Early LHC data preparations for SUSY searches at CMS

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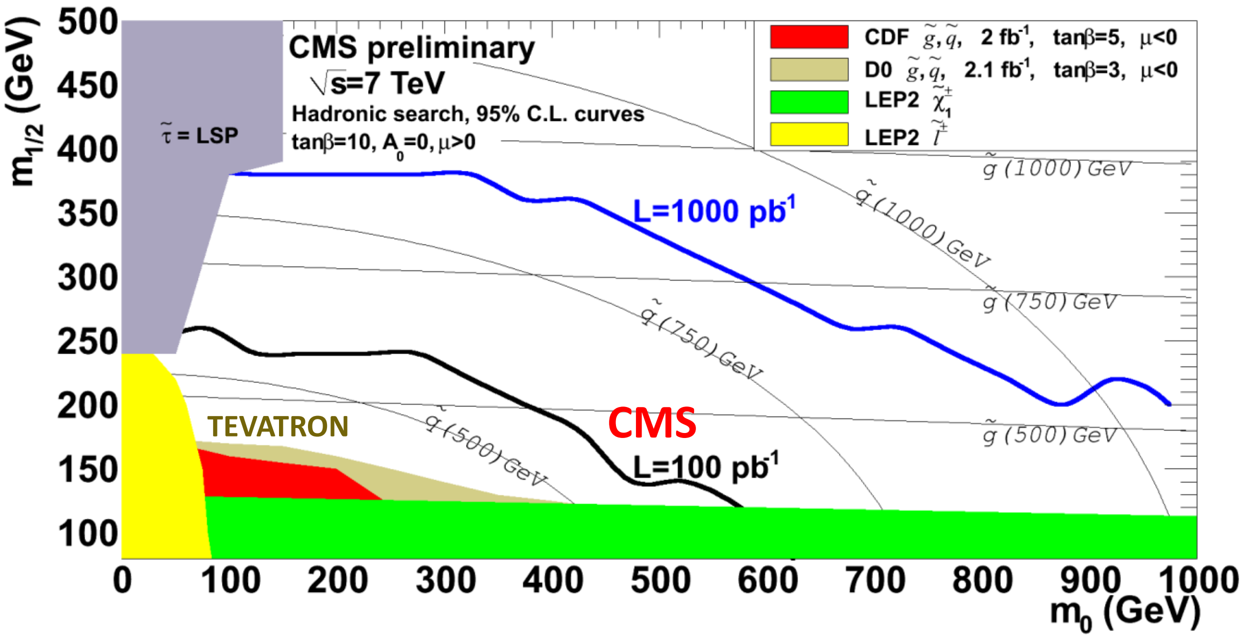
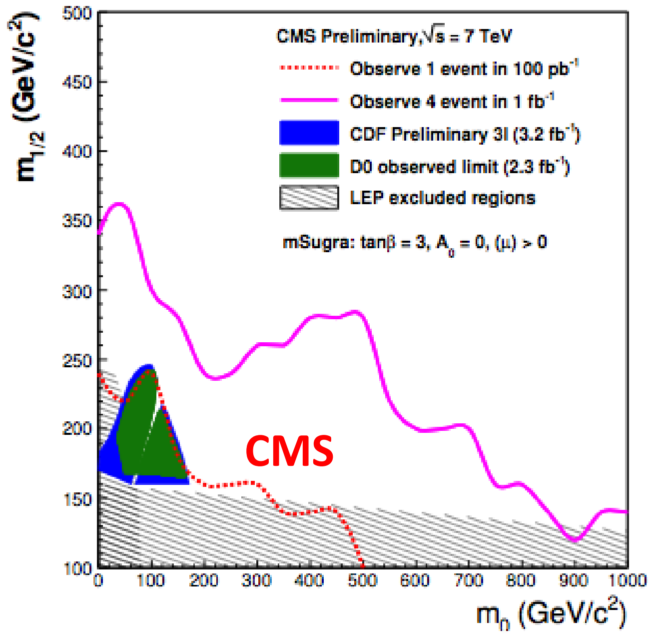
sensitivity to mSUGRA with fully hadronic signaure



Sensitivity with Same-Sign di-lepton



- 7 TeV data of ~100 pb^{-1} should provide sensitivity to SUSY parameter space well beyond the current limits set by TEVATRON
- The sensitivity reach strongly depends on how well we understand the SM backgrounds

Introduction

- Strategies to suppress and measure SM backgrounds are studied in detail using MC in the past years
- 7 TeV data used (11-65 nb^{-1}) for testing some of these methods in the available phase-space (not yet where we expect SUSY signal)
- QCD is not expected to be dominant background for most of the search topologies, but poorly known (large!) cross sections, need to be measured from data:
  - Suppressing QCD using topological observables
  - Predicting QCD contributions to Missing E_T (MET)
  - data-driven techniques to measure QCD background for lepton(s) + Jets +MET signatures

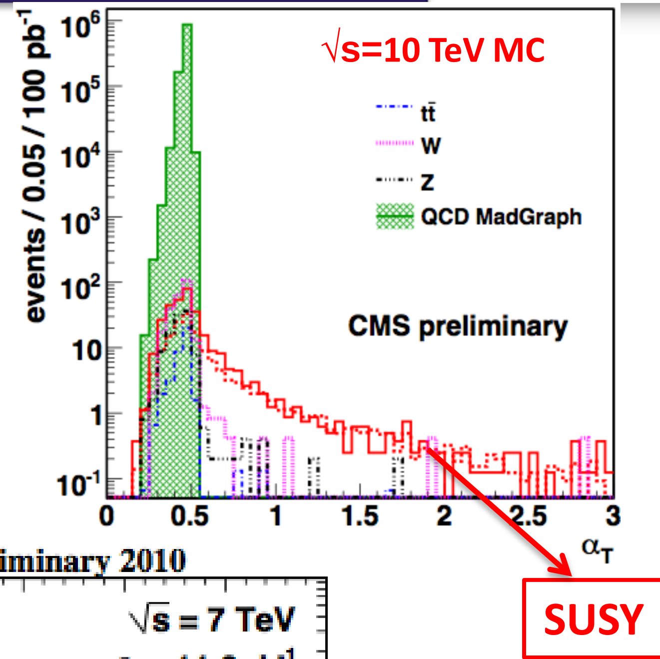
Material used in this presentation is documented in **SUS-10-001**, and see **JME-10-004** for detailed MET studies for SUSY searches, see Slide 18 for full references

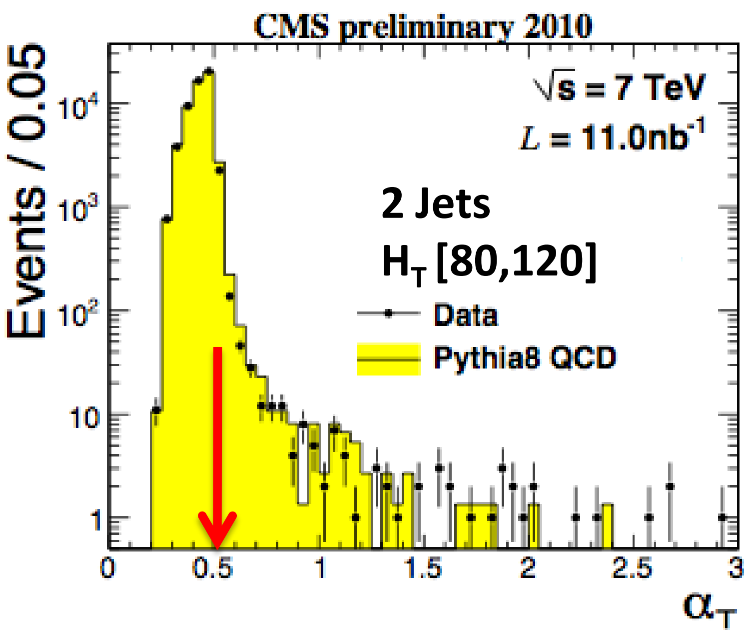
Suppressing QCD with α_T

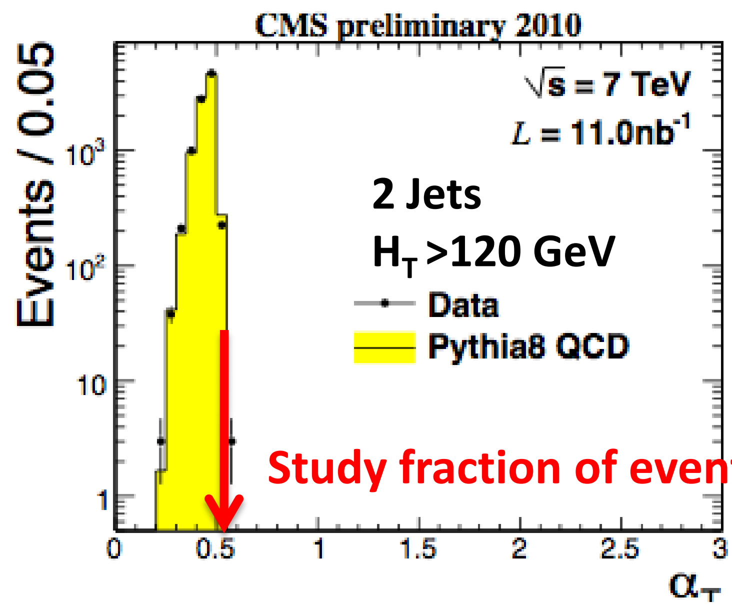
- A powerful variable for suppressing mis-measured QCD

$$\alpha_T \equiv \frac{p_{T2}}{M_T} \qquad \alpha_T = \frac{\sqrt{p_{T2}/p_{T1}}}{\sqrt{2(1-\cos\Delta\phi)}}$$

- Well measured back-to-back di-jet system $\alpha_T \approx 0.5$, if one jet is mis-measured $\alpha_T < 0.5$







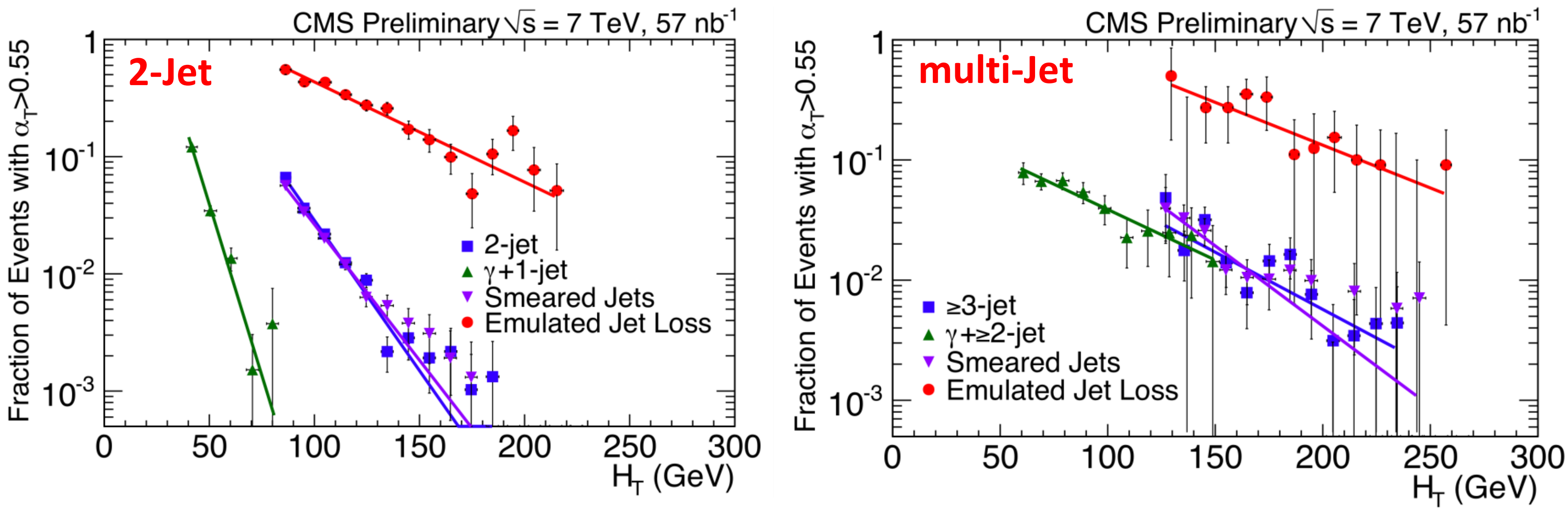
$$H_T = \sum_i p_T(\mathrm{jet}_i)$$

Study fraction of events with $\alpha_T > 0.55$

✓ **The data shows the expected sharp fall around $\alpha_T \sim 0.5$, improves for higher H_T**

H_T dependence of $\langle_T$

- **Rejection power of $\langle_T$ is expected to get better with increasing H_T**
- **Examine this assumption in the available H_T range:**



✓ **Expected decrease (approx. exponential) with H_T is observed for both 2-jet and ≥3-jets**

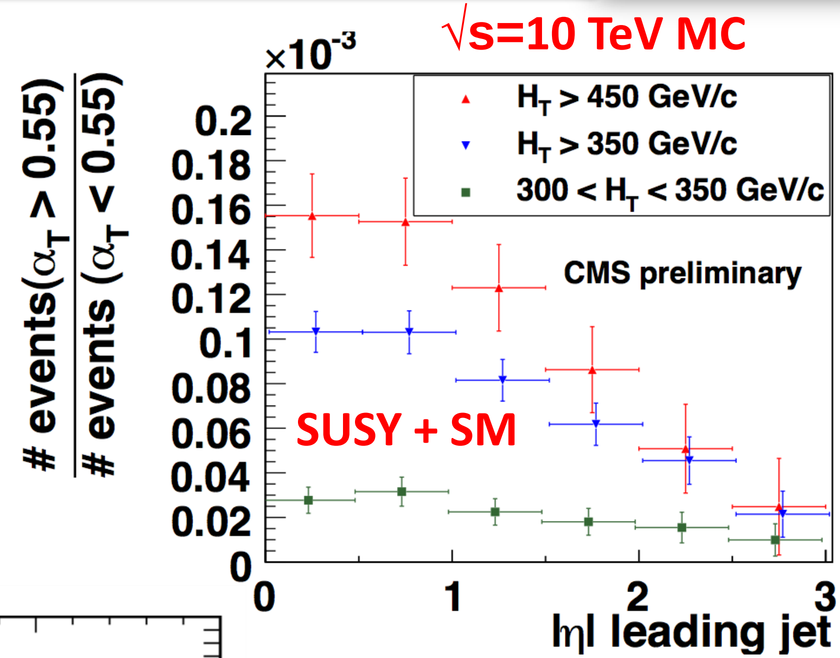
✓ **Better performance with increasing H_T holds also for:**

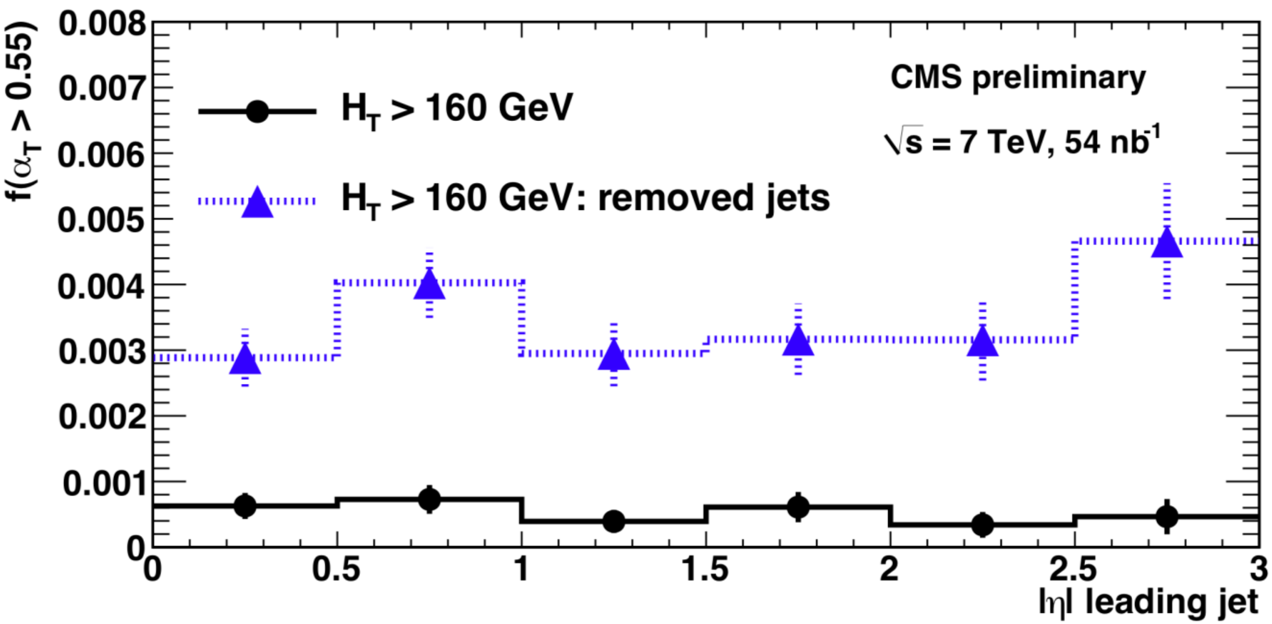
- In ©+jet(s) events where photon is treated as a jet
- Emulating extreme jet losses
- Smearing jet energies

✓ **Extended also for leptonic search channels (not shown here)**

$\langle_T$ versus pseudorapidity

- Having verified α_T behavior with H_T, one can use data at lower H_T to estimate SM background at high H_T by exploiting its expected uniformity versus |
- The method was studied with 10 TeV MC
- Fraction of events with α_T>0.55 as a function of the leading jet |

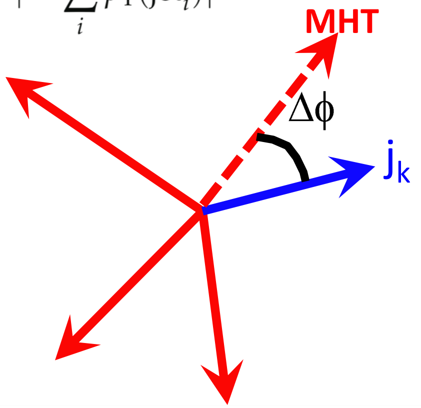




✓ **Flat behavior across |, even when a jet is removed**

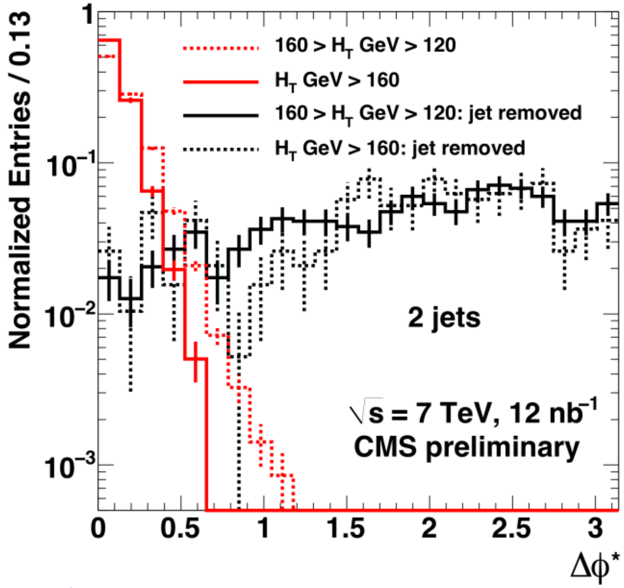
Suppressing QCD with Δφ*

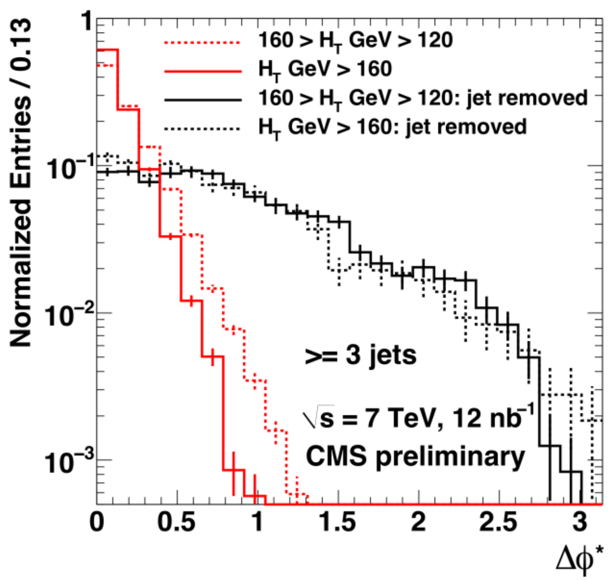
$$\mathrm{MHT} = |-\sum_i \vec{p}_\mathrm{T}(\mathrm{jet}_i)|$$



- A complementary observable, Δφ*, to diagnose background events where one jet mis-measured.
- Test each jet to see if it is responsible for the MHT (vectorial sum of the jet p_T)

$$\Delta\phi^* \equiv \min_{\mathrm{jets}\ k}\left(\left|\Delta\phi(\vec{p}_k, -\sum_{\mathrm{jets}\ i\neq k}\vec{p}_i)\right|\right)$$



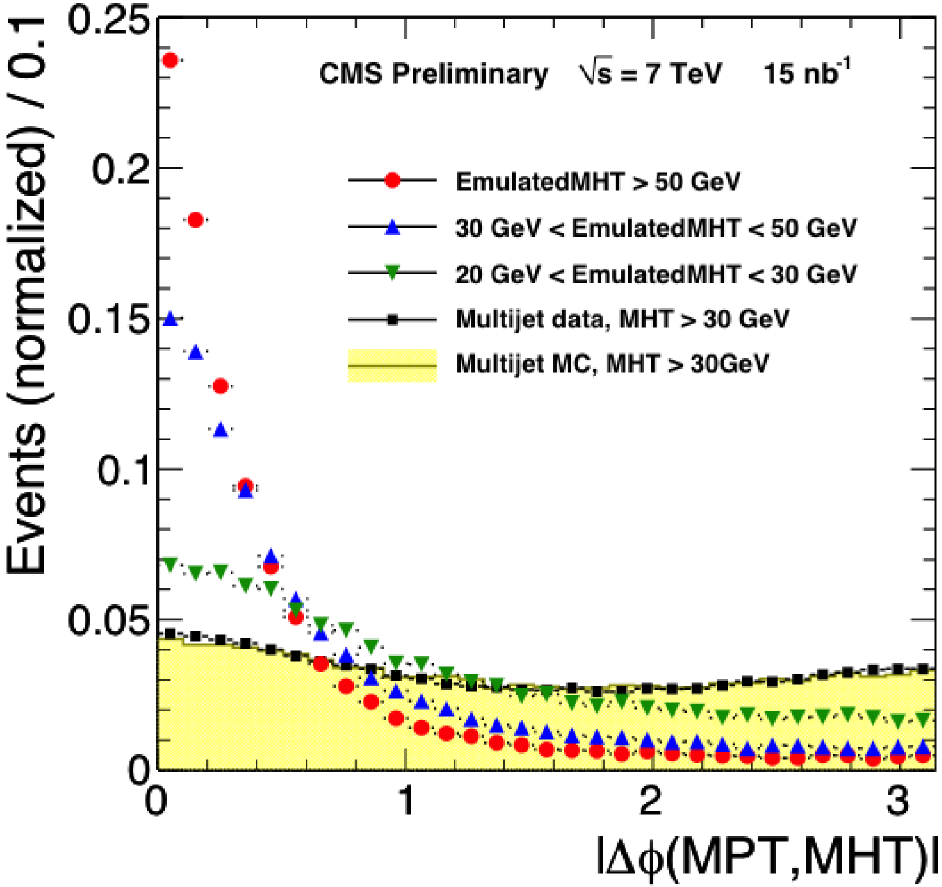


- expect small Δφ* for QCD
- more uniform for real MET (emulated by removing one jet)

✓ **Data confirms the expected behavior in both di- and multi-jets**

✓ **Resolution improves with H_T**

Tracker (MPT) vs Calorimeter (MHT)



- Independent measurement of missing momentum from Tracker & Calorimeter

$$\mathrm{MHT} = \left| -\sum_i \vec{p_T}(\mathrm{jet}_i) \right|$$

$$\mathrm{MPT} \equiv \left| -\sum_i \vec{p_T}(\mathrm{track}_i) \right|$$

- Compare the direction of MPT and MHT, Δφ(MPT,MHT)

✓ **Very little correlation between the directions of MPT and MHT when no real MHT is present (QCD)**

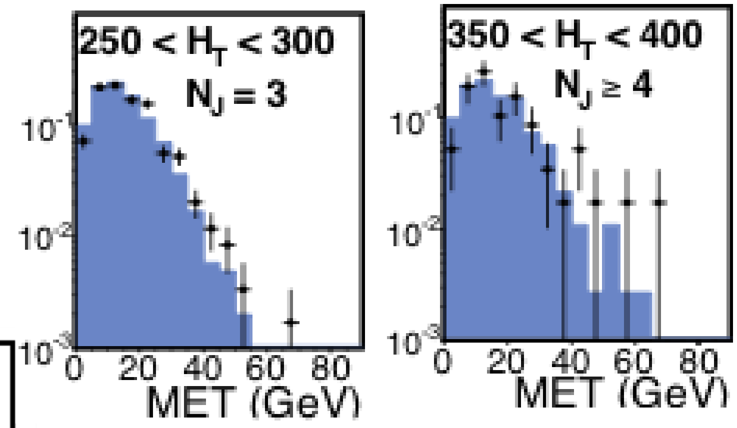
✓ **peaks towards zero for real MHT (emulated by removing a random jet)**

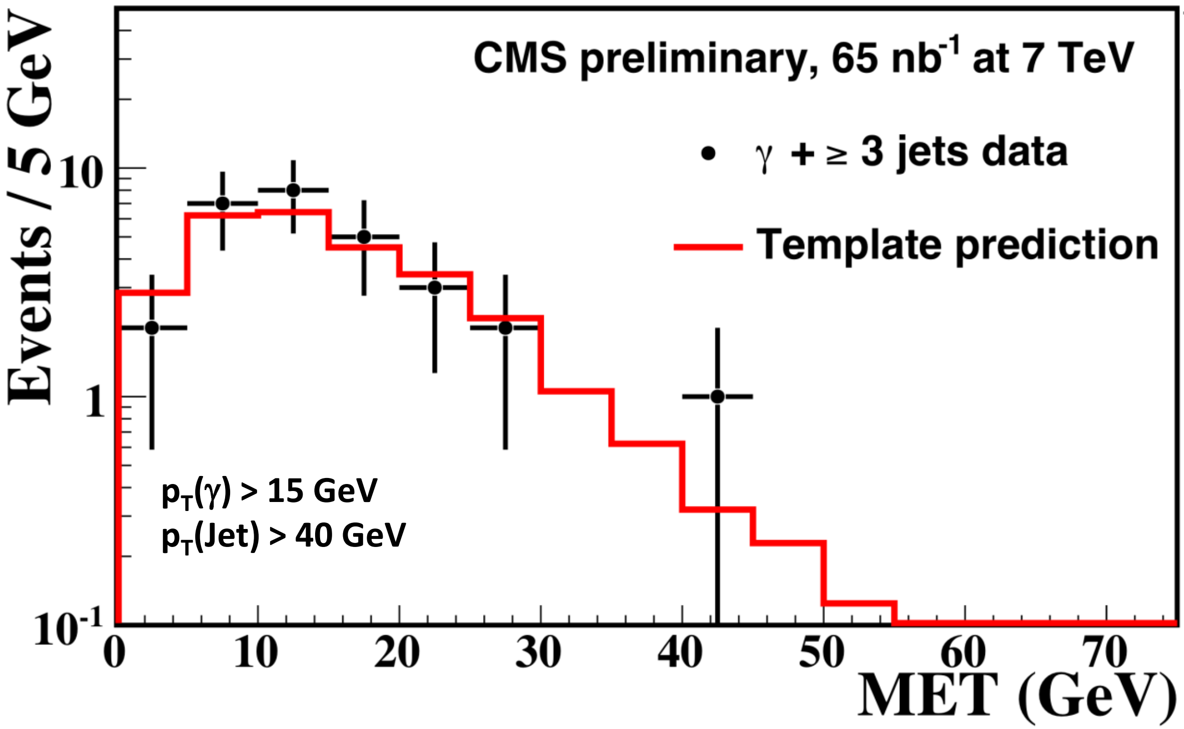
✓ **Also useful to remove events with a fake MHT due to noise in the calorimeter**

Predicting high MET tail

- MET background to lepton+jets+MET signatures from **real MET** (e.g. in W/Z) and **MET due to mis-measurements**
- **Test the method for the latter**
- Use MET templates from multi-jet events to predict MET for **γ+jets events**

MET templates from multi-jet events





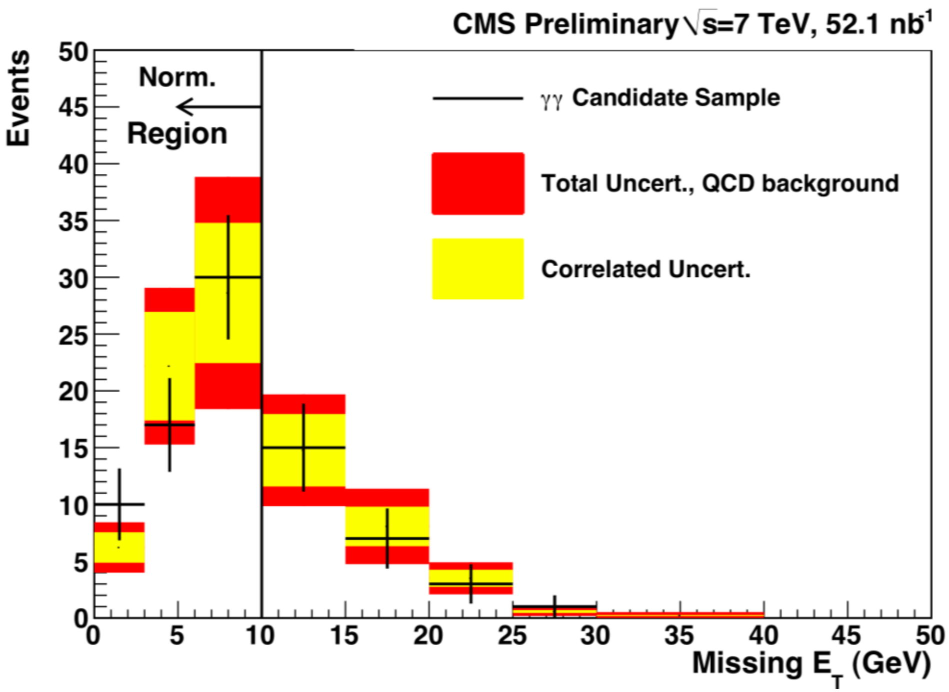
✓ Good agreement between predicted and observed distributions:

for MET > 15 GeV

predicted = 12.5

observed = 11

Predicting MET tail in γγ search



- γγ + MET is one of the early search channels
  - Physics backgrounds Wγγ/Zγγ
  - Wγ, electron mis-id as γ
  - **multi-jet (direct γγ) + fake MET (dominant)**

- Prediction:
  - Measure MET distribution in a control sample with 2 fake photons , selected by inverting Isolation requirement
  - Use number of selected events at MET < 10 GeV to normalize the measured templates.

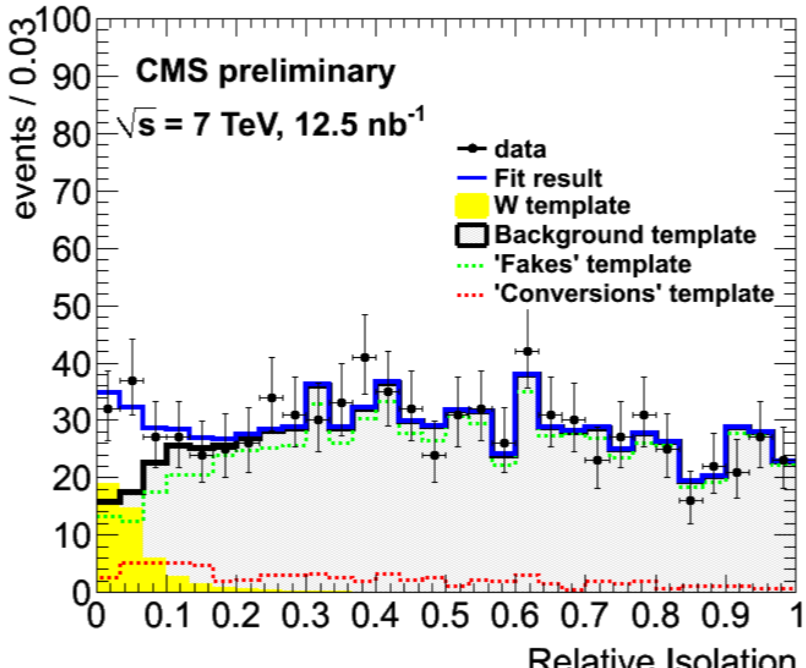
✓ **Prediction consistent with number of observed events,**
For MET > 20 GeV:
Predicted = 4.2 ± 1.5
Observed = 4 events

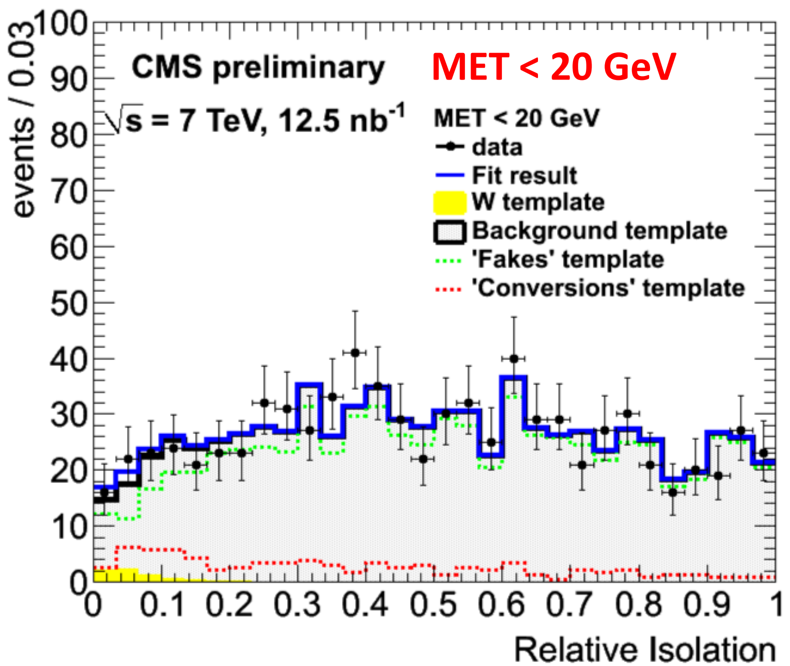
QCD background for e+Jets+MET

- QCD contributes to e + Jets+ MET signature
    - heavy-flavor decays and jets mis-identified as electron
    - electrons due to photon conversion
- Select control samples dominated by each of above sources by inverting selection cuts perform fit using Relative Isolation distributions

$$\mathrm{RelIso} = \frac{\sum(p_T^{\mathrm{Calo+Trk}})_{R<0.3}}{p_T(e)}$$

- Isolation template for W→eν contribution from MC



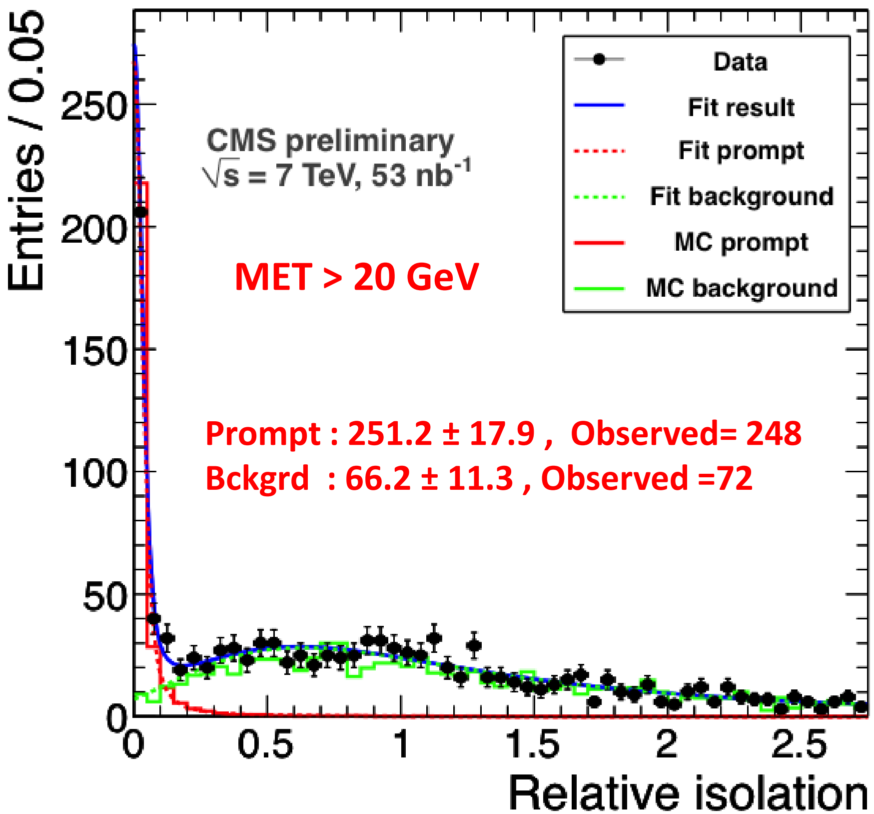


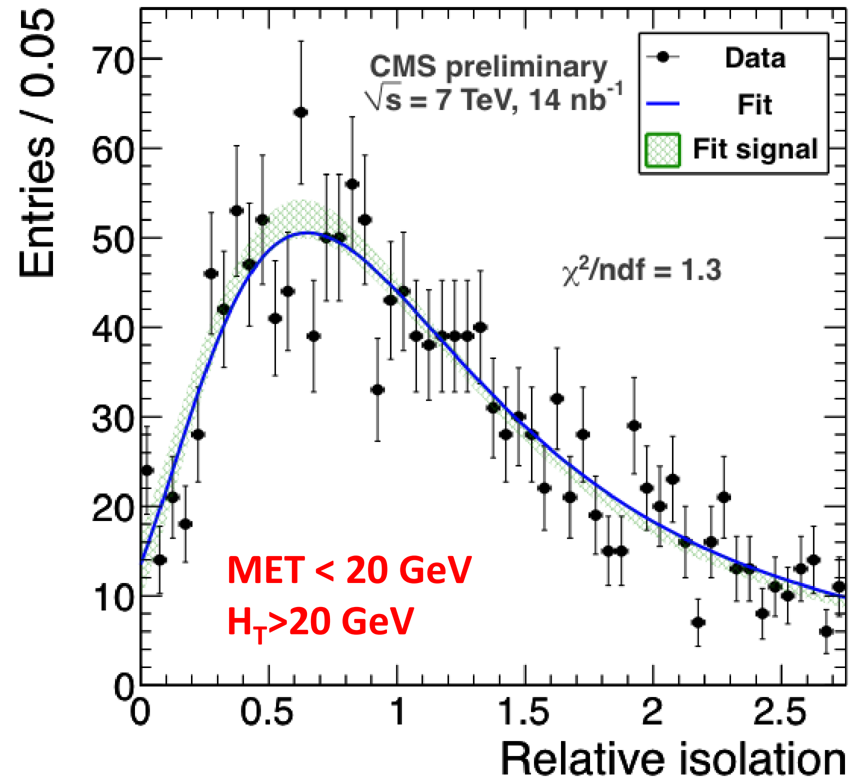
✓(RelIso<0.3) **Predicted : 224 ± 13**
Observed : 263

✓(RelIso<0.3) **Predicted : 215 ± 13**
Observed : 215

QCD background for ⌠+Jets+MET

- QCD contributes to ⌠ + Jets+ MET signature :
  - mainly due to heavy-flavor decays to muons
  - A fit procedure for Relative Isolation to predict bckgrd from non-prompt muons

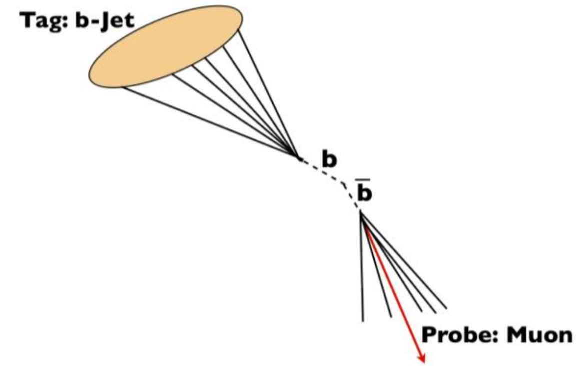


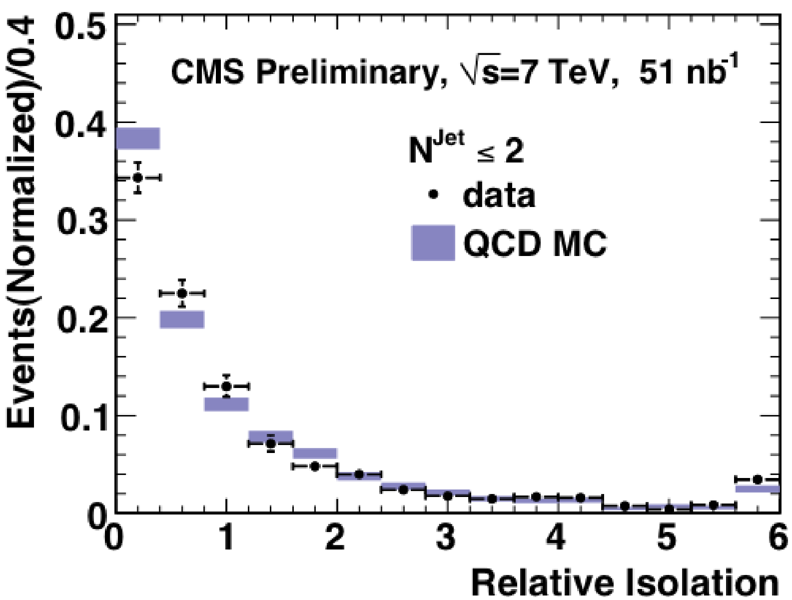


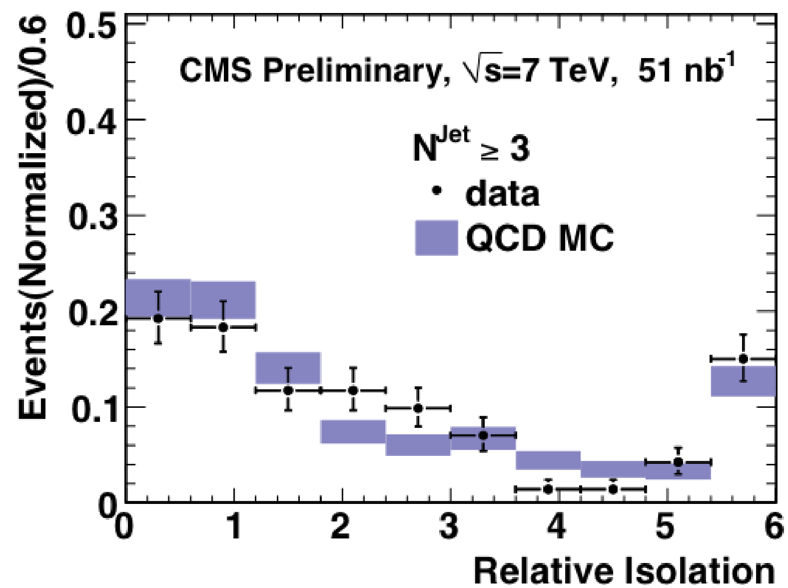
✓ **Good agreement between Predicted and Observed event yield in the signal region**

ttBar background for SS di-μ

- ttBar is the dominant background for Same-Sign (SS) di-μ signature: one from W and the other from b-decays
- Isolation is the main handle
- Tag&Probe method to measure isolation distribution of muons coming from heavy flavor decays



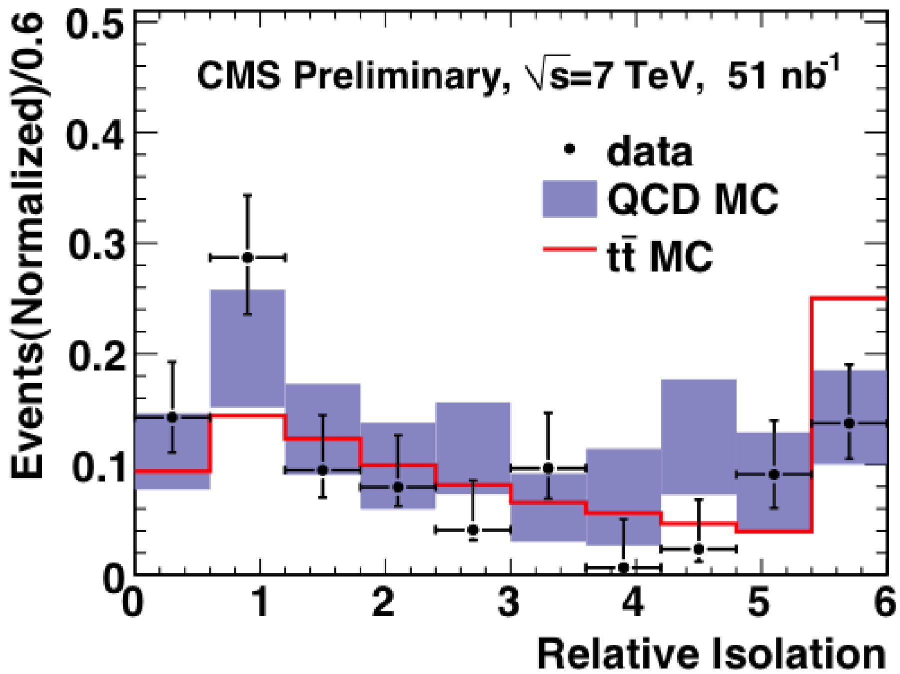




✓ **Strong dependency on the event topology, e.g. jet multiplicity**

Muon Isolation Template

- Significant differences in jet multiplicity and $p_T(\mu)$ in ttBar and generic QCD
- Re-weighting procedure to take this difference into account

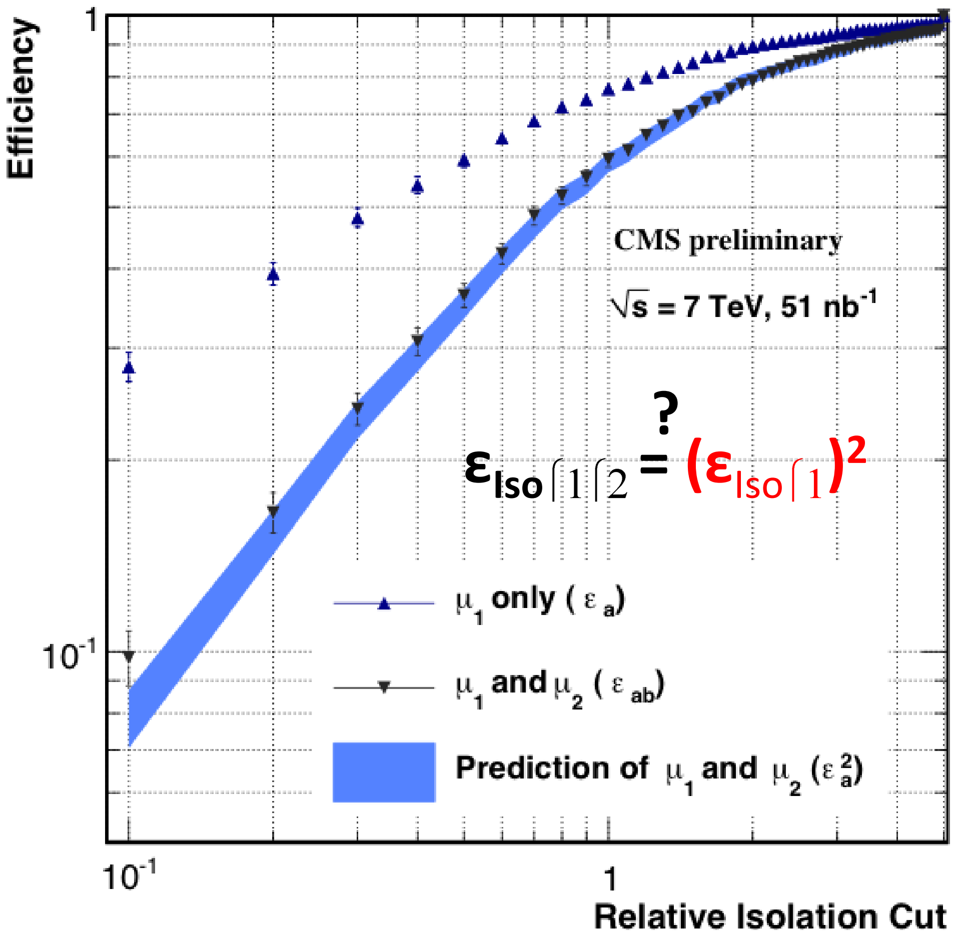


✓ **The agreement between QCD MC** (data-driven) **and ttBar MC** (matching to the generator level) **demonstrates the principle of the method**

✓ **Data agrees qualitatively with ttBar MC, for a quantitative prediction more data is necessary**

QCD background for SS di-μ

- QCD is expected to be the subdominant background for SS di-μ signature
- Exploit the fact that some selection cuts are uncorrelated ➔ selection efficiency for each cut can be measured in control samples



IsoCut(μ_1) : Isolation of μ_1, $\varepsilon_{Iso\,\mu1}$

IsoCut(μ_2) : Isolation of μ_2, $\varepsilon_{Iso\,\mu2}$

METCut : third jet and MET, ε_{MET}

$$\varepsilon_{AllCuts} = \varepsilon_{Iso\,\mu1} \cdot \varepsilon_{Iso\,\mu2} \cdot \varepsilon_{MET}$$

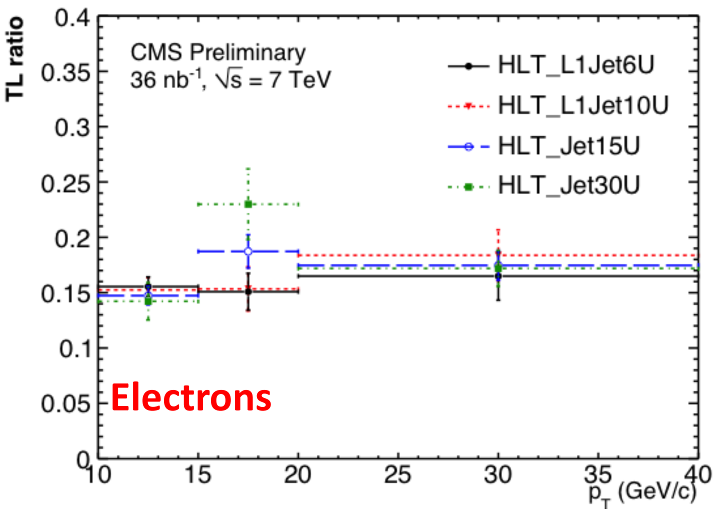
- **test the factorization of cuts IsoCut(μ_1) and IsoCut(μ_2), no jet & MET requirement yet**

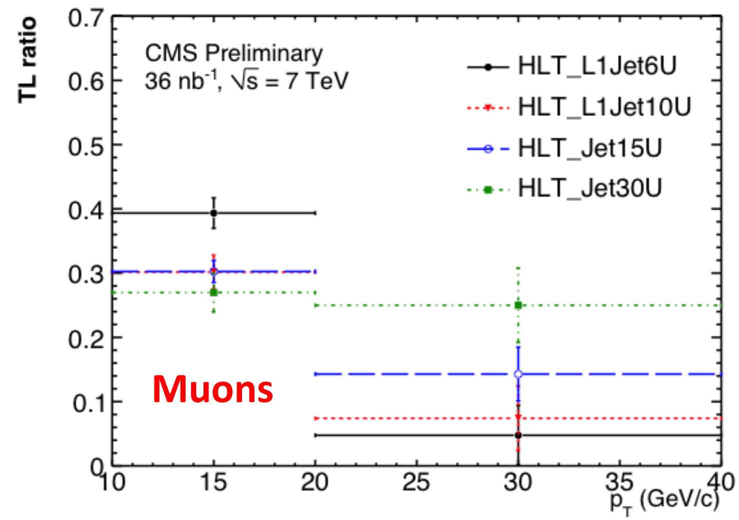
✓ **data indicates isolation of the μ_1 and μ_2 can be factorized**

SM background for SS di-lepton

- Data driven method for estimating SM background for SS *ee* , $\mu\mu$ and $e\mu$ channels
- Use a control sample (loose lepton-id & isolation) to measure efficiency of passing all analysis cuts, ("TL ratio"), as a function of lepton kinematics.

Monitor measured Tight-to-Loose-Ratios using different jet-triggered samples.





Predictions obtained using HLT_Jet15U

Channel	Predicted	Observed
ee	$0.43^{+0.18}_{-0.14}$	0
$e\mu$	$0.14^{+0.18}_{-0.09}$	1
$\mu\mu$	$0.22^{+0.51}_{-0.18}$	0

✓ **Measured TL ratio is stable within 50%**

✓ **Predicted & observed number of SS di-lepton events consistent**

Summary & Outlook

✓ **Understanding of the SM background is the first step towards BSM searches**

✓ **Dedicated methods to suppress the backgrounds and data-driven techniques to measure them from data are in place**

✓ **The data collected by CMS at 7 TeV allowed us to test some of these methods; data confirms the performance of the methods obtained with MC**

✓ **LHC performs very well; as of today four times more (~300 nb^{-1}) data than what is presented here is available**

✓ **Stay tuned for updates, we are at the beginning of an exciting journey**

References

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

1. "*Performance of Methods for Data-Driven Background Estimation in SUSY Searches*", CMS Physics Analysis Summary: **SUS-10-001**

2. "*CMS MET Performance in Jet Events from pp Collisions at sqrt s= 7 TeV*", **JME-10-004.**

3. "*The CMS physics reach for searches at 7 TeV* ", **CMS-NOTE-2010-008**

4. "*SUSY searches with dijet events*", CMS Physics Analysis Summary: **SUS-08-005**

5. "*Search strategy for exclusive multi-jet events from supersymmetry at CMS*", CMS Physics Analysis Summary: **SUS-09-001**

6. "*Data-Driven Background Estimates for SUSY Di-Photon Searches*", CMS Physics Analysis Summary: **SUS-09-004**

7. L.Randall and D. Tucker-Smith, "*Dijet searches for Supersymmetry at the LHC* ", Phys.RevLett. 101221803 (2008)