E161

MEASUREMENT OF

GLUON SPIN DISTRIBUTION IN NUCLEONS USING POLARIZED OPEN CHARM PHOTOPRODUCTION

- WHY MEASURE THIS
- SOME THEORY
- EXPERIMENTAL SETUP
- PROJECTED RESULTS
- OTHER EXPERIMENTS

E161 COLLABORATION

- UCLA
- Jefferson Lab
- University of Liverpool
- Los Alamos
- University of Massachusetts
- SACLAY
- Institut fur Kernphysik, Mainz
- Old Dominion University
- Ruhr-Universit$\widehat{\mathrm{B}}$ochum, Germany
- Smith College
- SLAC
- University of Virginia
- College of William and Mary
- Yerevan Physics Institute, Yerevan, Armenia

WHY MEASURE THE GLUON POLARIZATION?

1. **FUNDAMENTAL SUM RULE**
   $\mathbf{1/2 = 1/2 \cdot \Delta\Sigma + \Delta G + L_z}$
   – $\mathbf{\Delta\Sigma \sim 0.23 \pm 0.07}$ (from quarks)
   – $\mathbf{\Delta G}$ (from Gluons)
   – $\mathbf{L_z}$ includes quarks and gluons. Possible to measure it.

2. pQCD CONSISTENCY FOR ALL REACTIONS
   – $\mathbf{g_1}$ 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

UNPOLARIZED PARTON DISTRIBUTIONS

DIS LEPTON SCATTERING

SLAC	**electrons**	**1968-1986**
HERA	**electrons**	**1992-**
EMC	**muons**	**1976-1980**
NMC	**muons**	**1981-1990**
BCDMS	**muon**	**1981-1985**
CCFR	**neutrino**	**1980's**
NuTeV	**neutrino**	**1995**

PROTON-PROTON

DIRECT PHOTON PRODUCTION

High P_T JETS

Drell-Yan

Z, W, **top production**

⇒ SEARCH FOR NEW PHYSICS

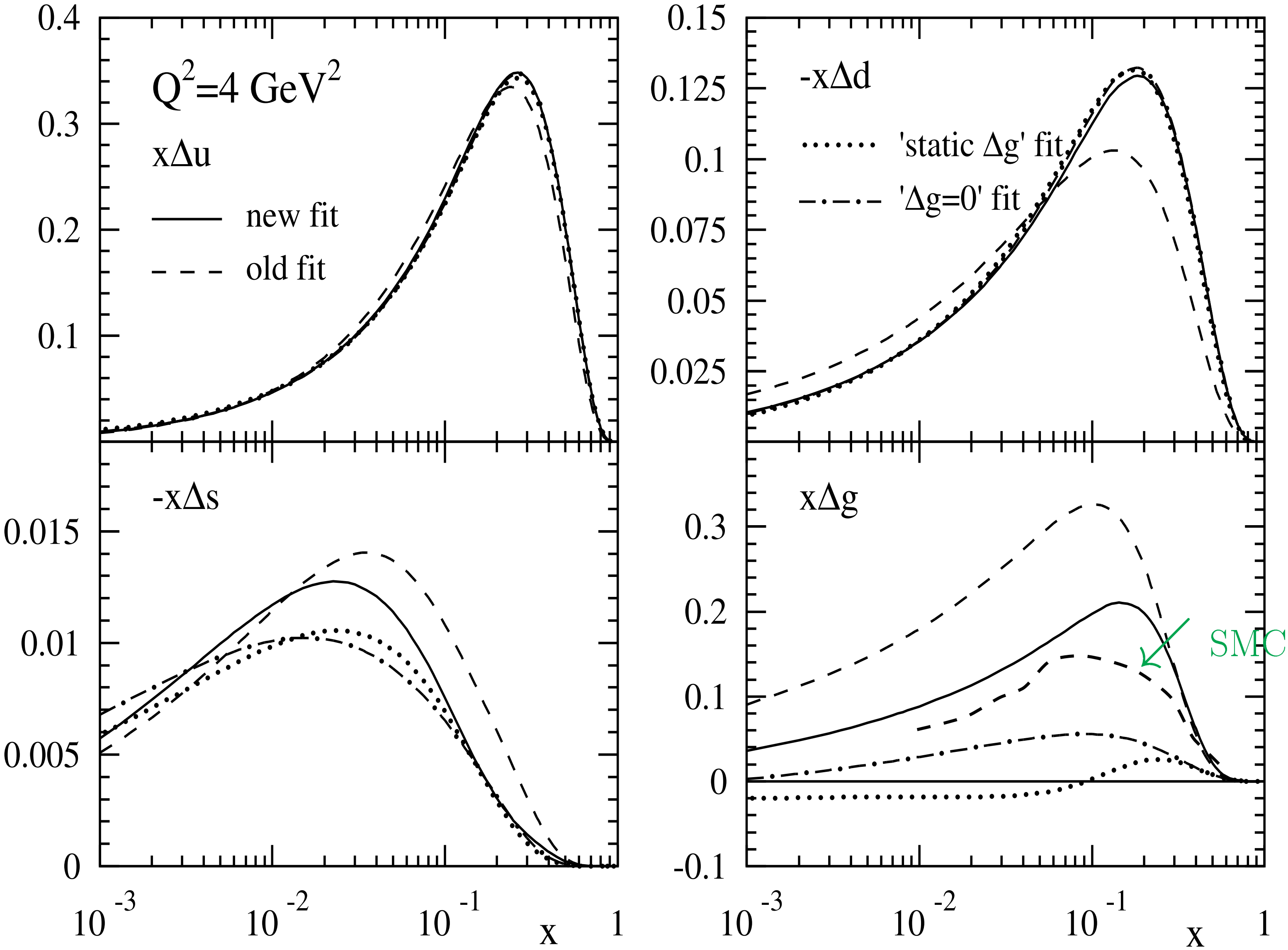
WHAT WE KNOW

POLARIZED PARTON DISTRIBUTIONS FROM pQCD EVOLUTION EQUATIONS.

THE FIT OF
Gluck, Reya, Stratmann and Vogelsang (1999)

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

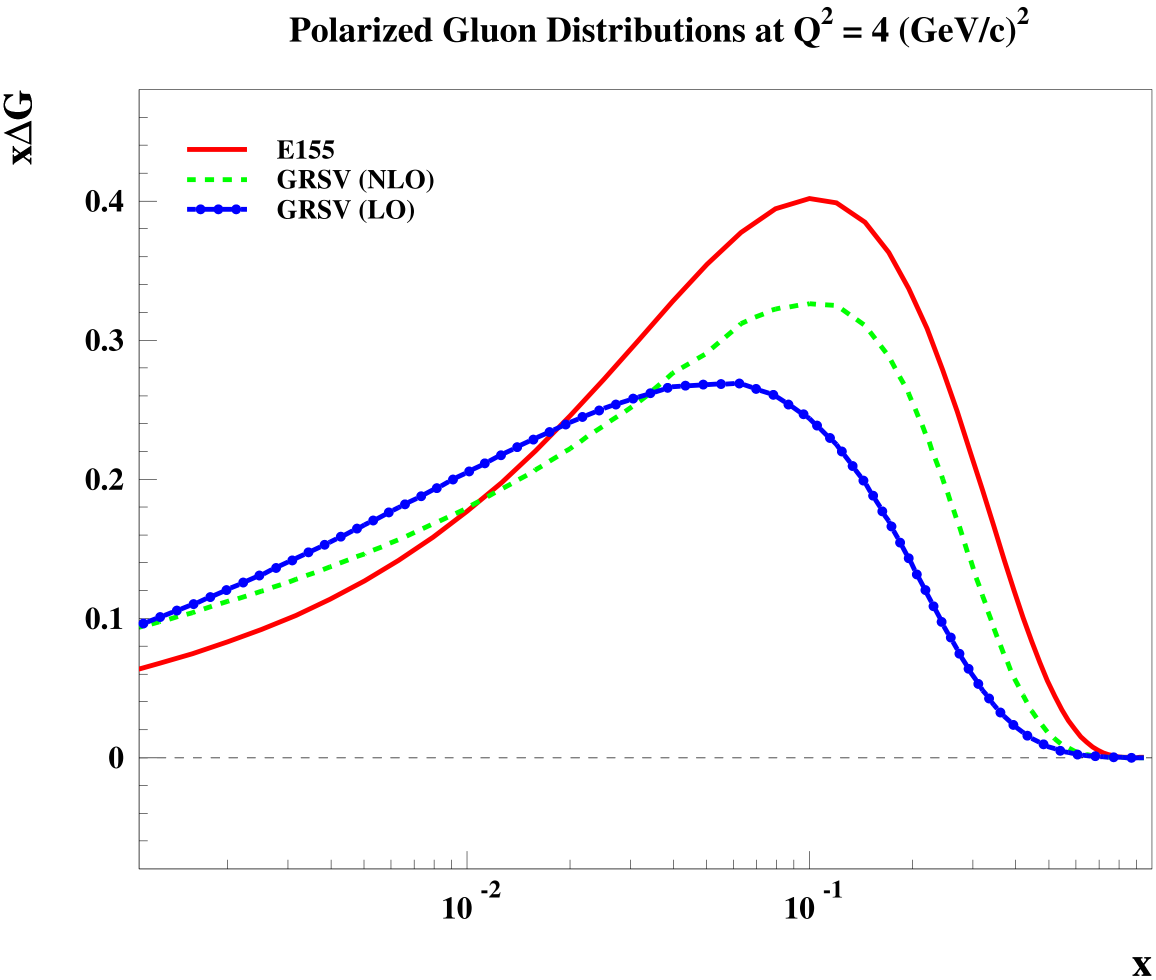
Δg ONLY APPEARS in NLO



POLARIZED PARTON DISTRIBUTIONS FROM pQCD EVOLUTION EQUATIONS.

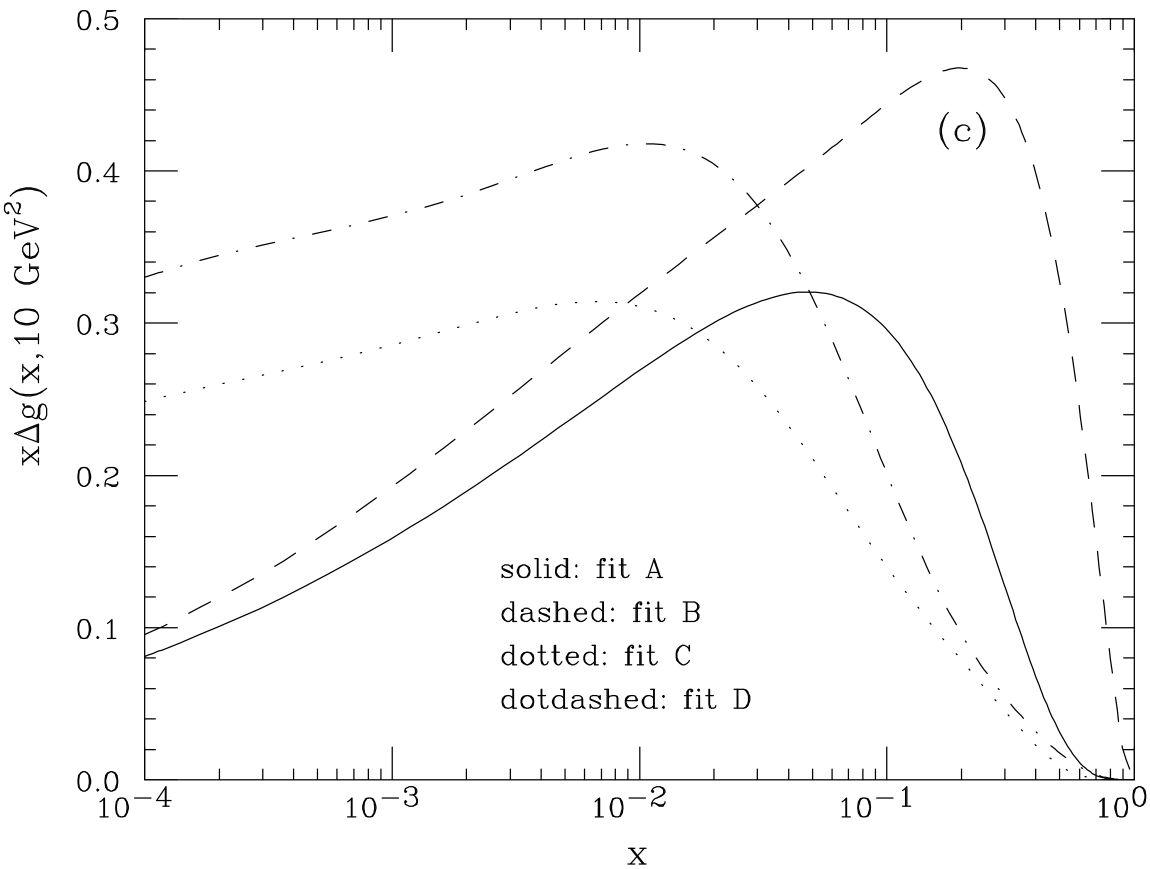
THE FIT OF E155 COLLABORATION (2000)

$$\Delta G = \int_0^1 g(x)dx = 1.6 \pm 0.8 \pm 1.1$$



POLARIZED GLUON DISTRIBUTIONS FROM pQCD EVOLUTION EQUATIONS.

THE FITS OF
Altarelli, Ball, Forte and Ridolfi (1998)
$\Delta G = 1$ to 2.2



POLARIZED GLUON DISTRIBUTIONS FROM pQCD EVOLUTION EQUATIONS.

VARIOUS FITS

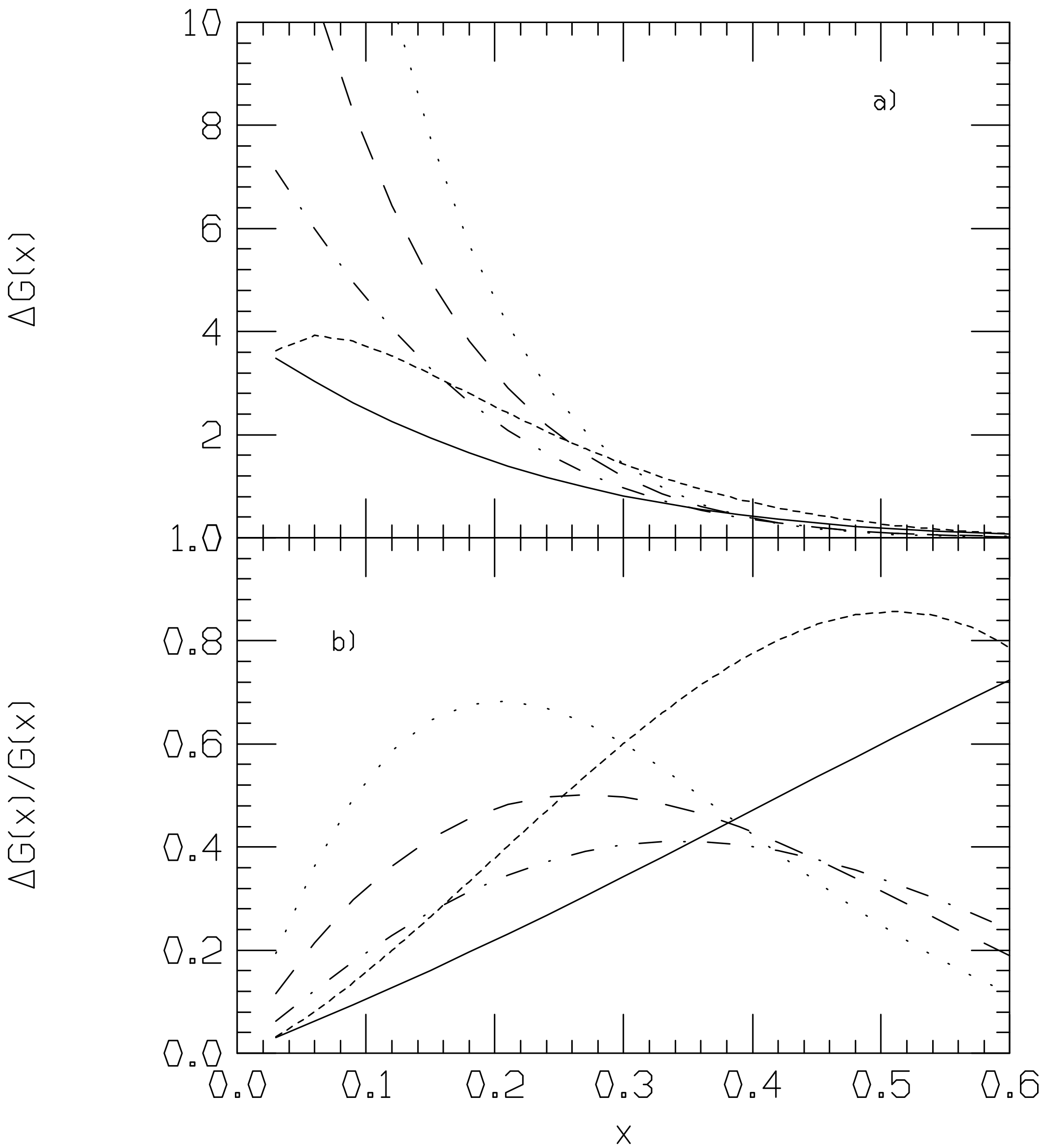
———— Brodsky (1995) $\Delta G = 0.7$

— — — Sterling (1996) $\Delta G = 1.7$

· · · · · · GRSV (1996) $\Delta G = 2.3$

— · — Ball AR Model (1996) $\Delta G = 1.1$

- - - - Ball OS Model (1996) $\Delta G = 1.0$

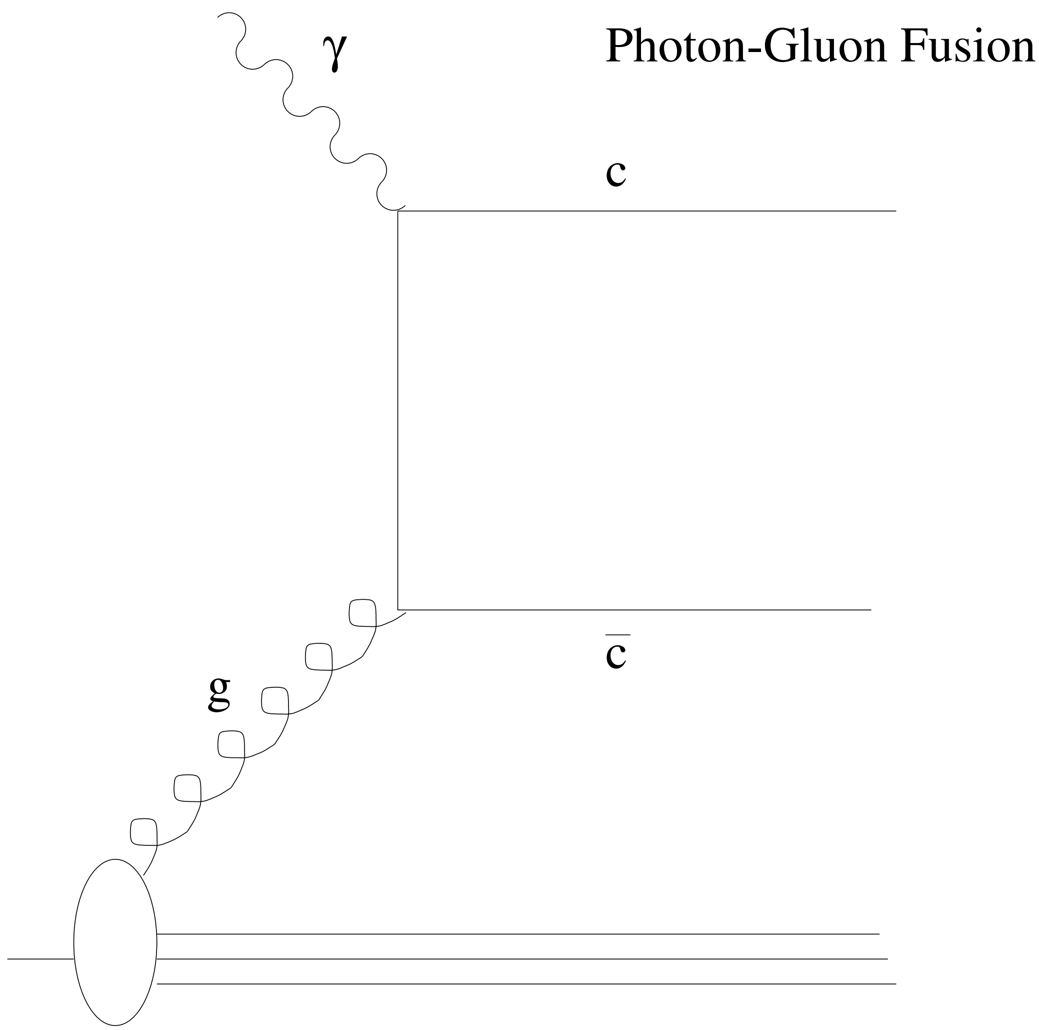


$\boxed{\textbf{HOW TO MEASURE } \Delta g(x, Q^2) \textbf{ DIRECTLY}}$

POLARIZED PHOTON BEAM

POLARIZED LiD TARGET

PHOTON-GLUON FUSION



TOTAL CHARM PHOTOPRODUCTION σ

$$\sigma_{\gamma p}(k) = \int_{x_{min}}^{1} g(x, Q^2) dx \int_{-1}^{1} \sigma(\hat{s}, \cos(\theta^*)) \, \beta \, d\cos(\theta^*)$$

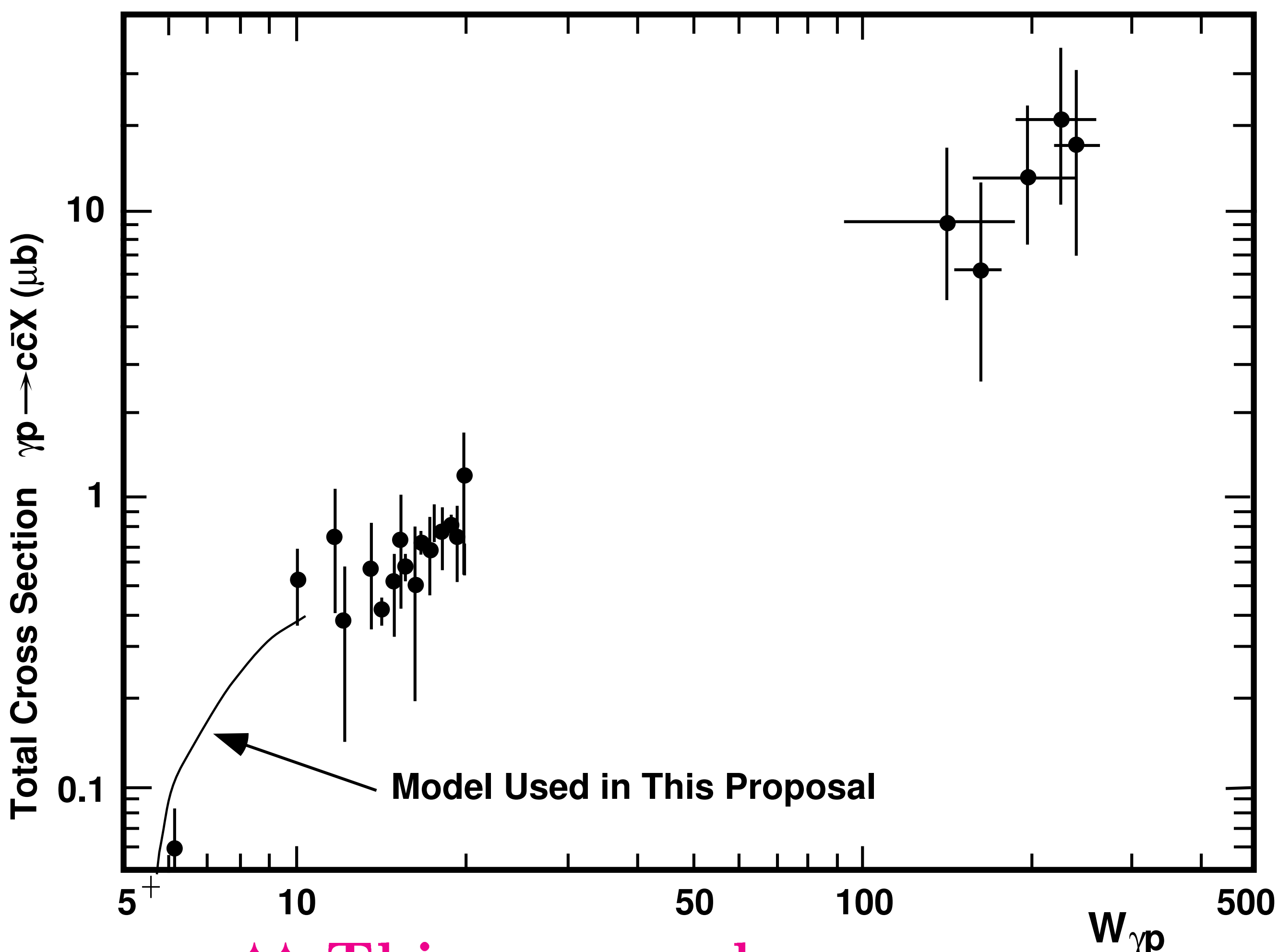
$\mathbf{x_{min} = 4m_c^2/2Mk}$

$s = 2Mk + M^2$

$\beta = \sqrt{1 - 4m_c^2/\hat{s}}$ **is the c.m. velocity of** $\mathbf{c, \bar{c}}$

$\hat{\mathbf{s}} = \mathbf{xs}$ **is the energy of the photon-gluon system squared**

$\sigma(\hat{s}, \cos(\theta^*))$ **is for the hard scattering**



↑↑ This proposal

POLARIZED $\mathbf{c\bar{c}}$ CROSS SECTION

$$\boxed{\boldsymbol{\Delta\sigma = \sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}}$$

$$\Delta\sigma_{\gamma p}(k) = \int_{x_{min}}^{1} \Delta g(x, Q^2) dx \int_{-1}^{1} \Delta\sigma(\hat{s}, \cos(\theta^*))\, \beta\, d\cos(\theta^*)$$

where

$$\Delta\sigma(\hat{s}, \cos(\theta^*)) = \frac{4}{9}\frac{2\pi\alpha\alpha_s(\hat{s})}{\hat{s}}[\frac{4m_c^4(\hat{t}^3+\hat{u}^3)}{\hat{t}^2\hat{u}^2} + 2\frac{\hat{t}^2+\hat{u}^2-2m_c^2\hat{s}}{\hat{t}\hat{u}}].$$

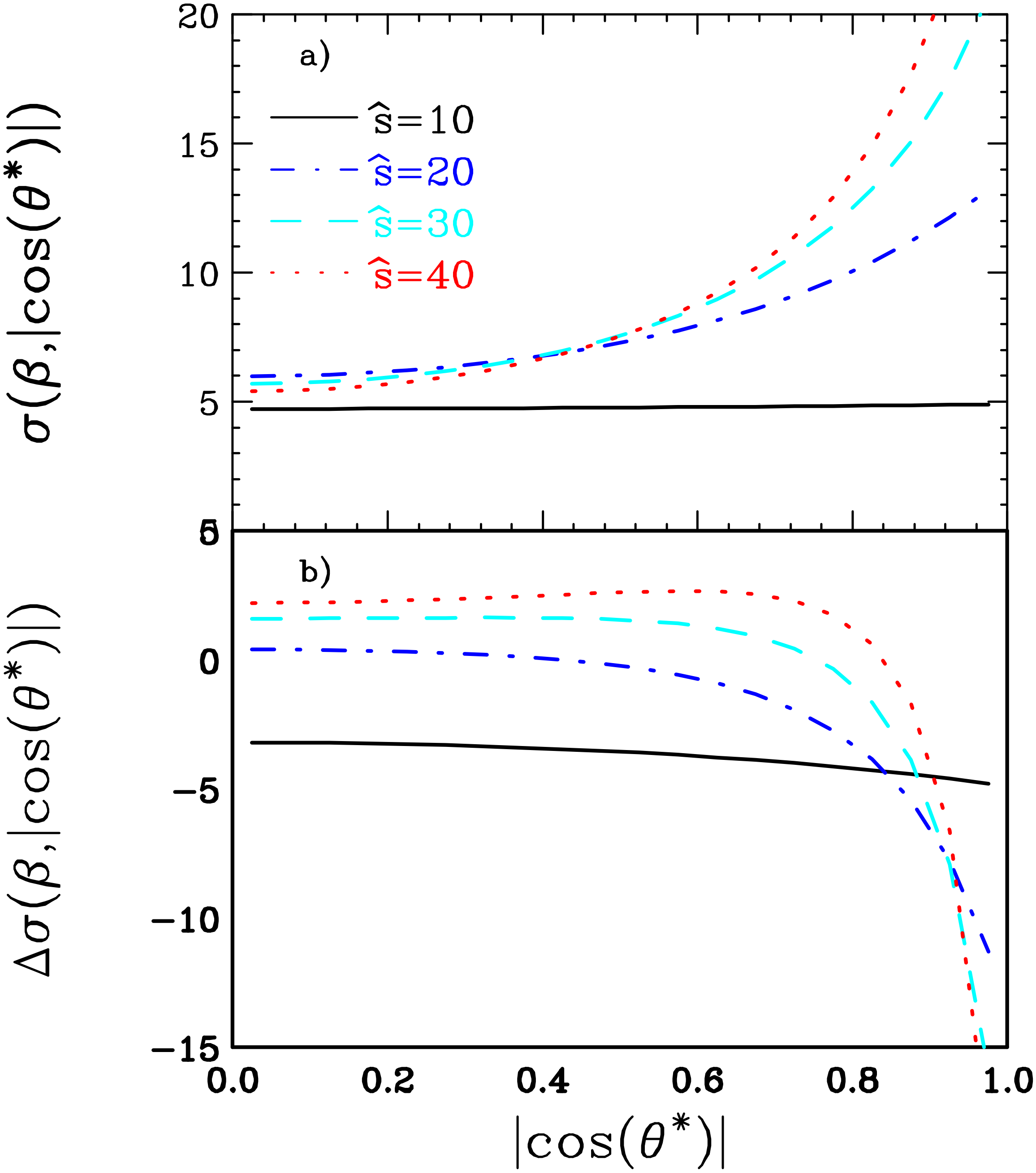
Integrated over $\cos(\theta^*)$**, this becomes**

$$\Delta\sigma(\hat{s}) = \frac{4}{9}\frac{2\pi\alpha\alpha_s(\hat{s})}{\hat{s}}[-3\beta + \ln\frac{1+\beta}{1-\beta}].$$

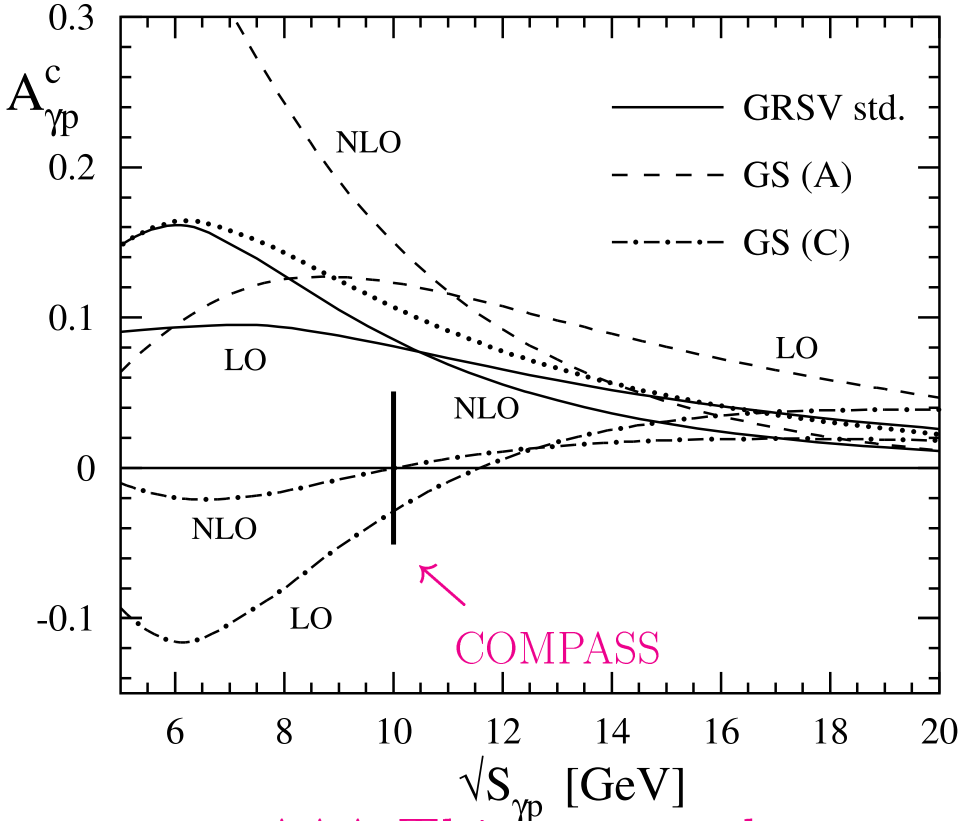
$$\boxed{\mathbf{A_{cc}(k) = \boldsymbol{\Delta\sigma}_{\gamma p}(k)/\boldsymbol{\sigma}_{\gamma p}(k) = \frac{1}{P_t P_b f}\frac{N^{\uparrow\uparrow}-N^{\downarrow\uparrow}}{N^{\uparrow\uparrow}+N^{\downarrow\uparrow}}}}$$

CROSS SECTION and $\Delta\sigma$

DEPENDENCY ON CENTER OF MASS ANGLE



NLO pQCD



↑↑↑ This proposal

(I. Bojak and M. Stratmann)
also calculated by Z. Merebashvili et al.

EXPERIMENTAL STRATEGY

TAG CHARM WITH SINGLE DECAY μ

VERY SHORT LIFETIME

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

Fraction of different charmed particles produced with k=40 GeV photons and a deuterium target with $p_T > 0.5$ GeV generated using PYTHIA 5.7. Also shown is the percent of muons of each charge which ORIGINATED from the parent charmed particle.

BEAM PARAMETERS

Electron Energy (GeV)	45.1	48.3	51.5 **
Electron Current (10^{10}/spill)	2.0	2.0	2.0
Peak Photon Energy (GeV)	35.0	40.0	45.0
Photons (10^7/spill) ♡	2	1.5	1.1
Circular Polarization	0.75	0.80	0.84
x_{min}	.10	.12	.14
High p_t Muons/day	160,000	140,000	120,000
days (at 120 Hz, 100% efficiency)	9	10	11

**** Use 48.3 GeV, Different Diamond Orientation**

♡ **E155 had** 3×10^9 e^- **into ESA**

BACKGROUNDS

OTHER SOURCES OF μ

- μ FROM K and π DECAY (Long Lifetime)
- Bethe-Heitler μ PAIRS
- J/ψ DECAY (Small)
- VECTOR MESON DECAYS (Small)

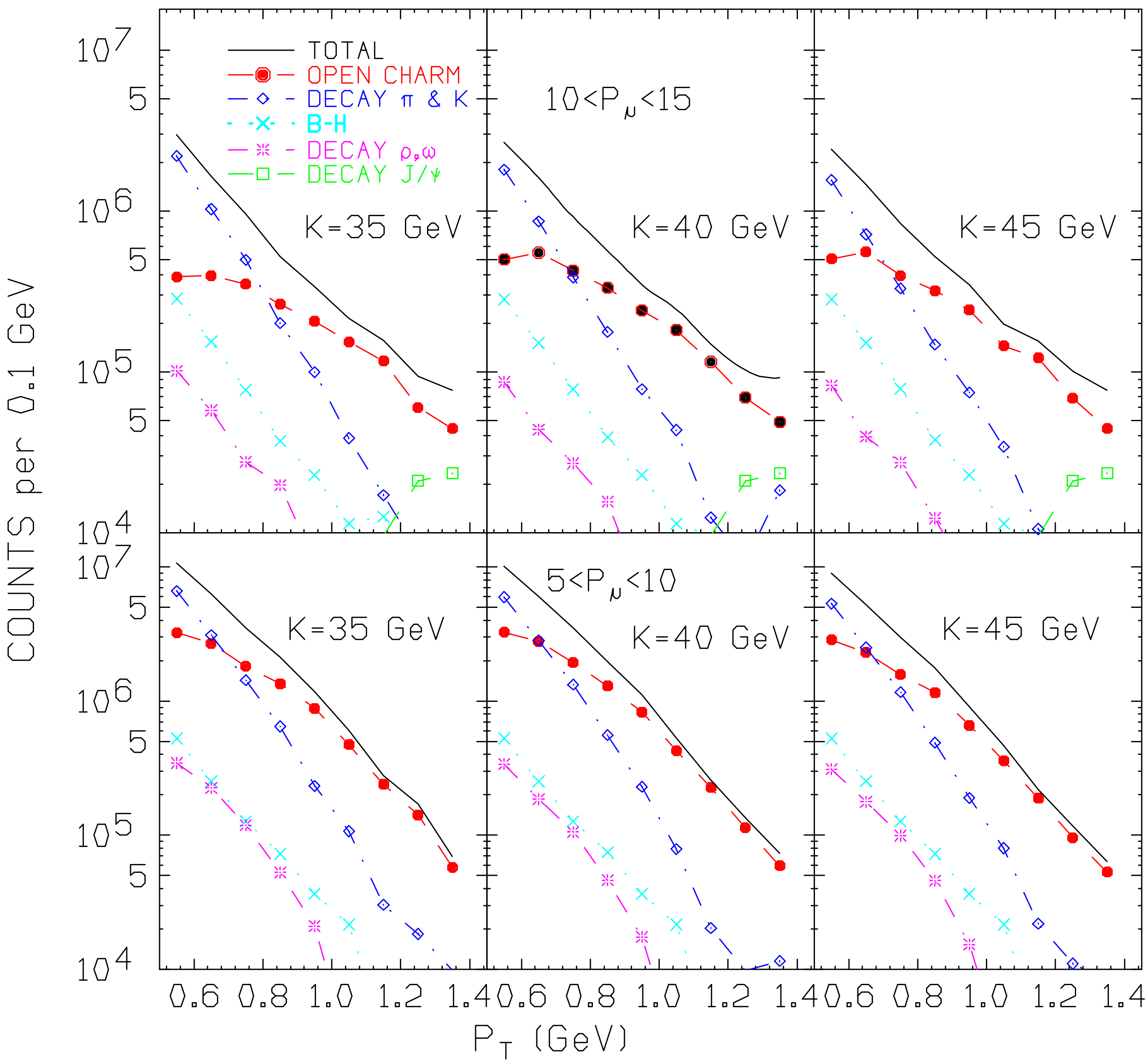
PHYSICS BACKGROUND

- ASSOCIATED PRODUCTION (Small)
- FINAL STATE INTERACTIONS (Small)
- DIFFRACTIVE PRODUCTION (Small)

NUMBER OF EXPECTED SINGLE μ

SIGNAL and BACKGROUNDS

BEFORE BACKGROUND SUBTRACTION

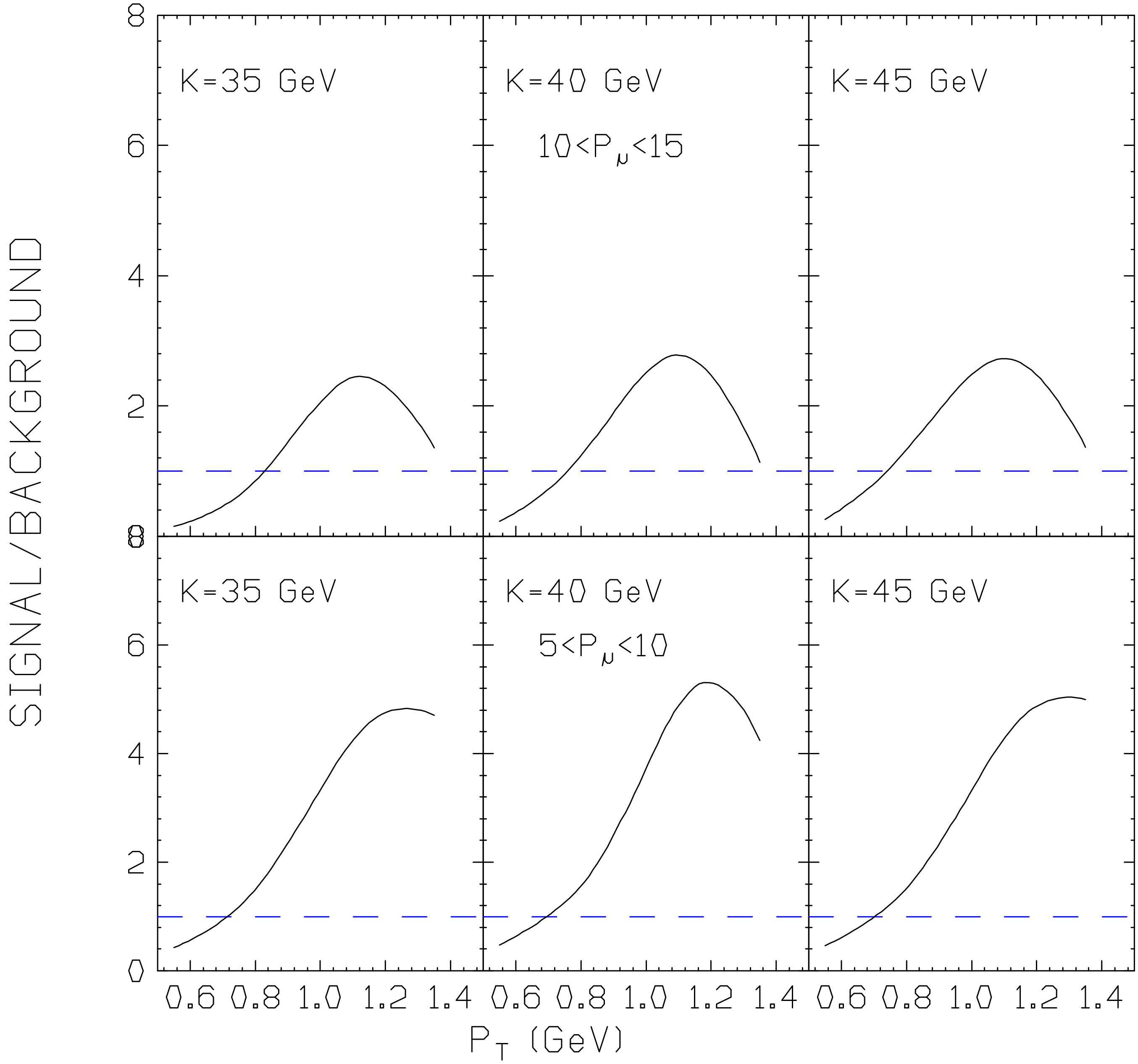


$\boxed{\text{EXPERIMENTAL STRATEGY}}$

- **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

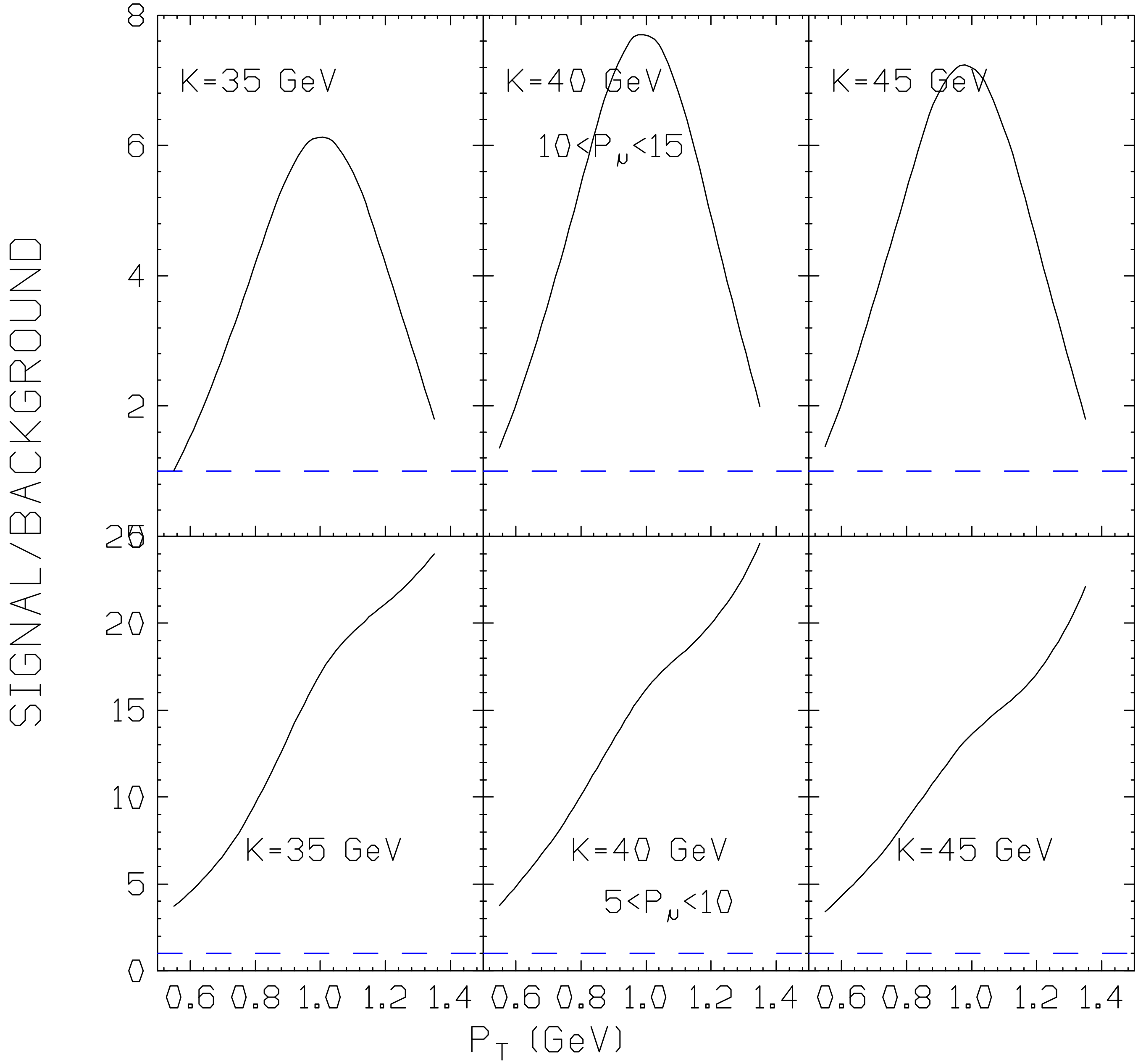
SIGNAL/BACKGROUNDS

BEFORE DECAY SUBTRACTION



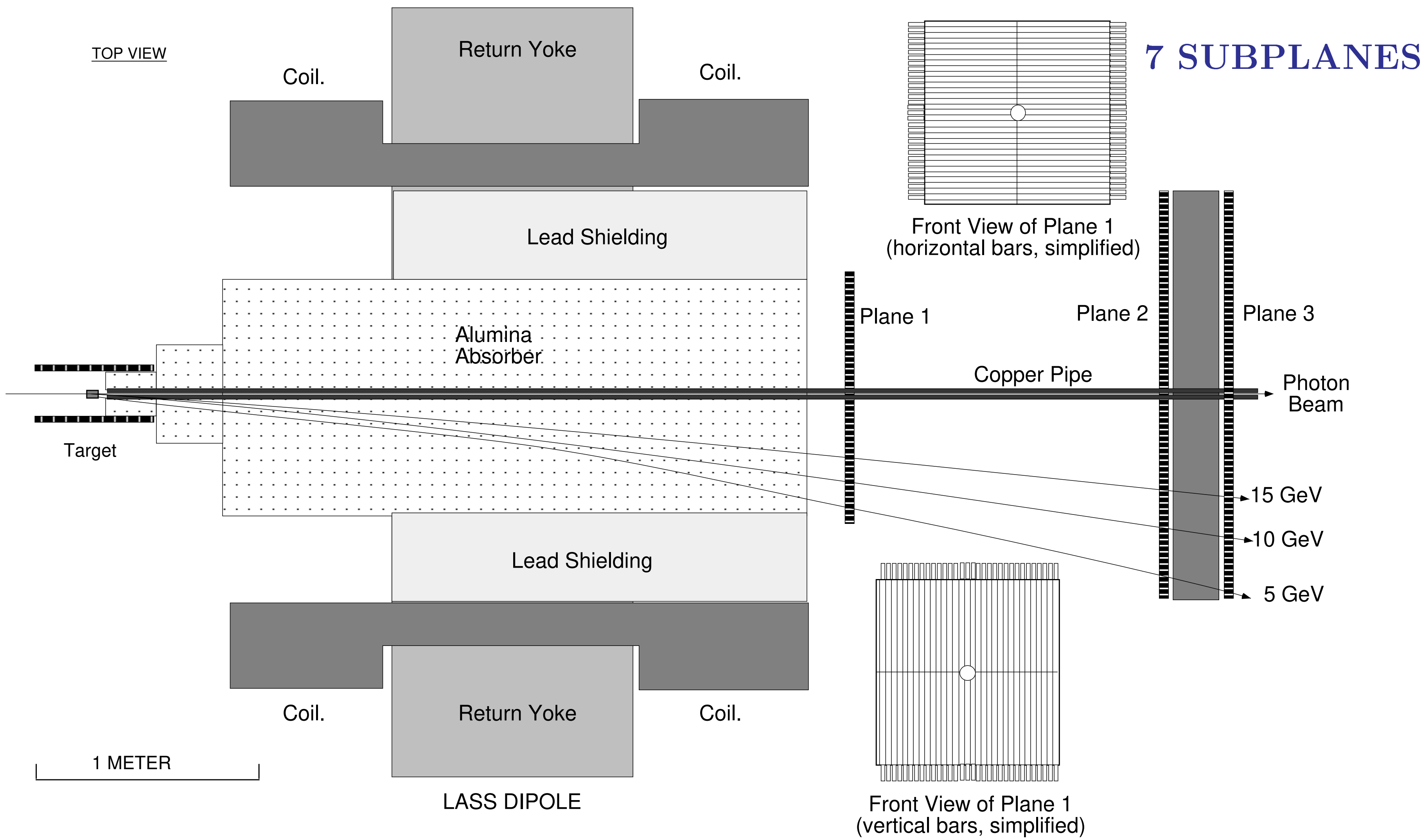
SIGNAL/BACKGROUNDS

DECAY SUBTRACTED



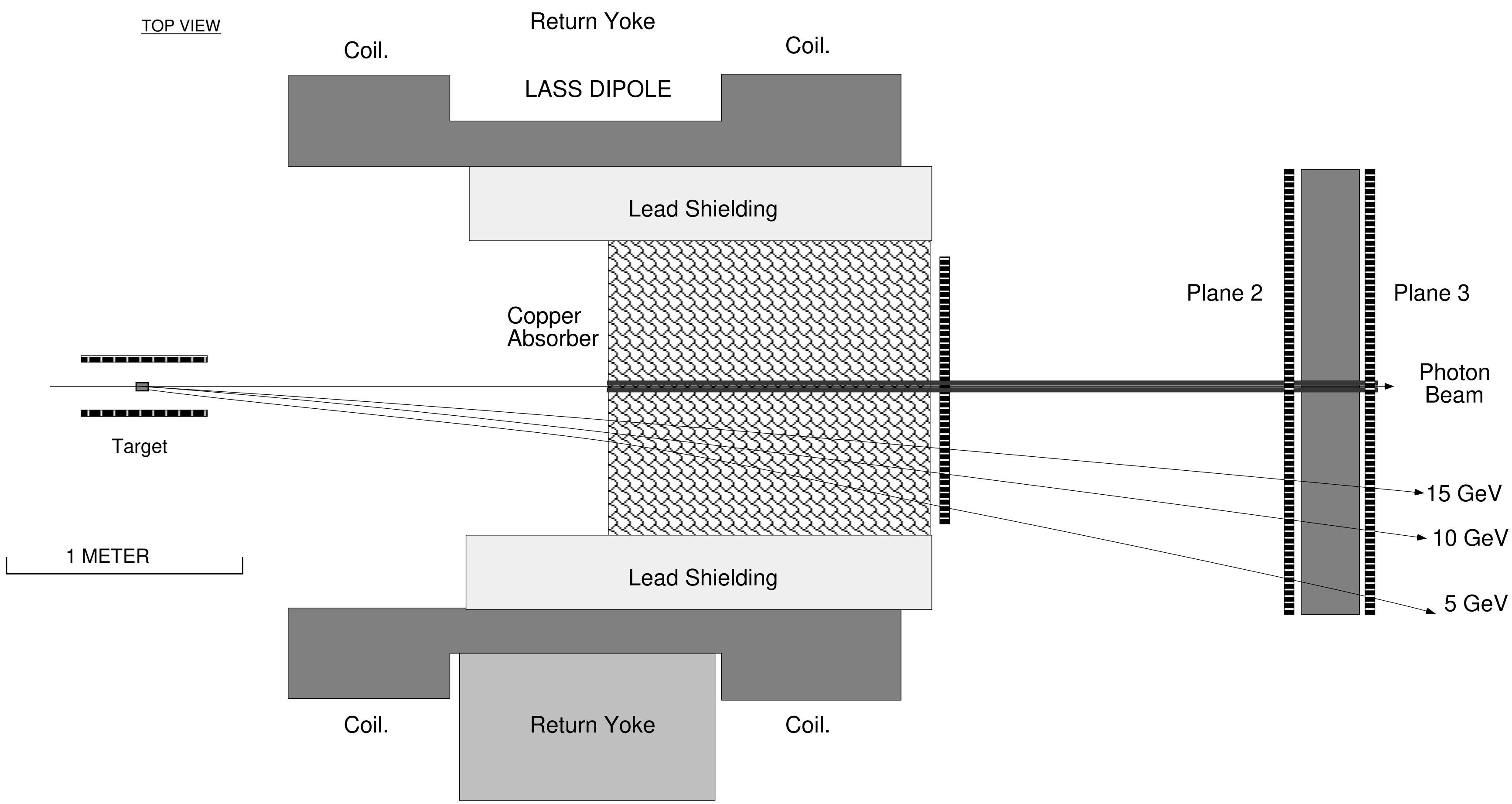
μ SPECTROMETER

NORMAL MODE



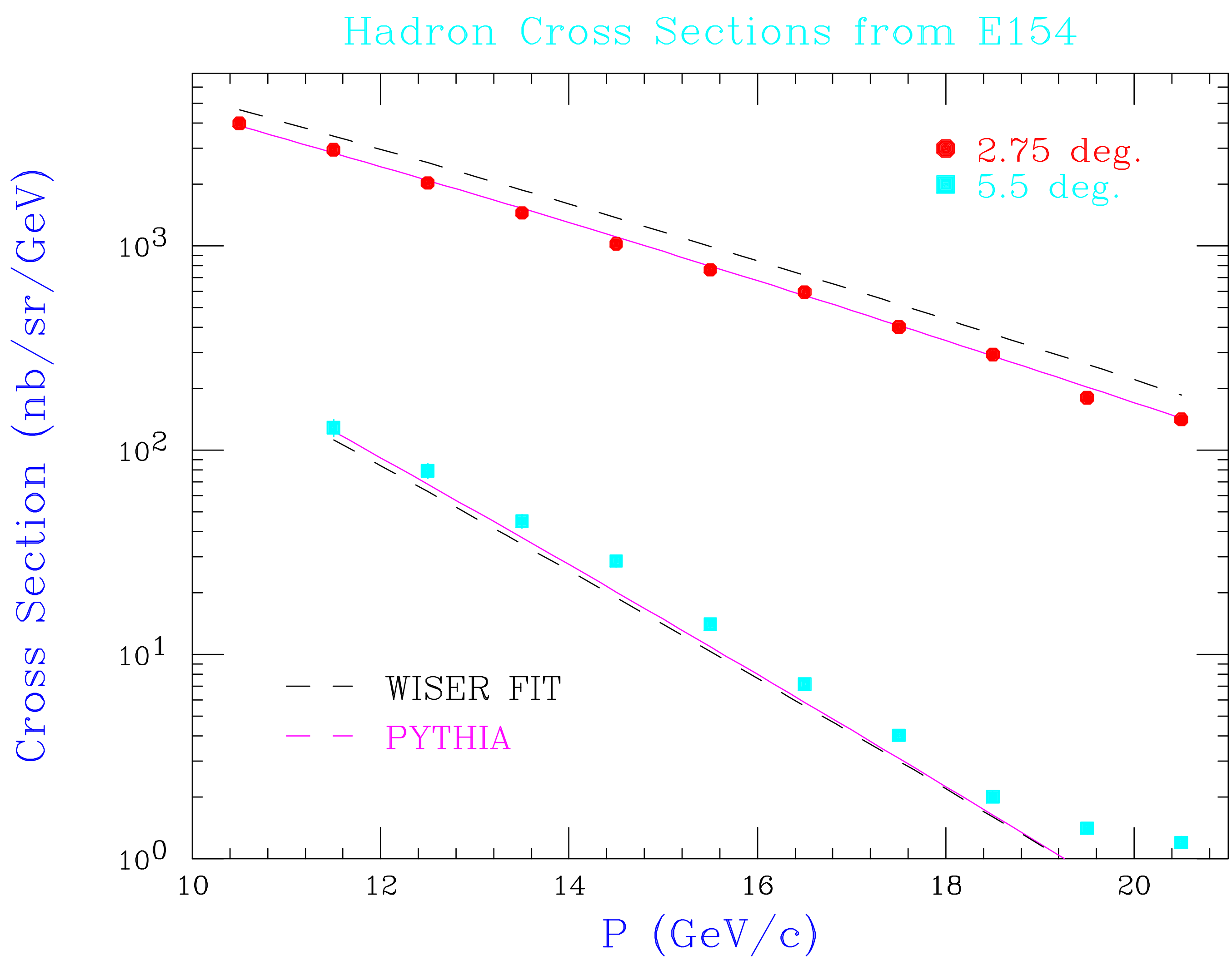
μ SPECTROMETER

BACKGROUND MODE



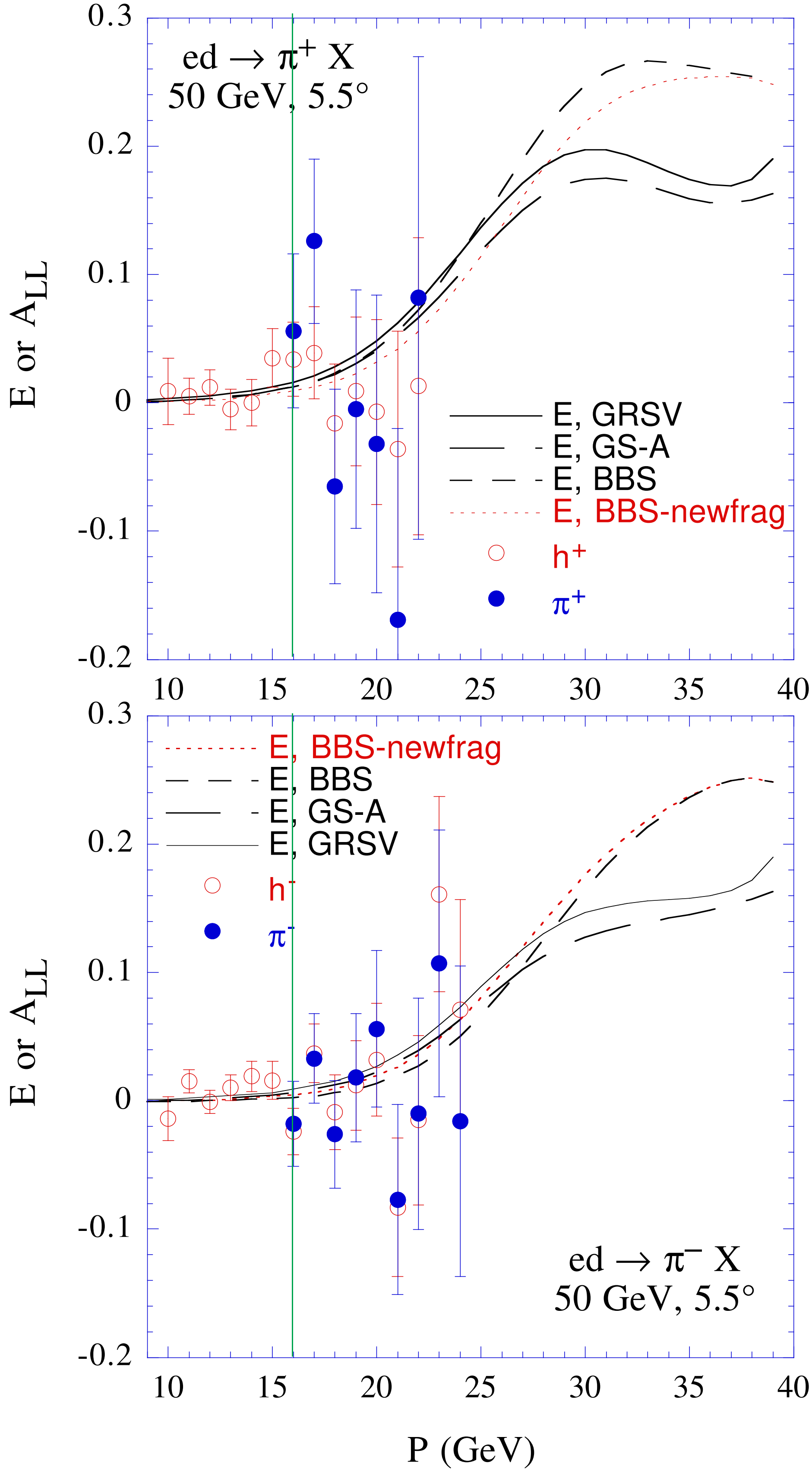
BACKGROUND: π, K DECAY

HOW WELL DO WE KNOW CROSS SECTION



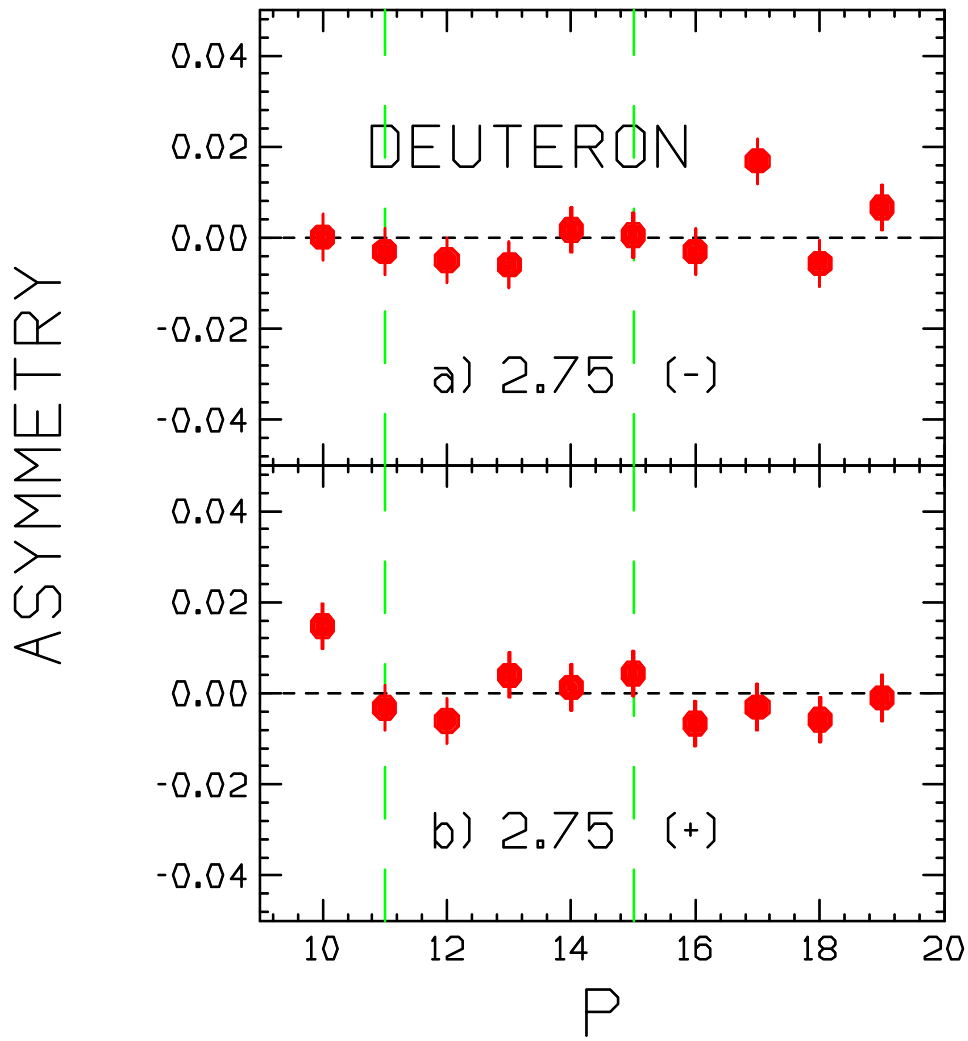
BACKGROUND: π, K DECAY

E155 HADRON ASYMMETRY 5.5°

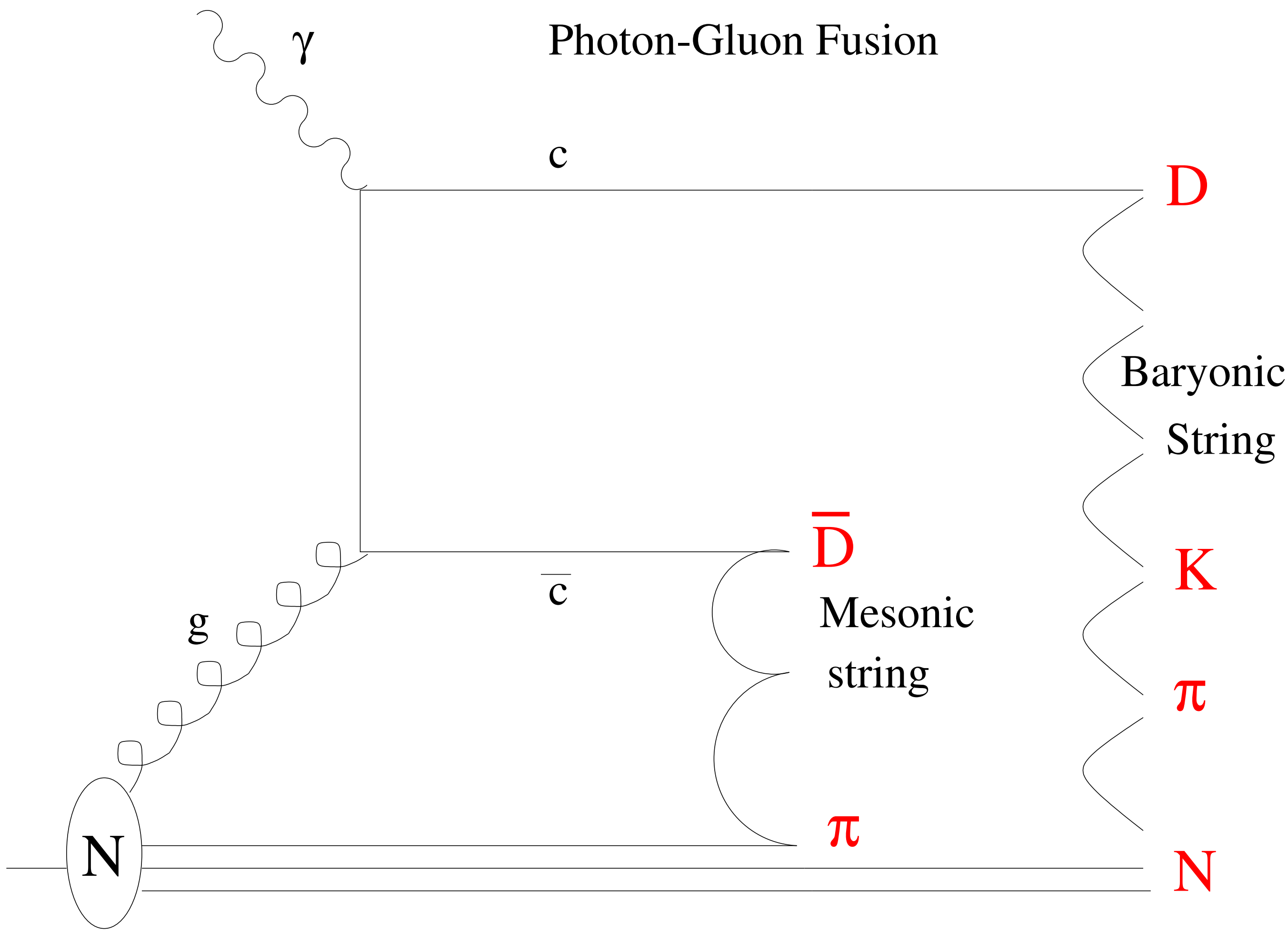


BACKGROUND: π, K DECAY

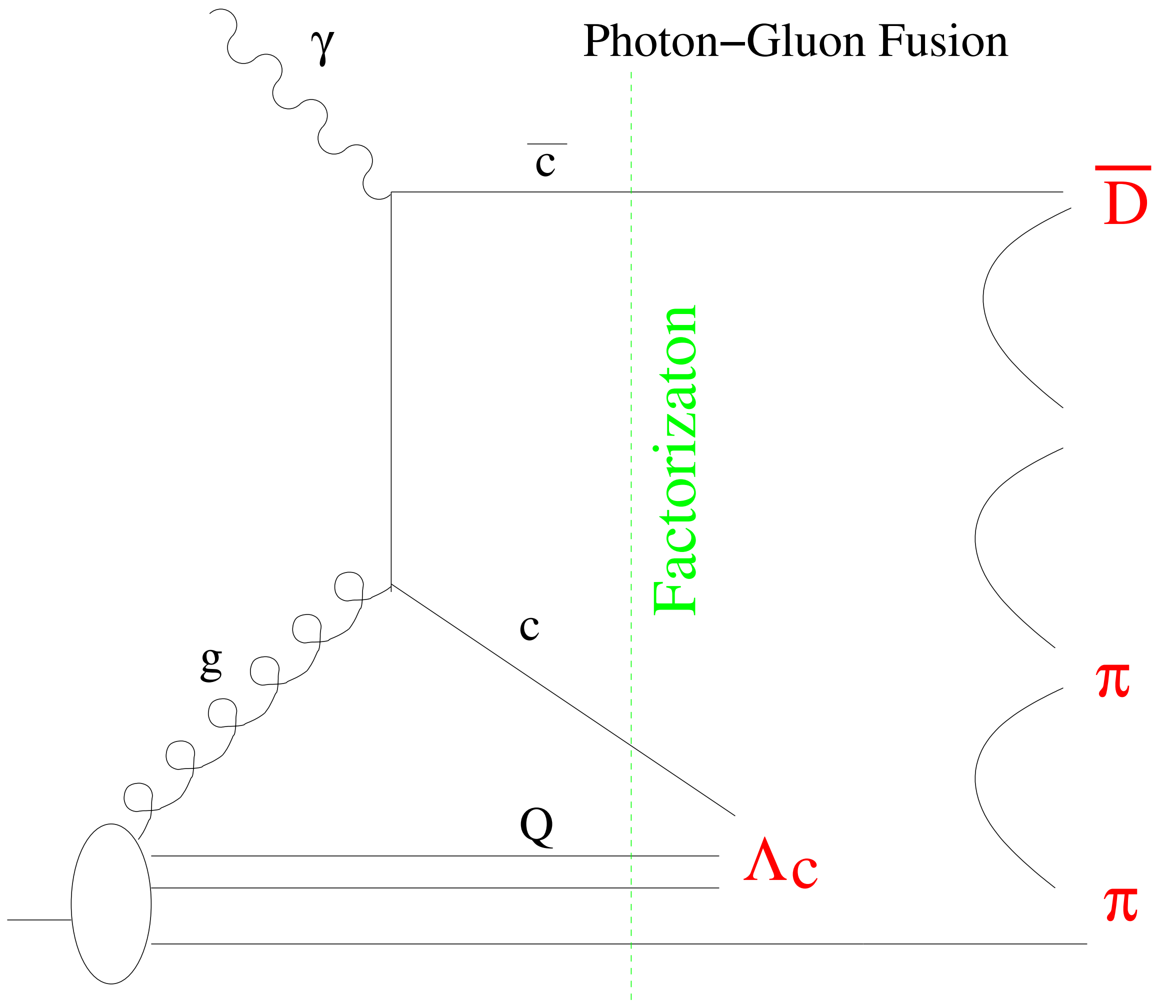
E155 HADRON ASYMMETRY 2.75°



PHYSICS BACKGROUND
NORMAL HADRONIZATION



PHYSICS BACKGROUND
ASSOCIATED PRODUCTION
POLARIZED FRAGMENTATION?

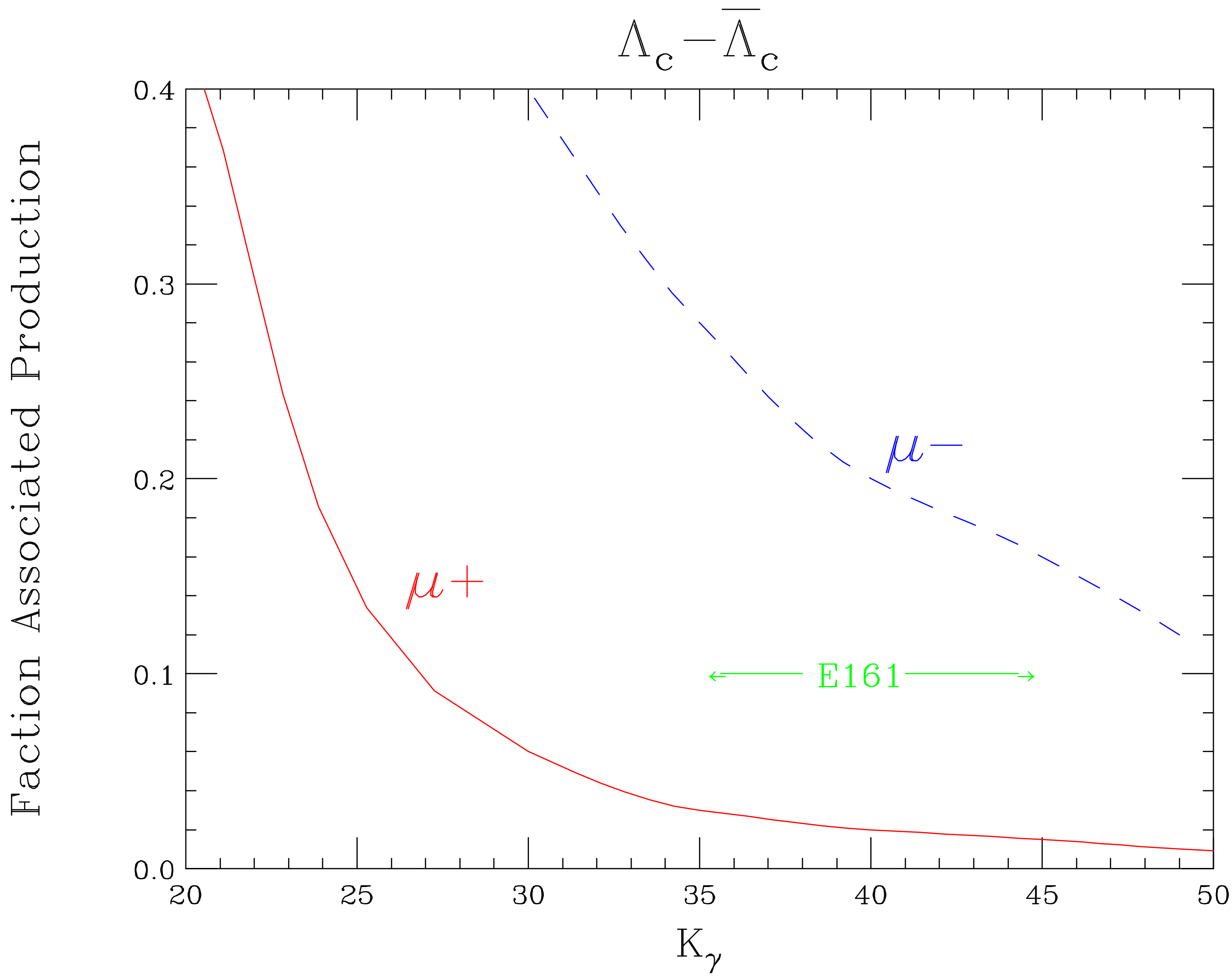


- FACTORIZATION
- RELATIVE DETECTED CROSS SECTION (Few Percent)
- HOW DOES *c* INTERACT WITH POLARIZED TARGET FRAGMENTS?

PHYSICS BACKGROUND

ASSOCIATED PRODUCTION

PRODUCTION RATE LOW



$\boldsymbol{\mu^+}$ **Mostly from $\boldsymbol{D}$ (c quark) $\Rightarrow$ No $\boldsymbol{\Lambda_c^+}$**

$\boldsymbol{\mu^-}$ **Mostly from $\boldsymbol{\bar{D}}$ ($\boldsymbol{\bar{c}}$ quark) $\Rightarrow$**
c quark can form $\boldsymbol{\Lambda_c^+}$

PHYSICS BACKGROUND
ASSOCIATED PRODUCTION
INTERACTION MECHANISM

Λ_c^+ PRODUCTION INDEPENDENT OF TARGET FRAGMENT POLARIZATION

- $\mathbf{\Lambda_c^+}$ **= cud with ud in Spin=0 State**
- **Production does NOT Depend on Polarization of c Quark.**
- **Production Does NOT Depend on Polarization of Target Fragments.**
- **Decay of Polarized Λ_c^+: small correction**

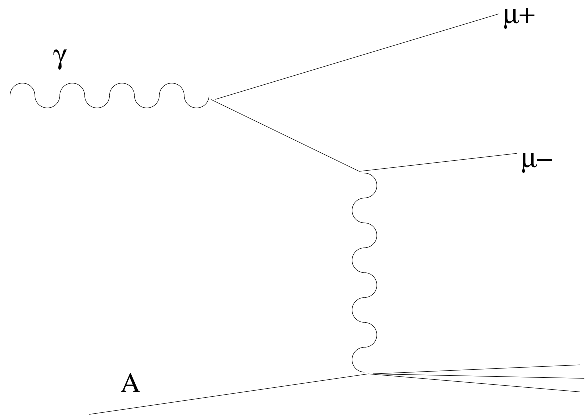
DIFFERENCE BETWEEN μ^+ and μ^-

- **Checks These Ideas**
- **Can Extrapolate to Zero Associated Production**

BEAM POLARIZATION MEASUREMENT

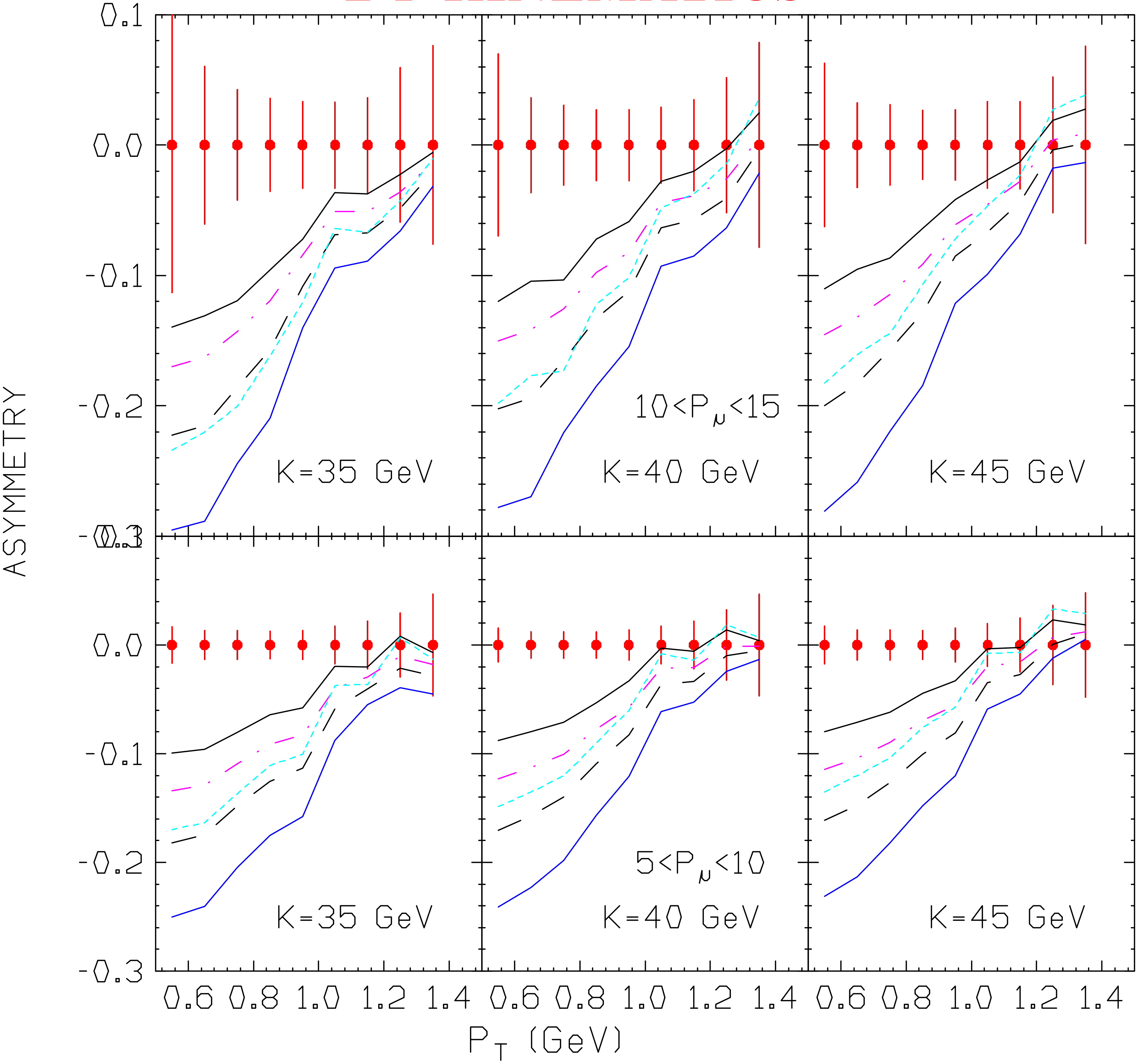
Use Bethe-Heitler Muon Pairs

Calculated by Gehrmann and Stratmann



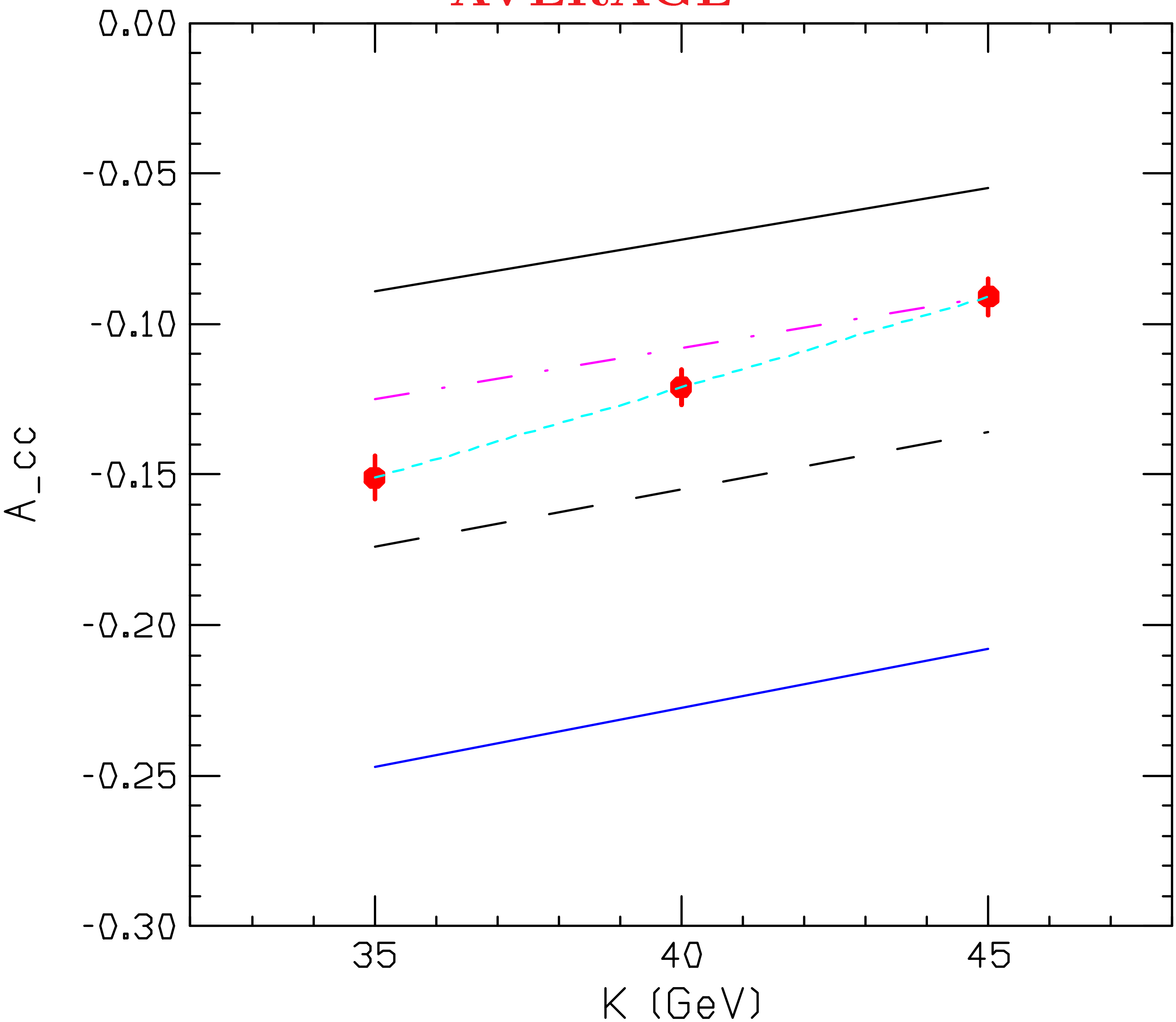
- **Polarization Data taken Simultaneously with PGF**
- **Pairs with $1.2 < M_{\mu\mu} < 2.8$ GeV.**
- **Pair Rate Greater Than the PGF rate.**
- **Elastic (from ^{6}Li), Quasi Elastic and Inelastic Contributions.**
- **Relative importance depends on kinematics.**
- **Depends on Nuclear and Nucleon Form Factors and Polarized Structure Functions.**
- **Asymmetry about 3% depending on Kinematics.**

EXPECTED RESULTS
BY KINEMATICS



EXPECTED RESULTS

AVERAGE



SYSTEMATIC ERRORS $\sim$ 8%

$\boxed{\text{OTHER EXPERIMENTS}}$

COMPASS

- NEXT GENERATION SMC
  5 TIMES SMC LUMINOSITY
- $\mu + d \to c\bar{c}$ (LiD TARGET)
- DETECT D, $\bar{D}$
- BEAM ENERGY = 160 GeV
- MOST OF DATA AT VERY LOW Q^2
- ALSO USE HIGH P_T JETS
- START UP JUNE 2001
- PROBABLY SLOW STARTUP

$\boxed{\text{OTHER EXPERIMENTS}}$

HERMES

- LOW ELECTRON ENERGY (27 GeV)
- LOW LUMINOSITY
- RUNNING NOW
- TWO "HIGH P_T JETS"
- $0.06 < x < 0.28$
- FIRST RESULTS: $\Delta G/G = 0.41 \pm 0.18$

RHIC

Gluon Compton Scattering

$$g + q \to \gamma + X$$

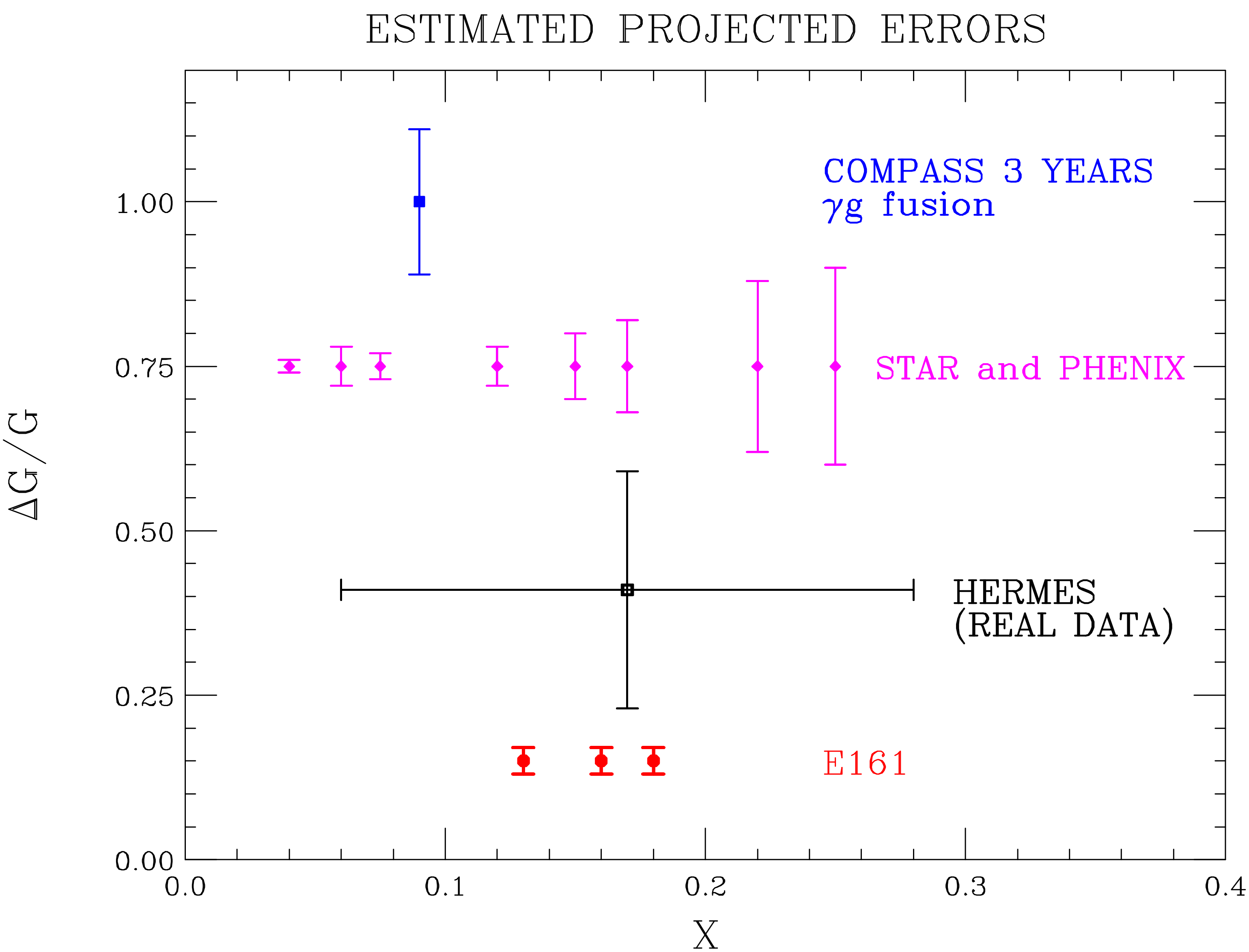
$$A_{LL} \cdot d\sigma \sim \sum_a \int \Delta q_a \cdot \Delta g \cdot d\Delta\sigma(q_a + g \to \gamma + X)$$

Gluon Fusion

$$g + g \to jet + jet$$

$$A_{LL} \cdot d\sigma \sim \int \Delta g \cdot \Delta g \cdot d\Delta\sigma(g + g \to X + X)$$

COMPARISON OF EXPERIMENTS

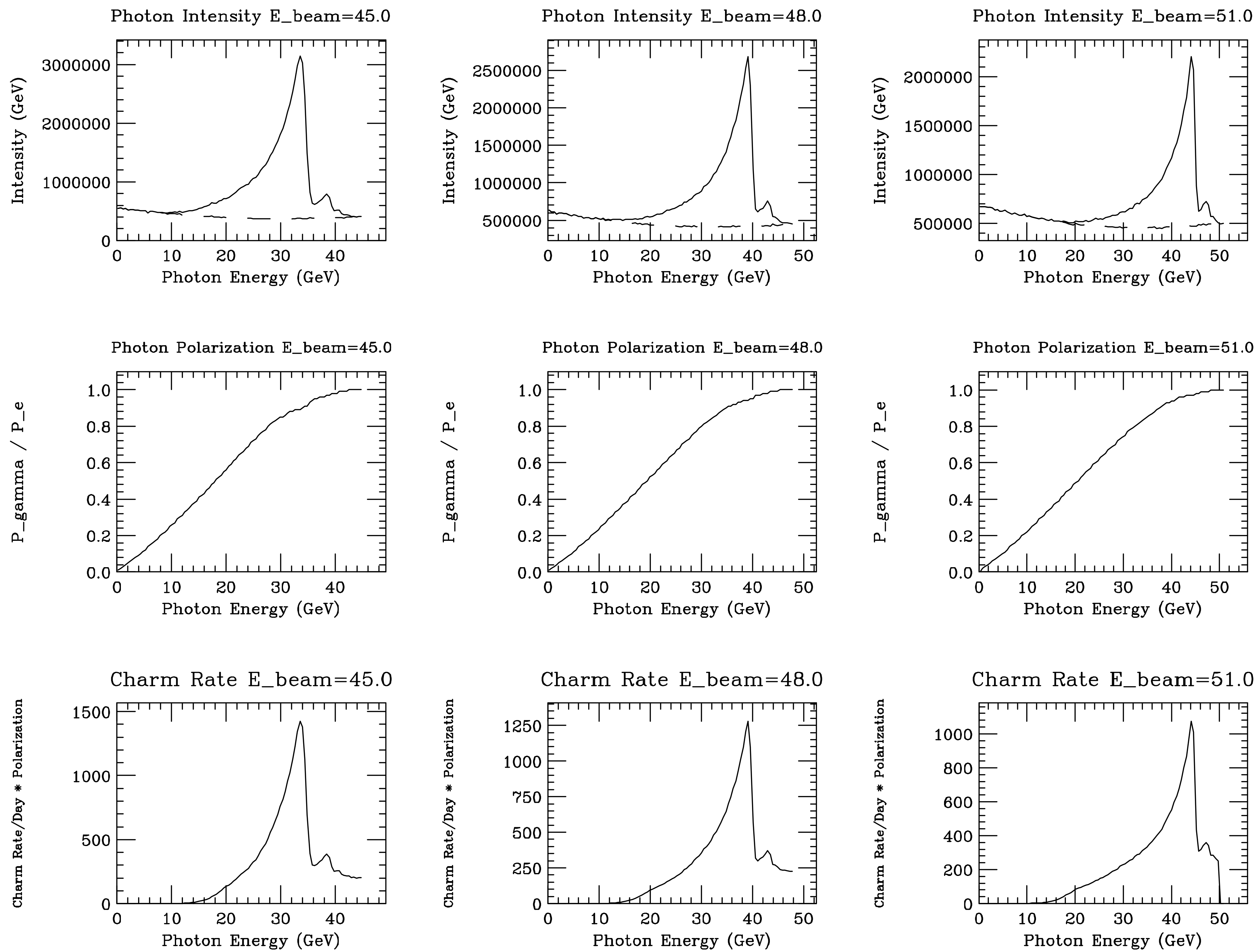


$\boxed{\text{REQUEST TO SLAC}}$

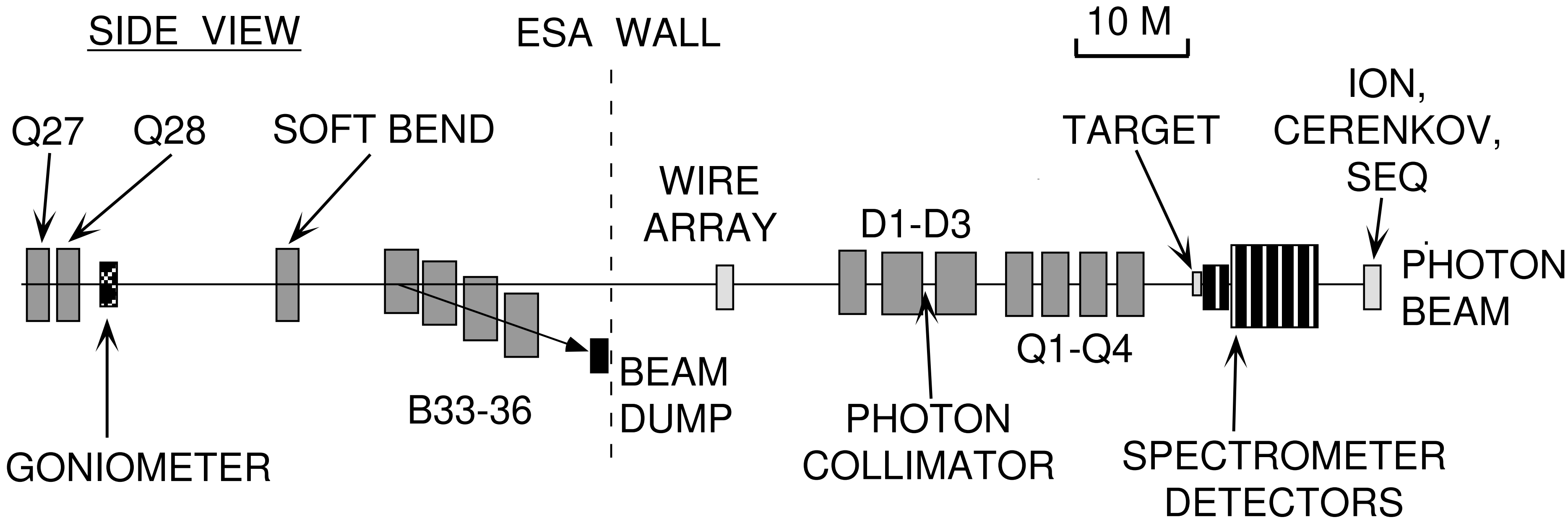
- **RESOURCES TO BUILD BEAM**
- **RESOURCES TO BUILD DETECTOR**
- **RESOURCES FOR TARGET MAGNET and μWAVE HARDWARE**
- **3 WEEKS CHECKOUT AT LOW REPETITION RATE**
- **2 MONTHS OF DATA TAKING**
  - **120 Hz Parasite on PEP-II**
  - **50% Data Collection Efficiency**

CONCLUSIONS

- IMPORTANT TO MEASURE $\Delta g/g$
- E161 CAN MEASURE $\Delta g/g$ DIRECTLY
- PRECISION $\geq$ OTHER EXPERIMENTS
- COMPLEMENTARY TO OTHER EXPERIMENTS USING DIFFERENT HARD SCATTERING PROCESSES
- GROUP WITH EXPERIENCE



Photon Intensity E_beam=45.0
Photon Intensity E_beam=48.0
Photon Intensity E_beam=51.0
Intensity (GeV)
Photon Energy (GeV)
Photon Polarization E_beam=45.0
Photon Polarization E_beam=48.0
Photon Polarization E_beam=51.0
P_gamma / P_e
Charm Rate E_beam=45.0
Charm Rate E_beam=48.0
Charm Rate E_beam=51.0
Charm Rate/Day * Polarization

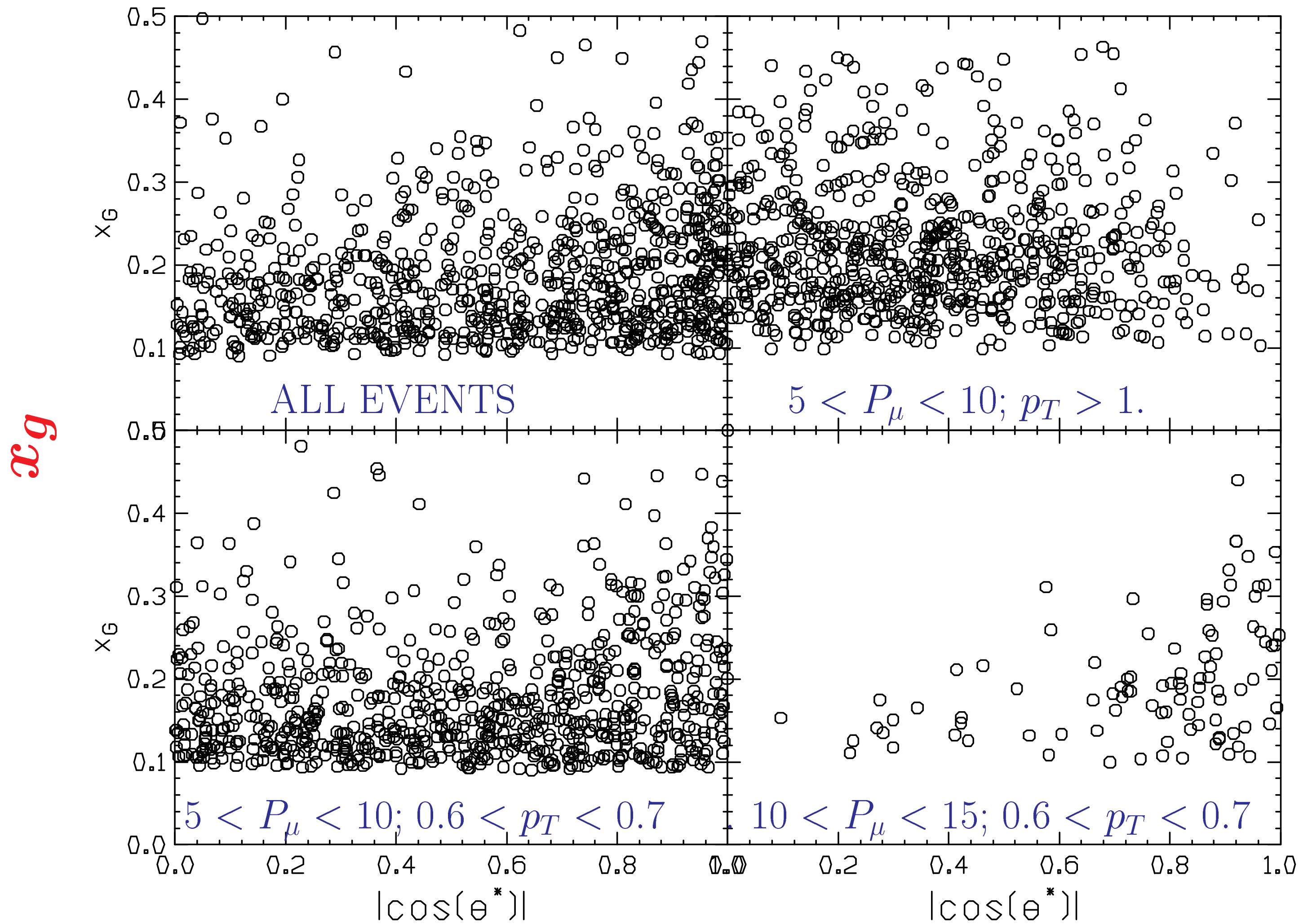

SIDE VIEW
ESA WALL
10 M
Q27
Q28
SOFT BEND
WIRE
ARRAY
D1-D3
TARGET
ION,
CERENKOV,
SEQ
PHOTON
BEAM
GONIOMETER
B33-36
BEAM
DUMP
PHOTON
COLLIMATOR
Q1-Q4
SPECTROMETER
DETECTORS

EXPERIMENT

$\boxed{\boldsymbol{\mu} \textbf{ and c KINEMATICS}}$

$$x_{min} = 4m_c^2/(2Mk)$$

Photon Energy	x_{min}
35.	0.14
40.	0.12
45.	0.10 $\Leftarrow$



COLLABORATION RESPONSIBILITIES

TASK	RESPONSIBILITY
HODOSCOPE CONSTRUCTION	Wm & Mary, ODU
TARGET	Virginia
DIAMONDS	Yerevan
BEAM MONITORING	UMass
ELECTRONICS	UMass
DAQ	SLAC

π AND KAON DECAY

μ Range Out at About 2 GeV

	π	KAON
Lifetime($10^{-8}sec$)	2.6	1.2
Branching Ratio to μ	1.00	.69
$c\tau$	7.8 m	3.7m
Distance - 10 GeV	560 m	74 m
Distance - 5 GeV	280 m	37 m