Update 17/03

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Averin Coupler – Carsten paper simulations

Coupler in charging regime: $\frac{E_C}{E_J} = 2$

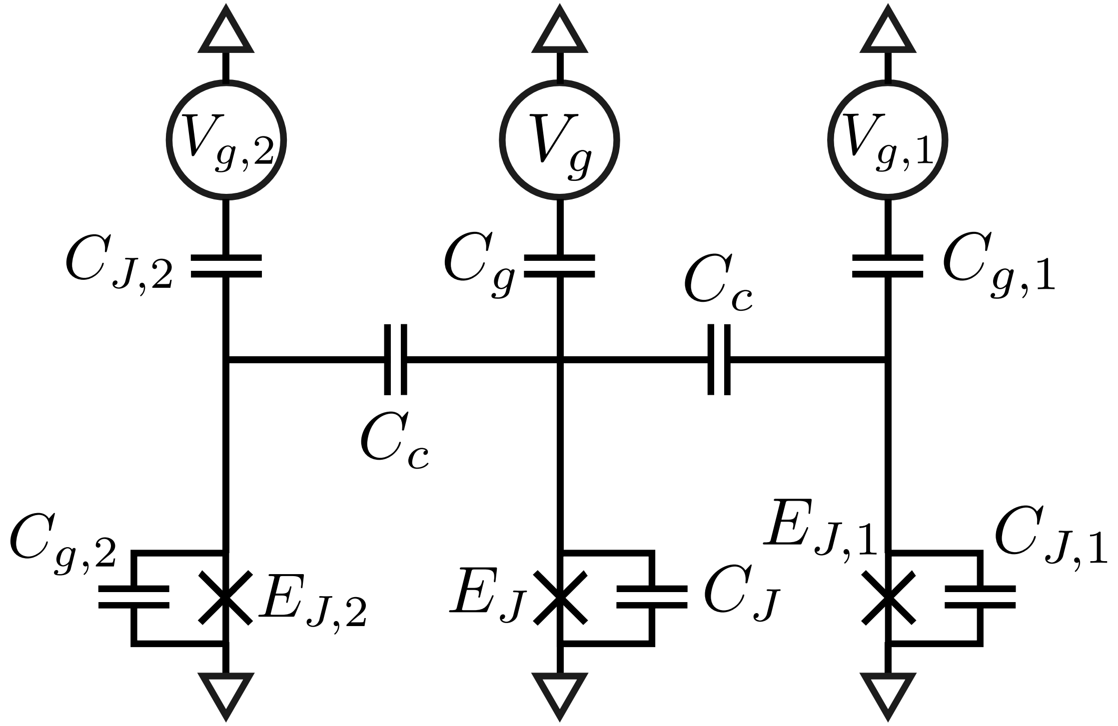
Qubit:

$E_J = 0.4\ \text{GHz},$
$C_J = 93\ \text{fF},$
$C_g = 1\ \text{fF}.$

Coupler:

$E_J = 2\ \text{GHz},$
$C_J = 9\ \text{fF},$
$C_g = 1\ \text{fF}.$

$\boxed{C_c = 5\ \text{fF}}$



Averin Coupler – Carsten paper simulations

Paper findings:

- Averin coupler can induce ZZ interaction between charge qubits, as well as (a usually small) YY interaction, resulting from non-adiabatic correction (beyond Born-Oppenheimer approximation)
- Charge regime $E_C \gg E_J$: tuneable ZZ, negligible YY
- Phase regime $E_J \gg E_C$: negligible ZZ, YY dominant and approximately constant

Averin Coupler – Carsten paper simulations

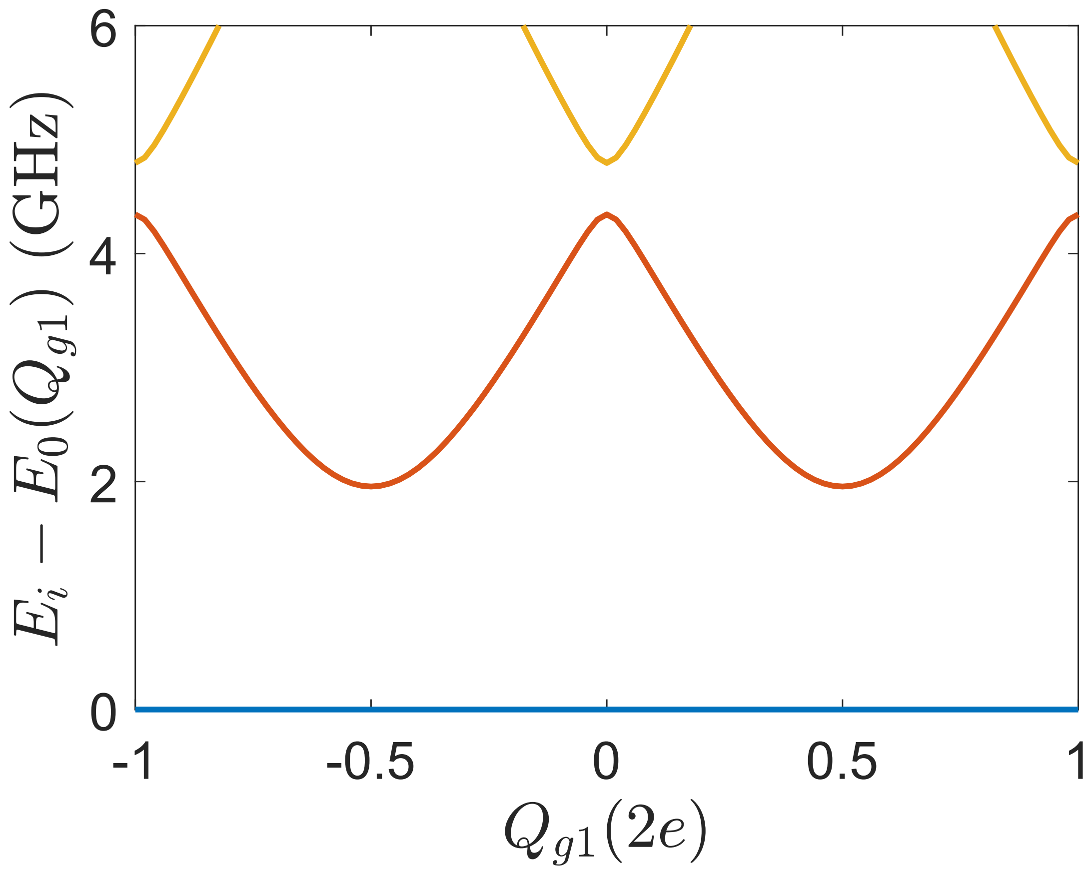
Paper findings:

NB: The requirement that the coupler remains in its ground state, adiabatically following the evolution of the qubits translates into $E_{J,i} < E_J$, which combined with the charging regime condition implies $E_{J,i} < E_J \ll E_C$ which means that very small critical current and/or capacitances are required.

Averin Coupler – Carsten paper simulations

Coupler spectrum:

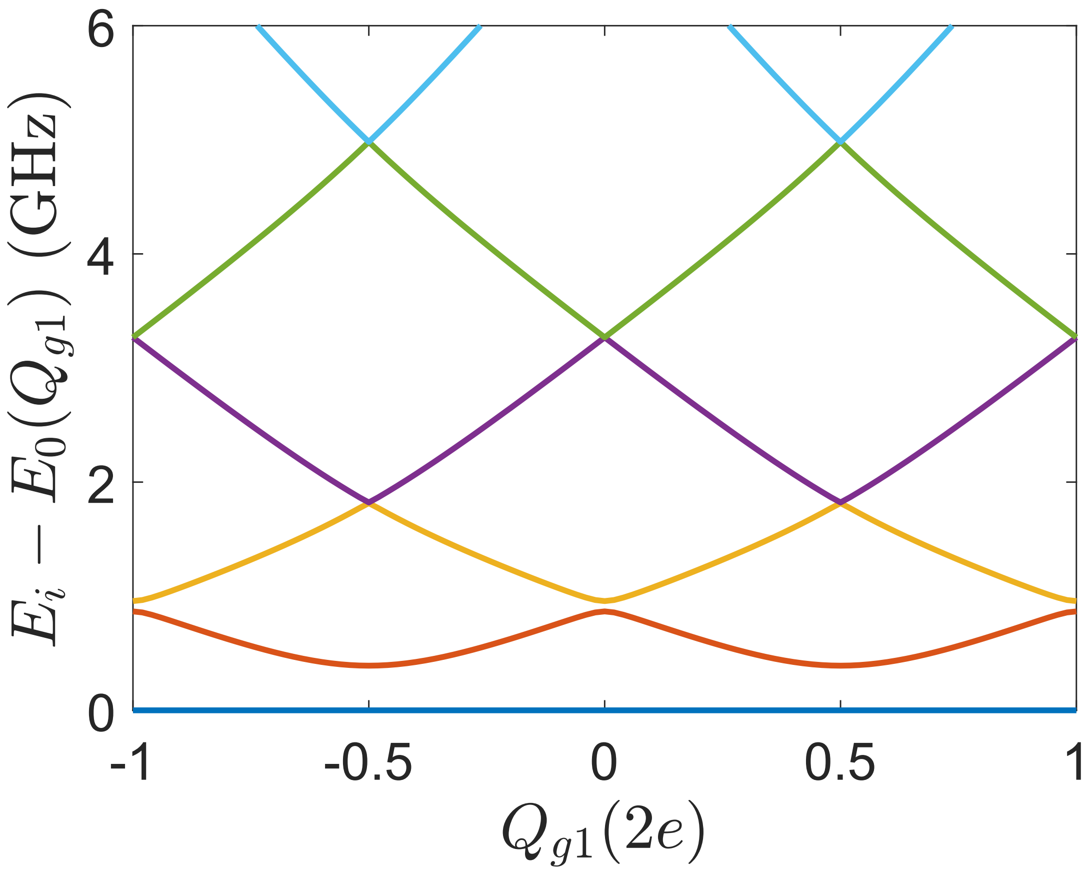
Loaded coupler island capacitance = 19.5 fF, $\frac{E_C}{E_J} = 2$ (charge regime).



Averin Coupler – Carsten paper simulations

Qubit spectrum:

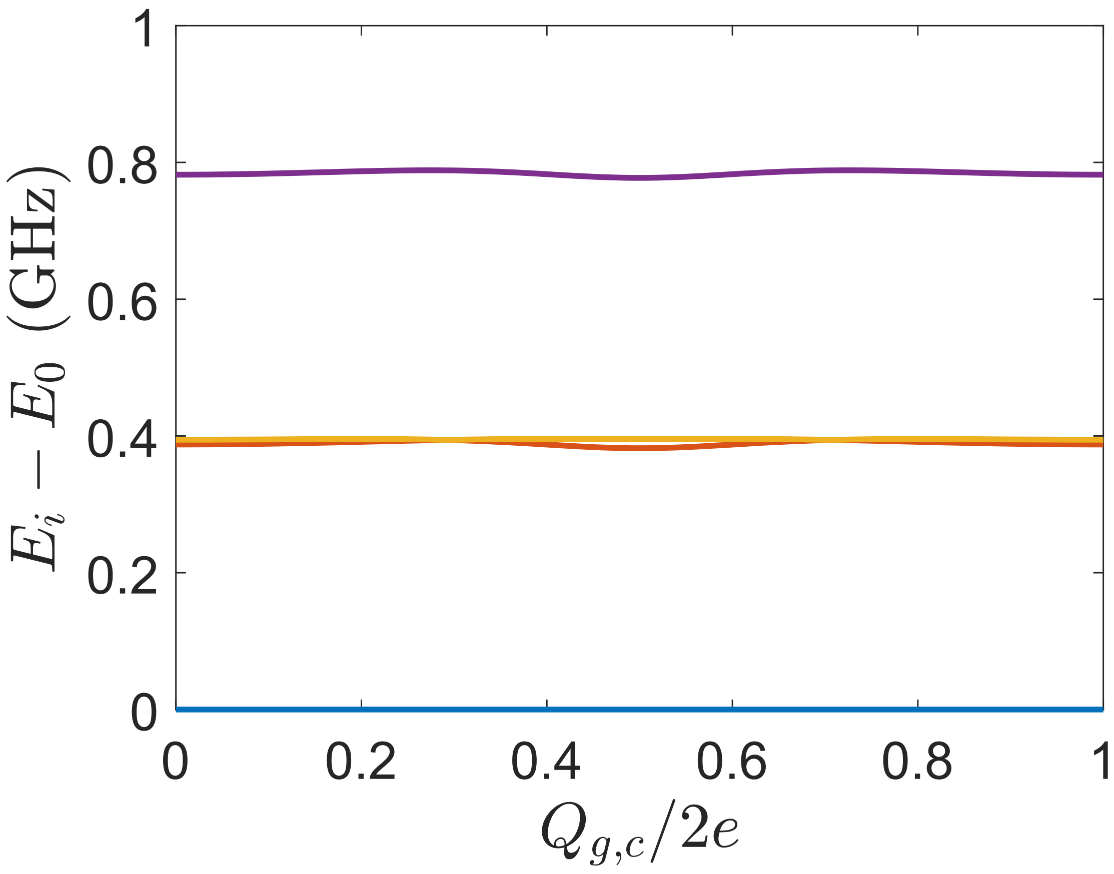
Loaded qubit island capacitance = 97.7 fF, $\frac{E_{Ci}}{E_{Ji}} = 2$, $\frac{E_{Ji}}{E_J} = 0.2$.



Averin Coupler – Carsten paper simulations

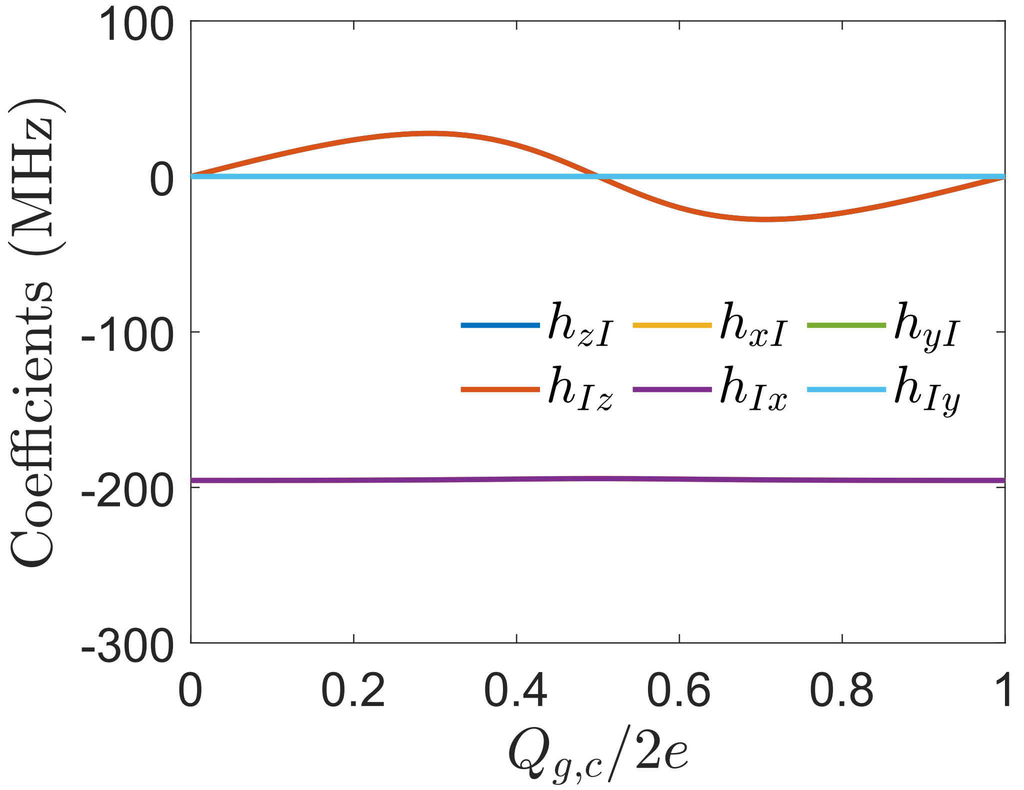
System spectrum:

Lowest 4 transition energies vs. coupler island charge bias (qubits biased at $\mathrm{Q}_{\mathrm{g,i}} = e$). Crossing between 1st and 2nd excited state: pairwise interaction tuned across zero.



Averin Coupler – Carsten paper simulations

Extracted params:



1-local:

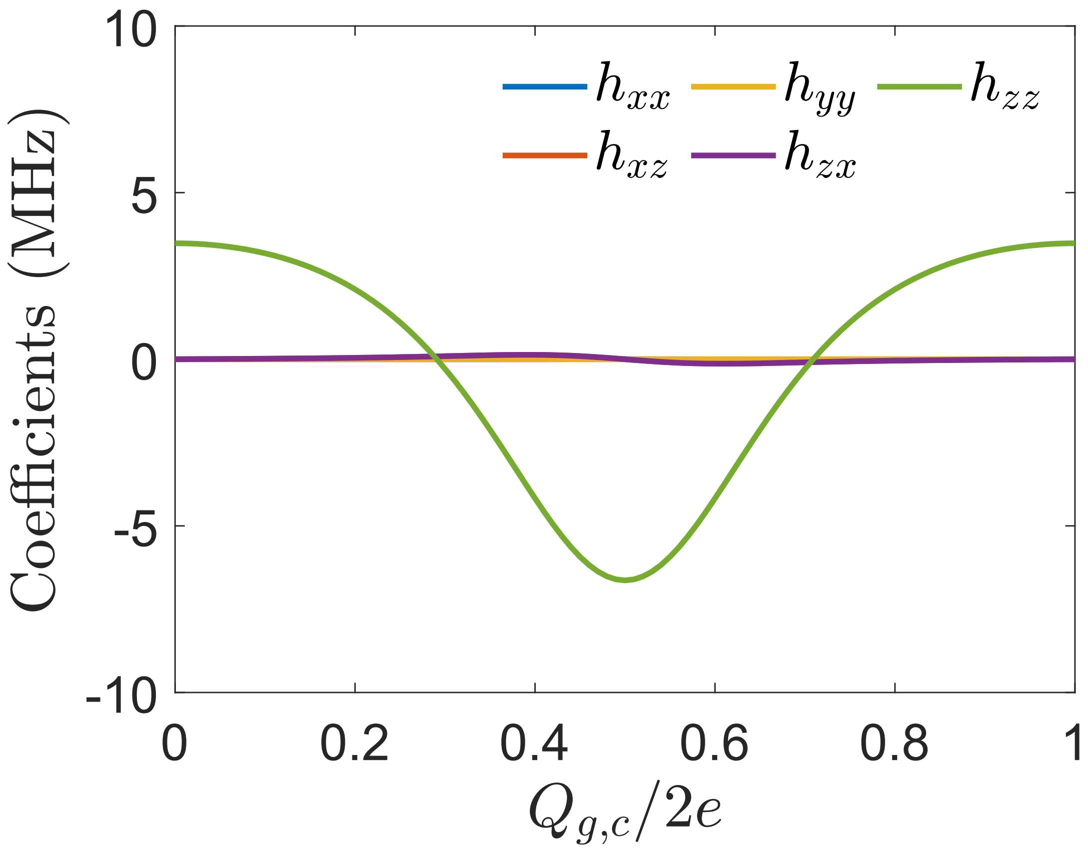
Tuning of the longitudinal field (voltage offset on coupler also offsets qubit island)

Averin Coupler – Carsten paper simulations

Extracted params:

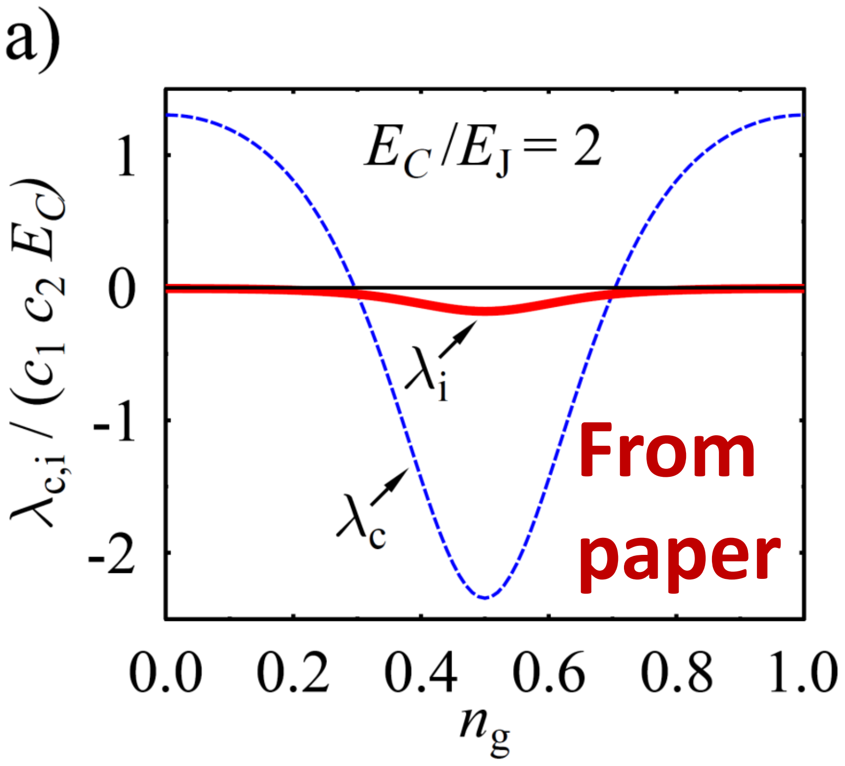
2-local:

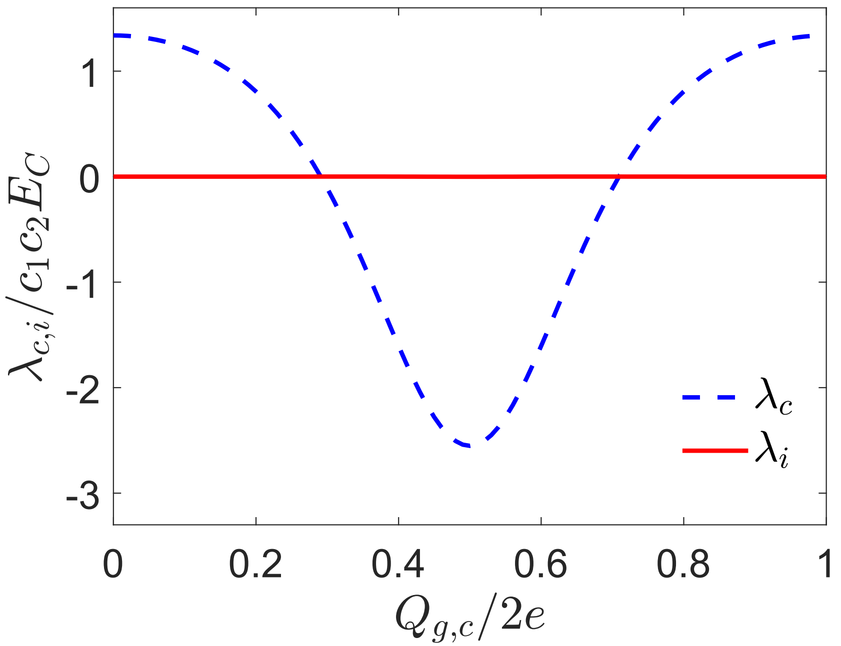
ZZ (+ZX + XZ) charge interaction, tuneable in magnitude and sign, < 10 MHz in absolute value. Negligible YY inductive interaction (non-adiabatic effect)



Averin Coupler – Carsten paper simulations

Comparison with paper: $\lambda_c = 4J_{zz}, \lambda_i = 4J_{yy}$.





Similar λ_c, λ_i everywhere negligible

Averin Coupler – Carsten paper simulations

Coupler in phase regime: $\frac{E_C}{E_J} = 0.5$

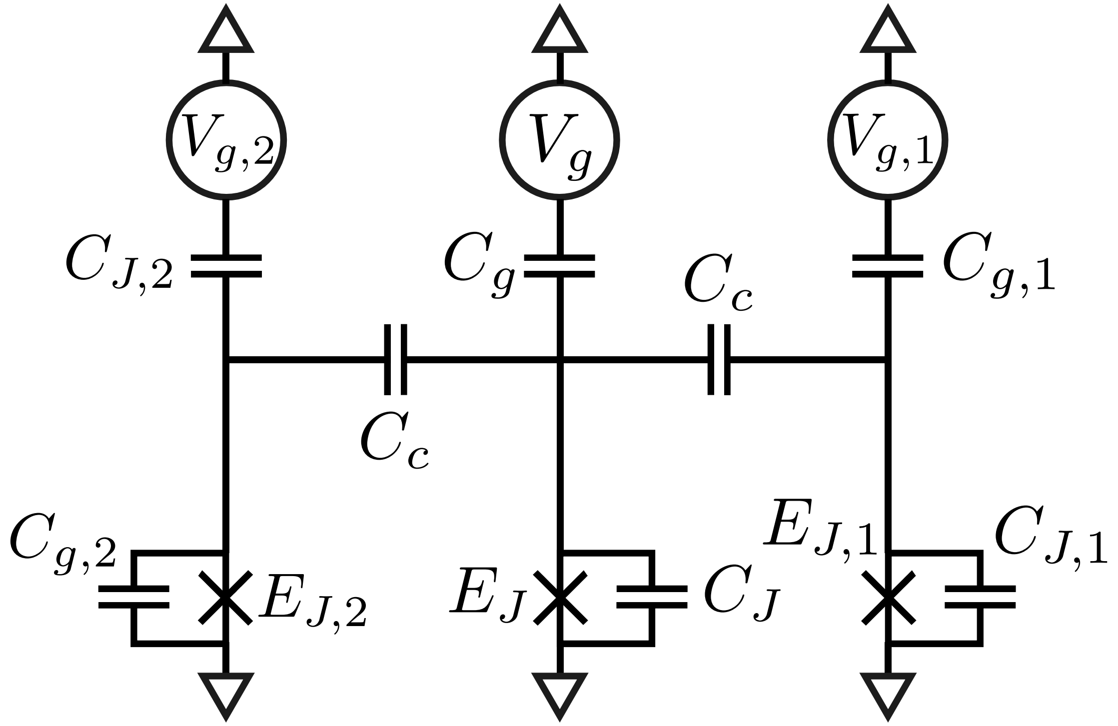
Qubit:

$E_J = 5.0$ GHz,
$C_J = 4.7$ fF,
$C_g = 1$ fF.

Coupler:

$E_J = 25$ GHz,
$C_J = 0$ fF,
$C_g = 0.9$ fF.

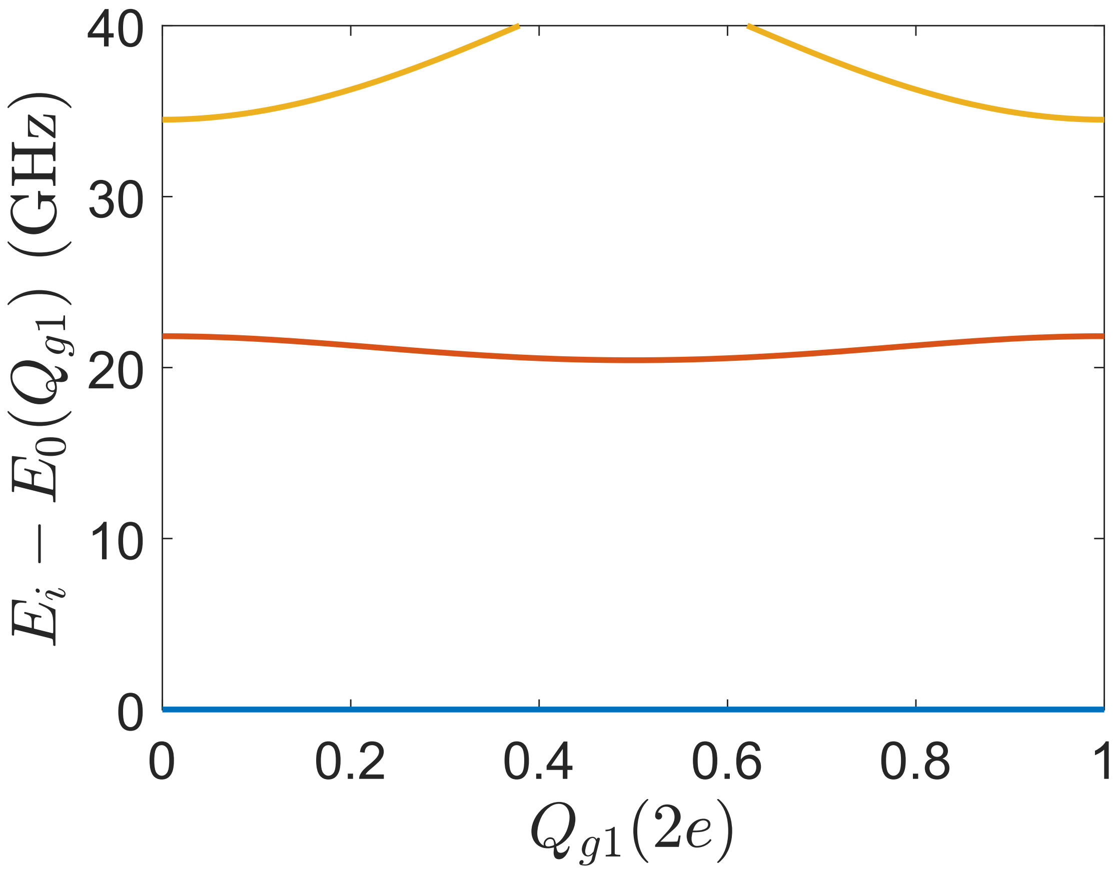
$\boxed{C_c = 5 \text{ fF}}$



Averin Coupler – Carsten paper simulations

Coupler spectrum:

Loaded coupler island capacitance = 6.2, $\frac{E_C}{E_J} = 0.5$ (charge regime).

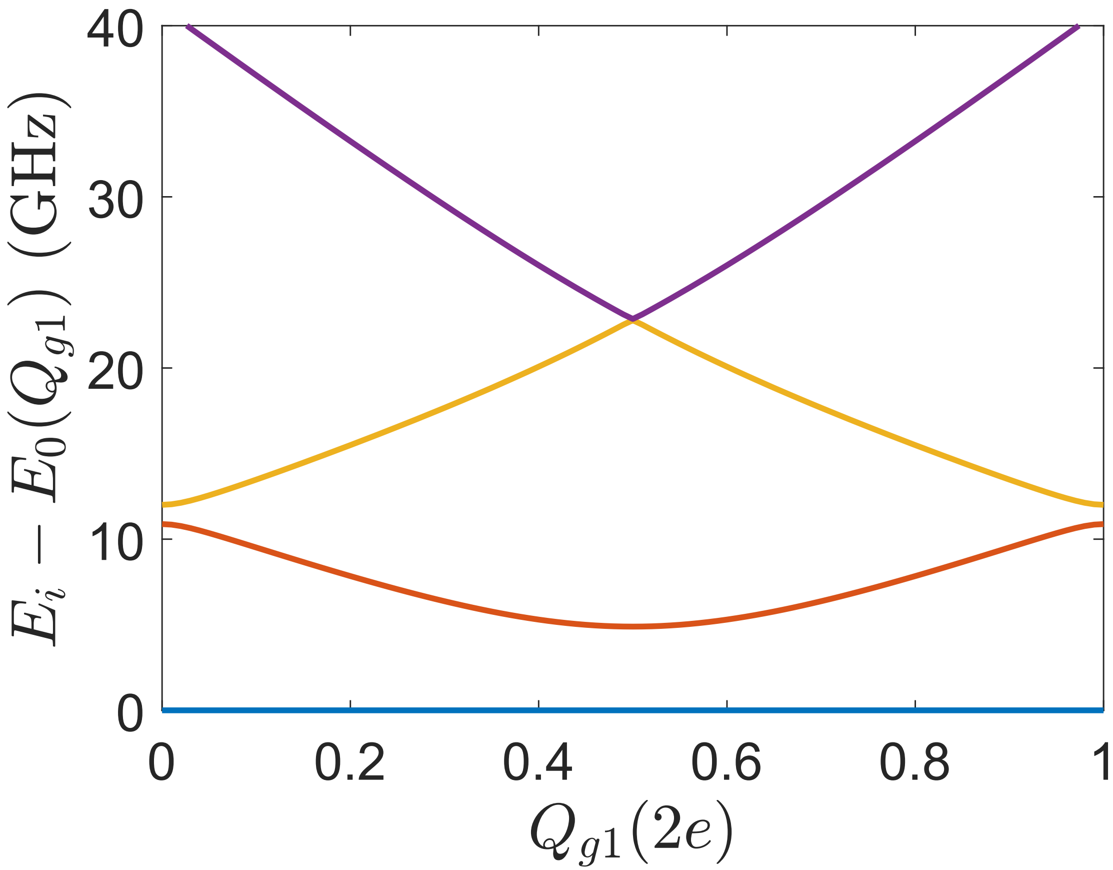


Averin Coupler – Carsten paper simulations

Qubit spectrum:

Loaded qubit island capacitance = 7.8 fF, $\frac{E_{Ci}}{E_{Ji}} = 2$, $\frac{E_{Ji}}{E_J} = 0.2$.

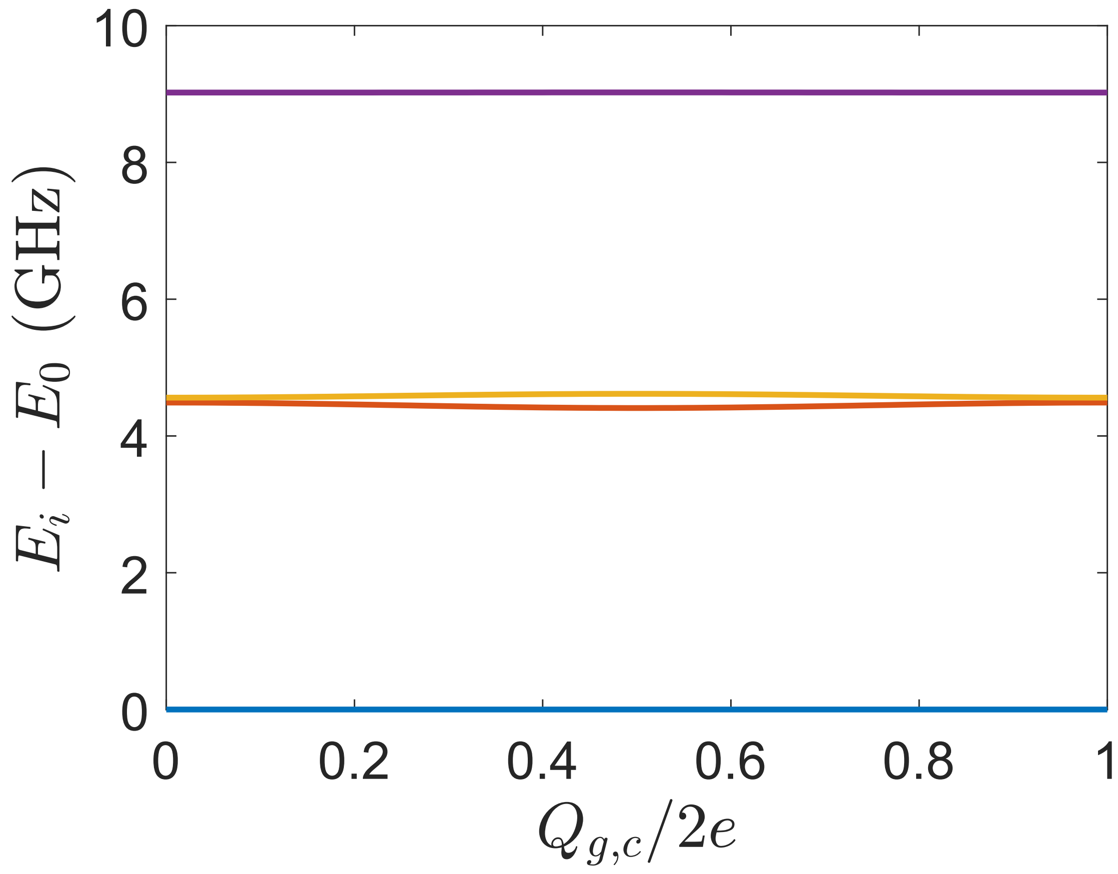
Note the bigger energy scales



Averin Coupler – Carsten paper simulations

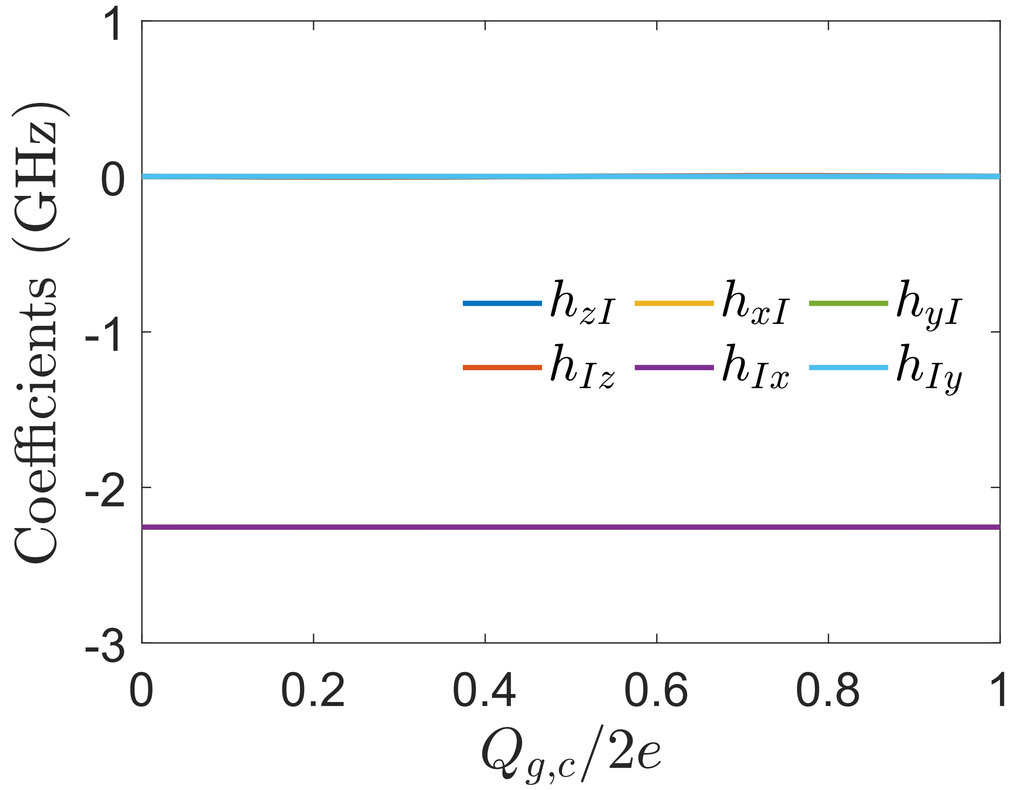
System spectrum:

Lowest 4 transition energies vs. coupler island charge bias (qubits biased at $Q_{g,i} = e$). No crossing between 1st and 2nd excited state: pairwise interaction is NOT tuned across zero.



Averin Coupler – Carsten paper simulations

Extracted params:



1-local:

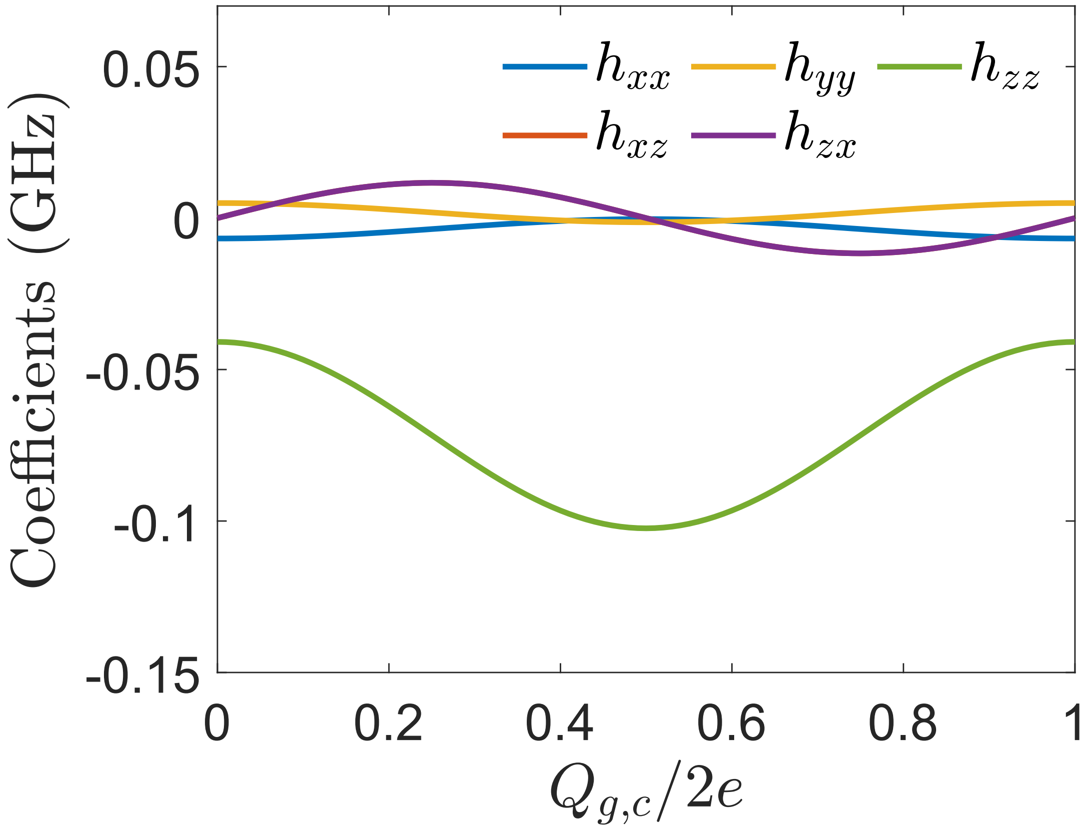
Tuning of the longitudinal field is negligible at this scale

Averin Coupler – Carsten paper simulations

Extracted params:

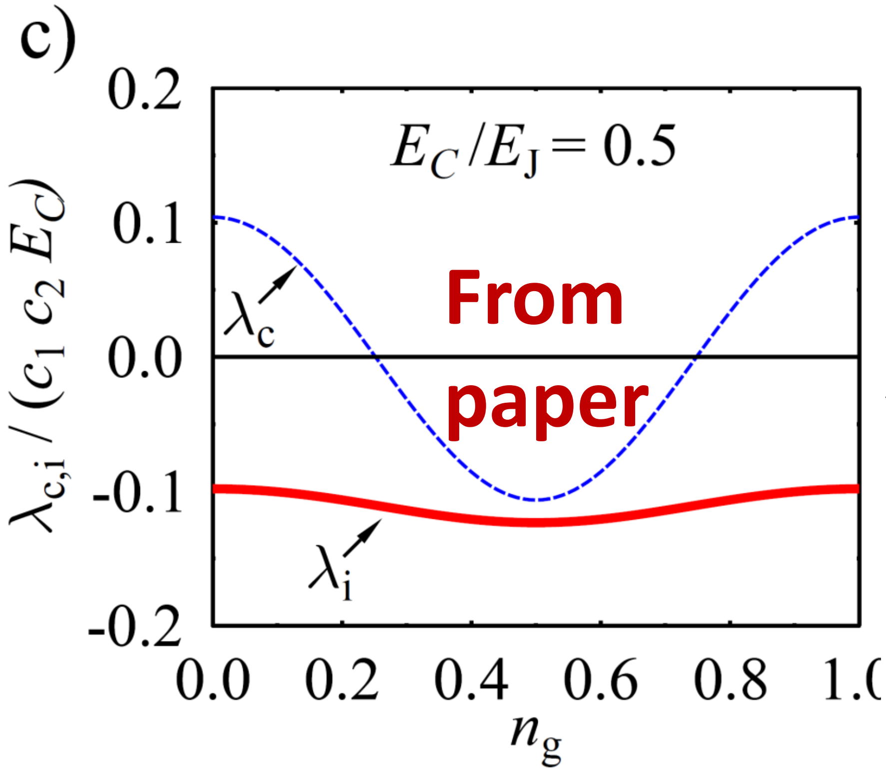
2-local:

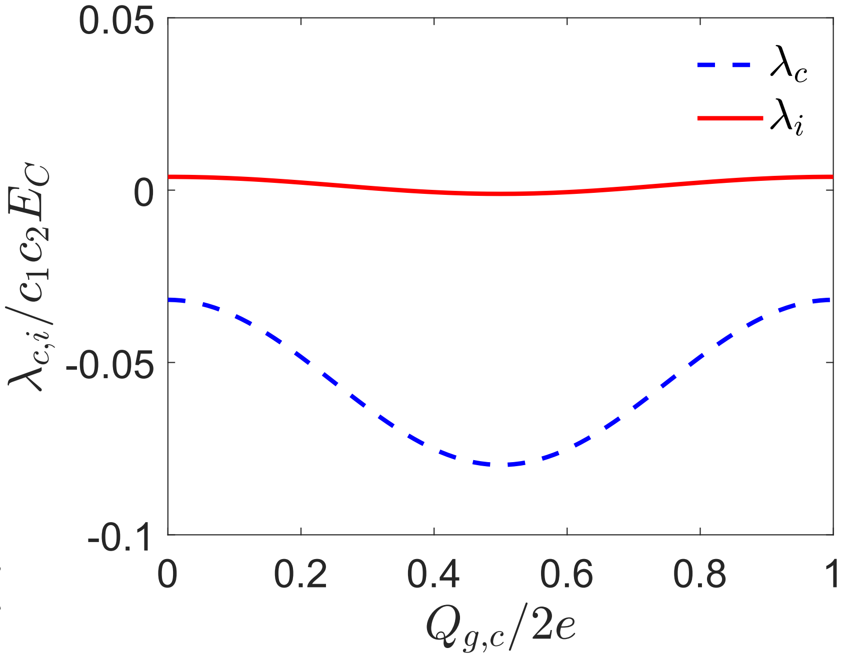
ZZ (+ZX + XZ) charge interaction, always negative, < 100 MHz in absolute value. Small YY (+XX) inductive interaction (non-adiabatic effect)



Averin Coupler – Carsten paper simulations

Comparison with paper: $\lambda_c = 4J_{zz}, \lambda_i = 4J_{yy}$.





λ_c uniformly shifted, smaller λ_i.
Note that all coefficients are smaller than in the charging regime relative to the system energy scale, as in the paper