What Do We Know about the Fundamental Forces?

- The Universe is made of quarks, leptons and force carriers.

name	field or force carried by boson	spin	electric charge	mass (MeV/c^2)
photon	electromagnetism *(light)*	1	0	0
W **Z**	weak force *(radioactivity)*	1	+1,-1 0	80400 91200
gluon	strong force *(nuclear force or color force)*	1	0	0
graviton *[predicted]*	gravity	2	0	0

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, …

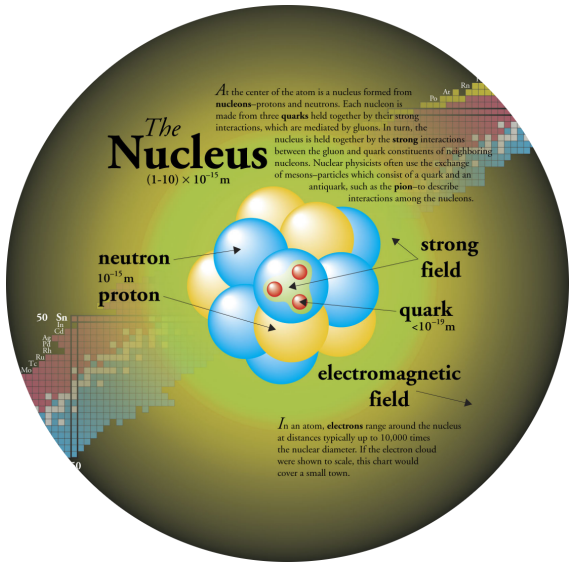
Leptons spin =1/2

Flavor	Mass GeV/c^2	Electric charge
ν_L lightest neutrino*	$(0-2)\times10^{-9}$	0
e electron	0.000511	−1
ν_M middle neutrino*	$(0.009-2)\times10^{-9}$	0
μ muon	0.106	−1
ν_H heaviest neutrino*	$(0.05-2)\times10^{-9}$	0
τ tau	1.777	−1

Quarks spin =1/2

Flavor	Approx. Mass GeV/c^2	Electric charge
u up	0.002	2/3
d down	0.005	−1/3
c charm	1.3	2/3
s strange	0.1	−1/3
t top	173	2/3
b bottom	4.2	−1/3

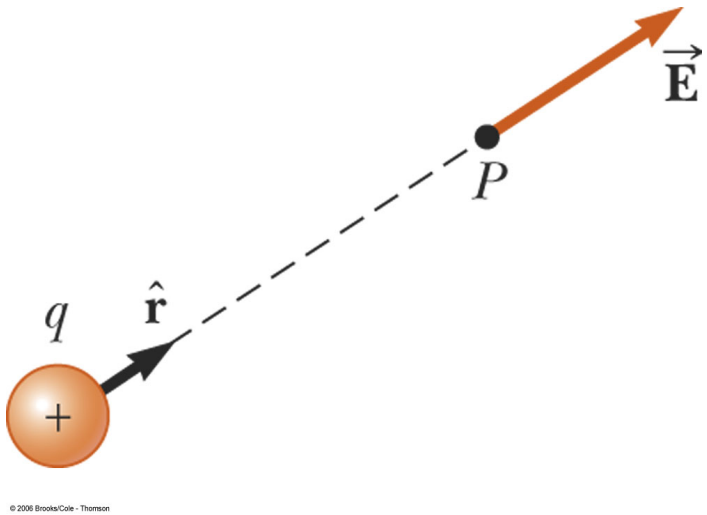
- The atomic nucleus is made of protons and neutrons bound by the strong force.



- The quarks are confined inside the protons and neutrons.
- Protons and neutrons are NOT confined.

The Electric and Magnetic Fields

$$d\vec{E} = k_e \frac{dq\hat{r}}{r^2}$$



The Electric and Magnetic Fields

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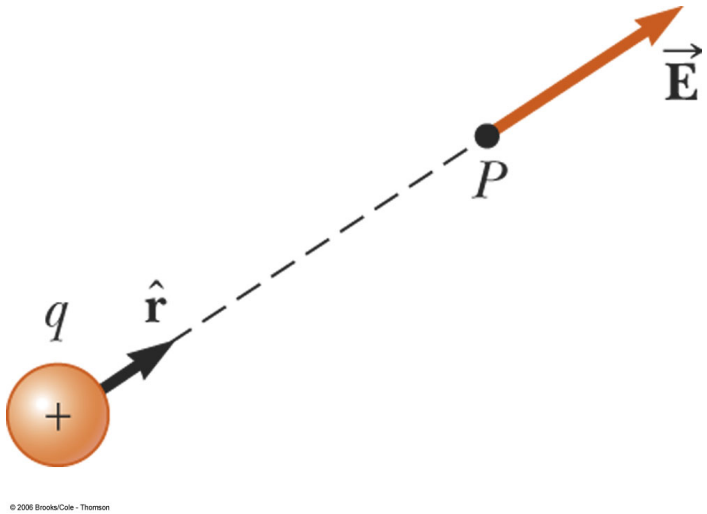
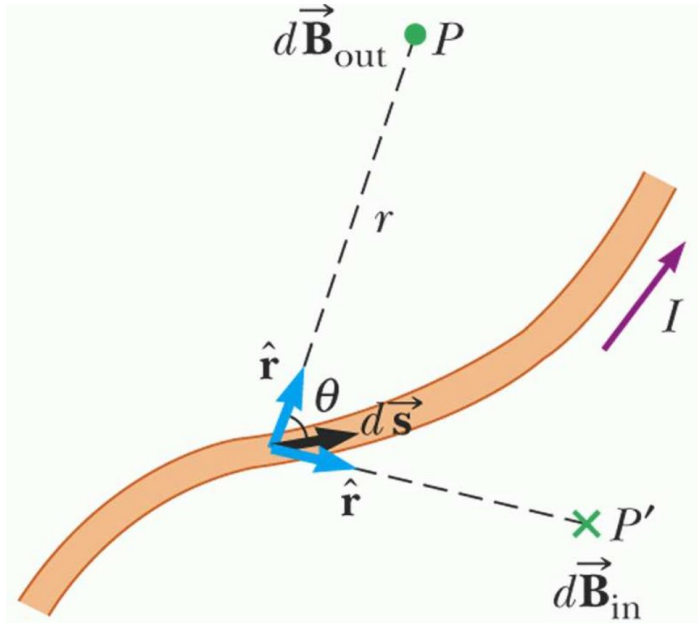
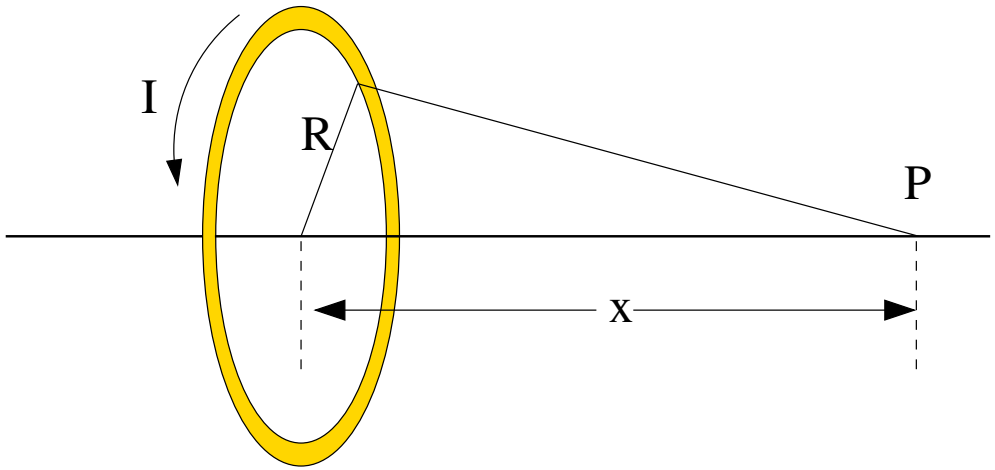


$$d\vec{B} = k_m \frac{Id\vec{s}\times\hat{r}}{r^2}$$

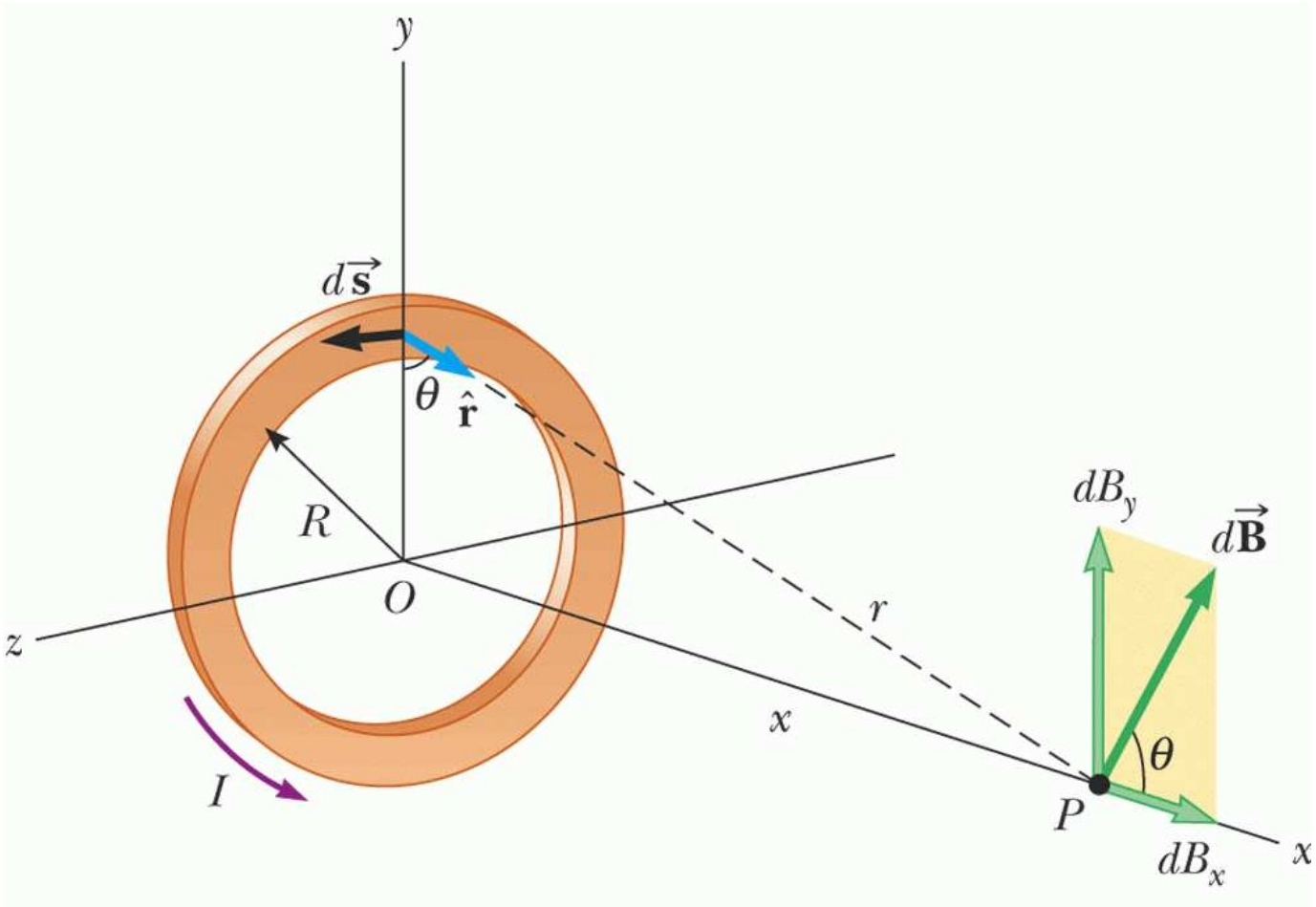


The Magnetic Field of a Current Loop

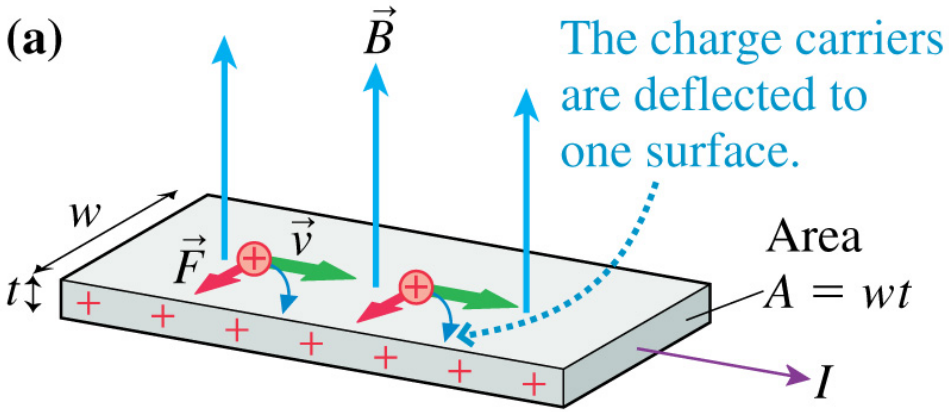
Consider a circular loop of radius R located in the $y - z$ plane and carrying a steady current I. What is the magnetic field at an axial point P a distance x from the center of the loop in terms of I, R, x, and any other constants?

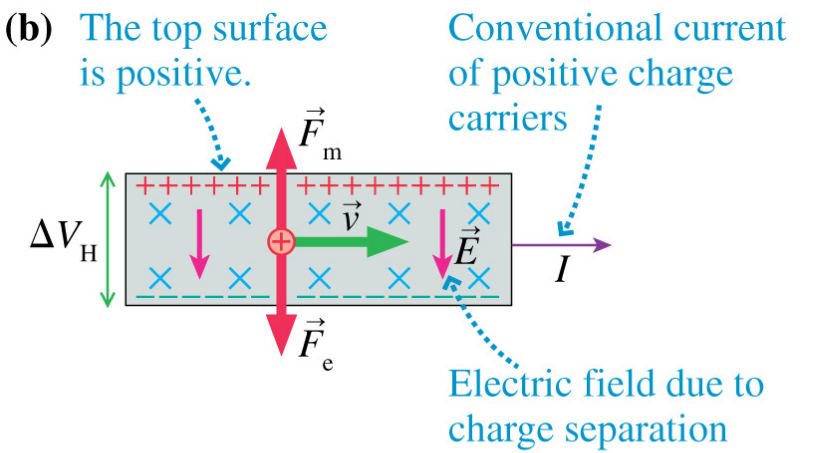


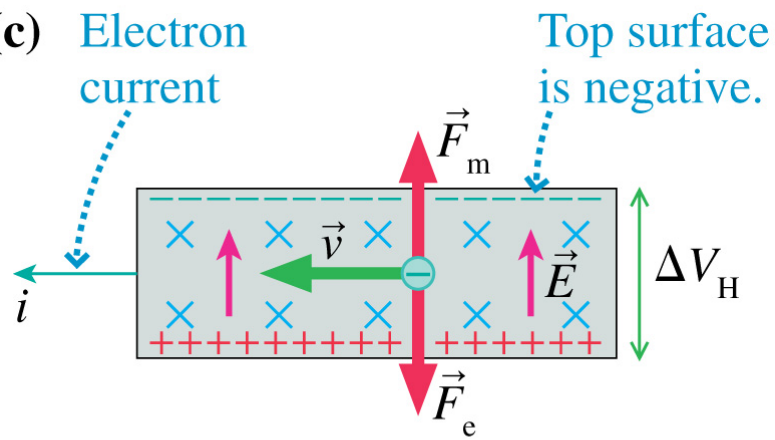
The Magnetic Field of a Current Loop



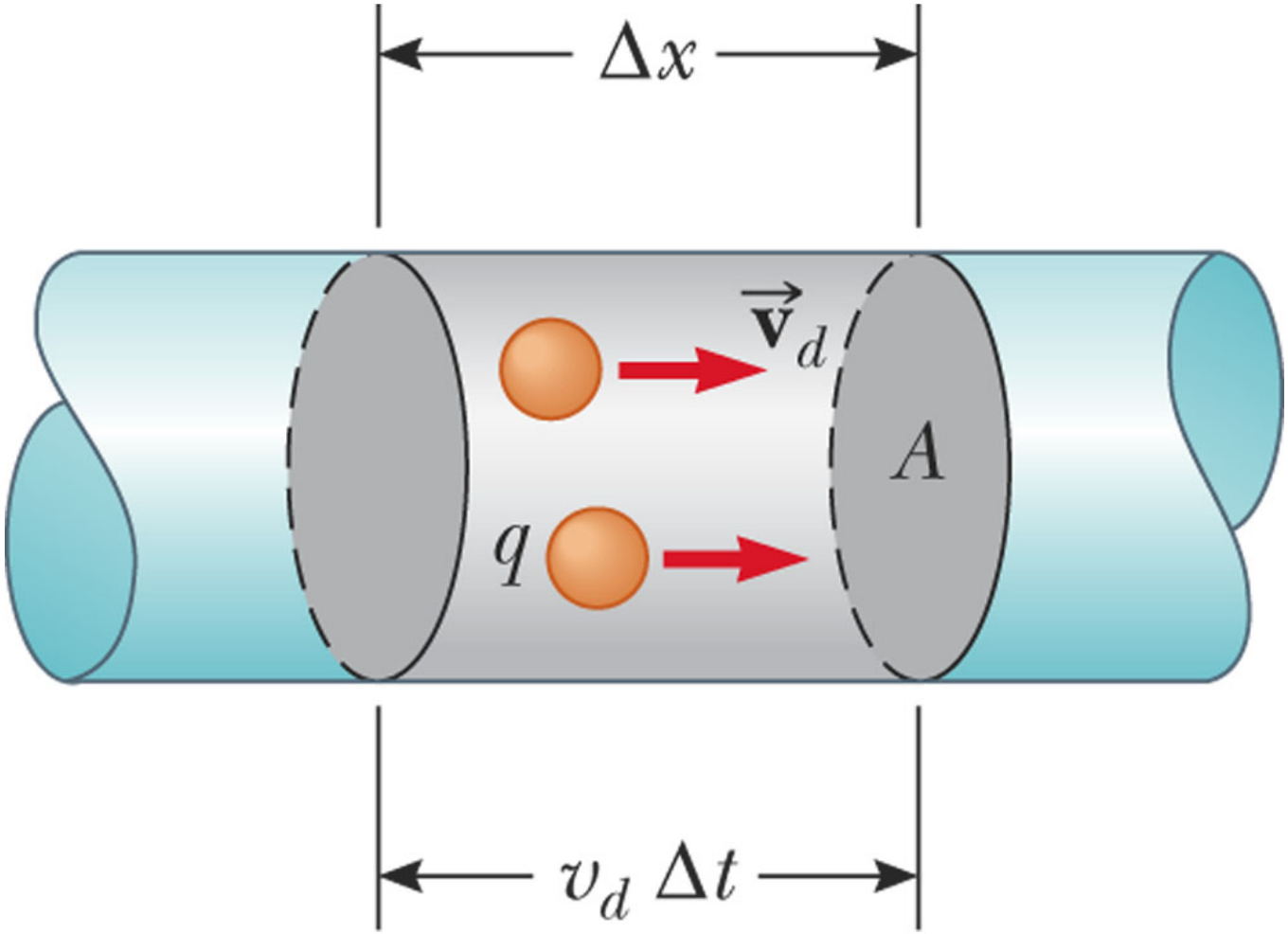
How the Sensor Works - The Hall Effect



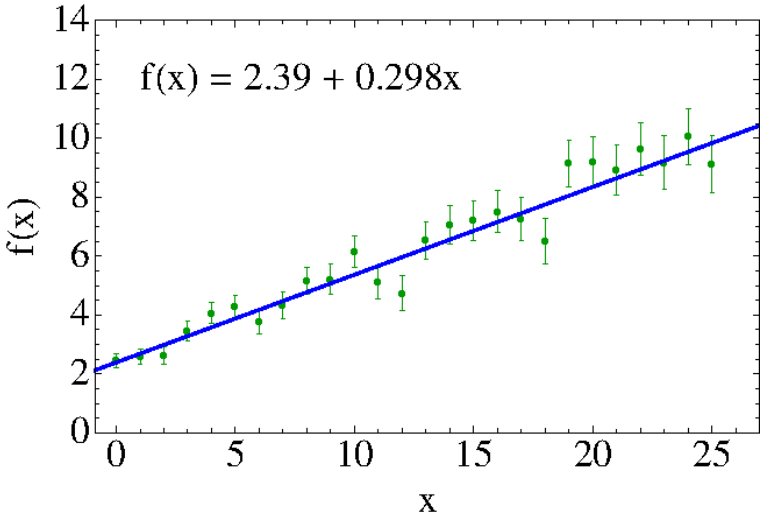


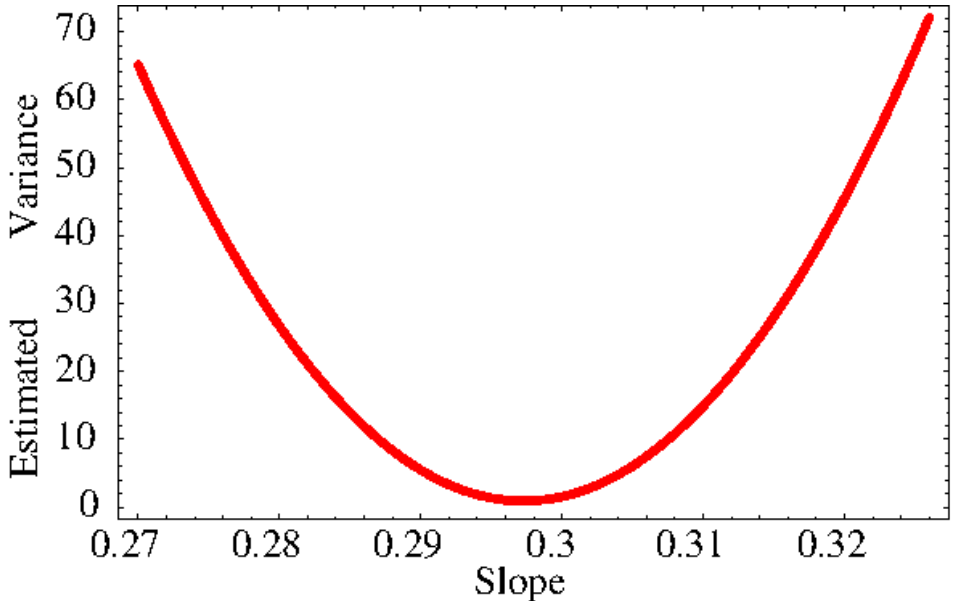


How the Sensor Works - Electric Current



Fitting the Data





In the plot above the value of the y-intercept is kept at its best fit value and the slope is varied. The estimated variance is the following.

$$\sigma^2 = \frac{\sum_{i=1}^{N}(y_i - (mx_i + b))^2}{N - d.o.f}$$

where N is the number of data points and $d.o.f$ is the number of degrees of freedom (*i.e.* free parameters) in the fit.

Using the Reduced χ^2

The χ^2 and reduced χ^2 are

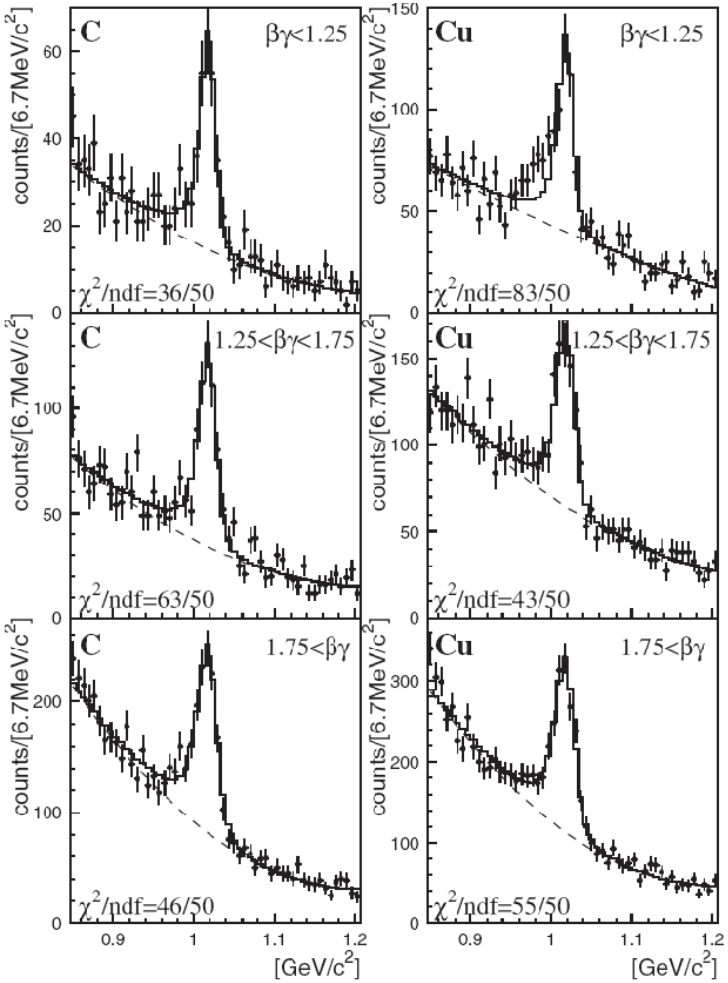
$$\chi^2 = \sum_{i=1}^{N} \frac{((y_i - f(x_i))^2}{\sigma_i^2}$$

and

$$\textit{reduced } \chi^2 = \frac{\chi^2}{N - d.o.f}$$

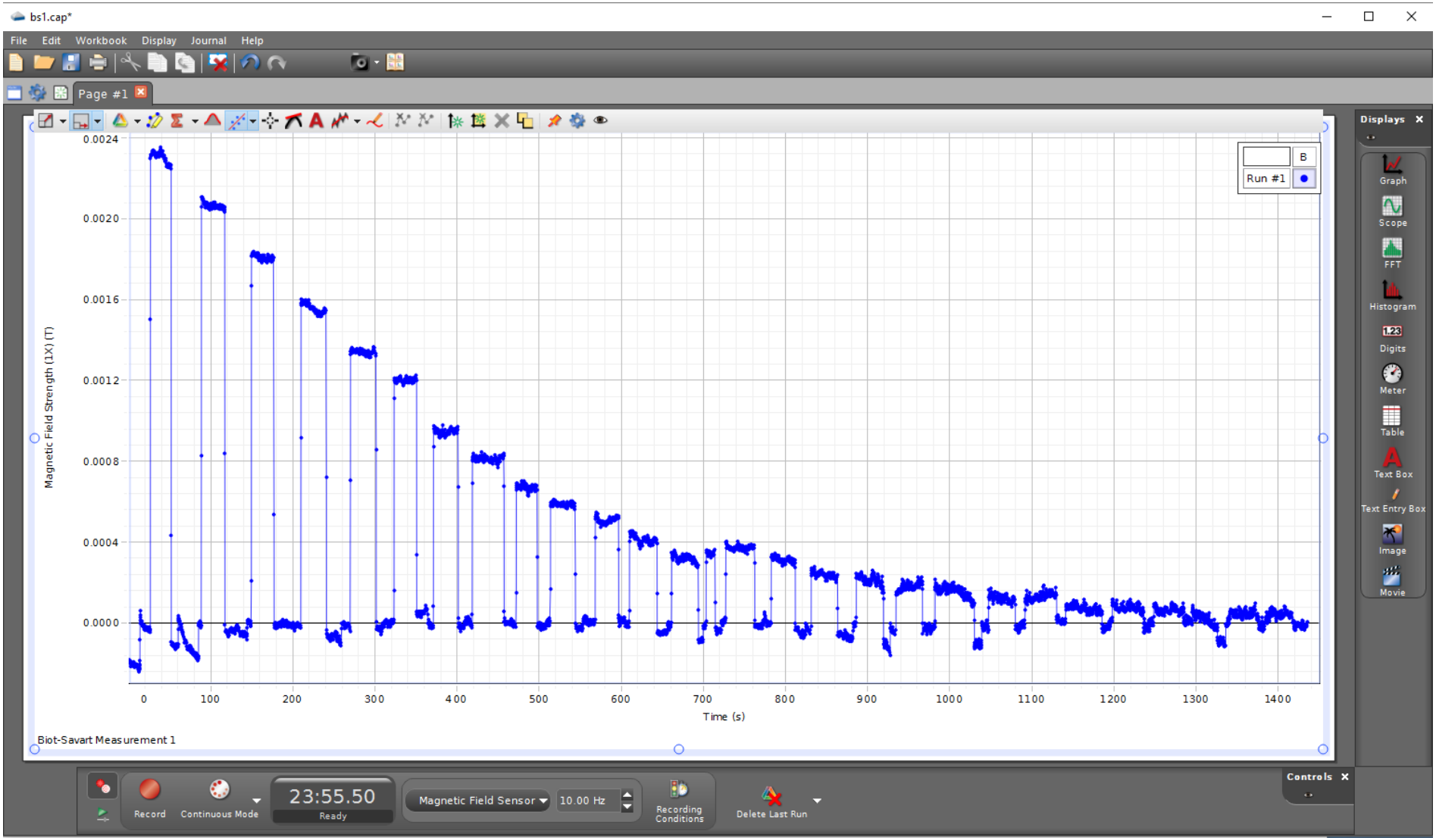
where N is the number of data points. In *Mathematica* the estimated variance is equal to the reduced χ^2 if the proper weighting is used.

$$pA \rightarrow e^+e^-X$$

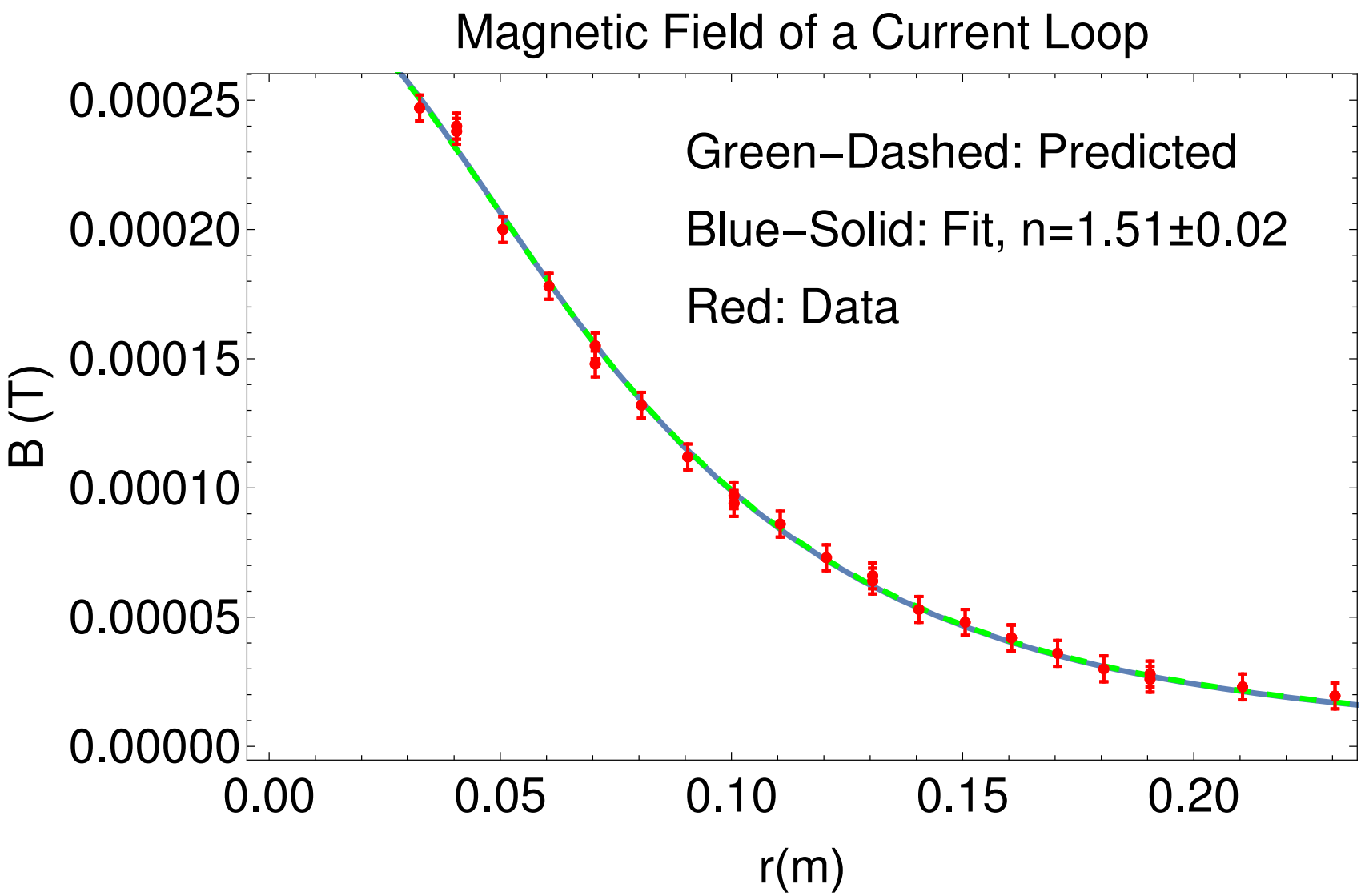


R. Muto *et al.*, *Evidence for In-Medium Modification of the ϕ Meson at Normal Nuclear Density*, Phys. Rev. Lett., **98**, 042501 (2007).

Using the Pasco Hall Probe

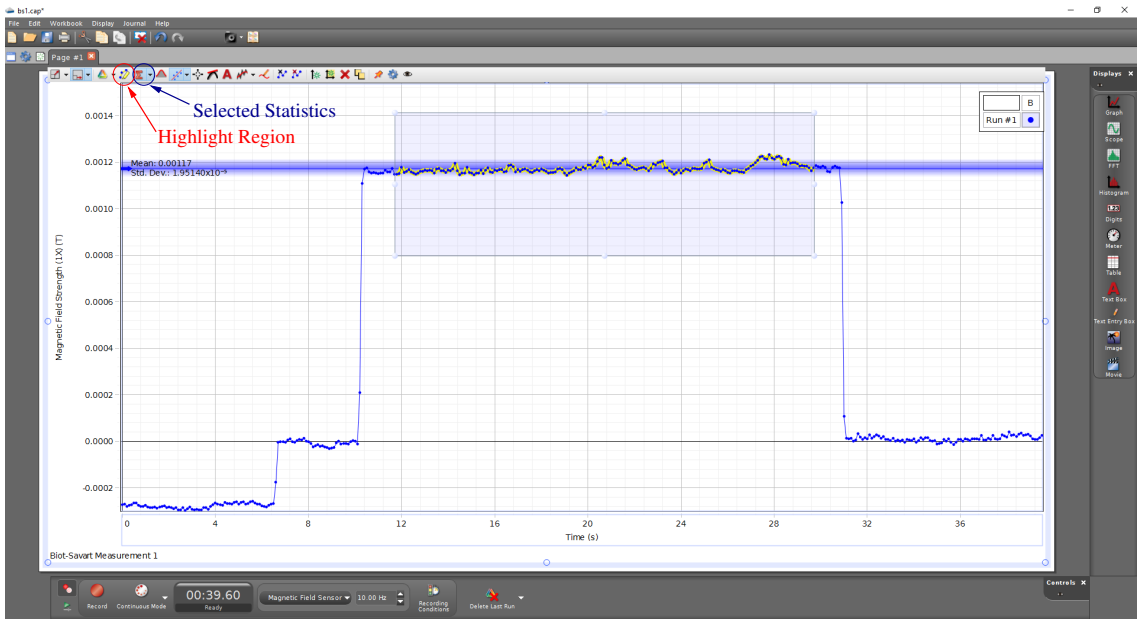


Biot-Savart Results



Averaging a Data Range in *Capstone*

- Zoom in on the data range of interest.
- Click on **Highlight Region** in the *Capstone* menu bar and use the box to select the data range. See the figure.
- Click on **Selected Statistics**. Check **Mean**, and **Standard Deviation**. The results will be displayed at the left in the plot.
- To change the output format in the statistics box, see the next slide.



Changing the Statistics Format in *Capstone*

- Go to **Workbook** in the *Capstone* menu bar and select **Show Tools Palette**.
- Click **Data Summary** on the left.
- Click on the **Show Sensor Data** tab if it's not visible.
- Click on the measurement you are working on and want to change.
- Click on the gear wheel icon to the right to select **Properties**. The **Properties** window will appear.
- Click **Numerical Format** and set the desired properties.