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


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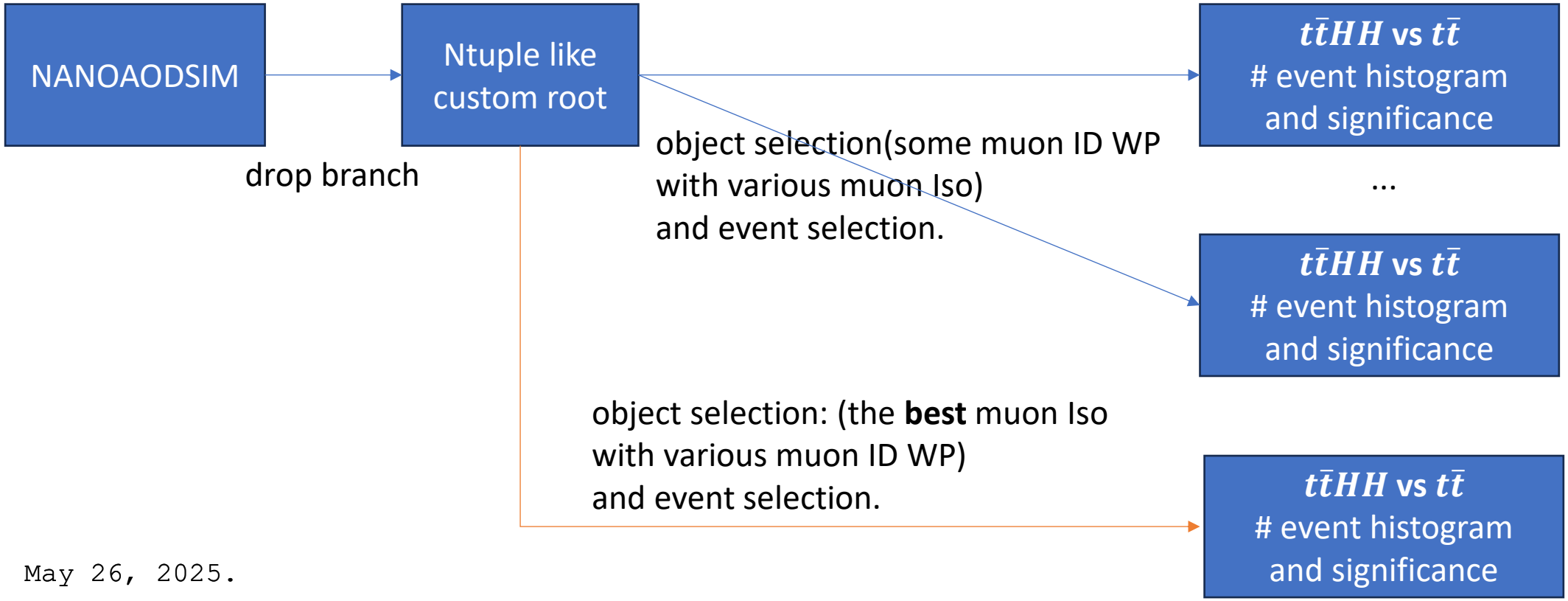
# Workflow

**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 $\tau$-lepton samples with 100k events. (by Tianyi Yang)

di-leptonic : private TTHH SL bbWW, including $\tau$-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)

※Target luminosity : $171.6\ fb^{-1}$

# 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

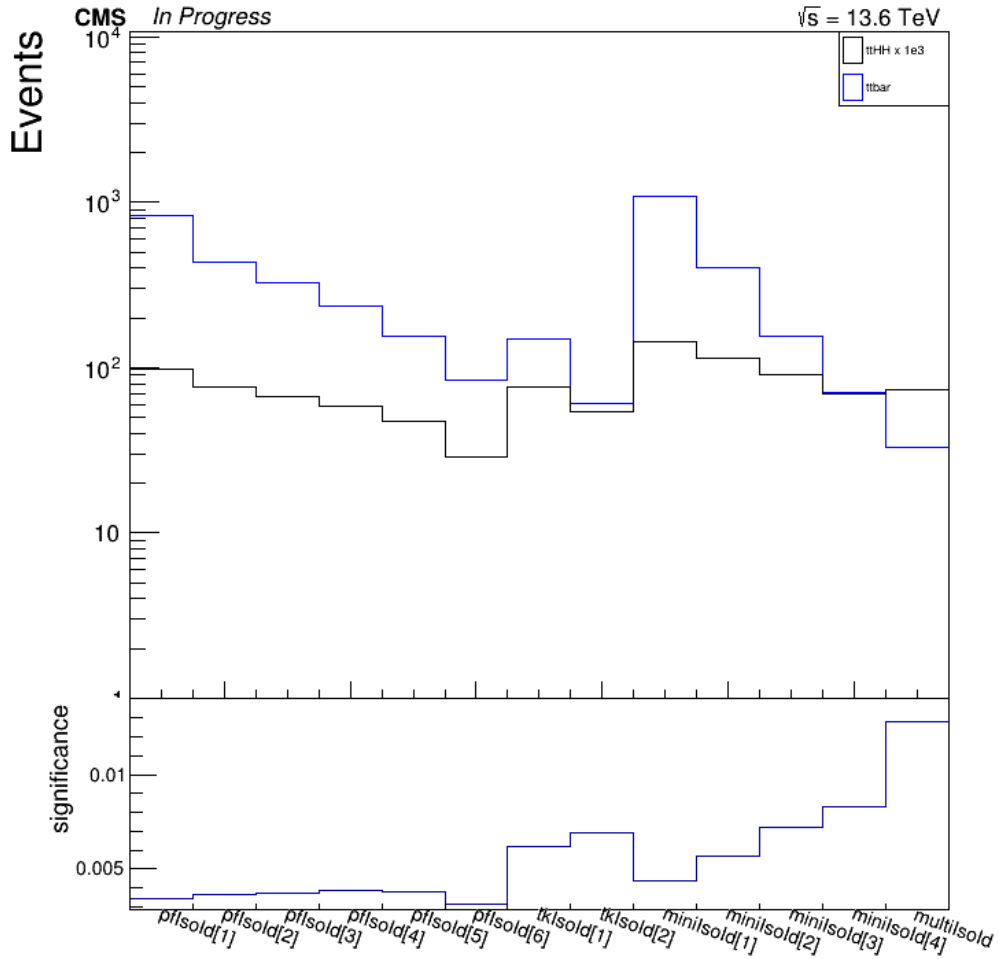
- 2 muons of Same-sign (or more muons)
- Least 4 b-jets

## Significance Definition

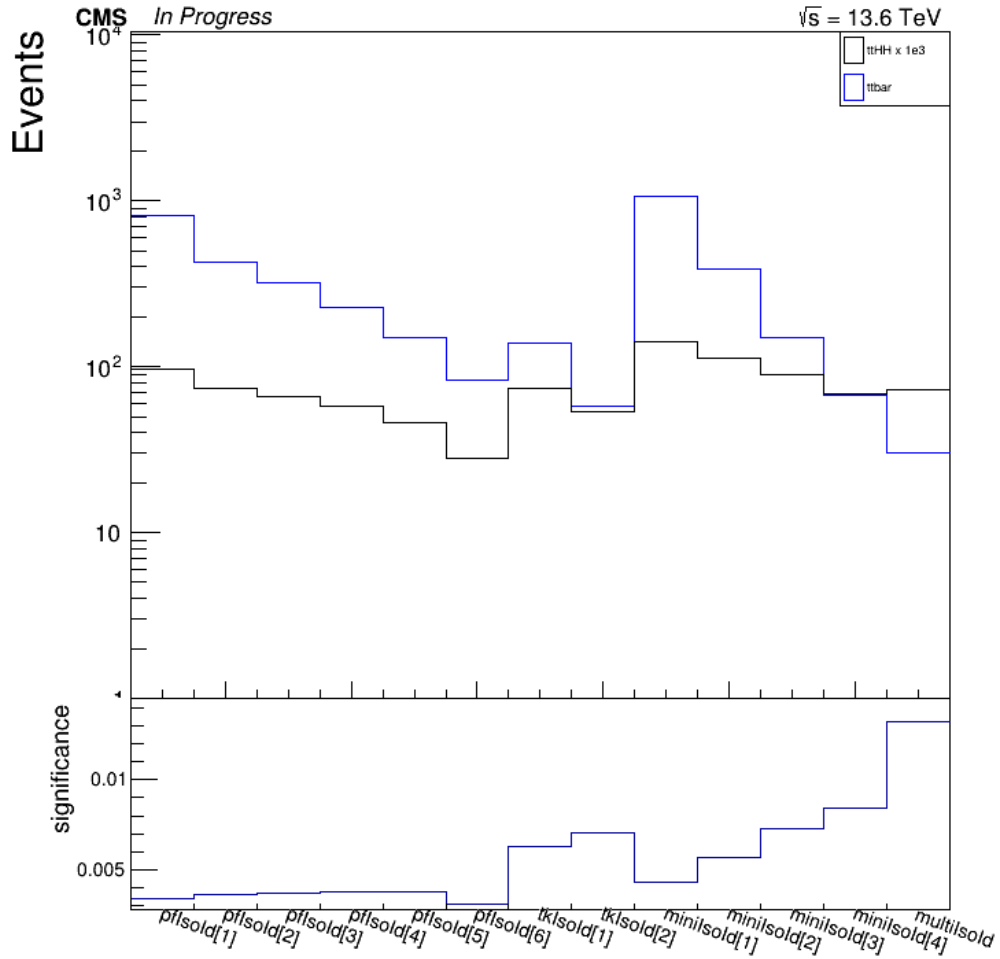
$$Significance = \frac{\#\ t\bar{t}HH \text{ selected events}}{\sqrt{\#\ t\bar{t} \text{ selected events}}}$$

# Result – Semi Leptonic

## Loose ID Muon

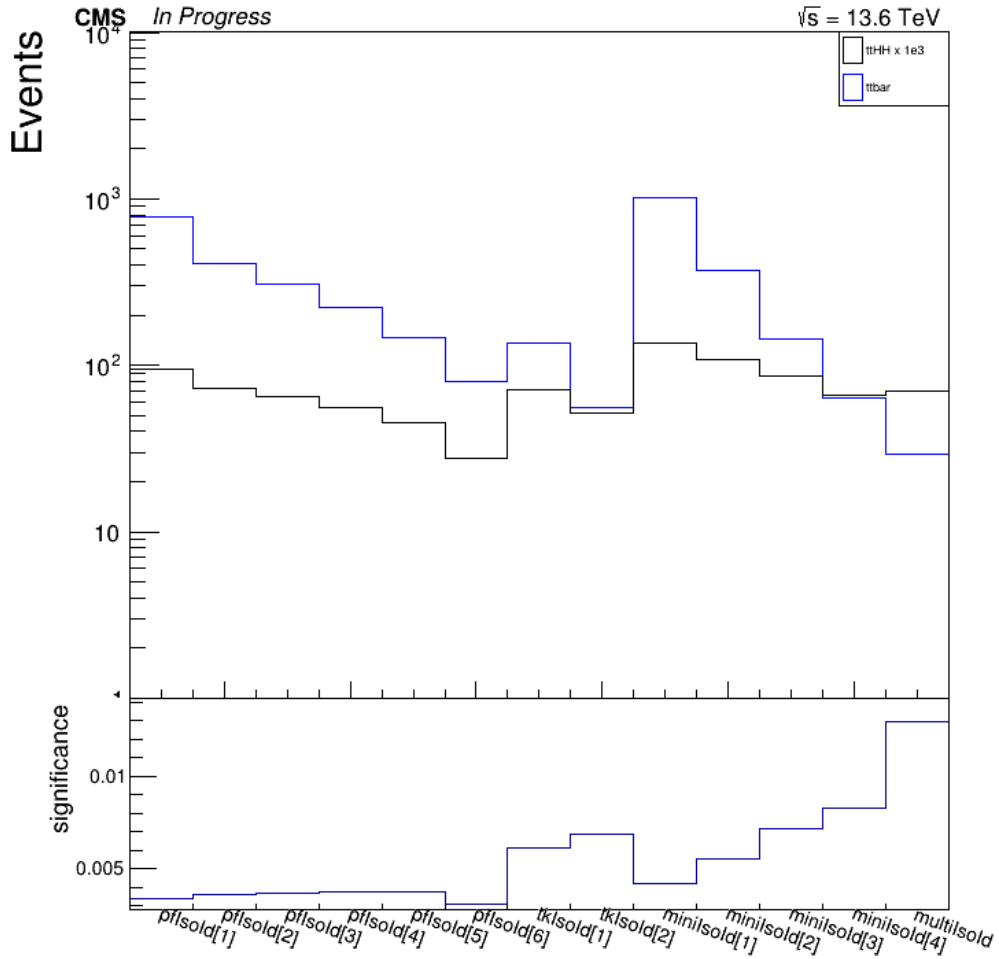



## Medium ID Muon

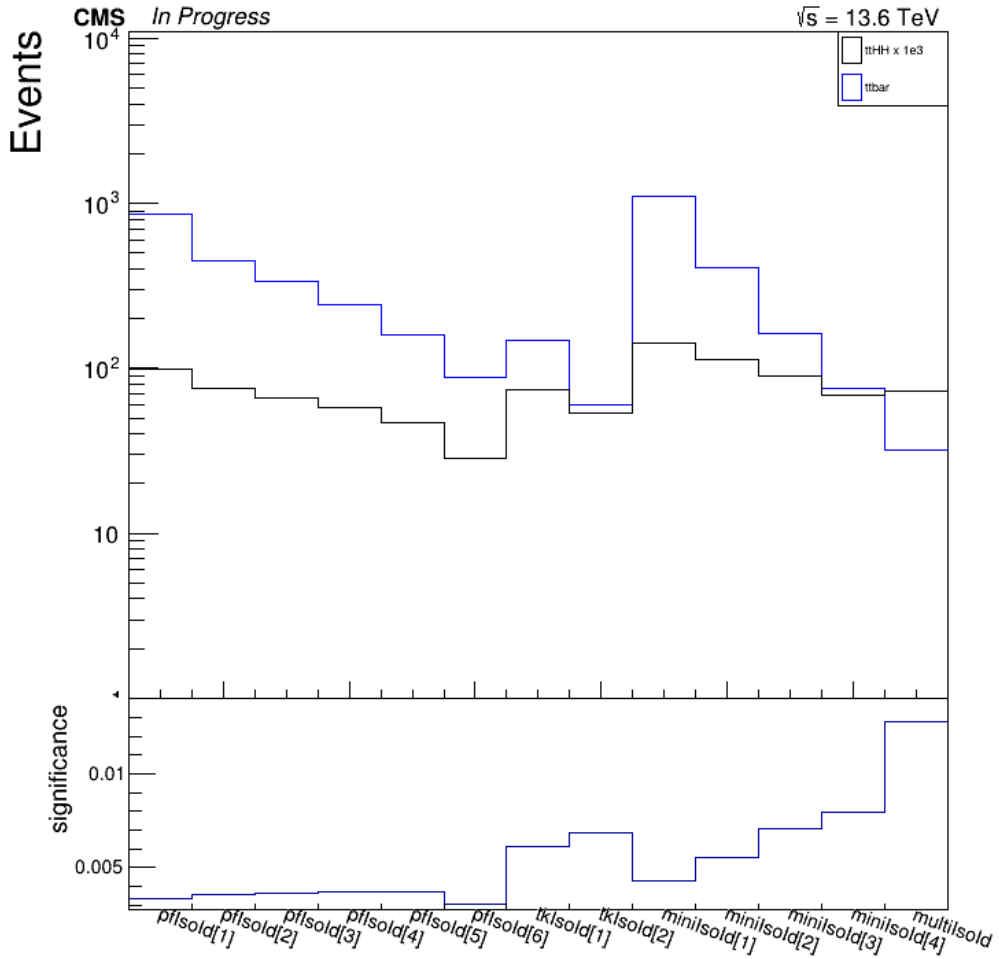


# Result – Semi Leptonic

## Tight ID Muon

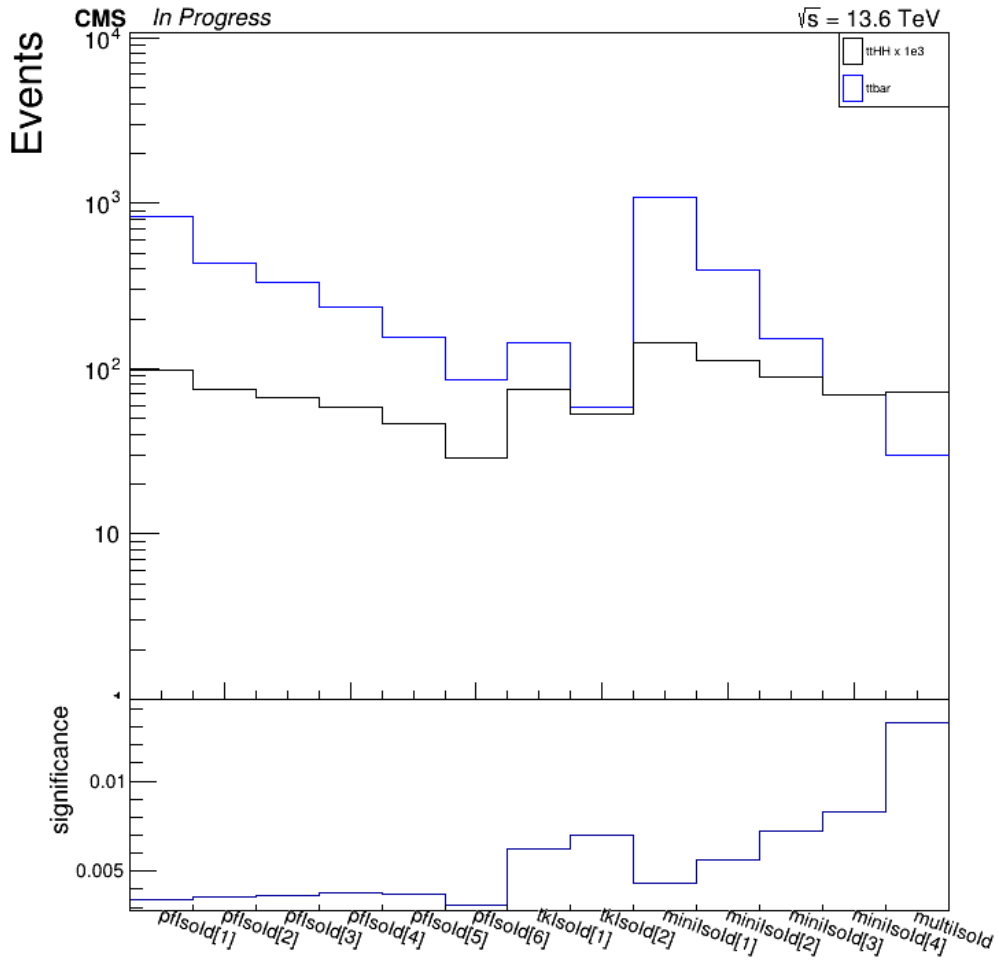



## Soft ID Muon

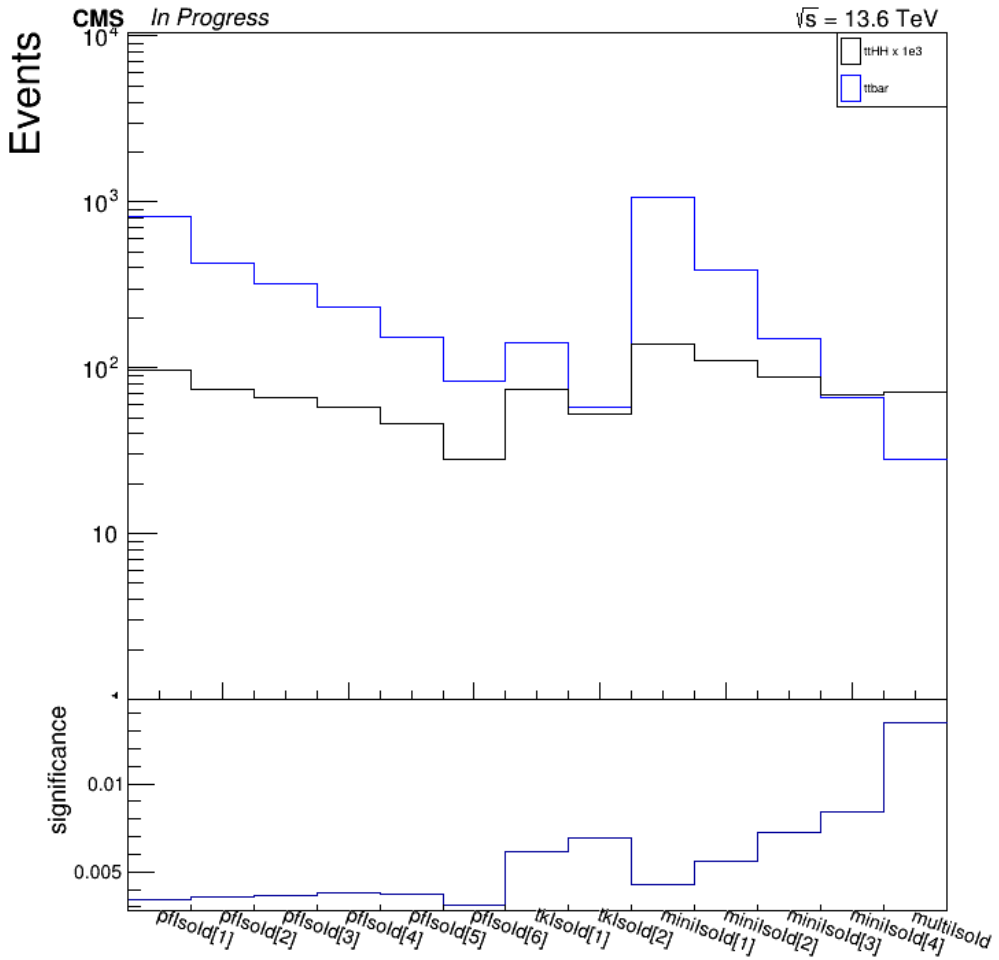


# Result – Semi Leptonic

## MVA WP medium Muon



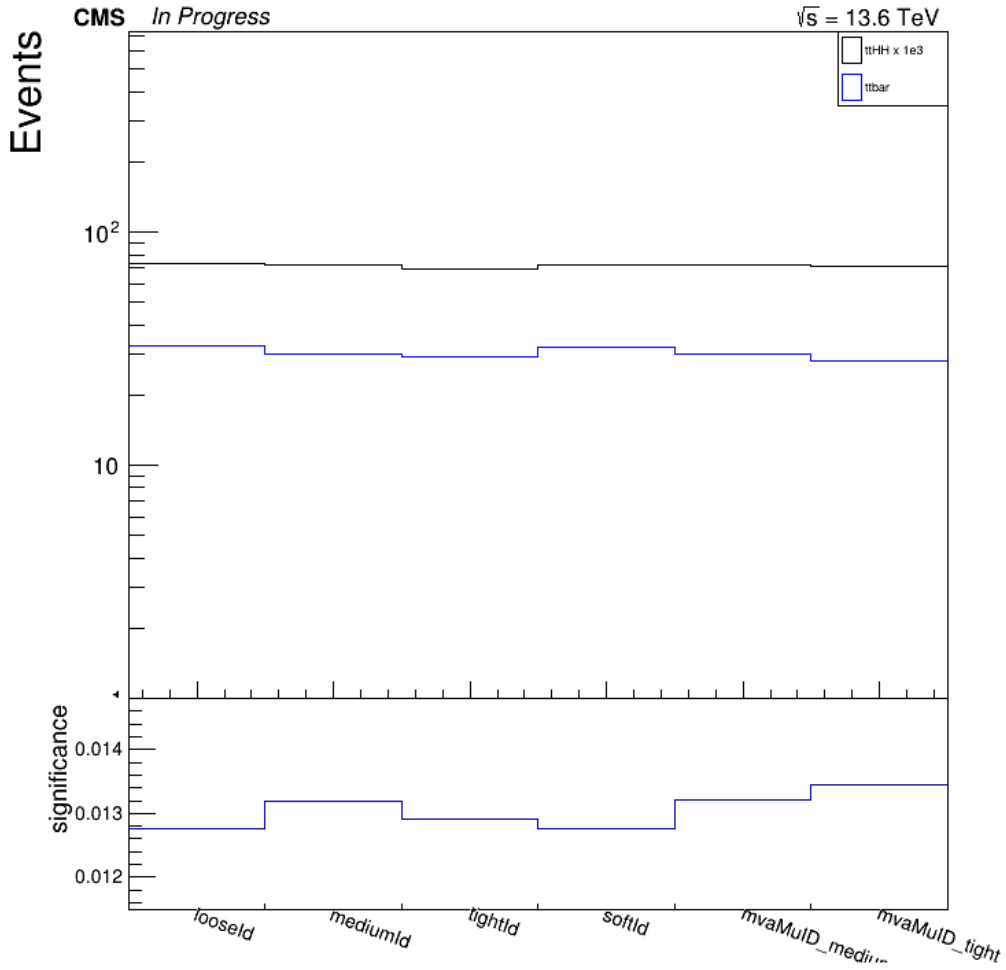

## MVA WP Tight Muon



# Result – Semi Leptonic

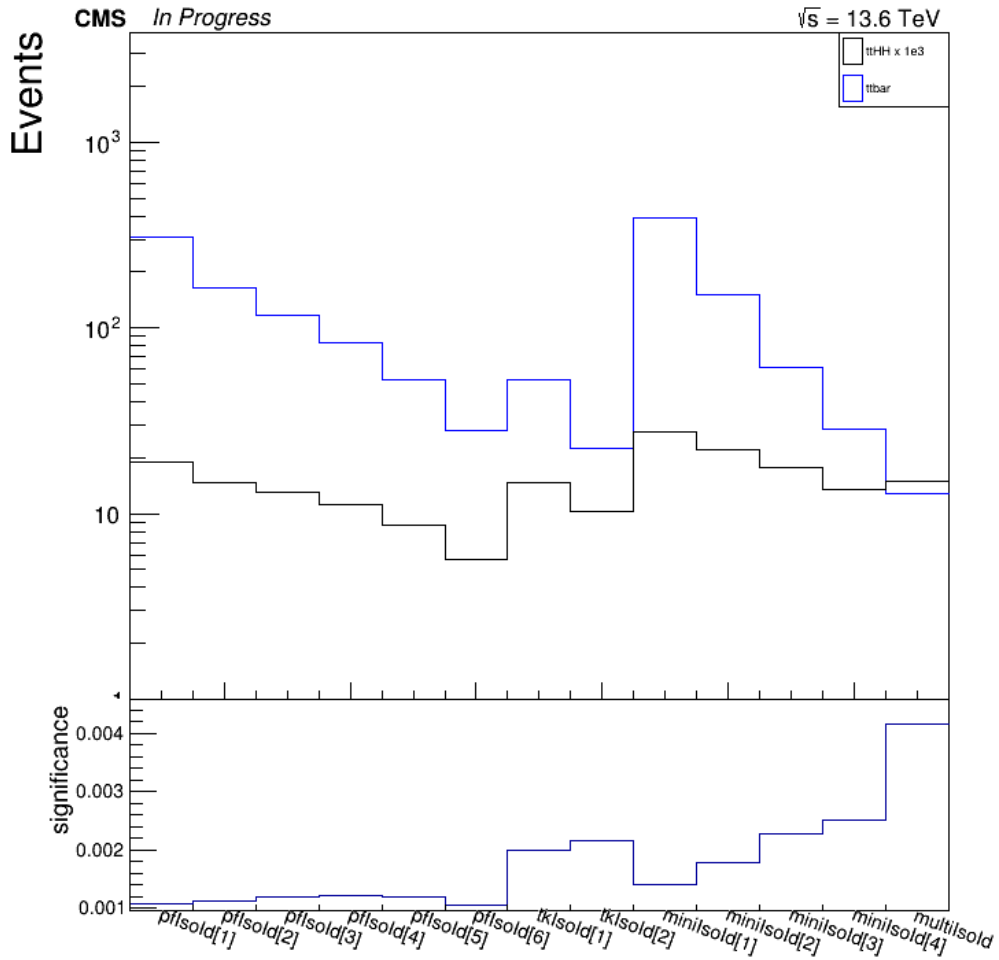
- For all ID case, Multi Isolation (Medium) has the best significance.
- For the Multi Isolation Muon case, MVA Tight Muon ID has the best significance.

Multi Isolation Muon

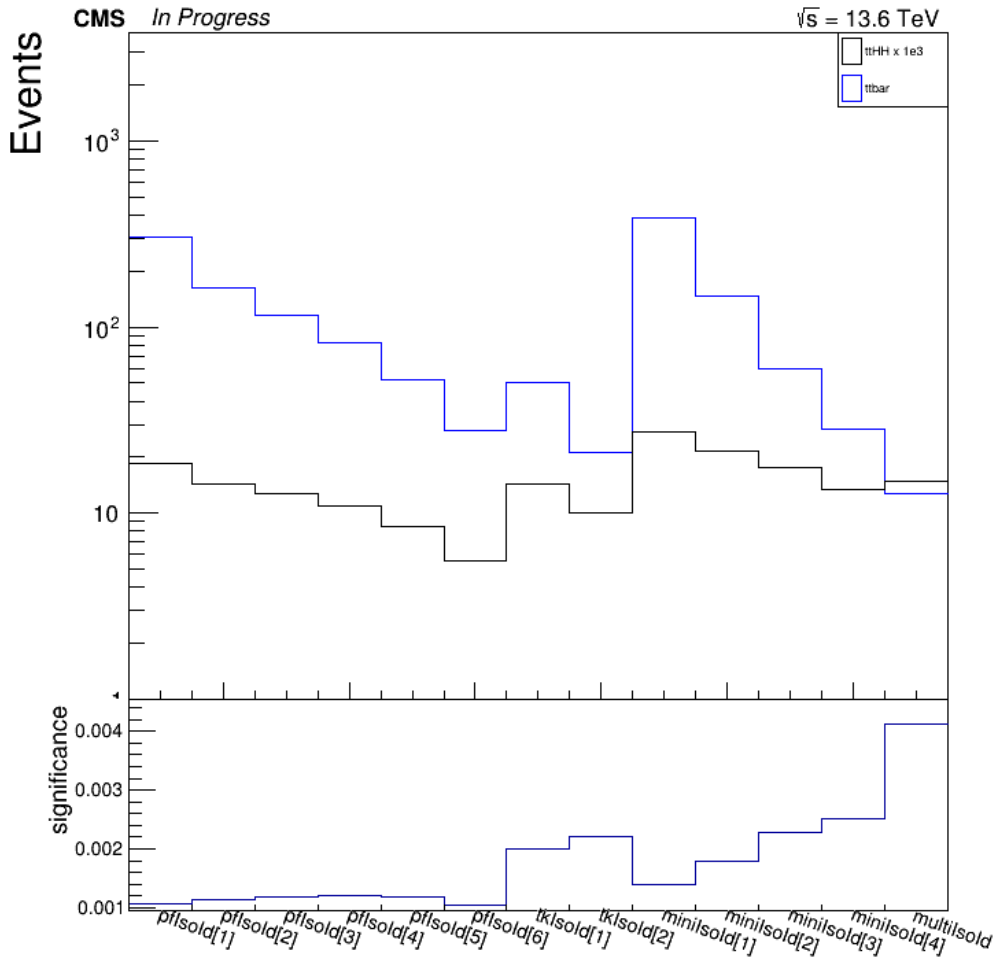


# Result – Di Leptonic

## Loose ID Muon

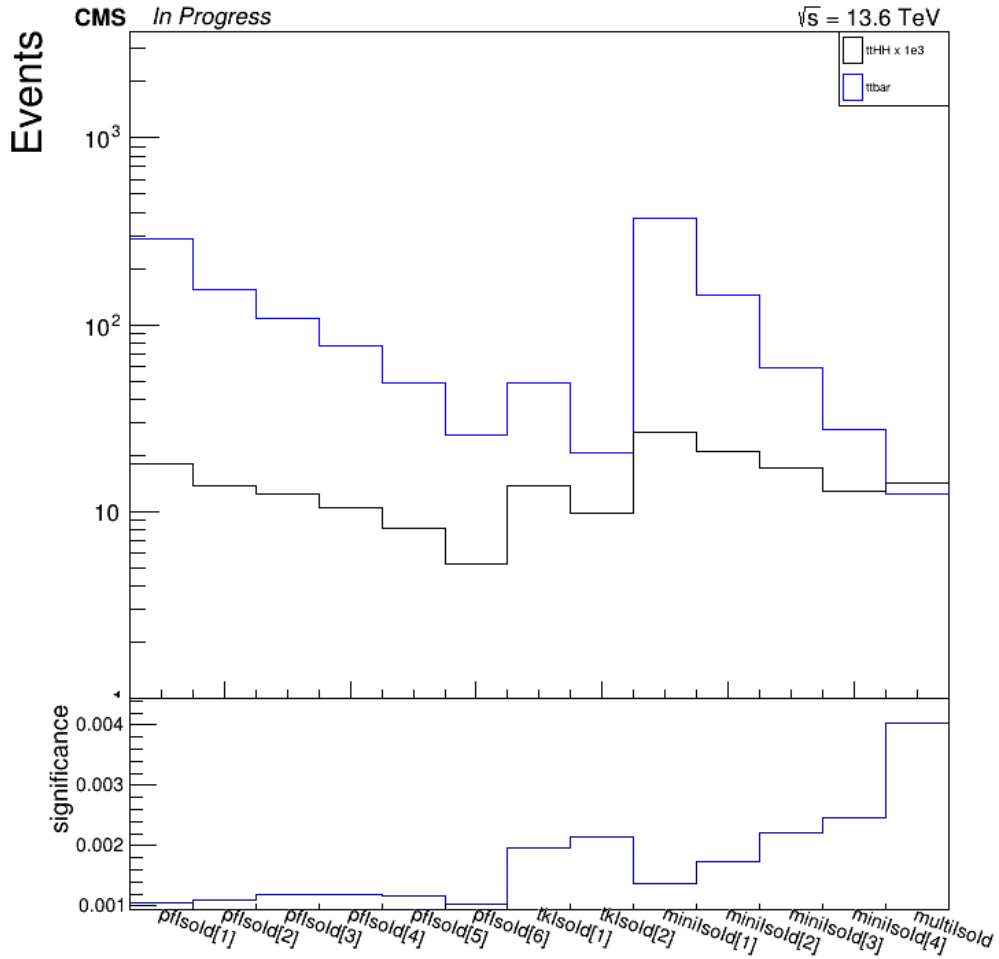



## Medium ID Muon

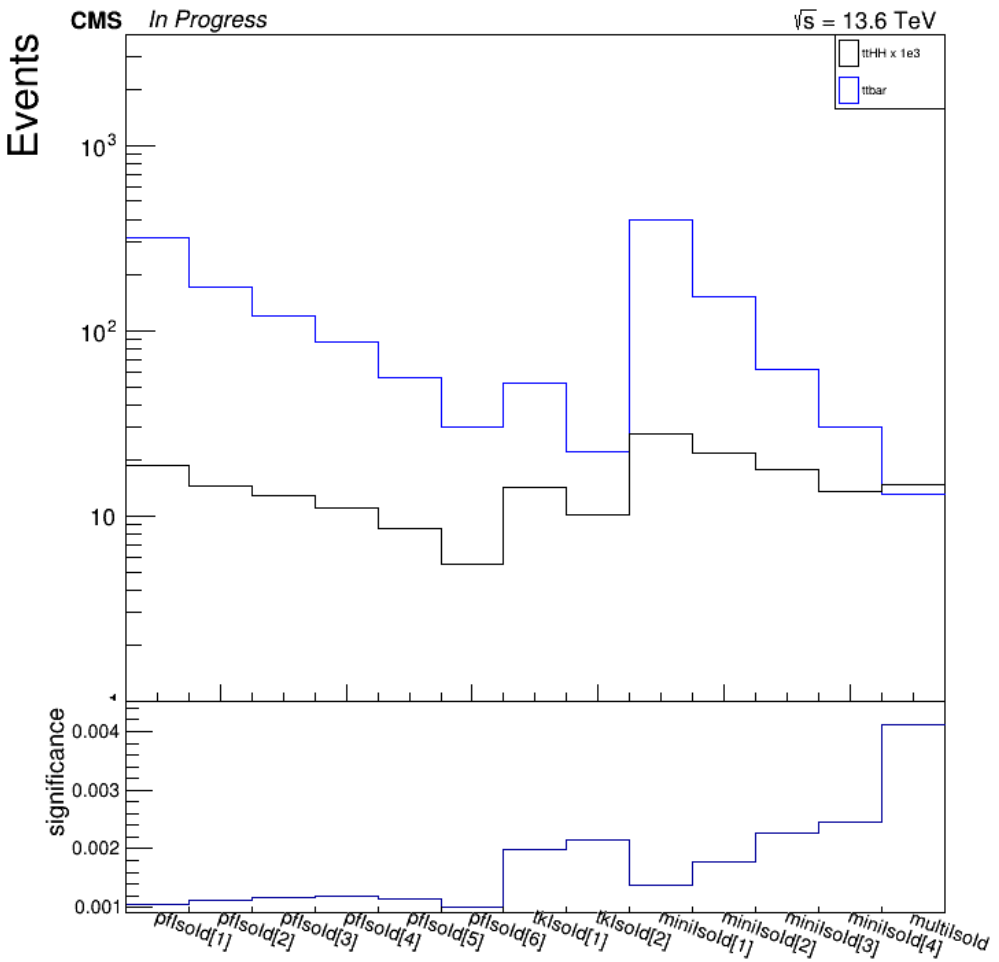


# Result – Di Leptonic

## Tight ID Muon

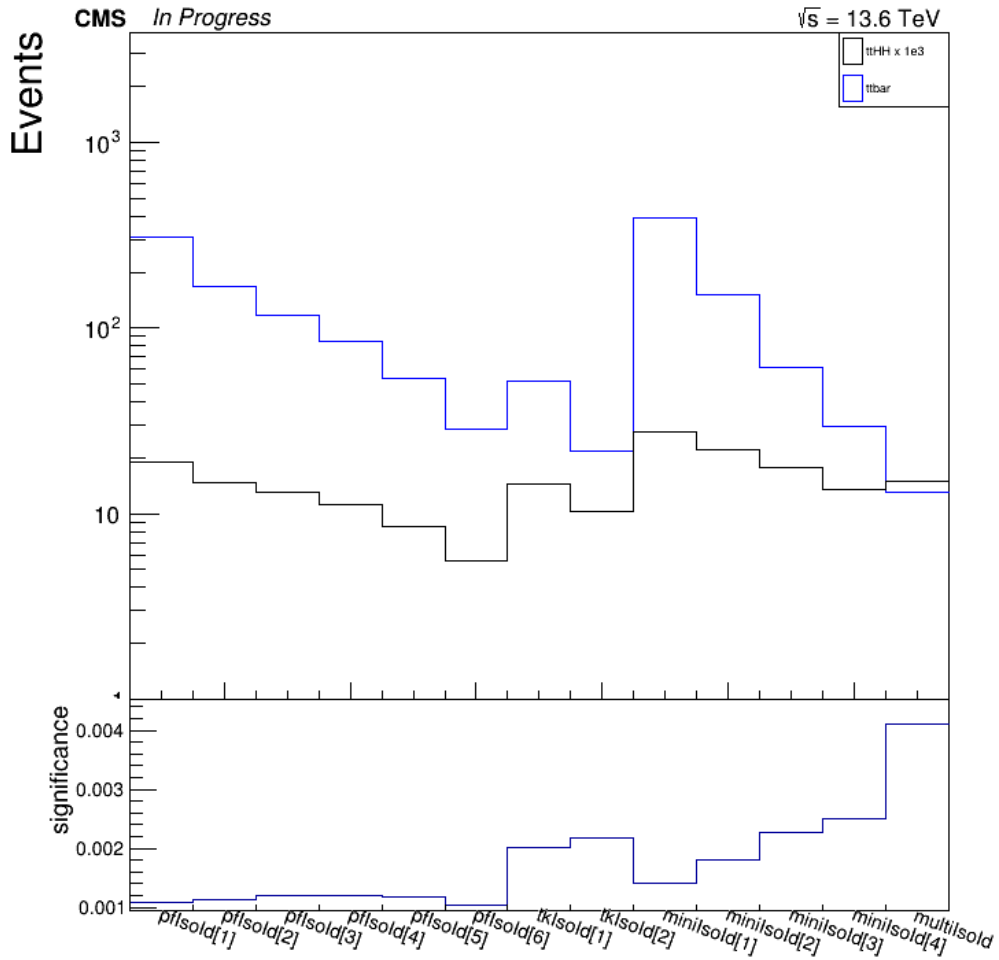



## Soft ID Muon

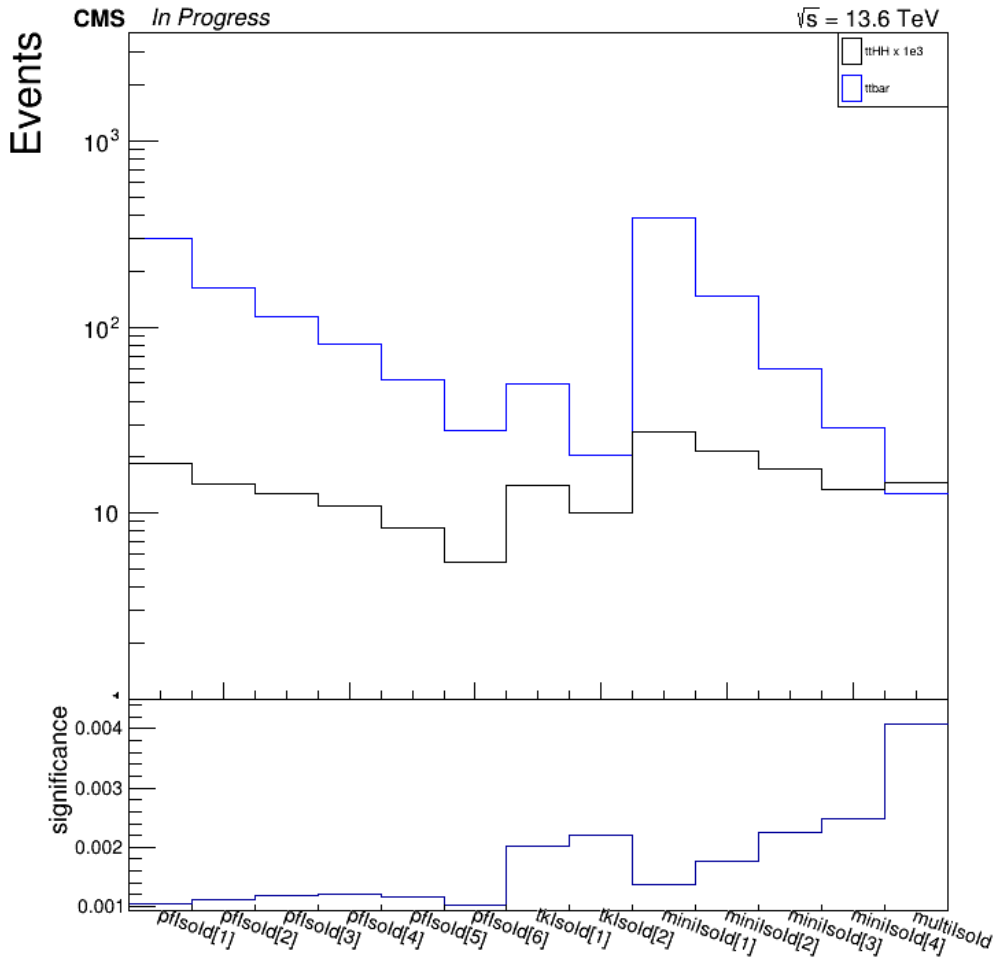


# Result – Di Leptonic

## MVA WP medium Muon




## MVA WP Tight Muon



# Result – Di Leptonic

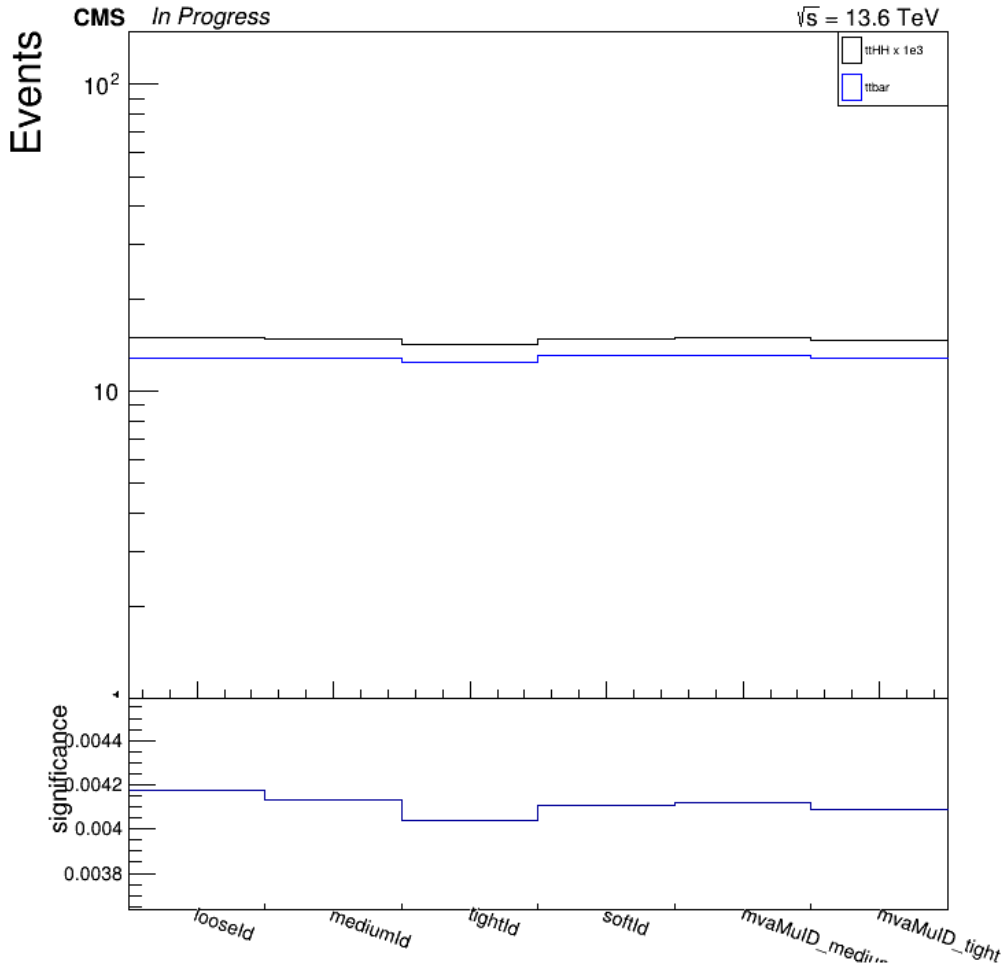
- For all ID case, Multi Isolation (Medium) has the best significance.

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

**Conclusion**

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

Multi Isolation Muon



# backup – Muon isolation definitions

- **Particle Flow(PF) Isolation**
  - $(\sum p_T(\text{ch.had from PV}) + \max(0, \sum E_T(\text{neut.had}) + \sum E_T(\text{phot}) - 0.5*\sum p_T(\text{ch.had from PU})))/p_T(\mu)$

- **Tracker-based Isolation**
  - using tracks from the leading PV in the event, which are in a cone of size ($\Delta R$) < 0.3.
  - ∑pT(tracker tracks from PV)/pT(μ)

- **Mini Isolation**
  - Miniisolation allows to recover efficiency when muons are produced in the decay chain of a boosted object.
  - when the boost is large, the muon overlaps with a jet produced in the same decay chain, failing a standard isolation cut.
  - Miniisolation is constructed by defining a cone whose radius varies with the pt 0.2 and 0.05. Isolation is then calculated for that muon

- **Multi Isolation**
  - Multiisolation is defined to select muons coming from prompt decays from muons coming from other sources.