The sign of new physics from top production at the Tevatron and its future confirmation at the LHC

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This talk is based on

- **Y.-k. Wang, B. Xiao, and S.-h. Zhu, PhysRevD.82.094011, (2010)**
- **B. Xiao, Y.-k. Wang, and S.-h. Zhu, (2010), arXiv:1011.0152**

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  - SM and experiment are not consistent
  - Most of the proposed New Physics cannot do better than SM

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SM and experiment are not consistent

Both CDF and D0 at the Tevatran reported the measurements of forward-backward asymmetry in top pair production.
The result shows 2σ deviation from the SM prediction.

A^{lab} $CDF(5.3fb^{-1}):\ 0.150 \pm 0.050 \pm 0.024$ $MCFM:\ 0.038 \pm 0.006$ $Numerical\ Calc:\ 0.051 \pm 0.006$	$A^{t\bar{t}}$ $CDF(5.3fb^{-1}):\ 0.158 \pm 0.072 \pm 0.017$ $MCFM:\ 0.058 \pm 0.009$ $Numerical\ Calc:\ 0.078 \pm 0.009$
	$A^{t\bar{t}}$ $D\emptyset(4.3fb^{-1}):\ (8 \pm 4(stat) \pm 1(syst))\%$ $MC@NLO:\ (1^{+2}_{-1}(syst))\%$

Note that for the D0 and MC@NLO results, the detect effects are not cleaned off, so these results cannot be compared directly with the Numerical Calc result

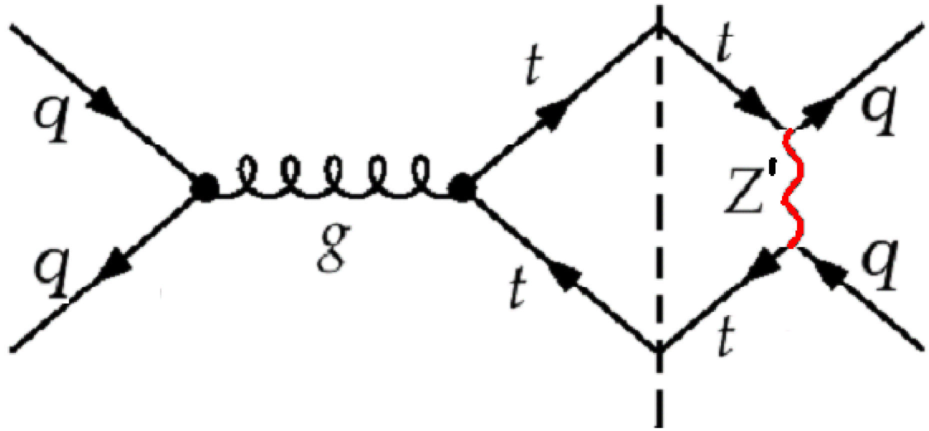
CDF note10224 (2010), Phys. Rev. D 77, 014003 (2008), D0 Note 6062-CONF (2010)

Most of the New Physics cannot do better than SM

Lots of New Physics are proposed to account for the Asymmetry anomaly. They can be classified into two categories.

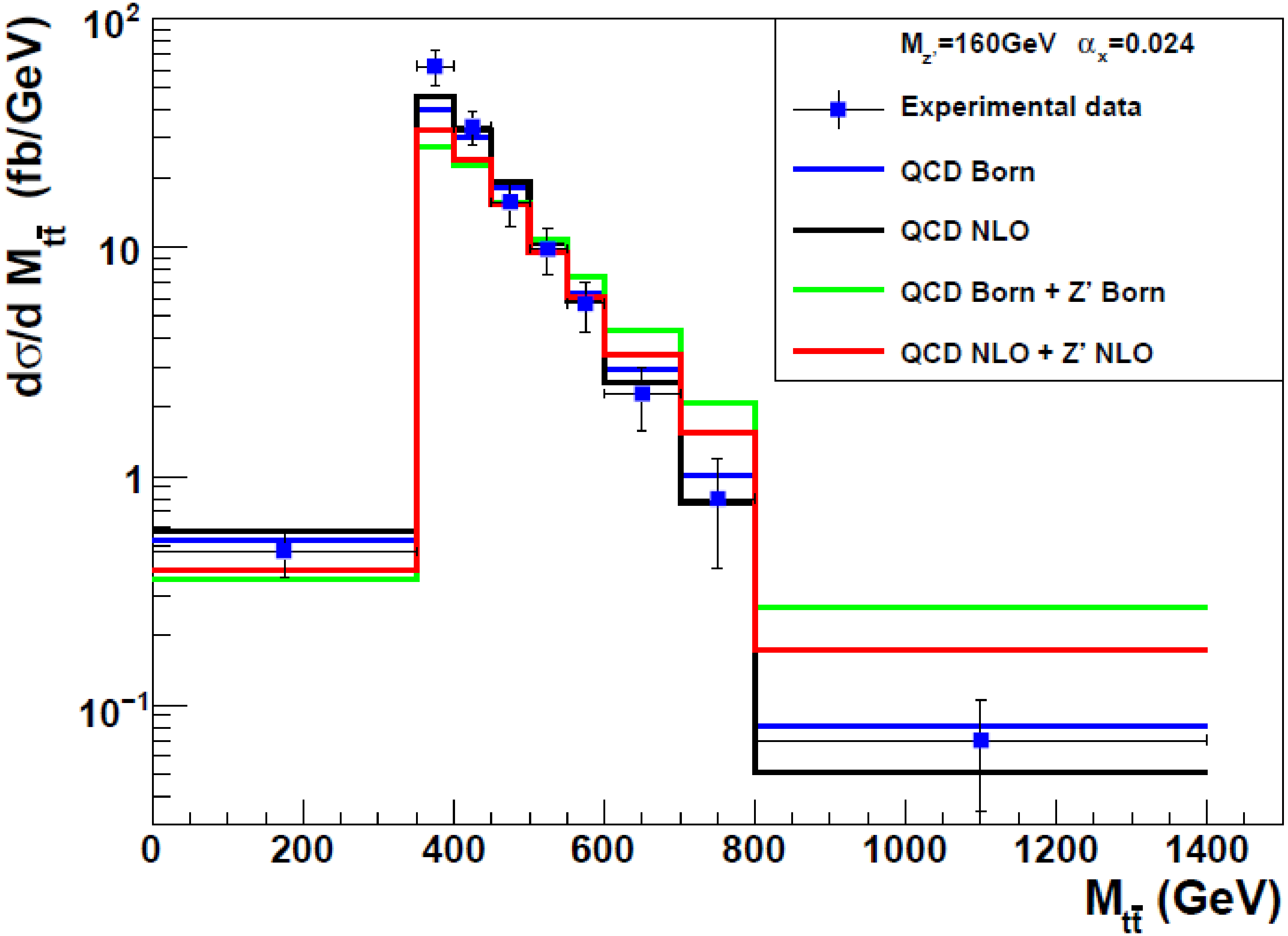
1. Introducing a W'/Z' which induce a t-channel $q\bar{q} \to t\bar{t}$ **.**

New Asymmetric Cross-Section is from the inteference of the new t-channel diagram with the usual QCD diagram.



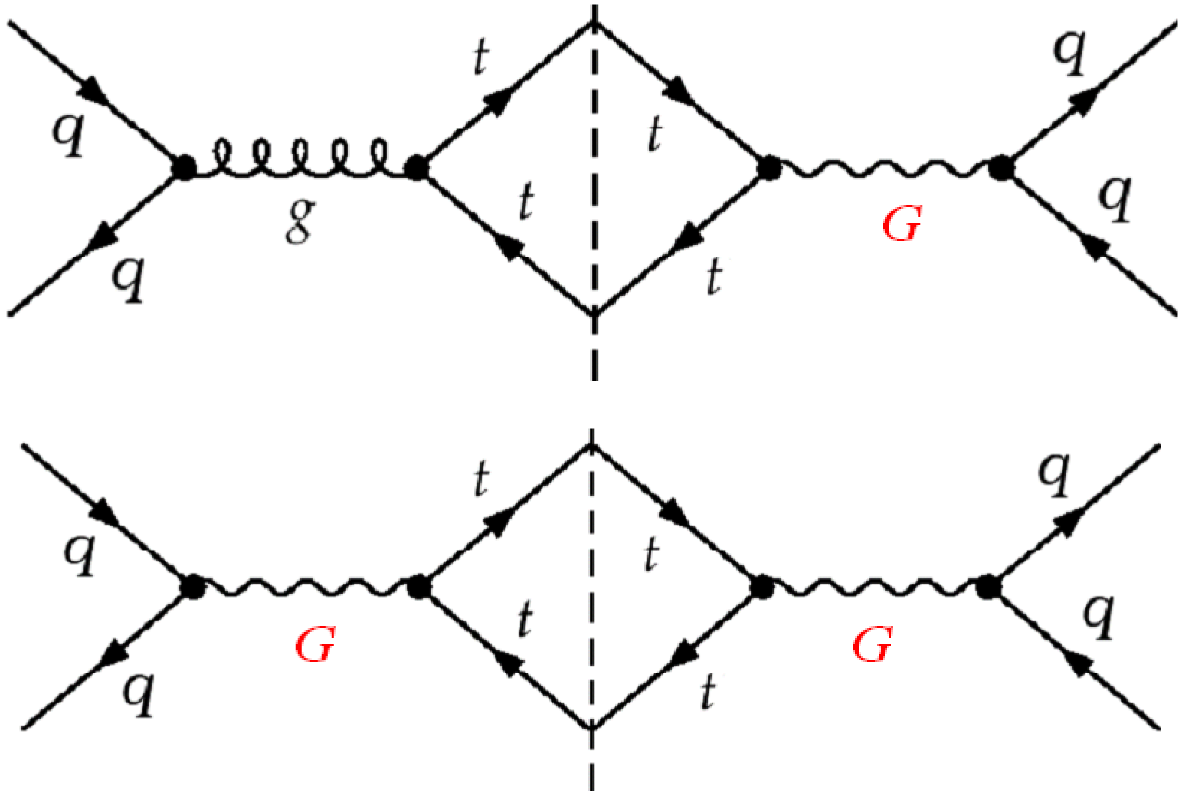
Most of the New Physics cannot do better than SM

However, the $d\sigma / dM_{t\bar{t}}$ distribution for top pair production is violated greatly



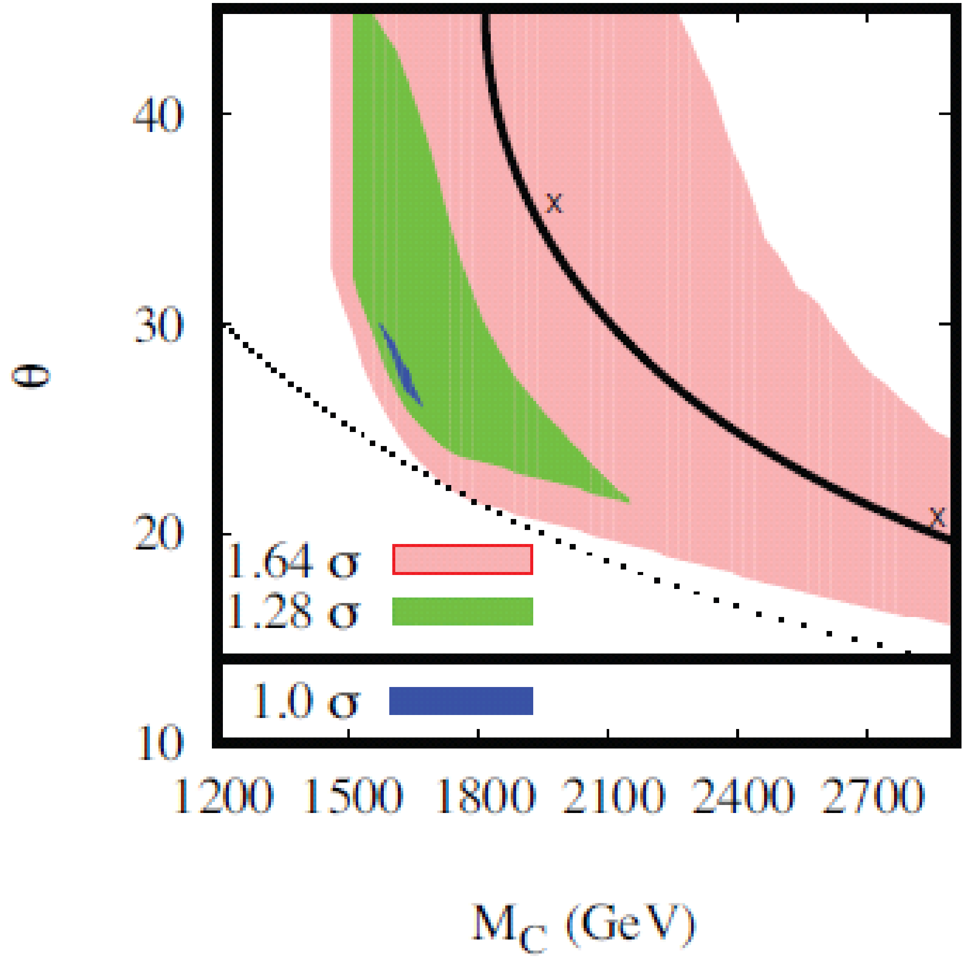
2. Introducing axigluon *G*.

New Asymmetric Cross-Section is from the inteference of the new s-channel $q\bar{q} \to t\bar{t}$ with the usual QCD diagram, and/or from its self-conjugation



Most of the New Physics cannot do better than SM

However, as has been argued in 1007.0260, suitable parameters to account for all existing measurements can hardly be found.



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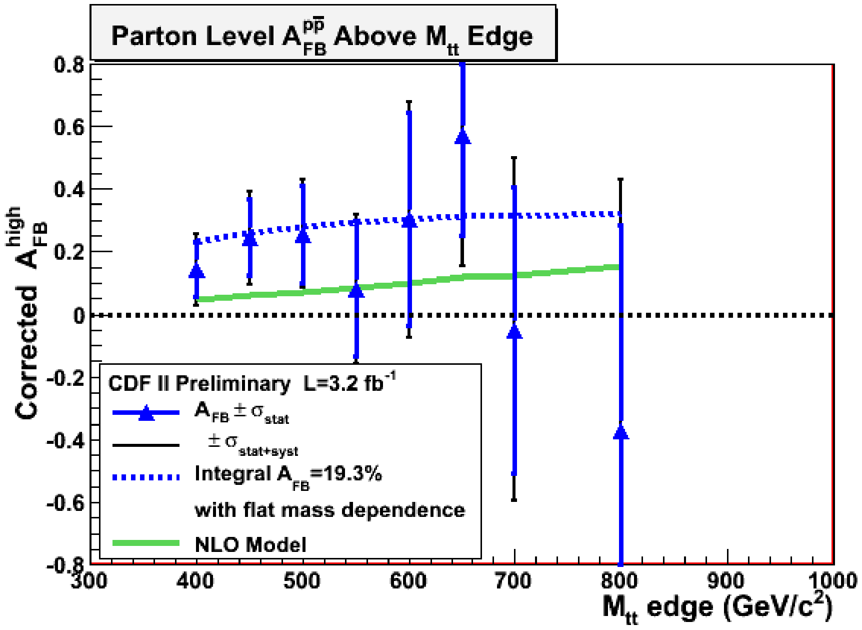
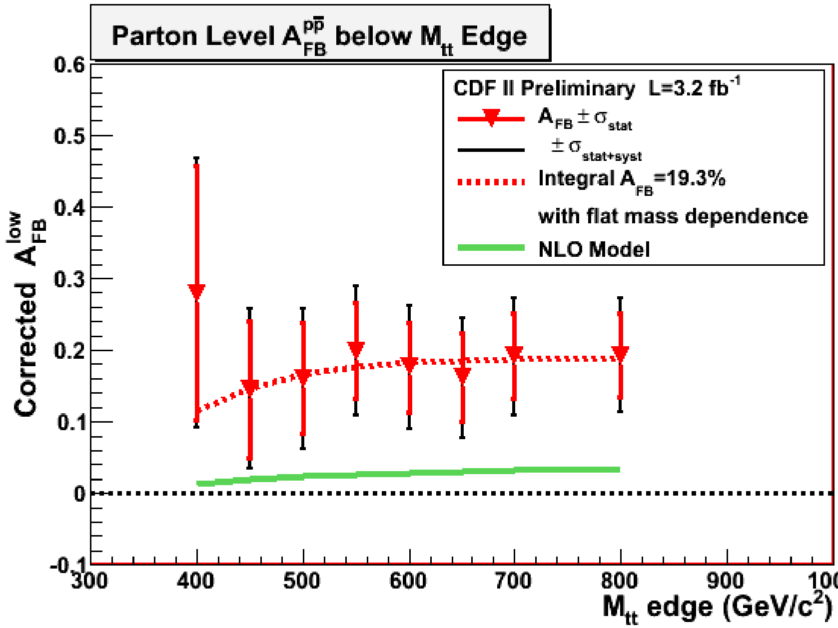
Motivation

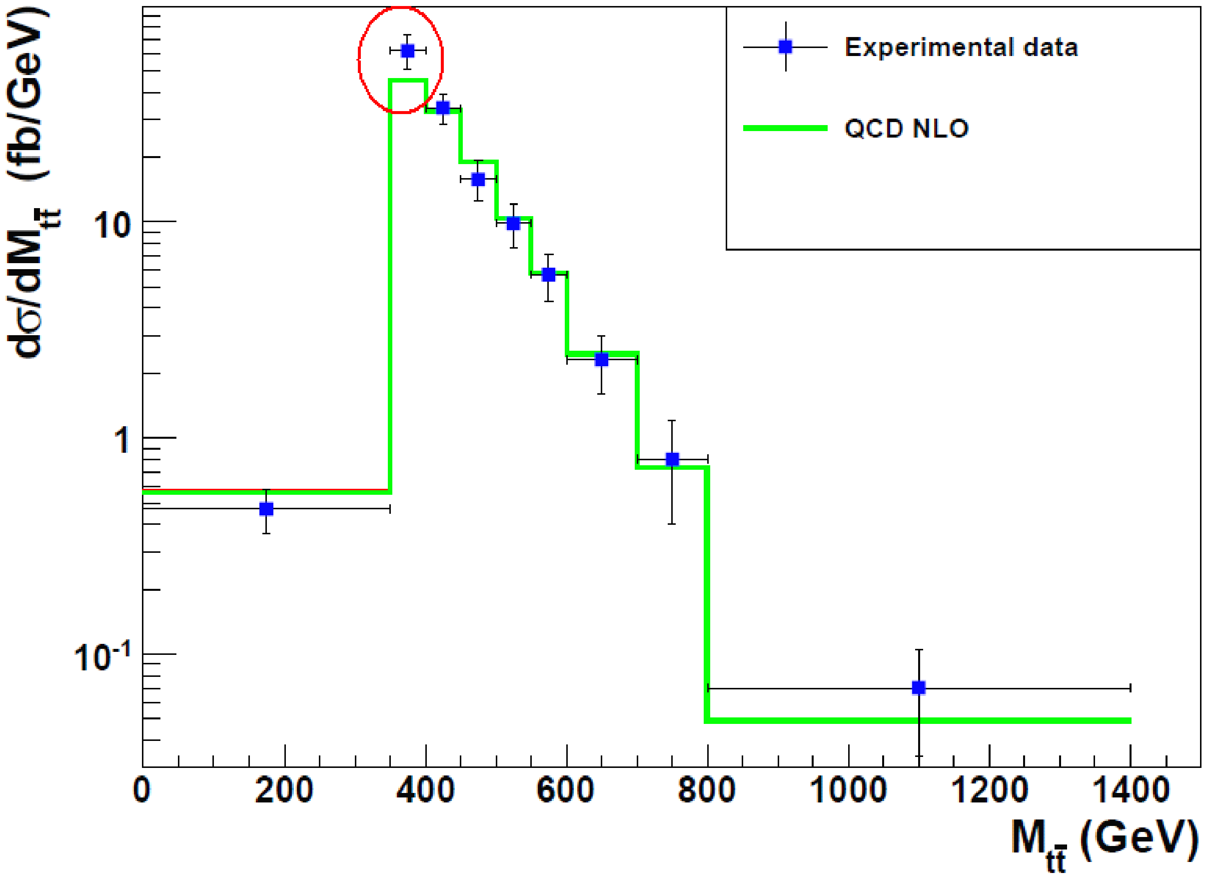
1. The "above" and "below" diagrams indicate that the deviation of Afb can be attributed to the events in the low Mtt region





Motivation

2. Meanwhile, we believe that there is also some deviation in the differential Cross-Section $d\sigma / dM_{t\bar{t}}$ **in the low Mtt region.**



Motivation

From these detailed experiment measurements and SM predictions, we can estimate that approximately an extra Asymmetric Cross-Section $\delta\sigma_A$ of 800fb which spread in the low Mtt region, and an extra Cross-Section $\delta\sigma$ of 700fb which settle mostly in the 350Gev-400Gev bin are needed.

(Of course, due to the large experiment uncertainty, other values of $\delta\sigma_A$ and $\delta\sigma$ are also permitted. But the basic characteristics of the final result would not change much according to different choice of values. As will be seen latter, the value we choose here will give an excellent fitting of the distributions of "above", "below" and $d\sigma / dM_{t\bar{t}}$.)

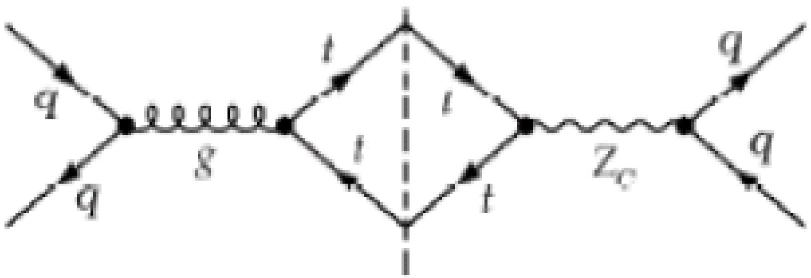
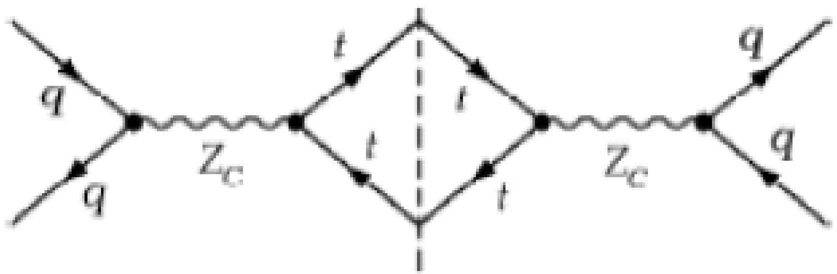
Now we try to search for a model that can fulfil these needs.

A new Color-Octet Axial-Vector Boson Zc

We introduce a new Color-Octet Axial-Vector Boson Zc, that have

- $-ig_A^t \gamma^\mu \gamma^5$ **coupling to top-quark,**
- $-ig_A^q \gamma^\mu \gamma^5$ **coupling to other quarks,**
- **and mass Mc just above 2 mt**

This Zc model will bring

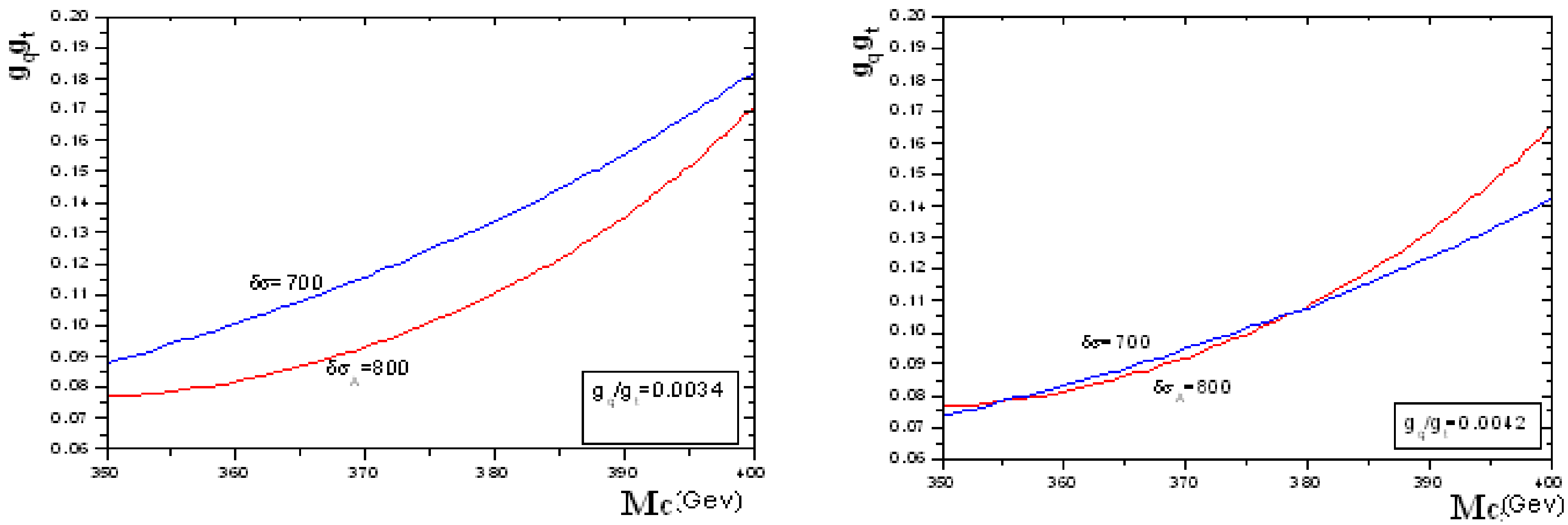
Asymmetric Cross-Section $\delta\sigma_A$ that proportional to β	Symmetric Cross-Section $\delta\sigma$ that proportional to β^2
	

Note: β **is small in the region where Mtt is just above 2 mt.**

This model has 3 free parameters g_t, g_q and Mc.

Now we should find out the region of parameter space that can explain the $d\sigma / dM_{t\bar{t}}$ and Asymmetry simultaneously. We will reduce the allowed region of parameter space step by step.

1. **The region of Mc<350Gev and Mc>400Gev is excluded trivially.**
2. **Constraining the parameters by $\delta\sigma = 700\text{fb}$ and $\delta\sigma_A = 800\text{fb}$ as announced earlier. Here is two examples**



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3. Exclude the parameters that violate obviously the distributions of "above", "below" and $d\sigma / dM_{t\bar{t}}$ **.**

The finally obtained region of parameter space is approximately described by

$$\begin{cases} 0.0040 < g_q / g_t < 0.0044 \\ g_q g_t \simeq 0.2 \dfrac{M_C - 290[\text{Gev}]}{m_t} \\ 350\text{Gev} < M_C < 380\text{Gev} \end{cases}$$

(Further constrains may come from other experiments for example di-jet measurement. However, it is obviously that the parameters obtained here is much smaller than the limit.)

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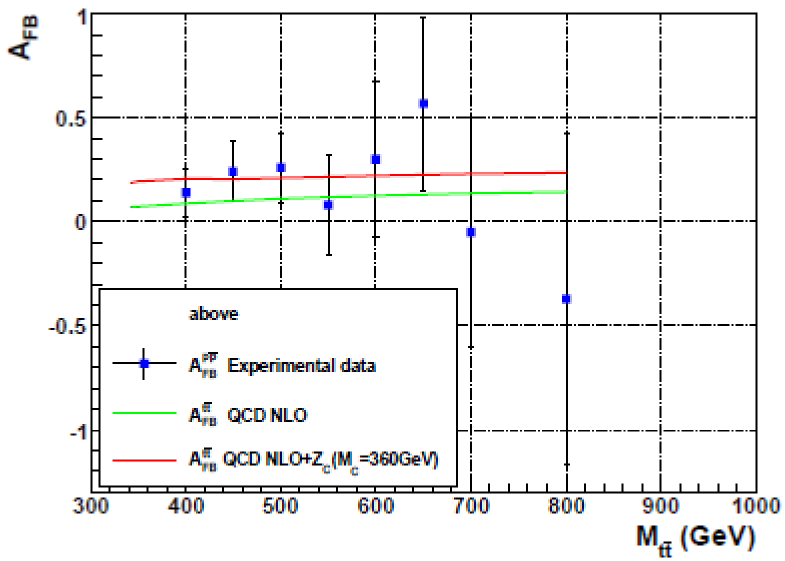
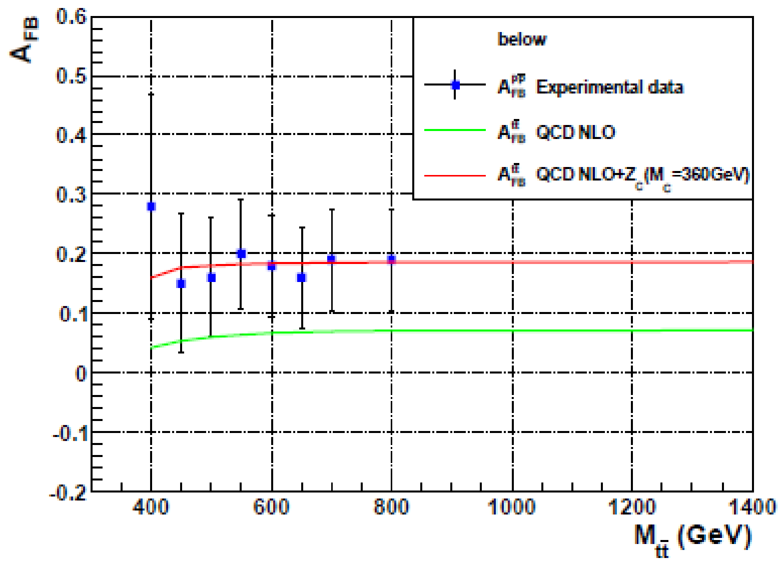
A new Color-Octet Axial-Vector Boson Zc

Excellent agreement between theoretical predictions and data is achieved after introducing this Zc model.

An example is shown in the following figure, where the parameters are choosen to be $g_q / g_t = 0.0042$ **and** $M_C = 360\text{GeV}$





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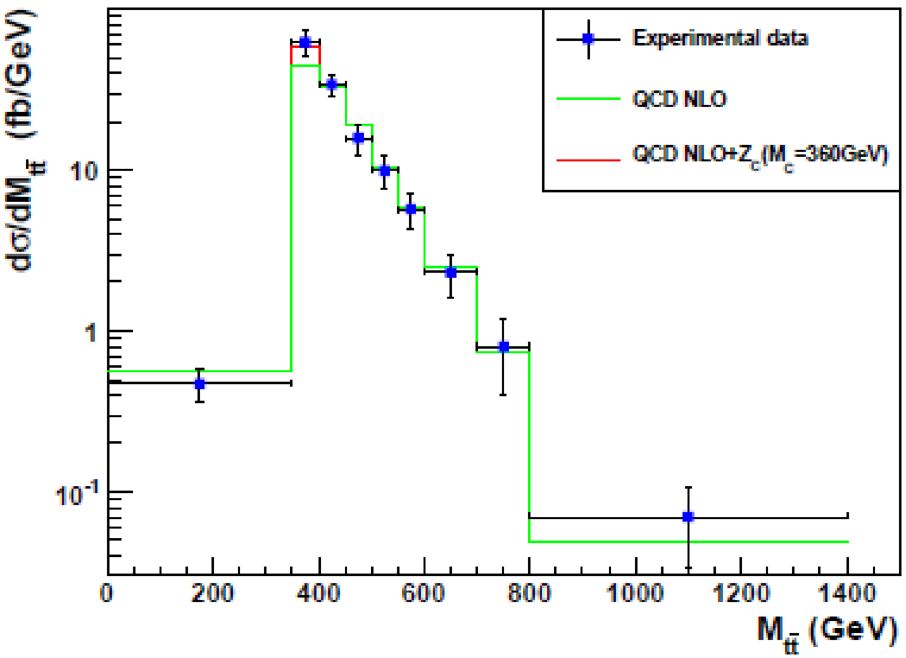

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This Zc VS the usual axigluon

The key difference between this Zc and the axigluon proposed by other authors to explain the Asymmtry is that,

- **for the latter, the mass of axial-gluon is set quite heavy (O(1)TeV) then the the axial-vector couplings with top and with other quarks have the opposite sign in order to induce a positive Asymmetric Cross-Section from interference,**

- **while in this Zc model, the Mc is assumed just above 2mt and the axial-vector couplings with top-quark and the other quarks have the same sign.**

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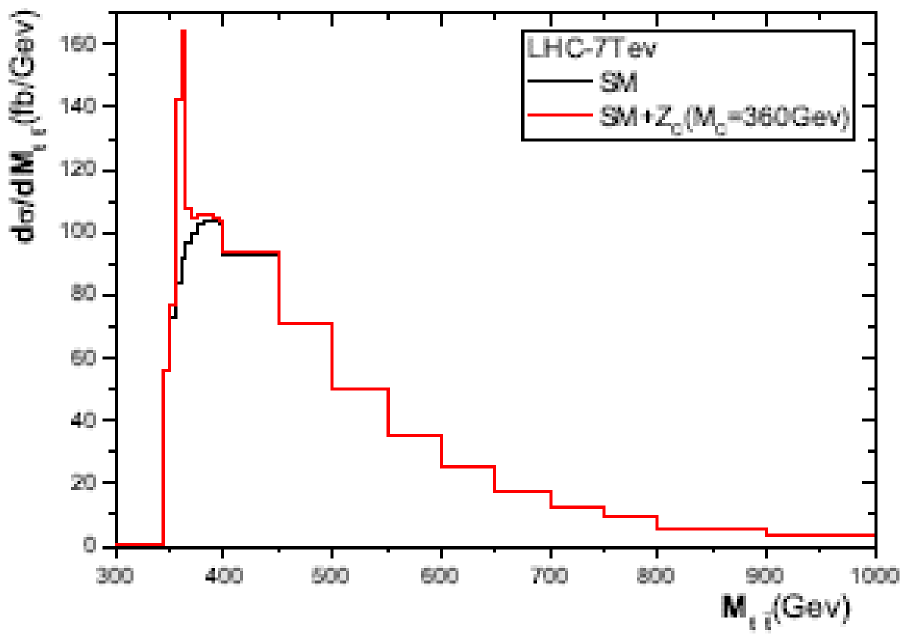
1. From the differential Cross-Section measurement.

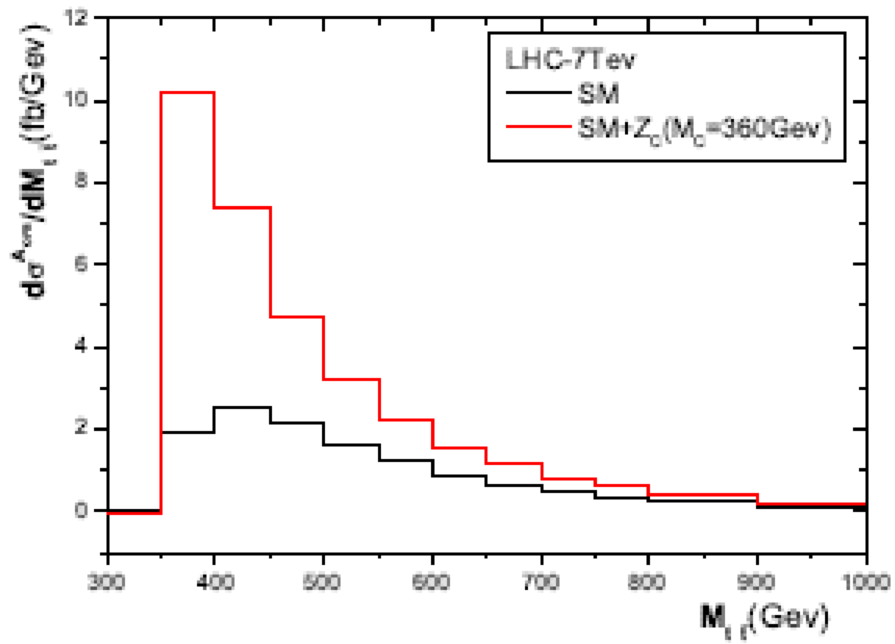
Zc brings sizable extra Cross-Secion around Mc in the $d\sigma / dM_{t\bar{t}}$ **spectrum through the subprocess** $q\bar{q} \rightarrow t\bar{t}$ **. The SM background mainly comes from** $gg \rightarrow t\bar{t}$ **. From the experience gained in an earlier work, we know that a proper** $P_{Z,t\bar{t}}$ **cut can suppress the** $gg \rightarrow t\bar{t}$ **background efficiently.**

The right diagram shows the Zc effects on the $d\sigma / dM_{t\bar{t}}$ **after applying the** $P_{Z,t\bar{t}}$ **cut** $P_{Z,t\bar{t}} > 600\text{Gev}$ **.**



2. From the "Forward-Backward" Asymmetry measurement at the LHC.

Zc also brings large extra Asymmetric Cross-Section in the subprocess $q\bar{q} \rightarrow t\bar{t}$, So people can measure the top-quark "One-side Forward-Backward Asymmetry Cross-Section" at the LHC to detect Zc. The right diagram shows the Zc effects on the "One-side Forward-Backward Asymmetry Cross-Section"



2. From the "Forward-Backward" Asymmetry measurement at the LHC

We can also integrate Mtt and get the total "One-side Forward-Backward Asymmetry Cross-Section", which is shown in the following table together with its signal significance.

TABLE I: Total one-side asymmetric cross section (fb) in Z_C+SM. In the SM, $\sigma_{\mathrm{SM(LO)}} \simeq 22.2\times10^3$, 75×10^3fb and $\sigma_{\mathrm{SM}}^{A_{\mathrm{OFB}}} \simeq 650$, 1650fb for $\sqrt{s}=7$ and 14 TeV respectively. Note that $P^z_{t\bar{t},\mathrm{cut}}$ is used for all the σ and $\sigma^{A_{\mathrm{OFB}}}$ calculations.

	$\sigma^{A_{\mathrm{OFB}}}_{\mathrm{SM}+Z_C}(M_C=)$			$Sig(M_C=)$		
	355.0	360.0	370.0	355.0	360.0	370.0
7 TeV	1623	1670	1716	20.63	21.62	22.61
14 TeV	3971	4096	4245	26.69	28.13	29.85

The significance is estimated by

$$Sig = \frac{\sigma^{A_{\mathrm{OFB}}}_{\mathrm{SM}+Z_C} - \sigma^{A_{\mathrm{OFB}}}_{\mathrm{SM}}}{\sqrt{\sigma_{\mathrm{SM}}}}\sqrt{\mathscr{L}},$$

L is chosen to be $10\mathrm{fb}^{-1}$

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Summary

1. A phenomenological model which contains a new color-octet boson Zc that of the properties

• Mc is just above 2 mt,

• the nature of couplings among Zc and quarks is axial-vector like,

• the axial coupling of Zc with top quark is much larger than that with light quarks, but are of the same sign,

can explain the distribution of asymmetry and the differential Cross-Section of Mtt in top pair production simultaneously.

2. If this scenario is true, the new Zc particle can be detected at the LHC with low integrated luminosity.

Thank you ☺