Copper Strand Thermal Shielding for Third-Scale Magnet

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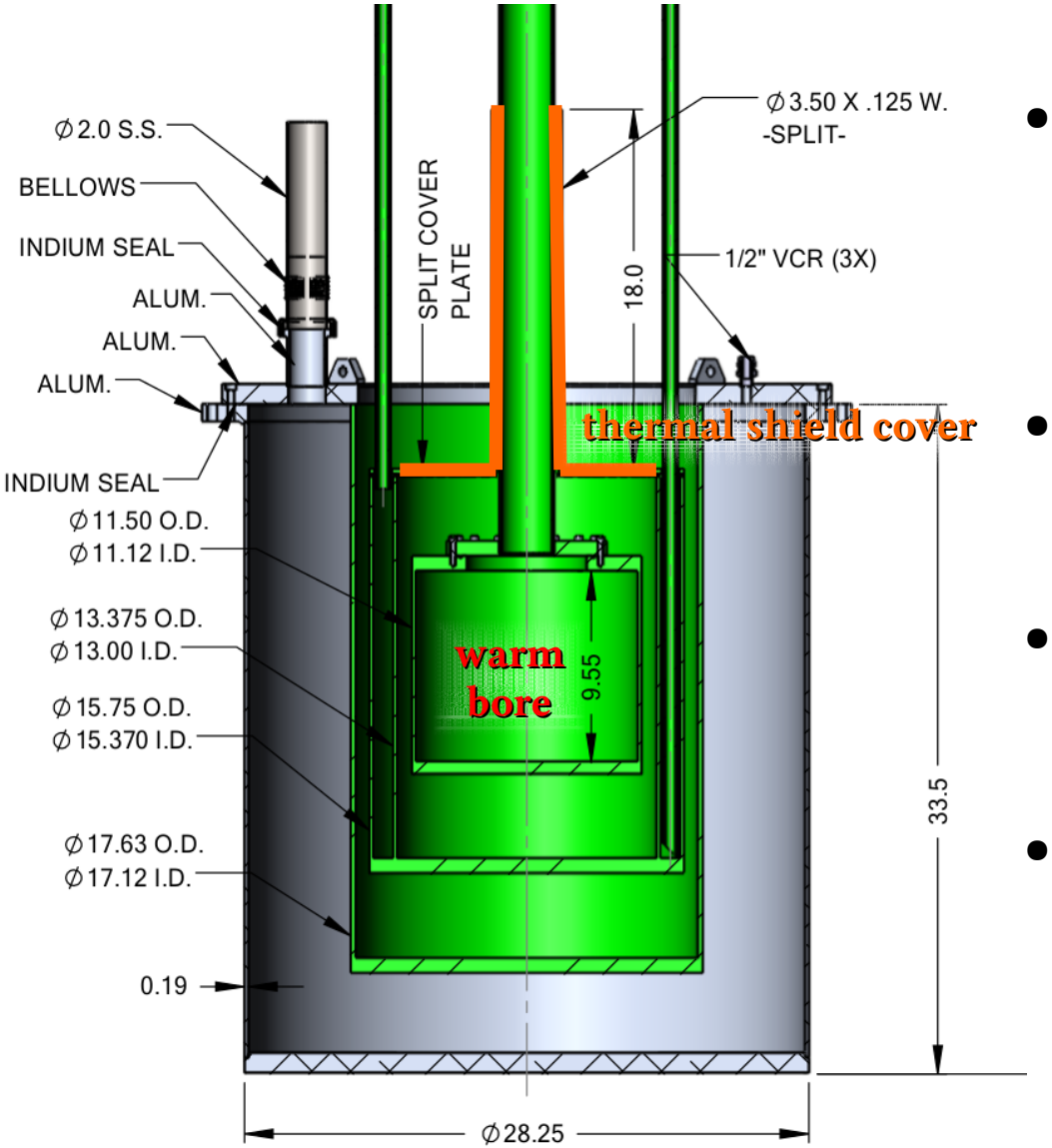
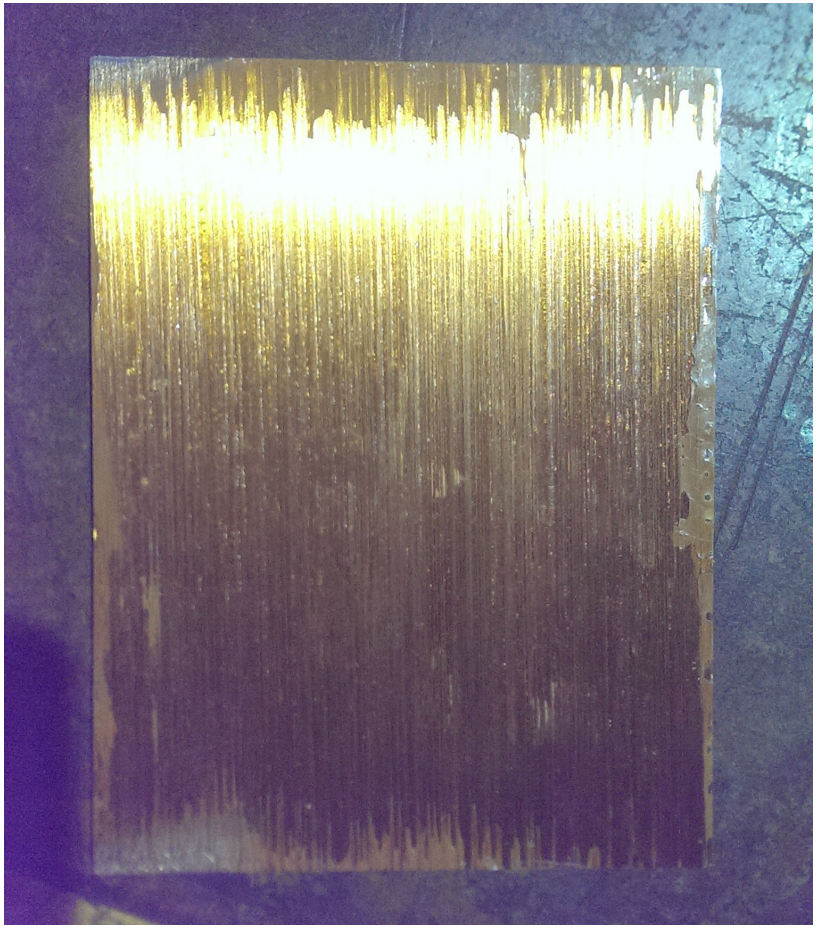
Third-Scale Magnet



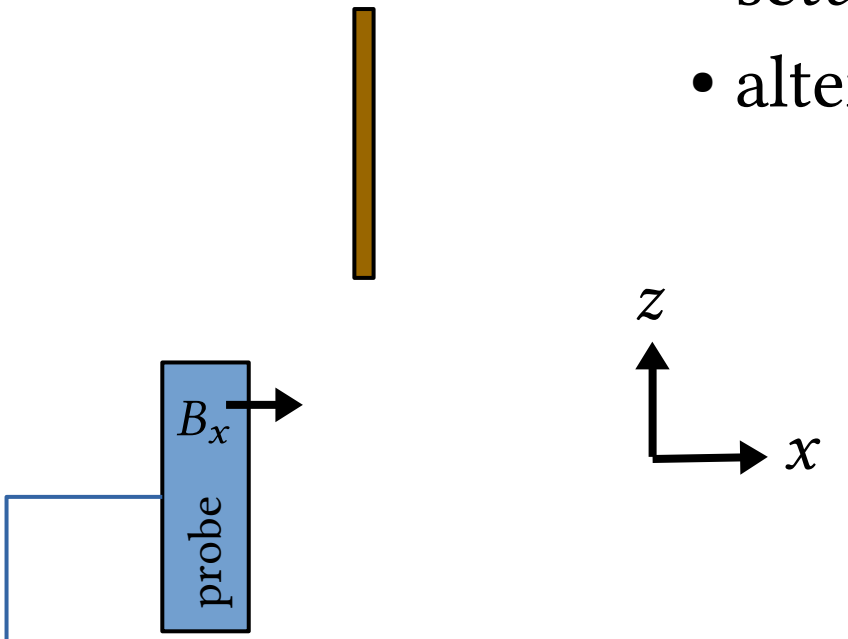
- superconducting lead (T_c = 7.2 K) for **B** field uniformity
- thermally-shielded warm bore to map **B** field
- copper plating on G-10 for insulation
- can't interfere with **B** field

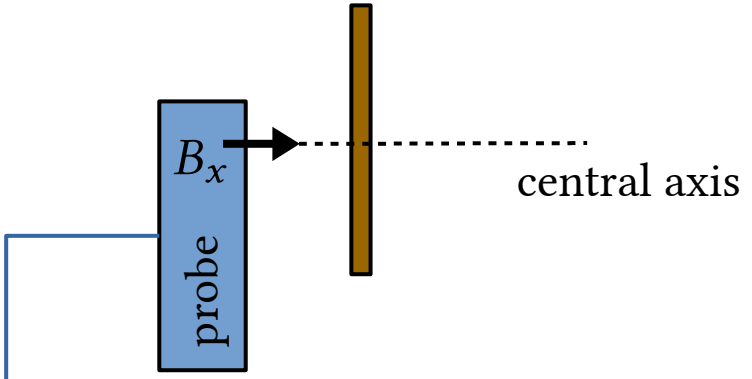
Our Thermal Shield



- strands of copper held together by epoxy
- currents can't jump between insulated strands
- no large-scale eddy currents
- measure **B** field interference and compare with copper plate

- setup inside B_0 coil driven by AC
- alternating field in x direction



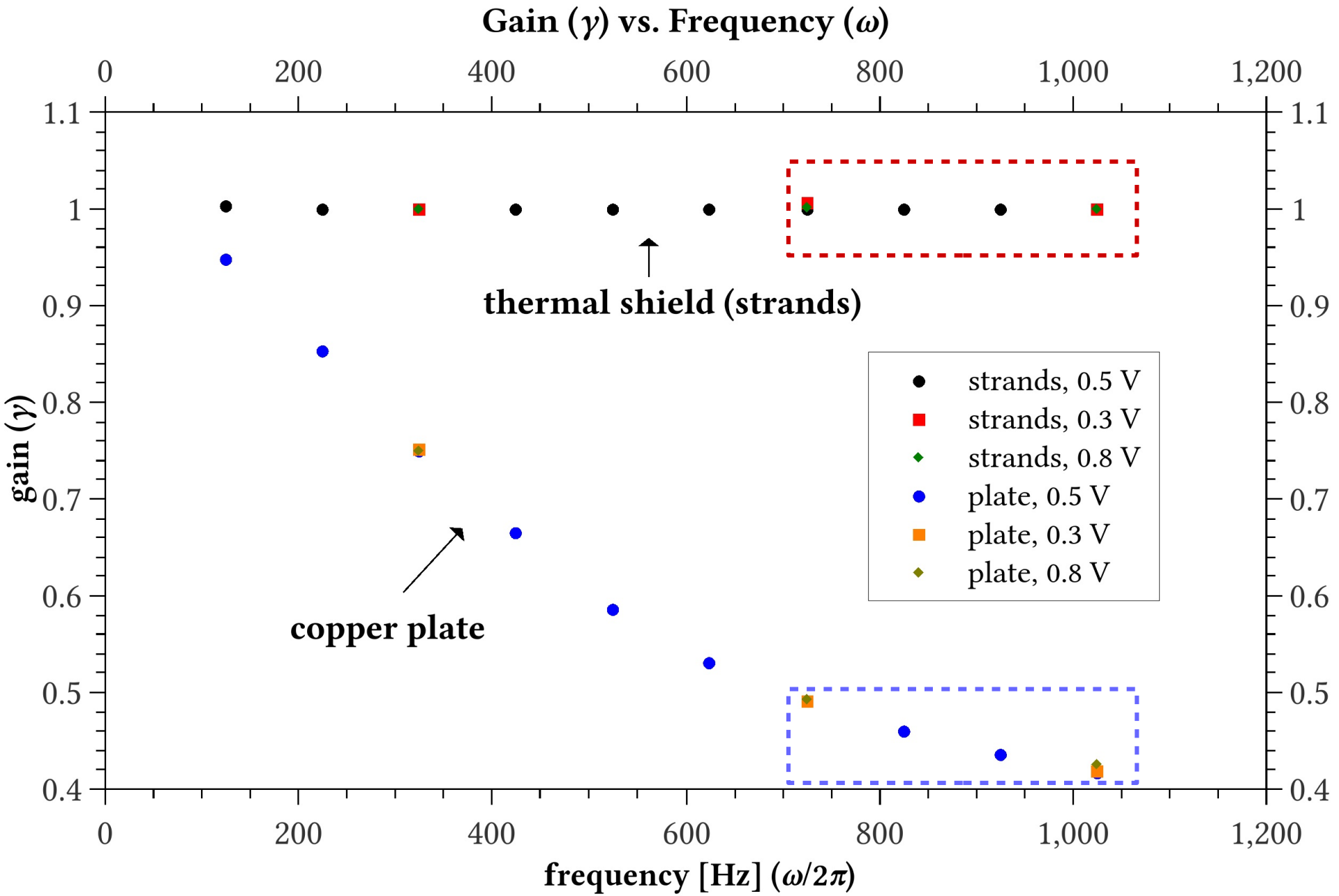


$$B_x = B_0 \cos(\omega t + \psi)$$

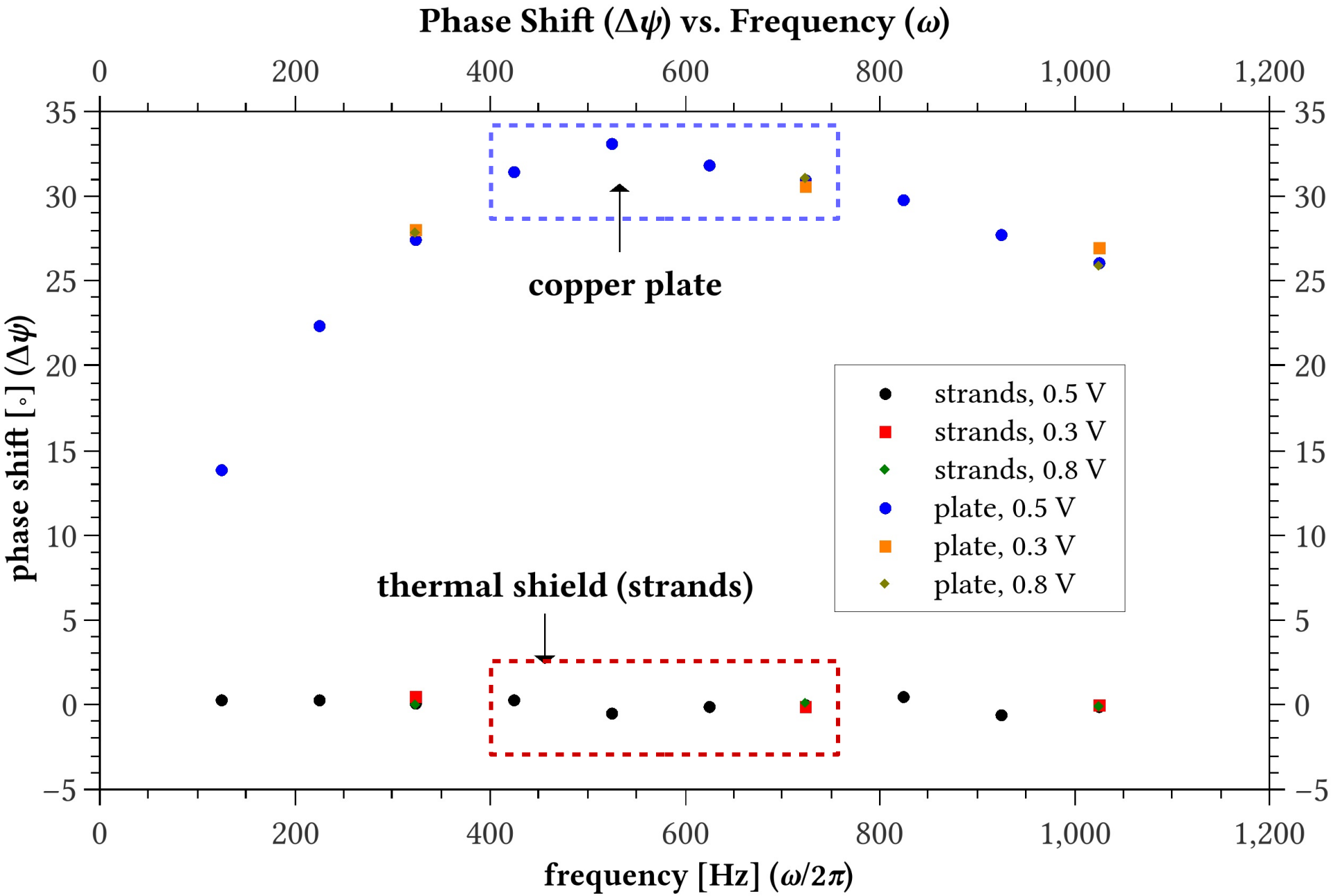
$$B'_x = B'_0 \cos(\omega t + \psi')$$

gain: $\gamma \equiv \dfrac{B'_0}{B_0}$

phase shift: $\Delta\psi \equiv \psi' - \psi$



$$\text{sensitivity} \approx \frac{\text{blue rectangle}}{\text{red rectangle}} = 0.454 \pm 0.0001$$

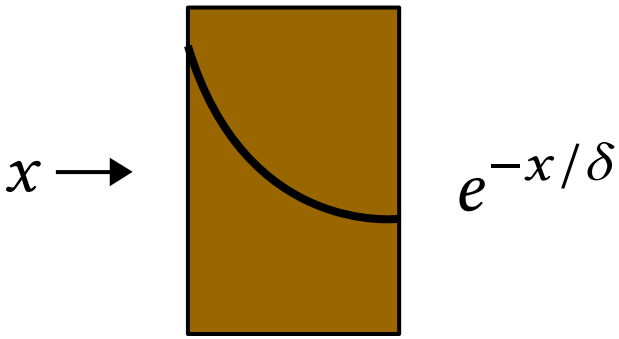


$$\text{sensitivity} \approx \frac{\text{red rectangle}}{\text{blue rectangle}} = 1.6 \times 10^{-3} \pm 1.2 \times 10^{-5}$$

Predicting $\gamma(\omega)$ and $\Delta\psi(\omega)$

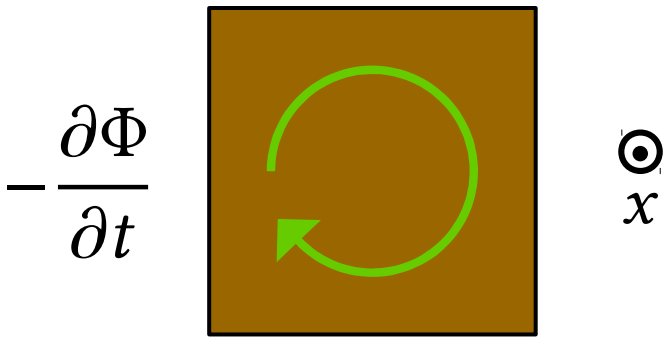
$$B_{x,\text{applied}} = B_0 \cos(\omega t + \psi)$$

skin depth shielding



$$\beta B_0 \cos(\omega t + \psi)$$

induction on plane



$$\alpha B_0 \sin(\omega t + \psi)$$

$$B_{x,\text{final}} = \gamma B_0 \cos(\omega t + \psi + \Delta\psi)$$

$$\gamma = \sqrt{\alpha^2 + \beta^2} \qquad \Delta\psi = -\arctan(-\alpha/\beta)$$

Remarks

- phase shift sensitivity in 400-800 Hz range:

$$1.6 \times 10^{-3} \pm 1.2 \times 10^{-5}$$

- shielding parameters:

$$\beta \sim \frac{1 + e^{-c/\delta}}{2} \qquad \alpha \sim \omega e^{-c/2\delta} \sinh\left(\frac{c}{\delta}\right)$$

$$\delta = \sqrt{\frac{2\rho}{\omega \mu_r \mu_0}}$$