Real Photon Experiments

New Polarized Coherent Bremsstrahlung Beam in SLAC End Station A

E159 - GDH Sum Rule

E160 - A-Dependence of J/ψ Photoproduction

E161 - Gluon Spin from Charm Photoproduction

SLAC/DOE Review
3-4 April 2002
R. Arnold

Real Photon Beam Program

Physics

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

Only at SLAC

- Builds on decades of quark structure and spin at SLAC
- Unique high intensity, high energy, polarized e- and γ beams
- Unique facilities -- linac, beamlines, spectrometers, ESA

Connections

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

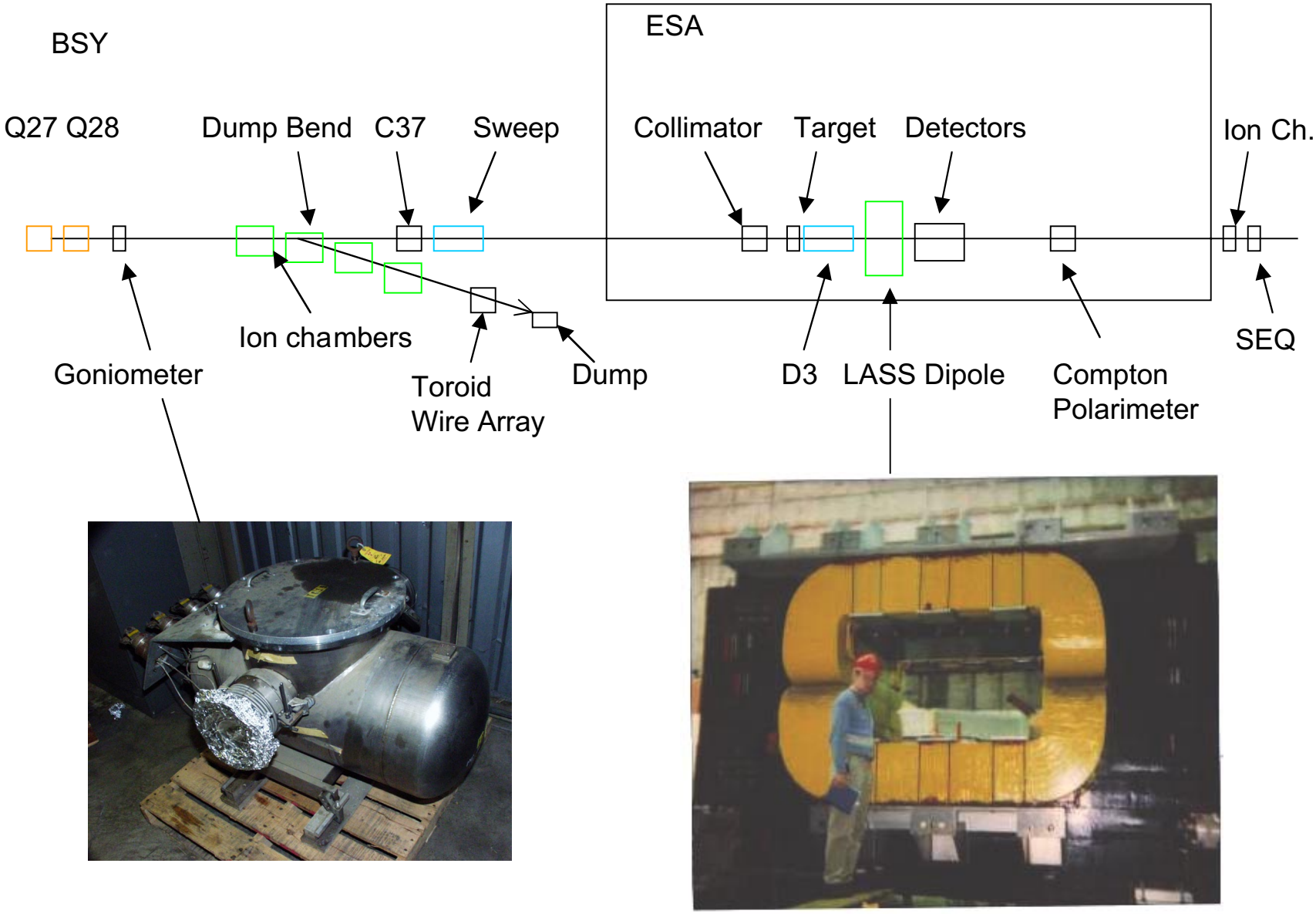
Real Photon Collaboration

April 2002

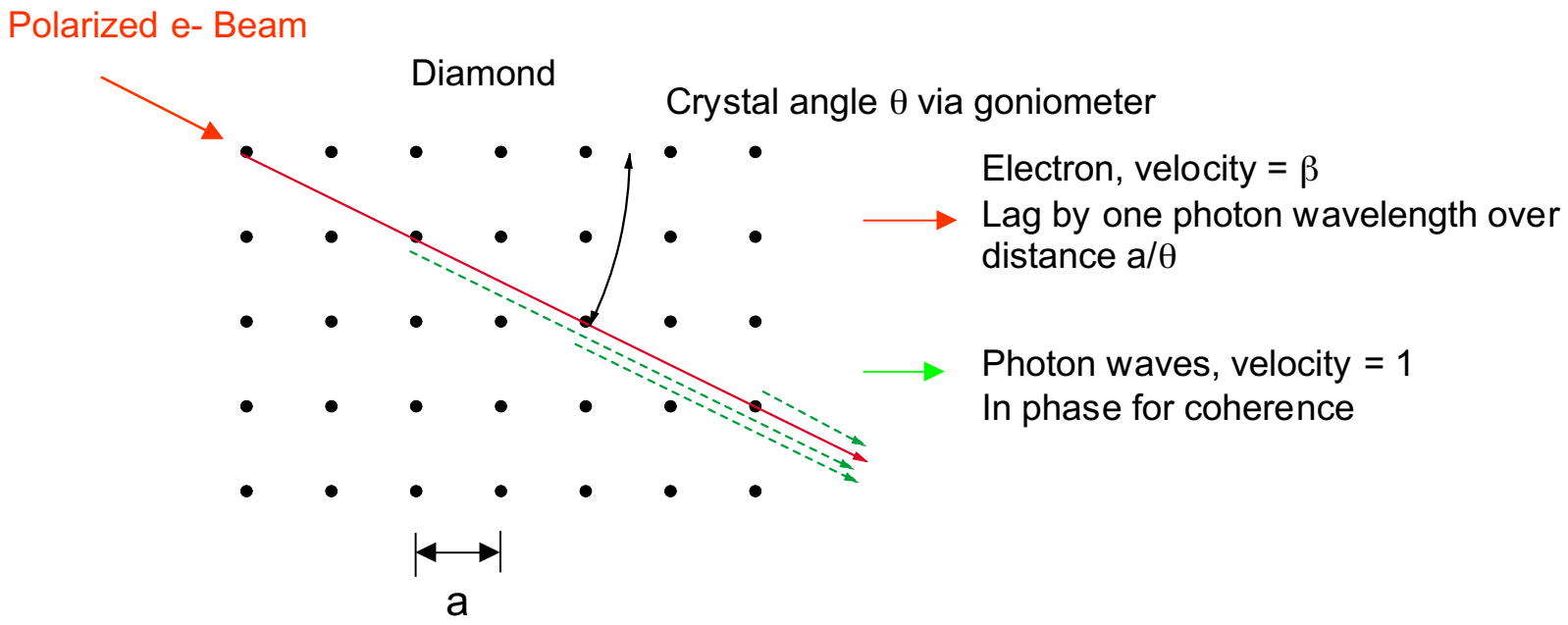
65 Physicists 20 Institutions 8 Countries

- 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

Photon Beamline for E160

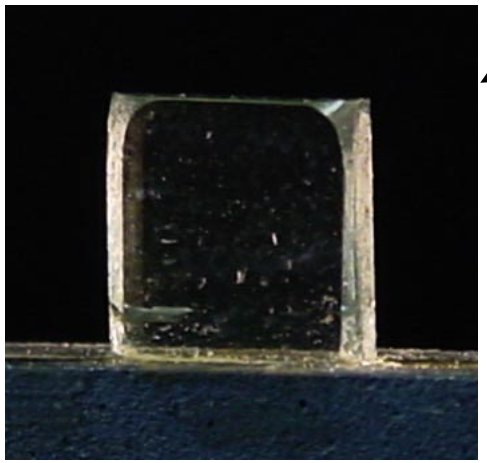


Coherent Bremsstrahlung



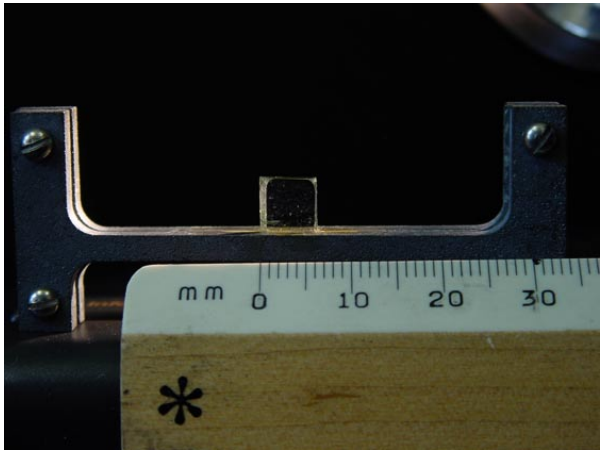
- Thin diamond radiators for low mosaic spread, low Z, small lattice spacing
- High flux quasi-monochromatic circularly polarized real photon beam
- Vary photon energy, flux, and polarization via beam energy and crystal angle

Diamonds and Goniometer



6 x 6 mm crystal

Be holder

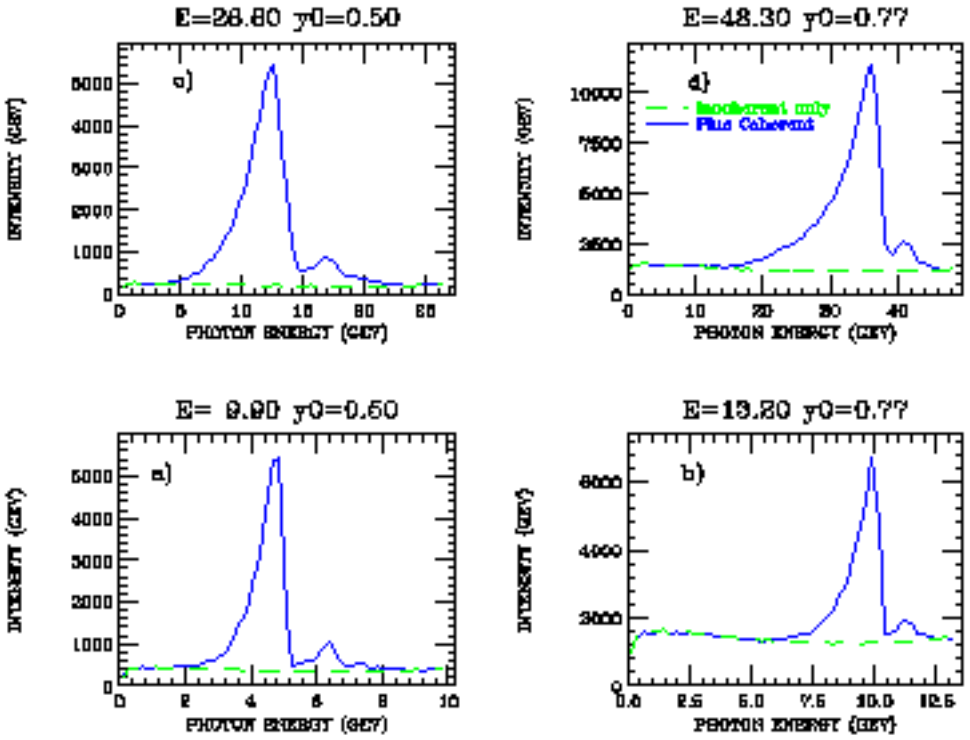


Goniometer used in SLAC experiments in 1970's

Two-crystal holder with remote positioning accurate in two angles

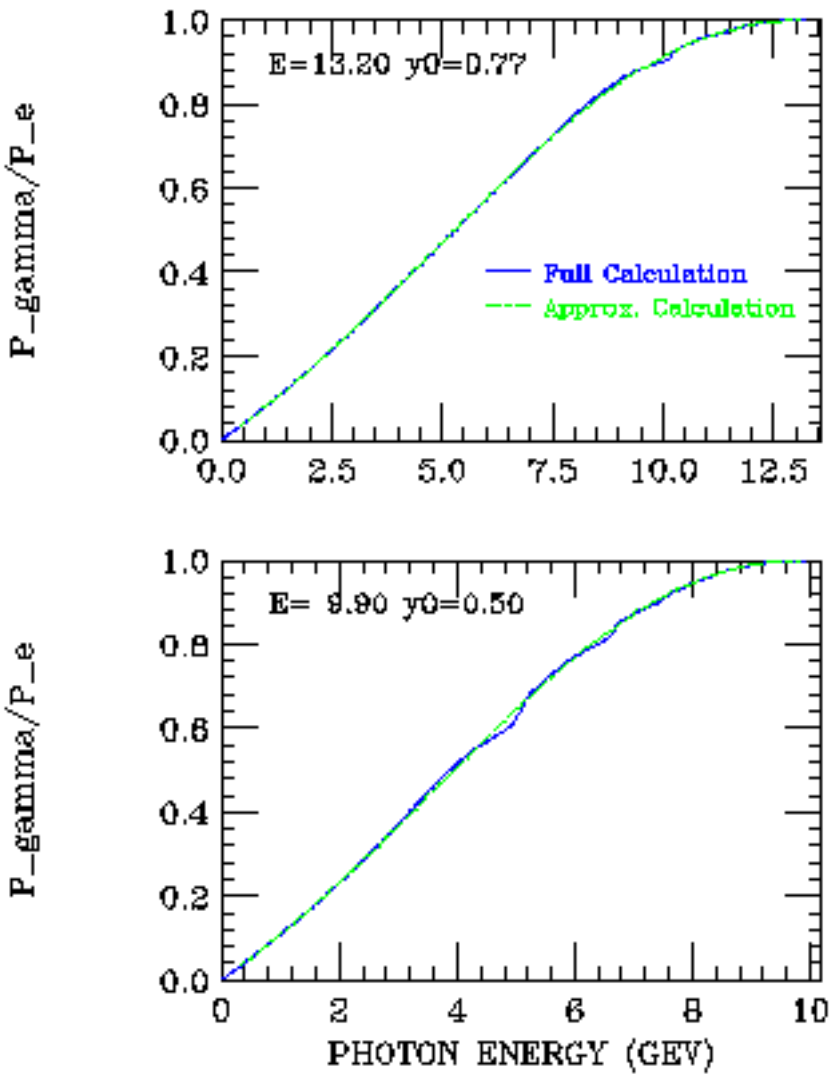
Representative Photon Intensities

Controlled by beam energy and crystal angle

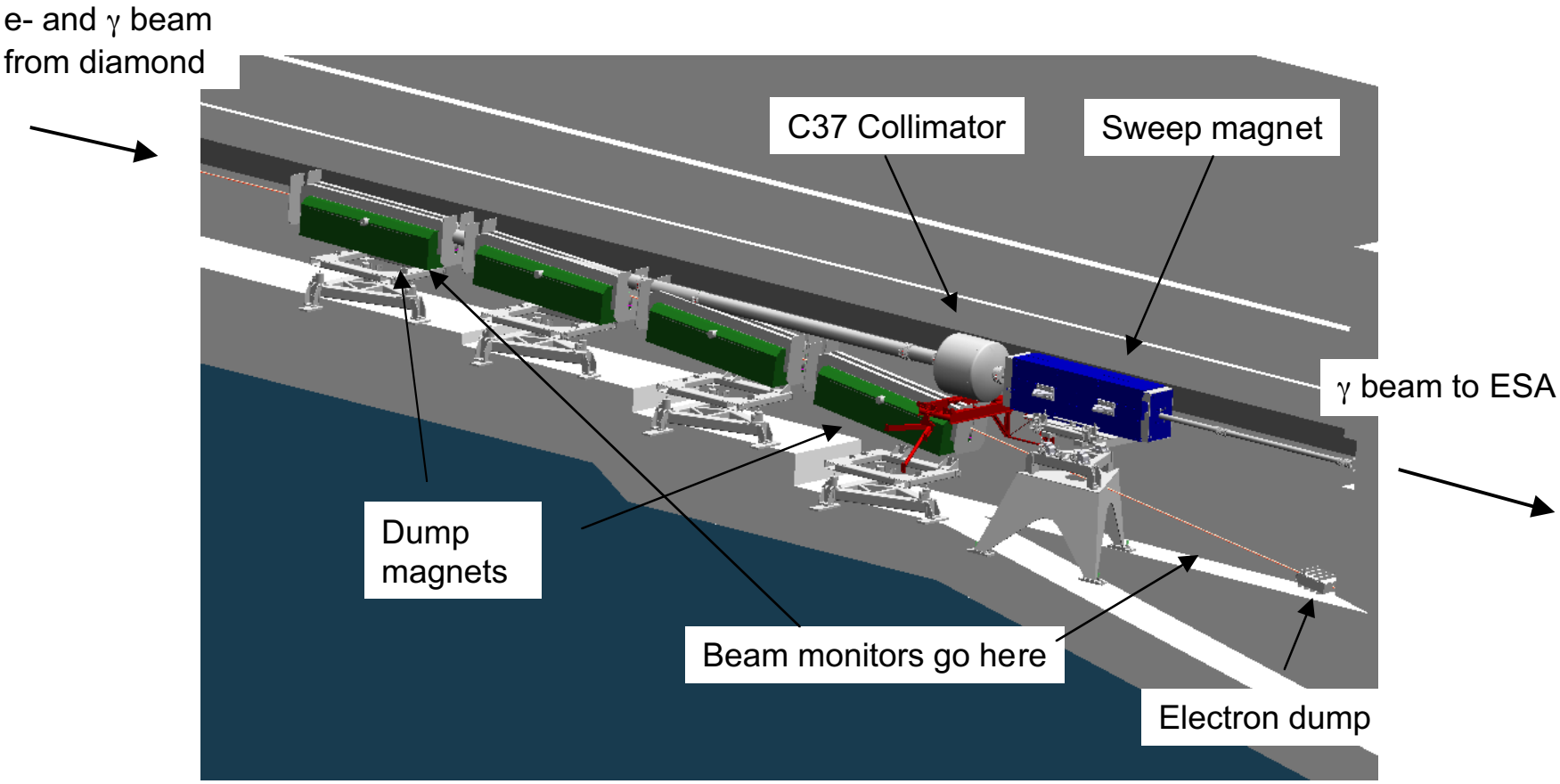


- Coherent contribution (blue lines)
- Incoherent contribution (green dashed lines)
- $y_0 = k/E$

Polarized e- Gives γ Circular Polarization



Photon Beamline in SLAC BSY



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

A-Dependence of J/ψ and ψ' Photoproduction

Goals

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

Measurement

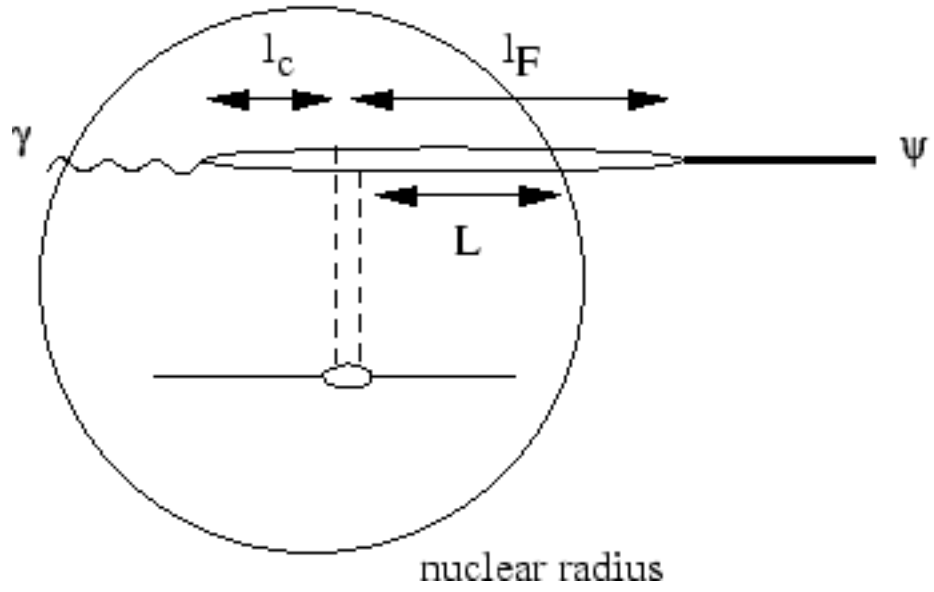
- Reconstruct J/ψ from μ+μ− pairs
- Be, Al, Cu, Pb targets
- Photon energy 15, 25, 35 GeV

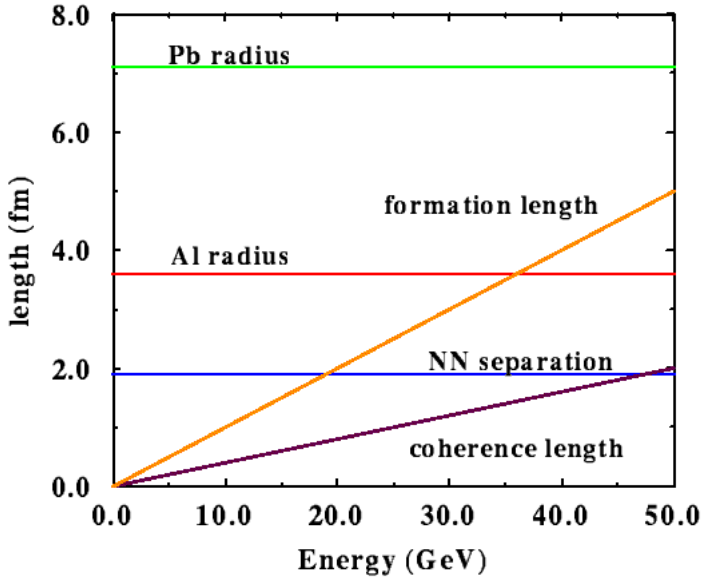
Results

- t - distributions
- Nuclear A-dependence
- ψ -nucleon cross section

Length Scales for J/ψ Propagation in Nuclei

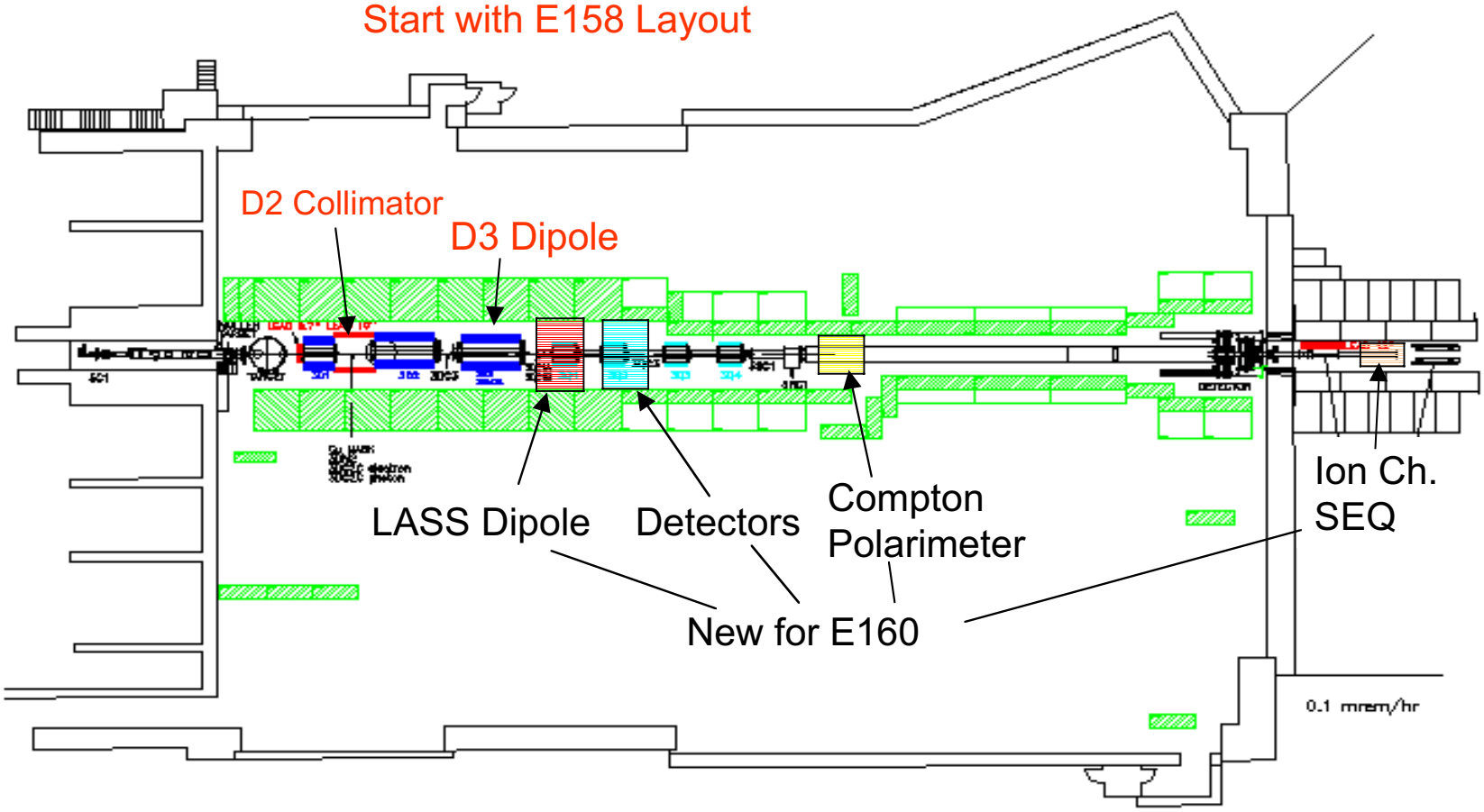
Coherence length Formation length



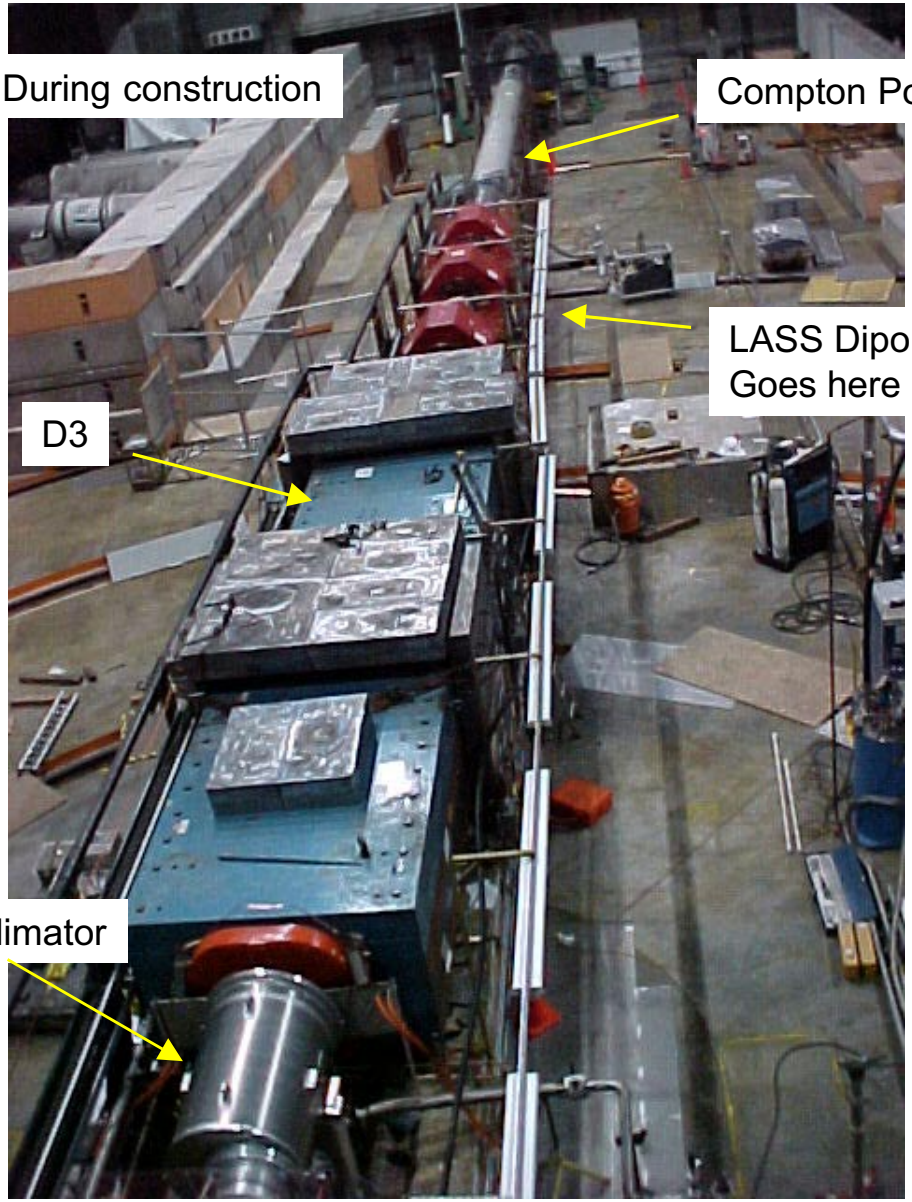


E160 range

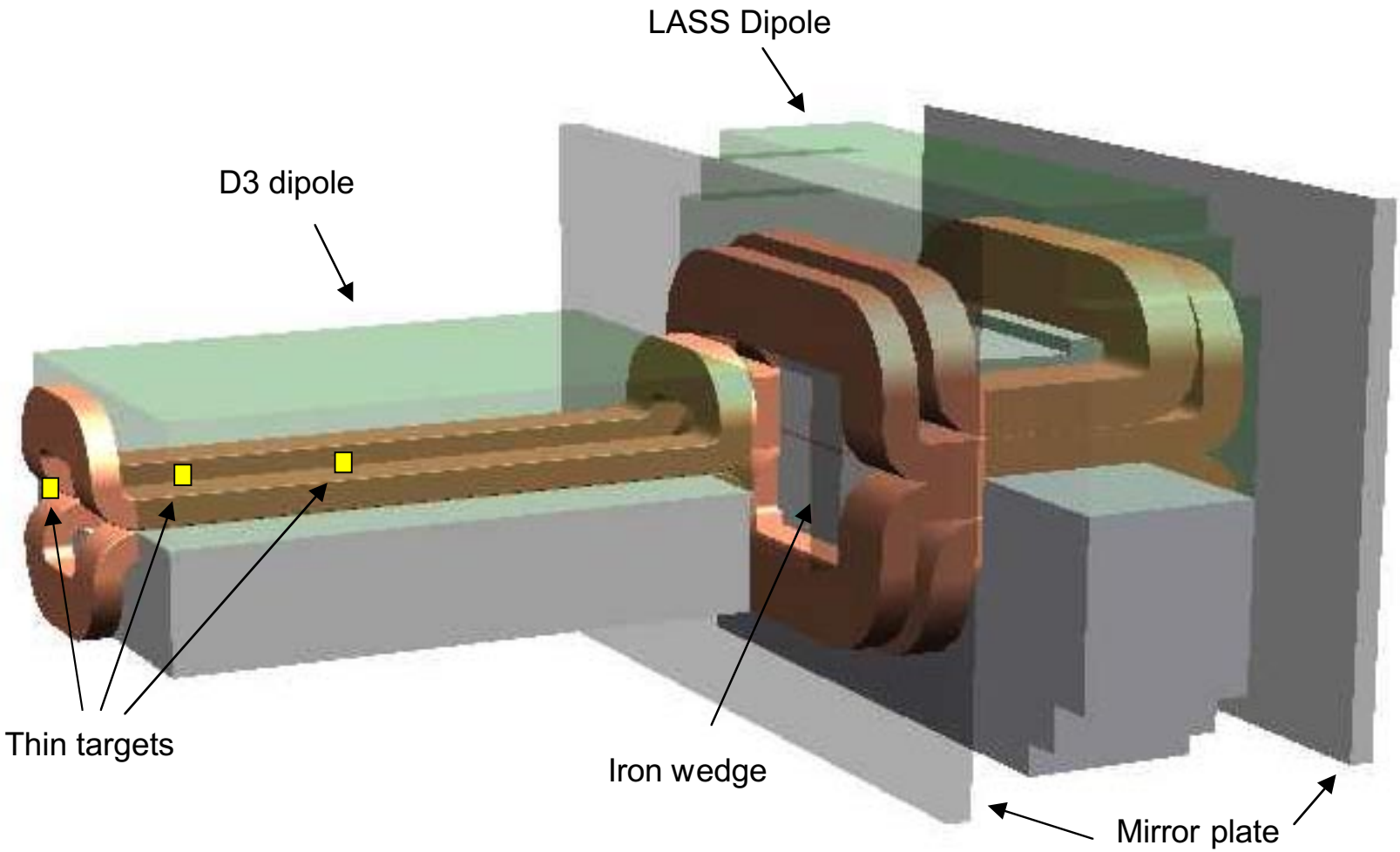
E160 End Station A Plan



End Station A Layout for E160

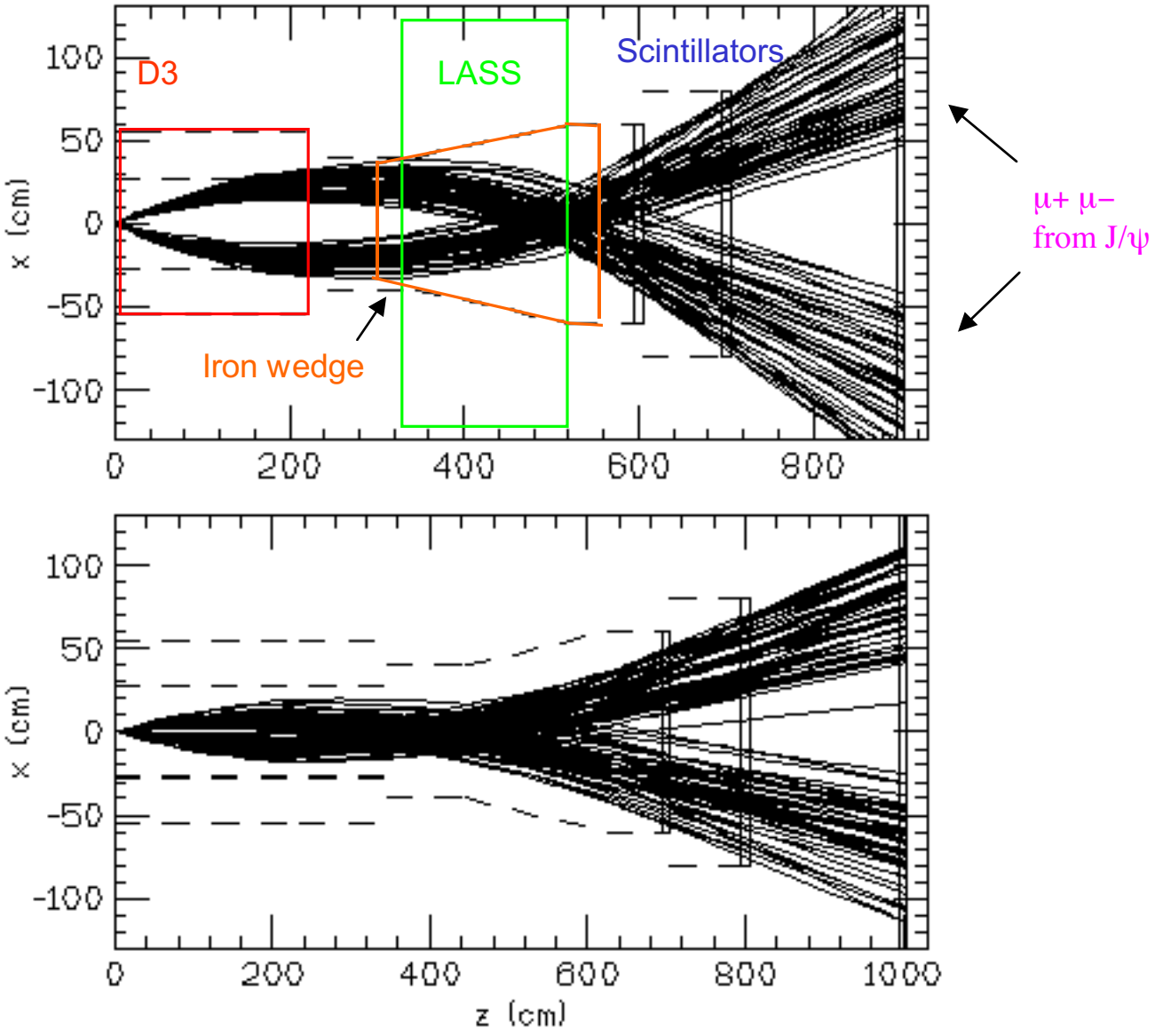


E160 Muon Spectrometer



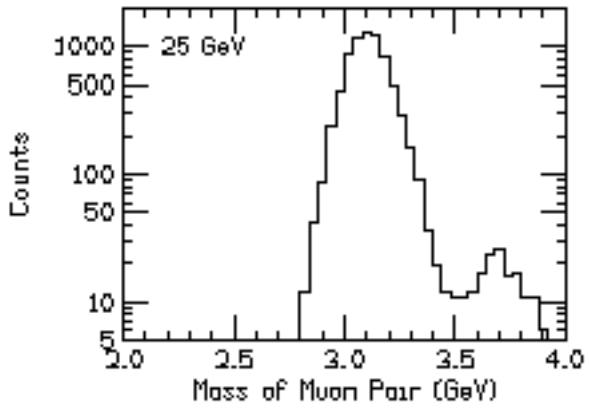
D3 DESIGN: RAY TRACE

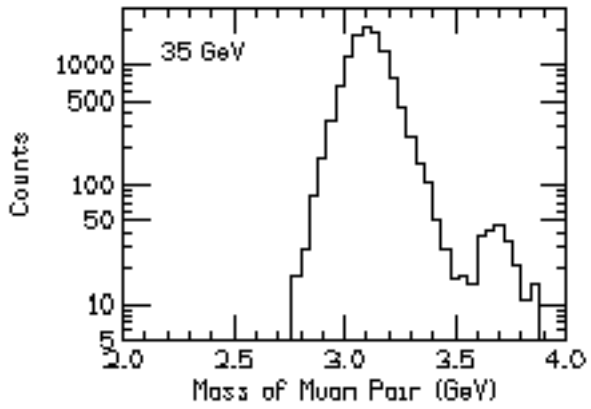
Plot shows 15 GeV (top) and 35 GeV (bottom) ray traces from top view.



Invariant Mass Spectrum at 25 and 35 GeV Beam

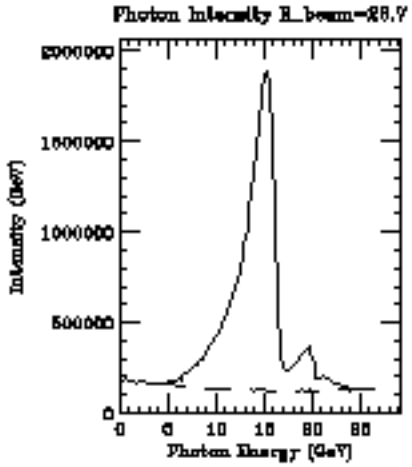
ψ' and J/ψ peaks clearly separated, even though 50x less ψ' . No acceptance from ψ' at 15 GeV. Plots don't include Bethe-Heitler background.

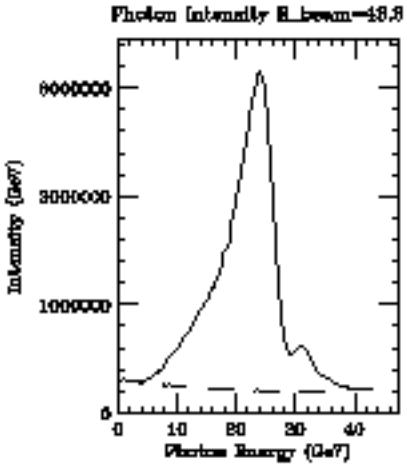


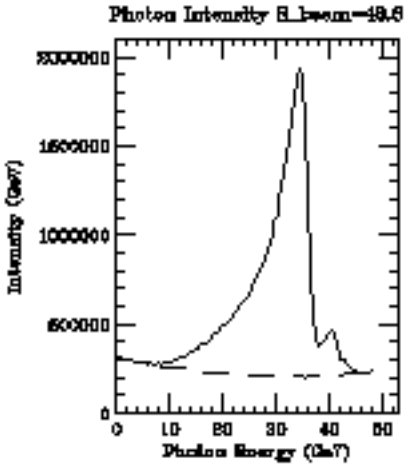


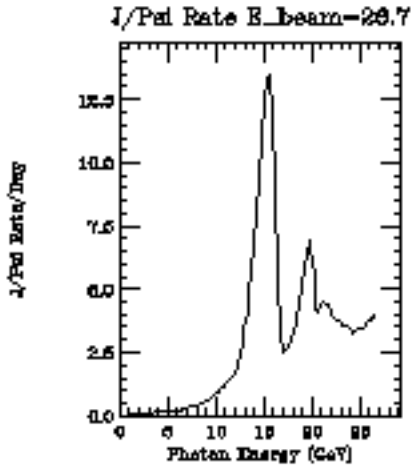
Photon Spectra and ψ Yield for Three Settings

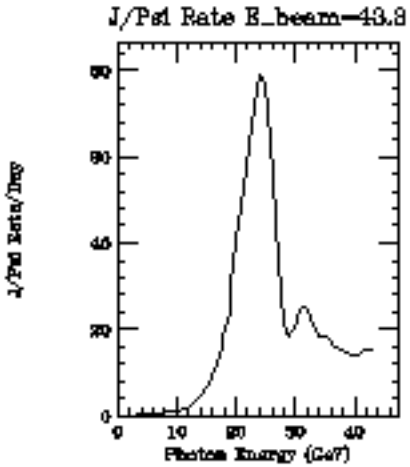
Beam Energy 27 GeV 43 GeV 48 GeV

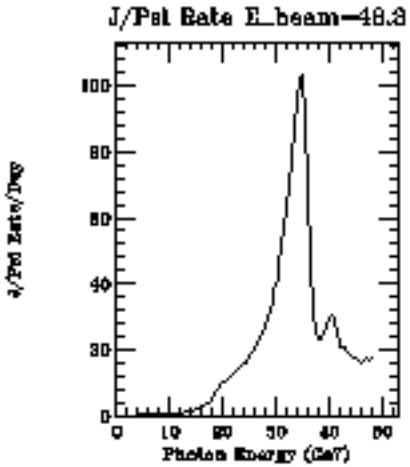








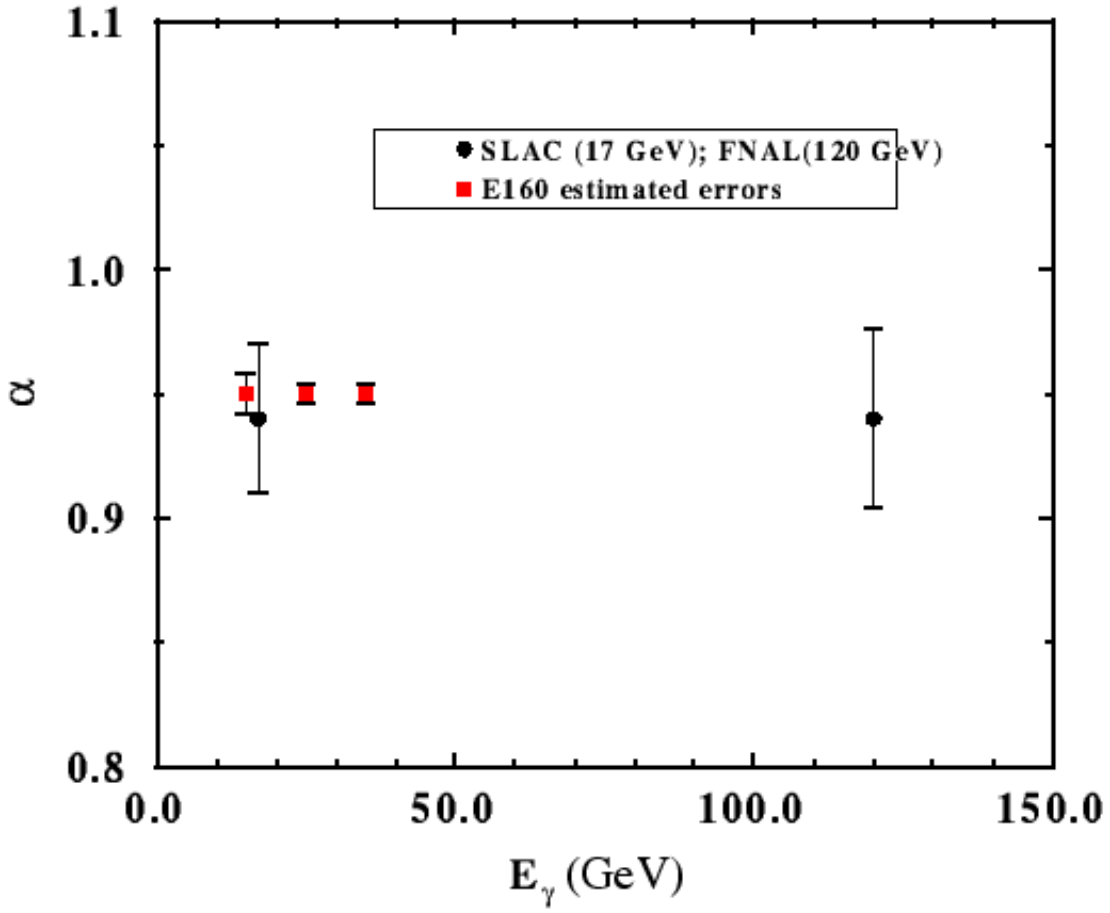




E160 Projected Results for A-Dependence

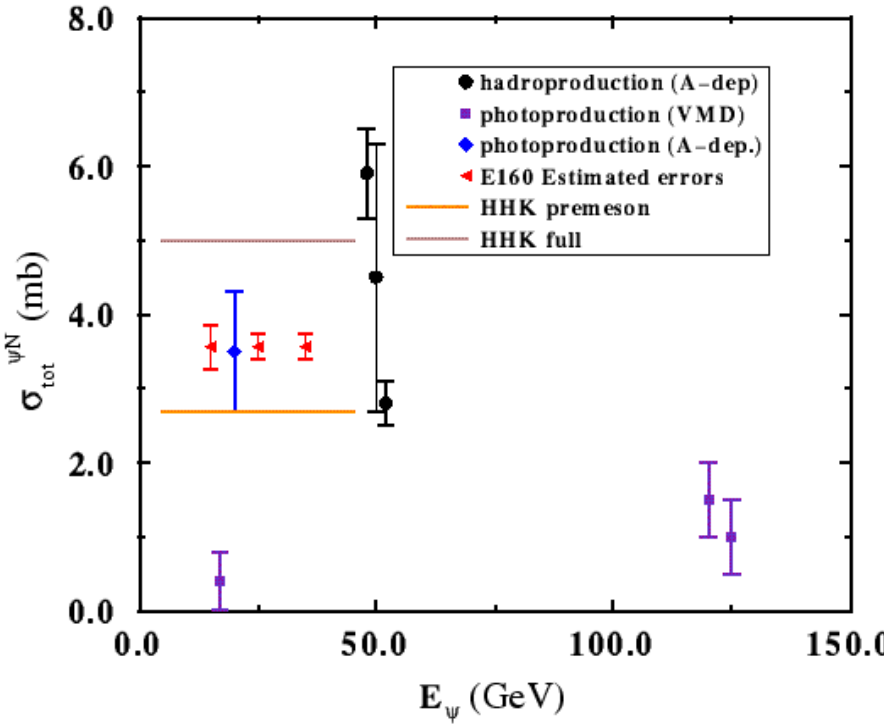
$\sigma(\psi,N) = A^{\alpha}$

Results to constrain ψ formation and coherence lengths

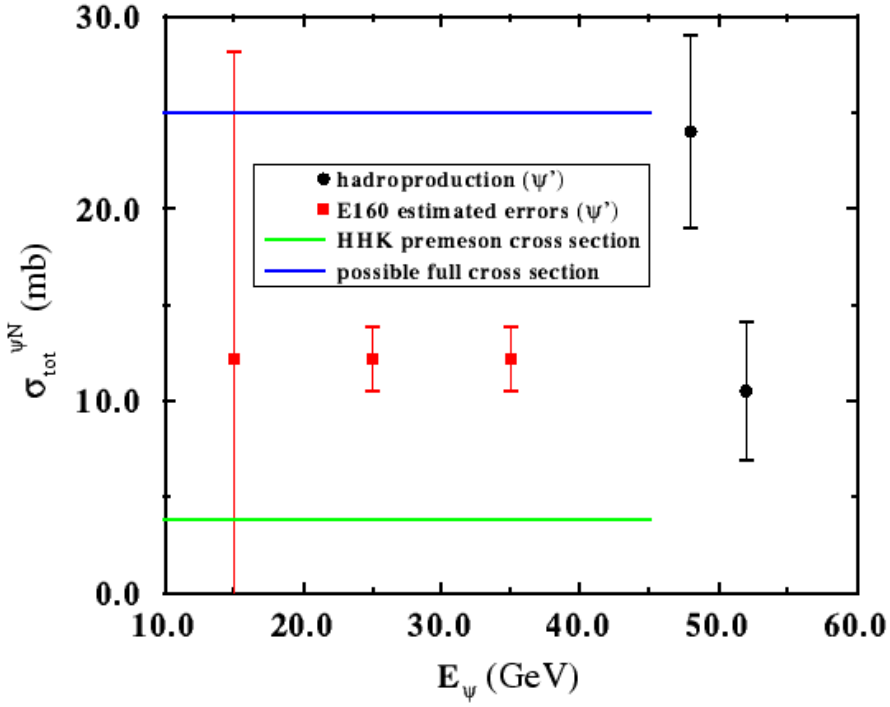


E160 Possible Results for Total ψ-N X-Sects Compared to Theory and Previous Data

ψ-Nucleon



ψ'-Nucleon



Horizontal bars represent range of theoretical estimates

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

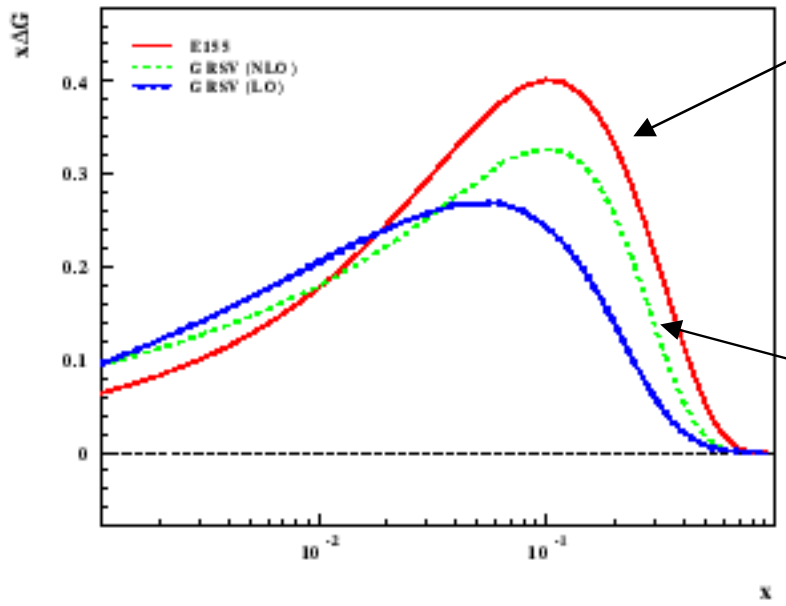
- Detect single high momentum μ (veto μ pairs)
- Polarized LiD target
- 35, 40, 45 GeV circularly polarized photons

Results

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

The Nucleon Spin - What We Know

Possible values for xΔG



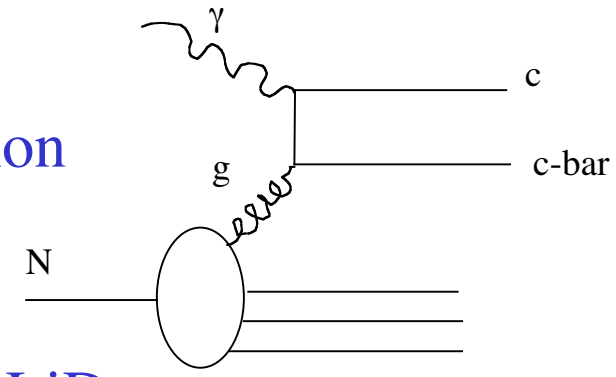
Fit to DIS data

NLO models

- $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$
- $\Delta\Sigma = 0.23 \pm 0.07$ 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 Experimental Strategy

- Probe gluons via photon-gluon fusion



- High polarization nucleon target -- LiD
- Measure μ momentum -- high field, fine grain hodoscopes, good time resolution
- Absorb K and π before decay
- Veto μ+μ– pairs -- Bethe-Heitler and vector meson decays

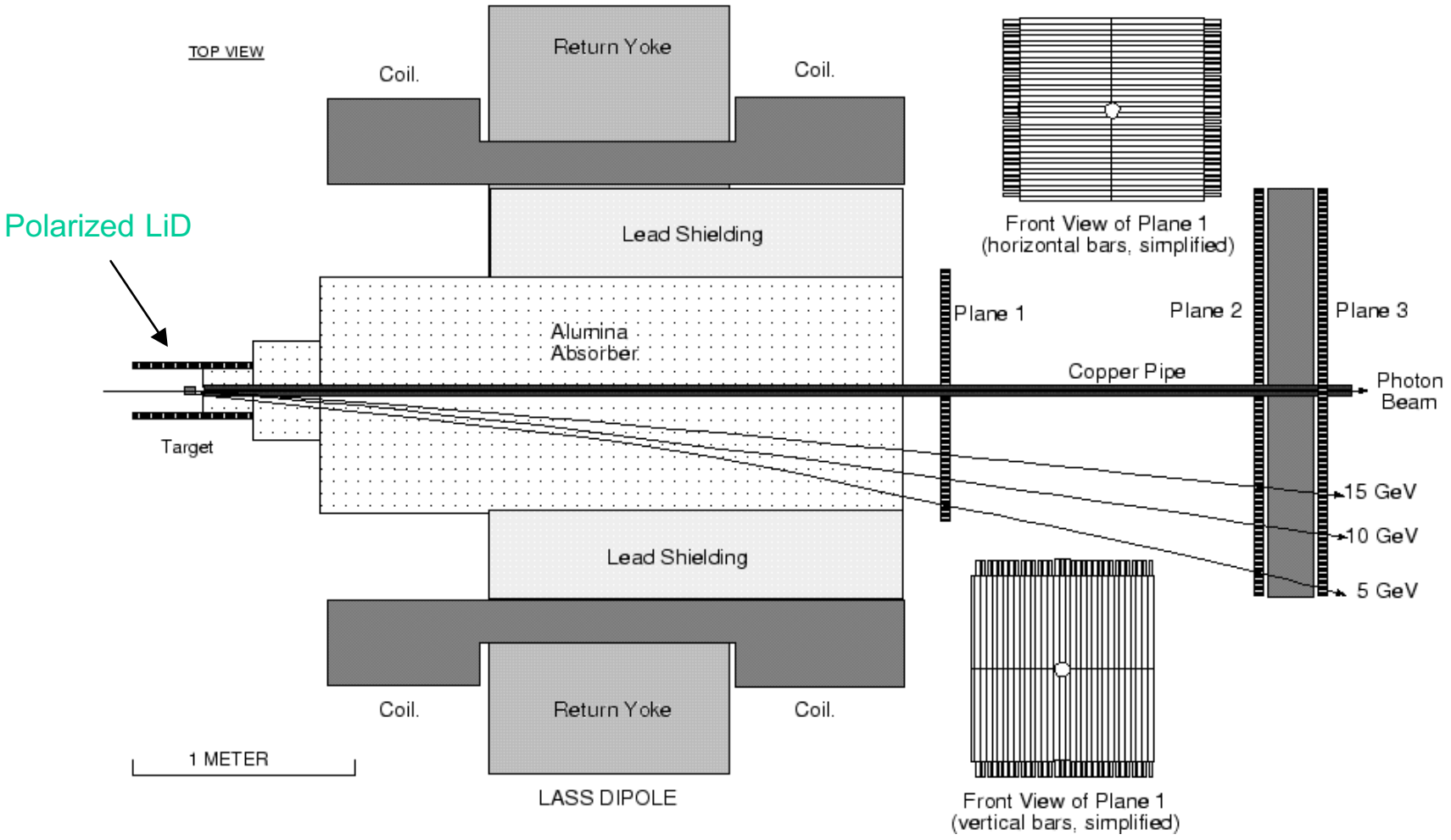
Tag Charm With Single Decay μ

	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^-	D^0	D_s^-	Λ_c^-
produced(%)	21	71	6	2
fraction of μ^-(%)	40	53	5	1

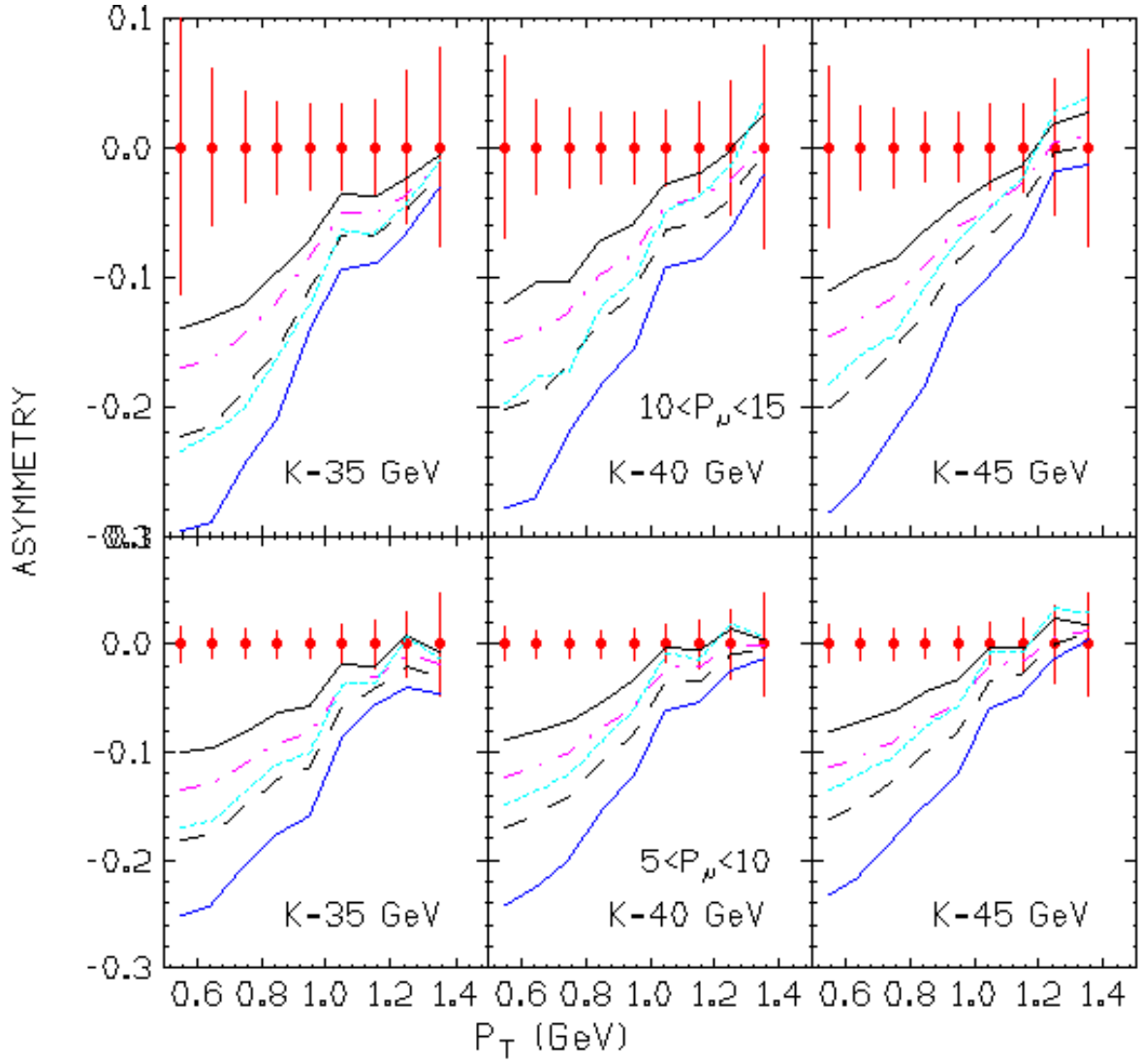
E161 Muon Spectrometer

LASS Dipole with hadron absorbers

Scintillator hodoscopes

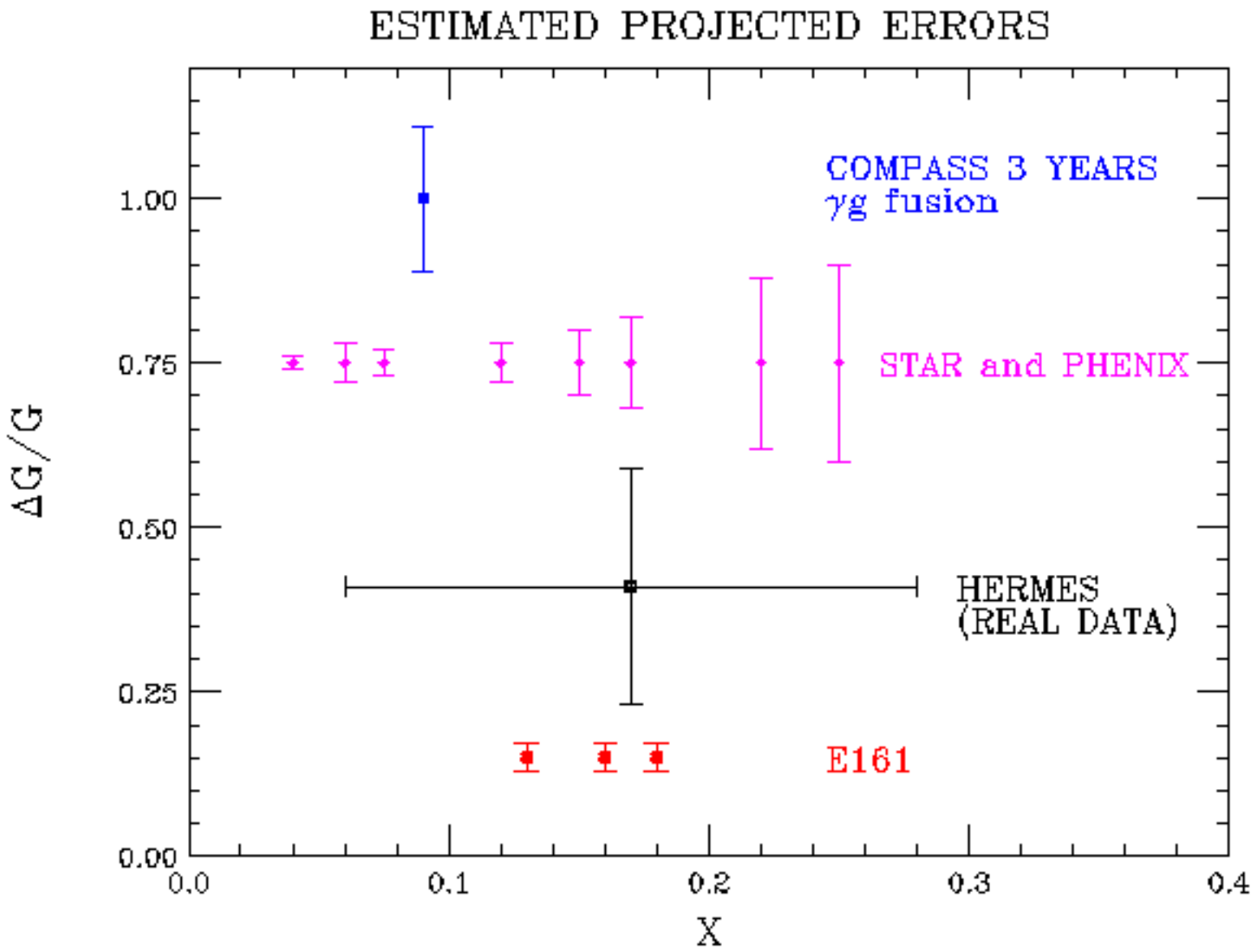


E161 Projected Results for ψ X-Sect Asymmetries



Curves for various theoretical estimates of ΔG

Comparison of Proposed ΔG/G Experiments



E159

Asymmetry in Total Photo-Nucleon X-Sect at High Energy and 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

The GDH Sum Rule

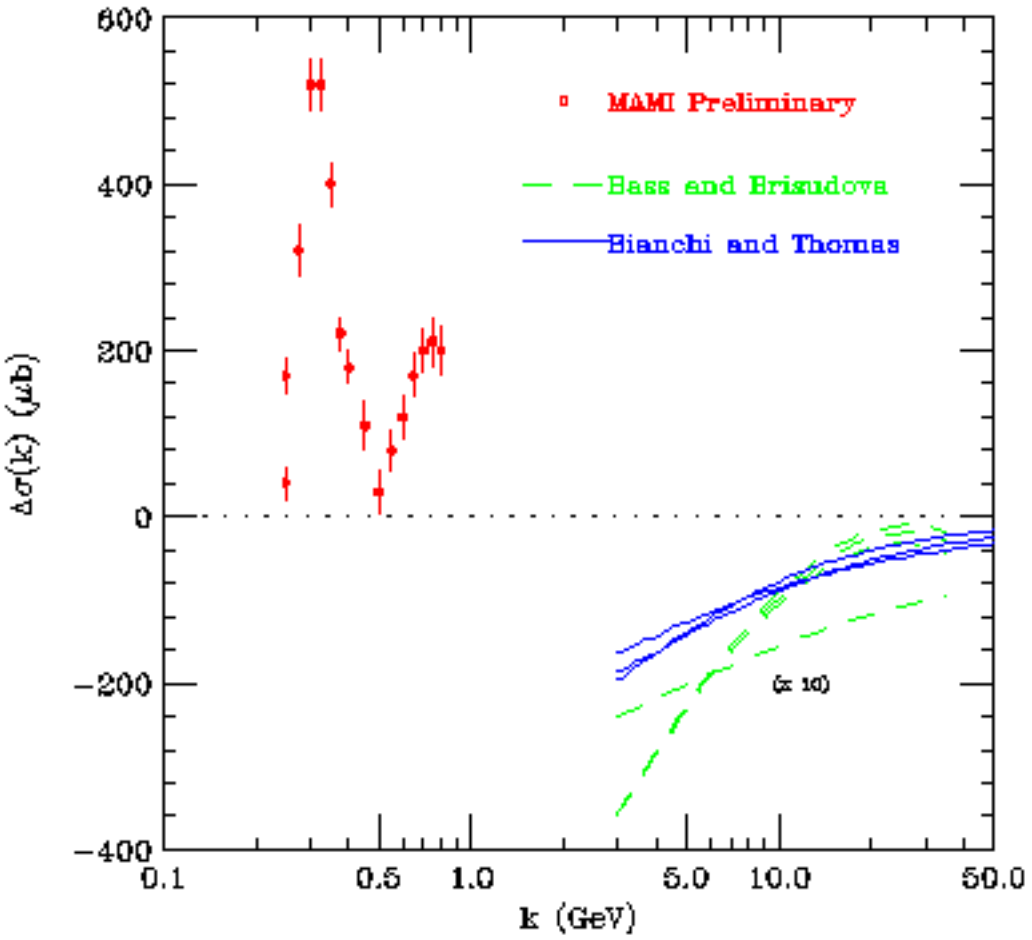
- Relates integral over asymmetry $\Delta\sigma^{\gamma N}(k)$ to the anomalous magnetic moment κ.

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

- 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.

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

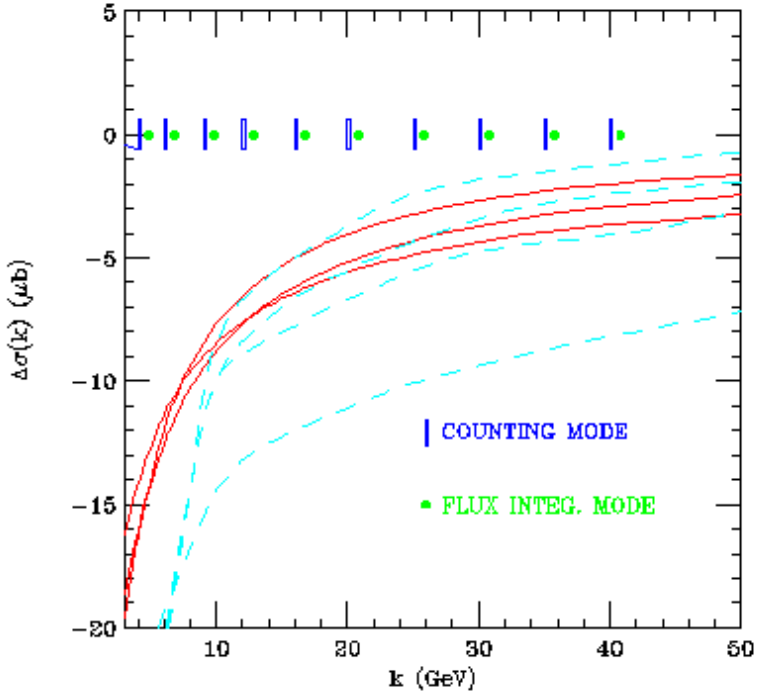
Previous proton data at low energy and predictions at high energy



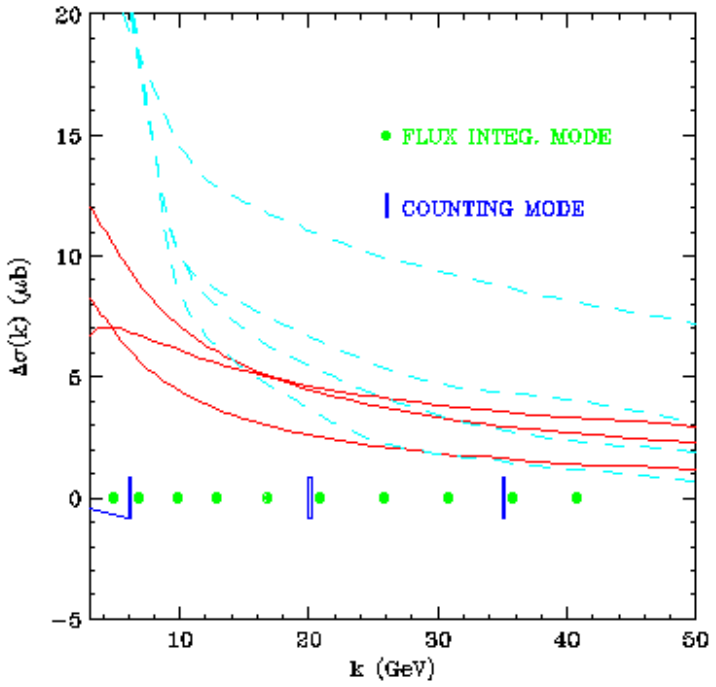
E159 range

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

Proton



Neutron



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

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 unique SLAC facilities: linac, beamlines, ESA.
- Requires high intensity, high energy, polarized e- and γ
  available only at SLAC.
- Fits in SLAC program with modest impact and cost.
- Provides important data for interdisciplinary questions:
  gluon spin, GDH sum rule, J/ψ signal for QG plasma
- Project underway for beamline to be ready in 2003.