Experimental Subatomic Physics

Student Research Opportunities for Summer 2018

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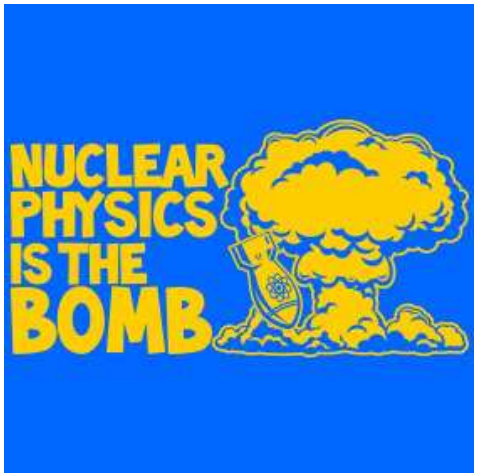
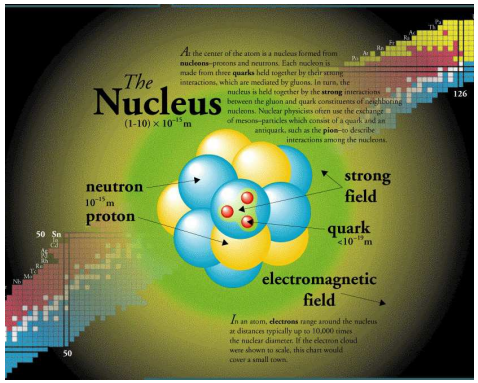
WHAT: Experimental Medium-Energy Subatomic Physics





WHAT: Experimental Medium-Energy Subatomic Physics

Low-A (small nuclei) Nuclear Physics

- Particle Physics' lower-energy older brother.
- Theory starts from basic principles.
- Shoot beams of photons at nuclei (usually just hydrogen, i.e. protons), and then detect and analyze reaction products.
- Currently working on near-threshold π-meson photoproduction, and Compton scattering from the proton and neutron.

WHY: Test Quantum Chromodynamics (or QCD)

"Can the theory of quark and gluon confinement quantitatively describe the detailed properties of hadrons?"

Perspectives on Subatomic Physics in Canada 2006–2016.

- Theory: QCD describes the strong force in terms of quarks and gluons.
- Nobel Prize in 2004 for **Asymptotic Freedom** in the pQCD regime...
- However, in the non-perturbative region, QCD is still unsolved.

One of the top ten challenges for physics!

How do we test QCD in the non-perturbative regime?

High-precision measurements with polarization observables.

Nucleon Polarizabilities

- Fundamental structure constants
- Response of internal structure to external fields
- Fertile meeting ground between theory and experiment
- Best measured via **Compton scattering**

Theoretical Approaches

- Subtracted Dispersion Relations
- Chiral Perturbation Theory
- Lattice QCD

Compton Scattering – Hamiltonian

Expand the Hamiltonian in incident-photon energy.

0th order $\longrightarrow$ charge, mass

1st order $\longrightarrow$ magnetic moment

2nd order $\longrightarrow$ **scalar polarizabilities**:

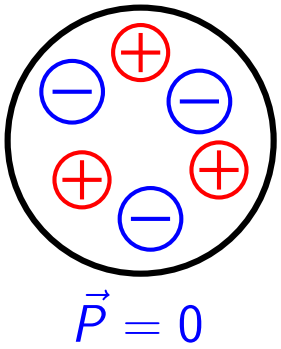
$$H_{\text{eff}}^{(2)} = -4\pi \left[\frac{1}{2} \alpha_{E1} \vec{E}^2 + \frac{1}{2} \beta_{M1} \vec{H}^2 \right]$$

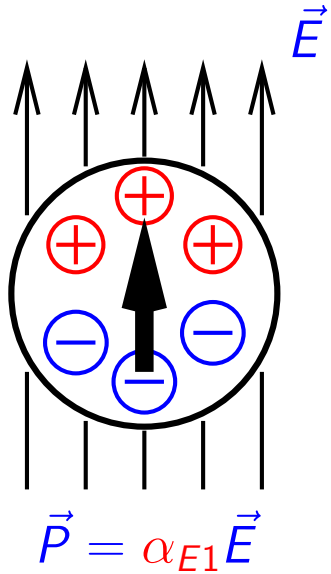
3rd order $\longrightarrow$ **spin (or vector) polarizabilities**:

$$H_{\text{eff}}^{(3)} = -4\pi \left[\frac{1}{2} \gamma_{E1E1} \vec{\sigma} \cdot (\vec{E} \times \dot{\vec{E}}) + \frac{1}{2} \gamma_{M1M1} \vec{\sigma} \cdot (\vec{H} \times \dot{\vec{H}}) \right.$$
$$\left. - \gamma_{M1E2} E_{ij} \sigma_i H_j + \gamma_{E1M2} H_{ij} \sigma_i E_j \right]$$

Scalar Polarizabilities – Conceptual

Electric Dipole Polarizability





- Apply an electric field to a composite system
- Separation of Charge, or **"Stretchability"**
- Proportionality constant between electric dipole moment and electric field is the electric dipole polarizability, α_{E1}.

Provides information on force holding system together.

Specific Projects

Specific projects involve mainly data analysis and simulation, along with running experimental shifts. Some hardware tasks.

Maeve Wentland – Compton Scattering from Helium

- New high-pressure, active helium target
- Background simulations
- Sensitivity studies

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Sara Ripley – Proton Radius Puzzle

- MUSE experiment at PSI
- Proton charge radius is different depending on measurement technique
- GEM detector simulations using GenFit code

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Talk to Maeve, Sara, or Robert for a student perspective...

WHERE: Sackville, Mainz, and maybe Villigen

A2 Collaboration
Institut für Kernphysik
Johannes Gutenberg Universität
Mainz, Germany

MUSE Collaboration
Paul Scherrer Institute
Villigen, Switzerland

Depending on the beam schedule, approximately 3 months of the summer will be spent in Germany/Switzerland, and the rest here in Sackville.

WHO:

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