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

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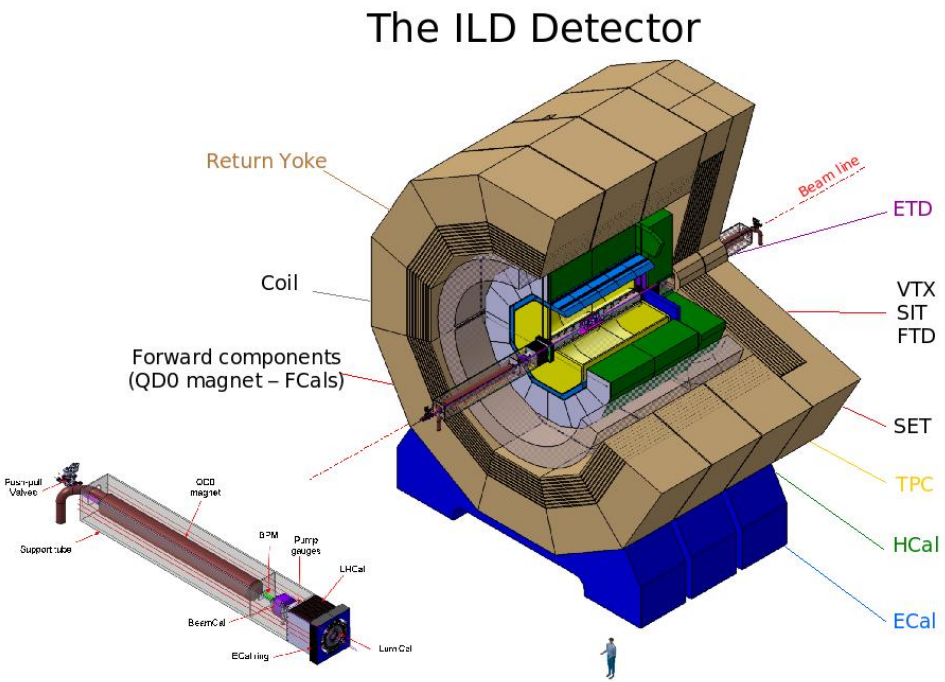
Outline

The Analysis

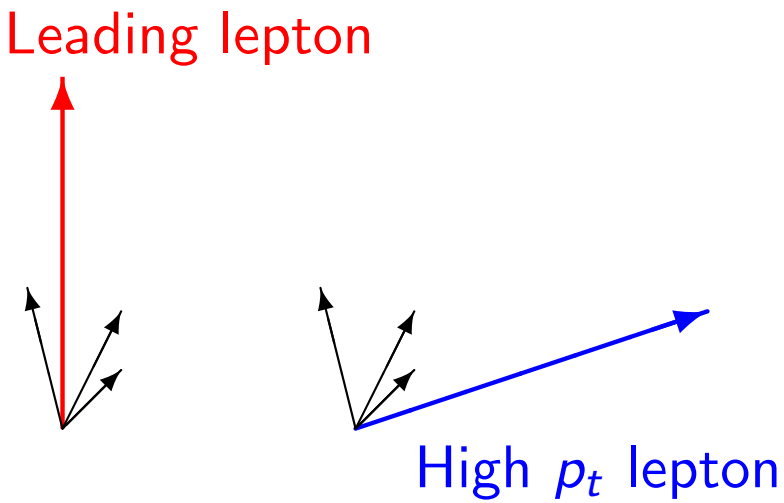
1. The analysis is done on the semi-leptonic decay of the top quark:
   $t\bar{t} \longrightarrow (bW)(bW) \longrightarrow (bqq)(bl\nu)$
2. We use the charge of the lepton to know the charge of the top.
3. The full simulation are done with the ILD detector (Mokka + Whizard software).
4. The reconstruction is based on the Particle Flow Algorithm (Pandora) and is done with Marlin on the data samples prepare for the LOI.

The International Large Detector (ILD)



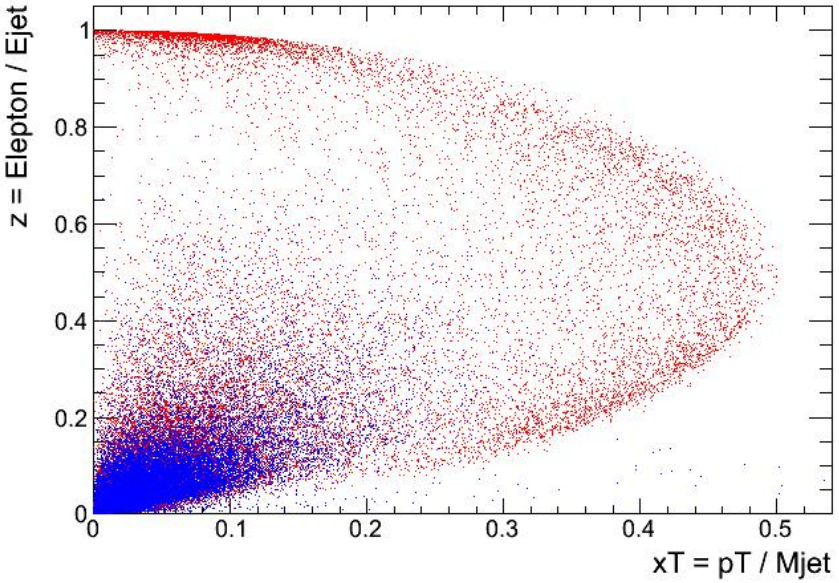
1. The ILD is one detector concept for the ILC.
2. The detectors are optimized for Particle Flow Algorithm.
3. Highly granular calorimeters are tested for the ILD.

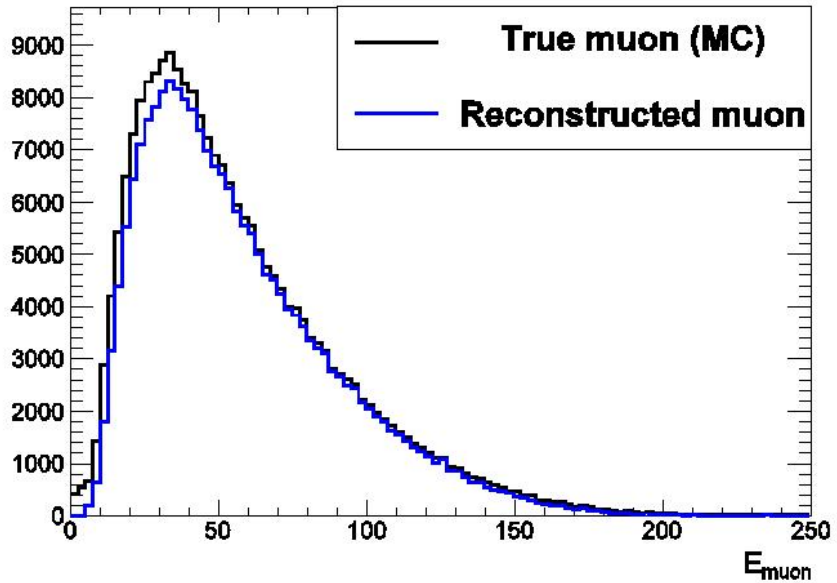
The Lepton isolation



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.

Isolation cuts

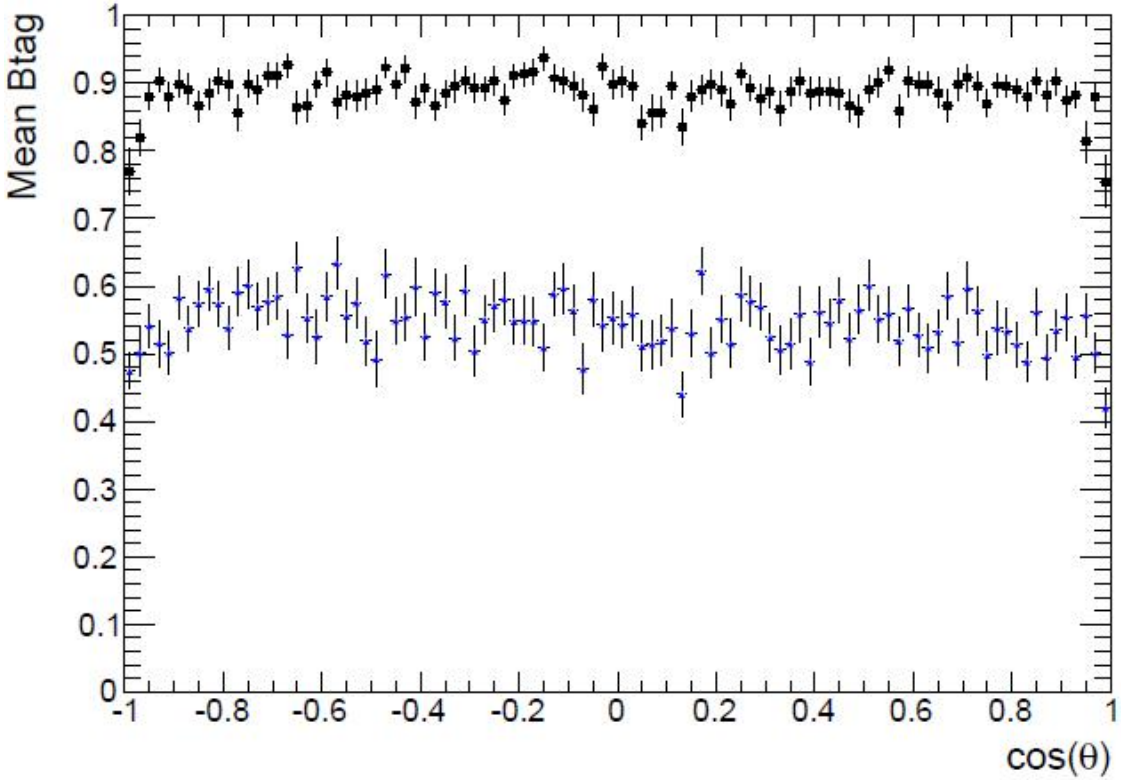




- Cut on x_T and z to removed the leptons not isolated (in blue) coming from full hadronic decay top.
- The cut is on $x_T > 0.25$ or $z > 0.6$.

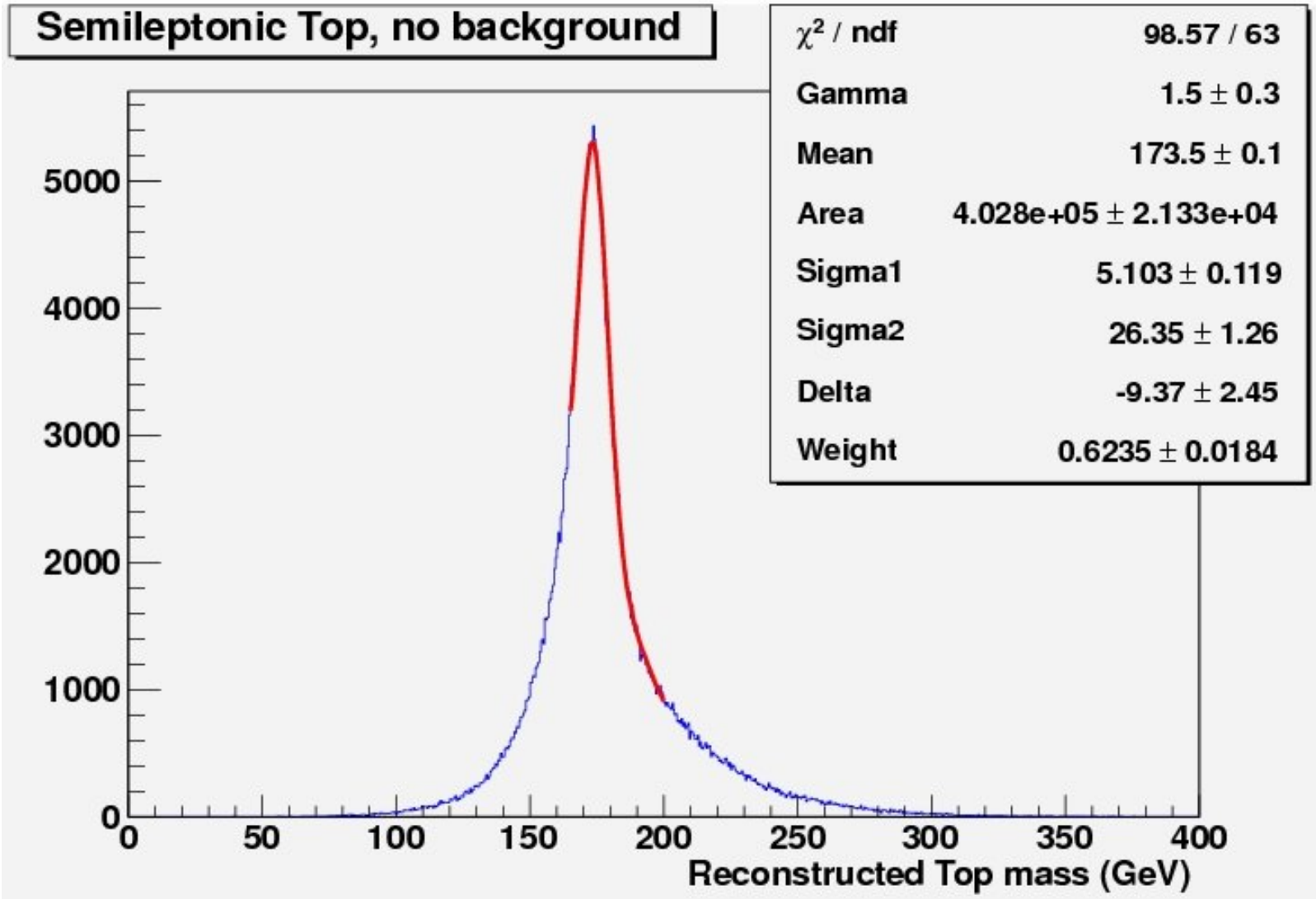
- With this cut we have an efficiency of 88% and a contamination of 0.3%.
- But the leptons with small energies are suppressed by the isolation cut.

B-tagging



- 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

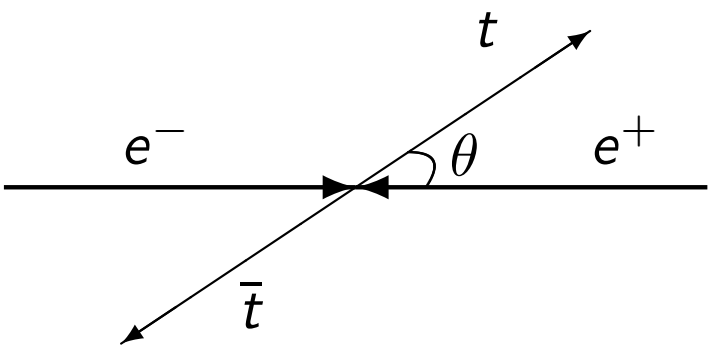


Fitted by a Breit-Wigner convoluted with the weighted sum of two Gaussians.

Method

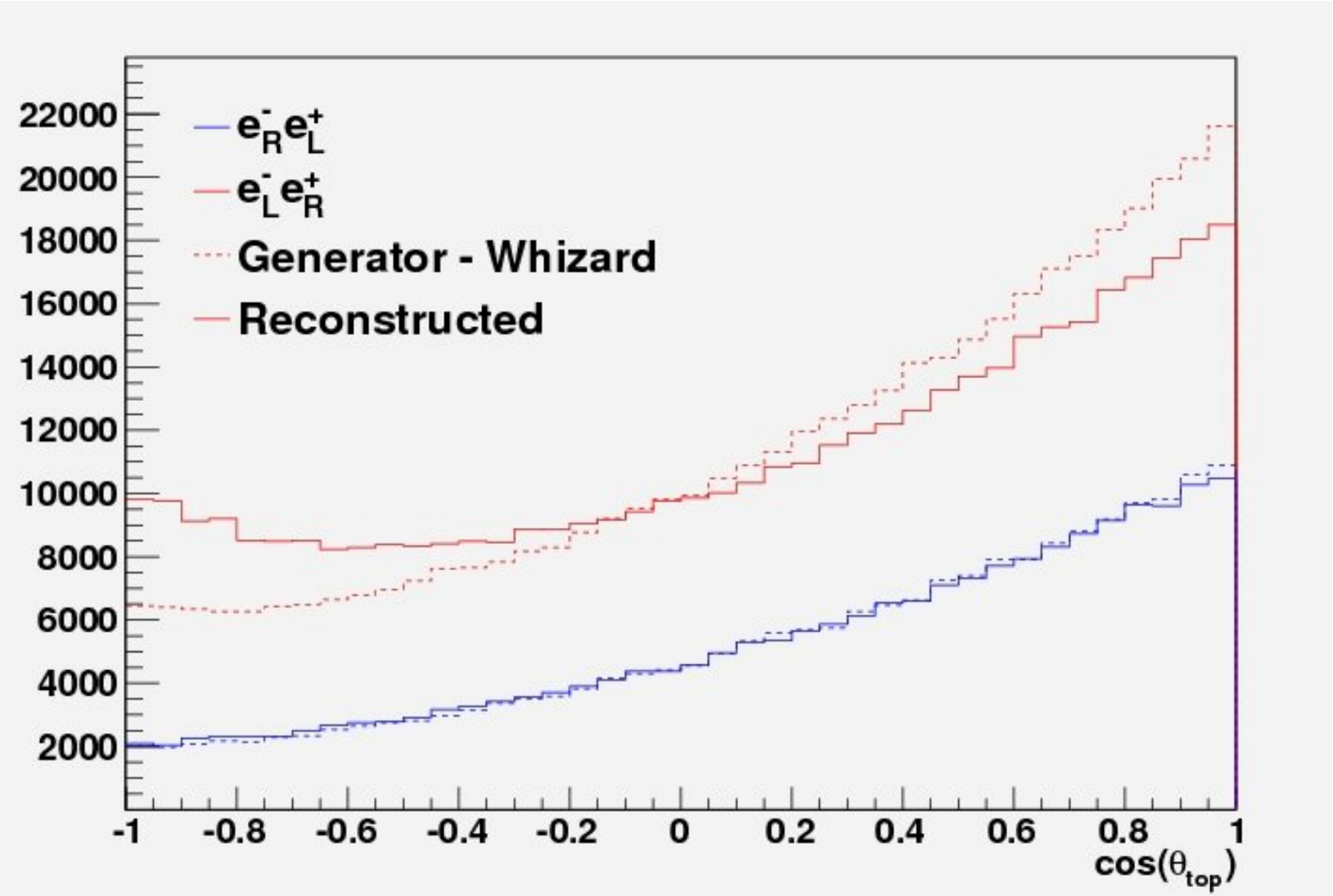
The Forward Backward Asymmetry

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



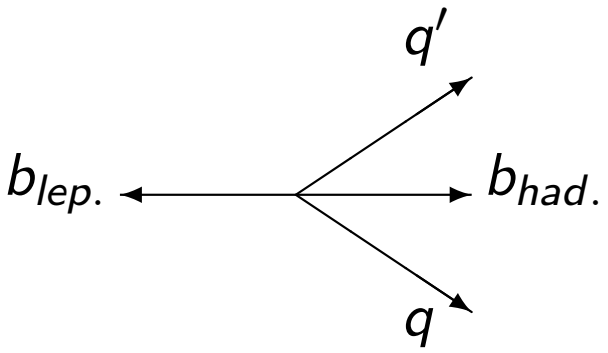
1. The sign of the top is the opposite one of the lepton.
2. For $\bar{t}$ we change θ to $\theta + \pi$.

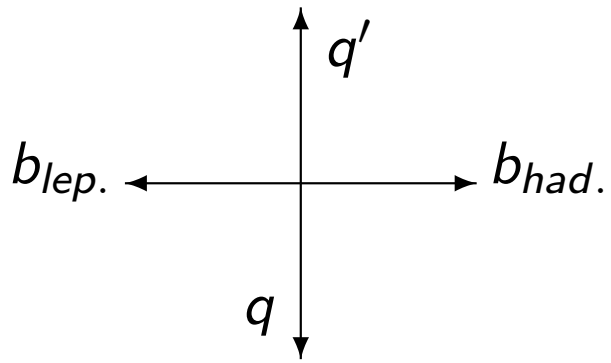
Results for A_{FB}



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

Where does this migration comes from ?





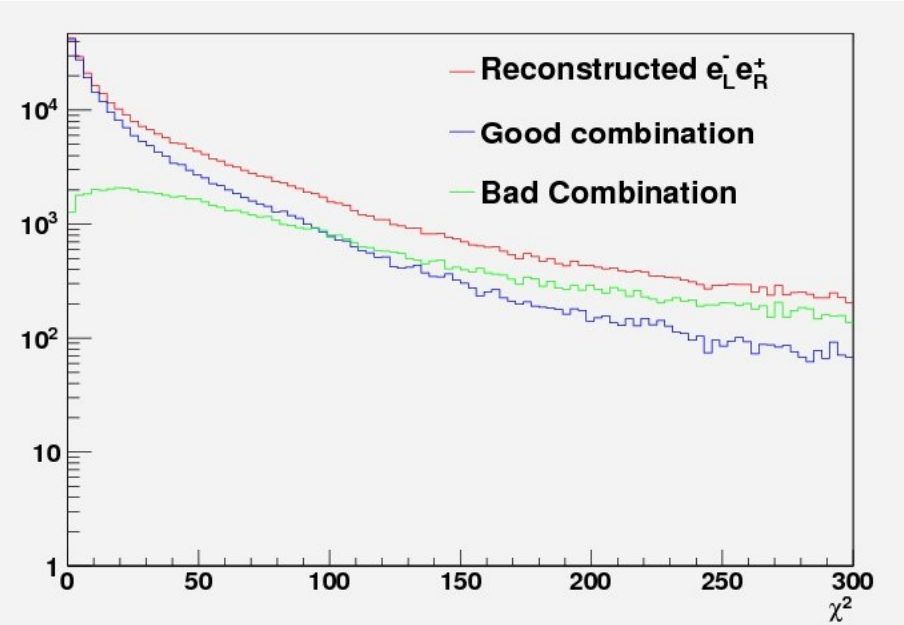
- Right-handed electron beam:
  The W is emitted into the flight direction of the top.
- In the case is the W is easily combine to the good b to reconstruct the top.

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

How to cure migration ?

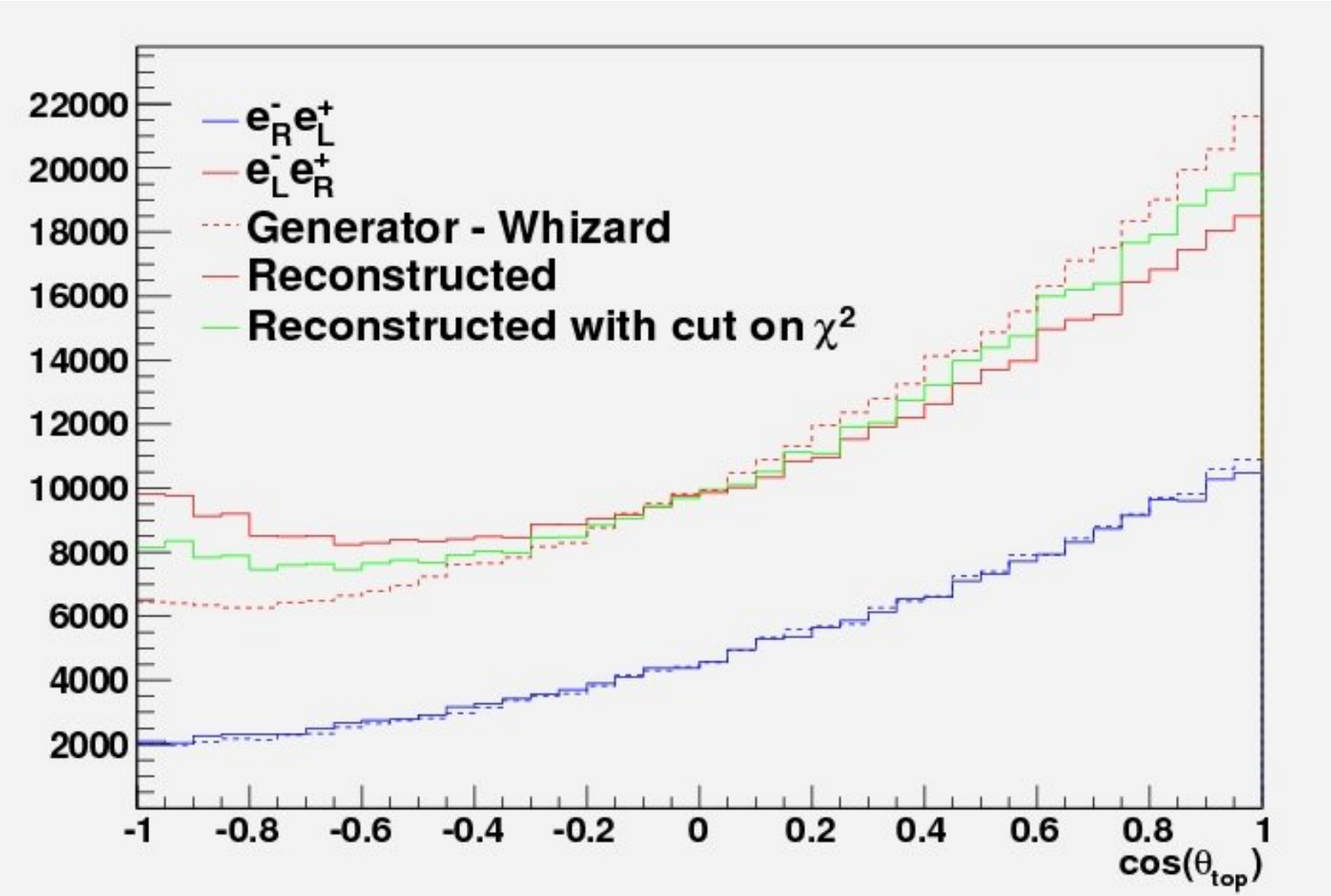
Make a χ^2 cut

$$\chi^2 = \frac{(M_t - 174)^2}{\sigma^2_{M_{top}}} + \frac{(E_t - 250)^2}{\sigma^2_{E_{top}}} + \frac{(P^*_b - 69)^2}{\sigma^2_{P^*_b}}$$



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 $\chi^2 < 50$ efficiency goes to 46%.

Final Results for A_{FB}

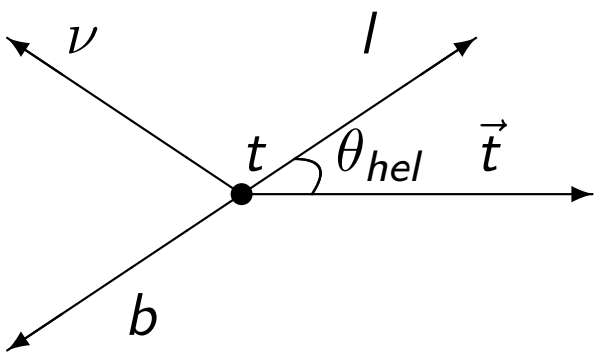


The cut on χ^2 reduce the migration effect for left-handed electrons.

Method

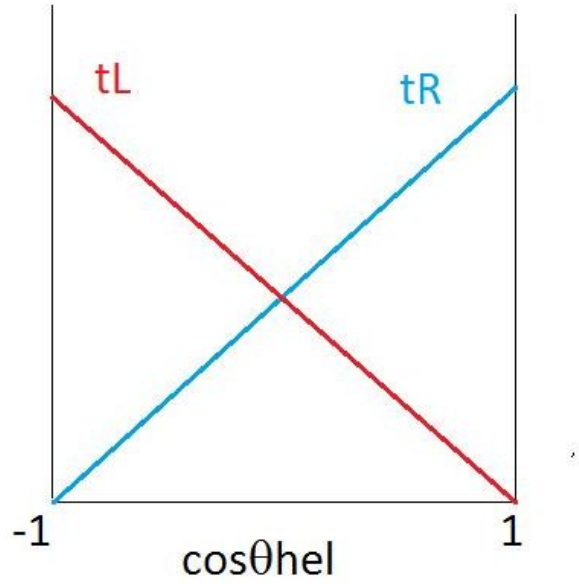
$\theta_{helicity}$

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

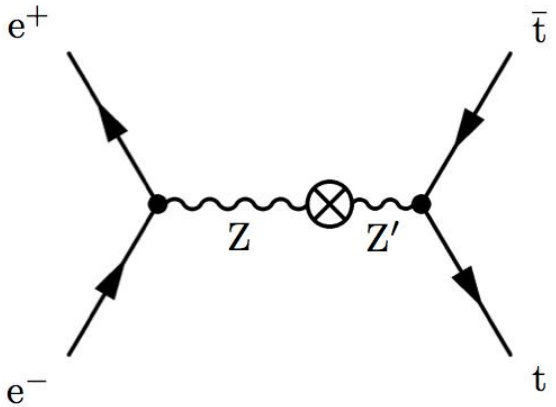


- We find the direction of the leptonic top by measuring the one of the hadronic top and assuming momentum conservation.
- Then we make a Lorentz transform to the top rest frame to calculate $cos(\theta_{hel})$.

Why this new observable

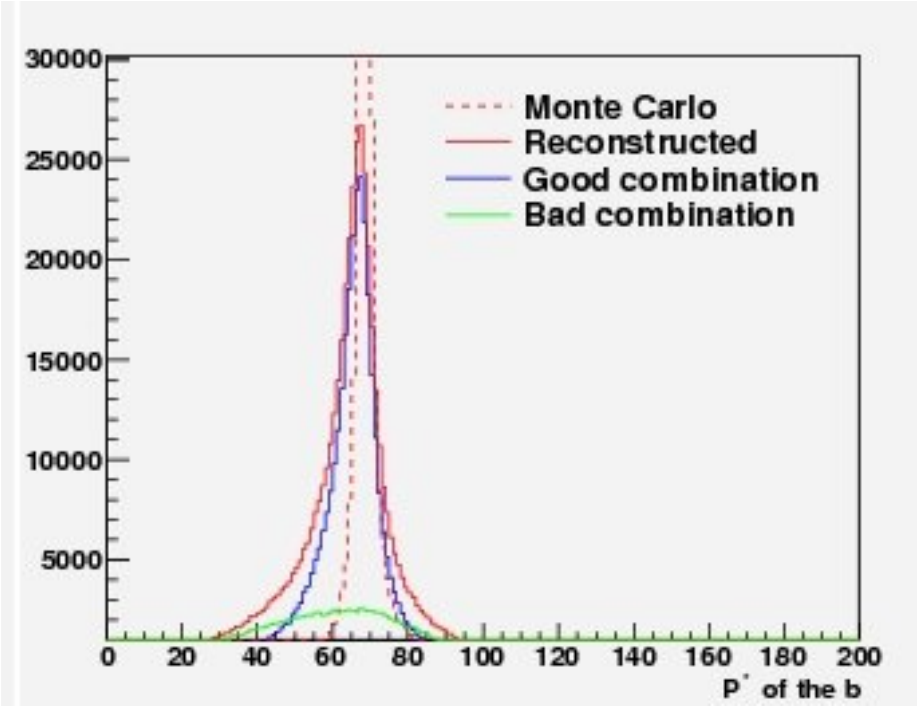


- $\frac{1}{\Gamma}\frac{d\Gamma}{dcos(\theta_{hel})} = \frac{1+\lambda_t cos(\theta_{hel})}{2}$ with $\lambda_t = -1$ for t_L, $\lambda_t = 1$ for t_R
- Then the slope give the fraction of t_L and t_R in the sample.



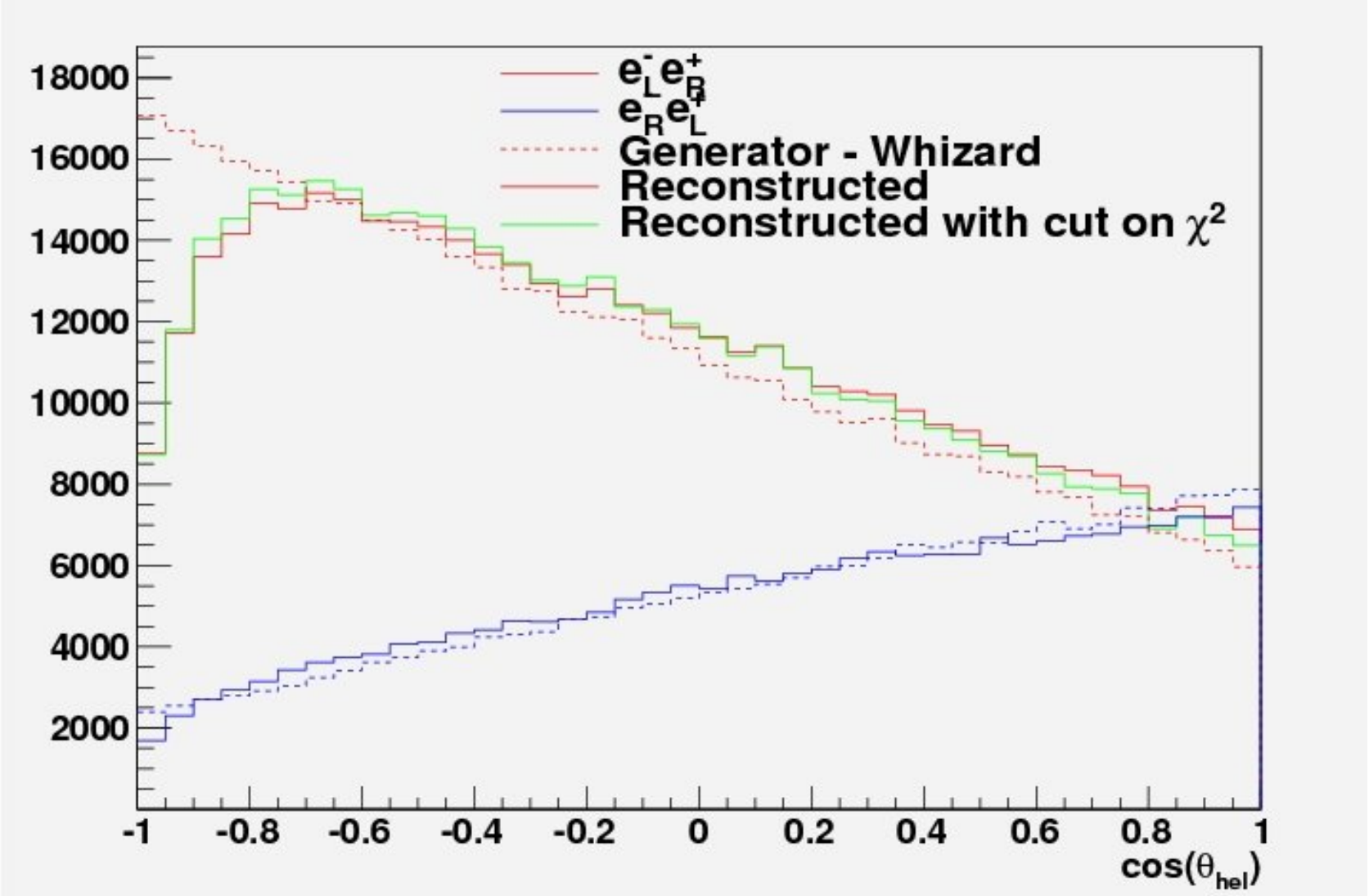
- The slope is more robust to migration effects.
- This measurement give access to coupling of top quarks to vector bosons.

P^* of the b



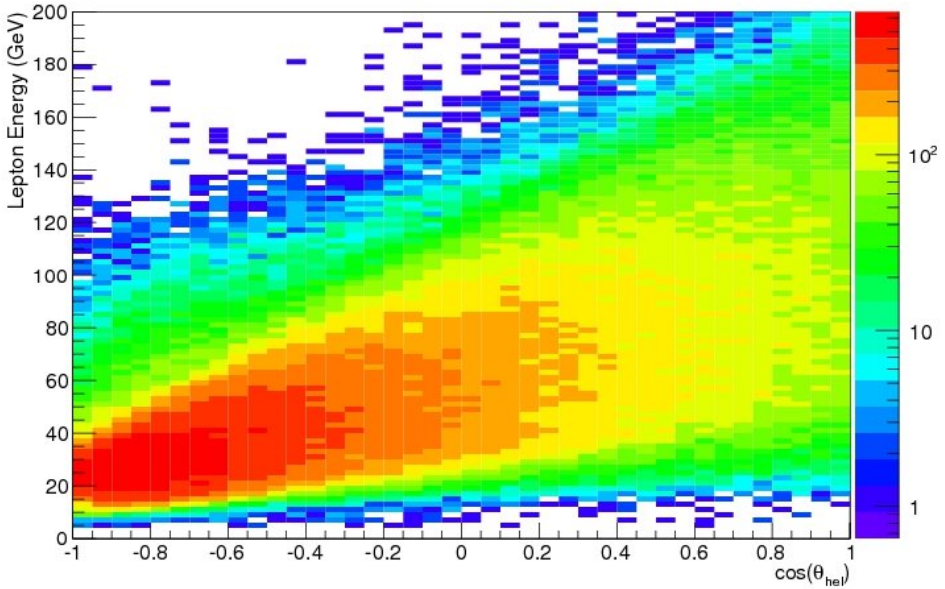
- In the rest frame of the top we also have access to the P^* of the b quark.
- The P^* should peak at 69 GeV and is a good variable to discriminate between the combination.

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 ?

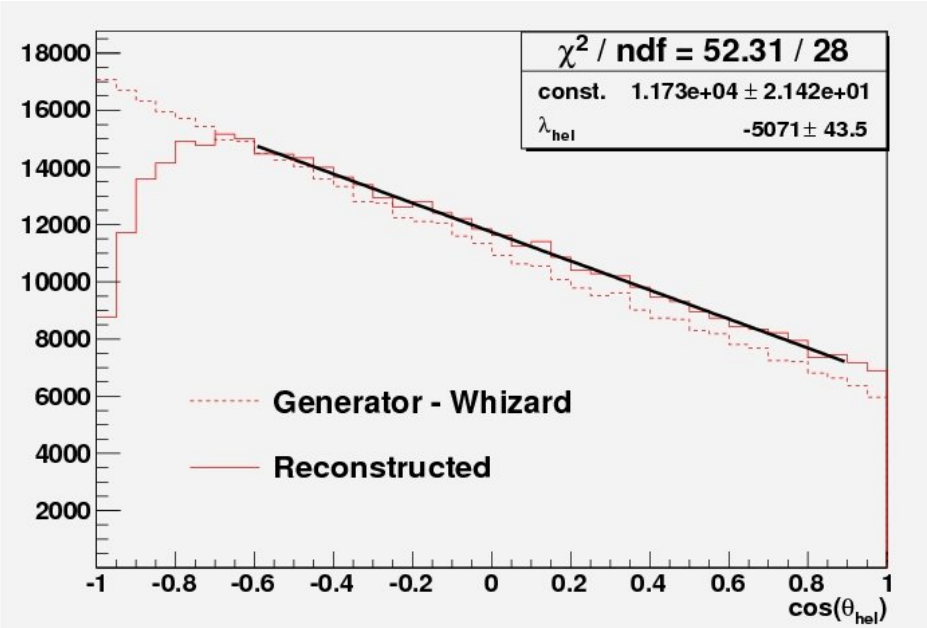


- Most of the leptons with $cos(\theta_{hel}) < -0.6$ have a low energy.
- These leptons are not well isolated in the jet.
- This hole comes from leptons that doesn't pass the isolation cuts.

How to deal with this hole

- This hole make the measurement of the helicity asymmetry difficult.
- Instead we can use the slope λ_{hel} of the distribution as observable.
- The slope have a linear dependence with the angular distribution, and is not affect by the hole.

Results



- Monte Carlo distribution: $\lambda_{hel} = -5340$ with a variation of 2 % depending on the fit range.
- Reconstructed distribution: $\lambda_{hel} = -5067$ with a variation of 0.8 % depending on the fit range.
- For the reconstructed with $\chi^2 < 50$ distribution: $\lambda_{hel} = -5484$ with a variation of 1 % depending on the fit range.

Conclusion

1. The semi-leptonic decay of the top is studied.
2. Two variables are of particular interest.
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. All the study are also done in parallel at IFIC with fast simulation.
6. The update of the study with the DBD simulation and reconstruction software is on going.