What Do We Know about the Fundamental Forces?

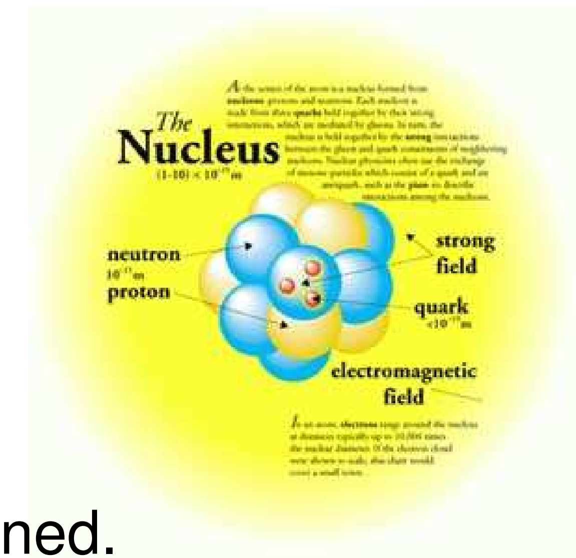
- The Universe is made of quarks, leptons and force carriers.

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			Quarks spin = 1/2		
Flavor	Mass GeV/c^2	Electric charge	Flavor	Approx. Mass GeV/c^2	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	−1	d down	0.006	−1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	−1	s strange	0.1	−1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	−1	b bottom	4.3	−1/3

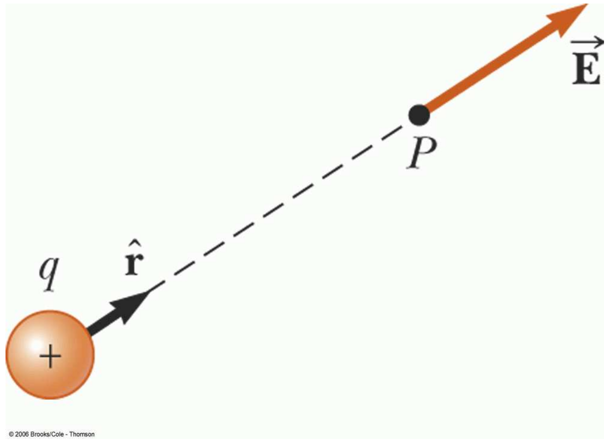
- The atomic nucleus is made of protons and neutrons bound by the strong force.



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

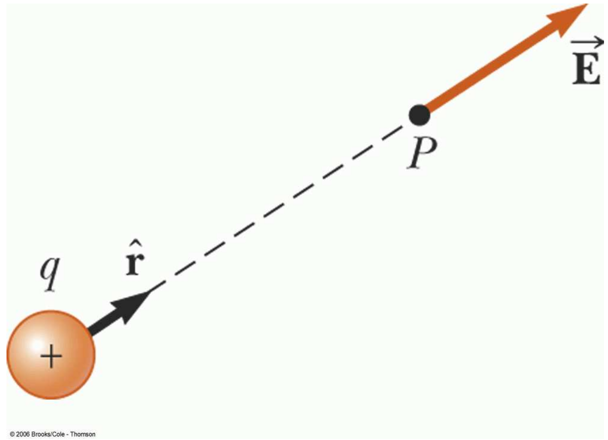
The Electric and Magnetic Fields?

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

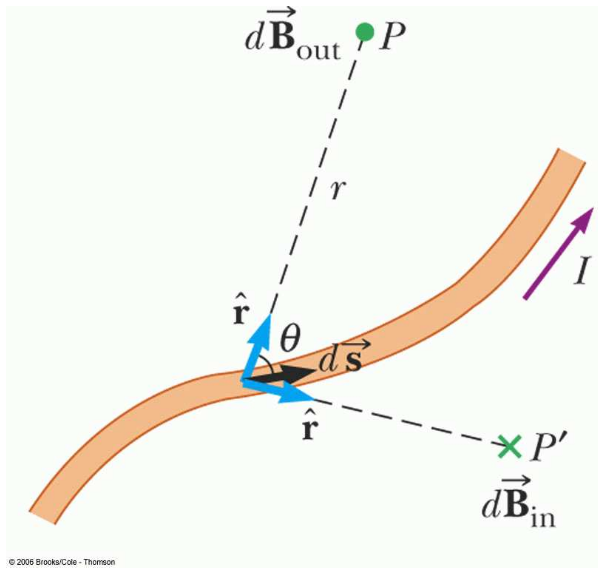


The Electric and Magnetic Fields?

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

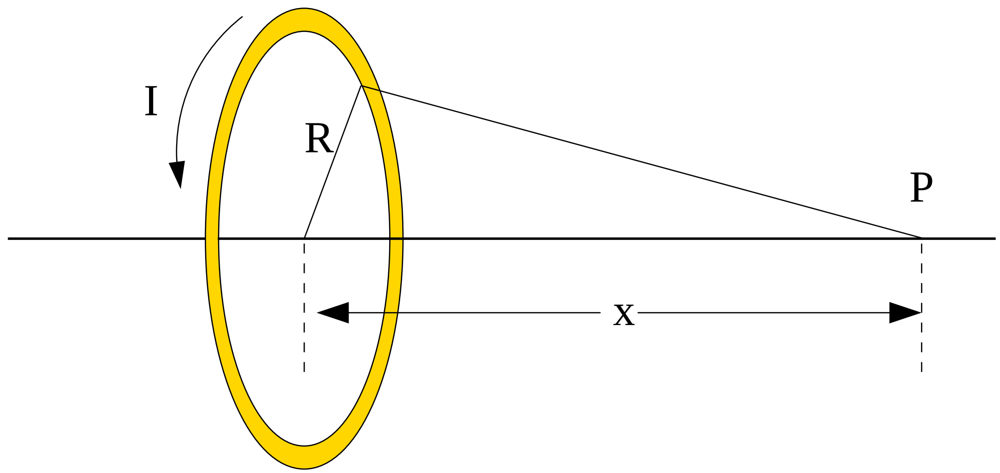


$$d\vec{B} = k_m \frac{I d\vec{s} \times \hat{r}}{r^2}$$

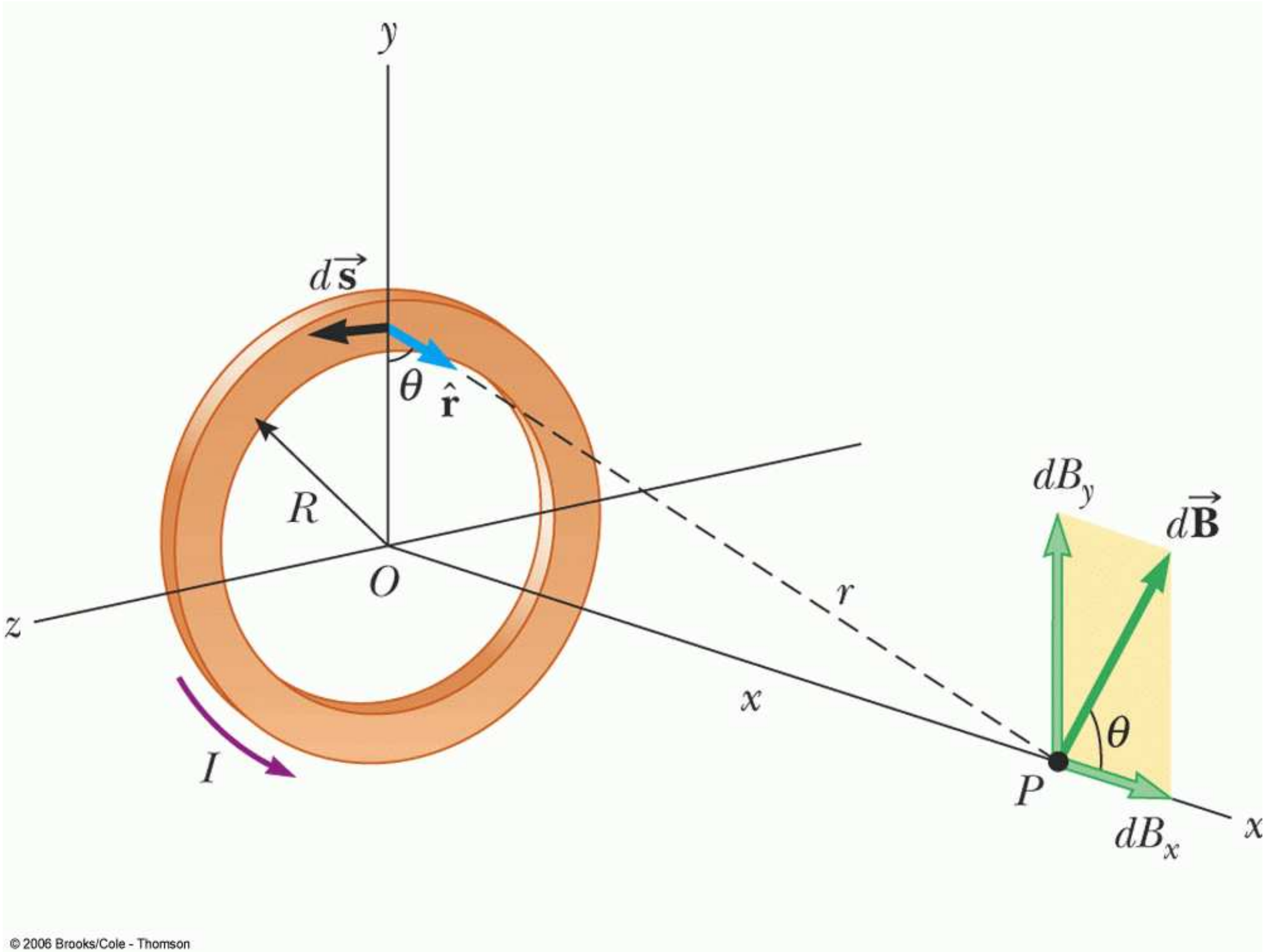


The Magnetic Field of a Current Loop

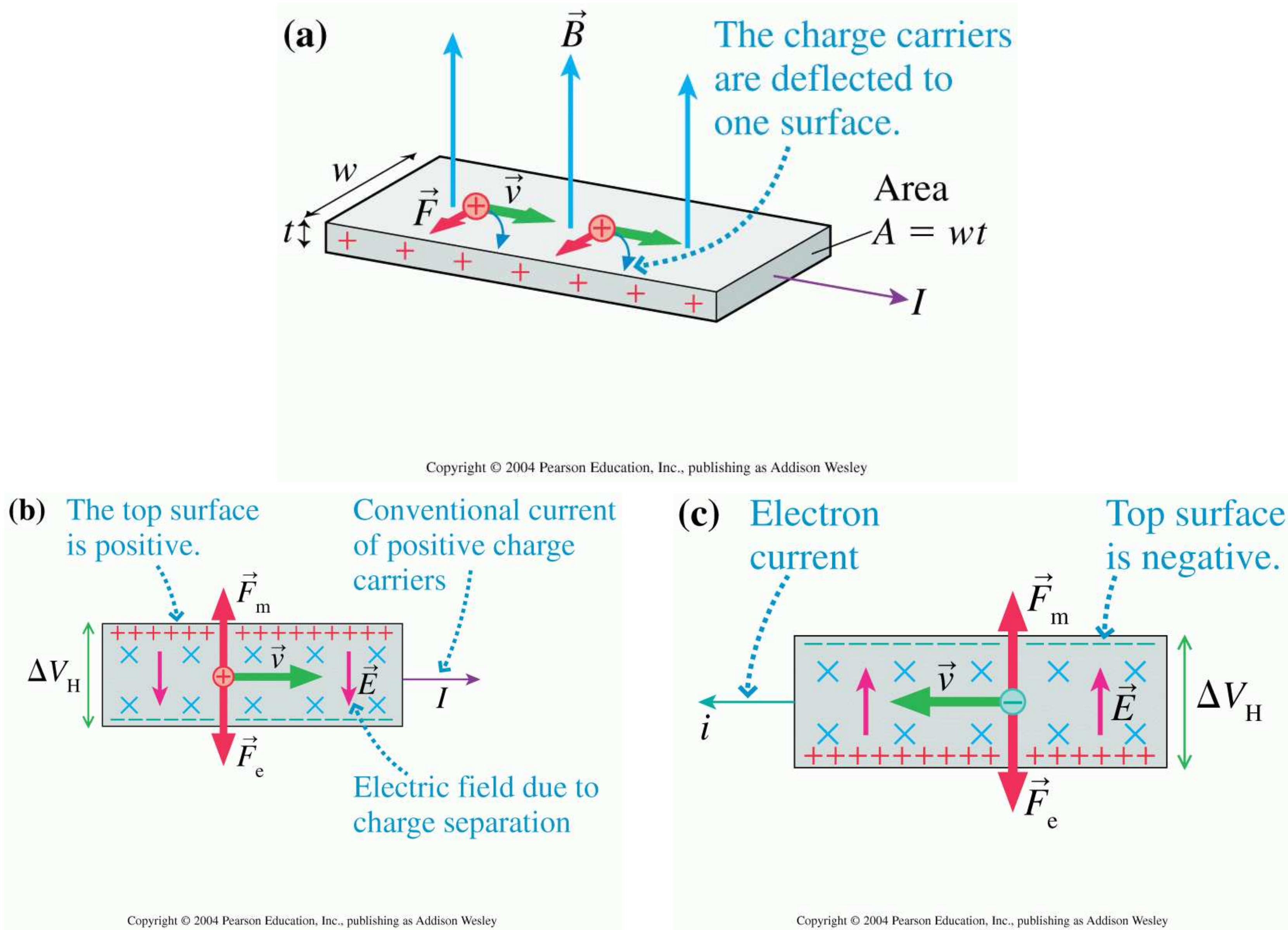
Consider a circular loop of radius R located in the $y-z$ plane and carrying a steady current I. What is the magnetic field at an axial point P a distance x from the center of the loop in terms of I, R, x, and any other constants?



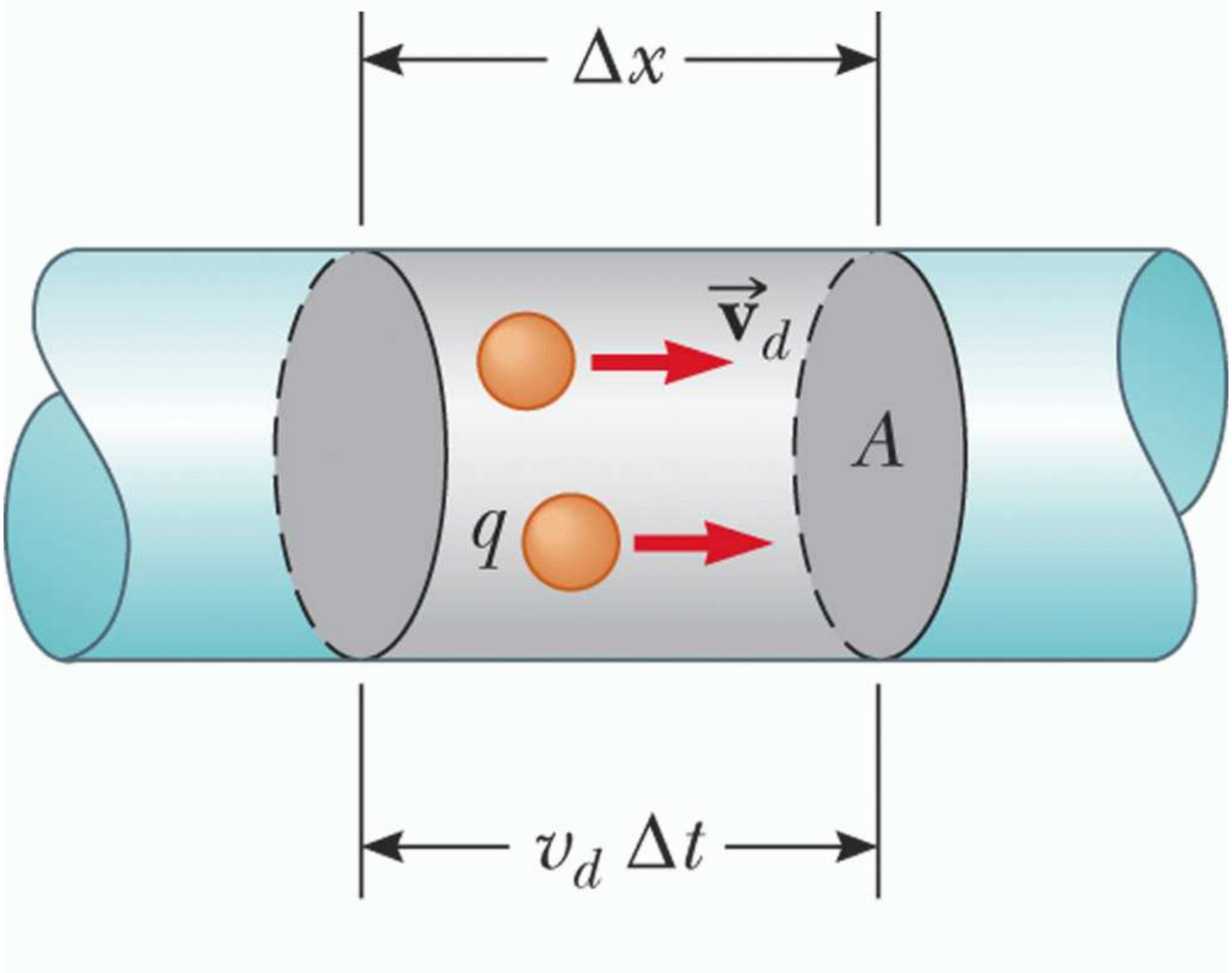
The Magnetic Field of a Current Loop



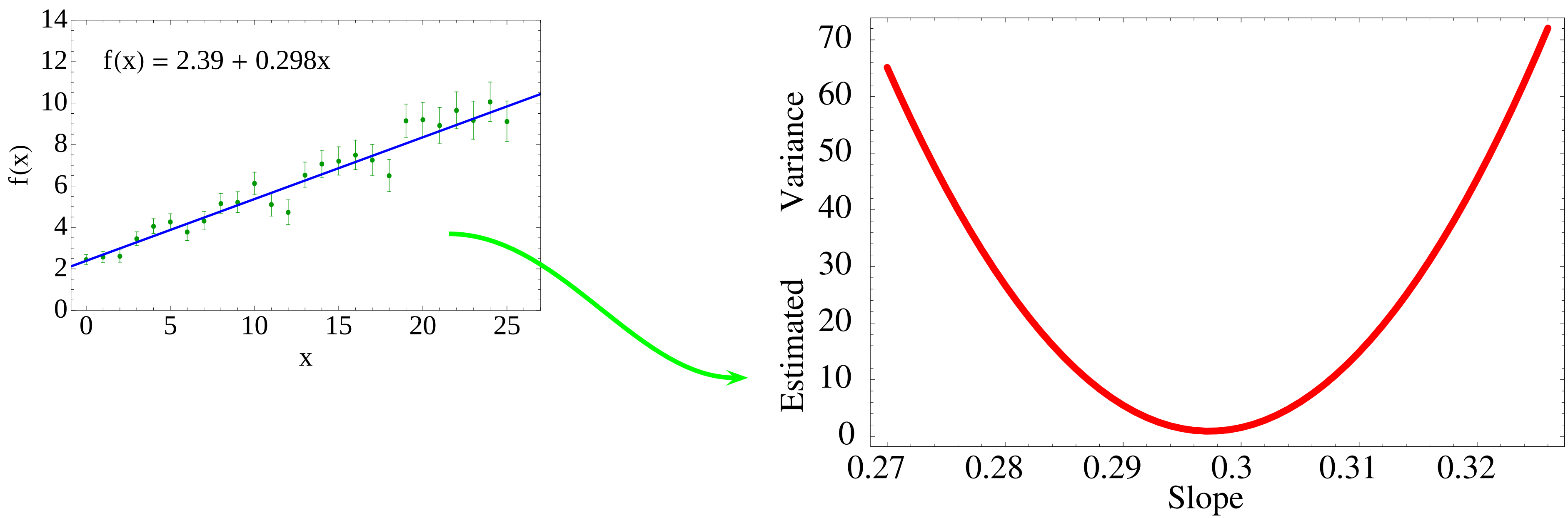
How the Sensor Works - The Hall Effect



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

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

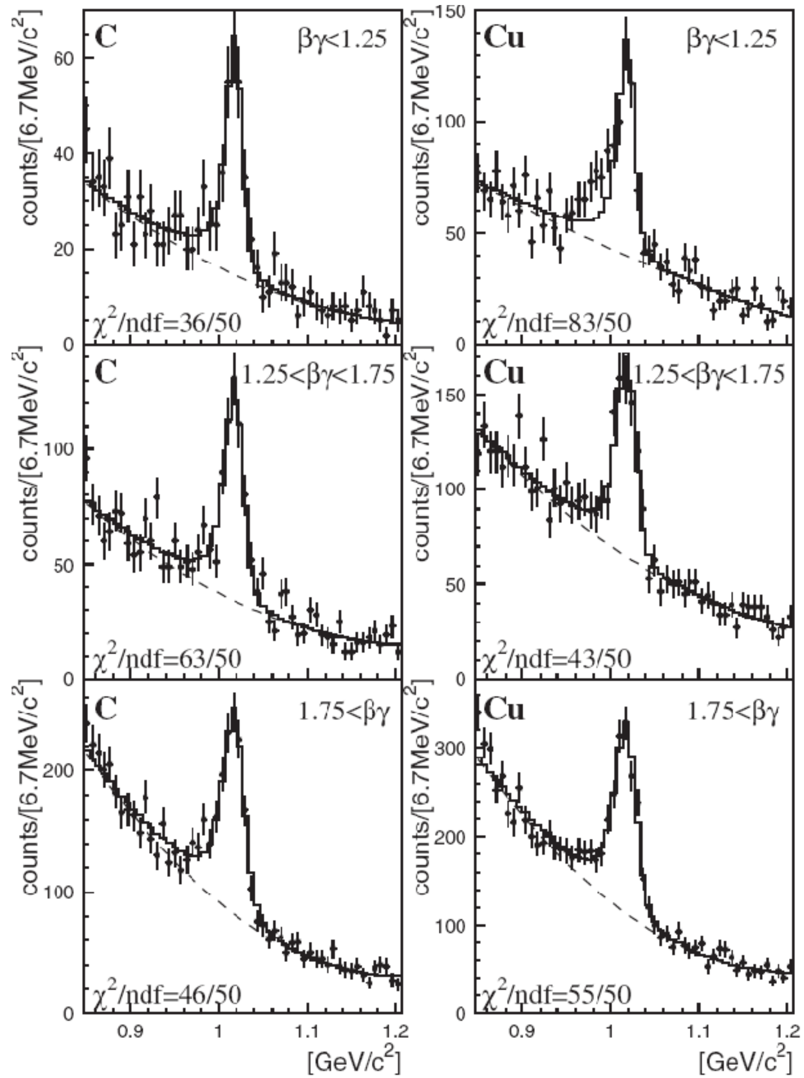
and

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

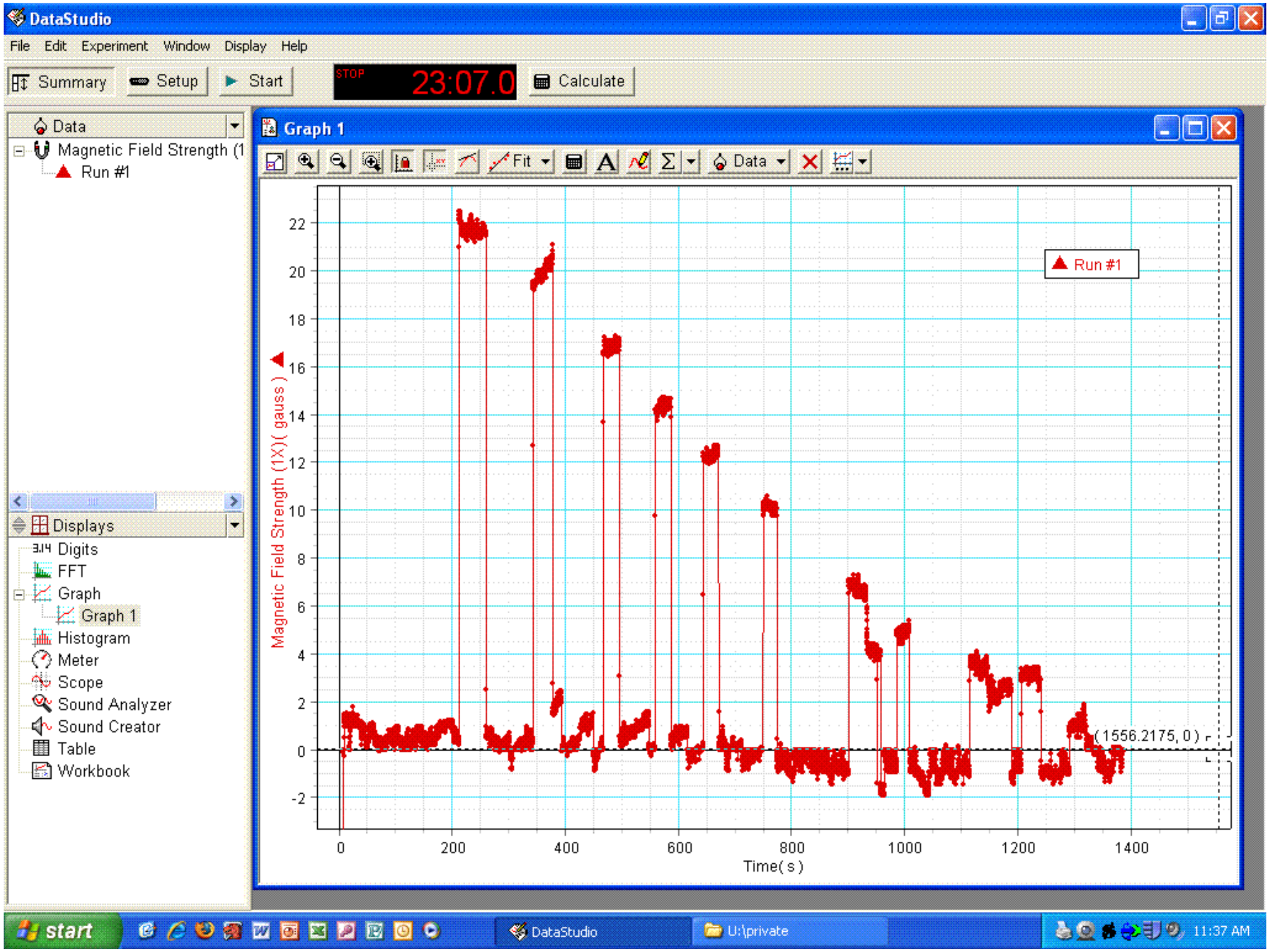
where N is the number of data points. In *Mathematica* the estimated variance is equal to the reduced χ^2 if the proper weighting is used.

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

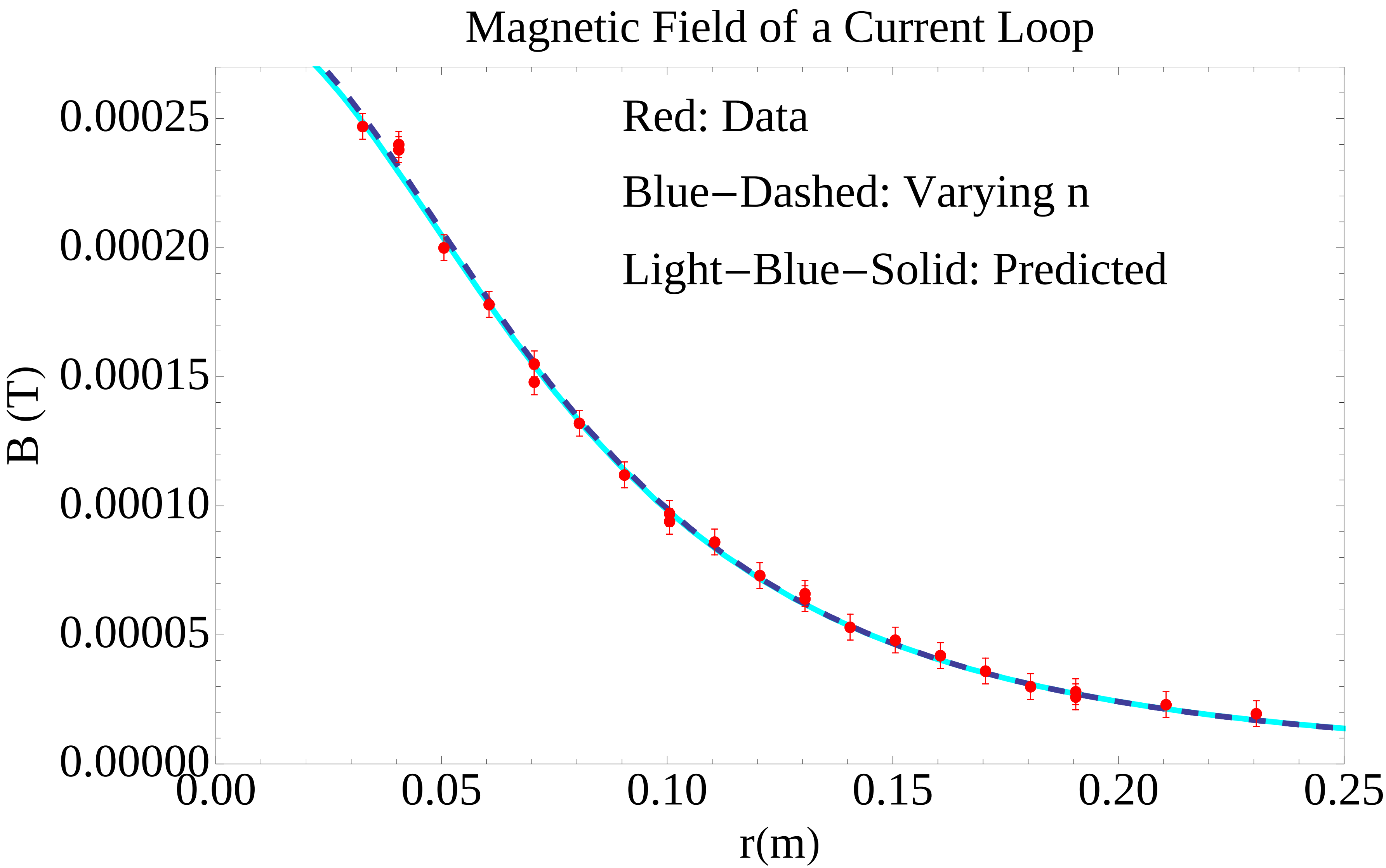
$$pA \rightarrow e^+e^-X$$



Using the Pasco Hall Probe



Biot-Savart Results



Averaging a Data Range in DataStudio

- Zoom in on the data range of interest.
- Click on `Selected Statistics` in the *DataStudio* menu bar. Check ‘Min’, ‘Max’, ‘Mean’, and ‘Standard Deviation’.
- Click and drag to highlight the points of interest. The results will be displayed in a box on the plot.
- To change the output format in the statistics box, (1) Double click on the data set listing (see ‘Data’ window on the left), (2) choose the ‘Numeric’ tab and (3) modify the ‘Style’ menu to suit.