

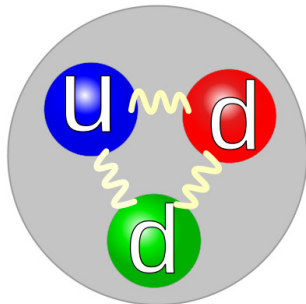
# Effects of a superconducting lead endcap on the magnetic field profile for the nEDM search

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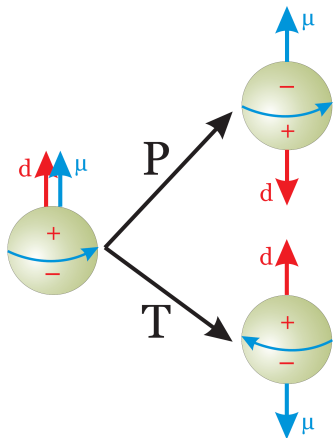
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# nEDM = neutron electric dipole moment

- ▶ 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



# why does the nEDM matter?



- ▶  $C : q \mapsto -q$
- ▶  $P : (t, x, y, z) \mapsto (t, -x, -y, -z)$
- ▶  $T : (t, x, y, z) \mapsto (-t, x, y, z)$
- ▶  $CPT$  symmetry
  - +  $P$  violation
  - +  $T$  violation
  - $\Rightarrow CP$  violation
- ▶ reformulations of Standard Model
- ▶ matter-antimatter asymmetry

## how do we measure the nEDM?

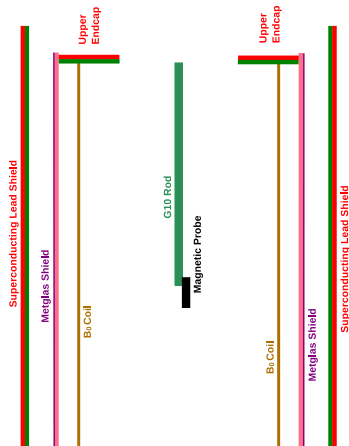
- ▶ put ultra-cold neutrons (UCN) in  $\mathbf{E}$  and  $\mathbf{B}$  fields
- ▶ neutron will precess at frequency  $\omega$

$$\omega_{\uparrow\uparrow} = -\frac{\mu_n B + d_n E}{J\hbar}, \quad \omega_{\uparrow\downarrow} = -\frac{\mu_n B - d_n E}{J\hbar} \quad (1)$$

$$\Delta\omega = \pm \frac{2d_n E}{J\hbar} \pm \Delta\omega_{geo} \quad (2)$$

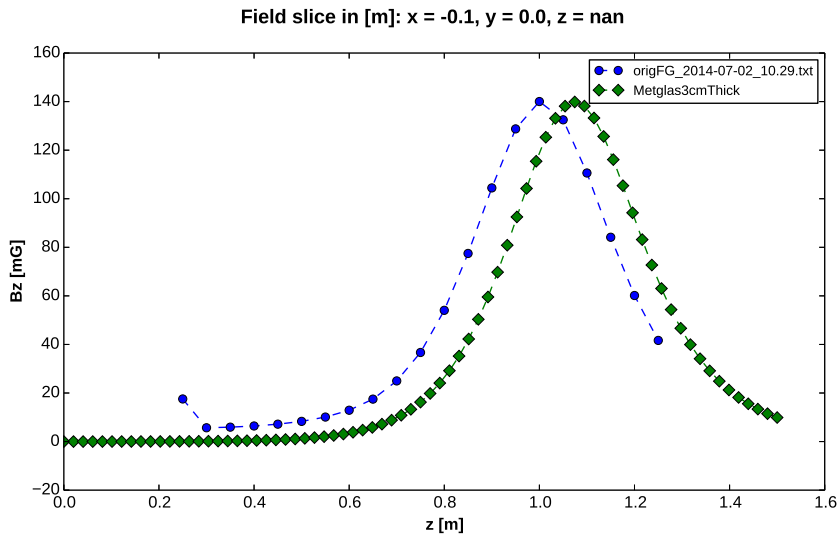
- ▶  $\frac{\partial \mathbf{B}}{\partial(x,y,z)} \neq 0 \Rightarrow \frac{\partial \mathbf{B}}{\partial t} \neq 0 \Rightarrow$  effect of  $\mathbf{E}$  field  $\Rightarrow \Delta\omega_{geo}$
- ▶ geometric phase  $\Rightarrow$  false measurement!

# creating an uniform magnetic field



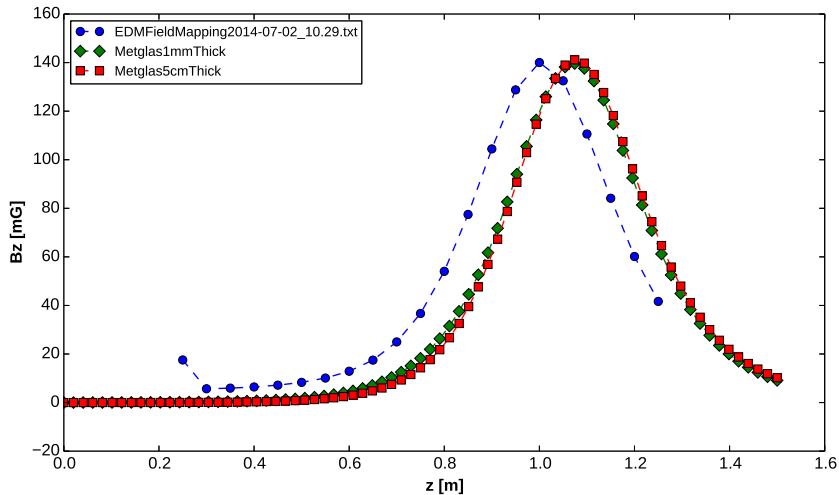
- ▶  $B_0$  coil:  $\cos \theta$  coil geometry, emulates sheet current
- ▶ ferromagnetic Metglas shield
- ▶ superconducting axial shield
- ▶ superconducting upper endcap

# original comparison, warm



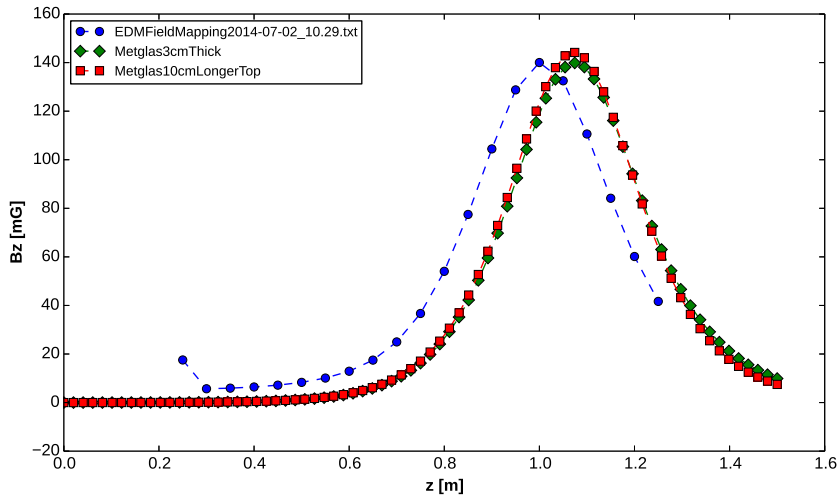
# Metglas thickness

Field slice in [m]:  $x = -0.1$ ,  $y = 0.0$ ,  $z = \text{nan}$



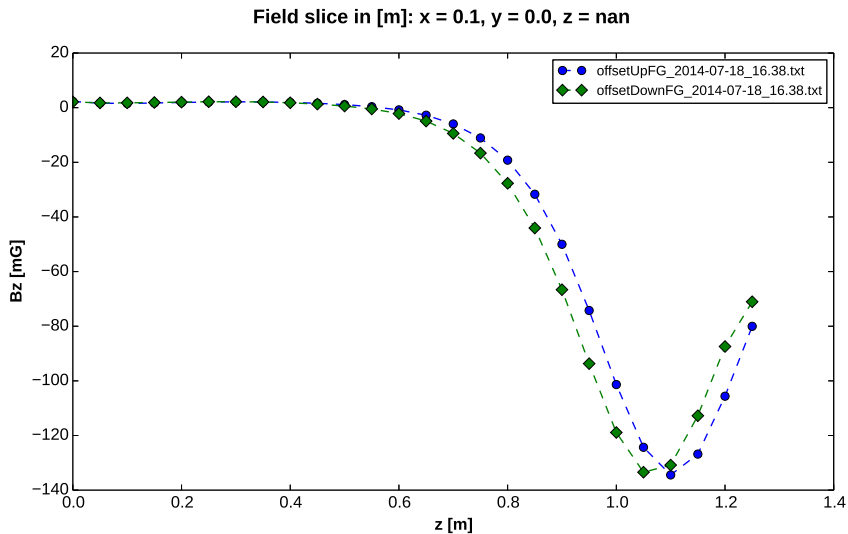
# Metglas 10 cm longer on top

Field slice in [m]:  $x = -0.1$ ,  $y = 0.0$ ,  $z = \text{nan}$

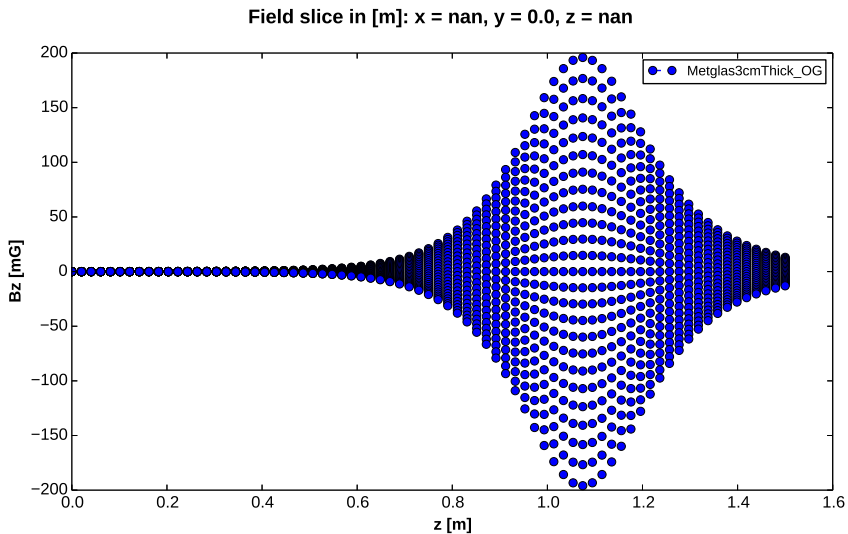




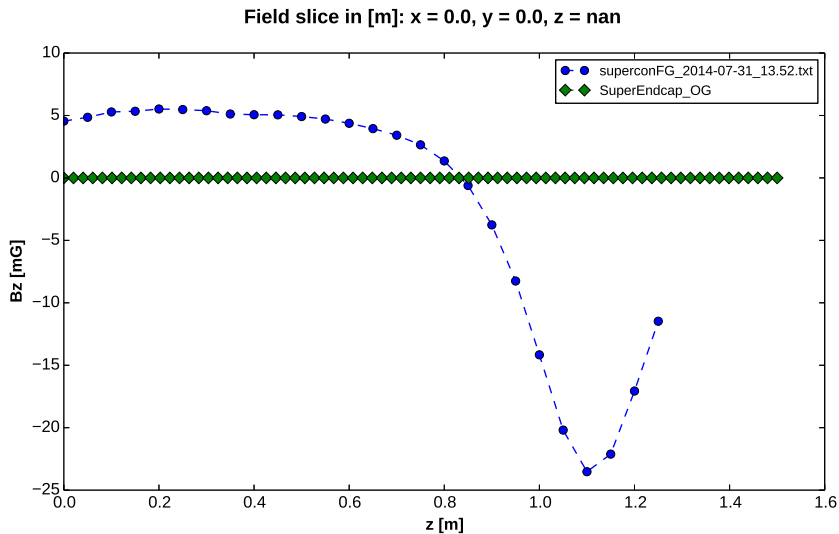
## correction 1: probe measurement time



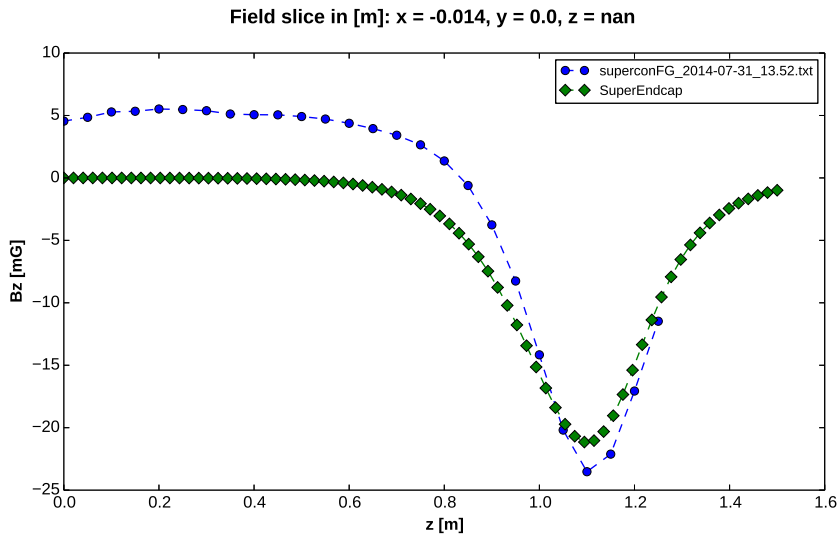
## correction 2: x centering



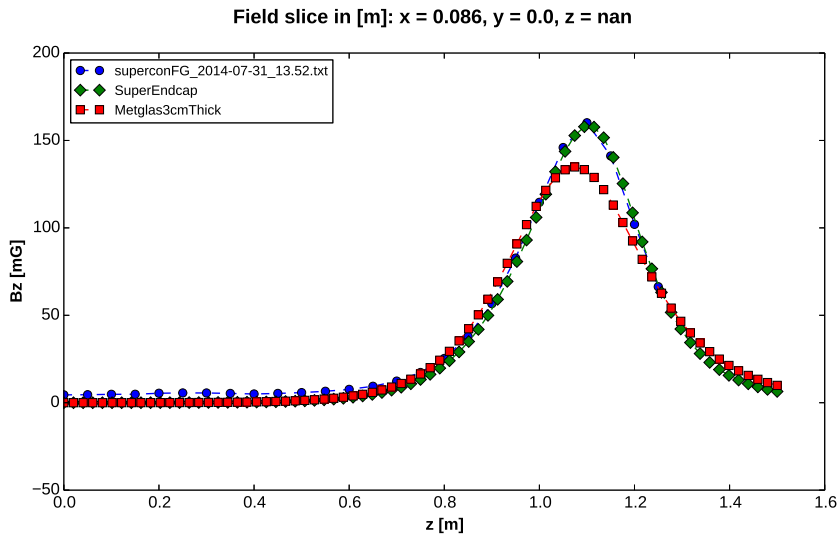
## correction 2: x centering, superconducting



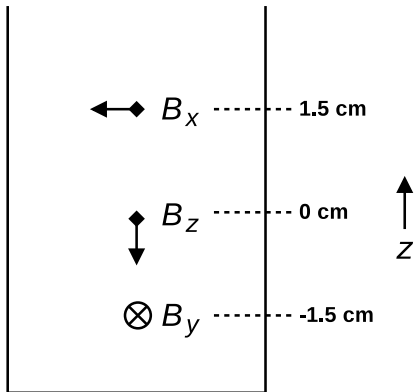
## correction 2: x centering, superconducting, 1.4 cm offset



# comparison, superconducting

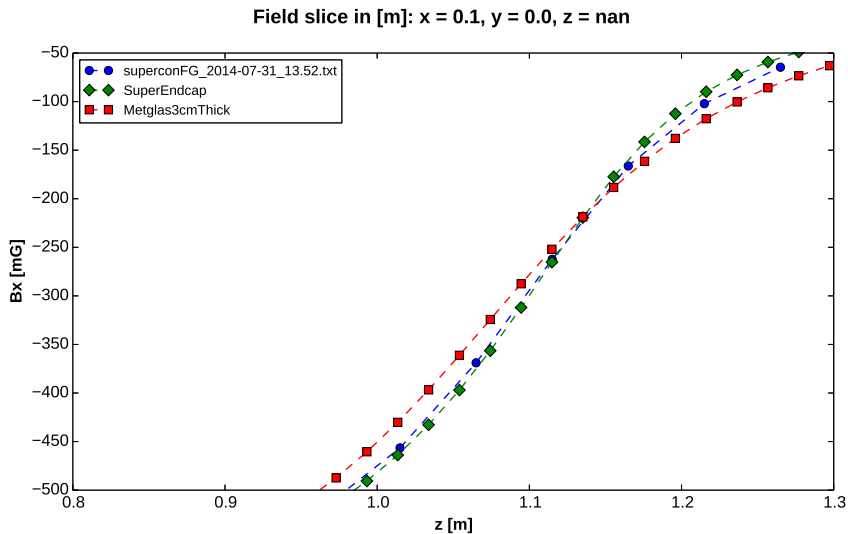


## correction 3: probe axis offset

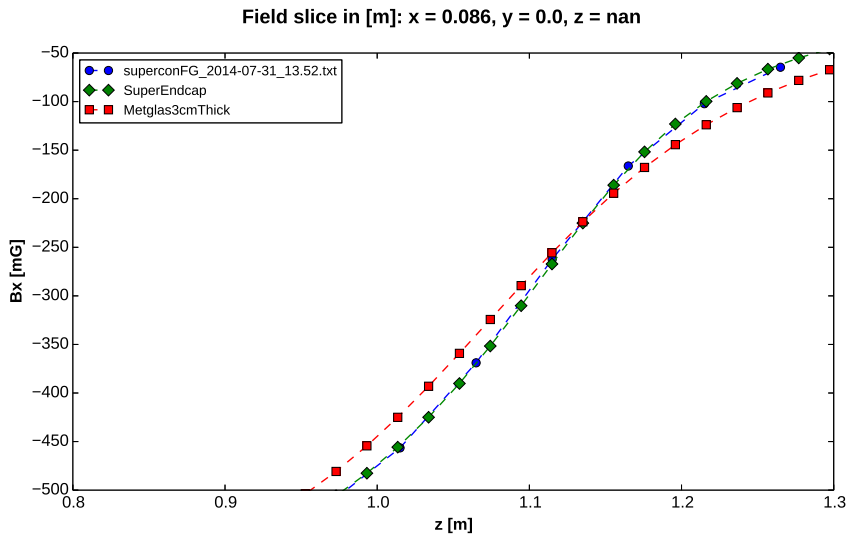


- ▶ 3 separate 1-axis probes
- ▶ incomplete vector map
- ▶ need to store z-axis offset vector along with z array
- ▶ `OffsetAxis` class to return proper spatial axis array based on desired vector component

# comparison, superconducting, no offsets

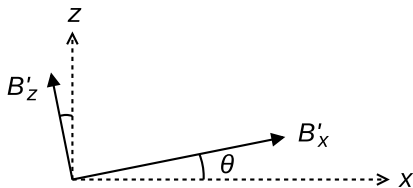


# comparison, superconducting, x-centering and axis offset





## correction 4: probe tilt



$$B_x = B'_x \cos \theta - B'_z \sin \theta, \quad B_z = B'_z \cos \theta + B'_x \sin \theta \quad (3)$$

1.  $\theta$  is small:

$$B_x = B'_x - B'_z \theta, \quad B_z = B'_z + B'_x \theta$$

2.  $B_z = 0$  at center:

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

# comparison, superconducting

Field slice in [m]:  $x = 0.086$ ,  $y = 0.0$ ,  $z = \text{nan}$

