Theoretical insight on the roles of disorder heterogeneity in enhancing the maximum gradients

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Higher Q, frequency & field gradient

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- What are the effects of disorder on the maximum field gradient?
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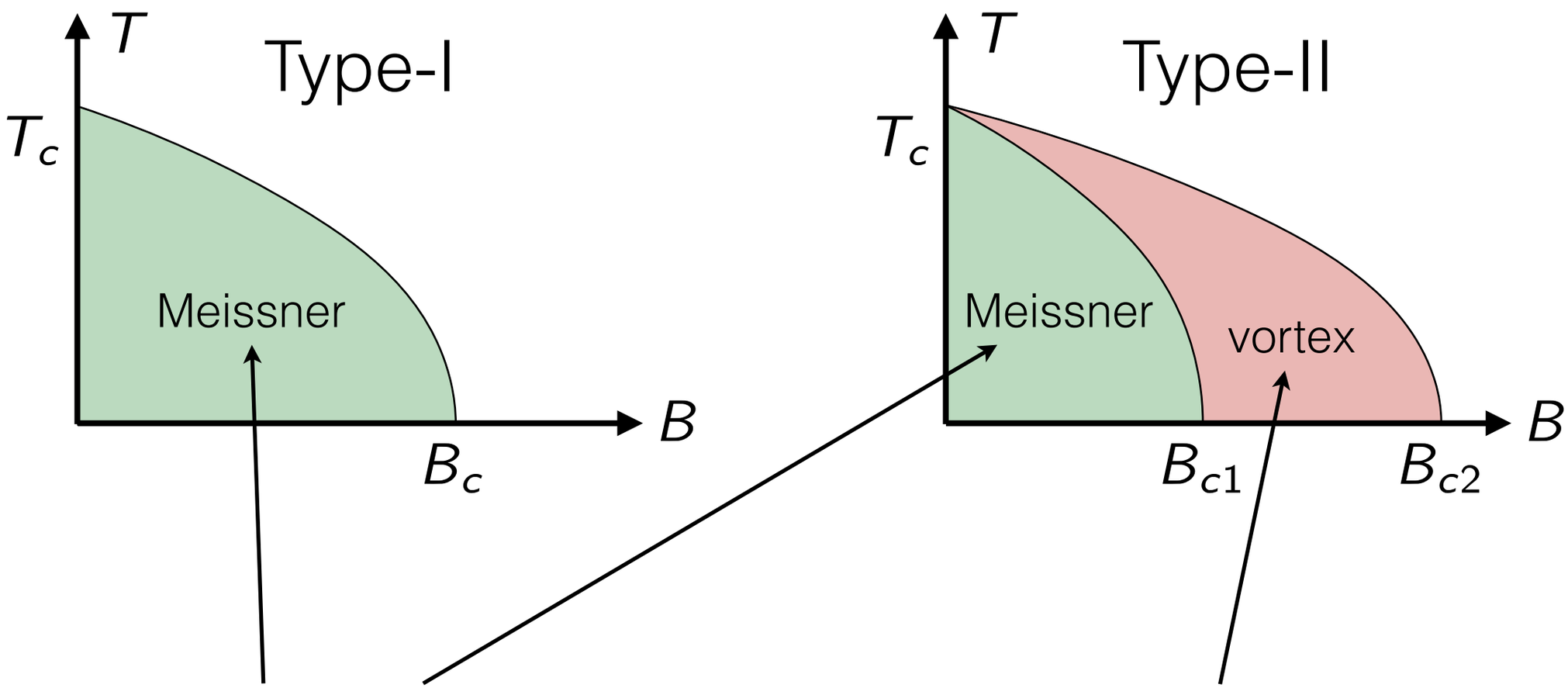
    1. How disorder affects the maximum gradient
    2. The role of disorder heterogeneity in enhancing the maximum gradient

Maximum field gradient is bound by the breakdown of Meissner state



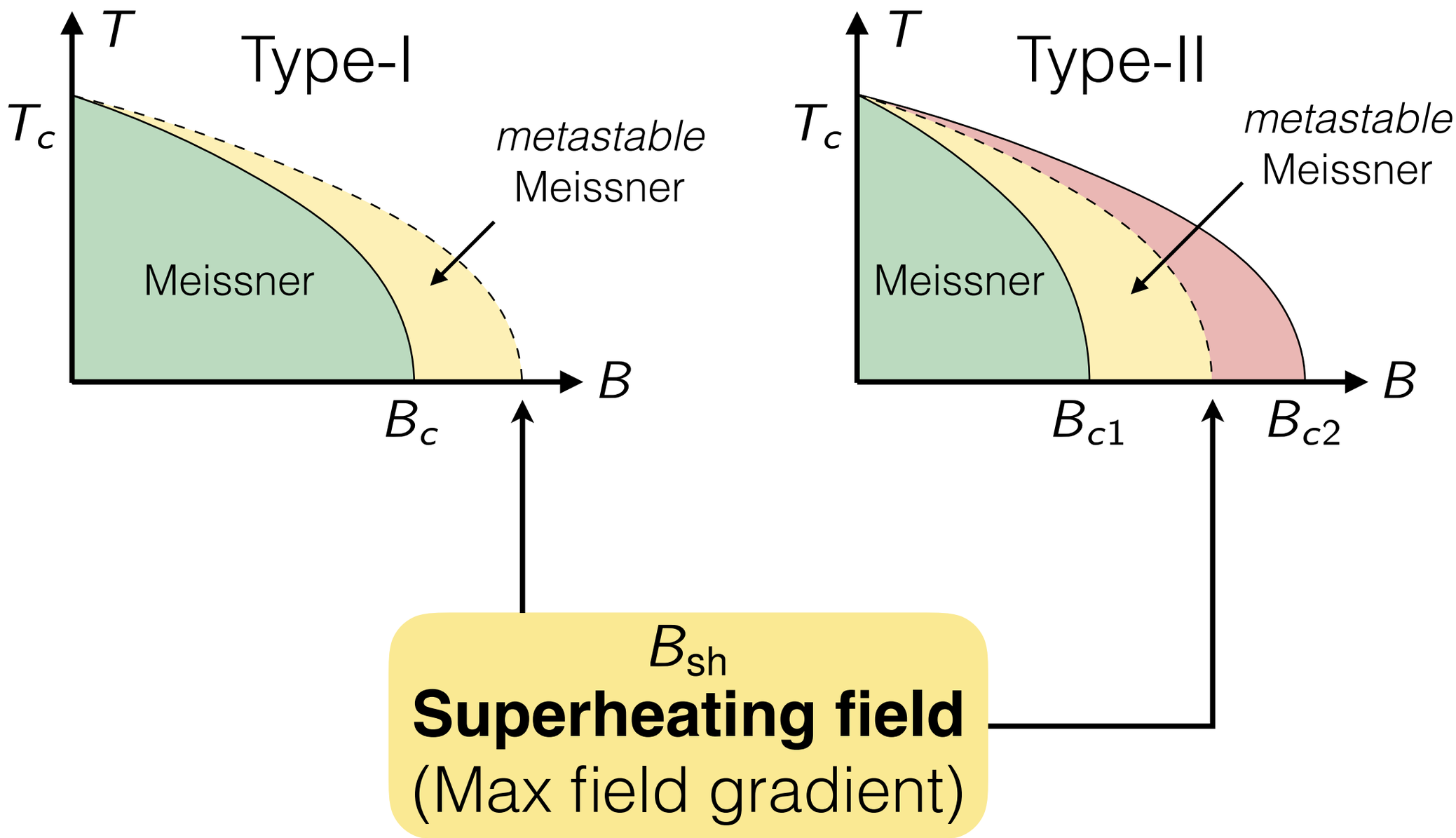
Perfect diamagnetism

✓ ***No dissipation!***

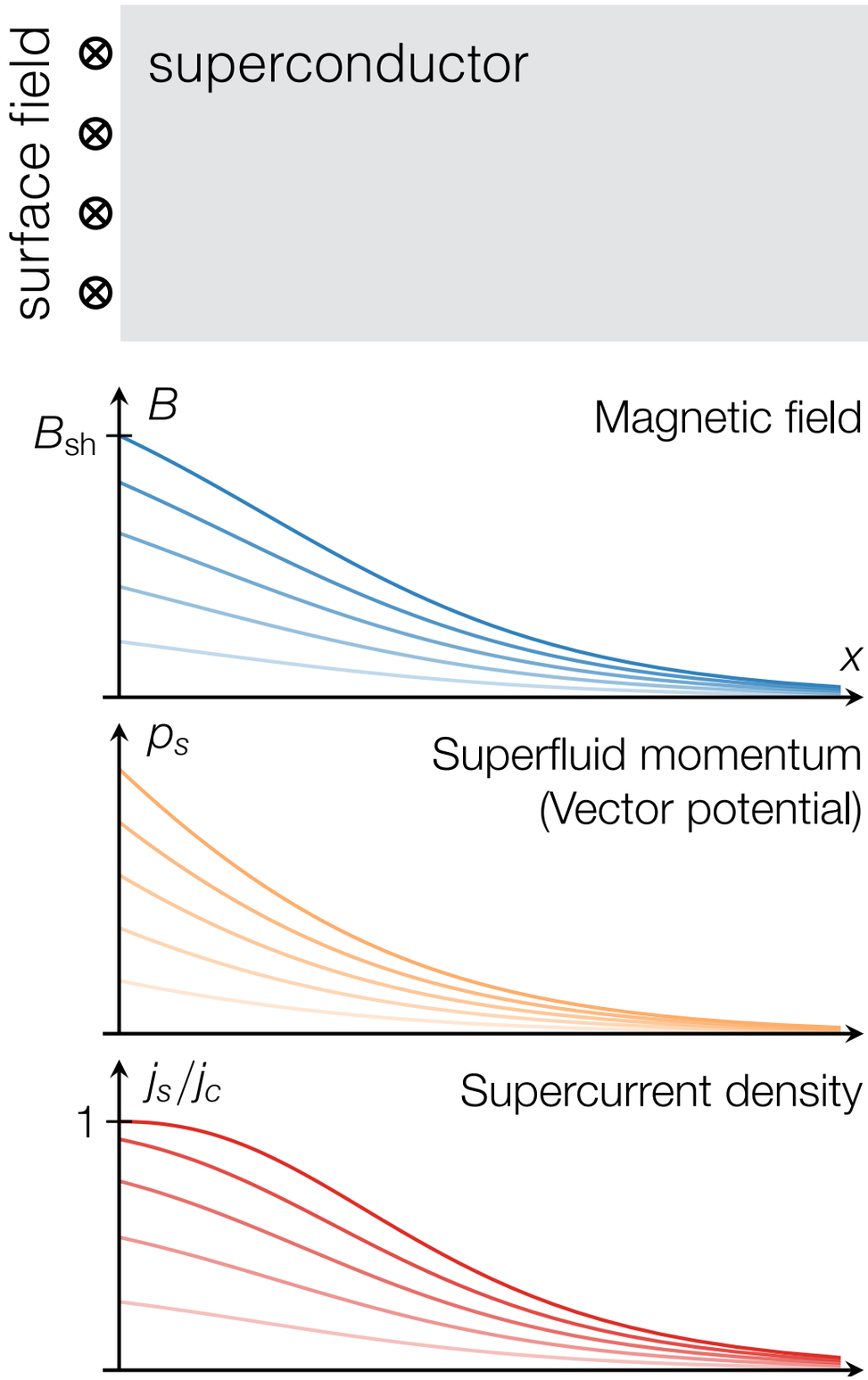
Vortices move under RF fields

✗ ***Energy dissipated***

Meissner state is stable up to the *superheating field*



Superheating field is determined from local critical current



- We solve *simultaneously*
  1. Eilenberger equation
     - for quasiparticle spectrum
  2. Gap equation
     - for excitation gap
  3. Impurity T-matrix equation
     - for the effect of disorder
  4. Maxwell's equation
     - for *B*-field and current profiles
- To obtain *superheating field,* increase surface field until current reaches critical value

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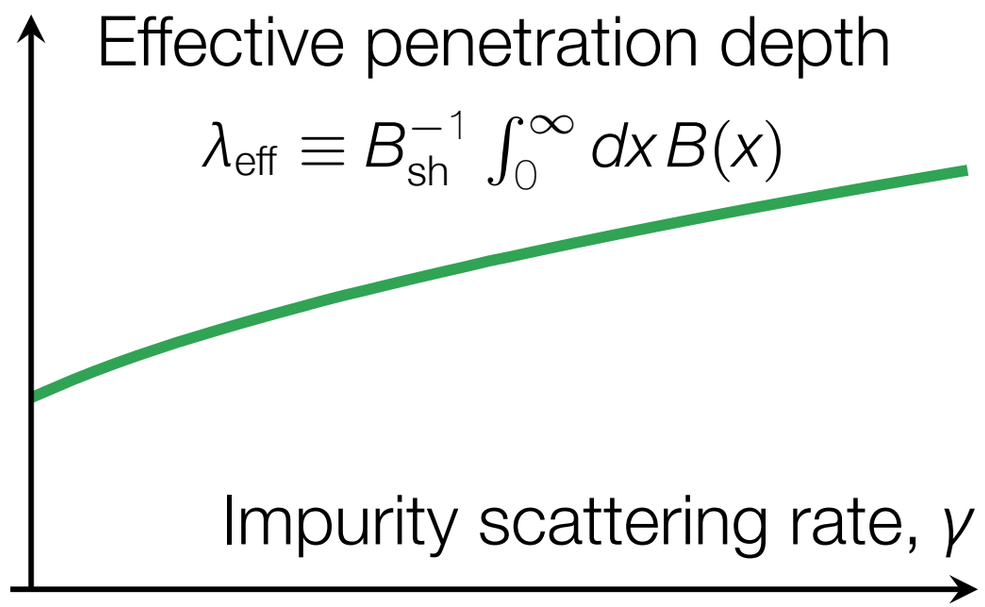
✓ Longer penetration depth

➤ *more* screening current



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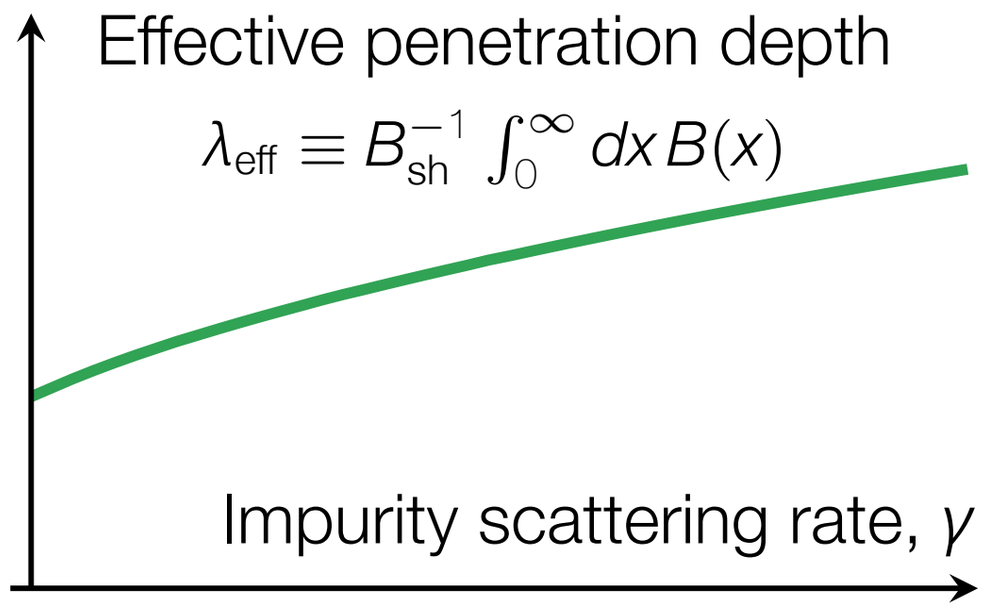

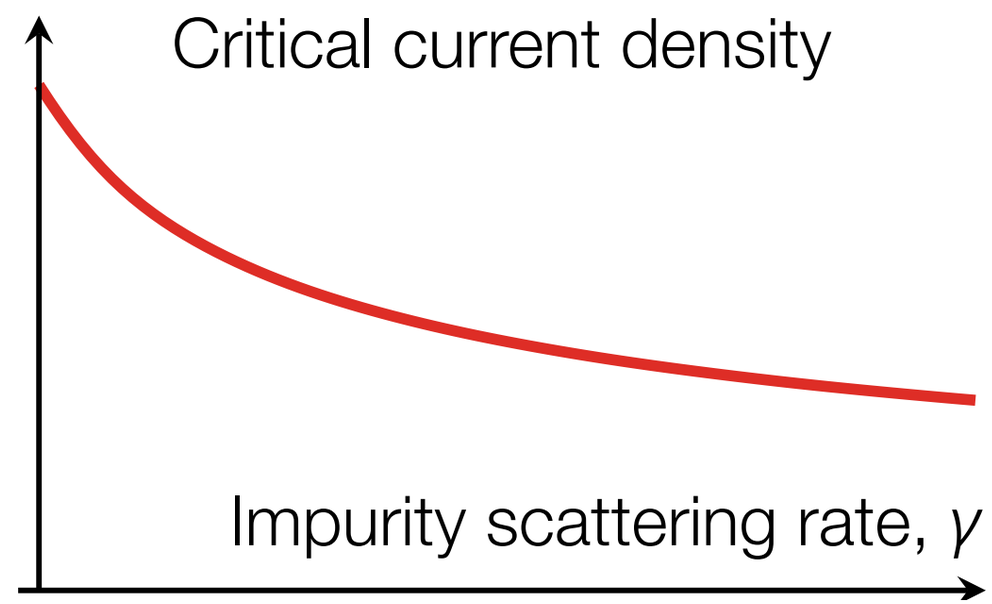

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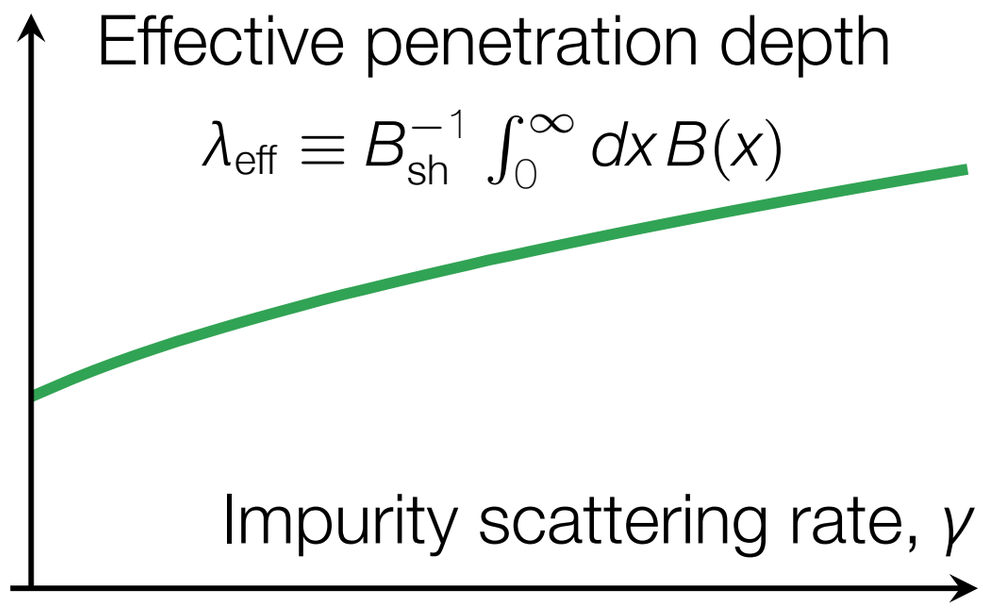

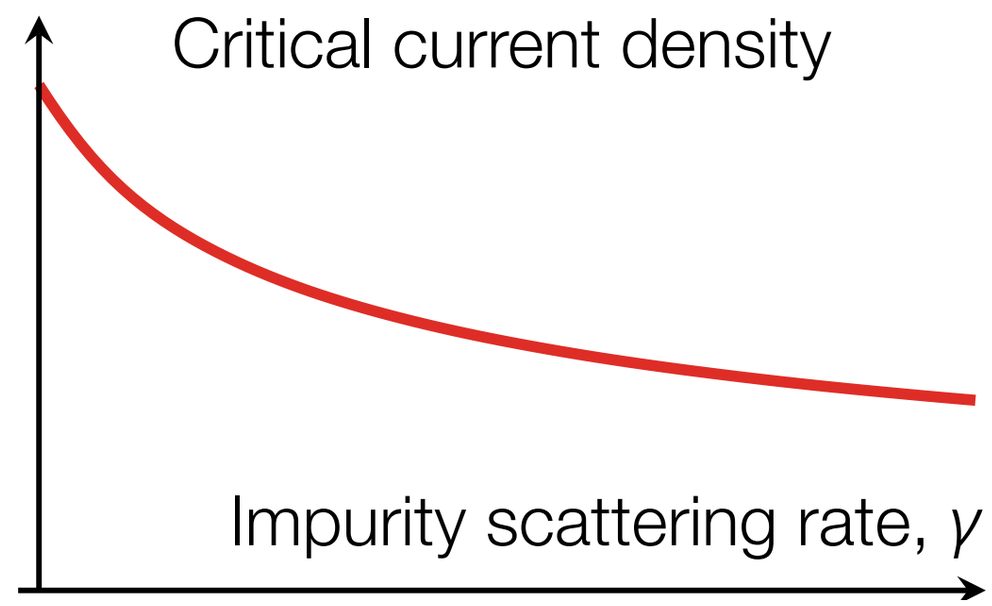

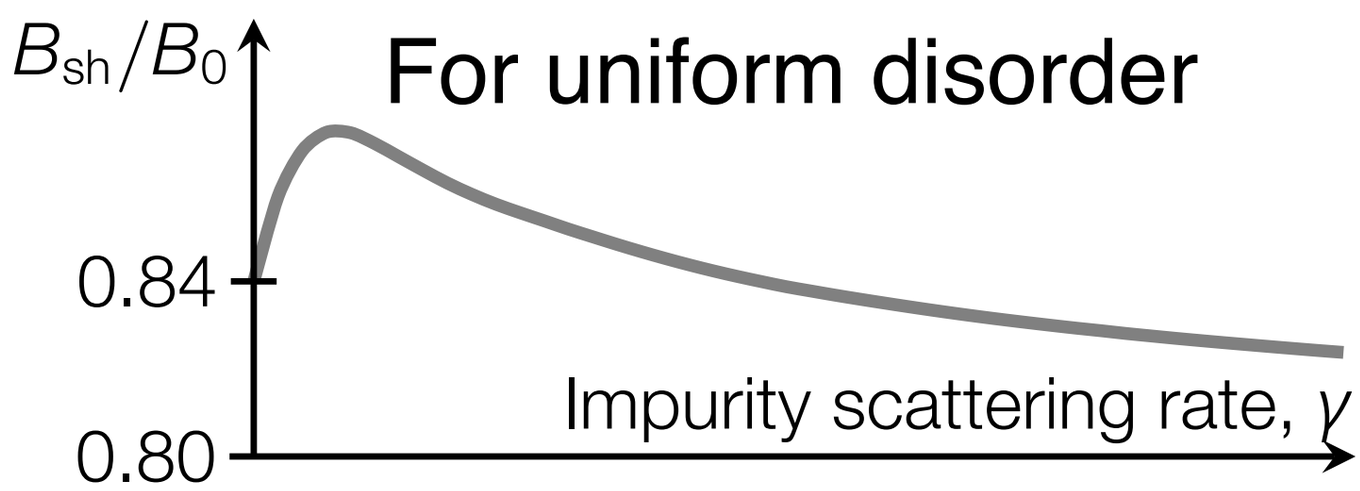

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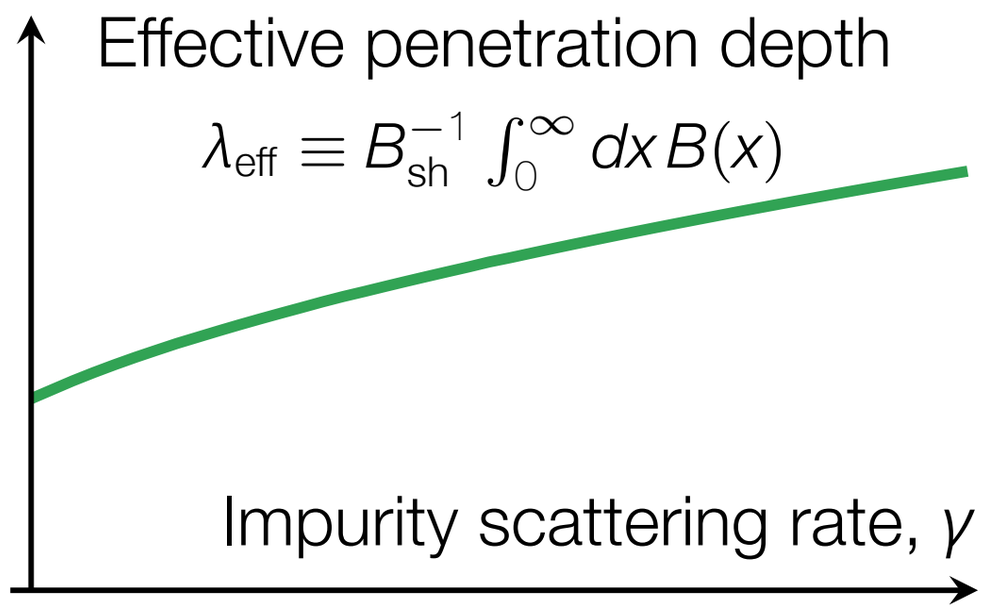

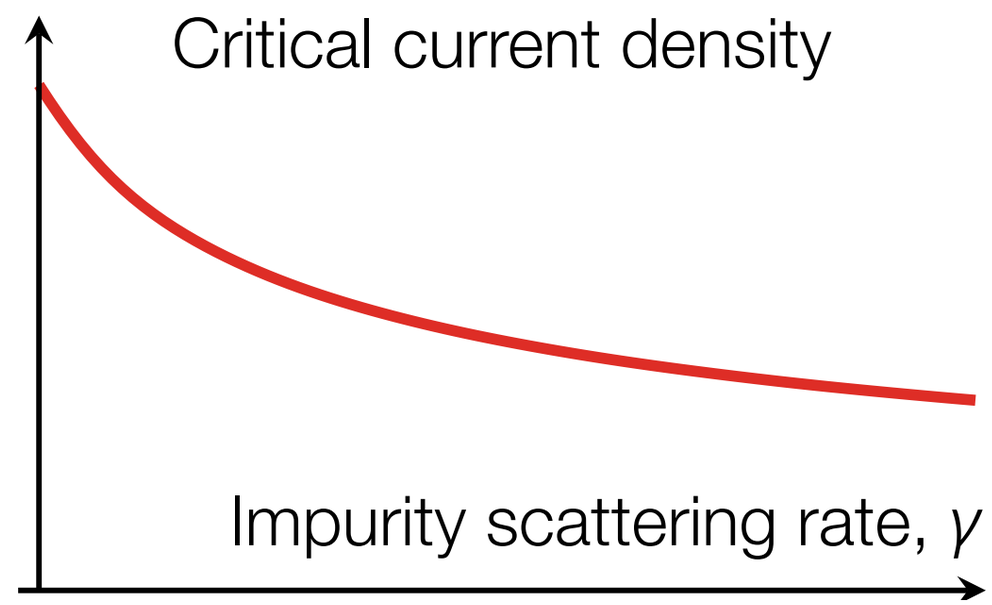

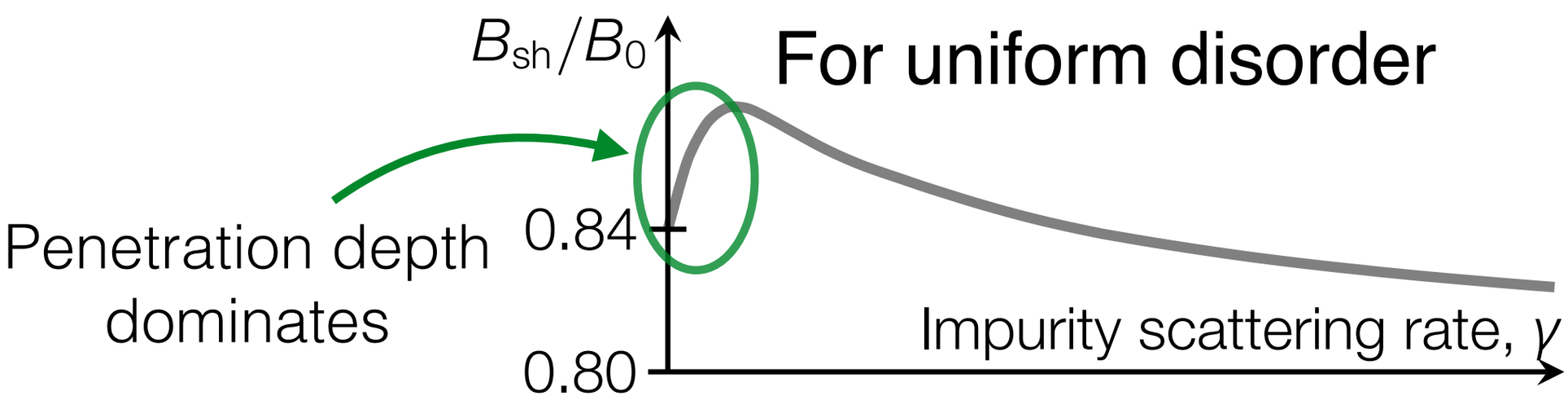

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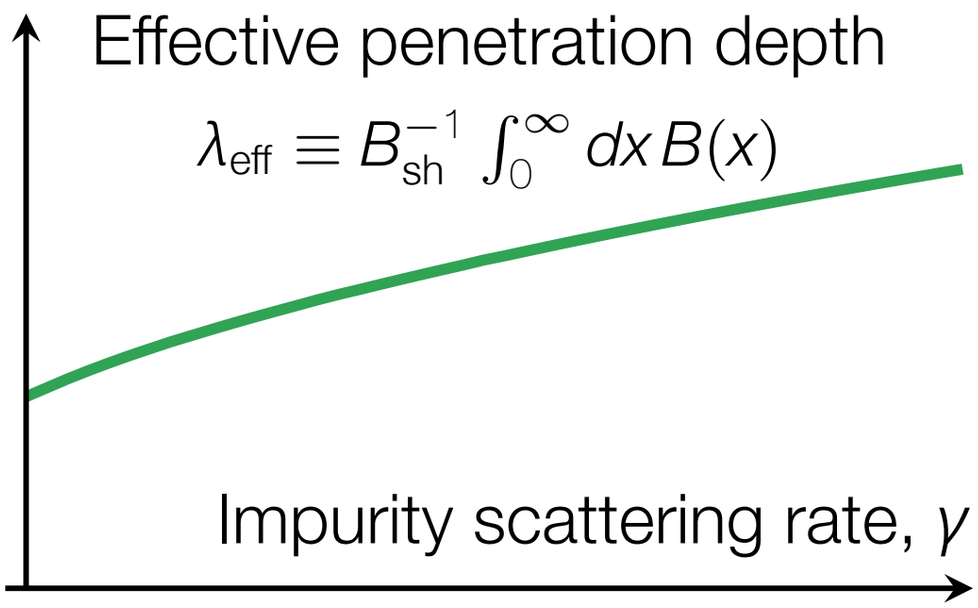

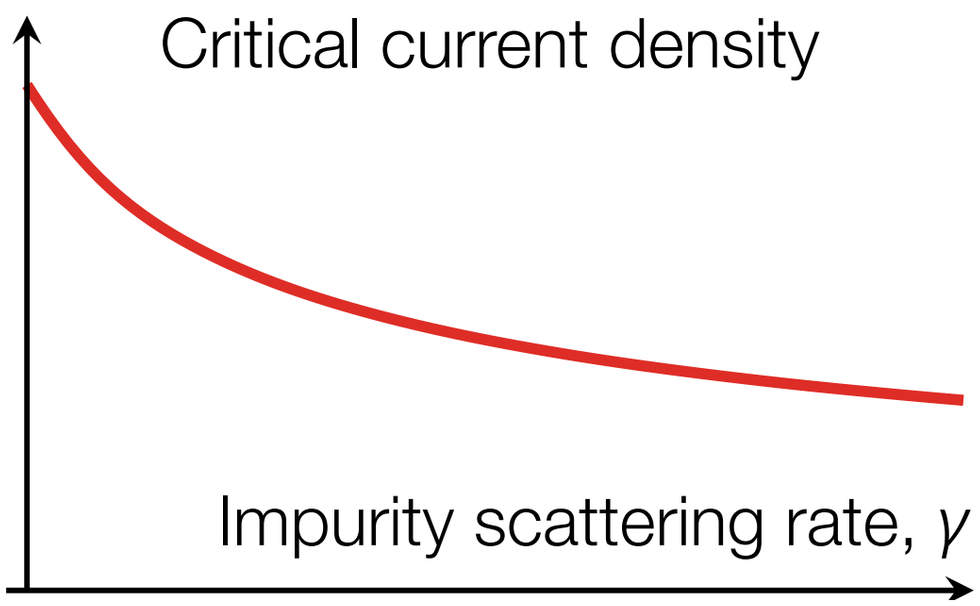

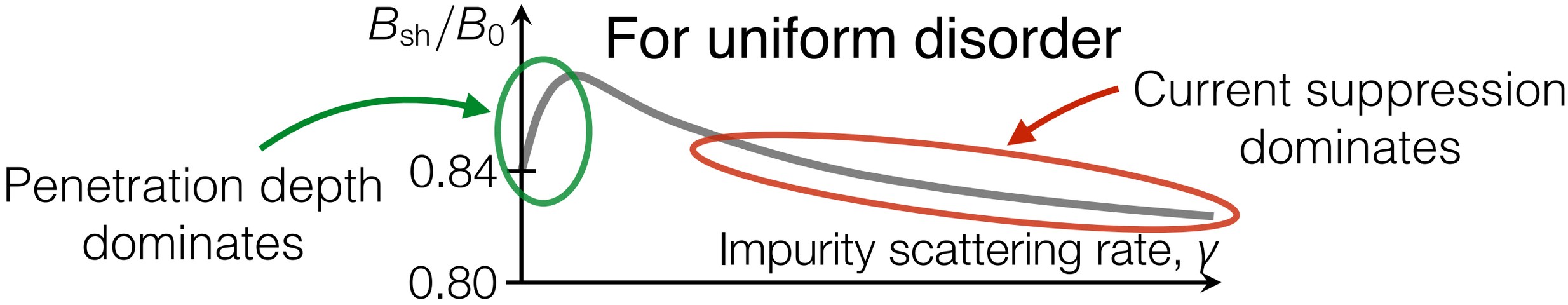

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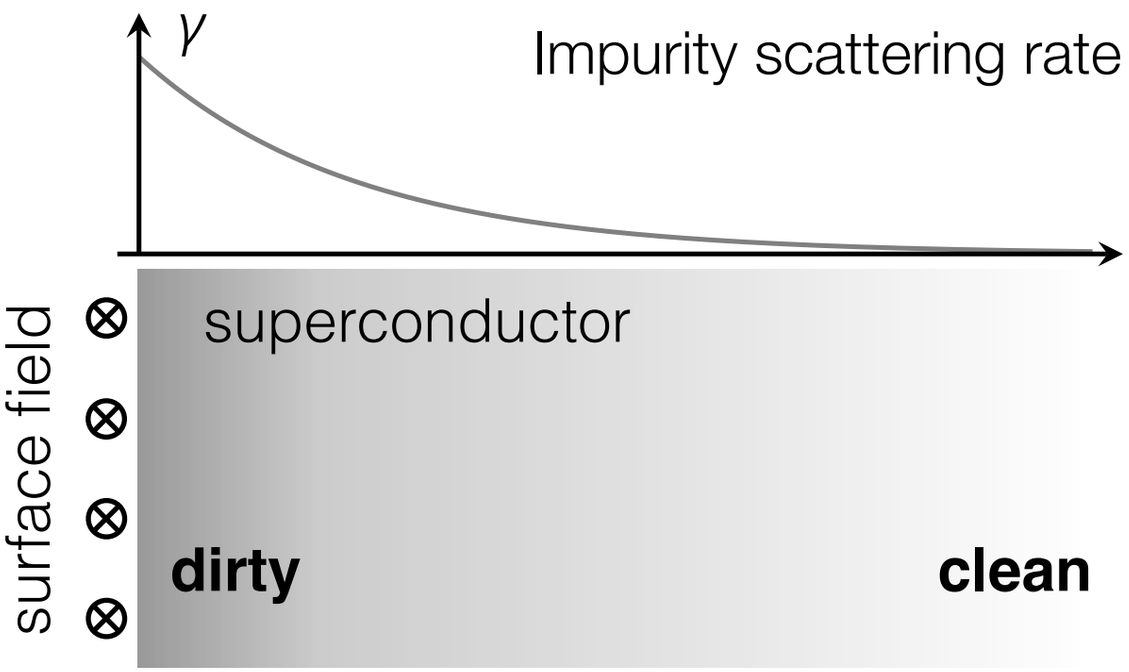

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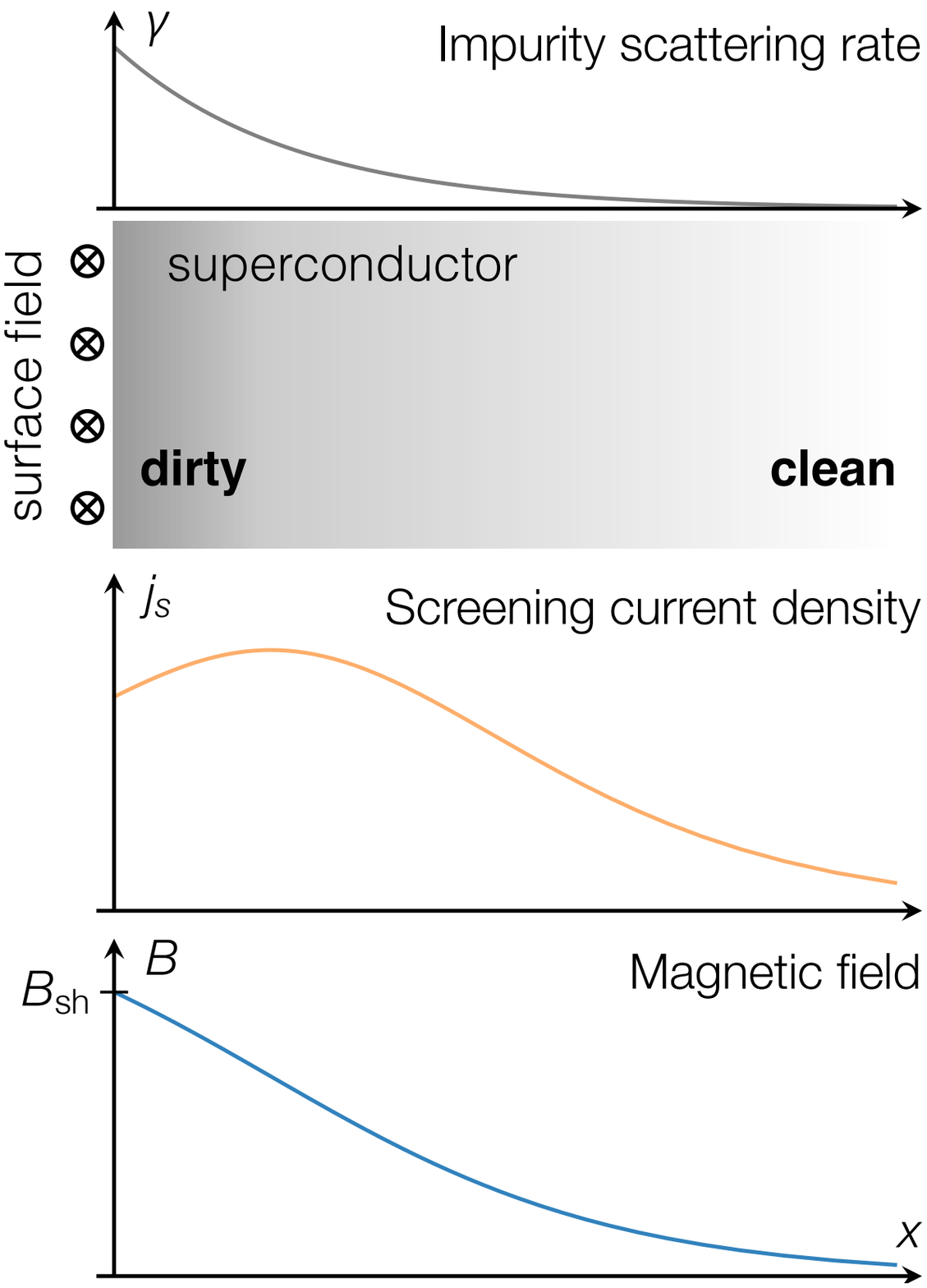

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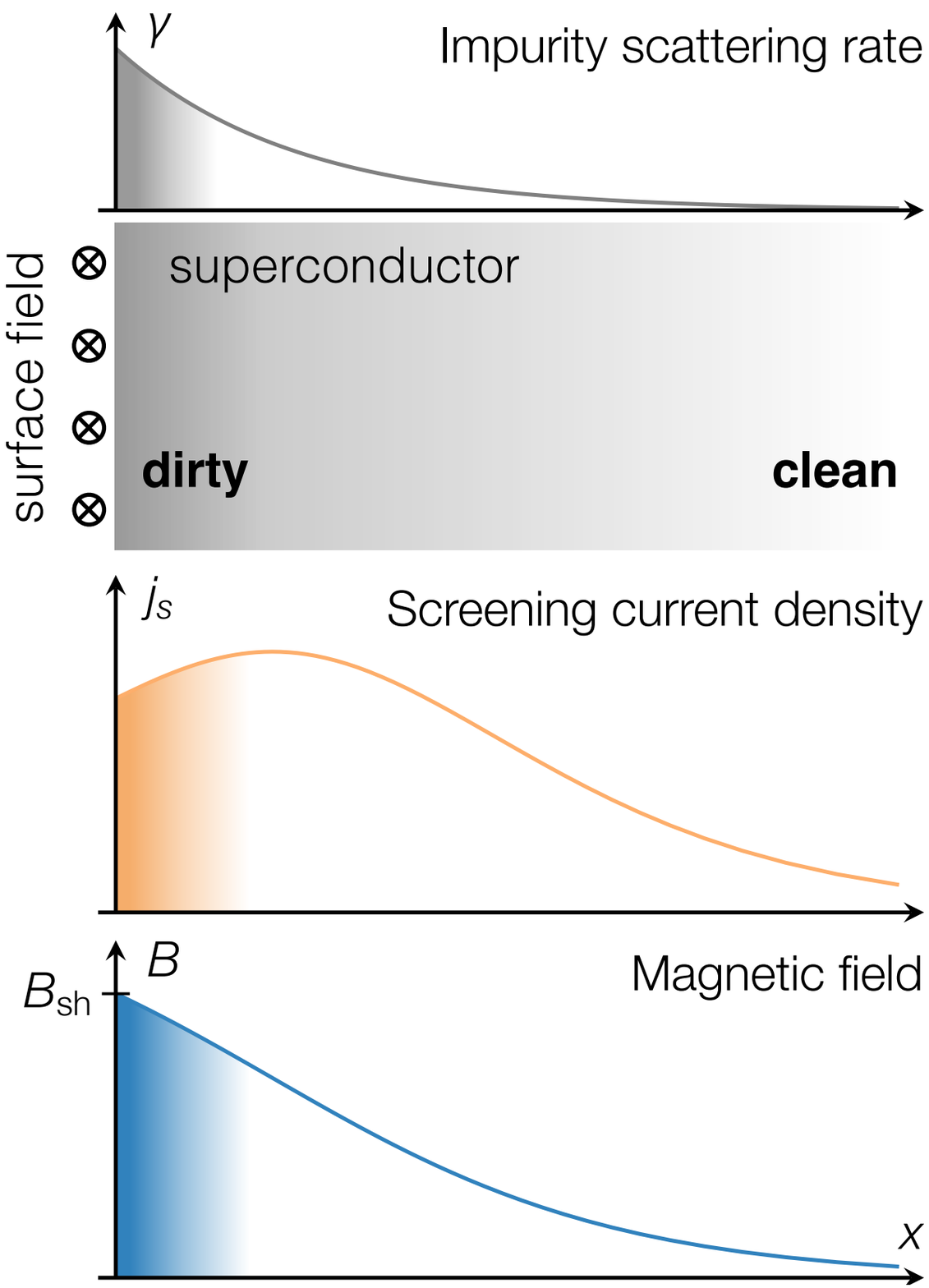

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- Slowly varying B-field requires less screening current density

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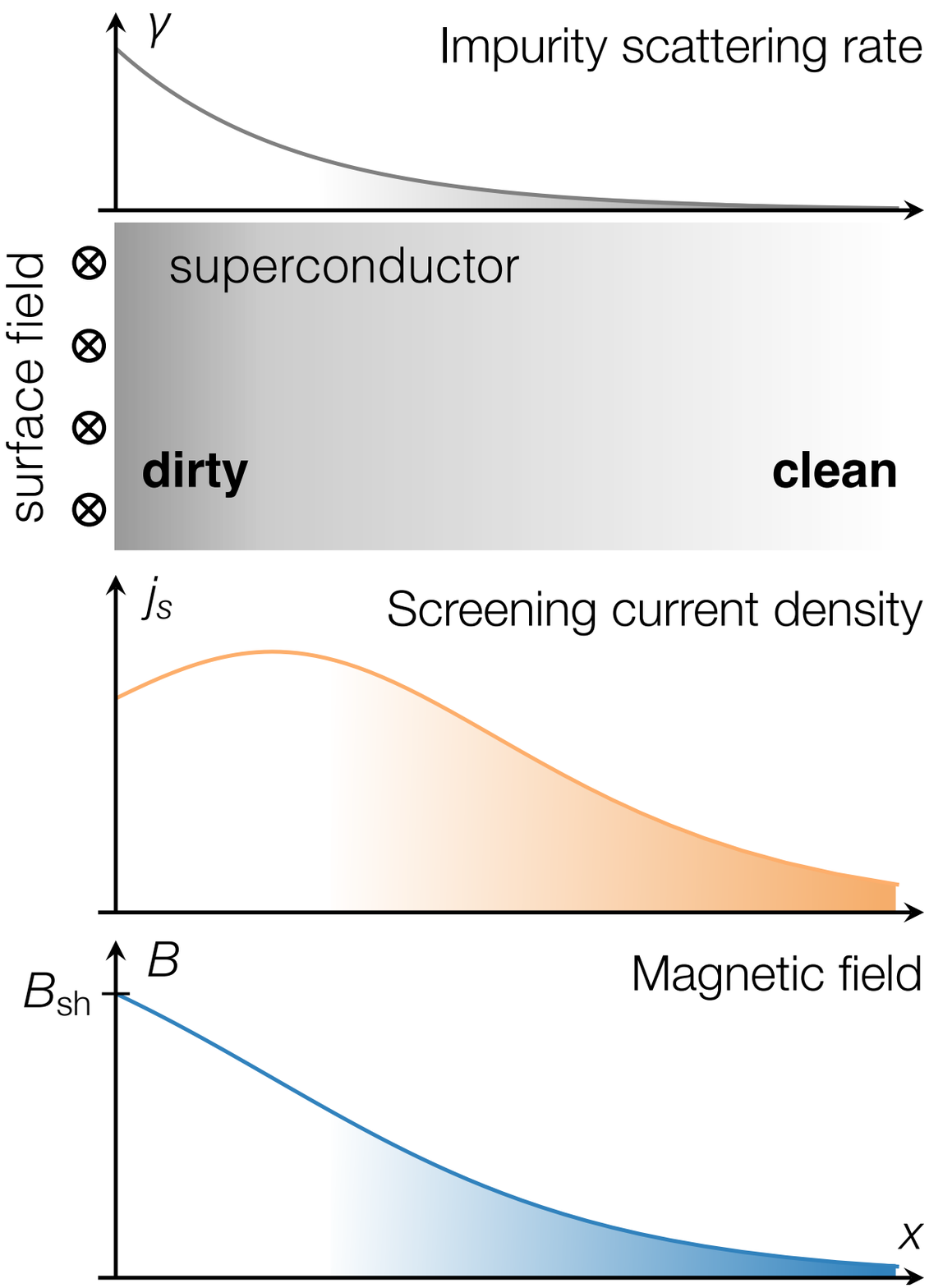

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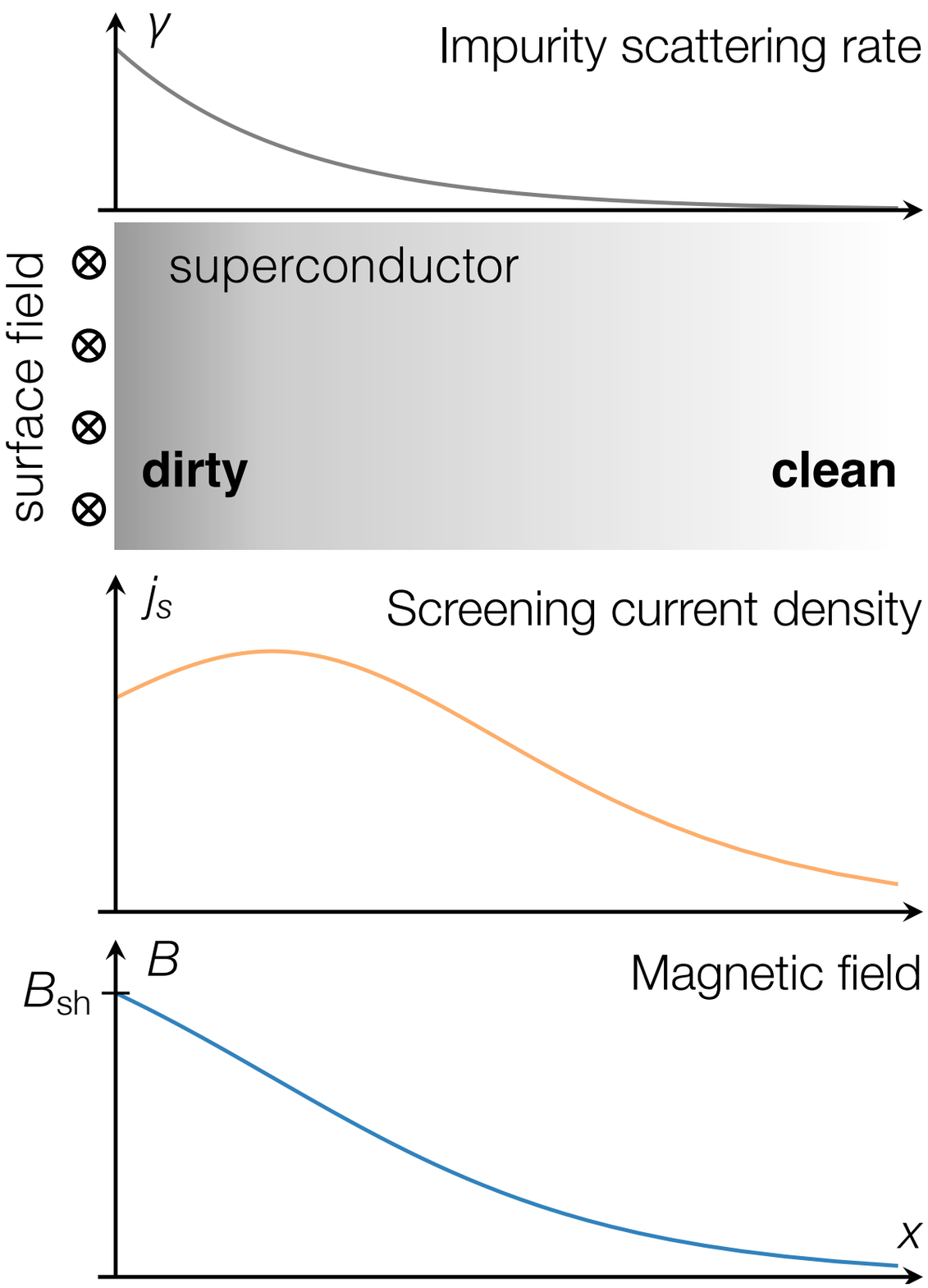

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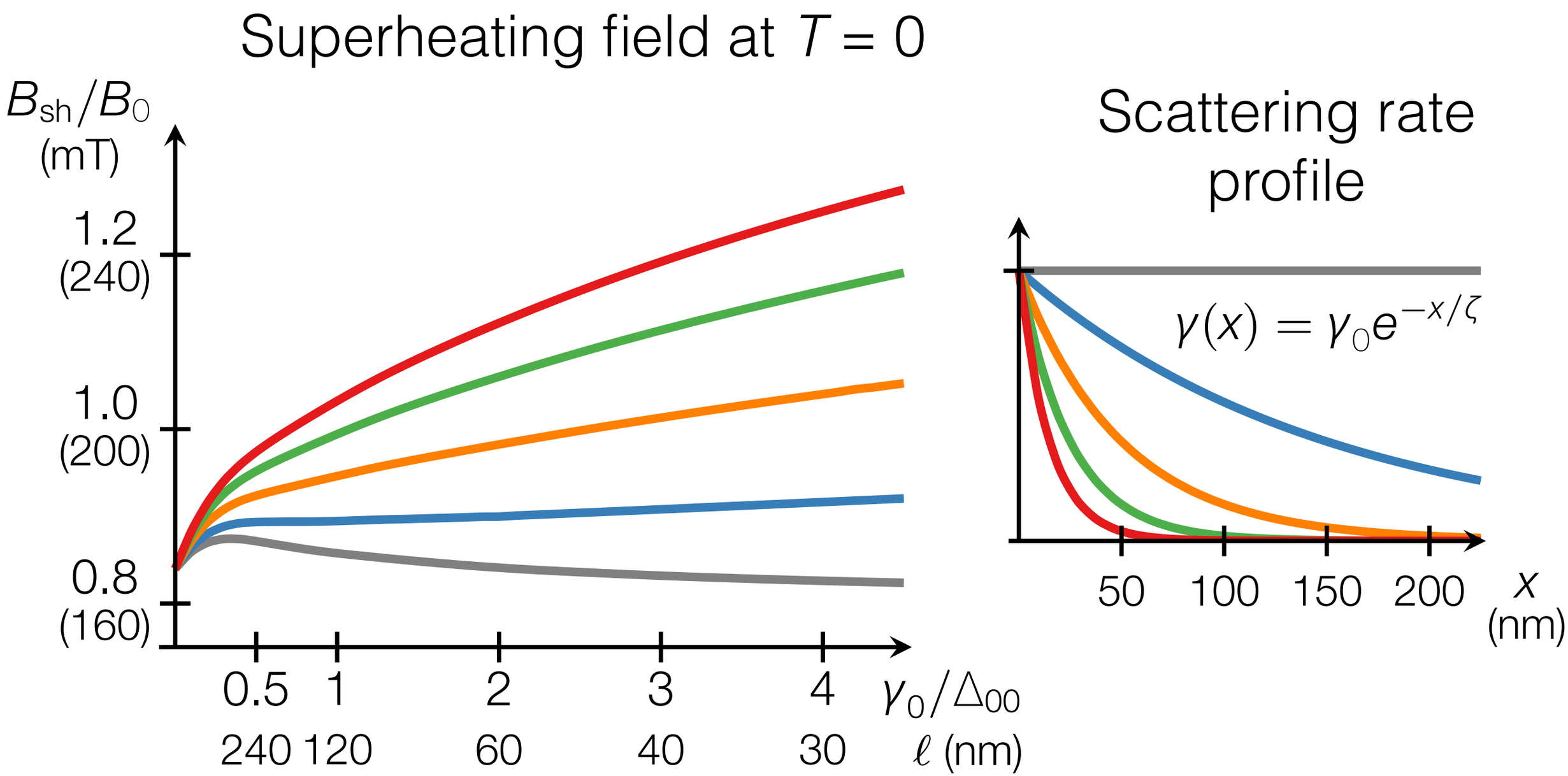
Results suggest *thin dirty layer* as design principle for optimal maximum gradient



Future work currently underway at Northwestern University

- **Finite temperature**
- **RF field** — At high superfluid momentum, effective superconducting gap can be comparable to RF
- **Finite-κ** — Our model addresses good type-II superconductors but for clean Nb $\kappa \approx 1$
- **What makes N so special?** — Realistic material analysis for real impurities and inclusions in Nb
  - ★ **Electron-phonon retardation** — Most works assume instantaneous electron-phonon coupling
  - ★ **Realistic Fermi surfaces and angle-resolved Fermi velocities** instead of the idealised isotropic surface

Thank you for you attention!

Collaborators

Northwestern

- Prof James Sauls
- Dr Oleksii Shevtsov
- Dr Mehdi Zarea

Fermilab

- Dr Mattia Checchin
- Dr Anna Grassellino
- Dr Martina Martinello
- Dr Alex Romanenko