Capillaries as self-organized electrostatic lenses

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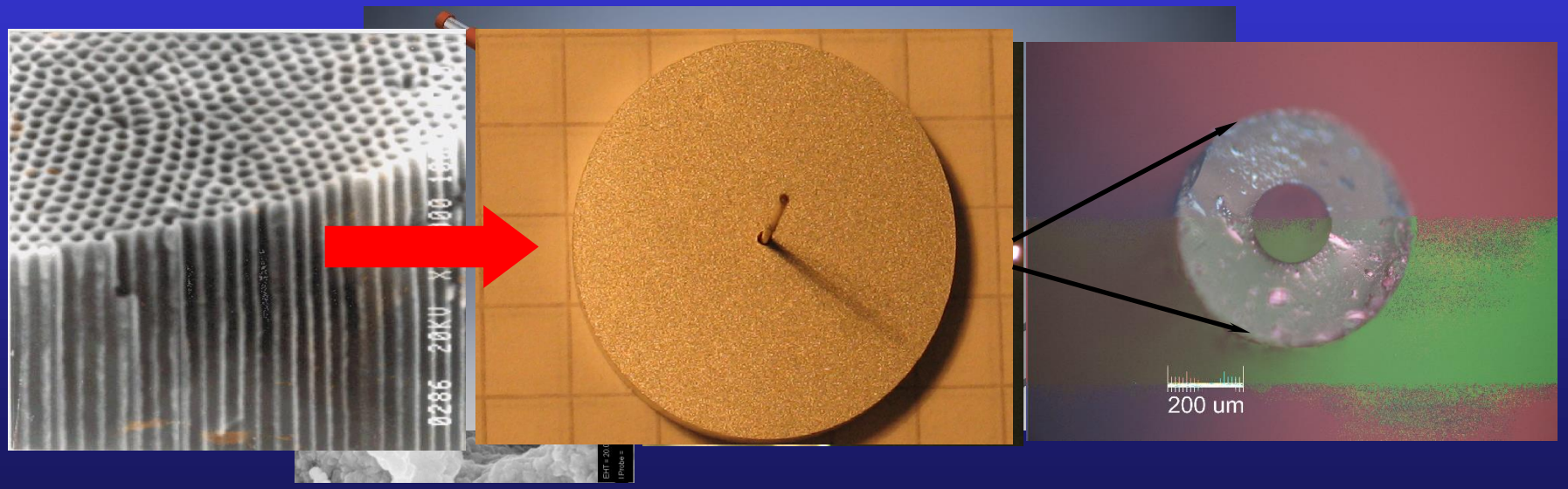

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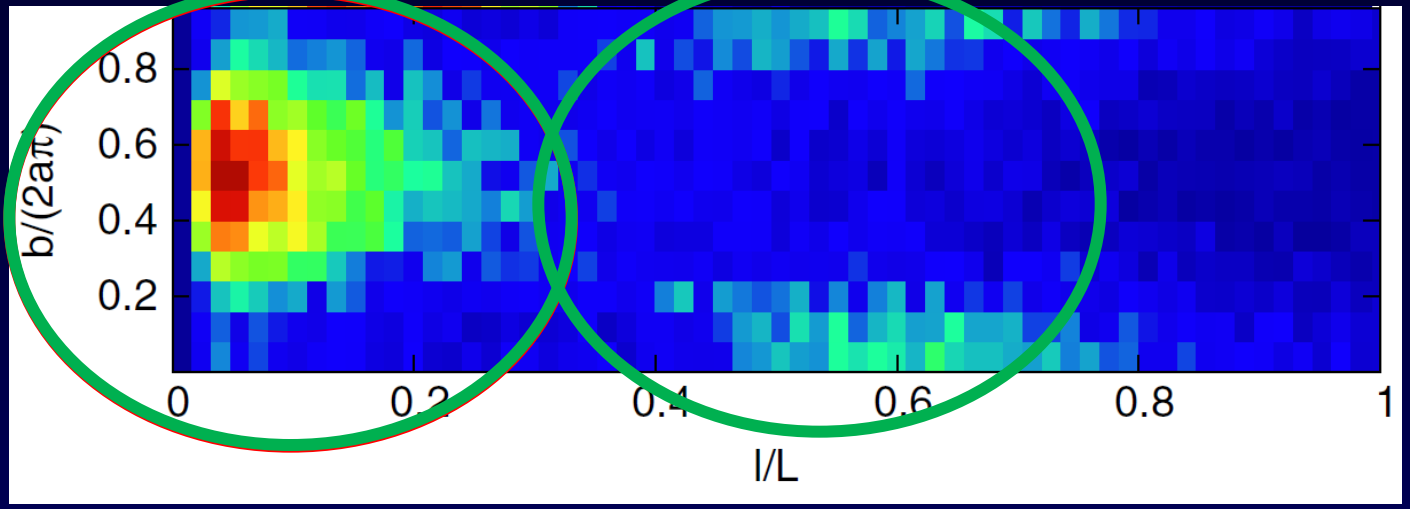
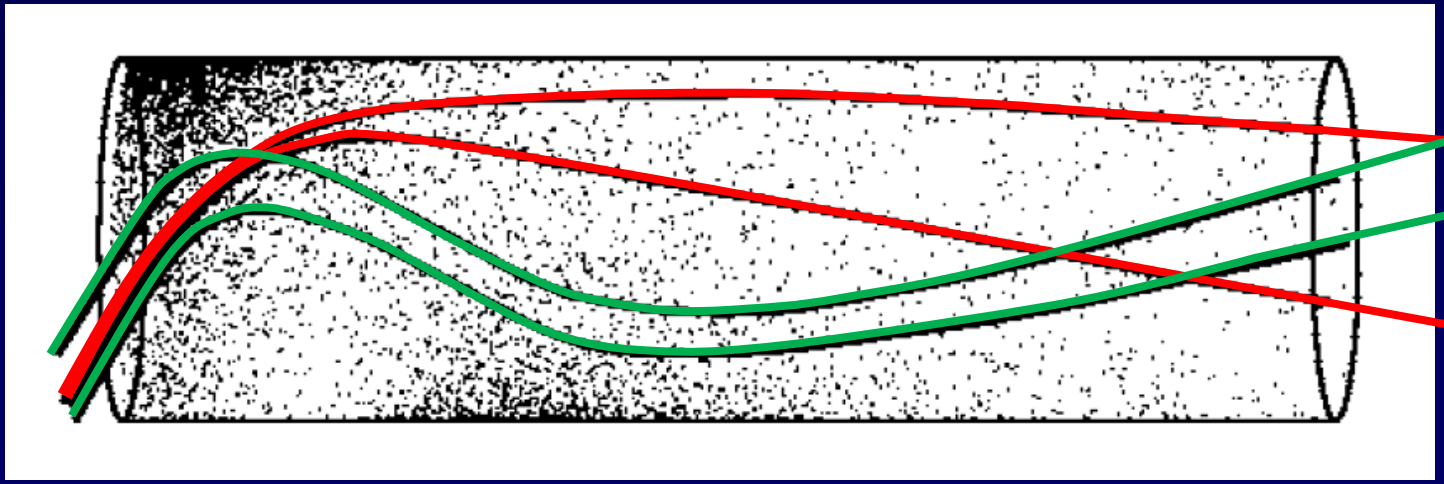
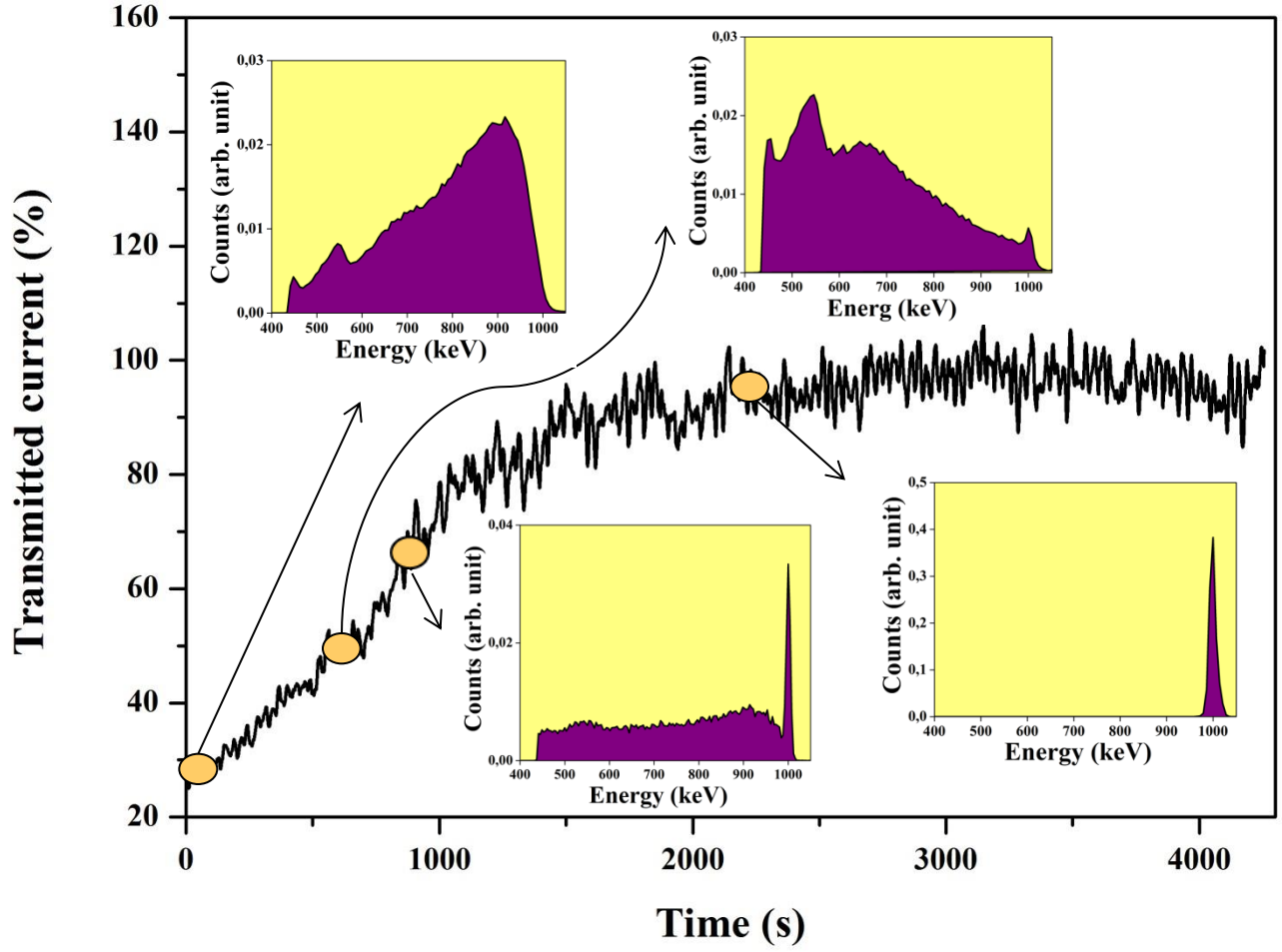
Capillary charging





Schiessl et al., PRA 72, 062902 (2005); PRL 102, 163201 (2009)

Time evolution



History

New type of the particle-transport with various samples:

- Nanocapillary arrays

Many uncertainties both from experimental and theoretical points of view:

- It is not possible to ensure a perfect parallelism of the nanocapillaries in the foil.
- The collective effect of all the neighboring tubes has to be taken into account.
- Charge deposition using highly charged ions.

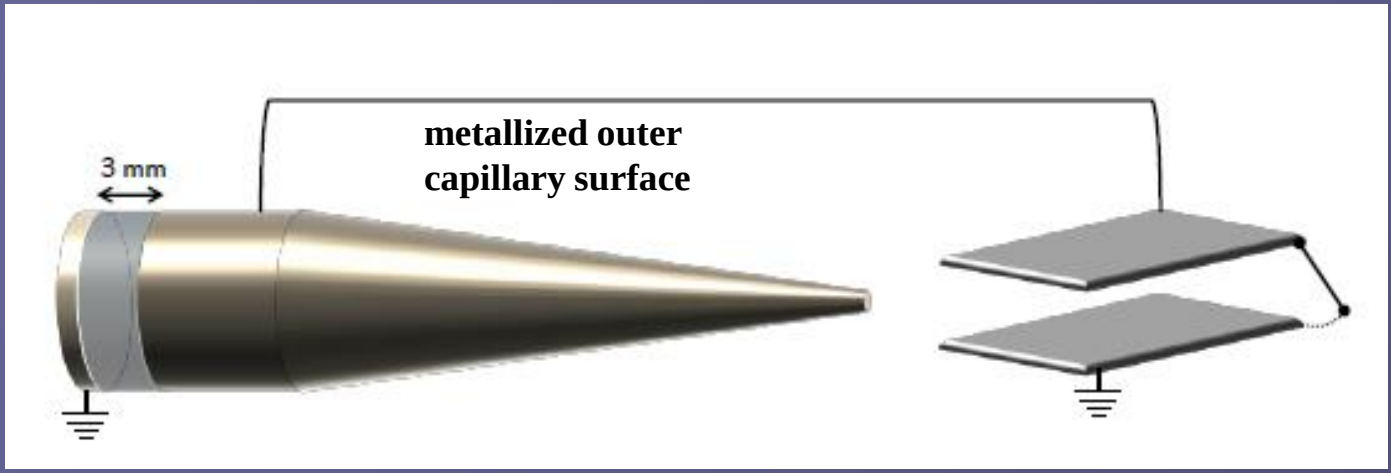
- Single microcapillary – technical applications

It is technically not possible to perform measurements with a single nanotube.

Previous experiments:

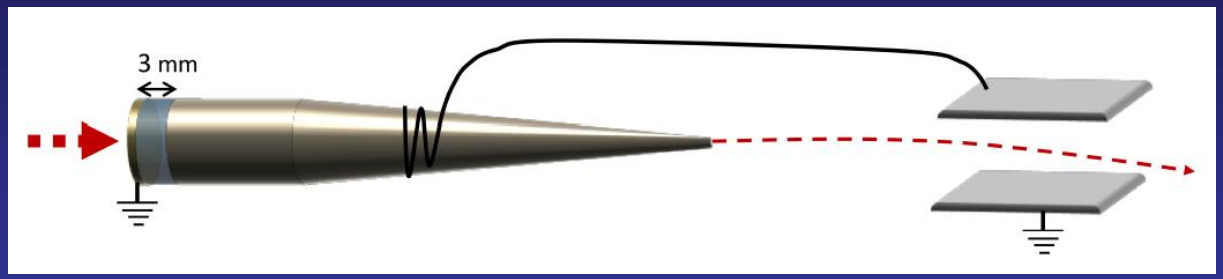
- slow, highly charged ions (Ne^{7+}, Ar^{9+})
- slow and fast electrons
- positron

Sample



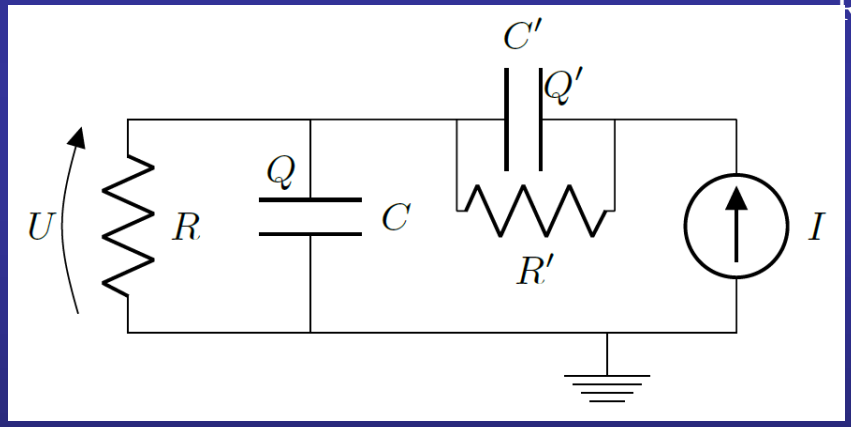
- Material: borosilicate glass microcapillary of 75 mm length, whose first segment of 35 mm is cylindrical while the end was conical-shaped.
- The diameter of the outlet of our conical capillary is 26 μm and is 33 times smaller than the diameter of the inlet (860 μm), reducing the geometrical transmission fraction to about 0.1%.
- The entrance of the capillary, in electric contact with the inlet collimator hole of 600 μm diameter is on ground potential.
- The outer surface of the capillary is covered with a conductive layer (silver paint), except for 3 mm behind the entrance.

Electrode setup of conical-shaped borosilicate capillaries with deflection plates.



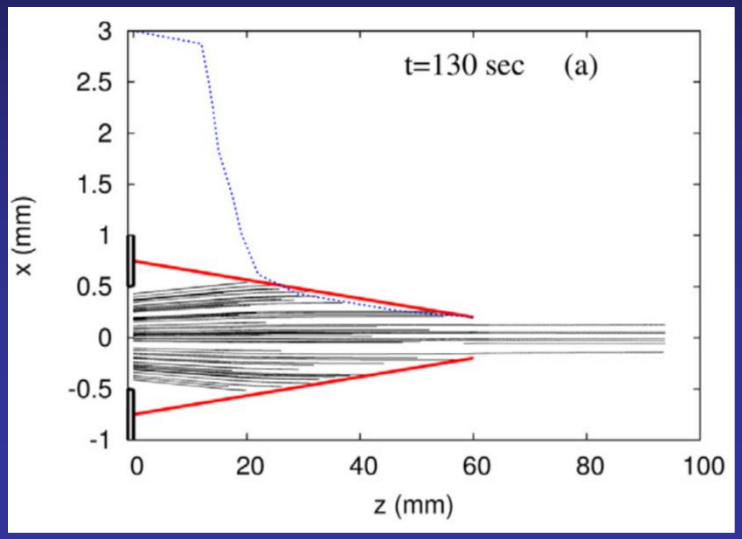
The deector plates have a surface of 9 cm2 and are separated by 1 cm, giving an estimated capacity of about 0.8 pF. The 3 mm of non-painted outer surface in between the grounded entrance and the painted layer covering the rest of the capillary have a resistance of R = 10^{15} Ohm.

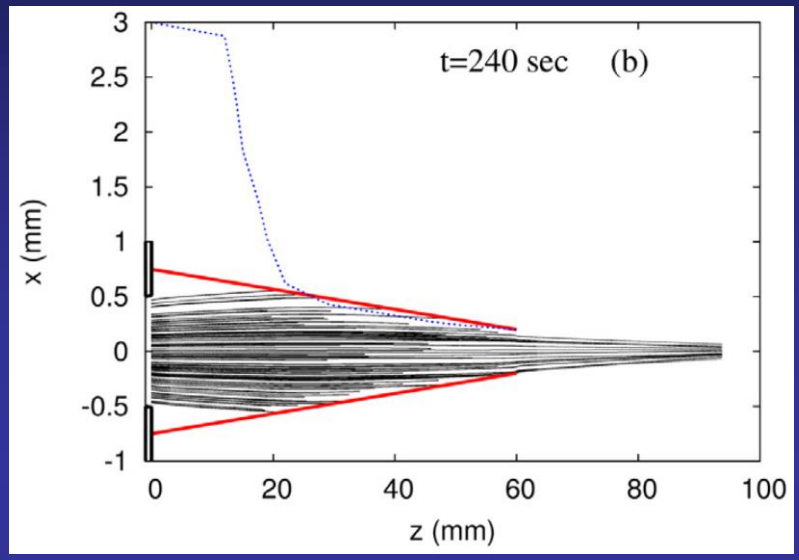
The incoming ion beam 0.3 pA - 16 pA. The beam divergence is estimated to be less than 0.3°.

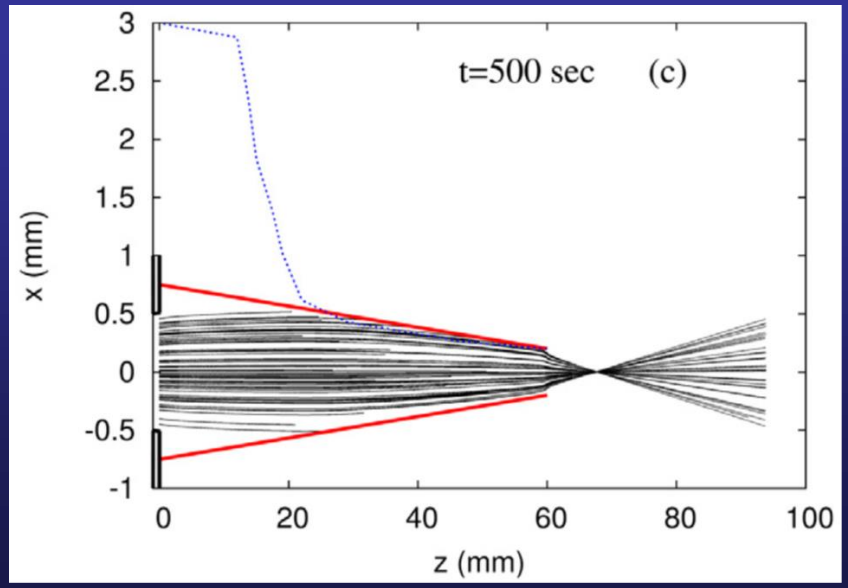


Equivalent circuit of painted capillary. The resistance R and C stand for the 3 mm gap of borosilicate and capacity of the deflection plates respectively. The capacity C’ and impedance R’ of the glass-metal interface at the outer capillary surface have been added for completeness, but are irrelevant for this study. They merly control the drop of the potential at the interface.

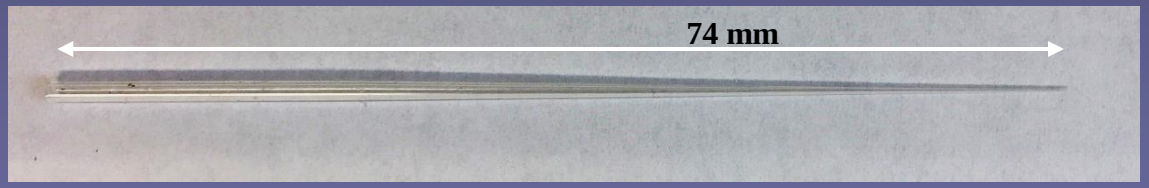
Simulation of particle trajectories

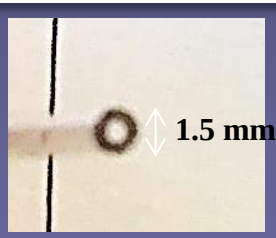


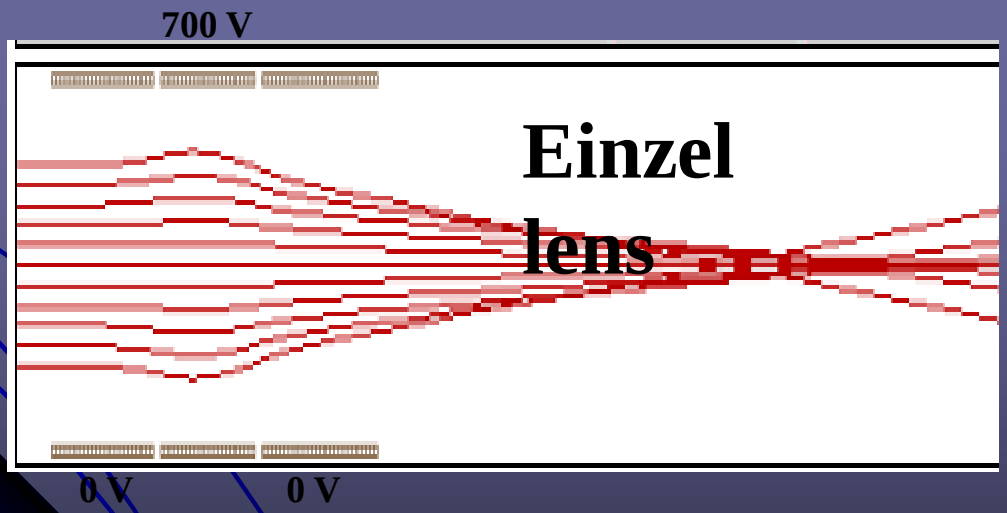




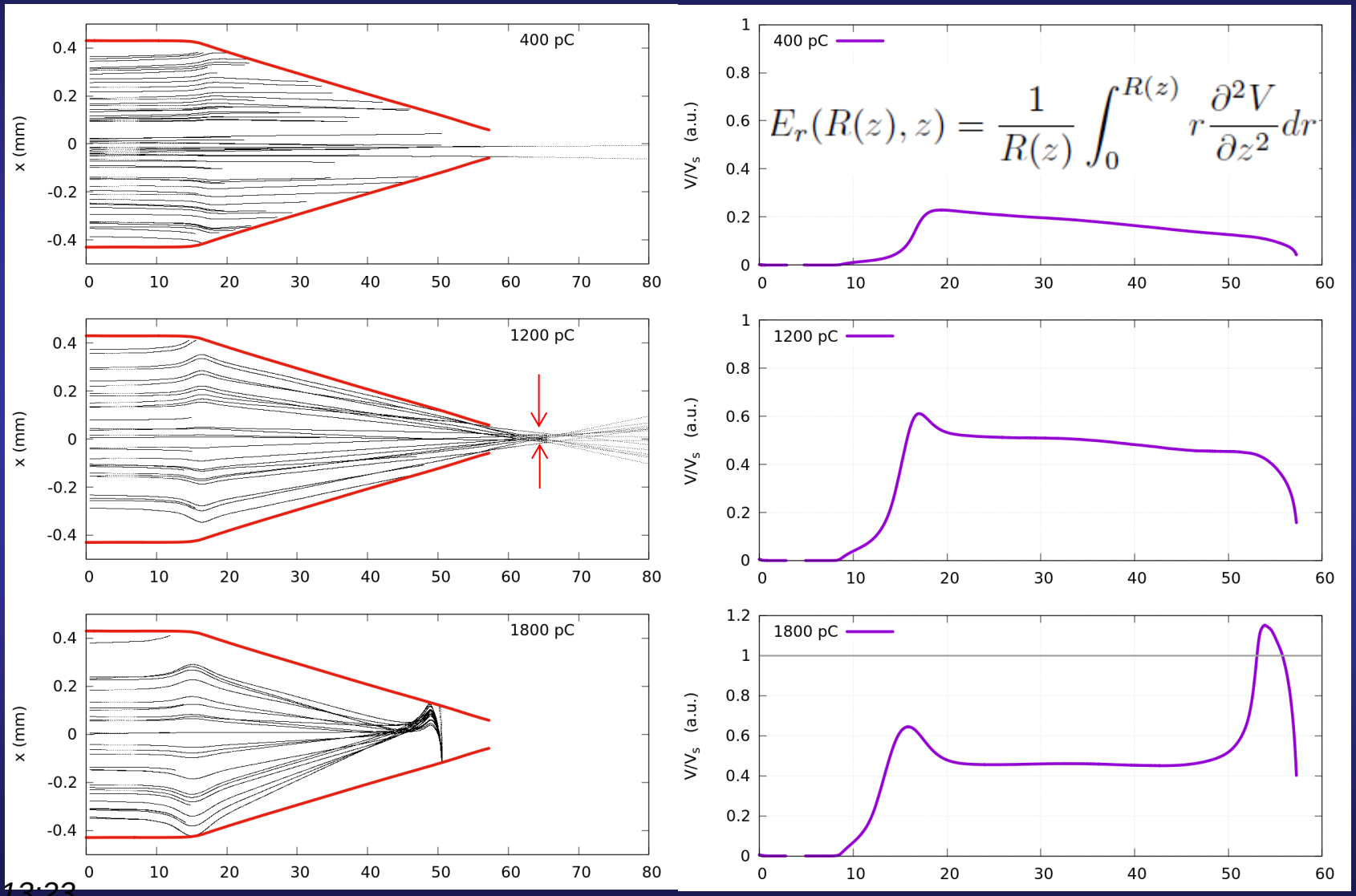
Give evidence of the self-organized axis-symmetric focusing in insulating tapered capillaries



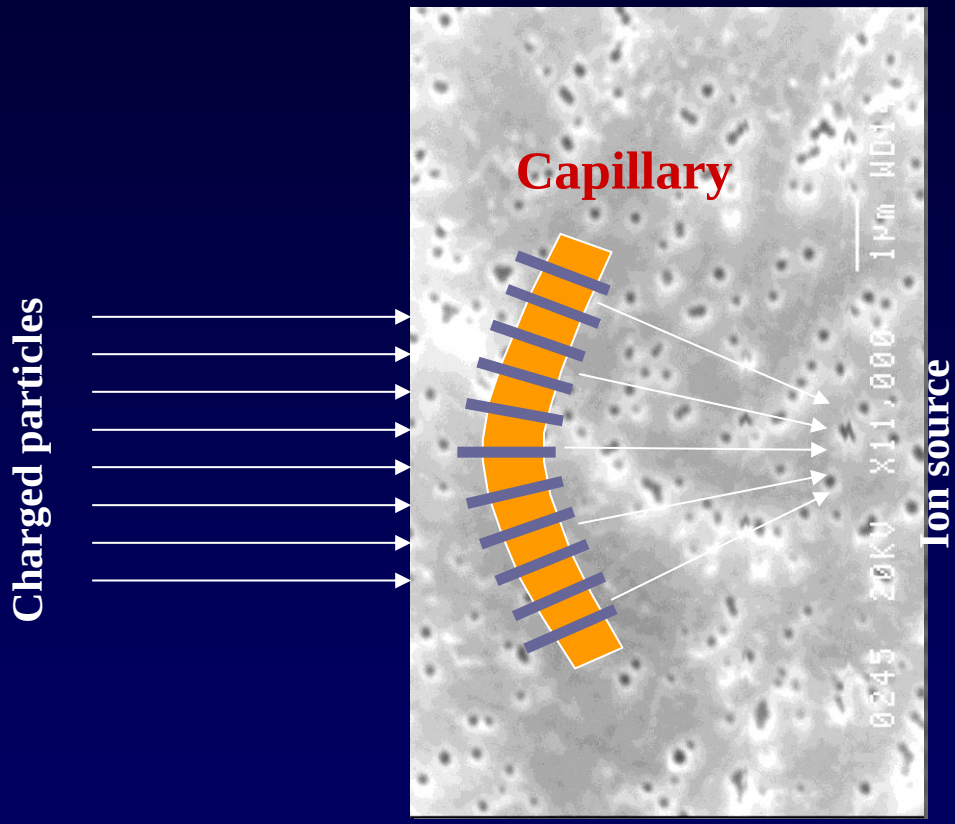




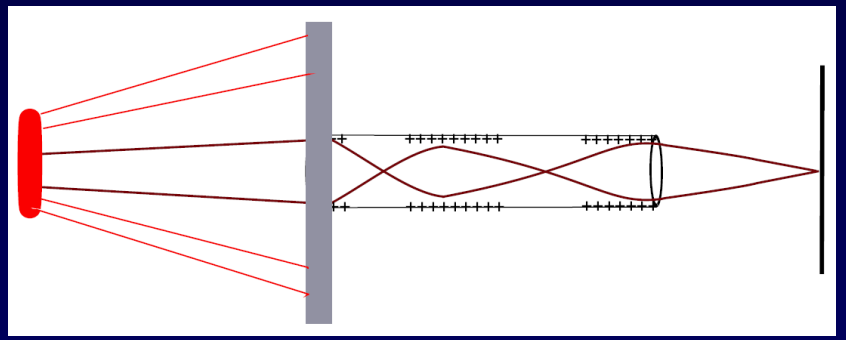
Axis symmetric focusing by conical glass capillary



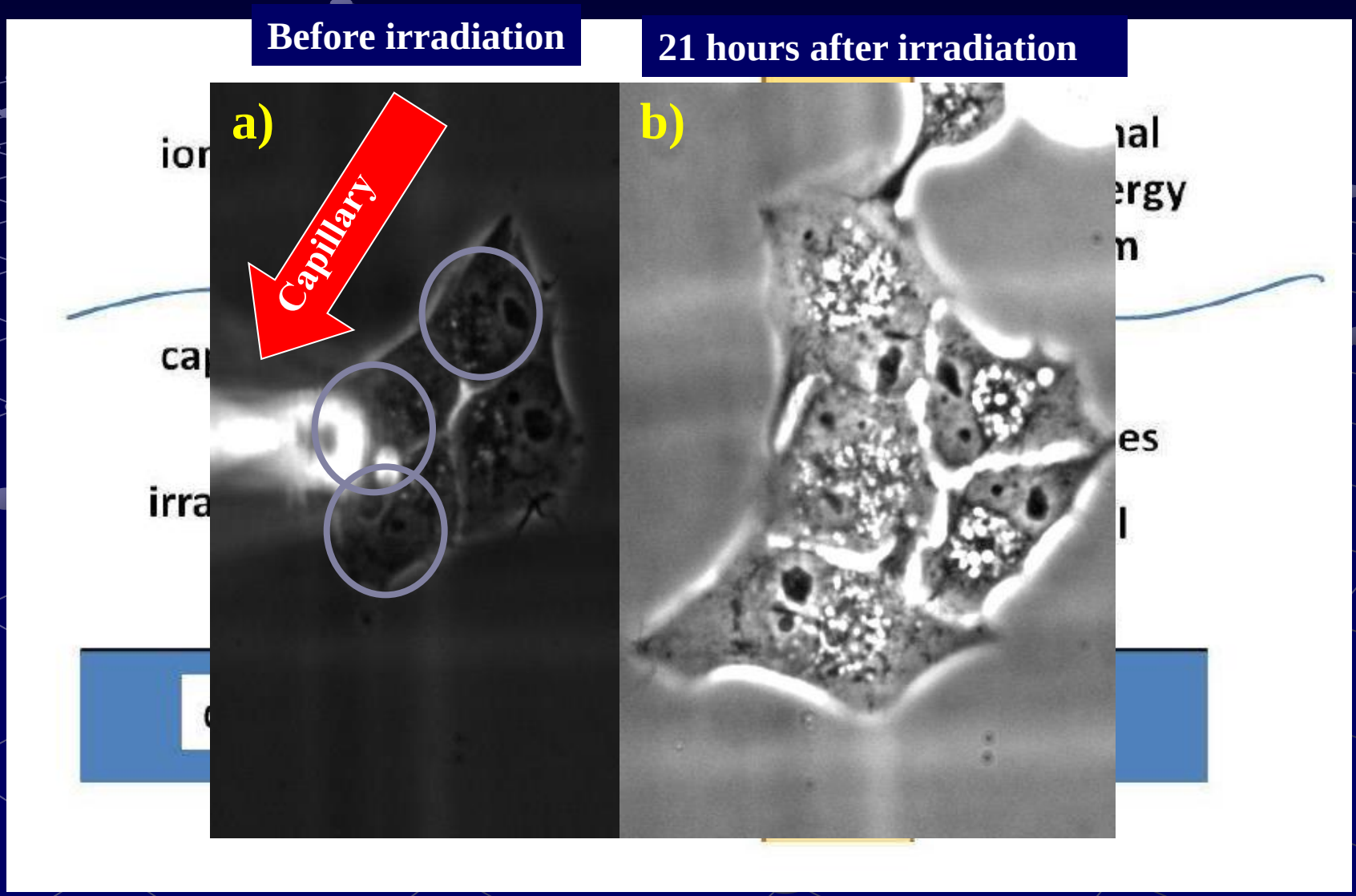
Possible application — alternative ion-optical tool



Single capillary



Possible application — living cells controlled irradiation



Conclusion

- We used the deflection of the transmitted beam as an ideal electrometer to monitor the potential of the capillary under charged particle impact.

- With our simple model, we were able not only to identify but also to quantify the leakage currents that characterize the capillary charge.

- We show that secondary electrons effect the charging of the capillary by adding a spurious neutralization channel, if the capillary is not suciently screened from secondary electron sources.

- Our measurements also show for the first time that a capillary is able to accumulate enough charge to generate electric potentials that approach and may even exceed the kV range.

- The insulating capillary can be used as a special electron-optical element to transport charged particles with significant emittance. The capillary starts to behave as an self-organized electrostatic lens, able not only to guide but also to focus the beam at the capillary exit

Thank you!