Multipinhole Thomson Parabola arrangement for ion spectroscopy

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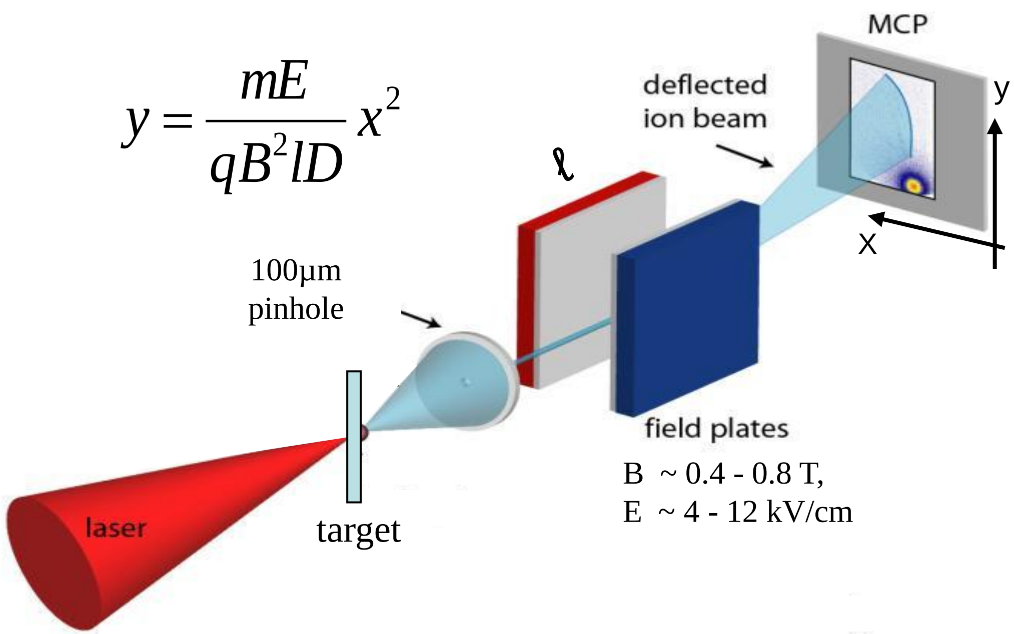
outline

- Thomson spectrometer - charged particle analyser
- Thomson spectrometer with high spatial resolution
- Time-resolving Thomson spectrometer
- Multipinhole Thomson spectrometer

Thomson spectrometer

Time integrated spectrogram is displayed on a two dimensional space

$$y = \frac{mE}{qB^2 lD} x^2$$



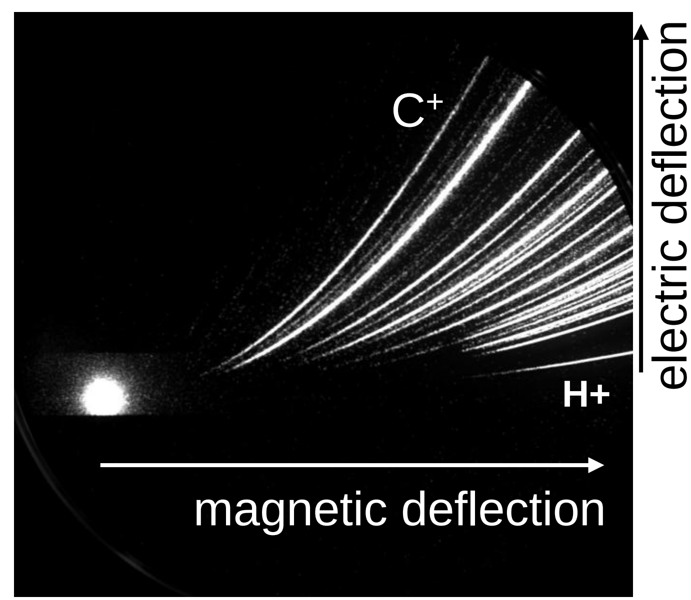
One can notice, that in the spectrogram only parabola shaped lines are used in the space.

The unused space between the lines can be utilized for the display of spatial or temporal information.

absolute calibrated MCP detectors makes the spectrometer setup unique for quantitative analyses of ion spectra

See talk by Rajendra Prasad

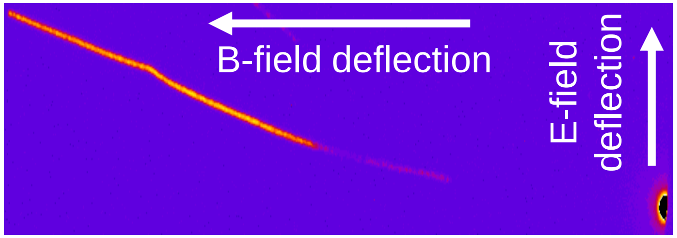
10 nm C, laser energy E~ 7J, 50 fs

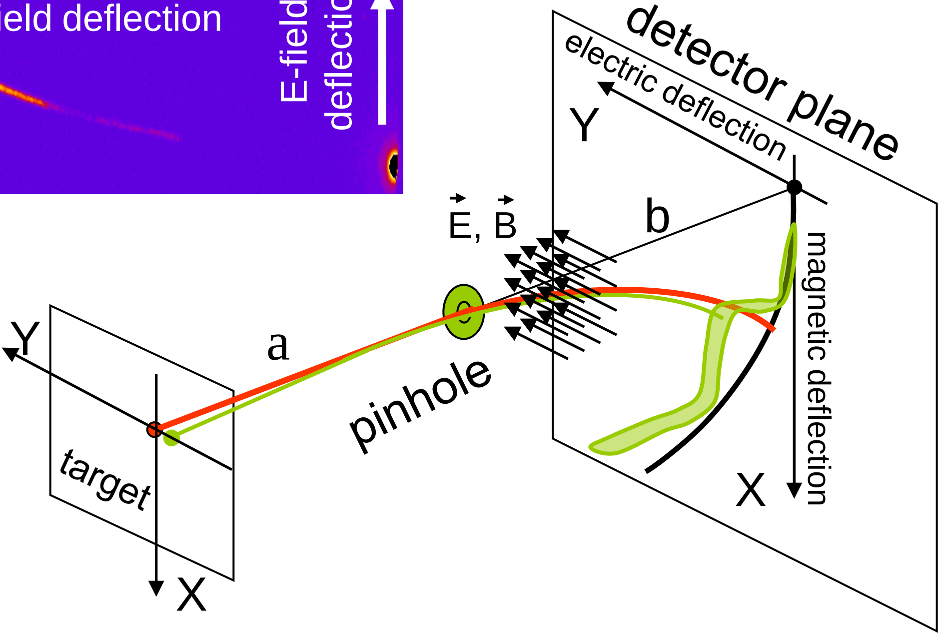


Ion spectra (Thomson parabola)

Thomson spectrometer with high spatial resolution

Thomson spectrometer in a 1:1 imaging





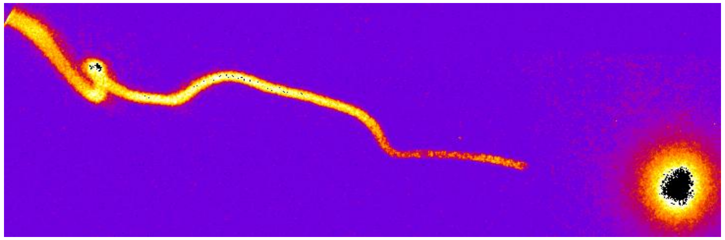
The spatial resolution:

$$\Delta l = \frac{a+b}{b} d$$

a=5 cm, b=75 cm, d=30µm

$$\Delta l = 30 \mu m$$

Thomson spectrometer in a 1:15 imaging

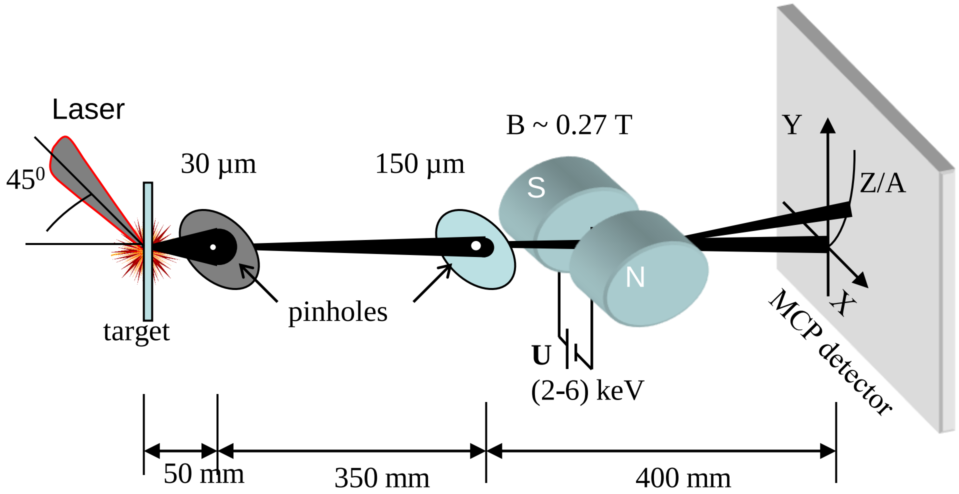


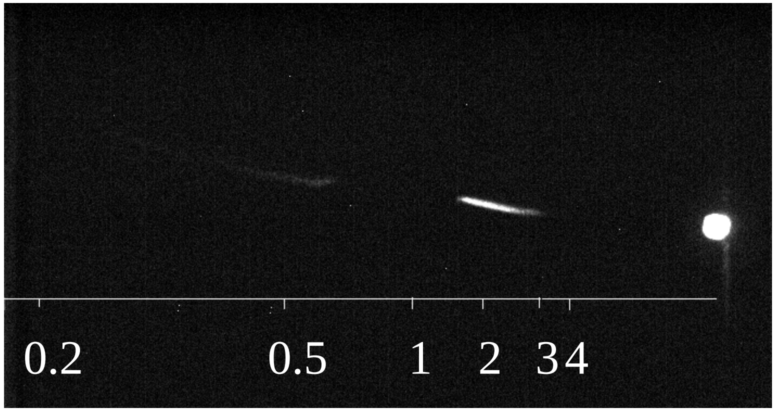
→ Strong spatial fluctuations of the proton emission area.

J. Schreiber, S. Ter-Avetisyanet al., Phys. Plasmas ***13****, 033111 (2006)*

Spatial fluctuations of proton source

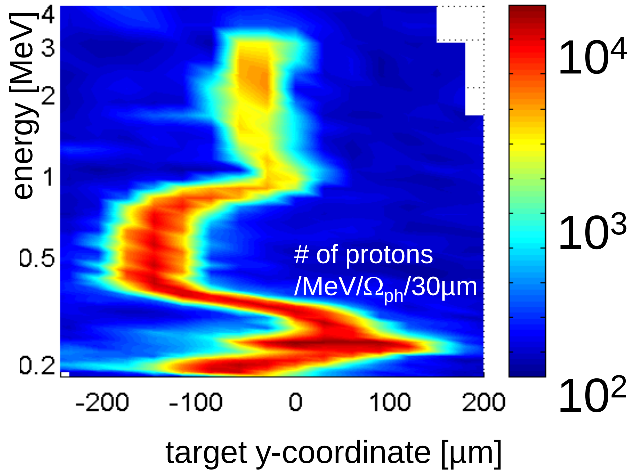
Thomson spectrometer with two entrance pinholes.



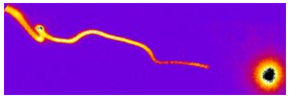


energy, MeV

The source emission coordinate as function of proton energy



remarkable variations of the emission direction of proton beams

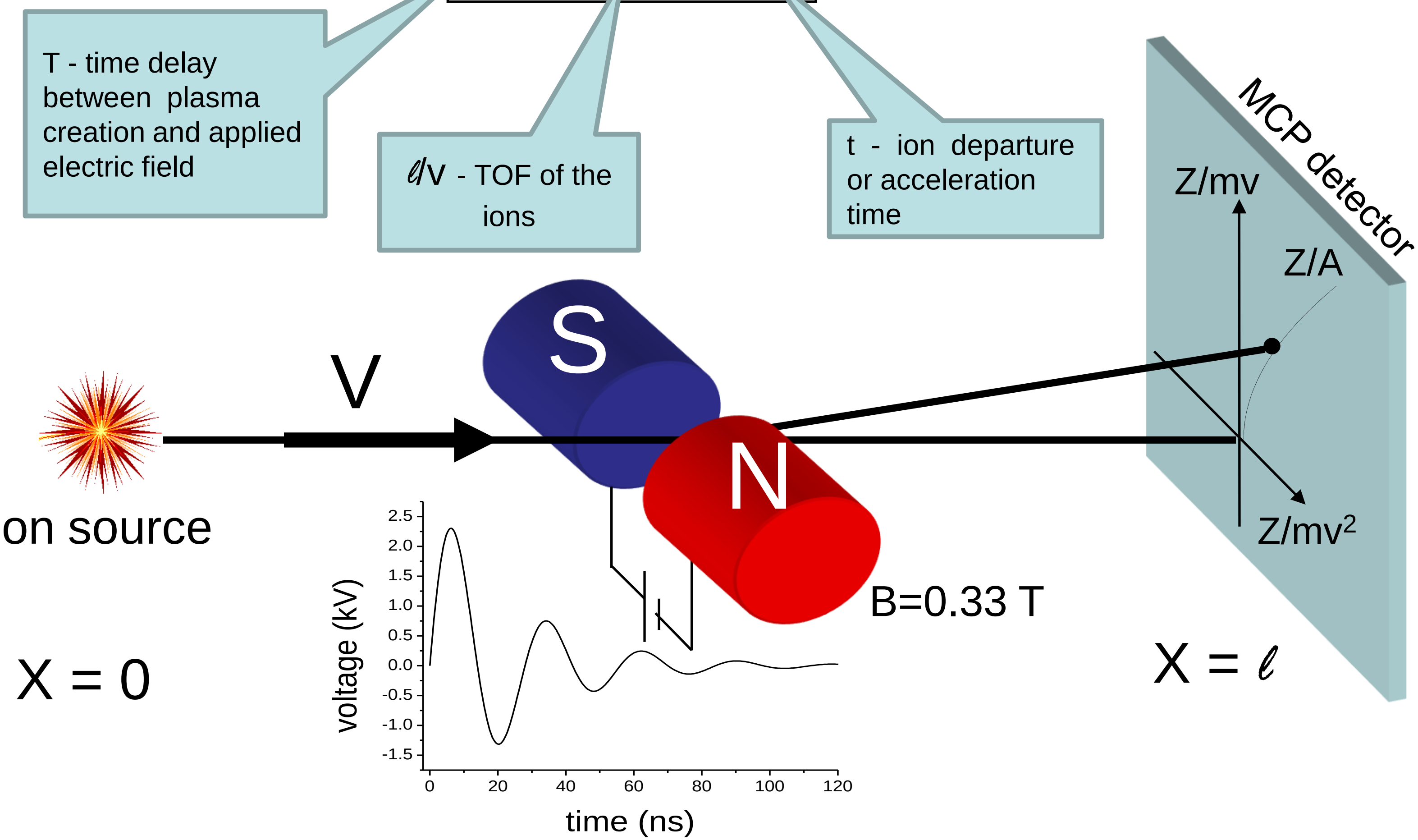


*Nakamura, Ter-Avetisyan, et al., Phys. Rev.E **77**, 036407 (2008)*

Time-resolving Thomson spectrometer

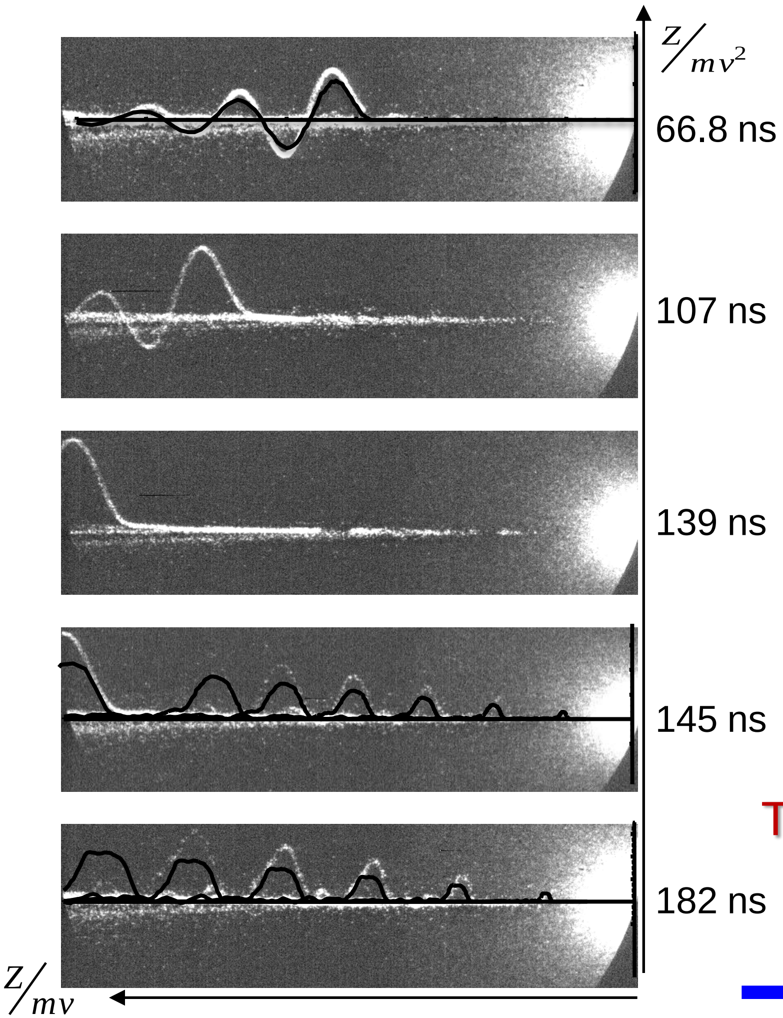
measurement of arrival time and velocity - not loosing the spectral information

$$T = \ell/v + \Delta t$$



Employed pulsed electric field producing a distinctively shaped spectral trace from which the energy of ions as a function of time can be deduced

Ion emission snap shots



- 100 keV - 2 MeV deuterons arrive at first
- Low energy deuterons with different oxygen ions
- Low energy oxygen ions arrive at the end

The modulated ions spectra
are in a good agreement with calculations,
which anticipates simultaneous ion acceleration.

$$\Delta t \leq (4-5)\cdot 10^{-10}\ s$$

Time resolution can be improved up to a ps-level

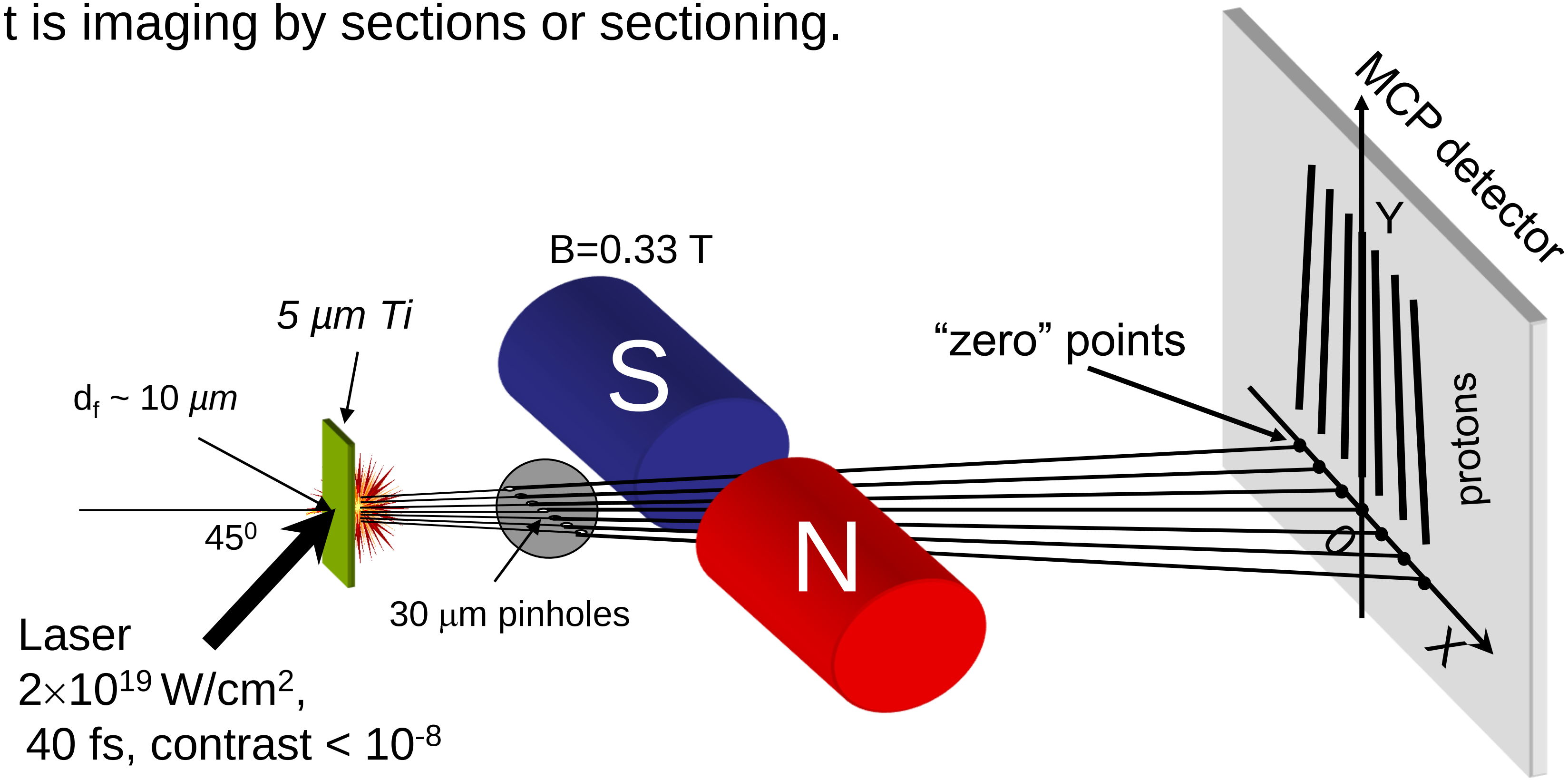
J. Phys. D: Appl. Phys. **38,** 863 (2005)

For a pulsed ion source that produces ions whose energy is a function of time,
a Thomson spectrometer with a pulsed electric field can be used to deduce time information

Proton source Tomography:

Tomographic reconstruction of laser driven proton source

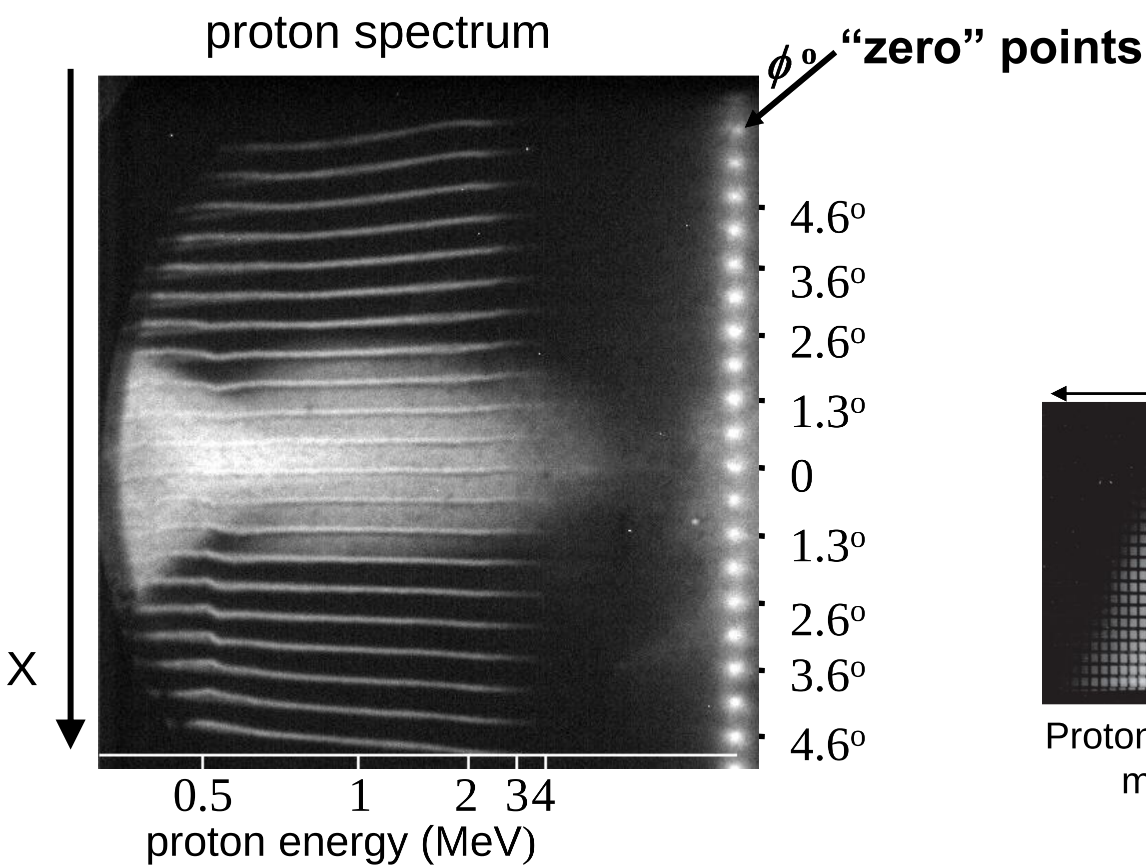
Tomography is a imaging method.
It is imaging by sections or sectioning.

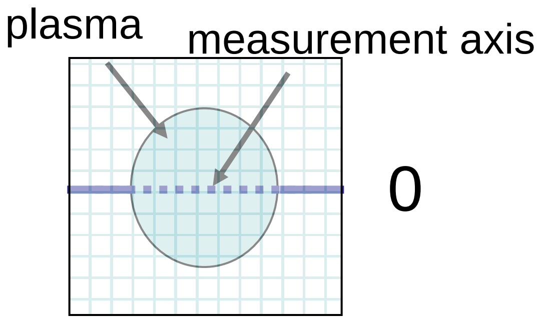


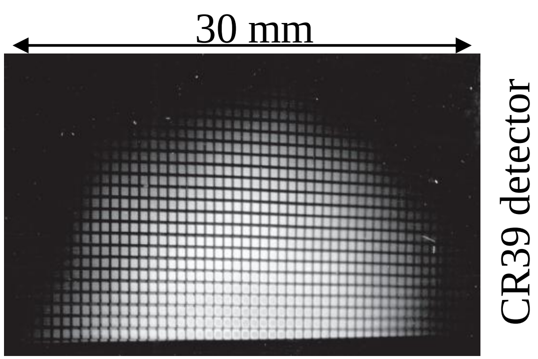
method allow to define spatial and momentum distribution of emitted ions

Ter-Avetisyan et al., Phys. Plasmas ***16****, 043108 (2009)*

Tomographic image of the source, energy dispersed







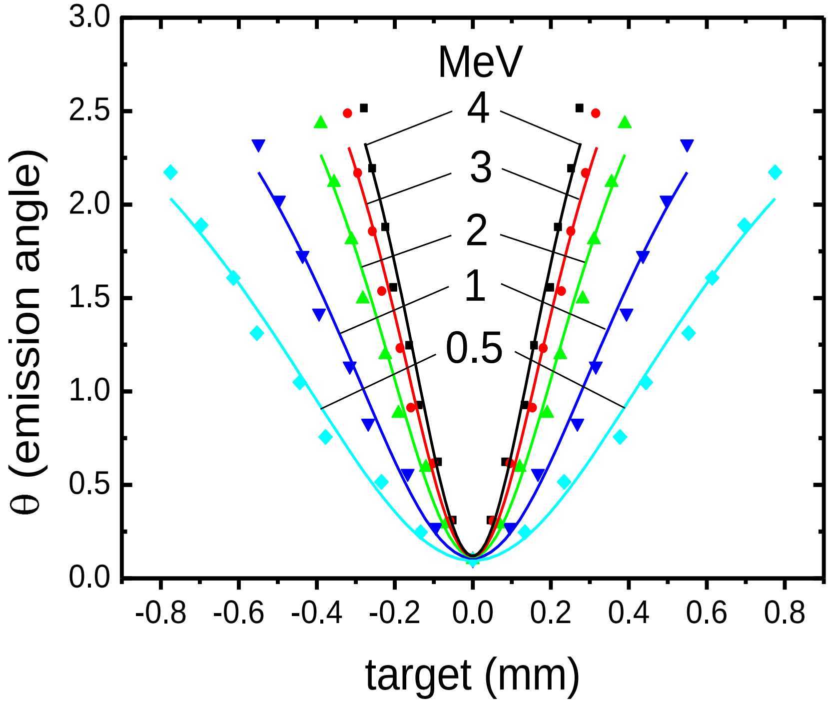
Proton imaging of the mesh
magnification 1:10

directional ~20°

In the ideal case each proton trace should originate from a point which corresponds to the axis of the spectrometer.

If there is a tilt of the proton trace from this axis, the coordinate of the protons differ from spectrometer axis

Correlation of proton emission coordinat, emission angle and energy



width of the source (Δx) is the exponential function of the proton energies:

$$\Delta x \sim E^{-0.5}$$

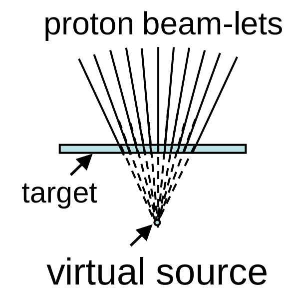
low energy - smaller emission angle, high energy - large emission angle

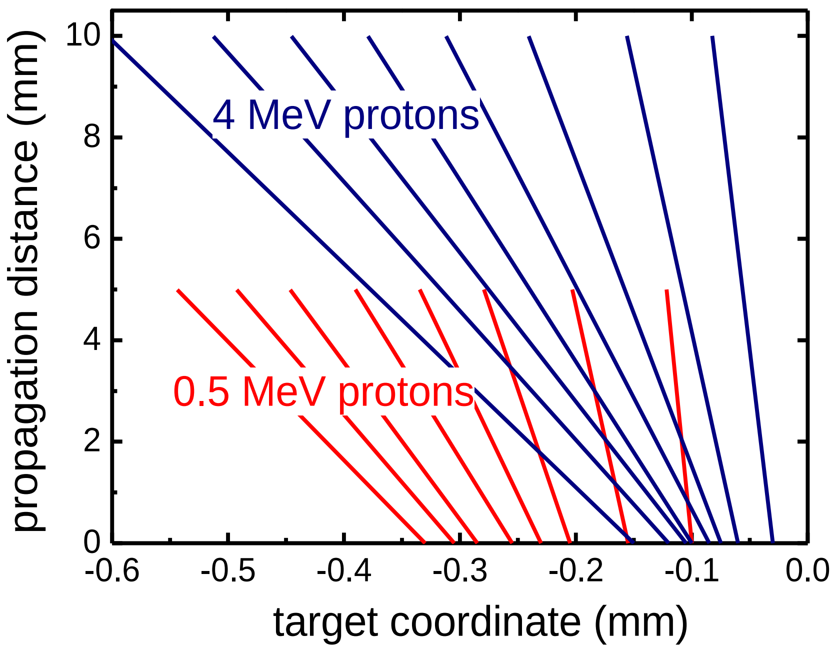
Trajectories of accelerated protons

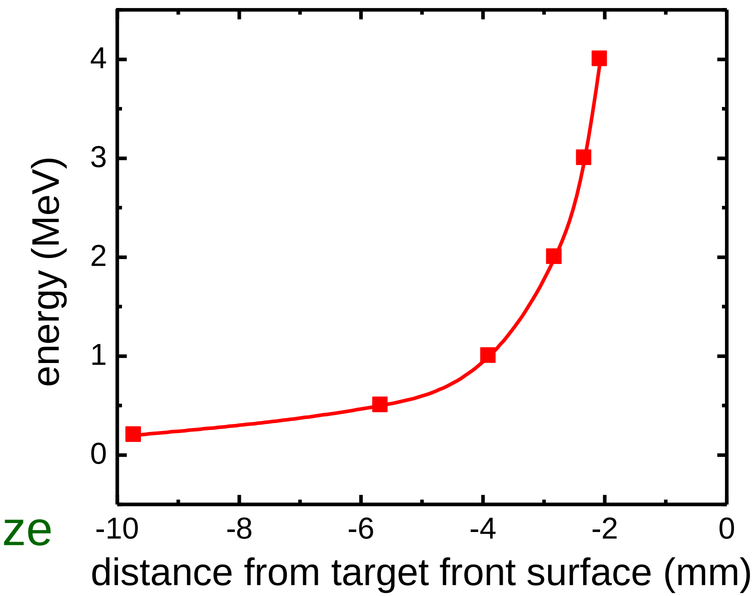
Reconstructed proton trajectories
as they are accelerated from the target

virtual source

- propagation of protons is ballistic
- no ion interaction within the beam,





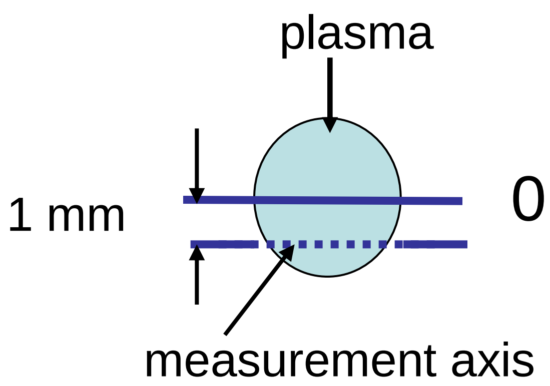


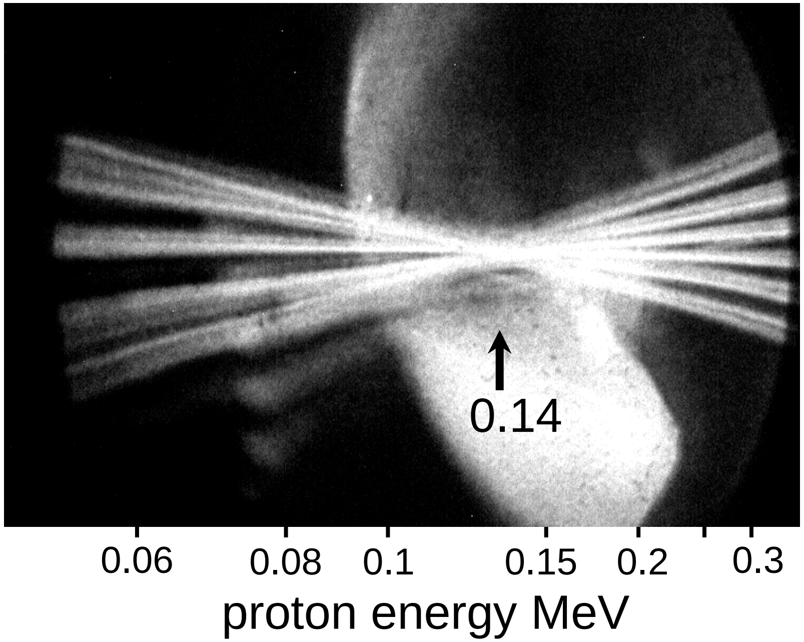
higher the proton energy - smaller the source size
but bigger the emission angle is

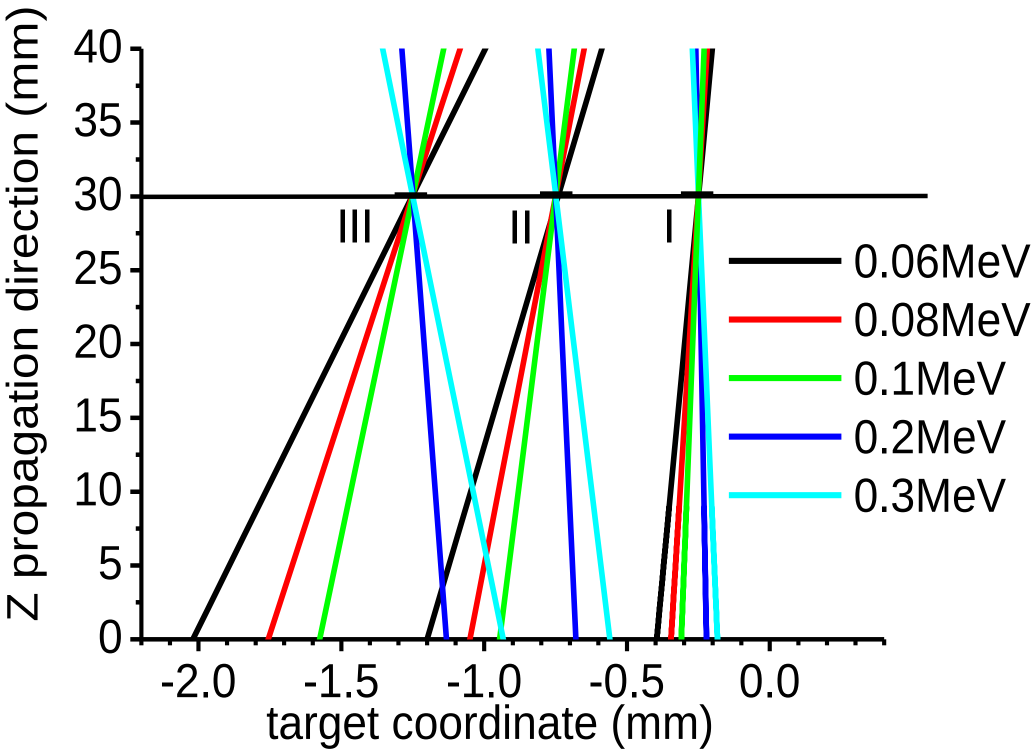
virtual ion source positions in front of the target
for different proton energies

Ter-Avetisyan et al., Phys. Plasmas ***17*** *(2010)*

Tomographic image of the source energy dispersed







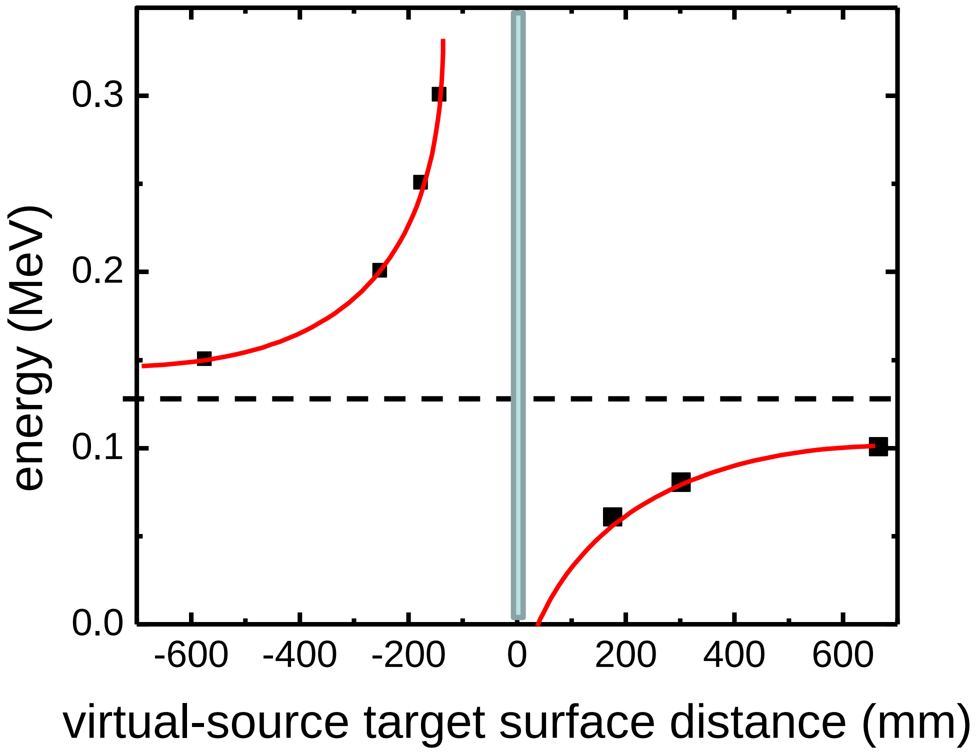
proton trajectories

from diverging – to converging

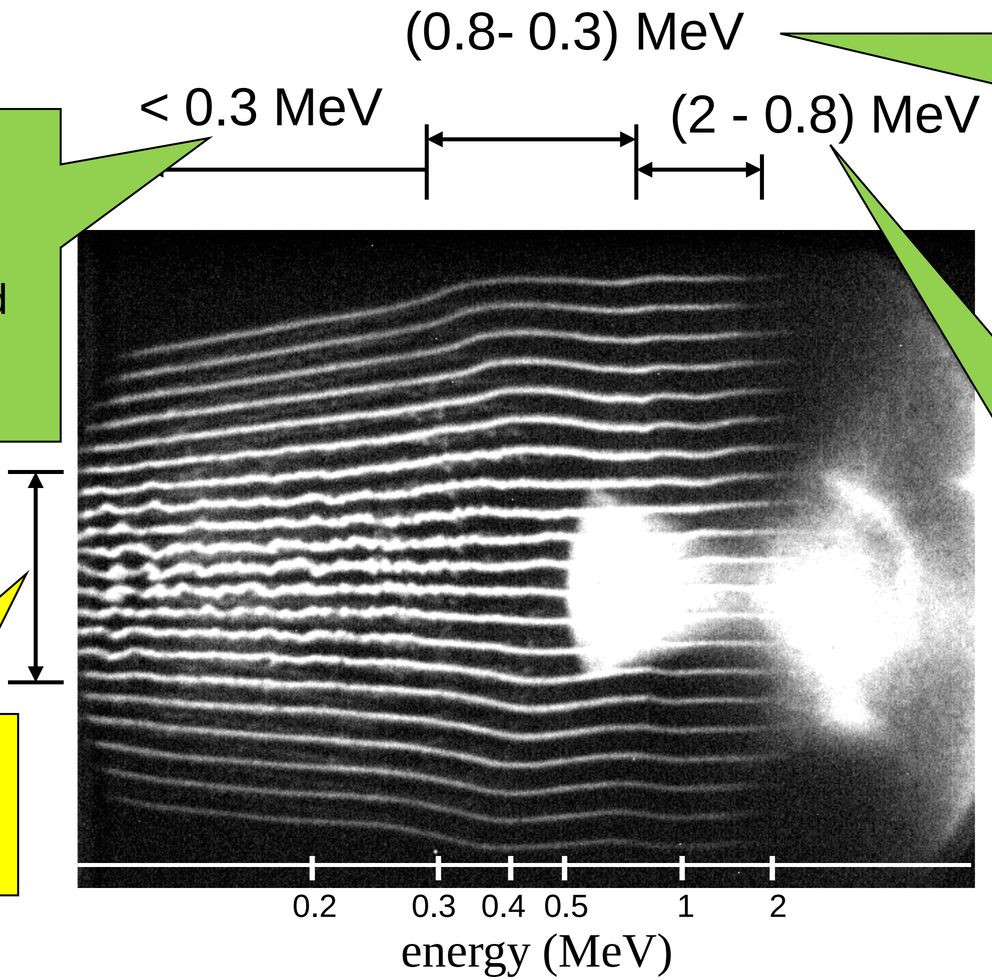
turning point - at 0.14 MeV

The virtual ion source

target front surface ← | → **target rear surface**



Tomographic image of the source, energy dispersed



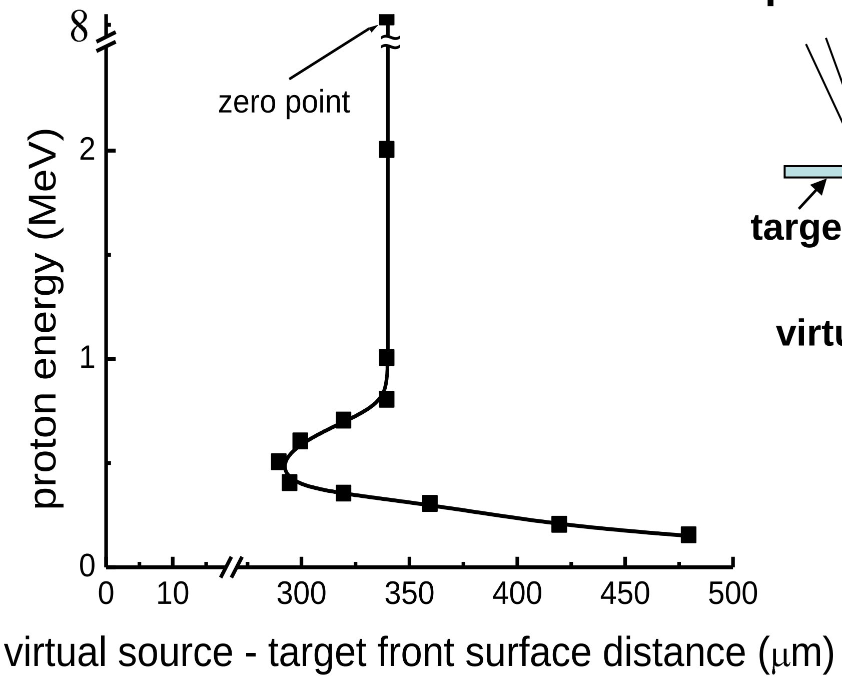
the divergence increases and decreases and coming back to the original divergence

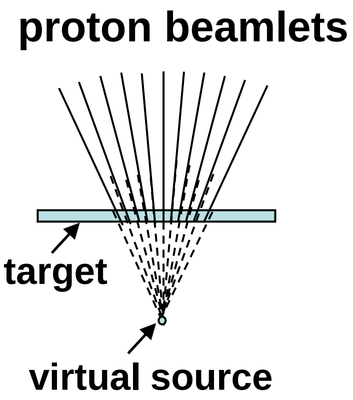
the protons are emitted from different target coordinates and under different angles.

irregularities or “oscillations” in the spectra

the ions in each trace are emitted from the same target coordinate along the spectrometers axes

The virtual ion source





The virtual ion source positions in front of the target for different proton energies

The laser driven ion source is a highly organized dynamic system. It relies on a well defined interrelation between spatial and momentum distributions of emitted ions.

The protons are emerging from a circular symmetric source and each source point behaves similar:
source point from where the proton with E_i energy is accelerated with θ_{Ei} angle (normal to the target surface) becomes a source point for a proton with $E_J < E_i$ energy emitted with $\theta_{EJ} < \theta_{Ei}$ angle.