Charge Transfer Properties Through Graphene for Applications in Gaseous Detectors

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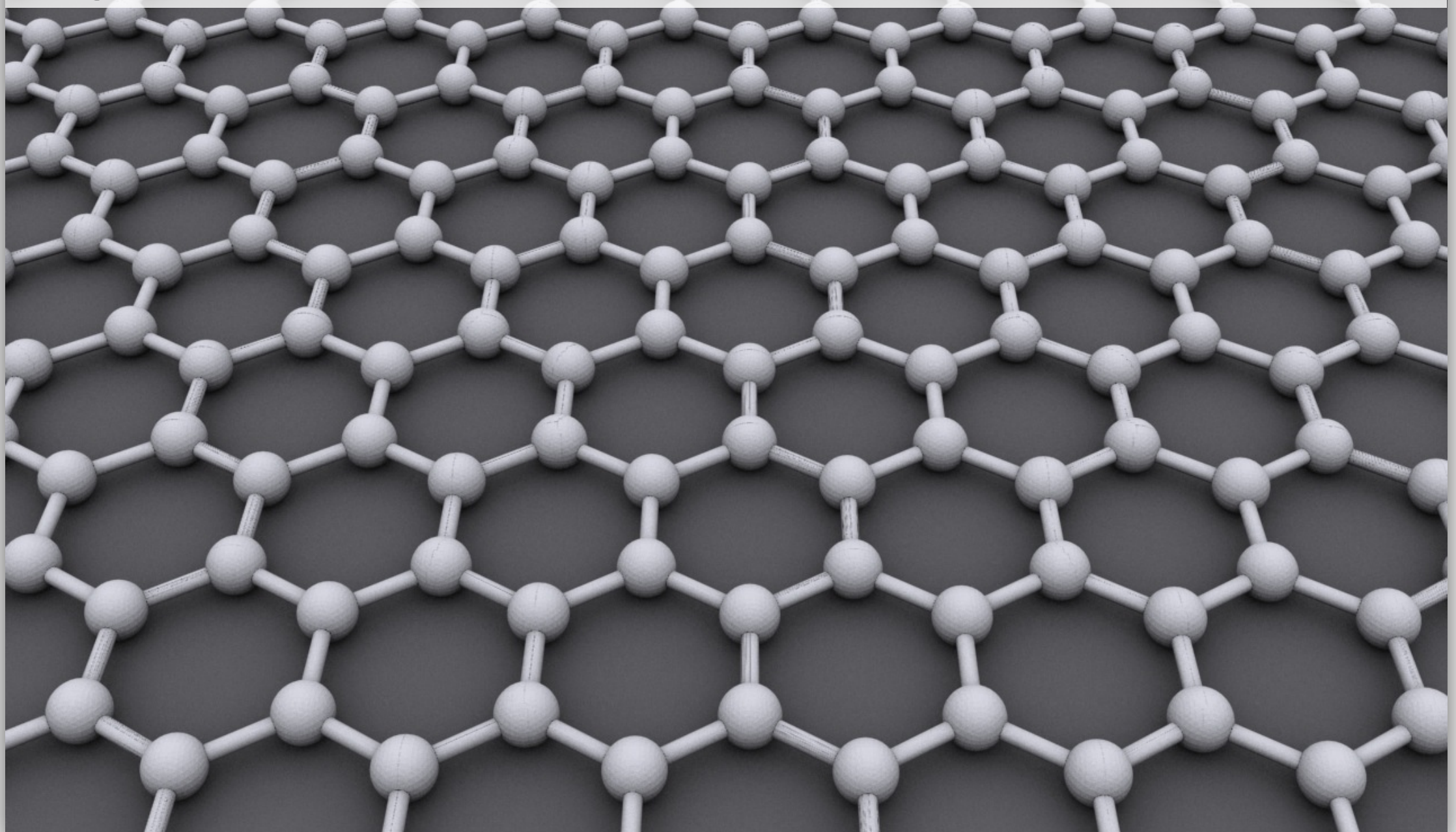[1]CERN, [2]ESS, [3]UCL, [4]TUW

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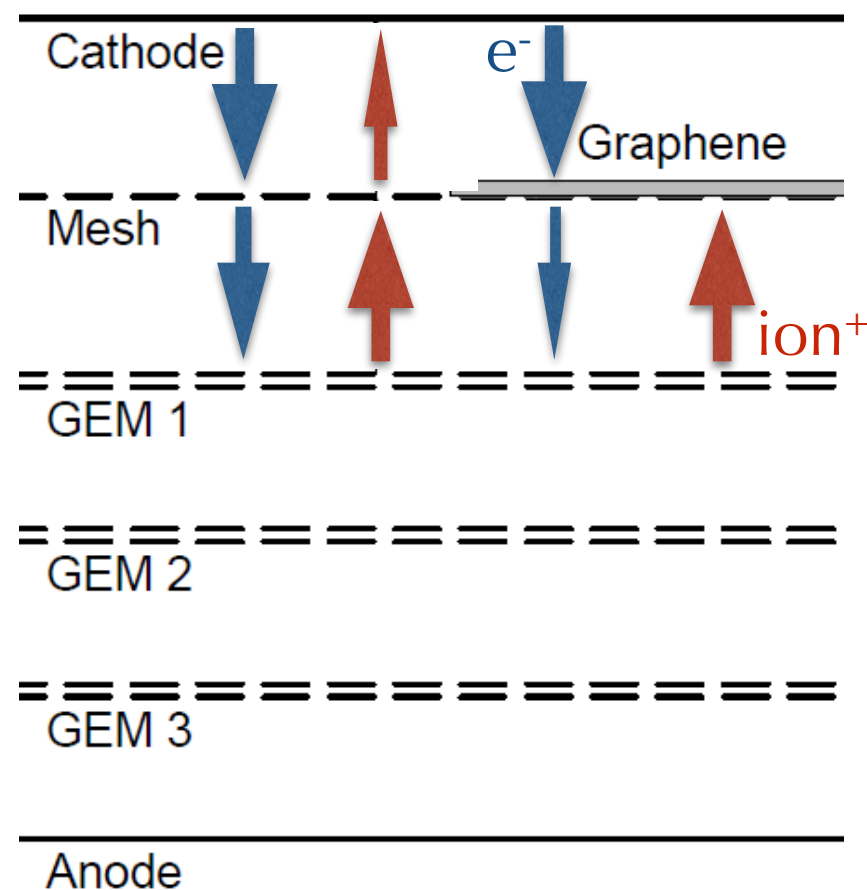J. J. Lopez *et al.*, J. Appl. Phys. 107, 104326
J. Longchamp *et al.*, Appl. Phys. Lett. 101, 113117
S. Srisonphan *et al.*, Sci. Rep. 4, 3764

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
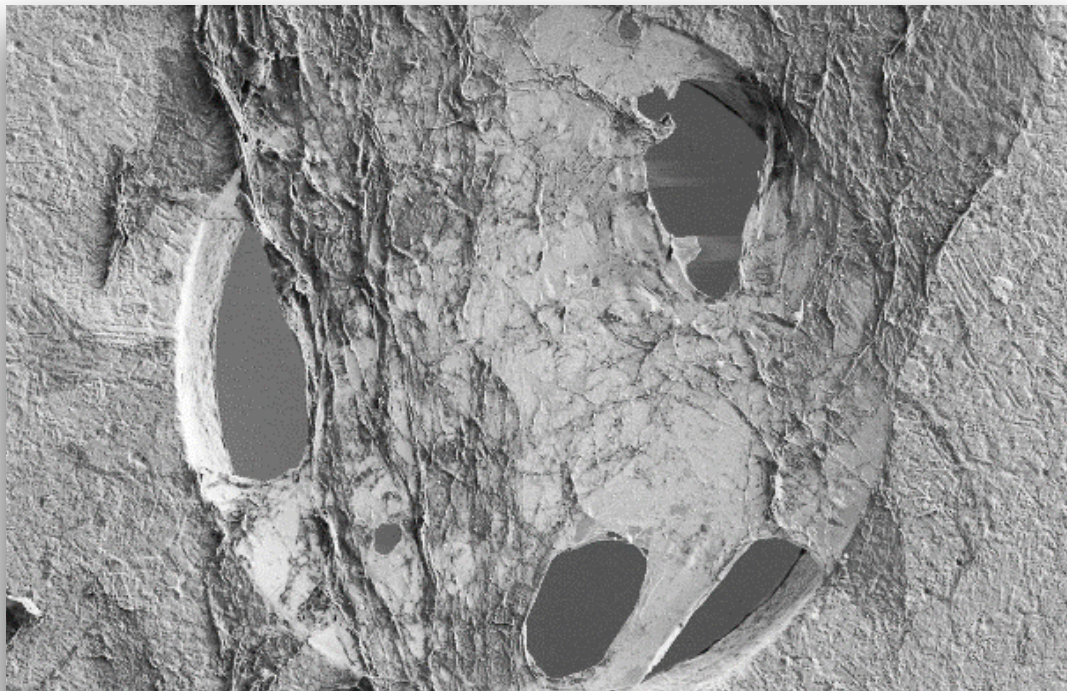
The goal

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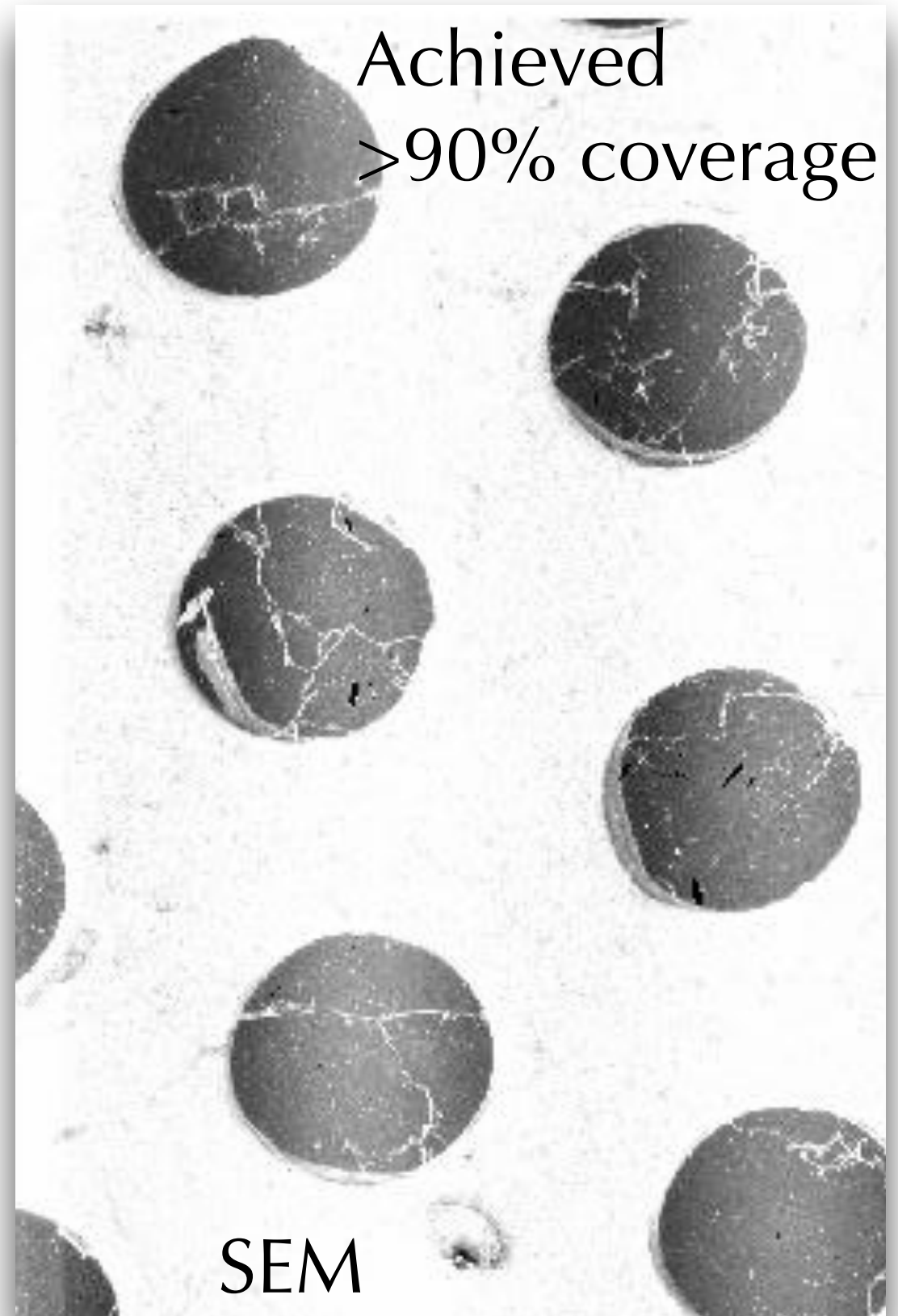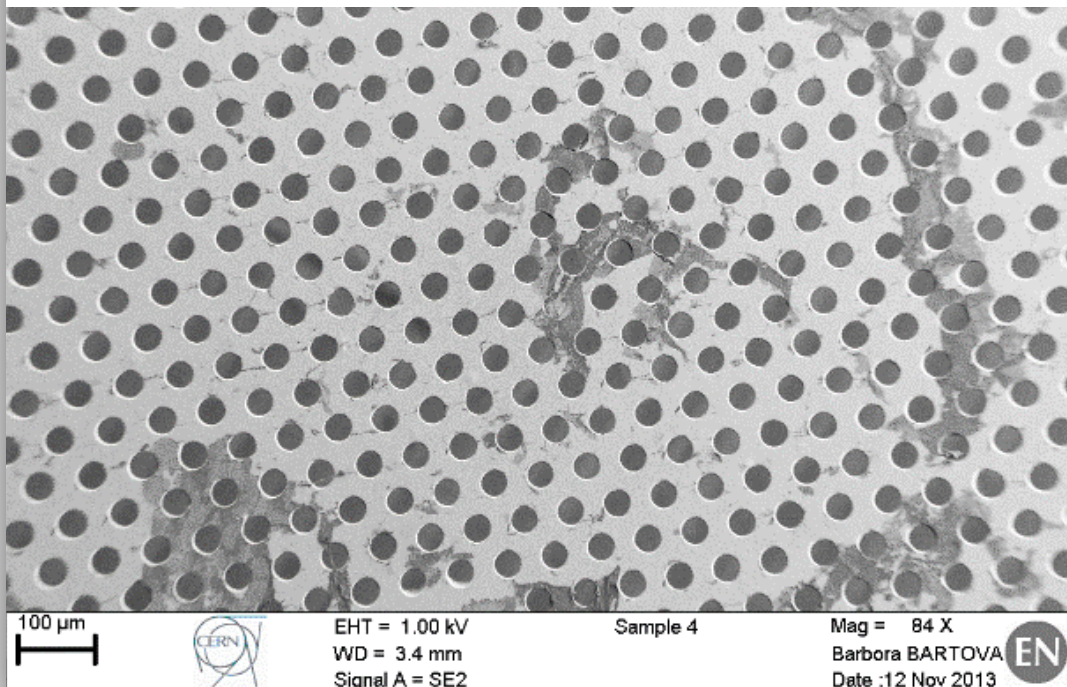
Single layer transfer

Graphene is extraordinarily **robust accounting for its thickness**
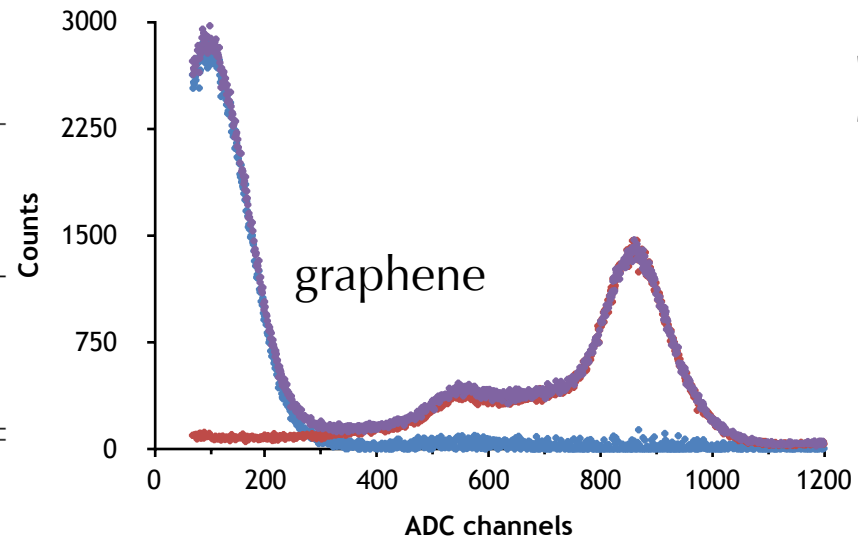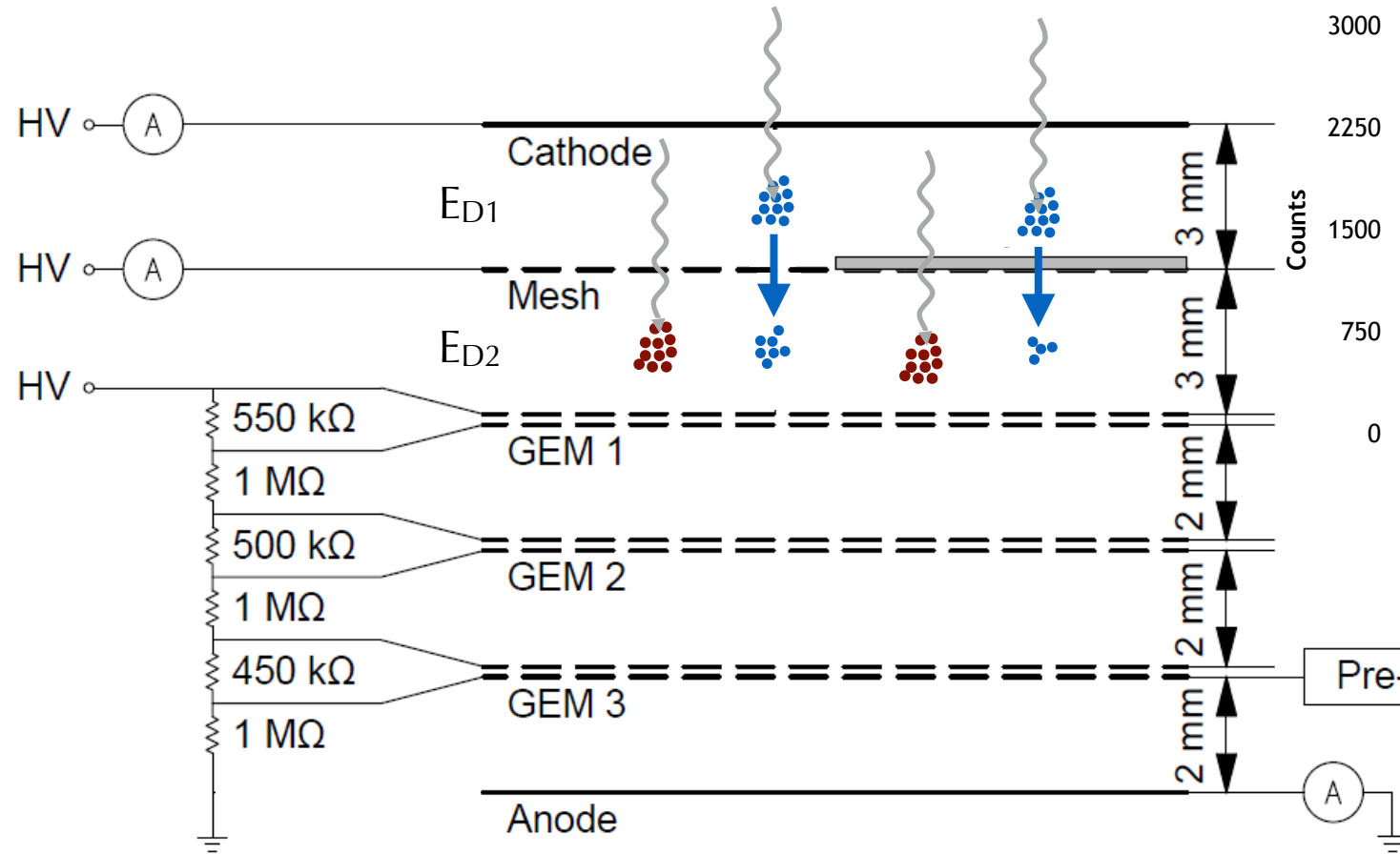It can be freely suspended over **tens of µm**
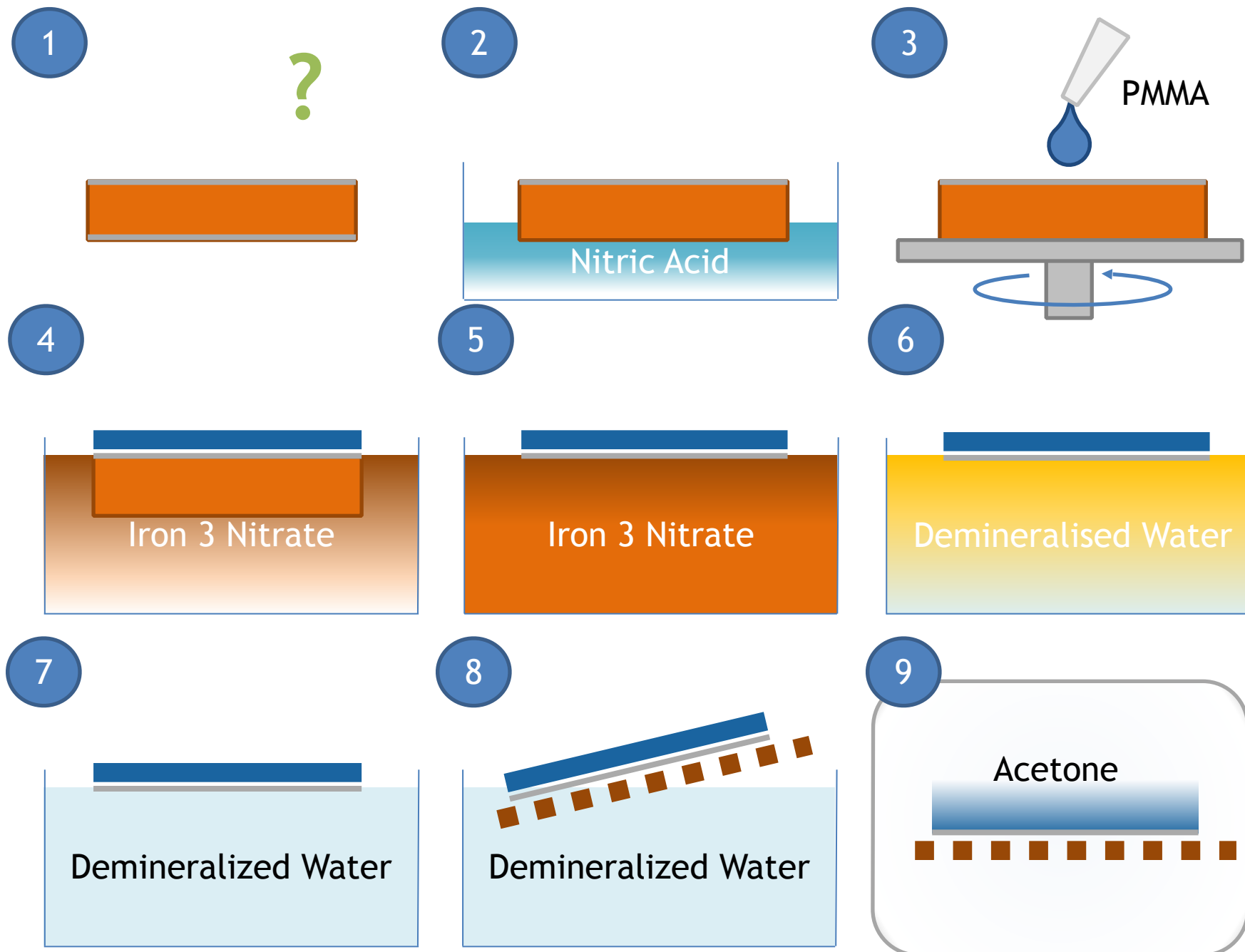
The samples

First samples:
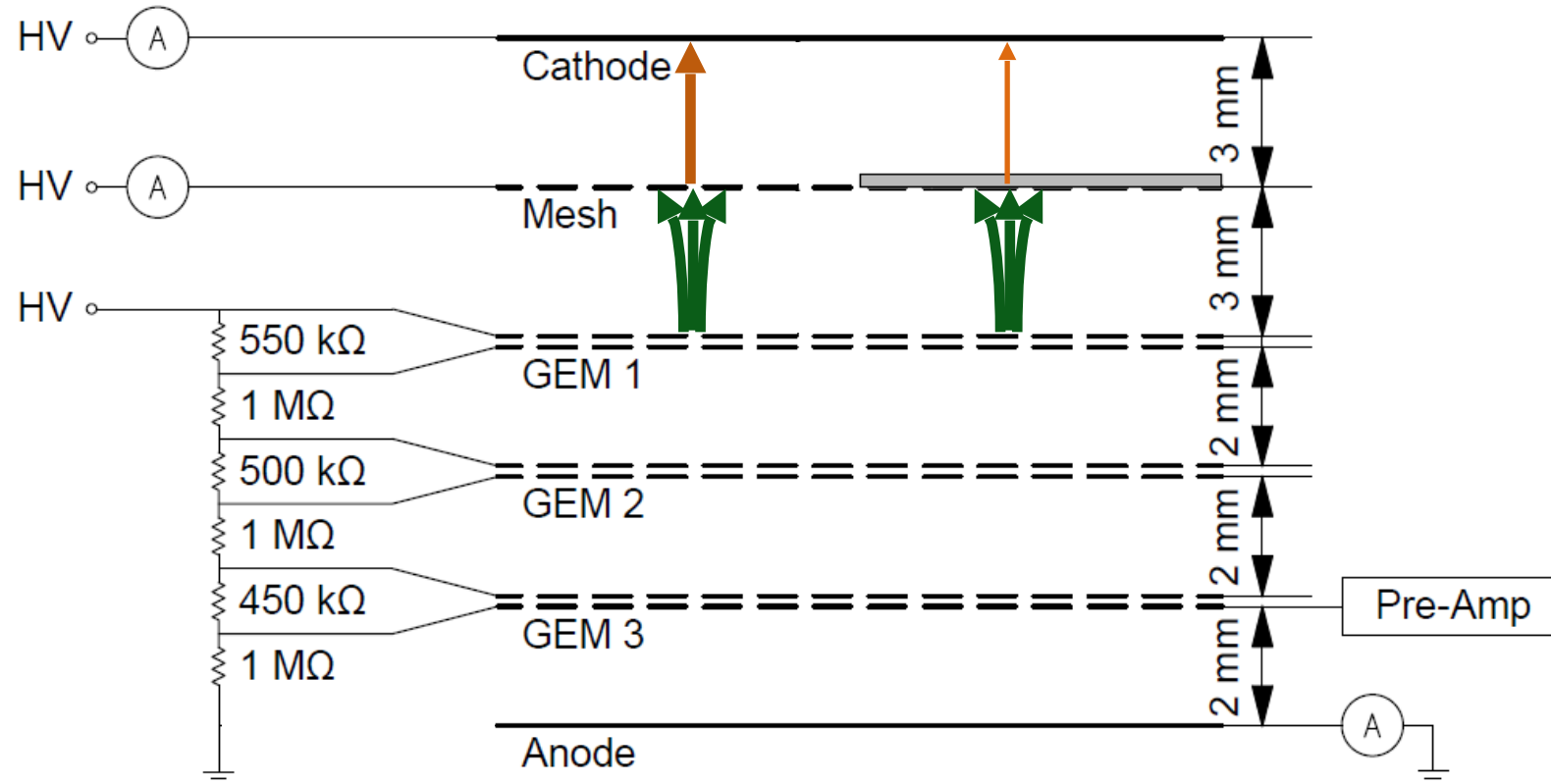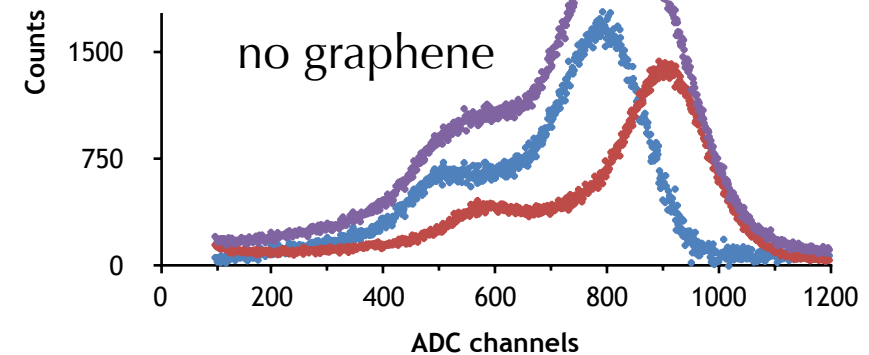Poor coverage

Achieved
>90% coverage

SEM

The measurement

Electrons

graphene

no graphene

Ions

GEM as ion generator

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

9

Focussing effect

No graphene

E_{D1}

E_{D2}
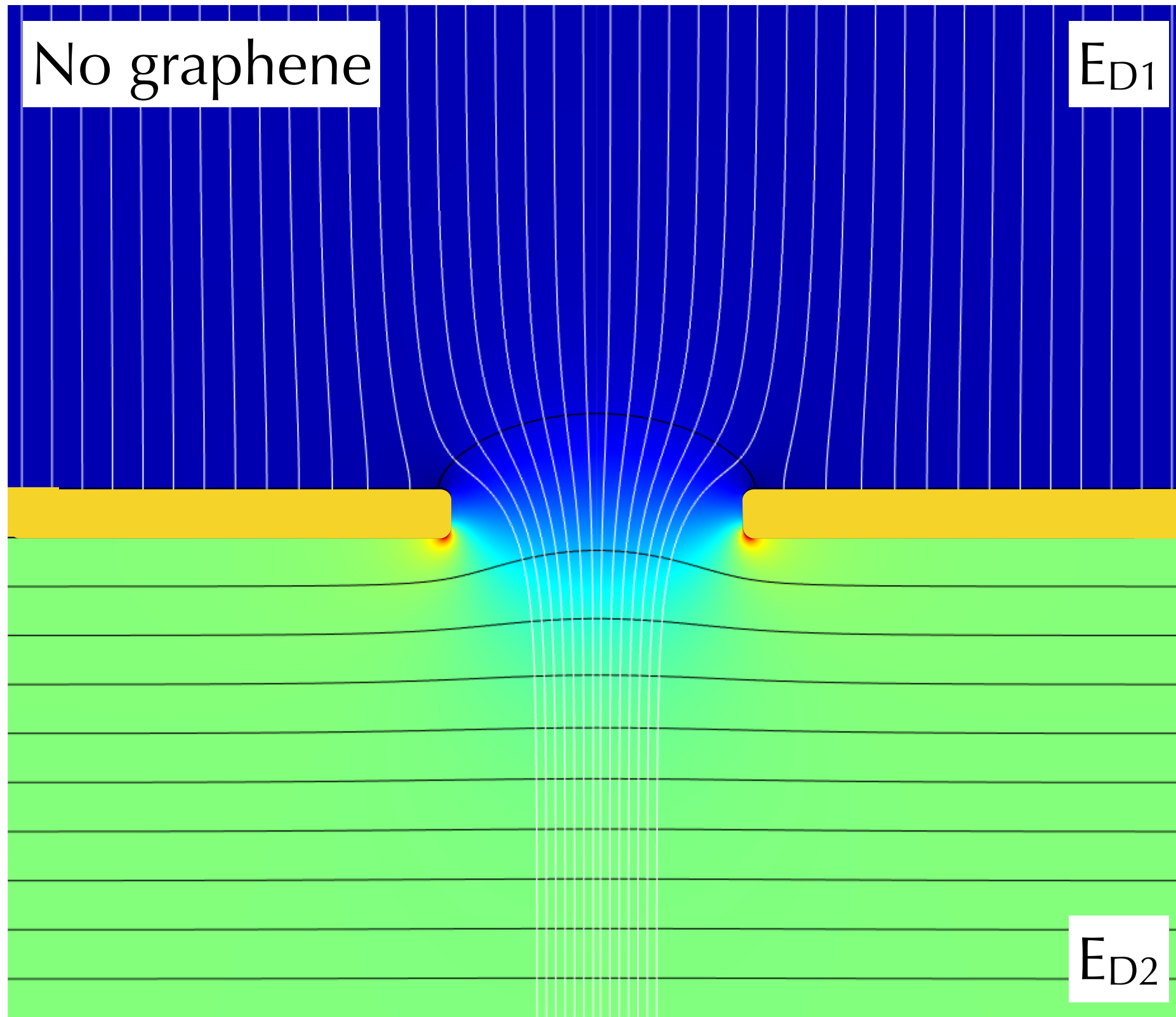
Focussing effect
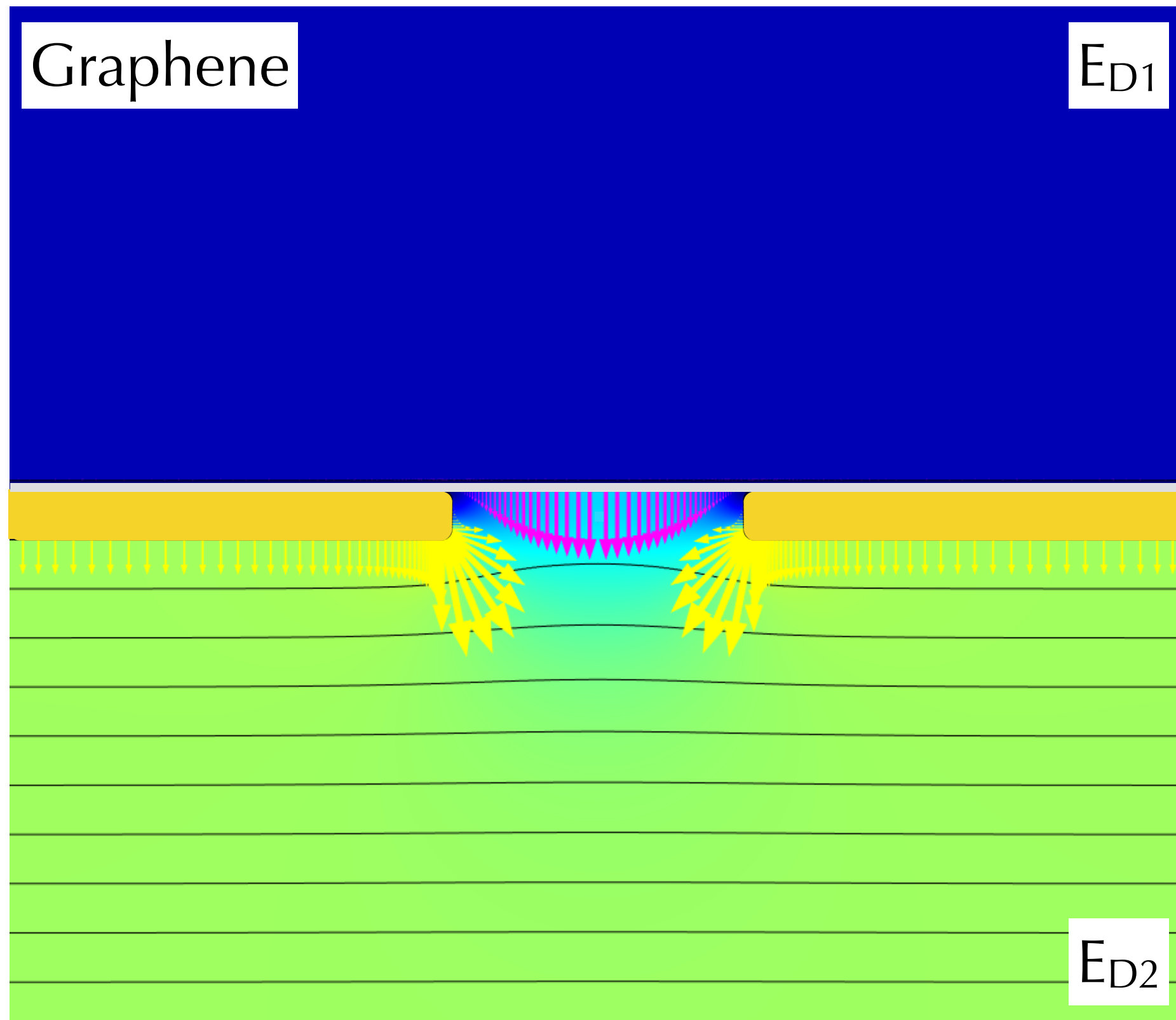
Transparencies

Ar/CO_2 90/10 mixture, 30µm ∅ 120µm pitch mesh
1mm ∅ collimated beam of 8keV Cu X-rays
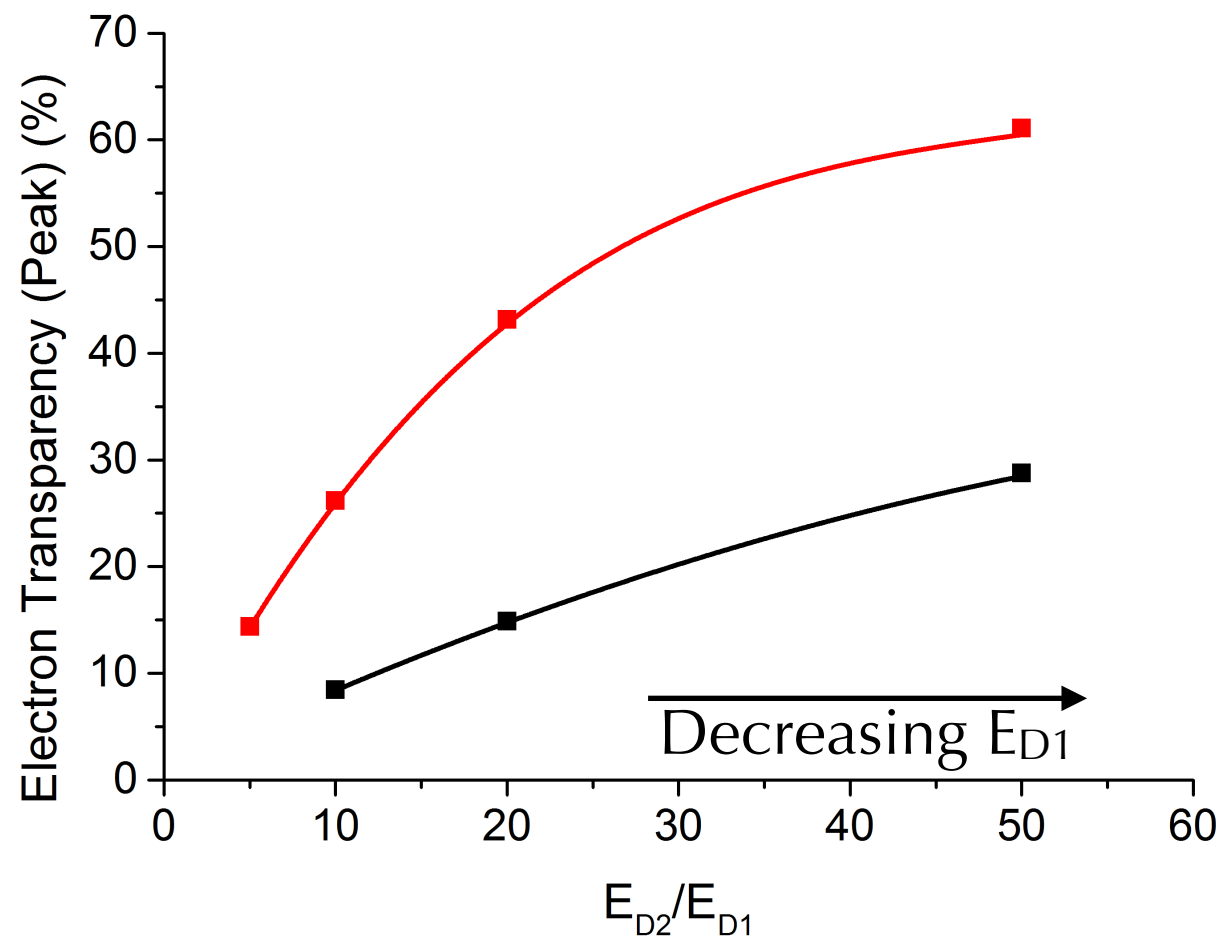
Reduced the electron and ion transparencies
Same behaviour of very **small optical transparency** mesh
Measurement is **dominated by defects** on graphene

Multi-layer transfer

Defects

Single layer

Triple layer:
~99% coverage
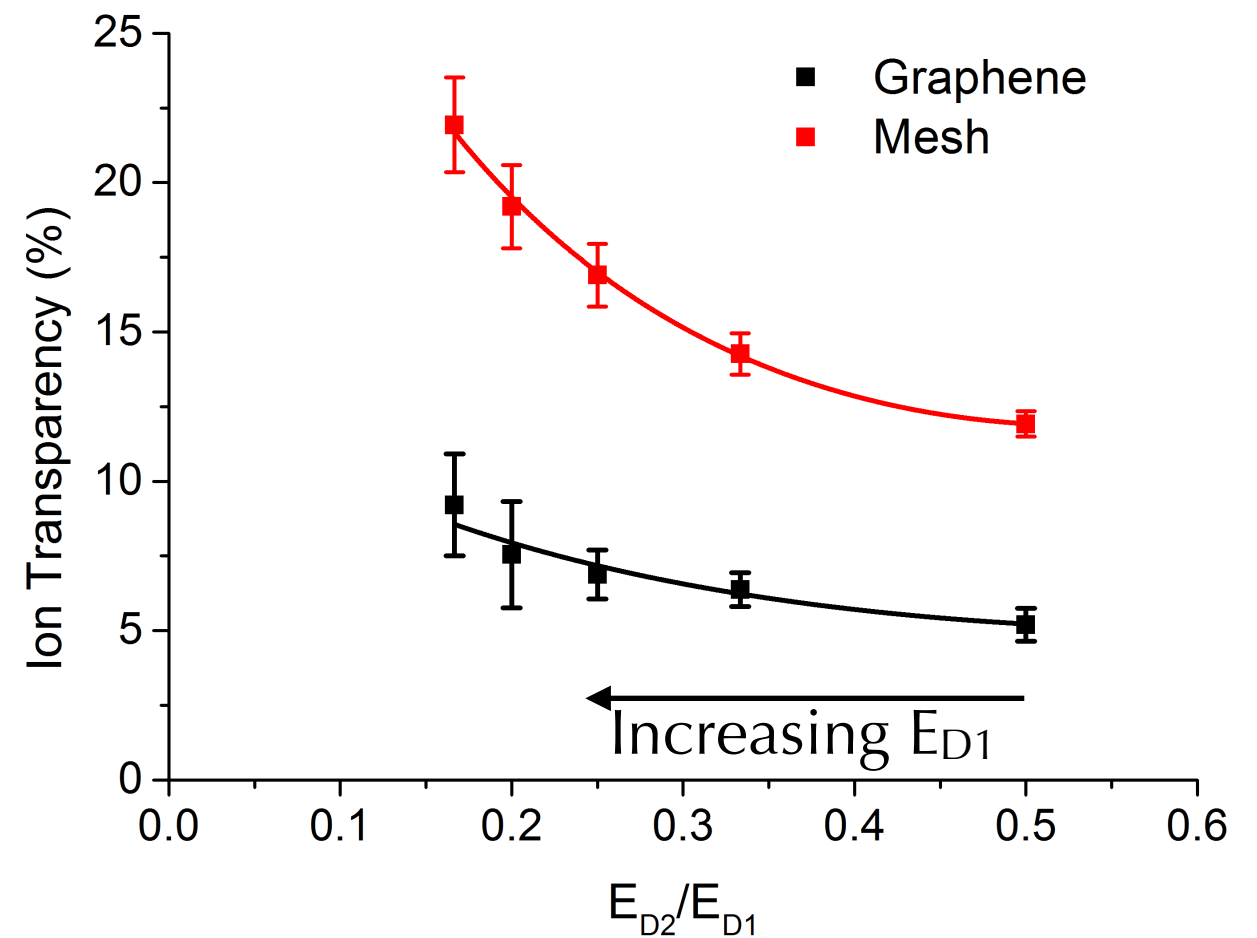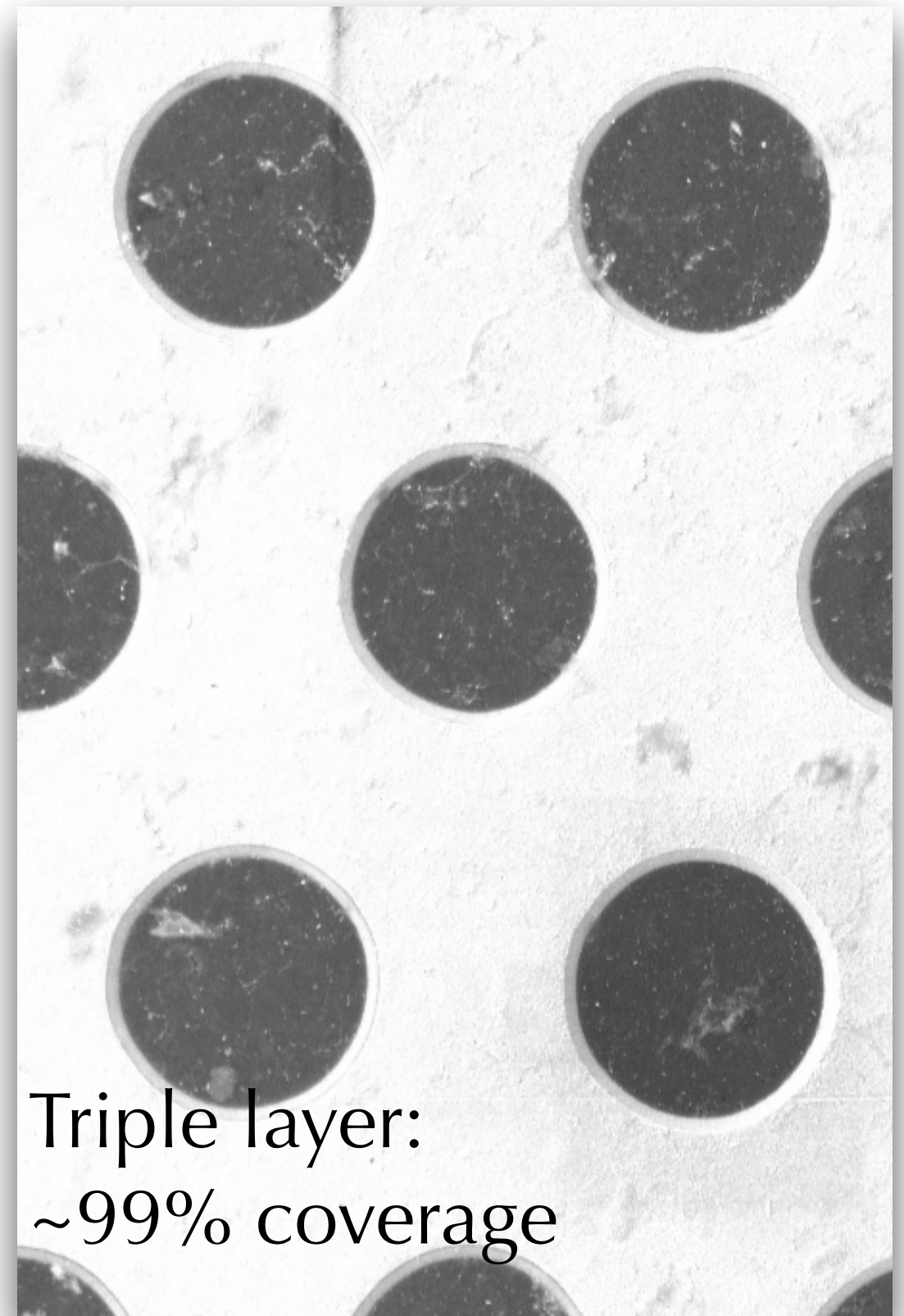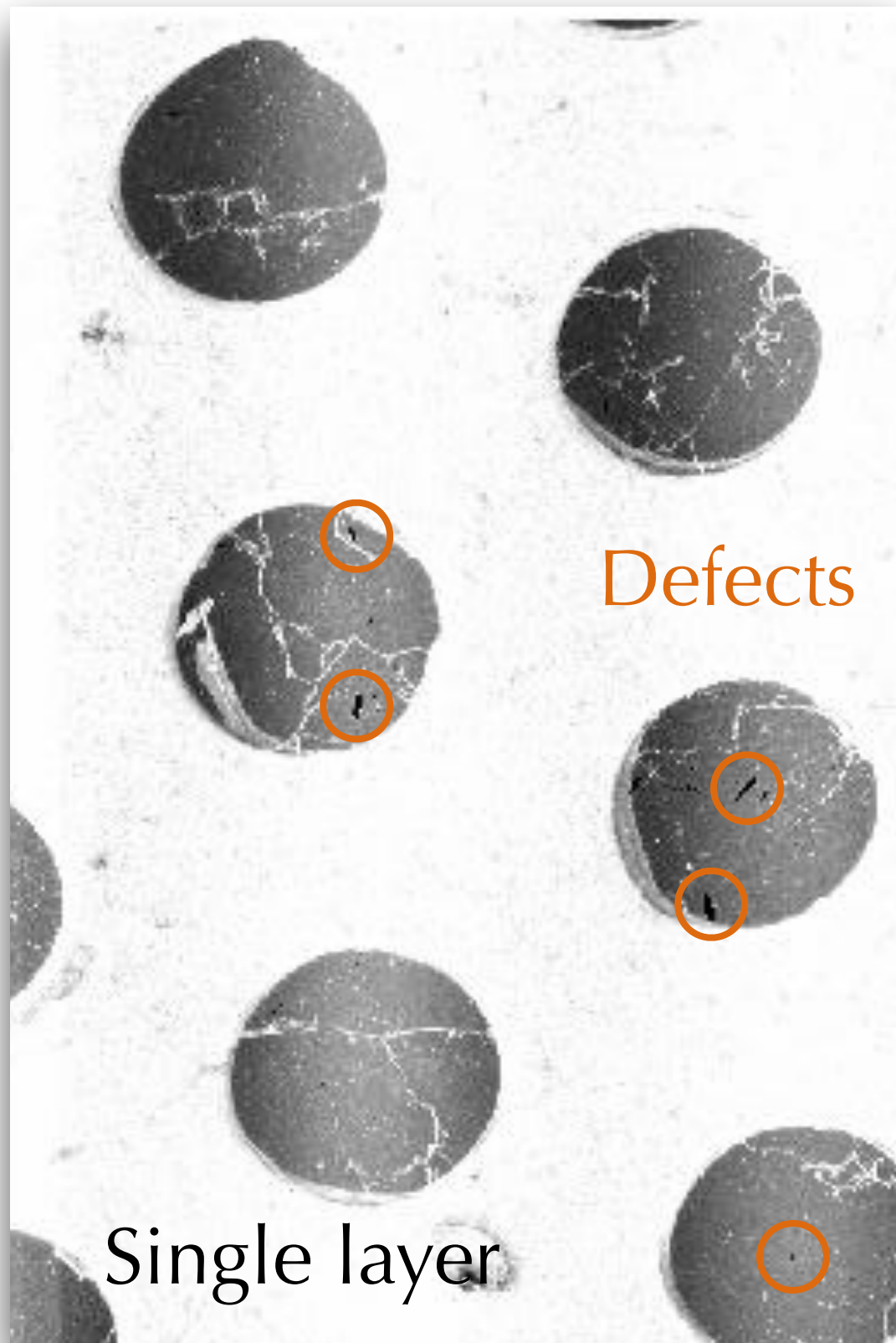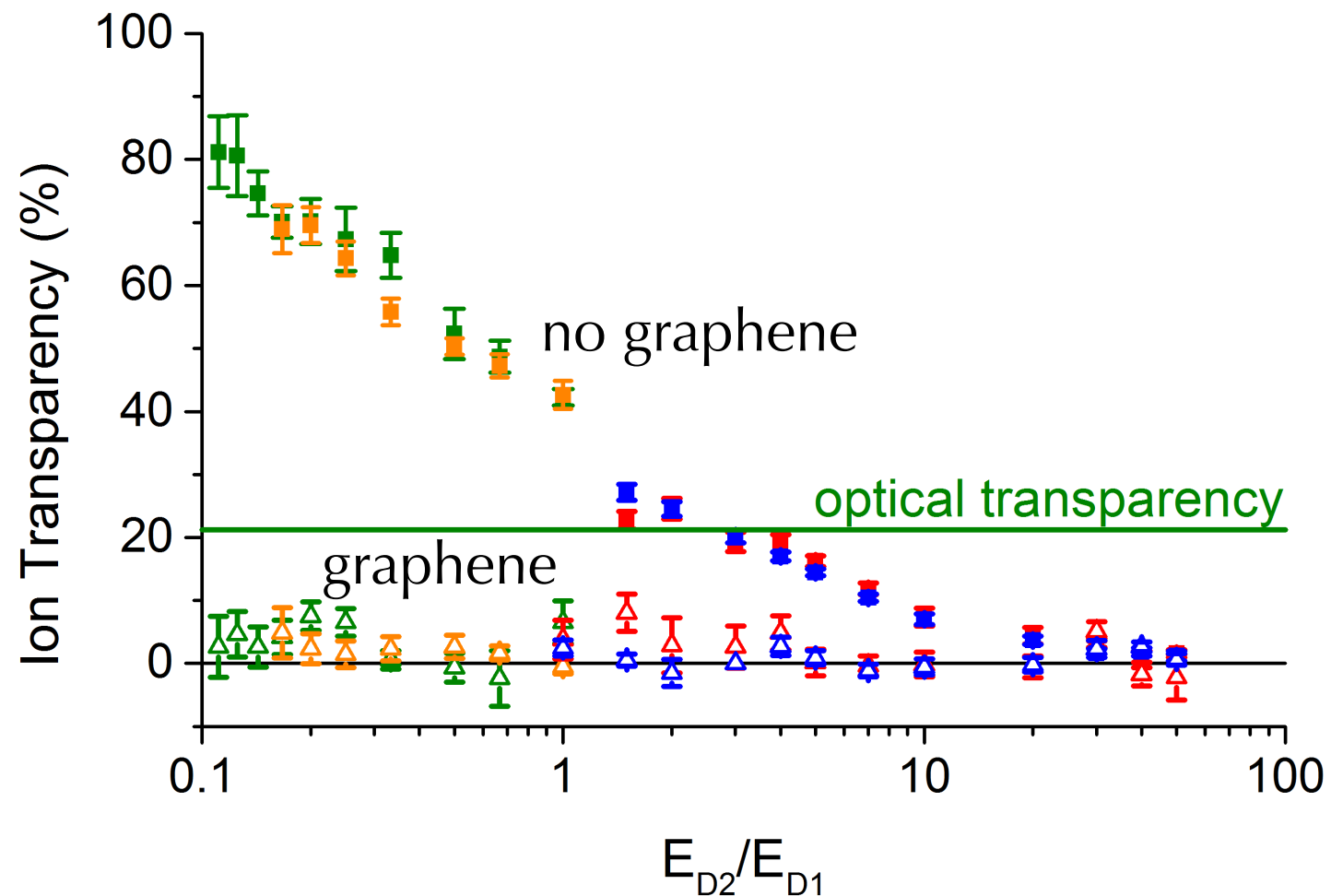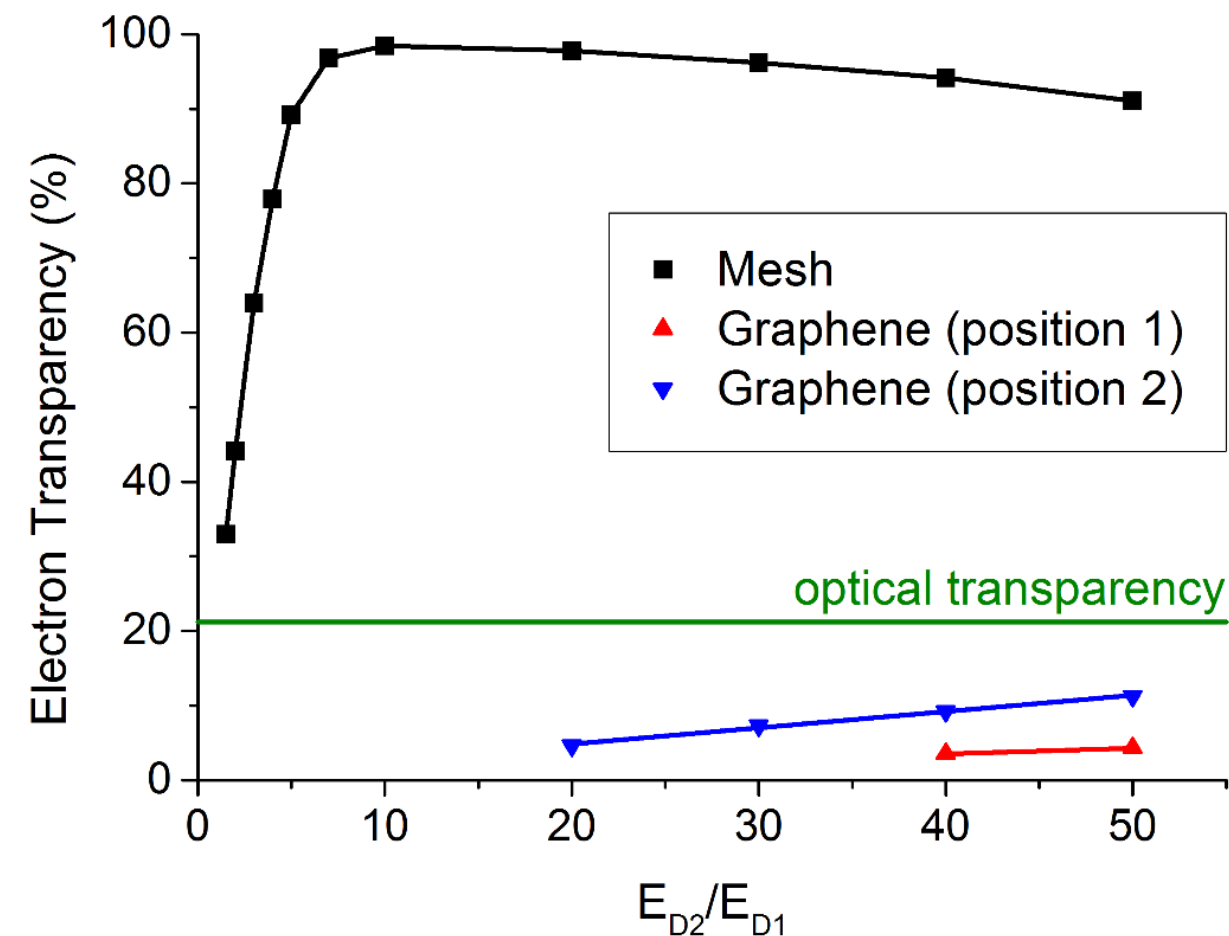
Transparencies

Ar/CO_2 70/30 mixture, 30µm $\varnothing$ 60µm pitch mesh

1mm $\varnothing$ 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)
- changing the electric field
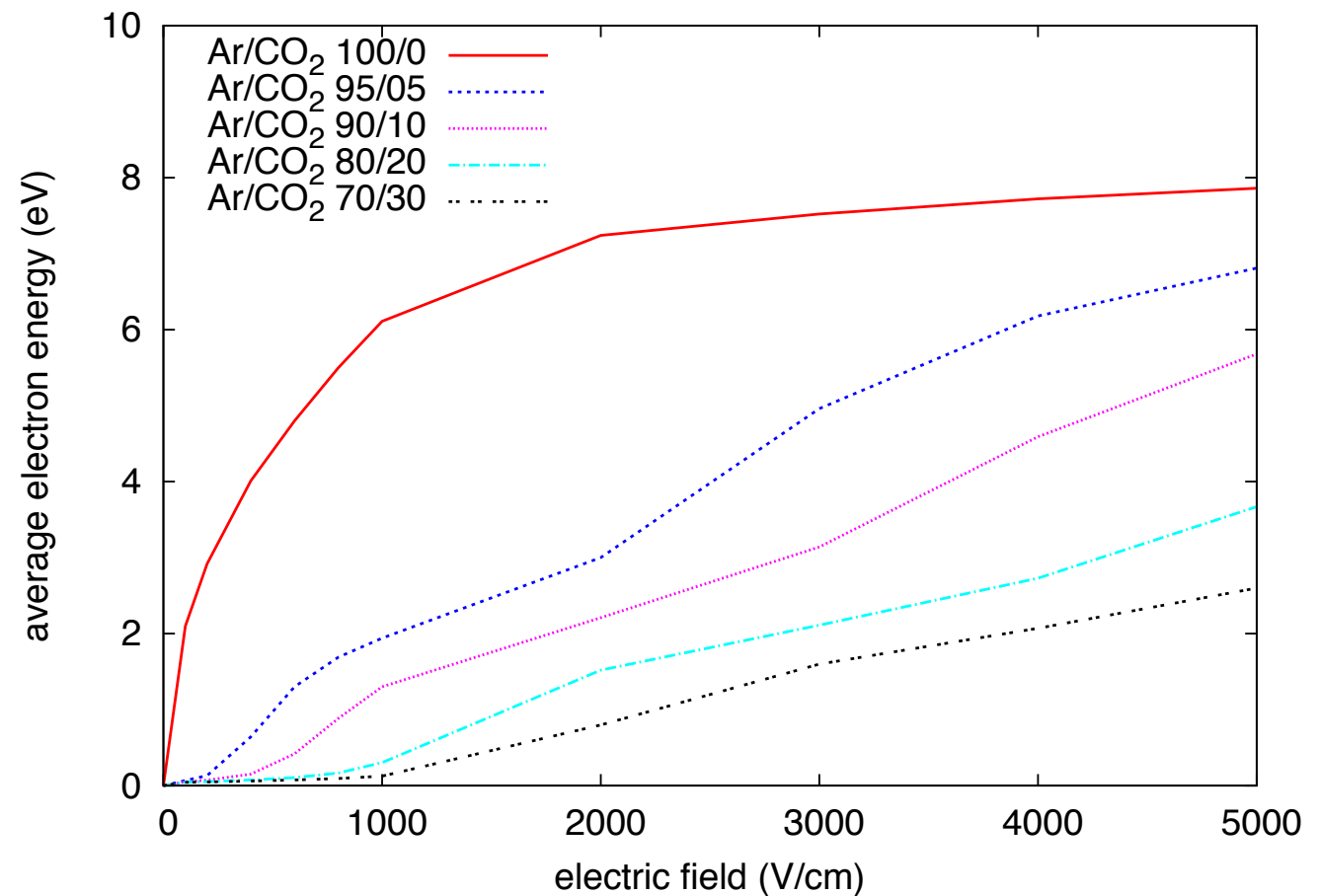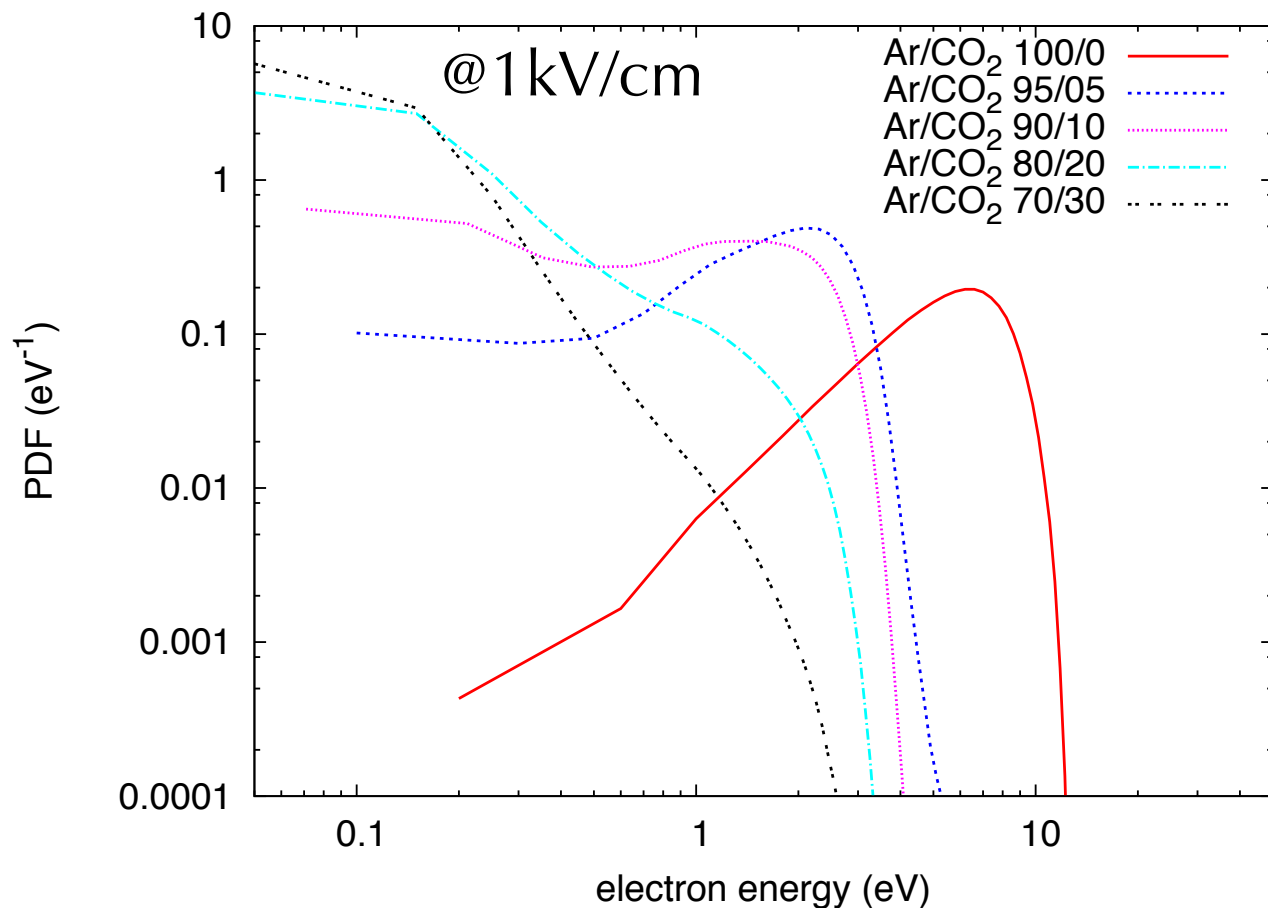
Why not transfer a **graphene layer on a GEM**?

2D map

Easy to develop short circuit in graphene-coated GEMs due to damaged layers (mainly on the edges of the graphene layer)
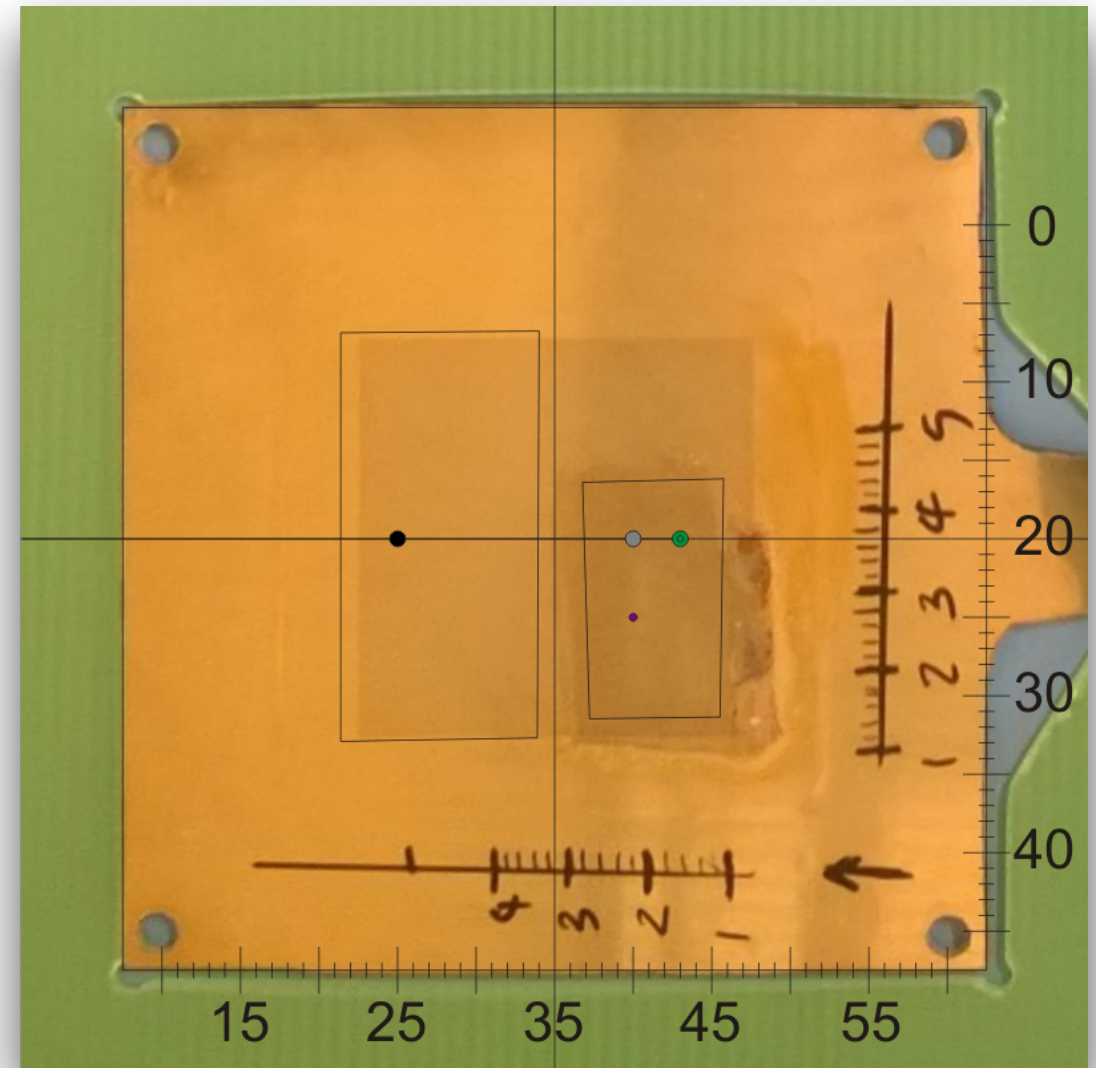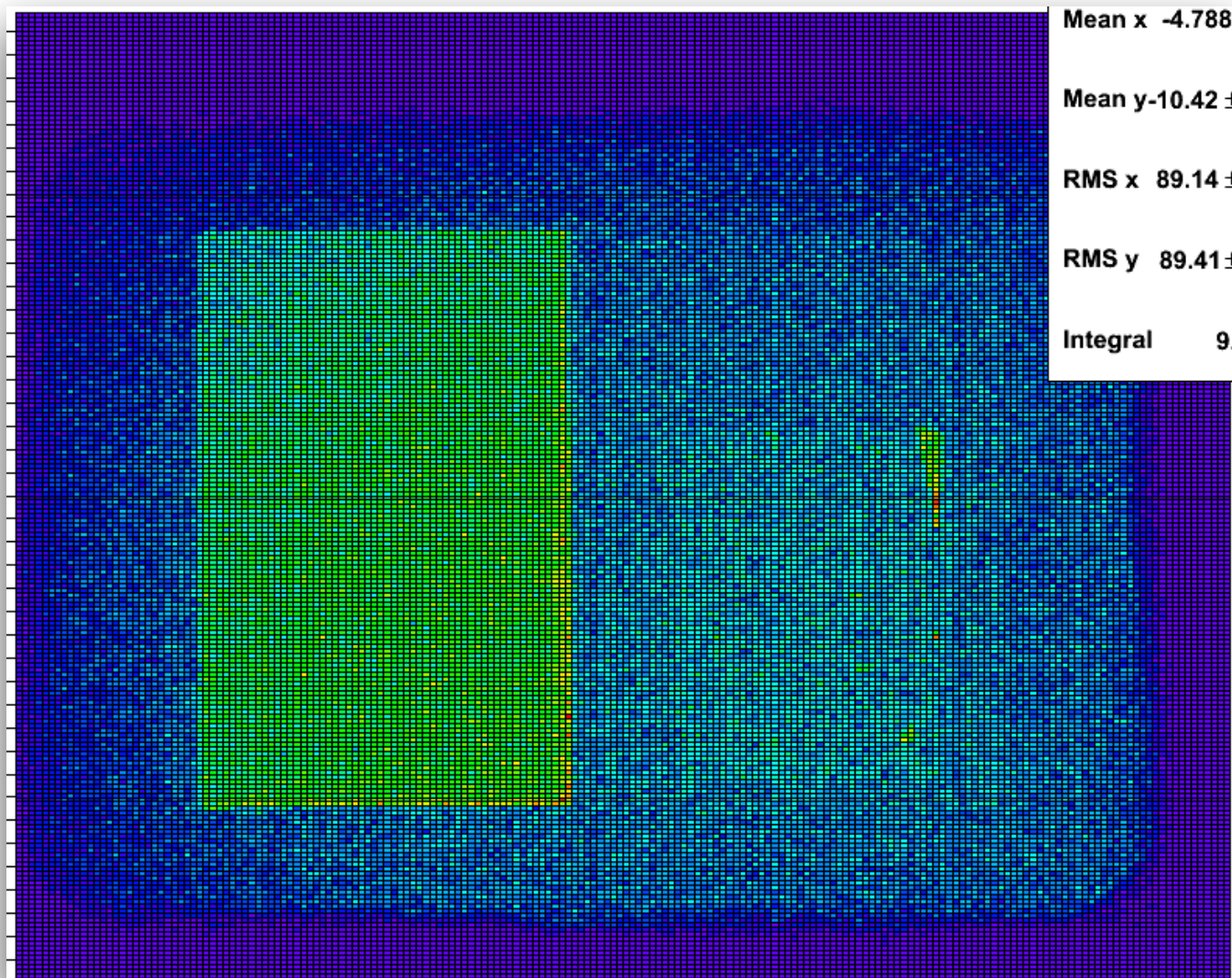
Transparencies at high fields

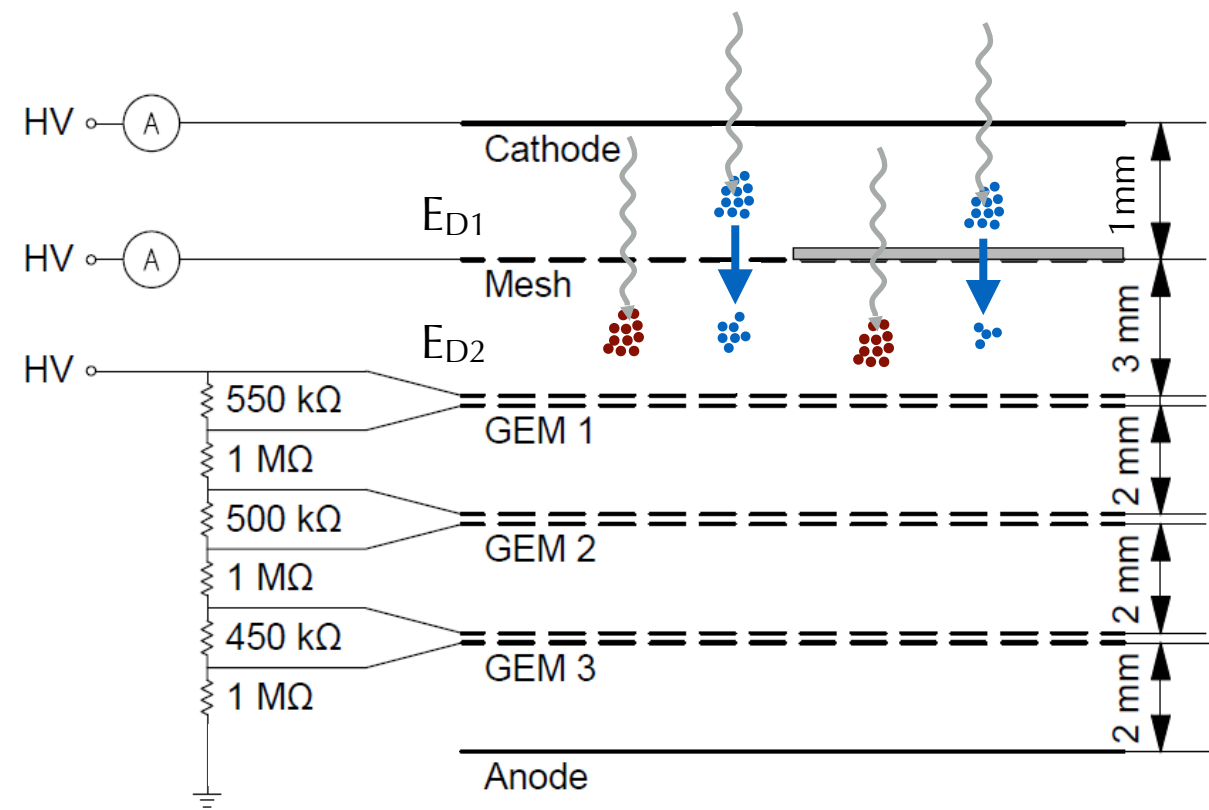Ar/CO$_2$ 70/30 mixture, 30μm ∅ 60μm pitch mesh
1mm ∅ collimated beam of 8keV Cu X-rays
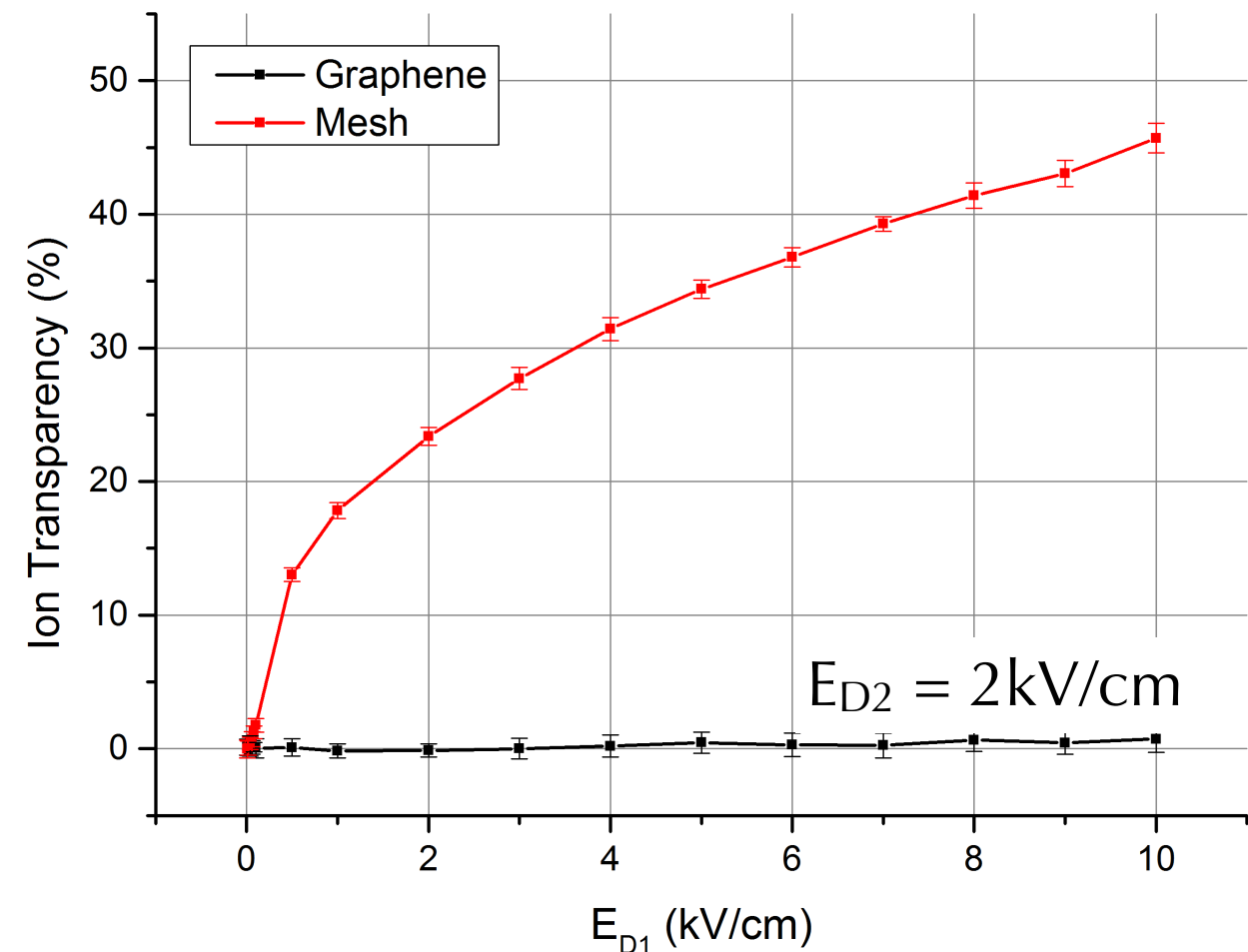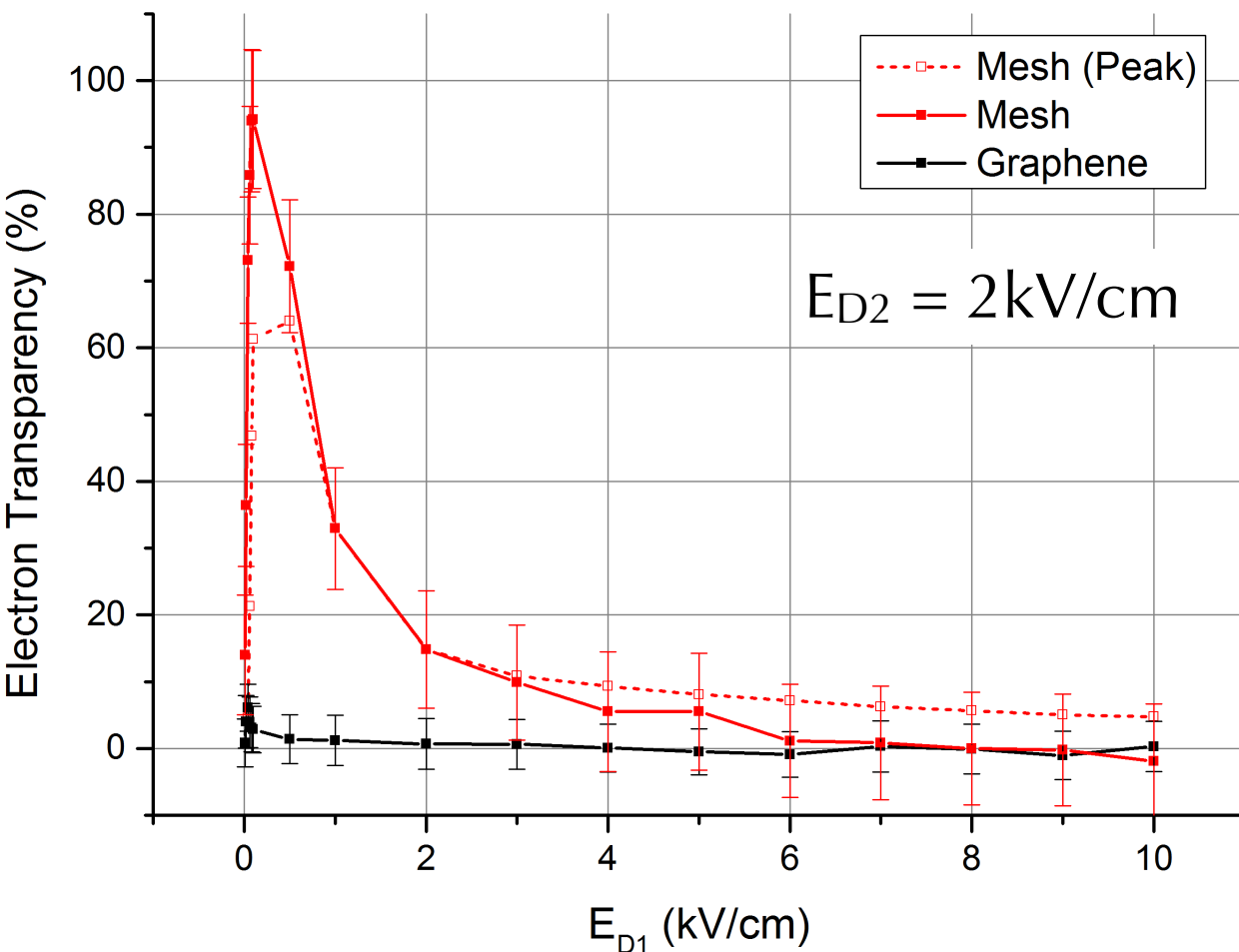
At 10kV/cm graphene is still opaque to electrons

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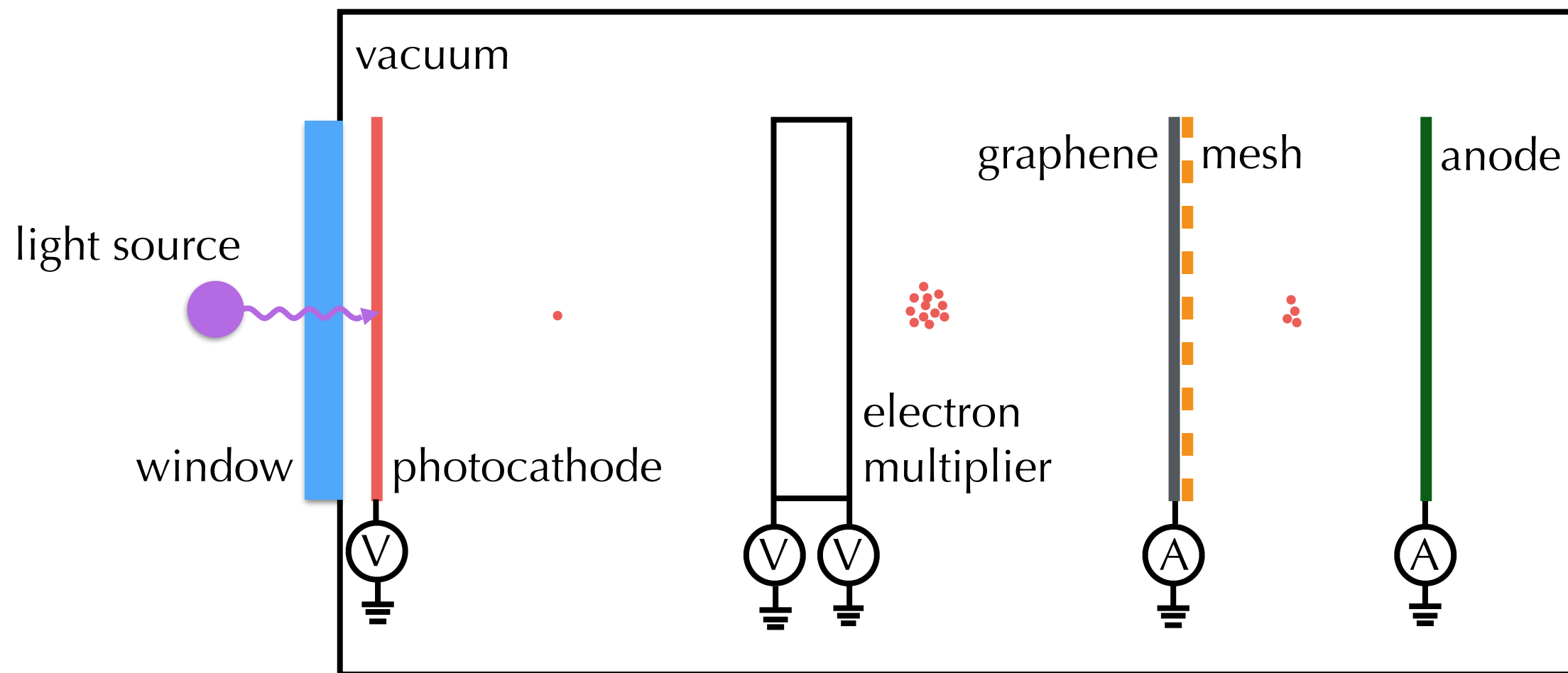
Electron multiplier may be not needed
if the light source is strong enough
Tune the electron **energy** at the eV scale

Transfer: changing approach

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

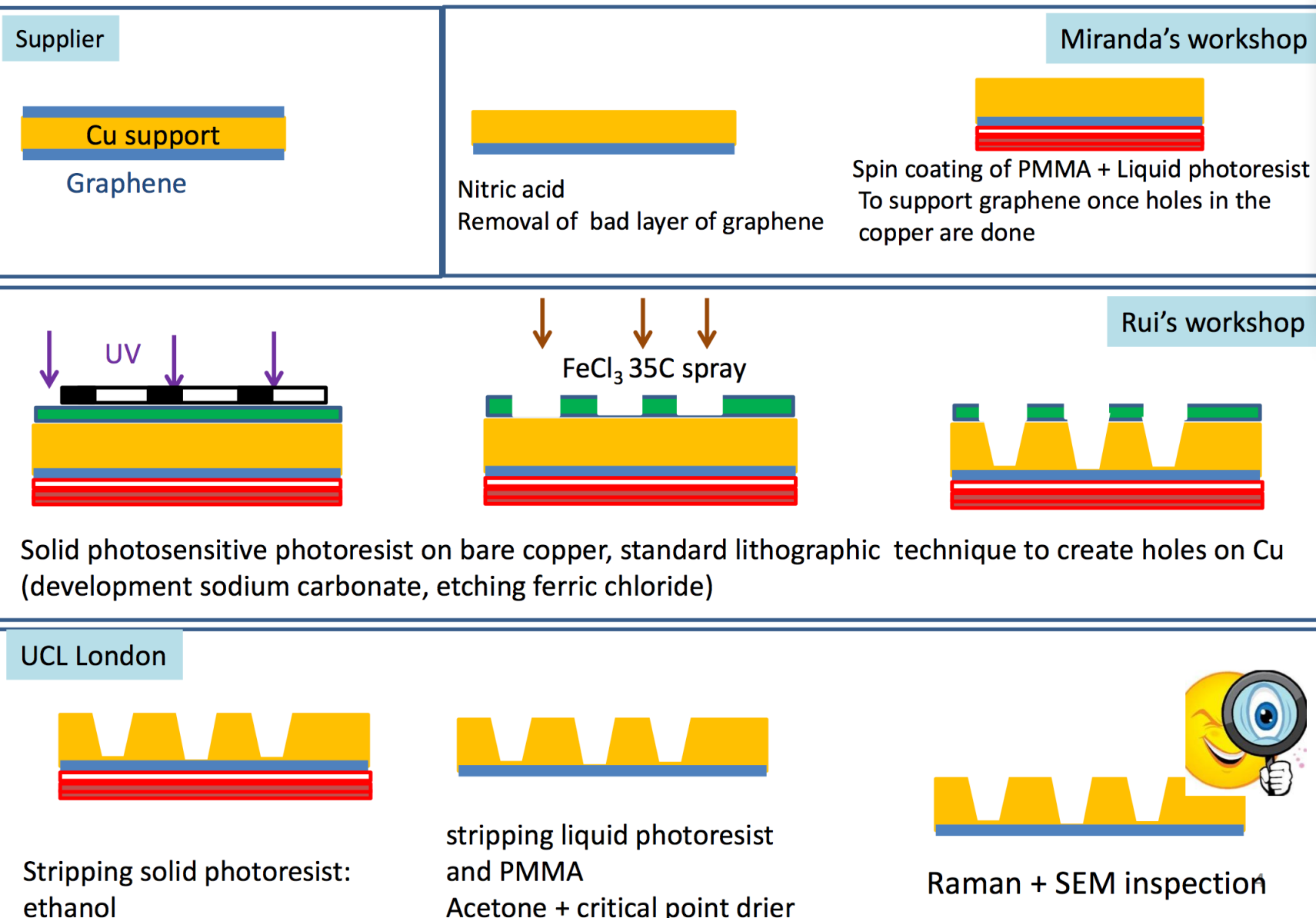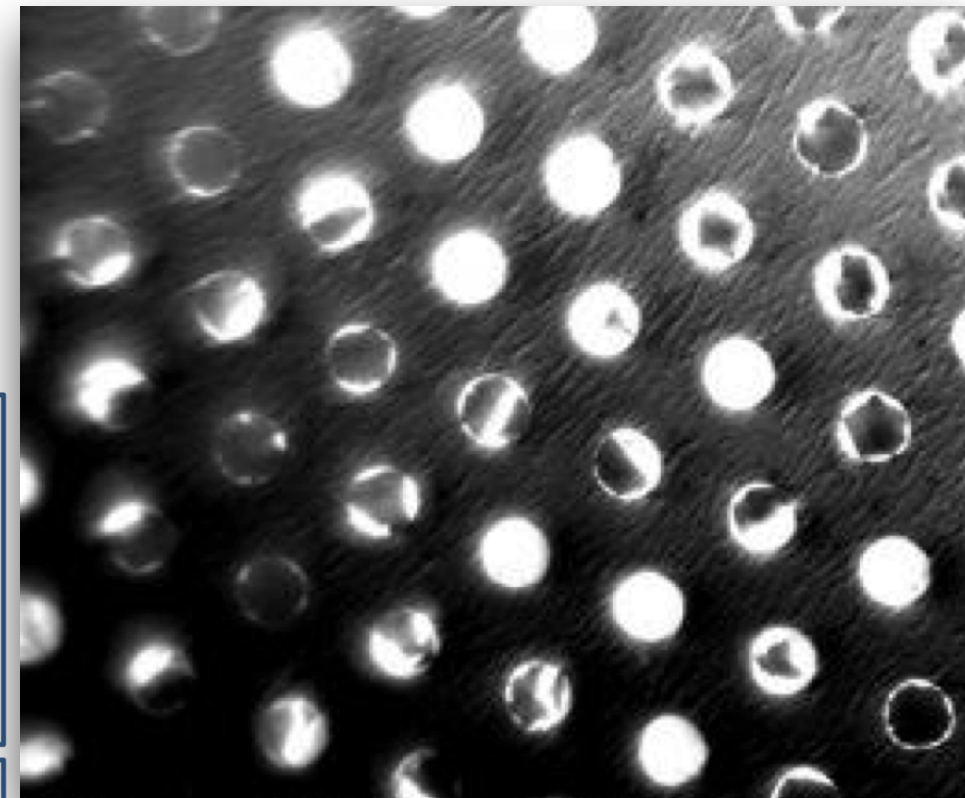| Supplier		Miranda's workshop
Cu support	Nitric acid	Spin coating of PMMA + Liquid photoresist
Graphene	Removal of bad layer of graphene	To support graphene once holes in the copper are done

Rui's workshop

UV

FeCl$_3$ 35C spray

Solid photosensitive photoresist on bare copper, standard lithographic technique to create holes on Cu
(development sodium carbonate, etching ferric chloride)

UCL London

Stripping solid photoresist:
ethanol

stripping liquid photoresist
and PMMA
Acetone + critical point drier

Raman + SEM inspection

Very promising preliminary results

Pure graphene (no contaminants), but damaged

Conclusions

- Developed a technique to transfer graphene

- Graphene transparency to e⁻/ions in gas under studies

- Behaviour of the single layer dominated by defects

- Three atomic layers proved to stop ions

- Electrons stopped because interspace or contaminants?