Charge Transfer Properties Through Graphene for Applications in Gaseous Detectors

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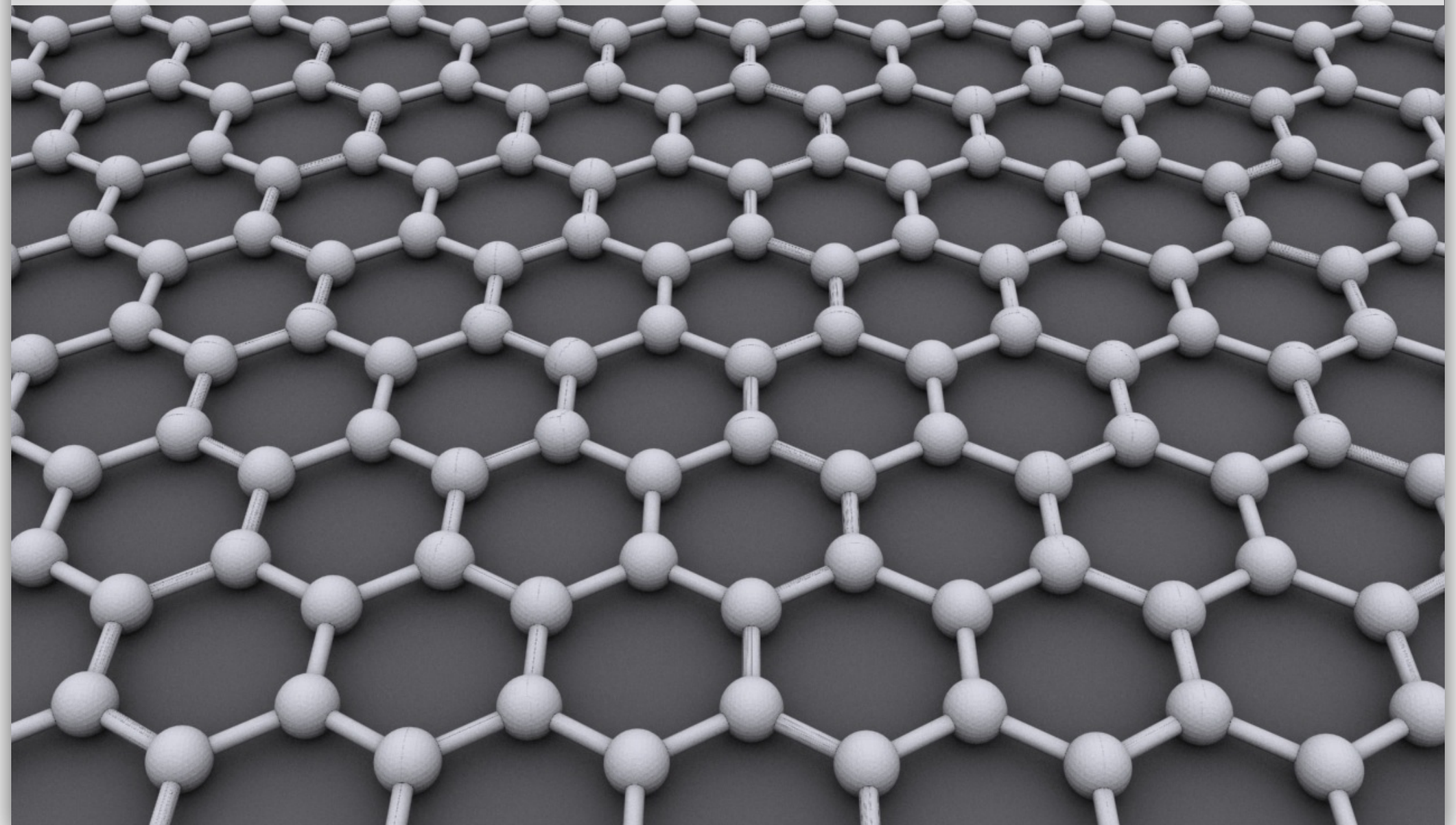
Overview

What is graphene
Why it is interesting
How we want to use it
What we did
What we still need to do

Graphene

Single layer of carbon atoms in an hexagonal lattice (~0.6 Å opening) with peculiar characteristics

Regarded as the thinnest and finest conductive mesh



The principle

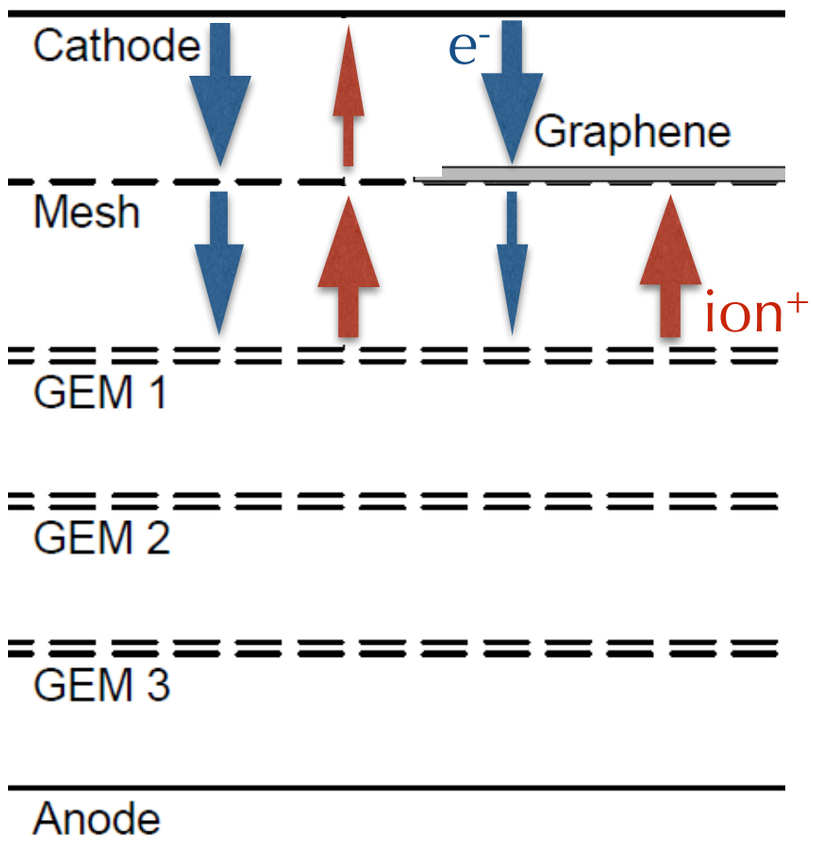
Reported a **strong asymmetry** in **electron and atom/ion transmissions** through graphene

J. S. Bunch *et al.*, Nano Letters 8, 2458
J. J. Lopez *et al.*, J. Appl. Phys. 107, 104326
J. Longchamp *et al.*, Appl. Phys. Lett. 101, 113117
S. Srisonphan *et al.*, Sci. Rep. 4, 3764

Ideally a membrane **opaque to ions** and **transparent to electrons**

The idea

Build a **suspended graphene layer** without defects transparent to the drifting electrons and opaque to ions **eliminating the ion back-flow** in gaseous detectors



It can also be used as **protective layer** (e.g. photocathodes) and to **enhance secondary electron emission** from materials

The goal

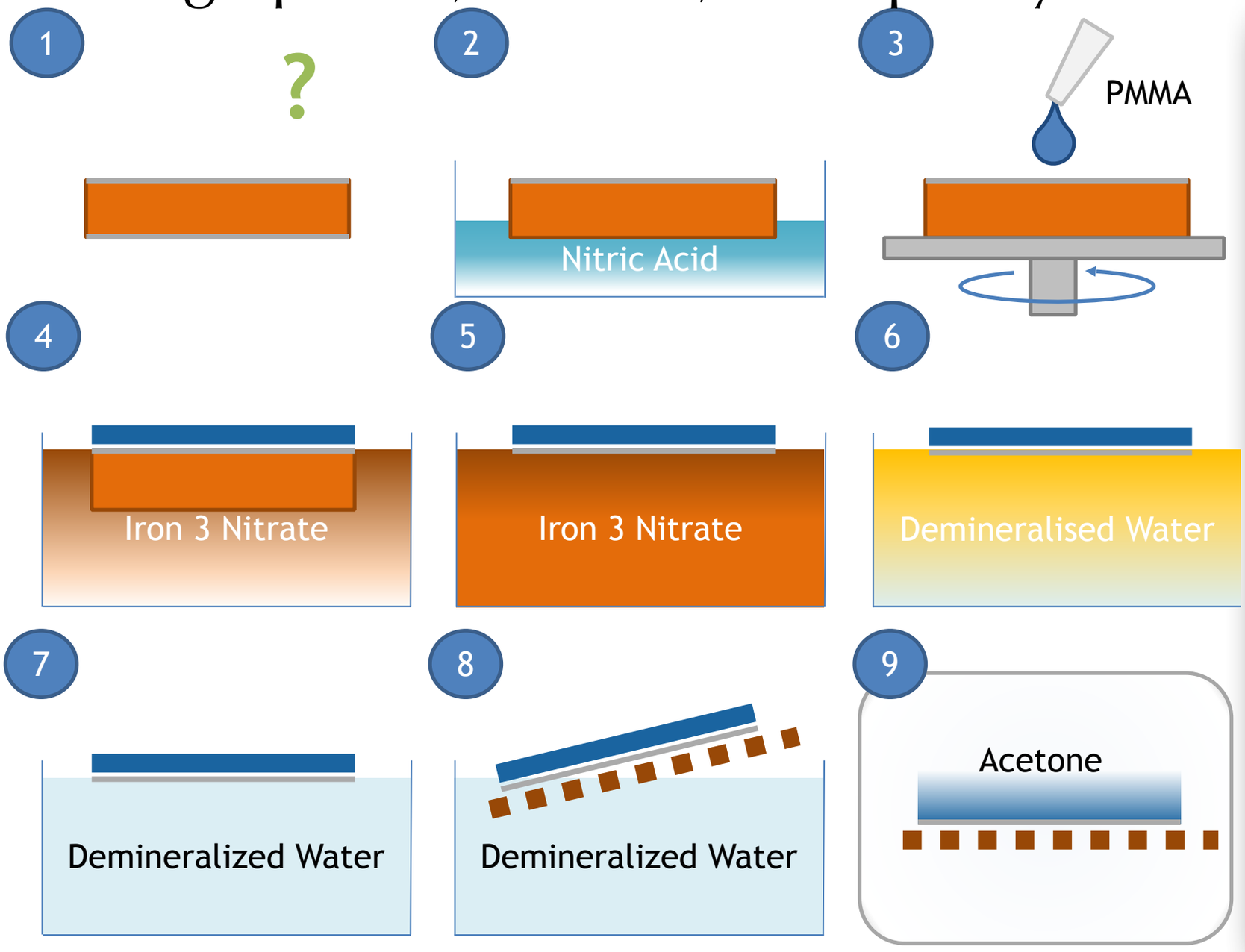
Measure electron and ion **transparencies** of a graphene $O(\mathrm{cm}^2)$ layer suspended on a metal mesh in gas as a function of **electric field** and **gas mixture**

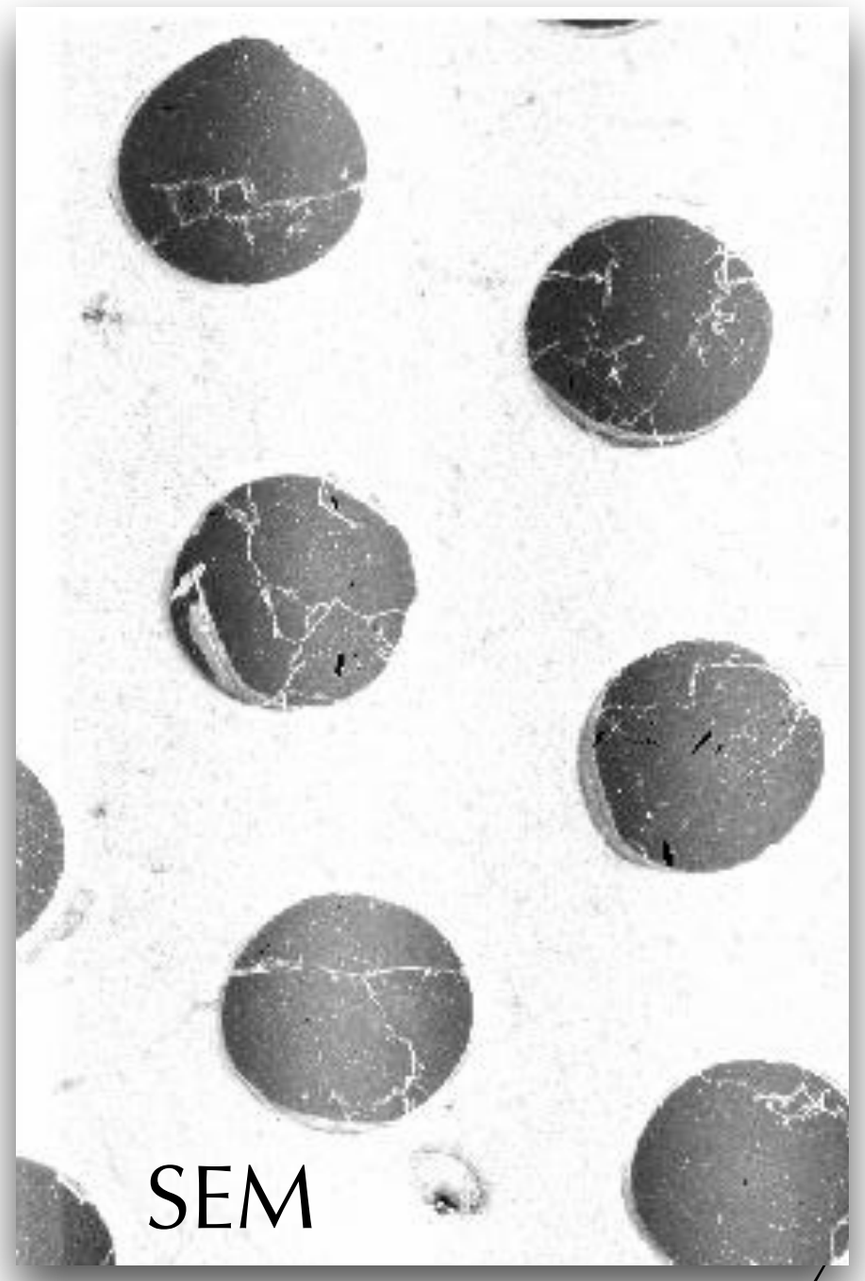
Single layer transfer

Graphene is extraordinarily **robust accounting for its thickness**

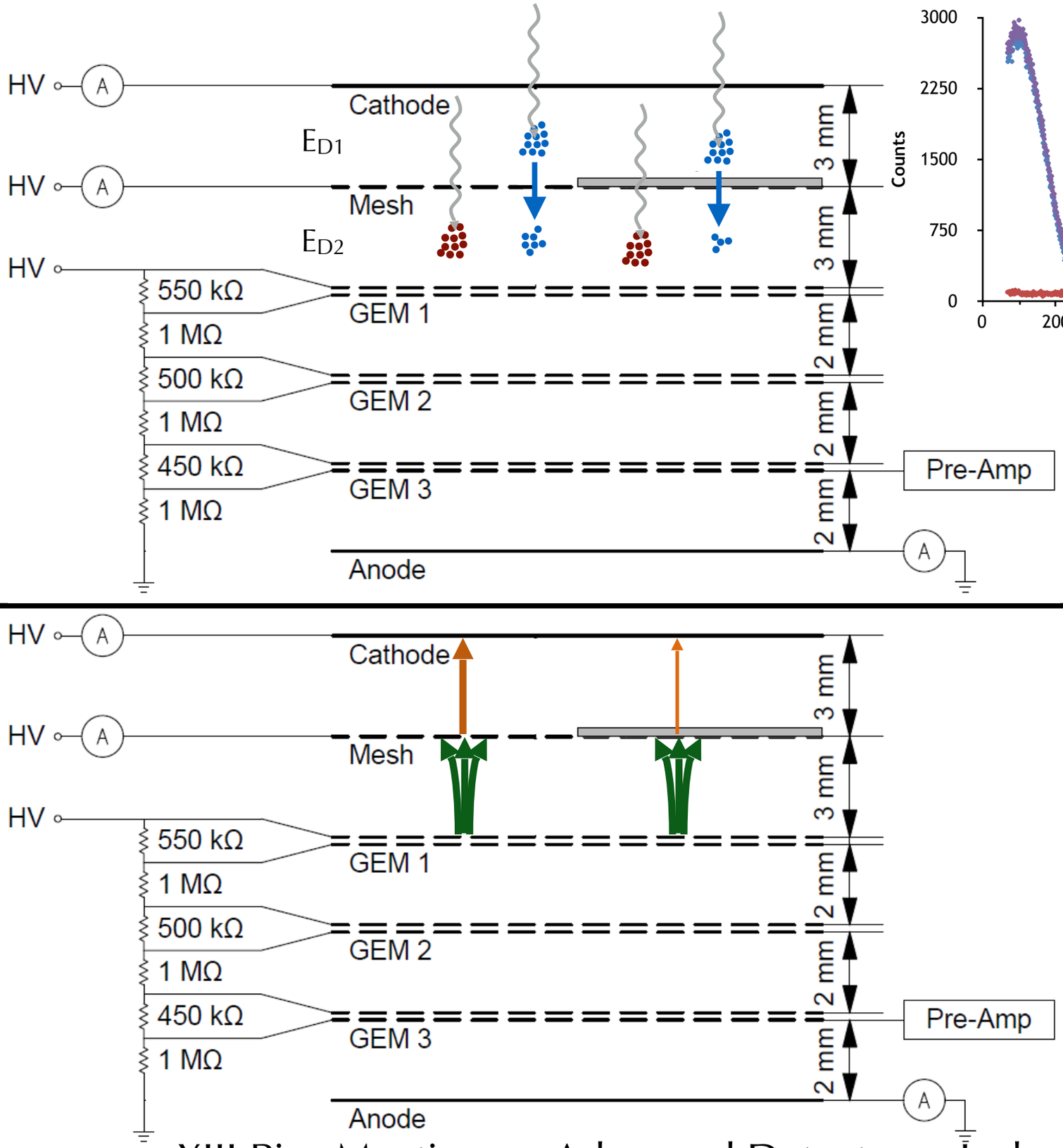
It can be freely suspended over **tens of µm**

CVD graphene, transfer, and quality checks done at UCL

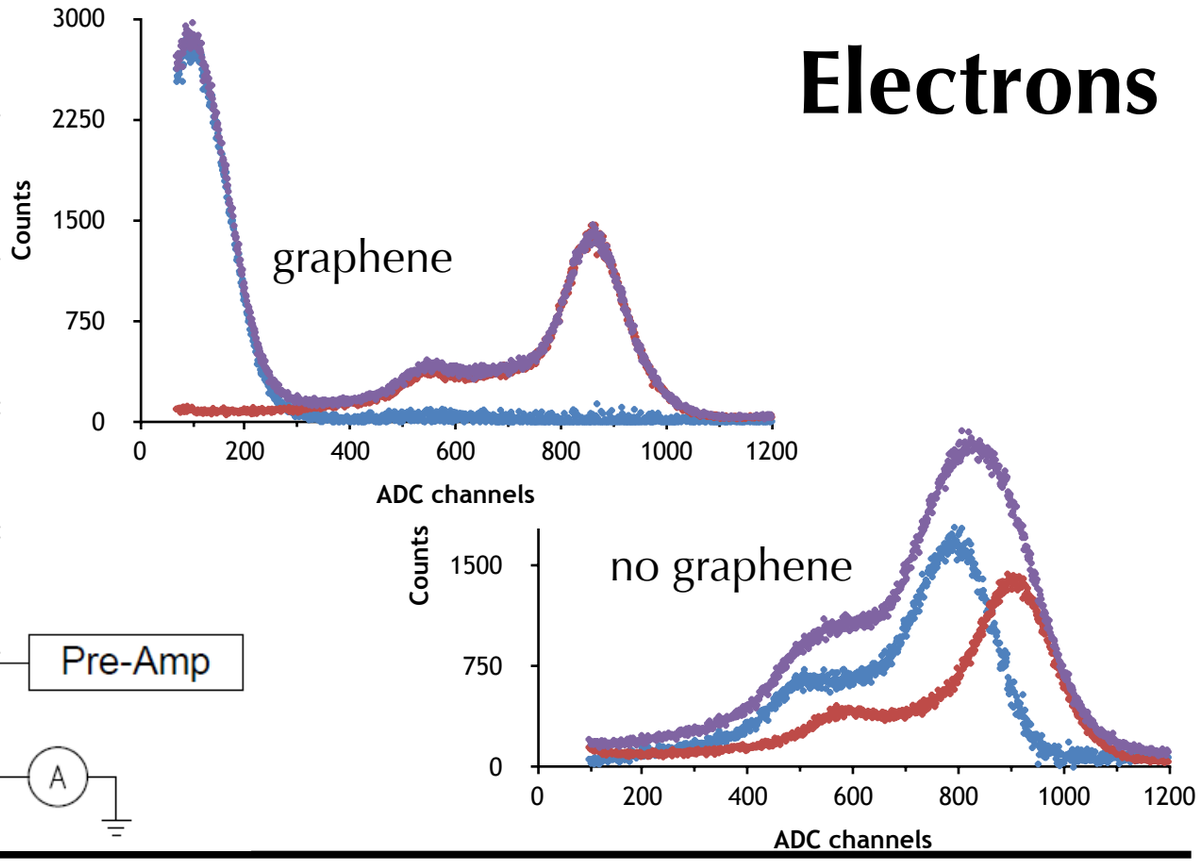




The measurement



Electrons



Ions

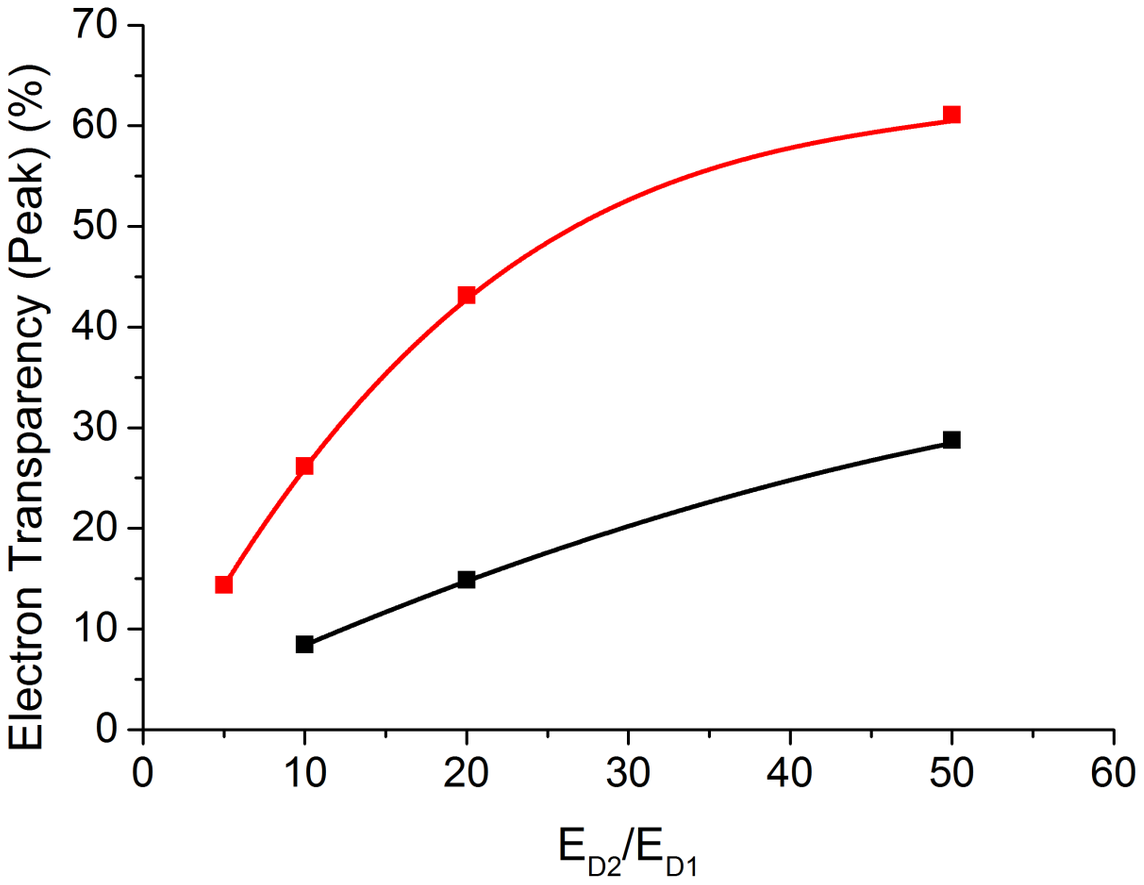
GEM as ion generator

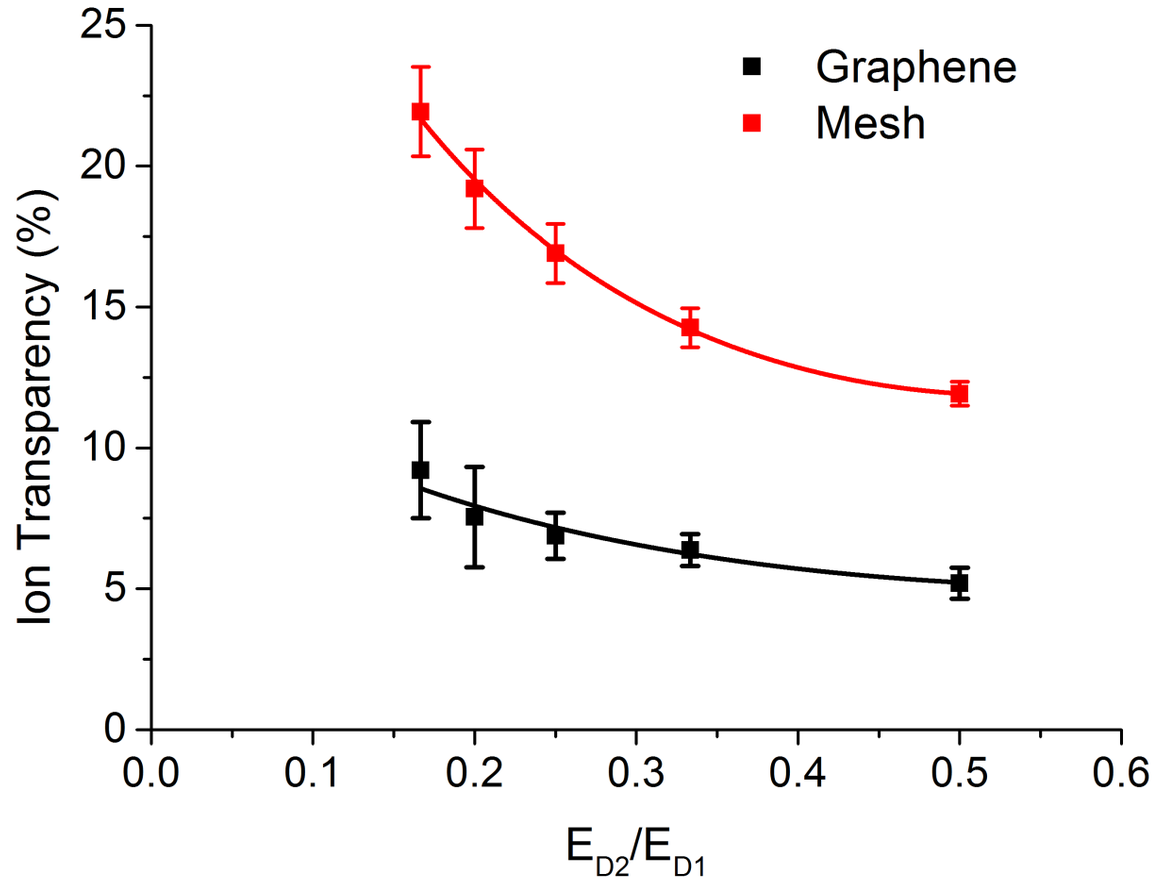
$T = I_{cath} / (I_{cath} + I_{mesh})$

Transparencies

Ar/CO_2 90/10 mixture, 30µm ⌀ 120µm pitch mesh

1mm ⌀ collimated beam of 8keV Cu X-rays



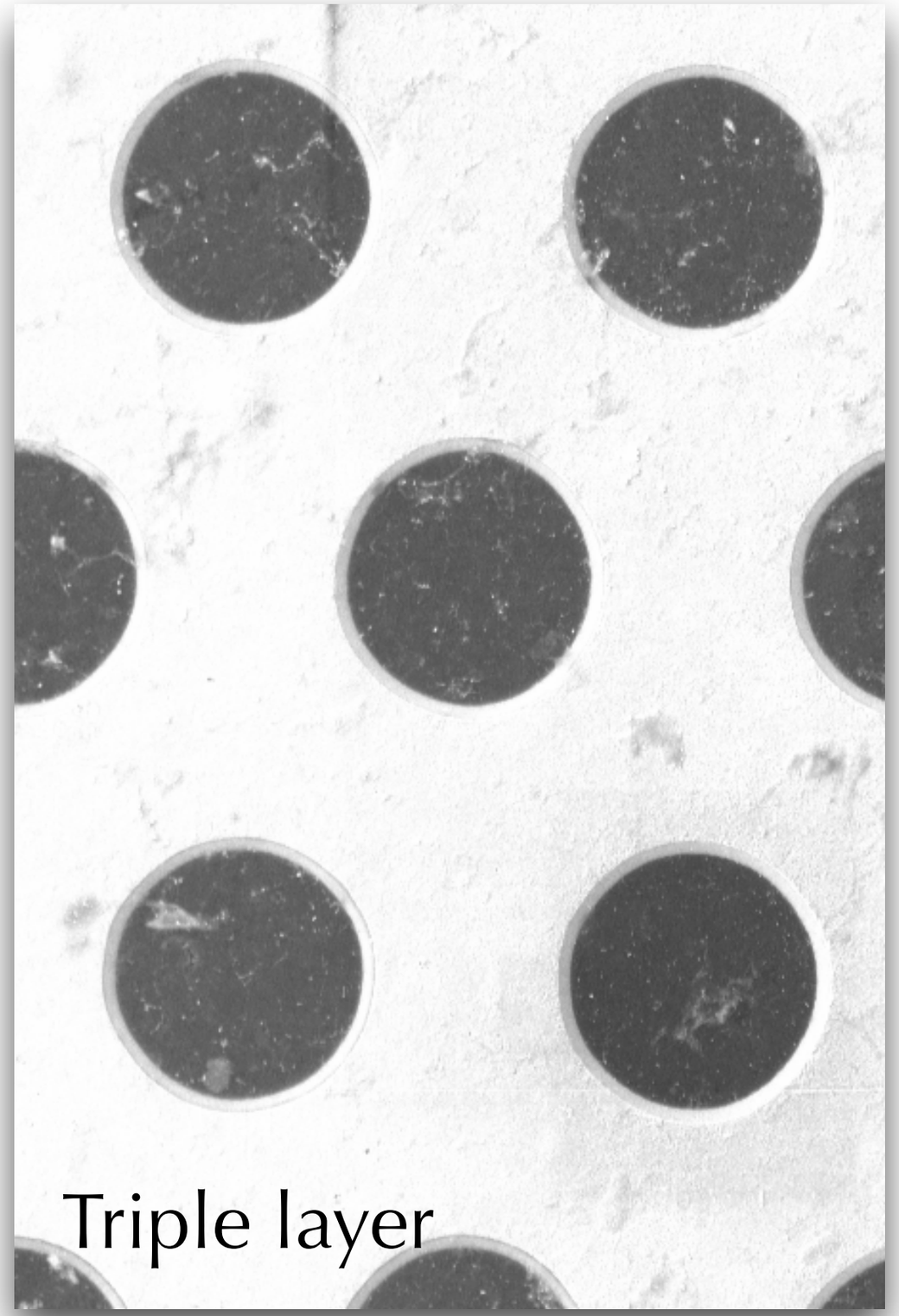


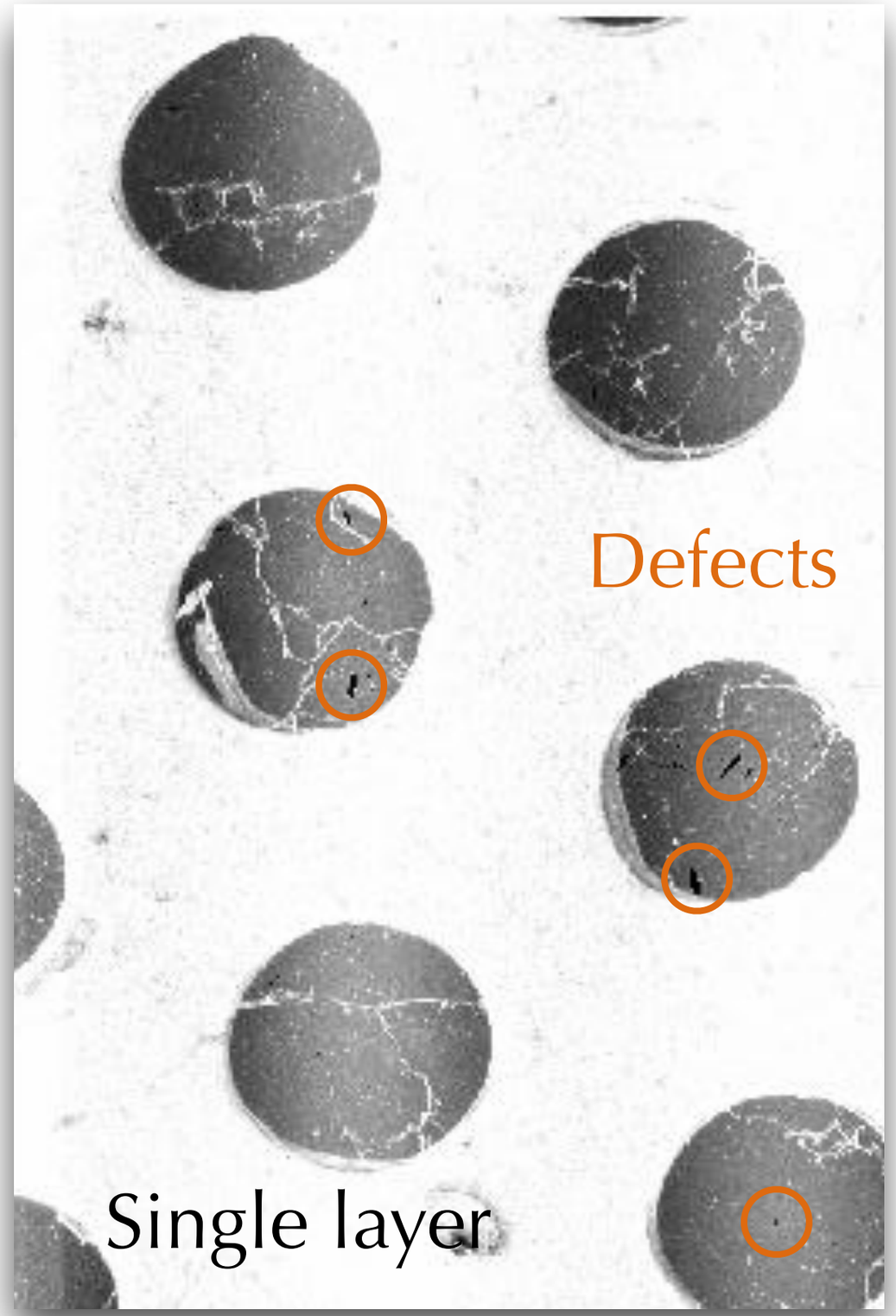
Reduced the electron and ion transparencies

Same behaviour of very **small optical transparency** mesh

Measurement is **dominated by defects** on graphene

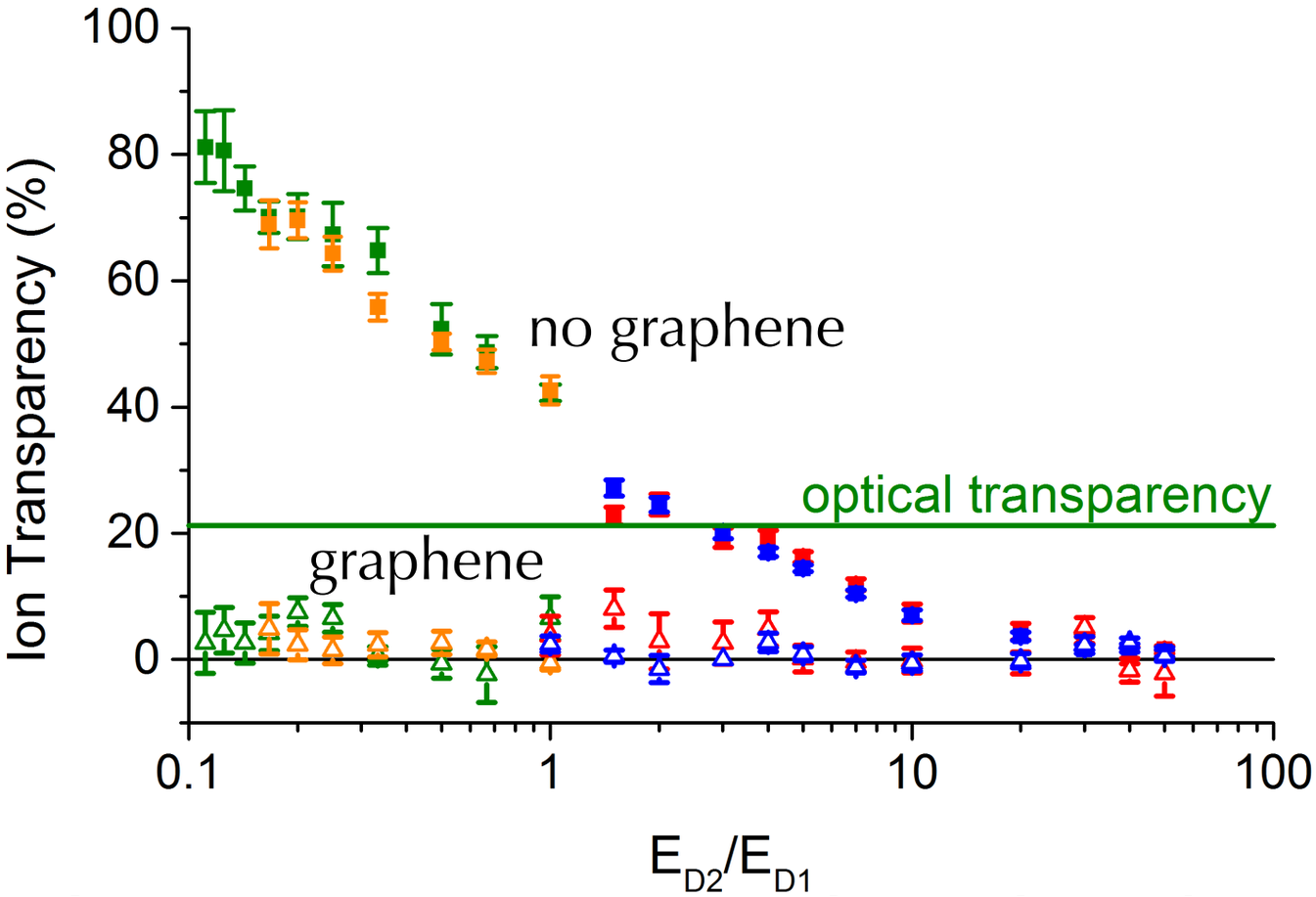
Multi-layer transfer

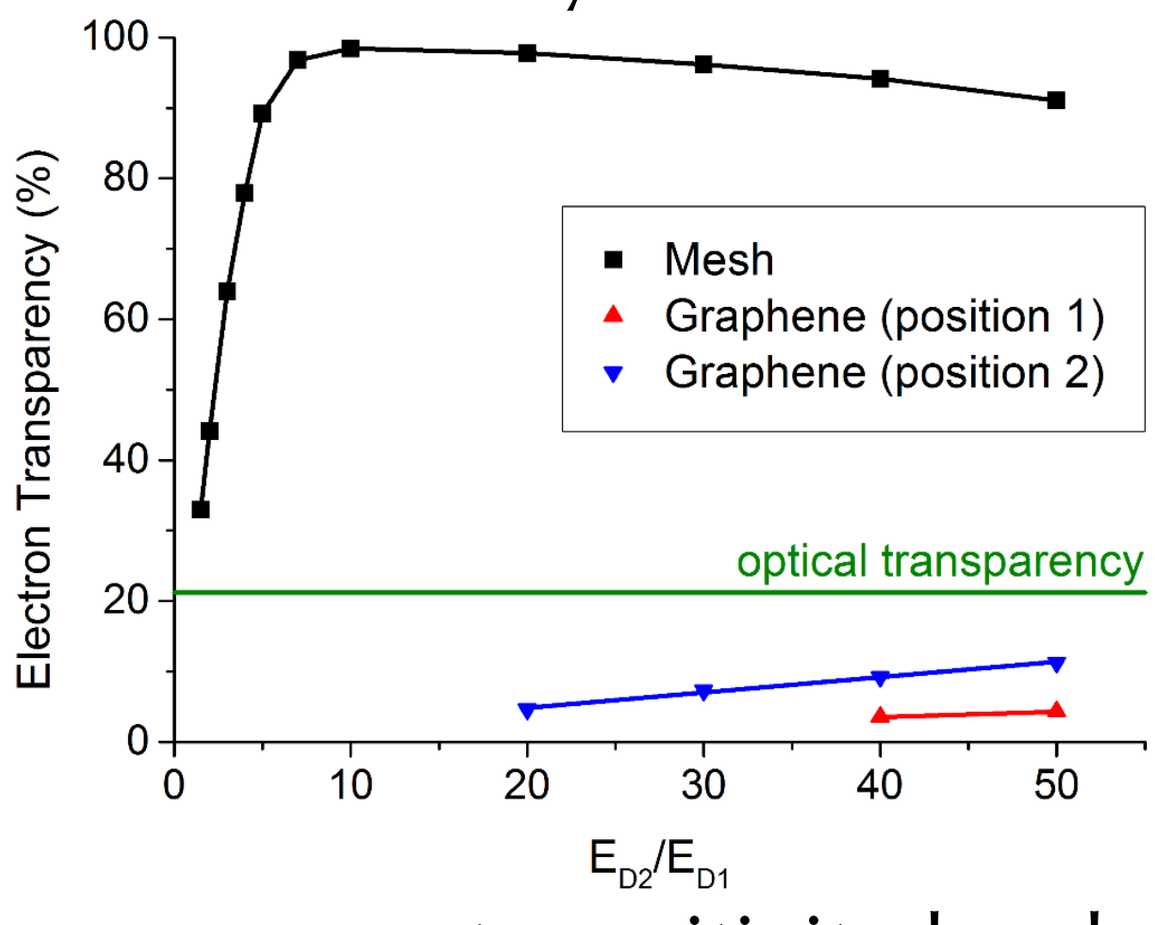




Transparencies

Ar/CO_2 70/30 mixture, 30µm ⌀ 60µm pitch mesh
1mm ⌀ collimated beam of 8keV Cu X-rays





Ion transparency reduced to the measurement sensitivity level

But electrons do not tunnel easily

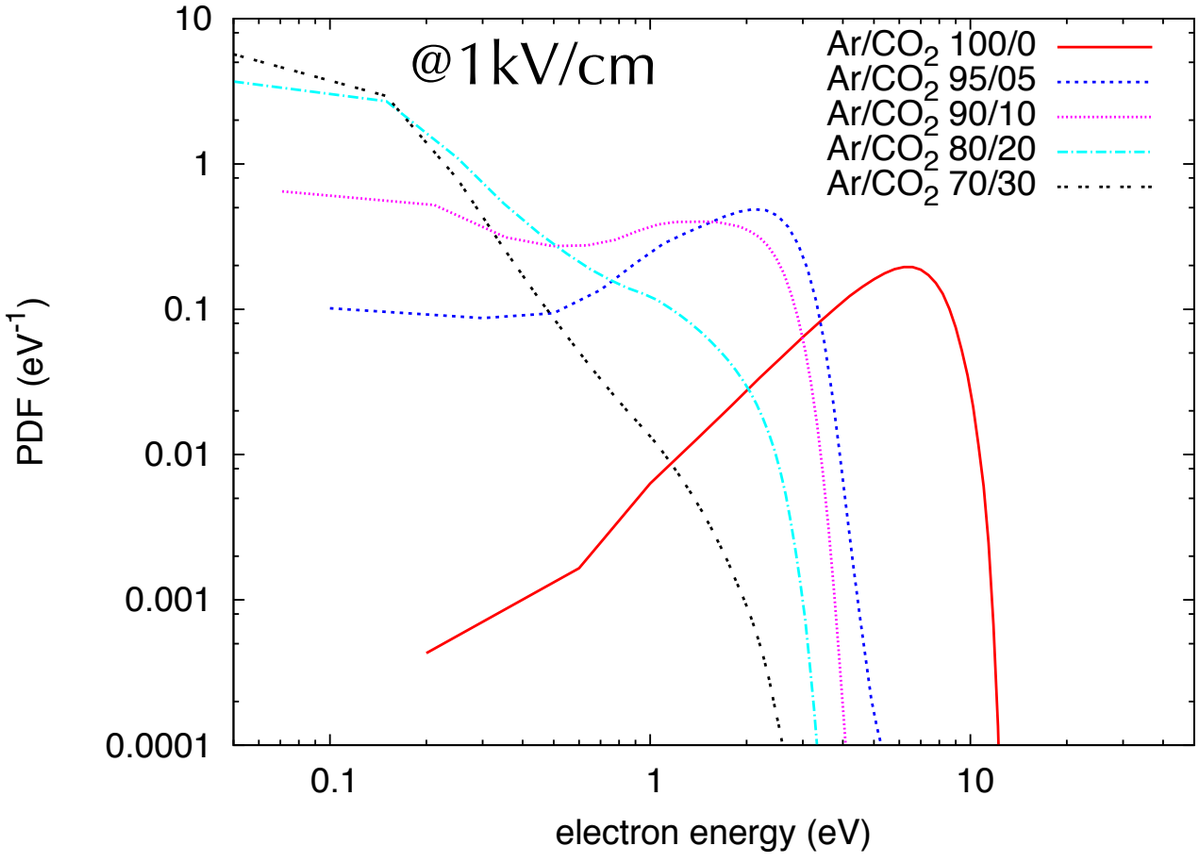
H. Hibino *et al.*, Phys. Rev. B 77, 075413
R. M. Feenstra *et al.*, Phys. Rev. B 87, 041406

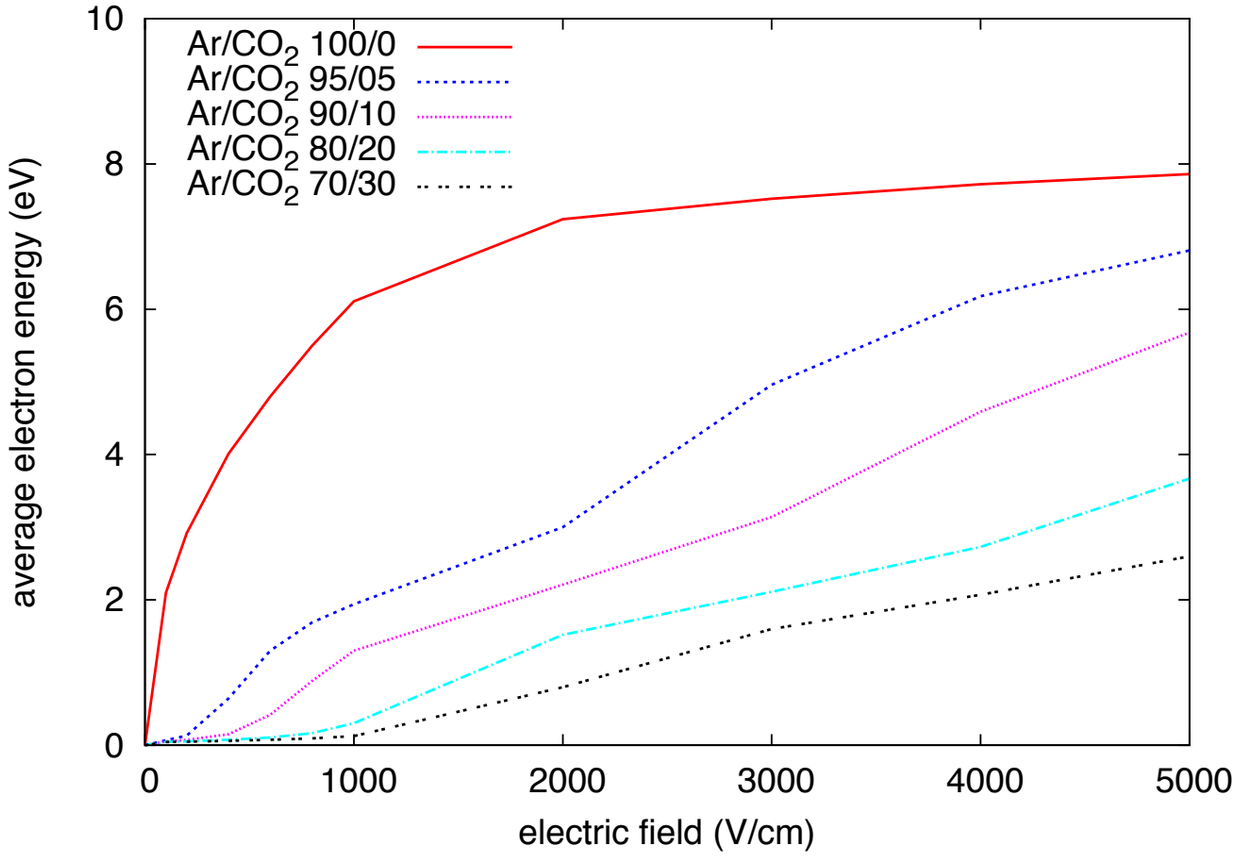
Space or contaminants between the layers? Still defects?

Close to measure intrinsic properties of graphene

Increasing e^- transparency

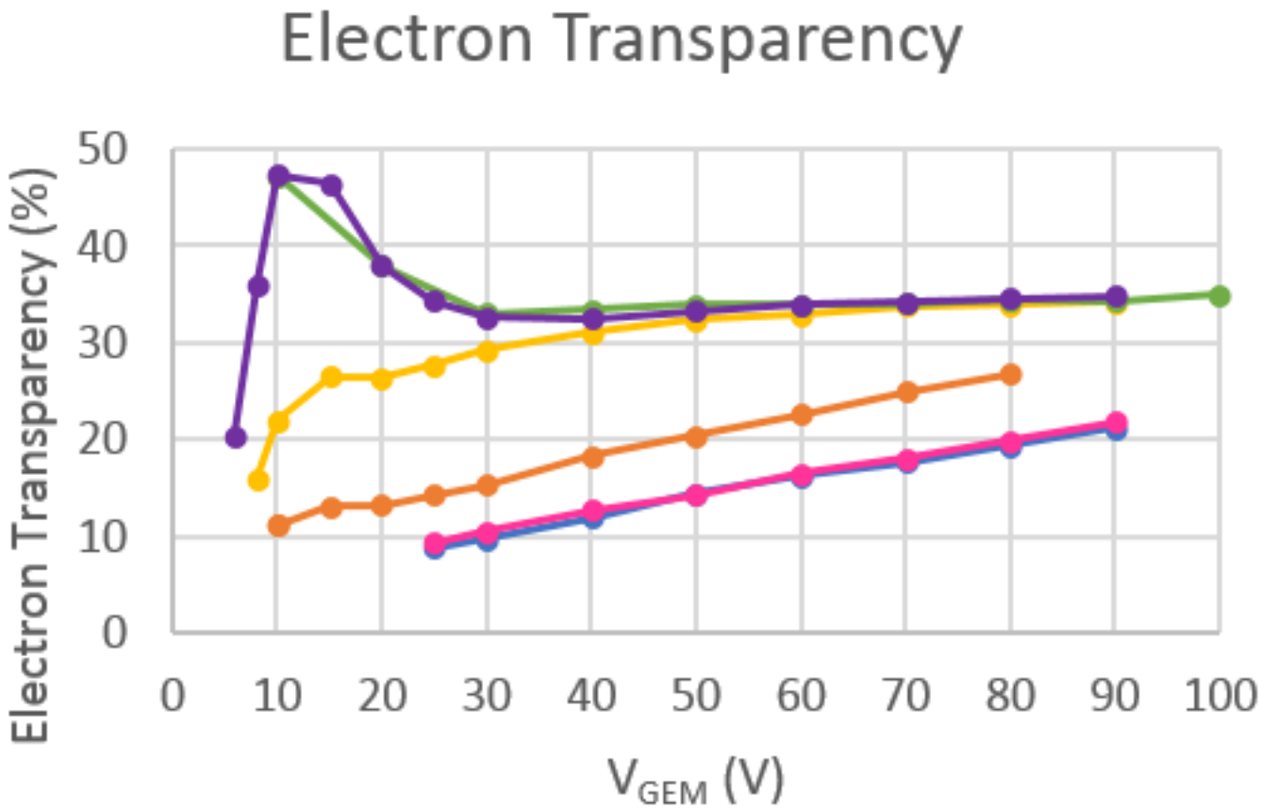
Changing the electron energy by:
- changing the gas mixture (more argon, neon)
- increasing the electric field

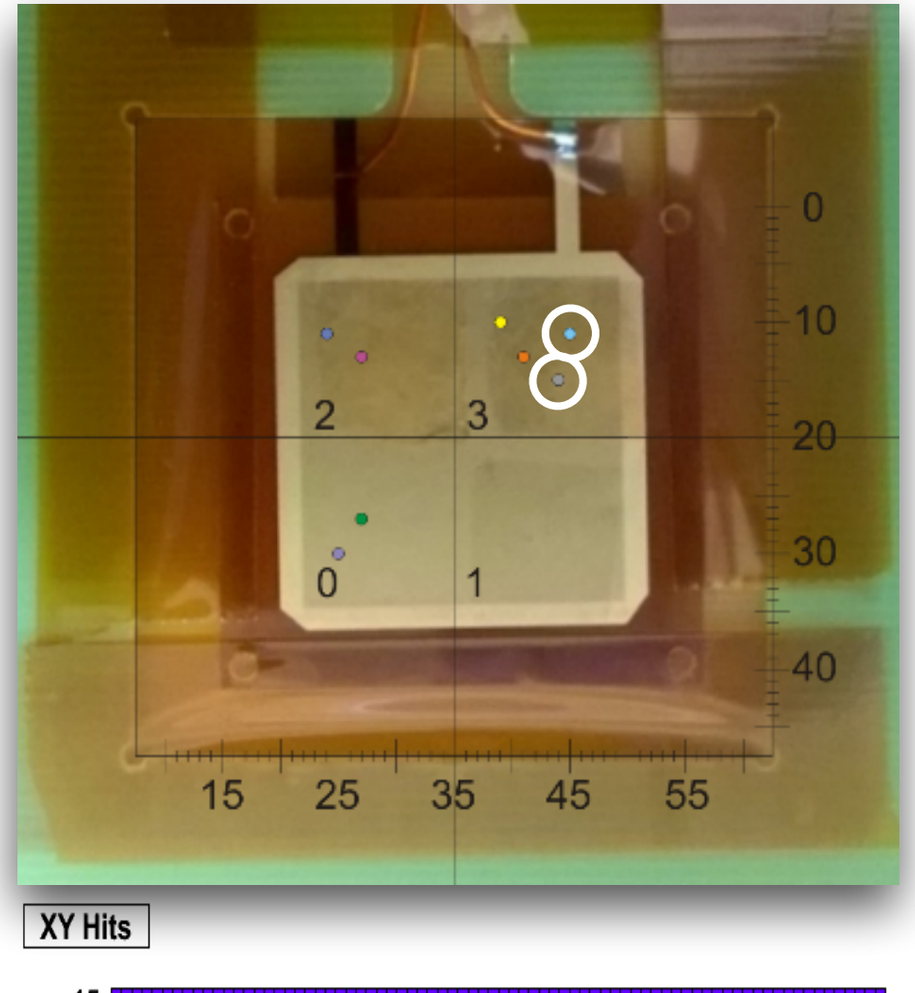




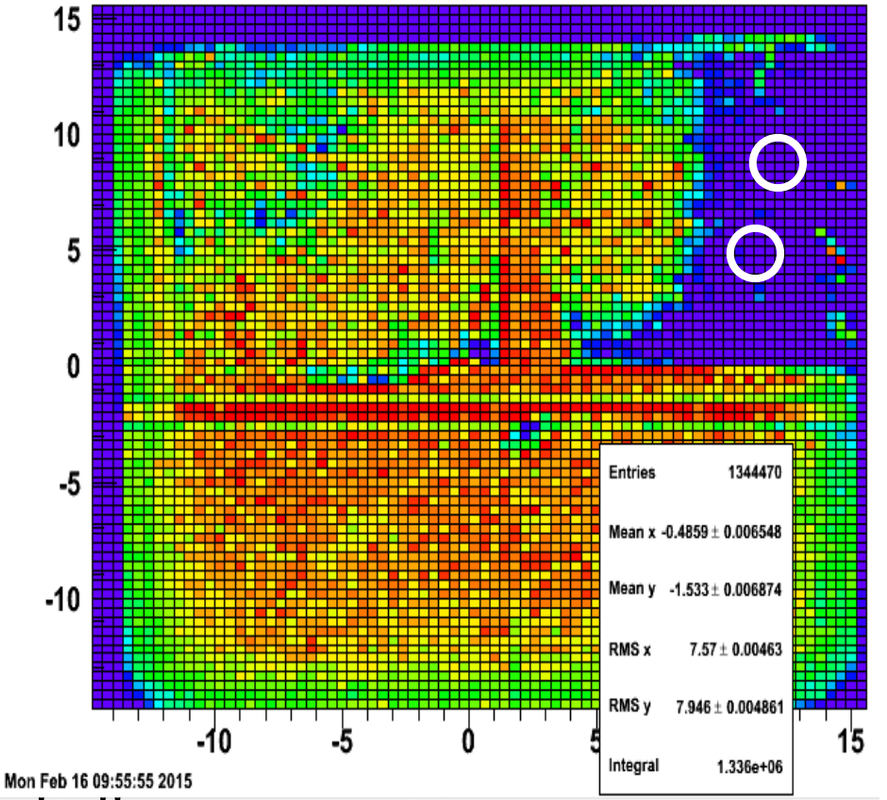
Why not transfer a **graphene layer on a GEM**?

On the GEM





XY Hits



Graphene on top of a GEM

Ar/CO_2 70/30

E_{D1} = 50V/cm, E_{D2} = 1kV/cm

X-ray beam (collimated and not)

Tri-layer not transparent to electrons

Graphene *shorted* the GEM electrodes

What do we still need

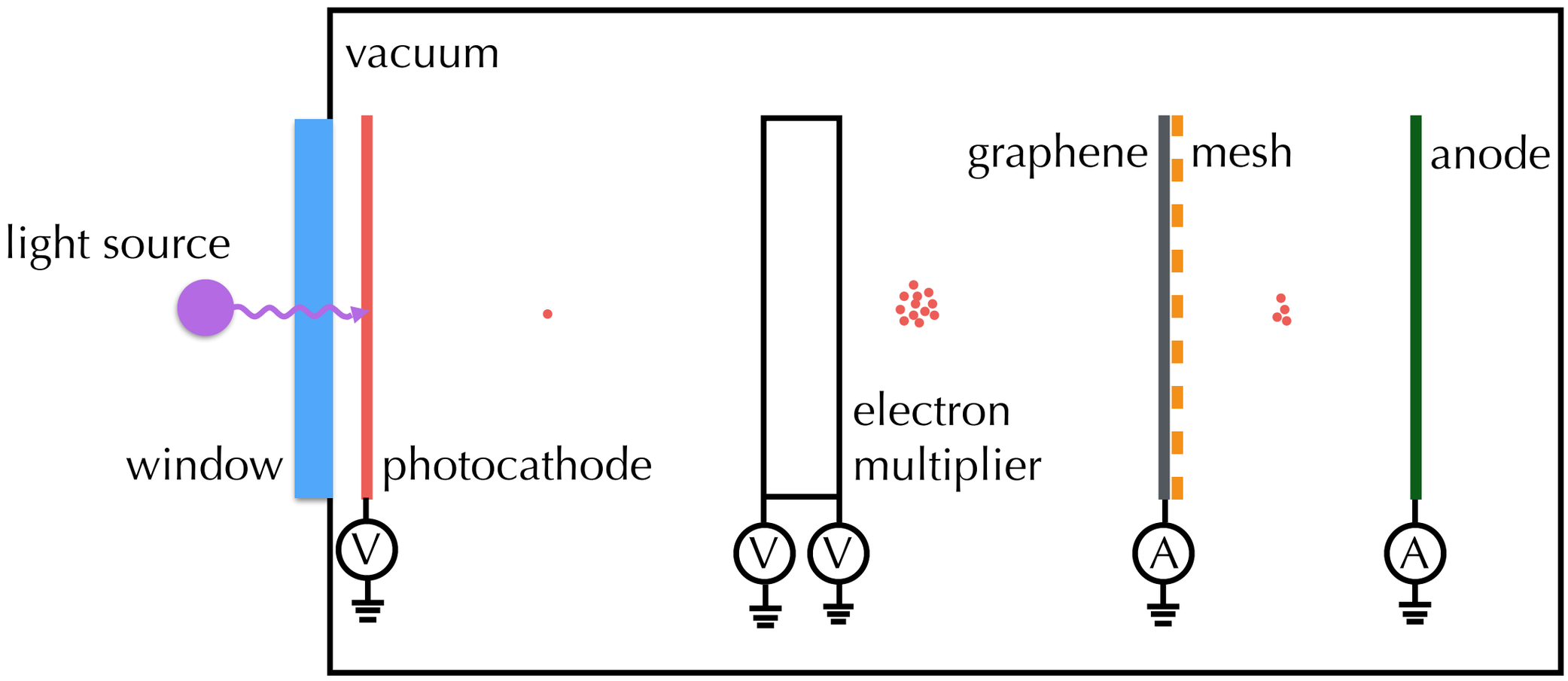
Real **tri-layer grown as a whole thing**
(quantum-mechanic object)

Direct measurement of the electron **transmission** as a function of the energy

Transfer the layer **without damaging** it
Maybe not transferring it at all?

Transmission in vacuum

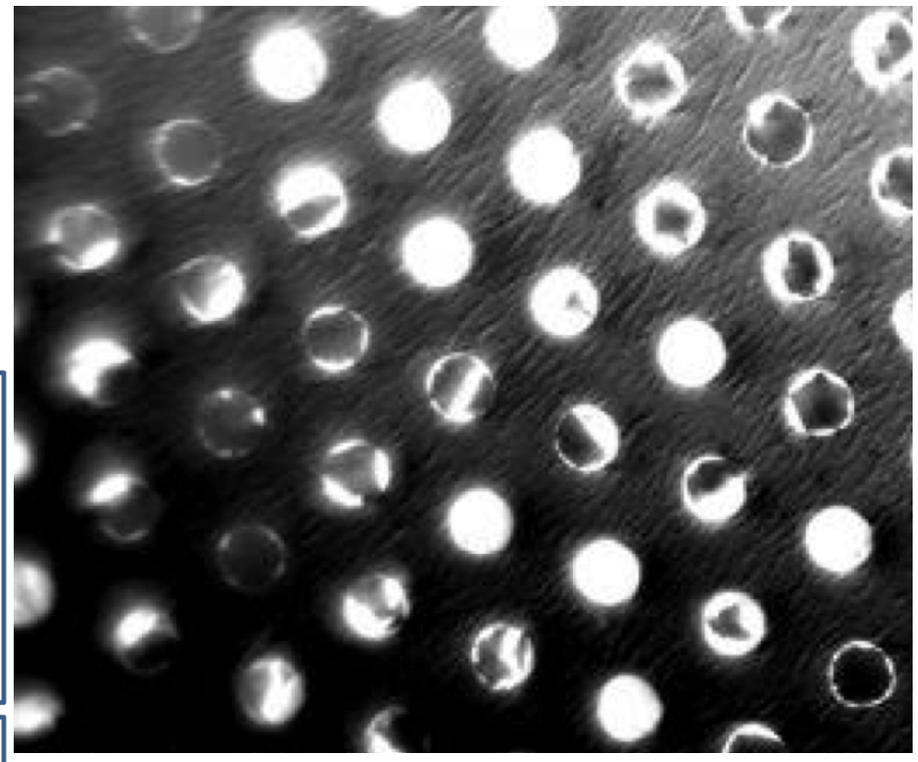
No direct measurement for low energy electrons
Transmittance extrapolated from reflectance

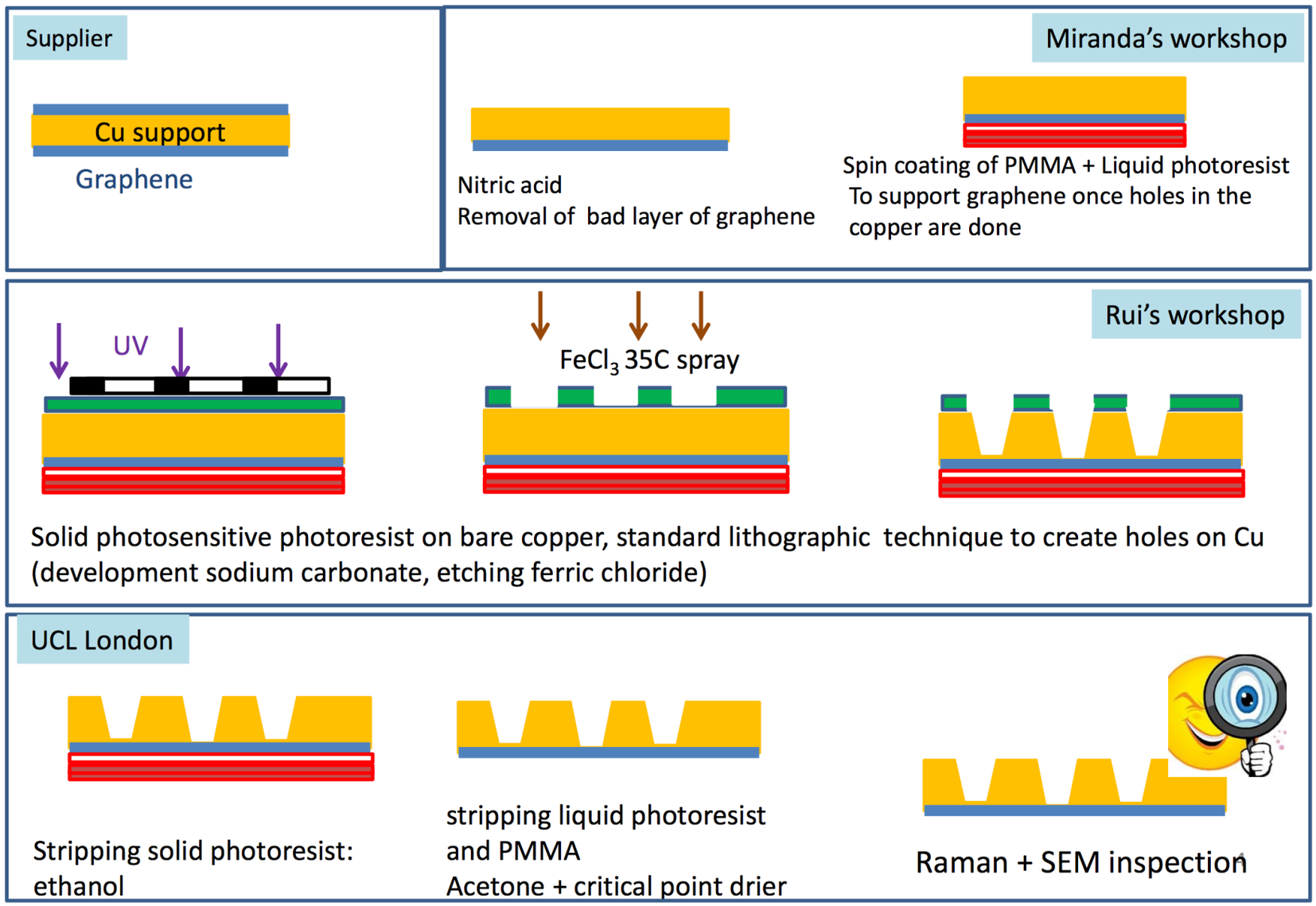


Electron multiplier may be not needed
if the light source is strong enough
Tune the electron **energy** at the eV scale

Transfer: changing approach

Etch a mesh from the substrate
so that the **transfer is no longer needed**





Very promising preliminary results

Pure graphene (no contaminants), but damaged

Conclusions

Developed a technique to transfer graphene layers onto different substrates

Charge transfer properties of graphene in gas are under studies

Behaviour of the single layer, though of very good quality, dominated by defects

Conclusions

Tri-layer graphene to minimise defects

Three atomic layers proved to stop ions

Electrons stopped because interspace or contaminants between the layers

Operated a GEM coated with graphene

Outlooks

Grow CVD tri-layer graphene
Continue testing graphene coated GEMs

Measure in vacuum the electron transparency as a function of the energy

Improve the etching techniques of the graphene substrate