Measurement of $t\bar{t}$ asymmetries with ILD at the ILC

Jérémy ROUËNÉ
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Laboratoire de l'Accélérateur Linéaire, Orsay

in collaboration with IFIC, Valencia

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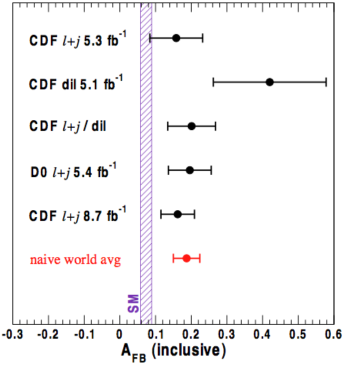
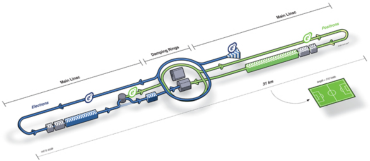
Outline

Theory



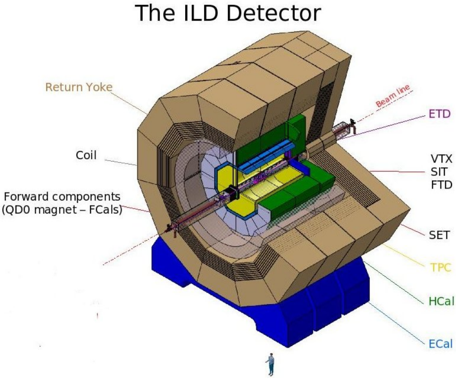
- The top quark is the heaviest elementary particle.
- The top decay before hadronization: correlation between angular distribution of the decay products and the spin of the top.
- The aims of the study is to measure the V-A coupling of the top quark with γ and Z boson via the precision measurement of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

The International Linear Collider (ILC)



1. The study is done in the case of the ILC with e^+e^- beams.
2. In this case we have polarized beams:
   $Pe^- = \pm 80\%$; $Pe^+ = \pm 30\%$
3. This allows to separate our observables between left-handed and right-handed ones.

The International Large Detector (ILD)



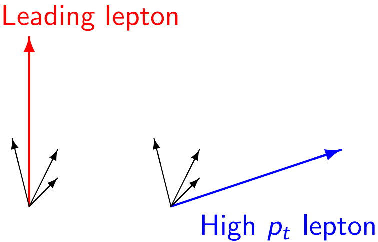
1. The ILD is one detector concept for the ILC.
2. The detectors are optimized for Particle Flow Algorithm.
3. Performances:
   - Vertex: $\sigma_b < 5 \oplus 10/p\beta(sin\theta)^{3/2}\ \mu m$
   - Tracking: $\delta(1/p_T) \approx 2 \times 10^{-5}\ c.GeV^{-1}$
   - Calorimetry: $\sigma_E/E \approx 30\%/\sqrt{E}$

The Analysis

1. The analysis is done on the semi-leptonic decay of the top quark:
   $t\bar{t} \longrightarrow (bW)(bW) \longrightarrow (bqq)(bl\nu)$
2. Analysis at $\sqrt{s} = 500\,GeV$ with an integrated luminosity $\mathcal{L} = 500\,fb^{-1}$.
3. We use the charge of the lepton to know the charge of the top.
4. The full simulation are done with the ILD detector (Mokka + Whizard software).
5. The reconstruction is based on the Particle Flow Algorithm (Pandora) and is done with Marlin on the data samples prepare for the LOI.

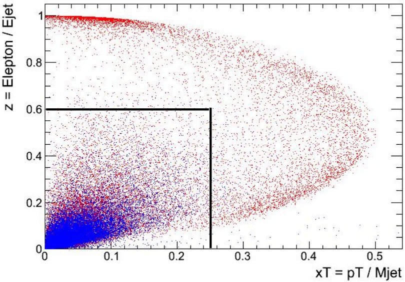
The Lepton isolation

Isolation algorithm that goes beyond cones algorithm.

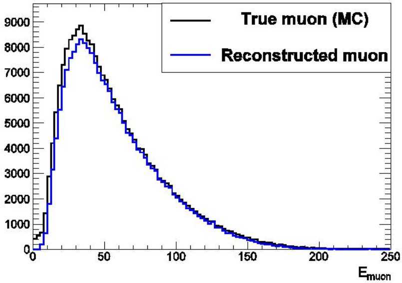


1. Force 4 jets clustering.
2. Isolate the lepton from one of the jets.
3. The two variables for the lepton isolation:
   $x_T = p_T / M_{jet}$ and
   $z = E_{lepton} / E_{jet}$
4. New 4 jets clustering without the lepton and flavour tagging.
5. Here we use only e and μ data samples, but we checked that τ doesn't degrade the results.

Isolation cuts

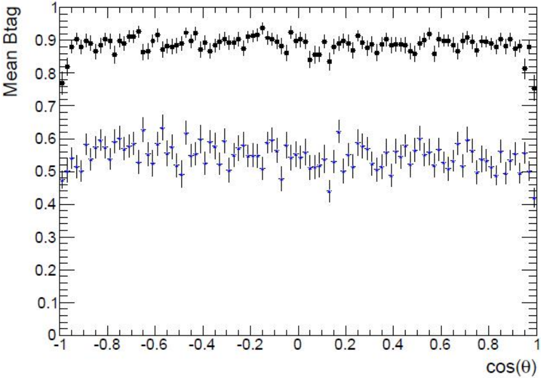


- Cut on x_T and z to removed the leptons not isolated (in blue) coming from full hadronic decay top.
- The cut is on $x_T > 0.25$ or $z > 0.6$.



- With this cut we have an efficiency of 88% and a contamination of 0.3% of bad reconstructed leptons.
- But the leptons with small energies are suppressed by the isolation cut.

B-tagging

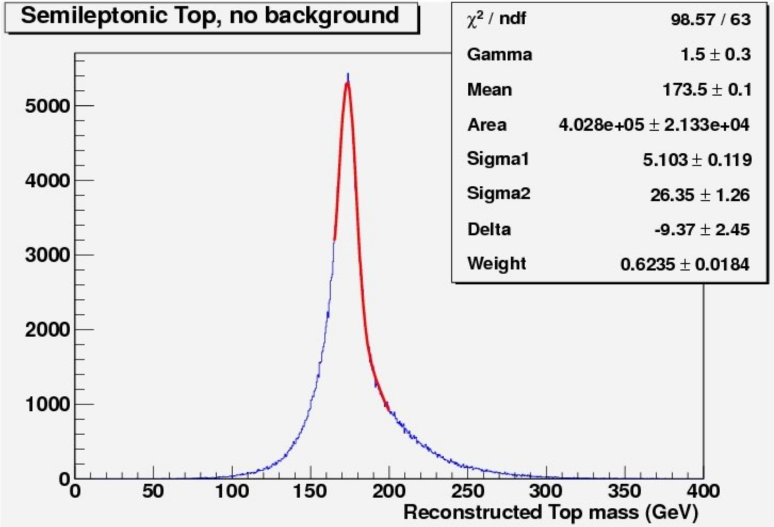


In black: B-tag value of the jet with the highest B-tag.

In blue: B-tag value of the jet with the second highest B-tag.

- B-tagging is done using LCFIVertex.
- We use the B-tag information to remove the background.
- At the end the efficiency is 72.7% with a contamination of 4.6%.

The Top mass

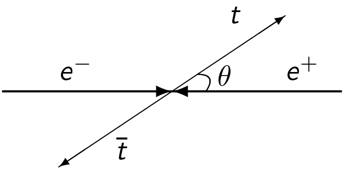


Fitted by a Breit-Wigner convoluted with the weighted sum of two Gaussians.

Method

The Forward Backward Asymmetry

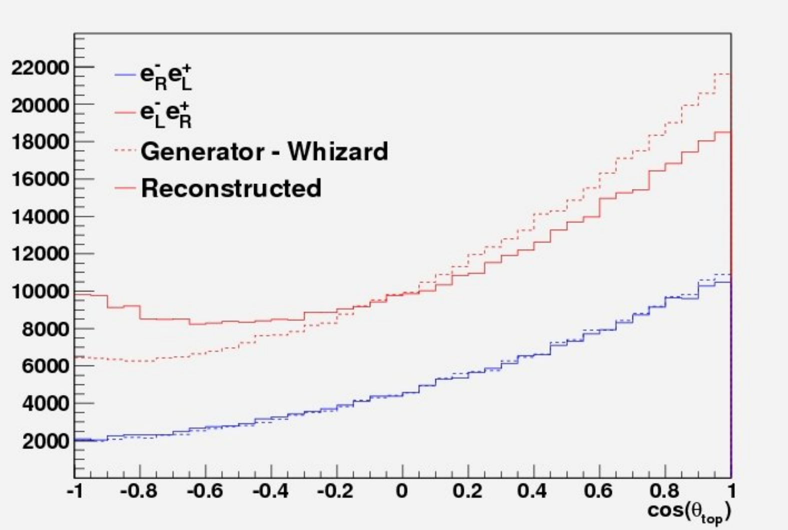
$$A_{FB} = \frac{N_{top}(cos(\theta)>0) - N_{top}(cos(\theta)<0)}{N_{top}(cos(\theta)>0) + N_{top}(cos(\theta)<0)}$$



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

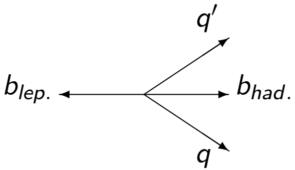
This observable is of particular interest because she shows tension with the standard model at Tevatron and also for the b quark at LEP.

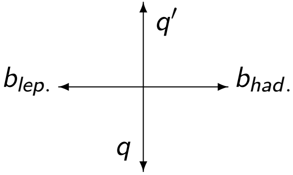
Results for A_{FB}



We see a clear migration effect for left-handed electrons.

Where does this migration comes from ?





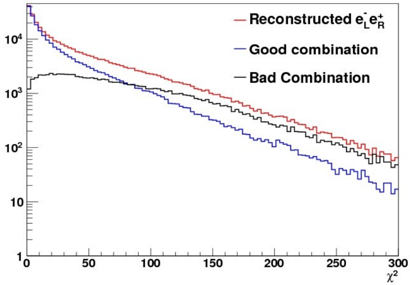
- Right-handed electron beam:
  The W is emitted into the flight direction of the top together with a soft b.
- In the case is the W is easily combine to the good b to reconstruct the top.

- 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.

How to cure migration ?

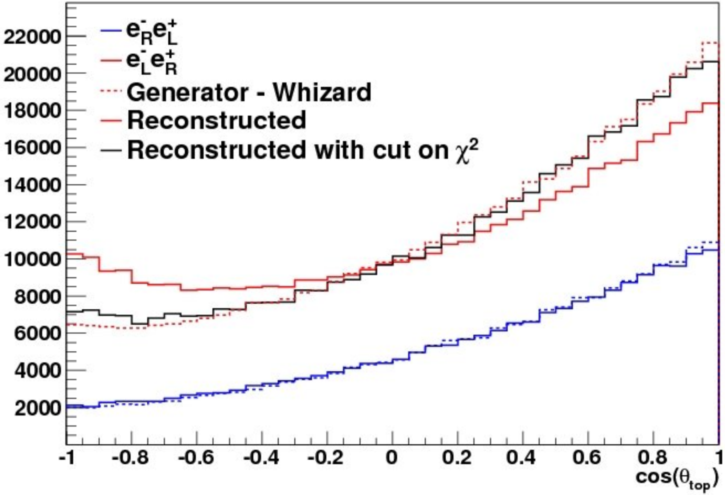
Make a χ^2 cut

$$\chi^2 = \frac{(M_t - 174)^2}{\sigma^2_{M_{top}}} + \frac{(E_t - 250)^2}{\sigma^2_{E_{top}}} + \frac{(P_b^* - 68)^2}{\sigma^2_{P_b^*}} + \frac{(cos(\theta_{Wb}) - 0.23)^2}{\sigma^2_{cos(\theta_{Wb})}}$$



1. A cut on χ^2 reduce the number of bad combination.
2. With no cut the efficiency is $\approx 70\%$ due to:
   - efficiency on the lepton tagging $\approx 88\%$.
   - cuts to suppress the background.
3. After a cut on $\chi^2 < 30$ efficiency goes to 38%.

Final Results for A_{FB}

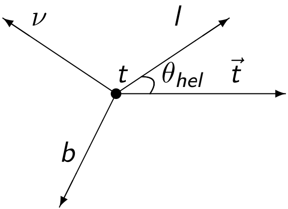


The cut on χ^2 remove the migration effect for left-handed electrons.

Method

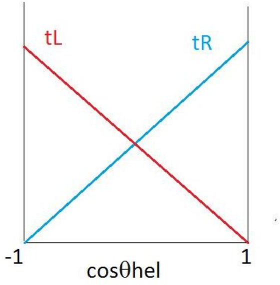
$\theta_{helicity}$

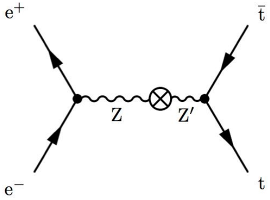
In the rest frame of the top, θ_{hel} is the angle between the direction of the top and the lepton.



- We find the direction of the leptonic top by measuring the one of the hadronic top and assuming momentum conservation.
- Then we make a Lorentz transform to the top rest frame to calculate $cos(\theta_{hel})$.

Why this new observable

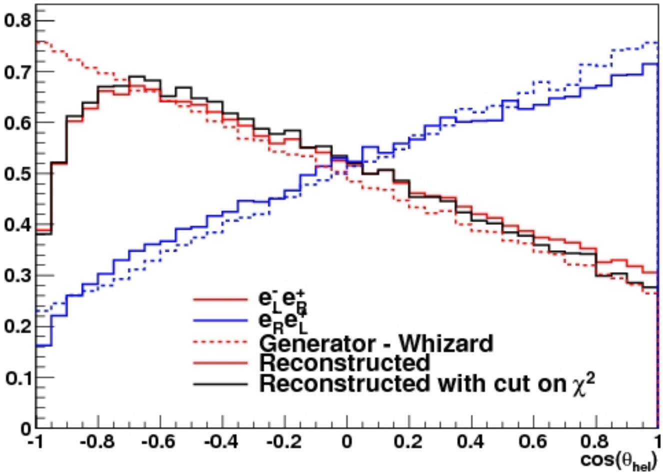




- $\frac{1}{\Gamma}\frac{d\Gamma}{dcos(\theta_{hel})} = \frac{1+\lambda_t cos(\theta_{hel})}{2}$ with $\lambda_t = -1$ for t_L, $\lambda_t = 1$ for t_R
- Then the slope give the fraction of t_L and t_R in the sample.

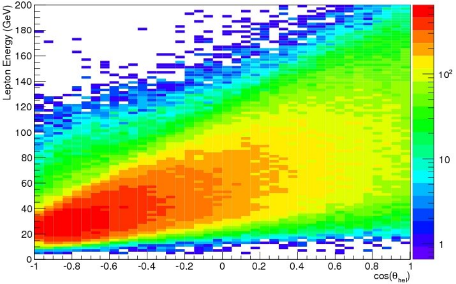
- We also measure the cross section of the process.
- All these measurements give access to coupling of top quarks to vector bosons.

Distribution of $cos(\theta_{hel})$



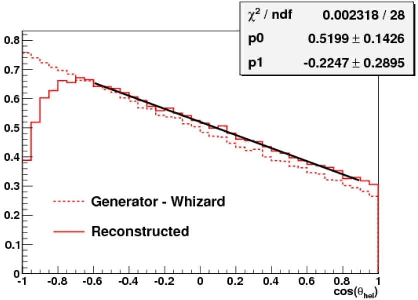
On a large part of the range the distribution is more robust to ambiguities, even without a χ^2 cut.

Where this hole for $cos(\theta_{hel}) < -0.6$ comes from ?



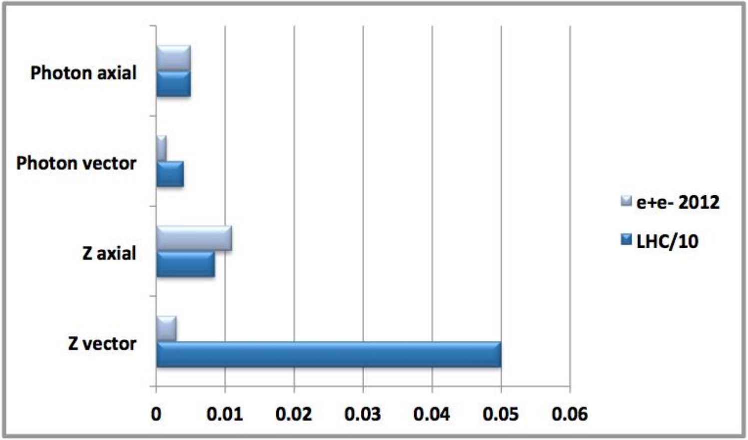
- Most of the leptons with $cos(\theta_{hel}) < -0.6$ have a low energy.
- These leptons are not well isolated in the jet.
- This hole comes from leptons that doesn't pass the isolation cuts.

Results



- Monte Carlo distribution: $\lambda_{hel} = -0.47$ with a variation of 2 % depending on the fit range.
- Reconstructed distribution: $\lambda_{hel} = -0.45$ with a variation of 0.9 % depending on the fit range.
- For the reconstructed with $\chi^2 < 30$ distribution: $\lambda_{hel} = -0.51$ with a variation of 0.6 % depending on the fit range.

Precision Reached

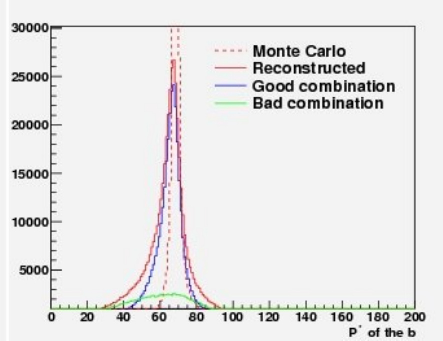


Preliminary estimation of the reachable precisions.

Conclusion

1. Show the importance of all the parts of the detector for this complex channel : lepton + 4 jets with 2 b jets.
2. Three observables are of particular interest: σ,A_{FB} and θ_{hel}.
3. For A_{FB} the migrations are understood and can be removed by a cut on χ^2.
4. For the helicity distribution is studied and seems more robust to probe new physics.
5. The update of the study with the DBD simulation and reconstruction software is on going.

P^* of the b



- In the rest frame of the top we also have access to the P^* of the b quark.
- The P^* should peak at 69 GeV and is a good variable to discriminate between the combination.