PDF Issues In MSSM Higgs Searches: $p\bar{p} \to b\bar{b}A \to bb\bar{b}\bar{b}$

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Outline

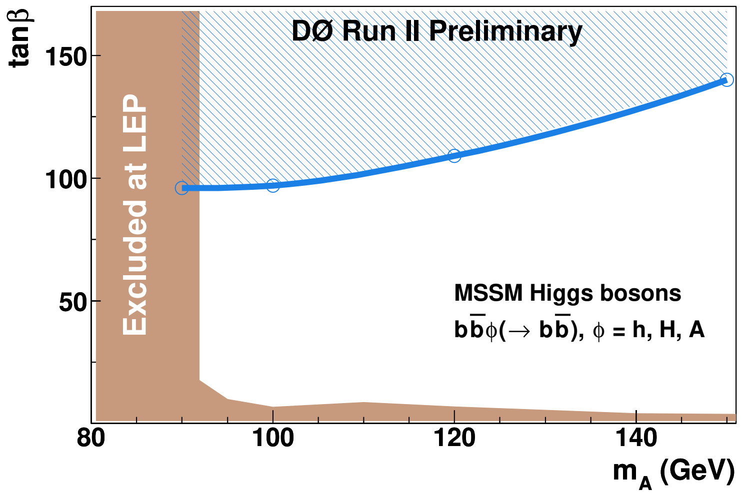
- Introduction
- Cross Section
- Acceptance
  - Increased statistic (3x) since last time
- x Value
- Conclusion and Observations

Why Search $b b \bar{b} \bar{b}$ Channel?

In the minimal supersymmetric extension to the Standard Model (MSSM), the $b\bar{b}A$ Yukawa coupling is proportional to $\tan\beta$, thus the cross section grows as $\tan^2\beta$ with respect to SM.

Typical lowest order Feynman diagrams for the signal channel.

DZero Run II vs. CDF Run I

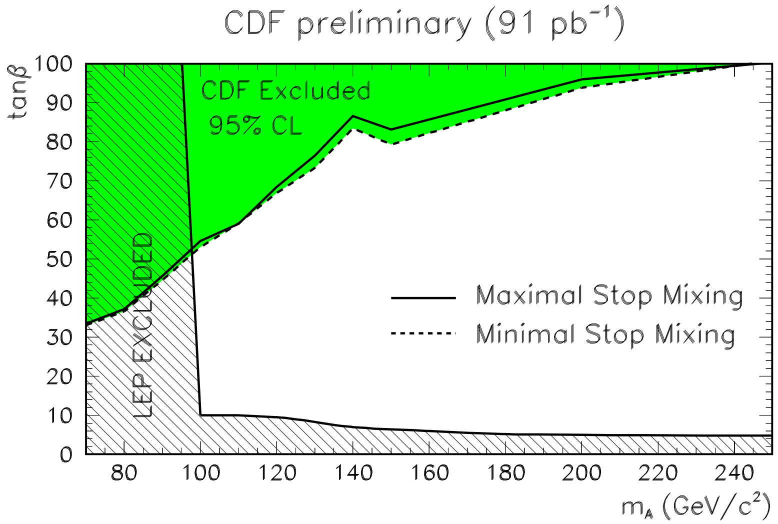


DZero Run II Limit; March 2004

Using 130 pb^{-1}

CDF Run I Limit; October 2000

Using 91 pb^{-1}



How can DZero Run II limit be worse?!

What is going on?

To see what might be causing the discrepancy between the Run I and the Run II analysis, we looked at the PDF's used in each analysis. CTEQ3L was used in the Run I analysis, but CTEQ5L is used in the Run II analysis.

- Differences in cross section due to PDF.
  - Using *PYTHIA* v6.216
  - Using PPHTT v1.1 from M. Spira
- Differences in acceptance.
  - Recreated CDF Run I event cuts.
- CDF Run I got lucky.
  - Run I analysis had less than expected background so it was able to set a better limit.

CTEQ3L vs. CTEQ5L: *PYTHIA*

Signal Cross Section (pb)

Mass A	$\tan\beta$	CTEQ3L	CTEQ5L
		PYTHIA	PYTHIA
90	30	10.0	6.7
90	50	27.0	18.3
100	30	6.7	4.4
100	50	18.3	12.0

There seems to be about a factor of 1.5 difference in the cross sections across the board.

CTEQ3L vs. CTEQ5L: *PPHTT* (As a Cross Check)

Signal Cross Section (pb)

Mass A	$\tan\beta$	CTEQ3L	CTEQ5L
		PPHTT v1.1	PPHTT v1.1
90	30	13.9	9.3
90	50	37.7	25.9
100	30	8.7	5.2
100	50	24.2	15.9

PPHTT v1.1 is a cross section calculator from M. Spira. It uses a leading order (LO) calculation where the scale used for the running b mass in the Yukawa coupling $Q = (M_H + 2 * M_b)/2$.

PPHTT shows the same trend as PYTHIA.

Back to *PYTHIA*: CTEQ3L vs. CTEQ5L

Signal Cross Section (pb) *PYTHIA*

Mass A	tanβ	Process	CTEQ3L	CTEQ5L
90	30	gg	10	6.6
		qq	5.1e-2	5.2e-2
90	50	gg	27	18
		qq	0.14	0.14
100	30	gg	6.6	4.3
		qq	3.4e-2	3.4e-2
100	50	gg	18	12
		qq	9.2e-2	9.3e-2

CTEQ5L has a softer the gluon/gluon interaction than CTEQ3L. However the quark/quark interactions seem to be the same.

CDF Run I Selection Cuts

We did our best to model the Run I selection cuts using current CDF Run II software.

- L2
  - 4 Jets $E_T > 15$ GeV
  - $\Sigma\ E_T > 125$ GeV
- Kinematics
  - M_A dependent cuts on jet energy (This case $M_A = 90$ GeV)
    - Hardest Jet > 42 GeV
    - 2^{nd} Hardest Jet > 34 GeV
    - 3^{rd} Hardest Jet > 14 GeV
- b-Tagging
  - At least 3 of the 4 hardest jets are b-tagged.
- bJetKin
  - $\Delta\phi > 109^o$ between the 2 hardest b-tagged jets.

Effect of the PDF on Acceptance: qq

PYTHIA Monte Carlo ($M_A = 90$; $\tan\beta = 50$)

		CTEQ3L(qq)	CTEQ5L(qq)
σ (pb)		0.14	0.14
Num MC		51k	59k
L2	Events	10935	12777
	Accept.(%)	21	22
	$\sigma \times Accept$	0.030	0.030
Kinematics	Events	2381	2774
	Accept.(%)	4.7	4.7
	$\sigma \times Accept$	0.007	0.007
b-Tagging	Events	330	356
	Accept.(%)	0.65	0.60
	$\sigma \times Accept$	0.0009	0.0008
bJetKin	Events	232	246
	Accept.(%)	0.46$\pm$.03	0.42$\pm$.03
	$\sigma \times Accept$	0.00063$\pm$.00004	0.00058$\pm$.00004

The ratio between the PDF's in the quark/quark process:

$0.00063/0.00058 = 1.1$

Effect of the PDF on Acceptance: gg

PYTHIA Monte Carlo ($M_A = 90$; $\tan\beta = 50$)

		CTEQ3L(gg)	CTEQ5L(gg)
σ		26.9	18.2
Num MC	Increased Stat.	352k	358k
L2	Events	2526	2376
	Accept.(%)	0.7	0.7
	$\sigma \times Accept$	0.19	0.13
Kinematics	Events	385	336
	Accept.(%)	0.11	0.09
	$\sigma \times Accept$	0.030	0.016
b-Tagging	Events	23	18
	Accept.(%)	0.007	0.005
	$\sigma \times Accept$	0.0018	0.0009
bJetKin	Events	19	11
	Accept.(%)	0.0054±.0012	0.0031±.0010
	$\sigma \times Accept$	0.0015±.0003	0.00056±.00017

The ratio between the PDF in the glue/glue process:

$$0.0015/0.00056 = 2.7$$

Effect of the PDF on Acceptance: Total (qq + gg)

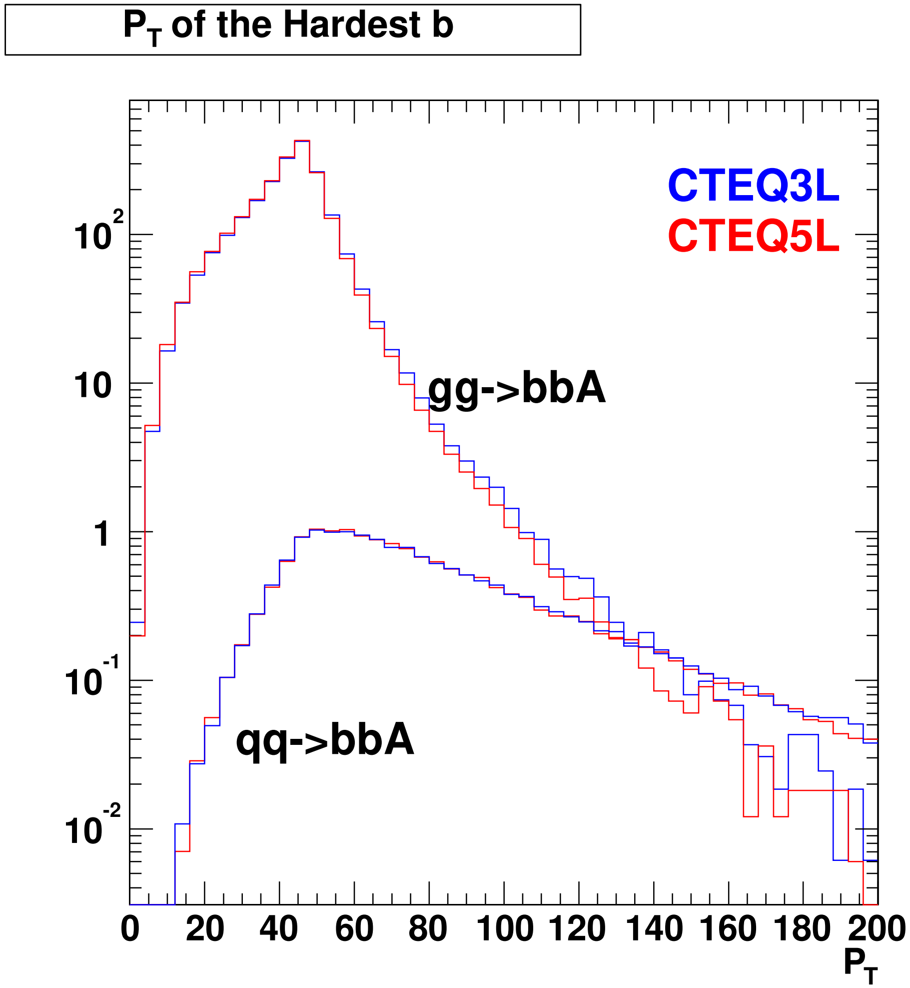
PYTHIA Monte Carlo ($M_A = 90$; $\tan\beta = 50$)

		CTEQ3L(total)	CTEQ5L(total)
σ		27.04	18.31
L2	Accept.(%)	0.81	0.86
	$\sigma \times Accept$	0.22	0.16
Kinematics	Accept.(%)	0.13	0.13
	$\sigma \times Accept$	0.035	0.023
b-Tagging	Accept.(%)	0.010	0.010
	$\sigma \times Accept$	0.0027	0.0019
bJetKin	Accept.(%)	0.0078±.0012	0.0063±.0010
	$\sigma \times Accept$	0.0021±.0003	0.0011±.00017

The total ratio between the PDF's:

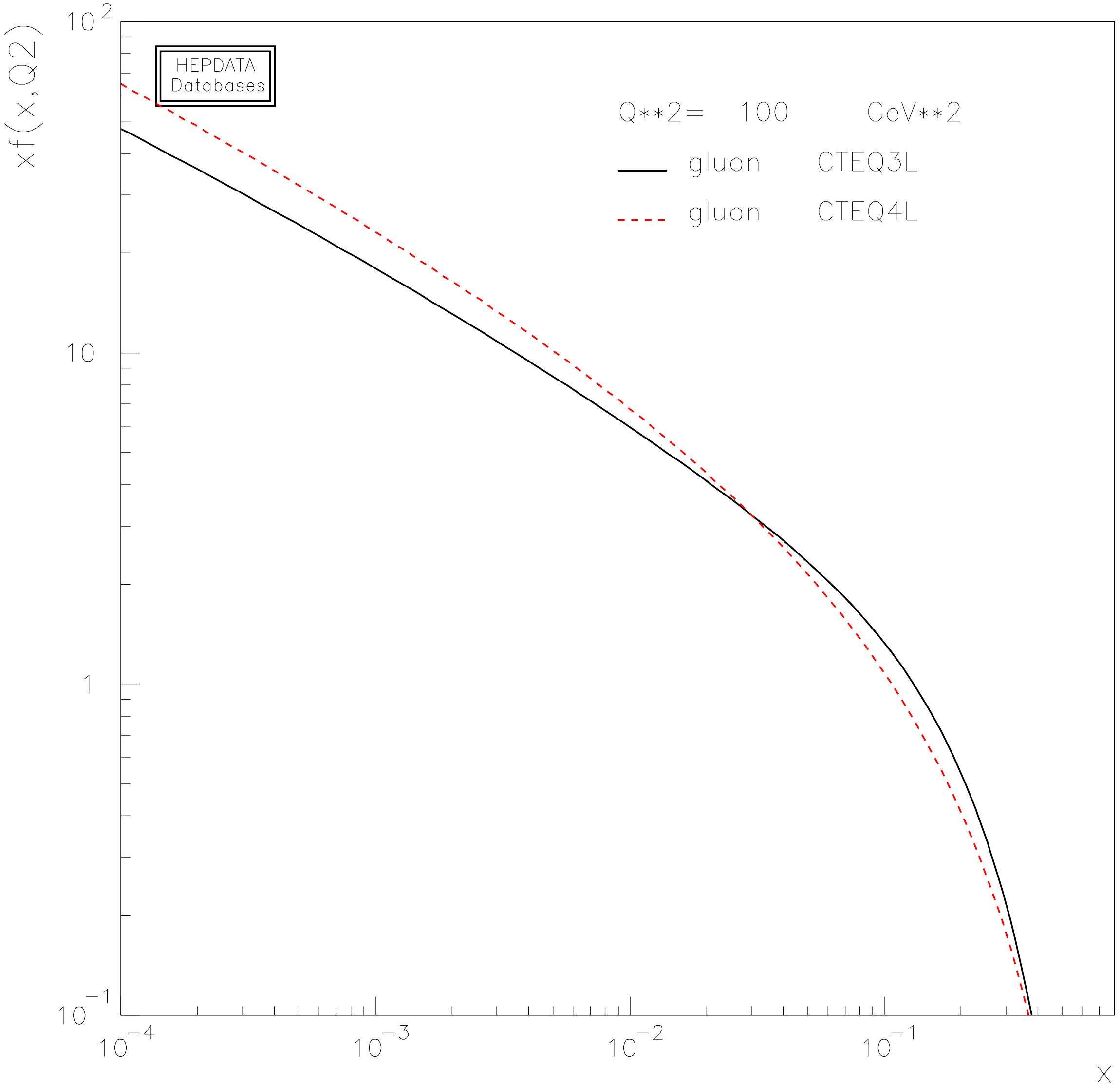
$0.0021/0.0011 = 1.9$)

Some Kinematic Plots

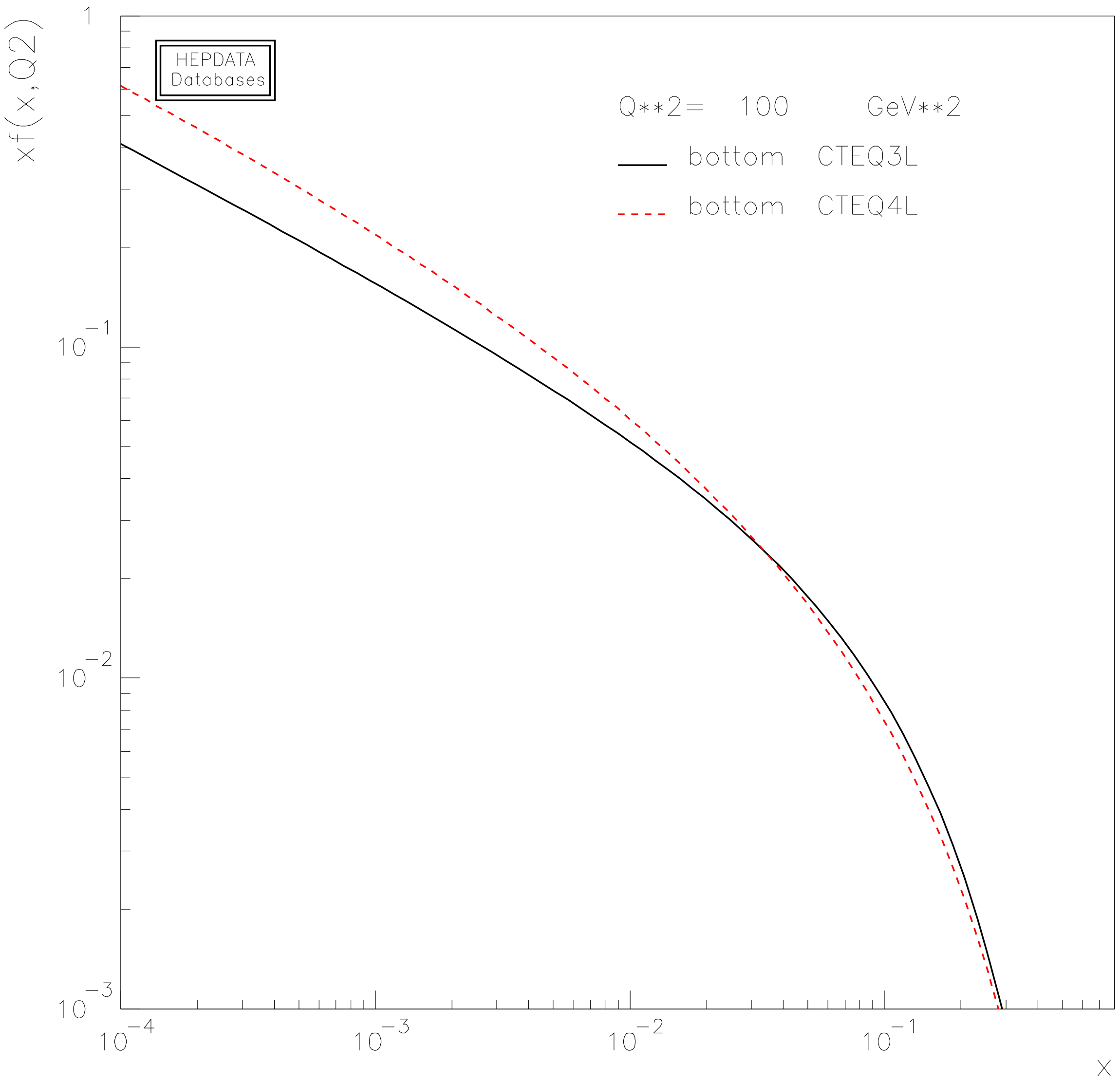


Out in the high P_T tails, it seems the slopes of the glue/glue process diverge.

x Values gg


HEPDATA
Databases
Q**2= 100 GeV**2
gluon CTEQ3L
gluon CTEQ4L
xf(x,Q2)
X
10^2
10
1
10^{-1}
10^{-4}
10^{-3}
10^{-2}
10^{-1}

x Values qq


HEPDATA Databases
Q**2= 100 GeV**2
bottom CTEQ3L
bottom CTEQ4L
xf(x,Q2)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
X

Conclusion

- CTEQ3L to CTEQ5L, the cross section dropped by a factor of 1.5.
- The acceptance also dropped by a factor of 1.2.
- The total (qq+gg) ratio ($\sigma * acceptance$) is factor of 1.9.
- Qualitatively this seems to account for some of the difference in the DZero Run II result and CDF Run I result.
- Now that this archeology is done, I'll move on, unhindered, toward my analysis result.

General Observations

- PDF's make significant difference in this analysis.
- There needs to be good ways to estimate the errors associated with PDF's. CTEQ6 does this but with lots of effort.
- Experimenters need to have guidance on how to use the new NLO calculations.