LATVIJAS UNIVERSITĀTE
ANNO 1919

Elektronu pāru skaldīšana nanoelektroniskajā "kvantu paātrinātājā"

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Partitioning of on-demand electron pairs

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1. Eksperiments veikts Hanoverē

Leibniz Universität Hannover

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1. Teorija izstrādāta Rīgā

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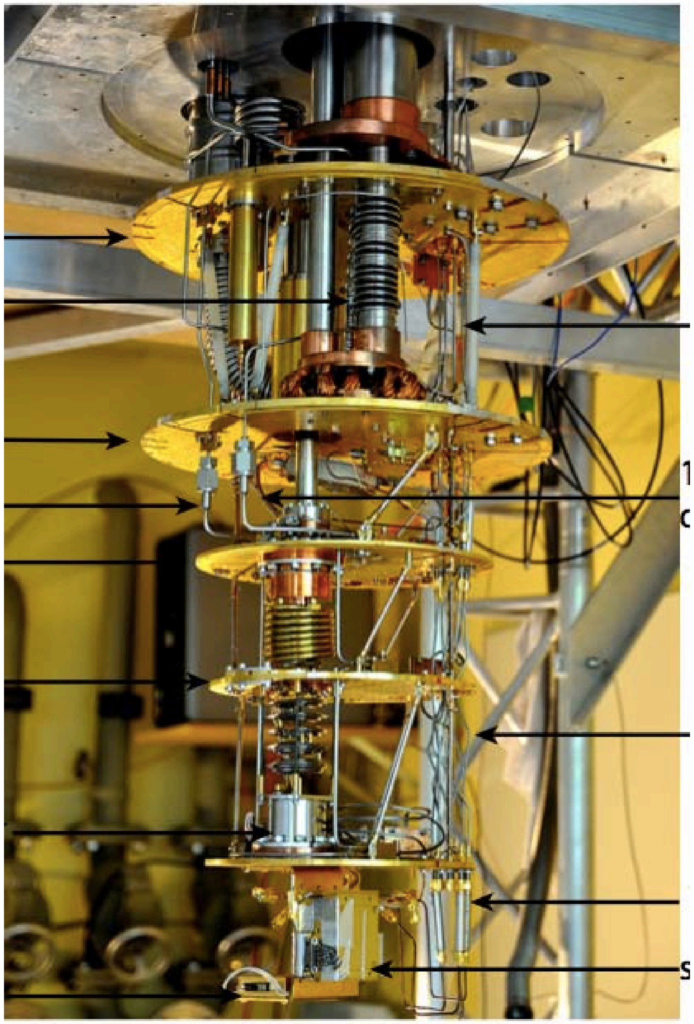
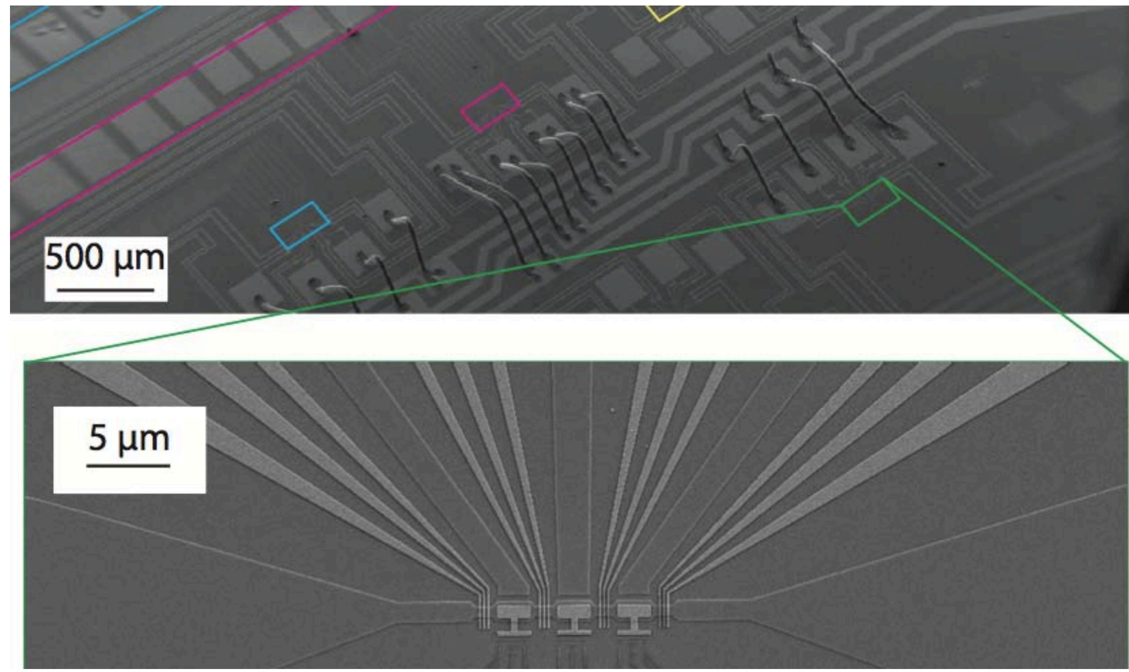
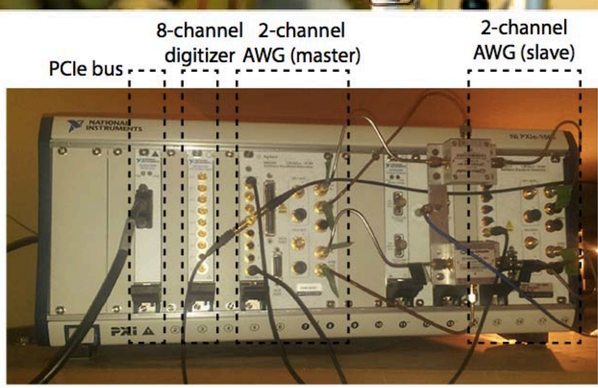






For a specific model calculation we consider a sudden onset of strong dot-lead coupling in a quantum-impurity-like model of the quantum dot and edge cahnnel, governed at $t > 0$ by the Hamiltonian

$$\mathcal{H} = \varepsilon_c(d_1^\dagger d_1 + d_2^\dagger d_2) + (\Delta\varepsilon + U d_1^\dagger d_1) d_2^\dagger d_2 \tag{S5}$$

$$+ \sum_{i=1,2} \sqrt{\gamma_i/(2\pi\nu)} \sum_k \left(d_i^\dagger c_k + c_k^\dagger d_i \right) + \sum_k \epsilon_k v_F c_k^\dagger c_k \,. \tag{S6}$$

Here $\varepsilon_c > E_b$ is the lowest single-electron energy level right after application of the emission pulse at $t = 0$; ν is the density of states in the lead with a quasi-continuous spectrum ϵ_k. d_1, d_2 and c_k are the usual fermionic anihilation operators for a single spin species. The level broadenings γ_1, γ_2 are on the order of $\hbar\Gamma_b$ which in turn is expected to be on the order of level-spacing $\Delta\varepsilon$. Pre-emission Coulomb charging energy is described by the Hubbard parameter U.

Starting from initial conditions at $t = 0$ with two electrons on the dot, $\langle d_1^\dagger d_1 \rangle + \langle d_2^\dagger d_2 \rangle = 2$, and a drained Fermi sea, $\langle c_k^\dagger c_q \rangle = 0$, time evolution of the two-particle wavefunction governed by Eq. (S6) can be solved exactly using standard methods. For $t \gg \Gamma_b^{-1}$, the solution converges to $|\Psi\rangle = \sum_{kq} \psi_{kq} |k\rangle \otimes |q\rangle$ where $\psi_{kq} = -\psi_{qk}$ and $|k\rangle$ are the single particle states in the lead cerated by $c_k^\dagger$. The asymptotic two-partcile amplitudes are

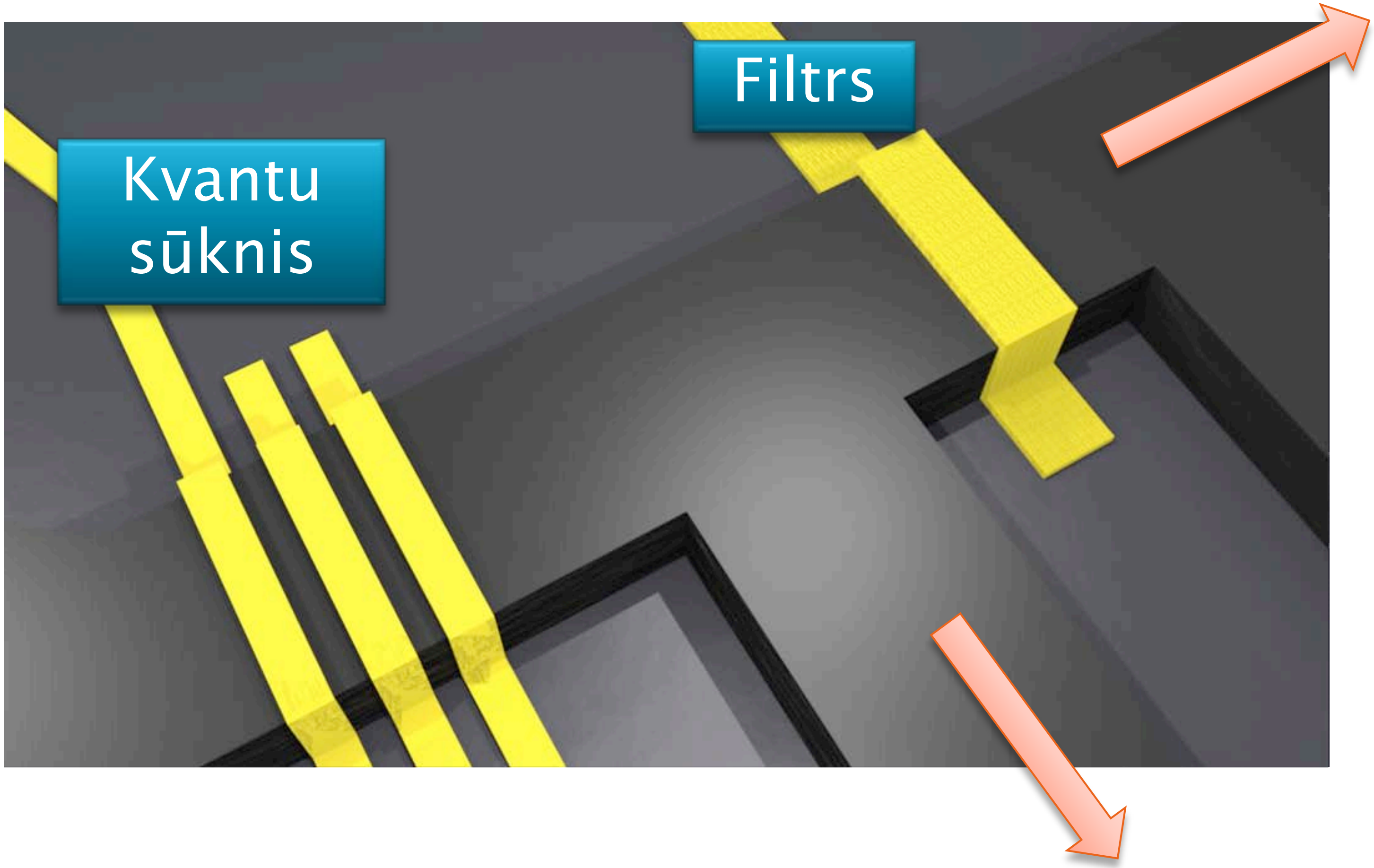
$$\psi_{kq} = \frac{1}{2\pi\nu\sqrt{2}} \frac{\Delta\varepsilon \sqrt{\gamma_1\gamma_2}}{(\epsilon_q - z_1)(\epsilon_q - z_2)(\epsilon_q + \epsilon_k - U - z_1 - z_2)} - (q \leftrightarrow k) \,. \tag{S7}$$

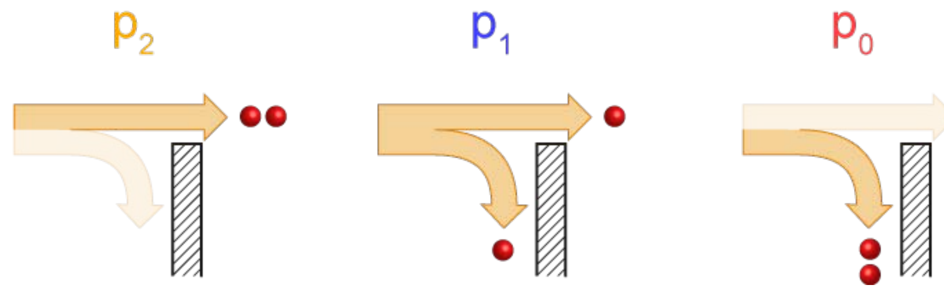
Here z_1 and z_2 are the (complex) roots of the secular quandratic equation: $(z - z_1)(z - z_2) = (z - \varepsilon_c + i\gamma_1/2)(z - \varepsilon_c - \Delta\varepsilon + i\gamma_2/2) + \gamma_1\gamma_2/4$.

For $\gamma_1 = \gamma_2 = \Delta\varepsilon$ (which mimics ballistic propagation over the exit barrier), the joint probability distribution to find one electron at energy ϵ_k and the other at ϵ_q is

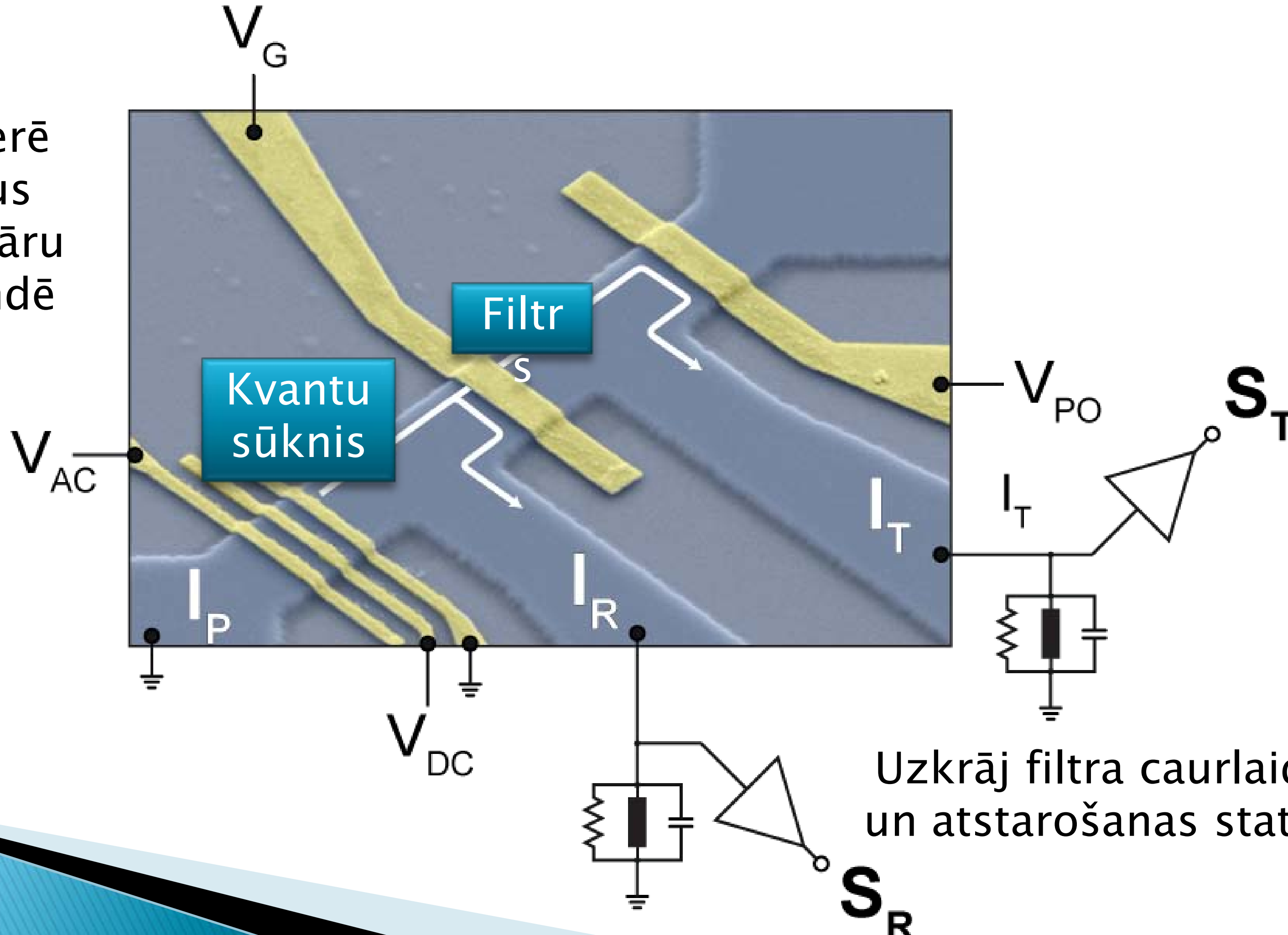
$$\nu^2 |\psi_{kq}|^2 = \frac{\Delta\epsilon^4}{8\pi^2} \frac{(\epsilon_k - \epsilon_q)^2[(\epsilon_k + \epsilon_q)^2 + \Delta\varepsilon^2]}{(\epsilon_k^2 + \Delta\varepsilon^2/4)(\epsilon_q^2 + \Delta\varepsilon^2/4)[(\epsilon_k + \epsilon_q - U)^2 + \Delta\varepsilon^2]} \tag{S8}$$

This result contains both fermionic ($\psi_{kk} = 0$) and interactions-induced (for $U > 0$) correlations. We plot the projected


Kvantu sūknis
Filtrs

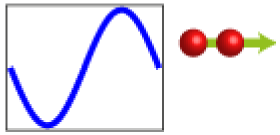


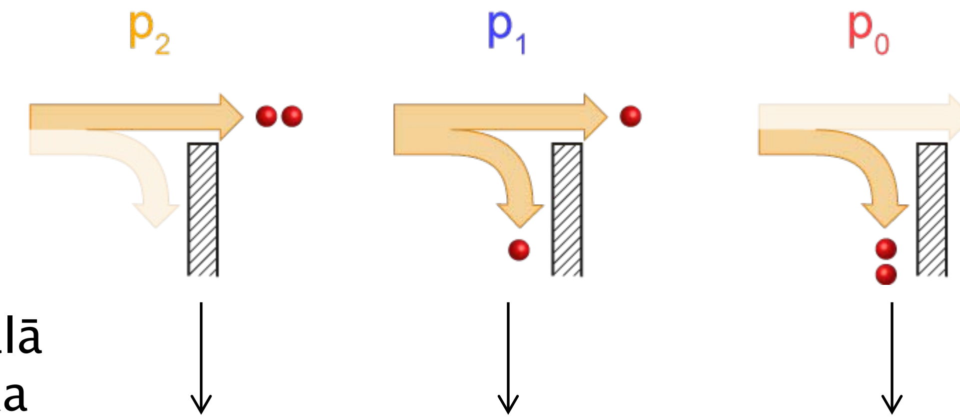
Sūknis ģenerē 240 miljonus elektronu pāru vienā sekundē



Uzkrāj filtra caurlaidības un atstarošanas statistiku

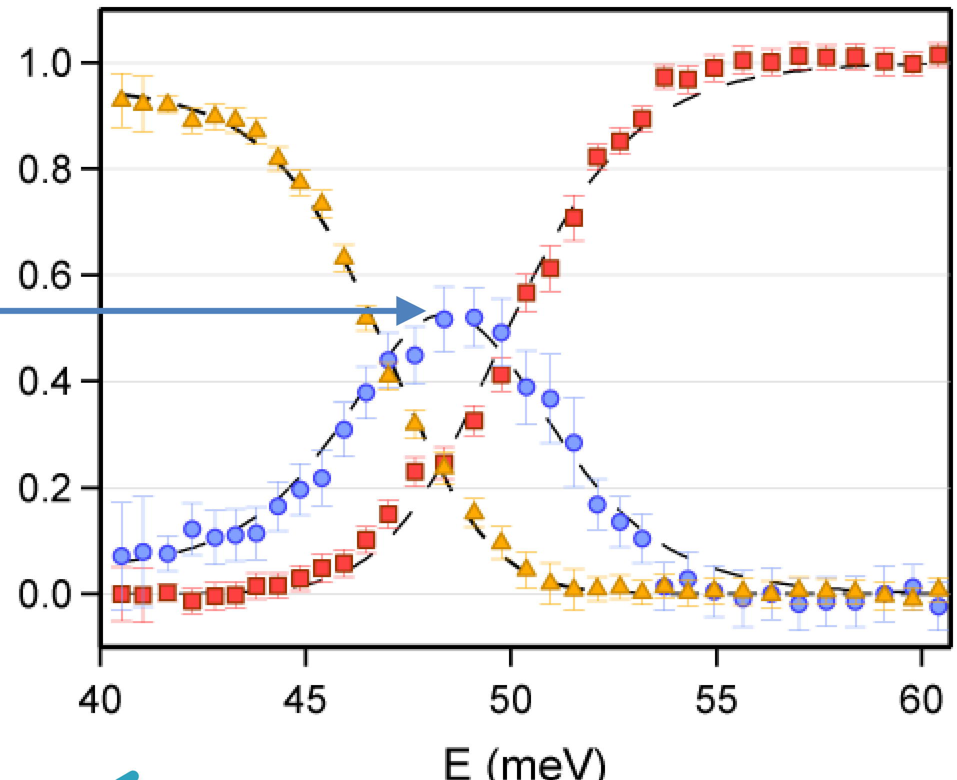
Divi elektroni secīgi





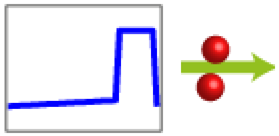
Binomiālā statistika

50%



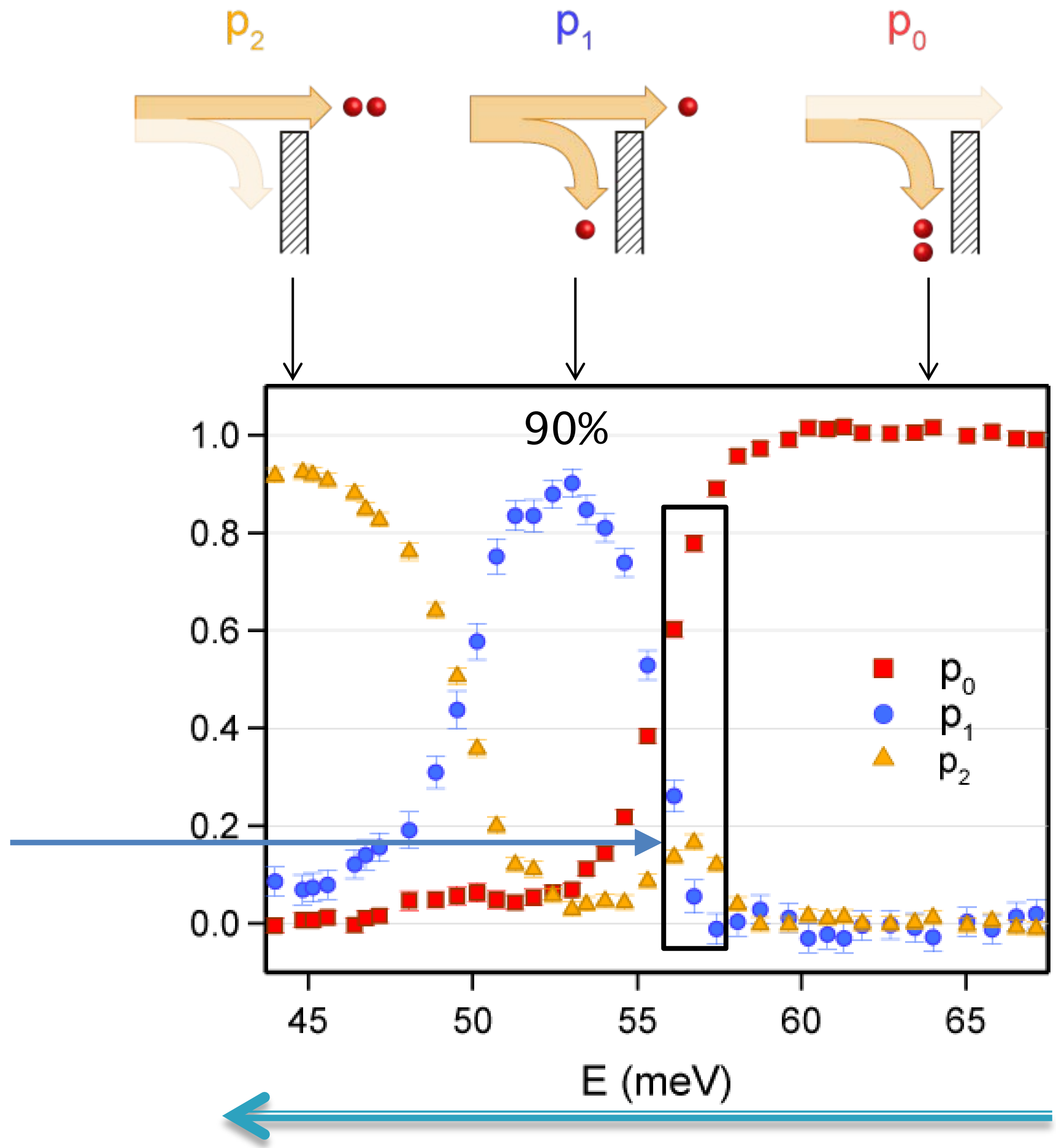
Filtra caurlaidība

Divi elektroni vienlaicīgi



Anomāla korelācija (saistība) !

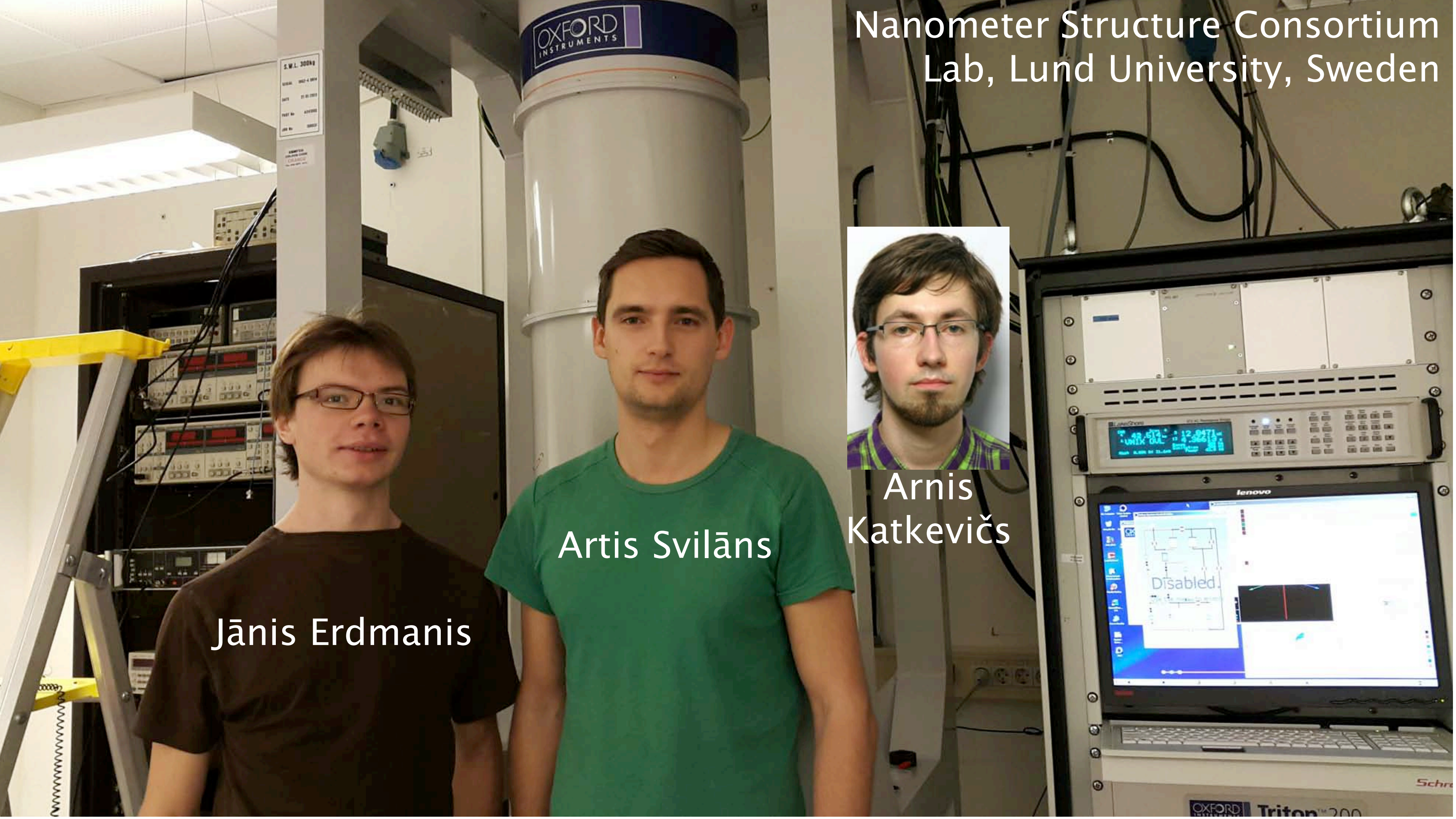
vai



Filtra caurlaidība

Secinājumi

- Demonstrēta augstas precizitātes atsevišķu elektronu “balistiskā stūrēšana”
- Elektronu kvantu optikā “staru dalītājs” ir nelineārs elements
- Novērotā “skaldīšanas statistikas” anomālija ir pretrunā ar līdz šīm zināmām teorijām
- Nākamais solis – kvantu interference nanoshēmā atsevišķu elektronu līmenī!



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Nelīdzsvara kvantu statistika elektroniskajās nanoierīcēs

LZP