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

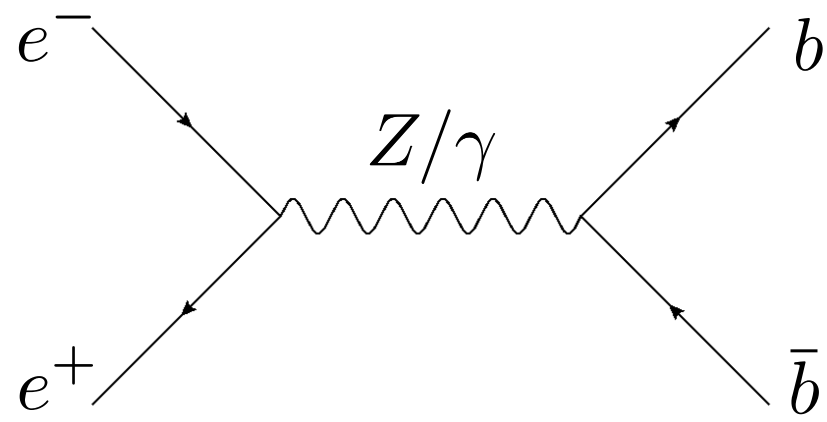
Update on b quark study

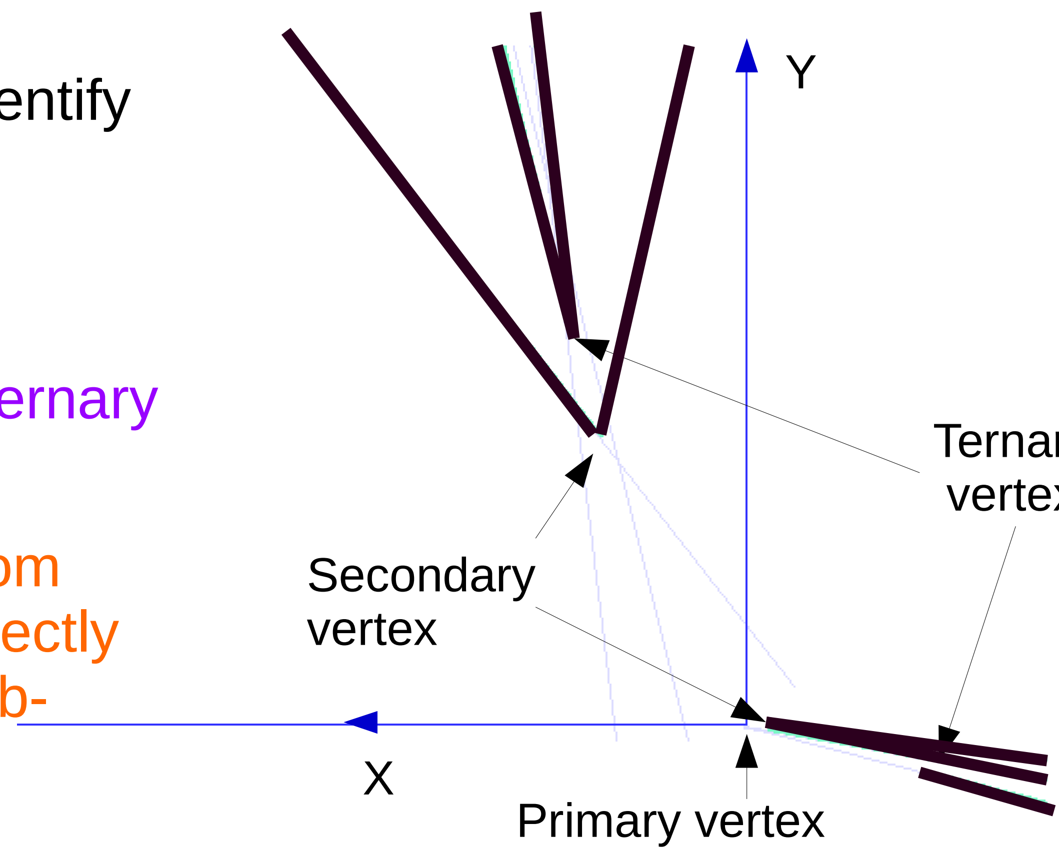
Poeschl R., Richard F., Bilokin S.
LAL, Orsay

ILD Software and Analysis meeting

Objective

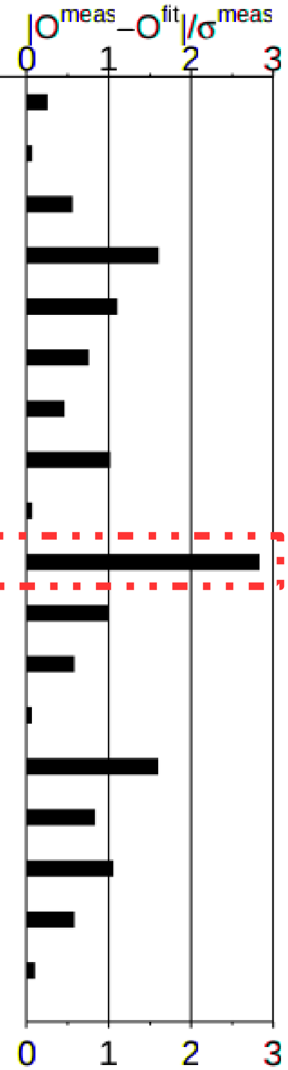
- Final goal of this work is estimation b quark asymmetry and cross section using $e^-e^+ \to b\bar{b}$ process
- For asymmetry calculation we are using b-jet charge identification technique
- We have two methods to identify b-jet charge:
- Charge of the b-quark is calculated as a sum of the charges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





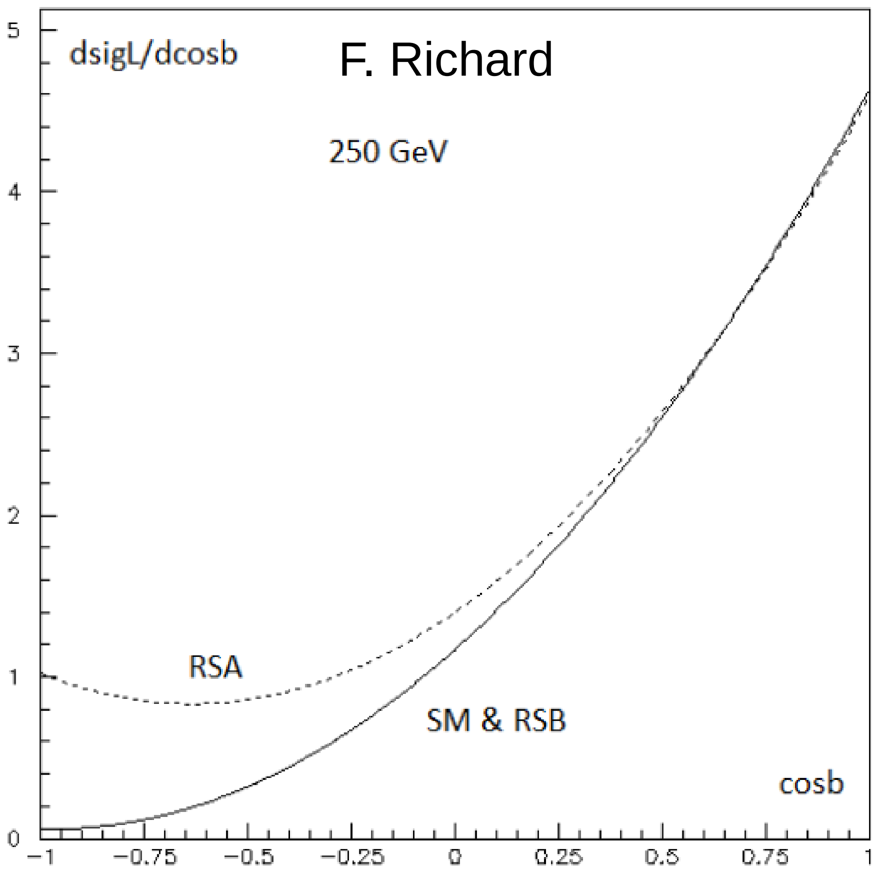
Motivation

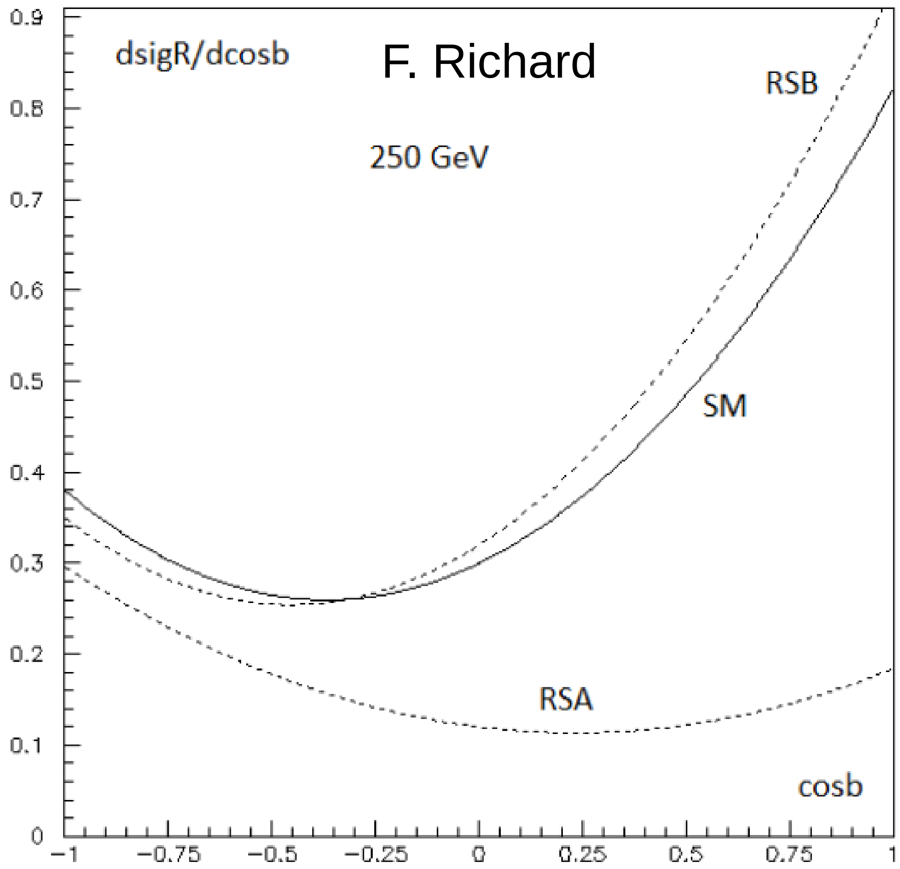
	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ_{had}^{0} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1037
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
$A_l(SLD)$	0.1513 ± 0.0021	0.1480
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5



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

Motivation





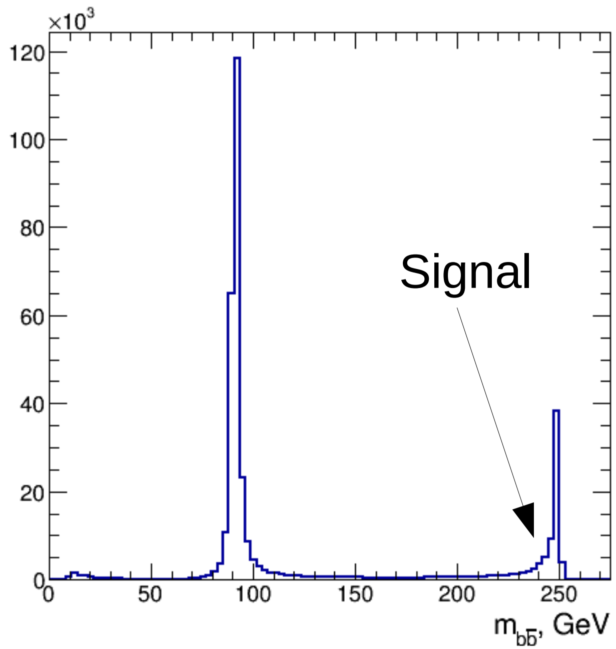
- Asymmetry is extremely strong for left-handed case
- Different Randall-Sundrum scenarios can affect SM polar angle spectrum
- Polarization of initial state is important

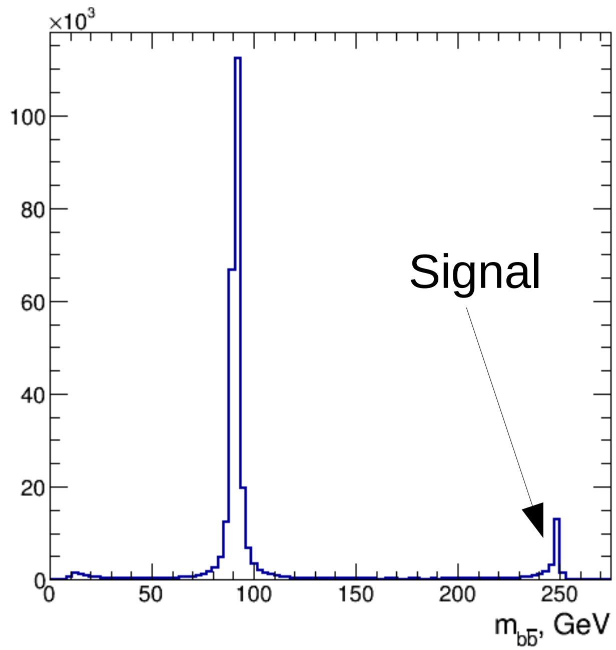
Research setup

- 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 H20:	~15 times more	~4 times more	

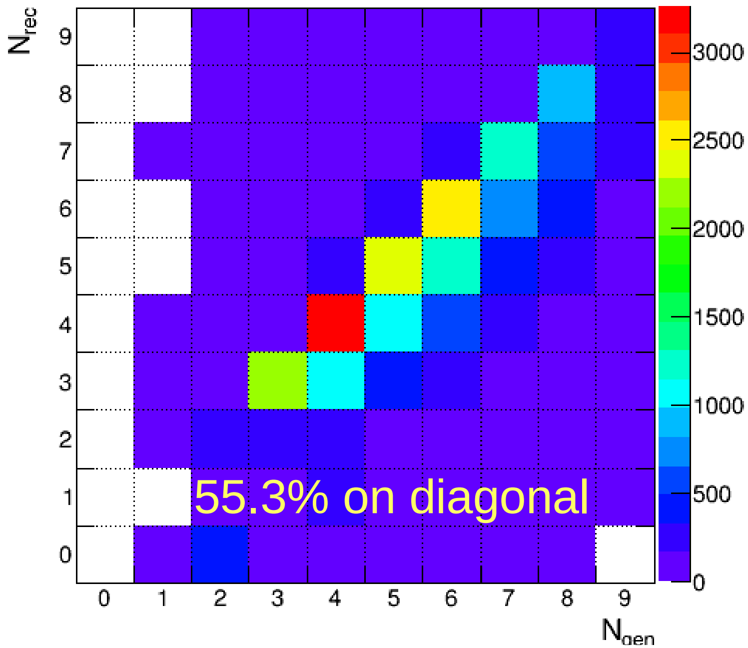


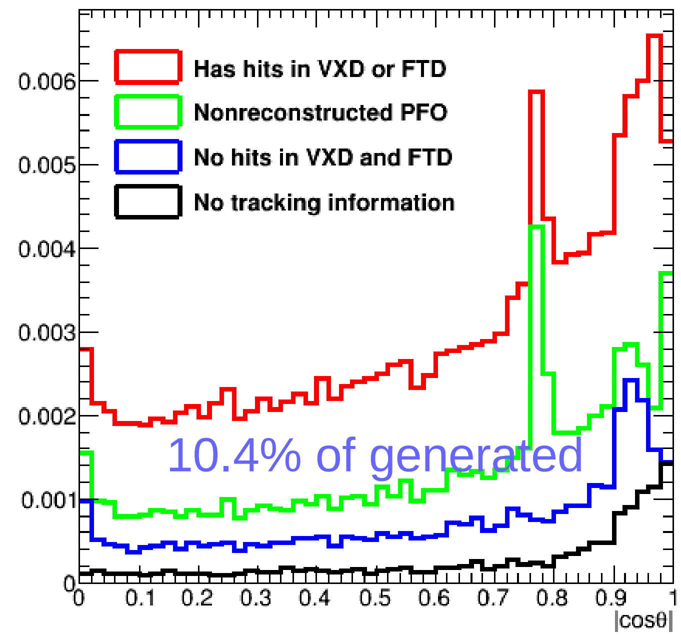


- Available MC samples are much smaller than we expect for H20 scenario

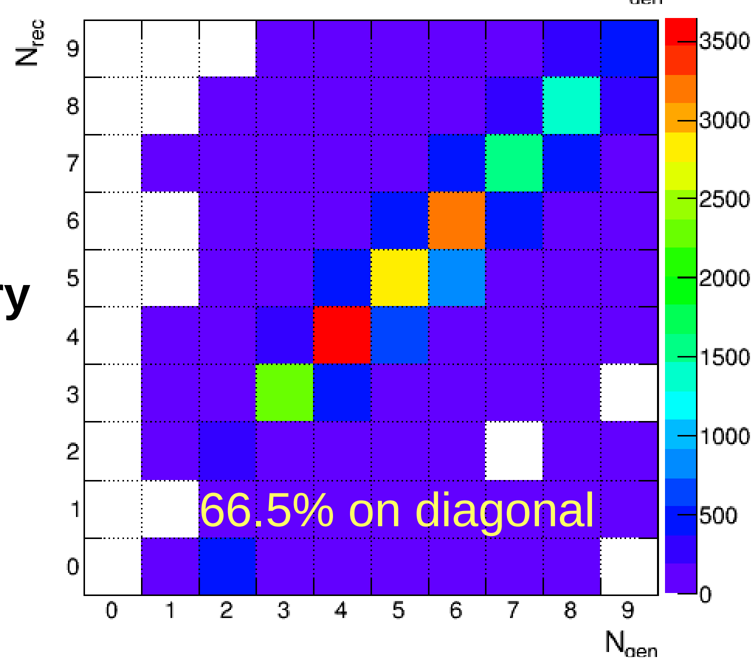
Reconstruction quality DBD vs Recovery

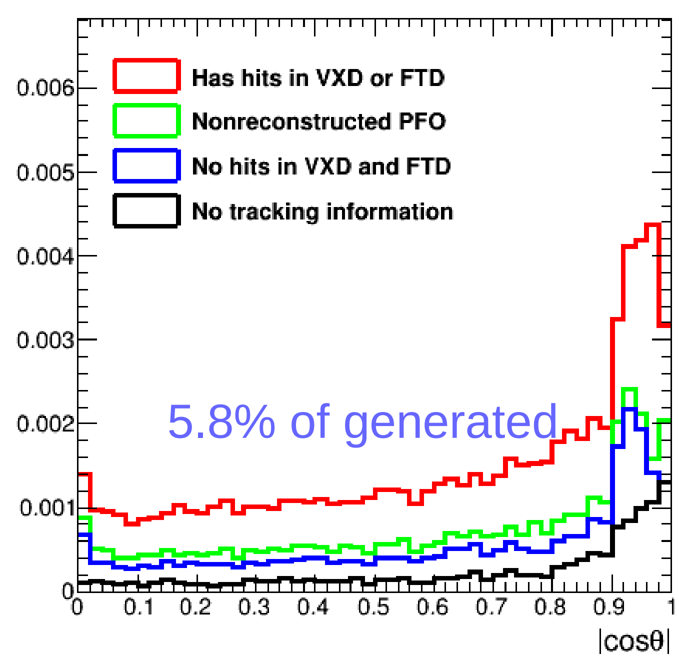
DBD





Recovery





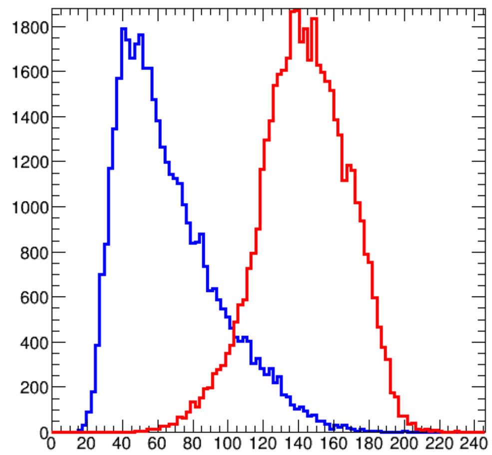
$$m(b\bar{b}) > 200\,GeV$$

Event preselection

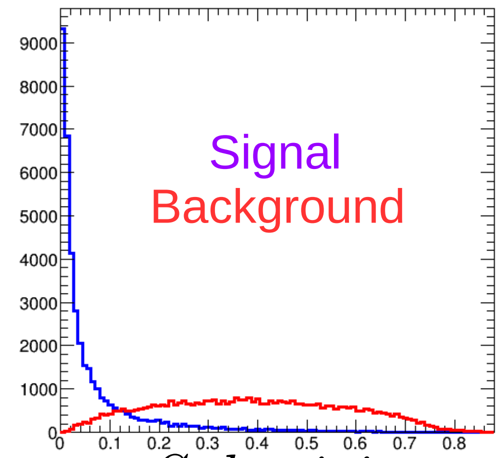
1) Sort jets by b-tag
2) B-tag cuts: 0.8 for high tagged jet and 0.3 for low tagged jet
3) For Z return rejection:
   - Invariant mass > 180 GeV and maximum photon energy < 40 GeV
4) Additional cuts on jet masses and sphericity are applied for right-handed polarization for diboson background rejection

$$m_{b-jet_1} + m_{b-jet_2} < 150\, GeV \text{ and } S < 0.3$$

- Efficiency is ~67% for both polarisations



$m_{b-jet_1} + m_{b-jet_2}$

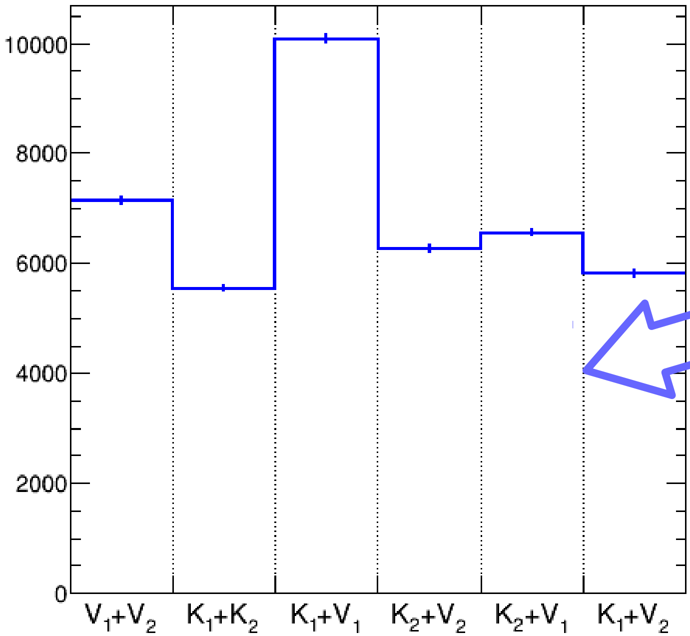


$Sphericity$

Event selection

- 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, zero sum is rejected
- Vertex charge is the sum of all secondary and ternary track charges, zero sum is rejected

Event selection



- We have kaon measurement and vertex charge measurement from two b-jets
  - 6 combination of two measurements possible
- Jets are sorted in preselection by b-tag, therefore vertex charge purity is different

```
Jet           VTX      KAON
B1:          -1       -1
B2:           1        1
Two vertices are used!
Two kaons are used!
Vertex + kaon for B1 is used!
Vertex + kaon for B2 is used!
Vertex2 + kaon1 is used!
Vertex1 + kaon2 is used!
ACCEPTED BY CHARGE:  1 2 3 4 6 5
```

Good

```
Jet           VTX      KAON
B1:          NAN      1
B2:          NAN      1
REFUSED BY CHARGE:  2
```

These events can be used to determine charge purity

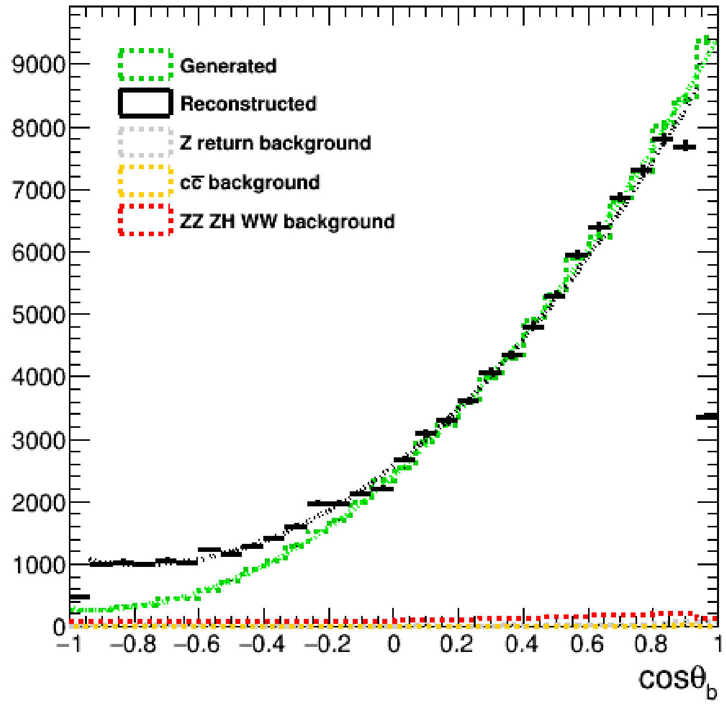
Bad

```
Jet           VTX      KAON
B1:           1        1
B2:           1        1
Vertex + kaon for B1 is used!
Vertex + kaon for B2 is used!
Not Correct!
REFUSED BY CHARGE:  1 2 6 5
ACCEPTED BY CHARGE:  3 4
CHARGE VALUE:  1 -1
CONTRADICTING RESULT
```

Ugly

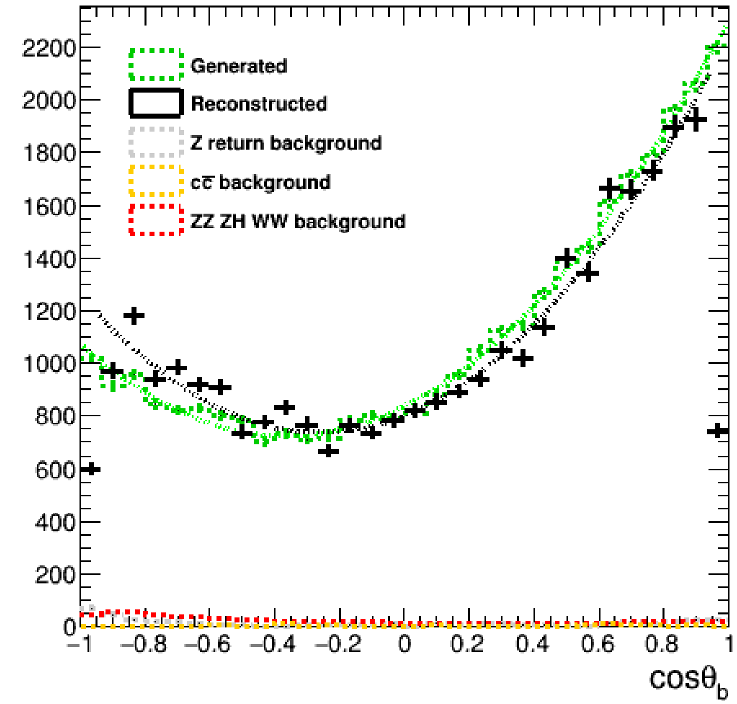
B polar angle after recovery

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



84.5% of generated Afb (fit)

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

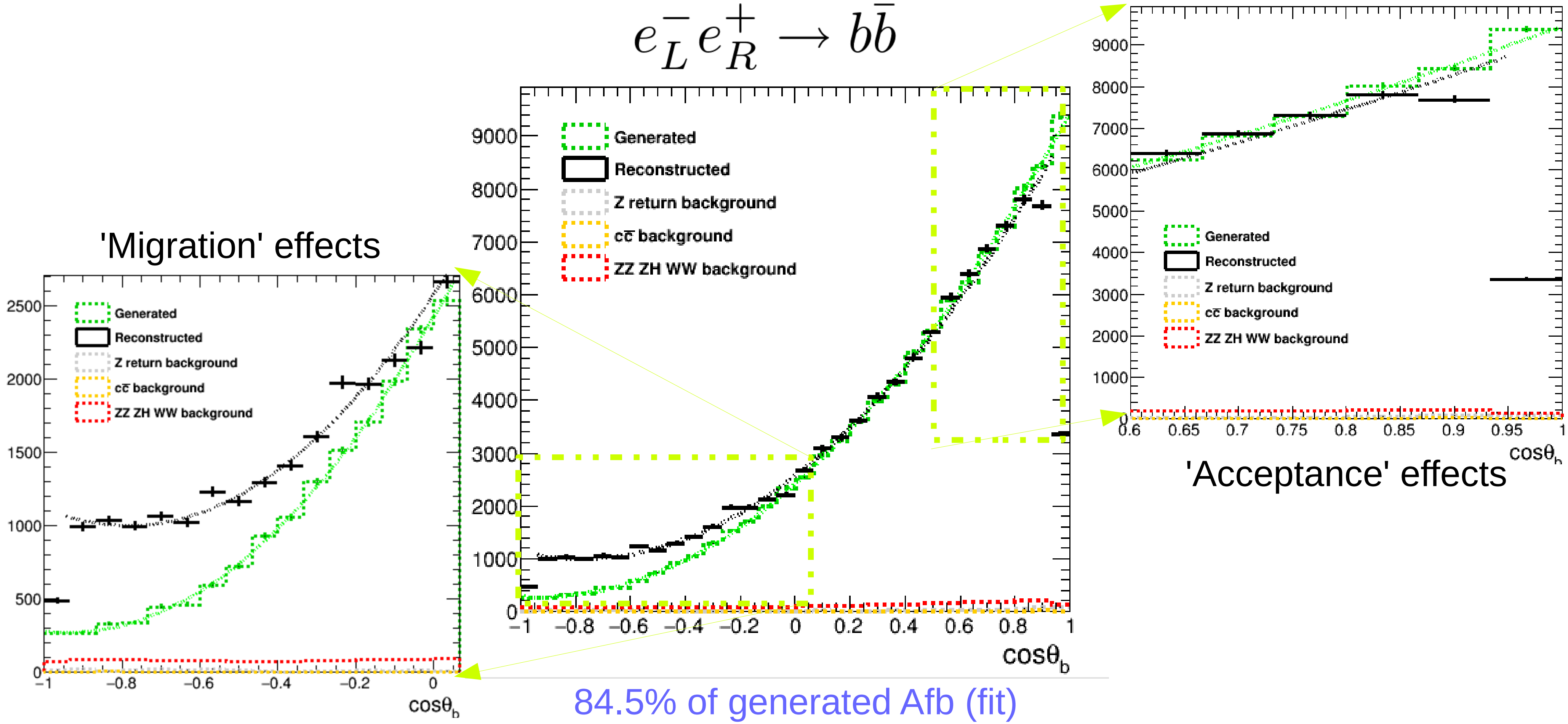


80.% of generated Afb (fit)

PRELIMINARY: ~31% of total efficiency

- Around 5% of accepted events are migrating due to an incorrect charge measurement
- Very careful background rejection is required

B polar angle after in details



84.5% of generated Afb (fit)

- '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

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

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

# of accepted events

- 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

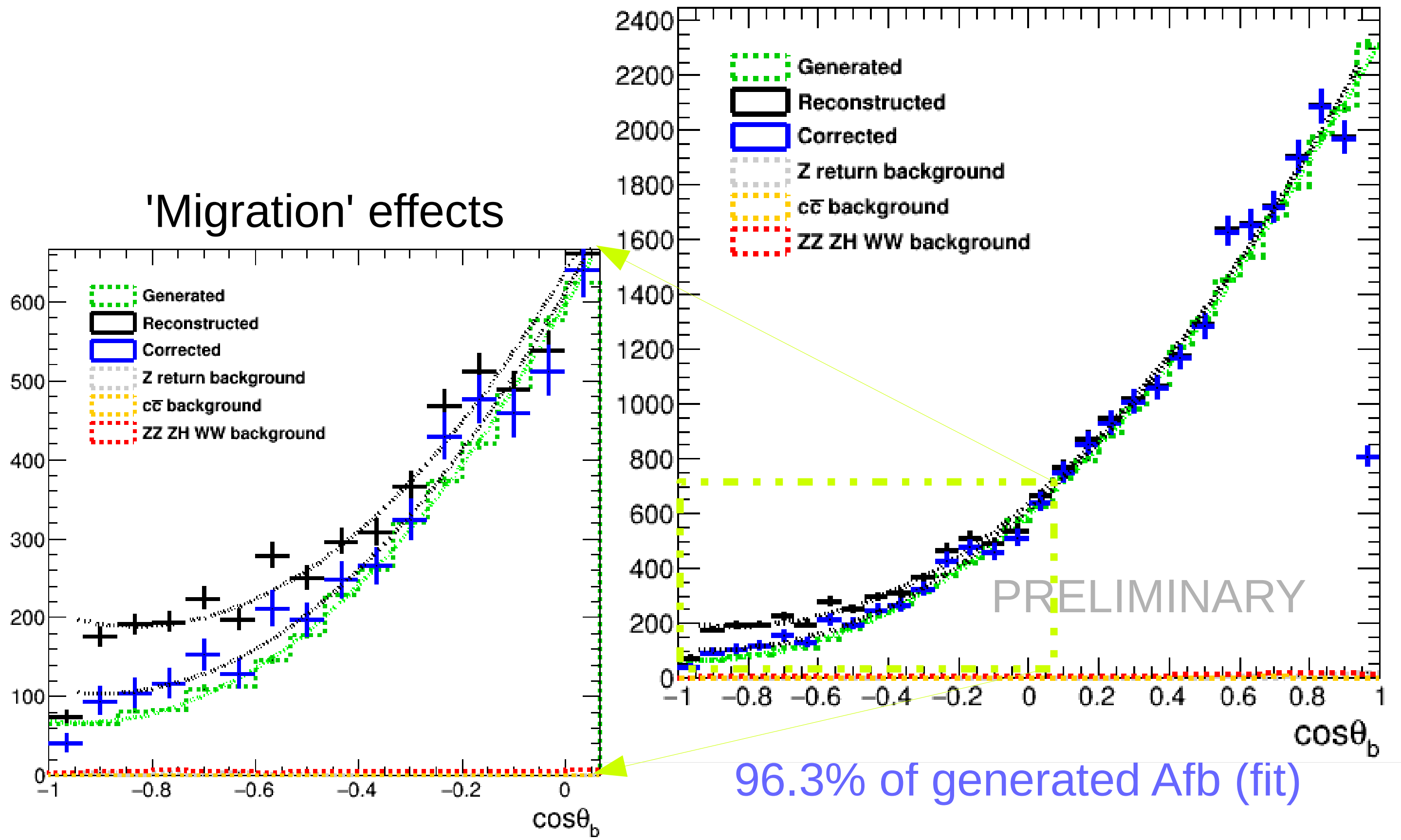
- Corrected values:

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

Works for independent measurements only

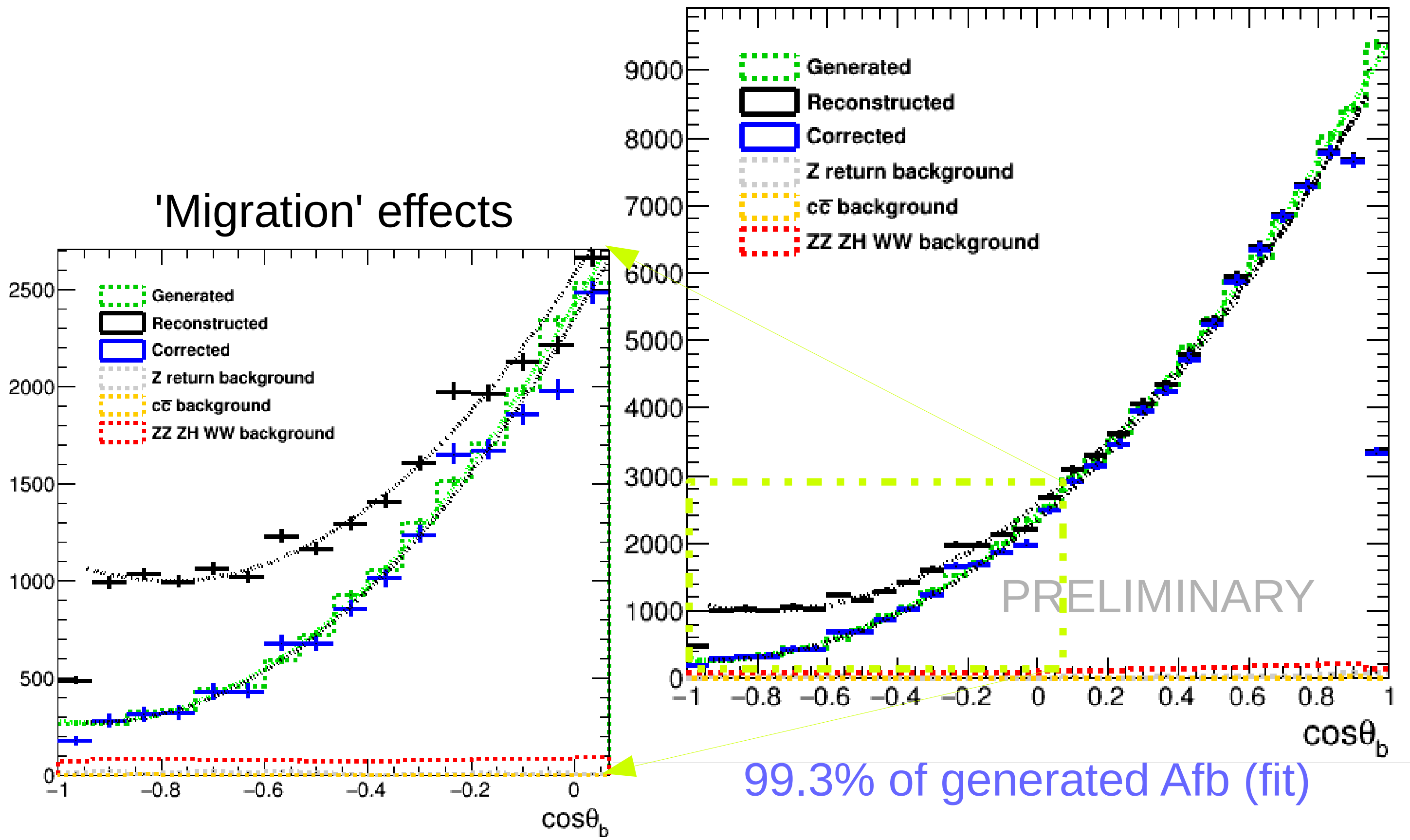
- We do not use generator information for the correction

Corrected b polar angle (exclusion)



- Method works well for asymmetry reconstruction, and for the polar angle
- Small caveat: mixed VTX+KAON events are excluded, efficiency penalty

Corrected b polar angle (factor)



- Method works well for asymmetry reconstruction, and for the polar angle
- Small caveat: an empirical factor is used for mixed VTX+KAON events (However, this factor can in principle be properly determined)

Conclusions

- Method of b charge measurement can be applied to the b bbar process directly
  - Further optimization is possible
    - e.g. remedy deficits of minivector algorithm
    - Rearrangement of forward tracking detectors
- Polar angle of the b quark for right-handed case is well reconstructable without further major corrections
- Asymmetry for left-handed case 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
  - Prevents determination of Afb by counting experiment

– Heavy quark doublet is fully measurable at ILC

Next steps

- Finalization of correction procedure
- Study influence of limited acceptance
- Determination of precision of cross section and polar angle measurement
- Extraction of coupling constants g_L^b g_R^b and interpretation in terms of models (connection with top quark analysis)
- First serious attempt to address LEP anomaly at ILC

Thank you!

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

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

$$N = N_a + N_r$$

$$N_r = 2pqN$$

- 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

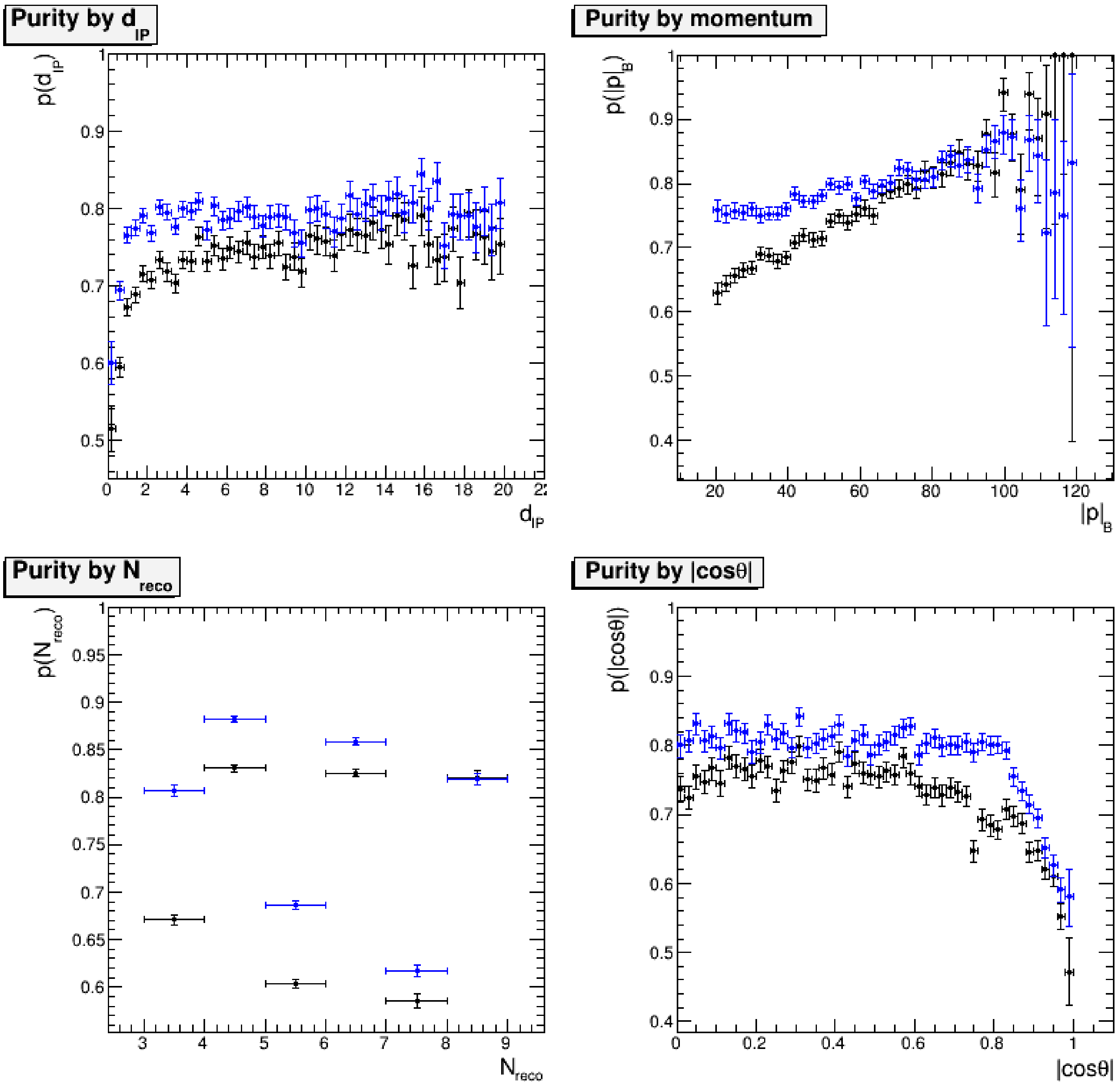
- Corrected values:

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

- Errors on corrected values can be computed

- We are not using generator information for correction

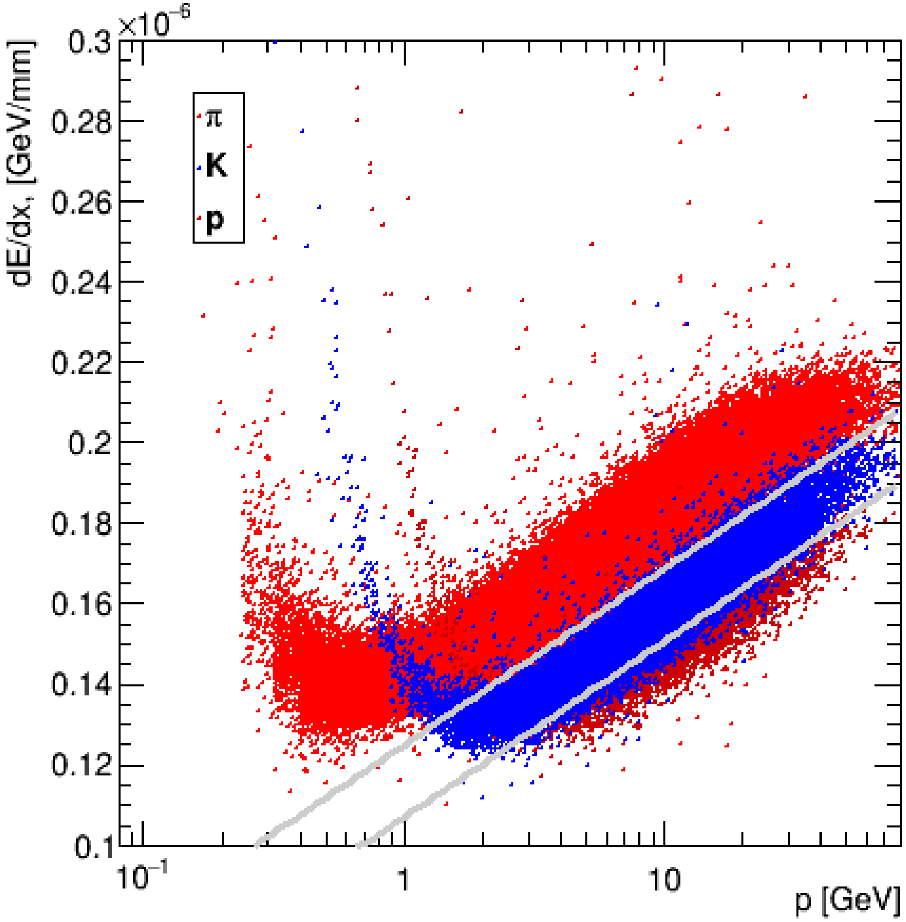
Purity



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|

Reducing angular dependence

Kaon selection after reducing the dE/dx angular dependence



Generated \ Reconstructed	π	K	p
p	162	232	1204
K	1175	14272	685
π	94114	206	20

97% purity and 88% efficiency

- After correction dE/dx does have a better kaon separation properties