muon WP estimation in $t\bar{t}HH$ vs $t\bar{t}$ events

권 우 연

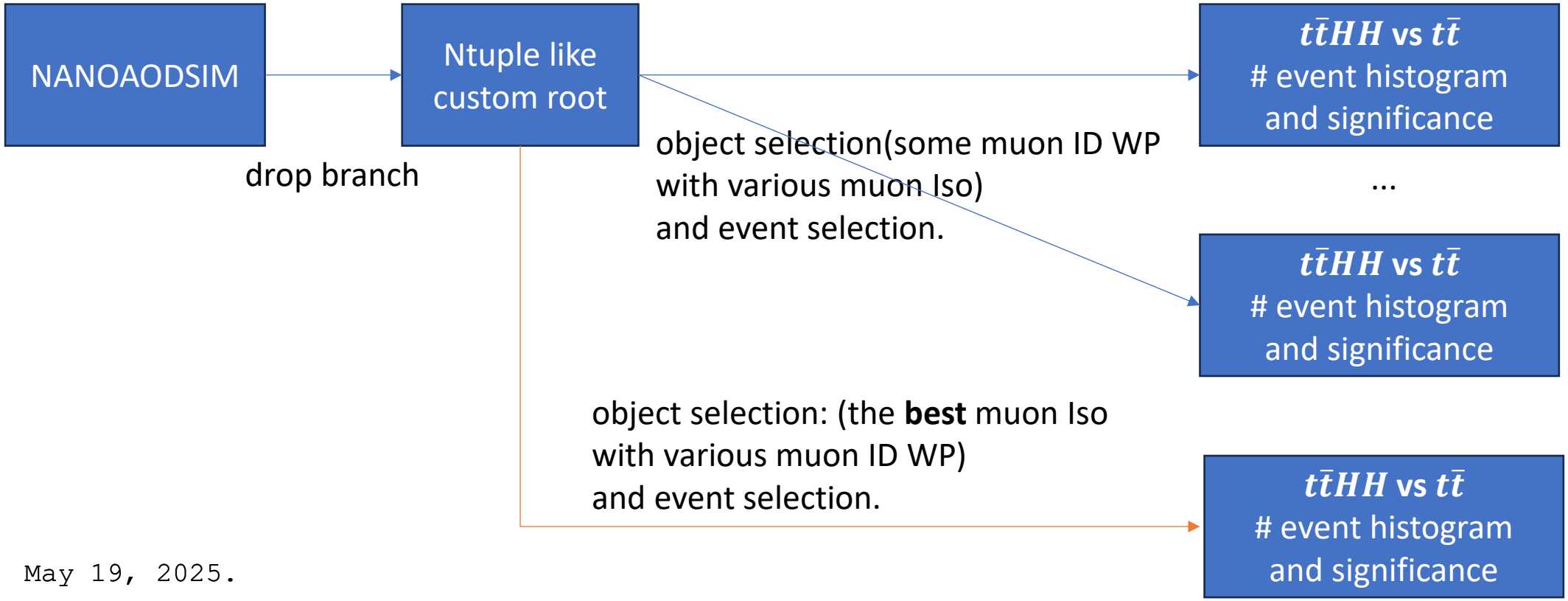
Wooyeon Kwon

wkwon@cern.ch

May 19, 2025

Workflow

Purpose : For $t\bar{t}HH$ events analysis, estimate various muon WP for distinguishing $t\bar{t}$ events which are main background of the analysis



MC Samples

$t\bar{t}HH$

semi-leptonic : private TTHH DL bbWW, including τ-lepton samples with 100k events. (by Tianyi Yang)

di-leptonic : private TTHH SL bbWW, including τ-lepton samples with 100k events. (by Tianyi Yang)

$t\bar{t}$

semi-leptonic : Run3Summer23, TTtoLNu2Q_TuneCP5_13p6TeV_powheg-pythia8

di-leptonic : Run3Summer23, TTto2L2Nu_TuneCP5_13p6TeV_powheg-pythia8

sample cross-sections

$t\bar{t}HH$ (SL : 0.0000618 pb, DL: 0.000012 pb)

$t\bar{t}$ (SL : 404.0 pb, DL: 96.9 pb)

※ Luminosity is normalized with each **$t\bar{t}HH$** event samples. (SL : 1618 ab^{-1} , DL : 8333 ab^{-1})

Object Selection

b-jet

- medium WP b-tag (85%) with PNet
- $p_T > 25\ GeV\ \&\&\ |\eta| < 2.5$

Muon

- Selection : $p_T > 15\ GeV\ \&\&\ |\eta| < 2.4\ \&\&\ |d_{xy}| < 0.05\ \&\&\ |d_z| < 0.1$

Muon ID	Muon Isolation
Loose ID	PFIsolation (very Loose(1) ~ very very tight(6))
Medium ID	Tracker-based Isolation (Loose(1),Tight(2))
Tight ID	Mini Isolation (Loose(1) ~ veryTight(4))
Soft ID	Multi Isolation (Medium(2)) (loose is meaningless)
MVA wp medium ID	
MVA wp tight ID	

test various ID and isolation combinations.

Event Selection

Event Selection

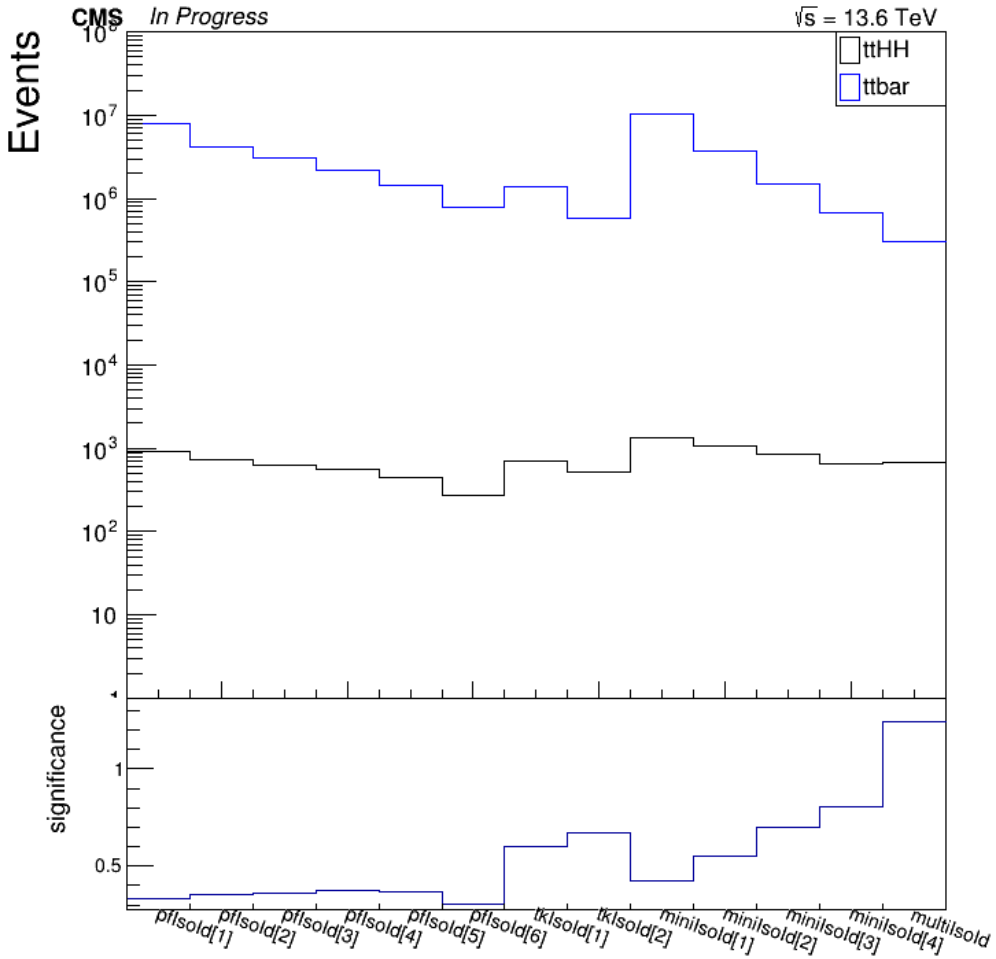
- 2 muons of Same-sign (or more muons)
- Least 4 b-jets

Significance Definition

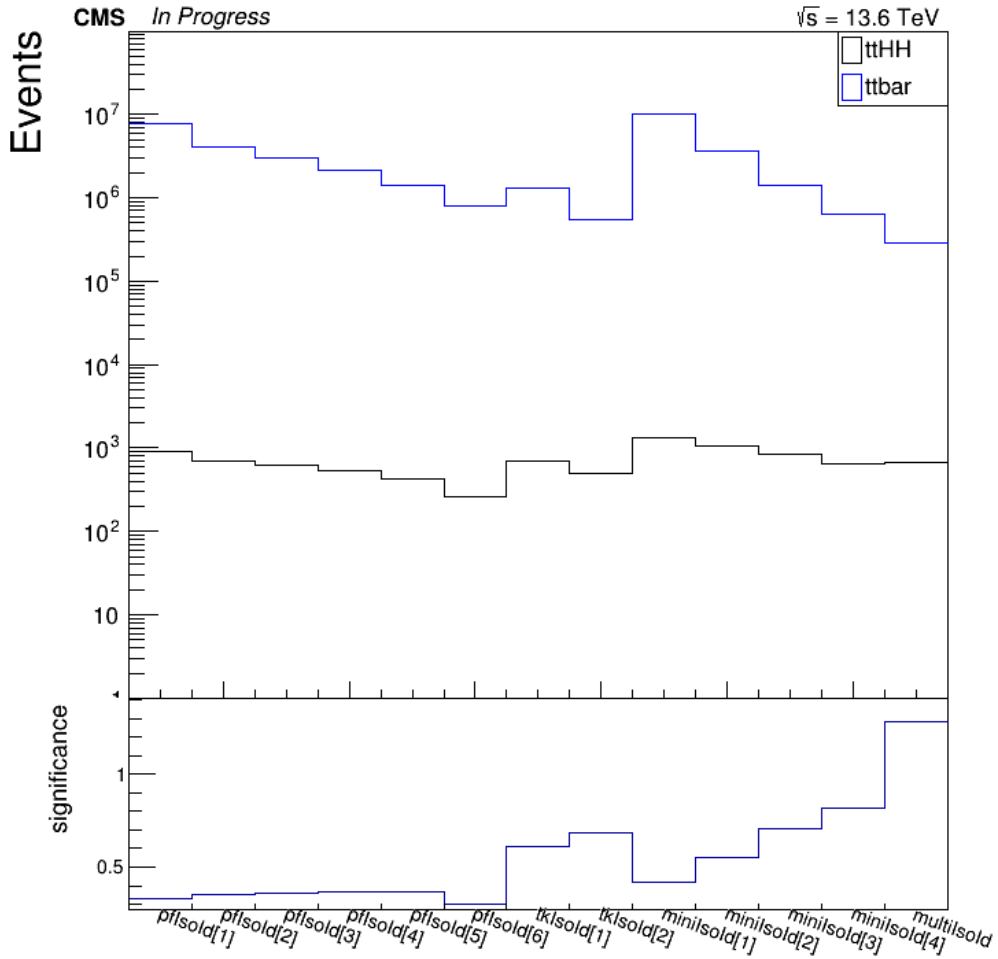
$$Significance = \frac{\#\ t\bar{t}HH \text{ selected events}}{\sqrt{\#\ t\bar{t} \text{ selected events}}}$$

Result – Semi Leptonic

Loose ID Muon

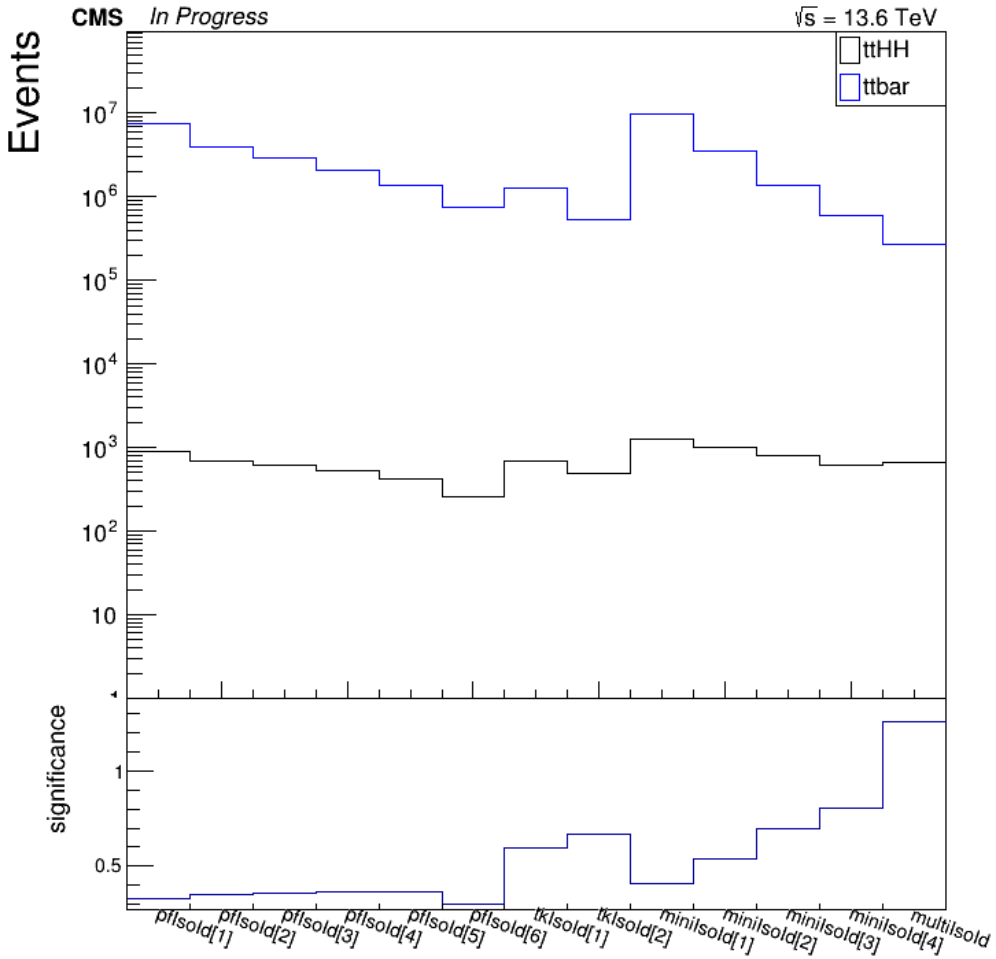


Medium ID Muon

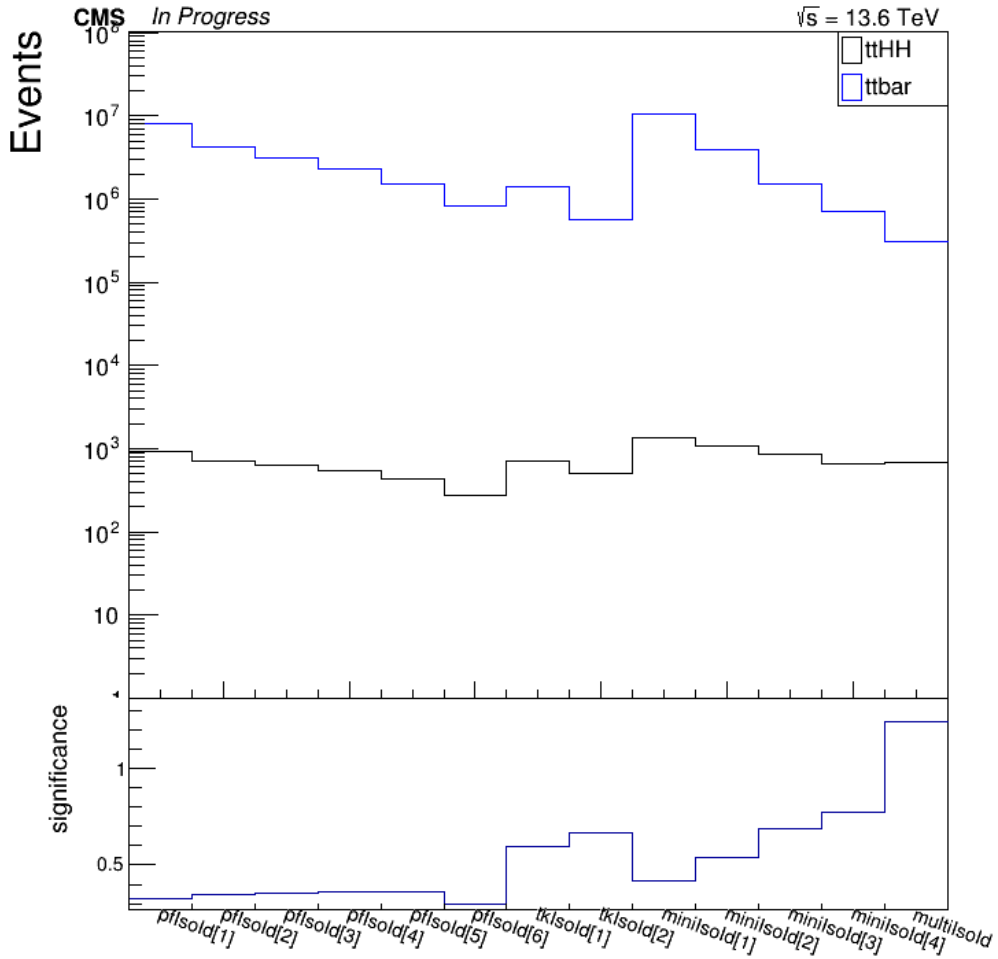


Result – Semi Leptonic

Tight ID Muon

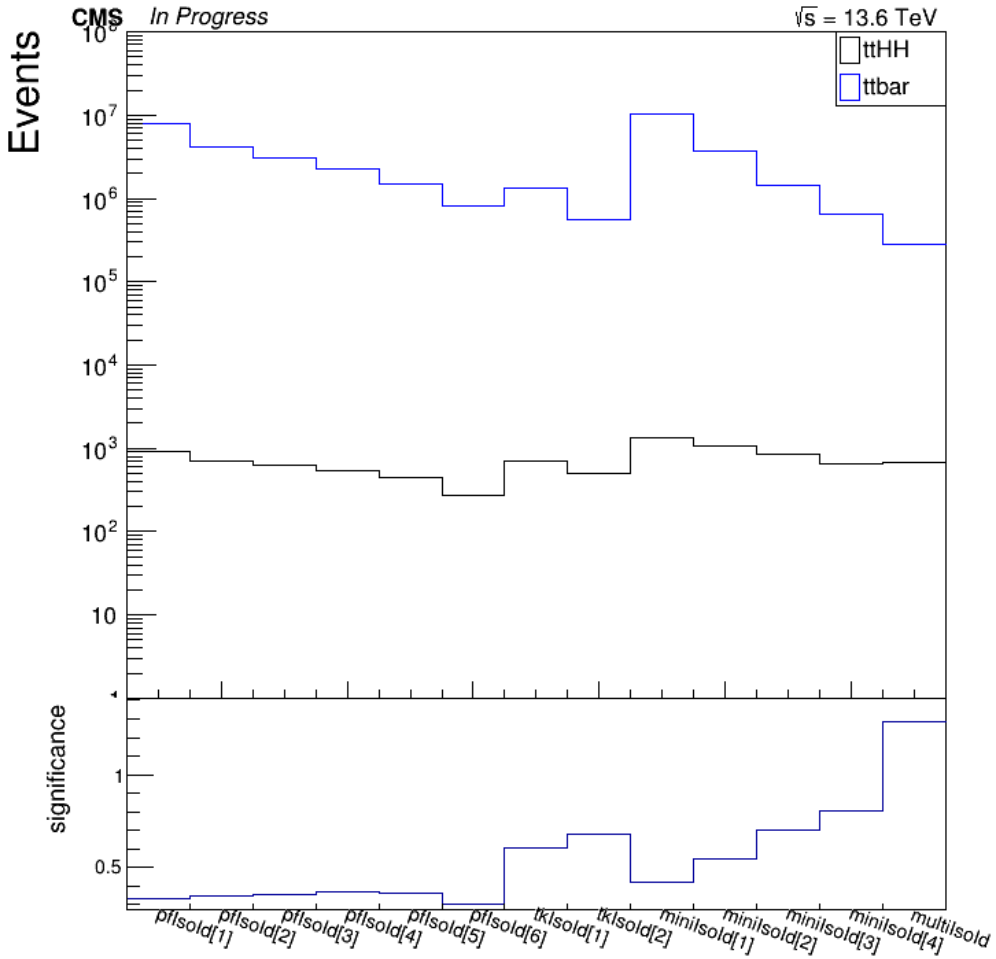


Soft ID Muon

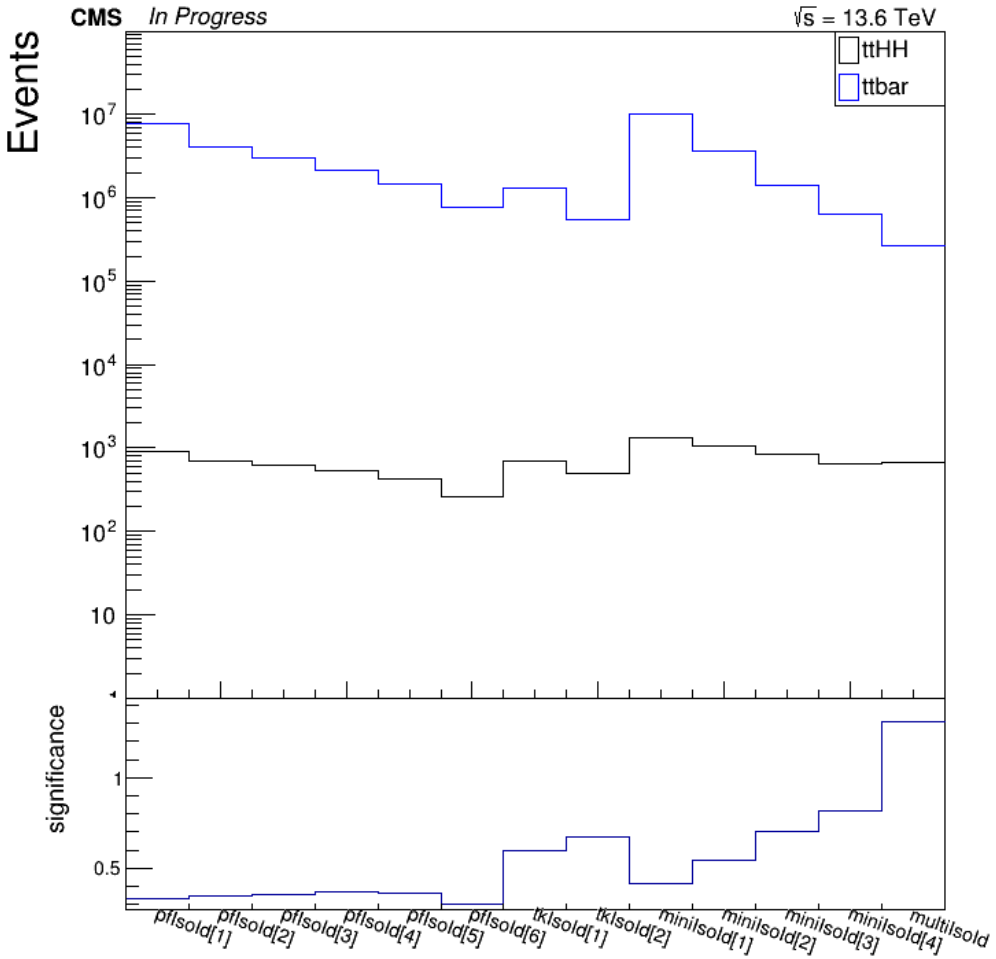


Result – Semi Leptonic

MVA WP medium Muon



MVA WP Tight Muon

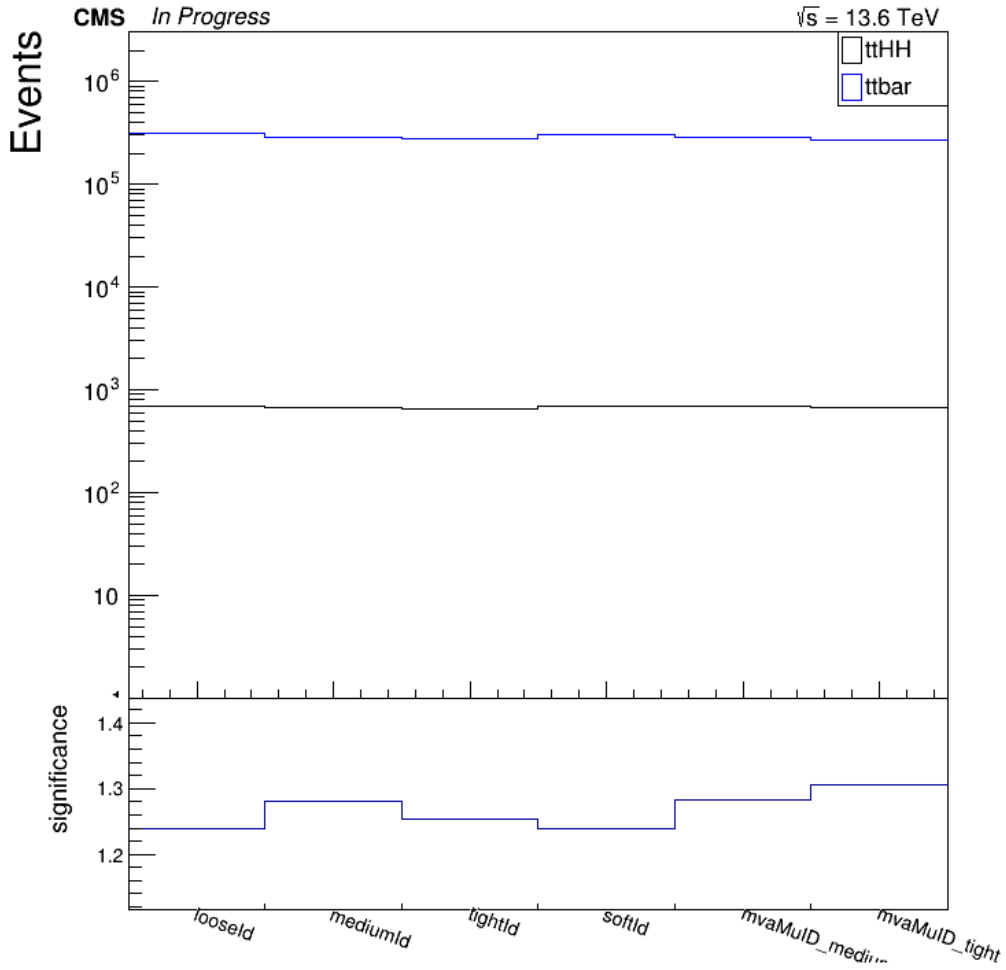


Result – Semi Leptonic

- For all ID case, Multi Isolation (Medium) has the best significance.

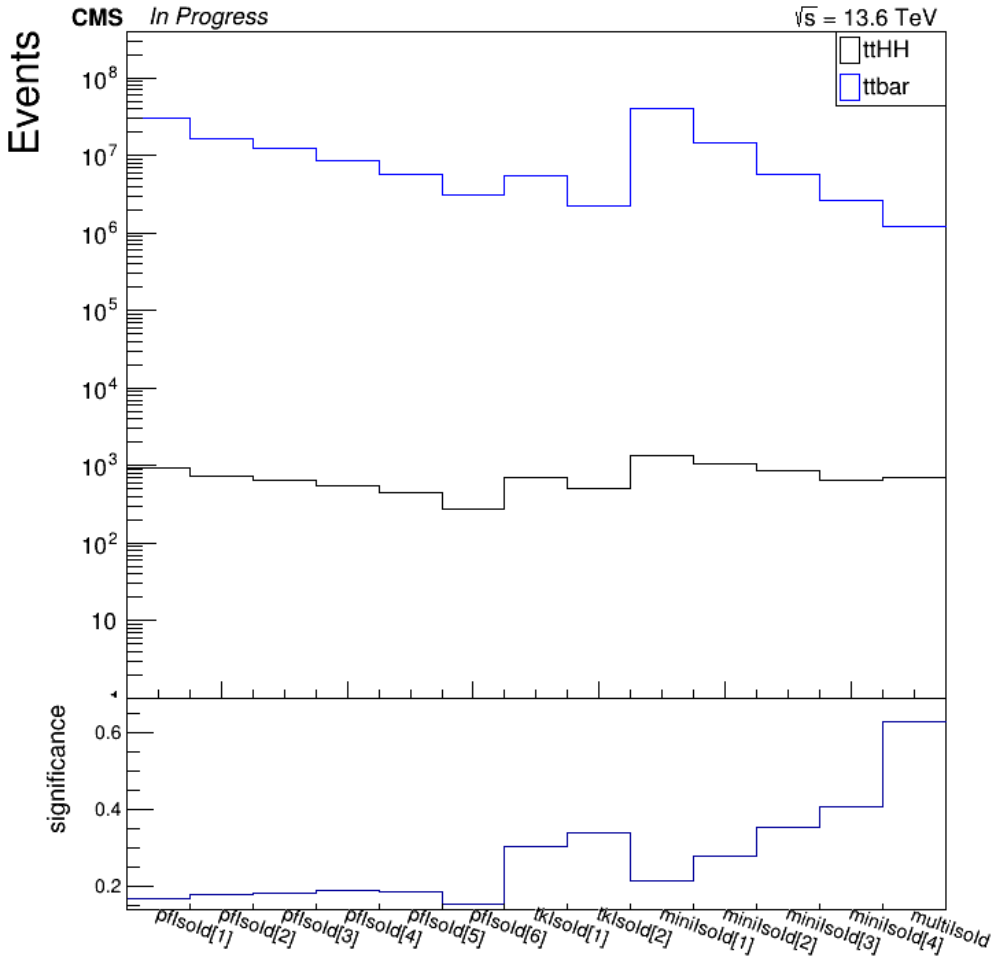
- For the Multi Isolation Muon case, MVA Tight Muon ID has the best significance.

Multi Isolation Muon

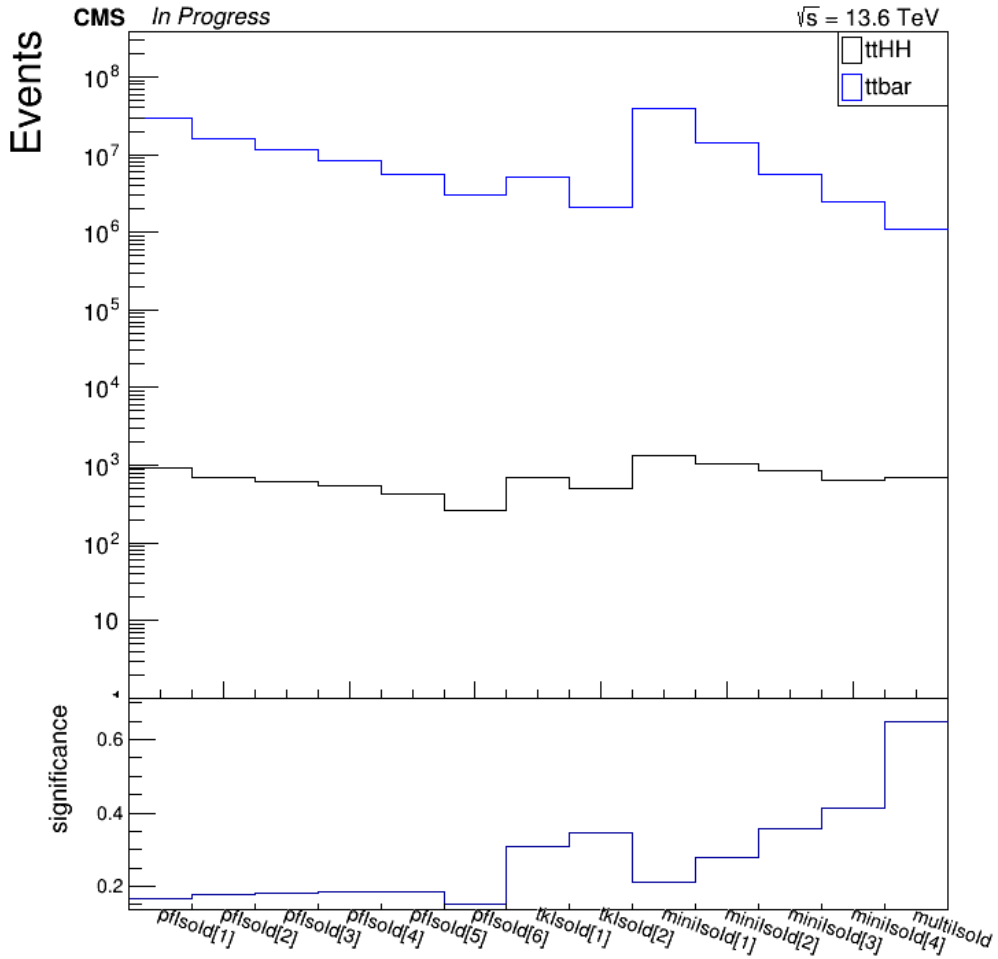


Result – Di Leptonic

Loose ID Muon

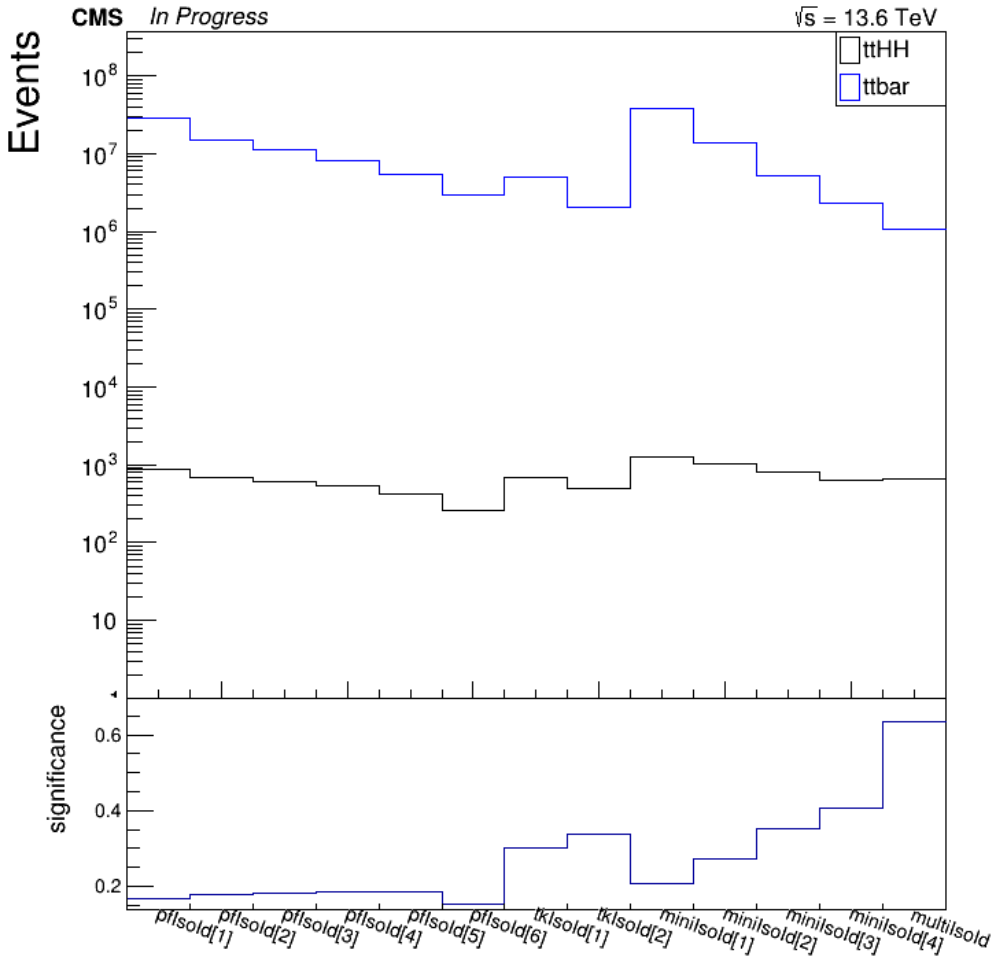


Medium ID Muon

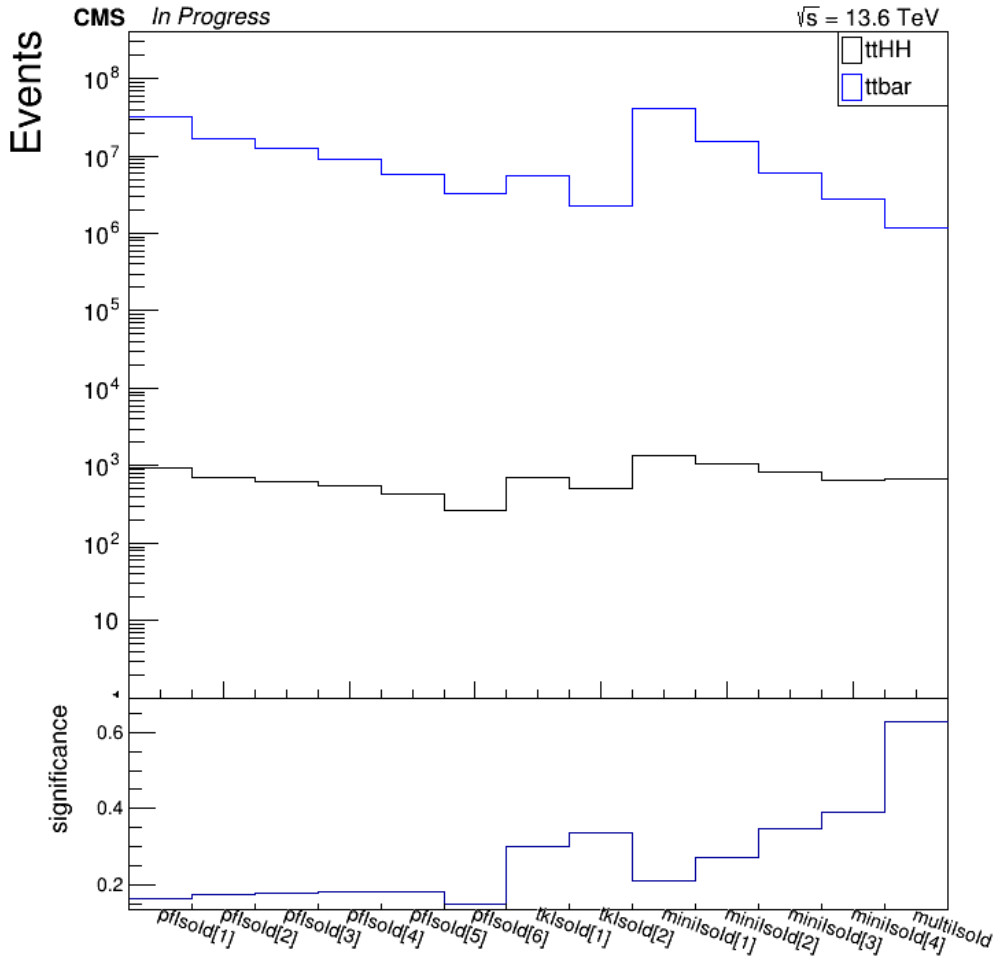


Result – Di Leptonic

Tight ID Muon

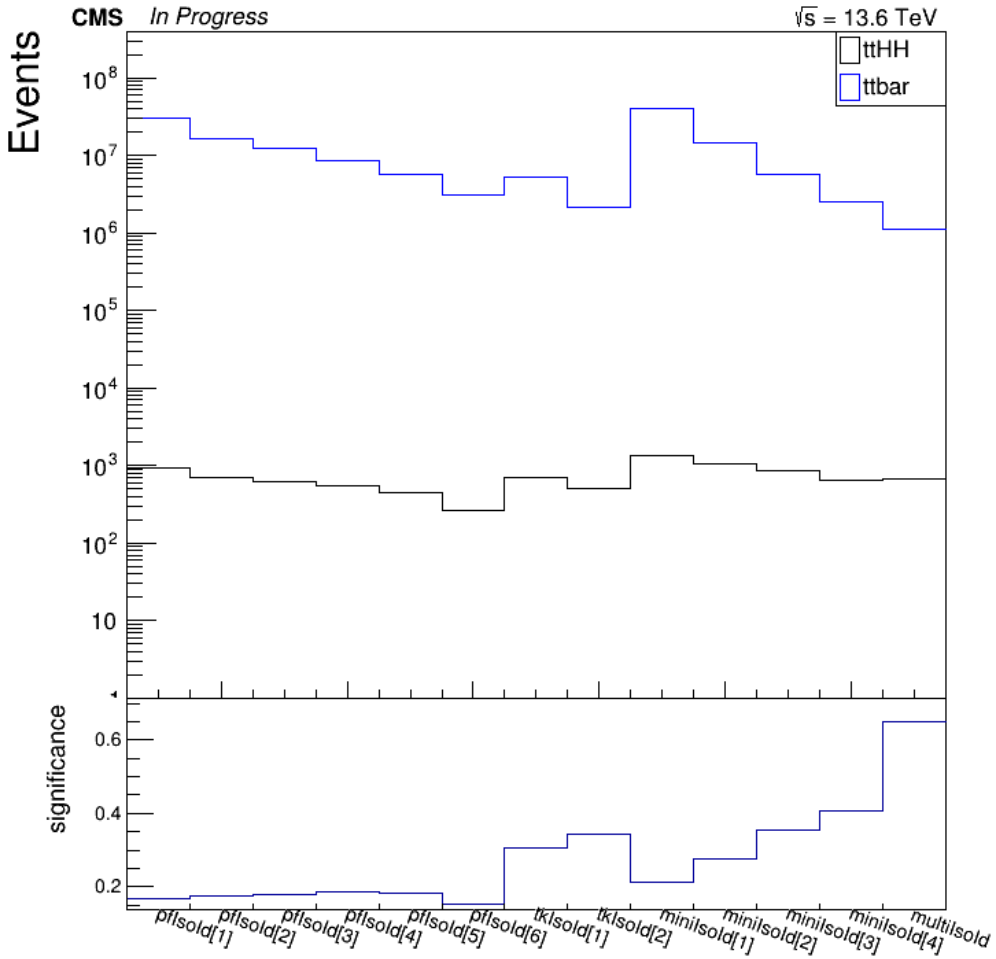


Soft ID Muon

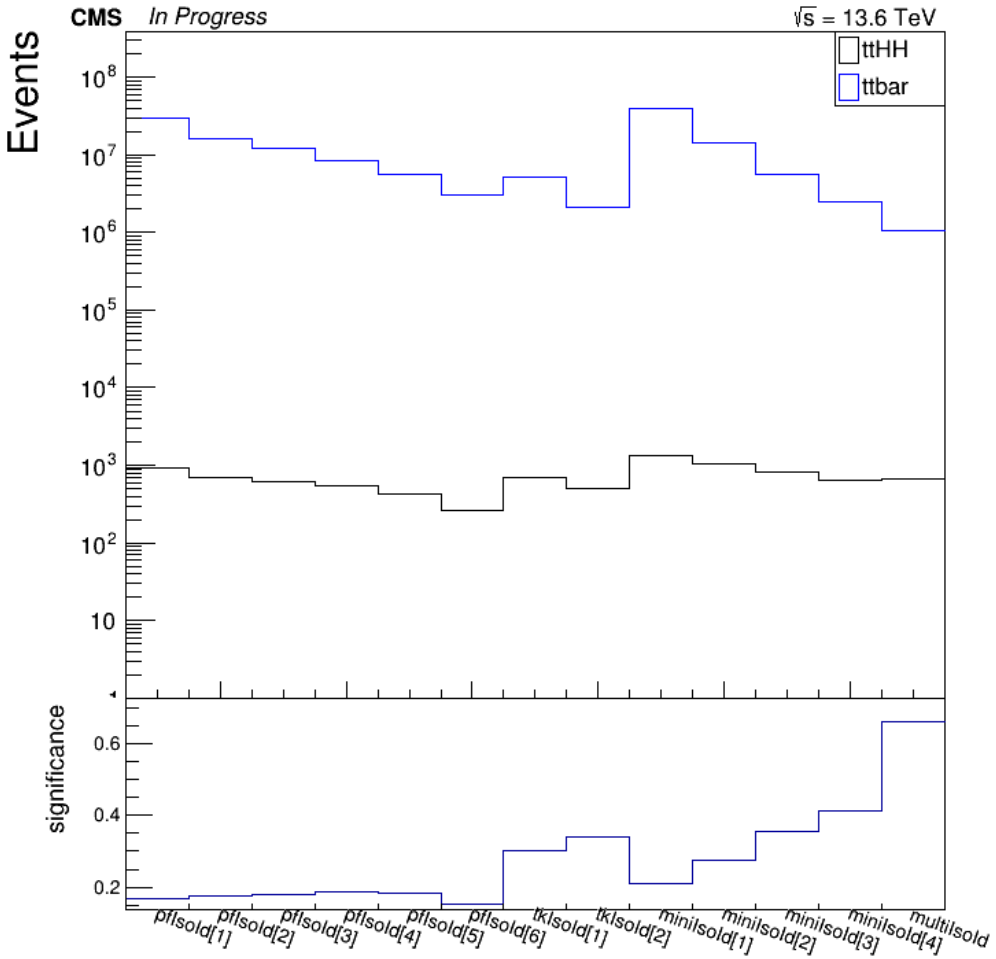


Result – Di Leptonic

MVA WP medium Muon



MVA WP Tight Muon



Result – Di Leptonic

- For all ID case, Multi Isolation (Medium) has the best significance.

- For the Multi Isolation Muon case, MVA Tight Muon ID has the best significance.

Conclusion

- **MVA tight Muon ID + Multi Isolation Muon** gives the best significance for the $t\bar{t}HH$ events, both SL and DL cases.

Multi Isolation Muon