Review on Studies of CP Conserving Couplings

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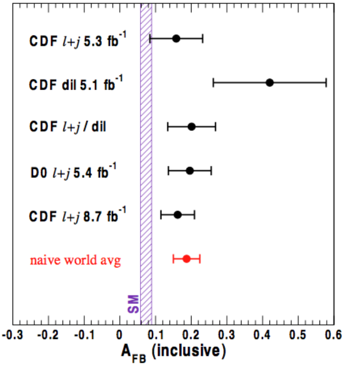
Outline

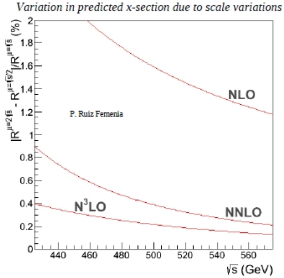
1. Theory
2. χ^2 Method and the Migration Effect
3. The B Charge Study
4. Conclusion and Outlook

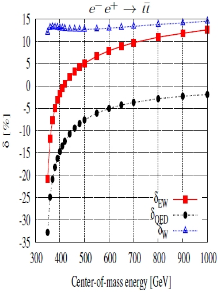
Motivation



- The top quark is the heaviest elementary particle.
- The top decay before hadronization: correlation between angular distribution of the decay products and the spin of the top.
- The aims of the study is to measure the V-A coupling of the top quark with γ and Z boson via the precision measurement of some observables.

Theoretical Uncertainties

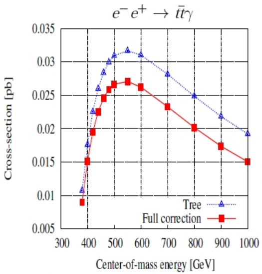


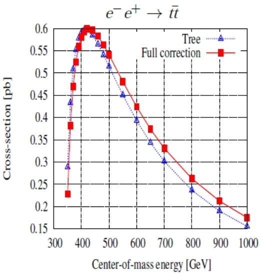


- Study from P. Ruiz Femenia: QCD correction at N^3LO is now at the per-mil level.

- Study from P. H. Khiem *et al.*: Electroweak correction at one loop level is $\approx 5\,\%$ for cross section, and $\approx 10\,\%$ for A_{FB}.
- Estimation of the size of two-loop corrections is ongoing.

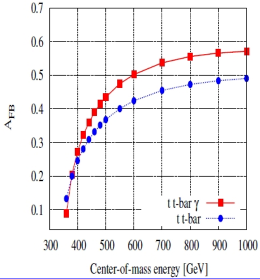
Other Theoretical Aspects





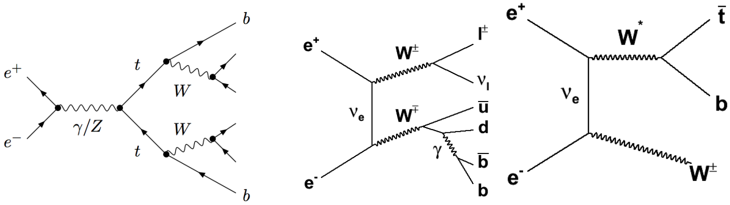
$E_\gamma \geq 10GeV, 0^0 \leq \theta_\gamma \leq 170^0.$

Full correction results



- $e^+e^- \longrightarrow t\bar{t}\gamma$ production gives different prediction.
- Show the importance to have the more possible physics effects in the generator (ISR, FSR, gluon radiation, ...).

Generator and Physics

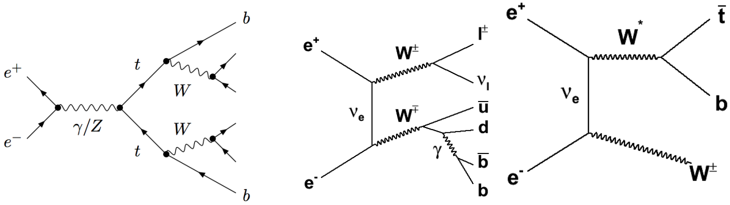


All these process are 6 fermions final state

They are irreducible background, even in the generator, but we are only interested in $t\bar{t}$ cross section.

- Is it meaningful to talk of $t\bar{t}$ cross section or should we consider 6 fermions cross section ?
- The last two diagrams have an opposite asymmetry with respect to the $t\bar{t}$ one.

Generator and Physics



Strategy

We should have the best generator possible, and try to match simulated data and nature data.

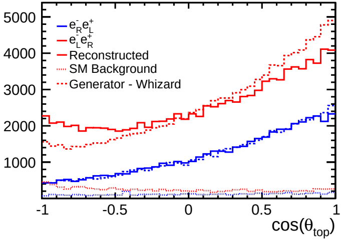
- Then it is to theorists to go from 6 fermions data to the Born $t\bar{t}$ level which is relevant for the couplings.
- But so far we only have simulated data. So we can only compare fully reconstructed simulated data and parton level.

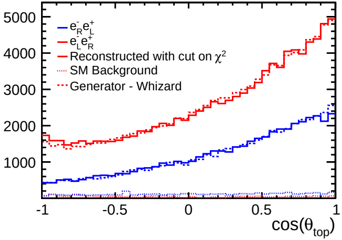
Generator and Physics

- Currently, for the DBD samples, the generation is done with Whizard and the hadronization with Pythia.
- But there are some problems:
  1. The hadronization is not done properly by Pythia for tops off-mass shell and other 6 fermions topologies.
  2. The gluon radiation is done in Pythia and not in Whizard, and we are missing the hard gluon radiation.
  3. The semi leptonic cross section is higher than the fully hadronic one while it should be the opposite.
- The DBD samples were simulated with an old version of Whizard and the new version 2.x have a better treatment of the color object which solve these problems.
- New simulation of the 6 fermions with Whizard 2.x is planned.

How to cure migration ? The "raison d'être" of the χ^2

$$\chi^2 = \frac{(\gamma_t - 1.435)^2}{\sigma^2_{\gamma_{top}}} + \frac{(P^*_b - 68)^2}{\sigma^2_{P^*_b}} + \frac{(cos(\theta_{Wb}) - 0.23)^2}{\sigma^2_{cos(\theta_{Wb})}}$$





- Forward-Backward asymmetry A_{FB}.
- A cut on χ^2 reduce the number of bad combination.
- After the χ^2 cut the fully reconstructed simulated data match the parton level.
- Also a way to reduce the non $t\bar{t}$ events from the 6 fermions.

Principle

Why using the b charge in the semi-leptonic decay

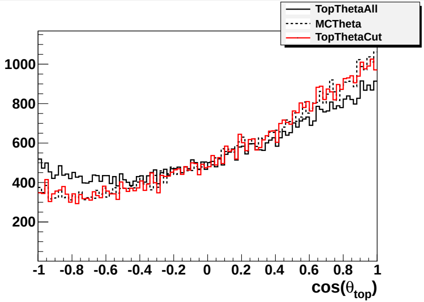
- With the charge of the lepton we can disentangle between t and $\bar{t}$.
- But missing the charge of the b leads to migrations for the left polarization.
- Measuring the b vertex charge should help to cure the migrations.

1. Same method than for the fully hadronic mode: Event charge: charge b1 - charge b2.
2. For each reconstructed top we can compare the lepton charge and the event charge to see if there is agreement.
3. Number of event for each case:
    - Good charge: 29181 (51.9%)
    - Bad charge: 12900 (23%)
    - Zero event charge: 14092 (25.1%)

Results

Cut using the B charge

$\gamma_{top} - 1.435 > -0.2$ for top with the good event charge.
$\gamma_{top} - 1.435 > -0.1$ for top with a null event charge.



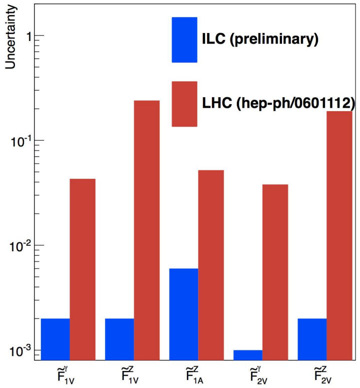
$A_{FB} = 31.56; Eff. = 30.8\%; \delta_{A_{FB}}/A_{FB} = 1.7$

Reminder with χ^2 cut:
$A_{FB} = 32.63; Eff. = 28.5\%; \delta_{A_{FB}}/A_{FB} = 1.7$

Advantages

1. New method to cure the migrations: having two methods is useful to estimate the systematic errors.
2. Tacking advantage of the vertex charge measurement capability of the vertex detector.
3. Become immediately more efficient with an optimized vertex charge measurement.
4. The vertex charge can also be measured from the semileptonic decay of the B meson.

Precision Reached on CP Conserving Couplings



Results of full simulation study for DBD at $\sqrt{s} = 500\ GeV$.

1. ILC might be up to two orders of magnitude more precise than LHC ($\sqrt{s} = 14\ TeV$, $300\ fb^{-1}$).
2. Disentangling of couplings for ILC, one variable at a time for LHC.
3. Potential for CP violating couplings at ILC under study (see R. Poeschl talk).

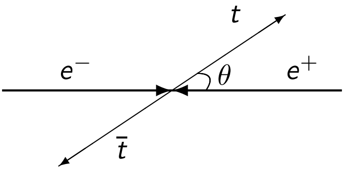
Conclusion and Outlook

1. Good collaboration with theorists to works on errors.
2. The identified problems of the generator will be solved in the next months.
3. On a longer term generator should be ameliorate (NNLO, hard gluon, ...) and the theoretical errors should reach, at least, the level of the statistical ones.
4. Using the b vertex charge to select the good events give the same results than the χ^2 method: always good to have different methods.

A_{FB}

The Forward Backward Asymmetry

$$A_{FB} = \frac{N_{top}(cos(\theta)>0) - N_{top}(cos(\theta)<0)}{N_{top}(cos(\theta)>0) + N_{top}(cos(\theta)<0)}$$

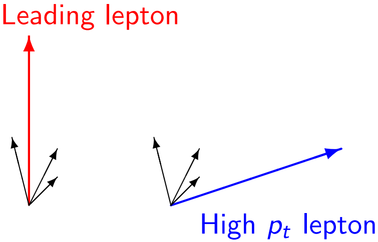


1. The sign of the top is the one of the lepton.
2. For $\bar{t}$ we change θ to $\theta + \pi$.

This observable is of particular interest because she shows tension with the standard model at Tevatron and also for the b quark at LEP.

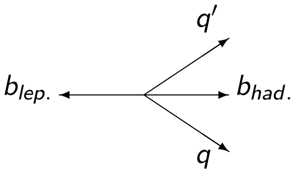
The Lepton isolation

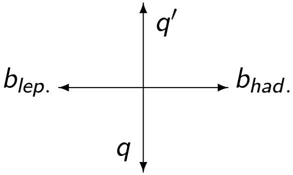
Isolation algorithm that goes beyond cones algorithm.



1. Force 4 jets clustering.
2. Isolate the lepton from one of the jets.
3. The two variables for the lepton isolation:
   $x_T = p_T / M_{jet}$ and
   $z = E_{lepton} / E_{jet}$
4. New 4 jets clustering without the lepton and flavour tagging.

Where does this migration comes from ?

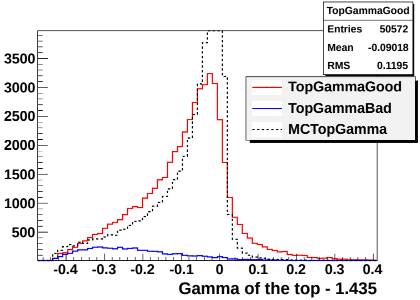




- Right-handed electron beam:
  The W is emitted into the flight direction of the top together with a soft b.
- In the case the W is easily combine to the good b to reconstruct the top.

- Left-handed electron beam:
  The W is emitted almost at rest together with a hard b.
- In the case it is harder to combine the W and the good b to reconstruct the top.

Using the B charge information



γ_{top} is lower for flipped top (γ_{top} is the one from relativity).

1. % of good combination for the reconstructed top in each type of events:
   - Good charge: 86.3%
   - Bad charge: 49.9%
   - Zero charge: 72.9%
2. Better rate for event with good charge or zero event charge.

Simple selection

Classification of the type of event depending on the charges (lepton+b) measurement and just one cut on one variable.

Method used at LEP/SLC

Using the semileptonic decay of the B meson into muon to probe the top quark charge.

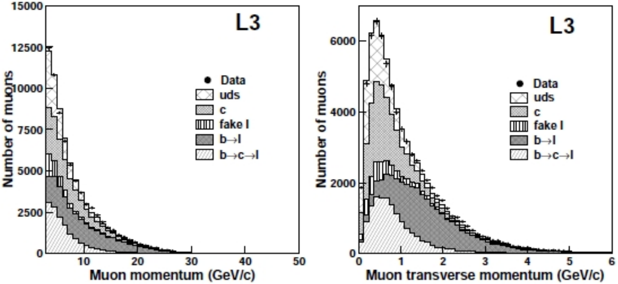
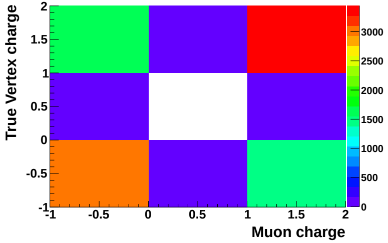


Figure 5.5: Muon momentum and transverse momentum spectra obtained by L3, together with expectations from simulation for the contributions from the various sources.

Plot from LEP paper: http://www.arxiv.org/abs/hep-ex/0509008

B Meson into SL: Correlation After the Cut $P_T > 1\ GeV$



The correlation increased with the cut on $P_T > 1\ GeV$.

In 65.7 % of the events with non isolated muon in jet0, the charge of the muon is the good one.

What are the reasons to measure a bad charge:

1. The muon is not coming from a B meson.
2. $B^0\bar{B}^0$ mixing.
3. $b \to c \to l$ contamination.