First Stark deceleration of SO_2

– a source of cold atoms and molecules

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Applications of cold molecules

- High resolution spectroscopy
  ND_3 HFS: EPJD **31**, 337 (2004)
- Evolution of fundamental constants
  fine structure constant: arXiv:physics/0601054
- Route to ultra-cold molecules
  sympathetic cooling
- Scattering experiments
  relaxation Cs_2: PRL **96** 023201 (2006), PRL **96** 023202 (2006)
- Quantum controlled reactions
  formaldehyde, hydroxyl: arXiv:physics/0508120

Controlled coupling

- Coherent coupling in thermal clouds

  Cs_2: EPJD **21**, 299 (2002) Li_2: PRA **68,** 051403 (2003)

- Coherent coupling in BECs

  Rb_2: PRL **95**, 063202 (2005) Na_2: PRA **72**, 041801 (2005)

- Cs_4 formation

  Phys. Rev. Lett. **94**, 123201 (2005)

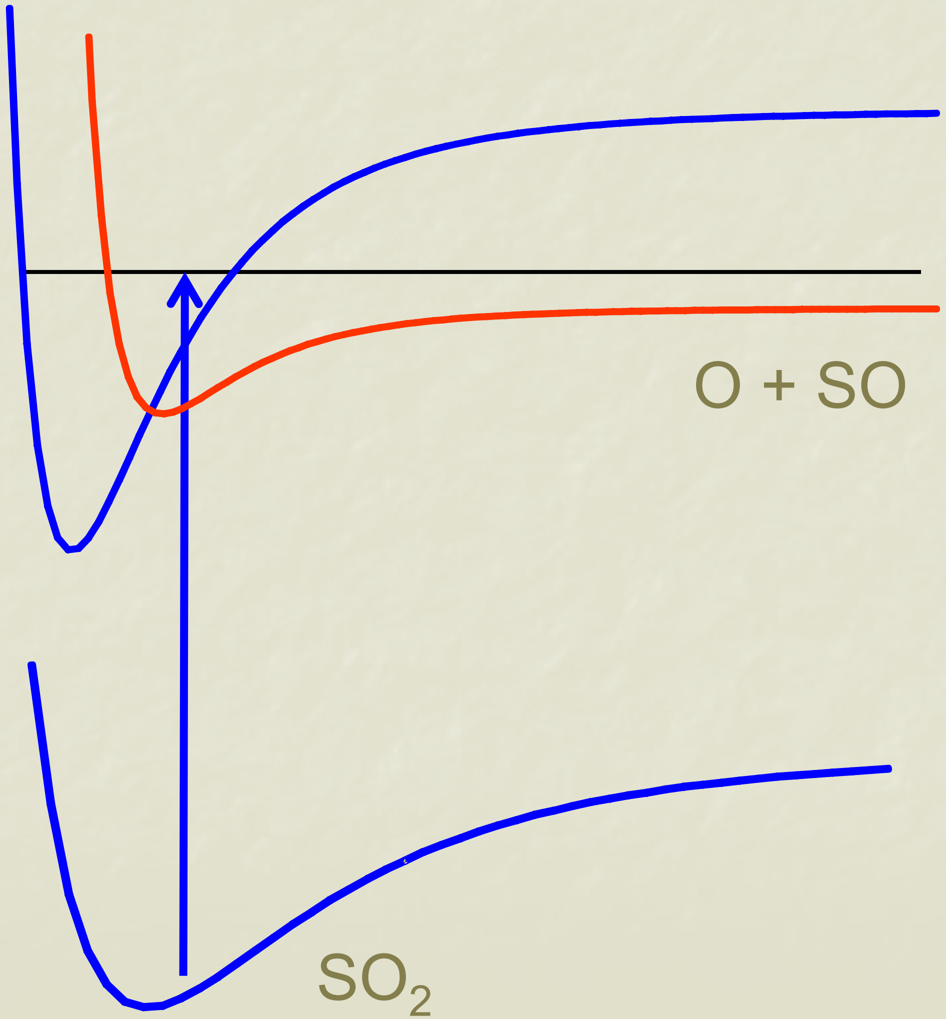
Applications of cold SO_2

- Photodissociation: new way to cold particles
- Trapping of SO_2 and fragments SO + O
- Control of pathways and energies
- Cold chemistry?
- Study of cold molecule – particle collisions

Overview

- Control: Photodissociation in electric fields
- Stark decelerator setup
- Stark decelerator principle
- Time of flight spectra
- Outlook

Predissociation



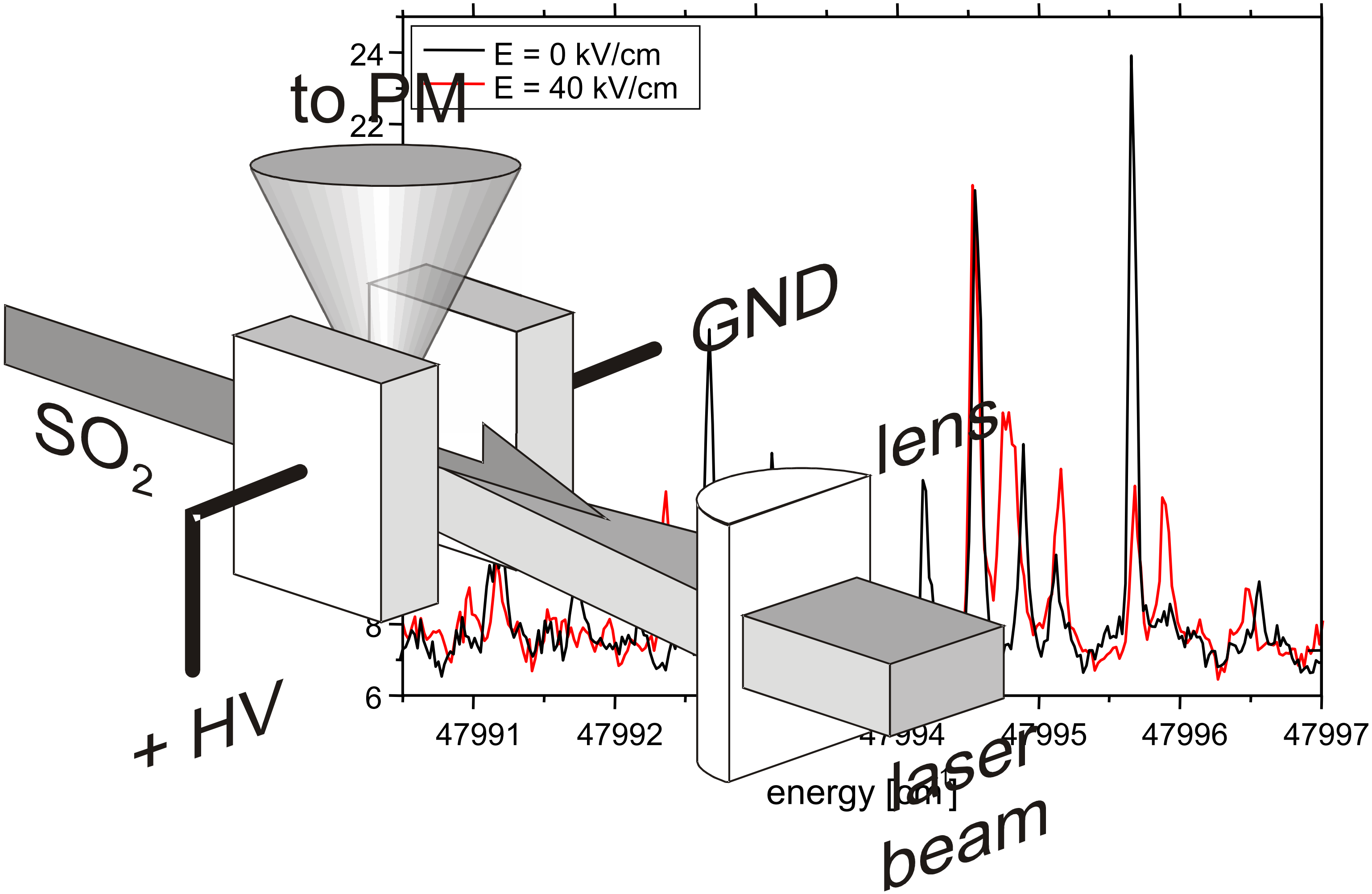
Bound states embedded in continuum:

Coupling between both excited states:

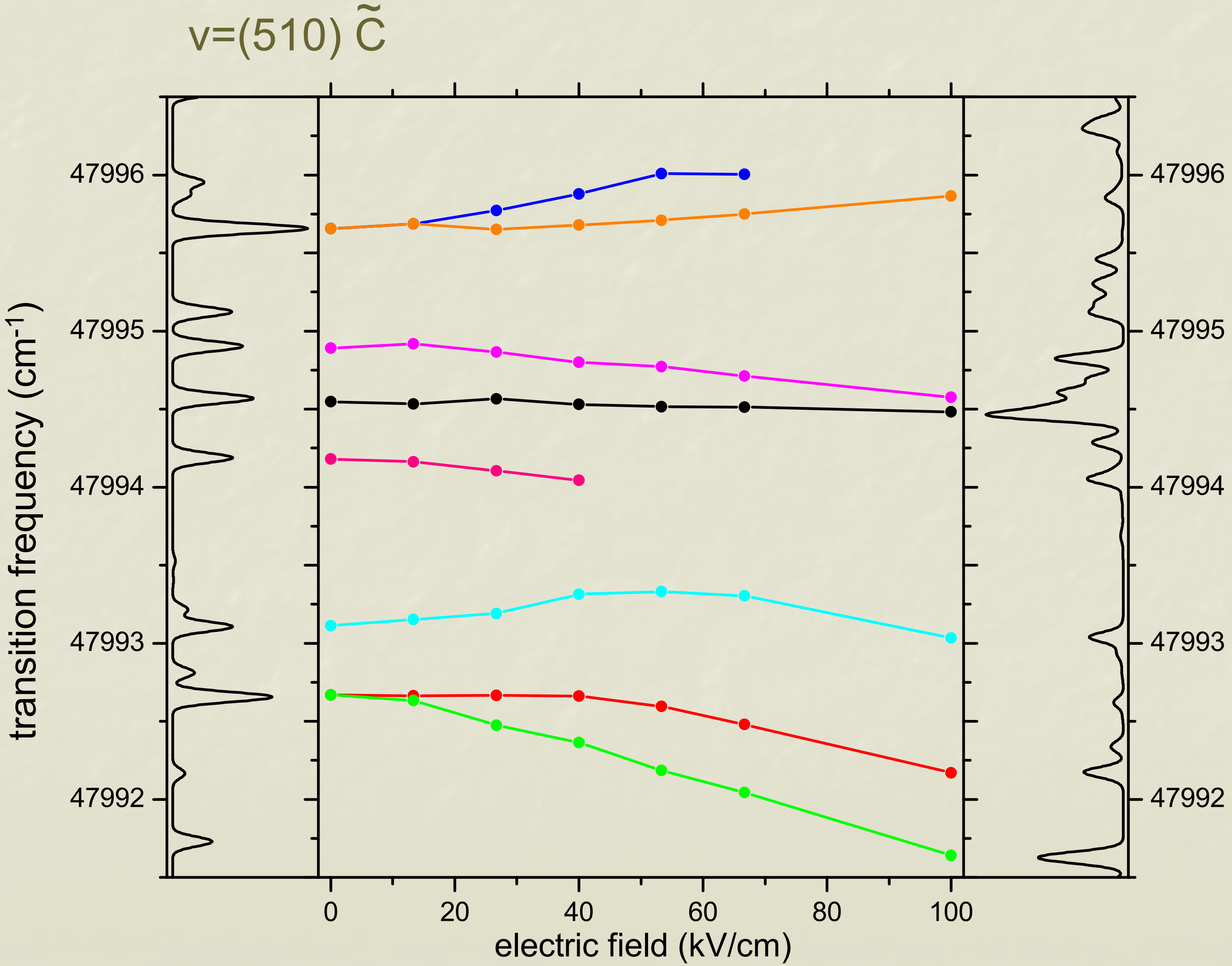
Predissociation

Excess energy and initial quantum state determined by predissociating level

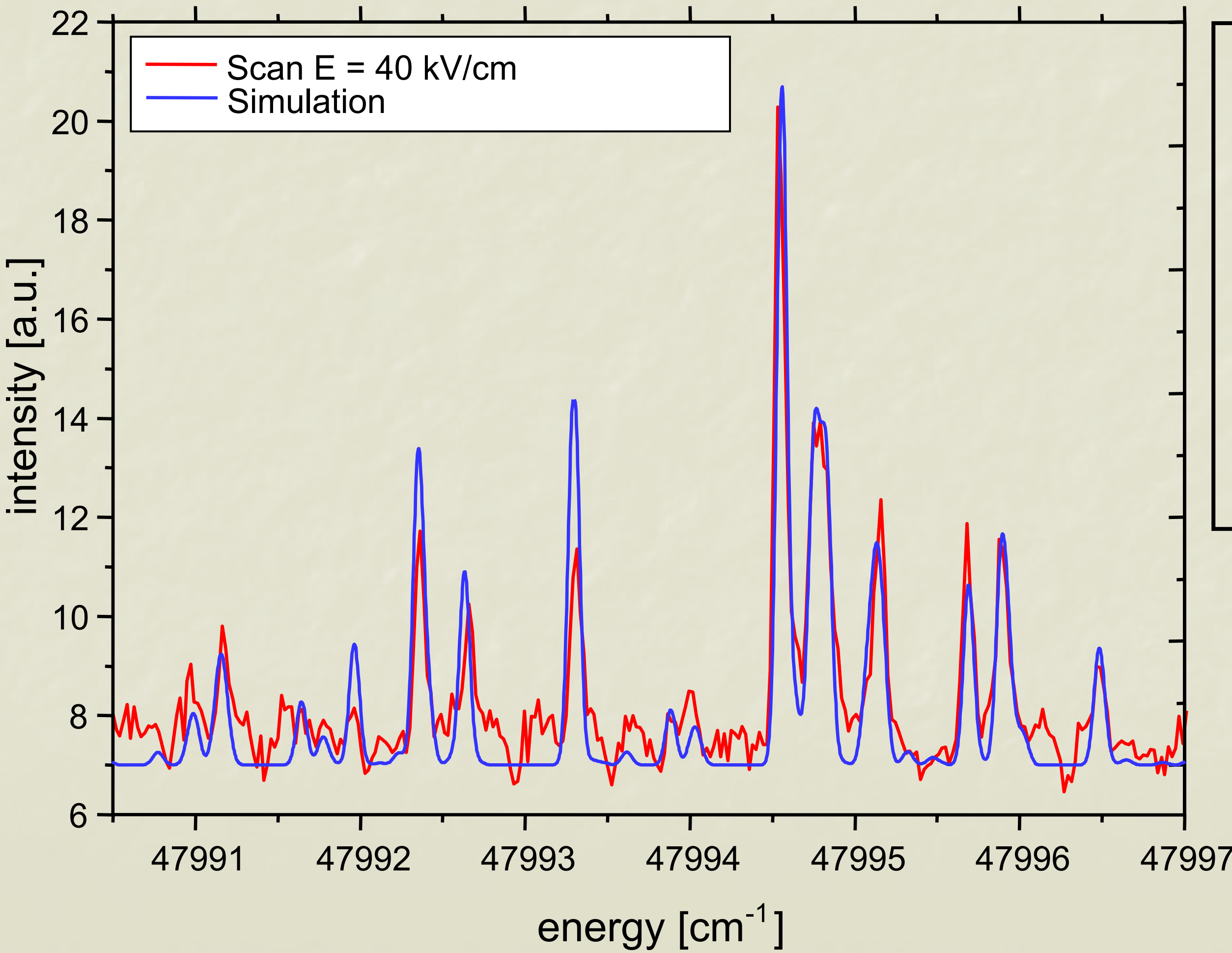
Stark effect measurement



Stark effect measurement



Stark effect measurement



parameters (field free):

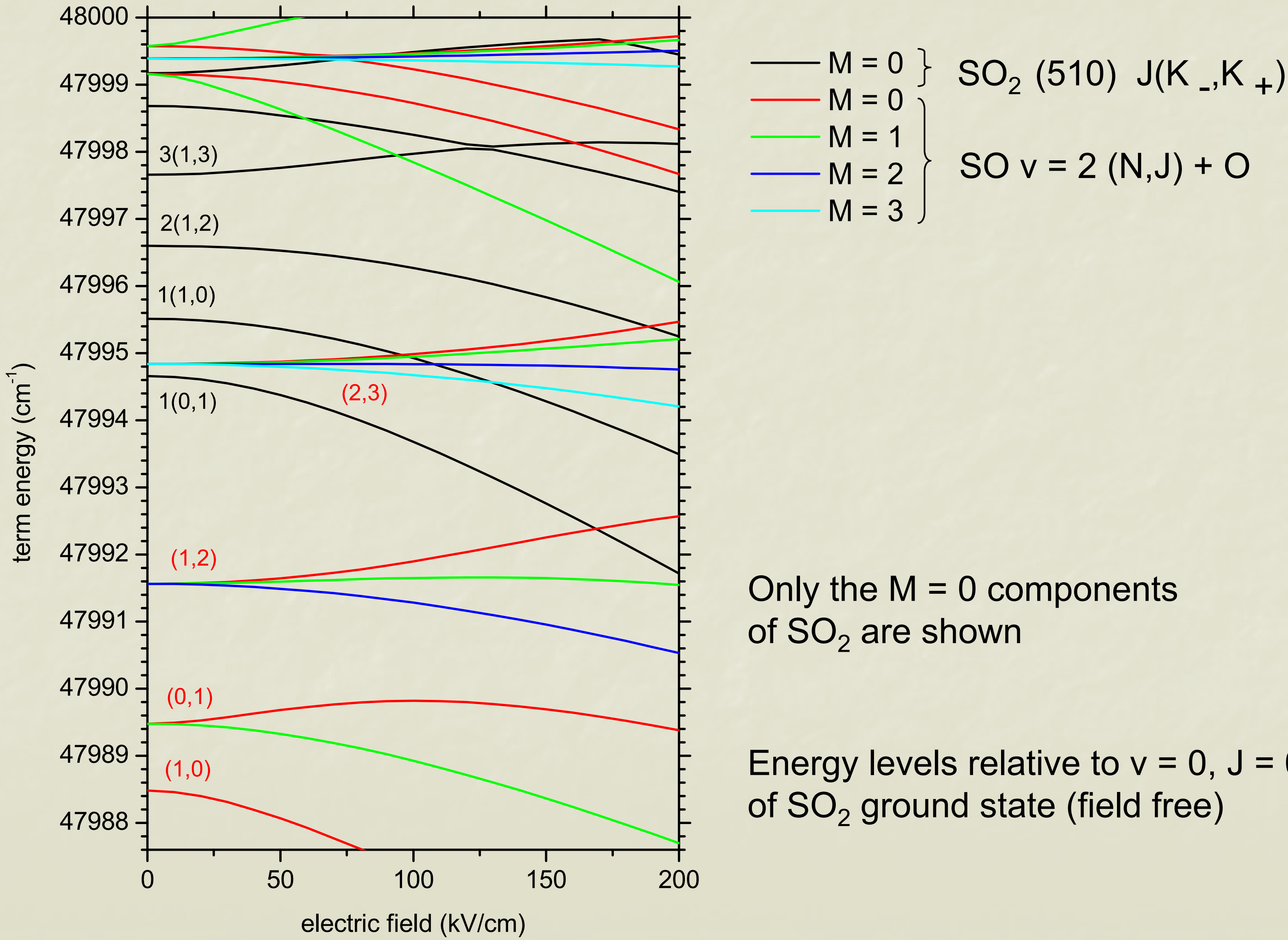
- rot. constants
- rot. temperature

free parameters:

- dipole moment
- geometry factor

μ_b = 1.99(6) D

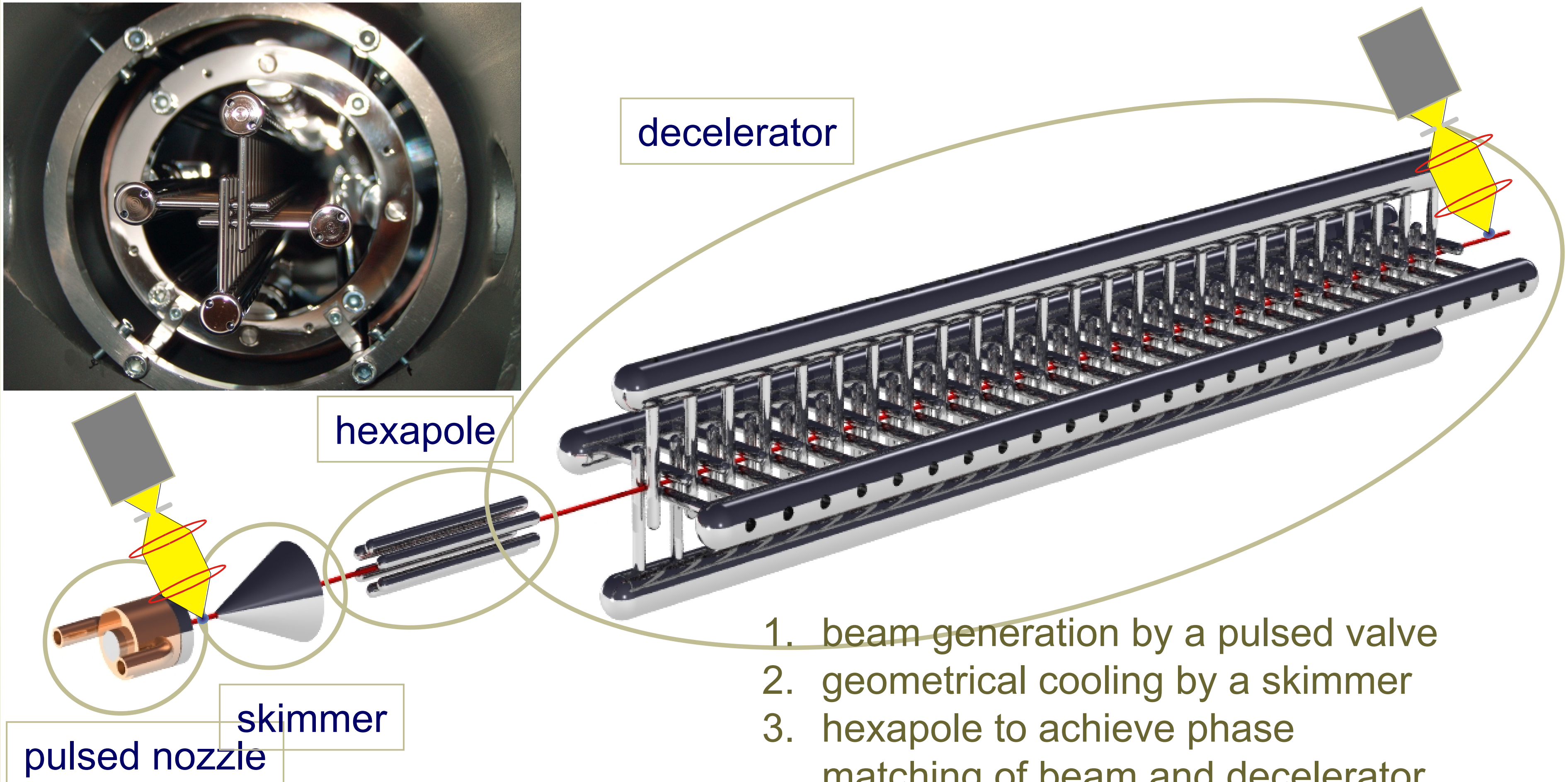
Tuneable kinetic energy



Only the M = 0 components of SO_2 are shown

Energy levels relative to v = 0, J = 0 of SO_2 ground state (field free)

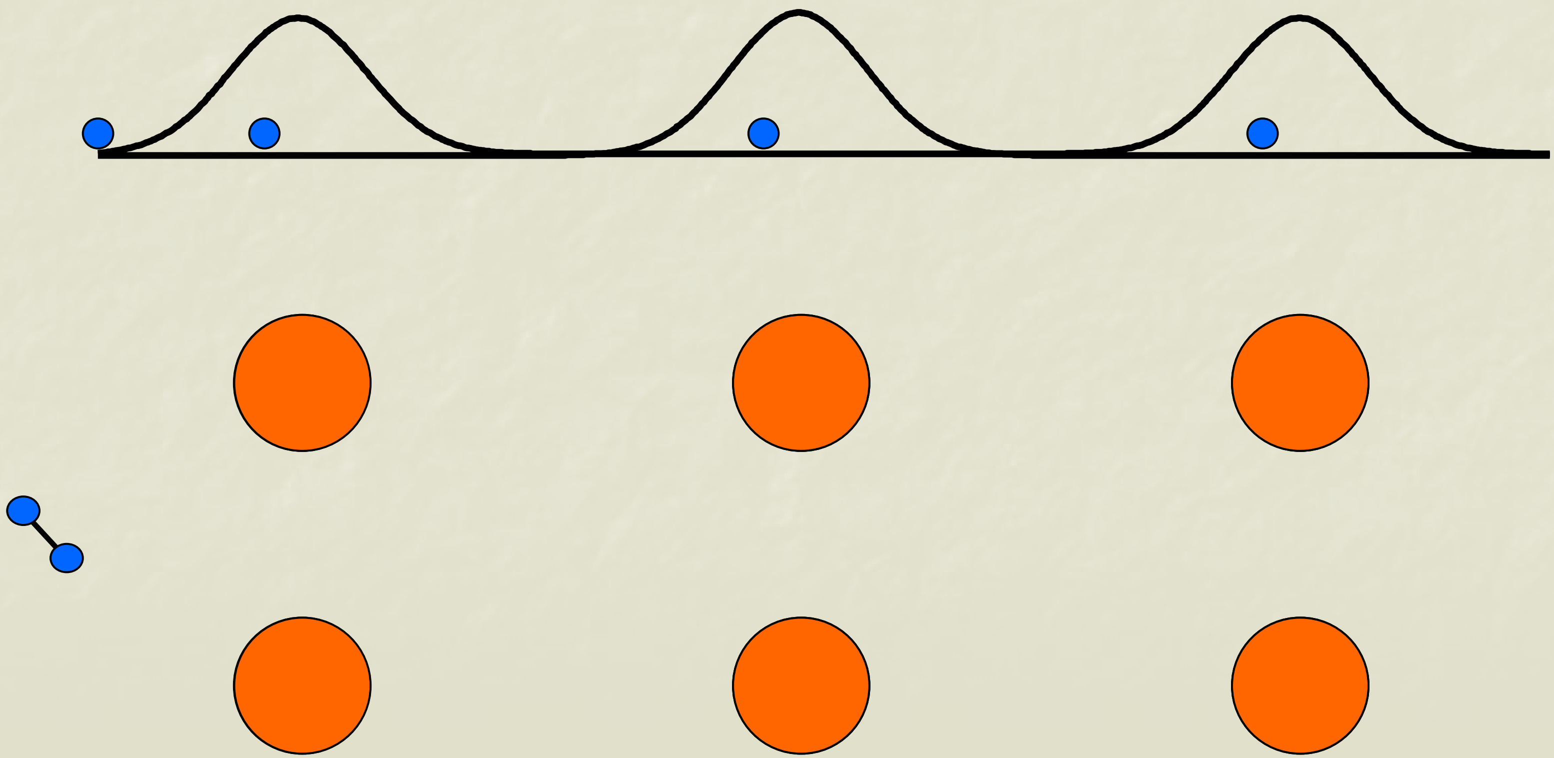
Experimental setup



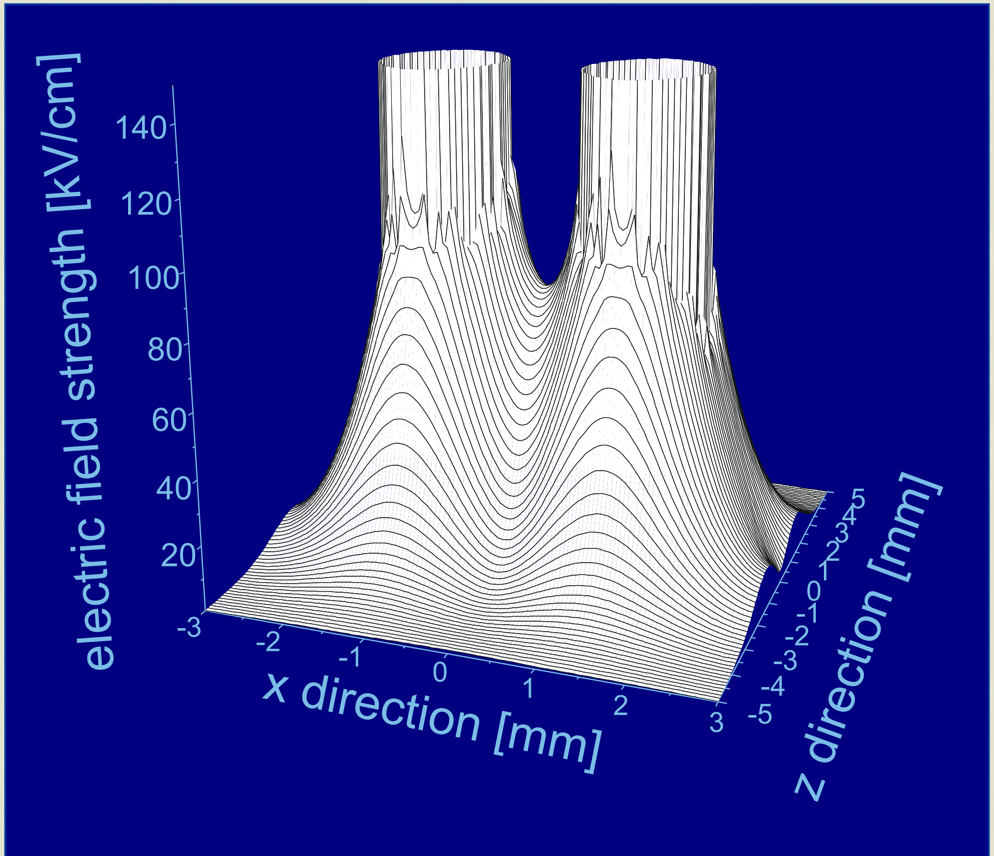
1. beam generation by a pulsed valve
2. geometrical cooling by a skimmer
3. hexapole to achieve phase matching of beam and decelerator
4. Stark decelerator for low-field seeking states
5. time of flight measurements

Decelerator principle

switching sequence for one molecule



Field of two electrodes



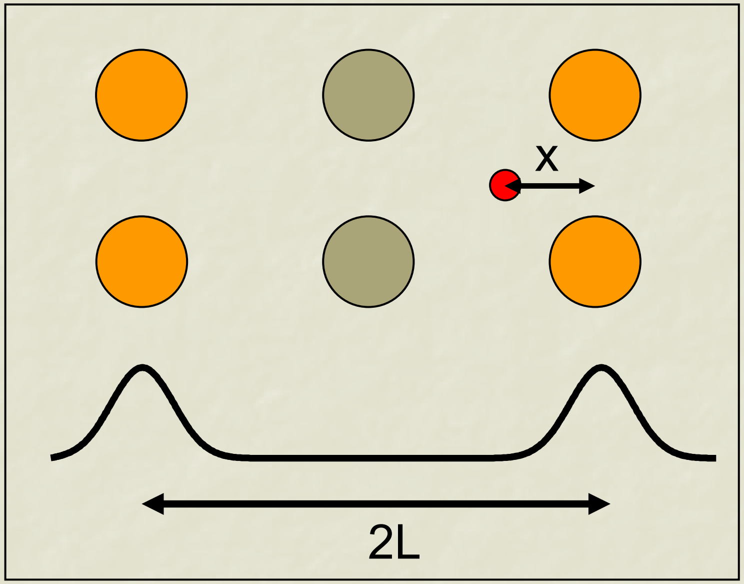
- minimum electric field on the molecular beam axis
- low-field seeking states experience a focusing force (guiding)
- no focusing in direction of the electrodes (y-axis)
- alternate horizontally and vertically positioned pairs

Deceleration properties: phase

Definition of phase:

relative position of a molecule to electrodes (periodicity of 2L) when switching the field

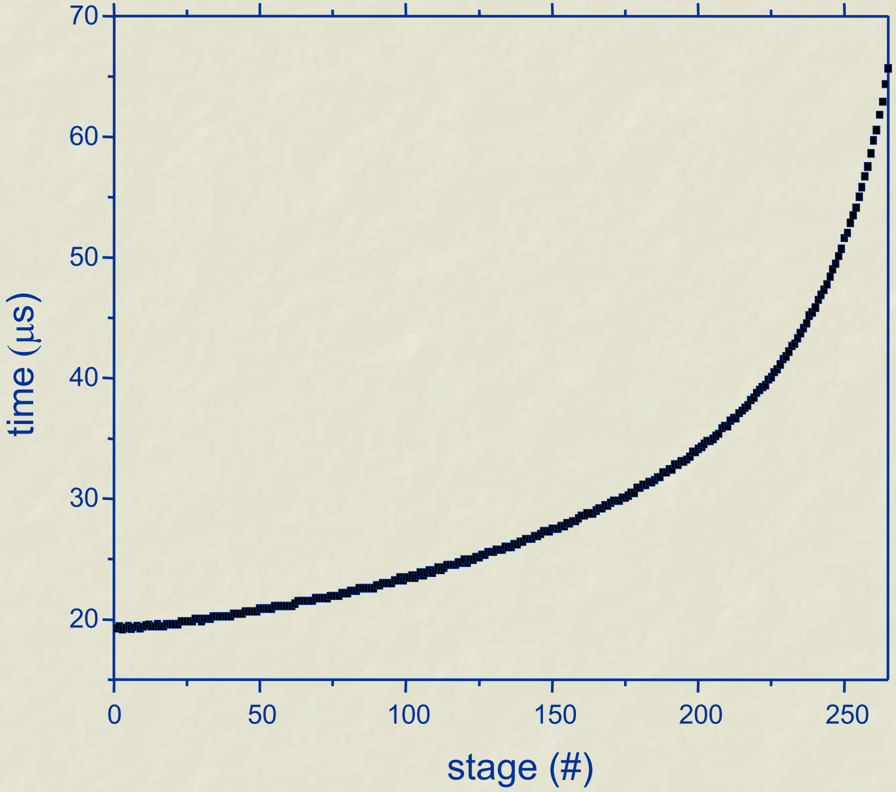
$$\phi = \frac{x}{2L} \cdot 360^\circ + 90^\circ$$



Deceleration requirements:

- switching intervals *T* must be gradually increased
- the bunch of molecules must be kept together

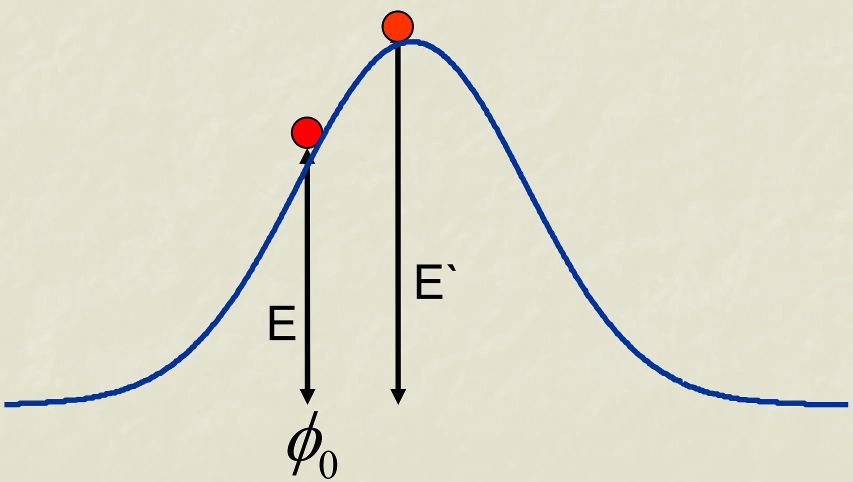
Switching times and phase stability



Molecules will oscillate with phase and velocity around the equilibrium values.

example:

$$\phi > \phi_0, v = v_0$$

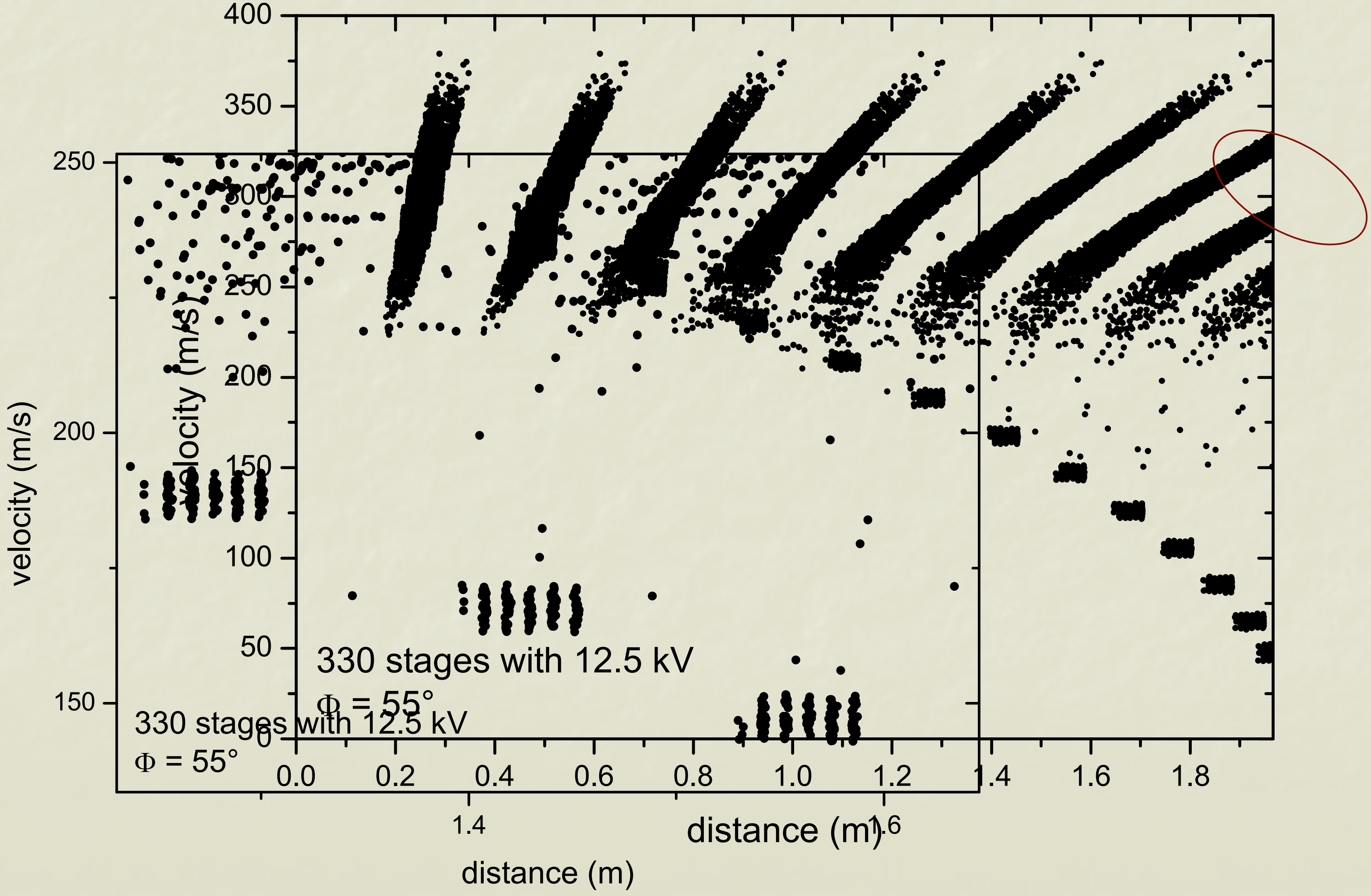


Switching intervals are calculated for one selected molecule (ϕ_0, v_0).

molecule loses more energy

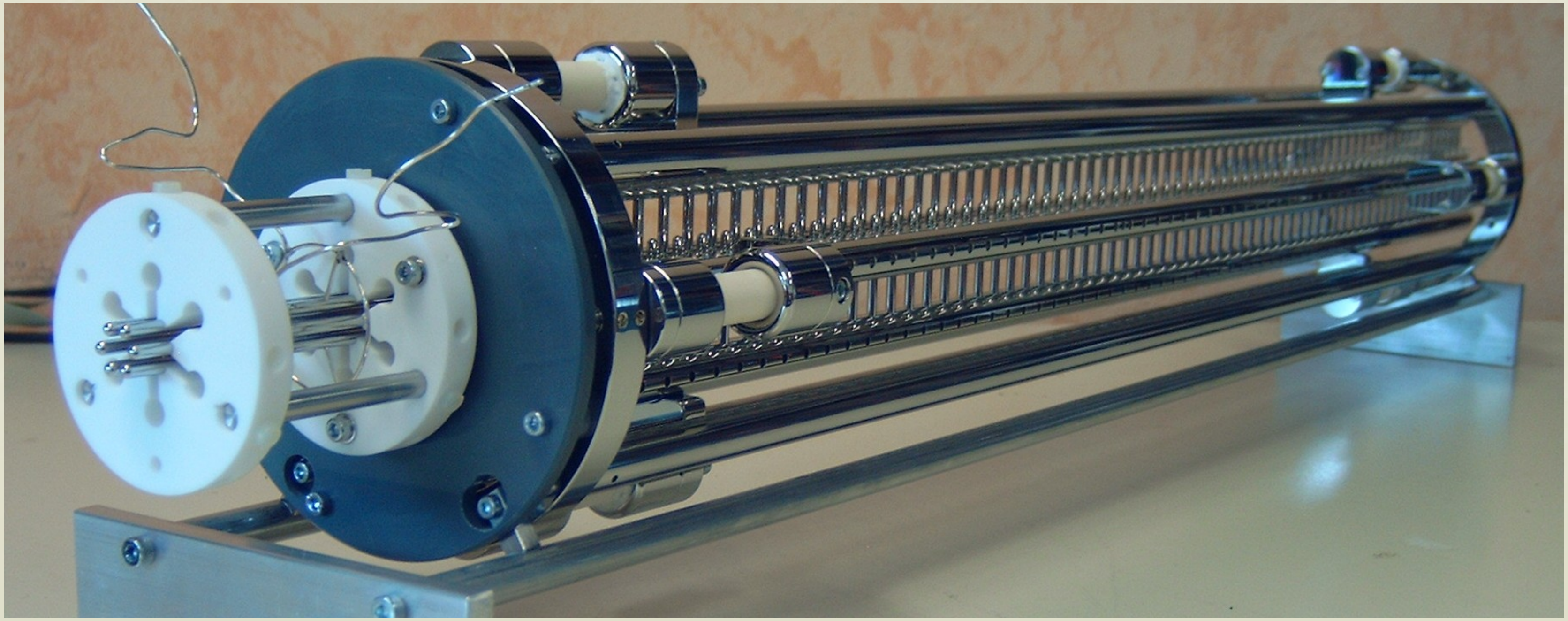
→ phase gets smaller

Phase space inside decelerator

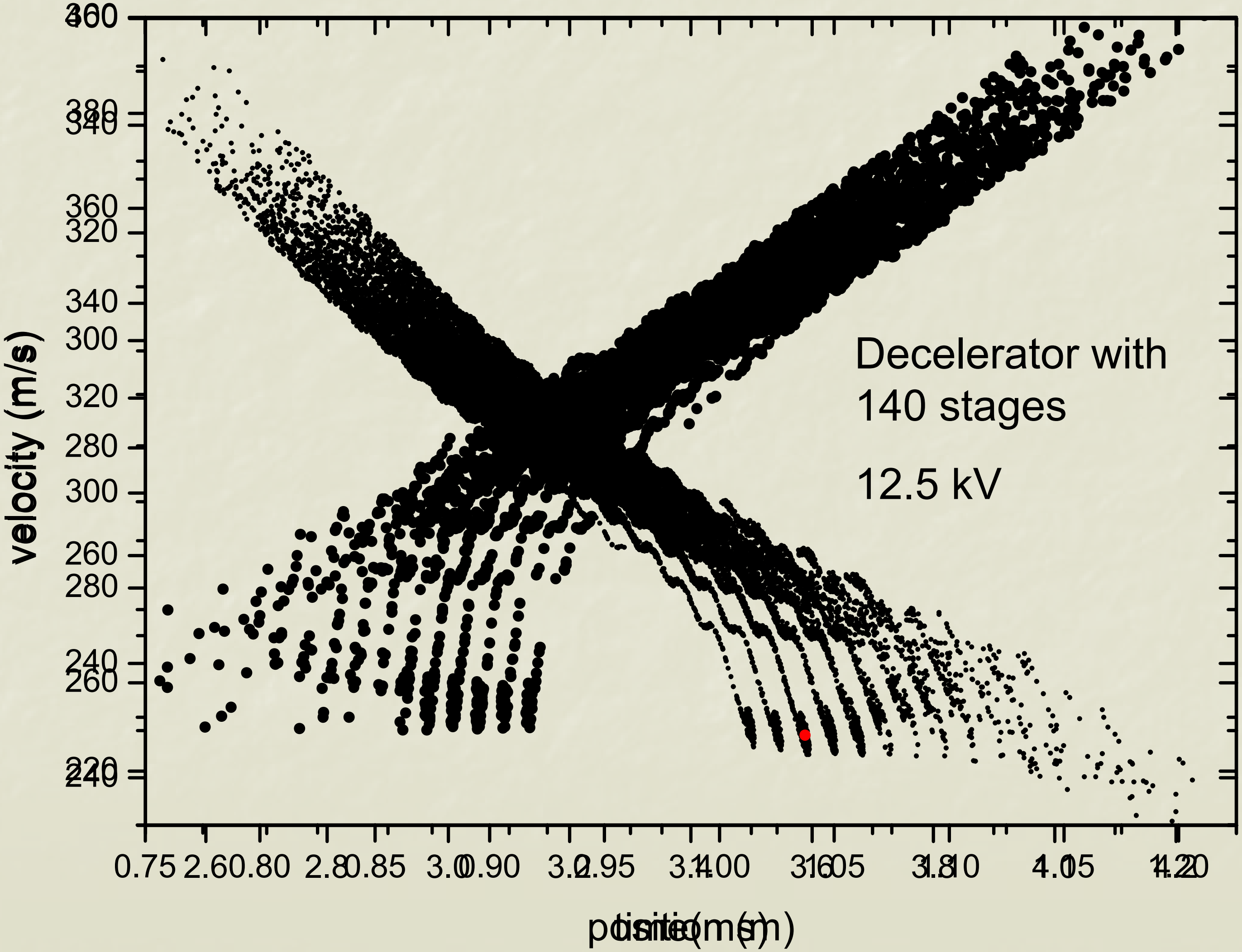


Our realized decelerator

- 140 stages
- Total length: 77 cm
- Potential difference: 25.0 kV, 125 kV/cm
  0.85 cm^{-1} per stage ≈ 1.22 K



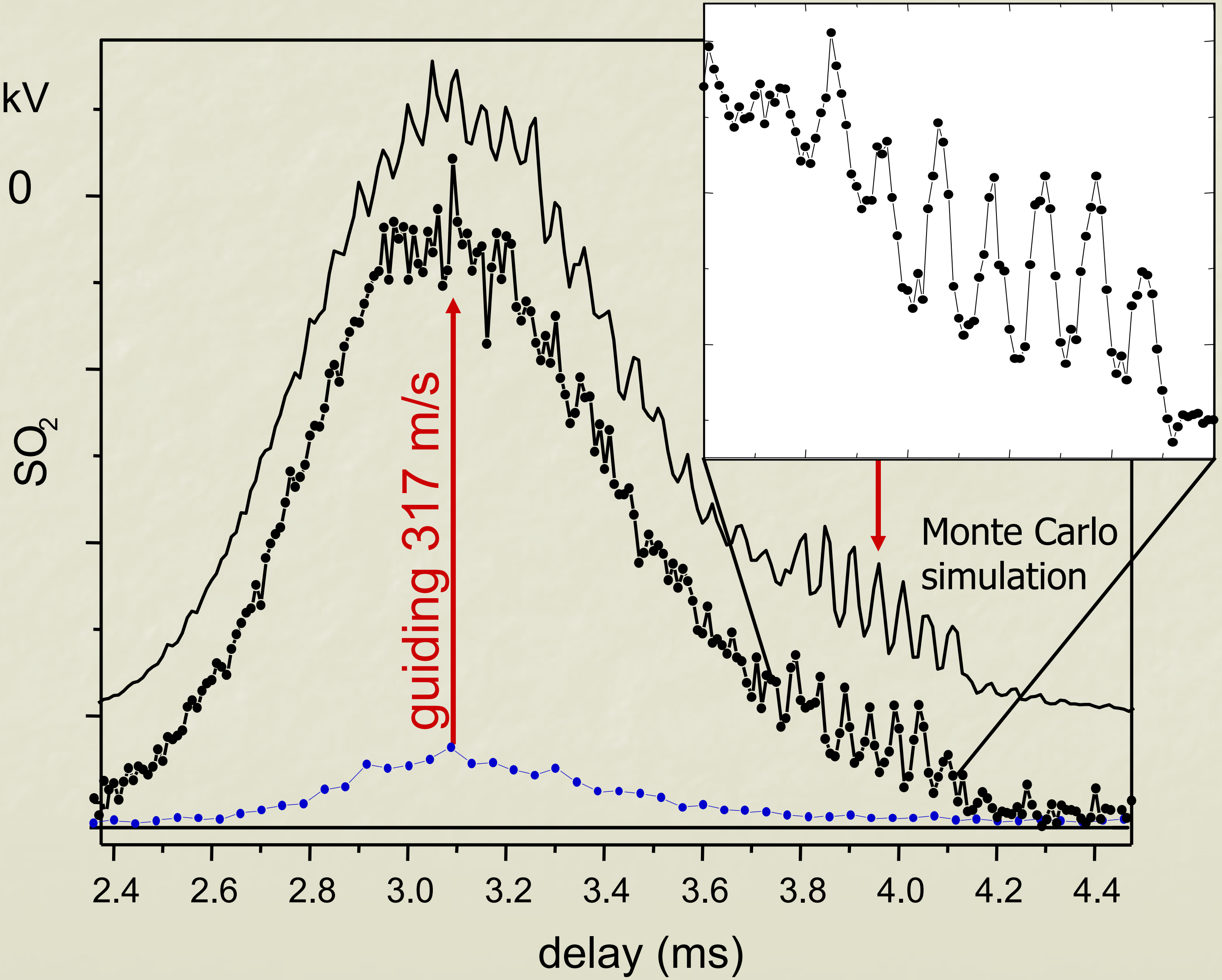
Phase space inside decelerator



Time-of-Flight spectrum

Φ = 55°
U = 12.5 kV

1_{11} |M| = 0



Outlook

- Building a Stark decelerator with 330 stages
- Photodissociation in electric fields and observation of kinetic energies
- Electrostatic trap for the SO_2 molecules
- Magnetic trap for SO and O

Summary

- Photodissociaiton: new way to cold particles
  - Cold radicals SO and O
  - Quantum state selective
  - Oriented
- Control of dissociation pathways
  - Stark effect tunes excess energy
- First decelerator for SO_2
  - Agreement with simulations allows to design the long decelerator
  - New decelerator can load a trap for SO_2