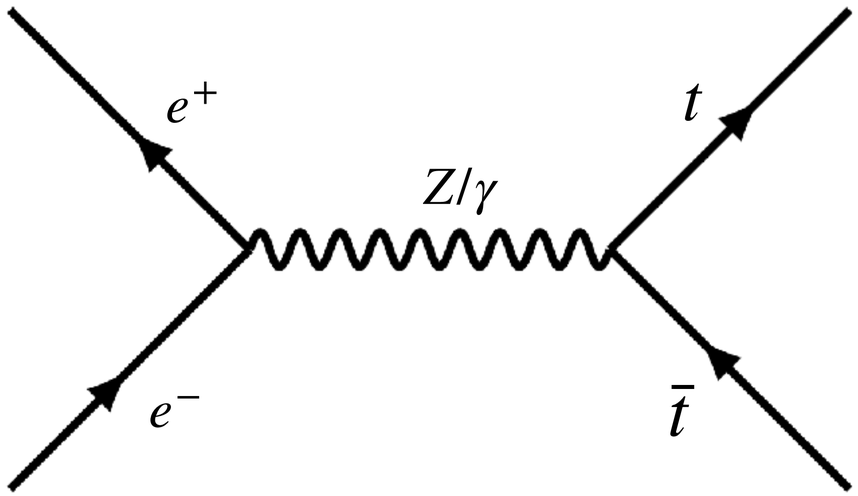
Update of $t\bar{t}$ Analysis

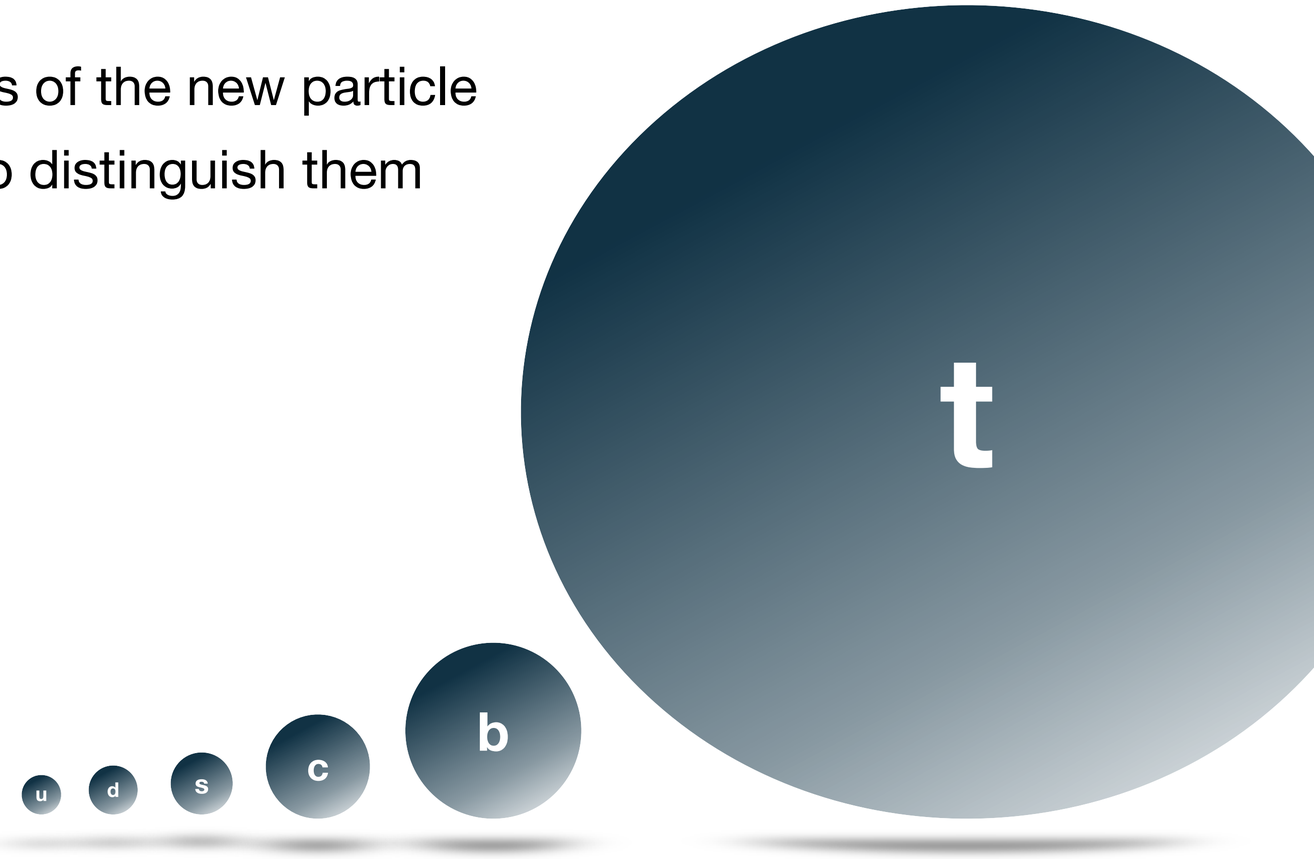
10/07/20 Y. Okugawa, R. Pöschl

ILD Working Group Meeting

Top Quark Pair Production at ILC

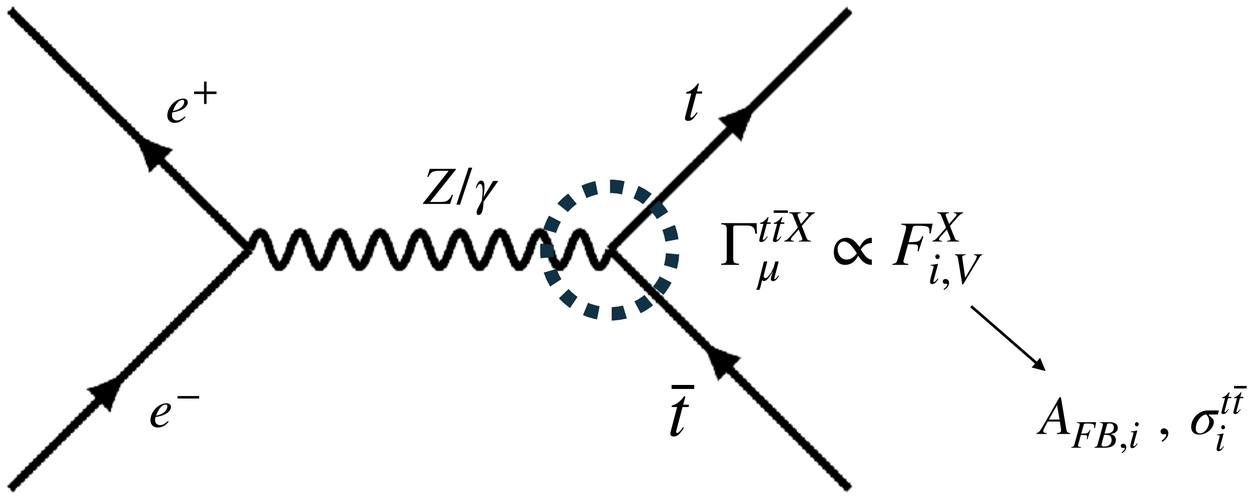
- ILC at $\sqrt{s} = 500$ GeV will produce many $t\bar{t}$ pairs, which allows a precision measurement on the heavy quark properties.
  - Play a central role for the indirect searches of the new particle beyond the Standard Model predictions to distinguish them from the various other theories.

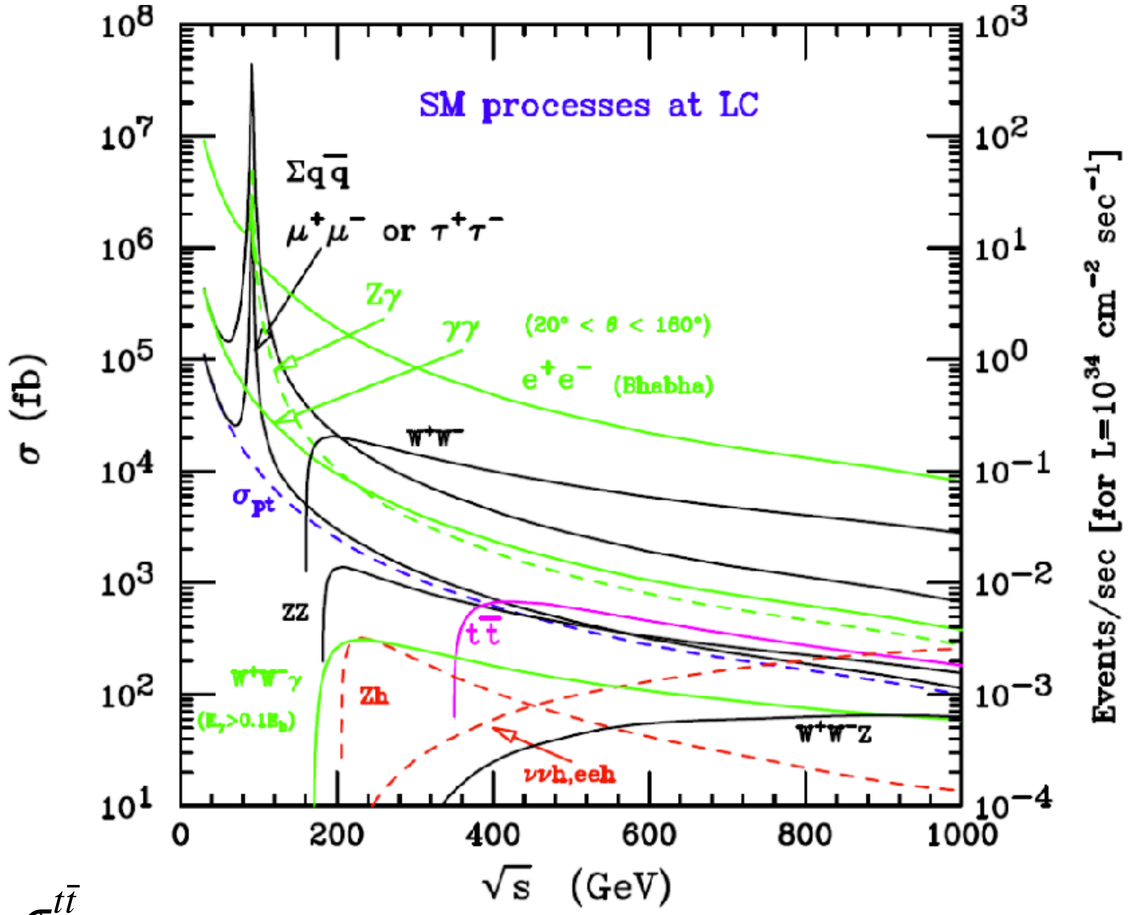




1. Introduction

- The couplings between pair of top and are parametrized in terms of form factors. A_{FB}^{t} is the measure for the level of the parity violation.
- ILC Integrated Luminosity: $\int L\ dt = 4{,}000\ \text{fb}^{-1}$
- $t\bar{t}$ cross section
  - $\sigma_{unpol} = 572$ fb, $\sigma_{eLpR} = 1564$ fb, $\sigma_{eRpL} = 724$ fb





T. Han 2005 hep-ph/0508097

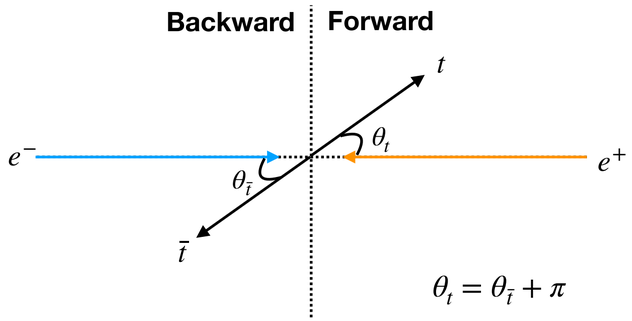
2. Analysis

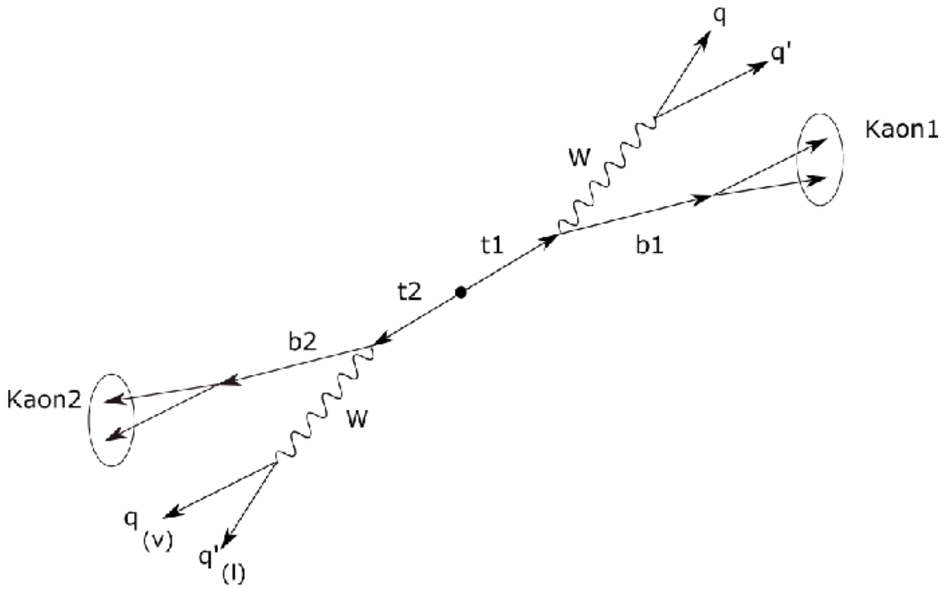
- Semi-leptonic process
  - 4-jets (final state: $b\bar{b}q\bar{q}'\ell\bar{\nu}$)
  - One isolated lepton, e or μ.

    (τ is ignored for the time being)
  - eLpR process
- Observable:

$$A_{FB}^{t} = \frac{\overbrace{N(\cos\theta_t > 0)}^{\text{forward}} - \overbrace{N(\cos\theta_t < 0)}^{\text{backward}}}{N(\cos\theta_t > 0) + N(\cos\theta_t < 0)}$$

	Final States	# of jets	B.R.
Full Leptonic	$t\bar{t} \to (b\ell\bar{\nu})(\bar{b}\bar{\ell}\nu)$	2 jets + 2 ℓ	10.5%
Semi Leptonic	$t\bar{t} \to (b\ell\bar{\nu})(\bar{b}q\bar{q}')$	4 jets + 1 ℓ	43.8%
Full Hadronic	$t\bar{t} \to (bq\bar{q}')(\bar{b}q\bar{q}')$	6 jets	45.7%





$$\sigma_{\mathscr{P}_{e^-},\mathscr{P}_{e^+}} = \frac{1}{4}[(1 - \mathscr{P}_{e^-}\mathscr{P}_{e^+})(\sigma_{L,R} + \sigma_{R,L}) + (\mathscr{P}_{e^-} - \mathscr{P}_{e^+})(\sigma_{R,L} - \sigma_{L,R})]$$

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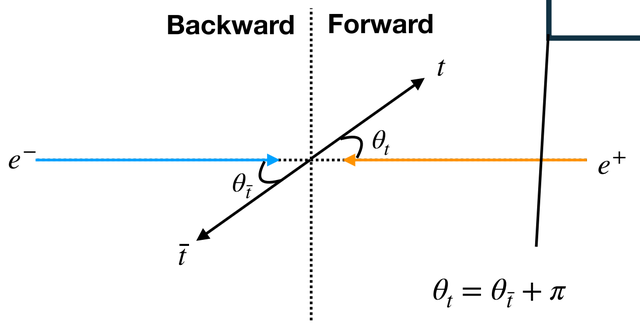

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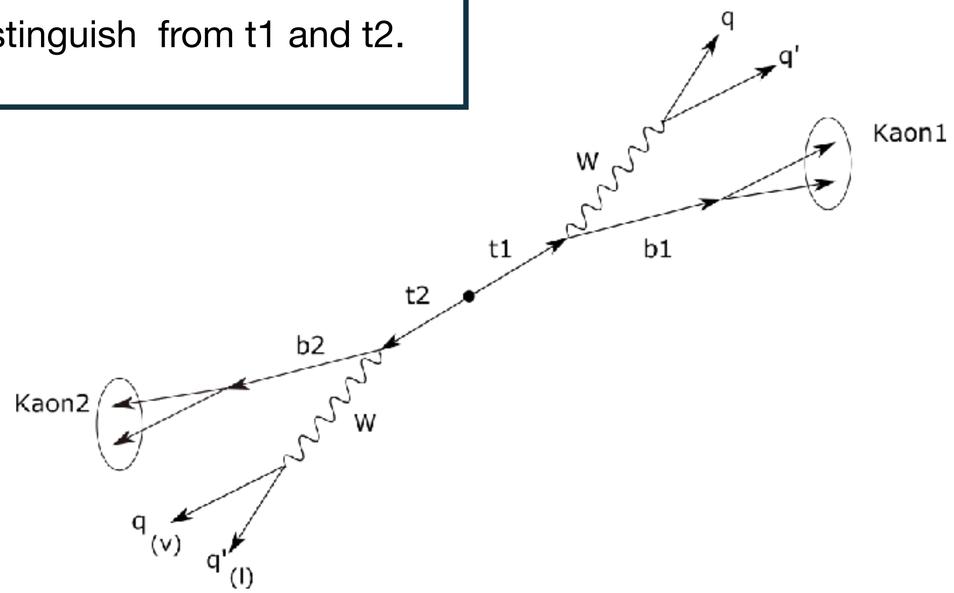

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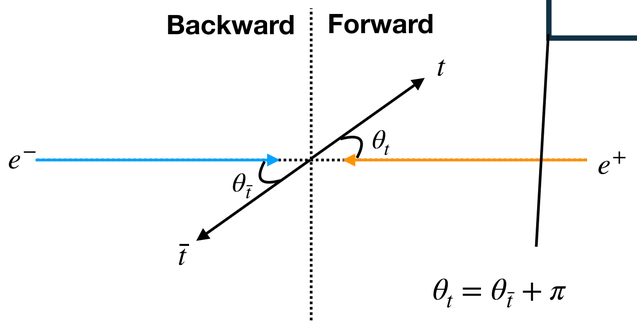

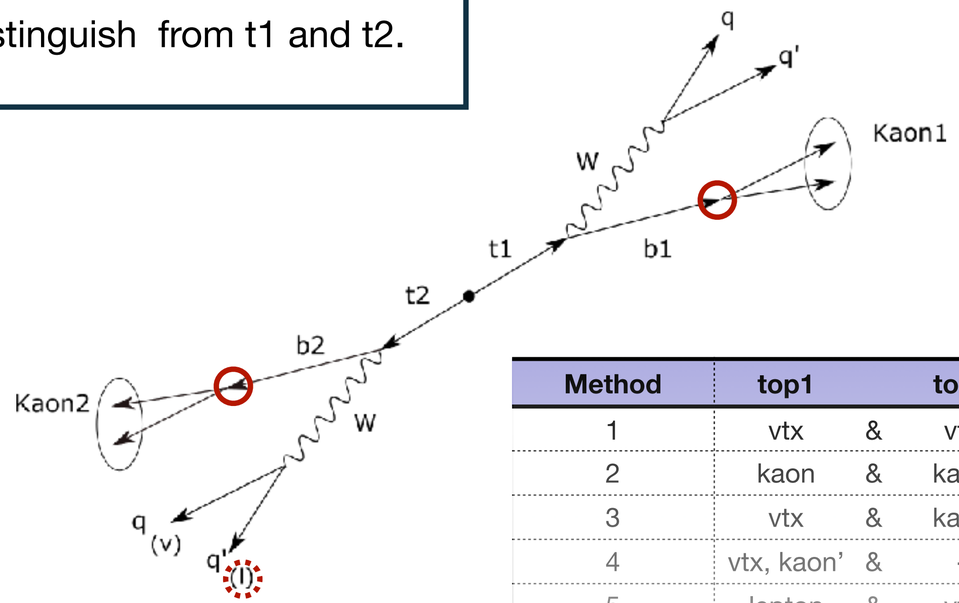

Method	top1		top2
1	vtx	&	vtx
2	kaon	&	kaon
3	vtx	&	kaon
4	vtx, kaon'	&	-
5	lepton	&	vtx
6	lepton	&	kaon
7	lepton	&	

$$\sigma_{\mathscr{P}_{e^-},\mathscr{P}_{e^+}} = \frac{1}{4}[(1 - \mathscr{P}_{e^-}\mathscr{P}_{e^+})(\sigma_{L,R} + \sigma_{R,L}) + (\mathscr{P}_{e^-} - \mathscr{P}_{e^+})(\sigma_{R,L} - \sigma_{L,R})]$$

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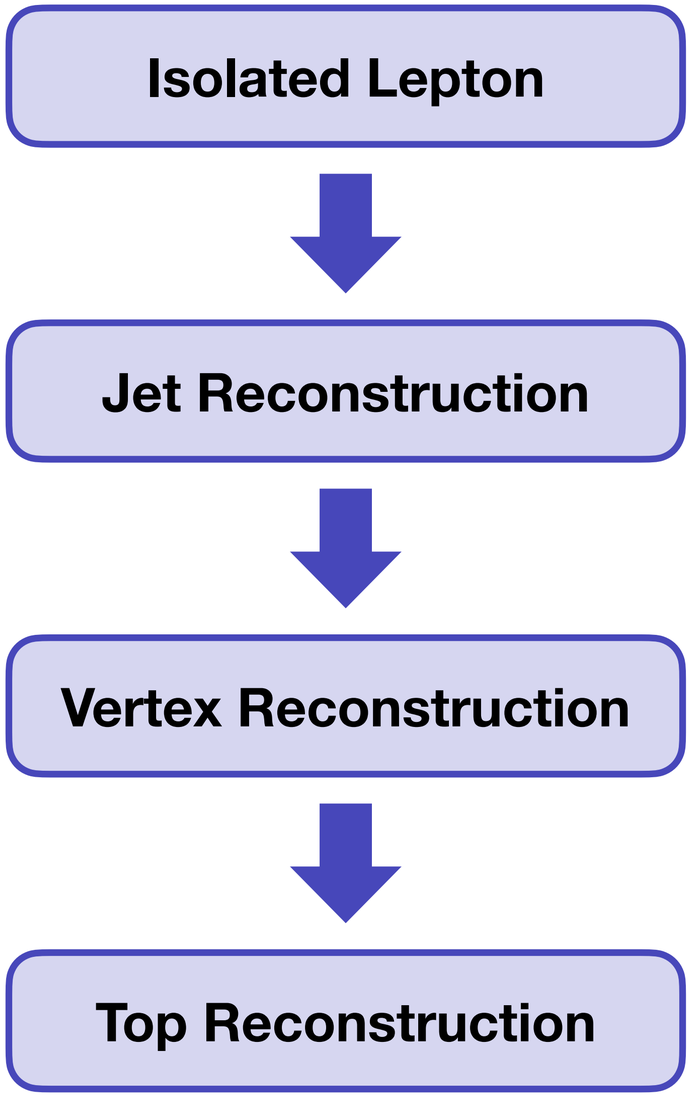


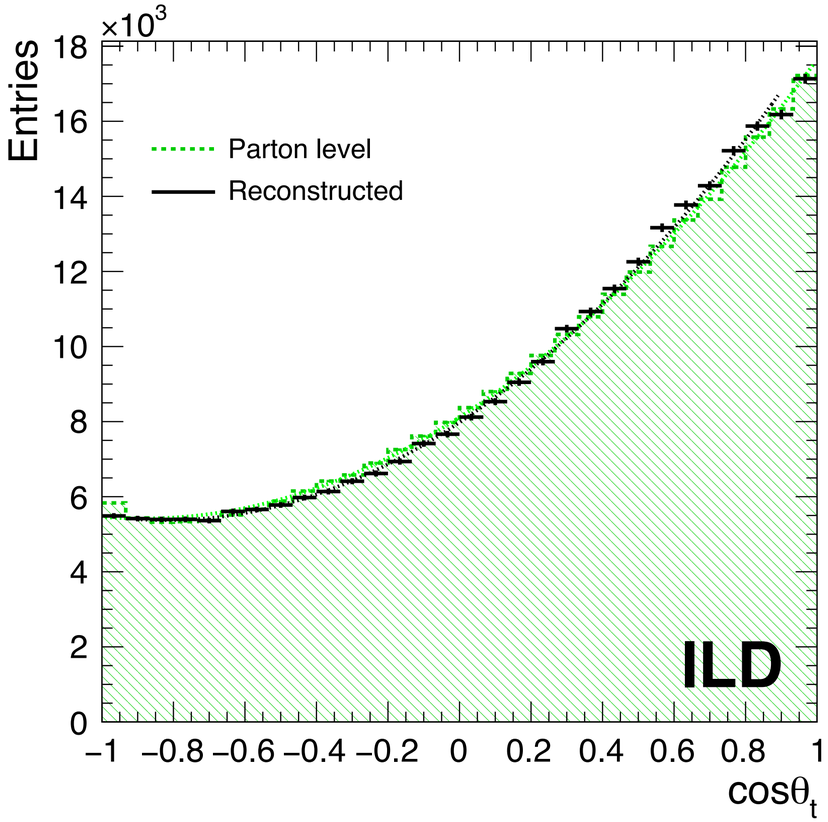
Semi-Leptonic Condition

	Semi-Leptonic
Isolated Lepton	Plep > 5 GeV
N jets	4
$W^{\pm}$ reco	isoLep + q jet

Cuts

種類	カット
b-tag	0.8 < b-tag < 0.3
Thrust	Thrust > 0.9
Mhad (GeV)	180 < Mhad < 420
Top mass (GeV)	120 < Mtop < 270
$W^{\pm}$had mass (GeV)	50 < MW < 270

3. Polar Angle



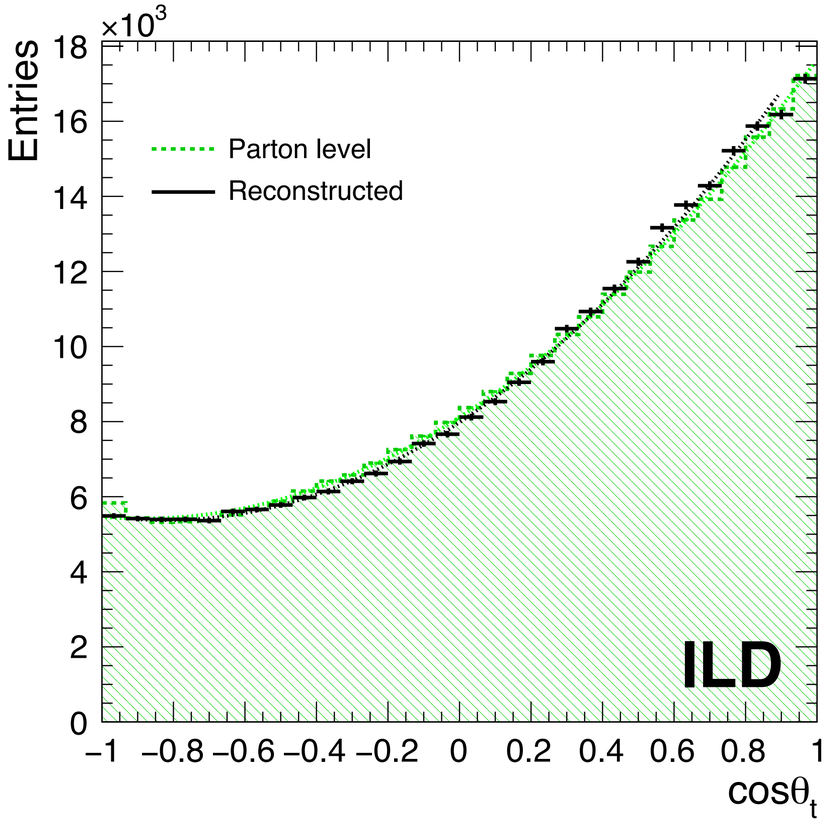
- Polar angle distribution of top quark for all reconstructed events

Result and Precision

$(\mathscr{P}_{e^-}, \mathscr{P}_{e^+})$	(-1, +1)	(+1, -1)
$A^t_{FB,gen}$	0.364	0.409
$A^t_{FB,reco}$	0.345	0.369
$\delta_{A^t_{FB}}$	0.0025	0.0020
Efficiency	34.6%	64.1%

- Efficiencies reconstructing A^t_{FB} for left-handed is lower due to kinematic constraints.
  - Left-handed : *b*-jet follows the top flight path.
    Right-handed : W follows the top flight path.

3. Polar Angle



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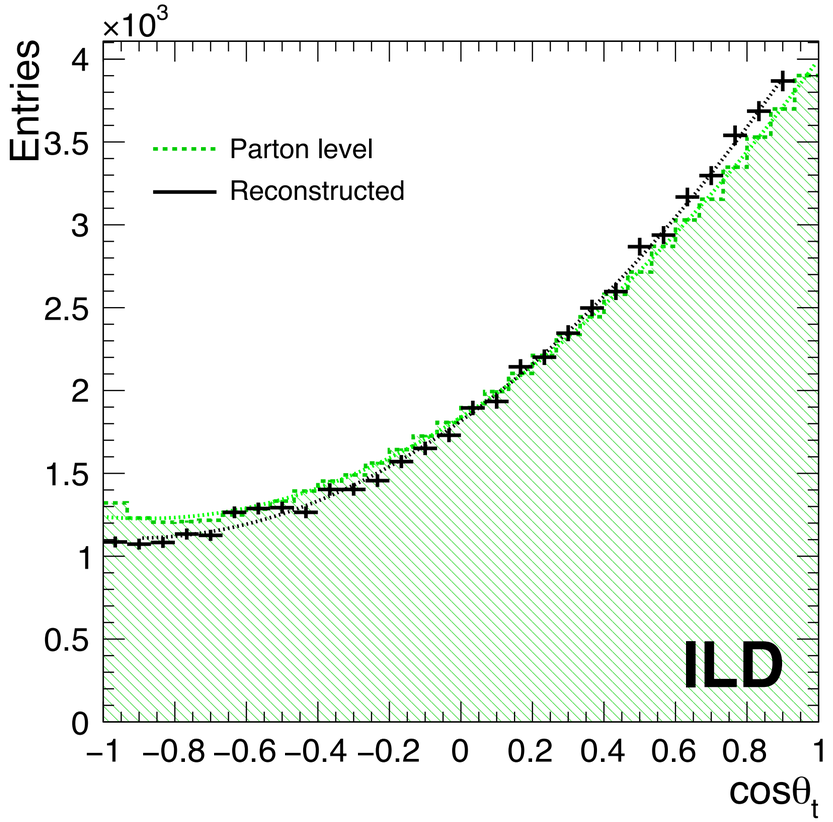
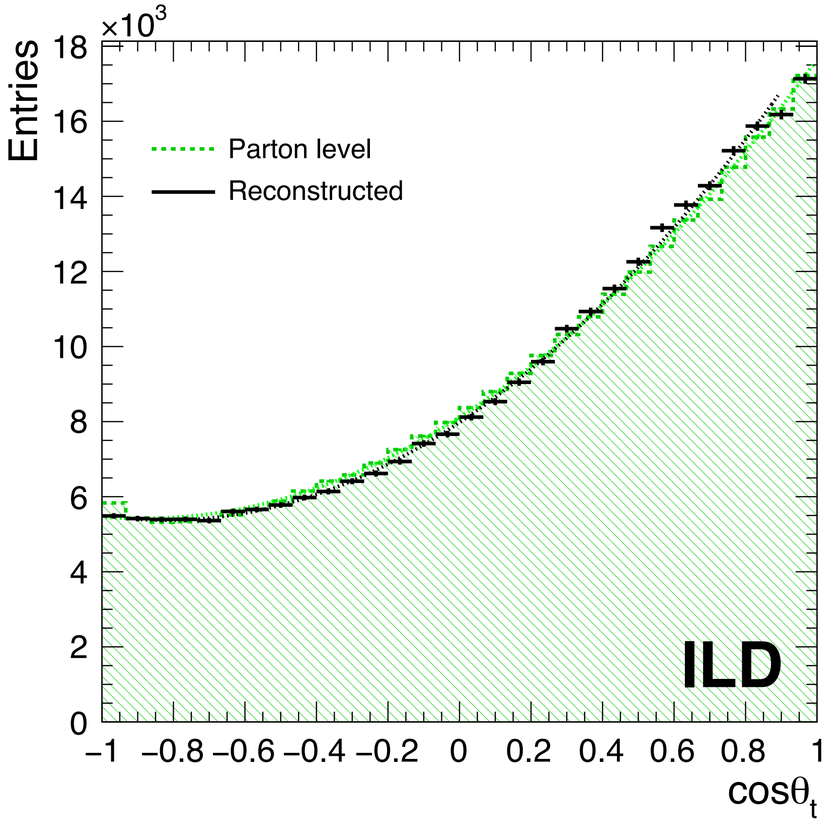


- Polar angle distribution of top quark only using vtx x vtx comparison.

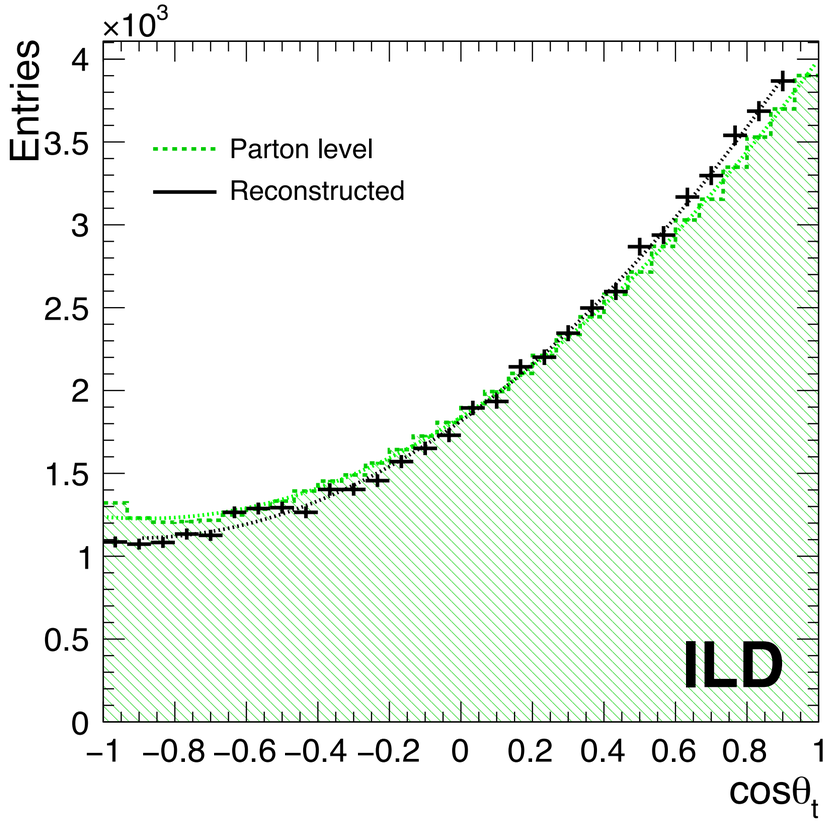
3. Polar Angle



- Polar angle distribution of top quark for all reconstructed events

Background?

- Mis-combination of b and W?
- Single Top Background?



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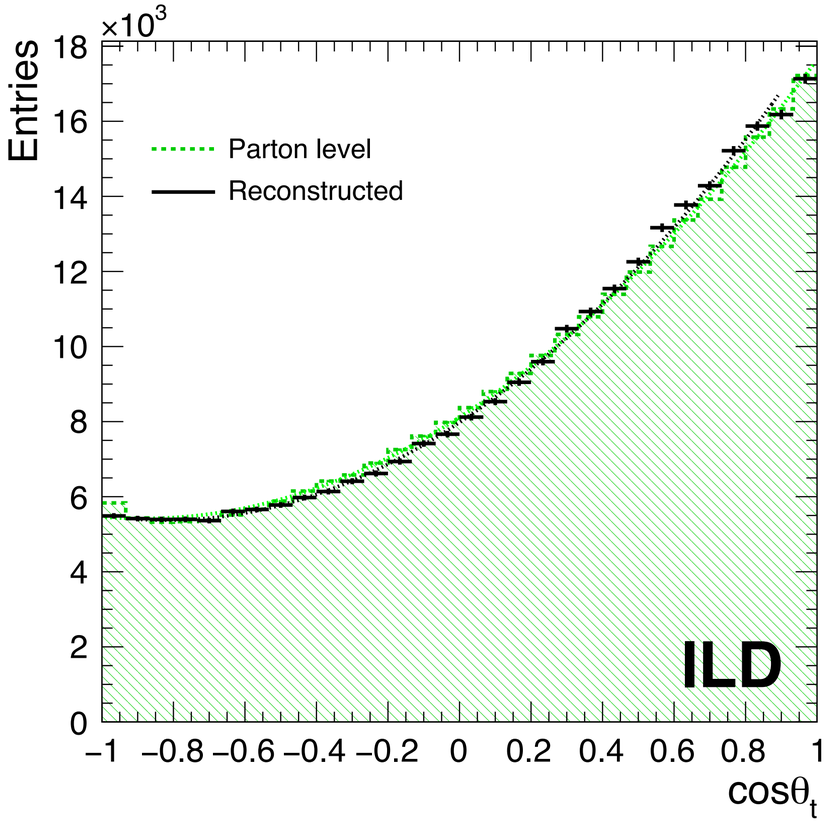

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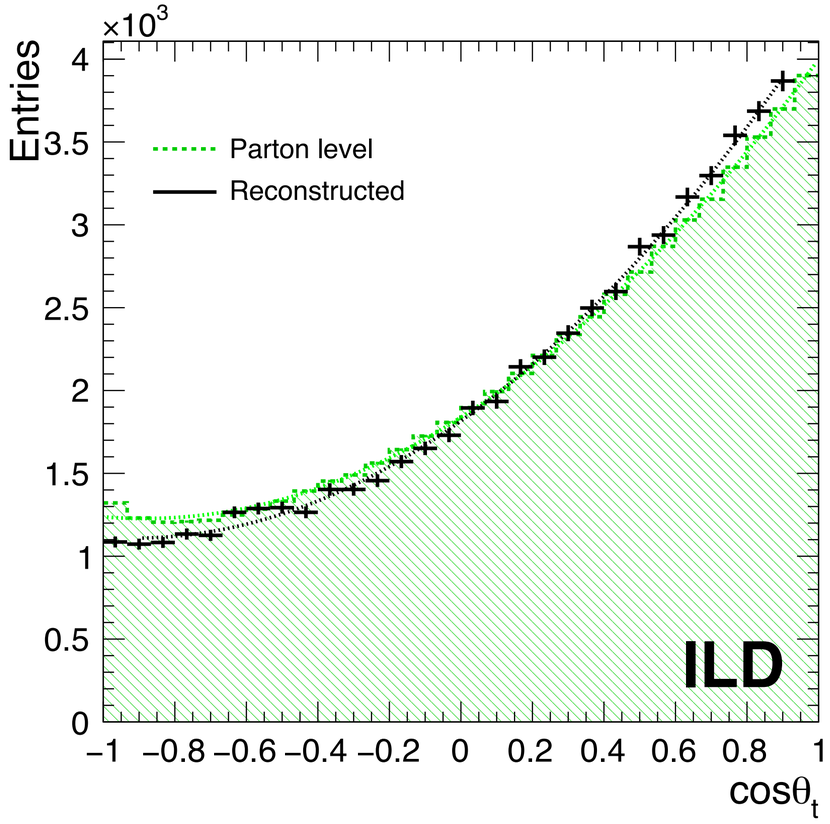
Source of systemic error



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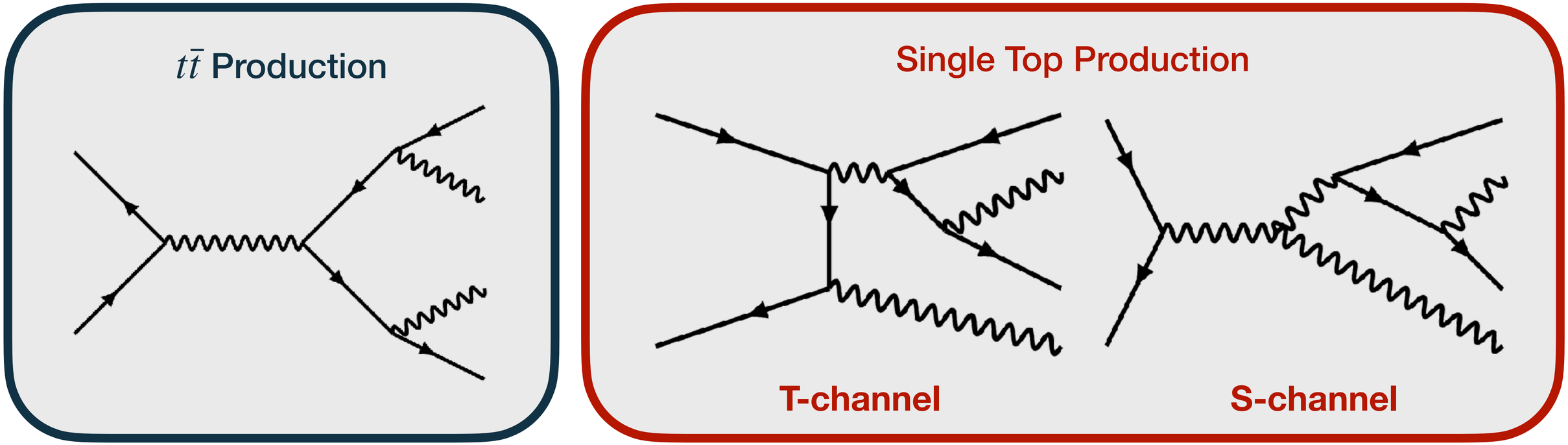
4. Single Top Analysis



- Two processes are difficult to be distinguished.
  - Share the same final states. ($b\bar{b}q\bar{q}'\ell\bar{\nu}$)
  - Events are mixed in the parton level.

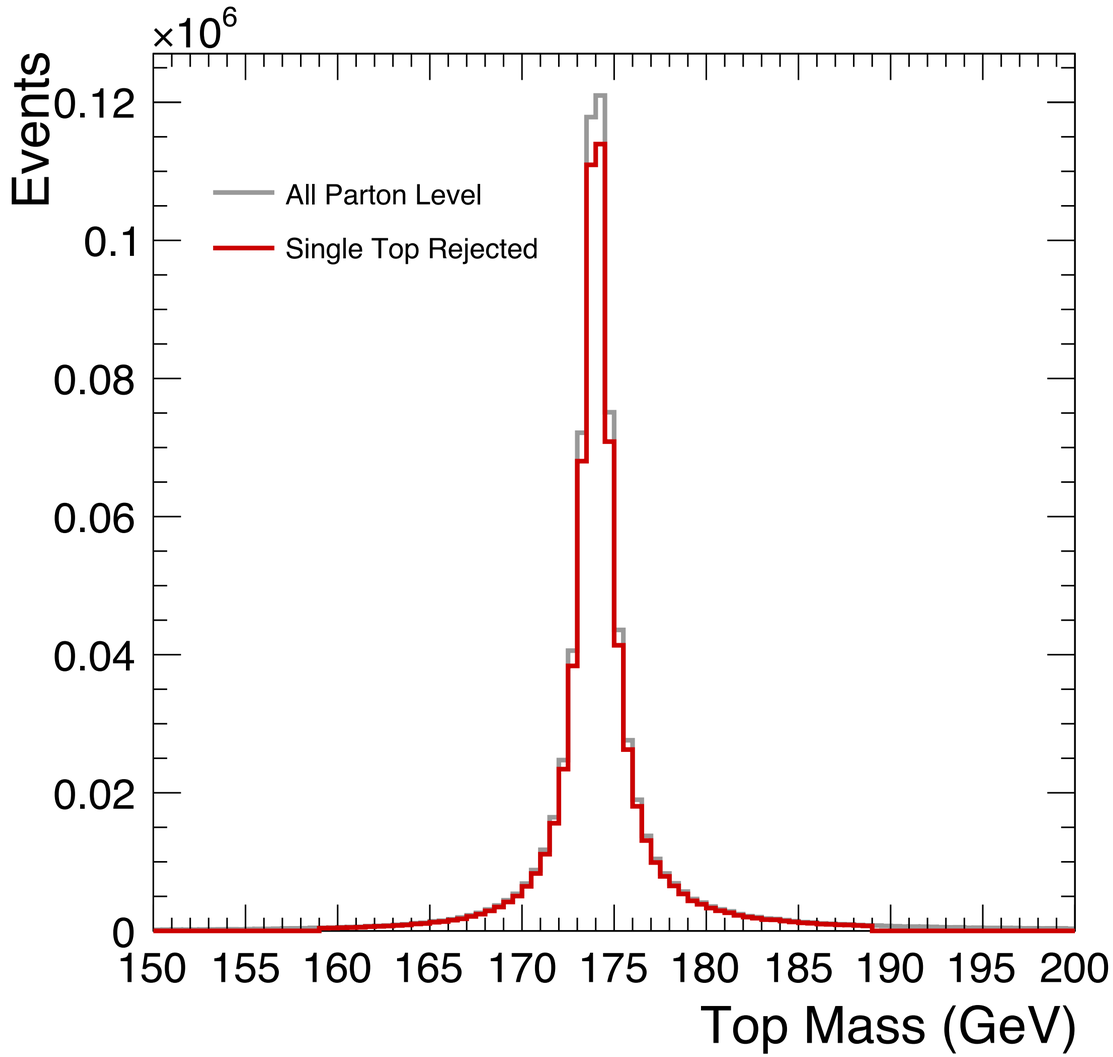
4. Single Top Analysis

- This analysis considered events to correspond to top quark pair production when the following criteria is satisfied for both of W and *b* pairs.

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

If only one of these pair meet this criterium, the events are labeled as single top quark event.

Fuster, J 2015, arXiv:1411.2355 [hep-ex]



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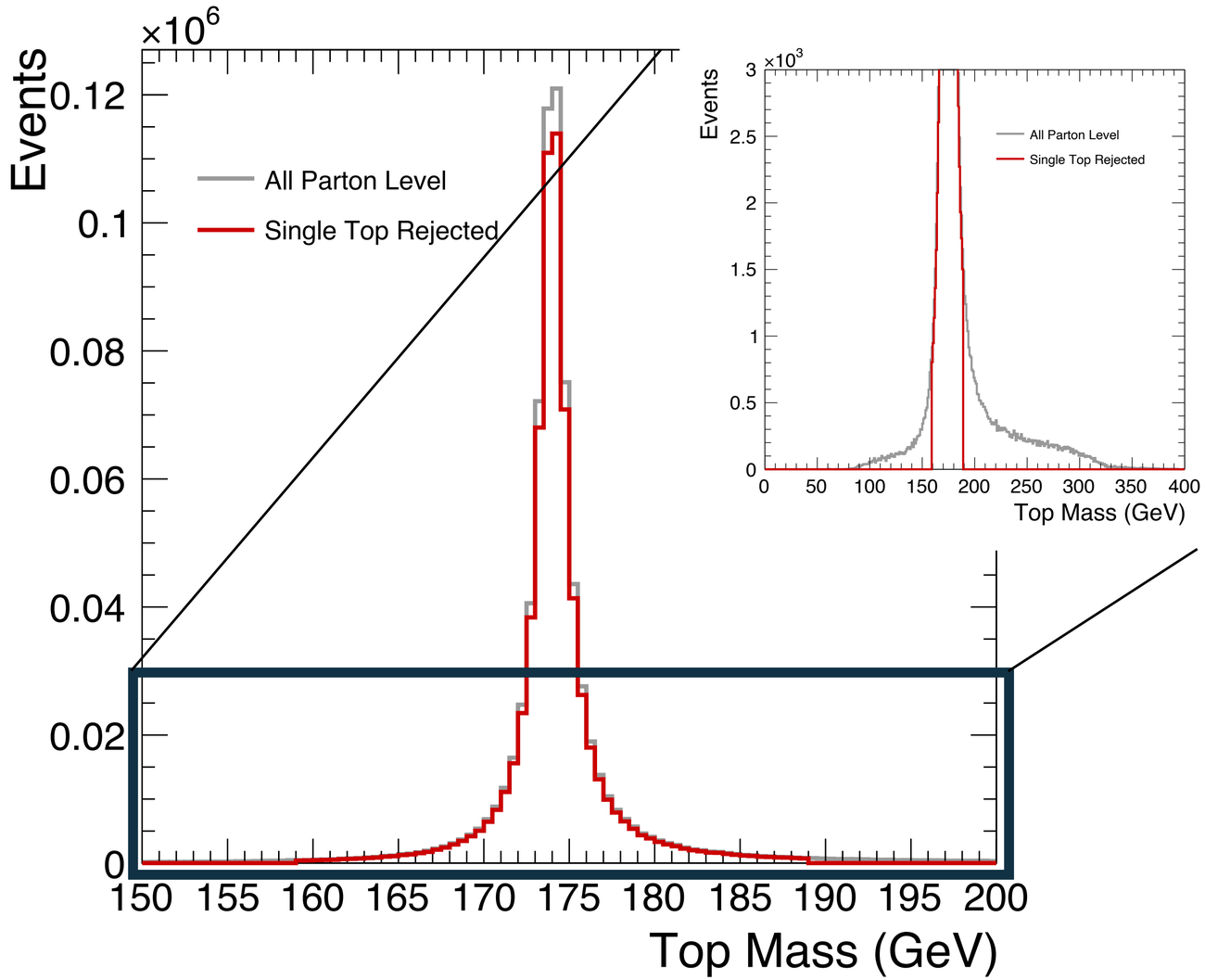
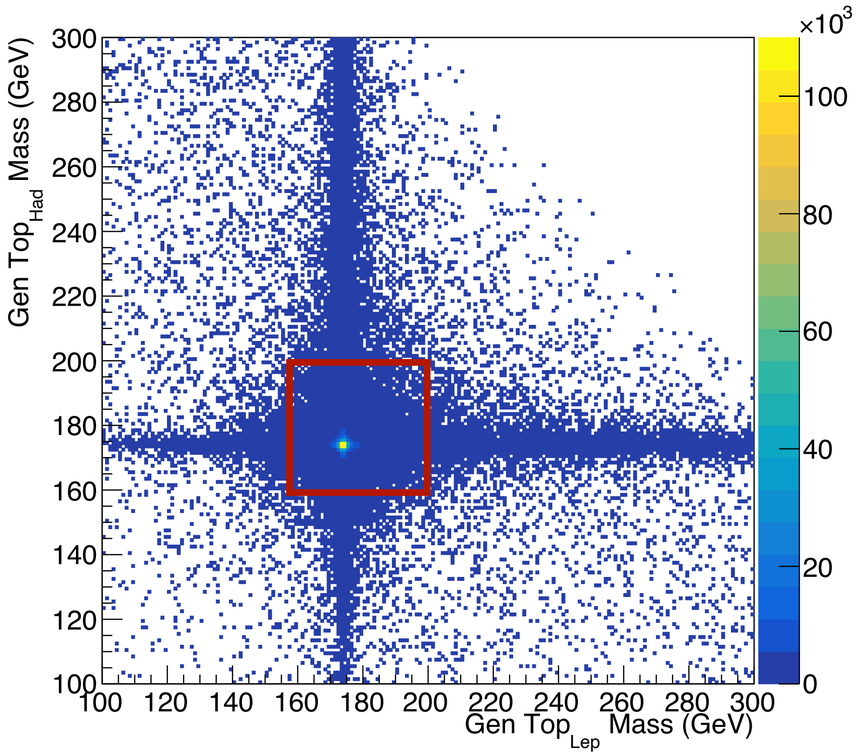
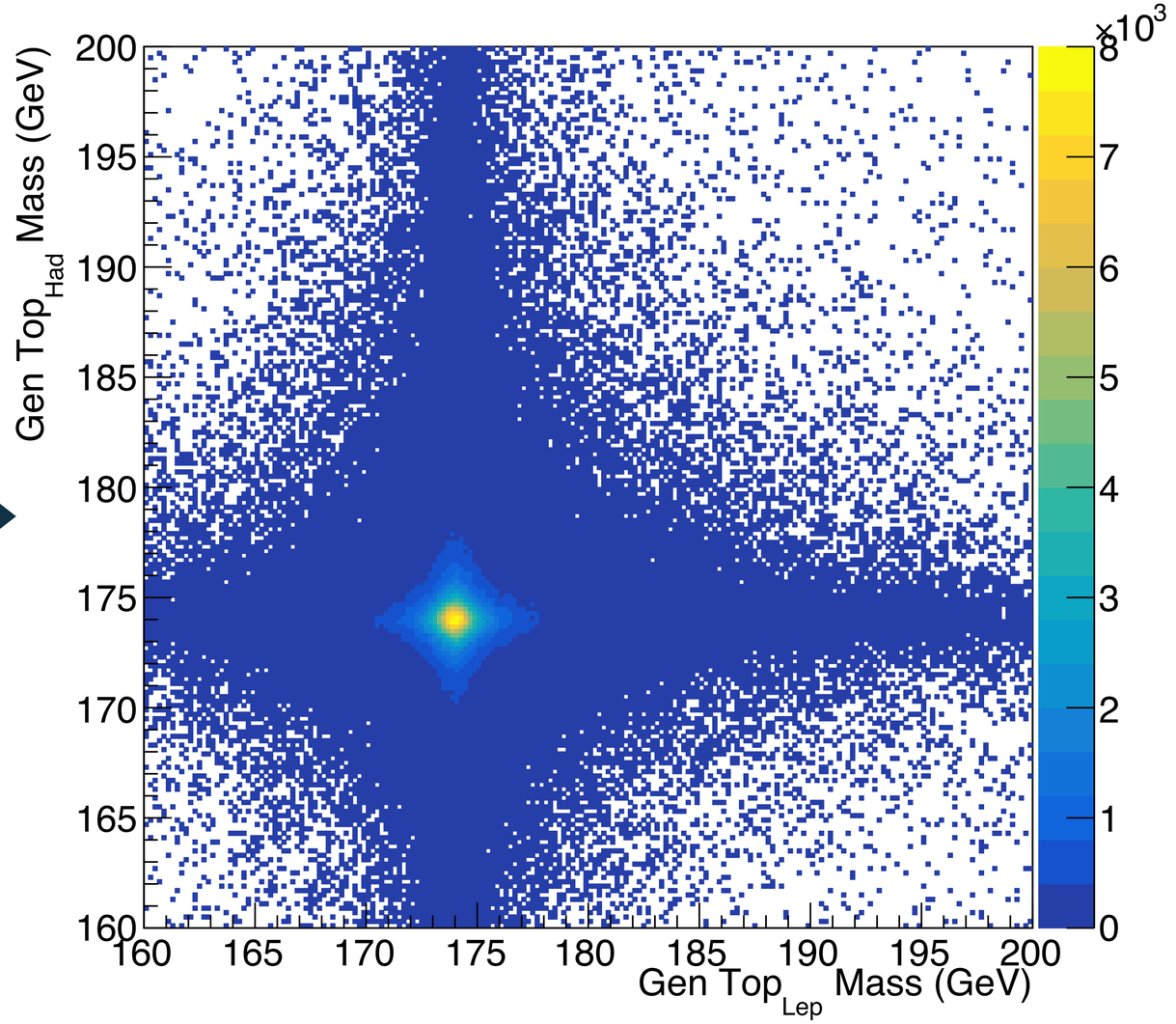
Fuster, J 2015 1434-6052



4. Single Top Analysis

- **Generated Lep/Had Top Mass**

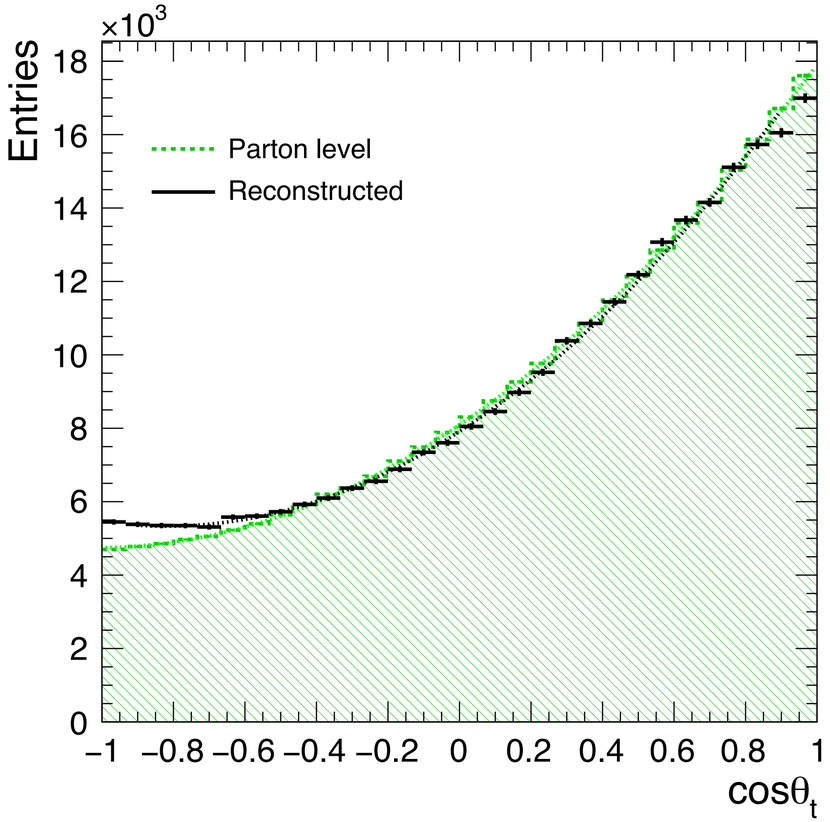




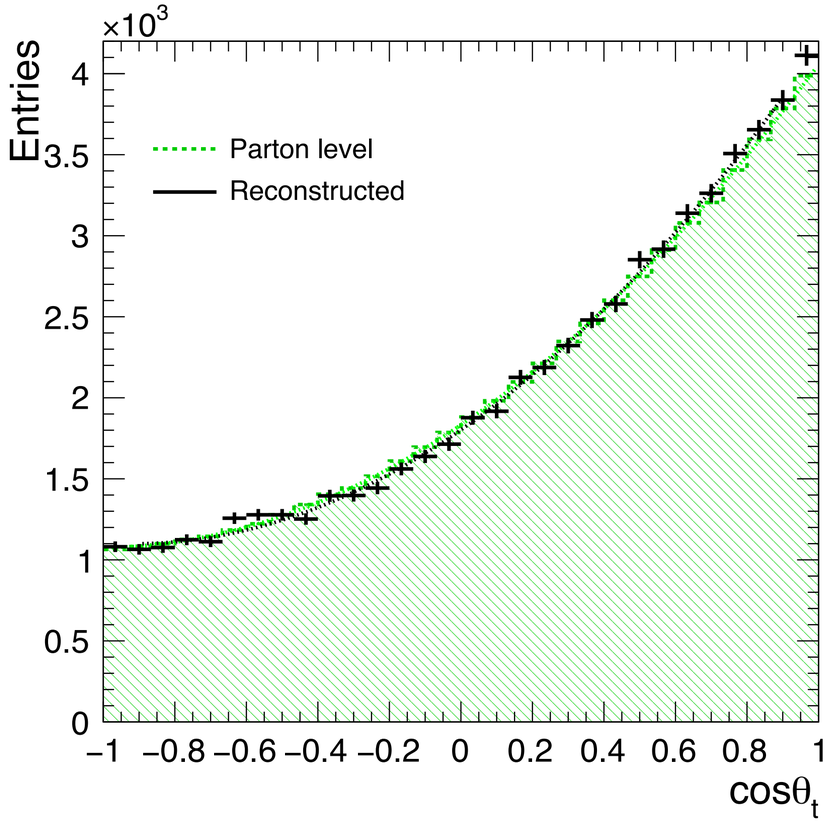
- Events clusters around 174 GeV region yet still huge amount of off-shell events.

4. Single Top Analysis

Polar Angle Distribution



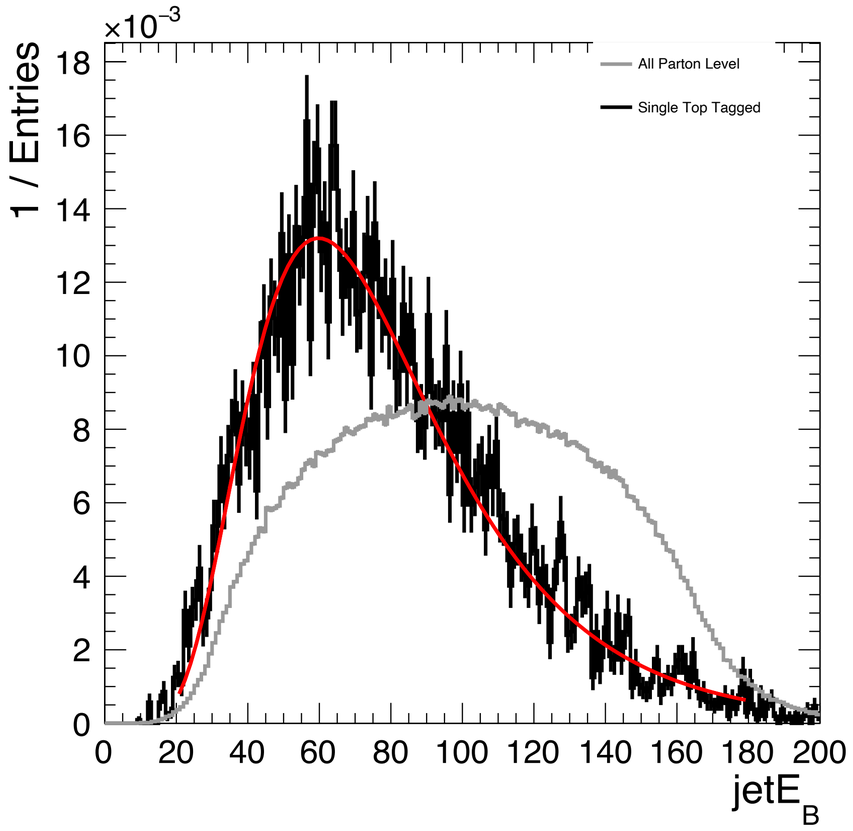
- Polar angle distribution of top quark for all reconstructed events after single top rejection from parton level

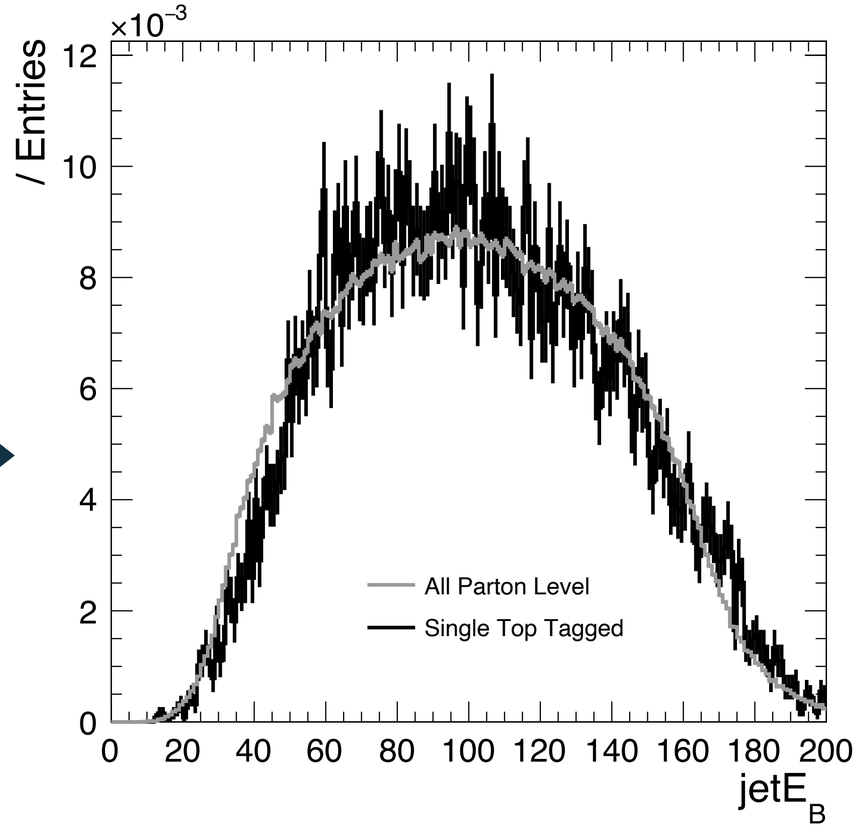


- Polar angle distribution of top quark only using vtx x vtx comparison after single top rejection from parton level

4. Single Top Analysis

b-jet Energy Distribution





- b-jet energy distribution of hadronic top for all reconstructed events.
- b-jet energy distribution of hadronic top only using vtx x vtx comparison.

4. Single Top Analysis

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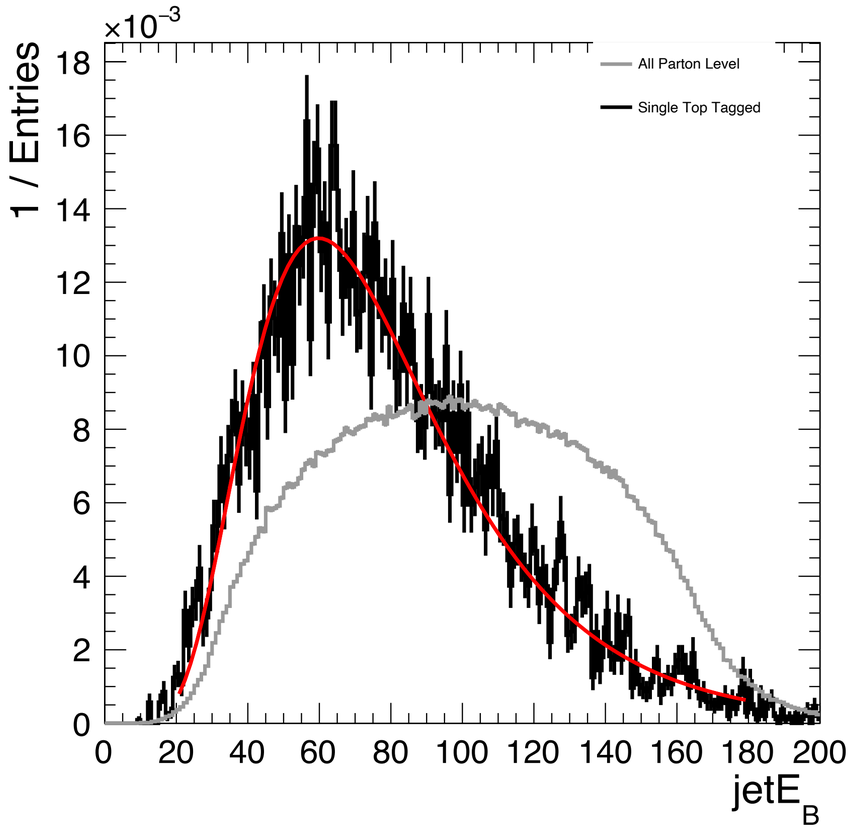

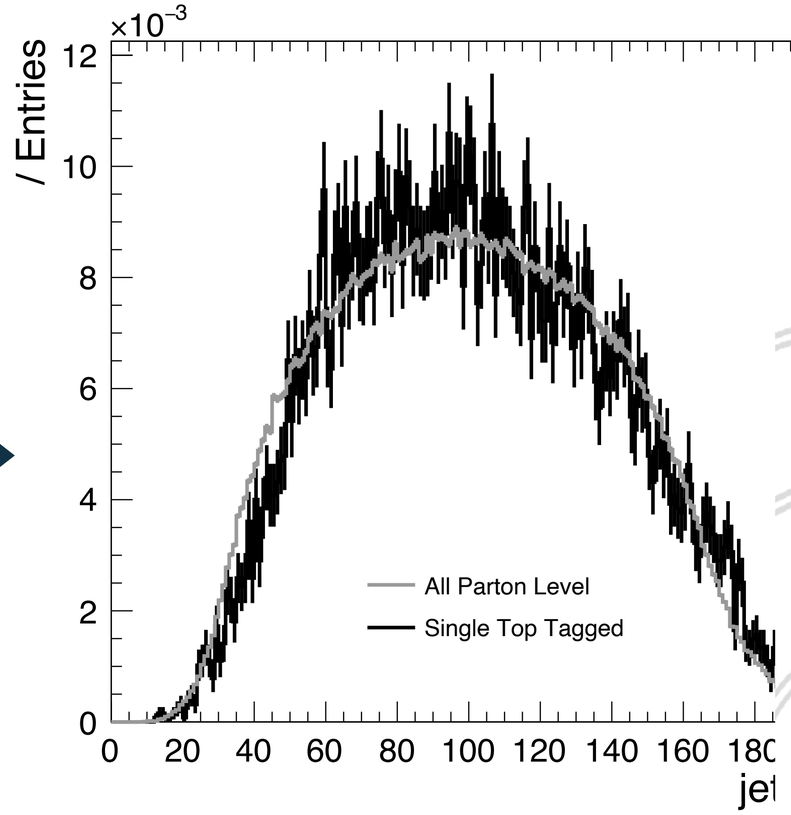

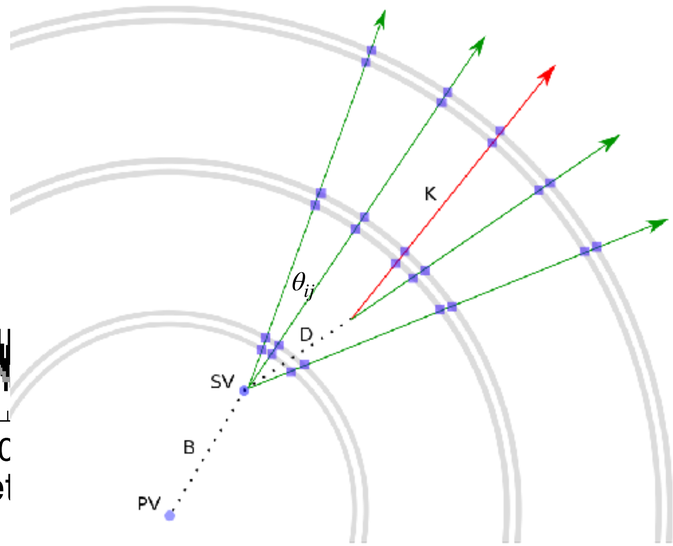

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- b-jet energy distribution of hadronic top only using vtx x vtx comparison.

➡ vtx x vtx method filters soft b's?

5. Summary

- **$t\bar{t}$ Pair Production**
  - $t\bar{t}$ production at the ILC at $\sqrt{s} = 500$ GeV for fully-left handed beam polarization using 900,000 events was processed.
- **Single Top Analysis**
  - Single top problem emerged as a source of systematic error, thus applied a selection for single top generated events on combined generated mass of *b* and W.
  - Generated single top events consist 12.5% of overall events.
  - Vtx x Vtx comparison scheme seems to eliminate such events by filtering out the soft b-jets.

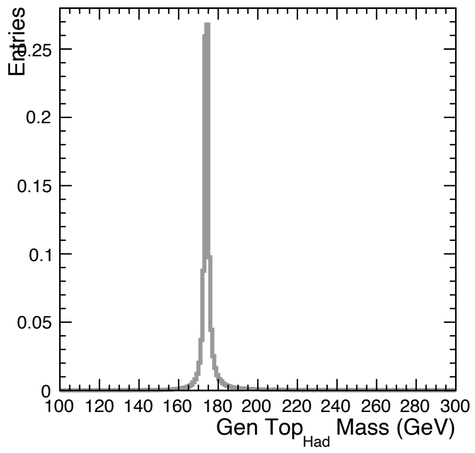
    ➡ Might worth to take a look at momentum distributions of tracks from b-jets in single top events to see if one of jets is indeed soft.

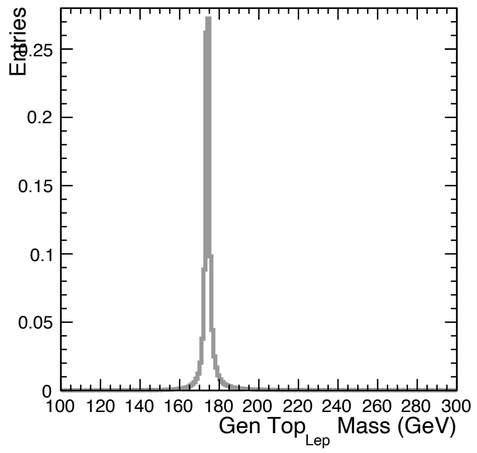
Thank you!

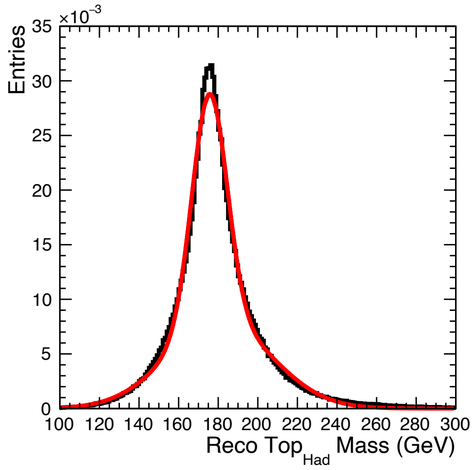
Backup

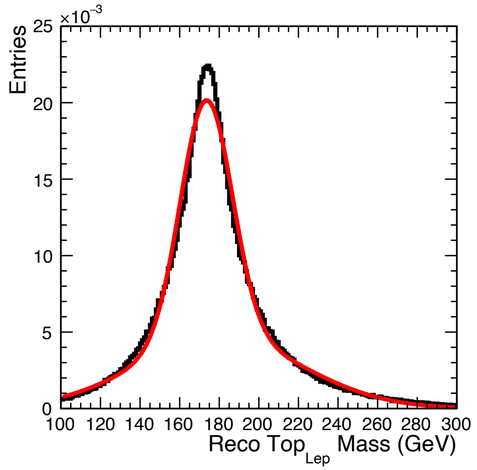
6. Backup

- **Gen/Reco Lep/Had Top Mass**



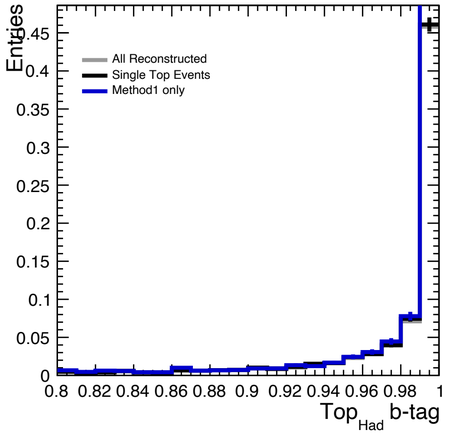


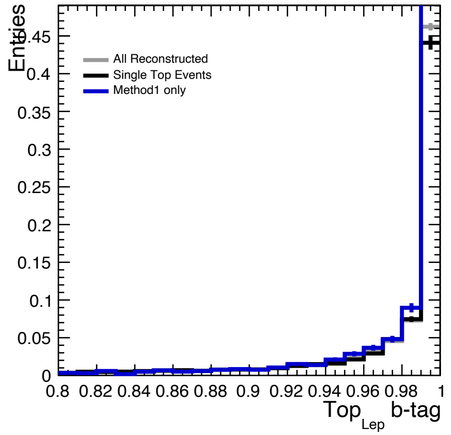




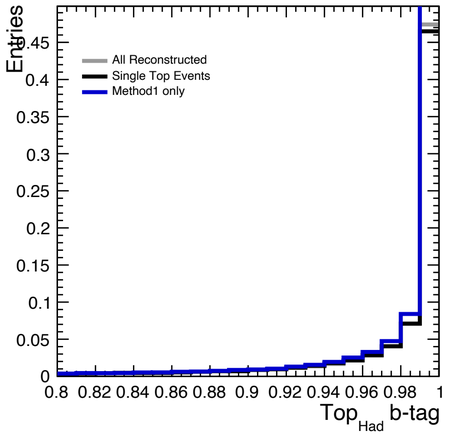
- Top mass distribution.

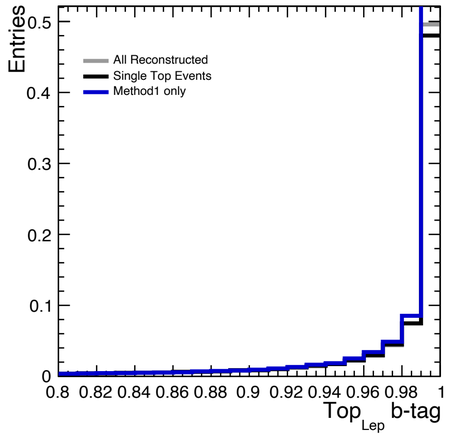
- **b-tag distribution**





- b-tag at $|\cos\theta_{MCtop}| < 0.9$





- Overall b-tag distribution.

4. Single Top Analysis

- **Reconstructed Lep/Had Top Invariant Mass**