Real Photon Experiments at SLAC

APPROVED BY THE SLAC EPAC IN 2000

APPROVED BY SLAC DIRECTOR

APPROVED BY DOE

New HIGH ENERGY Polarized Coherent Quasi–Monochromatic γ Beam

E159 – GDH Sum Rule

E160 – A–Dependence of J/ψ Photoproduction

E161 – Gluon Spin from Charm Photoproduction

NSAC
1 Nov 2002
Steve Rock

Real Photon Beam Program

Physics

- J/ψ propagation in nuclei, important for **QG plasma search**
- Open charm production for **gluon spin**
- Test of fundamental **Gerasimov–Drell–Hearn sum rule**

Only at SLAC

- Unique high intensity, **HIGH ENERGY** polarized beams
- Builds on decades of quark structure and spin at SLAC
- Energies (up to 45 GeV) well beyond 12 GeV Jlab Upgrage

Connections

- Large international collaboration with long experience
- Many students and publications
- High profile results at modest cost

FINANCIAL DIFFICULTIES AT SLAC

➔PRIORITY TO BABAR

➔NEW ELECTRICY COST STRUCTURE INHIBITS RUNNING PARASITICALLY WITH BABAR

➔MANAGEMENT HAS DECIDED THAT THESE EXPERIMENTS ARE NUCLEAR PHYSICS

➔EXPERIMENTS ARE PUT ON HOLD AFTER MUCH DESIGN WORK

➔MOST OF THE COLLABORATION IS SUPPORTED BY NUCLEAR PHYSICS

➔WE HAVE COME TO YOU TO APPEAL FOR HELP

PHOTON BEAM

- ➔ COHERENT BREMSSTRAHLUNG FROM DIAMOND
- ➔ QUASI–MONOCHROMATIC
- ➔ POLARIZED CIRCULAR or LINEAR
- ➔ ENERGY UP TO 45 GeV
- ➔ INTENSITY UP TO 10^{11} PHOTONS/SEC
- ➔ TECHNIQUE USED AT SLAC 25 YEARS AGO

E160

A–Dependence of J/ψ and ψ' Photoproduction

Goals

- **Understand cause of J/ψ suppression in heavy–ion collisions**
- Explore creation and interaction of ψ and ψ' in nuclei
- Understand why VMD and geometrical x–sects differ

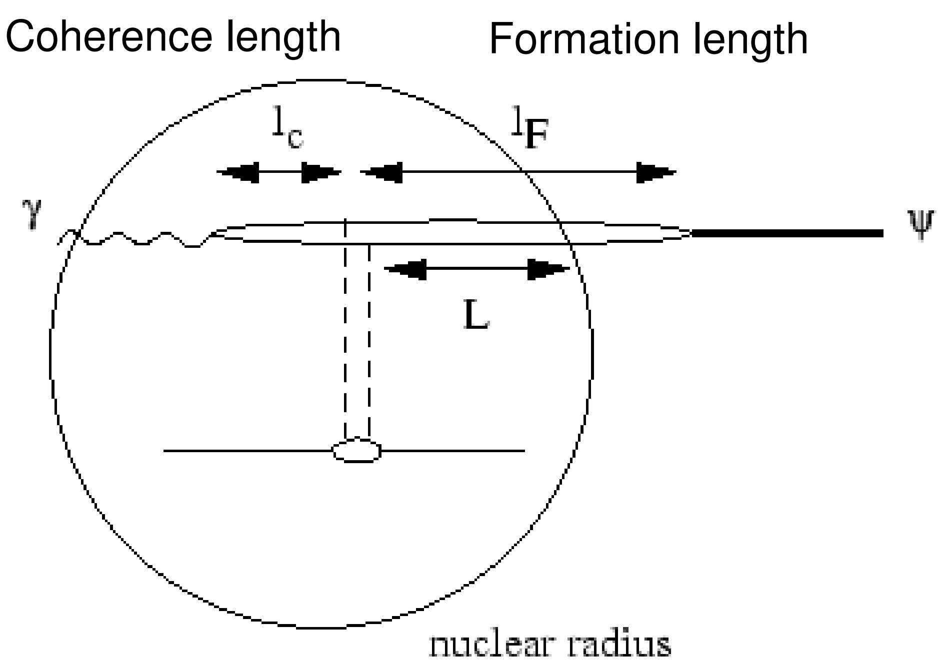
Measurement

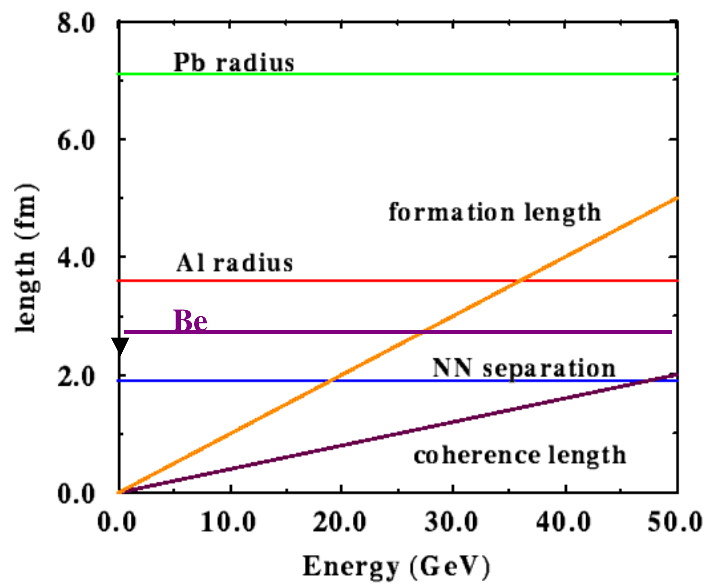
- Reconstruct J/ψ and ψ' from $\mu^+\mu^-$ pairs
- Be, Al, Cu, Pb targets
- Photon energy 15, 25, 35 GeV

Results

- Nuclear A–dependence
- ψ –nucleon cross section
- Ψ'–nucleon cross section

Length Scales for J/ψ Propagation in Nuclei

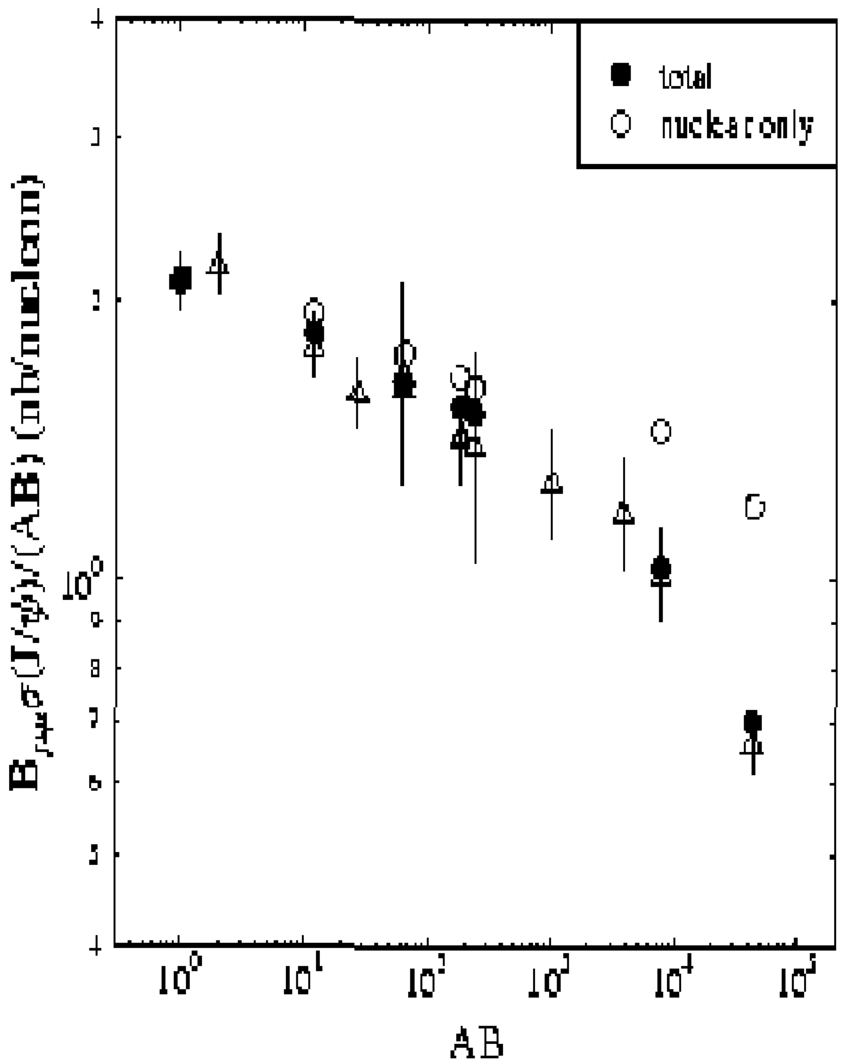




E160 range

UrQMD MICROSCOPIC MODEL USING SMALL COLOR TRANSPARENT CONFIGURATIONS

(Spieles,Vogt,Gerland,Bass,...Frankfurt,Strikman,..



— Ordinary nuclear

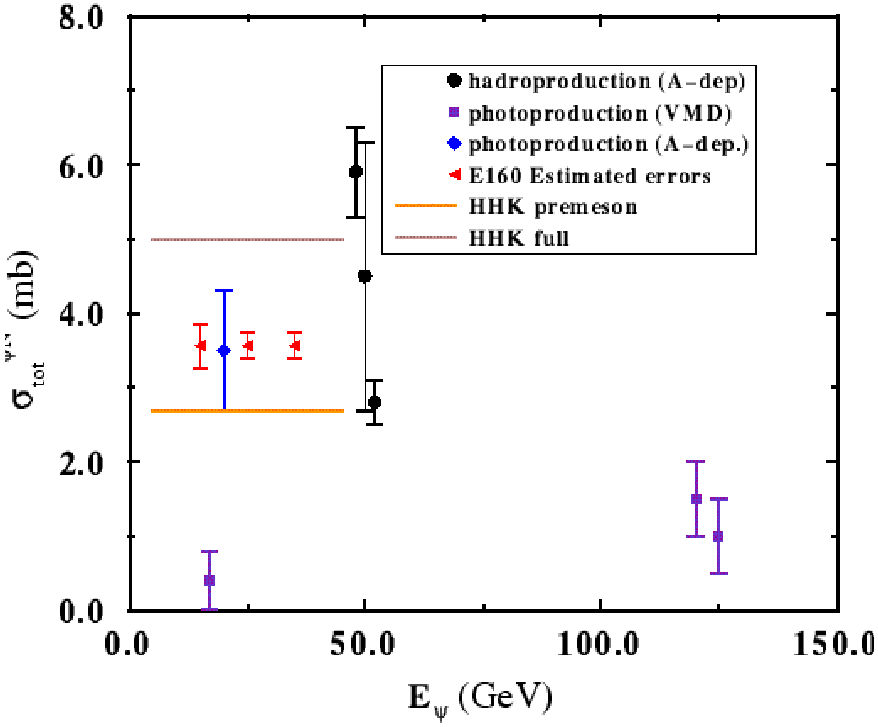
— This model

Δ Data

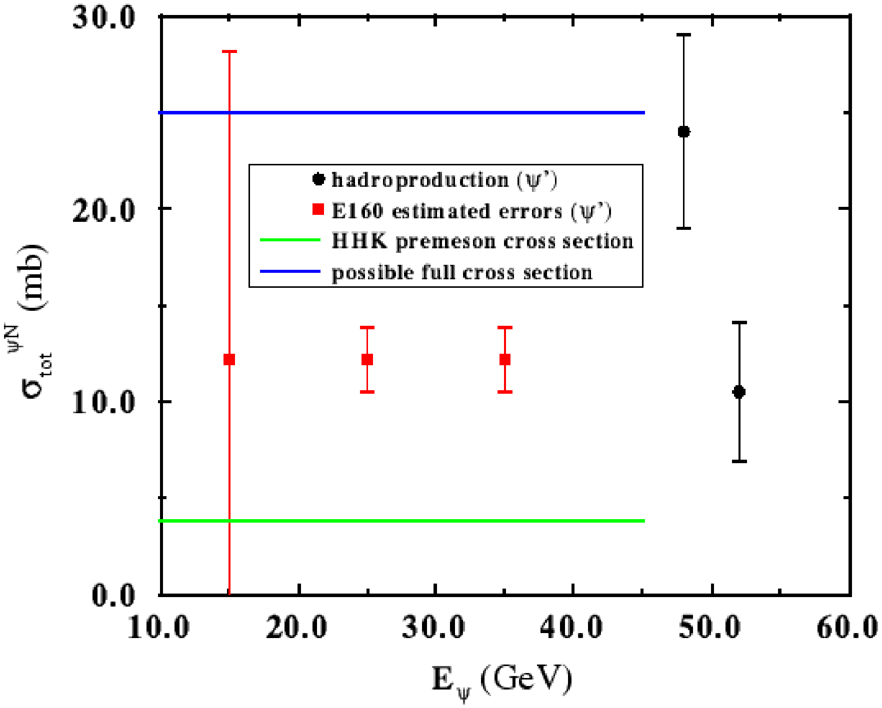
E160 Can Distinguish Between models

E160 Possible Results for Total ψ–N Cross–Sections Compared to Theory and Previous Data

ψ–Nucleon



Ψ'–Nucleon



Horizontal bars represent range of theoretical estimates

Ψ'→ Ψ So Very Important

E161

Gluon Spin from Polarized Open Charm

Goals

- Polarized gluon distribution of nucleons
- Constrain models for ΔG
- Help understand total nucleon spin

$$1/2 = 1/2\ \Delta\Sigma + \Delta G + Lz$$

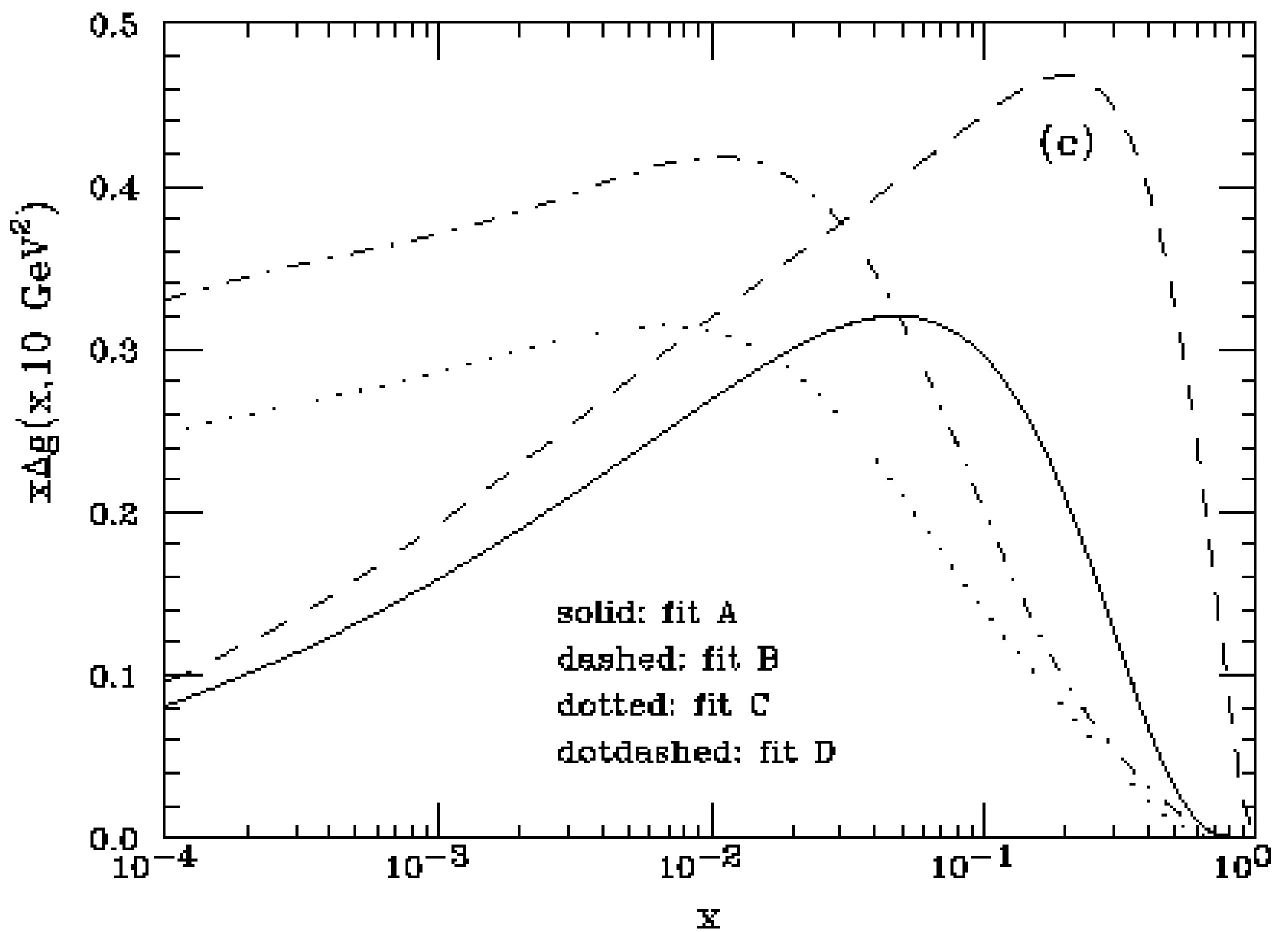
Measurement

- Detect single high momentum μ (veto μ pairs)
- Polarized LiD target (> 60%)
- 35, 40, 45 GeV circularly polarized photons

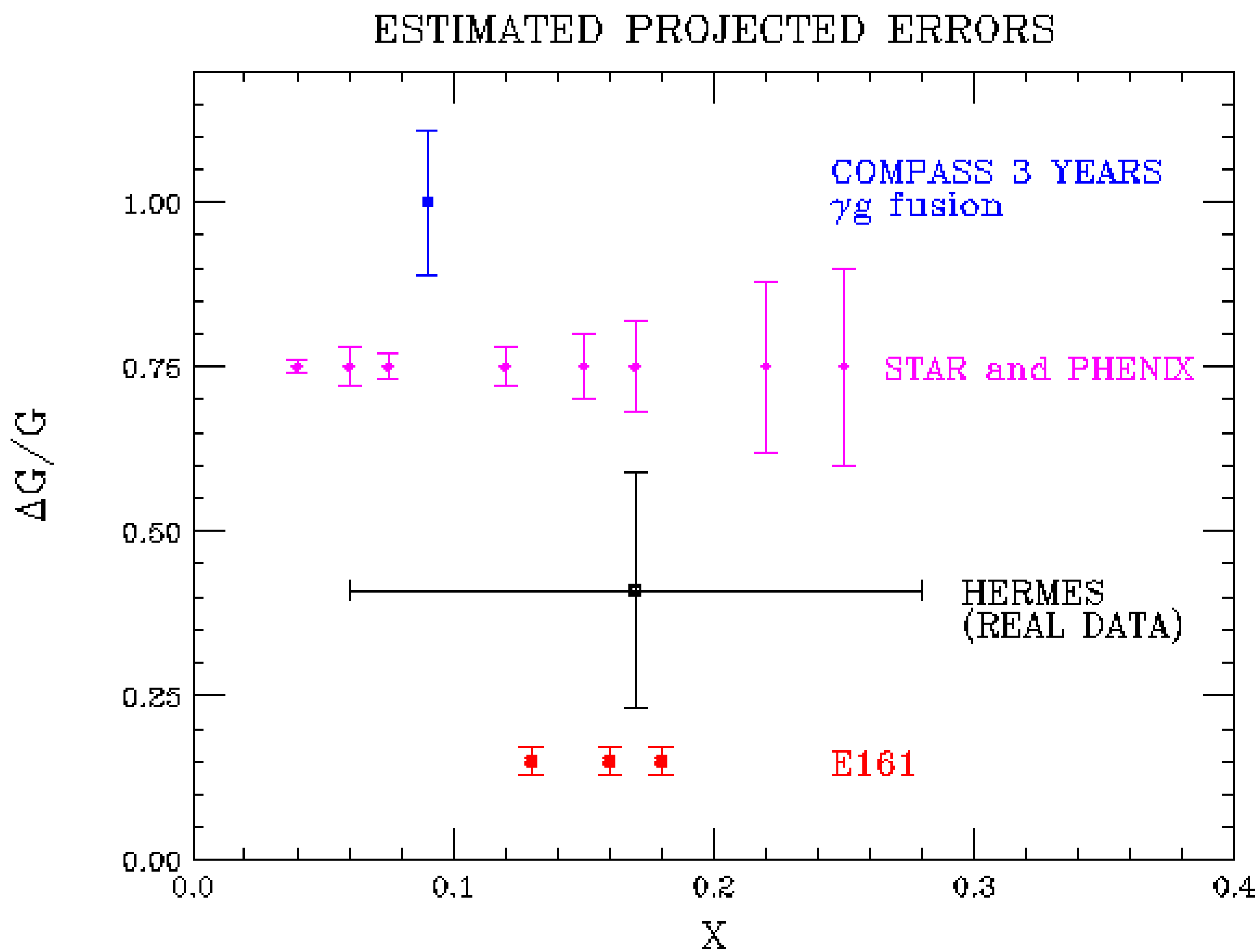
Results

- Longitudinal asymmetries for beam–target polarization
- Muon momentum distributions
- Extract $\Delta G/G$ for $0.1 < x < 0.2$

ALTARELLI et. al. from pQCD Evolution



Comparison of Proposed ΔG/G Experiments



E159

Asymmetry in Total PhotoNucleon Cross Section at High Energy

Gerasimov–Drell–Hearn Sum Rule

Goals

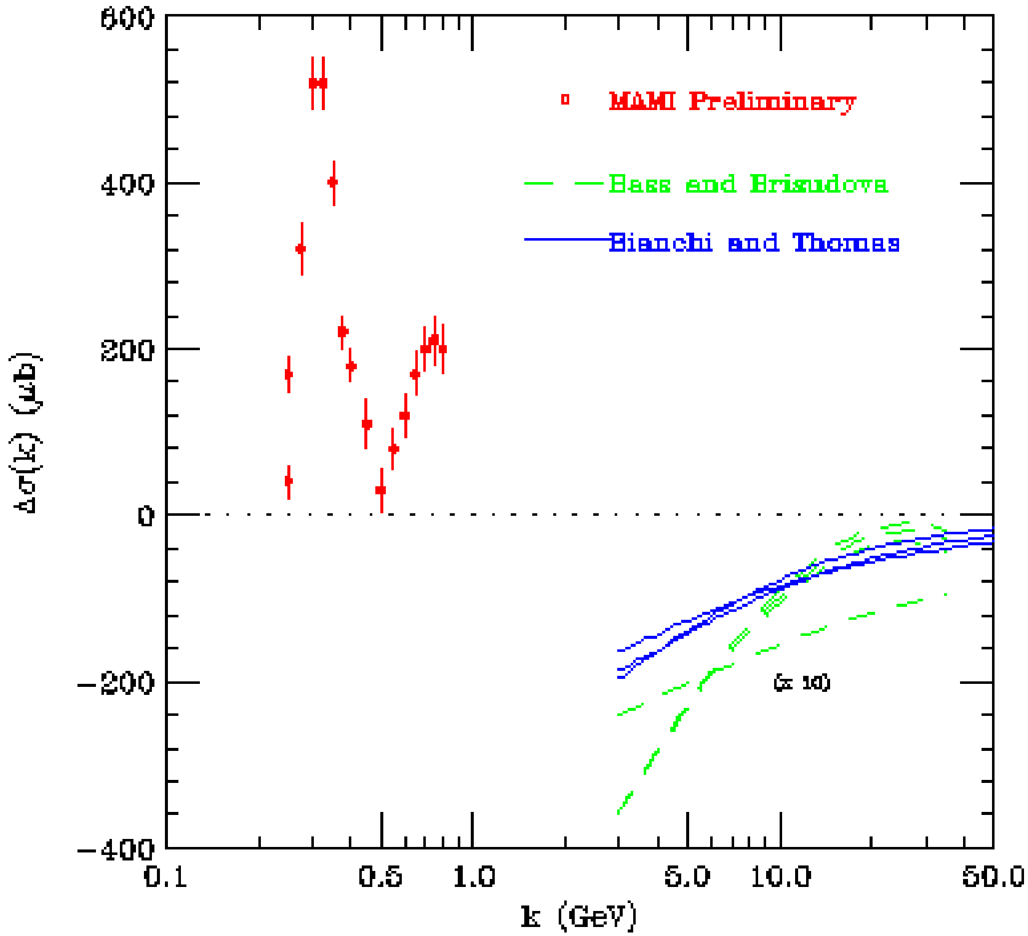
- Measure γN asymmetry **ABOVE** resonance region
- Probe region where asymmetry is predicted to change sign
- Measure **proton** and **neutron** for isovector & isoscalar parts
- Constrain the GDH sum

Measurement

- Identify hadrons from photoproduction
- Polarized ^{15}NH3 and ^{15}ND3 targets
- Circularly polarized photons 4 – 40 GeV

Asymmetry $\Delta\sigma^{\gamma N}(k)$

Previous proton data at low energy and predictions at high energy



E159 range

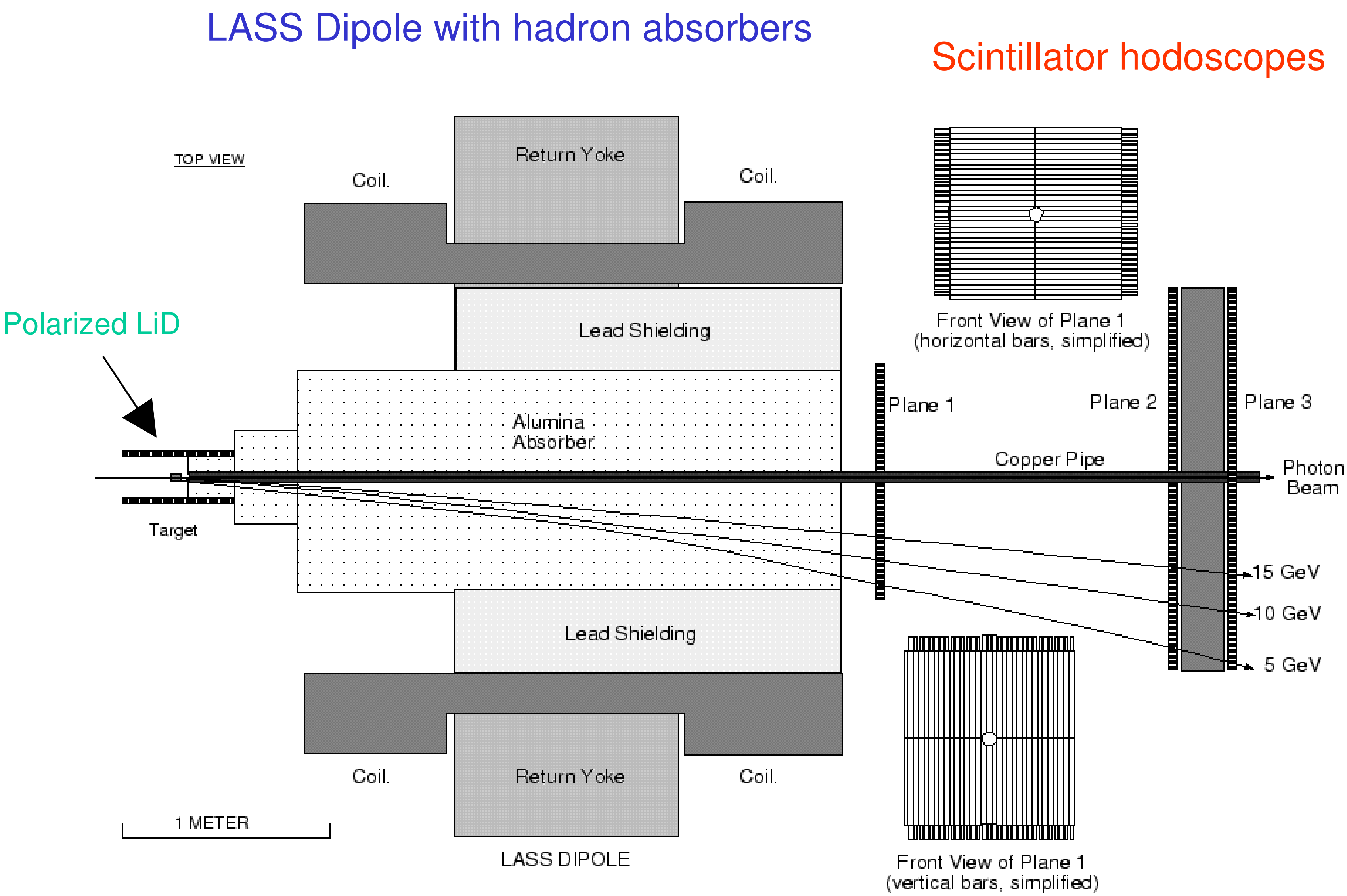
Real Photon Program Summary

- Fundamental physics of hadron spin structure and dynamics.
- Builds on 20 years of nucleon structure and quark spin at SLAC.
- Requires high intensity, **high energy**, polarized e– and γ

  available only at SLAC.
- Supplements and Complements work done at other Labs.
- Provides important data for interdisciplinary questions:

  gluon spin, GDH sum rule, J/ψ signal for QG plasma
- Other experiments under discussion
- **NEEDS SOME FINANCIAL SUPPORT FROM NUCLEAR PHYSICS**

E161 Muon Spectrometer



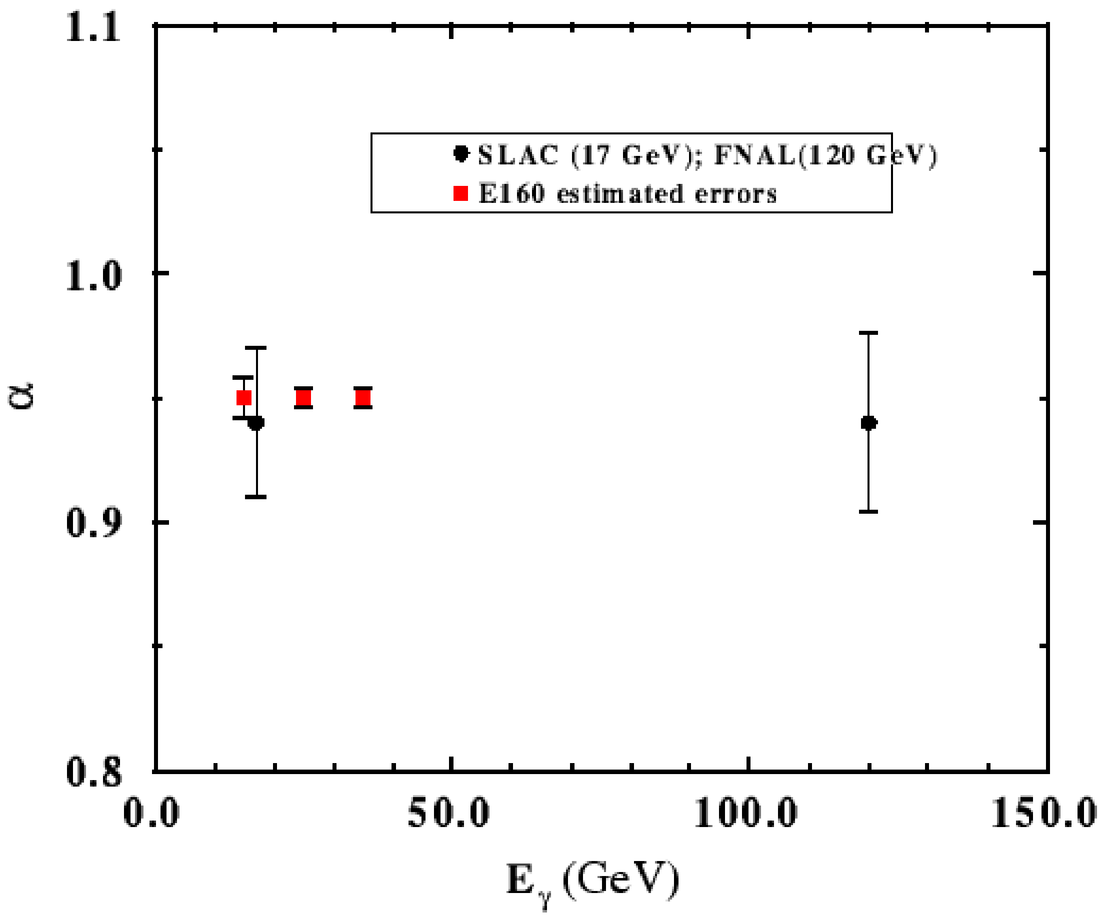
Beamline Progress

- Bend magnets out and new coils in progress
- Beamline layout for 50 GeV in design
- Instrumentation in design
- Goniometer being refurbished
- Plan installation in 2002–2003

E160 Projected Results for A−Dependence

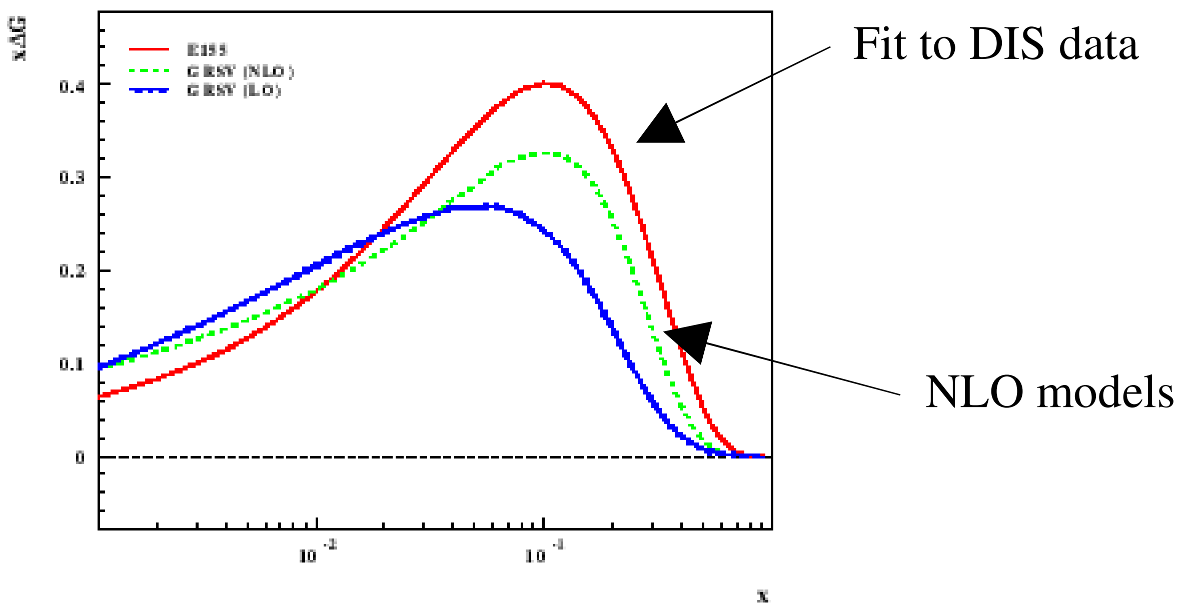
$$\sigma(\psi,N) = A^{\alpha}$$

Results to constrain ψ formation and coherence lengths



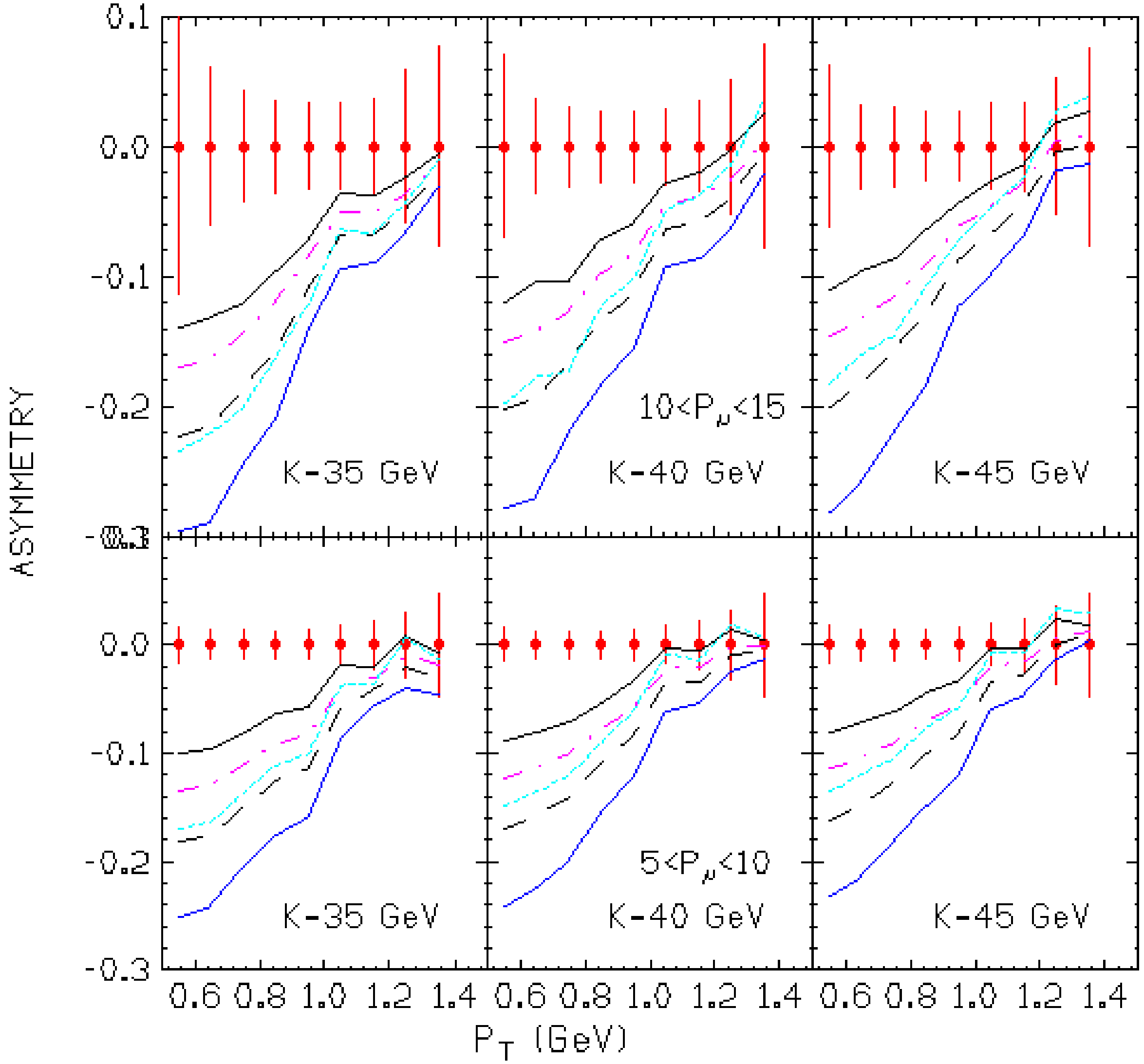
The Nucleon Spin – What We Know

Possible values for xΔG



- $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$
- $\Delta\Sigma = 0.23 \pm 0.07$ from NLO fit of E155.
- $\Delta G = 1.6 \pm 0.8 \pm 1.1$ from NLO fit of E155.
- Large uncertainty remains in ΔG (0.5–2.5).

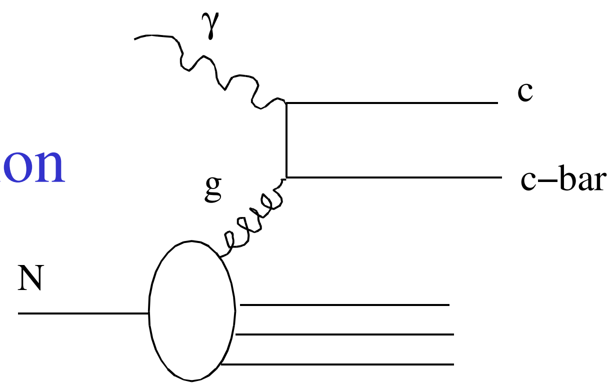
E161 Projected Results for ψ X–Sect Asymmetries



Curves for various theoretical estimates of ΔG

E161 Experimental Strategy

- Probe gluons via photon–gluon fusion



- High polarization nucleon target (>60%) –– LiD
- Measure μ momentum –– high field, fine grain hodoscopes,

  good time resolution

Charm Mesons Decay to Muons

- Absorb K and π before decay
- Veto μ+μ– pairs –– Bethe–Heitler and vector meson decays

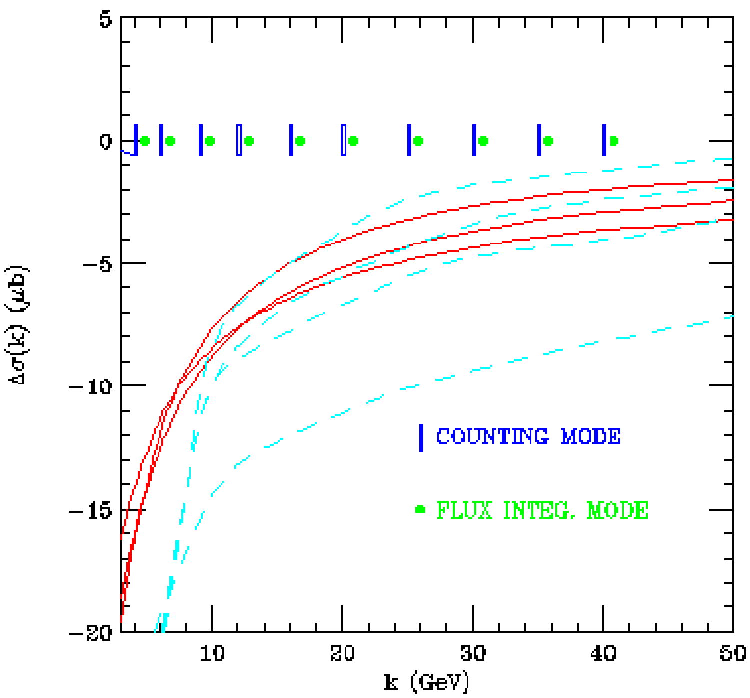
Real Photon Collaboration

65 Physicists   20 Institutions   8 Countries

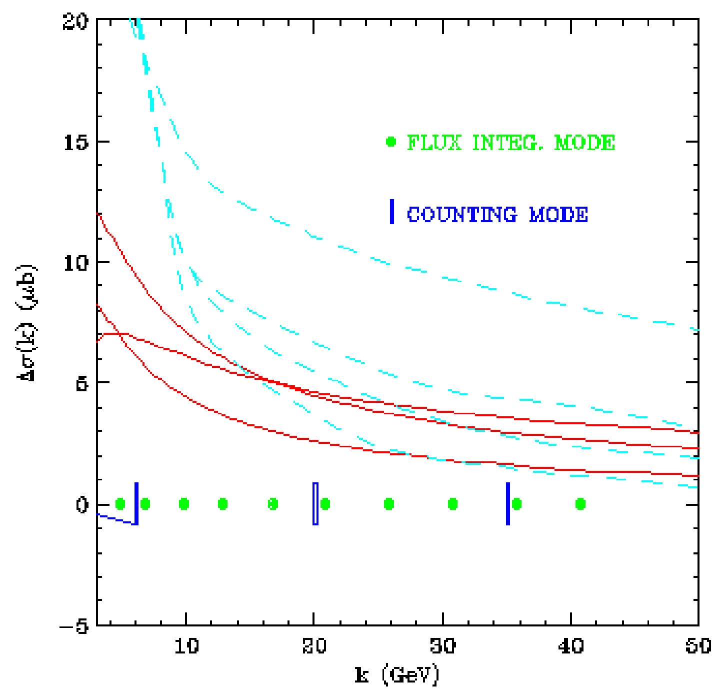
- Aarhus University, Denmark
- University of Capetown, South Africa
- UCLA
- Florida International University
- INFN Frascati, Italy
- Jefferson Lab
- University of Liverpool
- Los Alamos
- University of Massachusetts
- Mississippi State University
- Saclay, France
- Institute fur Kernphysik, Mainz
- Old Dominion University
- Ruhr–Universitat Bochum, Germany
- Smith college
- SLAC
- University of Virginia
- College of William and Mary
- University of Witwatersrand, South Africa
- Yerevan Physics Institute, Armenia

E159 Projected Data for $\Delta\sigma^{\gamma N}(k)$

Proton



Neutron



Together with low energy data this constrains GDH sum to 40 GeV

The GDH Sum Rule

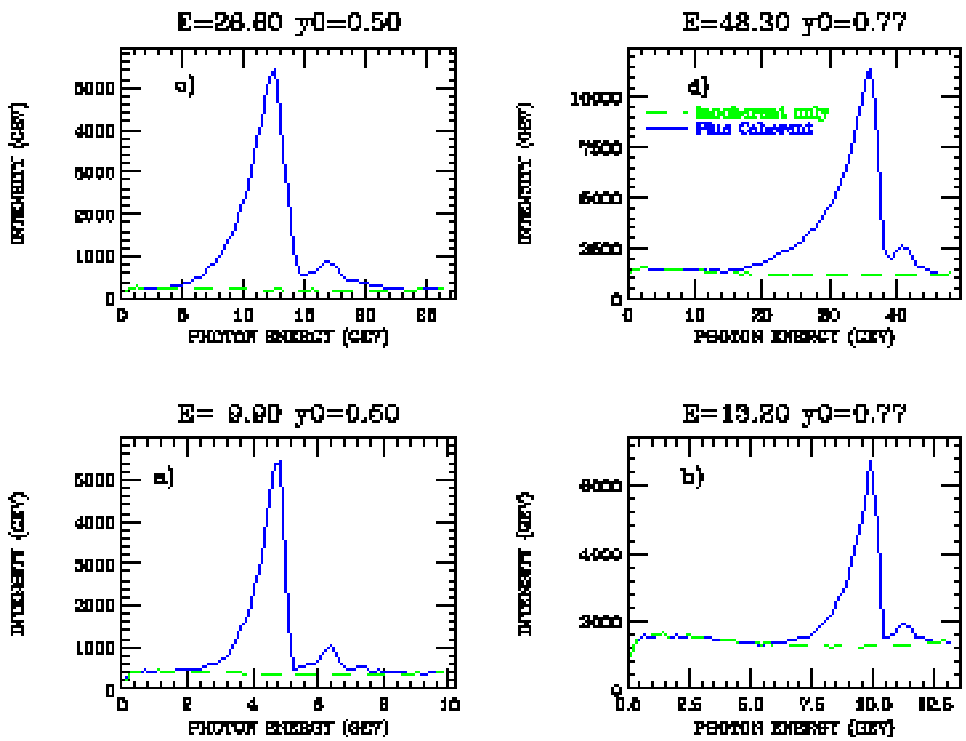
- Relates integral over asymmetry $\Delta\sigma^{\gamma N}(k)$ to the anomalous magnetic moment κ.

$$\int_{k_\pi}^{\infty} \frac{dk}{k} \Delta\sigma^{\gamma N}(k) = \frac{2\pi^2 \alpha \kappa^2}{M^2}$$

- Follows from general principles of causality, universality, Lorentz and electromagnetic guage invariance.
- Assumes unsubtracted dispersion relation.
- Scale of convergence from highest spin–flip excitations.
- Asymmetry $\Delta\sigma^{\gamma N}(k)$ must decrease at high k while total cross section $\sigma^{\gamma N}(k)$ is known to increase at high energies.
- World wide program at Mainz, Bonn, GRAAL, SPIN8, LEGS, JLAB, TUNL limited to 5 GeV maximum energy.

Representative Photon Intensities

Controlled by beam energy and crystal angle



- Coherent contribution (blue lines)
- Incoherent contribution (green dashed lines)
- $y_0 = k/E$