V+heavy flavors: MC and constraints from data

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Introduction

- Definitions:
  - V = W, Z, γ
  - HF = c-, b-quarks

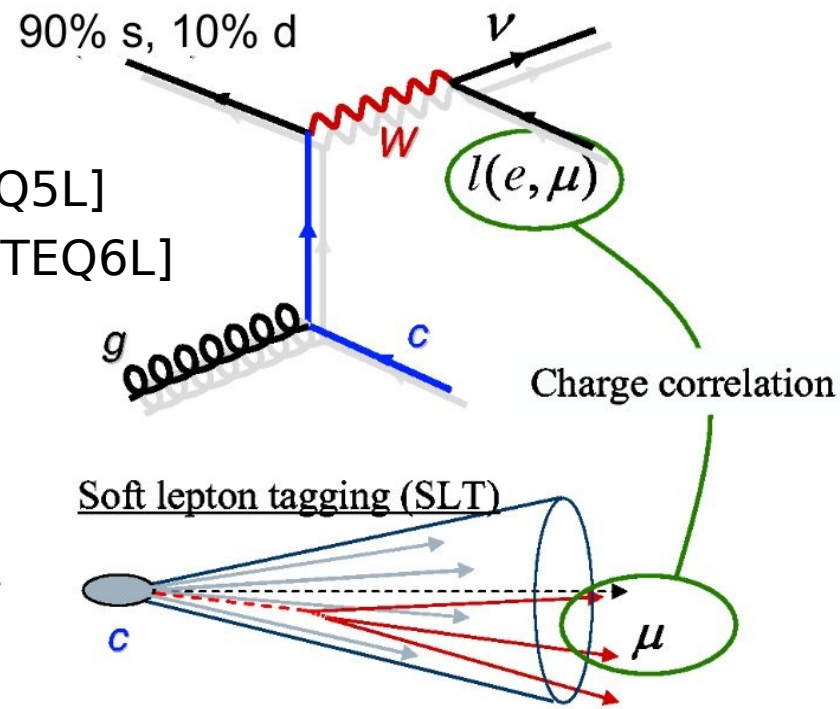
- V+HF understanding are very common backgrounds for many analysis : Higgs, single-top, top pairs
  - Important to check the theoretical predictions

- Today:
  - W+c
  - W+b
  - Z+b
  - γ+b/c

W + c

W+c

- Sensitive to s-quark content in protons (high Q^2)
- Select high pT isolated lepton (e or μ) + missing E_T
- Use a soft lepton tagger to identify the c-jet
  - Signal: lepton from W and μ in c-jet have opposite sign (OS)
  - Background: no correlation **#OS ≈ #SS** (same sign)



- MC:
  - CDF: alpgen(v2.1)+pythia(6.3) [CTEQ5L]
  - DØ: alpgen(v2.05)+pythia(6.323) [CTEQ6L]

- Subtract SS to OS :

$$\sigma_{Wc} \times \mathrm{BR}(W \to \ell\nu) = \frac{N_{\mathrm{tot}}^{OS-SS} - N_{\mathrm{bkg}}^{OS-SS}}{Acc \cdot \int L \, \mathrm{dt}}$$

Results

- CDF (1.8 fb^{-1}):

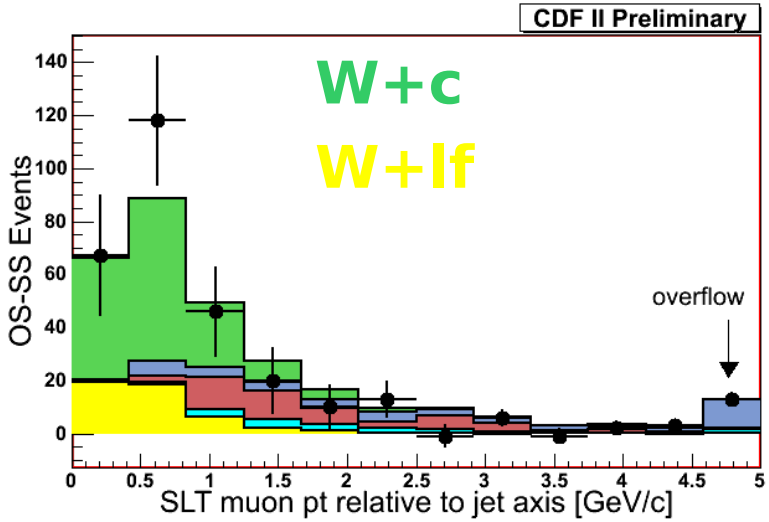
$$\sigma_{Wc}\,(p_{Tc} > 20\ \mathrm{GeV}/c,\ |\eta_c| < 1.5) \times \mathrm{BR}\,(W \to \ell\nu)$$

$= 9.8 \pm 2.8(\mathrm{stat})^{+1.4}_{-1.6}(\mathrm{syst})$ pb

NLO pQCD= $11.0^{+1.4}_{-3.0}$pb

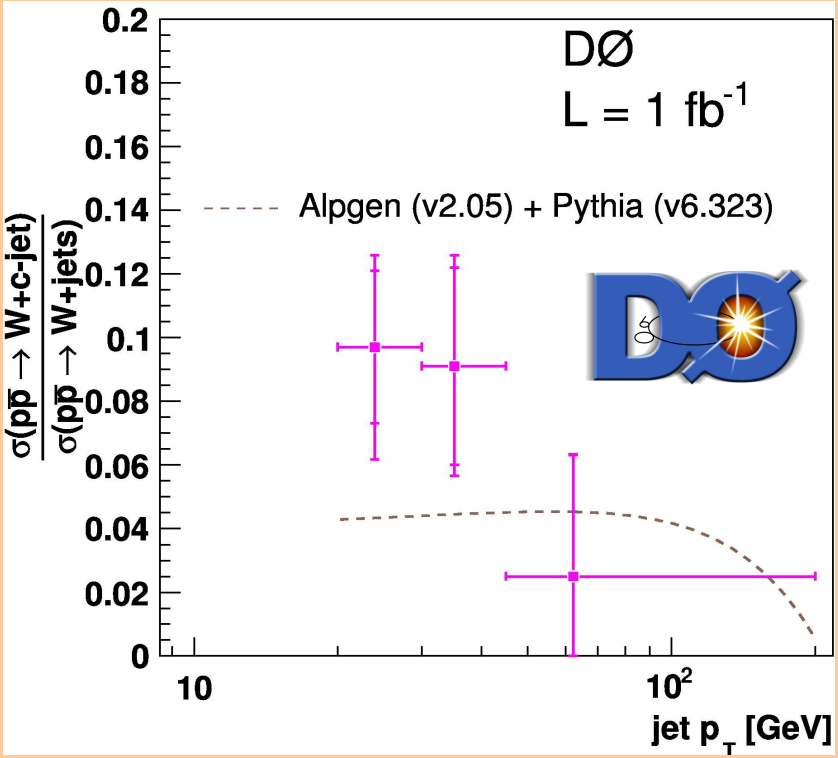
Good agreement

PRL 100, 091803 (2008)



- DØ (1 fb^{-1}):
  - Ratio W+c / W+lf
  - Good agreement

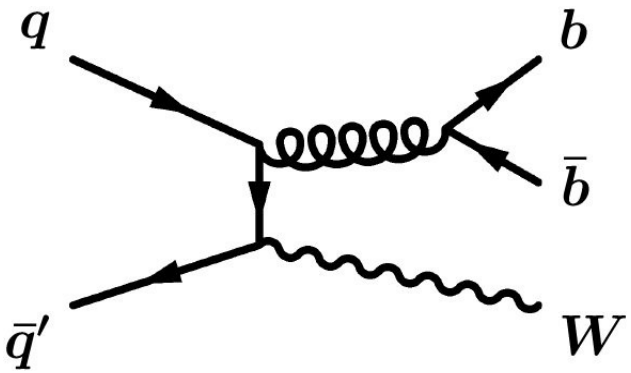
PLB 666, 23 (2008)



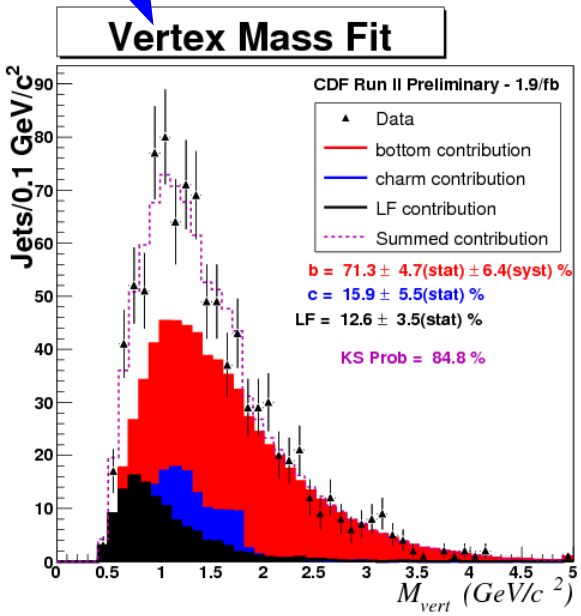
W + b

W+b

- Select an isolated lepton (e or μ)
- Missing transverse energy > 25 GeV
- 1 or 2 jets: pT>20 GeV, $|\eta|$<2.0
- Secondary vertex tagger
- MC: alpgen(v2.10)+pythia(v6.325)
- Fit the vertex mass distribution



with templates to determine the different contributions



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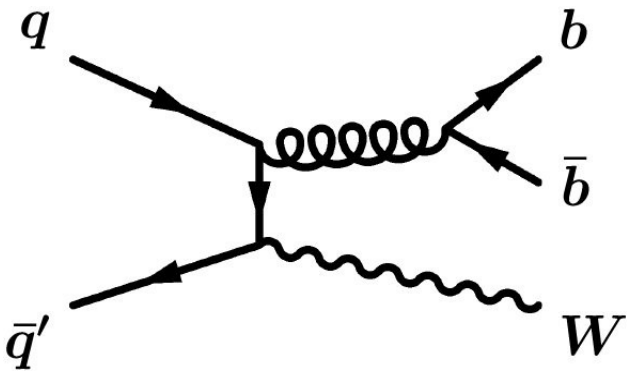

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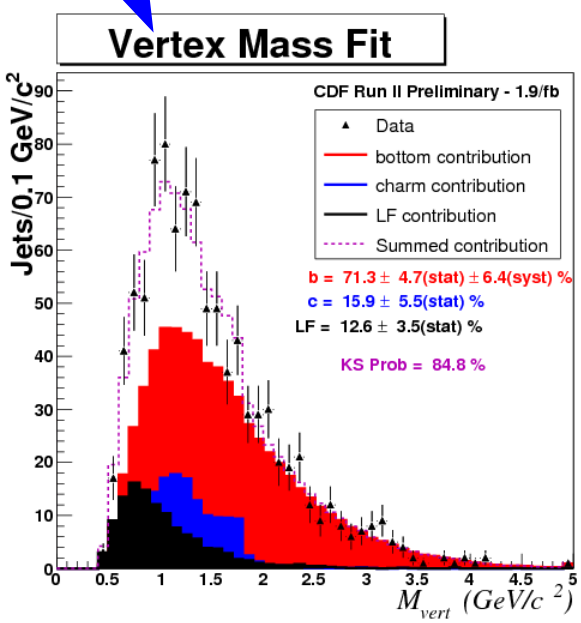


Measure:

σ=2.78±0.27(stat)±0.42(syst) pb

Alpgen: σ=0.78 pb

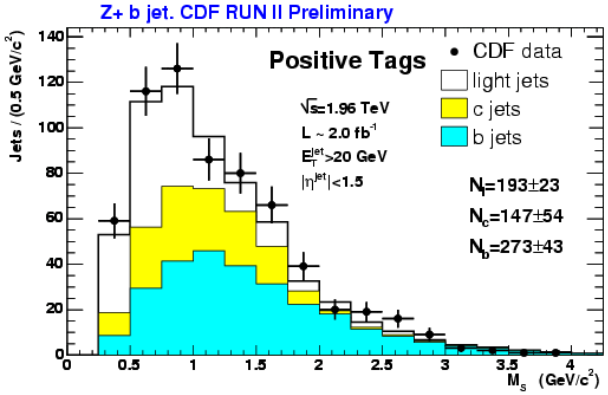
Factor ~3.5 larger than expected

Investigations are underway

Z + b

Z+b @CDF (2 fb^{-1})

- Same strategy as for W+b
- Z→ee/$\mu\mu$, 76<M<106 GeV
- Jets: pT>20 GeV, $|\eta|$<1.5
- MC: CTEQ5L+
  - alpgen+pythia or
  - Pythia
- Fit the vertex mass distribution



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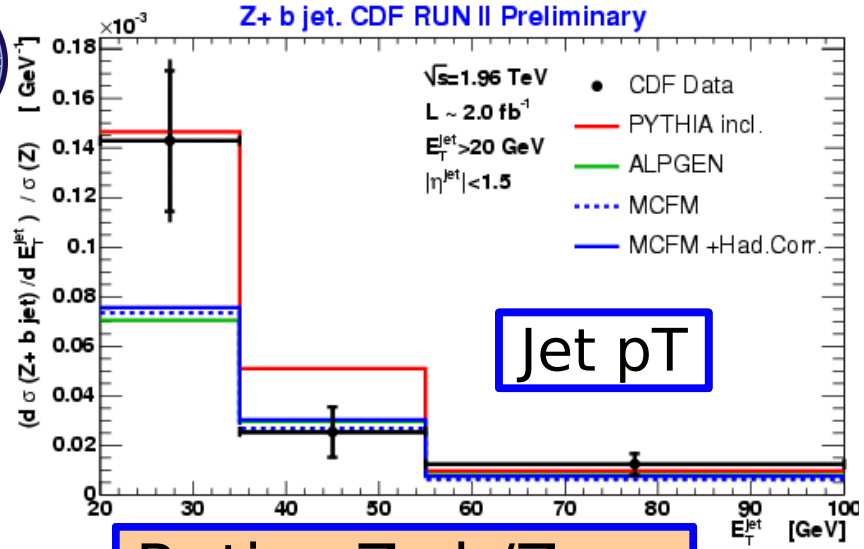
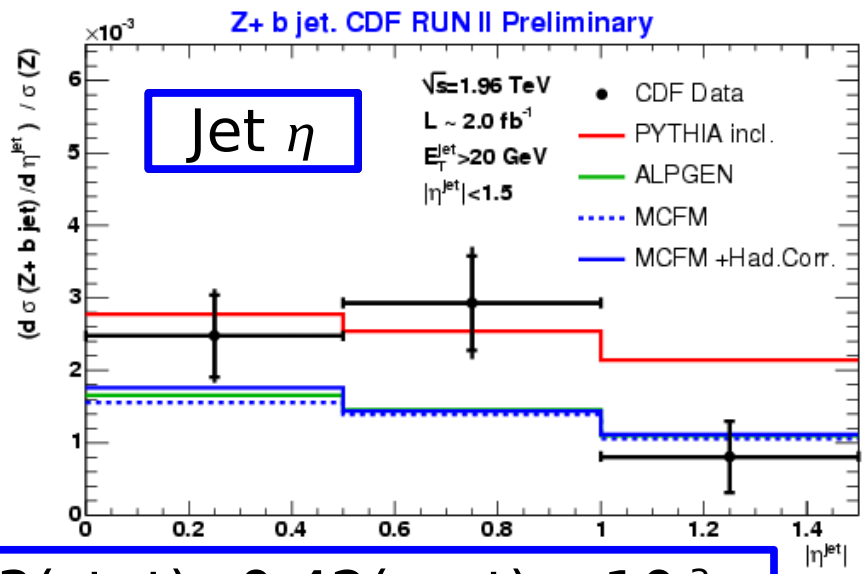
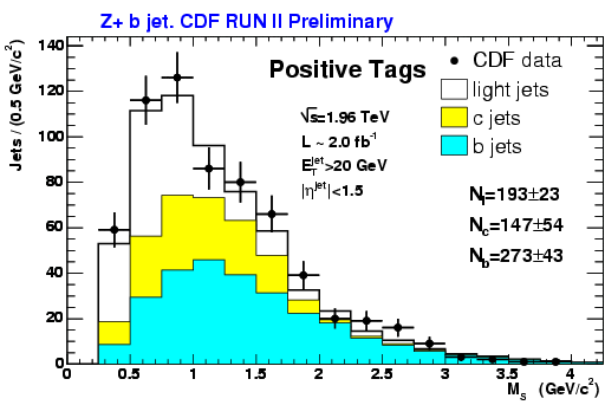


Ratios Z+b/Z+...





Ratios Z+b/Z+... = 3.32±0.53(stat)±0.42(syst) x 10^{-3}

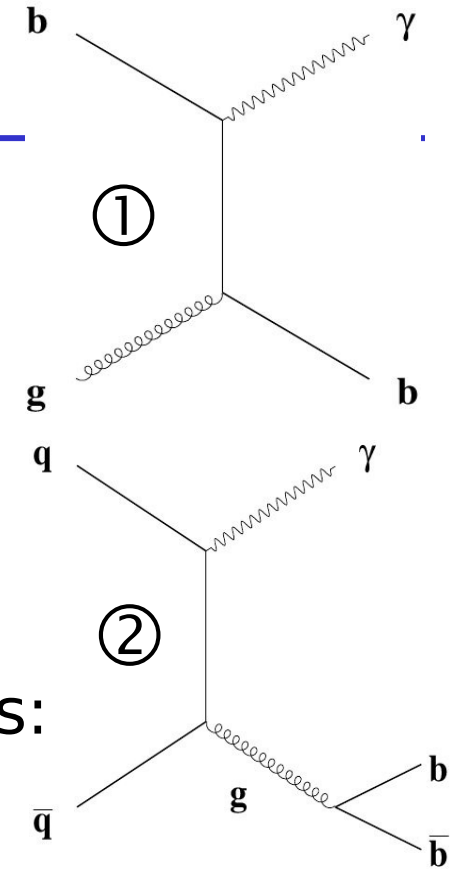
MCFM: 2.3x10^{-3} [$Q^2=m_Z^2+pT_Z^2$] / 2.8x10^{-3} [$Q^2=\langle pT_{jet}^2\rangle$]

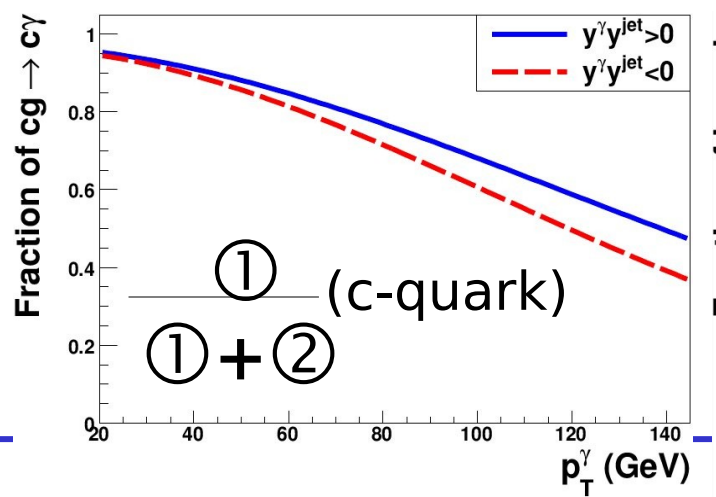
Submitted to PRD

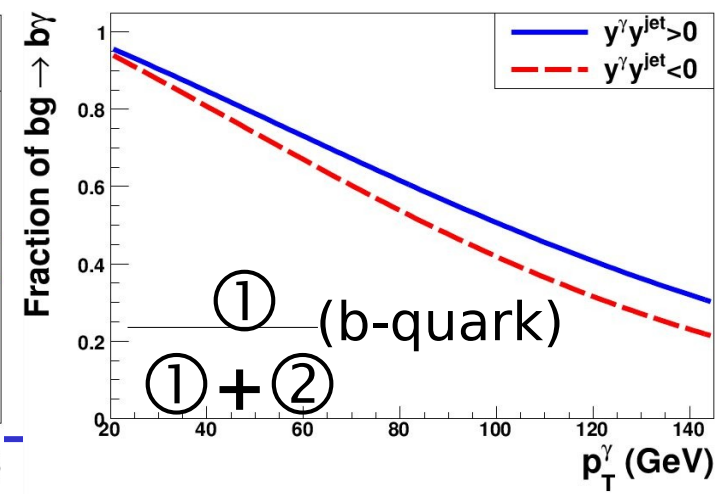
γ + b/c

γ + b/c @ D0

- 2 main sources:
  - ①:
    - Dominant in a large kinematic range
    - Mostly sensitive to b/c/g density (→pdf)
  - ②:
    - Dominant for pT(γ)>80-100 GeV
- Analysis performed in 2 kinematic regions:
  - $y^{\gamma}y^{jet}>0$: different x_1 and x_2
  - $y^{\gamma}y^{jet}<0$: similar x_1 and x_2

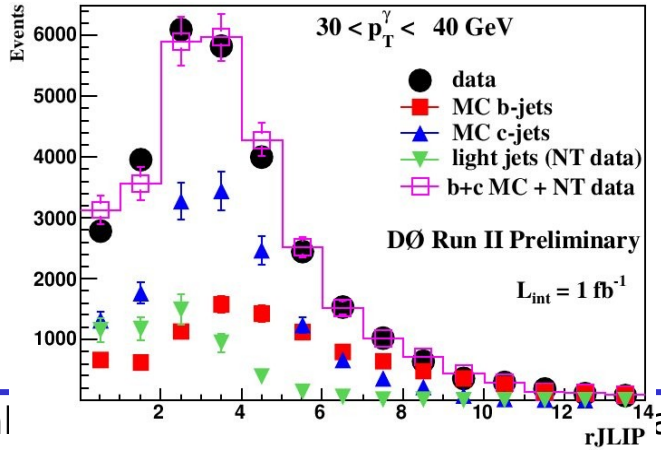


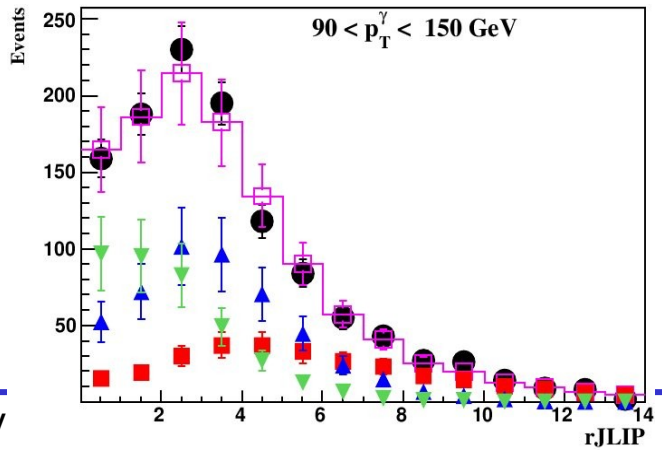




γ + b/c @ D0

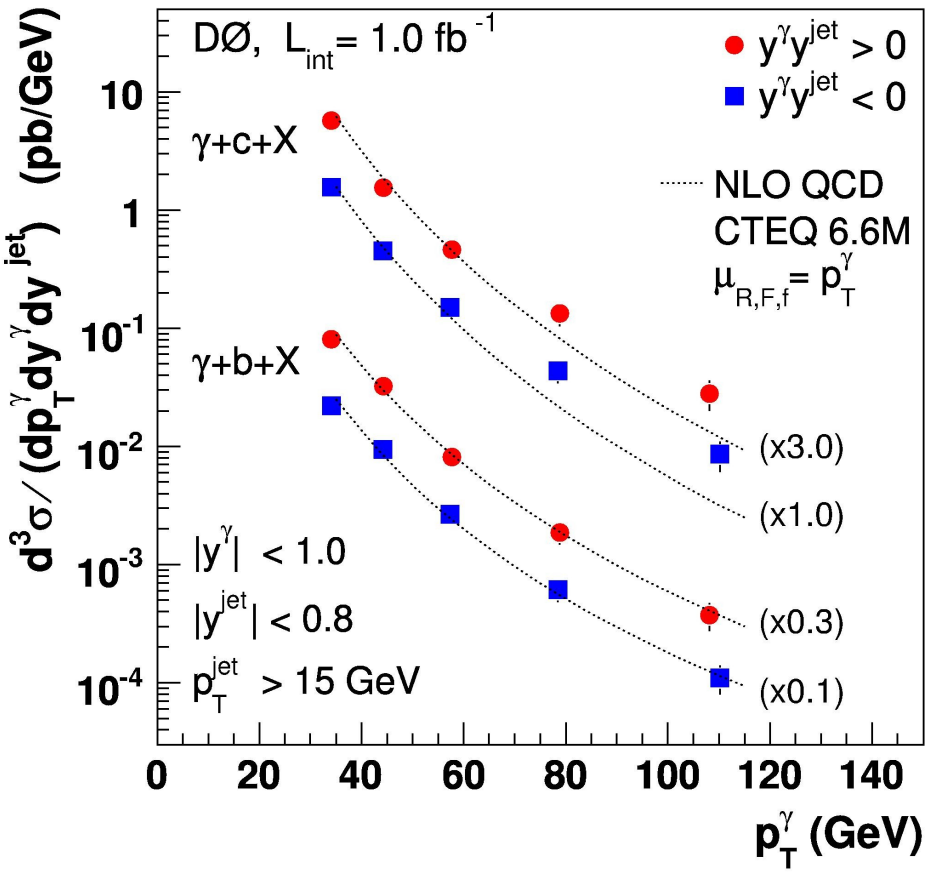
- MC: pythia (6.323), CTEQ6L1
- Selection (1 fb^{-1}):
  - $|y^{\gamma}|<1.0$, $|y^{jet}|<0.8$
  - $30<pT(\gamma)<150$ GeV, $15<pT(jet)$ GeV
  - $\Delta R(\gamma, jet)>0.5$
  - Missing energy < 0.7*pT(γ) [against W→eν]
  - Neural network for photon identification [against π^0, ρ]
  - Neural network for b-quark identification
- Fit *rJLIP* to estimate the different contributions
  - rJLIP: input variable of b-id NN

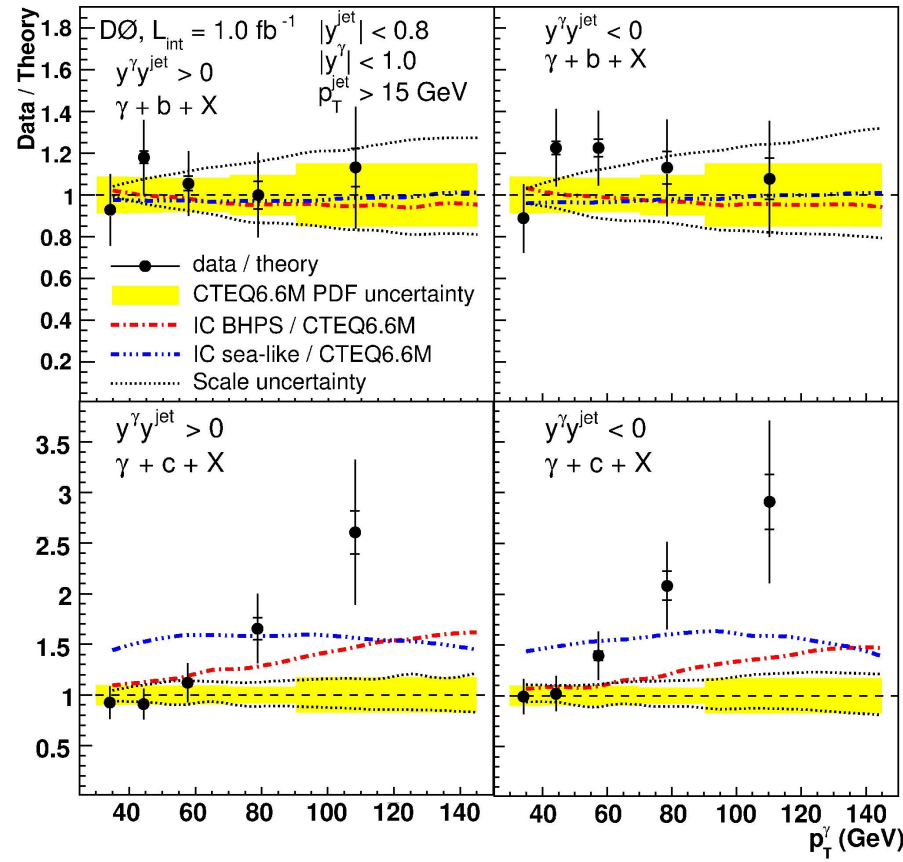




Results (submitted to PRL)

- Cross-section is unfolded (taking into account the detector resolution)

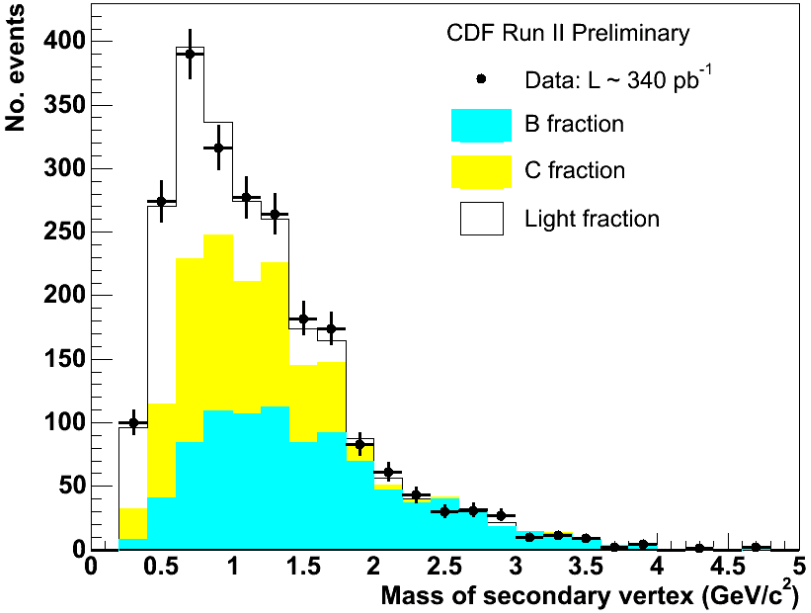


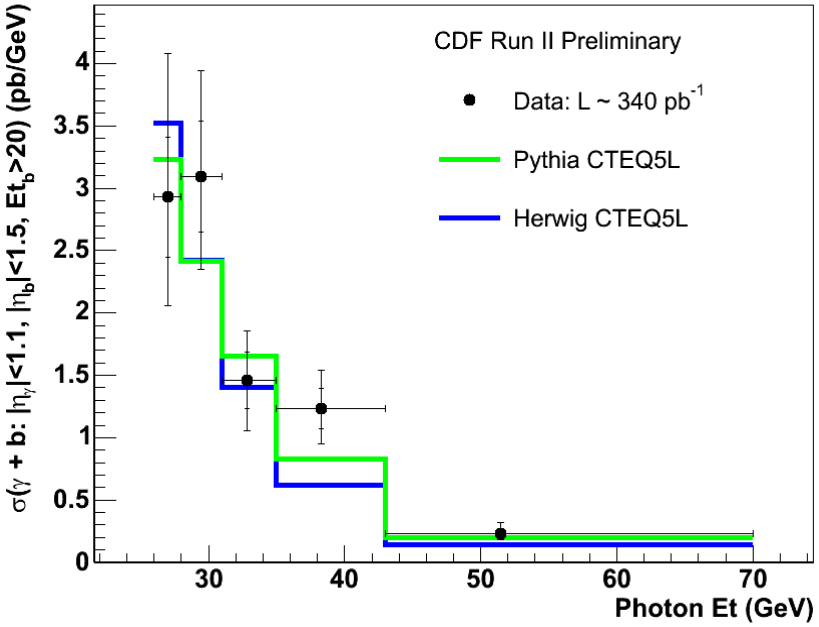


- γ+b in agreement with NLO
- γ+c shows discrepancies for pT(γ)> 50-70 GeV
- Complementary to W/Z+HF

γ + b @ CDF

- 340 pb^{-1}
- MC: pythia tune A, CTEQ5L
- Same method as DØ:
  - 26<pT(γ), 20<pT(jet) GeV, |η(jet)|<1.5
  - Secondary Vertex Tagger (→ select b-jet)
  - Fit secondary vertex mass → measure the composition
- Results in agreement with predictions





Conclusion

- V+HF are important background
- Tevatron results with differential distributions
- Often agreement between data and predictions
- Some discrepancies:
  - W+b
  - γ+c

Backup

W+c: systematic uncertainties (CDF)

Source	Factional Syst. Unc.	Contribution to σ_{Wc}
Lepton ID and Scale Factors	$\pm 1.4\%$	$\mp 1.4\%$
SLT tagging Efficiency	$\pm 5.1\%$	$\mp 5.1\%$
Jet Energy Scale	$\pm 1\sigma(JES)$	$+3.3/-2.1\%$
PDF's	$\pm 3\%$	$\mp 3\%$
Hadronization	$\pm 4.6\%$	$\mp 4.6\%$
ISR/FSR	-4.4/+7.7%	+4.4/-7.7%
P_{T} Modeling	$\pm 3\%$	$\mp 3\%$
W+l.f.	$\pm 13.6\%$	$\mp 4.5\%$
non-W	$\pm 29\%$	$\mp 8.6\%$
Drell-Yan	$\pm 13.0\%$	$\mp 3.7\%$
Luminosity	$\pm 5.6\%$	$\mp 5.6\%$
Total (not including luminosity)		+14.4/-15.5%

Z+b: systematic uncertainties (CDF)

Source of Uncertainty	Uncertainty (%)
MC E_T^{jet} dependence	8.0
MC η^{jet} dependence	2.8
track finding efficiency	5.7
b quark fragmentation	0.8
$b\bar{b}/b$, $c\bar{c}/c$ jet fractions	3.8
light jet template	1.7
b-tagging efficiency	5.3
jet energy scale	2.4
misidentified lepton background	1.9
other backgrounds	0.8
total	12.7

γ+b: systematic uncertainties (region 1)