Update on single lepton direct stop search

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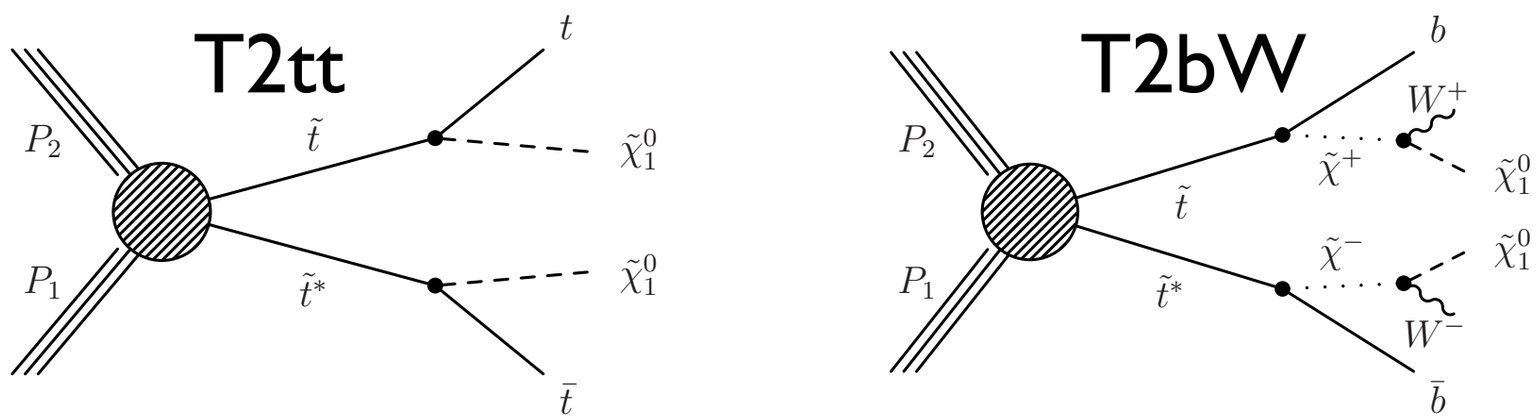
for single lepton stop working group
(UCSB/UCSD/FNAL,DESY,Strasbourg,Brown)

SUSY TBT Meeting
8th February 2013

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

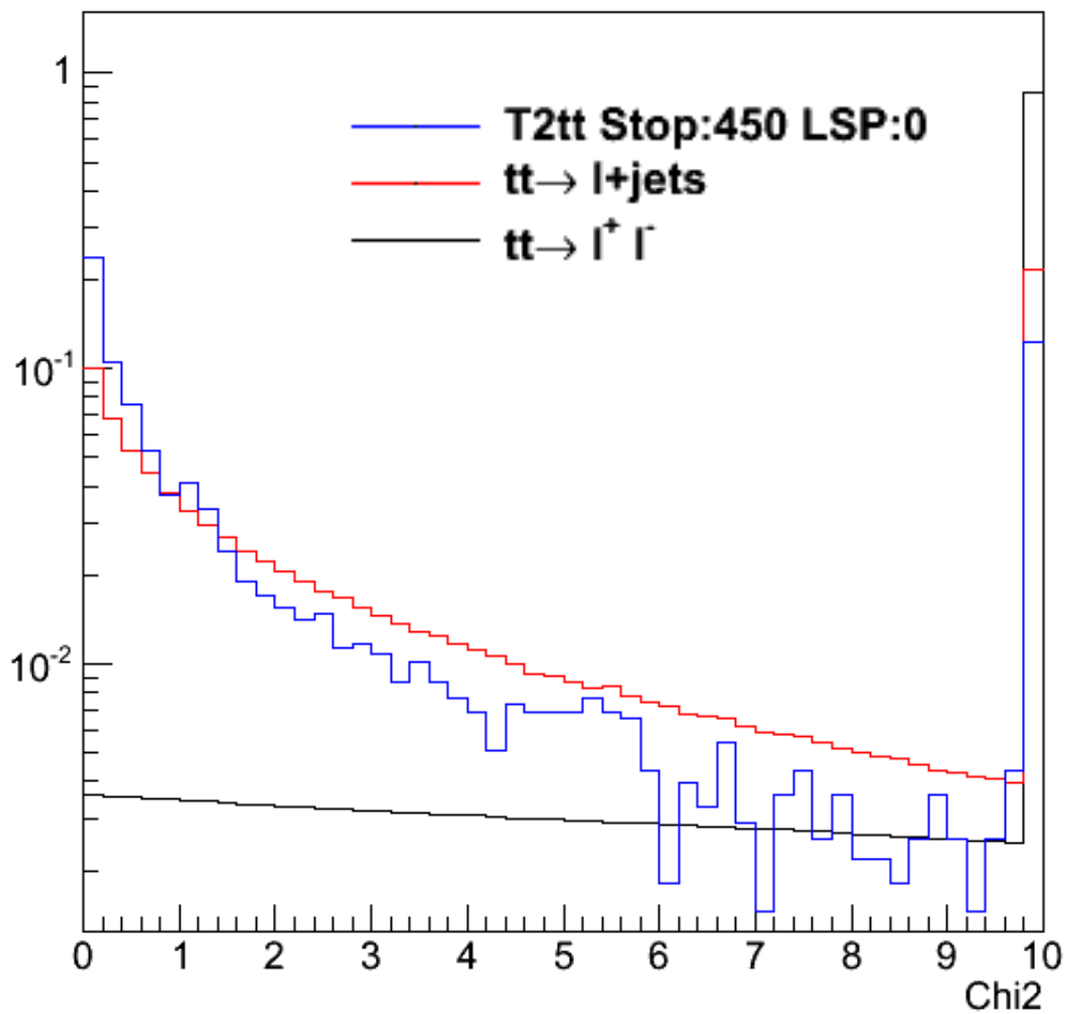
- In this talk I'll present updates from each sub-group:
  - Jet resolution studies from DESY
  - Work on $tt \rightarrow \ell\ \ell$ rejection from Strasbourg, including tau veto
  - Commissioning of new variables from UCSB/UCSD/FNAL

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
  - exploring the improvement in sensitivity provided by combining these variables into an MVA

chi2 of hadronic top reconstruction

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



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

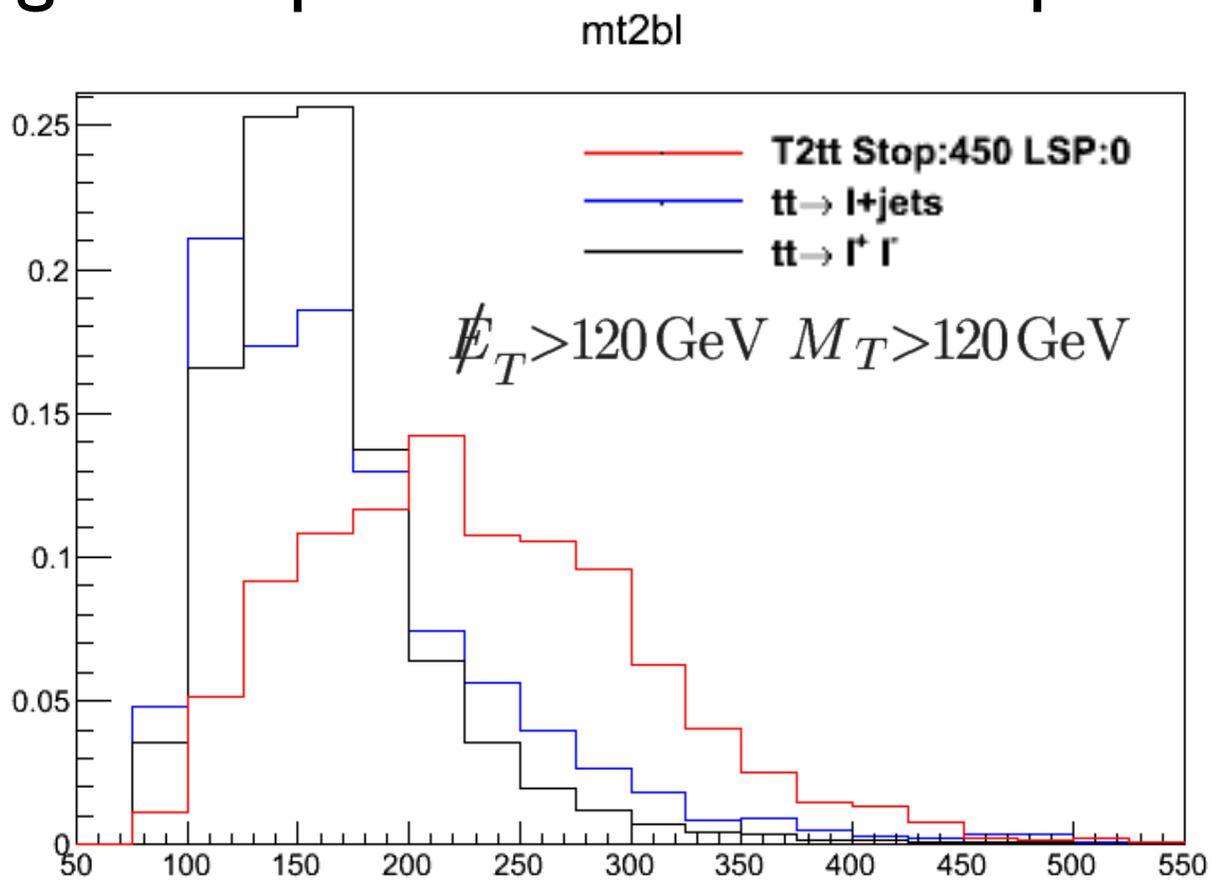
Plot shows ideal case of chi2 of correct combination of jets.

In reality we take the min chi2 of all possible combinations, which significantly worsens discrimination.

- 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

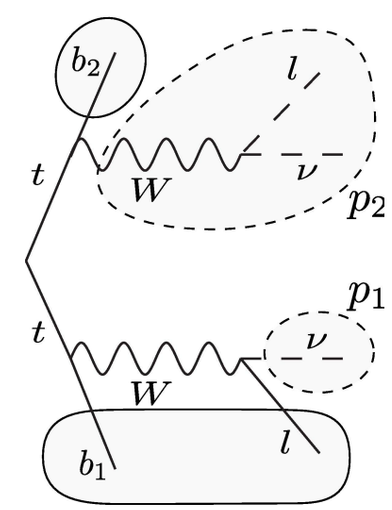
MT2-like variables

- Looking at several MT2-like variables, e.g. $MT2^{bl}$
  - show good separation between stop and top



$MT2^{bl}$: For ttbar, end point is at top mass

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



- more details:
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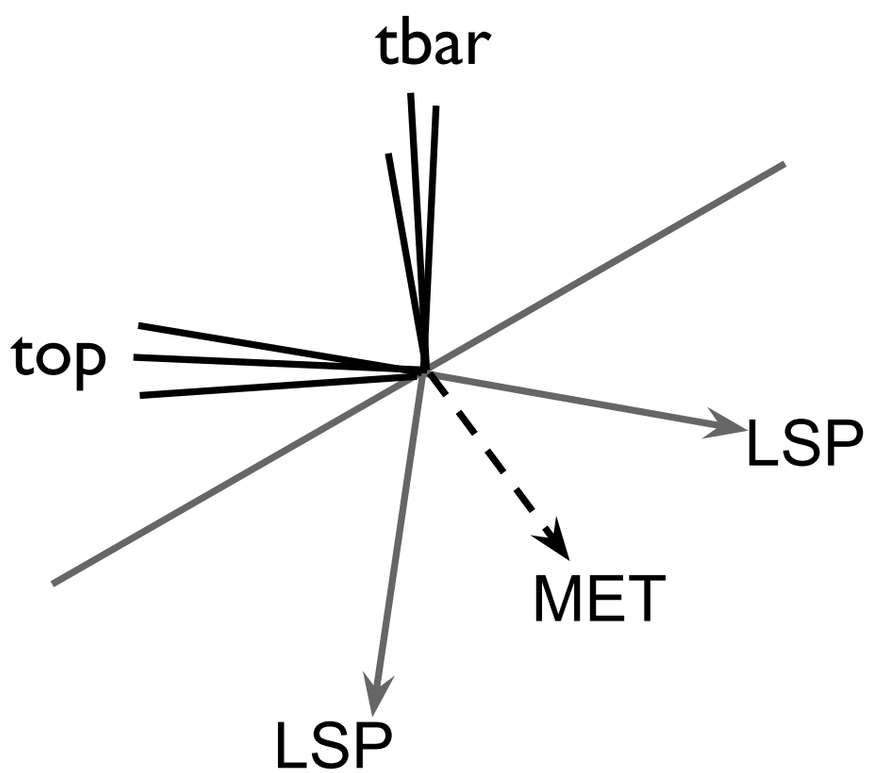
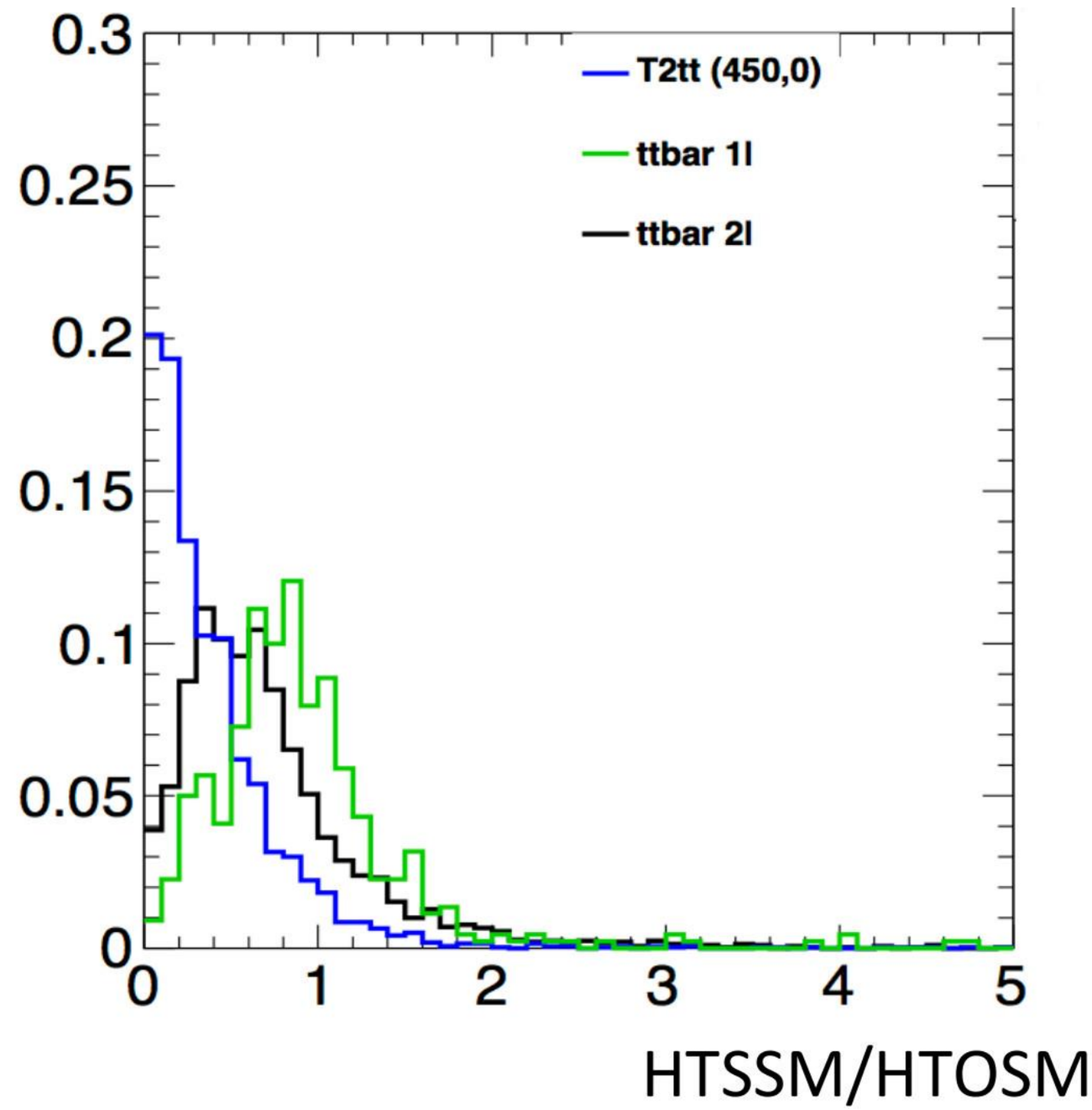
HT(SSM)/HT(OSM)

- 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

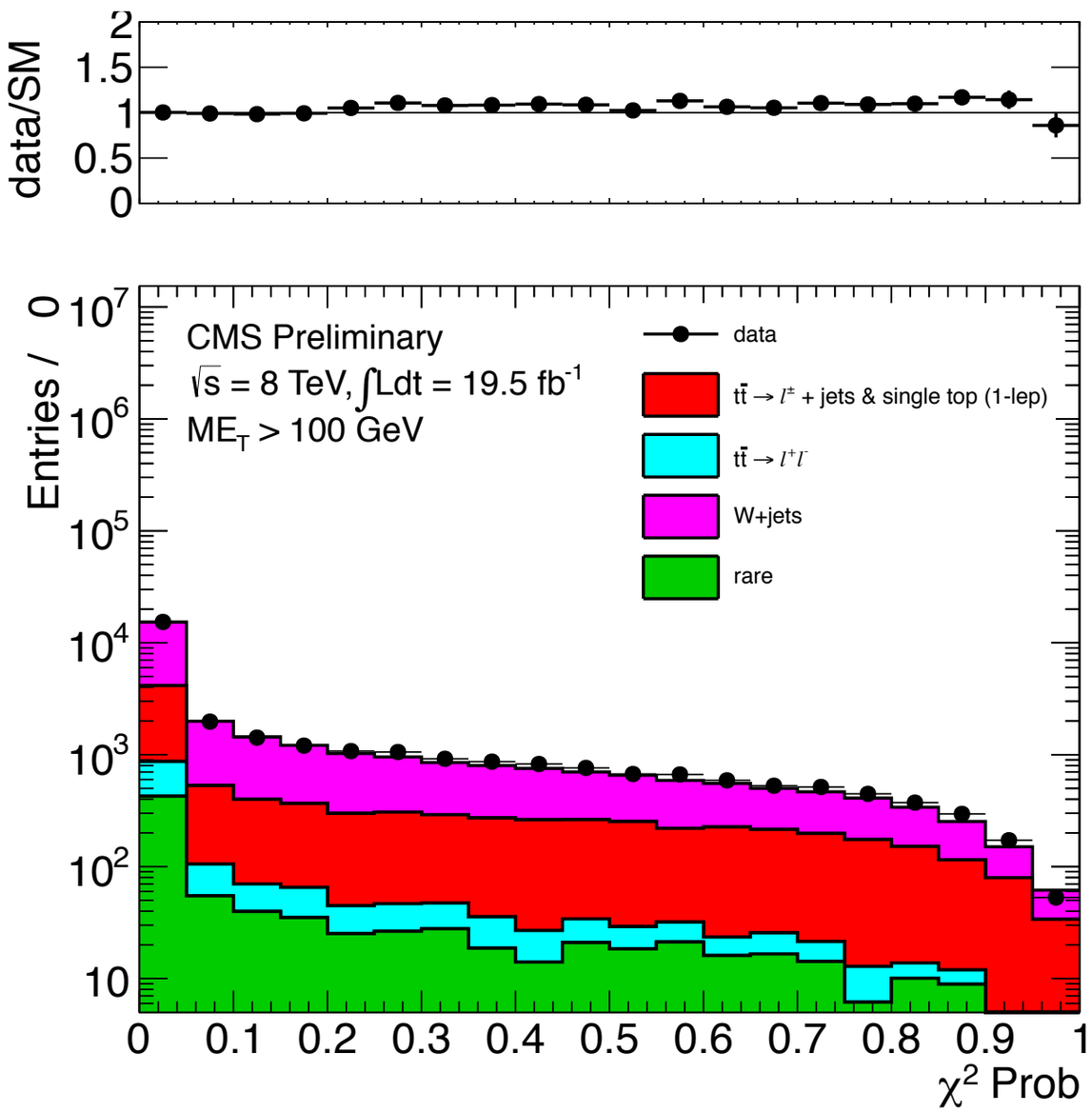
- Important to check the data/MC agreement of these new variables in our Control Regions (CRs)
- CR definitions:

Selection Criteria	exactly 1 ℓ	exactly 2 ℓ	1 ℓ + 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→ ℓ ℓ** dominated	CR5) **tt→ ℓ ℓ , tt→ ℓ τ, tt→ ℓ +fake**

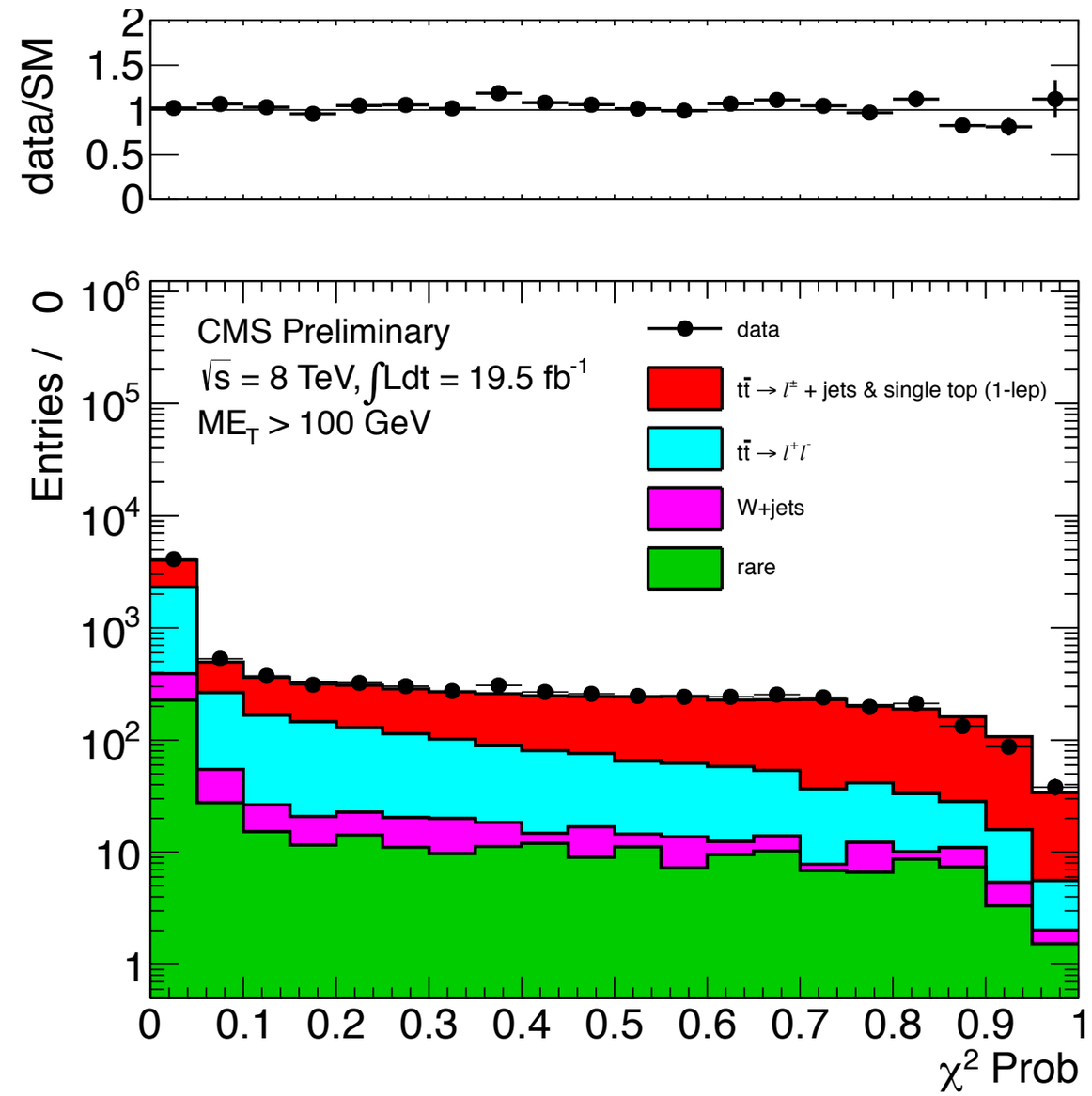
- Following slides show data/MC for 19.5 fb^{-1}
- Good agreement found in all CRs
- Plots for CR1 and CR5 on following slides, CR4 in backup

chi2 of hadronic top reconstruction

W+jets modeling (CR1)

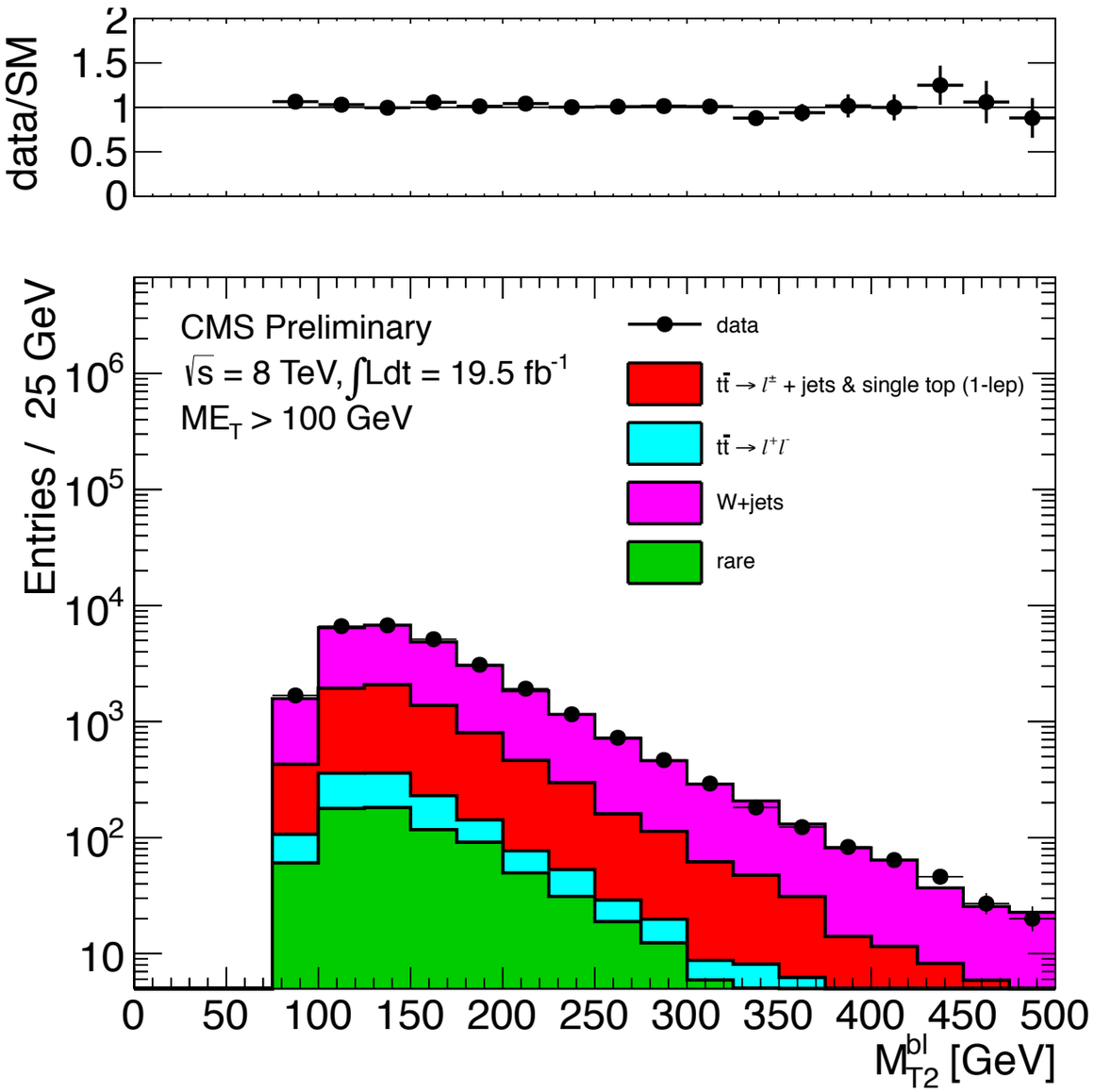


ttbar modeling (CR5)

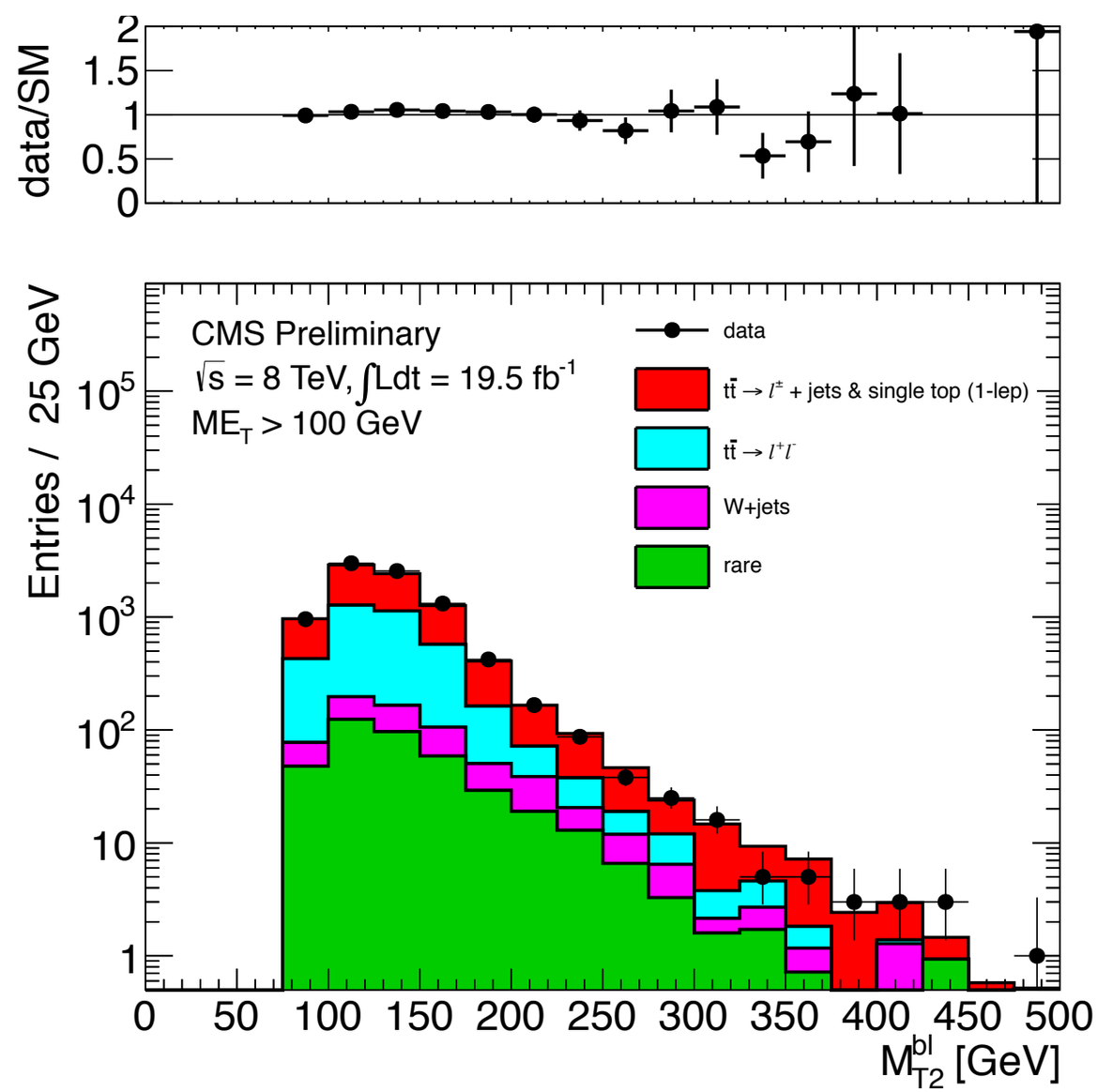


$MT2^{bl}$

W+jets modeling (CR1)



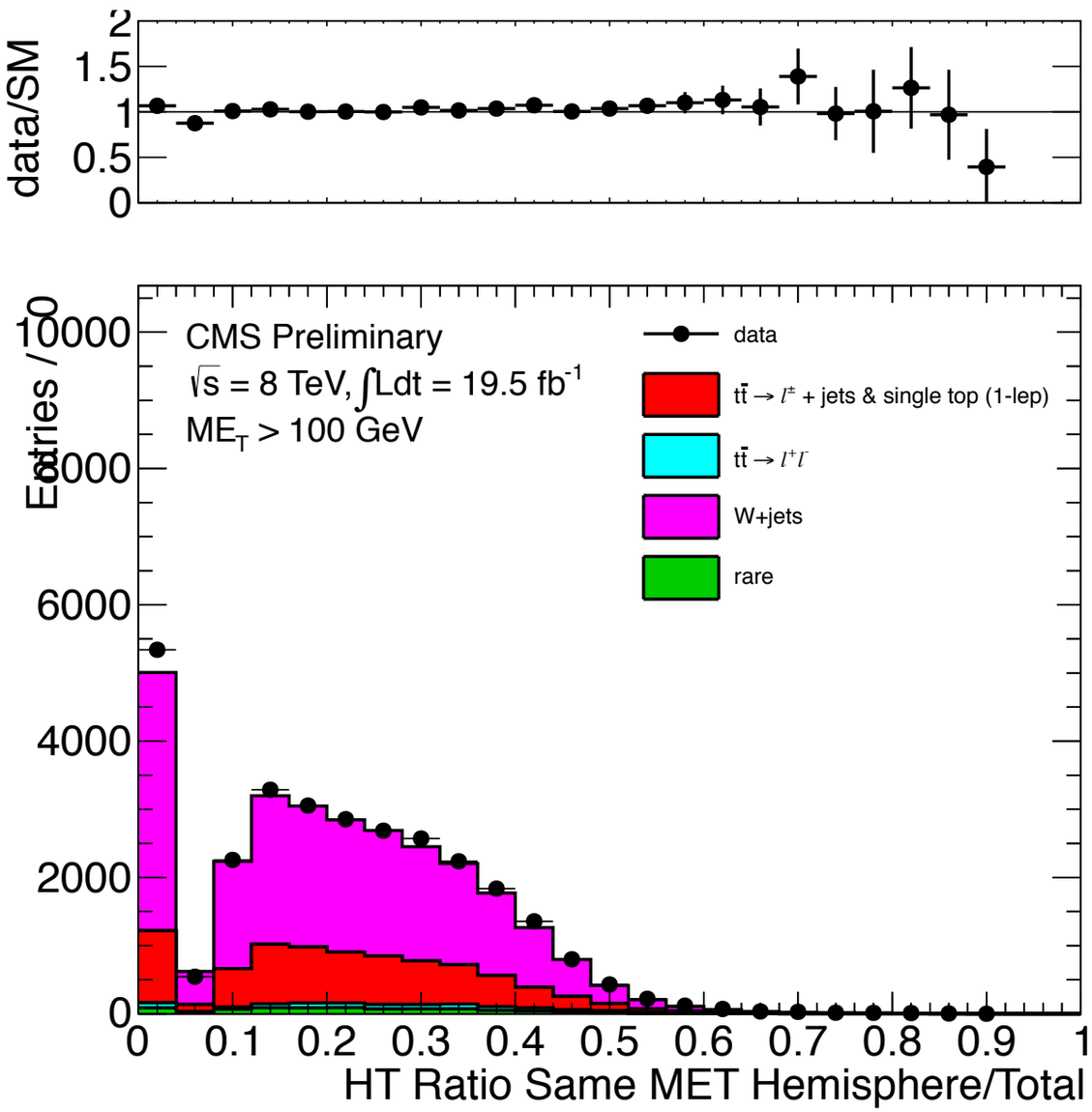
ttbar modeling (CR5)



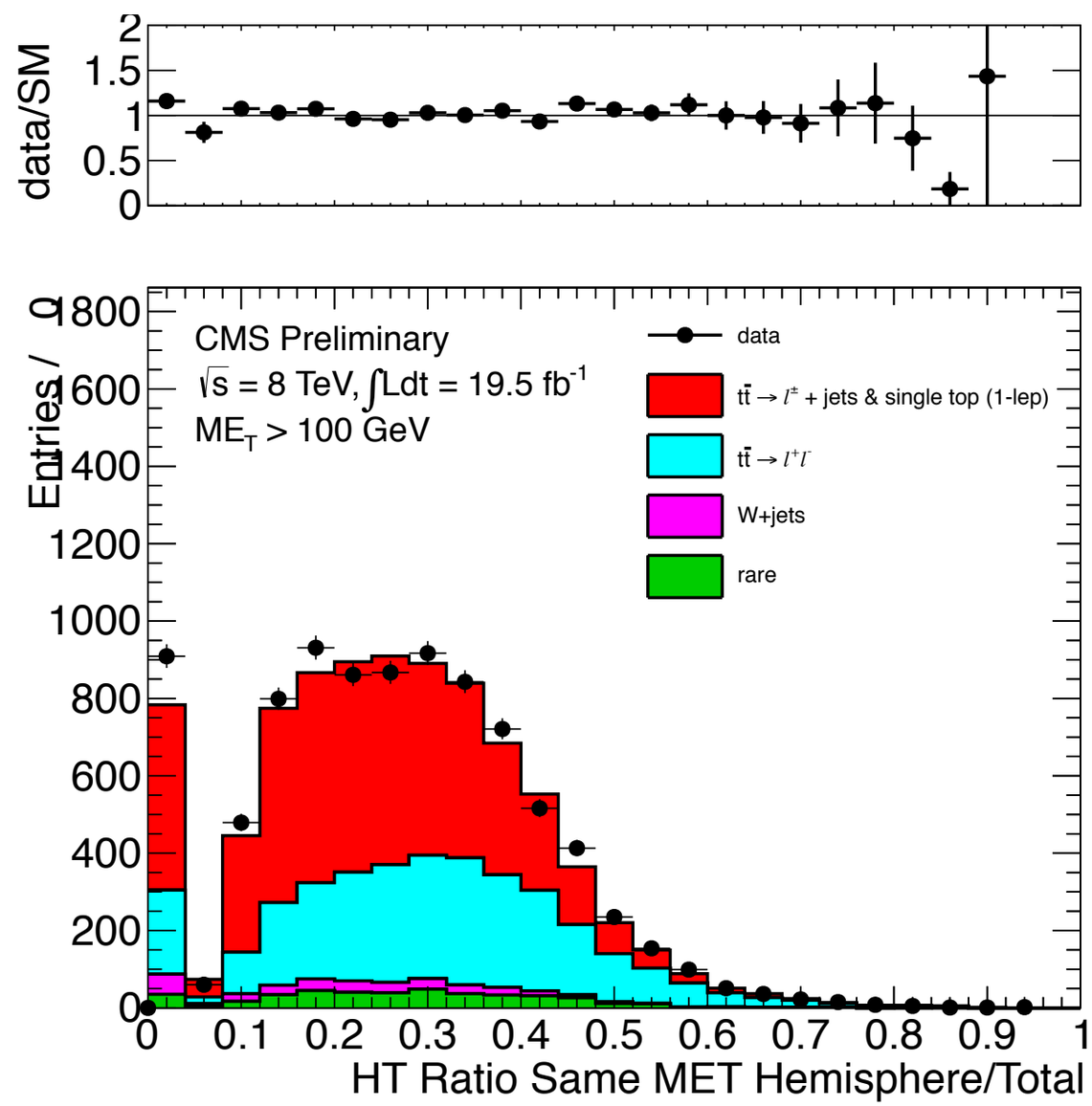
HT(SSM)/HT(OSM)

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

W+jets modeling (CR1)

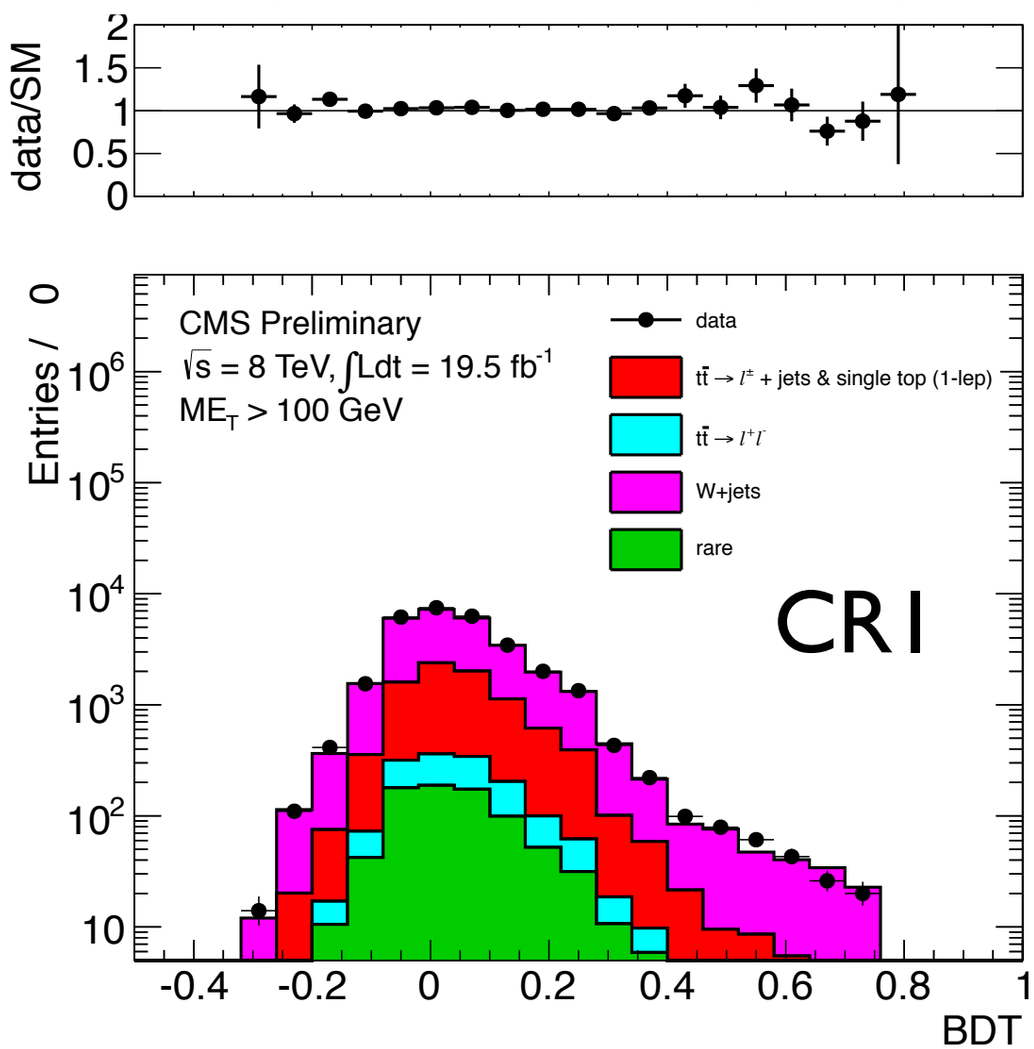


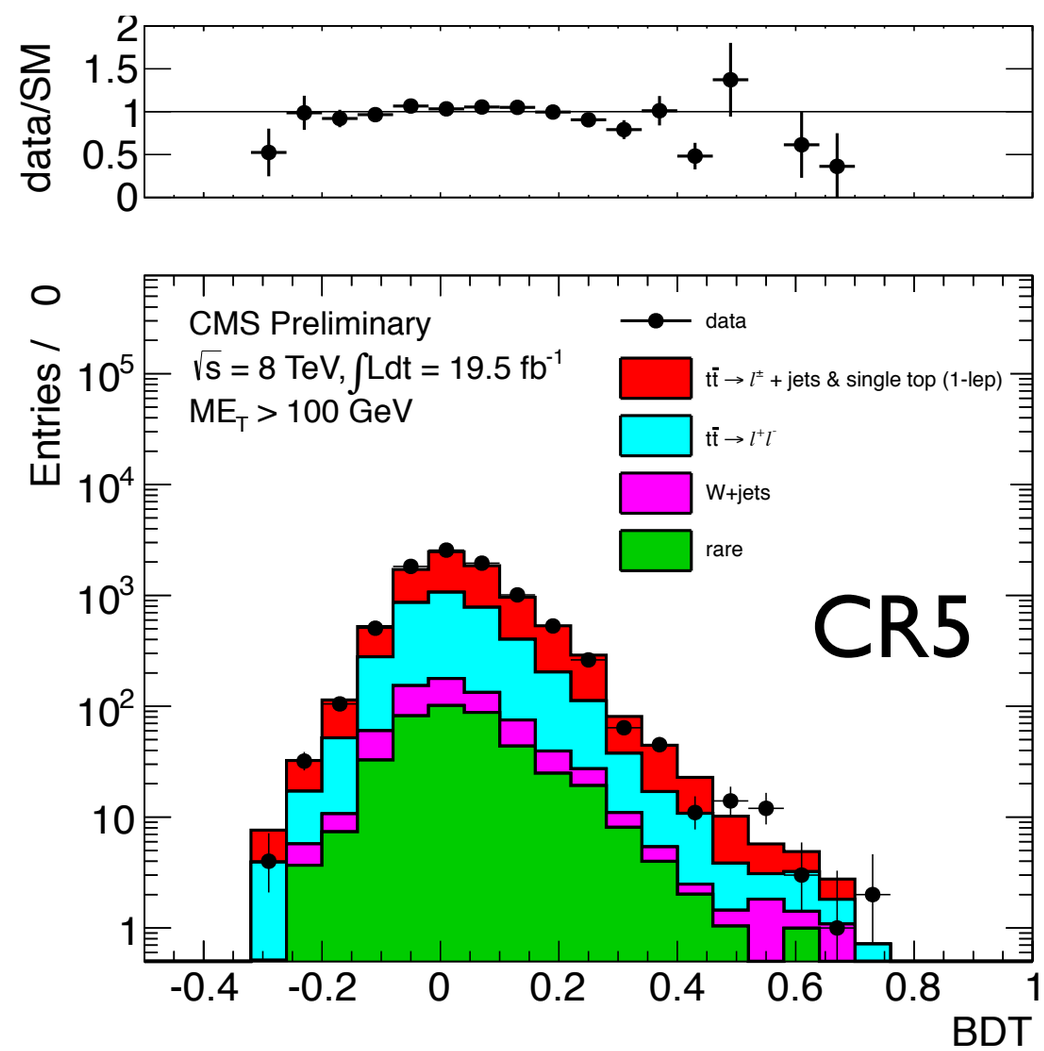
ttbar modeling (CR5)



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



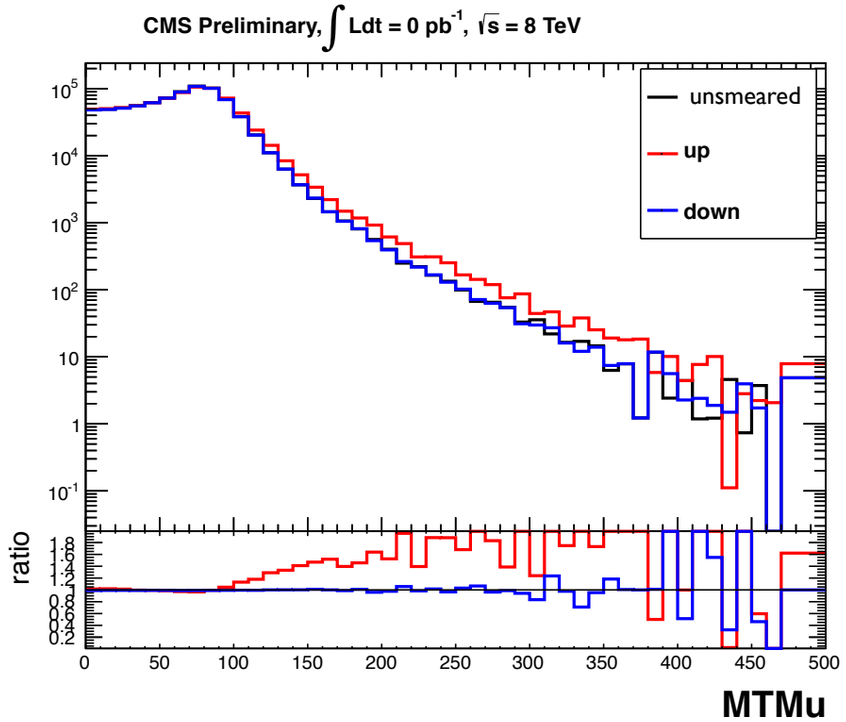


Jet resolution studies

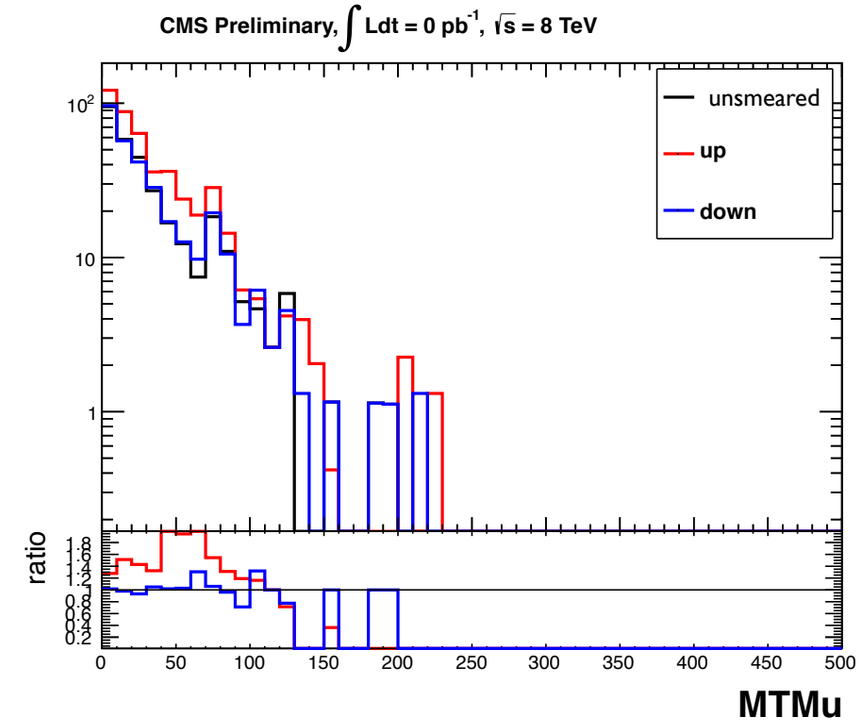
(from E. Ron, DESY)

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

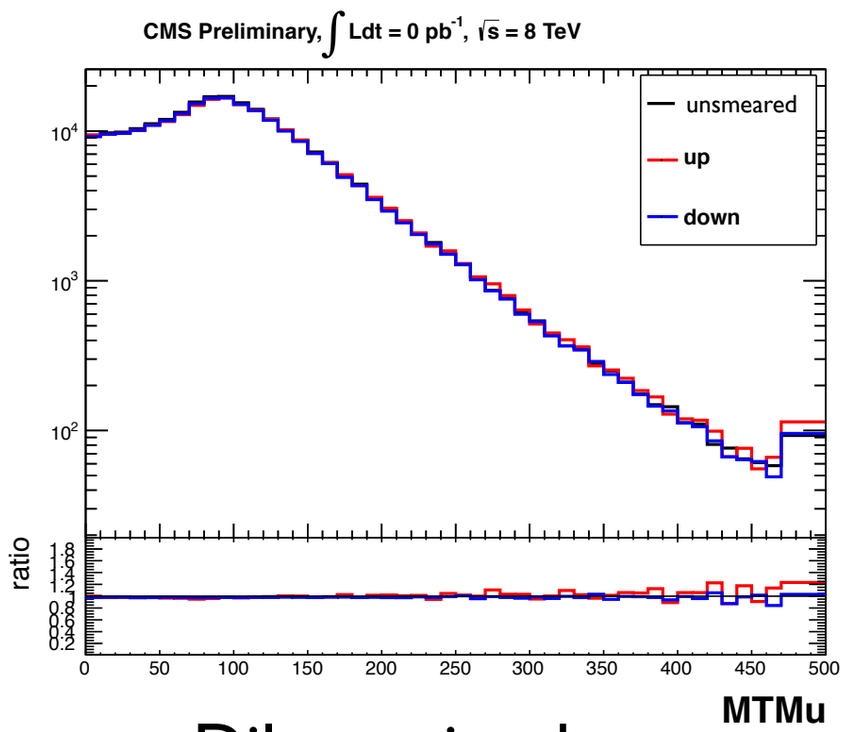
M_T with jet resolution smearing (μs)



Semileptonic ttbar



All hadronic ttbar



Dileptonic ttbar

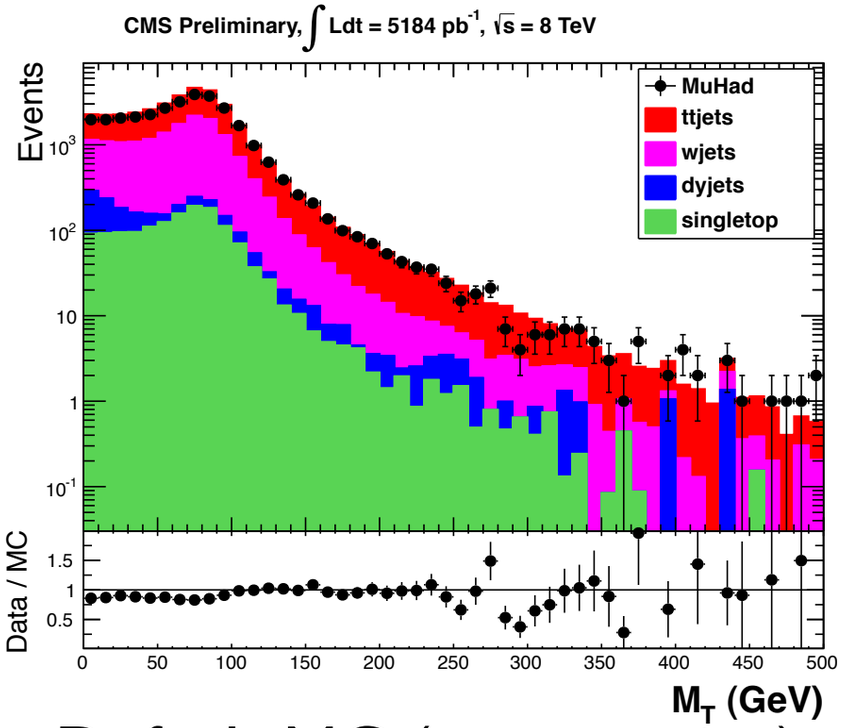
Selection:

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

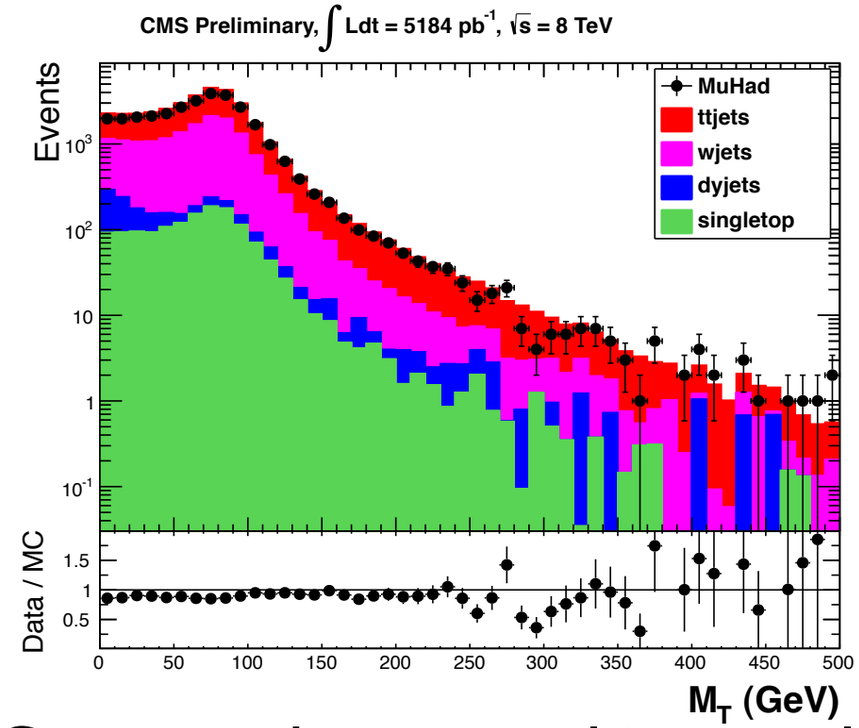
Jet Resolution smeared by the recommended factor $+1\sigma$ up and -1σ down, compared with the unsmeared.

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

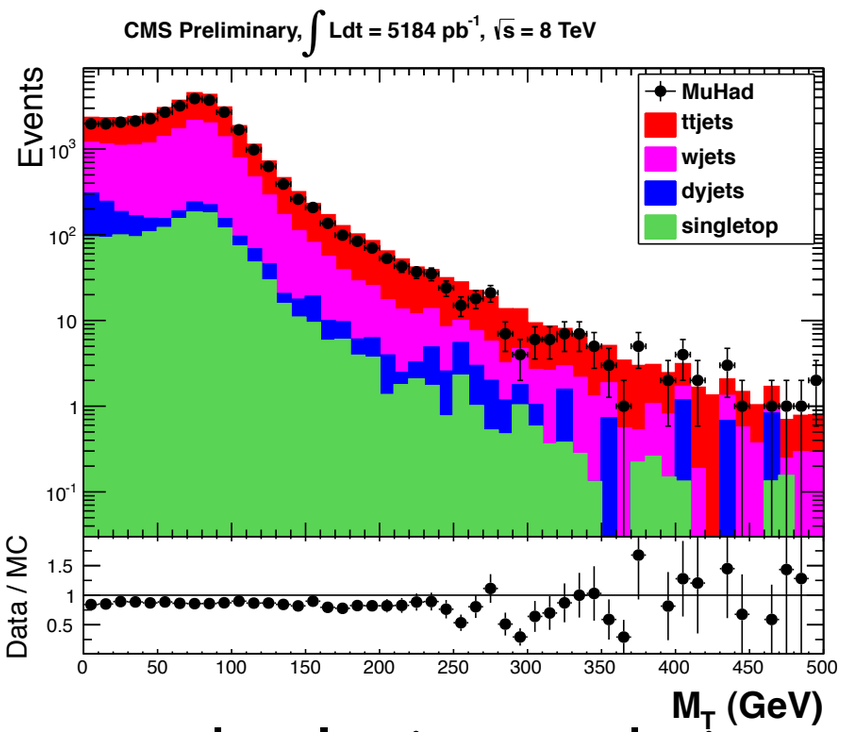
Data vs MC for M_T with different smearing (μs)



Default MC (no smearing)



MC smeared to central jet resolution



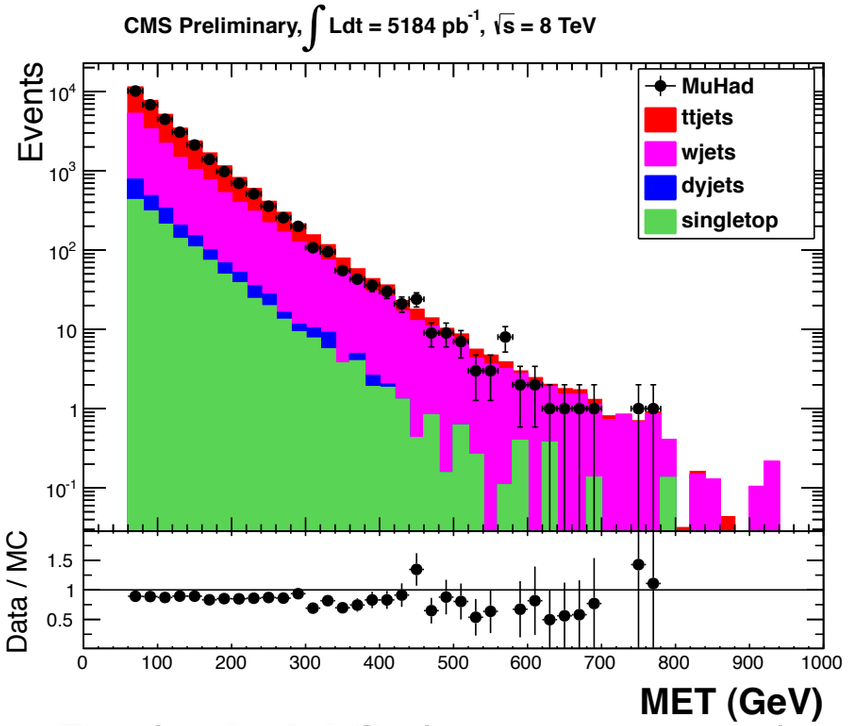
central + 1σ jet resolution

- The jet fourvector changes:

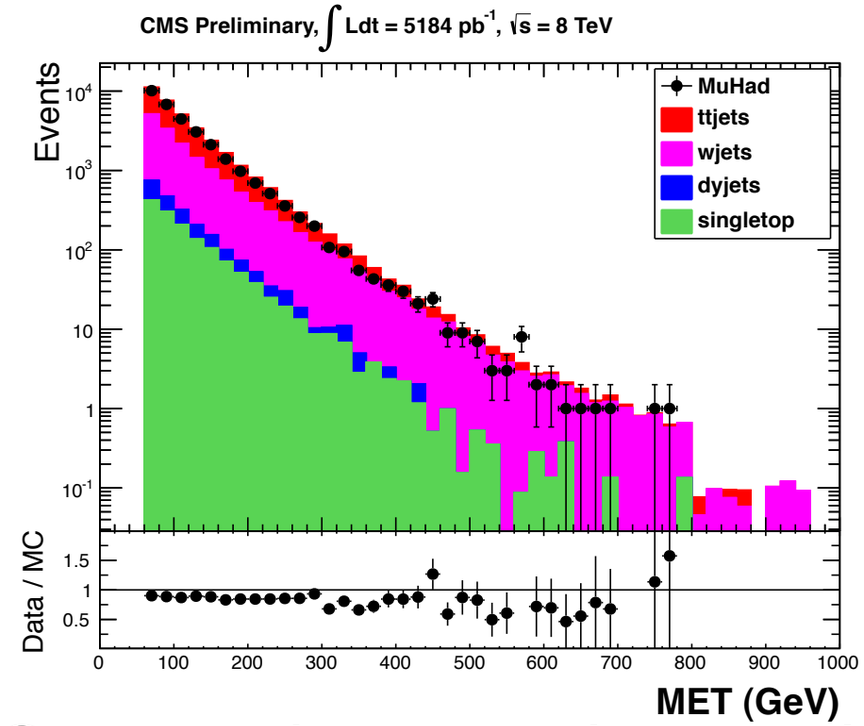
$$p_4^{Jet} \longrightarrow p_4^{Jet} \cdot \frac{p_T^{genJet} + SF(\eta^{Jet}) \cdot \left(p_T^{Jet} - p_T^{genJet}\right)}{p_T^{Jet}}$$

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

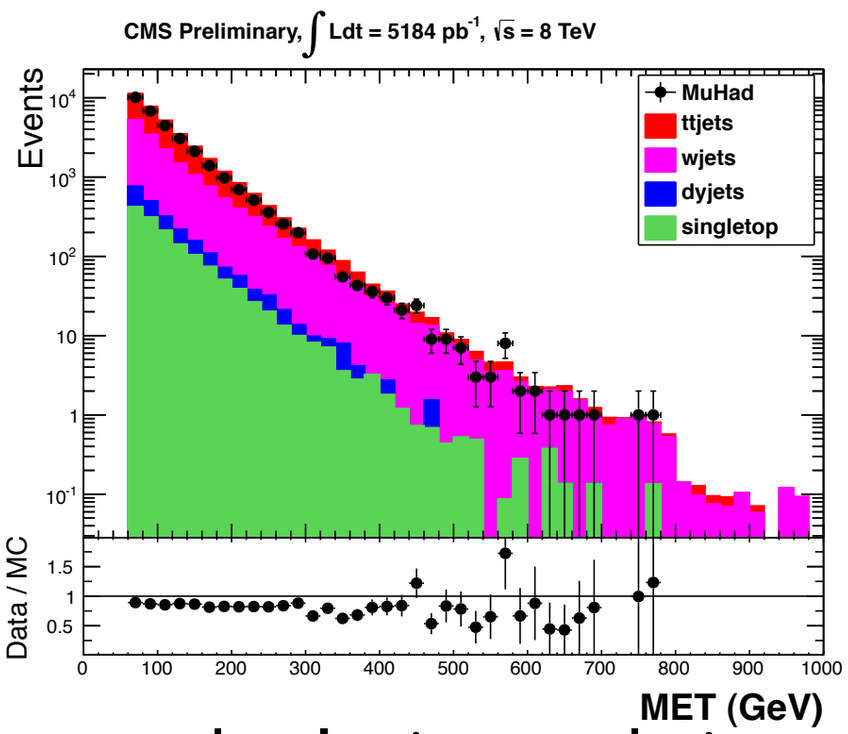
Data vs MC for MET with different smearing (μs)



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

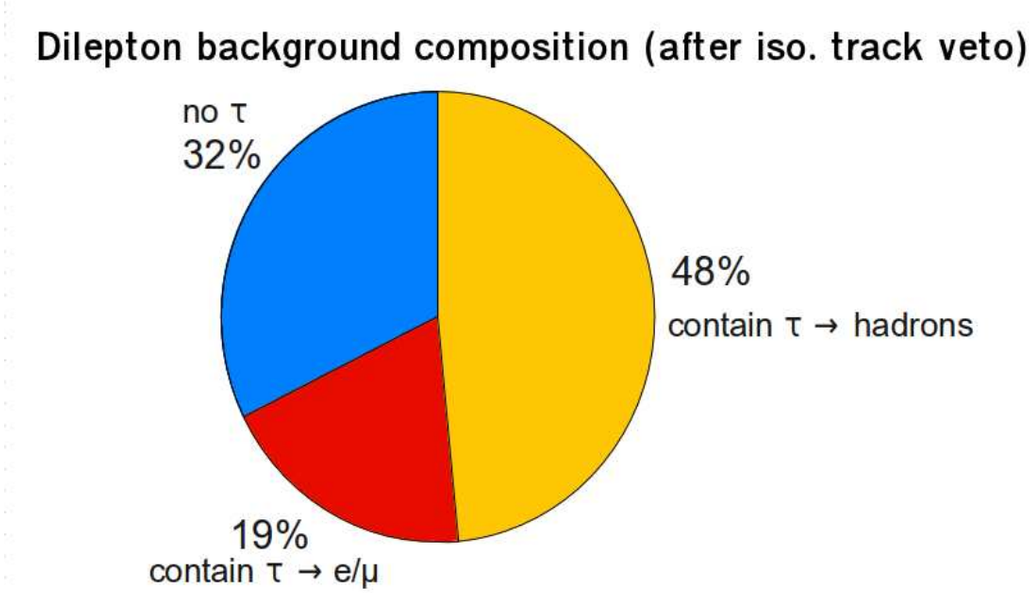
✓ We've already had a look at it for the Hcal Upgrade TDR and we think it is worth to try using it in the Single lepton + MT stop search.

Work on tt→ ℓ ℓ rejection (Strasbourg)

(from A.Aubin, IPHC)

Motivation for τ veto

About 50% of the remaining dilepton background contain an hadronic τ.



τ veto

Reject event containing a τ candidate satisfying :

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

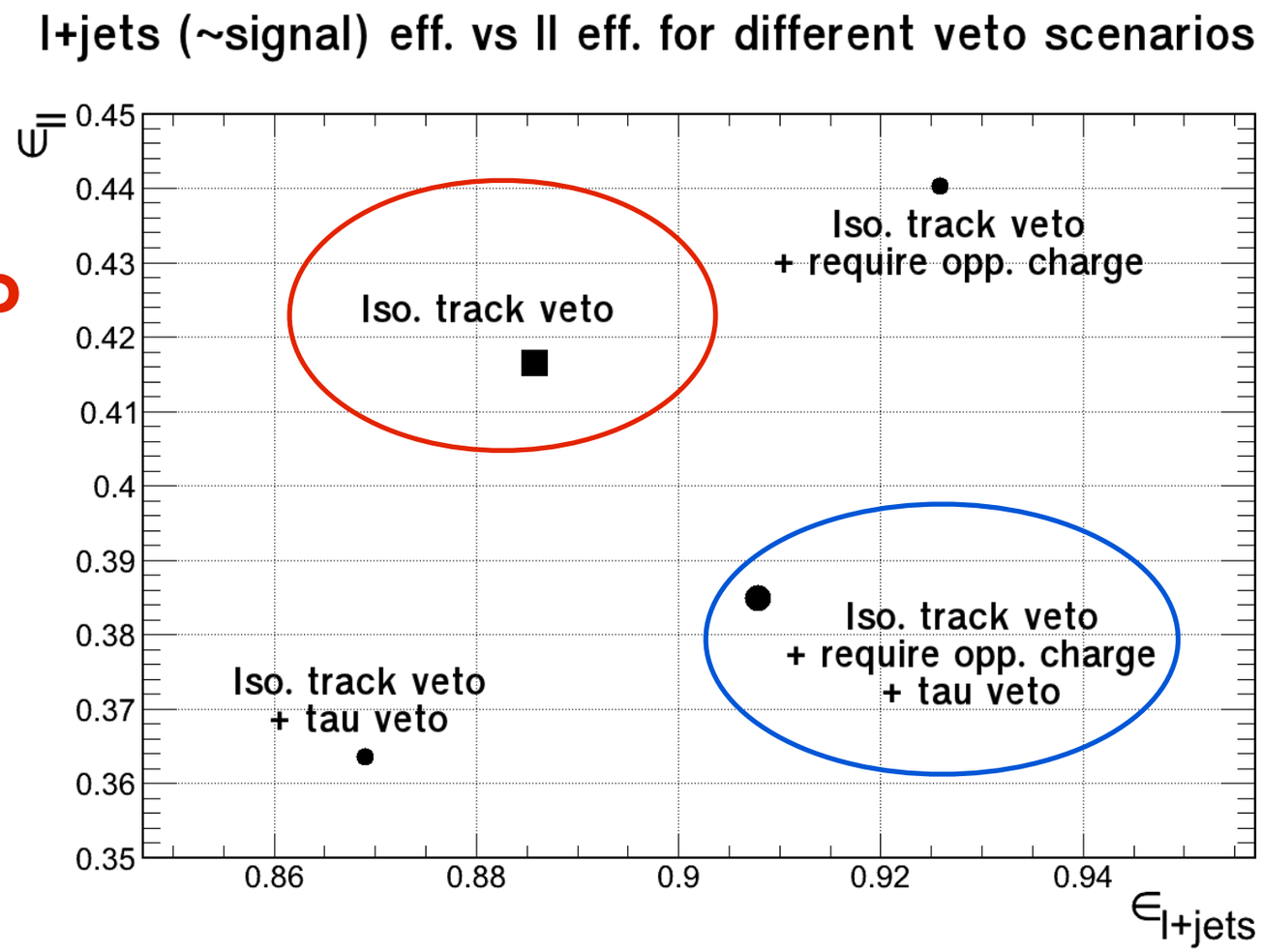
Work on tt→ℓ ℓ rejection (Strasbourg)

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



old WP

new WP

S/B improved by ~10%

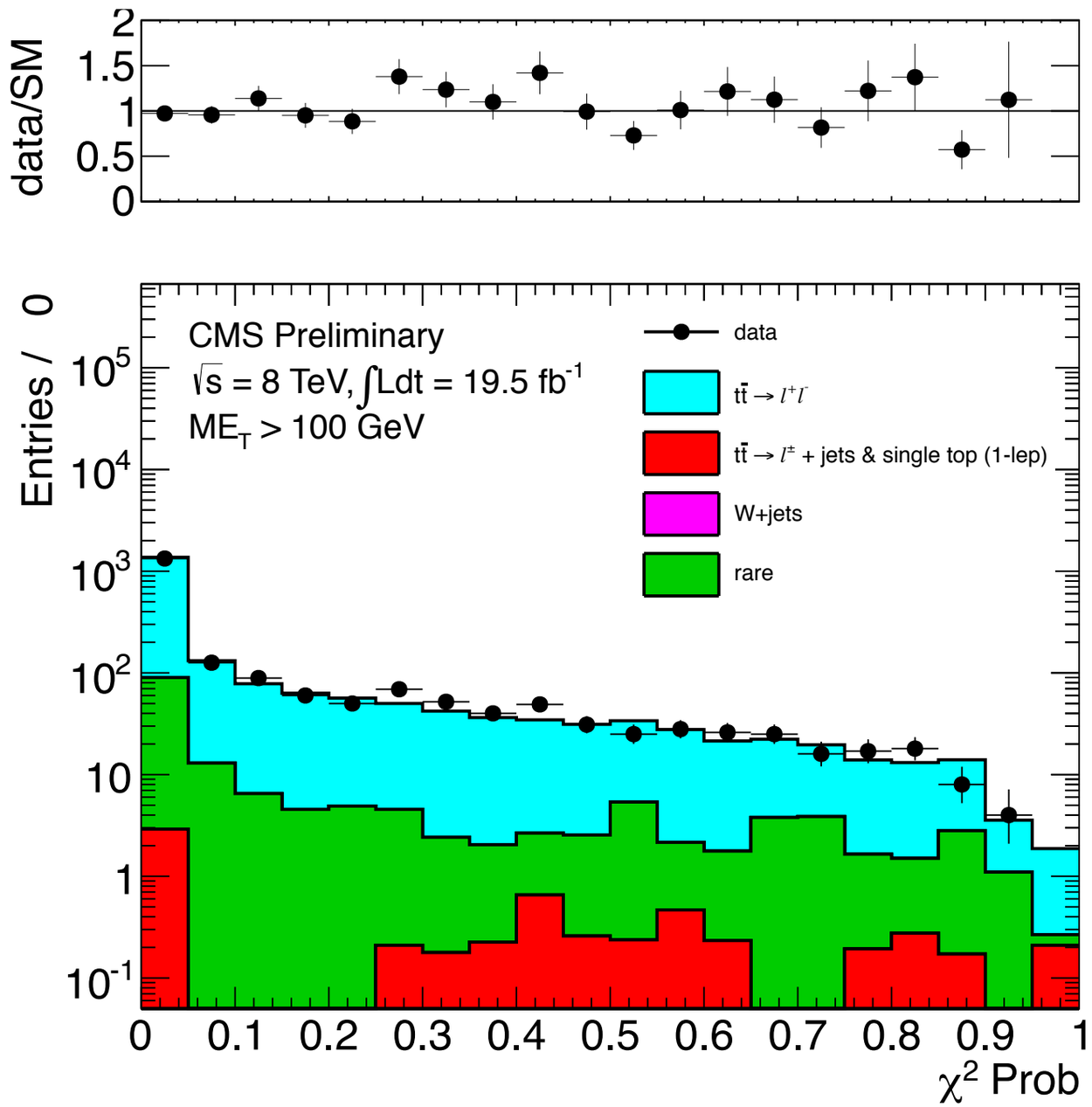
- Brown group also working on tt→ℓ ℓ rejection

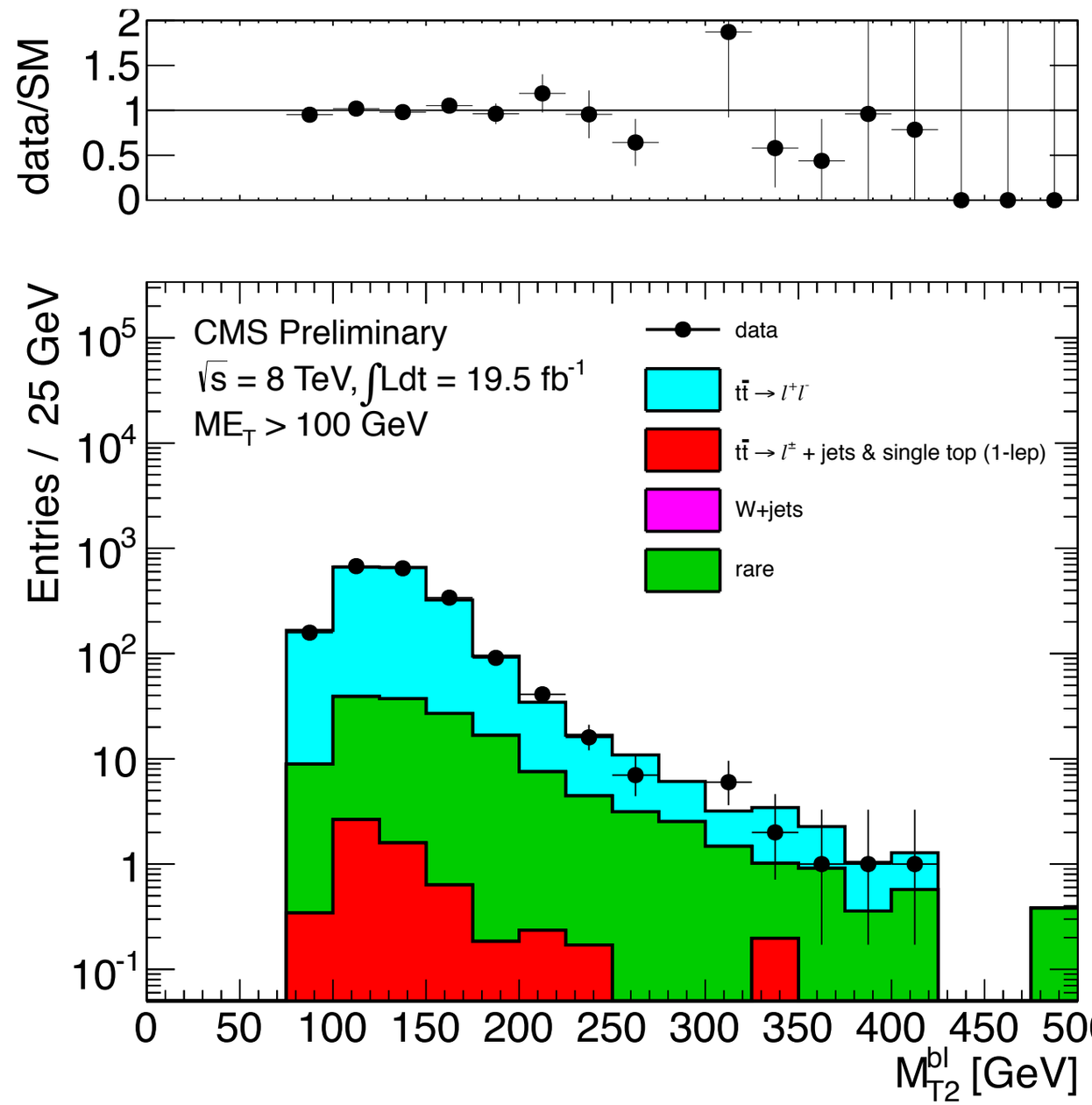
Summary

- 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→ ℓ ℓ rejection and greater signal efficiency from tau veto combined with restricting isolated track veto to opposite charge only

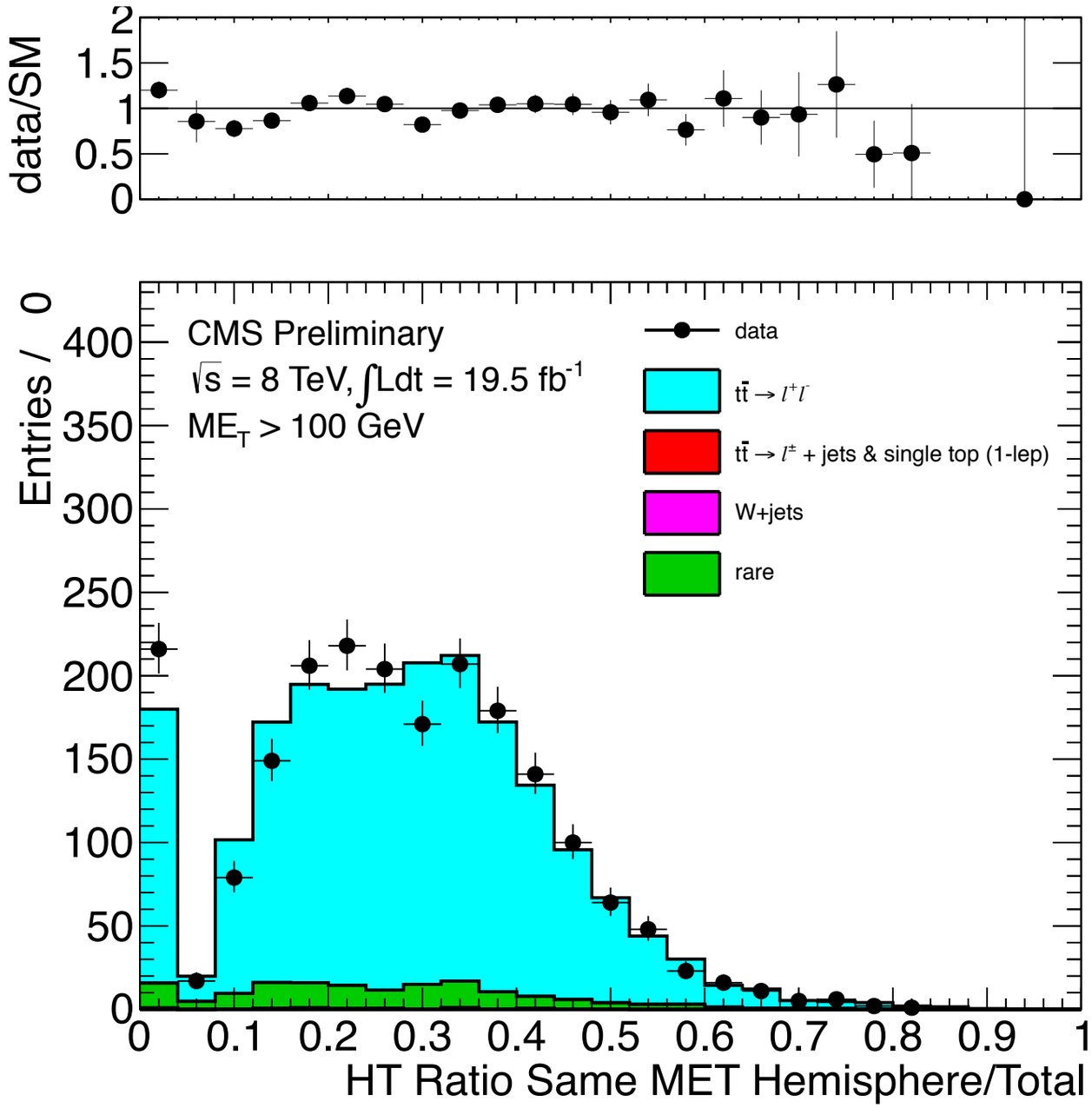
Backup

CR4 plots


data/SM
Entries / 0
CMS Preliminary
√s = 8 TeV, ∫Ldt = 19.5 fb-1
MET > 100 GeV
data
tt̄ → l+l-
tt̄ → l± + jets & single top (1-lep)
W+jets
rare
χ2 Prob


data/SM
Entries / 25 GeV
CMS Preliminary
√s = 8 TeV, ∫Ldt = 19.5 fb-1
MET > 100 GeV
data
tt̄ → l+l-
tt̄ → l± + jets & single top (1-lep)
W+jets
rare
MT2bl [GeV]

CR4 plots


data/SM
Entries / 0
CMS Preliminary
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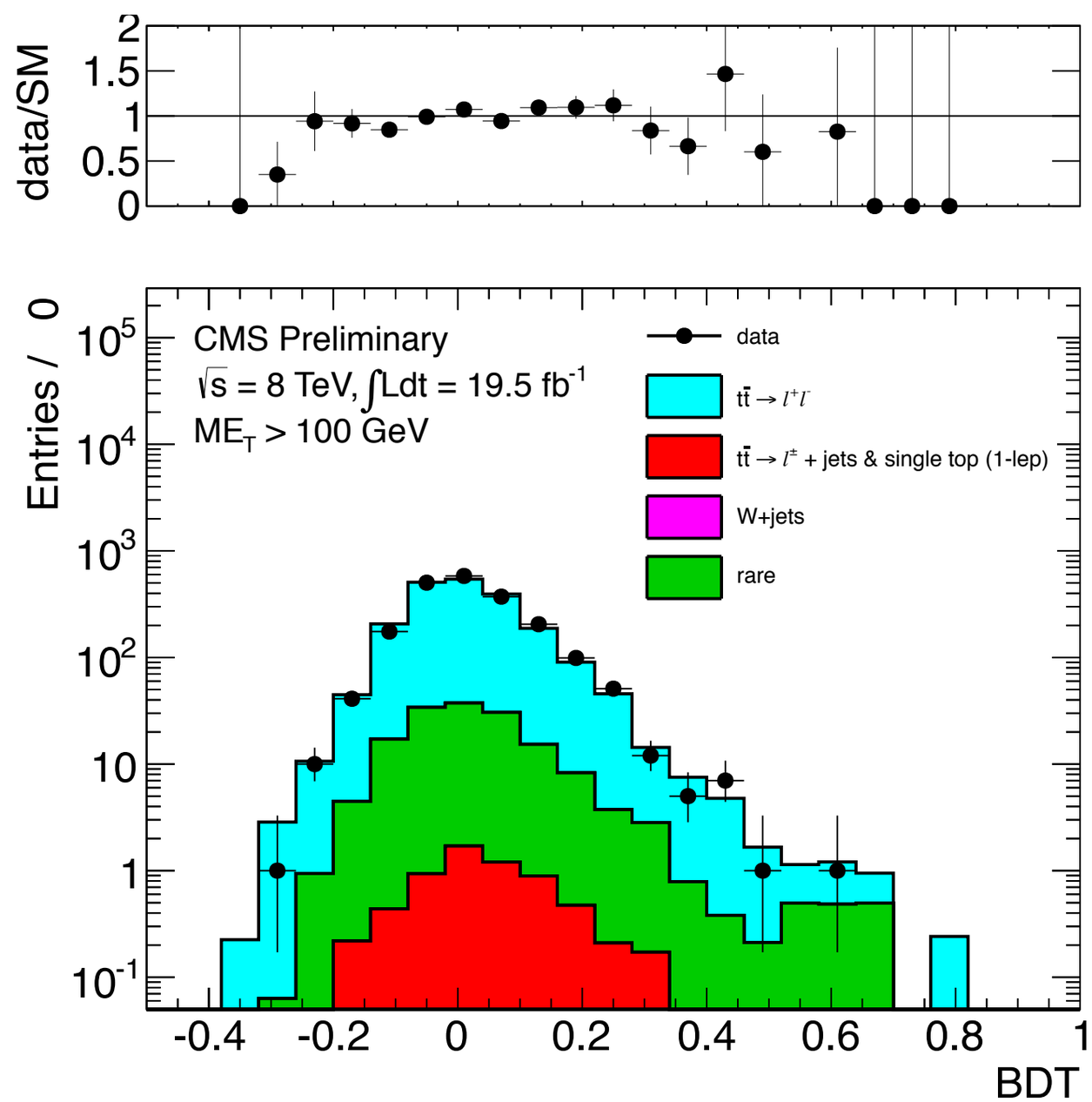
MET > 100 GeV
data
tt̄ → l+l-
tt̄ → l± + jets & single top (1-lep)
W+jets
rare
HT Ratio Same MET Hemisphere/Total


data/SM
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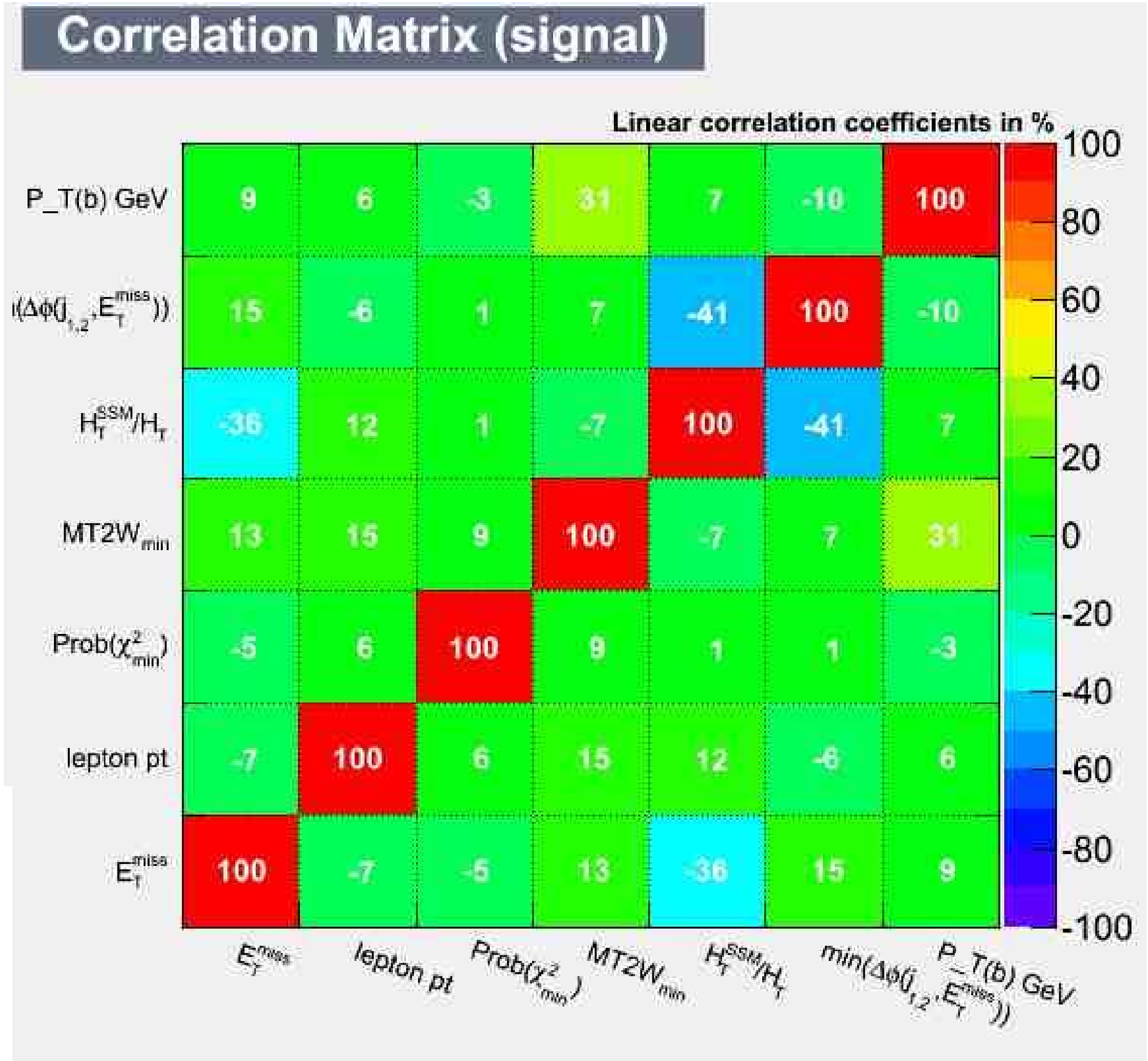
MET > 100 GeV
data
tt̄ → l+l-
tt̄ → l± + jets & single top (1-lep)
W+jets
rare
BDT

Correlation between variables