Search for electroweak SUSY production in events with 2 taus + MET at CMS

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on behalf of the CMS collaboration

DIS XXIV / DESY, Hamburg
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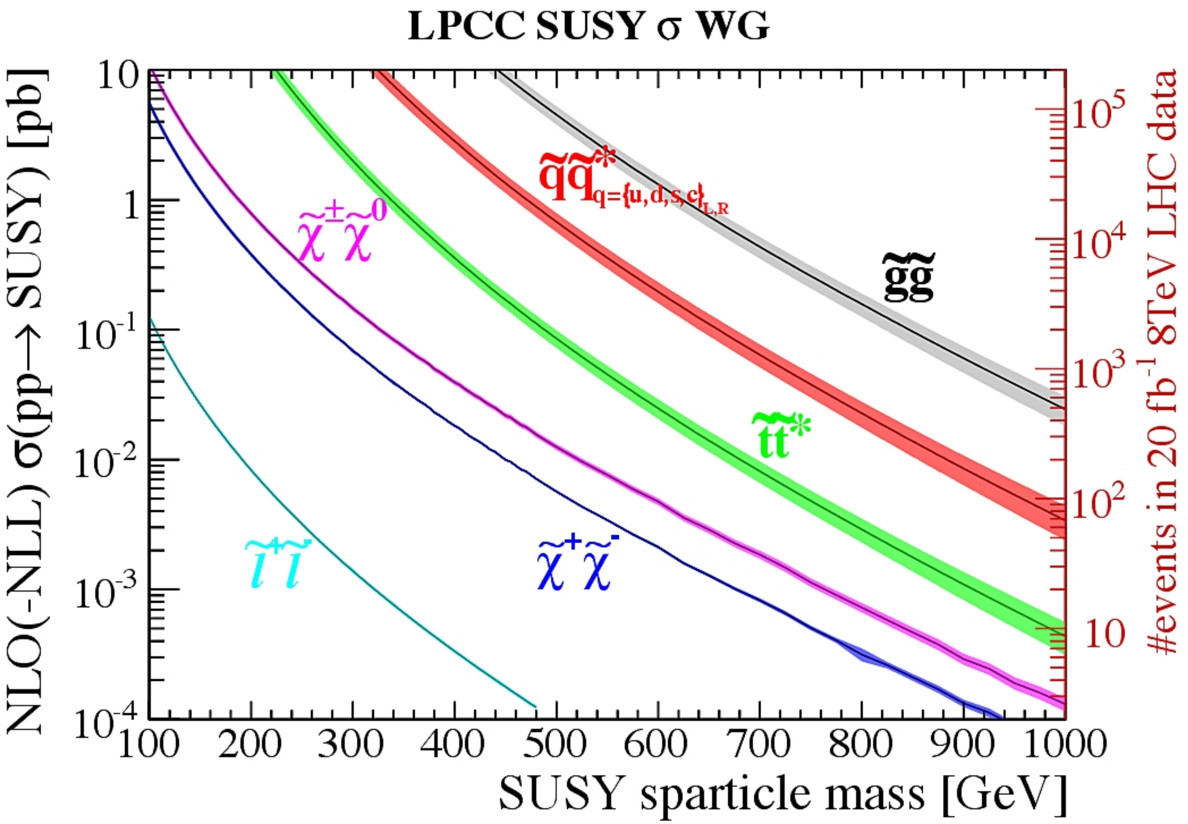
What is this talk about



https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections arXiv:1206.2892

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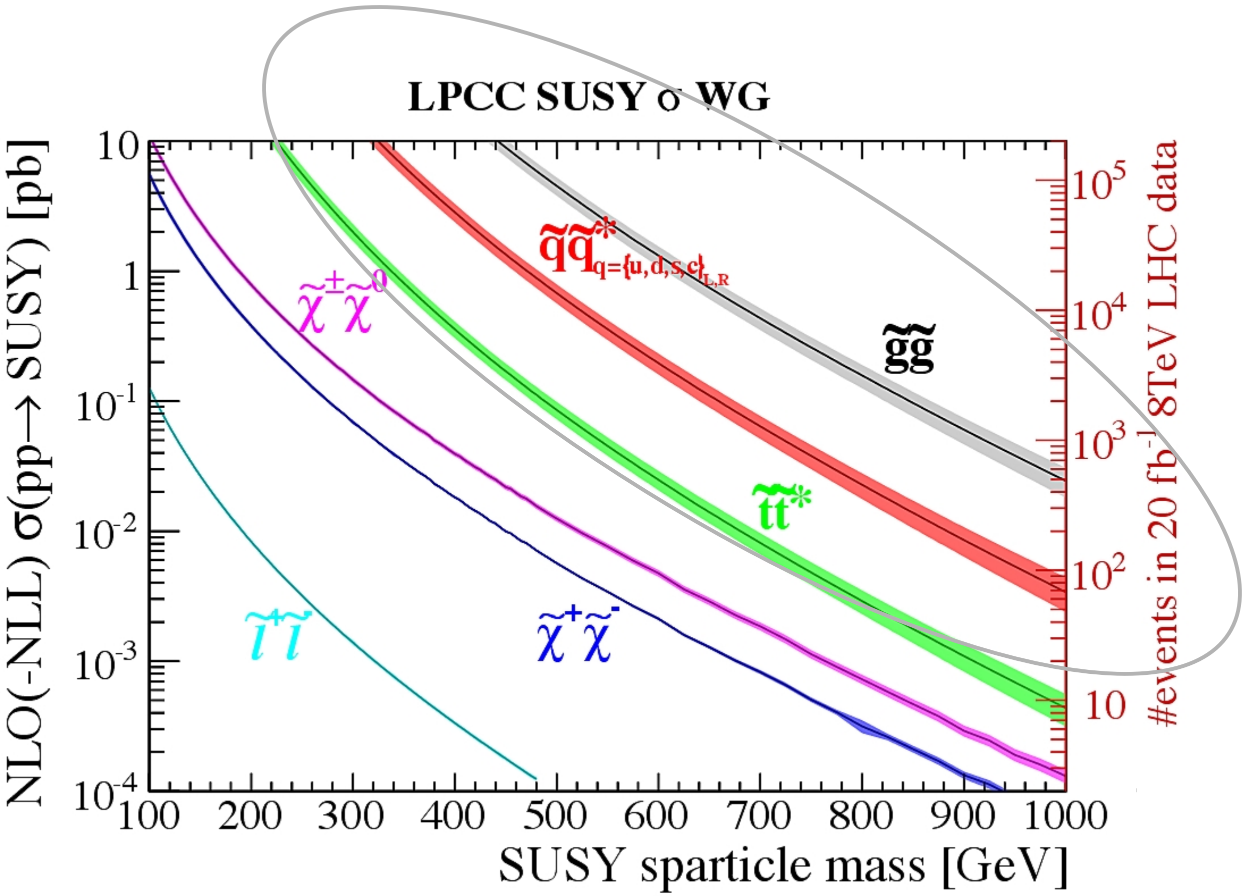

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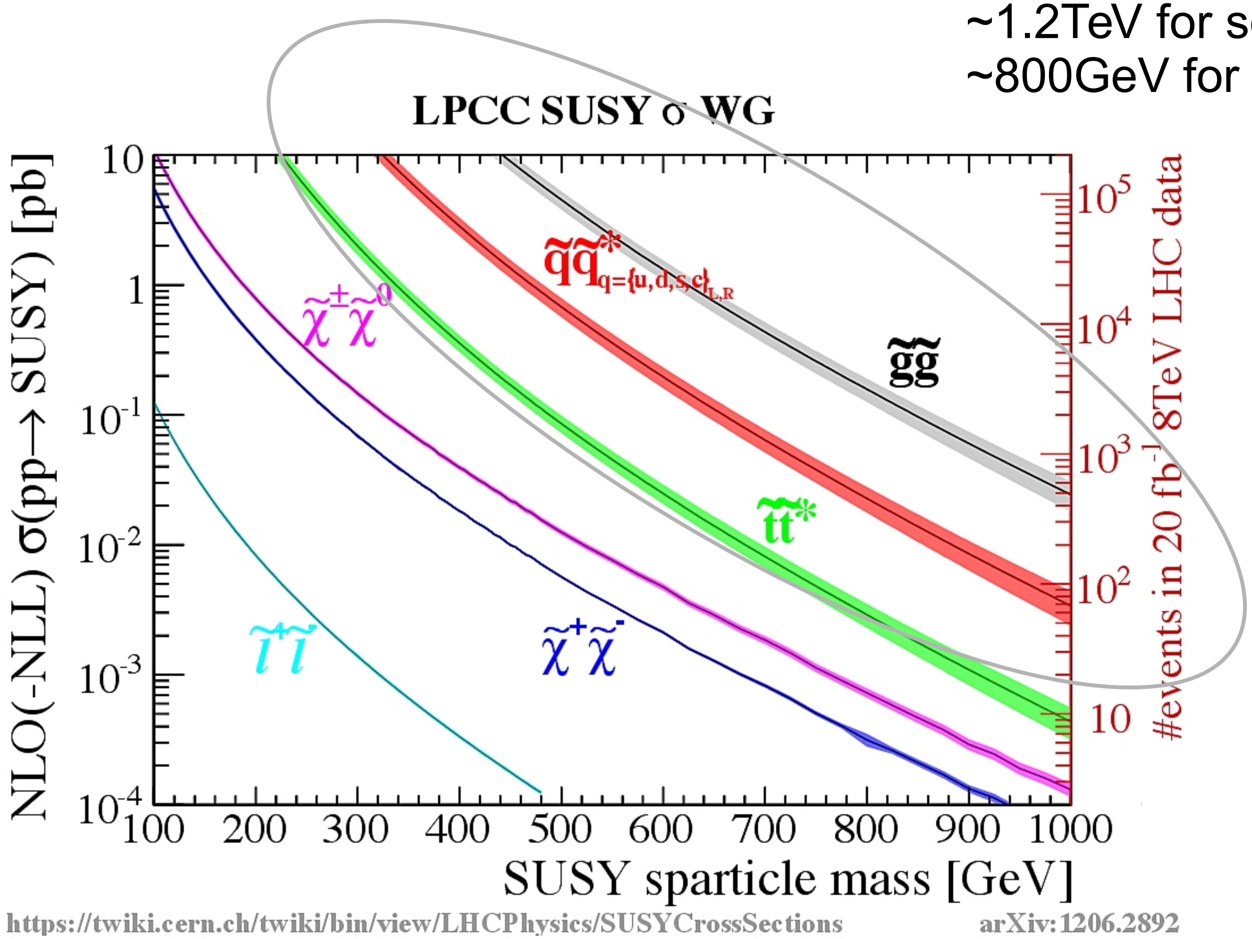
Nothing observed up to
- ~1.7 TeV masses for gluino
- ~1.2TeV for squarks
- ~800GeV for stop and sbottom



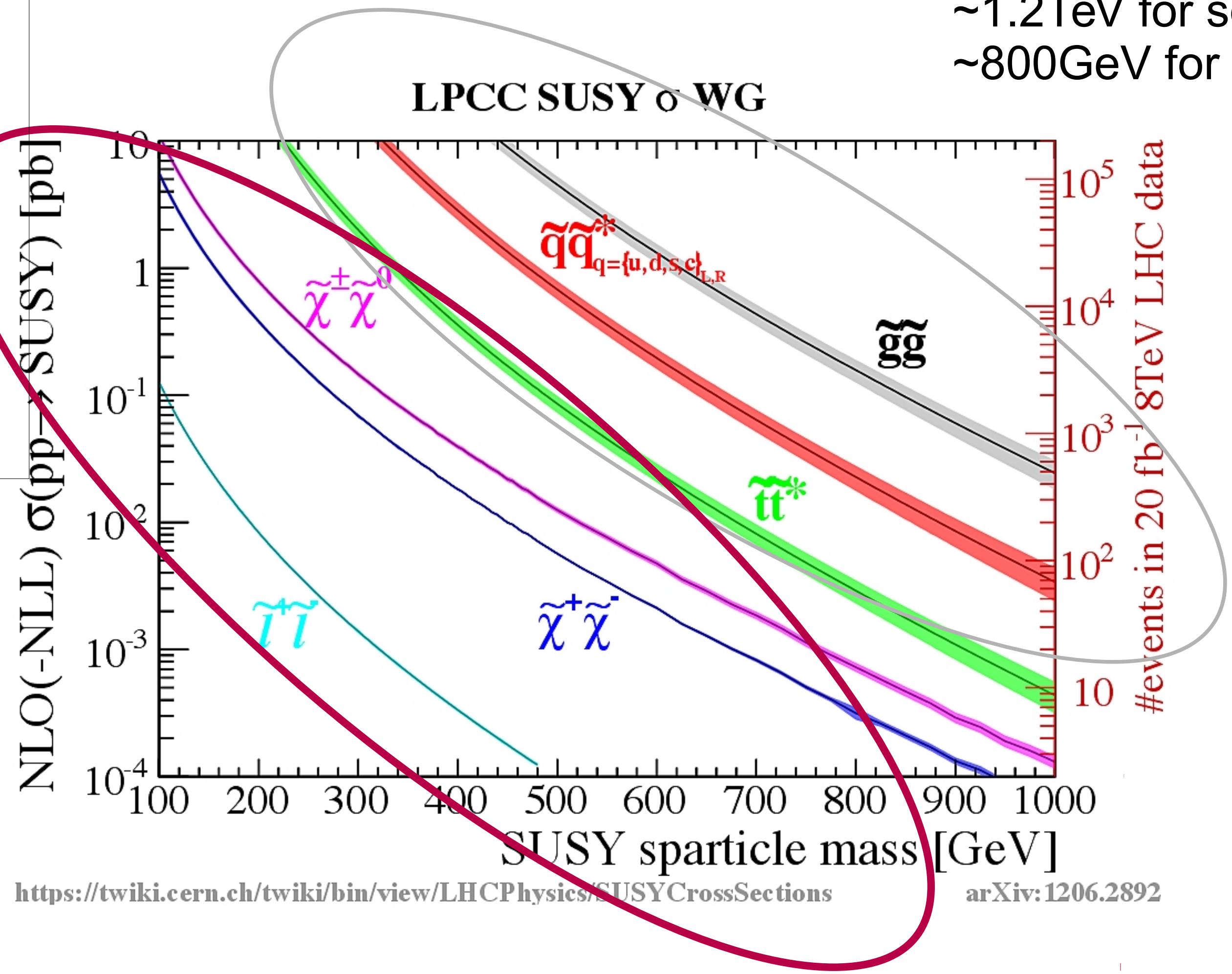
What is this talk about

Subject of this talk:

[very] Low cross sections

Clear Signatures

Nothing observed up to
~1.7 TeV masses for gluino
~1.2TeV for squarks
~800GeV for stop and sbottom



CMS Electroweakino Searches

All 8 TeV, but some are fresh

- charginos, neutralinos, and sleptons *decaying to* leptons and W, Z, and Higgs *Eur. Phys. J. C 74 (2014) 3036*
- neutralino and chargino decaying to Higgs, Z, and W *Phys. Rev. D 90 (2014) 092007*
- VBF production of SUSY *JHEP (JHEP 248P 0815)*
- Photon + MET *arxiv:1602.08772*
- 2 taus + MET *(SUS-14-022)*

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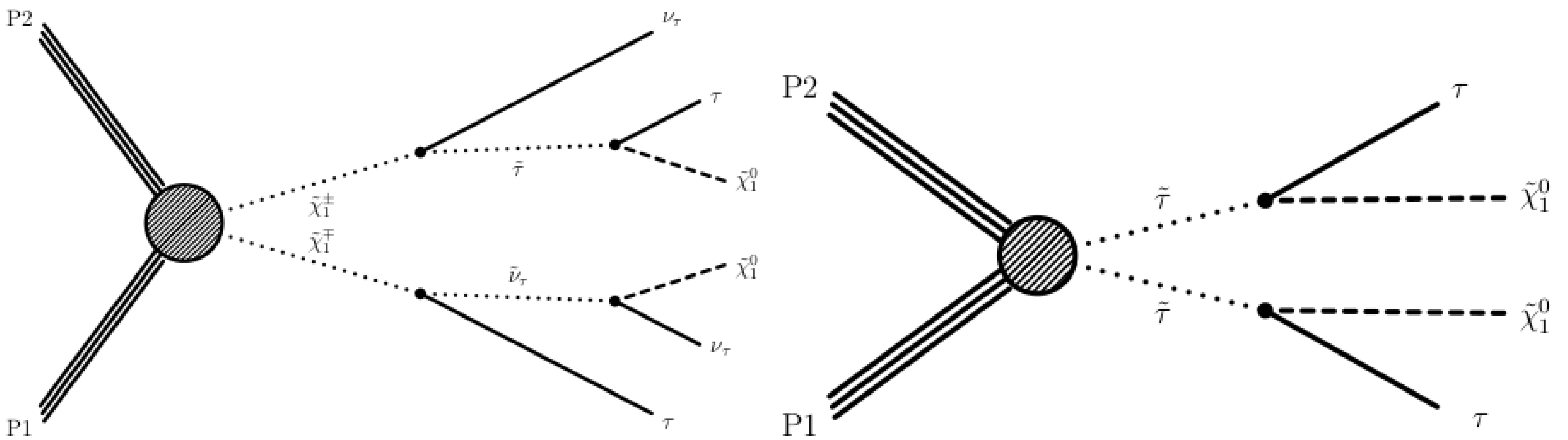
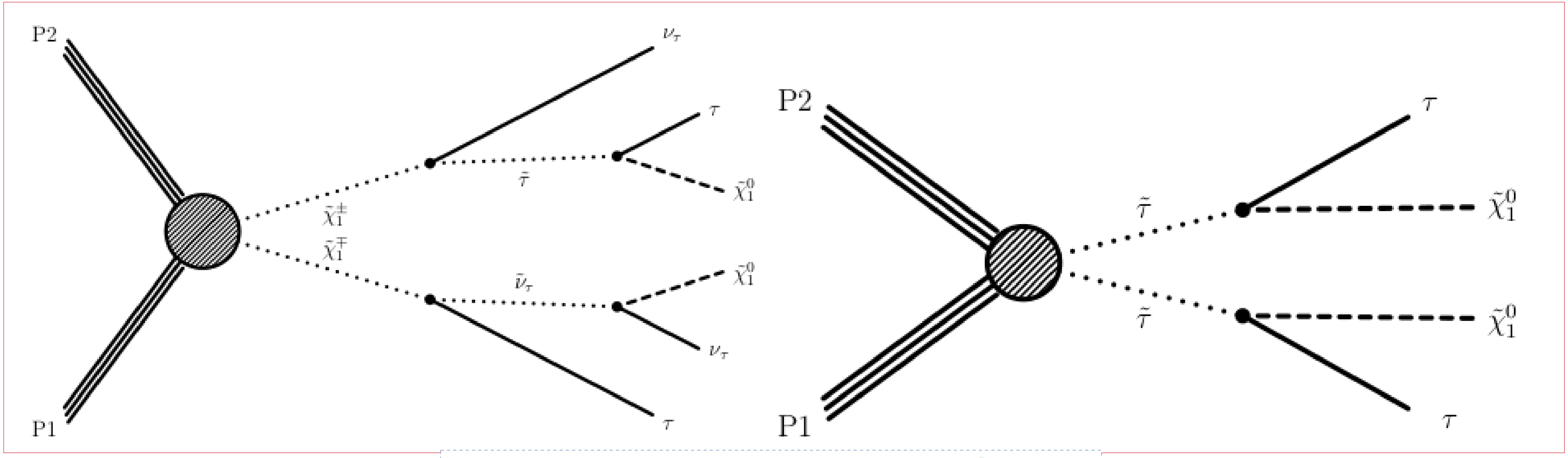
di tau + MET



- Naturalness : third generation s-particles get more interesting
- Light stau (~100GeV) is motivated in GMSB models to result consistent relic density
- Best stau limit so far > ~90GeV by LEP

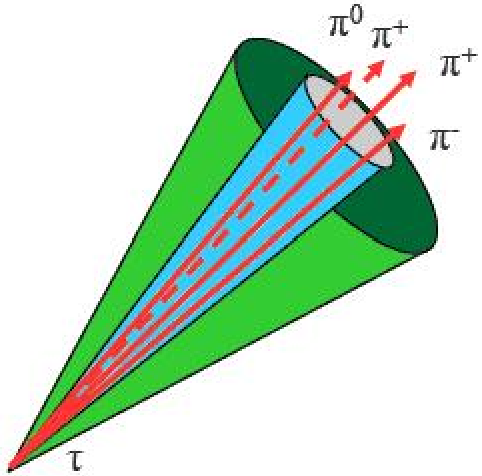
di tau + MET



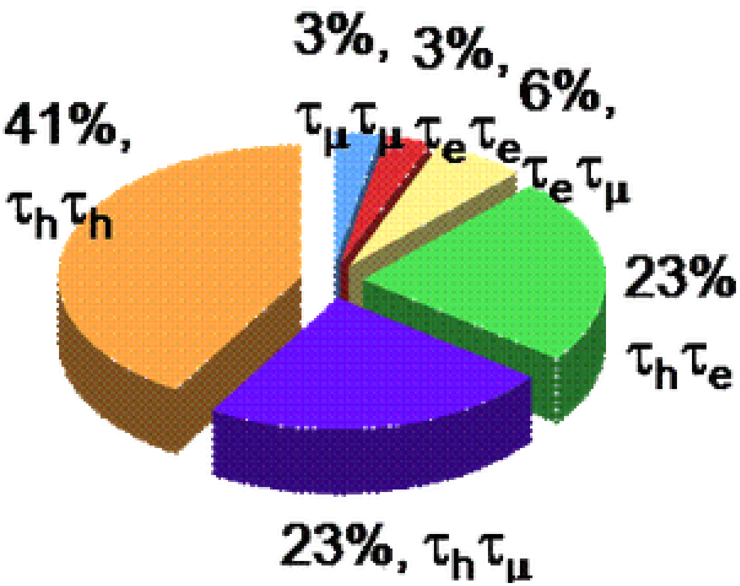
$$q\bar{q} \to (Z/\gamma)^* \to \tilde{\chi}_1^+ \tilde{\chi}_1^-$$

- Signal :
  - Resumino for the cross section
    - between 5pb to 5fb for chargino mass (100 , 500)GeV
    - Between 0.1 fb to 3 fb for stau mass (100 , 250) GeV
  - Pythia for the modeling

Tau decays and reconstruction



- Hadronic tau reconstruction:
  - Starts from jets
  - Based on the decay mode
  - 3 charged hadrons
  - One charged + up to 2 neutral pions



- Performance 50%
  - Tau-tau: 0.25 * 0.41 ~ 10%
  - Lep+ tau: 0.5 * 0.46 ~ 23%
- Higgs mass: lepton+tau the most sensitive
- Here: mu+tau / ele+tau / tau+tau combined

Leptons
Trigger and Offline selection

- For di hadronic tau :
  - 18.1 fb^{-1}
  - Trigger threshold :
    - pt > 35 GeV
    - $|\eta| < 2.1$
- Offline cuts :
  - Pt > 45 GeV
  - Medium Isolated
  - Cleaned against electrons/muons

- For lepton + tau :
  - 19.6 fb^{-1}
  - Trigger thresholds :
    - tau pt > 20
    - electron pt > 20/22
    - Muon pt > 17/18
- Offline cuts :

  > 25 GeV / $|\eta| < 2.3$ / Tight Iso

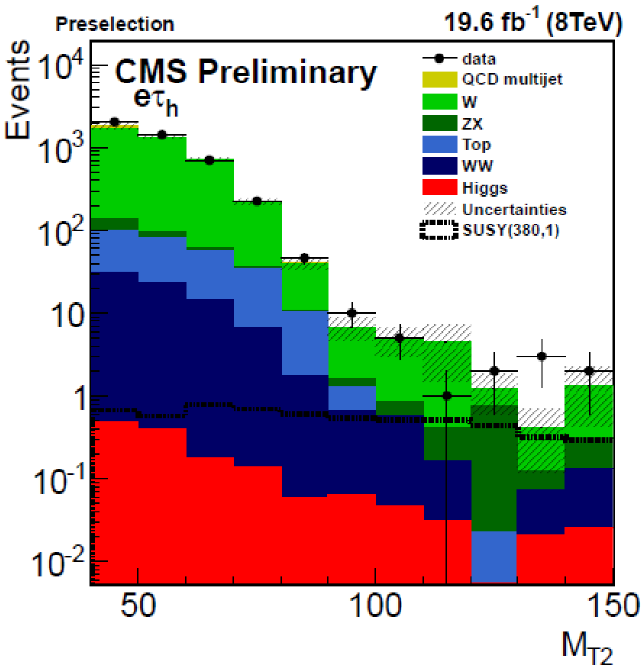
  > 25 GeV / $|\eta| < 2.1$ / Tight ID,ISO

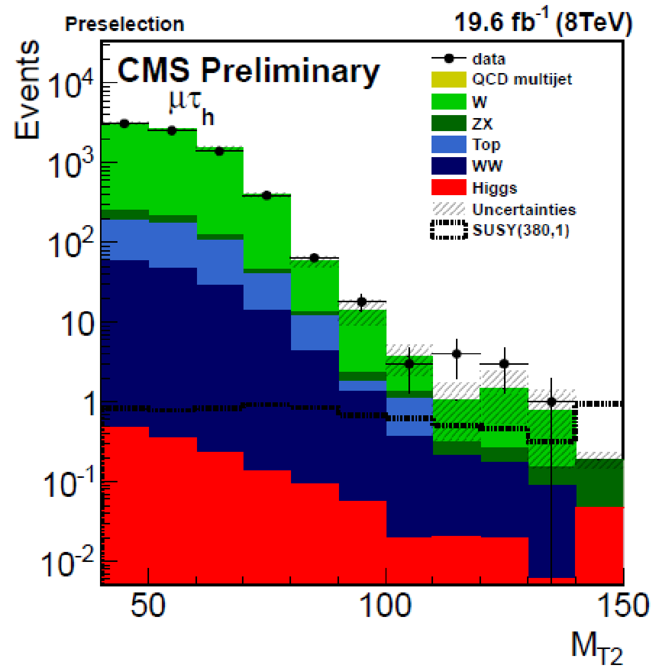
  > 20 GeV / $|\eta| < 2.1$ / Tight ID,ISO

Event Selection

- **Two opposite sign leptons are requested**
  - at least one hadronic decay of tau
  - Invariant mass > 15 GeV
  - Z-Veto cut on the invariant mass
- Reject events with any **extra leptons**
- **MET** > 30 GeV
- **MT2** > 40 GeV
  - MT2 represents the scale of the SUSY particle
  - A function of MET and leptons
- Minimum DeltaPhi of jets and MET > 1
  - Rejects **QCD** and **Wjets** backgrounds
- b-jet veto : rejects **ttbar** events

Lepton + Tau





- Selection is optimized to have the best reach :
  - low MT2 region :
    - sensitive to lower SUSY masses (NLSP/LSP)
    - large background
    - not used
  - MT2>90 GeV
  - Tau MT > 200 GeV

- Backgrounds with prompt lepton and tau are estimated from simulation
- The main backgrounds are fake taus :
  - To estimate it, the tau isolation cut is loosen
  - In control regions, the probability that a fake/prompt loose tau passes the tight cuts is measured
    - For fakes : 0.54 +- 0.01
    - For prompts : 0.766 +- 0.003
    - It is independent of tau attributes and event selection cuts

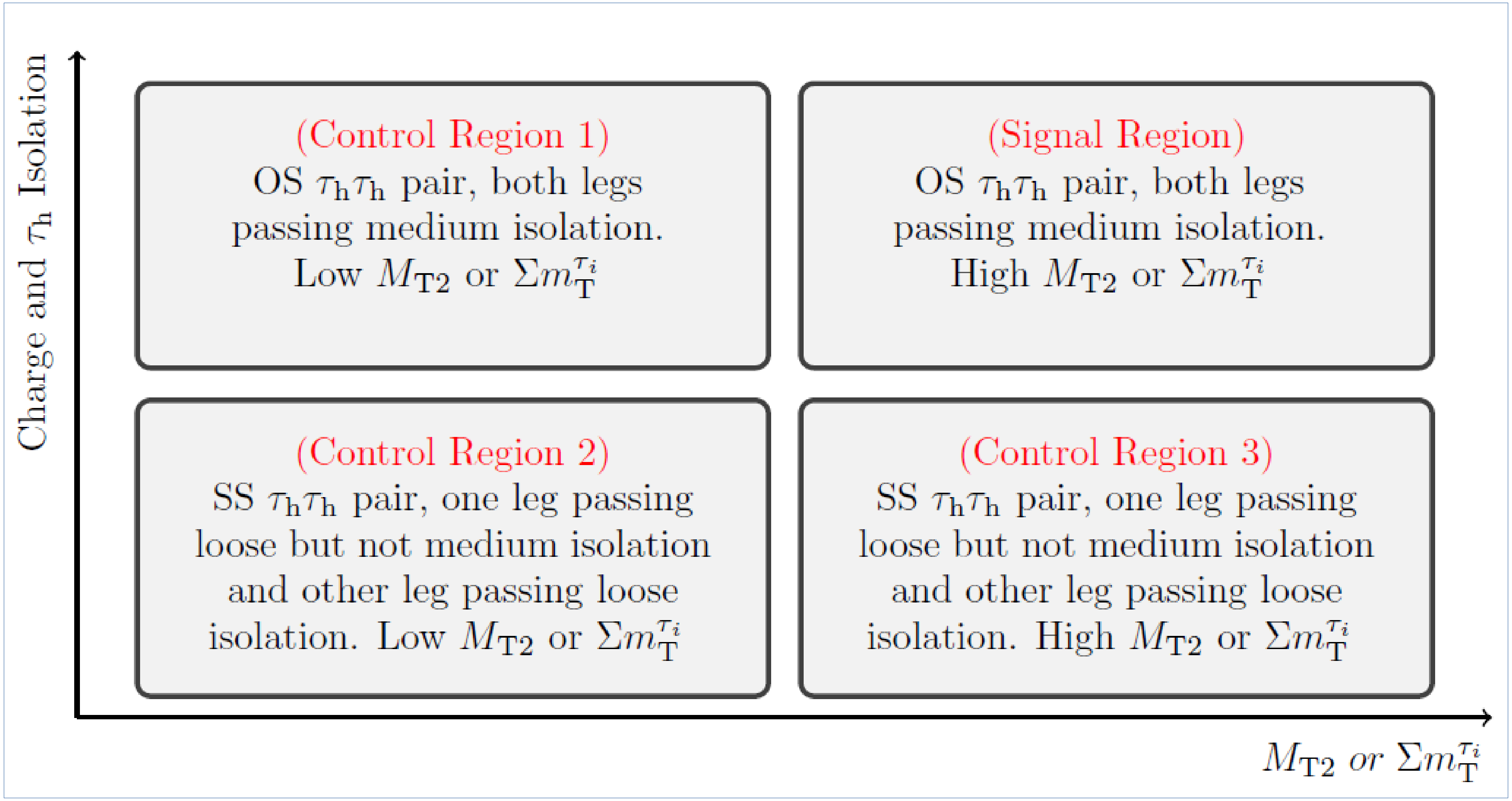
Channel	Total Fake	stat	r_{Fake} sys	r_{Real} sys	Total Unc
$\mu\tau_{\mathrm{h}}$	8.15	56%	18%	5%	59%
$e\tau_{\mathrm{h}}$	3.30	101%	17%	2%	102%

Tau+Tau Selection

- SR1 : High MT2 region (MT2 > 90 GeV) :
  - No extra cut is applied
  - Even the b-veto cut is relaxed (ttbar is already discarded)
- SR2 : Low MT2 region (MT2 < 90 GeV) :
  - Sum of the transverse masses of two hadronic taus is found the best variable to separate signal/bkg
  - SumMT > 200
  - Used by the ATLAS analysis

QCD backgrounds in tau-tau channels

- QCD and multi-jet backgrounds : Events with two fake taus



Signal Region	QCD Estimation
$\tau_h\tau_h$ SR1	$0.13 \pm 0.06(\text{stat}) \pm 0.18(\text{sys}) \pm 0.10(\text{fit})$
$\tau_h\tau_h$ SR2	$1.15 \pm 0.39(\text{stat}) \pm 0.70(\text{sys}) \pm 0.25(\text{fit})$

W/Z backgrounds in tau-tau channels

- MC is validated using mu+tau data events

- W+Jets
  - the efficiency of the MT2 and SumMT cuts are verified in data

Signal Region	W+jets Estimation
$\tau_h \tau_h$ SR1	0.72 ± 0.11 (stat) ± 0.11 (sys) ± 0.56 (shape)
$\tau_h \tau_h$ SR2	2.58 ± 0.35 (stat) ± 1.04 (sys) ± 0.69 (shape)

- Z events
  - Events under the z-peak are selected
  - The transverse momentum of the Z boson system, which is correlated with MT2 , is also well reproduced in simulation.

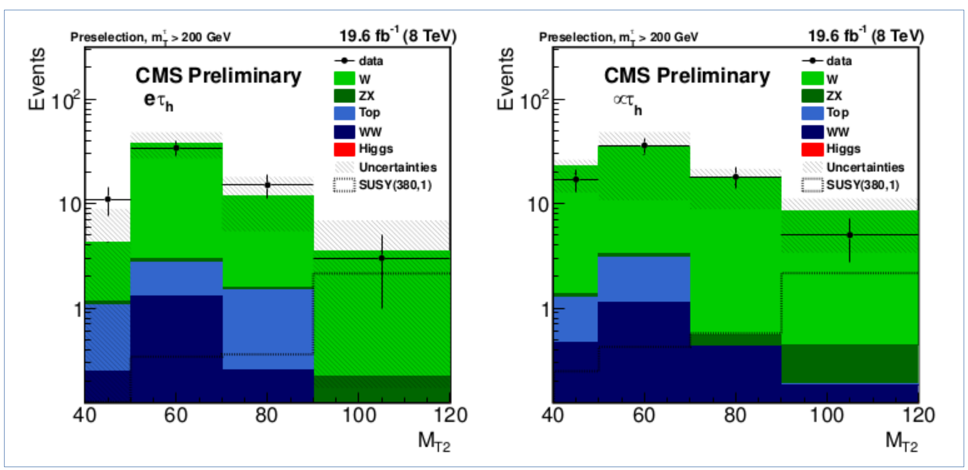
Signal Region	DY Estimation
$e\tau_h$	0.19 ± 0.04
$\mu\tau_h$	0.25 ± 0.06
$\tau_h \tau_h$ SR1	0.56 ± 0.07
$\tau_h \tau_h$ SR2	0.81 ± 0.56

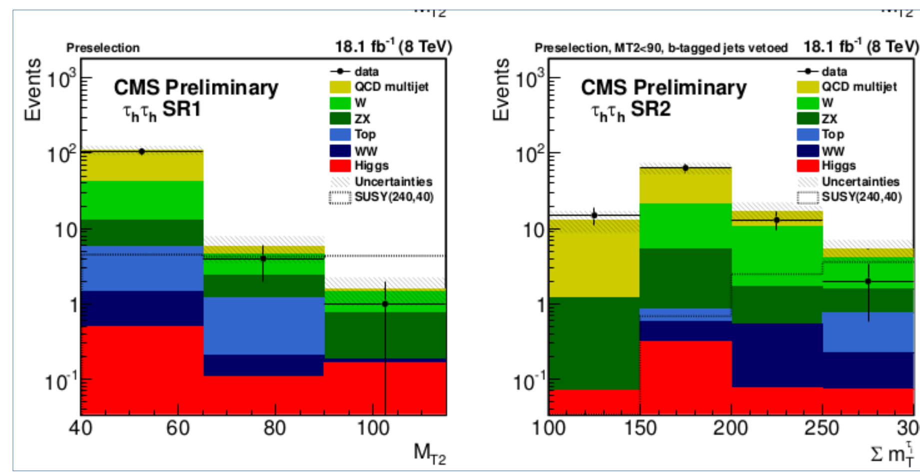
Systematic uncertainties

	Background			Signal		
Systematic uncertainty source	$\ell\tau_h$	$\tau_h\tau_h$ SR1	$\tau_h\tau_h$ SR2	$\ell\tau_h$	$\tau_h\tau_h$ SR1	$\tau_h\tau_h$ SR2
τ_h energy scale (*)	10%	15%		2-12%	3-15%	
τ_h id efficiency	6%	12%		6%	12%	
τ_h trigger efficiency	3%	9%		3%	9%	
Lepton trigger, id, iso efficiency	2%	-		2%	-	
p_T^{miss} (*)	5%			5%		
b-tagged jets veto	4%	-	4%	8%	-	8%
Pile-up	4%			4%		
Fast/Full τ_h id efficiency	-			5%	10%	
ISR (*)	-			3%		
$\Delta\phi_{min}$	-			6%		
PDF (*)	-			2%		
Luminosity	-			2.6%		
Total shape-altering sys.	11%	16%	16%	6-13%	7-16%	
Total non-shape-altering sys.	9%	16%	16%	14%	20%	21%
Total Systematic	14%	22%	22%	15-19%	21-25%	22-26%
Monte Carlo Statistic	22%	13%	70%	3-15%		
Total	26%	26%	73%	15-24%	21-29%	22-30%
Low rate backgrounds	50%			-		

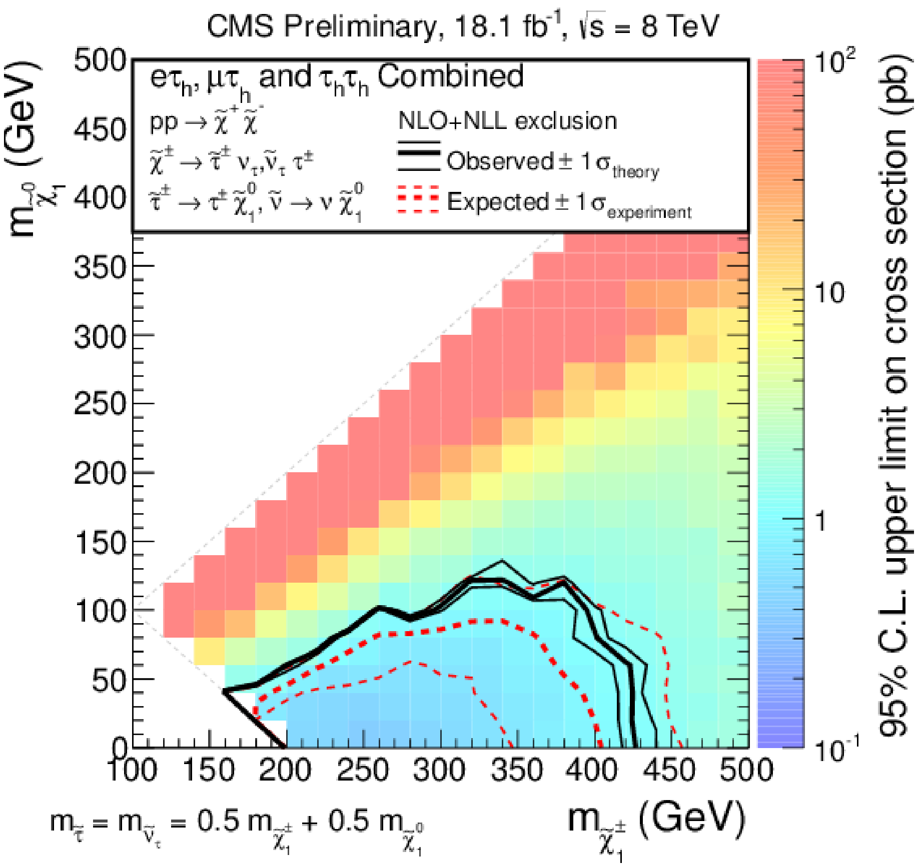
Results

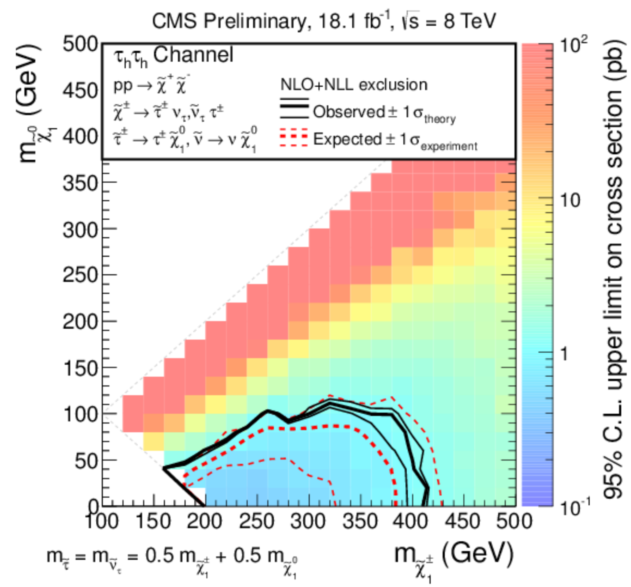
	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$ SR1	$\tau_h\tau_h$ SR2
Z+jets	$0.19 \pm 0.04 \pm 0.03$	$0.25 \pm 0.06 \pm 0.04$	$0.56 \pm 0.07 \pm 0.12$	$0.81 \pm 0.56 \pm 0.18$
$t\bar{t}$, VV, Higgs	$0.03 \pm 0.03 \pm 0.02$	$0.19 \pm 0.09 \pm 0.09$	$0.19 \pm 0.03 \pm 0.09$	$0.75 \pm 0.35 \pm 0.38$
W+jets	$3.30 \pm 3.35 \pm 0.56$	$8.15 \pm 4.59 \pm 1.53$	$0.72 \pm 0.11 \pm 0.57$	$2.58 \pm 0.35 \pm 1.25$
QCD multijet	-	-	$0.13 \pm 0.06 \pm 0.21$	$1.15 \pm 0.39 \pm 0.74$
SM Total	$3.52 \pm 3.35 \pm 0.56$	$8.59 \pm 4.59 \pm 1.53$	$1.60 \pm 0.15 \pm 0.62$	$5.29 \pm 0.70 \pm 1.51$
Observed	3	5	1	2

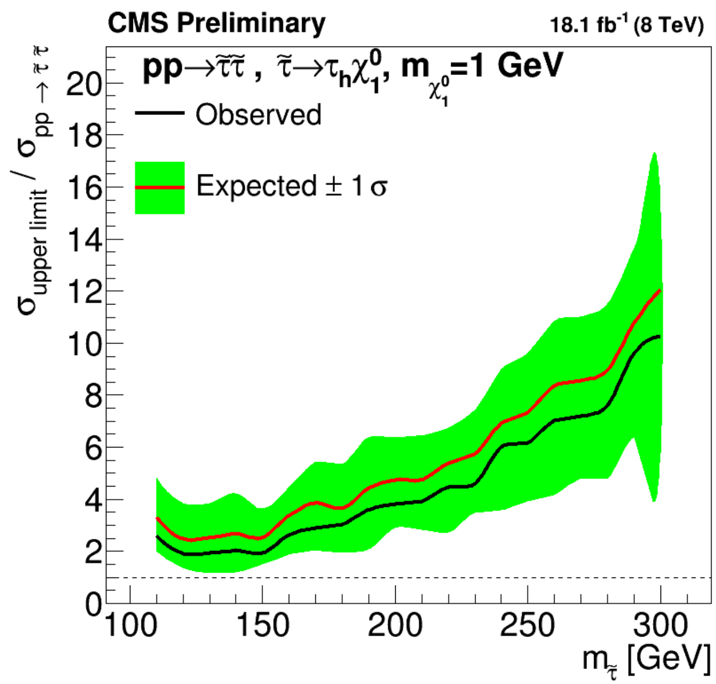




Interpretations





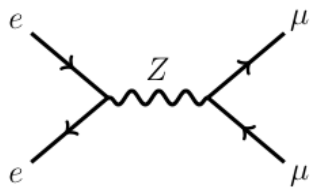


Summary and Conclusion

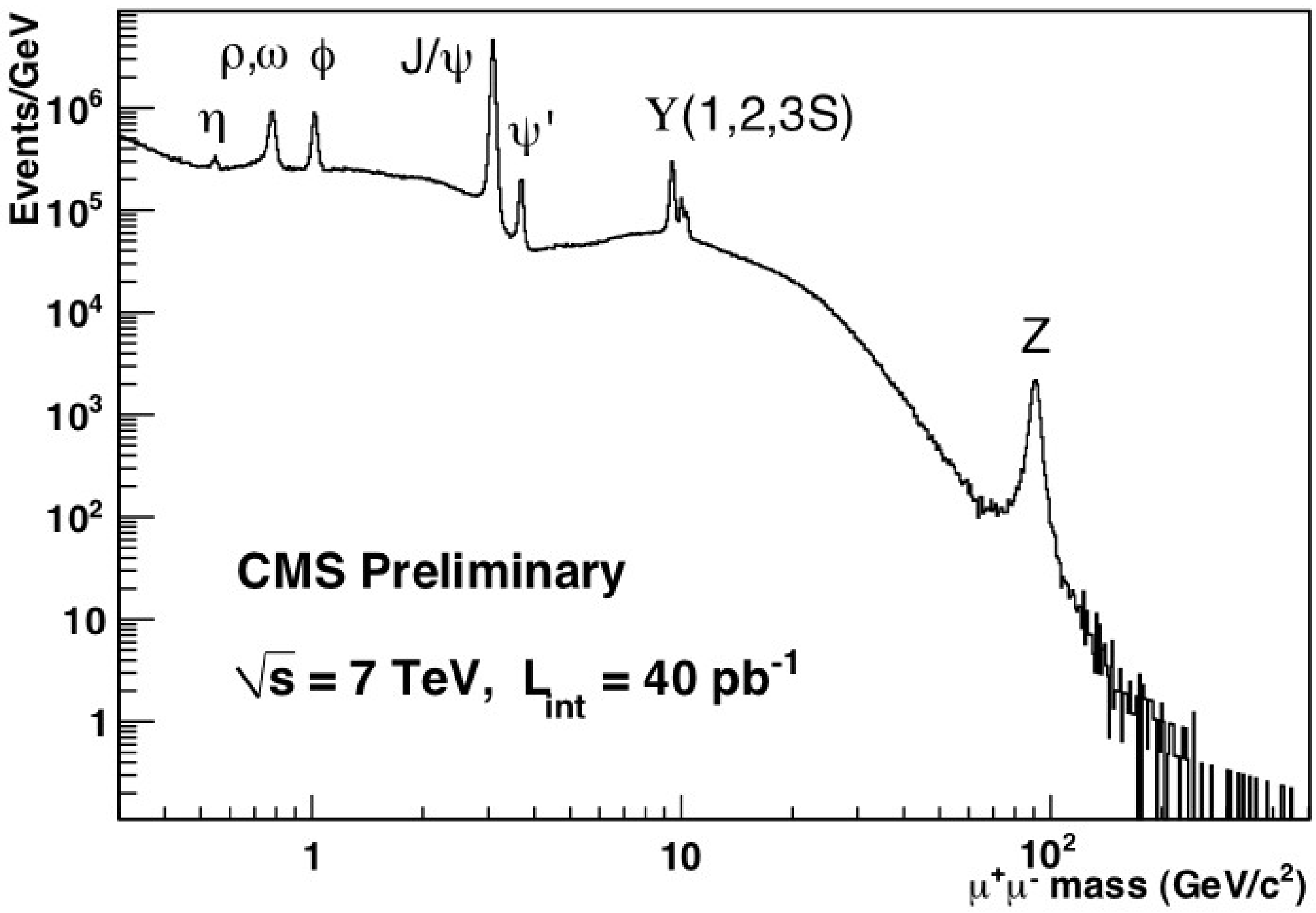
- A dedicated search for
  - direct stau production
  - chargino production decaying to stau
- MT2 is used to separate the signal and background
- 4 Signal regions
  - High MT2 : (Di-hadronic taus | e/mu + hadronic tau)
  - Low MT2 : Only di-hadronic taus / SumMT cut
- Backgrounds are estimated : Data Driven / Simulation verified using data
- No sign of new physics is observed
  - Chargino masses excluded up to ~420 GeV
  - Not sensitive to stau

Backup slides

MT2

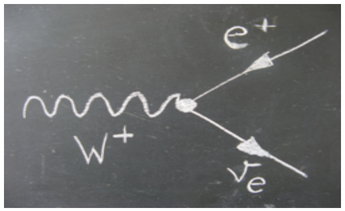


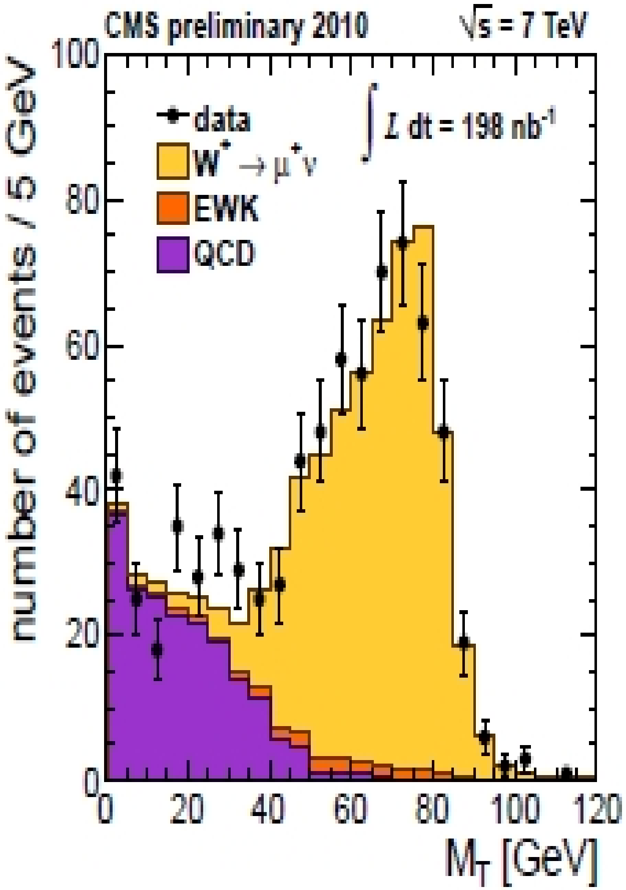
e
e
Z
μ
μ

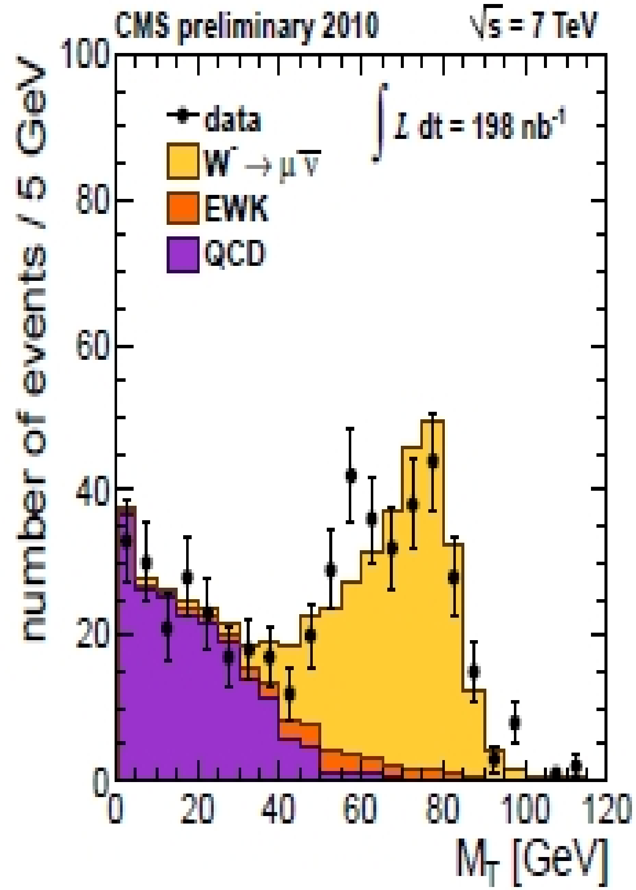


Events/GeV
η
ρ,ω
φ
J/ψ
ψ'
Υ(1,2,3S)
Z
CMS Preliminary
√s = 7 TeV, L_int = 40 pb^-1
μ+μ- mass (GeV/c2)

MT2

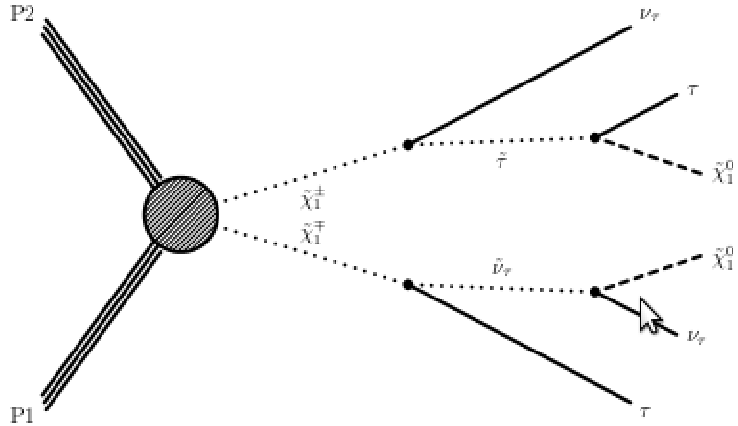






$$(m_{\mathrm{T}}{}^{(i)})^2 = (m^{\mathrm{vis}(i)})^2 + m^2_{\tilde{\chi}_1^0} + 2(E_{\mathrm{T}}^{\mathrm{vis}(i)} E_{\mathrm{T}}^{\tilde{\chi}_1^0(i)} - \vec{p}_{\mathrm{T}}^{\,\mathrm{vis}(i)} . \vec{p}_{\mathrm{T}}{}^{\tilde{\chi}_1^0(i)}).$$

MT2



$$M_{\mathrm{T2}}(m_{\tilde{\chi}_1^0}) = \min_{\vec{p}_{\mathrm{T}}^{\tilde{\chi}_1^0(1)} + \vec{p}_{\mathrm{T}}^{\tilde{\chi}_1^0(2)} = \vec{p}_{\mathrm{T}}^{\mathrm{miss}}} \left[\max \left\{ m_{\mathrm{T}}{}^{(1)}, m_{\mathrm{T}}{}^{(2)} \right\} \right].$$