Measurement of the $t\bar{t}$ cross section at the LC

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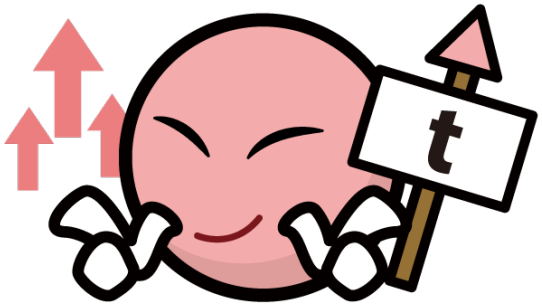
Motivation

Physics

- $e^+e^- \to t\bar{t}$ in ILC at $\sqrt{s} = 500$ GeV
- Top-quark is the heaviest elementary particle we know as far as the Standard Model (SM) suggests.
  - $m_{top} \approx 175$ GeV
  - On the same level as VEV of massive gauge boson.
- Could possibly be able to confirm electroweak symmetry breaking, indicating the physics Beyond SM.



Physical Observables

Forward and backward asymmetry

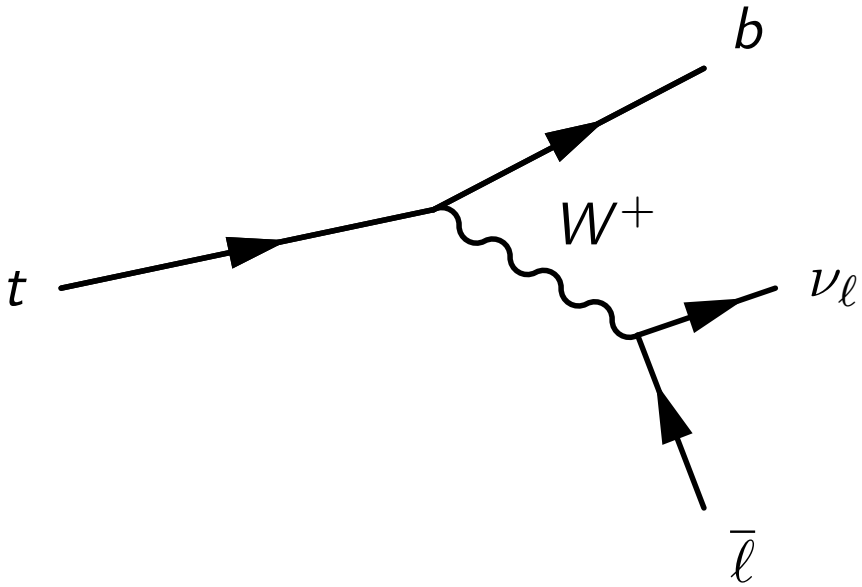
$$A_{fb} \equiv \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)}$$

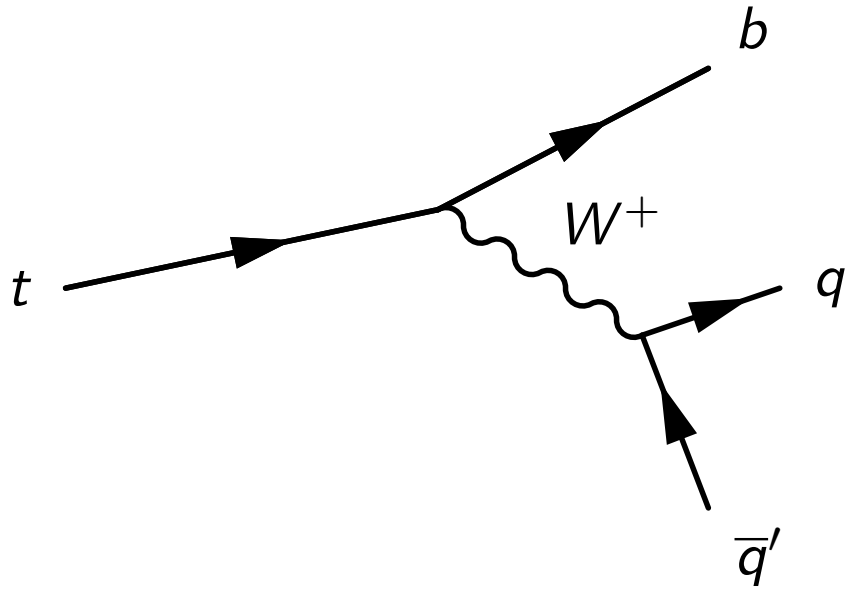
where θ is a polar angle of top quark with respect to the beam line.

- 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	$t\bar{t} \to b\bar{b}q\bar{q}'q\bar{q}'$	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%





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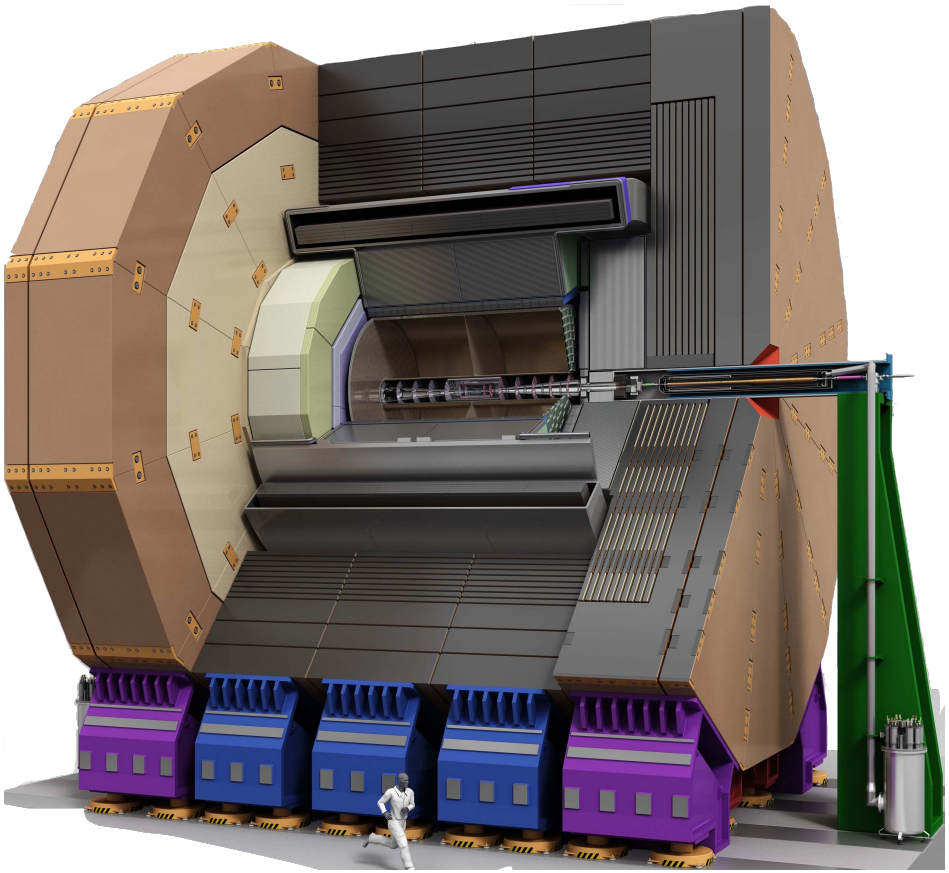
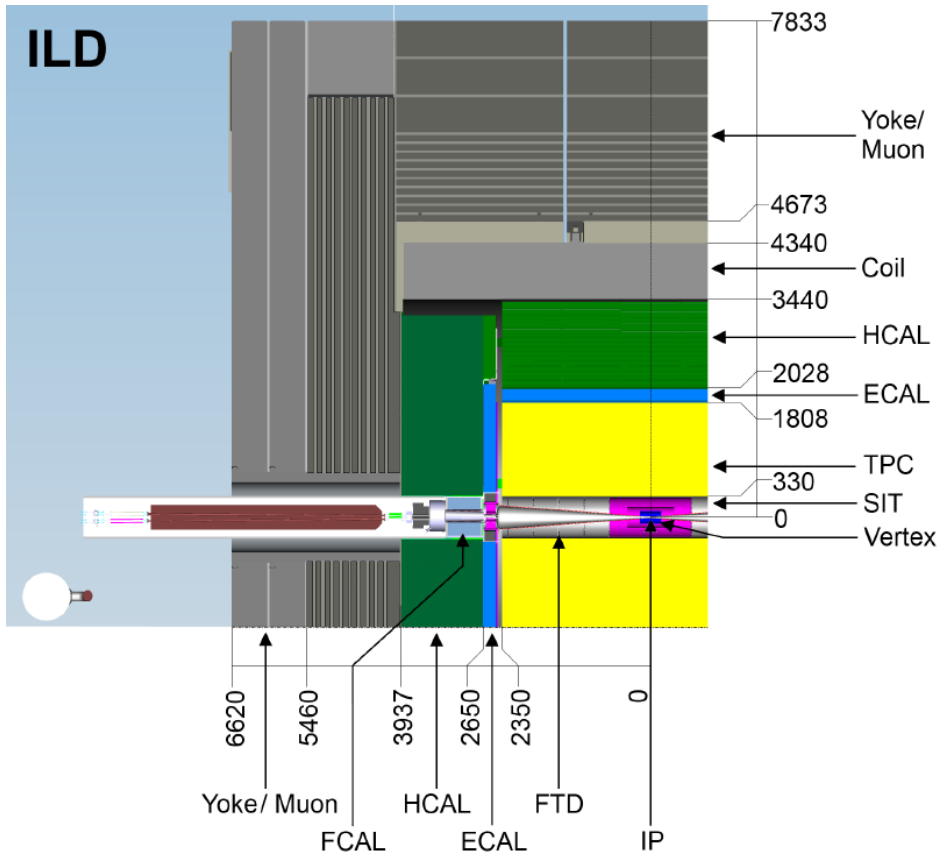
International Large Detector (ILD)

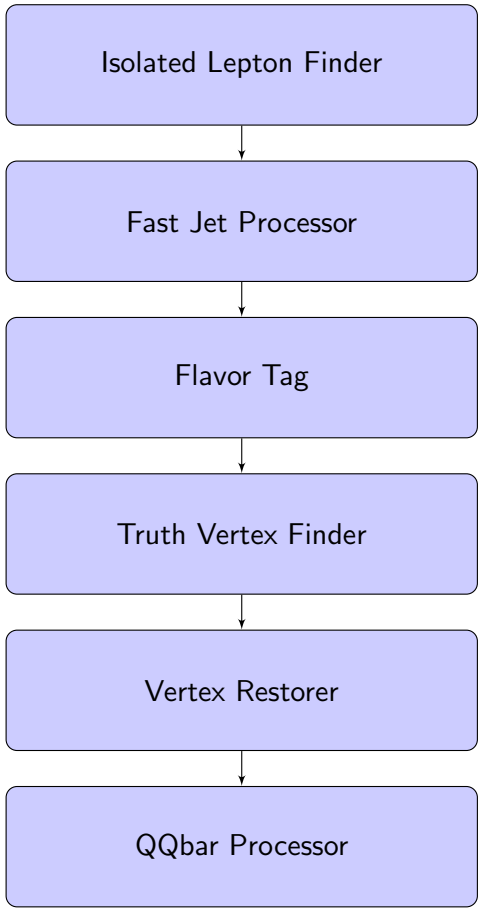




Processor Arrangement

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:

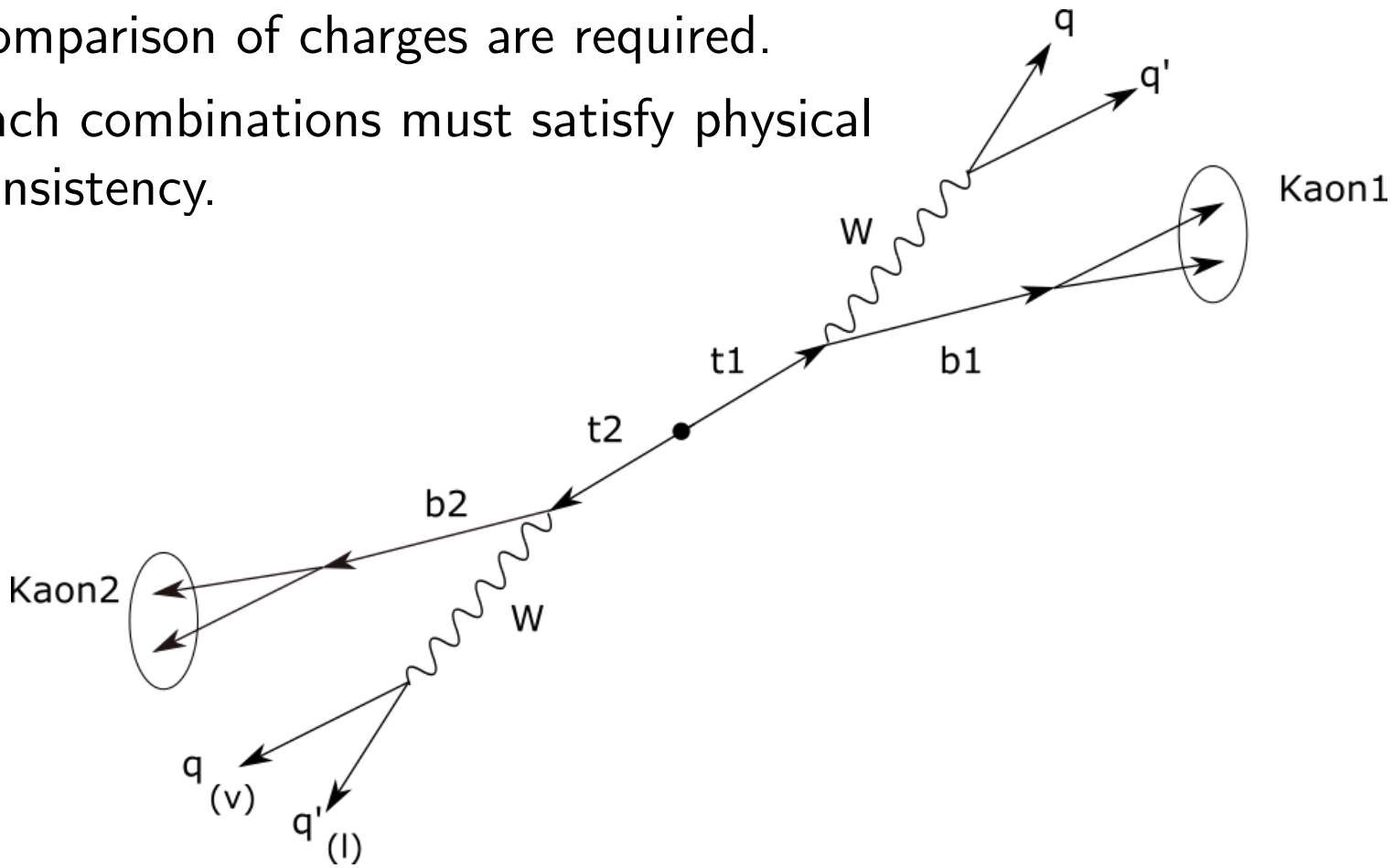
- $|p|_{had} > 15$ GeV

[1] Main 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. vtx × vtx
2. kaon × kaon
3. vtx × kaon
4. vtx × kaon'

Methods 5-6 (Iso Lep. chg info)

5. vtx × lepton, vtx' × lepton
6. kaon × lepton, kaon' × lepton

Example

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

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

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Selection Efficiency

Basic Selection Efficiency

	$e_L^- e_R^+ \to t\bar{t}$		$e_R^- e_L^+ \to t\bar{t}$	
	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%

[1] Out of 1.8 mil events

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

Polar Angle Distribution

Polar angle distribution for eLpR sample

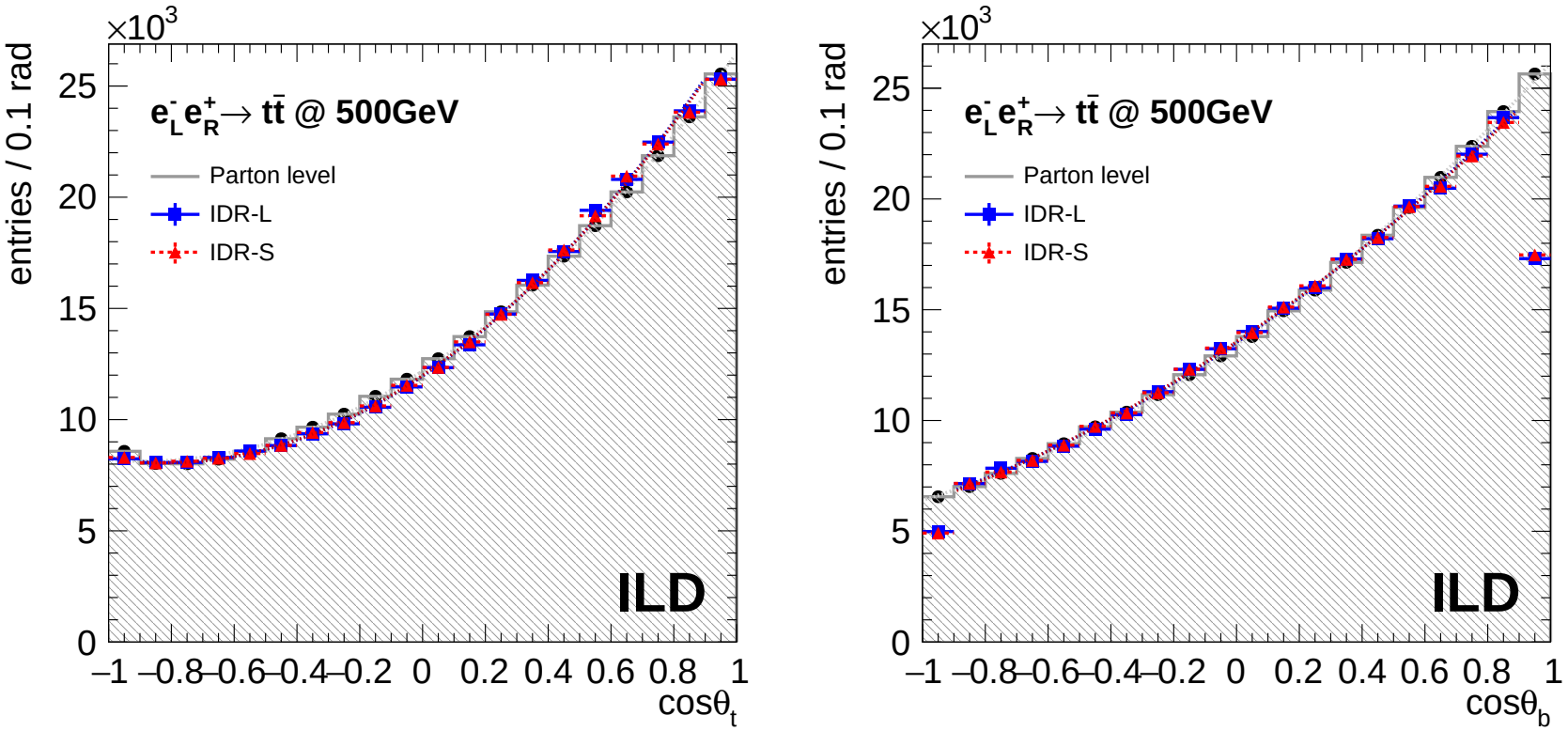

Figure: **Left**: Polar angle distribution of top quark pair. **Right**: Polar angle distribution of b quark pair.

Polar Angle Distribution

Polar angle distribution for eRpL sample

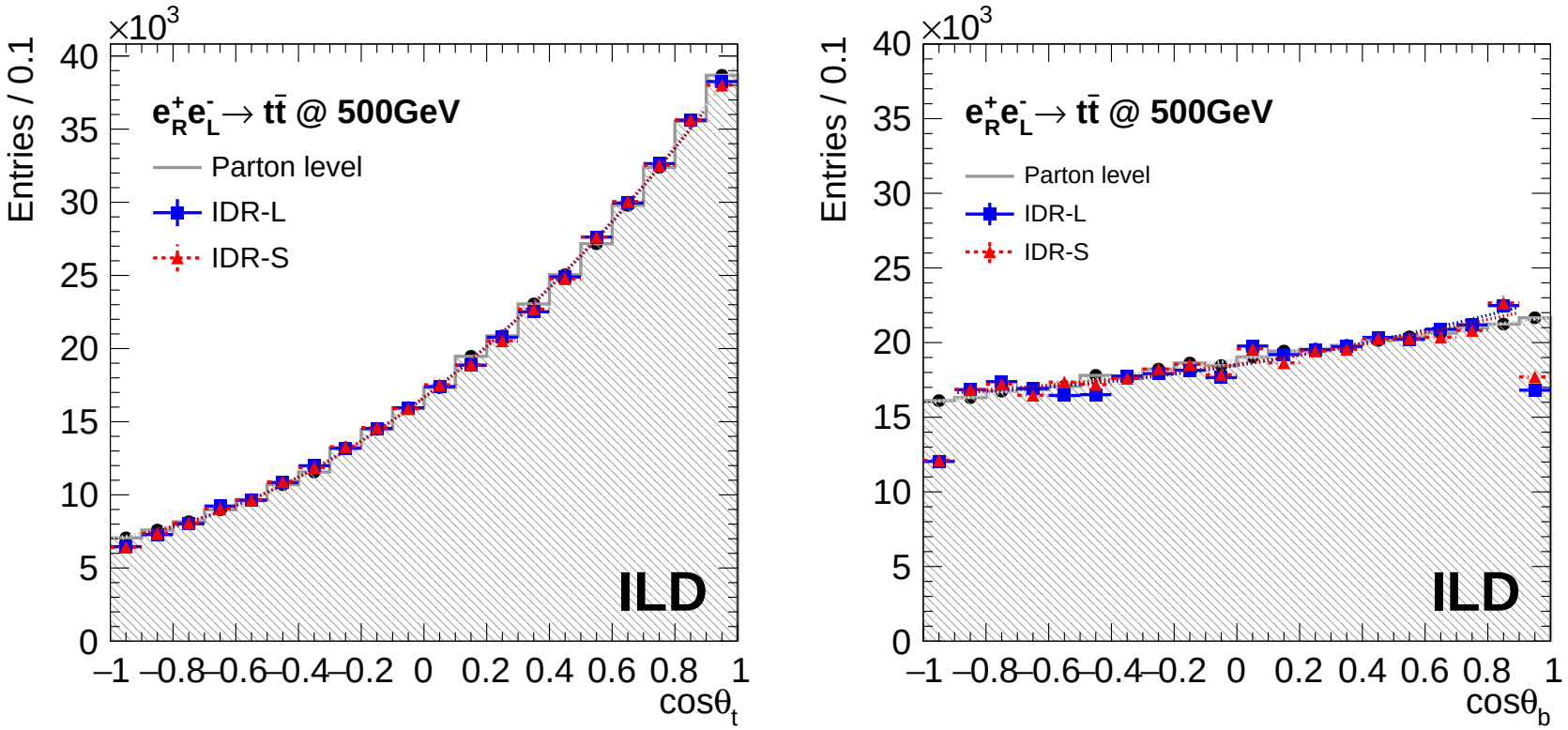

Figure: **Left**: Polar angle distribution of top quark pair. **Right**: Polar angle distribution of b quark pair.

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

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^0Z^0	422	1106	582
Z^0WW	40	151	8.7
$Z^0Z^0Z^0$	1.1	3.2	1.22

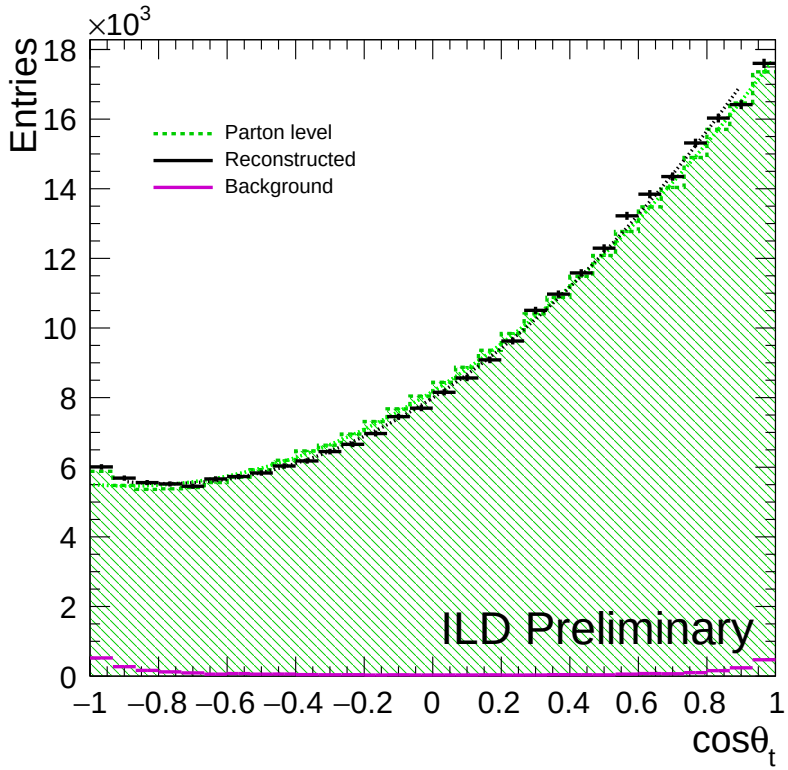

Figure: Polar angle distribution of top quark pair with backgrounds.

Background Analysis (Preliminary)

Background Ratio

$e_L^- e_R^+ \to t\bar{t}$ at 500 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.

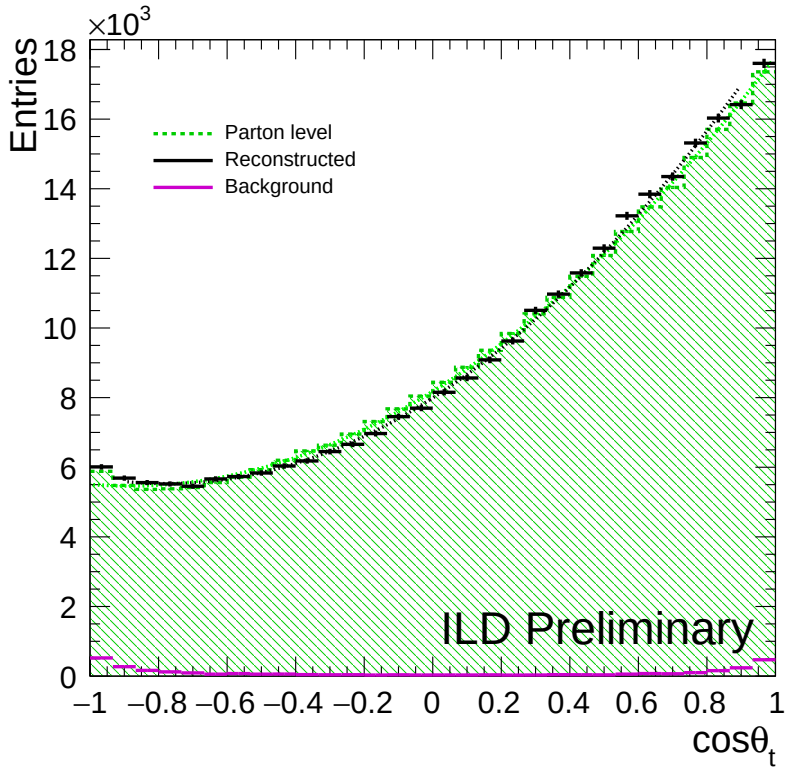

Figure: Polar angle distribution of top quark pair with backgrounds.

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Summary and Outlook

Some important remarks:

- Full detector simulation for $e^+e^- \to t\bar{t}$ is completed for both eLpR and eRpL samples.
- Background Analysis for semi-leptonic process

Future prospects:

- Extension to full-hadronic channel.

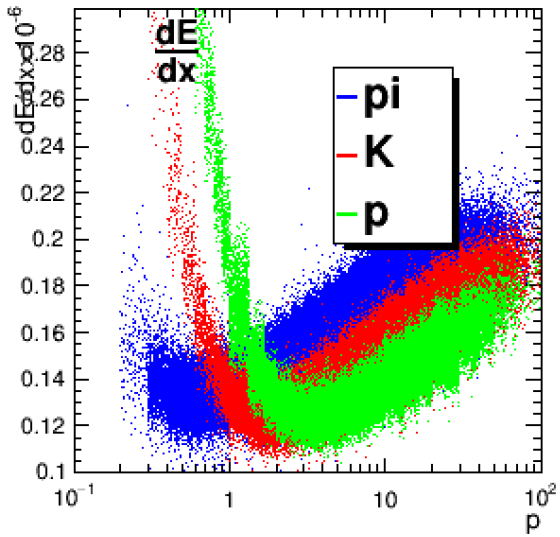
Backup

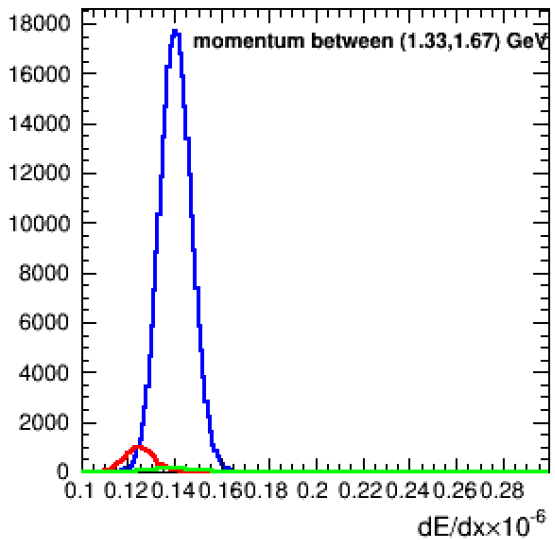
Efficiencies After Methods

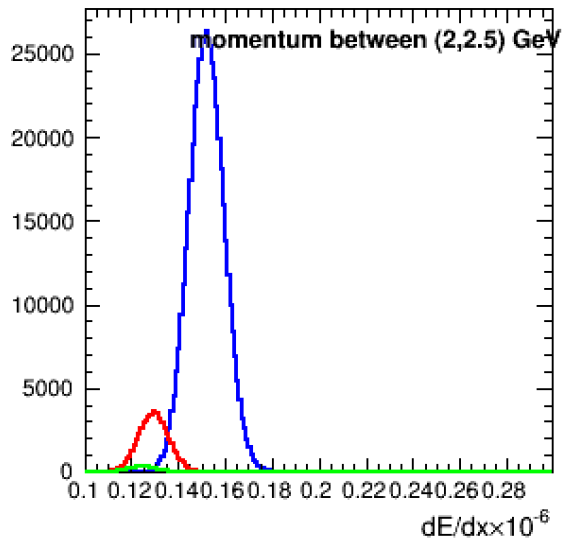
Methods (with pcut or gcut) Pcut and gcuts were applied individually to see how the number of events and efficiencies evolves though each methods.

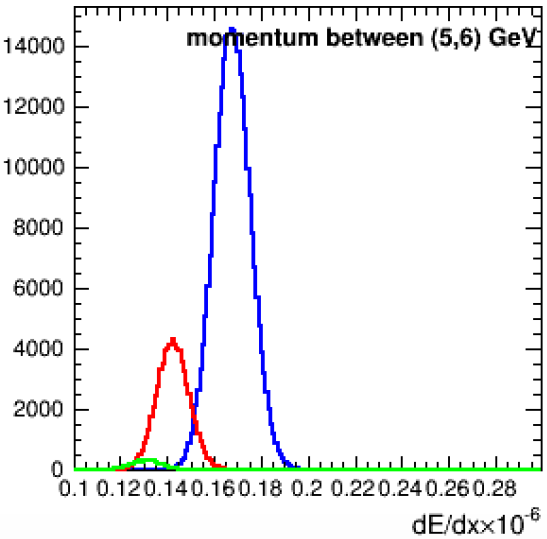
Methods	pcut		gcut		pcut + gcut	
after p or g cut	366744	(40.5%)	564015	(62.2%)	310352	(34.2%)
after method7	201677	(22.2%)	324110	(35.8%)	200263	(22.1%)
after method75	280559	(31.0%)	439778	(48.5%)	259614	(28.6%)
after method756	289984	(32.0%)	459087	(50.7%)	268498	(29.6%)
after method7561	299136	(33.0%)	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%)

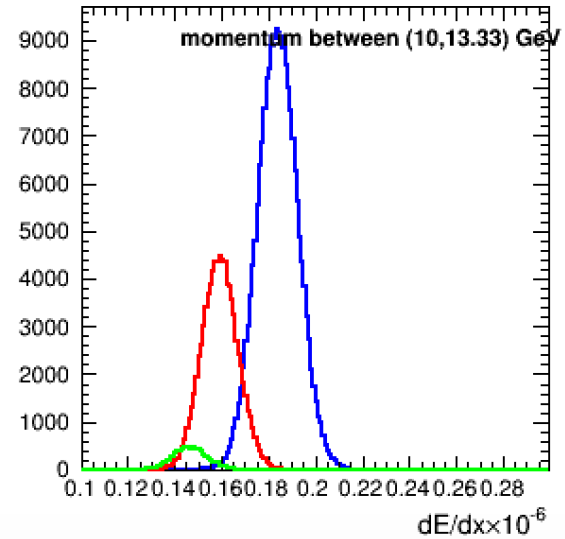
Kaon Selection

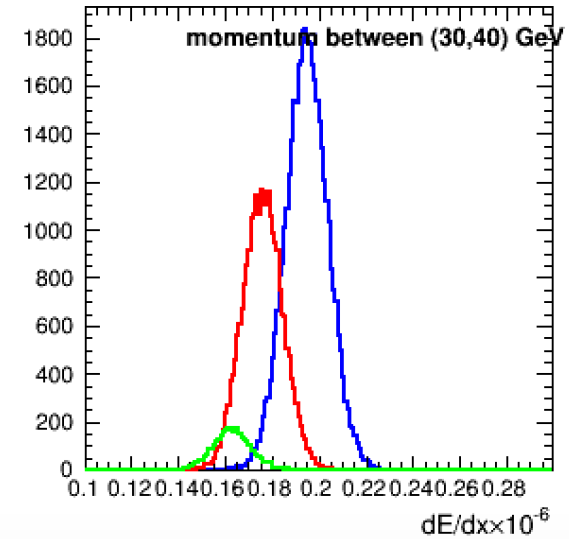












Purity of different methods

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

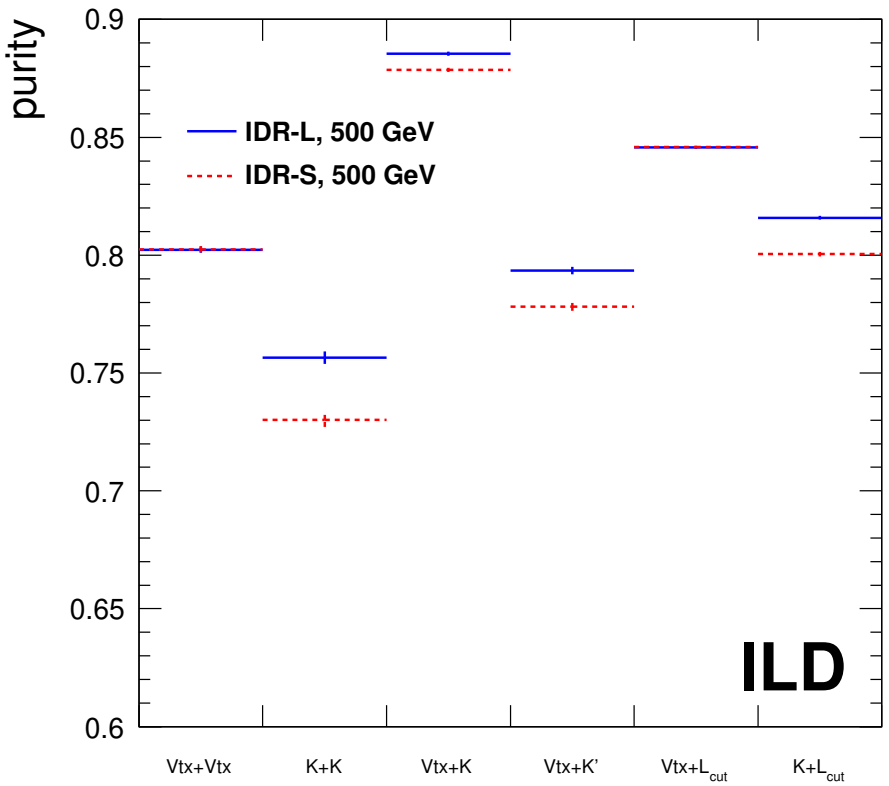


Figure: Purity with different methods