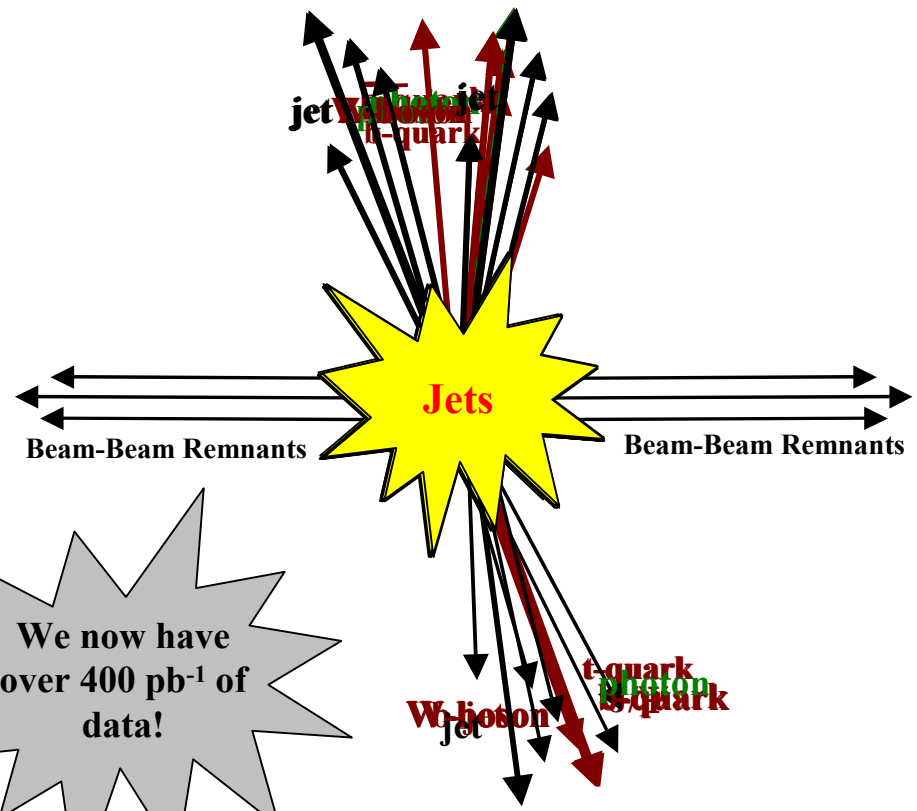
The Tevatron Connection

and comparisons with theory!

A Few CDF Run 2 Proton-AntiProton Cross Sections

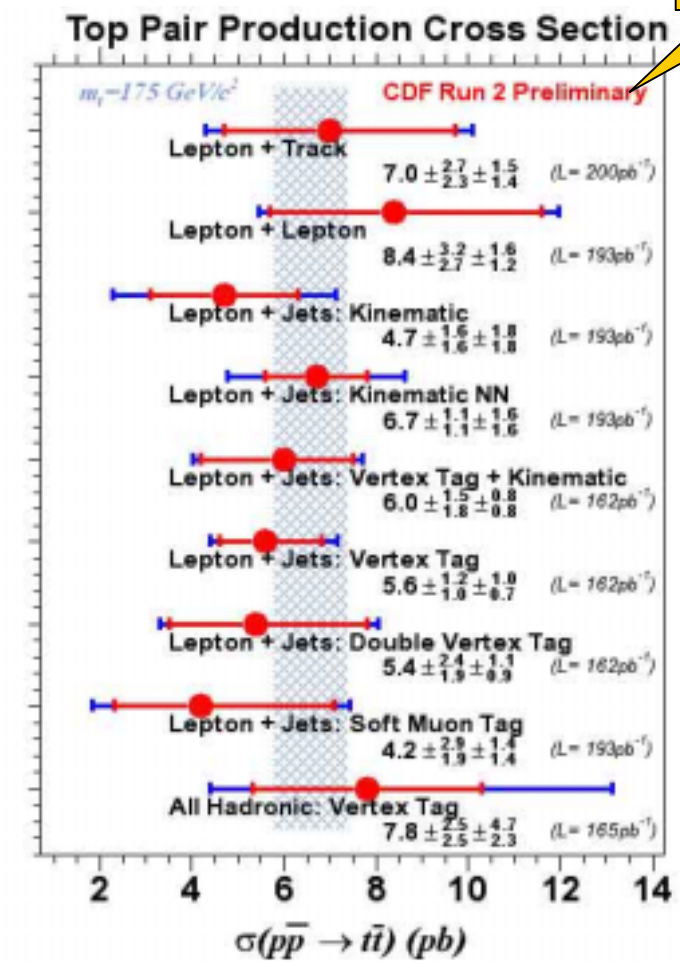
- Top Pair Cross-Section
- Single Top Cross-Section
- J/Ψ Cross-Section
- b-Hadron Cross-Section
- b-Jet & b-DiJet Cross-Sections
- Charm Meson Cross-Sections
- γ + b/c Cross-Sections
- γ + γ Cross-Section
- Z-boson Cross-Section
- W-boson Cross-Section
- W+n Jets Cross-Sections
- W/Z + γ Cross-Sections
- W + W Cross-Section
- Z + W & Z + Z Cross-Sections
- Inclusive Jet Cross-Sections

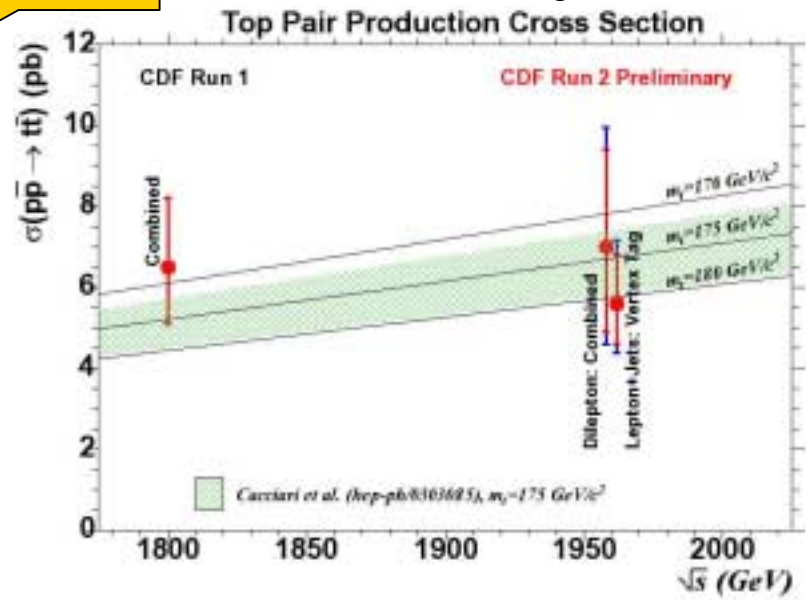


We now have over 400 pb^{-1} of data!

Top Pair Cross Section
CDF Run 2 Summary

200 pb^{-1}

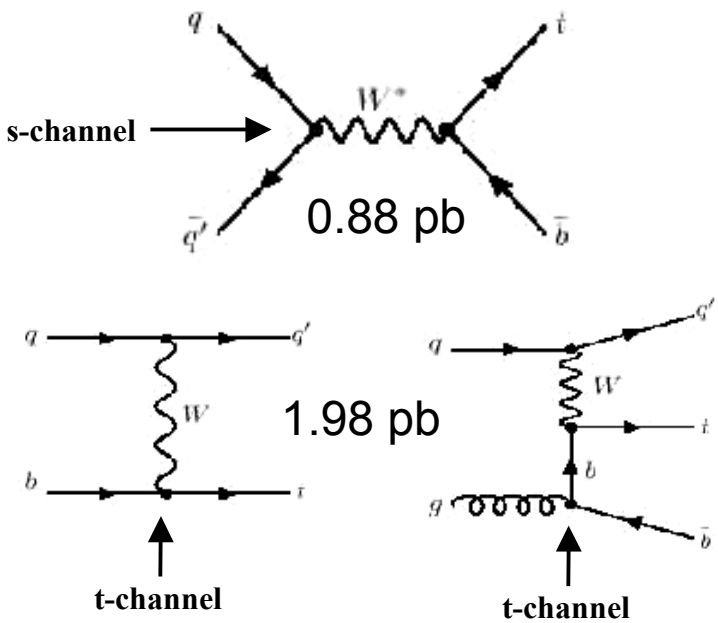


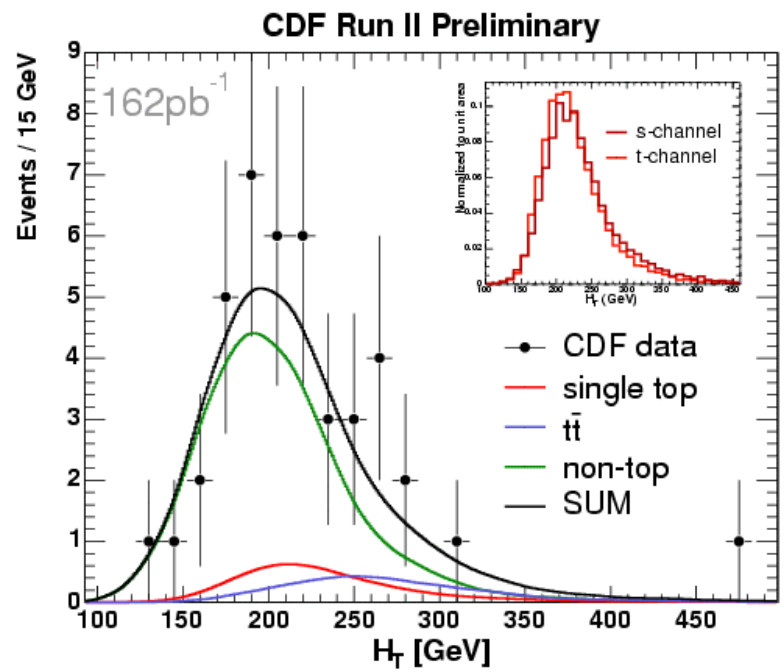


- **Observed cross sections consistent with each other and with the standard model prediction (1.96 TeV, m_t = 175 GeV)** $\sigma(t\bar{t}) = 6.7^{+0.7}_{-0.9}$ pb

Bonciani *et al.*, *Nucl. Phys.* **B529**, 424 (1998)
Kidonakis and Vogt, *Phys. Rev.* **D68**, 114014 (2003)

Single Top Cross Section
CDF Run 2 Search



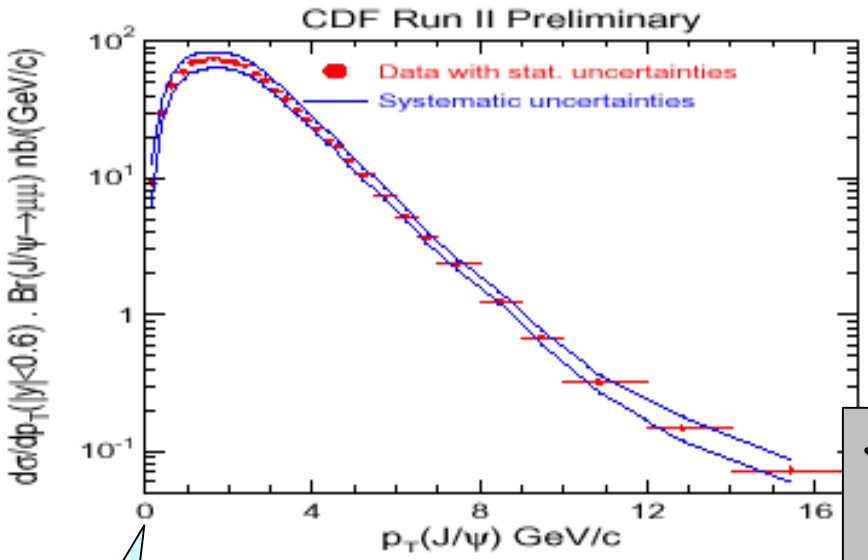


σ_t < 10.1 pb @ 95% CL

σ_{t+s} < 17.8 pb @ 95% CL

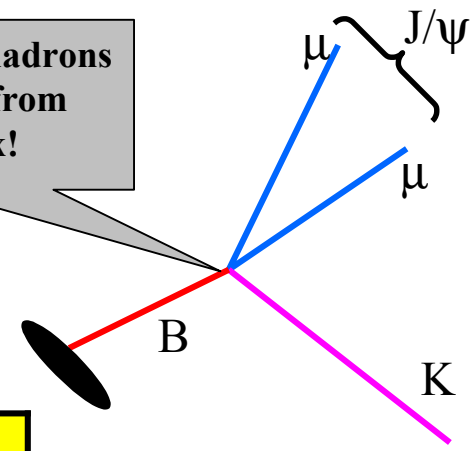
➡ **Search for W + 2 jets and tag one b. Do likelihood fit to H_T (s+t channed combined).**

The J/Ψ Cross Section CDF Run 2



- The J/ψ inclusive cross-section includes contribution from the direct production of J/ψ and from decays from excited charmonium, Ψ(2S), and from the **decays of b-hadrons, B-> J/ψ + X.**

J/ψ coming from b-hadrons will be displaced from primary vertex!



Down to $P_T = 0$!

39.7 pb^{-1}

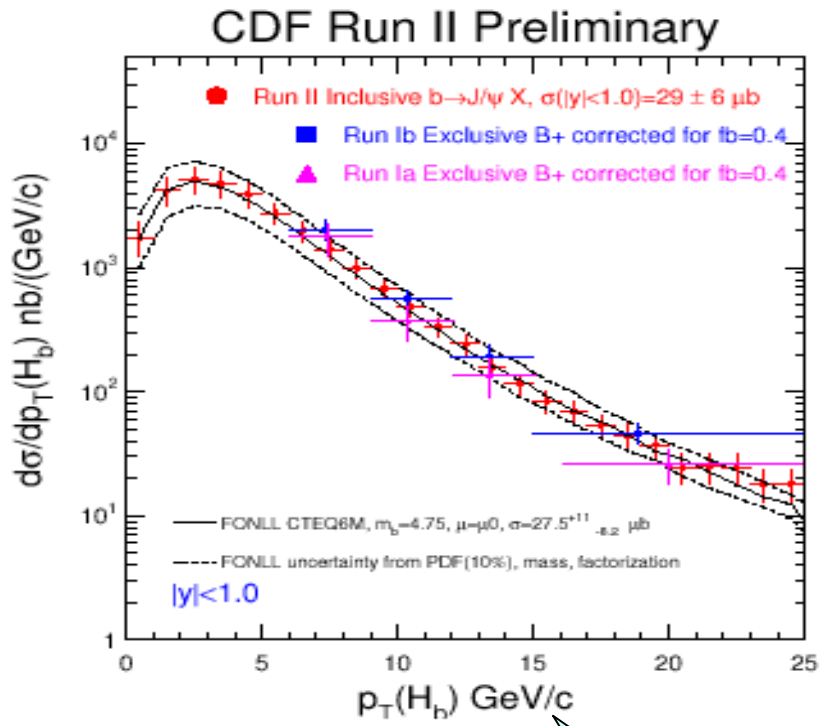
	CDF (μb)
σ(J/Ψ, |Y(J/Ψ)| < 0.6)	4.08±0.02(stat)+0.36(sys)-0.48(sys)

b-hadron Cross Section CDF Run 2

- Run 2 b-hadron P_T distribution compared with FONLL (CTEQ6M).

Cacciari, Frixone, Mangano, Nason, Ridolfi

- Excellent agreement between theory and experiment!



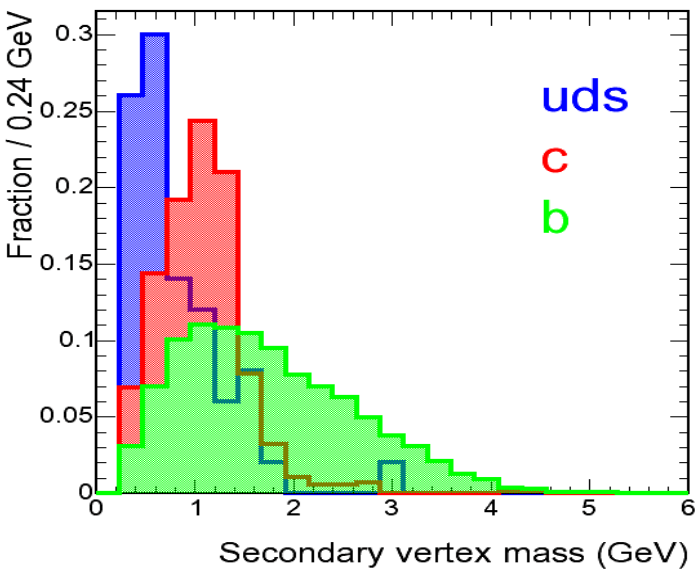
b-hadron P_T

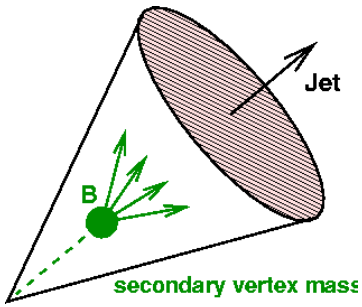
39.7 pb^{-1}

|Y| < 1.0

	CDF (μb)	FONLL (μb)
σ(b-hadron)	29.4±0.6(stat)±6.2(sys)	27.5+11-8.2

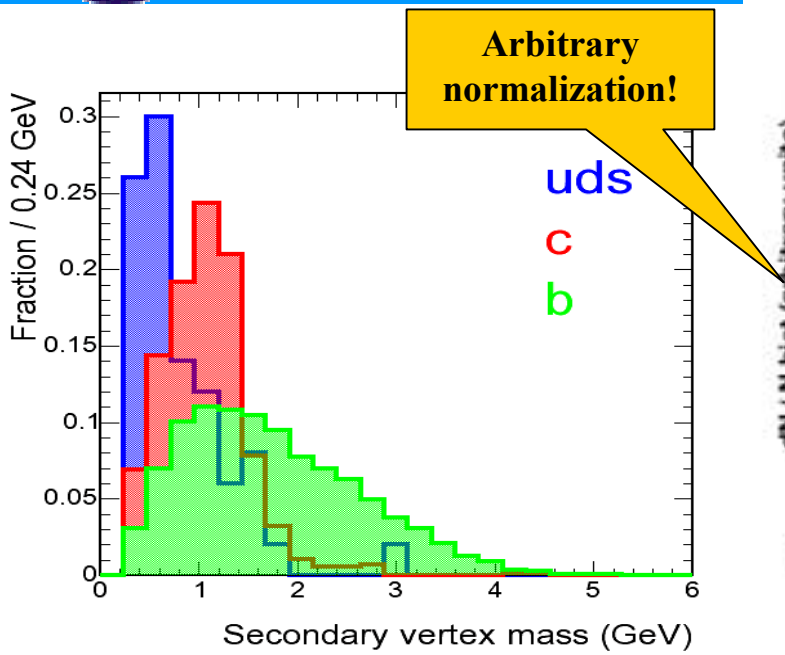
b-Jet Cross Sections
CDF Run 2

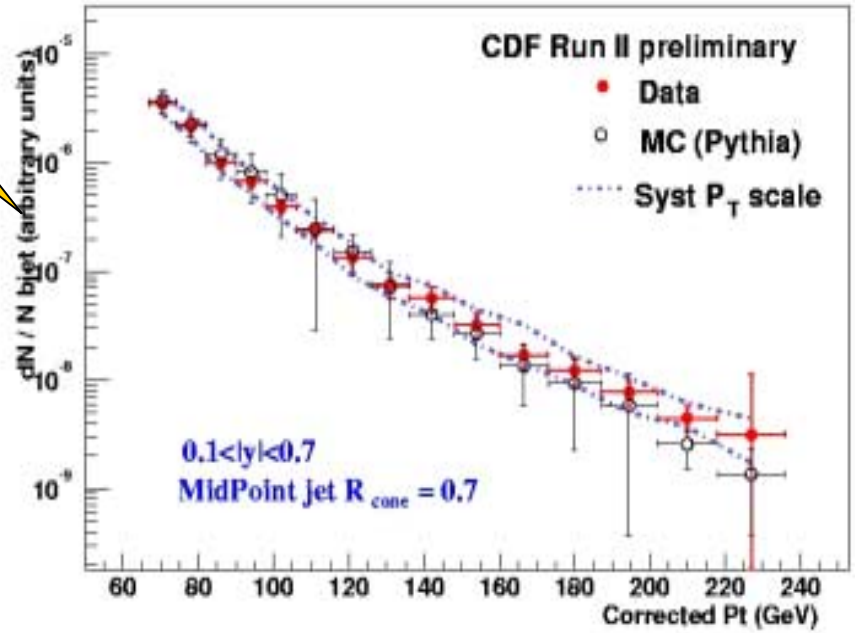




- **b-quark tag based on displaced vertices. Secondary vertex mass discriminates flavor.**
- **Require one secondary vertex tagged b-jet within 0.1 < |y|< 0.7 and plot the inclusive jet P_T distribution (MidPoint, R = 0.7).**

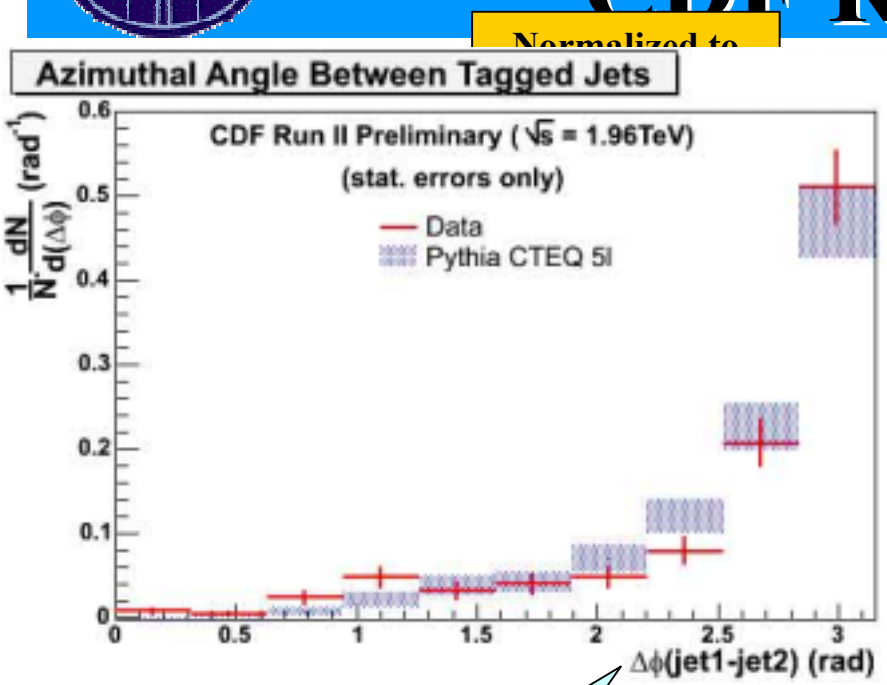
b-Jet Cross Sections
CDF Run 2

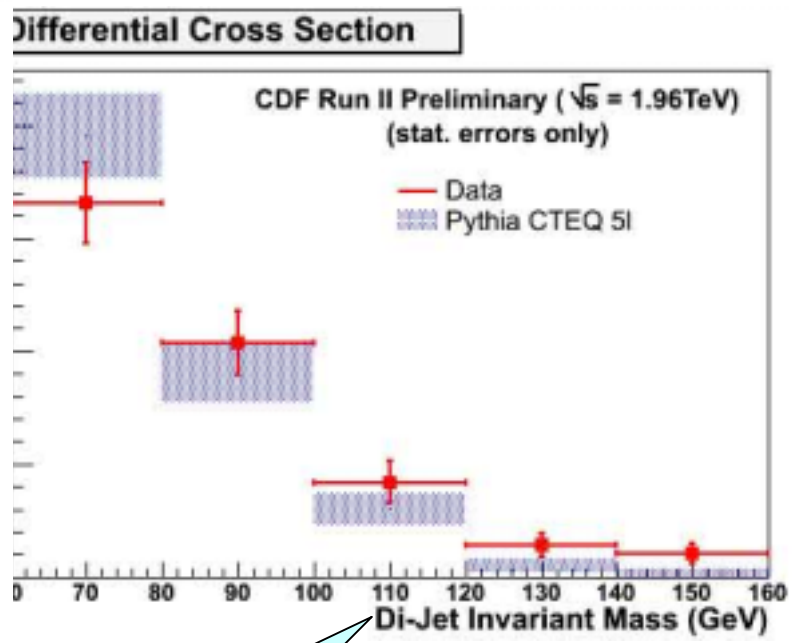




- **b-quark tag based on displaced vertices. Secondary vertex mass discriminates flavor.**
- **Require one secondary vertex tagged b-jet within 0.1 < |y|< 0.7 and plot the inclusive jet P_T distribution (MidPoint, R = 0.7).**

b-DiJet Cross Section
CDF Run 2





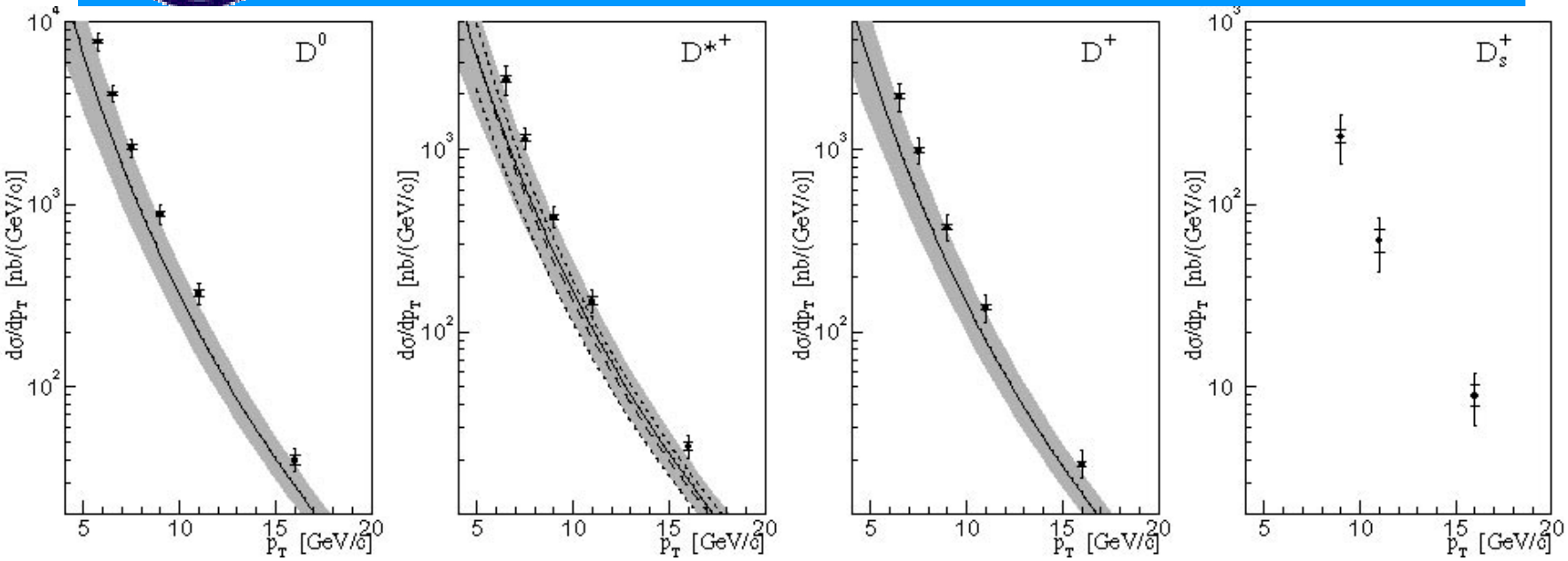
bJet-bbarJet Δφ

bJet-bbarJet invariant mass

- **Require two secondary vertex tagged b-[illegible]| < 1.2. One of these tagged jets has to have a corrected tranverse energy greater than 30 GeV, the other has to have a raw transverse energy greater than 10 GeV.**

Prompt Charm Meson Cross Sections

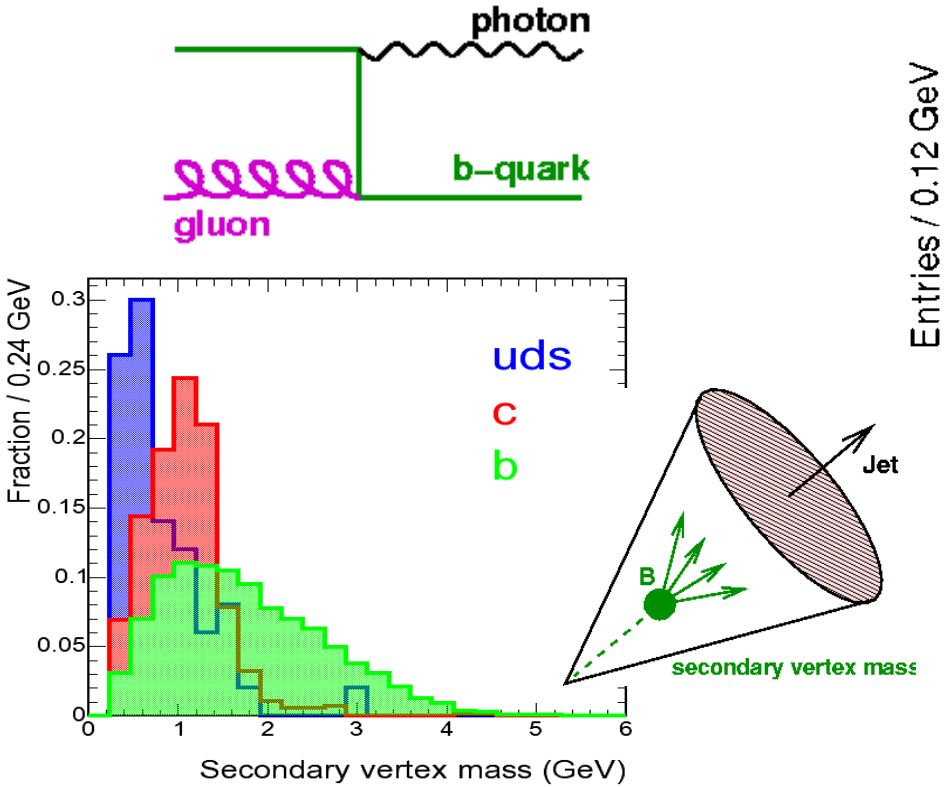
CDF Run 2

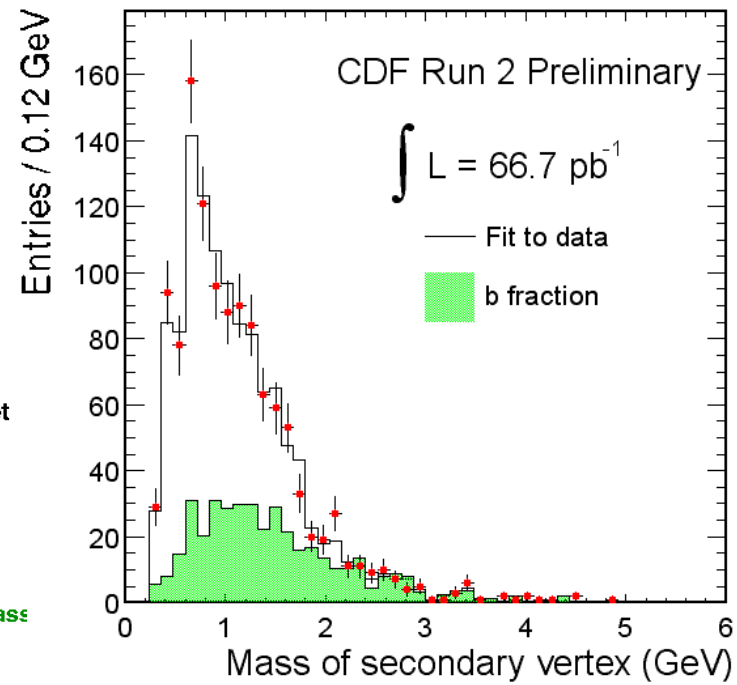


- **Theory calculation from M. Cacciari and P. Nason: Resummed perturbative QCD (FONLL), JHEP 0309,006 (2003)**

$$\sigma(D^0, p_T \geq 5.5\text{GeV}, |Y| \leq 1) = 13.3 \pm 0.2 \pm 1.5 \mu b$$
$$\sigma(D^{*+}, p_T \geq 6\text{GeV}, |Y| \leq 1) = 5.2 \pm 0.1 \pm 0.8 \mu b$$
$$\sigma(D^+, p_T \geq 6\text{GeV}, |Y| \leq 1) = 4.3 \pm 0.1 \pm 0.7 \mu b$$
$$\sigma(D_s^+, p_T \geq 8\text{GeV}, |Y| \leq 1) = 0.75 \pm 0.05 \pm 0.22 \mu b$$

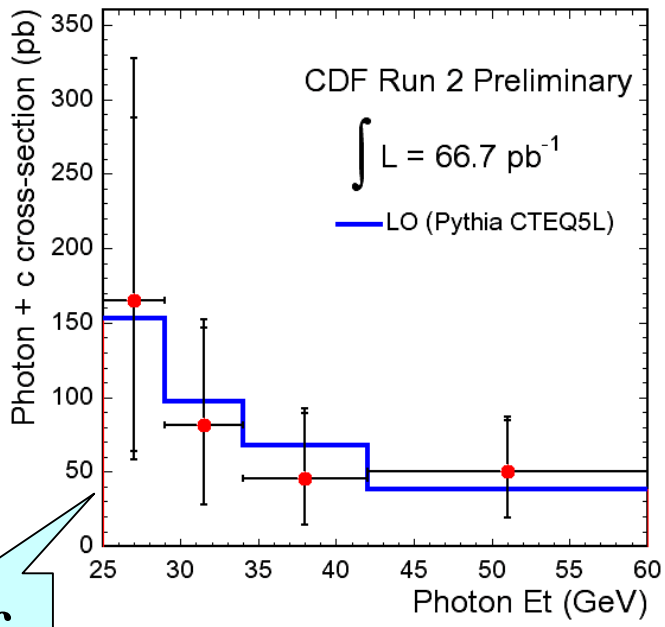
γ + b/c Cross Sections CDF Run 2



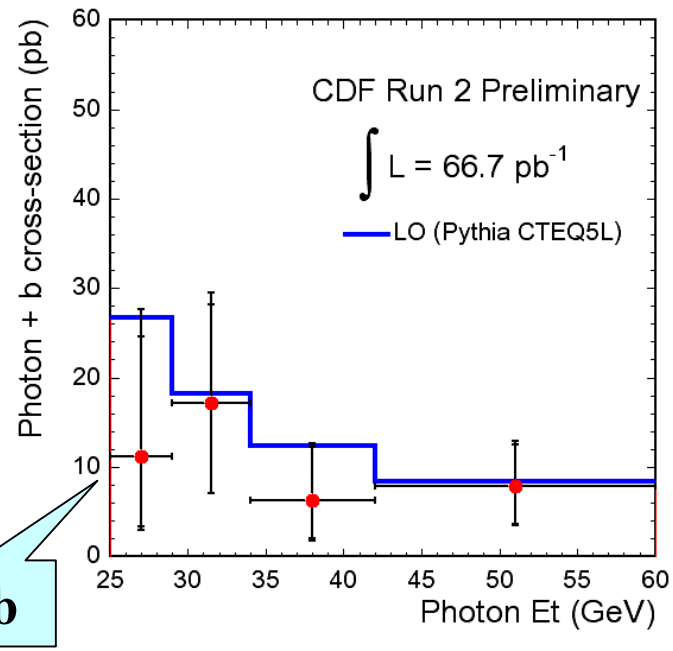


➡ **b/c-quark tag based on displaced vertices. Secondary vertex mass discriminates flavor.**

γ + b/c Cross Sections CDF Run 2



γ + c



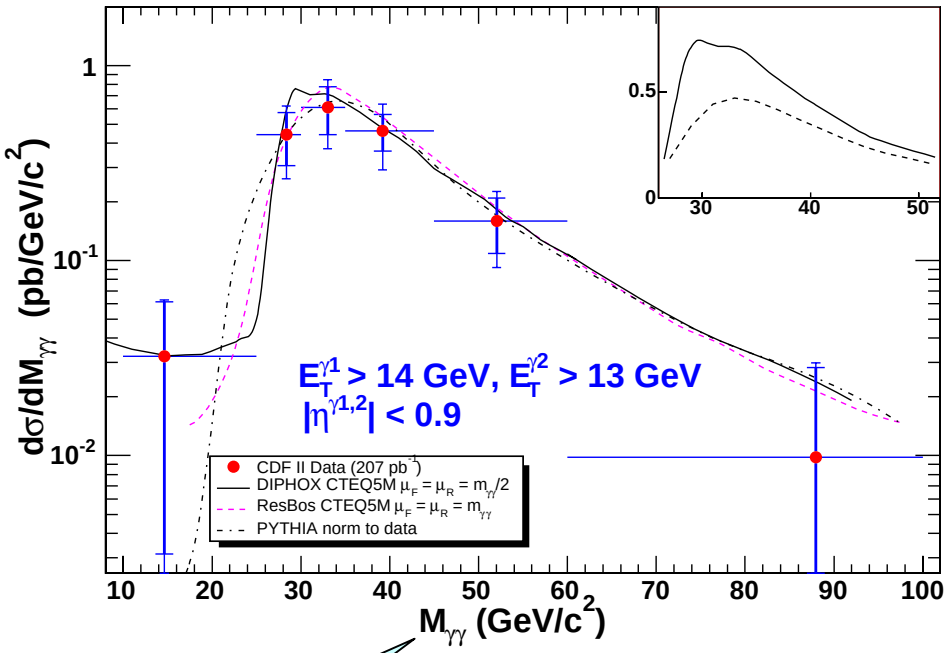
γ + b

- **PYTHIA Tune A correctly predicts the relative amount of u, d, s, c, b quarks within the photon events.**

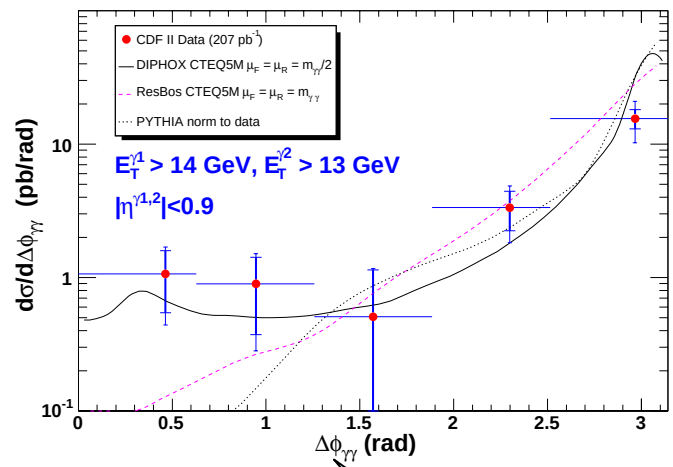
	CDF (pb)
σ(b+γ)	40.6±19.5(stat)+7.4(sys)-7.8(sys)
σ(c+γ)	486.2±152.9(stat)+86.5(sys)-90.9(sys)

$E_T(\gamma) > 25$ GeV

$\gamma + \gamma$ Cross Section CDF Run 2



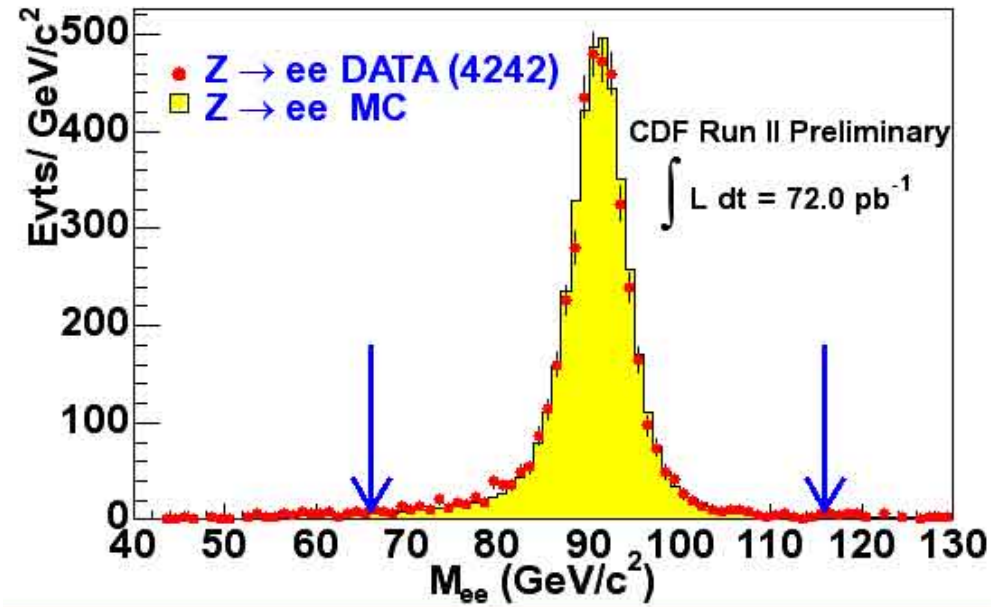
$\gamma + \gamma$ mass

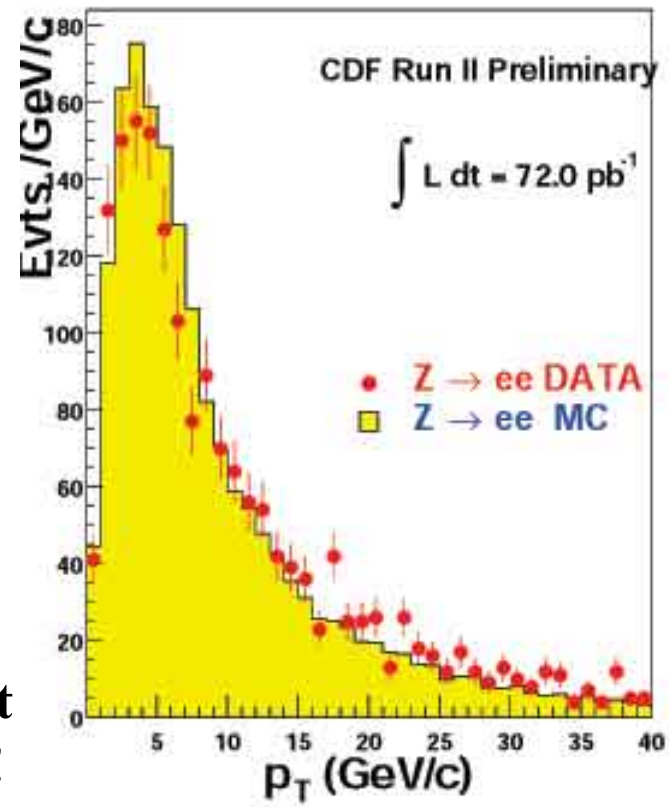


$\gamma + \gamma$ $\Delta\phi$

- **Di-Photon cross section with 207 pb^{-1} of Run 2 data compared with next-to-leading order QCD predictions from DIPHOX and ResBos.**

Z-boson Cross Section
CDF Run 2

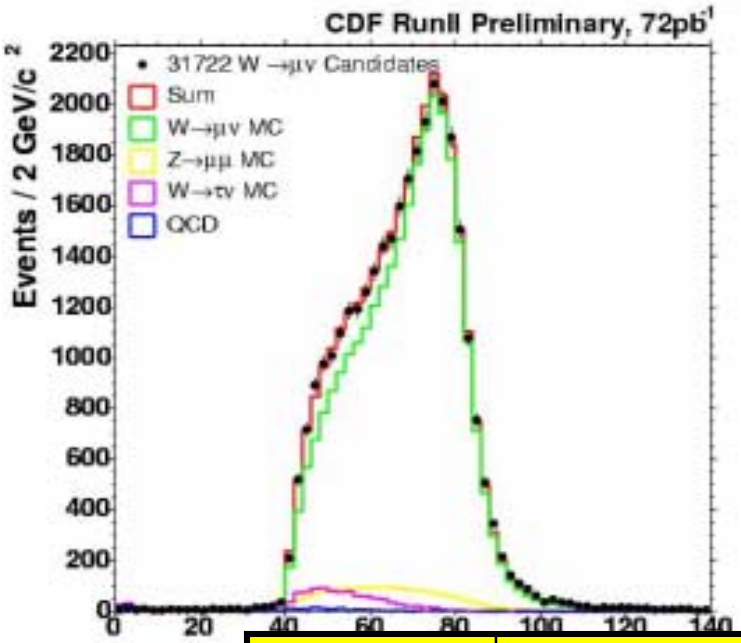


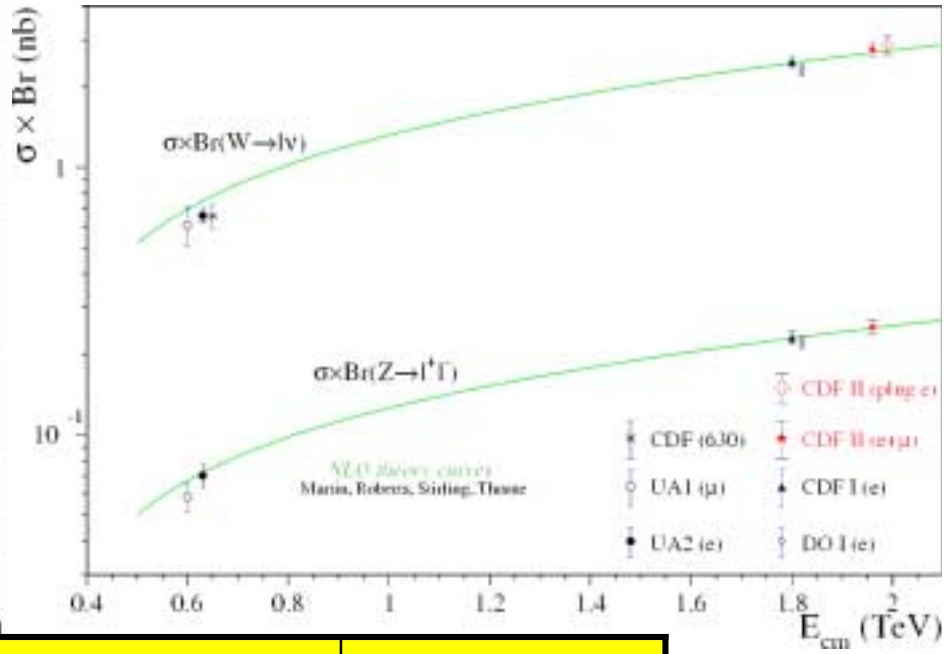


➡ **Impressive agreement between experiment and NNLO theory (Stirling, van Neerven)!**

	CDF (pb)	NNLO (pb)
σ(Z)	254.9±3.3(stat)±4.6(sys)±15.2(lum)	251.3±5.0

W-boson Cross Sections
CDF Run 2



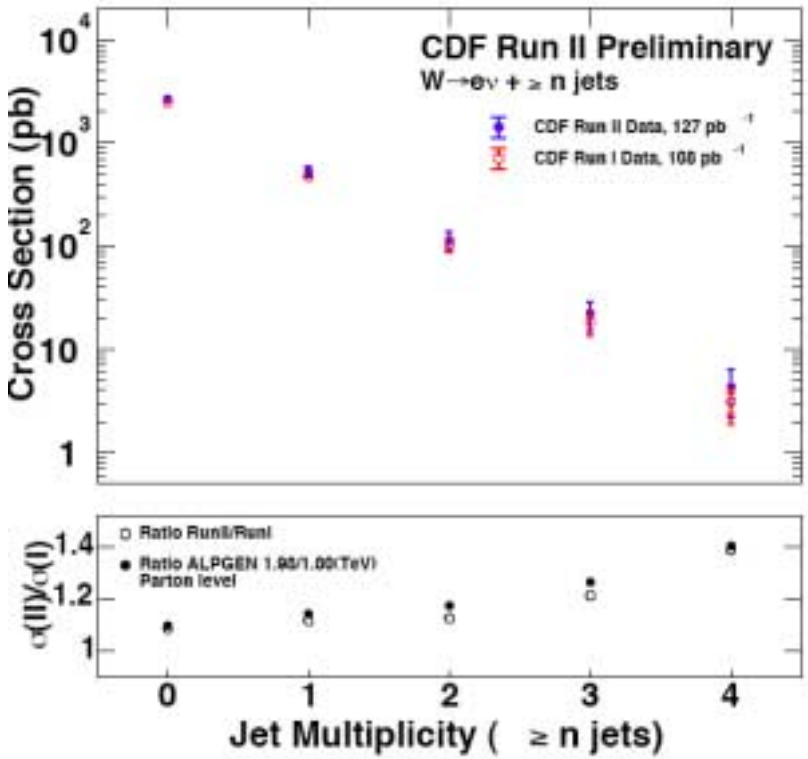


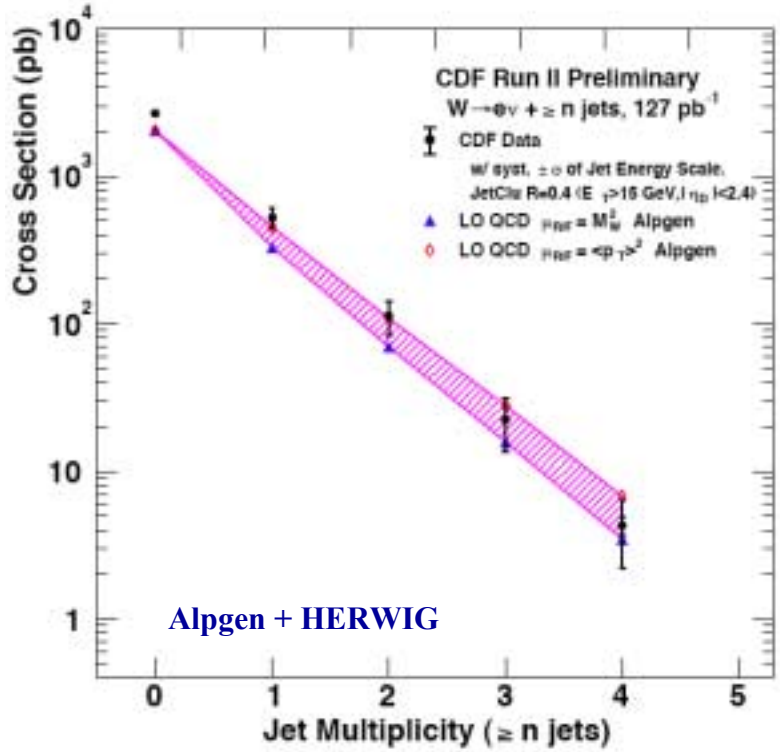
➡ Impressi ry
(Stirling,

	CDF	NNLO
σ(W)/σ(Z)	10.92±0.15(stat)±0.14(sys)	10.69±0.08

	CDF (pb)	NNLO(pb)
σ(W)	2775±10(stat)±53(sys)±167(lum)	2687±54

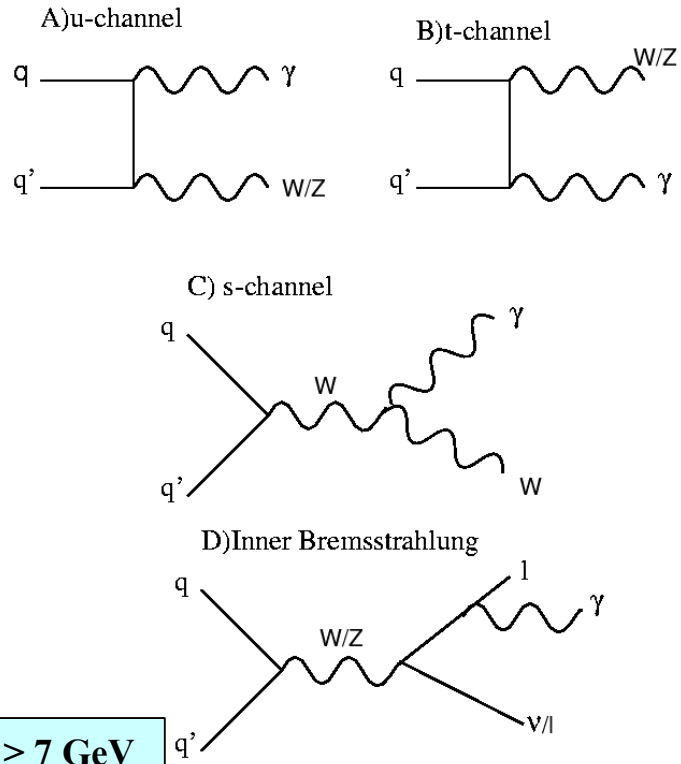
W + n Jets Cross Sections
CDF Run 2

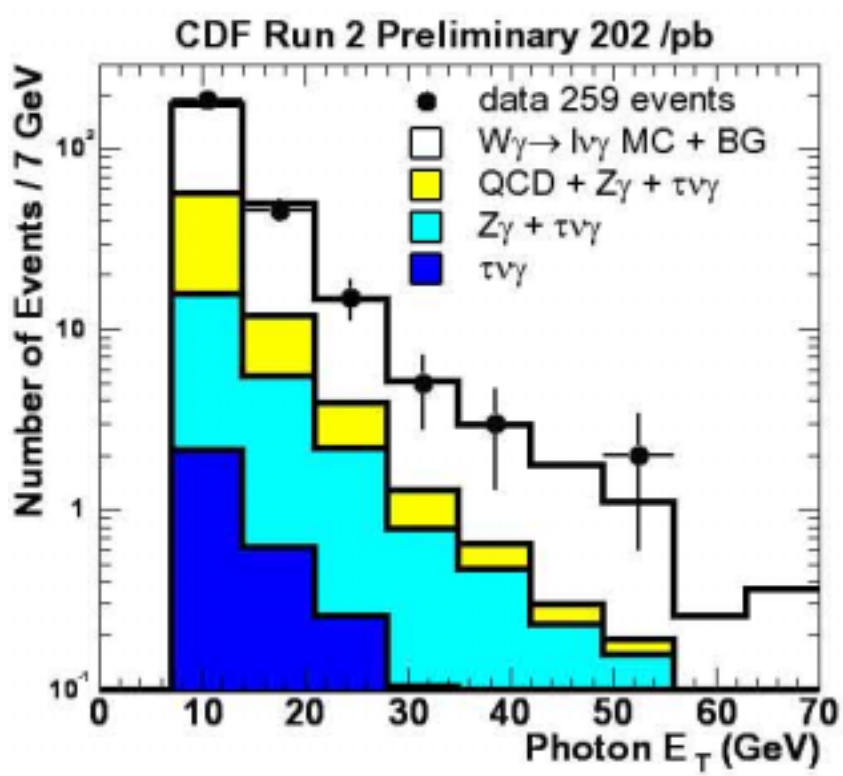




- **Run 2 W + n Jets Cross Section compared with Run 1 (JetClu, R = 0.4).**
- **Run 2 data compared with Alpgen + HERWIG.**

W + γ Cross Sections
CDF Run 2

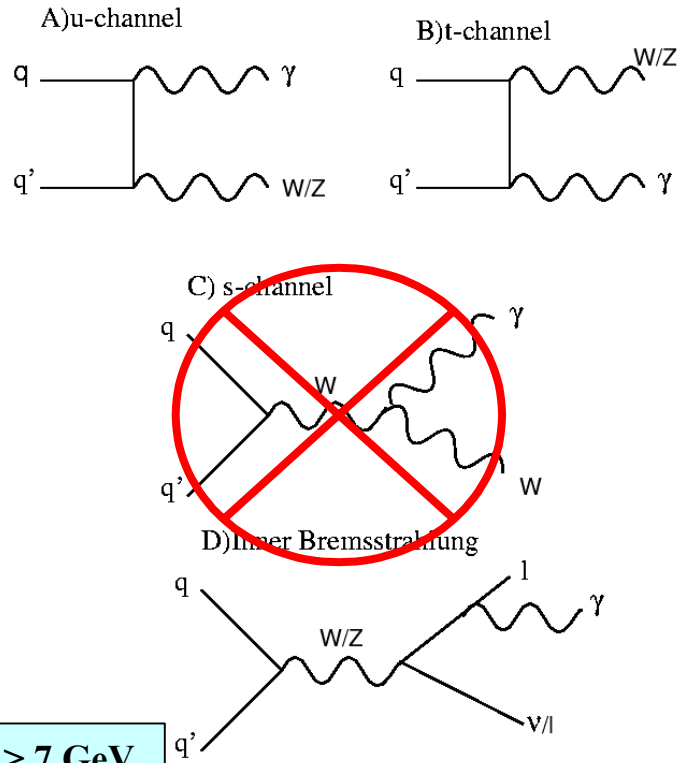


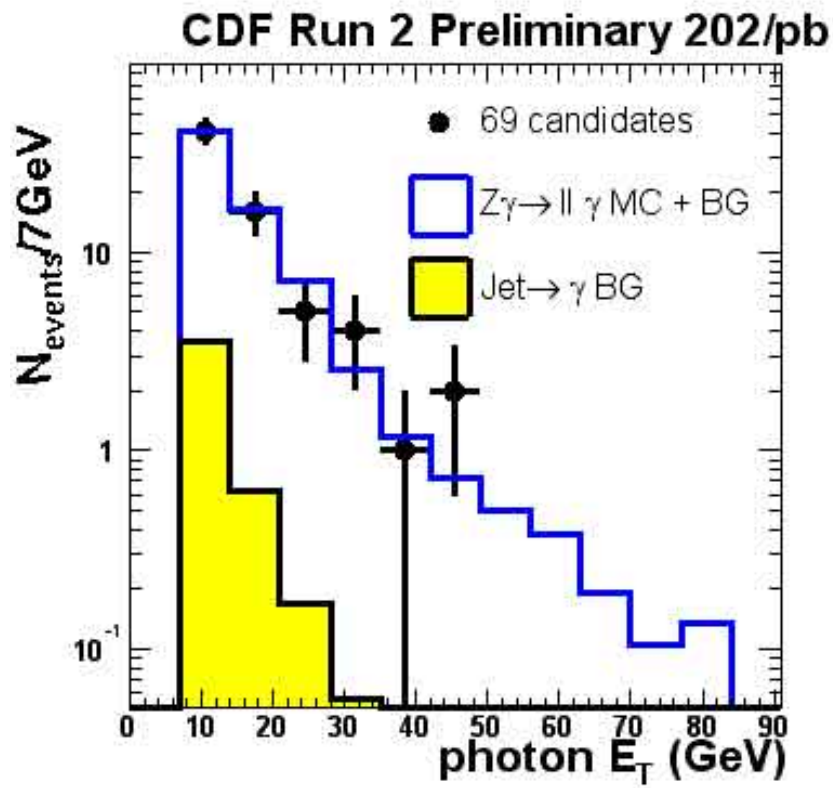


$E_T(\gamma) > 7$ GeV
$R(l\gamma) > 0.7$

	CDF (pb)	NLO (pb)
$\sigma(W+\gamma)*B_R(W\to l\nu)$	19.7±1.7(stat)±2.0(sys)±1.1(lum)	19.3±1.4

Z + γ Cross Sections
CDF Run 2

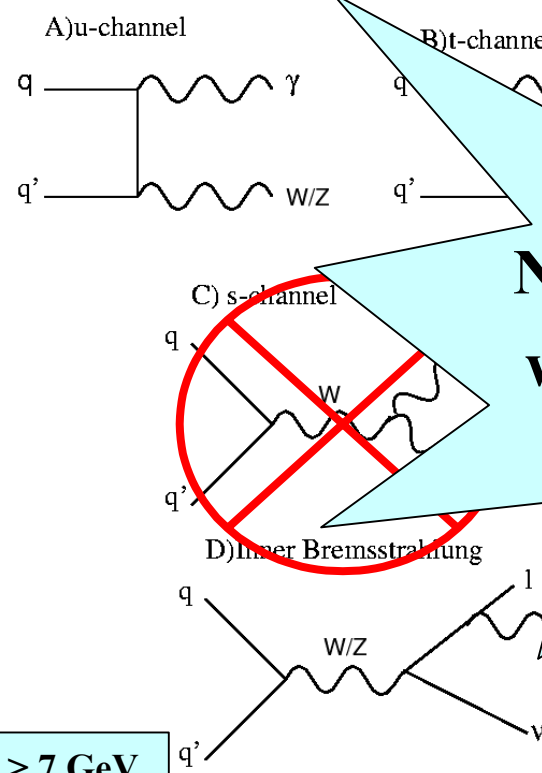


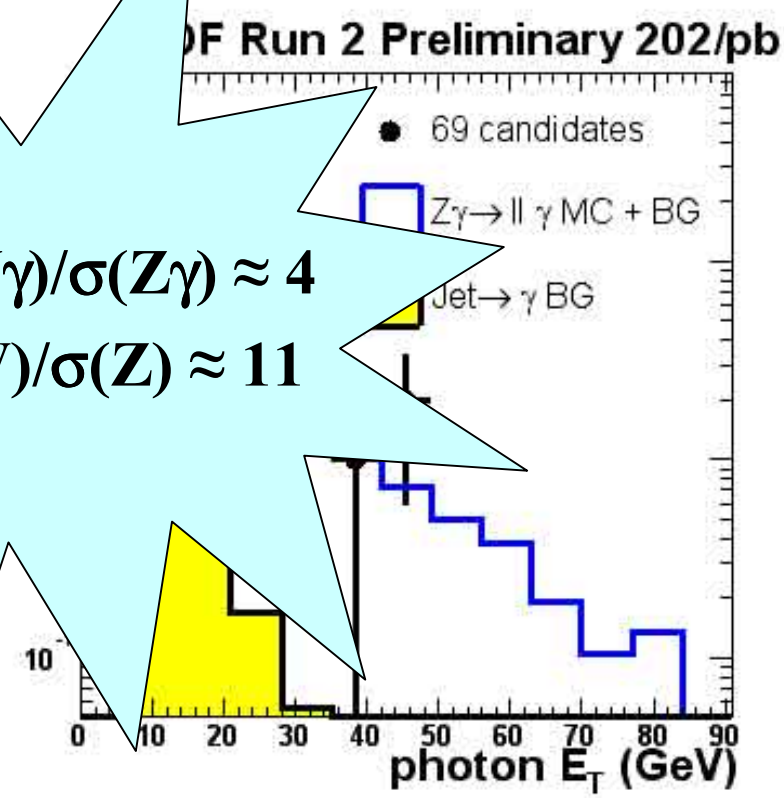


$E_T(\gamma) > 7$ GeV
$R(l\gamma) > 0.7$

	CDF (pb)	NLO (pb)
$\sigma(Z+\gamma)*B_R(Z\to ll)$	5.3±0.6(stat)±0.3(sys)±0.3(lum)	5.4±0.3

Z + γ Cross Sections CDF Run 2



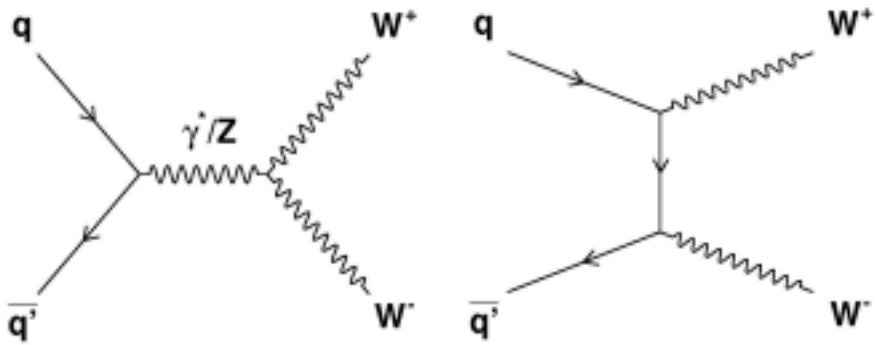


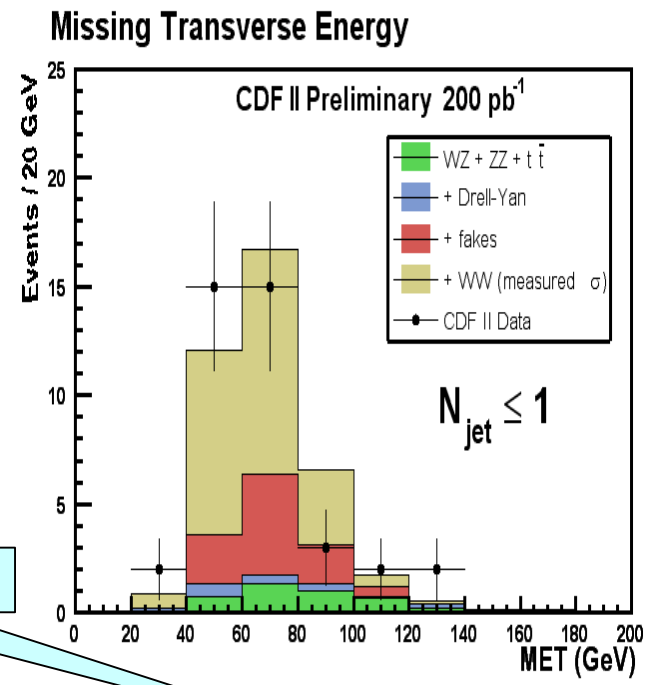
Note: $\sigma(W\gamma)/\sigma(Z\gamma) \approx 4$
while $\sigma(W)/\sigma(Z) \approx 11$

$E_T(\gamma) > 7$ GeV
$R(l\gamma) > 0.7$

	CDF (pb)	NLO (pb)
$\sigma(Z+\gamma)*B_R(Z\to ll)$	5.3±0.6(stat)±0.3(sys)±0.3(lum)	5.4±0.3

W+W Cross Section
CDF Run 2

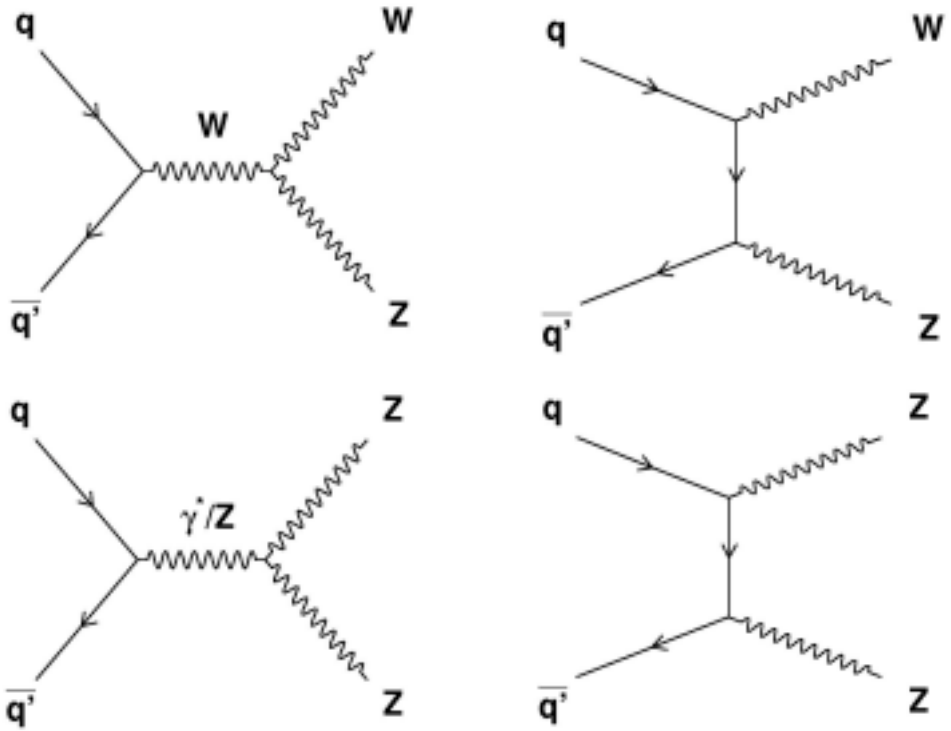




Campbell & Ellis 1999

	CDF (pb)	NLO (pb)
σ(WW) (e,μ)	14.3+5.6(stat)-4.9(stat)±1.6(sys)±0.9(lum)	12.5±0.8
σ(WW) (l+track)	19.4±5.1(stat)±3.5(sys)±1.2(lum)	12.5±0.8

Z+W, Z+Z Cross Sections
CDF Run 2



Upper Limit

	CDF (pb)	NLO (pb)
W+Z, Z+Z	< 13.9 (95% CL)	5.2±0.4

Z+W, Z+Z Cross Sections
CDF Run 2

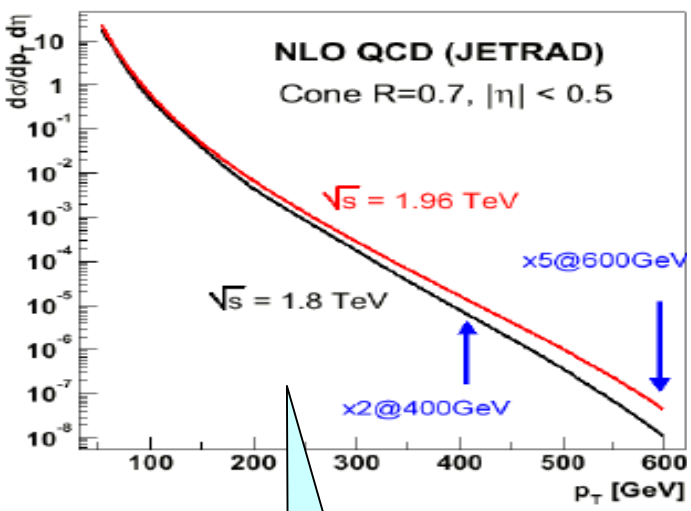
CDF Run II Winter 2004 Preliminary, $\mathcal{L}$=194 pb^{-1}

Process	$l_1 l_2 l_3 l_4$	$l_1 l_2 l_3 \not{E}_T$	$l_1 l_2 \not{E}_T$	Combined
ZZ	0.07 ± 0.01	0.13 ± 0.01	0.87 ± 0.14	1.07 ± 0.15
ZW	-	0.81 ± 0.07	0.86 ± 0.14	1.67 ± 0.19
ZZ+ZW	0.07 ± 0.01	0.94 ± 0.08	1.73 ± 0.27	2.74 ± 0.33
WW	-	-	1.26 ± 0.20	1.26 ± 0.20
Fake	0.01 ± 0.02	0.07 ± 0.06	0.56 ± 0.30	0.64 ± 0.34
Drell-Yan	-	-	0.31 ± 0.13	0.31 ± 0.13
$t\bar{t}$	-	-	0.08 ± 0.02	0.08 ± 0.02
Total Background	0.01 ± 0.02	0.07 ± 0.06	2.21 ± 0.38	2.29 ± 0.42
Expected S. + B.	0.08 ± 0.02	1.01 ± 0.10	3.94 ± 0.57	5.03 ± 0.64
Data	0	0	4	4

Upper Limit

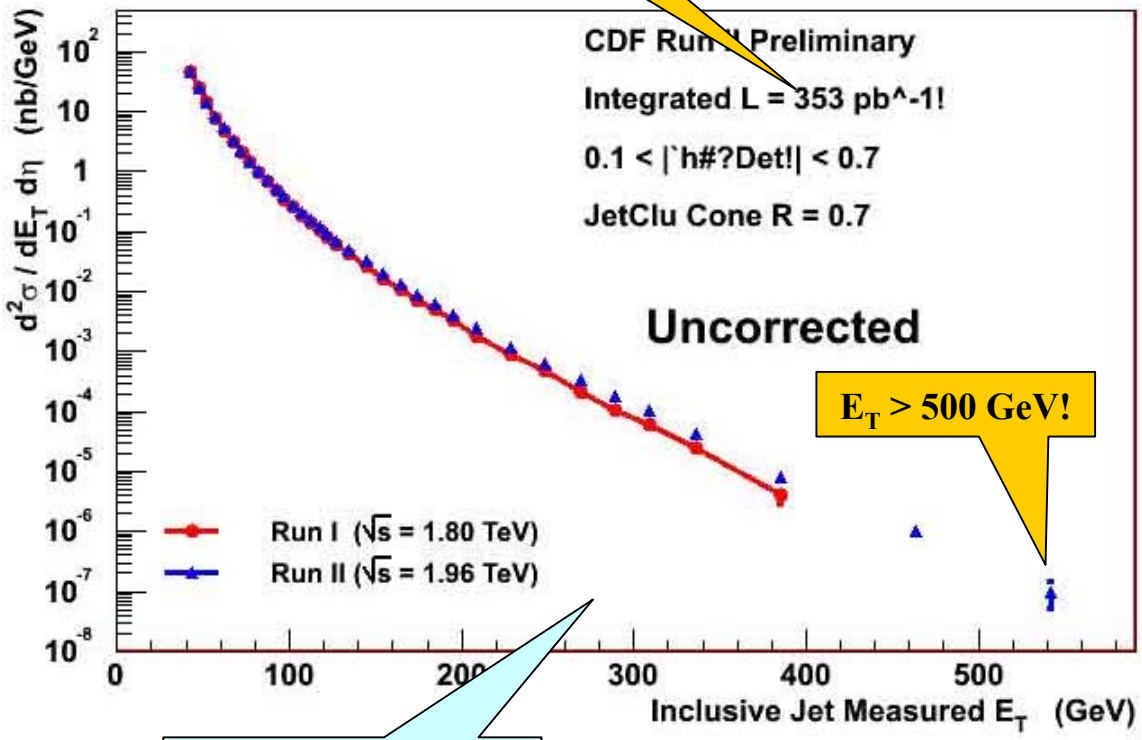
	CDF (pb)	NLO (pb)
W+Z, Z+Z	< 13.9 (95% CL)	5.2±0.4

Inclusive Jet Cross Section
CDF Run 2



Parton Level!

353 pb^{-1}!

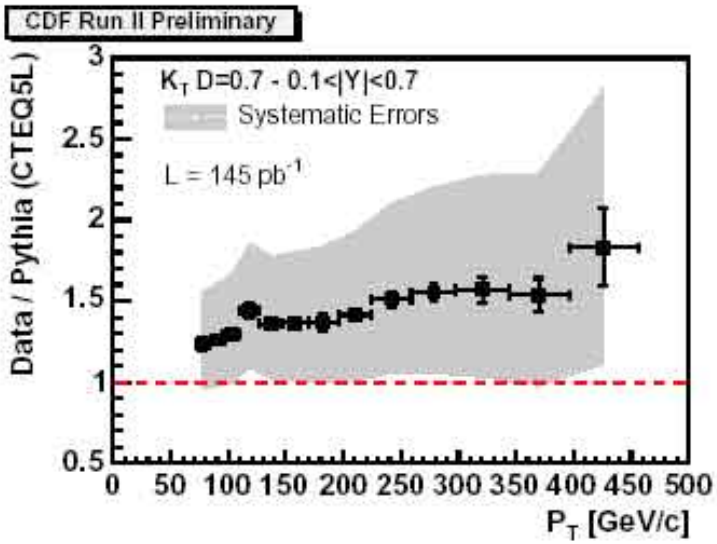


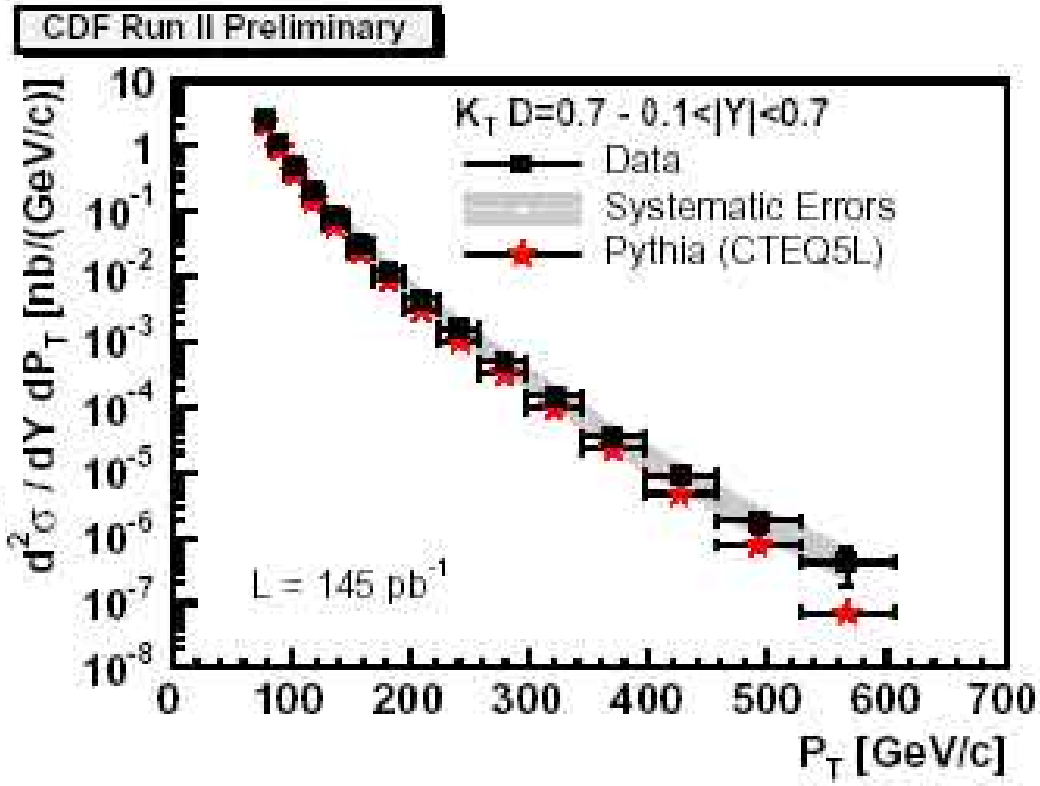
E_T > 500 GeV!

Calorimeter Level!

➡ **The challenge is that we measure the jets at the "calorimeter level". We do not measure partons!**

Inclusive Kt Jet Cross Section
CDF Run 2





We are using Kt and MidPoint in Run 2!

➡ **The Run 2 Kt inclusive jet cross section compared with PYTHIA Tune A (CTEQ5L).**

Inclusive Kt Jet Cross Section
CDF Run 2

I wish we had a QCD NLO Monte-Carlo Model with Parton-Showers, Fragmentation, Beam-Beam Remnants, etc.!

We are using Kt and MidPoint in Run 2!

- **The Run 2 Kt inclusive jet cross section compared with PYTHIA Tune A (CTEQ5L).**