Measurement of the photon structure function $F_{2,c}^{\gamma}$ from OPAL

PHOTON 2000

International Conference on

the Structure and Interactions of the Photon

Richard Nisius (CERN)

Ambleside, 27 August 2000

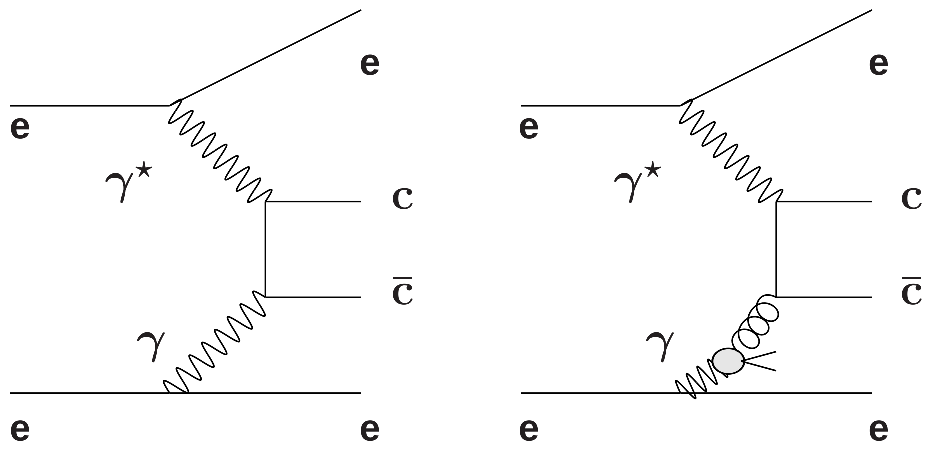
- Introduction

1. The Measurement of $F_{2,c}^{\gamma}$

- Conclusions

For the OPAL Collaboration

The contributions to $F_{2,\mathrm{c}}^{\gamma}$ or $F_{2,\mathrm{b}}^{\gamma}$



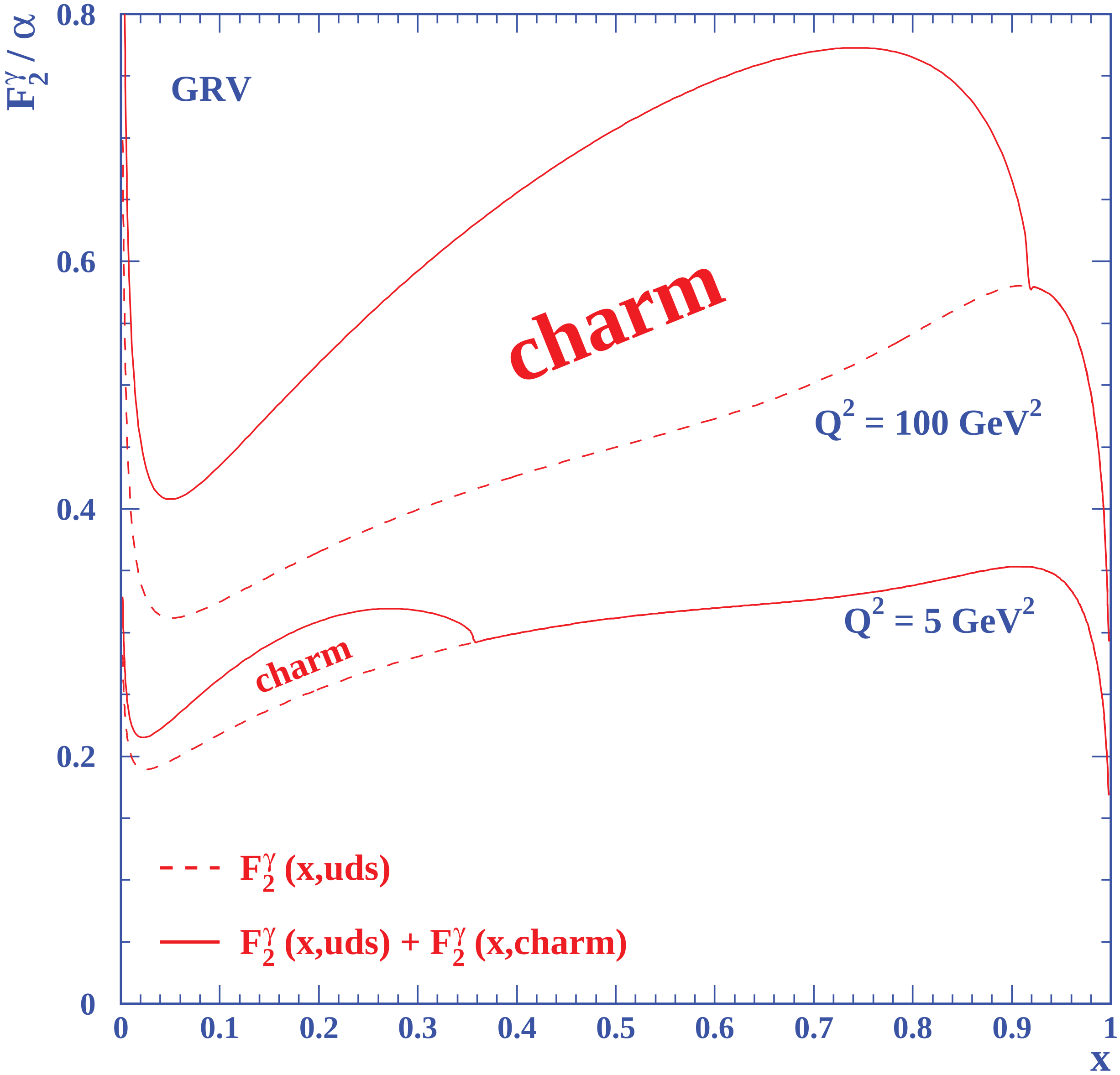
point-like
perturbative QCD
high-x

hadron-like
$\propto f_g^{\gamma}$
low-x

$$F_{2,\mathrm{h}}^{\gamma} = N_{\mathrm{c}} \frac{\mathrm{e}_{\mathrm{q_h}}^4 \alpha}{\pi} x \Bigg\{ \left[x^2 + (1-x)^2\right] \ln \frac{1+\beta\gamma}{1-\beta\gamma} - \beta + 6\beta x (1-x)$$
$$+ \left[2x(1-x) - \frac{1-\gamma^2}{1-\beta^2} - \left(1-\beta^2\right)(1-x)^2\right] \frac{\beta\gamma\left(1-\beta^2\right)}{1-\beta^2\gamma^2}$$
$$+ \left(1-\beta^2\right)(1-x) \left[\frac{1}{2}(1-x)\left(1+\beta^2\right) - 2x\right] \ln\left(\frac{1+\beta\gamma}{1-\beta\gamma}\right) \Bigg\}$$

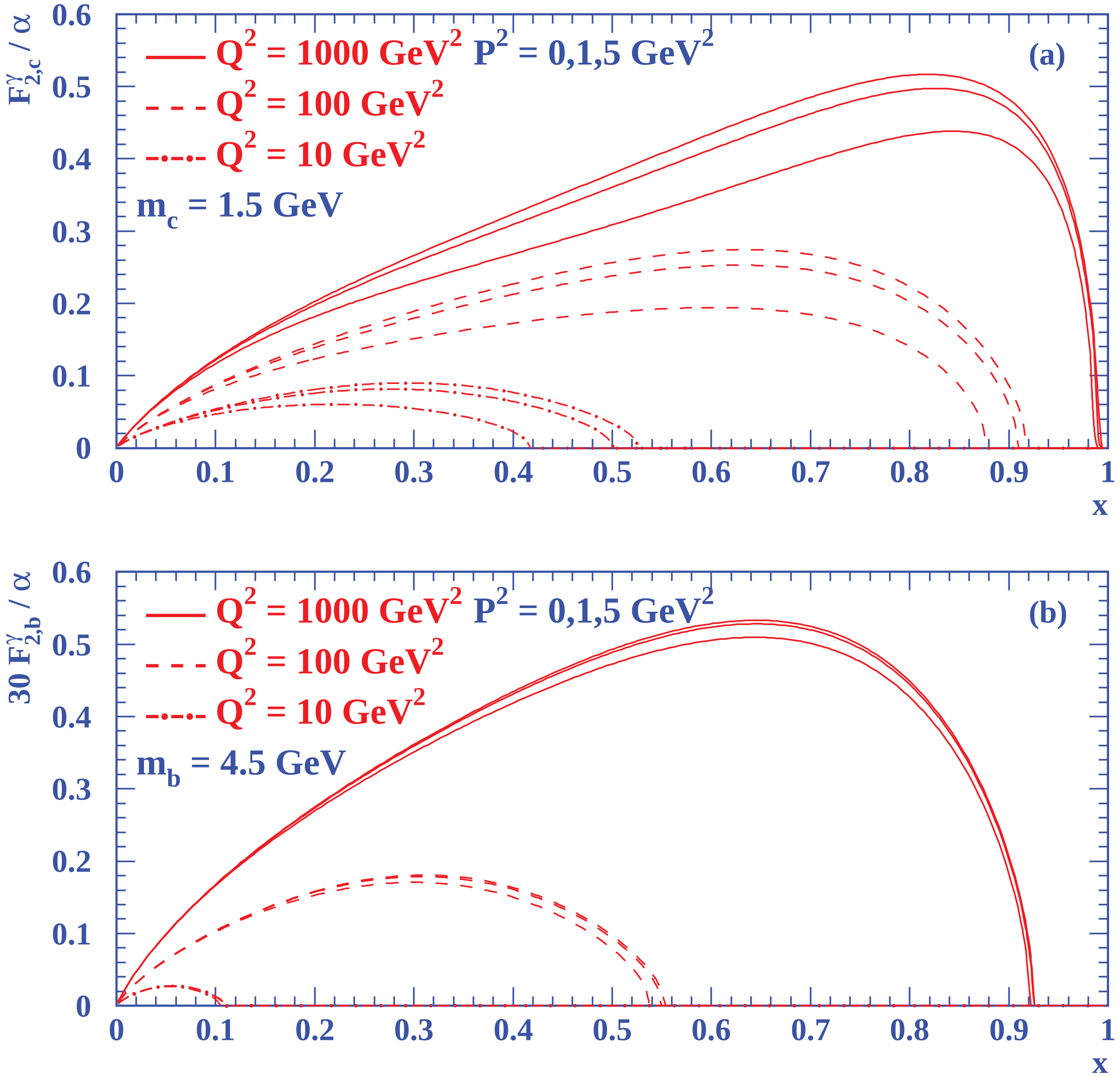
with: $\gamma = \sqrt{1 - \frac{4x^2P^2}{Q^2}}\,, \quad \beta = \sqrt{1 - \frac{4m_{\mathrm{h}}^2}{W^2}}$ and $\mathrm{h} = \mathrm{c}, \mathrm{b}\,.$

The importance of charm for F_2^γ



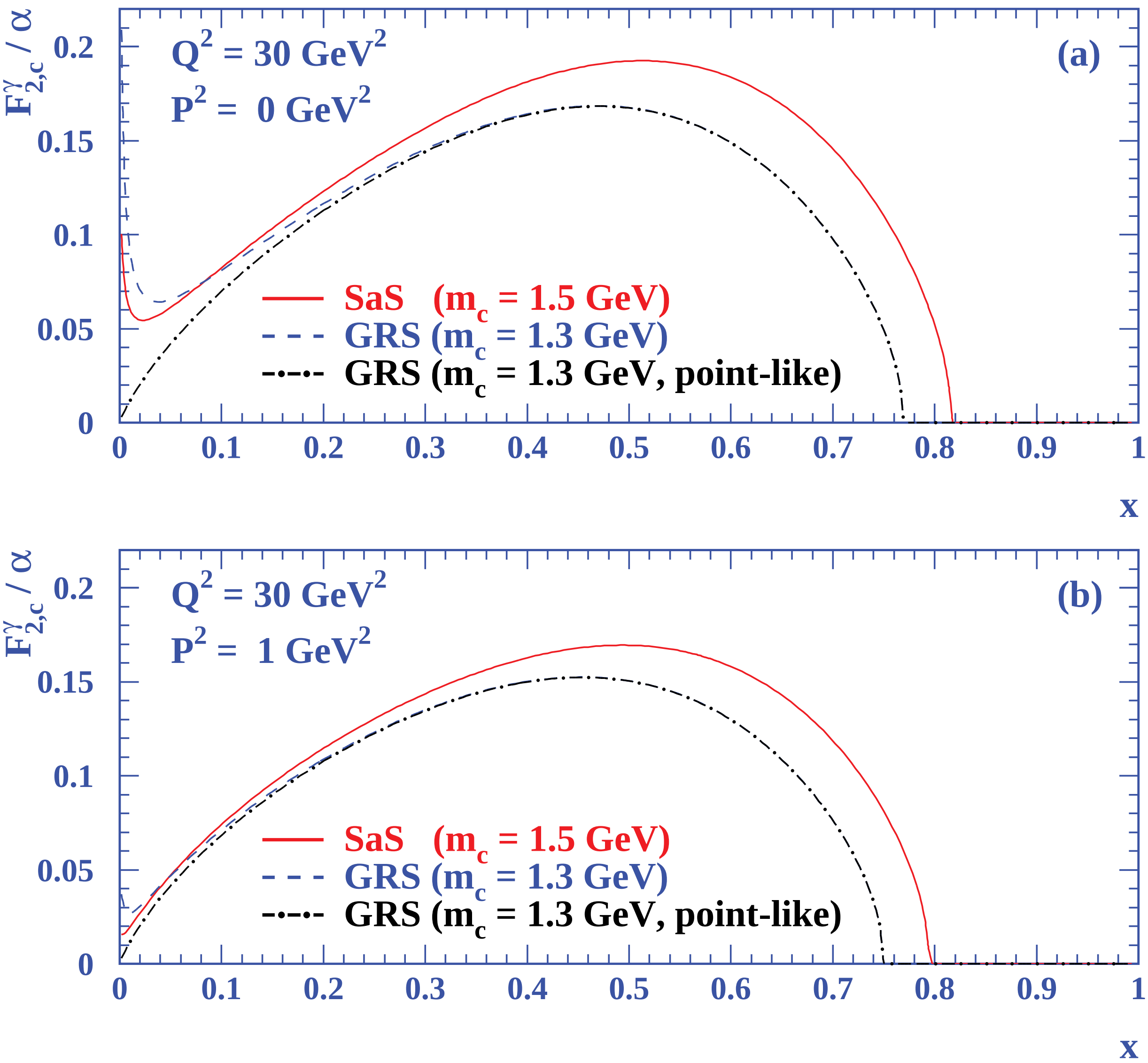
The importance of charm increases with Q^2.

The pointlike contribution to $F_{2,\mathrm{h}}^{\gamma}$: charm versus bottom



Bottom is too heavy and also disfavoured by the charge.

$F_{2,c}^{\gamma}$ for different P^2



The hadron-like component is much more suppressed with P^2 than the point-like component.

Some experimental details

1. **Data:**

   $\sqrt{s_{\rm ee}} = 183 - 189$ GeV with $\mathcal{L} = 220\,\mathrm{pb}^{-1}$

2. **Electron:**

   $E_{\rm tag} > 50$ GeV

   a) $33 < \theta_{\rm tag} < 55$ mrad or

   b) $60 < \theta_{\rm tag} < 120$ mrad

   $\Rightarrow$ $\boxed{5 < Q^2 < 100\ \mathrm{GeV}^2}$ with $\langle Q^2\rangle \approx 20\ \mathrm{GeV}^2$

3. **Hadronic final state:**

   $3.88 < W < 60\ \mathrm{GeV} \Rightarrow$ $\boxed{0.0014 < x < 0.87}$

4. **D*:**

   $f(c \to D^\star) = 0.235 \pm 0.011$

   charm is identified using $D^\star \to D^0\pi$ followed by:

   $D^0 \to K\pi$ $\quad$ $(\mathrm{BR} = 0.02630 \pm 0.00082)$ or

   $D^0 \to K\pi\pi\pi$ $\quad$ $(\mathrm{BR} = 0.0519 \pm 0.0029)$

   with $|\eta^{D^\star}| < 1.5$ and $p_{\rm T}^{D^\star} > 1(3)$ GeV for a (b)

   $x > 0.1$: $\epsilon = 0.21 \pm 0.02$ for V and H

   $x < 0.1$: $\epsilon = 0.18 \pm 0.02\ (0.30 \pm 0.03)$ for V(H)

   $\Rightarrow$ about 0.5% of all $c\bar{c}$ events are tagged.

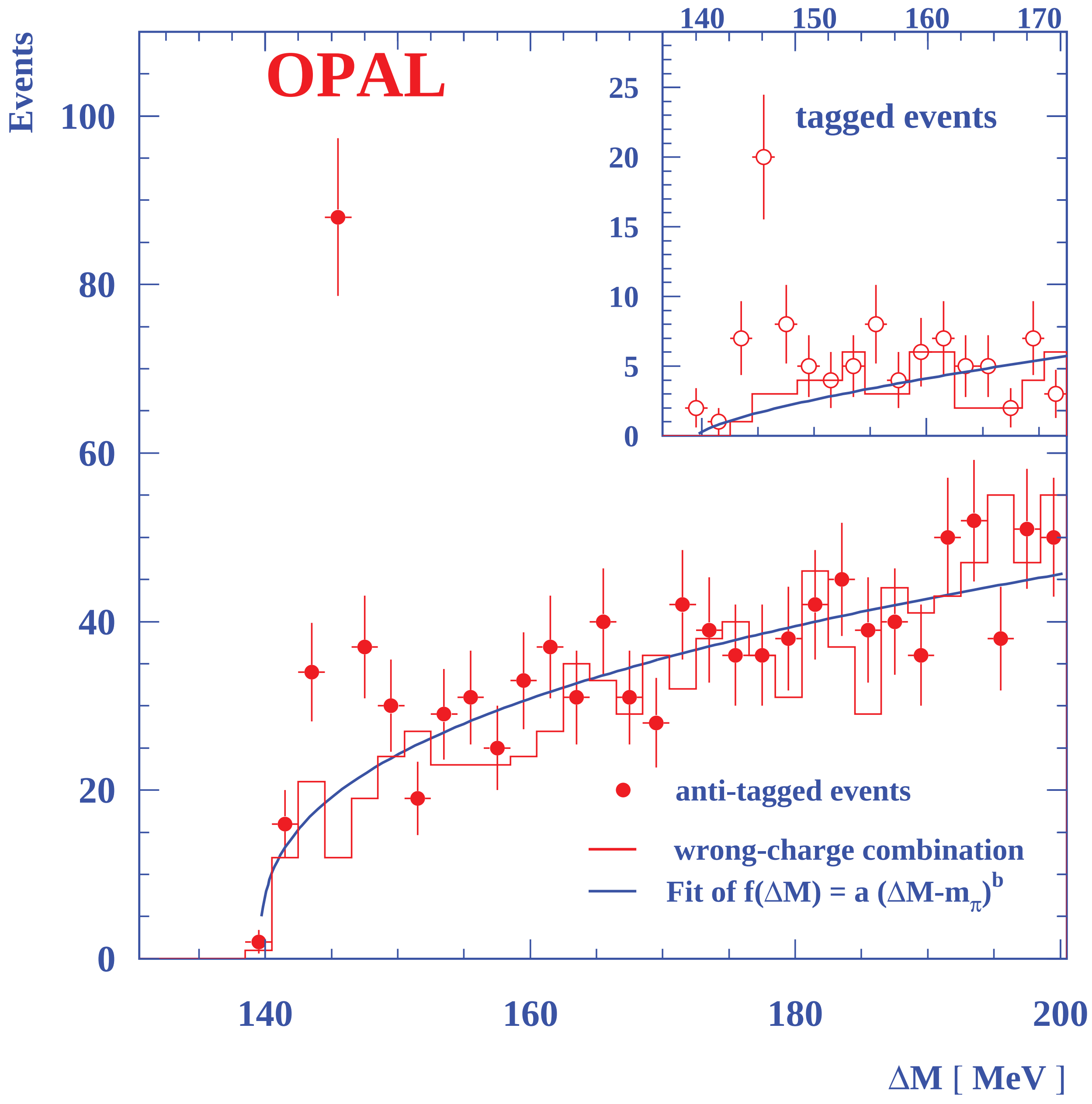
5. **Monte Carlos:**

   V = Vermaseren (only point-like component = QPM)

   H = HERWIG5.9 (point-like + hadron-like component, but massless matrix elements)

   both use final state charm quarks with $m_c = 1.5$ GeV

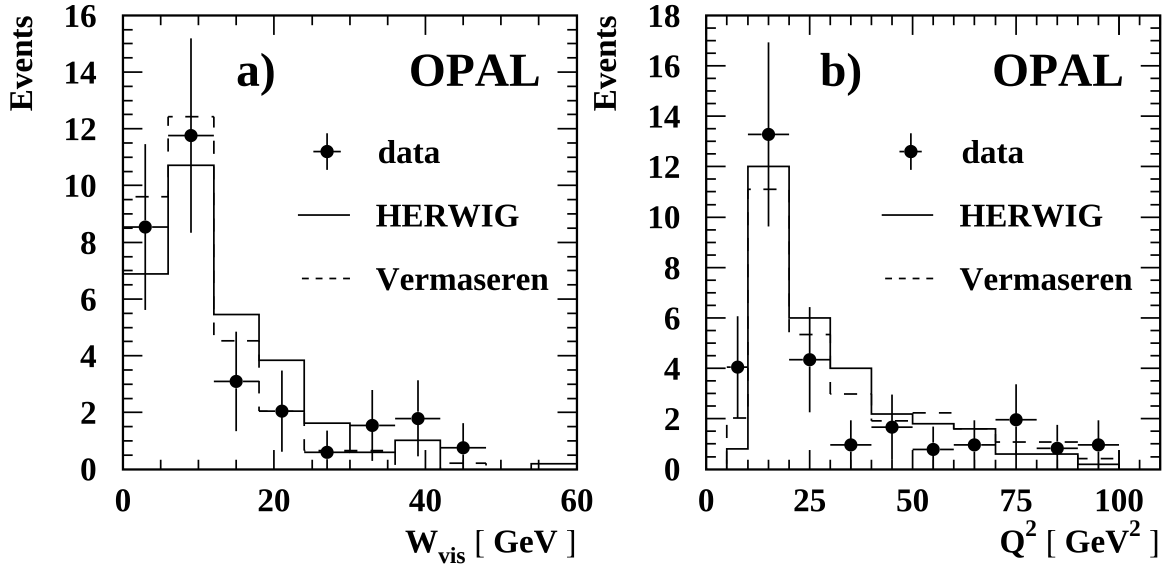
Charm production tagged by D*s

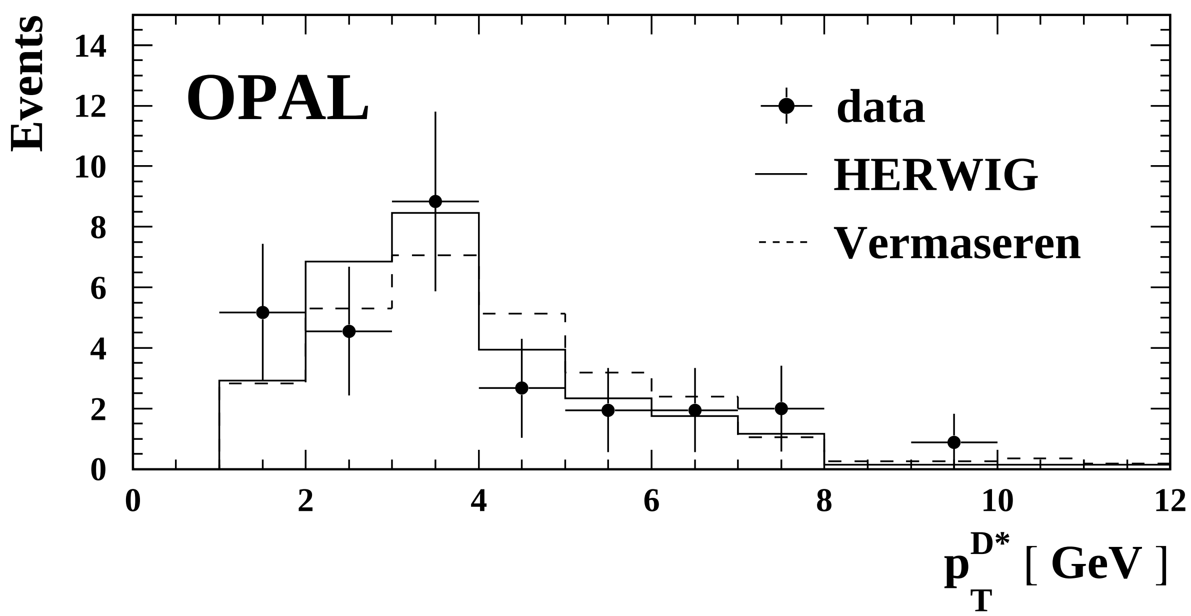


A clear signal in the $\Delta(M) = M(D^\star) - M(D^0)$ mass spectrum is seen for anti-tagged and tagged events

Comparison of final state observables

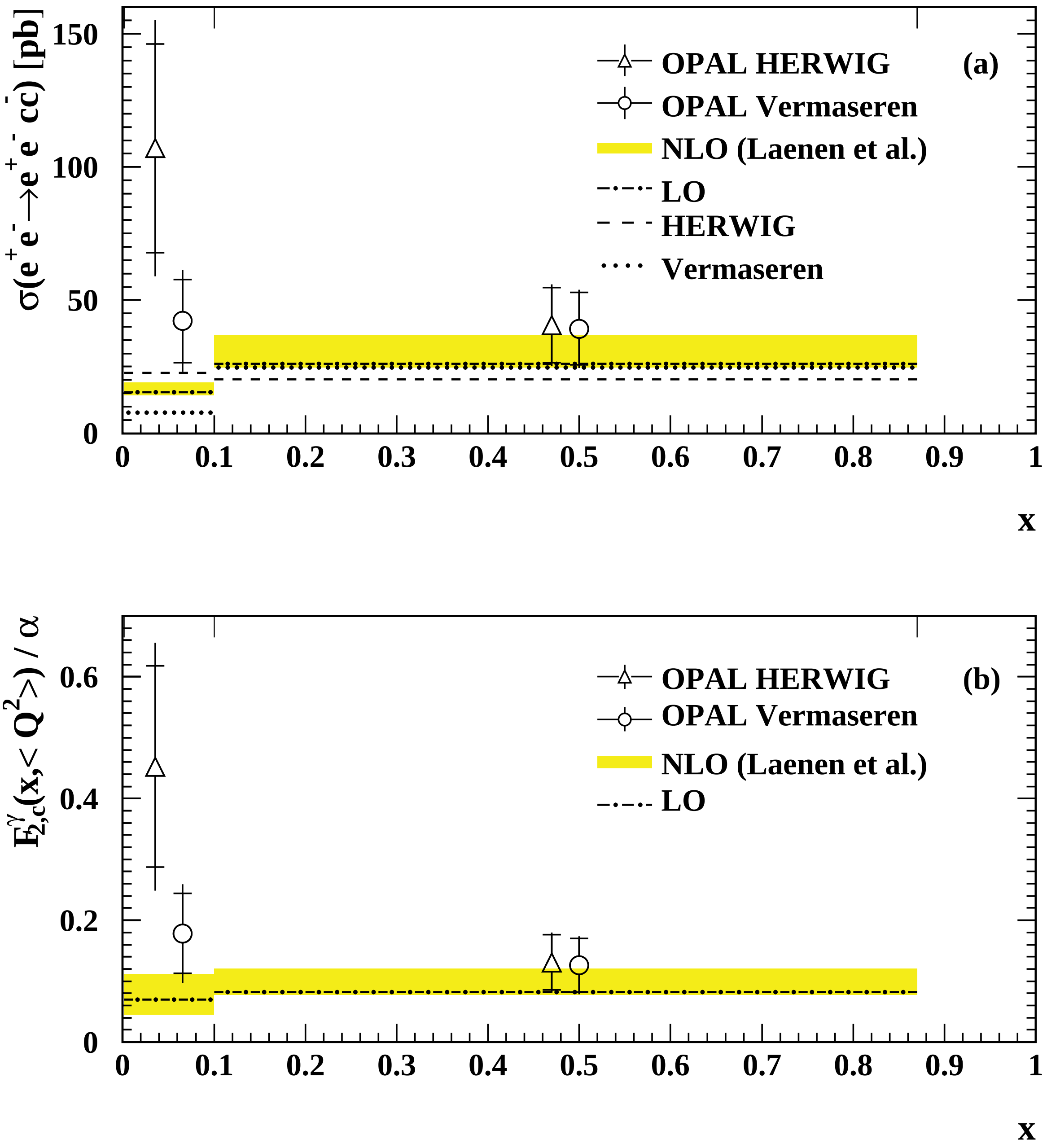
MC's are normalised to N_{data}





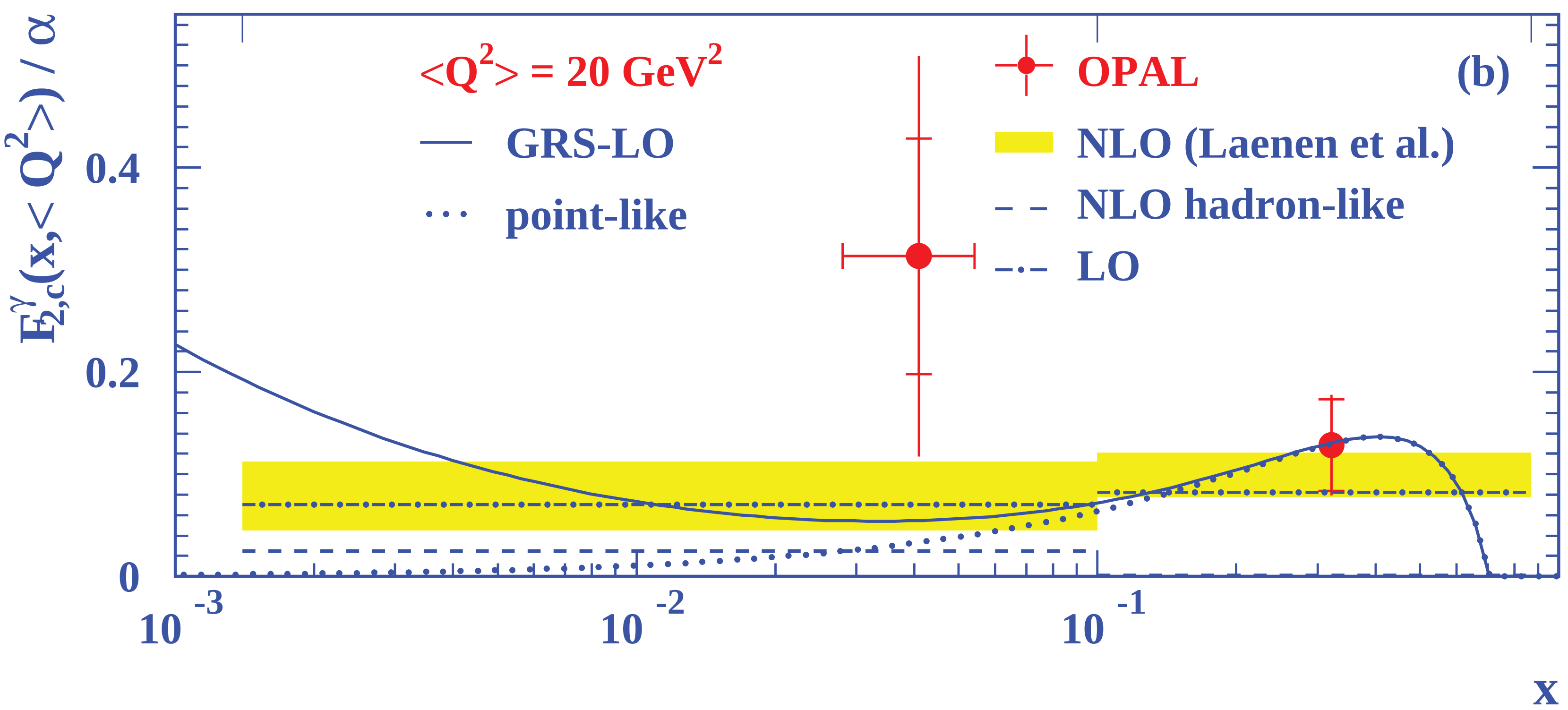
The shapes of the final state distributions are reasonably well described by the Monte Carlo models.

Uncertainty due to Monte Carlo



The Monte Carlos significantly differ at low-x, especially in the non-visible region.

The first measurement of $F_{2,c}^{\gamma}$

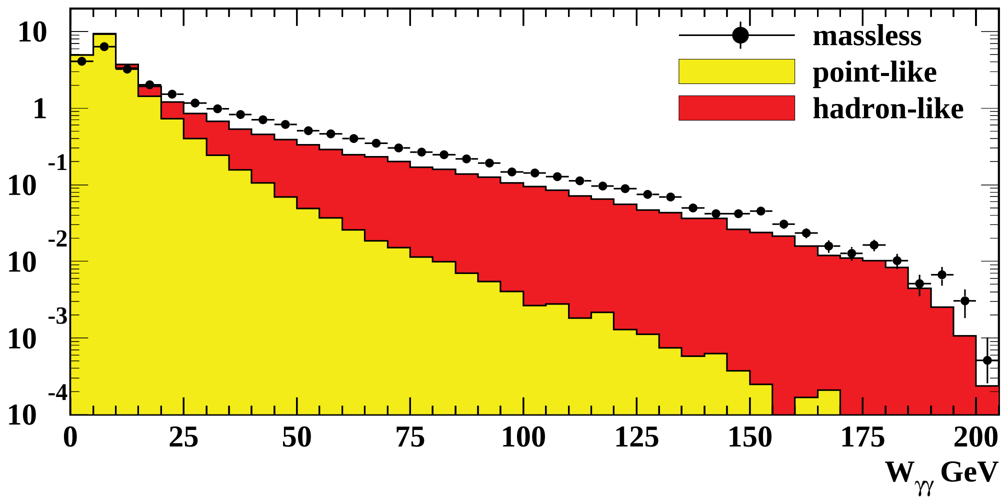


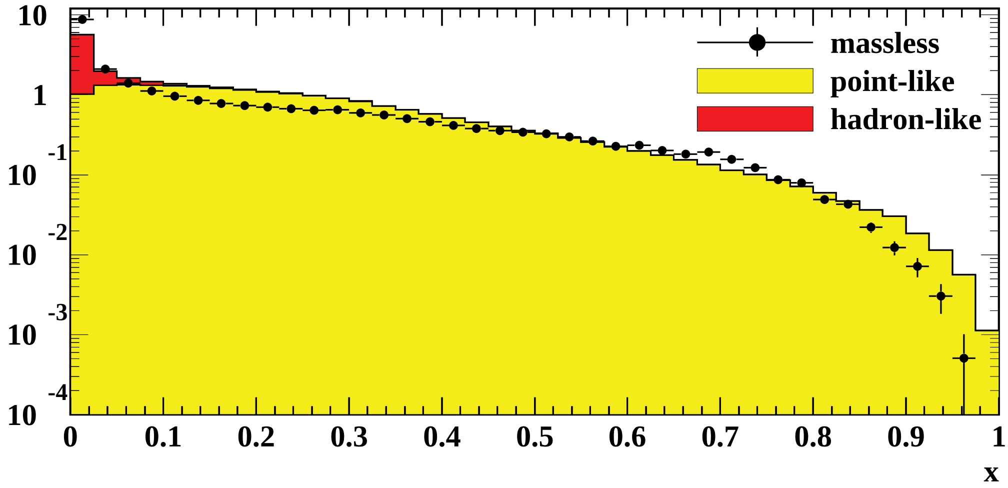
Good description by NLO perturbative QCD at high-x, $\mathcal{O}(20\%)$ test.

Largely model dependent result at low-x.

Future work

1. We will use the massive matrix elements which are implemented in HERWIG.





2. An update of the analysis incorporating about three times the statistics is under way.

Conclusions

1. Based on about 30 events, where the charm quarks were identified by D* mesons, the first measurement of $F_{2,c}^{\gamma}$ has been made.
2. At large-x the perturbative NLO calculation, with only m_c and α_s as free parameters, perfectly agrees with the data.
3. At low-x the data suggest a hadron-like component also for charm quarks, although in this region the model dependence is large.
4. In the near future, the analysis of much more data, and the reduction of the extrapolation uncertainty at low-x, by using massive matrix elements, will considerably improve on the precision.

Slides: http://home.cern.ch/nisius

More info: OPAL Collaboration, CERN-EP/99-157 and Richard Nisius, Phys. Rep. 332 (2000) 165.