OVERVIEW OF E159, E160, E161

D.O.E. Review April 3, 2001

P. Bosted

- A cohesive **program** of three fixed target photoproduction experiments.
- Significant overlaps in beam, target, and detectors; maximizes **physics output** for investment needed.
- Approved at Nov. 2000 EPAC meeting.
- Plan to run several calendar months each.

  2003: E160 A-dependence of J/ψ

  2004: E161 $\Delta G(x)$ from Open Charm

  2005: E159 GDH Sum Rule
- Experiments joined together to form Real Photon Collaboration

REAL PHOTON COLLABORATION

- **UCLA**
- **INFN Frascati, Italy**
- **Jefferson Lab**
- **University of Liverpool**
- **Los Alamos**
- **University of Massachusetts**
- **Saclay, France**
- **Institut fur Kernphysik, Mainz**
- **Old Dominion University**
- **Ruhr-UniversitB̑ochum, Germany**
- **Smith College**
- **SLAC**
- **University of Virginia**
- **College of William and Mary**
- **Yerevan Physics Institute, Yerevan, Armenia**

E160: MEASUREMENT OF THE A-DEPENDENCE OF J/ψ AND ψ' PHOTOPRODUCTION

K Griffioen, P. Bosted, D. Crabb co-spokespersons

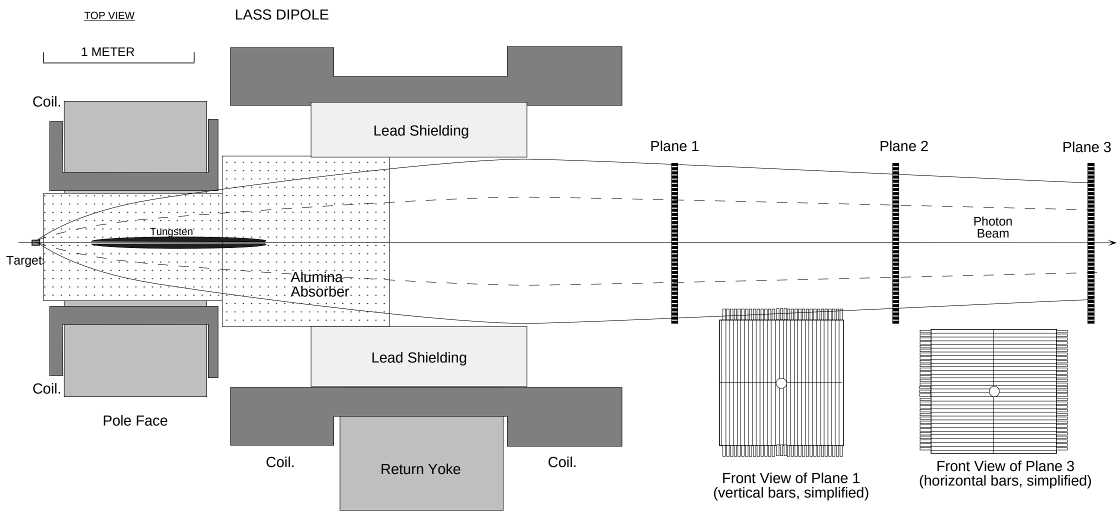
Planned to run in 2003

http:www.slac.stanford.edu/exp/e160/

- Goals:
  - Learn about creation and interaction of J/ψ and ψ' in nuclei.
  - Understand why VMD and geometrical expectations for $\sigma_{\rm tot}^{\psi N}$ are at odds.
  - Constrain causes for J/ψ suppression in relativistic heavy-ion collisions. by using simpler probe in same energy region.

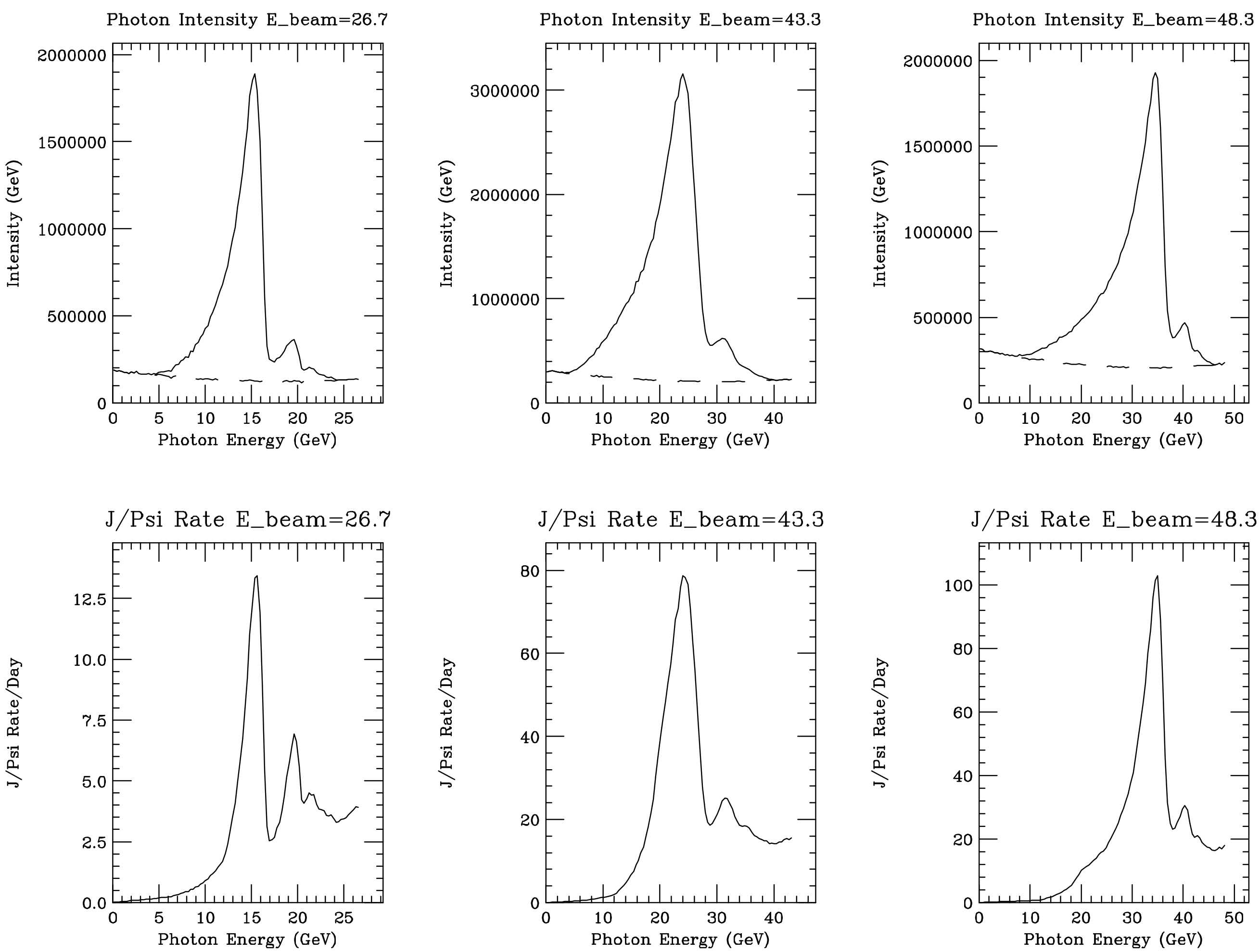
- **Measurement:**
  - **Reconstruct J/ψ from $\mu^+\mu^-$ pairs.**
  - **Identify quasi-elastic events with fit to p_t-distribution**
  - **Use Be, Al, Cu, Pb targets**
  - **Use 15, 25, and 35 GeV photons**
- **Anticipated Results:**
  - **t-distributions**
  - **α from $\sigma_A \propto A^\alpha$ at 15, 25, 35 GeV**
  - **ψ-nucleon cross section $\sigma_{\text{tot}}^{\psi N}$ at 15, 25, 35 GeV with much smaller errors than previous experiments.**
  - **First look at ψ'-nucleon cross section $\sigma_{\text{tot}}^{\psi N}$**

E160 Spectrometer

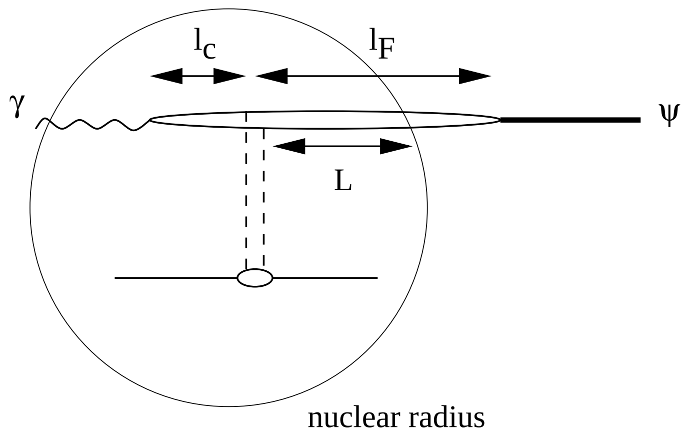


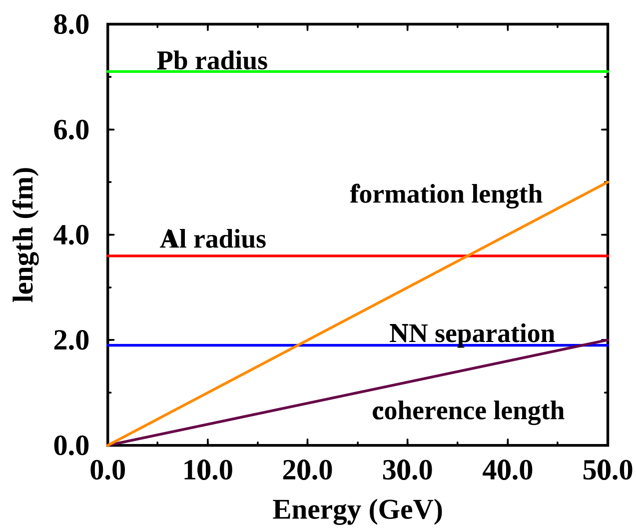
- **29D32 Dipole Magnet $\int \mathbf{B} \cdot d\boldsymbol{\ell} = 22$ kG-m**
- **70D43 LASS Dipole Magnet $\int \mathbf{B} \cdot d\boldsymbol{\ell} = 25$ kG-m.**
- **2.2 m alumina (Al_2O_3) absorber with tungsten core.**
- **3 planes of scintillator hodoscopes.**

Photon Intensity (Energy Weigthed Flux) and Acceptance-Weighted J/ψ Rate Versus Photon Energy for 3 Settings

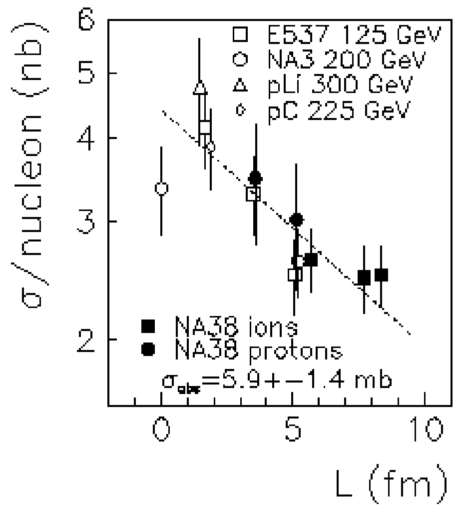


Length Scales





$\psi - N$ Cross Sections



- **Data:** nucl-th/9806023 review
- **Glauber:**

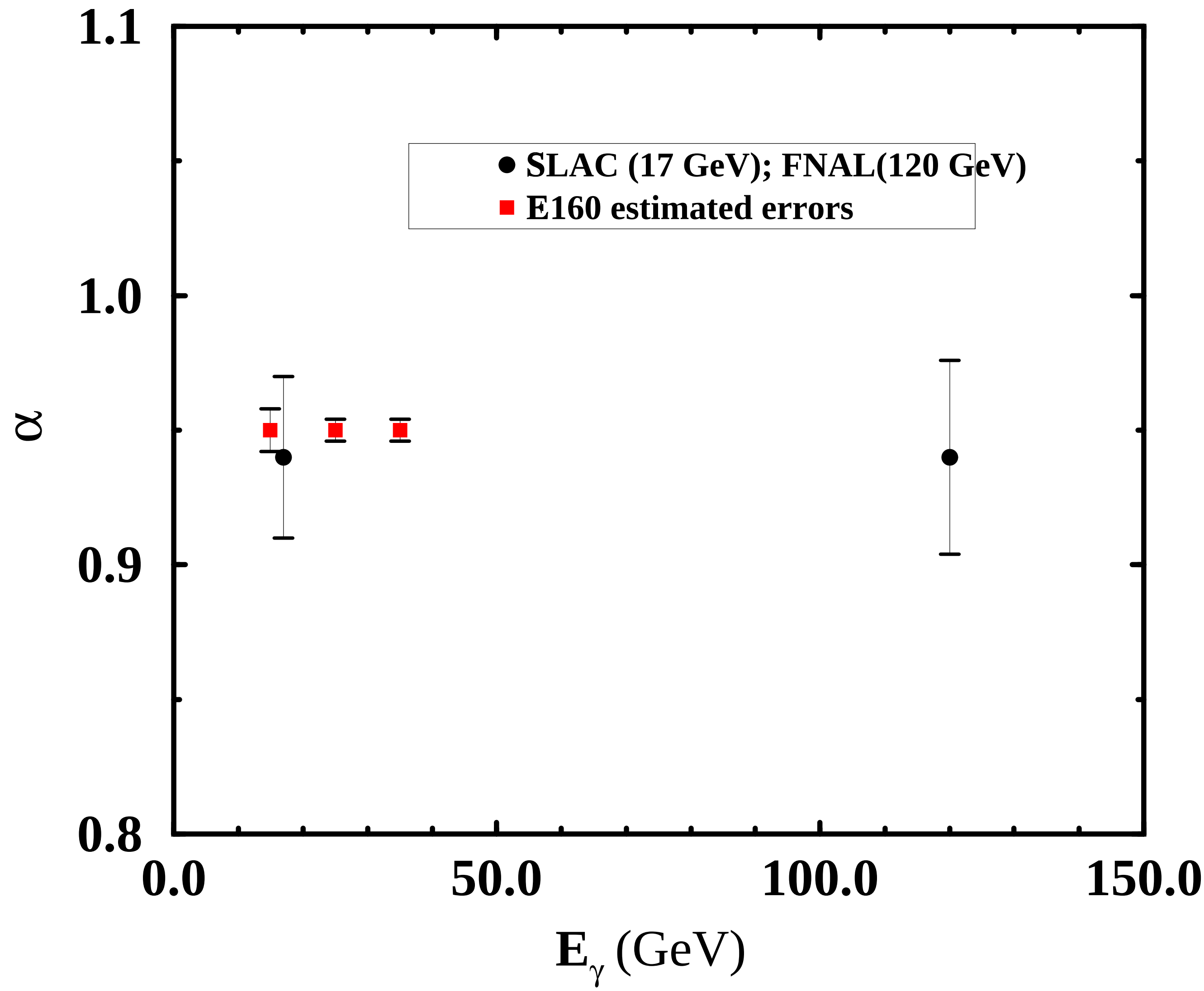
$$\frac{\sigma^{pA\to\psi}}{A\sigma^{pN\to\psi}} = e^{-L\rho_0\sigma^{\psi N}_{\rm tot}}.$$

  in which L is the length of absorption trajectory, ρ_0 is nuclear density. If $L \propto A^{\frac{1}{3}}$ then $\sigma^{\psi N}_{\rm tot} \propto A^{\alpha}$. $\sigma^{\psi N}_{\rm tot} \approx 6$ mb, $\alpha \approx 0.92$.

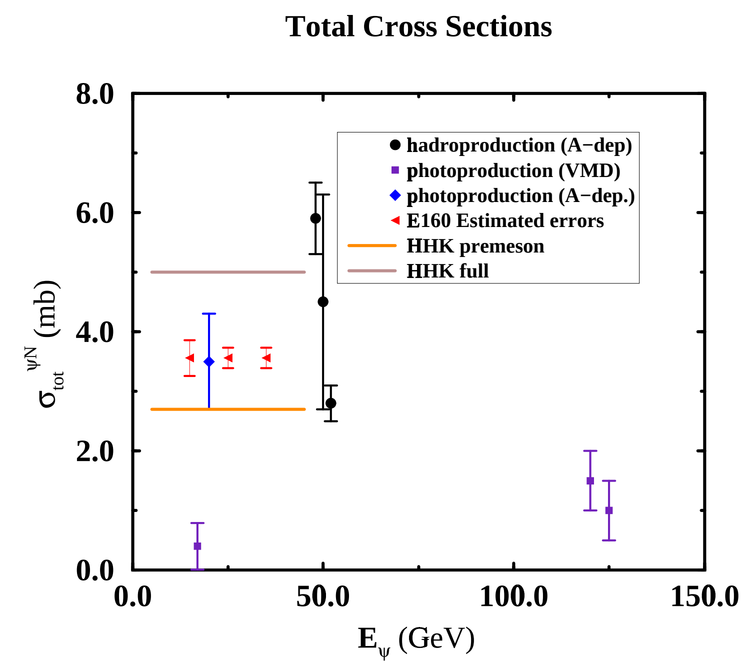
- **Vector Meson Dominance:** $\sigma^{\psi N}_{\rm tot} \propto \frac{d\sigma}{dt}(\gamma N \to \psi N)|_{t=0}$ by the optical theorem. $\sigma^{\psi N}_{\rm tot} \leq 1$ mb.
- **Geometry:** $\sigma^{\psi N}_{\rm tot}$ is proportional to the square radius. $\sigma^{\psi N}_{\rm tot} = 2 - 5$ mb.

Projected Results

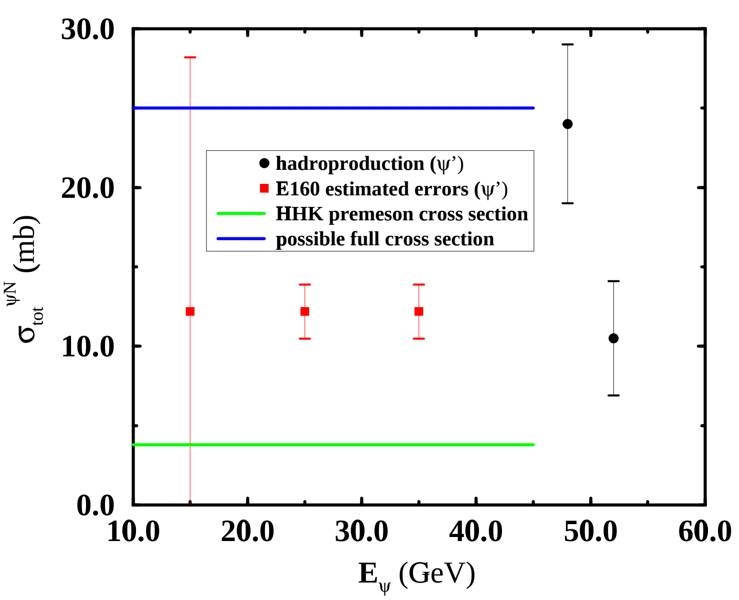
Photoproduction



Error Estimates on $\sigma_{tot}^{\psi N}$



Error Estimates on $\sigma_{tot}^{\psi N}$



E161

MEASUREMENT OF

GLUON SPIN DISTRIBUTION IN NUCLEONS USING POLARIZED OPEN CHARM PHOTOPRODUCTION

S. Rock, D. Crabb, P. Bosted co-spokespersons

Planned to run in 2004

http:www.slac.stanford.edu/exp/e161/

WHY MEASURE THE GLUON POLARIZATION?

1. FUNDAMENTAL SUM RULE
   $1/2 = 1/2 \cdot \Delta\Sigma + \Delta G + L_z$
   - $\Delta\Sigma \sim 0.23 \pm 0.07$ (from quarks)
   - ΔG (from Gluons)
   - L_z includes quarks and gluons. Possible to measure it.
2. pQCD CONSISTENCY FOR ALL REACTIONS
   - g_1 FROM DIS (SLAC,SMC,EMC,HERMES)
   - PHOTOPRODUCTION (COMPASS, HERMES, SLAC?)
   - P-P at RHIC
3. FUNDAMENTAL PROPERTY OF NUCLEON
   - 30 YEARS ON UNPOLARIZED PARTON DISTRIBUTIONS
   - 10 YEARS ON POLARIZED QUARKS

WHAT WE KNOW

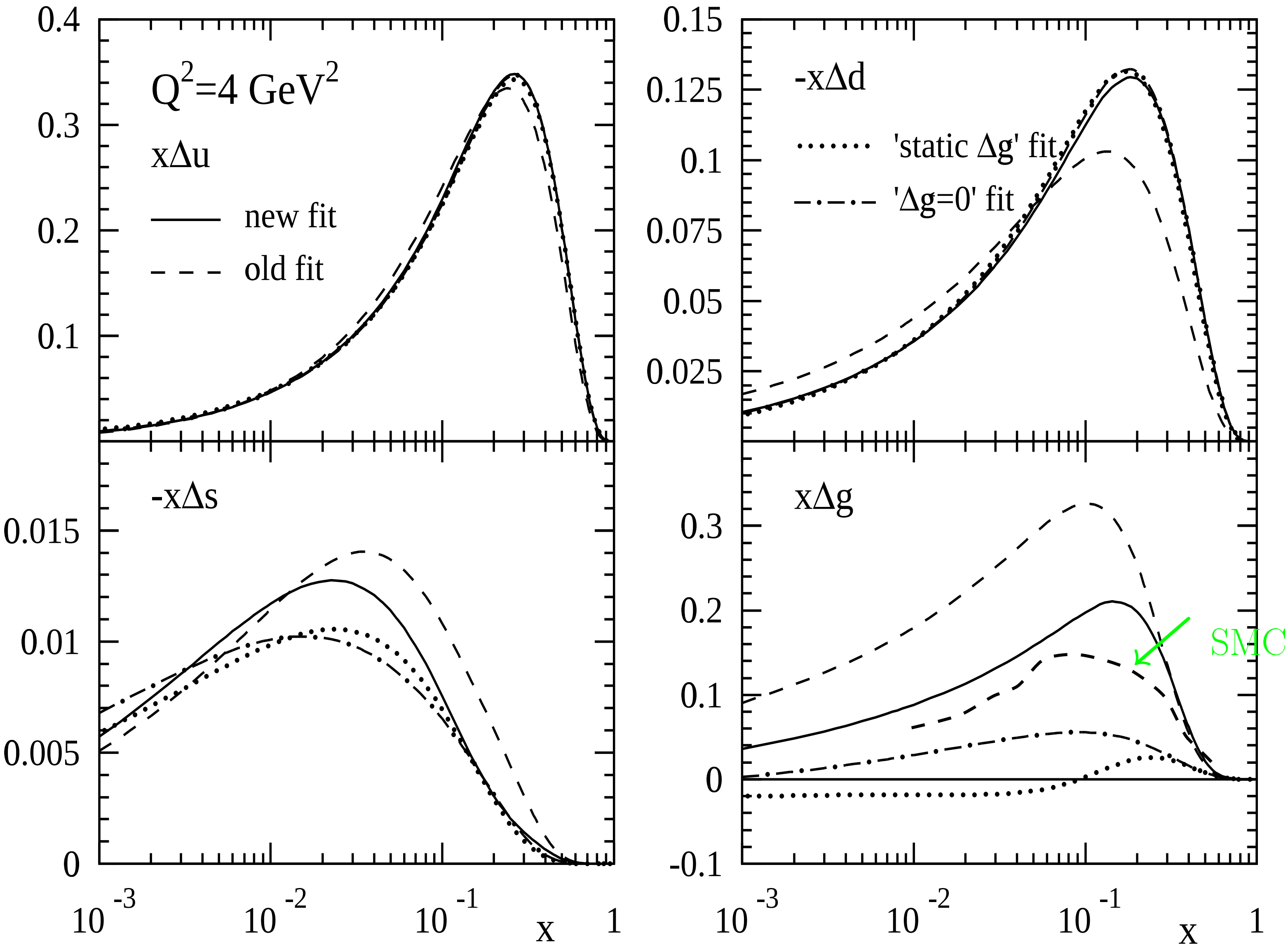
POLARIZED PARTON DISTRIBUTIONS FROM pQCD EVOLUTION EQUATIONS.

THE FIT OF

Gluck, Reya, Stratmann and Vogelsang (1999)

$$\Delta q(x, Q^2) = q_i^{\uparrow}(x, Q^2) - q_i^{\downarrow}(x, Q^2)$$

Δg ONLY APPEARS in NLO

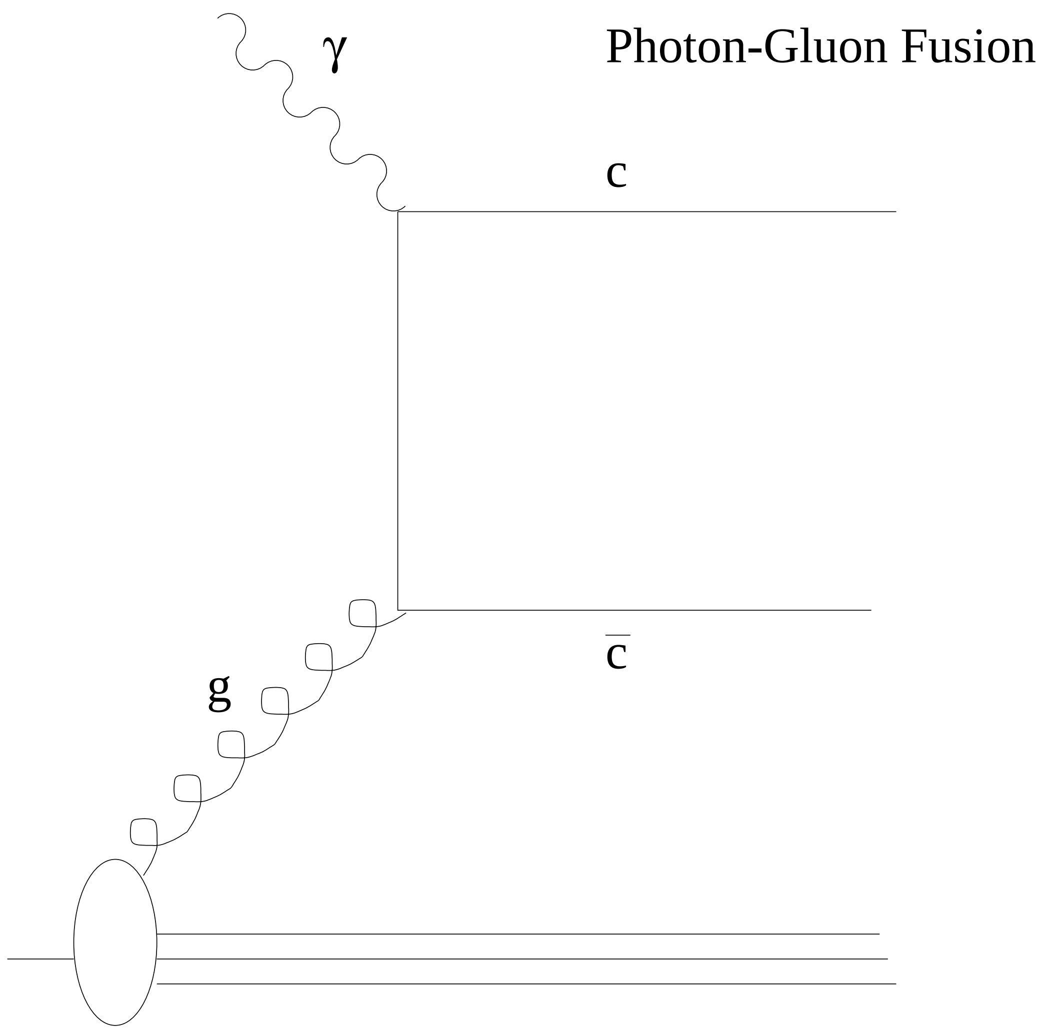


HOW TO MEASURE $\Delta g(x, Q^2)$ DIRECTLY

POLARIZED PHOTON BEAM

POLARIZED LiD TARGET

PHOTON-GLUON FUSION



EXPERIMENTAL STRATEGY

Tag Charm With Single Decay μ

	D^+	D^0	D_s^+	Λ_c^+
produced(%)	19	63	8	8
Branching Ratio(%)	17	7	8	4
fraction of μ^+(%)	37	47	8	4
	D^-	$\bar{D}^0$	D_s^-	Λ_c^-
produced(%)	21	71	6	2
fraction of μ^-(%)	40	53	5	1

BACKGROUNDS

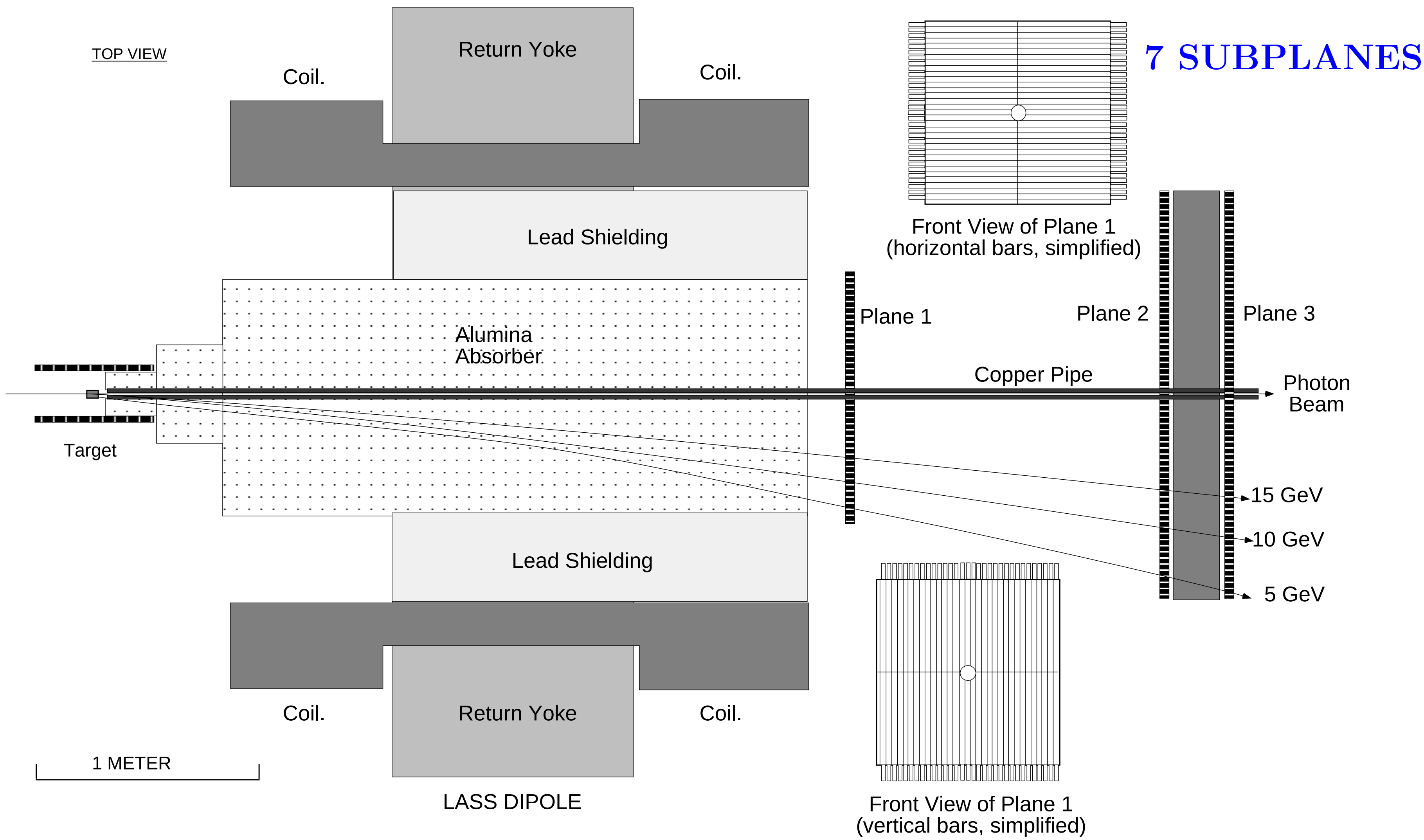
- μ FROM K and π DECAY (Long Lifetime)
- Bethe-Heitler μ PAIRS
- J/ψ DECAY (Small)
- VECTOR MESON DECAYS (Small)
- ASSOCIATED PRODUCTION (Small)
- FINAL STATE INTERACTIONS (Small)
- DIFFRACTIVE PRODUCTION (Small)

EXPERIMENTAL STRATEGY

- HIGH POLARIZATION TARGET
- HIGH POLARIZATION BEAM
- MEASURE MOMENTUM of μ
  - High Field Magnet
  - Fine Grain Hodoscopes
  - Good Time Resolution
- ABSORB K and π BEFORE DECAY
  - $\sim$ 10 Interaction Lengths (38 R.L.)
  - Monte Carlo Predicts Rates
  - Asymmetry Very Small (E155)
  - Two Absorber Setups
    75% and 25% of Time
  - Multiple Scattering of μ Almost the Same
- VETO $\mu^+\mu^-$ PAIRS
  (B-H, J/ψ, VECTOR MESONS)
  - Some Singles Remain (Acceptance)
  - Calculate Based on Pairs and Known σ

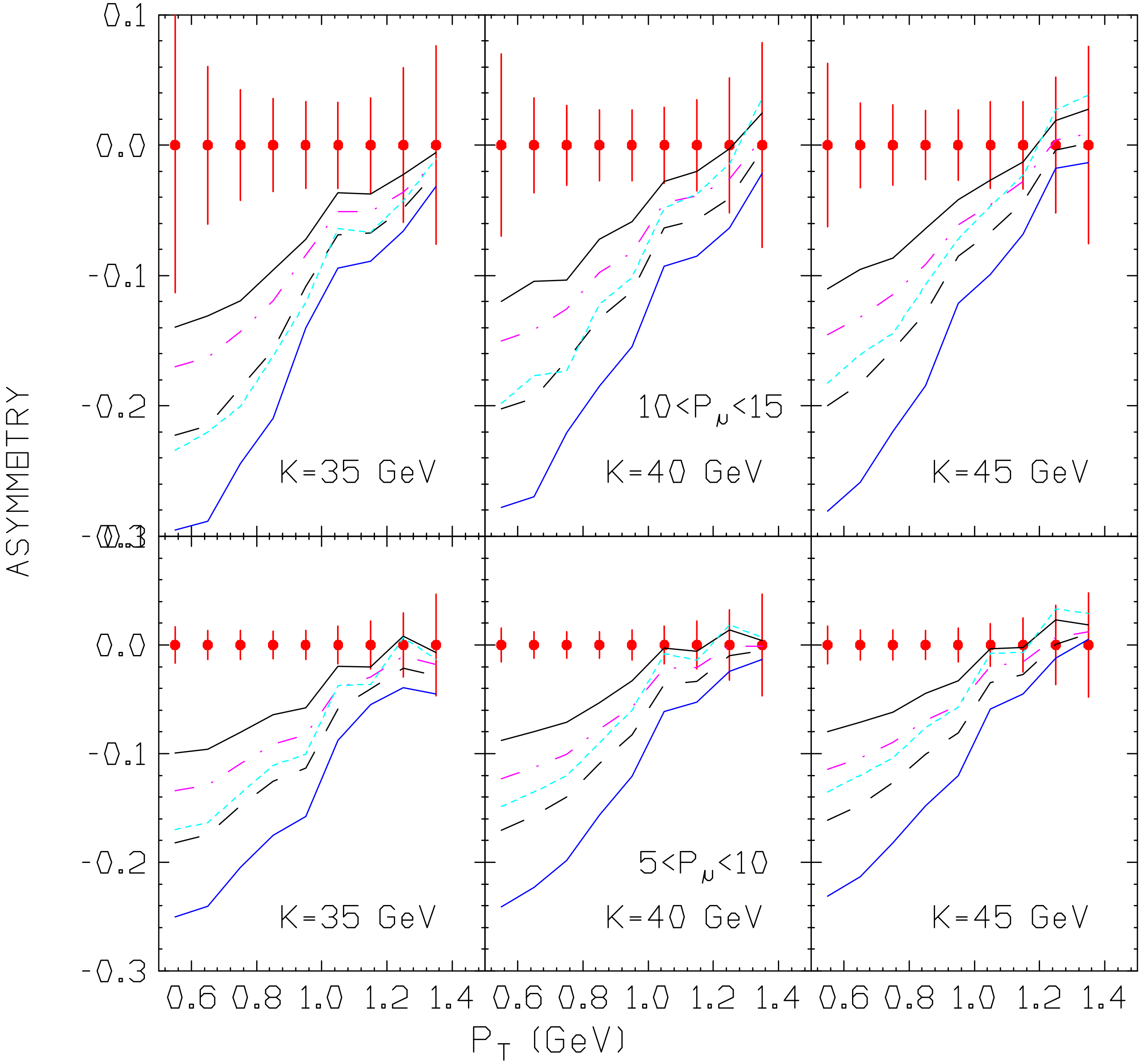
μ SPECTROMETER

NORMAL MODE

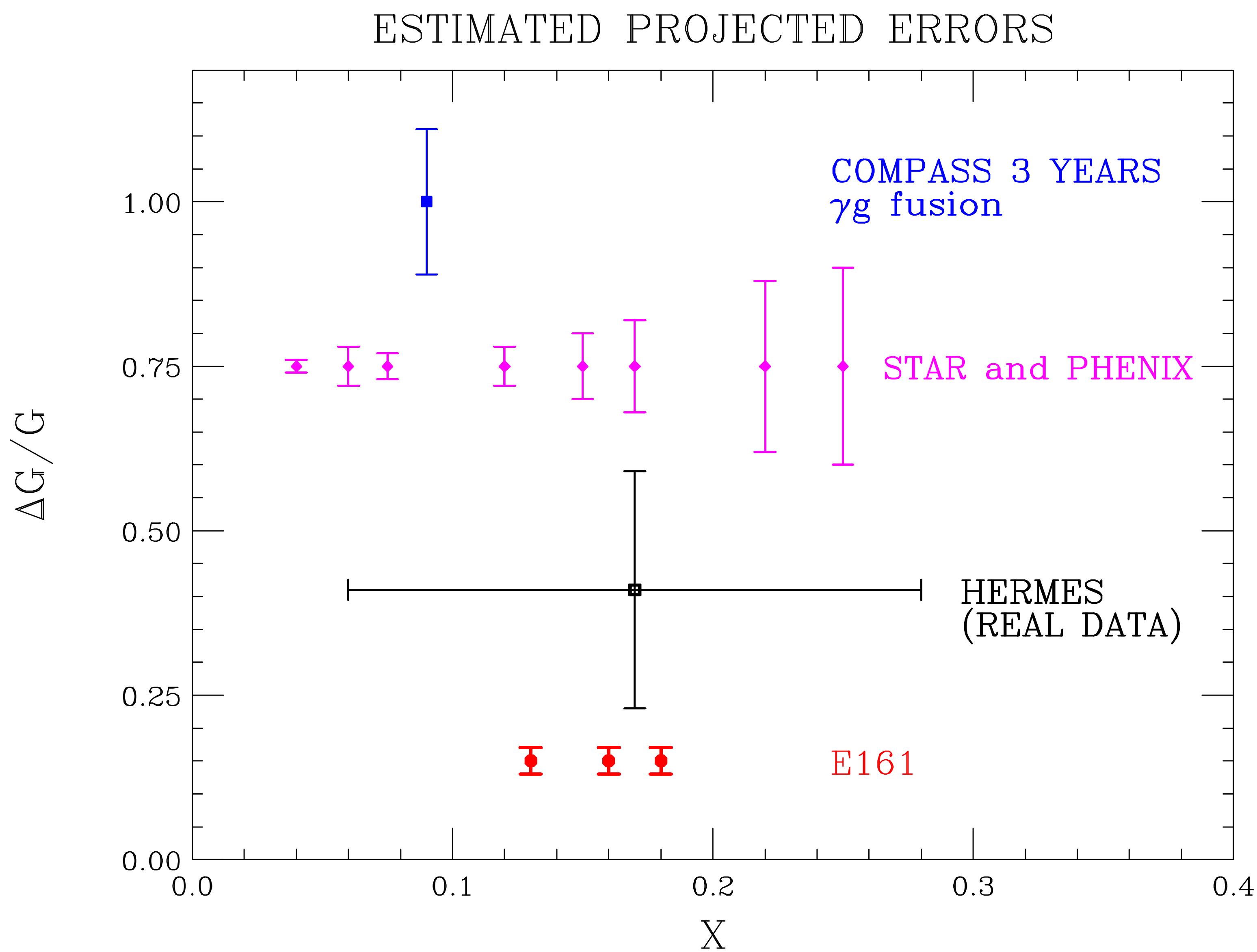


EXPECTED RESULTS

for Asymmetry in Cross Sections with photon/nucleon Spins parallel or anti-parallel



COMPARISON OF EXPERIMENTS



SLAC-PROPOSAL-E159

Proposal to Measure $\Delta\sigma^{\gamma N}(k)$ and the High Energy Contribution to the Gerasimov-Drell-Hearn Sum Rule

P. Bosted, D. Crabb co-spokespersons

Planned to run in 2005

http:www.slac.stanford.edu/exp/e159/

INTRODUCTION

- **Total photoabsoption cross section $\sigma^{\gamma N}(k)$ depends only on photon energy k for real photons.**
- **Can be decomposed into spin 1/2 and 3/2 final states $\sigma_{3/2}$ and $\sigma_{1/2}$, corresponding to helicity of photon aligned or anti-aligned with spin of nucleon.**
- **Spin-averaged $\sigma^{\gamma N}(k) = (\sigma_{1/2} + \sigma_{3/2})/2$ well-measured (including SLAC early 1970's). Roughly constant at 120 μb.**
- **We propose to measure**

$$\Delta\sigma^{\gamma N}(k) = \sigma_{3/2} - \sigma_{1/2}$$

using circularly polarized photons and longitudinally polarized nucleons.

The GDH SUM RULE

- Relates integral over $\Delta\sigma(k)$ to anomalous magnetic moment κ of target with spin S (composite or elementary).

$$\int_{k_\pi}^{\infty} \frac{dk}{k} \Delta\sigma^{\gamma N}(k) = \frac{2\pi^2 \alpha \kappa^2}{M^2} \qquad (1)$$

- Follows from general principles of causality, universality, Lorentz and electromagnetic gauge invariance.
- One assumption: that unsubtracted dispersion relation can be used for $f_2(\nu)$.
- Scale of convergence gives scale of highest spin-flip excitations of target.
- $\Delta\sigma^{\gamma N}(k)$ must decrease with k at high k for integral to converge. Contrast to $\sigma^{\gamma N}(k)$, known to increase with k at high energies.

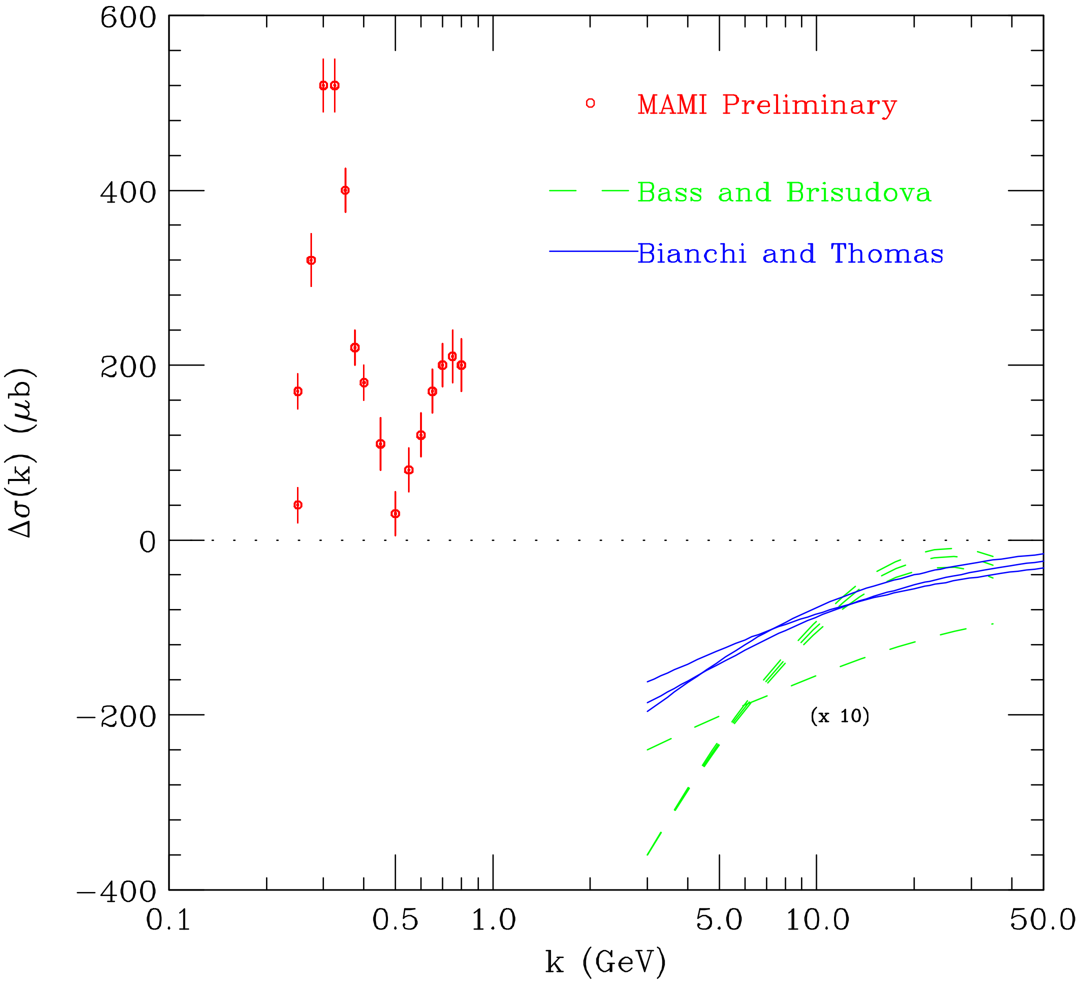
- **Direct measurements only exist up to 800 MeV for proton, but various resonance region multi-pole analyses have made estimates of integrals.**

target	$2\pi^2\alpha\kappa^2/M^2$	Analyses
proton	204 μb	257 to 289 μb
neutron	232 μb	169 to 189 μb
isoscalar (p+n)/2	219 μb	213 to 239 μb
isovector (p-n)/2	-15 μb	34 to 65 μb

- **Large discrepancy, especially isovector case.**
- **Non-resonant contribution important?**
- **High energy contributions important?**
- **Need data on both proton and neutron to find out.**
- **Worldwide program at Mainz, Bonn, GRAAL, SPIN8, LEGS, Jefferson Lab, TUNL, other, but limited to 5 GeV.**

LOW ENERGY BEHAVIOR OF $\Delta\sigma(k)$

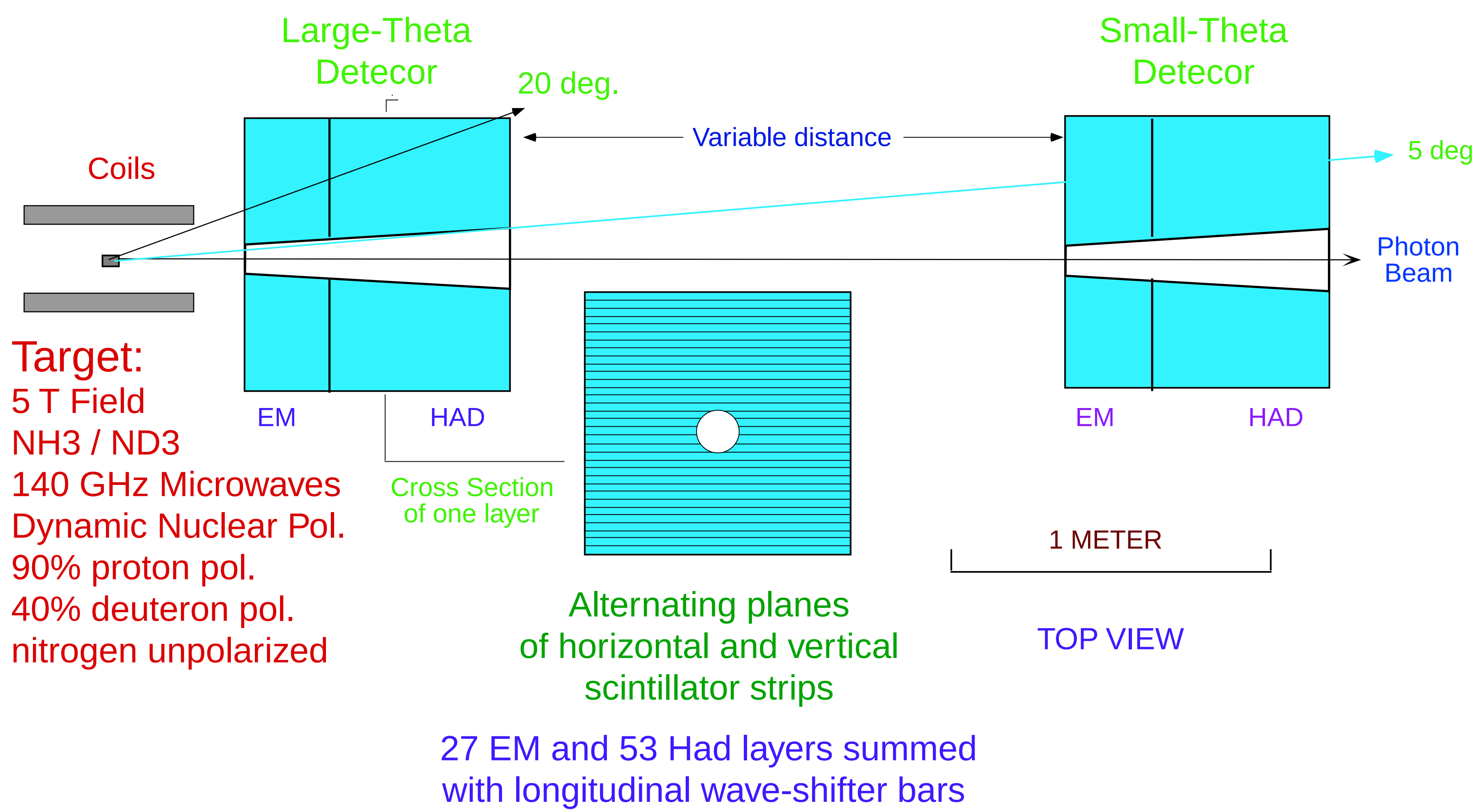
Preliminary data from Mainz on proton. Resonant excitations are evident (especially $\Delta(1232)$).



EXPERIMENTAL OVERVIEW

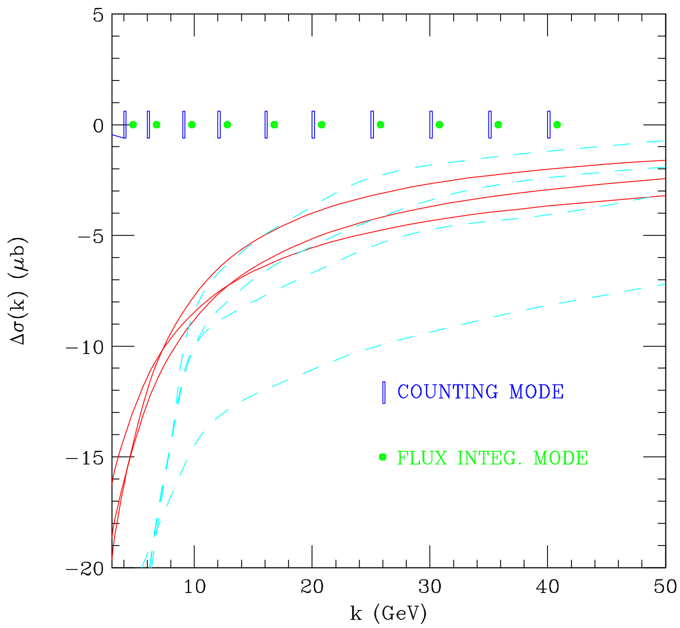
- Coherent bremsstrahlung provides circularly polarized photons $4 < k < 40$ GeV.
- Subtract incoherent contributions to obtain $\Delta\sigma(k)$ at discrete values of k.
- Longitudinally polarized NH_3 and ND_3 targets.
- Measure total cross section asymmetry with large calorimeters.
- Reject E.M. backgrounds with cuts, longitudinal segmentation of detector, and/or calculations
- Measure in Counting Mode for lower systematic error (each hadronic interaction is individually counted)
- Use Flux Integration Mode for smaller statistical errors (total hadronic energy summed over many interactions).

Target and Detectors

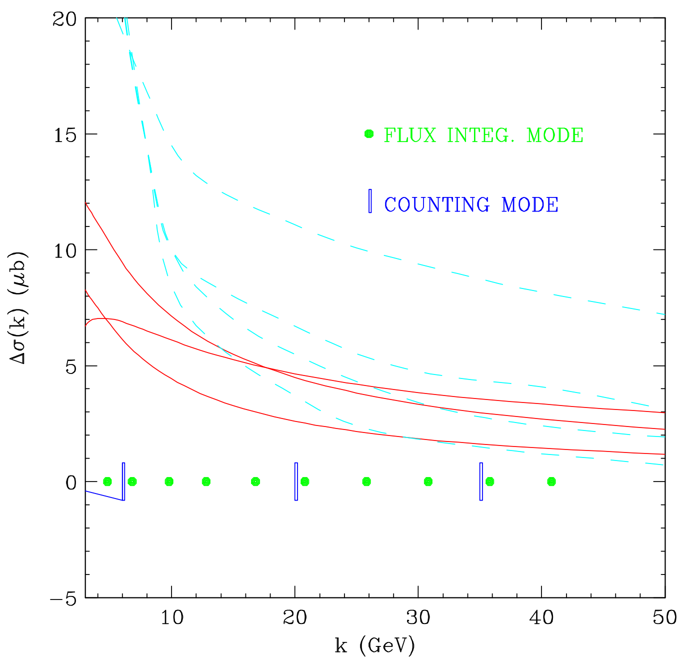


EXPECTED ERRORS FOR PROTON

Systematic errors (not shown) expected to be 6% to 8% (relative).



EXPECTED ERRORS FOR NEUTRON



SUMMARY OF E159

- A fundamental experiment, providing baseline for studies of spin structure of nucleon.
- Test convergence of isovector and isoscalar GDH Sum Rule.
- Connections to g_1 at low x, Bjorken Sum Rule.
- No existing data: surprises possible!
- Study QCD in non-perturbative regime with one of simplest possible interactions.
- SLAC is only place experiment can be done $5 < k < 40$ GeV.
- Energy range extends factor 8 beyond Jefferson Lab.
- Strong collaboration with experience and resources needed to do experiment.

SUMMARY OF REAL PHOTON EXPERIMENTS

- Unique opportunity: experiments cannot be done elsewhere (even if Jlab 12 GeV upgrade happens).
- Cost effective, using much existing equipment.
- Simultaneous operation with PEP-II will be possible.
- Interesting physics shedding light on charm, quark-gluon plasma, and spin structure of the nucleon.