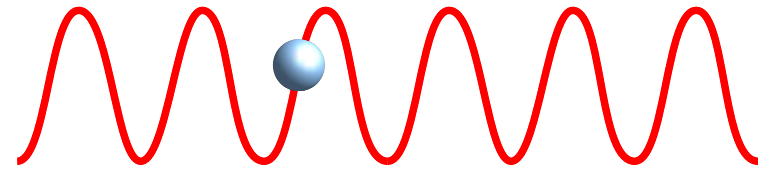


Outline today

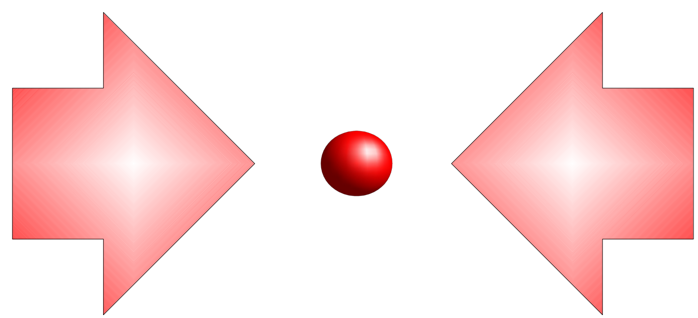
- Fractional resonances
- Velocity dependence
- Chaos

Atom optics kicked rotor

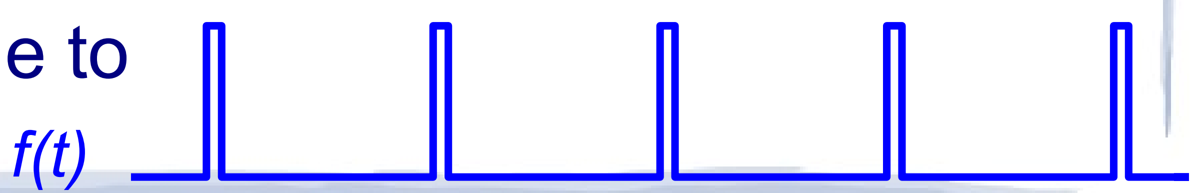
- Atoms in standing wave
  - Potential varies as cos 2kx



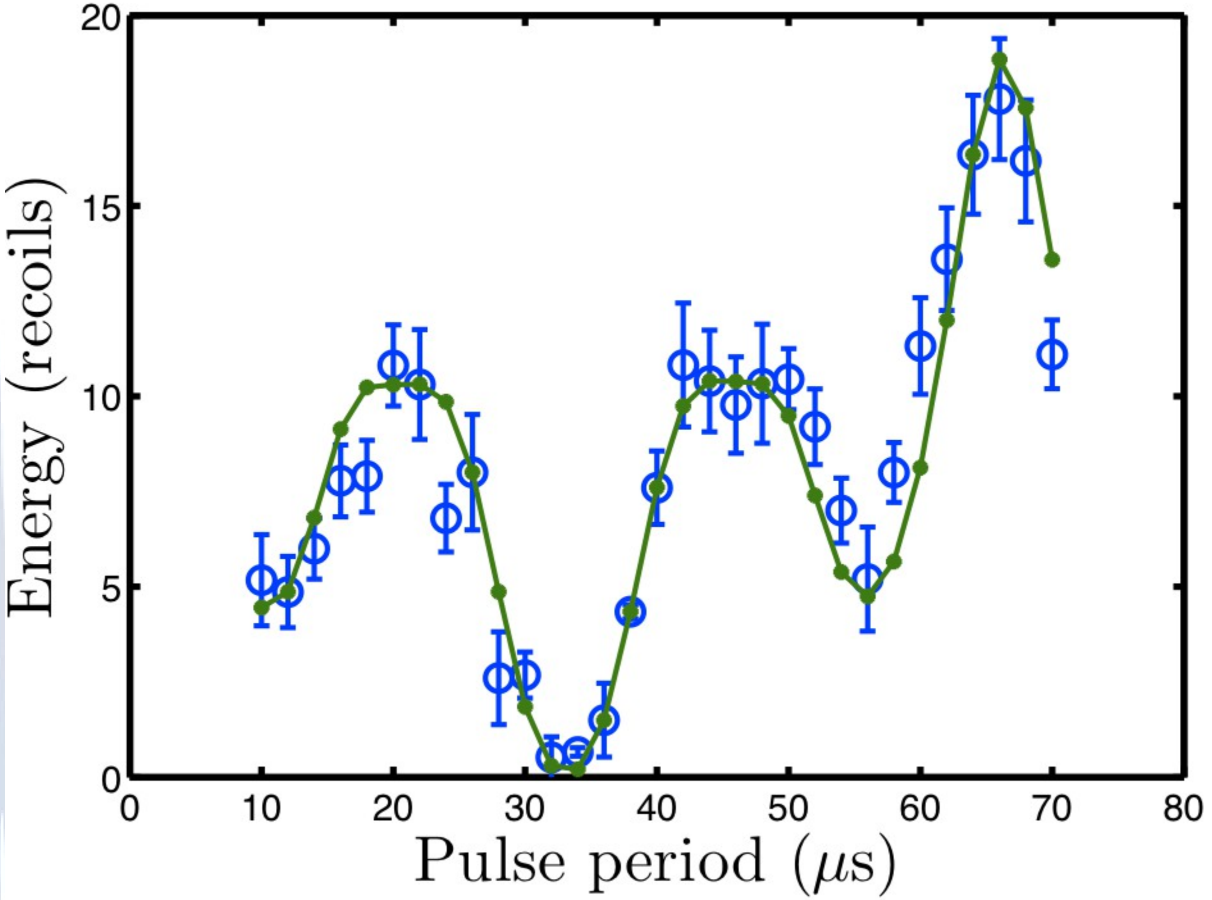
- MOT:
  - Hot, integrate over initial momentum states
  - Large, integrate over initial positions



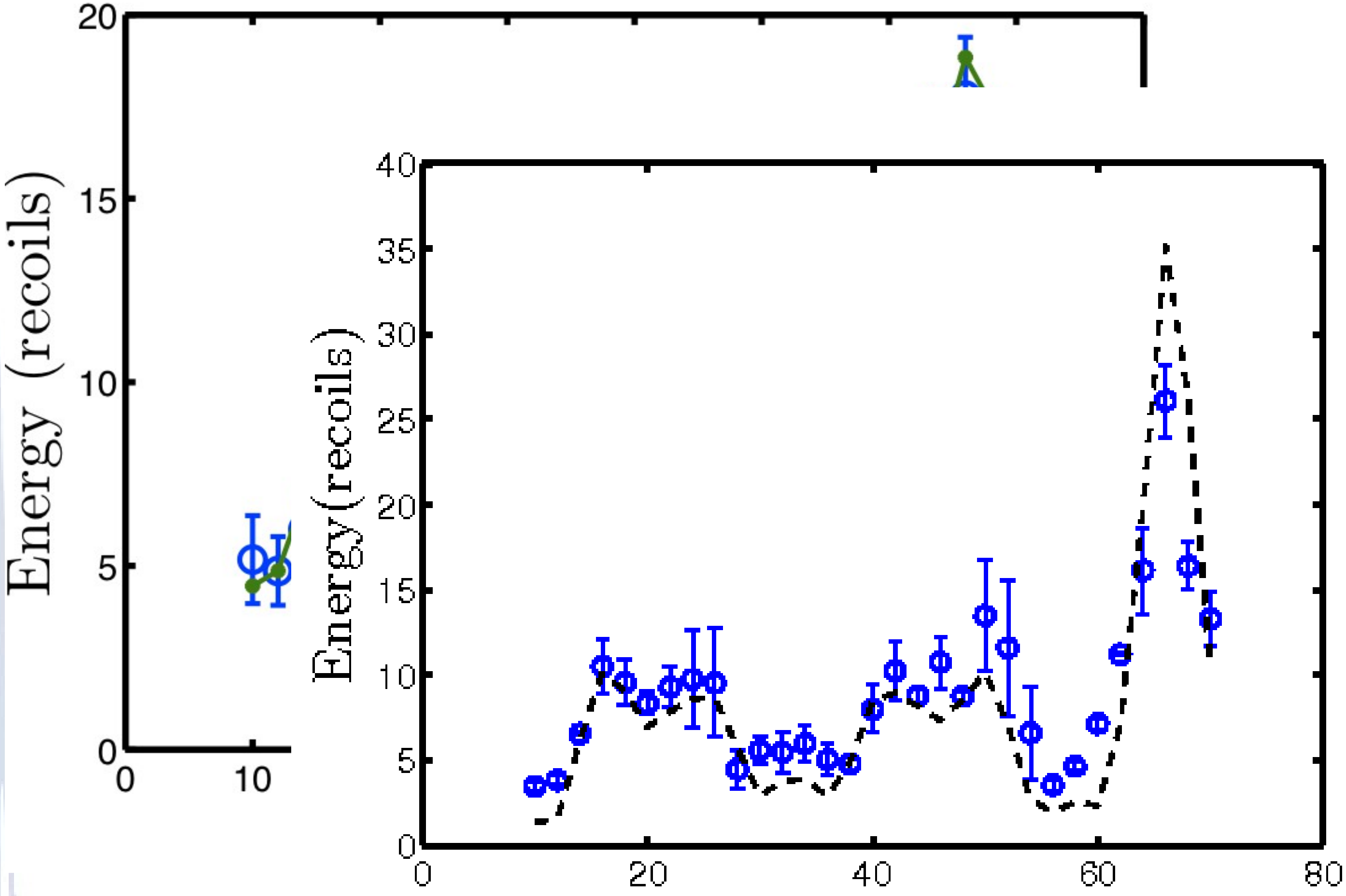
- BEC:
  - Cold
  - Position spread due to uncertainty



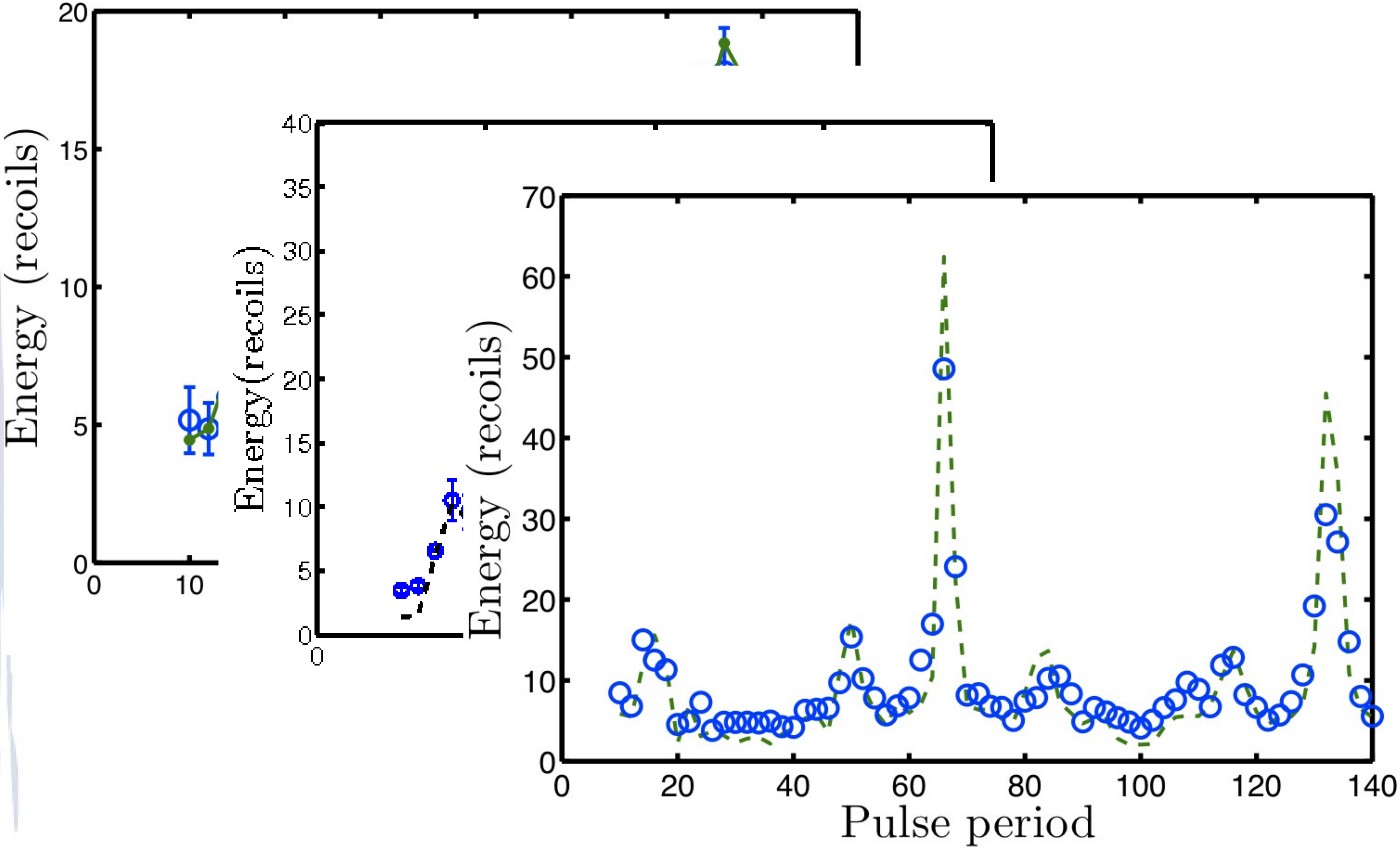
Varying period



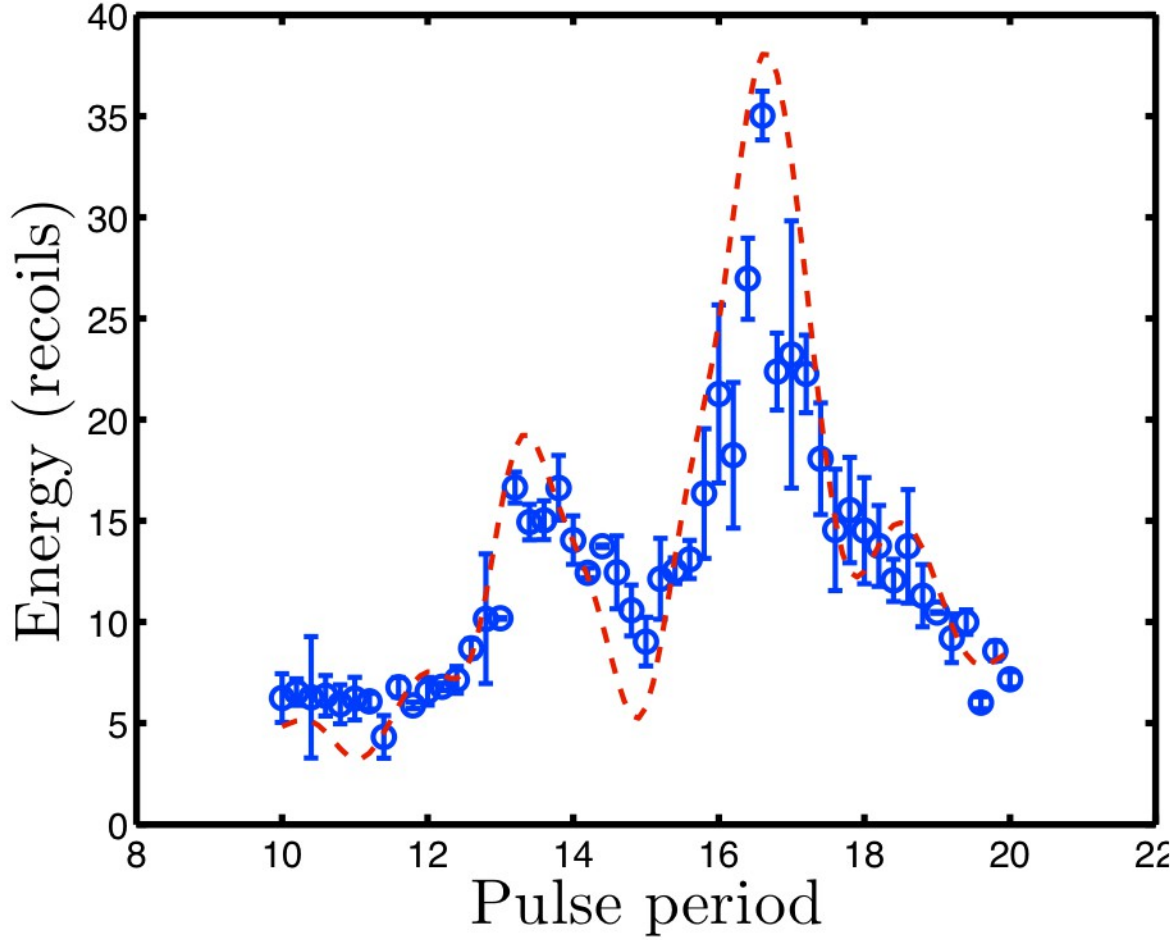
Varying period



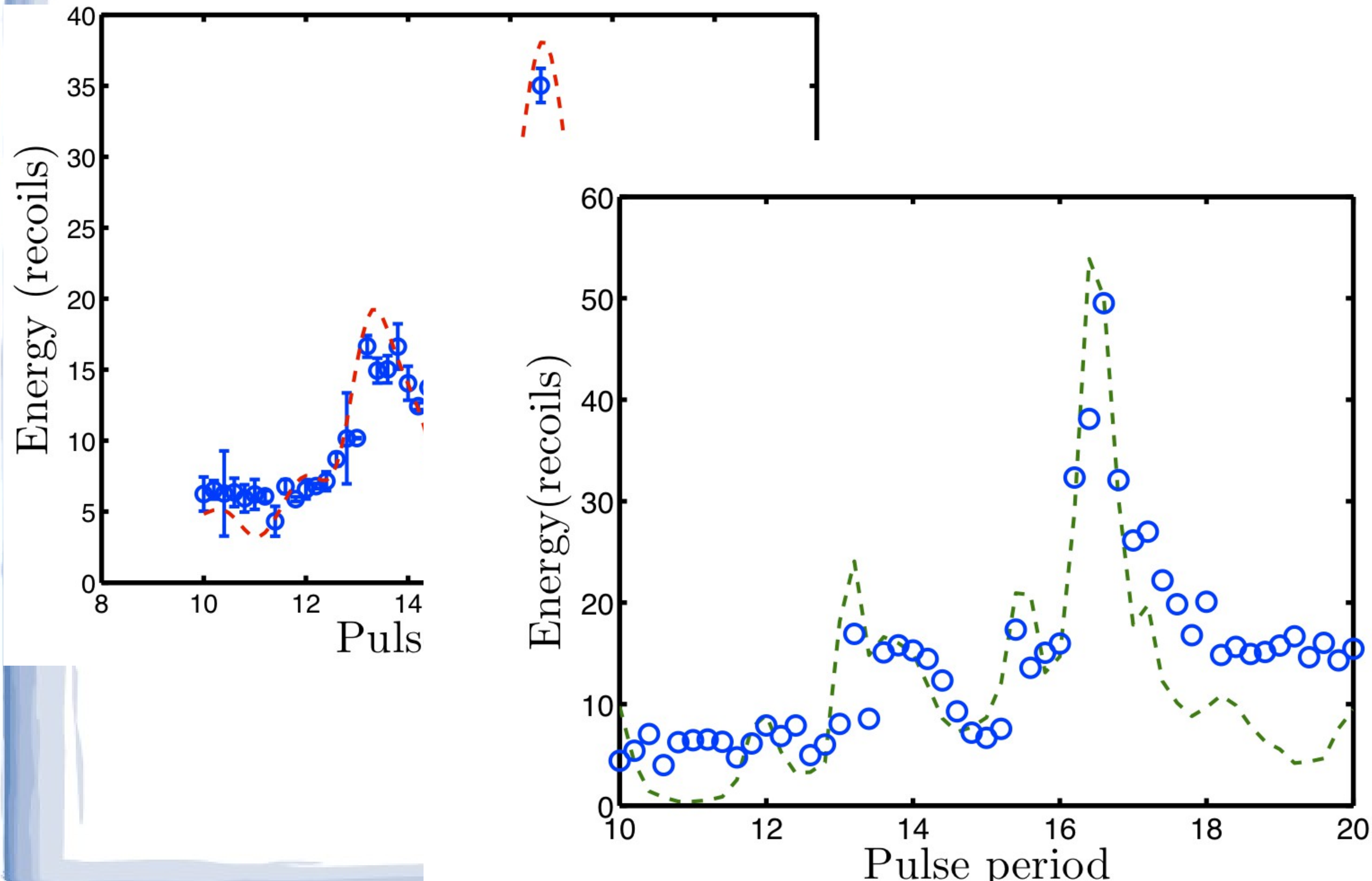
Varying period (5 kicks)



$T_T/4$ resonance

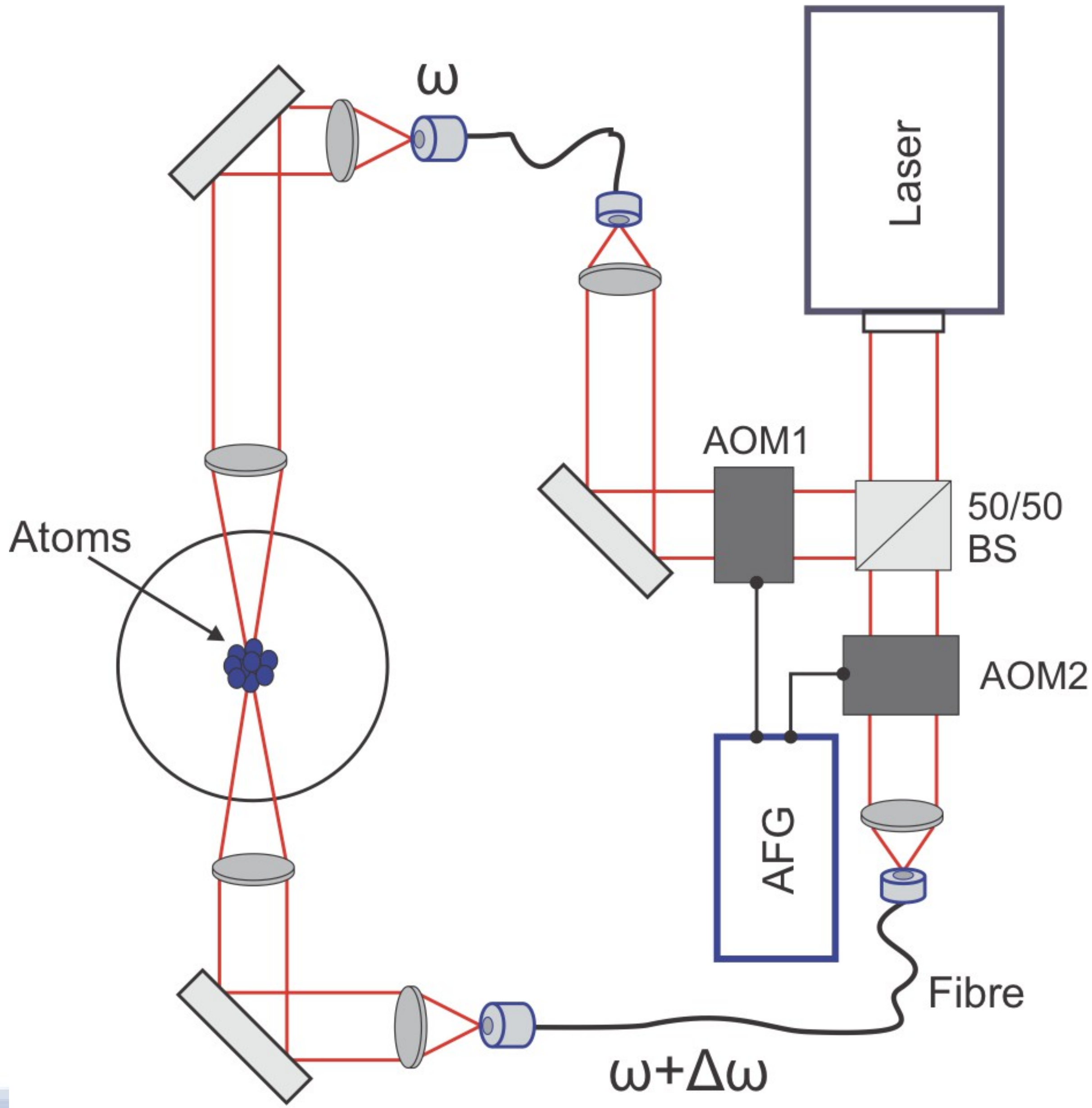


$T_T/4$ resonance

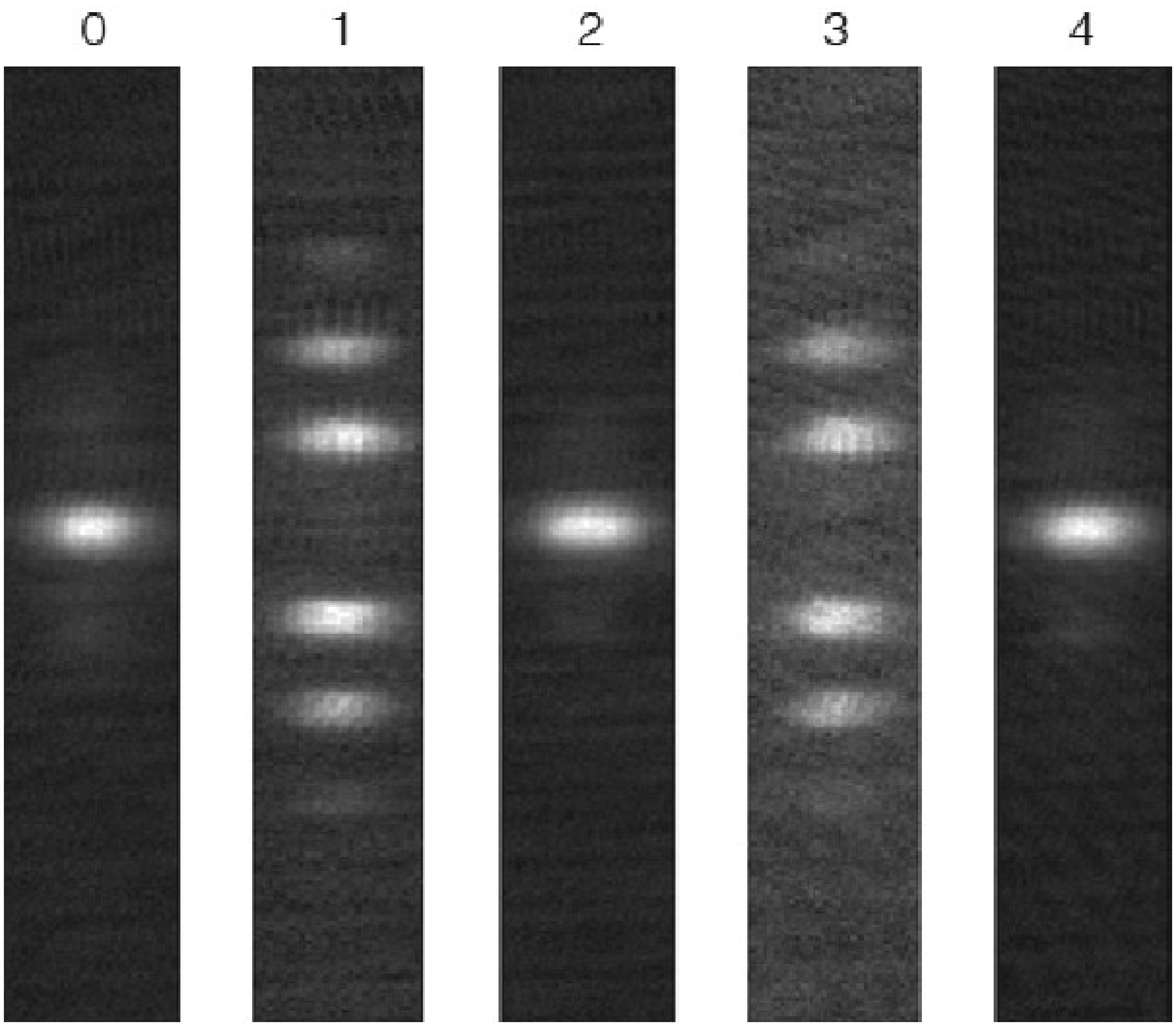


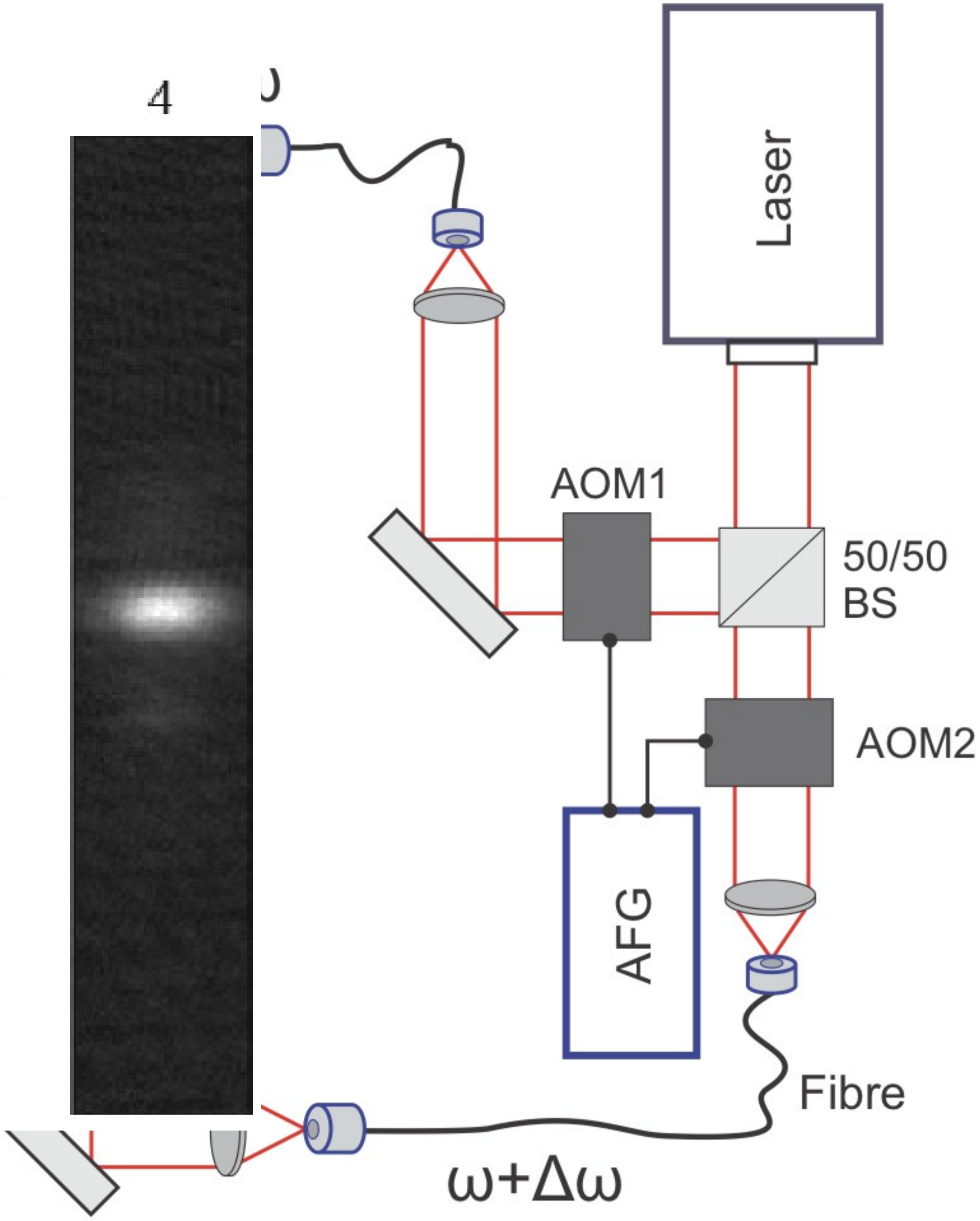
Initial momentum

Initial momentum



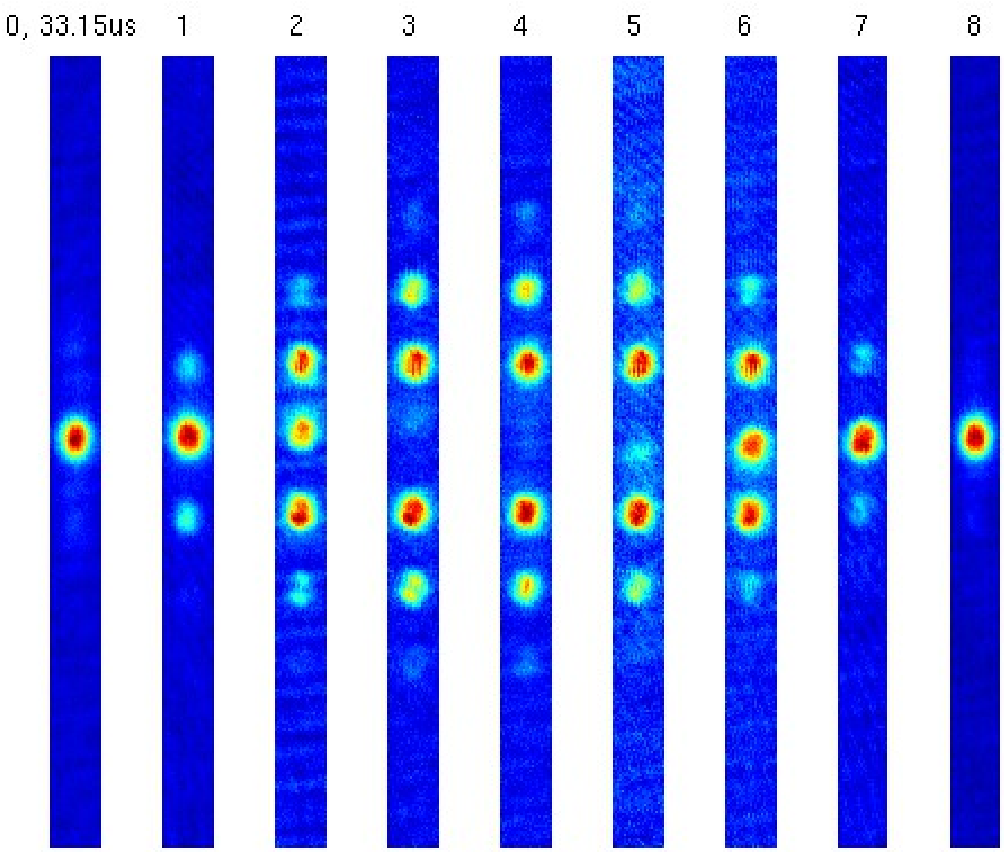
Initial momentum

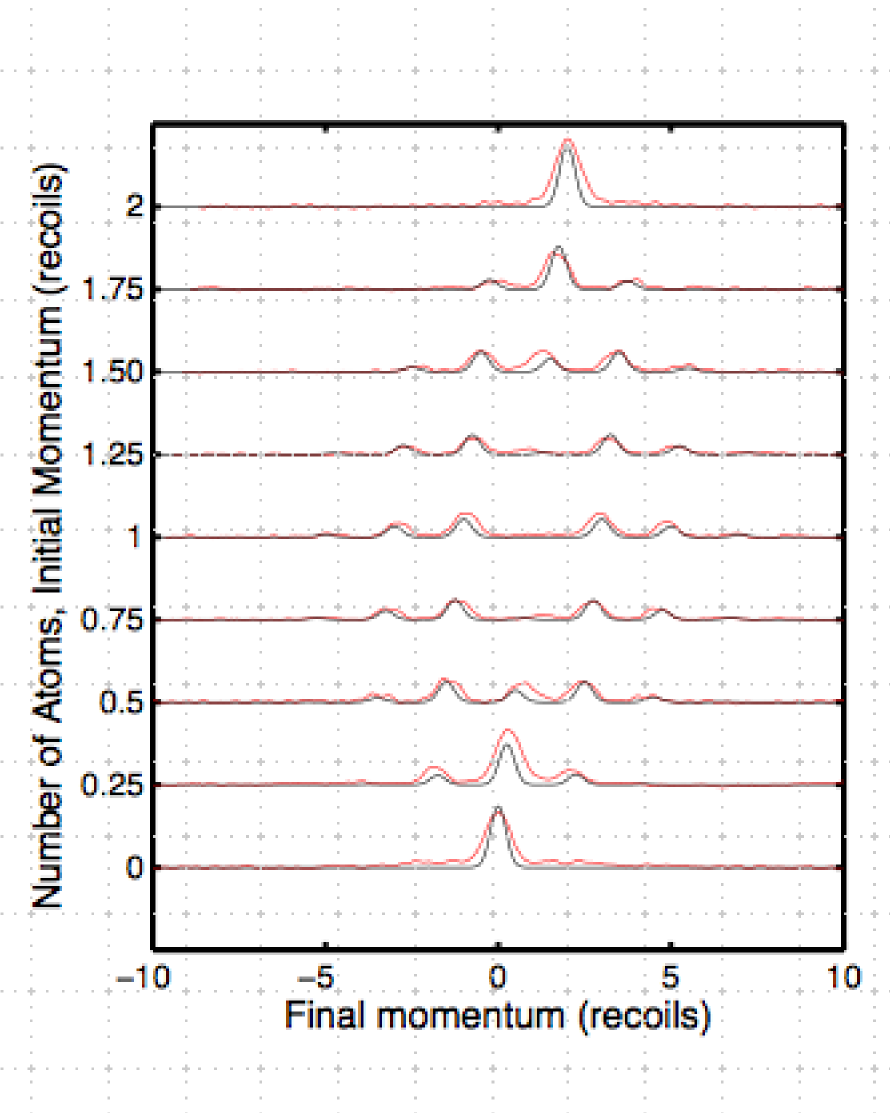




Two kicks

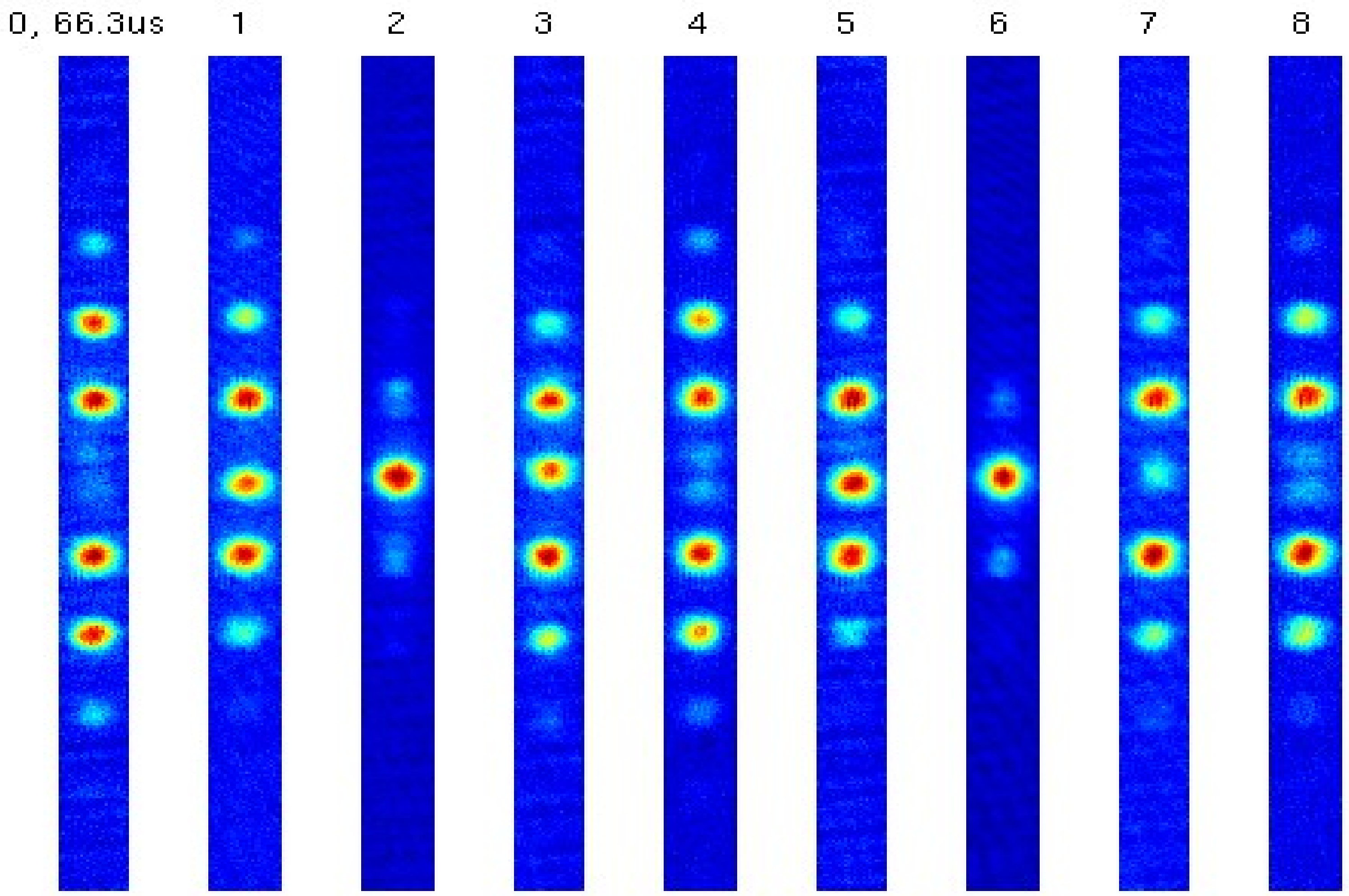
k=2π



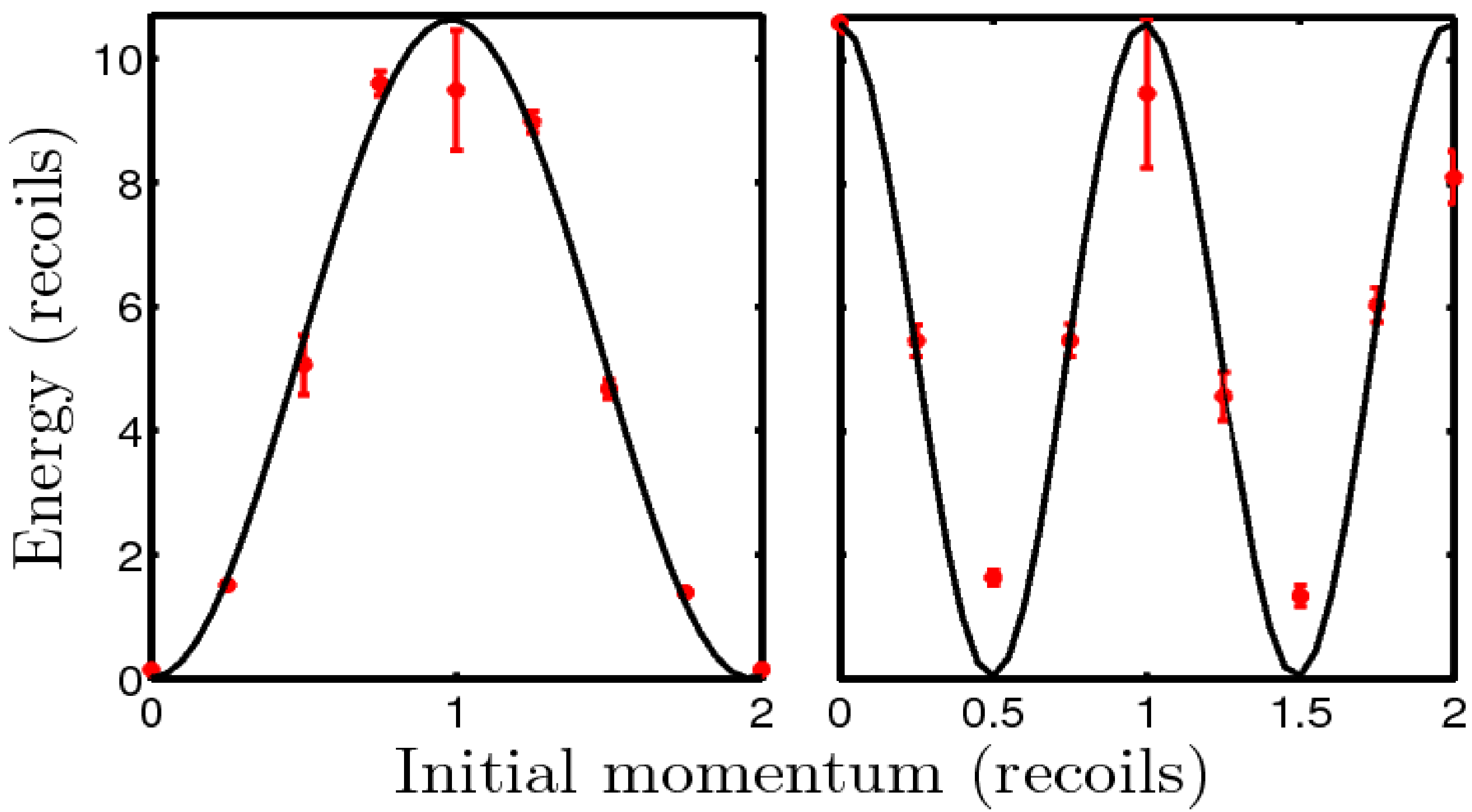


Two kicks

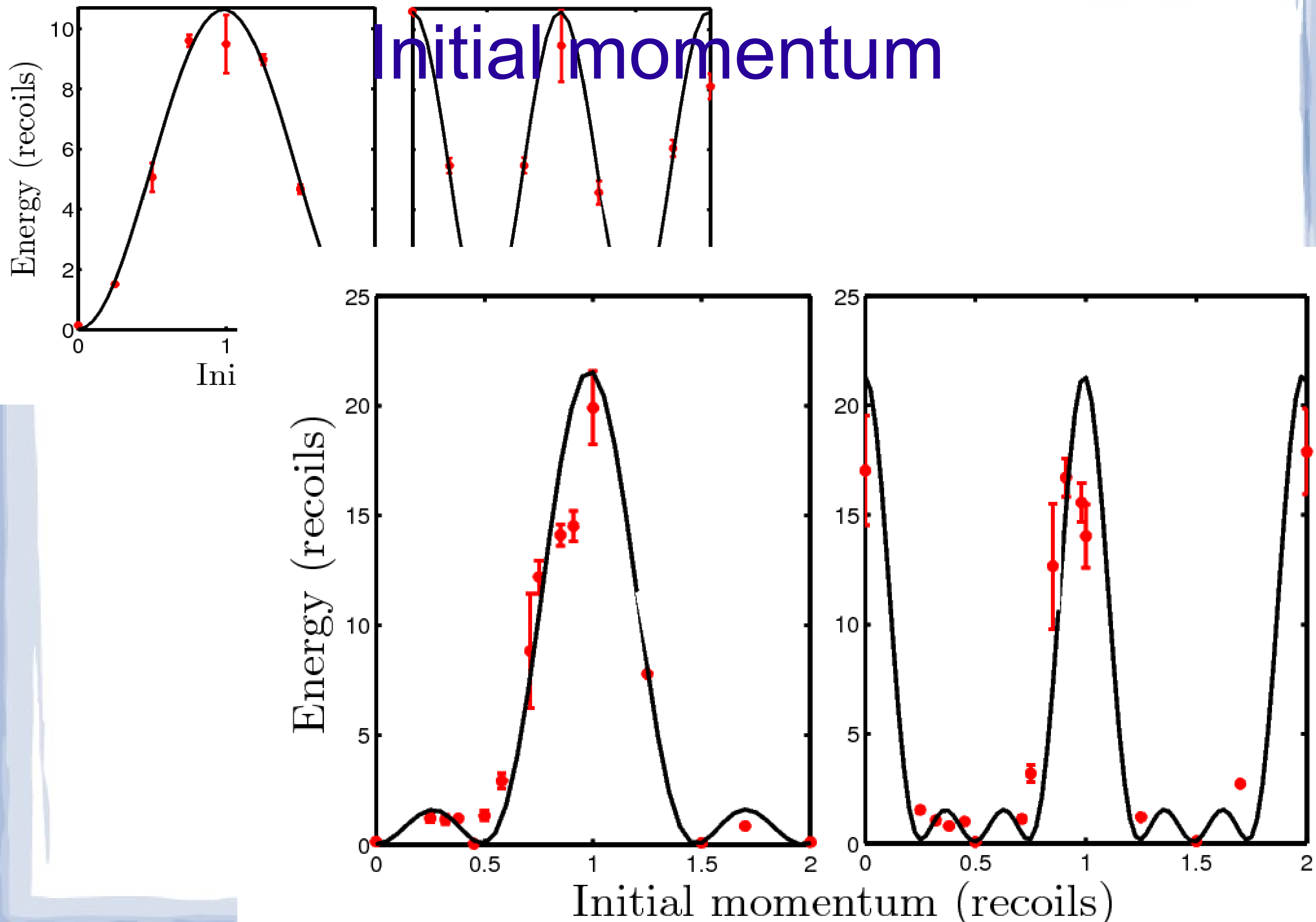
$k=4\pi$



Initial momentum



Initial momentum



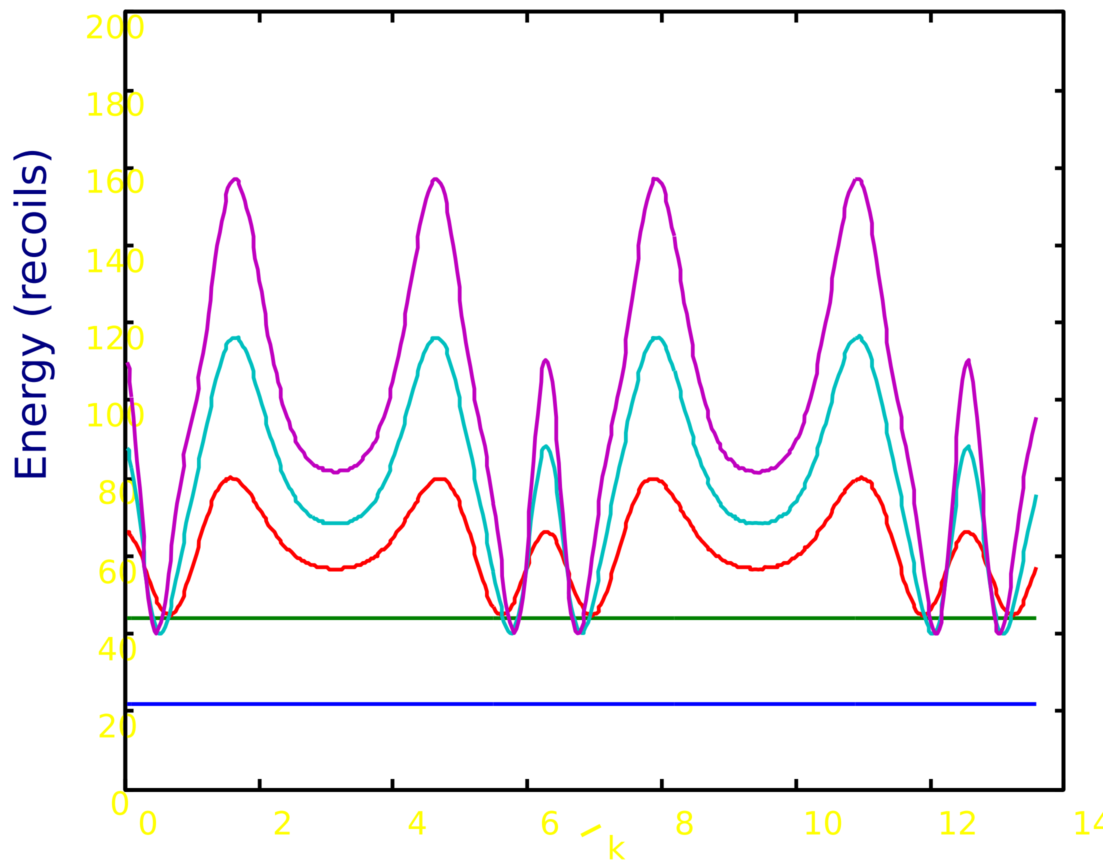
Warmer atoms

Analytical expressions

$$D_1 = \phi_d^2$$
$$D_2 = D_1$$
$$D_3 = D_2 - 2\phi_d^2 J_2(\kappa_q)$$
$$D_4 = D_3 + 2\phi_d^2 (J_3^2(\kappa_q) - J_1^2(\kappa_q))$$
$$D_5 = D_4 + 2\phi_d^2 J_2^2(\kappa_q)$$

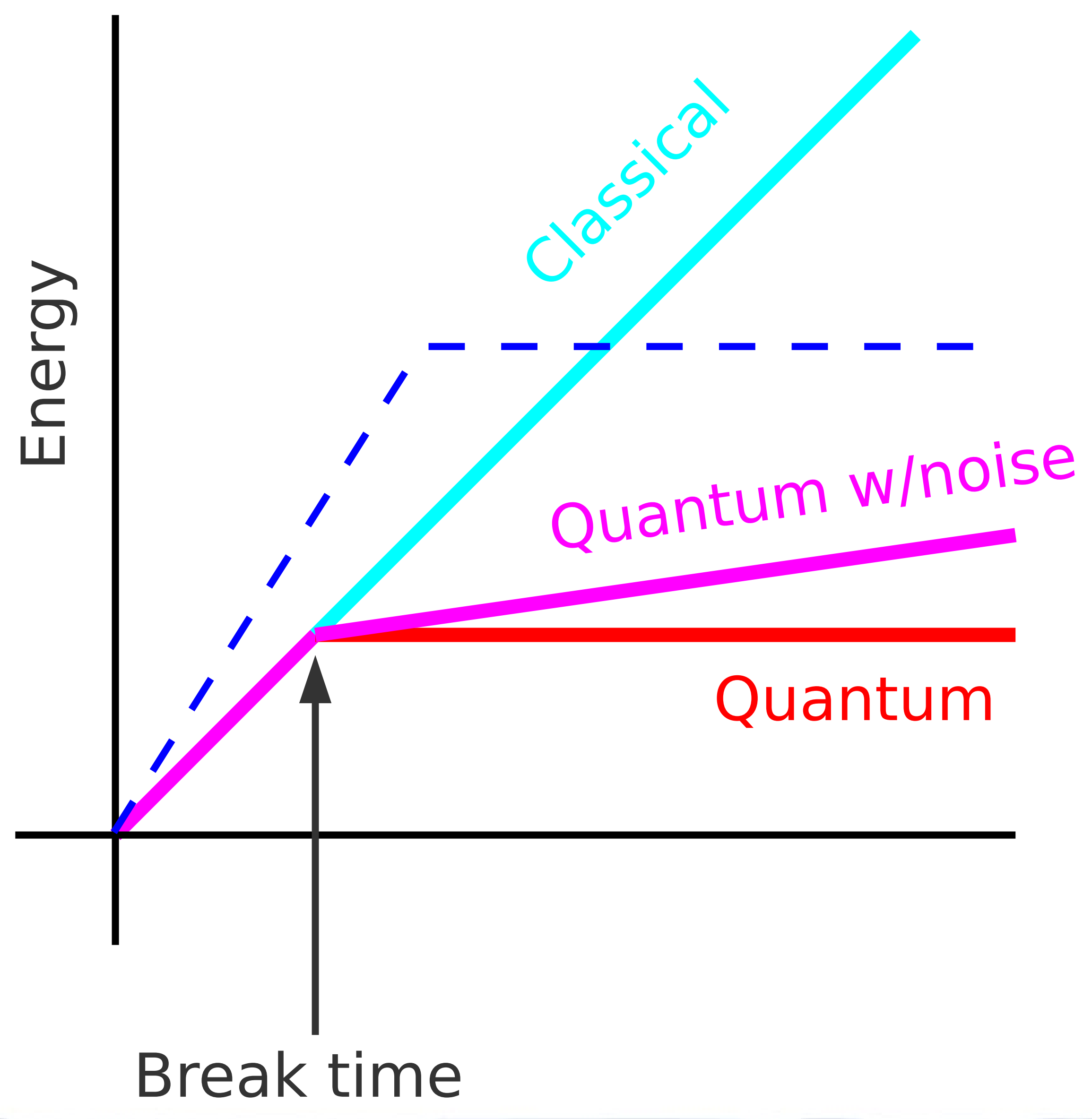
where

$$D_i = E_i - E_{i-1}$$
$$\phi_d = \frac{\kappa}{\hbar} = \frac{\Omega_{eff}\tau_p}{2}$$
$$\Omega_{eff} = \frac{\Omega^2}{\Delta}$$
$$\Omega^2 = \frac{\Gamma^2 I}{2 I_s}$$
$$\kappa_q = 2\phi_d \sin(k/2)$$

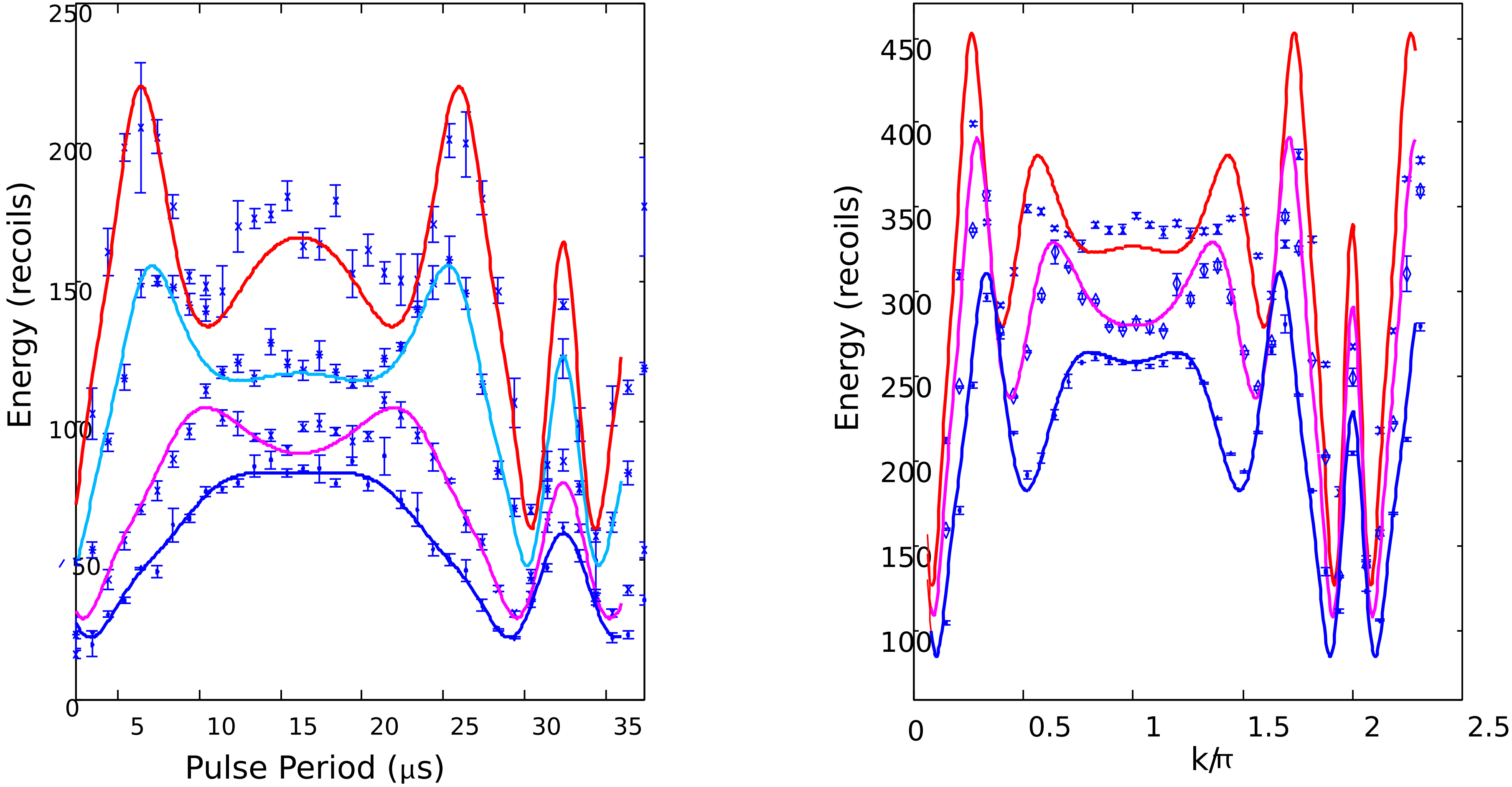


$J_n(x)$ is *n*th Bessel function

Dynamical Localisation

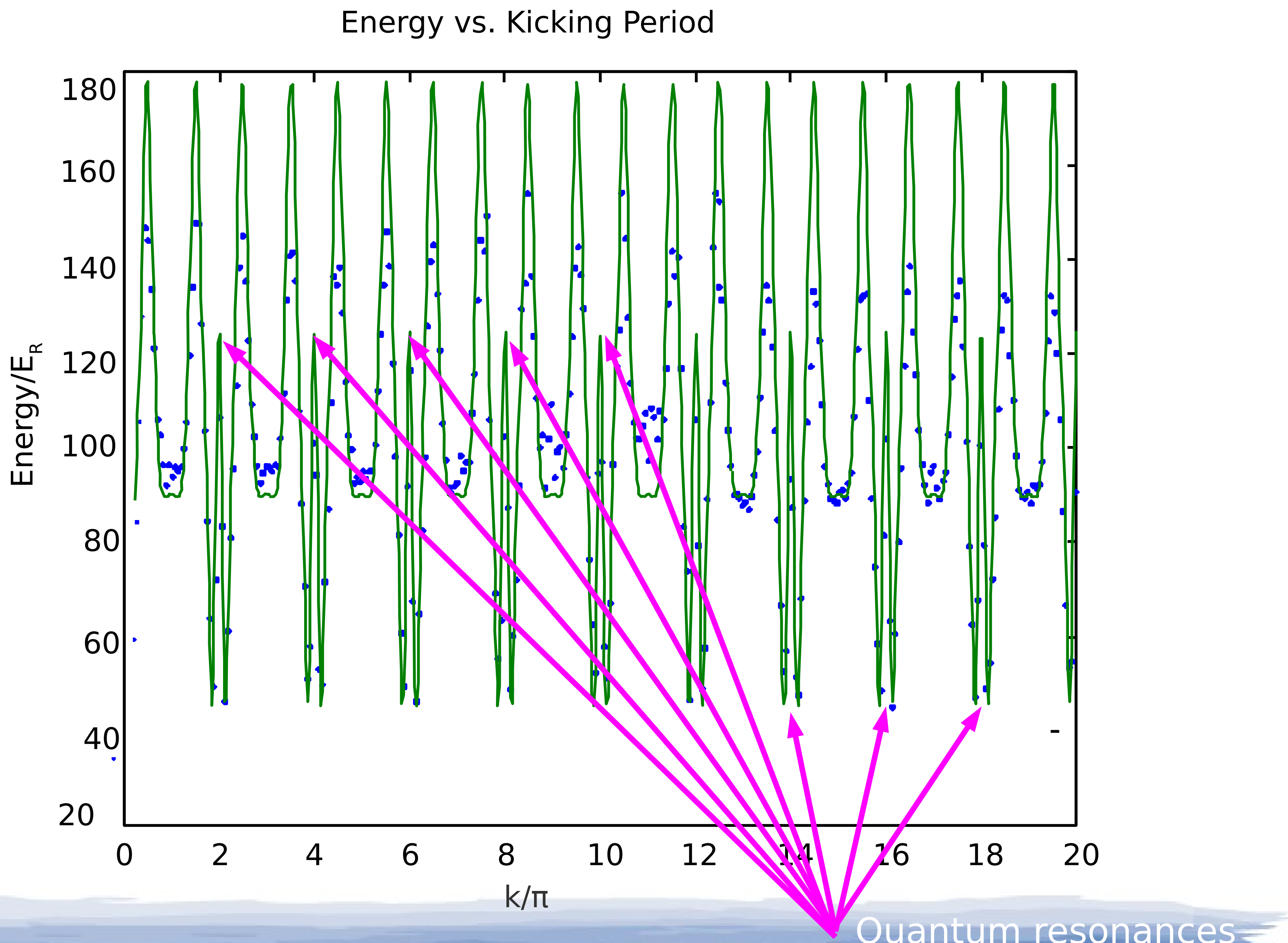


5 kicks



Energy (recoils)
Pulse Period (μs)
0
50
100
150
200
250
5
10
15
20
25
30
35
Energy (recoils)
k/π
100
150
200
250
300
350
400
450
0
0.5
1
1.5
2
2.5

Periodic kicked rotor energy



Time reversal in a chaotic system

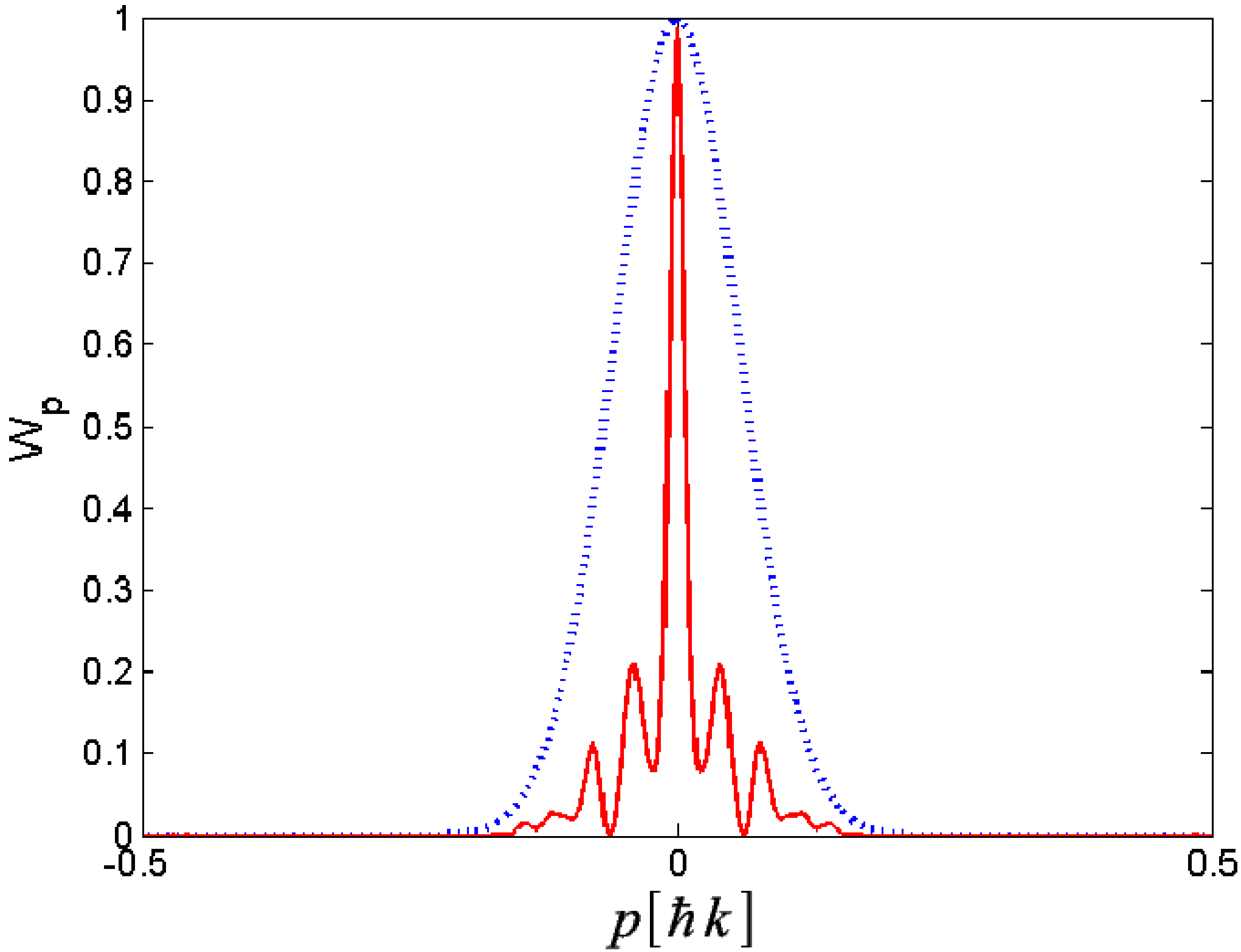
Time reversal

- System is classically chaotic
- Quantum motion
- Should be reversible!

- Apply number of kicks, $8\omega_R T = 4\pi + \varepsilon$
- Wait for sign change
- Reverse evolution by applying more kicks with $8\omega_R T = 4\pi - \varepsilon$

Time reversal

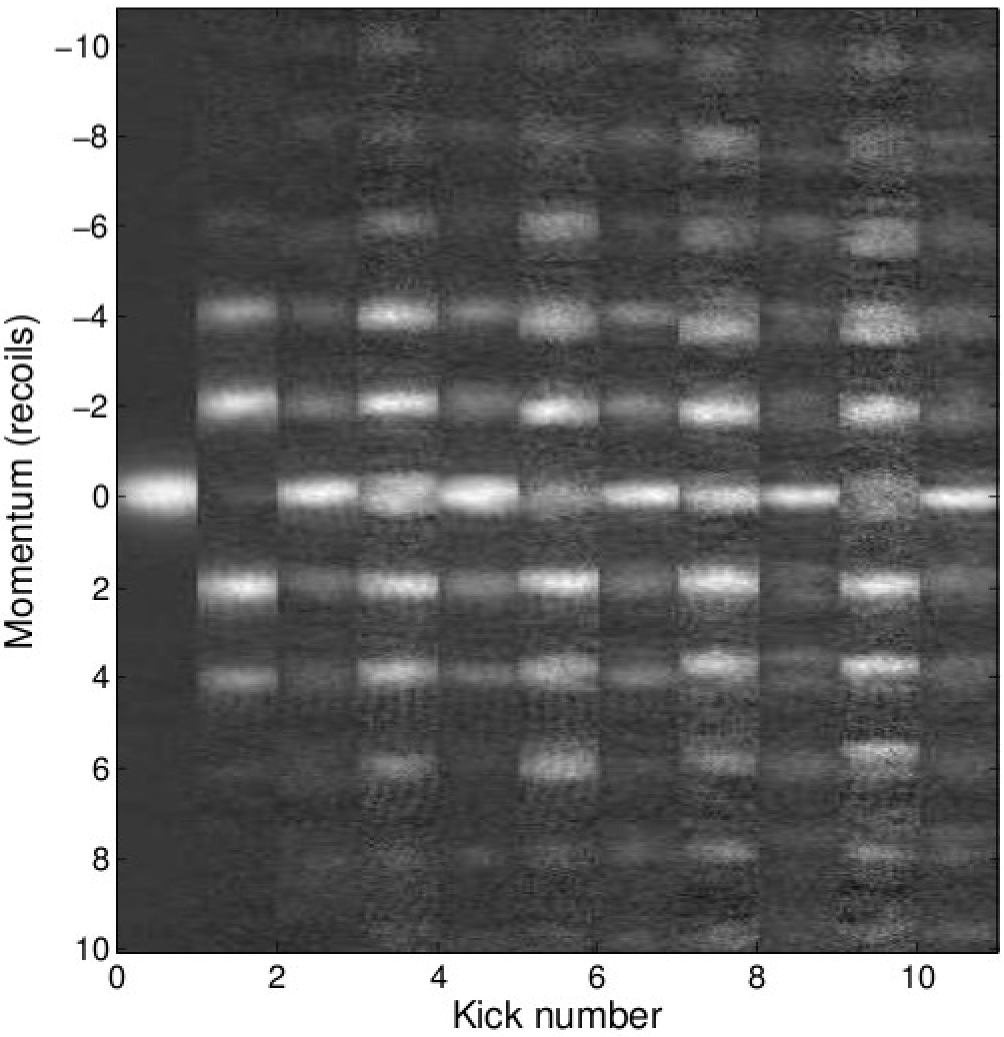
- Sy ... f
  cha ... +ε
- Qu ... ange
- Sh ... on
  e



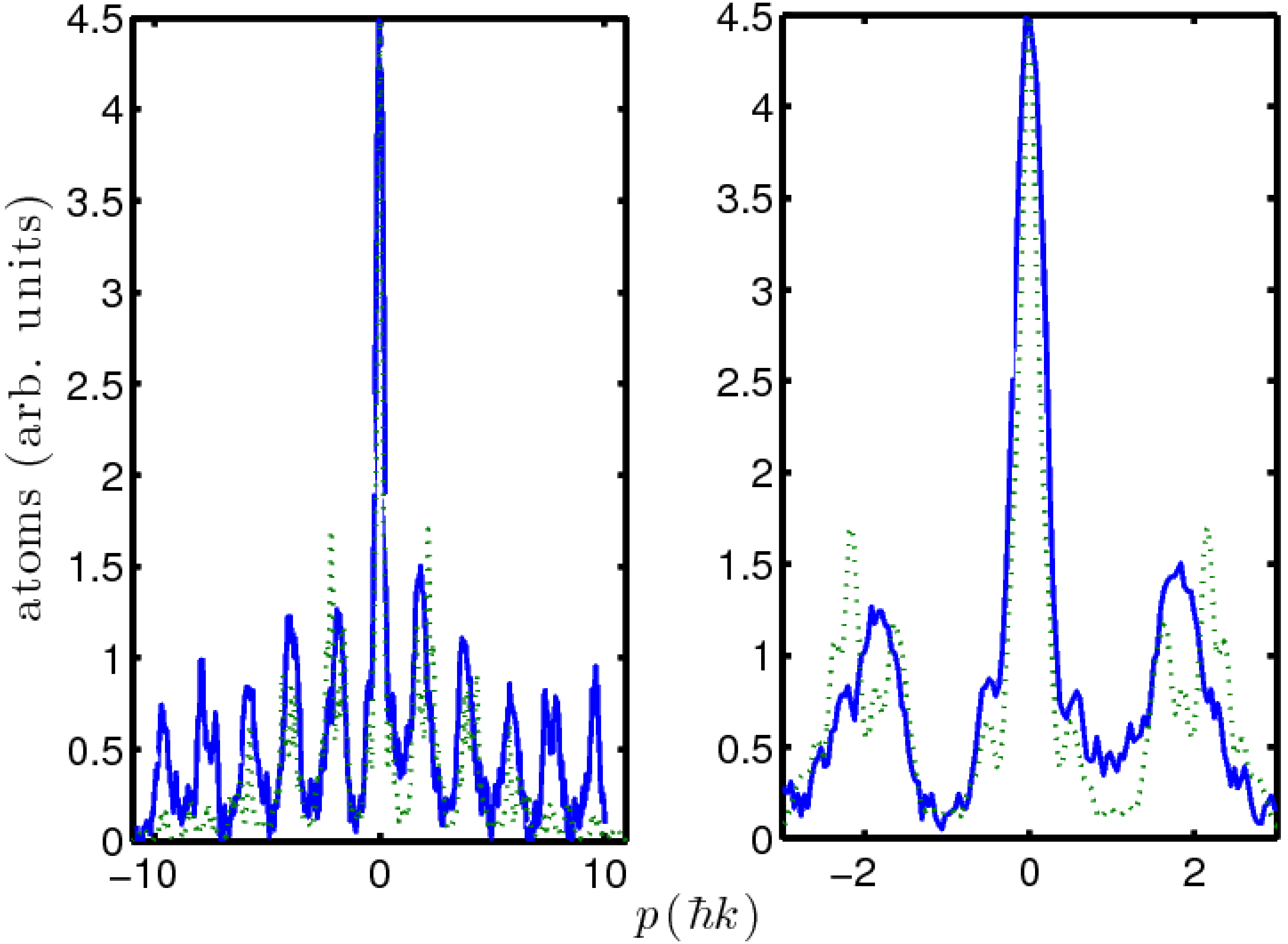
Time reversal

- Central peak shoul
reach same height
after pulse sequen

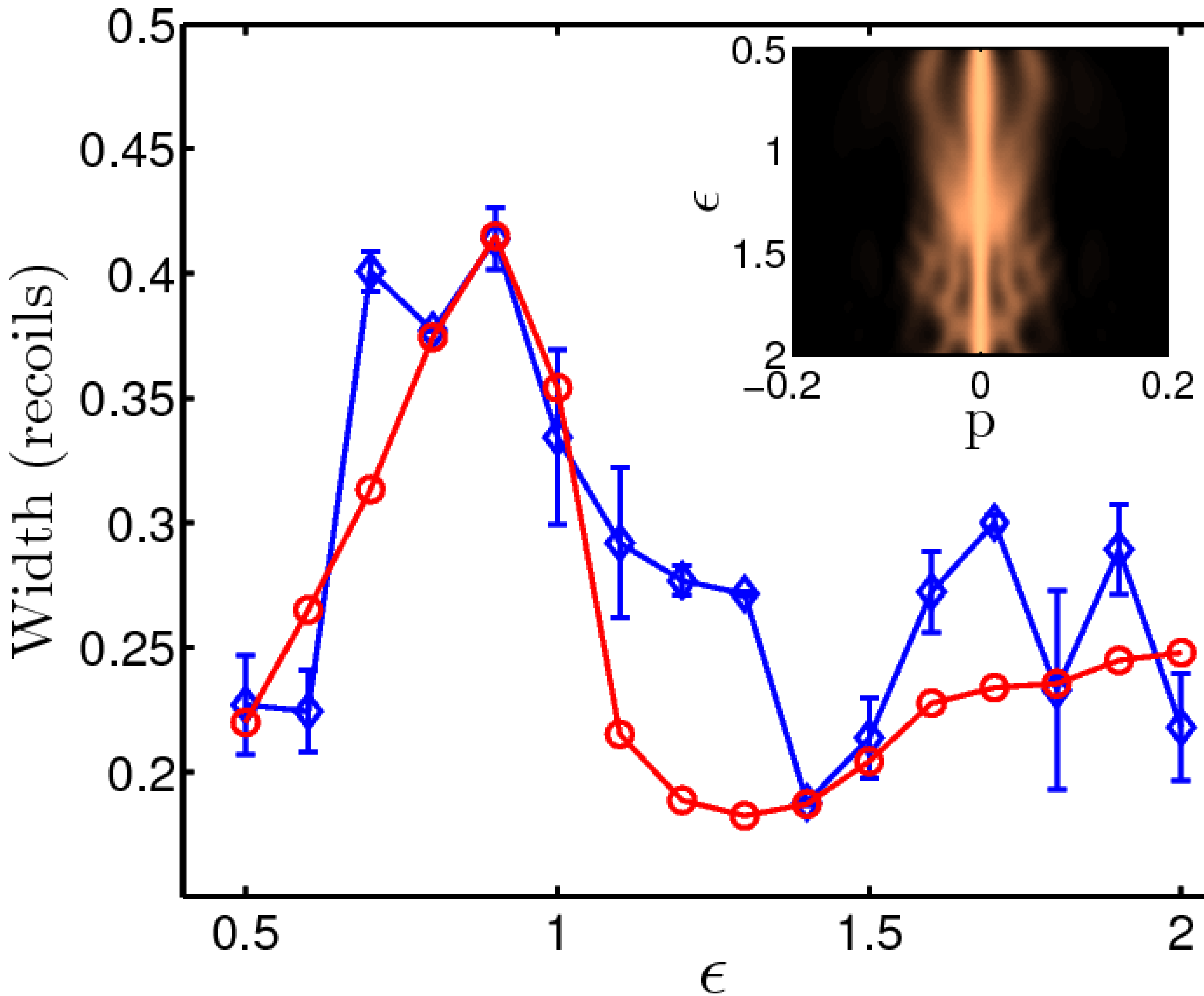
- Central peak more narrow after pulse sequence



Momentum distribution



Changing ε



Conclusions today

- Higher order resonances
- Initial momentum
- Time reversal
- Tomorrow: more fancy experiments