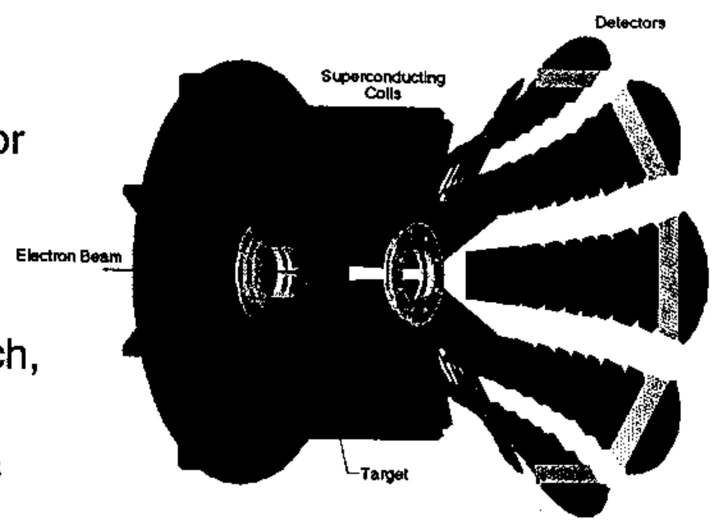
PR 00-006

G0 Experiment

Caltech, Carnegie-Mellon, W&M, Hampton, IPN-Orsay, ISN-Grenoble, Kentucky, La. Tech, NMSU, JLab, TRIUMF, UConn, UIUC, UMan, UMd, UMass, UNBC, VPI, Yerevan

- Determine contributions of strange quarks to charge and magnetization distributions of the nucleon
  - measure asymmetries at forward and backward angles
  - detect protons for forward angle measurement
  - detect electrons for backward angle measurement
  - → G_E^s, G_M^s to few percent of G_{dipole} for $0.1 \leq Q^2 \leq 1.0$ GeV^2
- working to develop deuterium measurement to map out effective $G_A^Z(Q^2)$ - related to nucleon anapole moment
- also measure inelastic transition form factor $G_A^{N\Delta}$
- Dedicated apparatus (Hall C)
  - superconducting spectrometer system (UIUC)
  - 20 cm LH_2 target (Caltech/UMd)
  - highly segmented detector system (UMd, et al.; Grenoble/Orsay)
  - additional detectors for electron detection (LaTech, TRIUMF)
  - custom timing electronics (Carnegie-Mellon; Grenoble/Orsay)
  - polarized source (JLab, VPI)
  - infrastructure, beam monitoring (JLab)



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Low Energy Nucleon Structure: Point-like Quarks

- Measure $G^{\gamma,p}, G^{Z,p}, G^{\gamma,n}$

  - e.g. $G^{\gamma,p} = \sum_j e_j^{\gamma} G^{j,p}$

$$= \frac{2}{3} G^{u,p} - \frac{1}{3}\left(G^{d,p} + G^{s,p}\right)$$

where $G^{j,p}$ are the contributions of the j^{th} flavor to the measured proton form factor

  -note:

$$\left.\begin{aligned} G^{u,p} &= G^{d,n} \\ G^{d,p} &= G^{u,n} \\ G^{s,p} &= G^{s,n} \end{aligned}\right\} \quad \text{isospin symmetry}$$

then

$$G_{E,M}^{u,p} = \left(3 - 4\sin^2\theta_W\right) G_{E,M}^{p,\gamma} - 4 G_{E,M}^{p,Z}$$

$$G_{E,M}^{d,p} = \left(2 - 4\sin^2\theta_W\right) G_{E,M}^{p,\gamma} + G_{E,M}^{n,\gamma} - 4 G_{E,M}^{p,Z}$$

$$G_{E,M}^{s,p} = \left(1 - 4\sin^2\theta_W\right) G_{E,M}^{p,\gamma} - G_{E,M}^{n,\gamma} - 4 G_{E,M}^{p,Z}$$

Neutral Weak Current from PV Electron Scattering

- $G^{Z,p}$ contributes to electron scattering

$$\sigma \propto \left| M^{\gamma} + M^{Z} \right|^2$$

  - interference term: **large** M^{γ} x small M^{Z}

- interference term violates parity: use $(\vec{e}, e')$

$$A^{PV} \equiv \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

$$\propto \frac{A_E + A_M + A_A}{2\sigma_{unp}}$$

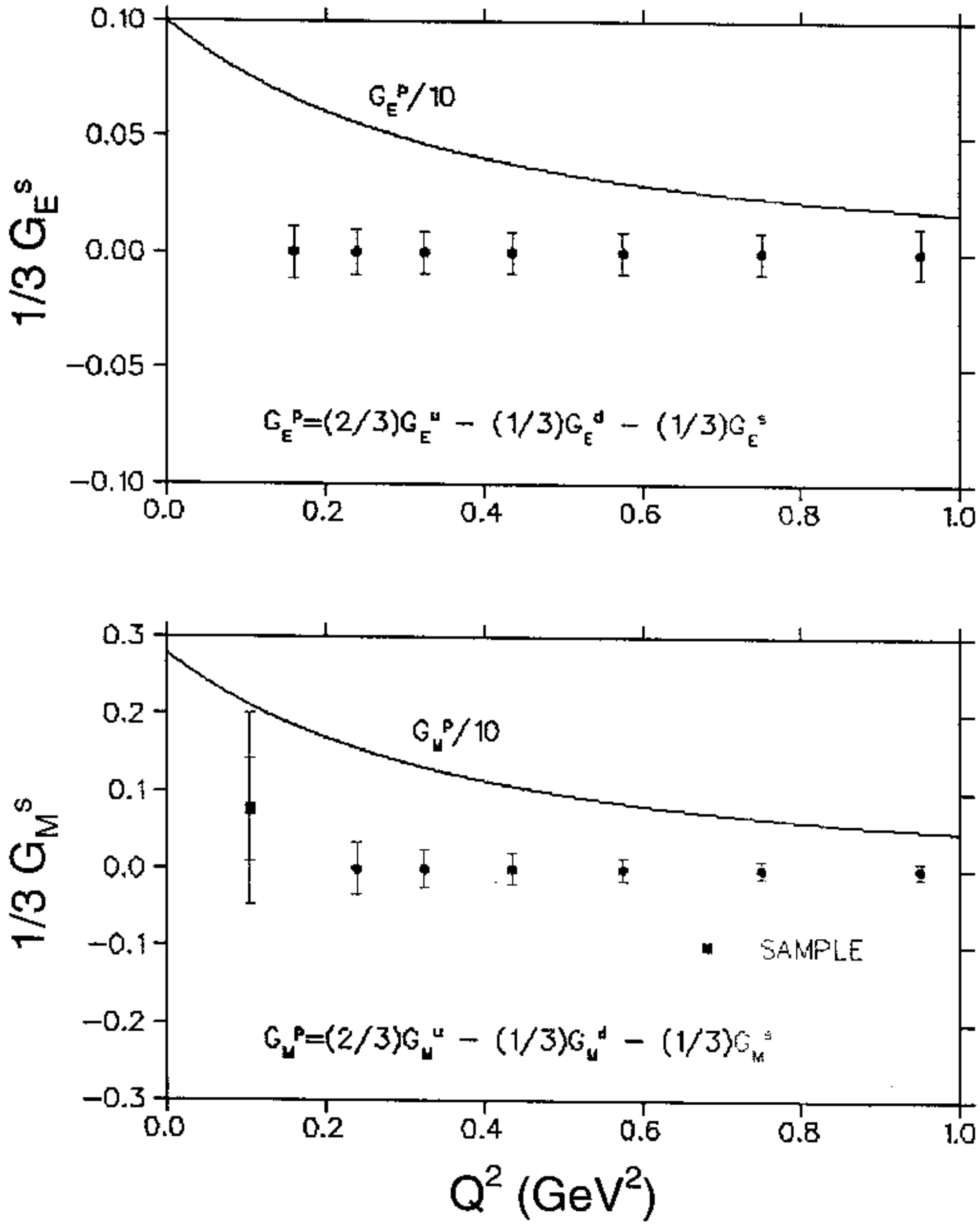
where

$$A_E = \varepsilon(\theta) G_E^{\gamma} G_E^{Z}$$

$$A_M = \tau G_M^{\gamma} G_M^{Z}$$

$$A_A = -\left(1 - 4\sin^2\theta_W\right)\varepsilon'(\theta)\, G_M^{\gamma} G_A^{Z}$$

G0 Experiment Expected Results

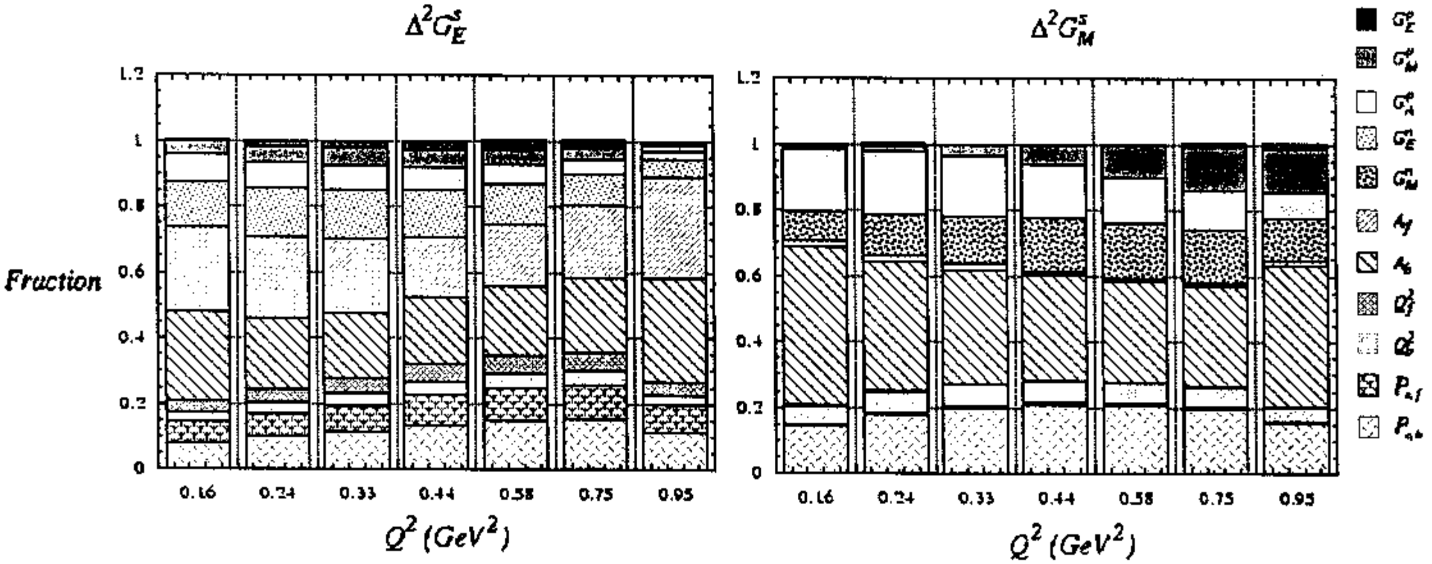


- measurements of s quark contribution to G_E, G_M to a few % over range of Q^2
  - uncertainties shown include statistical, systematic
  - based on HAPPEX measurements, false asymmetries expected to be very small

Optimized Uncertainties

- Running time is optimized to provide balance of statistical and systematic uncertainties
  - statistical and systematic uncertainties typically ~ 3 - 5 %

- False asymmetries small
  - false asymmetries from helicity-correlated beam parameters expected ~ few x 10^{-8}
    - uncertainty then expected to be < 10^{-8}
    - <u>smallest</u> measured asymmetry ~2 x 10^{-6}



Individual Uncertainties:

$\frac{\Delta G_E^p}{G_E^p} = 2\%$ $\frac{\Delta G_M^p}{G_M^p} = 2\%$ $\frac{\Delta G_A^e}{G_A^e} = 10\%$ $\frac{\Delta P_b}{P_b} = 2\%$ T = 700 h

$\frac{\Delta G_E^n}{G_E^n} = 20\%$ $\frac{\Delta G_M^n}{G_M^n} = 3\%$ $\frac{\Delta Q^2}{Q^2} = 1\%$ $P_b = 70\%$

Recent Theory

e.g. Hemmert, Kubis & Meissner

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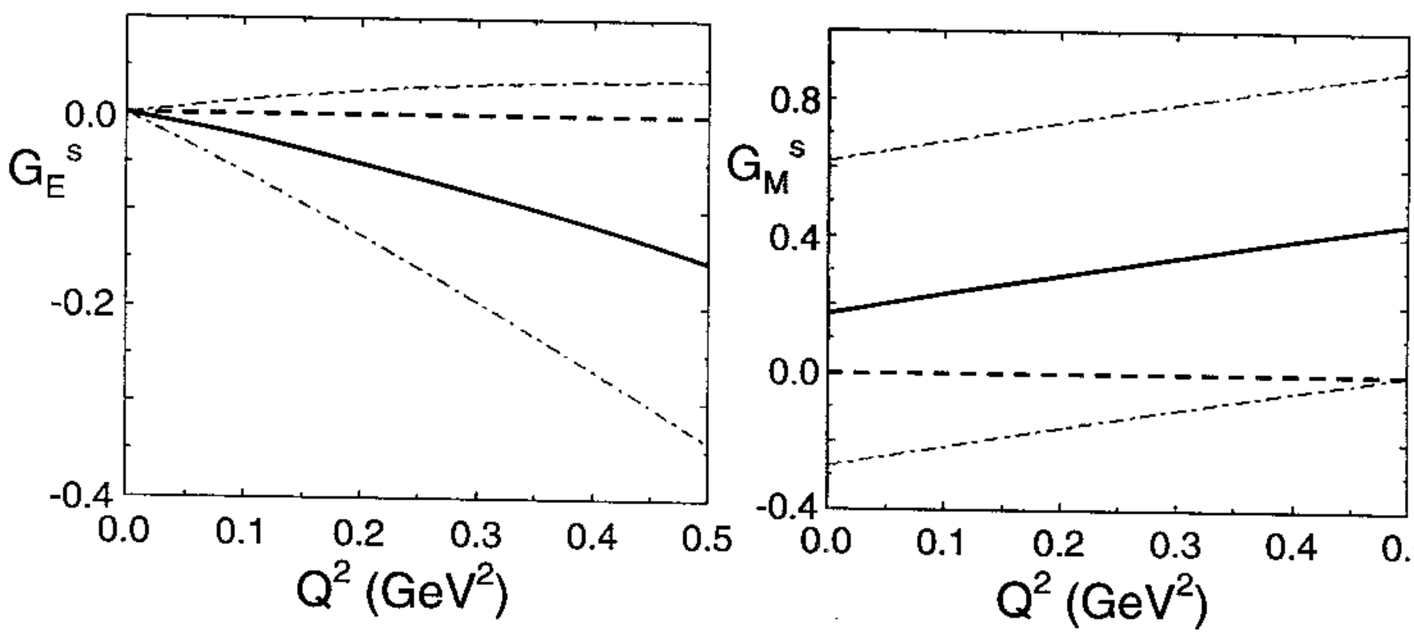
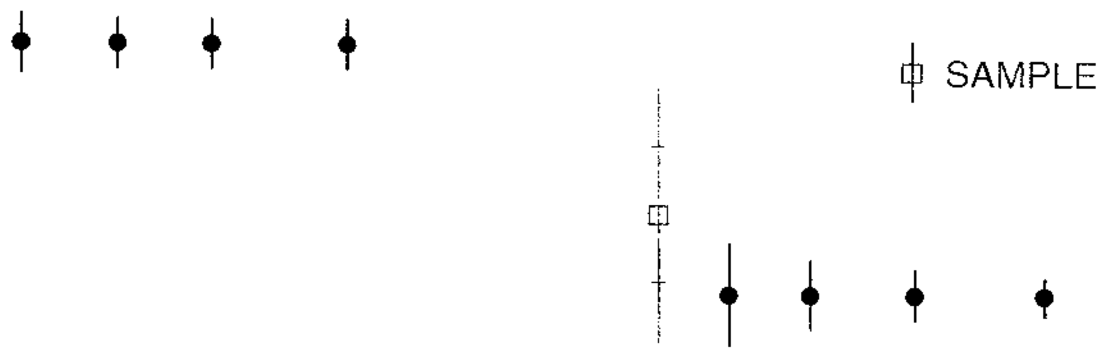


- Use SAMPLE and HAPPEX input
  - $G_M^s (Q^2 = 0.1\ \text{GeV}^2) = 0.23$
  - $G_E^s + 0.39\, G_M^s (Q^2 = 0.5\ \text{GeV}^2) = 0.023$
    - fix 2 (of 6) low energy constants
- Predict large values of individual form factors



- easily visible in G0 experiment

G0 Experiment False Asymmetries

- measured asymmetries corrected for measured *helicity-correlated* beam parameter effects

$$A_{corr} = A_{meas} - \sum_{i=beam\ parameters} \frac{d \ln Y}{dx_i} \Delta x_i$$

- main *helicity-correlated* effects from beam motion, beam energy changes
  - HAPPEX results (strained GaAs cathode)

    $\Delta x \sim 10$ nm, $\Delta E/E < 10^{-8}$ } $A_{false} \sim 10^{-8}$ in G0 experiment

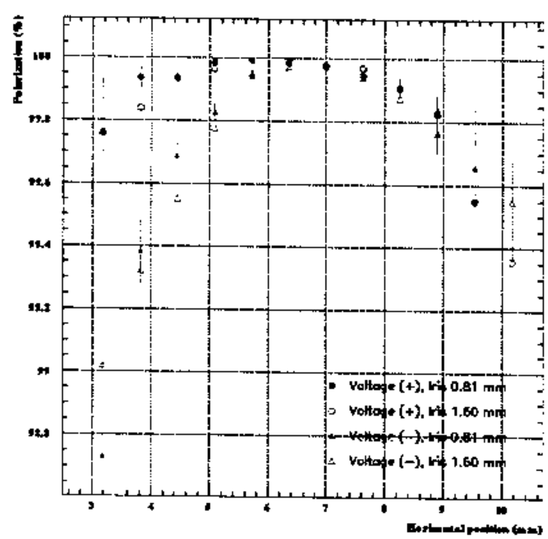
- non-linearity in dead-time correction
  - dead-time < 10%
  - HAPPEX results (strained GaAs cathode)
    - $\Delta Q/Q < 5$ ppm
  - → must know dead-time at ~ 0.2% level (2% relative measurement)
    - careful dead-time measurement in hardware

Polarized Injector Status for G0 (1)

- Pulsed operation
  - 40 uA average current
  - 32 ns spacing between beam pulses (31.25 MHz)
  - → higher bunch charge → care with space charge in injector
  - first test with G0 bunch charge this month

- High polarization operation
  - need to minimize helicity-correlated effects in beam
  - strained cathodes have more serious helicity-correlated effects
  - with careful setup, feedback, correlations have been reduced to near bulk GaAs performance (HAPPEX)

$$\frac{Q_+ - Q_-}{Q_+ + Q_-} \sim 1\ ppm, \quad x_+ - x_- \sim nm$$



- 5 MeV test and monitoring section
  - complete “parity-violation” diagnostics

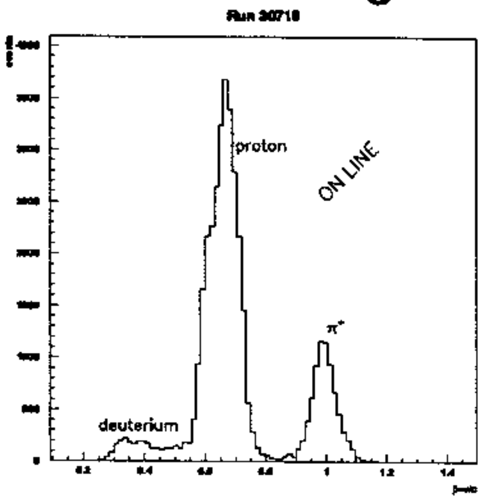
Polarized Injector Status for G0 (2)

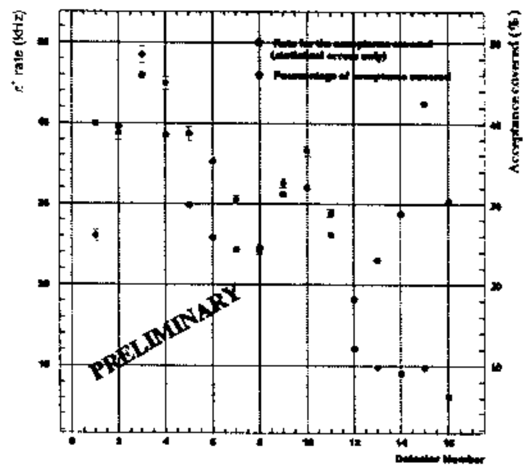
- Polarized source testing
  - fully instrumented 5 MeV region
  - plan continued short periods of testing for
    - new 32 ns bunch period (mode-locked) laser system
    - transport of high bunch charge beam in injector
    - helicity-correlated charge asymmetries and position differences
  - January 00 tests
    - ✓ 1/2 G0 bunch charge successfully transported with standard focussing (499 MHz)
    - ✓ cathode performance good (saturation, pol'n)
    - ✓ Hall C leakage into other beams 0.1% (as usual)
    - ✓ order pump laser for 32 ns bunch structure
    - ✓ see detailed report by C. Sinclair
  - do not anticipate any dedicated polarized source commissioning during 'G0 commissioning' time

- Impact of pulsed polarized source operation on running in other halls
  - testing to continue, but
  - expect no impact on running in Hall B
  - expect up to 100 μA polarized running in Hall A
  - do not expect leakage beam of ~ 50 pA @ 499 MHz from other Halls to adversely effect G0

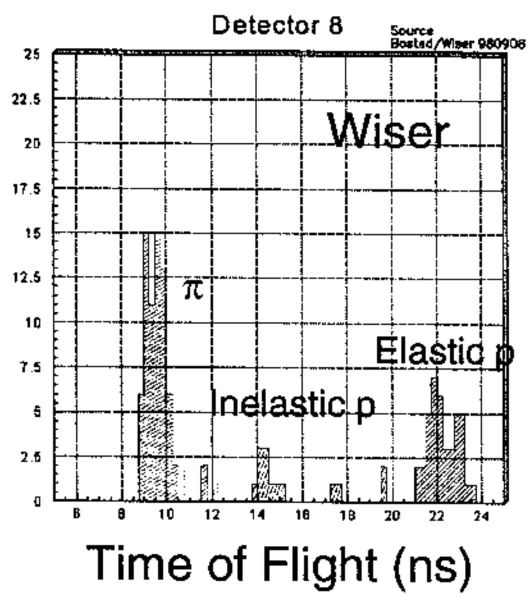
G0 BackgroundTest Measurement
(Dec 99)

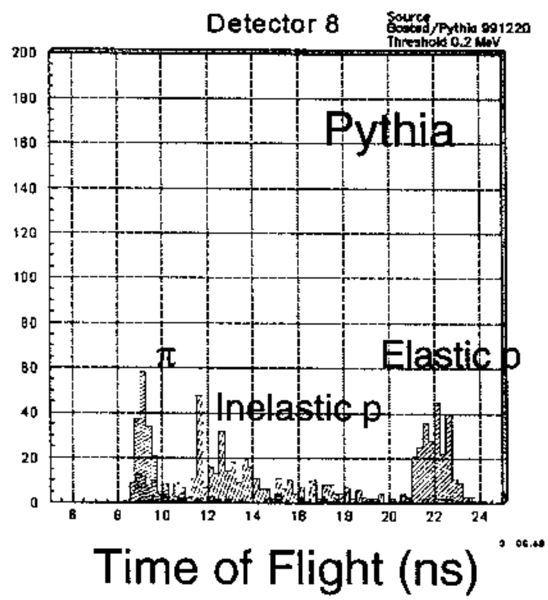
- Measurement of pi/p ratio with SOS for ~ forward angle kinematics (3.2 GeV)





- GEANT simulations





- Measurement of neutron backgrounds
  - unfold neutron energy distribution over eV - MeV range (with specialists from TRIUMF)
  - so far, numbers roughly consistent with JLab estimates (RadCon group)

JLab TAC Questions (1)

Theoretical

1. Uncertainties from form factors & other systematic uncertainties?
   - neutron form factors expectations holding
   - ordinary radiative corrections
     - corrections for forward and backward estimated at 10%
     - each correction known to about 10% of its value

Technical

1. Data-taking during commissioning time?
   - 46 days commissioning time re-approved by PAC15
     - includes 15 d for test asymmetry running:
       - 5 d in commissioning Run 1
       - 10 d in (final) commissioning Run 2
     - we will "return" any days of good data-taking during commissioning period

JLab TAC Questions (2)

Technical

2a. Polarized injector development (M. Pitt et al. VPI)

- testing of high bunch charge beam has begun
  - plan series of tests using 5 MeV beamline (after new mode-locked laser)
- improvement of strained cathode performance continuing - good enough to run

2b. Why 34 days at ~70% polarization?

- all expected results quoted since TDR (93) assume 70% polarization
  - 'best experiment' projection
  - → give approximate balance between statistical and all systematic uncertainties
- one month data-taking
- 4 days setup (assuming experiment rolled out after commissioning)

JLab TAC Questions (3)

Technical

3. False asymmetries from backgrounds

- measure background asymmetry concurrently
  - forward: out-of-time bins
  - backward: "non-elastic" detector pairs
- continuing detailed simulation of backgrounds using GEANT

4a. Commissioning electronics

- systems integration/testing begins this summer for North American octants with detectors and electronics coupled (source, gain monitoring pulser, cosmics)

4b. Estimated linearity?

- for helicity-correlated beam current asymmetry of 5 ppm, residual non-linearity of 2×10^{-3} will give false asymmetry of $A_{false} = 10^{-8}$
- estimated residual non-linearity with dead-time monitoring scheme ('buddy system') is 10^{-3}
- HAPPEX non-linearity is few x 10^{-3} (PMT's)

G0 Beam Time Request (PAC15)

- Request re-approval of 46 days of commisioning time approved in 1993
- Reaffirm high scientific rating

Run 1:

Week 1

Week 2

Symmetry 2d Target Centering

Week 3

Asymmetries

Run 2:

Week 1

Week 2

Systematics 4d Asymmetries 3d

Week 3

Asymmetries 7d

G0: Commissioning Milestones

1) Basic Equipment Checkout

2) Beam

- parameter measurements as planned in proposal
- polarization: ~ 70%
- current asymmetry (one run = 1 h): < 5 ppm
- position difference (one run): < 50 nm

3) Target

- fluctuations: ≤ 0.1% (i.e. small compared to statistics)

4) Magnet/target optics

- determine $\Delta\Omega(\theta,p)$ in order to determine Q^2 to 1%

5) Detection

- overall rates ≤ expected rates (~ 2 MHz)

6) Corrections

- all slopes characterized, stable

7) Asymmetries

- 5 d of 'near production' asymmetry running

Beam Time Request

- Request 4 d beam time for experiment setup after rollout
  - check operation in beam of target, detectors, electronics
  - check centering of beam, target in spectrometer
  - check response of spectrometer to beam properties

- Request 30 d beam time for forward angle physics run
  - measure all forward asymmetries for $0.1 < Q^2 < 1\ GeV^2$
  - asymmetries measured to few % statistical precision
  - optimized to give equal statistical and systematic uncertainties

G0 Overall Running Scenario

- Installation + Commissioning Run 1
  - June 01 - Nov 01
  - 2.8 - 3.0 GeV
- gap: experiment rolls out (other expts)?
- Commissioning Run 2
  - maybe Feb 02
  - 2.8 - 3.0 GeV
- gap: experiment rolls out (other expts)?
- Forward physics run
  - maybe continues after Run 2
  - 2.8 - 3.0 GeV
- gap: experiment rolls out (other expts)?
- Turnaround (~ 2 mo?)
- gap: experiment out (other expts)
- 1st back angle run (~ Jan 03?)
  - hydrogen and deuterium: ~ 30 d each
  - 330 < E < 930 MeV