# Electrostatically induced quantum dots in gapped bilayer graphene

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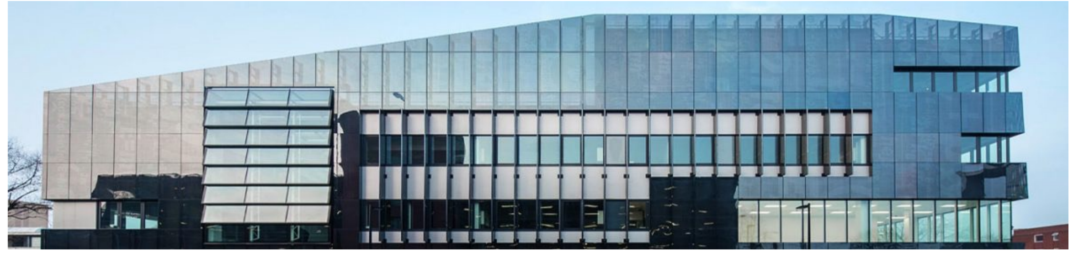

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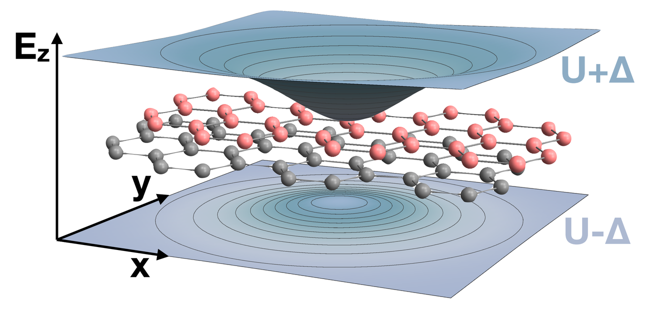
## Abstract

The properties of electrostatically defined nanostructures in gapped bilayer graphene (BLG) can manifest the minivalley structure and Berry curvature (via the associated magnetic moment of the states) [1,2]. We study electrons confined in a quantum dot in gapped BLG. The level spectra are influenced by both, the three minivalleys per valley in trigonally warped BLG (breaking rotational symmetry), and the orbital magnetic moment (entailing unusual angular momentum properties). For weakly or strongly gapped BLG, respectively, this leads to the formation of either almost degenerate duplets (associated with the angular momentum), or triplets (associated with the minivalleys). The different degeneracies split differently in a magnetic field [3].

## Electrostatic confinement in BLG

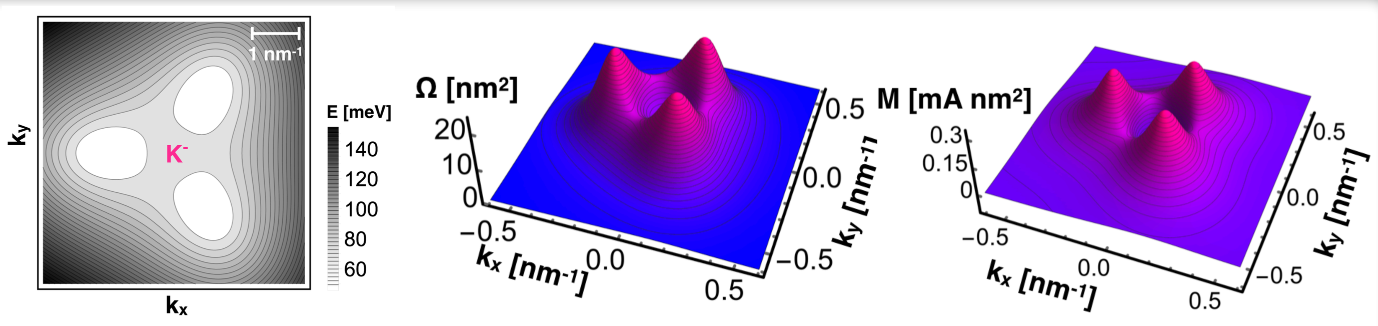



- Electrostatic confinement of electrons in a quantum dot in gapped Bernal stacked BLG
- Model: a smooth confinement potential U(**r**) and a spatially modulated gap Δ(**r**) in the four-band Hamiltonian of BLG:

$$U(\mathbf{r}) = \frac{U_0}{\cosh\frac{\mathbf{r}}{L}} \qquad \Delta(\mathbf{r}) = \Delta_0 - \frac{\beta\Delta_0}{\cosh\frac{\mathbf{r}}{L}}$$

**How do minivalleys & Berry curvature influence quantum dots in gapped BLG ?**

## Minivalleys and Berry curvature in BLG



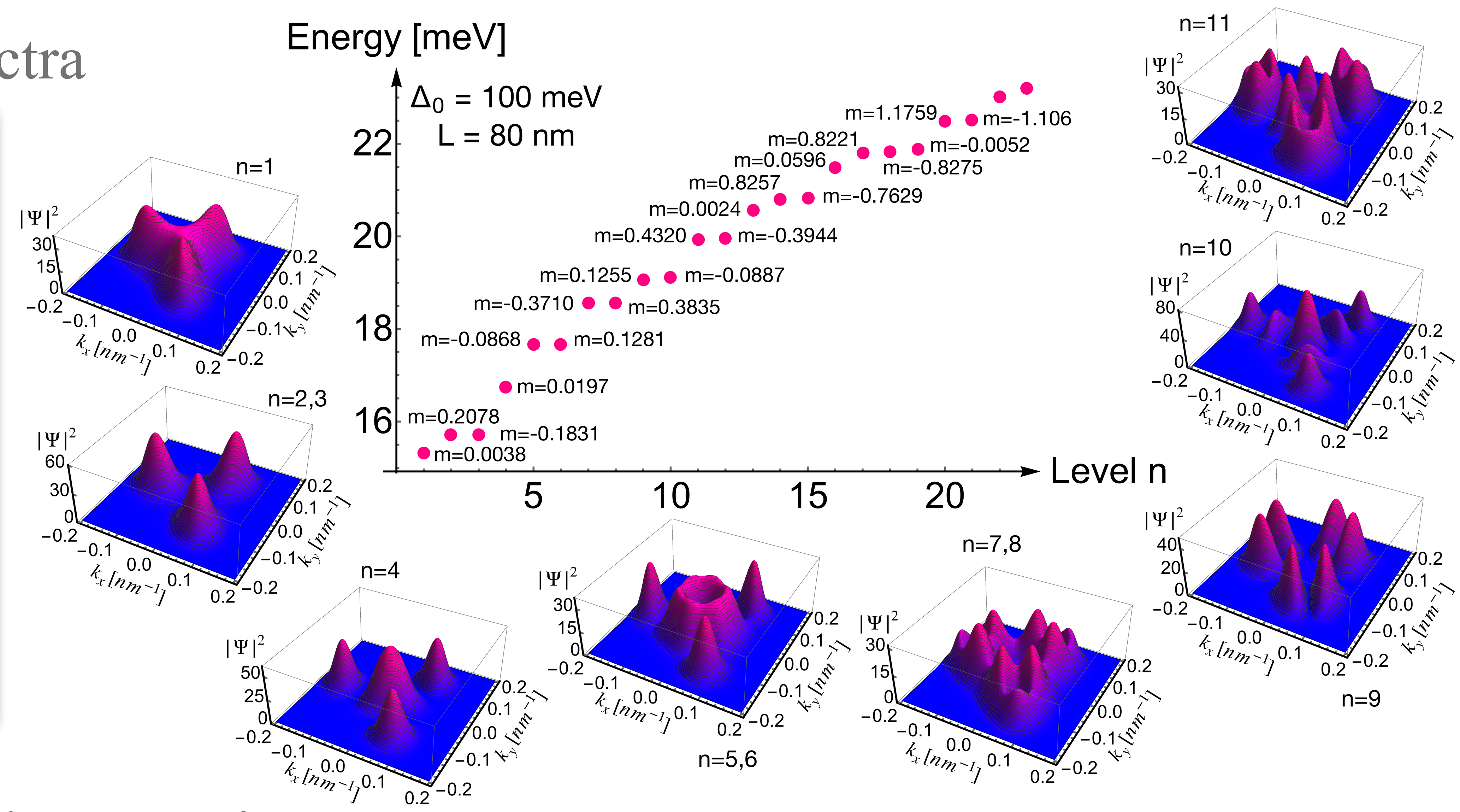

Lowest conduction band of gapped BLG around K⁻

Corresponding Berry curvature Ω and magnetic moment M. Both carry opposite sign in the opposite valley

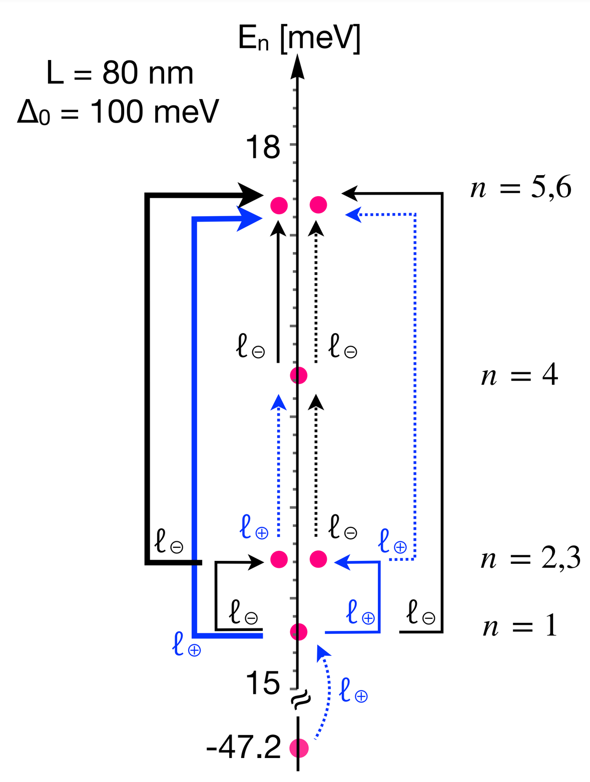
- Lowest conduction band of gapped BLG in the presence of trigonal warping features 3 minivalleys around each K point
- Both the Berry curvature, Ω, and the corresponding magnetic moment, M, are non-zero within the minivalleys

## Properties of the spectra

- Levels in QDs can be characterised by an angular momentum quantum number m
- here: rotational symmetry is broken (by the trigonally warped dispersion), angular momentum properties are altered (by the magnetic moment due to Berry curvature)
- ➡ unusual degeneracies and level splittings

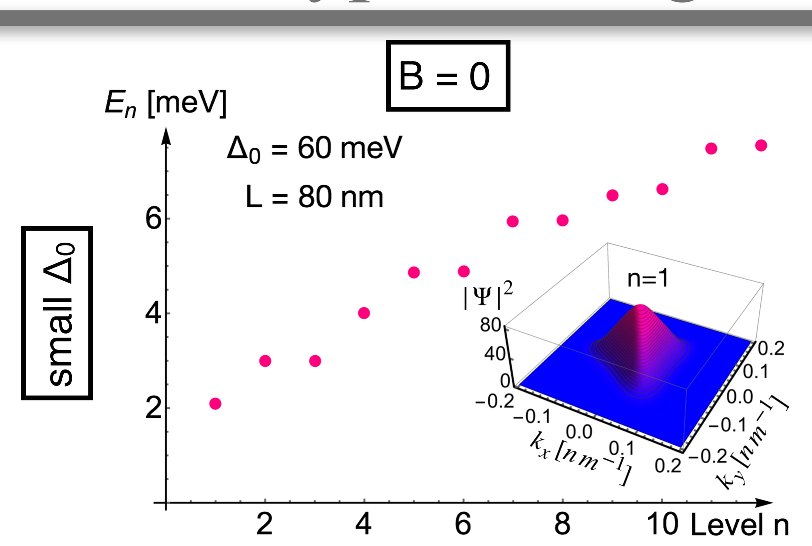



## Optical absorption

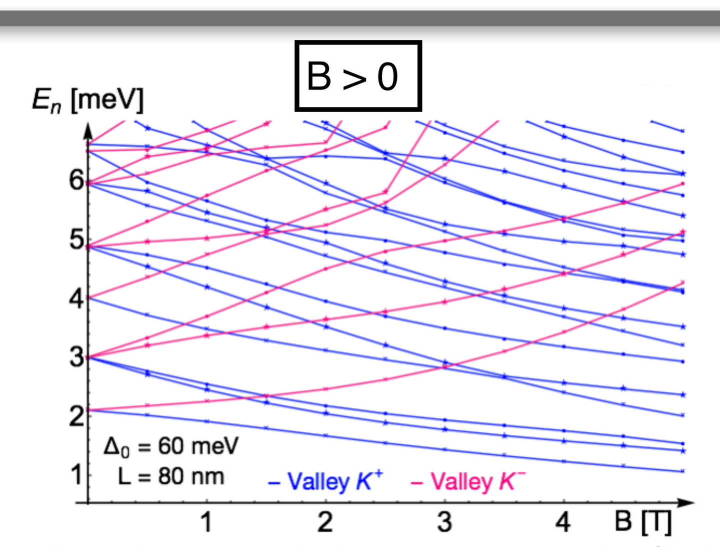



- Absorption channels for right ($\ell_\oplus$) and left-handed ($\ell_\ominus$) polarized light

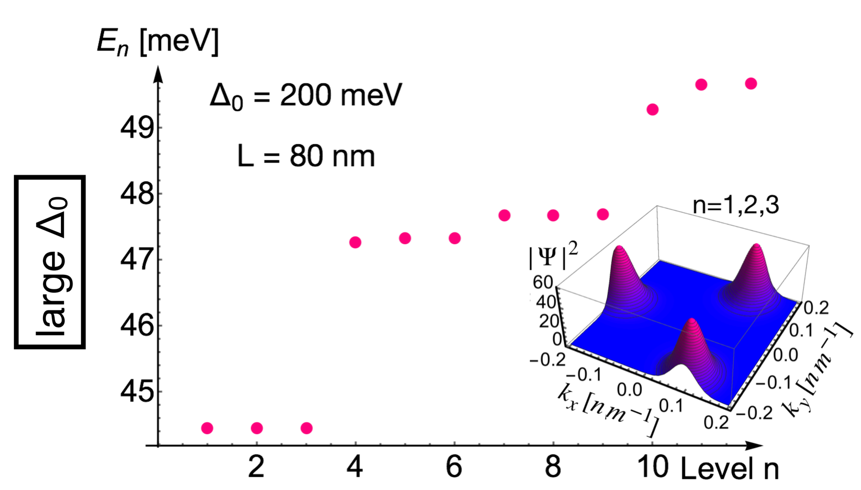
## Different types of degeneracies



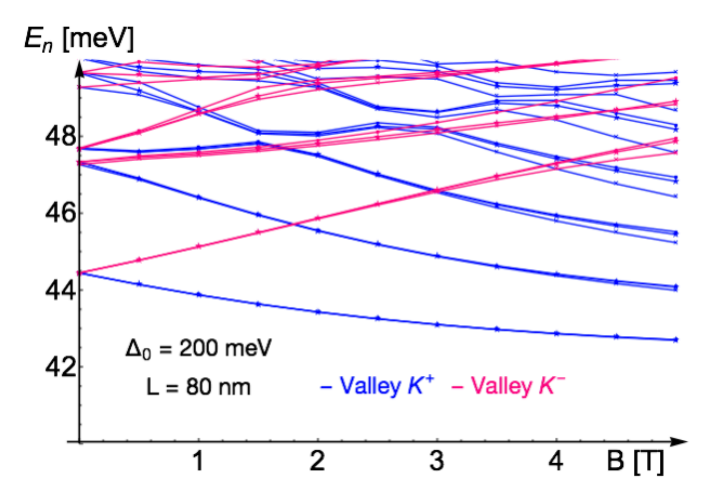

- Duplets, related to angular momentum




- Duplets split in a magnetic field




- Triplets, related to minivalleys




- Triplets remain degenerate

## Conclusions

**The minivalley structure and Berry curvature of gapped BLG alter the spectrum of electrostatically defined quantum dots**

- Anisotropy of the dispersion
  - ➡ breaks rotational symmetry
  - ➡ minivalleys introduce novel, threefold degenerate states
- Berry curvature, magnetic moment
  - ➡ alter angular momentum properties and splittings in a B field

## Open questions

- Validity of the single-particle picture ?
  - ➡Population of the single-particle levels by several electrons, mixing of the multiplets ?

European Research Council

Project ID: 319277

GRAPHENE FLAGSHIP

## References

[1] A. Knothe and V. Fal'ko, Phys. Rev. B 98, 155435 (2018)
[2] H. Overweg, A. Knothe, V. Fal'ko, K. Ensslin, T. Ihn, et al., Phys. Rev. Lett. 121, 257702 (2018)
[3] A. Knothe and V. Fal'ko, in preparation