Deuteron Polarized Tensor Structure Functions

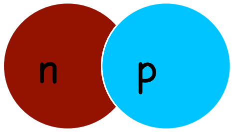
and a few other topics

K. Slifer, UNH

June 18, 2010

JLab Poltarg Meeting

Deuteron



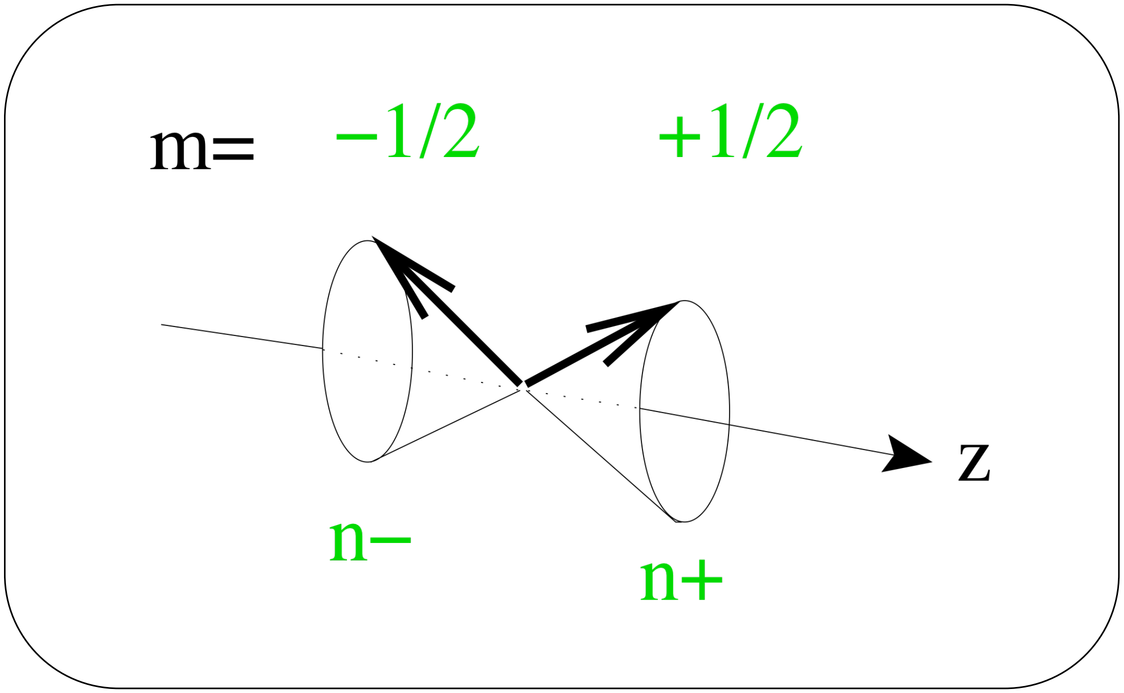
Spin-1 system

good testing ground for NN interaction because it's wave function is relatively well known

Reasonably easy to polarize

spin-1/2

Spin-1/2 system in B-field leads to 2 sublevels due to Zeeman interaction

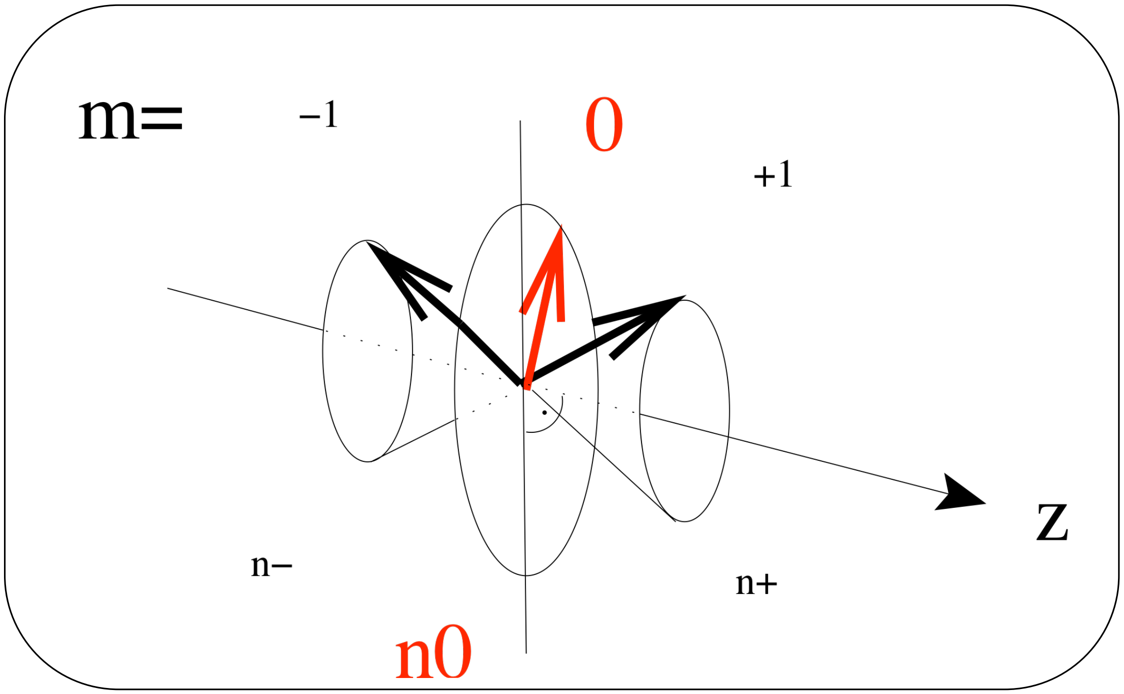


vector pol : $(n^+ - n^-)/(n^+ + n^-)$

(Any good figures in this talk were taken from thesis of Caroline Riedl, 2005
All the bad figures are my own)

spin-1

Spin-1 system in B-field leads to 3 sublevels due to Zeeman interaction

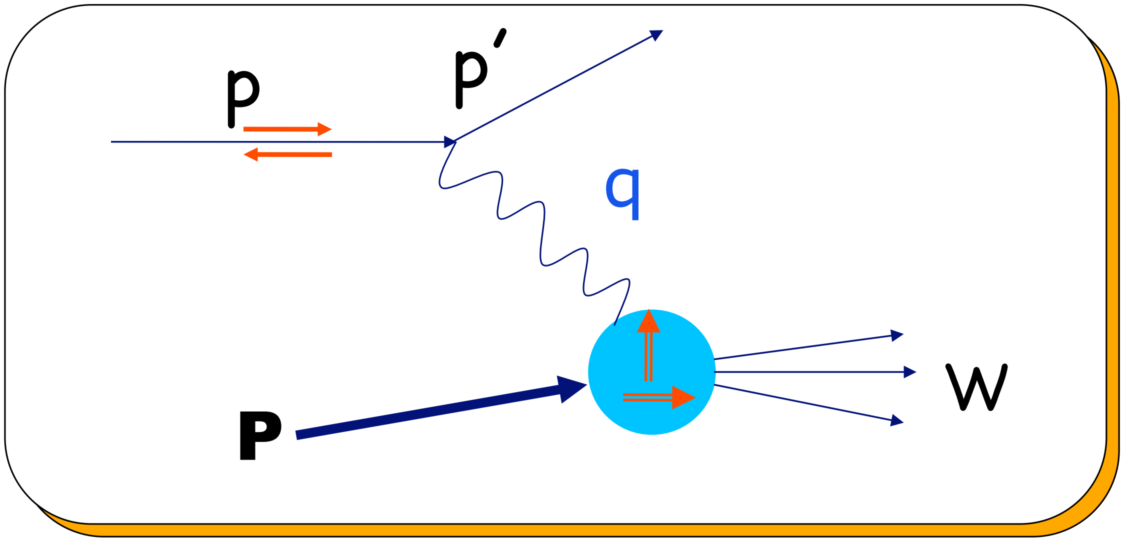


vector pol : $(n^+ - n^-)/(n^+ + n^- + n^0)$

and

Tensor pol : $(n^+ - n^- - 2n^0)/(n^+ + n^- + n^0)$

Inclusive Scattering (spin-1/2)



Construct the most general Tensor W consistent with Lorentz and gauge invariance

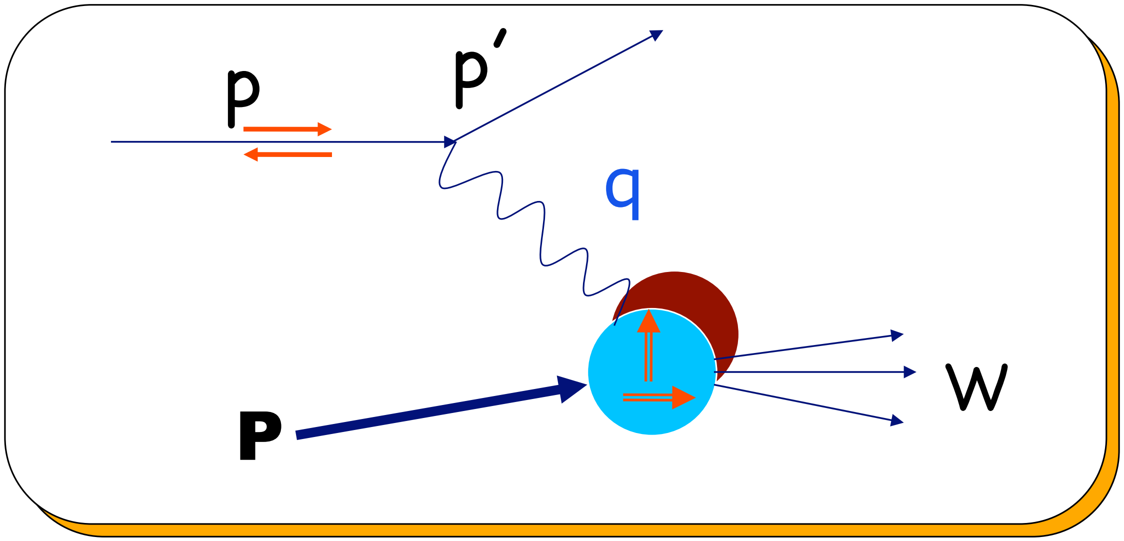
$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\frac{\theta}{2}\right]$$

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

Inclusive **Polarized** Cross Section

SFs parameterize everything we don't know about hadron vertex

Inclusive Scattering (spin-1)



Construct the most general Tensor W consistent with Lorentz and gauge invariance

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

$$+\epsilon b_1(x,Q^2) + \varepsilon b_2(x,Q^2) + \zeta\Delta(x,Q^2) + \eta b_3(x,Q^2)$$

Spin-1 => four more structure functions : b_1, b_2, b_3, Δ

Inclusive Scattering (spin-1)

four *more* structure functions ?

Inclusive Scattering (spin-1)

four *more* structure functions ?

Spin-1 Structure Functions

F_1, g_1 and b_1 are Leading Twist

i.e. easily interpretable in
simple non-interacting parton model

Spin-1 Structure Functions

F_1, g_1 and b_1 are Leading Twist

	Nucleon	Deuteron
F_1	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^{1/2} + q_{\downarrow\uparrow}^{-1/2}]$	$\frac{1}{3}\sum_q e_q^2[q_\uparrow^1 + q_\uparrow^{-1} + q_\uparrow^0]$

F_1 : quark distributions averaged over target spin states

Spin-1 Structure Functions

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g_1	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^{1/2} - q_\downarrow^{-1/2}]$	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^1 - q_\downarrow]$

F_1 : quark distributions averaged over target spin states

g_1 : difference of distributions of quarks aligned/anti-aligned with hadron

Spin-1 Structure Functions

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g_1	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^{1/2} - q_\downarrow^{-1/2}]$	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^1 - q_\downarrow]$
b_1	$\cdots$	$\frac{1}{2}\sum_q e_q^2[q^0 - q^1]$

F_1 : quark distributions averaged over target spin states
g_1 : difference of distributions of quarks aligned/anti-aligned with hadron

b_1 : difference of helicity-0/helicity non-zero states of *the deuteron*

1st measurement at Hera 2005

Spin-1 Structure Functions

F_1, g_1 and b_1 are Leading Twist

	Nucleon	Deuteron
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b_1	$\cdots$	$\frac{1}{2}\sum_q e_q^2[q^0 - q^1]$

b_2 related to b_1 by CallanGross relation

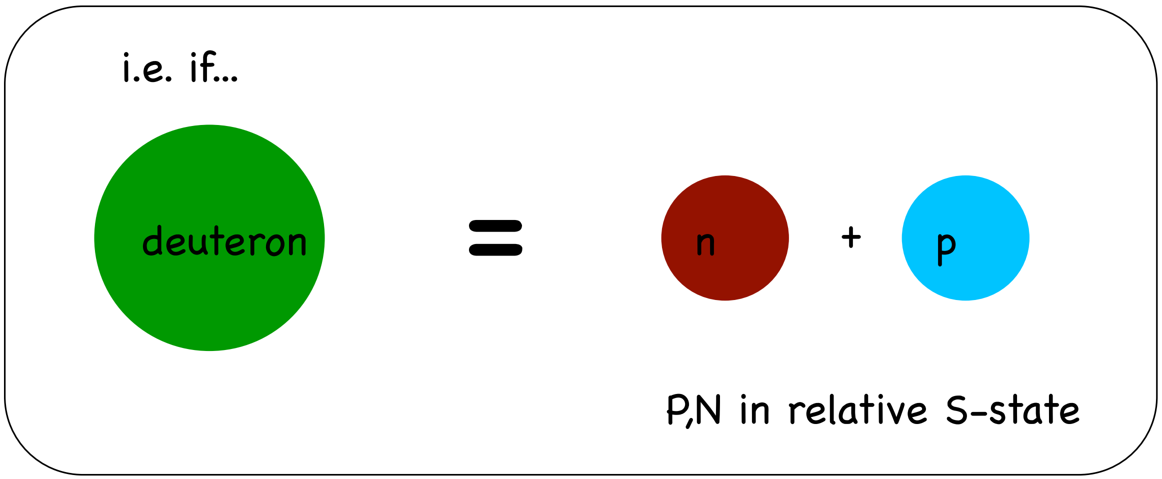
Δ: kinematically suppressed for longitudinal polarized target. Also, Leading Twist

b_3: higher twist, like g_2

b1

Hoodbhoy, Jaffe and Manohar (1989)

b1 vanishes in the absence of nuclear effects

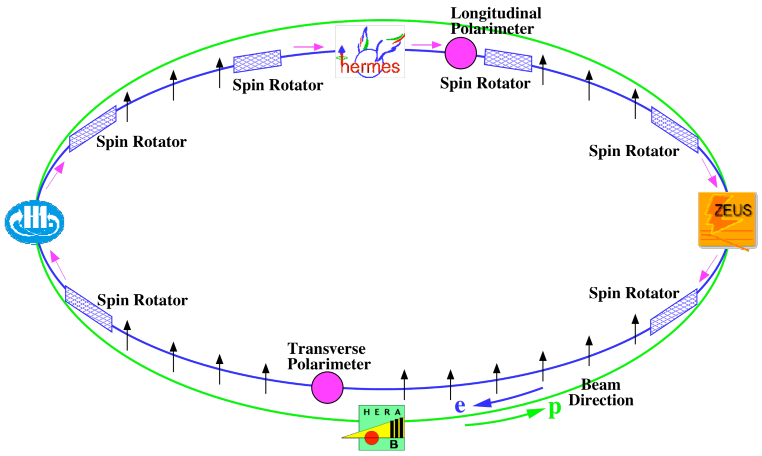


Nice mix of nuclear and quark physics

measured in DIS (so probing quarks), but depends solely on the deuteron spin state

Investigate nuclear effects at the level of partons

Hera Storage ring at Desy

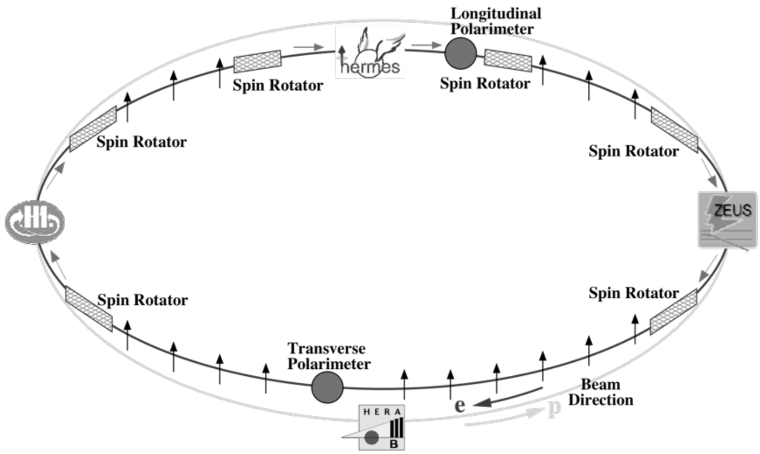


27.6 GeV positrons

Internal gas target

~Pure tensor polarization with little vector component

Hera Storage ring at Desy



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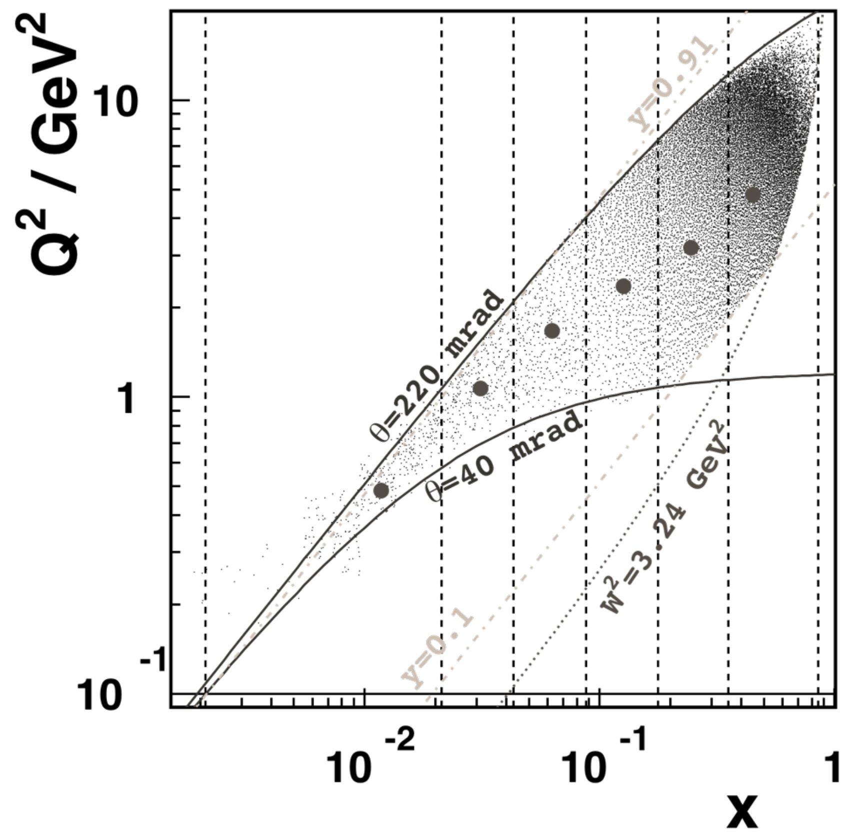
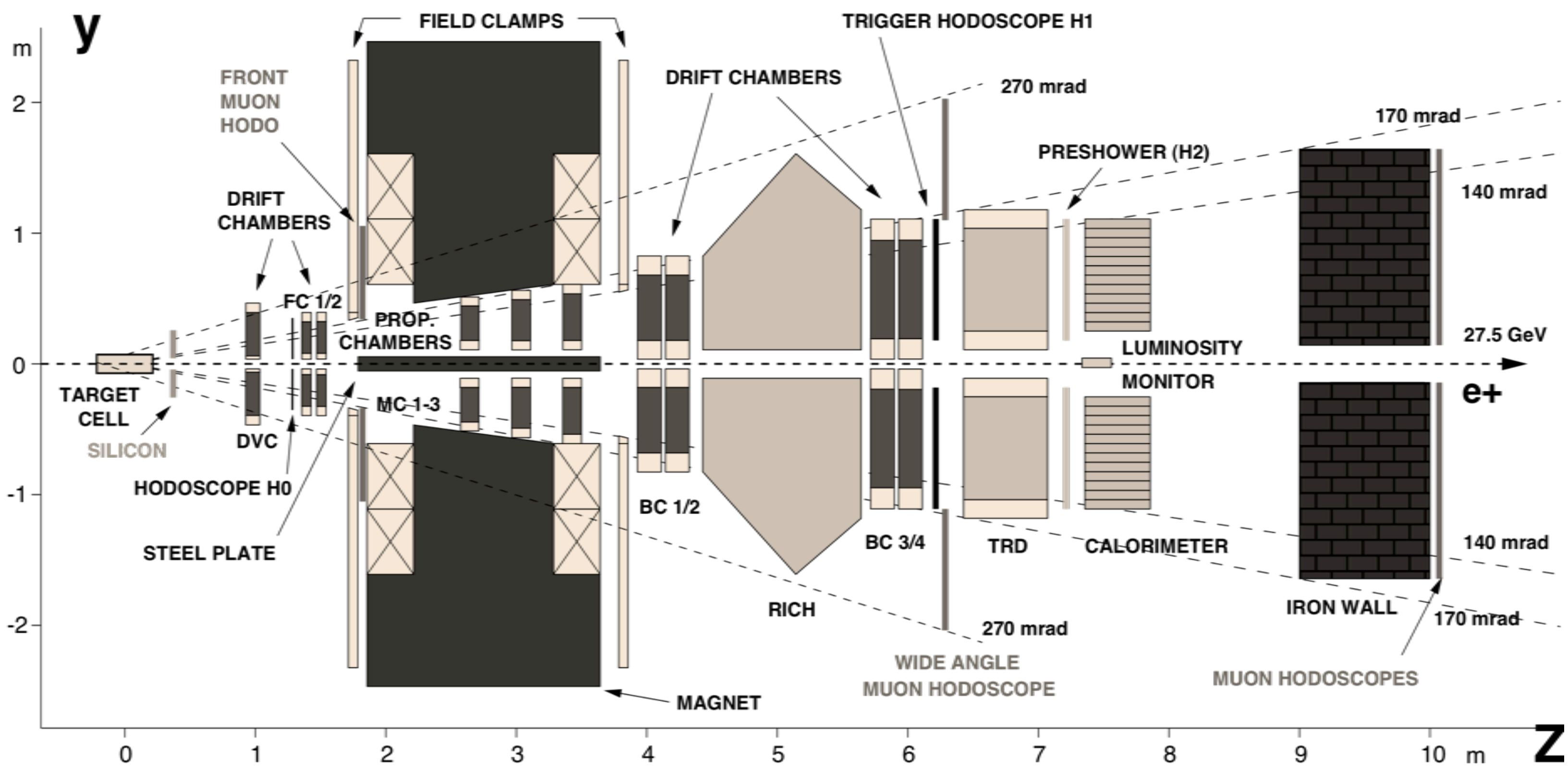


$0.01 < x < 0.45$

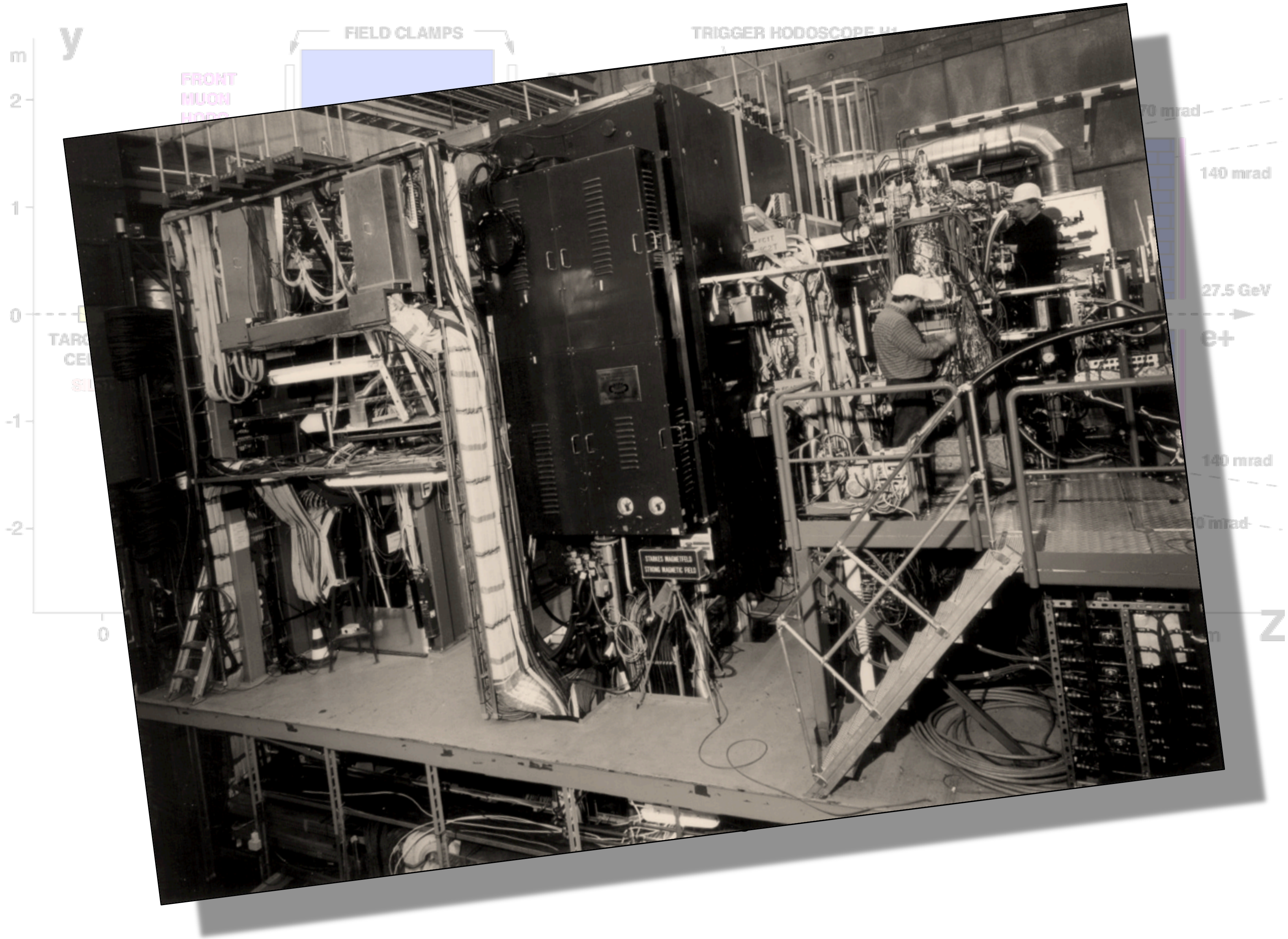
$0.5 < Q^2 < 5$ GeV^2

Hermes

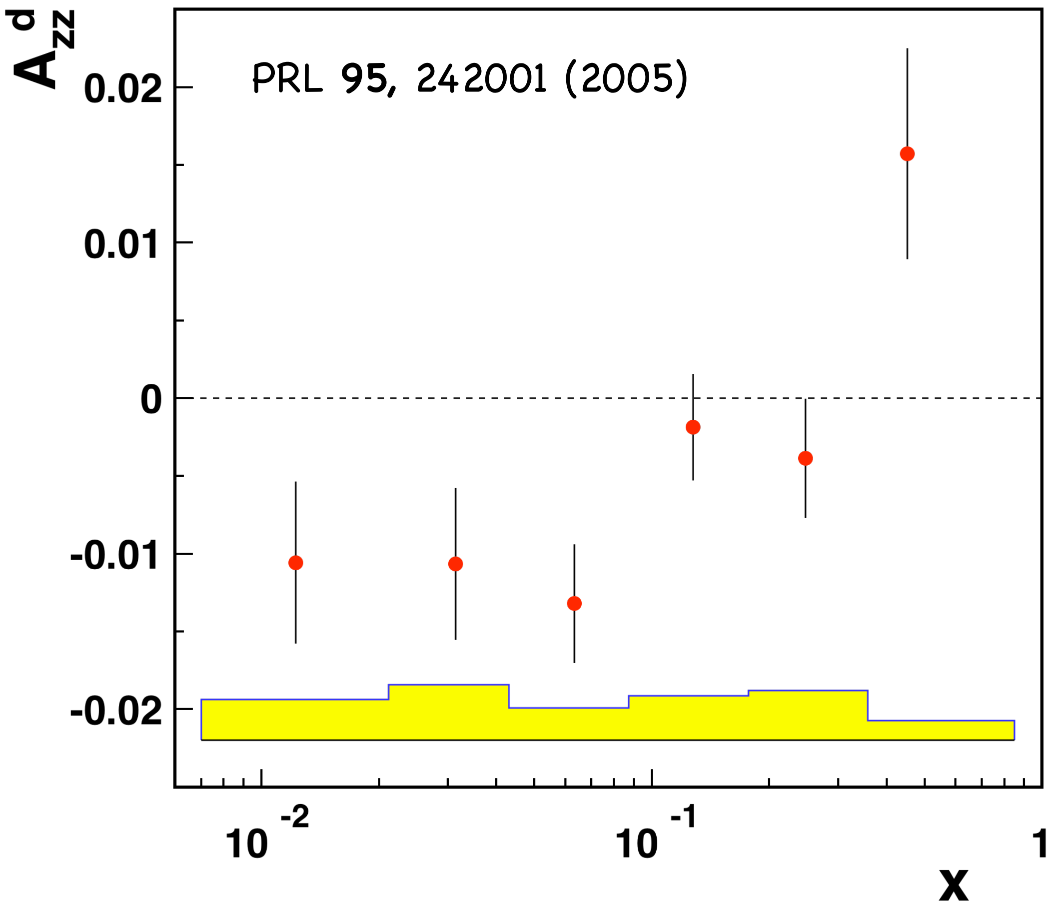


Forward angle, 40 mrad < Θ < 220 mrad
2π azimuthal coverage

Hermes



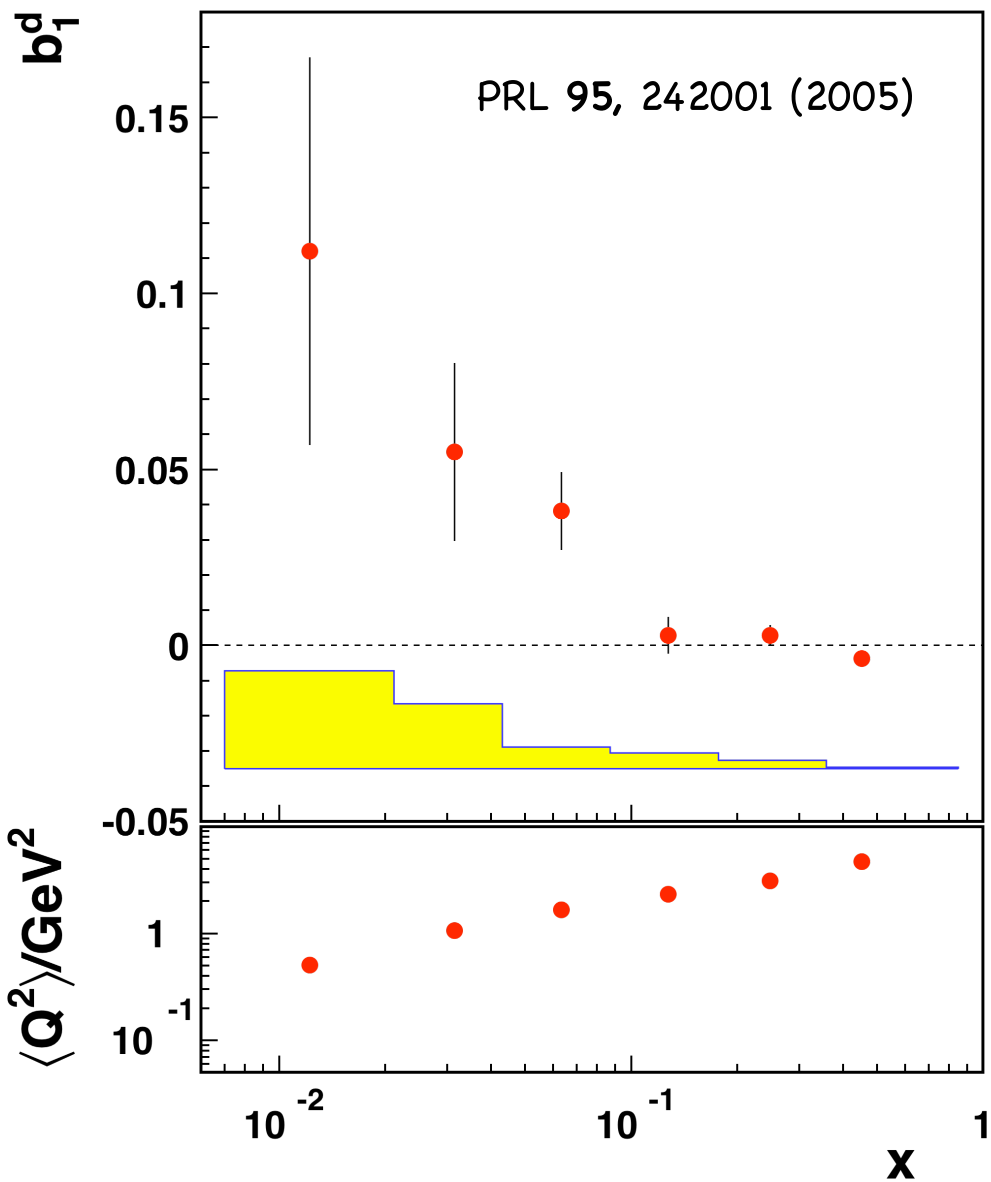
Tensor Asymmetry A_{zz}



$$A_{zz} = \frac{1}{P_{zz}} \frac{2\sigma^1 - 2\sigma^0}{3\sigma^u}$$

Hermes result was non-zero by about 2σ

b_1



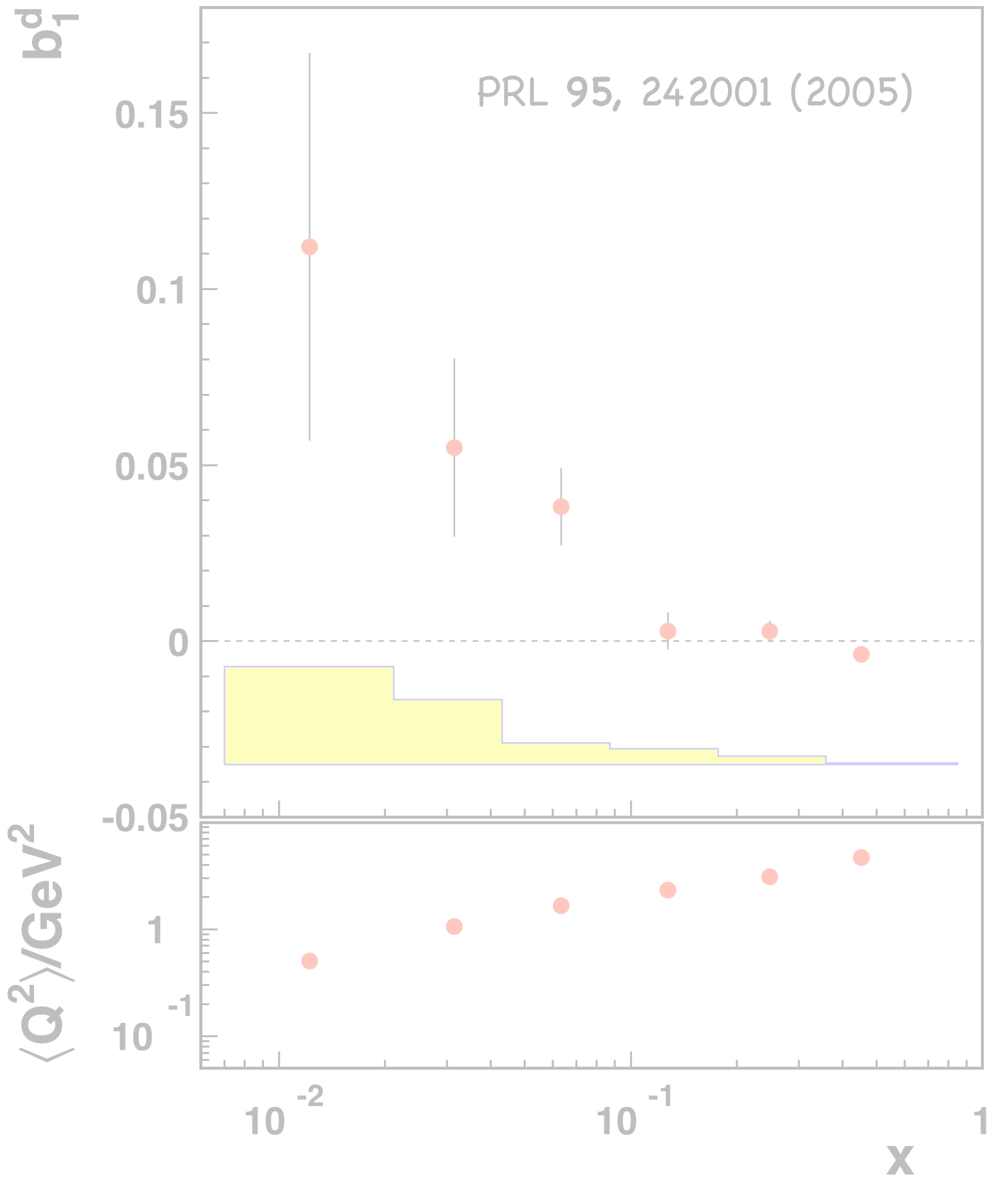
$$b_1 = -\frac{3}{2} F_1 A_{zz}$$

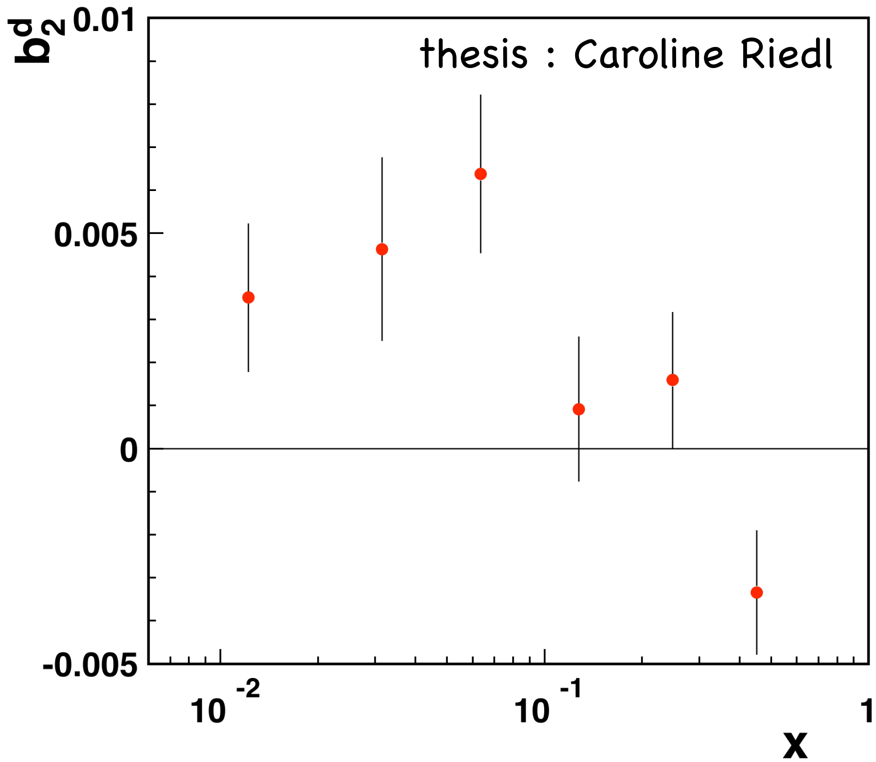
b_1 rise at low x can be related to same mechanism responsible for nuclear shadowing

Ashman et al. PLB 206, 364 (1988)

Also can be described in models with double scattering of lepton, first from the proton, then neutron

b2

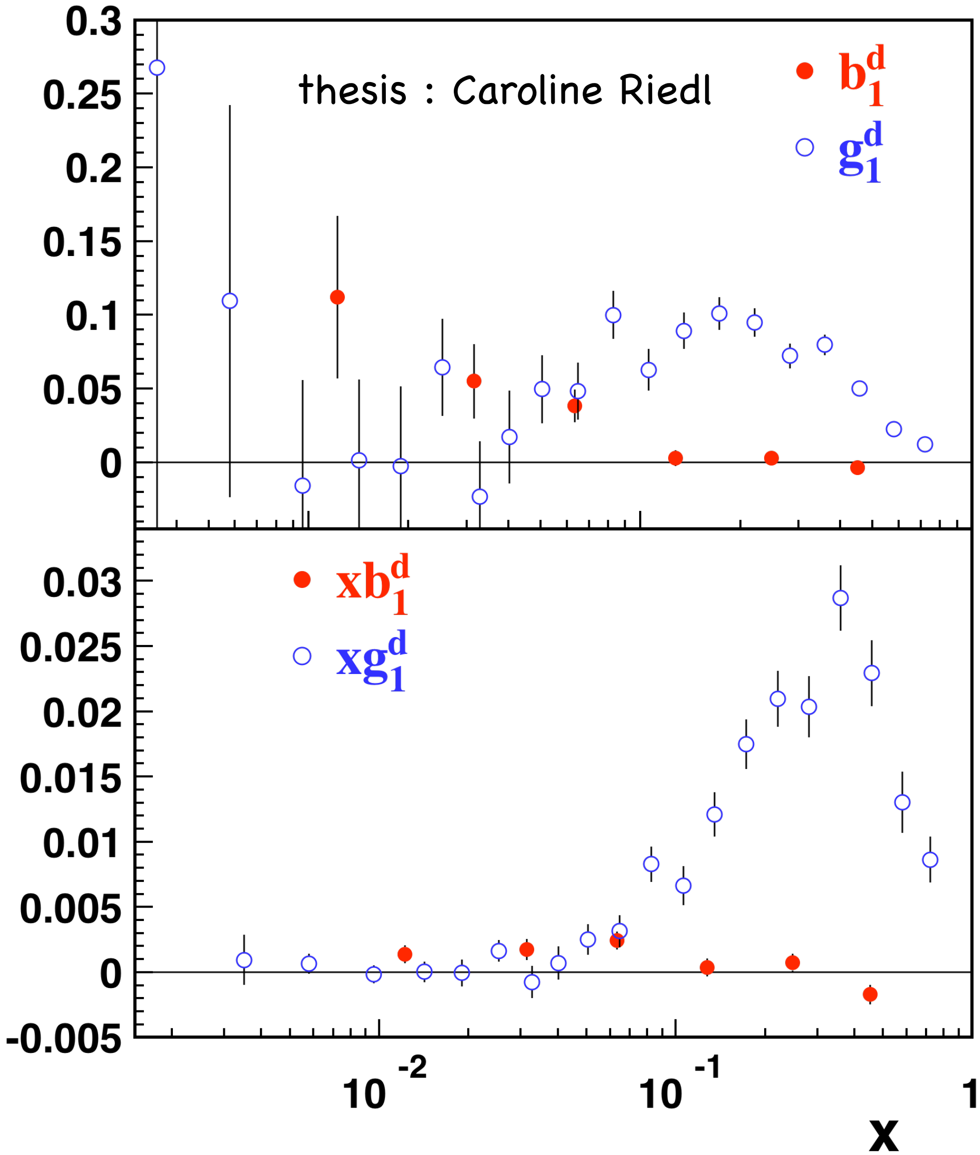




b_2 related to b_1 by CallanGross-like relation

$$2xb_1 = \left(\frac{1+\gamma^2}{1+R}\right) b_2$$

b_1 compared to g_1



Practical impact : b_1 historically ignored in extractions of g_1

But could be non-negligible...

Close-Kumano Sum Rule

$$\int b_1(x)dx = \frac{1}{9}\Theta Q_s$$

$$\int b_1(x)dx = 0$$

if the sea quark tensor polarization vanishes

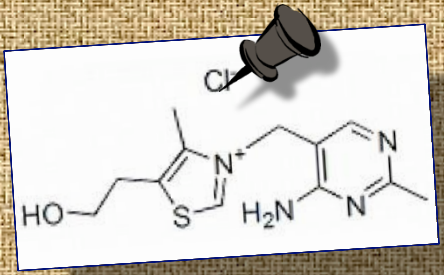
Hermes result

$$\int_{0.0002}^{0.85} b_1(x)dx = 0.0105 \pm 0.0034 \pm 0.0035$$

2.2 σ difference from zero

how handled the unmeasured extrapolations?

Possible measurement of b1 at JLab



JLab

Unpolarized Beam for b_1,
but better to use polarized beam to get simultaneous measurement of g_1,
and then isolate b_1 by spin averaging.

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UVa/JLab DNP Target : Longitudinal magnetic field to provide quant axis. Spin Flip desirable

Material : ND_3 (Could use other spin-1 targs ^{6}Li or maybe even ^{14}N)

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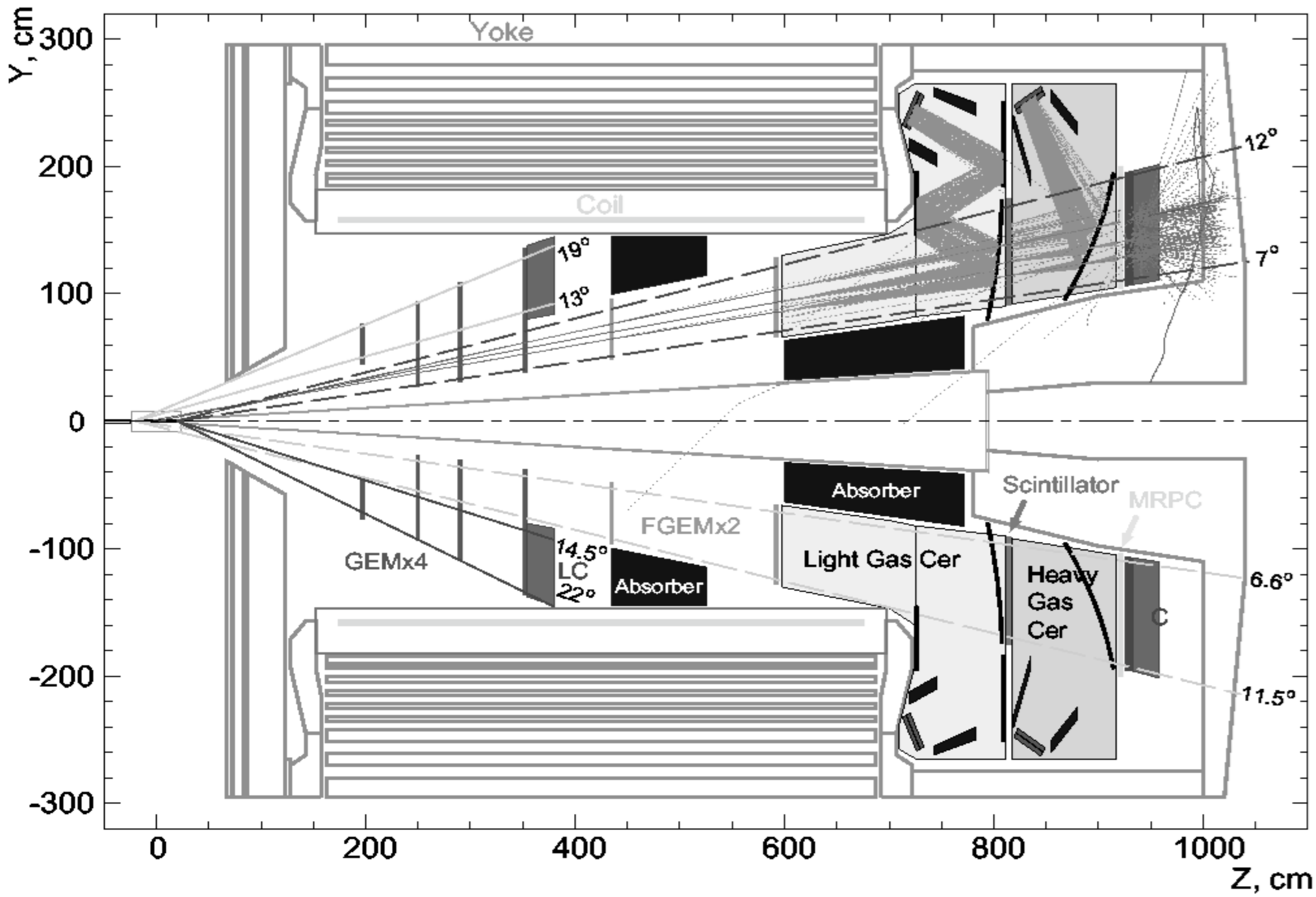
Material : ND_3 (Could use other spin-1 targs ^{6}Li or maybe even ^{14}N)

Vector polarization determined by standard NMR, then simple relation for tensor pol:

$$P_{zz} = 2 - \sqrt{4 - 3P_z^2}$$

Crabb et al. had some limited success in enhancing the tensor polarization in past

SOLID



Forward angle, 7 < Θ < 20 degree
2π azimuthal coverage

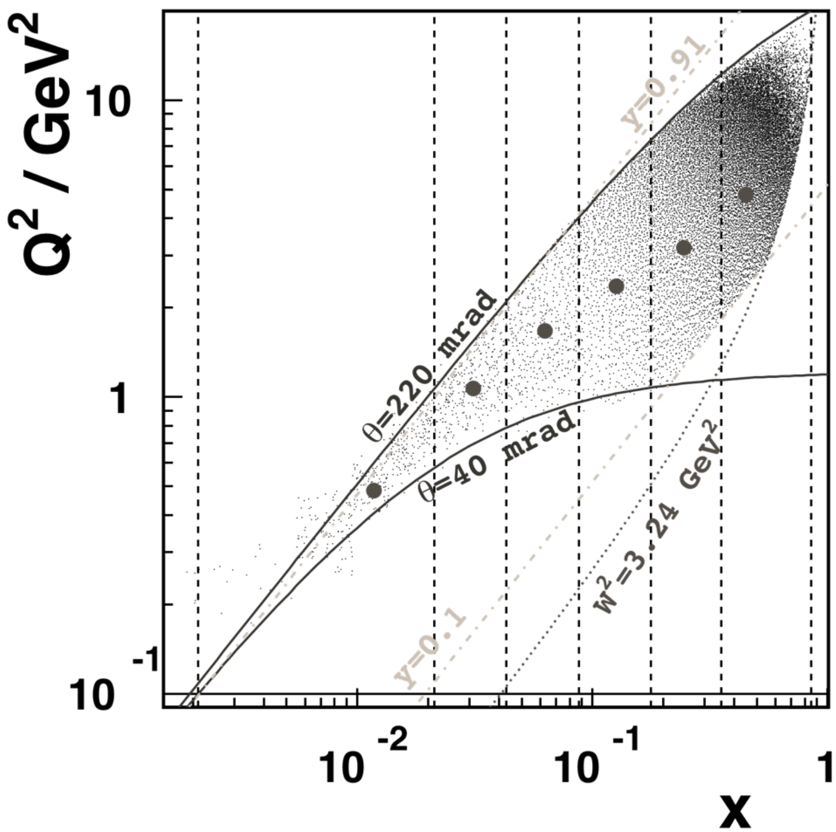
Hermes/JLab Comparison

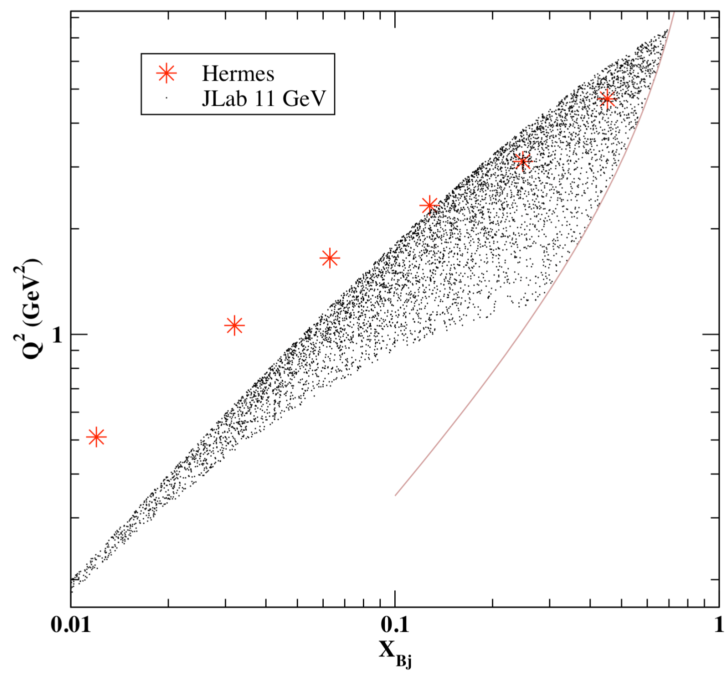
	Hermes	JLab (projected)
P_{zz}	0.8	0.2
Dilution	0.9	0.24 (or 0.36)
$\mathcal{L}$ (cm^{-2} s^{-1})	10^{31}	10^{35}
$\Delta\Theta$	1.13 sr	1.43 sr
ΔE	-	-

Hermes advantage : Large P_{zz} with negligible P_z. Very small dilution

JLab advantage : Luminosity

Kinematics

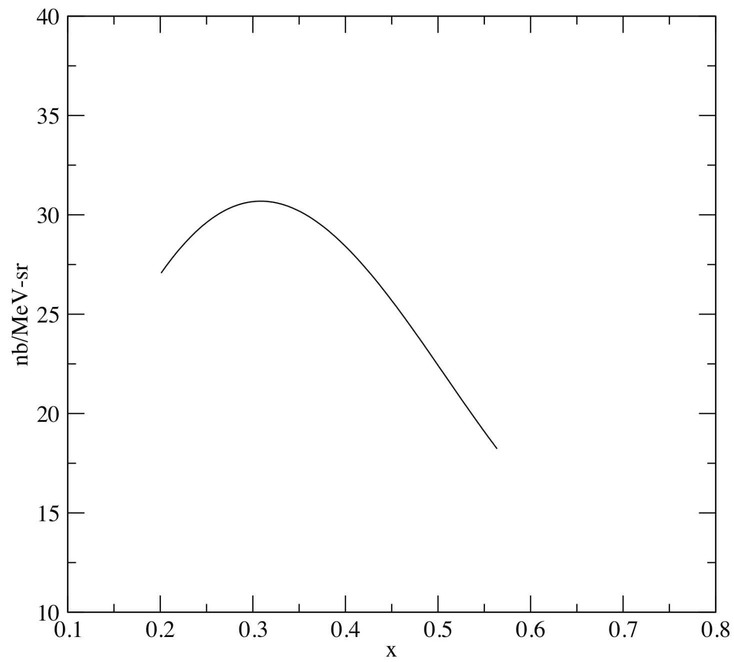


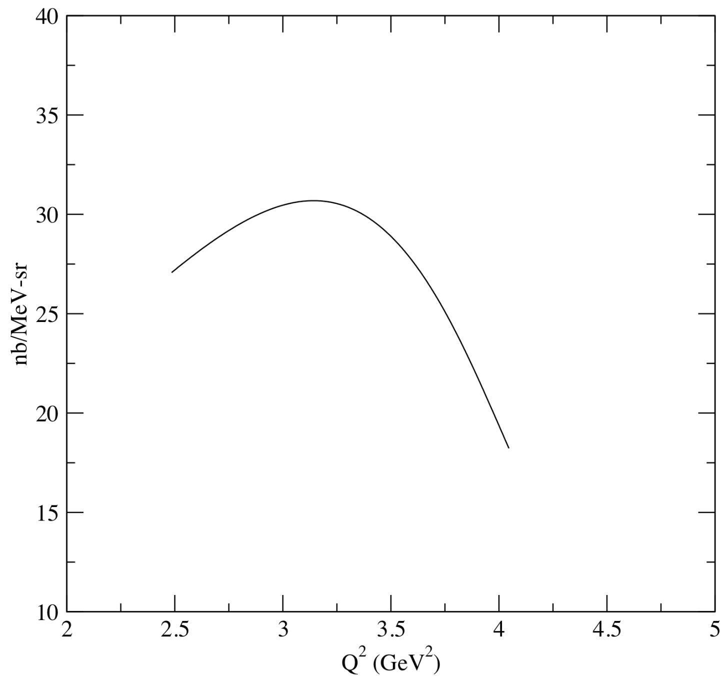


$0.01 < x < 0.45$

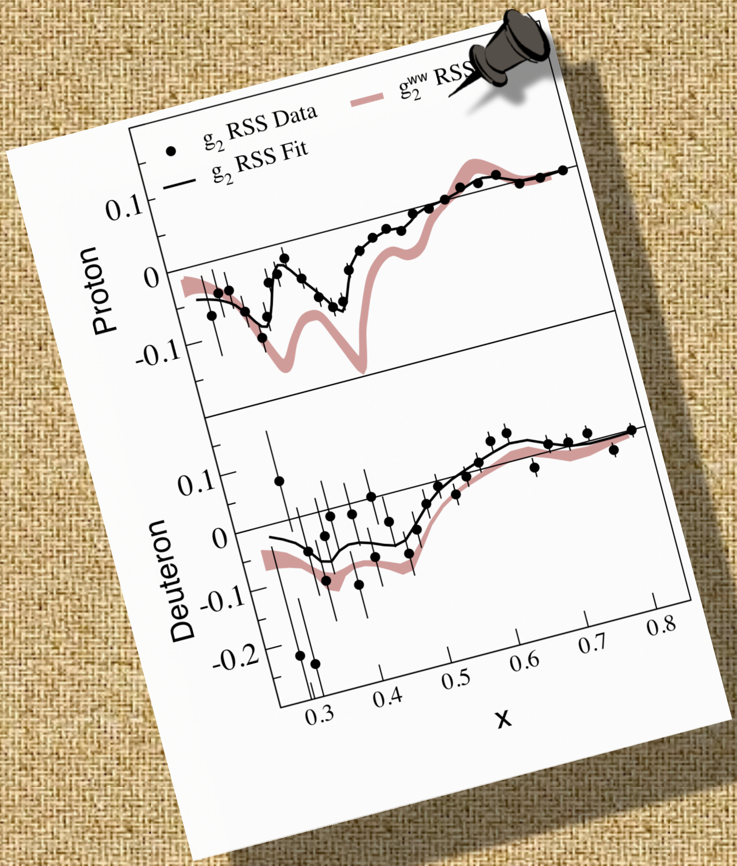
$0.5 < Q^2 < 5\ GeV^2$

Working on rates...





a comment on g_2



g_2 is ideal for studying HT

Wandzura-Wilczek relation PLB **72** (1977) 195

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

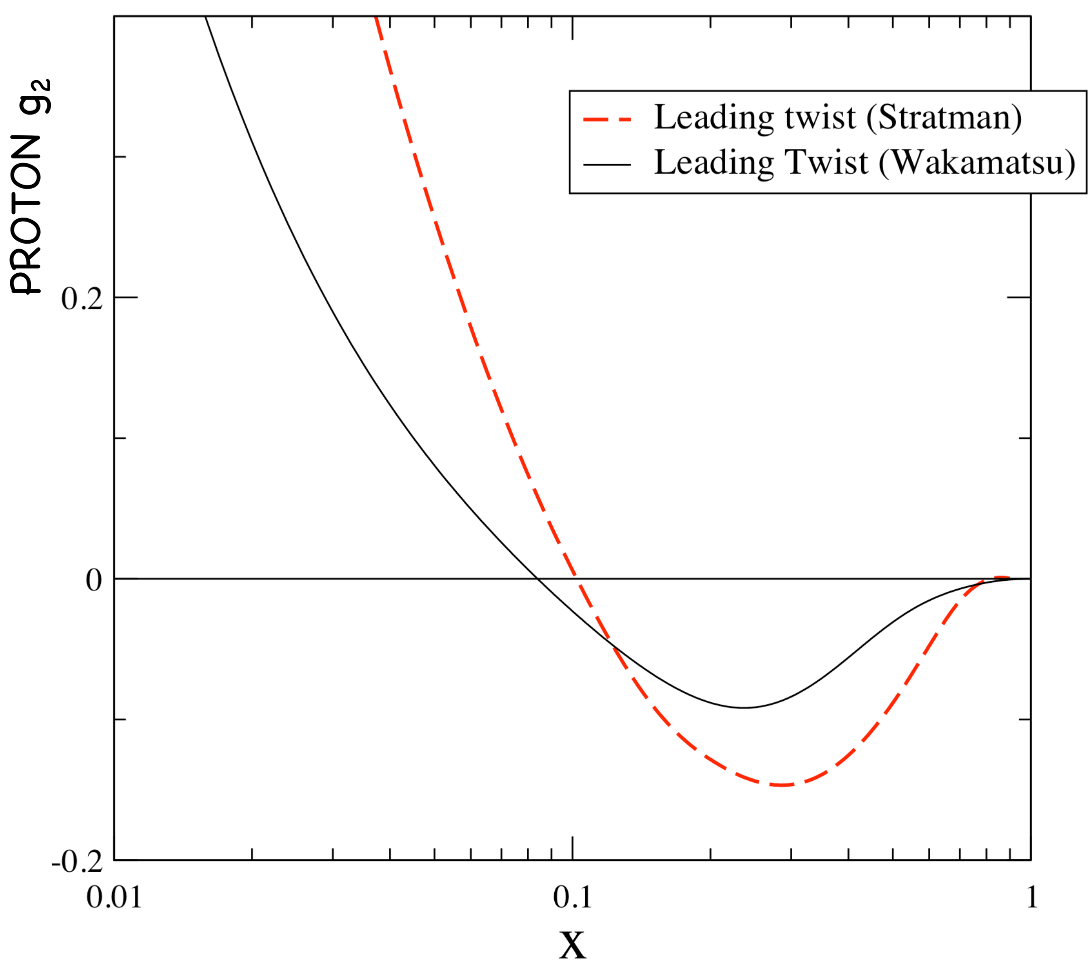
Leading twist determined entirely by g_1

$$g_2 = g_2^{WW} + \overline{g}_2$$

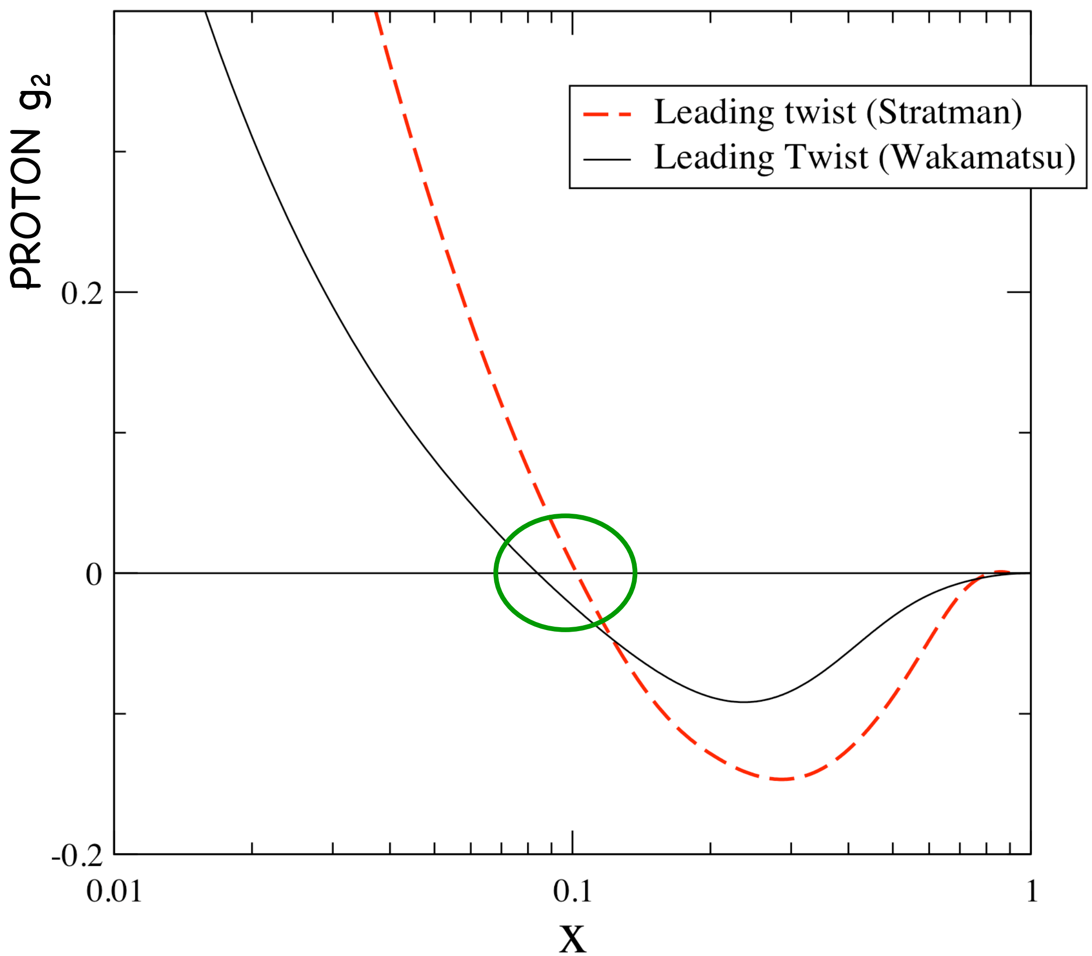
Higher twist

g_2 doesn't exist in Parton Model.
Good quantity to study higher twist

Higher Twist in g_2



Higher Twist in g_2



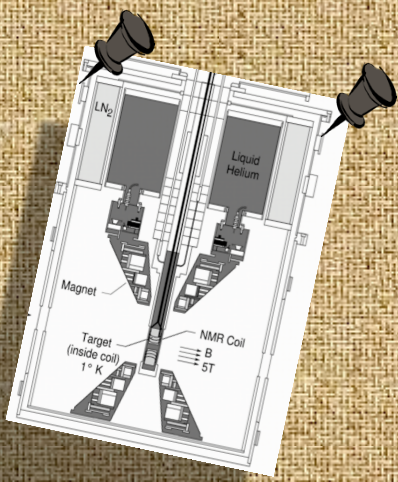
Look for the zero crossing of g2ww to measure clean Higher twist

Hat tip to Oscar Rondon, UVa

UNH_3 Lab

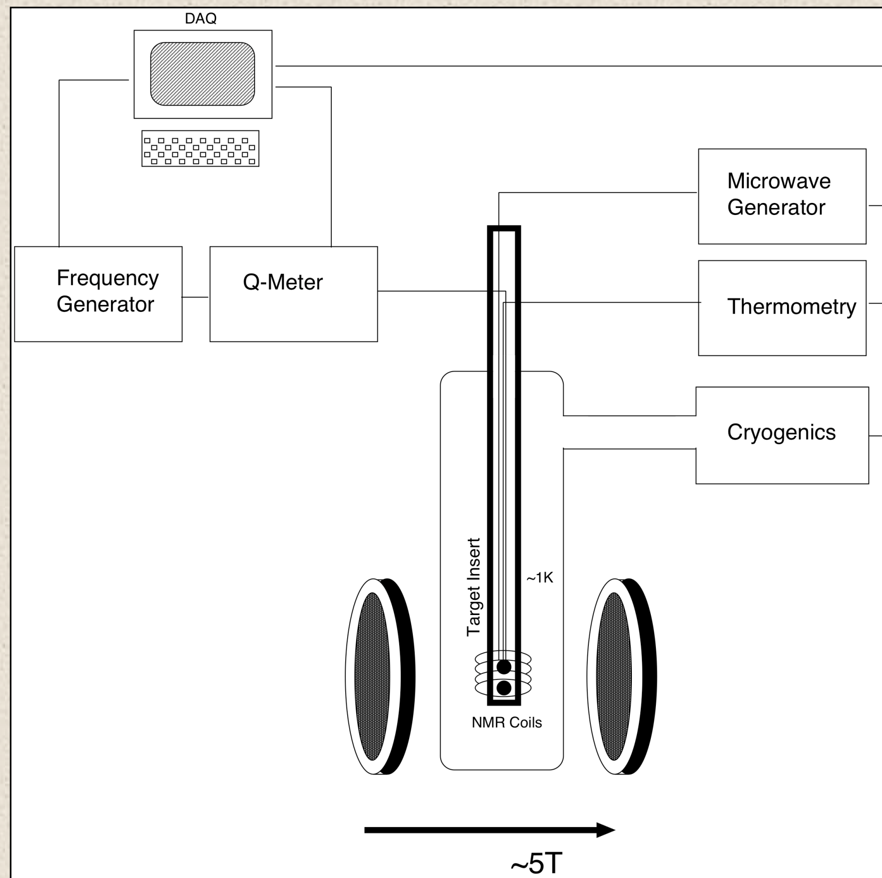
Short term goal : provide local (to NH) training ground for UNH graduate and undergrad students in preparation for the g2p and gep experiments

Long term : fully operational DNP system for future development



Crude outline of Polarizing system

1. Cryostat and Refrige
2. Polarizing Magnet
3. Microwave Source
4. NMR Polarimetery



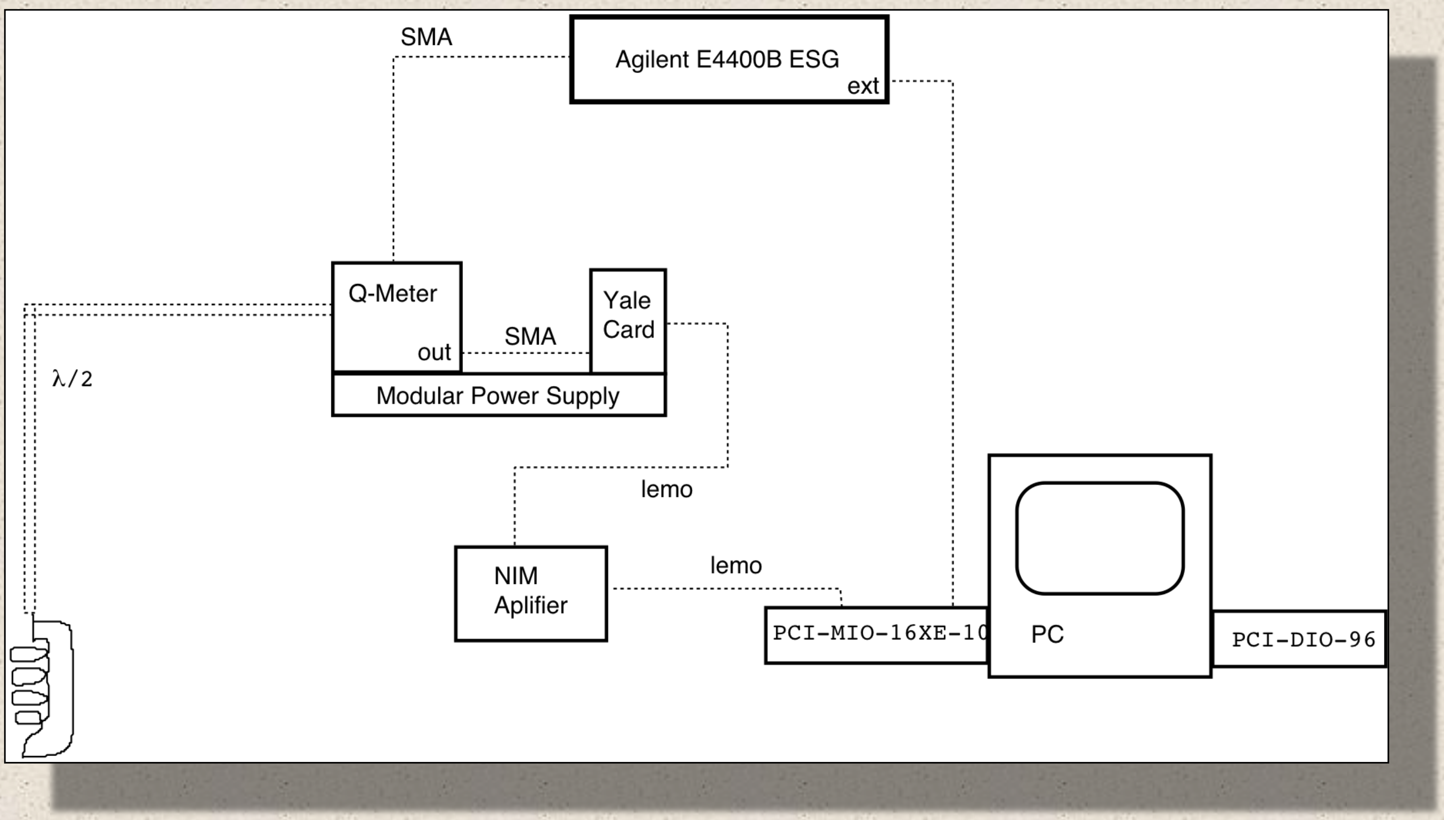
Gone thru 2 grant cycles with generally strong support from our reviewers of an attempt to establish a UNH target lab to help spread some of the expertise beyond UVa and JLab. But still we've recieved limited funding...

Have been focusing the request on the 6 GeV run, but really have to provide a better 12 GeV motivation.

For now, get the lab running with NMR system.

thanks to JLab and UVa loaners

NMR System almost complete



Have

Target PC
NI MIO card
Nim Amp
Q-Meter
Yale Card
Agilent FG 250kHz - 1.0 GHz
NI GPIB enet controller

Need (major)

pickup coil (target stick)
crystal oscillator

Need (minor)

Few more GPIB cables,
SMA connectors
lambda/2 cable
modular PS

UNH_3 Lab

UNH_3 Lab

UNH_3 Lab

Undergrads: John Donahy, Greg Hadcock and Trevor Bielarski
+ 3 new grad students in the fall