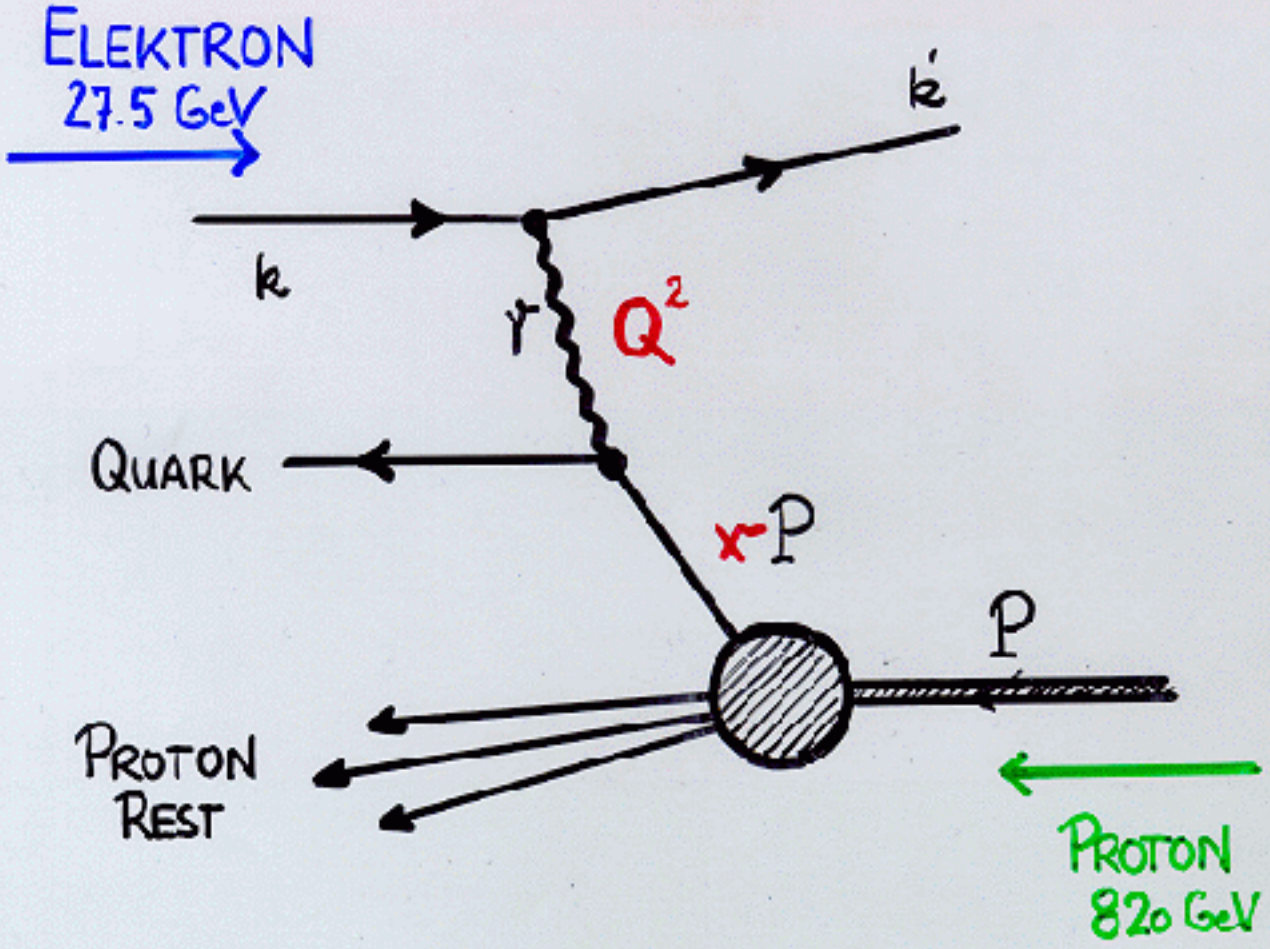
Experimentelle Untersuchung der Partondynamik am ep-Speicherring HERA

Hans-Christian Schultz-Coulon
für die HERA ep-Experimente

DPG-Tagung, Dresden
20. - 24. 3. 2000

KINEMATIK

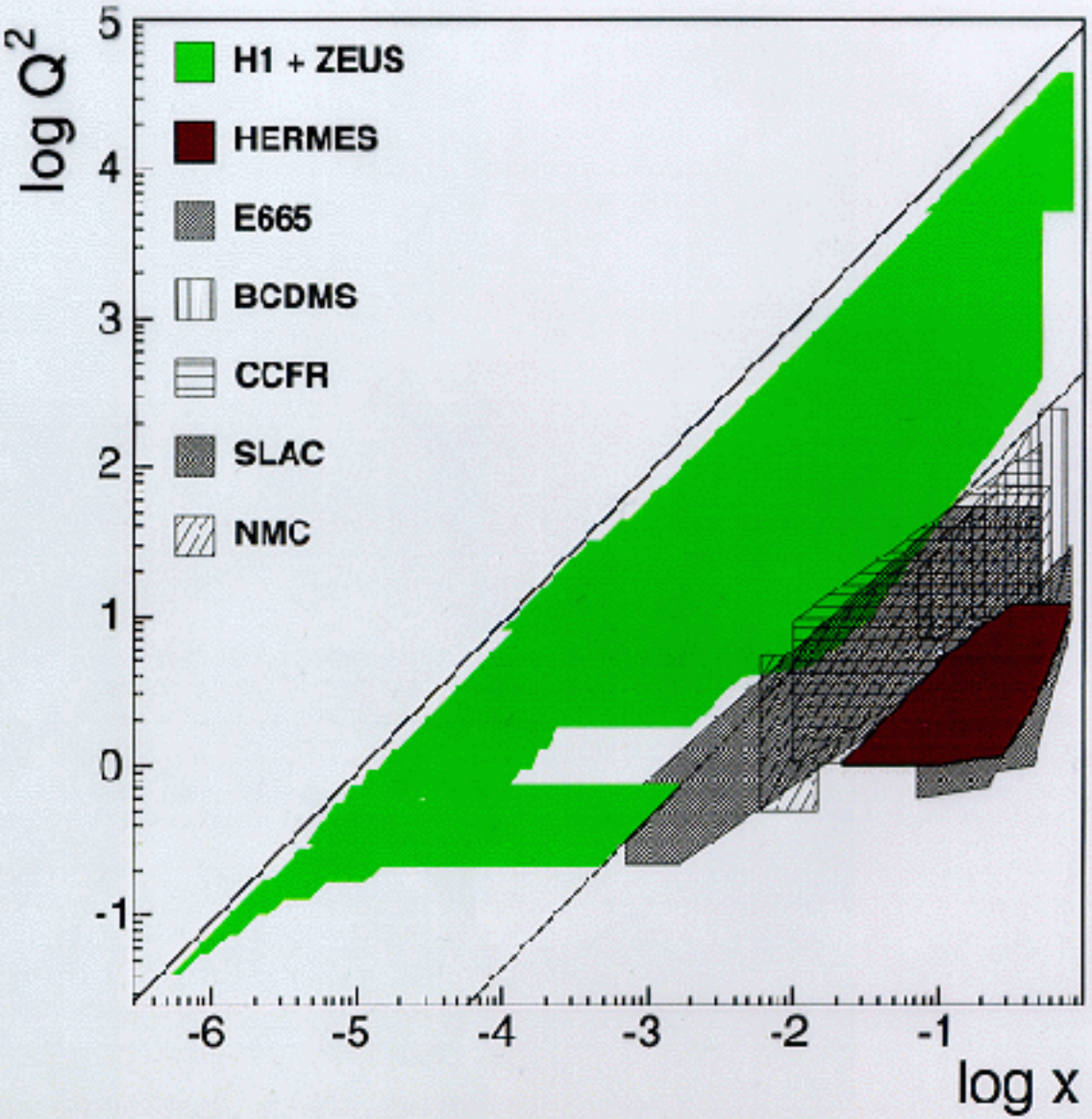


$$Q^2 = -(k - k')^2 = -q^2$$

$$x = Q^2 / 2Pq$$

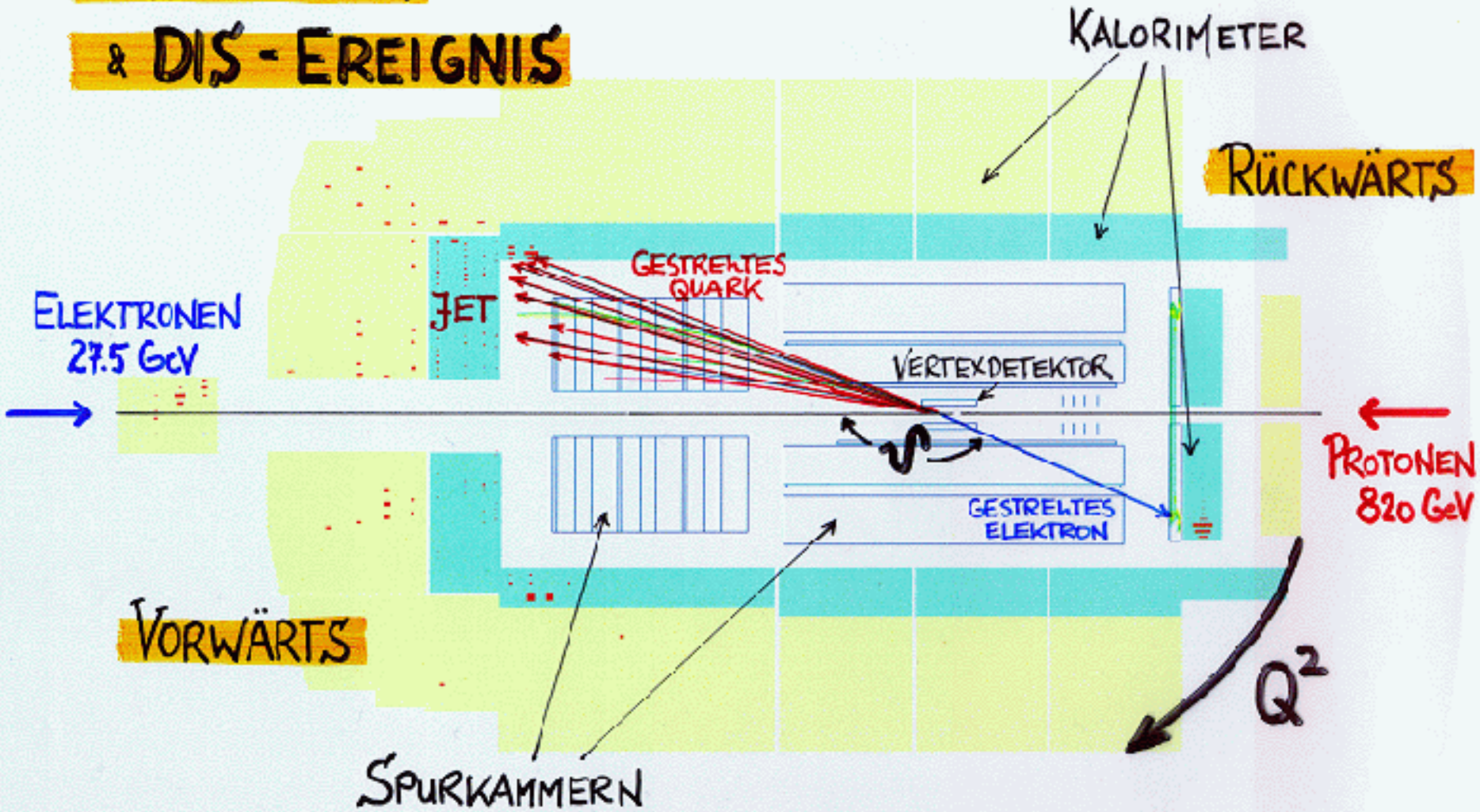
VIERERIMPULS-
ÜBERTRAG

BJORKEN SKALENVARIABLE

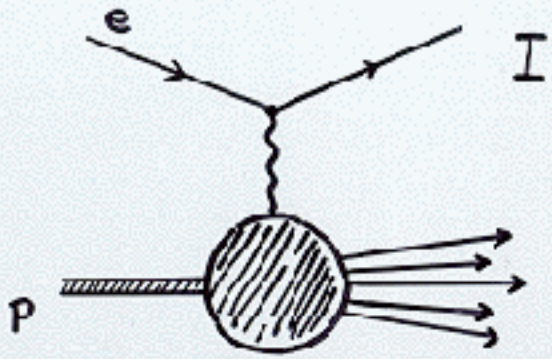

log Q^2
5
4
3
2
1
0
-1
H1 + ZEUS
HERMES
E665
BCDMS
CCFR
SLAC
NMC
-6
-5
-4
-3
-2
-1
log x

"TYPISCHER" HERA

DETEKTOR & DIS-EREIGNIS

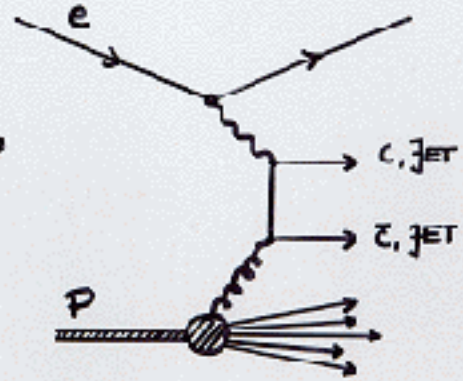


$$Q^2 = 4 E_e E'_e \cos^2 \vartheta_e/2$$

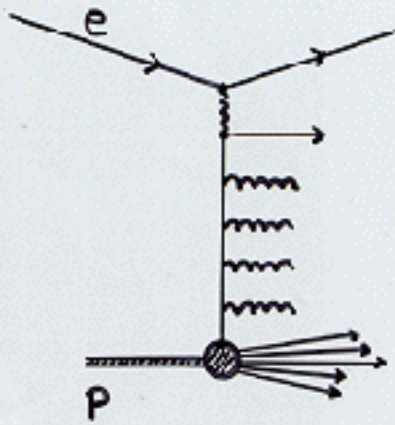


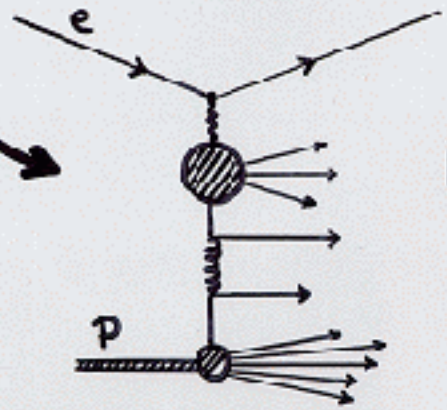
I. INKLUSIVE MESSUNGEN

II. 2-JET PRODUKTION



III. PARTON-LEITERN

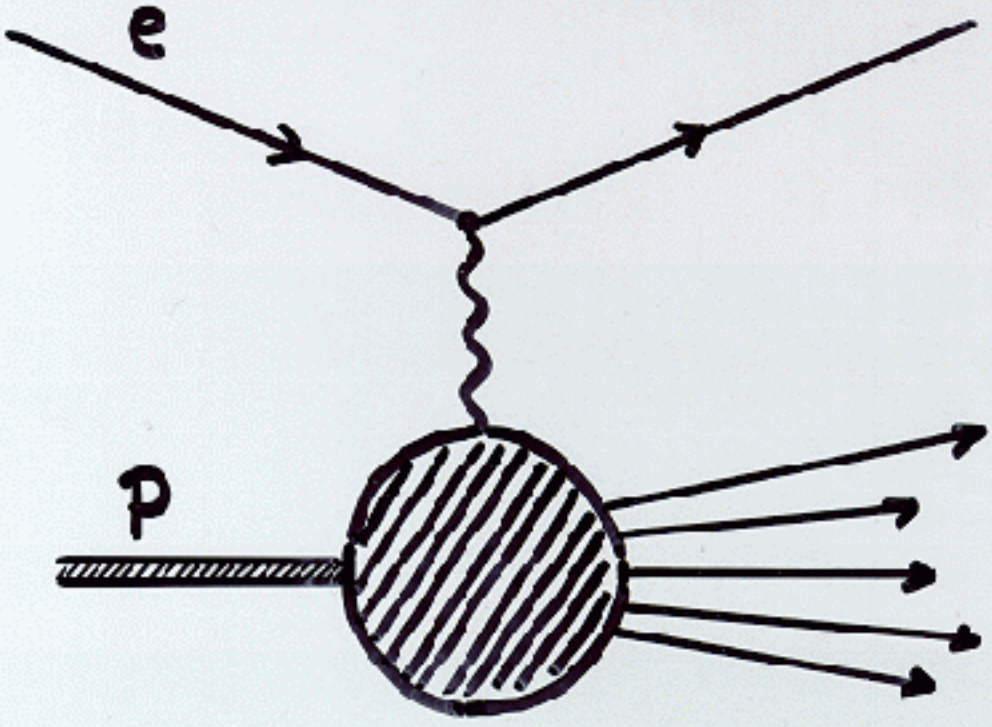




IV. PHOTON-STRUKTUR

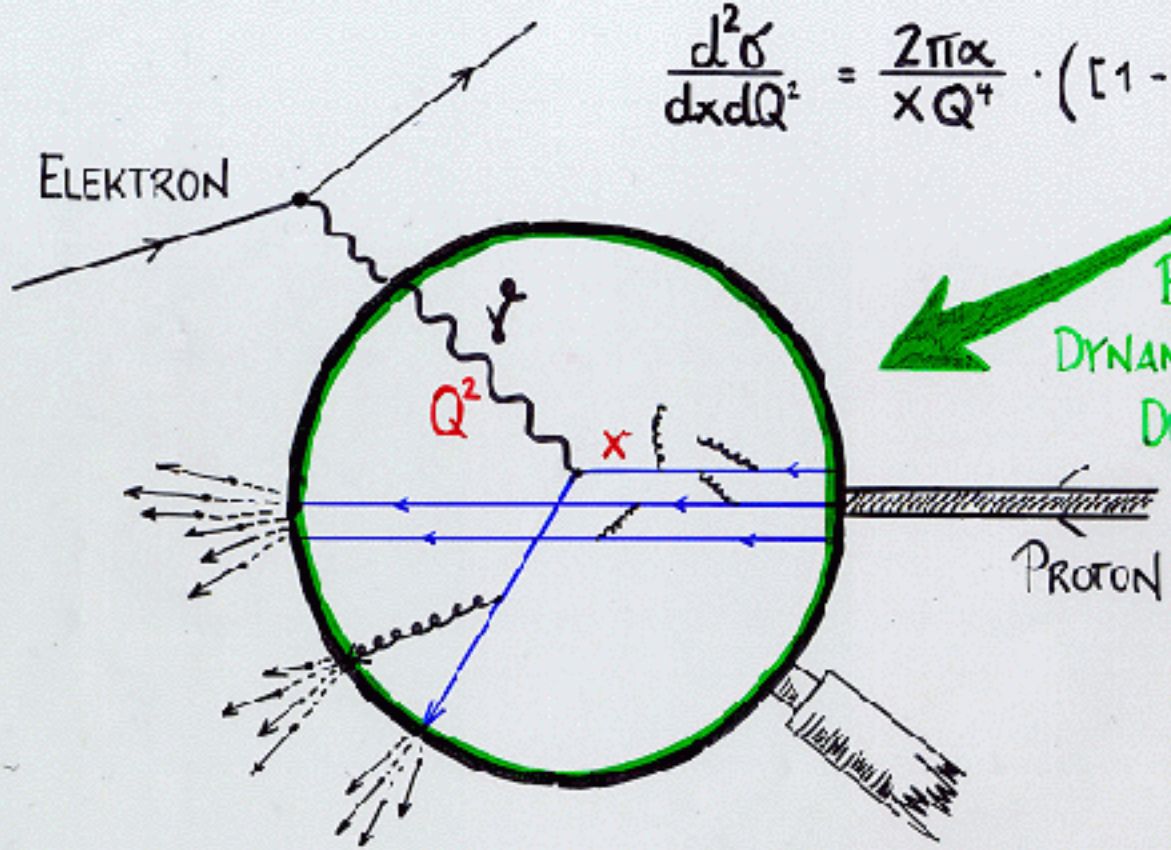
I.

Inklusive Messungen



ep-Streuung

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha}{xQ^4}\cdot\left([1-(1-y)^2]\,F_2(x,Q^2) - \underbrace{y^2F_L}_{\approx 0}\right)$$



Beschreibt
Dynamische Struktur
Des Protons

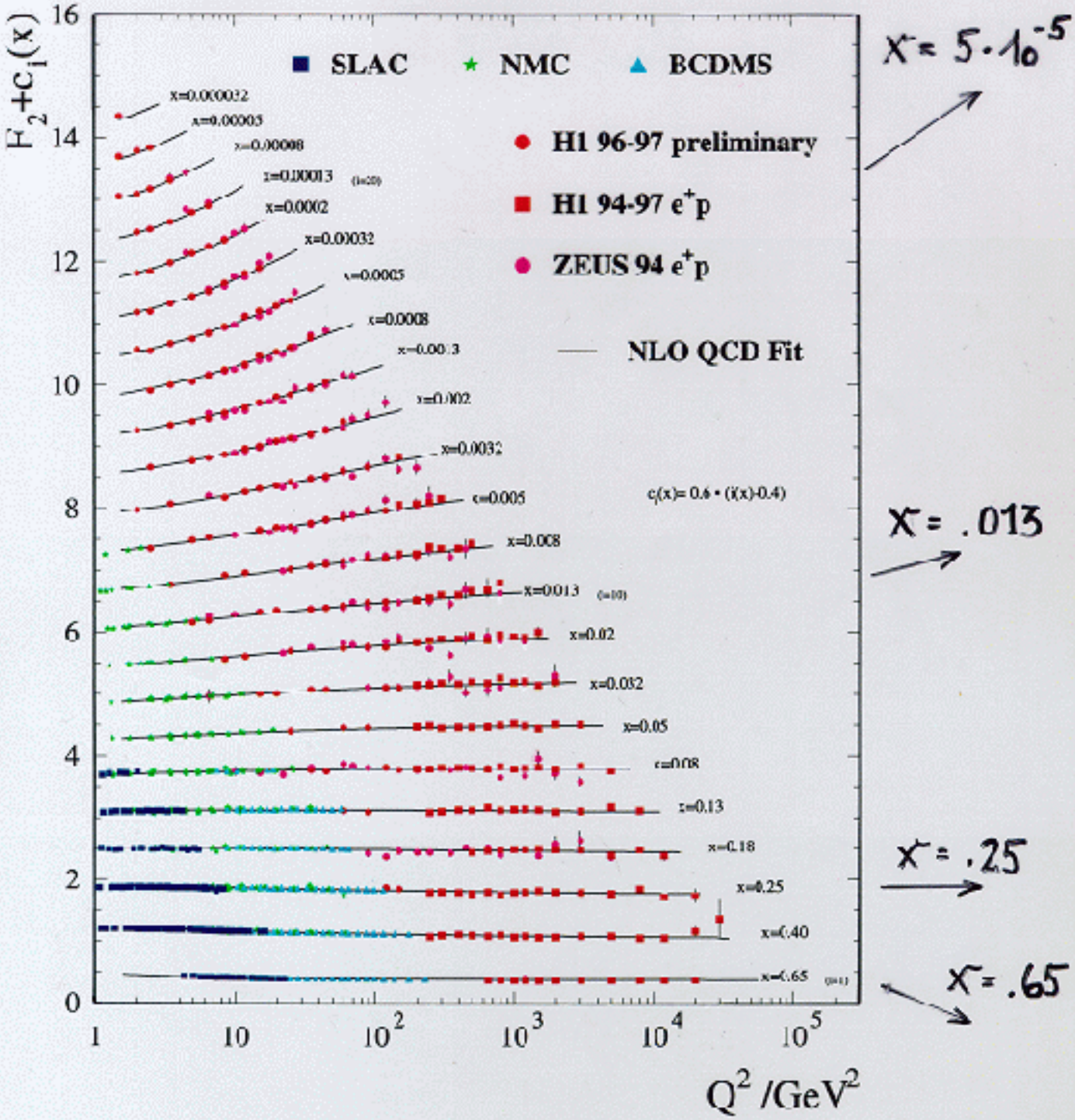
QPM:

$$F_2 = \sum_q e_q^2 \cdot xq(x)$$

HERA: Ideales Labor zur Untersuchung der (Parton)-Dynamik in ep-Wechselwirkungen

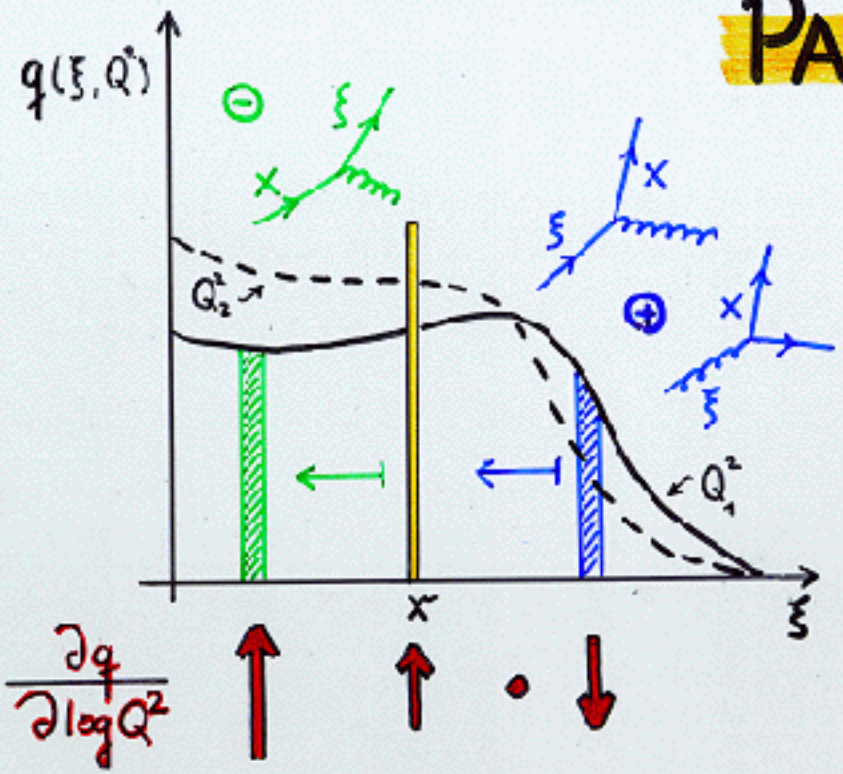
SKALENVERLETZUNG

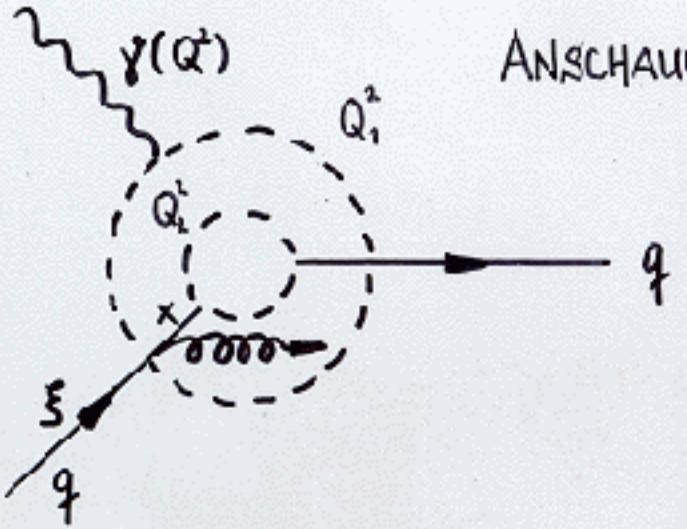
$$F_2(x,Q^2) = x \sum_q e_q^2 \, q(x,Q^2)$$



PARTONDYNAMIK IM RAHMEN DER PQCD

[DGLAP-ENTWICKLUNG]





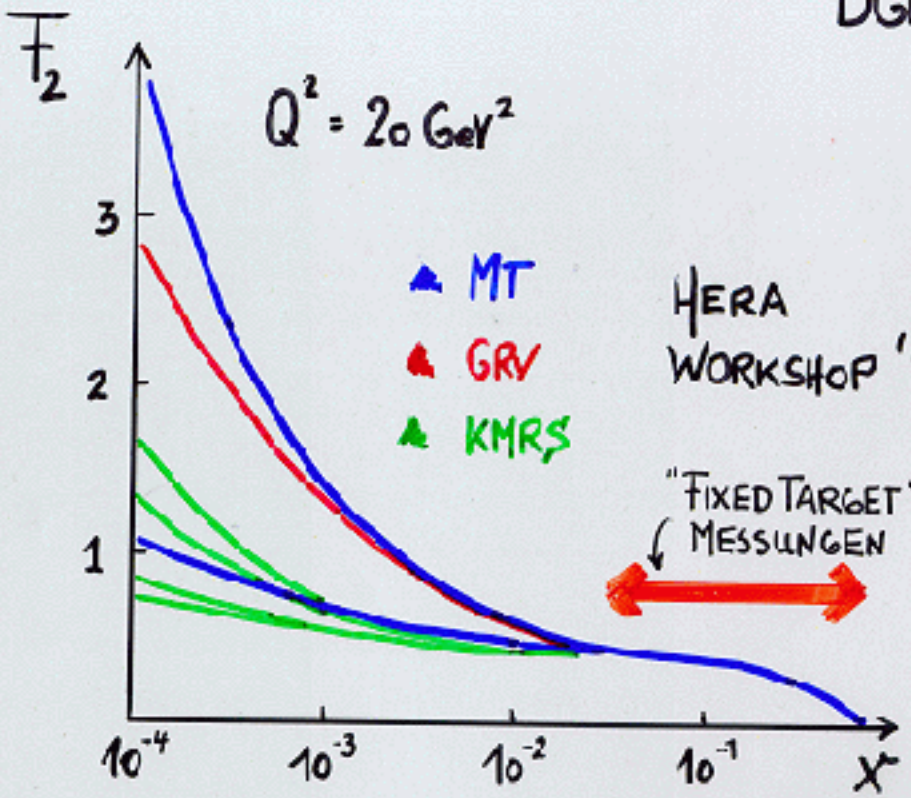
ANSCHAUUNG

$$\frac{\partial}{\partial \log Q^2}\begin{bmatrix} q(x,Q^2) \\ g(x,Q^2) \end{bmatrix} = \frac{\alpha_s}{2\pi}\begin{bmatrix} P_{q/q}\left[\;\right] & P_{q/g}\left[\;\right] \\ P_{g/q}\left[\;\right] & P_{g/g}\left[\;\right] \end{bmatrix} \otimes \begin{bmatrix} q(x,Q^2) \\ g(x,Q^2) \end{bmatrix}$$

WOBEI $\quad P \otimes f(x,Q^2) = \int_x^1 \frac{dy}{y} P(x/y) f(y,Q^2)$

F_2 BEI KLEINEN x

$$\frac{\partial}{\partial \log Q^2}\begin{pmatrix} q \\ g \end{pmatrix} = \frac{\alpha_s}{2\pi}\begin{bmatrix} P_{qq} & P_{qg} \\ P_{gq} & P_{gg} \end{bmatrix} \otimes \begin{pmatrix} q \\ g \end{pmatrix}$$



HERA WORKSHOP '91

"FIXED TARGET" MESSUNGEN

DGLAP: KEINE VORHERSAGE DER x-ABHÄNGIGKEIT VON F_2

[AUSG. ASYMPTOTISCHES VERHALTEN]
A. De Rujula et al. 1974

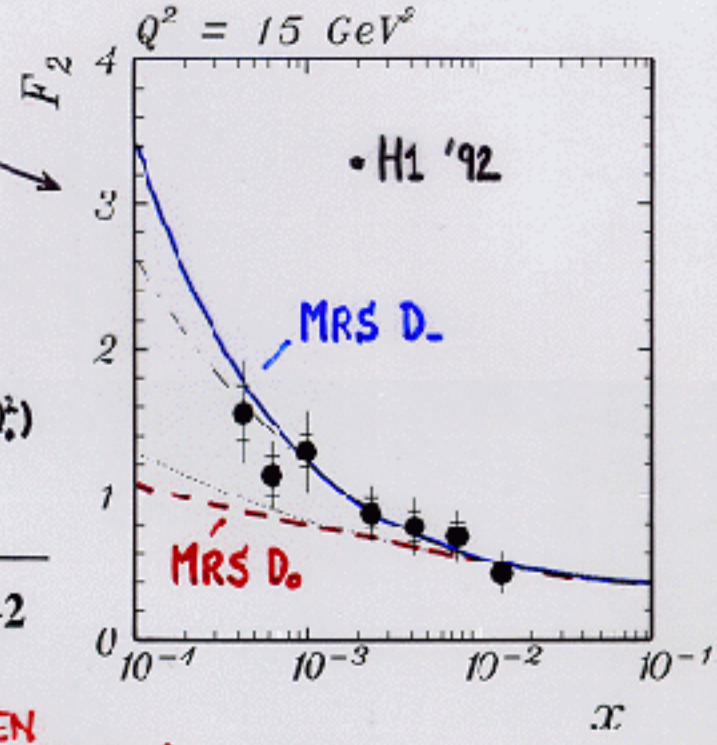
MESSEN!!

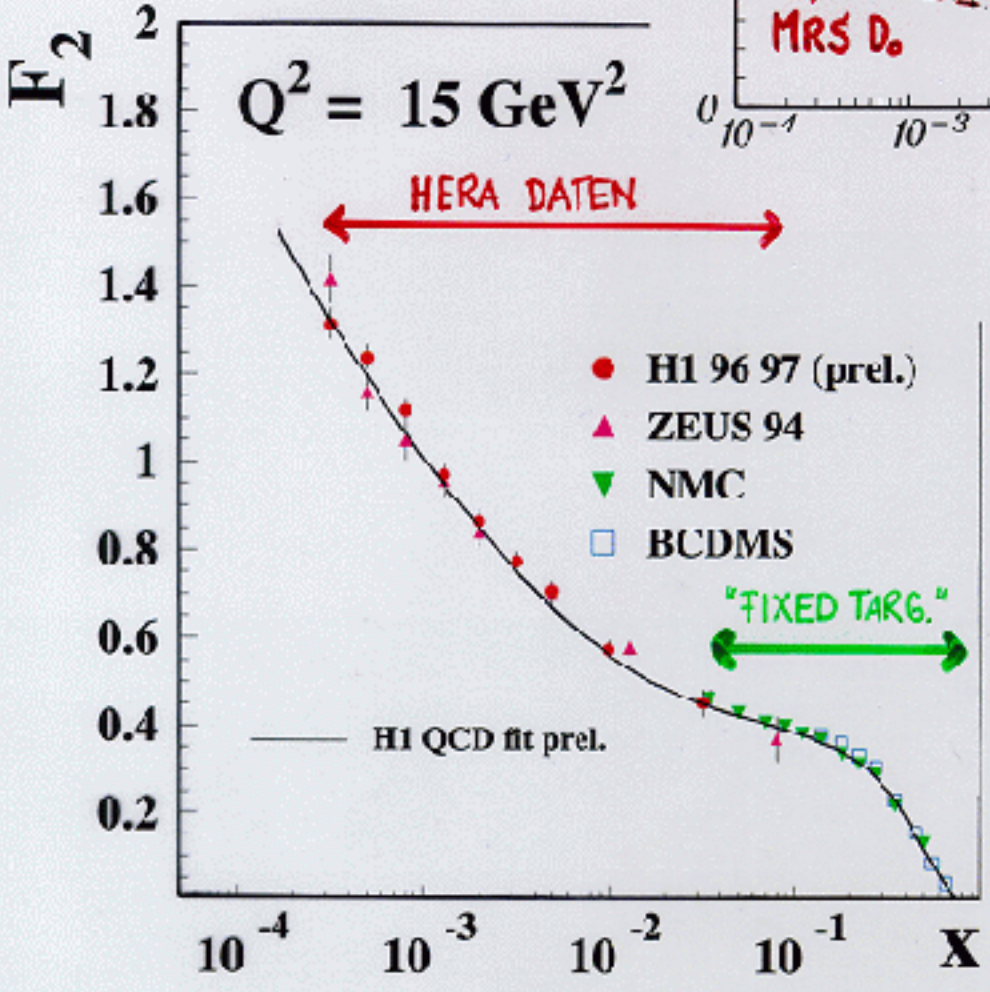
MÖGLICHKEIT ZUR BESTIMMUNG VON $g(x, Q^2)$

$F_2(x)$ BEI $Q^2 = 15\ GEV^2$

MRS D$_0$, D$_-$:

- ANPASSUNG AN FIXED TARGET DATEN
- UNTERSCHIEDLICHE ANNAHME FÜR $x^+g(x,Q_0^2)$





96/97er Daten:

2-3%

PRÄZISION

EXTRAKTION DER GLUONDICHTE

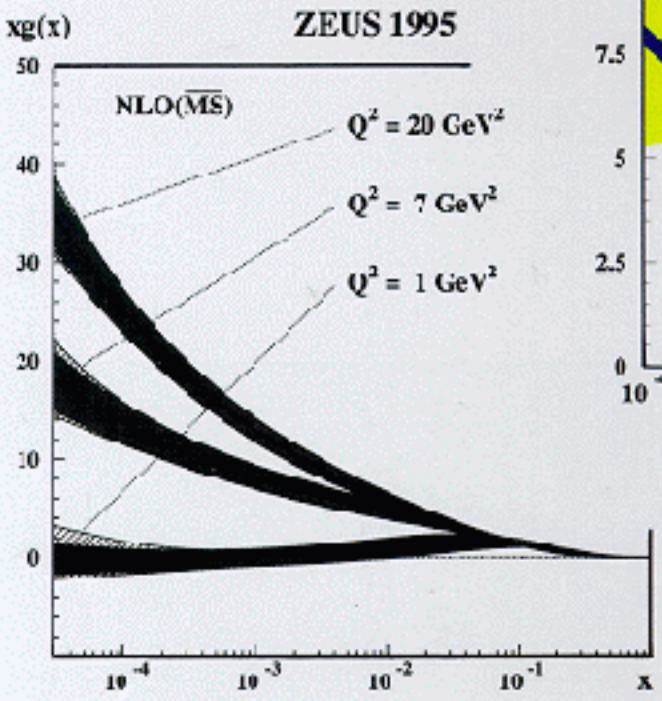
[NLO-QCD-FIT]

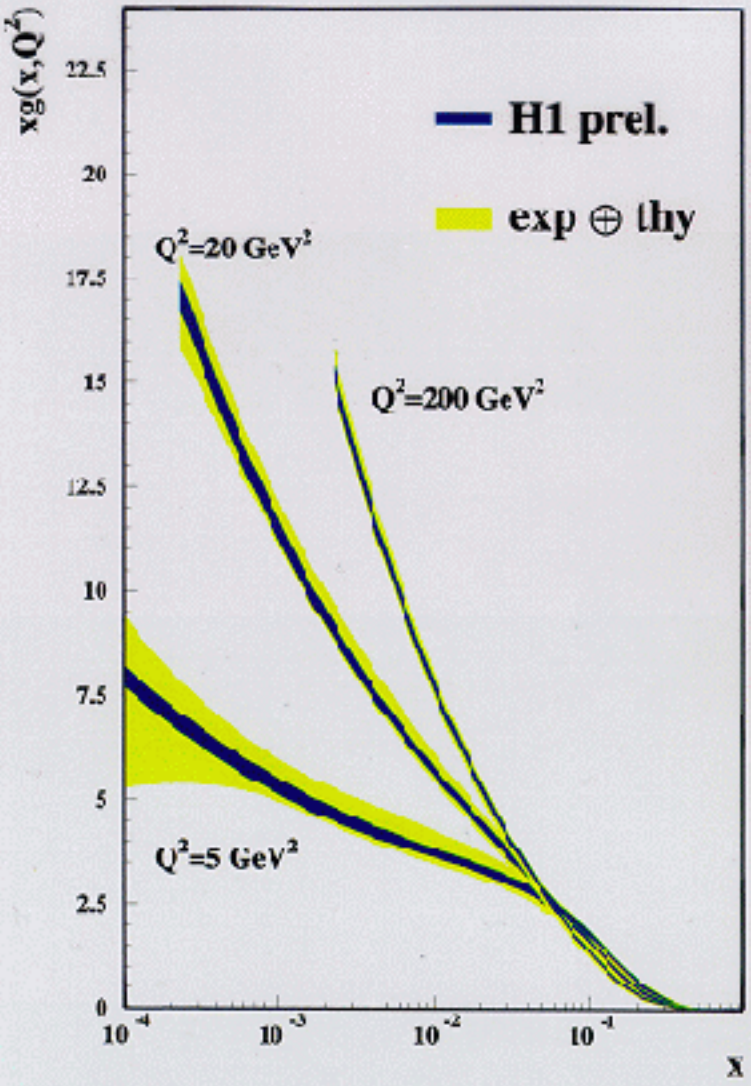
INPUT:

F_2^{HERA}

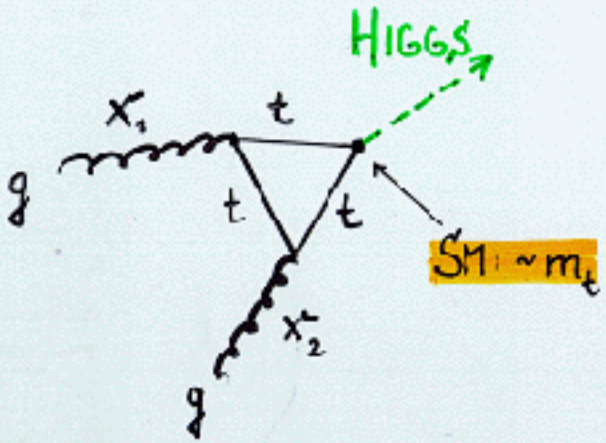
α_s

q_v \ VALENZQUARK-VERTEILUNG





Die Gluondichte, LHC und das Higgs

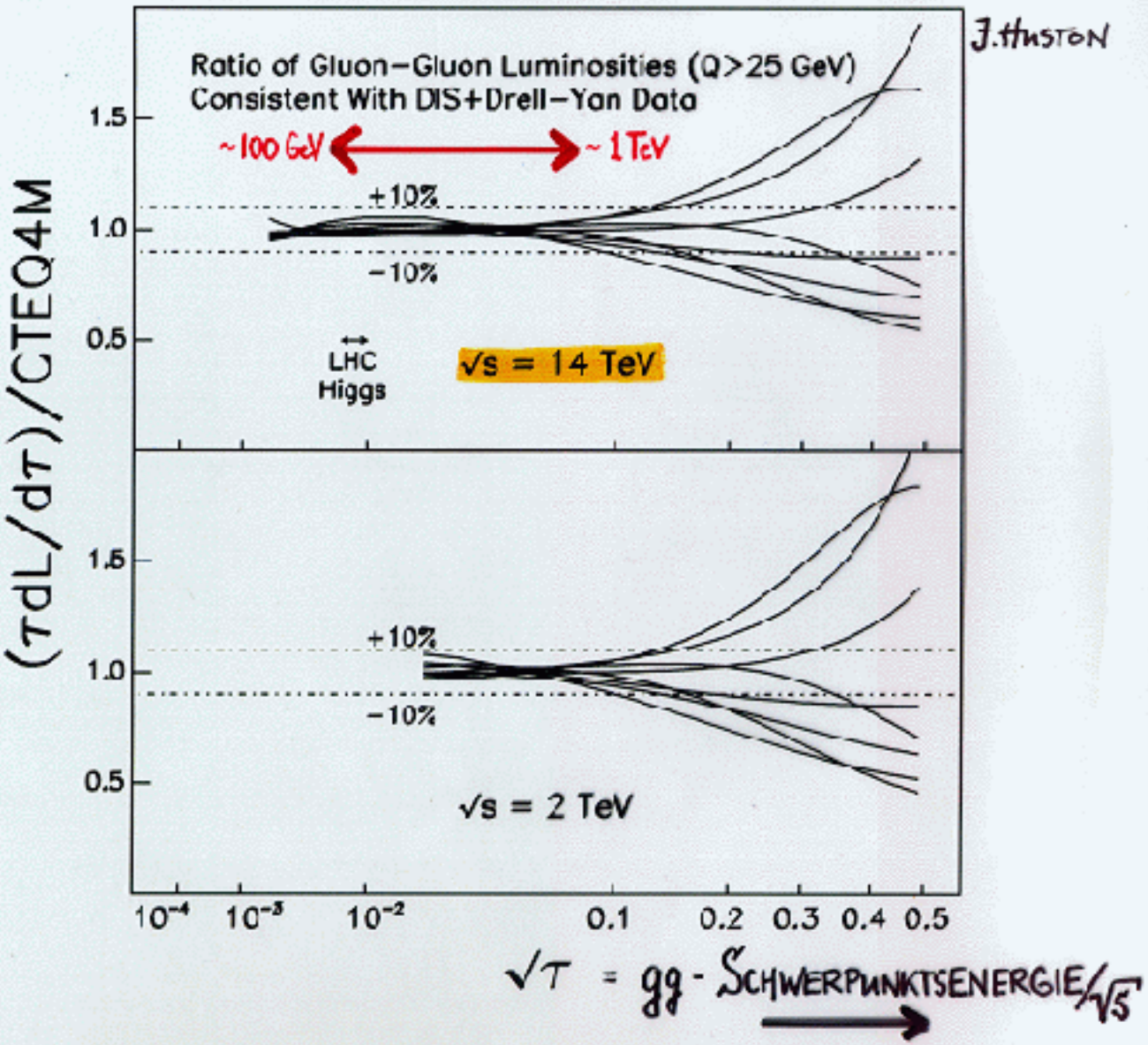


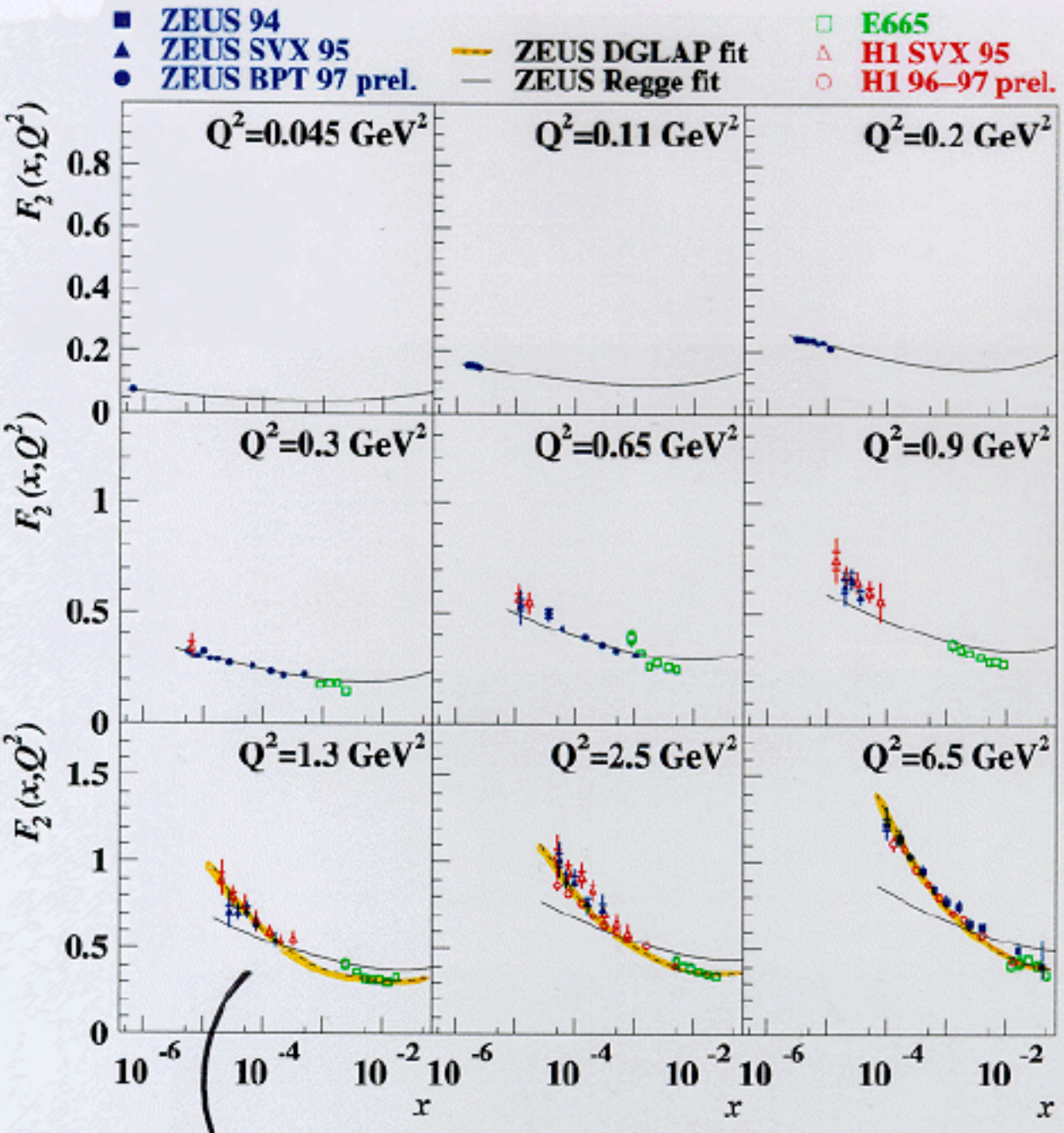
$M_H^2 = x_1 x_2 s =: \tau s$

Gluon - Gluon - Luminosität

$$\frac{\tau dL}{d\tau} = \int_\tau^1 G(x,Q^2)\, G(\tau/x, Q^2)\, \frac{dx}{x}$$

mit $Q^2 = \tau s$





pQCD BESCHREIBT INKLUSIVE
ep-DATEN BIS $Q^2 \sim 1\,GeV^2$

INKLUSIVE MESSUNGEN ZUSAMMENFASSUNG

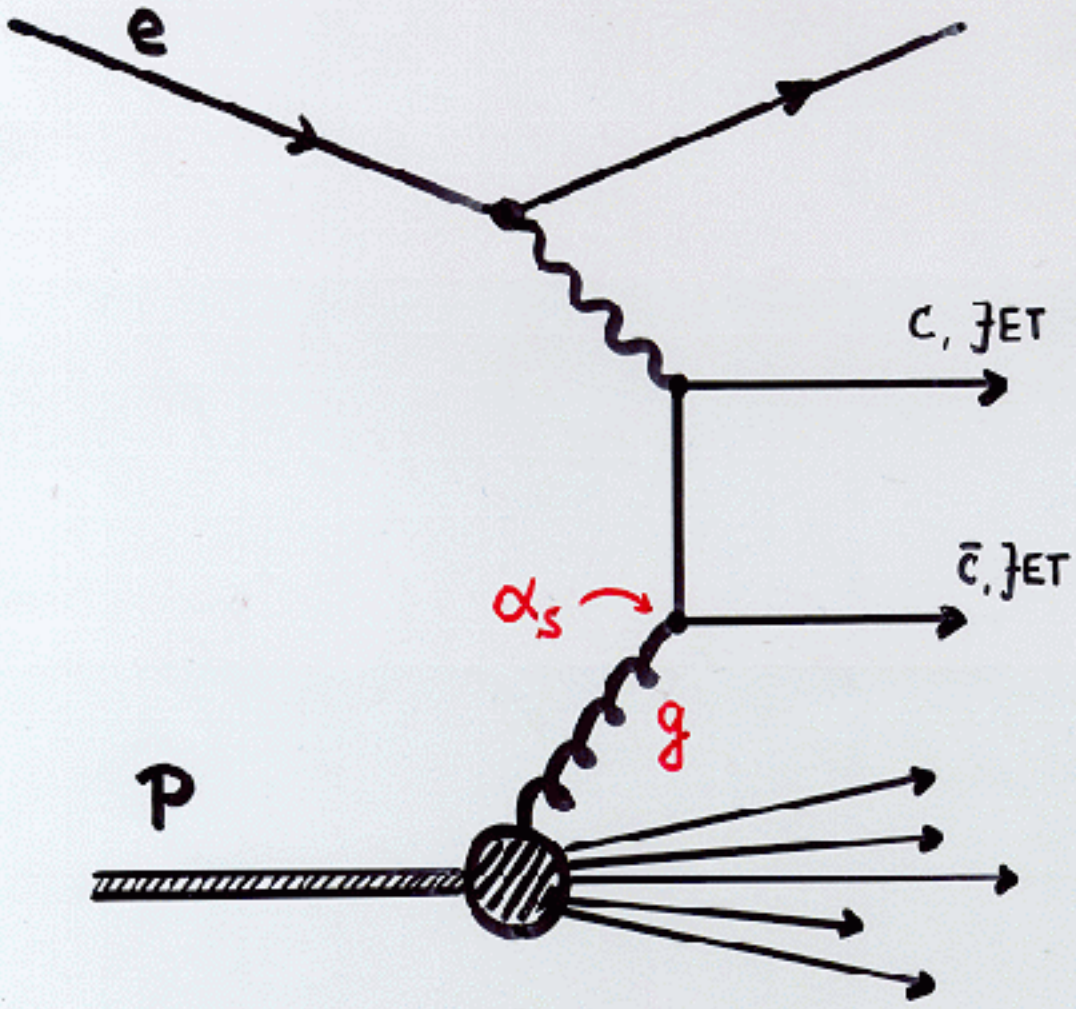
$\Delta F_2 / F_2 \sim 2\text{-}3\%$

DGLAP FORMALISMUS ✓
[BIS $Q^2 \sim 1 GeV^2$]

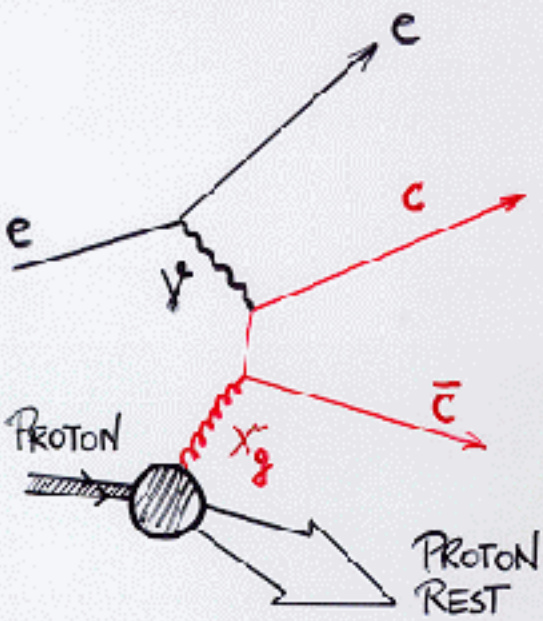
↳ $xg(x)$ [10 % GENAU]

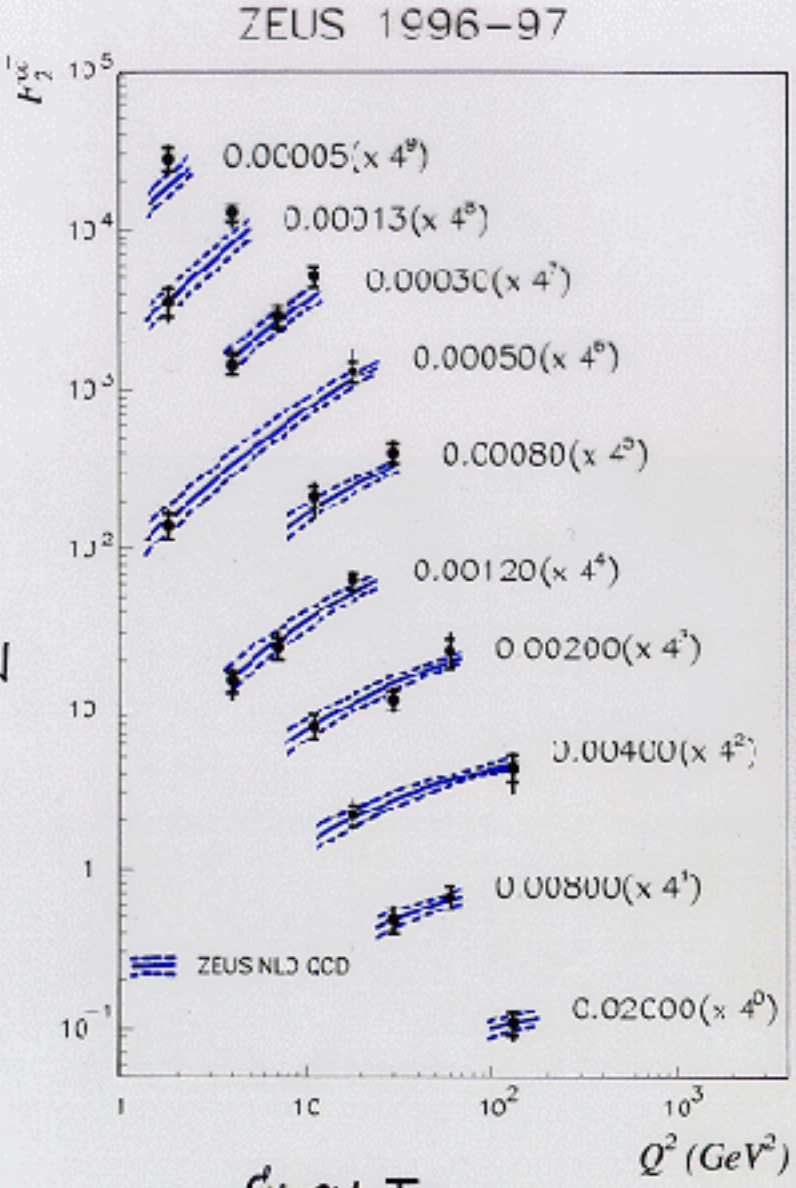
II.

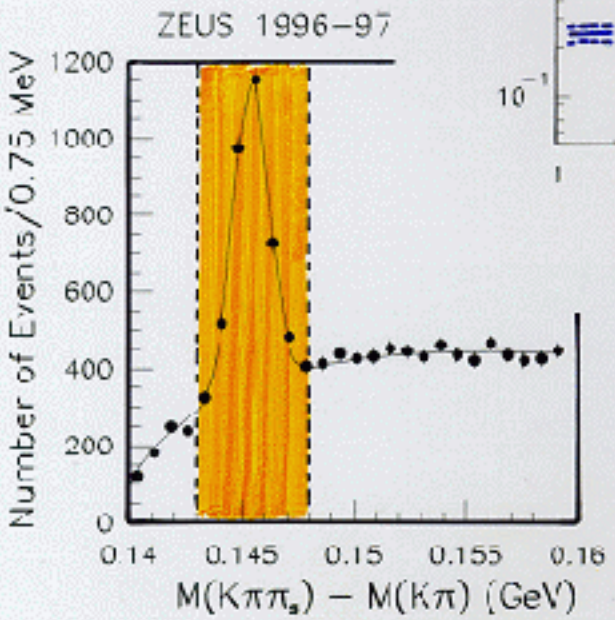
2-Jet Produktion



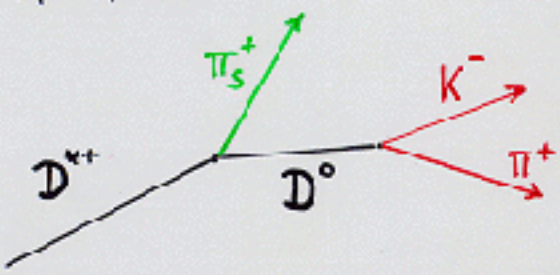
DIREKTE MESSUNG DER GLUONDICHTE







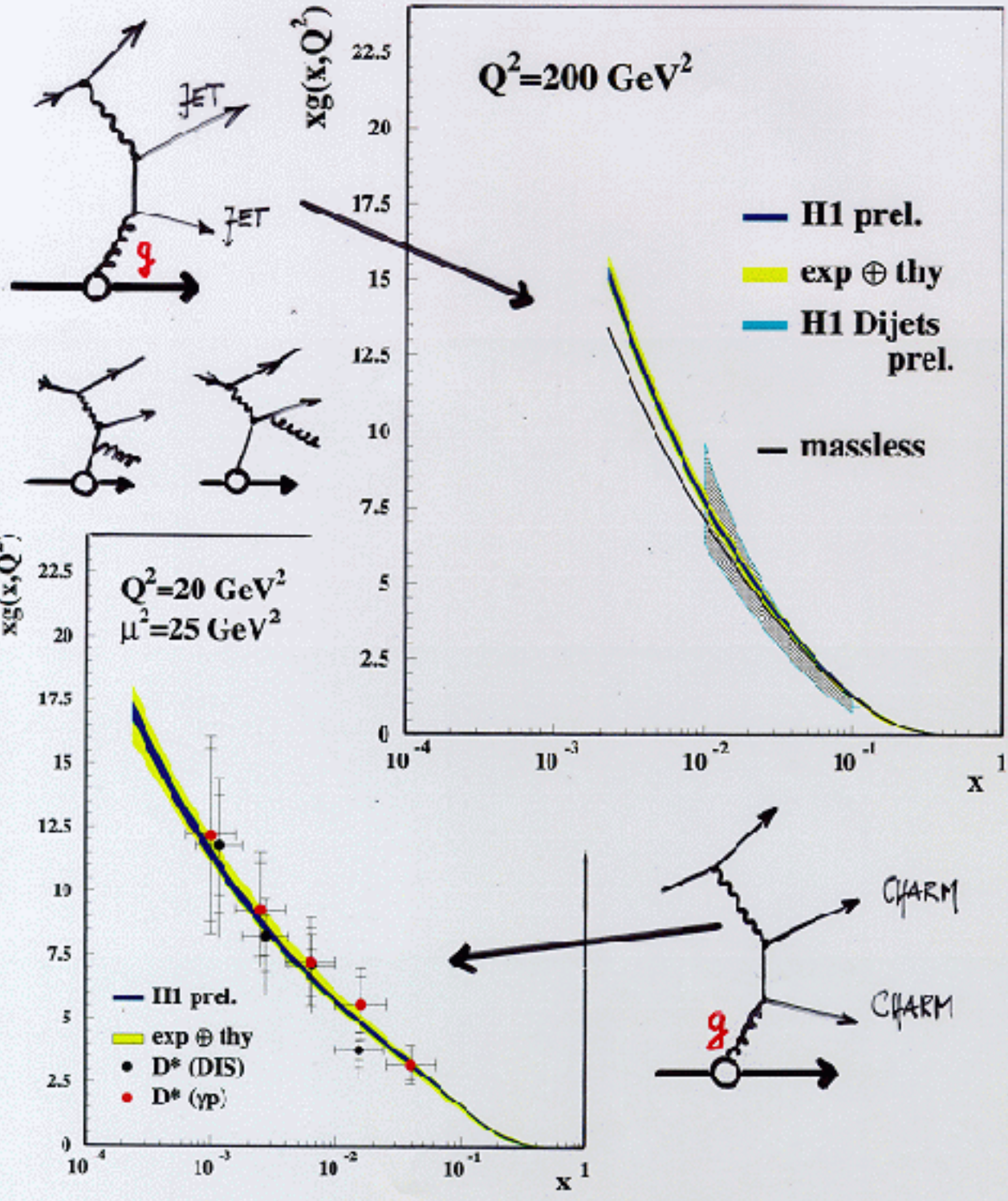
CHARM-TAG:



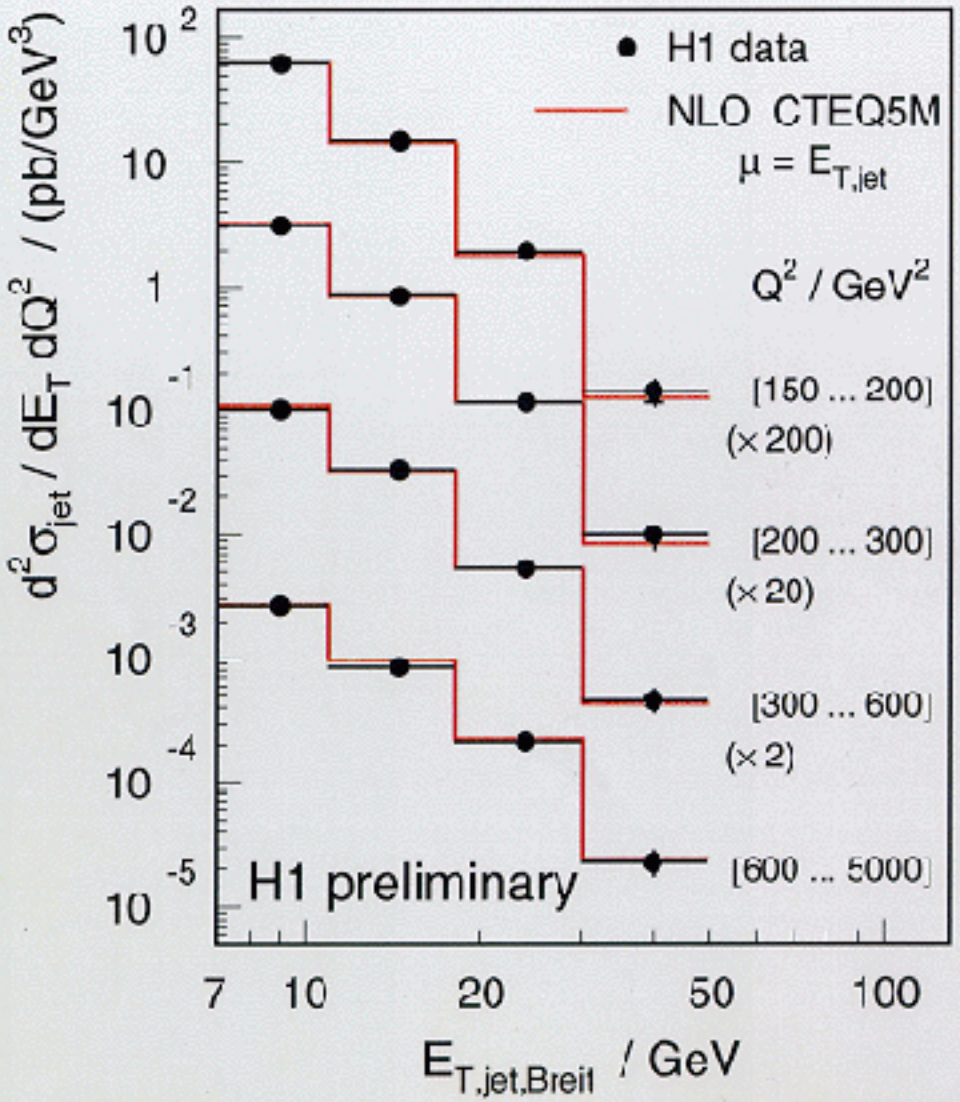
1. $D^{*+} \rightarrow D^0\pi^+ \rightarrow K\pi\pi^+$
2. $D^{*+} \rightarrow D^0\pi^+ \rightarrow K3\pi\pi^+$

DIE GLUONDICHTE AUS 2-JET UND CHARM PRODUKTION

H1 96-97



INKLUSIVER JET-WQ



PARTONVERTEIL.

$$\sigma_{JET}^{pQCD} = \sum_n \alpha_s^n \left(\sum_{i=qg} C_{i,n} \otimes f_i \right)$$

BERECHENBAR

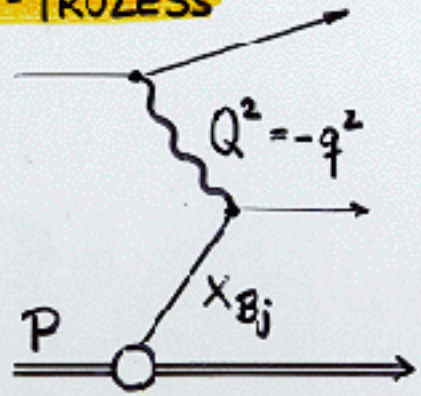
$$\sigma_{JET}^{GEM.} = \sigma_{JET}^{pQCD} \cdot (1 + \delta)$$

HADRONISIERUNGSKORR.: < 10%

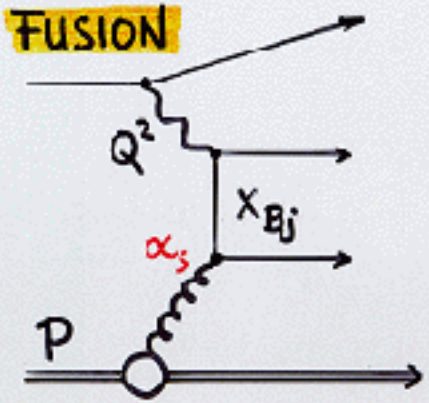
SENSITIVITÄT FÜR α_s !!!

Inklusiver Jet-WQ und das Breit-Syst.

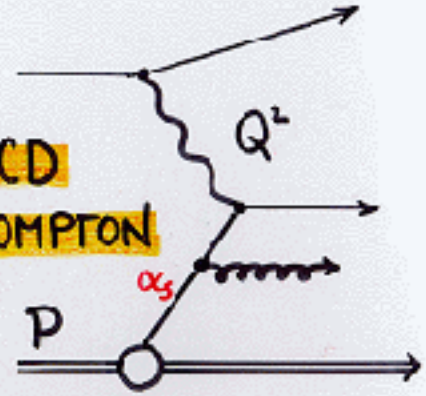
Born-Prozess



Boson-Gluon Fusion



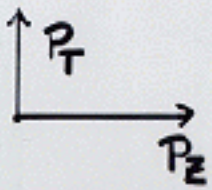
QCD Compton

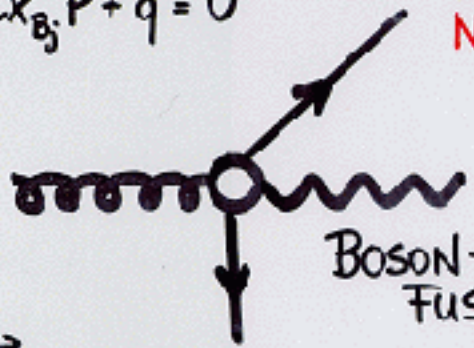


Breit-System: $2x_{Bj}\vec{P} + \vec{q} = 0$

E_T gross nur für $\mathcal{O}(\alpha_s)$

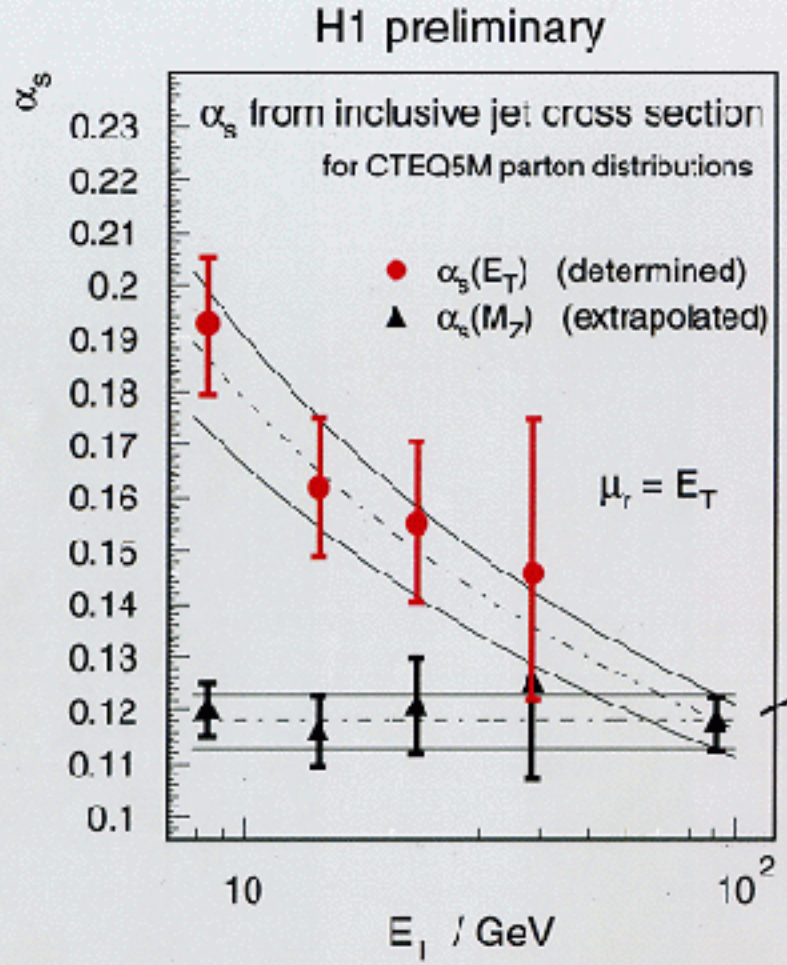
Born Prozess

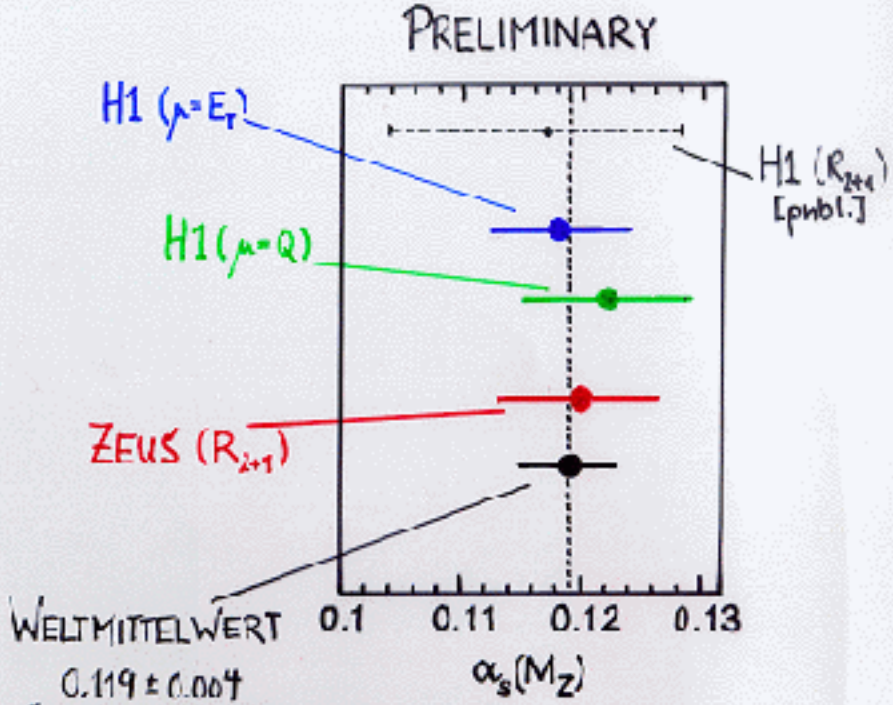




Boson-Gluon Fusion

Bestimmung von α_s





$\alpha_s(M_Z) = 0.1181 \pm 0.0030$ (exp.)

$^{+0.0039}_{-0.0046}$ (theo.)

$^{+0.0036}_{-0.0015}$ (PDF)

2-JET PRODUKTION ZUSAMMENFASSUNG

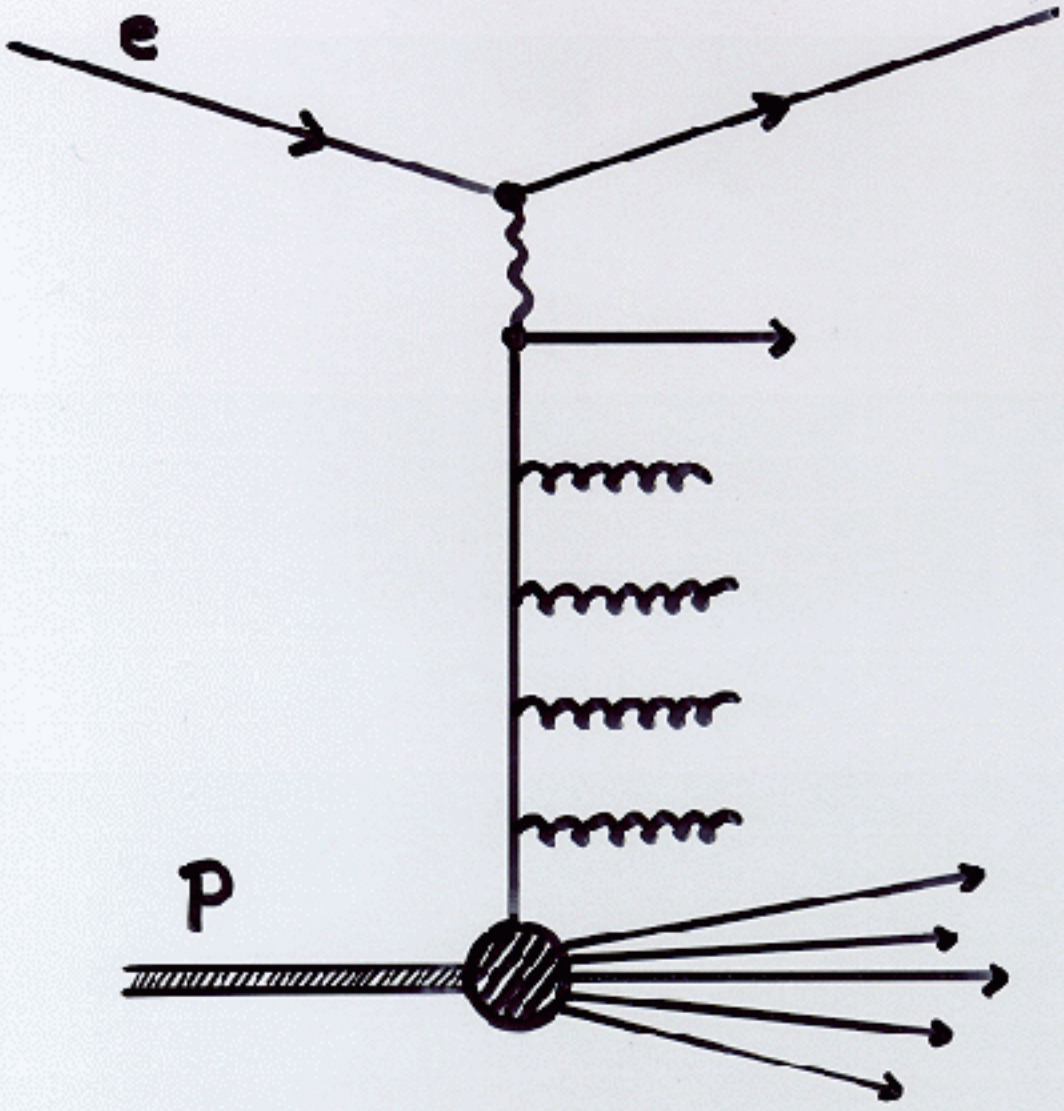
$$\alpha_s \otimes x g(x, Q^2)$$

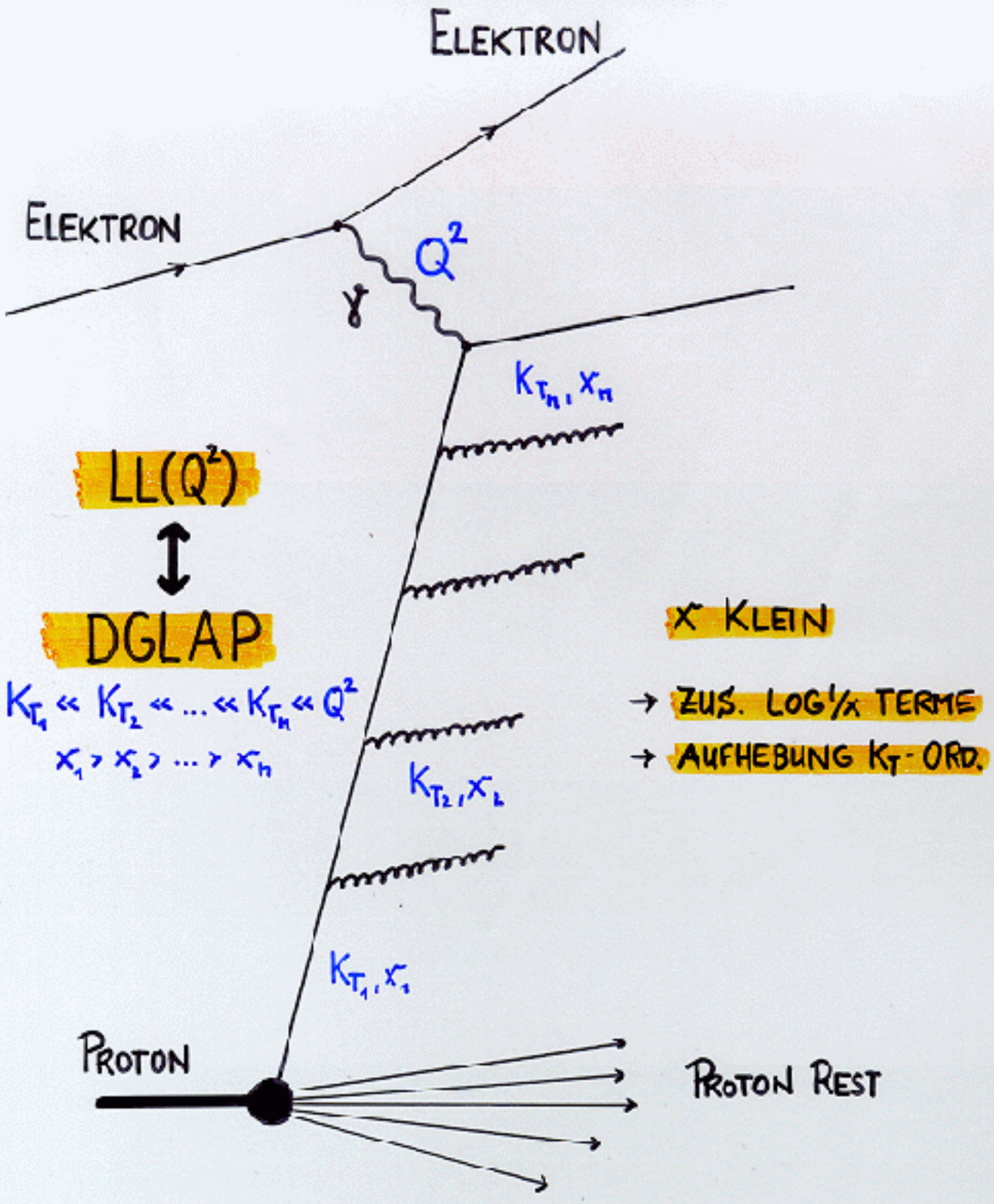
JET ANALYSE
[FEHLER ~5%]

CHARM ✓
DIJETS ✓
[KONSISTENZ MIT INKL. MESSUNG]

III.

PARTONLEITERN





LL(Q^2)

↕

DGLAP

$k_{T_1} \ll k_{T_2} \ll \ldots \ll k_{T_n} \ll Q^2$

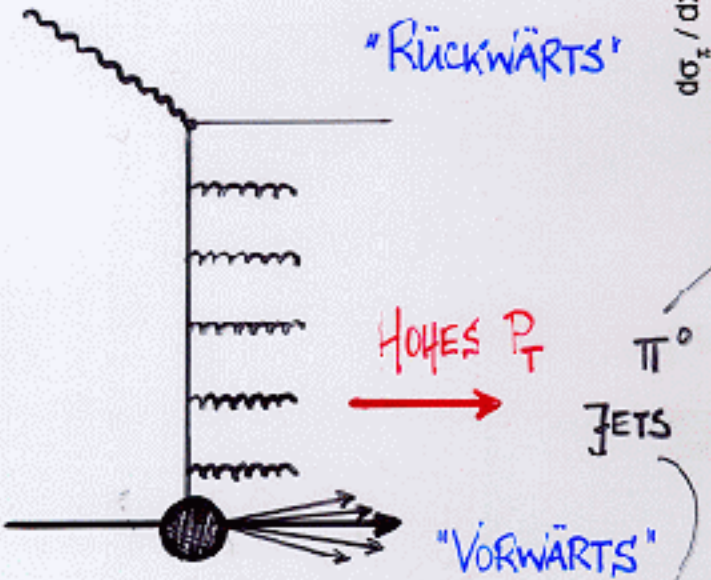
$x_1 > x_2 > \ldots > x_n$

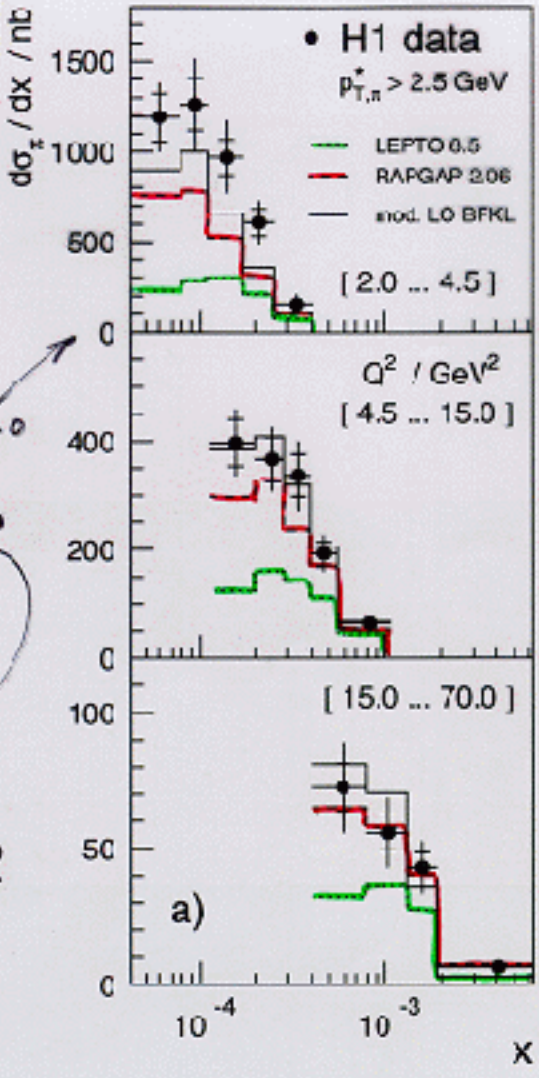
x KLEIN

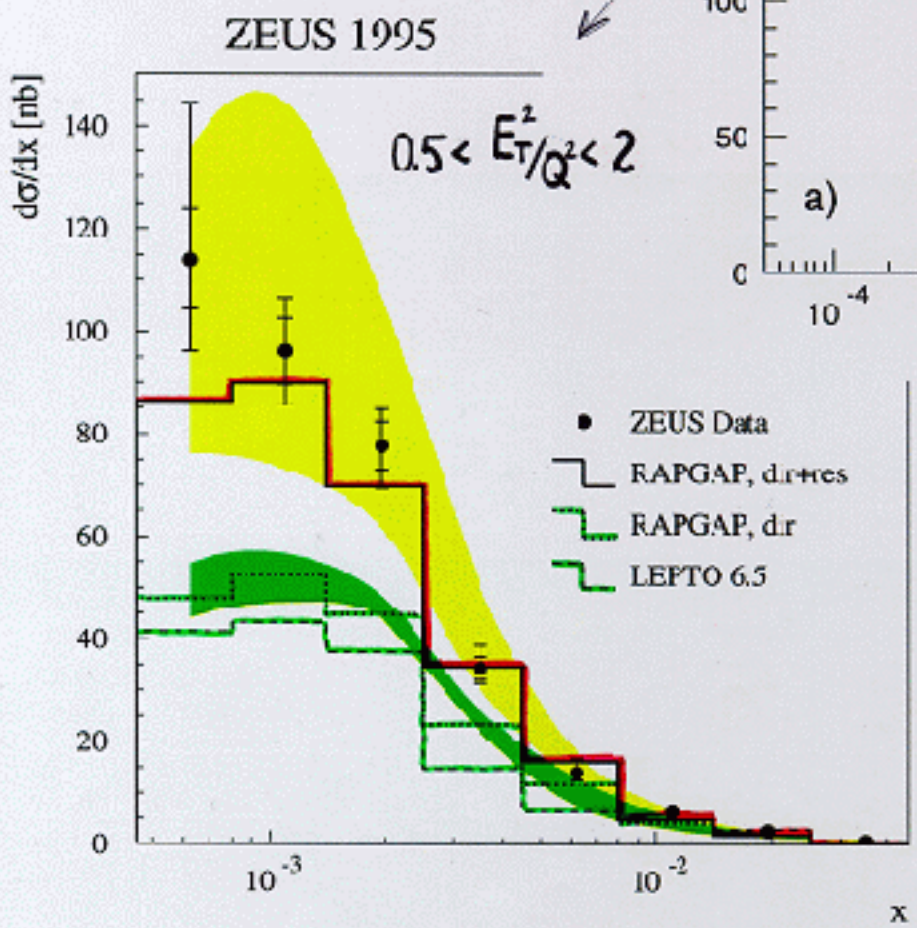
→ **ZUS. LOG 1/x TERME**

→ **AUFHEBUNG k_T-ORD.**

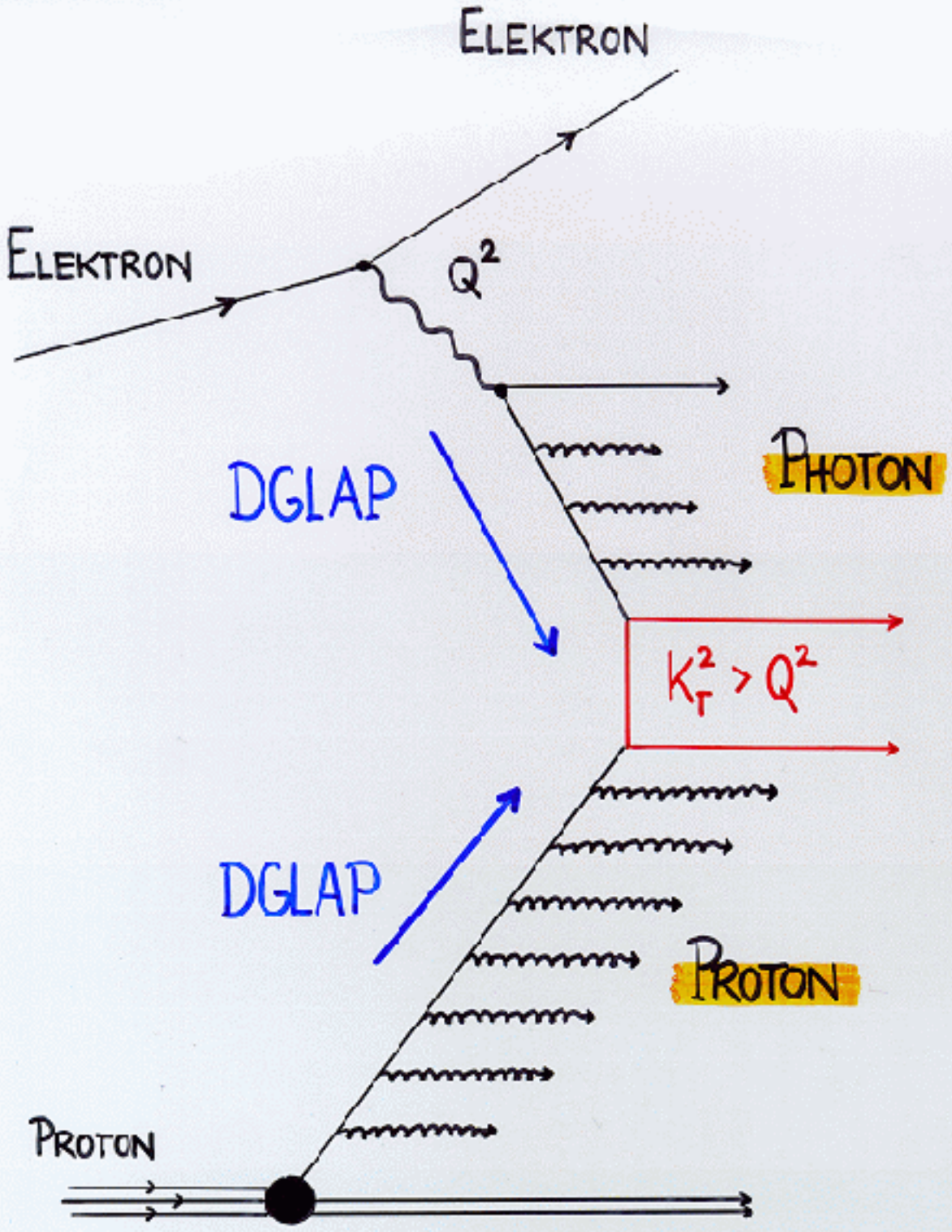
TEILCHENPRODUKTION IN VORWÄRTSRICHTUNG

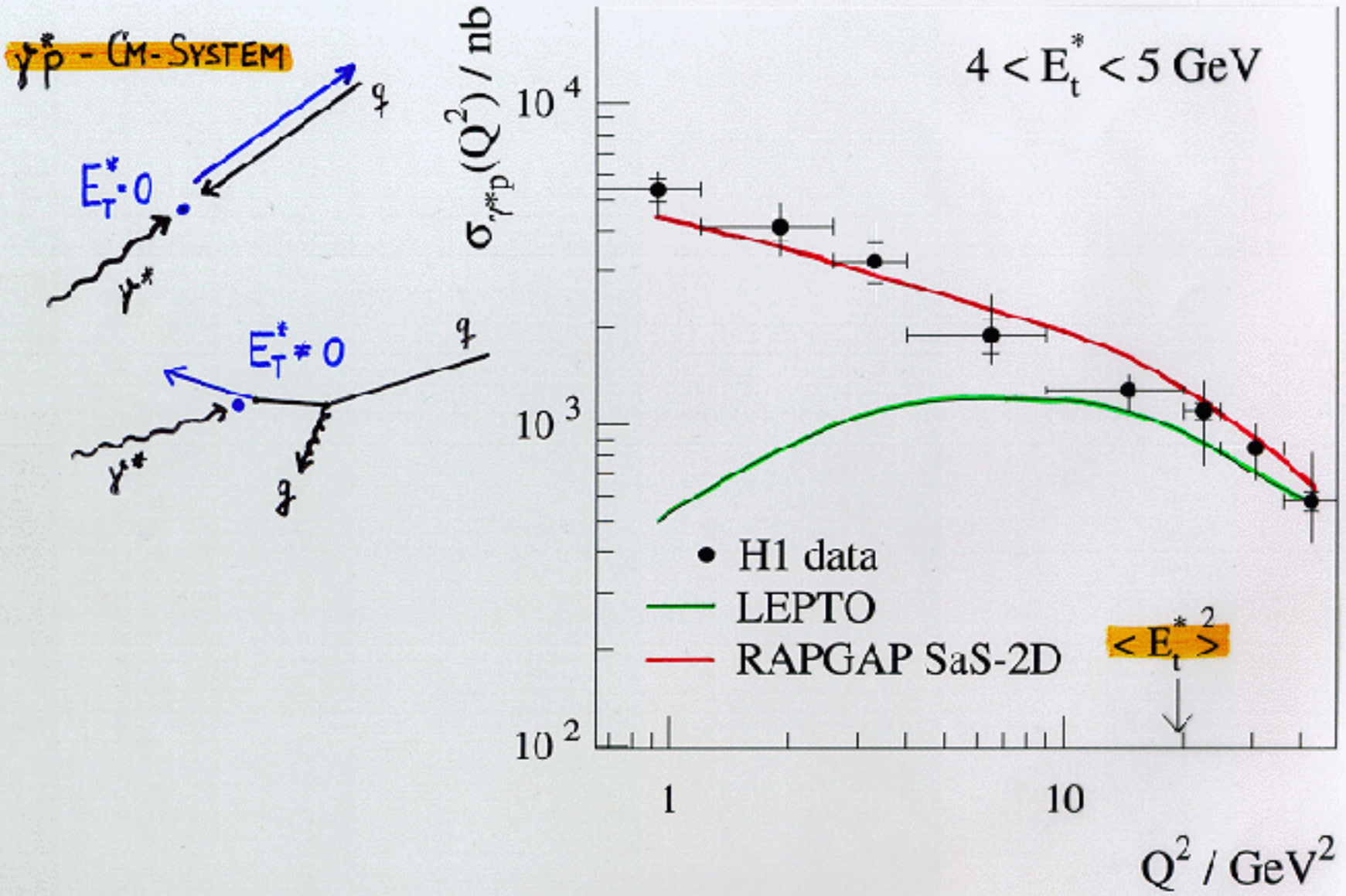






- DGLAP
- LOG 1/x - ENTW.
- PHOTONSTRUK.


ELEKTRON
ELEKTRON
Q^2
PHOTON
DGLAP
$K_T^2 > Q^2$
DGLAP
PROTON
PROTON


γ*p - CM-SYSTEM
q
$E_T^* \cdot 0$
γ*
$E_T^* \neq 0$
q
γ*
g
$\sigma_{\gamma^* p}(Q^2)$ / nb
10^4
10^3
10^2
$4 < E_t^* < 5$ GeV
H1 data
LEPTO
RAPGAP SaS-2D
$< E_t^{*\,2} >$
1
10
Q^2 / GeV^2

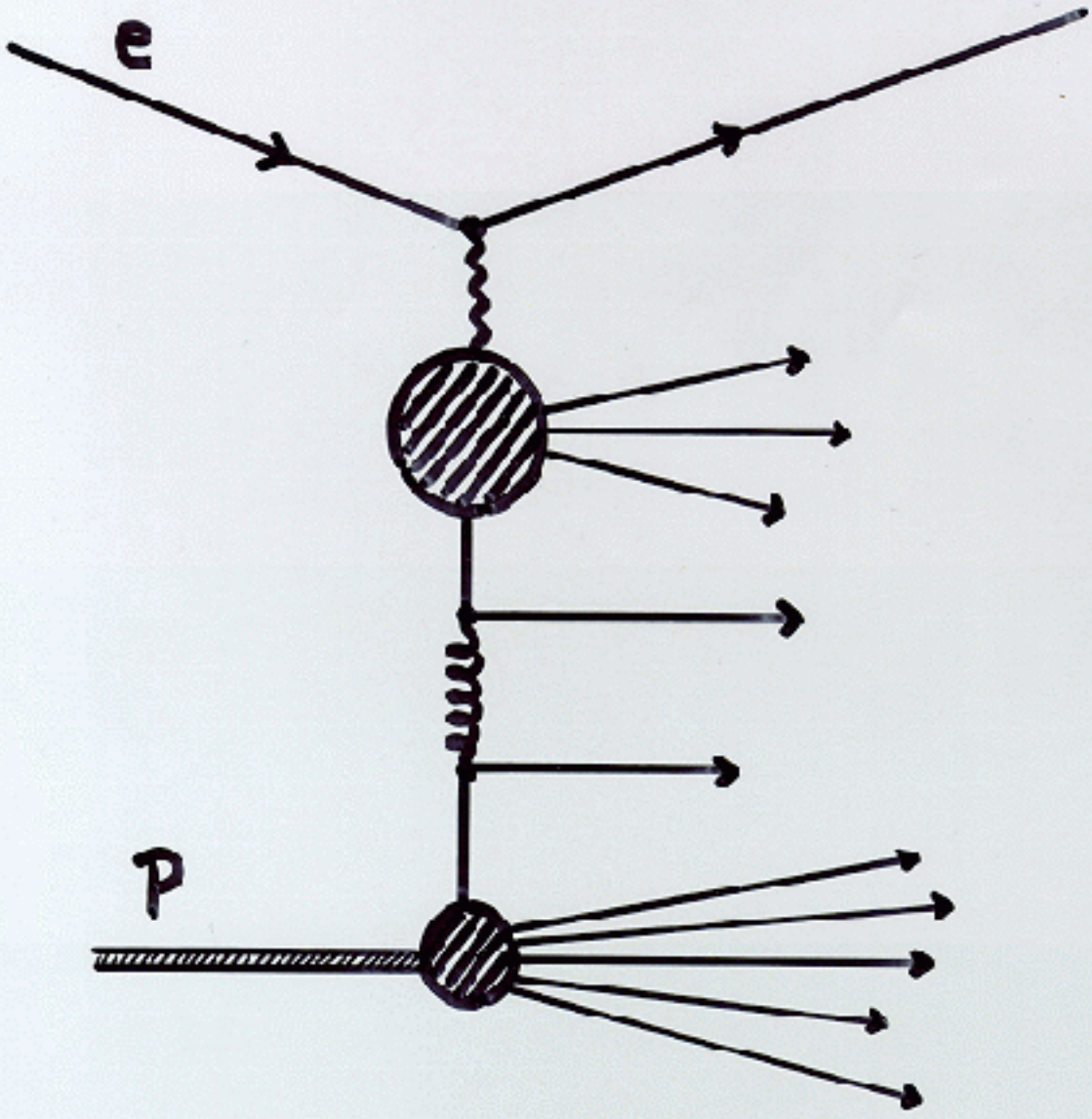
PARTONLEITERN ZUSAMMENFASSUNG

DGLAP NÄHERUNG NICHT KOMPLETT
[VORWÄRTSTEILCHENPRODUKTION]

KONZEPT DER PHOTONSTRUKTUR?

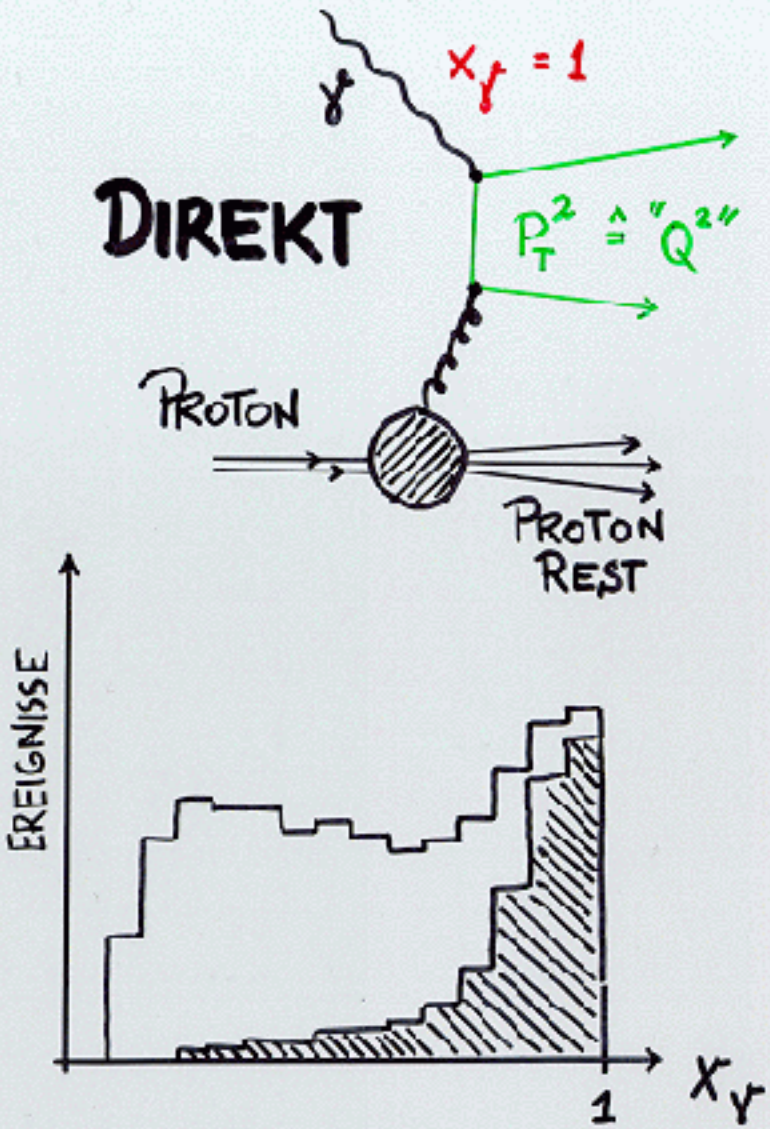
IV.

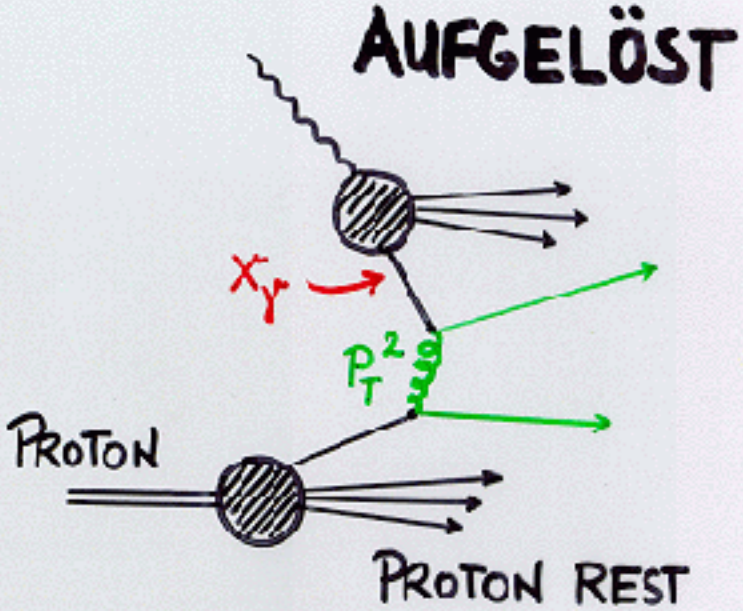
PHOTONSTRUKTUR



PHOTONSTRUKTUR

NOMENKLATUR





KANN HERA

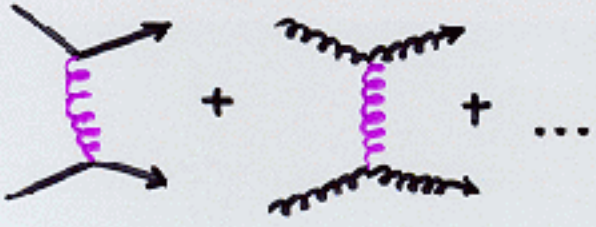
$$F_2^\gamma = x_\gamma \sum e_q^2 q^\gamma(x_\gamma, P_T^2)$$

MESSEN?

γp - ZWEI - JET WQ

$$\frac{d\sigma}{dx_\gamma dx_p d\hat{\eta}} = \frac{\tilde{f}_\gamma}{x_\gamma} \cdot \frac{\tilde{f}_p}{x_p} \cdot |M(\hat{\eta})|^2$$

WOBEI

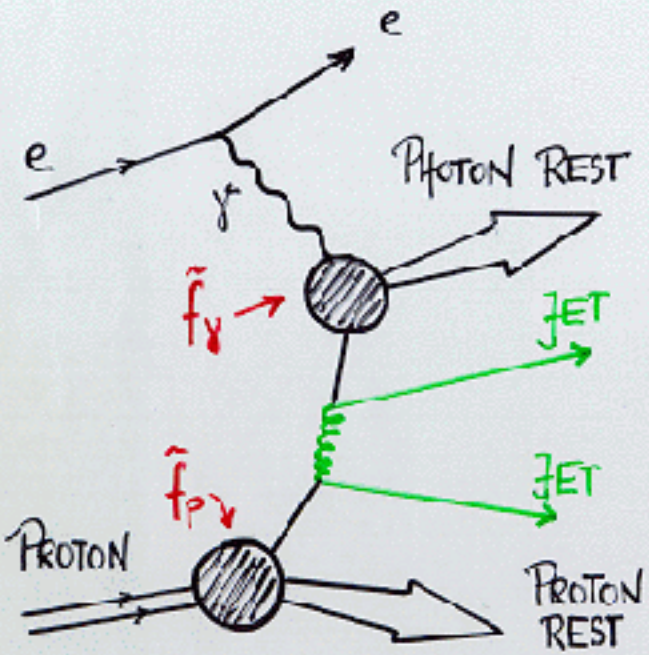
$M(\hat{\eta})$ =  + ...

$$\tilde{f}_\gamma = q^\gamma(x_\gamma, P_T^2) + \tfrac{9}{4} g^\gamma(x_\gamma, P_T^2)$$

$$\tilde{f}_p = q^p(x_p, P_T^2) + \tfrac{9}{4} g^p(x_p, P_T^2)$$

SENSITIVITÄT AUF xg^γ

γp Zwei-Jet Wirkungsquerschnitt



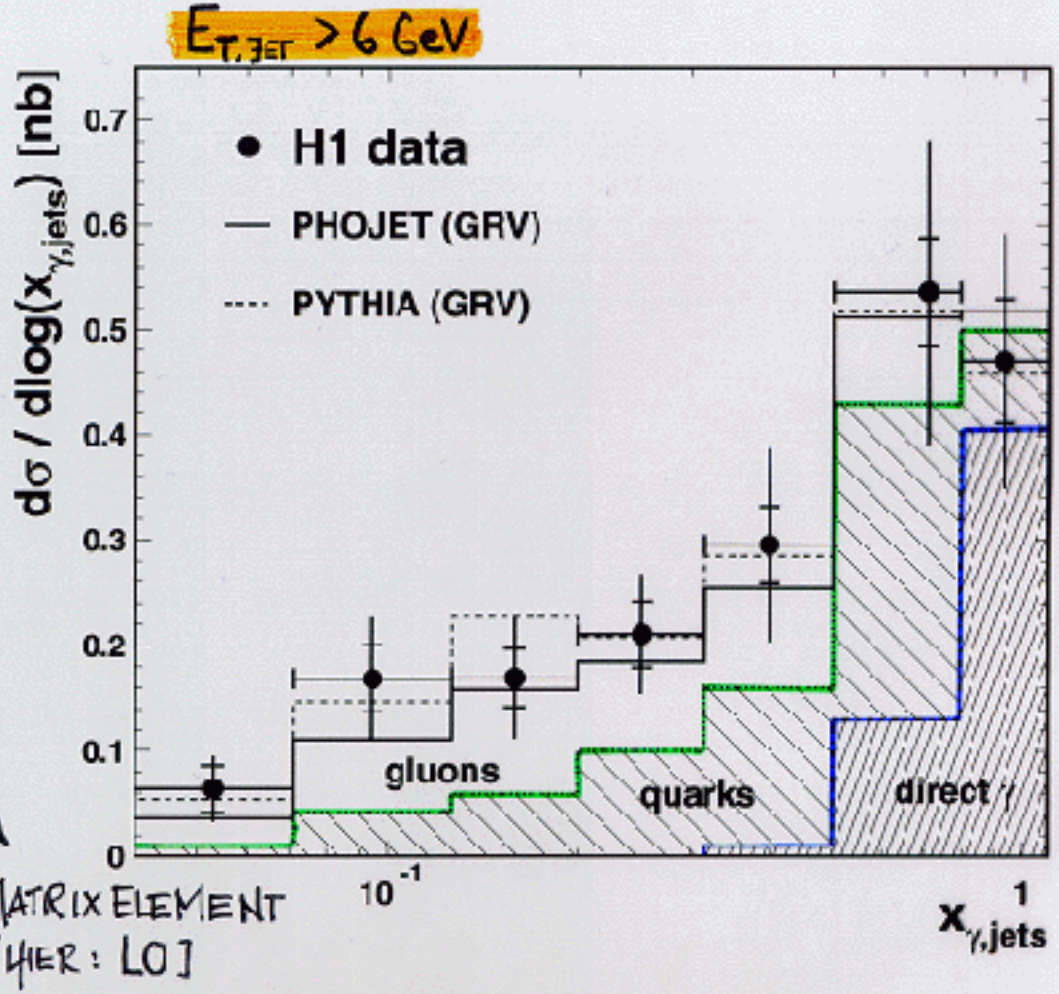
$$\sigma_{2\text{-Jet}} \sim f_{\gamma/e} \cdot \tilde{f}_p \cdot \tilde{f}_\gamma \cdot |M|^2$$

Photonfluss

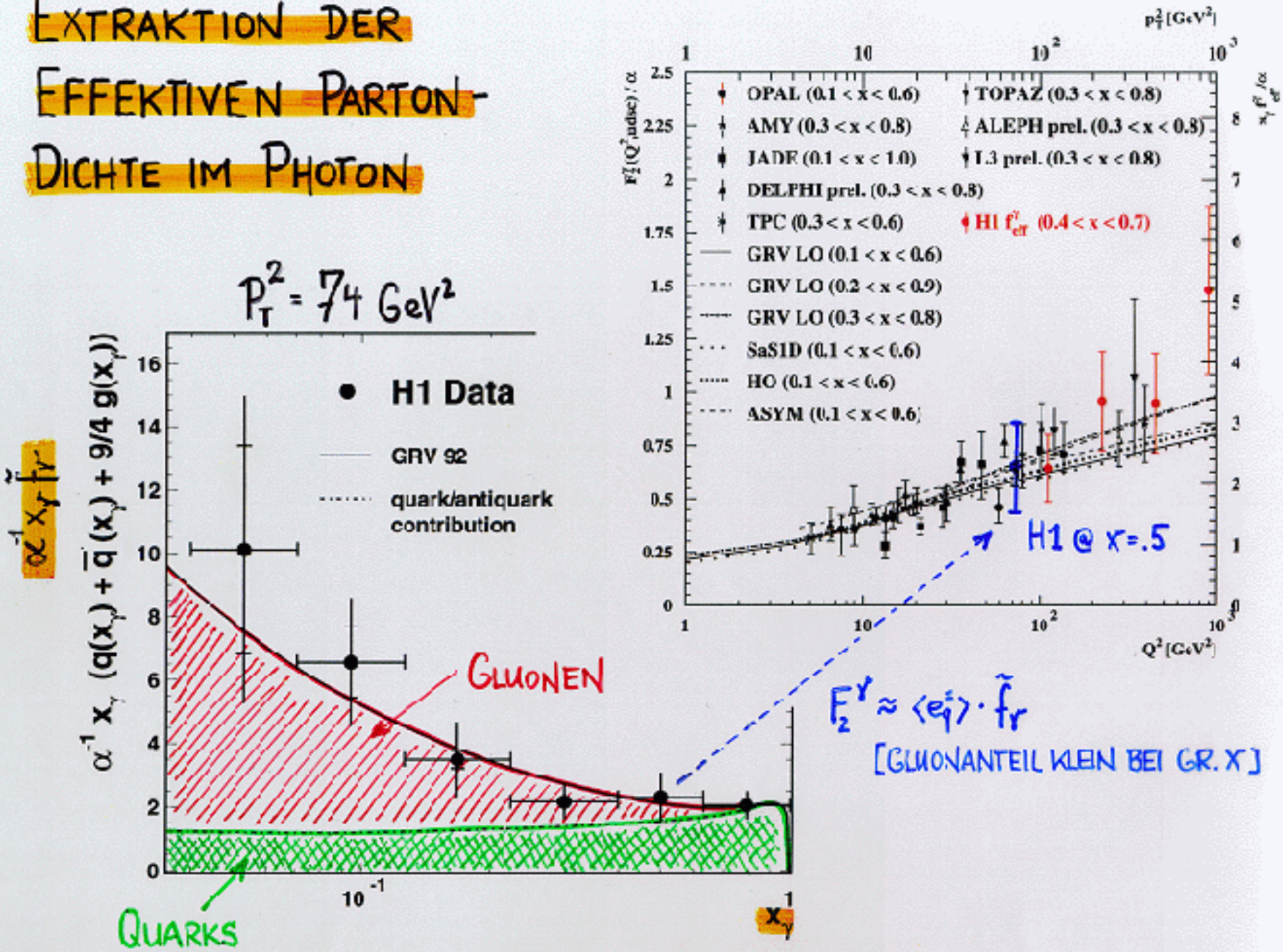
Eff. Partondichte im Proton

messen

Matrix Element [hier: LO]



EXTRAKTION DER EFFEKTIVEN PARTON-DICHTE IM PHOTON



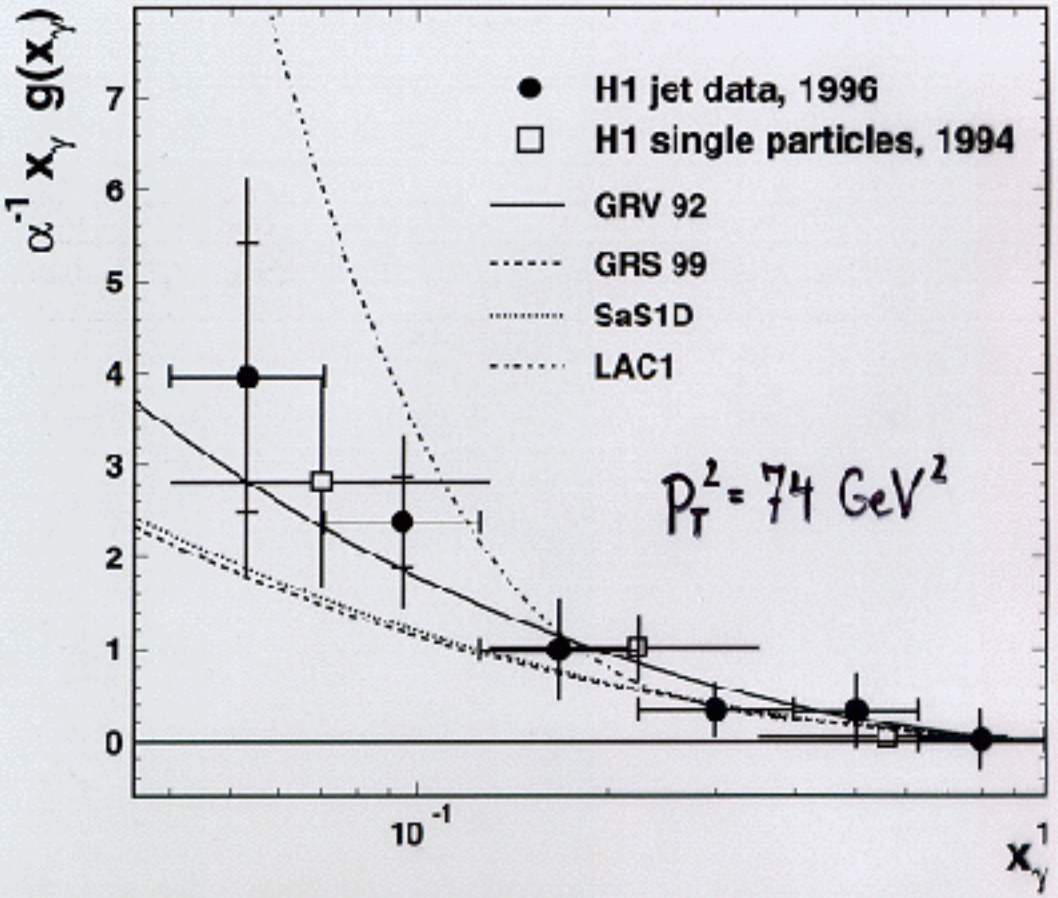
Gluondichte des Photons

$$\tilde{f}_\gamma = q(x, P_T^2) + \tfrac{9}{4}\, g(x, P_T^2)$$

Bekannt (z.B. LEP)

HERA

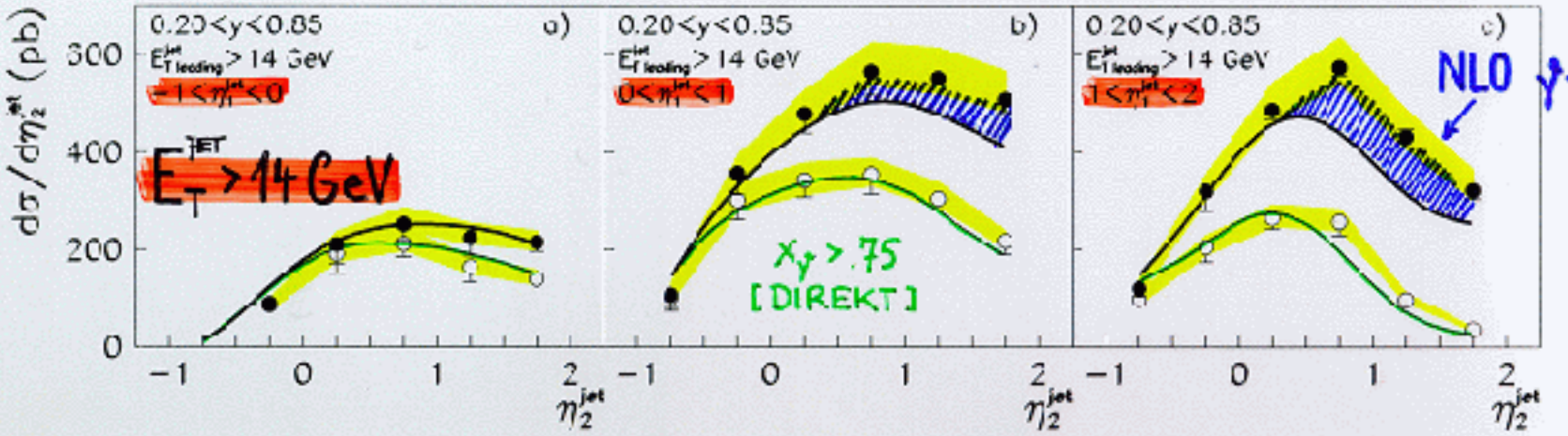
Anstieg für kleine x



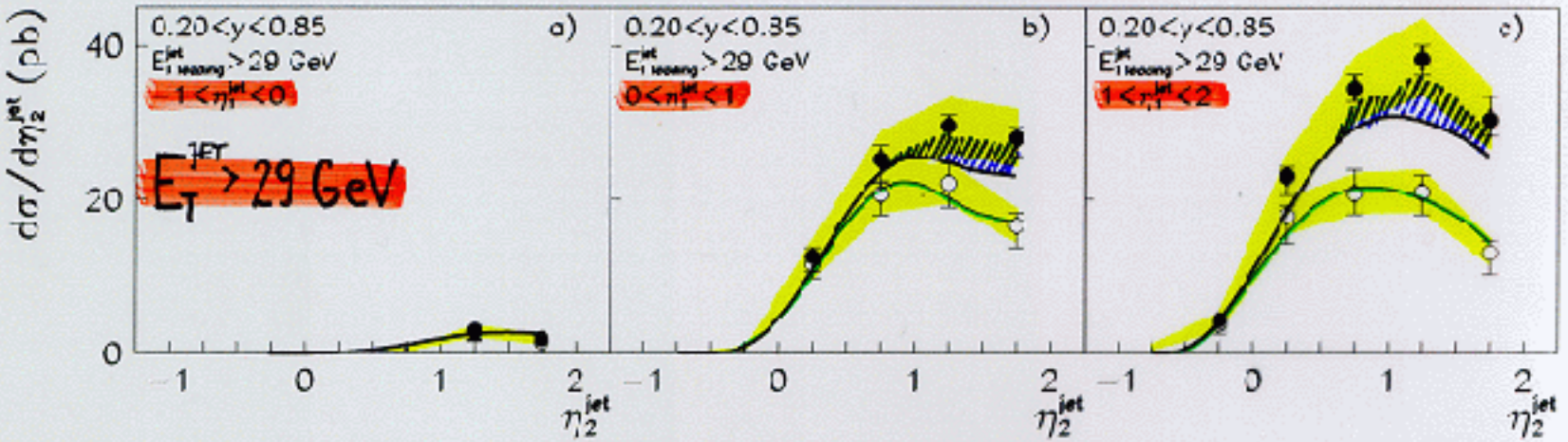
2-JET WIRKUNGSQUERSCHNITT BEI HOHEN E_T

VERGLEICH MIT NLO-RECHNUNG UND ENTSPR. PARAMETRISIERUNG DER γ-STRUKTUR

ZEUS 1996/1997 PRELIMINARY

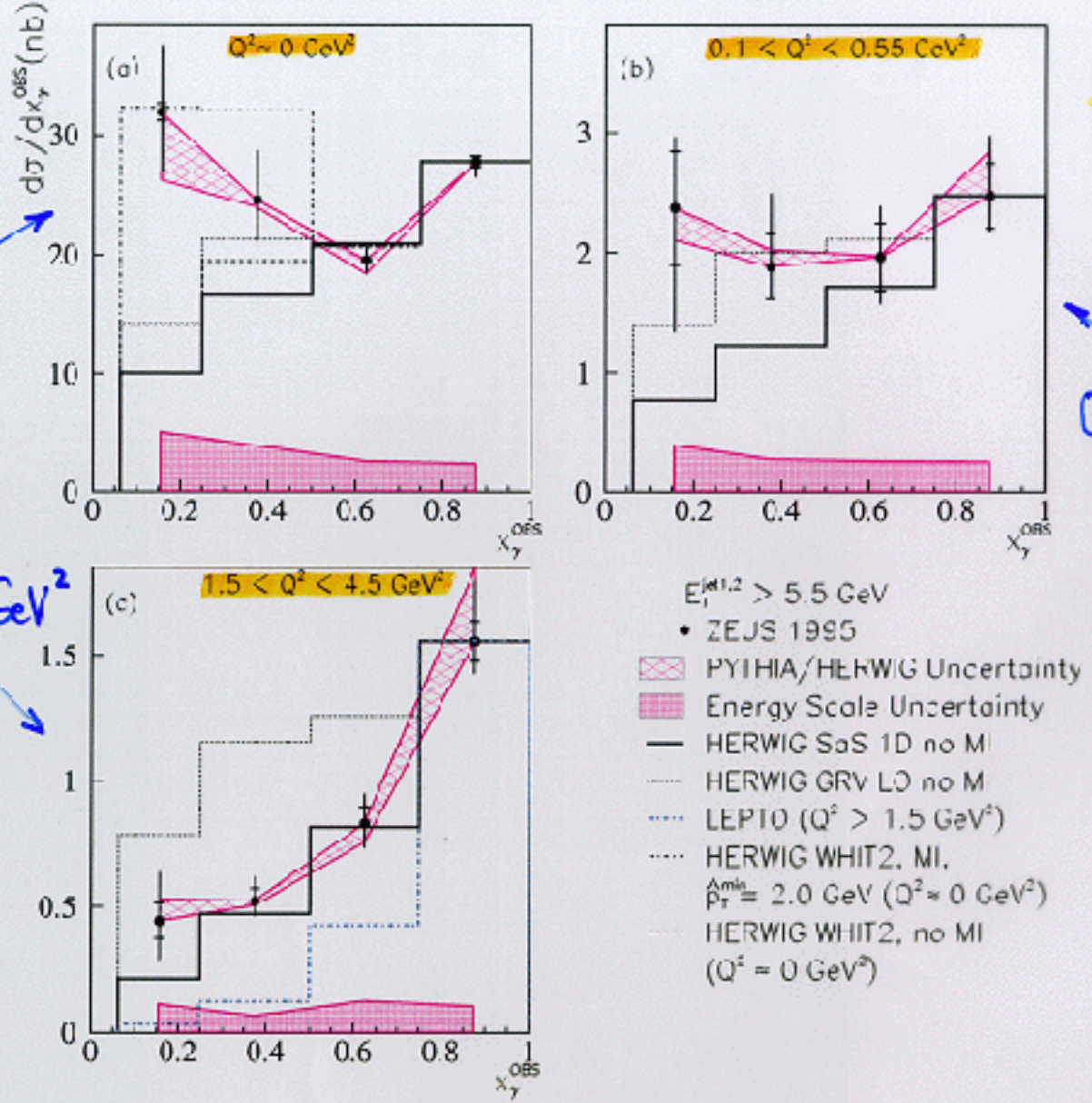


ZEUS 1996/1997 PRELIMINARY



x_γ ← GROSS ... KLEIN

STRUKTUR VIRTUELLER PHOTONEN

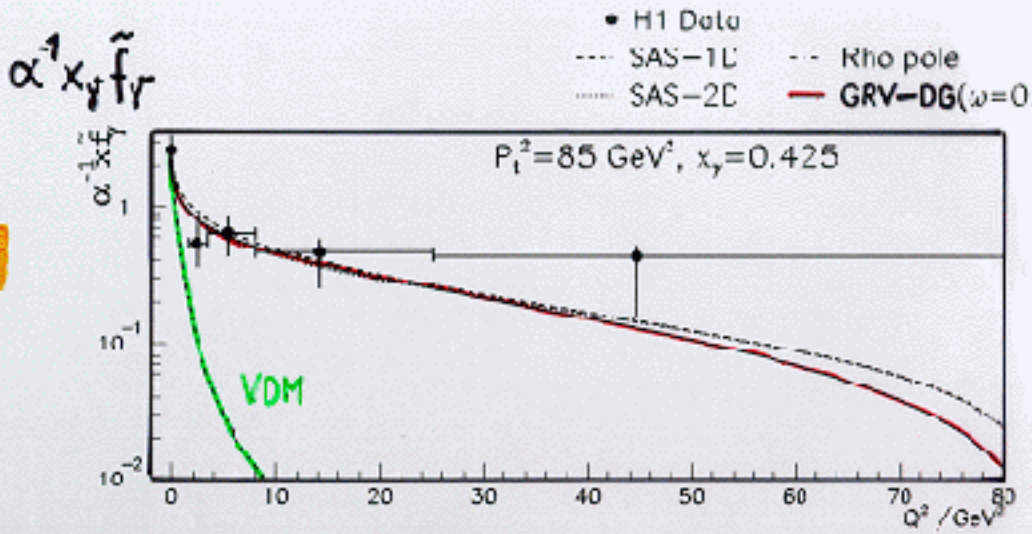


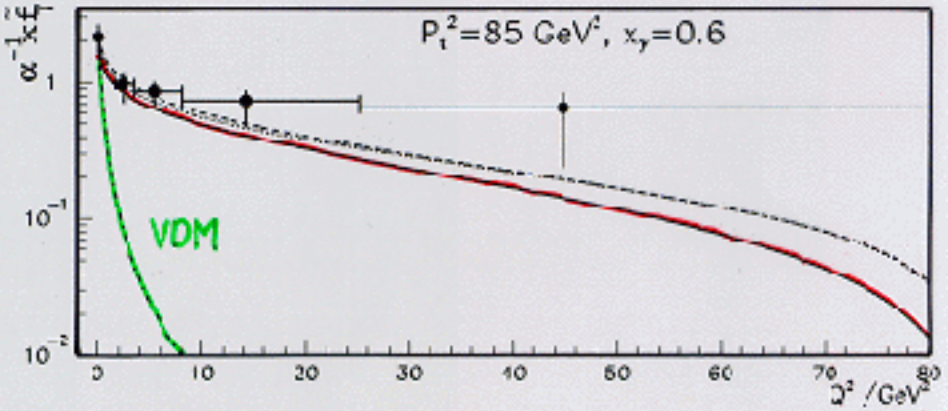
$Q^2 = 0$

$0.1 < Q^2 < 0.55$ GeV^2

$1.5 < Q^2 < 4.5$ GeV^2

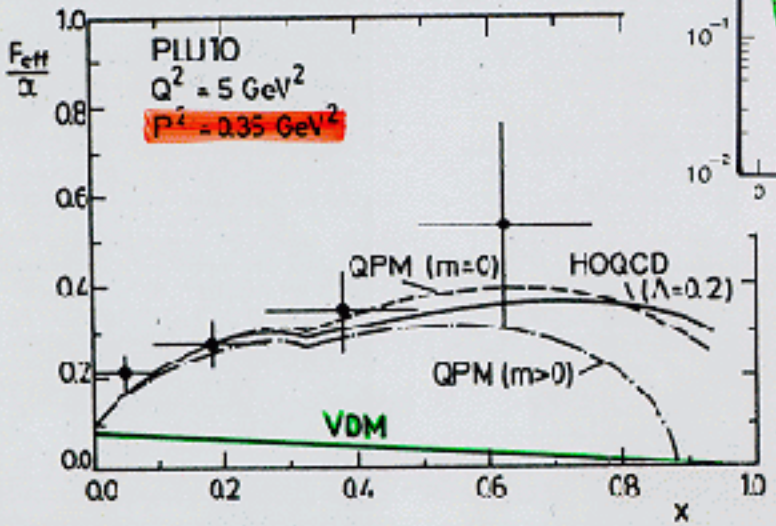
EFFEKTIVE PARTONDICHTE VIRTUELLER PHOTONEN





Q^2 [GeV^2]

EINZIGE PRE-HERA MESSUNG



PHOTONSTRUKTUR ZUSAMMENFASSUNG

γ STRUKTUR

LO: EFFEKTIVE PARTONDICHTE → $xg^{\gamma}(x)$

NLO: "AUFGELÖSTER ANTEIL" ?

γ^* STRUKTUR

VERSCHWINDET MIT Q^2

$\tilde{f}_{\gamma}(Q^2) \gg$ VDM $(E_T^2 = 85\,\mathrm{GeV}^2)$

SCHLUSS

HERA: QCD LABOR ZUR PARTONDYNAMIK

INKLUSIV

DGLAP ✓

$xg(x)$ ✓

SPEZIELLER

GÜLTIGKEIT DER pQCD (DGLAP)
[VORWÄRTSBEREICH, KL. Q^2]

FEHLENDE ORDNUNGEN
[γ-STRUKTUR]

HERA UPGRADE !!

EXKLUSIV
[MIT MEHR PRÄZISION]

SKALENPROBLEM
[η, E_T m_c m_b ...]