PHOTON '97

May 1997

Measurement of the photon structure function F_2^γ at low x in inelastic electron-photon scattering at LEP1

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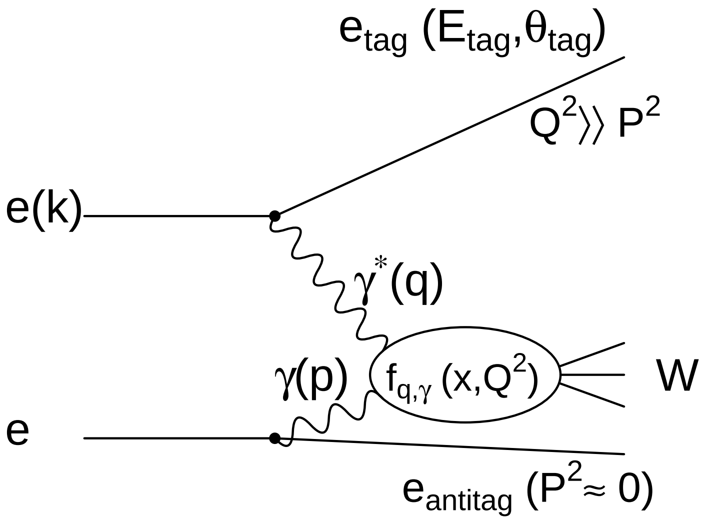
Introduction

- The published measurements of F_2^γ at medium x agree reasonably with the F_2^γ parametrisations, but
  little is known about the region $x < 0.05$.
  (TPC/2γ, PLUTO)

- This region is particularly interesting:
  Several **parametrisations** of $F_2^\gamma(x, Q^2)$; similar at medium x but **very different at** $x < 0.05$.
  A rise of the **proton** structure function at low$x$ observed at HERA .

- LEP beam energies:
  Detecting a scattered electron at small θ – in the OPAL luminosity calorimeter – lower x than before are accessed,
  at $Q^2 > 1\text{GeV}^2$ (pert. side).

Inelastic eγ scattering – "singly tagged" events



$$\frac{d^2\sigma_{e\gamma\to eX}}{dx dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\Big[\quad \left(1 + (1-y)^2\right) F_2^\gamma(x, Q^2)$$

$$-y^2 F_L^\gamma(x, Q^2) \quad \Big]$$

With $x = \frac{Q^2}{2p\cdot q}$, $\quad y = \frac{p\cdot q}{p\cdot k}$; $\quad$ y $\approx$ 0 in the sample
Q^2 , P^2 = photon virtualities,
$f_{q,\gamma}(x, Q^2)$ = parton densities of quasireal photon.

Event selection and data sample

Tag	$0.775\ E_{\text{beam}} < E_{\text{tag}} < 1.2\ E_{\text{beam}}$ 27 mrad $<\theta_{\text{tag}} <$ 55 mrad (OPAL luminosity calorimeter 'SW') $\Rightarrow 1.2\,\text{GeV}^2 < Q^2 < 6.3\,\text{GeV}^2$
Antitag	$E_a < 0.25 E_{\text{beam}}$; $E_a =$ highest cluster energy in hemisphere opposite to tag
Hadrons	$N_{track} > 2$ (reject $\gamma^\star\gamma \to l^+l^-$) $p_{\text{t,out}}$,$p_{\text{t,bal}} <$ 3GeV 2.5GeV $< W_{\text{vis}} <$ 40GeV

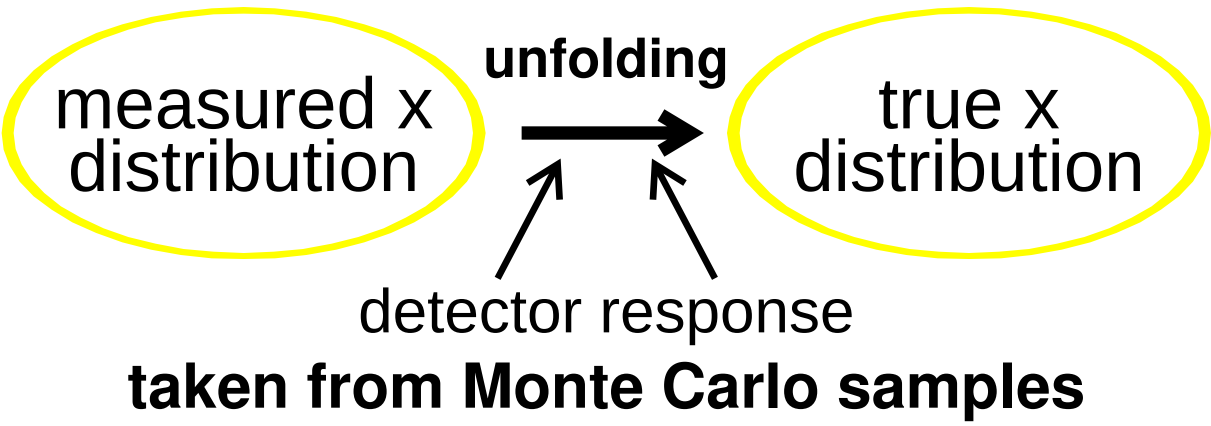
Data sample of 71 pb^{-1} int. luminosity:

selected events	largest backgrounds		
	$\gamma^\star\gamma \to \tau^+\tau^-$	$\gamma^\star\gamma \to e^+e^-$	$Z^0 \to$ hadrons
7112	85.6 ± 9.1	63.1 ± 7.7	11.8 ± 2.4

The estimated background from other sources is 0.2%.

Uncertainties of the hadronic system

W_{vis} and hence $x_{\text{vis}} = Q^2 \ /(Q^2 \ + W_{\text{vis}}^2 \ )$ are widely smeared around the true values.
(Photon '95)



⇒ The unfolding result may depend on the modelling of the $\gamma^\star\gamma$ fragmentation.
This was studied using different models.

Monte Carlo generation

HERWIG5.8d (cluster fragmentation),

PYTHIA5.722 (string fragmentation):

General purpose generators for hadronic processes with implementation for deep inelastic eγ scattering.

F2GEN: Simple two quark model for final state.

a) "pointlike" model (angular distrib. of $\gamma^{\star}\gamma \rightarrow l^{+}l^{-}$, assumed to describe hard limit).
b) "peripheral" model (very low P_T of the quarks in $\gamma\gamma$ CMS, assumed to describe soft limit).

Each of the three programs generates events according to a freely chosable F_2^{γ}:

Samples have been generated using the GRV, SaS (and DG) parametrisations for F_2^{γ}.

Data description and modelling of the $\gamma^{\star}\gamma$ fragmentation

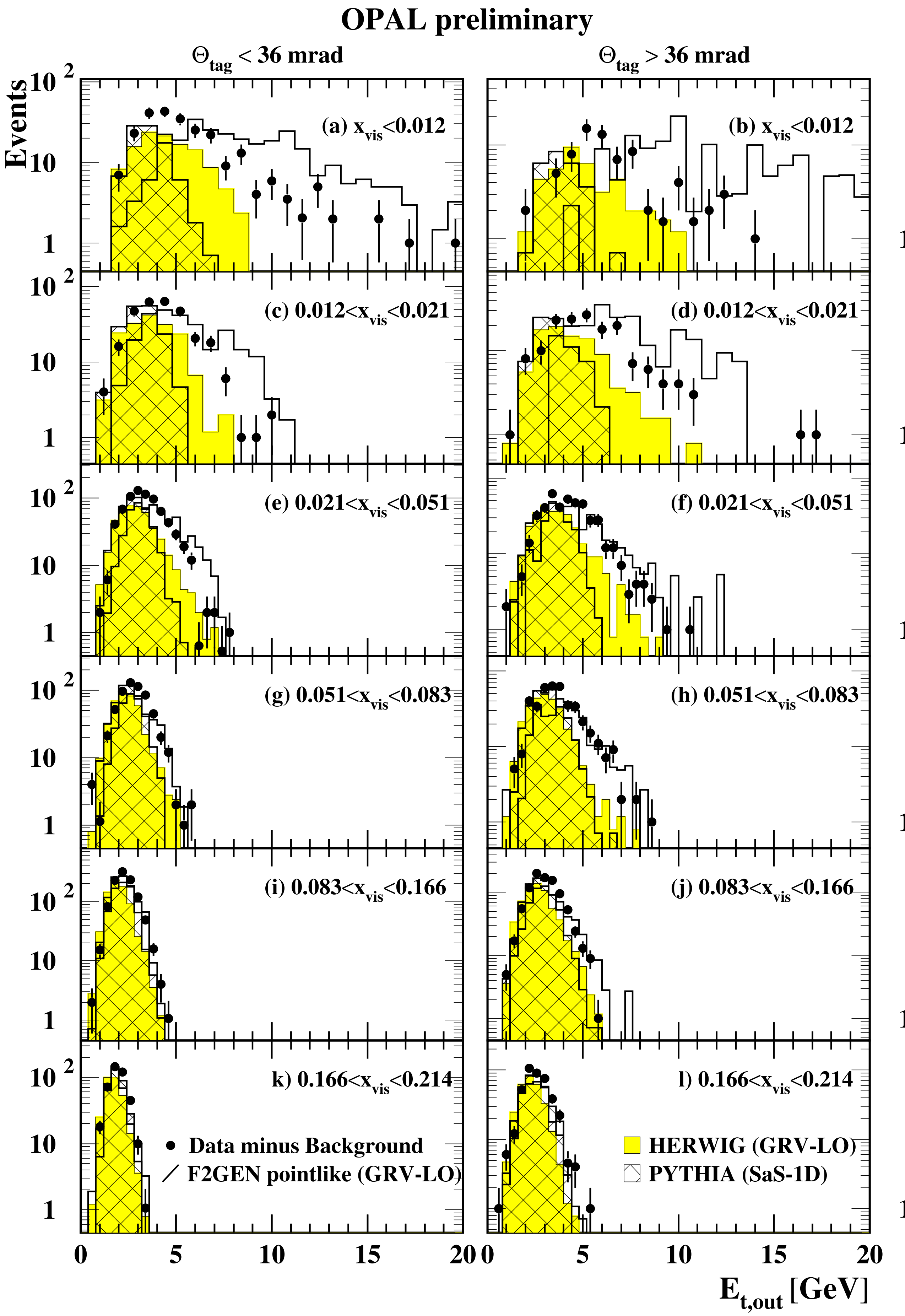
The shape of distributions insensitive to the topology of the hadronic final state are well described by Monte Carlo models.

Distributions of the hadronic final state show obvious discrepancies (data-MC, MC-MC):

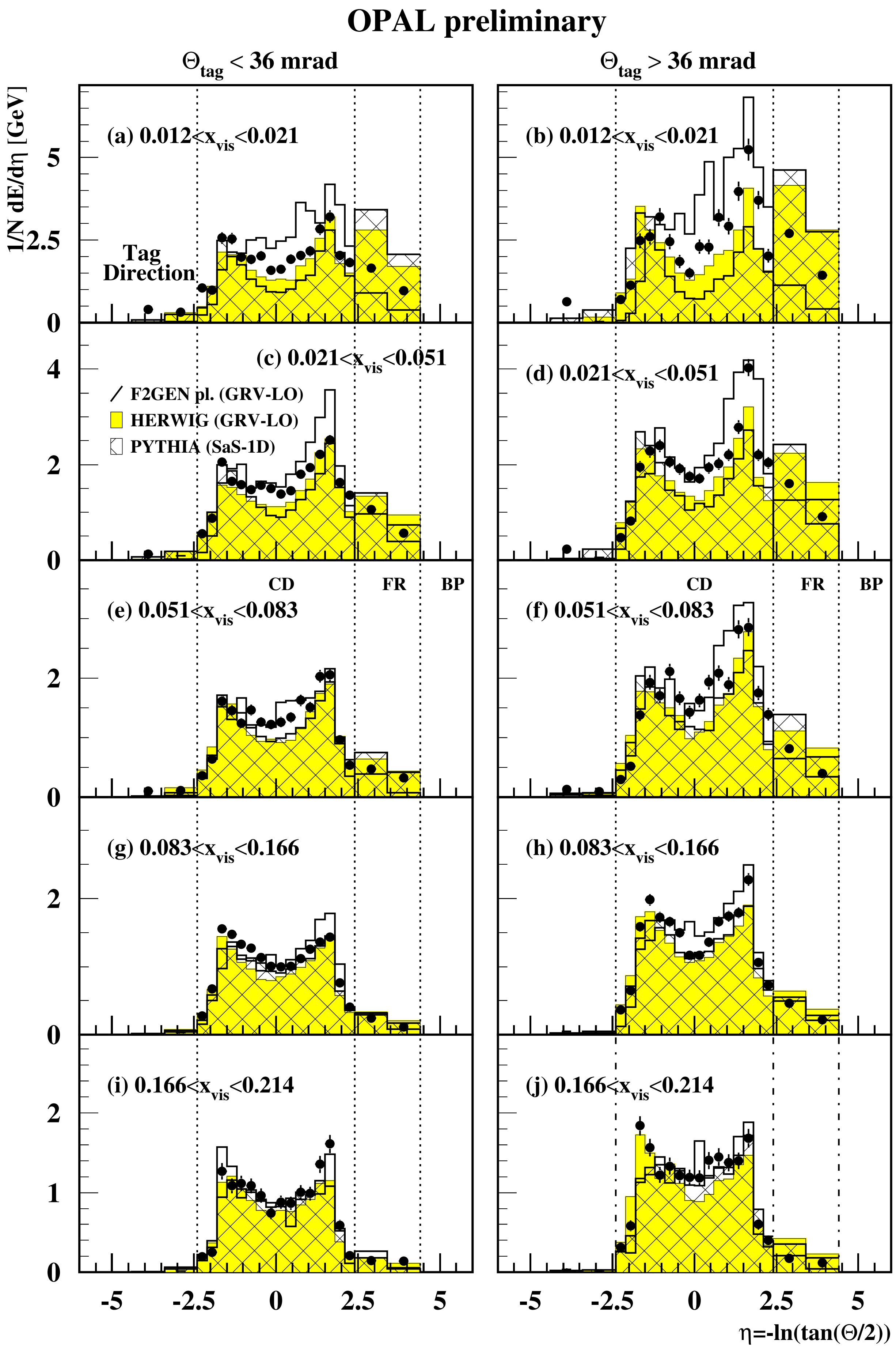
a) $E_{\text{t,out}}$ **:** Scalar sum of energy components perpendicular to the tag plane (plane defined by beam axis and tag direction) of all tracks and unassociated clusters. The tag is excluded.

b) Average **energy flow** per event of the hadronic system as a function of pseudorapidity η.
($\eta := -ln(tan(\theta/2))$, all tags at negative η)

The discrepancies tend to be $\left\{ \begin{array}{l} \text{small at } x_{\text{vis}} > 0.05 \\ \text{large at } x_{\text{vis}} < 0.02 \\ \text{larger in the higher } \theta_{tag} \text{ bin} \end{array} \right.$



OPAL preliminary
Θ_{tag} < 36 mrad
Θ_{tag} > 36 mrad
Events
(a) x_{vis}<0.012
(b) x_{vis}<0.012
(c) 0.012<x_{vis}<0.021
(d) 0.012<x_{vis}<0.021
(e) 0.021<x_{vis}<0.051
(f) 0.021<x_{vis}<0.051
(g) 0.051<x_{vis}<0.083
(h) 0.051<x_{vis}<0.083
(i) 0.083<x_{vis}<0.166
(j) 0.083<x_{vis}<0.166
k) 0.166<x_{vis}<0.214
l) 0.166<x_{vis}<0.214
Data minus Background
F2GEN pointlike (GRV-LO)
HERWIG (GRV-LO)
PYTHIA (SaS-1D)
$E_{t,out}$ [GeV]


OPAL preliminary
Θ_{tag} < 36 mrad
Θ_{tag} > 36 mrad
1/N dE/dη [GeV]
(a) $0.012<x_{vis}<0.021$
(b) $0.012<x_{vis}<0.021$
Tag Direction
(c) $0.021<x_{vis}<0.051$
(d) $0.021<x_{vis}<0.051$
F2GEN pl. (GRV-LO)
HERWIG (GRV-LO)
PYTHIA (SaS-1D)
CD
FR
BP
(e) $0.051<x_{vis}<0.083$
(f) $0.051<x_{vis}<0.083$
(g) $0.083<x_{vis}<0.166$
(h) $0.083<x_{vis}<0.166$
(i) $0.166<x_{vis}<0.214$
(j) $0.166<x_{vis}<0.214$
η=-ln(tan(Θ/2))

Determination of the photon structure function

Two Q^2 bins: A) $Q^2 < 2.5\mathrm{GeV}^2$,$<Q^2>= 1.86\mathrm{GeV}^2$
B) $Q^2 > 2.5\mathrm{GeV}^2$,$<Q^2>= 3.76\mathrm{GeV}^2$

F_2^γ is unfolded using the "RUN" program by Blobel.

In order to resolve the lowest accessible x values in the sample the unfolding is performed on a **logarithmic x-scale**.

HERWIG with GRV structure function is chosen as "reference unfolding" = result.

HERWIG (SaS), PYTHIA(SaS), F2GEN(GRV) are used for systematic studies.
F2GEN: A mixture is used which minimises the discrepancies in the lowest x bin. (19% point-like/81% peripheral)

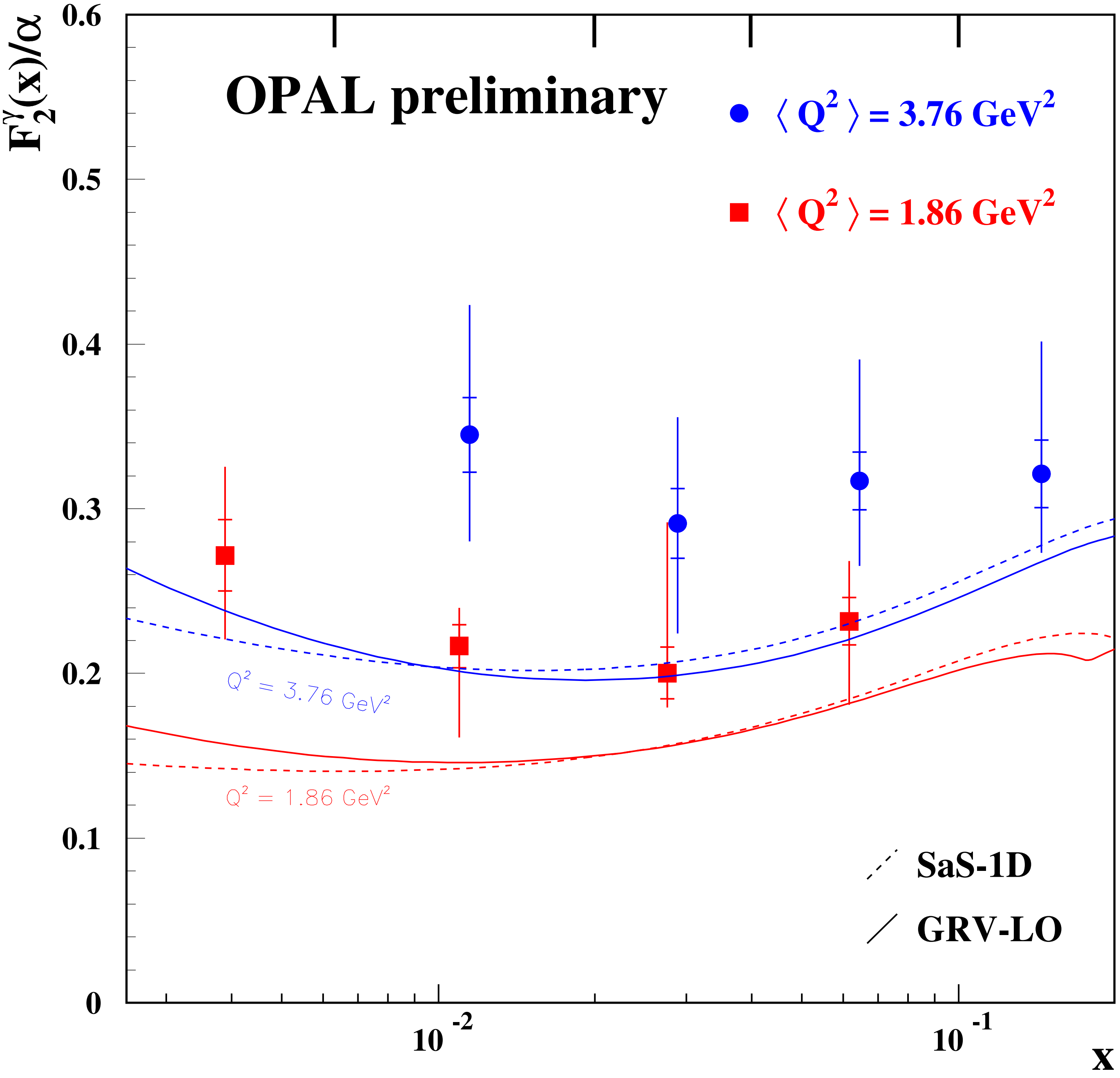
Systematic errors

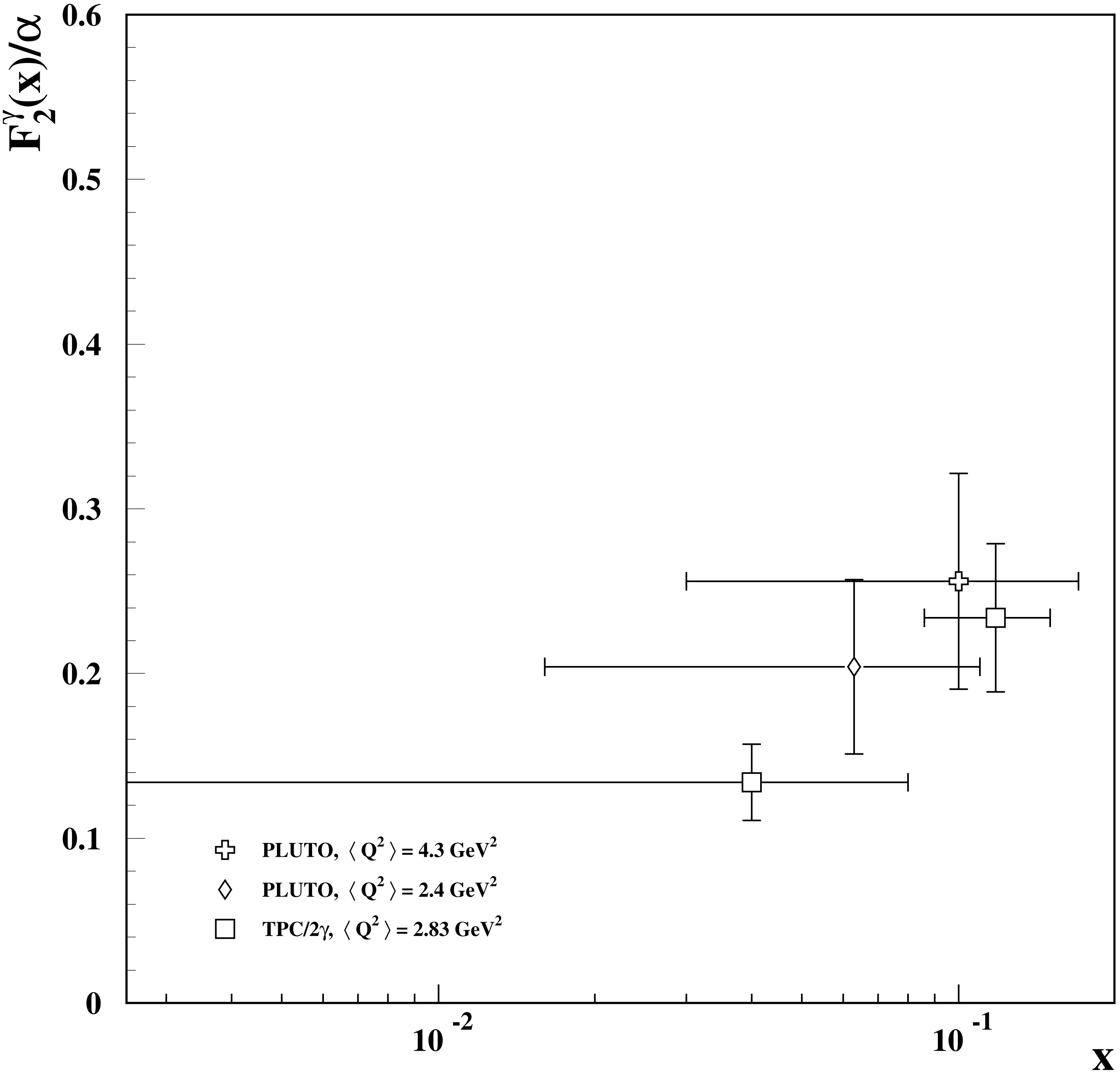
Four classes of variations are studied:

- Variation of selection cuts
- Variation of "quality cuts" = cuts for good tracks and clusters
- Variation of F_2^γ used in generation of unfolding Monte Carlo: unfolding with SaS (HERWIG)
- Variation of final state model: unfolding with PYTHIA (SaS) and F2GEN (GRV, mixture).

– In each class: maximum deviation from the reference unfolding on either side =: systematic error
– total systematic error := quadratic sum of all four single errors.

Result for F_2^γ





$F_2^{\gamma}(x)/\alpha$
0.6
0.5
0.4
0.3
0.2
0.1
0
10^{-2}
10^{-1}
x
PLUTO, $\langle Q^2 \rangle$ = 4.3 GeV^2
PLUTO, $\langle Q^2 \rangle$ = 2.4 GeV^2
TPC/2γ, $\langle Q^2 \rangle$ = 2.83 GeV^2

Summary and conclusions

$F_2^\gamma(x, Q^2)$ measured at $< Q^2 > = 1.86, 3.76$ GeV^2 down to **lower x than ever before** (lowest central value of a bin: x=0.004).

(*) Result consistent with flat $F_2^\gamma(x)$.

(*) Result consistent with shape of GRV, SaS but **significantly higher**.

(*) Steep rise or fall off excluded down to x=0.004.

With improved Monte Carlo models the error bars could be reduced a lot!!!