Higgs, top, and FCNCs

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For the CDF collaboration

Presentation at SUSY 2015

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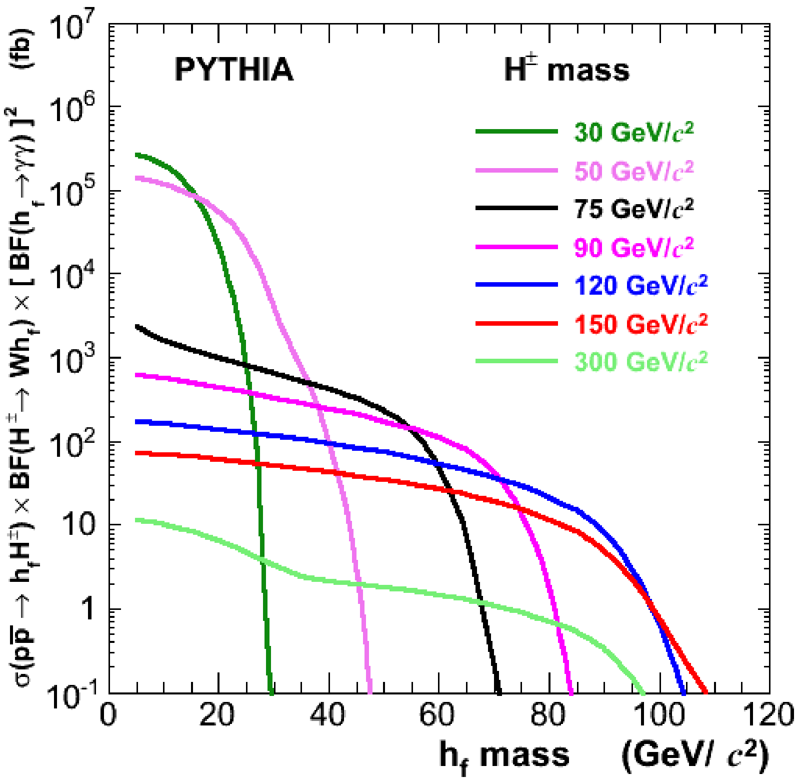
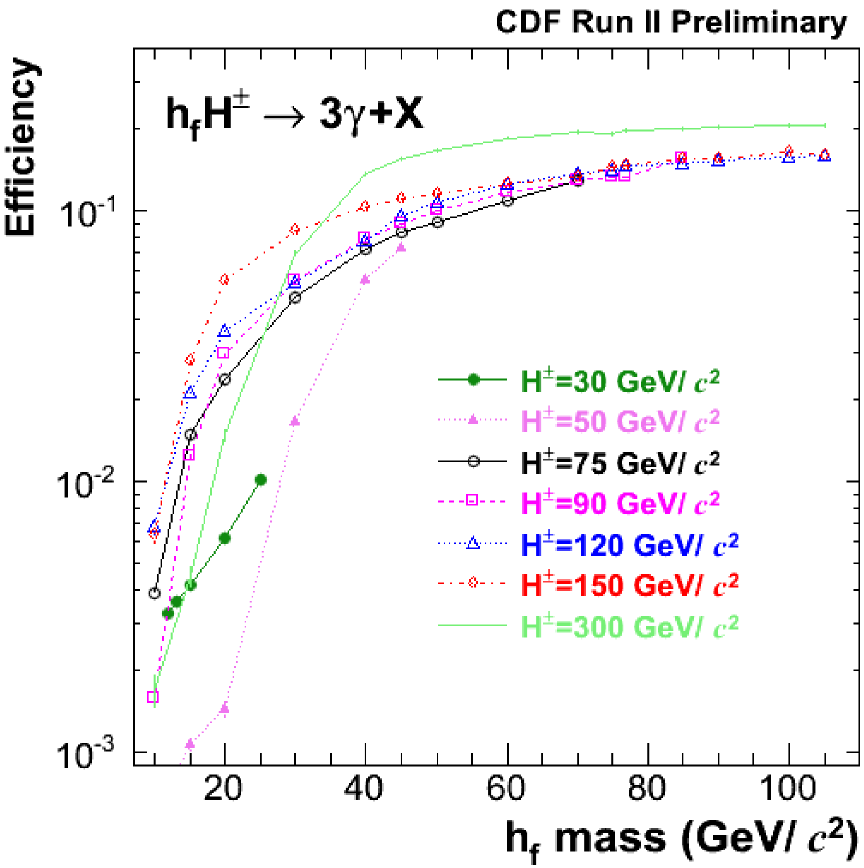
Search for Fermiophobic Higgs



- $qq' \to h_f H^{\pm} \to h_f (h_f W^{\pm}) \to (2\gamma)(2\gamma)+X$
- 2HDM (Type I)
  - H.E.Haber, G.L.Kane, and T.Sterling, Nucl. Phys. B161, 493 (1979)
- The h_f doesn't couple to fermions but only photon
- Four photons in the final state provide clean background for Higgs searching.
- Efficiency of finding four photons is too small. Looking for three photons instead.

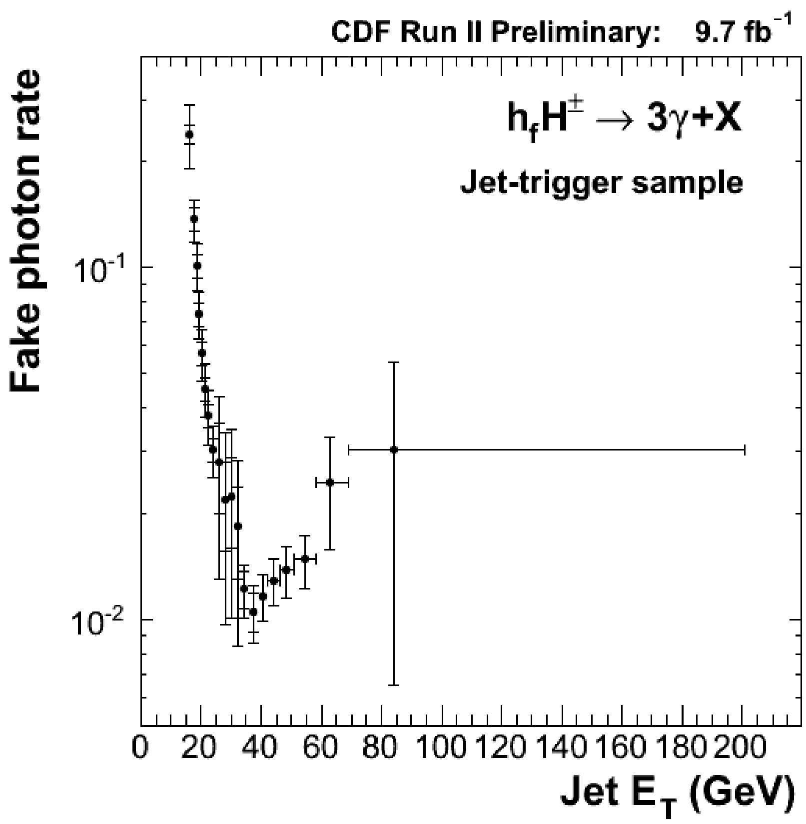
Event selection

- Diphoton triggers with $E_T > 12$ GeV
- Triphoton triggers with $E_T > 10$ GeV
- At least three photons with $E_T > 15$ GeV
- $|\eta| < 1.1$
- Isolation: no track associated
- Shower max rejection to reject π^0, η^0



- The efficiency of finding fermiophobic Higgs is mass dependent of course.
- For mass of h_f above 80 GeV/c^2 the efficiency is about 10%.

Backgrounds



- Finding fake photon rate is hard because real photon and neutral pion come into play.
- What definded here is the maximum fake rate.
- N_{fake} = 3.0 ± 0.2(stat) ± 1.2(sys)
- Direct 3γ events from quark anti-quark annihilation (LO), or quark gluon interaction (NLO)
- Electroweak processes, such as Z(ee)γ

Summary of background

$h_f H^\pm \to 3\gamma + X$	CDF Run II Preliminary: 9.2 fb^{-1}				
	Events ($E_T^{\gamma_1} + E_T^{\gamma_2} > 30$ GeV: control+signal regions)				
			(stat)		(syst)
Fake	3.0	$\pm$	0.2	$\pm$	1.2
Direct triphoton	6.9	$\pm$	0.1	$\pm$	2.4
Electroweak	0.4	$\pm$	0.1	$\pm$	0.3
Total	10.3	$\pm$	0.2	$\pm$	2.7
Data	10				

Systematic uncertainties

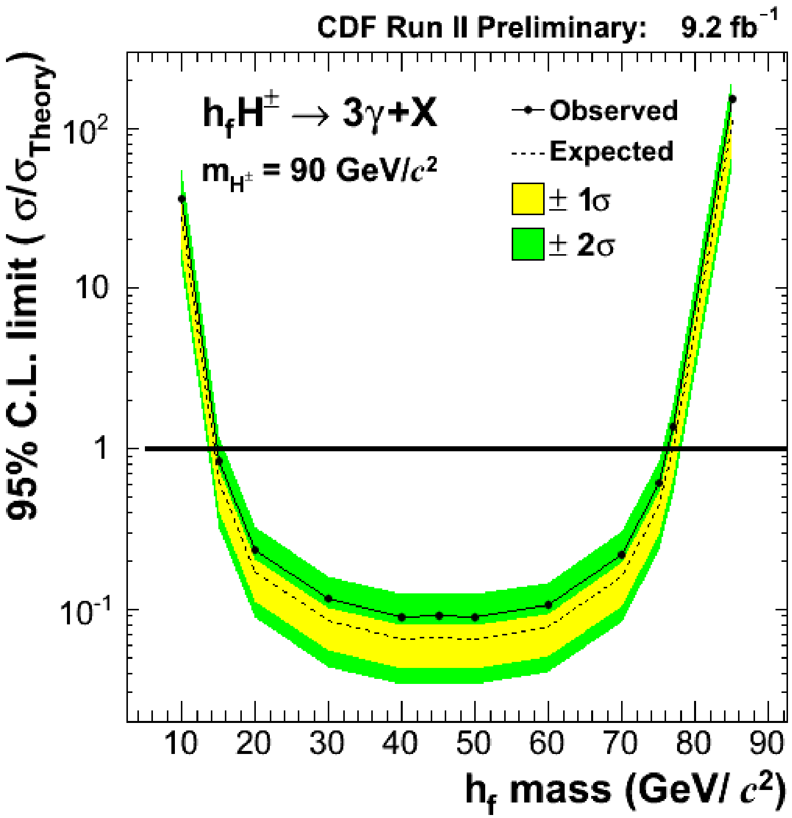
$h_f H^{\pm} \to 3\gamma + X$	CDF Run II Preliminary: 9.2 fb^{-1}			
Sources	Uncertainty (%)			
	Signal	Fakes	DTP	EWK
Photon selection	8	1	8	8
PDF	1	—	1	—
ISR/FSR	2	—	6	—
Fake rates	—	23	—	—
q/g composition	—	37	—	—
Parton-shower matching	—	—	1	—
Cross section	20	—	33	—
EWK normalization	—	—	—	70
Luminosity	6	—	6	6
Total	23	43	35	72

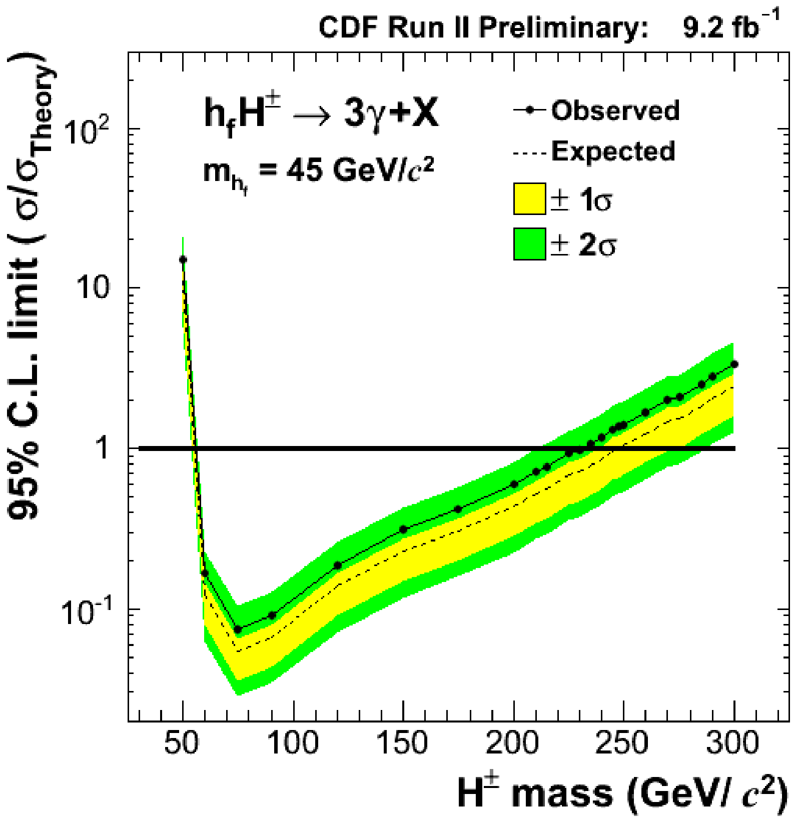
$h_f H^{\pm} \rightarrow 3\gamma + X$ CDF Run II Preliminary: 9.2 fb^{-1}

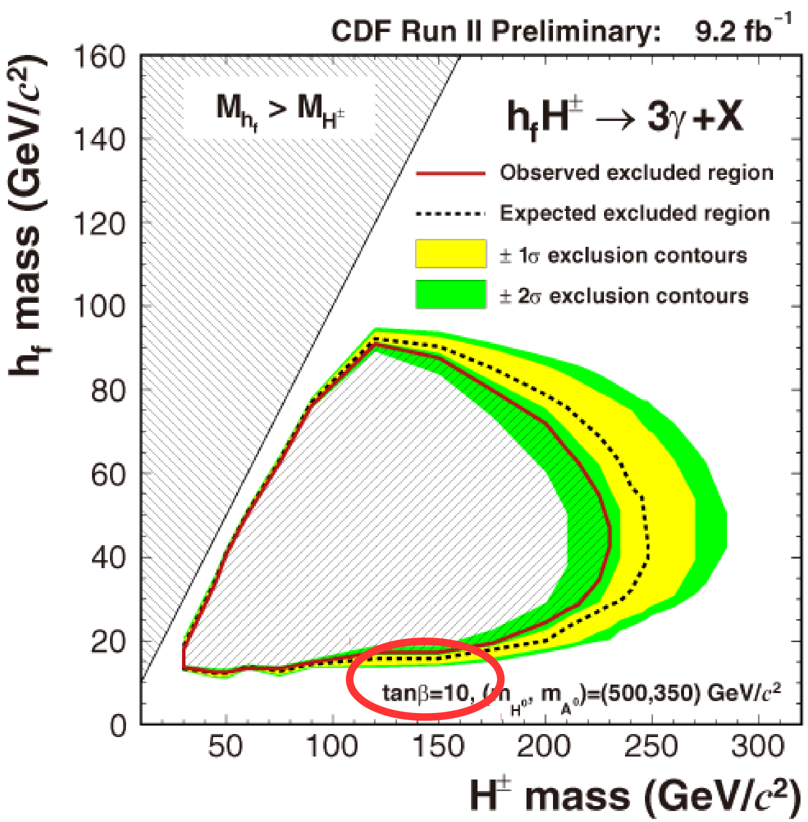
	Events ($E_T^{\gamma_1} + E_T^{\gamma_2} > 90$ GeV: signal region)				
			(stat)		(syst)
Fake	0.32	±	0.07	±	0.15
Direct triphoton	2.60	±	0.04	±	0.93
Electroweak	0.04	±	0.01	±	0.03
Total	2.96	±	0.08	±	0.94
Data	5				

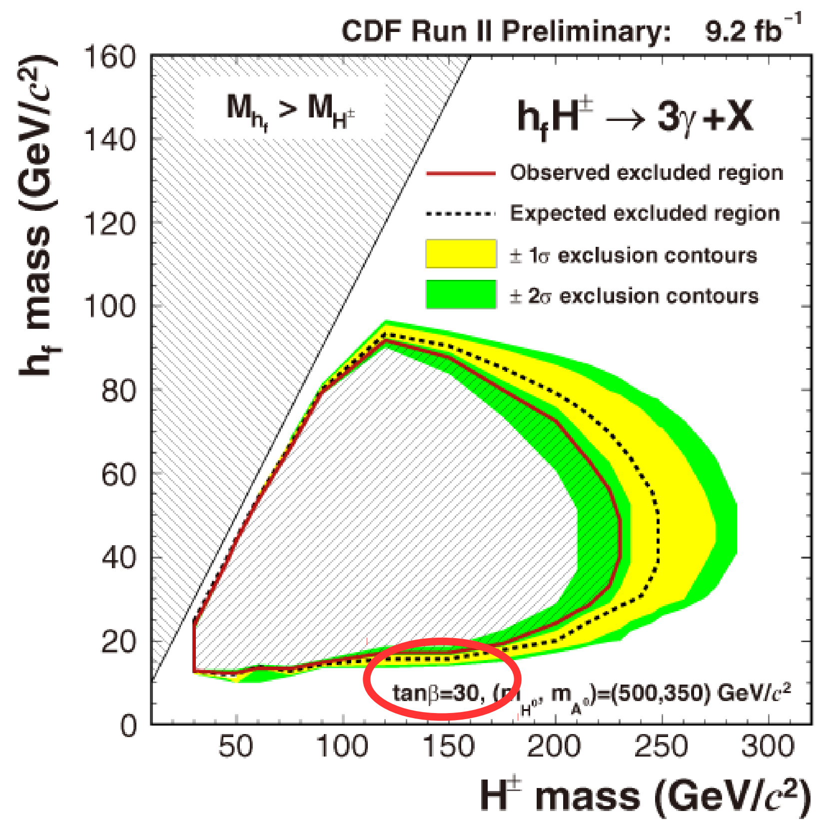
$h_f H^{\pm} \rightarrow 3\gamma + X$ CDF Run II Preliminary: 9.2 fb^{-1}

	Events (control region)				
			(stat)		(syst)
Fake	2.56	±	0.16	±	1.05
Direct triphoton	3.74	±	0.04	±	1.31
Electroweak	0.32	±	0.05	±	0.22
Total	6.62	±	0.17	±	1.69
Data	5				

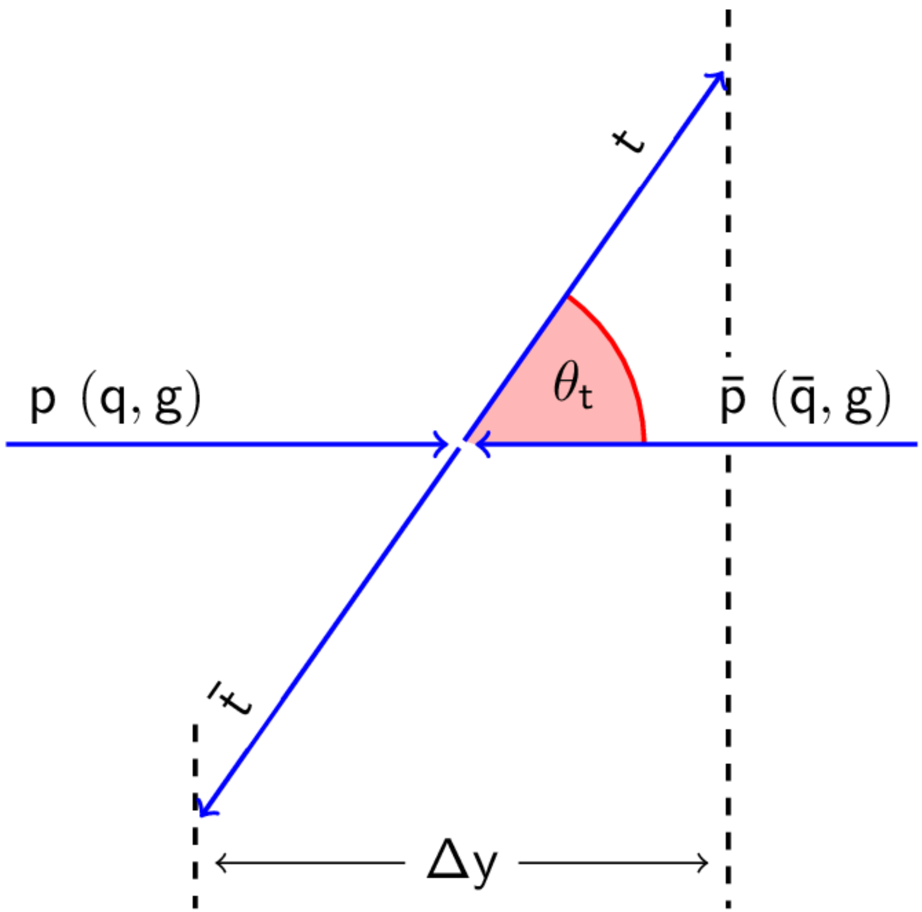

CDF Run II Preliminary: 9.2 fb^{-1}
$h_f H^{\pm} \rightarrow 3\gamma$+X
$m_{H^{\pm}}$ = 90 GeV/c^2
Observed
Expected
± 1σ
± 2σ
95% C.L. limit (σ/σ$_{Theory}$)
h_f mass (GeV/ c^2)


CDF Run II Preliminary: 9.2 fb^{-1}
$h_f H^{\pm} \rightarrow 3\gamma$+X
m_{h_f} = 45 GeV/c^2
Observed
Expected
± 1σ
± 2σ
95% C.L. limit (σ/σ$_{Theory}$)
$H^{\pm}$ mass (GeV/ c^2)


CDF Run II Preliminary: 9.2 fb^{-1}
$M_{h_f} > M_{H^\pm}$
$h_f H^\pm \rightarrow 3\gamma + X$
Observed excluded region
Expected excluded region
$\pm 1\sigma$ exclusion contours
$\pm 2\sigma$ exclusion contours
$\tan\beta$=10, (m_{H^0}, m_{A^0})=(500,350) GeV/c^2
h_f mass (GeV/c^2)
$H^\pm$ mass (GeV/c^2)
0
20
40
60
80
100
120
140
160
50
100
150
200
250
300

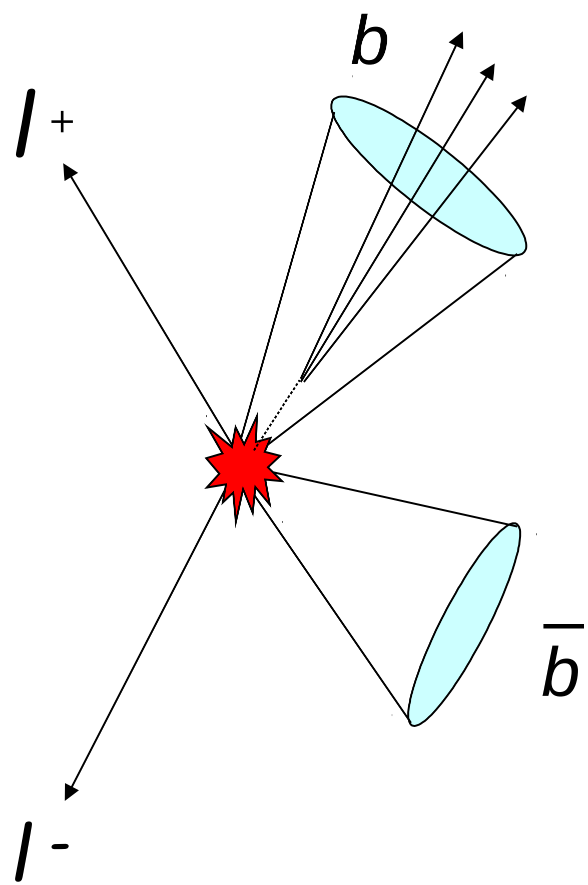

CDF Run II Preliminary: 9.2 fb^{-1}
$M_{h_f} > M_{H^\pm}$
$h_f H^\pm \rightarrow 3\gamma + X$
Observed excluded region
Expected excluded region
$\pm 1\sigma$ exclusion contours
$\pm 2\sigma$ exclusion contours
$\tan\beta$=30, (m_{H^0}, m_{A^0})=(500,350) GeV/c^2
h_f mass (GeV/c^2)
$H^\pm$ mass (GeV/c^2)
0
20
40
60
80
100
120
140
160
50
100
150
200
250
300

Top pair production asymmetry



- The asymmetry means top prefers to go along the direction of proton (quark), while anti-top prefers direction of anti-proton (anti-quark).
- In the SM the asymmetry arises in the NLO and higher order corrections.
- CDF and D0 first studied this asymmetry.
- ATLAS and CMS could observe this in the high |η| regions.

An update of the asymmetry based on di-lepton events from CDF



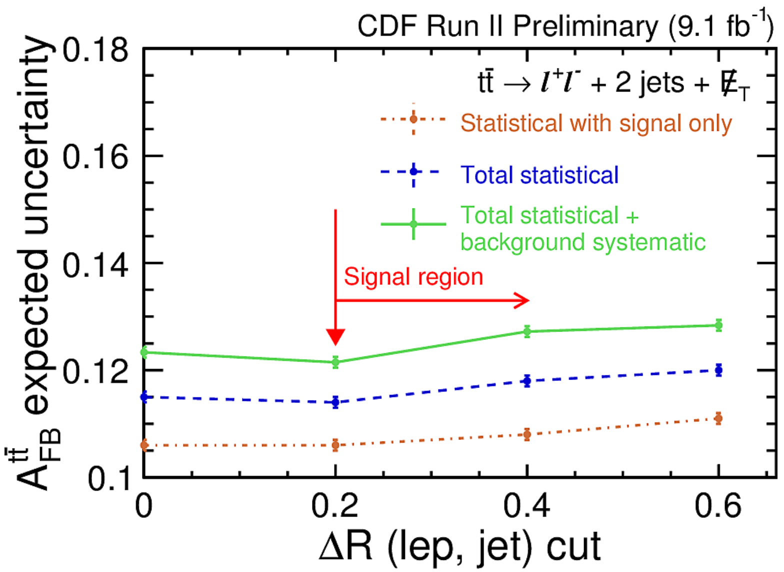
- Both W bosons from top and anti-top quarks decay into leptons plus neutrinos.
- The b quark and anti-b quark produce two jets.
- There are two netrinos missing in detection.
- Challenges in reconstruction
  - Identification of b jets.
  - Pairing of lepton and b jet.
  - Determination of neutrino energy.

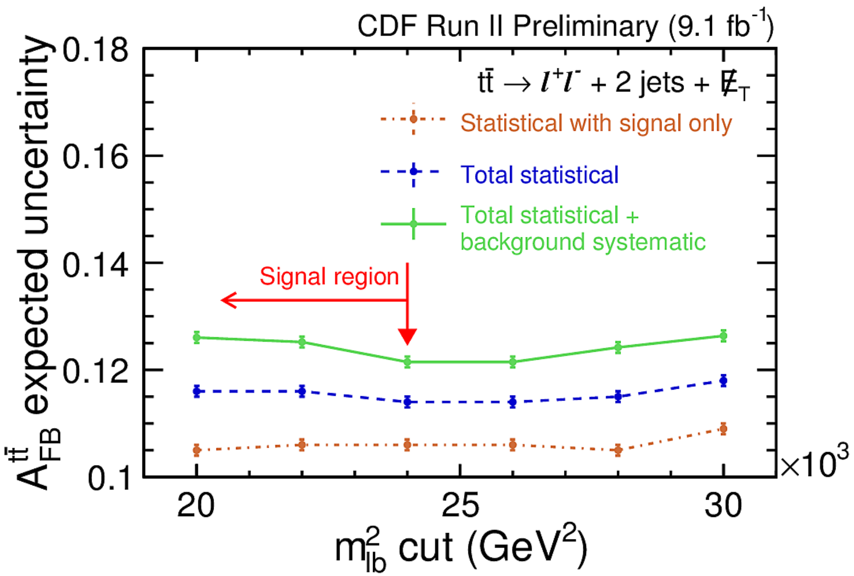
Event selection

CDF Run II Preliminary ($9.1\ fb^{-1}$)	
Expected and observed events ($t\bar{t} \rightarrow l^+l^- + 2\text{jets} + \not{E}_T$)	
Source	Events
Diboson	26 ± 5
Z/γ^*+jets	37 ± 4
W+jets	28 ± 9
$t\bar{t}$ non-dilepton	5.3 ± 0.3
Total background	96 ± 18
Signal $t\bar{t}$ ($\sigma = 7.4$ pb)	386 ± 18
Total SM expectation	482 ± 36
Observed	495

- Requires large missing energy: $E_T > 25$ GeV
- Two high p_T leptons,
- $p_T > 18$ GeV with $|\eta| < 2.5$
- At least two jets with $E_T > 15$ GeV
- $H_T > 200$ GeV
- Optimization of cuts

Examples of optimization

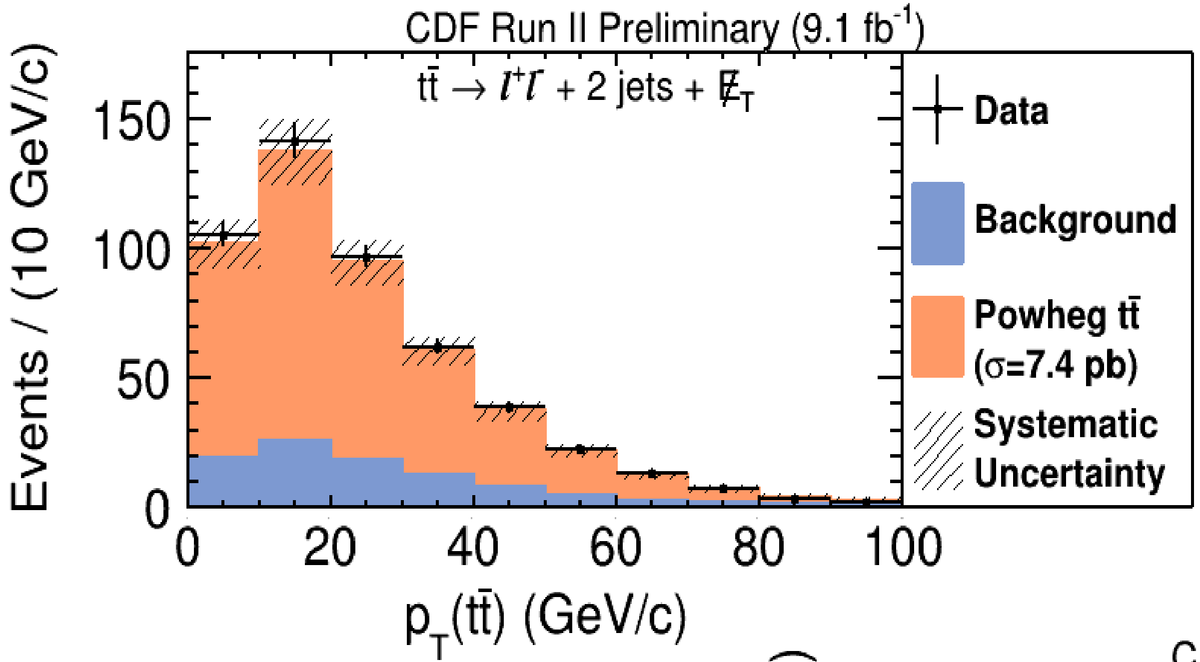


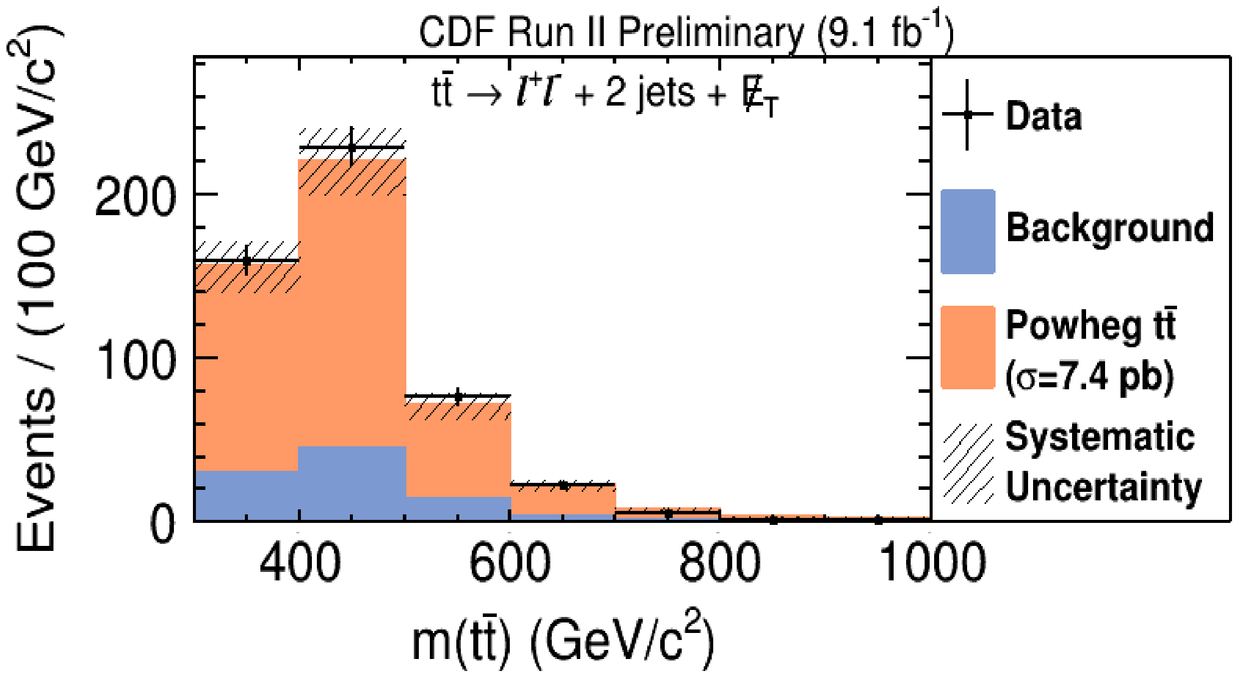


Top reconstruction

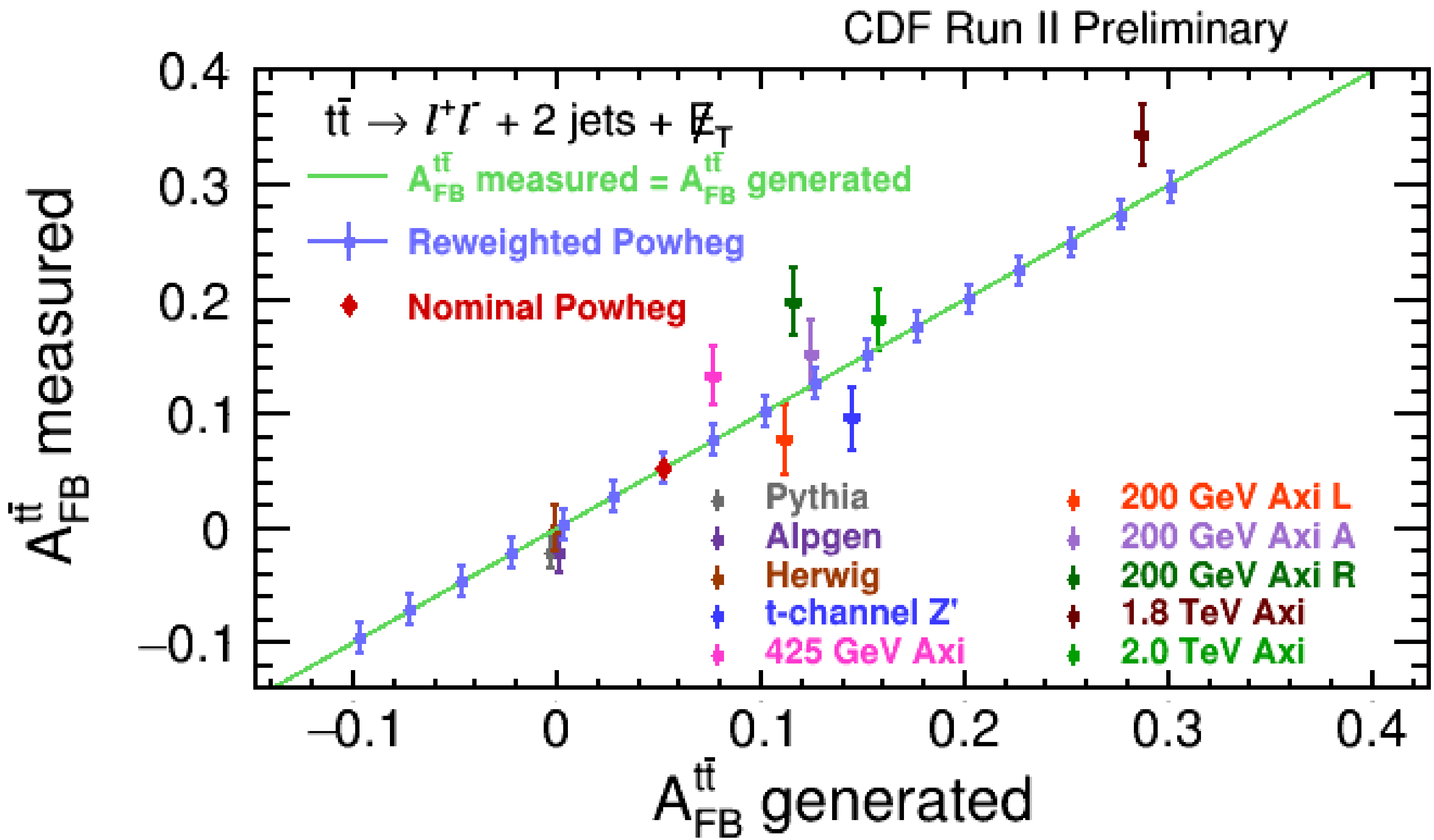
$$
\begin{aligned}
(W_1 + b_1)^2 - M_t^2 &= 0 \\
W_1^2 - M_w^2 &= 0 \\
l_1 + \nu_1 &= W_1 \\
(W_2 + b_2)^2 - M_t^2 &= 0 \\
W_2^2 - M_w^2 &= 0 \\
l_2 + \nu_2 &= W_2 \\
\vec{\nu}_{1t} + \vec{\nu}_{2t} &= \not{E}_T
\end{aligned}
$$

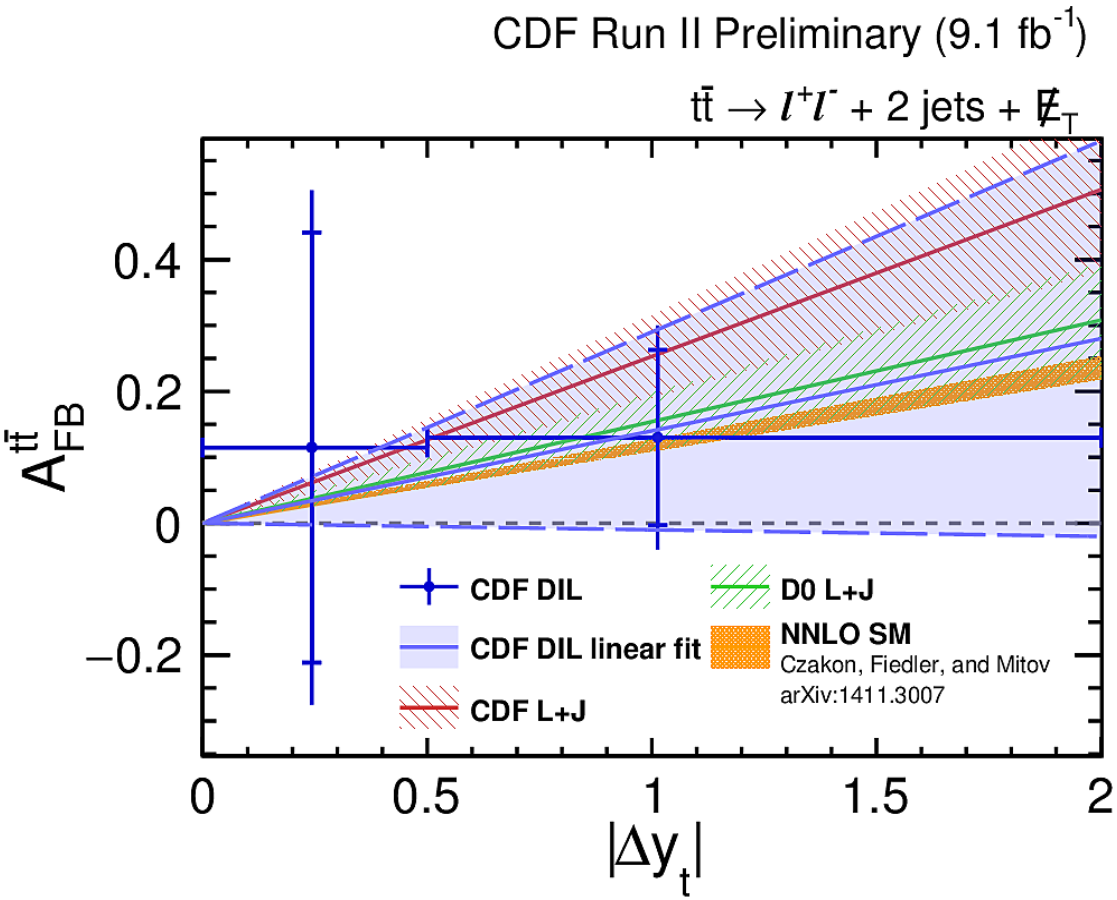
- Resolve the full set of energy momemtum conservation.
- Take into account the known masses of W boson and top quark.
- Try both combinations of lepton jet pairing.


CDF Run II Preliminary (9.1 fb-1)
tt̄ → l+l- + 2 jets + E̸T
Data
Background
Powheg tt̄
(σ=7.4 pb)
Systematic
Uncertainty
Events / (10 GeV/c)
150
100
50
0
0
20
40
60
80
100
pT(tt̄) (GeV/c)


CDF Run II Preliminary (9.1 fb-1)
tt̄ → l+l- + 2 jets + E̸T
Data
Background
Powheg tt̄
(σ=7.4 pb)
Systematic
Uncertainty
Events / (100 GeV/c2)
200
100
0
400
600
800
1000
m(tt̄) (GeV/c2)

Reconstructed asymmetry





$$A_{\mathrm{FB}}^{t\bar{t}}(|\Delta y_t| < 0.5) = 0.12 \pm 0.33(\mathrm{stat.}) \pm 0.20(\mathrm{syst.})$$
$$= 0.12 \pm 0.39$$
$$A_{\mathrm{FB}}^{t\bar{t}}(|\Delta y_t| > 0.5) = 0.13 \pm 0.13(\mathrm{stat.}) \pm 0.11(\mathrm{syst.})$$
$$= 0.13 \pm 0.17$$

CDF Run II Preliminary (9.1 fb^{-1})

($t\bar{t} \rightarrow l^+l^- + 2\text{jets} + \not{E}_T$)

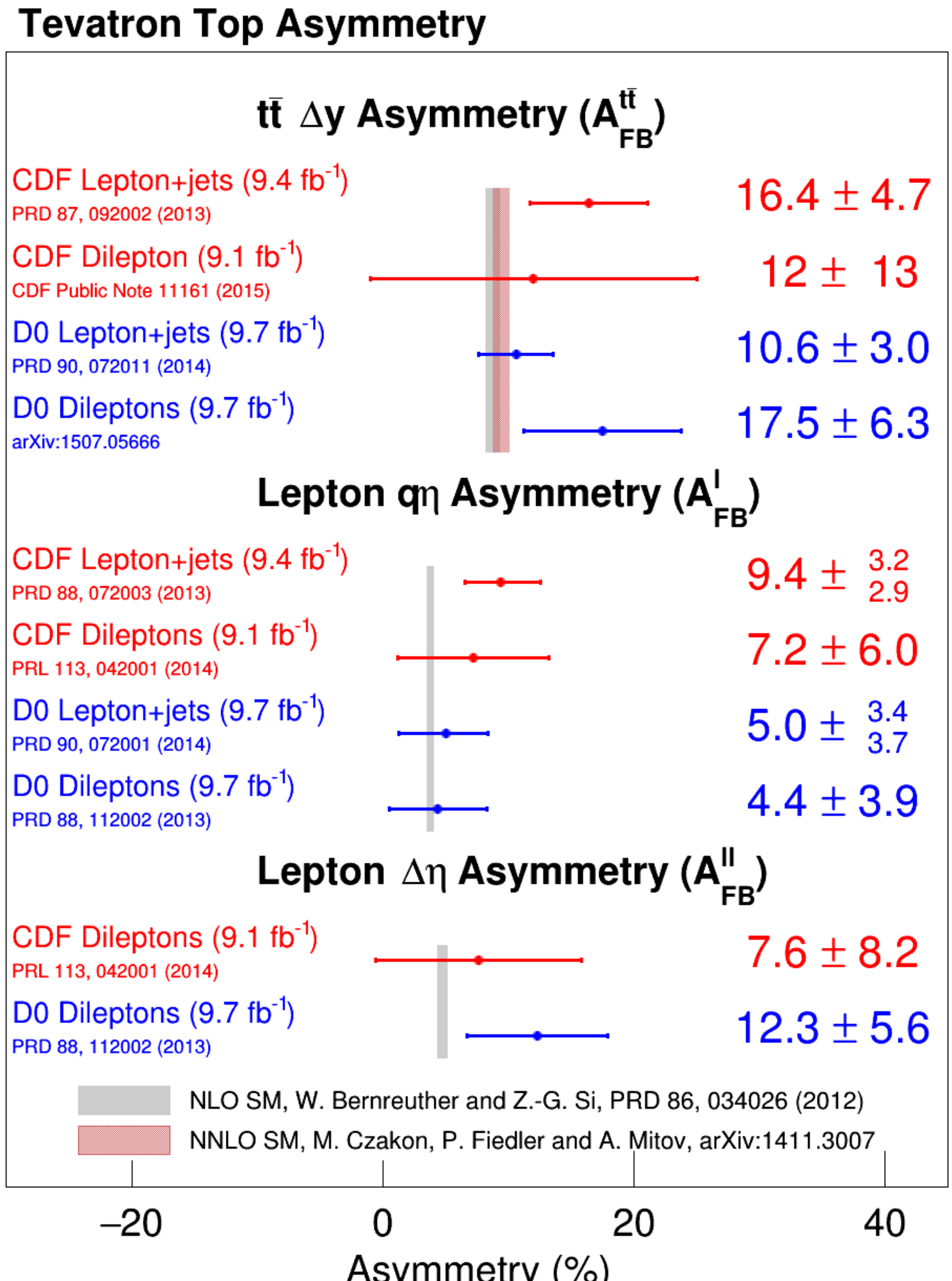
Source of uncertainty	$A_{FB}^{tt}(\lvert\Delta y\rvert < 0.5)$	$A_{FB}^{tt}(\lvert\Delta y\rvert > 0.5)$
Statistical	0.33	0.13
Background	0.13	0.06
Parton Showering	0.07	0.06
Color reconnection	0.12	0.06
I/FSR	0.05	0.03
JES	0.02	0.02
Unfolding	0.06	0.02
PDF	0.01	0.01
Total systematic	0.20	0.11
Total uncertainty	0.39	0.17

$$A_{\mathrm{FB}}^{t\bar{t}} = 0.12 \pm 0.11(\mathrm{stat.}) \pm 0.07(\mathrm{syst.})$$

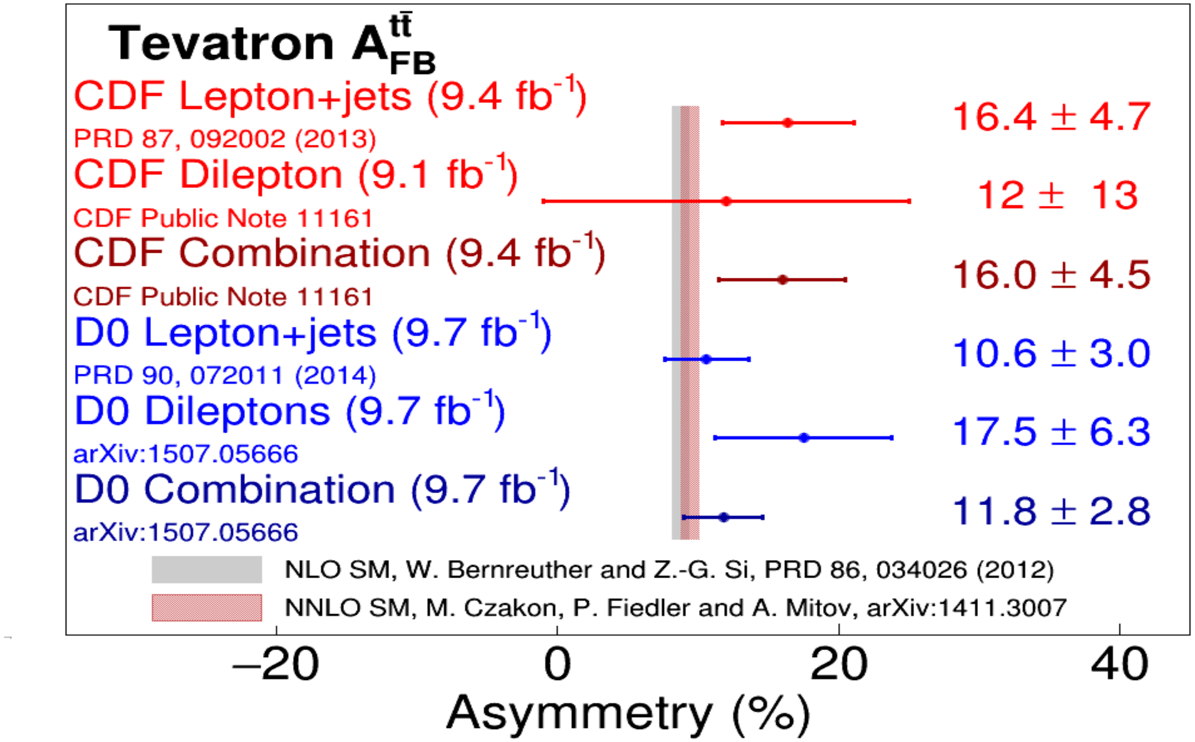
$$A_{\mathrm{FB}}^{t\bar{t}} = 0.12 \pm 0.13$$

CDF Run II Preliminary (9.1 fb^{-1})
($t\bar{t} \rightarrow l^+l^- + 2\mathrm{jets} + \not{E}_T$)

Source of uncertainty $A_{\mathrm{FB}}^{t\bar{t}}$	Value
Statistical	0.11
Background	0.04
Parton Showering	0.03
Color reconnection	0.03
I/FSR	0.03
JES	0.02
Unfolding	0.02
PDF	0.01
Total systematic	0.07
Total uncertainty	0.13



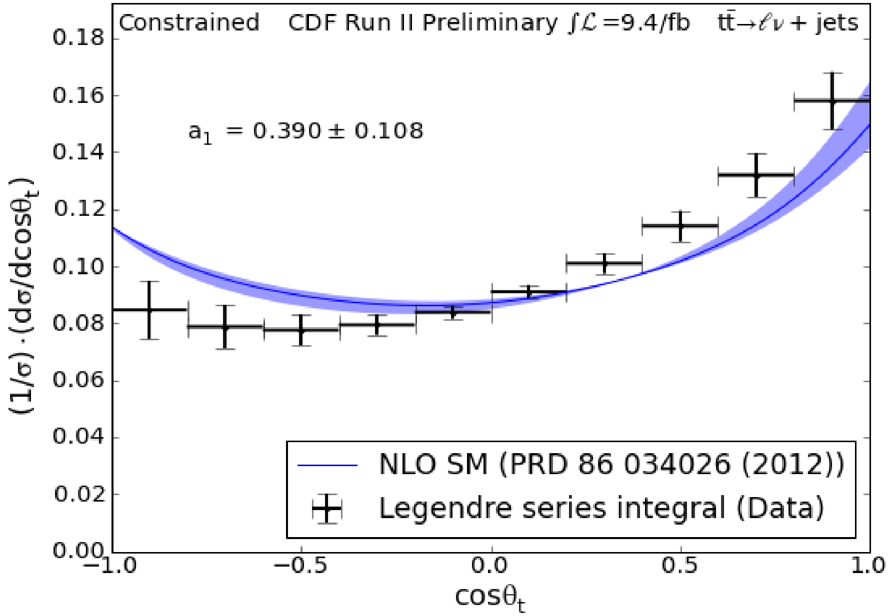
Tevatron Top Asymmetry
$t\bar{t}$ Δy Asymmetry ($A_{FB}^{t\bar{t}}$)
CDF Lepton+jets (9.4 fb^{-1})
PRD 87, 092002 (2013)
16.4 ± 4.7
CDF Dilepton (9.1 fb^{-1})
CDF Public Note 11161 (2015)
12 ± 13
D0 Lepton+jets (9.7 fb^{-1})
PRD 90, 072011 (2014)
10.6 ± 3.0
D0 Dileptons (9.7 fb^{-1})
arXiv:1507.05666
17.5 ± 6.3
Lepton $q\eta$ Asymmetry (A_{FB}^{l})
CDF Lepton+jets (9.4 fb^{-1})
PRD 88, 072003 (2013)
$9.4 \pm^{3.2}_{2.9}$
CDF Dileptons (9.1 fb^{-1})
PRL 113, 042001 (2014)
7.2 ± 6.0
D0 Lepton+jets (9.7 fb^{-1})
PRD 90, 072001 (2014)
$5.0 \pm^{3.4}_{3.7}$
D0 Dileptons (9.7 fb^{-1})
PRD 88, 112002 (2013)
4.4 ± 3.9
Lepton $\Delta\eta$ Asymmetry (A_{FB}^{ll})
CDF Dileptons (9.1 fb^{-1})
PRL 113, 042001 (2014)
7.6 ± 8.2
D0 Dileptons (9.7 fb^{-1})
PRD 88, 112002 (2013)
12.3 ± 5.6
NLO SM, W. Bernreuther and Z.-G. Si, PRD 86, 034026 (2012)
NNLO SM, M. Czakon, P. Fiedler and A. Mitov, arXiv:1411.3007
−20
0
20
40
Asymmetry (%)

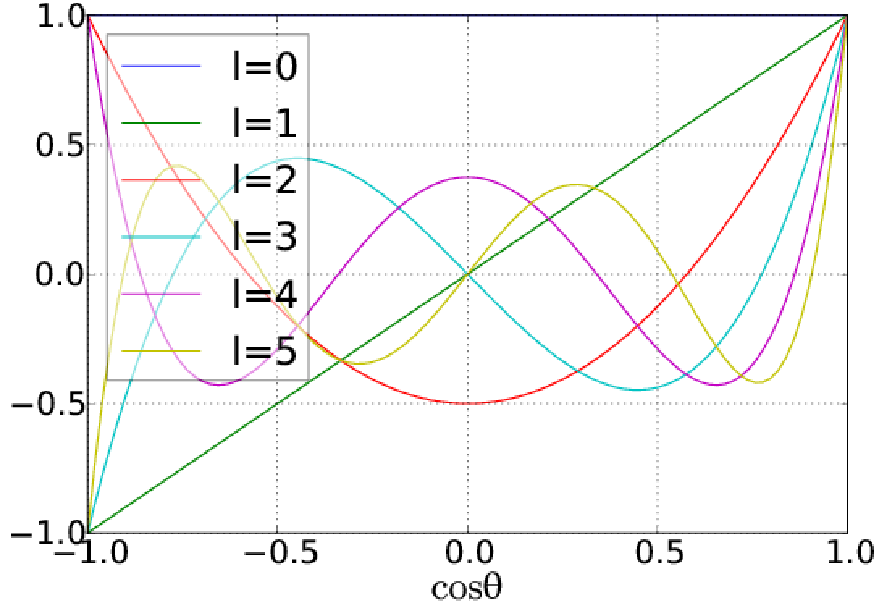


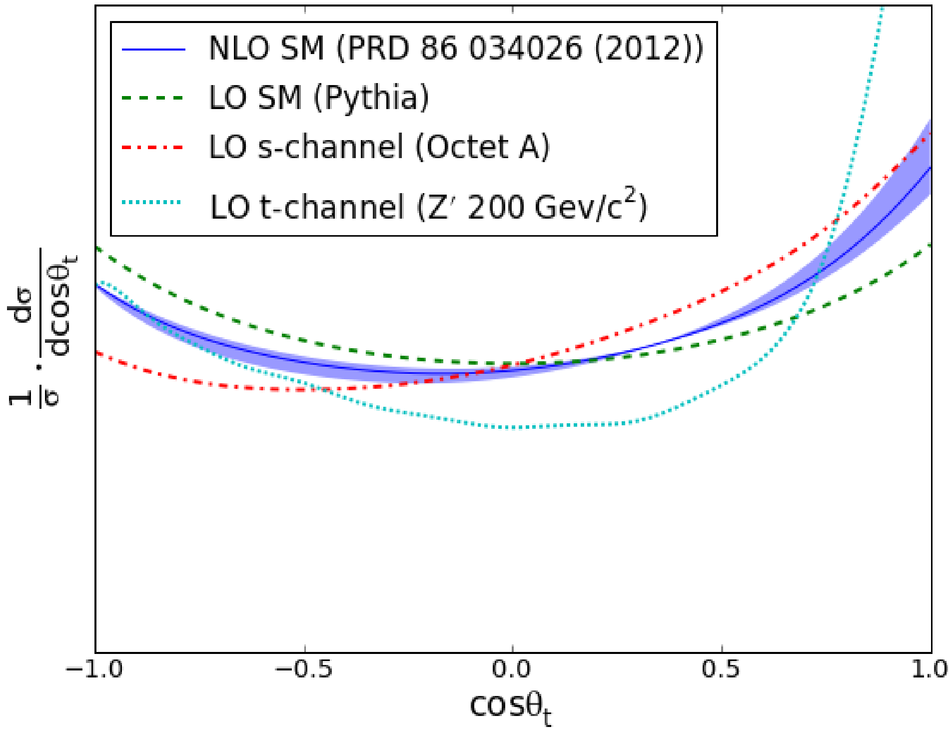
CDF Run II Preliminary

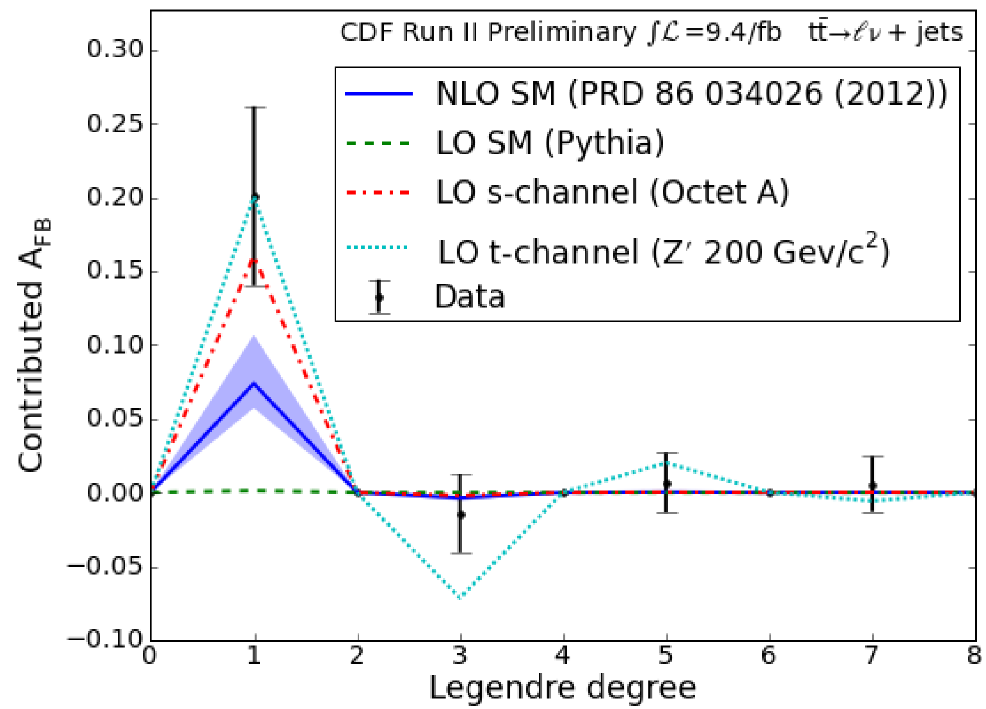
Source of uncertainty	L+J (9.4 fb^{-1})	DIL (9.1 fb^{-1})	Correlation
Background shape	0.018	0.04	0
Background normalization	0.013		
Parton shower	0.01	0.03	1
Jet energy scale	0.007	0.02	1
Inital- and final-state radiation	0.005	0.03	1
Correction procedure	0.004	0.02	0
Color reconnection	0.001	0.03	1
Partion-distribution functions	0.001	0.01	1
Total systematic	0.026	0.07	
Statistical	0.039	0.11	0
Total uncertainty	0.047	0.13	

Top asymmetry and FCNC









- Although Z' modle provides larger asymmetry, it deviates from data in the higher degree of Legendre polinomials.

Thanks!

Sea quark PDF asymmetry