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When Do We Need Non-Quasi-static CMOS RF-Models?

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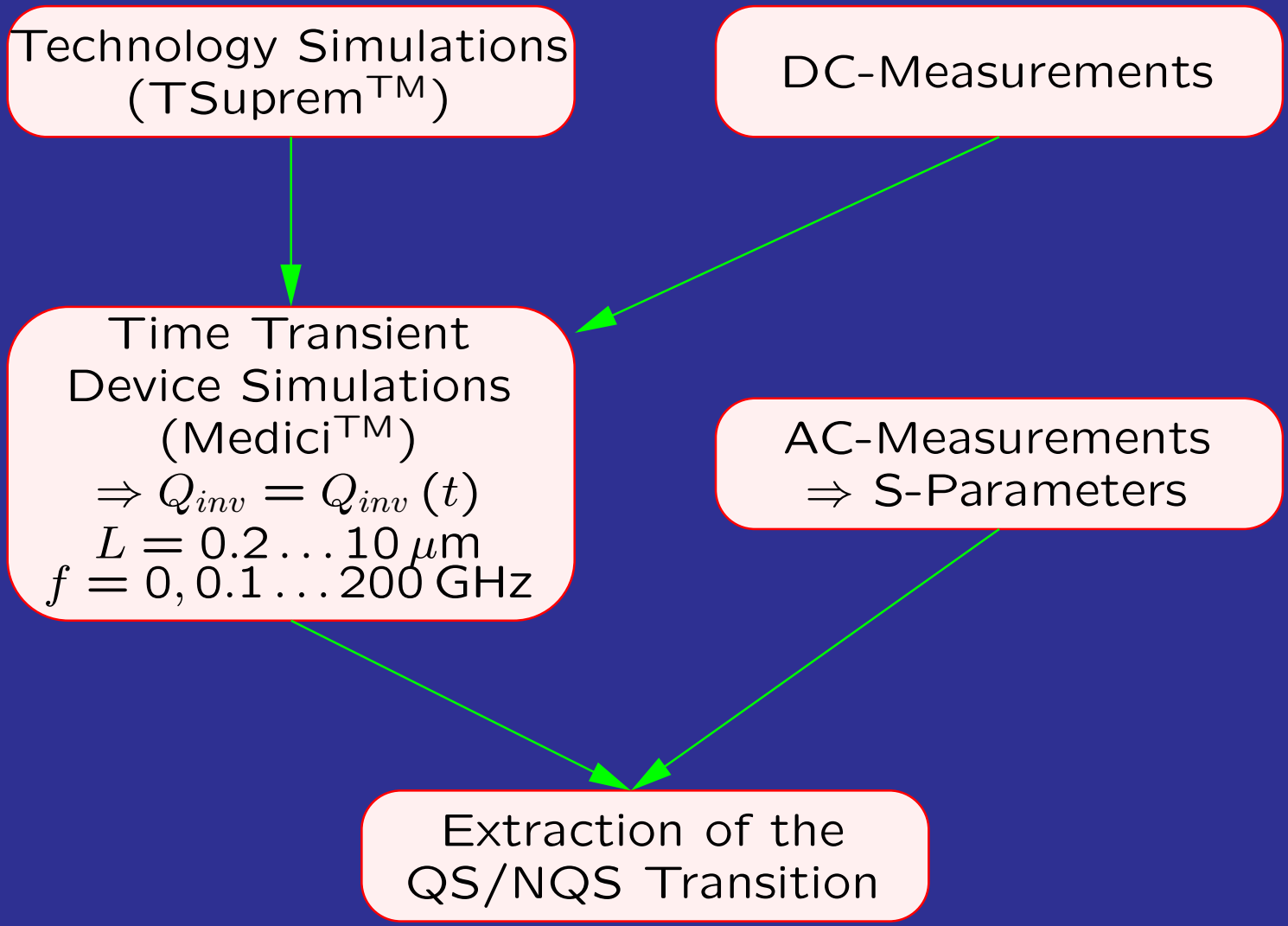
Session 19 — Modeling for RF Design

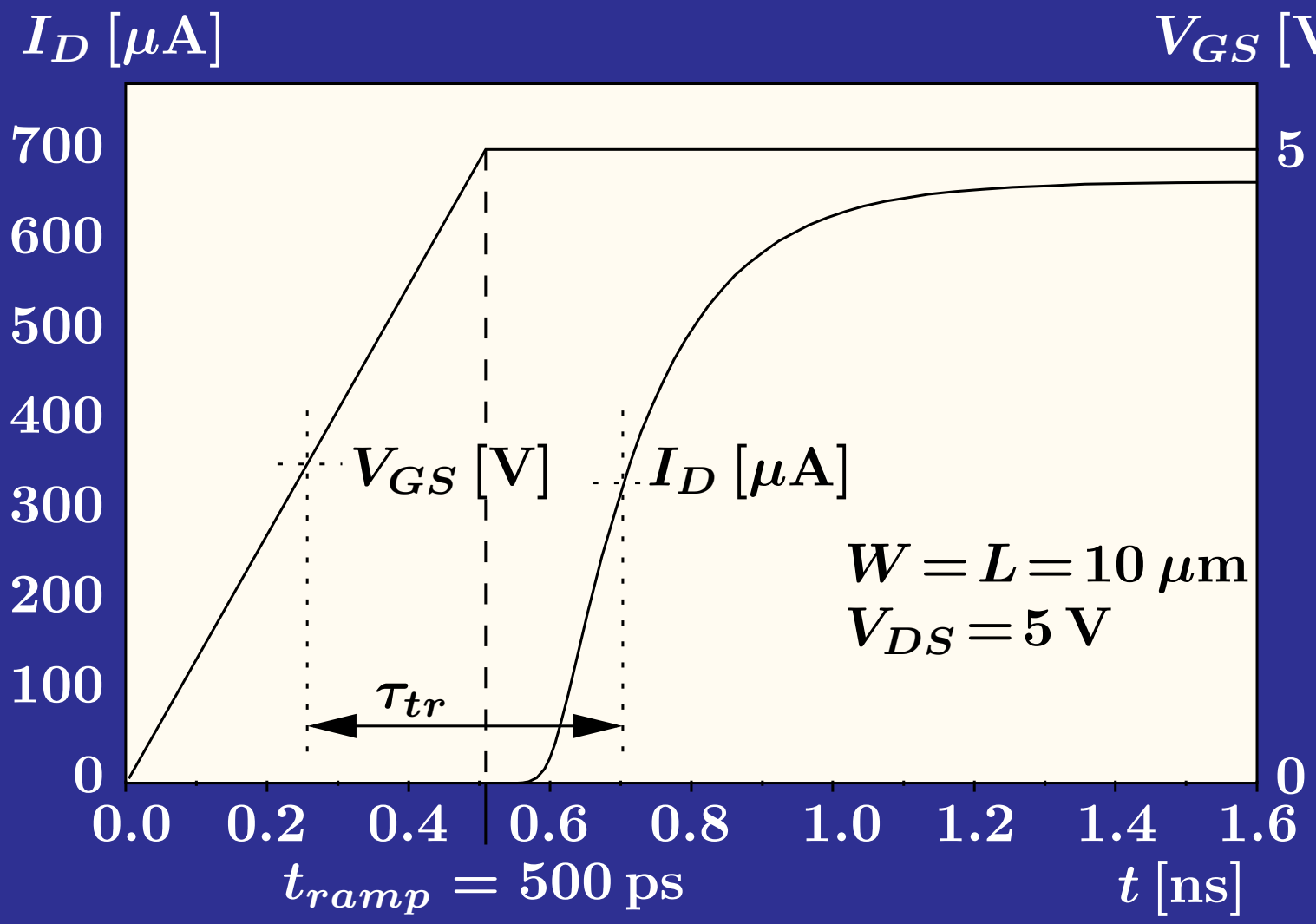
Motivation

- Increasing importance of non-quasistatic phenomena for the development of RF-models
- Only "rough indications" about the onset of NQS effects
- Frequency limits of validity [Tsividis, 1999, p. 492]
  - Simple models
    $\Rightarrow f_{NQS} \approx 10\,\% \cdot f_t$
  - Models with transcapacitors $(C_{dg} \neq C_{gd})$
    $\Rightarrow f_{NQS} \approx 33\,\% \cdot f_t$
- Investigations on a commercial process

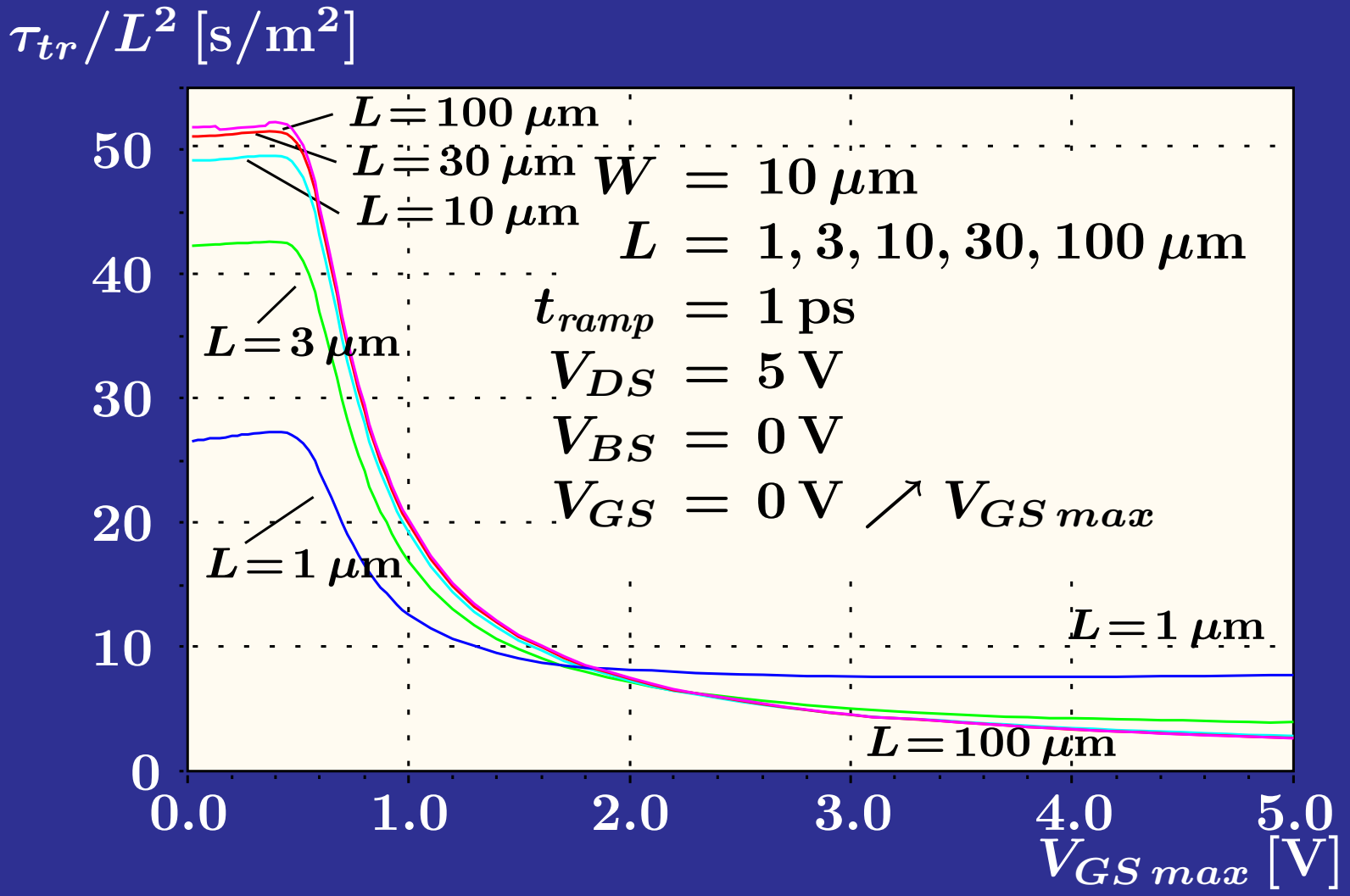
Proceeding of Investigation



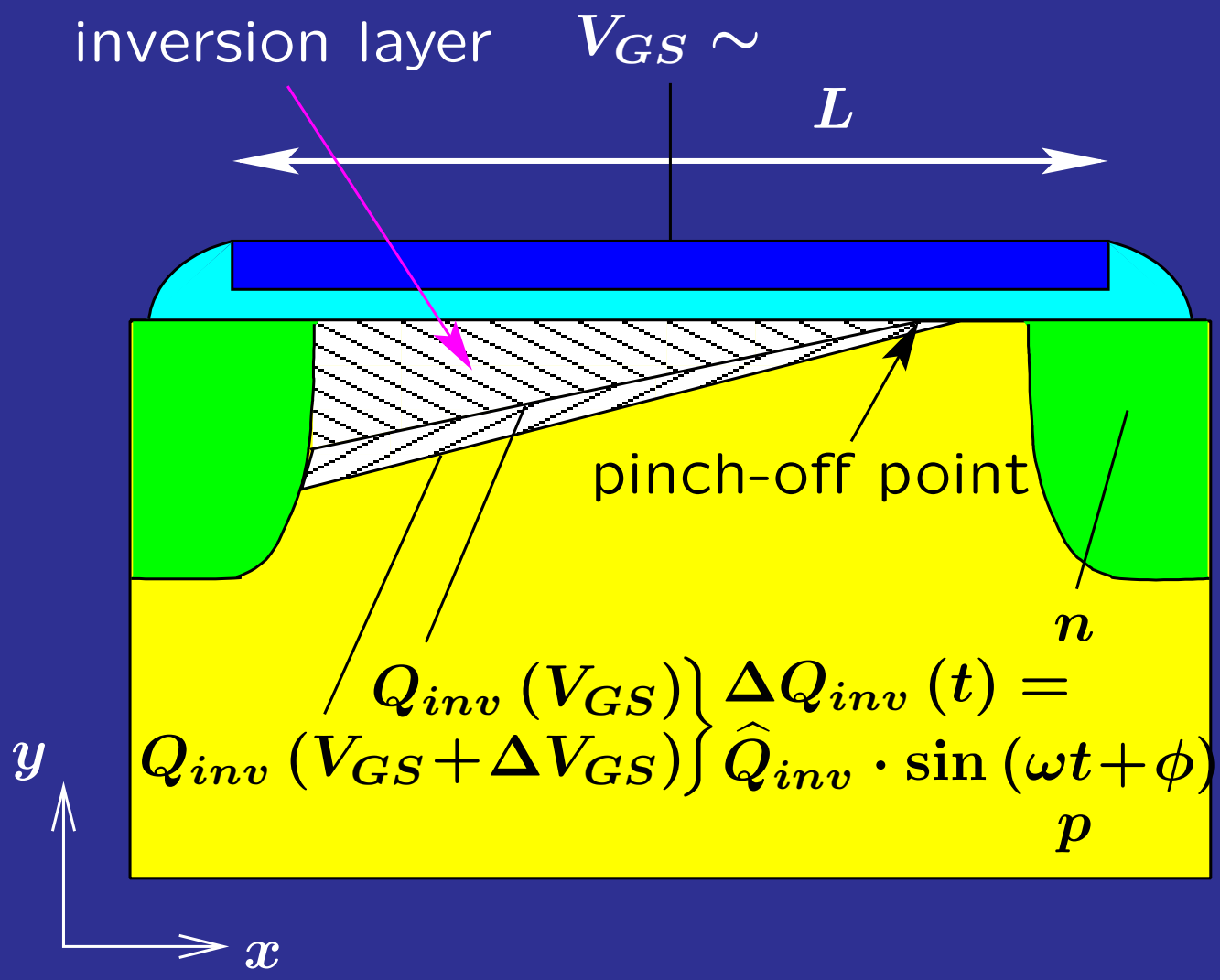
Usual Extraction of the Transit Time



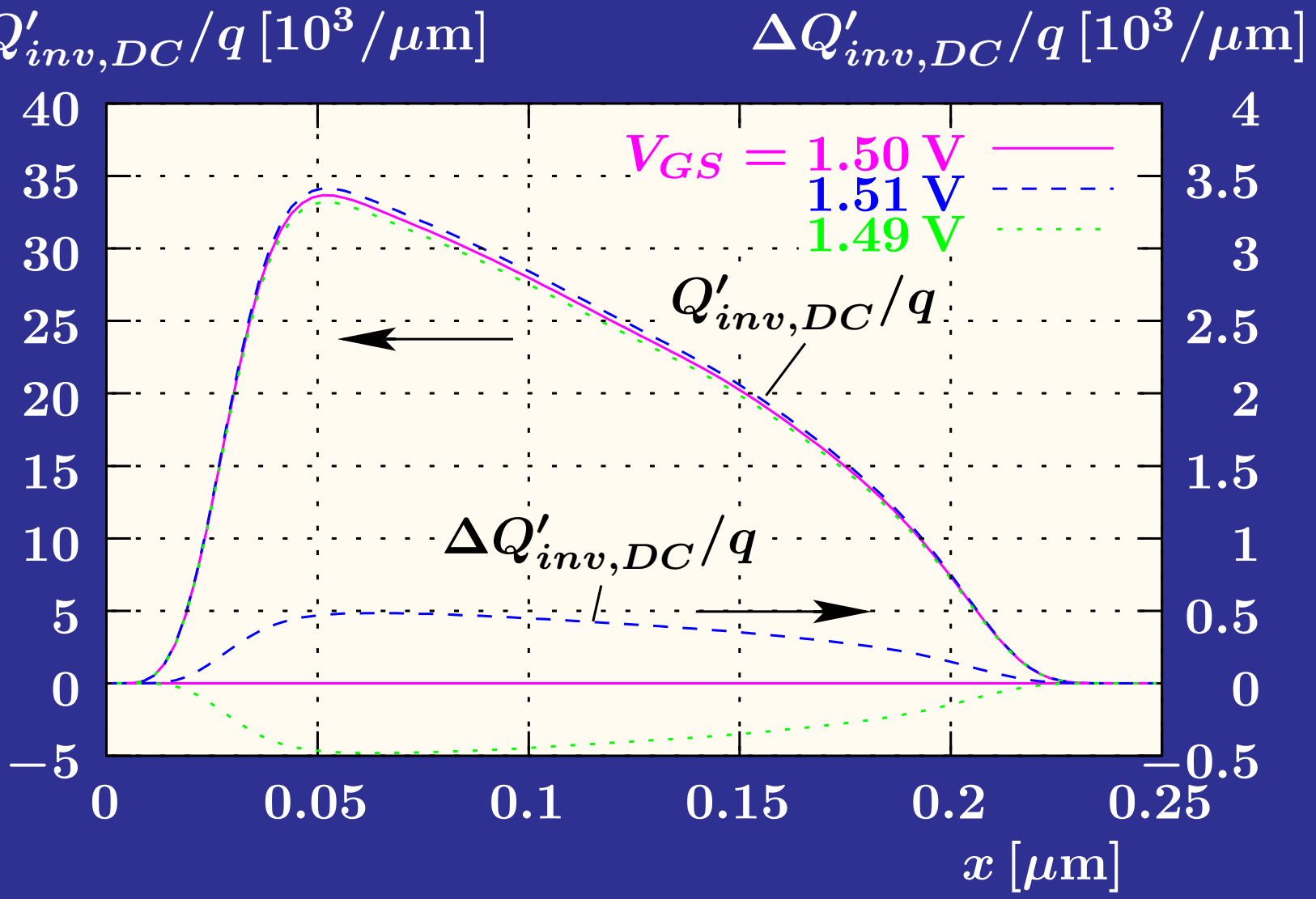
Transit Time



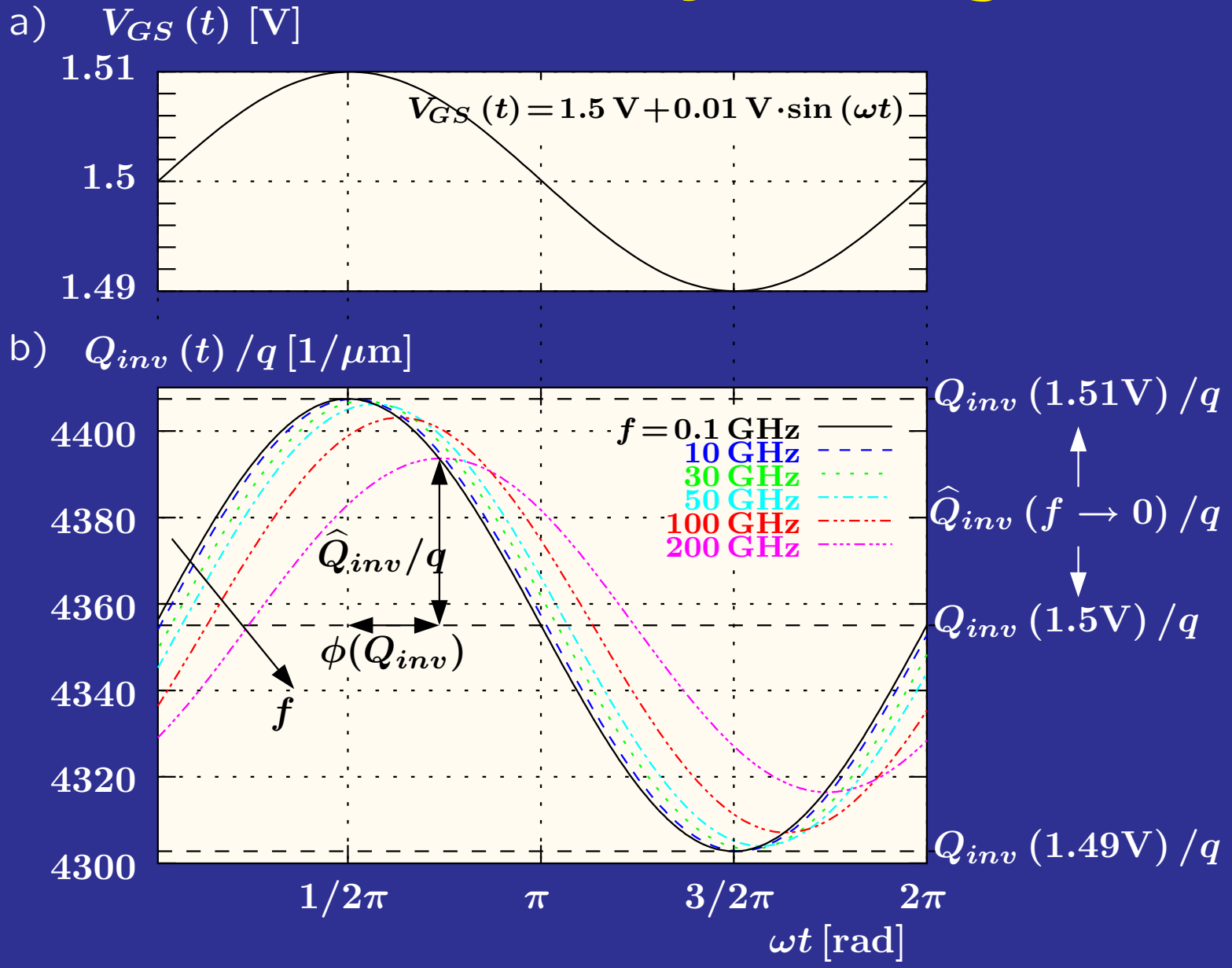
MOS Scheme


inversion layer
$V_{GS} \sim$
L
pinch-off point
n
$Q_{inv}(V_{GS})$
$Q_{inv}(V_{GS}+\Delta V_{GS})$
$\Delta Q_{inv}(t) =$
$\widehat{Q}_{inv} \cdot \sin(\omega t+\phi)$
p
y
x

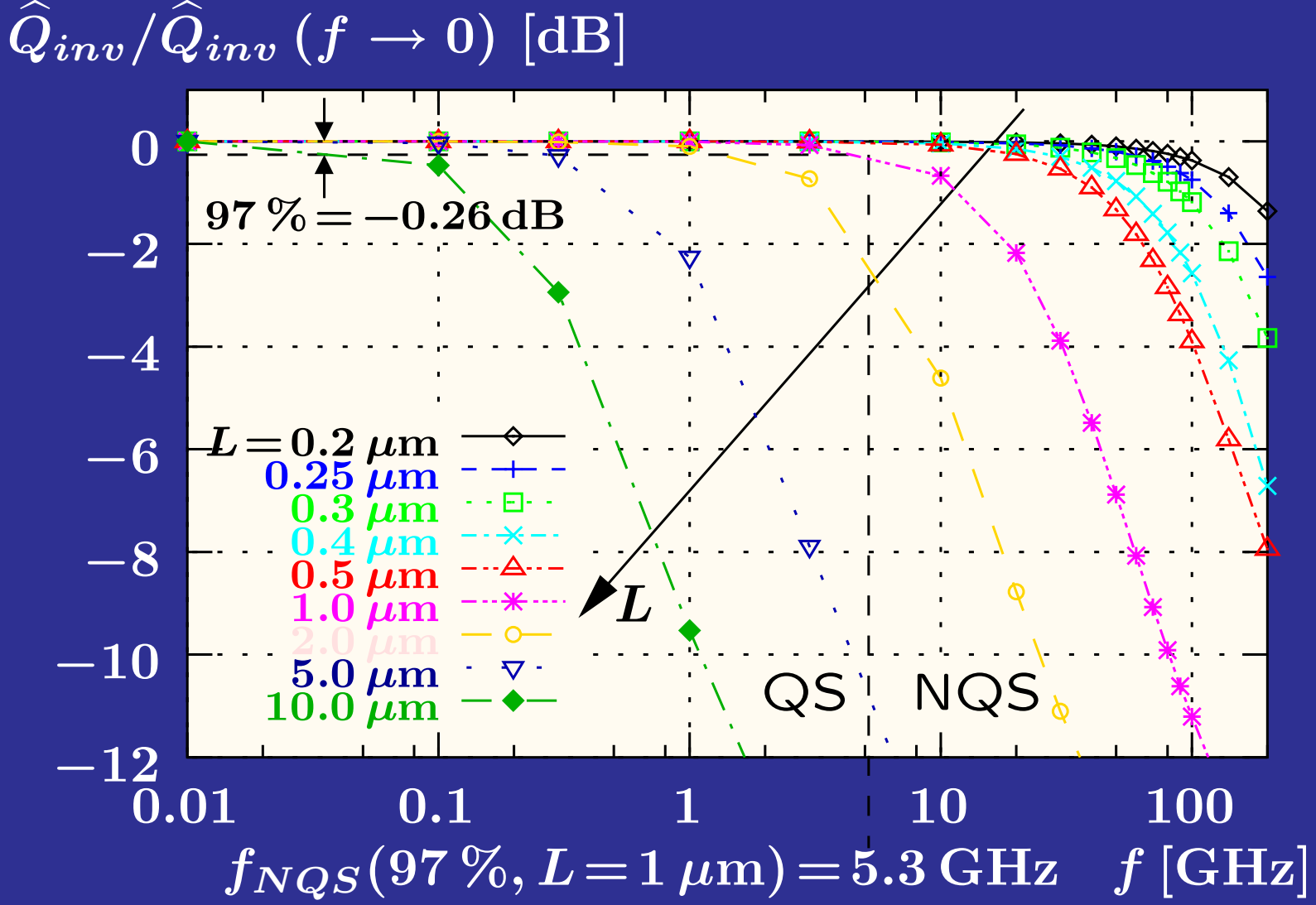
Local Inversion Layer Charge



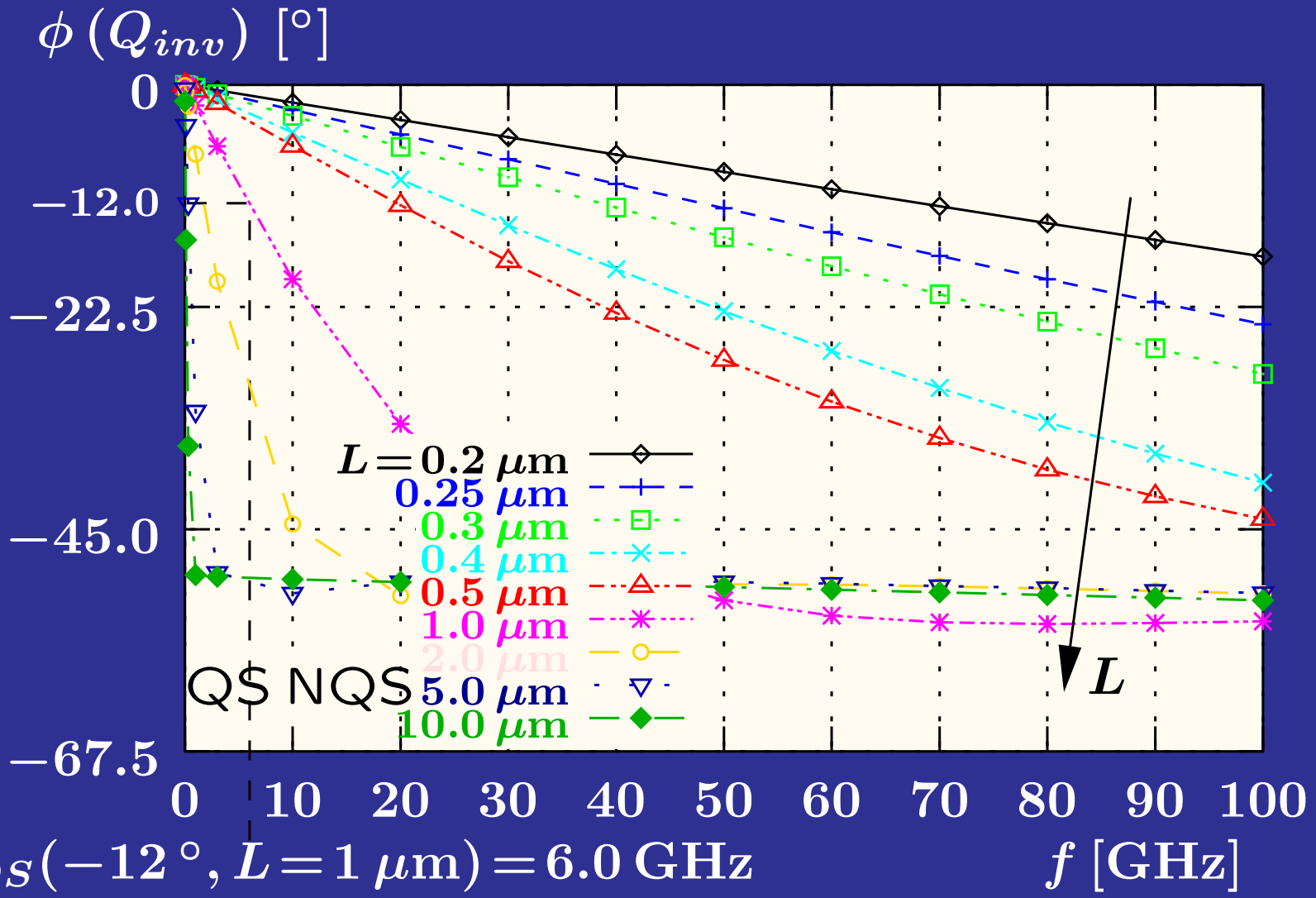
Inversion Layer Charge



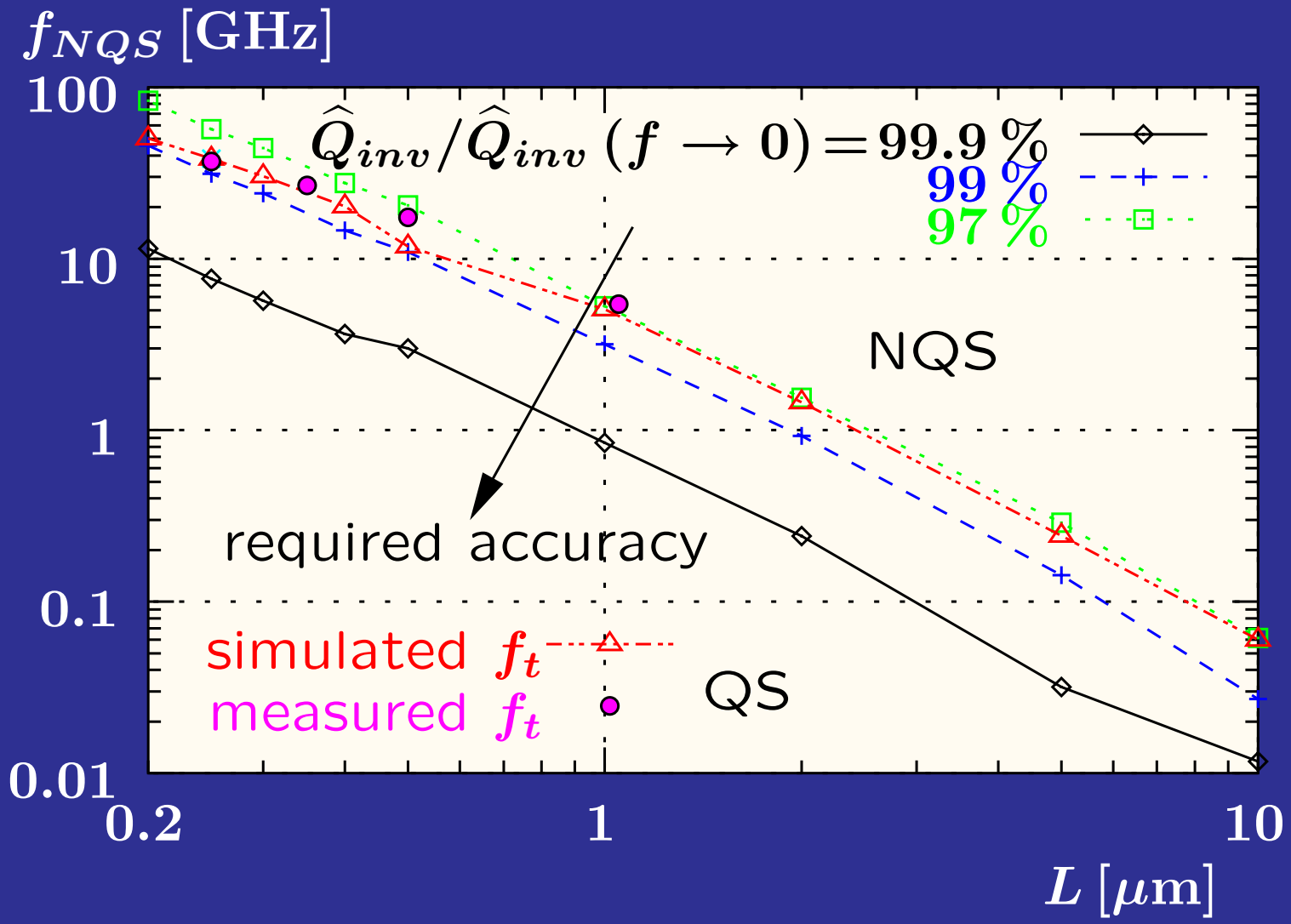
Normalized Inversion Layer Charge



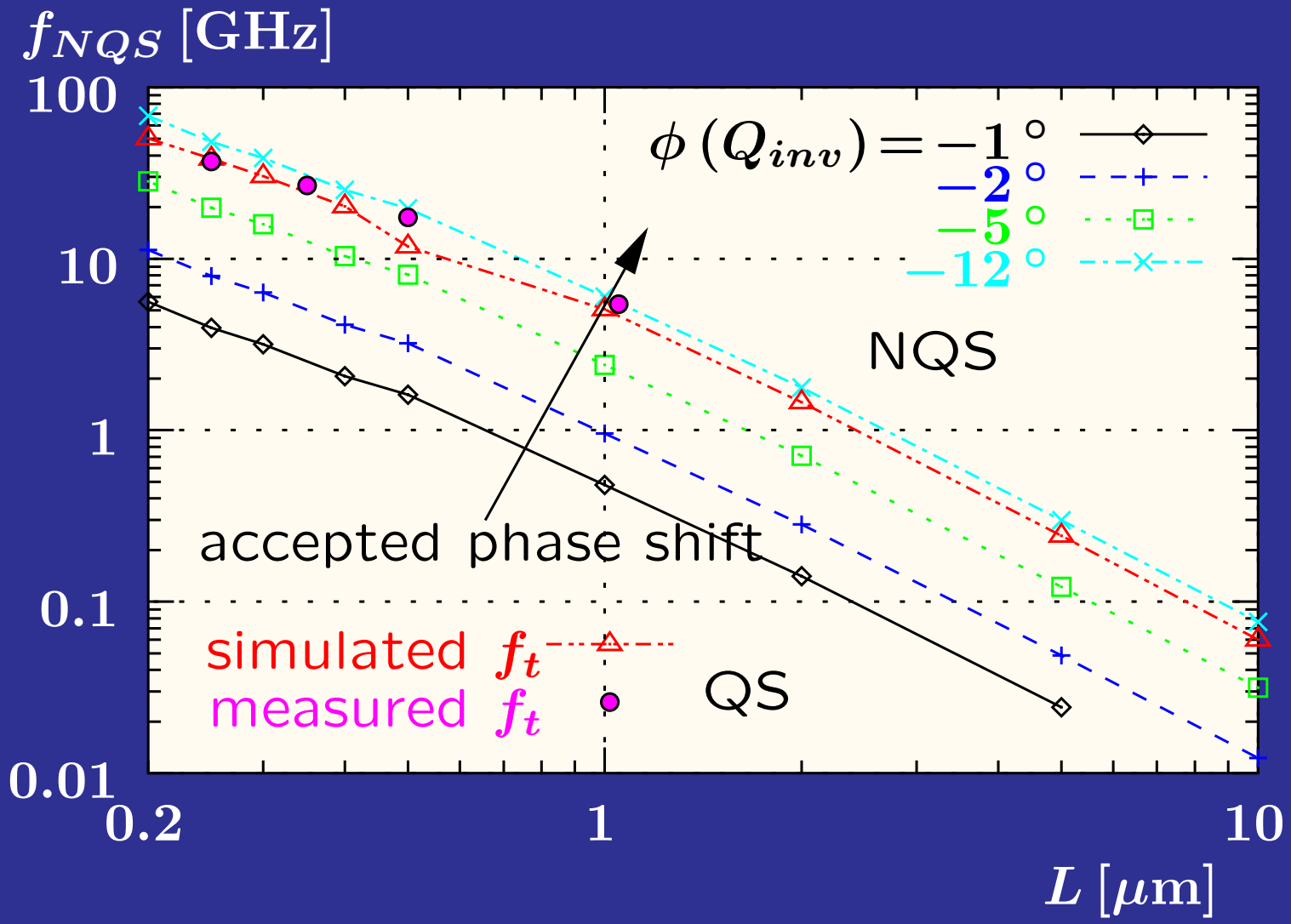
Phase of Inversion Layer Charge



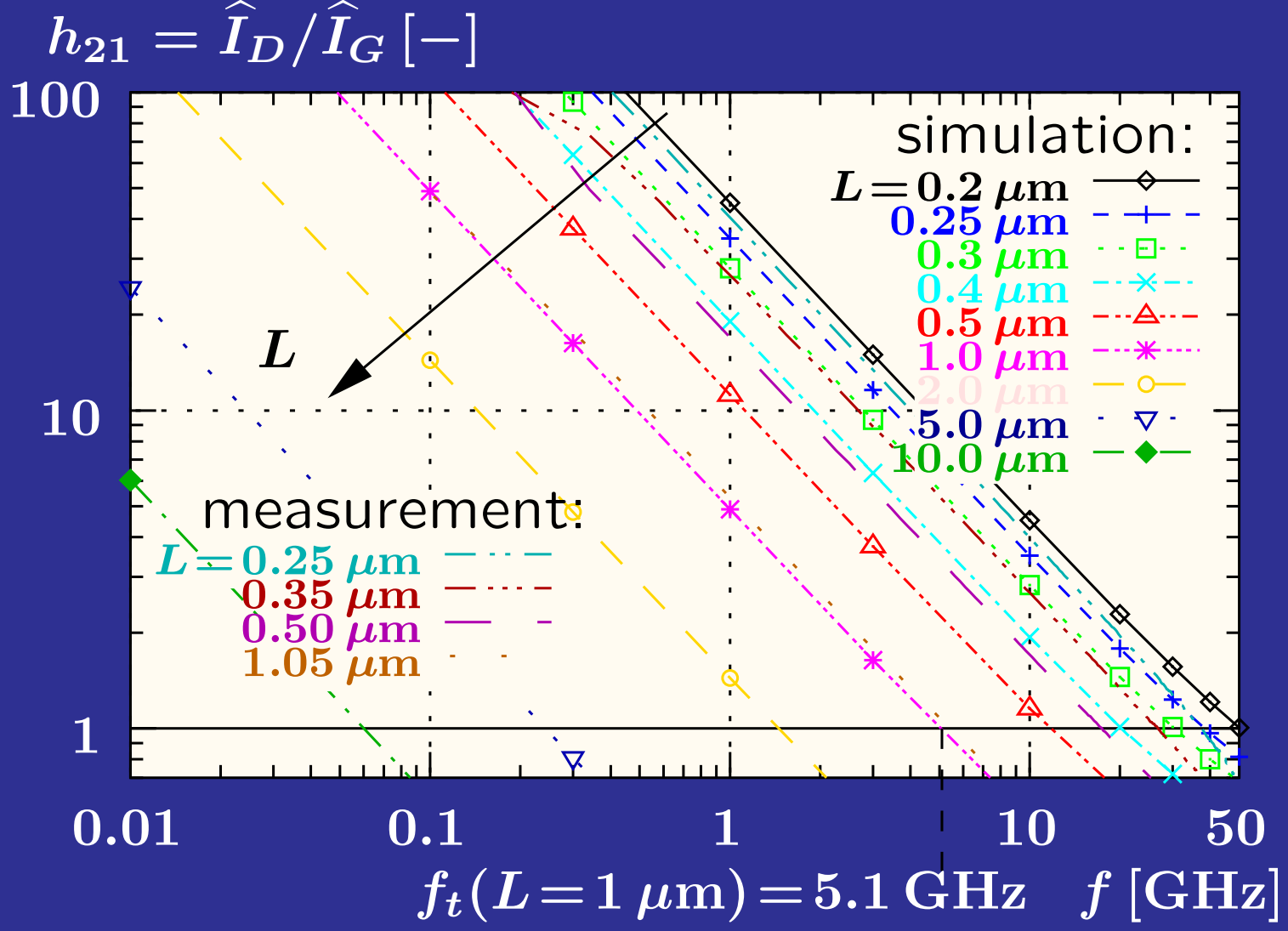
Frequency Limit Derived from Charge Amplitude



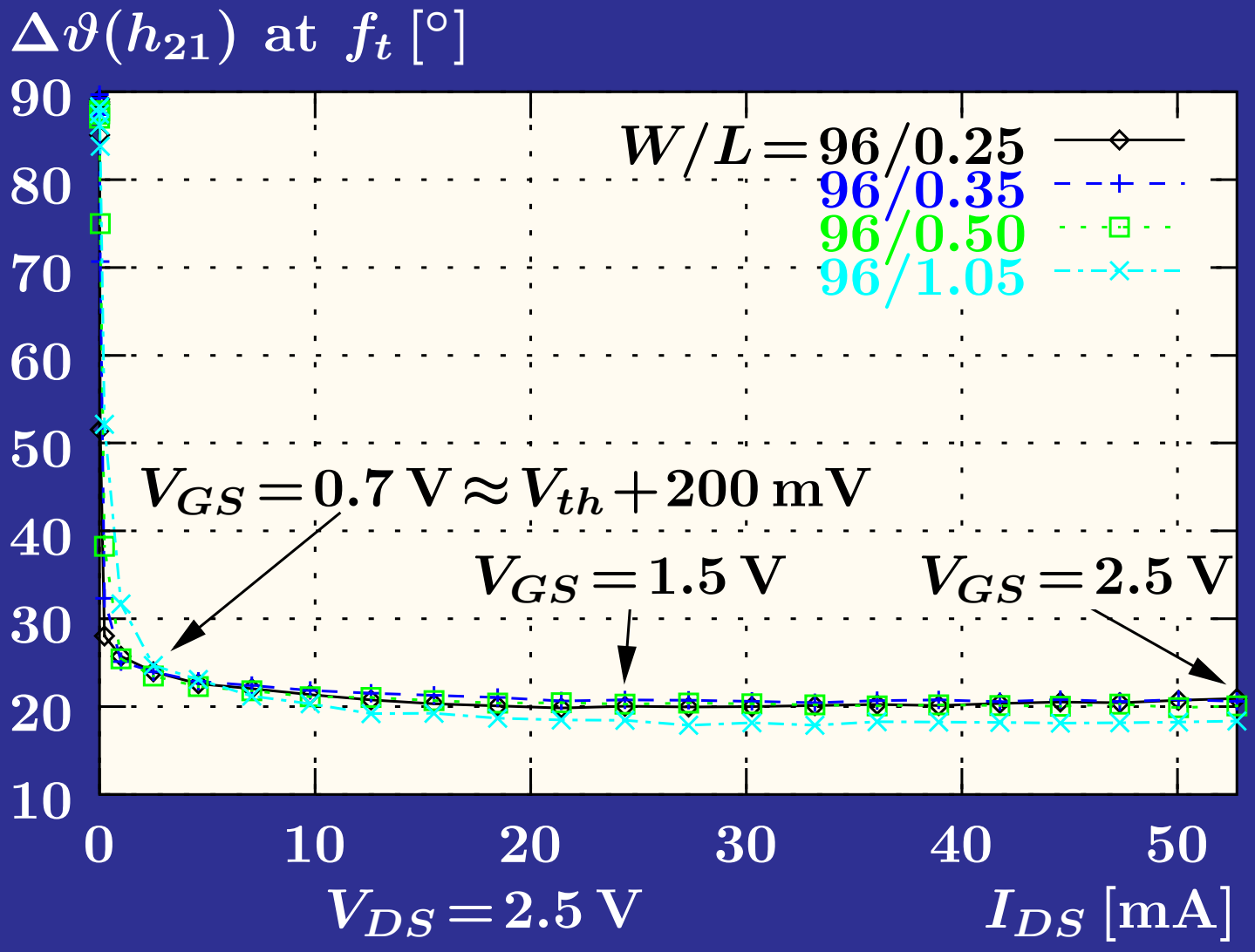
Frequency Limit Derived from Charge Phase



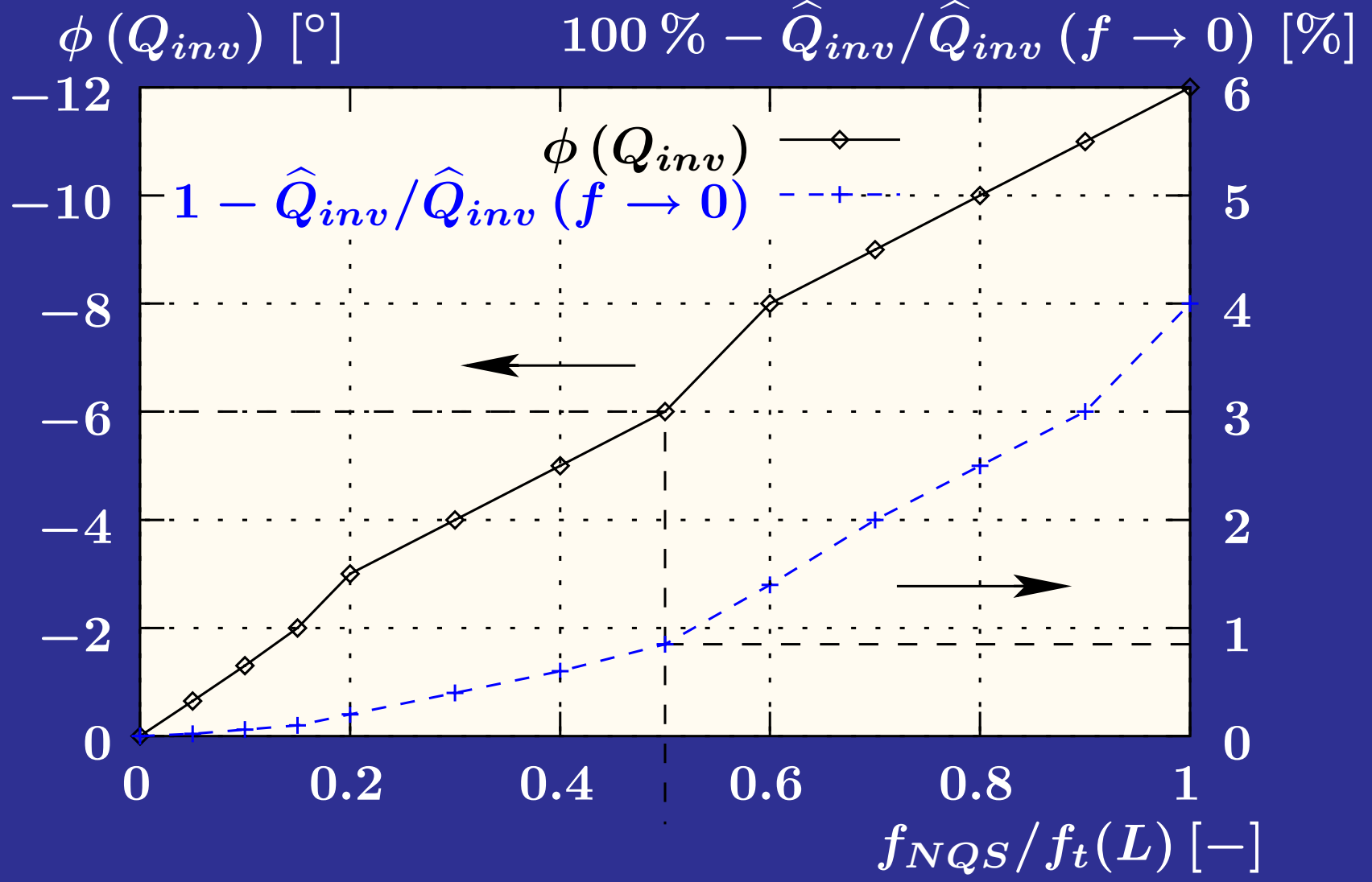
Extraction of the Transit Frequency



Current Gain at Transit Frequency



Trade-off between Accuracy and Frequency



Conclusion

- Increasing importance of RF-models
- Onset of NQS effects
  - applied frequency
  - gate length
  - required accuracy
  - (operation point)
- Commercial process with gate lengths from 0.2 to $10\,\mu\mathrm{m}$
  - $99\,\%$: QS for $10\,\mu\mathrm{m}$ up to $27\,\mathrm{MHz}$ and $0.2\,\mu\mathrm{m}$ up to $46\,\mathrm{GHz}$
  - $96\,\%$ and $-12\,^\circ$: QS for all gate lengths up to f_t