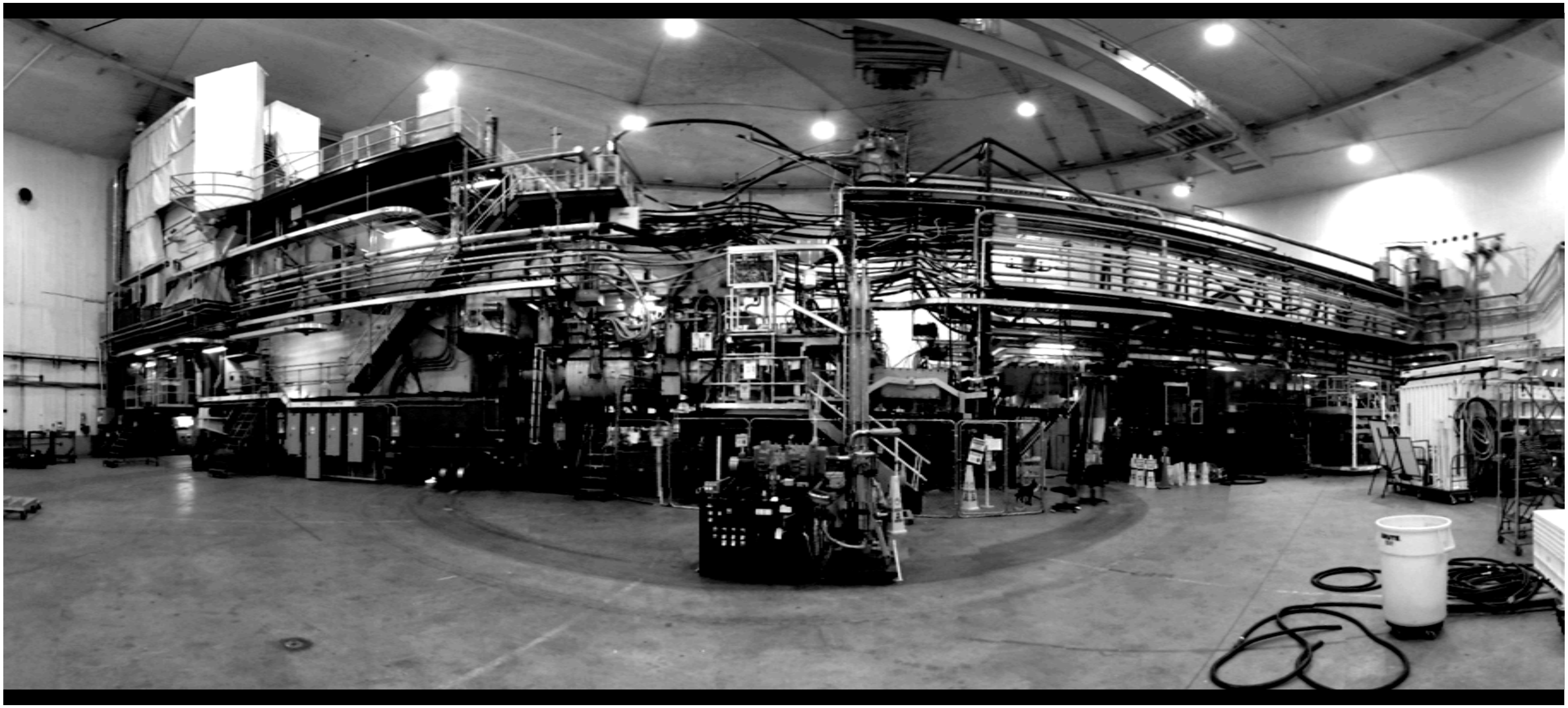


An Overview of the g2p Experiment

Melissa Cummings

HUGS 2012

June 21st 2012

Jefferson Lab

Outline

- The g_2p Experiment
  - Review of Inclusive Electron Scattering
  - A (small) Bit of Theory
  - Applications of g_2p
  - Snapshot of the Experiment
  - Electron Detection

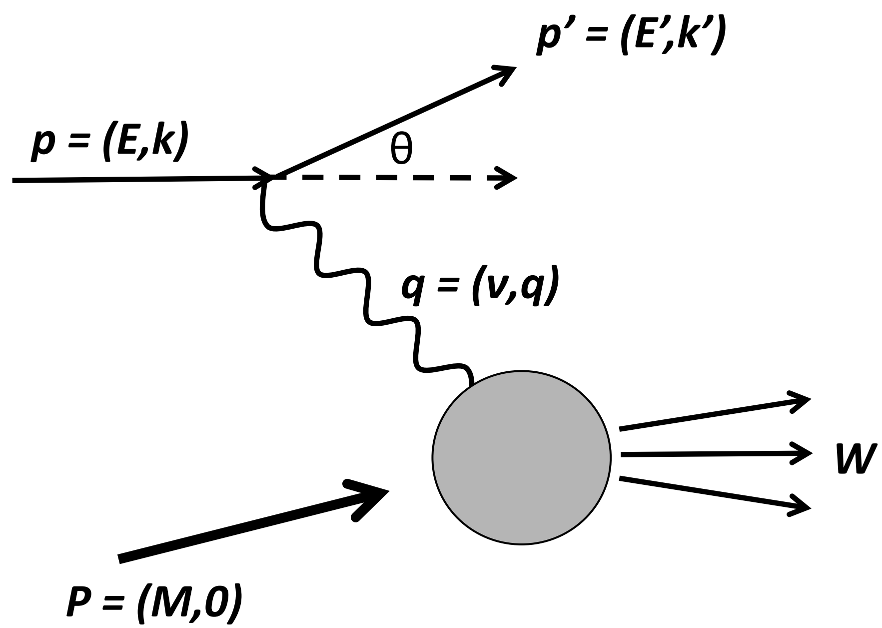
Inclusive Scattering

- Important Kinematic Variables

> Q^2: 4-momentum transfer
> x: Bjorken Scaling
> W: Invariant mass of target
> ν: Energy Transfer

- Proton Response is described by Structure Functions

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\frac{\theta}{2}]$$



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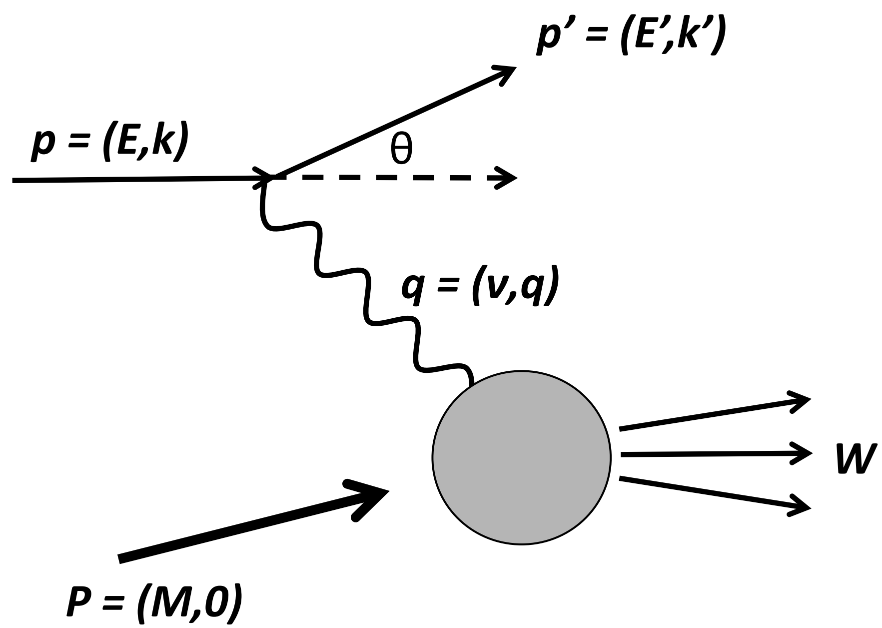
Unpolarized Case



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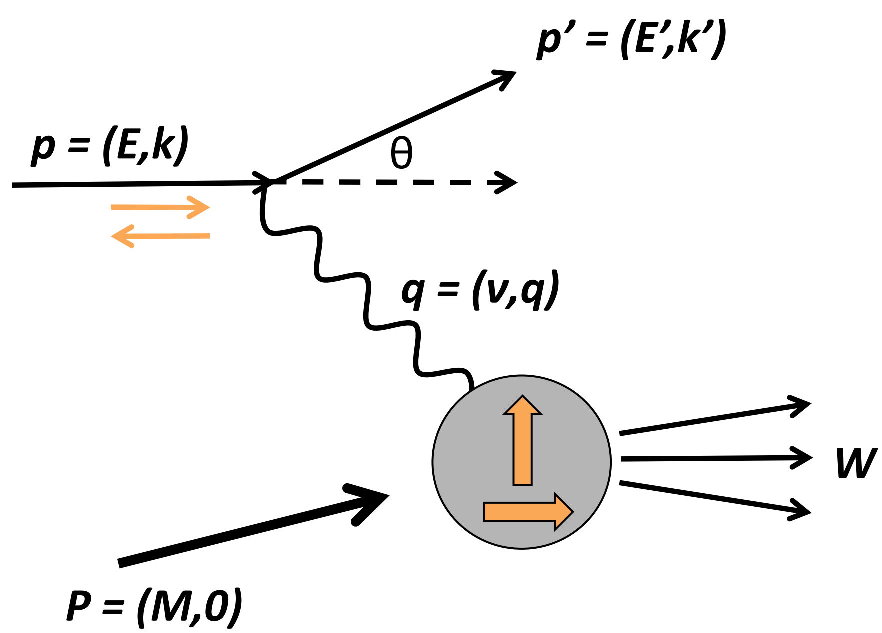
$$+\gamma g_1(x,Q^2) + \delta g_2(x,Q^2)]$$

Polarized Case



A Bit of Theory

$$F_1(x) = \frac{1}{2}\sum_f z_f^2(q_f(x) + \bar{q}_f(x))$$

$$g_1(x) = \frac{1}{2}\sum_f z_f^2(q_f(x) - \bar{q}_f(x))$$

→

F_2 can be determined in terms of F_1

A Bit of Theory

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F_2 can be determined in terms of F_1

No Analog for g_2!

$$g_2(x, Q^2) = g_2^{WW}(x, Q^2) + \bar{g}_2(x, Q^2)$$

A Bit of Theory

$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + \bar{g}_2(x,Q^2)$$

$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 \frac{dy}{y} g_1(y,Q^2)$$

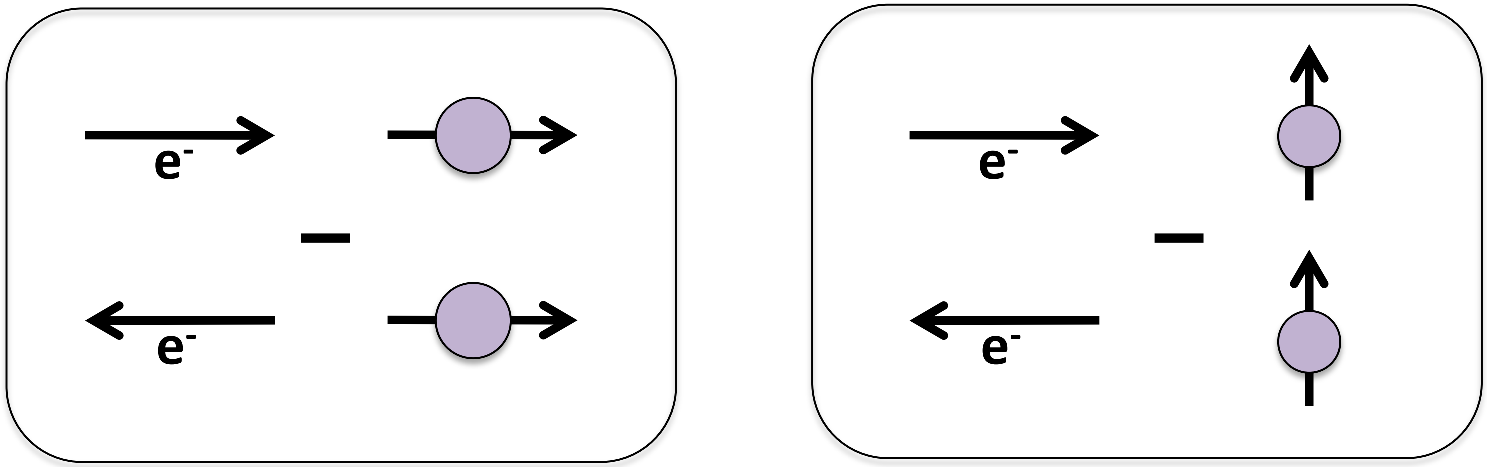
Leading twist-2 term

$$\bar{g}_2(x,Q^2) = -\int_x^1 \frac{\partial}{\partial y}\left[\frac{m_q}{M} h_T(y,Q^2) + \zeta(y,Q^2)\right]\frac{dy}{y}$$

h_T : Quark Transverse Polarization Distribution

ζ : Twist-3 contribution from quark-gluon interactions

Experimental Technique

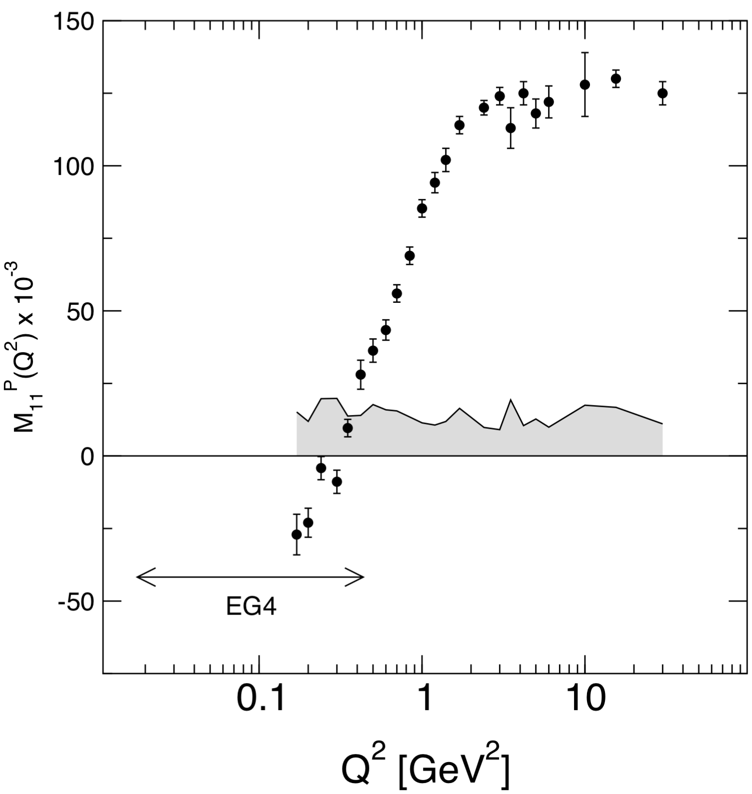


$$\frac{d^2\sigma^{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Uparrow}}{d\Omega dE'} = \frac{4\alpha^2}{\nu Q^2}\frac{E'}{E}[(E + E'\cos\theta)g_1 - 2Mxg_2]$$

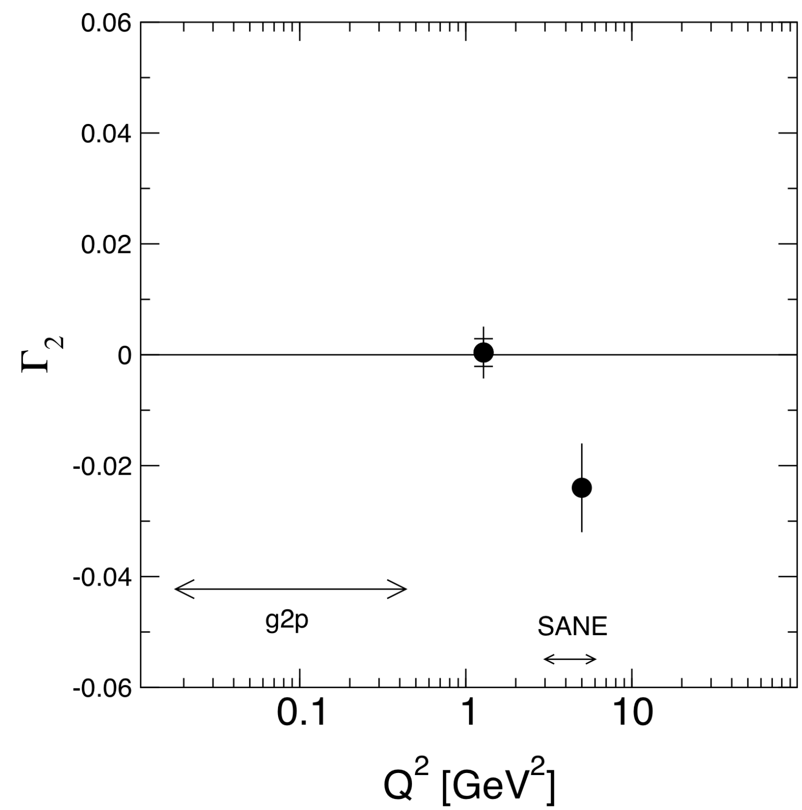
$$\frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2}{\nu Q^2}\frac{E'}{E}\sin\theta[g_1 + \frac{2ME}{\nu}g_2]$$

Existing Data

g_1p is very well known



g_2p, not so much…



Plots taken from: "A Measurement of g2p and the Longitudinal-Transverse Spin Polarizability" Experimental Proposal

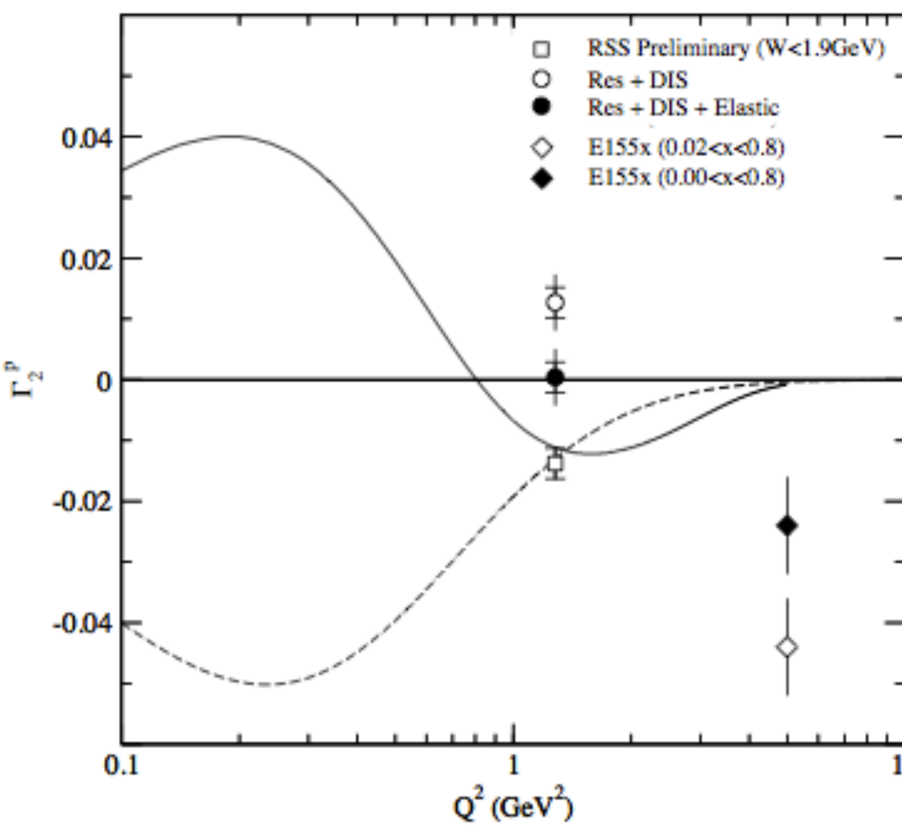
Additional Applications of g_2p

- The Burkhardt-Cottingham Sum Rule

$$\int_0^1 g_2(x, Q^2)dx = 0$$

- Fails if the virtual Compton Scattering amplitude (S_2) falls to zero faster than 1/x

- Fails if g_2 behaves as a delta function at x=0

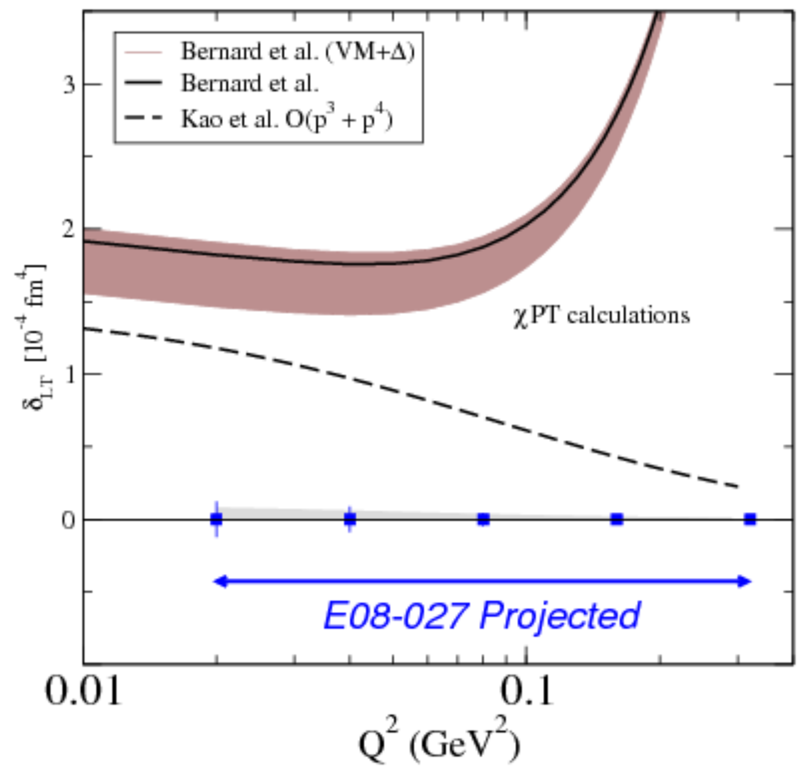


Plots taken from: "A Measurement of g2p and the Longitudinal-Transverse Spin Polarizability" Experimental Proposal

Additional Applications of g_2p

- Benchmark test of Chiral Pertubation Theory
- There is a yet undetermined range of Q^2 over which χ^{PT} is valid
- χ^{PT} calculations are being used to extrapolate to the physical region in Lattice QCD
  - Tests like this allow for minimal propagation of error
- Measurement of δ_{LT} would test χ^{PT} by measuring a nucleon observable that is insensitive to contributions from virtual π-Δ intermediate states

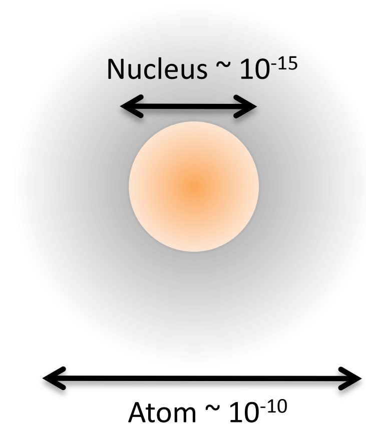
Longitudinal-Transverse Spin Polarizability



$$\delta_{LT}(Q^2) = \frac{16\alpha M^2}{Q^6}\int_0^{x_0} x^2[g_1(x,Q^2) + g_2(x,Q^2)]dx$$

Additional Applications of g_2p

- Bound State QED systems
- Calculations of the hydrogen hyperfine structure
- Hyperfine splitting in ground state of hydrogen has been measured to a relative accuracy of 10^{-13}
  - Calculations of this quantity are only accurate to a few ppm



$$\Delta_S = \Delta_Z + \Delta_{pol}$$

Related to g_2p!

Outline

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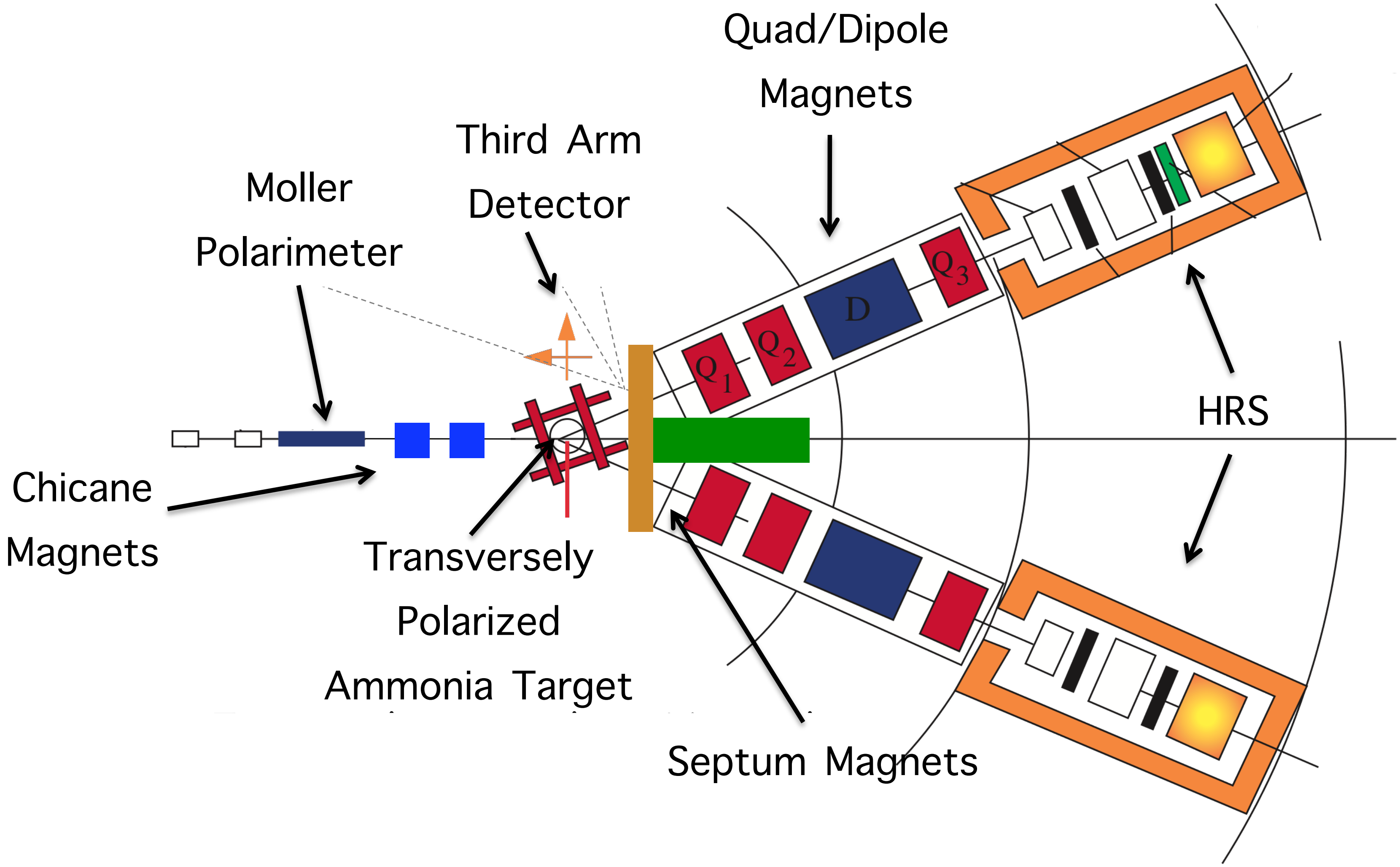
Snapshot of the Experiment

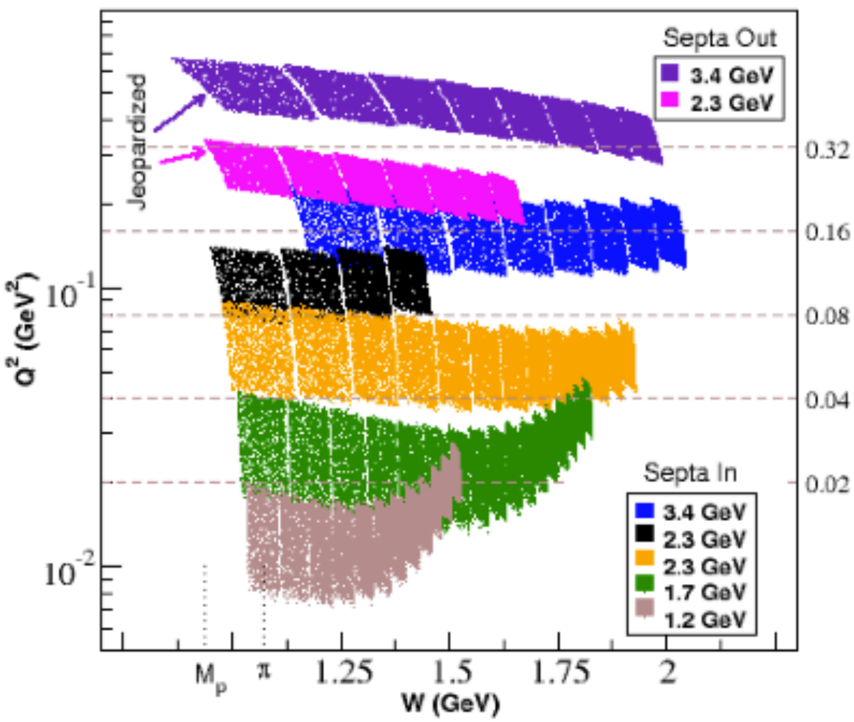


Timeline of Events

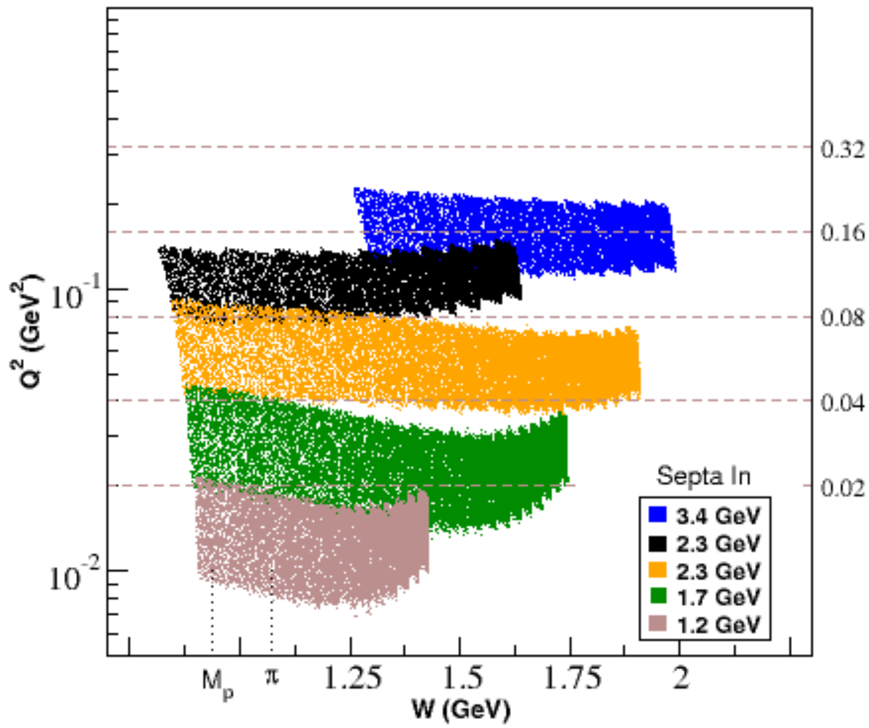
- September 2011: Hall C magnet quenches during a cool-down test
  - Decision is made to use Hall B magnet
- January 2012: Septum field lower than expected
  - Shims added to increase field strength
- February 2012: DAQ-mergency
  - Power supplies wired backwards, modules needed to be replaced/tested
- March 2012: Septum burns up
  - Able to bypass coils to run at reduced current

Kinematic Coverage

Proposed Experiment



Reduced Kinematics

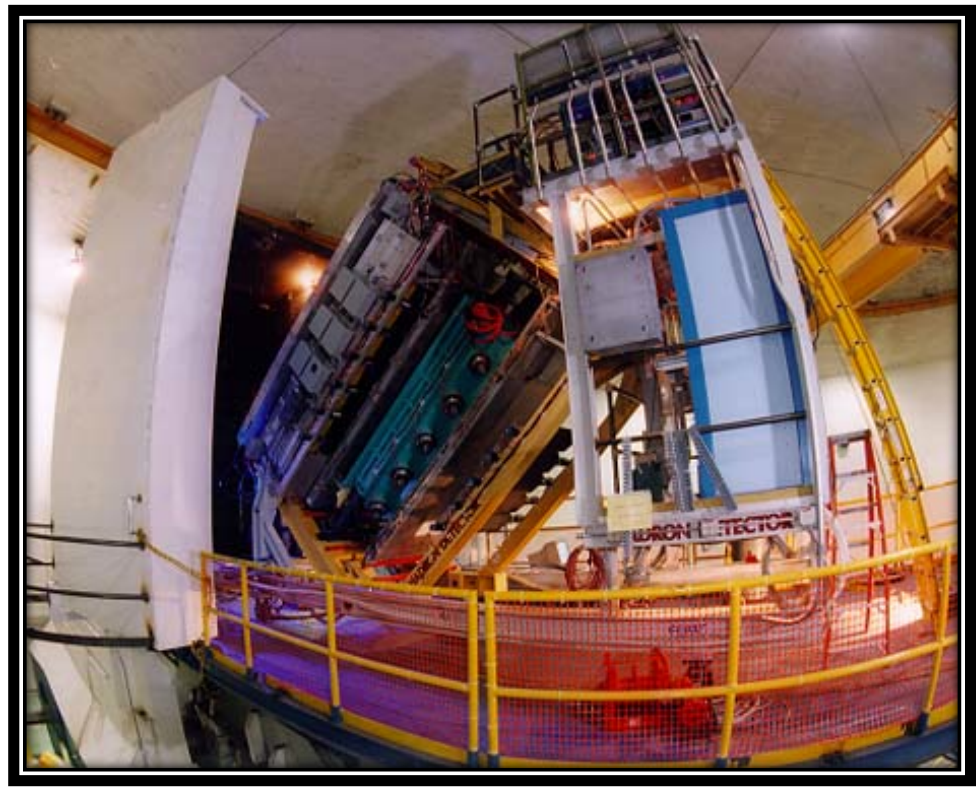


Detection of Scattered Electrons

- Each HRS is composed of a series of detectors

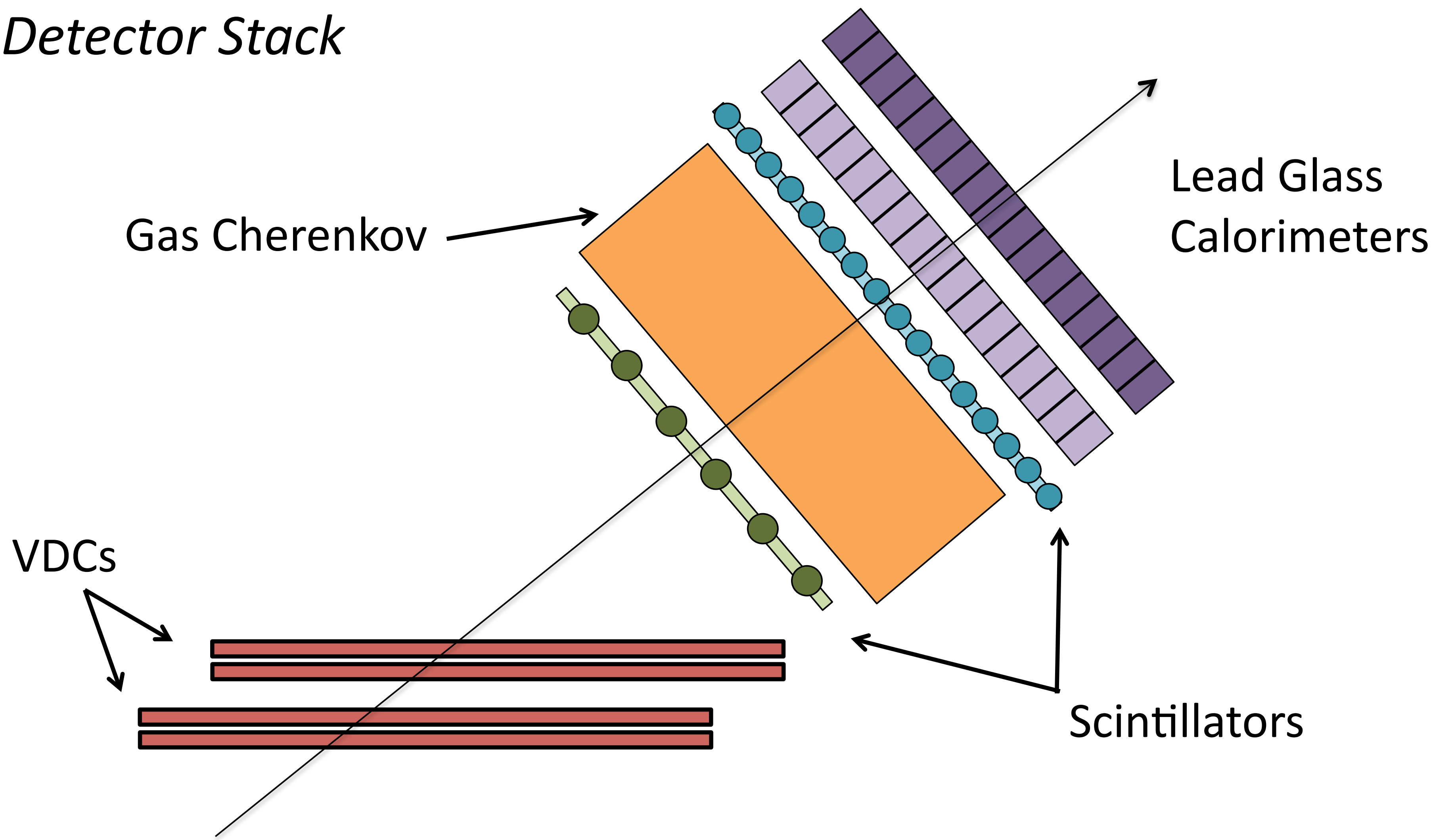
- High momentum resolution (10^{-4} level) over a range of 0.8 – 4.0 GeV/c

- Wide range of angular settings
  - 12.5° – 150° (LHRS)
  - 12.5° – 120° (RHRS)



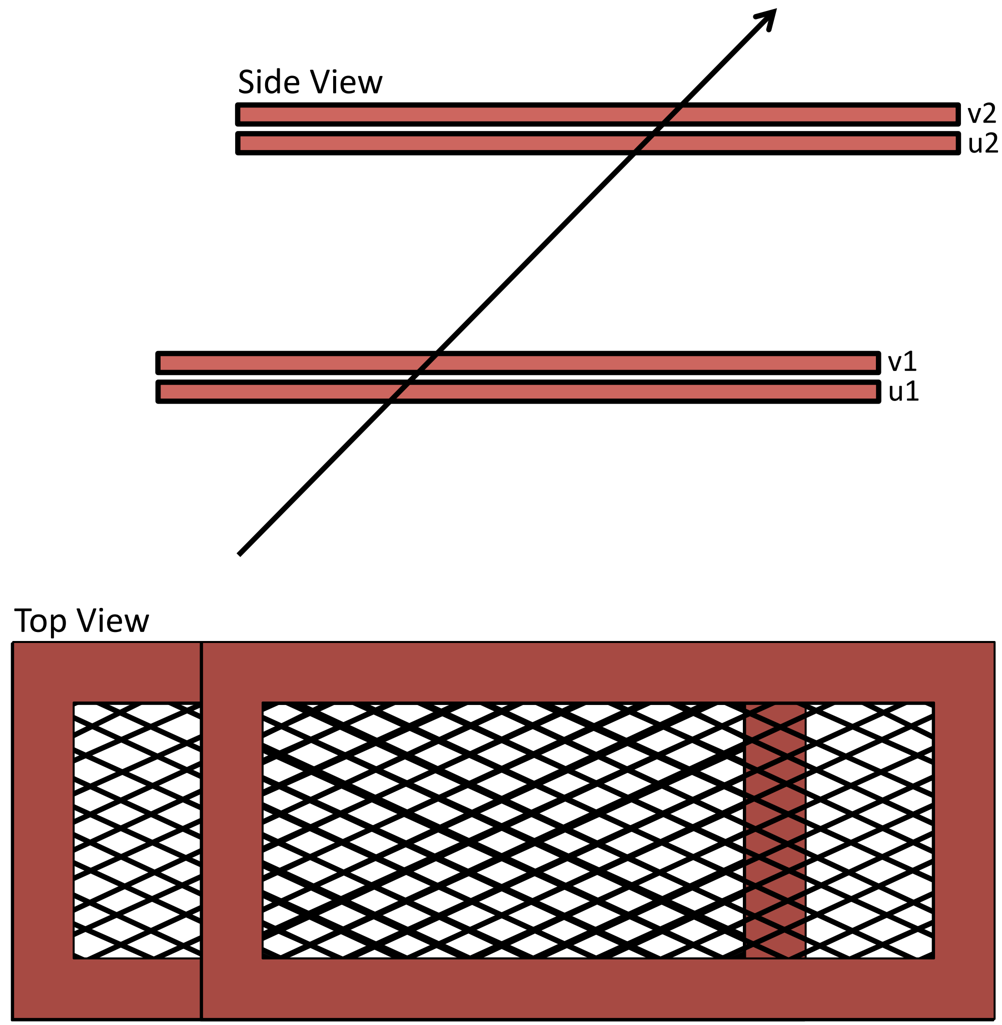
Hall A High Resolution Spectrometers

Detector Stack



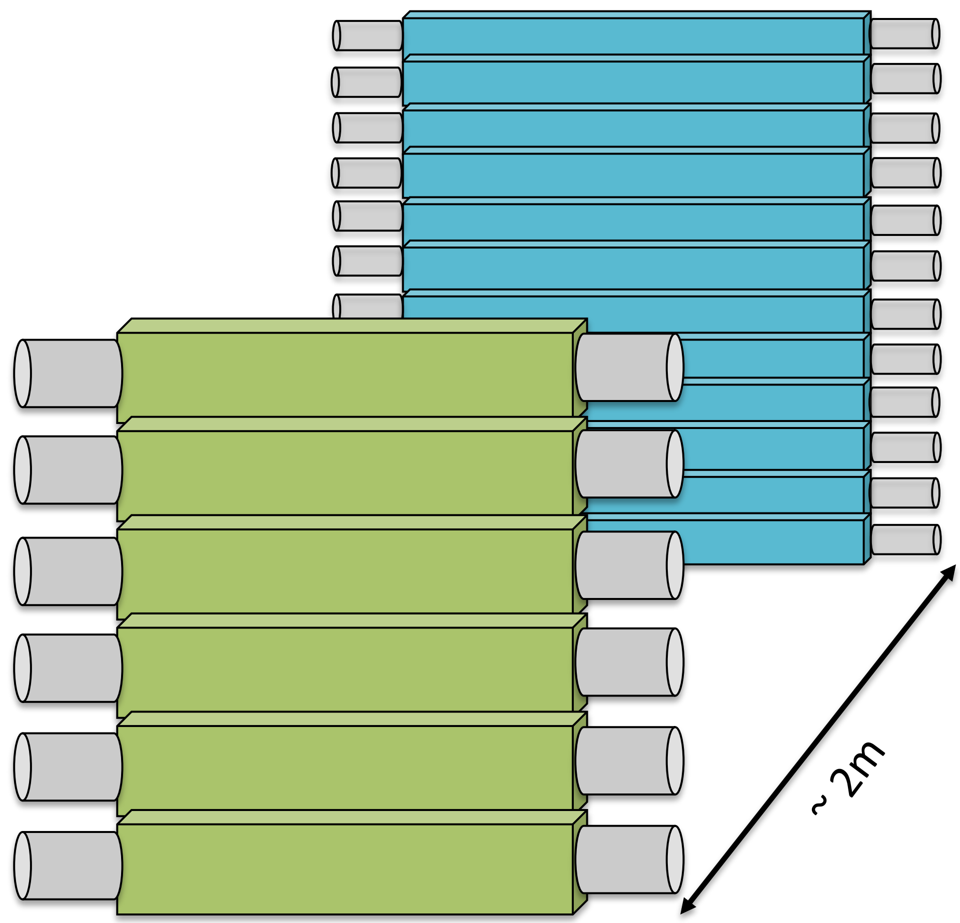
Vertical Drift Chambers (VDC)

- 4 total planes of wire chambers
  - 368 wires in each plane
  - Planes are rotated 90 deg
- Negative voltage is applied to the chamber
  - Positive ions drift towards cathode planes
  - Negatively charged ions drift towards ground wires
- Used for tracking information



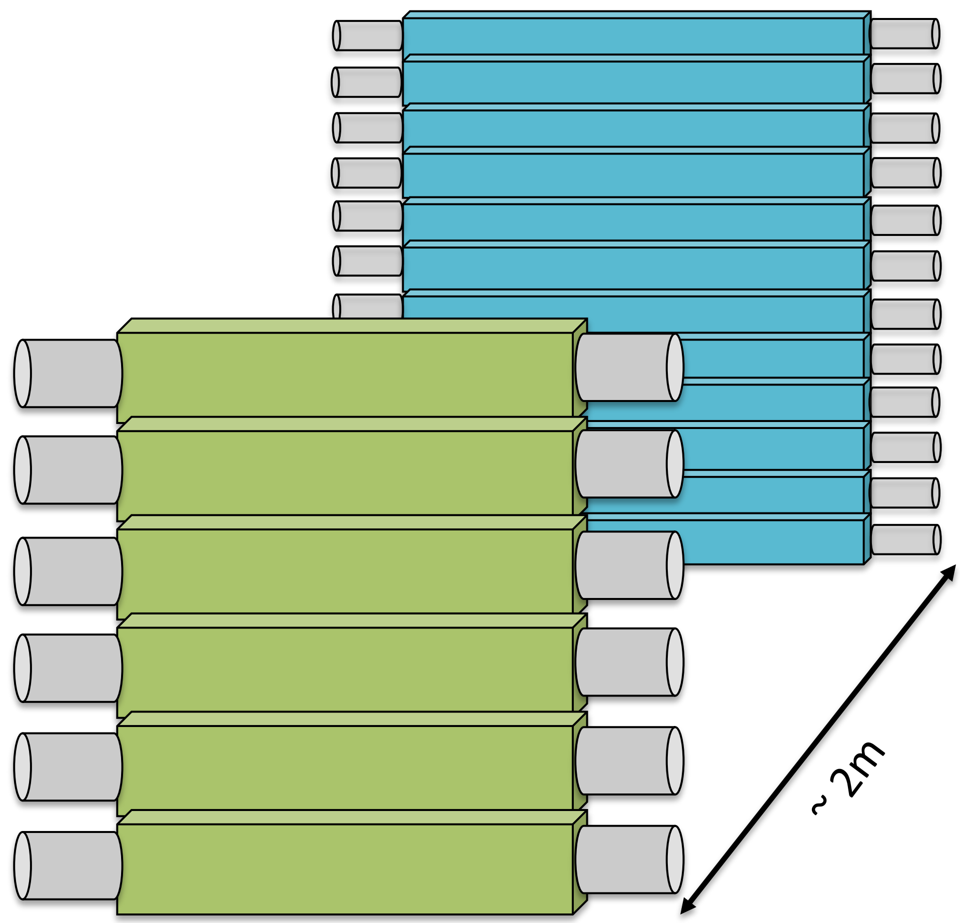
Scintillator Planes (s1 and s2m)

- Scintillate: “to sparkle”
- 2 planes, located ~2m apart
- 2 photomultiplier tubes (PMTs) on either side of paddle
- Used to form a “trigger” for the DAQ
- Also used for tracking information



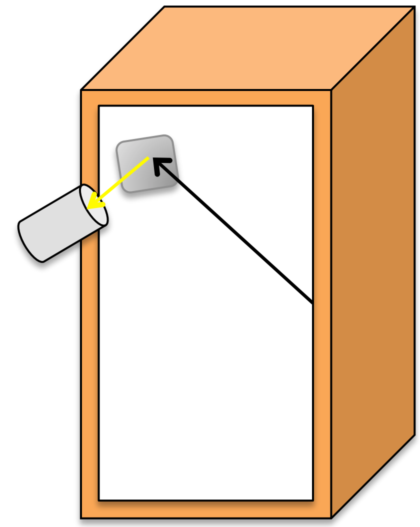
More About this “Trigger”...

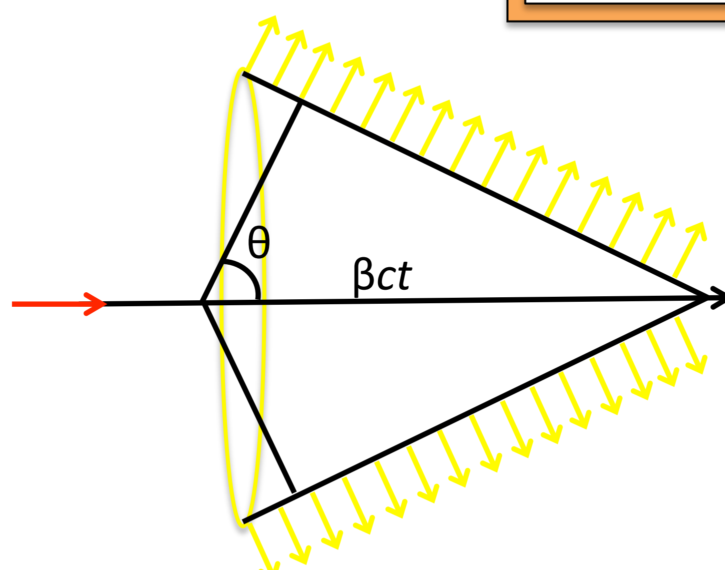
- PMTs on each paddle for a logical “AND”
- Each plane of paddles form a logical “OR”
- A particle which passes through s1 AND s2m forms a trigger
- A trigger tells the DAQ to read out information for that event



Gas Cherenkov

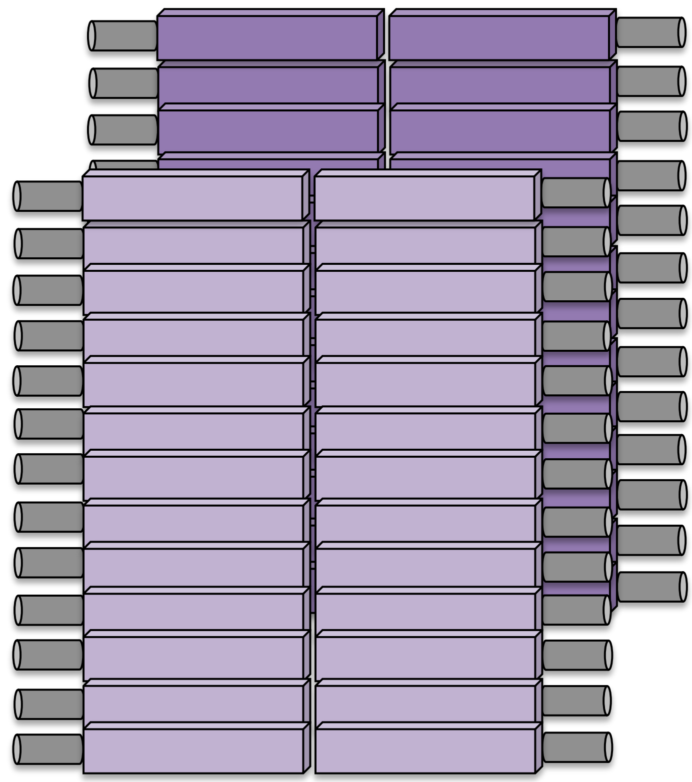
- Cherenkov Radiation
  - Occurs when a particle passes through a medium with a speed greater than the speed of light in that medium
- Electrons will produce Cherenkov light, heavier particles will not.
- Used for particle identification
- Part of an efficiency trigger





Lead Glass Calorimeters

- Two planes of lead glass blocks
- Particles deposit energy in the blocks
  - Causes a "shower" of electrons
- Used for particle identification
  - Pion rejection



Summary

- The g_2p Experiment
  - Little data existed previously for the polarized spin structure function (g_2) of the proton, specifically at low Q^2
  - Despite mechanical setbacks, we were able to accomplish most of our physics goals
  - Analysis is currently underway!

Thanks!

Graduate Students
Tobias Badman
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Ryan Zielinski

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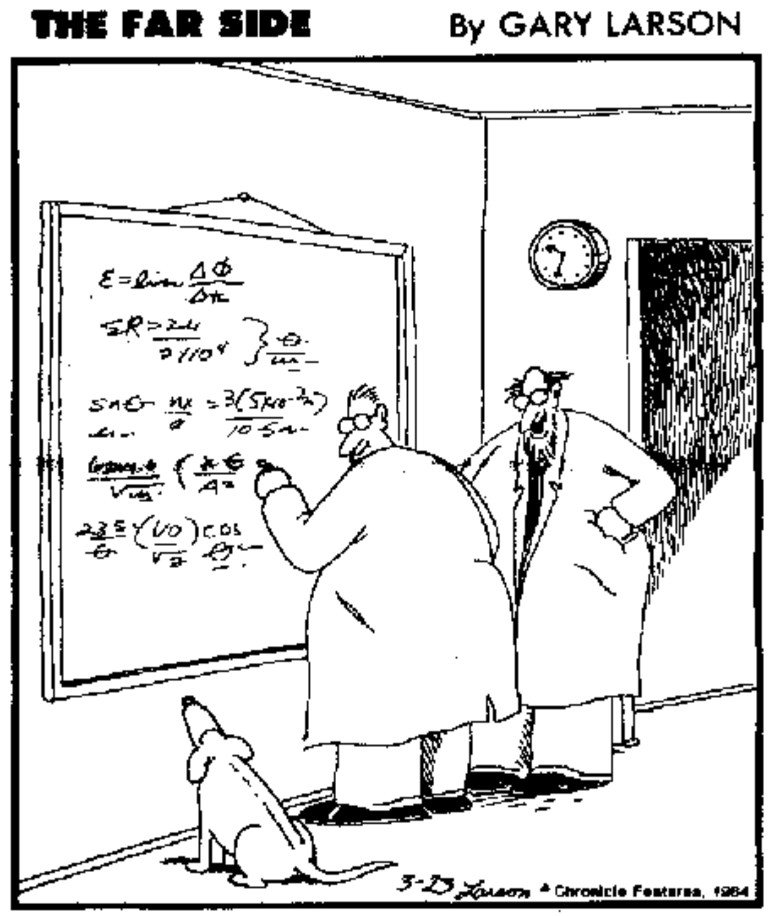
JP Chen
Alexandre Camsonne
Don Crabb
Karl Slifer

Post Docs
Kalyan Allada
James Maxwell
Vince Sulkosky
Jixie Zhang

JLab Target Group

Hall A Collaboration



"Ohhhhhhh . . . Look at that, Schuster . . . Dogs are so cute when they try to comprehend quantum mechanics."