Search for P-violating Term in $t\bar{t}$ Production with CDF Experiment at Tevatron

HOU Final Report Session, FNAL
Mar 19th 2012 Mon. 21:00(CDT) -

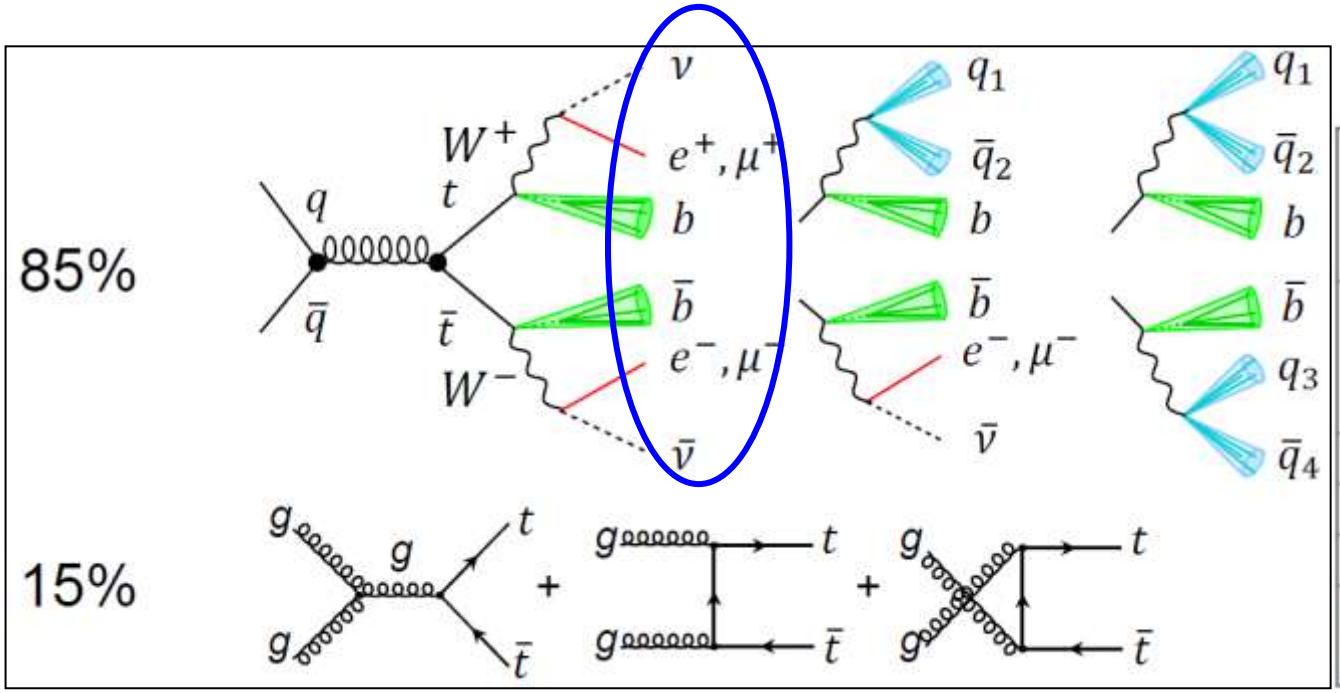
Kazuya MOCHIZUKI, Shinhong KIM,
Ken-ichi TAKEMASA, Yuji TAKEUCHI
Graduate School of Pure and Applied Sciences
University of Tsukuba

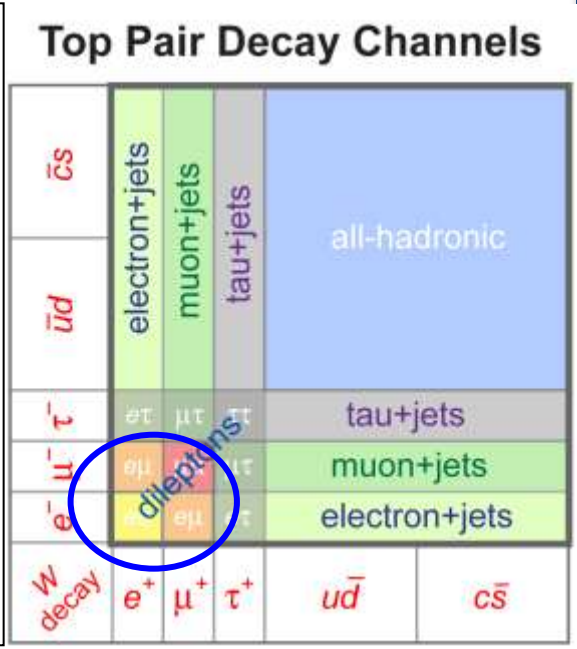
Contents

- Top quark and top pair production
- Spin correlation in top pair production and decay
- Motivation
- Fitting method
- 2x2 method
- Summary
- Appendix

Top Quark Pair Production

- Top quark
  - 3rd Generation, up type
  - $m_t \sim 173$ GeV
  - decays before hadronization
  - $\sim 100\%$ $t \rightarrow Wb$

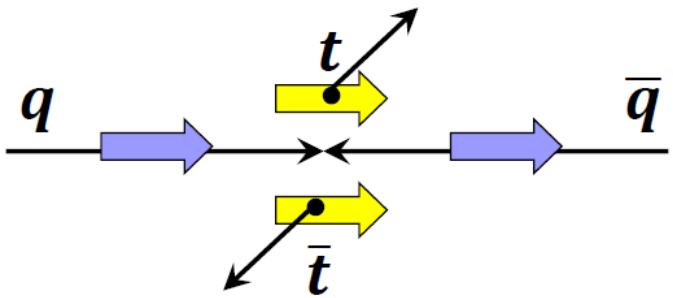


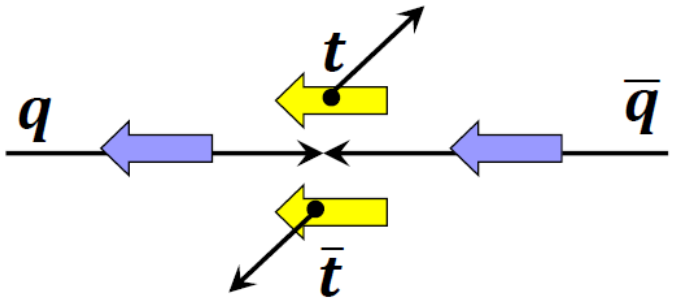


Spin Correlation in $t\bar{t}$

- Top and anti-top spins are correlated at production
- Top quark decays before losing polarization

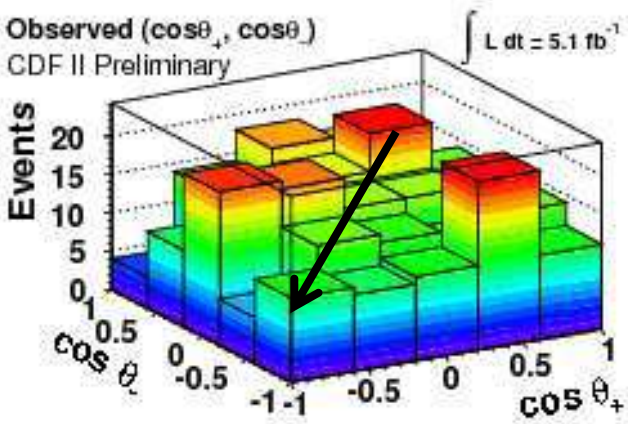
$q\bar{q} \rightarrow t\bar{t}$ (near threshold): Conservation of angular momentum

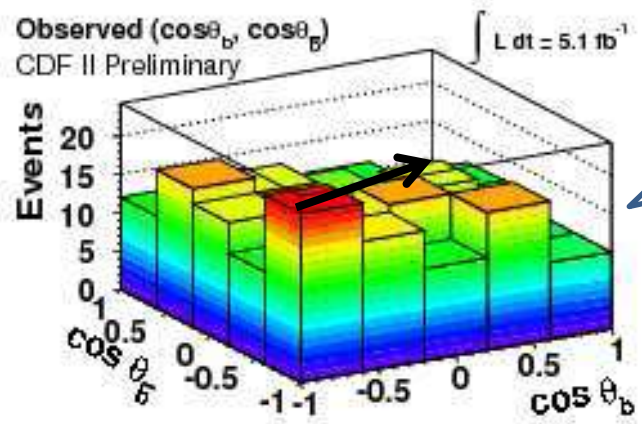




2-D Angular Distributions from Spin Correlation Analysis

Results from 5.1 fb-1

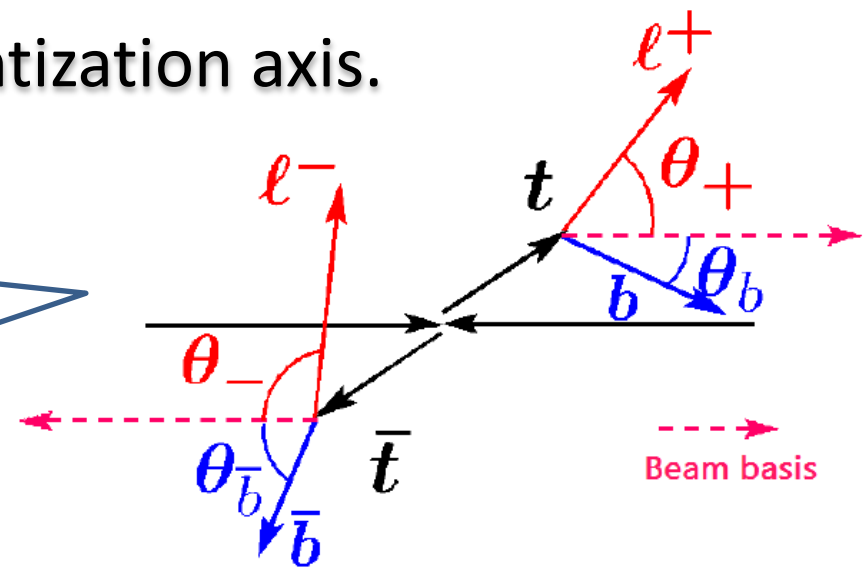




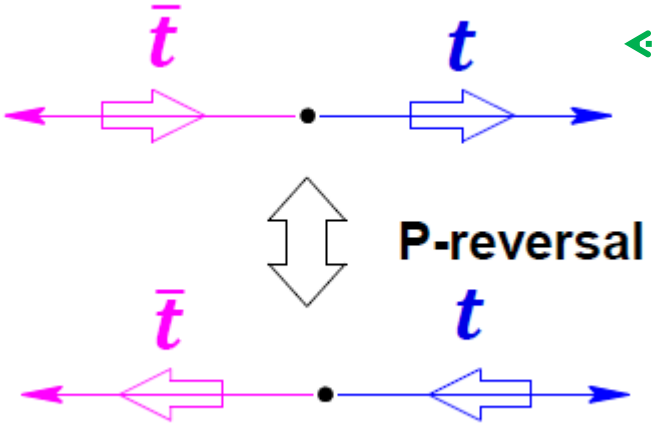
Look slope?
f(-1,-1) > f(1,1)

Take the beam axis as a quantization axis.

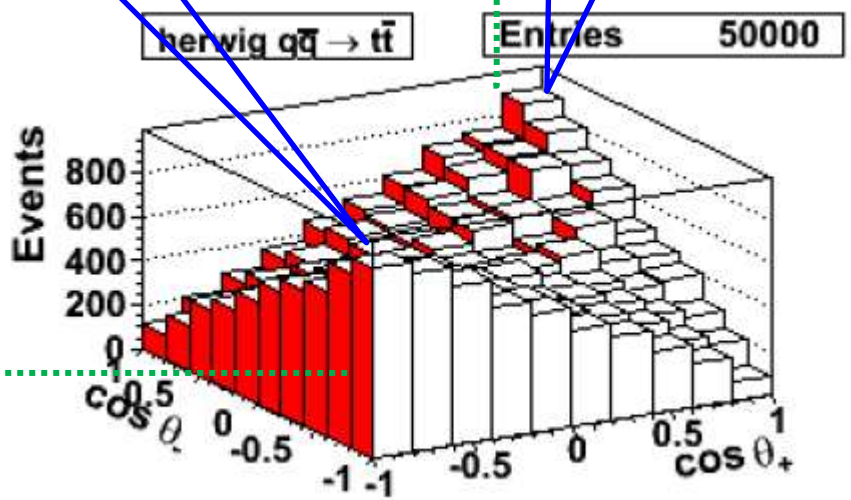
The directions of leptons b-jets are tend to be opposite



Motivation

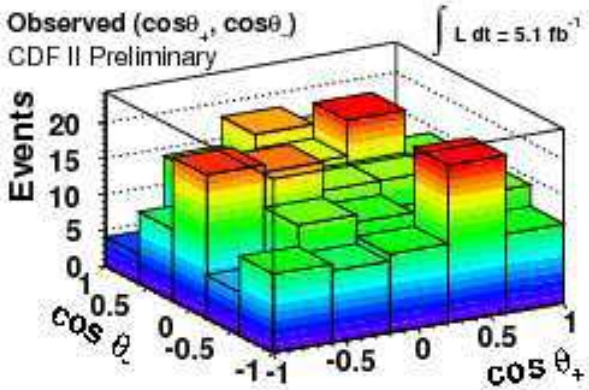


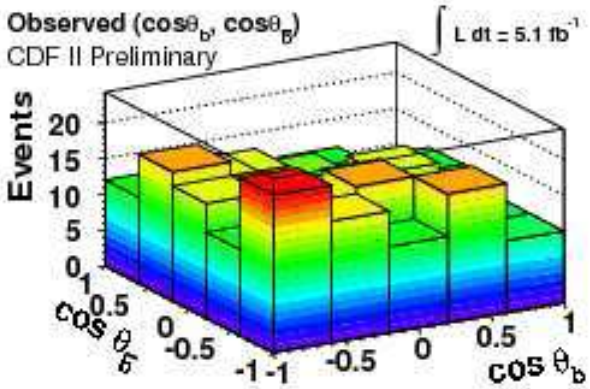
$N(\uparrow\downarrow) \neq N(\downarrow\uparrow)$ means Parity violation



Fitting Method

- Results from 5.1 fb-1



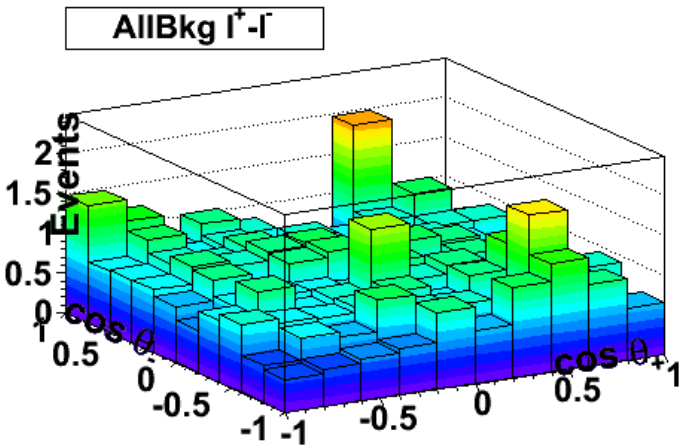


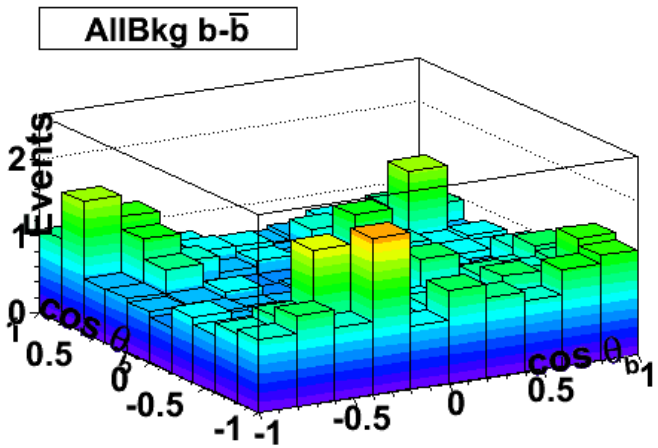
- Fit the distributions above to the function including P-violating term

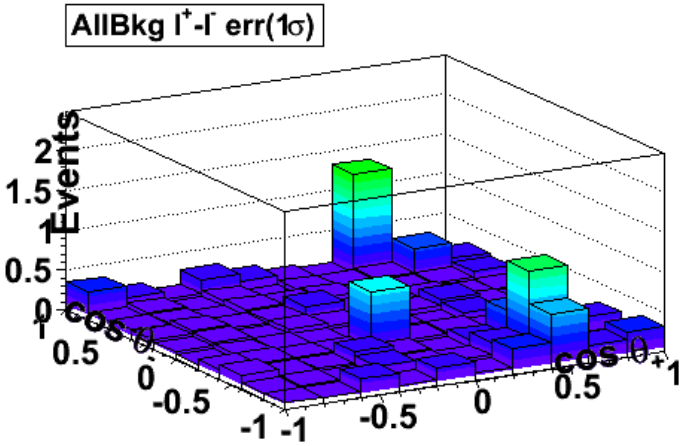
$$f(x,y) = \frac{C_0}{4}\Big[1 - C_1 - C_3 - C_5 + 3C_1\frac{x^2+y^2}{2} + C_2 xy + 5C_3\frac{x^4+y^4}{2} + C_4\frac{x^3y+xy^3}{2} + 9C_5x^2y^2 + P_0\frac{x+y}{2} + \cancel{P_0\frac{x+y}{2}P_1(x^2+xy+y^2)} + \cancel{P_0\frac{x+y}{2}P_2xy}\Big]$$

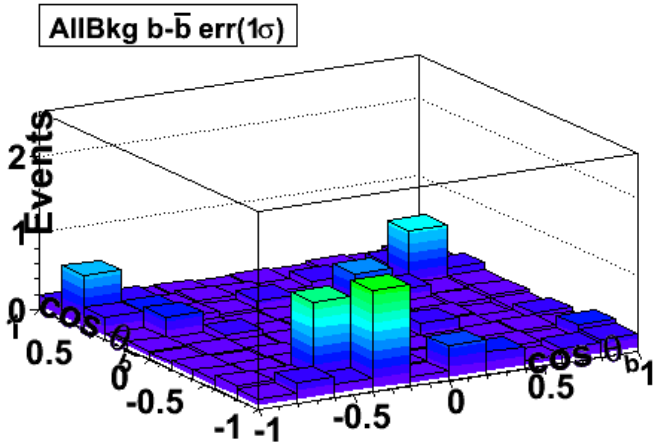
BG expectation

- 5.1 fb-1



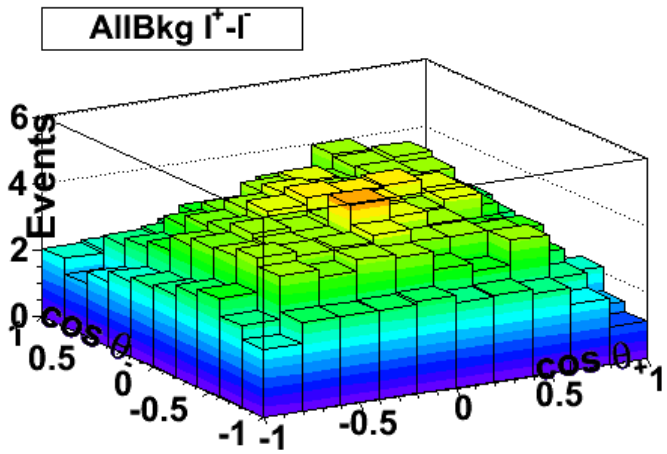


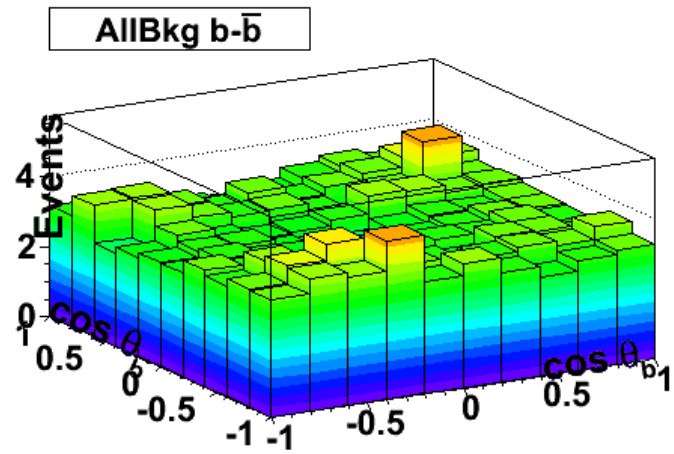


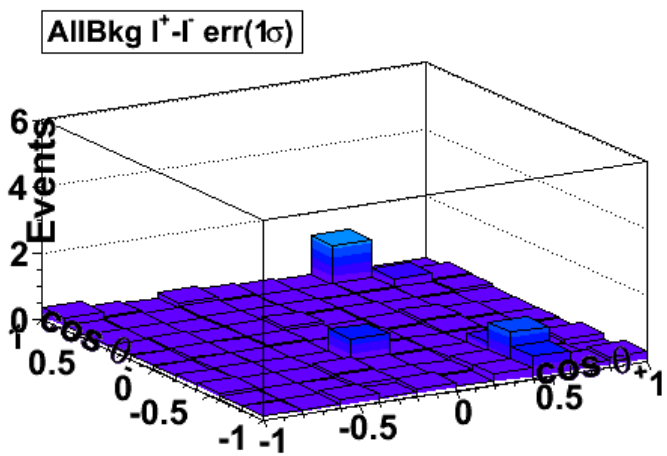


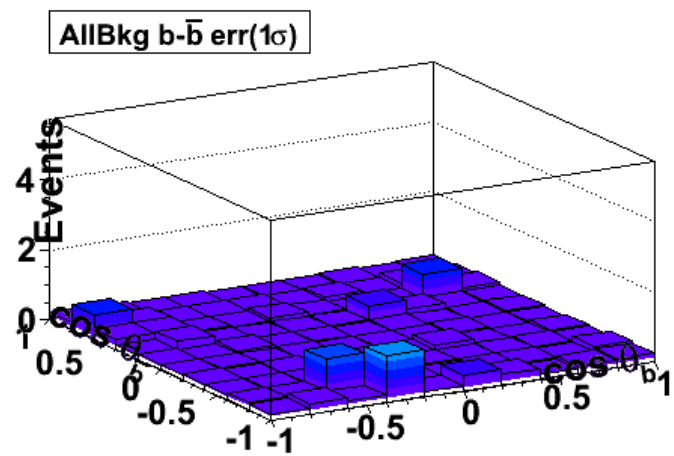
Signal (Herwig) + BG expectation

- 5.1fb-1



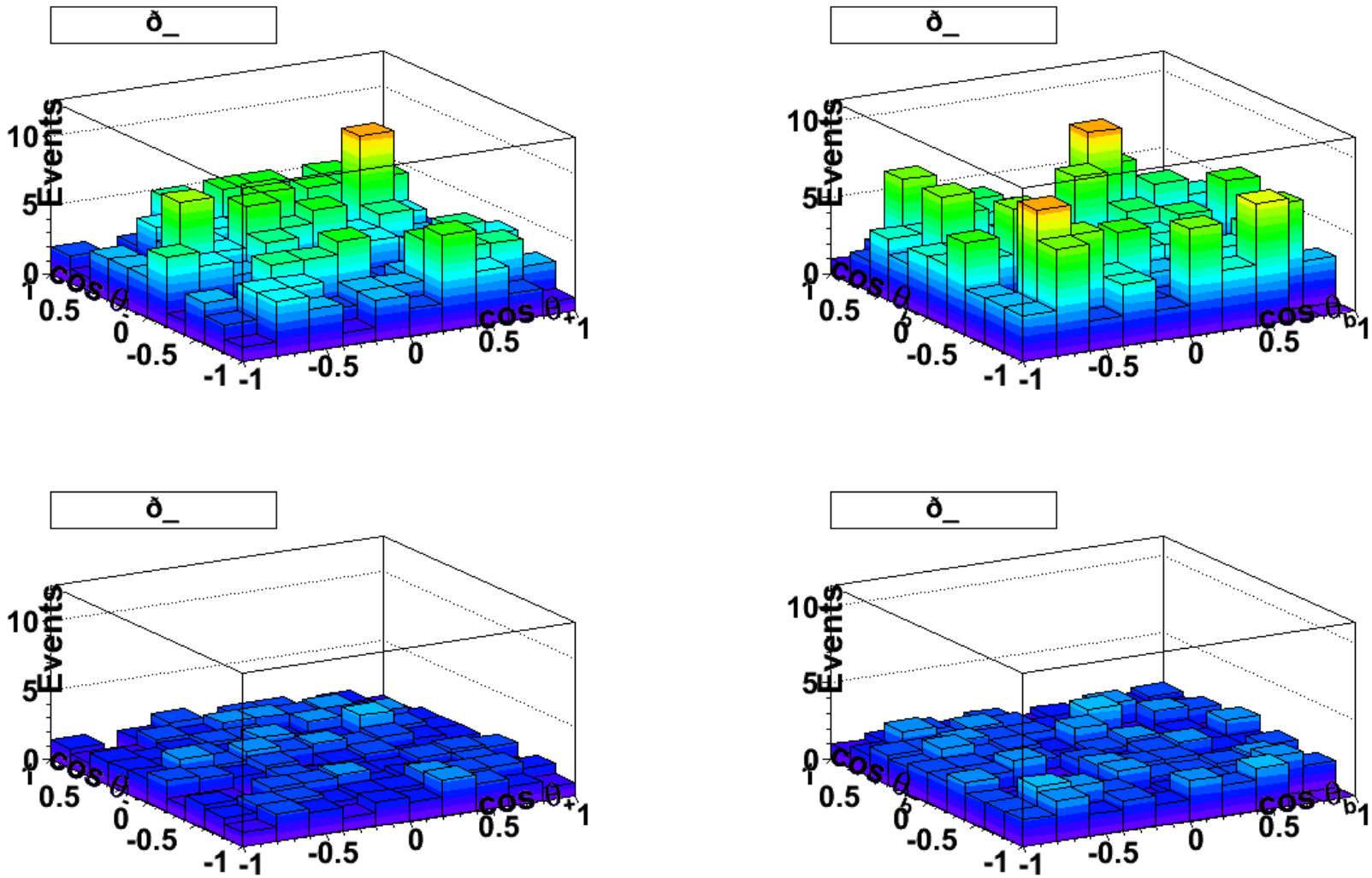






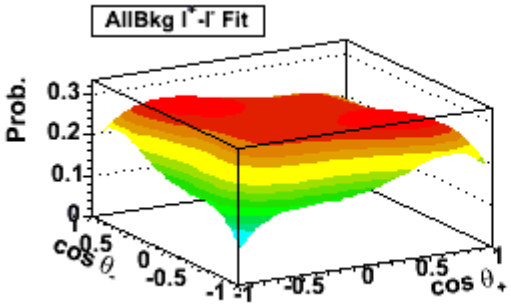
Observed data

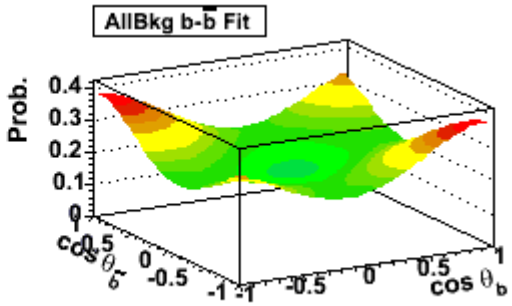
- 5.1 fb-1



Fitting results w/o P-violating term

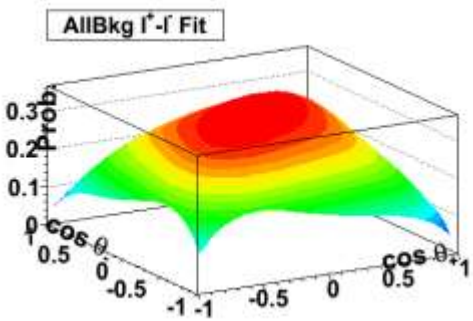
- Estimated BG

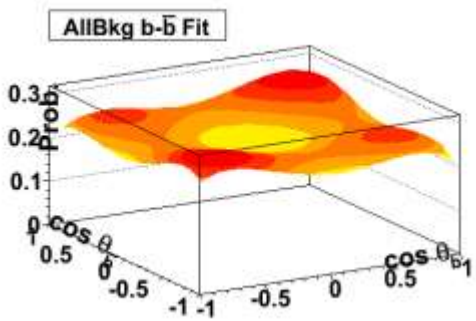




l	Value	Error
C1	0.119	0.116
C2	-0.262	0.194
C3	-0.272	0.0721
C4	0.0196	0.327
C5	-0.0381	0.0221

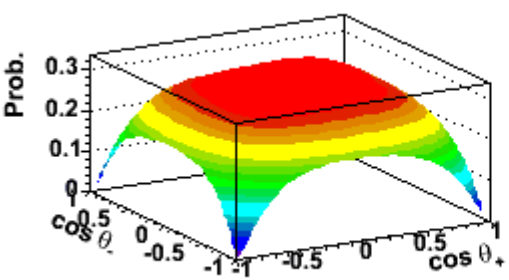
- Estimated Sig+BG

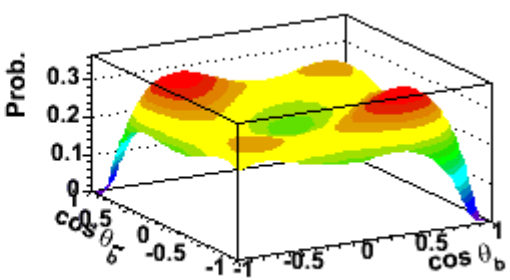




l	Value	Error
C1	-0.167	0.0407
C2	0.547	0.0649
C3	-0.223	0.0252
C4	-0.467	0.106
C5	0.0517	0.00739

- Observed data

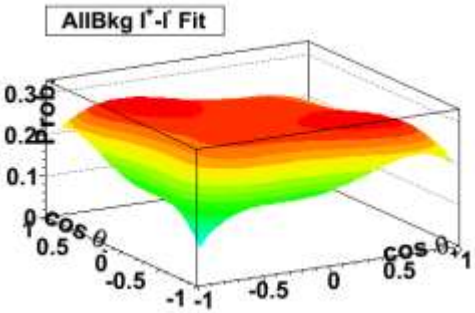


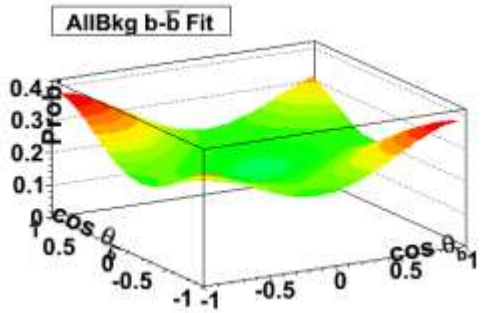


l	Value	Error
C1	0.141	0.357
C2	0.138	0.523
C3	-0.268	0.233
C4	-0.214	0.758
C5	-0.0529	0.0601

Fitting w/ P-violating term for leptons

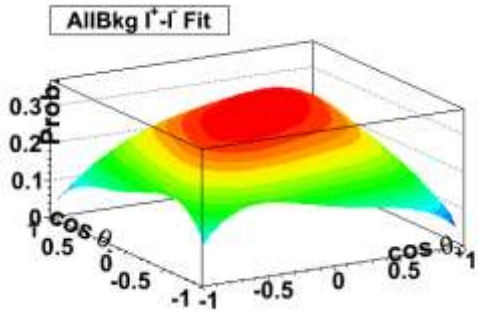
- Estimated BG

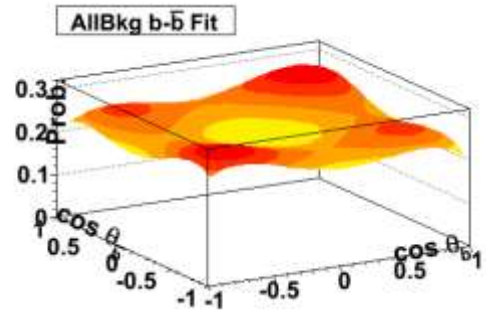




l	Value	Error
C1	0.116	0.0260
C2	-0.271	0.0474
C3	-0.271	0.0183
C4	0.0251	0.0756
C5	0.0380	0.0106
P0	-0.0286	0.0363

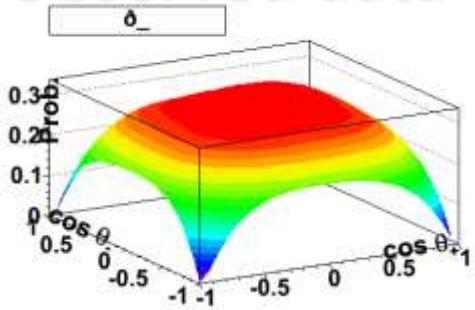
- Estimated Sig+BG

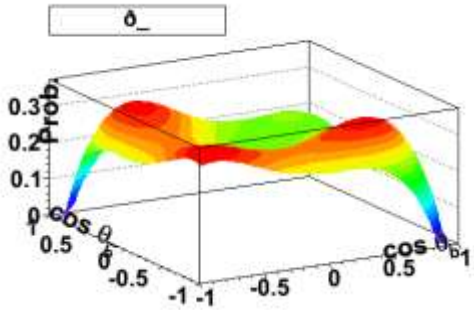




l	Value	Error
C1	-0.169	0.0390
C2	0.542	0.0624
C3	-0.222	0.0242
C4	-0.464	0.102
C5	0.0513	0.00725
P0	-0.0256	0.0127

- Observed data



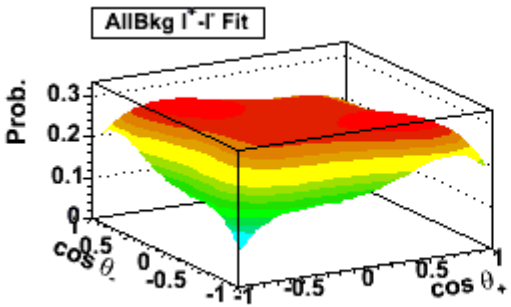


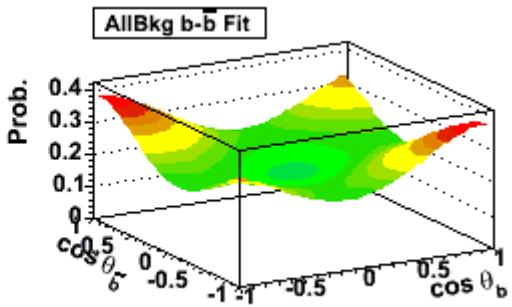
l	Value	Error
C1	0.140	0.353
C2	0.130	0.531
C3	-0.266	0.0230
C4	-0.200	0.0773
C5	-0.0530	0.0606
P0	0.0295	0.118

$P_0 \sim 0$ consistent

Fitting results w/o P-violating term

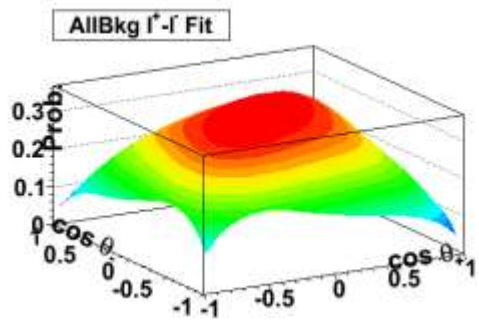
- Estimated BG

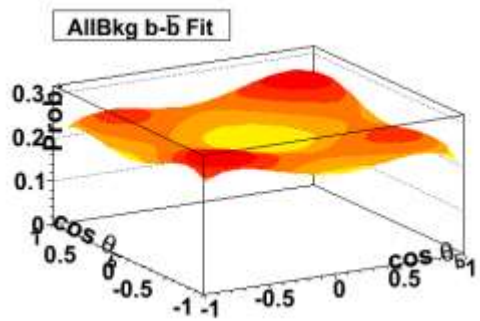




b	Value	Error
C1	0.404	0.109
C2	-0.481	0.195
C3	-0.203	0.0731
C4	0.397	0.343
C5	0.0564	0.0234

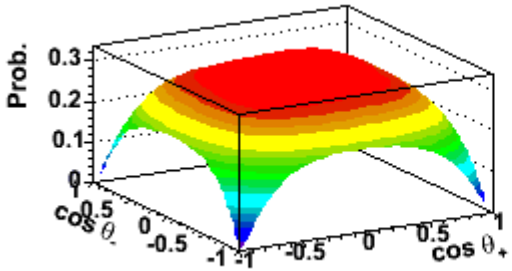
- Estimated Sig+BG

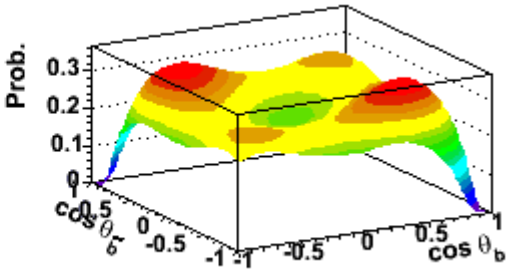




b	Value	Error
C1	0.324	0.0383
C2	0.0878	0.0656
C3	-0.192	0.0256
C4	-0.004	0.110
C5	-0.001	0.008

- Observed data

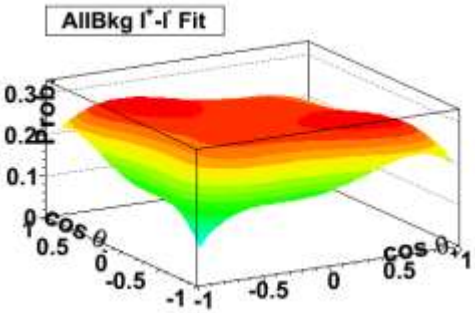


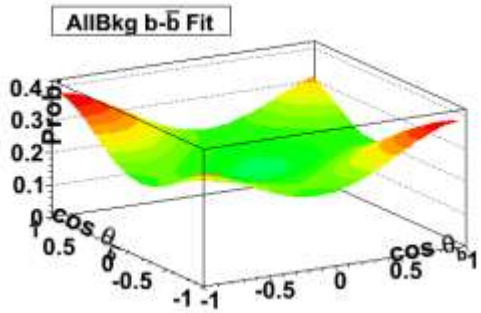


b	Value	Error
C1	0.702	0.329
C2	-1.02	0.544
C3	-0.449	0.221
C4	1.92	0.838
C5	-0.807	0.0618

Fitting results w/ P-violating term

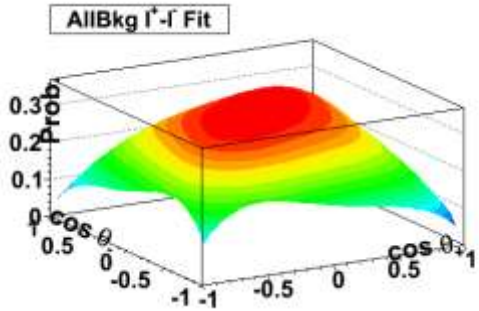
- Estimated BG

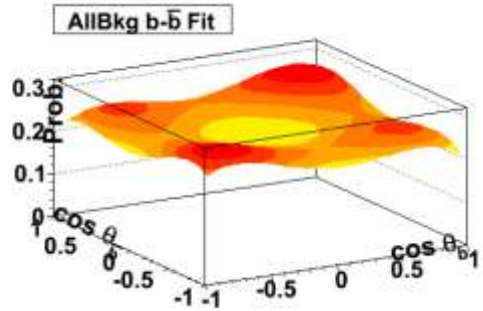




b	Value	Error
C1	0.408	0.0264
C2	-0.468	0.0616
C3	-0.204	0.0192
C4	0.3817	0.0107
C5	0.0555	0.0135
P0	-0.0519	0.0420

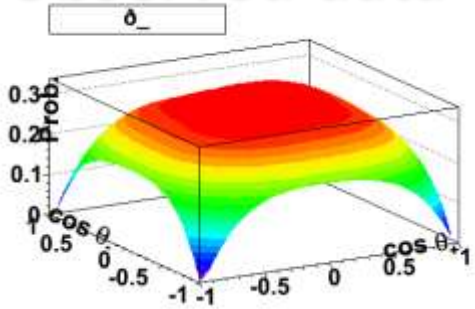
- Estimated Sig+BG

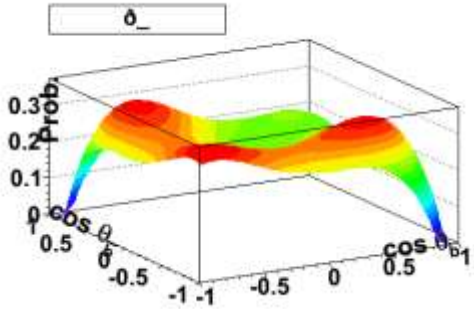




b	Value	Error
C1	0.324	0.00930
C2	0.0879	0.0198
C3	-0.192	0.00668
C4	-0.00396	0.0332
C5	-0.000401	0.00439
P0	0.0101	0.0147

- Observed data

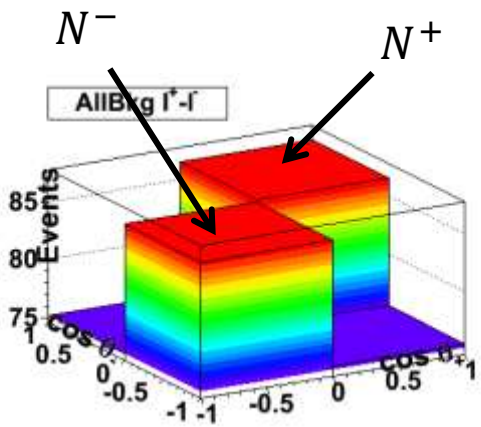




b	Value	Error
C1	0.673	0.317
C2	-1.01	0.544
C3	-0.443	0.221
C4	1.92	0.820
C5	-0.0734	0.0626
P0	-0.324	0.136

$P_0 \sim 2\sigma$ away from 0

Asymmetry for 2x2 binning



$$N = N^+ + N^-$$

$$P^+ = N^+/N$$

$$A = \frac{N^+ - N^-}{N^+ + N^-} = \frac{N^+ - N^-}{N} = 2P^+ - 1$$

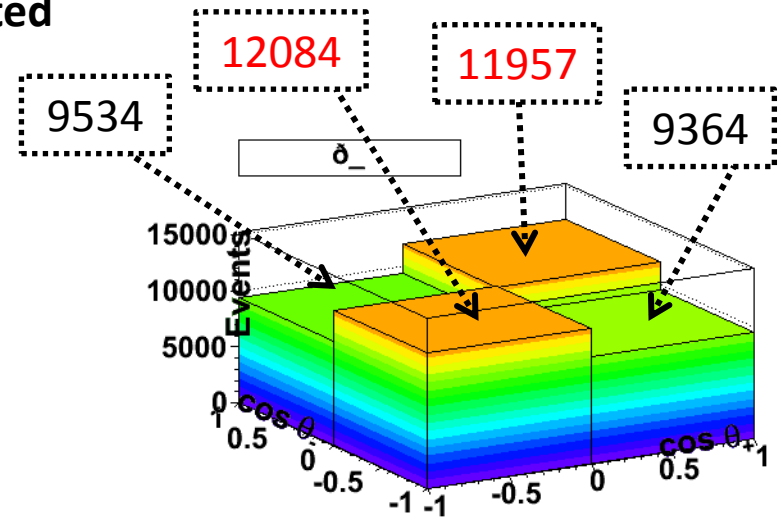
$$\delta A = 2\delta P^+ = \frac{2\delta N^+}{N}$$

$$= \frac{2\sqrt{NP^+(1-P^+)}}{N}$$

2x2 results

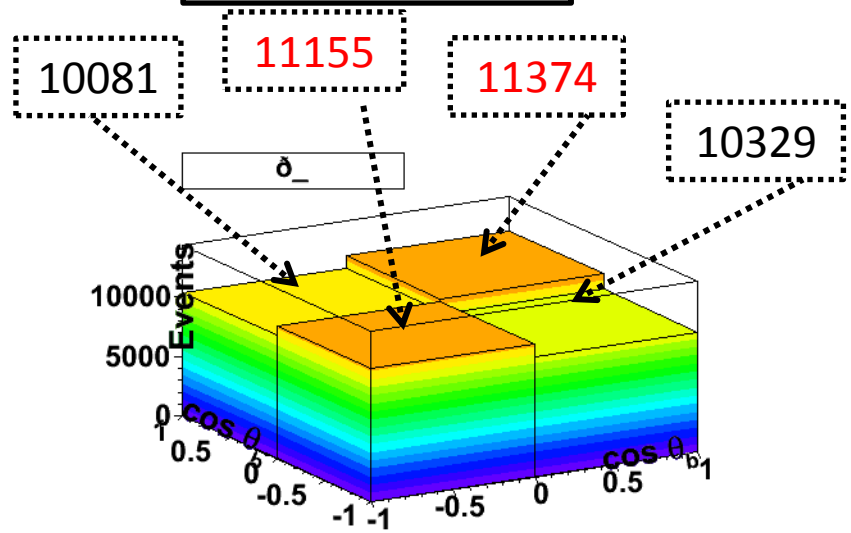
Herwig dtops0
Unweighted

$\ell^+\ell^-$



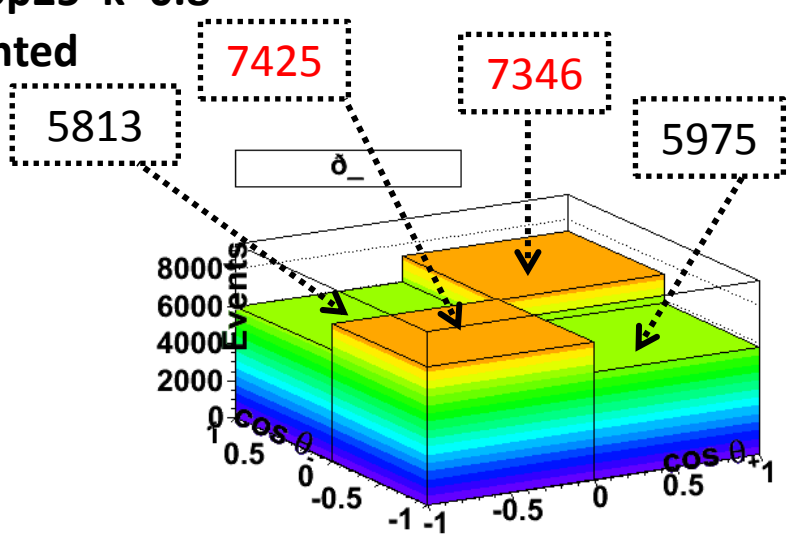
$A = -0.005 \pm 0.006$

$b\bar{b}$

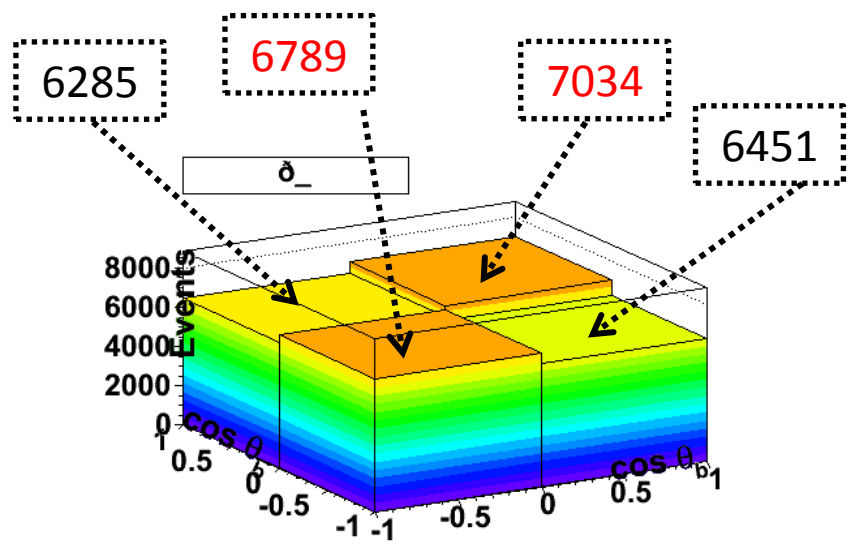


$A = 0.009 \pm 0.007$

pythia ttop25 k=0.8
Weighted



$A = -0.005 \pm 0.008$

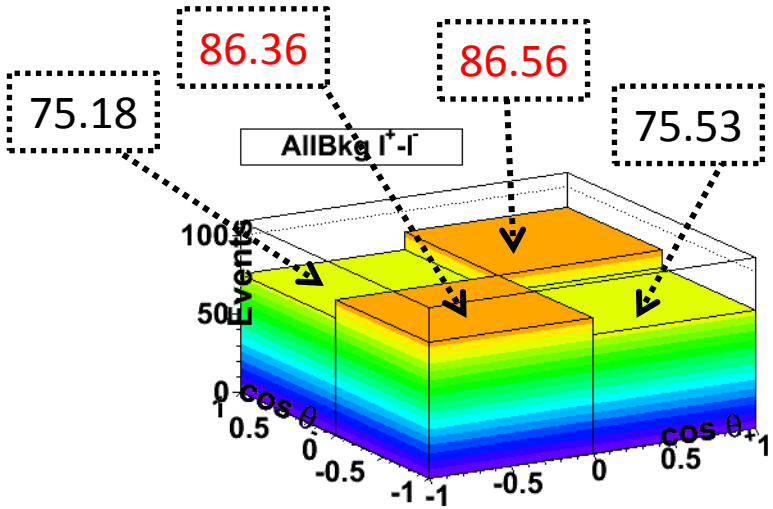


$A = 0.018 \pm 0.009$

2x2 results

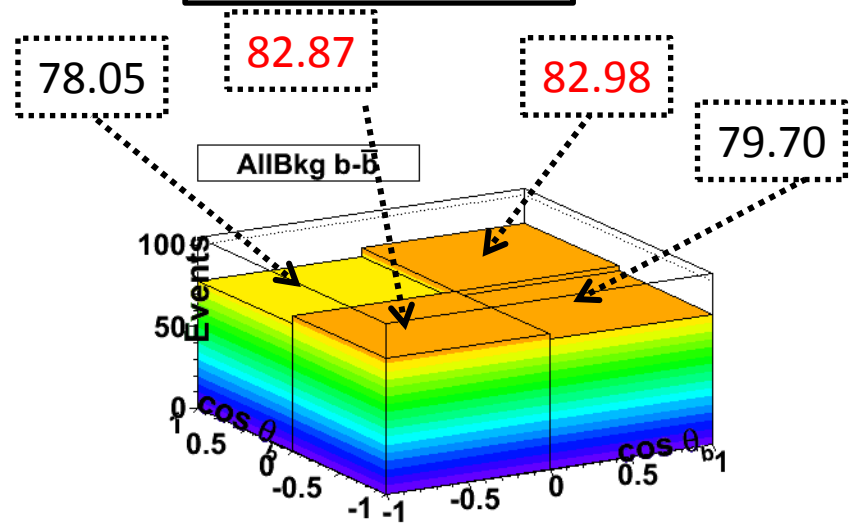
BG + Herwig dtops0

$\ell^+\ell^-$



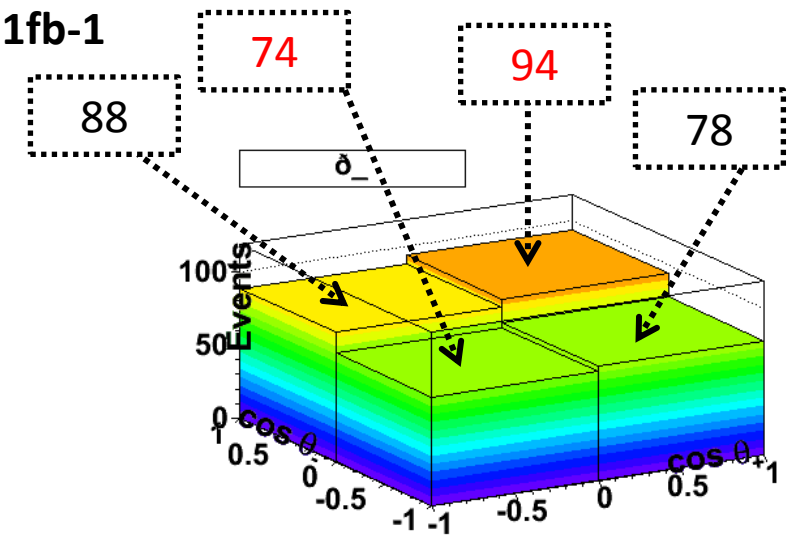
$A = 0.00114$

$b\bar{b}$

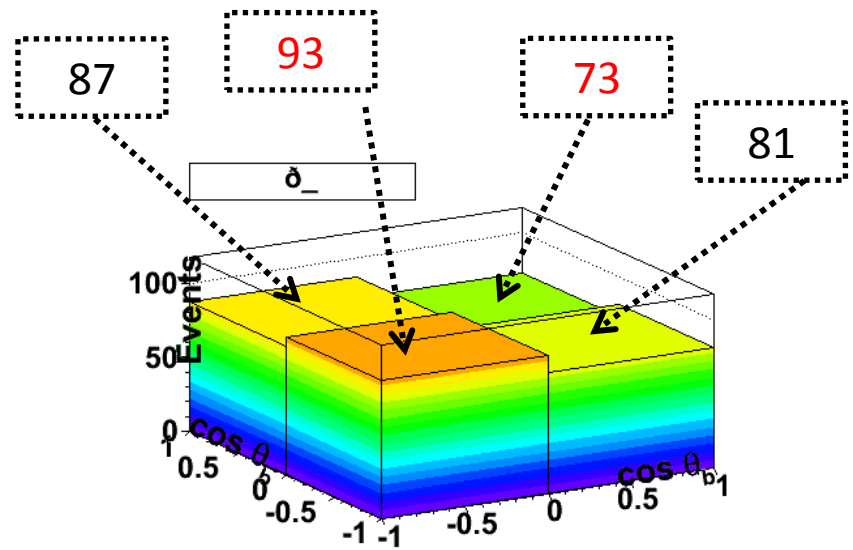


$A = 0.000563$

Data 5.1fb-1



$A = 0.12 \pm 0.08$



$A = -0.12 \pm 0.08$

Summary

Conclusion

- Observed data is consistent with assumption of no parity violation within statistical uncertainty (data is supporting V+A assumption at $1 \sim 2\sigma$ significance level)

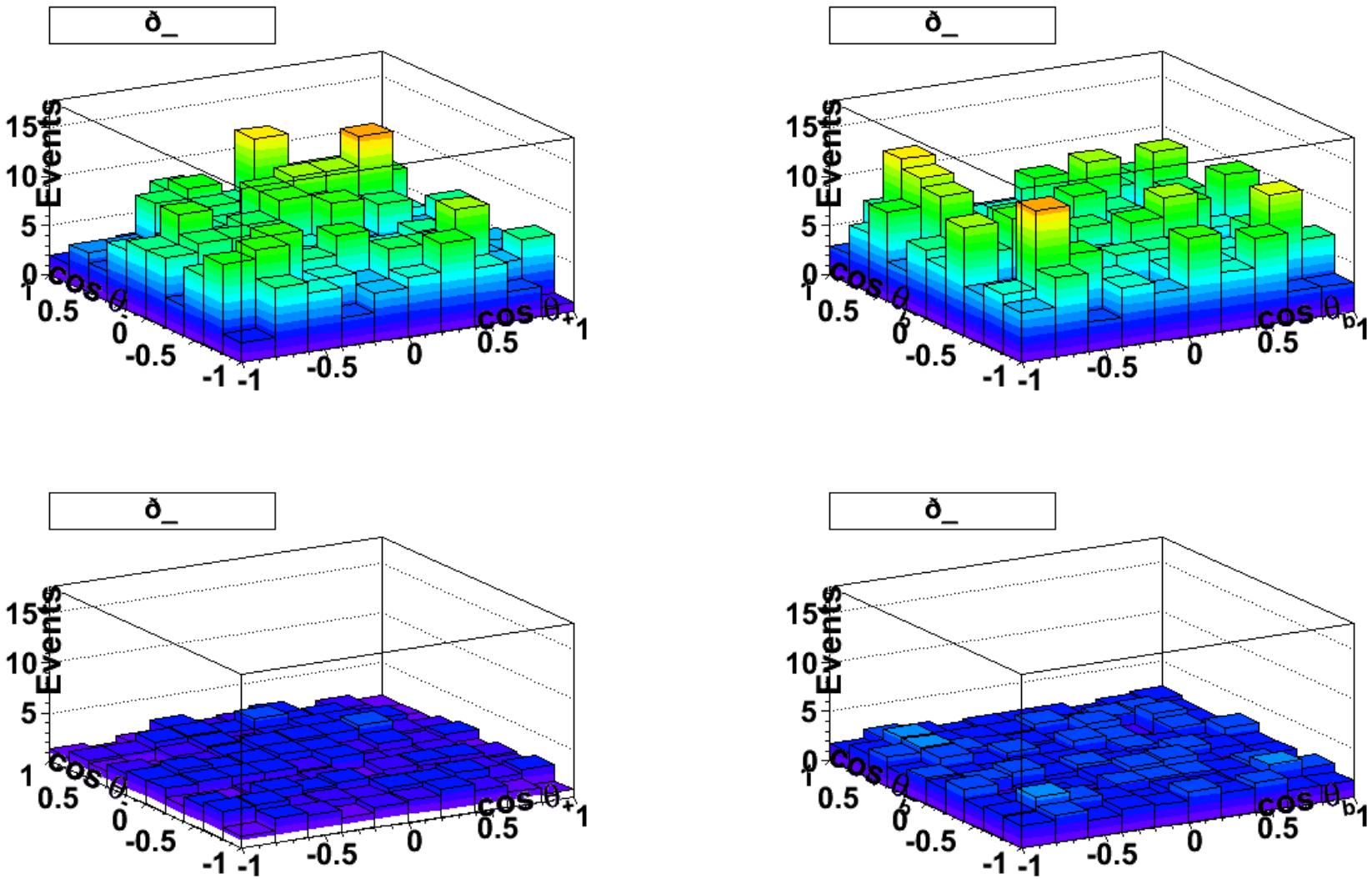
Plan

- ?

Thank you

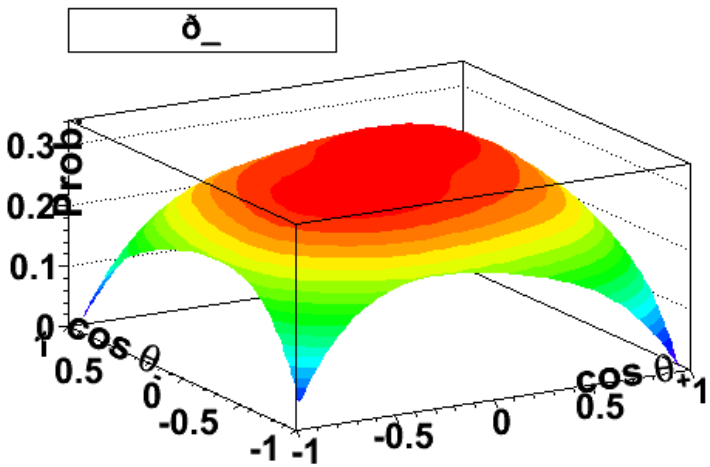
Appendix

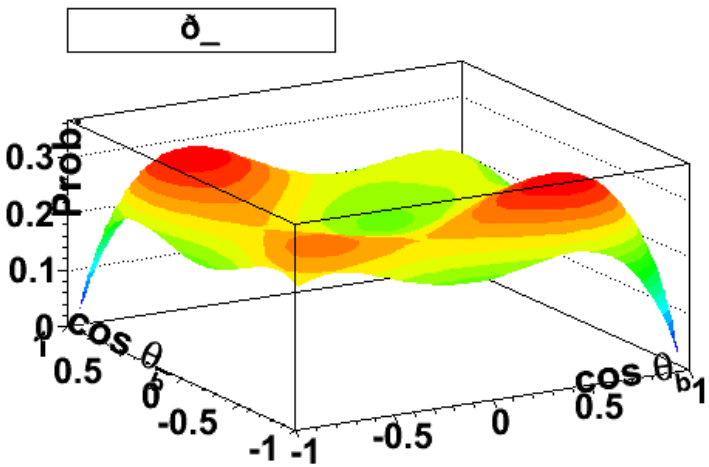
- Full data analysis 9.1fb-1



Fitting full data

- w/ P-violating term





l	Value	Error
C1	0.0684	0.265
C2	0.369	0.401
C3	-0.213	0.170
C4	-0.314	0.607
C5	-0.0485	0.0474
P0	-0.0142	0.0962

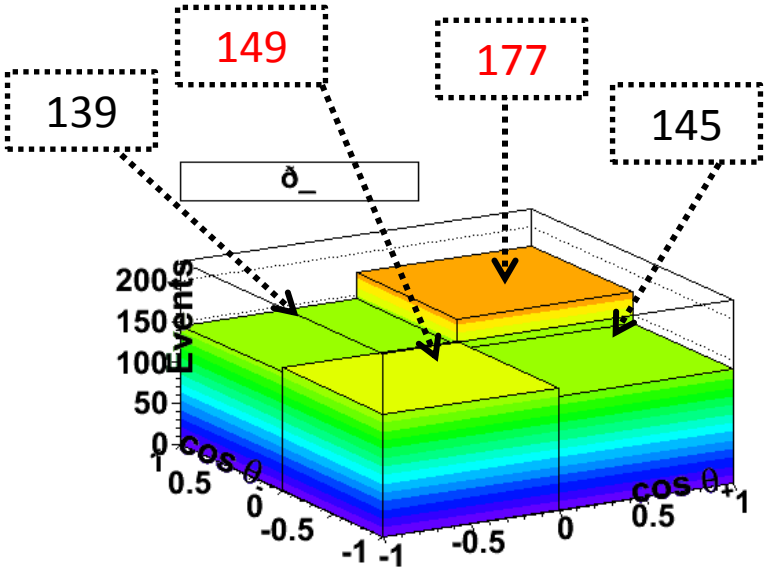
$P_0 \sim 0$ consistent

b	Value	Error
C1	0.602	0.0256
C2	-0.845	0.439
C3	-0.419	0.168
C4	1.34	0.704
C5	-0.0287	0.0492
P0	-0.133	0.0990

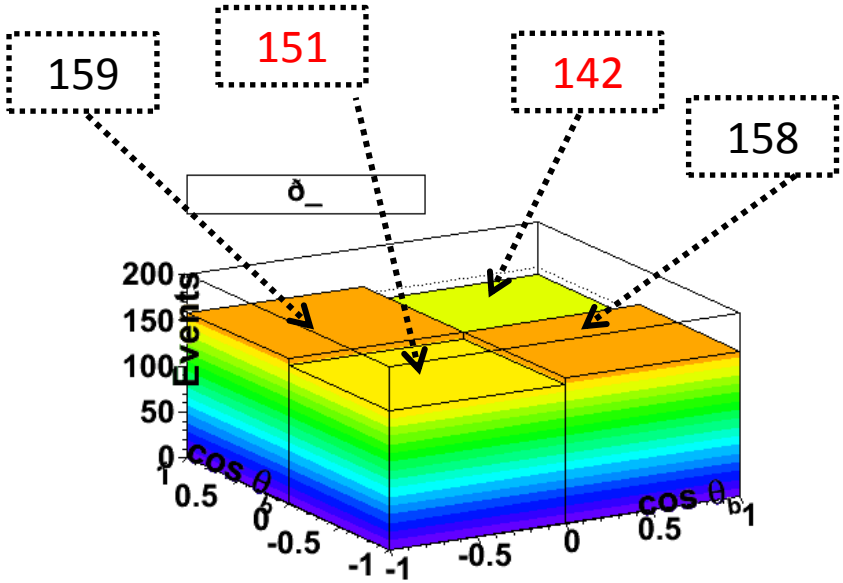
$P_0 \sim 1\sigma$ away from 0

2x2 full data

- Statistical fluctuation …….



$A = 0.086 \pm 0.055$



$A = -0.031 \pm 0.058$

BACKUP SLIDES

To Do List

Goal:

To get statistical significance of P-violating term from the observed data.

To do

- Try other fitting methods to get more reliable results

✓ 5.1 fb-1 => Look at the full data

2x2 results

	-1	0	+1
+1	75.18	86.56	
0	86.63	75.53	
-1			