# Update on single lepton direct stop search

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for single lepton stop working group
(UCSB/UCSD/FNAL,DESY,Strasbourg,Brown)

SUSY TBT Meeting
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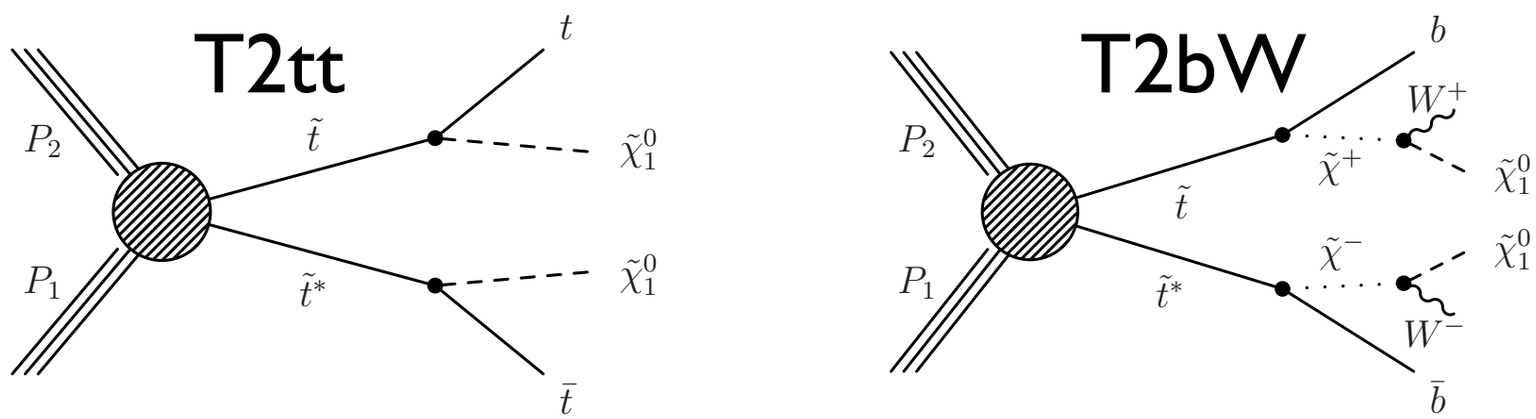
# Introduction

- We search for stop pair production in the single lepton channel
  - Signature: e/μ + ≥4 jets(≥1 b-tag) + MET




- Analysis strategy for last result (SUS-12-023 at HCP):
  - Counting experiment in MT tail
  - Signal regions by increasing MET cut
- Dominant backgrounds:
  - dilepton ttbar (tt->ll) : ~60-70% of total
  - single lepton backgrounds: ~15-30% (tt->l+jets, single top, W+jets)
  - other: ~5-10% (ttV, VV, VVV, tW, Z+jets)

# new single lepton stop working group

- UCSB/UCSD/FNAL group has joined forces with groups from Strasbourg, DESY and Brown
- We are close to being fully synchronised

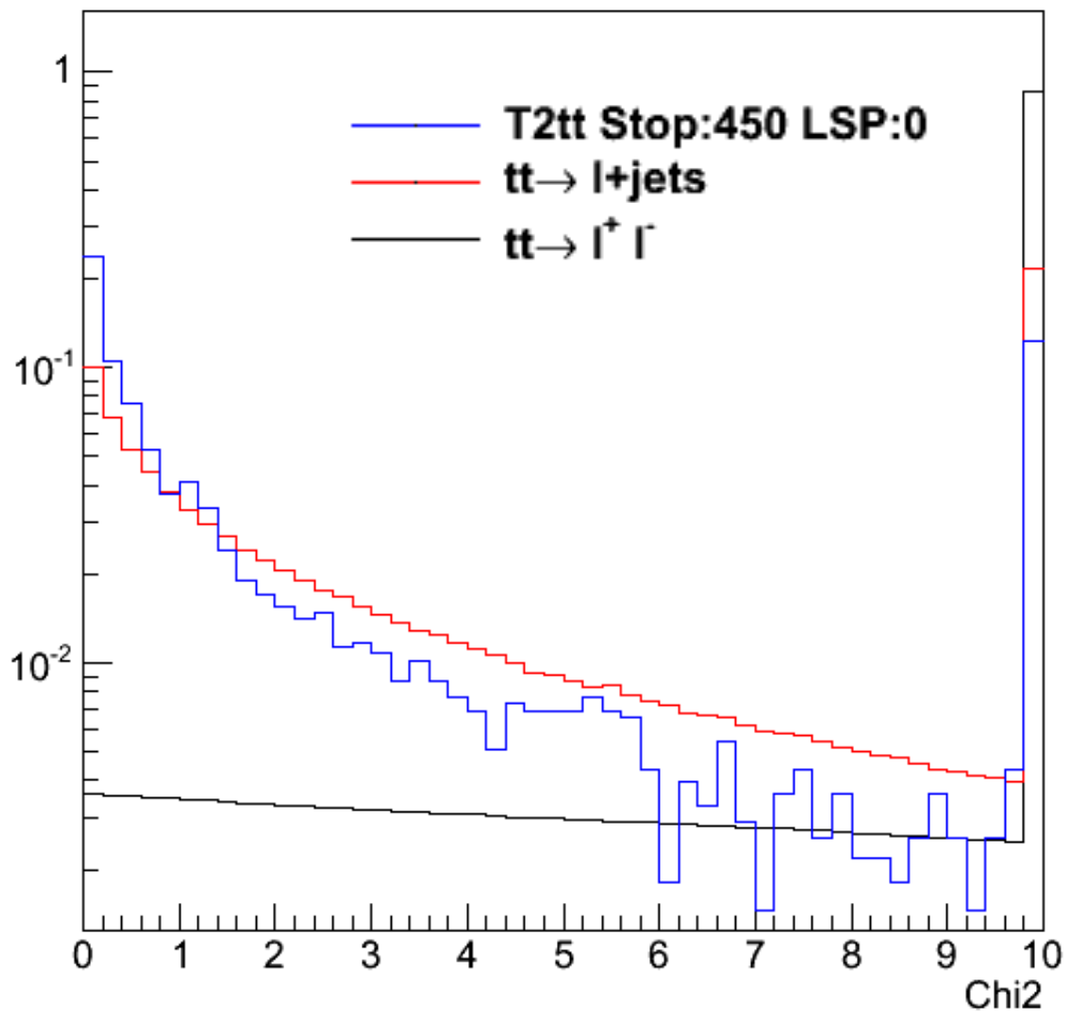
- In this talk I'll present updates from each sub-group:
  - Jet resolution studies from DESY
  - Work on $tt \rightarrow \ell\ \ell$ rejection from Strasbourg, including tau veto
  - Commissioning of new variables from UCSB/UCSD/FNAL

# UCSD/UCSB/FNAL update

- Last update 1 month ago:
  - https://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=227004
- We introduced some new variables that show good discrimination between signal and background
  - chi2 of hadronic top reconstruction (reject tt->ll)
  - MT2-like variables (separate stop from tt->l+jets and tt->ll)
  - HT(SSM)/HT(OSM) (separate stop from tt->l+jets and tt->ll)
- We intend to optimise our signal regions by using these new variables in place of the simple increasing MET cut
  - this will be achieved using a BDT output (exact form still to be decided)

# chi2 of hadronic top reconstruction

- Reconstructing the hadronic top helps to reject di-lepton background

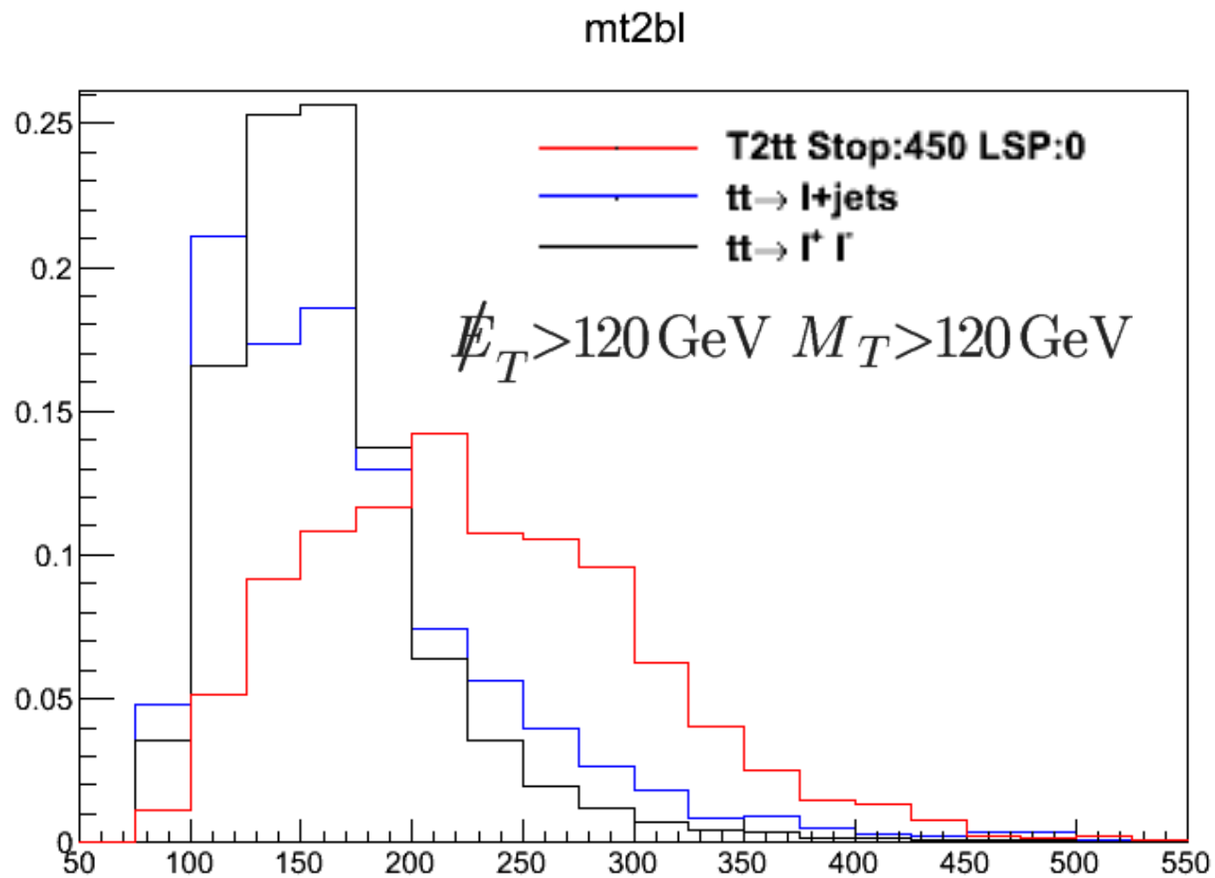



$$\chi^2 = \left(\frac{m_{jj} - m_W}{\sigma_{m_{jj}}}\right)^2 + \left(\frac{m_{jjj} - m_t}{\sigma_{m_{jjj}}}\right)^2$$

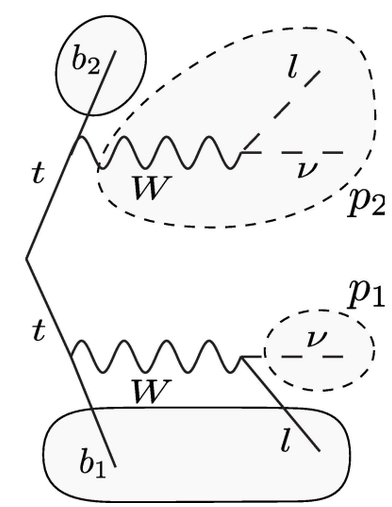
- more details:
  - https://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=227004
  - https://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=219261

# MT2$^{bl}$

- MT2$^{bl}$ shows good separation between stop and top




$$M_{T2}^{b\ell} = \min \left\{ \bigcup_{\vec{p}_1^T + \vec{p}_2^T = \vec{E}_T^{\text{miss}}} \max\left[ M_T(\vec{p}_{b_1} + \vec{p}_\ell, \vec{p}_1^T), M_T(\vec{p}_{b_2}, \vec{p}_2^T) \right] \right\}$$

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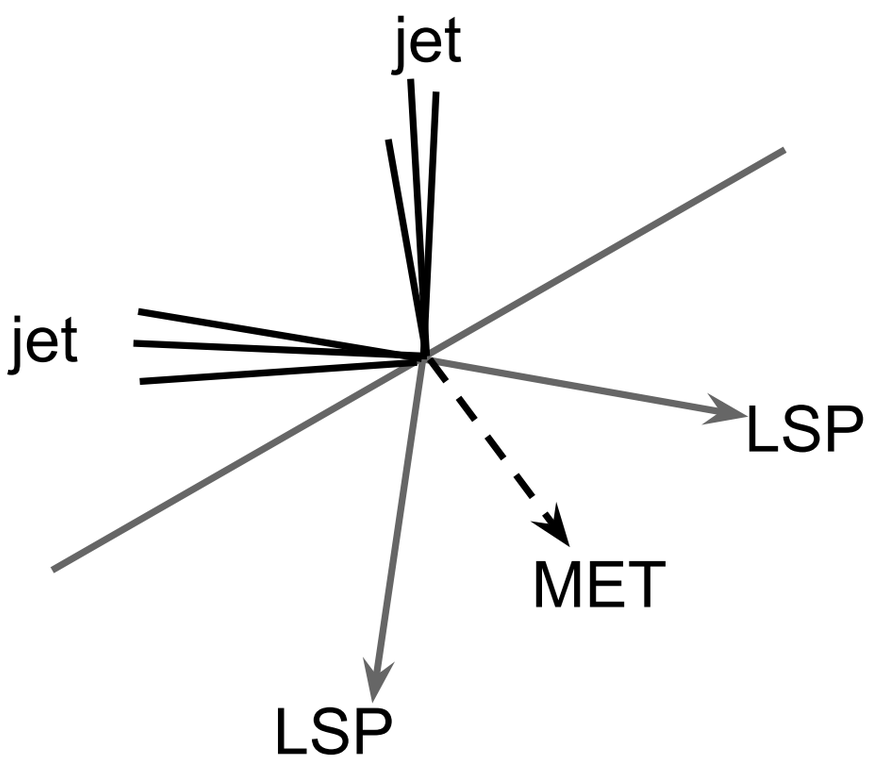
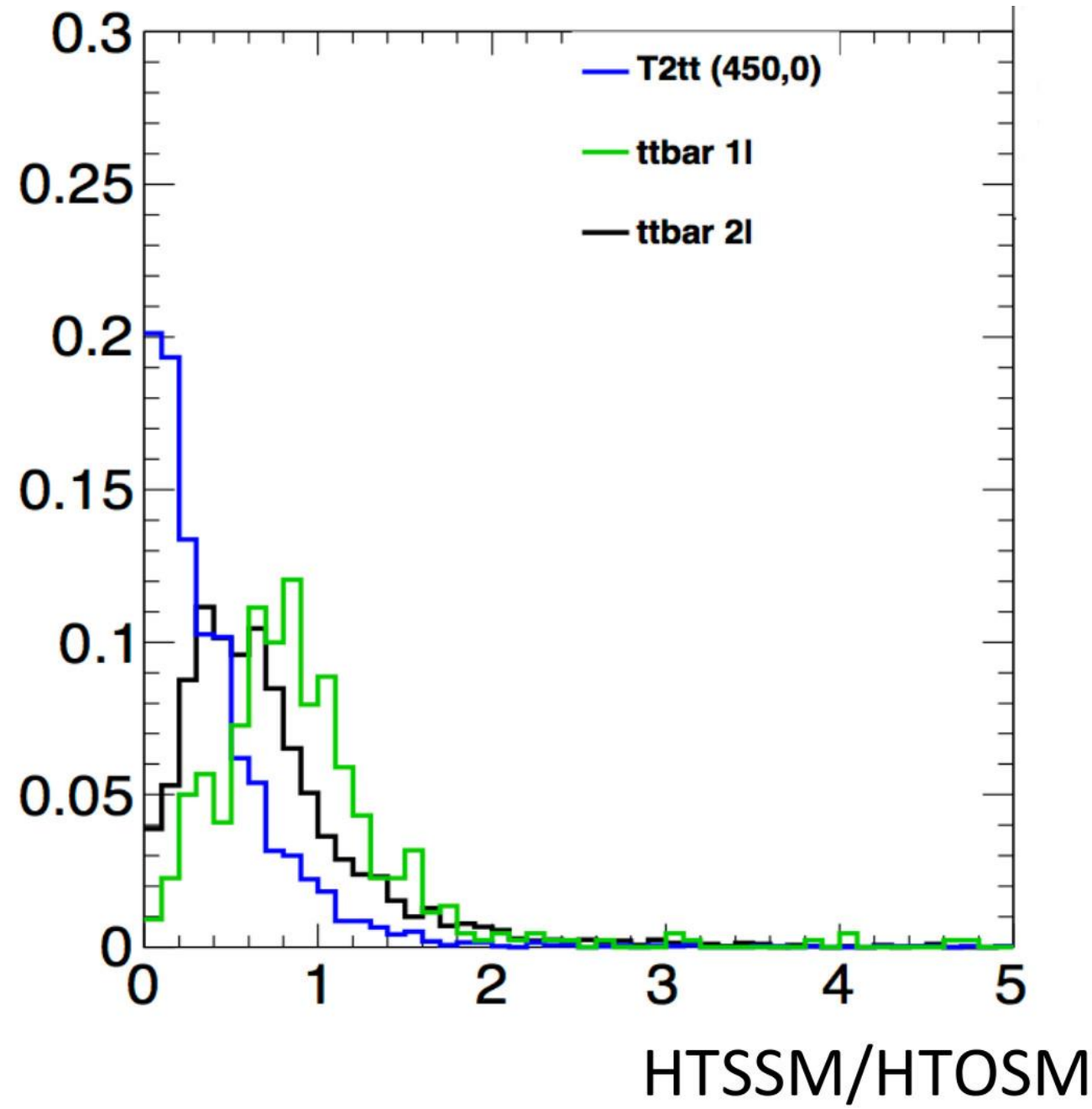
# HT(SSM)/HT(OSM)

- Ratio of HT(SSM)/HT(OSM)
  - SSM = same side of MET
  - OSM = opposite side of MET




- Shows good discrimination between all 3 categories

# data/MC comparison

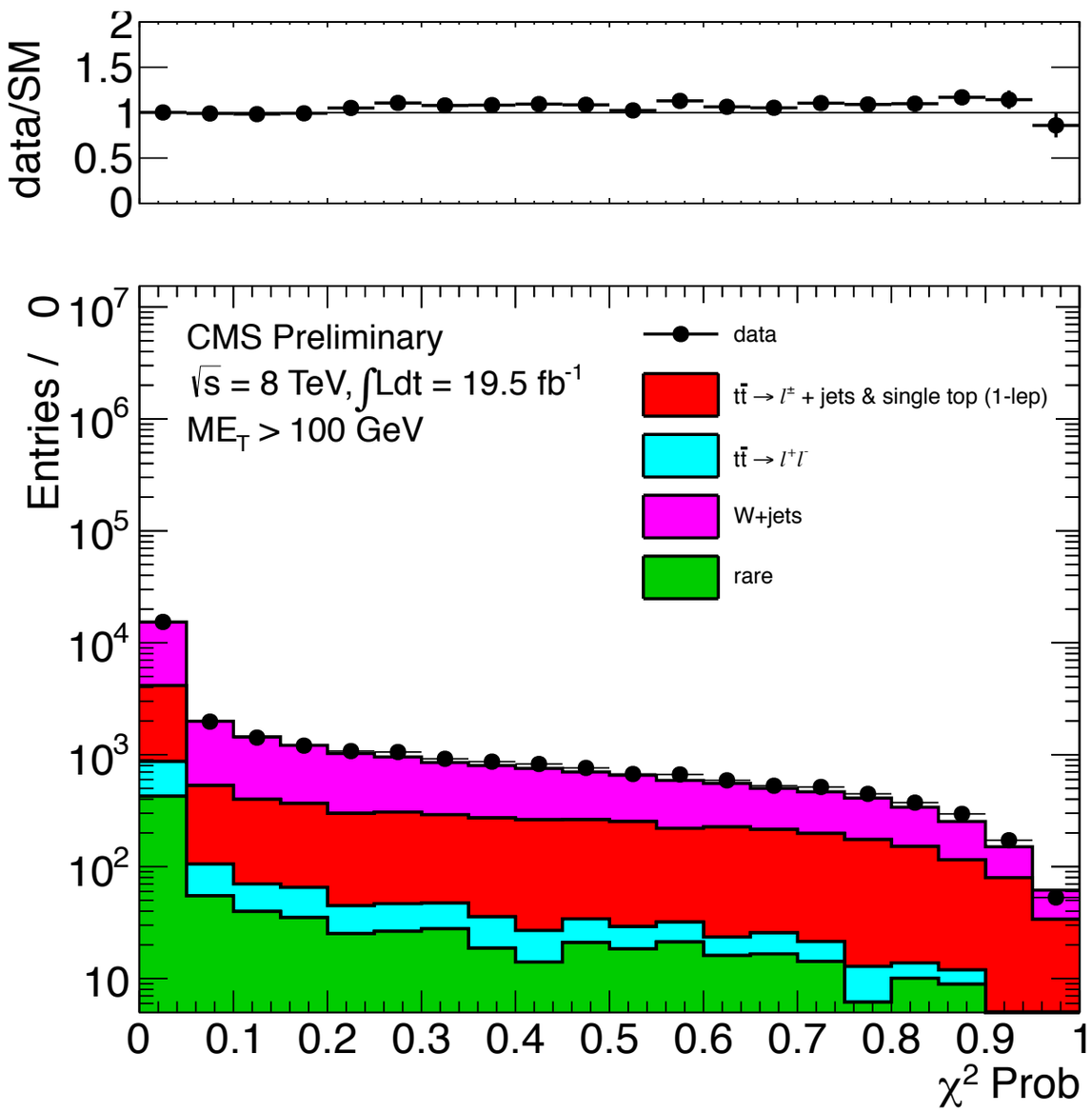
- Important to check the data/MC agreement of these new variables in our Control Regions (CRs)
- CR definitions:

| Selection Criteria | exactly 1 $\ell$ | exactly 2 $\ell$ | 1 $\ell$ + iso-track |
|---|---|---|---|
| **0 b-tags** | CR1) **W+jets**-dominated | CR2) Apply Z-mass constraint → **Z+jets** dominated | |
| **≥1 b-tags** | SIGNAL REGION | CR4) Apply Z-mass veto **tt→ $\ell$ $\ell$** dominated | CR5) **tt→ $\ell$ $\ell$ , tt→ $\ell$ τ, tt→ $\ell$ +fake** |

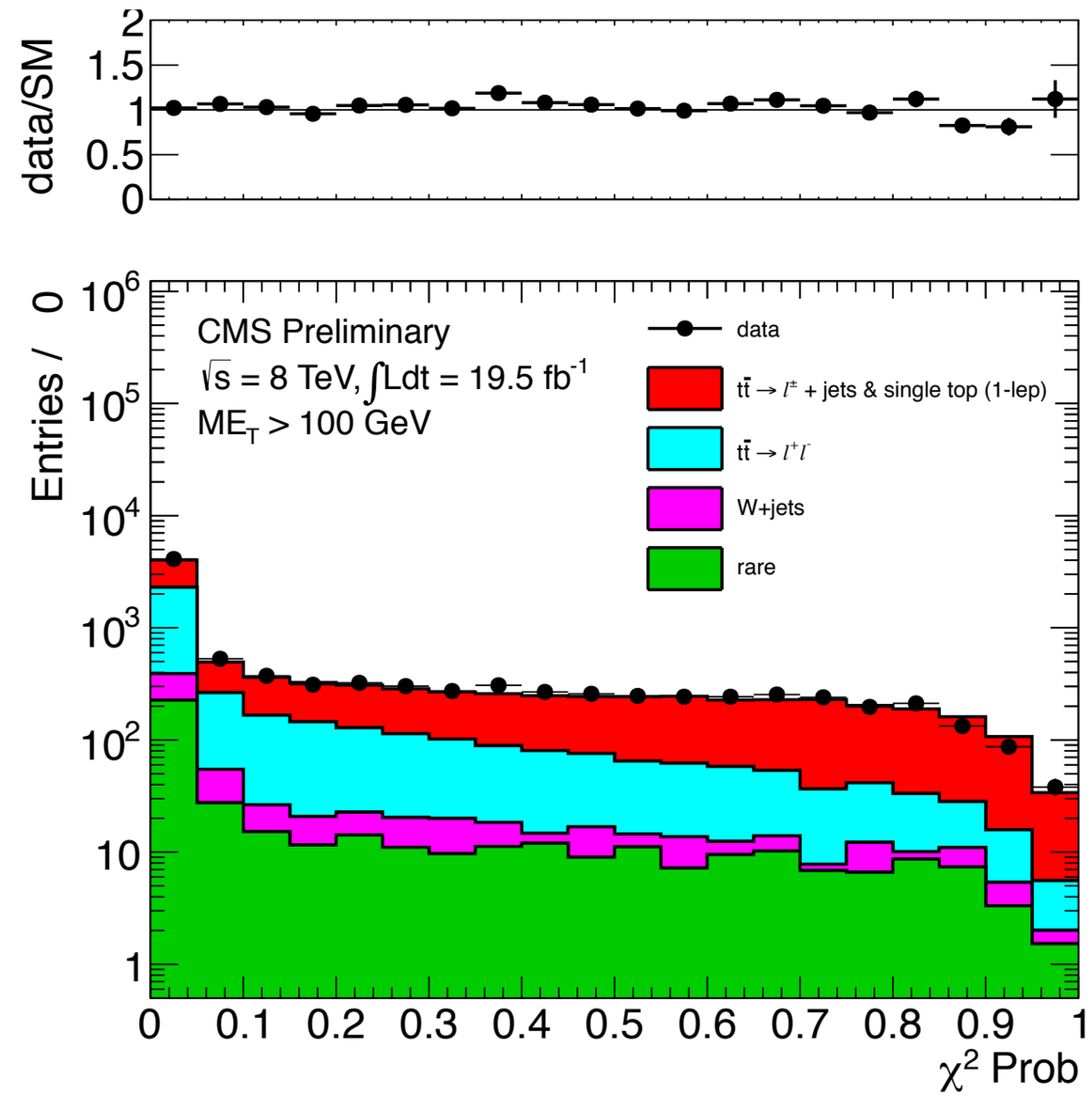
- Following slides show data/MC for 19.5 $fb^{-1}$
- Good agreement found in all CRs
- Plots for CR1 and CR5 on following slides.

# chi2 of hadronic top reconstruction

## W+jets modeling (CR1)

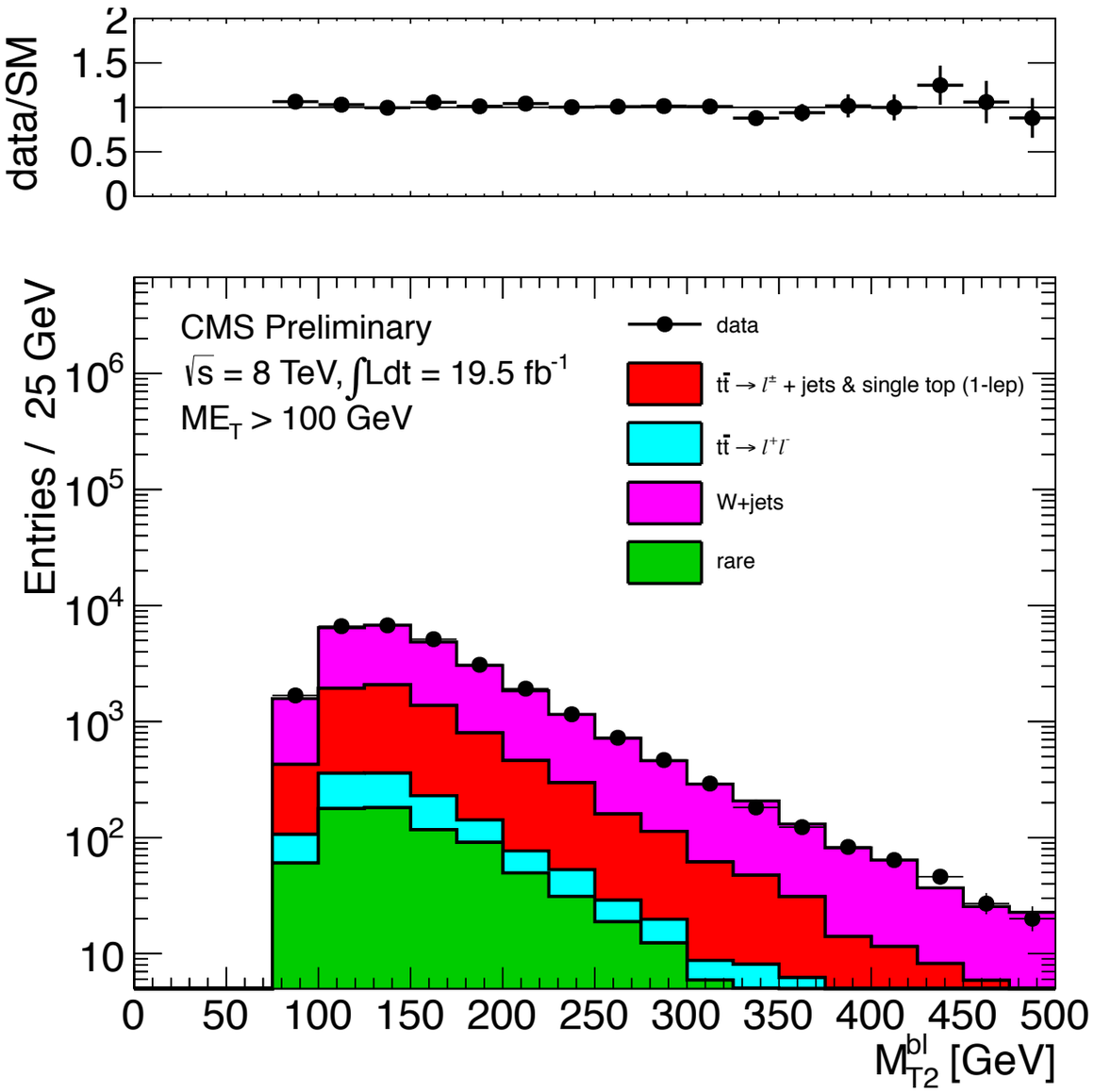



## ttbar modeling (CR5)

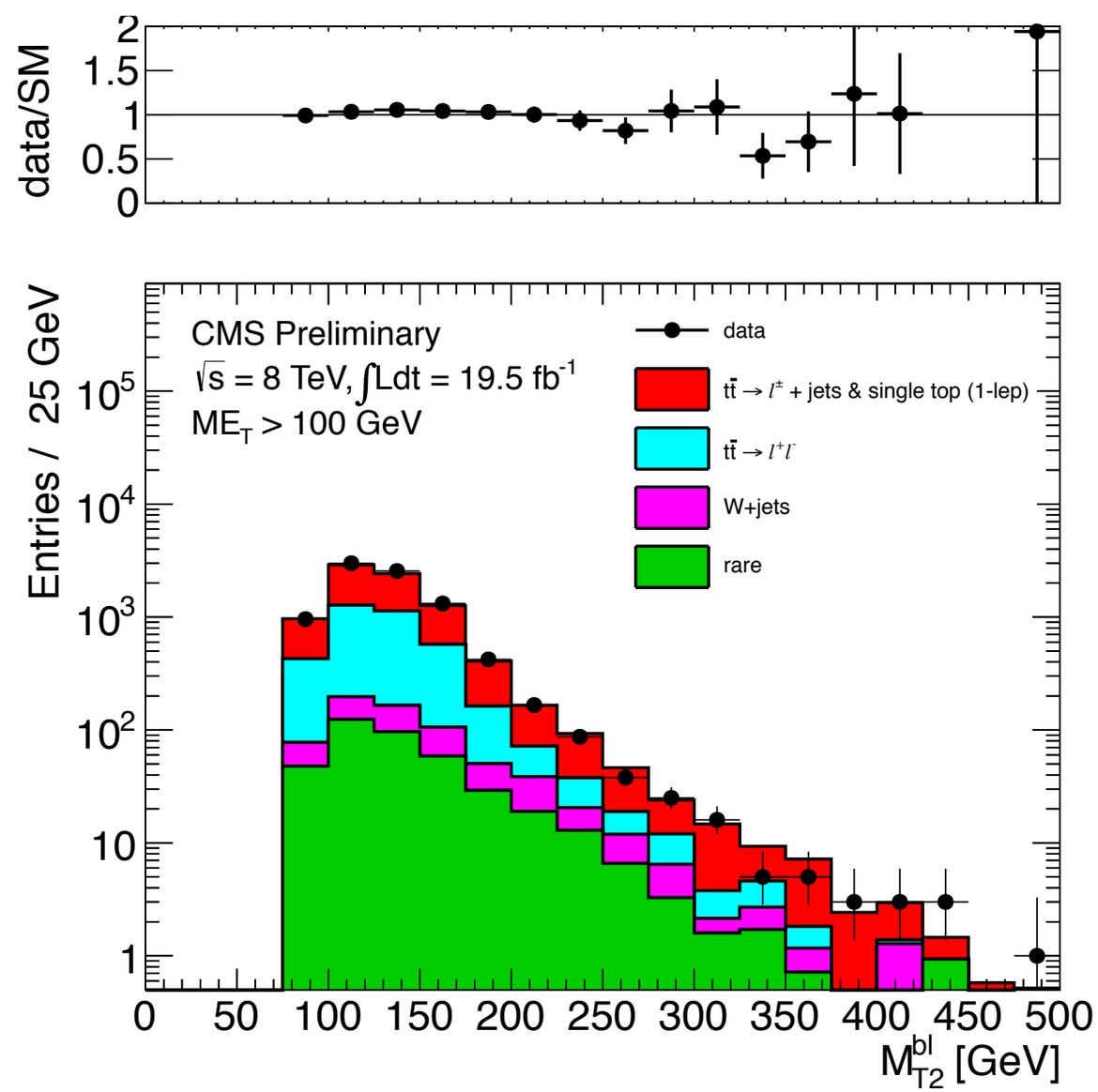


# $MT2^{bl}$

## W+jets modeling (CR1)



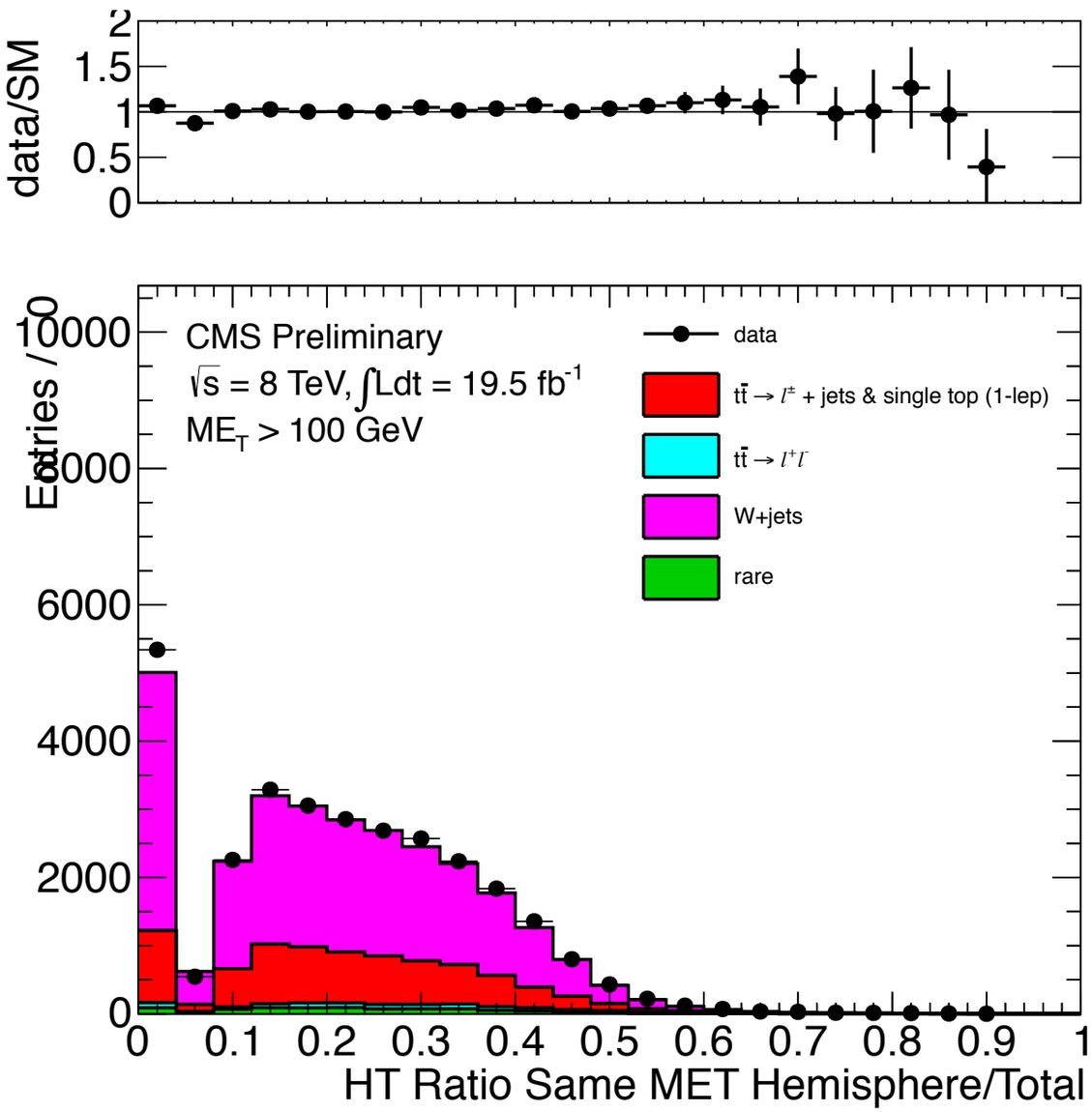

## ttbar modeling (CR5)



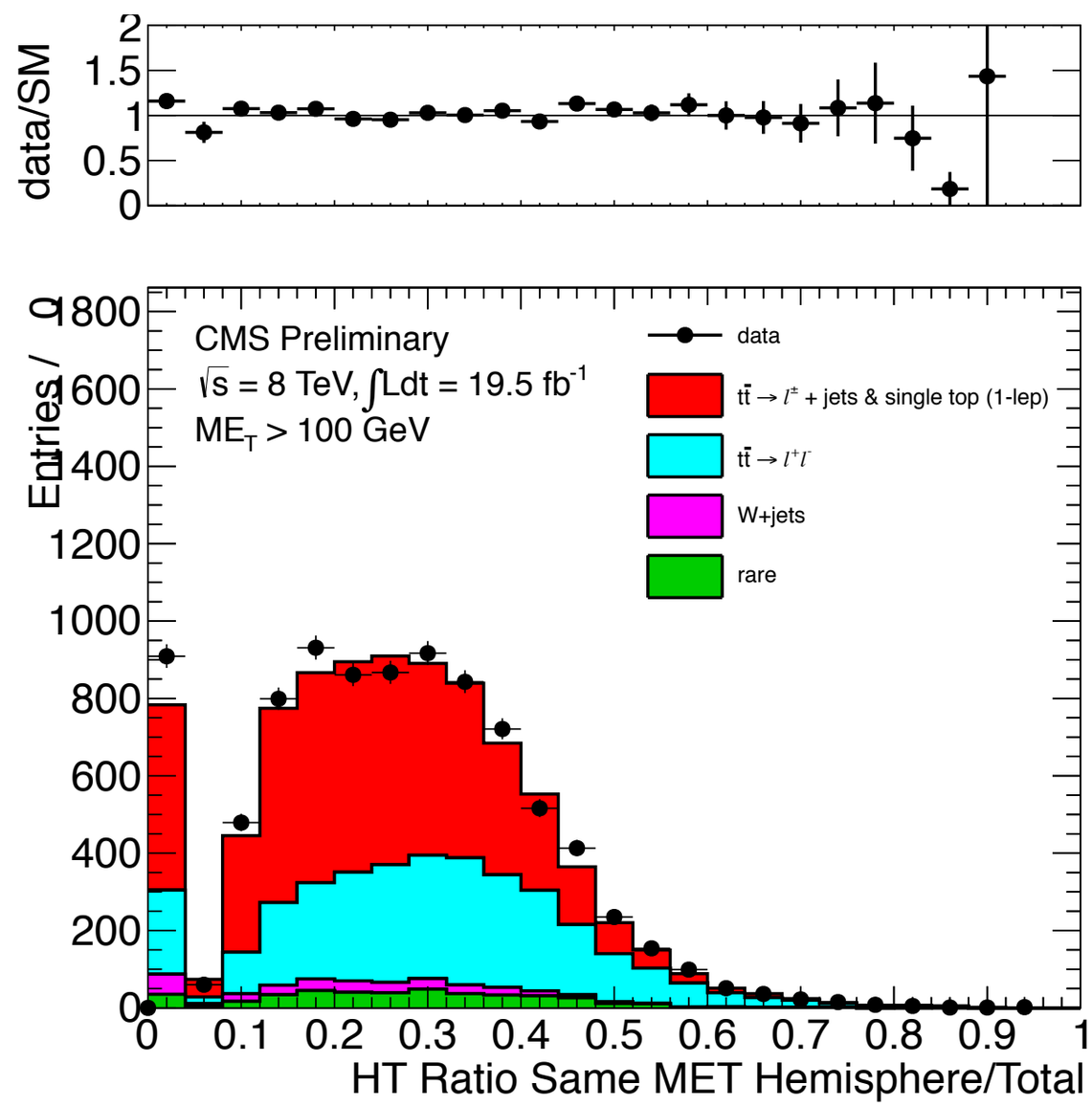
# HT(SSM)/HT(OSM)

- Plot HT(SSM)/[HT(SSM) + HT(OSM)] to give range from 0-1

W+jets modeling (CR1)

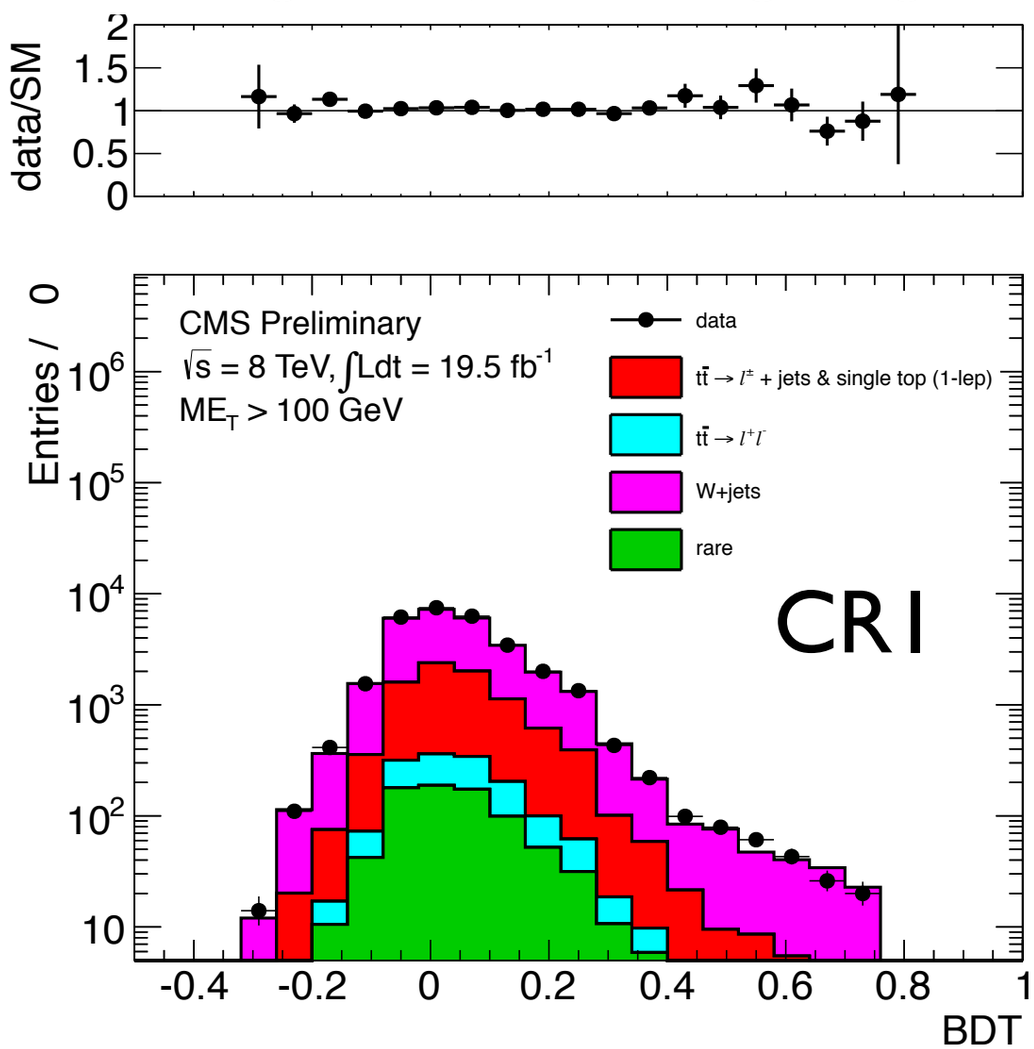


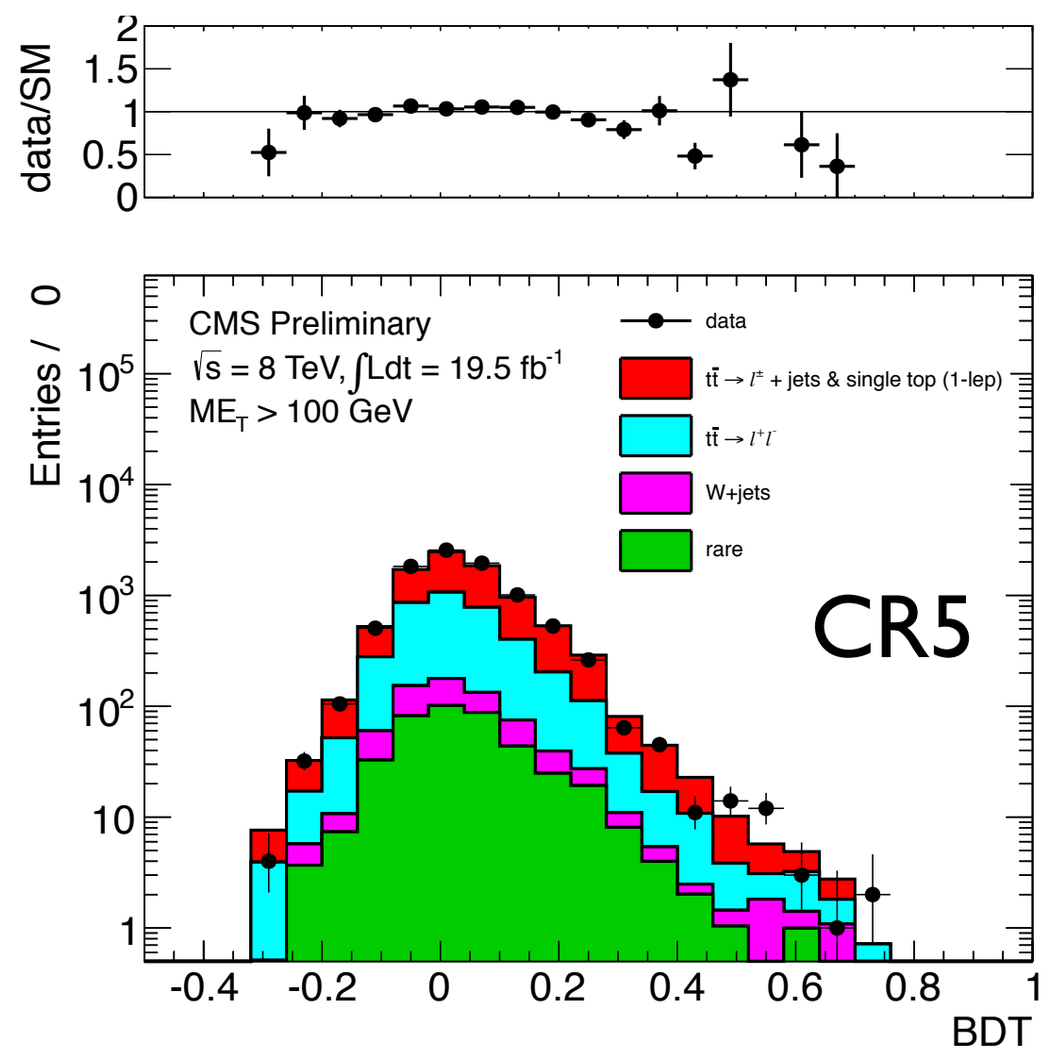

ttbar modeling (CR5)



# BDT output

- Example BDT output (using new variables + MET)
  - surprisingly good agreement "out of the box"!
- Still developing strategy for using BDT
  - separate training for different areas of stop and lsp mass for both T2tt and T2bW quickly gives unmanageably large number of signal regions
  - looking at ways to merge regions



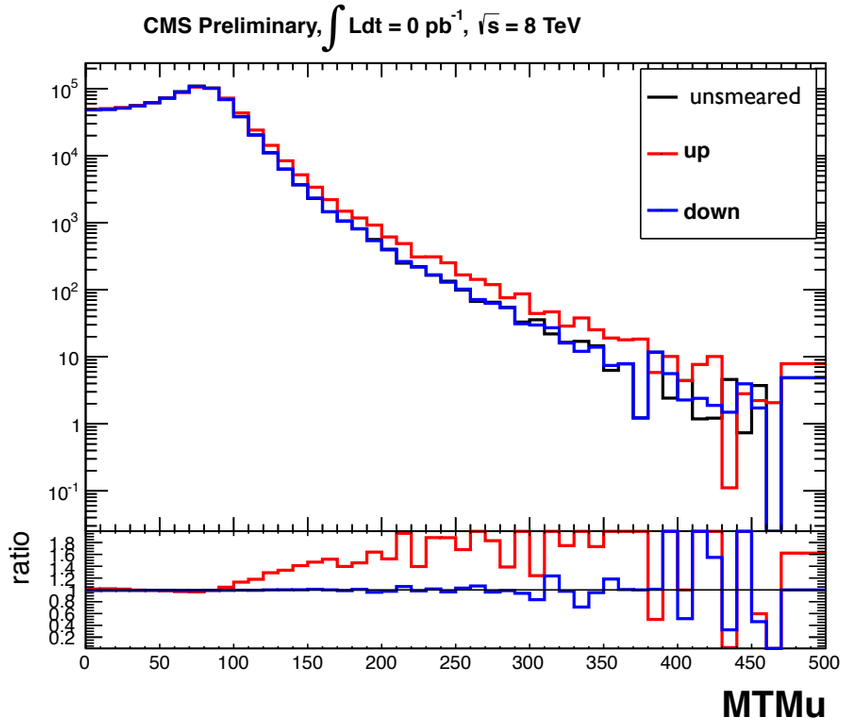



# Jet resolution studies

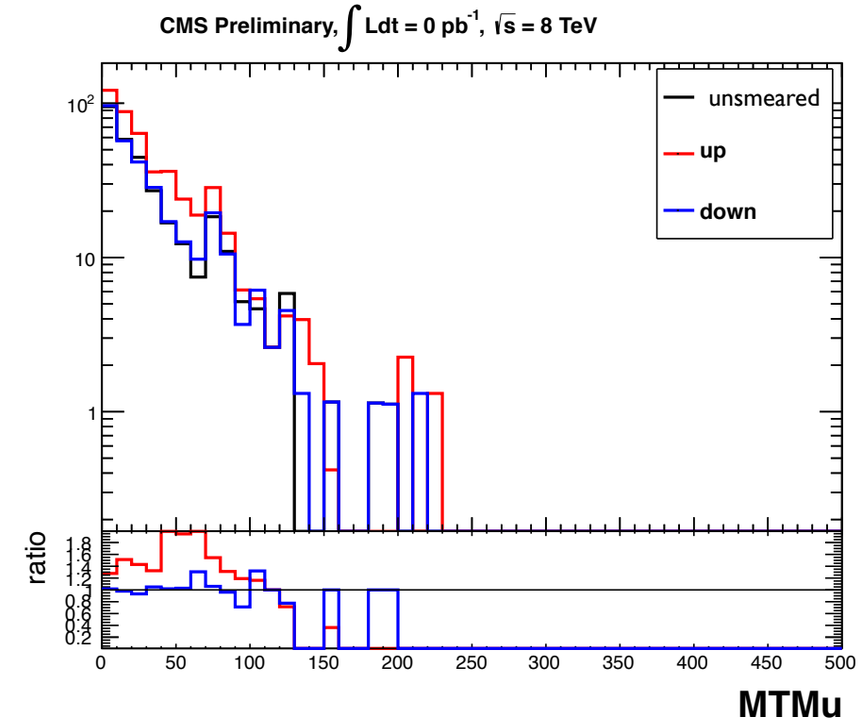
(from E. Ron, DESY)

- $M_T$ tails are not well modeled in MC in single lepton ttbar (significant deficit compared to data)
  - used a SF to account for this in the HCP analysis
- $M_T$ tails come mostly from mismeasured MET, so this might be partly a result of the superior jet resolution in MC
- Can test this by smearing the MC jets to adjust their resolution
  - $$p_4^{Jet} \rightarrow p_4^{Jet} \cdot \frac{p_T^{genJet} + SF(\eta^{Jet}) \cdot \left(p_T^{Jet} - p_T^{genJet}\right)}{p_T^{Jet}}$$

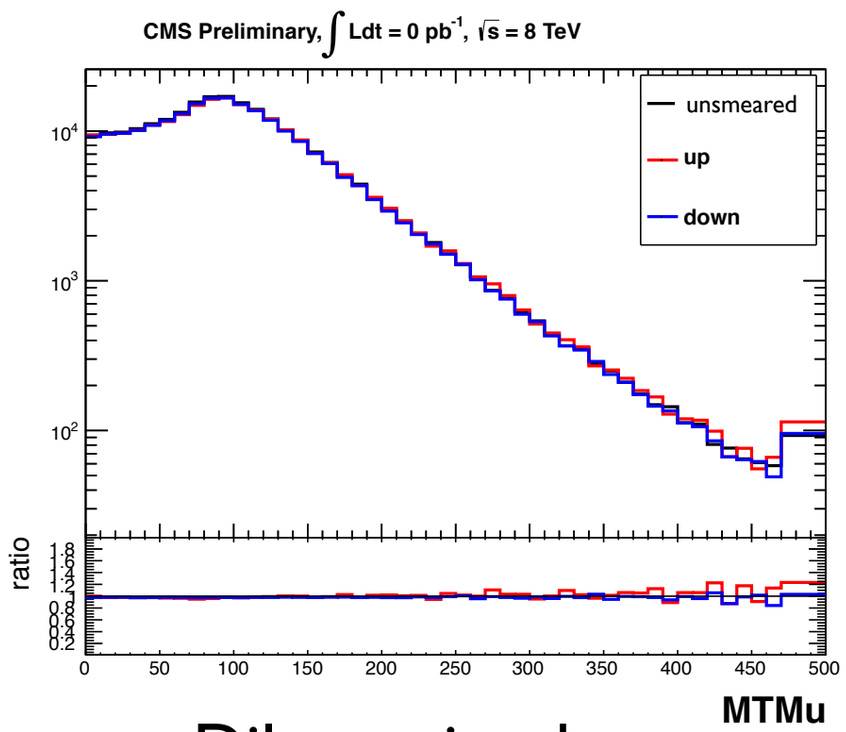
# $M_T$ with jet resolution smearing (μs)




Semileptonic ttbar




All hadronic ttbar




Dileptonic ttbar

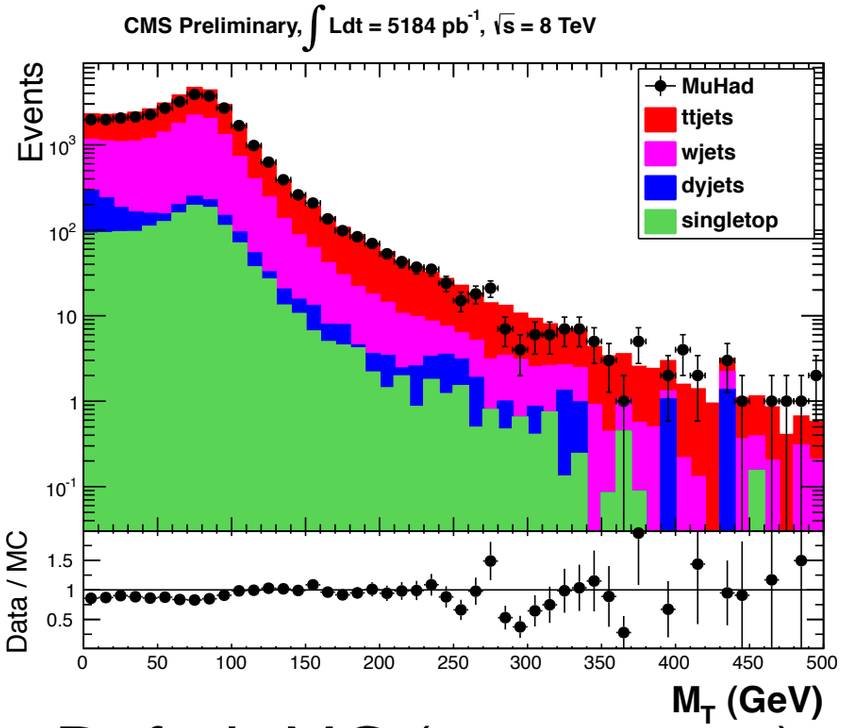
Selection:

- IsoMu17 eta2p1 TriCentralPFJet30
- exactly one good muon, veto on looser muon and electrons.
- $N_{jets} > 2$, $H_T > 300$, $MET > 60$, No btag requirements.

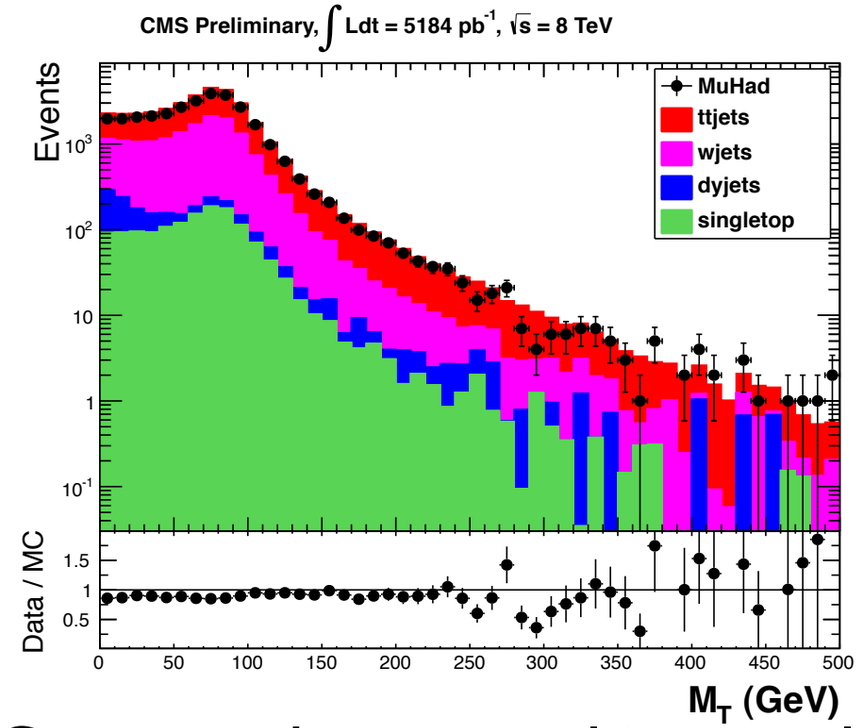
Jet Resolution smeared by the recommended factor $+1\sigma$ up and $-1\sigma$ down, compared with the unsmeared.

- left $\longrightarrow$ Semi leptonic $t\bar{t}$
- right $\longrightarrow$ Hadronic $t\bar{t}$
- bottom $\longrightarrow$ Di-leptonic $t\bar{t}$

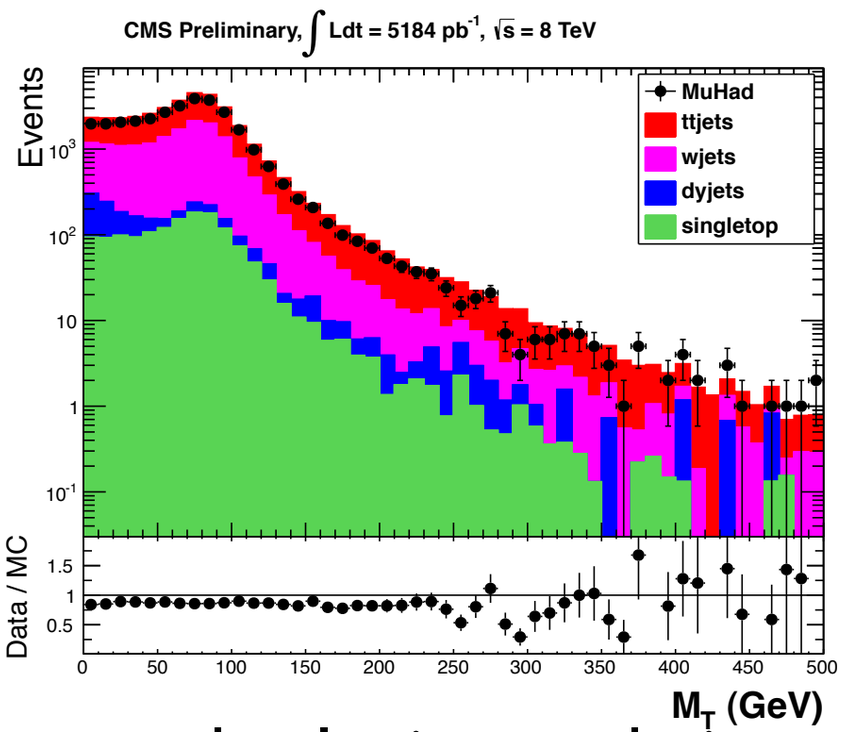
# Data vs MC for $M_T$ with different smearing (μs)




Default MC (no smearing)




MC smeared to central jet resolution



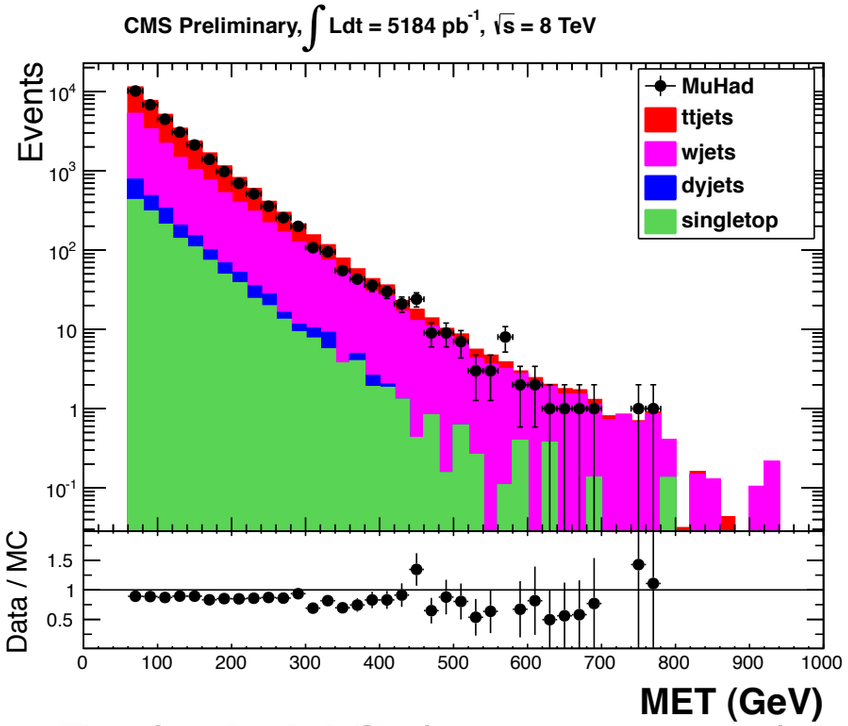

central + 1σ jet resolution

- The jet fourvector changes:

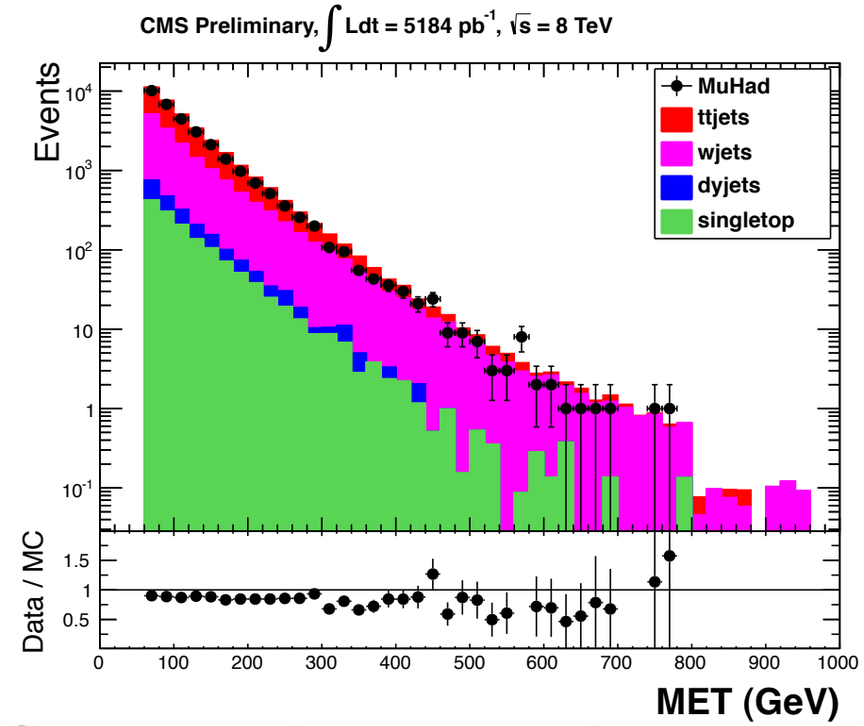
$$p_4^{Jet} \longrightarrow p_4^{Jet} \cdot \frac{p_T^{genJet} + SF(\eta^{Jet}) \cdot \left(p_T^{Jet} - p_T^{genJet}\right)}{p_T^{Jet}}$$

- left $\longrightarrow$ unsmeared distribution
- right $\longrightarrow$ central (recommended) jet resolution
- bottom $\longrightarrow$ central + $1\sigma$ jet resolution uncertainty.

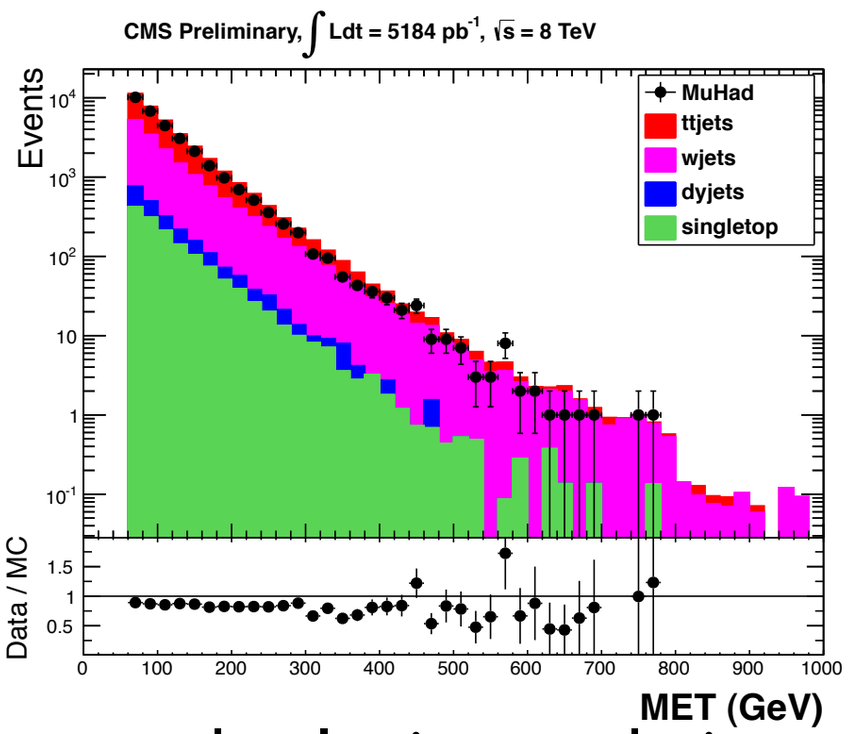
# Data vs MC for MET with different smearing (μs)




Default MC (no smearing)




MC smeared to central jet resolution




central + 1σ jet resolution

- left $\rightarrow$ unsmeared
- right $\rightarrow$ central (recommended) jet resolution
- bottom $\rightarrow$ central $+ 1\sigma$ jet resolution uncertainty.

# Summary of jet resolution studies

The effects of the smearing of jets due to jet resolution have been studied.

- The jet fourvector changes:

$$p_4^{Jet} \rightarrow p_4^{Jet} \cdot \frac{p_T^{genJet} + SF(\eta^{Jet}) \cdot \left(p_T^{Jet} - p_T^{genJet}\right)}{p_T^{Jet}}$$

- The effect of the smearing is especially visible in the $M_T$ distribution, where it improves the comparison of the MC with the data

In addition, currently looking into the PileUp JetID, which is a good way of rejecting Jets from Pile Up interactions.

- https://twiki.cern.ch/twiki/bin/viewauth/CMS/PileupJetID

✓ Pileup JetID is used by all Higgs analysis

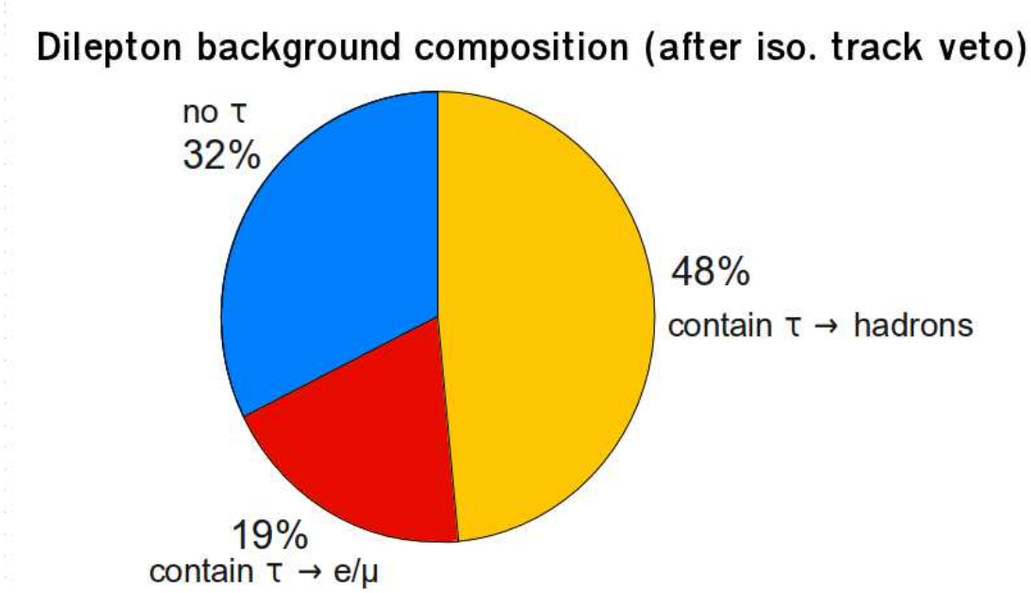
✓ We've already had a look at it for the Hcal Upgrade TDR and we think it is worth to try using it in the Single lepton + MT stop search.

# Work on tt→ $\ell$ $\ell$ rejection (Strasbourg)

(from A.Aubin, IPHC)

**Motivation for $\tau$ veto**

About 50% of the remaining dilepton background contain an hadronic $\tau$.




**$\tau$ veto**

Reject event containing a $\tau$ candidate satisfying :

- byLooseCombinedIso. DeltaBetaCorr3Hits ;
- $p_T > 20$ GeV ;
- have opp. charge with respect to the selected lepton.

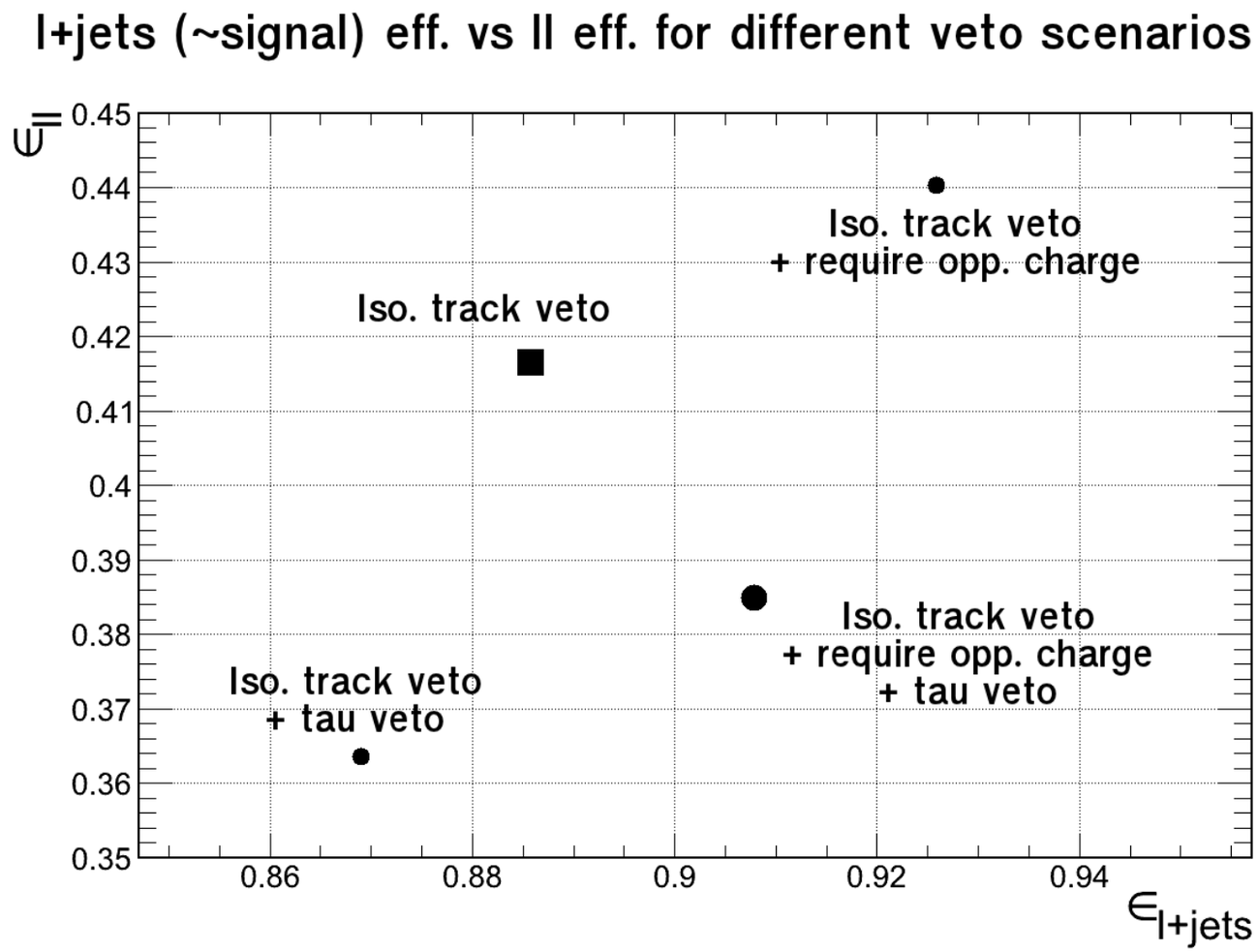
# Work on tt→ ℓ ℓ rejection (Strasbourg)

**Opposite charge requirement (for iso. track veto)**

→ Require the isolated track to have opposite charge (w.r.t selected lepton) when vetoing.

Expected to reduce the signal loss.

**Current results**




- Brown group also working on tt→ ℓ ℓ rejection

# Summary

- Powerful new variables well modeled by MC in control regions
  - converging on how to implement these variables in a coherent analysis strategy
- Jet resolution smearing improves data/MC agreement in MT tails
- More tt→ $\ell$ $\ell$ rejection and greater signal efficiency from tau veto combined with restricting isolated track veto to opposite charge only