# Effectiveness of a superconducting lead endcap in minimizing magnetic field gradients for the nEDM search

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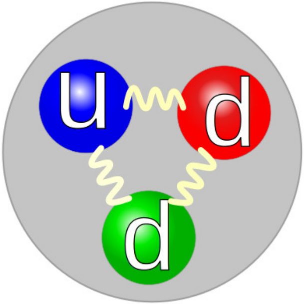
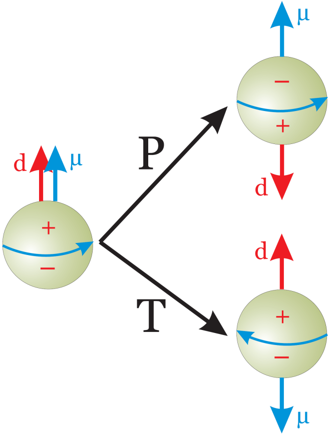
# nEDM = neutron electric dipole moment

- up quark: $\frac{2}{3}e$
- each down quark: -$\frac{1}{3}e$
- electric dipole moment: vector measuring separation between + and - charges and their orientation




Horvath A. Quark structure neutron. Wikimedia.

# why does the nEDM matter?




- $C : q \mapsto -q$

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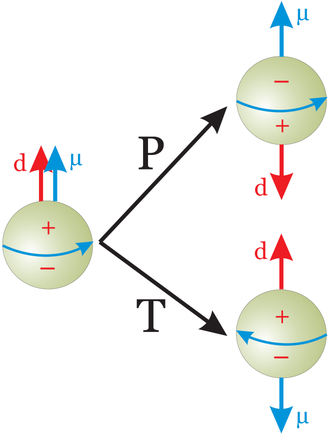


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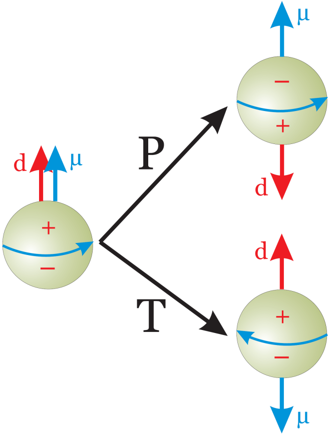


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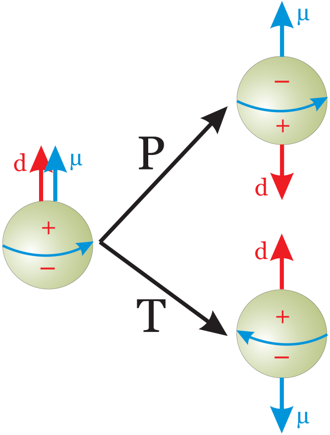


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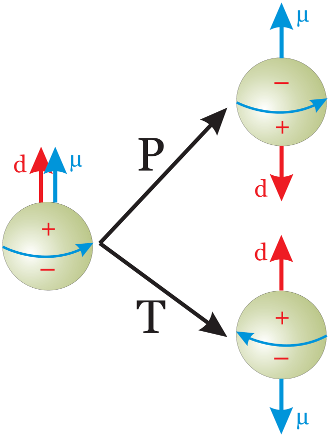


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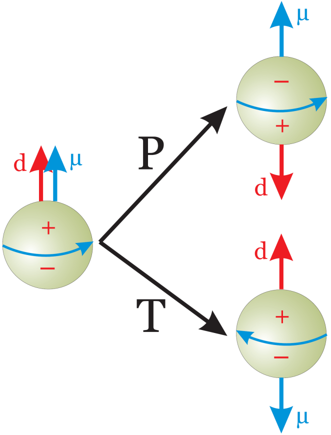


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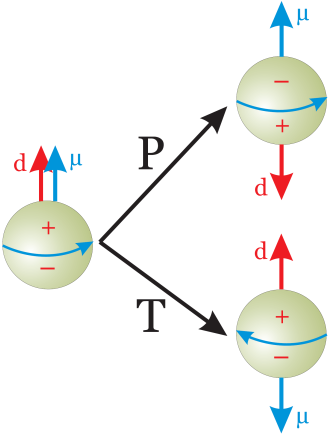


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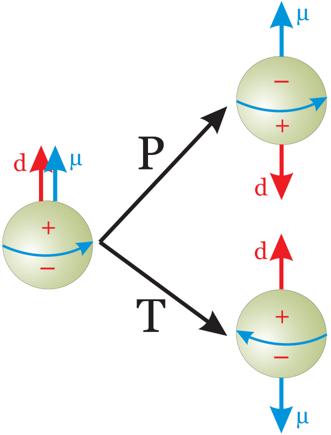


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- reformulations of Standard Model
- matter-antimatter asymmetry

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# how do we measure the nEDM?

- put ultra-cold neutrons (UCN) in **E** and **B** fields

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Pendlebury et. al. Geometric-phase-induced false electric dipole moment signals for particles in traps. Phys. Rev. A. 70, 032102 (2004).

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- geometric phase $\Rightarrow$ false measurement!

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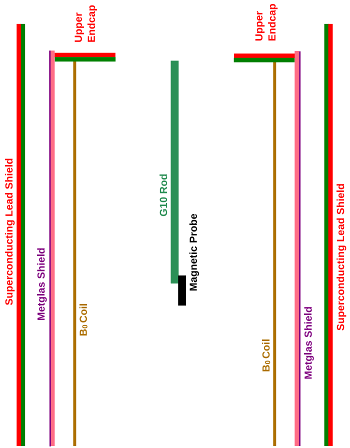
# creating an uniform magnetic field



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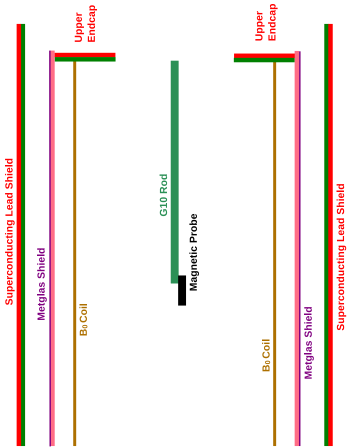


- $B_0$ coil: $\cos\theta$ coil geometry, emulates sheet current

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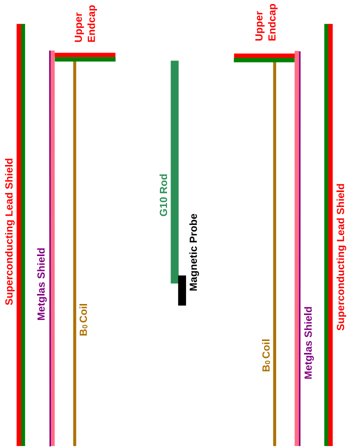


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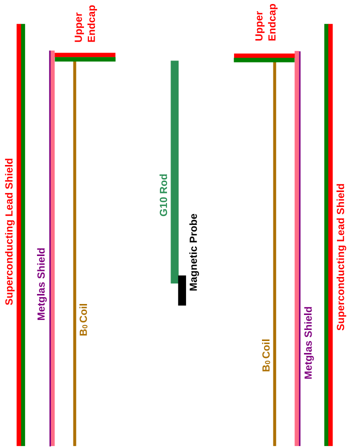


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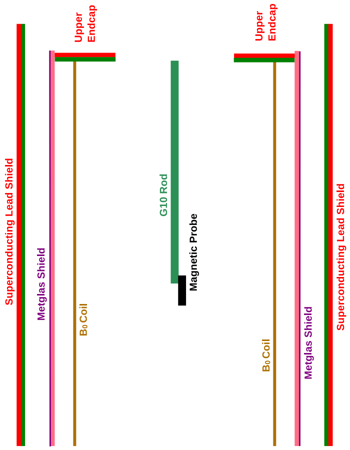
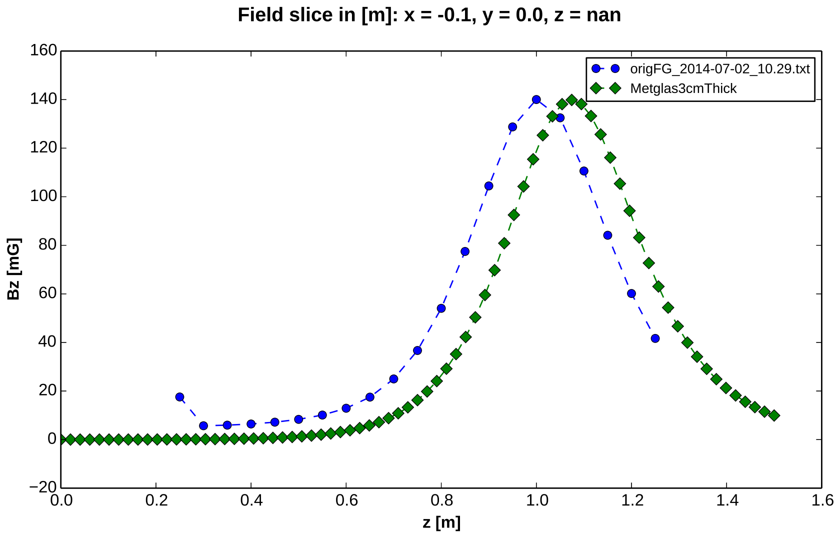
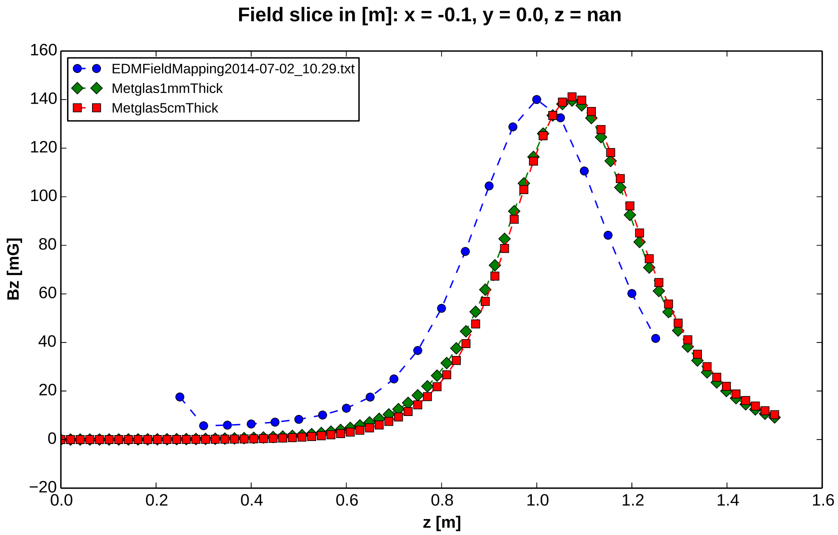



- $B_0$ coil: $\cos\theta$ coil geometry, emulates sheet current
- ferromagnetic Metglas shield
- superconducting axial shield
- superconducting upper endcap

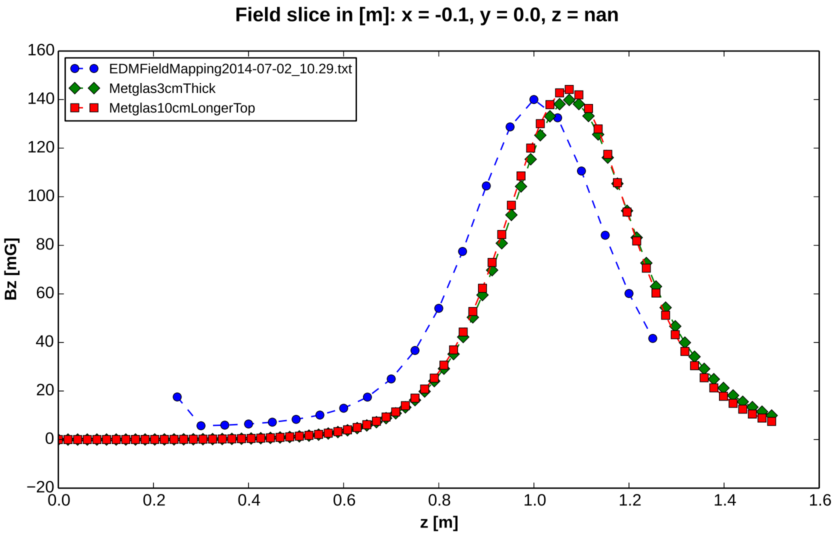
# original comparison, warm



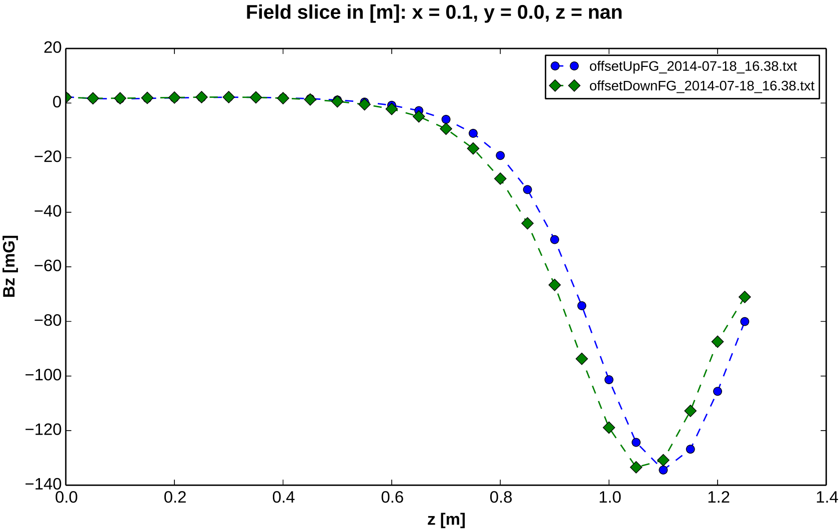
# Metglas thickness



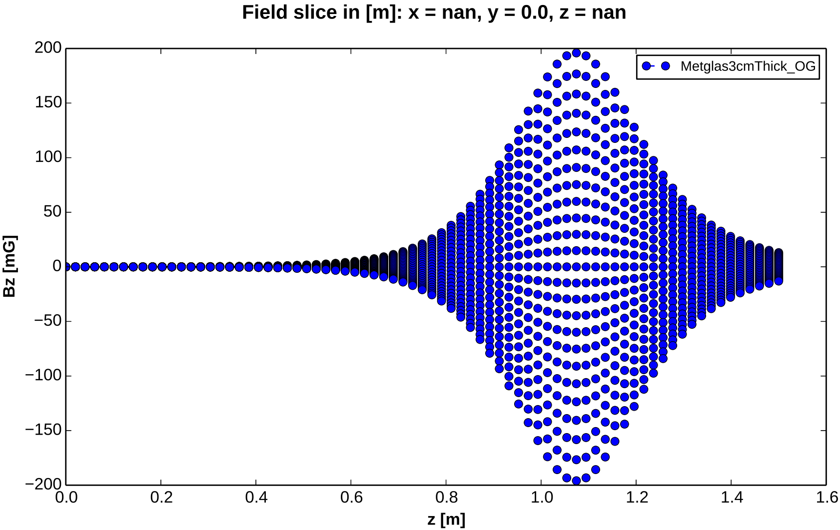
# Metglas 10 cm longer on top



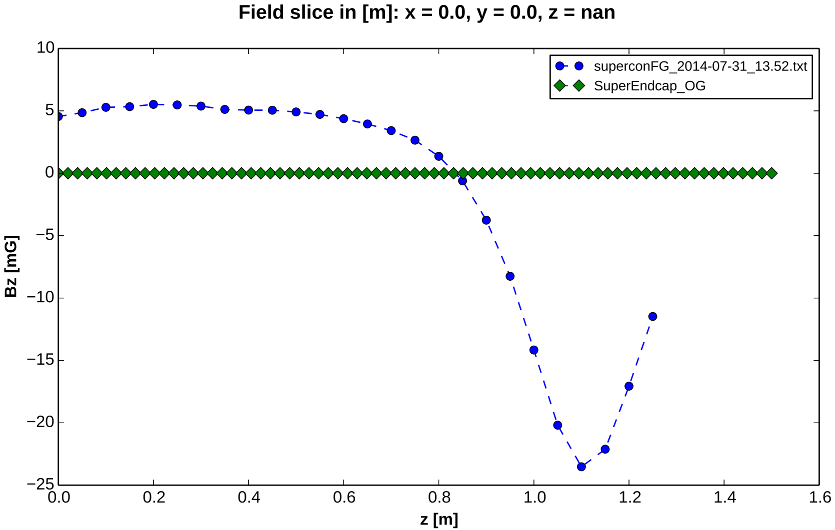
# correction 1: probe measurement time



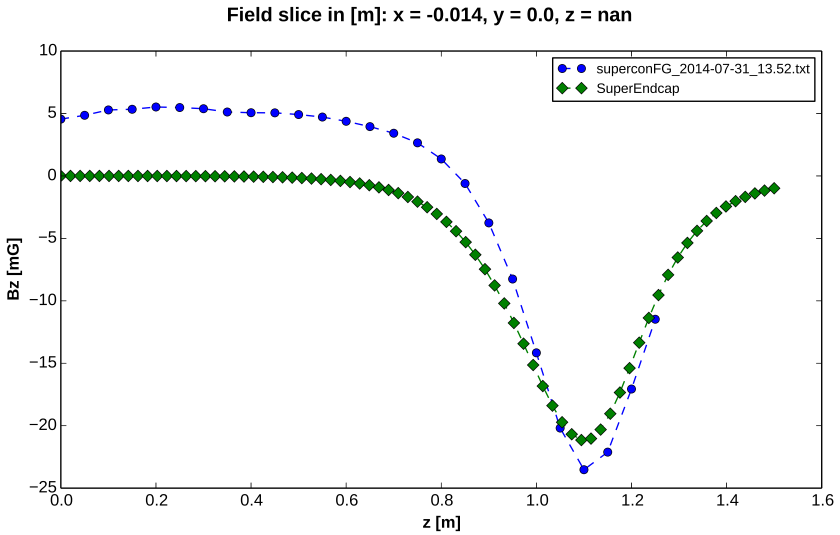
# correction 2: $x$ centering



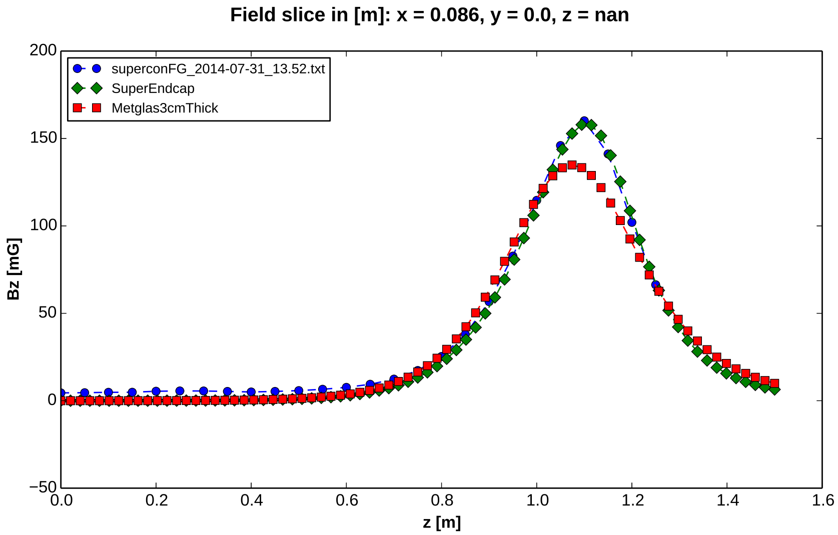
# correction 2: $x$ centering, superconducting



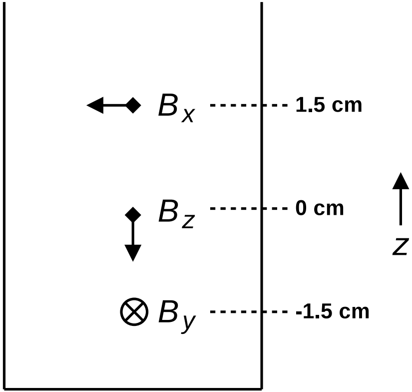
# correction 2: $x$ centering, superconducting, 1.4 cm offset



# comparison, superconducting



# correction 3: probe axis offset




- 3 separate 1-axis probes

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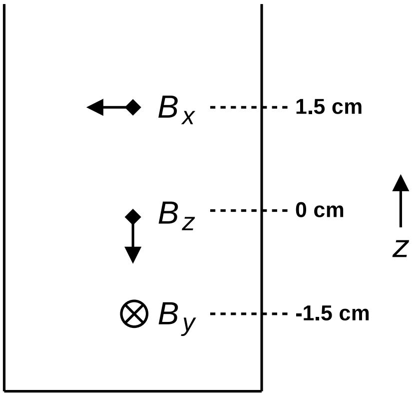


- 3 separate 1-axis probes
- incomplete vector map

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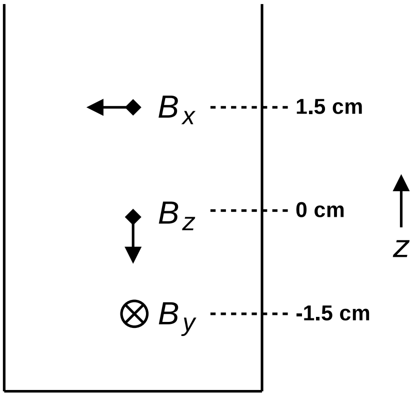


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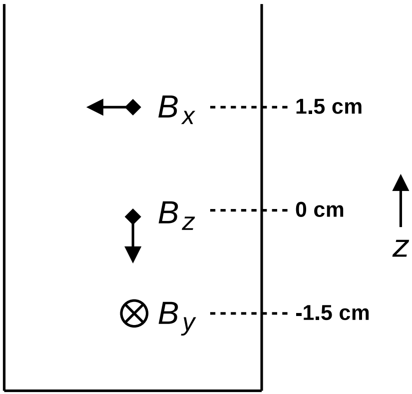


- 3 separate 1-axis probes
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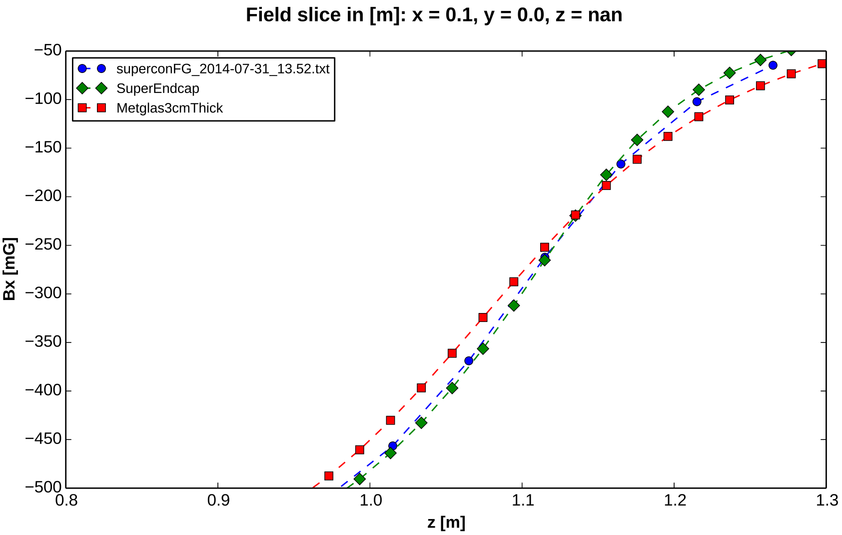
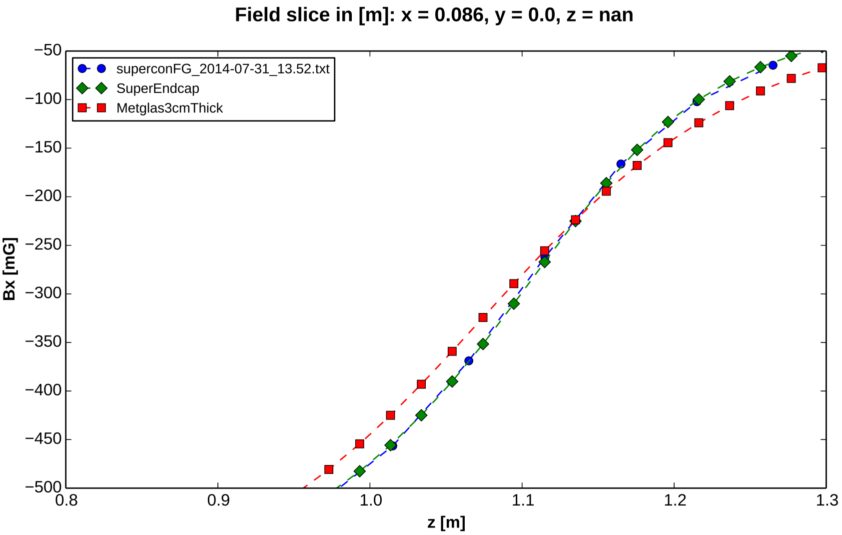
- need to store $z$-axis offset vector along with $z$ array
- `OffsetAxis` class to return proper spatial axis array based on desired vector component

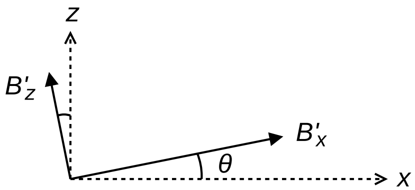
# comparison, superconducting, no offsets



# comparison, superconducting, $x$-centering and axis offset



# correction 4: probe tilt



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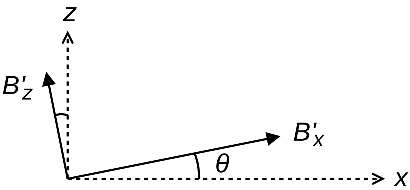


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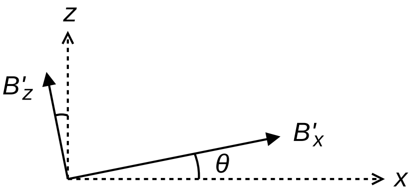


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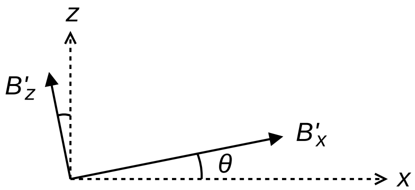


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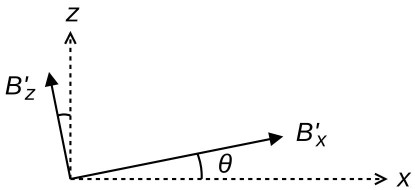


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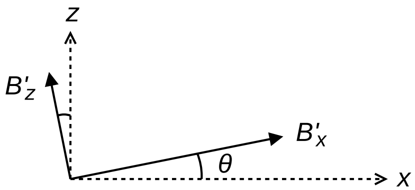


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$$\theta = -\frac{B'_z}{B'_x}$$

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