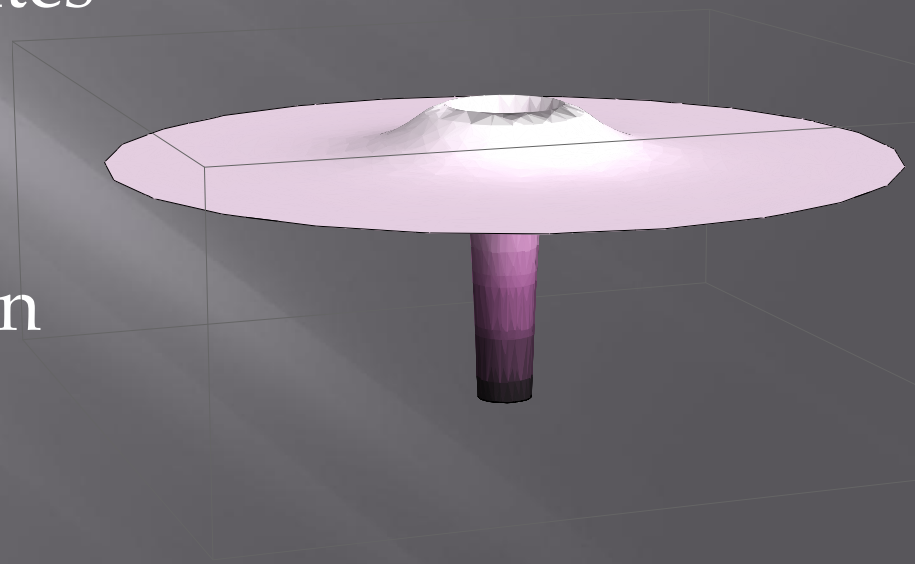
PROBING THE NEUTRON WITH THEORY

Using Light Front Quantum Mechanics
to Determine the Charge Distribution
of the Neutron

Outline

- Relativity
- Light Front Coordinates
- Quantum Mechanics
- Light Front QM
- Modeling the Neutron
  - Charge Radius
  - Charge Distribution
- Relativistic Effects

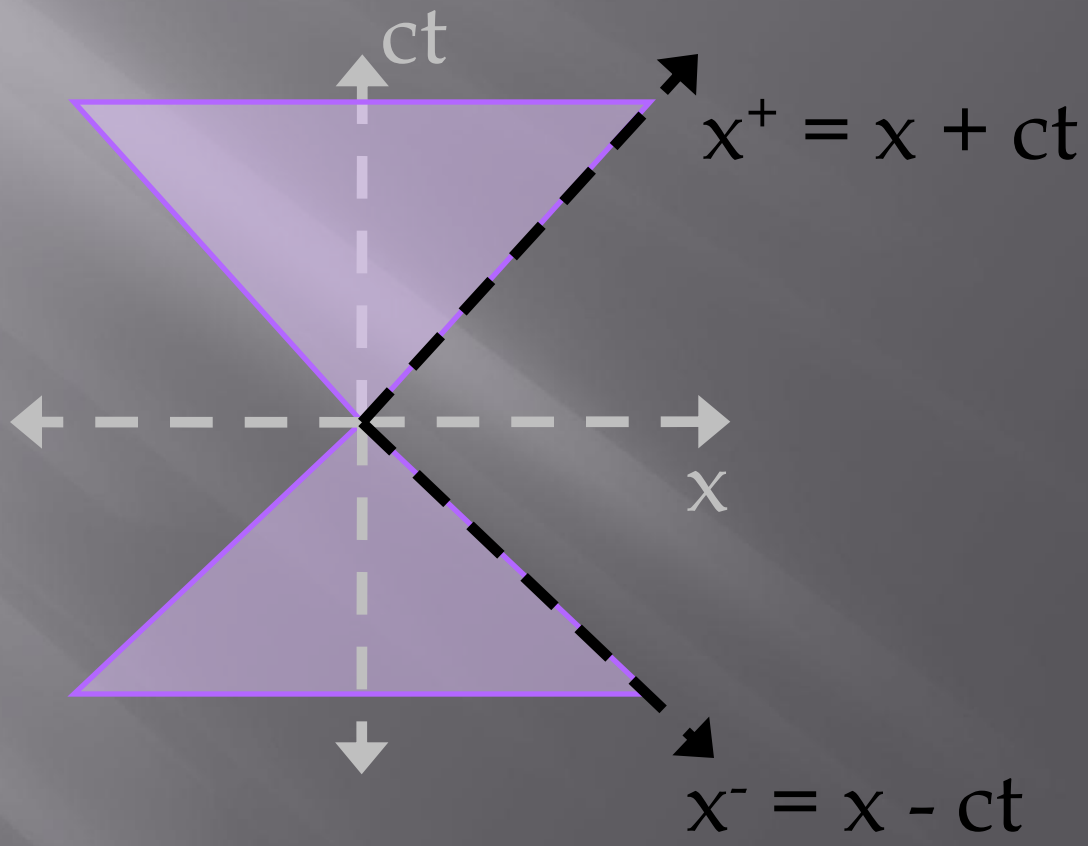


Special Relativity

$$ct' = \frac{ct - \frac{v}{c}x}{\sqrt{1 - \frac{v^2}{c^2}}} \quad x' = \frac{x - \frac{v}{c}ct}{\sqrt{1 - \frac{v^2}{c^2}}} \quad y' = y \quad z' = z$$

$$E = \sqrt{p^2c^2 - m^2c^4}$$

Light Front Coordinates



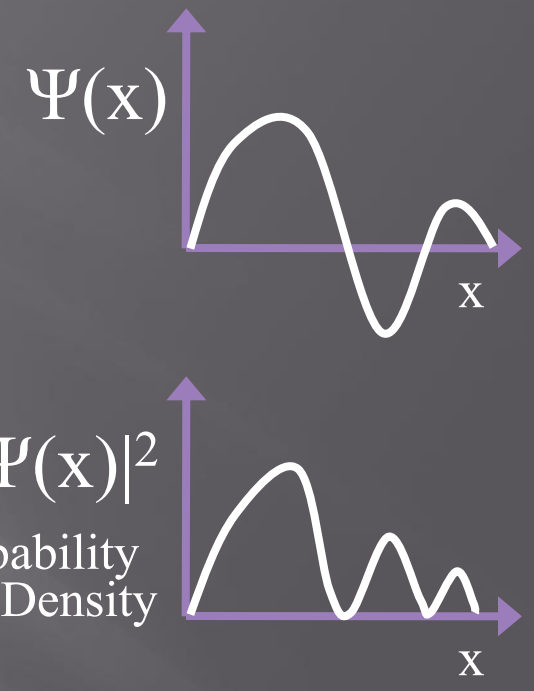
Quantum Mechanics

Schrodinger Equation:

$$(-\hbar^2 \frac{d^2}{dx^2} + V(x))\Psi(x) = i\hbar \frac{d\Psi(x)}{dt}$$

Time Independent Schrodinger Equation:

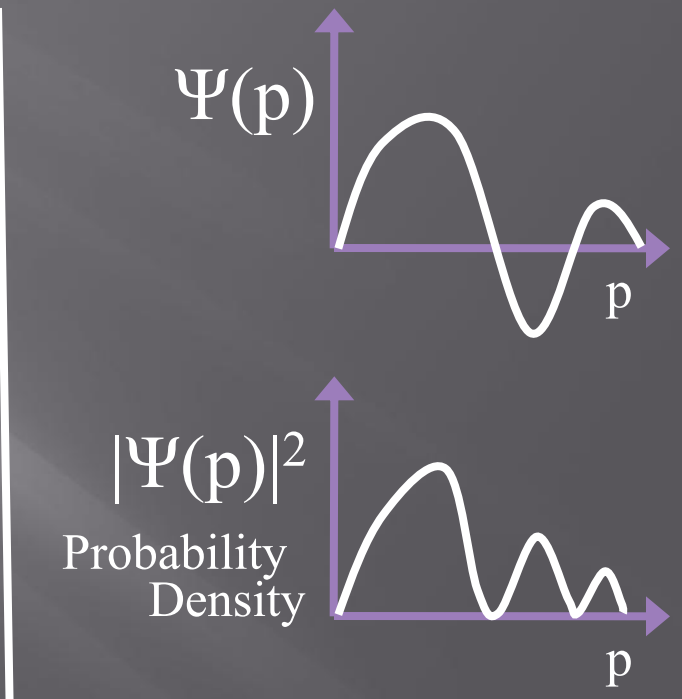
$$(-\hbar^2 \frac{d^2}{dx^2} + V(x))\Psi(x) = E\,\Psi(x)$$



Quantum Mechanics in Momentum Space

Schrodinger Equation:

$$i\hbar \frac{d\Psi}{dt} = \left(\frac{p^2}{2\,m} - V\right)\Psi$$

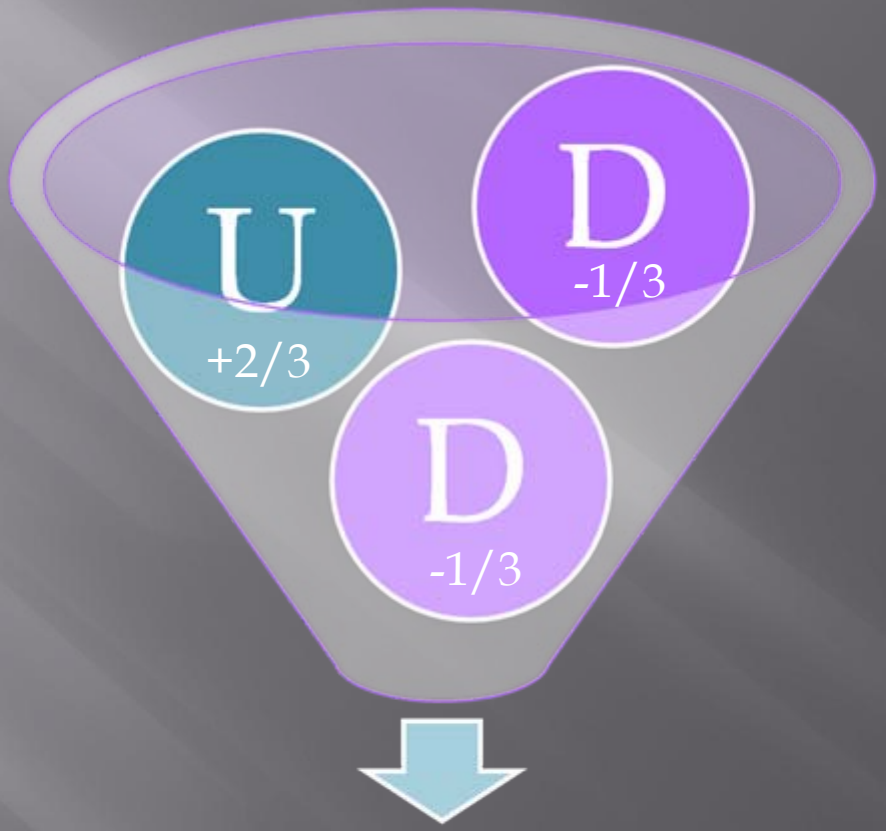


Light Front Quantum Mechanics

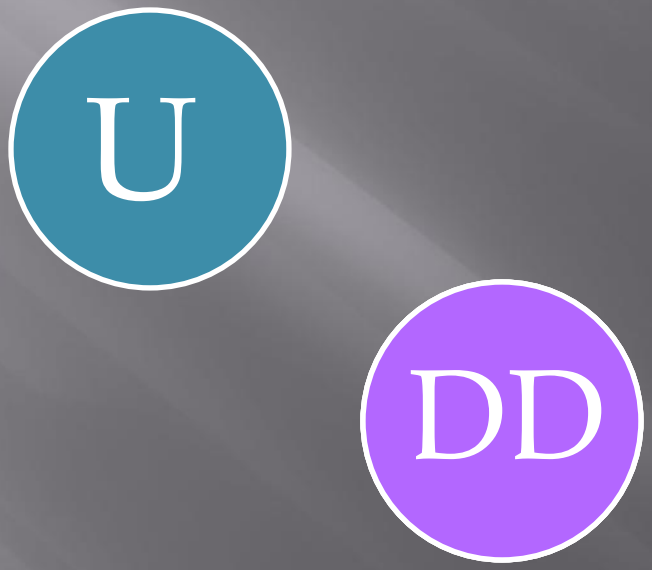
Light Front Schrodinger Equation:

$$i\hbar \frac{d\Psi}{dx^+} = (P^- - V)\Psi$$

Modeling the Neutron

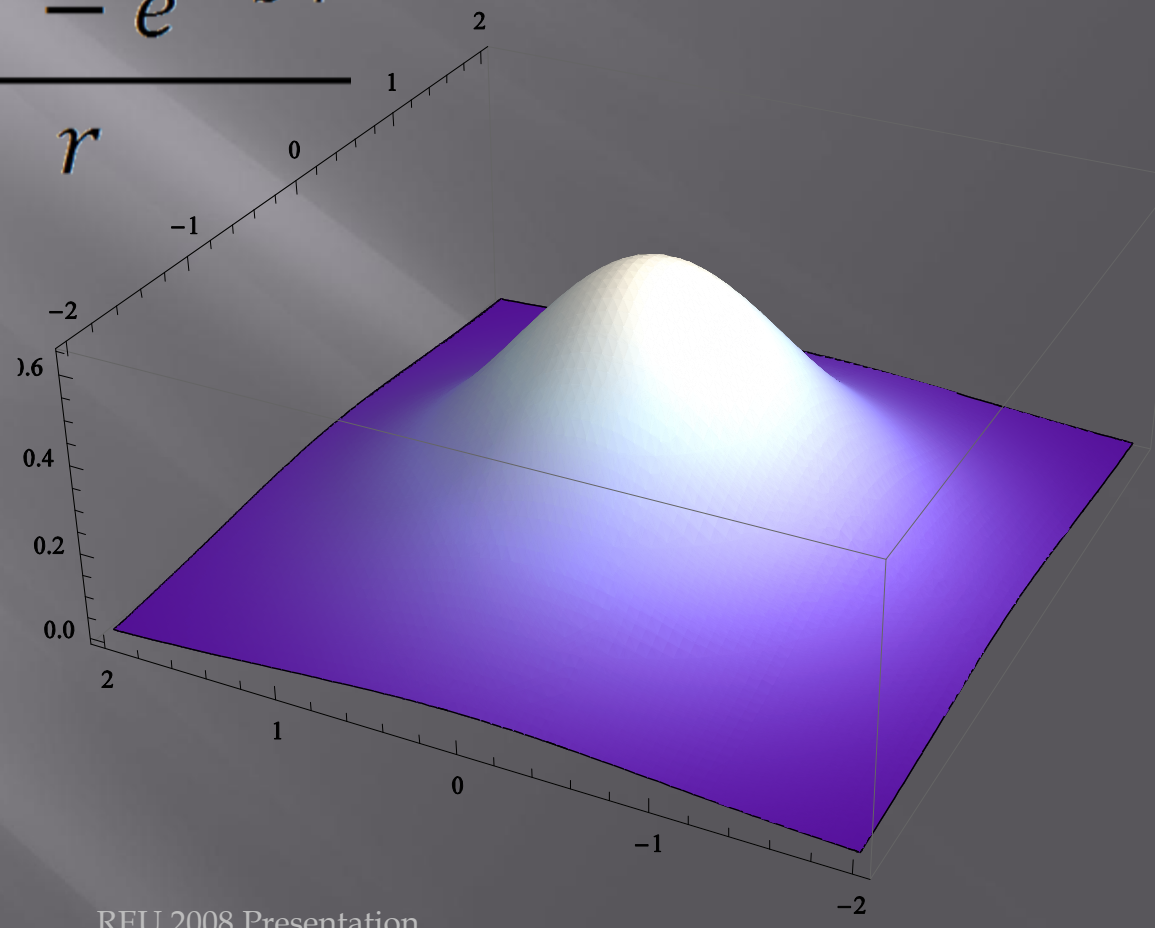


Quark and Di-Quark

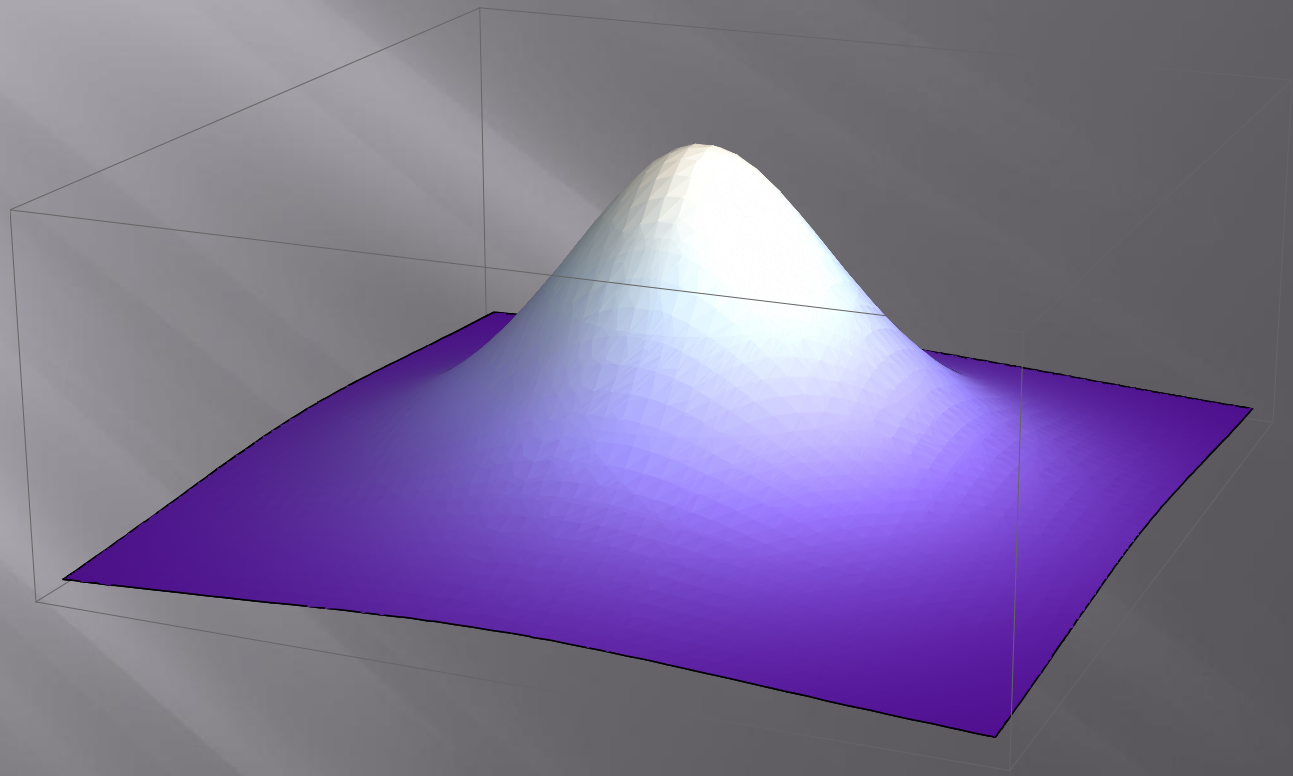


Wavefunction

$$\Psi(r) = N \frac{e^{-a\,r} - e^{-b\,r}}{r}$$



Momentum Space



The Classical Form Factor

$$F(q) = \int \rho(\vec{x}) e^{i\,\vec{q}\cdot\vec{x}}\, d^3x$$

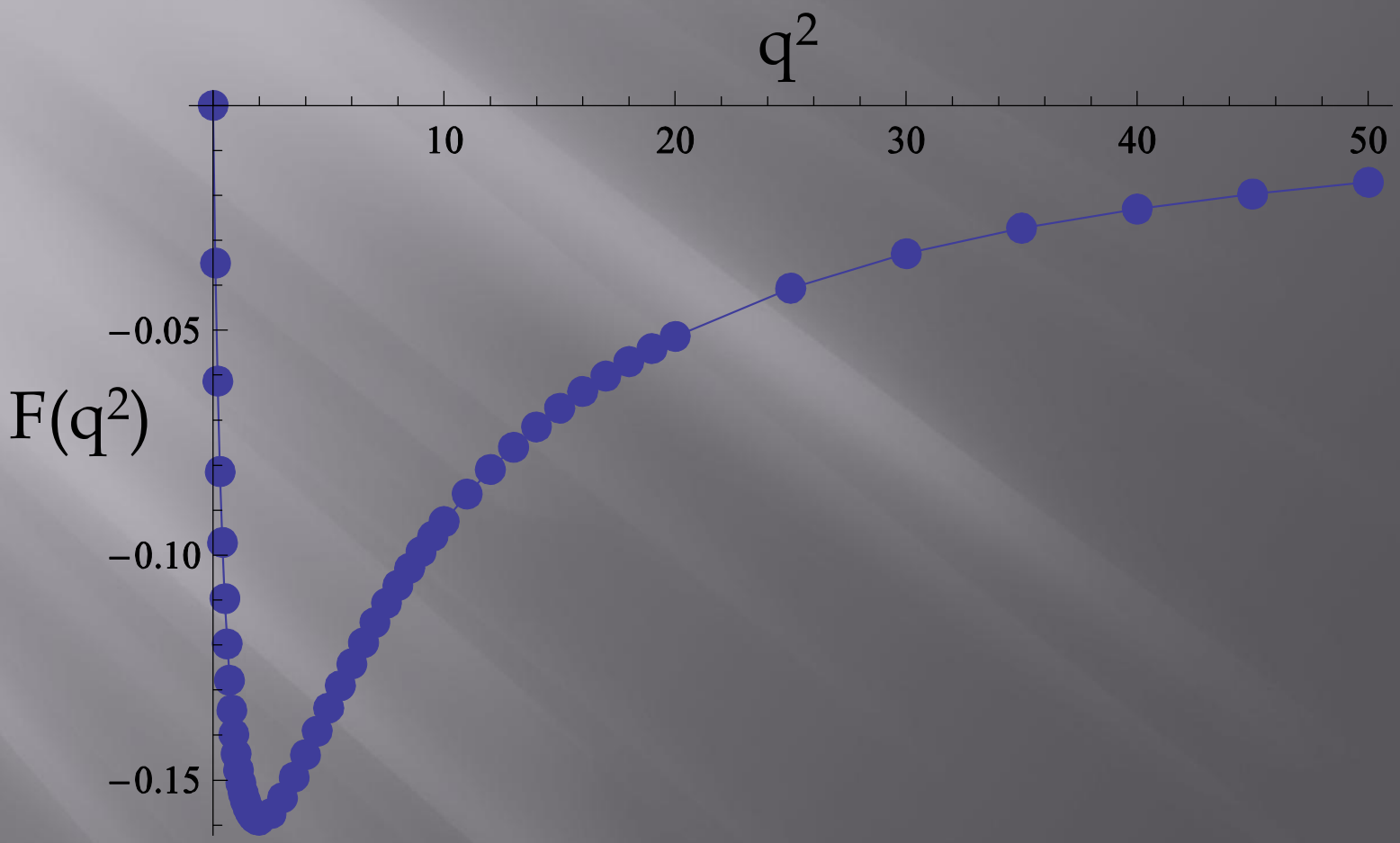
$$F(q) = \int \rho(\vec{x})\left(1 + i\,\vec{q}\cdot\vec{x} - \frac{1}{2}(\vec{q}\cdot\vec{x})^2 + \cdots\right) d^3x$$

$$F(q) = \int \rho(r)\left(1 - \frac{1}{2}(q\,r\,\cos\theta)^2 + \cdots\right) r^2 \sin\theta\, dr\, d\theta\, d\phi$$

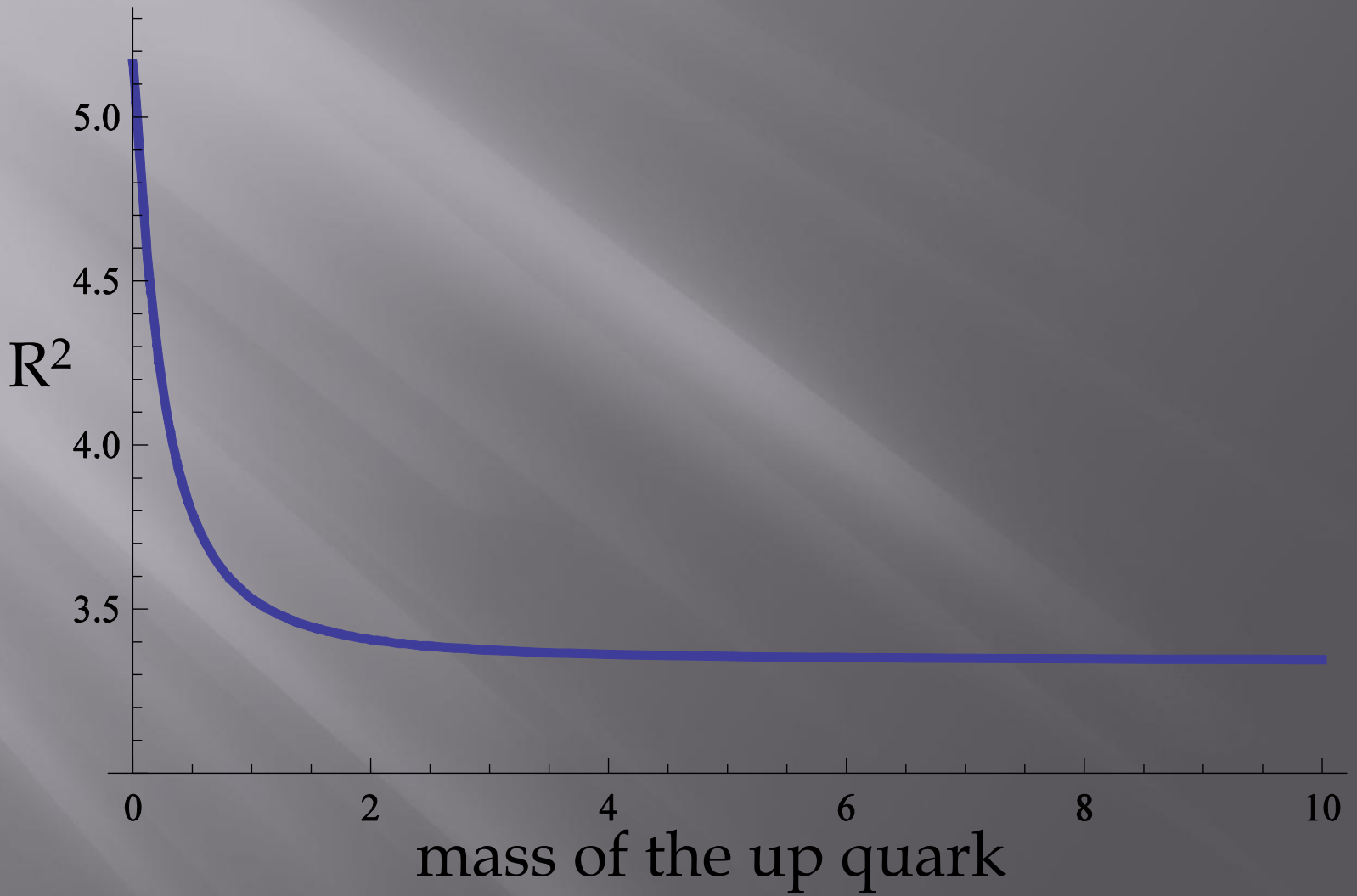
$$F(q) = 1 - \frac{1}{6} q^2 < r^2 > + \cdots$$

$$< r^2 >= -6 \lim_{q \to 0} \frac{dF}{dq^2}$$

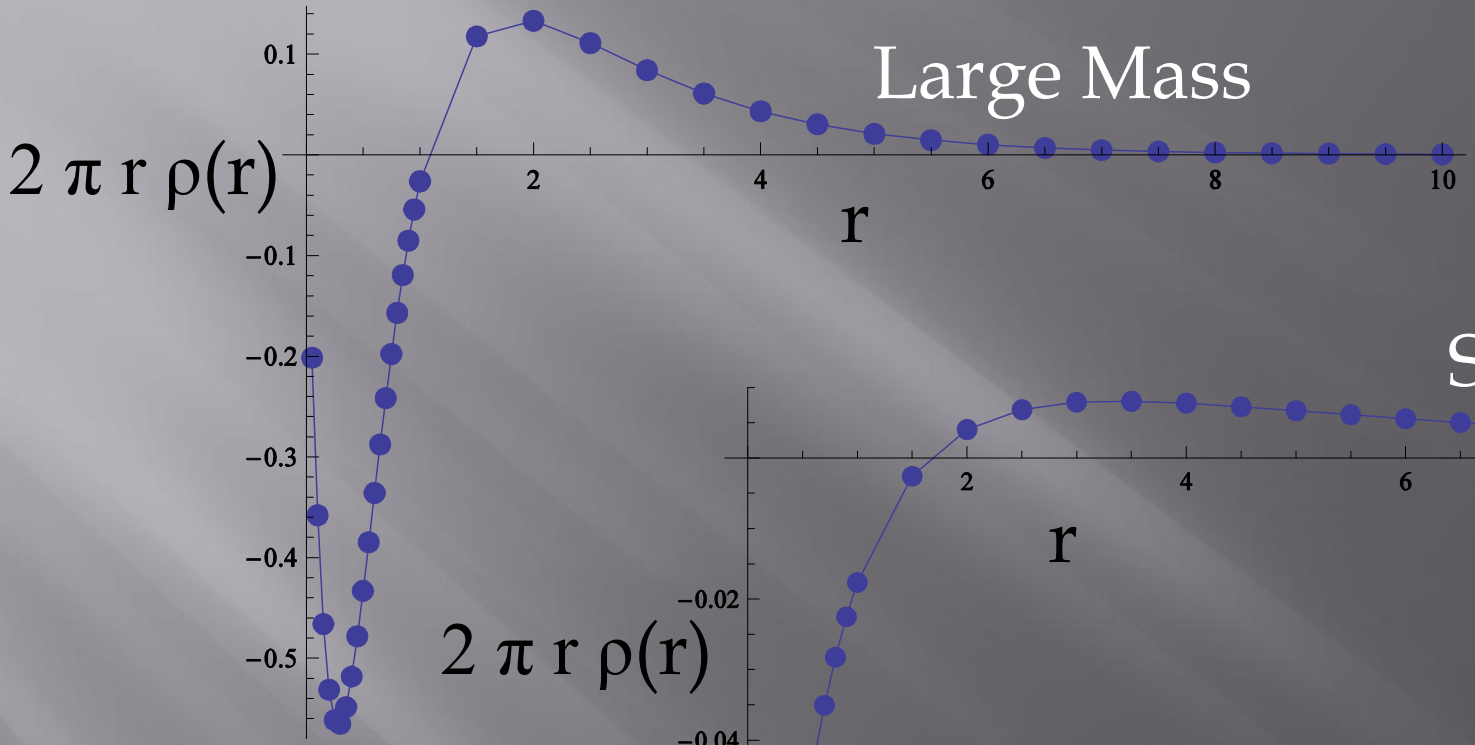
Form Factor

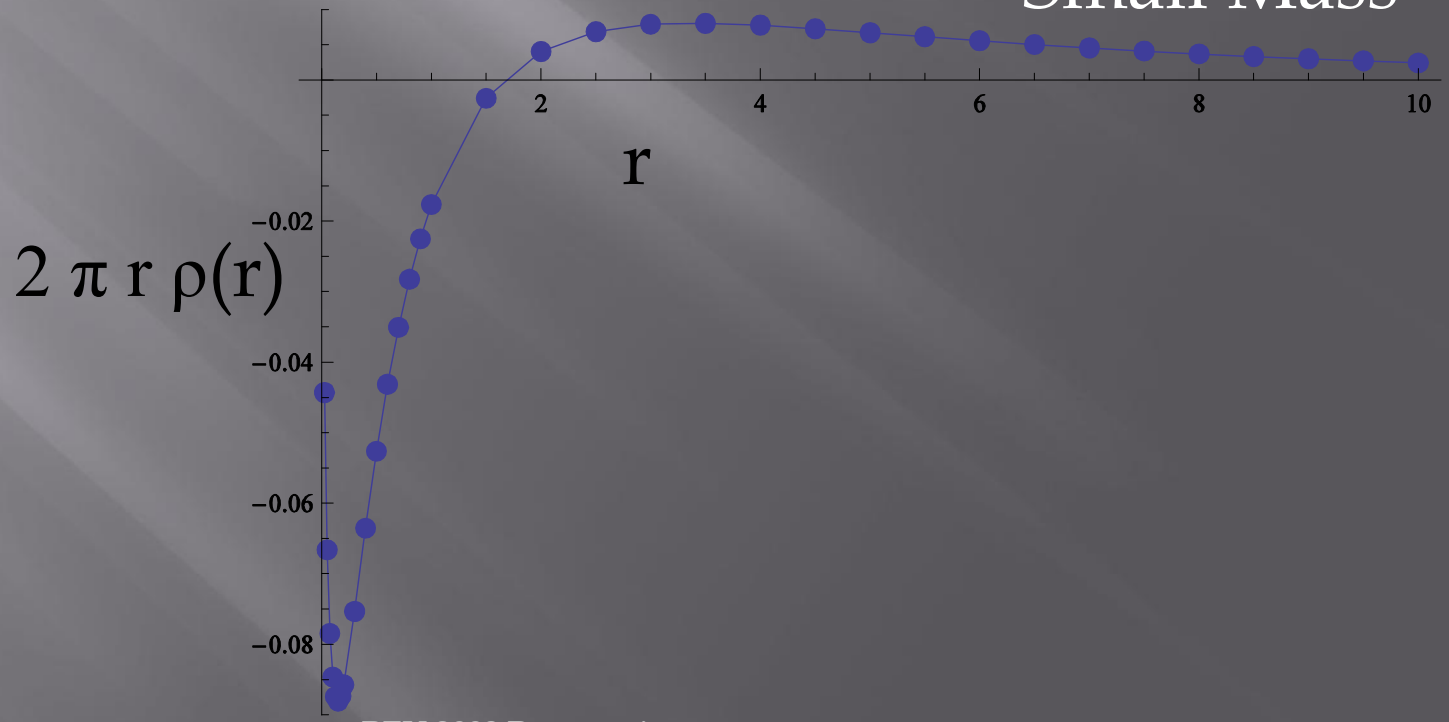


Charge Radius Squared

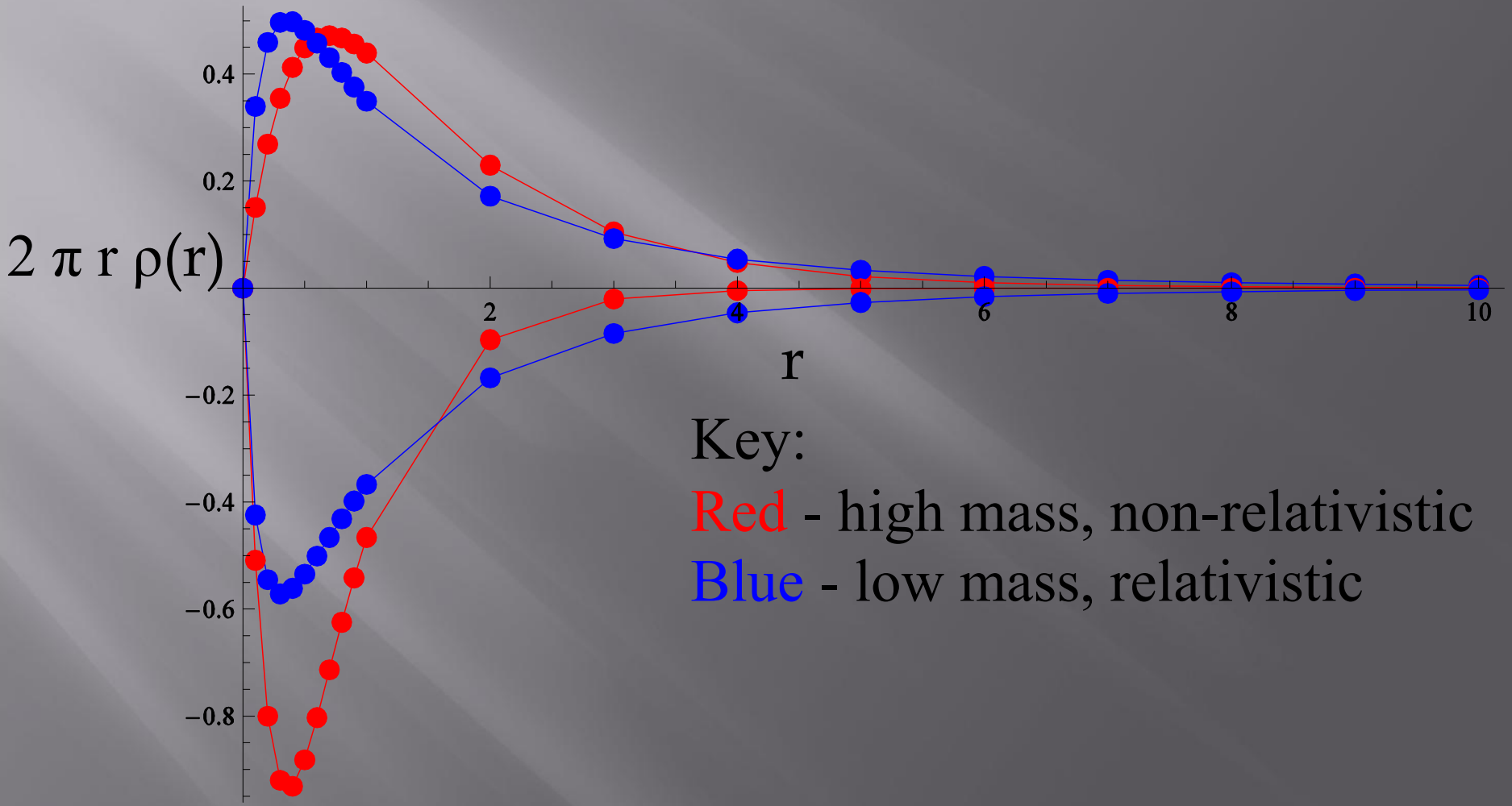


Charge Distribution





Charge Distribution in Relativistic Limit



Key:

Red - high mass, non-relativistic

Blue - low mass, relativistic

Acknowledgements

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Proton and Pion