

t \bar{t} SPIN
CORRELATION AT
D-ZERO

Suyong Choi (Korea University)

$t\bar{t}$ SPIN CORRELATION MEASUREMENT

◉ Channel: $t\bar{t} \rightarrow \ell^+ \nu b \ell^- \bar{\nu} \bar{b}$

- Lepton is the most sensitive probe of top-quark spin
- 5.4 fb^{-1} of $p\bar{p}$ @ $\sqrt{s} = 1.96 \text{ TeV}$ collected with D-Zero detector

◉ Spin correlation parameter C

$$\frac{1}{\sigma} \frac{d^2\sigma}{d \cos \theta_1 d \cos \theta_2} = \frac{1 - C \cos \theta_1 \cos \theta_2}{4}$$

- Angle of lepton and spin-quantization axis in the t or \bar{t} rest frame
- For beamline basis: $C = 0.777^{+0.027}_{-0.042}$ at NLO
- Full reconstruction of missing neutrino momenta necessary

EVENT SELECTION

- MC Signal

- MC@NLO with or without spin correlation
- HERWIG for fragmentation and hadronization

- MC backgrounds

- Drell-Yan
- Diboson

- Selection

- Two leptons (e or μ) $p_T > 15$ GeV
- Two jets $p_T > 20$ GeV $|\eta| < 2.5$ - jets should point back to the correct primary vertex
- Missing ET or missing ET significance cuts

$t\bar{t}$	Z/γ^*	Diboson	Instrumental	Total	Observed
341 ± 30	93 ± 15	19 ± 3	28 ± 5	481 ± 39	485

ANALYSIS

- Likelihood is calculated
 - Spin correlation hypothesis
 - Uncorrelated spin hypothesis

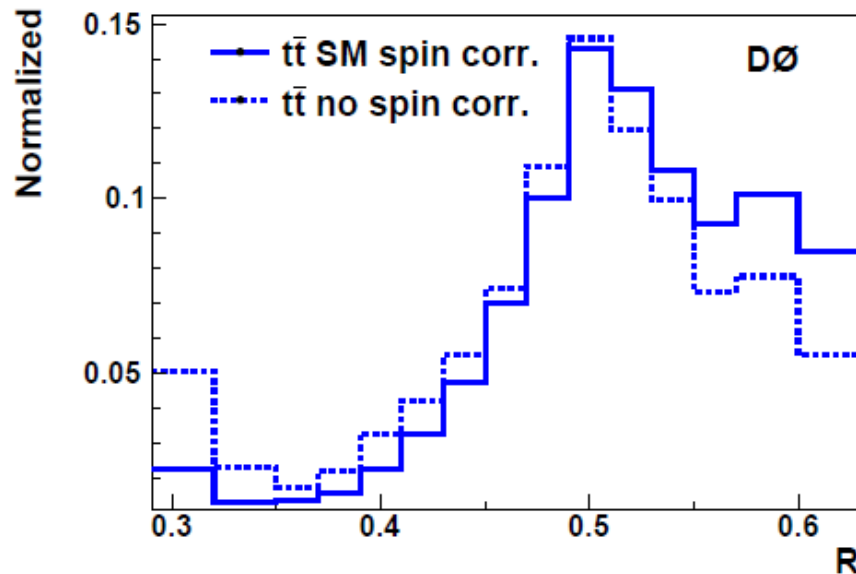
$$P_{\text{sgn}}(x; H) = \frac{1}{\sigma_{\text{obs}}} \int f_{\text{PDF}}(q_1) f_{\text{PDF}}(q_2) dq_1 dq_2 \cdot \frac{(2\pi)^4 |\mathcal{M}(y, H)|^2}{q_1 q_2 s} W(x, y) d\Phi_6.$$

- Use LO matrix element

DISCRIMINANT

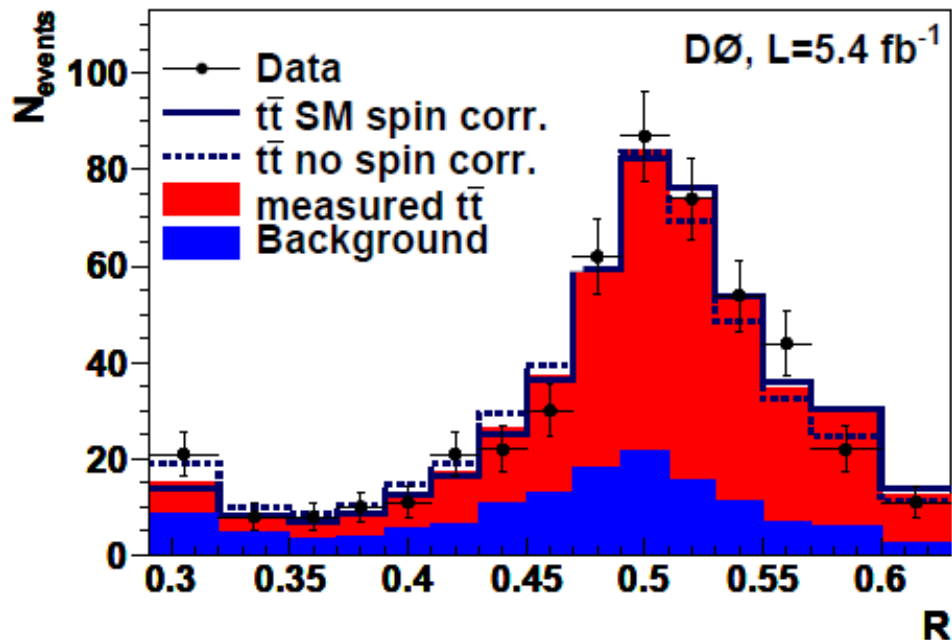
$$R = \frac{P_{\text{sgn}}(H = c)}{P_{\text{sgn}}(H = u) + P_{\text{sgn}}(H = c)}$$

- Larger values of R indicates higher likelihood for spin correlation hypothesis



- Information is irretrievably lost + confusion of assignment produce bias in R

DISCRIMANT FOR DATA AND FULLY SIMULATED MC



- ⊙ Fraction of spin-correlated events is extracted through a fit to distribution of R

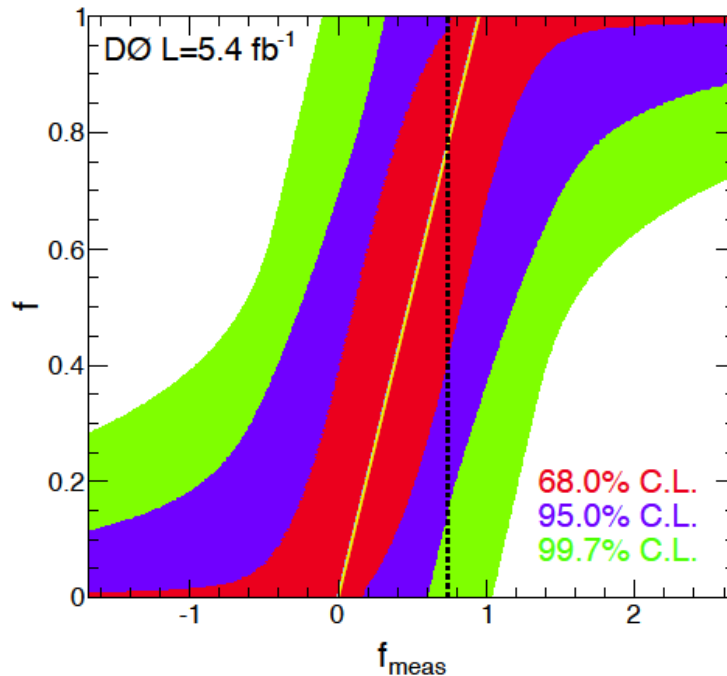
$$m^{(i)} = f_{\text{meas}} m_c^{(i)} + (1 - f_{\text{meas}}) m_u^{(i)} + \sum_j m_j^{(i)}$$

RESULT

- Measured fraction

$$f_{meas} = 0.74_{-0.41}^{+0.40} (stat + syst)$$

- Exclude $f=0$ at 97.7% CL



$$C_{meas} = 0.57 \pm 0.31$$

RECENT SEARCHES FROM CMS

Suyong Choi (Korea University)

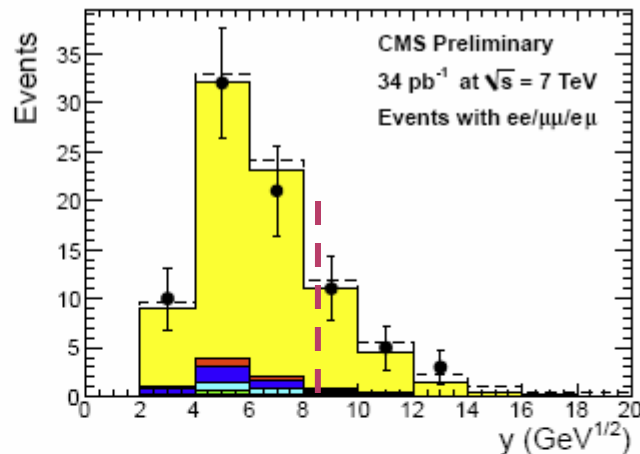
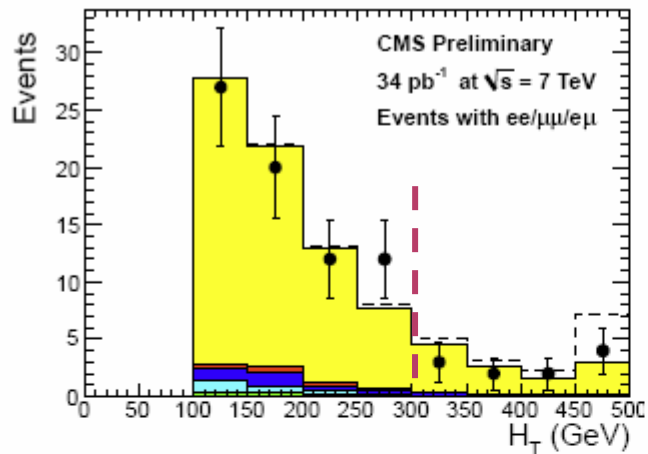
CONTENTS

⊙ Searches

- Searches in dilepton + jets
- Searches in diphoton channels
- MSSM Higgs Searches in $\tau\tau$

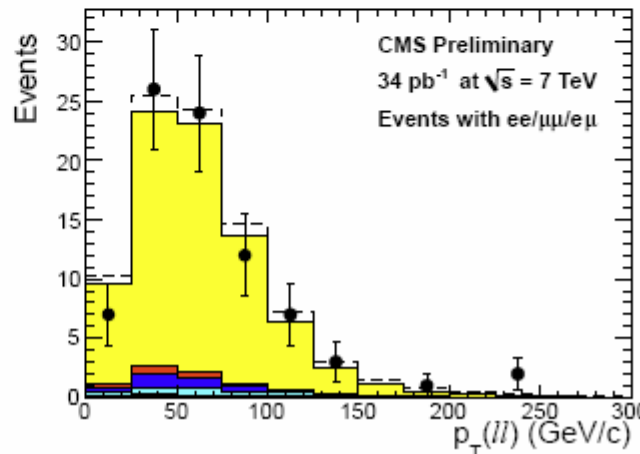
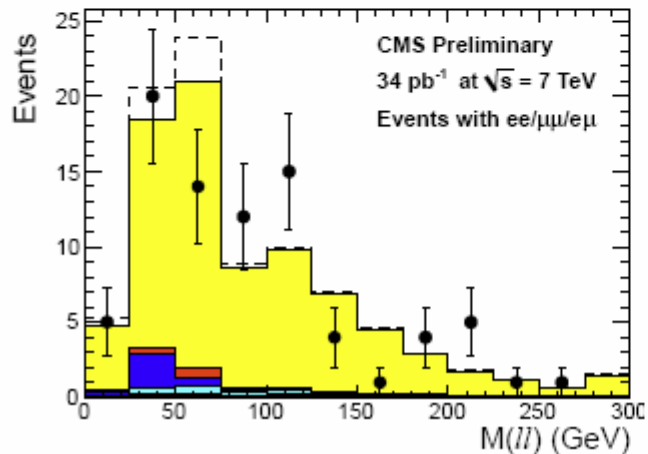
⊙ Summary

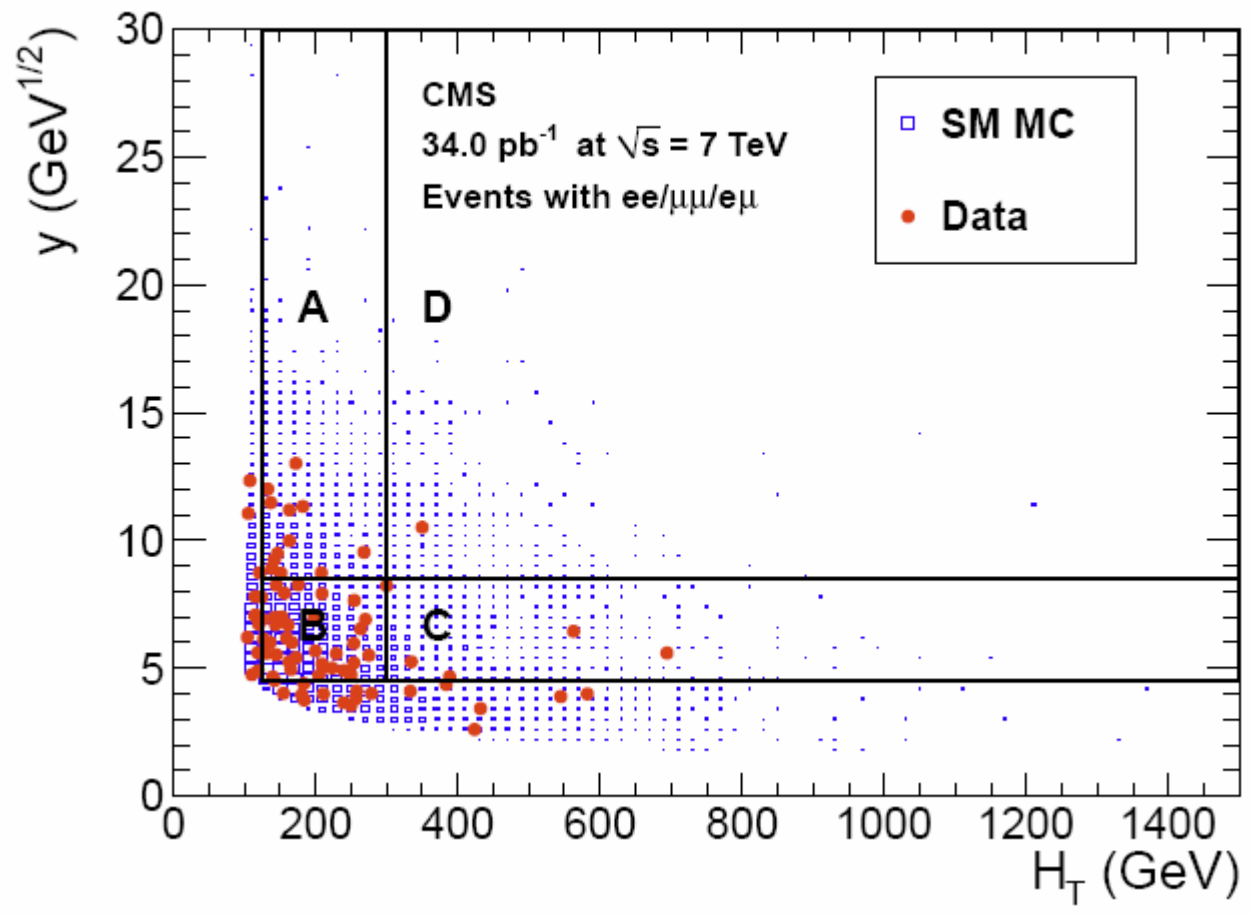
GENERIC SEARCHES IN OPPOSITE SIGNED DILEPTON + 2 JETS + MET



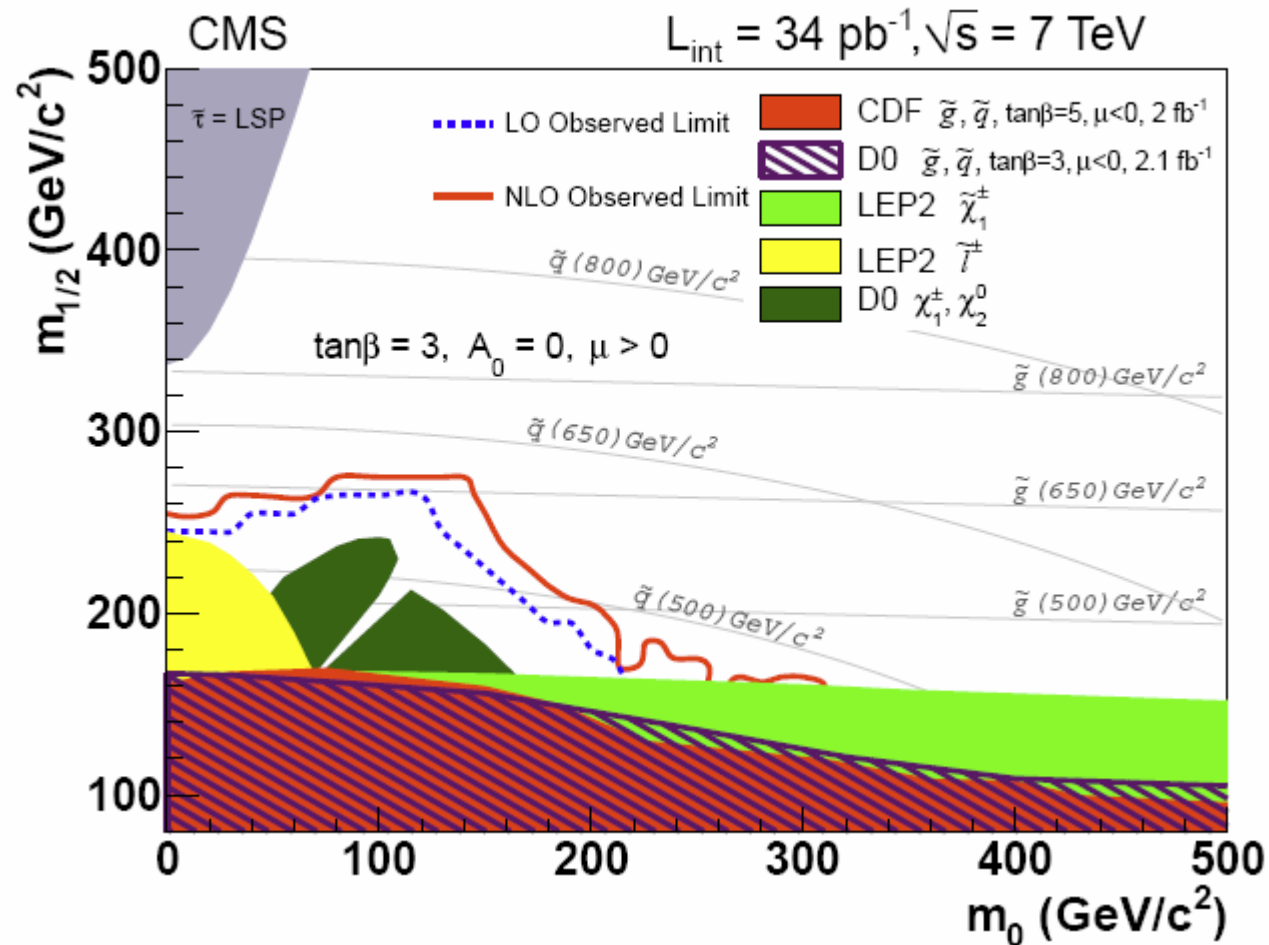
$$y = \frac{MET}{\sqrt{H_T}}$$

- data
- $t\bar{t} \rightarrow l^+l^-$
- $t\bar{t} \rightarrow ot$
- DY
- single
- VV
- $W + j\bar{j}$
- LM1





SUSY SEARCH IN OPPOSITE SIGNED DILEPTONS (ARXIV:1103.1348)



TRIGGERS AND SELECTION

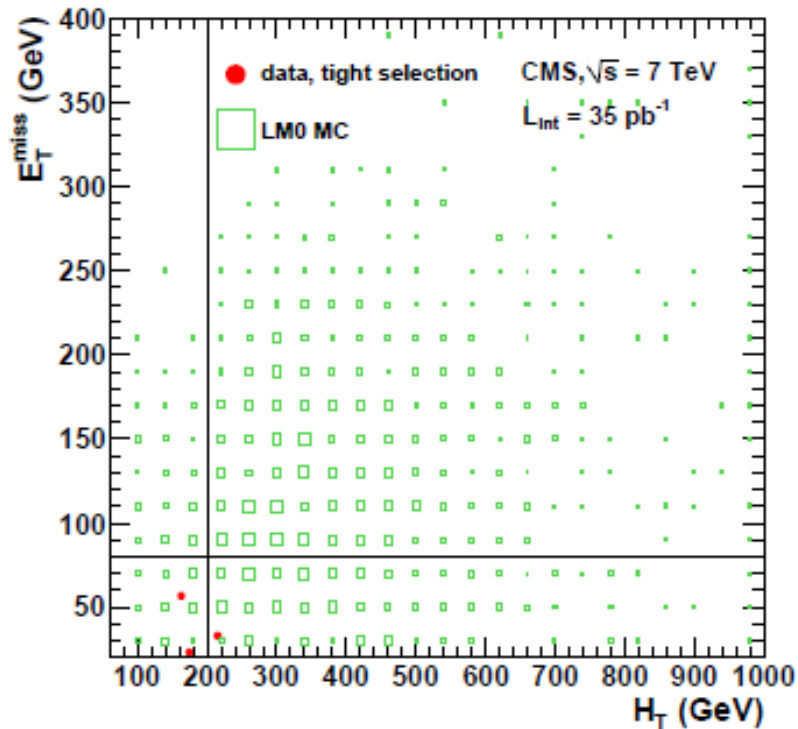
⊙ Triggers

- Lepton triggers
 - Reach lower values of H_T
- Hadronic H_T triggers
 - Reach lower p_T for leptons
 - Include hadronic Tau final states

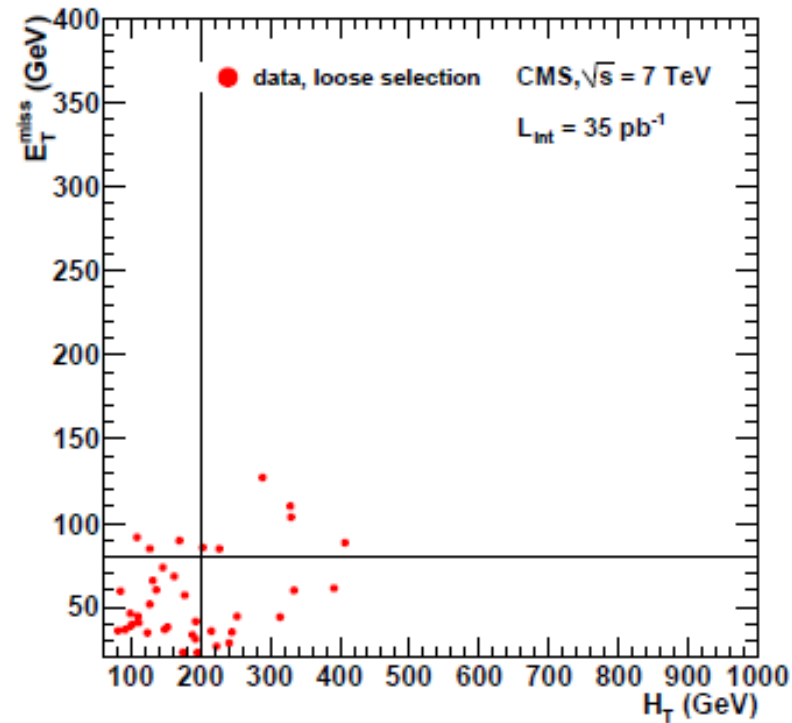
⊙ Selection

- Leading $p_T > 20$, second $p_T > 10$
- Isolation
- 2 jets $p_T > 30$ GeV
- Signal search region $MET > 80$ GeV or $H_T > 200$ GeV

AFTER BASELINE SELECTION



2 isolated leptons



1 isolated lepton

SIGNAL REGION

Lepton triggered events

Search Region	ee	$\mu\mu$	$e\mu$	total	95% CL UL Yield
Lepton Trigger					
$E_T^{\text{miss}} > 80 \text{ GeV}$					
MC	0.05	0.07	0.23	0.35	
predicted BG	$0.23^{+0.35}_{-0.23}$	$0.23^{+0.26}_{-0.23}$	0.74 ± 0.55	1.2 ± 0.8	
observed	0	0	0	0	3.1
$H_T > 200 \text{ GeV}$					
MC	0.04	0.10	0.17	0.32	
predicted BG	0.71 ± 0.58	$0.01^{+0.24}_{-0.01}$	$0.25^{+0.27}_{-0.25}$	0.97 ± 0.74	
observed	0	0	1	1	4.3

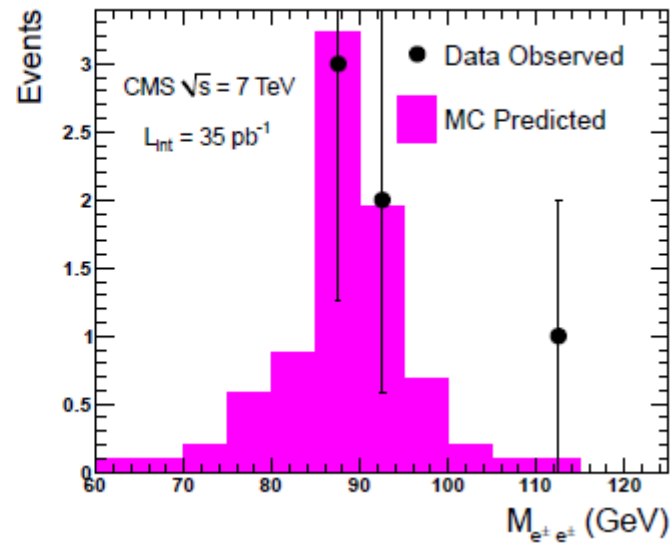
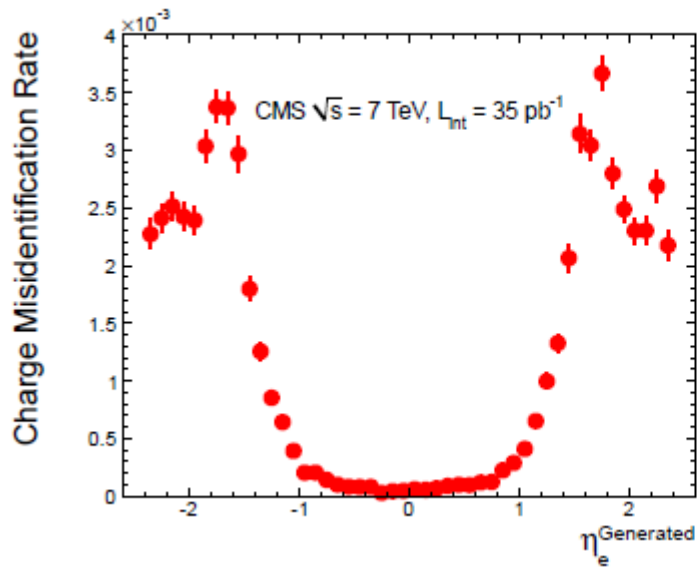
0.01 event from charge mis assignment

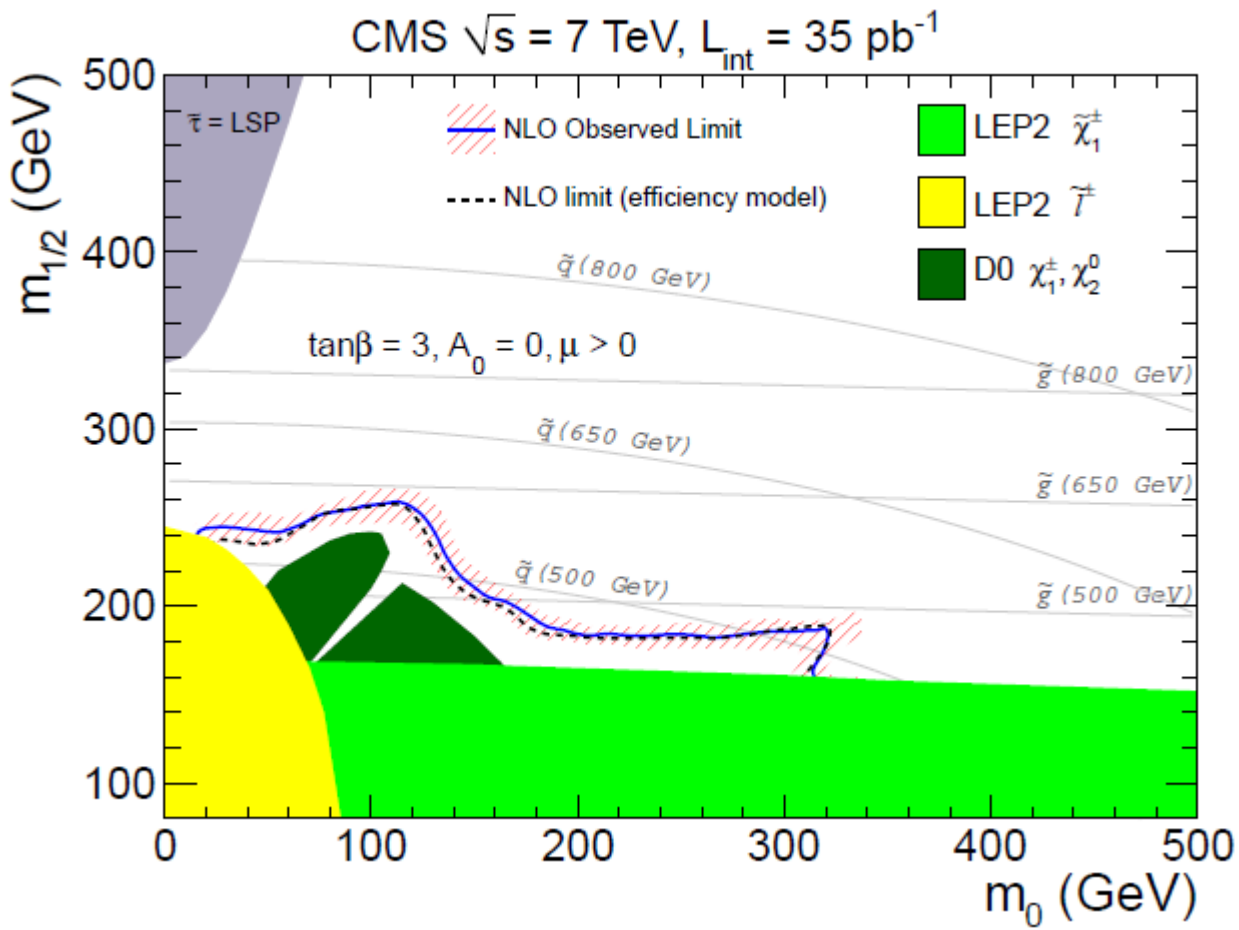
SIGNAL REGION

⊙ H_T Triggered events

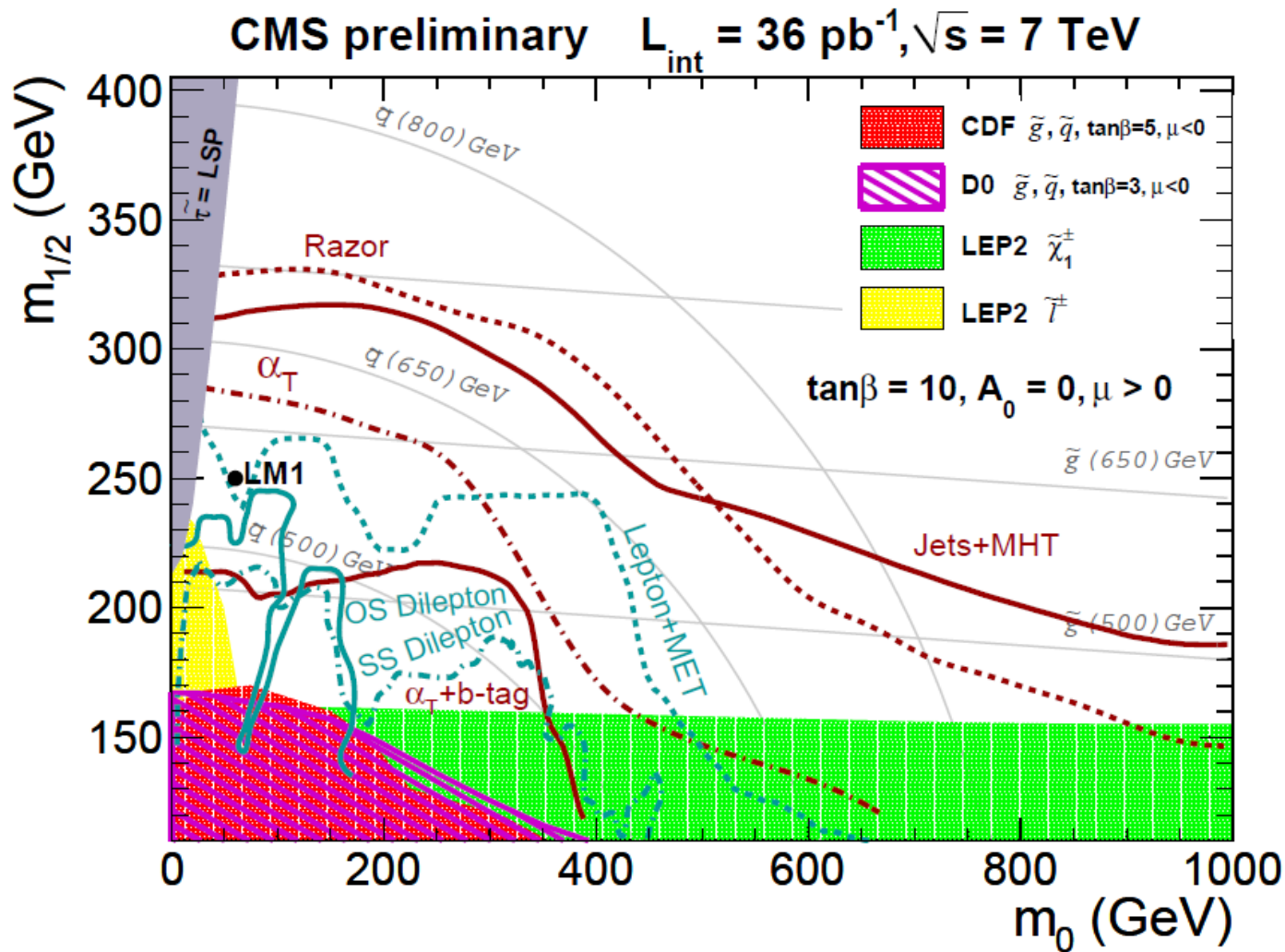
Search Region	ee	$\mu\mu$	$e\mu$	total	95% CL UL Yield
H_T Trigger					
Low- p_T MC	0.05	0.16	0.21	0.41	
predicted BG	0.10 ± 0.07	0.30 ± 0.13	0.40 ± 0.18	0.80 ± 0.31	
observed	1	0	0	1	4.4
	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$	total	95% CL UL Yield
τ_h enriched MC	0.36	0.47	0.08	0.91	
predicted BG	0.10 ± 0.10	0.17 ± 0.14	0.02 ± 0.01	0.29 ± 0.17	
observed	0	0	0	0	3.4

ELECTRON CHARGE MISID RATE





CMS COMBINED SUSY SEARCH RESULT



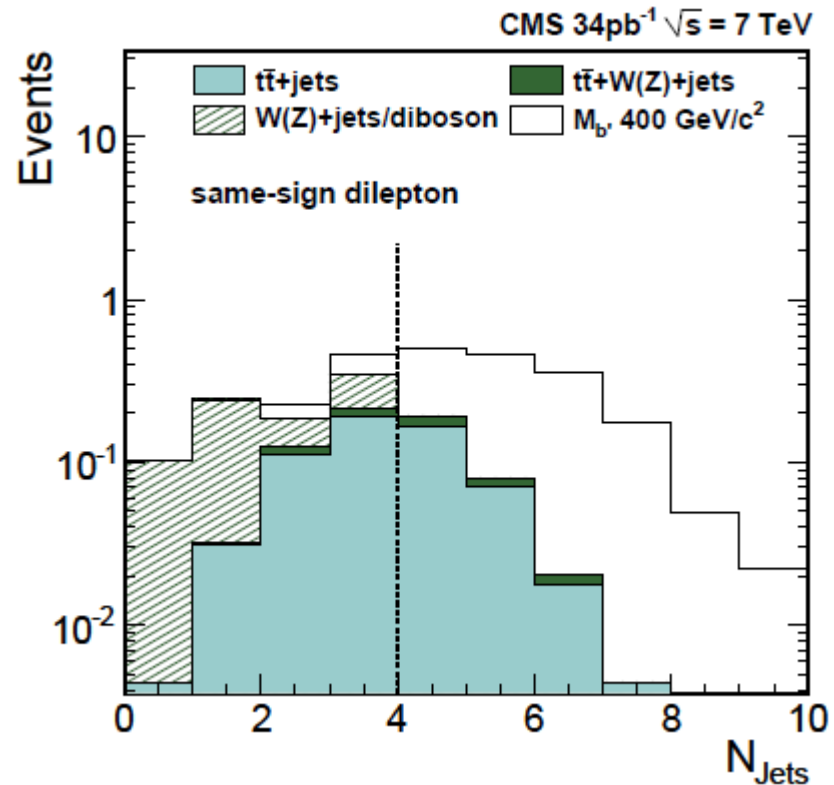
4TH GENERATION B QUARK SEARCH

- ⊙ $b'\bar{b}' \rightarrow t\bar{t}W^+W^- \rightarrow b\bar{b}W^+W^+W^-W^-$
 - Dominant mode for $m_{b'} > m_t + m_W$
 - 2 jets + MET + multilepton from W decays
- ⊙ Final state : likesign lepton pair or trilepton
 - 7.3% of total

4TH GENERATION B QUARK SEARCH

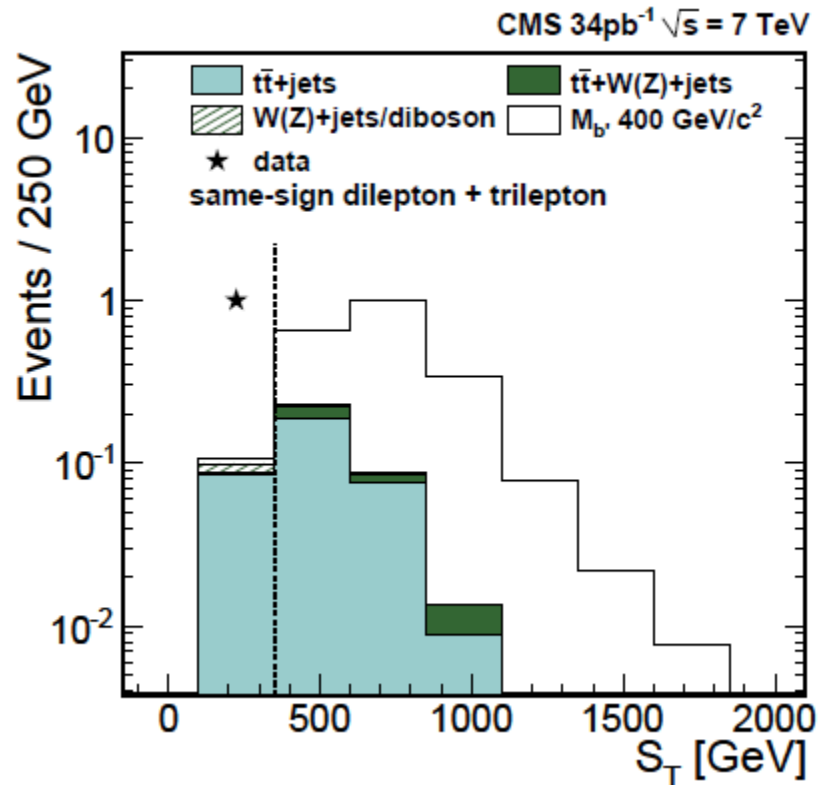
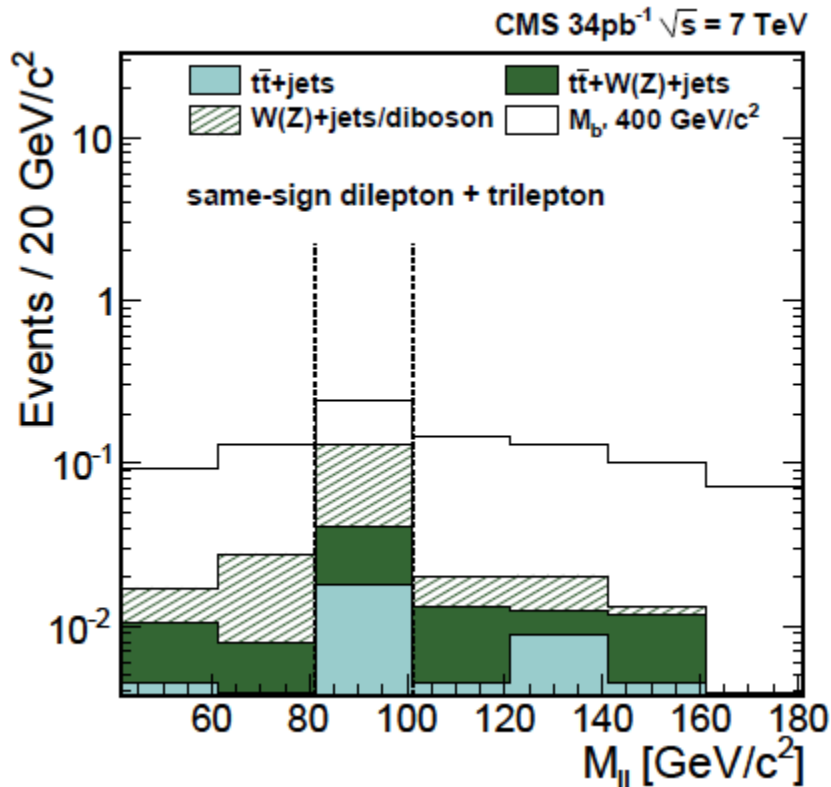
○ Selection

- Two like-sign lepton pair or trilepton
- 4 or more jets $p_{T>25}$ GeV
- Z veto
- Scalar E_T sum >350 GeV

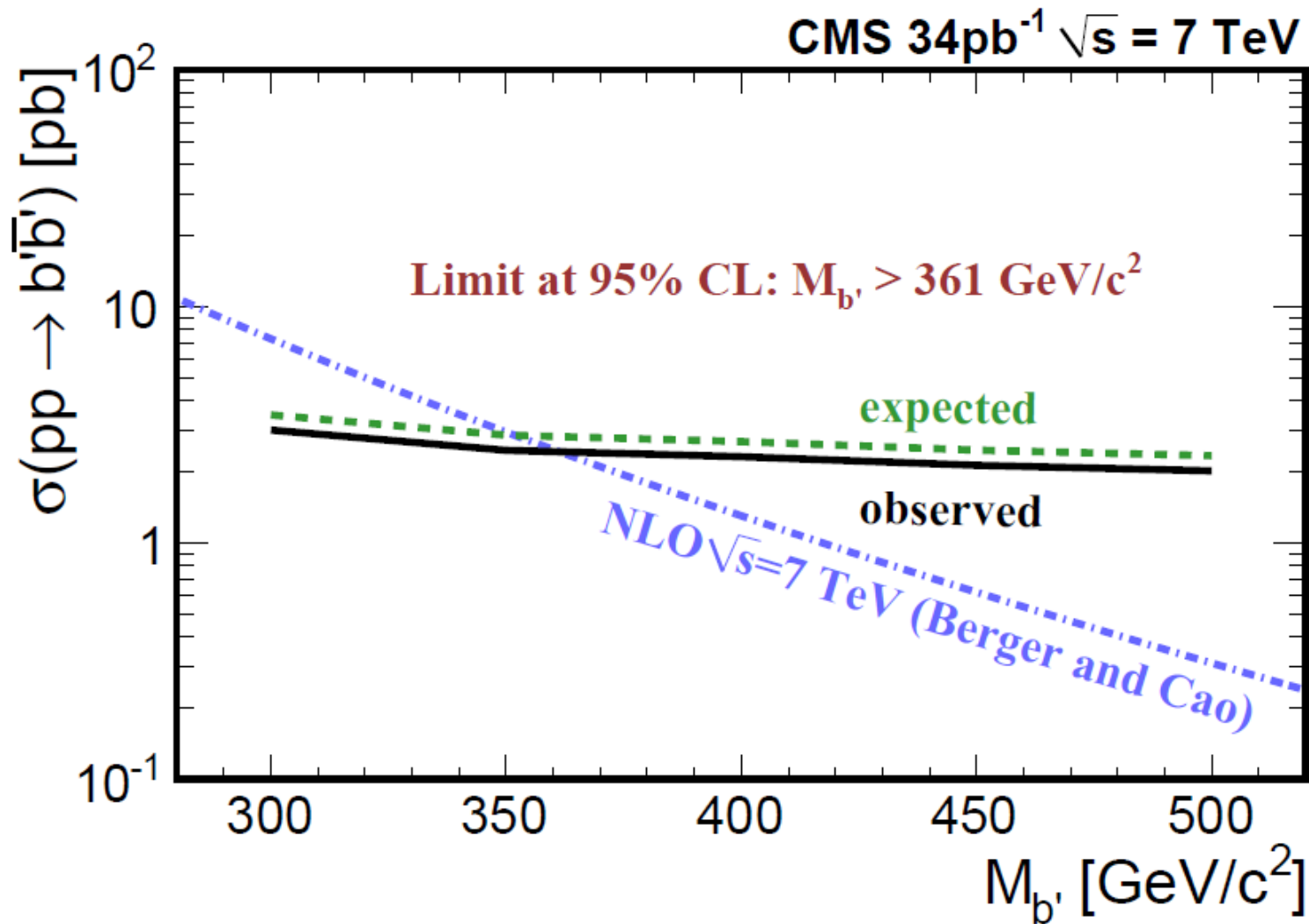


4TH GENERATION B SEARCH

- 0.32 Events expected background
- Signal acceptance: 3.0~4.5% for 300~500 GeV

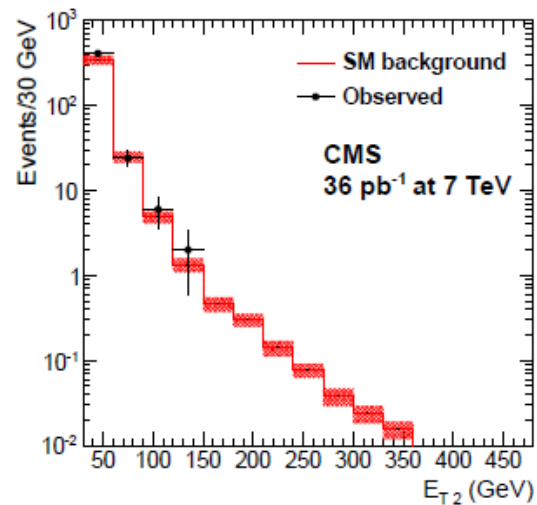
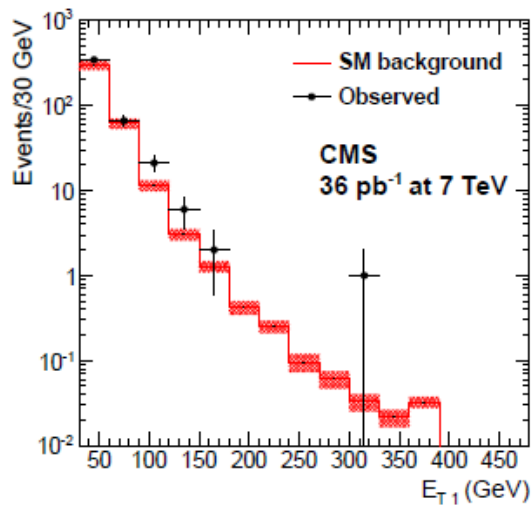
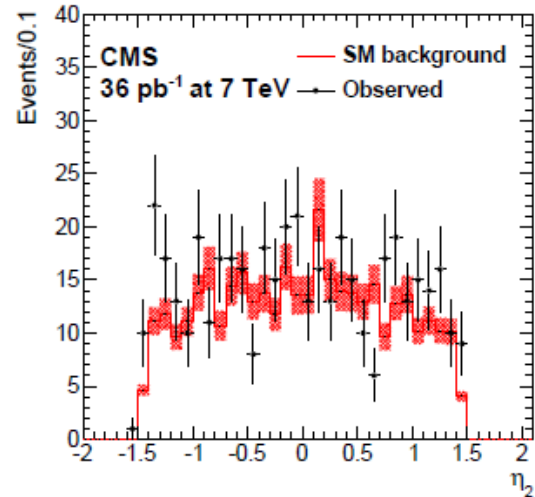
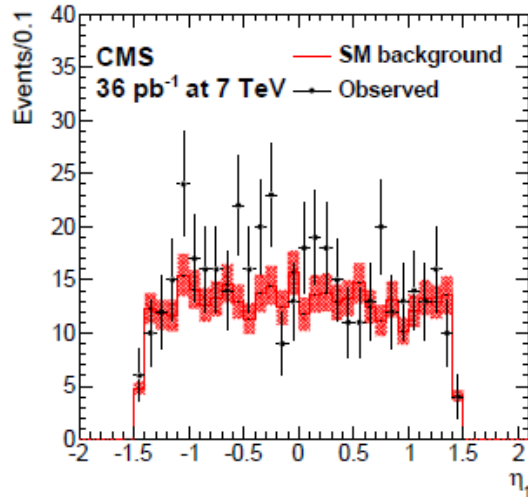


EXCLUSION LIMITS



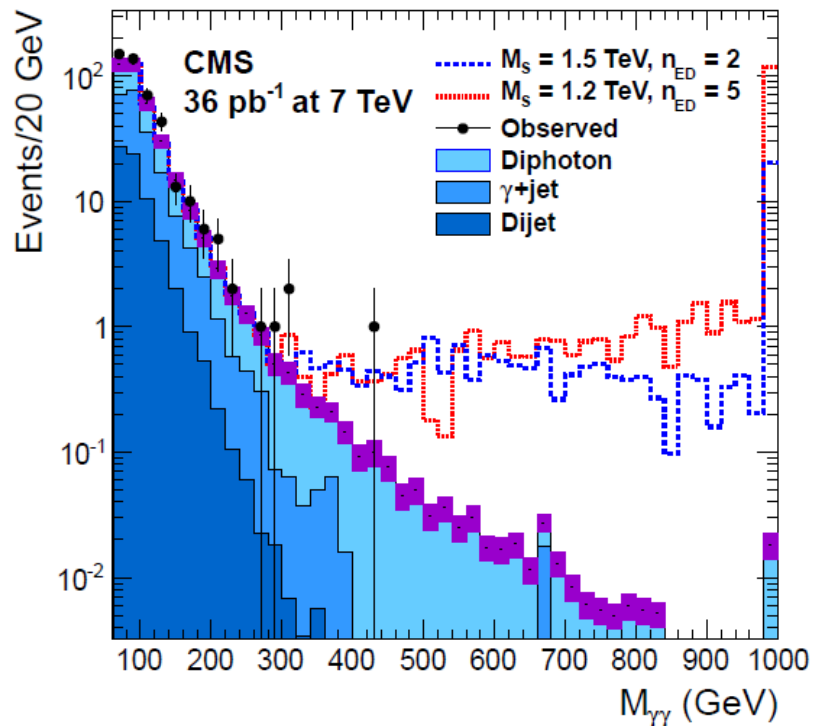
SEARCHES IN DIPHOTON CHANNEL

ISOLATED PHOTON DISTRIBUTIONS



DIPHOTON MASS SPECTRUM AND LIMITS ON LED

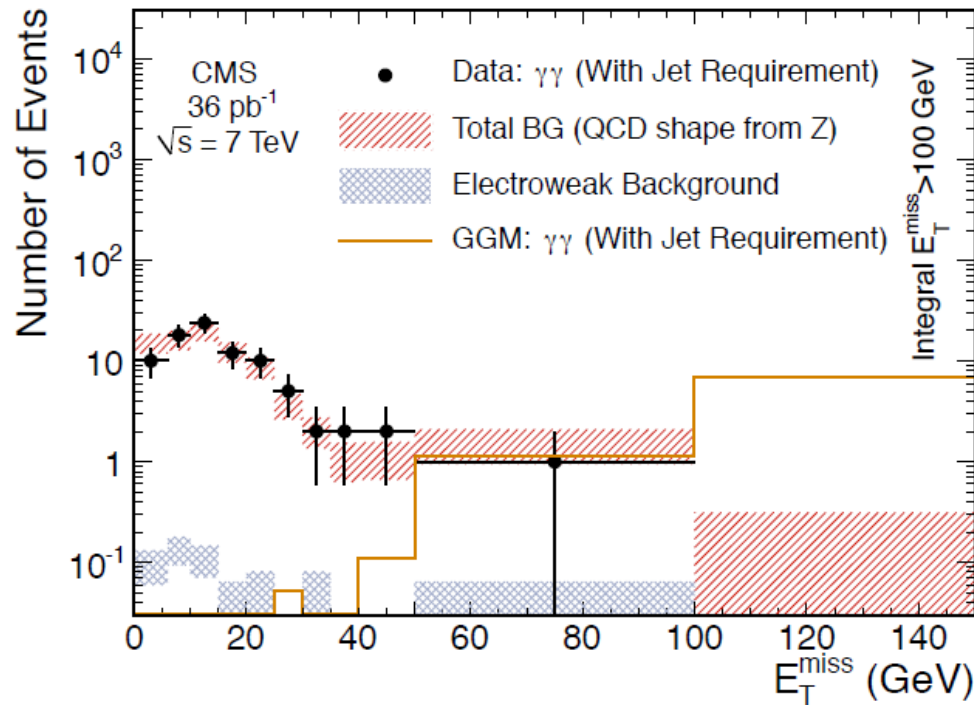
- 20% uncertainty due to K-factor



	GRW	Hewett		HLZ					
		Pos.	Neg.	$n_{ED} = 2$	$n_{ED} = 3$	$n_{ED} = 4$	$n_{ED} = 5$	$n_{ED} = 6$	$n_{ED} = 7$
Full	1.94	1.74	1.71	1.89	2.31	1.94	1.76	1.63	1.55
Trunc.	1.84	1.60	1.50	1.80	2.23	1.84	1.63	1.46	1.31

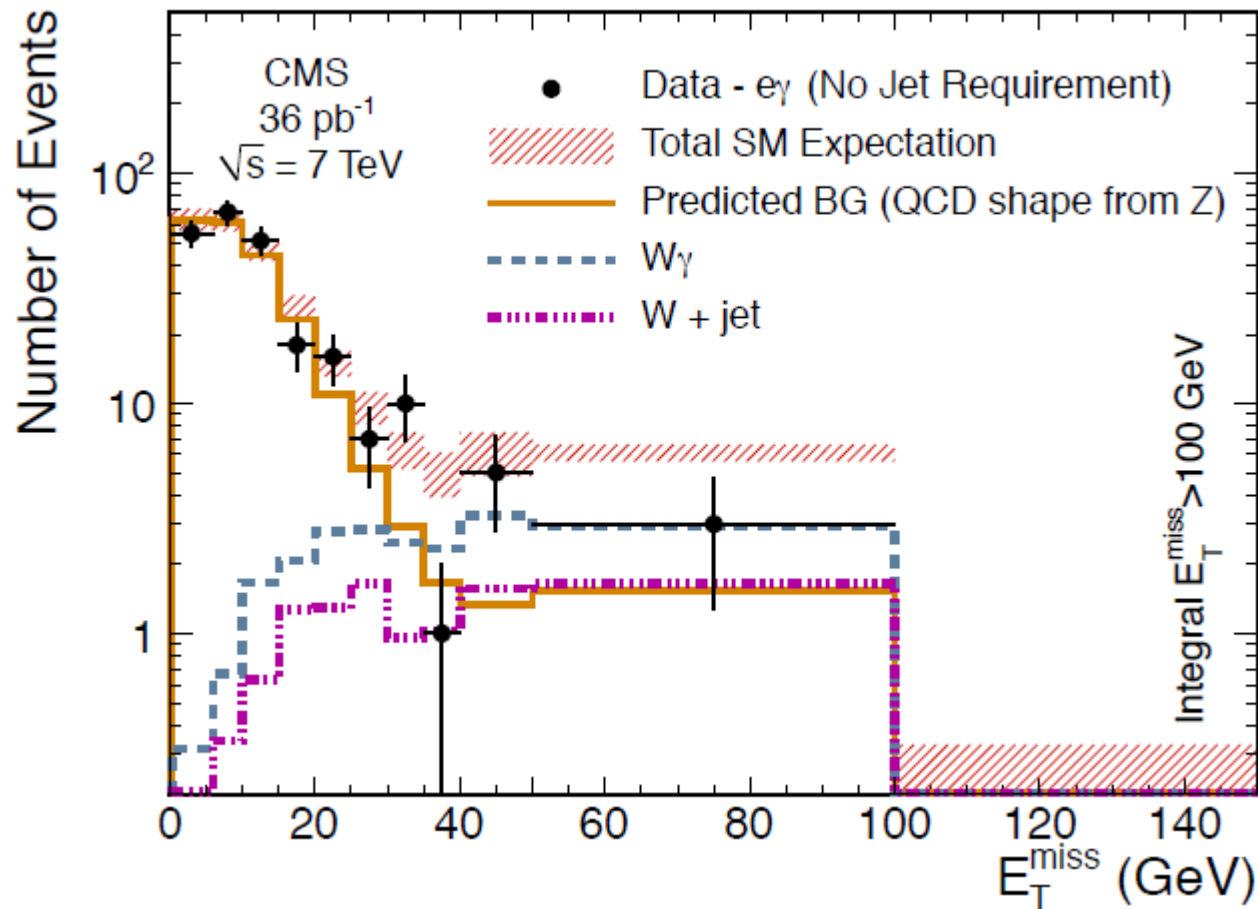
GENERAL GAUGE MEDIATION SCENARIO

- ◉ Final state: $\gamma\gamma + MET + jets$
- ◉ Selection
 - Isolated photon $E_T > 30$ GeV and $|\eta| < 1.4$
 - At least 1 jet $p_T > 30$ GeV away from photons



BACKGROUND CROSS CHECK

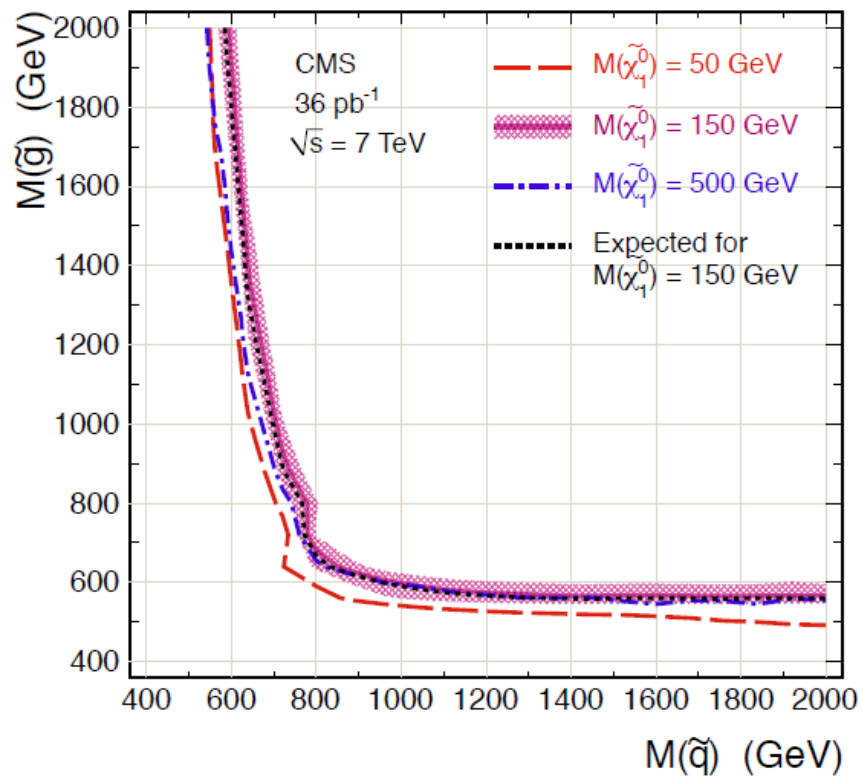
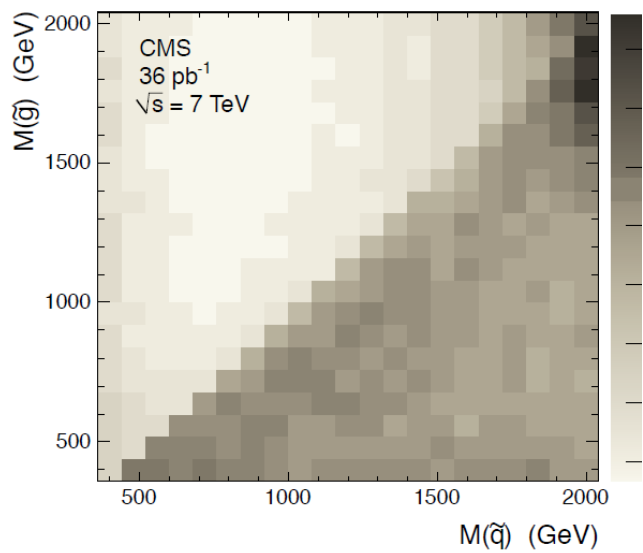
○ Events with no hadronic jets



Type	Number of events	Stat error	Reweight error	Normalization error
$\gamma\gamma$ events	1			
Electroweak background estimate	0.04 ± 0.03	± 0.02	± 0.0	± 0.01
QCD background estimate (ff)	0.49 ± 0.37	± 0.36	± 0.06	± 0.07
QCD background estimate (ee)	1.67 ± 0.64	± 0.46	± 0.38	± 0.23
Total background (using ff)	0.53 ± 0.37			
Total background (using ee)	1.71 ± 0.64			
Combined total background	1.2 ± 0.8			
Expected from GGM sample point	8.0 ± 1.7			

⊙ Squark, gluino mass 720 GeV example

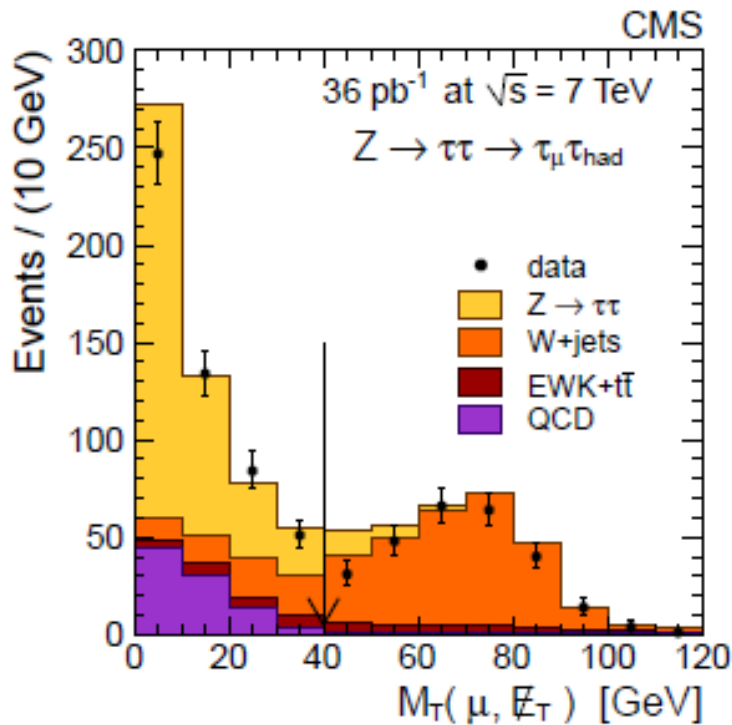
- 1.04 pb cross section
- Accetance 0.203
- Cross section upper limit 0.585 pb



MSSM HIGGS SEARCH IN

$$\phi \rightarrow \tau\tau$$

$$Z \rightarrow \tau\tau$$



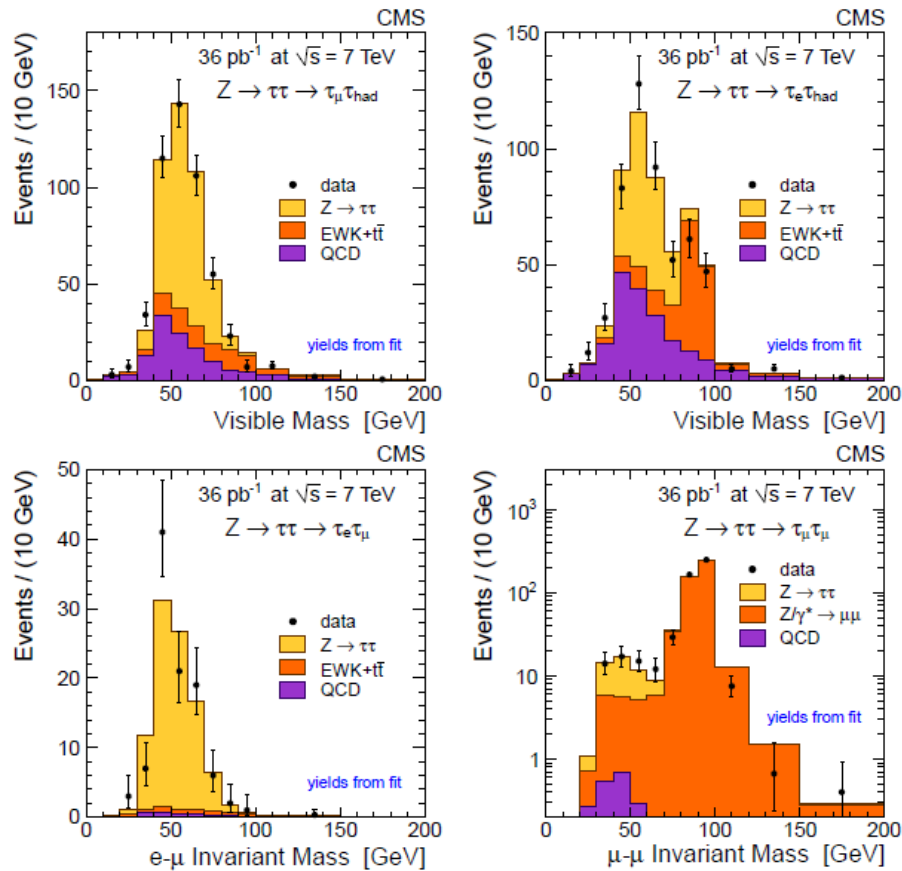
○ Final state

- $e\mu, e\tau_h, \mu\tau_h$

○ Selection

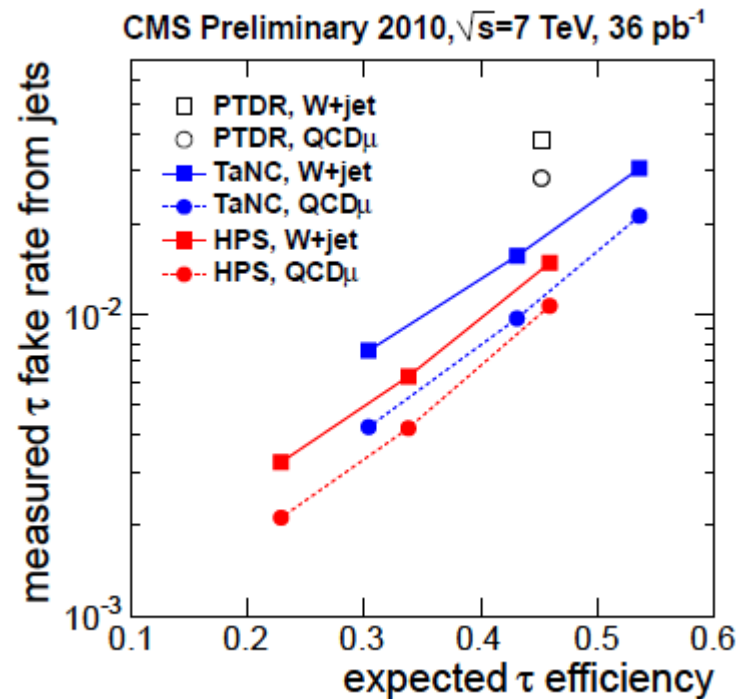
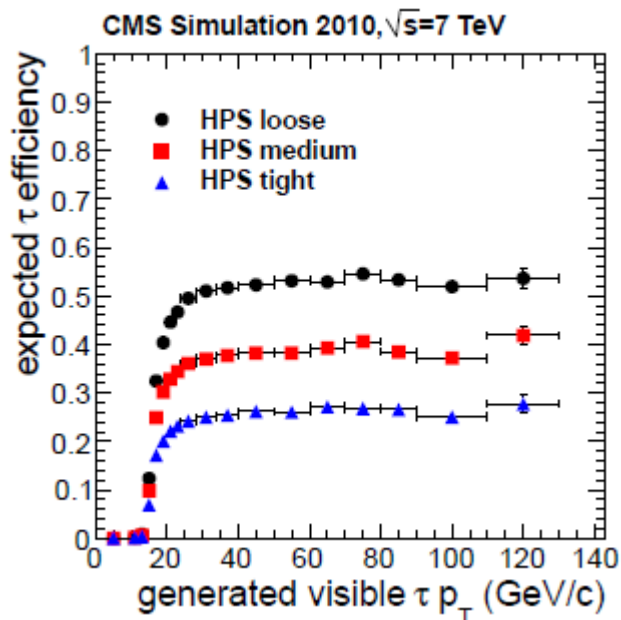
- Isolated $p_T > 15$ (e, μ)
- isolated τ_h $p_T > 20$ GeV
- opposite charge
- $M_T < 40$ GeV to veto W+jets

Z → ττ VISIBLE MASS



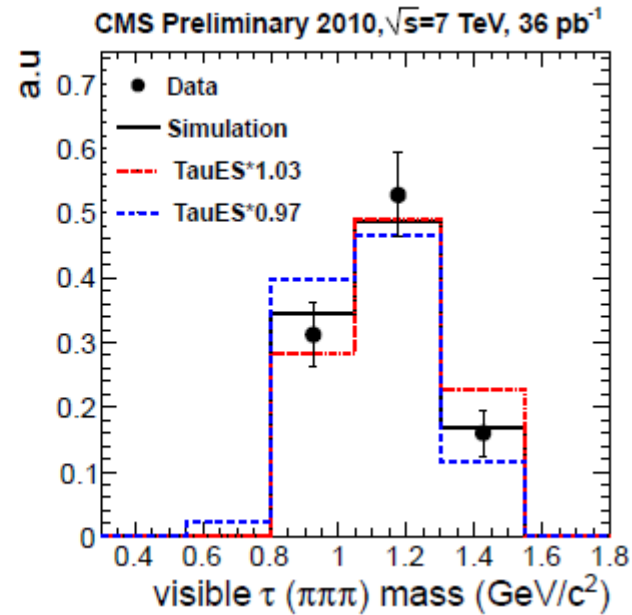
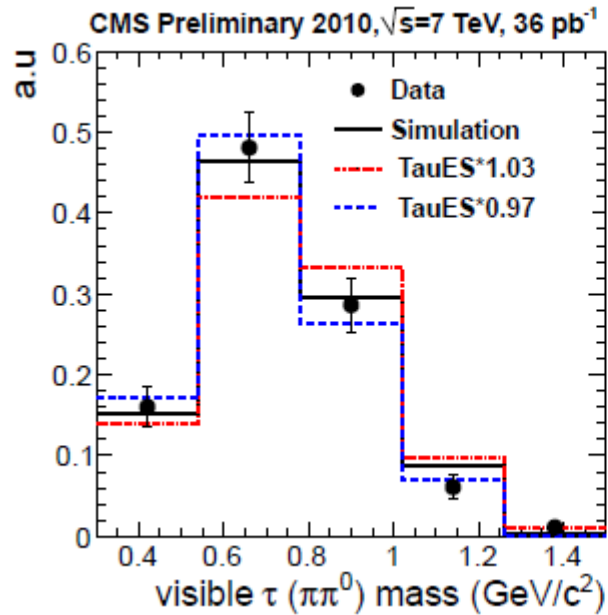
	τ _μ τ _{had}	τ _e τ _{had}	τ _e τ _μ	τ _μ τ _μ
Acceptance \mathcal{A}	0.13	0.12	0.074	0.16
Selection efficiency ϵ	0.37	0.23	0.55	0.17
Mass window correction f_{out}	0.03	0.03	0.02	0.01

TAU RECONSTRUCTION PERFORMANCE

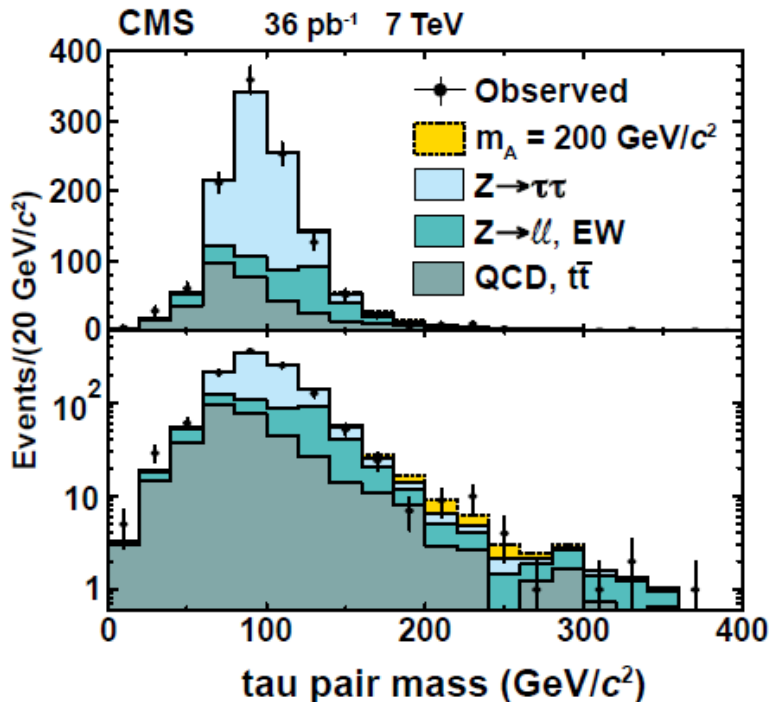


VISIBLE TAU MASS

- 1 prong and 3 prong



RECONSTRUCTED $\tau\tau$ MASS



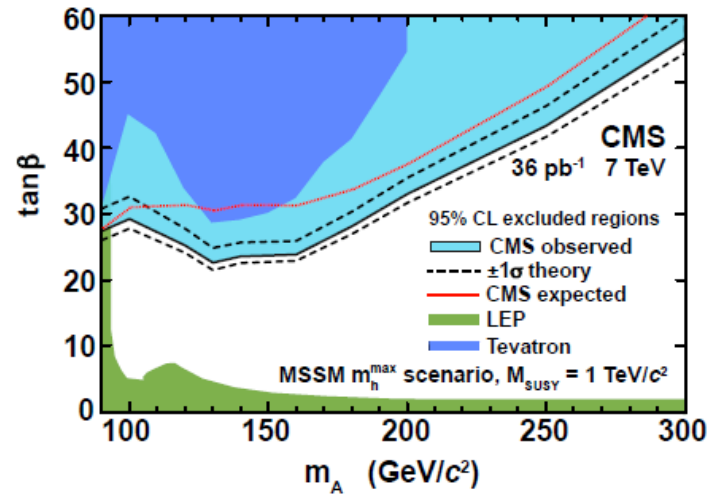
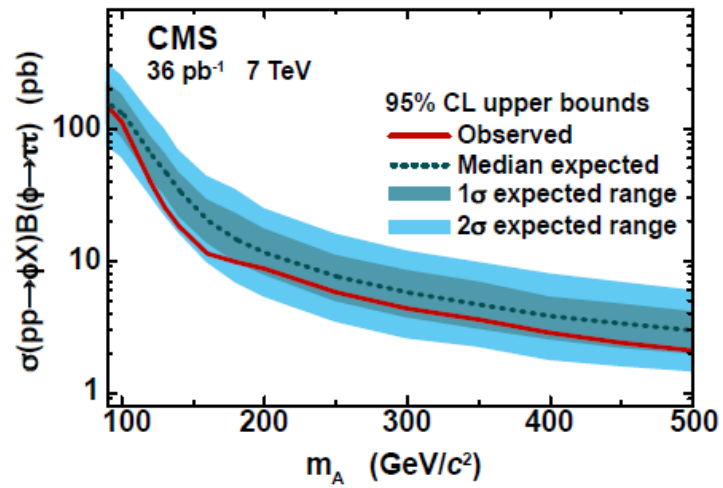
○ Likelihood method to reconstruct tau momenta

- 21% mass resolution for $m=130 \text{ GeV}$
- 24% for visible mass

CUT FLOW

Process	$\mu\tau_h$	$e\tau_h$	$e\mu$
$Z \rightarrow \tau\tau$	329 ± 77	190 ± 44	88 ± 5
$t\bar{t}$	6 ± 3	2.6 ± 1.3	7.1 ± 1.3
$Z \rightarrow \ell\ell, \text{jet} \rightarrow \tau_h$	6.4 ± 2.4	15 ± 6.2	-
$Z \rightarrow \ell\ell$	12.9 ± 3.5	109 ± 28	2.4 ± 0.3
$W \rightarrow \ell\nu$	54.9 ± 4.8	30.6 ± 3.1	
$W \rightarrow \tau\nu, \tau \rightarrow \ell\nu\bar{\nu}$	14.7 ± 1.3	7.0 ± 0.7	1.5 ± 0.5
QCD multijet and γ +jet	132 ± 14	181 ± 23	
WW/WZ/ZZ	1.6 ± 0.8	0.8 ± 0.4	3.0 ± 0.4
Total	557 ± 79	536 ± 57	102 ± 5
Observed	517	540	101
Signal Efficiency	0.0391	0.0245	0.00582

LIMITS



SUMMARY AND OUTLOOK

- ◉ Detector and accelerator is performing well and our understanding is improving
- ◉ Exciting results to come by summer using 1 fb⁻¹
- ◉ Check for latest updates
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults>