Asymmetries from semi-inclusive polarized DIS

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for the SMC collaboration

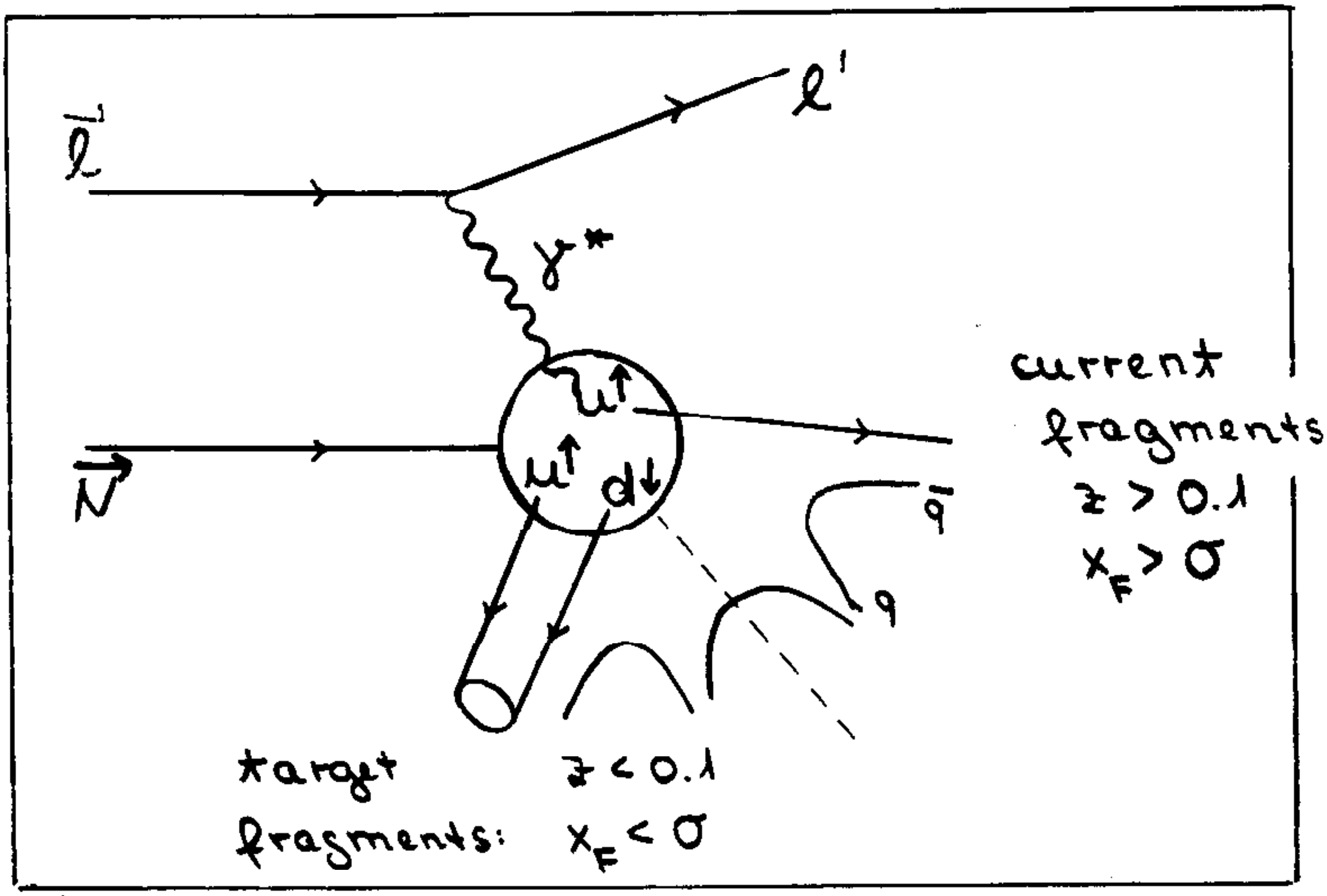
- Analysis of DIS events with hadrons measured in the SMC spectr.

- New method to determine inclusive asymmetries at small x

- Result for semi-inclusive asymmetr. and polarized quarkdistributions using all SMC data

Semi-inclusive DIS

$$\vec{l} + \vec{N} \to l' + \text{hadron} + X$$



Lepton:

$$Q^2 = -(p-p')^2$$

$$\nu \overset{Lab}{=} E - E'$$

$$x = Q^2/2M\nu$$

$$W^2 = M^2 + 2M\nu - Q^2$$

Hadrons:

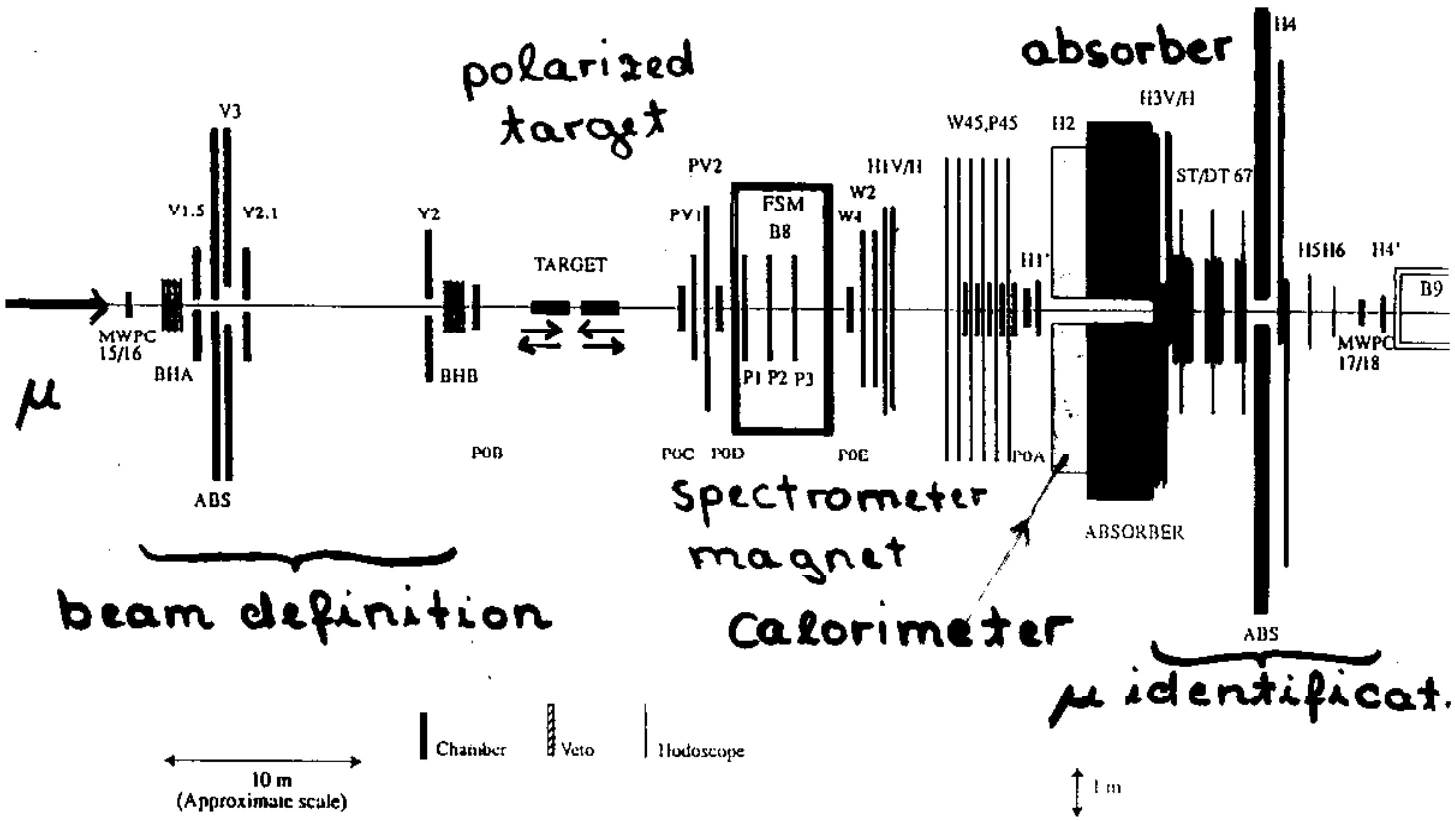
$$z \overset{Lab}{=} E_h/\nu$$

$$p_\perp$$

$$x_F = \frac{p^*_{\parallel}}{W}$$

($p^*_{\parallel}$ in $\gamma^* N$-syst.

SMC experiment



Measurement of

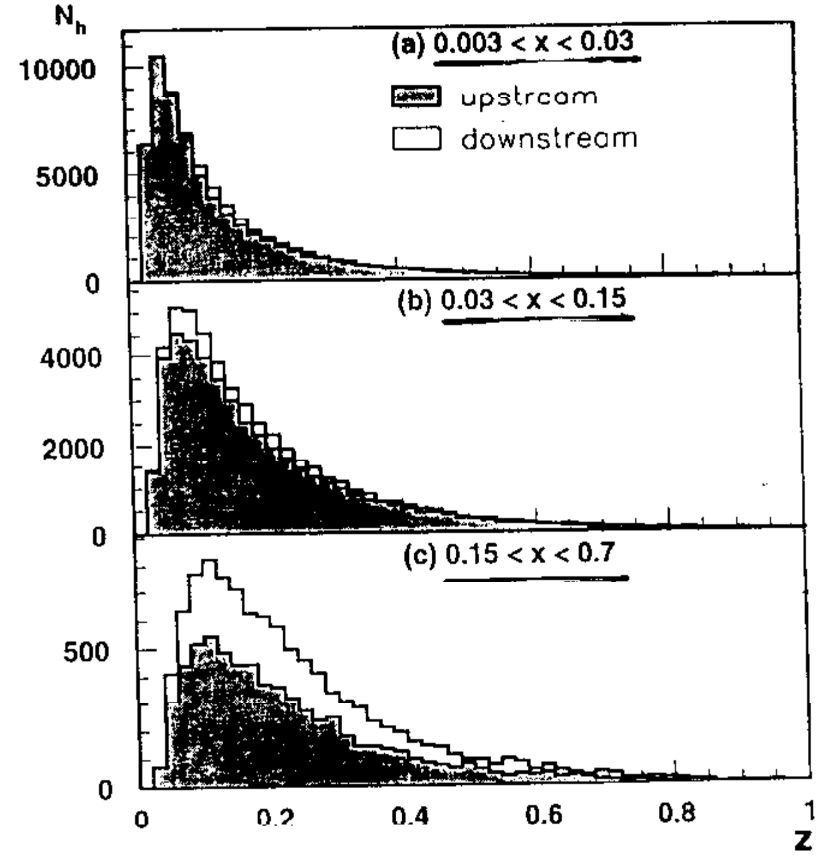
incoming + scattered μ

charged hadrons $p_h > 5\,\text{GeV}$

neutral hadrons via decay vertex or γ conversion

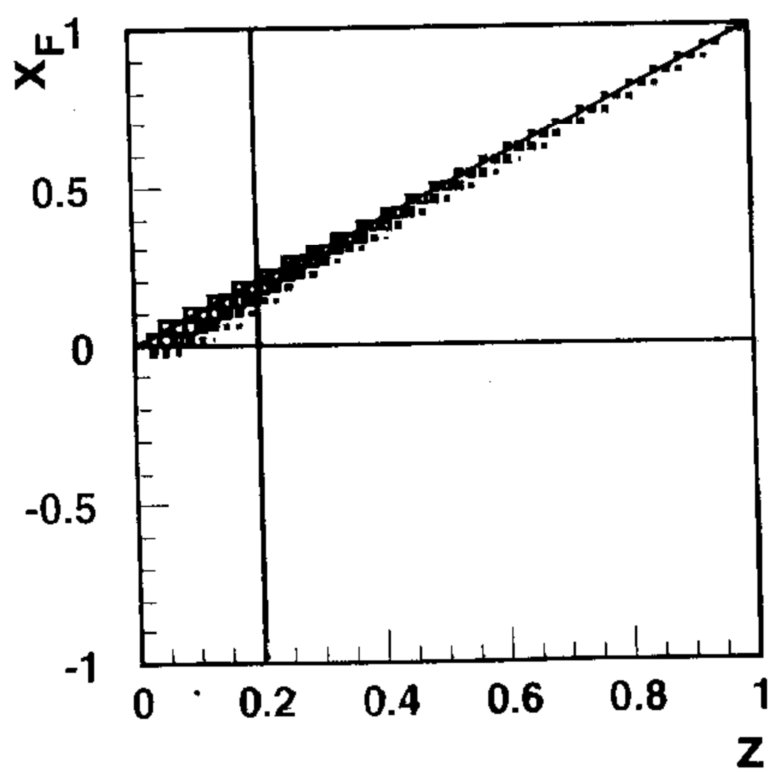
Hadron distributions

z distribution (190 GeV μ, NH_3)



$z_{min} \sim 0.05$
due to
spectrom.
acceptanc

x_F - z correlation



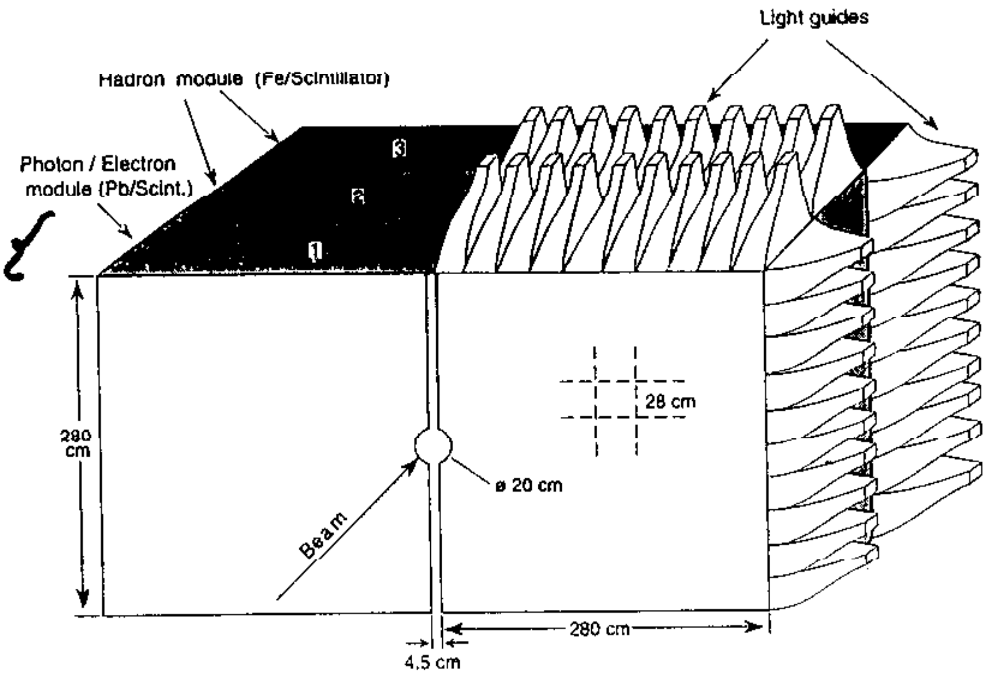
only
$x_F > 0$

$x_F \approx z$
(for $z > .2$

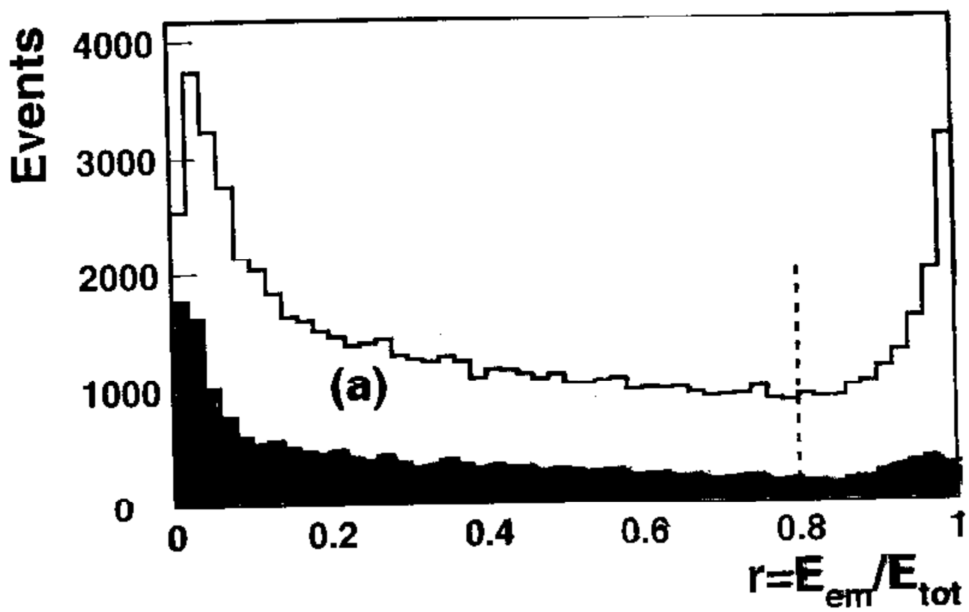
Hadronidentification

Calorimeter: total 5.5 int. length

elm. part
$20 X_0$



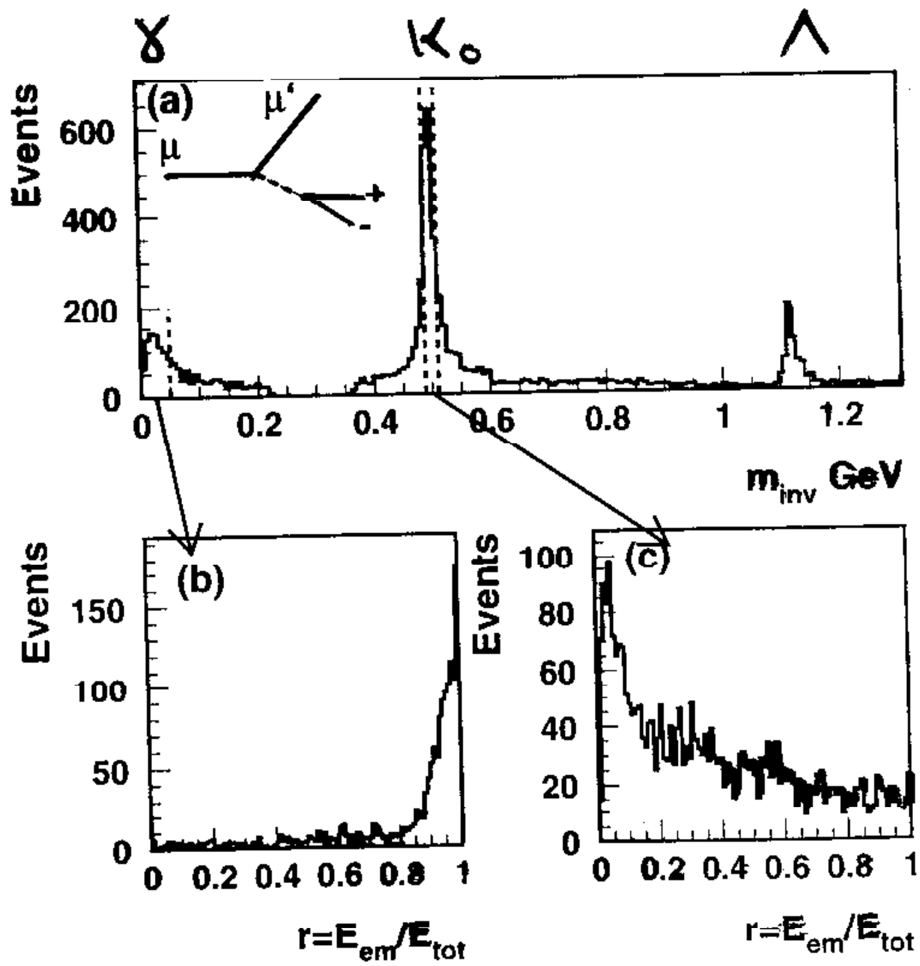
$\Rightarrow$ total energy deposit E_{tot}
energy in electromagnetic part E_{em}



$r > 0.8$

$\underbrace{\qquad\qquad}_{\text{hadrons}}$ $\underbrace{\quad}_{\text{electrons}}$

Reconstructed neutral particles from V_0-Vertices



Determination of inclusive asymmetries

Motivation

measured: $A^{\gamma N}_{meas} = \frac{1}{D} \frac{\Delta\sigma_{tot}}{\sigma_{tot}}$

D: Depol. factor

wanted: $A^{1\gamma N} = \frac{1}{D} \frac{\Delta\sigma_{1\gamma}}{\sigma_{1\gamma}}$

$\Rightarrow$ needs radiative corrections

$$\Delta\sigma_{tot} = \lambda \Delta\sigma_{1\gamma} + \Delta\sigma^{tail}$$

$$\sigma_{tot} = \underset{\substack{\uparrow \\ \text{vacuumpol} \\ \text{vertex corr.}}}{\lambda} \sigma_{1\gamma} + \underset{\substack{\uparrow \\ \text{bremsstrahlung}}}{\sigma^{tail}}$$

$$\Rightarrow \quad \boxed{A^{1\gamma N} = \frac{\sigma_{tot}}{\lambda\sigma_{1\gamma}} A^{\gamma N}_{meas} - \frac{1}{D} \cdot \frac{\Delta\sigma^{tail}}{\lambda\sigma_{1\gamma}}}$$

measurement diluted by radiative events (in add. to unpolarized material in the target)

radiative tails

standard inclusive measurement

$$\sigma^{tail} = \underbrace{\sigma^{tail}_{elastic} + \sigma^{tail}_{quasi\text{-}el.}}_{\text{large contribution at small } x} + \sigma^{tail}_{inelast.}$$

pure DIS events

$$\sigma^{tail} = \sigma^{tail}_{inelast.}$$

⇒ **Method**

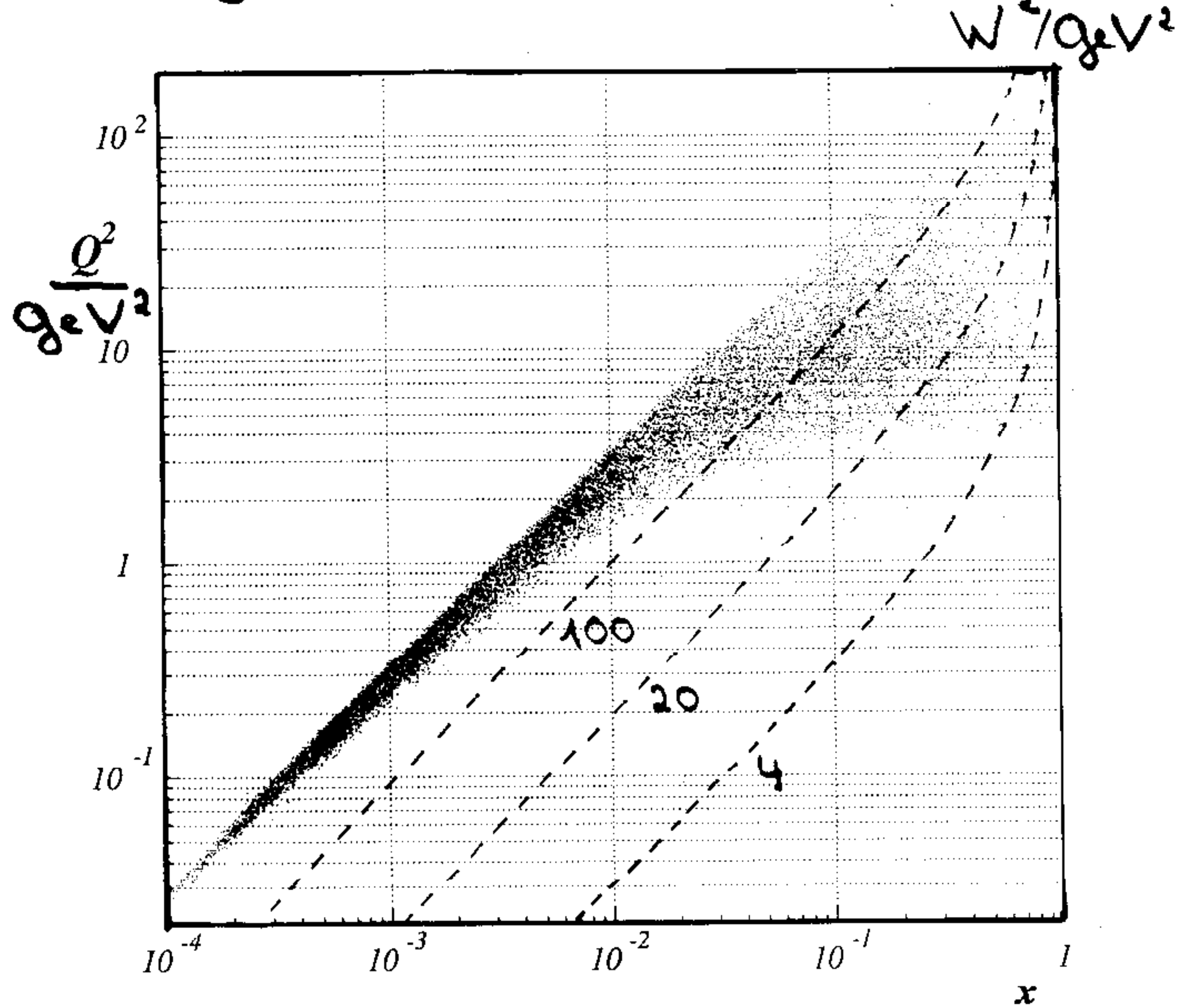
- use DIS events signalled by hadrons in add. to scattered μ (and rad. γ)
- much less diluted at small x
- improvement of statiscal precision

needs:

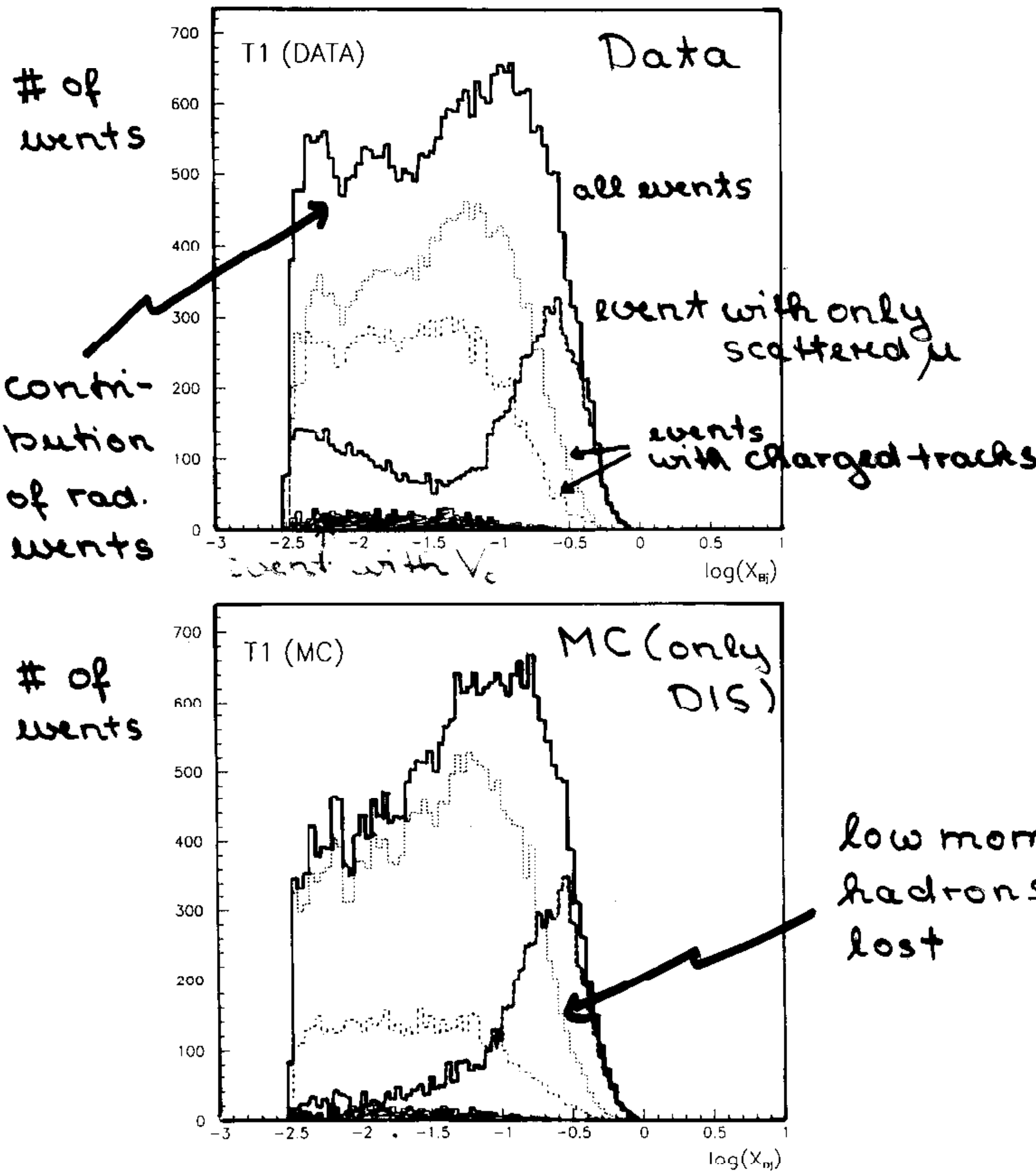
efficient selection of DIS events

Kinematics for 190 GeV

- event distribution from standard inclusive analysis (no cuts)
- x < 0.1 only high W^2 => several hadrons with high momenta
  => good acceptance of SMC spectr.

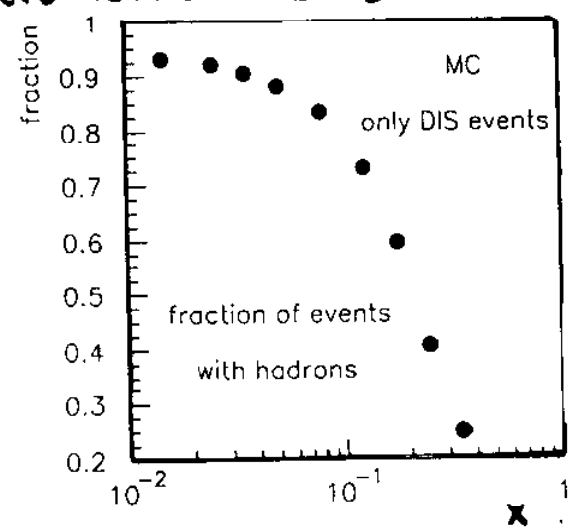


x distribution of reconstructed events

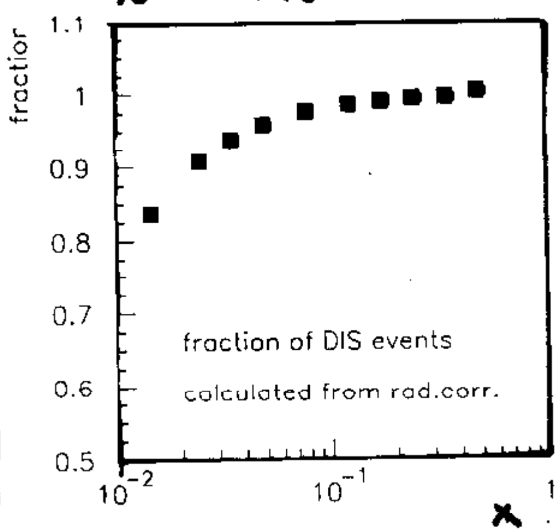


Result from MC

Fraction of events with reconstr. hadron



$$\frac{N^{DIS}}{N^{DIS} + N^{Rad.}}$$



- fraction of events with hadrons reconstr.

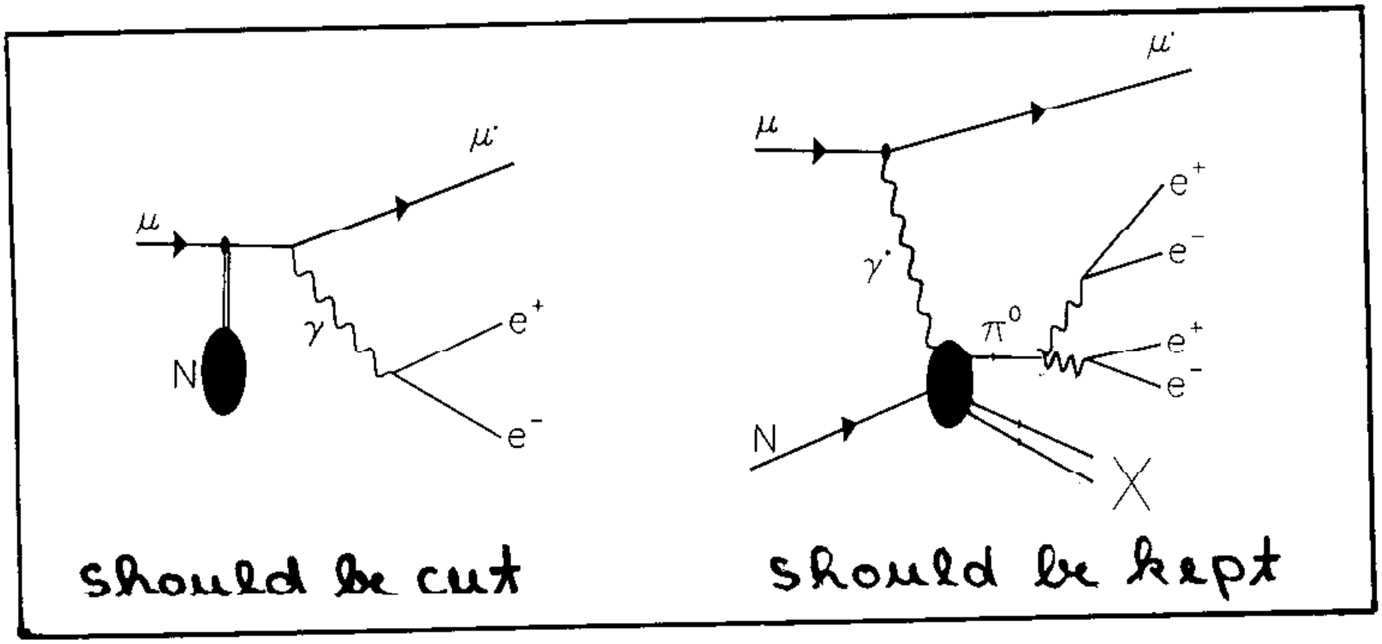
  $> 90\ \%$ for $x < 0.1$

- but : high contribution of rad. events for small x

  => electrons from γ conversion may simulate DIS events

Suppression of rad. events

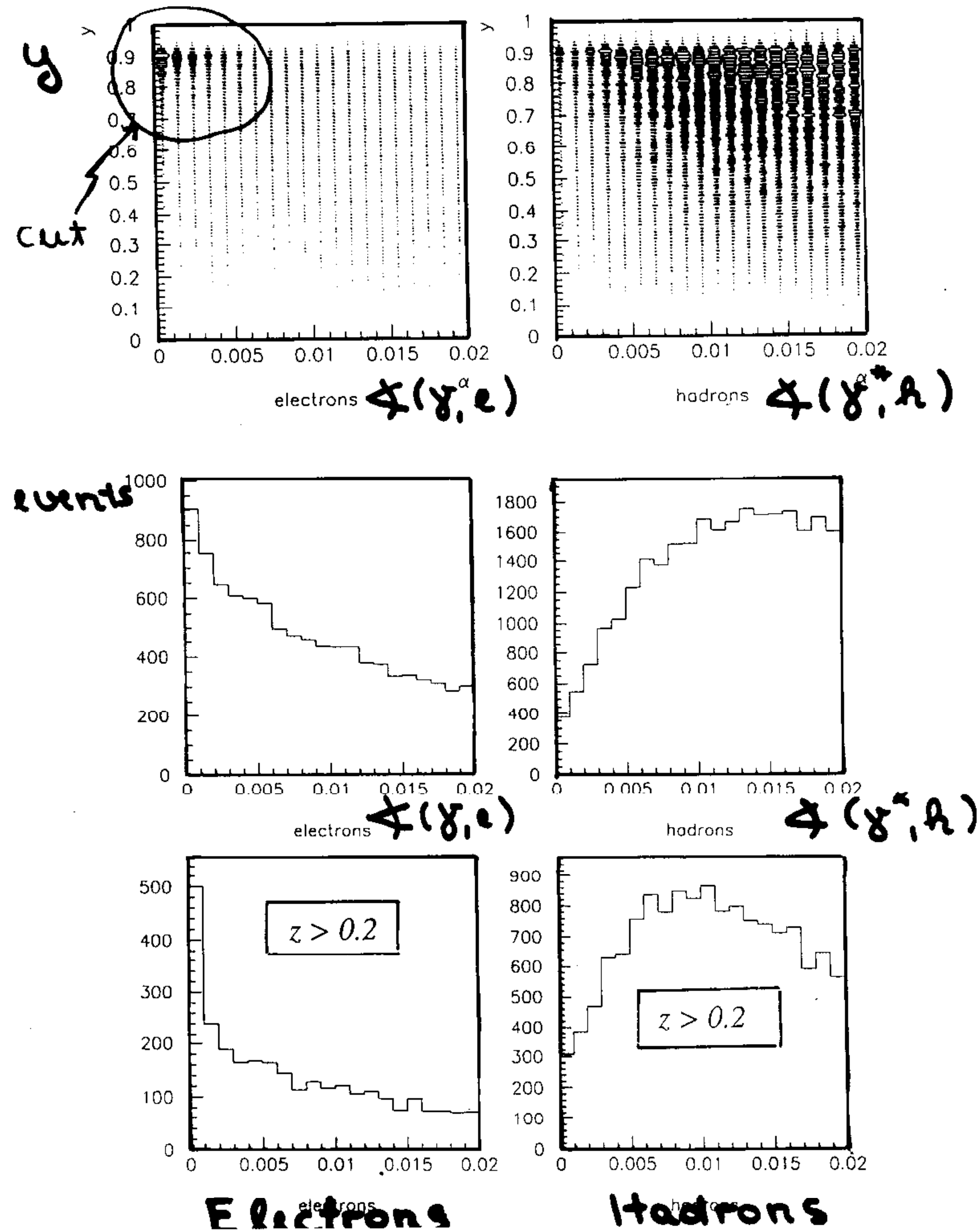
- two contributions to events with $e^\pm$ only



- events with $e^\pm$ from π^0's : low x electrons ($x \gtrsim 0.25$), all y

- events with $e^\pm$ from real γ (elastic, quasielast. tail):
  - high x, high y
  - Bremsstrahlung γ reconstructed from μ kinematics
  - $\alpha = \sphericalangle(\gamma, e^\pm)$ small

$y - \sphericalangle(\gamma, \tilde{h})$ distribution



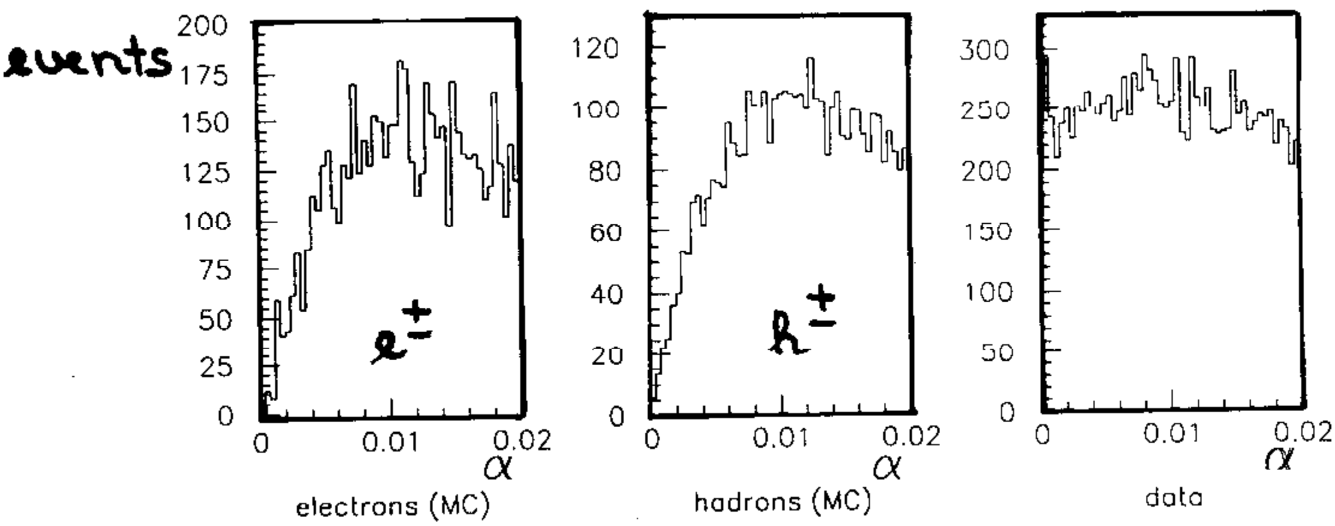
Cuts

- for identified electrons ($E_{em}/E_{tot} > 0.8$)

  $x > 0.2$
  $y > 0.6$
  $\sphericalangle(\gamma, e) < 0.004$

- problem: unidentified tracks due to beam hole in calorimeter

MC (DIS only) Data



- MC : $\sphericalangle(\gamma^*, {e \atop h})$ large for true DIS ev.

=> apply electoncuts to unident. tracks will cut only small fraction of DIS ev.

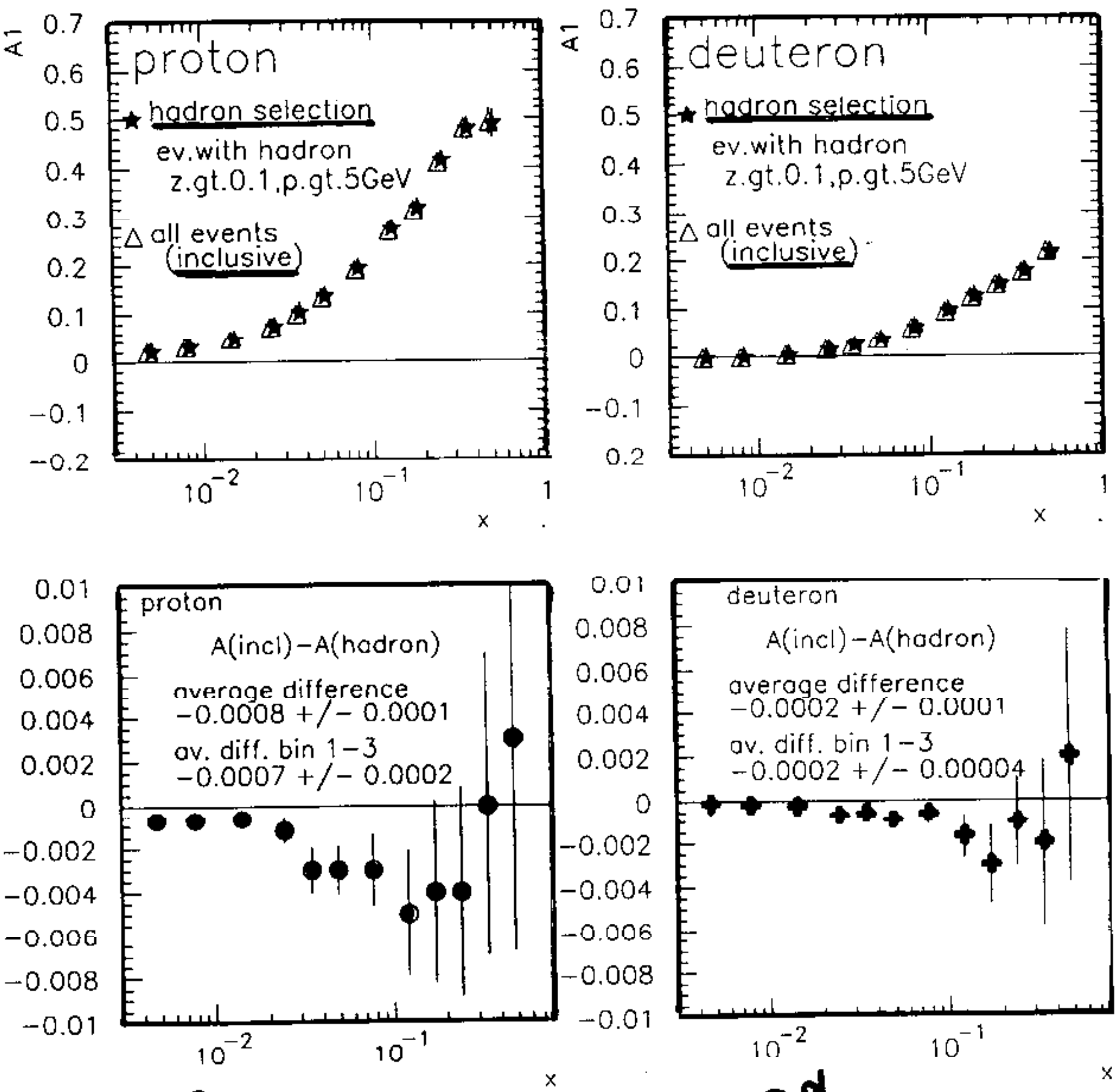
Does the hadron method determine inclusive A_1?

- check with MC simulation of pol. DIS

MC (pol. DIS)

A_1^p A_1^d

ΔA_1^p ΔA_1^d

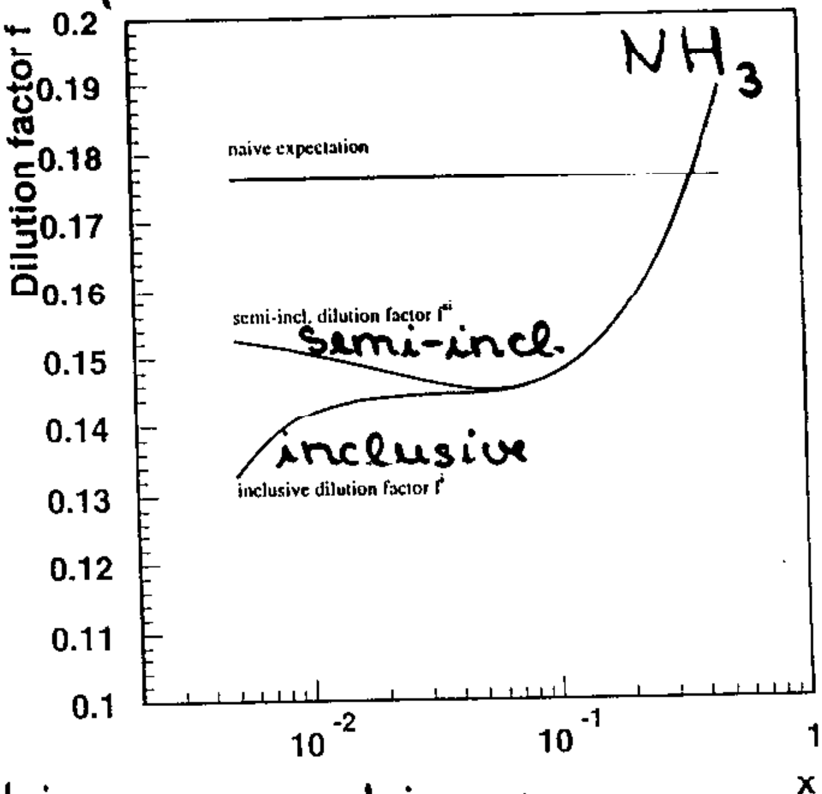


$$\frac{\Delta A_1^p}{A_1^p} \approx 1-3\% \qquad \frac{\Delta A_1^d}{A_1^d} \approx 5-6\%$$

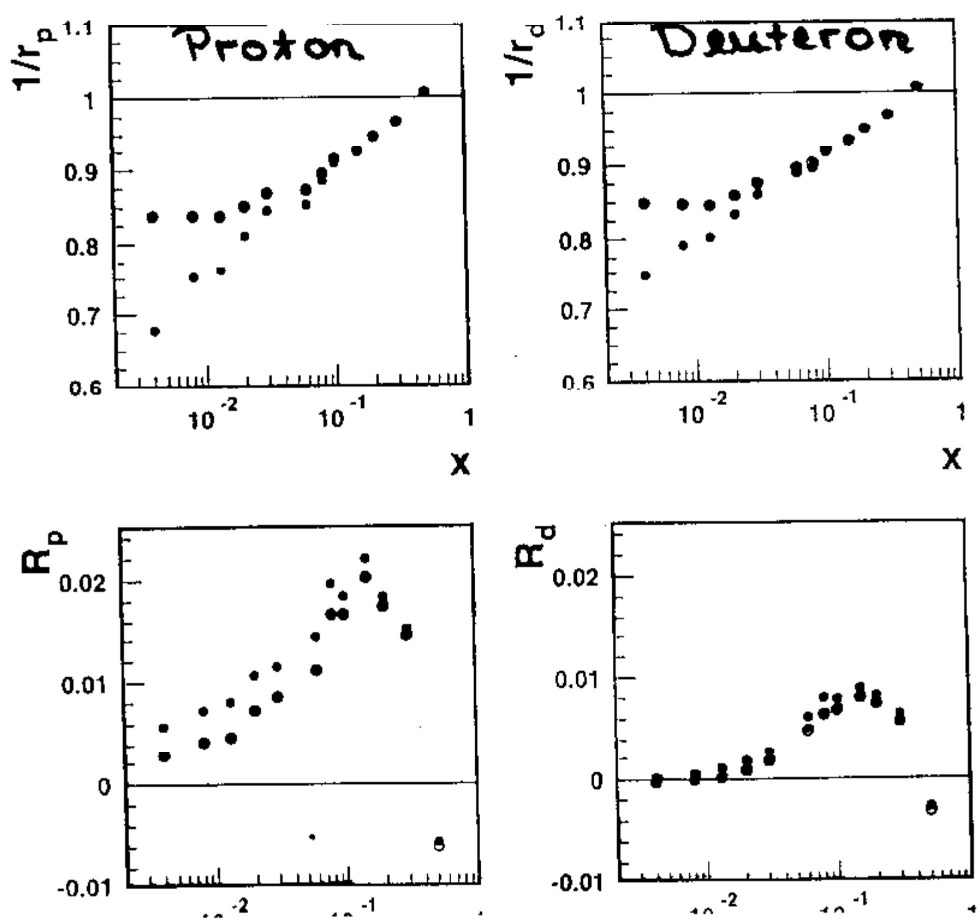
- $\Delta A = A^{incl} - A^{hadron}$ is small comp. to stat. error
- will be included in systematic error

Change of corrections

Dilutionfactor

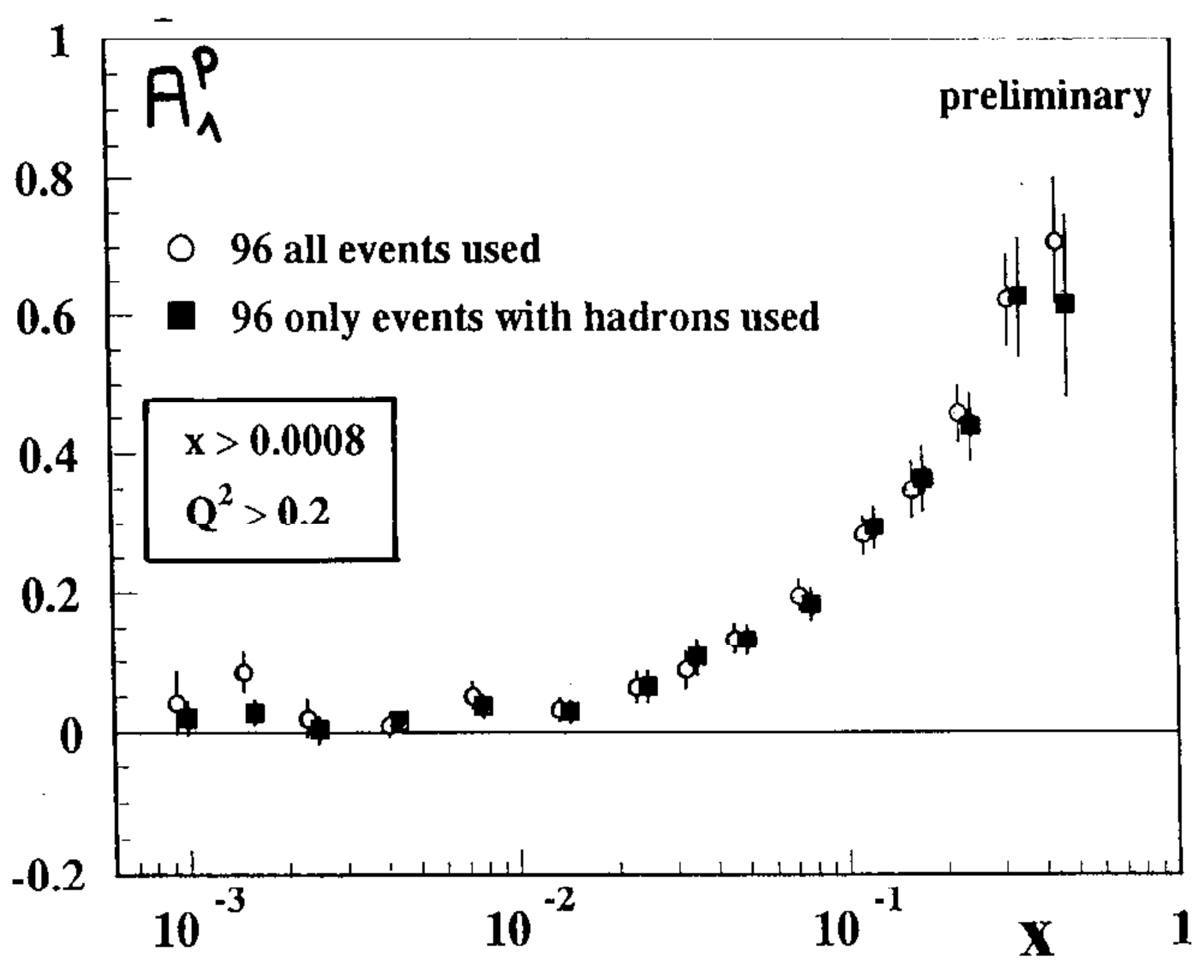


Radiative corrections $(A^{1\gamma} = r\, A^{meas} - R)$



Results for inclusive asymmetry A_1^p

- good agreement with stand. analysis
- stat. errors at low x smaller by 0.6 – 0.9



- work is goingon :
  refinement of radiative corr.
  systematic errors
  refinement of cuts
  analyse all data

Semi-inclusive asymmetries

semi inclusive cross section for
$\vec{\ell} + \vec{N} \rightarrow \ell' + h + X$:

<u>QPM</u>

$$\sigma_h^{1/2,3/2}(x,z) \sim \sum e_q^2 \left(q^{\uparrow,\downarrow}(x) D_q^h(z) + \bar{q}^{\uparrow,\downarrow}(x) D_{\bar{q}}^h(z) \right)$$

$q^{\uparrow,\downarrow}(x)$: polarised quark distributions

$D_q^h(z)$: fragmentation function

$$\Rightarrow \boxed{\begin{aligned} A^h(x,z) &= \frac{\sigma_h^{1/2}(x,z) - \sigma_h^{3/2}(x,z)}{\sigma_h^{1/2}(x,z) + \sigma_h^{3/2}(x,z)} \\ &= \frac{\sum e_q^2 \left(\Delta q \cdot D_q^h + \Delta \bar{q} \cdot D_{\bar{q}}^h \right)}{\sum e_q^2 \left(q \cdot D_q^h + \bar{q} \cdot D_{\bar{q}}^h \right)} \end{aligned}}$$

$$\Delta q = q^{\uparrow} - q^{\downarrow}$$

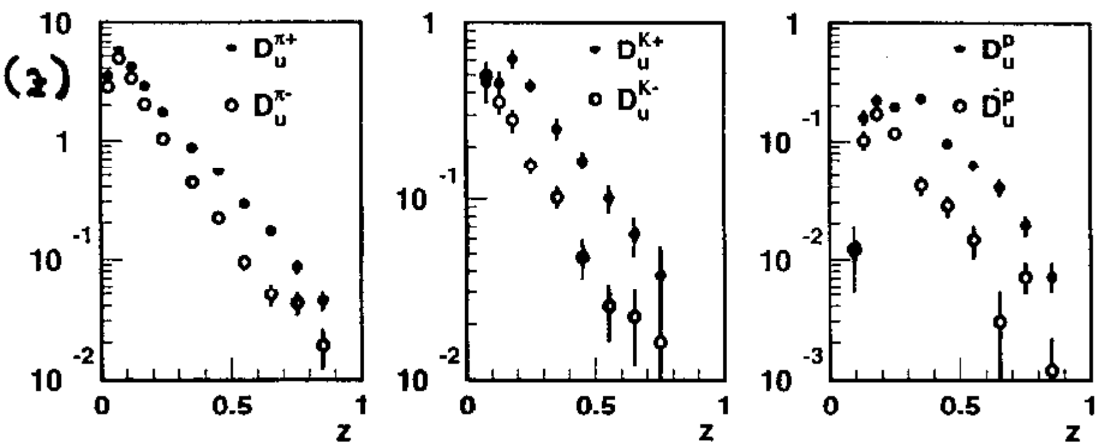
<u>QCD</u>

$$q = q(x, Q^2)$$
$$D_q^h = D_q^h(z, Q^2)$$

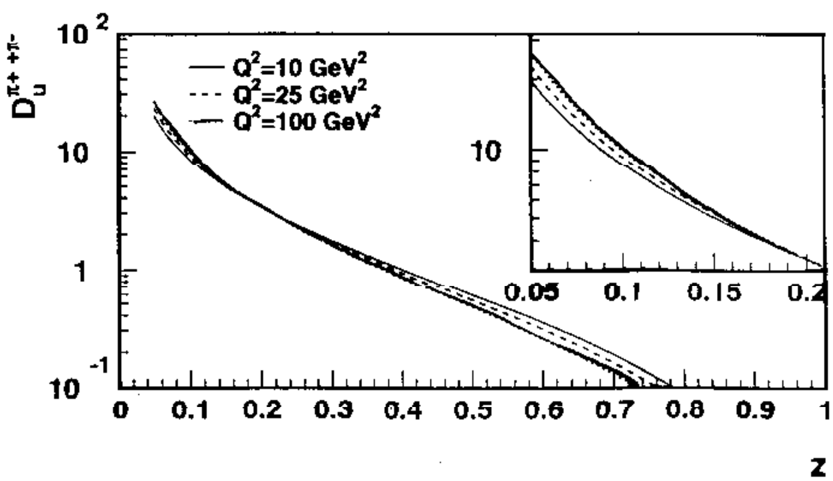
- $A^h(x,z)$: quarkdistr. weighted by D_q^h
- $D_q^h \neq D_{\bar{q}}^h$: separation of Δq and $\Delta\bar{q}$ for $z \gtrsim 0.2$
- measurements of fragmentation funct.

  • favoured ff
  ∘ unfavoured ff

$D_q^h(z)$



- Q^2-dependence of D_q^h



SMC analysis

- measurement of A^h for diff. targets and hadrons

  $\Rightarrow$ x dependence of $\Delta q_i(x)$

- SMC targets: proton, deuteron

  hadrons: pos., neg. hadrons

  (no hadronidentification $\Rightarrow$ 80% π + 20% K, p)

- important: clean hadron sample

  $\Rightarrow$ use of identified hadrons only with $E_{em}/E_{tot} < 0.8$

- all SMC data analysed:

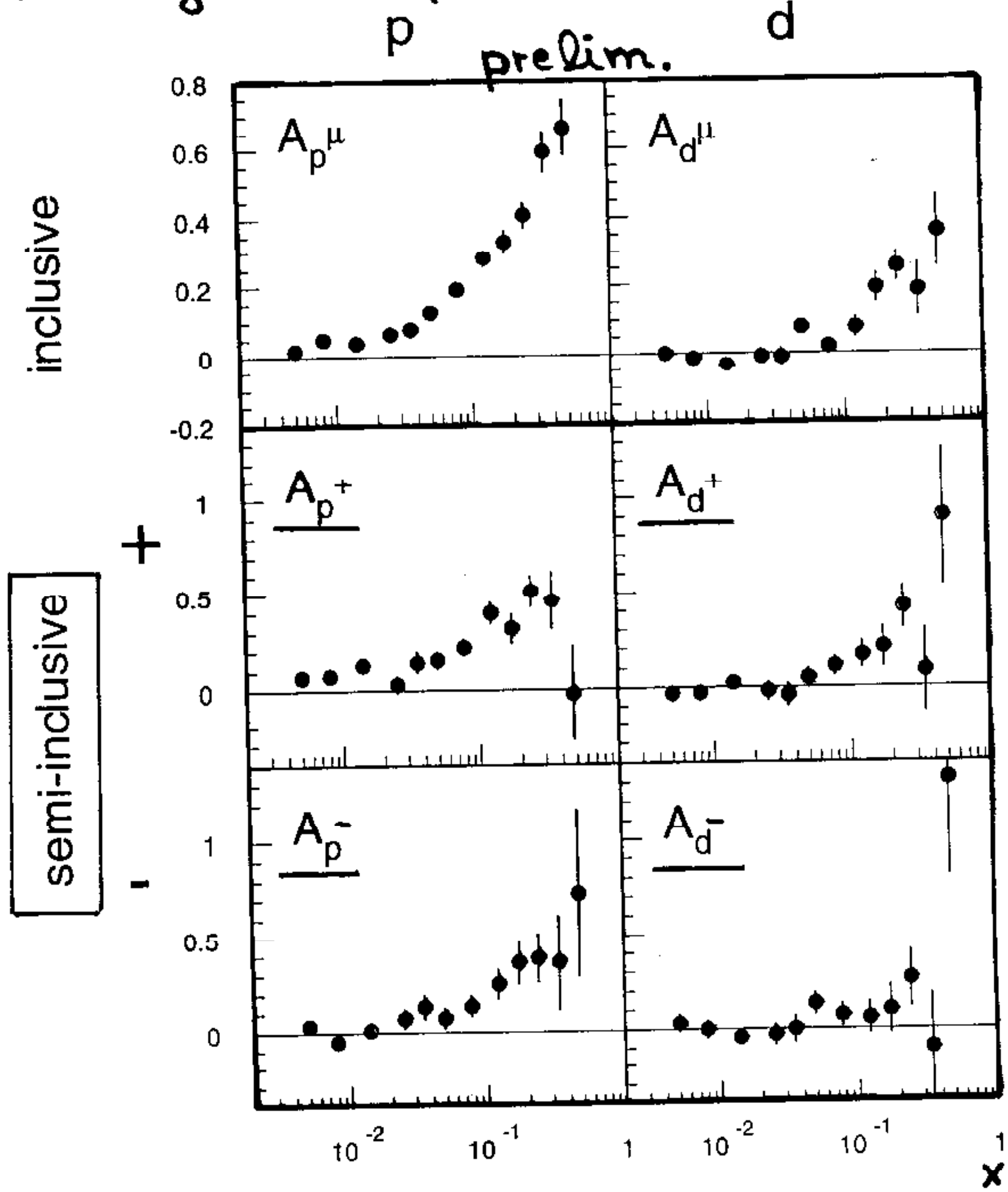
  $0.003 < x < 0.7$
  $1 < Q^2 < 80$ GeV^2
  $\nu > 15$ GeV

- $33 \cdot 10^6$ incl. events

  $5 \cdot 10^6$ h^+
  $3{,}8 \cdot 10^6$ h^-

Results for asymmetries

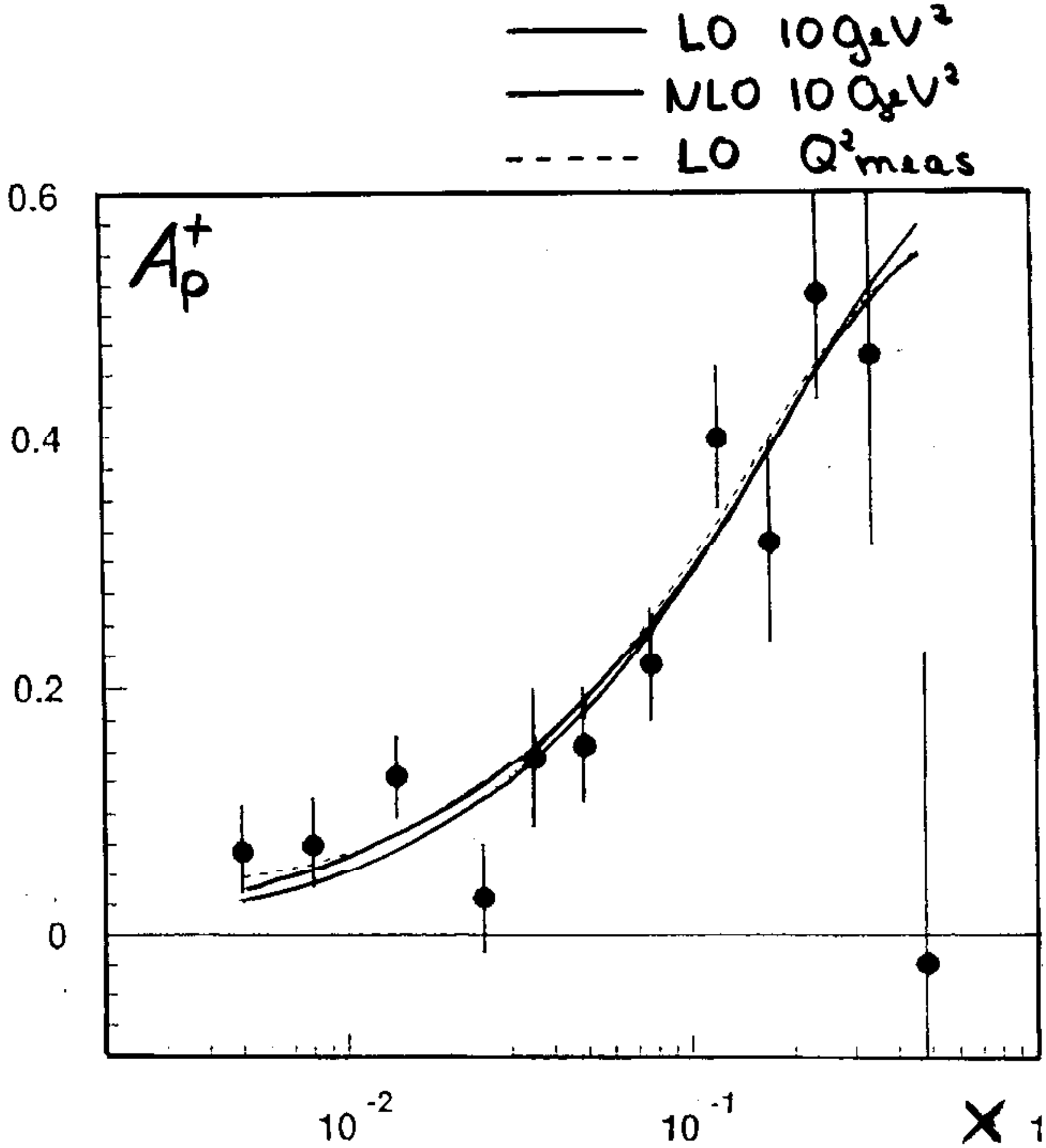
- $$A_h^{\gamma N} = \frac{1}{f \cdot D \cdot P_b \cdot P_t} A_{exp}^{\gamma N}$$
- semi-incl. radiative correction applied
- integrated from $z = 0.2$ to $z = 1$



- syst. errors < stat. errors

Q^2 dependence of A^h

- prediction using GRV q and Δq



- Q^2 dependence negligible
- $A^h(x, 10\,GeV^2) = A^h(x, Q^2_{meas})$ used

Determination of $\Delta q(x)$

- 6 measured asymmetries

  unknown: $\Delta u_v, \Delta d_v, \Delta\bar{u}, \Delta\bar{d}, \Delta\bar{s}$

$$\begin{pmatrix} A_1^p \\ A_1^d \\ A_p^+ \\ A_p^- \\ A_d^+ \\ A_d^- \end{pmatrix}(x) = C\left(q(x), \int_{0.2}^{1} D_q^{\pm}(z)\right) \begin{pmatrix} \Delta u_v \\ \Delta d_v \\ \Delta\bar{u} \\ \Delta\bar{d} \\ \Delta\bar{s} \end{pmatrix}(x)$$

- inputs:

  $D_q^{\pm}(z)$ EMC measurements

  $q(x)$ GRV parametrisation

- assumptions:

  $\int_{0.003}^{1}(\Delta s + \Delta\bar{s})\,dx = -0.1$, $\Delta s = \Delta\bar{s} \sim s$

  no sensitivity to Δs as no $A^{K^\pm}$

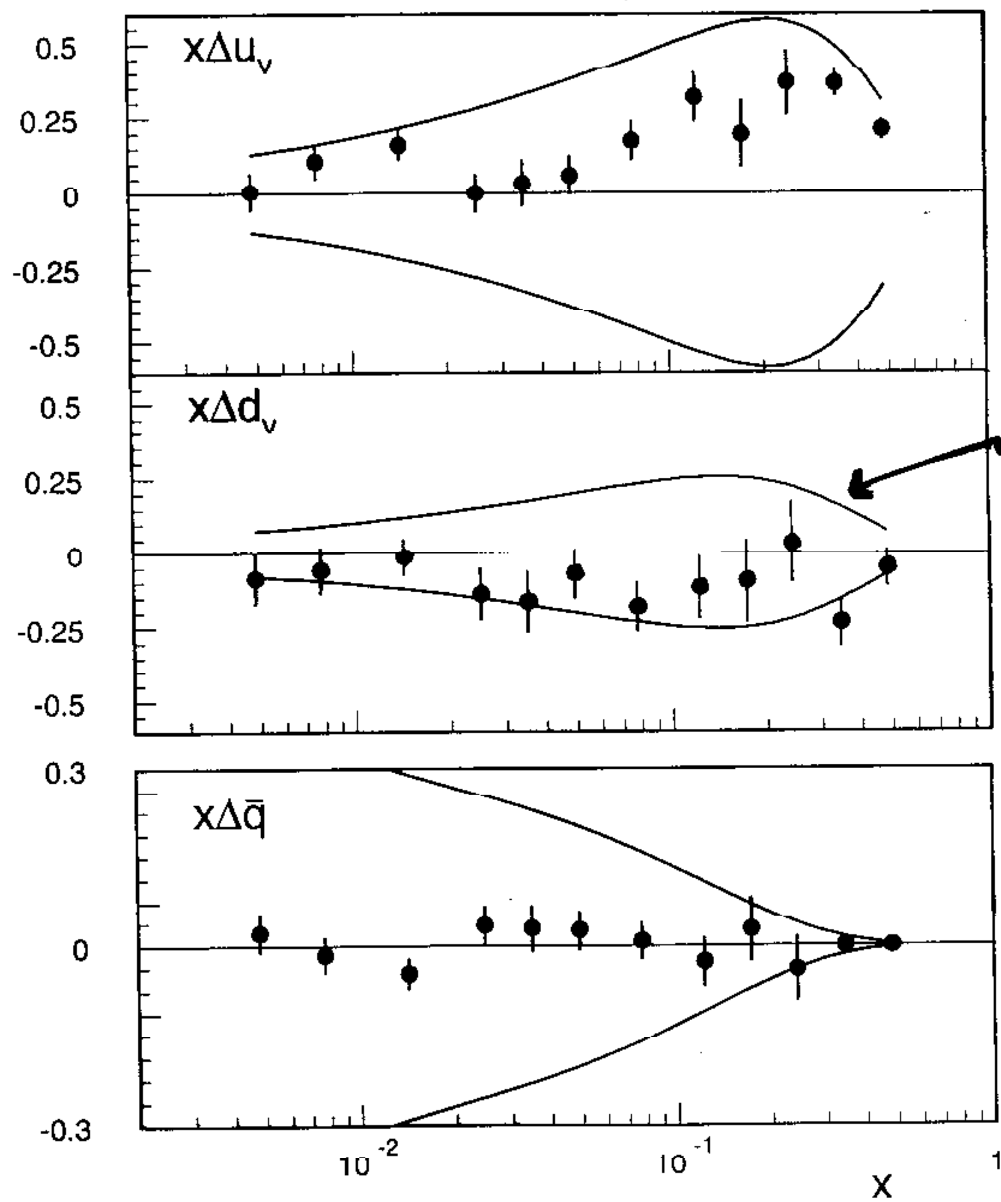
  $\Delta\bar{u}(x) = \Delta\bar{d}(x) = \Delta\bar{q}(x)$

  limited statistics

Results for $\Delta u_v, \Delta d_v, \Delta \bar{q}$

- $|\Delta \bar{q}(x)| < \bar{q}(x)$ imposed

preliminary



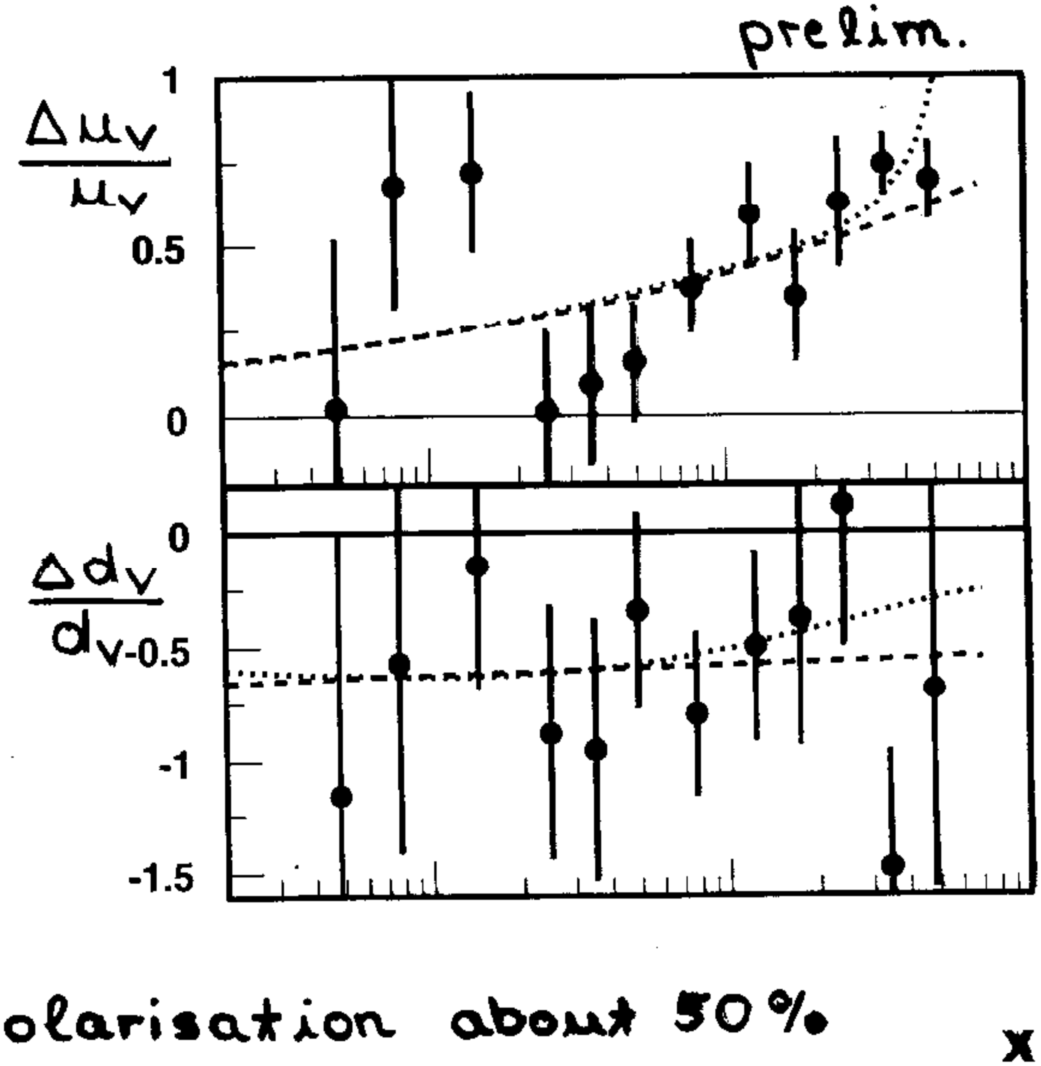
$Q^2 = 10\ GeV^2$

unpol. quarkdist.

- main contrib. to systematic errors :

  error on P_b, P_t, $q(x)$, $D_q^h(z)$, acceptance variation

Polarisation of valencequarks



- polarisation about 50%

Integrals

prelim.

$$\int_{0.003}^{0.7} \Delta u_v(x)\,dx = 0.88 \pm 0.11 \pm 0.06$$

$$\int_{0.003}^{0.7} \Delta d_v(x)\,dx = -0.48 \pm 0.15 \pm 0.05$$

$$\int_{0.003}^{0.7} \Delta \bar{q}(x)\,dx = -0.01 \pm 0.05 \pm 0.01$$

- extrapolation to $x=1$: negligible contribution
- extrapolation to $x=0$: under study

  use parametrisations from QCD fits to g_1

  fit of parametr. of diff. forms to Δq

  e.g. $\Delta q \sim x^a (1-x)^b q(x)$
- size of contribution :

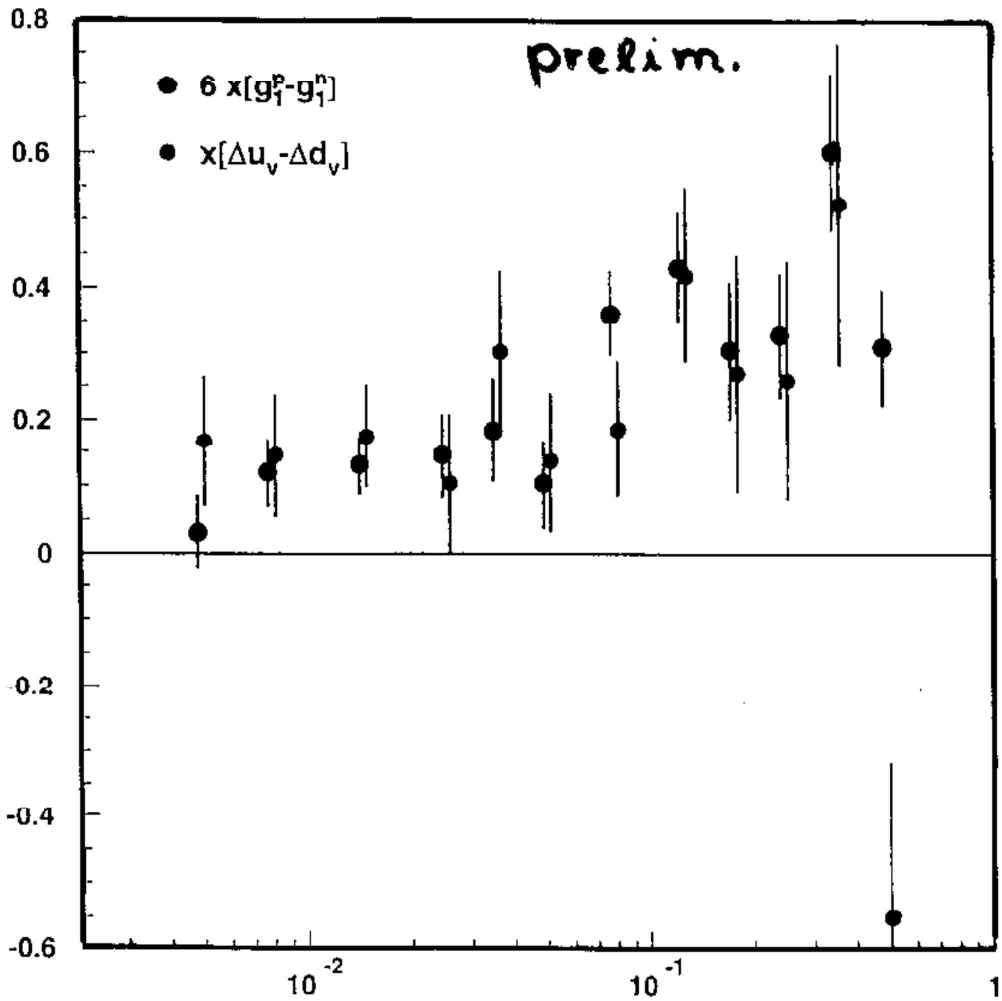
  about 0.05 with similar error

Comparison with inclusive results

- $$6x\,(g_1^p(x) - g_1^n(x)) = x\,(\Delta u_v(x) - \Delta d_v(x))$$

  $\underbrace{6x\,(g_1^p(x) - g_1^n(x))}_{\text{calc. from inclusive results}}$ $\underbrace{x\,(\Delta u_v(x) - \Delta d_v(x))}_{\text{from semi-incl. analysis}}$

- good agreement
  check of asumptions in semi-incl. anal



Summary

- hadron measurement with the SMC spectrometer

<u>inclusive asymmetries</u>

- selection of DIS events and background suppression
- improved dilution factor, smaller radiative corrections
- improved stat. accuracy for A_1 at small x

<u>semi-inclusive asymmetries</u>

- selection of charged hadrons with $z > 0.2$
- prelim. asymmetries for pos. and neg. hadrons from all SMC data for proton and deuteron
- extraction of pol. quarkdistributions $\Delta q(x)$ and integrals for $0.003 < x < 0.8$
- valence quark polarisation ~ 50%
  no polarisation of non-strange sea