Structure Functions with Charged and Neutral Current

a) Neutral current.

   I. The xF3 nucleon structure function (the γZ interference contribution)

   II. F_L – Large background at high y => need some e+ data for background subtraction

   III. Parity violation in weak neutral current

b) Charged current.

   i. up-type or down-type flavors.

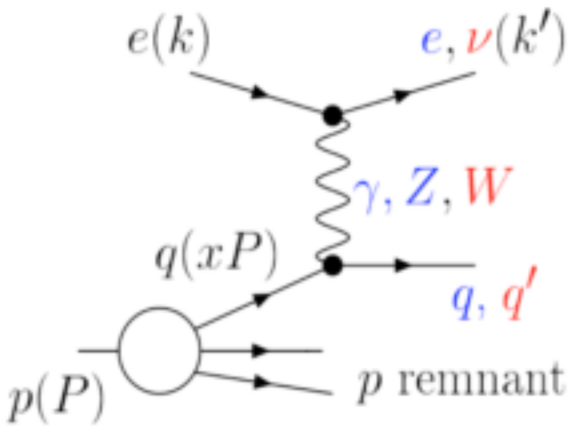
   ii. The charm and anticharm production in charged current DIS to extract strange and anti-strange distributions.

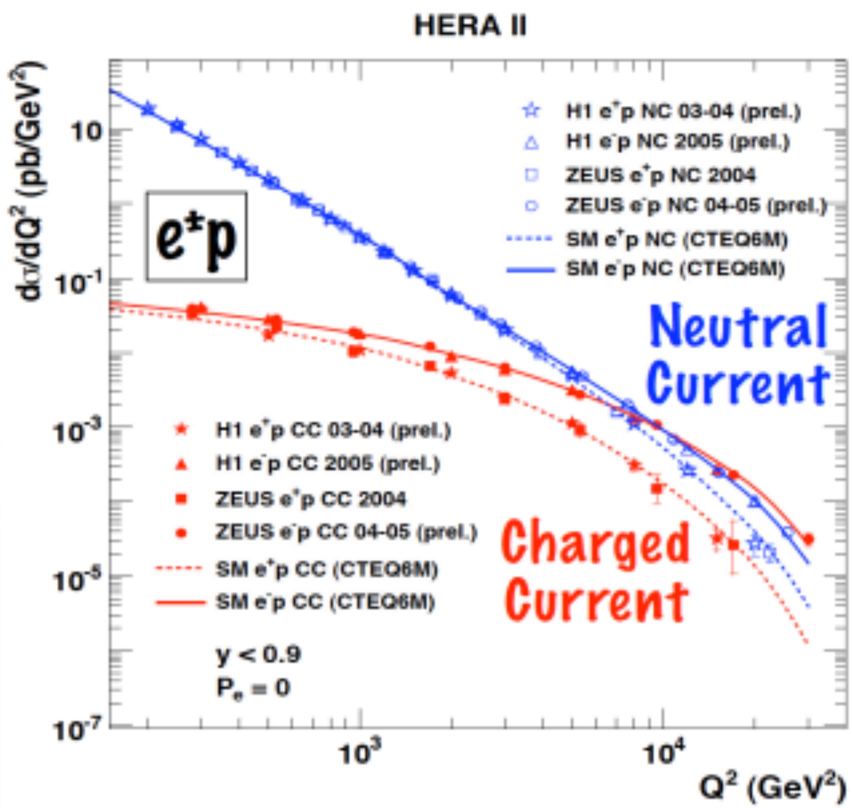
   iii. The production of Ds+ mesons in diffractive charged current DIS - information on the gluon structure of the diffraction mechanism in QCD.

   iv. Right-handed W-boson exchange.

c) NC+CC : The flavor separation of the pion and kaon structure

NC and CC DIS





$$\frac{d^2\sigma^{NC}}{dxdQ^2} \sim \left|\frac{A}{Q^2} + \frac{B}{Q^2+M_Z^2}\right|^2 \times \mathrm{pdf's}$$

$$\frac{d^2\sigma^{CC}}{dxdQ^2} \sim G_F^2\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \times \mathrm{pdf's}$$

Neutral Current DIS: xF3

$$\frac{d^2\sigma^{NC}(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2) - y^2 F_L(x,Q^2)]$$

EM
.PDFs

EW
.important at high Q2,
.changes sign for e+/e-
.sensitiv to γZ interference
.sensitiv to valence quarks

EW
.enegligible
at high Q2& x

- Structure functions (polarized)

$$\tilde{F}_2 = F_2^\gamma - (v_e \pm P_e a_e)\chi_Z F_2^{\gamma Z} + ((v_e^2 + a_e^2) \pm P_e 2 v_e a_e))\chi_Z^2 F_2^Z$$
$$\tilde{F}_3 = - (a_e \pm P_e v_e)\chi_Z F_3^{\gamma Z} + ((2 v_e a_e \pm P_e (v_e^2 + a_e^2))\chi_Z^2 F_3^Z$$

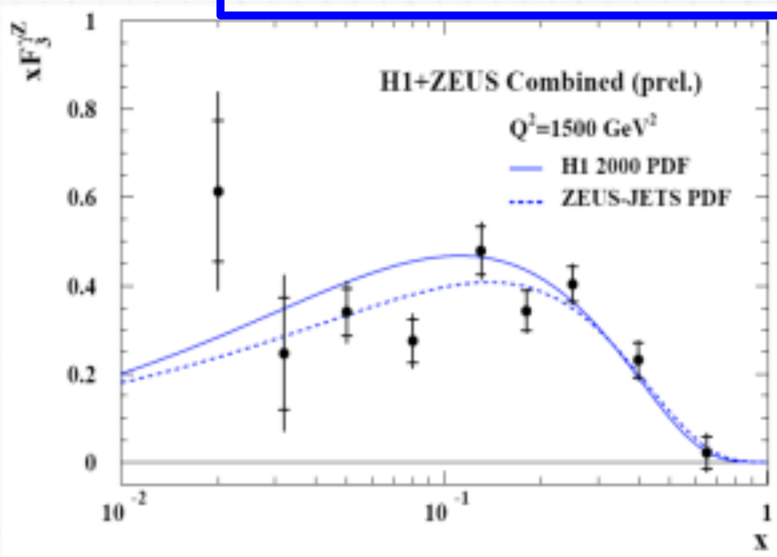
pure γ (EM) γ-Z interference (EW) pure Z (EW)

$$Y_\pm = 1 \pm (1-y)^2$$

$$x\tilde{F}_3 = \frac{Y_+}{2Y_-}[\tilde{\sigma}(e^- p) - \tilde{\sigma}(e^+ p)]$$

$$F_2^{\gamma Z} = 2 e_f v_f \Sigma_i x[q_f + \overline{q_f}]$$
$$F_2^Z = (v_f^2 + a_f^2)\Sigma_i x[q_f + \overline{q_f}]$$
$$F_3^{\gamma Z} = 2 e_f a_f \Sigma_i x[q_f - \overline{q_f}]$$
$$F_3^Z = 2 v_f a_f \Sigma_i x[q_f - \overline{q_f}]$$

$$v_f = T^3{}_f - 2 e_f \sin^2\theta_W$$
$$a_f = T^3{}_f$$



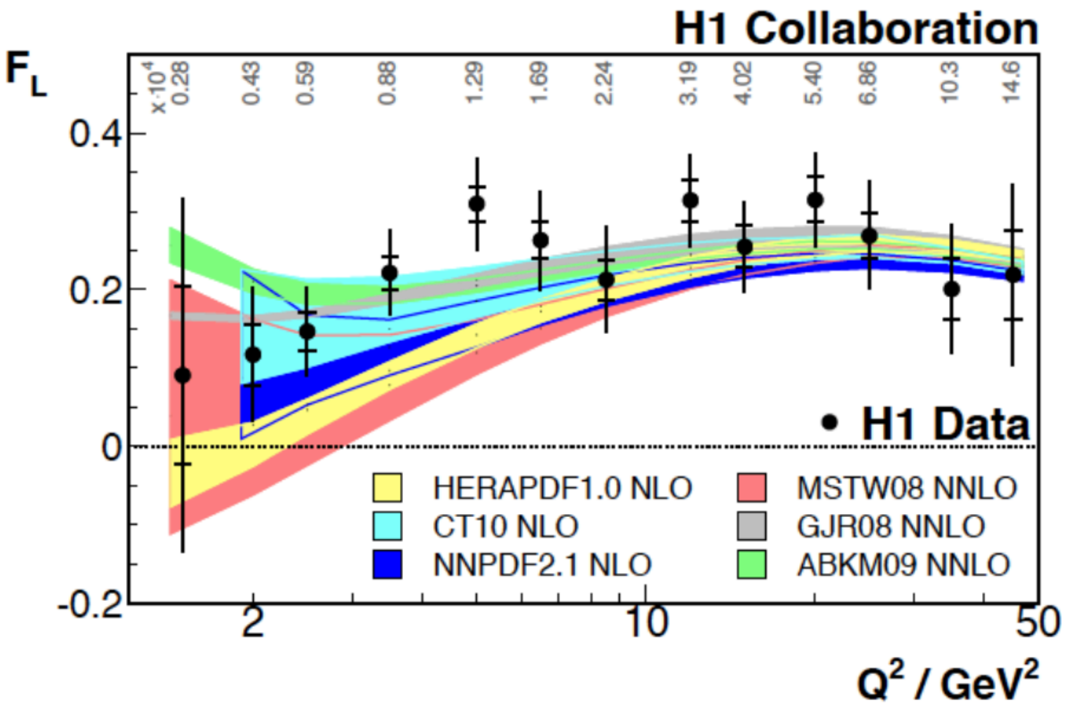
- Four lepton beams (+ and -, L and R) give vector- and axial-vector coupling of quarks (mainly u and d quarks)

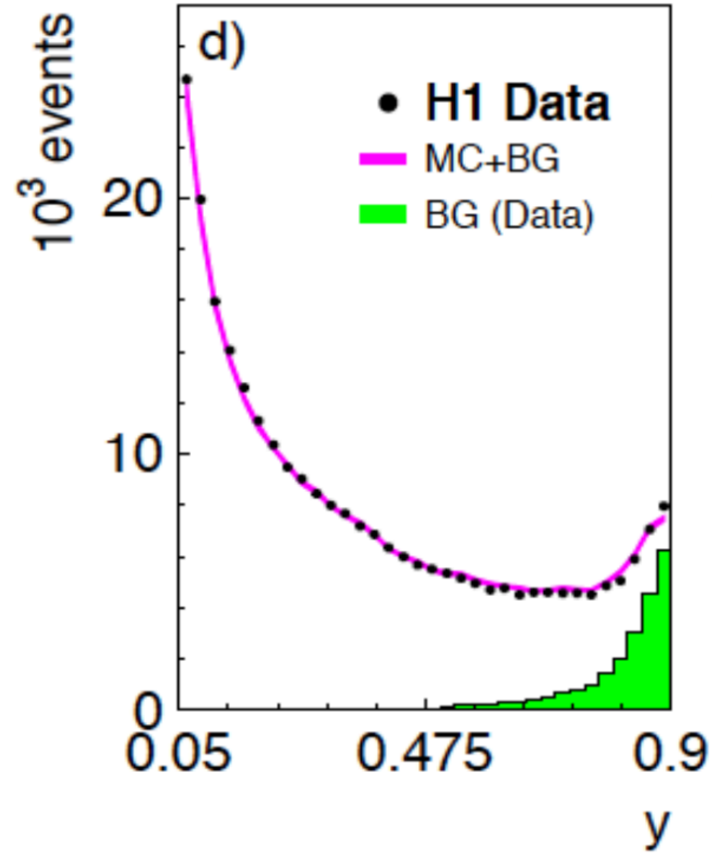
- The difference between the e+p and e-p NC cross sections give direct access to the structure function xF3 .

M.Kuze/ HERA

Max Klein

HERA - Lessons on F_L

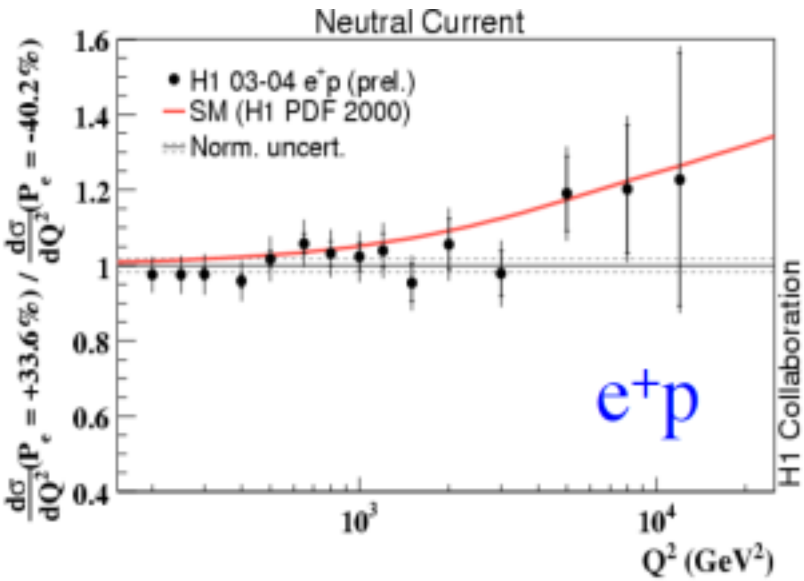


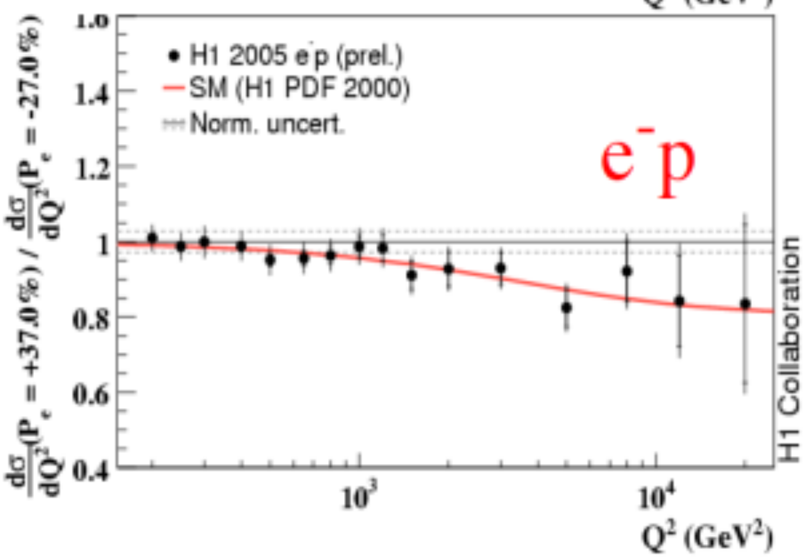


Large backgrounds at high $y=1-E'/E_e$
Subtraction with opposite beam charge data, corrected for background charge asymmetry

- → Need very high luminosity at minimal three energy settings
- → Need some e^+ data
- → Need $E_e \rightarrow E'$ as large as possible (y=0.9 is E'=1 GeV for 10 GeV electron beam energy)
- → Need tracker in front of backward calorimeter, charge measurement [H1 BST..]
- → Need efficient photoproduction tagger

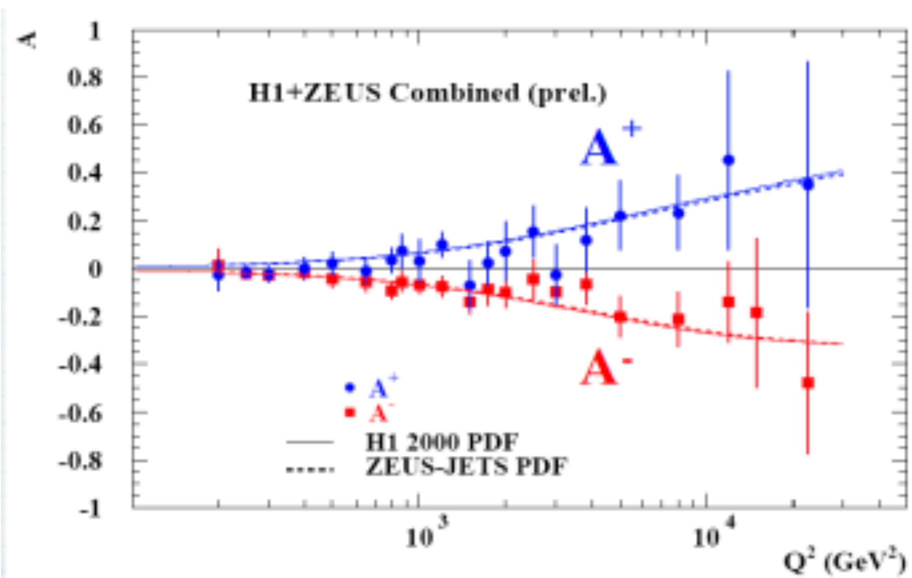
Neutral Current DIS at HERA





- Polarization asymmetry
- Parity violation in weak neutral current at EW scale: observed for the first time in DIS

$$A^{\pm} = \frac{2}{P_R - P_L} \cdot \frac{\sigma^{\pm}_{NC}(P_R) - \sigma^{\pm}_{NC}(P_L)}{\sigma^{\pm}_{NC}(P_R) + \sigma^{\pm}_{NC}(P_L)} \qquad \begin{array}{l} P_R > 0 \\ P_L < 0 \end{array}$$



Neutral Weak Coupling C3q Using Polarized Positron and Electron Beams

For proton

$$A_p^{e_L^- - e_R^+} = \left(\frac{3G_F Q^2}{2\sqrt{2}\pi\alpha}\right)\frac{y(2-y)}{2}\frac{2C_{2u}u_V - C_{2d}d_V + 2C_{3u}u_V - C_{3d}d_V}{4u+d}$$

For deuteron

small

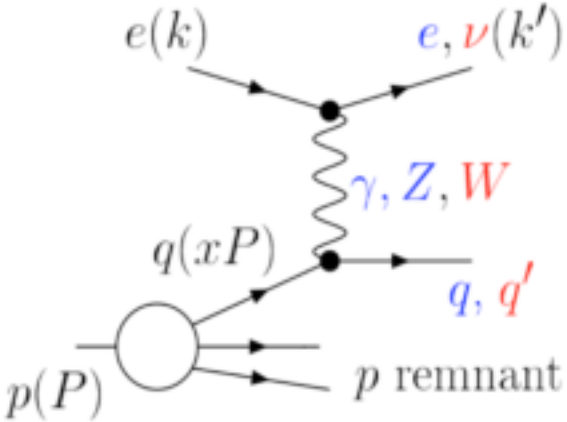
$$A_d^{e_L^- - e_R^+} = \left(\frac{3G_F Q^2}{2\sqrt{2}\pi\alpha}\right)\frac{y(2-y)}{2}\frac{(2C_{2u} - C_{2d} + 2C_{3u} - C_{3d})R_V}{5}, \qquad (9)$$

where $R_V \equiv (u_V + d_V)/(u+d)$. Note that contributions from s and c quarks have been neglected in this derivation.

http://dx.doi.org/10.1063/1.3232025

X. Zheng

CC DIS



Charged Current DIS:

$$\frac{d^2\sigma(e^+p)}{dxdQ^2} = \frac{G_F^{\ 2}}{2\pi}\left(\frac{M_W^{\ 2}}{M_W^{\ 2}+Q^2}\right)^2\{(\bar{u}+\bar{c})+(1-y)^2(d+s)\}$$

$$\frac{d^2\sigma(e^-p)}{dxdQ^2} = \frac{G_F^{\ 2}}{2\pi}\left(\frac{M_W^{\ 2}}{M_W^{\ 2}+Q^2}\right)^2\{(u+c)+(1-y)^2(\bar{d}+\bar{s})\}$$

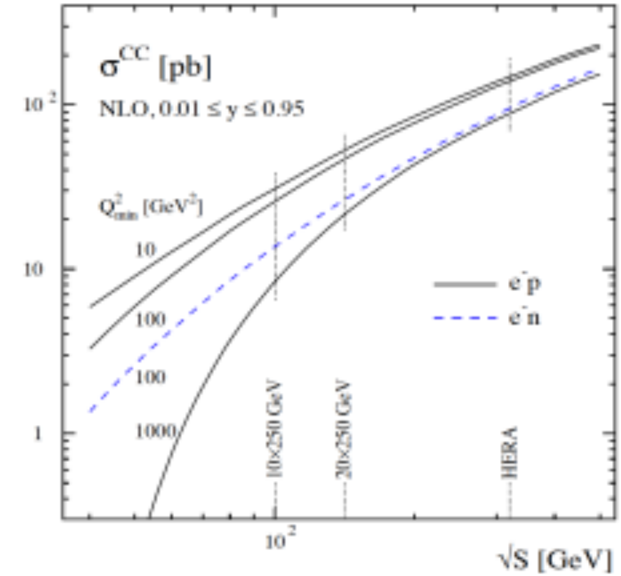
Charged current process: up-type or down-type flavors.

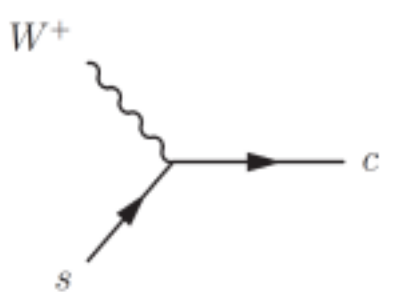
Charm production in Charged Current DIS

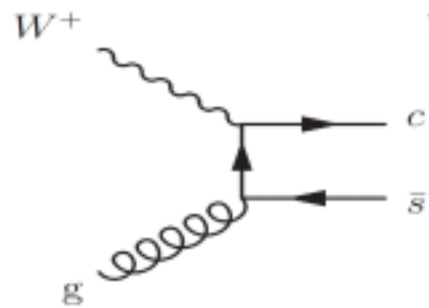
Elke A.

$\sigma(e{+}p \to \nu_e + X) \sim 50\text{pb}$ (HERA $Q^2 > 200\text{GeV}^2$)
$\sigma(e{+}p \to \nu_e + c + X) \sim 5\text{pb}$ (HERA $Q^2 > 200\text{GeV}^2$)

At EIC :
$\sigma(\text{CC DIS}) \sim 10$ pb ($Q^2 > 10\text{GeV}^2$)
$\sigma(\text{CC DIS + charm}) \sim 1$ pb (?)
=> ~ 1 event/ minute (with $L \sim 10^{34}$)





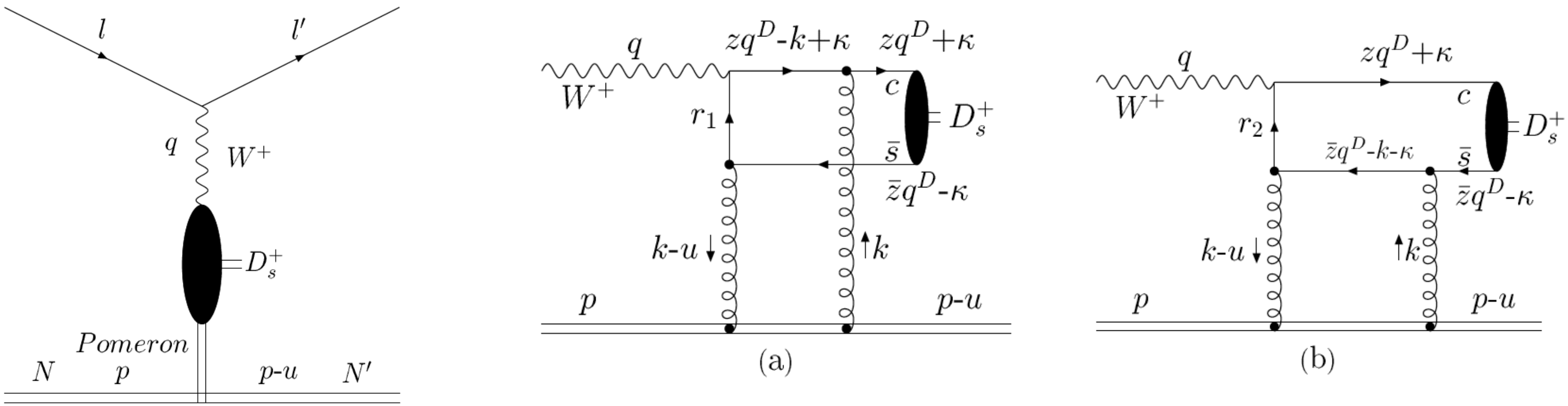


The charm and anticharm production in charged current DIS to extract strange and anti-strange distributions.

- Measurements of strange
- distribution (+polarization)
- $W^+ s \to c$
- $|V_{sc}| = 0.97$
- Flavor mixing
- $W^+ d \to c$
- $|V_{cd}| = 0.224$

- BGF
- $W^+ g \to c\ s$

The production of Ds+ mesons in diffractive charged current DIS

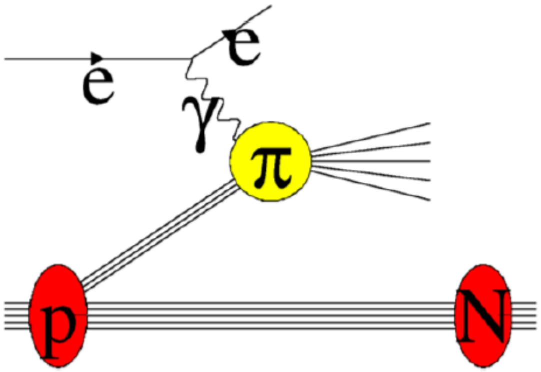


The production of Ds+ mesons in diffractive charged current DIS - information on the gluon structure of the diffraction mechanism in QCD

"Diffractive Ds production in charged current DIS"
Zhongzhi Song and Kuang-Ta Chao

Electroweak Pion and Kaon Structure Functions

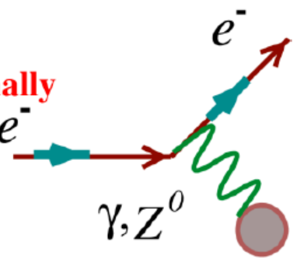
Tanja Horn



- The Sullivan Process will be sensitive to u and dbar for the pion, and likewise u and sbar for the kaon.
- Logarithmic scaling violations may give insight on the role of gluon pdfs
- Could we make further progress towards a flavor decomposition?

1) Using the Neutral-Current Parity-violating asymmetry A_{PV}

2) Determine xF_3 through neutral/charged-current interactions



$$F_2^{\gamma} = \sum_q e_q^2\, x\,(q+\bar{q})$$

In the parton model: $$F_2^{\gamma Z} = 2\sum_q e_q\, g_V^q\, x\,(q+\bar{q})$$ *Use different couplings/weights*

$$x\,F_3^{\gamma Z} = 2\sum_q e_q\, g_A^q\, x\,(q-\bar{q})$$ *Use isovector response*

$$F_2^{W^+} = 2x\,(\bar{u}+d+s+\bar{c}) \quad F_3^{W^+} = 2\,(-\bar{u}+d+s-\bar{c}) \quad F_2^{W^-} = 2x\,(u+\bar{d}+\bar{s}+c) \quad F_3^{W^-} = 2\,(u-\bar{d}-\bar{s}+c)$$

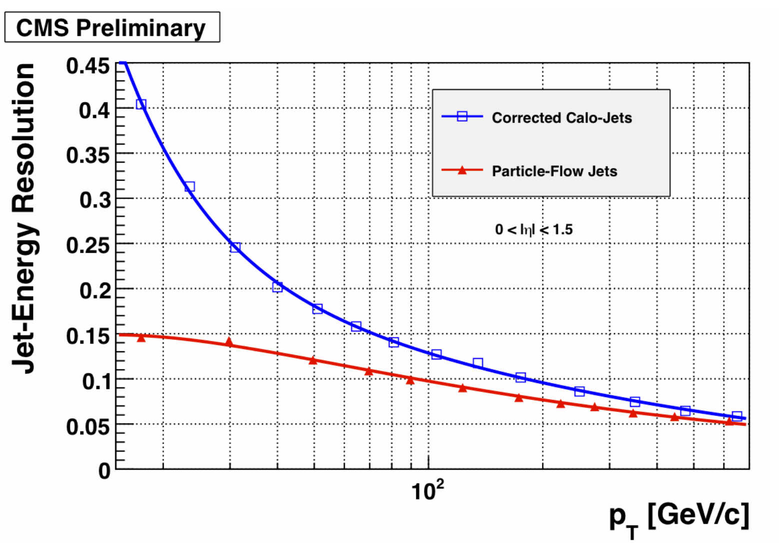
3) Or charged-current through comparison of electron versus positron interactions

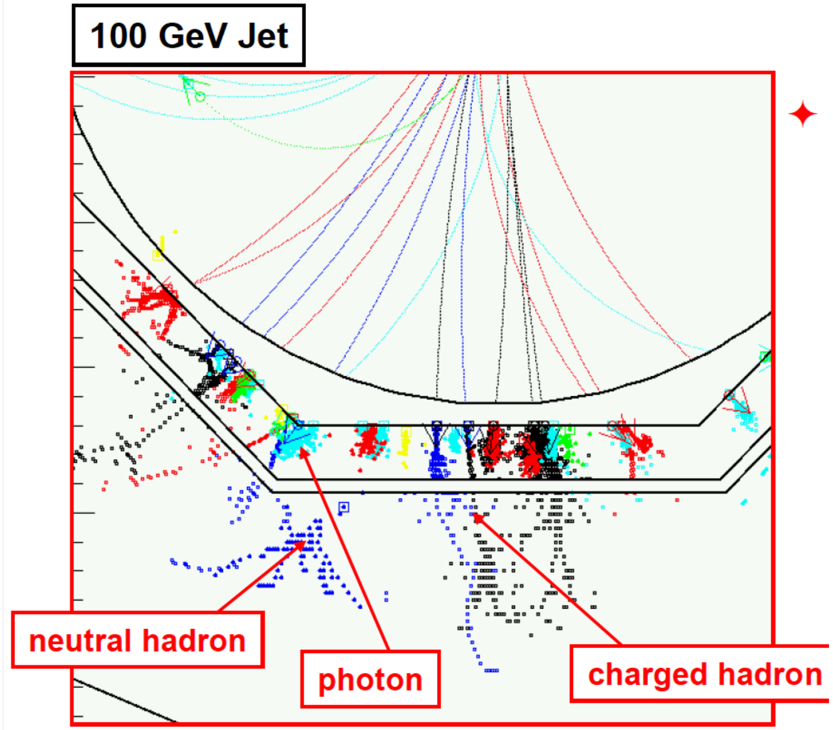
$$A = \frac{\sigma_R^{CC,e^+} \pm \sigma_L^{CC,e^-}}{\sigma_R^{NC} + \sigma_L^{NC}} \qquad A = \frac{G_F^2\, Q^4}{32\,\pi^2\,\alpha_e^2}\left[\frac{F_2^{W^+} \pm F_2^{W^-}}{F_2^{\gamma}} - \frac{1-(1-y)^2}{1+(1-y)^2}\,\frac{xF_3^{W^+} \mp xF_3^{W^-}}{F_2^{\gamma}}\right]$$

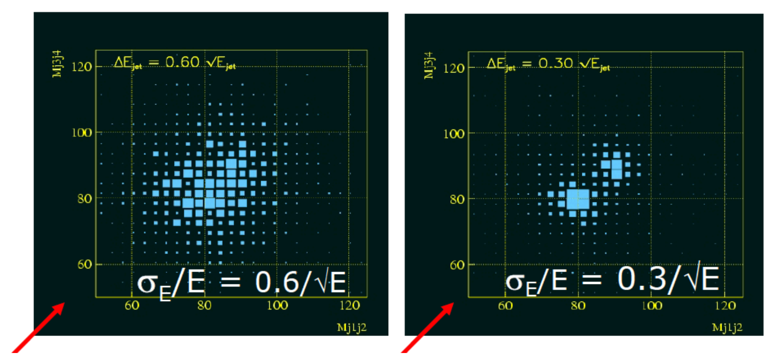
Detector requirements for Charged Current DIS

1. 4π Hadronic calorimeter
   - ➢ for Pt_miss
   - ➢ No electron in the final state. (x,Q2) should be reconstructed from hadronic final state => good resolution

   - ➢ Jets measurements: Particle flow calorimeter: Attempt to measure the energy/momentum of each particle in a hadronic jet with the detector subsystem providing the best resolution







Mark Thomson, Jose Repond

Testing the chiral structure of the weak interaction with Charged Current DIS

- Clear linear dependance:

$$\sigma_{CC}^{e^{\pm}p}(P_e) = (1 \pm P_e) \cdot \sigma_{CC}^{e^{\pm}p}(P_e = 0)$$

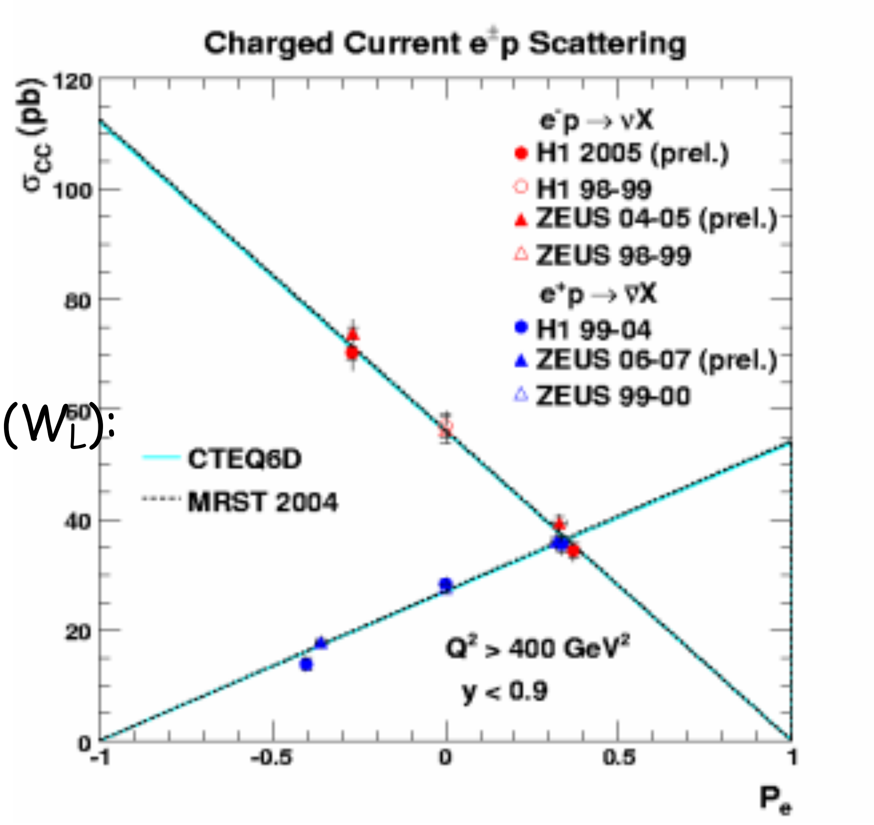
Clear left-handed nature of weak currents (W_L):

extrapolation to $P_{e^+} = -1$:

- $\sigma_{CC}^{tot} = -1.0 \pm 1.8_{stat} \pm 1.1_{sys}$ pb

- If not 0 for e- @P=1 or e+@ P=-1
- => new physics

Extrapolation to P=±1 => limits on W_R



- Backup