Forward backward asymmetry measurements in $e^-e^+ \to b\bar{b}$ at ILC@250GeV

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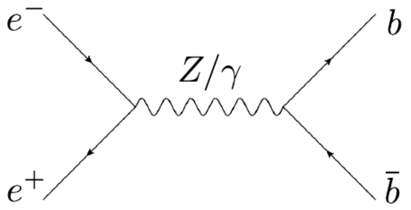
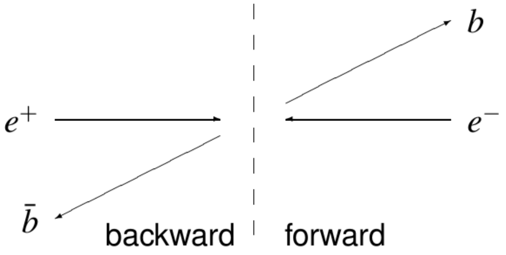
LCWS18 at UTA, Texas

Motivation

- B-quark electroweak couplings can be inferred from cross section and forward backward asymmetry (Afb) observables.





$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

$$\frac{d\sigma^I}{d\cos\theta} = A^I(1+\cos^2\theta) + B^I\cos\theta + C^I\sin^2\theta \qquad I = L, R$$

where the $A\ B\ C$ are

A^I cross section magnitude $\propto \mathcal{F}^I_{1V}, \mathcal{F}^I_{2V}, \mathcal{F}^I_{1A}$

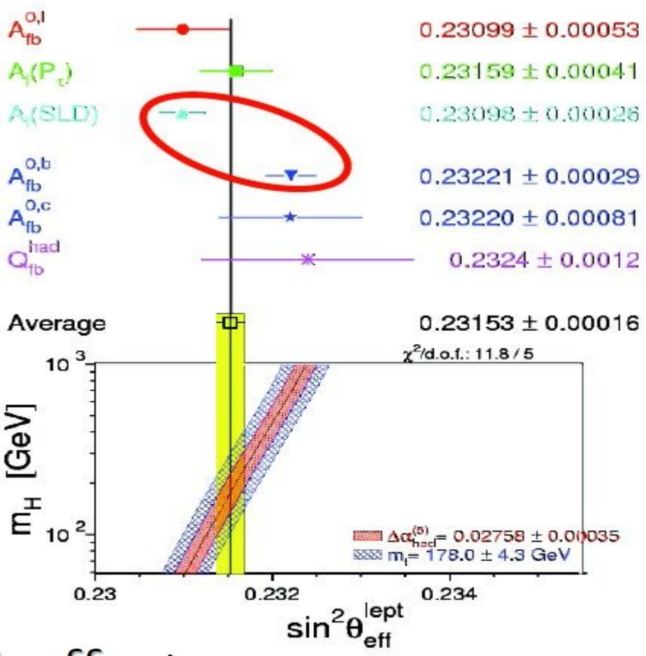
B^I asymmetry magnitude $\propto \mathcal{F}^I_{1A}, \mathcal{F}^I_{1V}, \mathcal{F}^I_{2V}$

C^I spin flip $\propto \gamma^{-1}\mathcal{F}^I_{1V}, \gamma\mathcal{F}^I_{2V}$

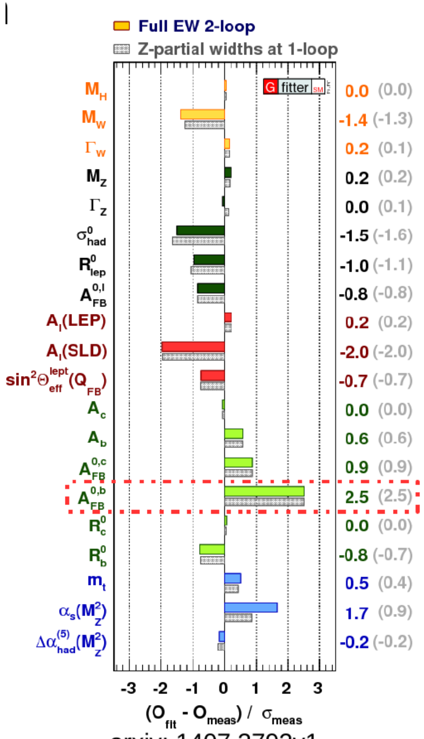
- Afb has been measured in SLC and LEP at the Z-pole

Motivation

- Current LEP & SLC **measurements** show **tension** between their **Afb** measurement
- Even more, current Afb measurement is the one with largest tension with the SM fit.



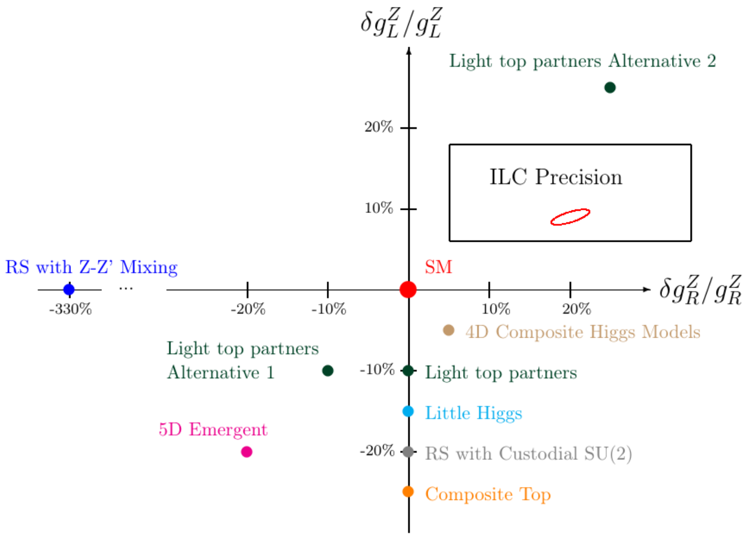
LEP1 effect

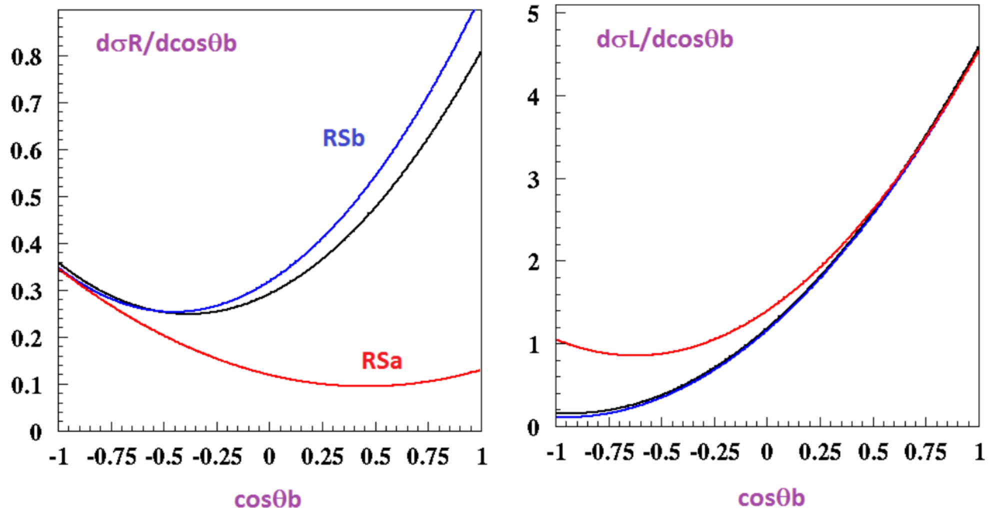


arxiv: 1407.3792v1

Motivation

- Many **composite models predict deviations** in the fermion **electroweak couplings** (specially in the heavy flavors)
  - can be observed in the cross sections and **Afb** measurements **if measured at the % level**
  - See M. Peskin's talk from yesterday.
- ILC provides bb events produced at the Z-pole and and far of it with polarized beams.





Example of **Randal Sundrum extra dimension** models prediction for b-quark asymmetry.

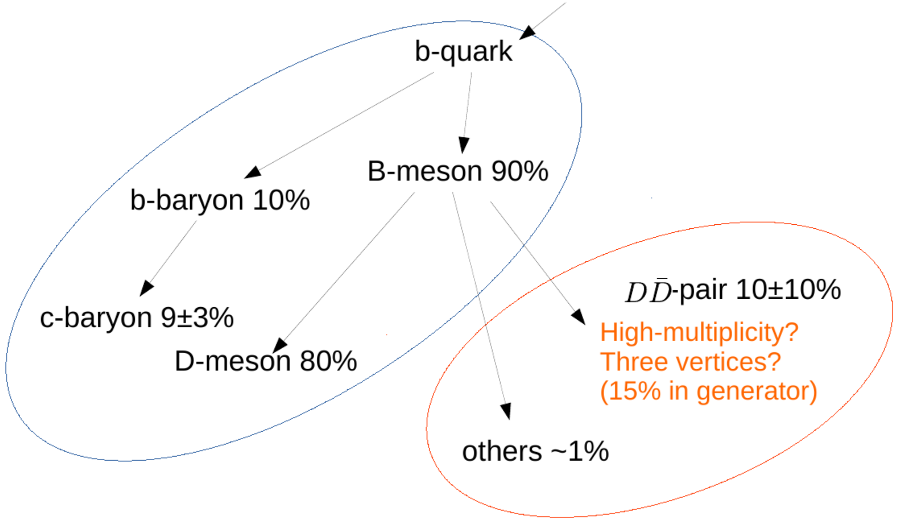
(F. Richard et al)

Process overview

- The goal is to measure the asymmetry basically by measuring the **direction** of the two final state jets and their **charge**. **How?**

Process overview

- Hadronization and decay modes of b-quark:



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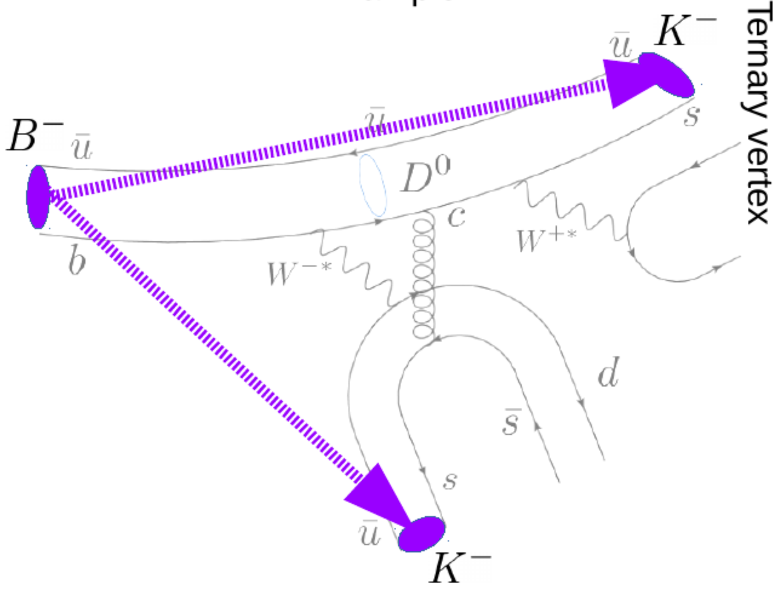
Example



Secondary vertex

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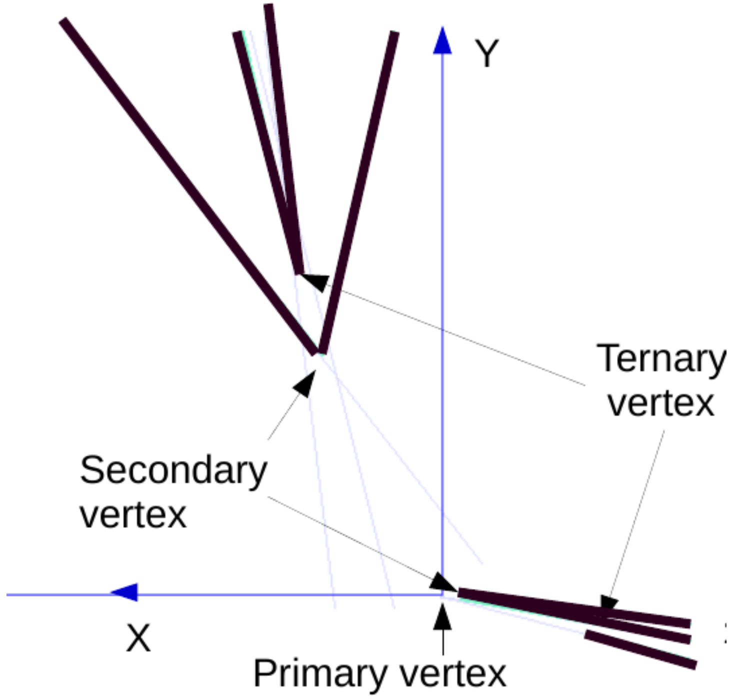
b-asymmetry measurement

- The goal is to measure the asymmetry basically by measuring the direction of the two final state jets and their charge. **How?**



- We have two methods to identify b-jet charge:
  - With the charge of the b-quark, calculated as a sum of the charges of secondary and tertiary vertex

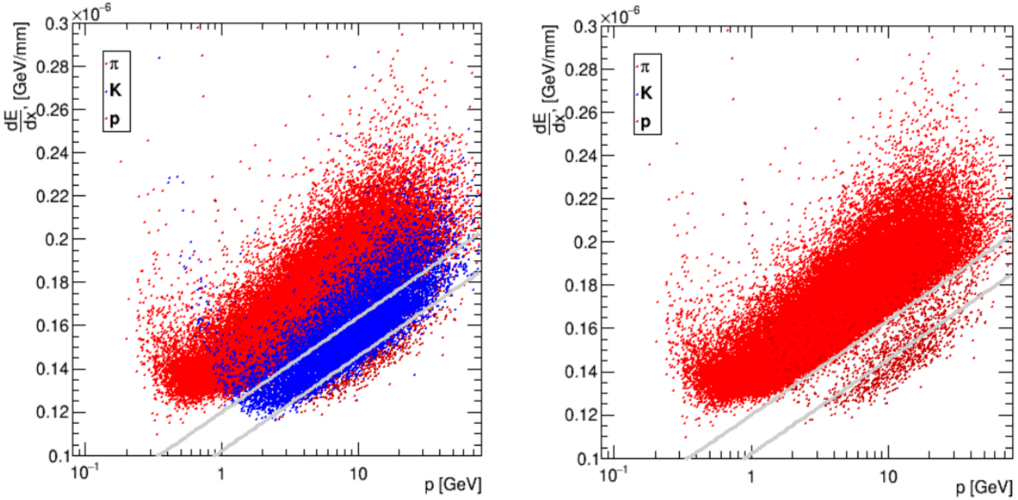
    → we call this method the Bc method (or vtx method)

  - With the charge of K-mesons, from B-decays, in secondary and tertiary vertexes

    → we call this method the Kc method (or kaon method)

Kaon identification

dE/dx as function of a track momentum for different types of particles from secondary and ternary vertices



- It is possible to identify kaons with high purity
- In current analysis kaons are selected using generator information for ternary tracks with TPC hits > 60 and $|cos\theta| < 0.95$

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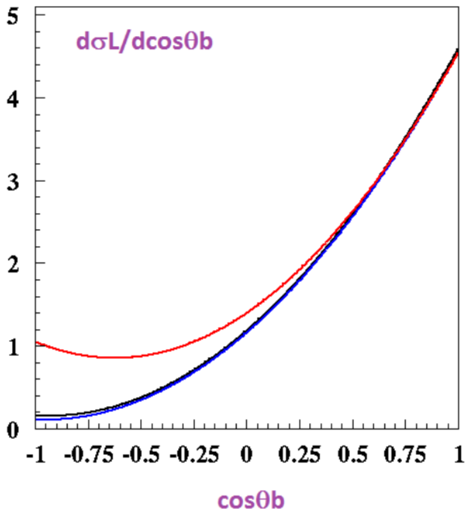
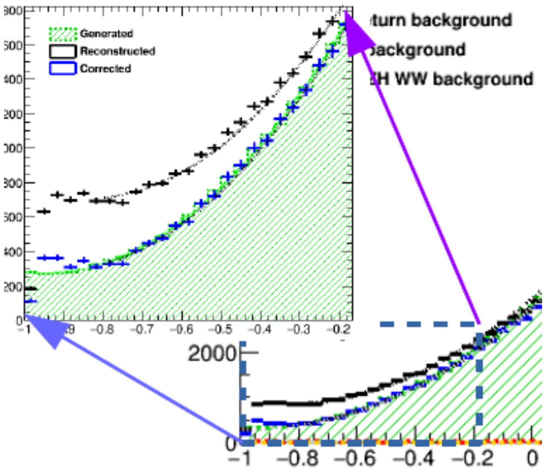
- Kaon identification
  - 88% eff
  - 95% purity

$b\bar{b}$-asymmetry measurement

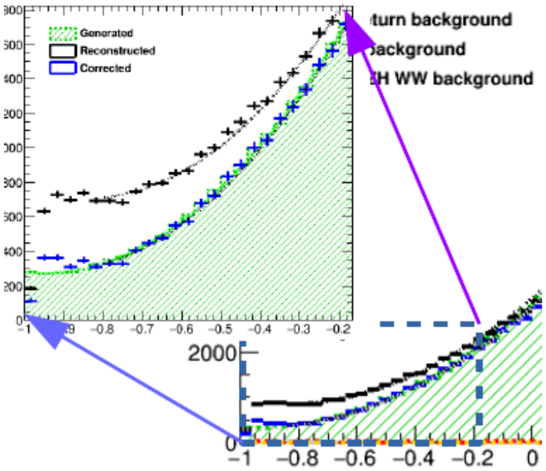
- All results shown here are for the bb asymmetry measurement (cosθ) using $e^+e^- \rightarrow b\bar{b}$, 250 GeV, for pure left and right handed polarizations.
  - /ilc/prod/ilc/mc-dbd/ild/dst-merged/250-TDR_ws/2f-highM_Z_hadronic + ILCsoft v01-17-06
  - Each sample has~250 fb-1 (reweighting to be done)
- Preselection
  - Durham with 2 exclusive jets
  - Btag(j1)>0.9 && btag(j2)>0.2
  - Recoil cut (events with a photon with E>40GeV or m(j1j2)<180GeV rejected)
  - m(j1)+m(j2)<120

- The $\frac{d\sigma^I}{d\cos\theta}$ distribution is very asymmetric specially for the electron left-handed polarization case.
- If the charge calculation is not perfect, events from positive angles will counted as negative in some cases (or the opposite). As the distribution is very stiffed, this effect will be asymmetric





- The migration effect can be corrected using the data (next slide)



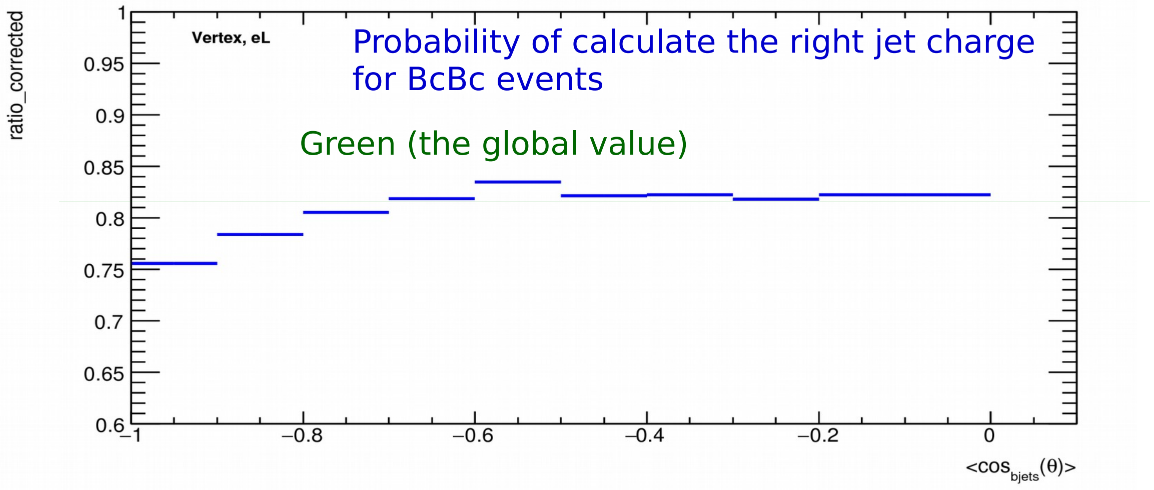
- The migrations are fixed by determining the purity of the charge calculation using double tagged events with compatible and uncompatible charges
  - with the assumption of only 2 quarks produced in the hard interaction.

- Assume that around a certain value $|cos\theta_b|$ we have rejected N_r events as being contradictory, selected N_a^+ events as having $|cos\theta_b| > 0$ and N_a^- events with $|cos\theta_b| < 0$
- Then one can write

$$N_a = N_a^+ + N_a^- = p^2 N + q^2 N$$

- Where *p* is a charge purity, *q=1-p*
- We can find *p* by solving these equations.

- The migration feature limits the efficiency: we can only use events with double charge measurement (double tagged)
  - In the first attempt, we only considered pure & exclusive double tagged events using one or the other method (so both jets charge measured with the Bc or the Kc methods)
  - Also, we were only considering measurements in different jets.
  - The reason for those limitations is that the correction was not working for "crossed" combinations.
  - This is solved by using a differential correction, instead of a global value for the purity..



- 6 categories are defined.
  - **BcBc opposite** jets and I do not care about Kc. **Category 1** (non exclusive)
  - **KcKc opposite jets,** and again I don not care about Bc, **Category 2** (non exclusive but not category 1)
  - **BcKc** in the **same** jet (the one with higher b-tag) with the other jet Kc and Bc =0. **Category 3** (not category 1-2)
  - the **same**, but in the jet with smaller btag. **Category 4** (not category 1-3)
  - **BcKc**, **opposite** jets, with the other Kc and Bc =0. **Category 5** (not category 1-4)
  - **KcBc**, **opposite** jets, with the other Bc and Kc =0. **Category 6** (not category 1-5)

- Similar to the old approach, although before we consider only exclusive combinations (categories 1–2)
- 4 new categories defined now (categories 3–6)

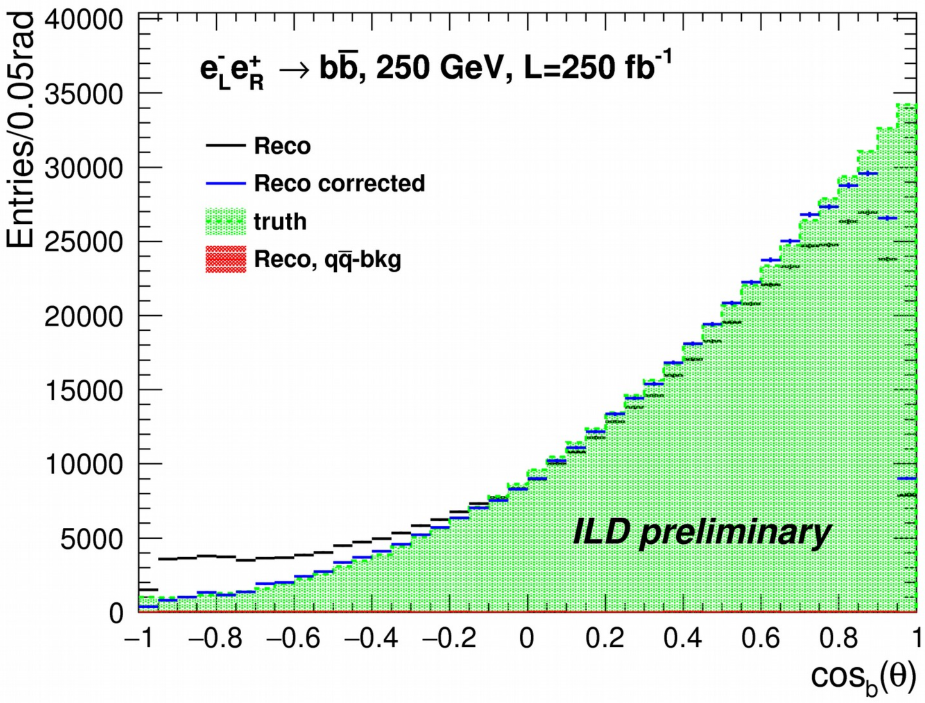
Charge calculation categories

250GeV, eL, DBD		
Step	**Eff**	**Bkg(qq)**
Preselection:	62,9 %	0,5 %
BcBc:	12,8 %	0,2 %
KcKc:	4,7 %	0,1 %
BcKc(jet1):	4,4 %	0,1 %
BcKc(jet2):	2,4 %	0,0 %
BcKc:	1,5 %	0,0 %
KcBc:	2,4 %	0,0 %
total	**28,2 %**	**0,4 %**

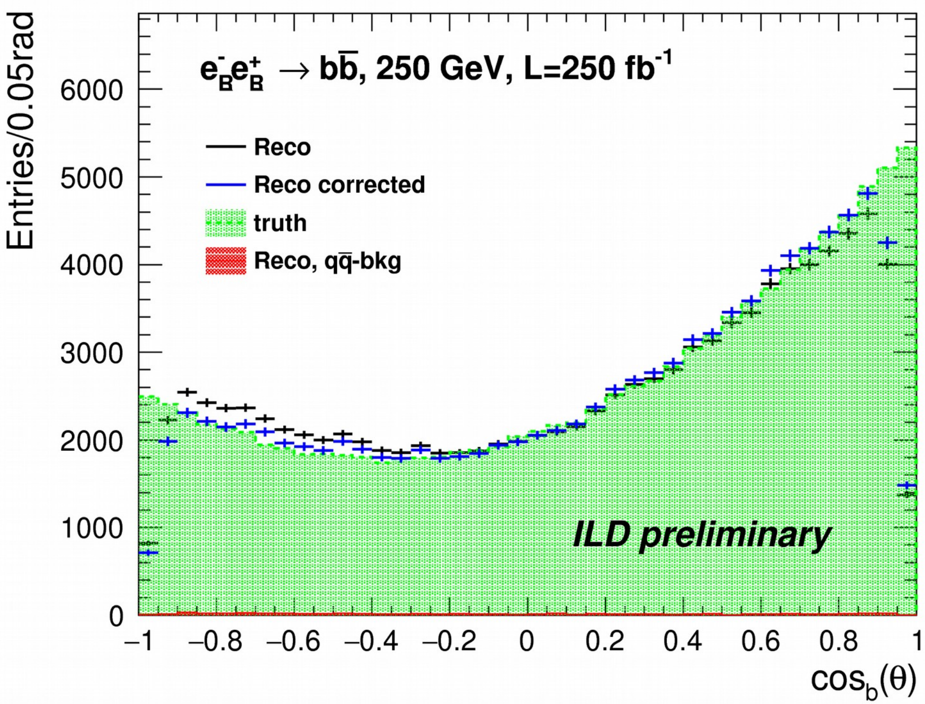
250GeV, eR, DBD		
Step	**Eff**	**Bkg(qq)**
Preselection:	63,1 %	0,9 %
BcBc:	12,9 %	0,3 %
KcKc:	4,6 %	0,1 %
BcKc(jet1):	4,4 %	0,1 %
BcKc(jet2):	2,4 %	0,0 %
BcKc:	1,5 %	0,1 %
KcBc:	2,4 %	0,0 %
total	**28,2 %**	**0,7 %**

- **The use of dE/dX allows to multiplicate the efficiency by 2.2**

Result

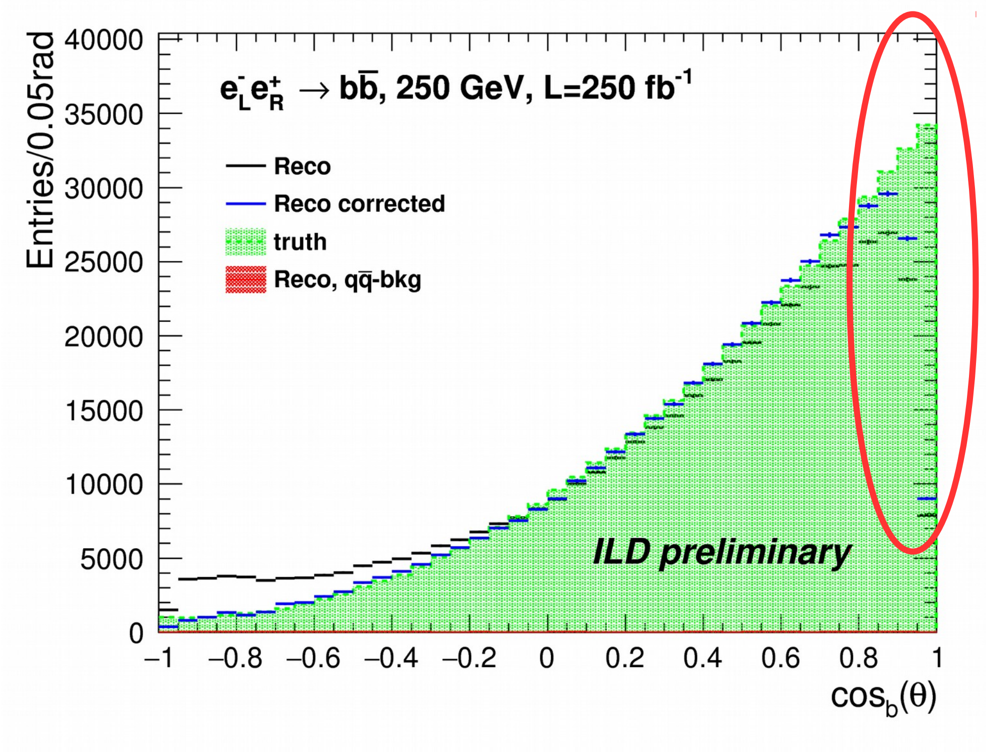


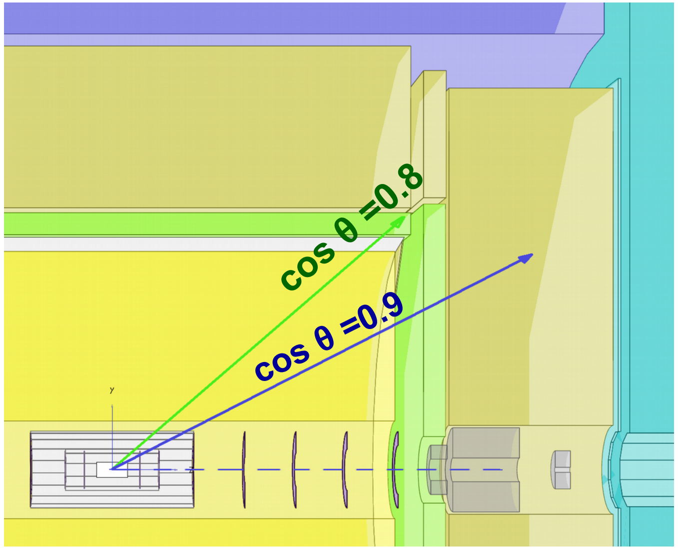
$e^-_L e^+_R \to b\bar{b}$, 250 GeV, L=250 fb^{-1}
Reco
Reco corrected
truth
Reco, $q\bar{q}$-bkg
ILD preliminary
Entries/0.05rad
$\cos_b(\theta)$



$e^-_R e^+_L \to b\bar{b}$, 250 GeV, L=250 fb^{-1}
Reco
Reco corrected
truth
Reco, $q\bar{q}$-bkg
ILD preliminary
Entries/0.05rad
$\cos_b(\theta)$

Result

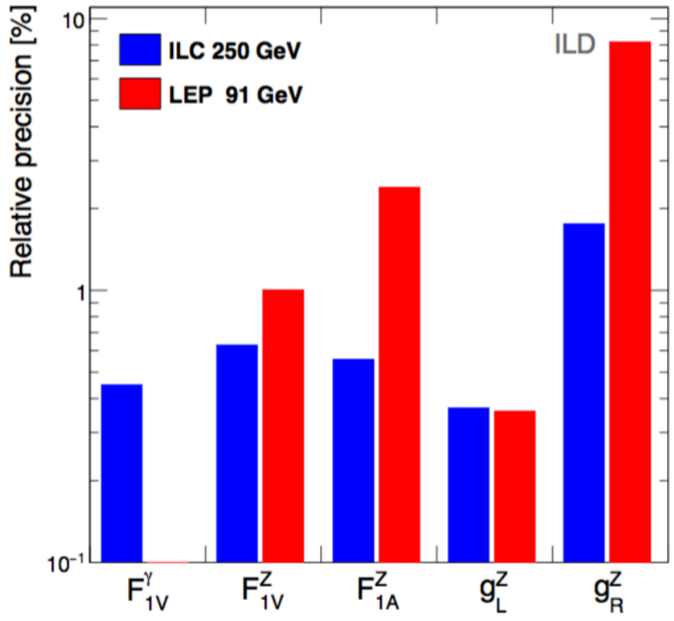




- Defficiency in vertexing for cos θ > 0.9 (and 0.8)
  - Gap between VTX barrel and first FTD disk

Conclusions

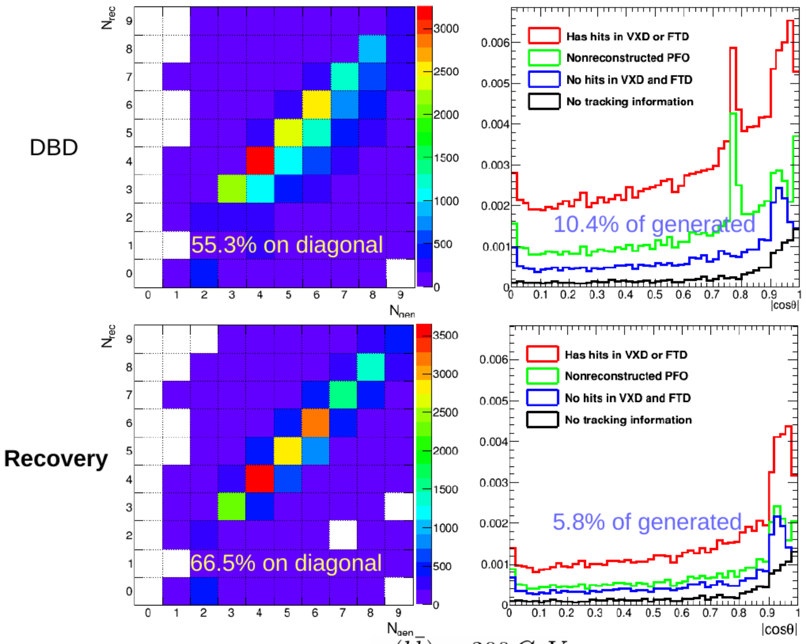
- Two fermion final states are an excellent probe for new physics:
  - i.e. compositeness models as Randall Sundrum models.
  - See M. Peskin's talk for a short introduction.
- Cross sections and Afb observables measurement with high precision are needed.
- ILC will be able to do these measurements with high precision
  - unprecedented &, competing with current levels of theoretical predictions
- In addition, Afb(b) has been proven to be a very suitable observable for detector optimization and benchmarking.
  - It uses information from all subdetectors (including dE/dX)
  - It reveals some detector limitations



- Experimental precision for 500 fb^{-1} with 13% efficiency assumed
  - Including full bkg estimations
  - Results to be updated with the new efficiencies

Back-up slides

Reconstruction quality DBD vs Recovery



$m(b\bar{b}) > 200\,GeV$

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- Method developed in S. Bilokin thesis to recover lost vertexes.
- Tested in bb and tt (semileptonic) final states.
- Manages to recover ~50% of the lost vertexes.
- Used in all results shown here (except in the ttbar fully hadronic)
- Processor is in https://github.com/QQbarAnalysis/VertexRestorer
- To be checked, updated and pushed to the ILCsoft repository… where?

B polar angle correction

- To cope with 'migration' effect, we have used the large sample of events with contradictory charges
- Assume that around a certain value $|cos\theta_b|$ we have rejected N_r events as being contradictory, selected N_a^+ events as having $|cos\theta_b| > 0$ and N_a^- events with $|cos\theta_b| < 0$
- Then one can write

$$N_a = N_a^+ + N_a^- = p^2 N + q^2 N$$

- Where *p* is a charge purity, *q=1-p*
- We can find *p* by solving these equations.

B polar angle correction

- One is left with the following equations:

$$\begin{cases} N_a^+ = p^2 N_{true}^+ + q^2 N_{true}^- \\ N_a^- = p^2 N_{true}^- + q^2 N_{true}^+ \end{cases}$$

Migration terms

- Where $N_{true}^{\pm}$ are the two unknown number of events with positive and negative polar angles
- Corrected values:

$$\begin{cases} N_a^{+\prime} = p^2 N_{true}^+ \\ N_a^{-\prime} = p^2 N_{true}^- \end{cases}$$

- Errors on corrected values can be computed
- We are not using generator information for correction