

Heavy Flavor Working Meeting

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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.
- **Full simulation** of the ILD Detector $\sqrt{s} = 500$ GeV is performed.
(with both left and right electron polarization)

Channel

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

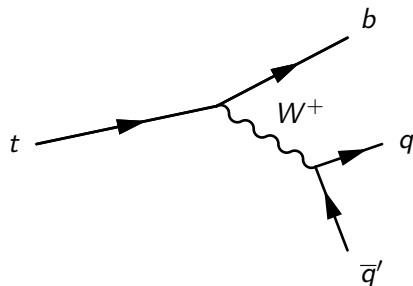
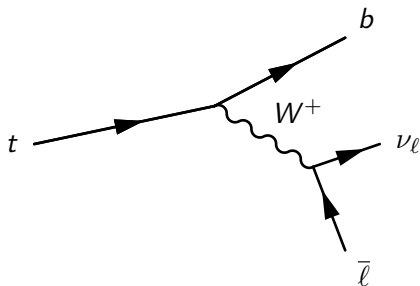


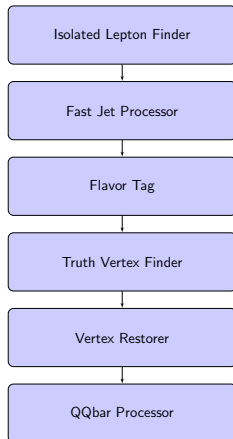
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Processor Arrangement

Steps for Analysis

- 1 Measurement of vertex charge
- 2 Comparison of charges from hadronic and leptonic top
- 3 Background estimation
- 4 Calculation of forward and backward asymmetry (A_{FB})



Event Selection

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:

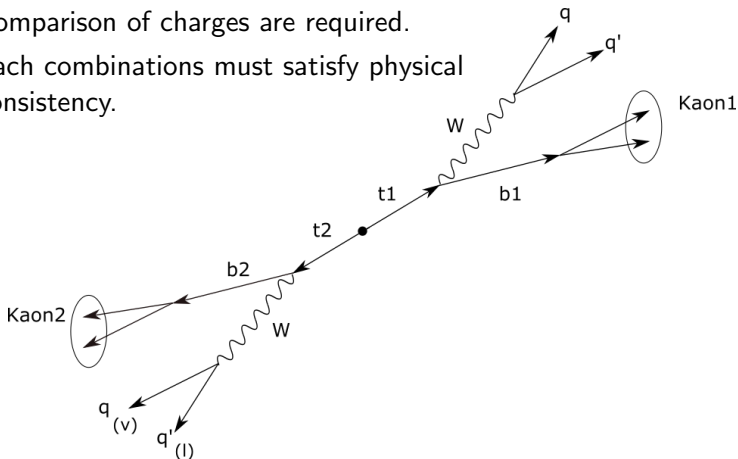
- $|p|_{had} > 15$ GeV

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

Methods

Combination

- Comparison of charges are required.
- Each combinations must satisfy physical consistency.



Methods

Methods 1-4 (Had chg. info)

- 1 $\text{vtx} \times \text{vtx}$
- 2 $\text{kaon} \times \text{kaon}$
- 3 $\text{vtx} \times \text{kaon}$
- 4 $\text{vtx} \times \text{kaon}'$

Methods 5-6 (Iso Lep. chg info)

- 5 $\text{vtx} \times \text{lepton}, \text{vtx}' \times \text{lepton}$
- 6 $\text{kaon} \times \text{lepton}, \text{kaon}' \times \text{lepton}$

Example

Methods	Top1	Top2
1	+	-
2	-	-
3	-	+
4	+	0
5	+	-
6	+	-
final	+	-

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

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 - Single Top Process
 - Semi-Leptonic
 - Full-Hadronic
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Selection Efficiency

Basic Selection Efficiency

	$e_L^- e_R^+ \rightarrow t\bar{t}$		$e_R^- e_L^+ \rightarrow t\bar{t}$	
	IDR-L	IDR-S	IDR-L	IDR-S
Isolated Lepton	92.1%	92.1%	94.1%	94.0%
$btag_1 > 0.8$ or $btag_2 > 0.3$	81.2%	81.1%	84.9%	84.8%
Thrust < 0.9	81.2%	81.1%	84.9%	84.8%
Hadronic mass	78.2%	78.2%	82.2%	82.3%
Reconstructed m_W and m_t	73.4%	73.4%	77.6%	77.5%

¹Out of 1.8 mil events

²Efficiency progression after each cuts, not including background effects.

Single Top Process

Single top process diagrams

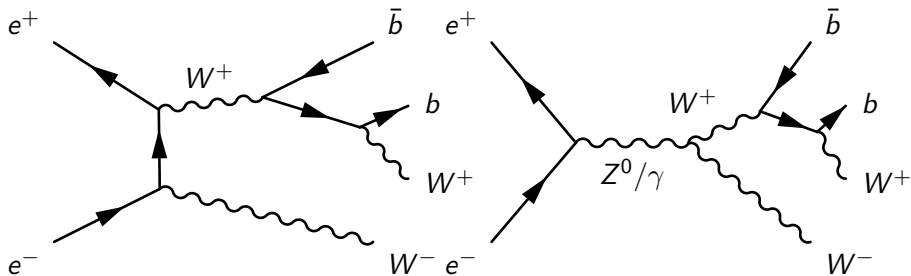


Figure: T-channel (left) and S-channel (right) of Feynman diagram for single top production. Occupies 12% of the entire $b\bar{b}l\nu q\bar{q}$ samples.

Single Top Process

Single top process

- Generated top info does not exist. Need to combine gen b and W information to obtain gen top info.
- Not all gen b and W comes from the gen top. One of b 's might be coming from W .
- Which will eventually contaminate the polar angle spectrum.

Gen top mass selection

$$|m_{Wb} - m_t| < 15 \text{ GeV}$$

Single Top Process

Generated Top mass distribution

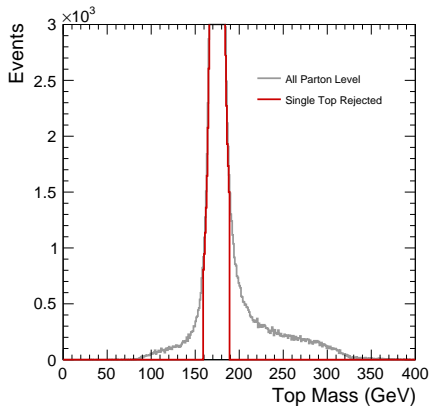
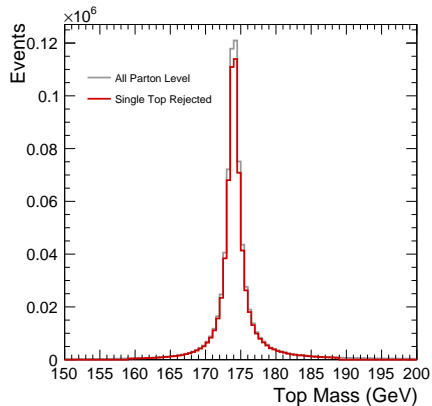


Figure: **Left:** Gen top mass. **Right:** Zoomed

Single Top Process

Polar angle distribution for eLpR sample (method 7 only)

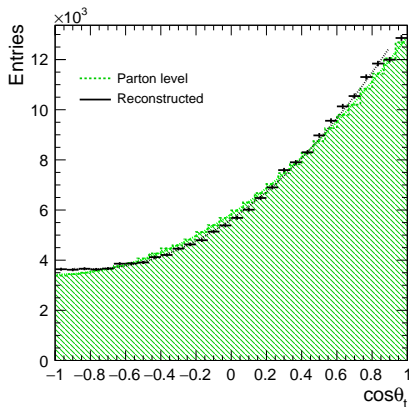
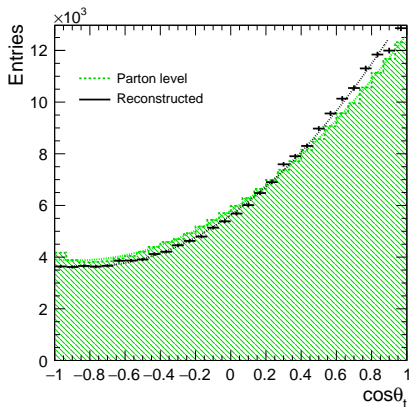


Figure: **Left:** Polar angle with single top. **Right:** Polar angle with single top rejection

Polar Angle Distribution

Polar angle distribution for eLpR sample

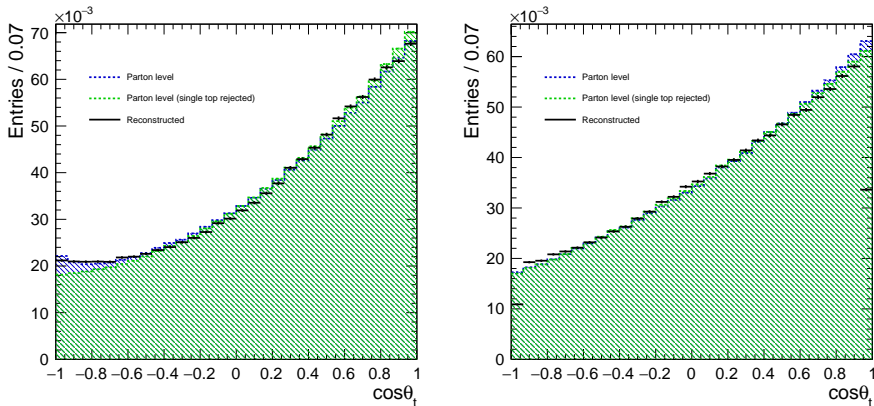


Figure: **Left:** Polar angle distribution of top quark pair. **Right:** Polar angle distribution of b quark pair.

Polar Angle Distribution

Polar angle distribution for eRpL sample

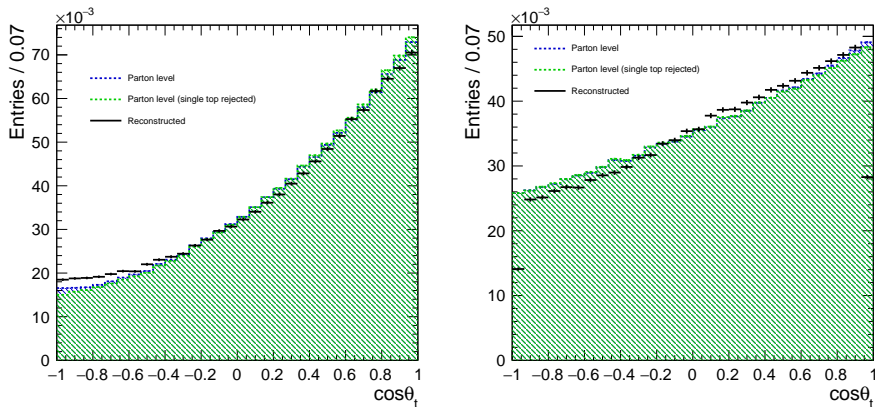


Figure: **Left:** Polar angle distribution of top quark pair. **Right:** Polar angle distribution of b quark pair.

A_{FB} and Uncertainties

A_{FB} calculation

	$e_L^- e_R^+$		$e_R^- e_L^+$	
	IDR-L	IDR-S	IDR-L	IDR-S
$A_{FB,gen}$	0.329		0.430	
$A_{FB,reco}$	0.342	0.340	0.430	0.430
Final Efficiency (%)	30.6	30.4	64.1	64.1

Uncertainties

	$\mathcal{P}_{e^-}, \mathcal{P}_{e^+}$	$(\delta\sigma/\sigma)_{stat.} (\%)$	$(\delta A_{FB}/\sigma A_{FB})_{stat.} (\%)$
IDR-L	-0.8, +0.3	0.17	0.70
	+0.8, -0.3	0.25	0.53
IDR-S	-0.8, +0.3	0.17	0.70
	+0.8, -0.3	0.25	0.53

Polar Angle Distribution (Full-Hadronic)

Polar angle distribution for eLpR sample

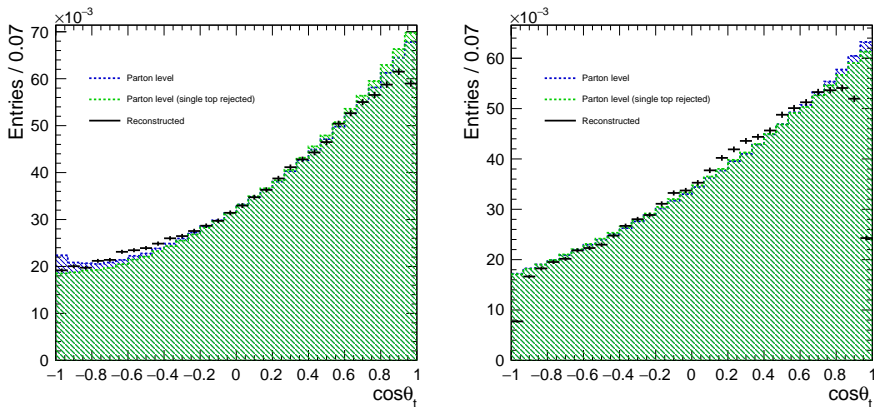


Figure: **Left:** Polar angle distribution of top quark pair. **Right:** Polar angle distribution of b quark pair.

Background Analysis (Preliminary)

Considered Background

Channel	$\sigma_{unpol.}$ [fb]	σ_{LR} [fb]	σ_{RL} [fb]
$t\bar{t}$	572	1564	724
$\mu\mu$	456	969	854
$u\bar{u} + c\bar{c} + s\bar{s} + d\bar{d}$	2208	6032	2793
$b\bar{b}$	372	1212	276
γZ^0	11185	25500	19126
WW	6603	26000	150
$Z^0 Z^0$	422	1106	582
$Z^0 WW$	40	151	8.7
$Z^0 Z^0 Z^0$	1.1	3.2	1.22

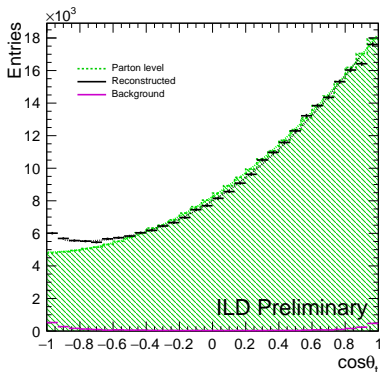


Figure: Polar angle distribution of top quark pair with backgrounds.

Background Analysis (Preliminary)

Background Ratio

$$e_L^- e_R^+ \rightarrow t\bar{t} \text{ at } 500 \text{ GeV}$$

	IDR-L
Isolated Lepton	51.1%
$btag_1 > 0.8$ or $btag_2 > 0.3$	1.10%
Thrust < 0.9	1.10%
Hadronic mass	0.619%
Reconstructed m_W and m_t	0.435%

Background ratio after each selection.

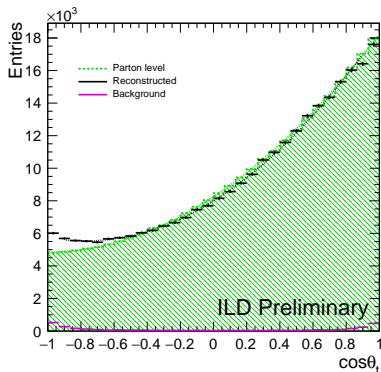


Figure: Polar angle distribution of top quark pair with backgrounds.

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Summary and Outlook

Some important remarks:

- Full detector simulation for $e^+e^- \rightarrow t\bar{t}$ is completed for both eLpR and eRpL samples.
- Both full-hadronic and semi-leptonic channel were processed.
- Effects of single top events was evaluated at the parton level.

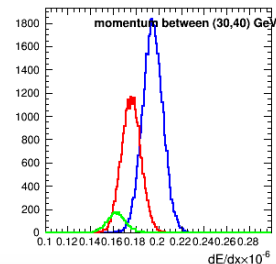
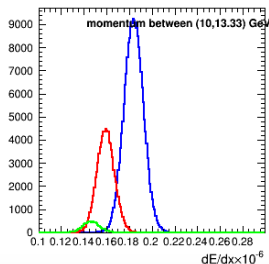
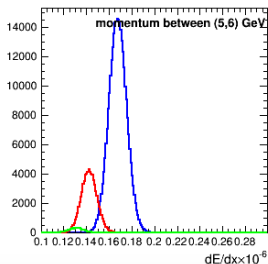
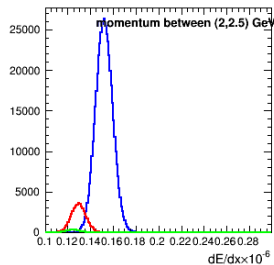
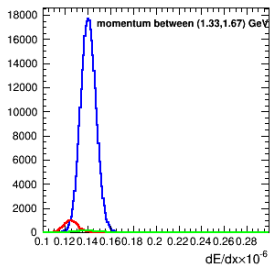
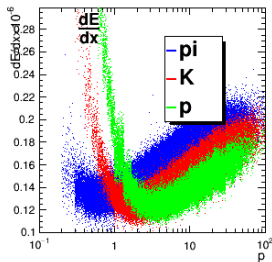
Backup

Efficiencies After Methods

Methods (with pcut or gcut) Pcut and gcuts were applied individually to see how the number of events and efficiencies evolves though each methods.

Methods	pcut		gcut		pcut + gcut	
after p or g cut	366744	(40.5%)	564015	(62.2%)	310352	(34.2%)
after method7	201677	(22.2%)	324110	(35.8%)	200263	(22.1%)
after method75	280559	(31.0%)	439778	(48.5%)	259614	(28.6%)
after method756	289984	(32.0%)	459087	(50.7%)	268498	(29.6%)
after method7561	299136	(33.0%)	464904	(51.3%)	272574	(30.1%)
after method75612	303071	(33.4%)	467435	(51.6%)	274418	(30.3%)
after method756123	307113	(33.9%)	471805	(52.1%)	276209	(30.5%)
after method7561234	309578	(34.1%)	473195	(52.2%)	277392	(30.6%)
after method1234	153775	(17.0%)	176093	(19.4%)	130252	(14.4%)

Kaon Selection



Purity of different methods

- Consistently lower purity for methods with Kaon usage in case of IDR-S
- Consistent observation was made for $e^+e^- \rightarrow b\bar{b}$

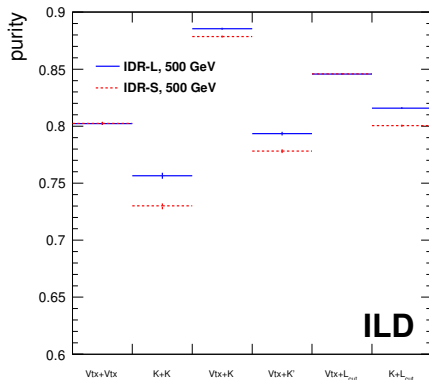


Figure: Purity with different methods

Charge Combination and Combinatorial Background

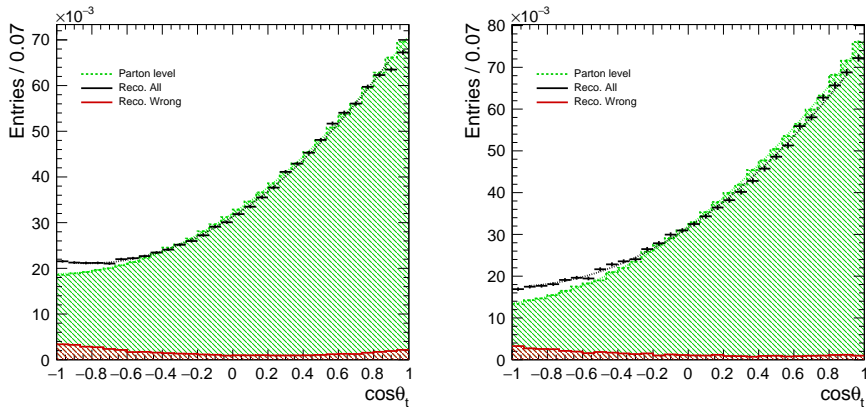


Figure: Top polar angle of $e_L^- e_R^+$ (left) and $e_R^- e_L^+$ (right) in semi-leptonic channel compared with truth information.

Charge Combination and Combinatorial Background

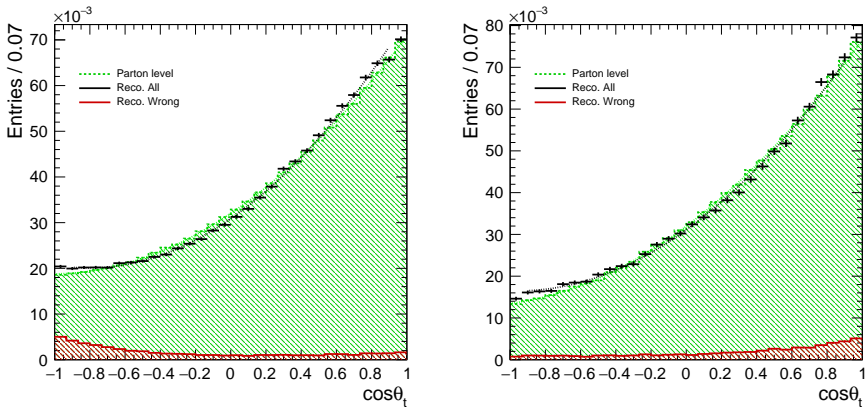


Figure: Top polar angle of $e_L^- e_R^+$ (left) and $e_R^- e_L^+$ (right) in semi-leptonic channel only using isolated lepton charge as an identifier.

Charge Combination and Combinatorial Background

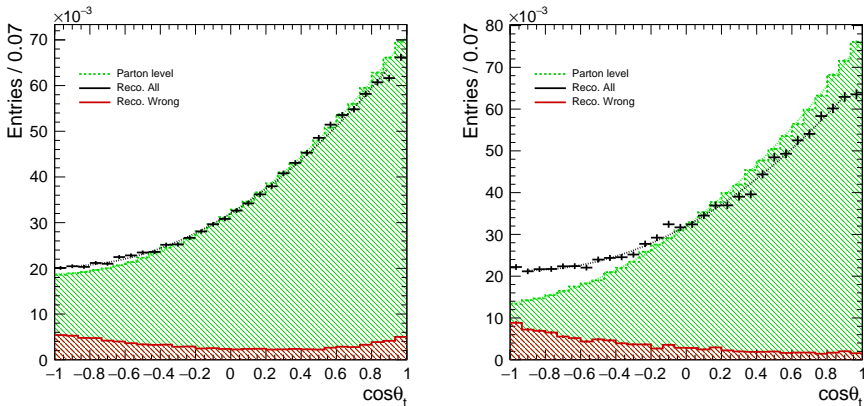


Figure: Top polar angle of $e_L^- e_R^+$ (left) and $e_R^- e_L^+$ (right) in semi-leptonic channel only using hadronic charge as an identifier.