



A Quantum Gas Jet for Non-Invasive Beam Profile Measurement

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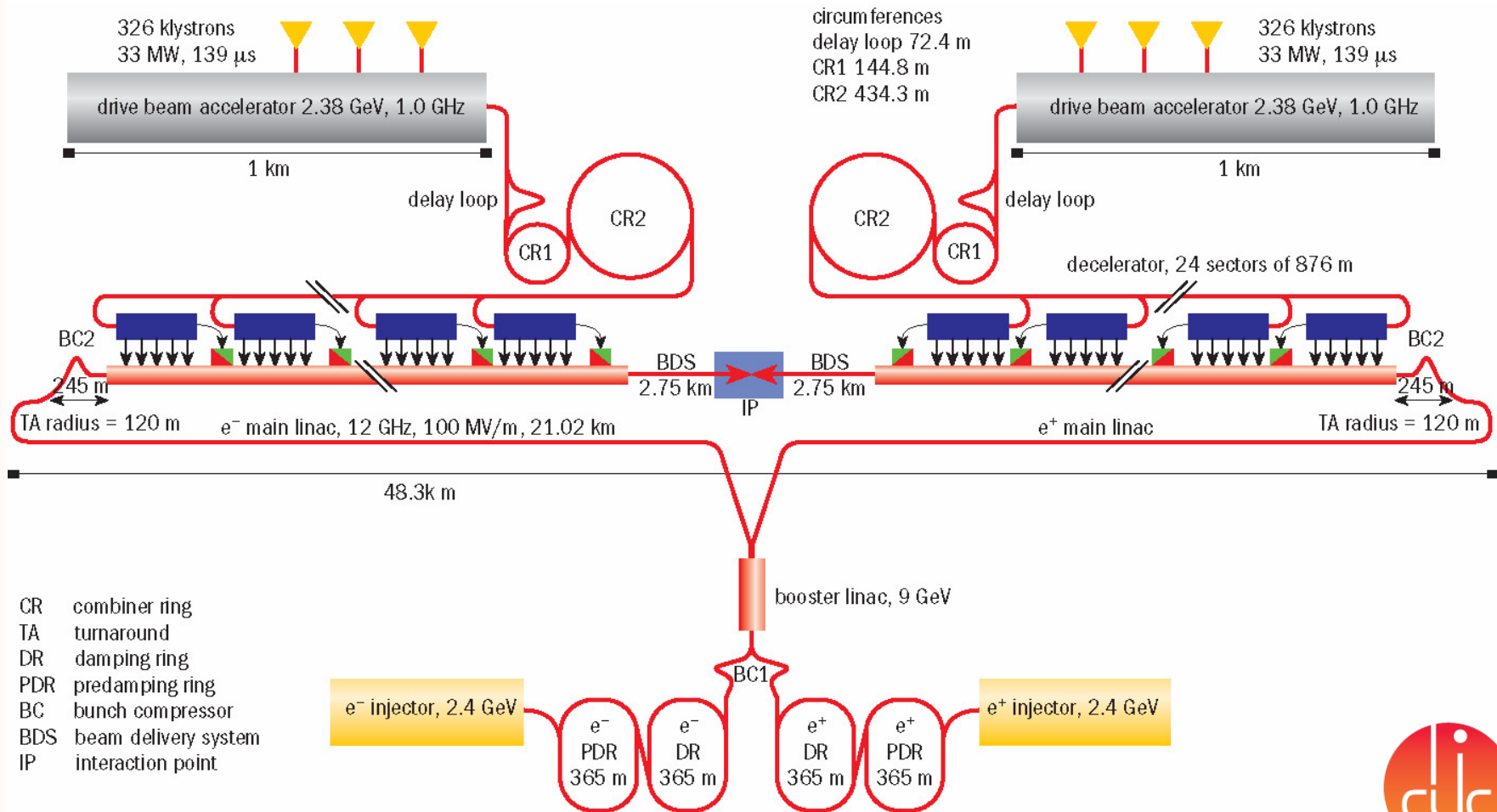


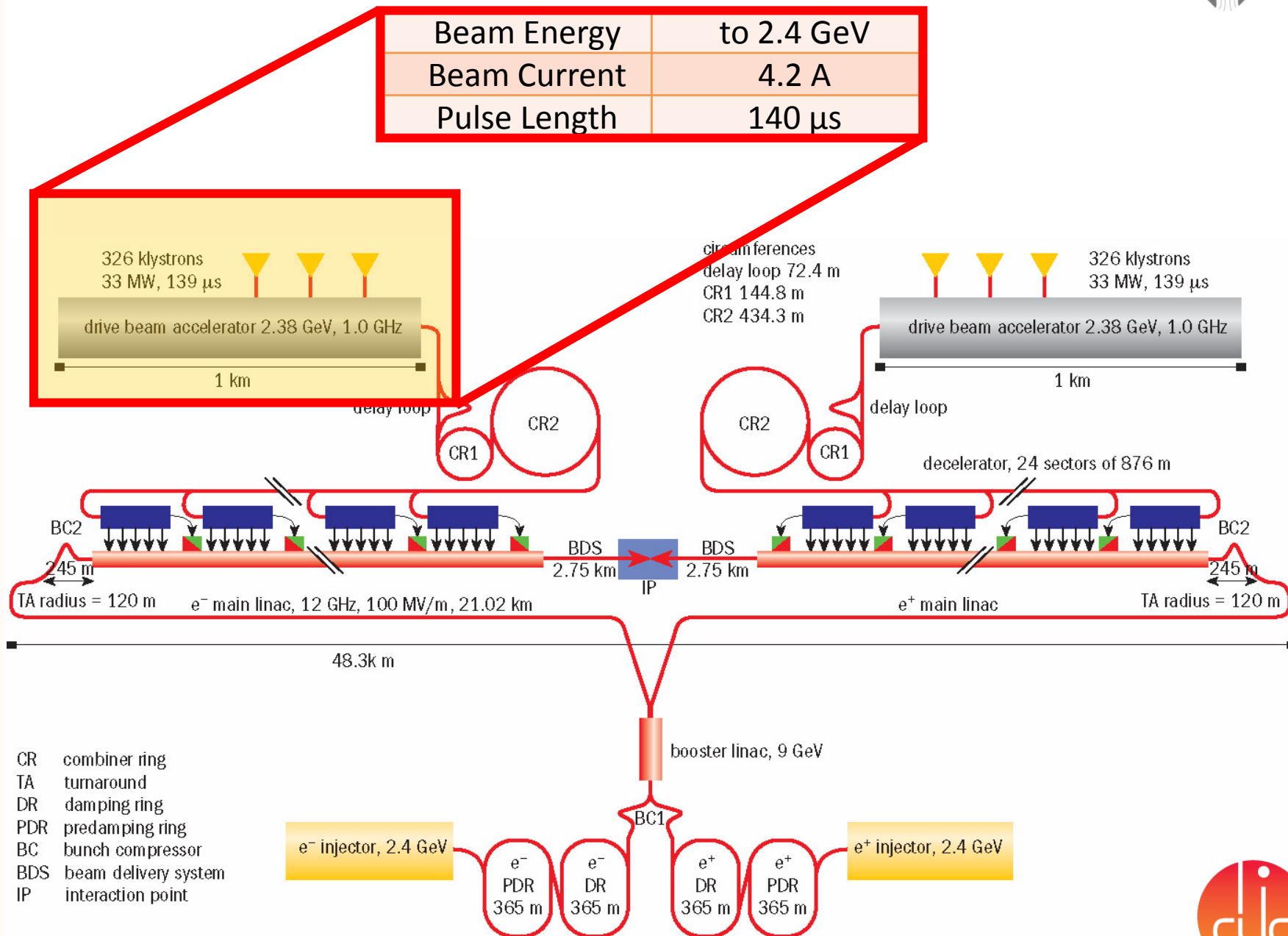
International Beam Instrumentation Conference
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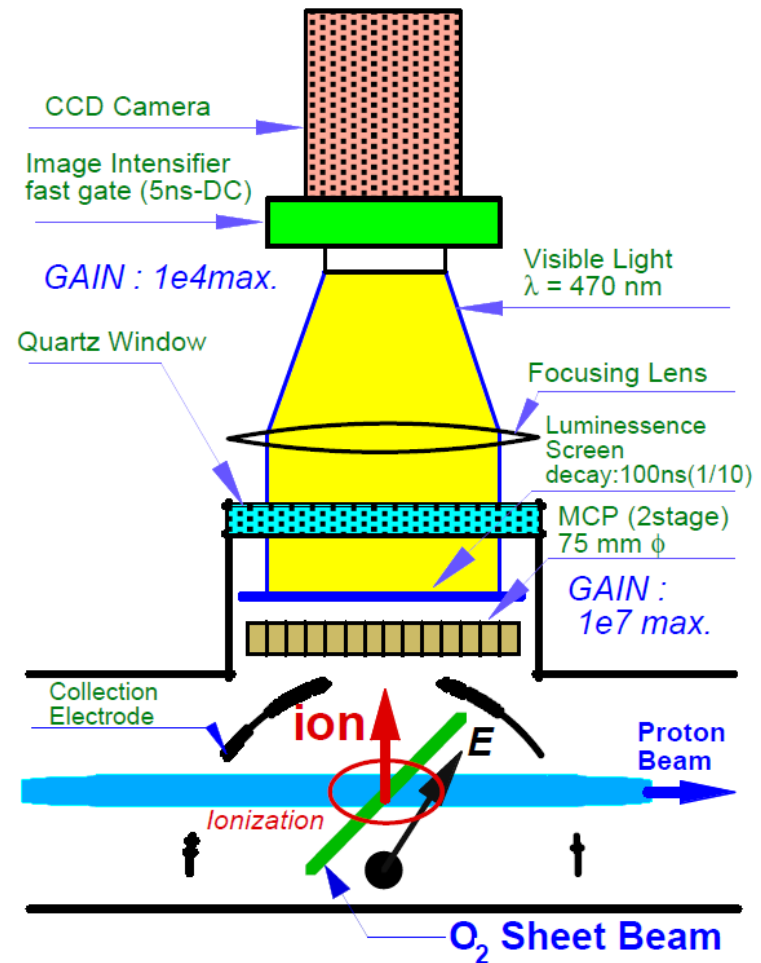
Contents

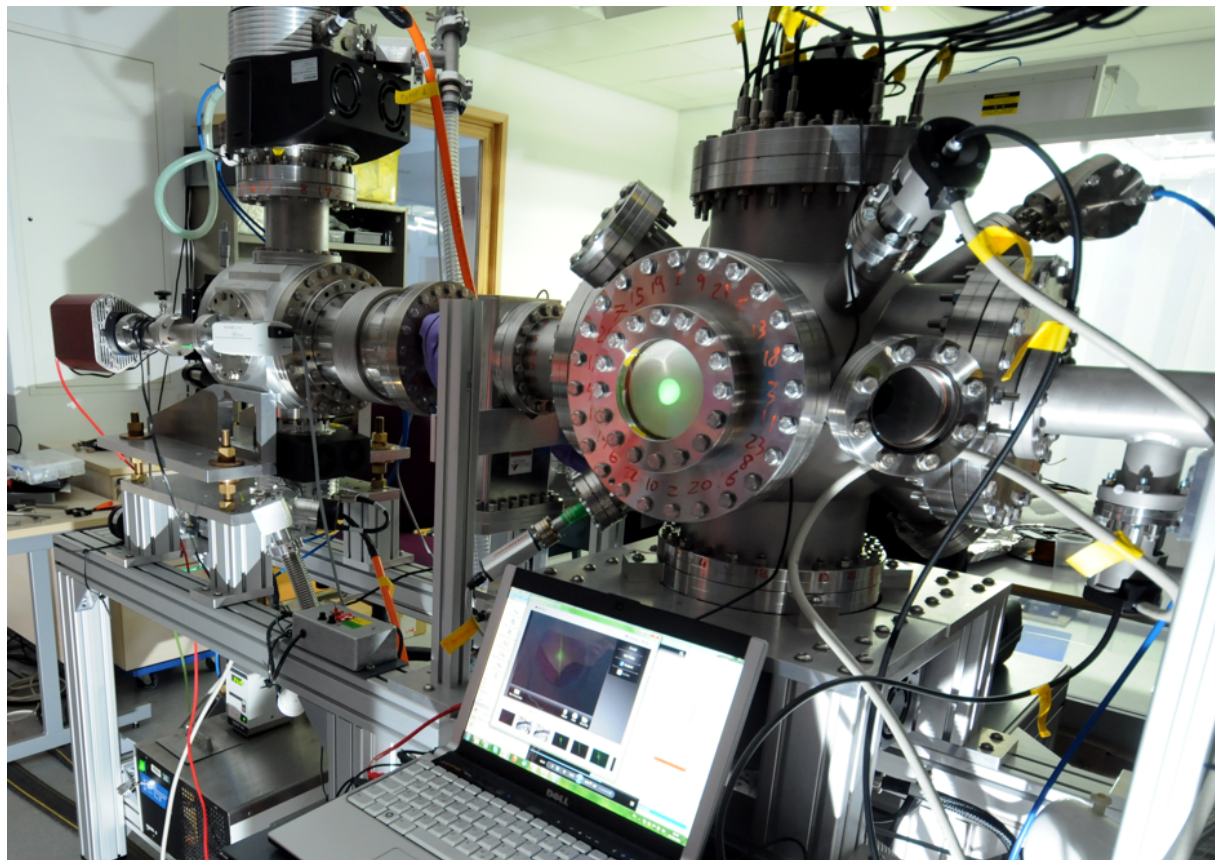
- The CLIC Drive Beam
- Jet monitor principle
- Jet generation & shaping
- Test Stand @ the Cockcroft Institute
- Experimental Results
- Quantum focusing
- Prospects (sieve)

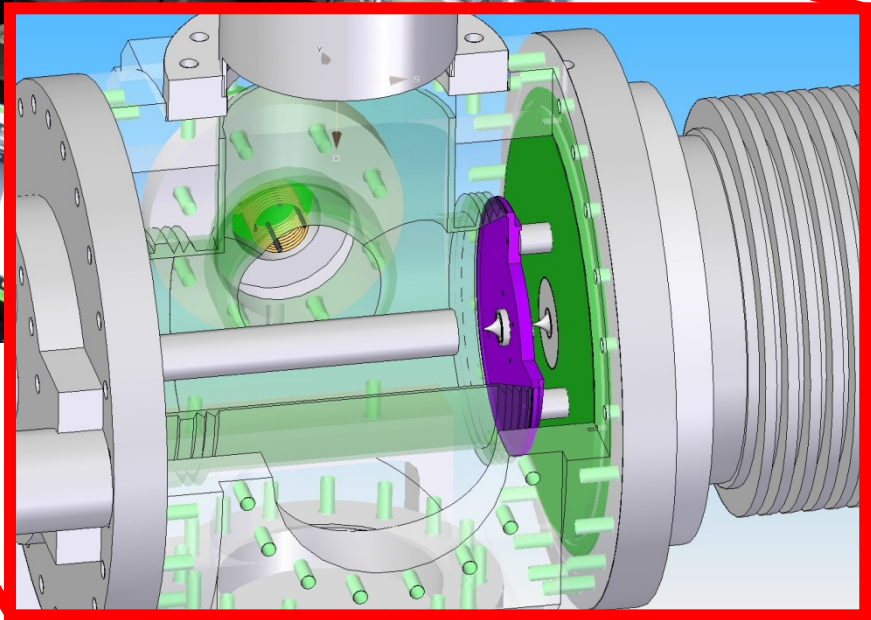
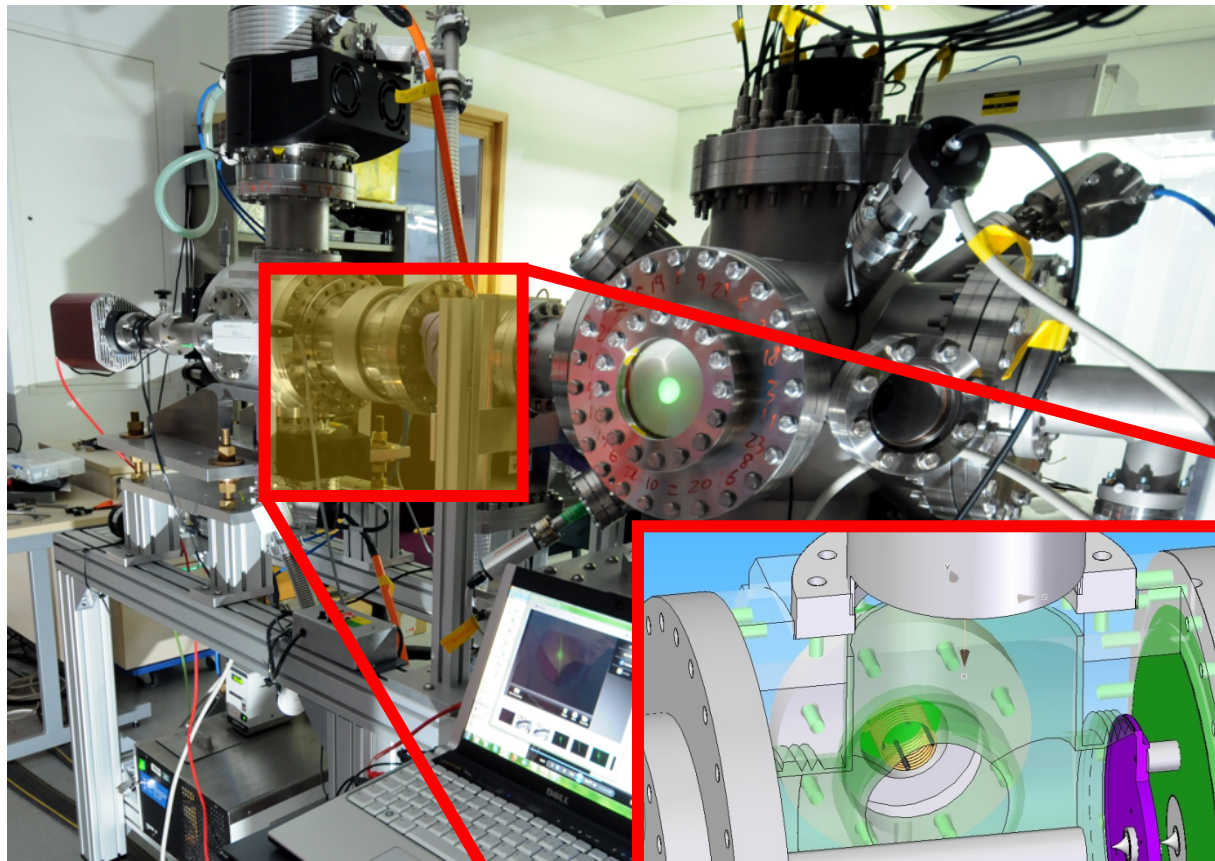




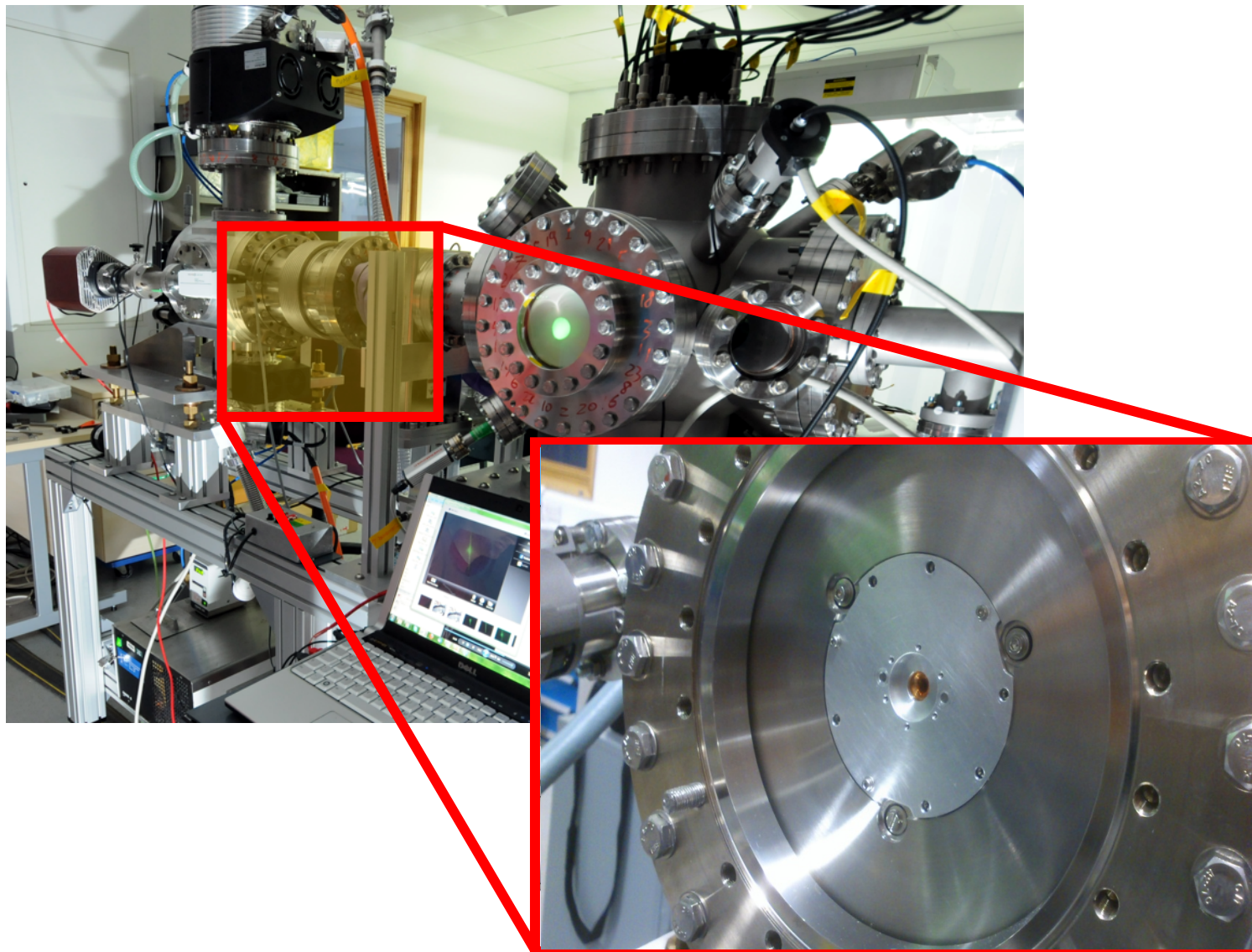
- Generate thin atom gas curtain,
- Ionize atoms with primary particle beam,
- Extract ions via electric field,
- Monitor on MCP, P screen.



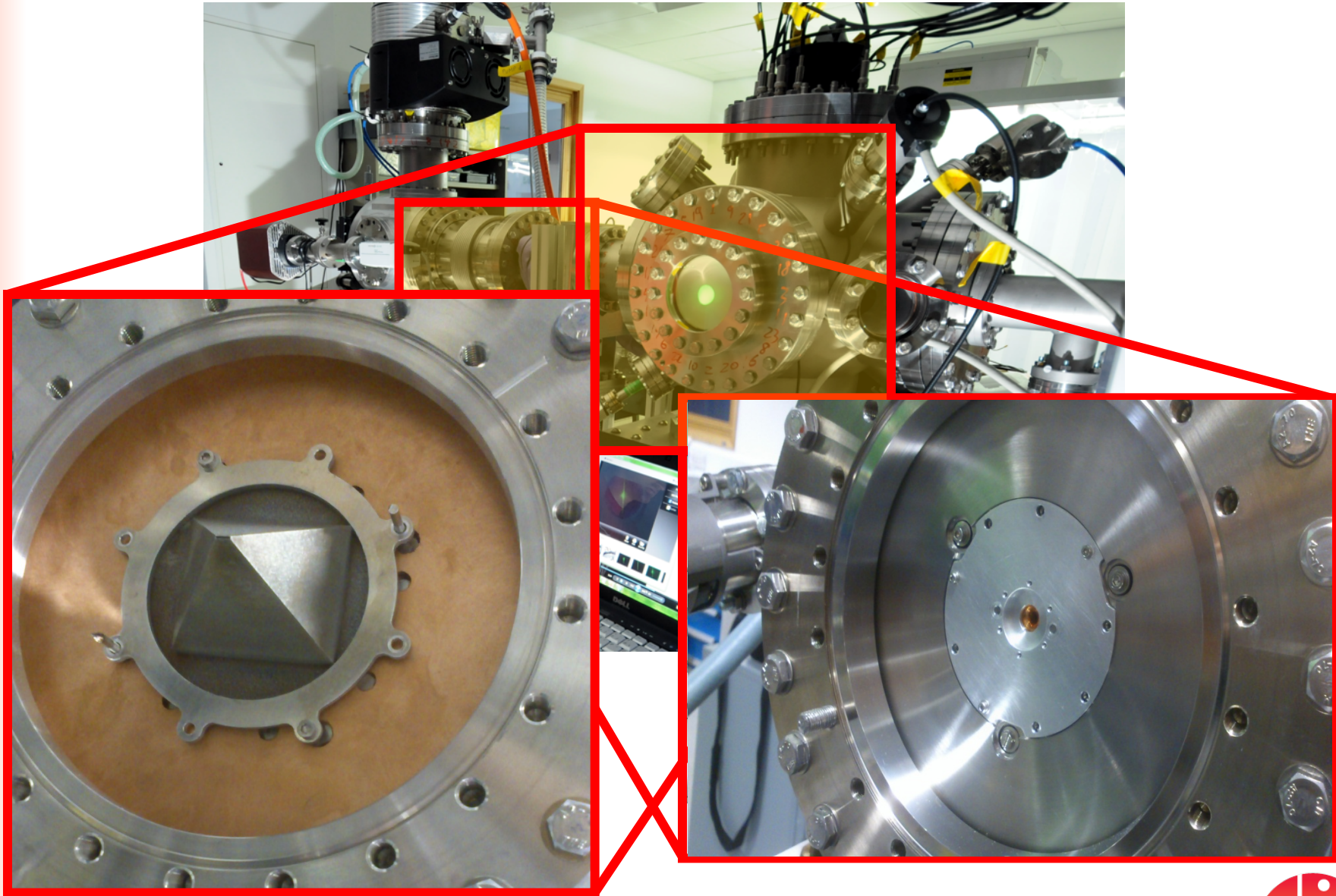




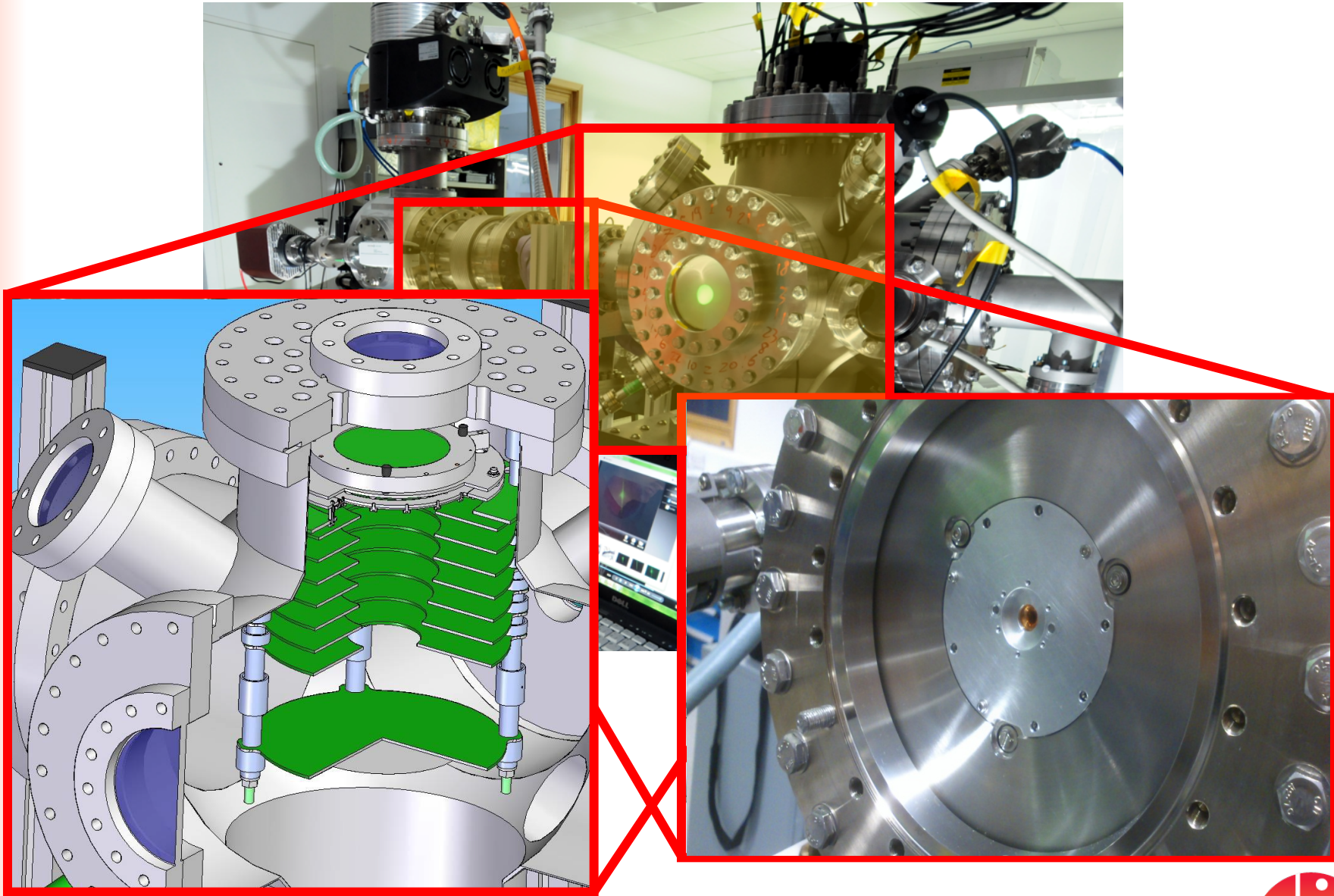
Thanks to M. Putignano



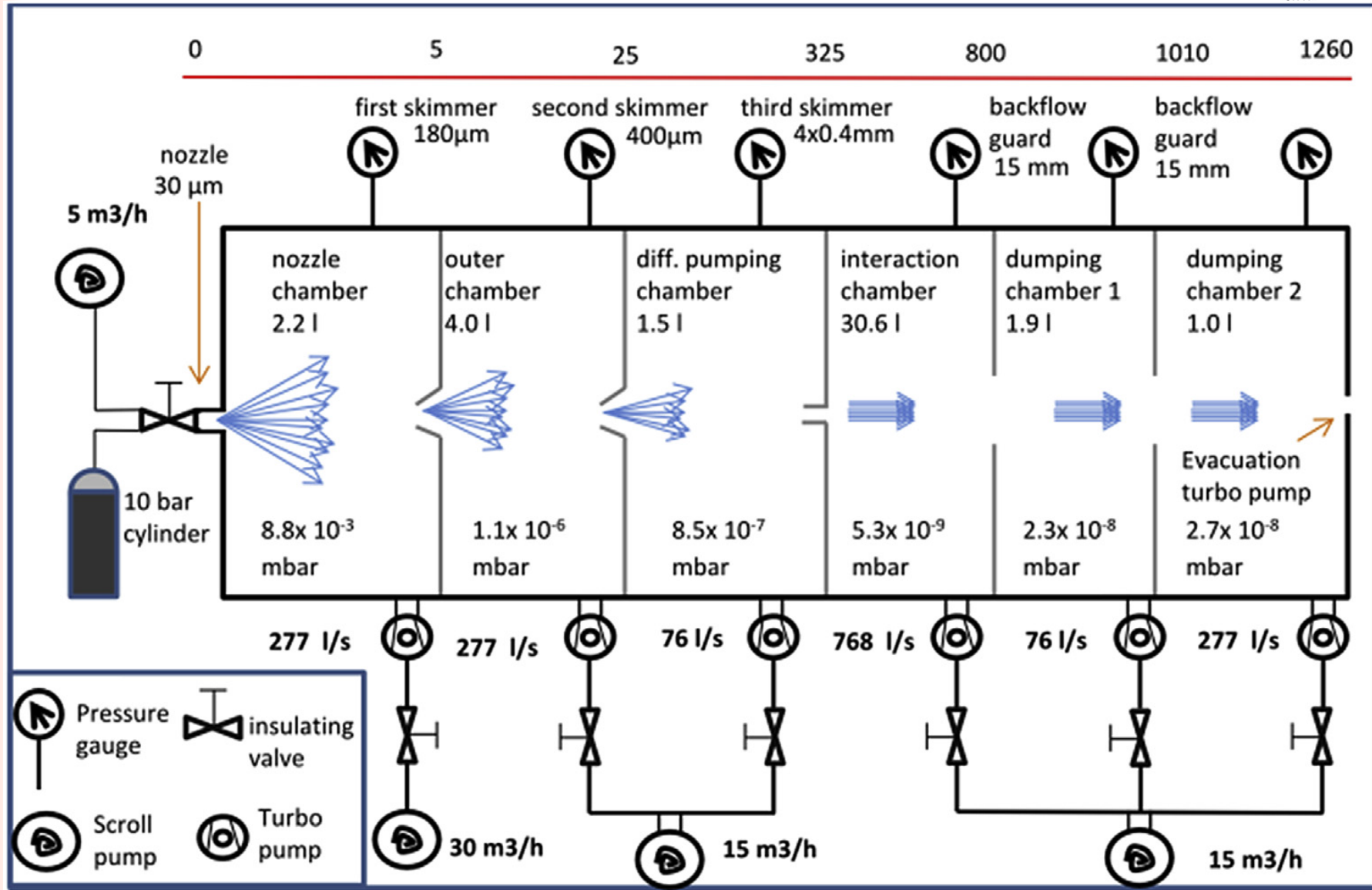
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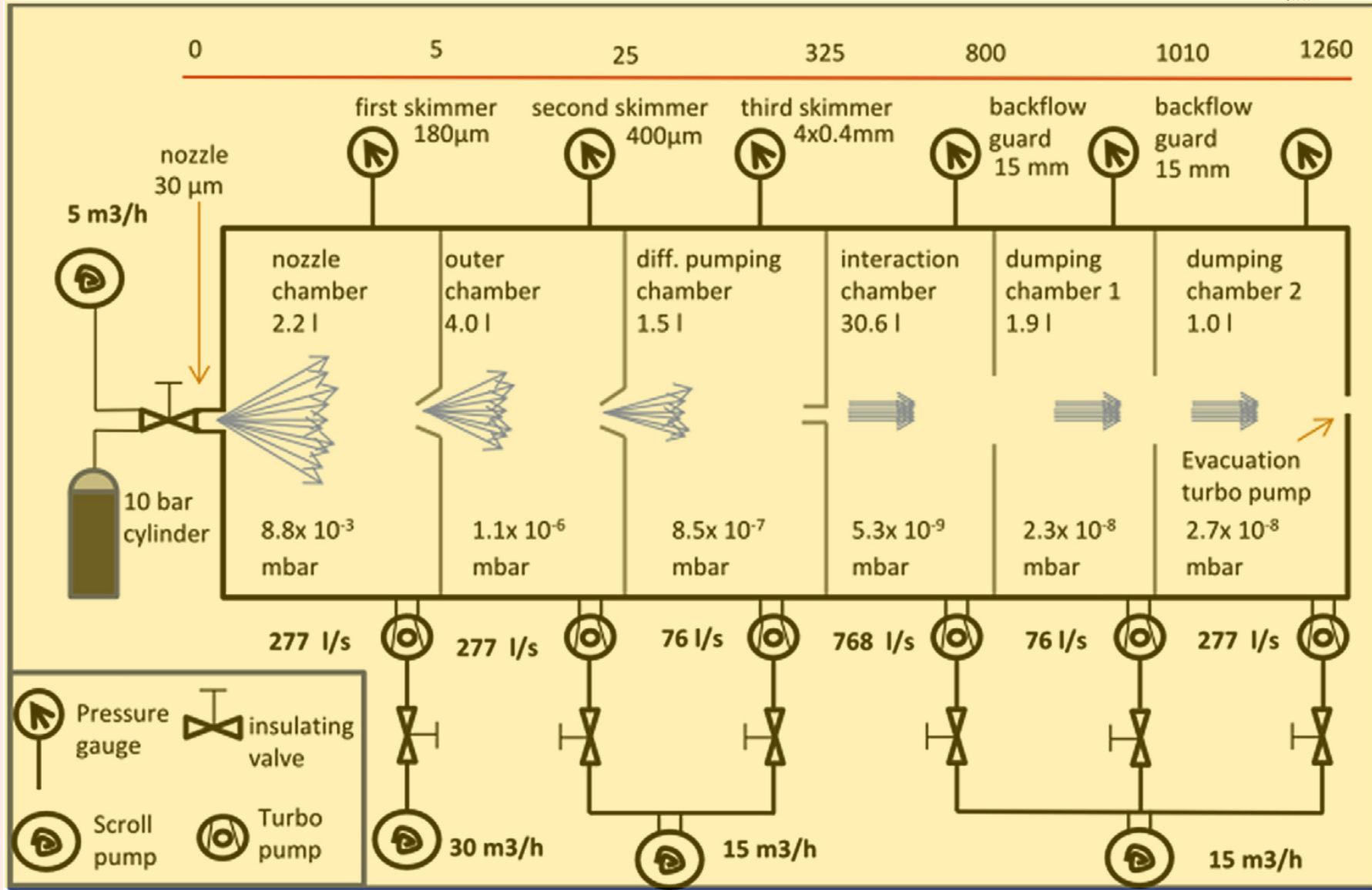


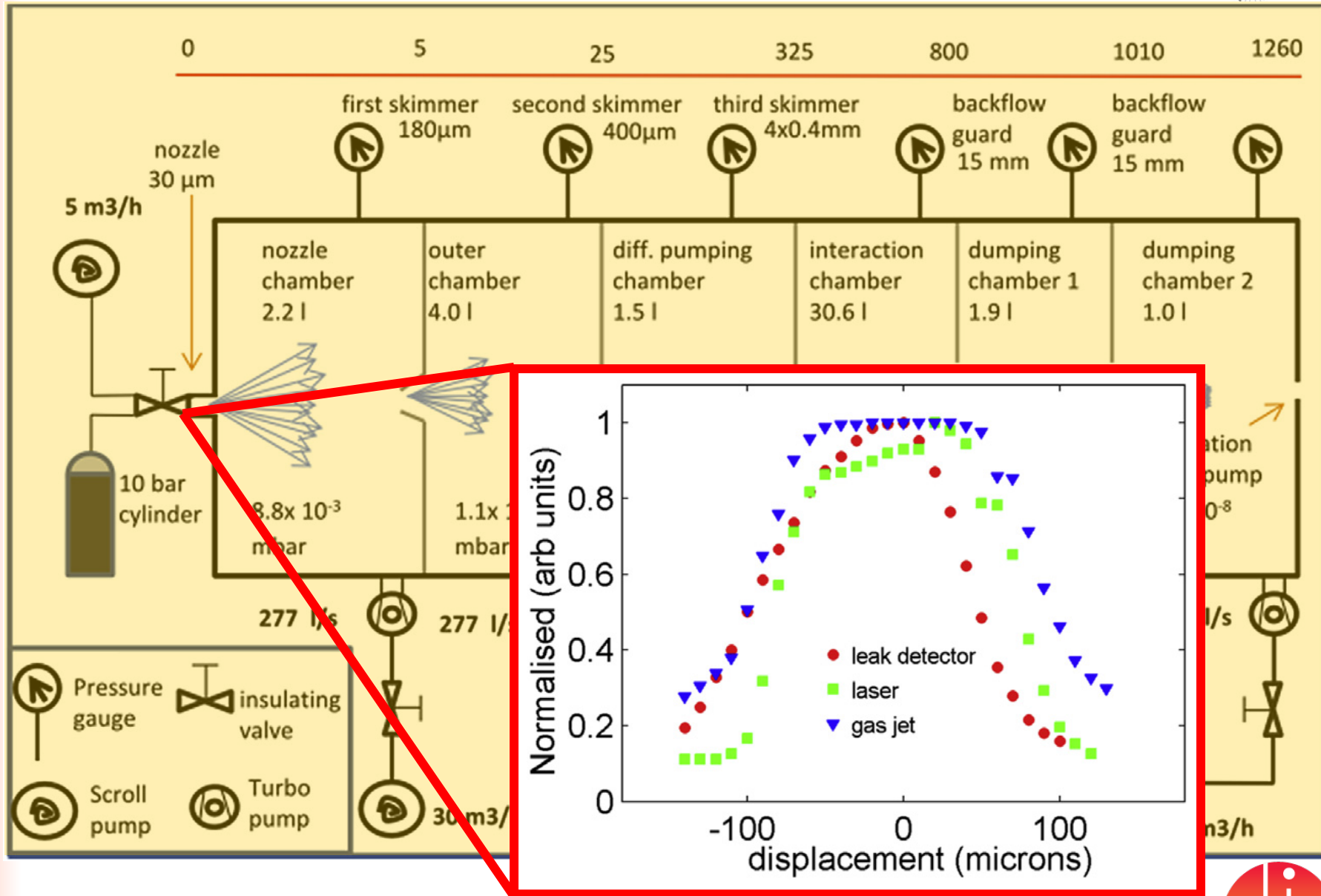
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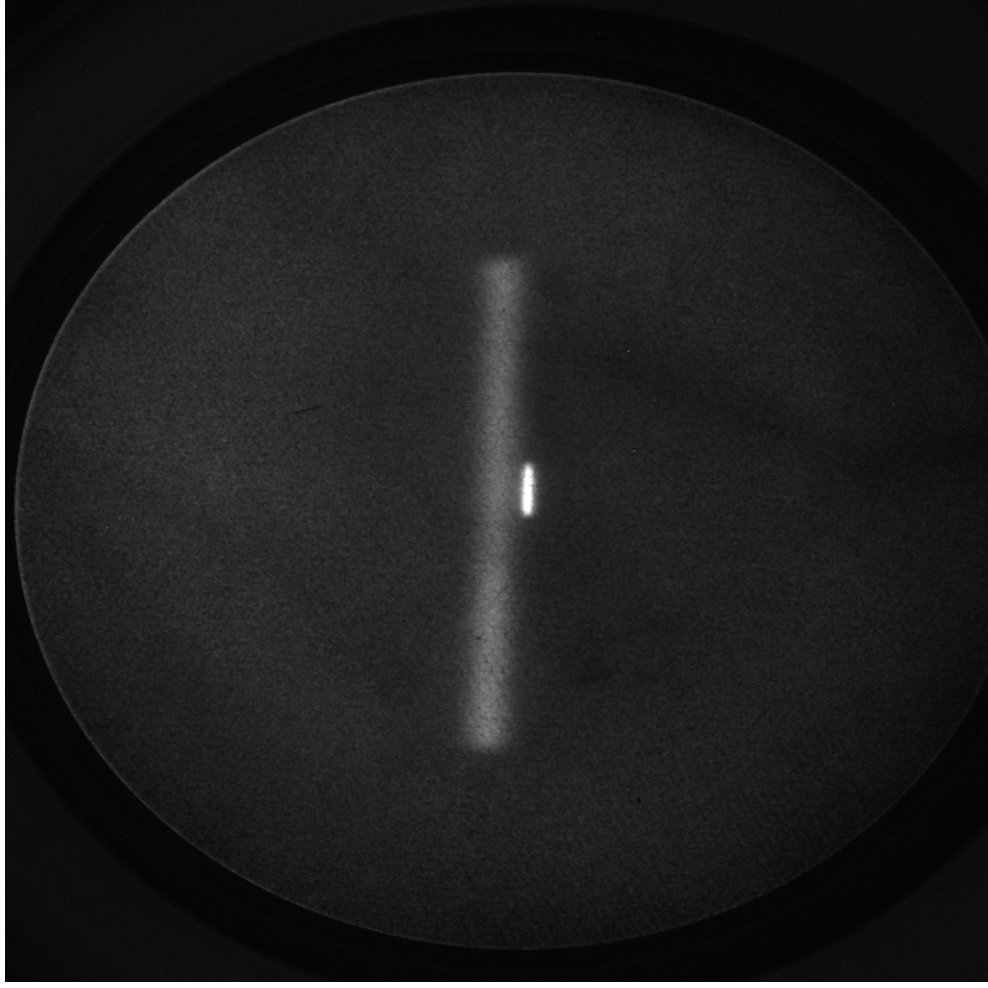


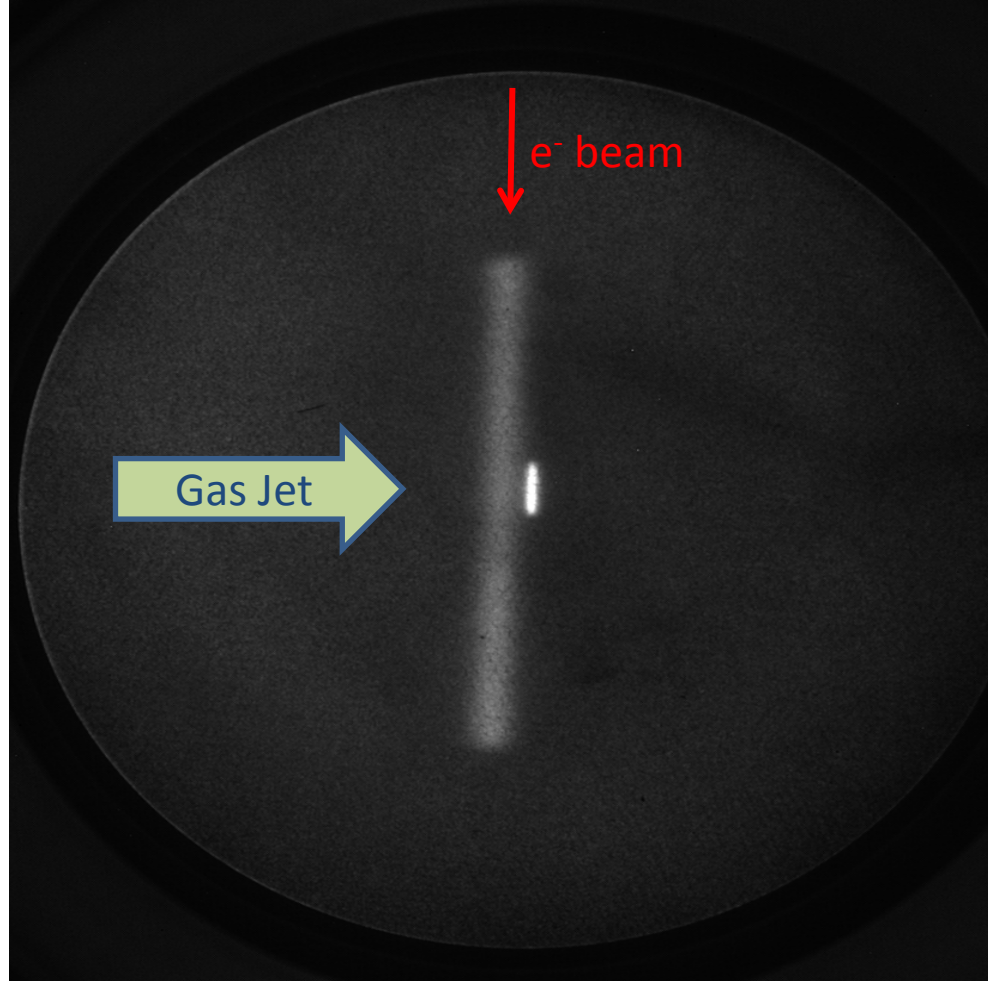
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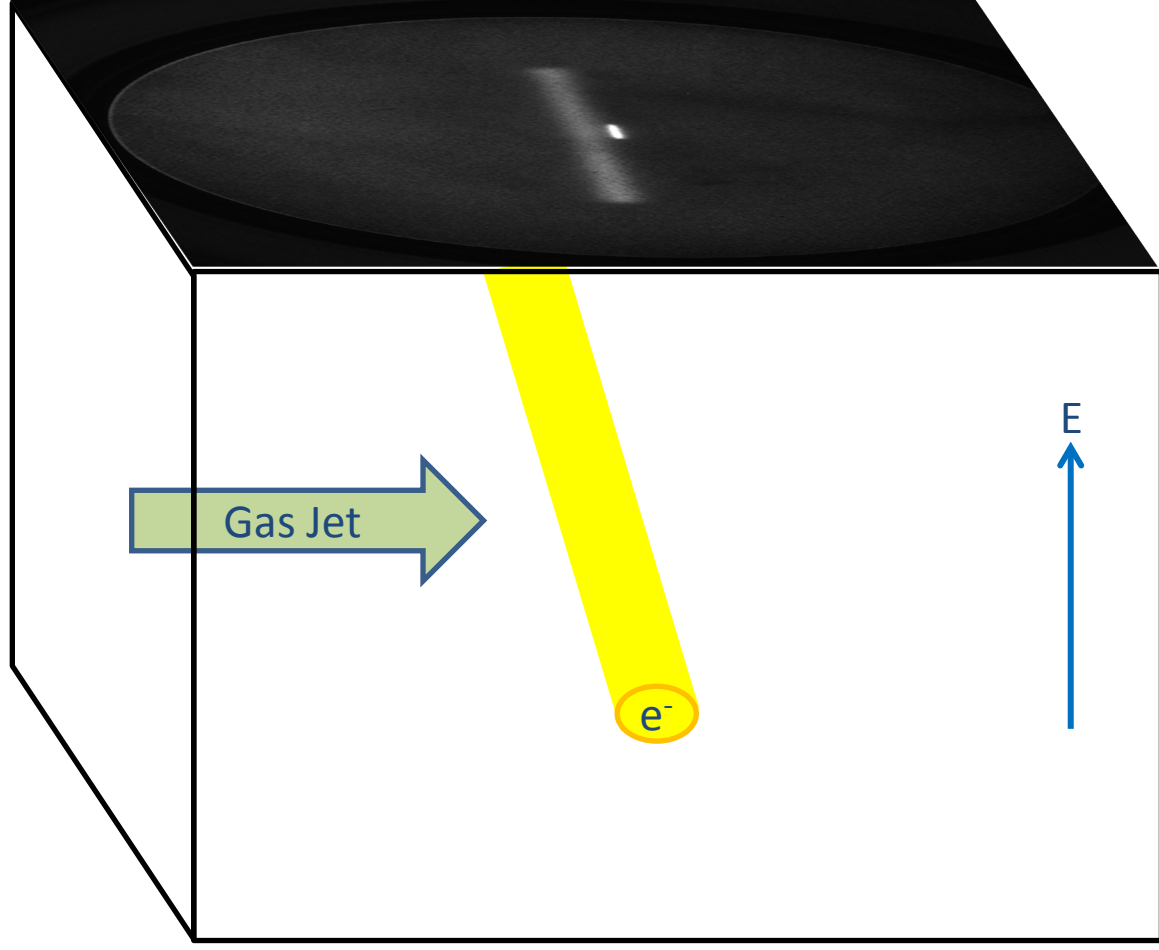


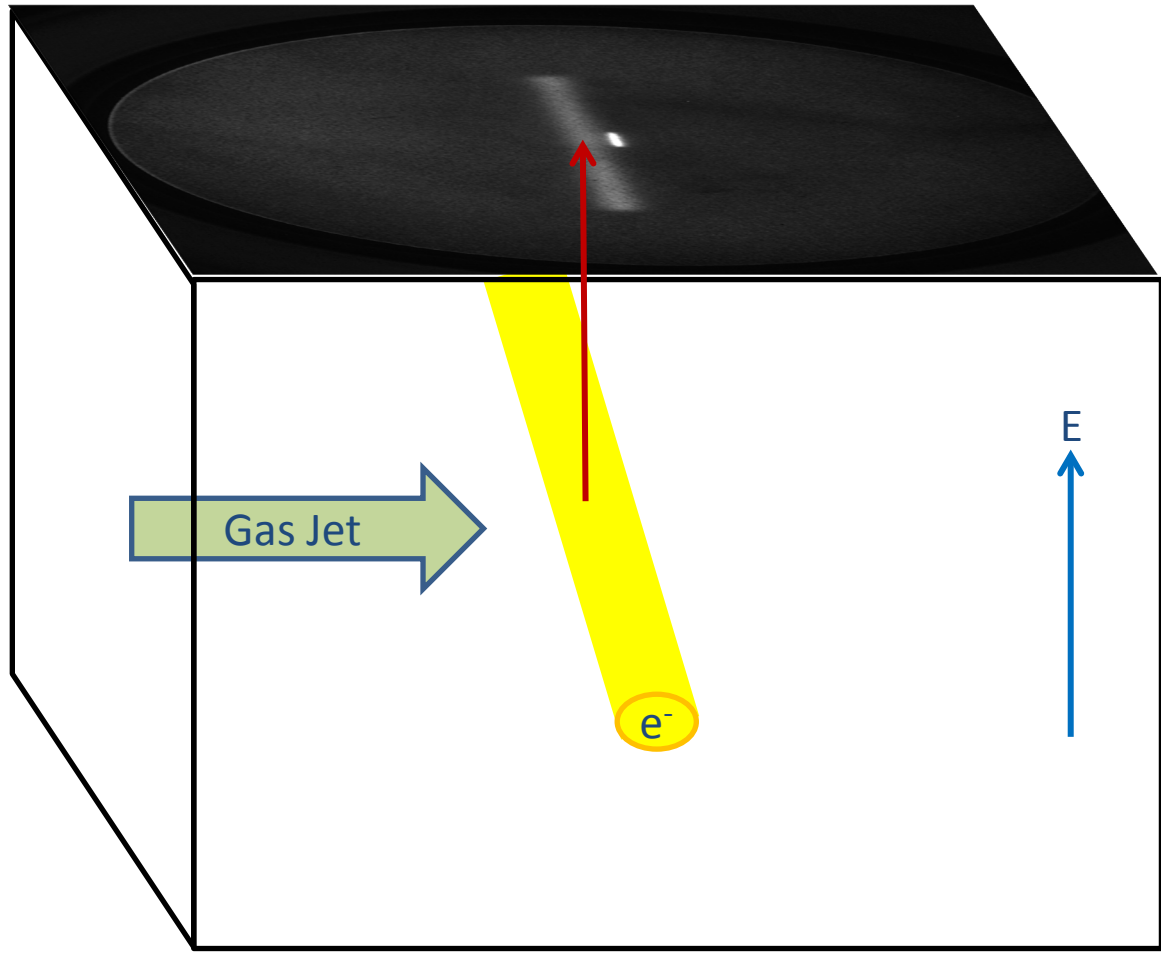


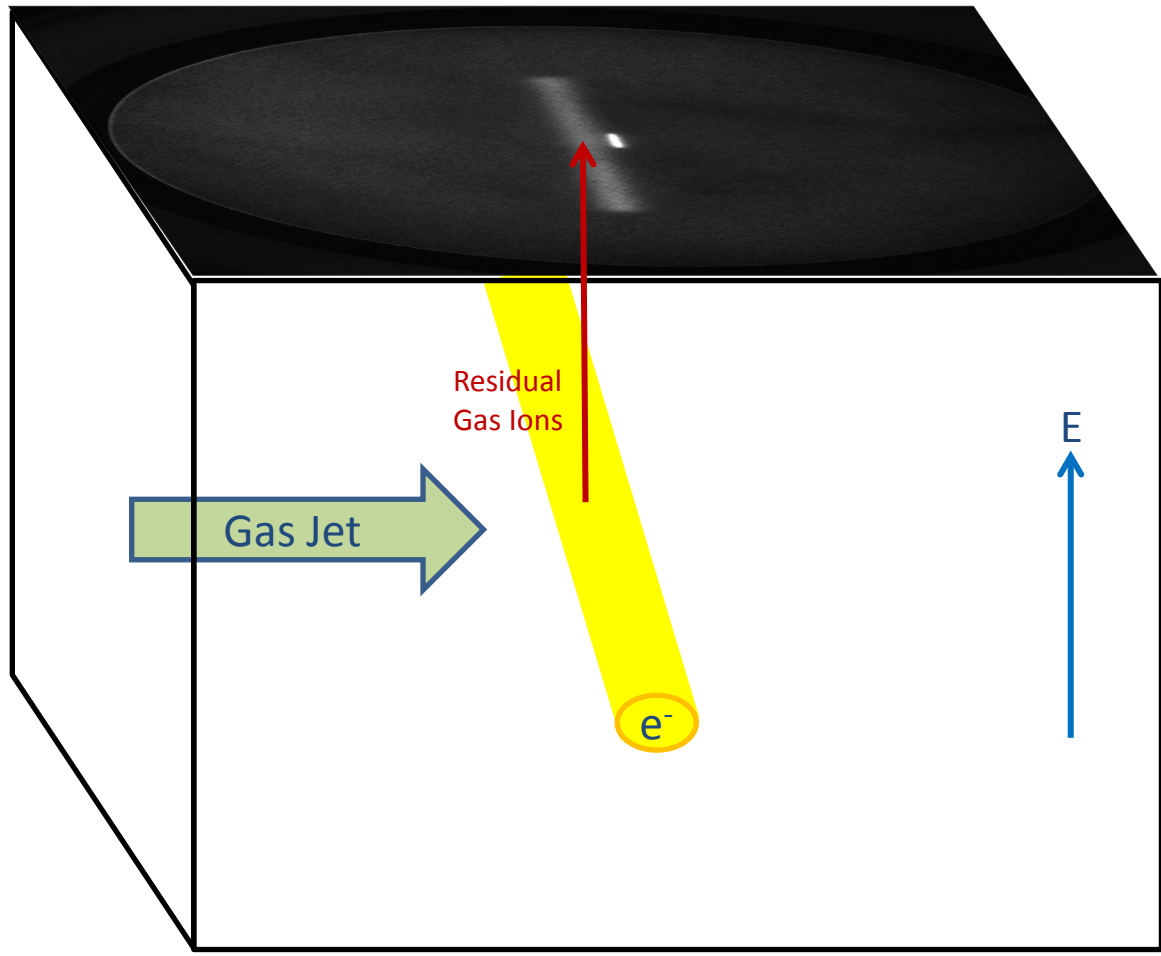


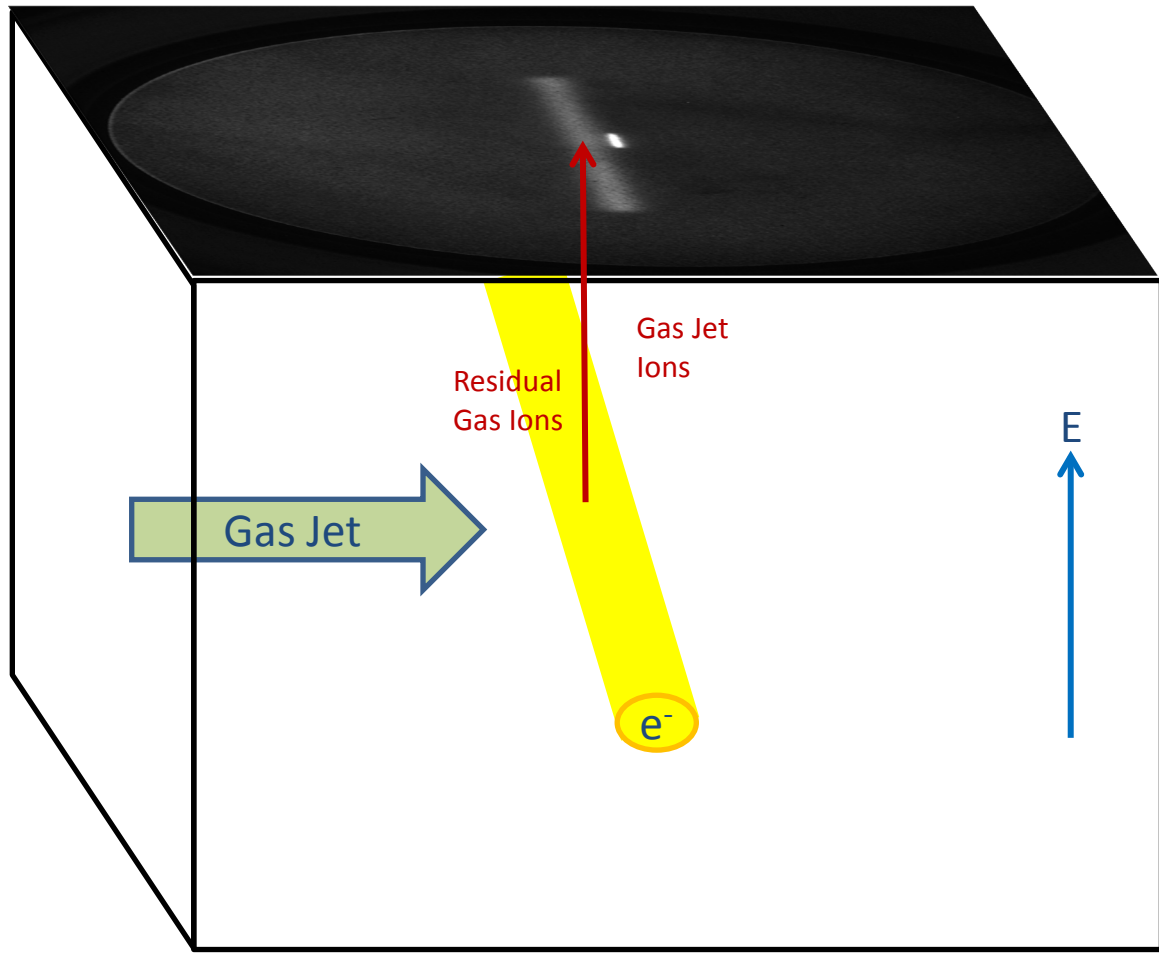


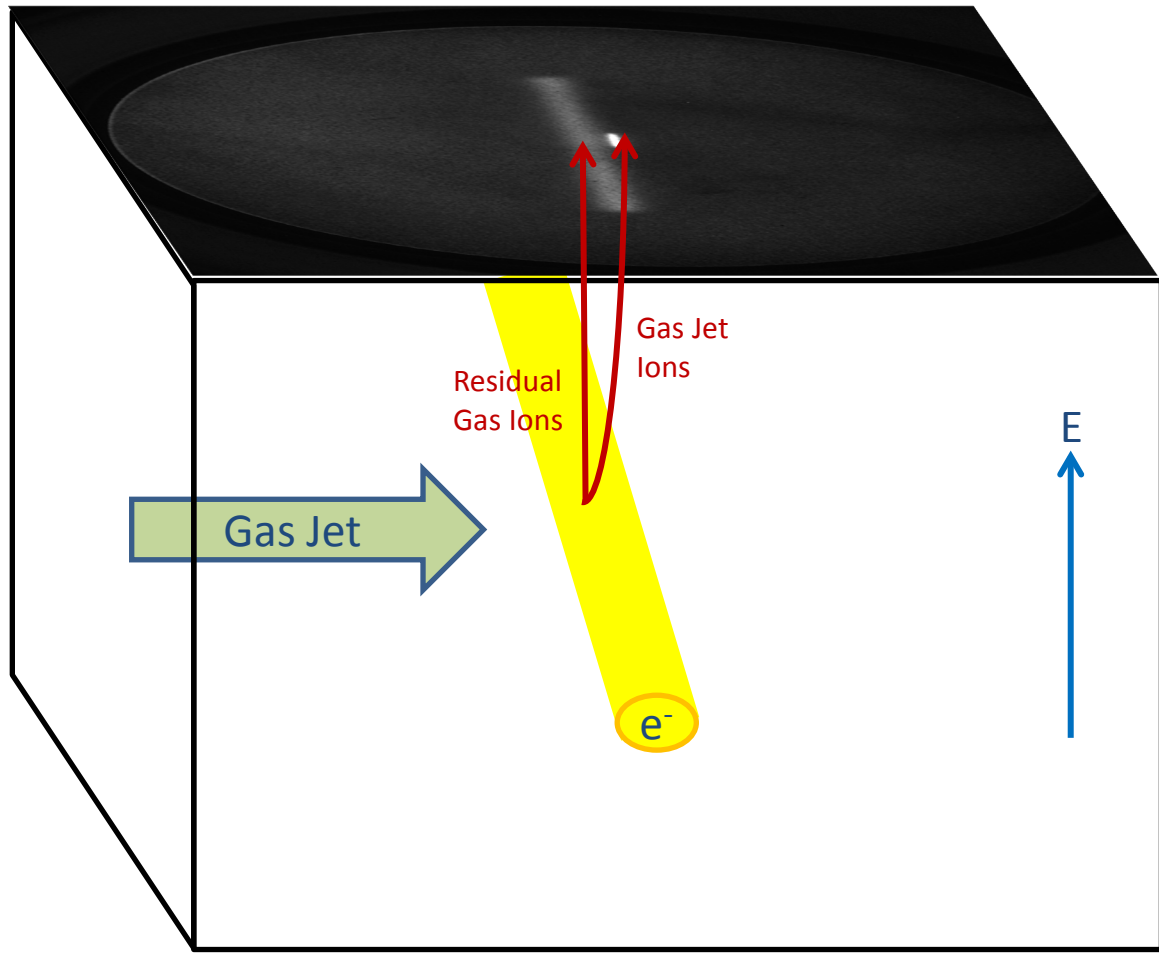


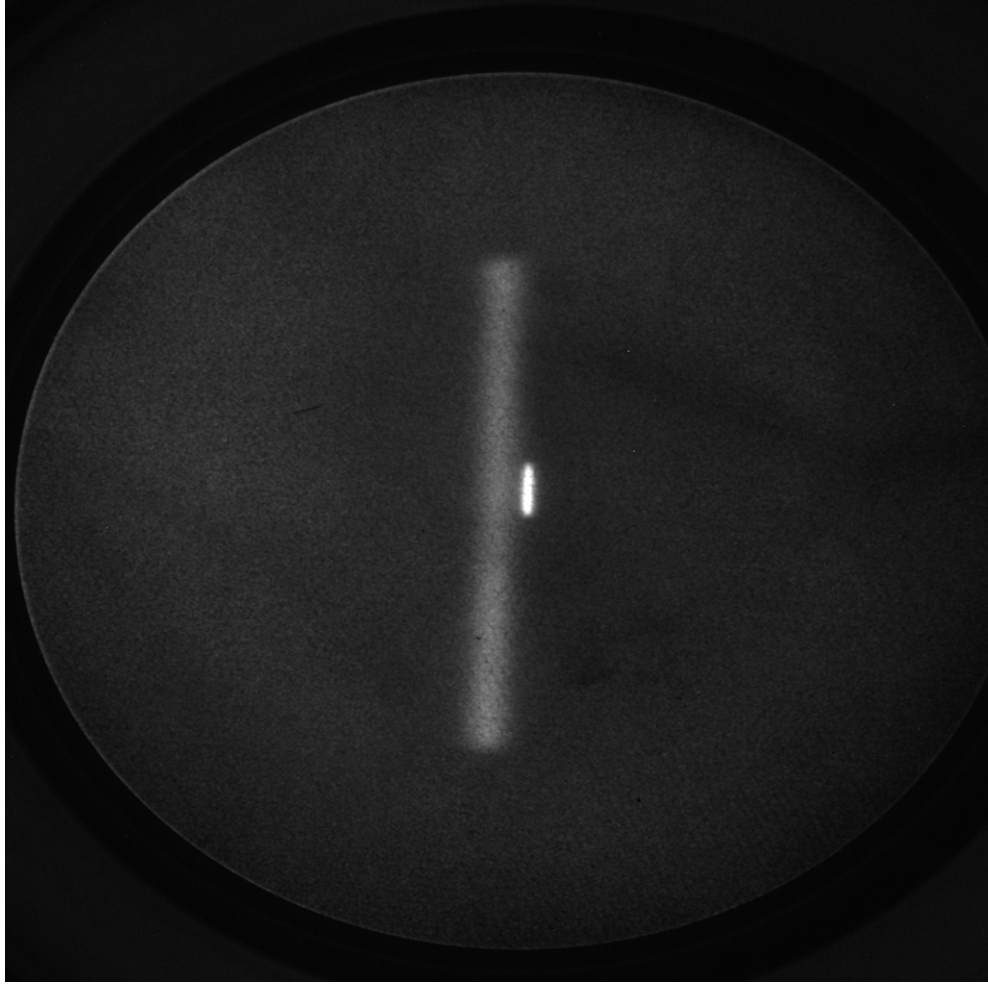


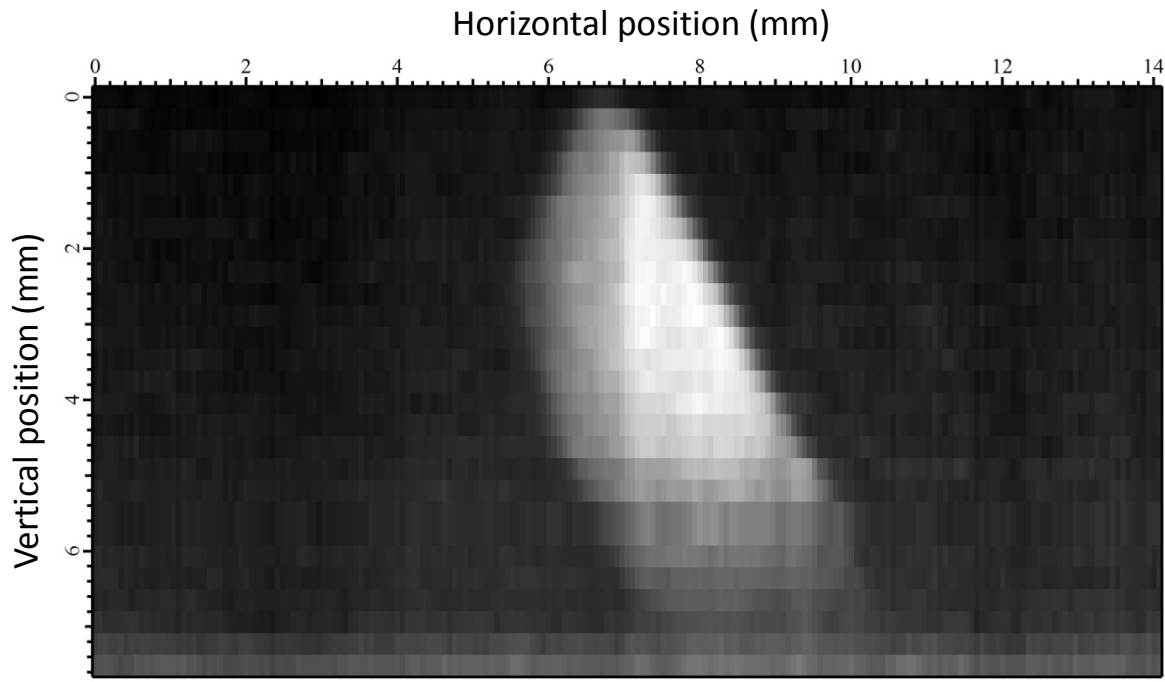




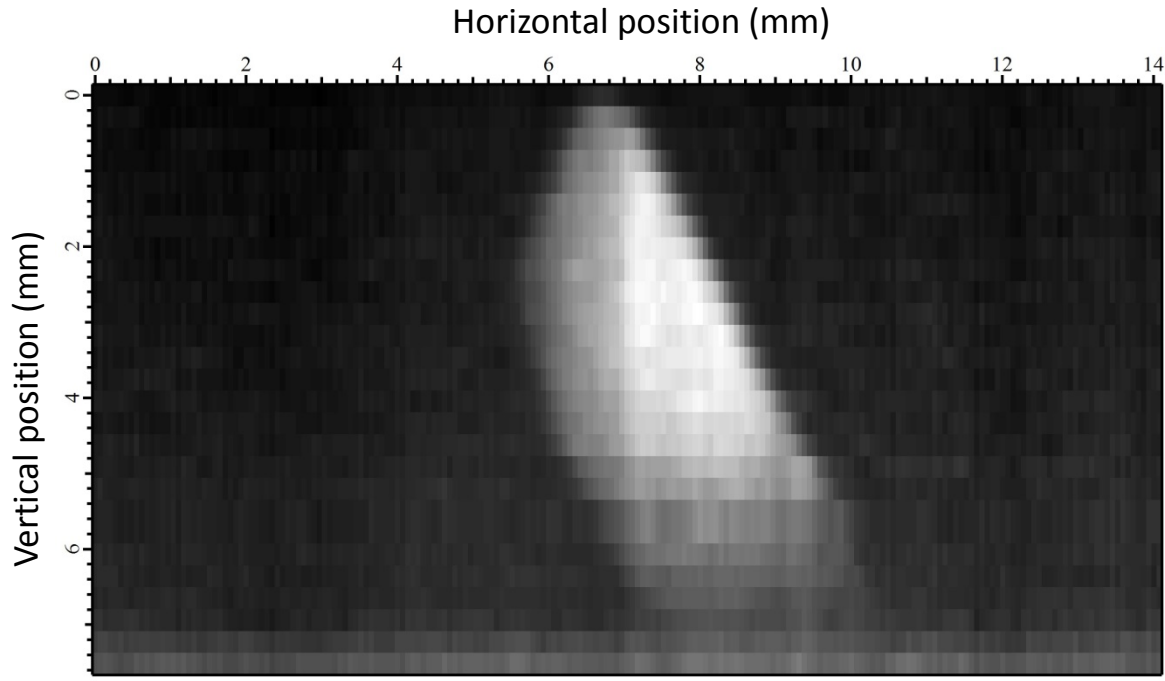




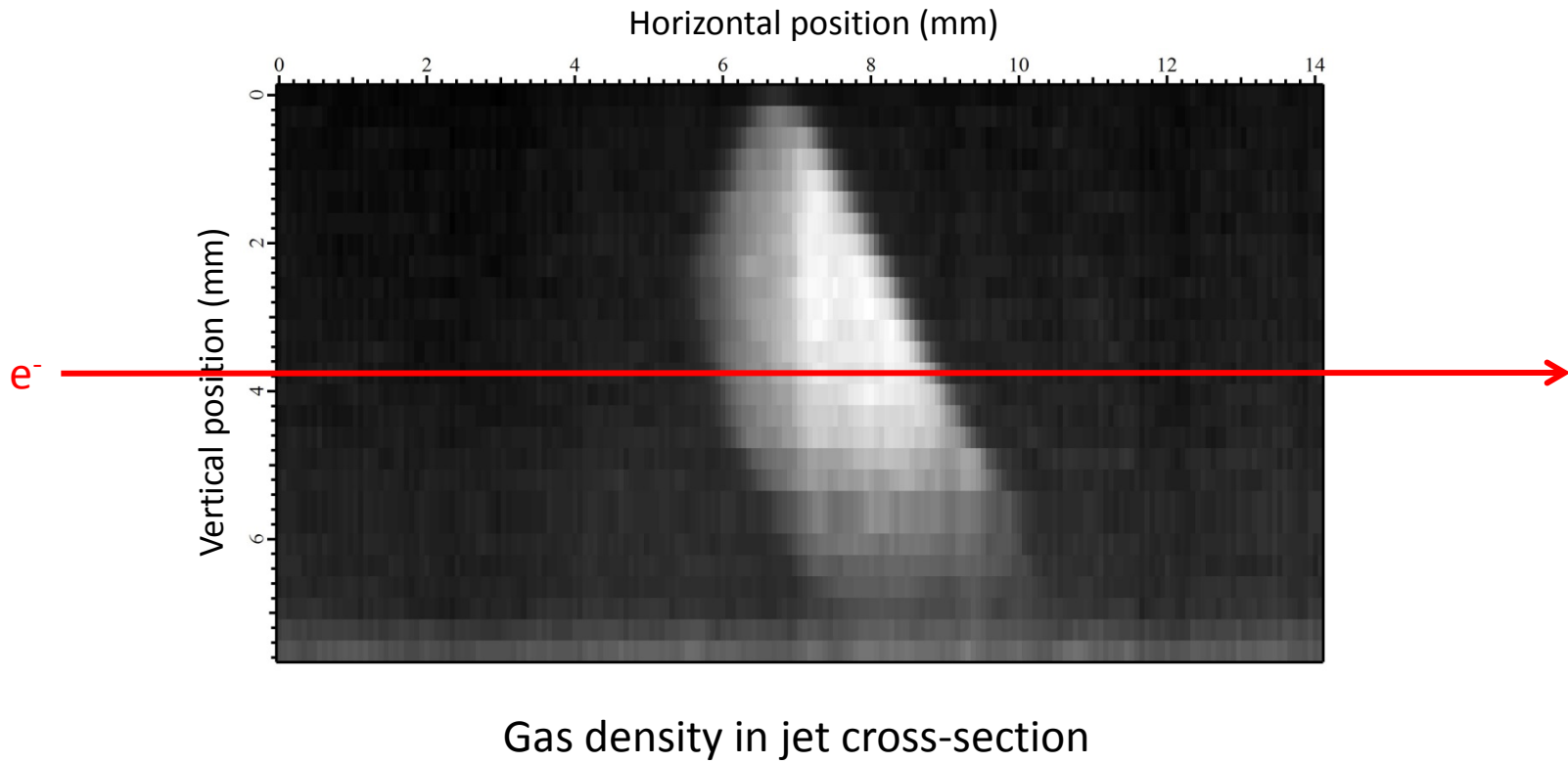


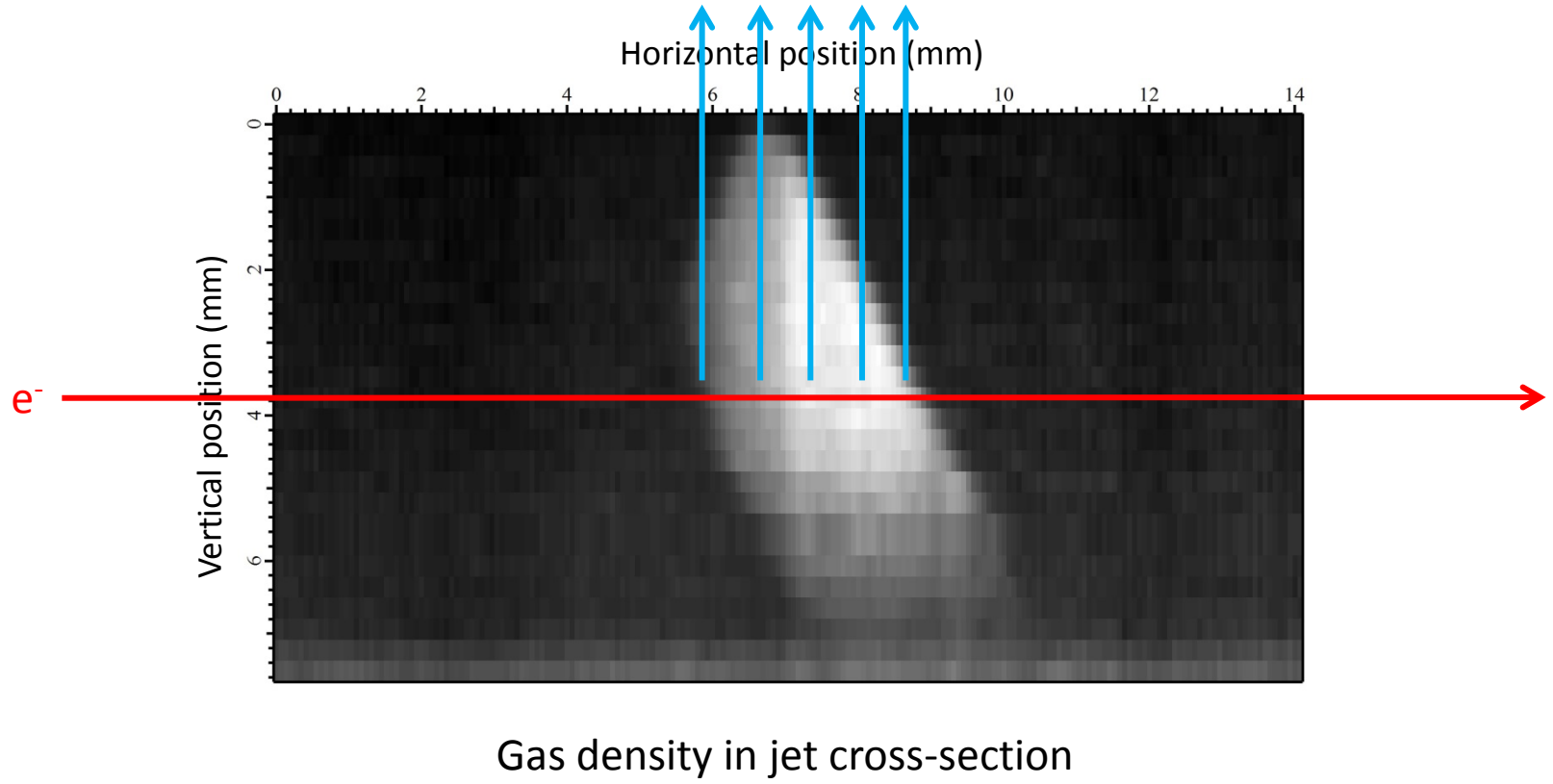


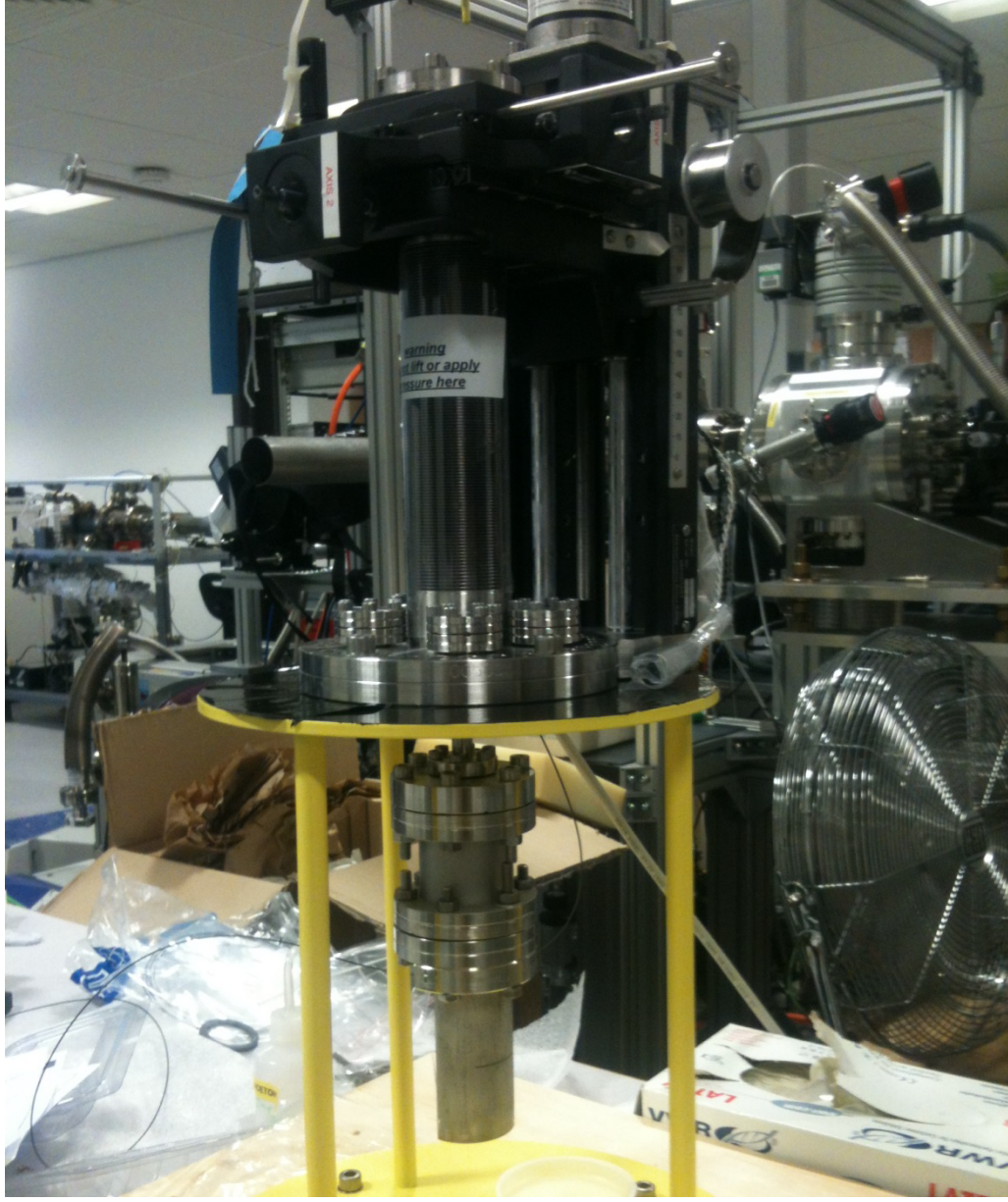
Gas density in jet cross-section

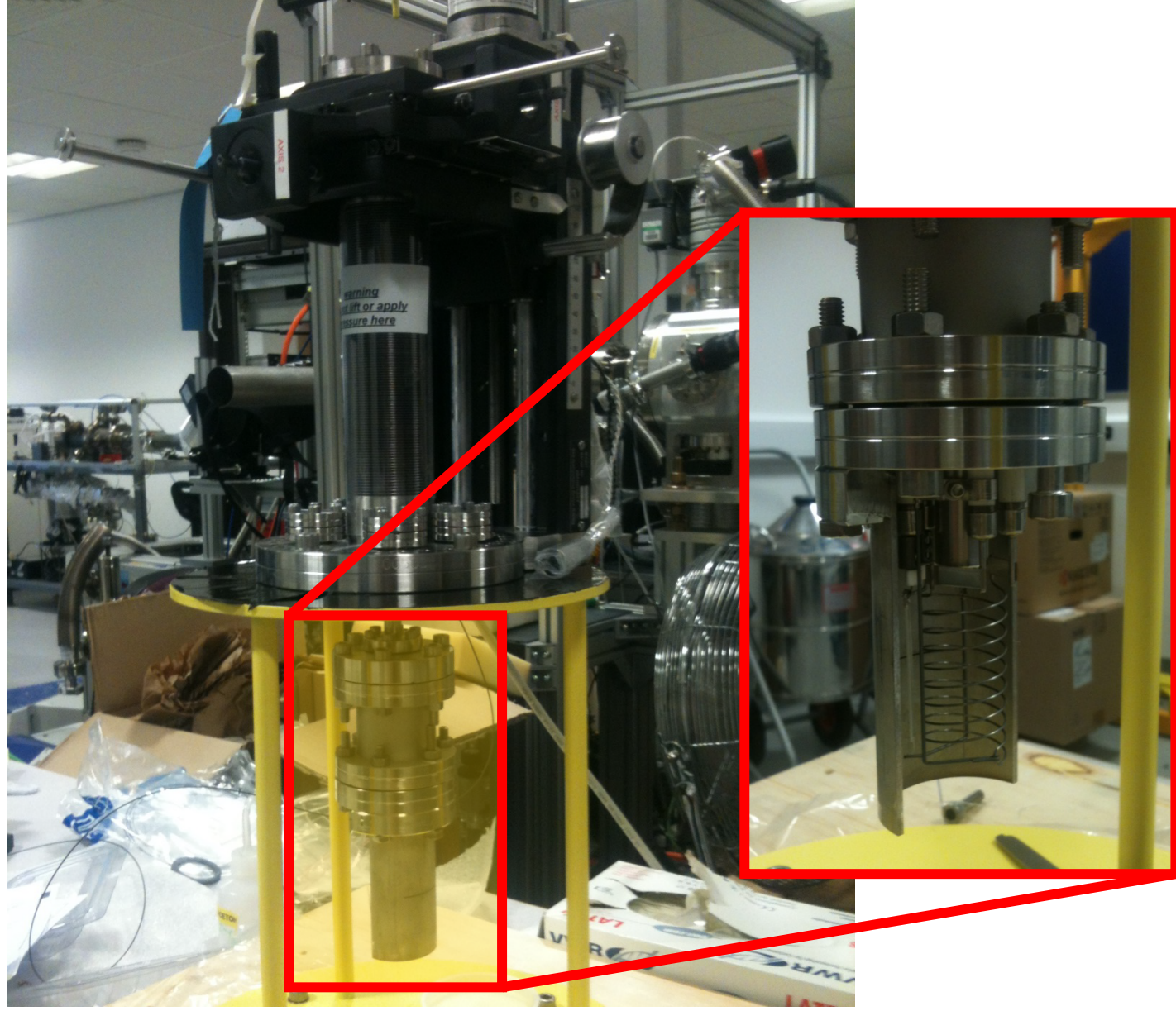
e^- 

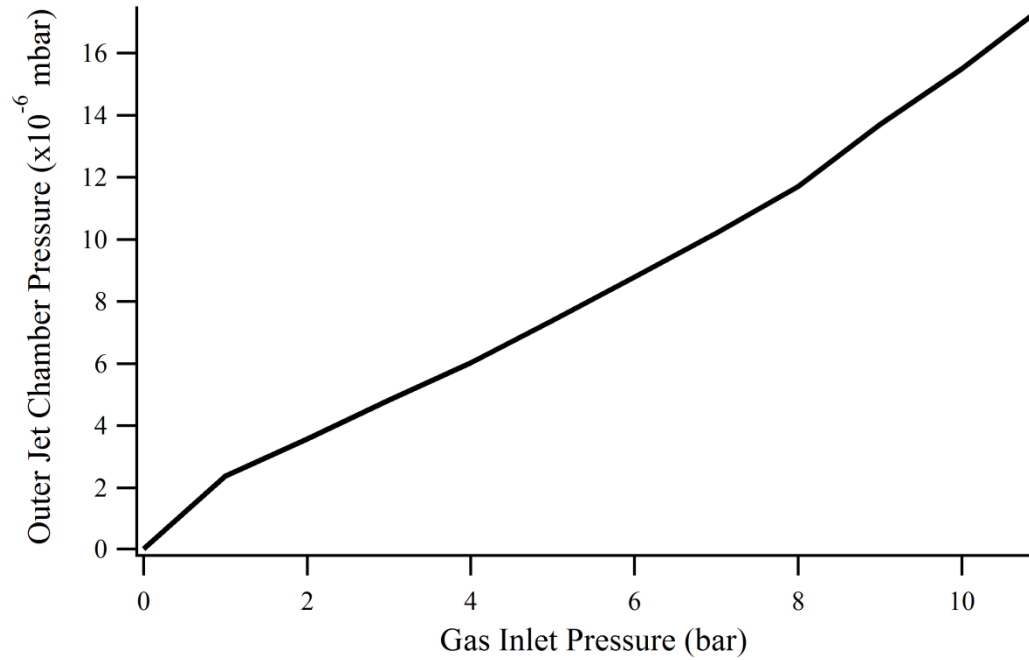
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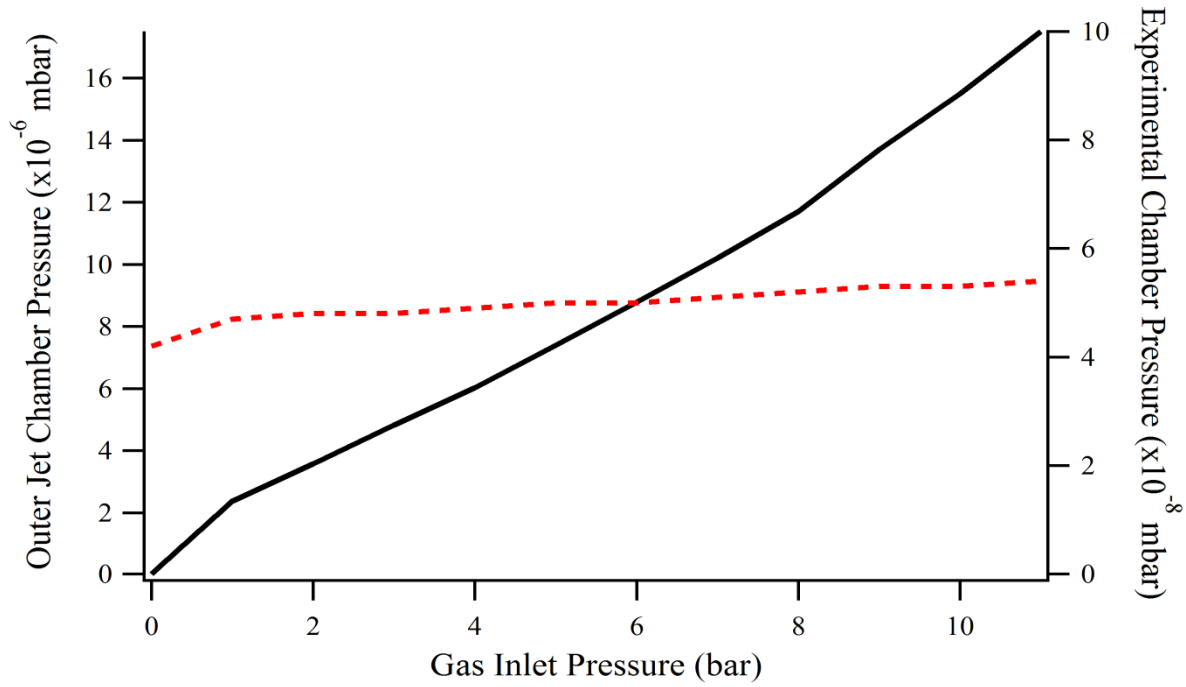




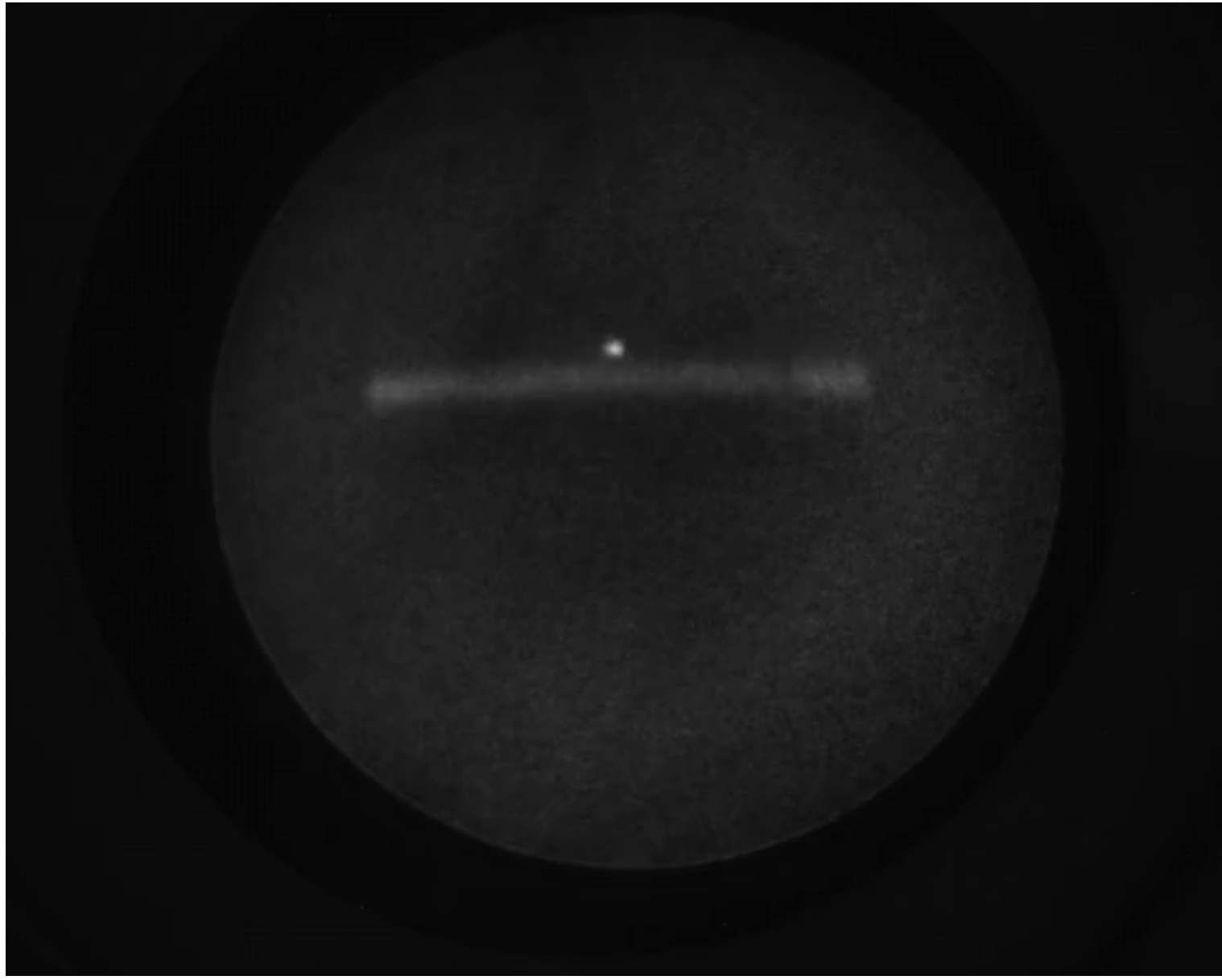


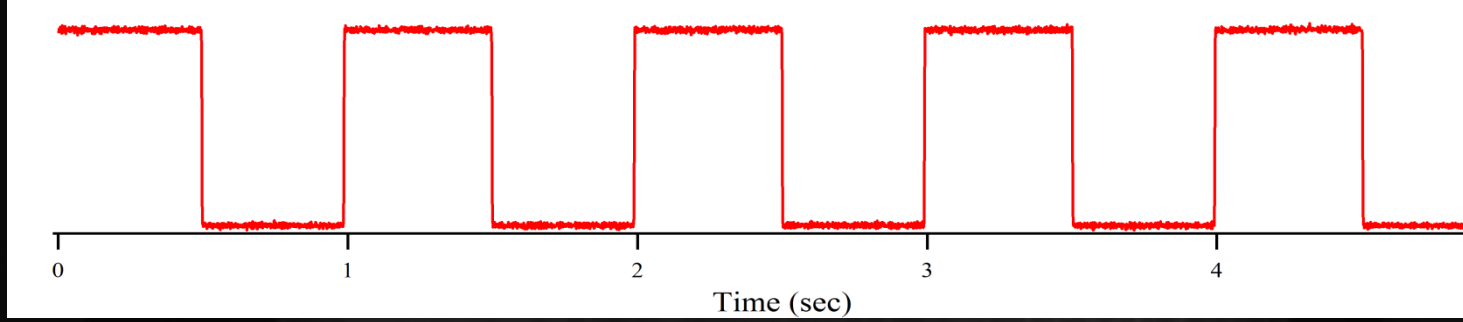


V. Tzoganis, A. Jeff, C. Welsch , “Gas dynamics considerations in a non-invasive profile monitor for charged particle beams”, Vacuum (2014), [dx.doi.org/10.1016/j.vacuum.2014.07.009](https://doi.org/10.1016/j.vacuum.2014.07.009)

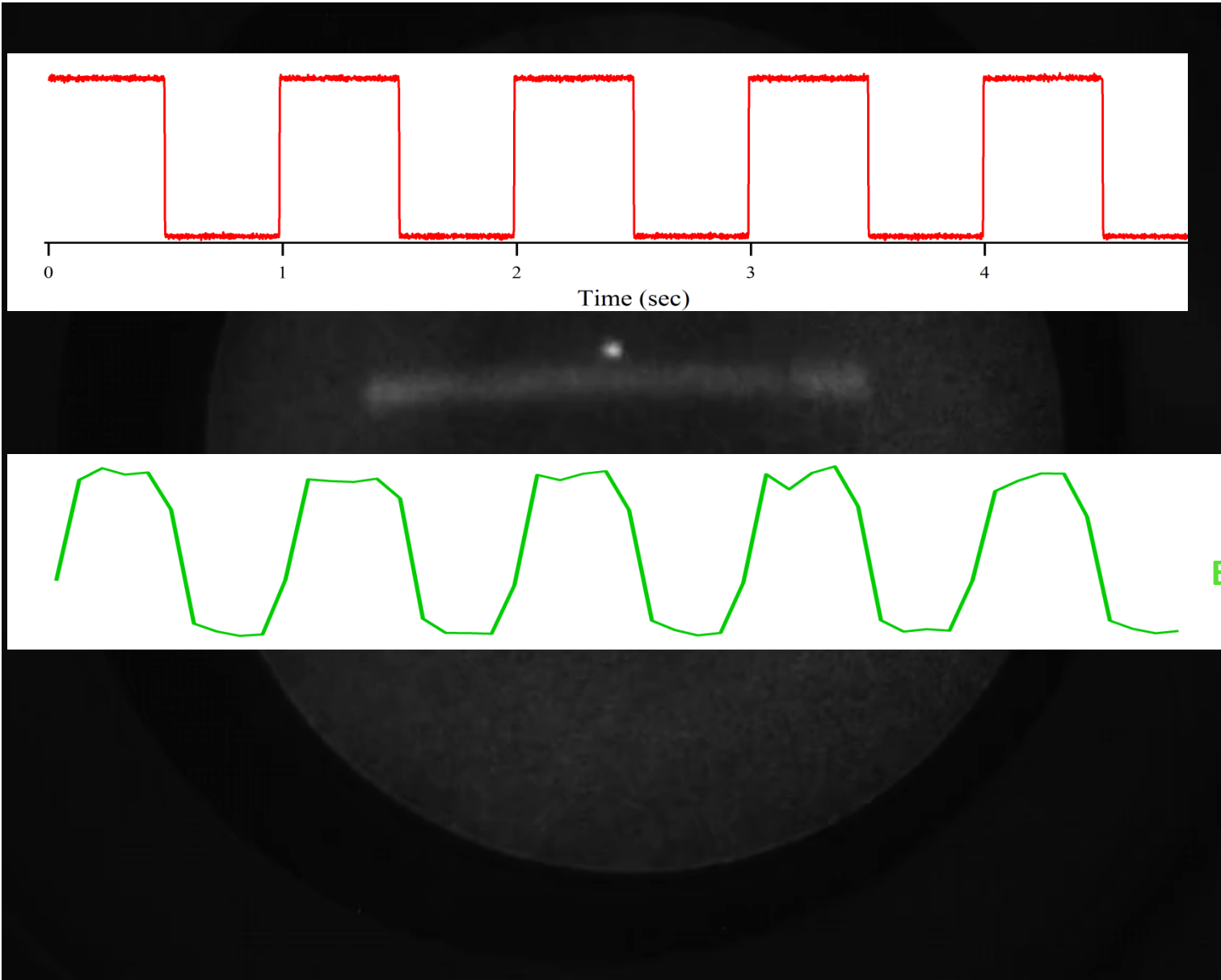


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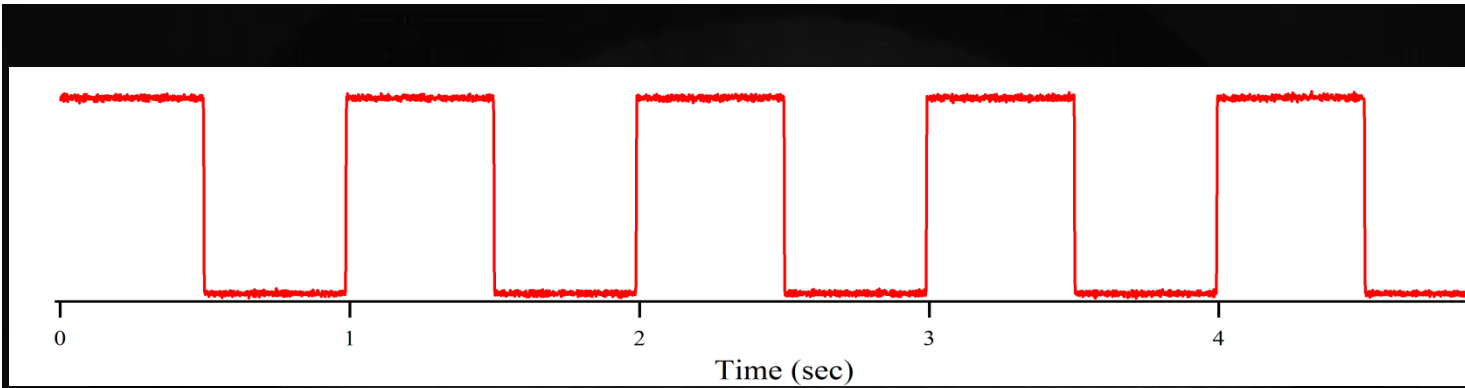
**Valve
Control**



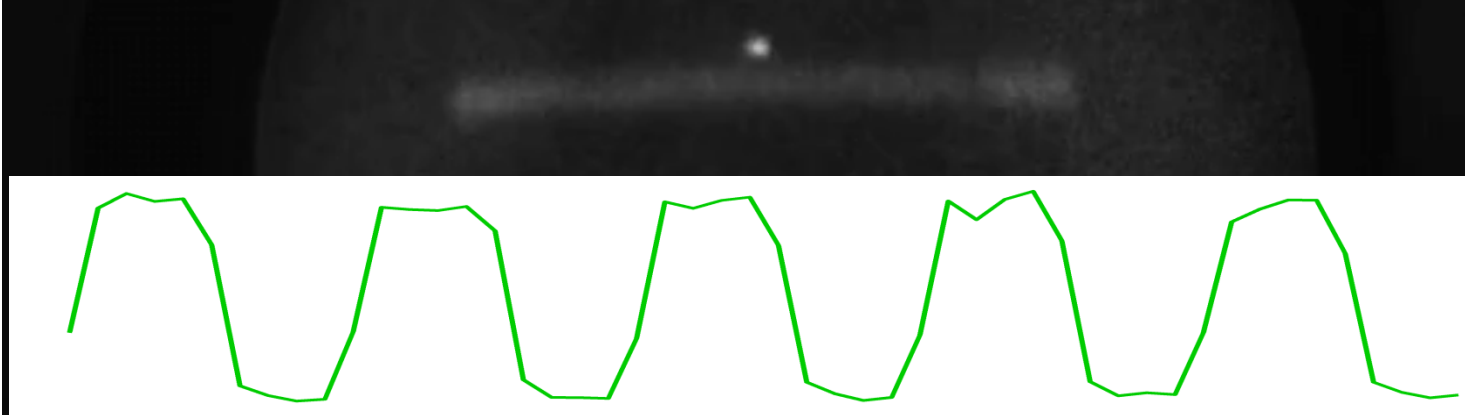
**Valve
Control**

**Jet
Brightness**

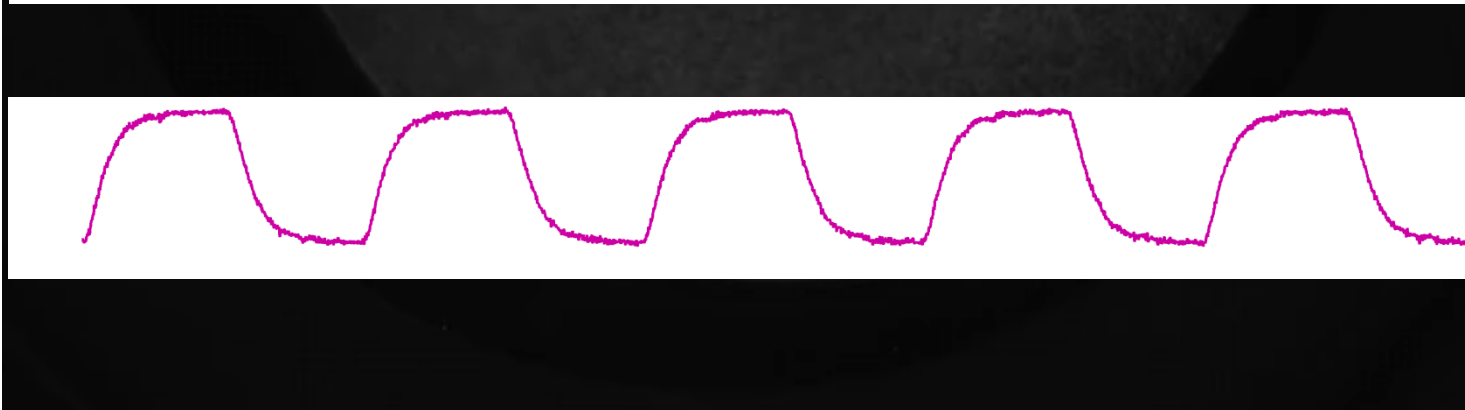
**Valve
Control**



**Jet
Brightness**



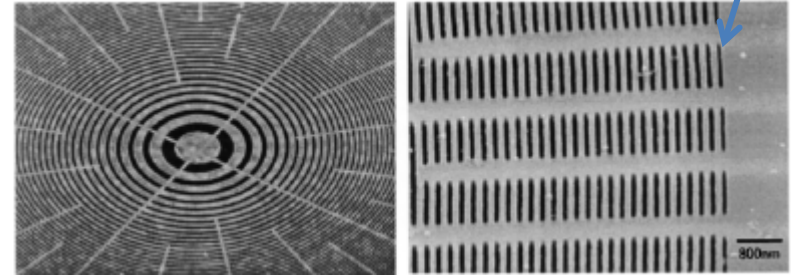
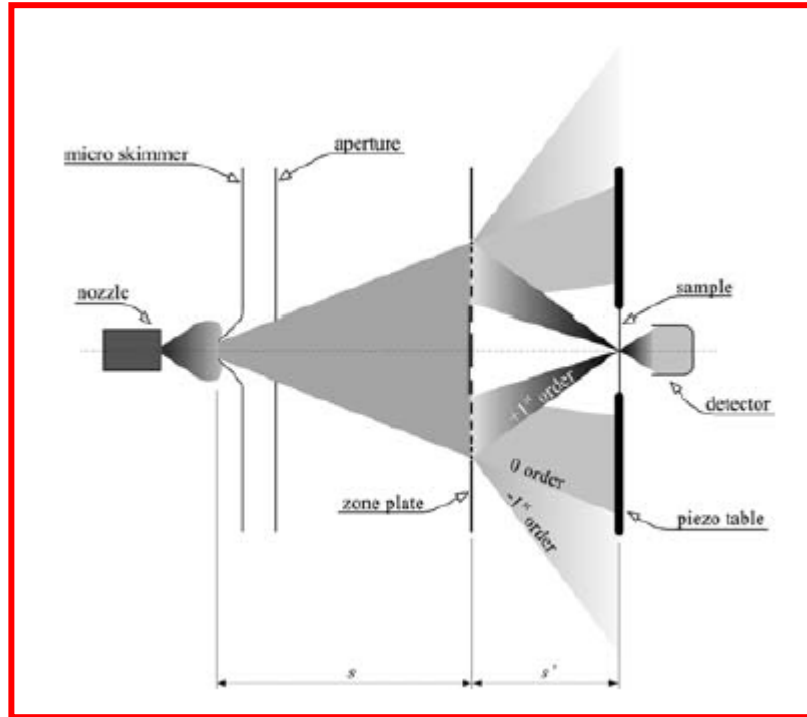
**Chamber
Pressure**



- Planar jet suitable for large beams only
 - Difficult to make the jet thin enough for CLIC Drive Beam
 - Space Charge also a problem
- Solution: Gas Jet Scanner
 - Generate a thin pencil jet and scan it through the beam
 - Like a wire scanner but non-interceptive
 - Still collect ions but position not important: not affected by space charge
 - Need a way to generate a thin jet...

Matter-Wave Focusing for a Thin Neutral Jet

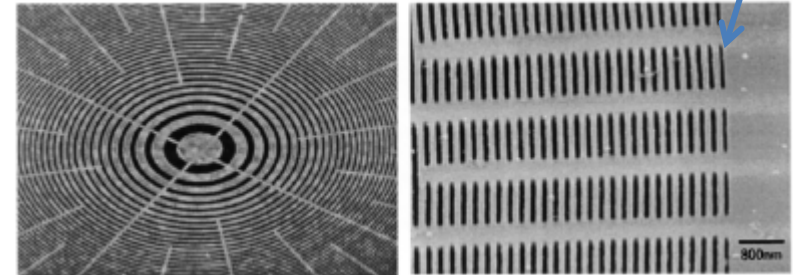
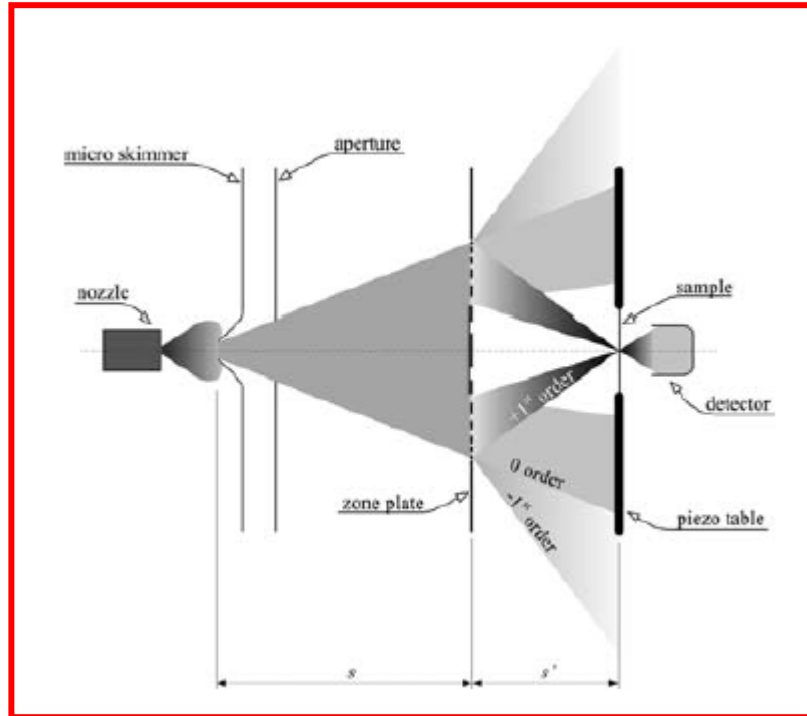
Smallest zone 100 nm



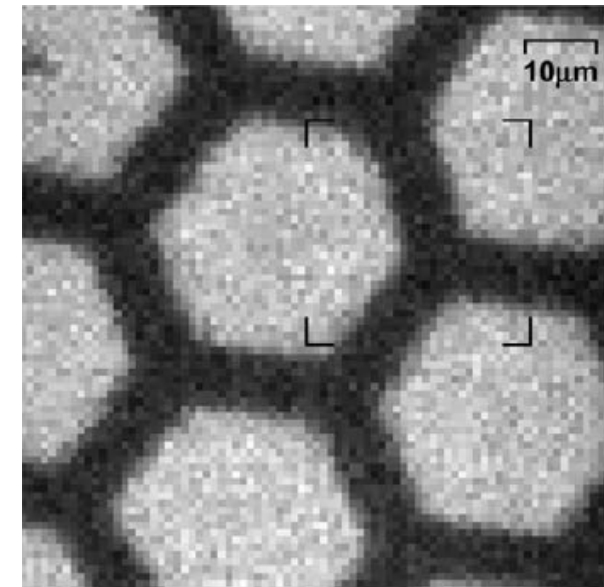
T. Reisinger, S. Eder, M.M. Greve, H.I. Smith, B. Holst, "Free-standing silicon nitride zoneplates for neutral-helium microscopy", *Microelectronic Engineering* **87** (2010)

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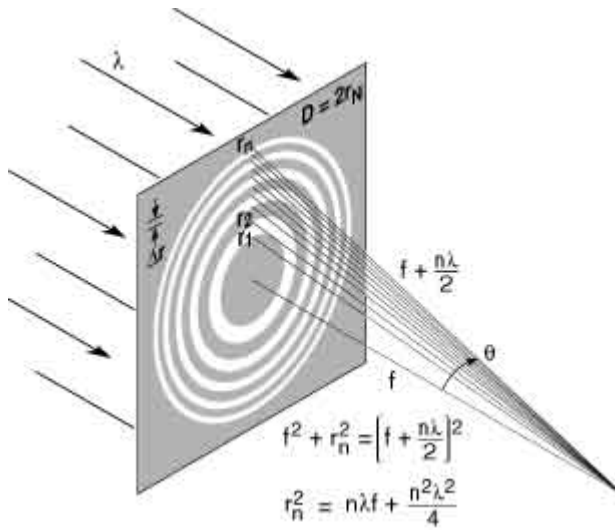
Smallest zone 100 nm



FWHM at focus $2\mu\text{m}$!



T. Reisinger, S. Eder, M.M. Greve, H.I. Smith, B. Holst, "Free-standing silicon nitride zoneplates for neutral-helium microscopy", *Microelectronic Engineering* **87** (2010)



- The path difference between each successive light ring is equal to 1 wavelength (at the focal point) constructive interference.
- Each zone is equal in area
- Focal spot size is roughly the width of the narrowest (outer) zone
- Compared to traditional lens: no spherical aberration, large chromatic aberration

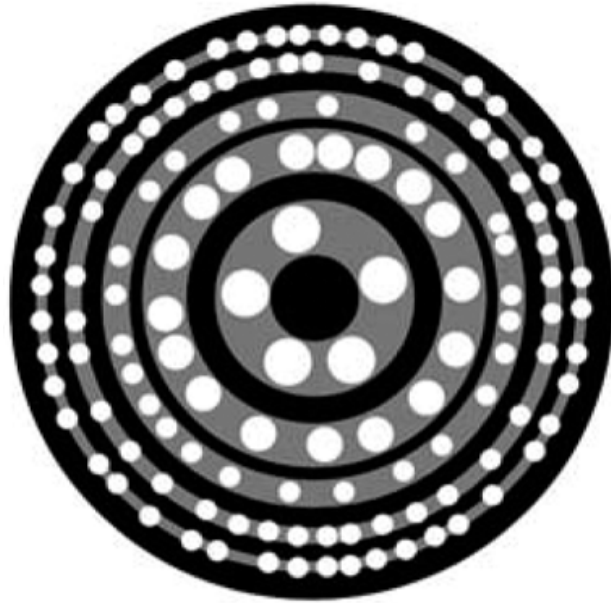
DeBroglie wavelength ≈ 0.05 nm
for room temperature Helium

Focal length of zone plate $f = \frac{2r_N \Delta r_N}{\lambda}$

radius of outer zone
width of outer zone

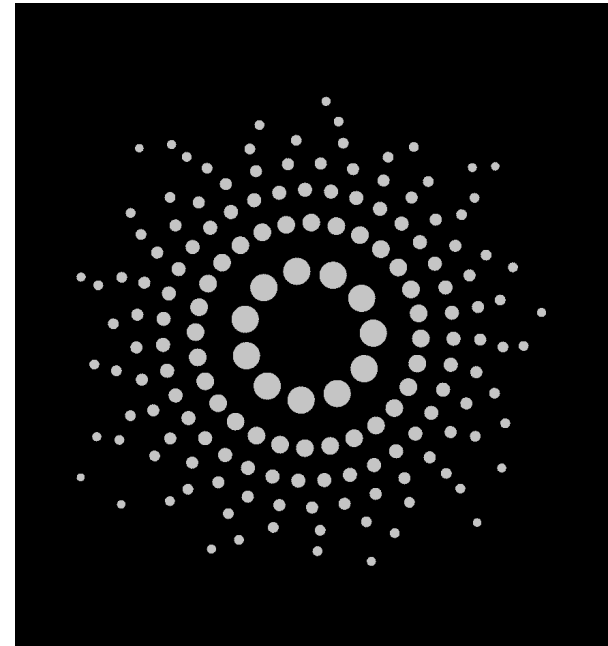
Resolution $\approx$ width of smallest zone (ignoring chromatic effects)

Photon Sieve replaces clear zones of an FZP with a series of holes

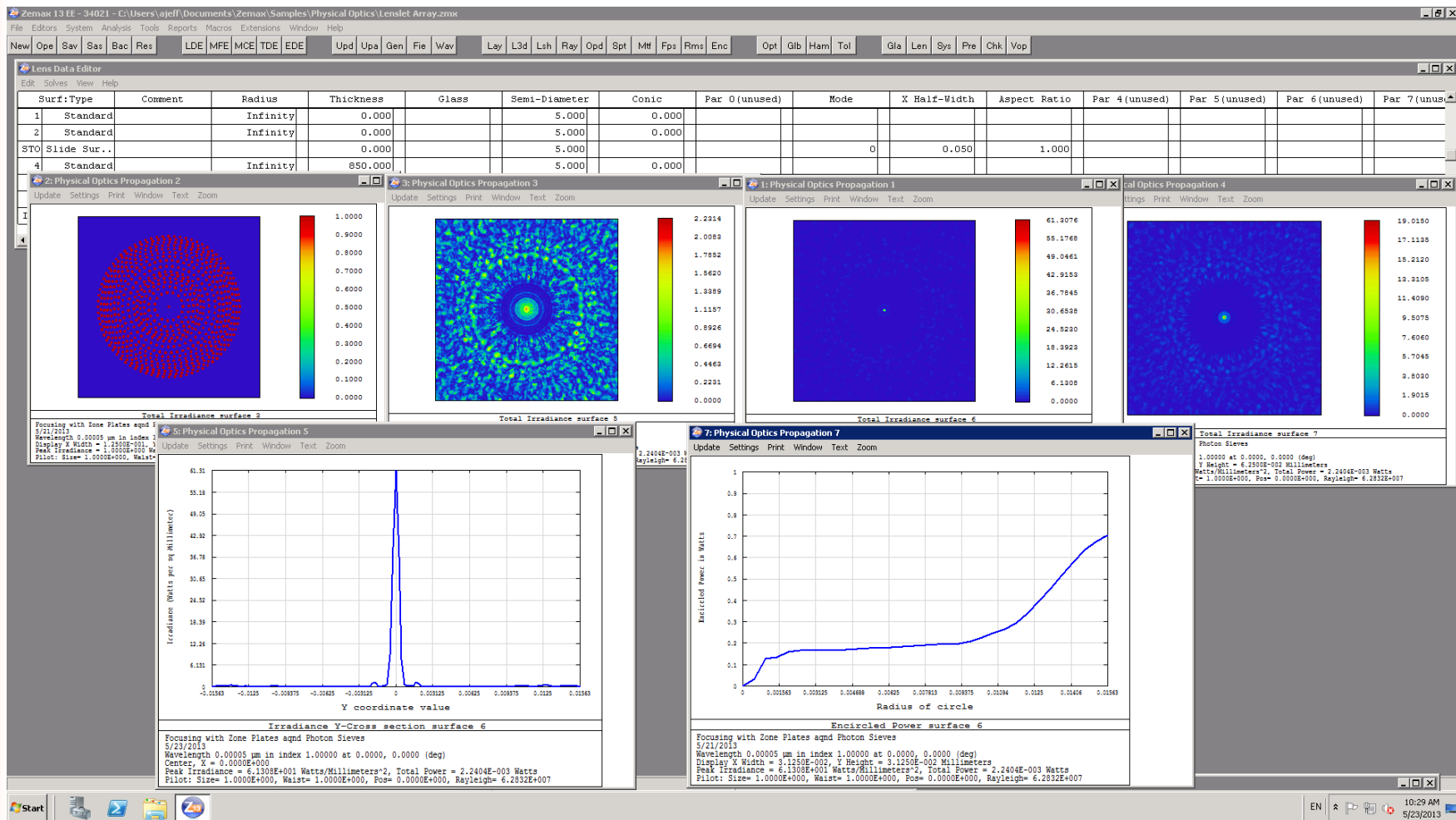


- + Sharper focusing
- Lower transmission
- + Easier to manufacture

Apodised Photon Sieve reduces higher order diffraction, increases central maximum

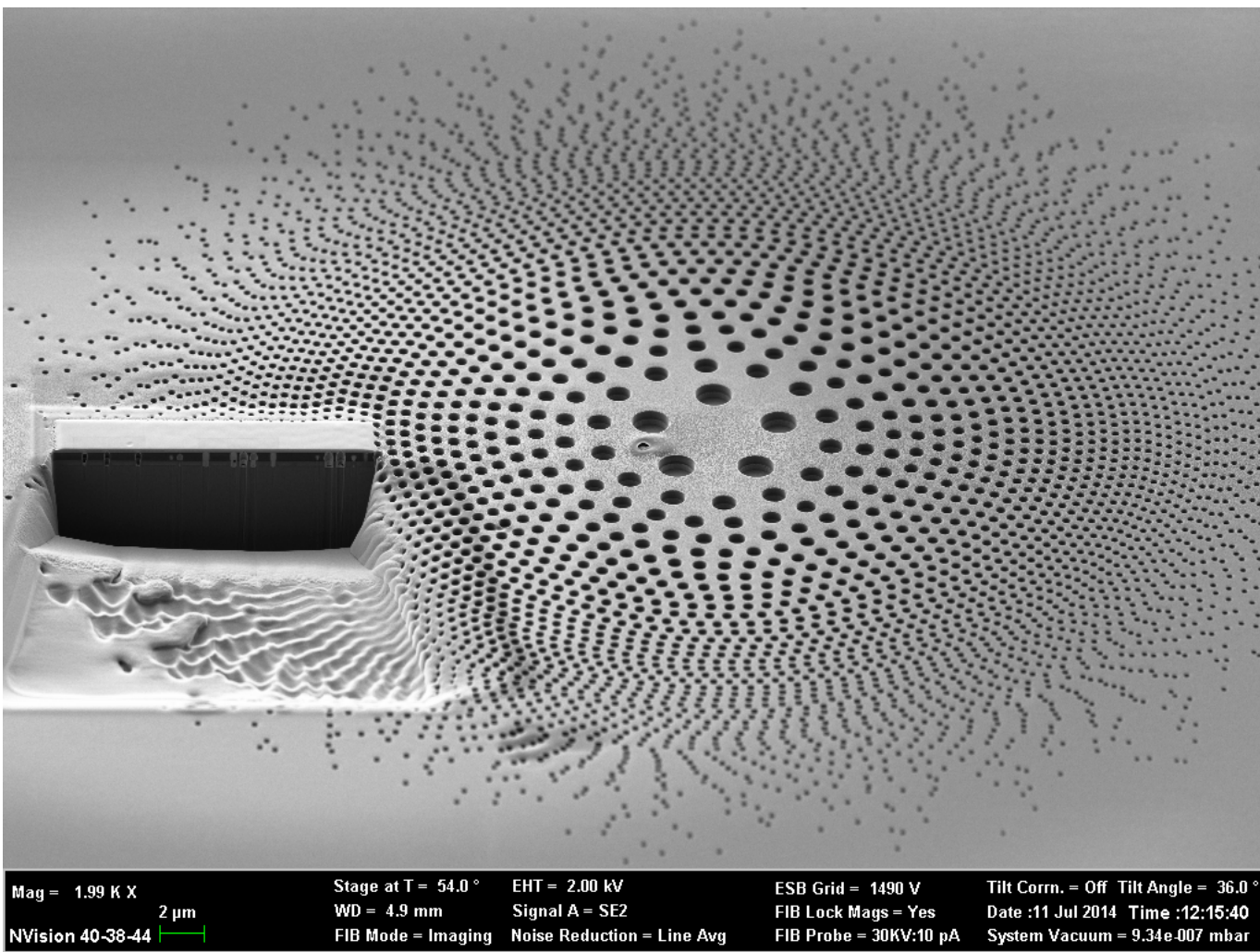


L. Kipp et al, "Sharper images by focusing soft X-rays with photon sieves", Nature **414** (2001)





The Atomic Sieve



Conclusions

- The test setup at the Cockcroft Institute has demonstrated reliable gas jet operation, and can be used for profile measurement in both continuous and pulsed mode.
- Thanks to efficient dumping of the jet and differential pumping in the jet generator, the effect on the beam vacuum system is small.
- For measurement of smaller beams with intense space charge, a new gas jet scanner is proposed.
- A focusing method based on the deBroglie wavelength of the neutral gas atoms will be tested.
- The 'atomic sieve' is under production and will be tested later this year.



Thank you for your Attention

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Vasilis Tzoganis^{2,3}, Carsten Welsch^{2,3} and Hao Zhang^{2,3}

¹CERN ²University of Liverpool ³Cockcroft Institute



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