UNIVERSITÄT DUISBURG ESSEN

Open-Minded

An Experimental Setup to Generate Ultra-Short Ion Pulses for Use in Pump-Probe Experiments

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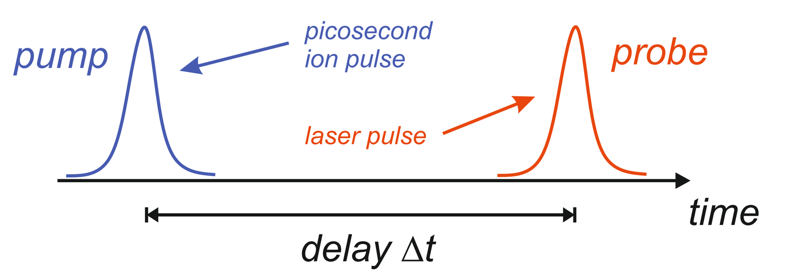
SFB 1242

DFG Deutsche Forschungsgemeinschaft

Motivation

- Can we generate ion pulses of picosecond time resolution in the keV-range for observation of ultra-short dynamics via pump-probe technique?

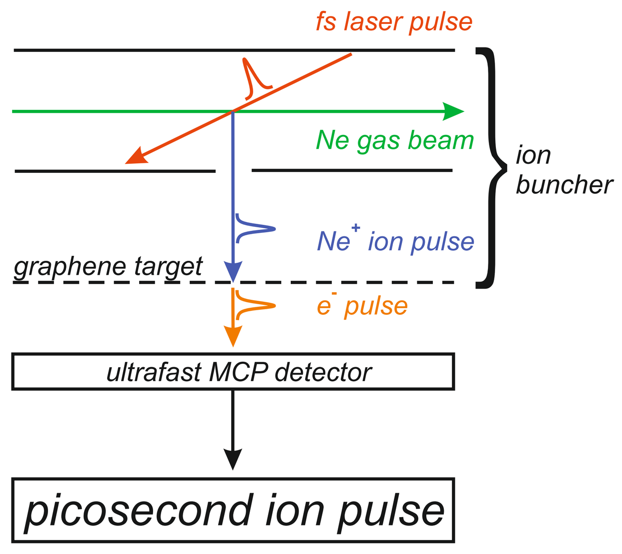


- generation of ultra-short ion pulses: difficult task due to space-charge broadening and velocity distribution of ions at a given temperature

⇨ supersonic gas expansion - control over number density and temperature distribution in gas beam

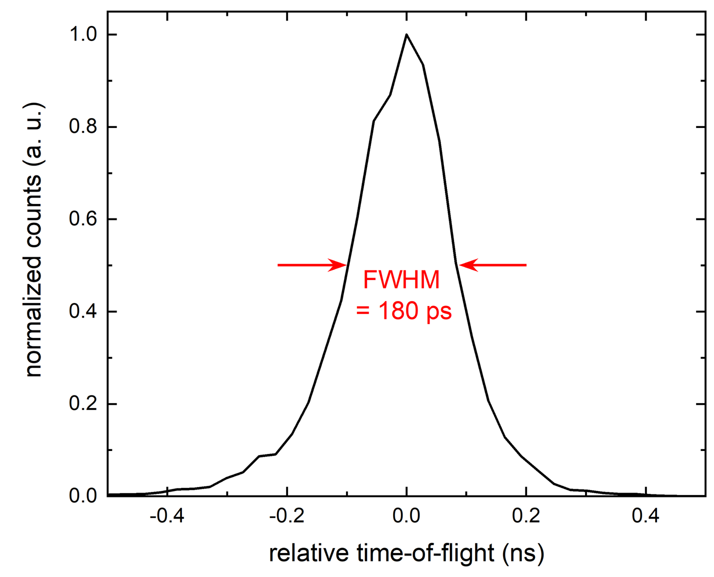
Concept

- intersection of supersonic gas beam with intense fs laser pulse and subsequent bunching of generated ions

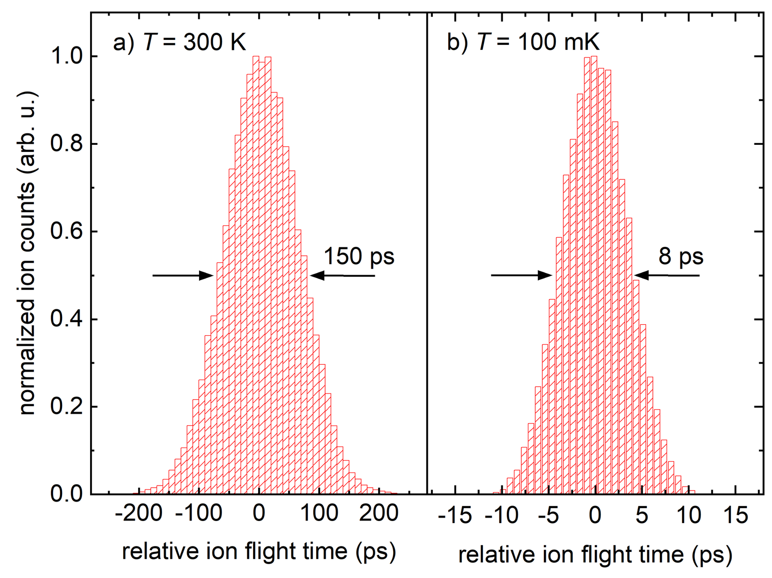


Goal: ion source with picosecond time resolution

ion pulse width at T = 300 K



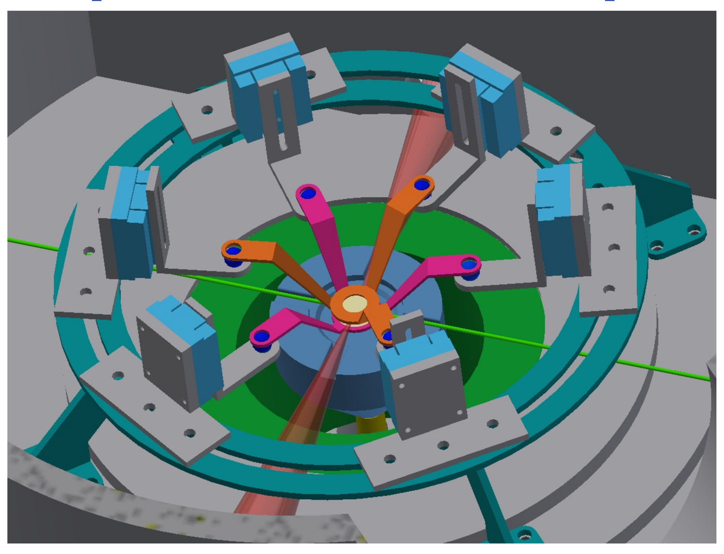
simulated flight time distributions

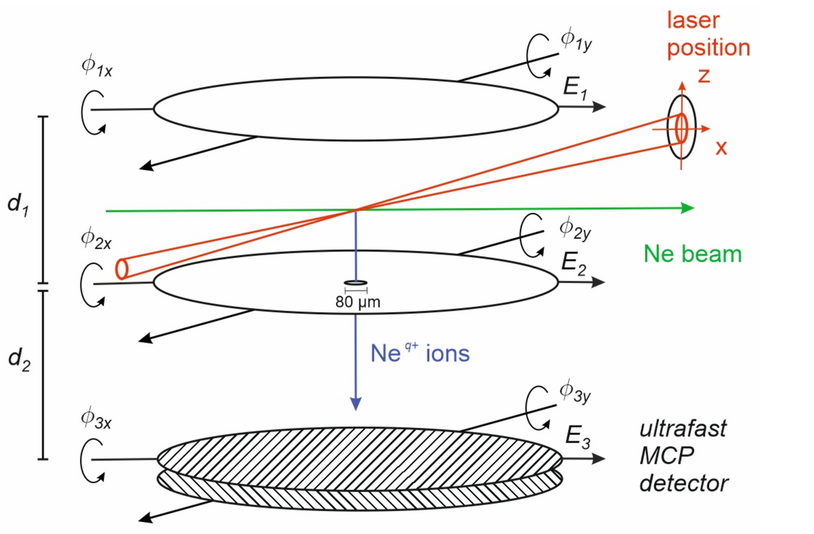


- shortest ion pulse width with ion buncher and backfilled gas at room temperature: **180 ps** [1]
- reduction of thermal velocity distribution allows to further compress ion pulses within buncher

⇨ combination of ion buncher with ultracold molecular beam leads to a picosecond ion source!

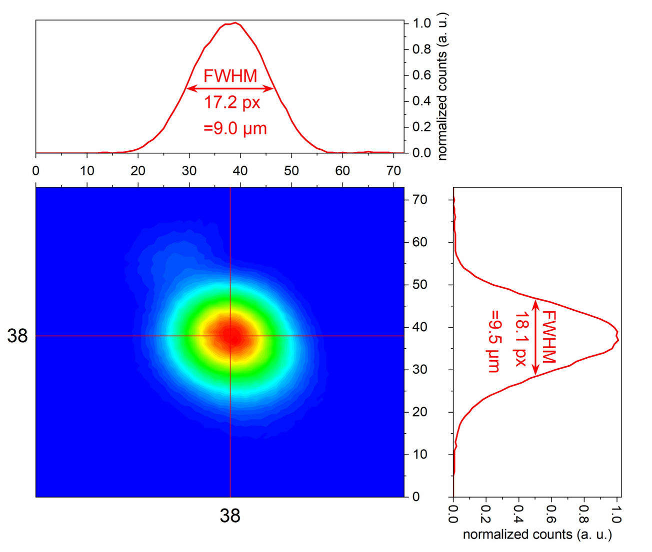
Experimental setup

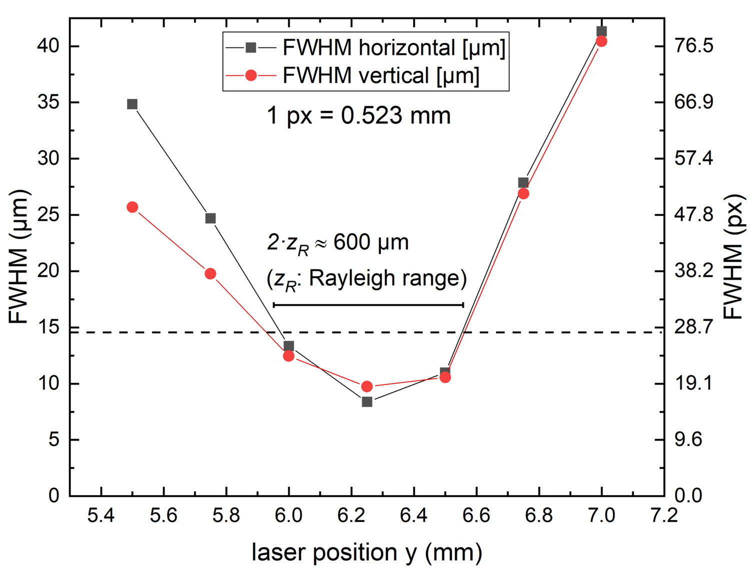




- 6 **piezo motors** allow *in-situ* alignment of electrodes for distances $d_{1,2}$ and angular tilt $\phi_{x,y}$

Characterization of fs photoionization laser





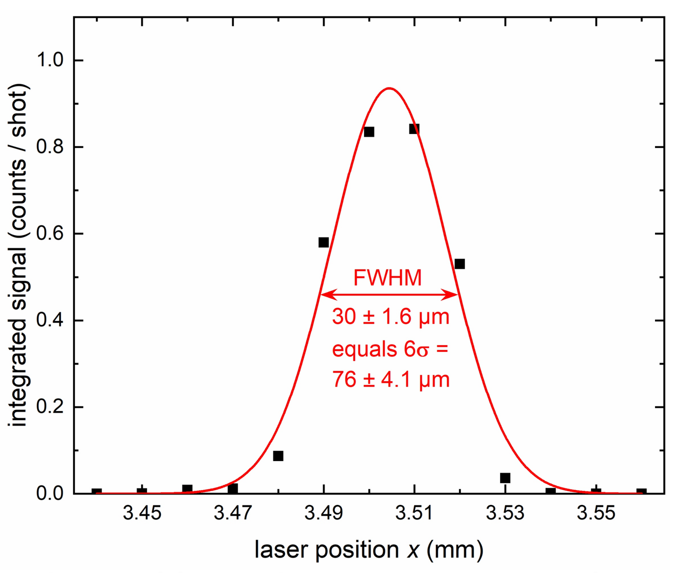
beam properties:
- 800 nm
- 50 fs
- 1.5 mJ per pulse
- 1 kHz

- symmetrical laser spot profile with diameter < 10 µm and Rayleigh range of $z_R \approx 300$ µm
- measured spot profile leads to a maximum peak intensity $I_0 \approx 3.5 \times 10^{16}$ W/cm^2

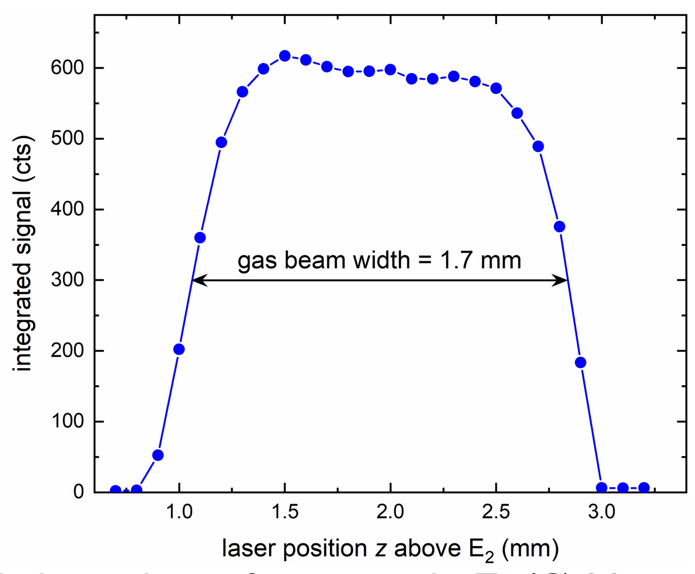
⇨ intensity allows in principle to create Ne^{q+} with charge state q = 1, 2, 3

Geometric Boundaries

horizontal laser beam scan

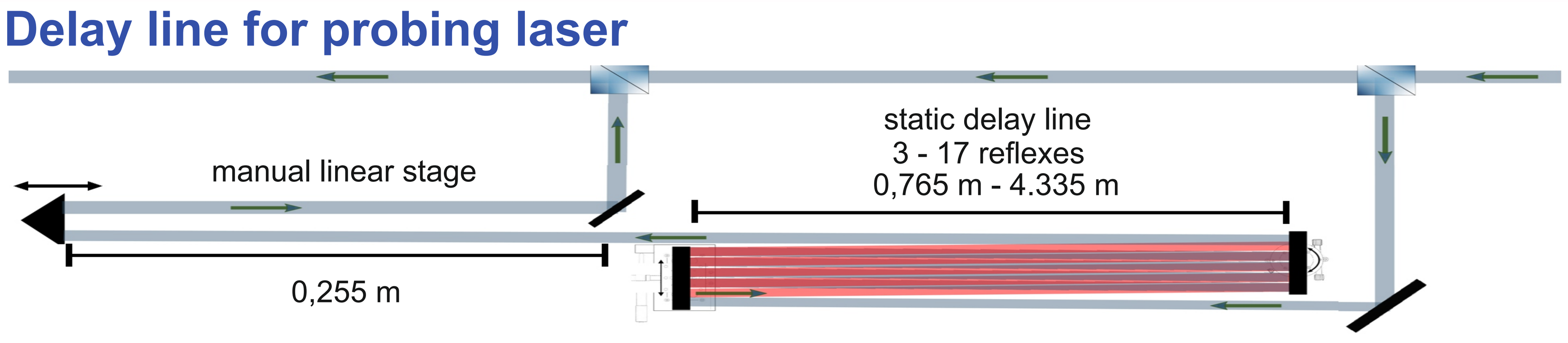


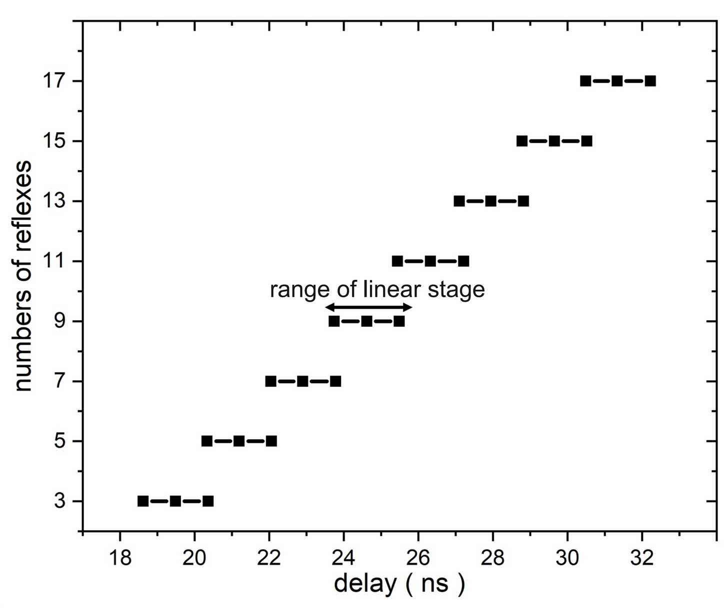
vertical laser beam scan

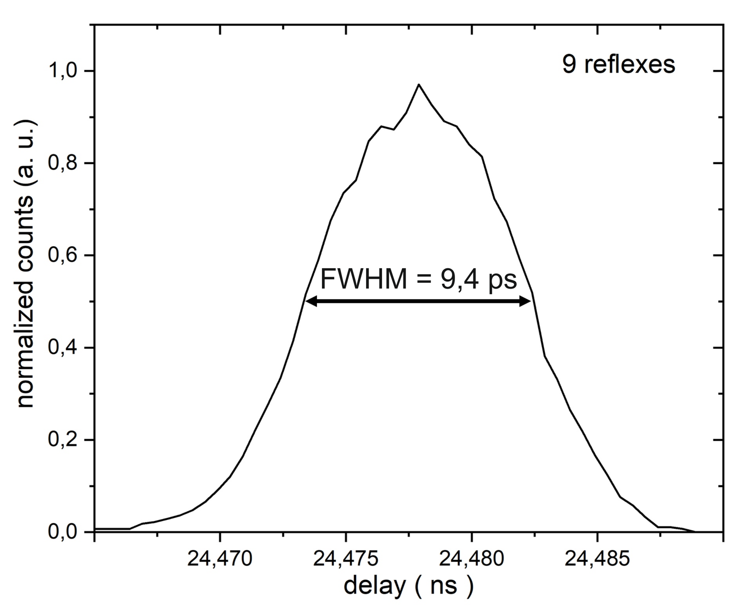


- horizontal laser beam scan reveals geometric boundary of aperture in E_2 (Ø 80 µm)
- symmetric profile of Neon beam at ionization point defined by skimmer of Ø 1 mm

Delay line for probing laser



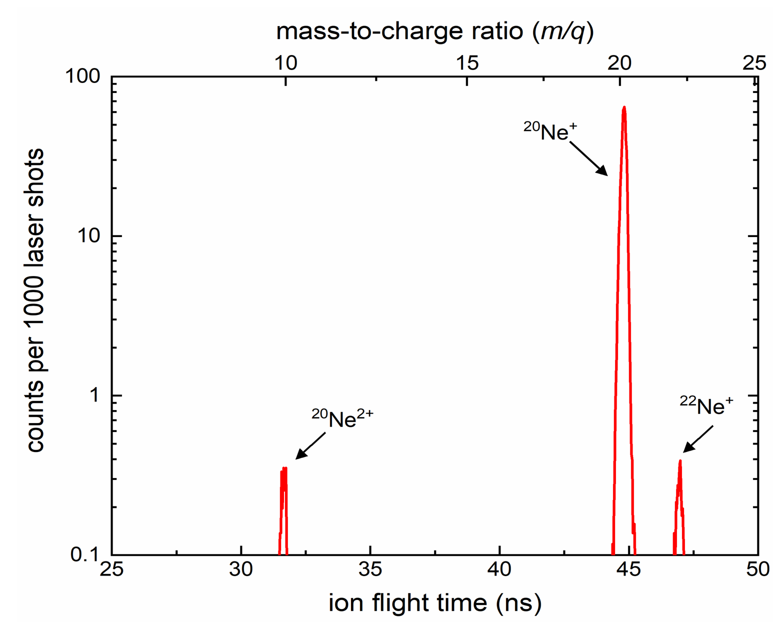




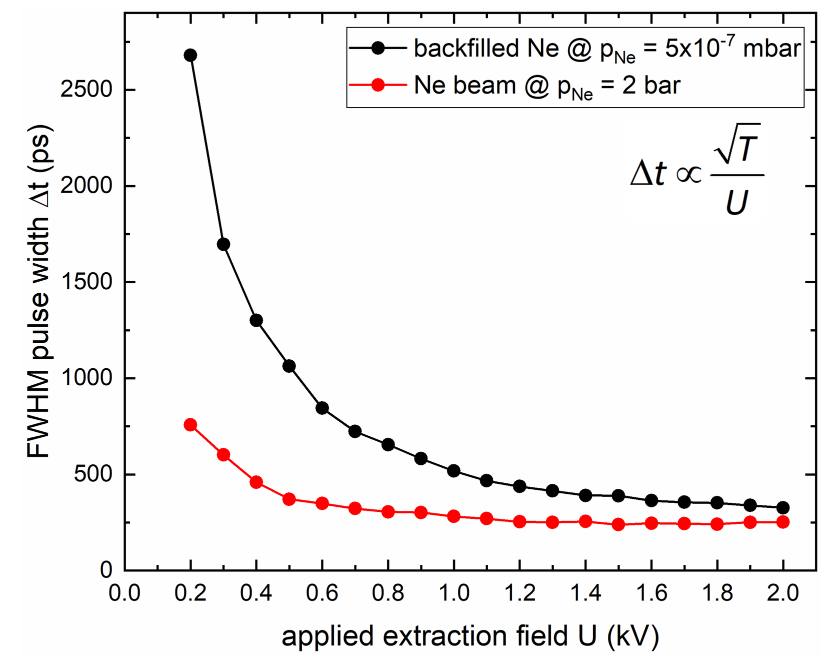
- long ion flight times demand delayed probing pulse of < 20 ns and a stability of a few ps
- uncertainty of delay is within the resolution limit of used detector

Results

ion flight time spectra



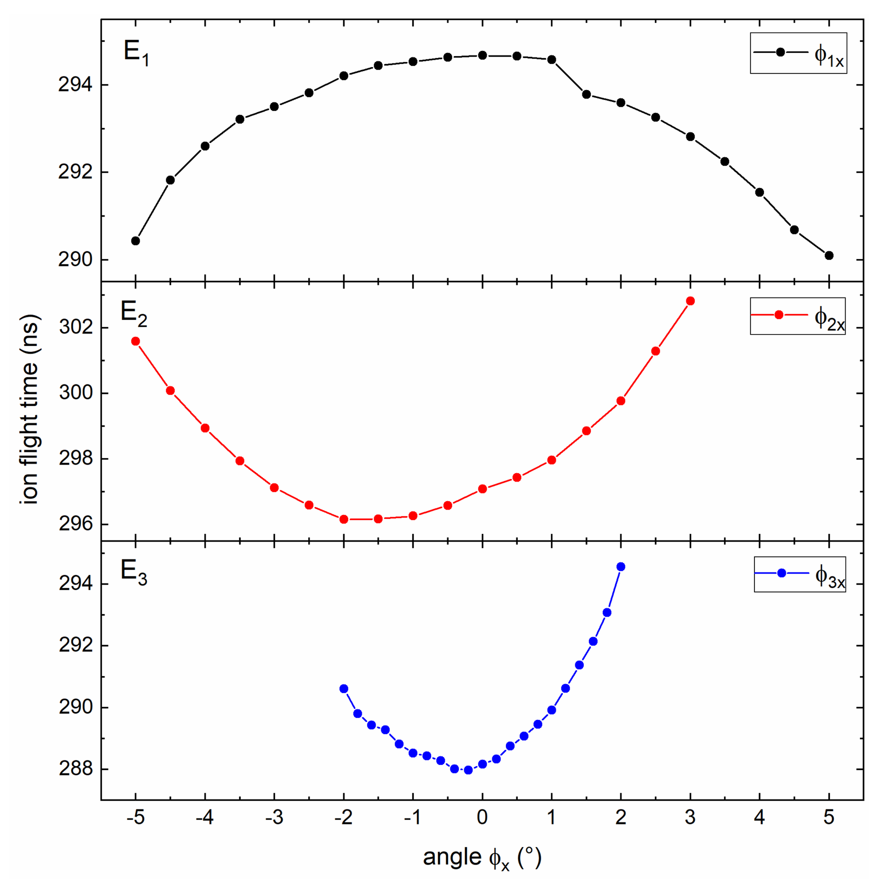
comparison Ne beam & bulk



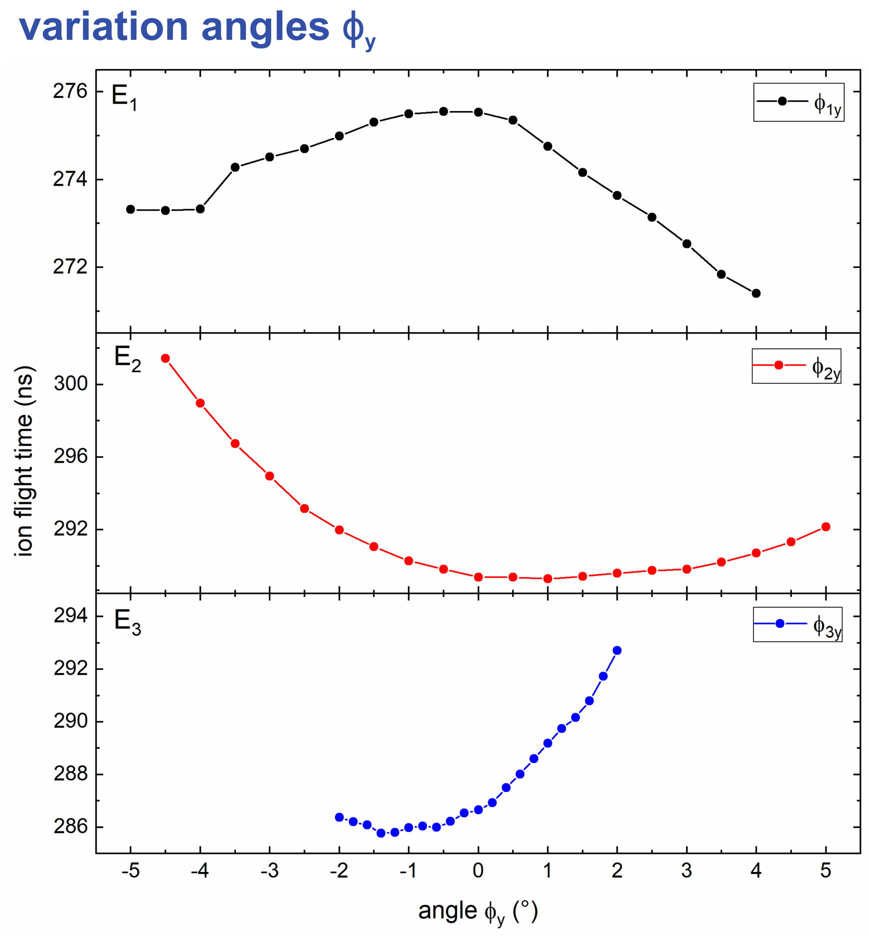
- Neon ions $^{20}Ne^{q+}$ (q = 1&2, $^{20}Ne^{2+}/^{20}Ne^+ \approx 0.03$) accessible at modest beam pressure of 2 bar
- thermal velocity distribution can be reduced drastically by cold molecular beam (below 1 K)

In situ alignment of each electrode

variation angles ϕ_x



variation angles ϕ_y



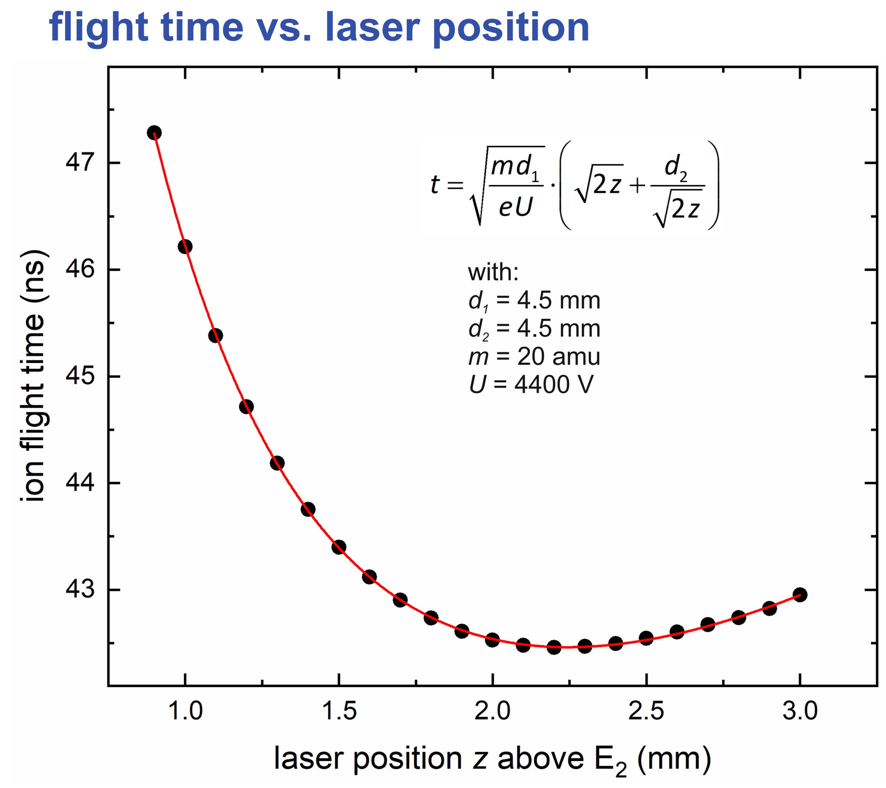
- small extraction field (U = 200 V) between E_1 and E_2 → long ion flight times

⇨ allows to monitor ion flight time behaviour under variation of angles $\phi_{x,y}$ for E_1, E_2 and E_3

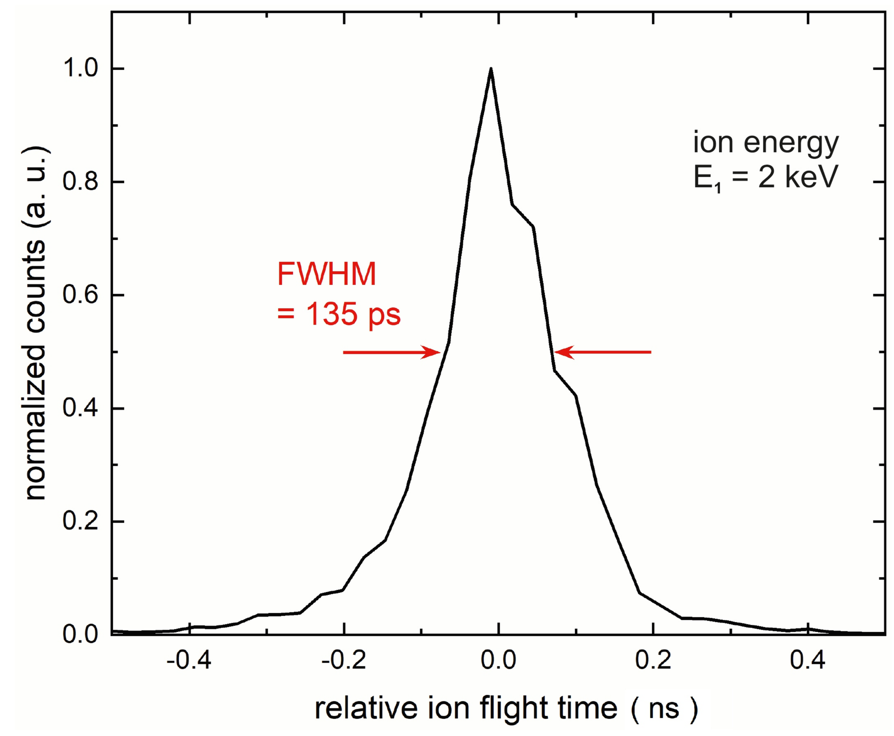
⇨ flight time maxima (for E_1) and minima visible (E_2 and E_3) visible → optimal buncher alignment

Flight time focus and measureds ion pulse width

flight time vs. laser position



pulse shape at flight time minimum



- flight time as a function of laser position matches the theoretically expected behaviour

⇨ allows to extract and align distances d_1 and d_2 in geometric arrangement

⇨ shortest Ne^+ pulse measured yields a FWHM of **135 ps** (FWHM) @ 2 keV ion energy

⇨ resolution limit of used detector is reached, new technique needed to verify ps pulses

Ref.: [1] *Golombek, A., Generation of ultrashort keV-Ar⁺ ion pulses via femtosecond laser photoionization* (accepted for publication in NJP)