revealing pairing patterns in 1D Fermi gases through shot noise correlations

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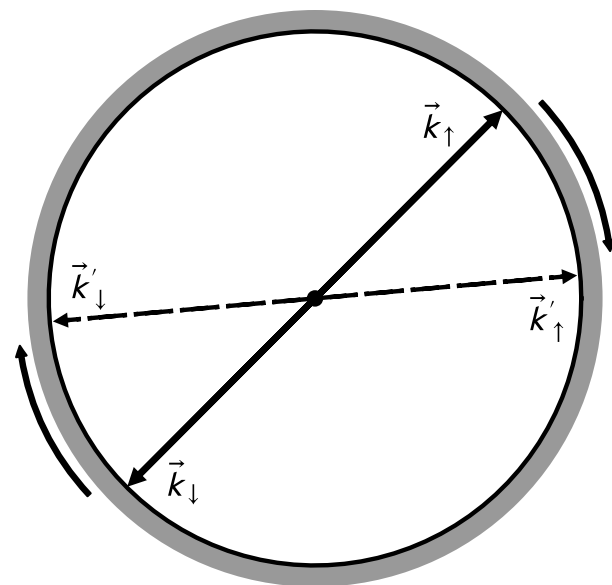735. WE-Heraeus-Seminar, December 15, 2020
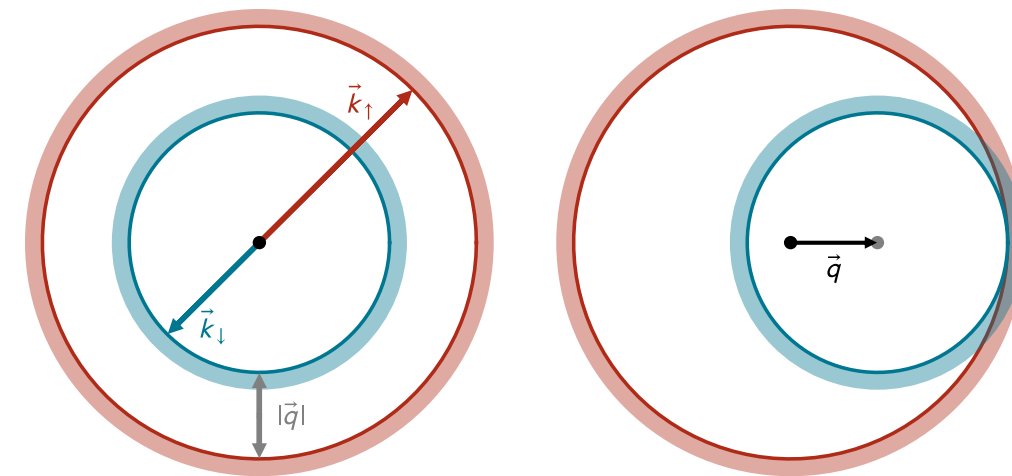
nothing will be placed here

pairing in a nutshell

$$\hat{H} = -\sum_{s=\uparrow,\downarrow} \int \mathrm{d}x \; \hat{\psi}_s^\dagger(\vec{x}) \left(\frac{\hbar^2 \vec{\nabla}^2}{2m_s} \right) \hat{\psi}_s(\vec{x}) \quad + \quad g \int \mathrm{d}x \; \hat{\psi}_\uparrow^\dagger(\vec{x}) \, \hat{\psi}_\uparrow(\vec{x}) \, \hat{\psi}_\downarrow^\dagger(\vec{x}) \, \hat{\psi}_\downarrow(\vec{x})$$

spin-balanced

"conventional"
BCS type pairing

unequal spin populations

FFLO type pairing
[Fulde,Ferell '64,
Larkin,Ovchinnikov '64]
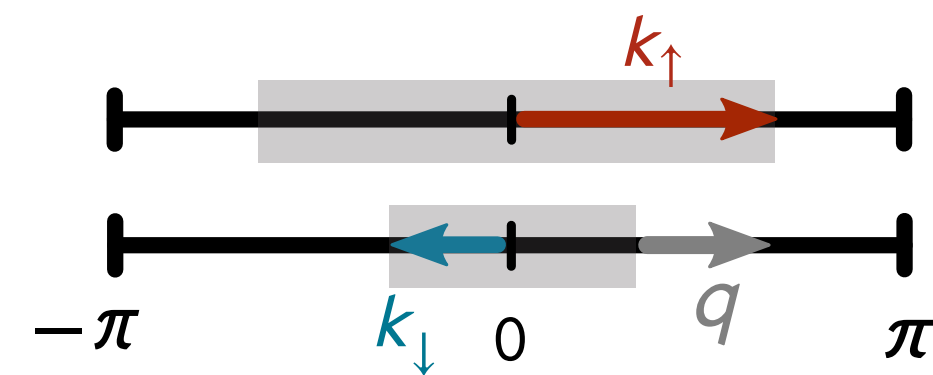
pairing in a nutshell

(attractive) contact interaction

$$\hat{H} = -\sum_{s=\uparrow,\downarrow} \int \mathrm{d}x \; \hat{\psi}_s^\dagger(\vec{x}) \left(\frac{\hbar^2 \vec{\nabla}^2}{2m_s} \right) \hat{\psi}_s(\vec{x}) \quad + \quad g \int \mathrm{d}x \; \hat{\psi}_\uparrow^\dagger(\vec{x}) \, \hat{\psi}_\uparrow(\vec{x}) \, \hat{\psi}_\downarrow^\dagger(\vec{x}) \, \hat{\psi}_\downarrow(\vec{x})$$

spin-balanced

unequal spin populations

"conventional" BCS type pairing

FFLO type pairing

[Fulde,Ferell '64, Larkin,Ovchinnikov '64]

$k_\uparrow$

$k_\downarrow$

$-\pi$ 0 π

$k_\uparrow$

$k_\downarrow$ q

$-\pi$ 0 π

first step: pair momentum distribution

[LR, Drut, Braun '20]

$$p = (N_\uparrow - N_\downarrow)/(N_\uparrow + N_\downarrow)$$
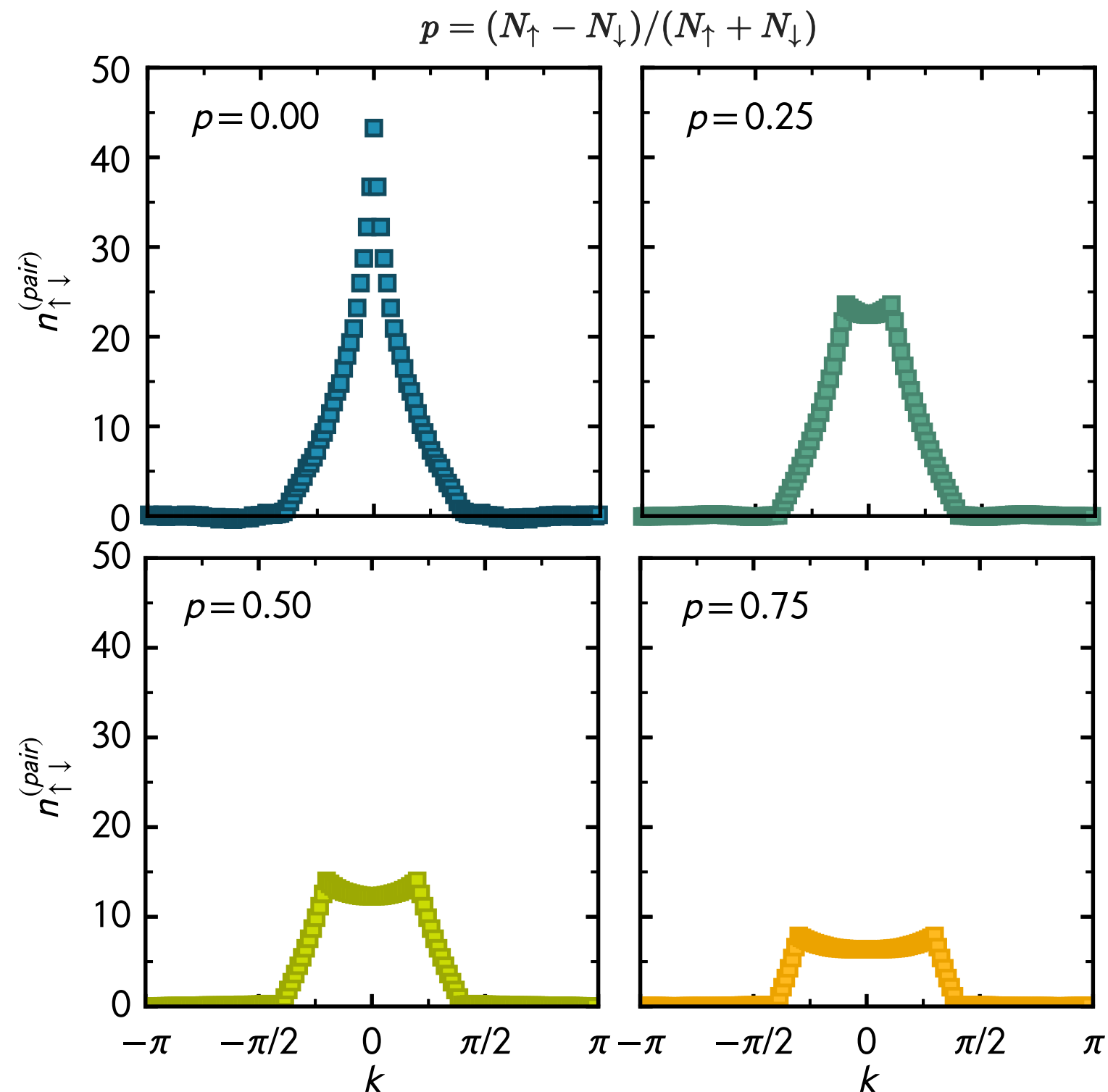
$$n_{\uparrow\downarrow}(k) = \int \mathrm{d}p\,\mathrm{d}q\, \langle \hat{\psi}^\dagger_{-p-k,\uparrow}\, \hat{\psi}^\dagger_{p,\downarrow}\, \hat{\psi}_{k-q,\downarrow}\, \hat{\psi}_{q,\uparrow} \rangle$$

~ likelihood to find a pair with momentum k
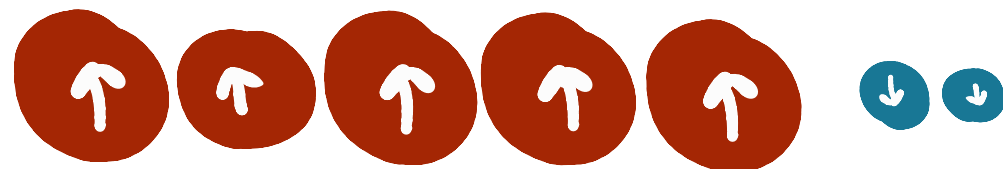
off-center peak:
hallmark of **FFLO type pairing**
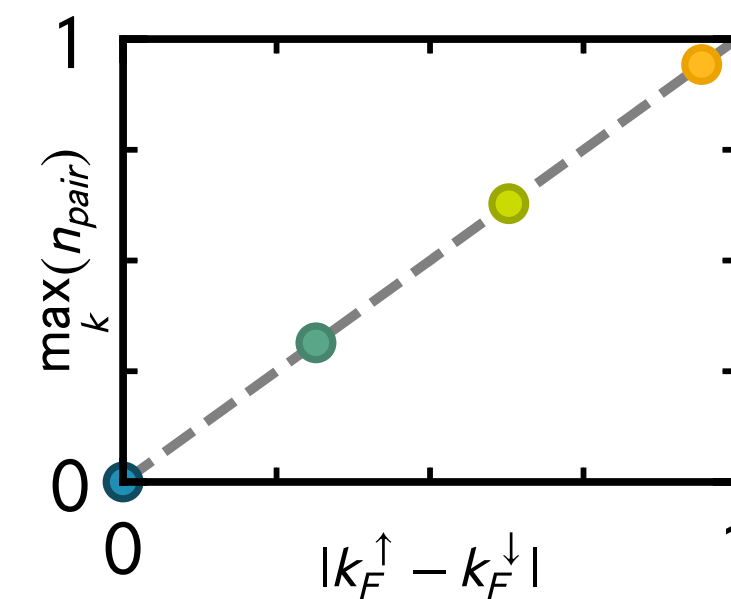
numerical results obtained with complex Langevin method (statistical error ≲ symbol size)
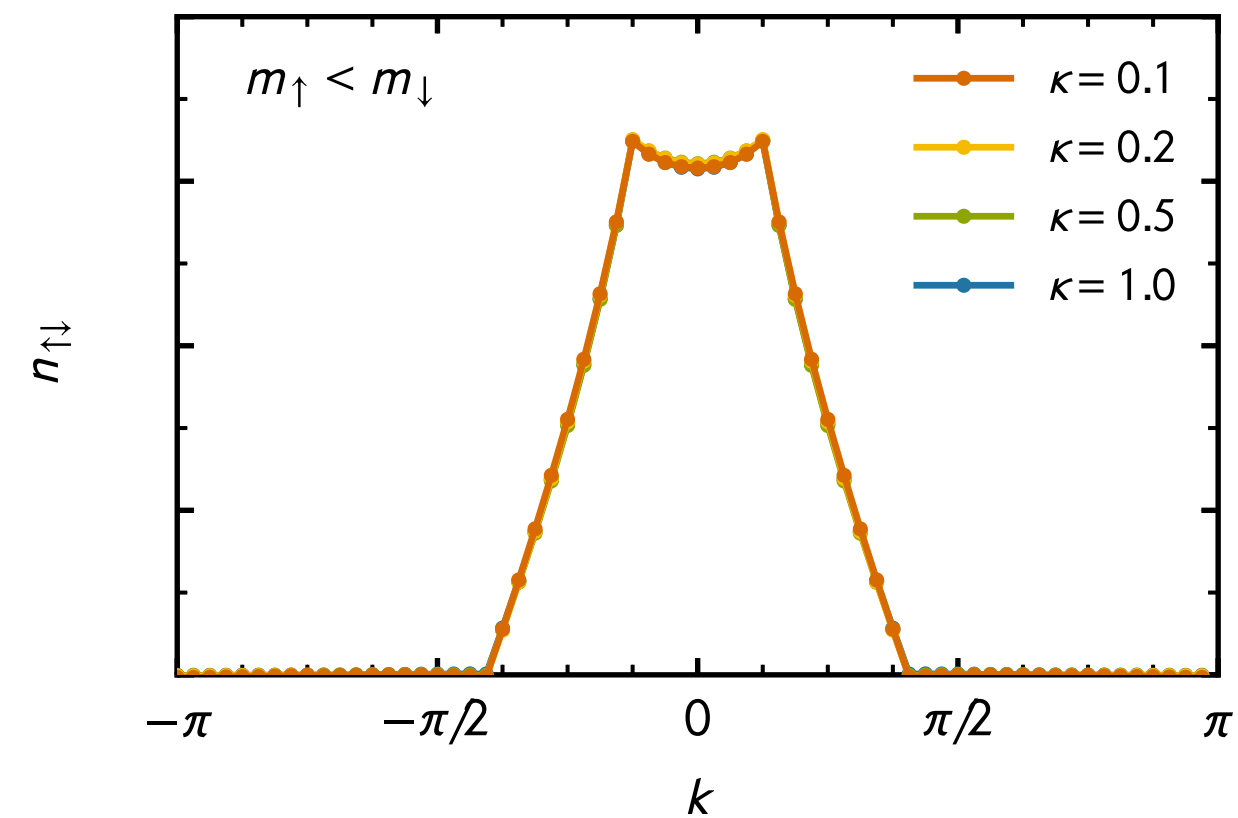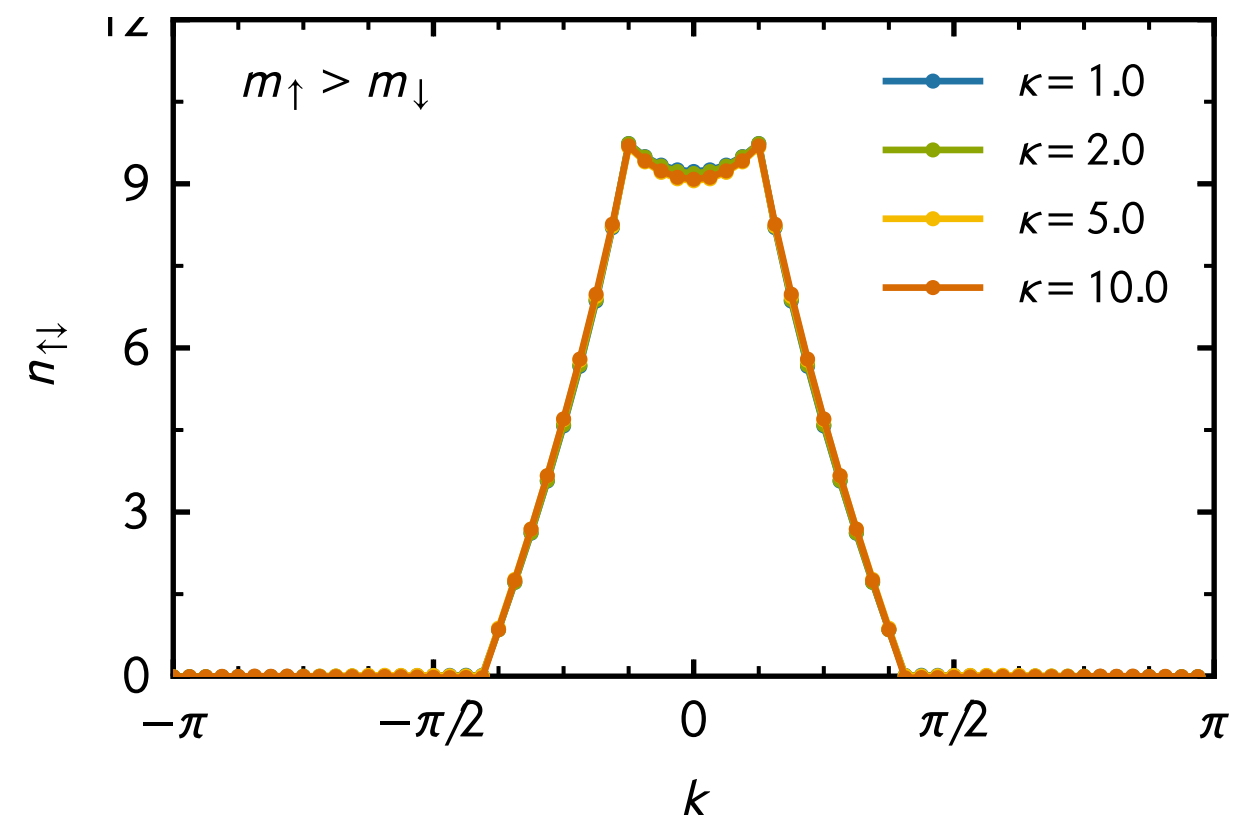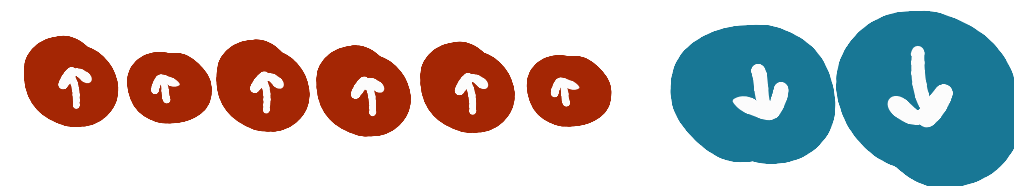
mass-imbalanced systems

heavy majority

heavy minority

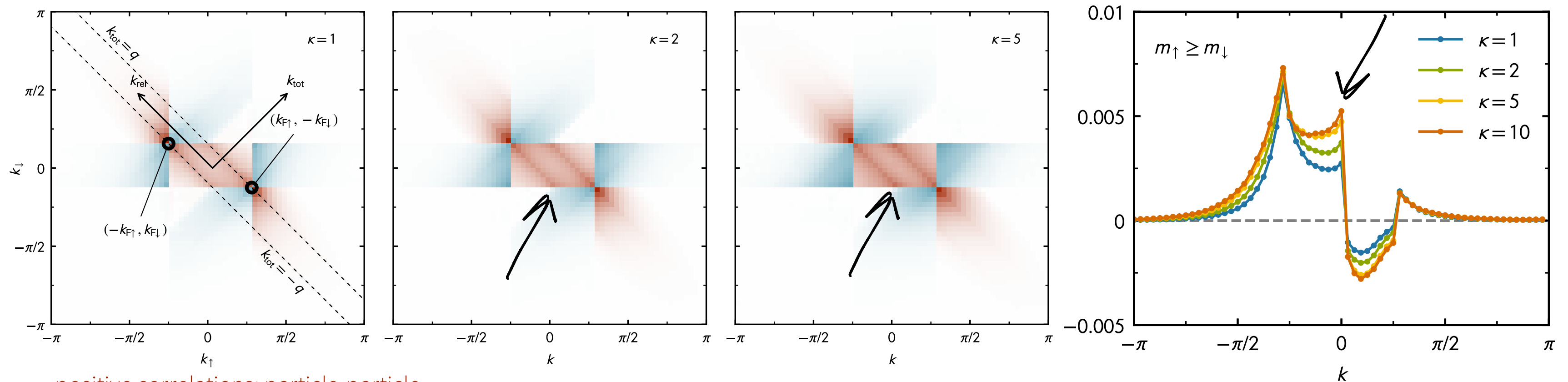$$\kappa = \frac{m_\uparrow}{m_\downarrow}$$

almost no change up to relatively large mass ratios

better: density-density correlation (shot noise)

[LR, Drut, Braun '20]

$$G_{\uparrow\downarrow}(k, k') = \langle \delta\hat{n}_{k\uparrow} \delta\hat{n}_{k'\downarrow} \rangle = \langle \hat{n}_{k\uparrow} \hat{n}_{k'\downarrow} \rangle - \langle \hat{n}_{k\uparrow} \rangle \langle \hat{n}_{k'\downarrow} \rangle$$

positive correlations: particle-particle

negative correlations: particle-hole

secondary peaks emerge with growing mass ratio

better: density-density correlation (shot noise)

[LR, Drut, Braun '20]

$$G_{\uparrow\downarrow}(k, k') = \langle \delta \hat{n}_{k\uparrow} \delta \hat{n}_{k'\downarrow} \rangle = \langle \hat{n}_{k\uparrow} \hat{n}_{k'\downarrow} \rangle - \langle \hat{n}_{k\uparrow} \rangle \langle \hat{n}_{k'\downarrow} \rangle$$

paring at the respective Fermi surfaces

heavy component scatters from deep below the Fermi surface