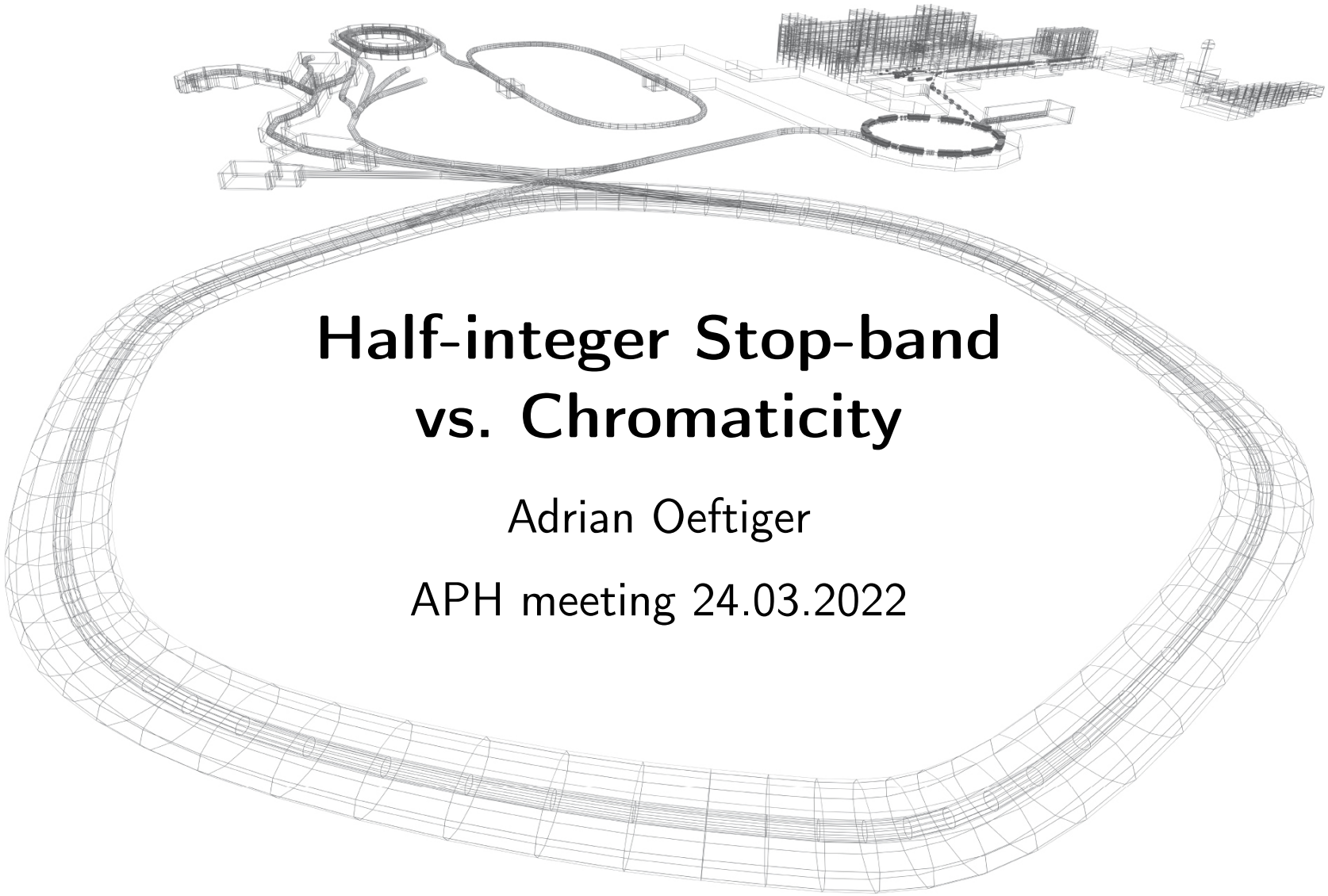


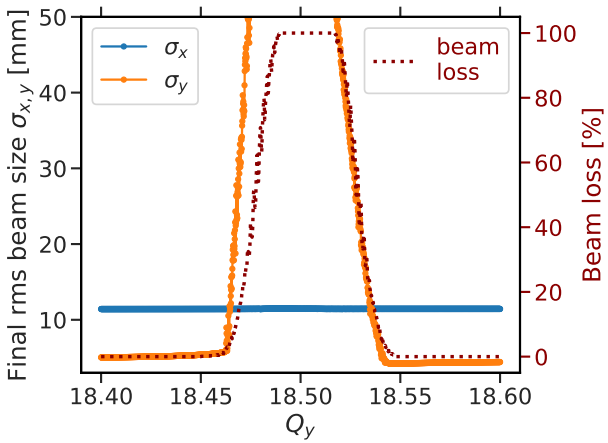
Half-integer Stop-band vs. Chromaticity

Adrian Oeftiger

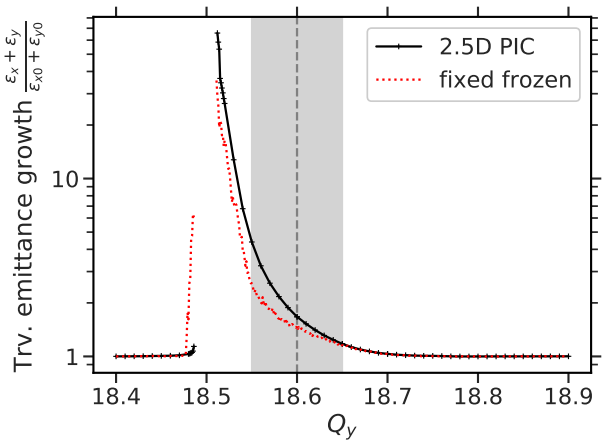
APH meeting 24.03.2022

Context

- SIS100 lattice has 2 radiation-hard warm quadrupoles
  $\Longrightarrow$ breaking symmetry of cold lattice, beta-beat
- this gradient error leads to finite extent of half-integer stop-band
- consider integral strength $k_2 L$ of warm quads = cold quads
- stop-band as in SIS100 beam loss paper:



(a) no space charge



(b) full space charge (SC), max. $\Delta Q_y^{SC} = -0.3$

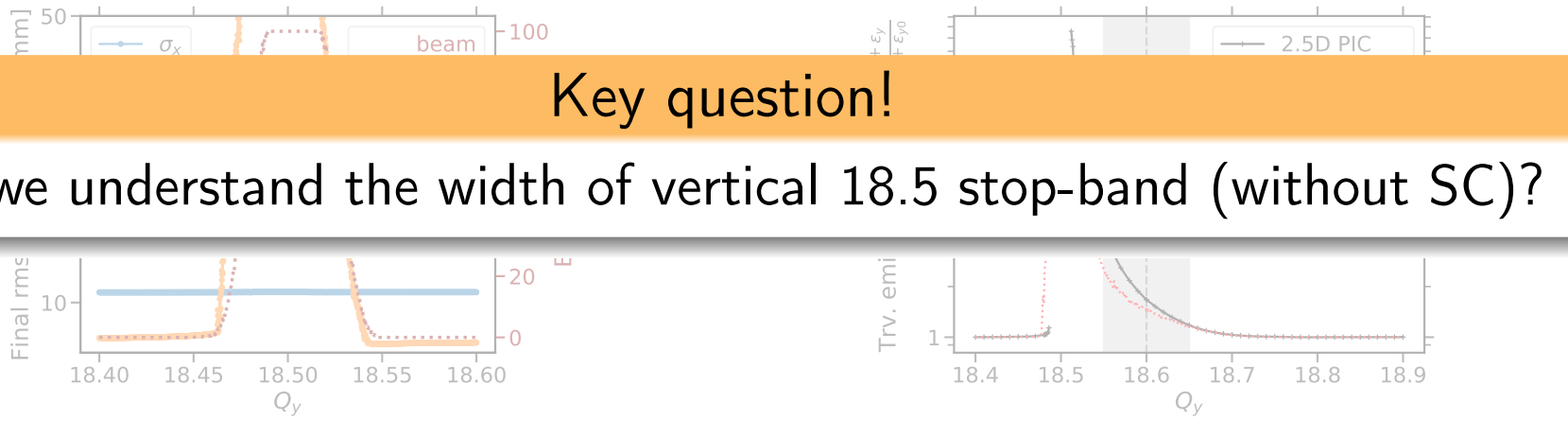
Figure: bunched beam around half-integer in warm SIS100 lattice

Context

- SIS100 lattice has 2 radiation-hard warm quadrupoles
  $\Longrightarrow$ breaking symmetry of cold lattice, beta-beat
- this gradient error leads to finite extent of half-integer stop-band
- consider integral strength $k_2 L$ of warm quads = cold quads
- stop-band as in SIS100 beam loss paper:

Key question!

Do we understand the width of vertical 18.5 stop-band (without SC)?



(a) no space charge

(b) full space charge (SC), max. $\Delta Q_y^{SC} = -0.3$

Figure: bunched beam around half-integer in warm SIS100 lattice

Computation

Relevant half-integer stop-band integral:

$$F_{37,y} = \int_0^C ds\, \beta_y(s)\, \Delta k(s) \exp\left(-i\, 37\, \frac{2\pi \mu_y(s)}{Q_{y0}}\right)$$

gives analytical stop-band width of $\Delta Q_{1/2} = |F_{37,y}| = 0.023$.

Simulated stop-band width for full bunch is much larger, $\Delta Q_{1/2,bunch} = 0.08$:

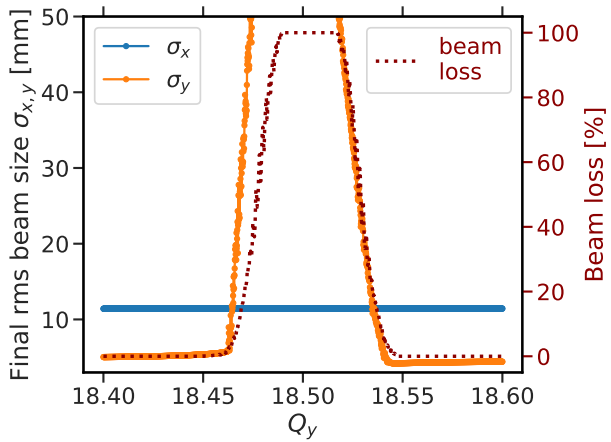
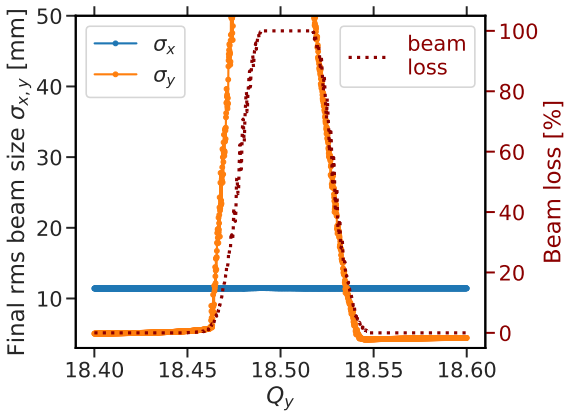


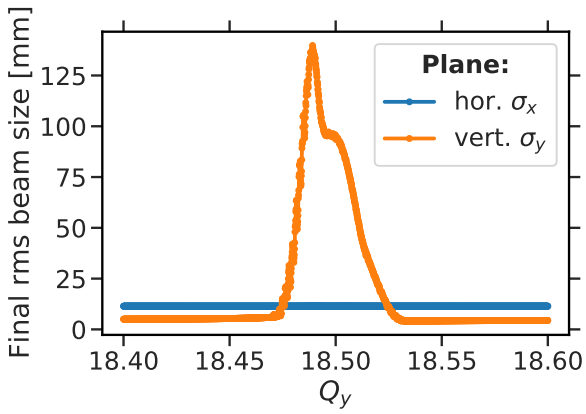
Figure: simulated half-integer stop-band, bunched beam

Chromaticity

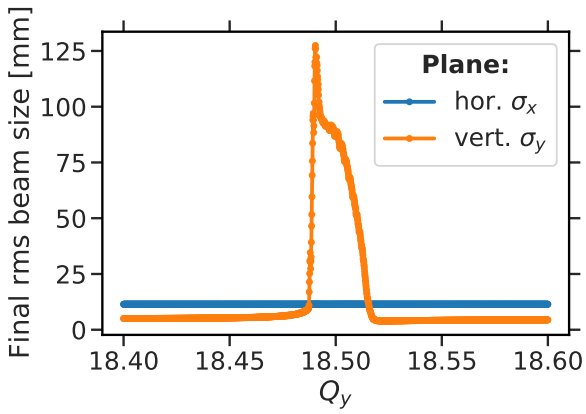
Key ingredient: chromaticity! ($Q'_y = -22.5$ and $\sigma_{\Delta p/p_0} = 0.5 \times 10^{-3}$)



(a) full momentum spread



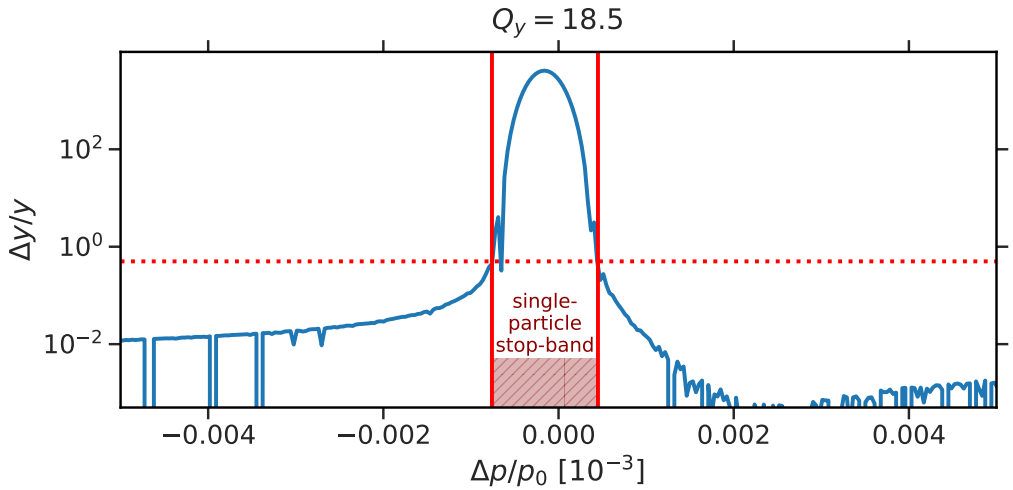
(b) half momentum spread



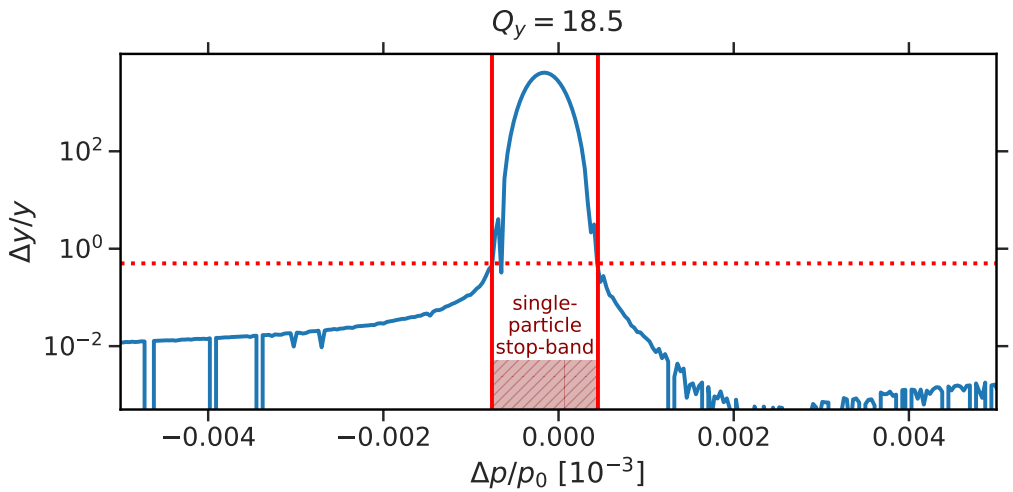
(c) 10% momentum spread

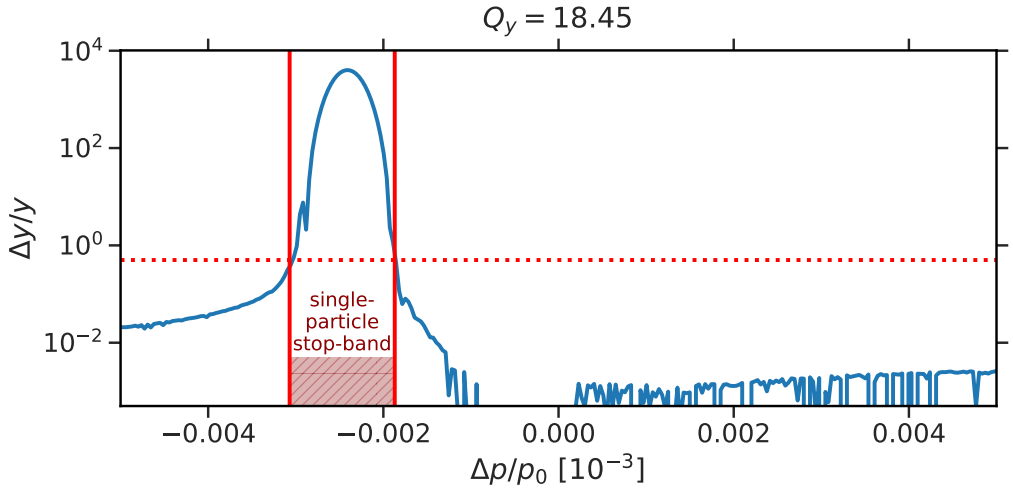
$\Longrightarrow$ at vanishing $\sigma_{\Delta p/p_0} \to 0$, simulated stop-band width matches analytical expectation of $\Delta Q_{1/2} = 0.023$

Single-particle vs. $\Delta p/p_0$

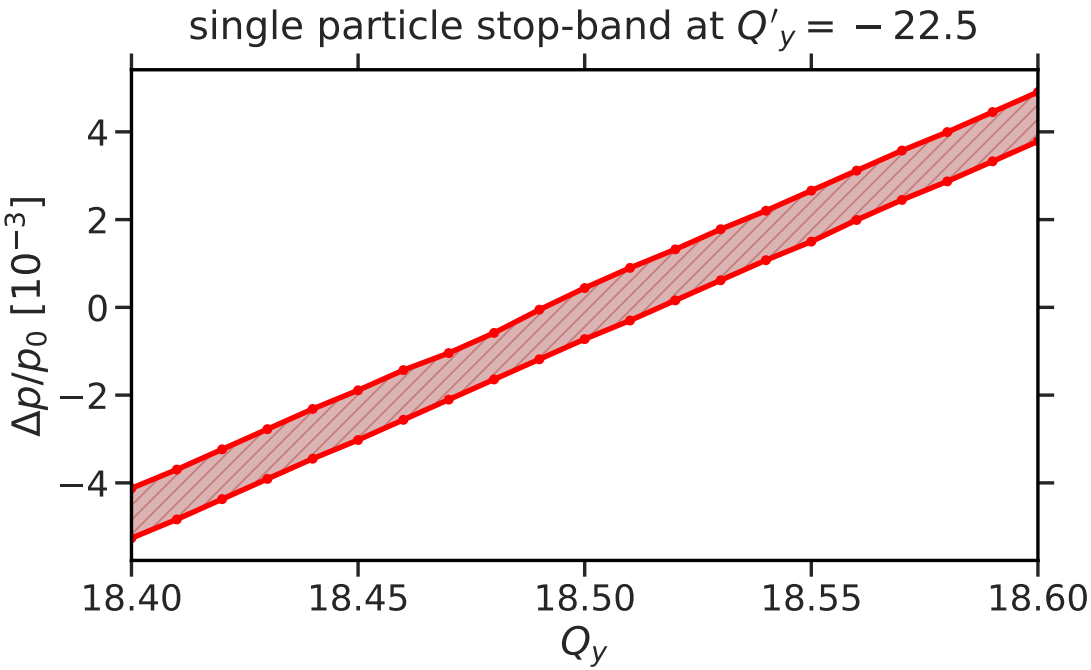


Single-particle vs. $\Delta p/p_0$

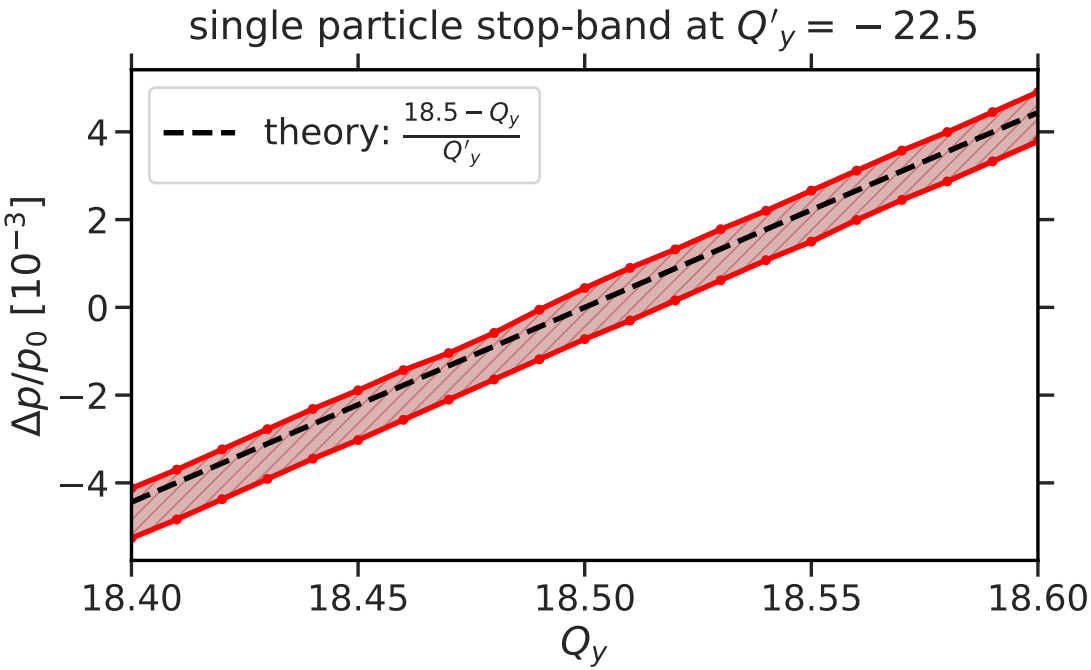




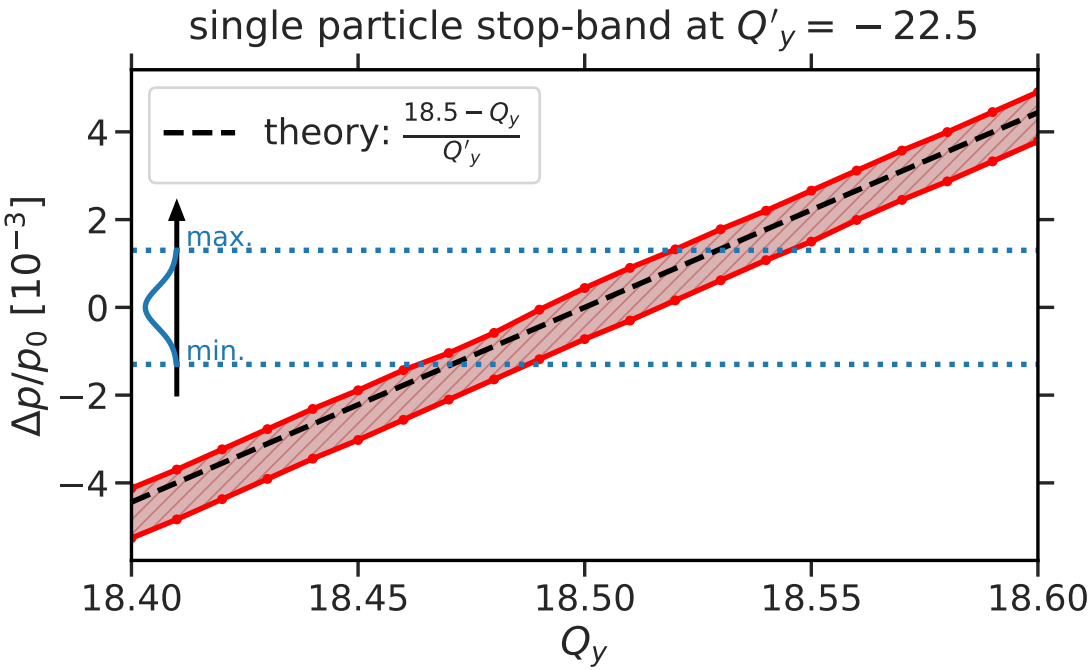
Conclusion


single particle stop-band at $Q'_y = -22.5$
$\Delta p/p_0$ [10^{-3}]
4
2
0
−2
−4
18.40
18.45
18.50
18.55
18.60
Q_y

Conclusion


single particle stop-band at $Q'_y = -22.5$
theory: $\frac{18.5 - Q_y}{Q'_y}$
$\Delta p/p_0$ [10^{-3}]
4
2
0
−2
−4
18.40
18.45
18.50
18.55
18.60
Q_y

Conclusion


single particle stop-band at $Q'_y = -22.5$
theory: $\frac{18.5 - Q_y}{Q'_y}$
max.
min.
$\Delta p/p_0$ [10^{-3}]
4
2
0
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18.40
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18.50
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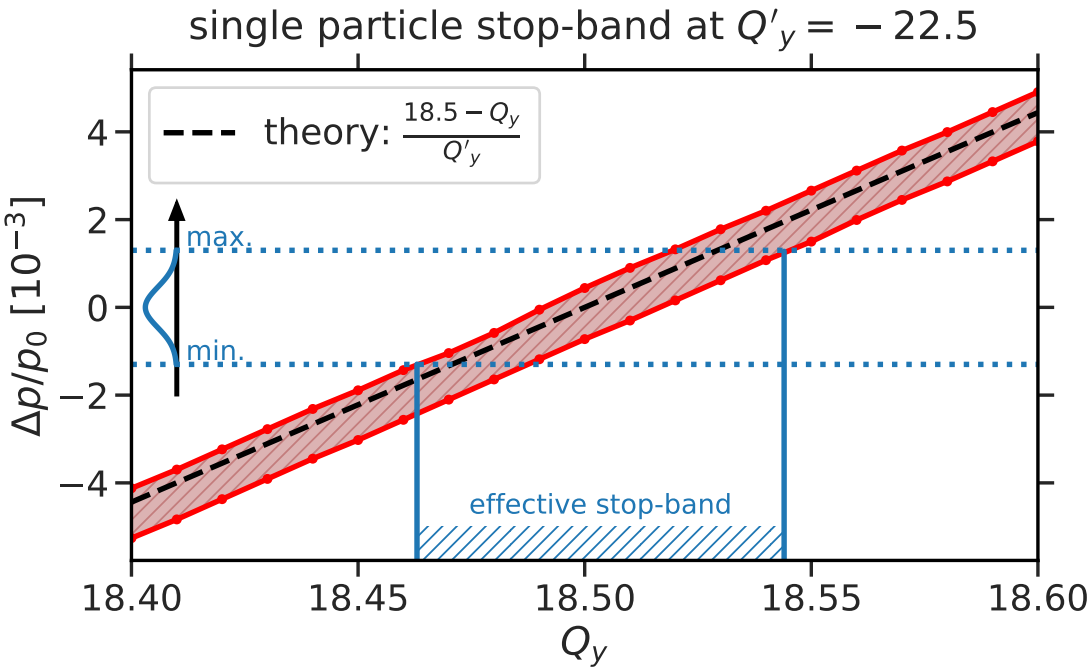
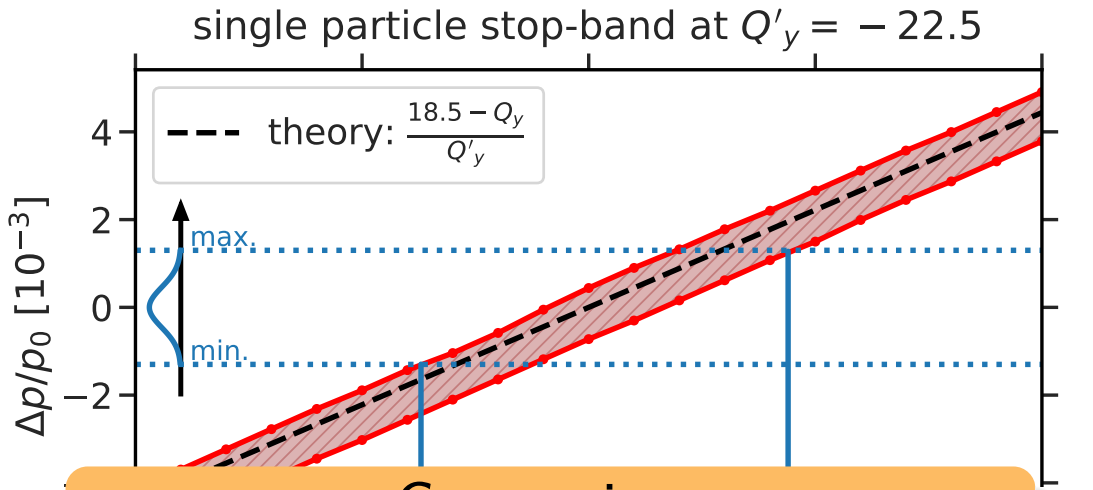
18.60
Q_y

Conclusion


single particle stop-band at $Q'_y = -22.5$
theory: $\frac{18.5 - Q_y}{Q'_y}$
max.
min.
effective stop-band
$\Delta p/p_0$ [10^{-3}]
Q_y
4
2
0
−2
−4
18.40
18.45
18.50
18.55
18.60

Conclusion



Comparison