



Recursive Star-Mesh Transformations for Substantially Expanding Access to Quantized Resistances

Dean G. Jarrett¹, Yanfei Yang¹, Alireza R. Panna¹, Ngoc Thanh Mai Tran^{1,2}, Heather M. Hill¹, David B. Newell¹, Dominick S. Scaletta³, and Albert F. Rigosi¹

¹ National Institute of Standards and Technology (NIST), Gaithersburg, MD, United States

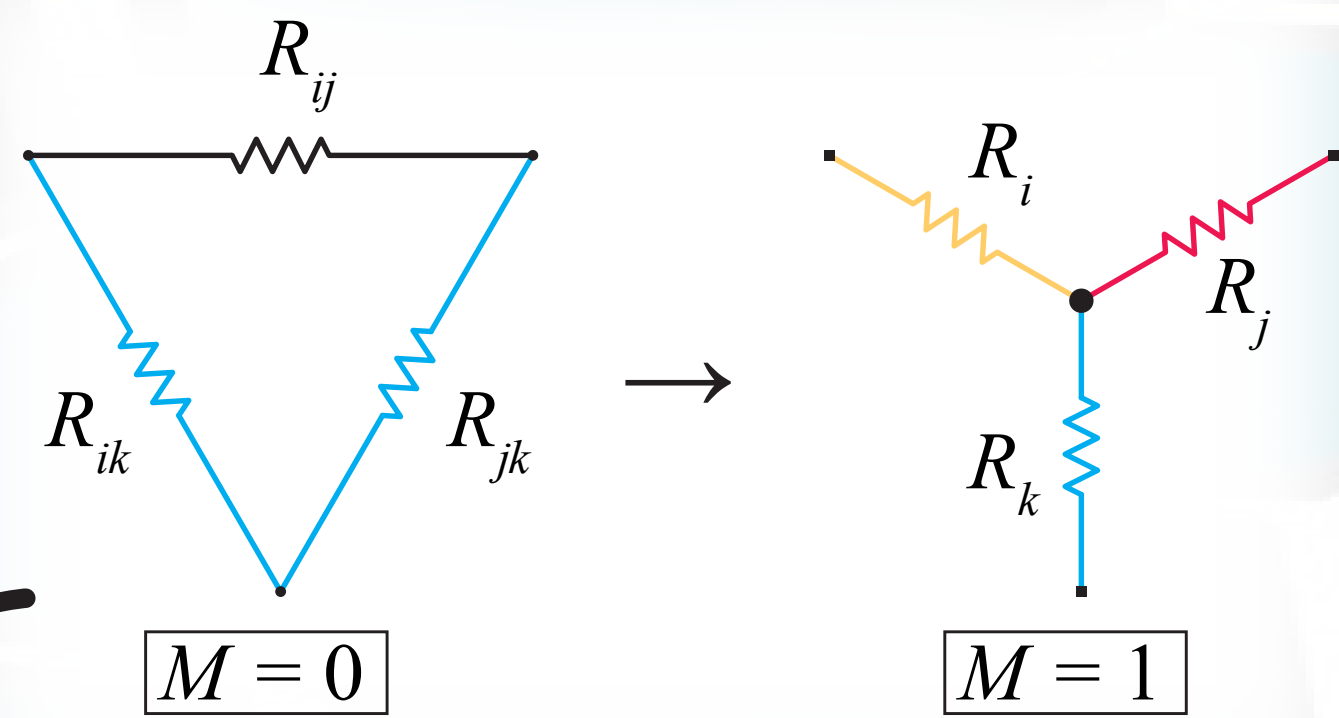
² Joint Quantum Institute, University of Maryland, College Park, MD, United States

³ Mount San Jacinto College, Menifee, CA, United States

1

Recall the Wye-Delta Transformation

$$R_{ij} = R_i R_j \sum_{\alpha=i}^N \frac{1}{R_\alpha}$$

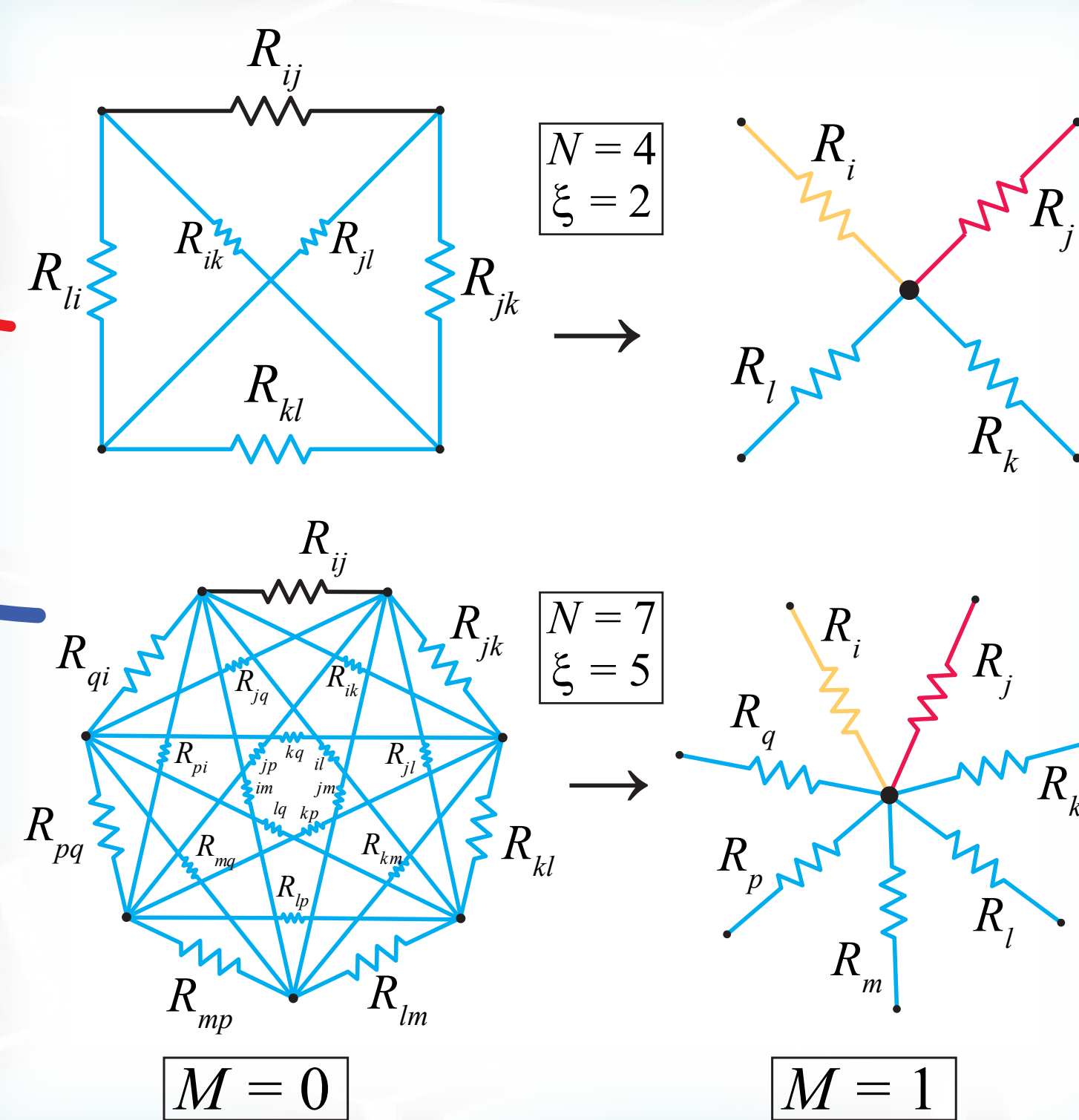


$$q \equiv \frac{R}{R_H}$$

$$q_{ij} = q_i + q_j + \frac{q_i q_j}{q_k} + \frac{q_i q_j}{q_l} + \dots + \frac{q_i q_j}{q_N}$$

2

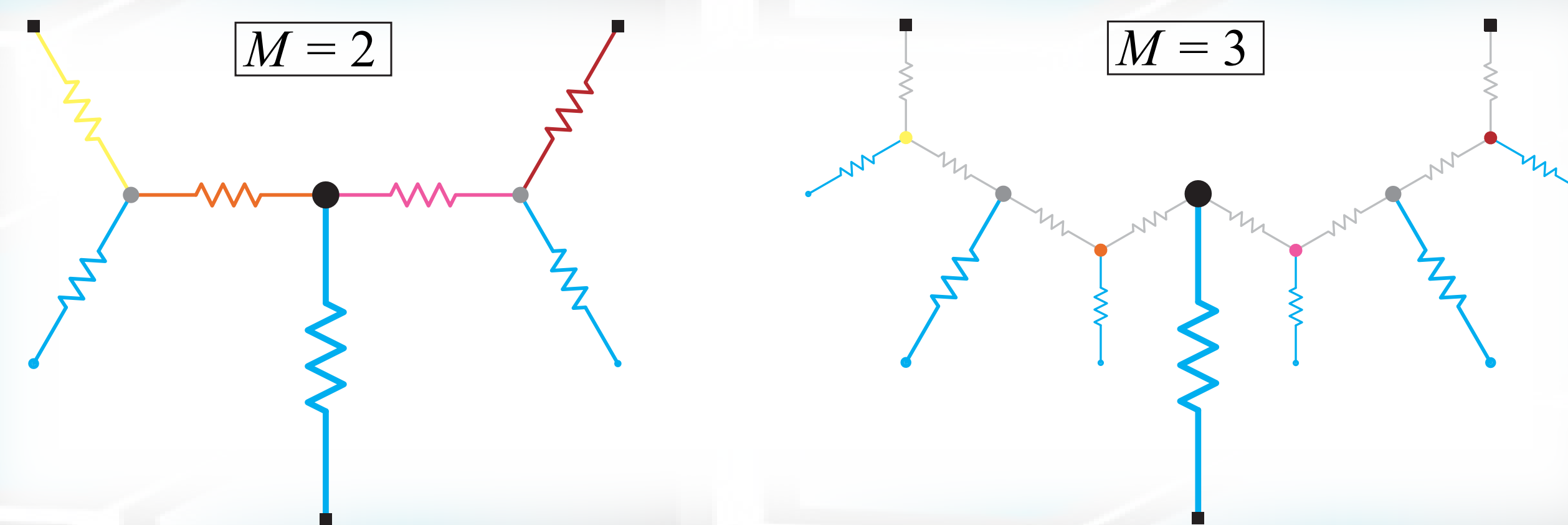
$\xi \equiv \#$ of grounded branches



Expanding to the Star-Mesh Transformation

3

Fractal-Like Recursion to Establish Optimization Process

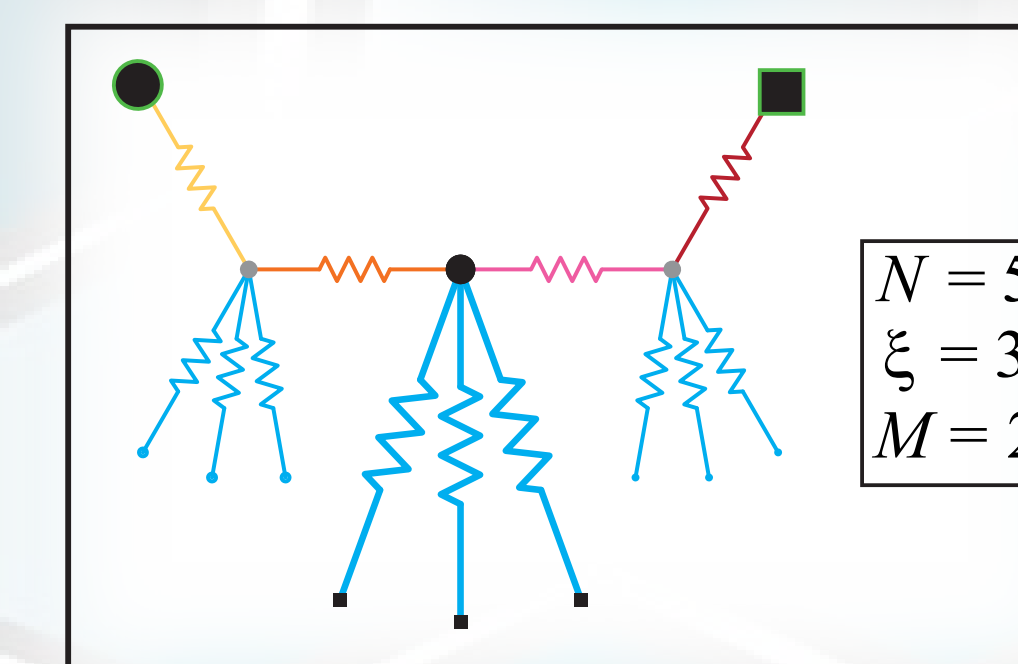
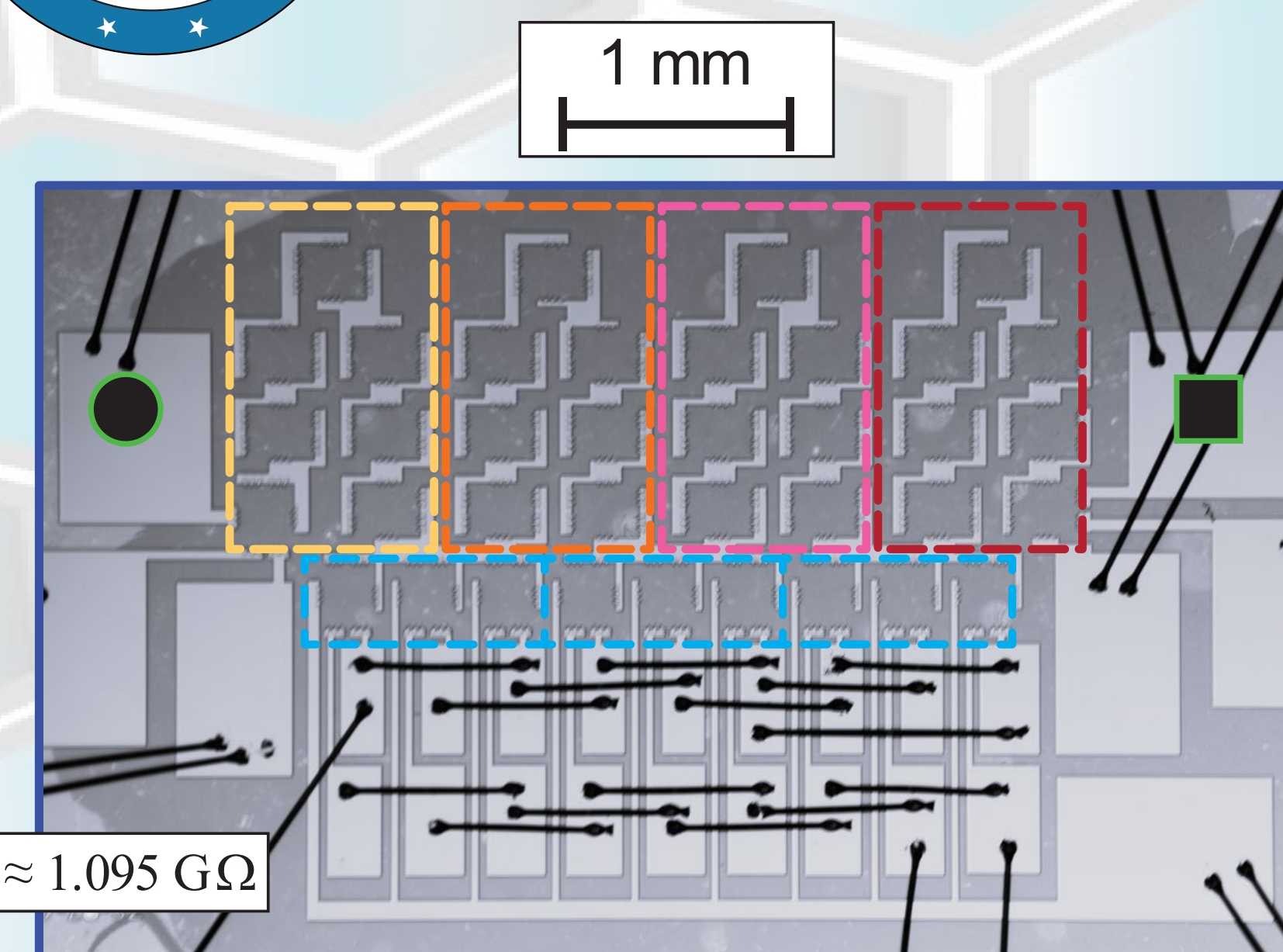


- Number of graphene array elements drastically reduce with recursive expansion of non-grounded resistances (by a factor of at least one million!)
- Assuming device symmetry, optimization process can approximately provide very high, desired quantized resistances ($q_{M:ij}$)
- Single-element approximation: $q_{M:i} = \frac{1}{\xi} (\xi q_{M:ij} + 1)^{2^{-M}} - \frac{1}{\xi}$
- Rounding to integer values of $q_{M:i}$ can yield a device with elements totaling (D_T):

$$D_T(M, \xi, q_{M:ij}) = \frac{2^M}{\xi} (\xi q_{M:ij} + 1)^{2^{-M}} - \frac{2^M}{\xi} + (2^M - 1)\xi$$

5

Example Device and Data

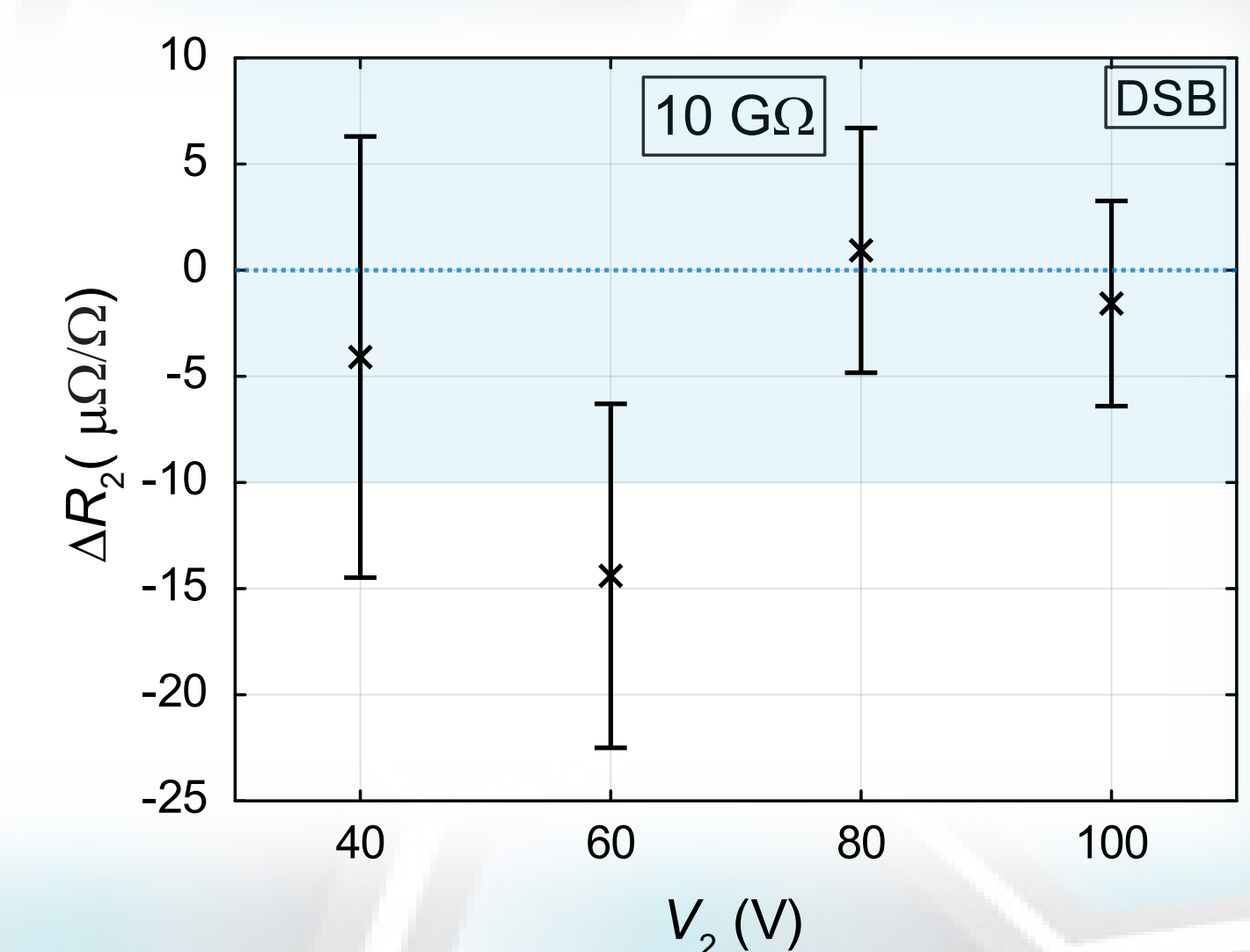
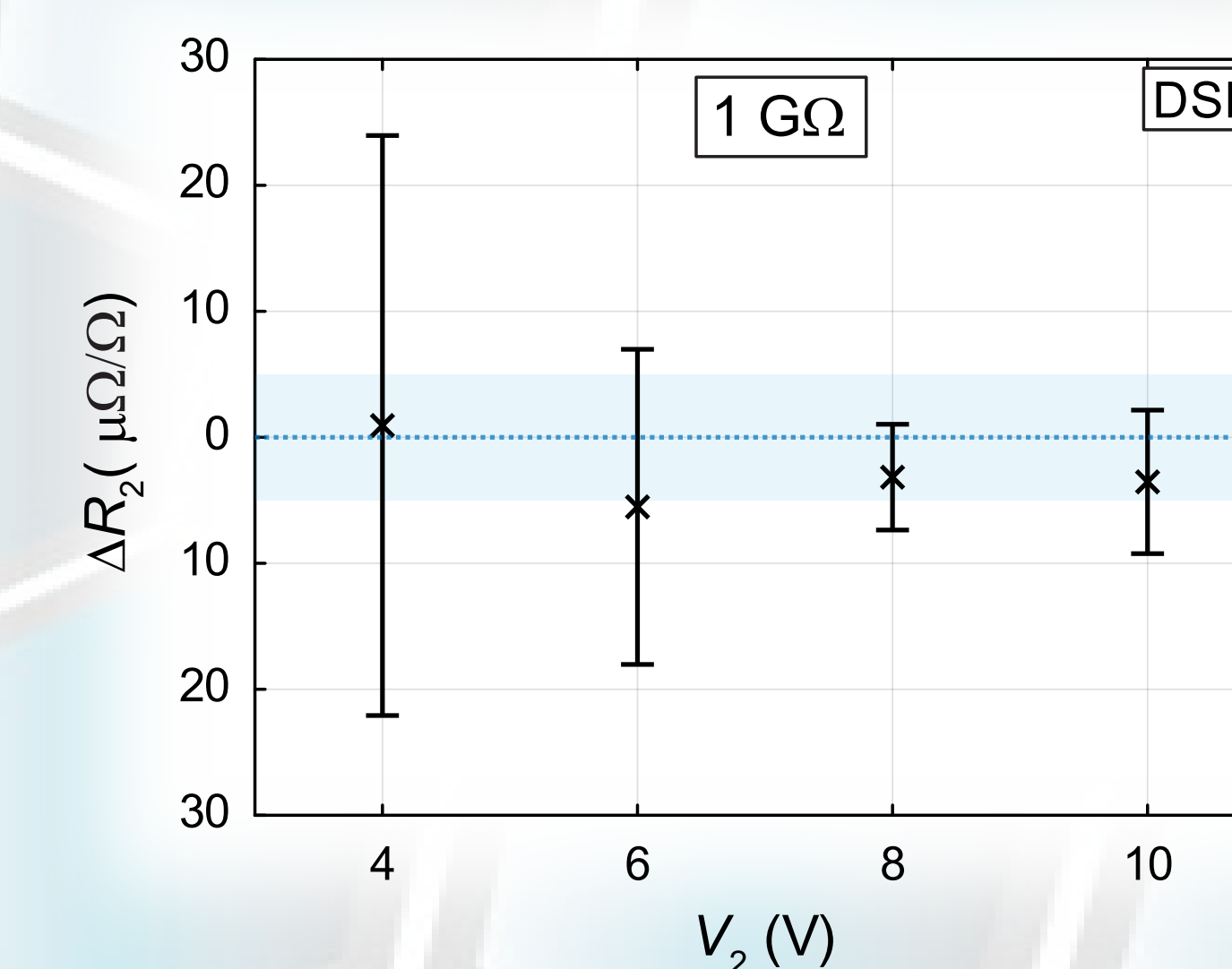
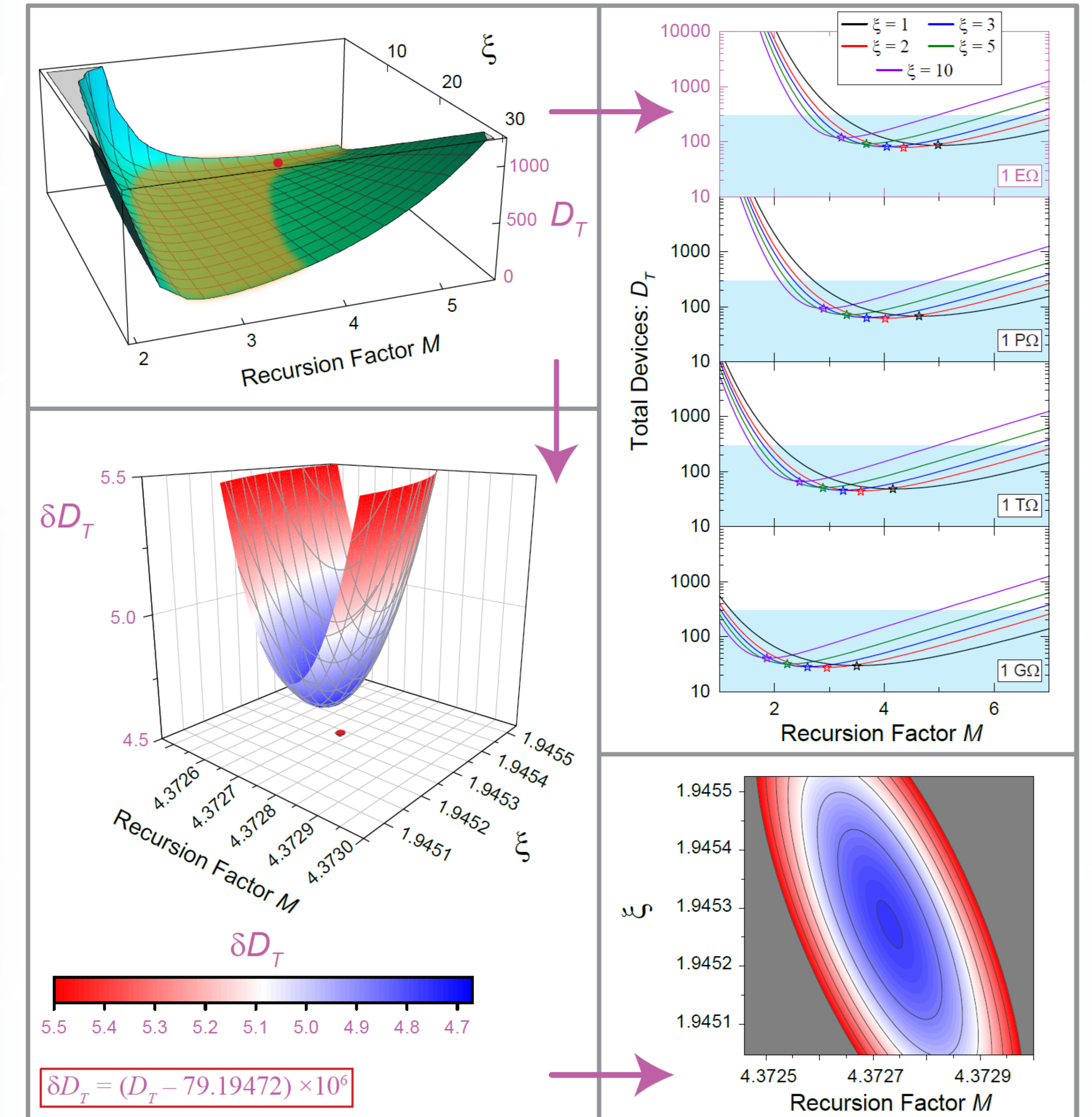


➤ Epitaxial Graphene Quantum Hall Array

➤ Use of Dual-Source Bridge

4

Optimization to Neighborhood of High Resistances



*Error bars (new data) and shaded regions (conventional path of scaling) are the combined standard uncertainties.