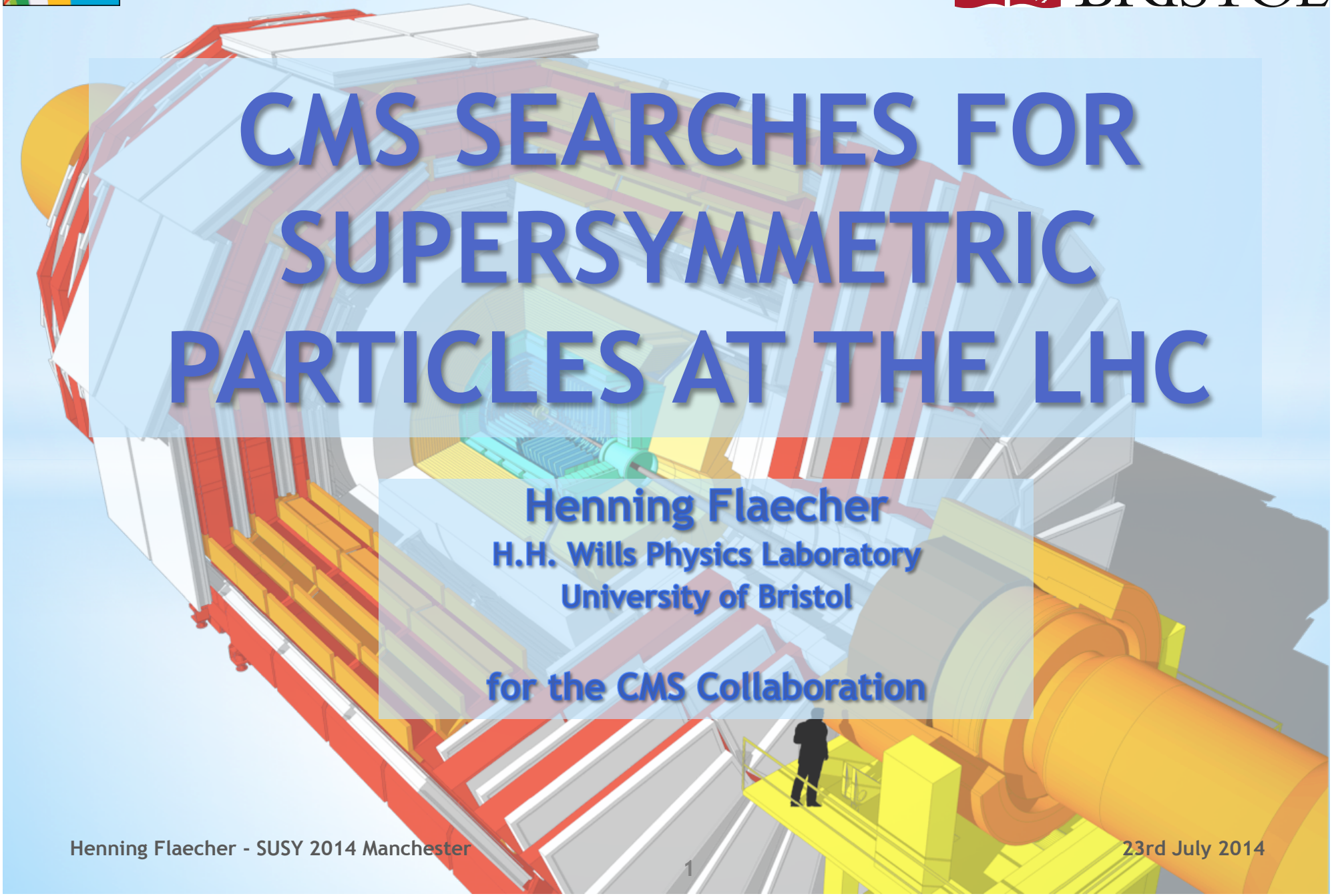


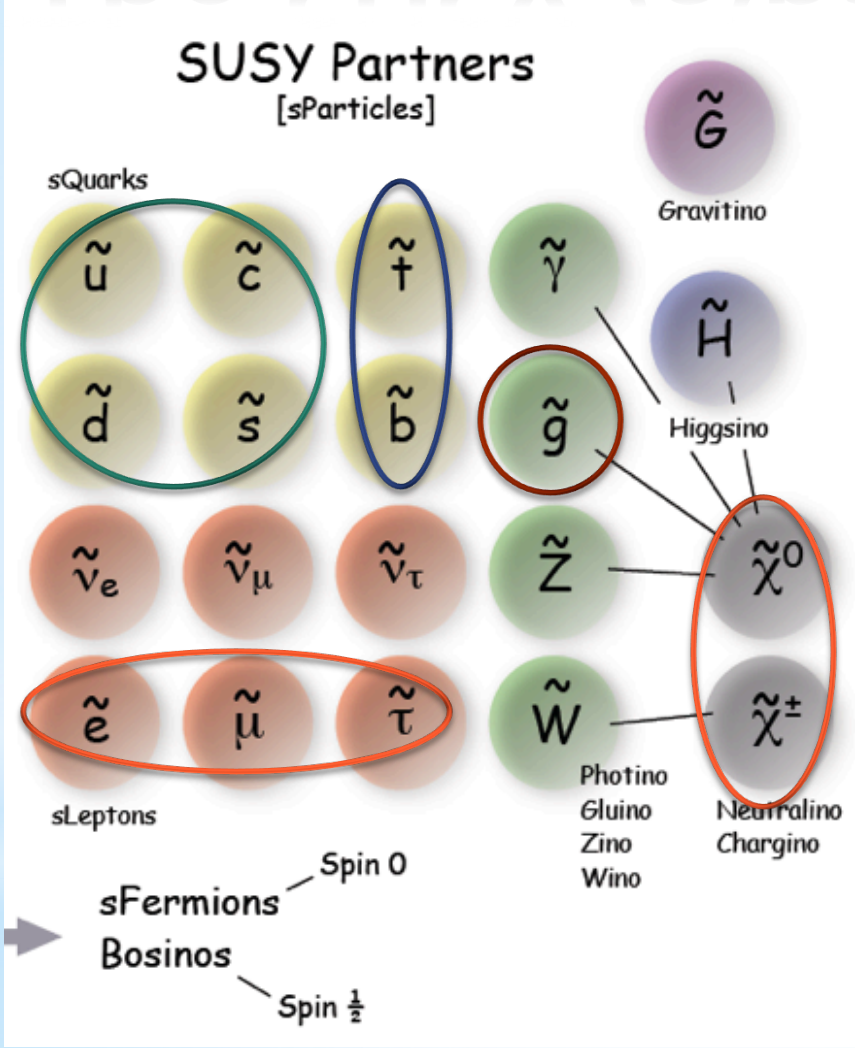
CMS SEARCHES FOR SUPERSYMMETRIC PARTICLES AT THE LHC

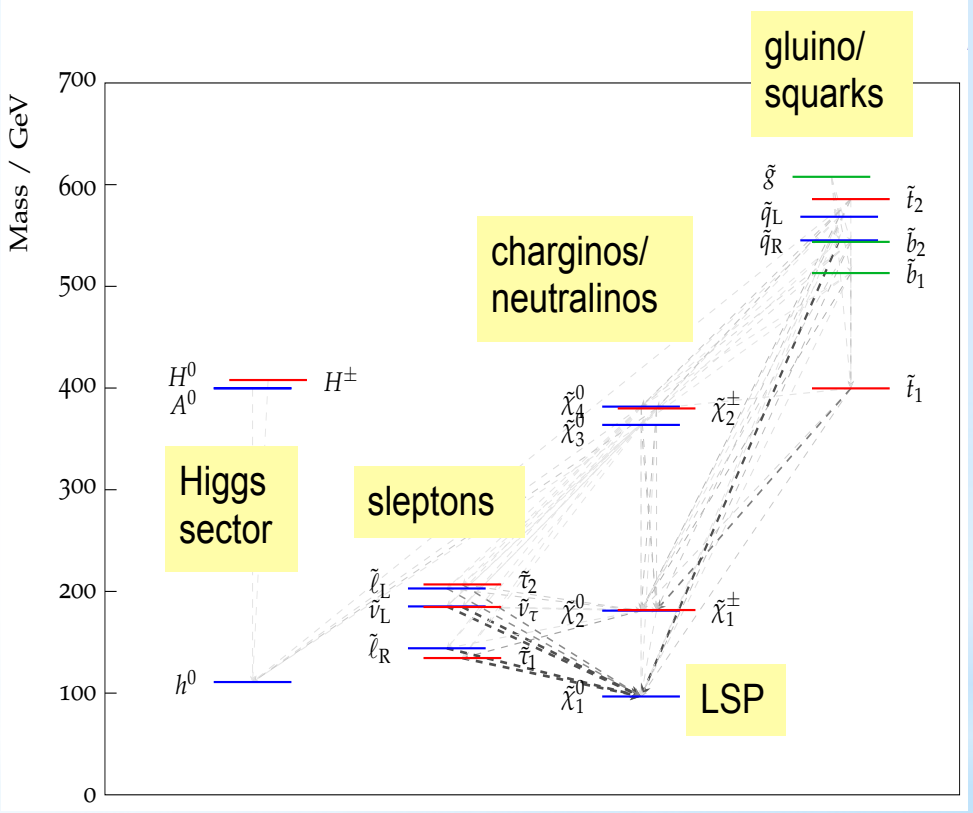
Henning Flaecher

H.H. Wills Physics Laboratory
University of Bristol

for the CMS Collaboration

*The SUSY (s)particle spectrum

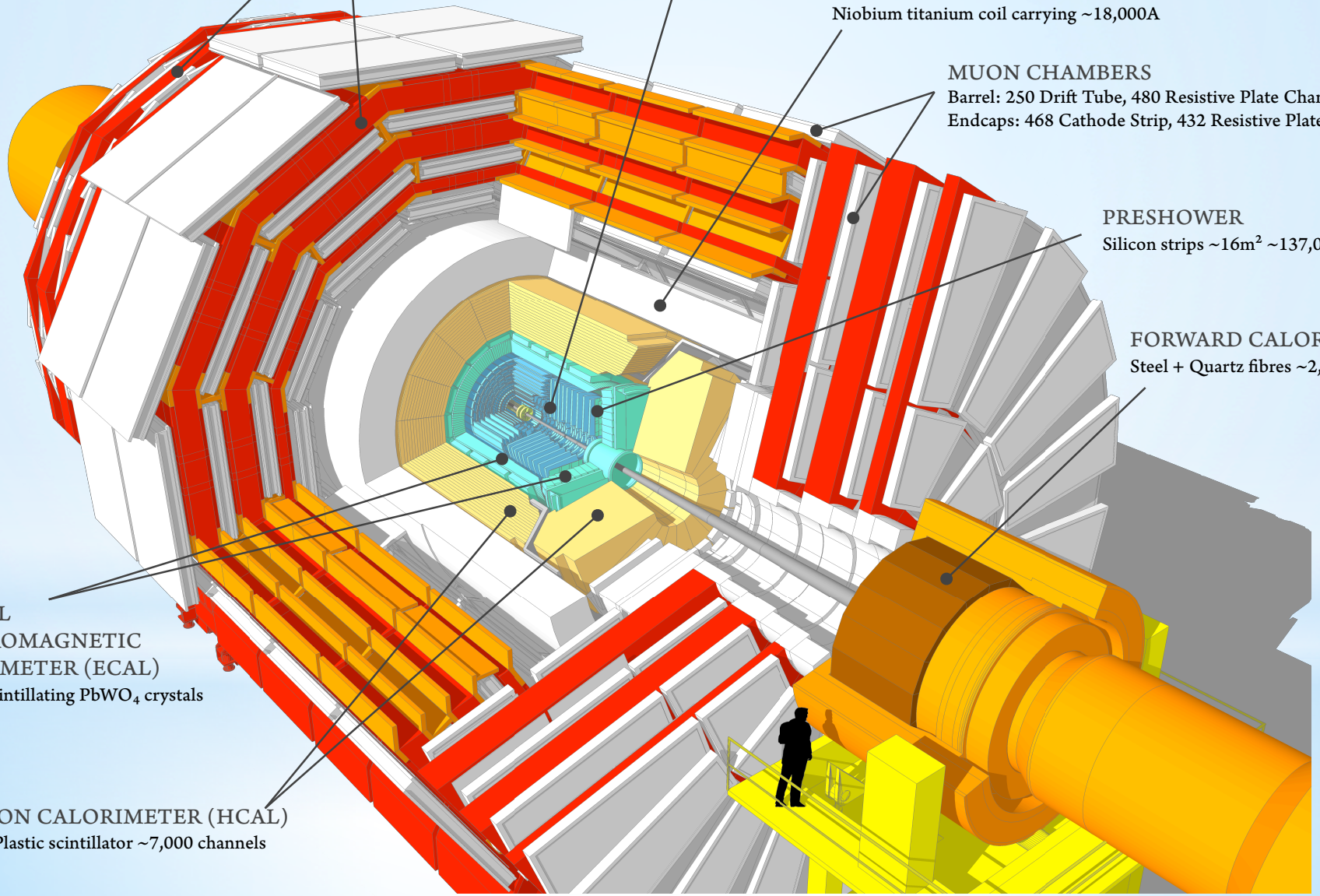




*Search for ~all of these, produced either directly or in cascades

CMS DETECTOR

Total weight	: 14,000 tonnes
Overall diameter	: 15.0 m
Overall length	: 28.7 m
Magnetic field	: 3.8 T



STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

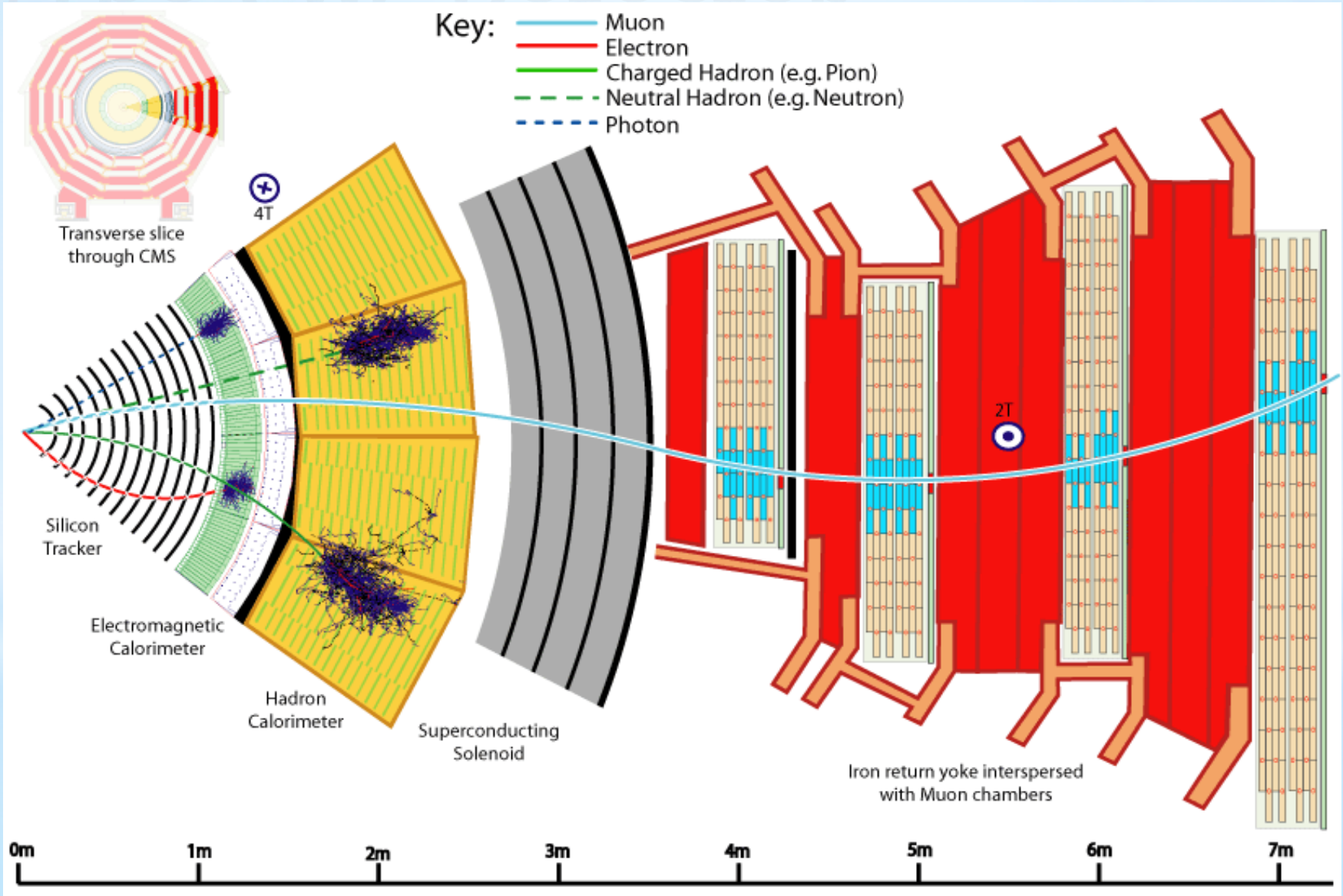
PRESHOWER
Silicon strips ~16m² ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

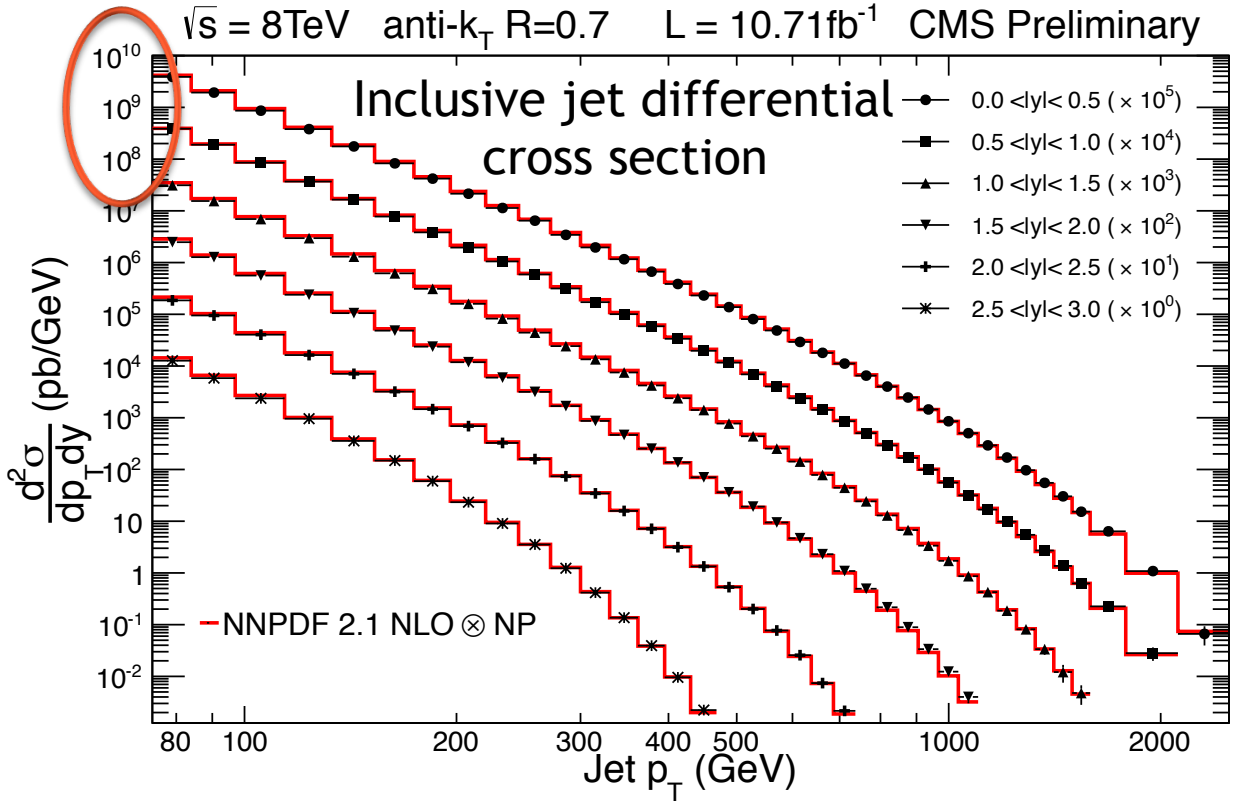
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

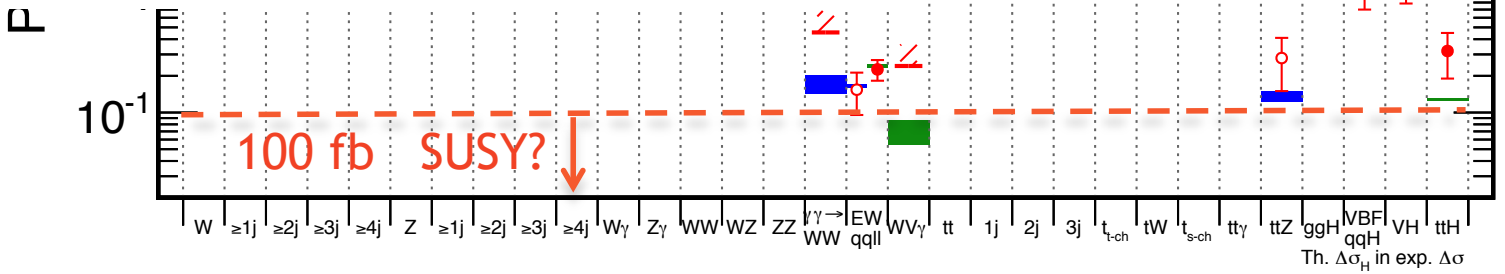
The CMS Detector

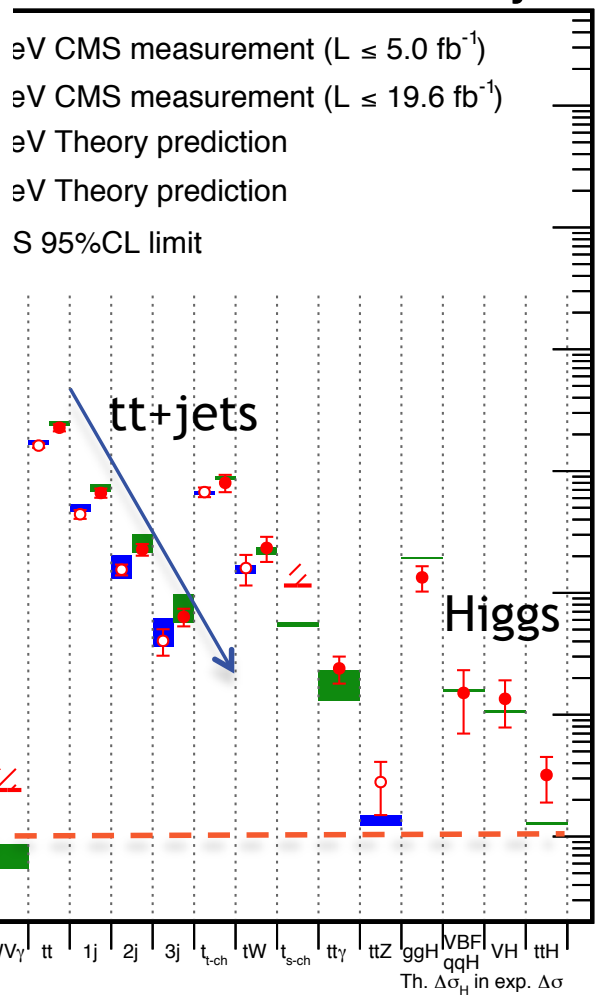


The experimental challenge

- SUSY signal likely small compared to SM backgrounds

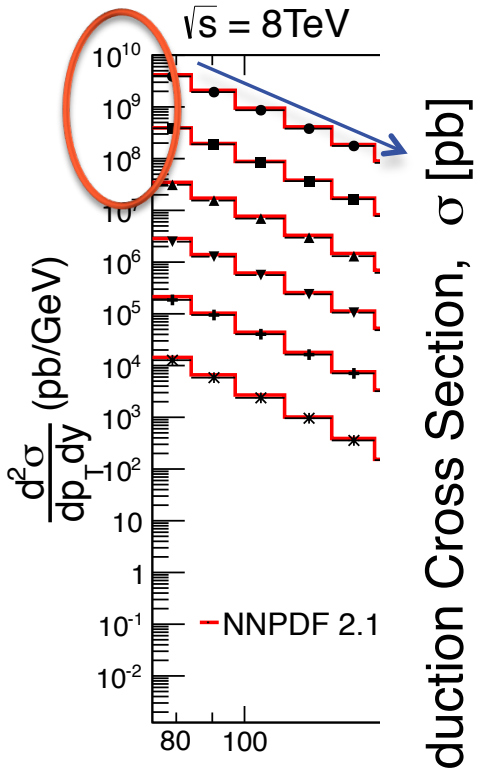




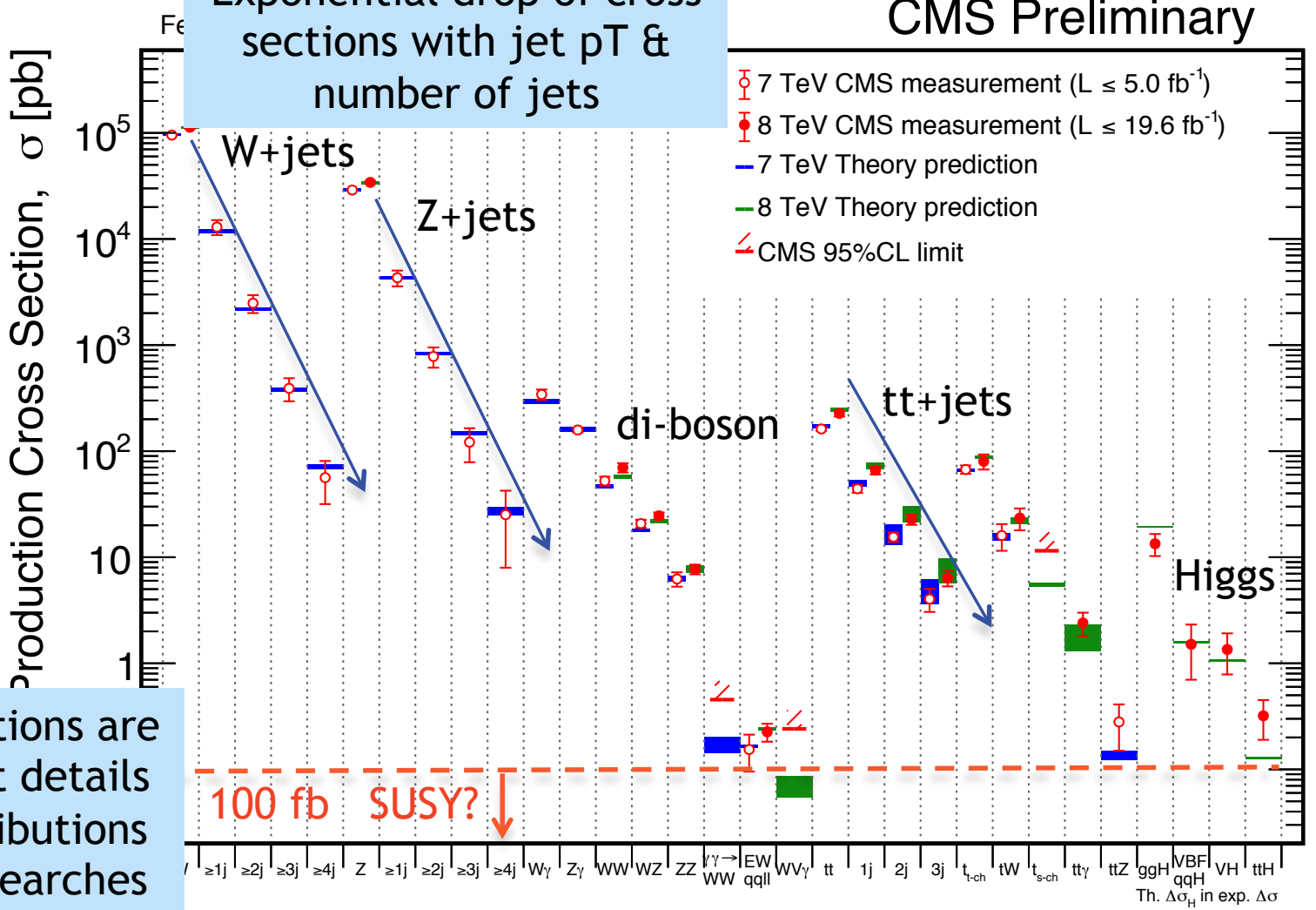


*The experimental challenge

*SUSY signal likely small compared to SM backgrounds



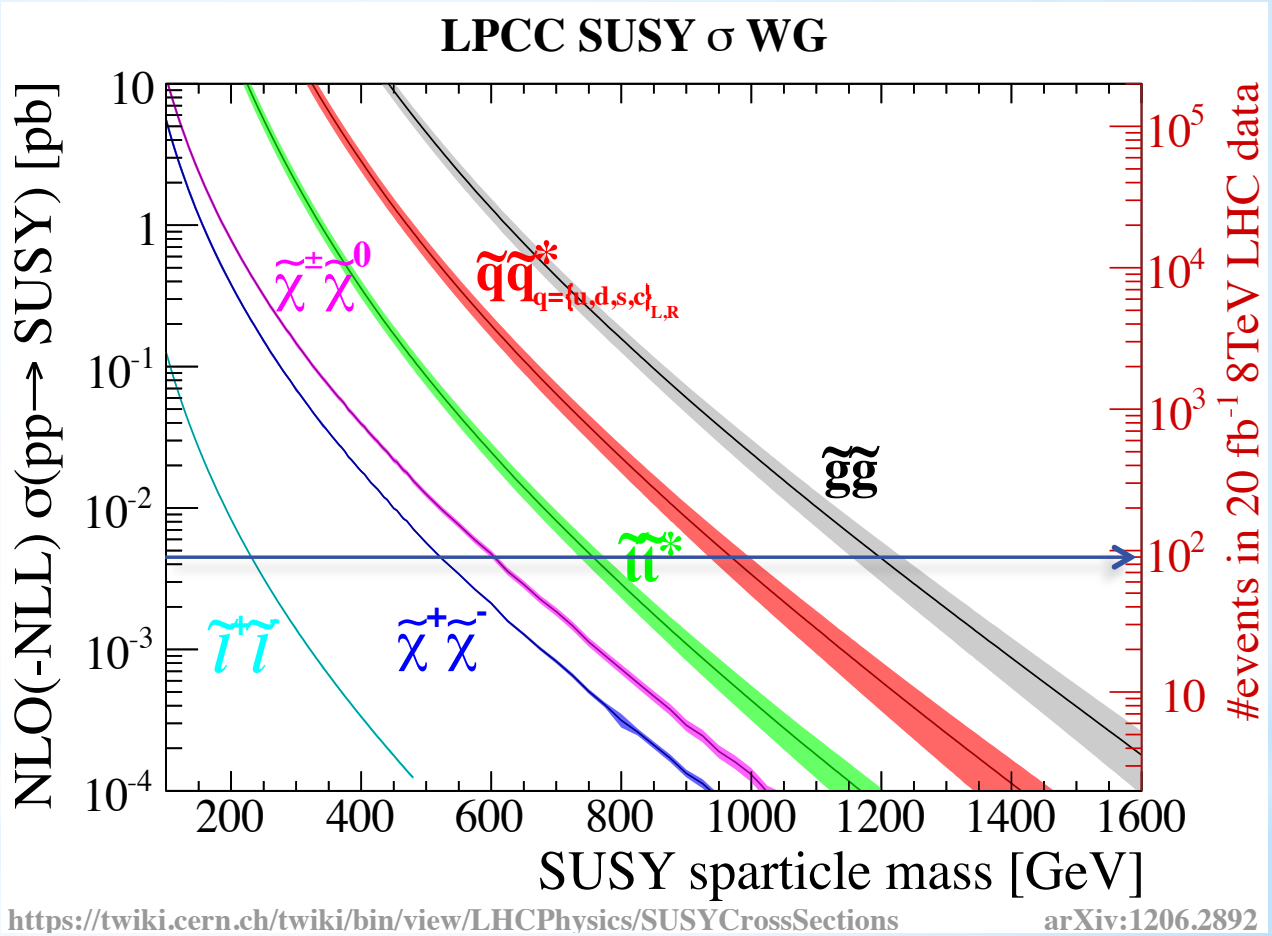
Exponential drop of cross sections with jet pT & number of jets



Inclusive cross sections are well measured but details of kinematic distributions are key for SUSY searches

*Focus of current searches

* stops and sbottoms (special role wrt to Higgs)
* gluinos and "light" squarks
  * search again for stop and sbottoms in gluino decays
* charginos, neutralinos, sleptons
* searches for Higgs in SUSY cascade decays
* RPV searches



Focus of current searches

* stops and sbottoms
  * Direct stop pair production
    SUS-13-015, SUS-14-011
  * Monojet search for stop-> charm χ_1^0
    SUS-13-009
  * Search for sbottom production
    SUS-13-018
* gluinos and "light" squarks
  * search again for stop and sbottom in gluino decays
  * Inclusive search with M_{T2}
    SUS-13-019
  * Inclusive search with razor
    SUS-14-011
* searches for Higgs in SUSY cascade
  * $stop_2$ -> $stop_1$ + higgs/Z search
    SUS-13-024
  * $neutralino_1$ -> higgs + gravitino
    SUS-13-022
* charginos, neutralinos, sleptons
  * channels with Higgs, Z & W bosons
    SUS-13-006, SUS-14-002
  * OS dilepton edge – SUS-12-019
  * GGM searches with photons –
    SUS-14-008
* RPV searches
  * SUS-12-015, SUS-13-010

* There are many many more results, please check:
* https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

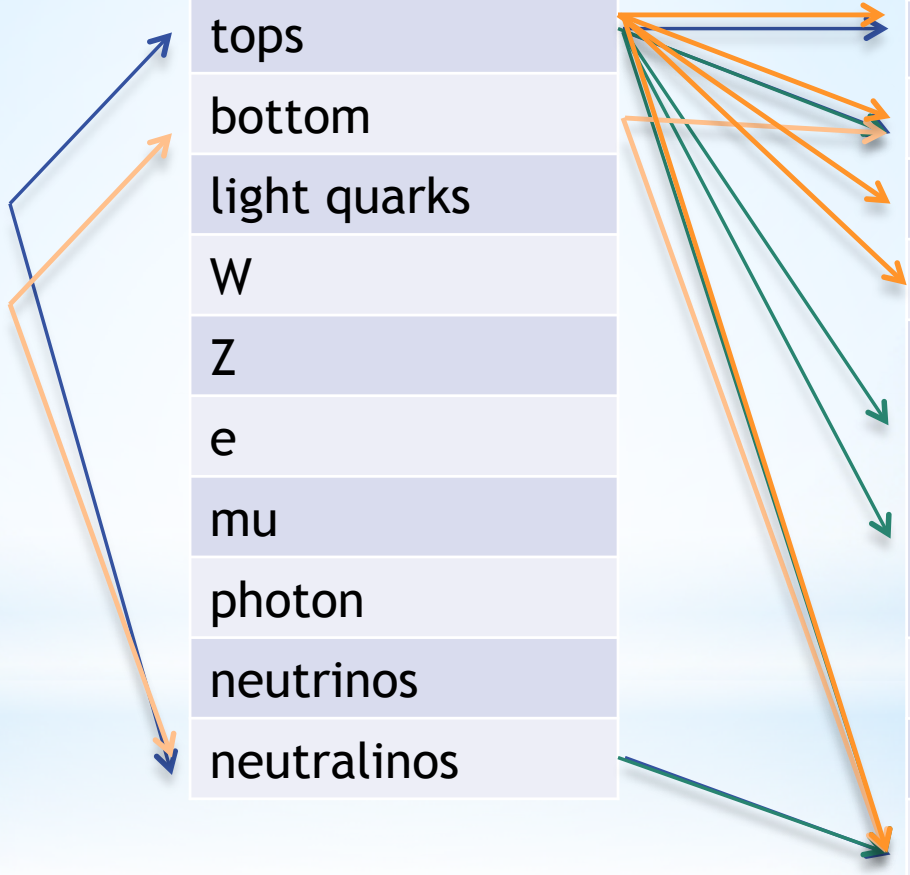
*Signature based searches

*split by no. of jets, b-jets, leptons, photons, …

Sparticles
gluinos
squarks (1st & 2nd gen)
stops
sbottom
charginos
neutralinos
sleptons

Decay products
tops
bottom
light quarks
W
Z
e
mu
photon
neutrinos
neutralinos

Physics Objects
jets
b-jets
electrons
muons
dilepton pairs • opposite sign • same sign • opposite flavour • same flavour
multileptons
photons
missing energy



Many possible final states for decay of one particle – can get complicated quickly!

*Signature based searches

*split by no. of jets, b-jets, leptons, photons, …

Sparticles	
gluinos	✔
squarks (1st & 2nd gen)	✔
stops	✔
sbottom	✔
charginos	
neutralinos	
sleptons	

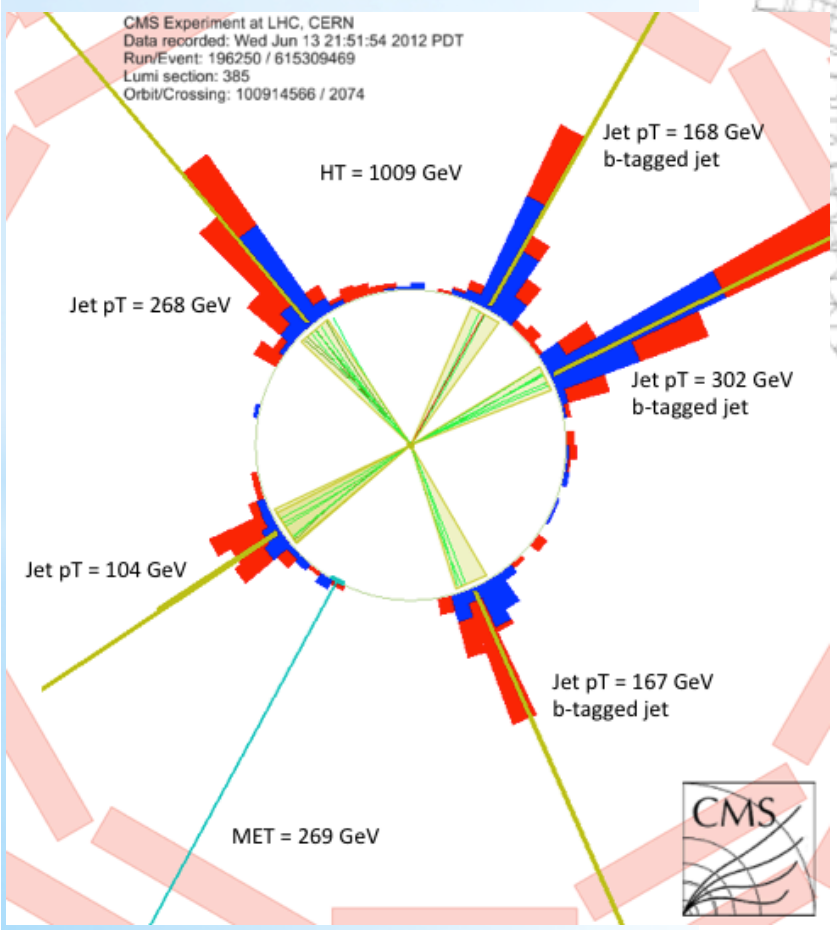
Decay products	
tops	✔
bottom	✔
light quarks	✔
W	✔
Z	
e	
mu	
photon	
neutrinos	✔
neutralinos	✔

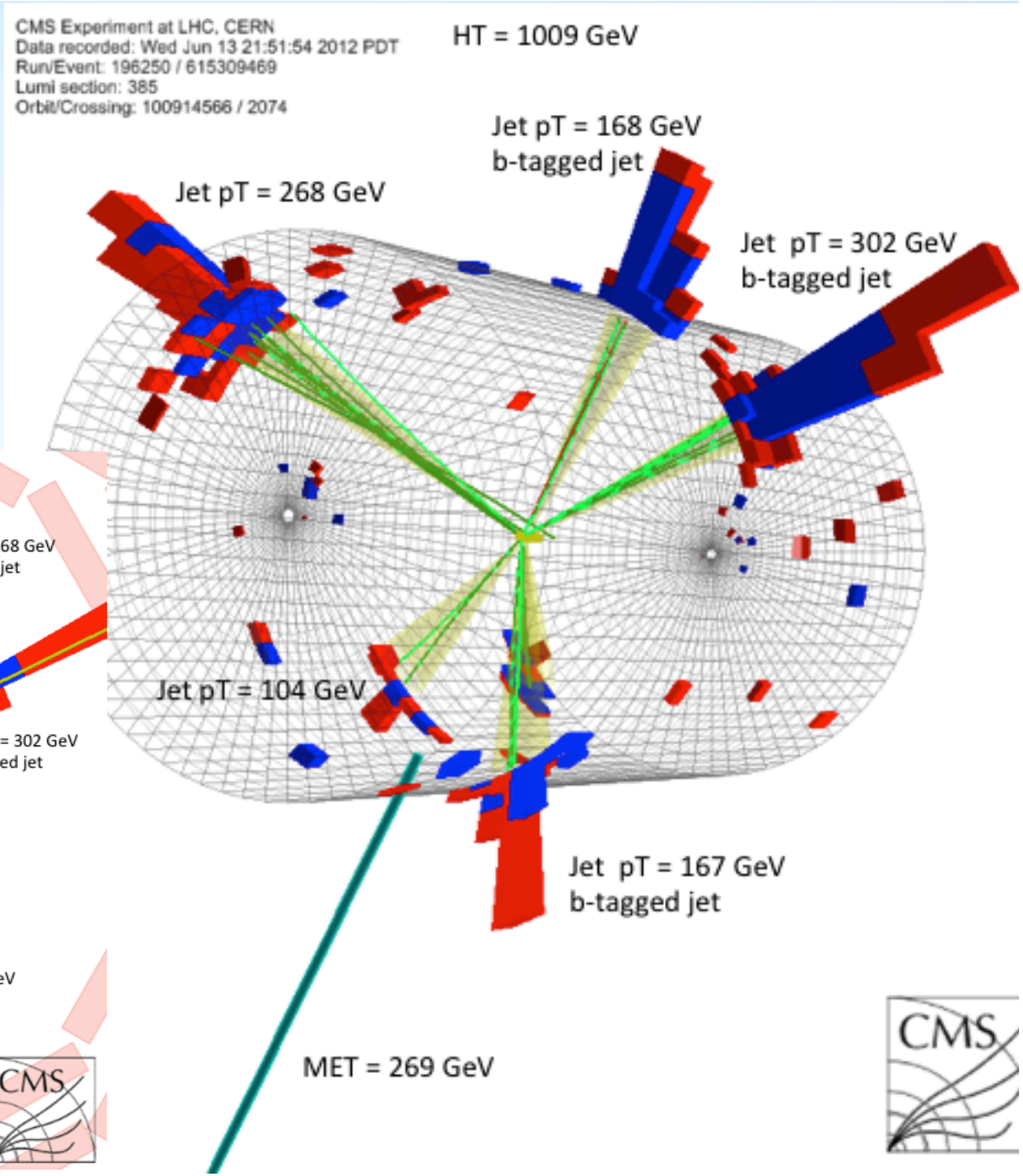
	Physics Objects
✔	jets
✔	b-jets
	electrons
	muons
	dilepton pairs • opposite sign • same sign • opposite flavour • same flavour
	multileptons
	photons
✔	missing energy

given final state often sensitive to more than one decay chain

Real Data Event Display

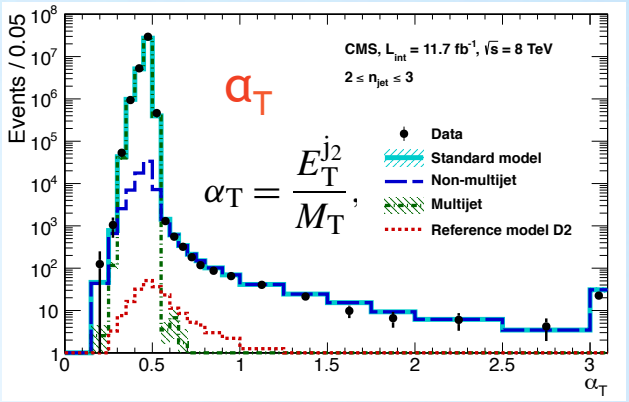
multi-jet
multi-b
missing energy



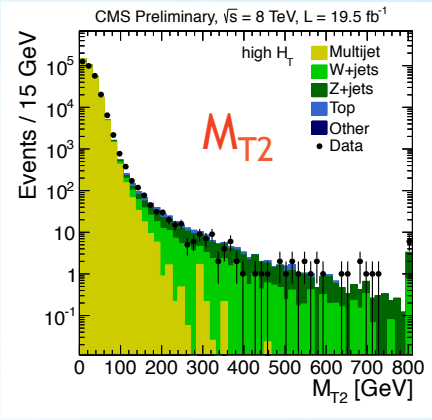


Search strategies

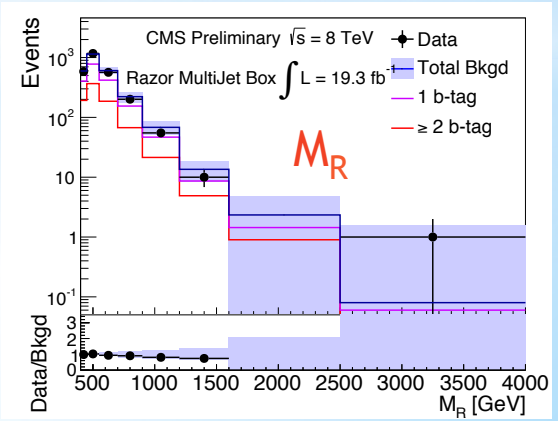
- Define signal regions such to keep expected backgrounds small, by using novel kinematic variables, e.g., α_T, M_{T2}, M_{CT}, R^2, M_R etc.
- Define background enriched control samples that are kinematically similar to signal region
- Extrapolate from control -> signal regions using extrapolation factors derived from simulation and data wherever possible
- Verify extrapolation and its accuracy from independent control regions



$$M_{T2}(m_{\tilde{\chi}}) = \min_{\vec{p}_T^{\tilde{\chi}(1)} + \vec{p}_T^{\tilde{\chi}(2)} = \vec{p}_T^{\text{miss}}} \left[\max\left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

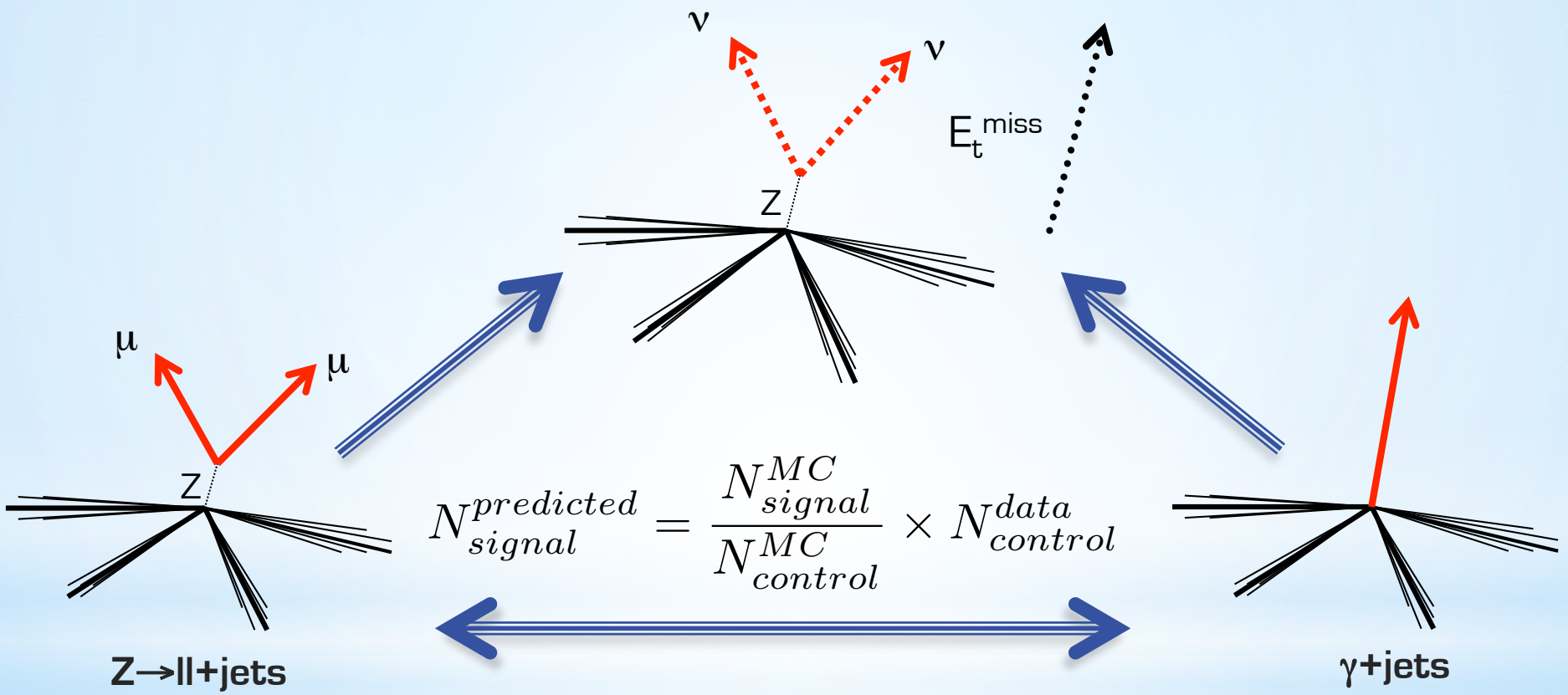


$$M_R \equiv \sqrt{(p_{j_1} + p_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$



* Analysis methods for background estimation

An illustrative example: Z→νν+jets,
irreducible background for Jets+E_t^{miss} search



Strength:
- very clean, easy to select

Weakness:
- low statistic: factor 6 suppressed wrt. to Z →νν

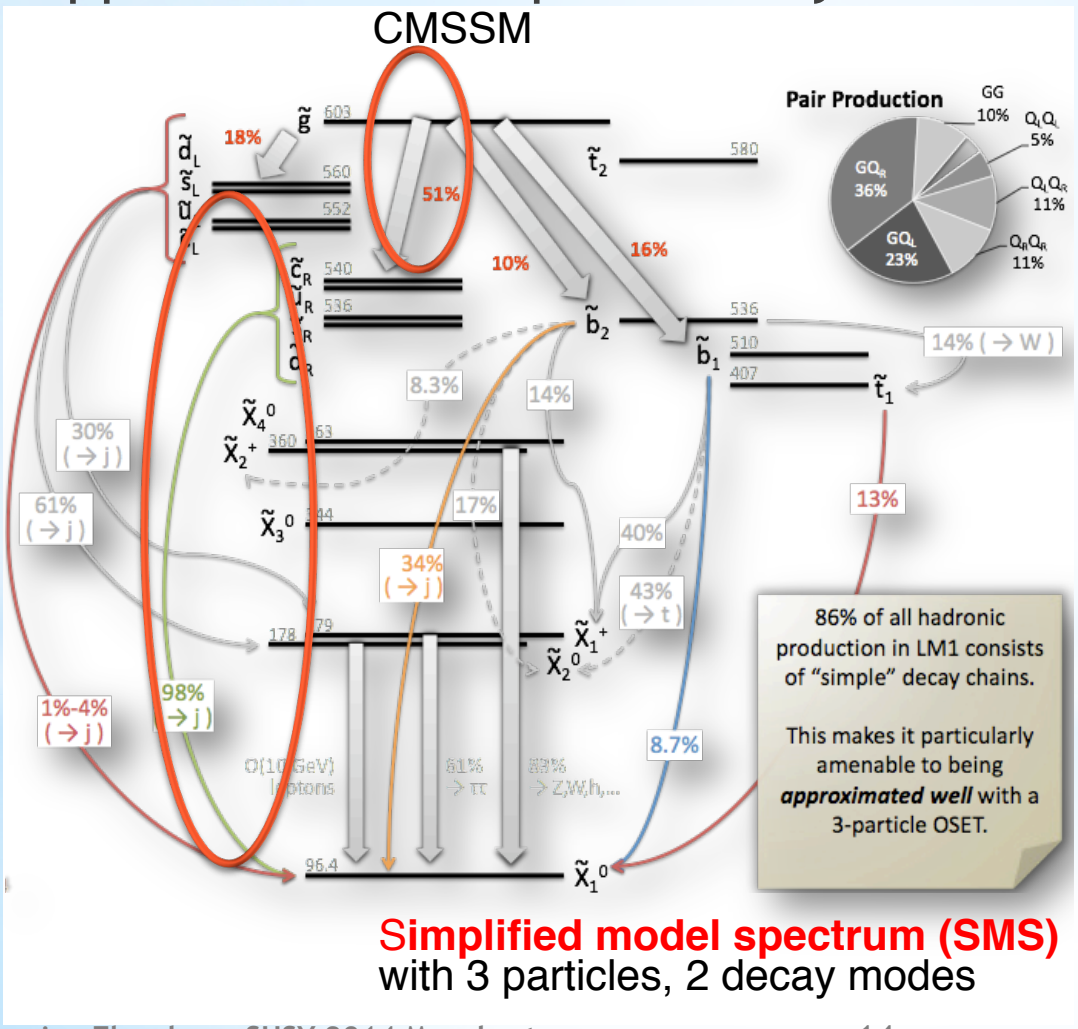
Verify MC extrapolation factor by "predicting", e.g., Z+jets from W+jets

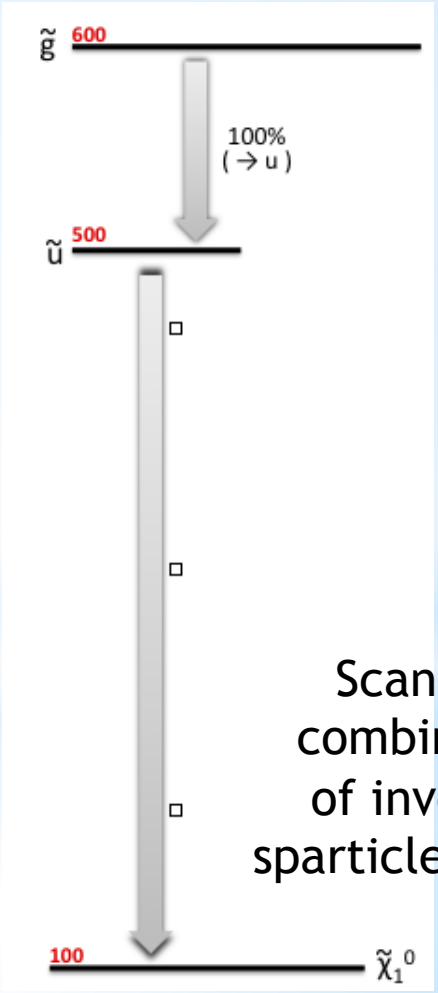
Strength:
- large stat, clean for high E_γ

Weakness:
- not clean for E_γ<100 GeV,
- theoretical uncertainties

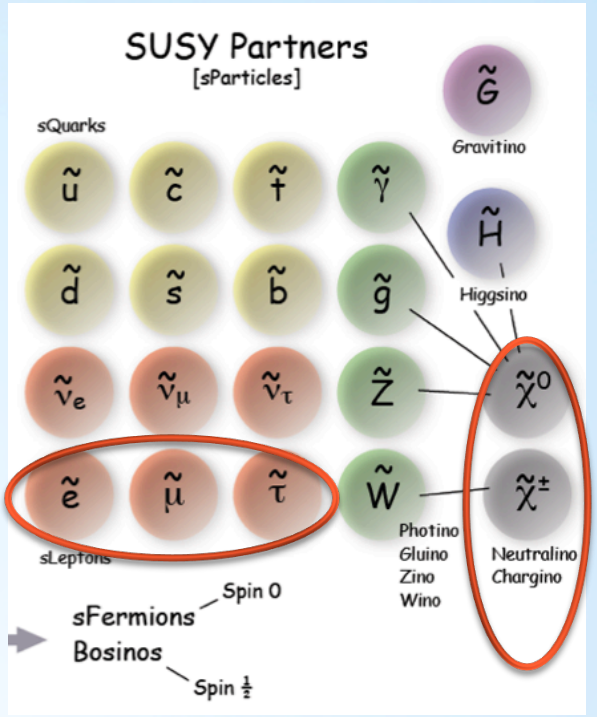
Interpretation of searches: from full spectra to simplified models

- often a few dominant decay chains
- approximate full spectrum by a few decay chains





Scan any combination of involved sparticle masses



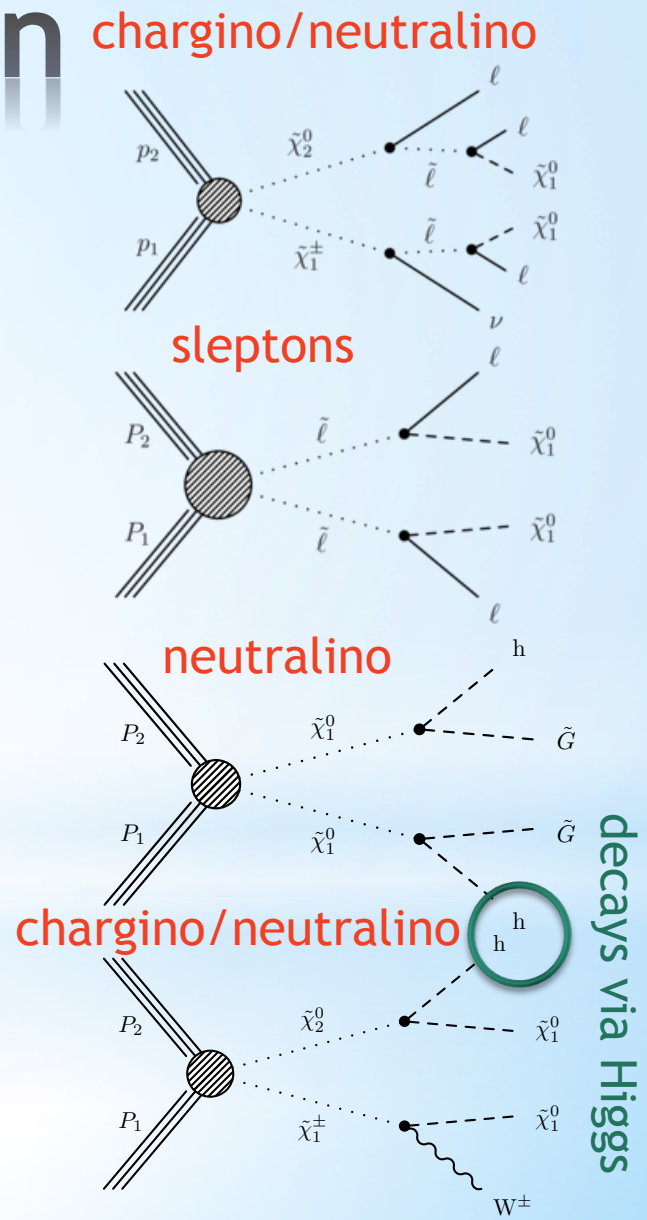
*Searches for charginos, neutralinos and sleptons

Searches for electroweak SUSY production

- Electroweak production characterized by
  - smaller predicted cross sections
  - lower levels of hadronic activity

- CMS carried out comprehensive search programme covering di-boson + MET final states: WW, WZ, ZZ, Wh, Zh, hh
  - with h -> ZZ, WW, γγ, bb

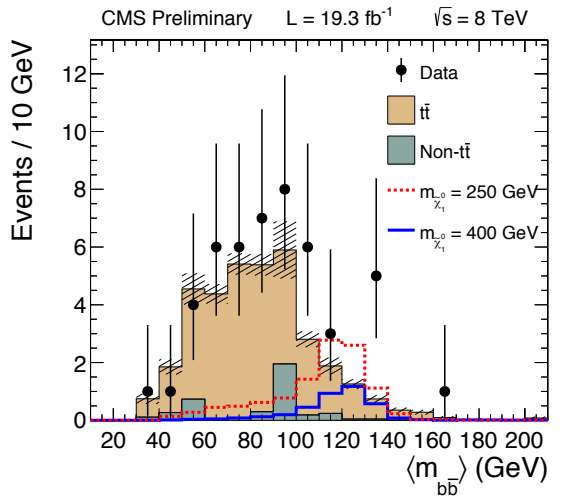
- Higgs discovery opens up new SUSY searches:
  - Lightest neutral CP-even Higgs (h) expected to be SM-like, if others are heavy.
  - Charginos and neutralinos decay to h+LSP or V+LSP, with V=W,Z.

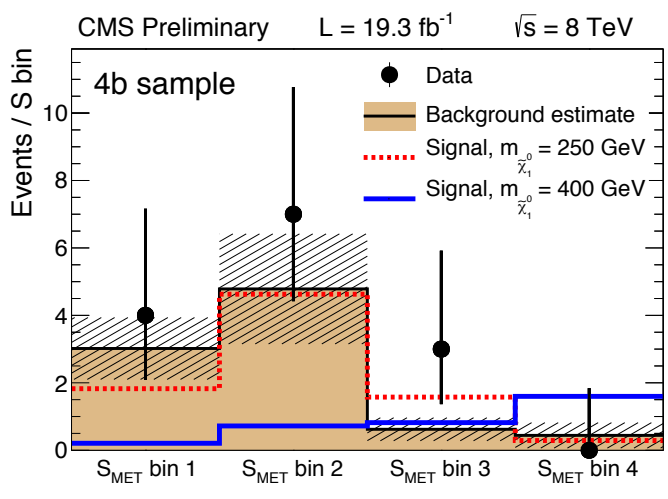


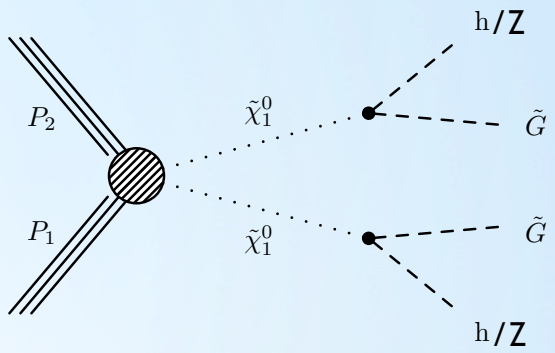
*Search for decay to Zh and hh

SUS-14-002

*hh->bbbb channel

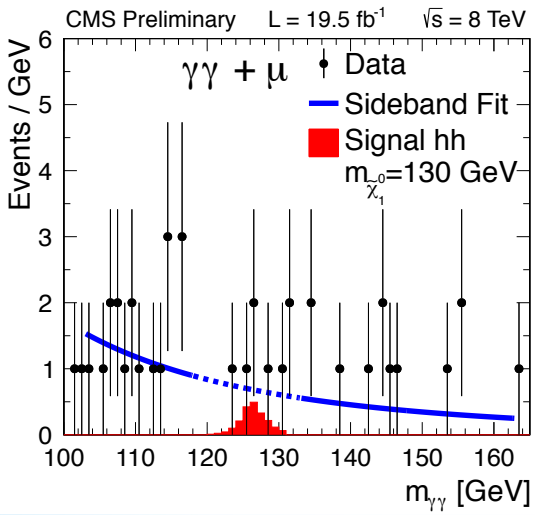




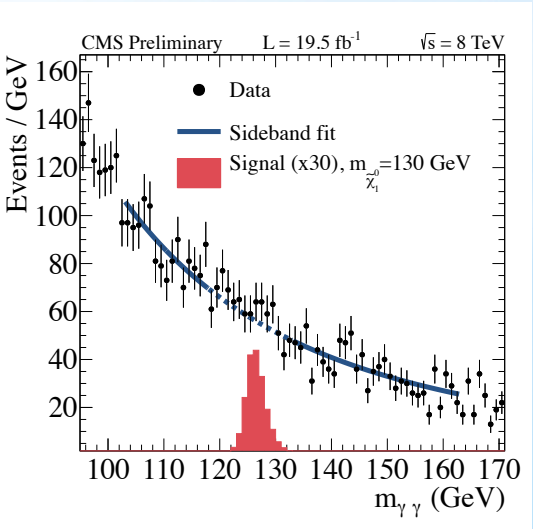


*hh, hZ, and hW channels with one h → γγ decay

hh, hZ, and hW → γγ+muons



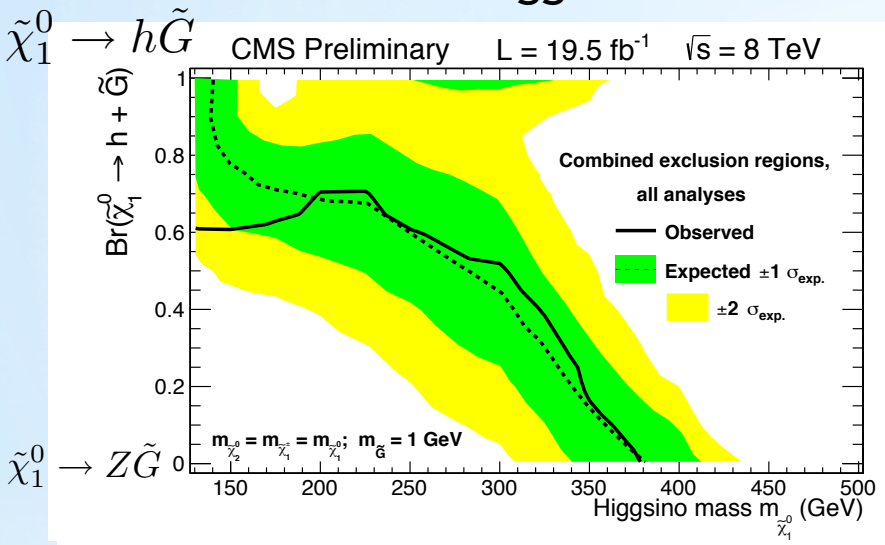
hZ and hW → γγ+2 jets

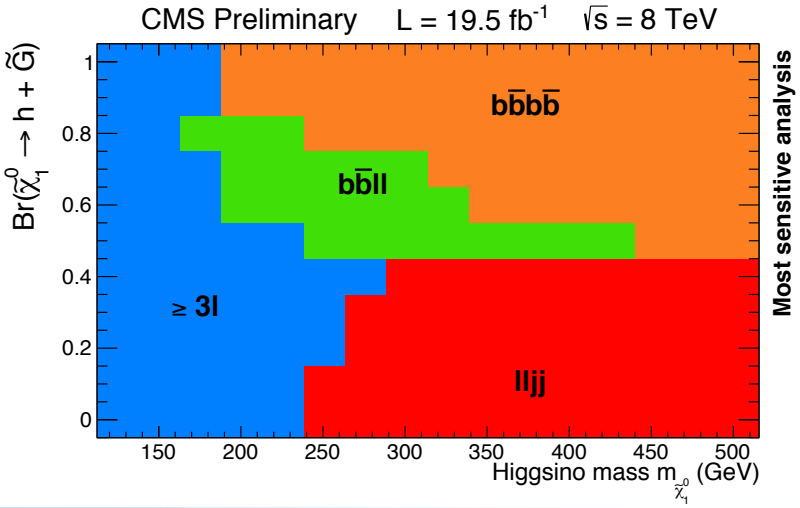


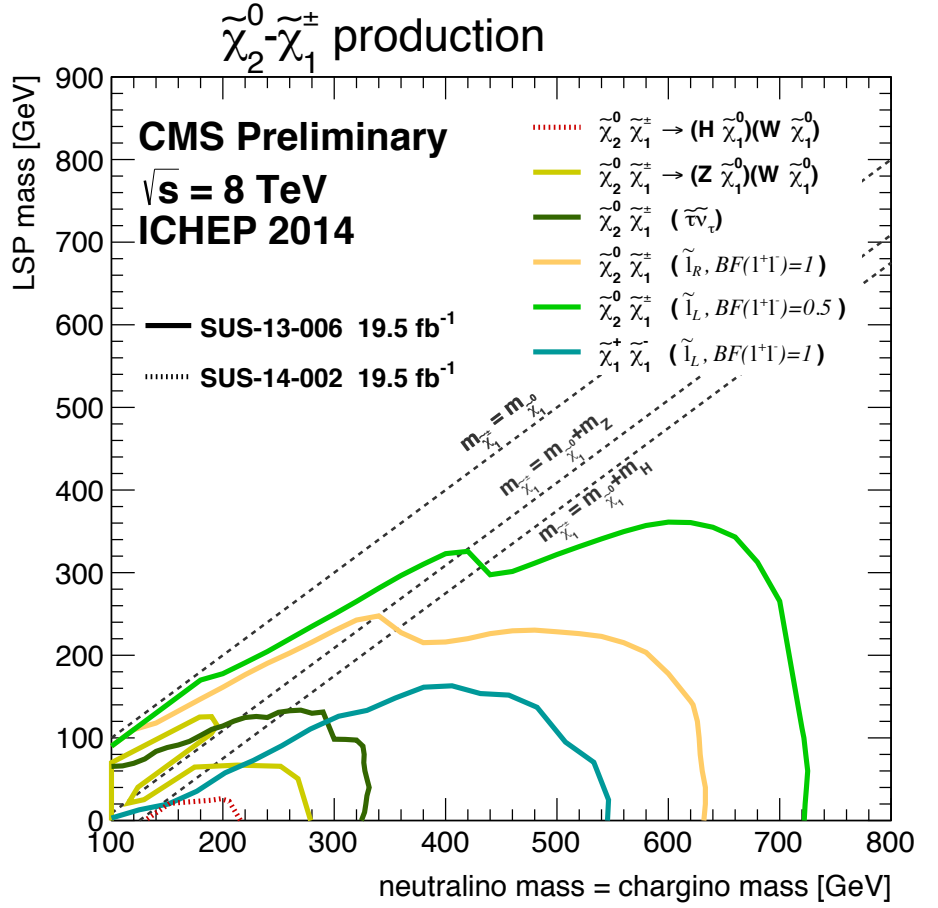
* Interpretations in Simplified models

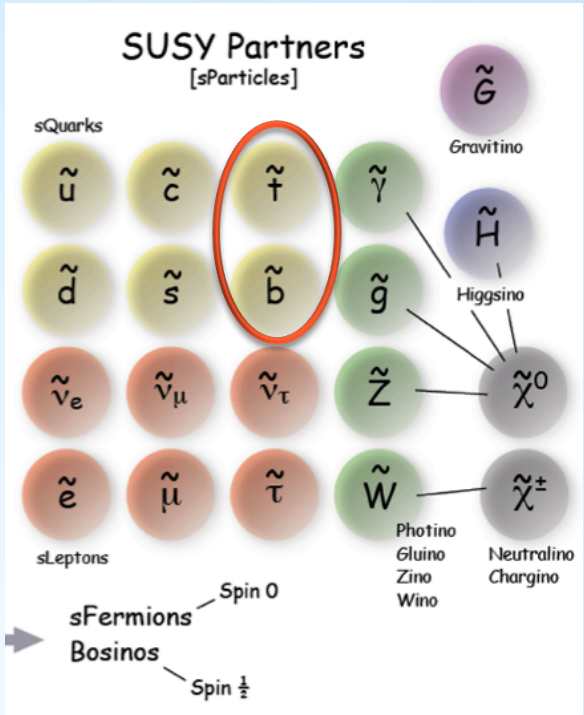
SUS-14-002 & arXiv:1405.7570

GMSB Higgsino



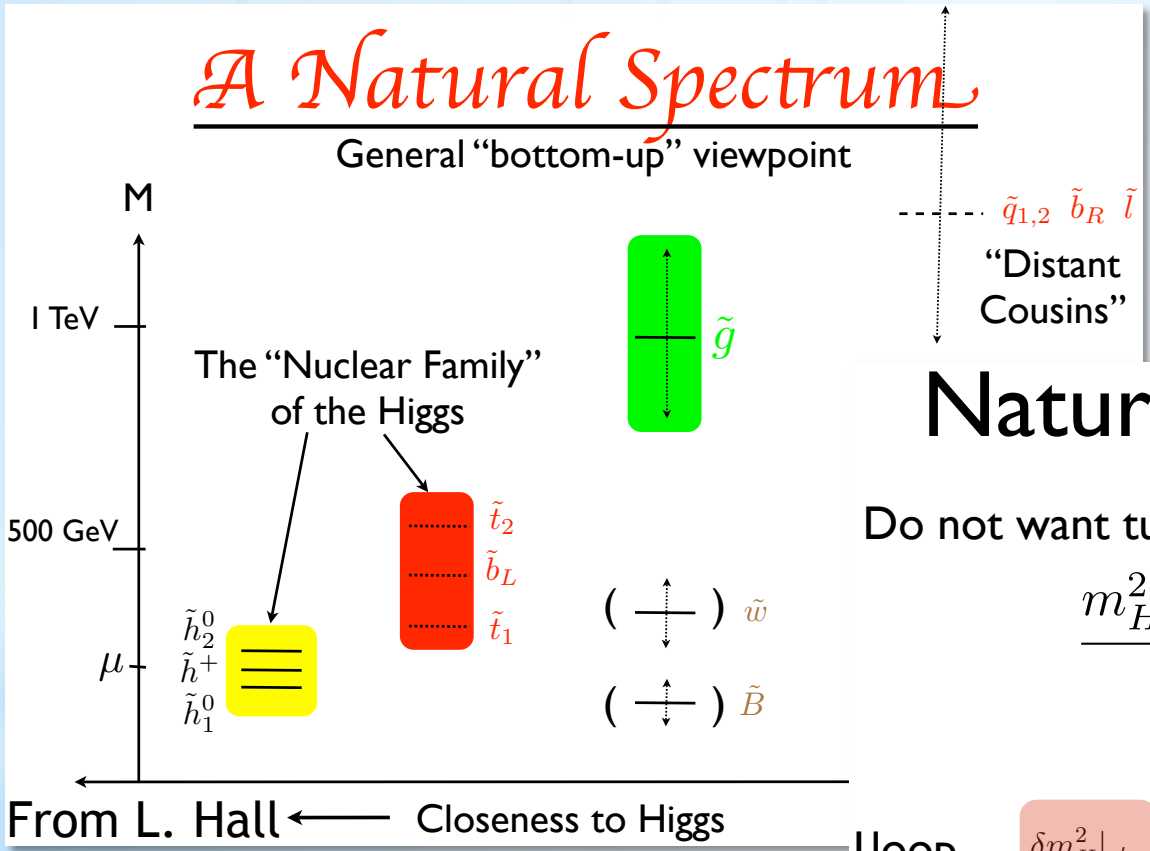






* direct production of stops and sbottoms

*Search for 3rd generation SUSY - stop and sbottom searches



Mass hierarchies that avoid fine-tuning

Natural EWSB & SUSY*

* valid beyond MSSM

Do not want tuning in (Higgs mass)^2

$$\frac{m^2_{Higgs}}{2} = -|\mu|^2 + \ldots + \delta m^2_H$$

Higgsinos

1loop $$\delta m^2_H|_{stop} = -\frac{3}{8\pi^2} y_t^2 \left(m^2_{U_3} + m^2_{Q_3} + |A_t|^2\right) \log\left(\frac{\Lambda}{\text{TeV}}\right)$$

stops, sbottom$_L$

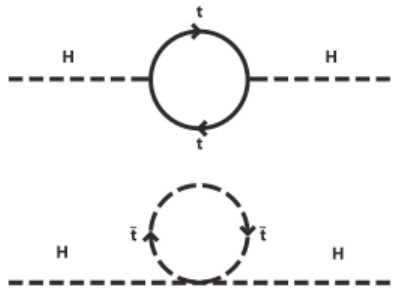
2loop $$\delta m^2_H|_{gluino} = -\frac{2}{\pi^2} y_t^2 \left(\frac{\alpha_s}{\pi}\right) |M_3|^2 \log^2\left(\frac{\Lambda}{\text{TeV}}\right)$$

gluino

From A. Weiler

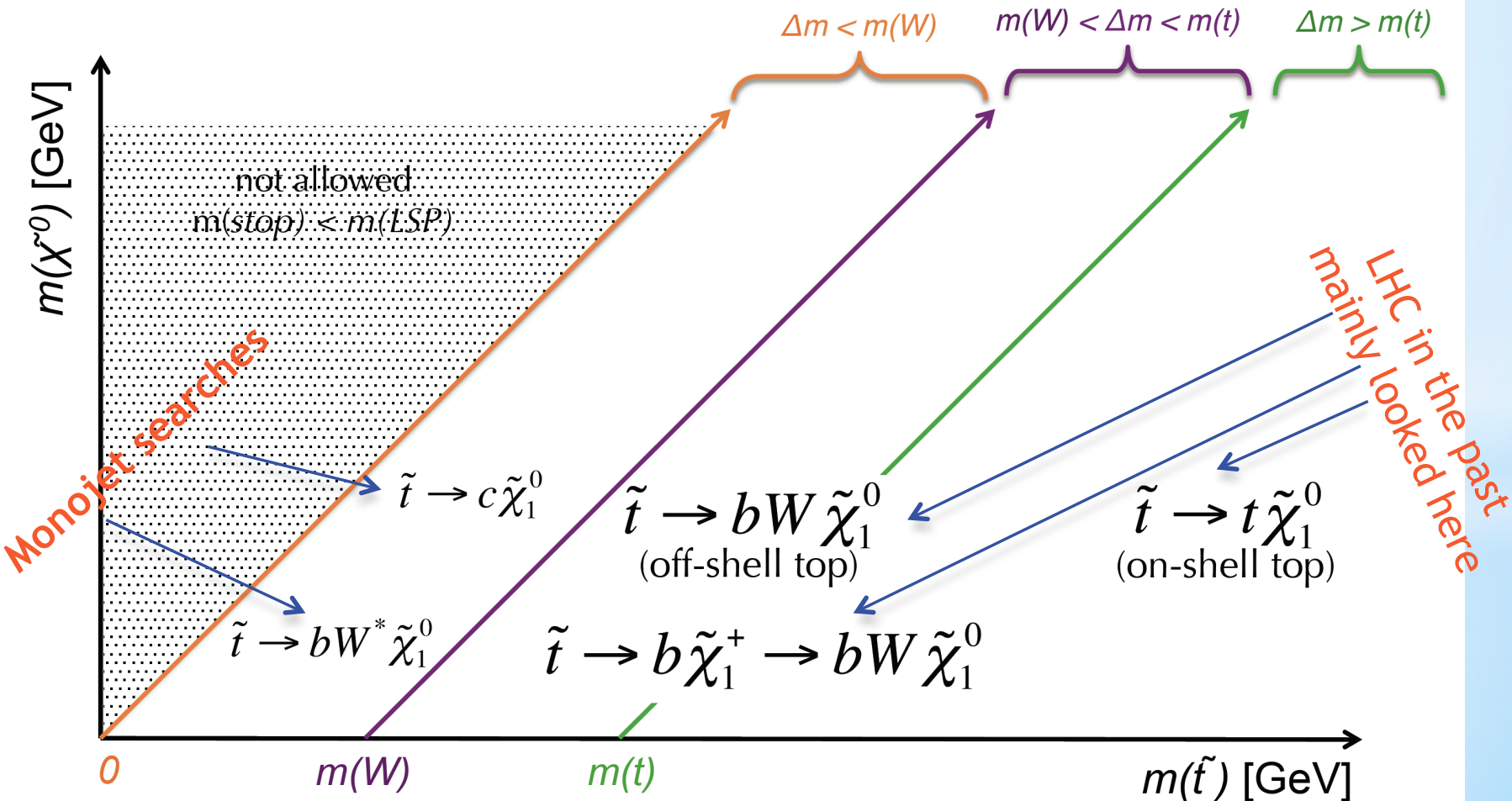
Stop searches

- Dominant stop decay channel largely depends on available phase space



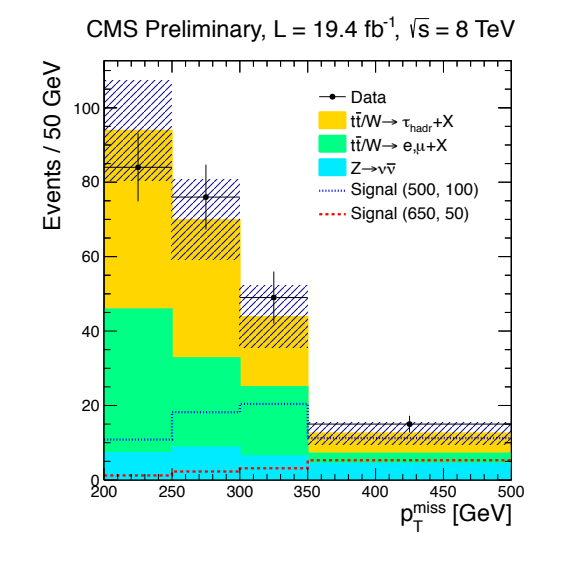
Decay modes in the m($\tilde{t}$) vs. m($\tilde{\chi}^0$) plane

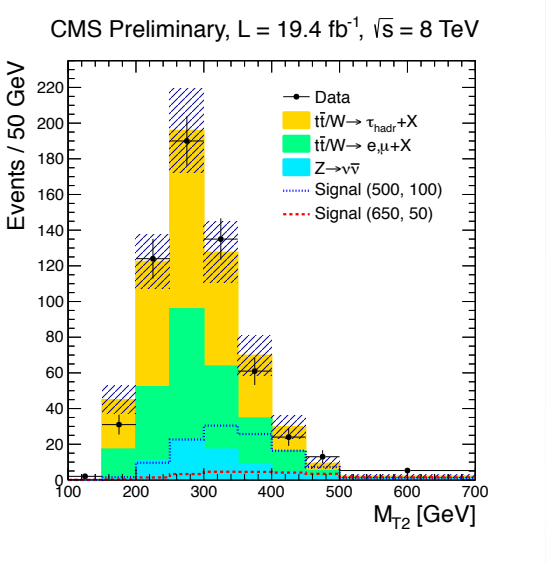
$\Delta m = m(\tilde{t}) - m(\tilde{\chi}^0)$

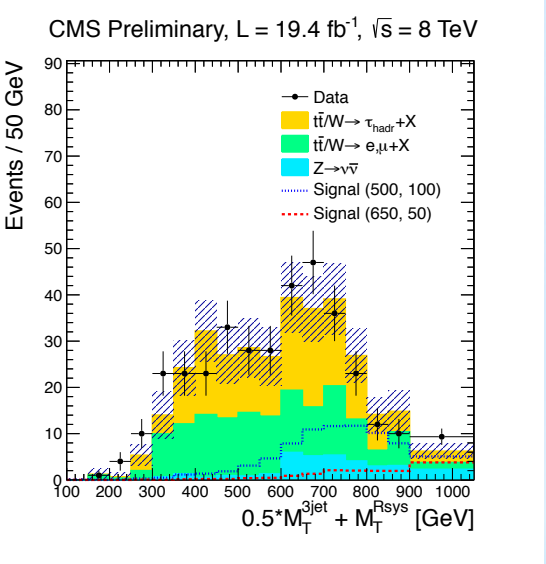


Direct stop production - SUS-13-015

- Hadronic decay channel, aims at reconstructing tops
- Uses p_{Tmiss}, M_{T2}, M_T^{Rsys} and M_T^{3jet} distributions as discriminating variables



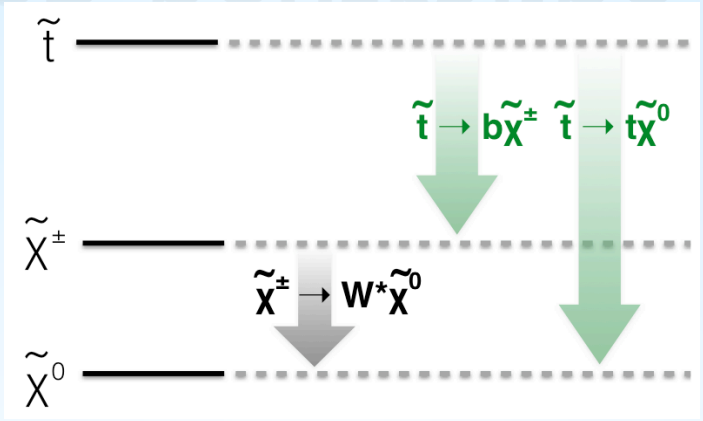




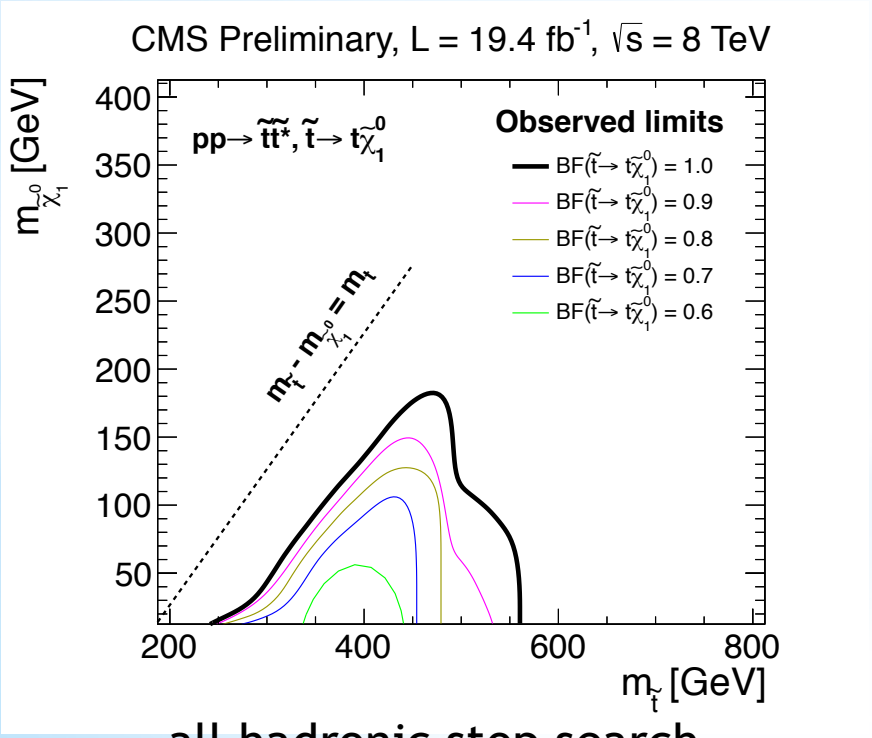
Search region	$Z \to \nu\bar{\nu}$	$t\bar{t}/W \to e,\mu+X$	$t\bar{t}/W \to \tau_h+X$	QCD	Rare processes	Total background	Obs. data
$p_T^{miss} > 200$ GeV, $N_{b\text{-jets}} \geq 1$	$35.8^{+16.3}_{-19.0}$	$89.3^{+21.9}_{-21.0}$	$120.2^{+11.8}_{-11.9}$	$3.2^{+18.2}_{-3.2}$	$5.8^{+2.9}_{-2.9}$	$254.3^{+35.0}_{-31.0}$	254
$p_T^{miss} > 350$ GeV, $N_{b\text{-jets}} \geq 1$	$13.2^{+6.5}_{-7.9}$	$8.2^{+4.0}_{-4.0}$	$16.5^{+3.4}_{-3.4}$	$1.0^{+1.9}_{-1.0}$	$2.0^{+1.0}_{-1.0}$	$40.9^{+8.6}_{-9.6}$	45
$p_T^{miss} > 200$ GeV, $N_{b\text{-jets}} \geq 2$	$6.1^{+15.3}_{-5.5}$	$33.8^{+10.3}_{-10.0}$	$45.3^{+7.0}_{-7.0}$	$0.1^{+0.6}_{-0.1}$	$3.1^{+1.6}_{-1.6}$	$88.4^{+19.8}_{-13.5}$	83
$p_T^{miss} > 350$ GeV, $N_{b\text{-jets}} \geq 2$	$1.8^{+6.8}_{-1.6}$	$1.2^{+1.0}_{-1.0}$	$4.3^{+1.7}_{-1.8}$	$0.1^{+0.5}_{-0.1}$	$1.2^{+0.6}_{-0.6}$	$8.6^{+7.1}_{-2.7}$	15

Limit in stop-neutralino mass plane

- Dependence on stop BF

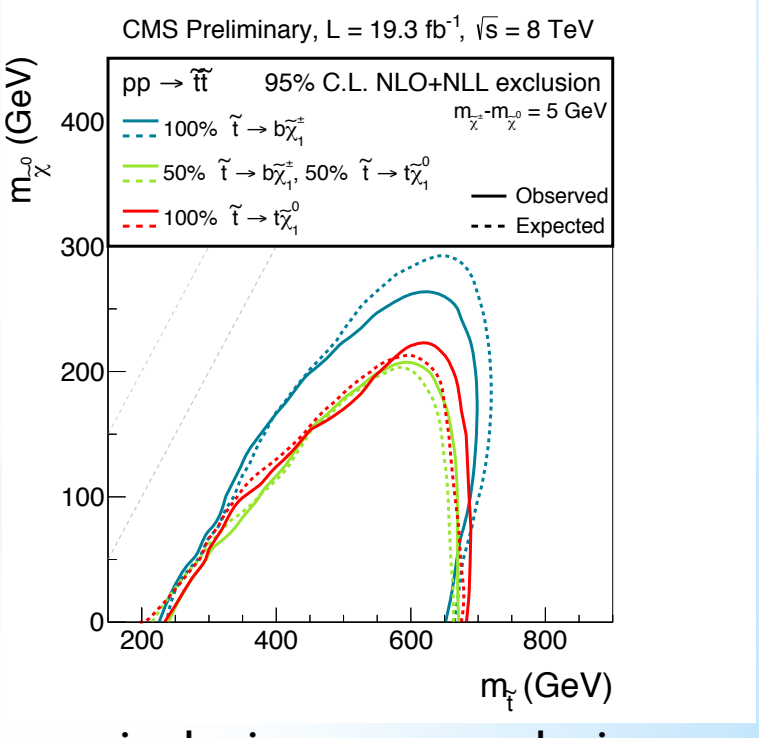


SUS-13-015



all hadronic stop search

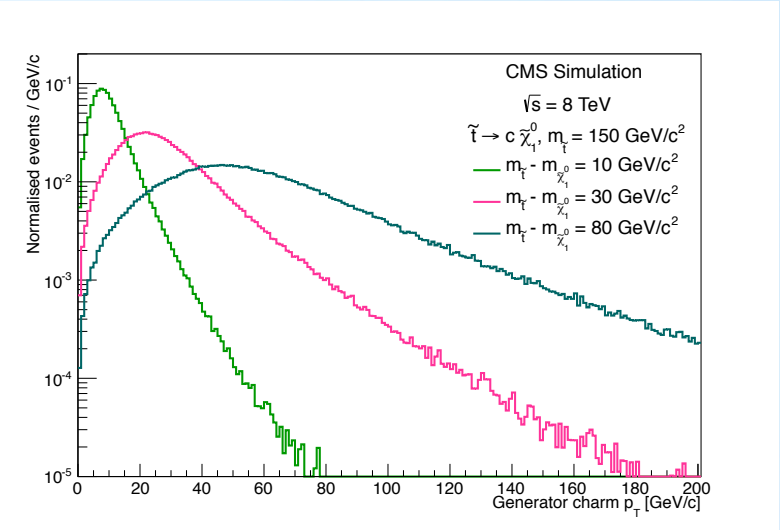
SUS-14-011

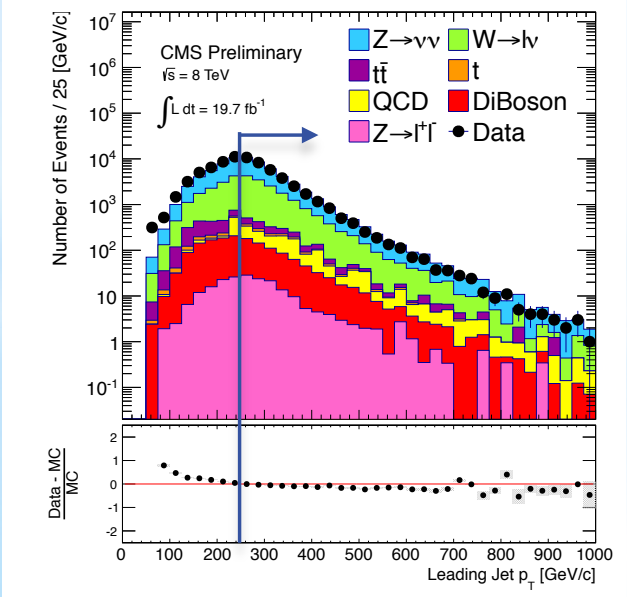


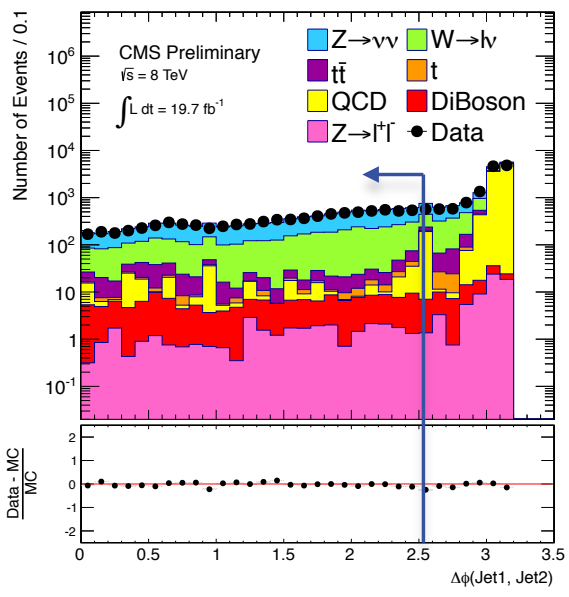
inclusive razor analysis

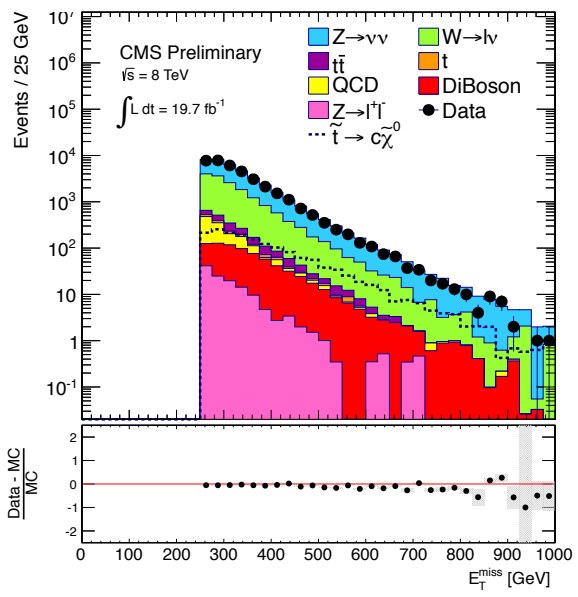
Monojet search for stop->charm χ_1^0 SUS-13-009

- Monojet search as function of leading jet p_T (> 250 GeV, … , >550GeV)
  - MET > 250 GeV
- Allow for second jet with p_T > 60 GeV, veto 3rd jet
- Stop decay "invisible"
  - only soft decay products



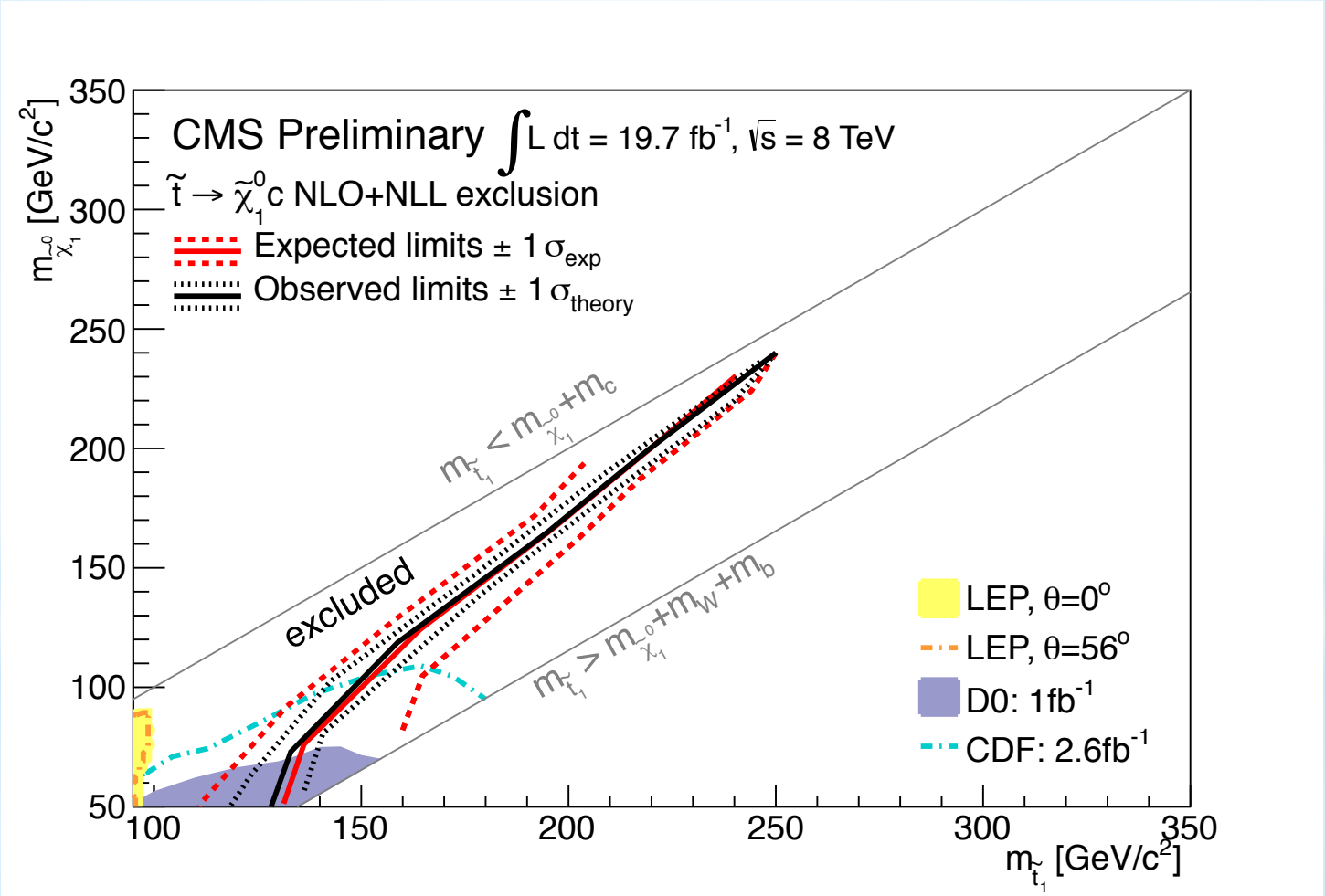






*Interpretation - SUS-13-009

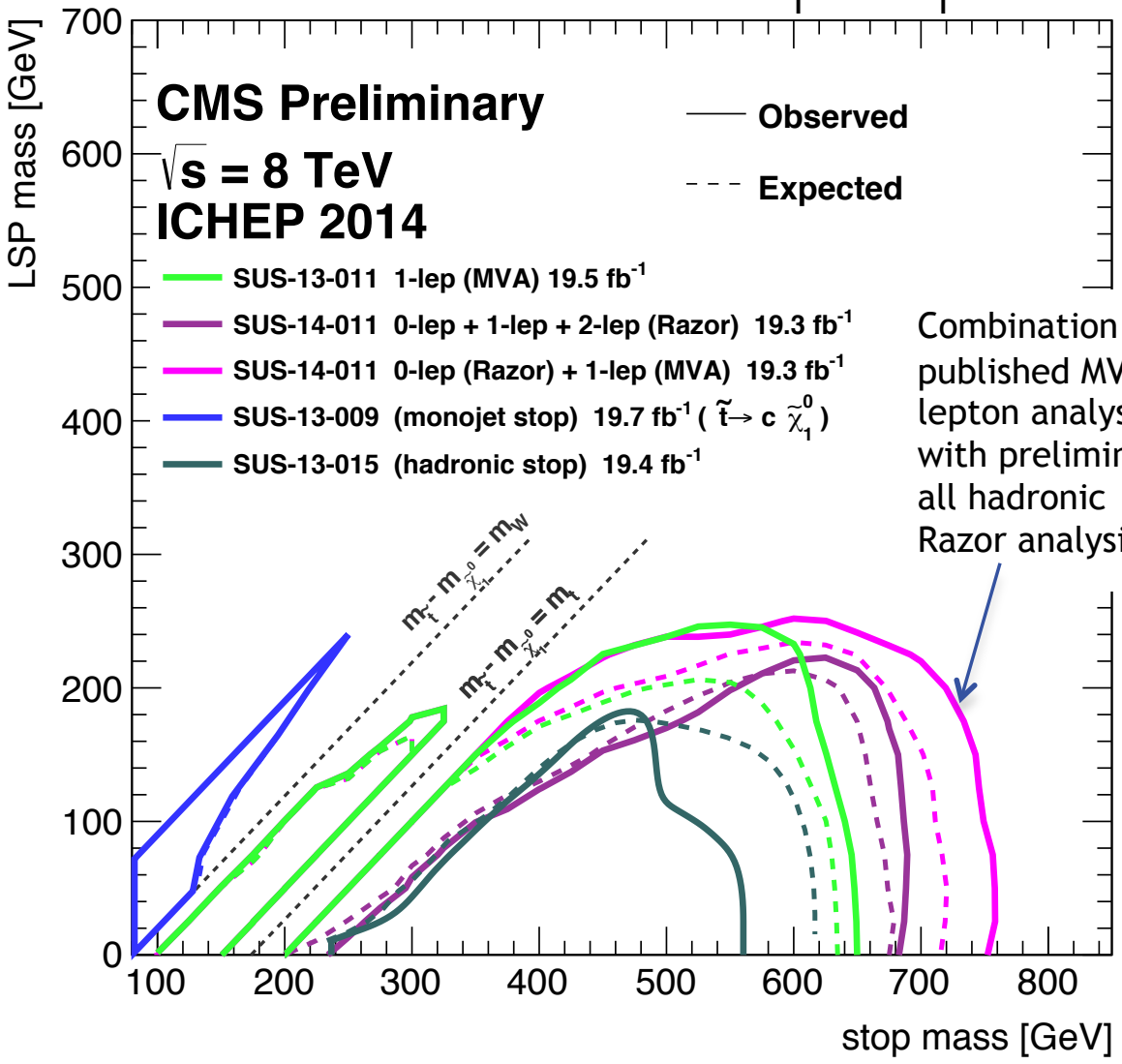
$p_T(j_1)$ (GeV/c)	> 250	> 300	> 350	> 400	> 450	> 500	> 550
Total SM	35862±1474	17409±803	8064±437	3907±250	2098±160	1096±106	563±71
Data	36582	17646	8119	3896	1898	1003	565



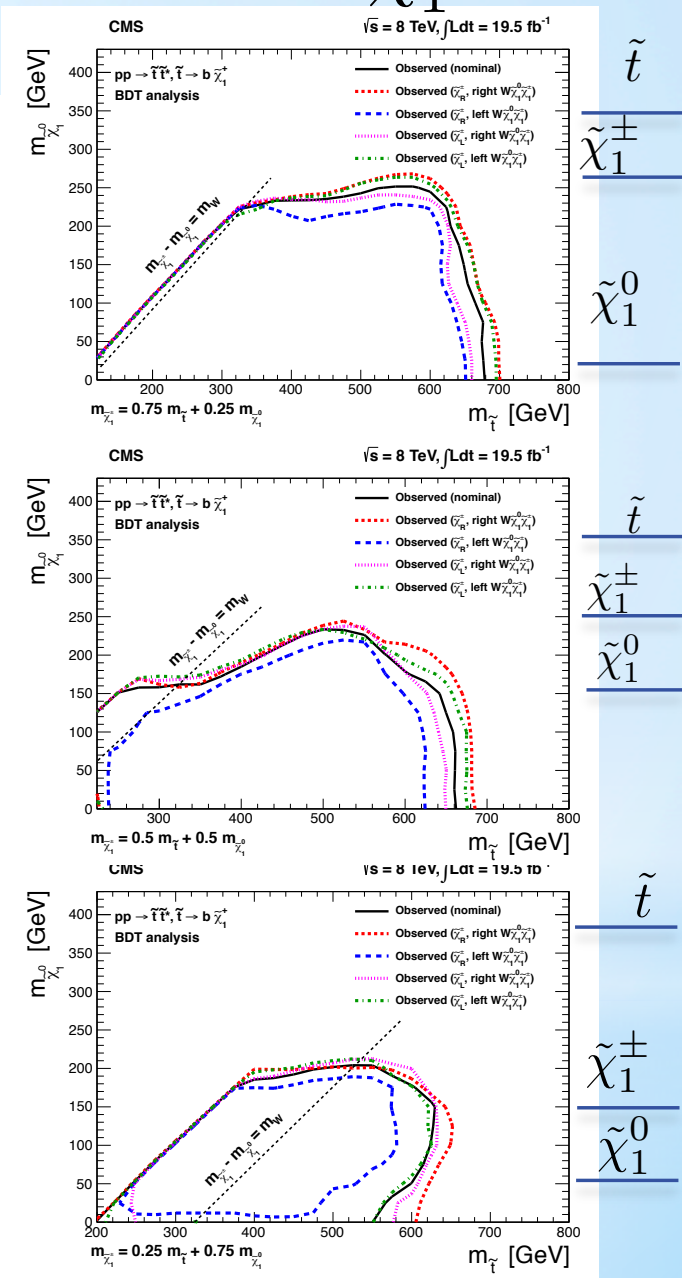
*Stop summary

$\tilde{t} \rightarrow b\tilde{\chi}_1^{\pm}$

$\tilde{t}$-$\tilde{t}$ production, $\tilde{t} \rightarrow t\,\tilde{\chi}_1^0 / c\,\tilde{\chi}_1^0$



Combination of published MVA 1-lepton analysis with preliminary all hadronic Razor analysis.



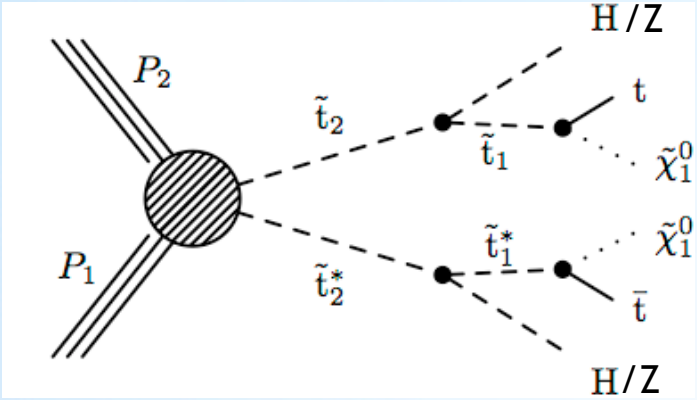
$\tilde{t}$ $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$

$\tilde{t}$ $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$

$\tilde{t}$ $\tilde{\chi}_1^{\pm}$ $\tilde{\chi}_1^0$

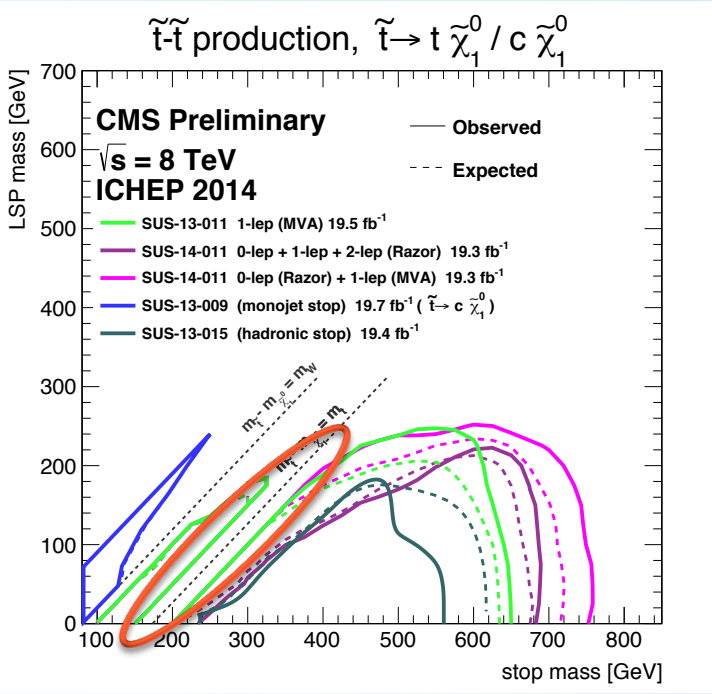
*$Stop_2$ search with decay via Z and H

SUS-13-024



close the gap where

m_{stop}-$m_{\chi_1^0}$ = m_{top}



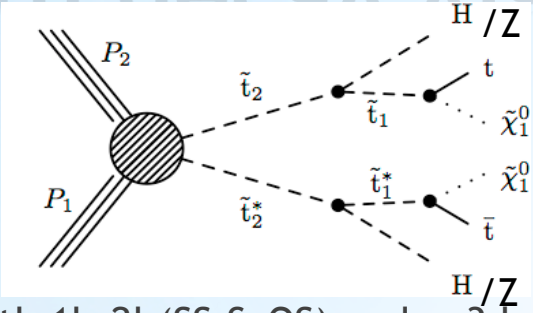
*Search regions:

Sensitive to H->bb, H->ZZ & H->WW decays

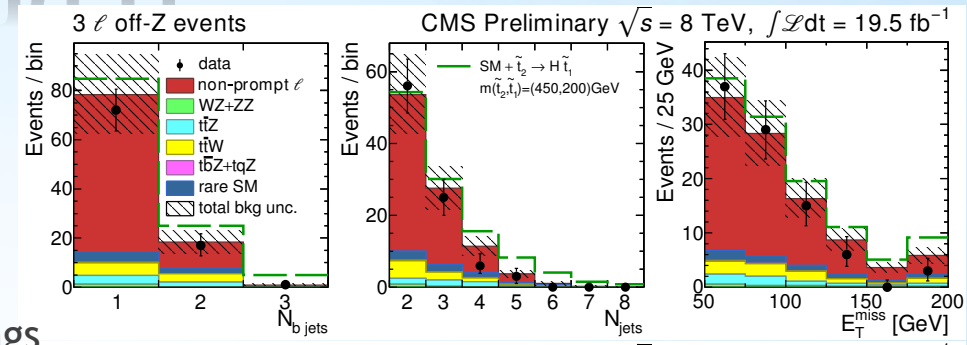
N_ℓ	Veto	$N_{\text{b jets}}$	N_{jets}	$E_{\text{T}}^{\text{miss}}$ [GeV]	Additional requirements [GeV]
1	track or τ_h	$= 3$ ≥ 4	≥ 5 ≥ 4	≥ 50	$m_{\text{T}} > 150$ $m_{\text{T}} > 120$
2 OS	extra e/μ	$= 3$ ≥ 4	≥ 5 ≥ 4	≥ 50	$(N_{\text{bb}} = 1$ with $100 \leq m_{\text{bb}} \leq 150)$, $N_{\text{bb}} \geq 2$
2 SS	extra e/μ	$= 1$ ≥ 2	$[2,3]$, ≥ 4	$[50,120]$, ≥ 120	for low/high-p_{T}: $H_{\text{T}} \in [200,400]$, ≥ 400
≥ 3	—	$= 1$ $= 2$ ≥ 3	$[2,3]$, ≥ 4 ≥ 3	$[50,100]$, $[100,200]$, ≥ 200	for on/off-Z: $H_{\text{T}} \in [60,200]$, ≥ 200

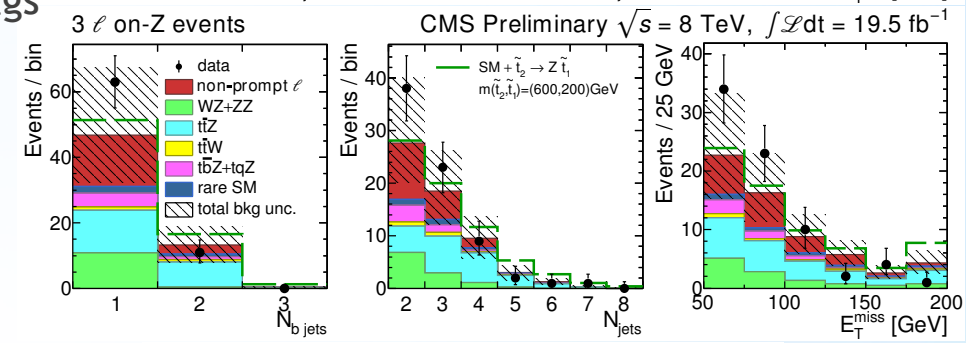
* Higgs in SUSY cascades - $Stop_2$ search with decay via Z and H

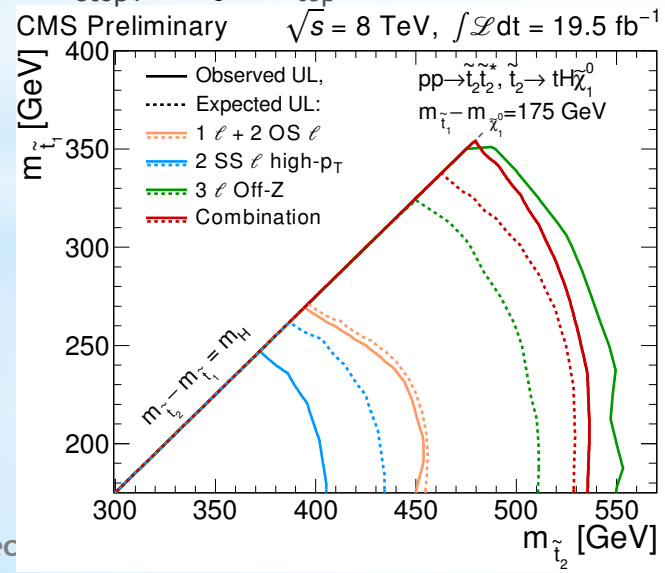
SUS-13-024

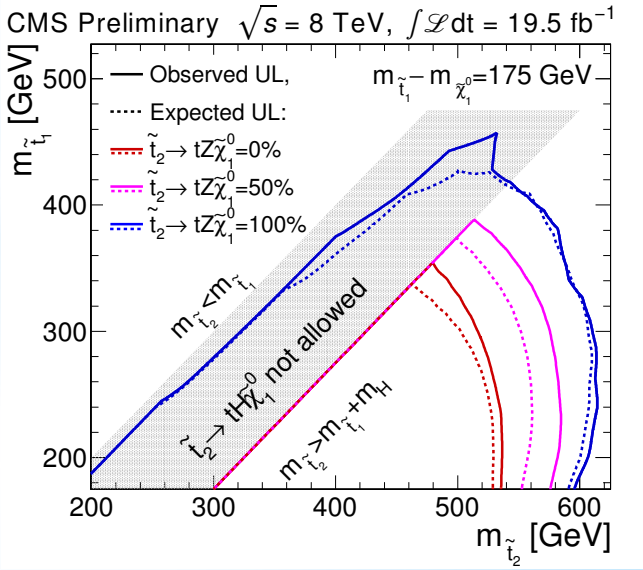


* search with 1l, 2l (SS & OS) and >=3 leptons + b-tags
  * sensitive to H->bb, H->ZZ & H->WW decays
* >=3 lepton selection is the most sensitive
  * split by on Z and off Z
* search closes the gap where m_{stop}-$m\chi_1^0$ = m_{top}
* For all points: m_{stop1}-$m\chi_1^0$=m_{top}









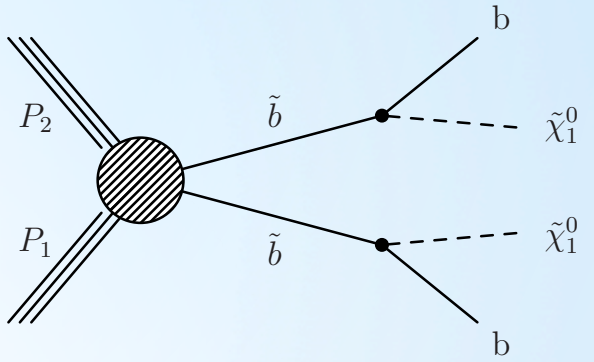
*Search for sbottom with M_{CT}

*Search in events with exactly 2 jets with 1 or 2 b-tags

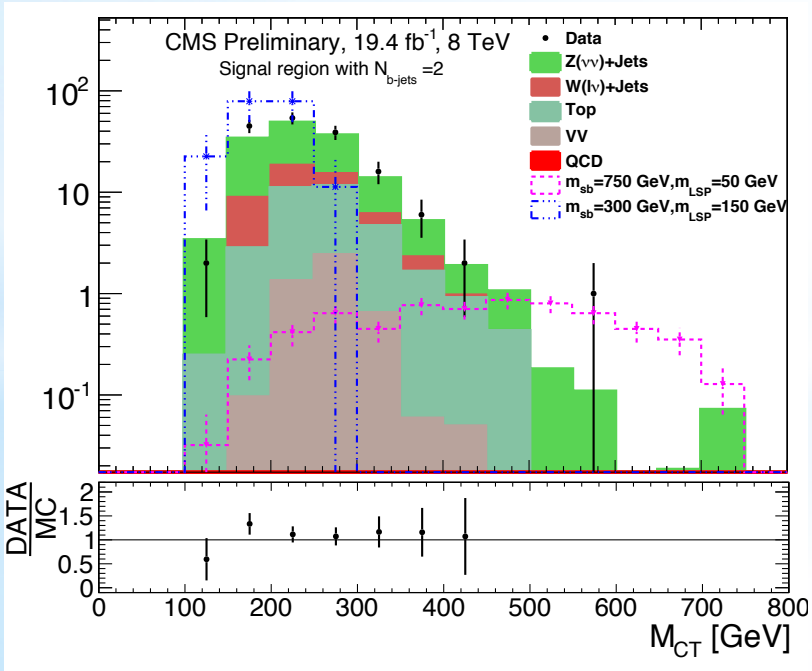
SUS-13-018

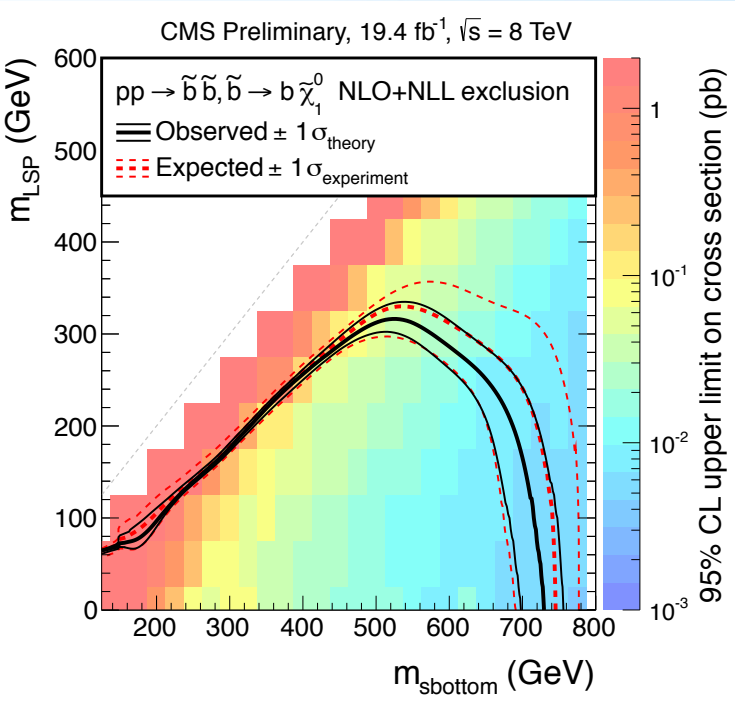
*Uses M_{CT} as discriminating variable:

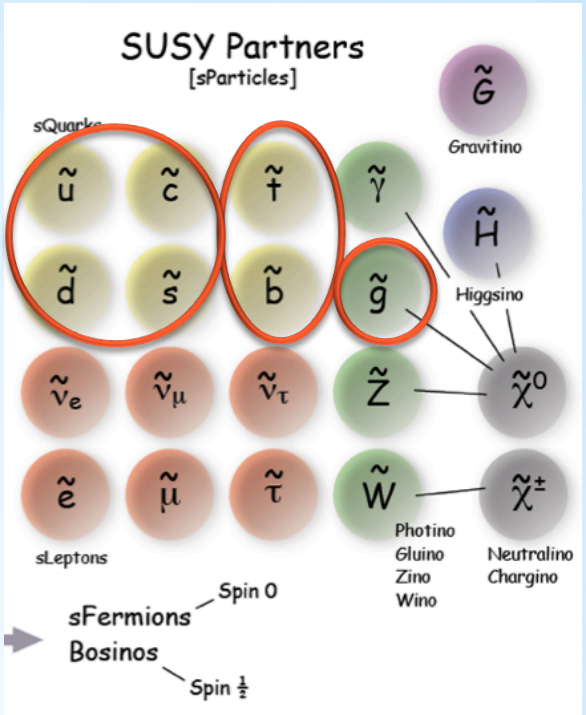
$$M^2_{CT}(J_1,J_2) = [E_T(J_1)+E_T(J_2)]^2 - [\mathbf{p_T}(J_1)-\mathbf{p_T}(J_2)]^2$$
$$= 2p_T(J_1)p_T(J_2)(1+\cos\Delta\phi(J_1,J_2)),$$



No. of b-jets	M_{CT}	M_{CT}	M_{CT}	M_{CT}
$N_{b-jets} = 1$	< 250 GeV	250 - 350 GeV	350 - 450 GeV	> 450 GeV
$N_{b-jets} = 2$	< 250 GeV	250 - 350 GeV	350 - 450 GeV	> 450 GeV







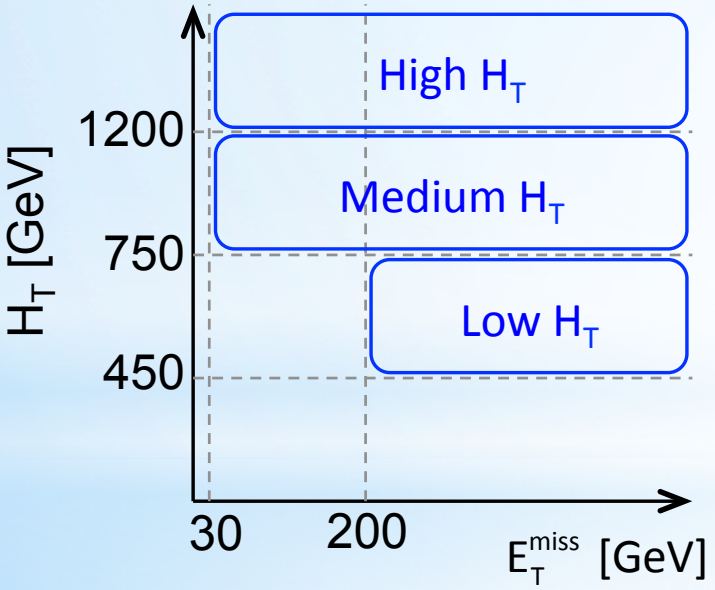
*inclusive searches (for squarks and gluinos)

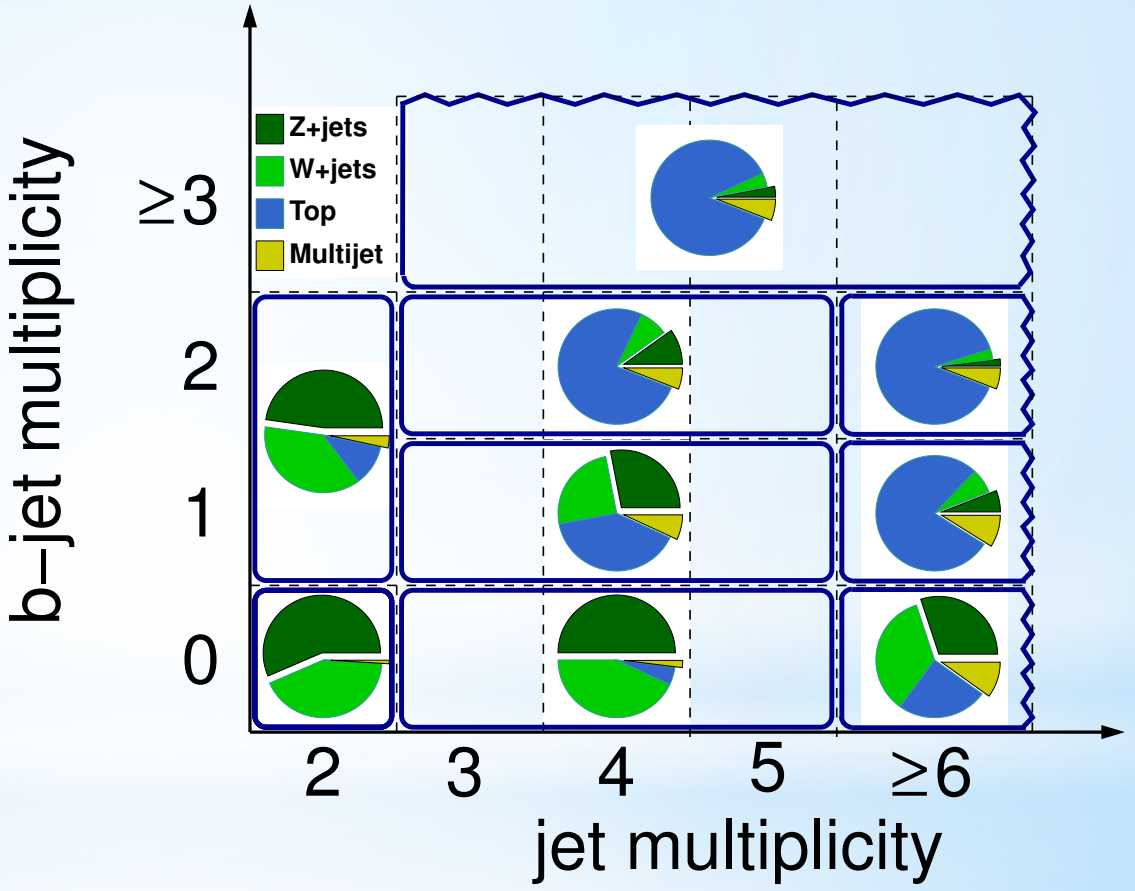
Inclusive search with M_{T2} - SUS-13-019

- Search for excess in M_{T2} distribution in data binned by HT and number of b-tags

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

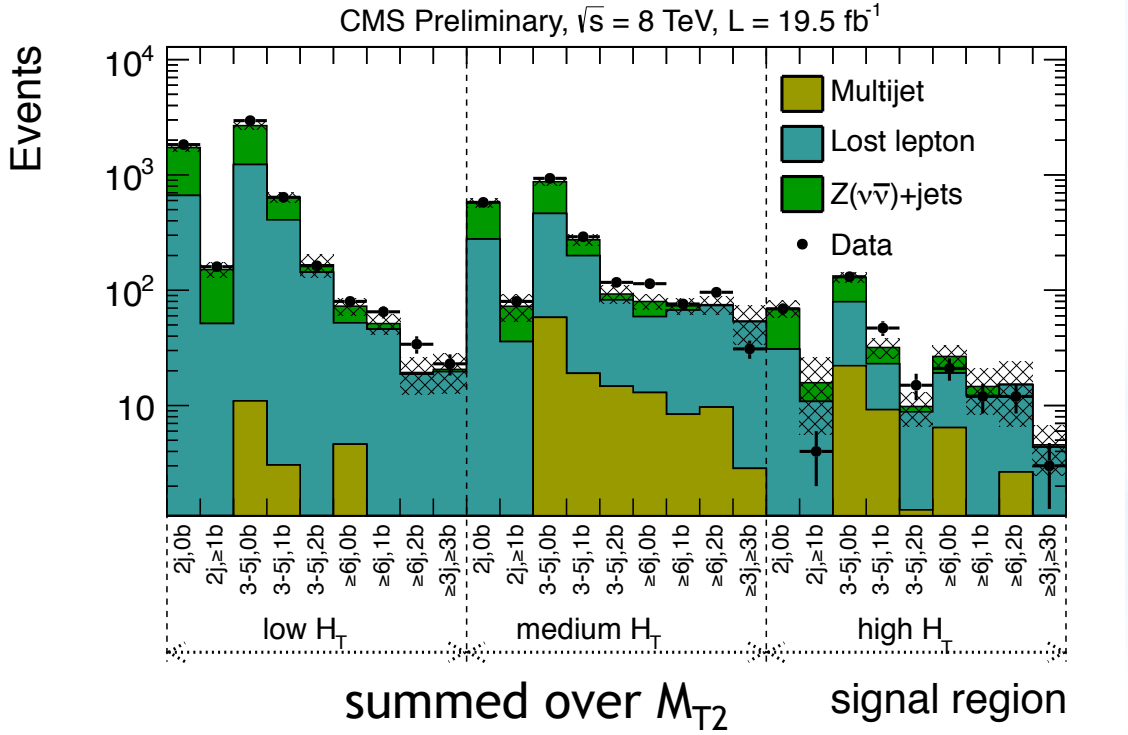
$$(M_{\mathrm{T}}^{(i)})^2 = (m^{\mathrm{vis}(i)})^2 + m_{\tilde{\chi}}^2 + 2\left(E_{\mathrm{T}}^{\mathrm{vis}(i)} E_{\mathrm{T}}^{\tilde{\chi}(i)} - \vec{p}_{\mathrm{T}}^{\,\mathrm{vis}(i)} \cdot \vec{p}_{\mathrm{T}}^{\,\tilde{\chi}(i)} \right)$$

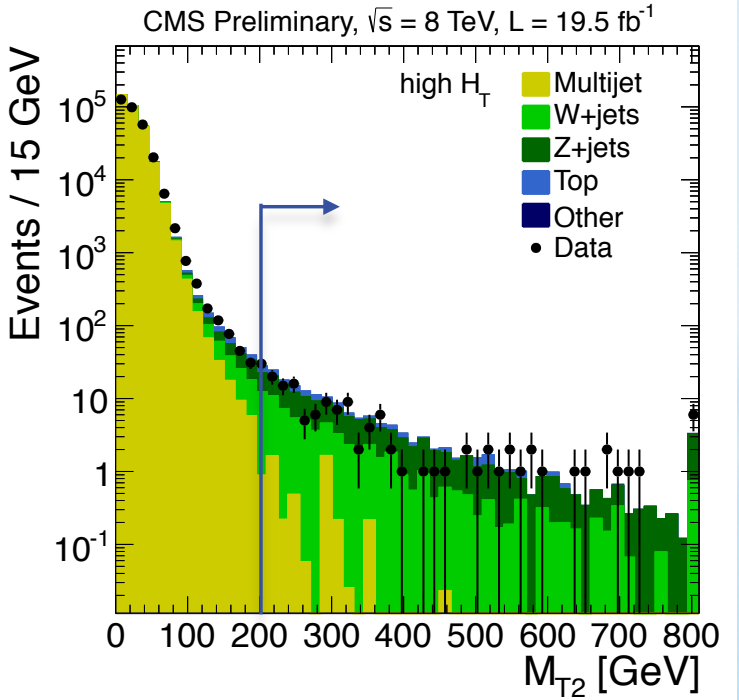




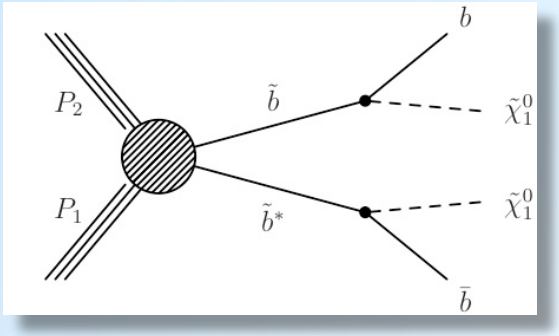
Inclusive search with M_{T2} - SUS-13-019

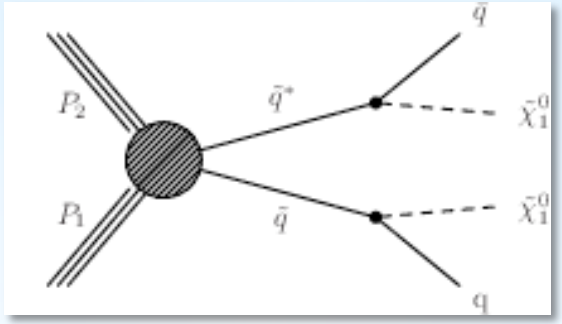
- data-driven background estimations
  - single muon sample for W+jets and tt+jets
  - photon + jets and di-muon sample for Z+jets
  - QCD from M_{T2} sideband extrapolation
- Search in bins of M_{T2} with M_{T2} > 200 GeV

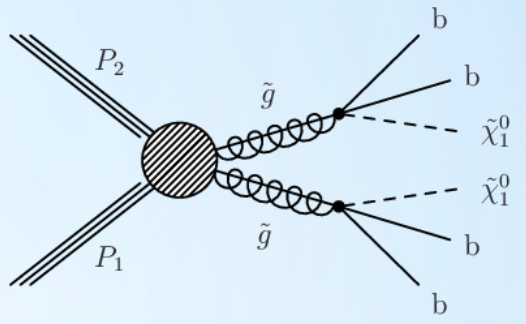


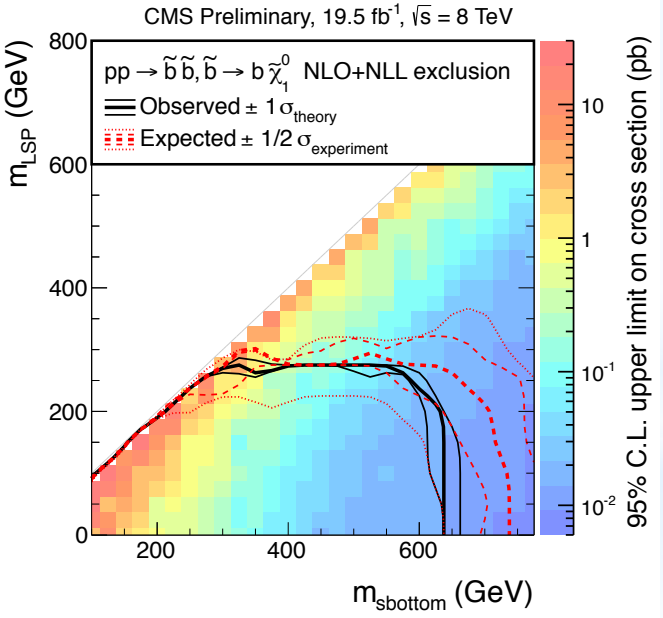


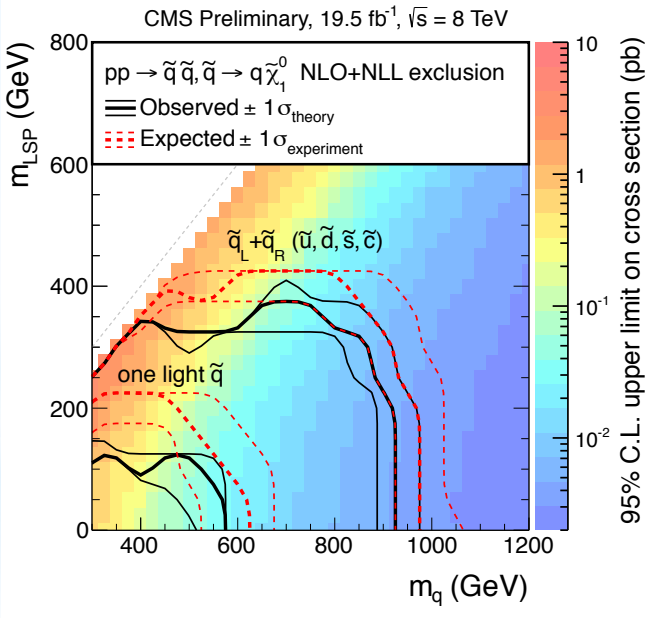
*Inclusive search with M_{T2} - SUS-13-019

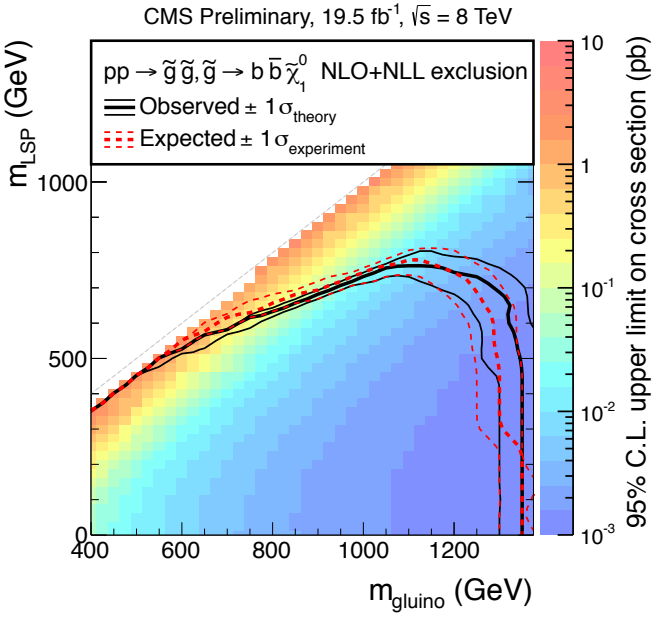










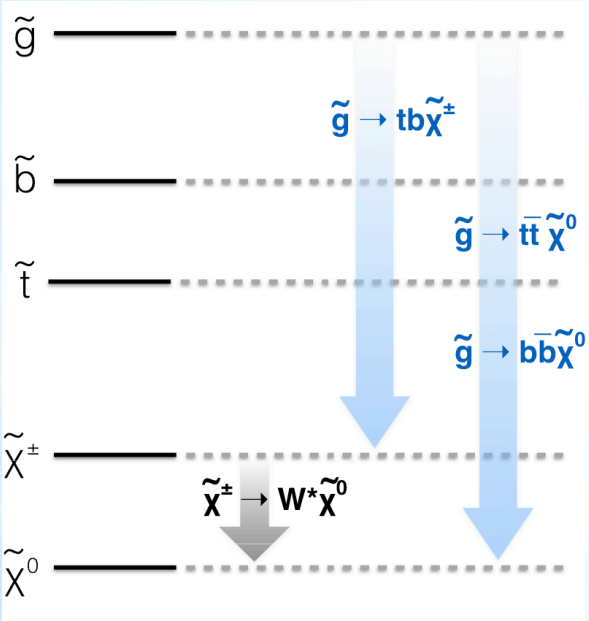


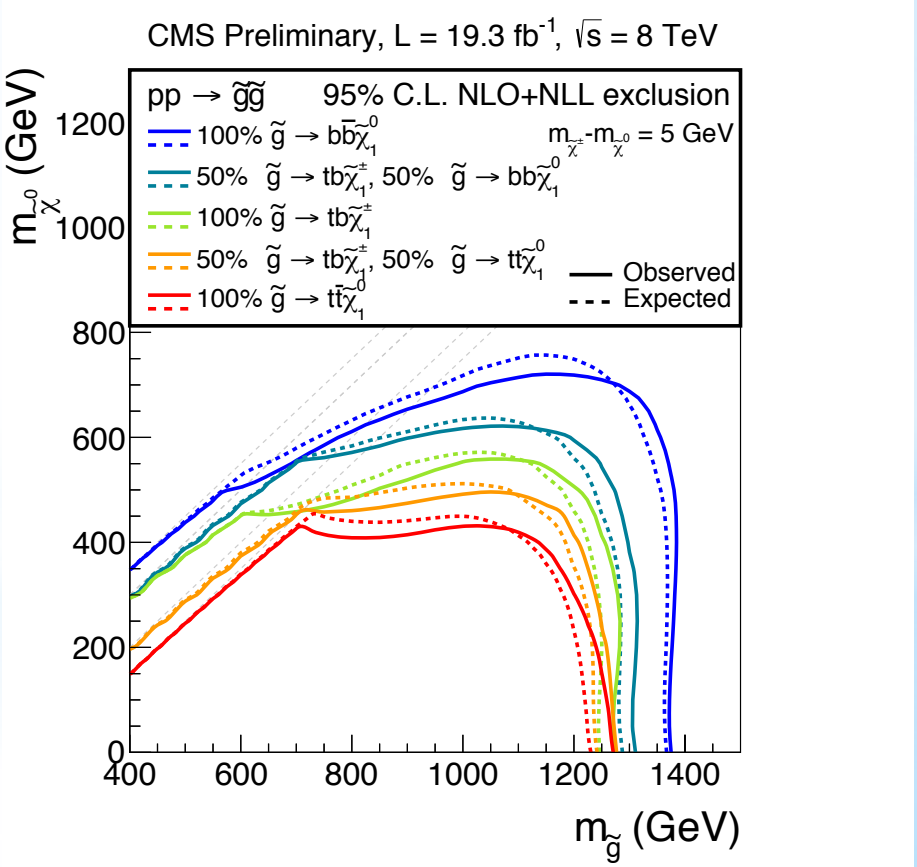
*additional interpretations available

Inclusive razor analysis with b-tags

- Testing natural SUSY scenario with ~TeV gluino, possible lighter stops and sbottoms and a nearly degenerate chargino/ neutralino triplet.

SUS-13-004, SUS-14-011



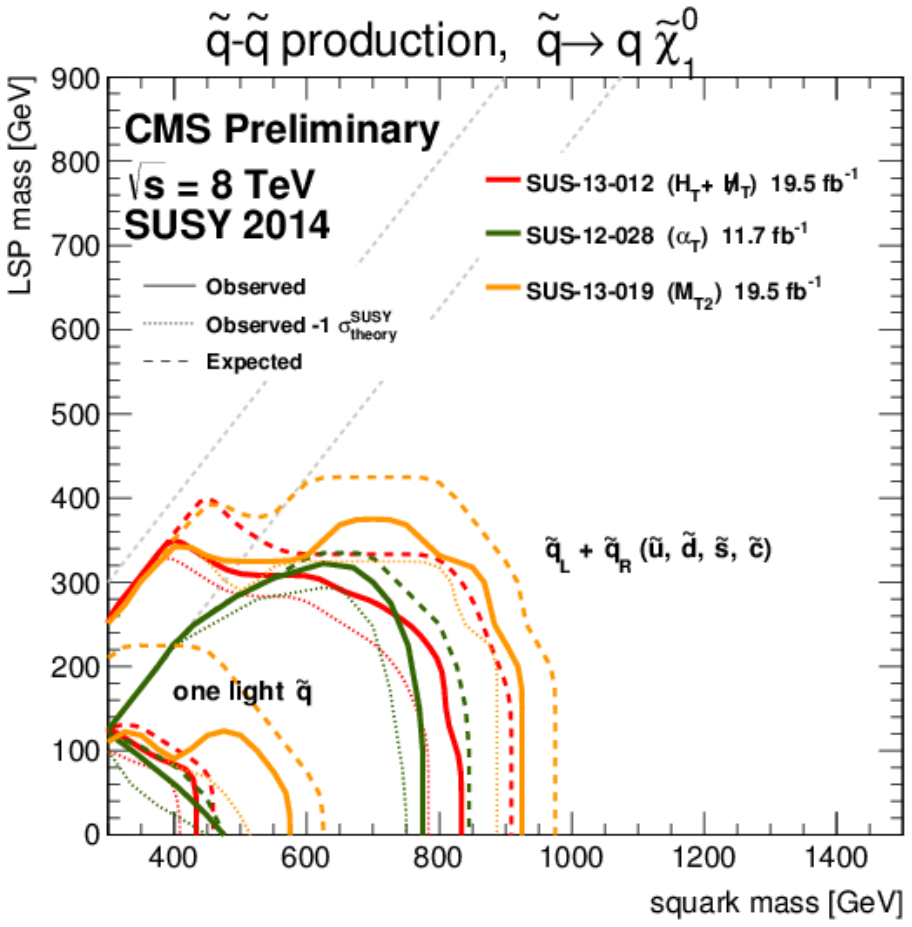


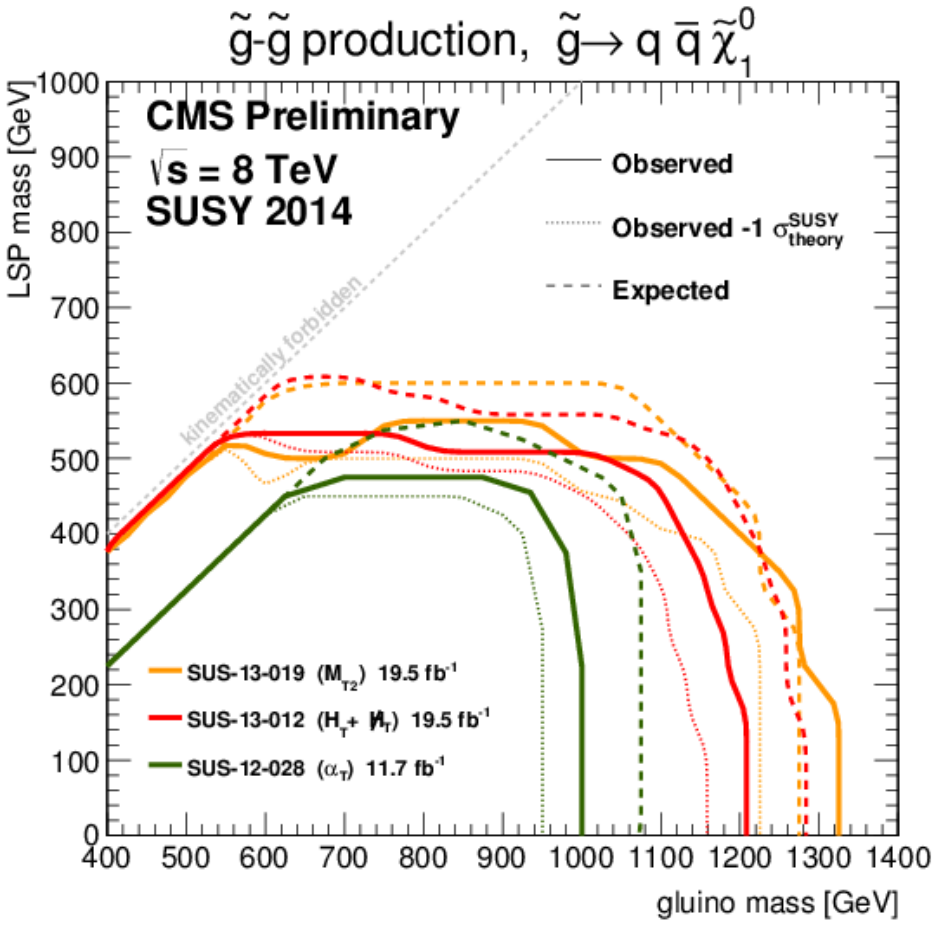
- covering all possible combinations of partial widths to third generation squarks

Overview of squark & gluino searches

1st & 2nd generation

- Direct squark production:
  - sensitivity around 650-750 GeV
- Gluino pair production:
  - sensitivity around 1.0-1.3 TeV

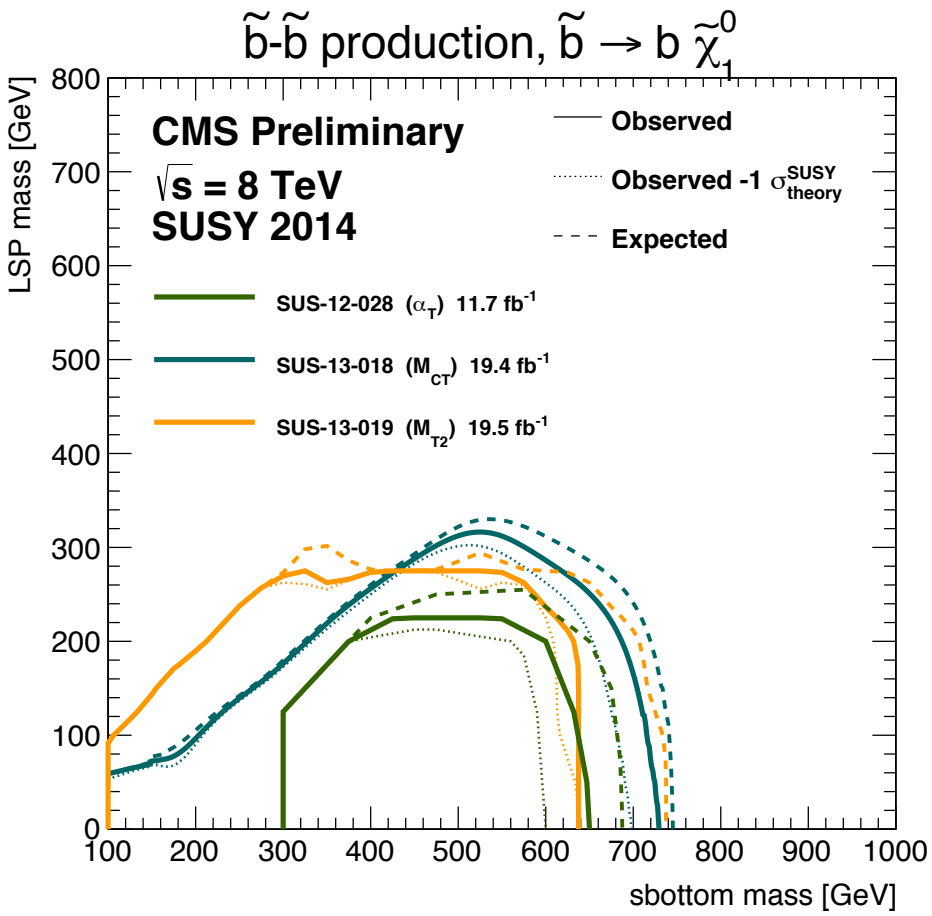


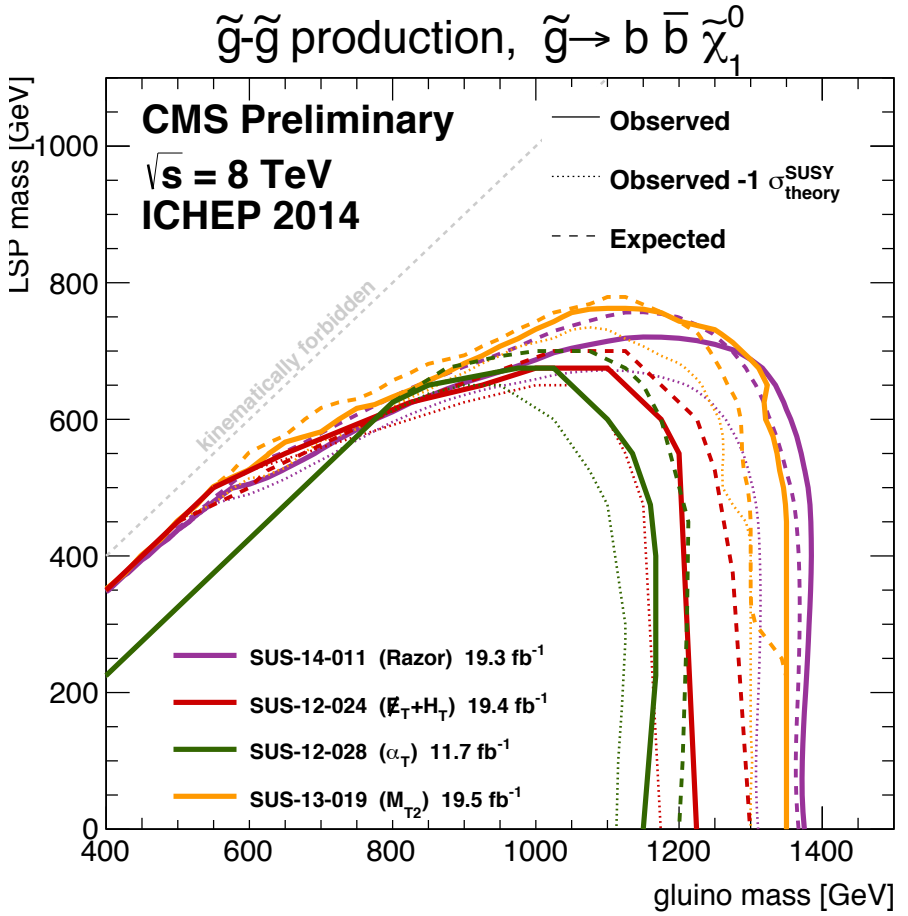


Overview of squark & gluino searches

sbottoms

- Direct squark production:
  - sensitivity around 650-750 GeV
- Gluino pair production:
  - sensitivity around 1.0-1.3 TeV

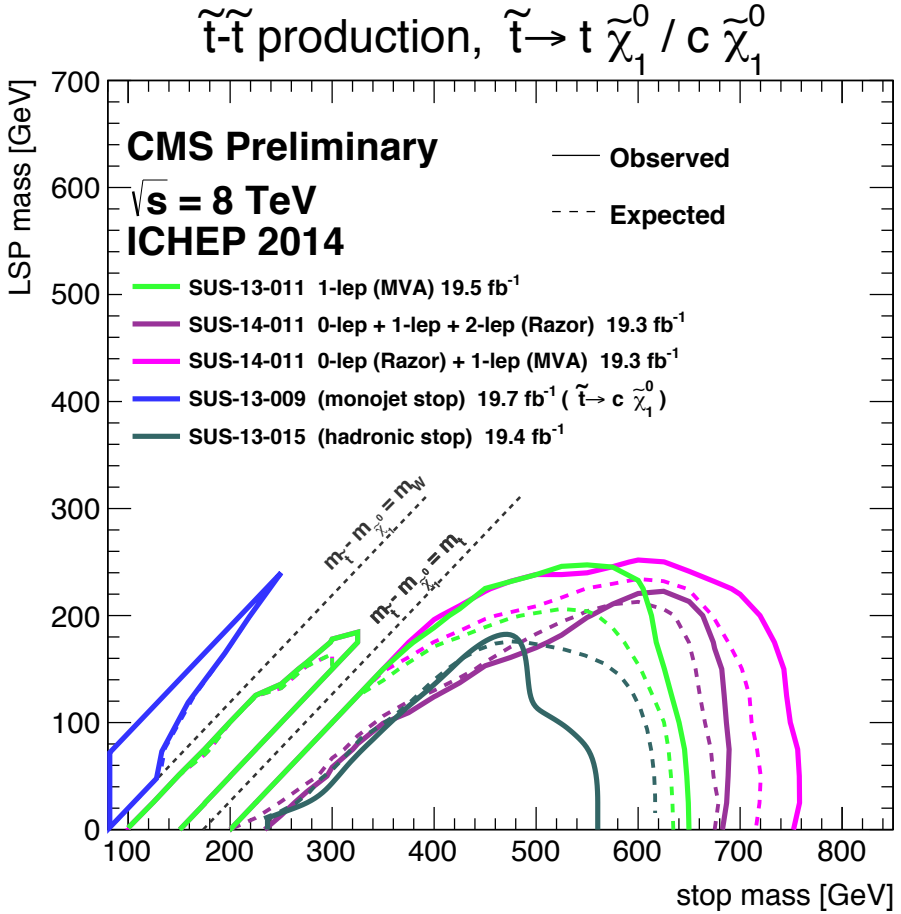


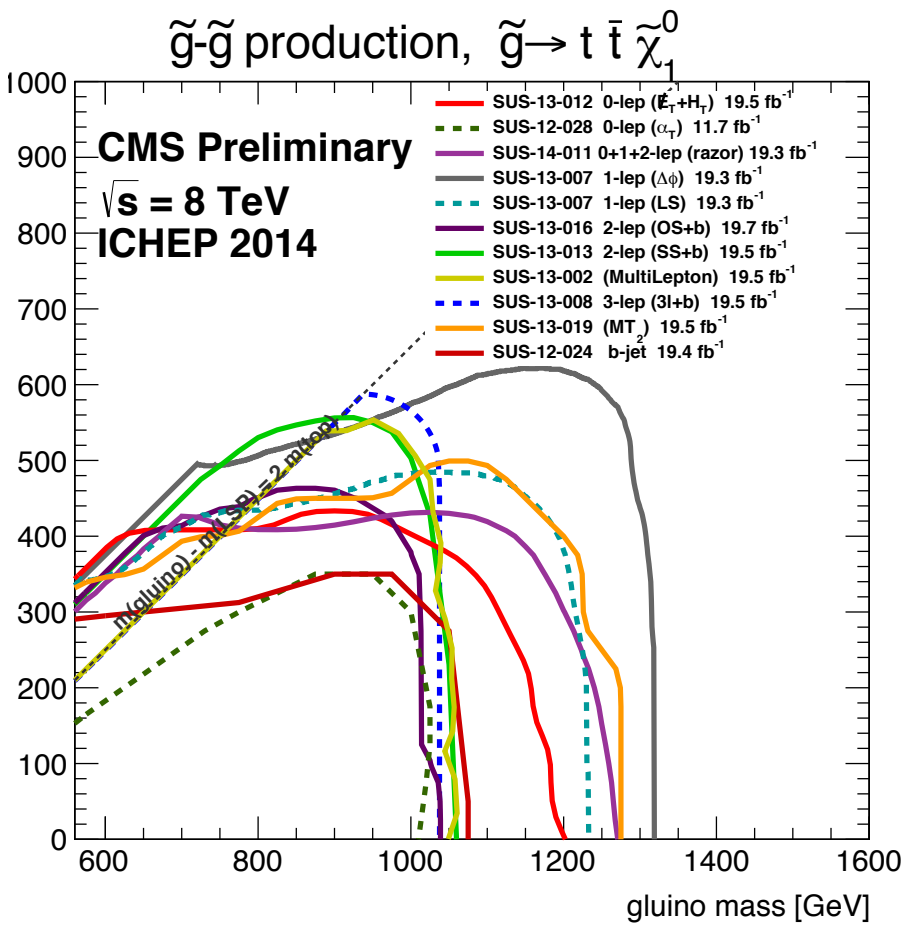


Overview of squark & gluino searches

stops

- Direct squark production:
  - sensitivity around 650-750 GeV
- Gluino pair production:
  - sensitivity around 1.0-1.3 TeV





*SUSY signatures with photons

Diphoton search with razor variables

New for SUSY14

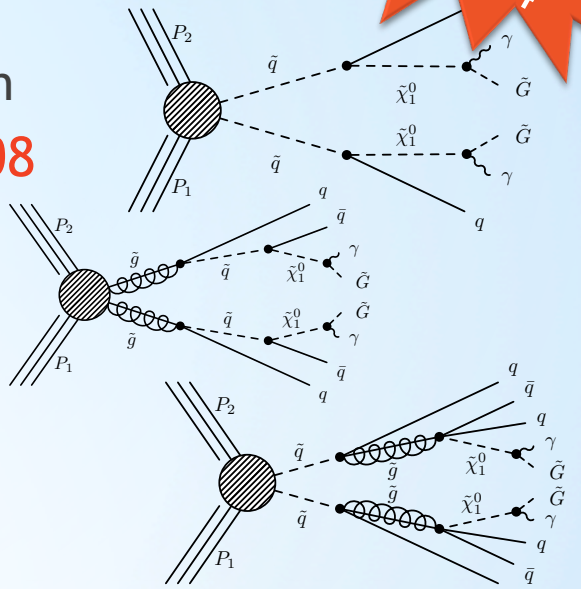
- General gauge mediated models (GGM) give rise to signals with photons.
- Bino-like neutralino LSP with decay to gravitino + photon

$$R = \frac{M_T^R}{M_R}$$

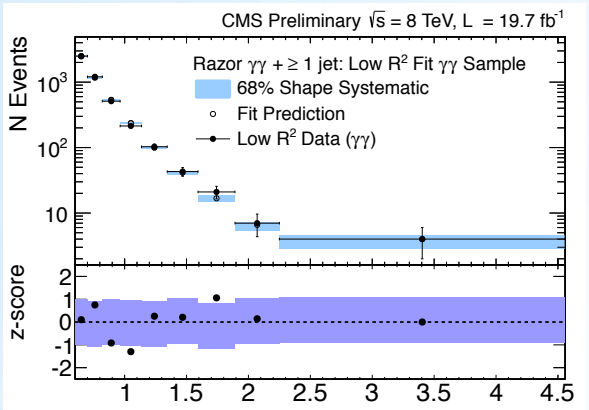
$$M_R = \sqrt{(|\vec{p}_{j_1}| + |\vec{p}_{j_2}|)^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_T^R = \sqrt{\frac{E_T^{miss}(p_T^{j_1} + p_T^{j_2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T{}^{j_1} + \vec{p}_T{}^{j_2})}{2}}$$

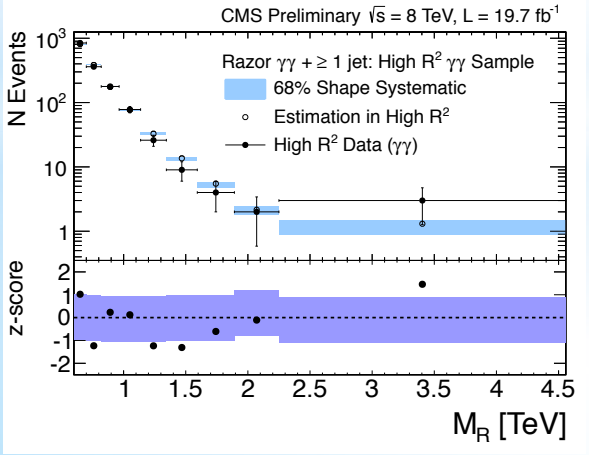
SUS-14-008

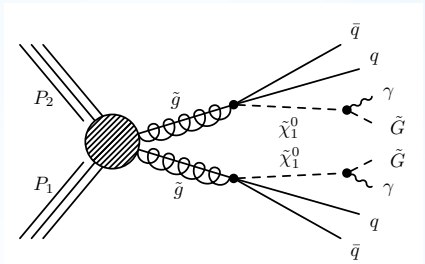


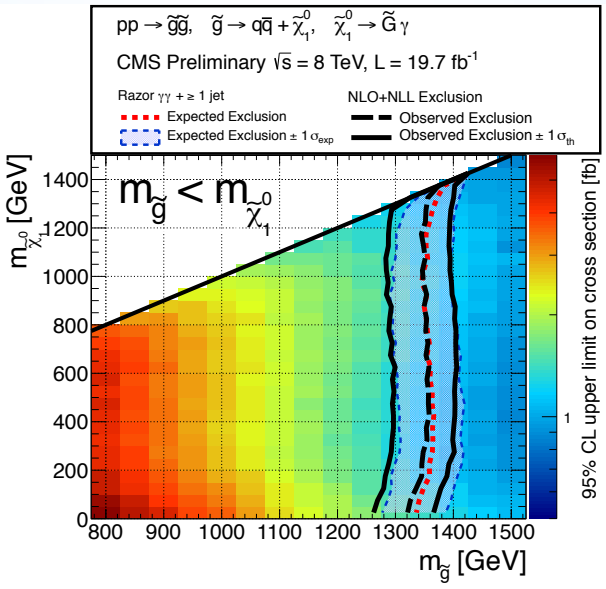
low R^2 control region

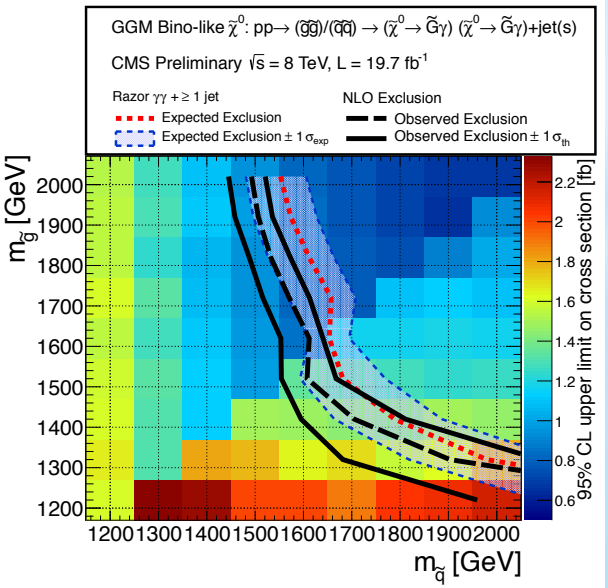


high R^2 signal region









$\tilde{\chi}_1^0$ Mass fixed to 375 GeV

*Search for kinematic edge from di-leptons

Kinematic edge in opposite sign, same flavour dilepton events

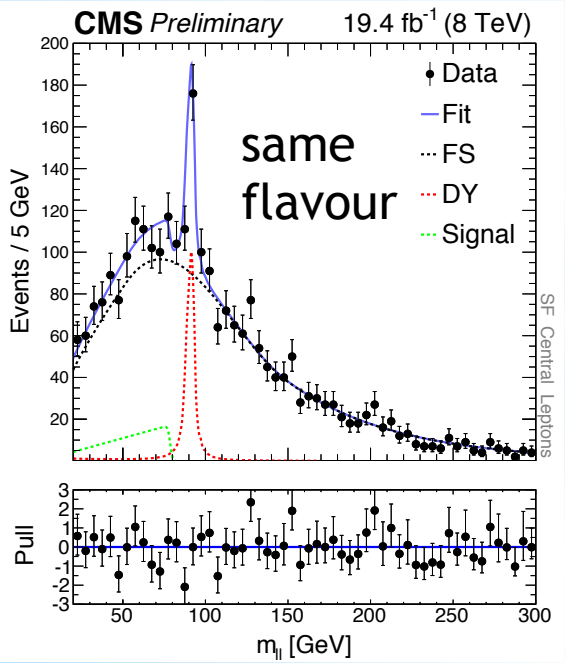
SUS-12-019

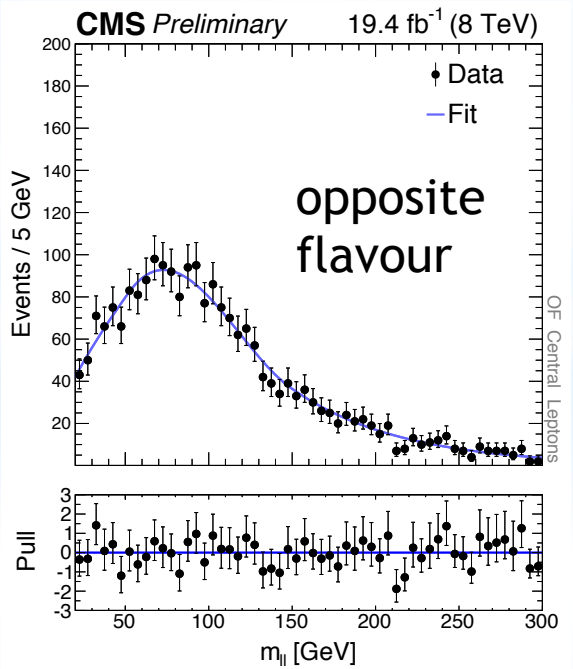
* Generic search for kinematic endpoint in dilepton mass spectrum, e.g.,
  * $\tilde{\chi}_2^0 \to l\tilde{l} \to \chi_1^0 l^+ l^-$ (produces triangular shape with endpoint)
  * three body decays of $\tilde{\chi}_2^0 \to \chi_1^0 l^+ l^-$ (produces an "edge")

New for SUSY14

* Background estimation with opposite sign, opposite flavour leptons
  * Two search regions: central $|\eta| < 1.4$, forward $1.6 < |\eta| < 2.4$

* Signal and background contributions determined from kinematic fit





Signal as triangular shape convolved with Gaussian:

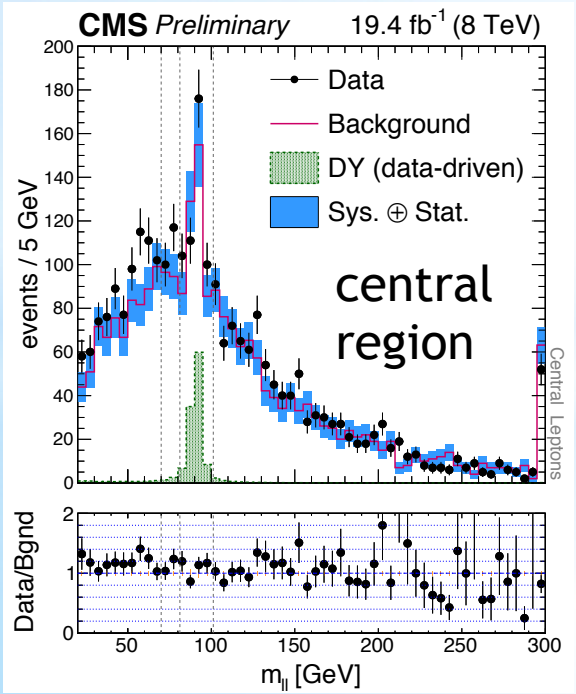
$$\mathcal{P}_S(m_{\ell\ell}) = \frac{1}{\sqrt{2\pi}\sigma_{\ell\ell}} \int_0^{m_{\ell\ell}^{edge}} y \cdot \exp\left(-\frac{(m_{\ell\ell}-y)^2}{2\sigma_{\ell\ell}^2}\right) dy.$$

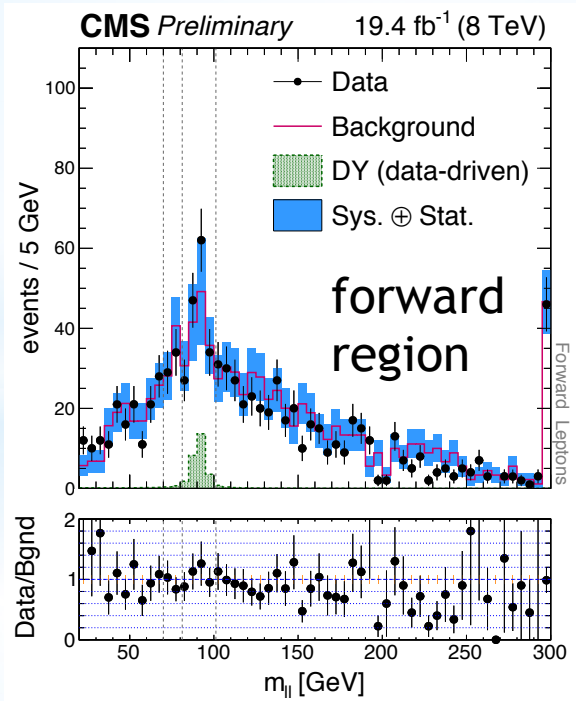
	Central	Forward
Drell–Yan	158 ± 23	71 ± 15
Flav. Sym. [OF]	2270 ± 44	745 ± 25
$R_{SF/OF}$	1.03	1.02
Signal events	126 ± 41	22 ± 20
$m_{\ell\ell}^{edge}$ [GeV]	78.7 ± 1.4	

Kinematic edge in opposite sign, same flavour dilepton events SUS-12-019

* Generic search for kinematic endpoint in dilepton mass spectrum, e.g.,
  * $\tilde{\chi}_2^0 \to l\tilde{l} \to \chi_1^0 l^+ l^-$ (produces triangular shape with endpoint)
  * three body decays of $\tilde{\chi}_2^0 \to \chi_1^0 l^+ l^-$ (produces an "edge")

* In addition, cut and count analysis of events with 20 GeV < m_{ll} < 70 GeV (no shape assumption)

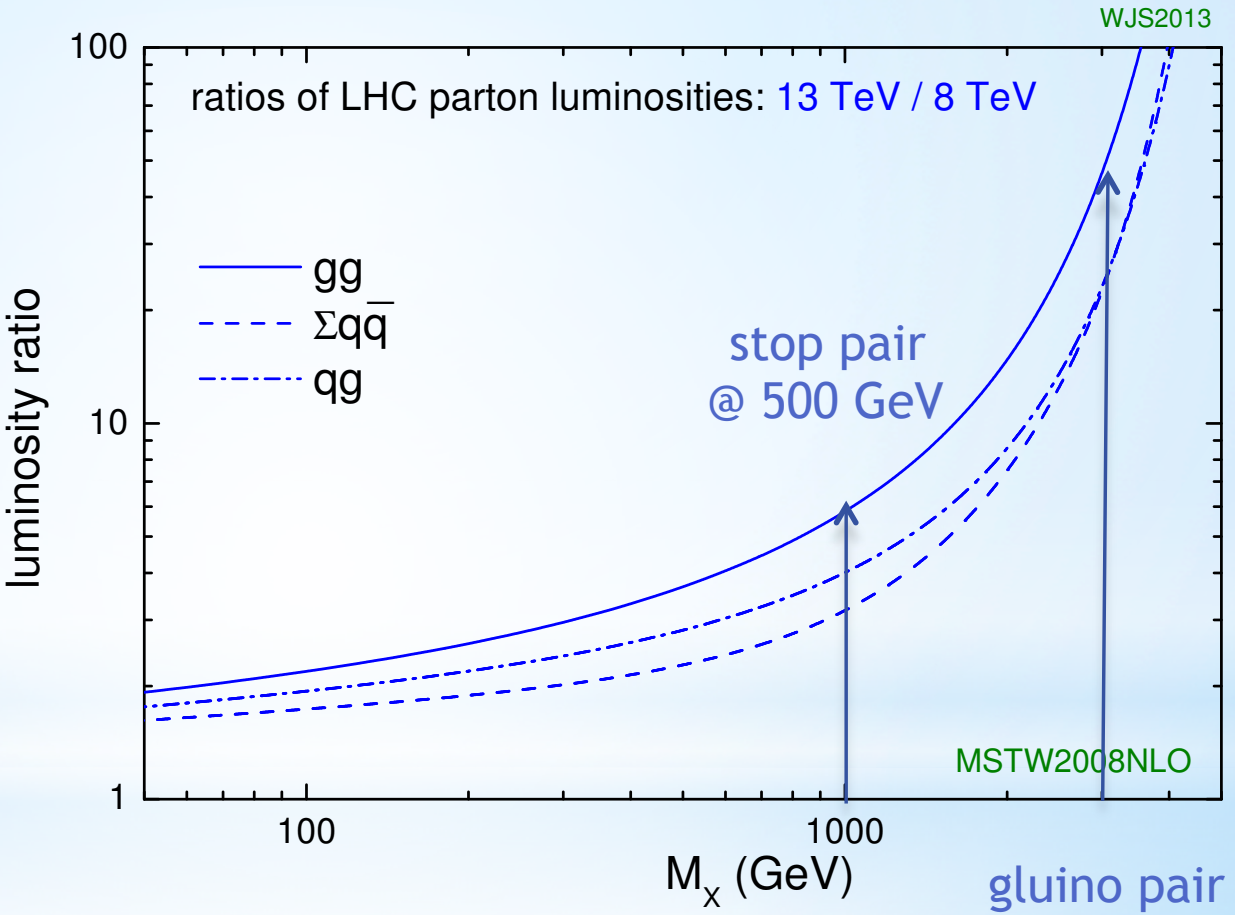




	Central	Forward
Observed [SF]	860	163
Flav. Sym. [OF]	$722 \pm 27 \pm 29$	$155 \pm 13 \pm 10$
Drell–Yan	8.2 ± 2.6	1.7 ± 1.4
Total estimates	730 ± 40	157 ± 16
Observed – Estimated	130^{+48}_{-49}	6^{+20}_{-21}
Significance [σ]	2.6	0.3

*Prospects for 2015 & 13 TeV

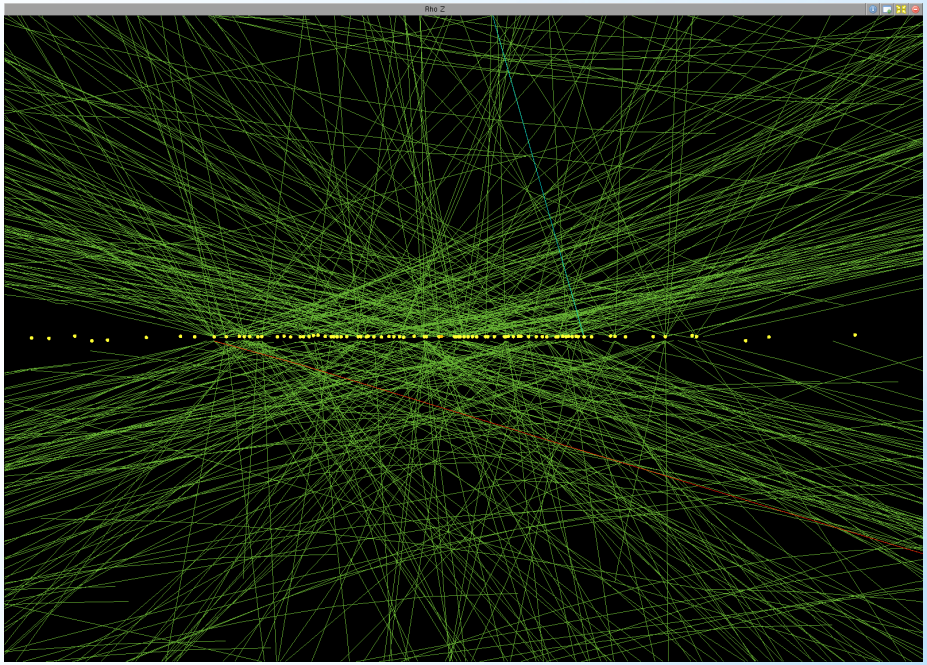
* Good prospects for SUSY from energy increase from 8->13 TeV
* much larger than just ratio of CM energies
* up to factor ~50 for pair production of 1.5 TeV gluinos
* factor 6 for stop pairs of 500 GeV
* Not only good for SUSY but also other heavy objects such as Z' etc.



Experimental Challenges in 2015

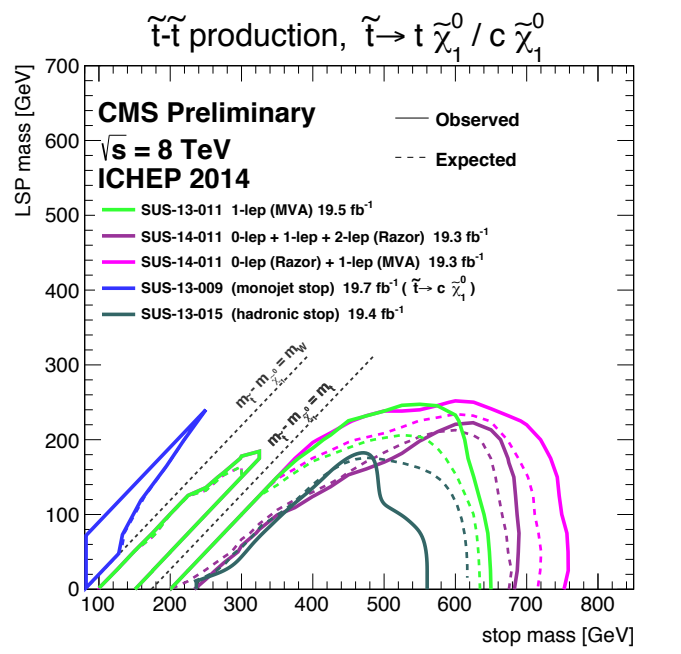
- Unfortunately boost in sensitivity from increase in CM energy doesn't come for free
- Currently still uncertain running and beam conditions and luminosity profile
- Large increase in pile-up guaranteed
- Effects on:
  - trigger performance
  - object reconstruction
  - isolation variables

Real data event with 78 reconstructed verteces from high pile-up run

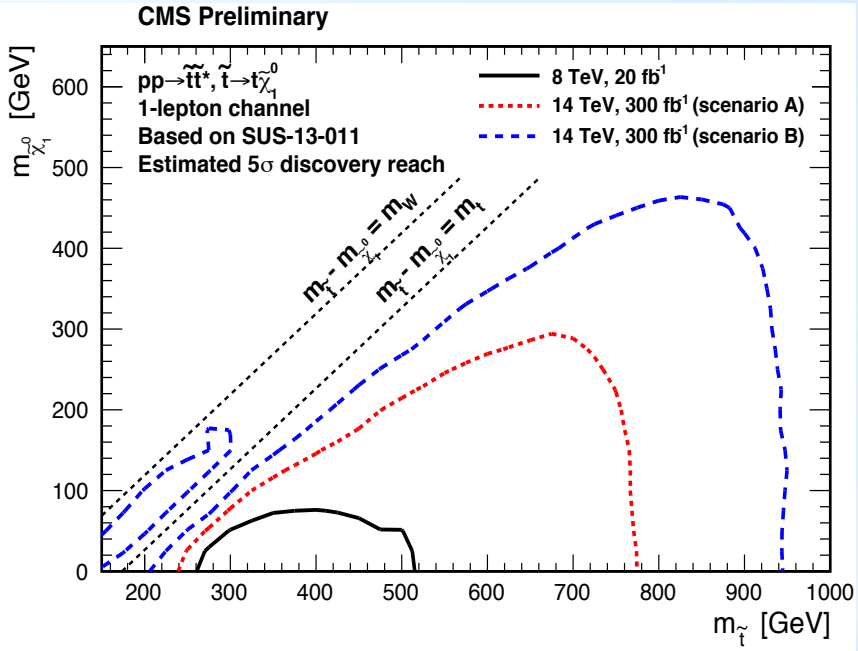


*Projections for 300/fb @ 14 TeV

Exclusion with 20/fb @ 8 TeV



Discovery with 300/fb @ 14 TeV

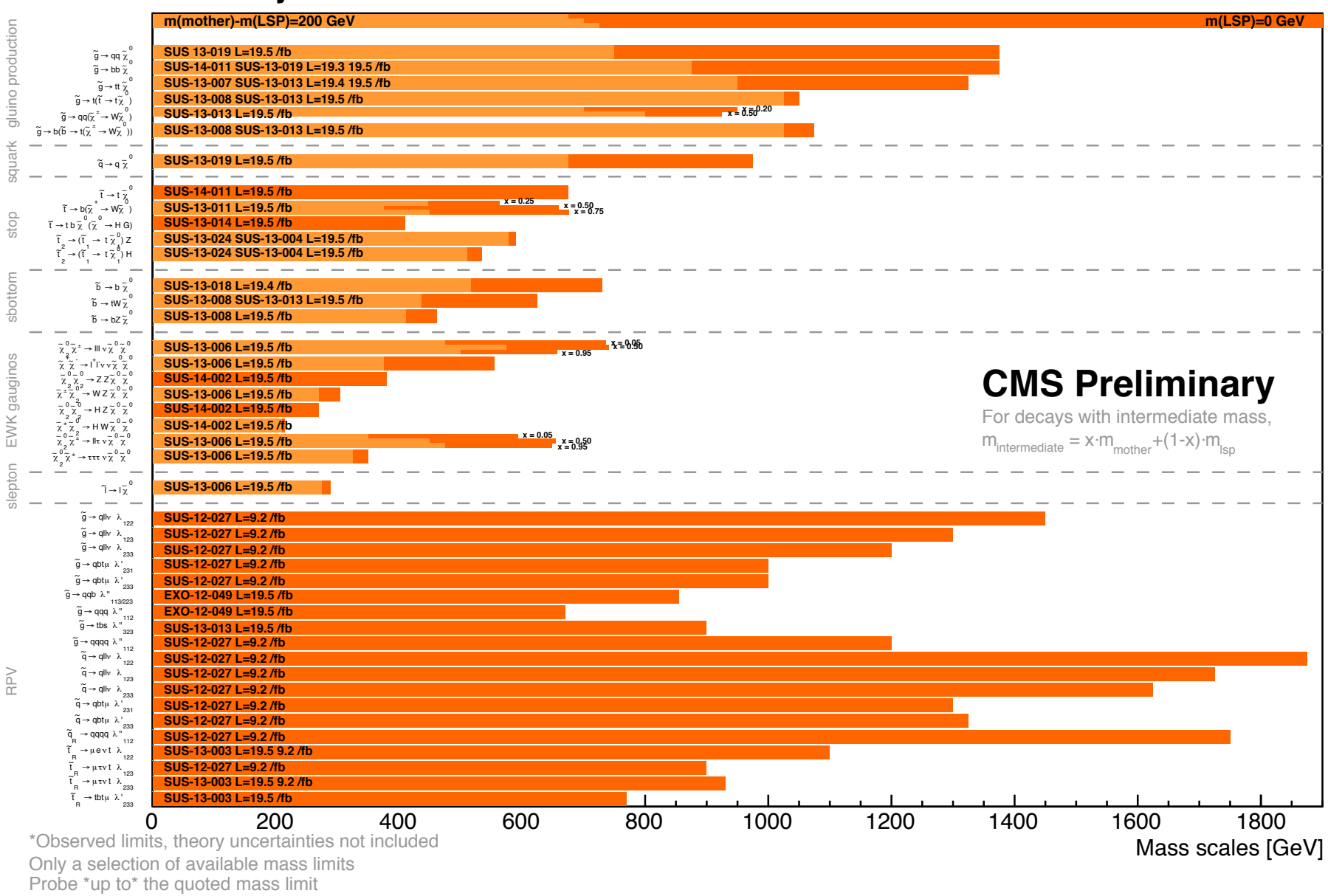


* Searches will cover the interesting region of stop masses up to 1 TeV with 300/fb @ 13 TeV
* Neutralino masses up to 500 GeV
* In gluino mediated models, reach up to m_{gl} of 2 TeV

*CMS parallel talks

* Inclusive SUSY Particle Searches with Jets and MET
  * Kristin Goebel – Tue 14:30, D7
* Searches for Direct Electroweak Production of Charginos, Neutralinos and Sleptons with Leptons and MET
  * Santiago Folgueras – Fri 17:10, D1
* Searches for Gluino, Stop and Sbottom Production in Channels with b-Jets and MET
  * Nadja Strobbe, Fri 16:50, D1
* Searches for SUSY in Final States with Photons
  * Gail Hanson, Tue 17:30, D1
* Searches for Signatures of R-Parity Violating Models
  * Halil Saka, Mon 14:30, D1
* Searches for Dark Matter Production with Mono-objects and MET
  * Bhawna Gomber, Mon 14:30, F14

*backup


Summary of CMS SUSY Results* in SMS framework
ICHEP 2014
m(mother)-m(LSP)=200 GeV
m(LSP)=0 GeV
gluino production
squark
stop
sbottom
EWK gauginos
slepton
RPV
SUS 13-019 L=19.5 /fb
SUS-14-011 SUS-13-019 L=19.3 19.5 /fb
SUS-13-007 SUS-13-013 L=19.4 19.5 /fb
SUS-13-008 SUS-13-013 L=19.5 /fb
SUS-13-013 L=19.5 /fb
SUS-13-008 SUS-13-013 L=19.5 /fb
SUS-13-019 L=19.5 /fb
SUS-14-011 L=19.5 /fb
SUS-13-011 L=19.5 /fb
SUS-13-014 L=19.5 /fb
SUS-13-024 SUS-13-004 L=19.5 /fb
SUS-13-024 SUS-13-004 L=19.5 /fb
SUS-13-018 L=19.4 /fb
SUS-13-008 SUS-13-013 L=19.5 /fb
SUS-13-008 L=19.5 /fb
SUS-13-006 L=19.5 /fb
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SUS-14-002 L=19.5 /fb
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SUS-13-006 L=19.5 /fb
SUS-12-027 L=9.2 /fb
SUS-12-027 L=9.2 /fb
SUS-12-027 L=9.2 /fb
SUS-12-027 L=9.2 /fb
SUS-12-027 L=9.2 /fb
EXO-12-049 L=19.5 /fb
EXO-12-049 L=19.5 /fb
SUS-13-013 L=19.5 /fb
SUS-12-027 L=9.2 /fb
SUS-12-027 L=9.2 /fb
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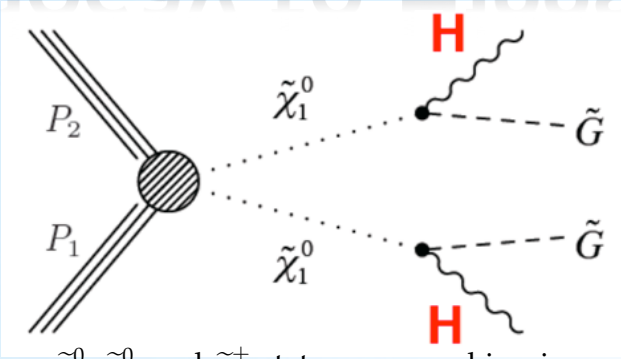
SUS-12-027 L=9.2 /fb
SUS-13-003 L=19.5 9.2 /fb
SUS-12-027 L=9.2 /fb
SUS-13-003 L=19.5 9.2 /fb
SUS-13-003 L=19.5 /fb
CMS Preliminary
For decays with intermediate mass,
m_intermediate = x·m_mother+(1-x)·m_lsp
0
200
400
600
800
1000
1200
1400
1600
1800
Mass scales [GeV]
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

*Higgs in SUSY cascade

* EWK production of Higgsinos with decay to Higgs -SUS-13-022



$\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^\pm$ states are pure higgsinos,

$\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^\pm$ mass degenerate

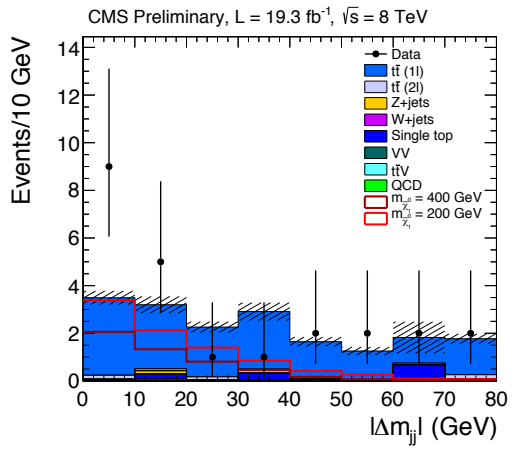
* 4 b-jet final state

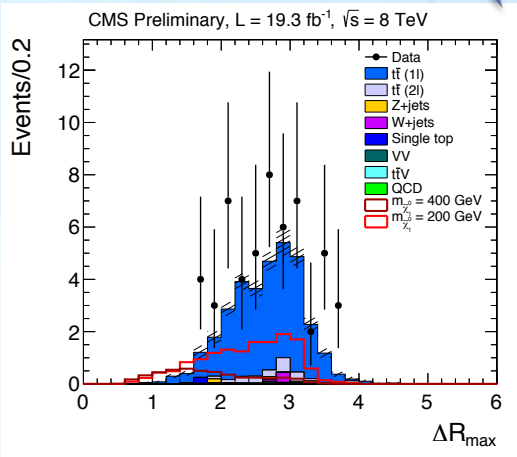
* Uses MET significance S_{MET} as discriminating variable as well as ΔR between b-jets of H candidates and

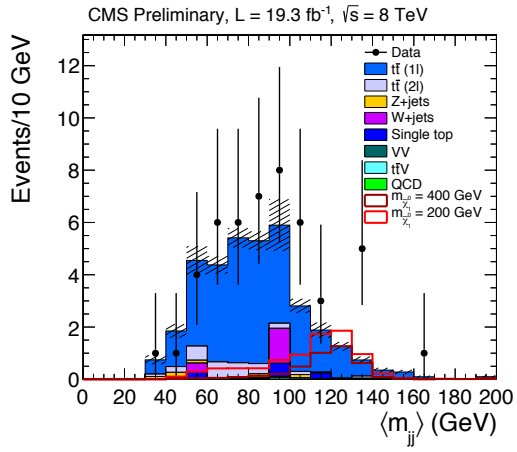
$$|\Delta m_{jj}| \equiv |m_{jj,1} - m_{jj,2}|$$

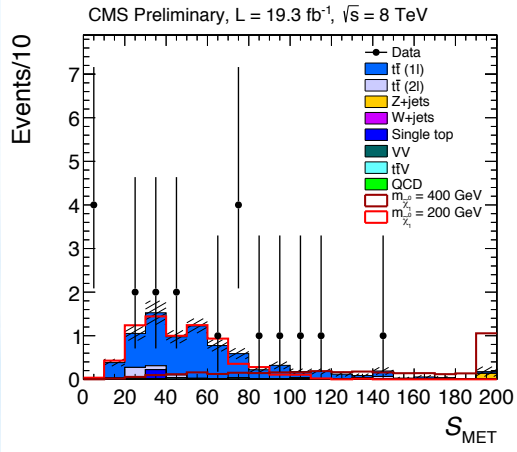
$$\langle m_{jj} \rangle \equiv (m_{jj,1} + m_{jj,2})/2.$$

of Higgs candidates





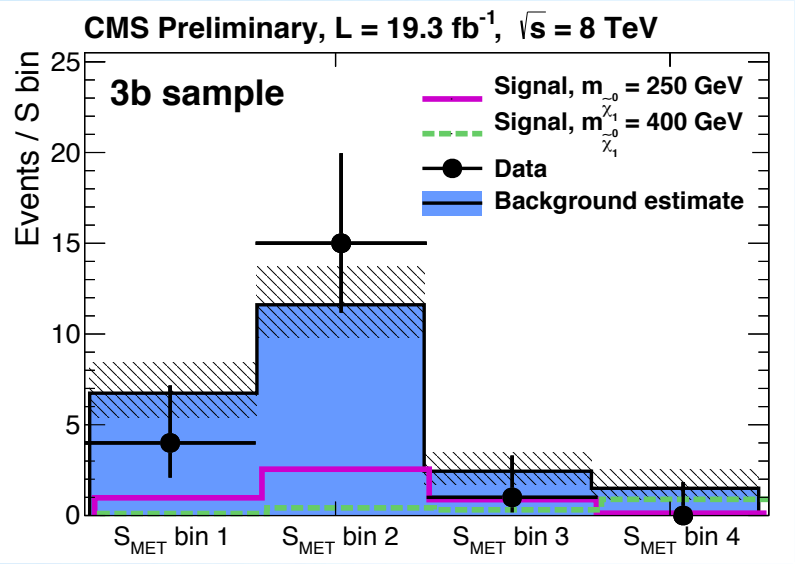


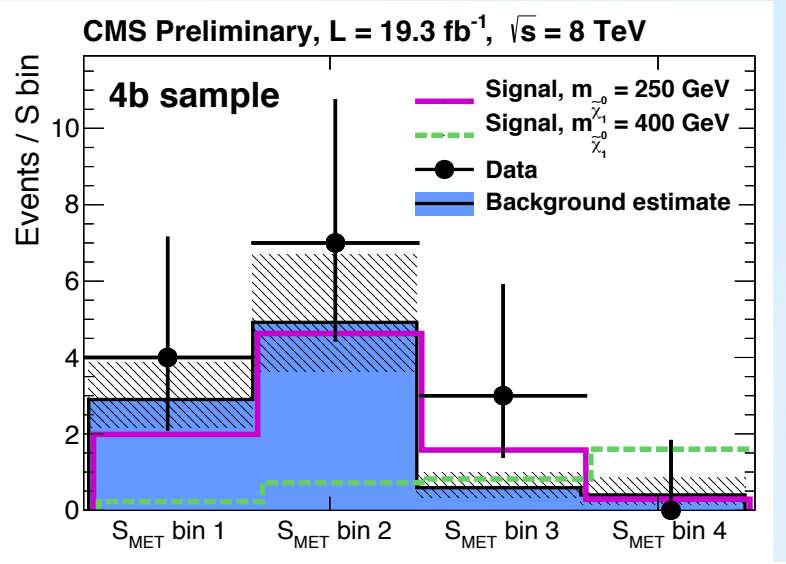


Example distributions for 4-b events

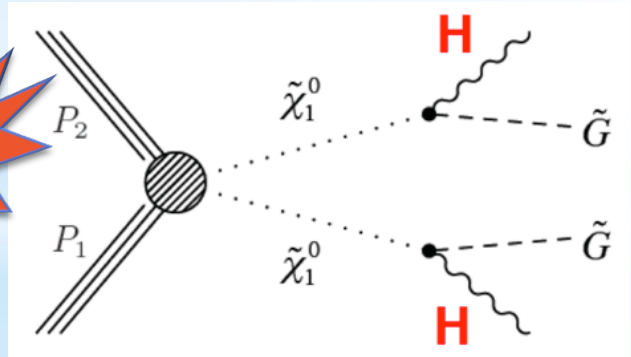
* Interpretation in GMSB model- SUS-13-022

S_{MET} = [30-50], [50-100], [100-150], [>150]





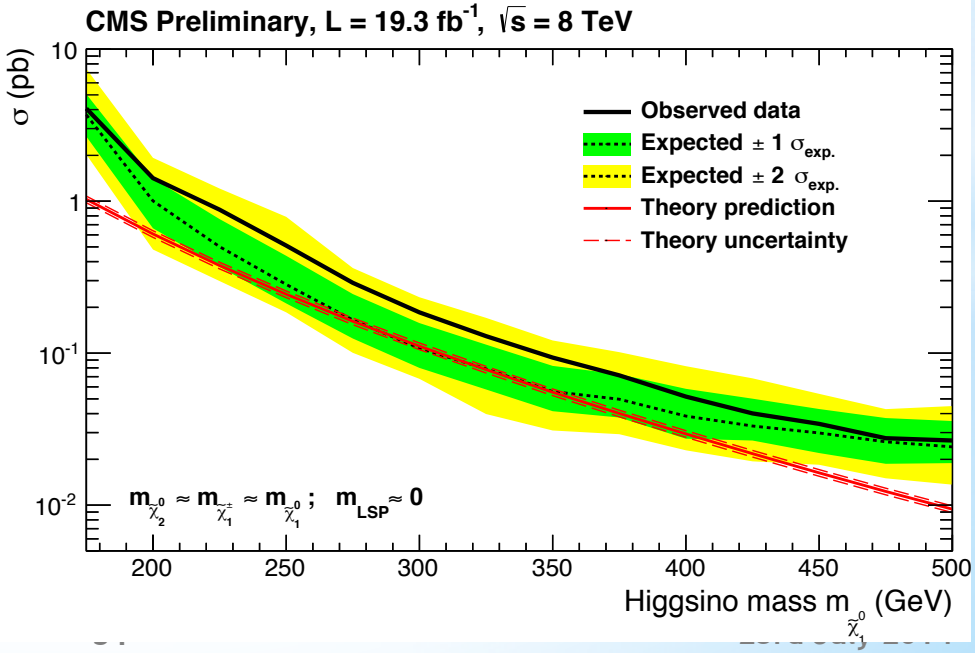
NEW!!



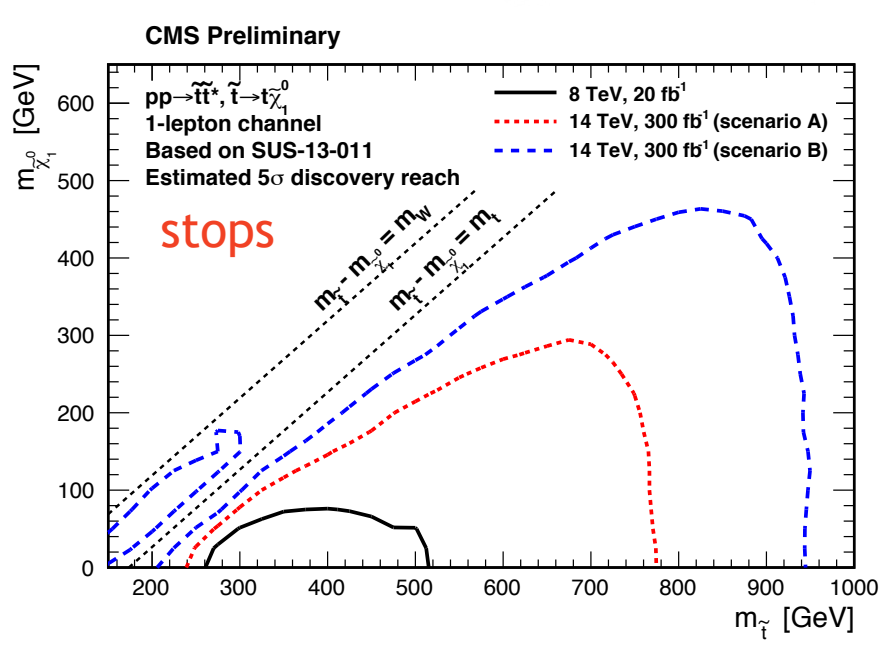
$\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^\pm$ states are pure higgsinos

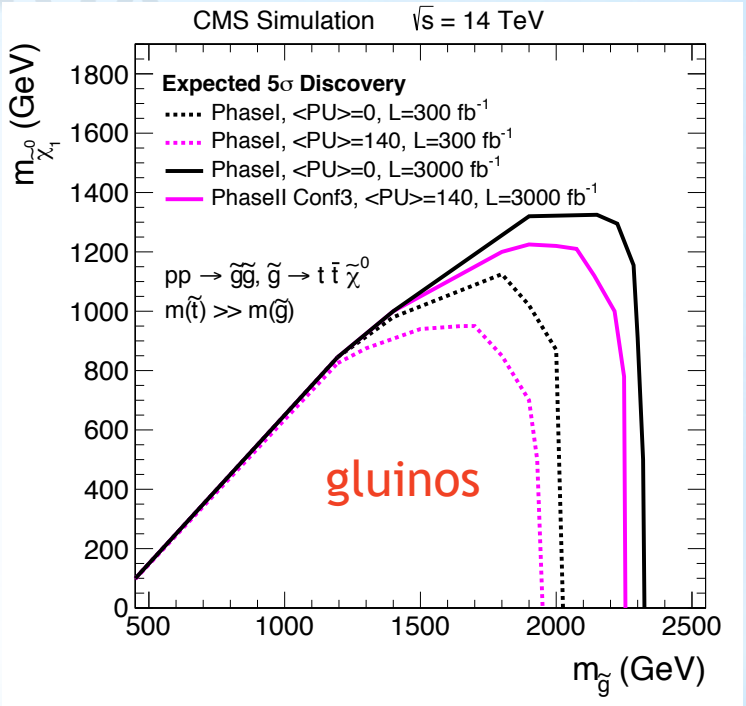
$\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^\pm$ mass degenerate

K. Matchev & S. Thomas,
Phys. Rev. D 62 (2000) 077702



Projections for 300/fb & 3000/fb @ 14 TeV

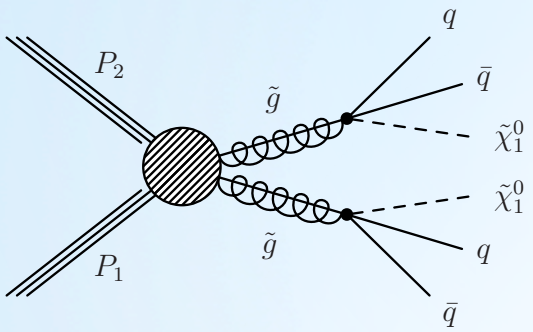


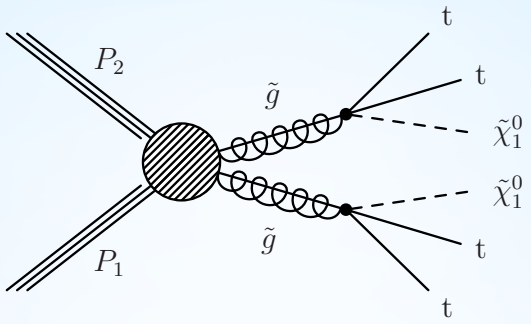


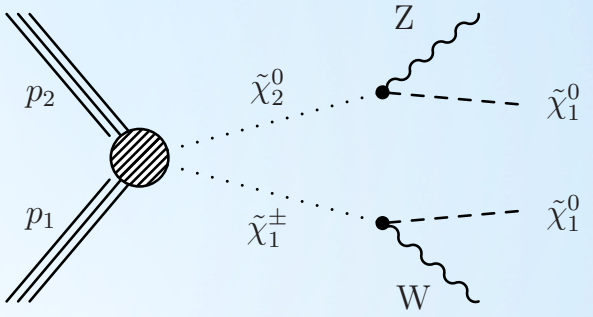
- Searches will cover the interesting region of stop masses up to 1 TeV with 300/fb @ 13 TeV
- Neutralino masses up to 500 GeV
- In gluino mediated models, reach up to m_{gl} of 2 TeV

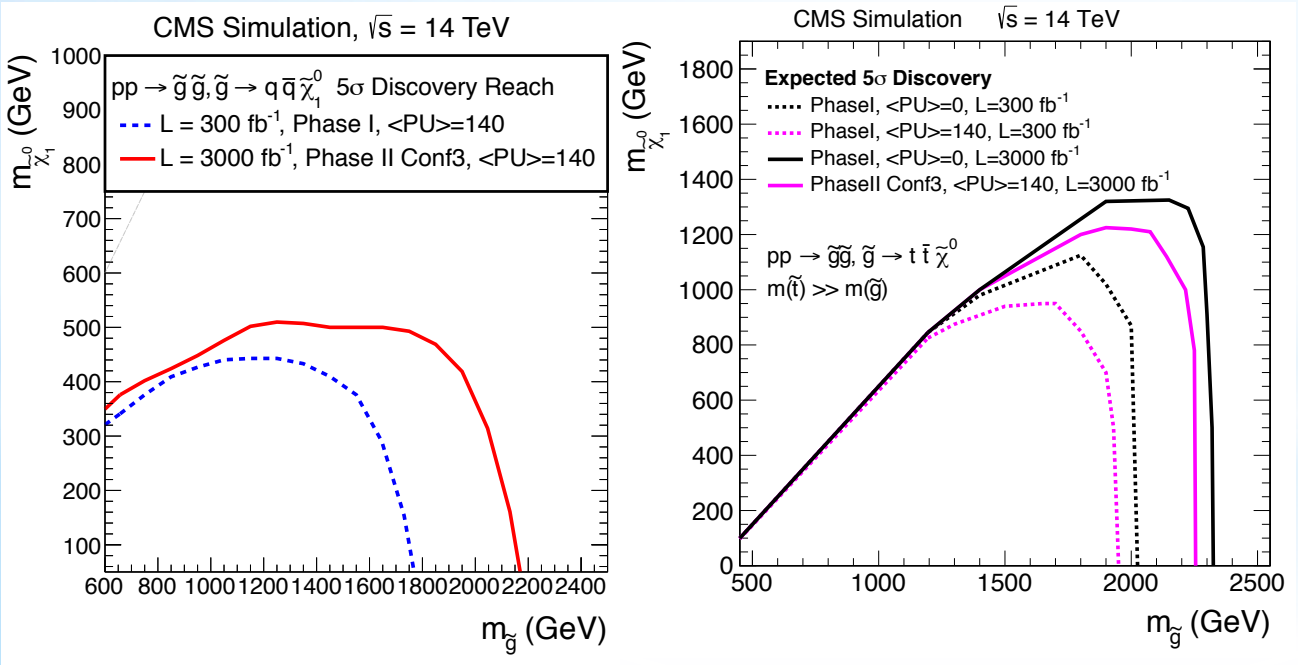
*Expected sensitivity @ 14 TeV

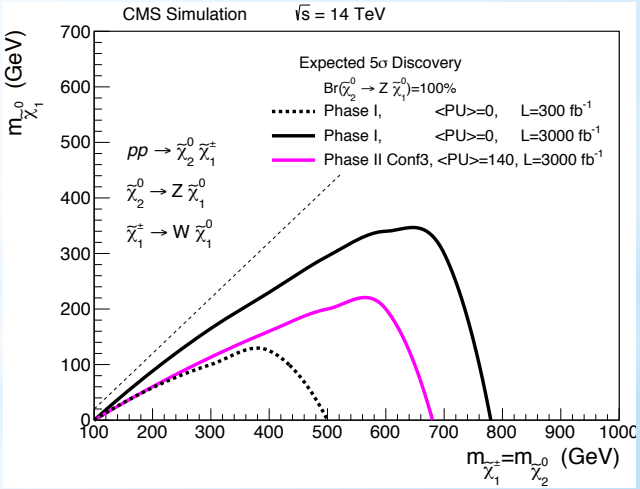
CMS contribution to ECFA workshop







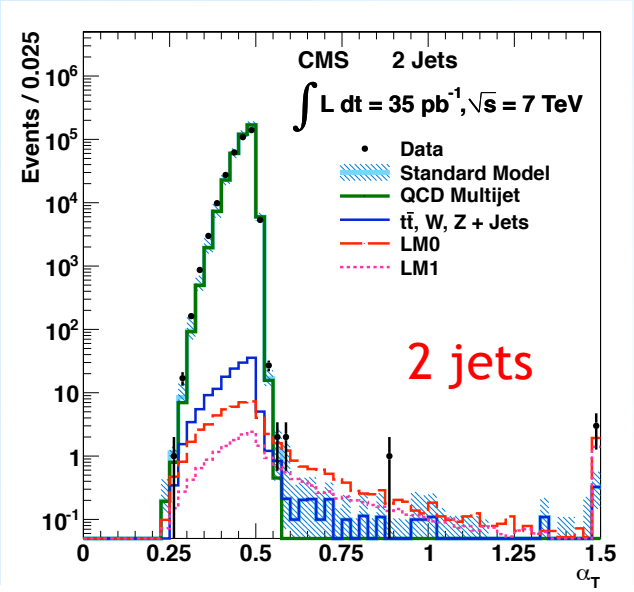


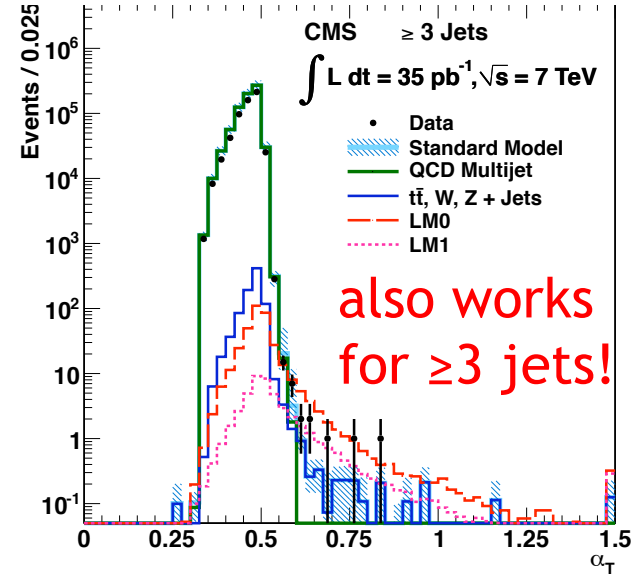


SMS assume 100% BF for these decays!

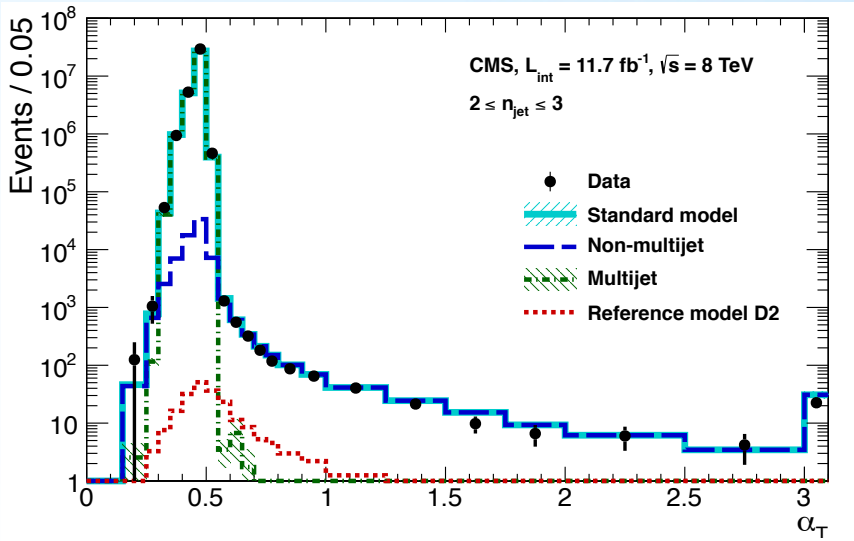
*from 2010 -> 2012

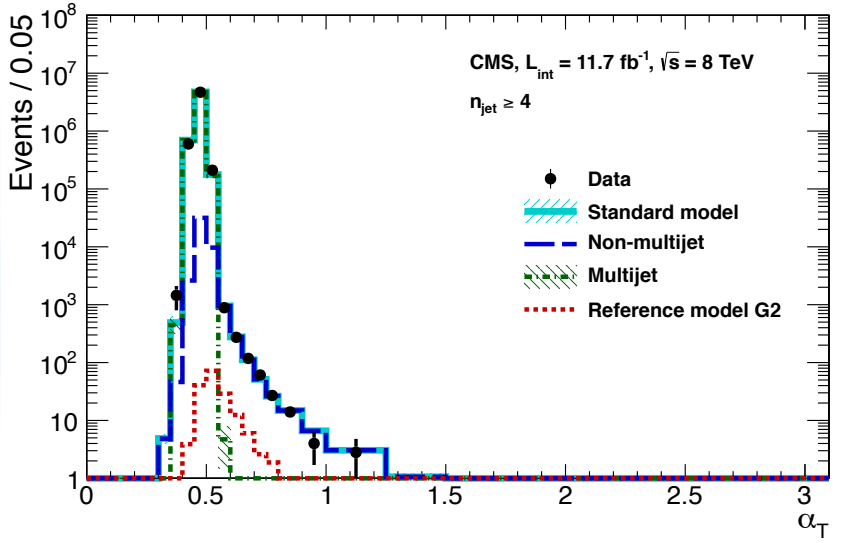
13 candidate events



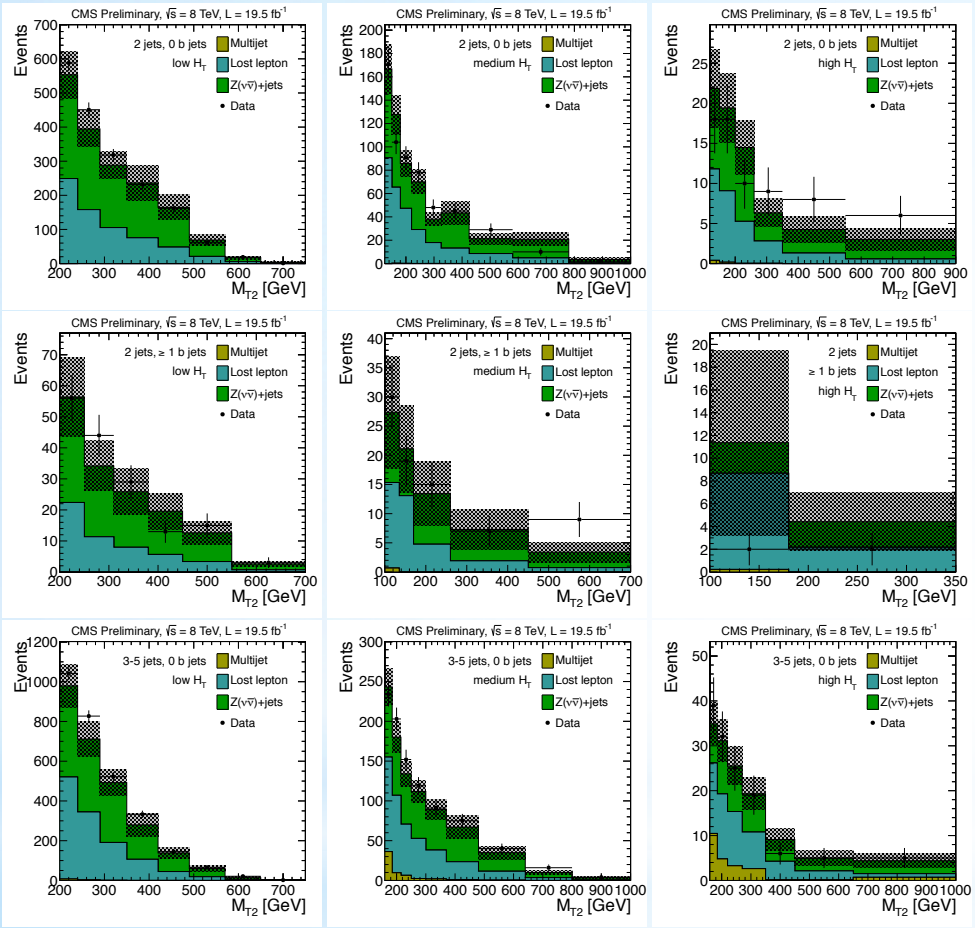


1000's of candidate events, split by HT, N_{jets} and $N_{b\text{-}jets}$





*MT2 - SUS-13-19



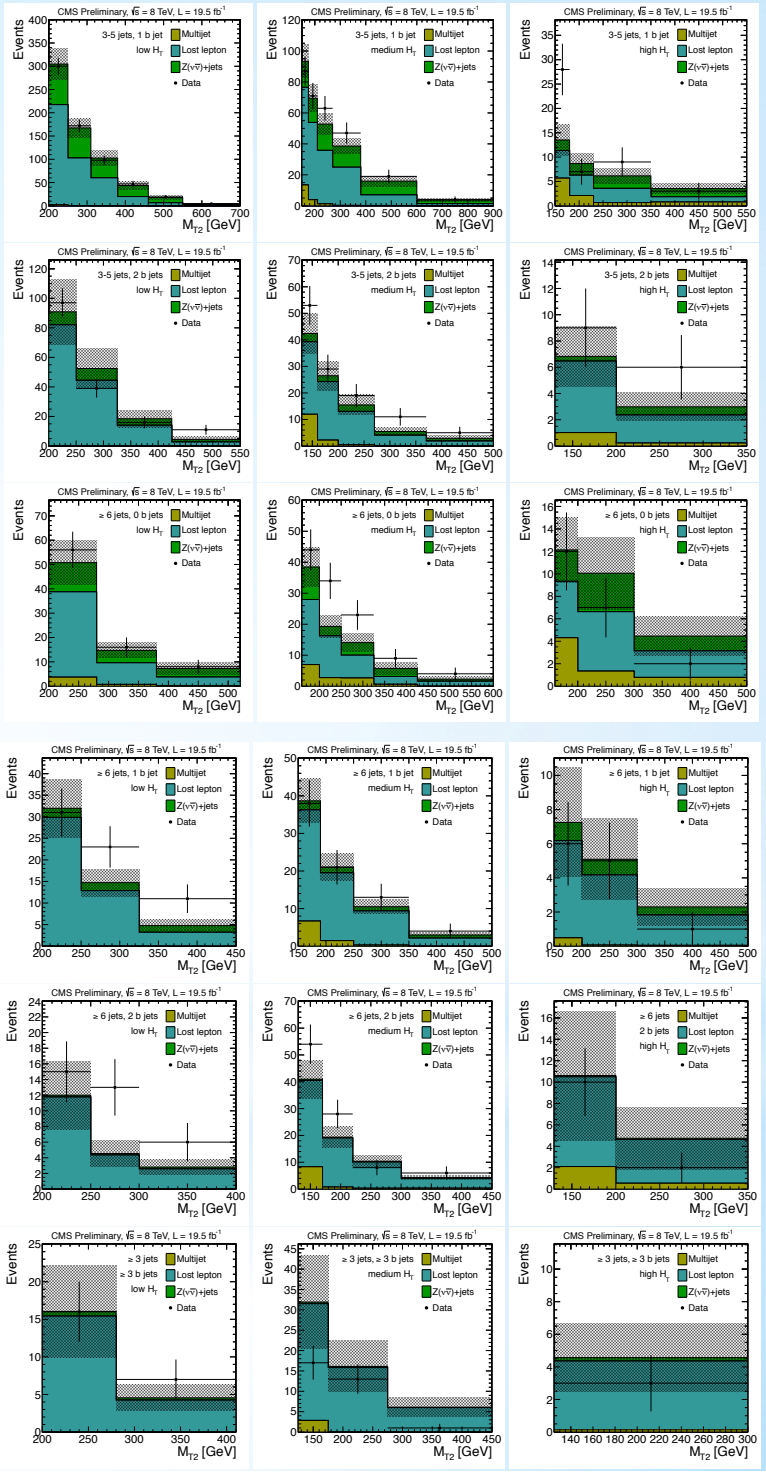


Figure 7: M_{T2} distributions from data-driven background estimates compared to data for low H_T (left), medium H_T (middle), and high H_T (right). The topological region in the jet − b-jet multiplicity is given in each plot. They are from top to bottom: $N_j = 2$ and $N_b = 0$, $N_j = 2$ and $N_b \geq 1$, $3 \leq N_j \leq 5$ and $N_b = 0$. The data correspond to an integrated luminosity of 19.5 fb^{-1}. All selection cuts are applied. The uncertainty band drawn in this figure does not contain shape uncertainties of the lost-lepton estimate.

M_{T2} Higgs search - SUS-13-019

- Slightly modified search cuts:
  - $N_j \geq 4$,
  - $N_b \geq 2$, with $p_T \geq 20\,\text{GeV}$[1],
  - $450 \leq H_T < 750\,\text{GeV}$, $E_T^{miss} > 200\,\text{GeV}$, and $M_{T2} > 200\,\text{GeV}$ - called the low H_T region,
  - $H_T \geq 750\,\text{GeV}$, $E_T^{miss} > 30\,\text{GeV}$, and $M_{T2} > 125\,\text{GeV}$ - called the high H_T region.

- Look for excess in invariant mass distribution of two b-jets