Schlieren imaging measurements of the Rb plasma column – results & lessons learned

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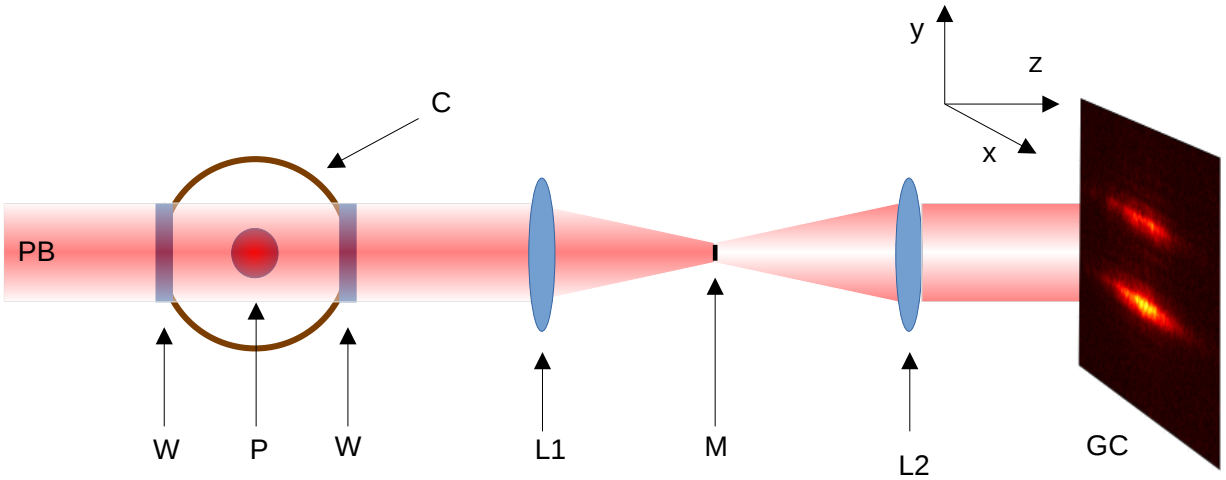
Outline

- Schlieren imaging – what we measured (reminder)
- Evaluating the measurements, plasma parameters we deduced
- Some interesting results
- Possible improvements

Schlieren measurements

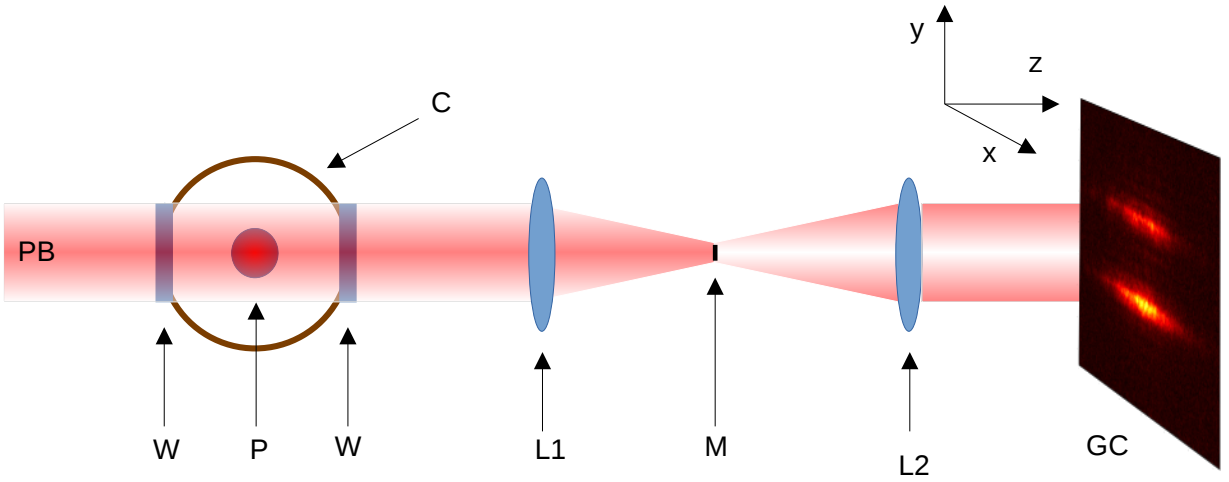


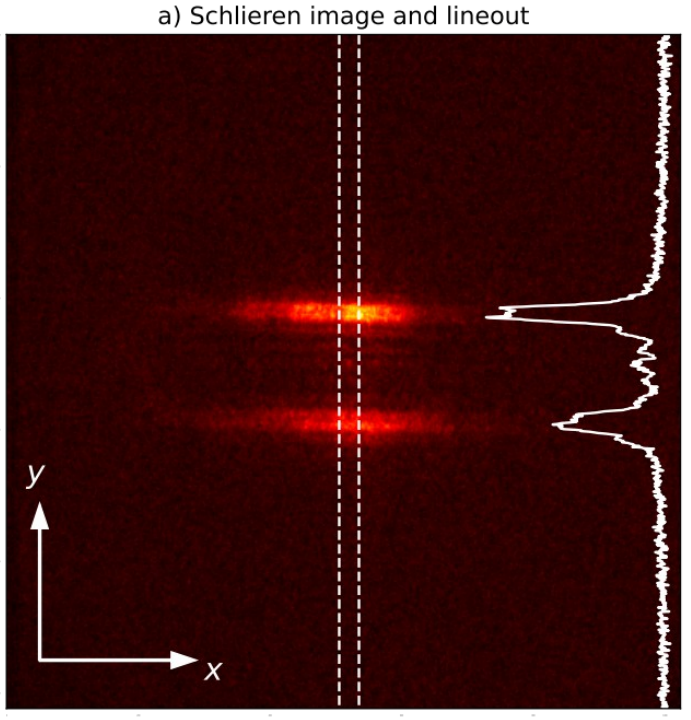
Laser probes changes in *n(x,y,z)* – vapor ↔ plasma

Very sensitive because:

- Probe wavelength close to D_2 resonance
- direct light is blocked by mask in Fourier plane

Schlieren measurements





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Obtaining plasma parameters from the measurements:

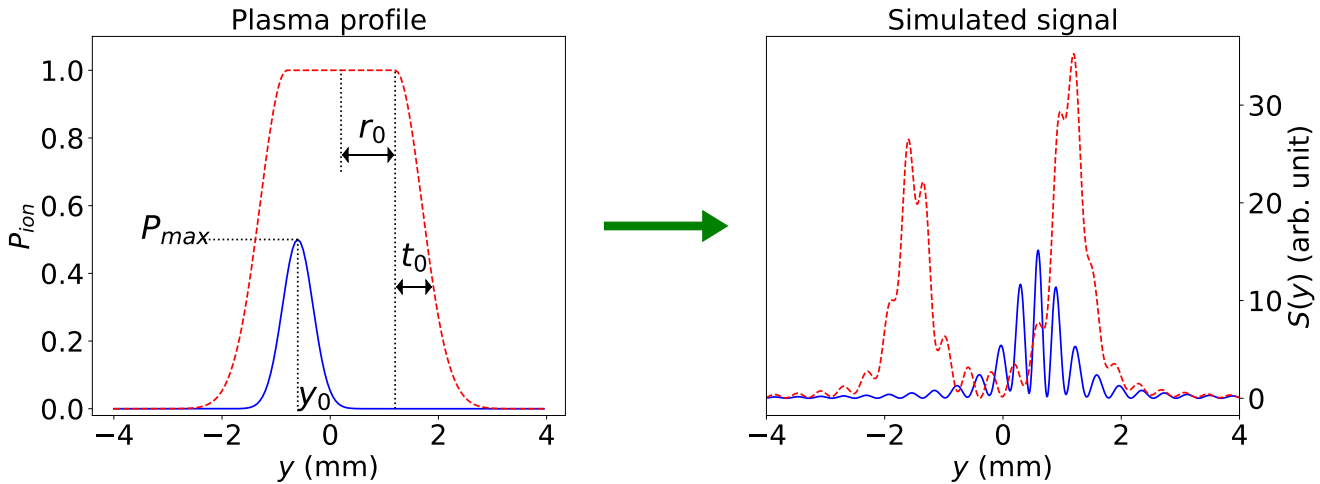
Ideal plasma, simulated ‘measurements:’

$$P_{max}\ if\ r<r_0$$

$$P_{max}\cdot\exp\left(-(r-r_0)^2/t_0^2\right)\ if\ r>r_0$$

r_0 – core radius

t_0 – sheath layer width



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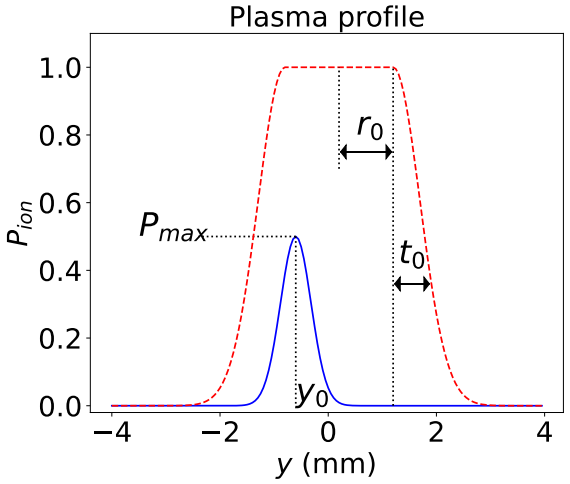
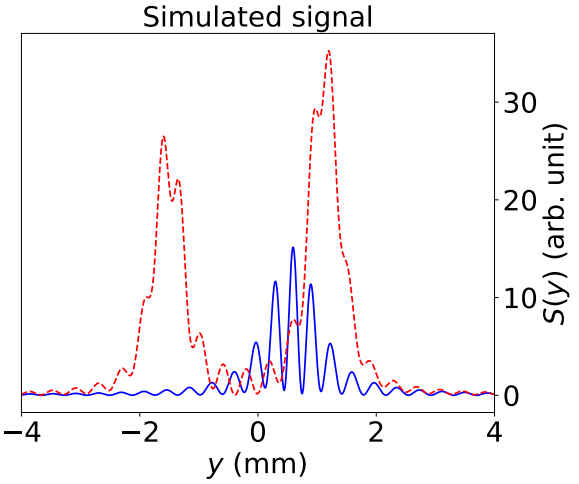
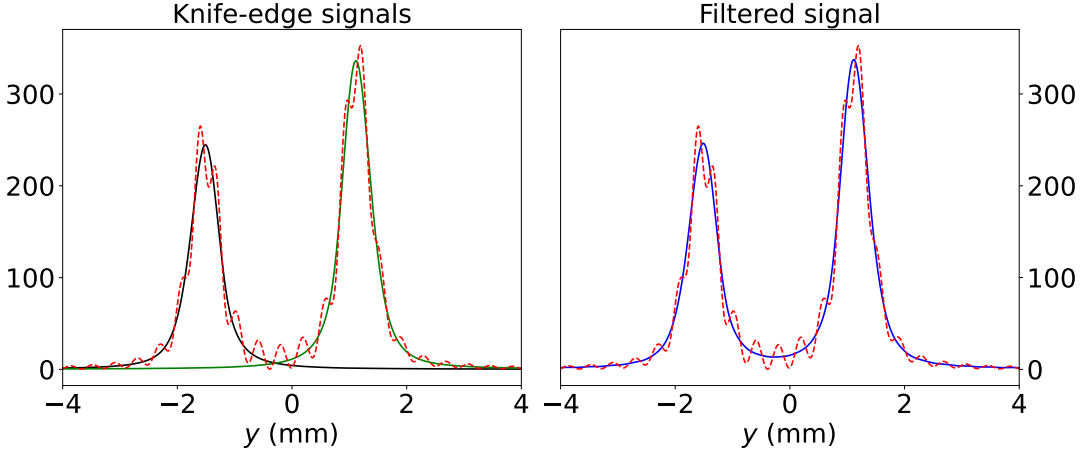






Get rid of interference:

lowpass filter, $f < \lambda L/D_{mask}$

Obtaining plasma parameters from the measurements:

Calculate signals, filter, find properties that predict plasma parameters:

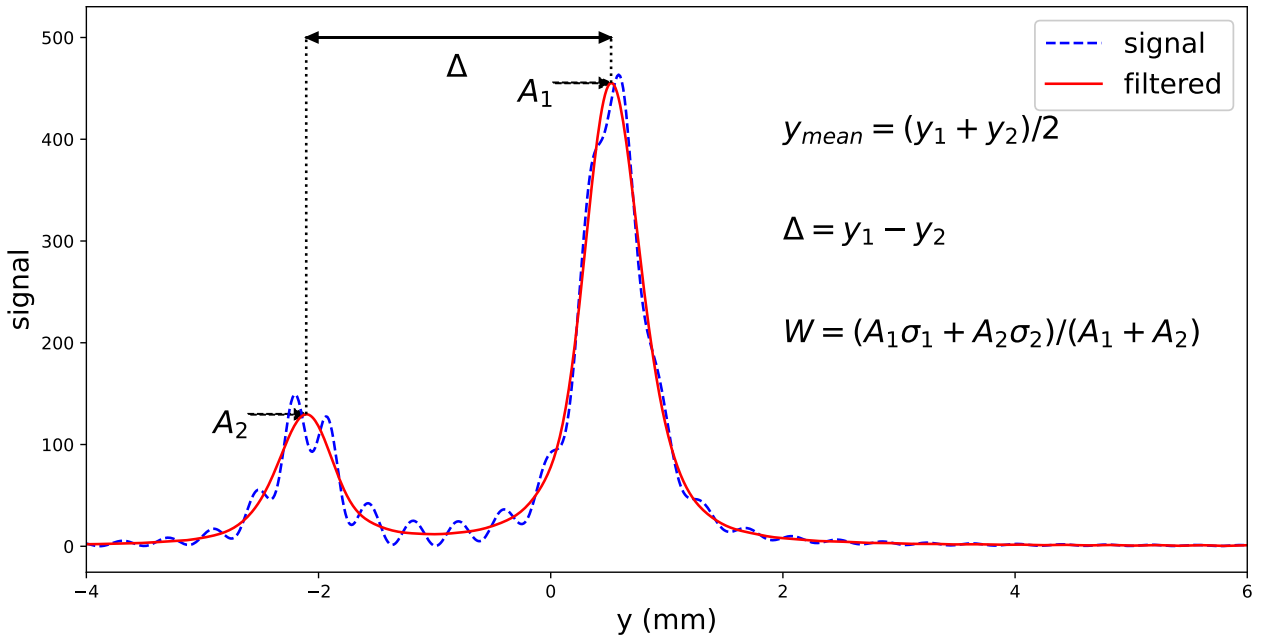
Peak finding:

$y_{mean}(y_0, r_0, t_0)$

$\Delta(y_0, r_0, t_0)$

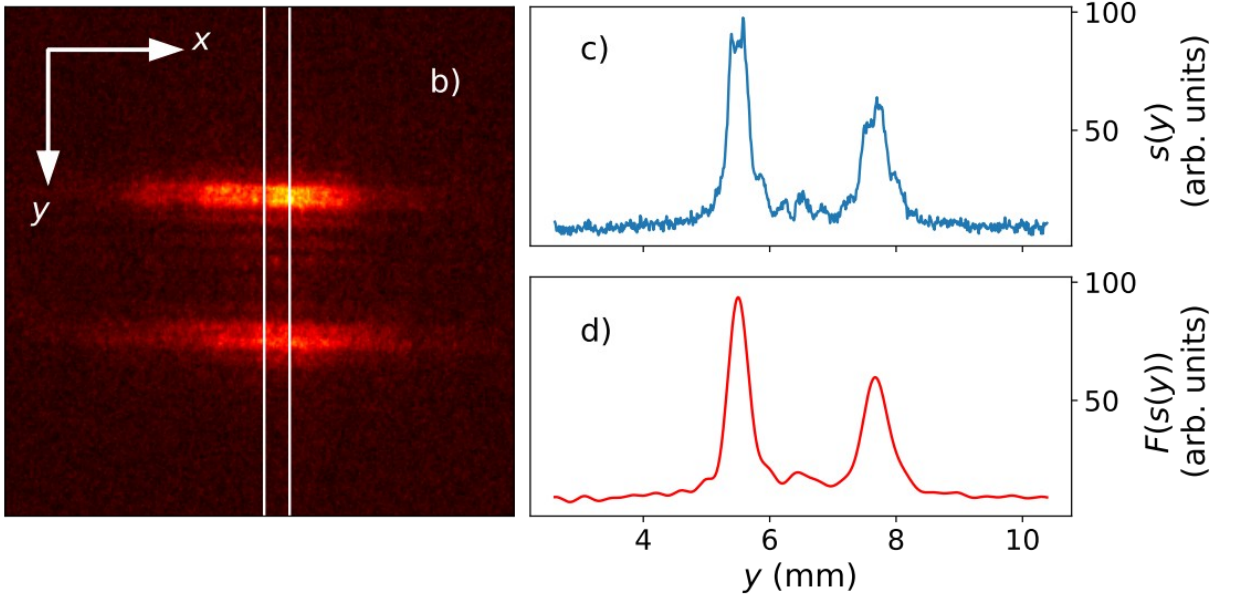
$W(y_0, r_0, t_0)$

Simple functional dependence



Schlieren image evaluation:

- Obtain lineout
- Frequency filter
- Peak finding



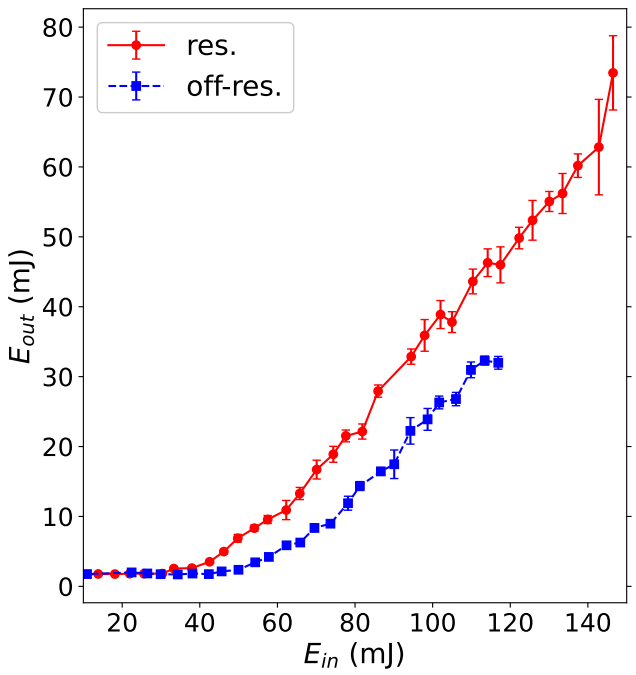
Derive y_{mean}, Δ, W → y_0, r_0, t_0 can be estimated

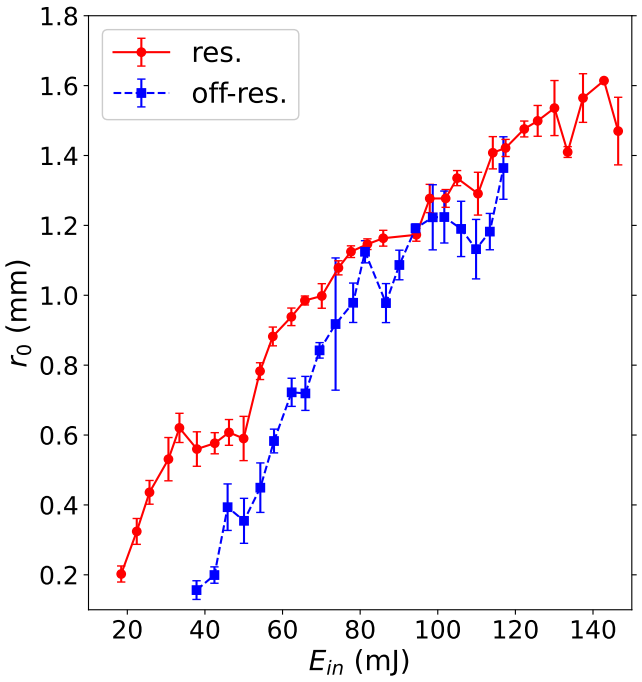
More precisely: we can associate the set {y_0, r_0, t_0} with the image.

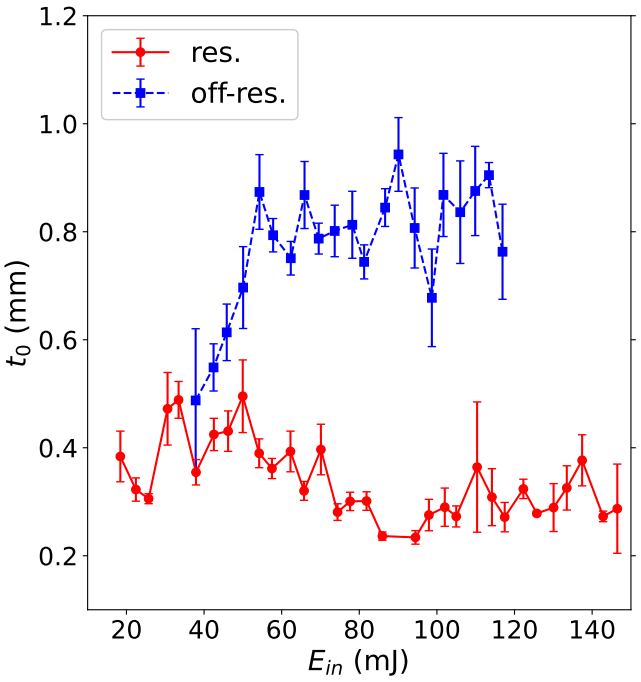
Note that we don't estimate P_{max} now ...

Sample results

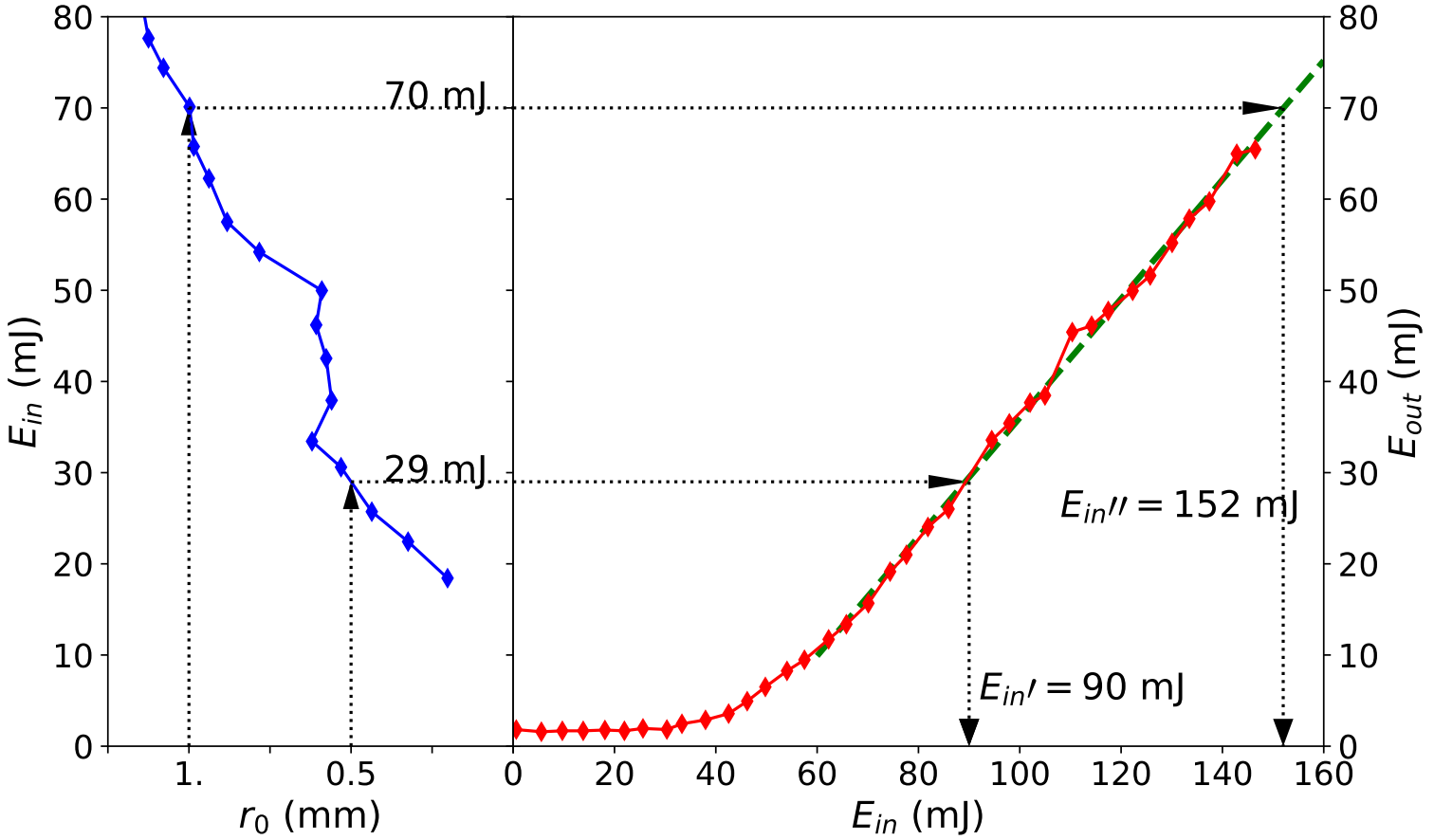
Propagation measurements with on-resonant (780 nm) and off-resonant (810 nm) ionizing pulses.







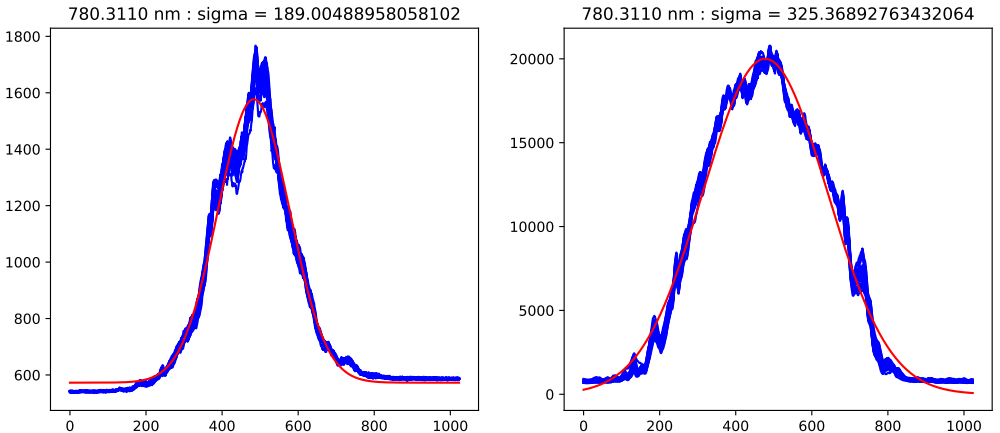
Estimating required pulse energy for 20 m column



• Discussion: Probe beam quality & parameters

Compared experiment to simulated measurement →probe parameters are important!

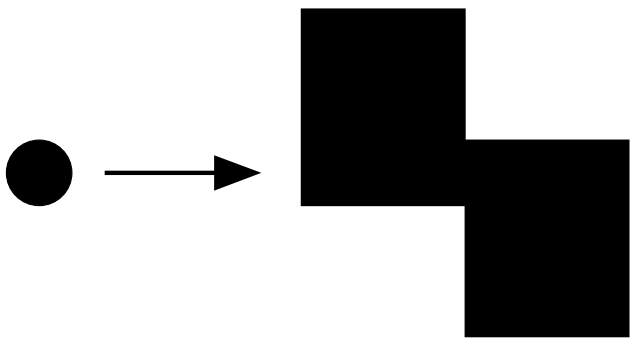
- Gaussian beam? Beam location / amplitude / width? – GC images without mask



- Probe wavelength? – refractive index vs. absorption – collision broadening dominant for $N = 10^{14} – 10^{15}$ density!
- Mask size? – beam quality, placing accuracy, signal amplitude, filtering limit

Discussion: possible improvements

- Independent beam profiling, monitoring – a ‘virtual line’
- Probe power monitoring
- Smaller mask on translation stage, precision movement – higher signal amplitude, signal filtering less distorting.
- Probe wavelength: “ideal” wavelength is different for each density!
- Plasma column constant along *x* direction of view. Cylindrical optics? Focal line + double knife-edge mask



Summary

- Schlieren imaging yields important information on the plasma profile
- Can be made more reliable / accurate with sensible improvements
- Perhaps applicable to other plasma sources at AWAKE?

Thank you for the attention!