Update on graphene activity: Dirac points observed

D. Goretti

J. Scherzinger

Università di Pisa

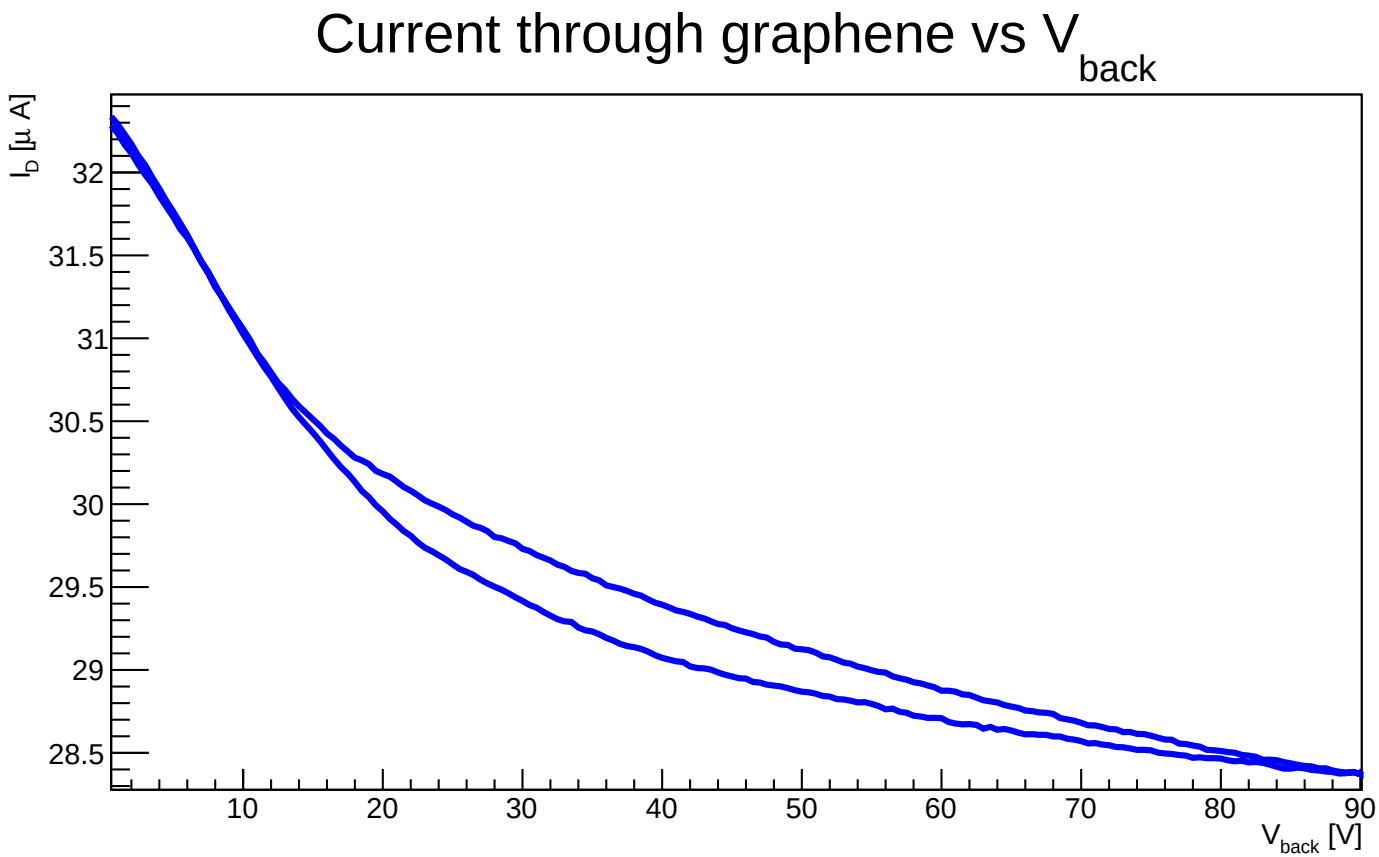
06/04/2018

Status one week ago

We received a new structure from NEST with around 10/25 cells with graphene implants;
Unfortunately the firsts results on them, were not completely satisfying: sweeping the back contact while maintaining the top contact at 0 V and V_D - V_S = 10 mV showed a modulation of the current through graphene but no Dirac point have been seen with this procedure.

Status one week ago

Plot for one of the G-FETs of cell 7. The other structures showed a completely analogous result.

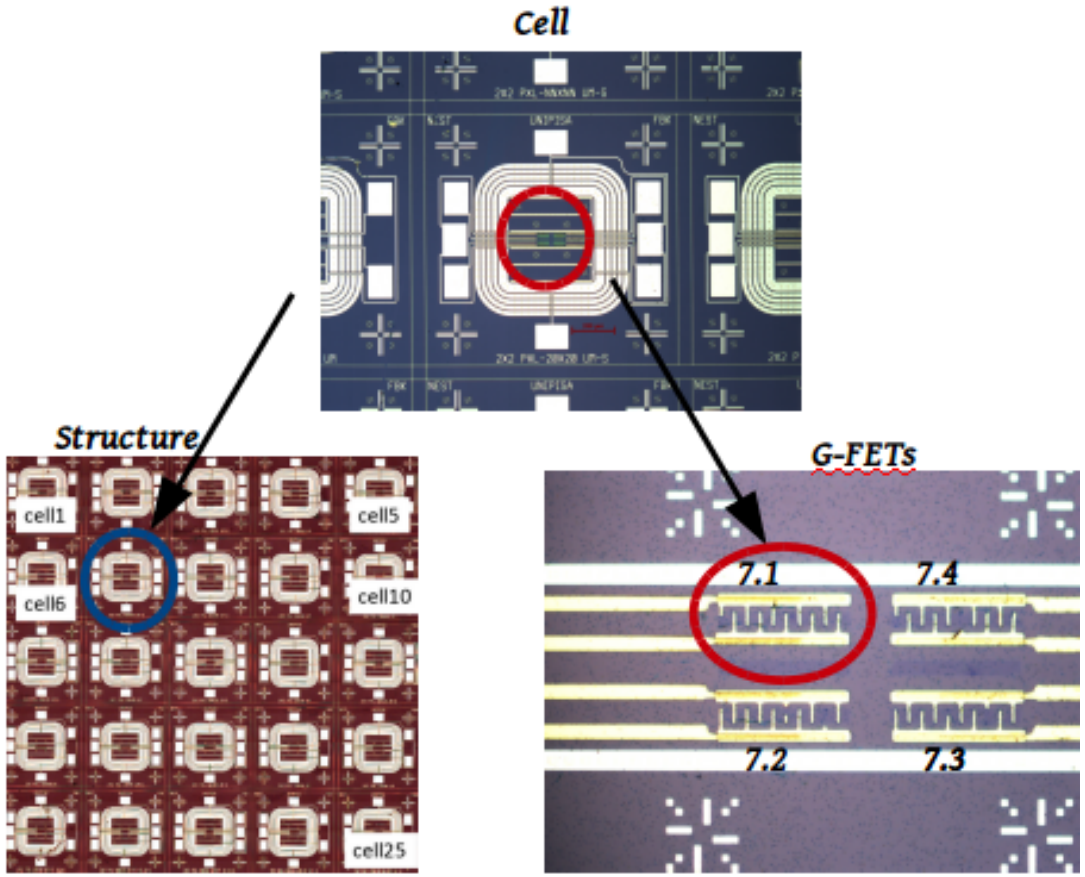


Status now

Using a different approach (sweeping both the top and the back contacts) we found 5 G-FETs that showed a clear Dirac point on the chip given in two interesting cells (cell 7 and cell 8).
Not all G-FETs of the sample given have been connected since two cells with graphene are under the clamp or so near to it to make them unreachable with the needles of the probes.

First Dirac point observed

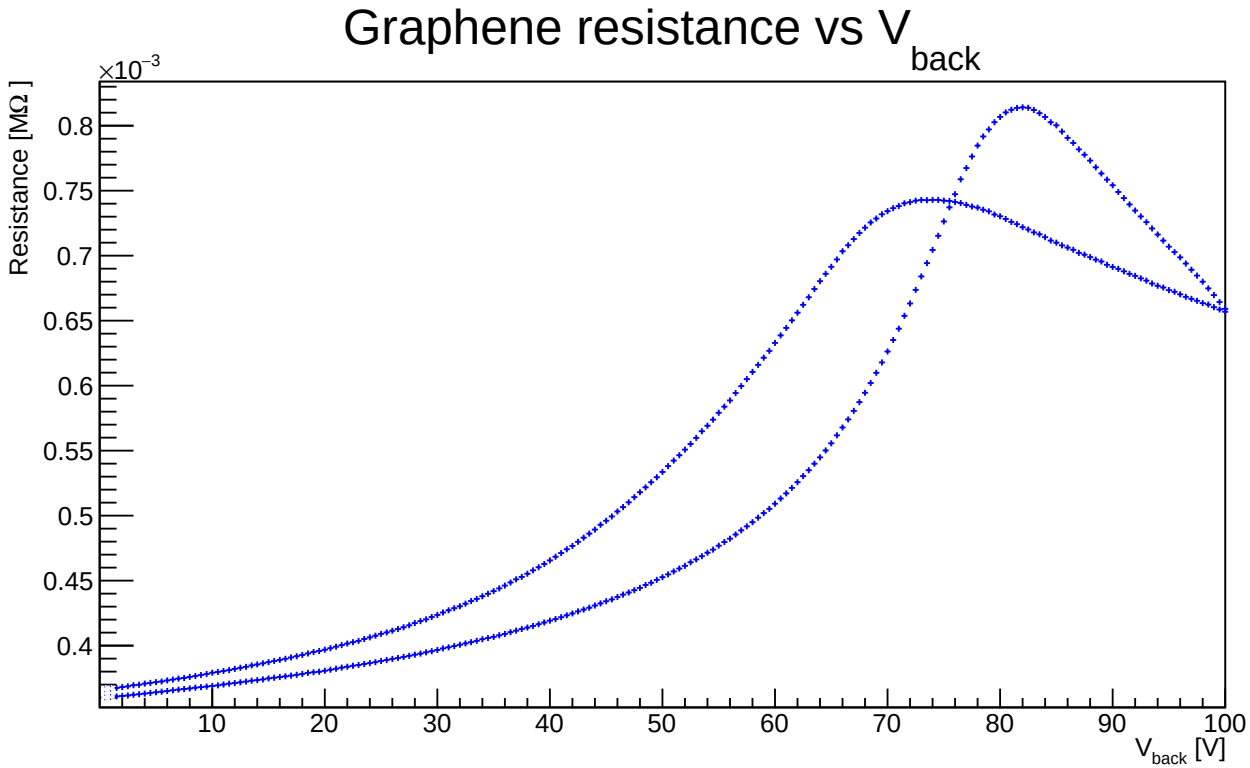
The first Dirac point was observed on one of the structure of the cell 7 of the structure with 300nm thick SiO_2.



UNIVERSITÀ DI PISA

First Dirac point obtained

The Dirac point was obtained maintaining at the same value the voltage at the top and back contact while sweeping them from 0 V to 100 V.

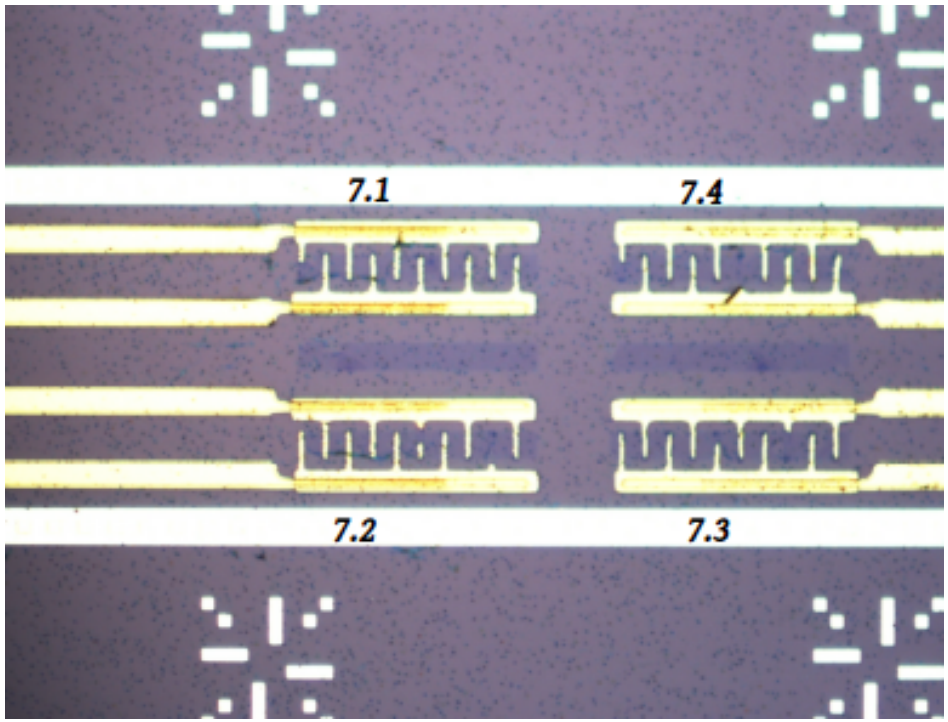


Different strategy to obtain the Dirac point

Since we would like to deplete the silicon below graphene we tried to obtain the Dirac point sweeping the top contact and the back together, while maintaining an offset between the two of: V_{back}-$V_{top} = 20$ V corresponding to the one to assure depletion.
Also with this strategy the Dirac point was observed only at a slightly different V_{back}.
We measured the Dirac points for 5 different G-FETs belonging to cell 7 and cell 8 of the structure given.

Cell 7 Dirac point

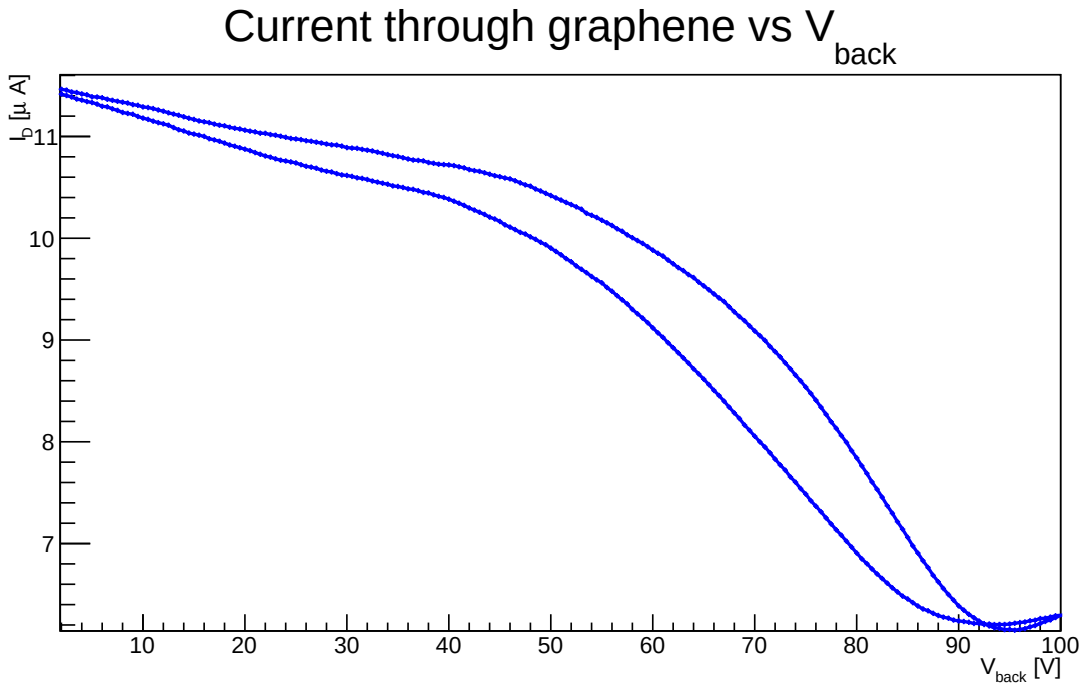
We connected the cell 7 with this nomenclature for the G-FETs present on it. For the cell 8 was used an identical nomenclature.



UNIVERSITÀ DI PISA

Results on G-FET 7.1

The measure was performed with the top contact swept from -20 V to 80 V. The back voltage was swept from 0 to 100 V. V_D-V_S = 5 mV.



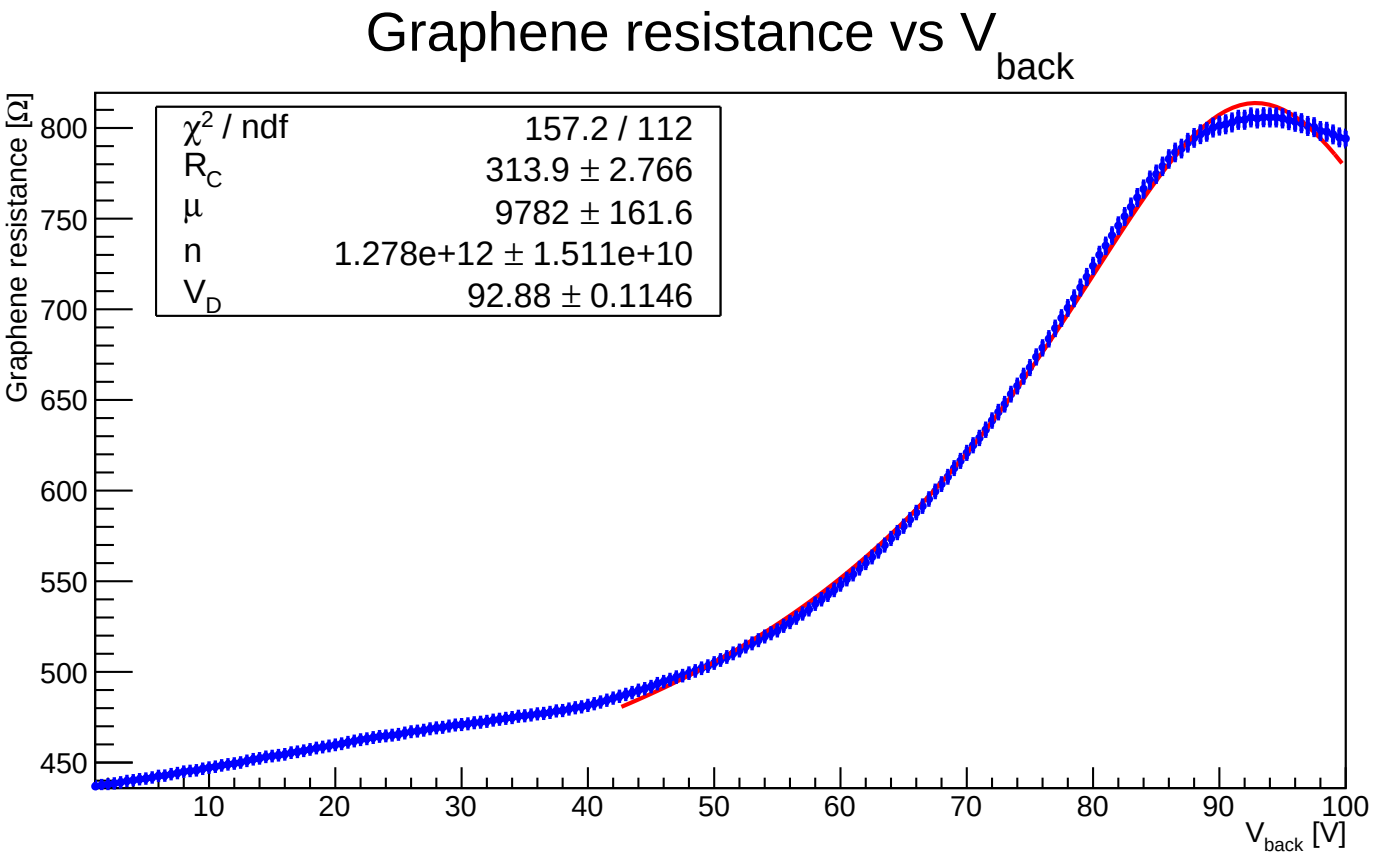
Results on G-FET 7.1

We translated the information on the current through graphene in an information in the resistance and we fitted the plot obtained with the known formula:

$$R_{graphene} = R_C + \frac{N_{sq}}{\mu e \sqrt{n^2 + (c_{ox}/e)^2 (V_G - V_D)^2}} \tag{1}$$

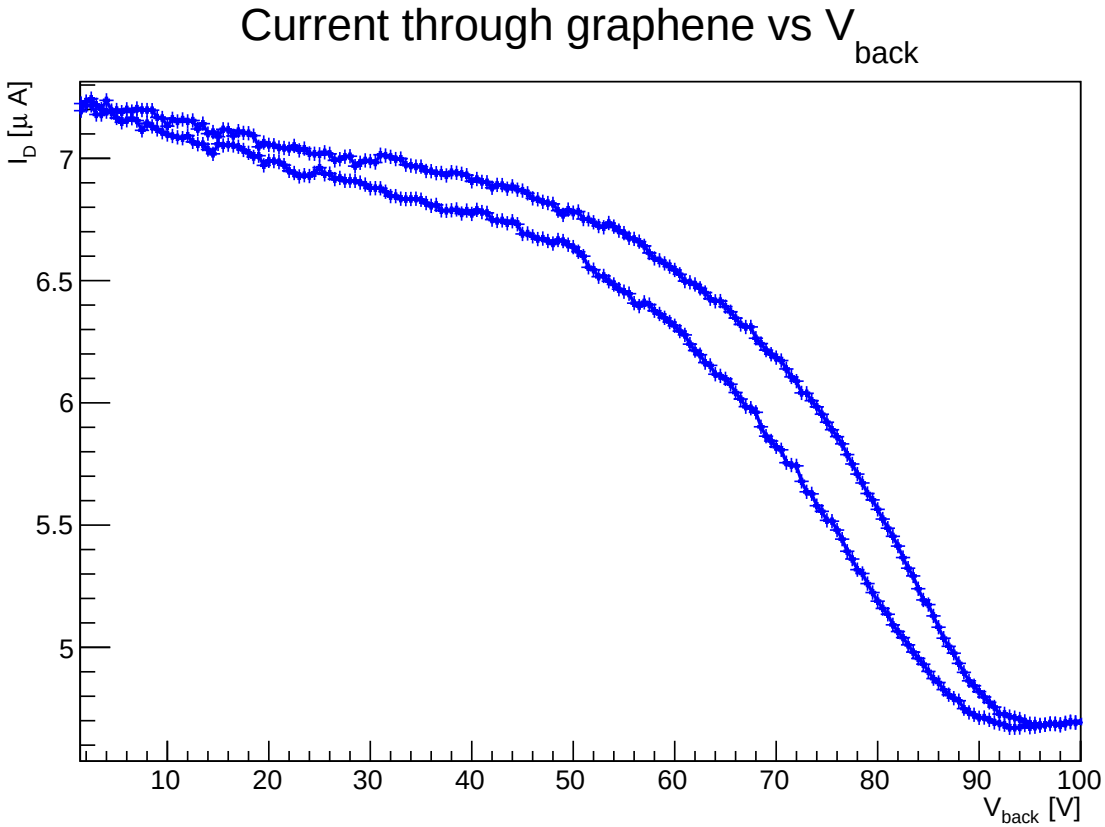
where e is the charge of an electron, μ the mobility, c_{ox} the capacitance of the SiO_2, N_{sq} the number of squares (L/W), n the residual charge in graphene, R_C the contact resistance, V_G the back gate voltage, and V_D the Dirac point voltage.

Results on G-FET 7.1



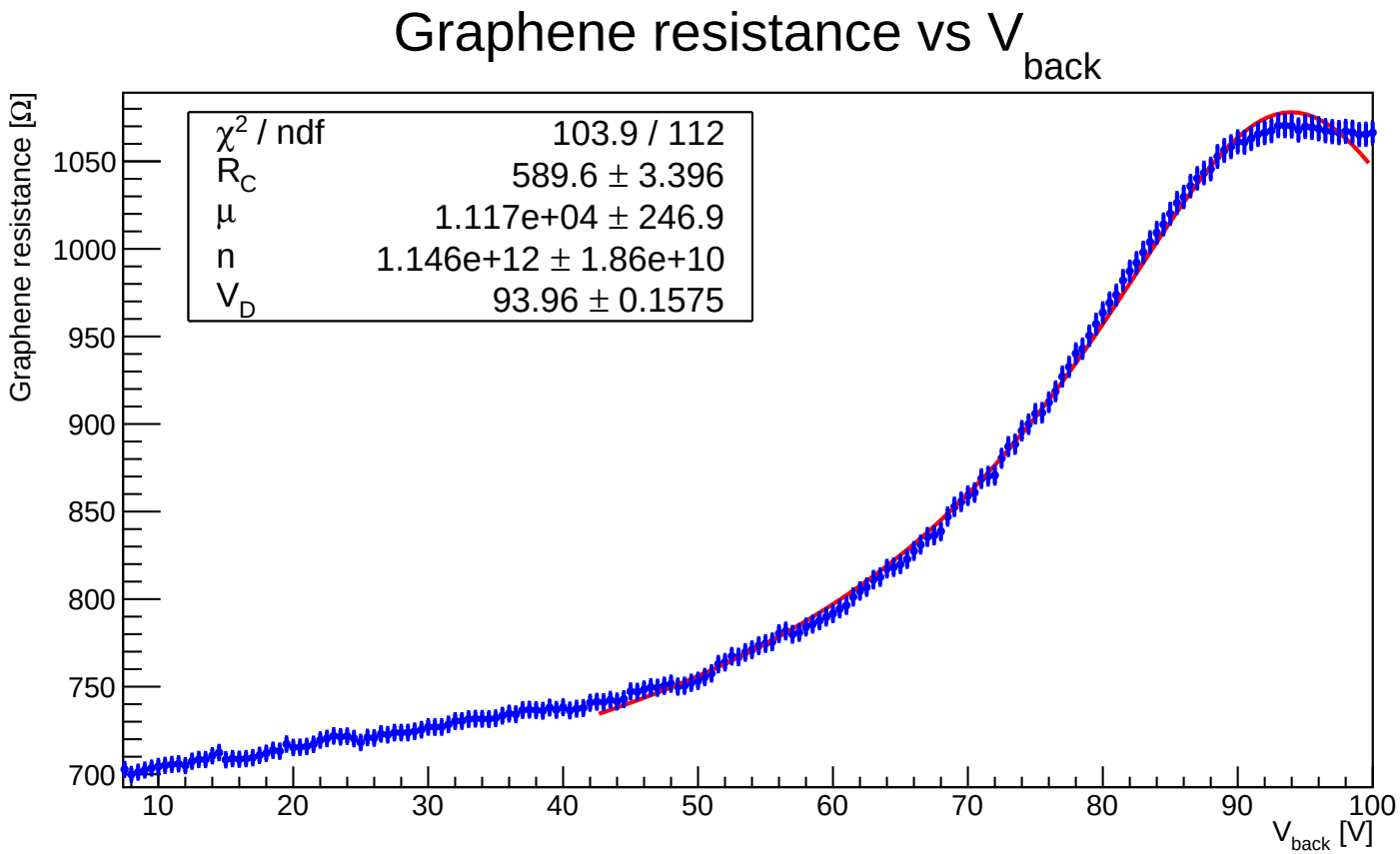
Results on G-FET 7.2

The measure was performed with the top contact swept from -20 V to 80 V. The back voltage was swept from 0 to 100 V. V_D-V_S = 5 mV.



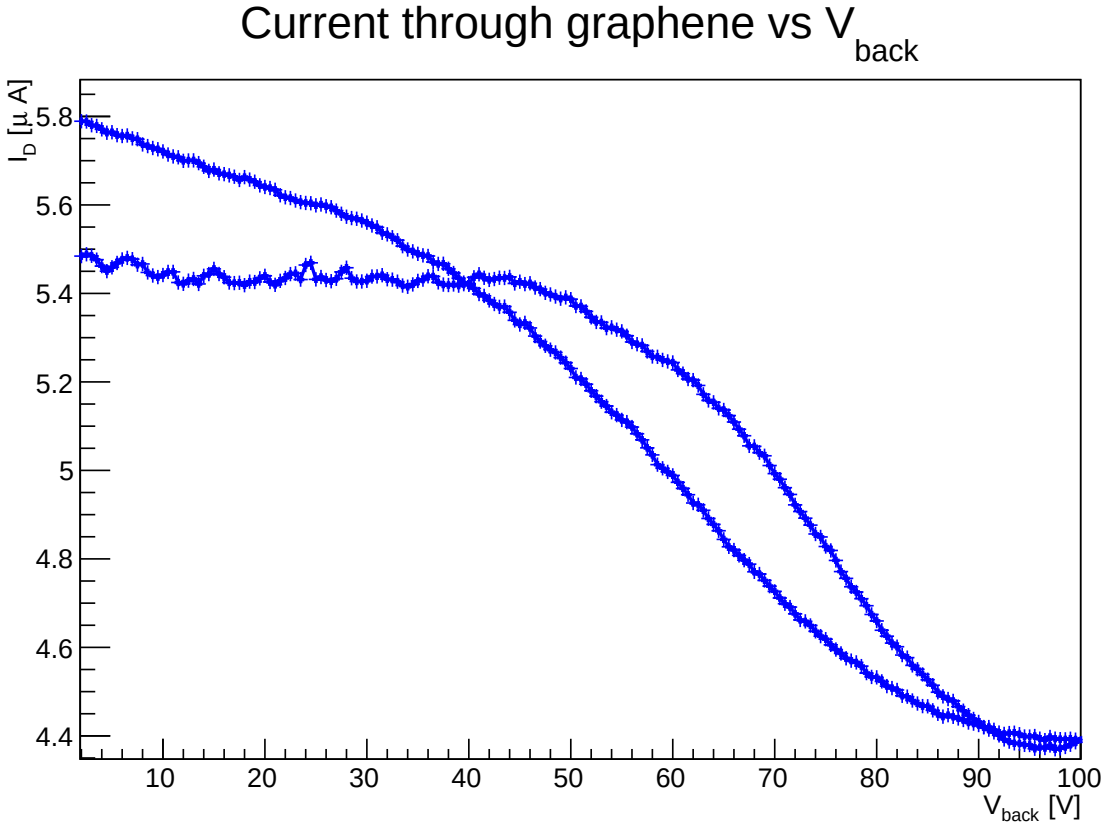
UNIVERSITÀ DI PISA

Results on G-FET 7.2

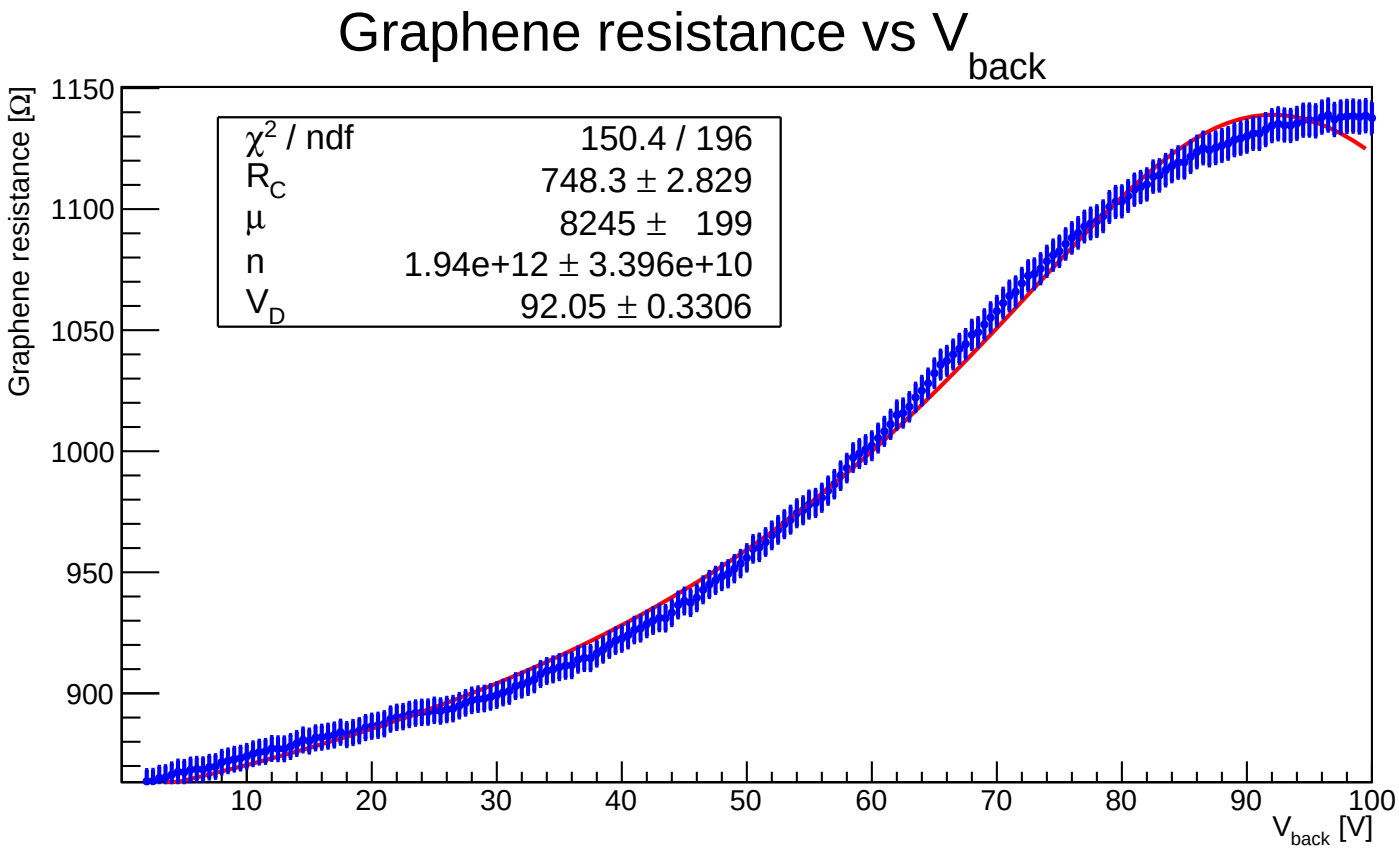


Results on G-FET 7.3

The measure was performed with the top contact swept from -20 V to 80 V. The back voltage was swept from 0 to 100 V. V_D-V_S = 5 mV.

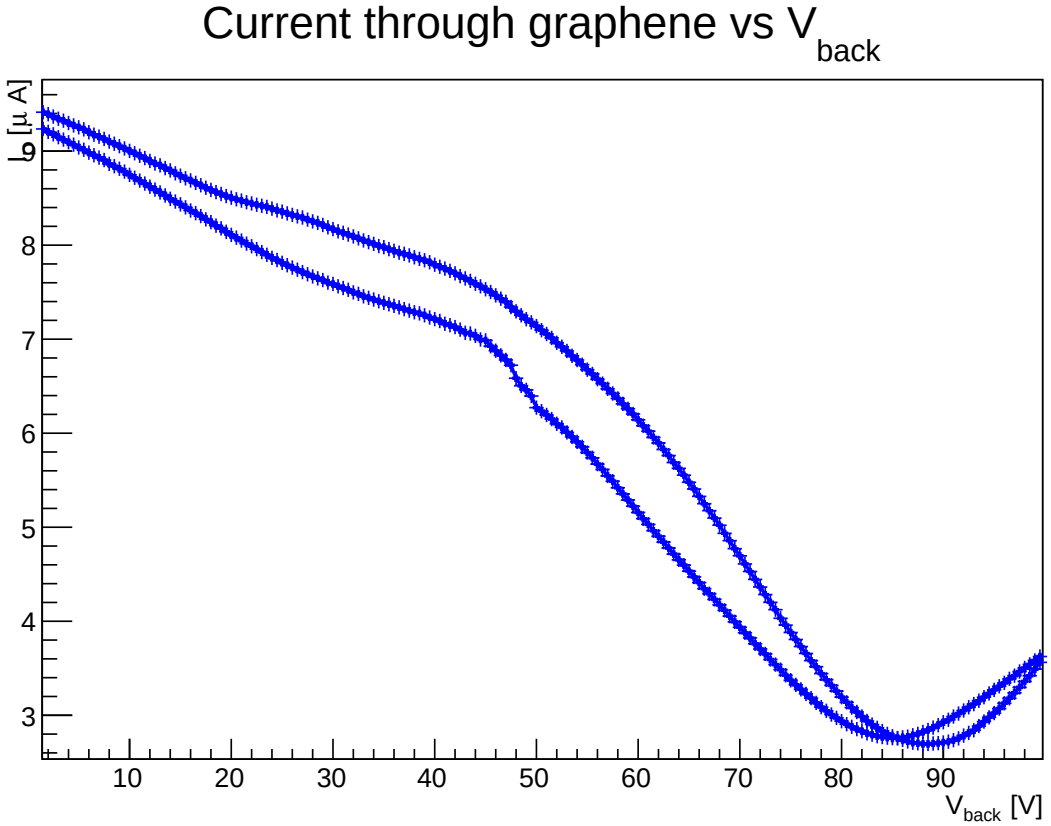


Results on G-FET 7.3

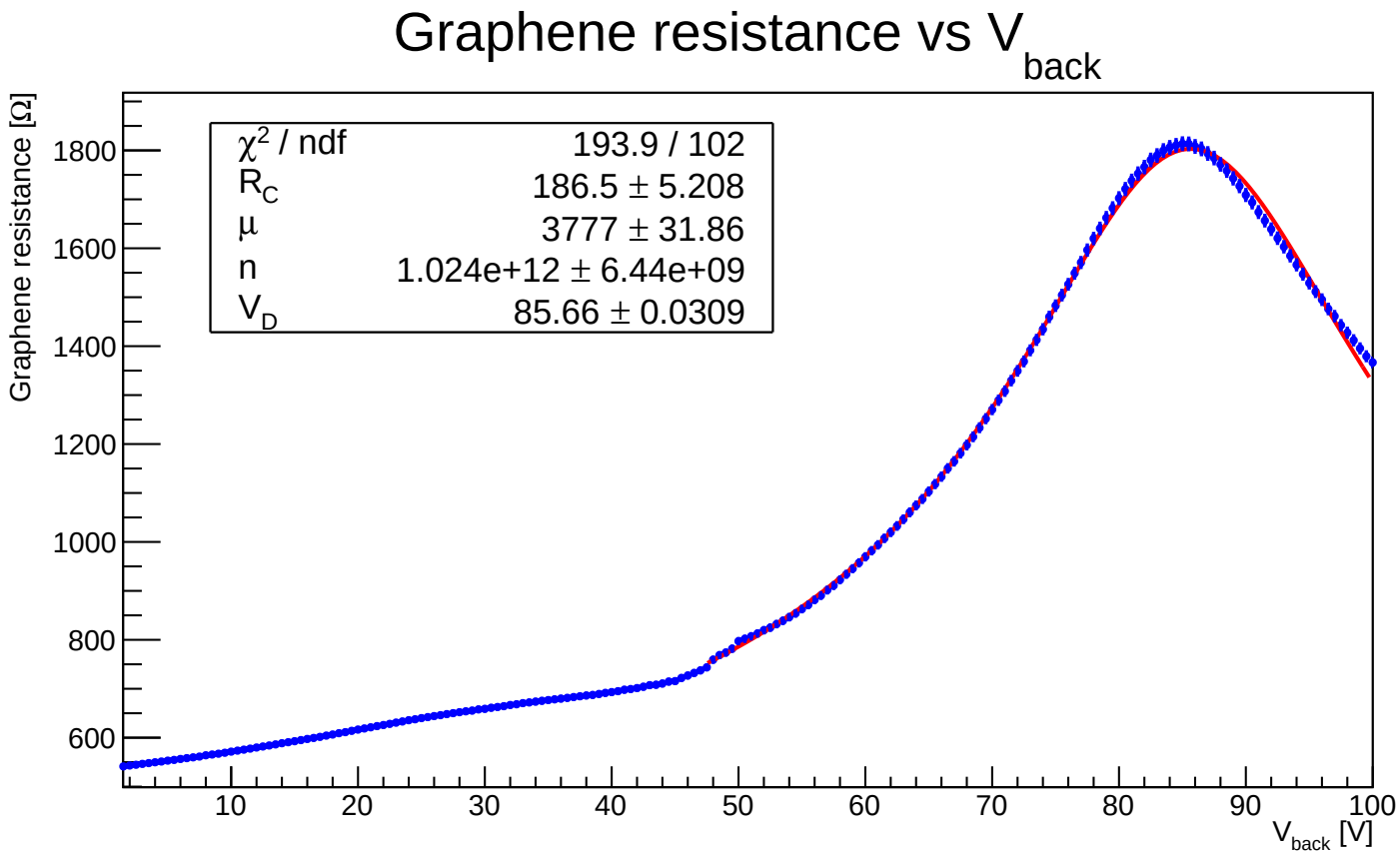


Results on G-FET 8.3

The measure was performed with the top contact swept from -20 V to 80 V. The back voltage was swept from 0 to 100 V. V_D-V_S = 5 mV.

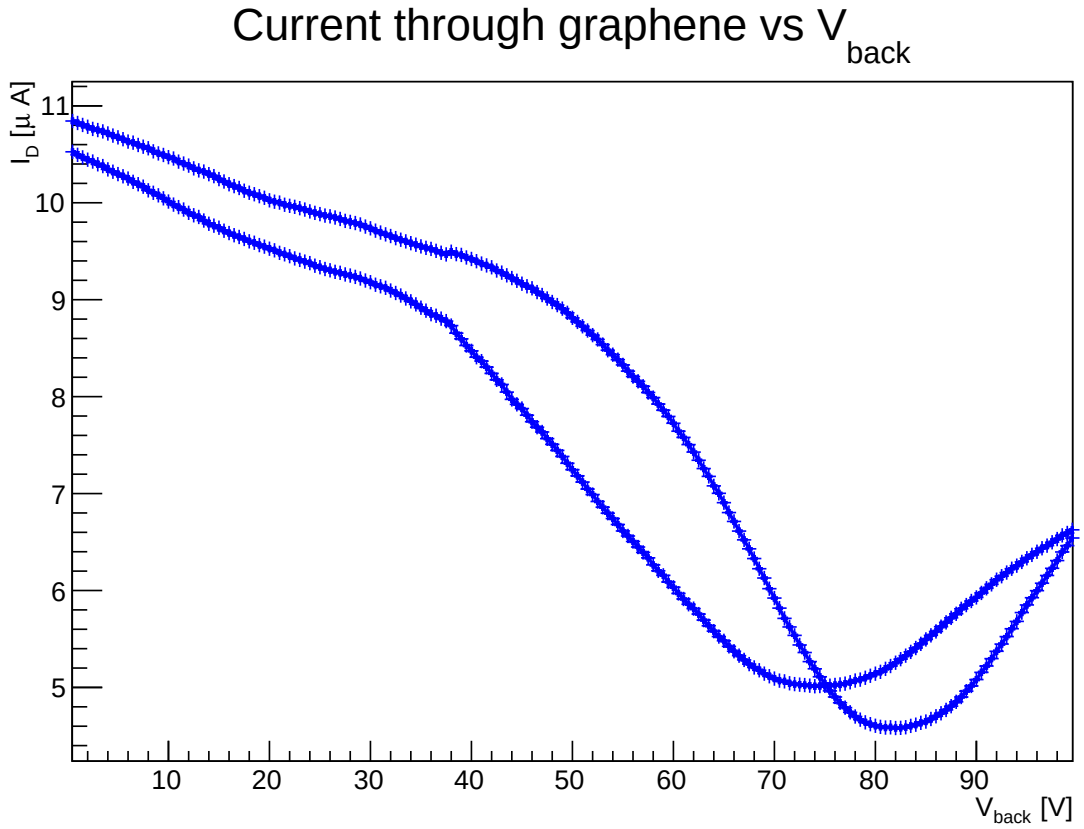


Results on G-FET 8.3



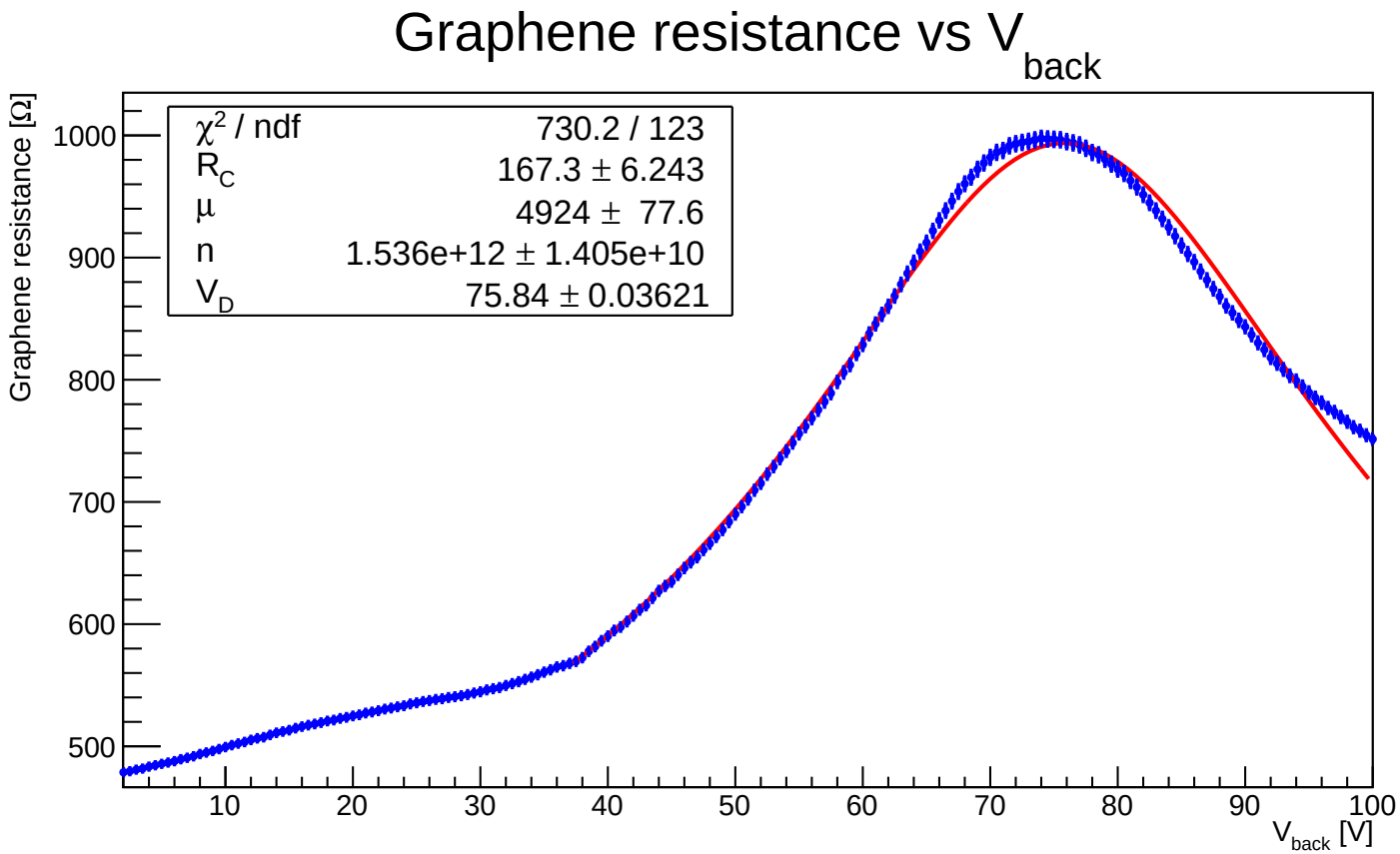
Results on G-FET 8.4

The measure was performed with the top contact swept from -20 V to 80 V. The back voltage was swept from 0 to 100 V. V_D-V_S = 5 mV.



UNIVERSITÀ DI PISA

Results on G-FET 8.4



Results

Table 1: Fit results cell 7

Parameter	7.1	7.2	7.3
Mobility μ [$cm^2/V{\cdot}s$]	9780 ± 162	11170 ± 250	8250 ± 200
Residual charge in graphene n [e/cm^2]	$(1.278 \pm 0.015) \cdot 10^{12}$	$(1.146 \pm 0.019) \cdot 10^{12}$	$(1.94 \pm 0.03) \cdot 10^{12}$
Dirac point voltage V_D [V]	92.9 ± 0.1	93.9 ± 0.2	92.1 ± 0.3
Contact resistance $R_C[\Omega]$	314 ± 3	590 ± 3	748 ± 3

Table 2: Fit results cell 8

Parameter	8.3	8.4
Mobility μ [$cm^2/V{\cdot}s$]	3780 ± 30	4920 ± 78
Residual charge in graphene n [e/cm^2]	$(1.024 \pm 0.006) \cdot 10^{12}$	$(1.536 \pm 0.014) \cdot 10^{12}$
Dirac point voltage V_D [V]	85.66 ± 0.3	75.84 ± 0.04
Contact resistance $R_C[\Omega]$	187 ± 5	167 ± 6

Table 3: Expected results from NEST

Parameter	Graphene
Mobility μ [$cm^2/V{\cdot}s$]	1000-10.000
Residual charge in graphene n [e/cm^2]	$> 1{\cdot}10^{11}$
Dirac point voltage V_D [V]	60 - 80
Contact resistance $R_C[\Omega]$	100-1000

Prospects

– Next week a new sample with G-FETs to be tested should arrive in our labs;
– as a next step we would like to test the device response to a laser in order to understand if it is possible to extract the information on the intensity of the beam hitting the device from the change in resistance induced in graphene.

UNIVERSITÀ DI PISA