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

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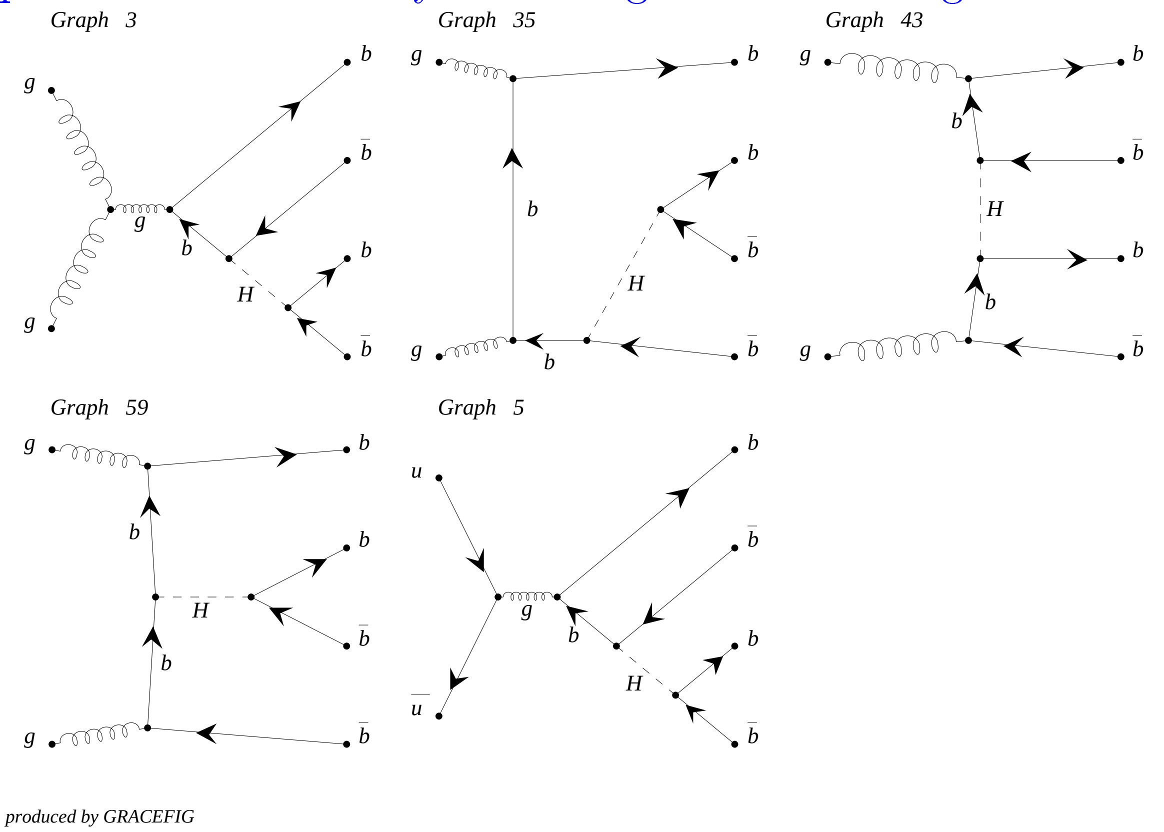
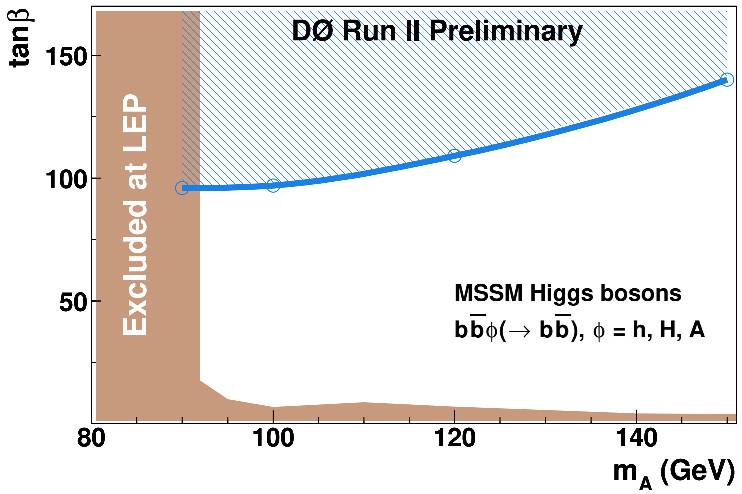
Why Search $bb\bar{b}\bar{b}$ Channel?

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

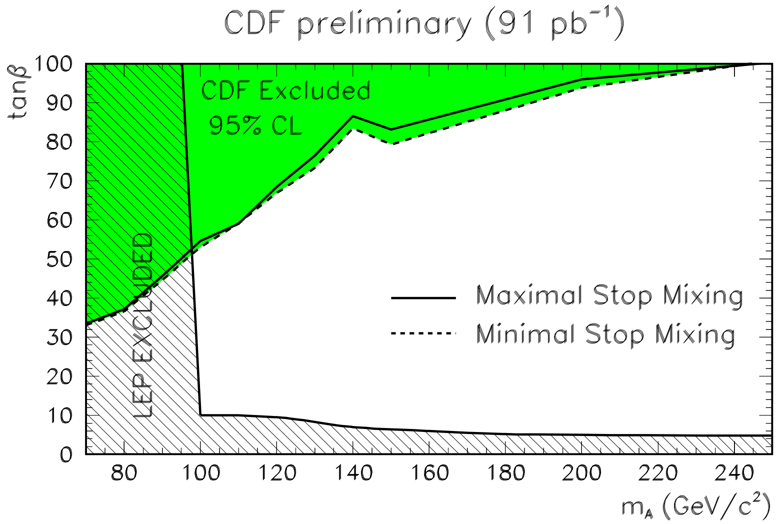


DZero Run II Limit; March 2004

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 discrepency between the Run I and the Run II analyses, 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 analyses.

- 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 PYTHIA	CTEQ5L 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 PPHTT v1.1	CTEQ5L 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
  - Σ $E_T > 125$ 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
	$\sigma * Accept$	0.030	0.030
Kinematics	Events	2381	2774
	Accept.(%)	4.7	4.7
	$\sigma * Accept$	0.007	0.007
b-Tagging	Events	330	356
	Accept.(%)	0.65	0.60
	$\sigma * Accept$	0.0009	0.0008
bJetKin	Events	232	246
	Accept.(%)	0.46	0.42
	$\sigma * Accept$	0.00063	0.00058

The difference 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		101k	140k
L2	Events	710	888
	Accept.(%)	0.7	0.6
	$\sigma * Accept$	0.19	0.12
Kinematics	Events	105	130
	Accept.(%)	0.10	0.09
	$\sigma * Accept$	0.028	0.017
b-Tagging	Events	12	8
	Accept.(%)	0.010	0.006
	$\sigma * Accept$	0.0032	0.0010
bJetKin	Events	9	5
	Accept.(%)	0.0089	0.0036
	$\sigma * Accept$	0.0024	0.00065

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

$$0.0024/0.00065 = 3.7$$

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

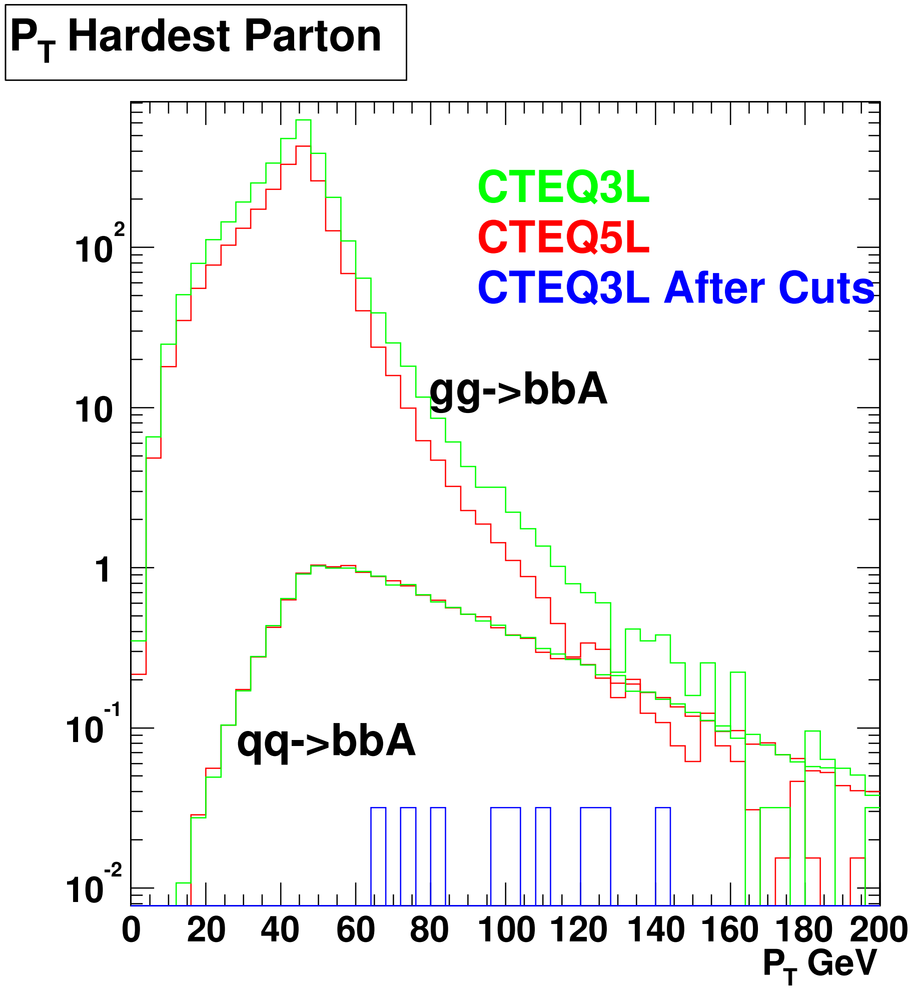
PYTHIA Monte Carlo ($M_A = 90$; $\tan\beta = 50$)

		CTEQ3L(total)	CTEQ5L(total)
σ		27.04	18.31
Num MC		—	—
L2	Events		
	Accept.(%)	0.81	0.79
	$\sigma * Accept$	0.22	0.15
Kinematics	Events		
	Accept.(%)	0.13	0.13
	$\sigma * Accept$	0.035	0.023
b-Tagging	Events		
	Accept.(%)	0.015	0.010
	$\sigma * Accept$	0.0041	0.0019
bJetKin	Events		
	Accept.(%)	0.011	0.0067
	$\sigma * Accept$	0.0030	0.0012

The total difference between the PDF's:

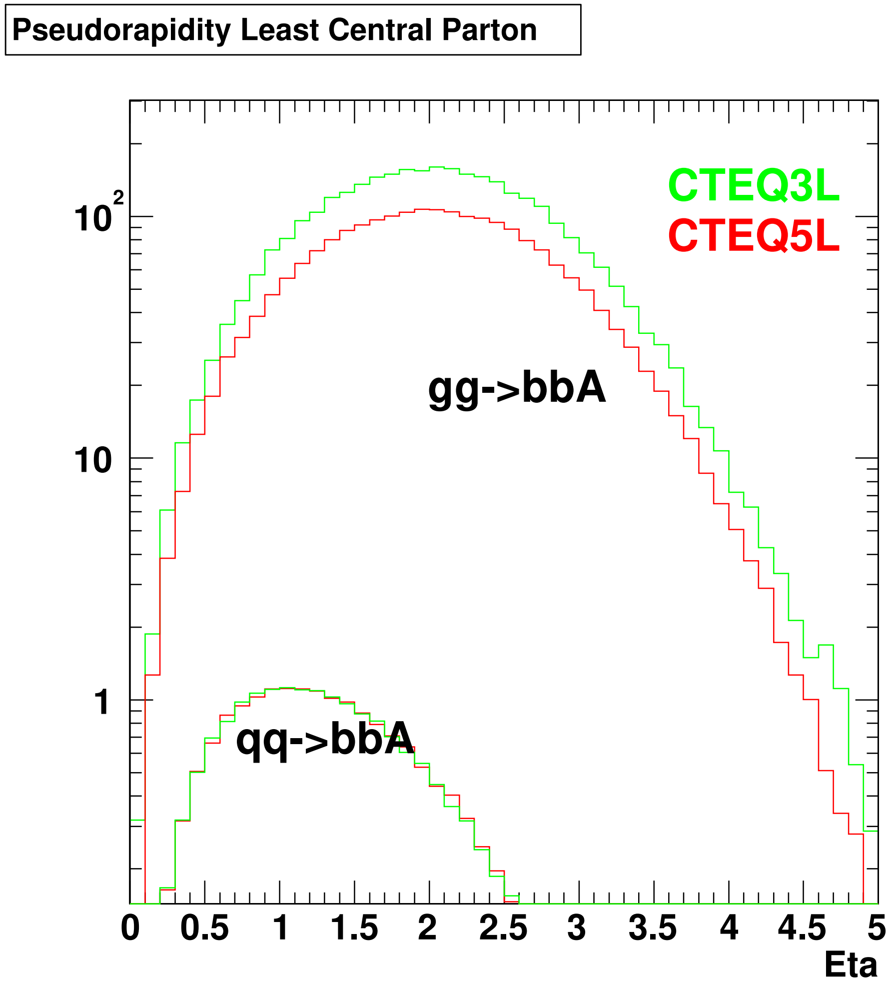
$$0.0030/0.0013 = 2.5$$

Some Kinematic Plots



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

Some Kinematic Plots



How Sure are We?

There are very low statistics after all of the selection cuts. More Monte Carlo is needed to make the difference more statistically significant.

How well do we trust the cross sections produced by these packaged program? There is a factor of 1.3 between the cross section given by $PYTHIA$ and the cross section given by PPHTT.

These are questions that require more time and help from theorists!

Conclusion

- CTEQ3L to CTEQ5L, the cross section dropped by a factor of 1.5.
- The acceptance also dropped by a factor of 1.7.
- The total difference ($\sigma * acceptance$) is factor of 2.6.
- This seems to be consistent with the difference in the DZero Run II result and CDF Run I result.

General Observations

- PDF's make significant difference in this analysis.
- When played against each other these programs produce different cross sections. How do we trust these black boxes?
- There needs to be a better way to estimate the errors associated with PDF's. Theorist can be very helpful with this task.
- I think this is an issue that will be important for CMS and Atlas.