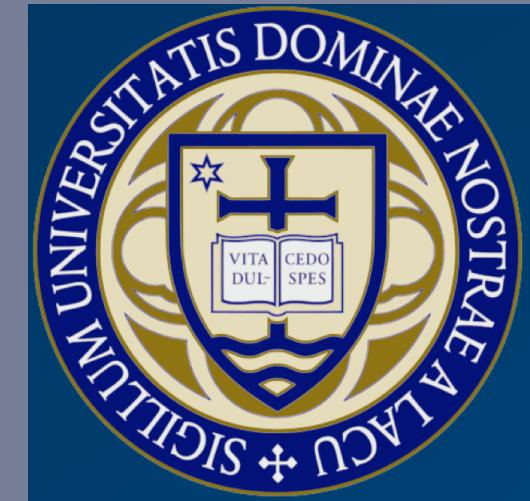
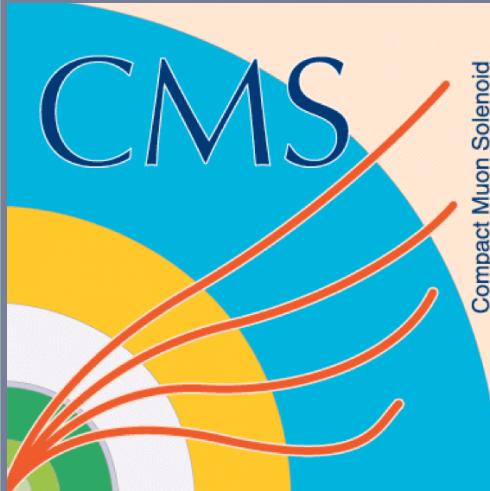
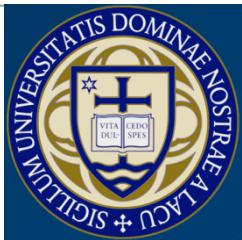
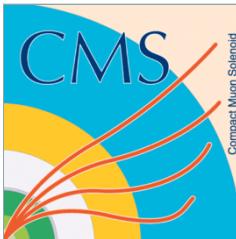


Beyond Standard Model Higgs Decaying to Tau Pairs at CMS

1

Jamie Antonelli (Notre Dame)
on behalf of the CMS
collaboration

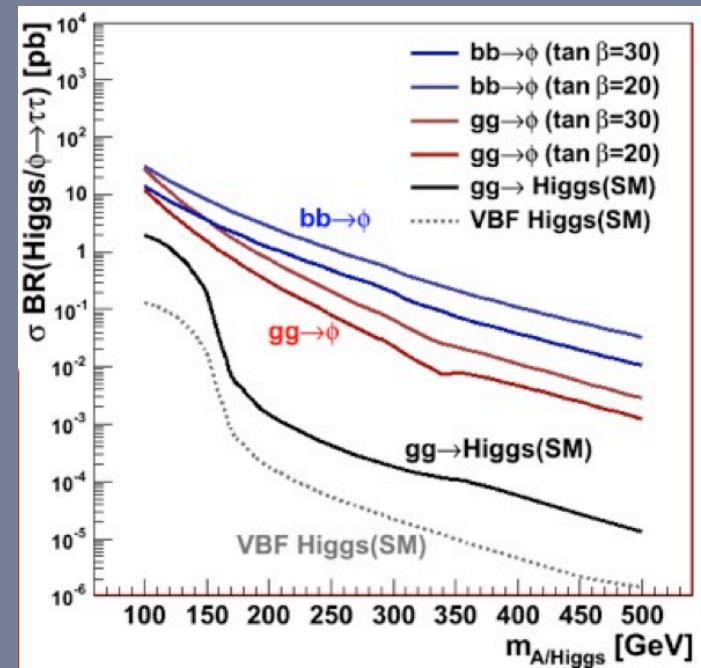
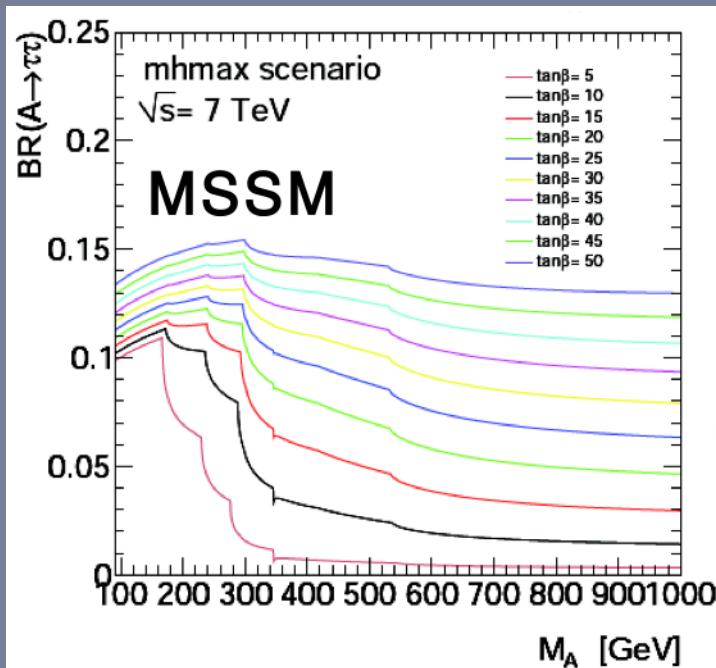


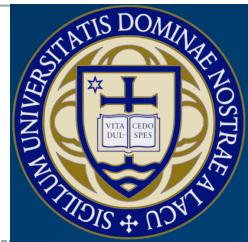


Introduction

2

- MSSM: Minimal Supersymmetric Standard Model
 - Parameters of interest: M_A and $\tan(\beta)$
- Branching Ratio to taus enhanced with high $\tan(\beta)$

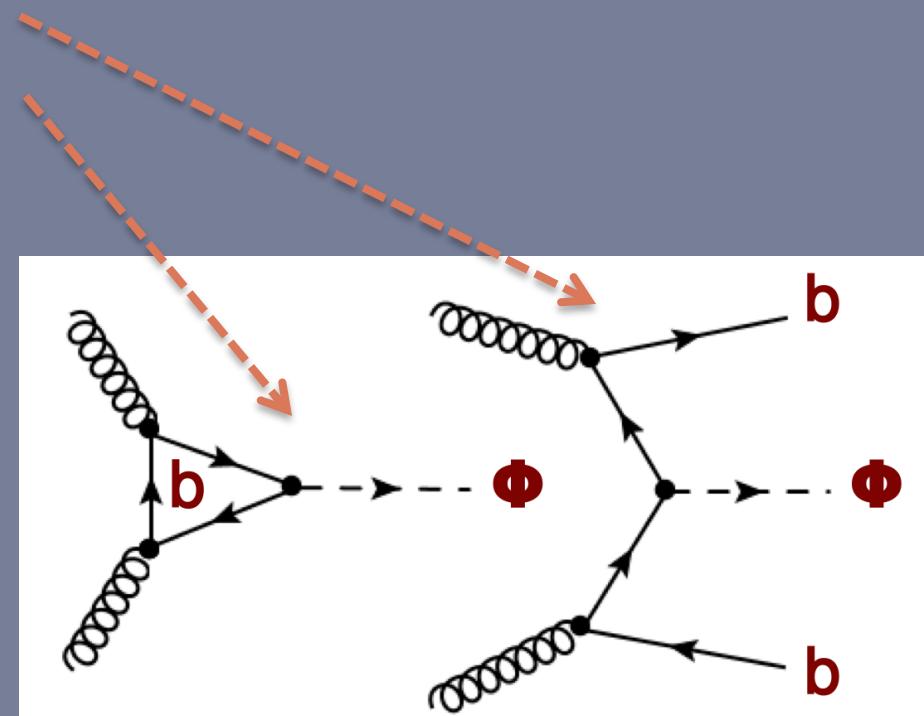




LHC Production Mechanisms

3

- We have mutually exclusive event categories to identify each production channel separately
 - Number of b-tagged jets ≥ 1
 - Number of b-tagged jets = 0
- Two channels considered separately in limit calculations

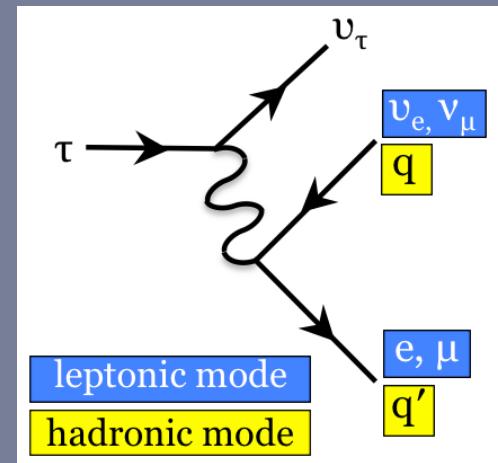




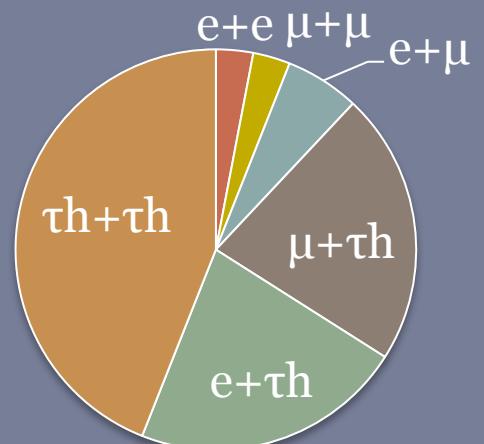
Tau Decay Modes

4

- Taus decay before reaching tracker
- Leptonic decays (35%)
 - e or μ & 2 neutrinos
- Hadronic decays (65%)
 - Narrow, isolated jet & neutrino
- Can't fully reconstruct Higgs mass
 - Fit visible mass distributions to extract limits



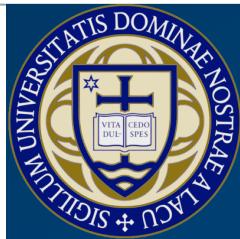
Tau Pair Branching Fractions





Tau Pair Final States

5



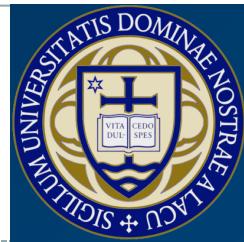
- Muons are much cleaner than electrons
- Leptonic decays are cleaner than hadronic
 - Trade-off with lower branching fractions

Final State	Advantages/Disadvantages	
<i>Not Used -></i>		
$e + e$	High background from $Z/\gamma^* \rightarrow ee$	Fully Leptonic
$\mu + \mu$	High background from $Z/\gamma^* \rightarrow \mu\mu$	
$e + \mu$	Very low background / Low statistics	
$\mu + \tau_h$	Higher statistics, Low backgrounds	
$e + \tau_h$	Higher statistics / Higher backgrounds	
<i>Not Used -></i>		
$\tau_h + \tau_h$	Very high statistics / High QCD background	Fully Hadronic

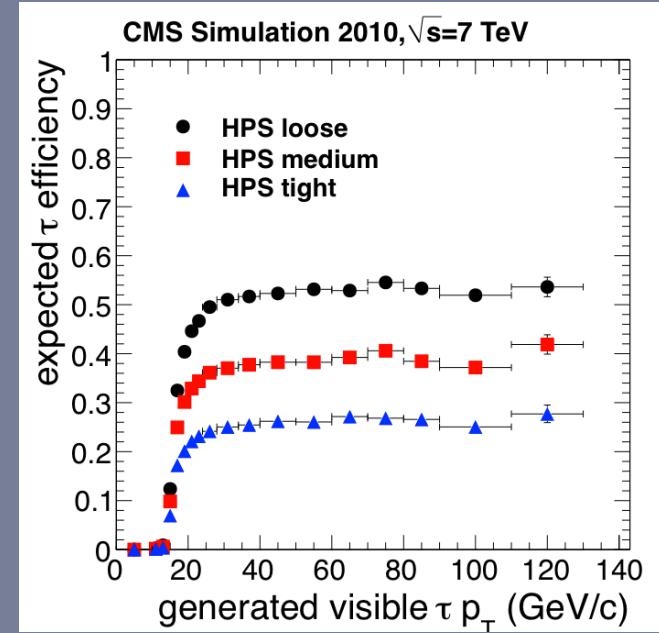
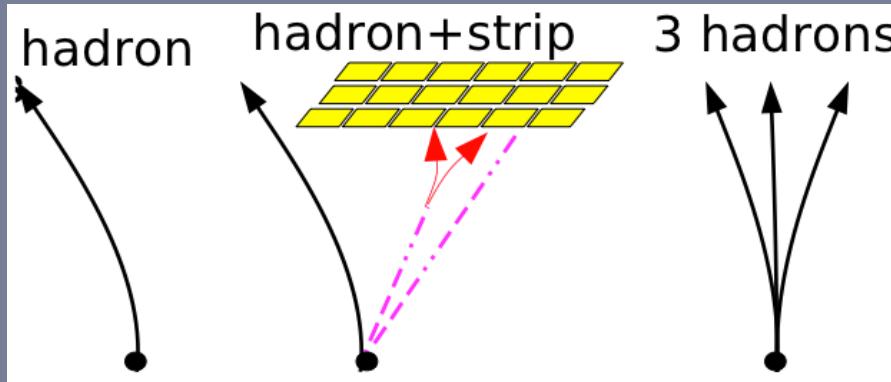


Tau Reconstruction & Identification

6



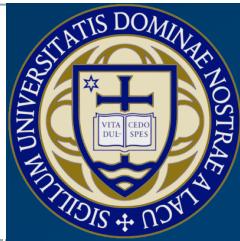
- Tau \Leftrightarrow hadronic tau decay
- Use Particle Flow objects as input
 - Attempts to uniquely identifies each particle in event
- Hadron Plus Strips (HPS) algorithm
 - Identify specific decay mode
 - ✖ 1 prong, 1 prong + π_0 , 3 prong





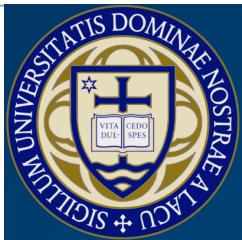
Lepton Selections

7



1. Use standard CMS reconstructions for Jets, ME_T , Electrons, Muons
2. Kinematic and acceptance cuts

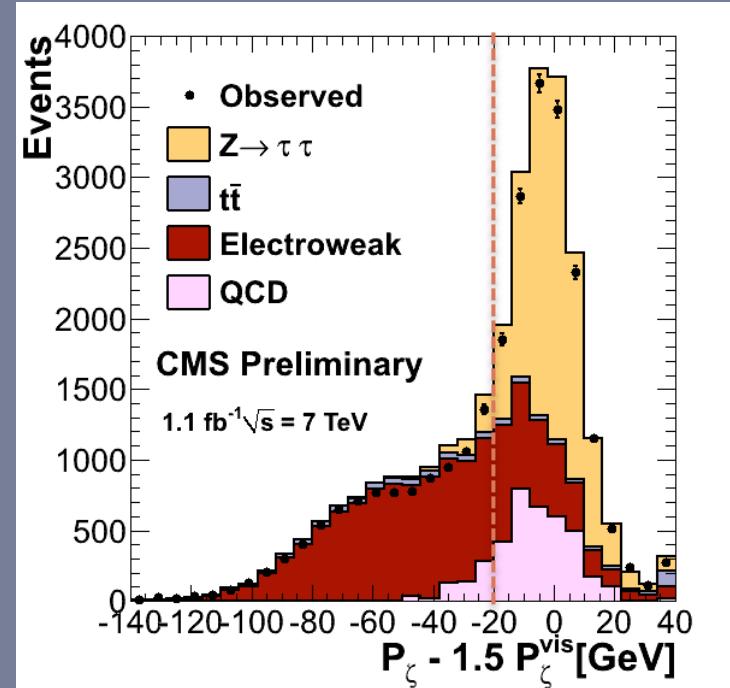
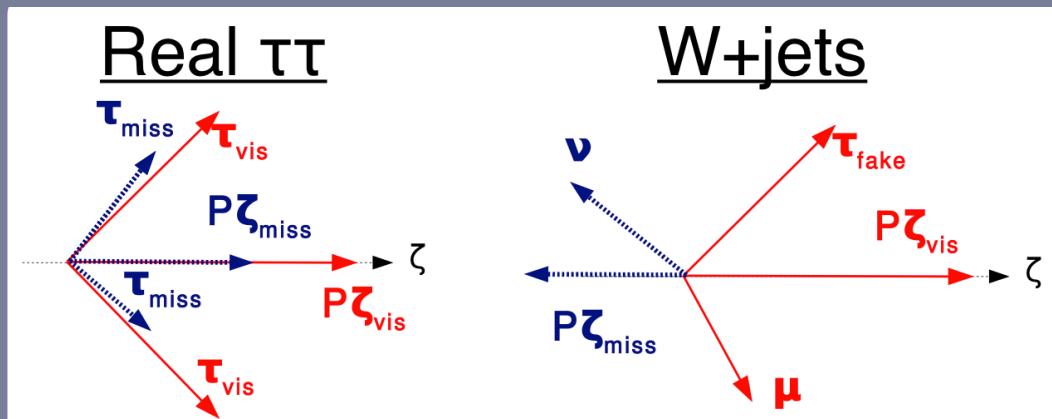
Channel		Min P_T (GeV)	Max $ \eta $
$\mu + \mu$	μ_1	20	2.1
	μ_2	10	2.4
$e + \mu$	e	20 (10)	2.5
	μ	10 (20)	2.1
$\mu + \tau_h$	μ	15	2.1
	τ_h	20	2.3
$e + \tau_h$	e	15	2.1
	τ_h	20	2.3



Event Selections

8

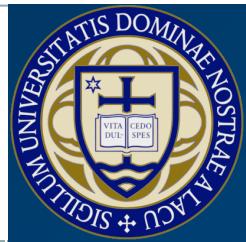
- Oppositely charged legs of di-tau candidate
- P_ζ variable inherited from CDF
- Mumu channel adds:
 - MET < 65 GeV
 - Likelihood based selection



We reject events below -20



Selected $\mu + \mu$ events



9

No b-tag

Background

 15645 ± 105

Data

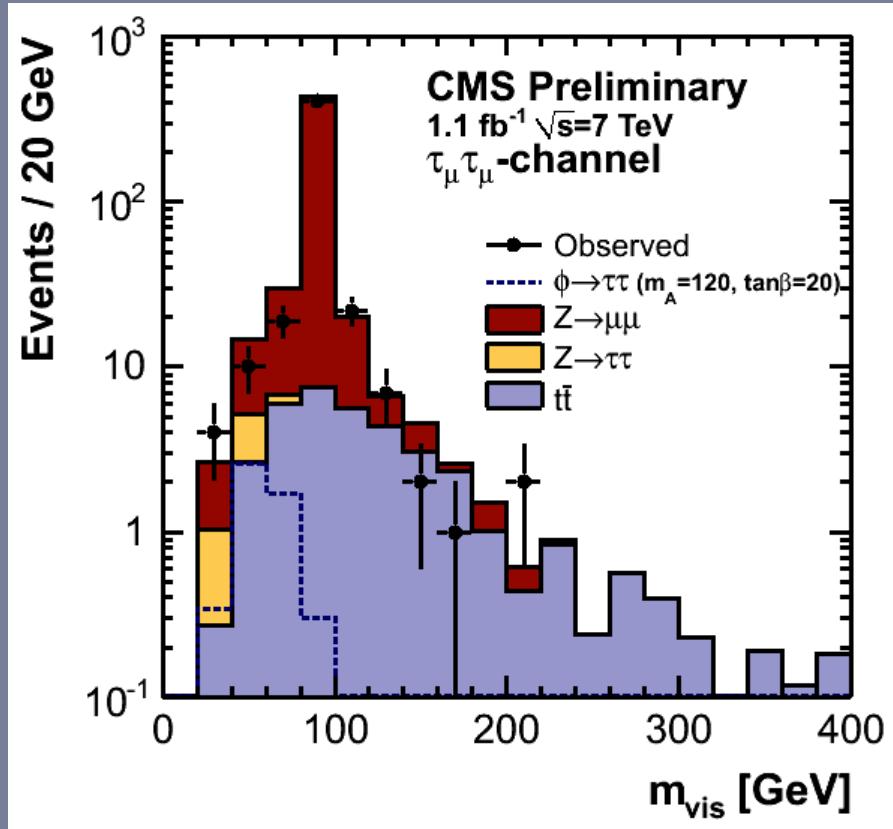
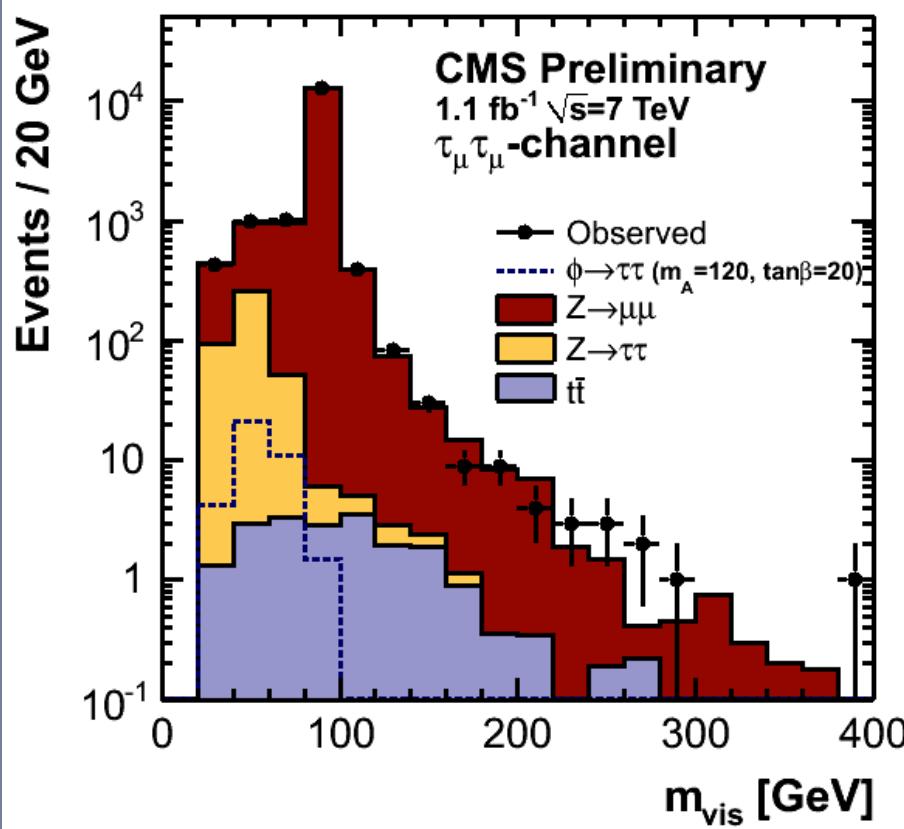
15711

Background

 460 ± 12

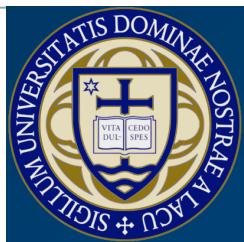
Data

479





Selected $e + \mu$ events



10

No b-tag

Background

 3643 ± 131

Data

3942

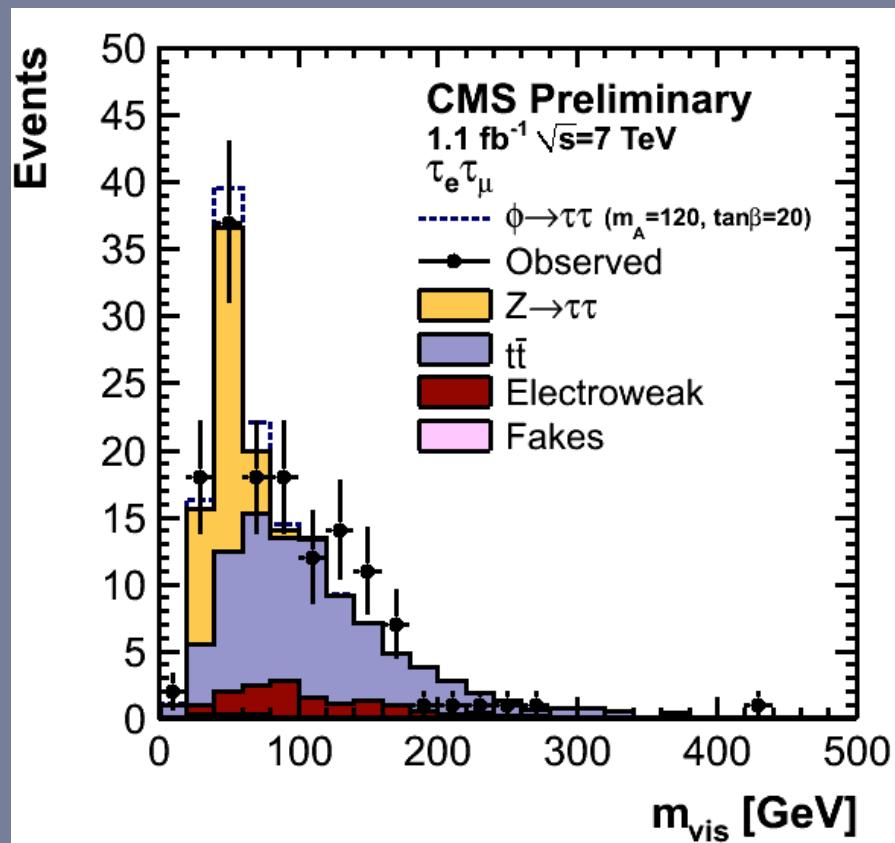
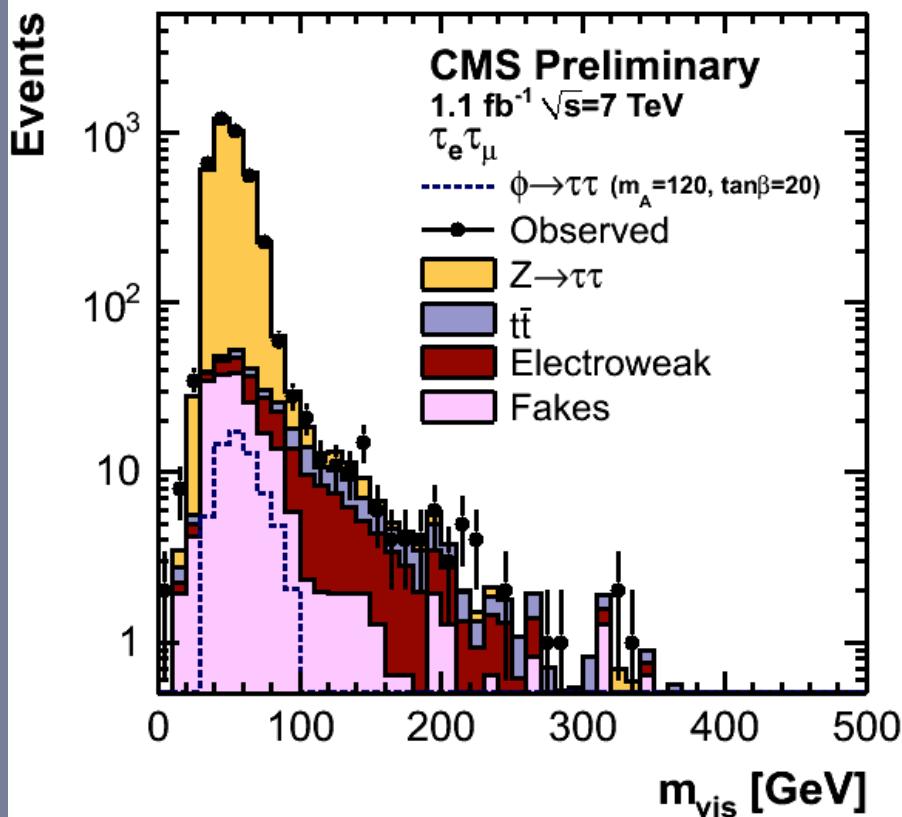
b-tag

Background

 150 ± 12

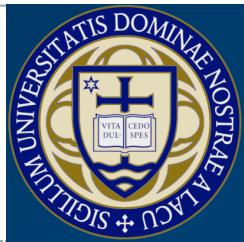
Data

143





Selected $\mu + \tau_h$ events



11

No b-tag

Background

 14514 ± 640

Data

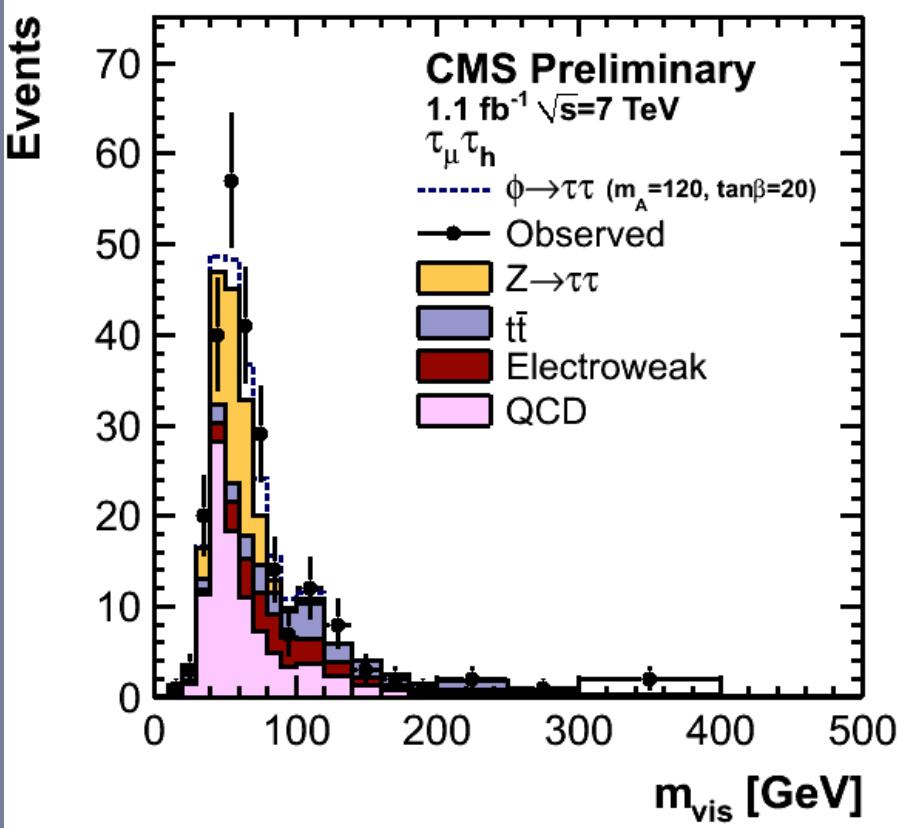
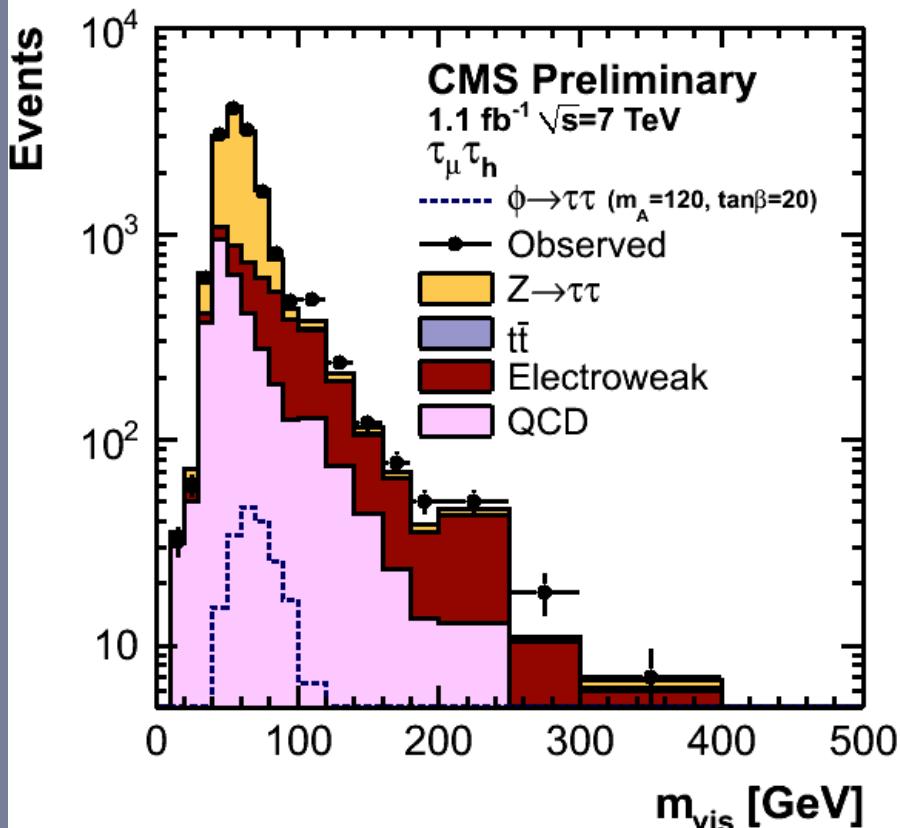
15057

Background

 193 ± 13

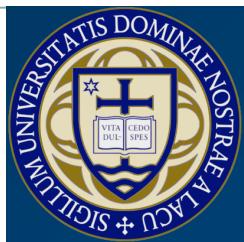
Data

b-tag





Selected $e + \tau_h$ events



12

No b-tag

Background

 9398 ± 320

Data

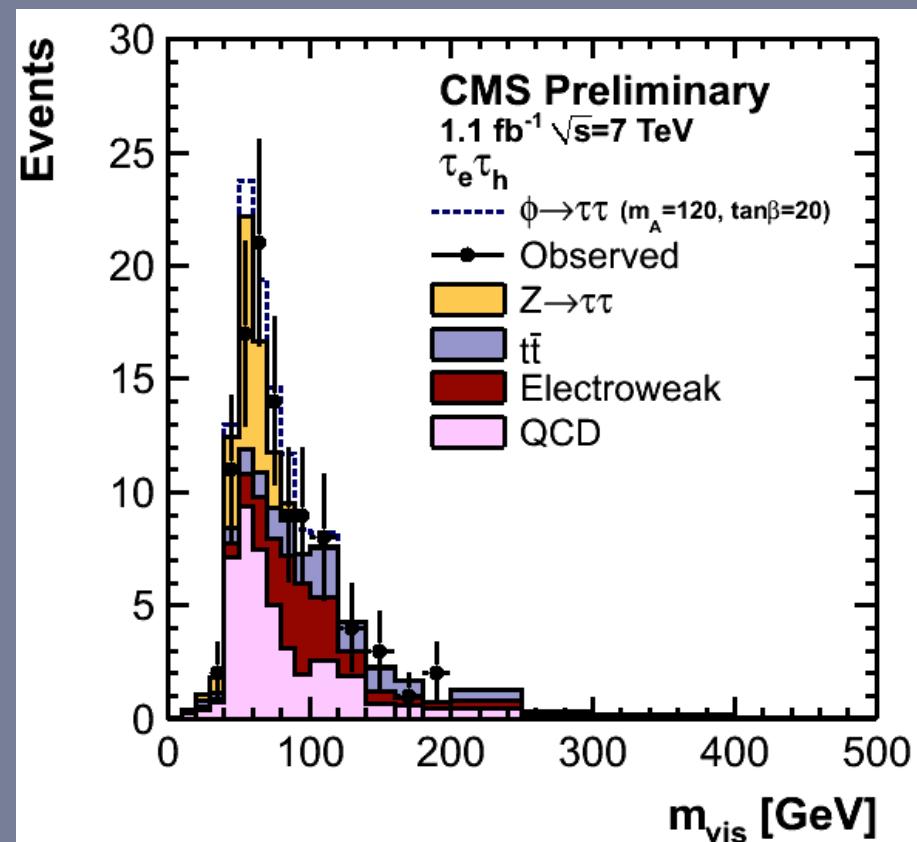
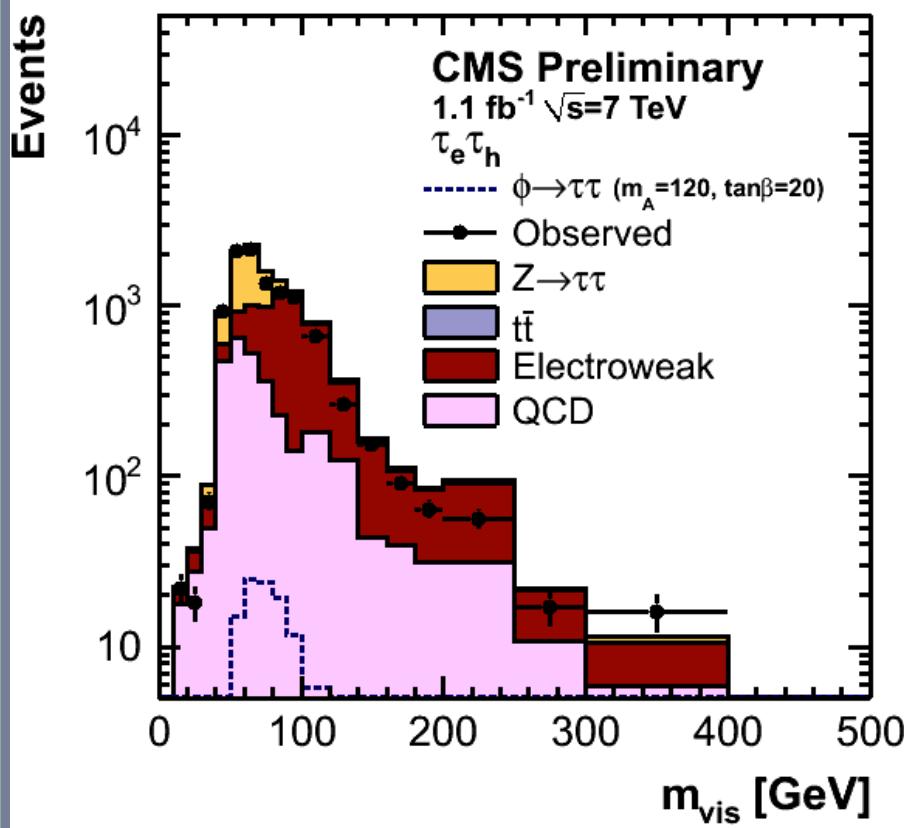
10283

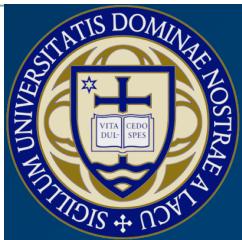
Background

 105 ± 9

Data

101





Background Estimations

13

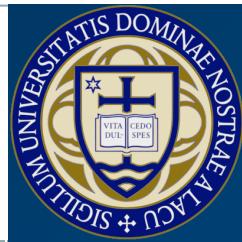
- For each background, we need:
 - The shape of the visible mass spectrum
 - The overall amount (normalization)

Background	Shape	Normalization
QCD	Use OS/SS method on SS data	
Z- $\tau\tau$	MC	CMS σ result
W+Jets	MC	P_ζ sideband
TTbar	MC	CMS σ result
Di-boson	MC (very small contribution)	
Z- ee , Z- $\mu\mu$	CMS results, fake rate method in e μ	



Systematics

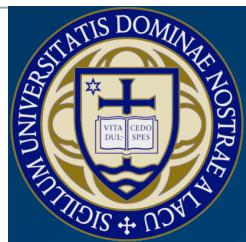
14



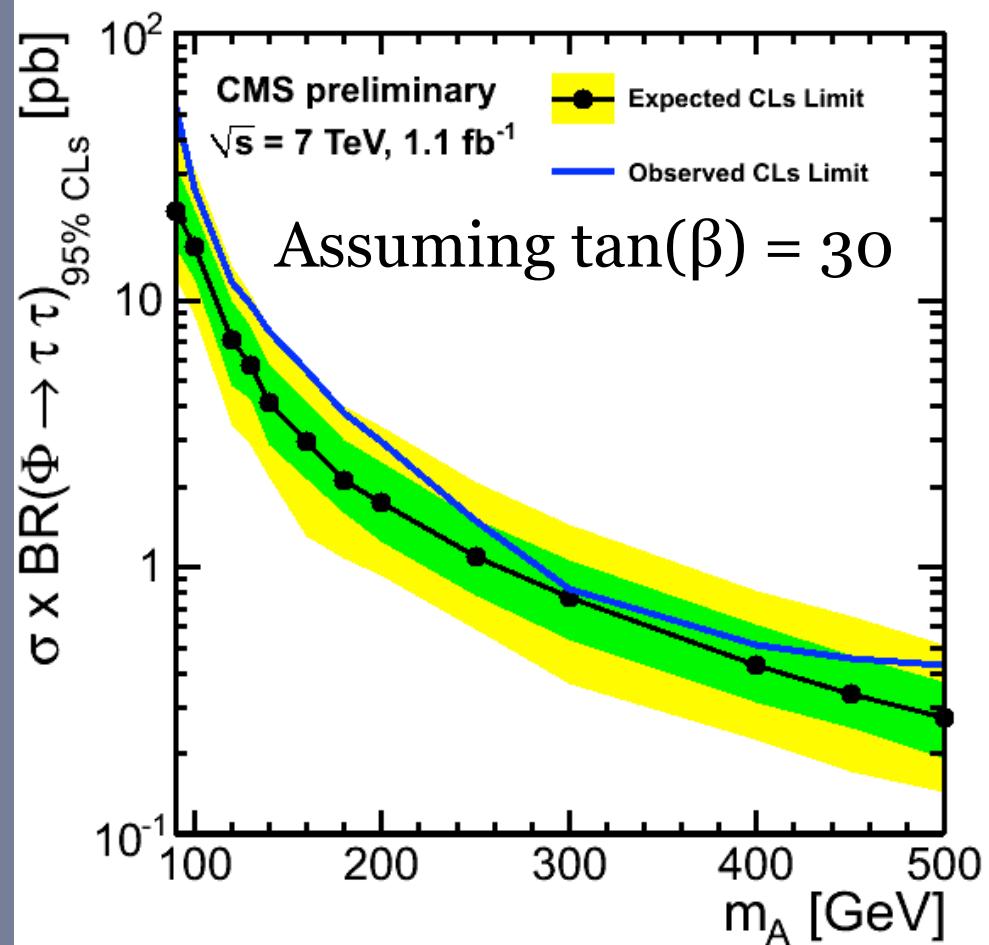
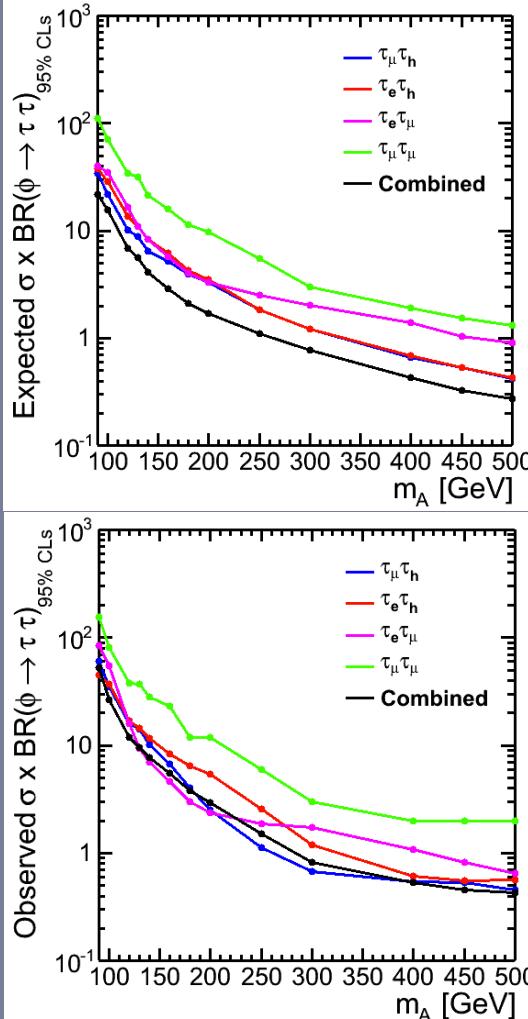
Source	Uncertainty	Usage
Lepton ID /trigger	1%	Efficiency correction factors
Tau ID efficiency	6%	Efficiency correction factors <- was 23%
Tau energy scale	3%	Shape uncertainties
$\sigma(Z \rightarrow \mu\mu/\text{ee})$	3%	Z $\rightarrow \tau\tau$ yield normalization
$\sigma(t\bar{t})$	12%	TTBar yield normalization
B-Tag Efficiency	10%	Correction factors
B-Tag Mistag rate	14%	Correction factors
Jet energy scale	2-5%	JEC in acceptance for BTagging/VBF
PDFs	3%	Uncertainty in cross section
UE/Parton Shower	4%	Uncertainty in cross section
QCD Scale	4-12%	Uncertainty in cross section
Luminosity	6%	



$\sigma \times \text{BR}$ Limits



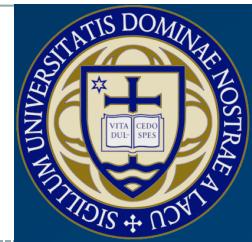
15



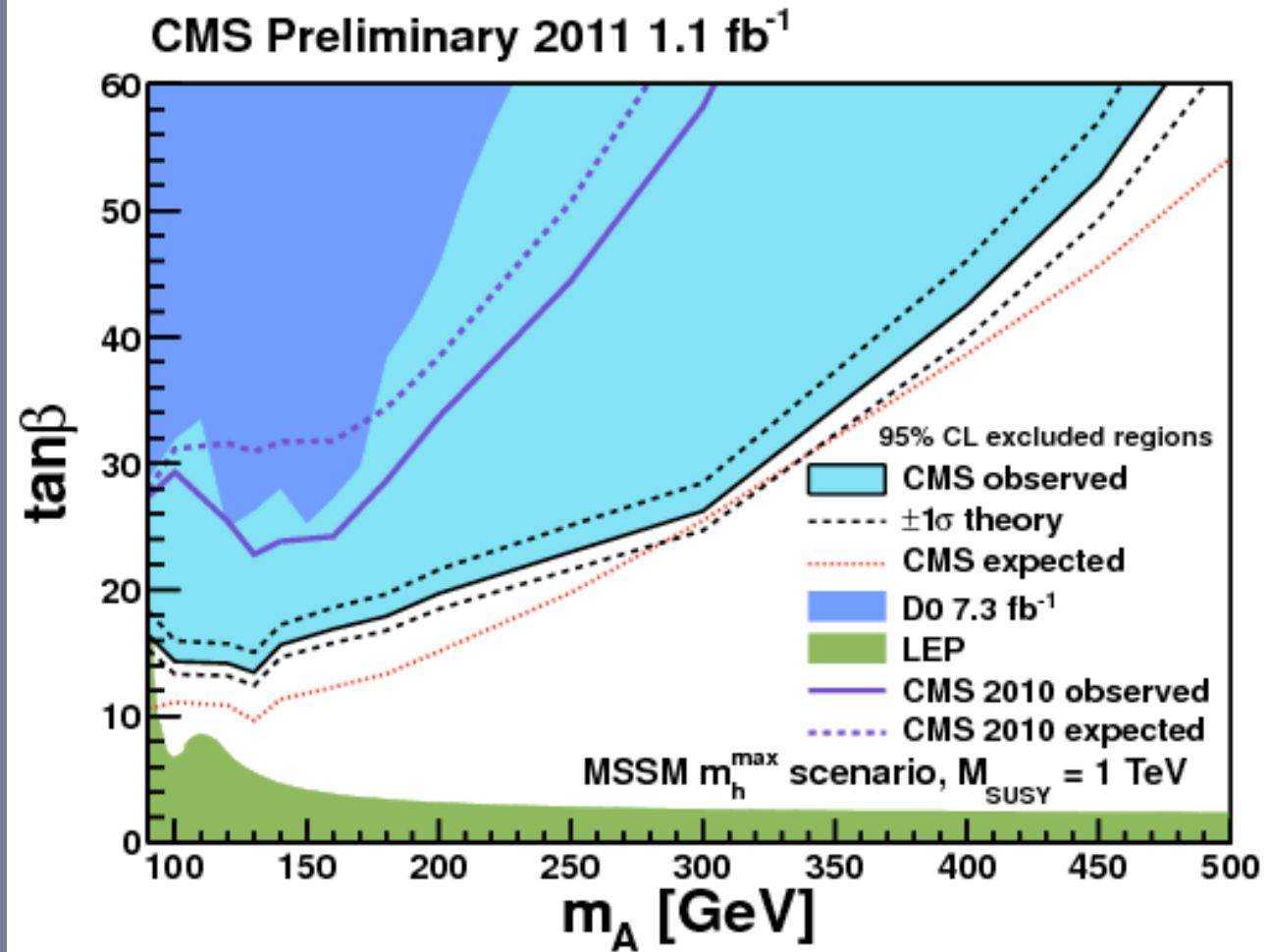


MSSM Interpretation

16



Big improvement from 2010 measurement!

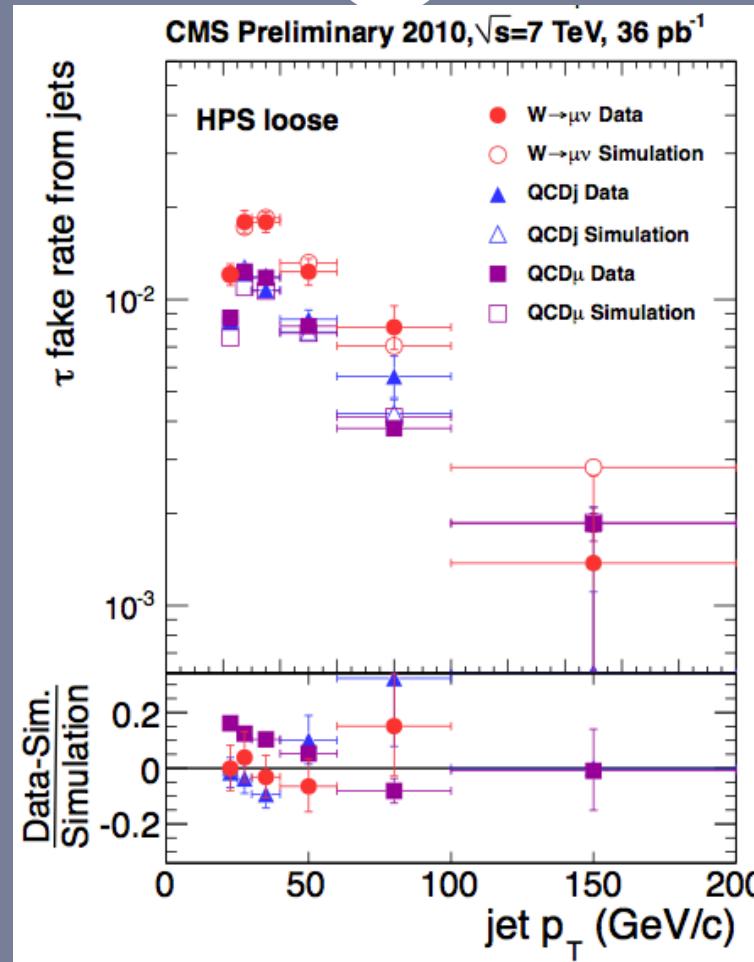


BACKUP

17

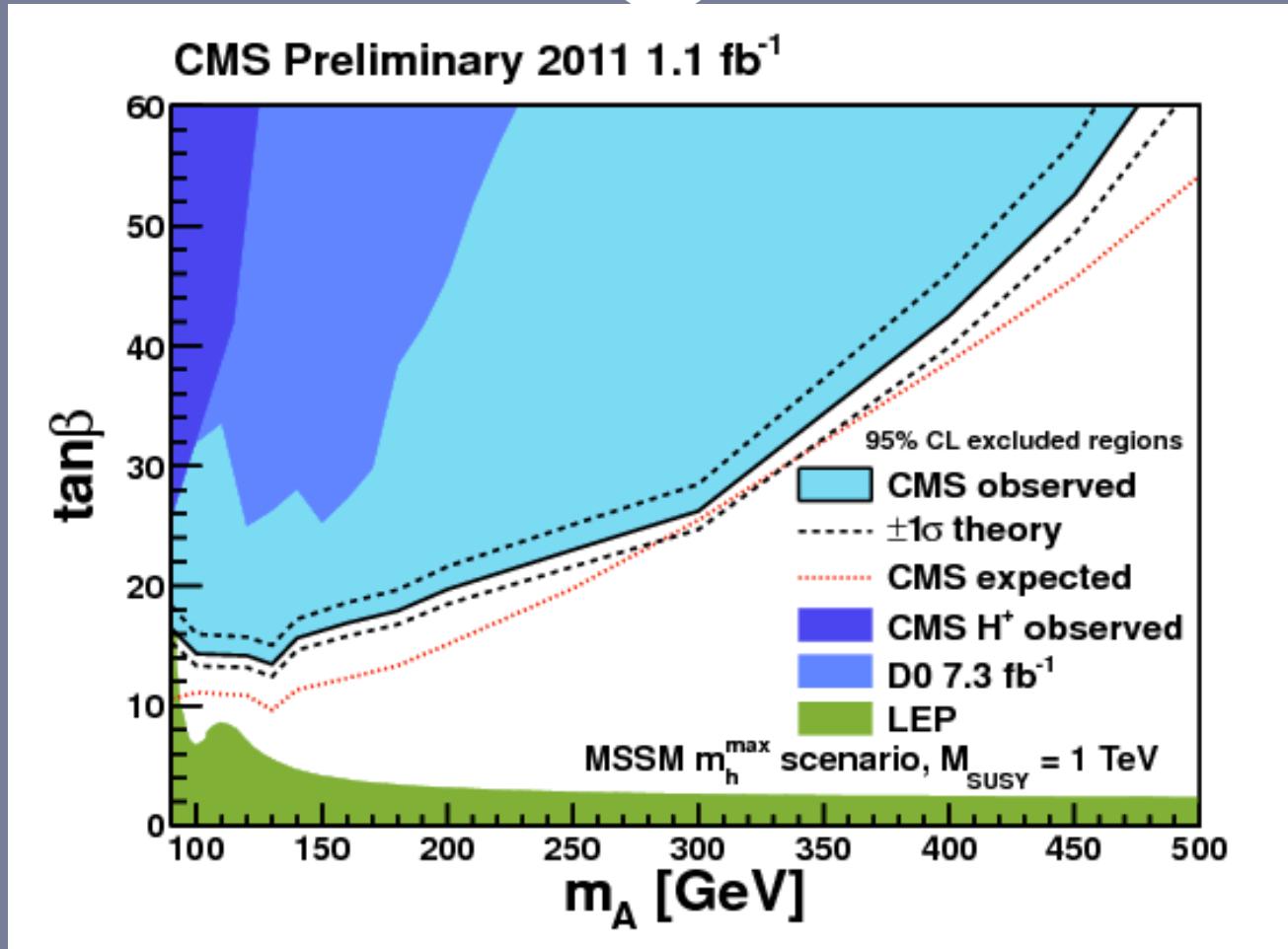
HPS performance

18



MSSM space with H⁺ result

19



SM Higgs->tautau limit

20

