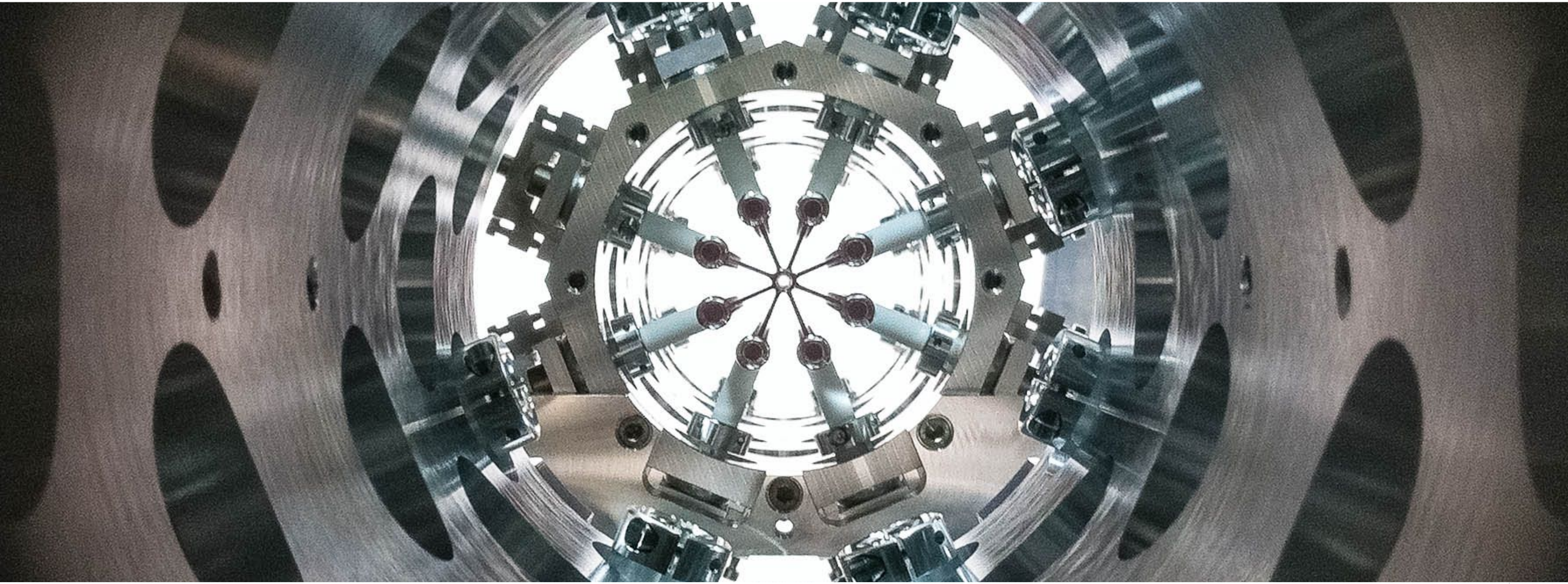
Fundamental interactions:
The electron as probe of new physics



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Nikhef

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Fundamental interactions:
The electron as probe of new physics

The electron's electric dipole moment (eEDM)
New Nikhef research program since 2016

Funded as program by NWO for 2017-2023

Scientific staff:
- Anastasia Borschevsky
- Rick Bethlem
- Steven Hoekstra
- Klaus Jungmann
- Rob Timmermans
- Wim Ubachs
- Lorenz Willmann

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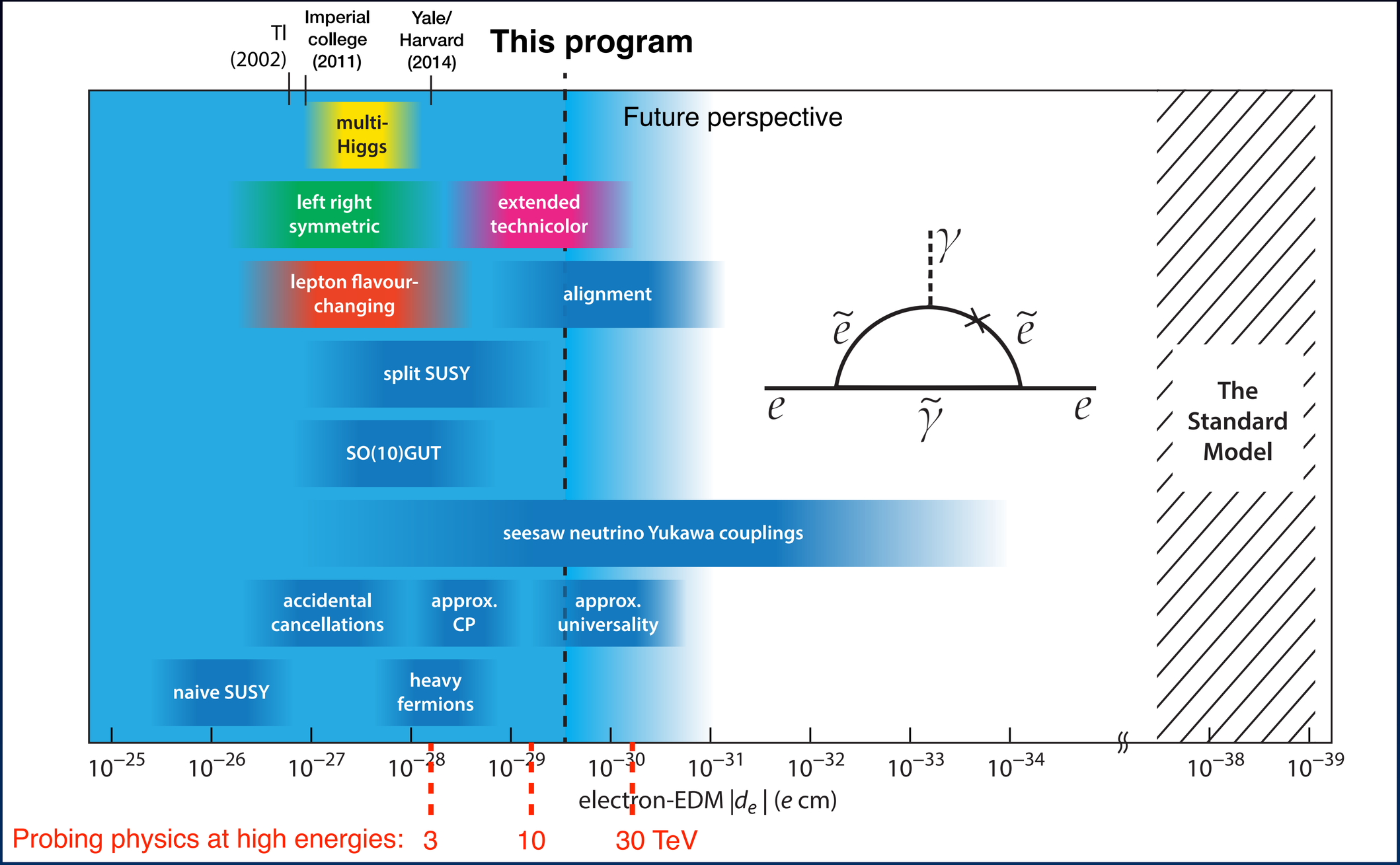
The Electric Dipole Moment of the electron (eEDM)

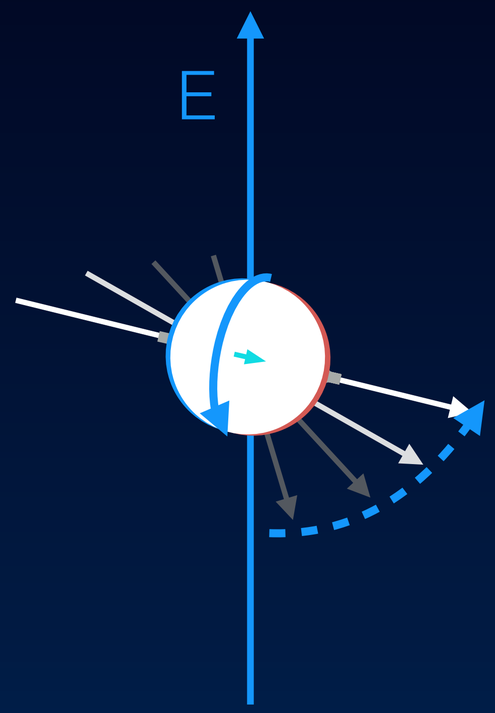
‘Is the electron round?’

eEDM violates P, T and CP symmetry (provided CPT holds)

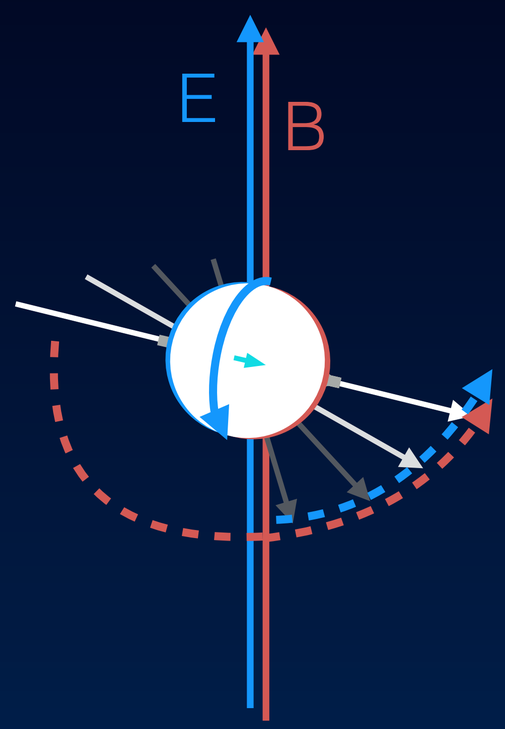


Next-generation experiment

How to measure a dipole moment?



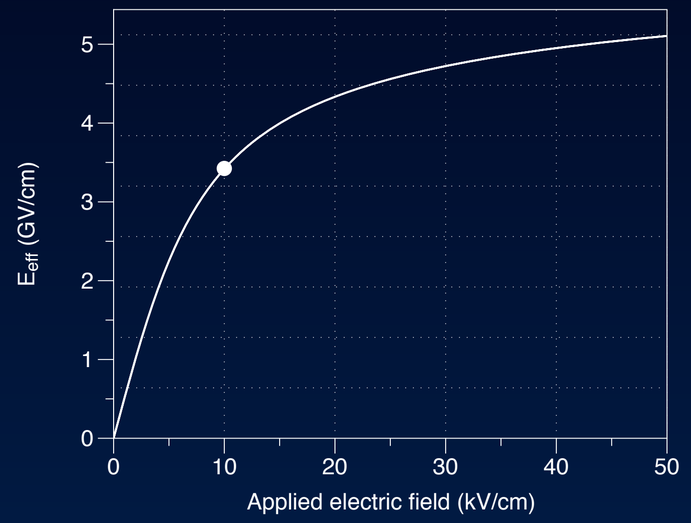
precession!



However, also magnetic dipole moment (and charge!)

polar molecule

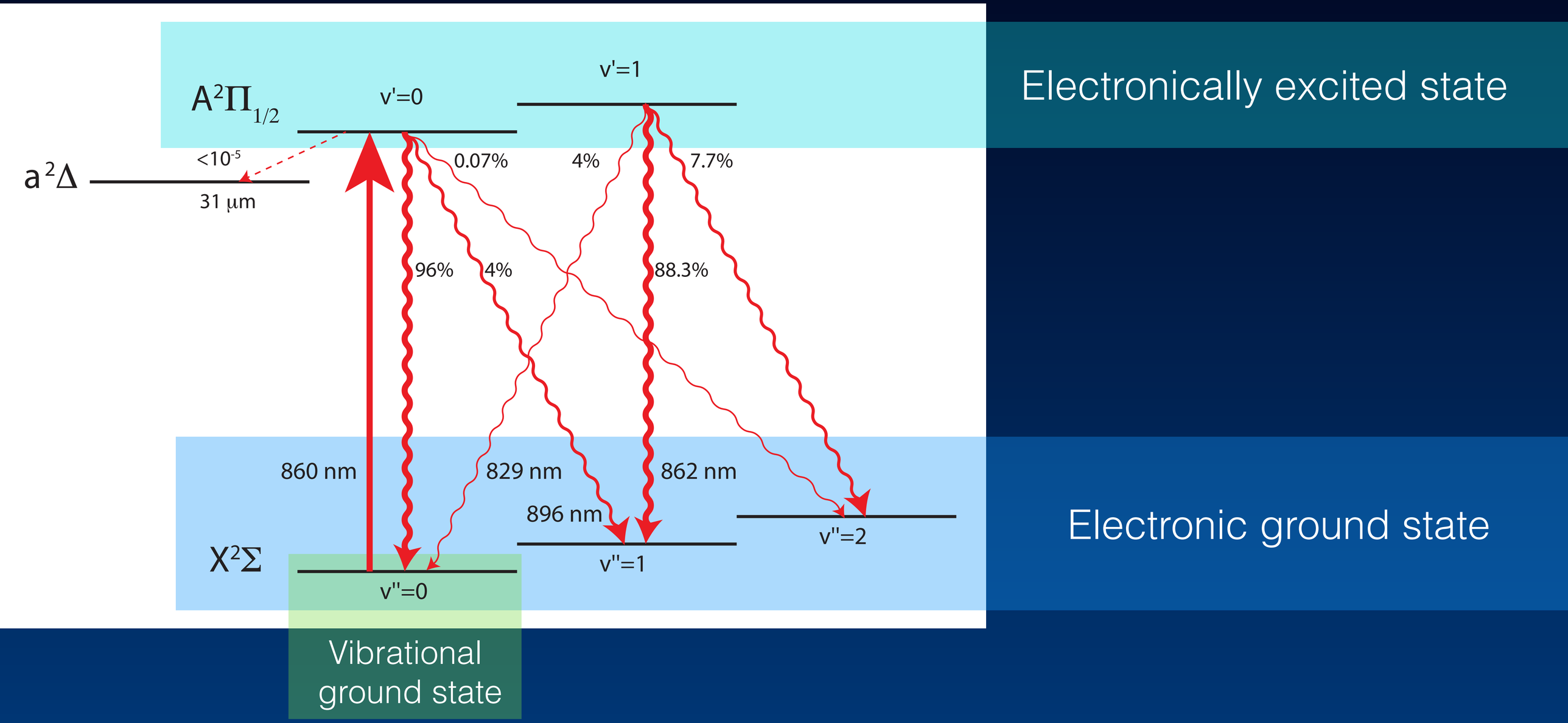
Effective electric field



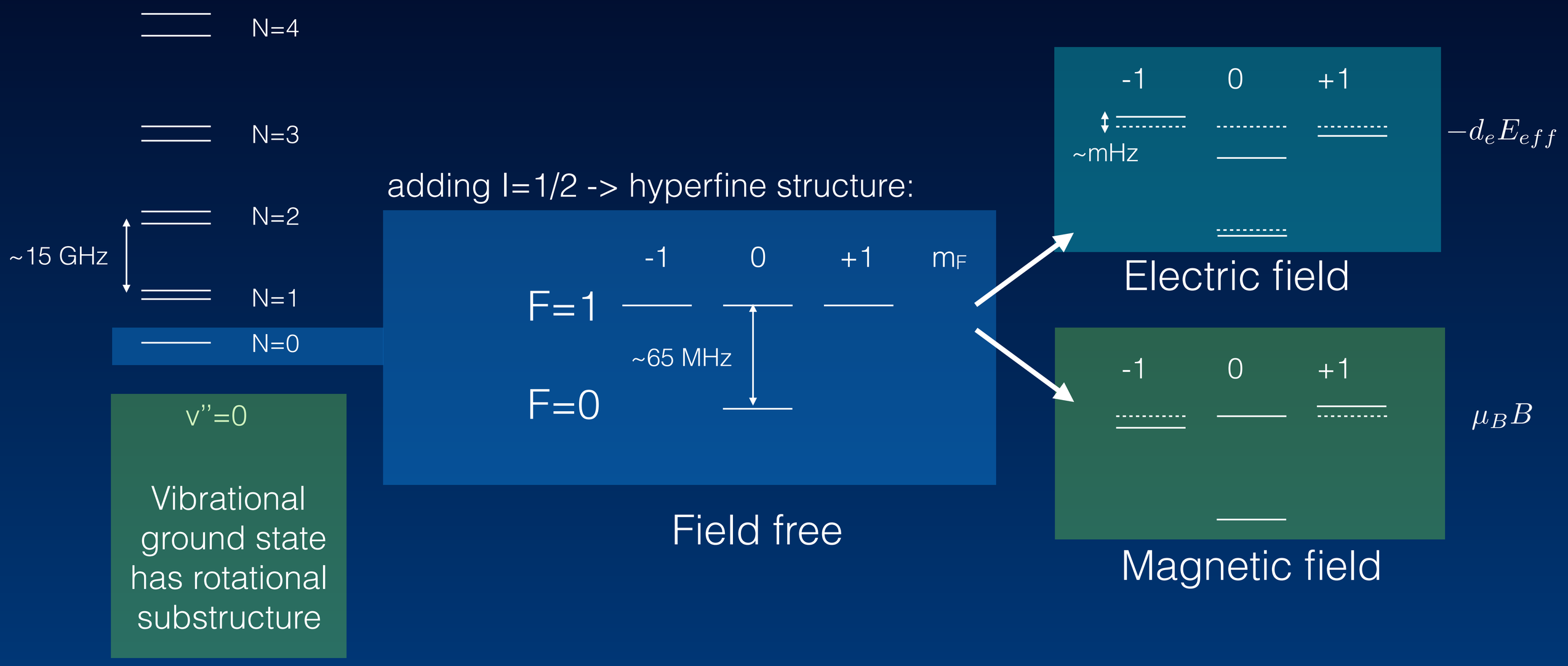
Solution:
use electron embedded in a polar molecule!

We have selected BaF

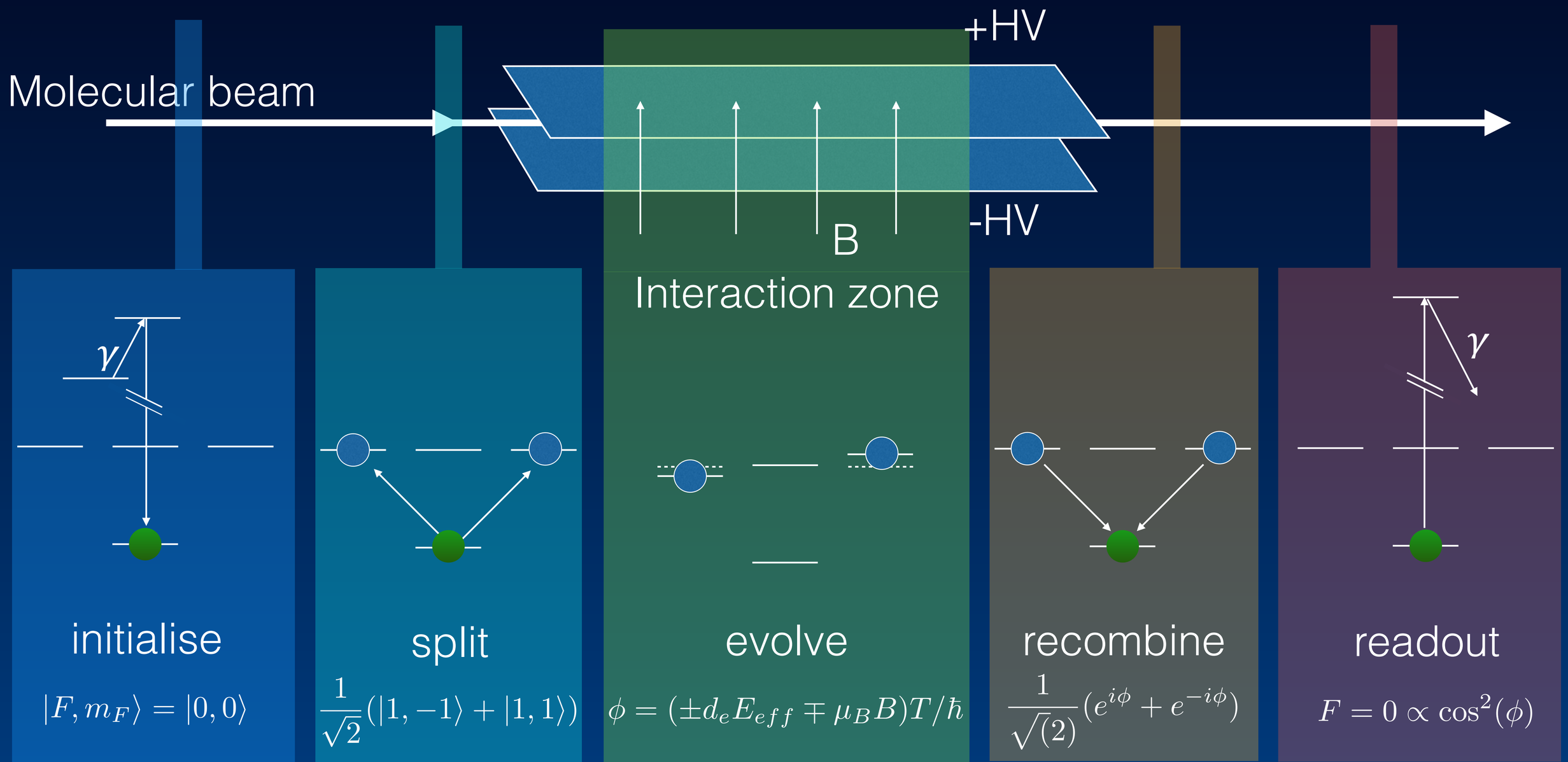
Energy level structure of the BaF molecule



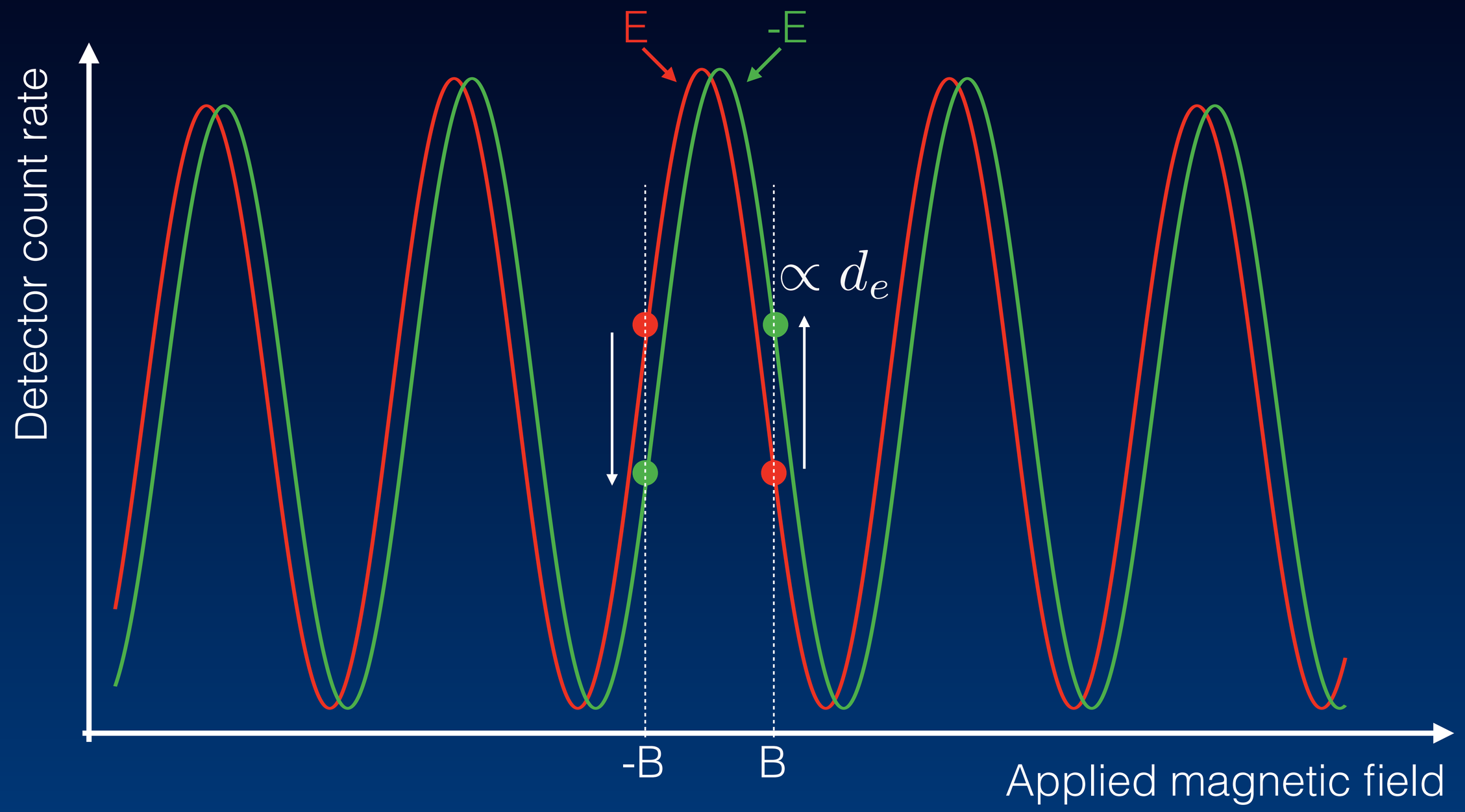
Energy level structure of the BaF molecule



How to read out small energy shifts: spin interferometer



Interferometer phase $\phi = (\pm d_e E_{eff} \mp \mu_B B)T/\hbar$



after slide by Ed Hinds

Increasing the eEDM sensitivity

Measure energy shift that correlates with electric field direction reversal

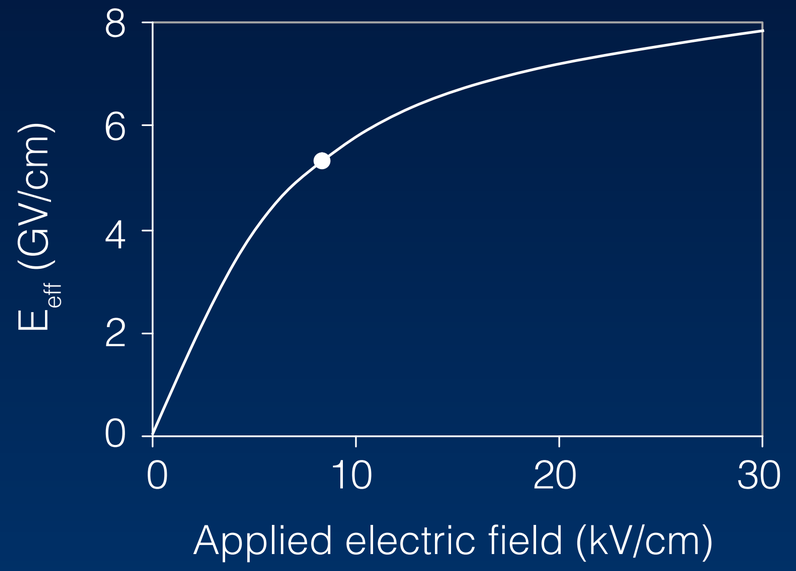
statistical error: $$\sigma_d = \frac{\hbar}{e}\frac{1}{2\mathcal{E}_{\mathrm{eff}}\tau\sqrt{N}}$$

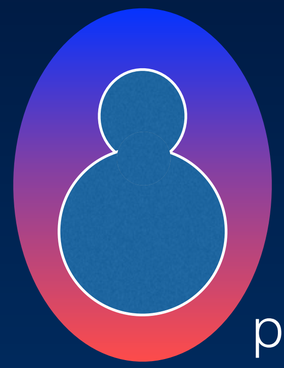
Effective electric field

Cold Molecules

Number of detected molecules

Coherent interaction time





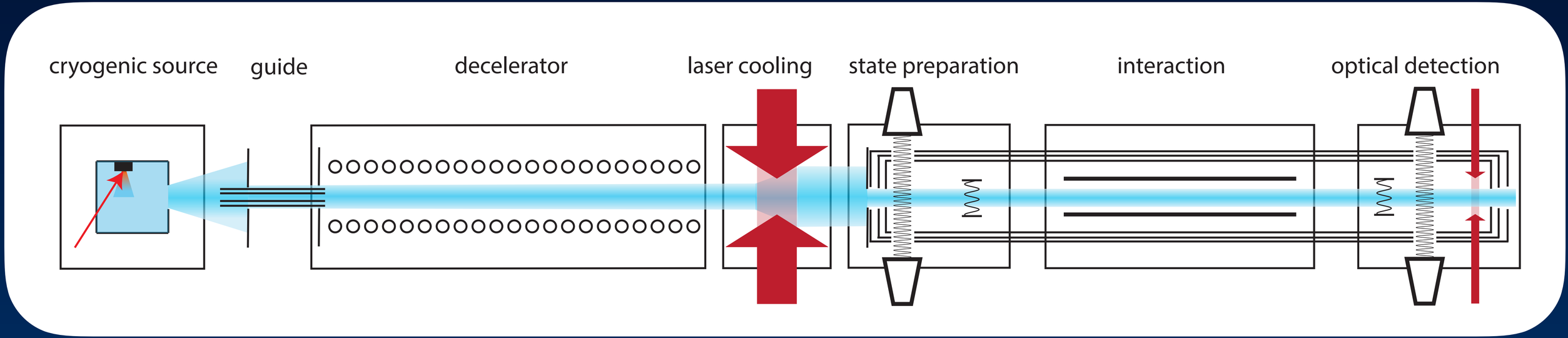
polar molecule

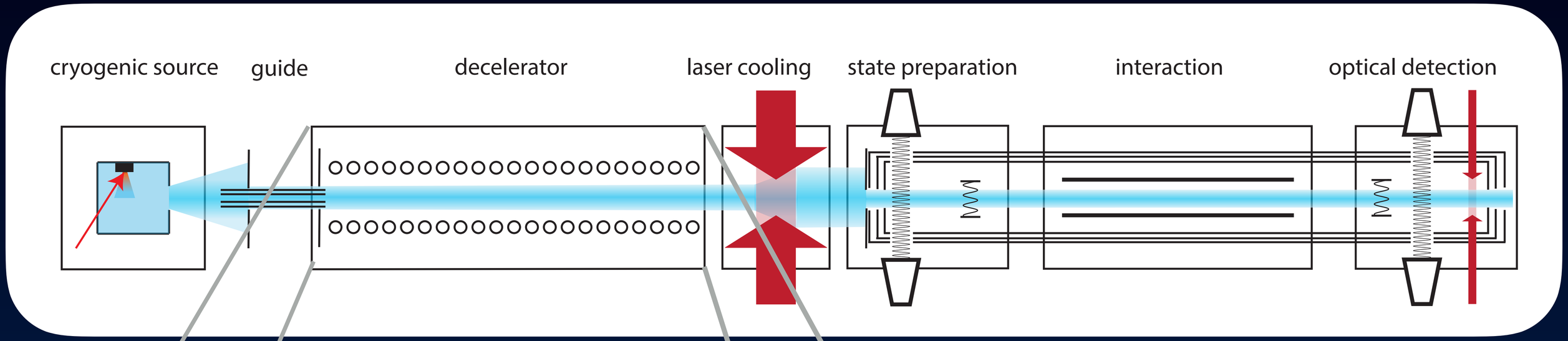
Cold molecules:

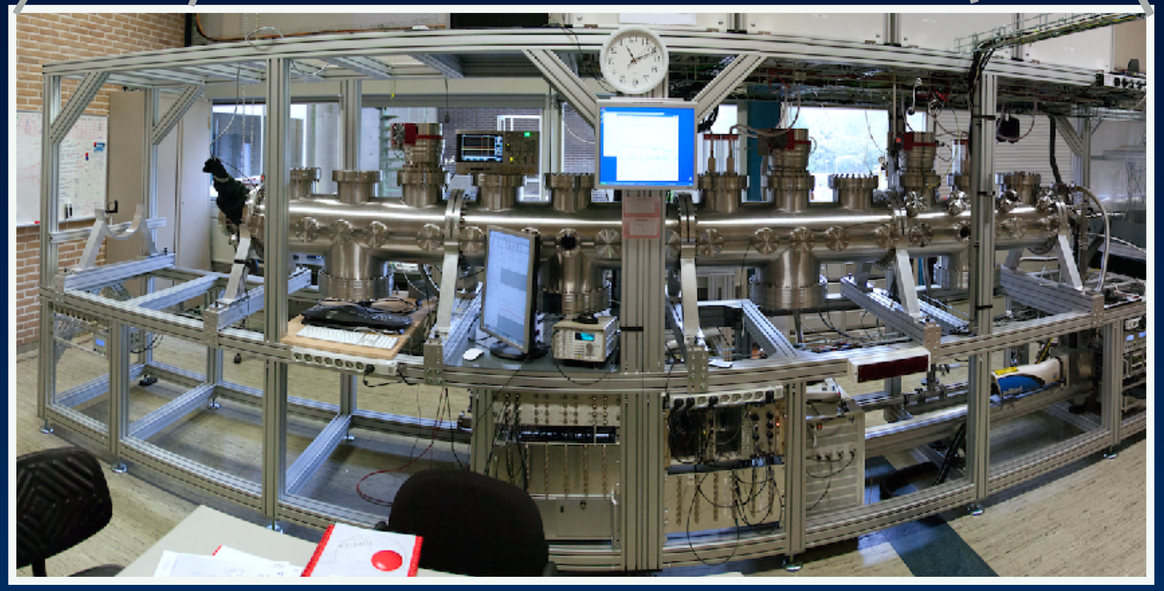
Combining three recent experimental breakthroughs

1) Cryogenic source
2) Stark deceleration - Dutch invention!
3) Molecular laser cooling - a new opportunity

Using BaF molecules, we can create a very **intense, slow and cold** beam





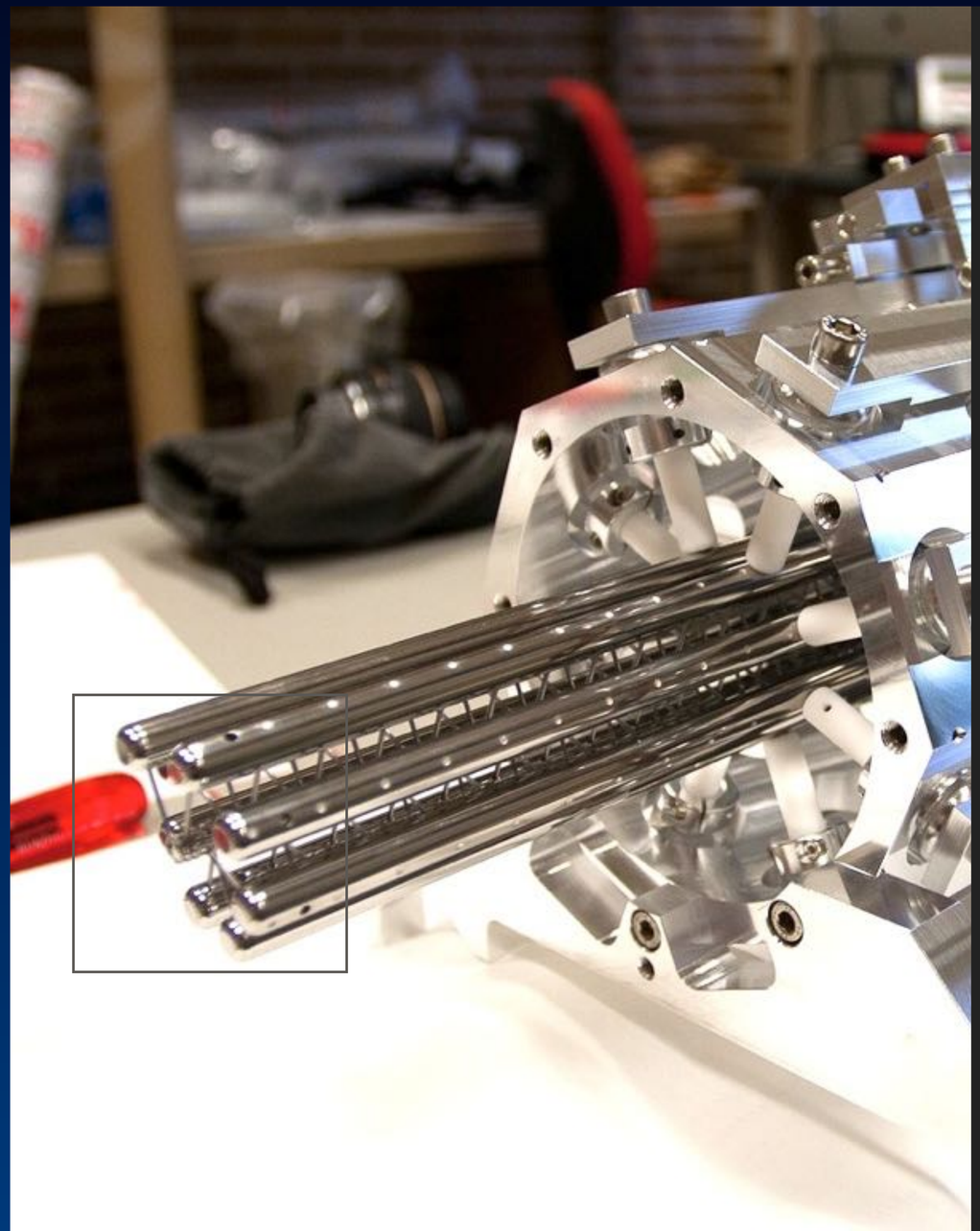


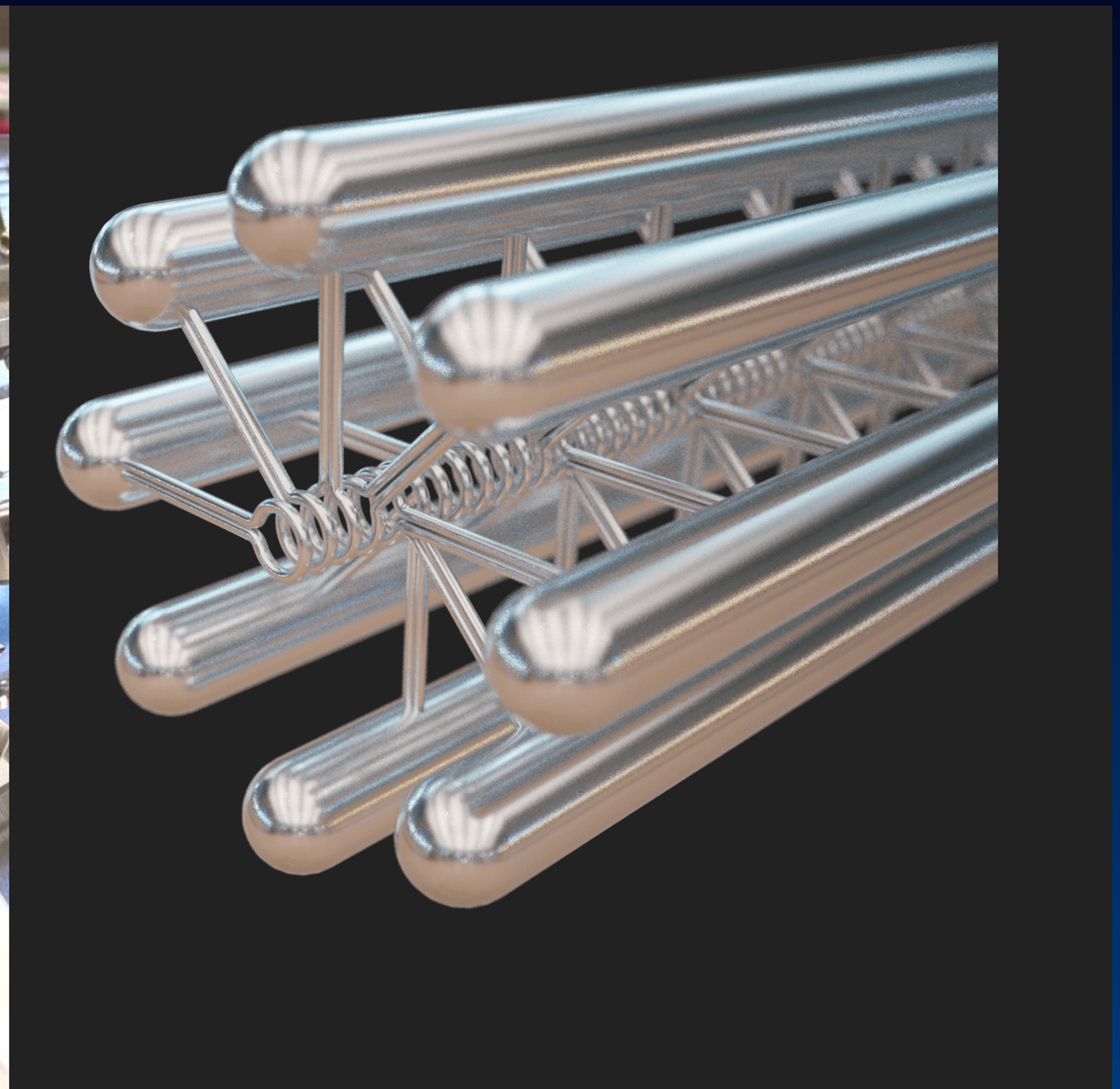
4.5 m long molecule decelerator @ VSI
Built with great effort of KVI-CART workshop

Current status:

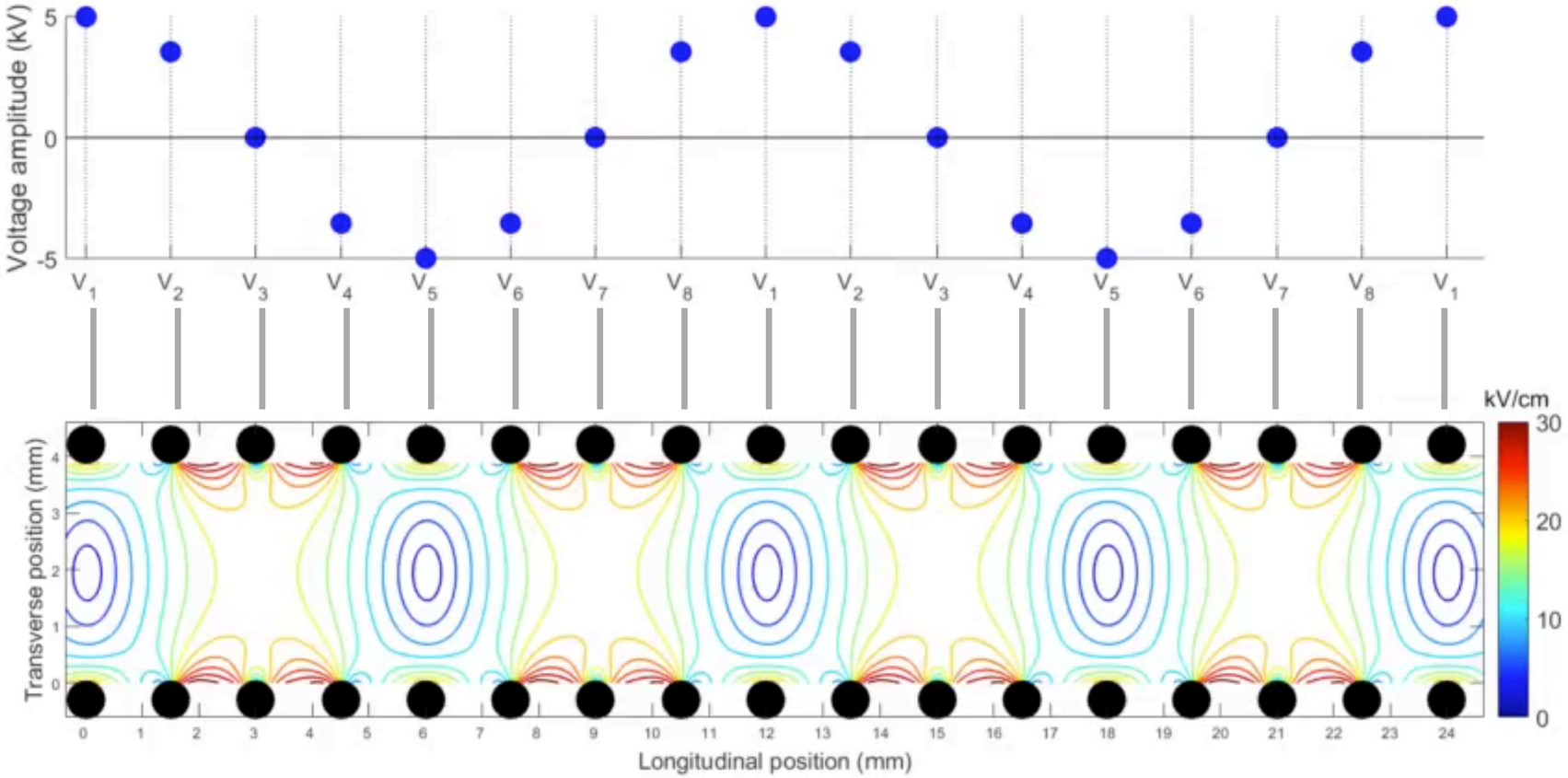
Team is formed
First results form theory obtained
Experiment under construction

Traveling-wave decelerator



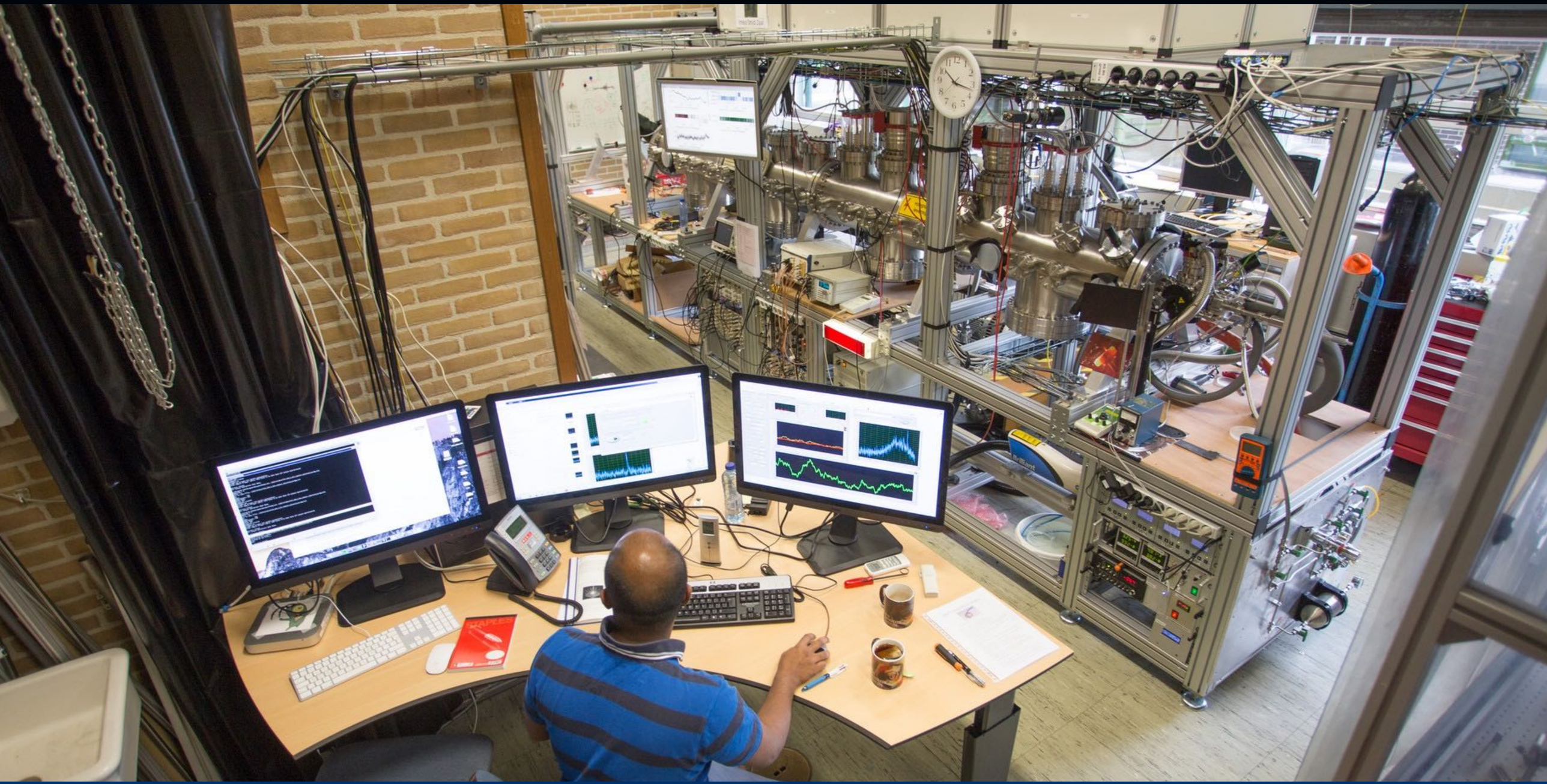


Traveling-wave decelerator - operating principle



Allows us to create intense molecular beam
Temperature ~ 10 mK, forward velocity ~ 30 m/s

Cold Molecules Lab - eEDM data-taking planned in 3 years from now



Young and active research community

12-17 June 2107, eEDM program kickoff meeting and international summerschool, Ameland
“Low-energy precision measurements of physics beyond the standard model”

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