Associated Production of Single Top Quark and W boson in dilepton decay channel at 13 TeV

*Priyanka** *(University of Delhi), Dr. Stefan Gieseke (KIT)*

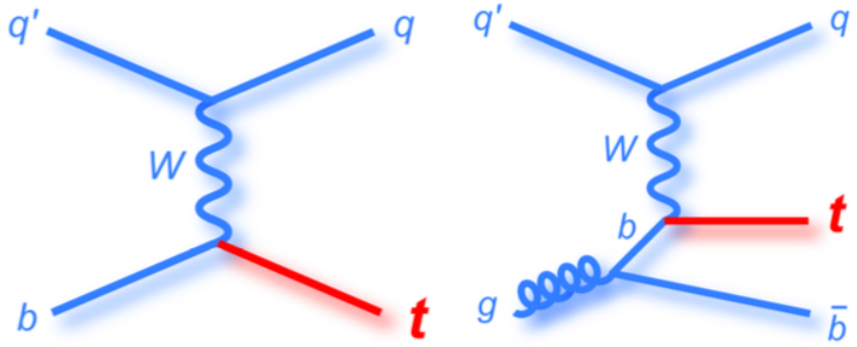
McNet Meeting

4th April 2016

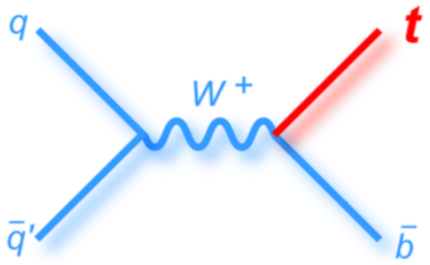
Outline

- ➢ Introduction to Single top-quark production at LHC
- ➢ Motivation & Challenge
- ➢ Signal and Backgrounds
- ➢ tW at NLO
- ➢ Diagram Removal & Diagram Subtraction
- ➢ tW Vs tW(DR) Comparison plots
- ➢ Summary & Outlook

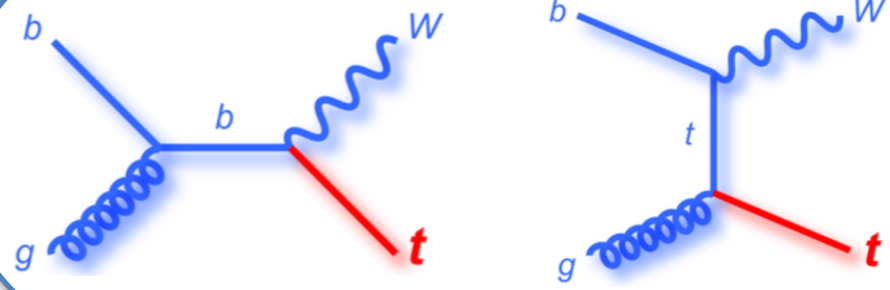
Single top-quark production at LHC



- t-channel: Dominant process at LHC.



- s-channel: Least dominant process at LHC.



- Associated production of top quark & W boson (tW-channel): 2nd most dominant process at LHC.

Motivation

➢ Cross-section of Single top-quark production => |Vtb| matrix element of CKM matrix.

➢ Sensitive to non-SM couplings of Wtb vertex.

☞ ***Challenge for tW-Channel:*** Interference at NLO level with top-quarks (tt~) pair production for extraction of tW signal.

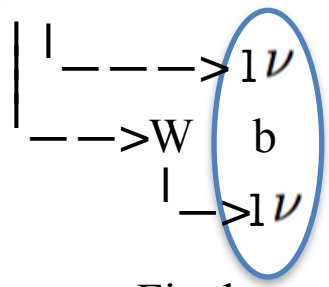
- Theoretical difficulty overcome by Diagram Removal (DR)[1] & Diagram Subtraction (DS)[1].
- DR: Removes resonant tt~ effect at amplitude level.
- DS: Removes resonant tt~ effect at cross-section level.
- Matchbox framework at MCnet Short-term studentship from 1st January (4 months,KIT).

[1]Single-top hadroproduction in association with a W boson, Stefano Frixione, Eric Laenen, Patrick Motylinski and Chris White, Bryan R. Webber

Signal & Backgrounds

Signal

➢ pp −−>tW



Final state

Channel study consists:

eμ2ν b, ee2ν b, μμ2ν b

➢ In final state we have 2 opposite charge leptons. Leptons include e^+, e^-, μ^+, μ^-

➢ Also we have 2 neutrinos which left undetected in detector so constitute Missing Energy

➢ Also b-jet

Backgrounds

☞ $t\bar{t}: t\bar{t} \longrightarrow$ WWbb $\longrightarrow$ 2l2ν2b & 1b is not detected.

☞ **Z+jets:** Z decays to e^+e^- or $\mu^+\mu^-$ & mis-measurement of jet energy causes the missing energy.

☞ **W+jets:** W decays leptonically & one of the jets fake as lepton.

☞**ZZ:** One Z decays to e^+e^- or $\mu^+\mu^-$ & Second decays hadronically, but mis-measurement of jet energy causes the missing energy.

☞**WZ:** (i) Either W decays hadronically & Z leptonically, but mis-measurement of jet energy causes the missing energy OR (ii) W decays leptonically & one of the Z decays leptonically.

☞**WW:** Both W decays leptonically.

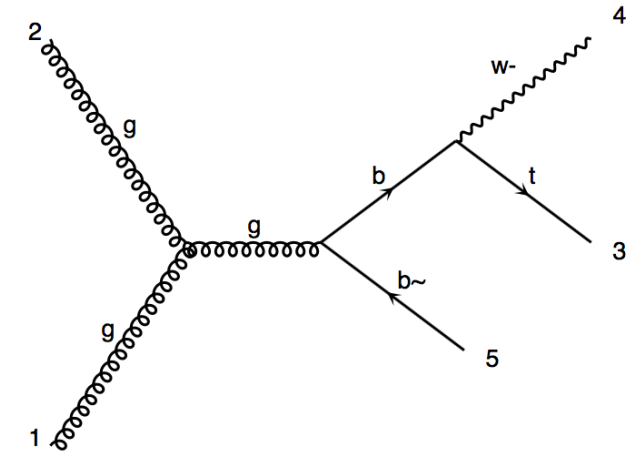
Theoretical (experimental) cross sections (in pb) for top quark production at approximate NNLO.

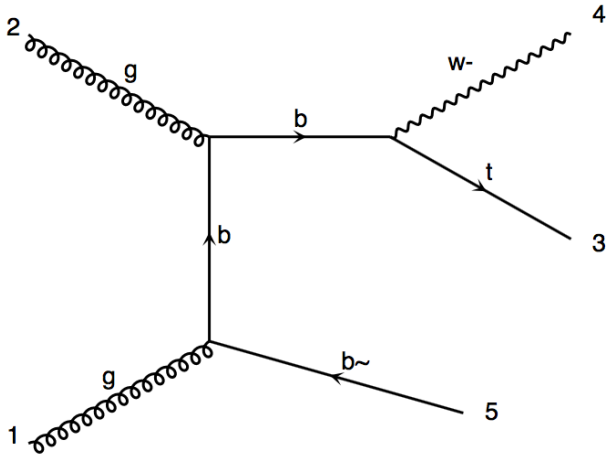
Center of mass Energy	t-Channel (NNLO)	s-Channel (NNLO)	tW-Channel (NNLO)	tt~ (NNLO)
Tevatron (ppBar) 1.96TeV	$2.08^{+0.00}_{-0.04}\pm0.12$ $(3.04^{+0.54}_{-0.49})$	$1.05^{+0.00}_{-0.01}\pm0.06$ $(1.29^{+0.26}_{-0.24})$	0.22 ± 0.08 (—)	$7.164^{+0.11+0.169}_{-0.20-0.122}$
LHC (pp) 7TeV[1,3,4]	$63.89^{+1.92+2.19}_{-1.25-2.19}$ (67.2 ± 6.1)	$4.29^{+0.12}_{-0.1}\pm0.14$ (<26.5)	$15.74\pm0.4^{+1.1}_{-1.14}$ (16^{+5}_{-4})	$173.60^{+4.46}_{-5.85}\pm8.85$
LHC (pp) 8TeV[2,3,4]	$84.69^{+2.56+2.76}_{-1.68-2.76}$ (85 ± 12)	$5.24^{+0.15}_{-0.12}\pm0.16$ (<11.5)	$22.37\pm0.60\pm1.40$ (23.4 ± 5.4)	$247.74^{+6.26}_{-8.45}\pm11.47$
LHC (pp) 13TeV[3,4]	$216.99^{+6.62}_{-4.62}\pm6.16$	$10.32^{+0.29}_{-0.24}\pm0.27$	$71.7\pm1.8\pm3.4$	$815.96^{+19.37}_{-28.61}\pm34.38$ at NNLO+NNLL $(772\pm60\pm62)$

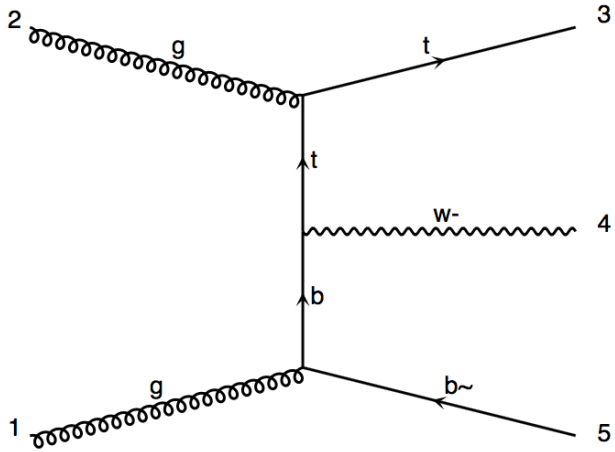
References:

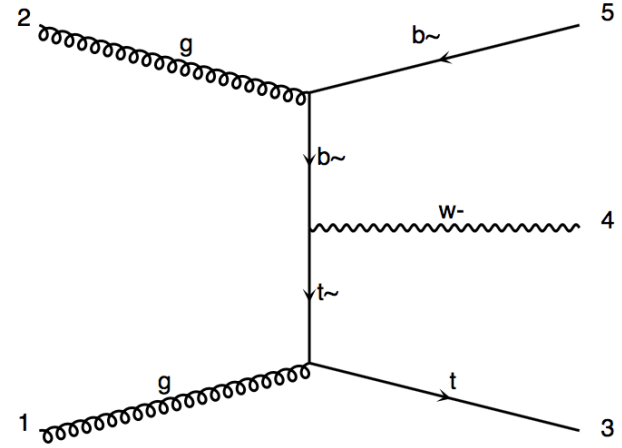
- [1]Evidence for Associated Production of a Single Top Quark and W Boson in pp Collisions at 7TeV, PRL 110, 022003 (2013).
- [2]Observation of the Associated Production of a Single Top Quark and a W Boson in pp Collisions at 8TeV, PRL 112, 231802 (2014)
- [3]https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SingleTopRefXsec#Single_top_t_channel_cross_secti
- [4]https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TtbarNNLO#Top_quark_pair_cross_sections_at

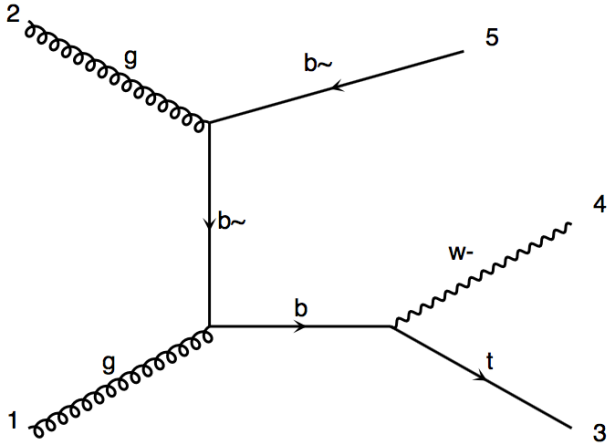
tW(NLO)

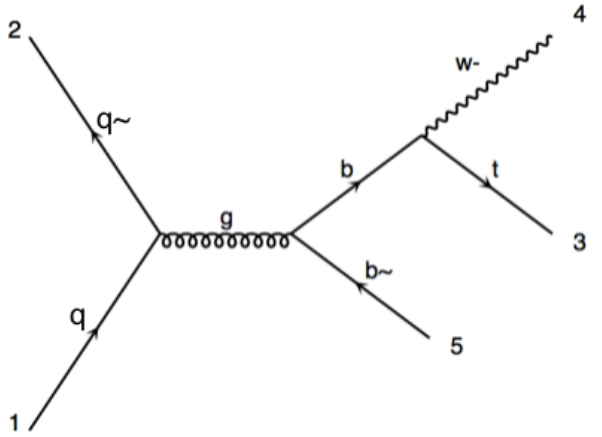

2
g
g
1
g
b
w-
t
4
3
b~
5


2
g
g
1
b
b
w-
t
4
3
b~
5

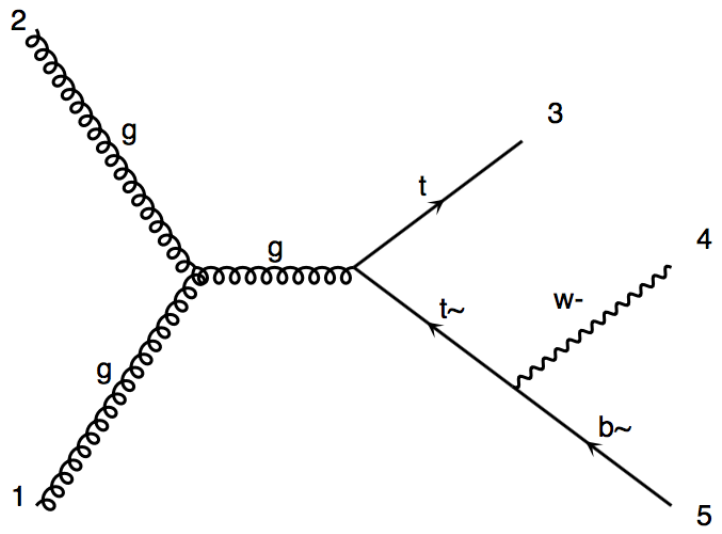

2
g
g
1
t
t
b
w-
4
3
b~
5

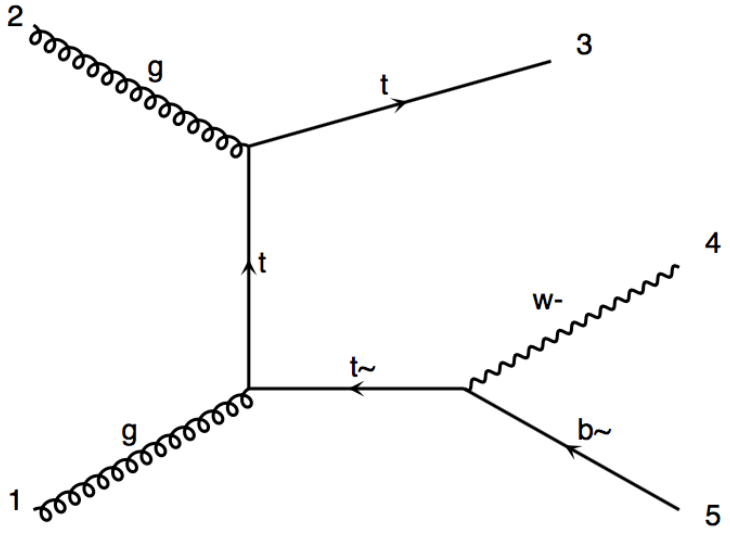

2
g
g
1
b~
b~
t~
w-
4
5
t
3

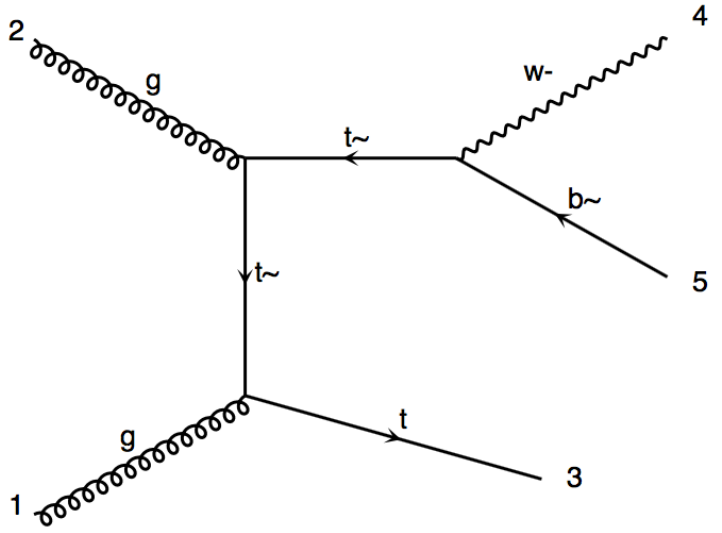

2
g
g
1
b~
b~
b
w-
5
4
t
3

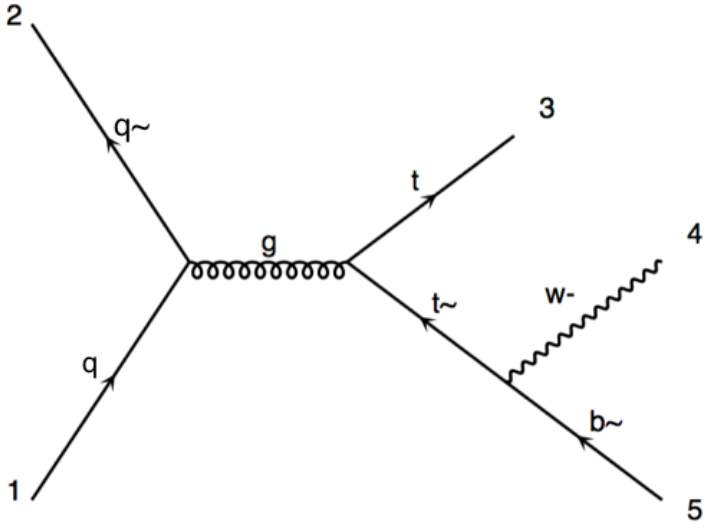

2
q~
q
1
g
b
b~
w-
t
4
3
5

tW(NLO-interference)









DR & DS

$$\mathcal{M} = \mathcal{M}^{(\mathbf{tw})} + \mathcal{M}^{(\mathbf{tt\sim})}$$

$$|\mathcal{M}|^2 = |\mathcal{M}^{(\mathrm{tw})}|^2 + 2\mathrm{Re}\{\mathcal{M}^{(\mathrm{tw})}\mathcal{M}^{(\mathrm{tt\sim})*}\} + |\mathcal{M}^{(\mathrm{tt\sim})}|^2$$

- **Diagram Removal (DR)**: Removes doubly resonant diagrams in NLO Wt amplitudes.

$$|\mathcal{M}|^2 = |\mathcal{M}^{(\mathrm{tw})}|^2$$

- **Diagram Subtraction (DS)**: Implement a subtraction term to locally cancel the tt~ contribution to modify the NLO Wt cross section.

$$|\mathcal{M}|^2 = |\mathcal{M}^{(\mathrm{tw})} + \mathcal{M}^{(\mathrm{tt\sim})}|^2 - C^{\mathrm{SUB}}$$

Subtraction term (C^{SUB})

$$g + g \rightarrow W^- + t + \bar{b}$$

k_1 k_2 k_3

$$C^{SUB} = \frac{(m_t\Gamma_t)^2}{((k_1+k_2)^2 - m_t^2)^2 + (m_t\Gamma_t)^2} \, |\mathcal{M}^{t\bar{t}}(\Phi_3')|^2$$

Φ_3' : 3-body phase space point obtained by reshuffling Φ_3 kinematics to get

$$(k_1 + k_3)^2 = m_t^2$$

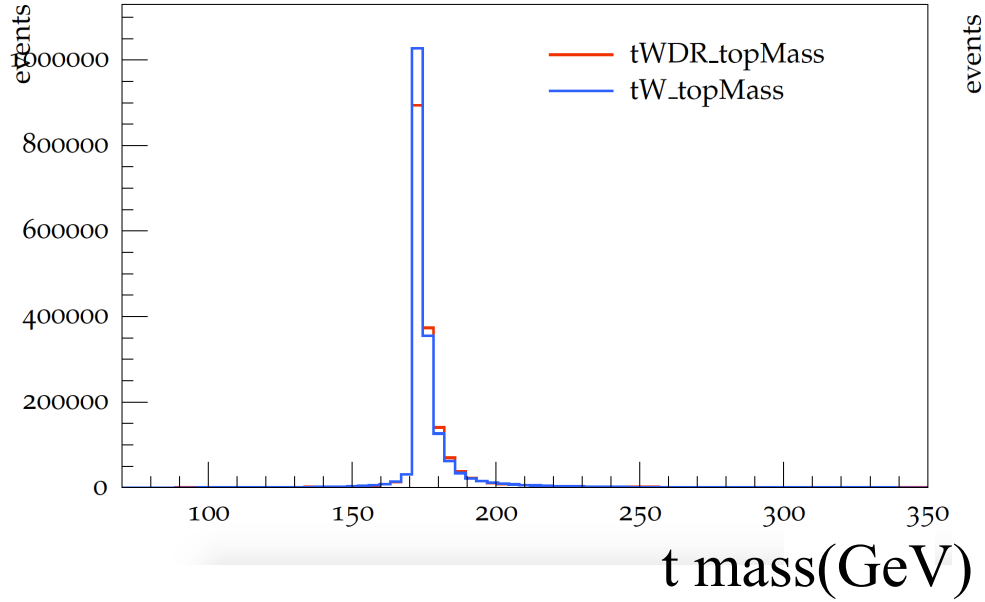
➢ ***DR-DS*** $= |\mathcal{M}^{(tw)}|^2 - [|\mathcal{M}^{(tw)} + \mathcal{M}^{(tt\sim)}|^2 - C^{SUB}] = 2\mathrm{Re}\{\mathcal{M}^{(tw)}\mathcal{M}^{(tt\sim)*}\}$

Interference

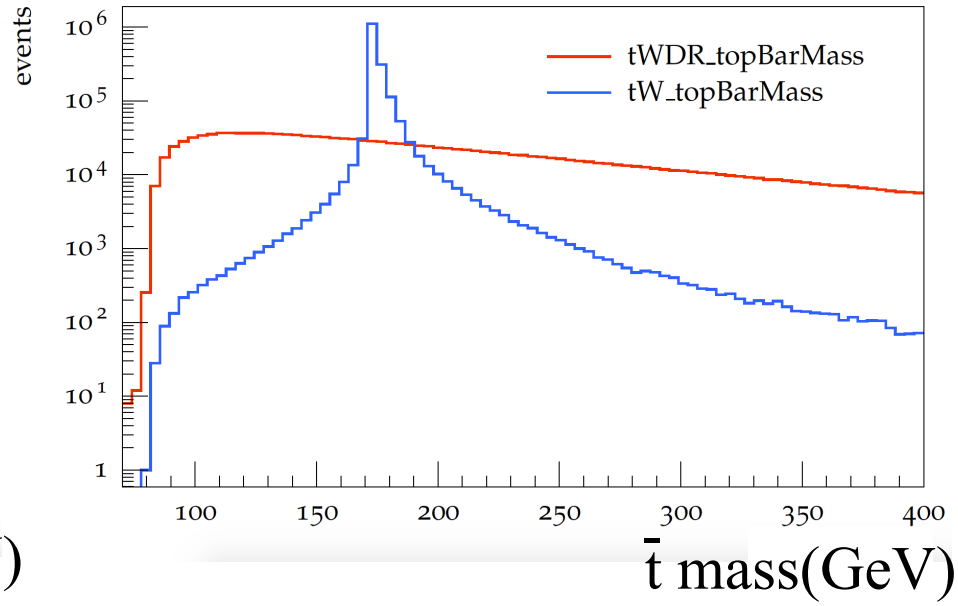
tW Vs tW(DR) Comparison

tW Vs tW(DR) comparison-I

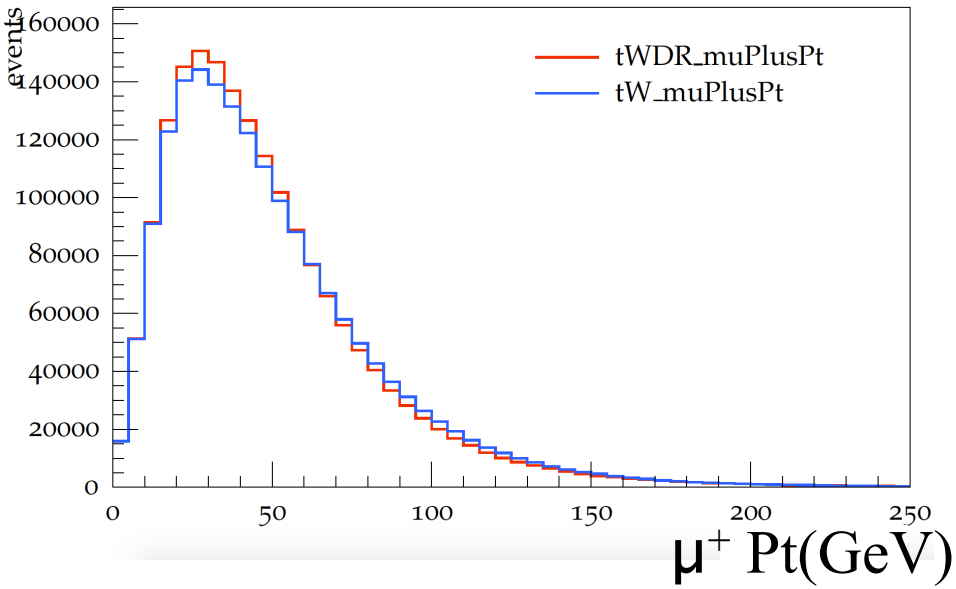
top quark mass

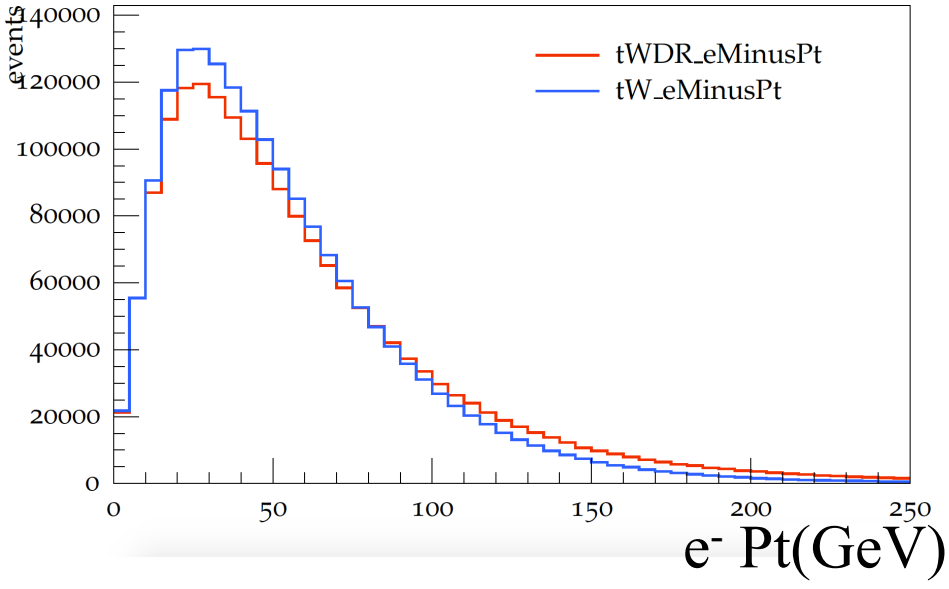


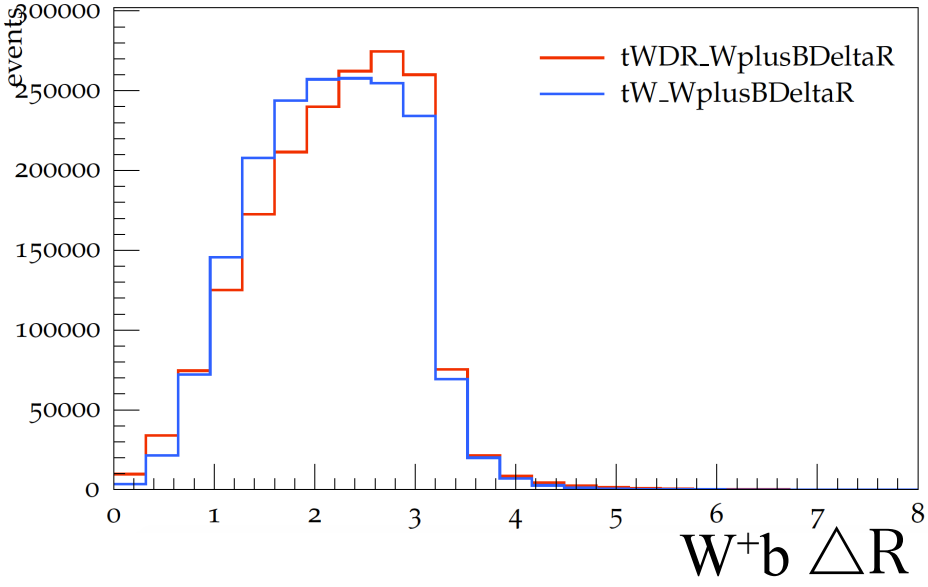
anti-top quark mass

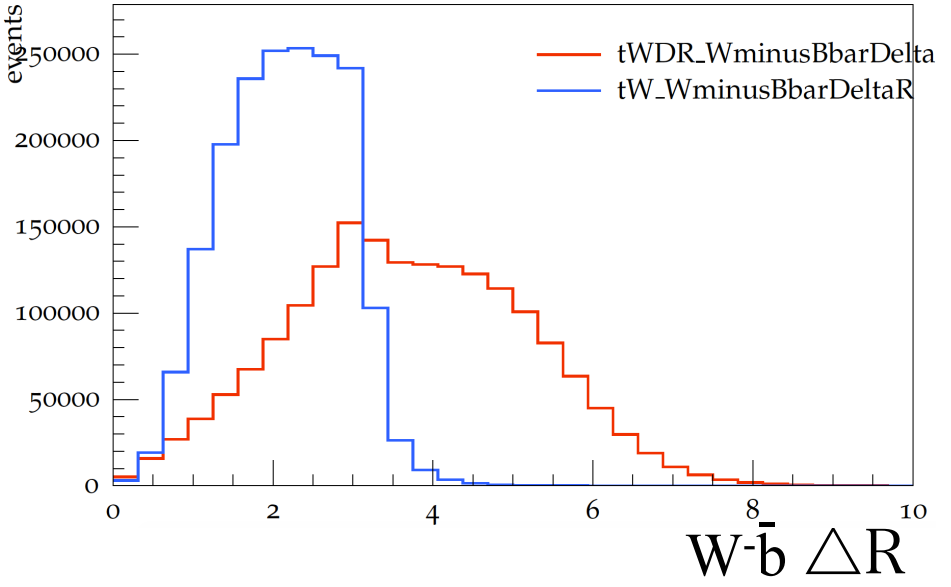


tW Vs tW(DR) comparison-II

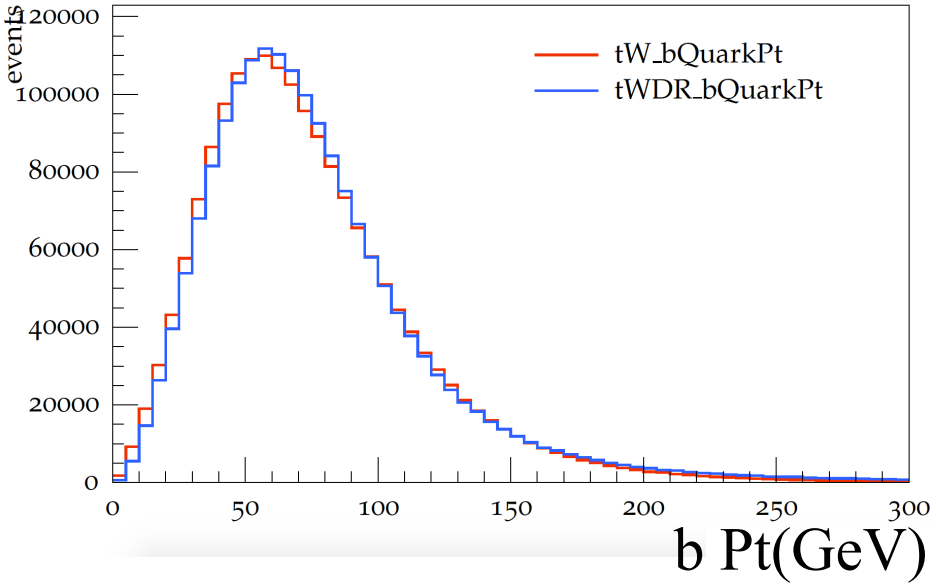


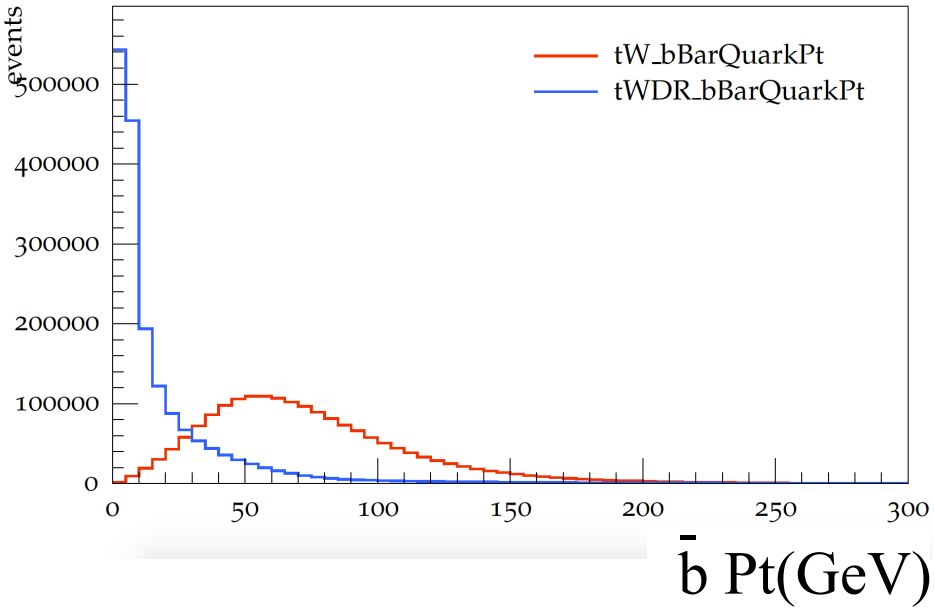


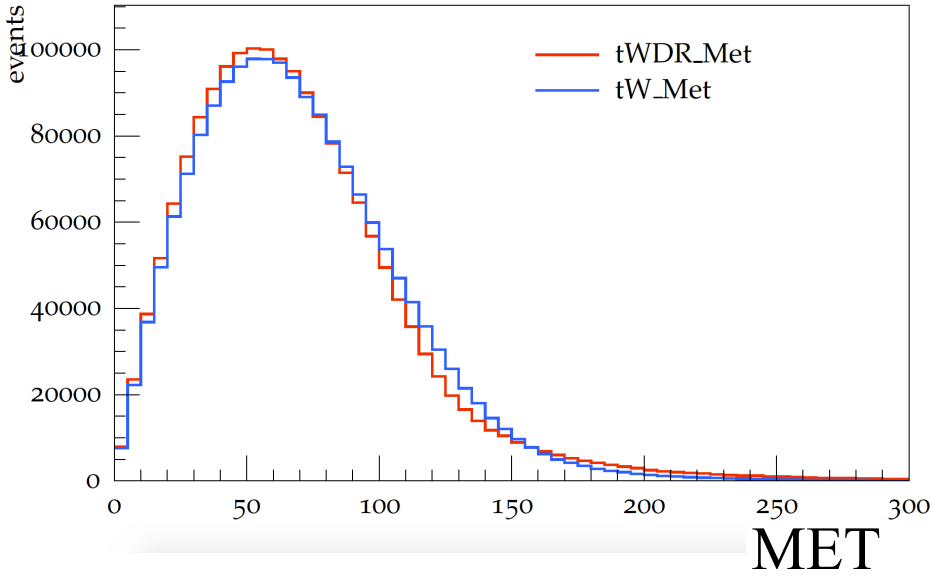




tW Vs tW(DR) comparison-III







Summary & Outlook

➢Recently started with tW channel (in di-leptonic decay mode).

➢Done with the DR.

➢Next step is to apply DS.

➢Compare two methods: DR & DS.

➢Further work on the interference.

THANK YOU

Back-up Slide