

$e^+e^- \rightarrow t\bar{t}$ in the continuum

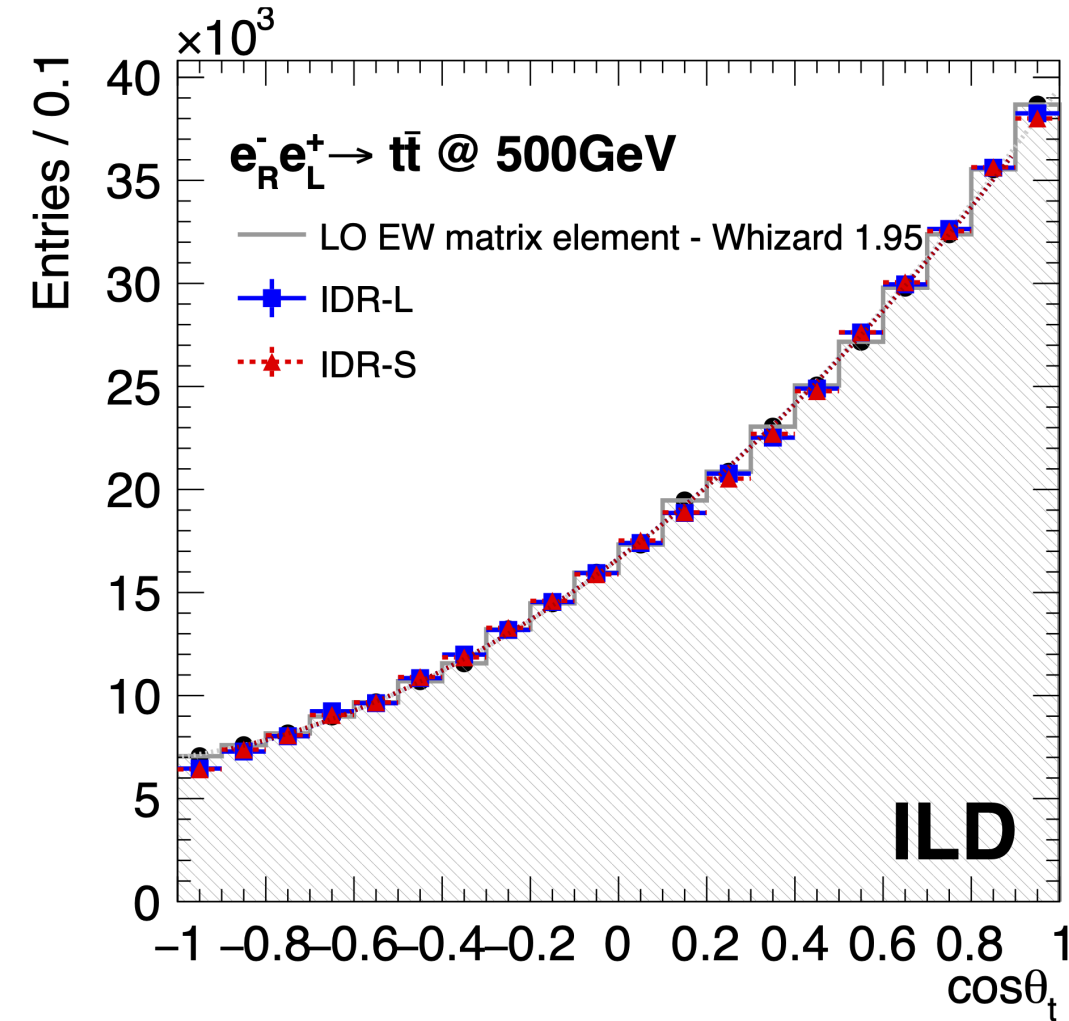
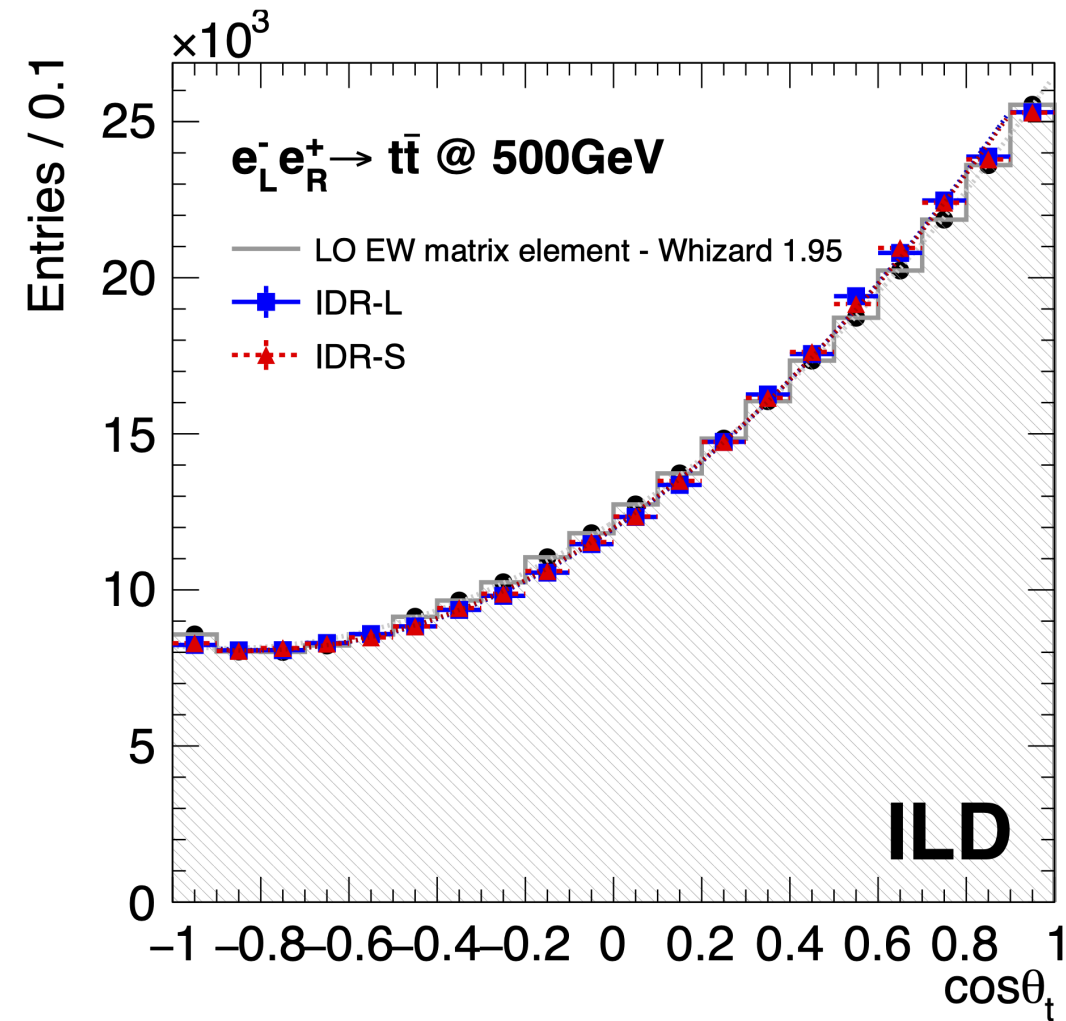
Open Issues

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Based on work done by Yuichi Okugawa and Adrian Irles



ILD Top/HF Meeting January 2021



ILD-Note-2019-007

Master thesis
Yuichi

Collab:
IJCLab, U Tohoku
UPSaclay

- Nice results for semi-leptonic mode
- Results are still based largely on identification of final state lepton and (in)famous Chi2 cut
- Started over summer to further scrutinise methods based on hadronic final state only

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

General selection cuts	IDR-L	IDR-S
Isolated Lepton	92.1%	92.1%
$btag_1 > 0.8$ or $btag_2 > 0.3$	81.2%	81.1%
Thrust < 0.9	81.2%	81.1%
Hadronic mass	78.2%	78.2%
Reconstructed m_W and m_t	73.4%	73.4%
<i>t</i> quark polar angle spectrum		
$\gamma_t^{had.} + \gamma_t^\ell > 2.4$	62.2%	61.8%
$ p_{B, had} > 15 \text{ GeV}$	34.5%	33.9%
“ <i>t</i> \bar{t} identification”	30.6%	30.2%
<i>b</i> quark polar angle spectrum		
No additional cuts		

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

General selection cuts	IDR-L	IDR-S
Isolated Lepton	94.1%	94.0%
$btag_1 > 0.8$ or $btag_2 > 0.3$	84.9%	84.8%
Thrust < 0.9	84.9%	84.8%
Hadronic mass	82.2%	82.3%
Reconstructed m_W and m_t	77.6%	77.5%
<i>t</i> quark polar angle spectrum		
$\gamma_t^{had.} + \gamma_t^\ell > 2.4$	64.1%	64.1%
<i>b</i> quark polar angle spectrum		
<i>Vtx+Vtx</i>	10.8%	10.3%

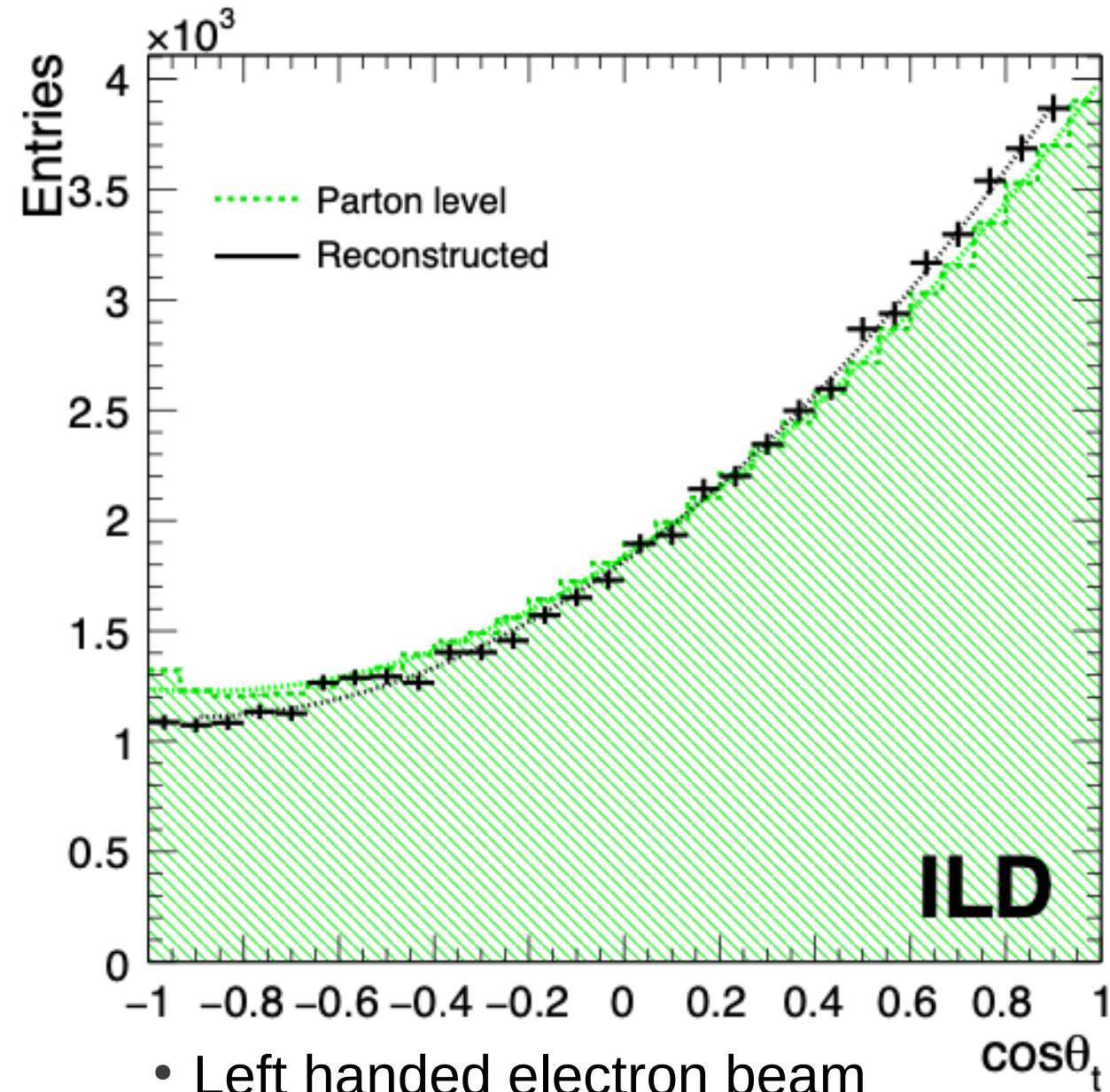
Total cross section
Typical efficiency 75%
Independent of
beam polarisation

Differential cross section

Note, difference for different
beam polarisations
Left hand polarisation
more vulnerable to migrations
Requires information
from hadronic final state
Vtx, Kaon as in *bb*-case

Methods	IDR-L	IDR-S
1 <i>L_{cut}</i>	22.1%	21.9%
2 <i>L+Vtx</i>	28.6%	28.4%
3 <i>L+K</i>	29.6%	29.3%
4 <i>Vtx+Vtx</i>	30.1%	29.7%
5 <i>K+K</i>	30.3%	29.9%
6 <i>Vtx+K</i> (same jet)	30.5%	30.1%
7 <i>Vtx+K</i> (different jet)	30.6%	30.2%

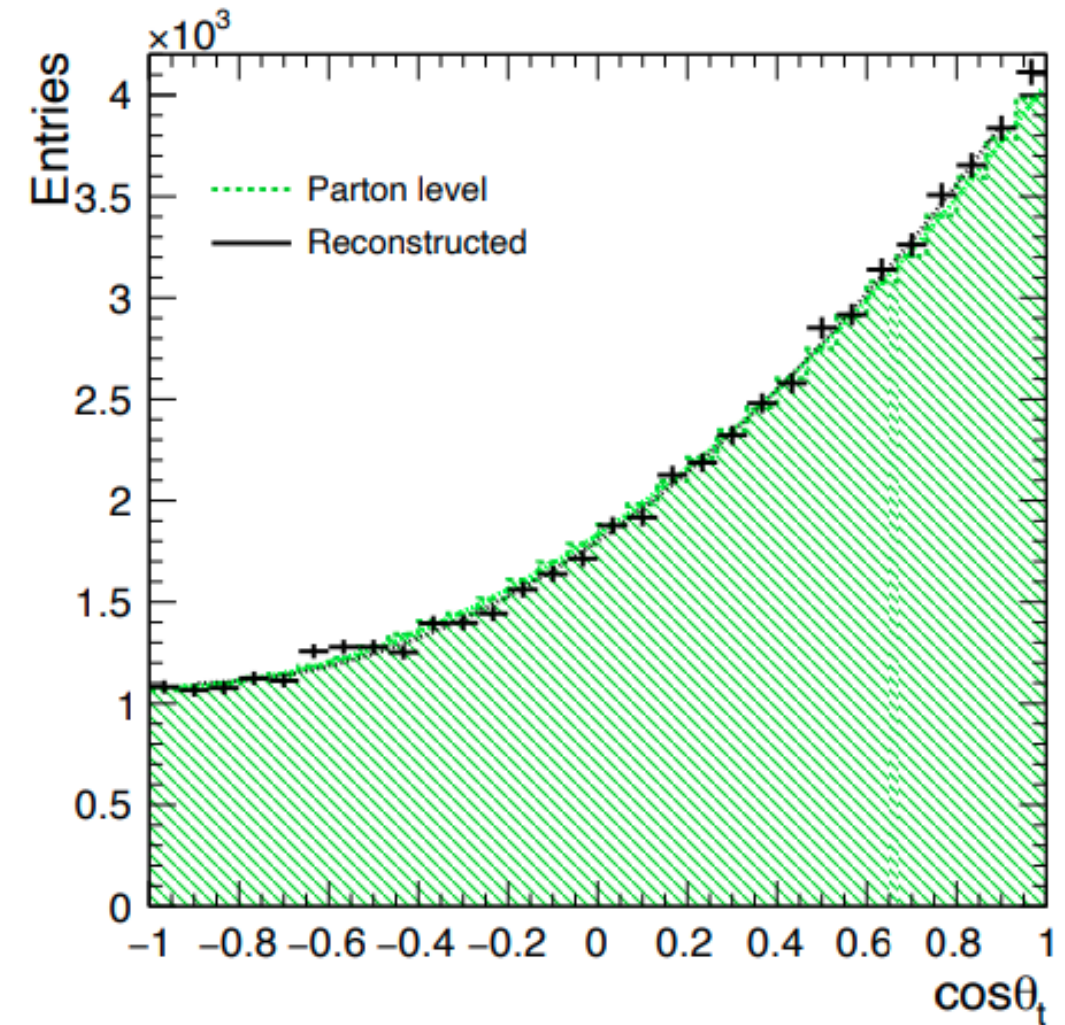
Table 4: Efficiency increase after the progressive application of the various methods introduced to ensure a correct association of the *W* boson and the *b* quark in case of $e_L^- e_R^+ \rightarrow t\bar{t}$. The final efficiency in the last line of this table corresponds to the efficiency given in the line “*t* \bar{t} identification” of Table 3.



- Left handed electron beam
- Clear tilt in spectrum !
- Deficit towards $\cos\theta = -1$

“Single top cut” on generator level:
(à la arxiv: 1411.2355)

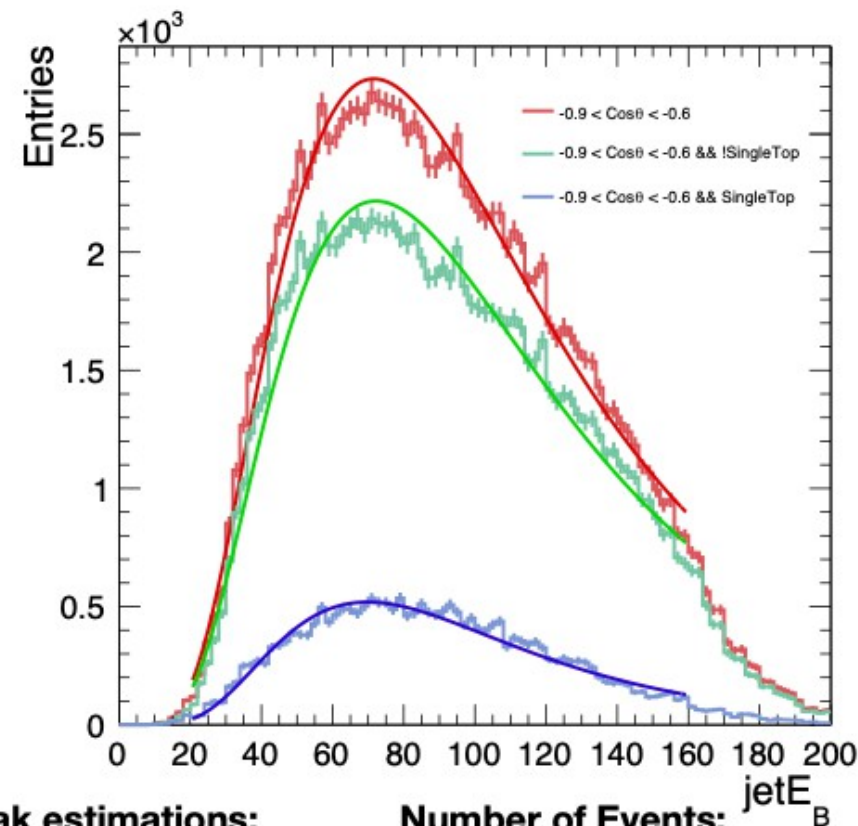
$$|m_{Wb} - m_t^{MC}| < 15 \text{ GeV}$$



“Perfect” agreement

b-jet energies for backward scattered tops

jetE_b for $-0.9 < \cos \theta_t < -0.6$



Peak estimations:

Number of Events:

maxRed = 71.6 GeV

Red Events: 132855

maxGreen = 72.2 GeV

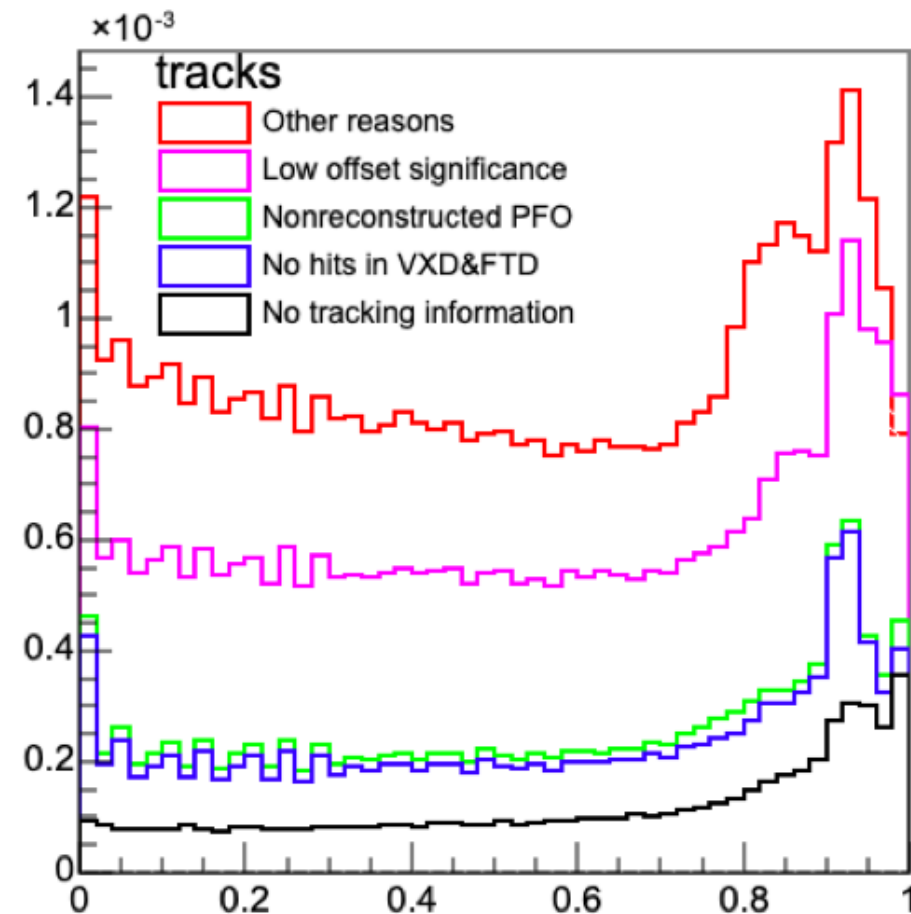
Green Events: 109538

maxBlue = 69.8 GeV

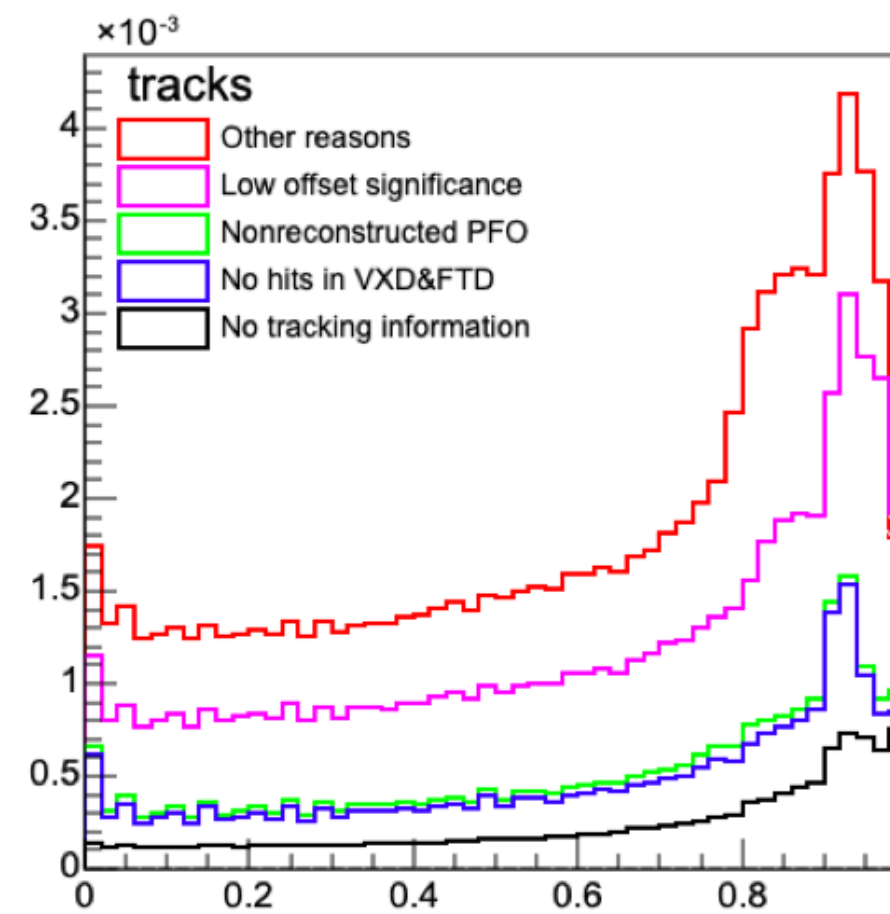
Blue Events: 23317

- (Comparatively) small b-jet energies
- No clear difference between “regular” ttbar and “so-called” single-top events
- Both produce low energetic b-jets in backward region
- Thus “single top suppression” suppresses also a fraction low energetic b-jets

- Polar angle distribution of the missing prongs for ($\cos\theta_{\text{Gen } t} < 0$) and ($\cos\theta_{\text{Gen } t} > 0$)

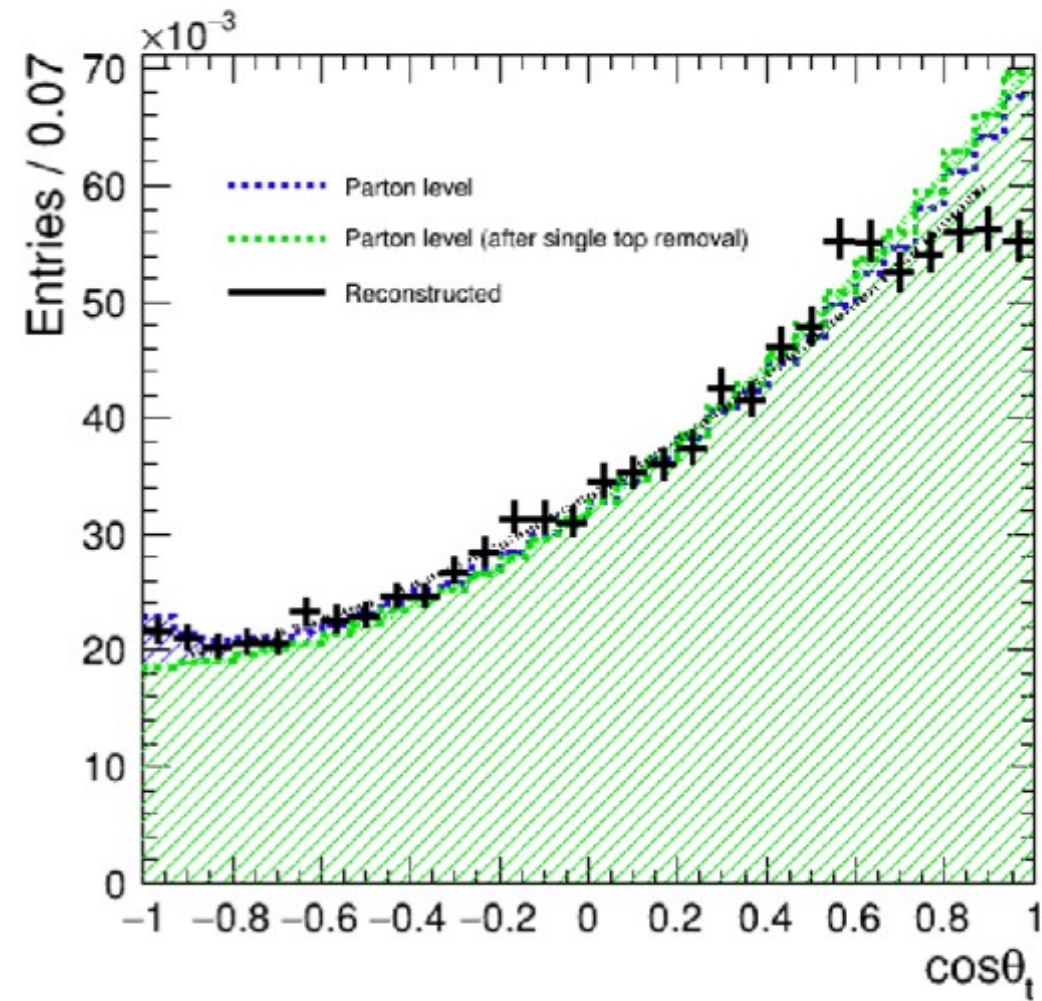


- $\cos\theta_{\text{Gen } t} < 0$



- $\cos\theta_{\text{Gen } t} > 0$

- Clear difference in spectrum of missed tracks between forward and backward scattered tops
 - Result here after vertex recovery (before see talk by Yuichi on 17/12/20)
- Softer b = softer tracks in case of backward scattered tops



- Kaon polar angle spectrum shows deficit in forward region
- Bug or feature?

- **Kaon x Kaon**

- Hadronic final state variables of $t\bar{t}$ require further understanding
- Tilted spectrum in vtx-vtx method, deficit for KaonxKaons
- What to do?
 - Revision of cuts?
 - Need to look at different maybe two dimensional distributions
 - b-quark/B-hadron reconstruction in $t\bar{t}$ -production is function of polar angle and b-jet energy (or b-hadron momentum)
- Revision of vertex recovery,
 - Alternative algorithms (SLD), TMVA?
- Calibration with simpler final states ($ee \rightarrow bb$) at different energies (GigaZ, 250 GeV and 500 GeV)?
- Kaons and particle ID needs further understanding and scrutinisation
- $t\bar{t}$ at 500 GeV bears the potential of $\sim 0.5\%$ precision, but ...
 - a) Would prefer that all used methods lead to consistent results (and not that deficits compensate each other)
 - b) Without understanding what's going on there is no way to address the fully hadronic final state

- Who?
 - This is no option for Yuichi's PhD since it has been already subject of his master thesis
 - But ... Yuichi and Adrian could supervise a (sufficiently long) master thesis
 - All tools are there
 - Adrian said that we wants to look into that but help is for sure welcome

Backup