Semi-leptonic Study with New Samples

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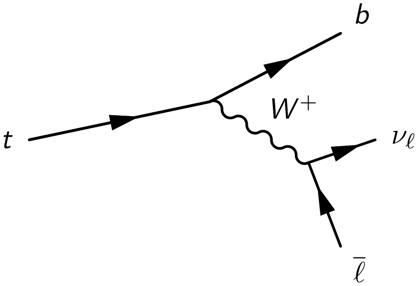
Motivation

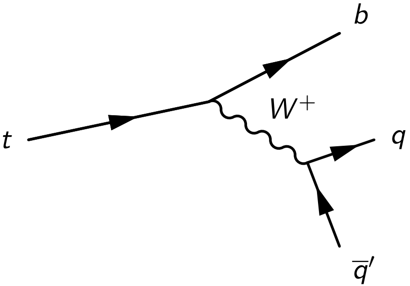
Physics

- We look at top-quark pair production via electron-positron collision in ILC at 500 GeV scenario.
- Top-quark is the heaviest elementary particle we know as far as the Standard Model (SM) suggests. It's mass $m_{top} \approx 175$ GeV is on the same level as that of massive gauge boson.
- If we could assess the the coupling between Top quark and W boson, we would possibly be able to confirm electroweak symmetry breaking, indicating the physics Beyond SM.

Channel

Channel	Decay Channel	Probability
Full Hadronic	$t\bar{t} \to b\bar{b}q\bar{q}'q\bar{q}'$	45.7%
Semi-leptonic	$t\bar{t} \to b\bar{b}\ \nu\bar{\ell}q\bar{q}'$	43.8%
Full leptonic	$t\bar{t} \to b\bar{b}\ \bar{\ell}\ell\nu\bar{\nu}$	10.5%



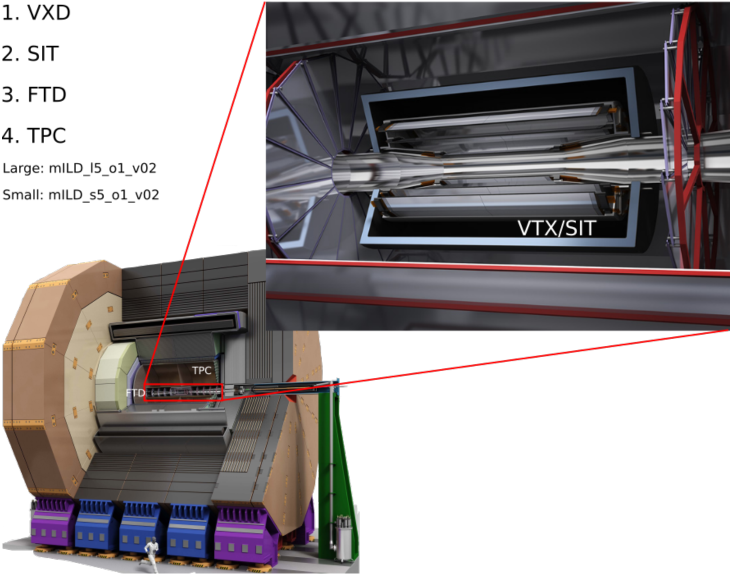


International Large Detector (ILD)

1. VXD
2. SIT
3. FTD
4. TPC

Large: mILD_l5_o1_v02

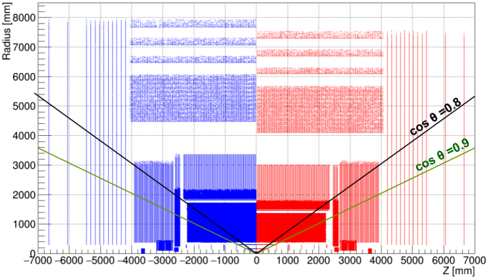
Small: mILD_s5_o1_v02



Small and Large Detectors

Comparison of Small and Large Samples

	TPC Radius (mm)	B-field (T)
Large	1808	3.5
Small	1460	4.0



Physical Observables

Forward and backward asymmetry

$$A_{fb} \equiv \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)}$$

where θ is a polar angle of top quark with respect to the beam line.

- A_{fb} is used as a key estimator for the electroweak coupling between top-quark in this analysis, yet does not address on actual physical values in this analysis.
- Decent measurement performance on vertex charge measurement is required to distinguish top and anti-top, in order to calculate reliable A_{fb} value.
- For the simplicity in reconstruction, we only focused on polarization with *left-handed electron* case. (namely, eLpR)

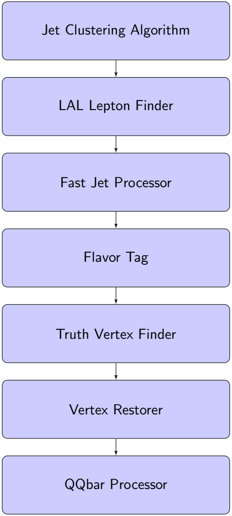
Strategy

Steps for Analysis

1. Measurement of vertex charge
2. Comparison of charges from hadronic and leptonic top
3. Calculation of forward and backward asymmetry (Afb)

Benchmark Studies

- Inspection on samples with different detector geometries (small and large)
- Distribution of polar angle for top and b quarks



Cuts

Basic selection cuts:[1]

- Lepton cut: Iso.Lep. > 5 GeV
- Hadronic mass: $180 < M_{Had} < 420$
- $btag1 > 0.8$ or $btag2 > 0.3$
- Thrust: $thrust < 0.9$
- Top1 mass: $120 < m_{t1} < 270$
- W1 mass: $50 < m_{W1} < 250$

Lorentz Gamma cuts:

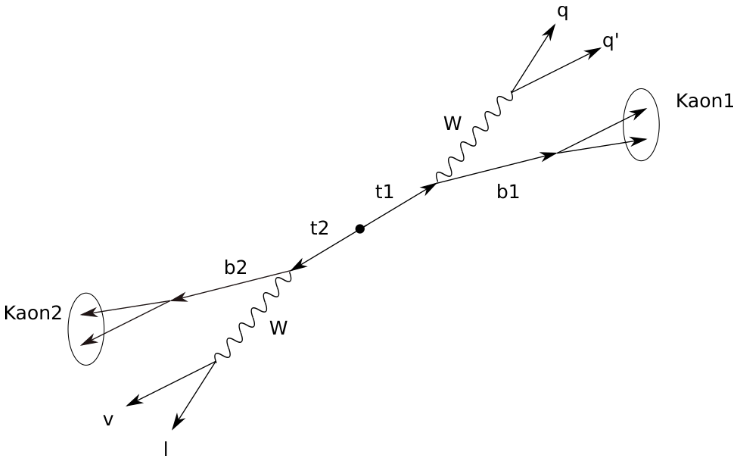
- $\gamma_t^{had} + \gamma_t^{lep} > 2.4$
- $\gamma_t^{lep} < 2.0$

b-quark Momentum cuts:

- $|p|_{had} > 15$ GeV

[1] Main distinct algorithm to distinguish top and anti-top.

Methods



Methods

Methods 1-4 (Rely only on hadronic charge information)

1. vtx $\times$ vtx
2. kaon $\times$ kaon
3. vtx $\times$ kaon
4. vtx $\times$ kaon'

Methods 5-6 (Use isolated lepton charge)

5. vtx $\times$ lepton, vtx' $\times$ lepton
6. kaon $\times$ lepton, kaon' $\times$ lepton

[1] All methods that have been used should be consistent with one another.

[2] Methods rely on algorithm used in Dr. Sviatoslav Bilokin's thesis. [Bilokin 2017]

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Basic Selection Efficiencies

Small Detector

nEvents	85056	(100.%)
after lepton cuts	73376	(86.3%)
after btag cuts (0.8 & 0.3)	68021	(80.0%)
after thrust cut	68021	(80.0%)
after hadronic mass cut	66431	(78.1%)
after reco T & W mass cut	60885	(71.6%)

Large Detector

nEvents	85056	(100.%)
after lepton cuts	73277	(86.2%)
after btag cuts (0.8 & 0.3)	67842	(79.8%)
after thrust cut	67842	(79.8%)
after hadronic mass cut	66254	(77.9%)
after reco T & W mass cut	60880	(71.6%)

Top Polar Angle Distributions

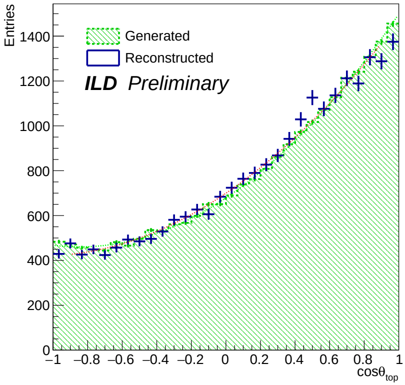


Figure: Top polar (small)

Afb gen	0.329730	N: 164292
Afb reco	0.337263	N: 23409
Final efficiency	28.4968%	

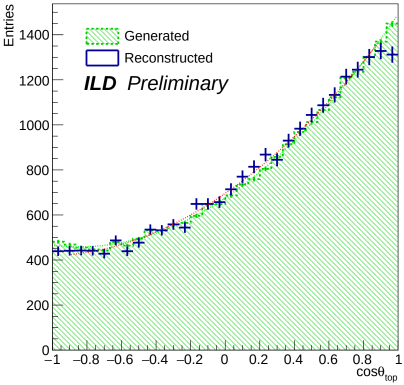


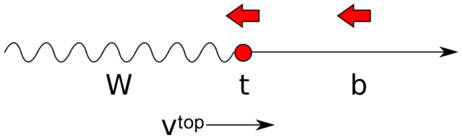
Figure: Top polar (large)

Afb gen	0.329718	N: 164292
Afb reco	0.337681	N: 23306
Final efficiency	28.3714%	

b-quark

Approach using b-quark

- Because W boson only couples to left-handed particles and right-handed anti-particles, we expect b-quark to follow same flight direction as top quark especially in left handed electron case.
- b-quark is a main tool to distinguish top and anti-top, which will be also the case for full-hadronic channel.



b Polar Angle Distributions

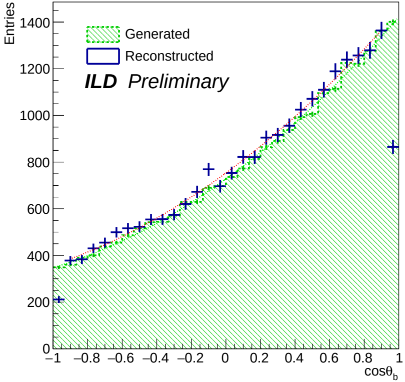


Figure: b polar (small)

Afb gen	0.341952	N: 164292
Afb reco	0.330428	N: 23409
Final efficiency	28.4968%	

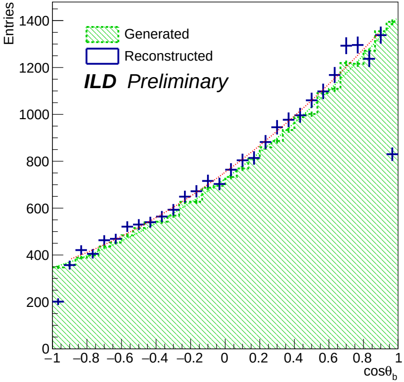


Figure: b polar (large)

Afb gen	0.341952	N: 164292
Afb reco	0.330301	N: 23306
Final efficiency	28.3714%	

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Conclusion

Some important remarks:

- Inspection on samples with different detector geometries
- Distribution of polar angle for top and b quarks

Future prospects:

- Revision on purity of track reconstruction.
- Contribution to IDR (ILD Design Report)
- Extension to full-hadronic channel.

References

Sviatoslav Bilokin (2017)
'Hadronic showers in a highly granular silicon-tungsten calorimeter and production of bottom and top quarks at the ILC'
Ph.D thesis, Université Paris Saclay, Orsay France

Thank you

Backup

Method 7

Method 7:
Method 7 is based on availability of isolated lepton and $chi2\ (= \chi^2_{top}) < 15$, where

$$\chi^2_{top} = \left(\frac{\gamma_t^{had} - 1.435}{\sigma_{\gamma_t}}\right)^2 + \left(\frac{p_b^* - 68}{\sigma_{\gamma_{p_b^*}}}\right)^2 + \left(\frac{\cos\theta_{bW} - 0.23}{\sigma_{\cos\theta_{bW}}}\right)^2$$

Top Efficiency and Afb (w/o Consistency Check)

Small Detector

Afb gen	0.32973	N: 164292
Afb reco	0.325618	N: 31454
Final efficiency	38.2904%	

Large Detector

Afb gen	0.329718	N: 164292
Afb reco	0.327559	N: 31518
Final efficiency	38.3683%	

Top Polar Angle Distributions (w/o Consistency Check)

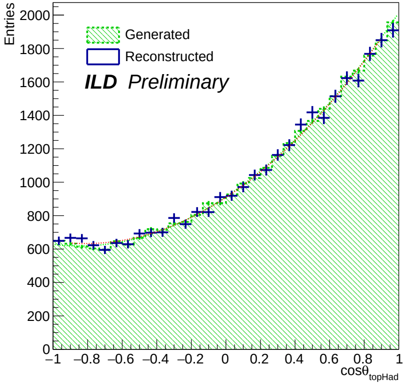

Figure: Top polar (small)

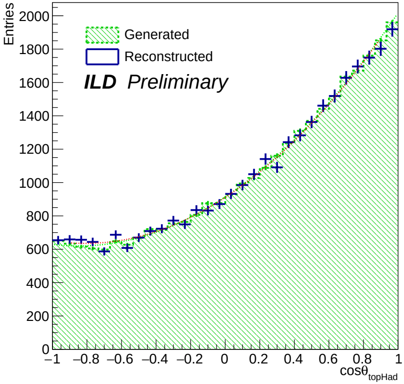

Figure: Top polar (large)