$$e^+e^- \rightarrow b\bar{b}$$

b charge measurement

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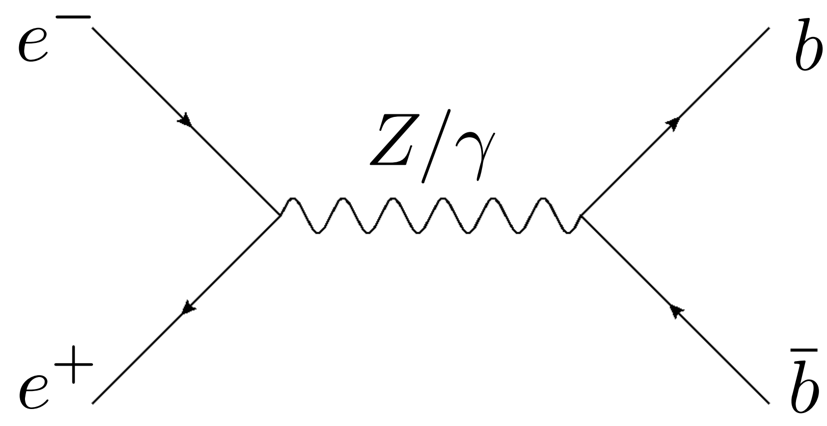
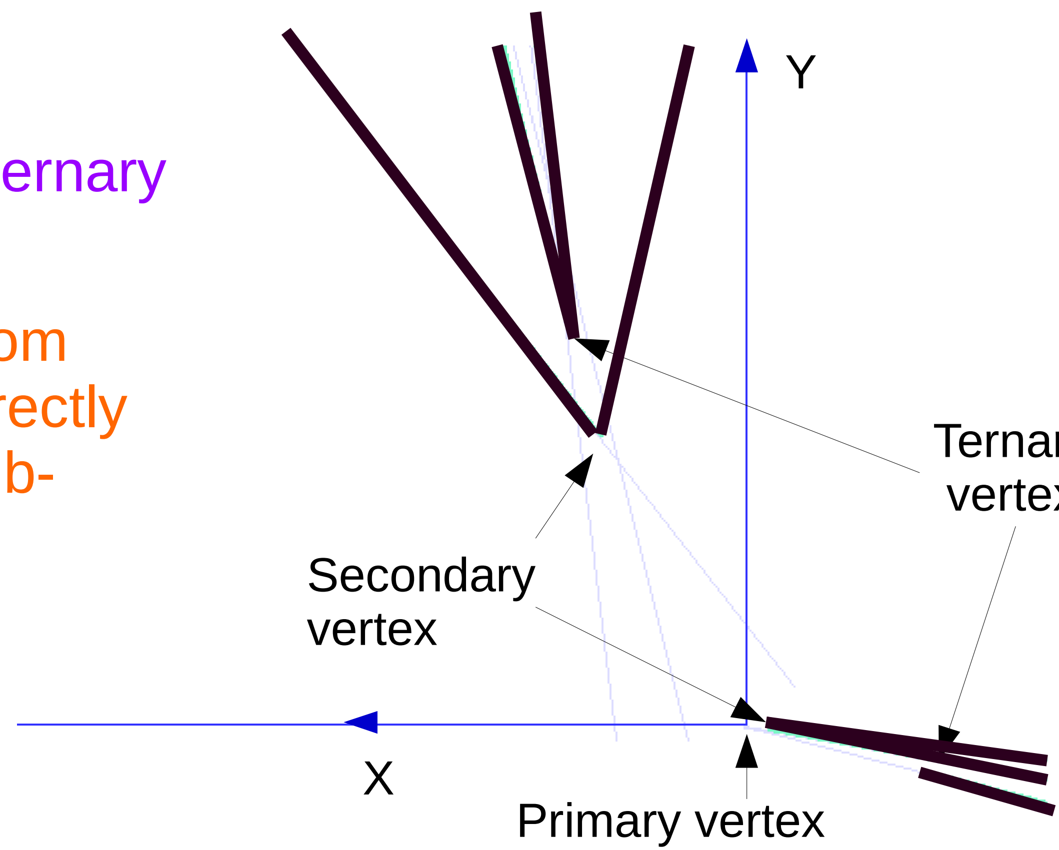
ILD Software and Analysis meeting

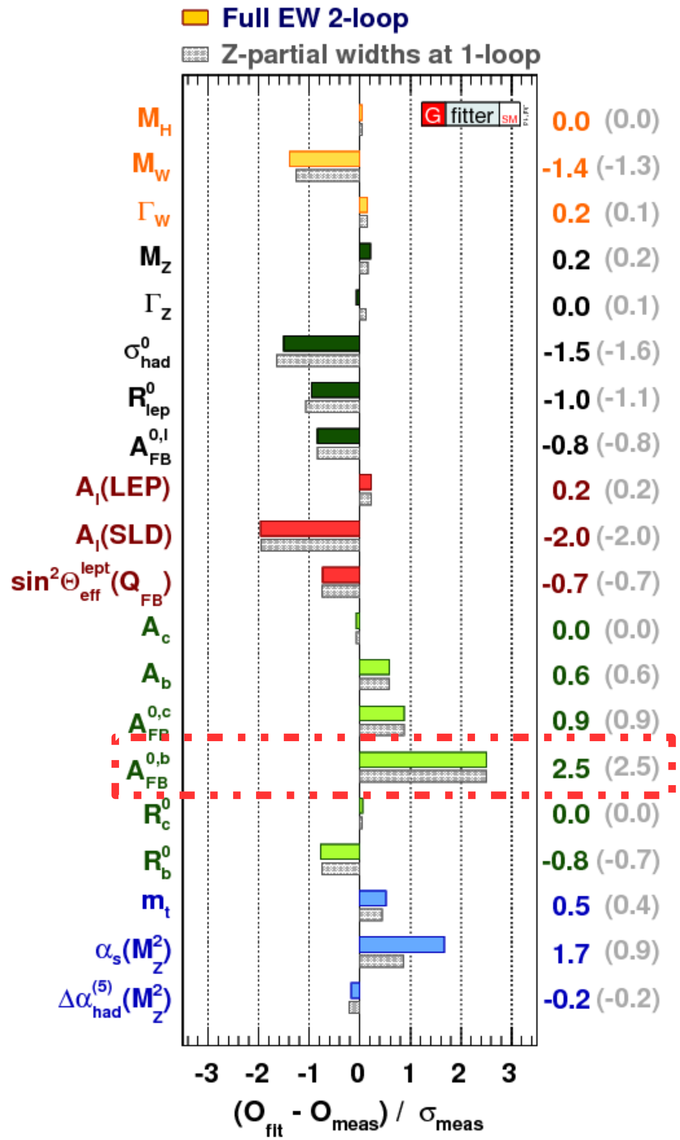
Objective

- Final goal of this work is estimation b quark asymmetry and cross-section of $e^-e^+ \to b\bar{b}$ process
- We have two methods to identify b-jet charge:
- Charge of the b-quark is calculated as a sum of the charges of secondary and ternary vertex particles
- The charge of K-mesons from reconstructed vertices is directly connected to the charge of b-quark



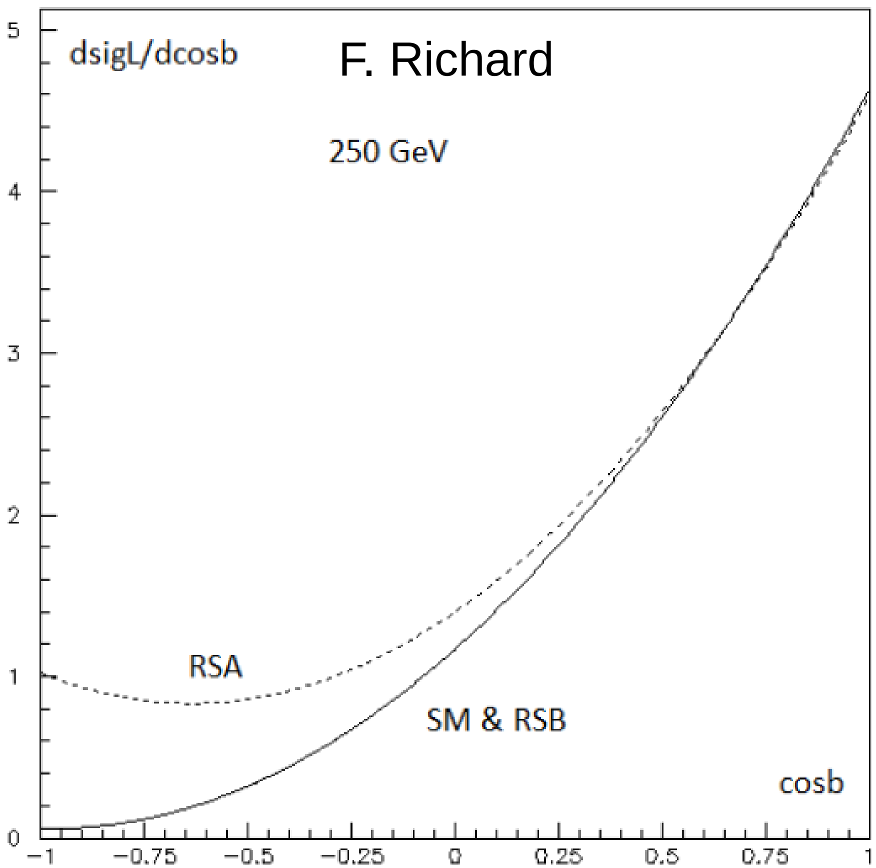


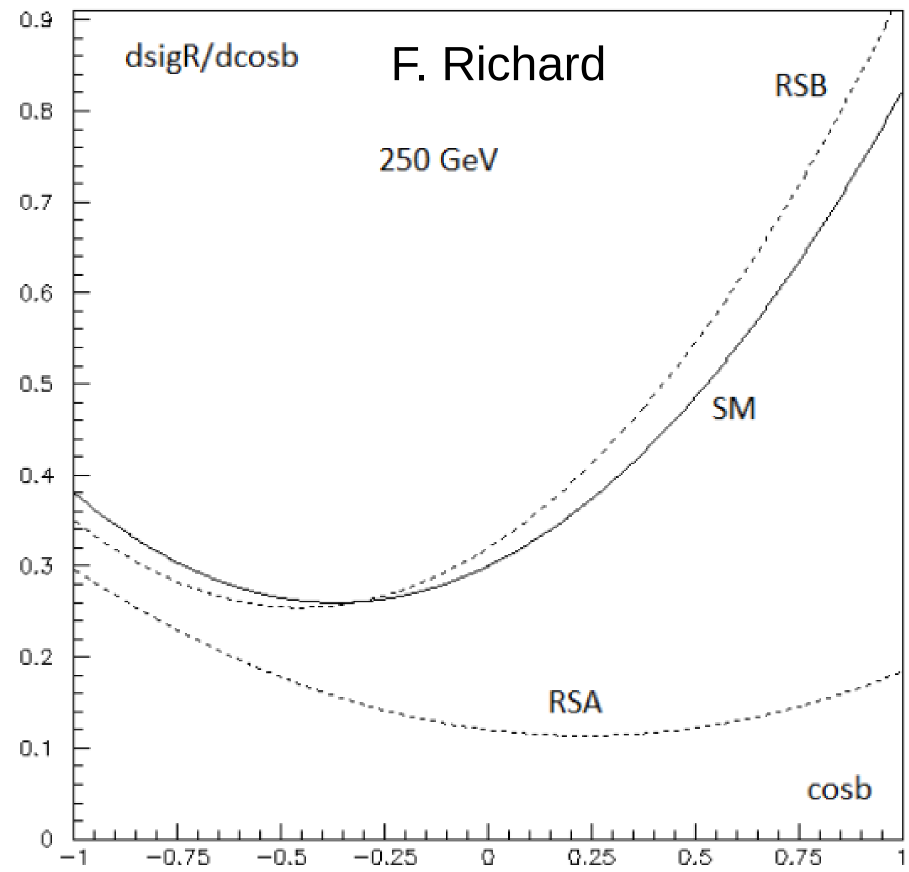
Motivation



- The measured value of Afb for b-quarks has the highest tension with Standard Model expectation

Motivation





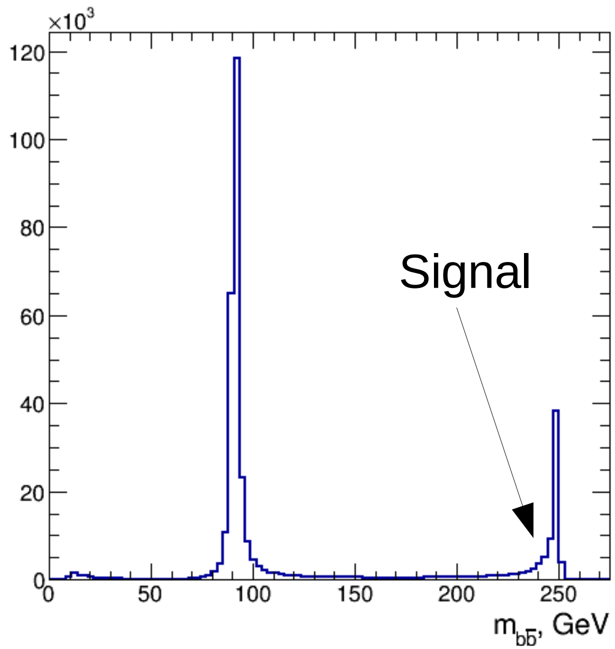
- Asymmetry is extremely strong for left-handed case
- Different Randall-Sundrum scenarios can affect SM polar angle spectrum
- Polarization of initial state is important

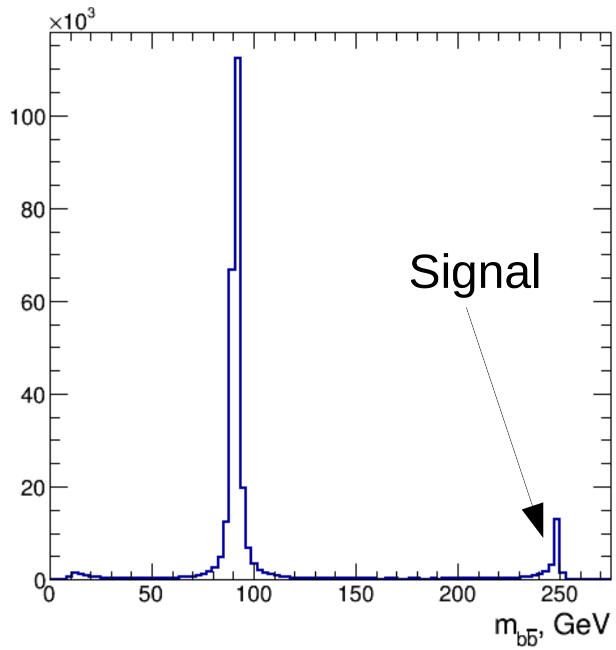
Research setup

- We are using 250 GeV Z -> q qbar sample with pair background v01-16-05 (DBD)
- For background estimation WW, ZZ and HZ samples are used
- TruthVertexFinder from MarlinReco/Analysis to get the generated vertices
- Modified version of VertexChargeRecovery from MarlinReco/Analysis (Recovery)

Available samples

	$13.53\,fb^{-1}$ $e_L^- e_R^+$	$e_R^- e_L^+$ $20.01\,fb^{-1}$	
$Z/\gamma \rightarrow b\bar{b}$	20.2% events	19.8% events	of $Z/\gamma \rightarrow q\bar{q}$
$m(b\bar{b}) > 200\,GeV$	21.7% events	8.9% events	of $Z/\gamma \rightarrow b\bar{b}$
	75k events	25k events	
Expected for 500 fb-1: (assuming luminosity sharing)	~15 times more	~4 times more	





- Available MC samples are much smaller than we expect for H20 scenario

Cross-section measurements

To measure the cross-section we need to know the purity and efficiency of our selection

	$e^-_L e^+_R \rightarrow b\bar{b}$	$e^-_R e^+_L \rightarrow b\bar{b}$
	$b - tag_{1,2} > 0.85$	$b - tag_{1,2} > 0.85$
Sum of jet masses	$m_1 + m_2 < 140\,GeV$	$m_1 + m_2 < 100\,GeV$
Event sphericity	$S_I < 0.15$	$S_I < 0.1$
Invariant mass	$m_{inv} > 180\,GeV$	$m_{inv} > 200\,GeV$
Max photon energy	$E^\gamma_{max} < 40\,GeV$	$E^\gamma_{max} < 40\,GeV$
	97.7% purity 40.4% efficiency	97.3% purity 33.1% efficiency

- Using double over single tag ratio to derive the tagging efficiency as for LEP I (Steinberger J. [https://cds.cern.ch/record/326438/files/open-97-013.pdf])

Event preselection for polar angle

1) Sort jets by b-tag

2) B-tag cuts: 0.8 for a high-tagged jet and 0.3 for a low-tagged jet

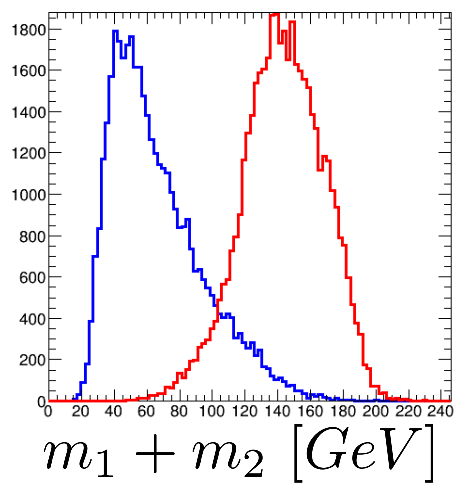
3) For Z return rejection:

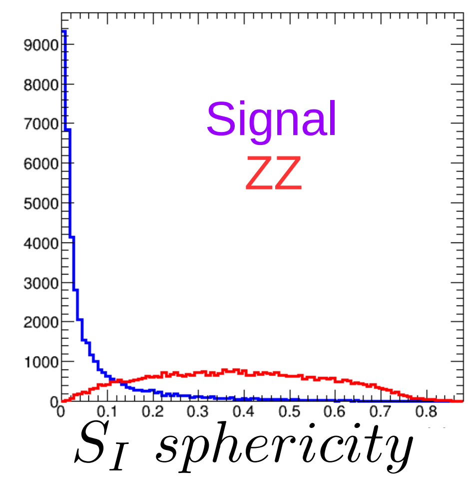
  – Invariant mass > 180 GeV and maximum photon energy < 40 GeV

4) For diboson background rejection

  – Sum of jet masses < 120 GeV and event sphericity < 0.2

- Efficiency of the preselection is **~55%** for both polarizations





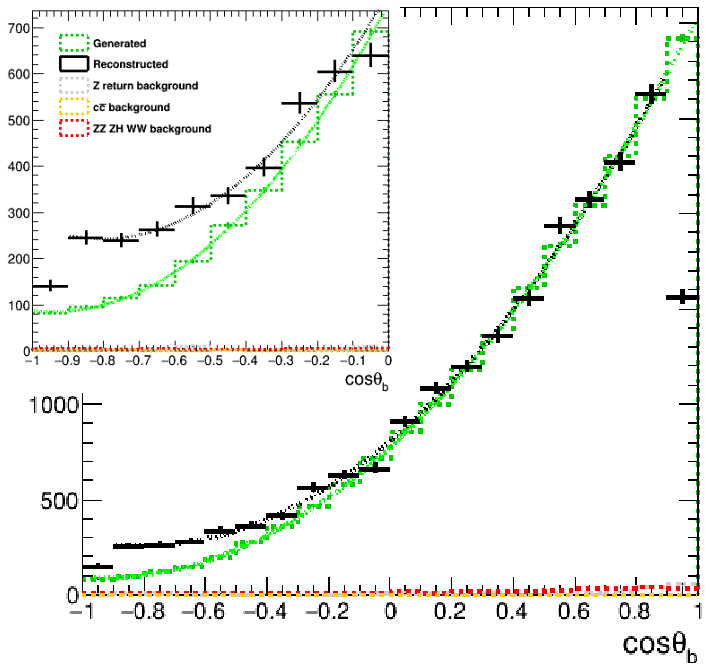
Event selection for polar angle

- We are using kaon charge and vertex charge combination to define a charge of a bjet
- Kaons are identified using generator information on each particle in a reconstructed secondary or ternary vertex
  - but we introduce ~94% purity and 88% efficiency, according to our previous PID studies
- Kaon charge is a sum of charges of all kaons found in jet vertices, zero sum is rejected
- Vertex charge is the sum of all secondary and ternary track charges in a jet, zero sum is rejected
- Only independent combinations are used to avoid charge correlations in the final result:
  - Vertex charge from one jet, vertex charge from another jet
  - Kaon charge from one jet, kaon charge from another jet
  - Event is accepted if charges are opposite

B polar angle

PRELIMINARY

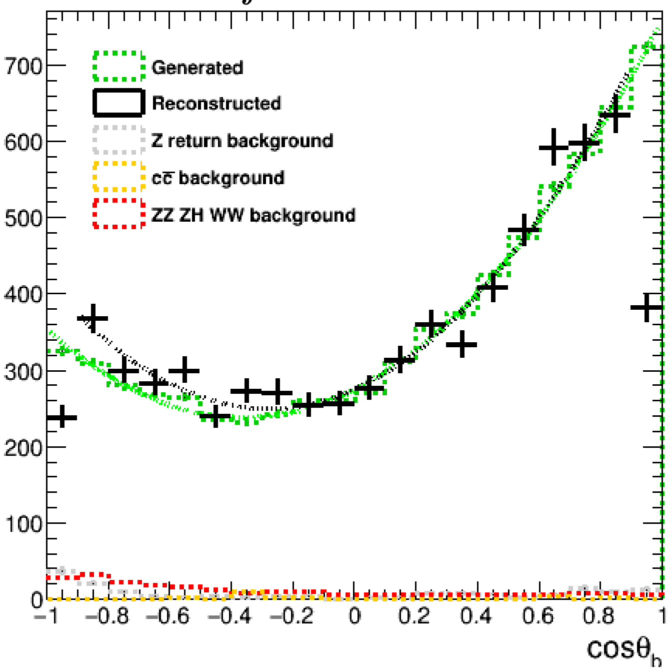
$$e^-_L e^+_R \to b\bar{b}$$
$$A^{gen}_{fb} = 0.708$$



89.% of generated Afb (fit)

$$A^{rec}_{fb} = 0.63 \pm 0.01 (1.6\%)$$

$$e^-_R e^+_L \to b\bar{b}$$
$$A^{gen}_{fb} = 0.2753$$



85.6% of generated Afb (fit)

$$A^{rec}_{fb} = 0.23 \pm 0.013 (5.6\%)$$

- There is a difference between reconstructed and generated plots and values, due to residual charge misreconstruction and B0 oscillations => correction is required

B polar angle correction

- We can use refused events with contradictory charges as a measure of our charge purity and calculate correction factors
- Let *q* be a probability of an incorrect charge measurement of a jet
- Then *p = 1 – q* is a correct charge probability
- We can compute it from the following equations:

# of refused events

$$N = N_a + N_r$$

# of accepted events

$$N_a = N_a^+ + N_a^- = p^2 N + q^2 N \qquad N_r = 2pqN$$

- We define a number of true events:

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

Migration terms

- Corrected values:

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

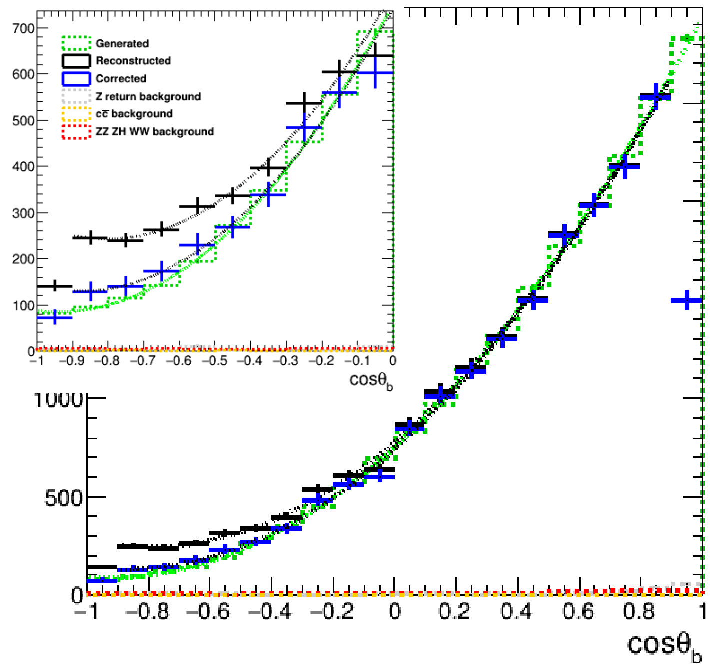
- We do not use generator information for correction

B polar angle after recovery

PRELIMINARY

$e_L^- e_R^+ \rightarrow b\bar{b}$

$A_{fb}^{gen} = 0.708$

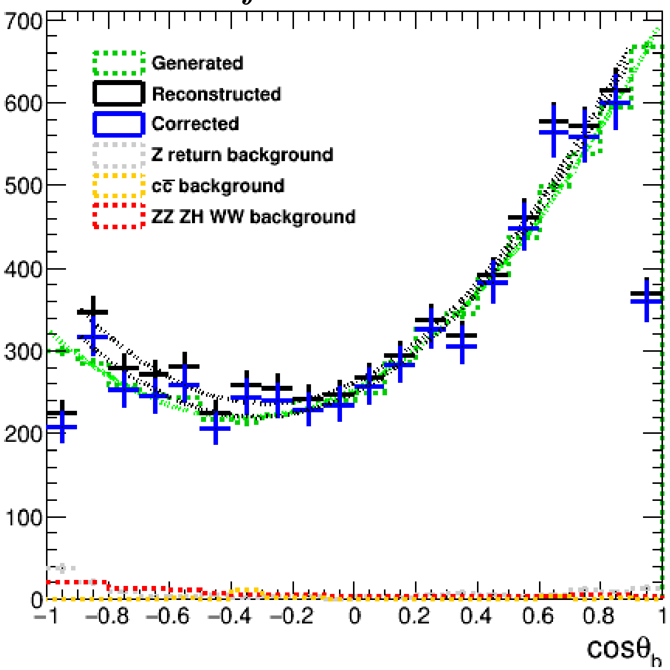


97.2% of generated Afb (fit)

$$A_{fb}^{rec} = 0.69 \pm 0.015 (2.3\%)$$

$e_R^- e_L^+ \rightarrow b\bar{b}$

$A_{fb}^{gen} = 0.2753$



97.4% of generated Afb (fit)

$$A_{fb}^{rec} = 0.27 \pm 0.019 (7\%)$$

- Errors on the asymmetry are statistical
- We need more statistics for publication

Conclusions

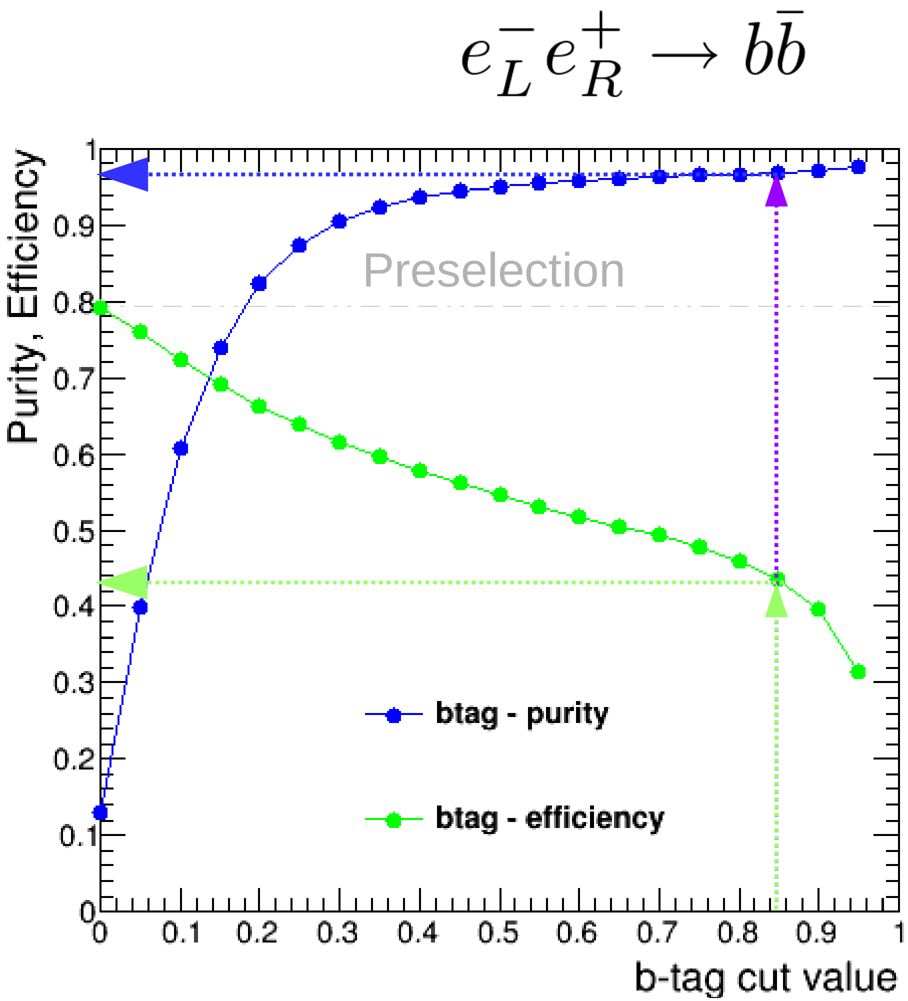
- Selection efficiency for cross-section measurement is higher than LEP I with the same purity
- Asymmetry for left-handed case is very strong
  - 5% migrating events contaminate backward hemisphere completely
- Using the refused events we can correct the asymmetry and polar angle distribution
- Strong acceptance loss towards large polar angles
- The results can be published, but...

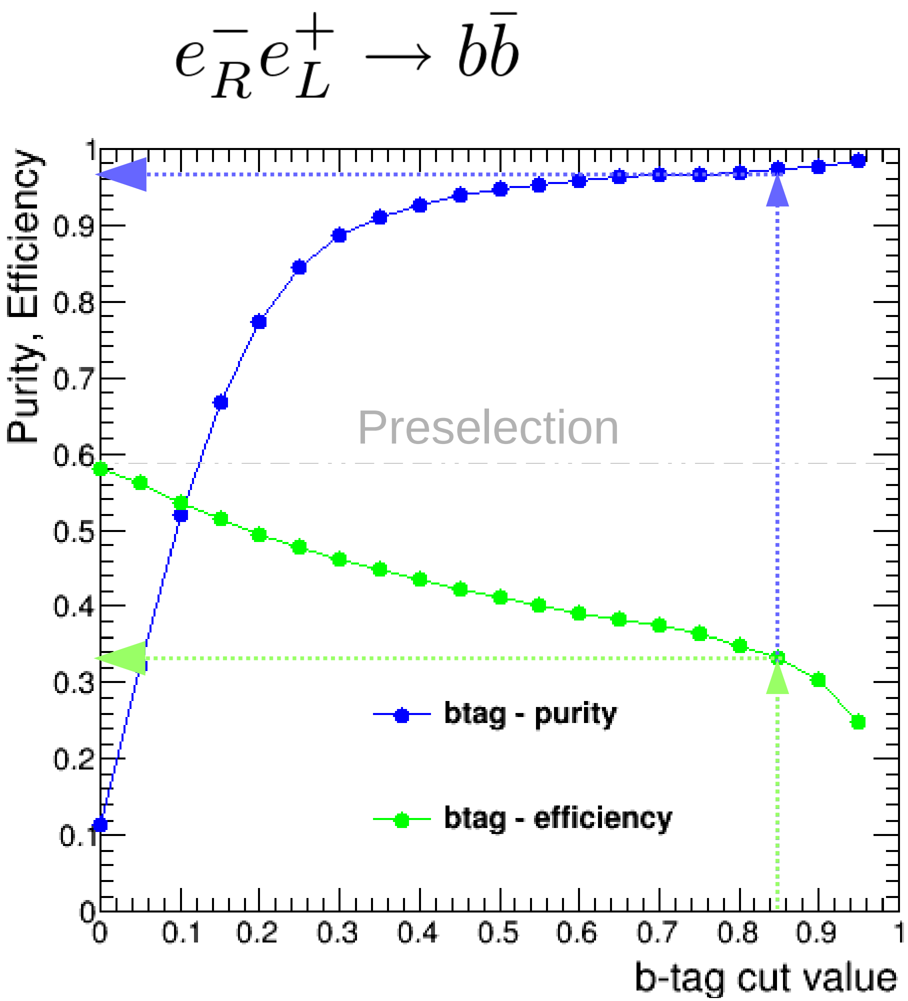
Needed for publication

- More statistics is required
- Request to ILD:
  - 250 fb-1 for both polarizations (for b bbar on center-of-mass)
- Study influence of limited acceptance (sys. error)
- Interpretation of the results including extraction of coupling constants g_L^b g_R^b

Thank you!

B cross section

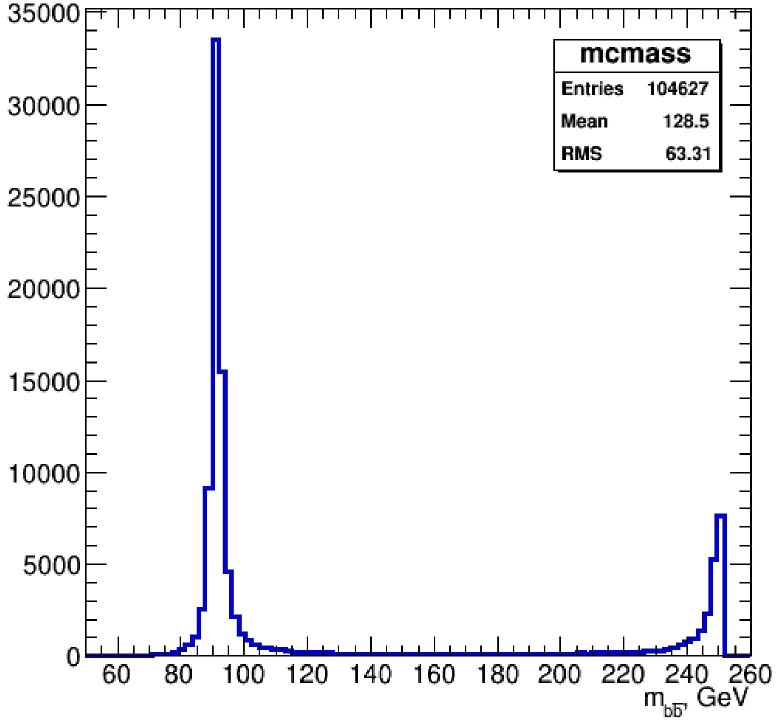


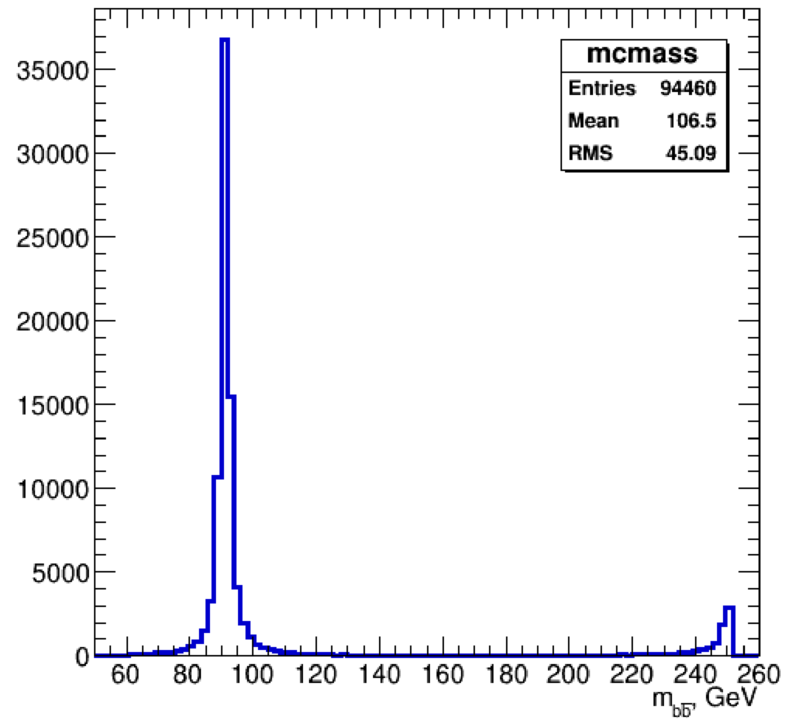


- High b-tag cuts for both jets > 0.85
- There is an impact of higher Z return background for right-handed case

Invariant mass distributions

	$e^-_L e^+_R$	$e^-_R e^+_L$	
$Z/\gamma \rightarrow b\bar{b}$	20.2% events	19.8% events	of $Z/\gamma \rightarrow q\bar{q}$
$m(b\bar{b}) > 200\,GeV$	21.7% events	8.9% events	of $Z/\gamma \rightarrow b\bar{b}$

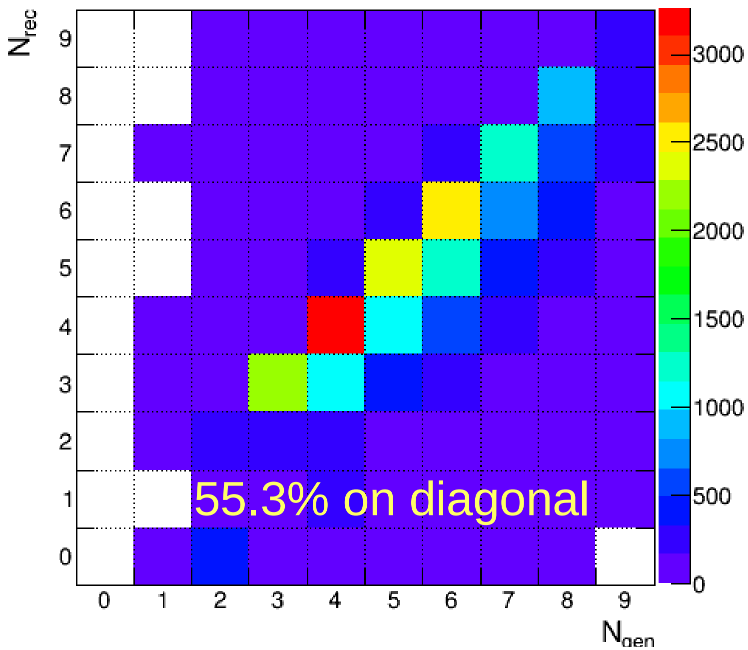


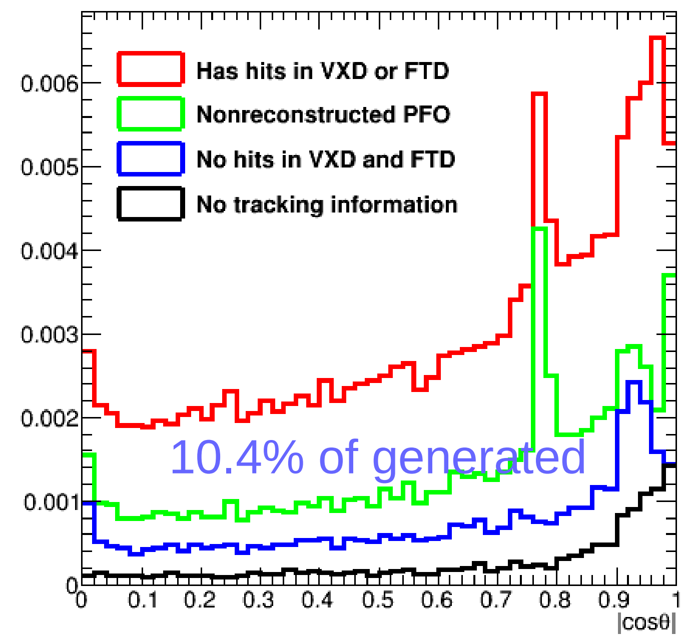


- Radiative Z return events are excluded by a cut on generated invariant mass

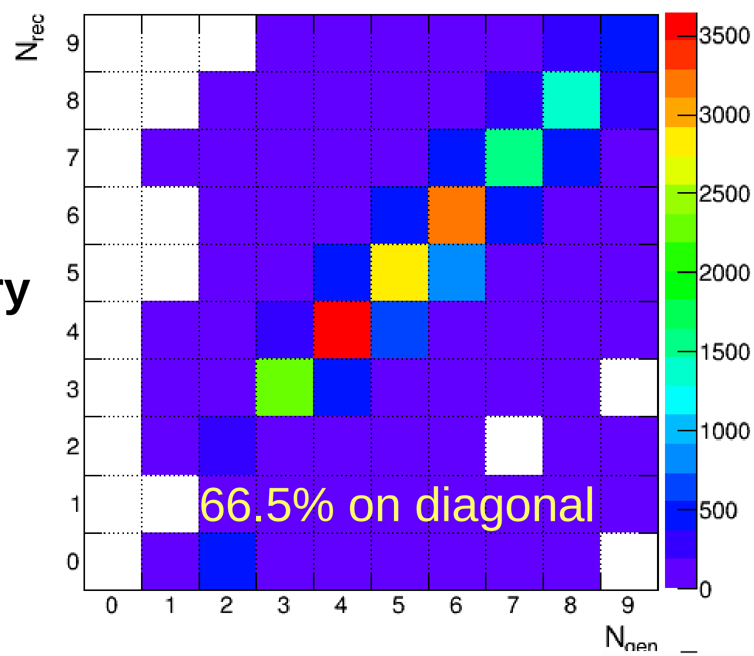
Reconstruction quality DBD vs Recovery

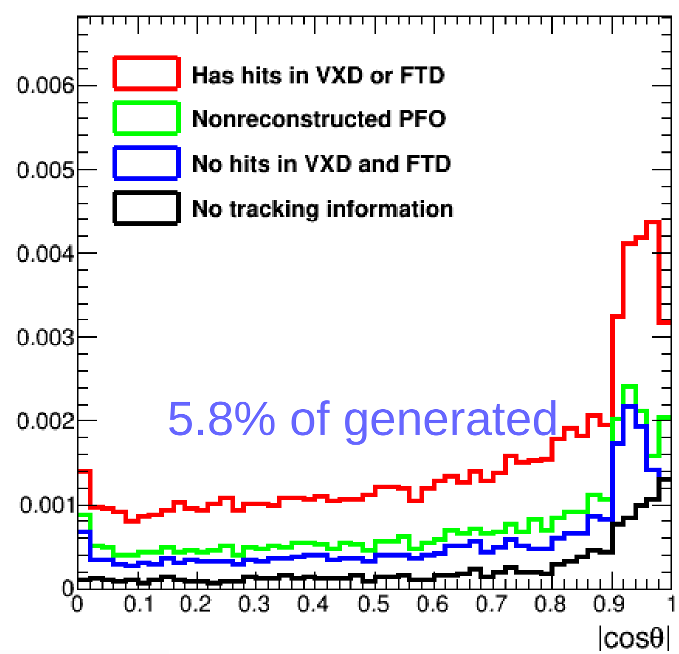
DBD





Recovery



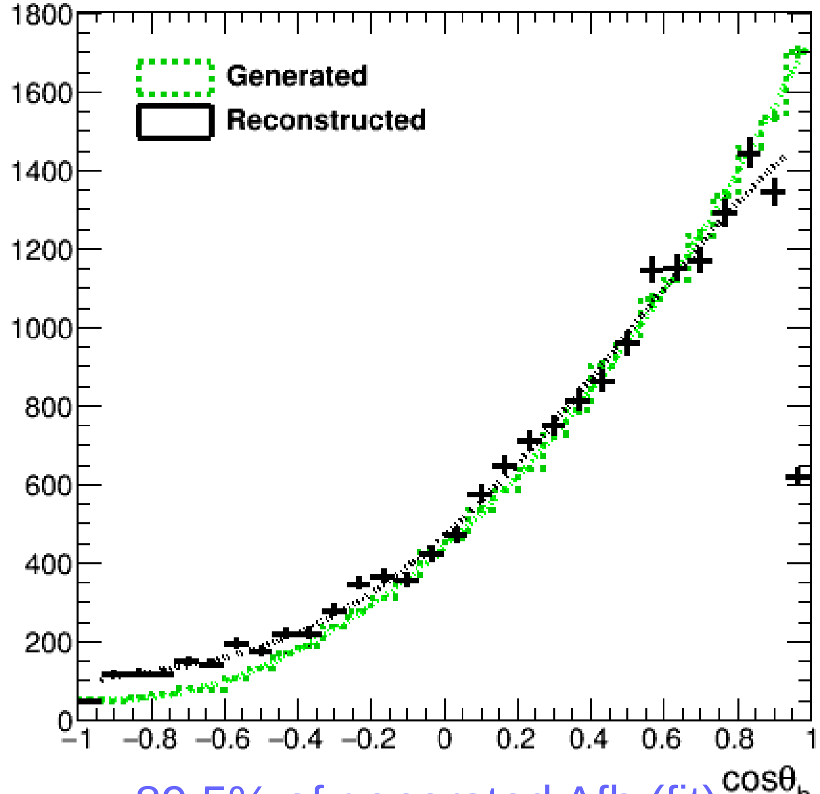


$m(b\bar{b}) > 200\,GeV$

B polar angle after recovery

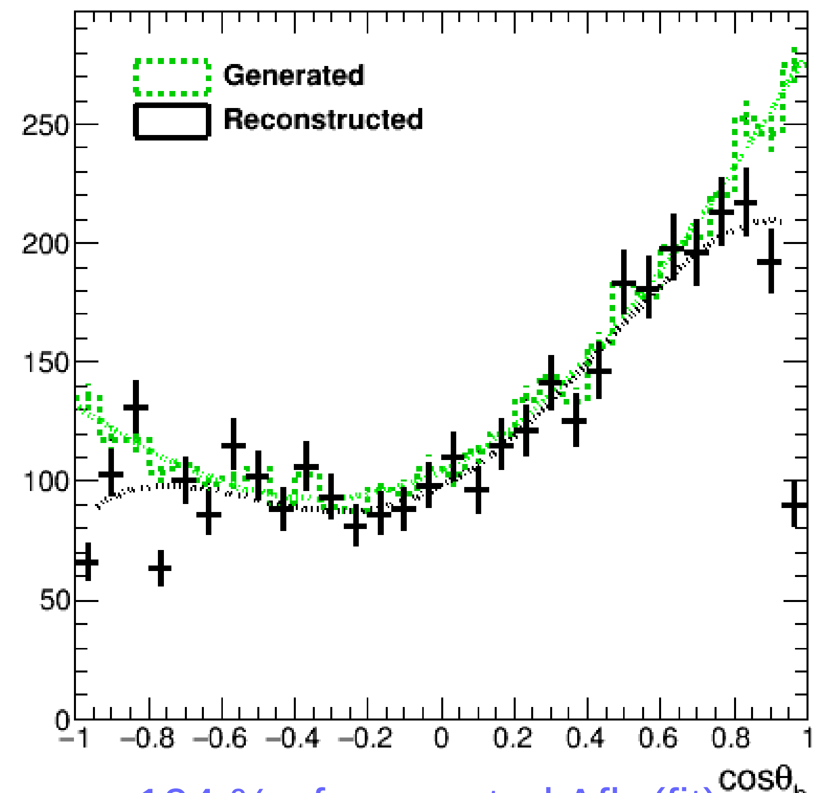
$m(b\bar{b}) > 200\,GeV$ Generated kaons Signal only

$e^-_L e^+_R \rightarrow b\bar{b}$



89.5% of generated Afb (fit)

$e^-_R e^+_L \rightarrow b\bar{b}$



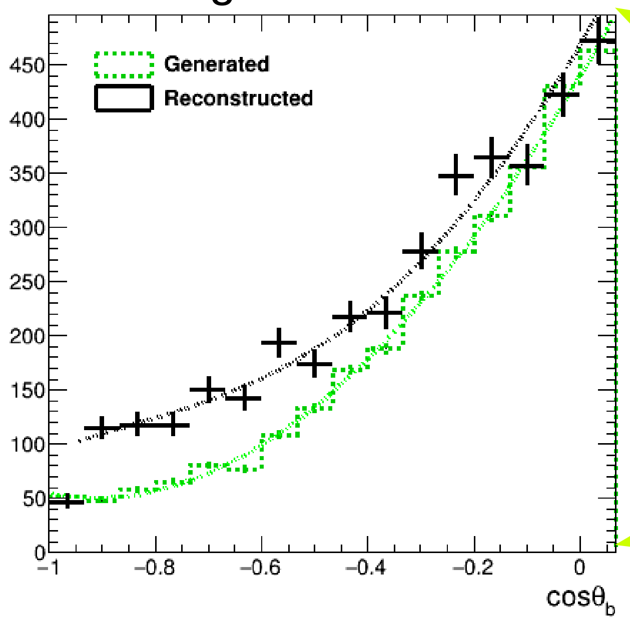
104.% of generated Afb (fit)

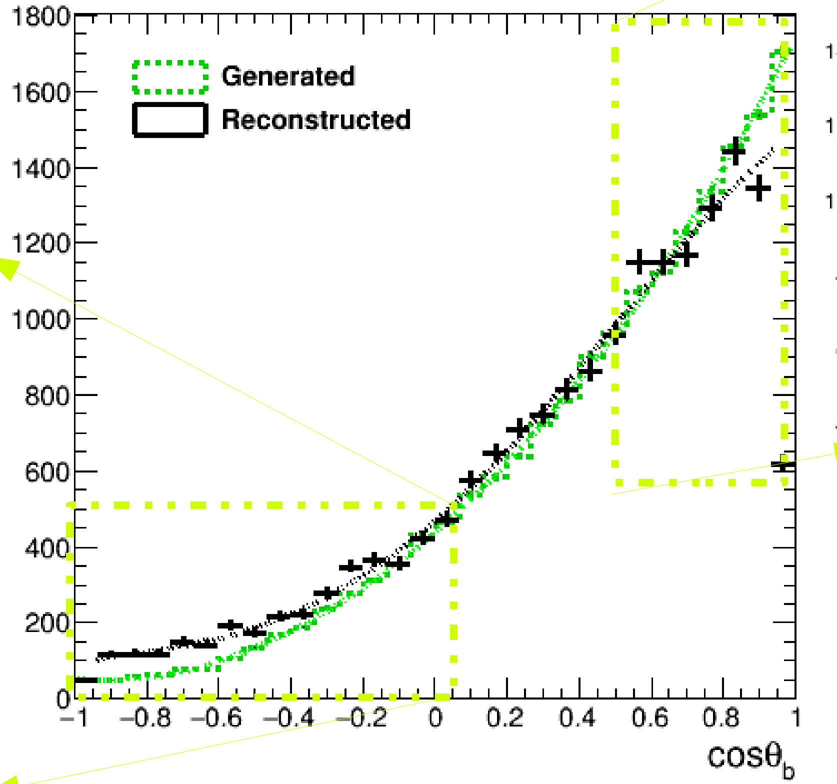
- Around 5% of accepted events are migrating due to an incorrect charge measurement

Corrected b polar angle

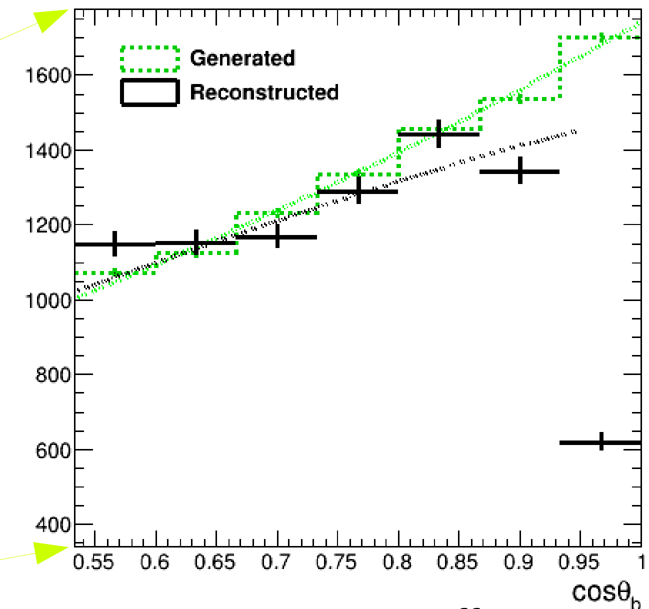
$m(b\bar{b}) > 200\,GeV$ Generated kaons and vertex combination

'Migration' effects





89.5% of generated Afb (fit)



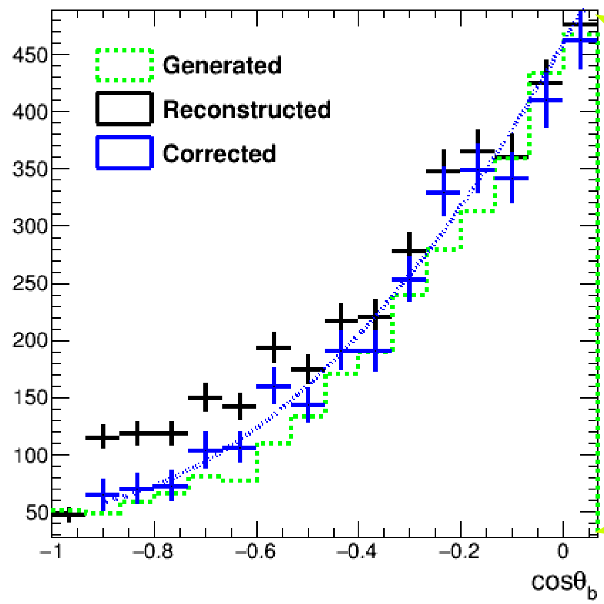
'Acceptance' effects

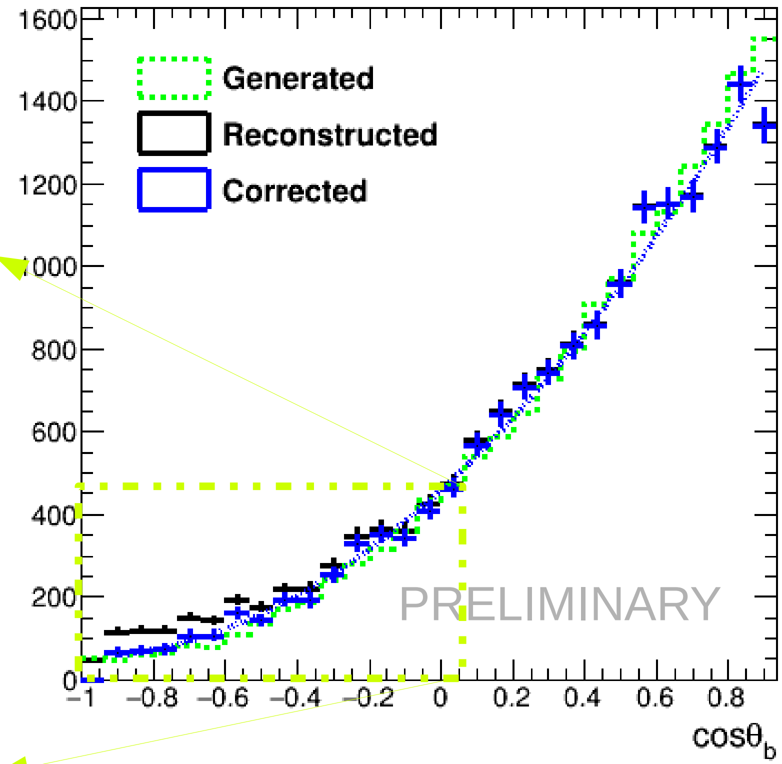
- 'Migration' problem in the backward hemisphere and 'acceptance' effects in the forward region have to be addressed
- In this talk we discuss 'migration' effect only

Corrected b polar angle

$m(b\bar{b}) > 200\,GeV$ Generated kaons and vertex combination

'Migration' effects





95.3% of generated Afb (fit)

- Method works well for asymmetry reconstruction, and for the polar angle
- Small caveat: there are technical problems with correction factors for mixed VTX+KAON events

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

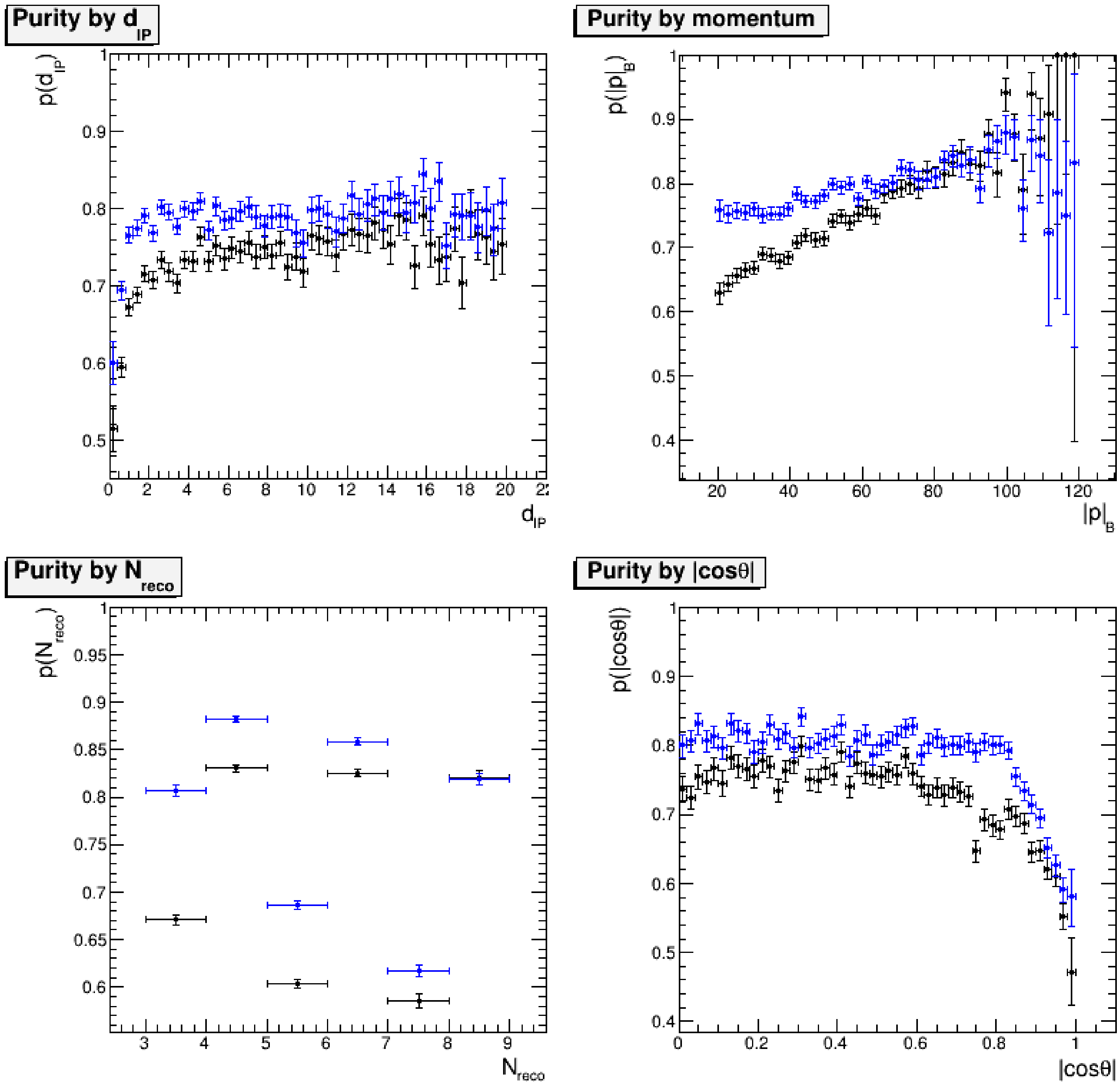
- Corrected values:

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

- Errors on corrected values can be computed

- We are not using generator information for correction

Purity


Purity by d_IP
p(d_IP)
d_IP
Purity by momentum
p(|p|_B)
|p|_B
Purity by N_reco
p(N_reco)
N_reco
Purity by |cosθ|
p(|cosθ|)
|cosθ|