POLARIZATION AT HERA

A. DE ROECK / DESY

INTRODUCTION HERA 1992 → 2000+

PHYSICS WITH POLARIZED ELECTRONS (COLL. (SHORT)

PHYSICS WITH POLARIZED ELECTRONS AND PROTONS

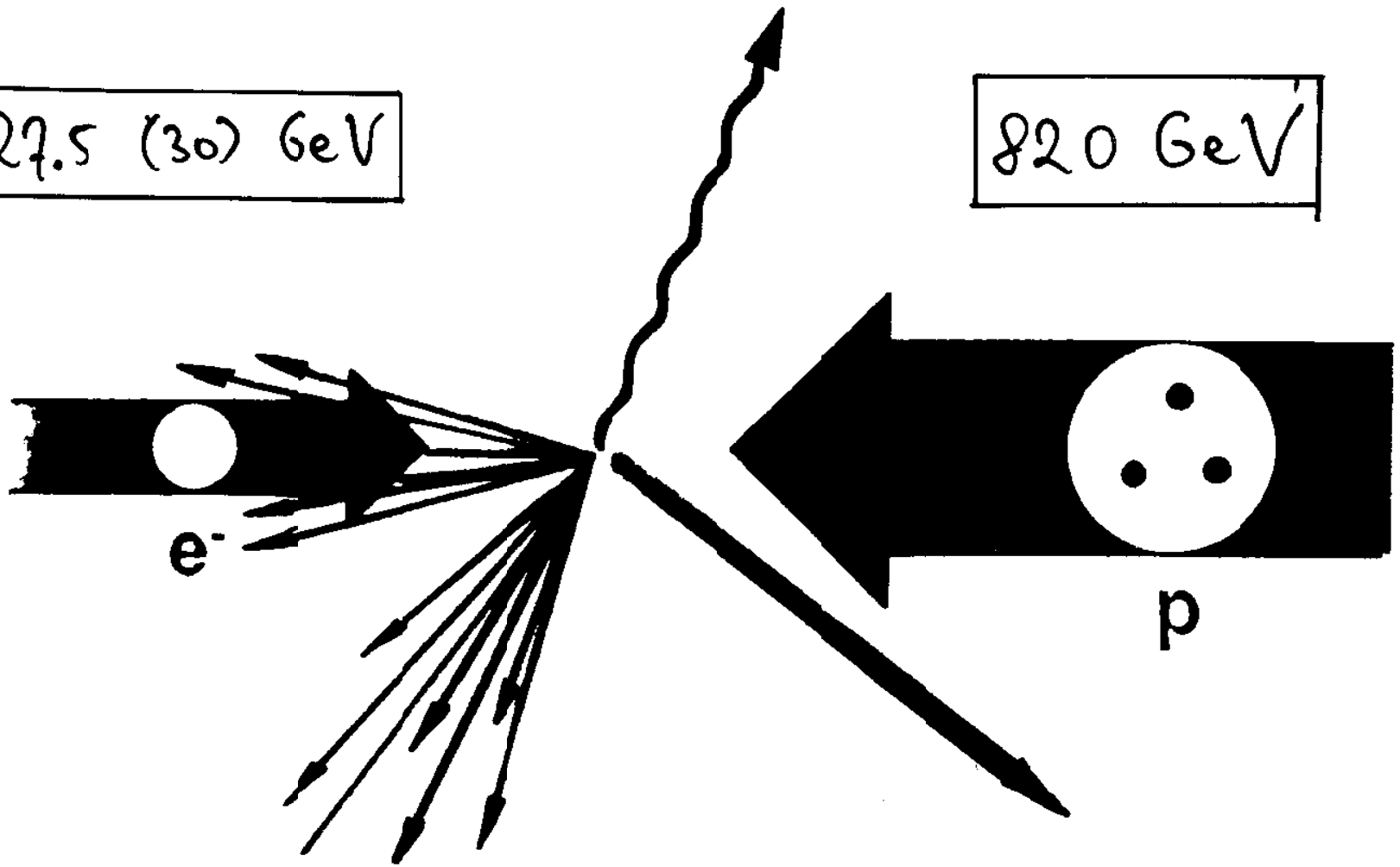
PHYSICS WITH POLARIZED PROTONS

OUTLOOK / TIME PLANING

HERA : ELECTRON-PROTON COLLISIONS

27.5 (30) GeV

820 GeV



C.M.S ENERGY : $\sqrt{s} \simeq 300$ GeV

+ FIXED TARGET (HERMES, HERA

WORKSHOP

Sept. 95 to May 96

Aim:

Study of future physics potentials at HERA in collider and fixed target modes, including high luminosity, polarized beams and nuclei

Working Groups:

- Structure Functions
- Electroweak Physics
- Beyond the Standard Model
- Heavy Quark Production and Decay
- HERA Upgrades and Impacts on Experiments
- Jets and High E_T Phenomena
- Diffractive Hard Scattering
- Polarized Protons and Electrons
- Light and Heavy Nuclei in HERA

http://www.desy.de/heraws96/proceedings/

Start-up Meeting:

25. Sept. 95, 10:00 until 26. Sept. 95 16:00 at DESY, Hamburg

Invited Talks:

- **HERA, Status and Prospects**
- **Reports and Insights from: H1, ZEUS, HERMES, HERA-B**
- **QCD at HERA**
- **New physics at HERA**

Working Group Meetings and Reports

Follow-up Meetings: planned for February and May 96

Organizing Committee:
Gunnar Ingelman, Uppsala/DESY (Chairman)
Albert De Roeck, DESY
Robert Klanner, DESY

Secretary:
Ms. H. Haerte
DESY-FH1K
Notkestraße 85
Phone: 0049-40-8998-3105
Fax: 0049-40-8998-3093

Email: HERA-WORKSHOP95@DESY.DE

Further information, including contact persons for working groups under WWW:
Http://www.desy.de/conferences/hera-workshop95.html

Advisory Commitee
W. Buchmüller, T. Feltesse
A. Levy, H. Schröder, J. van den Brand, A. Wagner

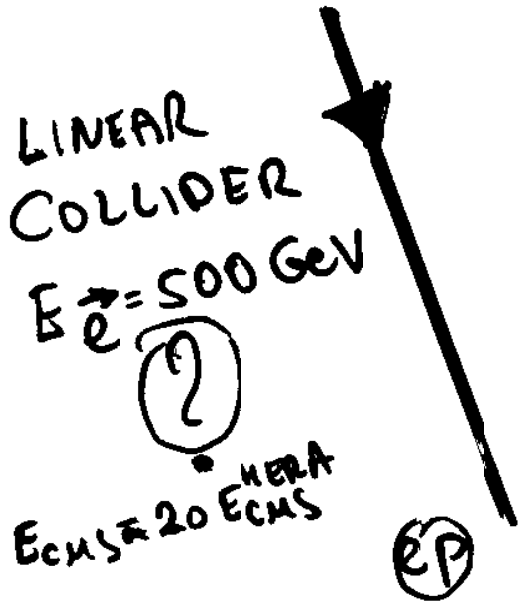
Future Physics at HERA

Proceedings of the Workshop 1995/96

Edited by
G. Ingelman, A. De Roeck, R. Klanner

Volume 2

http://www.desy.de/~heraws96

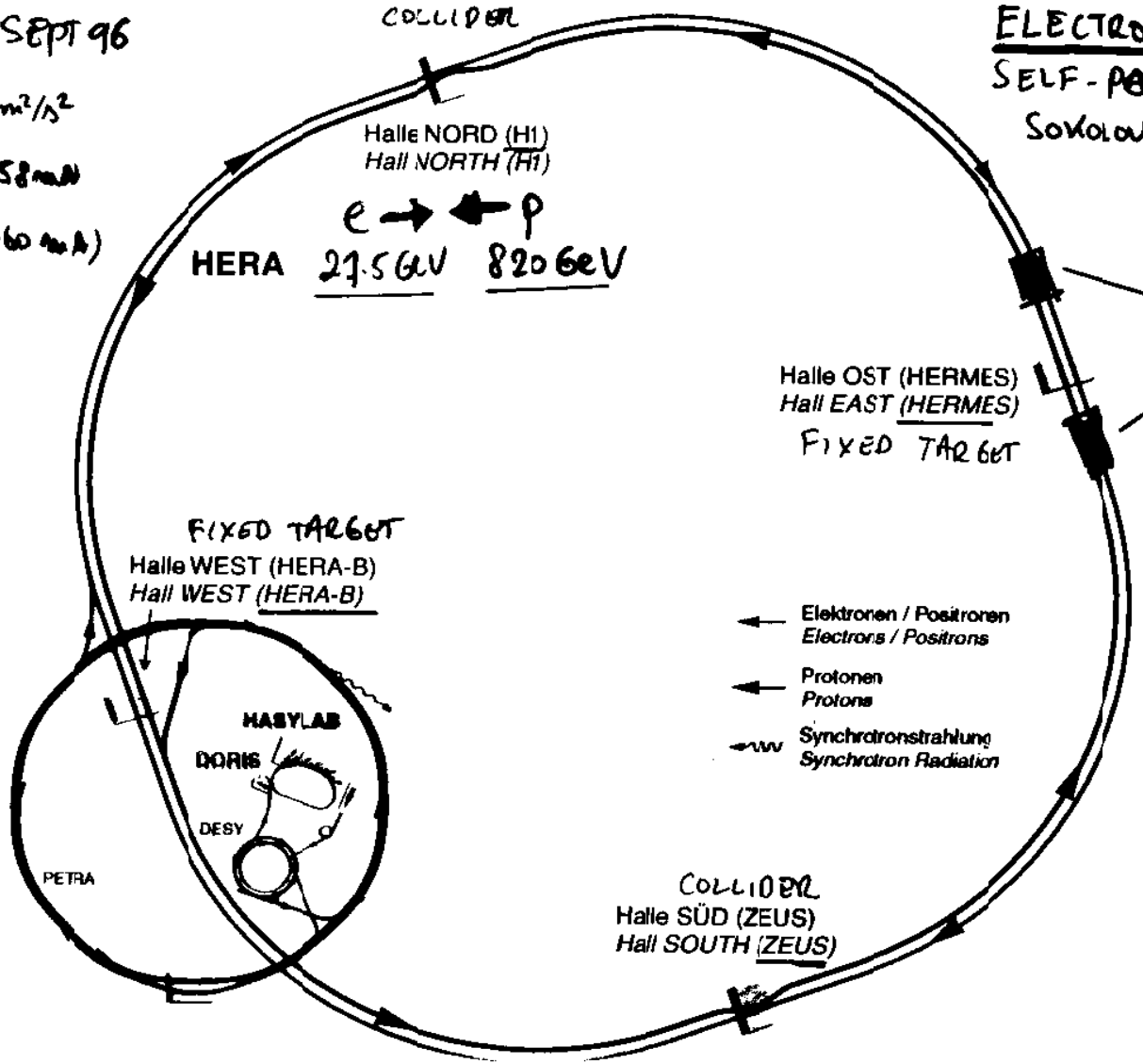

LINEAR
COLLIDER
$E_{\vec{e}} = 500$ GeV
?
$E_{CMS} = 20\, E_{CMS}^{HERA}$
ep

HERA SEPT 96

$L_{PEAK} = 7 \cdot 10^{30} / cm^2 / s^2$

$I_e = 30$ mA (58 mA)

$I_p = \sim 60$ mA (160 mA)



ELECTRON BEAM

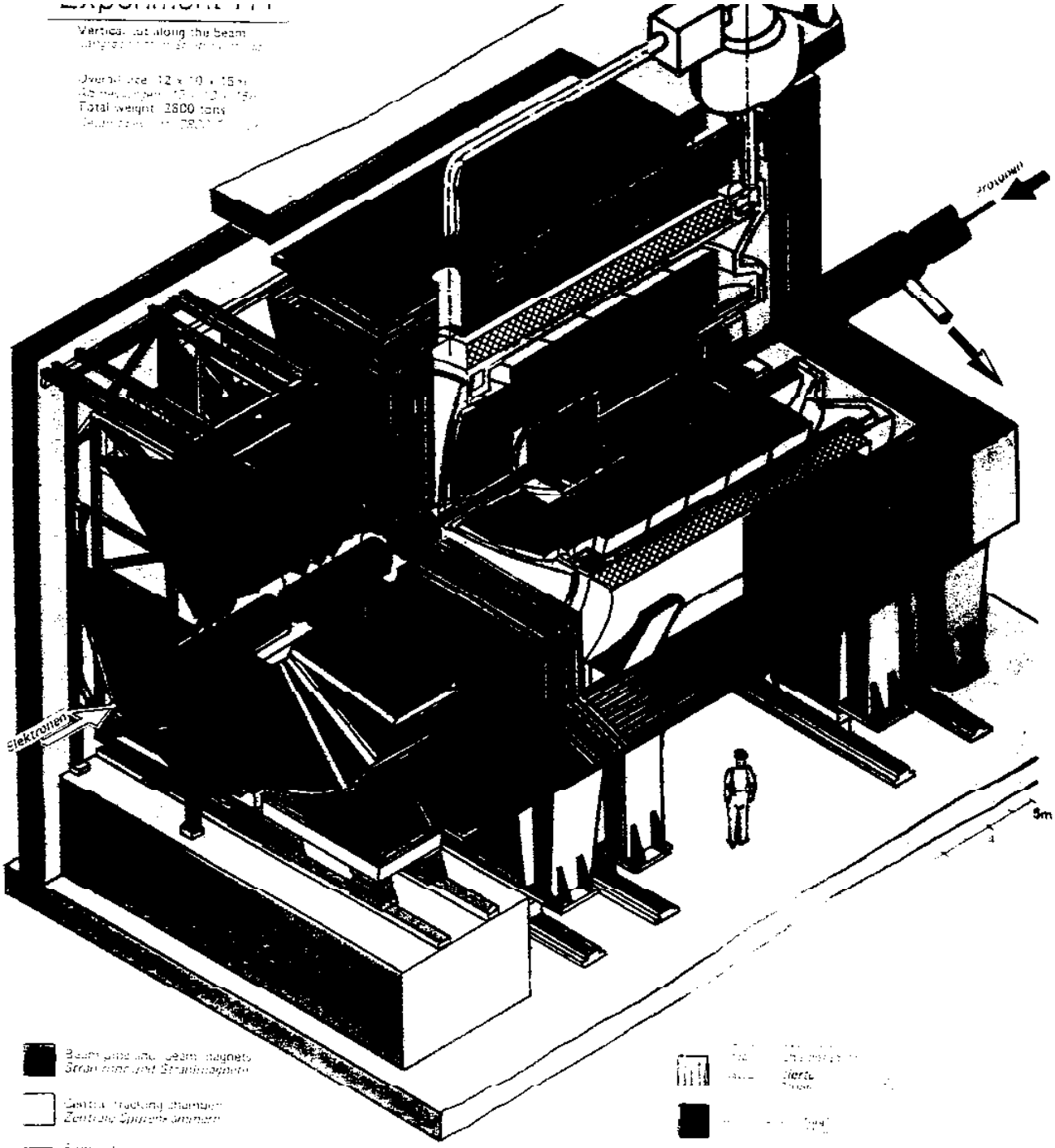
SELF-POLARISING

SOKOLOV-TERNOV EF

SPIN ROT

Pa 60-7

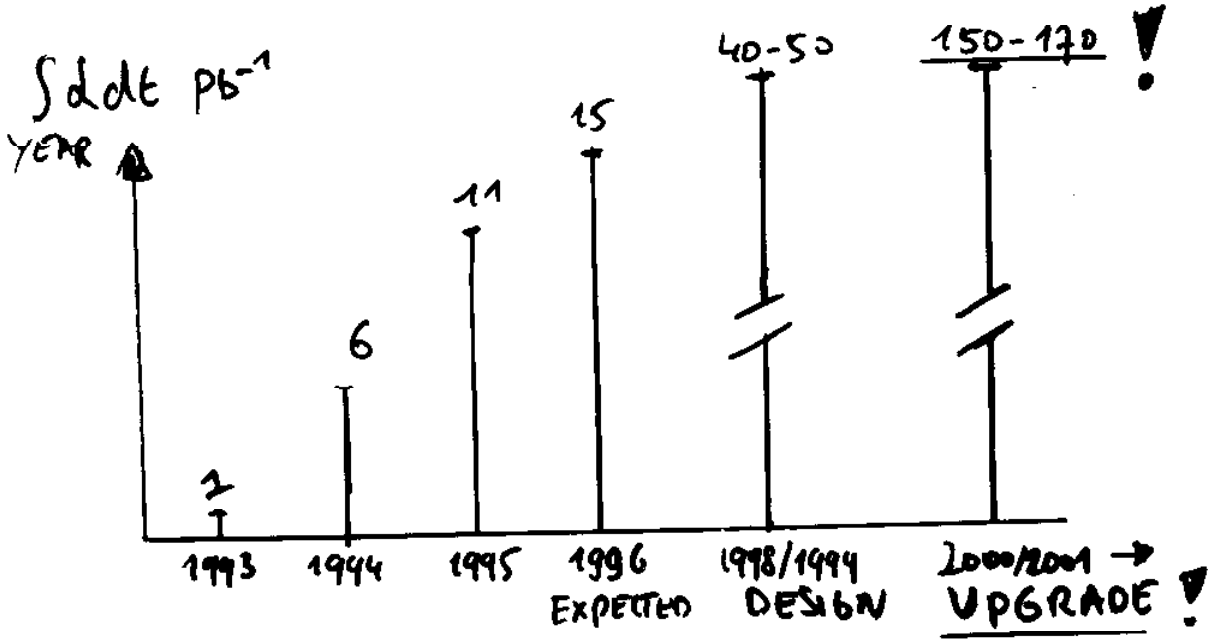
(10-15 m


Elektronen
5m

* OPERATIONAL SINCE 1992
  ↳ UNPOLARIZED BEAMS FOR H1, ZEUS (COLLIDER)

* e^- POLARIZATION SINCE 1995
  ↳ HERMES EXPERIMENT (FIXED TARGET)

* STEADY INCREASE OF LUMINOSITY WITH TIME



PROGRAM

* IMPROVE EFFICIENCY (35% → 70%)
* MORE RF POWER FOR e^- BEAM
* IMPROVE TRANSFER LINE (p) / INJECTOR CHAIN
* REPLACE PUMPS IN THE e^- RING
* ~~(NEW LINAC II (p))~~
* REDESIGN INTERACTION REGION (REDUCE β-FUNCTIONS OF p-BEAM) → 150-170 pb^{-1} PER YEAR

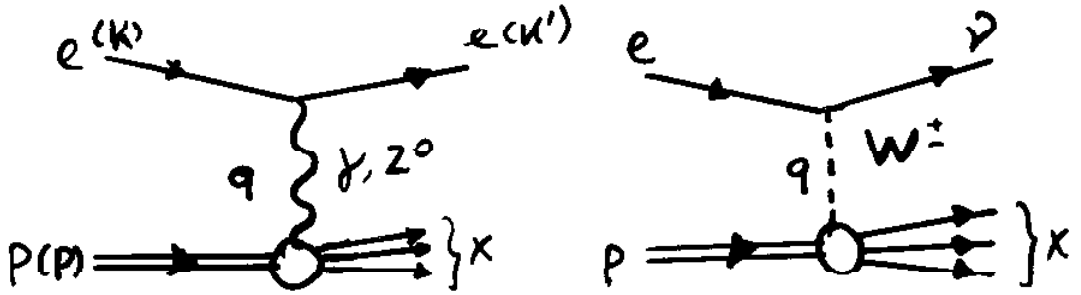
40-50 pb^{-1} PER YEAR

$\vec{e}$ p COLLISIONS AT $\sqrt{s}$ = 300 GeV

POLARIZATION: SOKOLOV-TERNOV EFFECT
$P \sim 70\%$

NEEDED: SPIN ROTATORS FOR H1, ZEUS
HIGH LUMINOSITY ($\sim 1\,fb^{-1}$)

➡ **ELECTROWEAK MEASUREMENTS**



NEUTRAL CURRENT (NC) CHARGED CURRENT (CC)

$Q^2 = -q^2 = -(k-k')^2$ $\quad s = (k+p)^2 \simeq (300\,GeV)^2$

$x = \frac{Q^2}{2p(k-k')}$ $\quad y = \frac{Q^2}{xs}$

➡ LIMITS ON RIGHT HANDED CHARGED CURRENTS

➡ ELECTROWEAK PRECISION TESTS (M_W, (M_{top}, M_{Higgs}

➡ QUARK NEUTRAL CURRENT COUPLINGS

REGION OF LARGE SPACE-LIKE Q^2 (10^3-10^4 GeV

~70% POL.

POLARIZED e-BEAMS & $\int \mathcal{L} dt \sim 1\ fb^{-1}$

⬇ ELECTROWEAK / NEW PHYSICS

LIMITS ON RIGHT HANDED CHARGED CURRENTS

$\sigma_R/\sigma_L \lesssim 0.02$ (95 % C.L.)

SENSITIVITY TO δM_W

$\delta M_W \simeq 50 - 100$ MeV

NEUTRAL CURRENT QUARK COUPLINGS

$\delta v_{u,d} = 5-15\%$, $\delta a_{u,d} \simeq 5-15\%$

$\vec{e}p$... (ALL Q^2)

$\Lambda / \bar{\Lambda}$ PRODUCTION → SPIN TRANSFER IN QUARK FRAGMENTATION

$1\ fb^{-1} \rightarrow \sim \underline{2.10^5}$ $\Lambda/\bar{\Lambda}$ RECONSTRUCTED IN H1 / ZEUS (CURRENT FRAGMENTATION REGION)

→ ... NOT STUDIED YET

ep COLLISIONS AT $\sqrt{s}$ = 300 GeV

POLARIZATION: POLARIZED SOURCE
ACCELERATE POLARIZED BEAM
STORE POLARIZED BEAM AT 820 GeV

NEEDED: UPGRADE FULL p-ACCELERATOR CHAIN OF HERA FOR POLARIZATION (SNAKES / SPIN ROTATORS / POLARIMETERS ...) → SIMILAR TO RHIC
POLARIZED SOURCE ($\gtrsim$ 20 mA) SEEMS FEASIBLE

PROBLEMS: SEVERAL THOUSAND RESONANCES ON THE WAY TO 820 GeV AND MANY OF THEM ARE KILLERS

CURE: SIBERIAN SNAKES
(ROTATES A SPIN BY π FOR ALL ENERGIE AROUND AN AXIS IN THE HORIZONTAL PLANE → SPIN TUNE INDEPENDENT OF ENERGY)

STATUS: FEASIBILITY STUDY FOR HERA ON GOING
(DESY GROUP / SPIN COLLABORATION)
→ DIFFICULT BUT CERTAINLY NOT HOPELESS

NEXT 18 MONTHS MAY BE DECISIVE FOR THE POLARIZED PROTON CASE AT HERA
(CALCULATIONS / TEST / PHYSICS)

Obtaining Polarized Proton Beams

- Resonance Excitation by the Stern Gerlach Effect
  $\Longrightarrow$ Very difficult phase space gymnastics
- Spin flip by Scattering of Polarized Electrons
  $\Longrightarrow$ Very long polarization times
- Spin filter with polarized target (FILTEX at TSR)
  $\Longrightarrow$ Very long polarization times and for low energies
- Acceleration of Polarized Protons from Rest

Has been tested at:

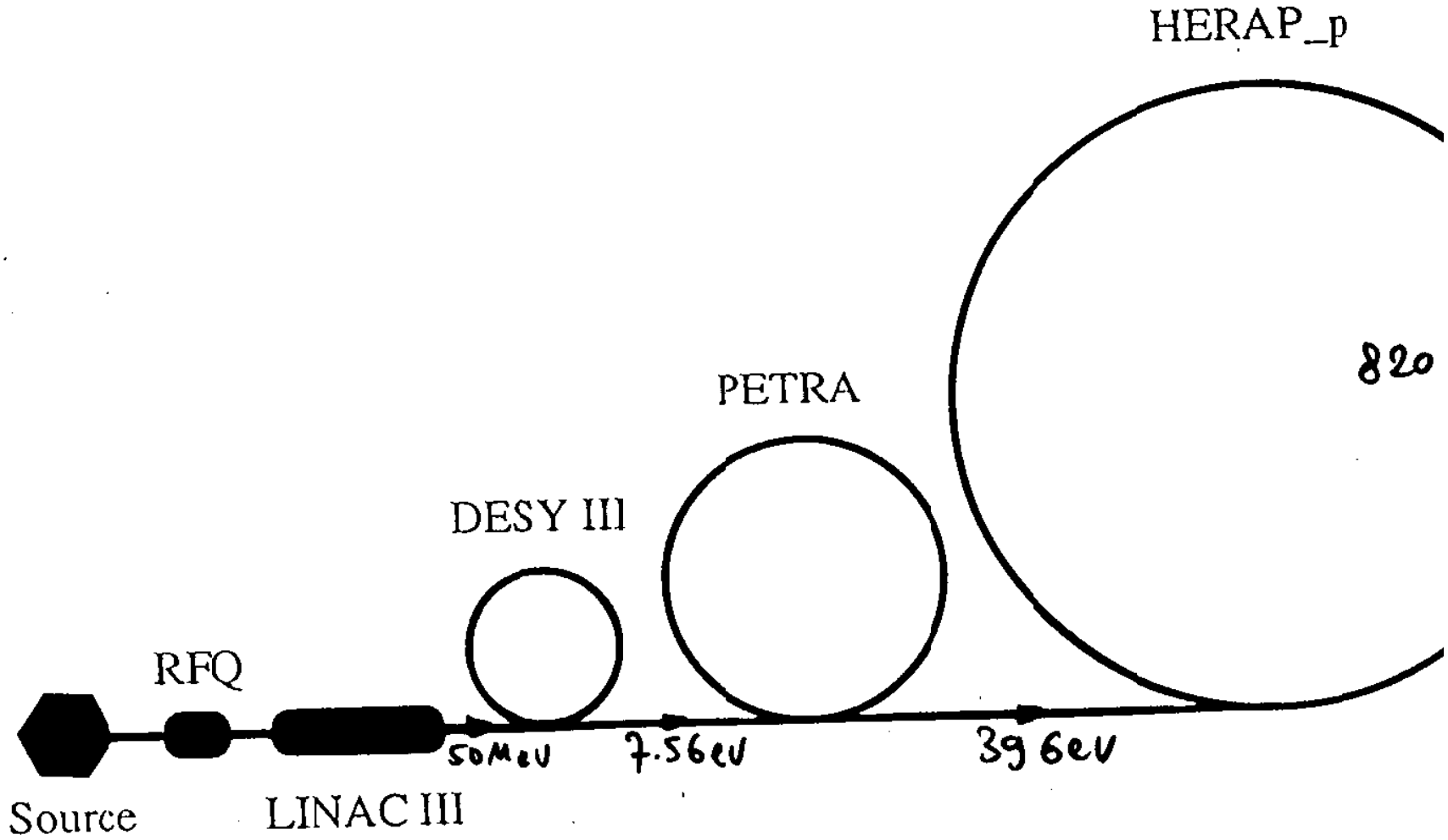
ZGS	12 GeV
AGS	22 GeV
IUCF	1 GeV
Saturn II	3 GeV
PSI Cyclotron	0.59 GeV
TRIUMF Cyclotron	0.5 MeV
LAMPF	0.8 MeV

Is the proposed principle of the new projects:

ANALYSED PROJECTS

Fermilab Main Injector	120 GeV
Fermilab TEVATRON	900 GeV
LISS	20 GeV
RHIC	250 GeV
HERA	820 GeV

The HERA Proton Chain



Currently the most pressing problems for polarized protons in HERA

- 20mA polarized H^- source
- which Siberian snake arrangements allow storage of high polarization
- which Siberian snake arrangements allow acceleration at all energies
- design of short Siberian snakes for HERA and PETRA

A KRISCH ET AL., SPIN GROUP REPORT UM...

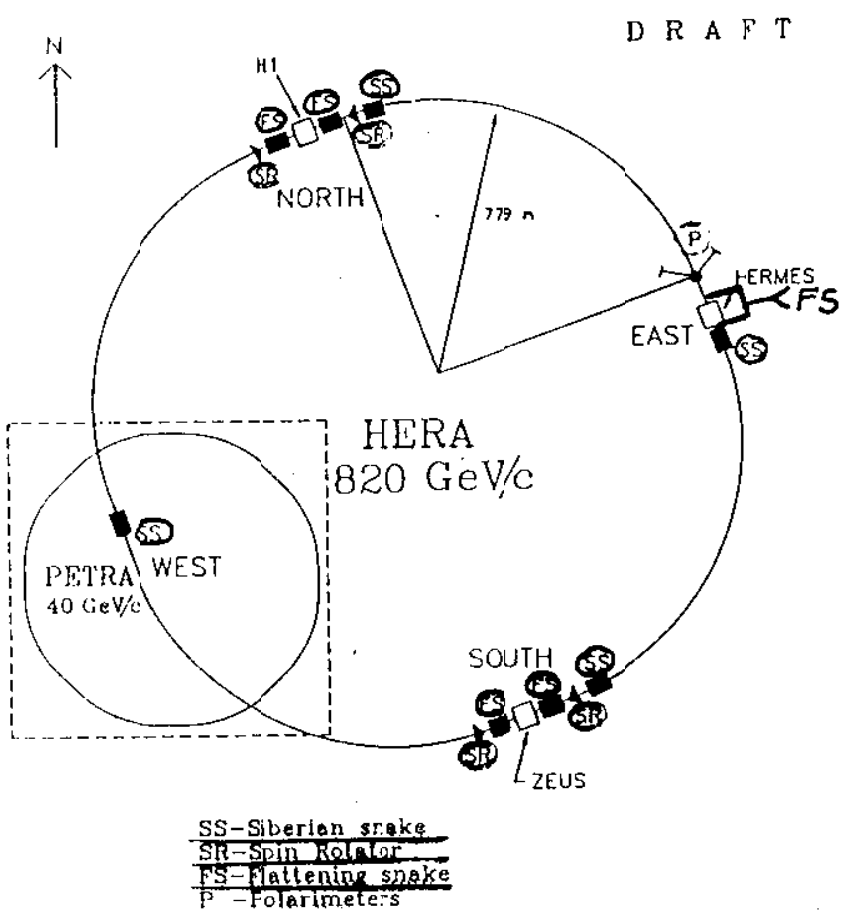


Figure 1.1. The proposed modifications for an 820 GeV/c polarized proton beam at DESY.

OF SNAKES NEEDED STILL UNDER STUDY

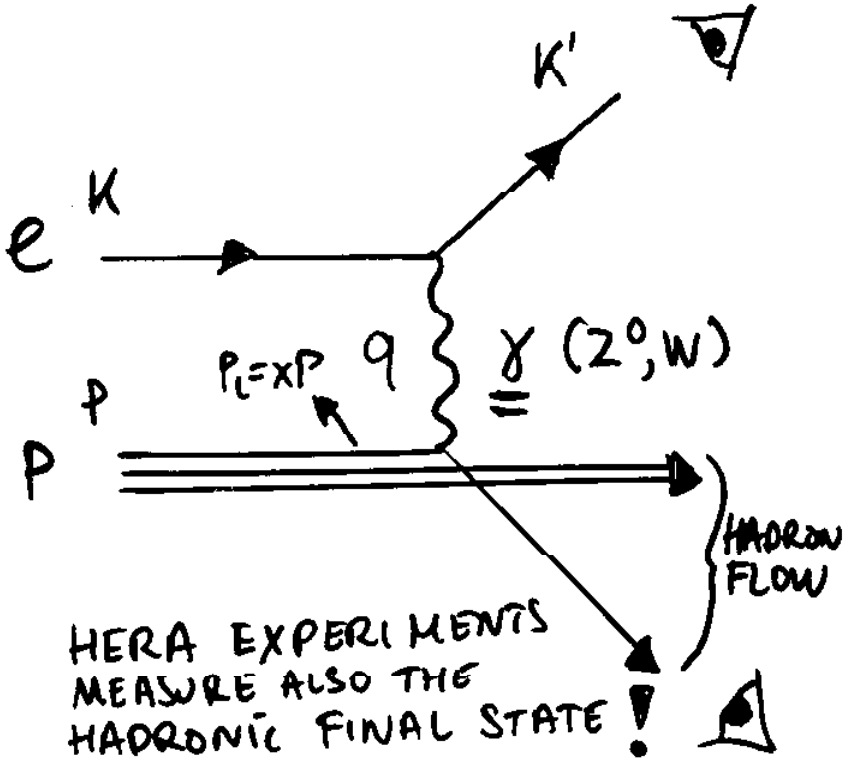
The estimated total cost to obtain an 820 GeV/c polarized proton beam capability at DESY is given in 1996 DM. Our estimate of about DM 25 Million seems a quite reasonable investment for the expected physics results. Moreover this cost might be considerably lower if the SPIN Collaboration fabricated some or all of the polarization hardware. However, this estimate assumes that some inexpensive way is found to overcome the possible spin stability problem in HERA with only four Siberian snakes.

Preaccelerator		DM 4.2 M
Polarized H^- ion source	DM 2.7 M	
RFQ and power supply (20 keV to 750 KeV)	DM 0.6 M	
Low energy beam transport, switching magnets, and vacuum system	DM 0.6 M	
Building change	DM 0.3 M	
50 MeV LINAC		DM 0.2 M
50 MeV polarimeter (p-Carbon)	DM 0.2 M	
7.5 GeV/c DESY III Booster		DM 0.7 M
Solenoid partial Siberian snake (ramped warm)	DM 0.2 M	
Pulsed quadrupoles or kicker magnets with power supplies	DM 0.3 M	
7.5 GeV/c polarimeter (Relative)	DM 0.2 M	
40 GeV/c PETRA Ring		DM 2.1 M
Two warm Siberian snakes	DM 1.0 M	
Power supplies and connections	DM 0.3 M	
40 GeV/c polarimeters (CNI, Relative, and possibly Inclusive)	DM 0.8 M	
820 GeV/c HERA Ring		DM 8.4 M
4 Superconducting Siberian snakes	DM 2.0 M	
4 Superconducting flattening snakes	DM 2.0 M	
4 Superconducting spin rotators	DM 1.5 M	
Power supplies and cryogenic connections	DM 1.5 M	
820 GeV/c polarimeters (CNI, Inclusive, Relative, Elastic)	DM 1.1 M	
Spin Flippers	DM 0.3 M	
Miscellaneous		DM 1.7 M
Transfer line spin rotators	DM 0.5 M	
Computers, control modules, cables, and interface	DM 1.2 M	
Accelerator Subtotal		DM 17.3 M
Contingency (25%)		DM 4.3 M
ACCELERATOR TOTAL		DM 21.6 M
HERA Internal Target Experiment	DM 2.5 M	
Install Mark-II polarized Jet and spectrometer		DM 2.5 M
SPIN Experiment subtotal		DM 0.6 M
Contingency (25%)		DM 3.1 M
SPIN EXPERIMENT TOTAL		DM 24.7 M
GRAND TOTAL		

~3% OF THE TOTAL HERA COST

→ EXTENTION OF THE ONGOING D.I.S. PROGRAM IN A NEW KINEMATICAL REGIME

→ **THE PROTON SPIN STRUCTURE** ←



KINEMATICS

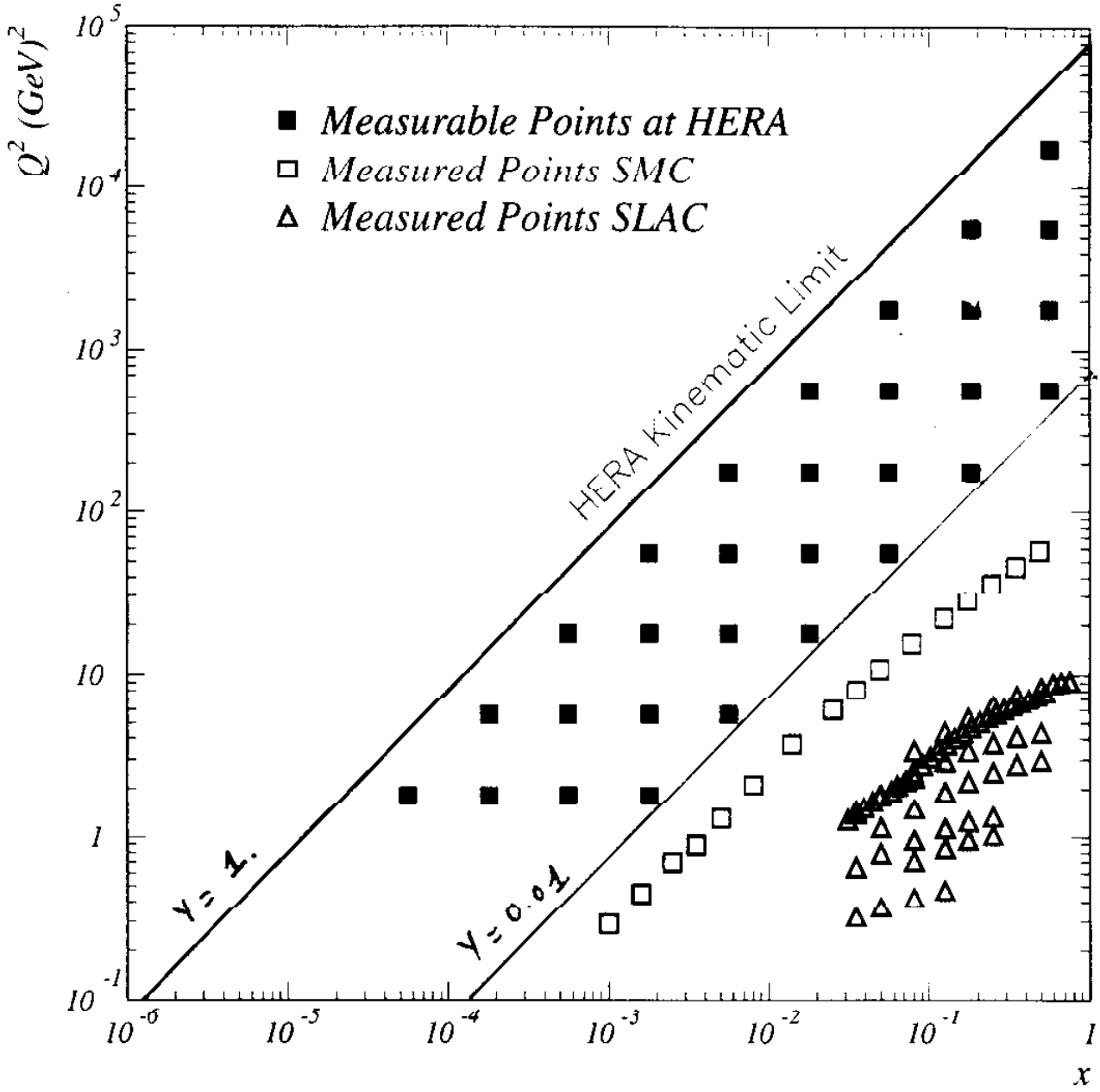
* $Q^2 = -q^2$ ←
* $x = \frac{Q^2}{2Pq} \simeq \frac{P_i}{P}$ ←
* $y = \frac{Pq}{Pk}$
* $S = \frac{Q^2}{xy}$
* $W^2 = (q+P)^2 = \frac{Q^2(1-x)}{x}$

HERA → VALUES OF $x \gtrsim 10^{-5}$ AND $Q^2 \gtrsim 10^4 GeV^2$ CAN BE REACHED

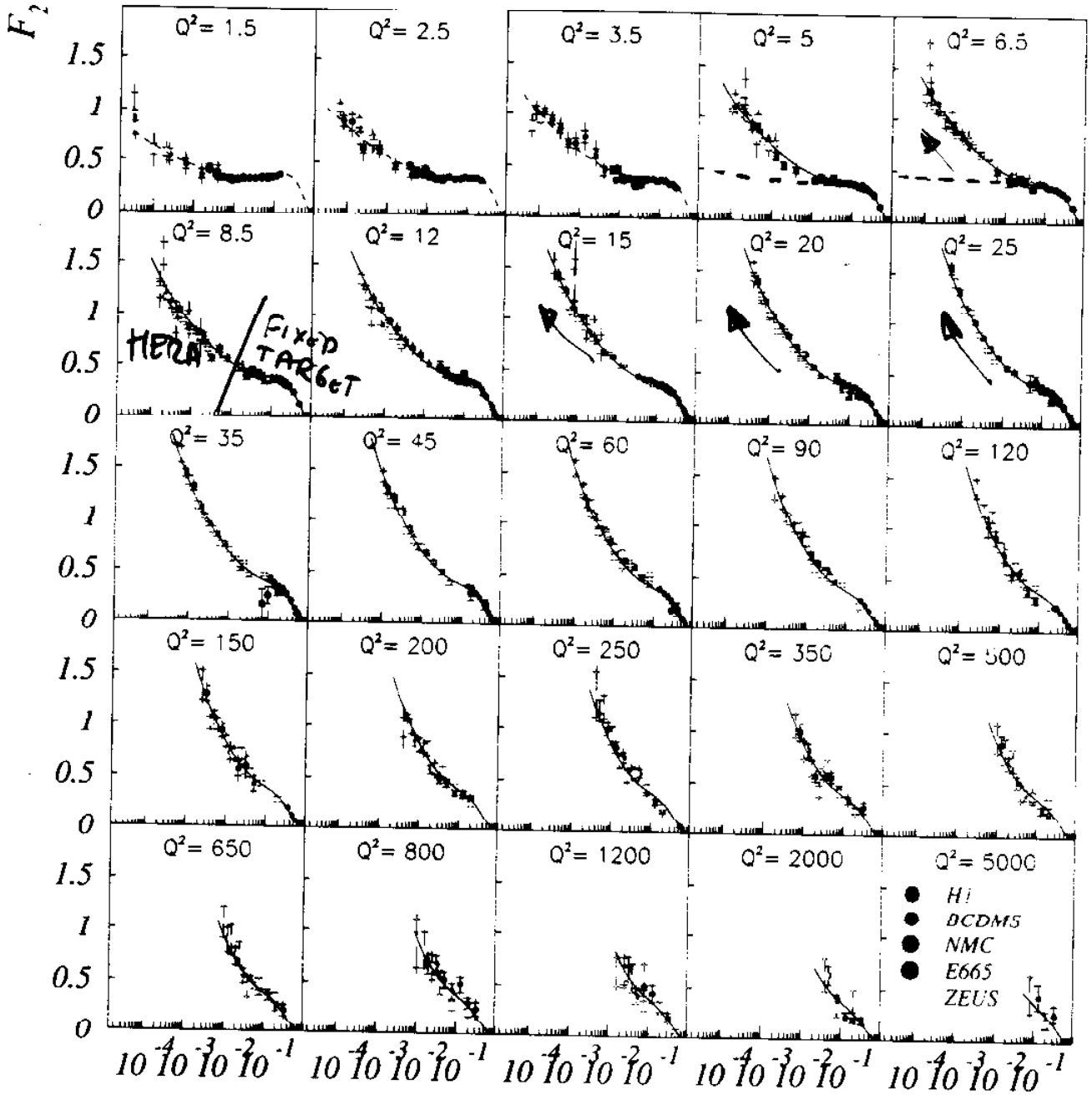
TOPICS

* THE STRUCTURE FUNCTION $g_1(x, Q^2)$
* $\Delta G(x, Q^2)$ FROM DIS 2-JET EVENTS
* THE STRUCTURE FUNCTION $g_5(x, Q^2)$ IN CC EVENTS
* PHOTOPRODUCTION ($Q^2 \simeq 0$) → ΔG PROTON AND Δq PHOTON

(... + SPIN IN DIFFRACTION (POMERON), ...)


Q^2 (GeV)^2
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
Measurable Points at HERA
Measured Points SMC
Measured Points SLAC
HERA Kinematic Limit
Y = 1.
Y = 0.01

INITIAL SURPRISE: STRONG RISE OF F_2 WITH DECREASING x



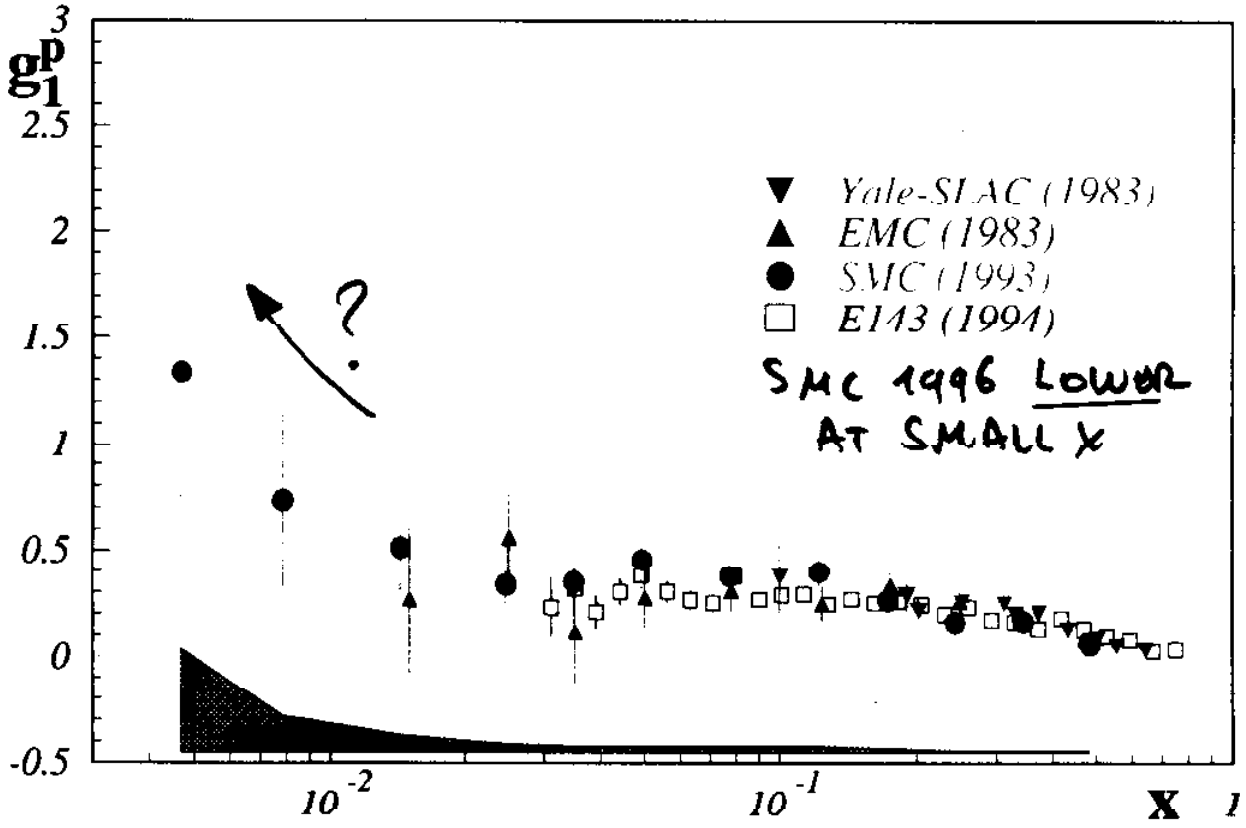
NOW INTERPRETED IN TERMS OF PQCD

$g_1(x,Q^2) = \frac{1}{2}\sum_q e_q^2 \left[q^{\uparrow}(x,Q^2) + q^{\downarrow}(x,Q^2) \right]$

PROTON SPIN

$\frac{1}{2}\hbar = \frac{1}{2}\hbar(\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s}) + \hbar\Delta G + L\hbar$

$\left(\Delta q = \int_0^1 (q^{\uparrow}(x,Q^2) - q^{\downarrow}(x,Q^2))\,dx\right)$



A TYPICAL FIT (GEHRMAN + STIRLING) GIVES AT $Q^2 = 4\,GeV^2$

Δu (VAL + SEA) $= 0.86$
Δd (VAL + SEA) $= -0.40$
$\Delta\bar{s} = \Delta s = \Delta\bar{u} = \Delta\bar{d} = -0.06$

$\Delta u + \Delta d + 4\Delta s = 0.22$
SPIN PUZZLE

$\Delta G = 1$–2 LARGE! → NEEDS EXPERIMENTAL EVIDENCE

BALL, DESHPANDE, FORTE, HUGHES, LICHTENSTADT, RIDOLFI

$g_1(x, Q^2)$: STANDARD MEASUREMENT FOR POLARIZED DEEP INELASTIC SCATTERING

→ INCLUSIVE MEASUREMENT

→ NEW KINEMATIC REGION

$x \sim 10^{-5}$ $\quad g_1(x \to 0)$ RISE? DROP? FLAT?

$Q^2 \sim 10^4\ GeV^2$

SMALL X CONTRIBUTION TO SUM RULES

→ LARGE LEVER ARM FOR QCD EVOLUTION (WITH FIXED TARGET DATA)

→ MEASURE OF ΔG

→ VERIFY QCD (DGLAP) EVOLUTION

→ BFKL ↔ DGLAP DYNAMICS AT SMALL-X!

BARTELS ET AL

$$g_1(x, Q^2)^{NS} \sim x^{-0.41}$$

$$g_1(x, Q^2)^{S} \sim x^{-1.02} \quad \text{(RISE WITH } x \text{)}$$

→ TRIANGLE ANOMALY DIAGRAM

HOWEVER ASYMMETRIES EXPECTED TO BE SMALL: 10^{-3}-10^{-4}

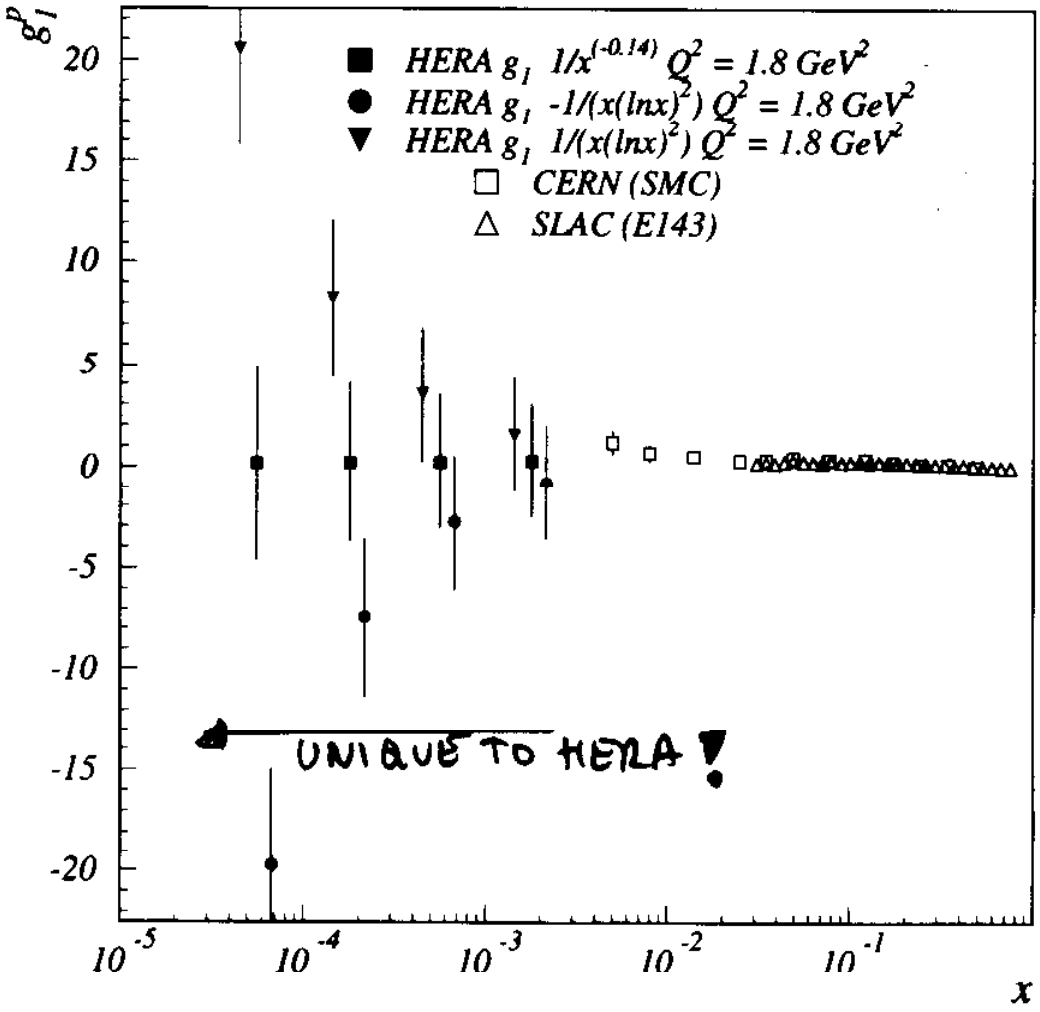
(BASED ON PRESENT NLO FIT PREDICTIONS)

→ EXPERIMENTAL CHALLENGE

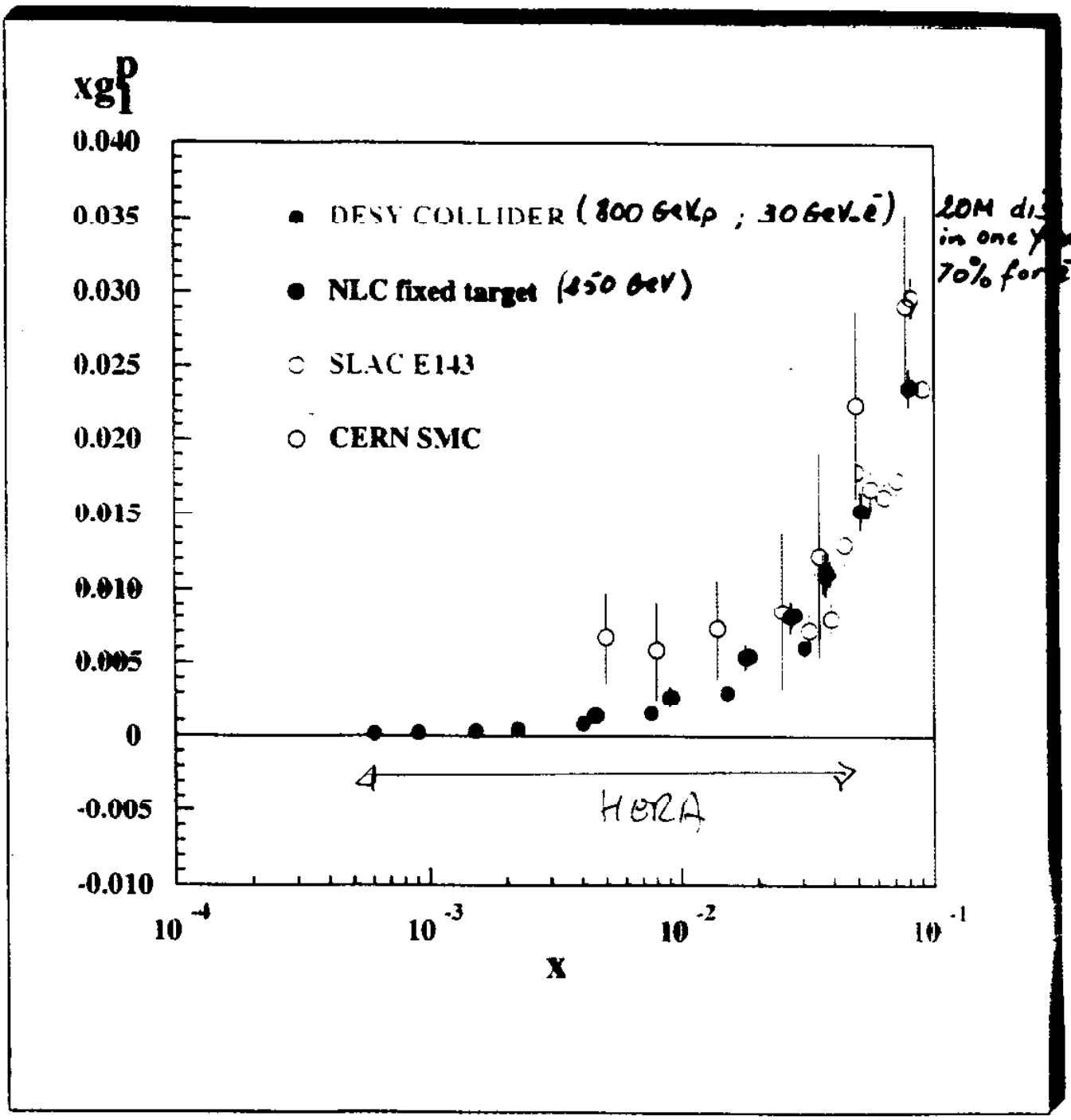
* E.G. $g_1^p(x)$

STATISTICAL ERRORS $1\,fb^{-1}$

↳ 3 PREDICTIONS FOR SCENARIOS ALLOWED BY PRESENT DAY DATA (SEPT '96)



Proton Spin Structure Function



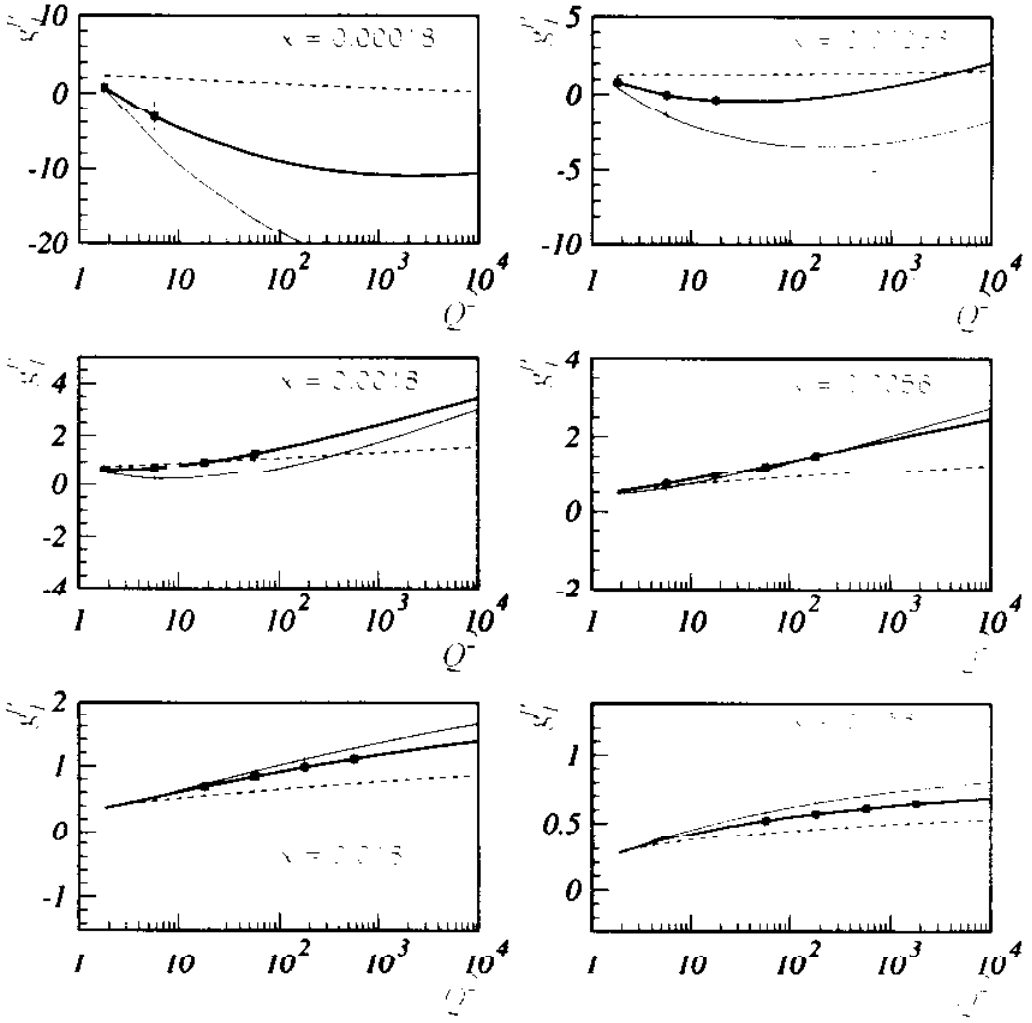
VERSUS Q^2

- - - $\int \Delta G\, dx = 0$

——— $\int \Delta G\, dx = 1.3$

——— $\int \Delta G\, dx = 1.8$

AT $Q^2 = 1\,GeV^2$



NLO FIT

WITHOUT HERA $\int \Delta G\, dx = 1.3 \pm 0.56$

WITH HERA $200\,pb^{-1}$ $\int \Delta G\, dx = 1.3 \pm 0.28$ ←

$1\,fb^{-1}$ $\int \Delta G\, dx = 1.3 \pm 0.22$

$\Delta G(x, Q^2)$ IS THE KEY QUANTITY TO DETERMINE, TO UNDERSTAND THE QCD SPIN PROPERTIES OF THE PROTON

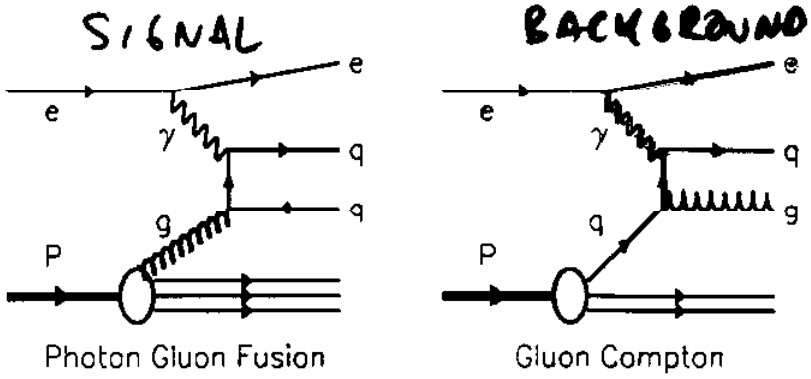
HERA (UNPOLARISED CASE) → xG $(10^{-4} - 2.10^{-1})$

→	- SCALING VIOLATIONS OF F_2 (QCD FITS)	NLO
→	- JET MEASUREMENTS IN DIS.	LO (NLO)
*	- CHARM PRODUCTION	LO (NLO)
*	- VECTOR MESON PRODUCTION (ρ, J/ψ)	LO
	- F_L	NLO
*	- PHOTOPRODUCTION OF JETS	LO NLO

→ GLUON HAS **BEEN** EXTRACTED

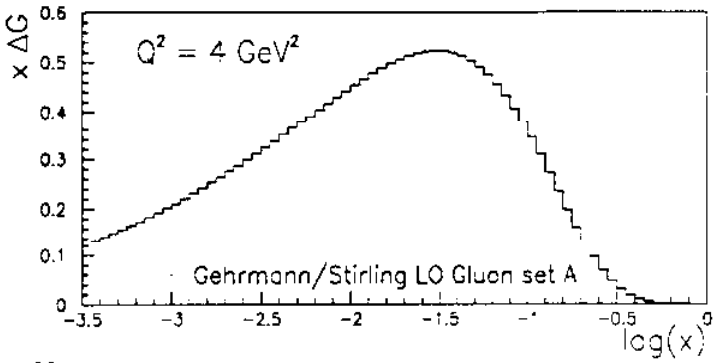
*: SENSITIVITY TO GLUON HAS BEEN SHOWN

→ STUDIED:
EXTRACTION OF ΔG FROM 2-JET EVENTS
- DIRECT MEASUREMENT -



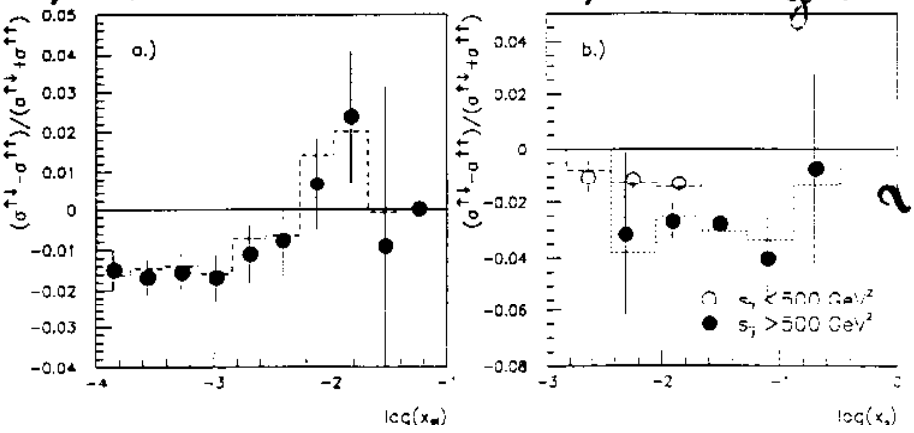
MIRIAM RAJDER SCHÄFER WU

- Measure crosssection for (2+1)-jet events
- In LO: $\sigma \sim \alpha_s \times G \Rightarrow \frac{\Delta G}{G} \sim \frac{1}{P_e P_p D} \times \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$ $\quad \delta(\frac{\Delta G}{G}) \sim 10\text{-}15\,\%$



$Q^2 > 5\,\text{GeV}^2$; $P_T^{JET} > 5\,\text{GeV}$ $\qquad 0.002 < x_g < 0.2$

ASYMMETRY

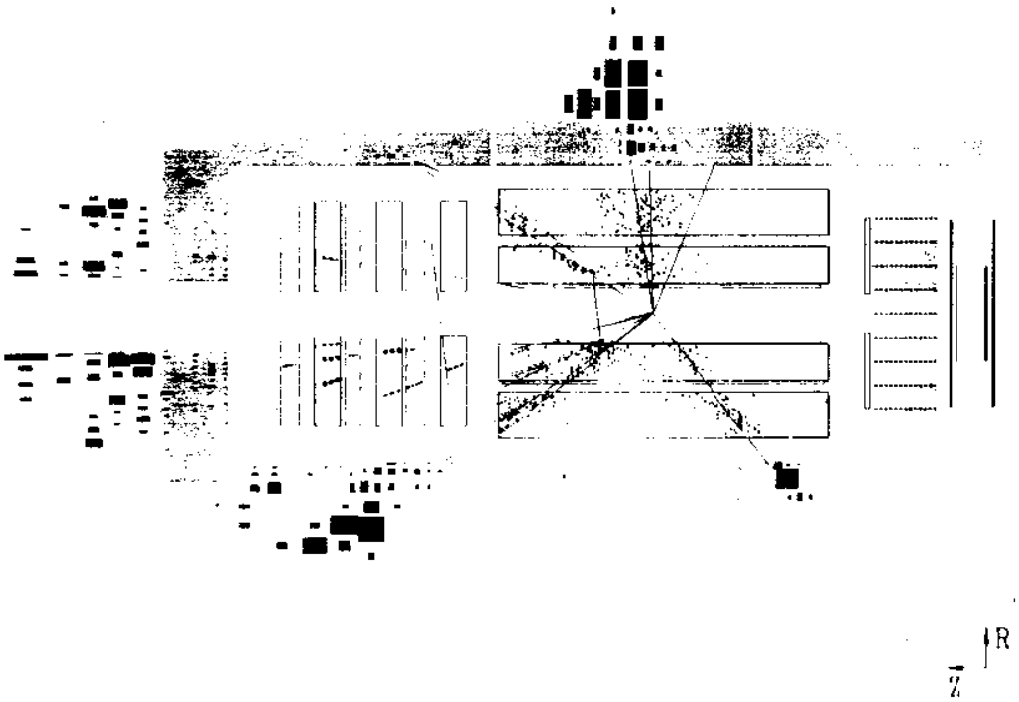


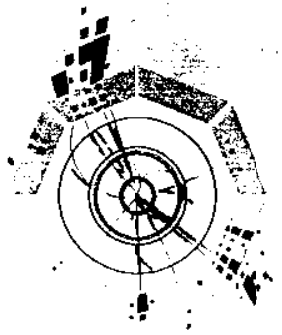
A FEW %

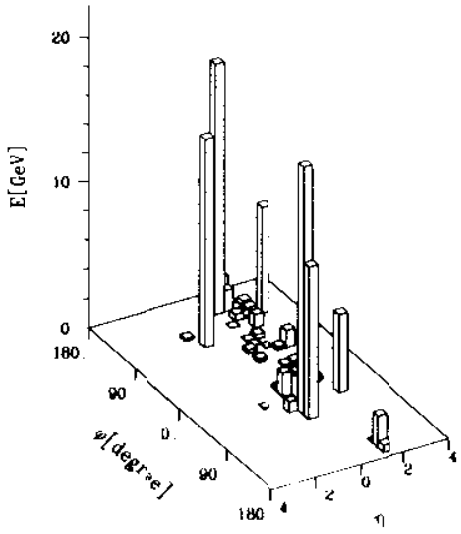
- **Asymmetries vs. a) $\log(x_{Bj})$ and b) $\log(x_g)$ at the parton level(histogram), and at the detector level(•, ∘ with error bars) assuming HERA $\mathcal{L} = 200\ \text{pb}^{-1}$.**

NLO PROGRAM IN PREPARATION

Run 57197 Event 1113 Class: 8 9 12 16 20 22 23 28 Date 25/04/19



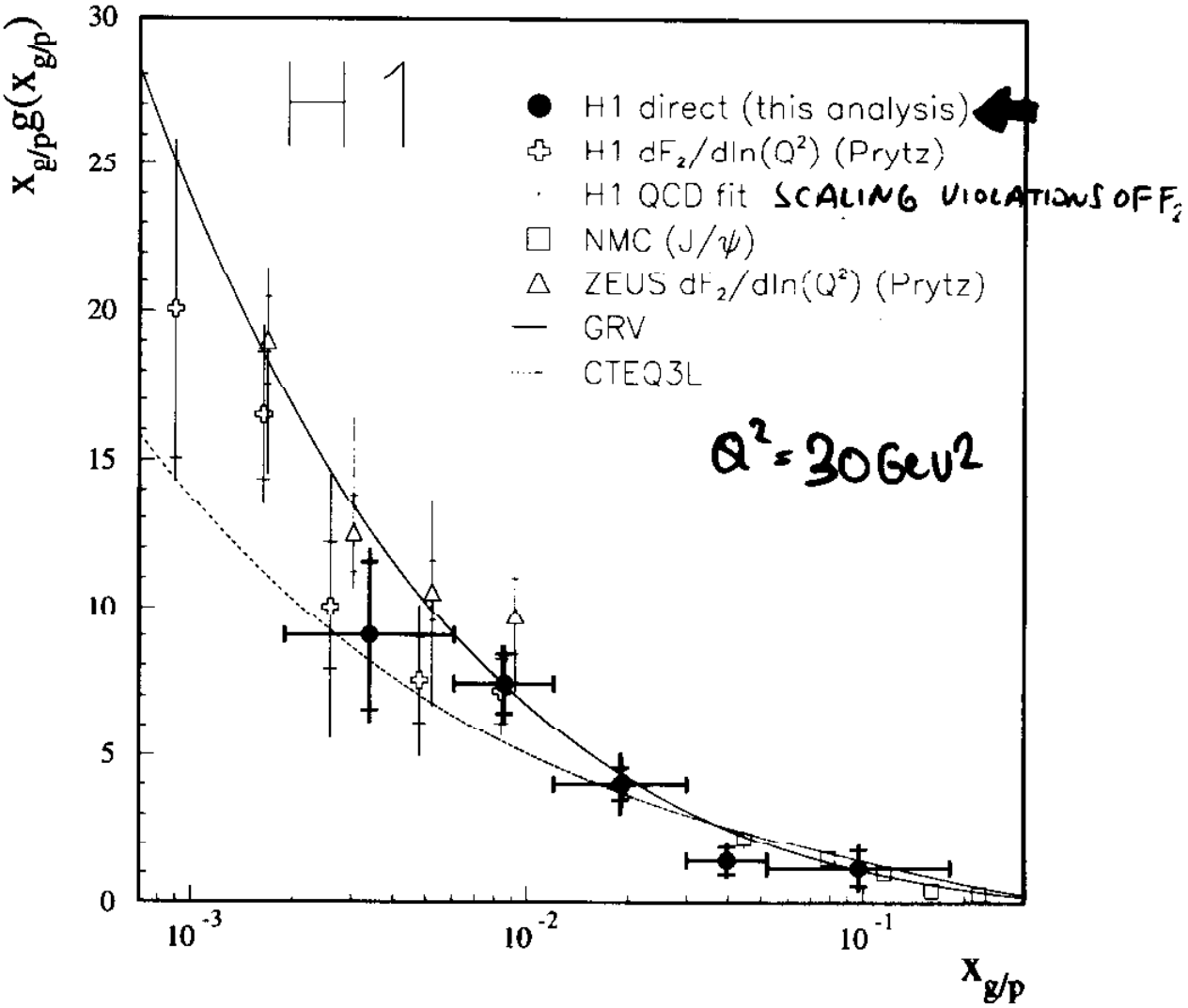




H1 1993 DATA $\int \mathcal{L}\,dt = 0.24\ \mathrm{pb}^{-1}$

NUCL. PHYS. B449 (1995) 183

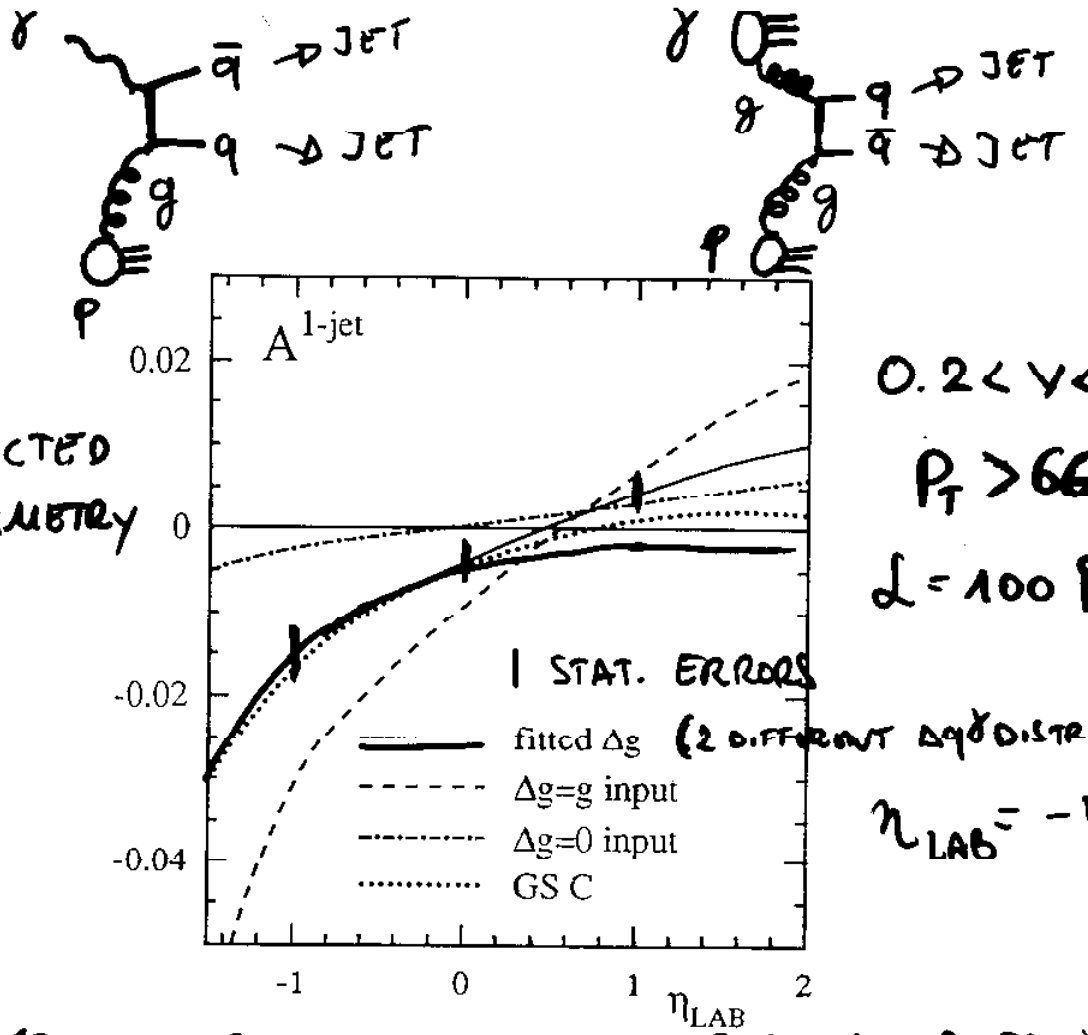
GLUON AT LEADING ORDER



→ GOOD AGREEMENT WITH OTHER METHODS

[JETS : $p_T^{JET} > 5$ GeV
CONE ALGORITHM]

SYST: 15 - 30 %



PREDICTED ASYMMETRY

$0.2 < y < 0.85$

$P_T > 6\,GeV$

$\mathcal{L} = 100\ pb^{-1}$

$\eta_{LAB} = -\ln \tan \frac{\theta_{LAB}}{2}$

'DIRECT PHOTON'

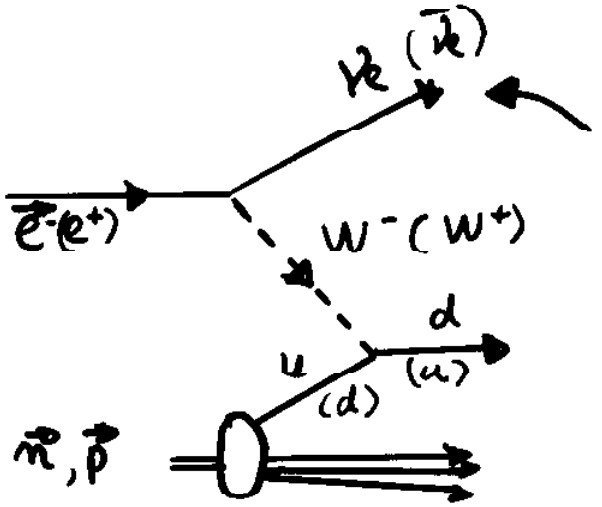
'RESOLVED PHOTON'

→ LARGE SENSITIVITY TO $\int_{PROTON} \Delta G\, dx$

→ POSSIBLE FIRST SIGNAL OF SPIN ASYMMETRY IN RESOLVED PHOTON SENSITIVE TO AMOUNT OF GLUON IN THE PHOTON

(ALSO FROM HEAVY QUARK PRODUCTION)

→ STUDY OF $e^- p$ CHARGED CURRENT EVENTS



IDENTIFIED VIA MISSING MOMENTUM (PRESENTLY $p_\perp > 25$GeV)
↳ $Q^2 > 600$GeV

$$A_{cc} = \frac{d\sigma^{\uparrow\downarrow} - d\sigma^{\uparrow\uparrow}}{d\sigma^{\uparrow\downarrow} + d\sigma^{\uparrow\uparrow}} = \frac{a\, g_5^{W^\pm} + 2b\, g_1^{W^\pm}}{a\, F_1^{W^\pm} + b\, F_3^{W^\pm}}$$

$a = 2(2 - 2y + y^2)$; $b = y(2-y)$

$$g_5^{W^-} = -[\underline{\Delta u} + \Delta c - \Delta\bar{d} - \Delta\bar{s}](x, Q^2)$$
$$g_5^{W^+} = -[\underline{\Delta d} + \Delta s - \Delta\bar{u} - \Delta\bar{c}](x, Q^2)$$

→ $g_5^{W^+} + g_5^{W^-} = -[\Delta u_v + \Delta d_v](x, Q^2)$

$$g_1^{W^-} = [\underline{\Delta u} + \Delta c + \Delta\bar{d} + \Delta\bar{s}](x, Q^2)$$
$$g_1^{W^+} = [\Delta\bar{u} + \Delta\bar{c} + \underline{\Delta d} + \Delta s](x, Q^2)$$

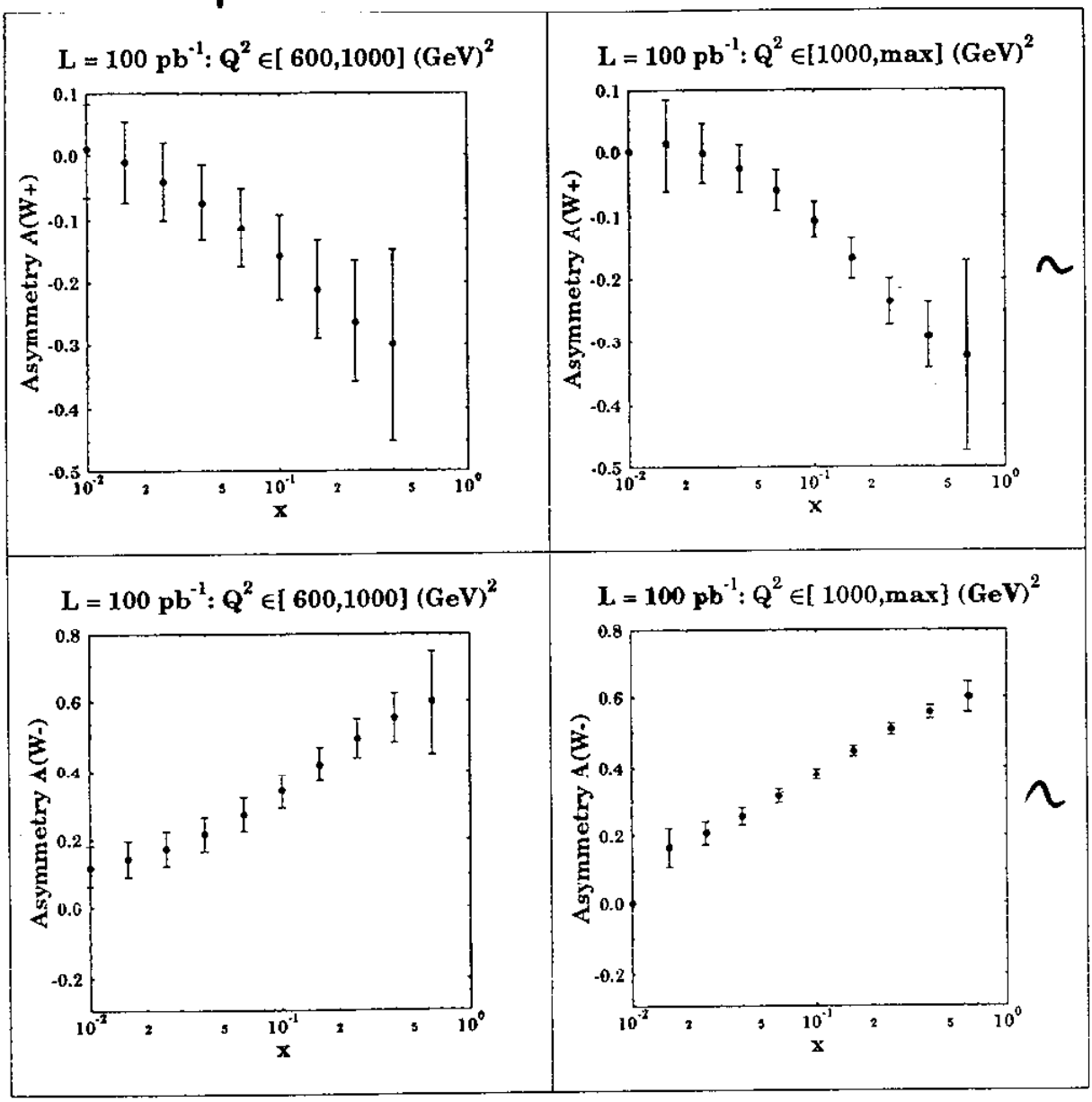
→ $g_1^{W^+} + g_1^{W^-} = \Sigma(x, Q^2)$

$$g_1^{W^+} - g_1^{W^-} = [\Delta d_v - \Delta u_v](x, Q^2)$$

→ DIRECT ACCESS TO Δu, Δd AT LARGE x, AND LARGE Q^2 (↔ HERMES ; EVOLUTION)

ASYMMETRIES: LARGE!

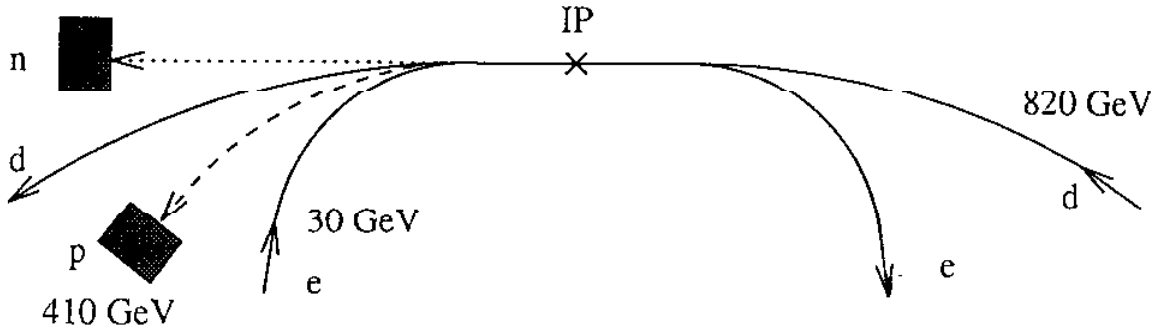
$100\ pb^{-1}$



* STATISTICAL ERRORS FOR $\mathcal{L} = 200\ pb^{-1}$
* BOTH e^+ AND e^- SAMPLES NEEDED

DÜREN

OF SPECIAL INTEREST: TAGGING OF THE SPECTATOR PROTON OR NEUTRON → {SYSTEMATICS LUMI
(NO NUCLEAR EFFECTS)



→ *TEST OF THE FUNDAMENTAL BJORKEN SUM RULE

$$\int_0^1 (g_1^p - g_1^n)\, dx$$

* Δu , Δd , ΔS , $\Delta\Sigma$ $(= \Sigma(\Delta q + \Delta\bar{q}))$

* MORE CONSTRAINTS ON NLO QCD FITS

PROBLEM : ROTATING THE SPIN : TRANSVERSE → LONGITUDINAL

^3He ? (SAID TO BE ~ PROTON)

SUMMARY FOR POLARIZED PROTON BEAMS

PROVIDED:

TOTAL LUMINOSITY $\gtrsim 200\ pb^{-1}$
$P_e \cdot P_p \sim 0.5$

AN ATTRACTIVE PHYSICS PROGRAM CAN BE CARRIED OUT WITH THE EXISTING H1 & ZEUS DETECTORS, TO MEASURE FUNDAMENTAL PROPERTIES OF QCD, ESPECIALLY ON:

- $g_1(x, Q^2)$ AT LOW x (MORE SURPRISES?)
- $\Delta G(x, Q^2)$ FROM JETS IN DIS AND γp
- Δu_v, Δd_v FROM CC EVENTS
- POLARIZED PARTON DISTRIBUTIONS IN THE PHOTON

+ OTHER PROCESSES, NOT YET STUDIED IN DETAIL

- GLUON FROM ρ AND ψ MESON PRODUCTION
- DIFFRACTIVE DIS EVENTS
- SEMI-INCLUSIVE MEASUREMENTS

...

COLLISIONS AT HERA

KOROTKOV
MURGIA
NOWAK
NURUSHEV
TERYAN
TKABLADZE

$\vec{N}N$ AND $\vec{N}\vec{N}$ COLLISIONS AT $\sqrt{s} = 40$ GeV (FIXED TARGET)

POLARIZATION : PHASE I — POLARIZED TARGET, UNPOLARIZED BEAM

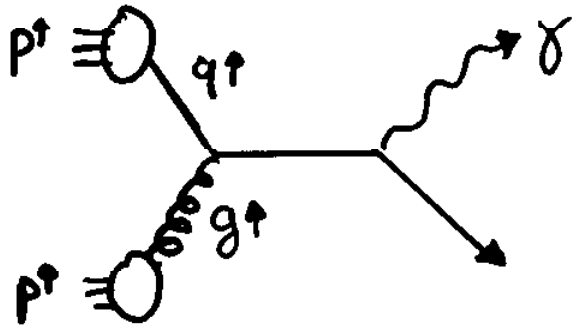
PHASE II — POLARIZED TARGET, POLARIZED BEAM

SINGLE & DOUBLE SPIN ASYMMETRIES

SINGLE SPIN : VALIDATION OF pQCD ONSET REGION / HIGHER TWISTS

DOUBLE SPIN : MEASUREMENT OF POLARIZED GLUON DISTRIBUTION ΔG

E.G.



$p + p \rightarrow \gamma + X$, γ + JET, JET + X, JET + JET.

MOTIVATION:

A VERY SURPRISING RESULT IN 1992 FROM FNAL

$p\vec{p} \to \pi^{\pm} X$ AT $E_{CM} = 20$ GeV →

- LO (TWIST2) QCD PREDICTION: NO ASYMMETRY
- NO CONVINCING EXPLANATION YET

$$\frac{d\sigma}{dp_T dx_F} \sim F_{q/N} \cdot \hat{\sigma} \cdot D_{\pi/q}$$

$F_{q/N}$: INTRINSIC p_T IN PARTON DISTRIBUTIONS?

$\hat{\sigma}$: HARD SCATTERING
HIGHER TWIST EFFECT?
q-GLUON CORREL?

$D_{\pi/q}$: INTRINSIC p_T IN FRAG. FUNCTION

EFFECT OBSERVED AT $\langle p_T \rangle = 0.4$ GeV

→ MEASURE AT HIGHER p_T (INCLUSIVE PION & PROMPT PHOTON) / MANY DIFFERENT CHANNELS

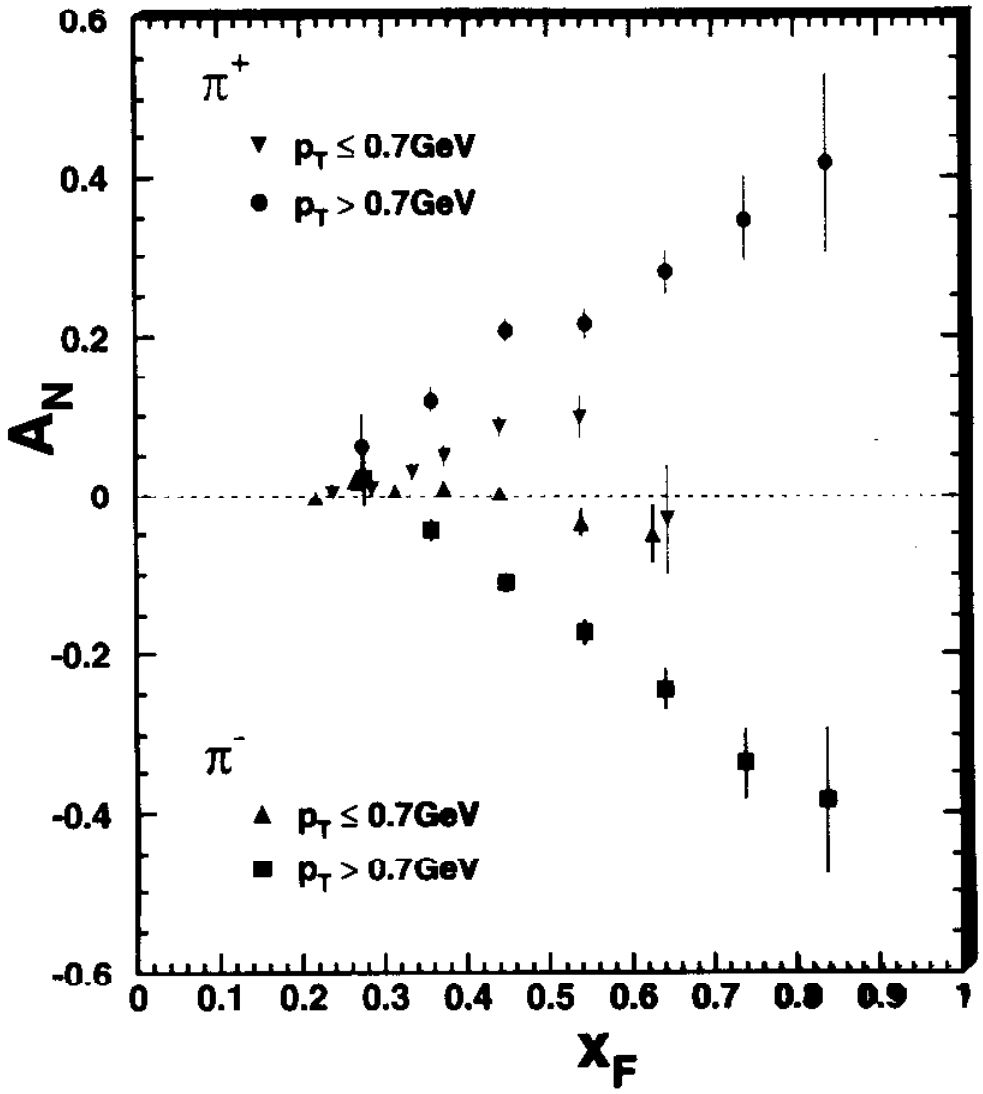
→ REQUIRES A LARGE ANGLE DETECTOR (~40°)

* STATISTICAL PRECISION BASED ON 240 pb^{-1}

→ $I_B = 80$ mA
TARGET DENSITY = $3 \cdot 10^{13}$ ATOMS/cm^2
$1.6 \cdot 10^{7}$ s

→ 2-3 YEARS OF DATATAKING

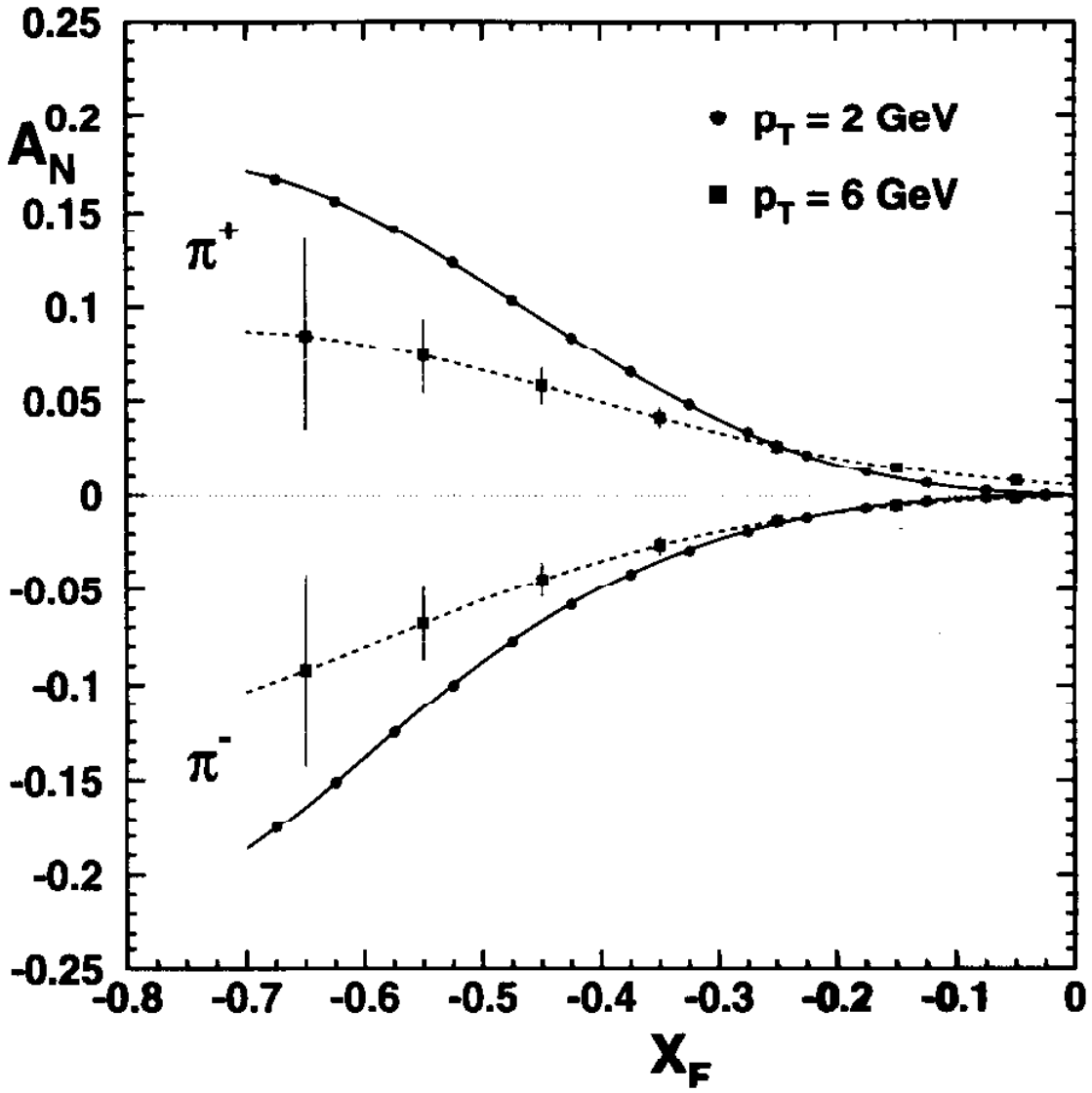
$p^{\uparrow}p \to \pi^{\pm} + X$ at 200 GeV



E704 data show intriguing contradiction to pQCD (twist-2) prediction:

$$A_N^{pQCD} = 0$$

BUT: $A_N^{E704}(x_F = 0.8) = \pm 0.40$

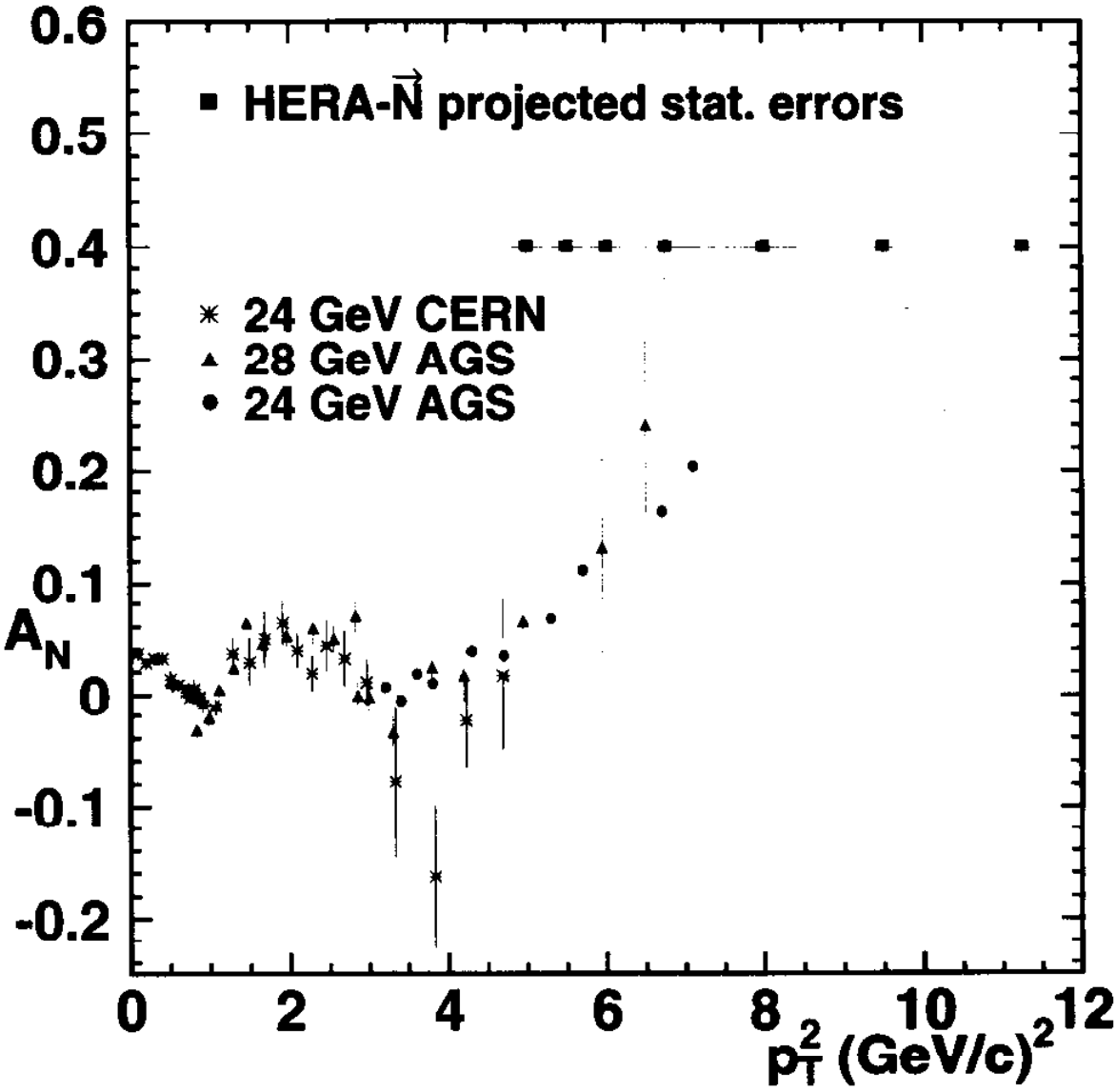


Anselmino-Murgia model predictions
(intrinsic $k_\perp$ in parton distribution functions)
in comparison to expected statistical accuracy
with HERA-$\vec{N}$

$\int \mathcal{L}\, dt = 240\ pb^{-1}$

$\mathcal{L} \cdot T = 240 pb^{-1}$

HERA-$\vec{N}$, E_p=820 GEV, $PP^{\uparrow} \rightarrow P + P$



ELASTIC
→ $\vec{p}p$ ASYMMETRIES STILL UNEXPLAINED

pQCD: $A_N \equiv 0$!

→ HERA-N CAN CONTRIBUTE IN THE HIGH p_T REGION

MOTIVATION:

ACCESS TO $\Delta G(x)$ AT LARGE x $\quad 0.1 < x < 0.3$

MOST PROMISING PROCESS

$$\vec{p}\vec{N} \longrightarrow \gamma + \text{JET} + X$$

$$qg \longrightarrow \gamma + g \qquad \text{DOMINATING}$$

$$q\bar{q} \longrightarrow \gamma + q \qquad \text{SMALL AT LARGE } x$$

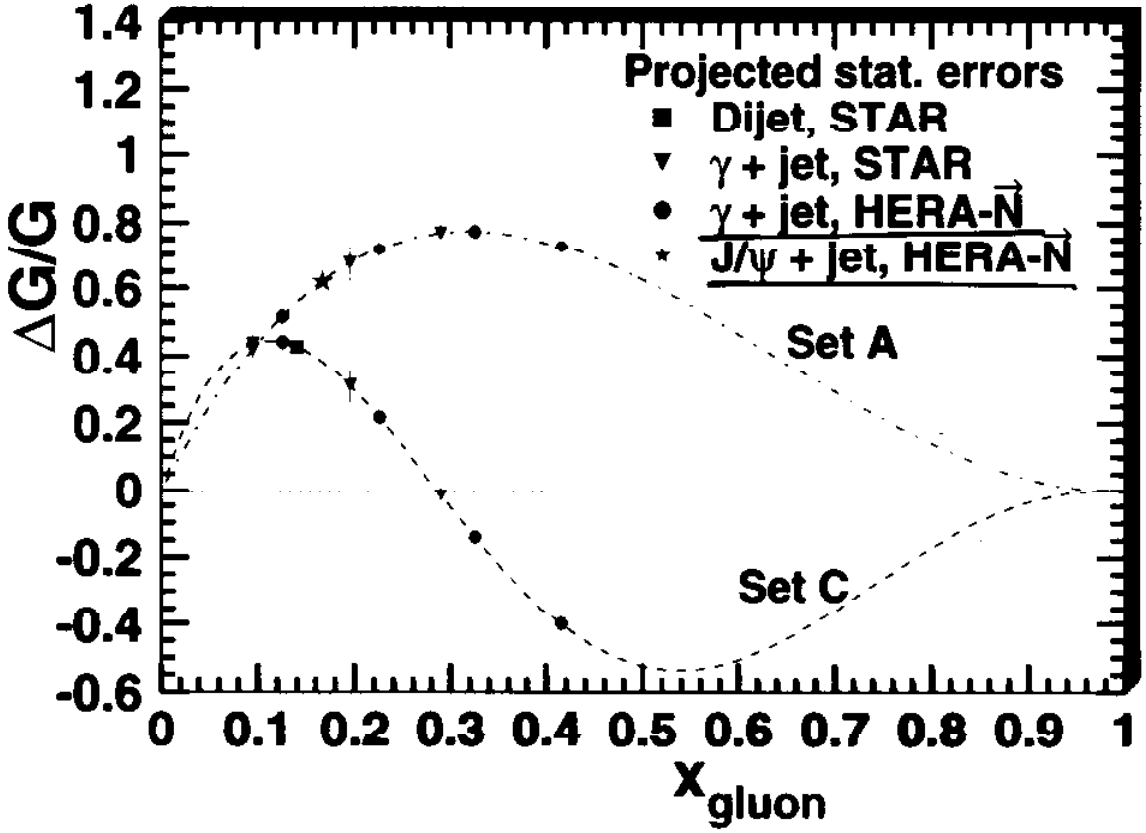
$$\frac{\Delta\sigma}{\sigma} = \frac{g_1(x)\,\Delta G(x)\,\Delta\hat{\sigma}}{F_1(x)\,G(x)\,\hat{\sigma}}$$

KNOWN ? KNOWN

- x-REGION COMPLEMENTARY TO $\vec{e}\vec{p}$ AT $\sqrt{s} = 300$ GeV
- STATISTICAL PRECISION COMPARABLE TO RHIC

OTHER PROCESSES

J/ψ PRODUCTION (COLOUR OCTET? K-FACTOR?)
Λ PRODUCTION
DY PAIRS
⋮



study $\Delta G/G$ in

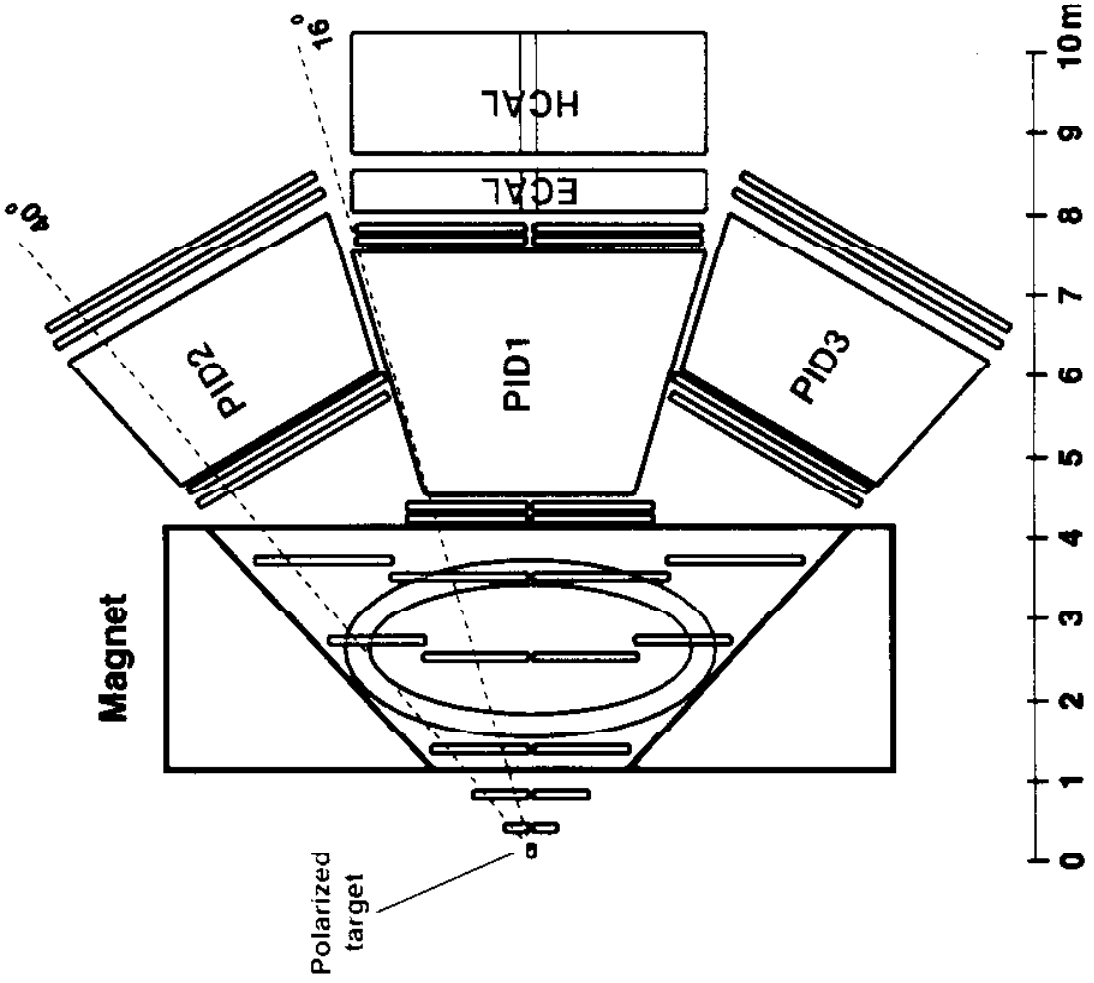
HERA-$\vec{N}$	2	4	6	8	pQCD onset region
RHIC	10	20	30		deep perturb. region

$\longrightarrow p_T$

Complementary exp'ts!

Phase I: Single spin asymr
(inclusive + elast
Phase II: Polarimeter for H

Phase II:
Double spin asymmetries
(ΔG measurement)



PHASE I $N\vec{N}$ COLLISIONS

→ STUDY THE MYSTERIOUS SINGLE SPIN ASYMMETRIE

→ STUDY ELASTIC $p\bar{p}$ ASYMMETRY

→ INFORMATION ON HIGHER TWIST CONTRIBUTIONS / NON-PERT QCD EFFECTS

→ PQCD ↔ NON-PQCD

PHASE II $\vec{N}\vec{N}$ COLLISIONS

→ MEASUREMENT OF ΔG IN THE REGION $0.1 < x < 0.4$

NOTE: HERMES: ACCEPTANCE TOO SMALL
HERA-B: ACCEPTANCE OK, BUT "BUSY"

↳ BEST SOLUTION WOULD BE A NEW DEDICATED NUCLEON-NUCLEON SPIN EXPERIMENT

~ 40 people
To DATE

1997 WORKSHOP ON

PHYSICS WITH POLARIZED PROTONS AT HERA

HTTP://WWW.DESY.DE/~GEHRT/HERASPIN/

March - September, 1997
DESY-Hamburg and DESY-Zeuthen

Programme for the first meeting, March 6/7, DESY-Hamburg
Summary of the first meeting, March 6/7, DESY-Hamburg
Next meeting: May 26/27, DESY-Hamburg

Tools and related pages

- Technical Data Sheet for Polarized Protons at HERA
- Polarized Monte Carlo Generators: e-p (PEPSI), p-p and gamma-p (SPHINX)
- Polarized Parton Distributions
- HERA-N homepage
- DESY Proton Polarization Group homepage

Aims and scope

The working group "Polarized Protons and Electrons" of last year's "Future physics at HERA" workshop has established the physics interest for polarization of the HERA proton beam. As a result, the option of polarized protons appears now to be one of the most promising scenarios for the mid-term future of HERA.

In order to create a sufficiently strong "physics case" for polarized protons at HERA, it is now necessary

CONTRIBUTIONS WELCOME !

PHYSICS WITH POLARIZED PROTONS AT HERA

* EXTEND STUDIES USE NEW DATA — E.G. ΔG FROM JETS → NLO
* DETECTOR EFFECTS
* ANALYSIS OF SYSTEMATICS OF THE 'KEY MEASUREMENTS' / RADIATIVE CORRECTIONS
* NEW TOPICS →
* FURTHER THEORETICAL PROJECTS (E.G. MEPJET IN NLO) AND MONTE CARLO PROGRAM UPGRADES (E.G. g_5, PARTON SHOWERS IN PEPSI)
* DISCUSSION GROUP FOR POLARIMETRY AT HIGH PROTON ENERGIES (WITH RHIC & OTHERS)
  ↳ GETTING STARTED
* DISCUSSION GROUP FOR D, ^{3}He BEAMS (WITH RHIC)
  ↳ THIS SUMMER
* RUNNING HERA AT LOWER ENERGIES?
  FURTHER DETECTOR REQUIREMENTS

* g_1 STUDY OF SYSTEMATICS
CHARM PART OF g_1

* ΔG JETS LO/NLO
CHARM PRODUCTION
VECTOR MESONS
PROMPT PHOTONS
HIGH p_T TRACKS
↑ JET MEASUREMENTS IN γp

* g_5 CHARGED CURRENTS

* NLO QCD FITS g_1
g_1 (+g_5) (+JETS) ...

* SEMI INCLUSIVE MEASUREMENTS

* DIFFRACTION

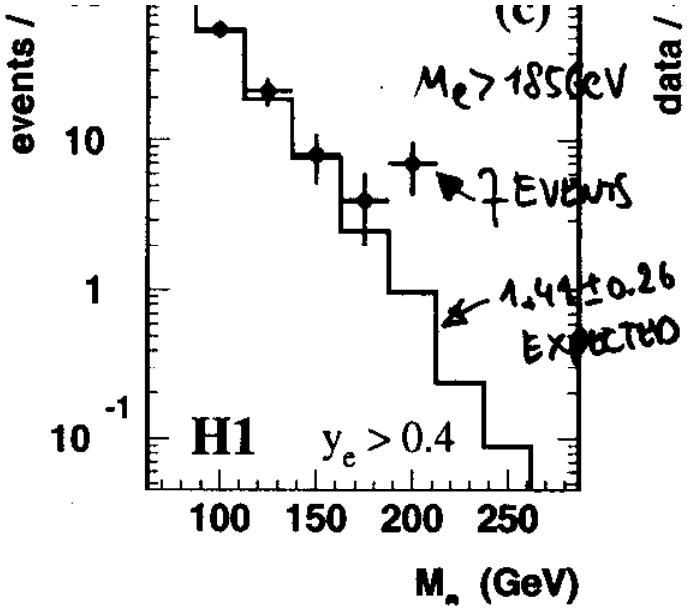
* POLARIZED PARTONS IN THE PHOTON

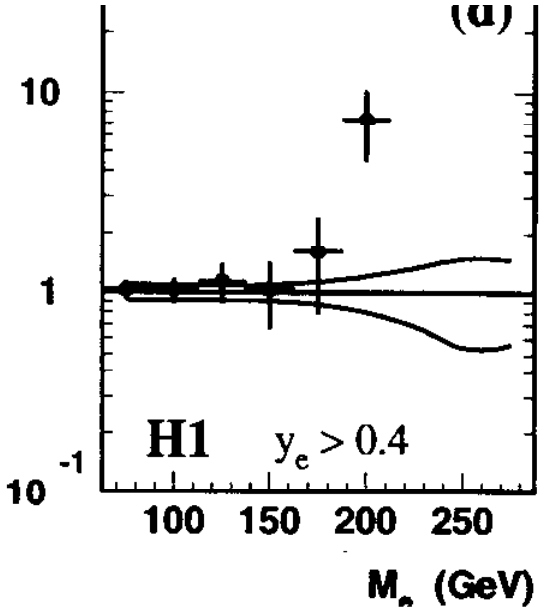
* DEEPLY VIRTUAL PHOTON SCATTERING

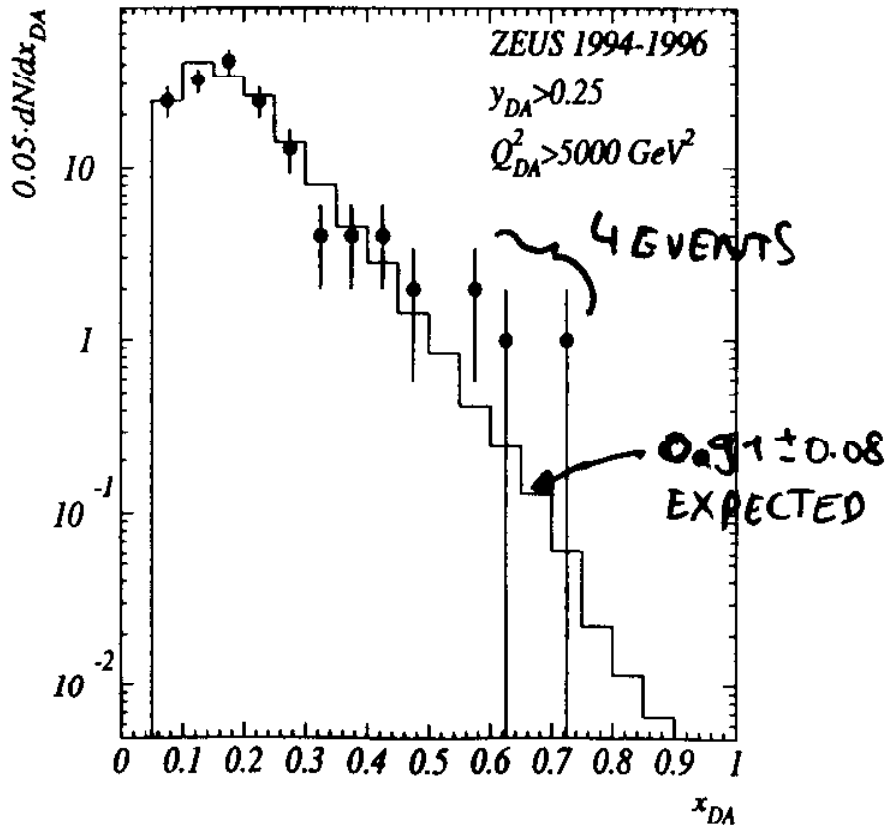
* ? HIGH Q^2 EVENTS OBSERVED IN H1/ZEUS

* TRANSVERSE SPIN QUESTIONS? g_2? h_1?

* $\vec{p}\vec{p}$: DRELL-YAN / VECTOR MESONS / OPEN CHARM







$X > 0.55$

J ELLIS. : USE POLARIZED $\vec{e}\vec{p}$ COLLISIONS TO STUDY
J. COLLINS THE SPIN STRUCTURE OF THE "NEW INTERACTION"
N. KOTCHELEV (Δu, Δd)

POLARIZED BEAMS OF PROTONS AND ELECTRONS PROVIDE AN ATTRACTIVE AND UNIQUE PHYSICS PROGRAM AT HERA, COMPLEMENTARY TO STUDIES AT OTHER MACHINES

- $g_1(x, Q^2)$ AT LOW x
- ΔG : $0.002 < x < 0.4$ (DIRECTLY)
- $g_5(x, Q^2)$ FROM CC EVENTS
- Δq IN THE PHOTON
- $\vec{N}\vec{N}$ ASYMMETRIES

(- ELECTROWEAK TESTS)

...

TIME PLANS

* WORKSHOP : NOW → FALL '94

$\vec{e}p$ AT $\sqrt{s} = 300$ GeV
SPIN ROTATORS : INSTALATION PLANNED FOR SHUTDOWN 1999/2000

$\vec{e}\vec{p}$ AT $\sqrt{s} = 300$ GeV
? POLARIZED PROTONS : 2005 ± ? (UNDER DISCUSSI

$\vec{p}p$ AT $\sqrt{s} = 40$ GeV → NEEDS EXP. / POLAR. TARGET

$\vec{p}\vec{p}$ AT $\sqrt{s} = 40$ GeV → Σ ($\vec{e}\vec{p} + \vec{p}p$)