DMRadio-Core

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Collaboration Meeting – Oct 9, 2025

50L vs m^3

50L

Toroidal magnet – harder to build and work with ✗

Superconducting resonator – high Q, scan rate enhancement ✓

50L vs m^3

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Toroidal magnet – harder to build and work with ✗

Superconducting resonator – high Q, scan rate enhancement ✓

m^3

Solenoidal magnet – easier to build and work with ✓

Copper pickup – Q set by loss in non-SC copper ✗

50L vs m^3

50L	m^3
Toroidal magnet – harder to build and work with ✗	Solenoidal magnet – easier to build and work with ✓
Superconducting resonator – high Q, scan rate enhancement ✓	Copper pickup – Q set by loss in non-SC copper ✗

Can we design a superconducting high-Q resonator with a solenoidal magnet?

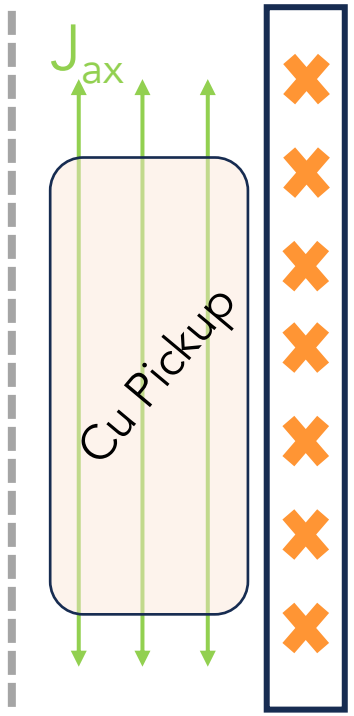
Solenoidal magnet & m^3

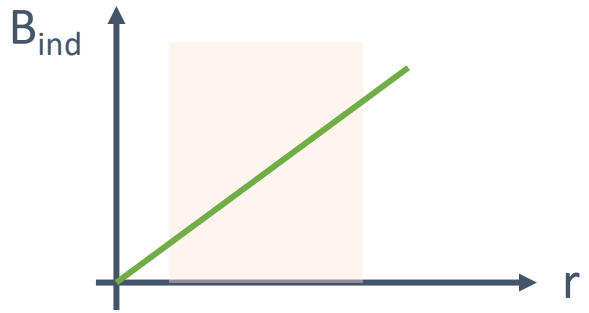
Care about coupled energy:

$$U_c = \frac{\Phi^2}{2L}$$

where

$$\Phi = \int \vec{B}_{\text{ind}} \cdot da$$





Solenoidal magnet

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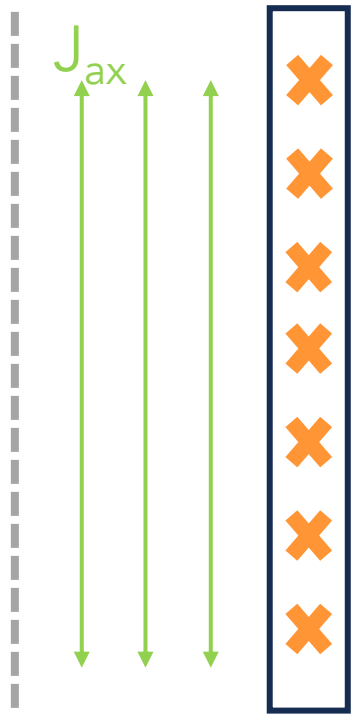

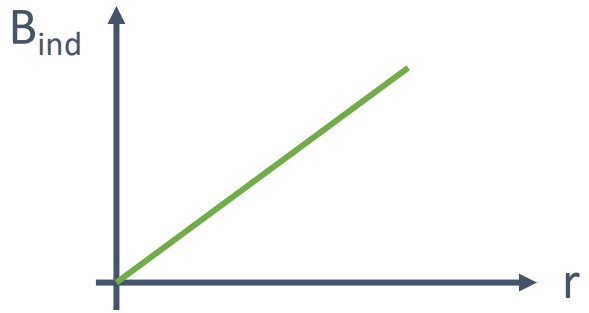

But B_{ind} exists beyond magnet coil

Solenoidal magnet

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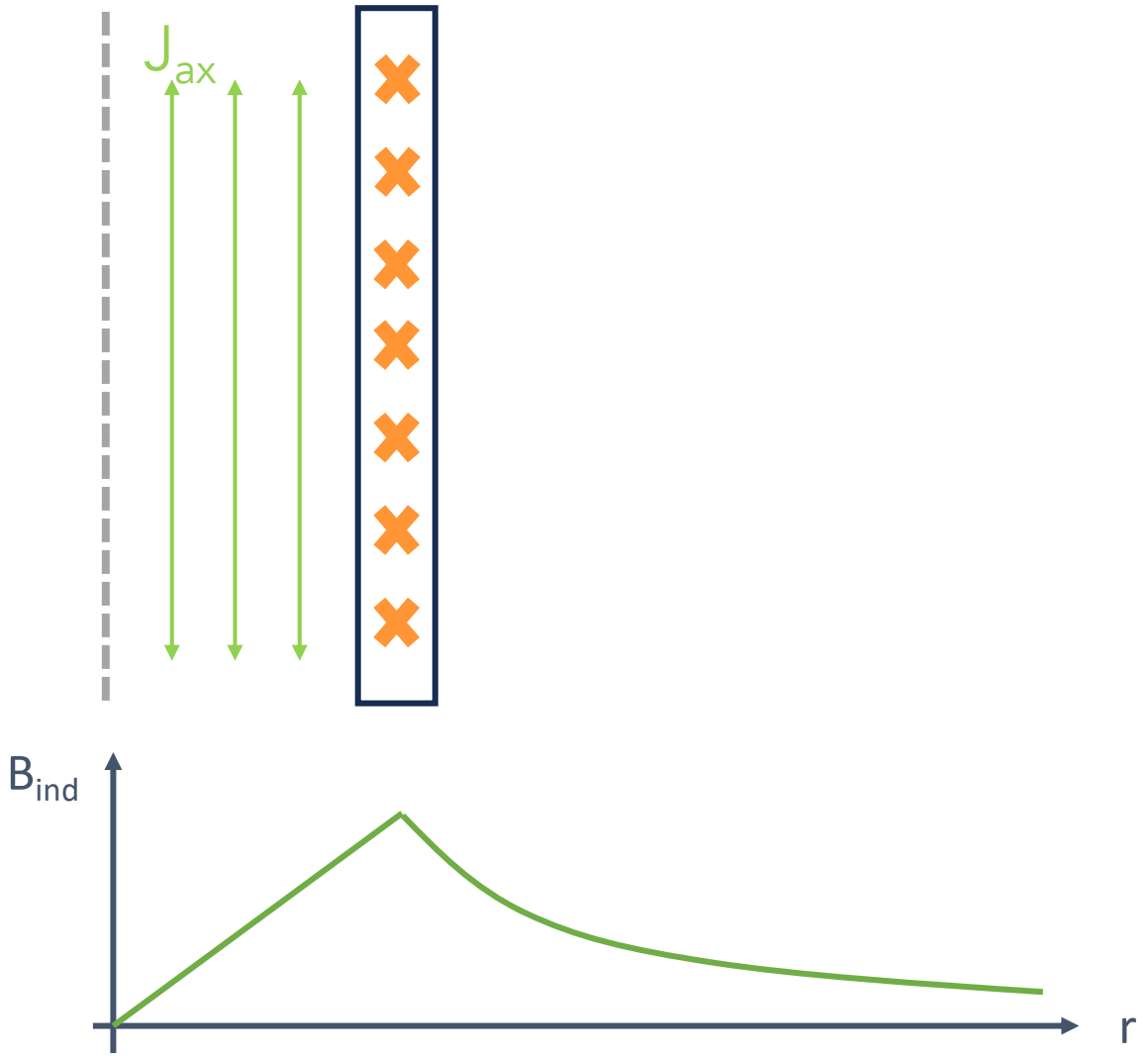

Solenoidal magnet & DMRadio-core

Care about coupled energy:

$$U_c = \frac{\Phi^2}{2L}$$

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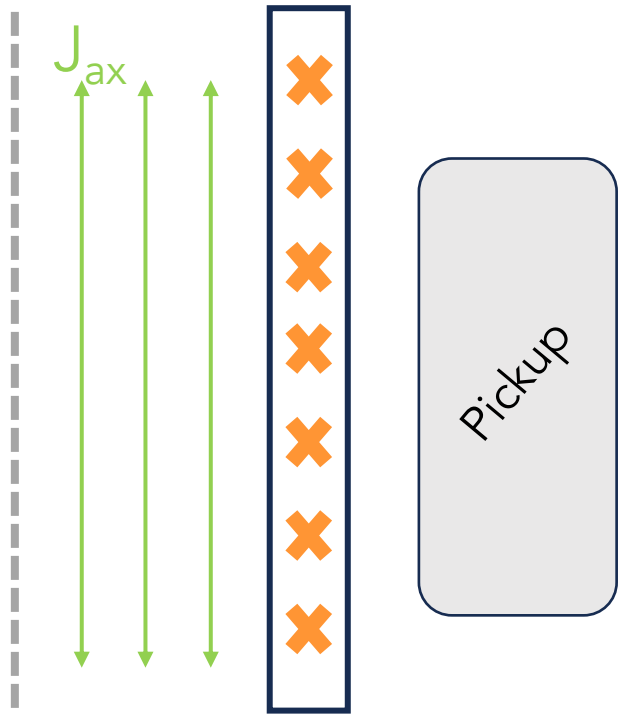
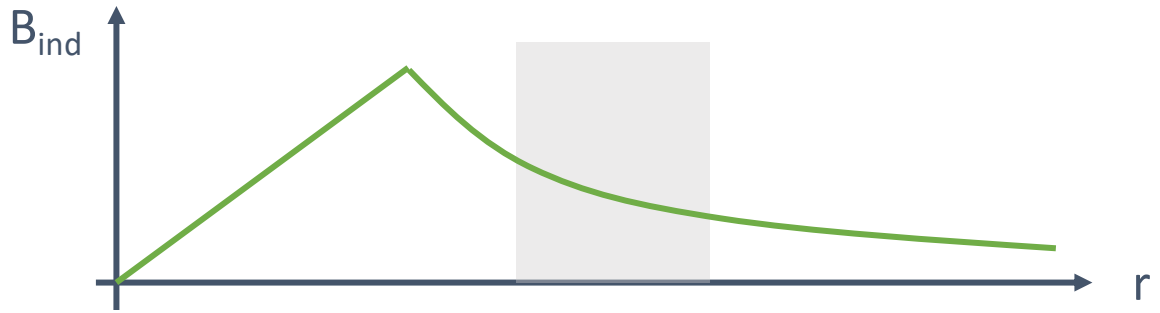
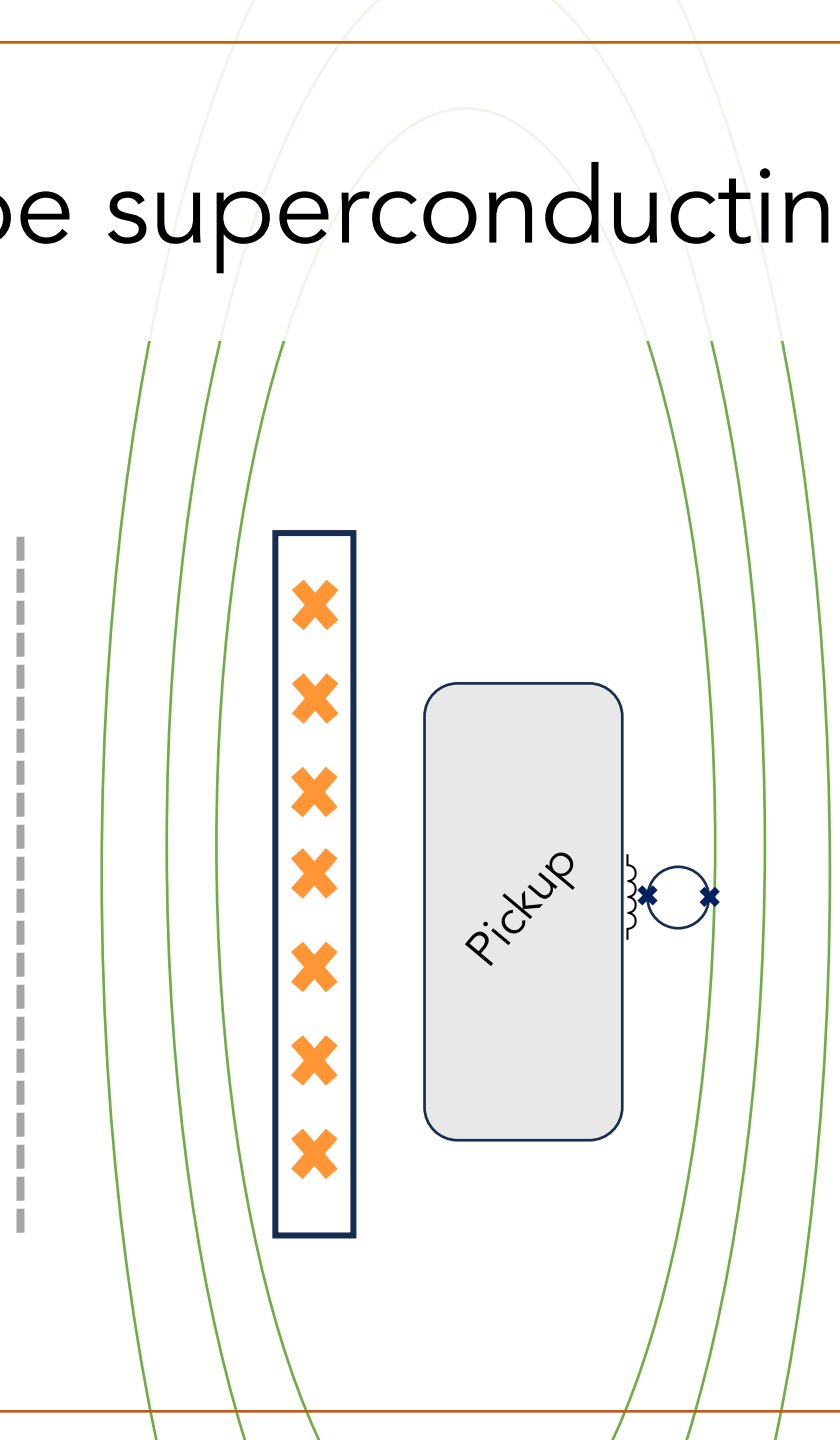




Pickup volume is now decoupled from magnetic field volume

Can this be superconducting?



Magnet + iron slabs could be designed to keep pickup in a low field region such that it is superconducting

Fit SQUIDs in low field region

m^3 vs core

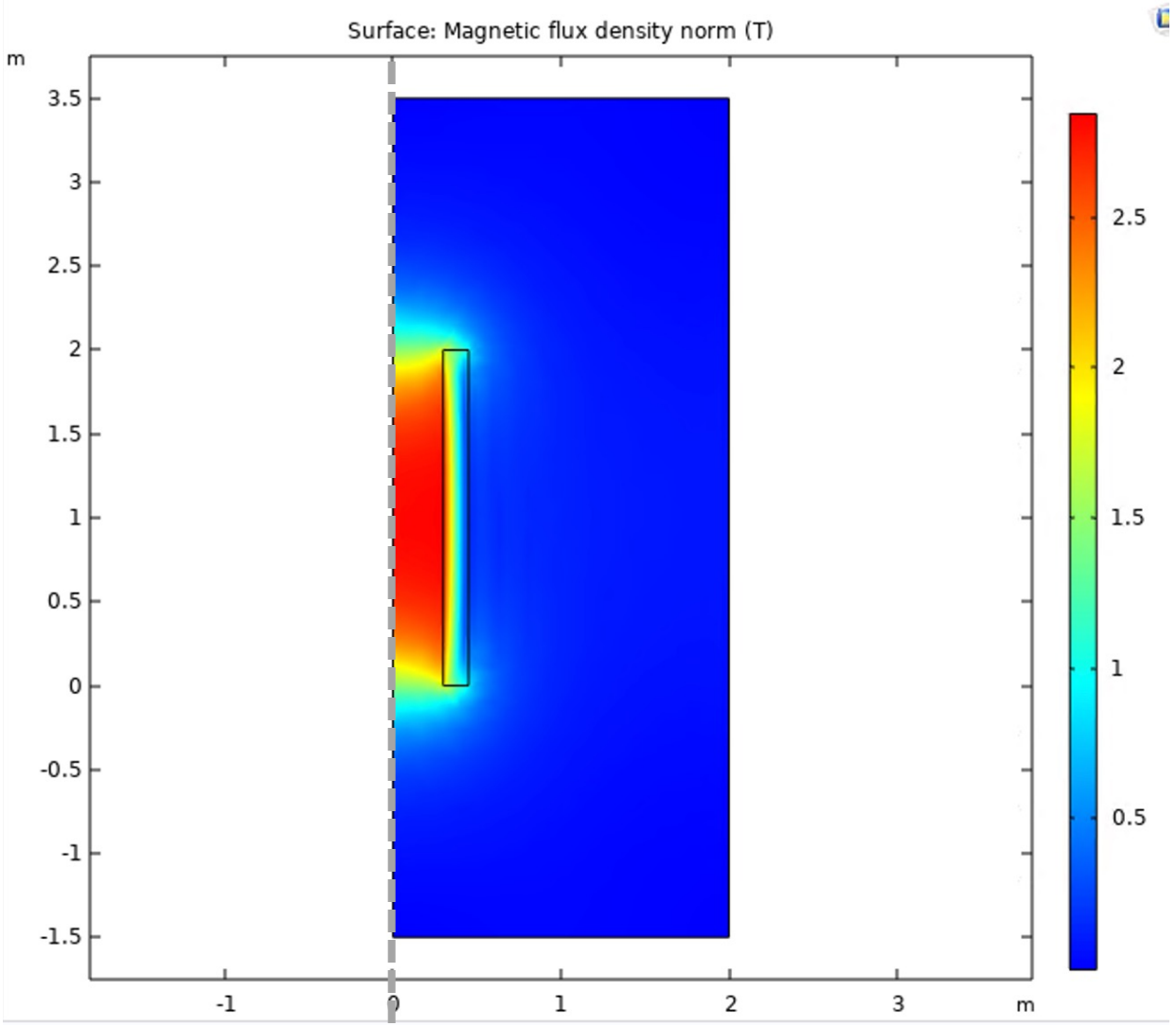
Scan rate scales as (coupled energy)^2. Compare core vs m^3

as back of the envelope calculation:

$$\frac{\left(\frac{\Phi^2_{\text{core}}}{2L_{\text{core}}}\right)^2}{\left(\frac{\Phi^2_{m^3}}{2L_{m^3}}\right)^2} \sim 25$$

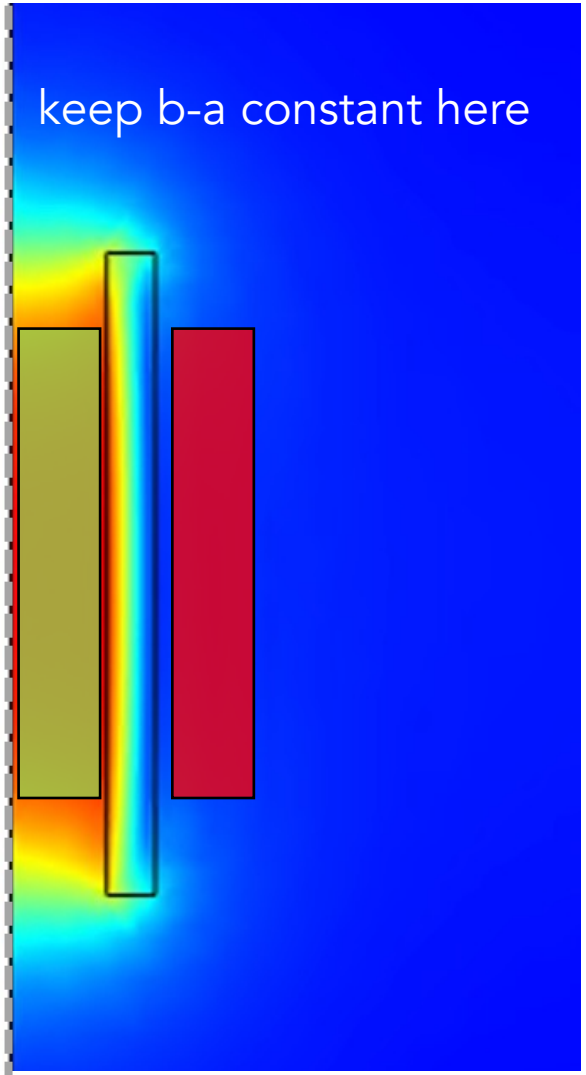
enhancement for same magnet, same Q, same noise, same r_{out}/r_{in} ratio

m^3 vs core COMSOL simulations



60 cm diameter bore solenoidal magnet, 2 m tall, ~2.6 T peak field

m^3 vs core COMSOL simulations

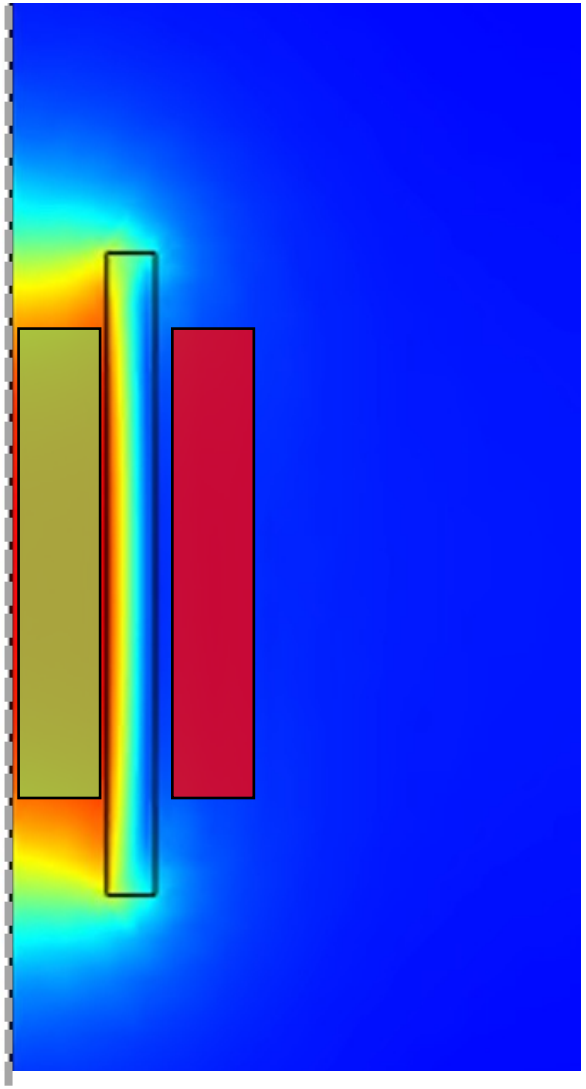


m^3-like geometry. Copper coax within magnet **but** slit is on the side

core-like geometry. Slit on outside. Compare two scenarios:

1. Copper coax
2. Superconducting coax (set $Q=10^6$)

m^3 vs core COMSOL simulations



m^3-like geometry. Copper coax within magnet **but** slit is on the side

Evaluate in MQS (~1 MHz)

core-like geometry. Slit on outside. Compare two scenarios:

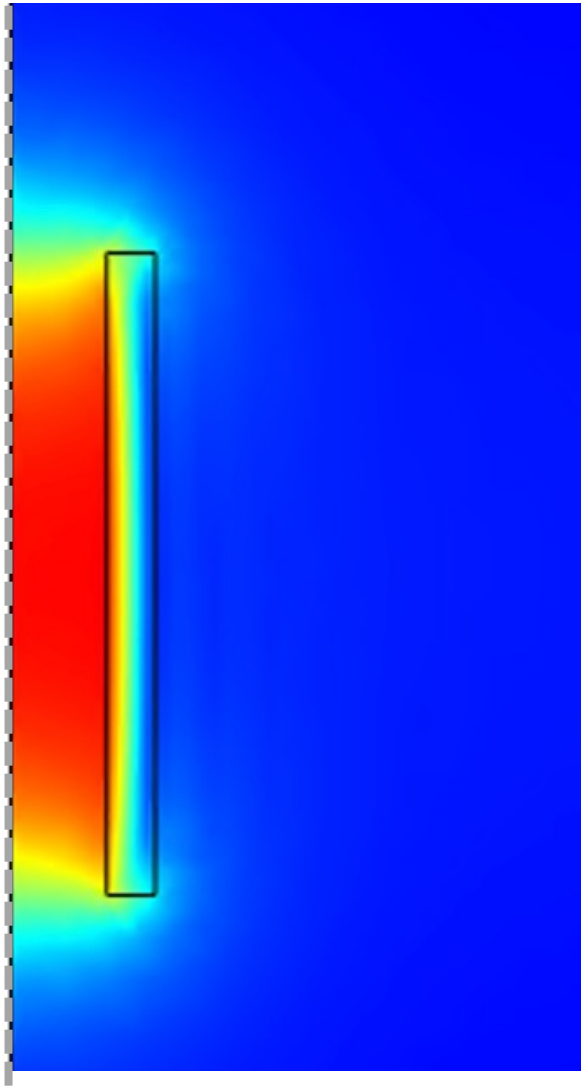
1. Copper coax

~60x enhancement in scan rate

2. Superconducting coax (set Q=10^6)

~450x enhancement in scan rate

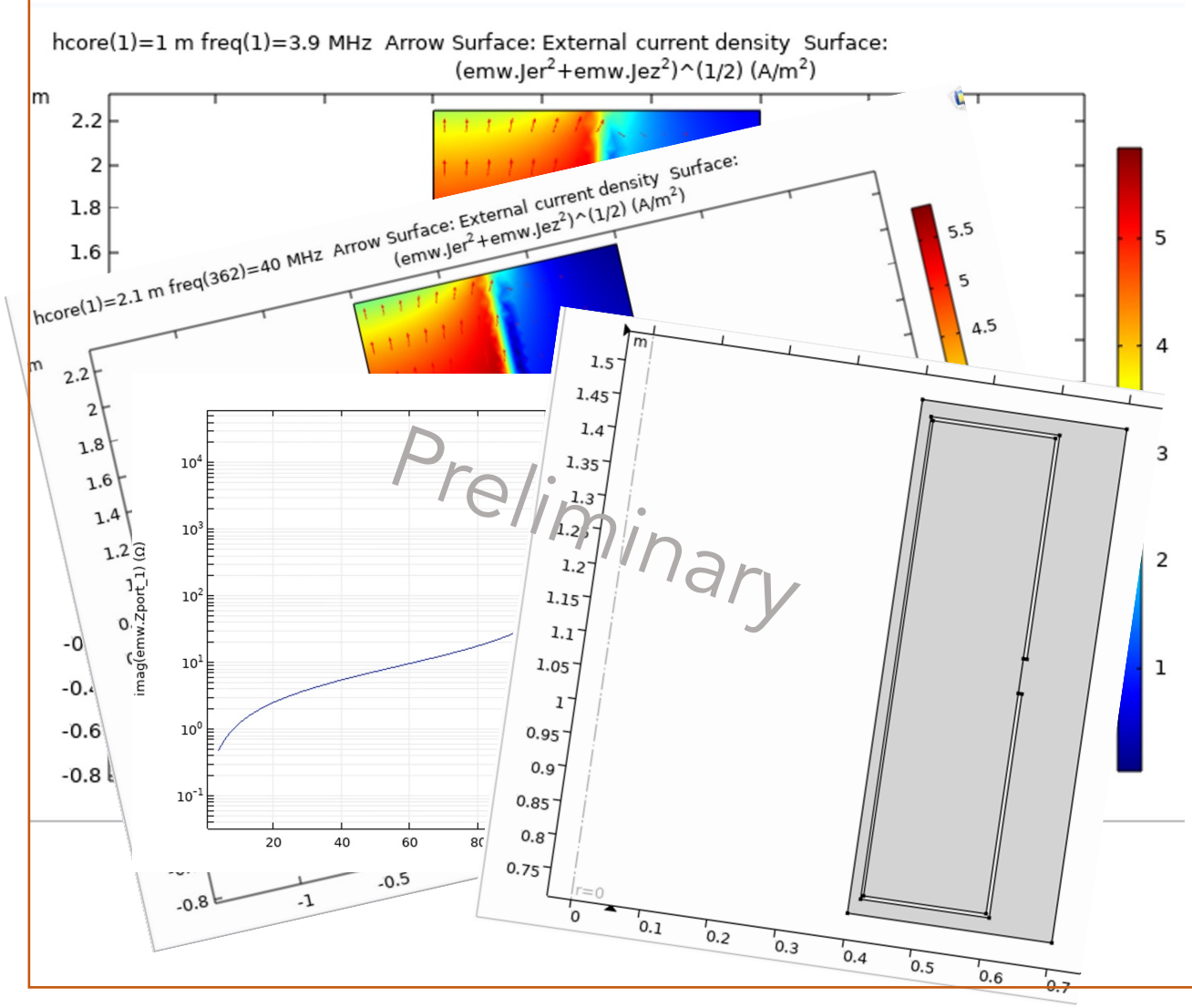
Core



Pencil-limit (tall, small bore) magnet will likely be optimal. This could be a 2+ m tall magnet

Optimization of cost and science reach is outstanding question

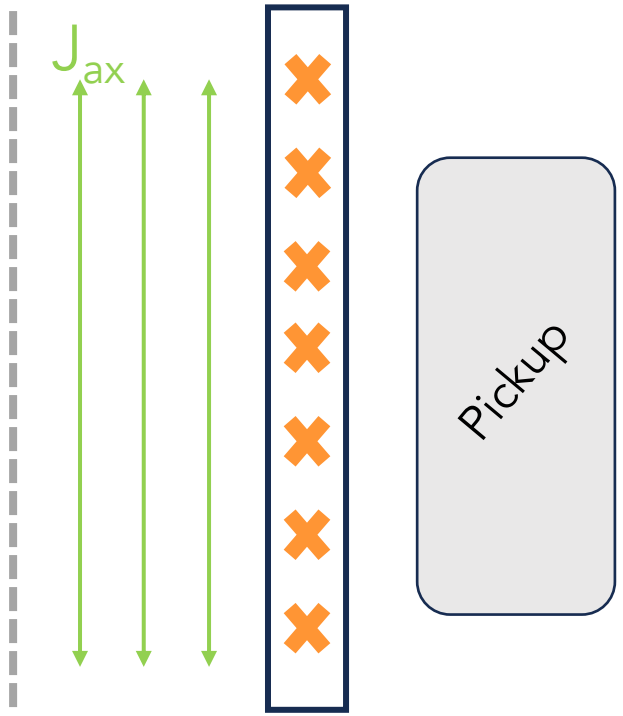
Core status



Running many COMSOL simulations to understand constraints of pickup, magnet, slit location, etc

Nothing conclusive yet but making sense of what works

Core future



- Continue extensive modeling to optimize magnet and pickup

- Pilot demonstration as LDRD in 2026
- No optimal frequencies determined
- Magnet size is part of pilot demonstration