Cold molecules from deceleration and photodissociation

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Cold Molecules

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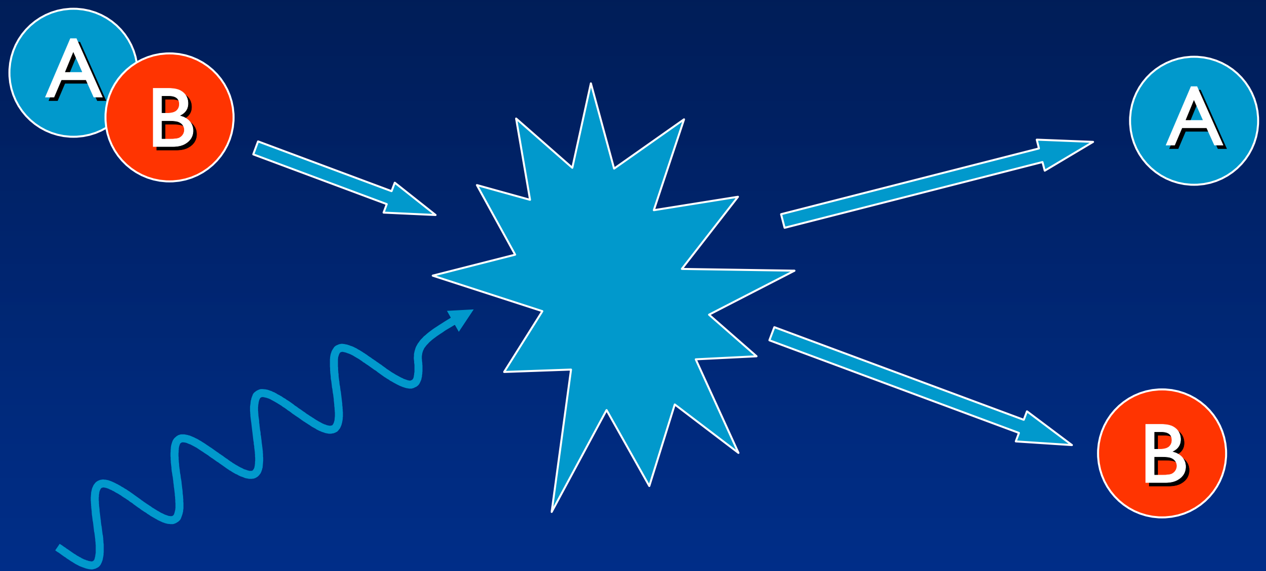
Overview

- Motivation
- Reactive collisions, Feshbach resonances, and photodissociation
- Photodissociation SO_2
- Deceleration experiment with SO_2 molecules
  - Stark effect
  - Molecular beam source
  - Hexapole lens
  - Design of the decelerator
- Summary

Applications of cold molecules

- Trapping of molecules
- High resolution spectroscopy
- Study of cold molecule – particle collisions
- Control of dissociation near the threshold
- Quantum chemistry

Cold collisions and photodissociation



Control of both reactant AB and photon,

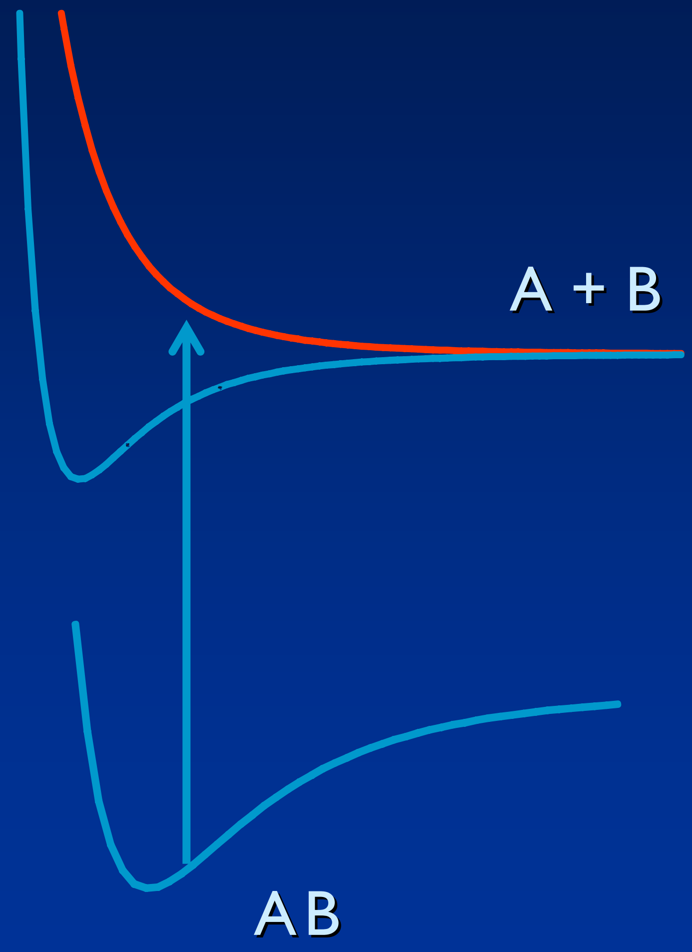
observation of products

»Cold« means close to the threshold

Photodissociation

- Complementary aspects to reactive and cold collisions
- Control of one particle only
- Steering by laser light
- Suitable system required

Photodissociation



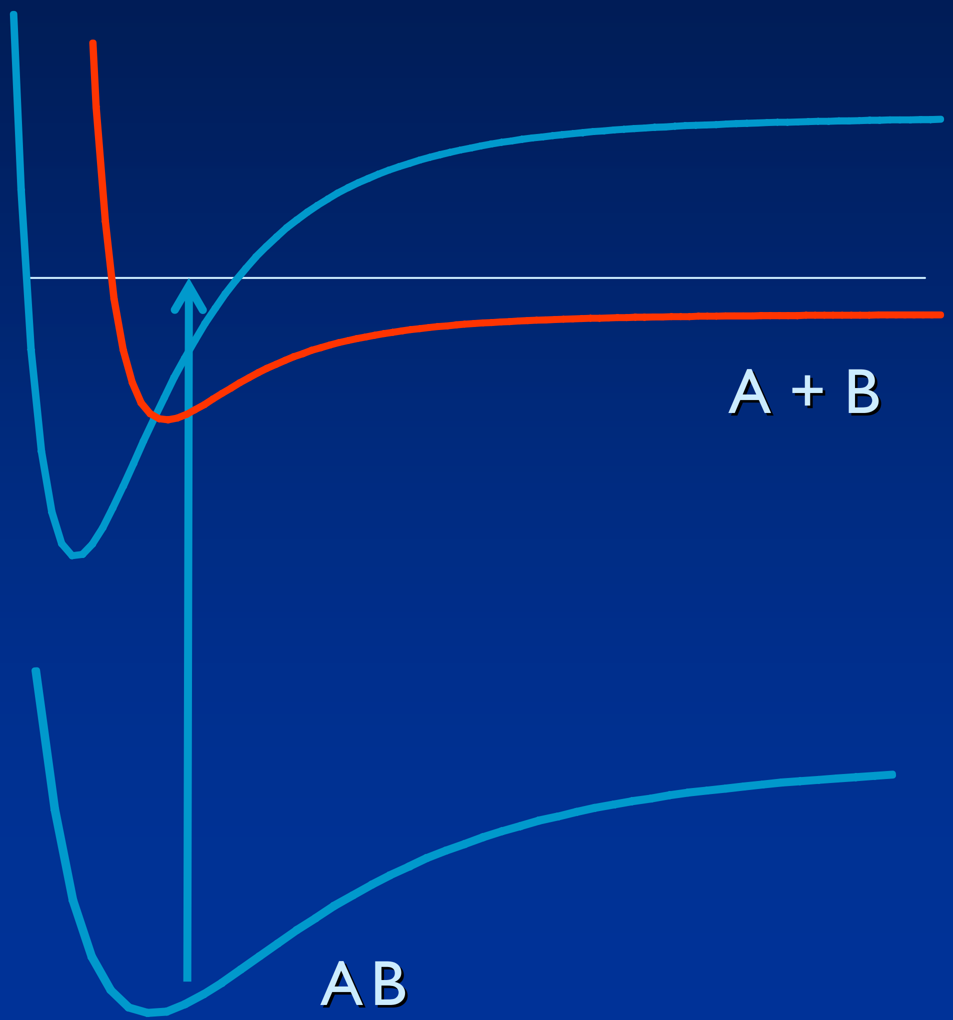
Excitation of repulsive state

or

Excitation above threshold

Excess energy determined by photon energy

Predissociation



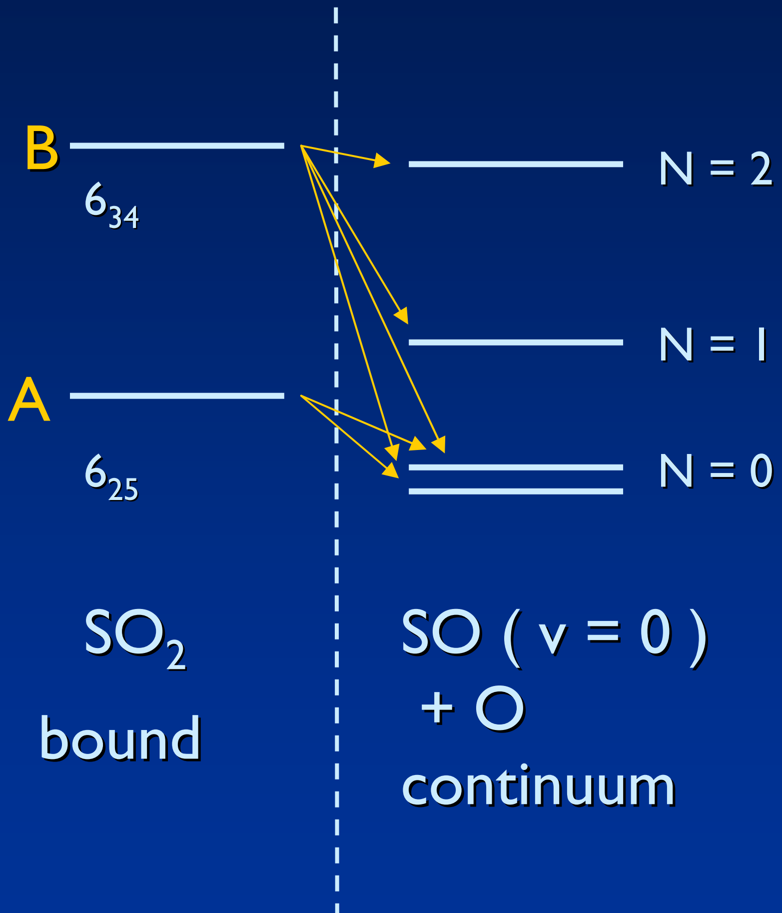
Bound states embedded in continuum:

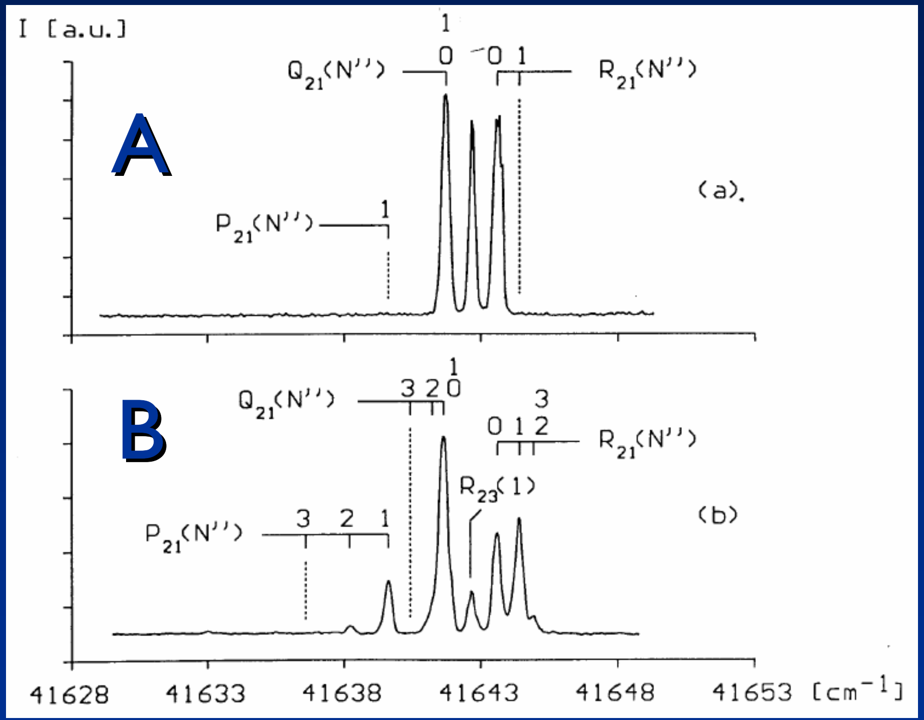
Coupling between both exited states:

Predissociation

Excess energy and initial quantum state determined by predissociating level

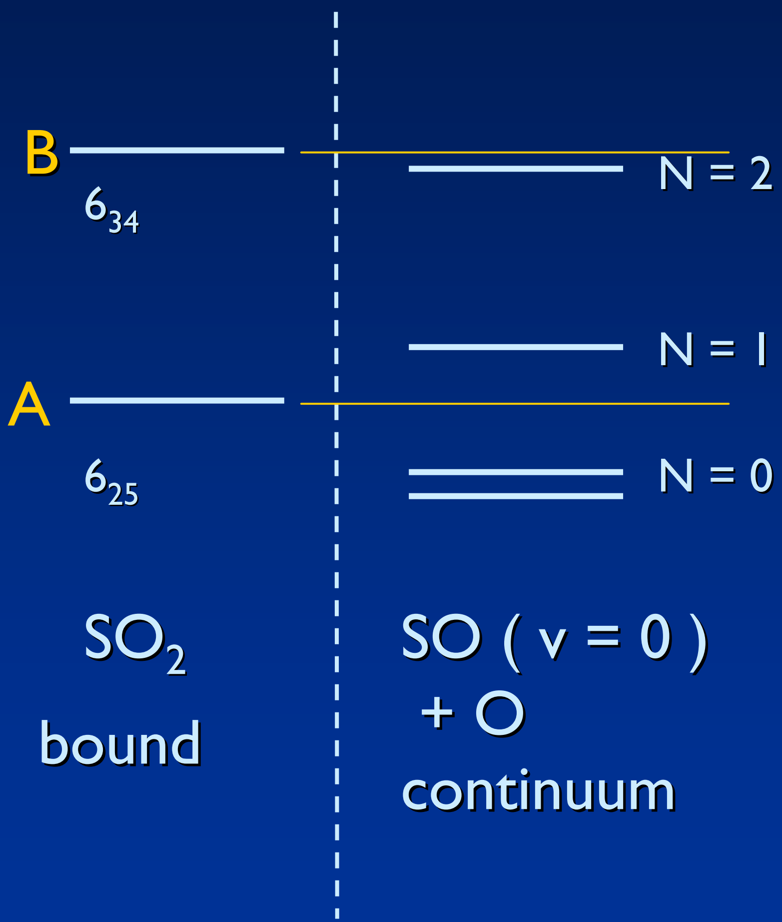
Observed fragments





- studied in our group
- spectroscopic knowledge is highly important

Kinetic energy of SO + O

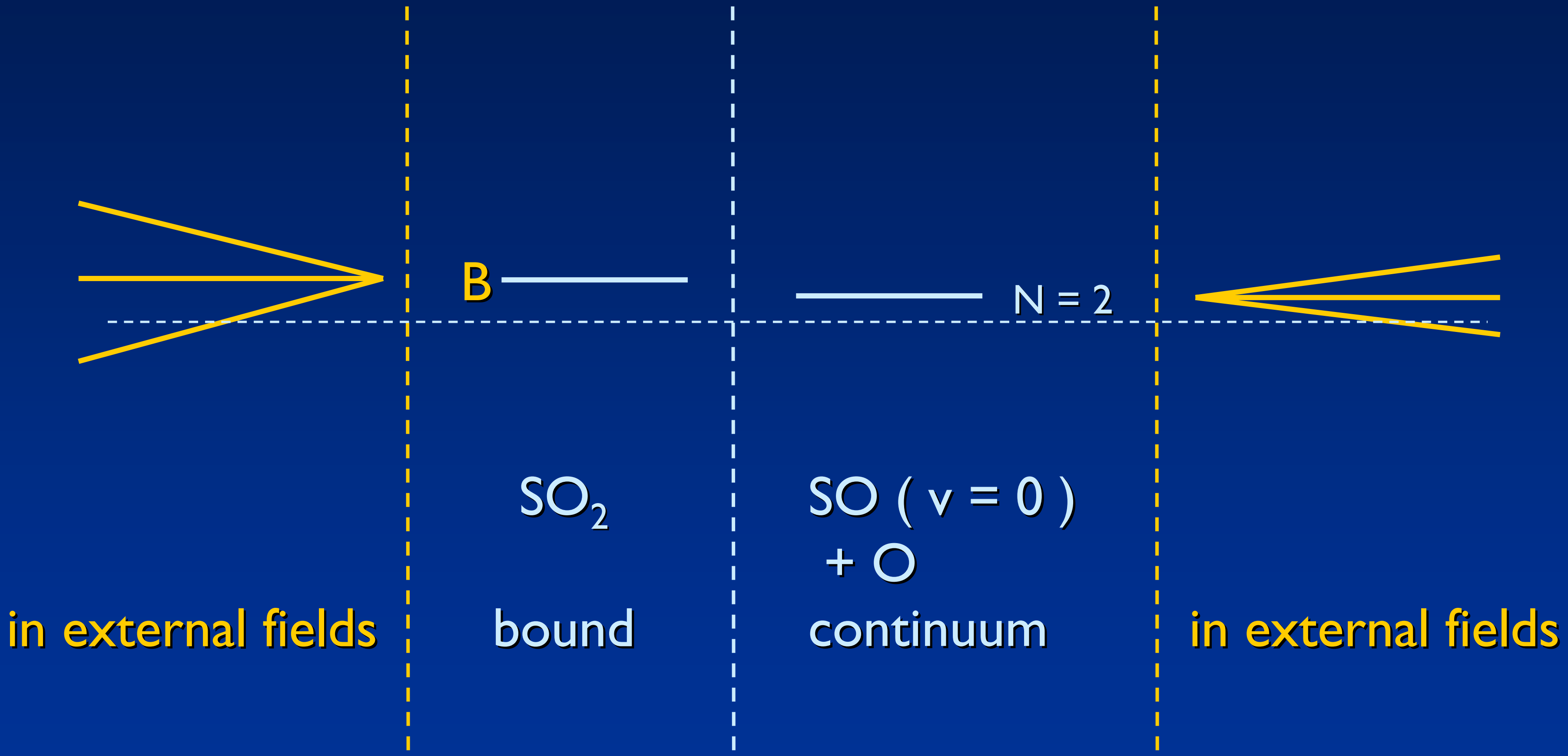


Kinetic energy of fragments is given by relative position of levels SO_2 and SO + O

Dissociation of SO_2

SO and O,
kinetic energy gained
can be below 200 mK

Tunable kinetic energy



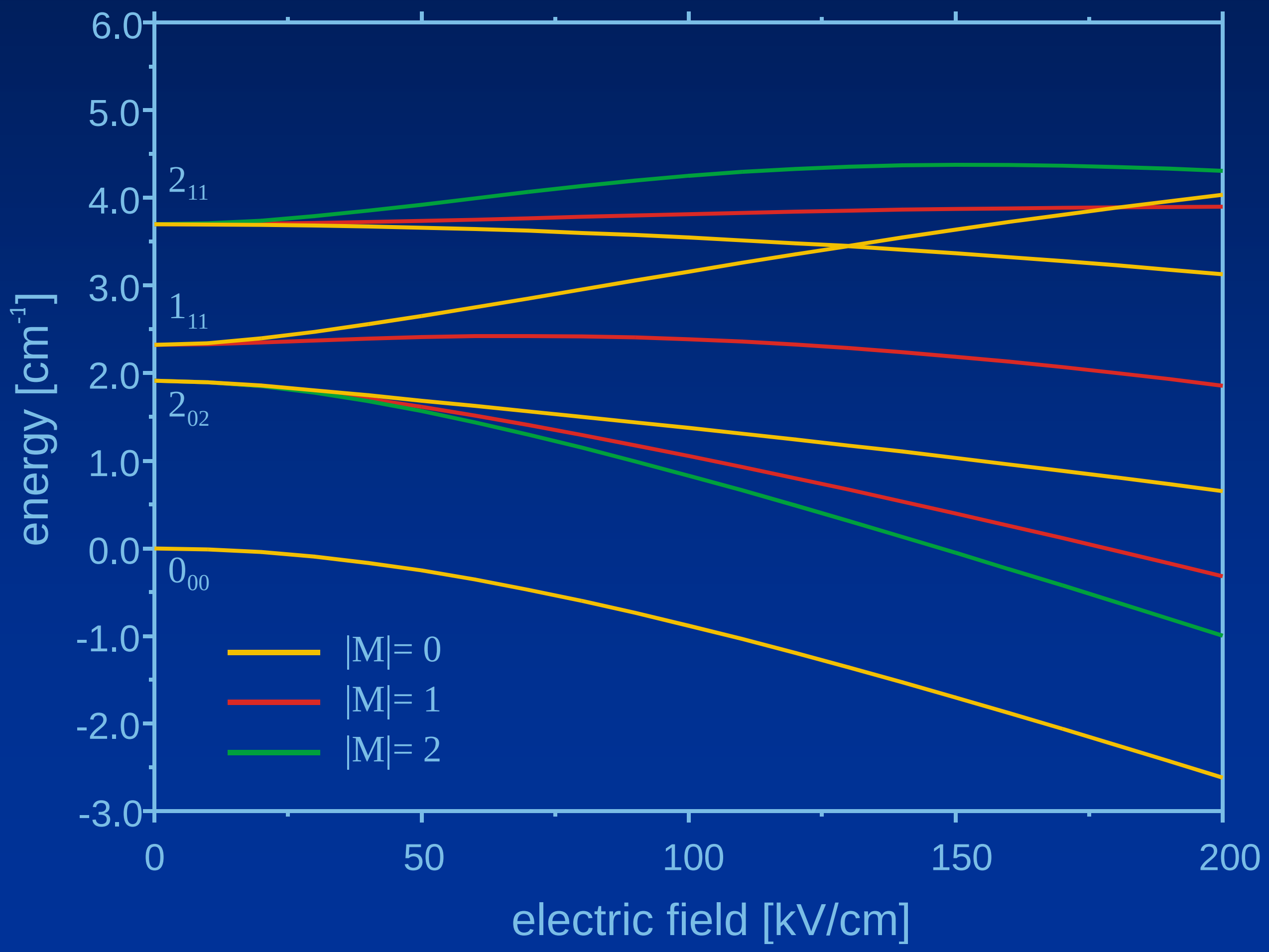
SO and O in triplet states:

Magnetic trapping ? Accumulation in phase space ?

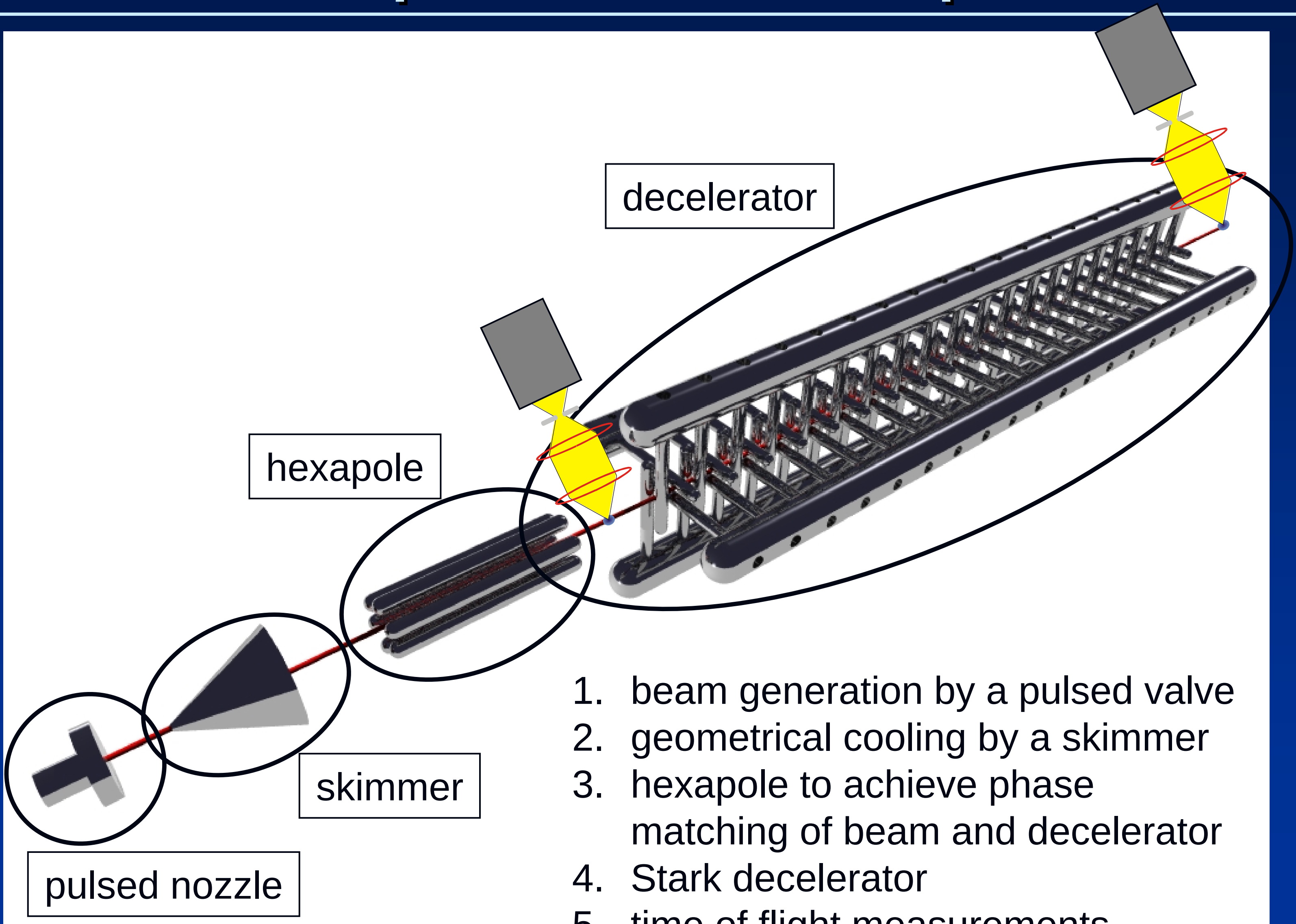
Experimental part

- Cold SO_2 is required for long observation time and cold fragments
- SO_2 comes in bottles
- Supersonic beam for high population in the lowest levels
- Deceleration of the molecules (Stark decelerator)

Ground state Stark effect



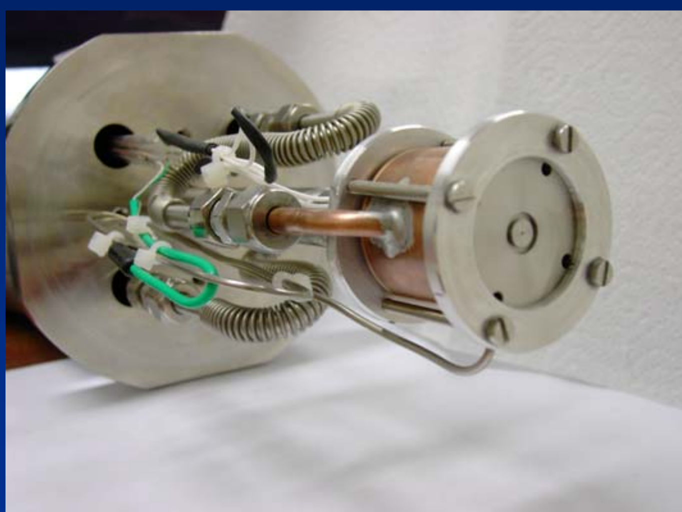
Experimental setup



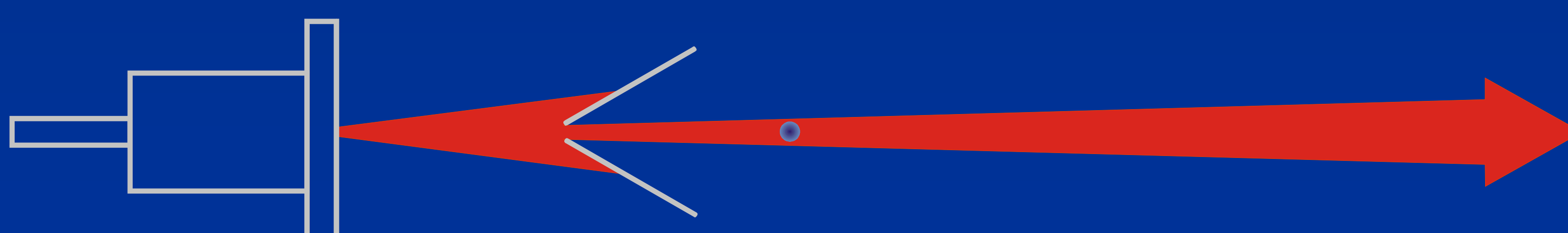
1. beam generation by a pulsed valve
2. geometrical cooling by a skimmer
3. hexapole to achieve phase matching of beam and decelerator
4. Stark decelerator
5. time of flight measurements

Pulsed valve

supersonic expansion is used to produce internally cold molecules with narrow velocity distribution

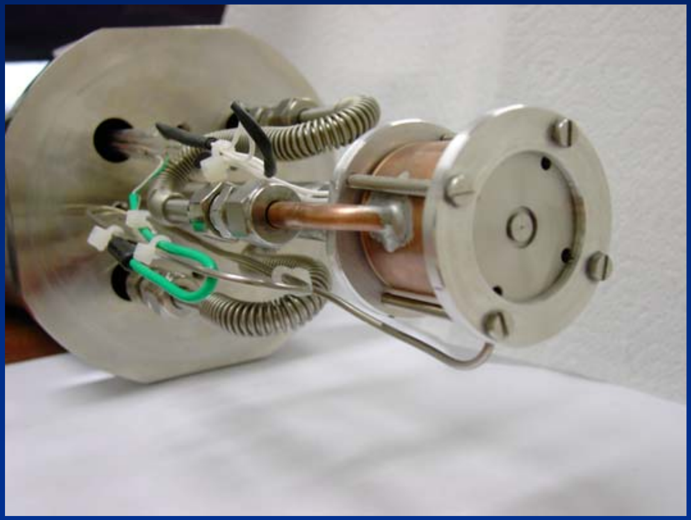


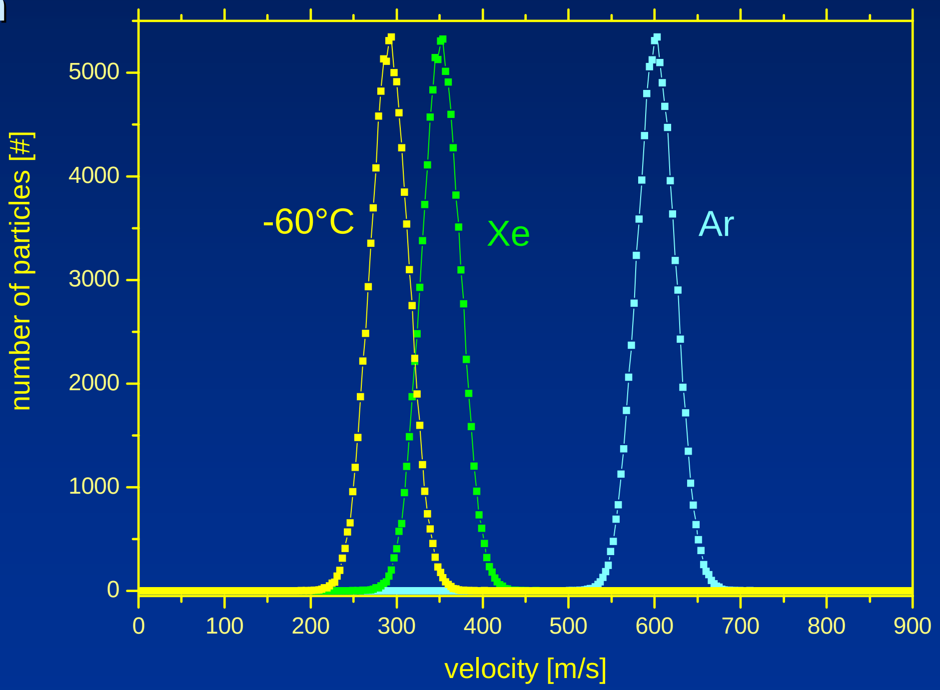
Principle:
- cooled gas
- gas expansion with high pressure into vacuum
- multiple collisions
- high average velocity
- narrow velocity distribution

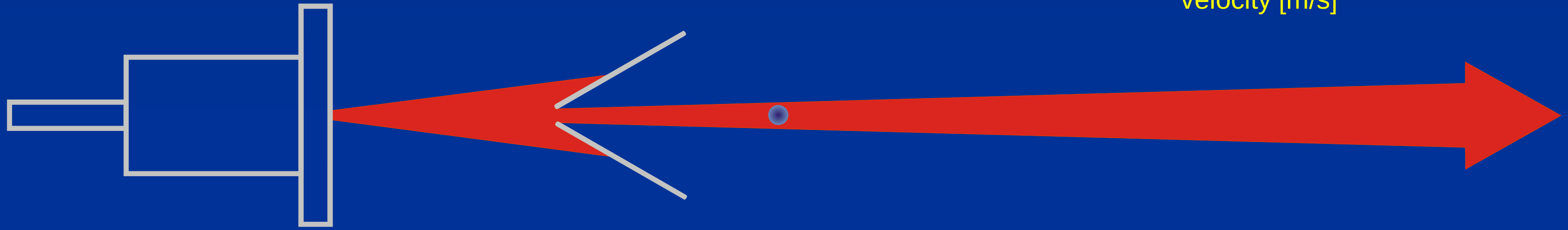


Pulsed valve

supersonic expansion is used to produce internally cold molecules with narrow velocity distribution

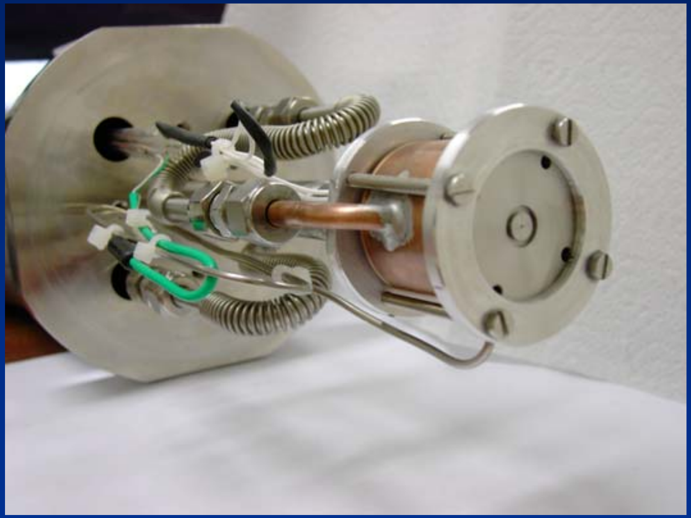


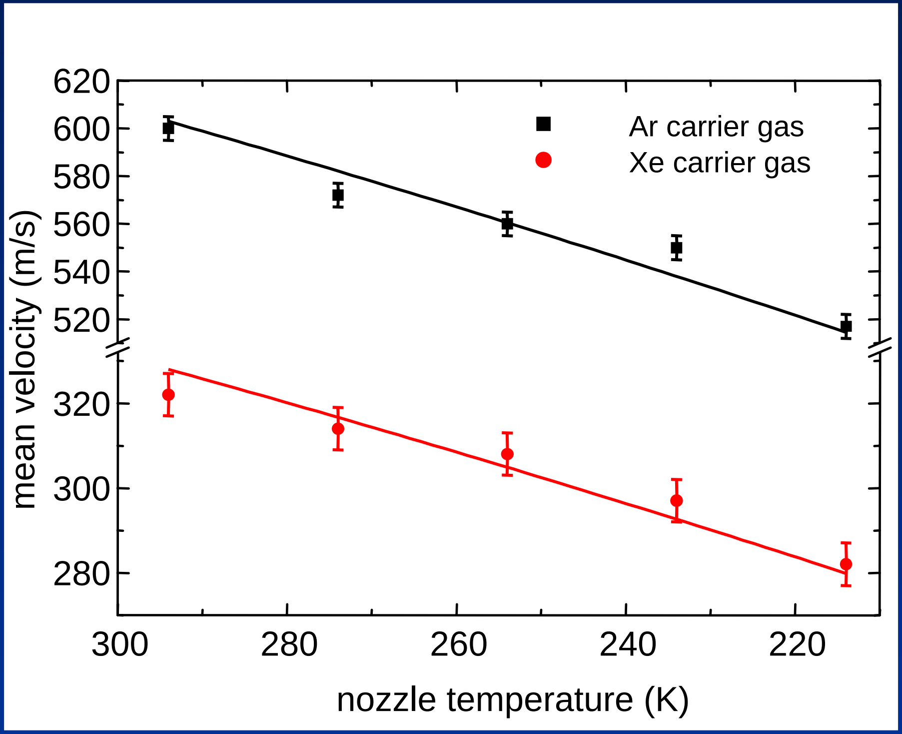


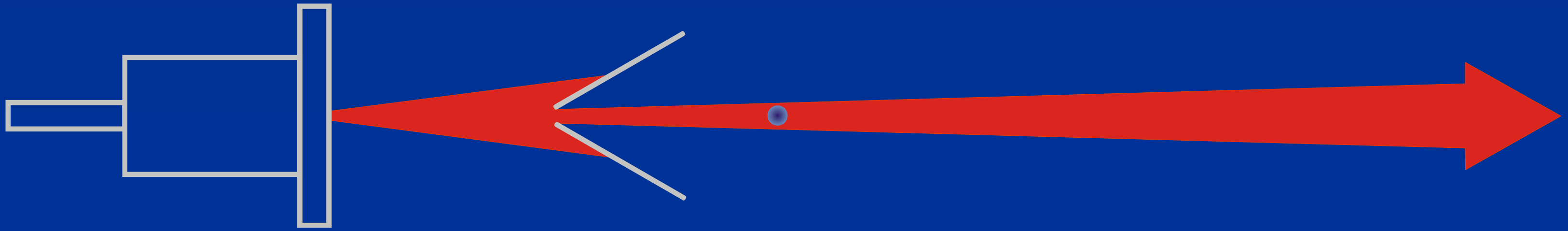


Pulsed valve

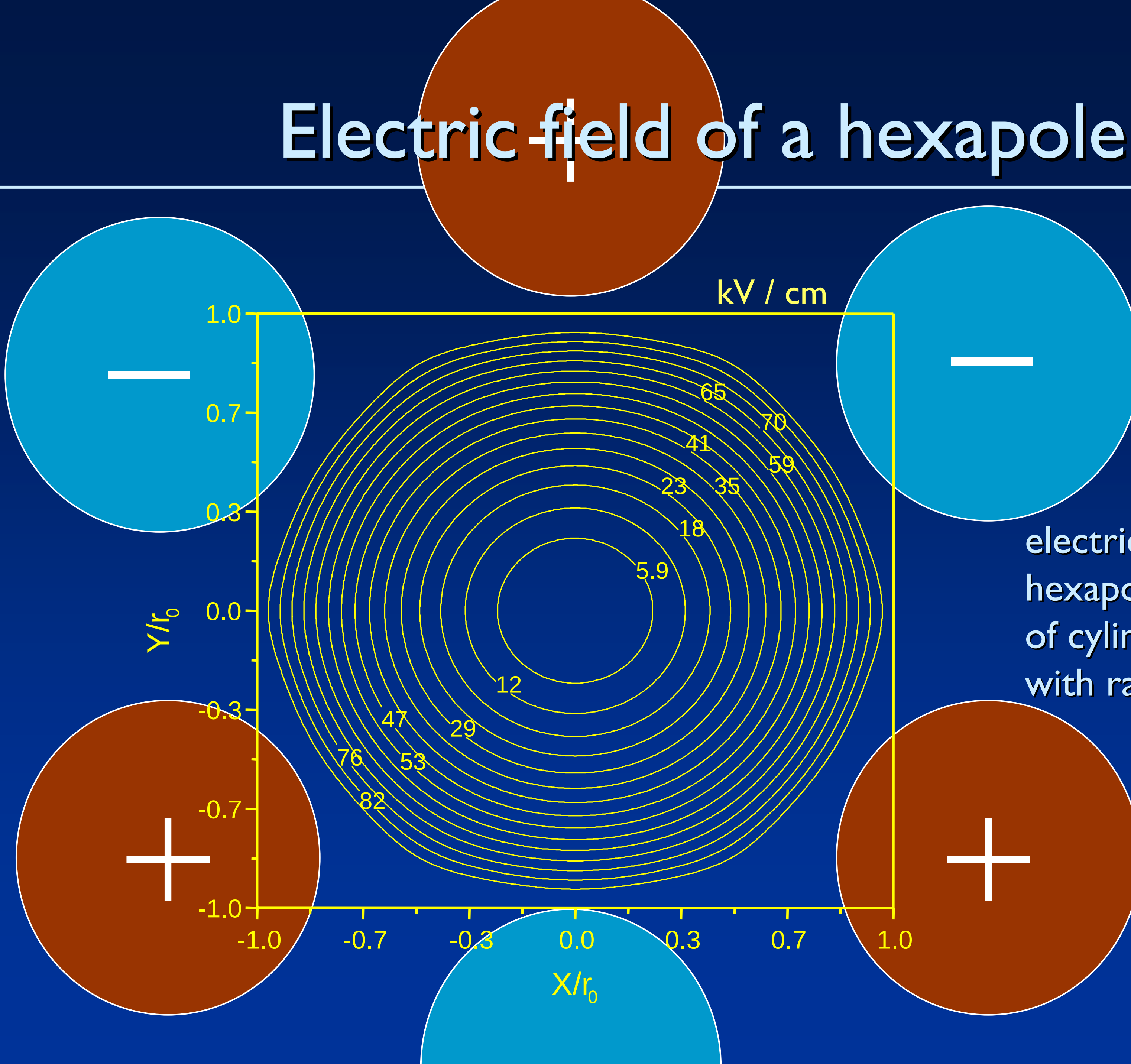
supersonic expansion is used to produce internally cold molecules with narrow velocity distribution







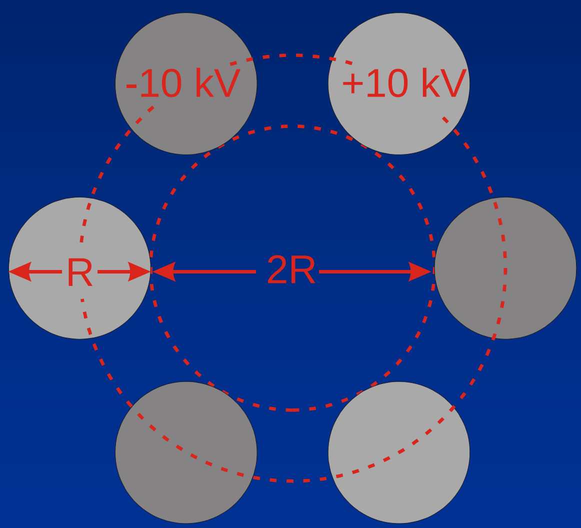
Electric field of a hexapole

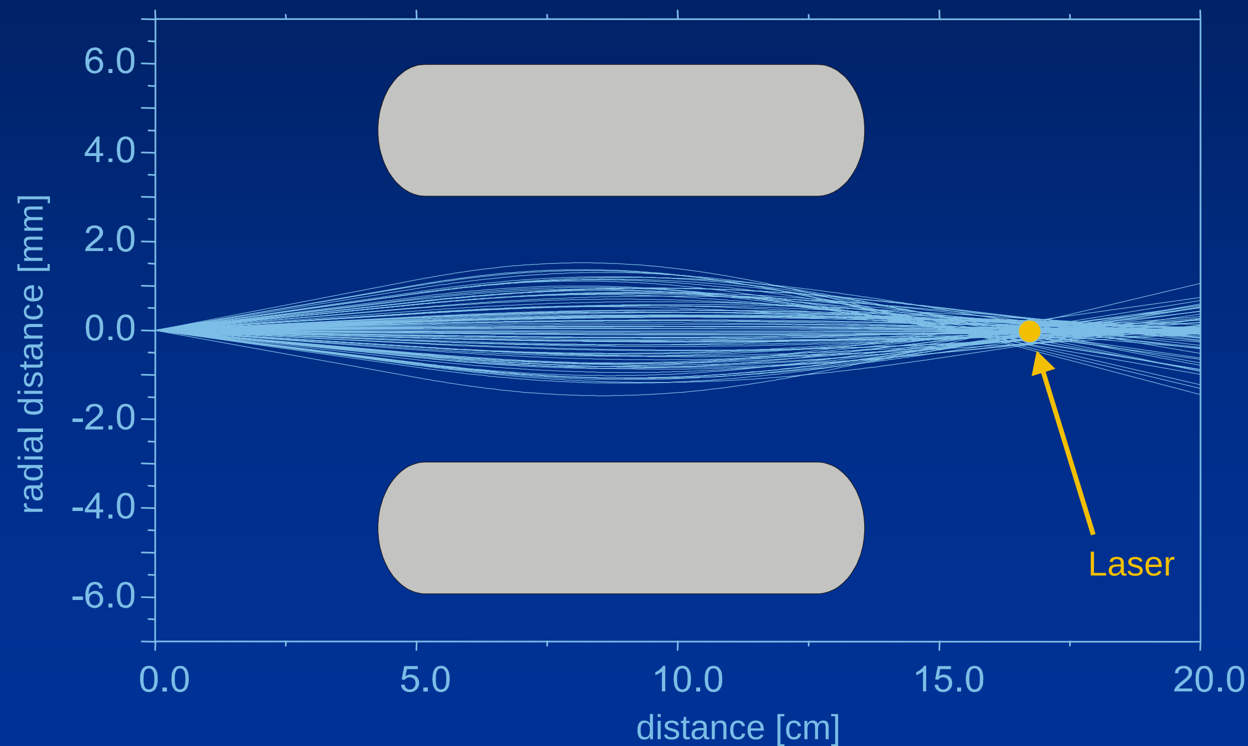


electric field for a hexapole constructed of cylindrical rods with radius $r = 0.5\ r_0$

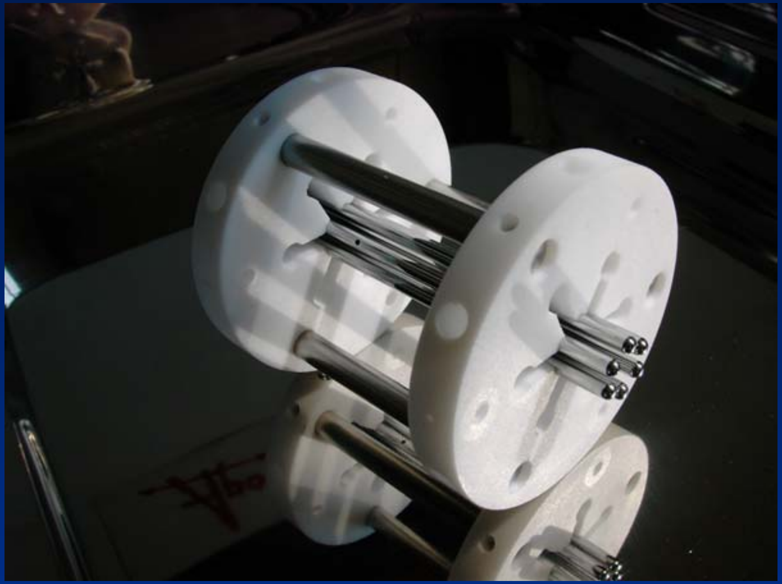
Simulation of hexapole

Simulated trajectories of the $|J\ M\rangle = |1_{1\,1}0\rangle$ state

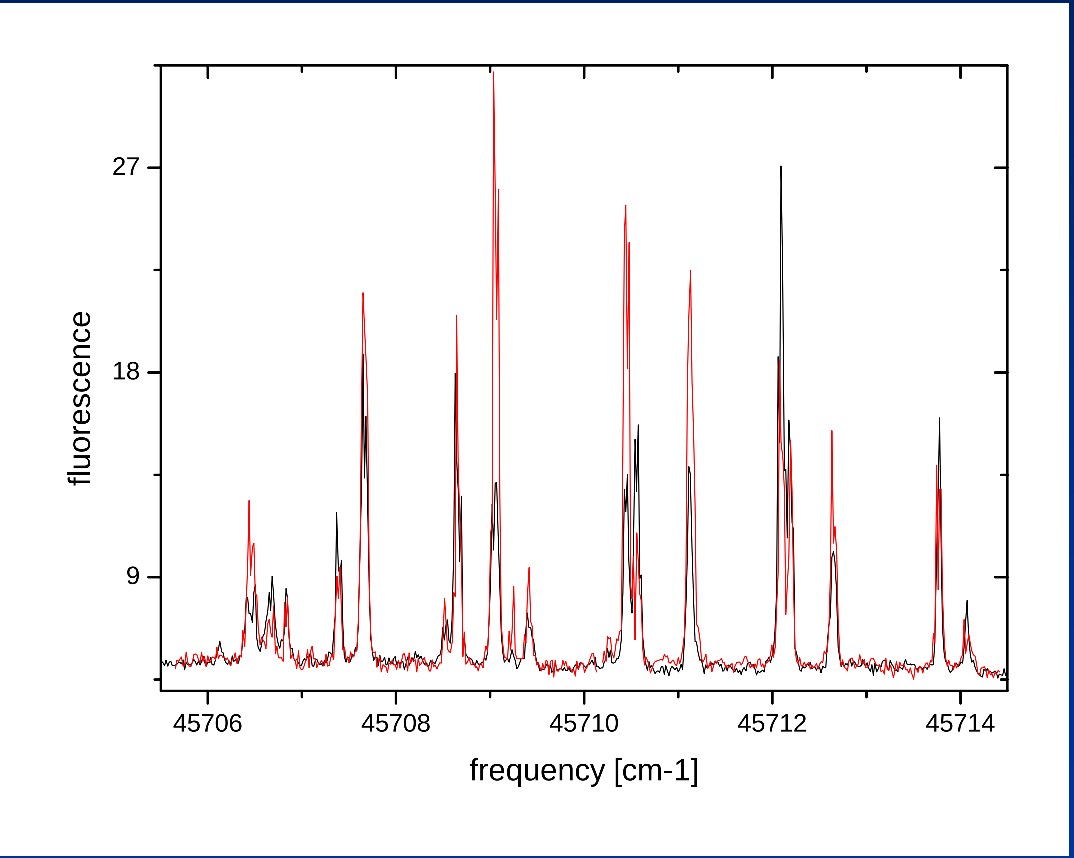




Hexapole measurements



$$U_{hexapole} = \pm 11.0kV$$

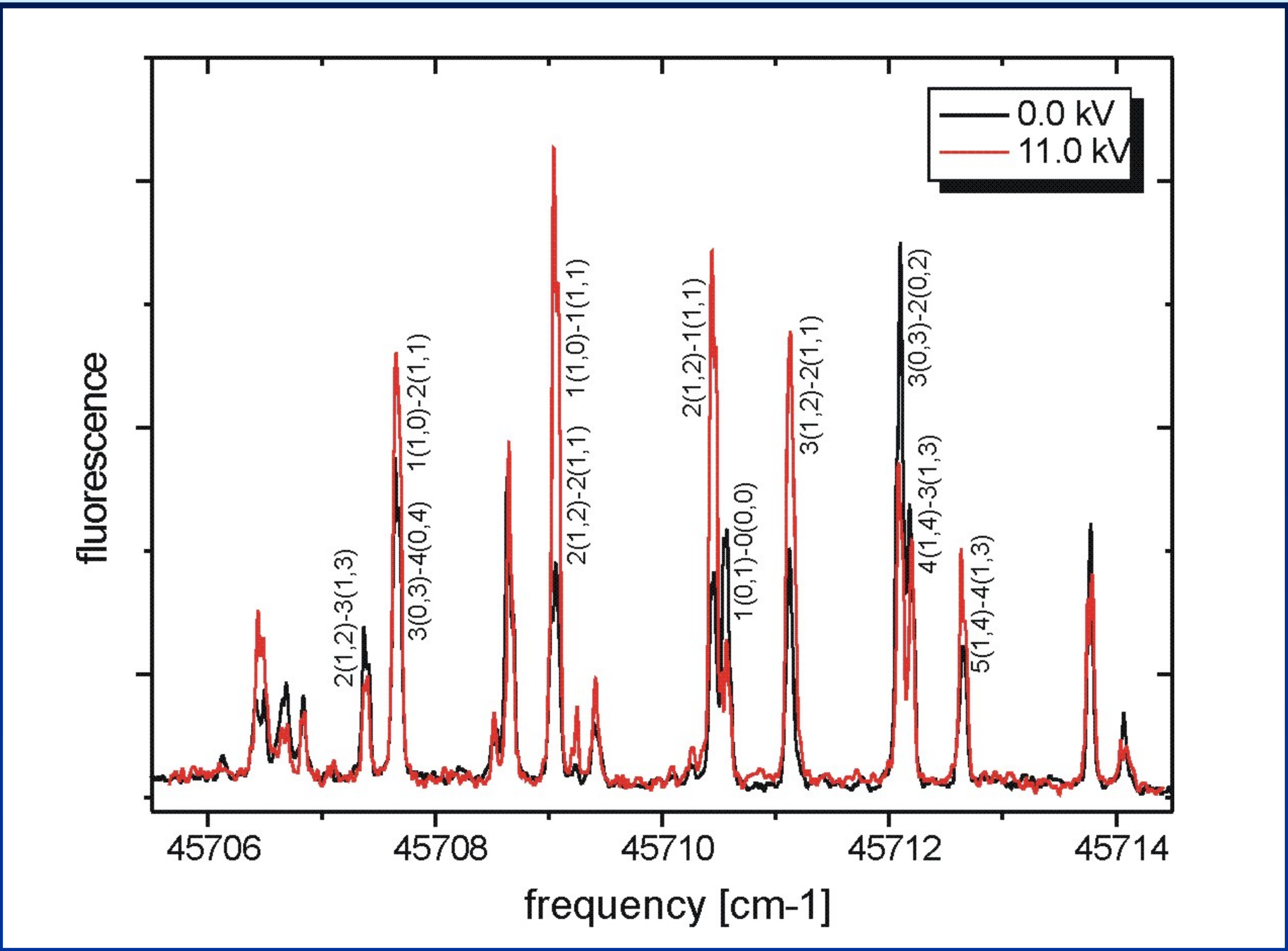


with and without voltage at the hexapole

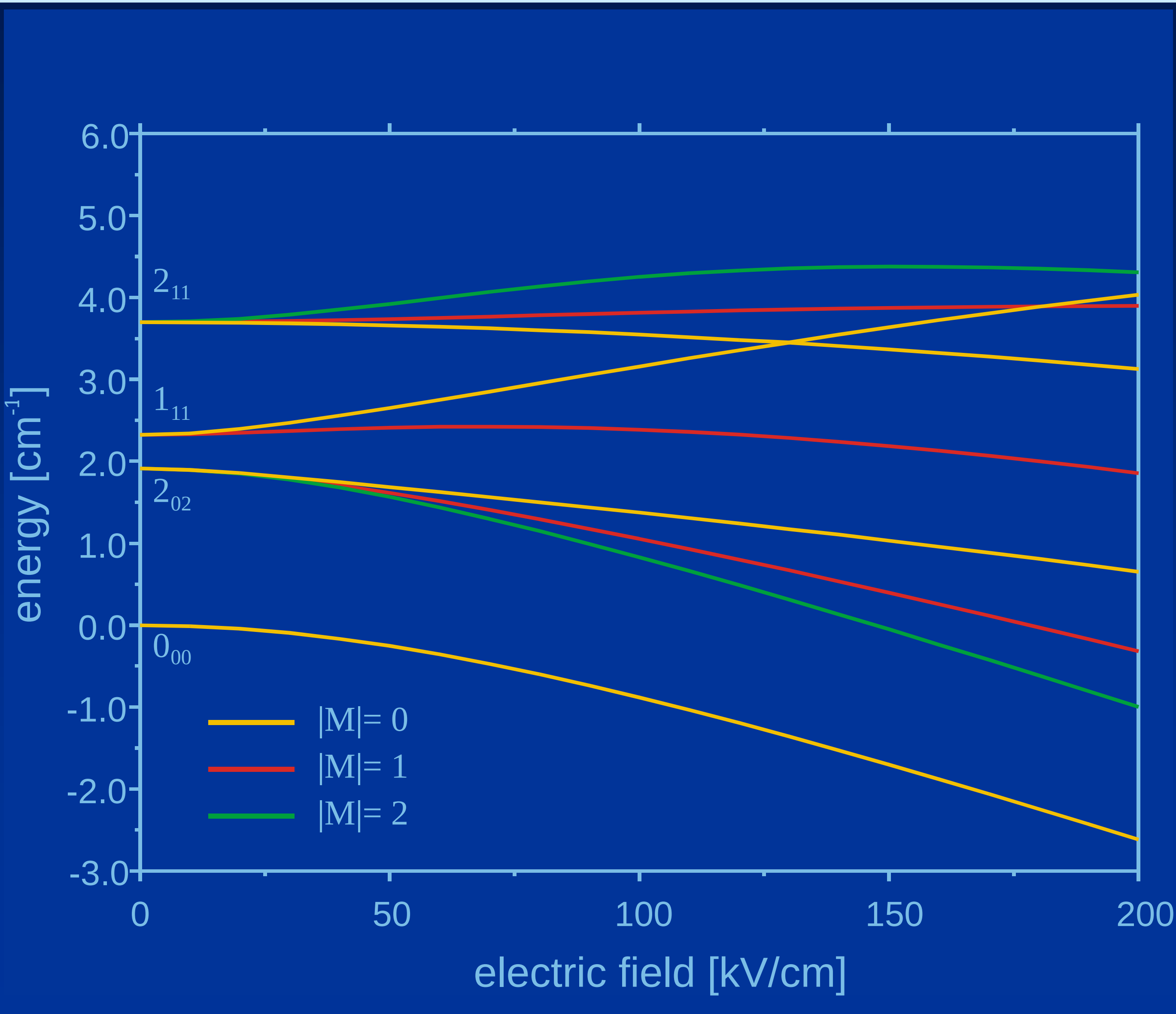
⇓

Stark selection:
focussing + defocussing

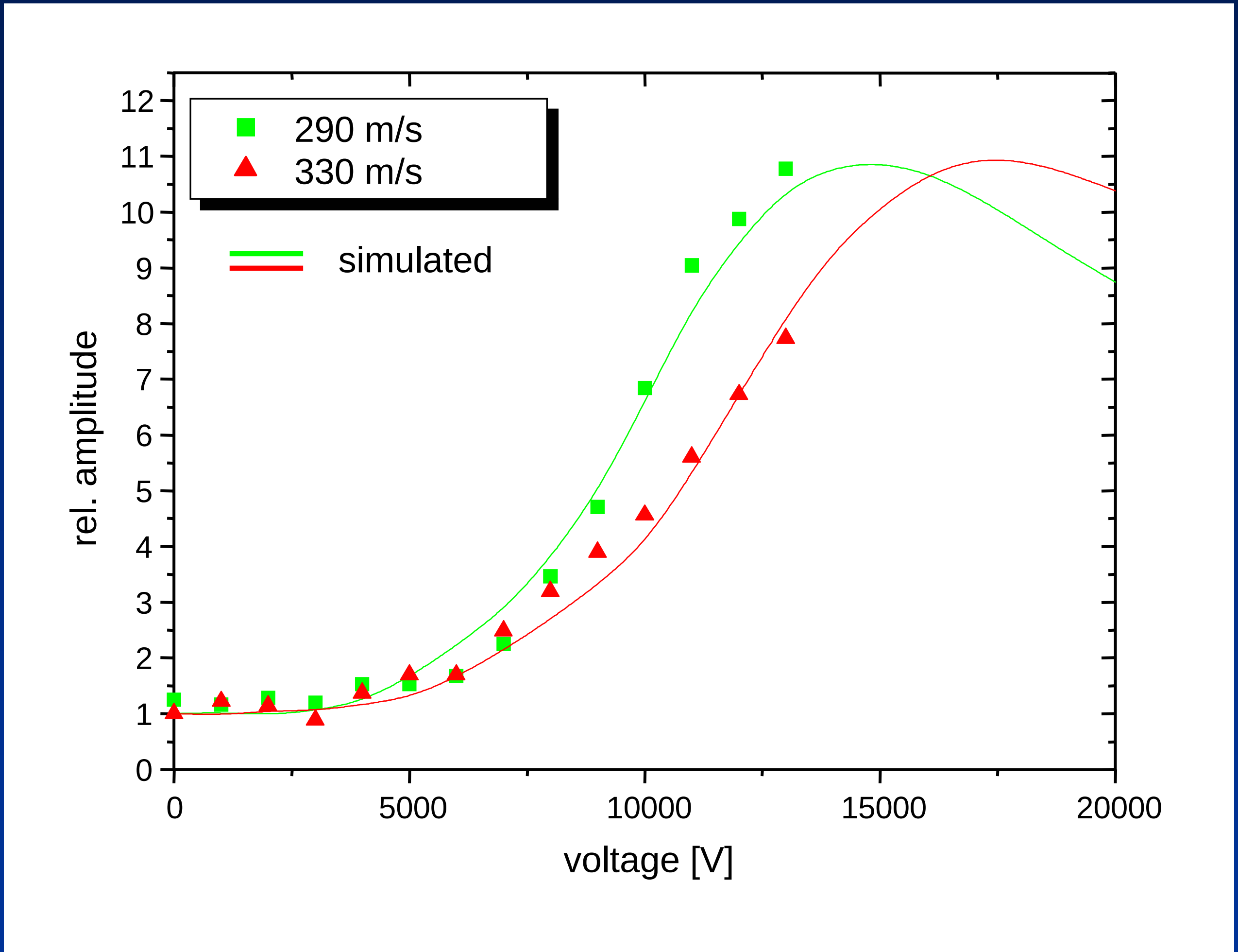
Hexapole measurements



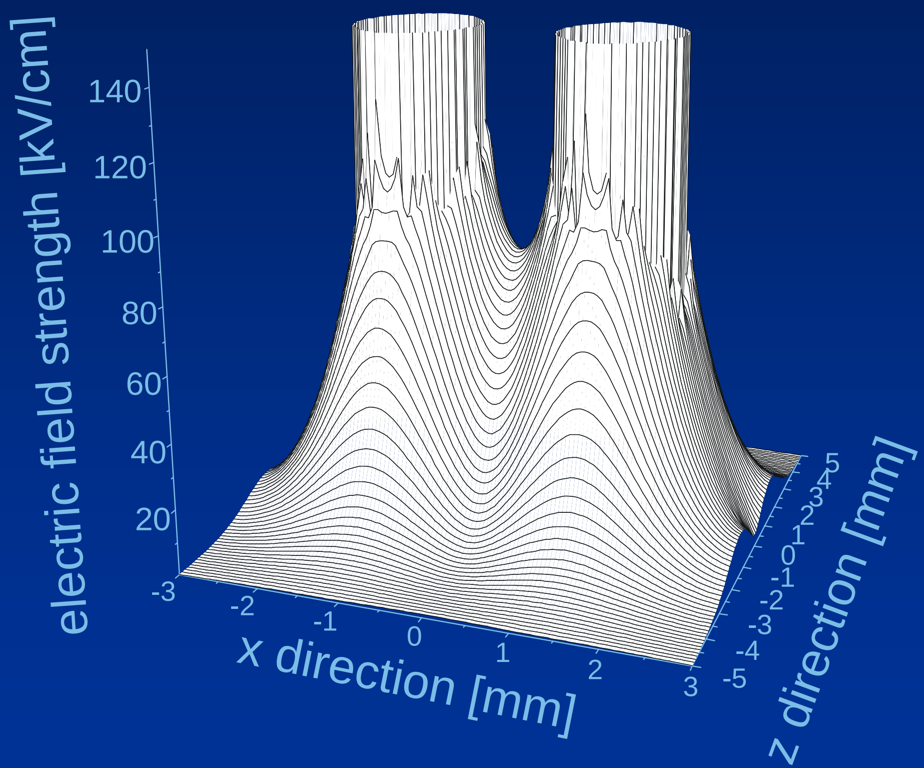
Hexapole measurements



Hexapole measurements



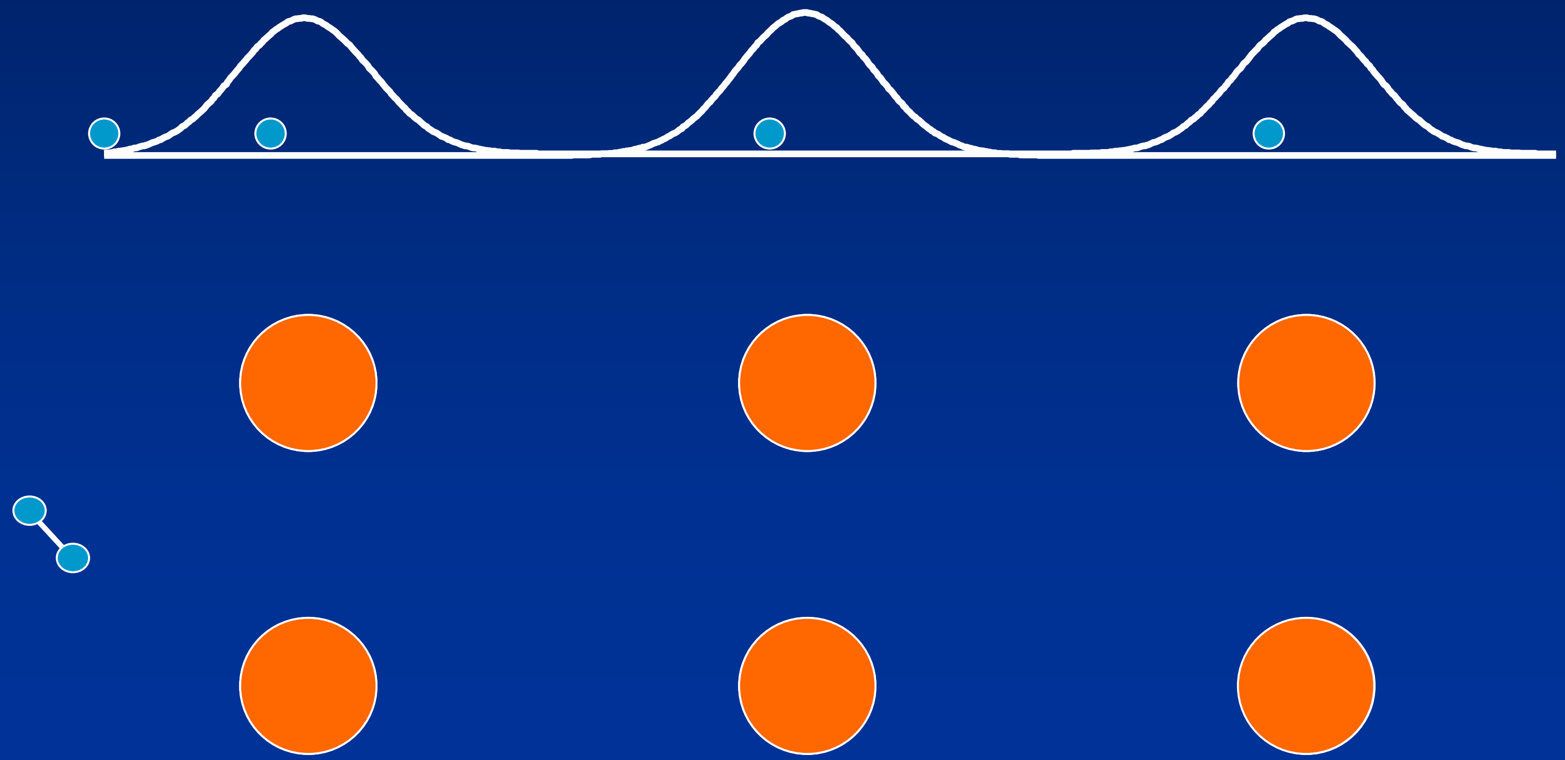
Field of two electrodes



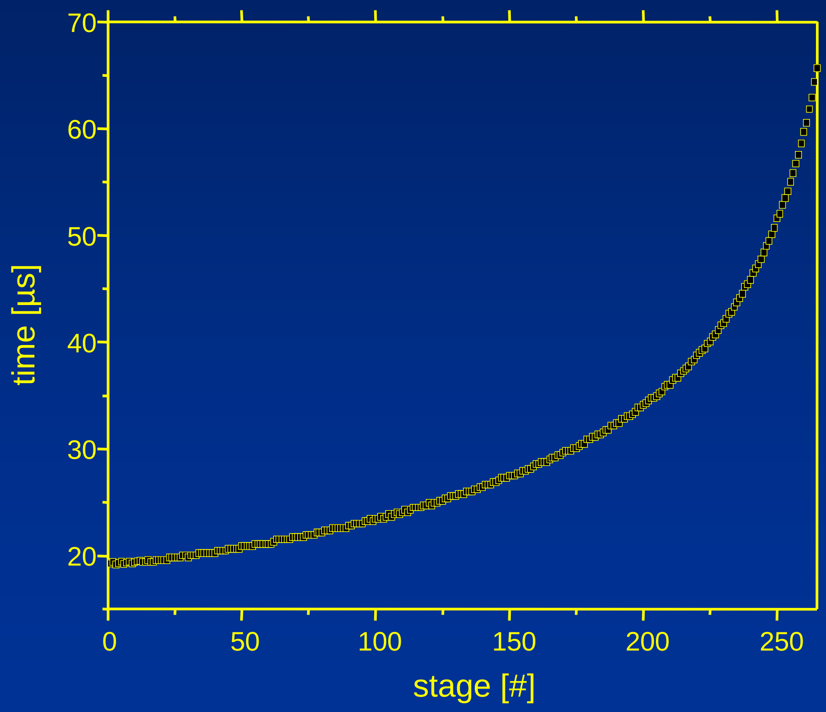
- minimum electric field on the molecular beam axis
- low-field seeking states experience a focusing force (guiding)
- no focussing in the plane parallel to the electrodes
- alternate horizontally and vertically positioned pairs

Decelerator principle

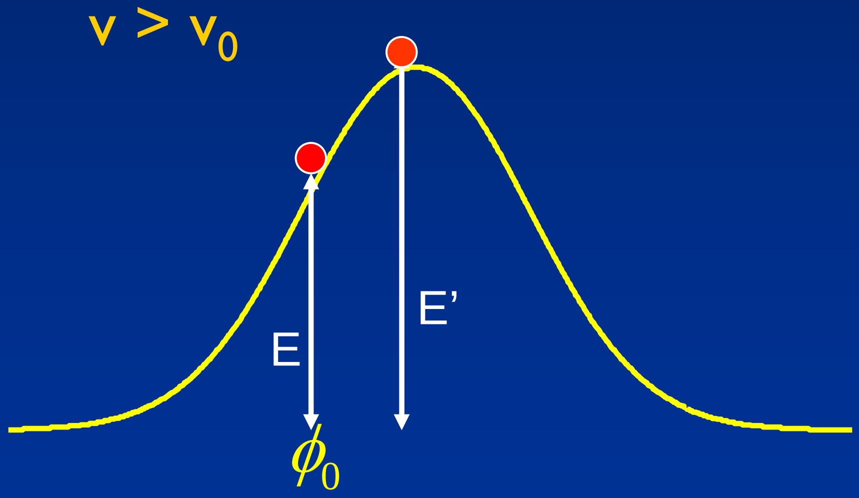
switching sequence for one molecule



Switching intervals and bunching



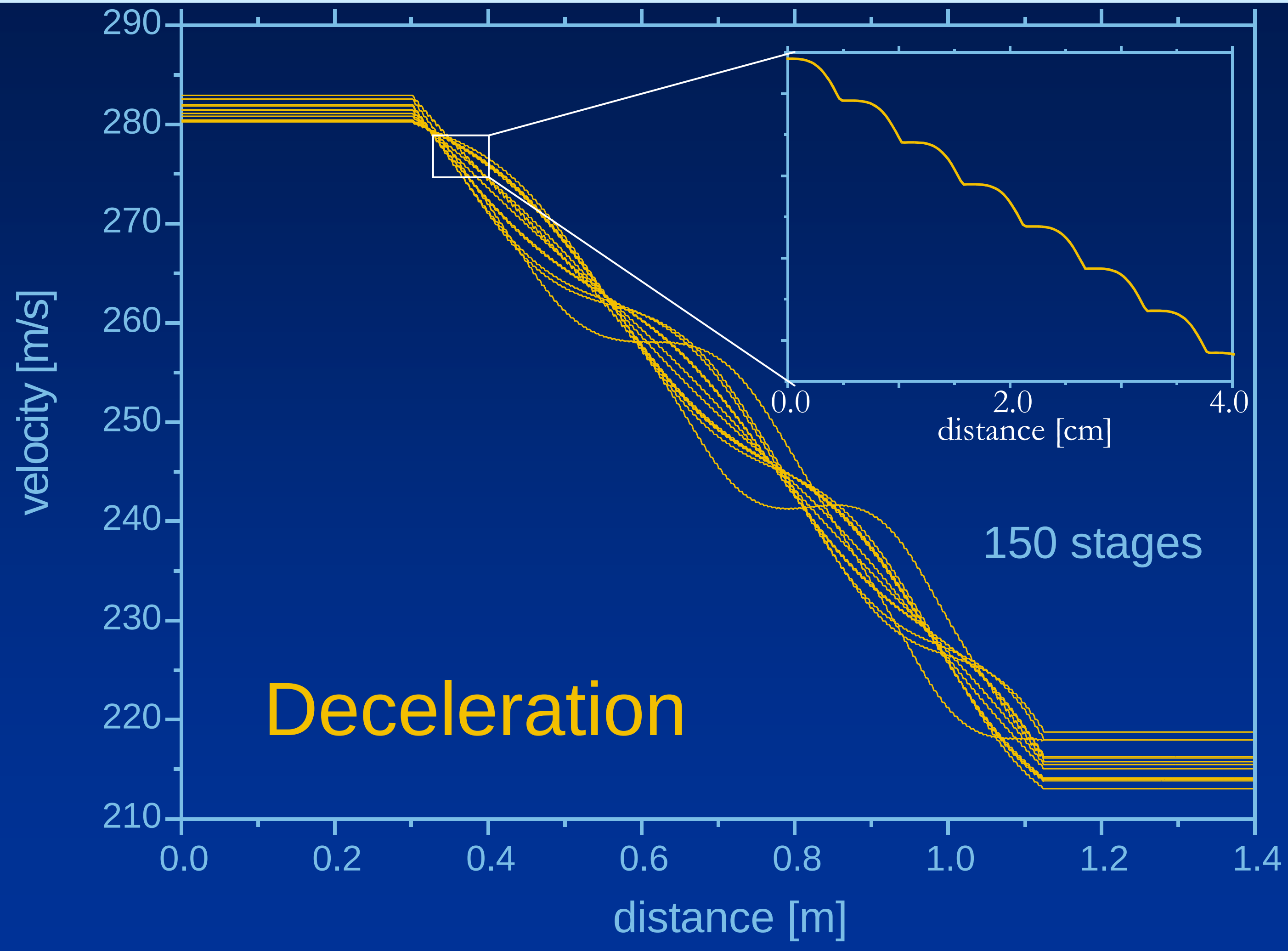
Molecules will oscillate with phase and velocity around the equilibrium values.



molecule looses more energy

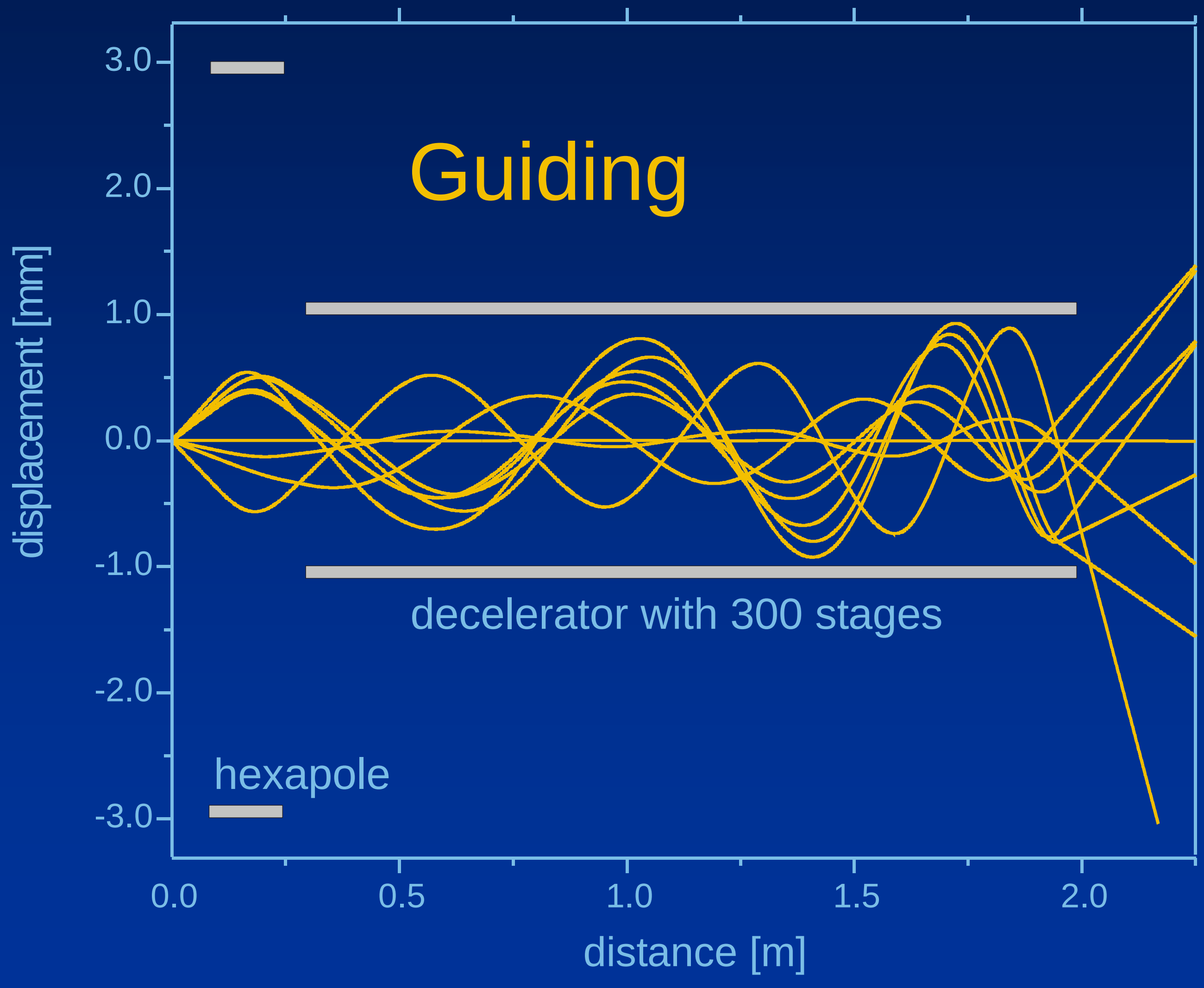
→ velocity and phase get smaller

Simulations of decelerator



v_{start} = 282 m/s, distance of stages 5.5 mm

Simulations of decelerator



First decelerator

The first decelerator will have 100 stages and should reduce the velocity from 285 m/s to 240 m/s.

This corresponds to 30% of the kinetic energy!

Summary

- Dissociation of cold SO_2
- Source of cold particles SO + O
- Trapping of radicals SO and O, accumulation in phase space

} forward + backward

- Feshbach resonances: Tuning of velocities, switching of channels
- Successful focussing of SO_2
- Feasibility of a Stark decelerator