Searches for Supersymmetry at CMS

status and prospects

Wolfgang Adam

Institute of High Energy Physics
Austrian Academy of Sciences

ÖAW

Laboratoire de l'Accélérateur Linéaire

Univ. Paris-Sud, Orsay, Feb. 10, 2017

Outline

- Introduction

- Searches for SUSY production (strong & EWK production)
- Some more exotic SUSY models
- Interpretations
- Future

- Summary

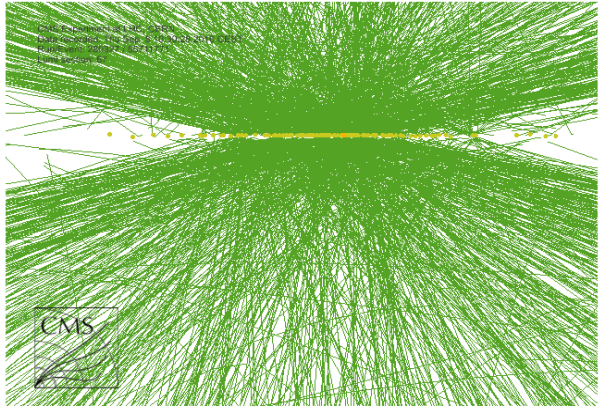
SUSY in 13 TeV pp collisions

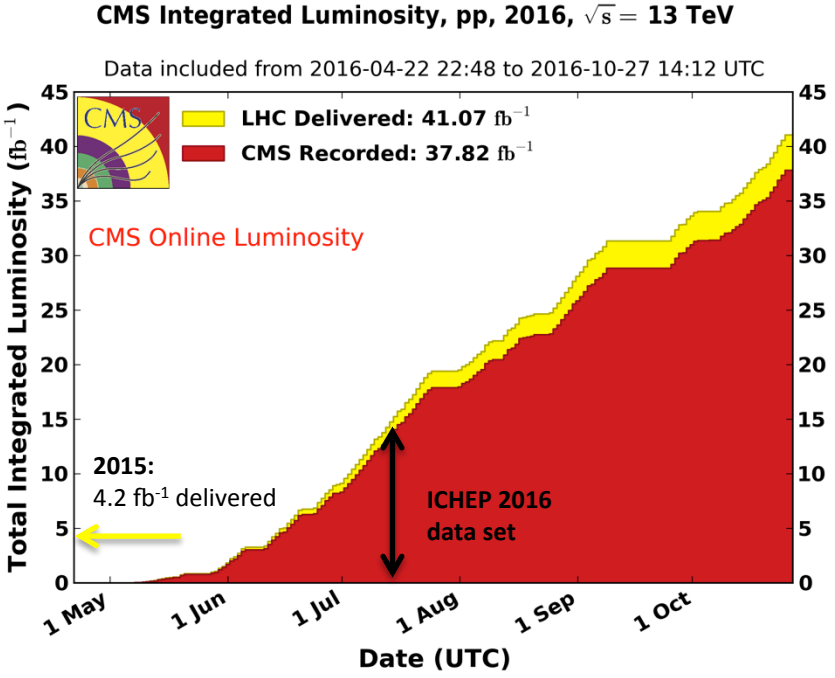
Extraordinary LHC performance in 2016

- exceeded design value inst. luminosity
- total $\int \mathcal{L}$ (2016) ~ 10 x $\int \mathcal{L}$ (2015) !

Experimental challenges

- keep trigger rates under control
- deal with increasing pileup
- changes in data-taking conditions (inst. luminosity)

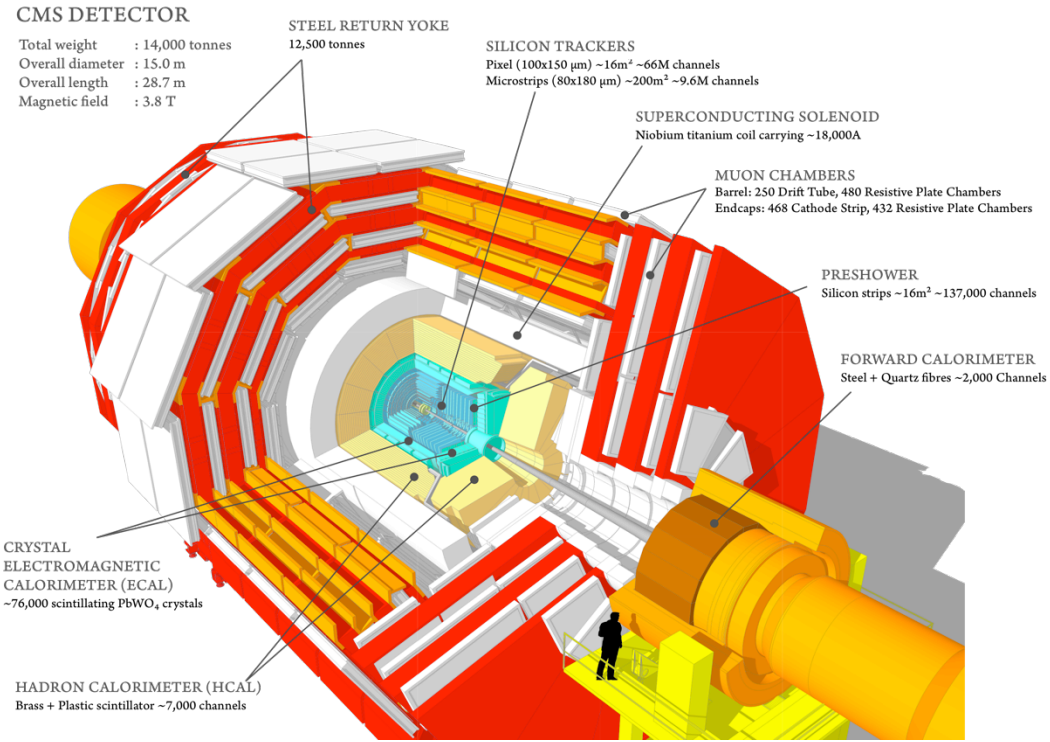




High PU event

- recorded in Sep. 2016
- 86 reconstructed vertices

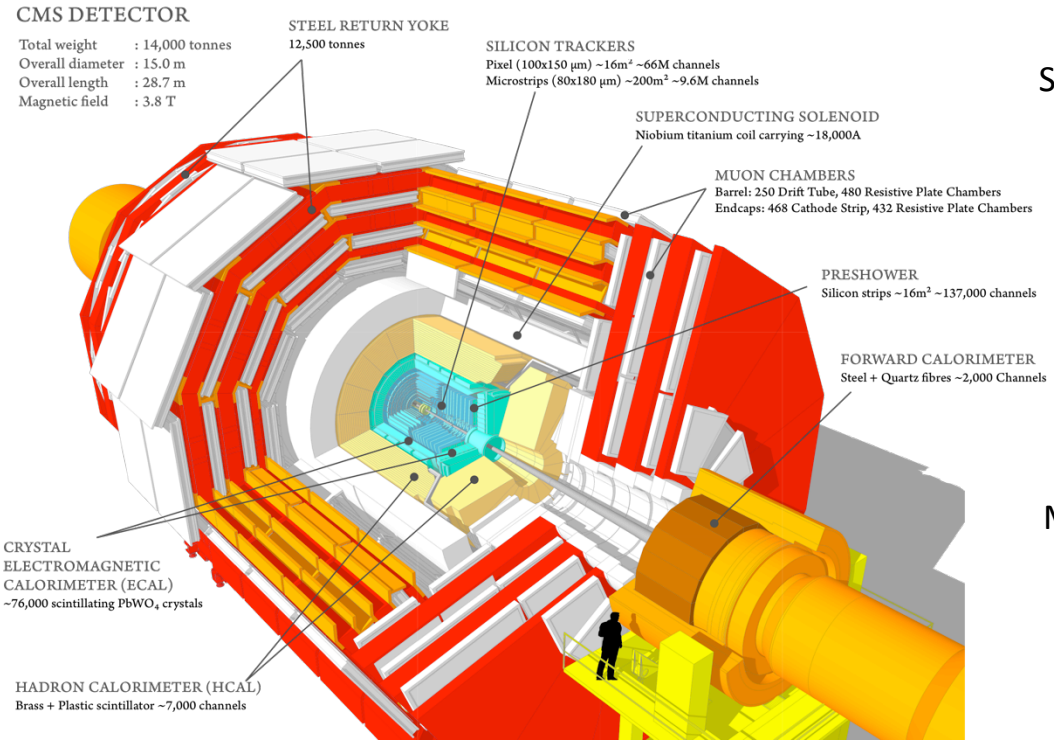
CMS


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 PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

CMS in (early) Run 2

4th muon station added (CSC/RPC)

new DAQ system



SiPMs for HO

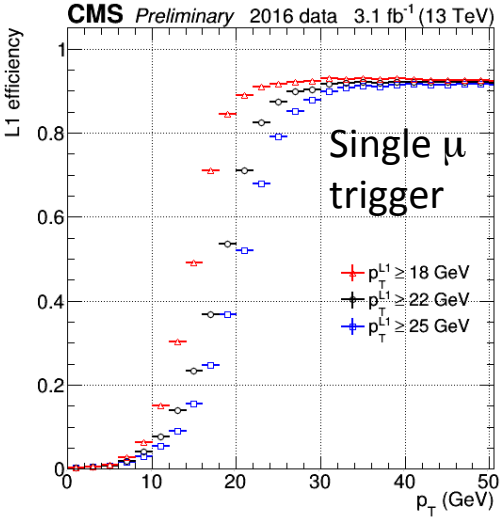
Multi-anode PMTs in HF

new L1 trigger:
improved PU subtraction, e/γ isolation, τ trigger, increased granularity, more algorithms

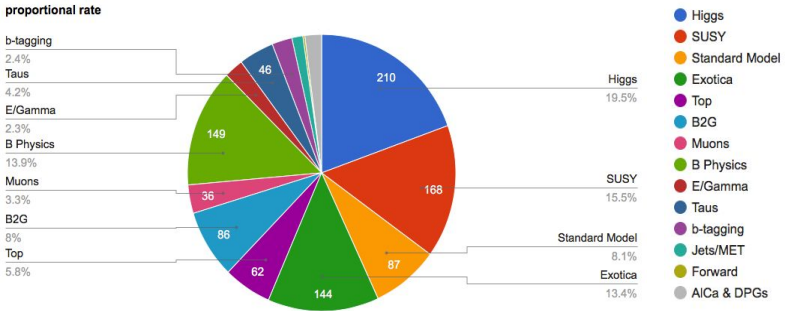
SUSY in CMS

Input

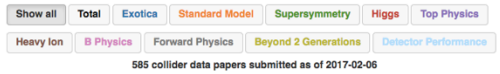
- Triggers: in 2016, CMS used about 1/6 of it output rate for SUSY-specific triggers



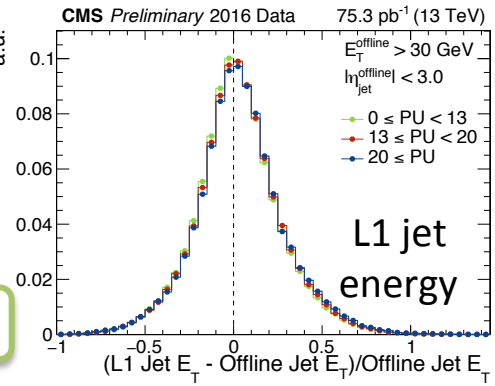
DP-2016-050



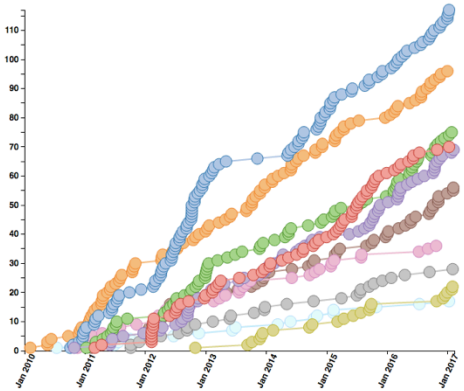
"Output"



Central

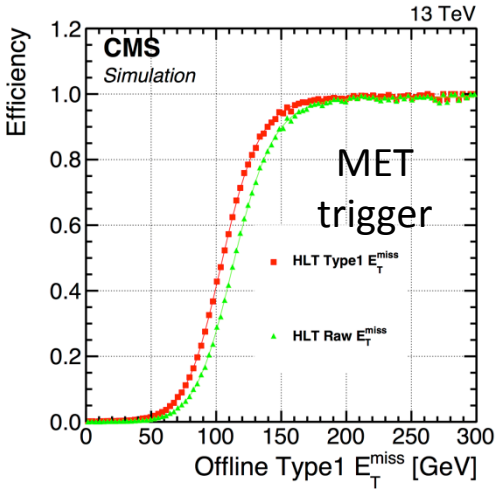


DP-2016-034

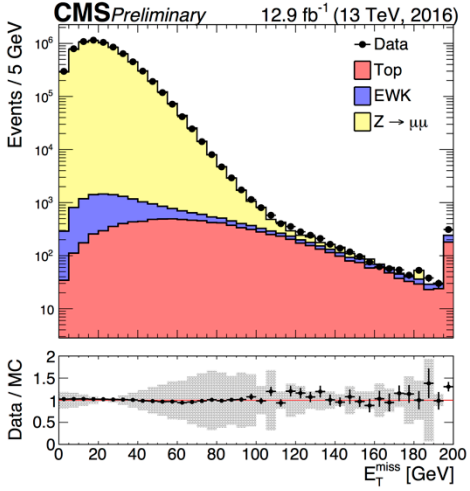


Missing transverse energy at 13TeV

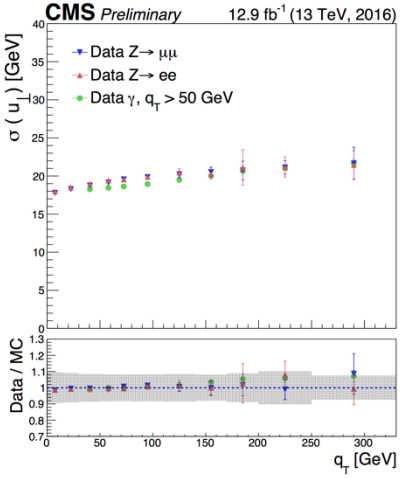
- calculated from particle flow candidates
- corrected for jet energy scale



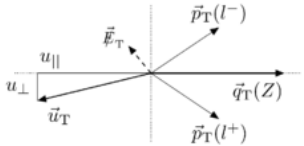
Impact of JECs on
HLT turn-on curves



MET in Z→μμ



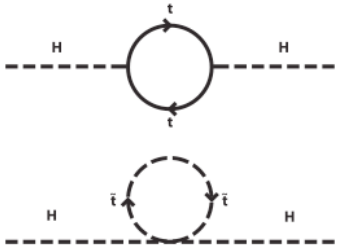
MET component
resolution in Z→μμ



JME-16-004

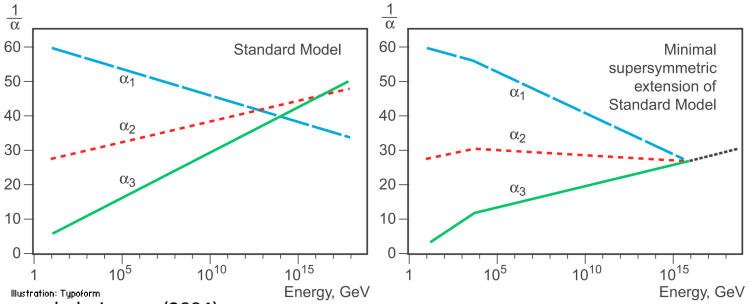
Why look for SUSY after LHC Run1?

The main motivations remain



Hierarchy problem

- low-mass top squarks cancel SM contributions to m(H)
  (+ light higgsinos, gluinos)



nobelprize.org (2004)

Unification of gauge couplings

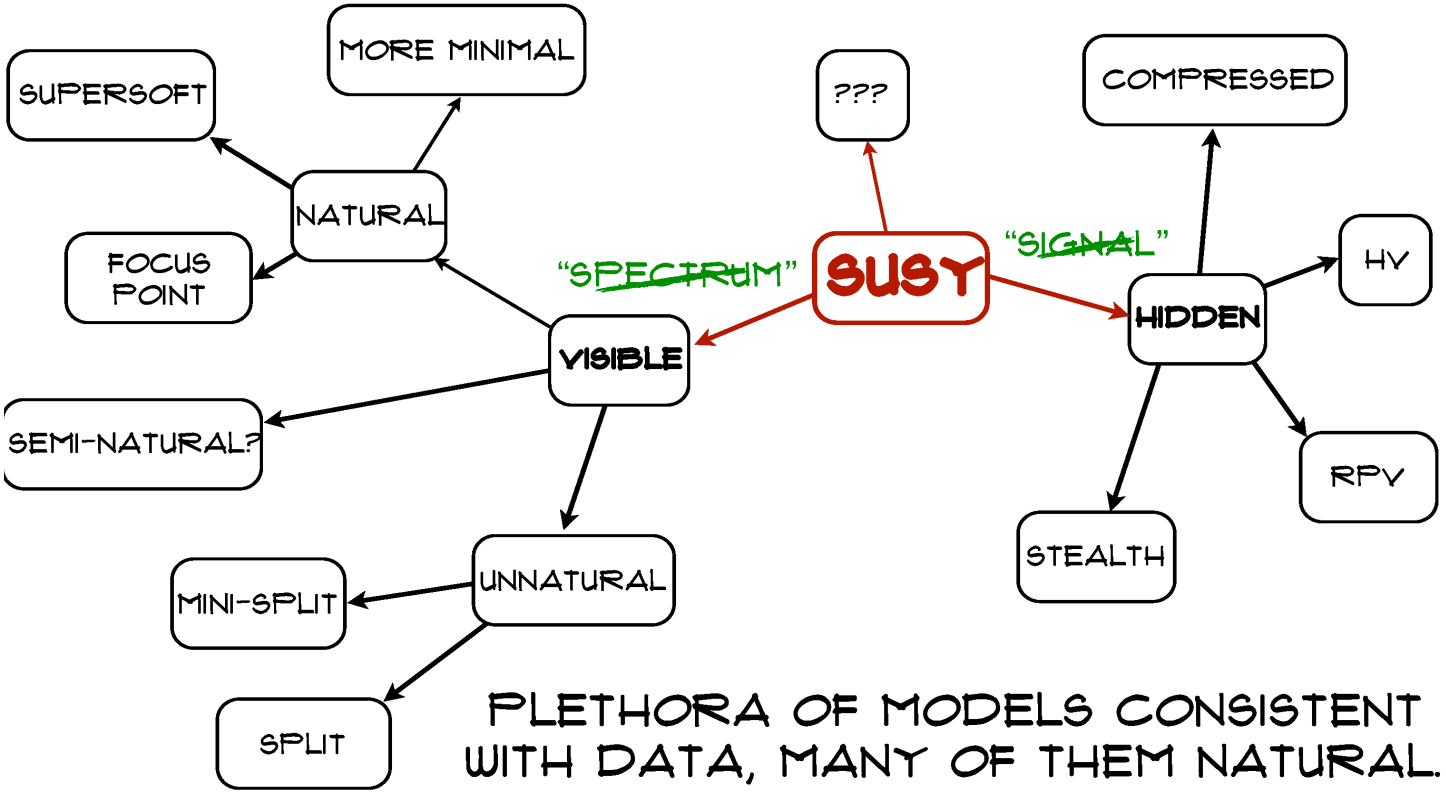
- Presence of sparticles changes running of couplings

Dark matter

- lightest SUSY particle can be massive, stable, and weakly interacting

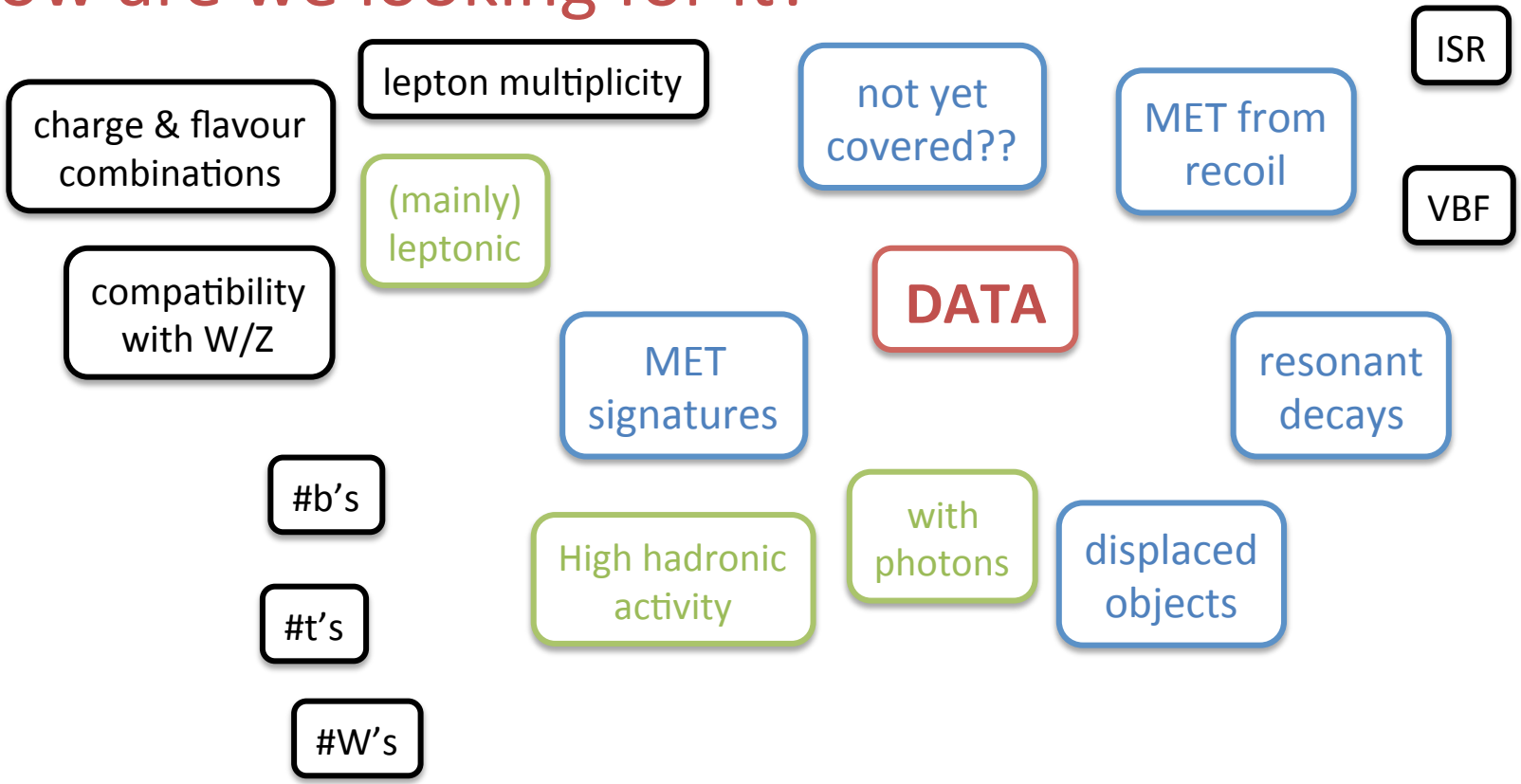
NASA / Chandra

What are we looking for?



from N. Craig
LHCP2014

How are we looking for it?



The SUSY hunter's toolbox

Standard objects

- isolated charged (light or τ) leptons
- jets, b-tagged jets
- missing transverse momentum (energy sum (MET) or from jets (MHT))

Kinematic variables

- m_T (lepton/MET, b/MET)
- m_{T2} (stransverse mass) + variations
- m_{CT} (contransverse mass)

common feature: endpoint at m(parent)

- hemispheres
- razor

Hadronic / total energy

- H_T (scalar sum of (jet) p_Ts)
- E_T^{sum} (sum of all particle p_Ts)

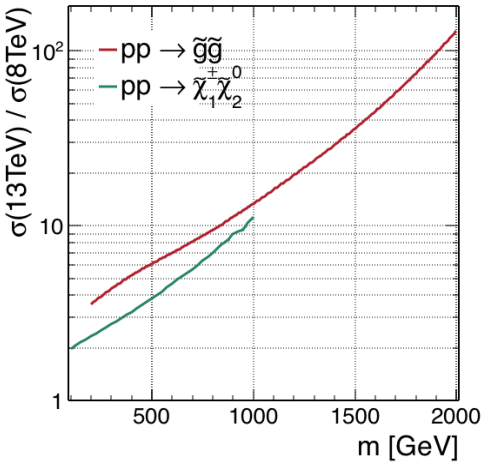
Composite (boosted) objects

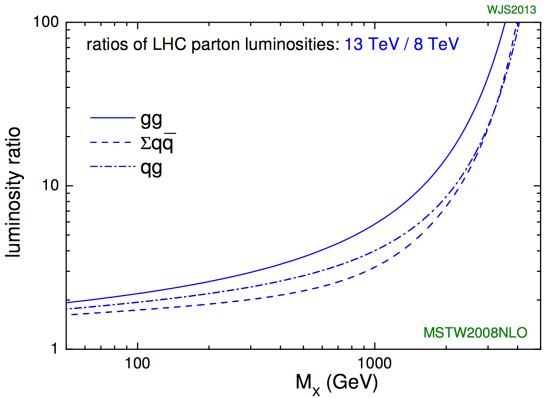
- topness
- boosted W and top taggers
- jet substructure
- jet masses

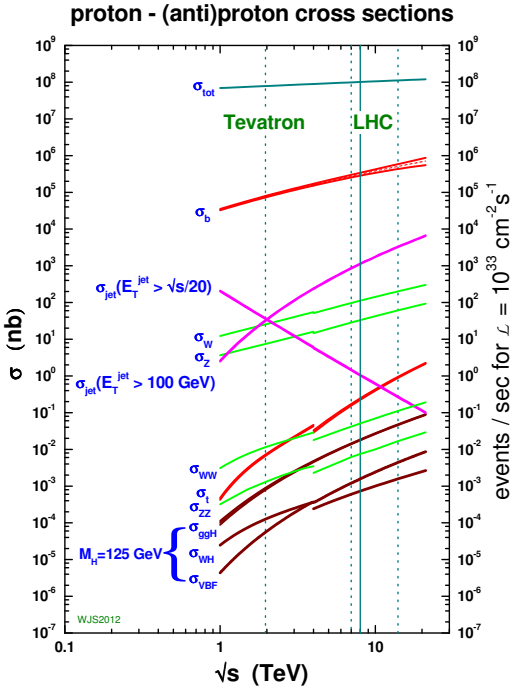
SUSY in 13 TeV pp collisions

Considerably higher cross sections w.r.t. Run1

- in particular for gluon-gluon
- most important gain for the highest masses
  - for many SUSY searches higher than for dominant SM backgrounds (W, tt)

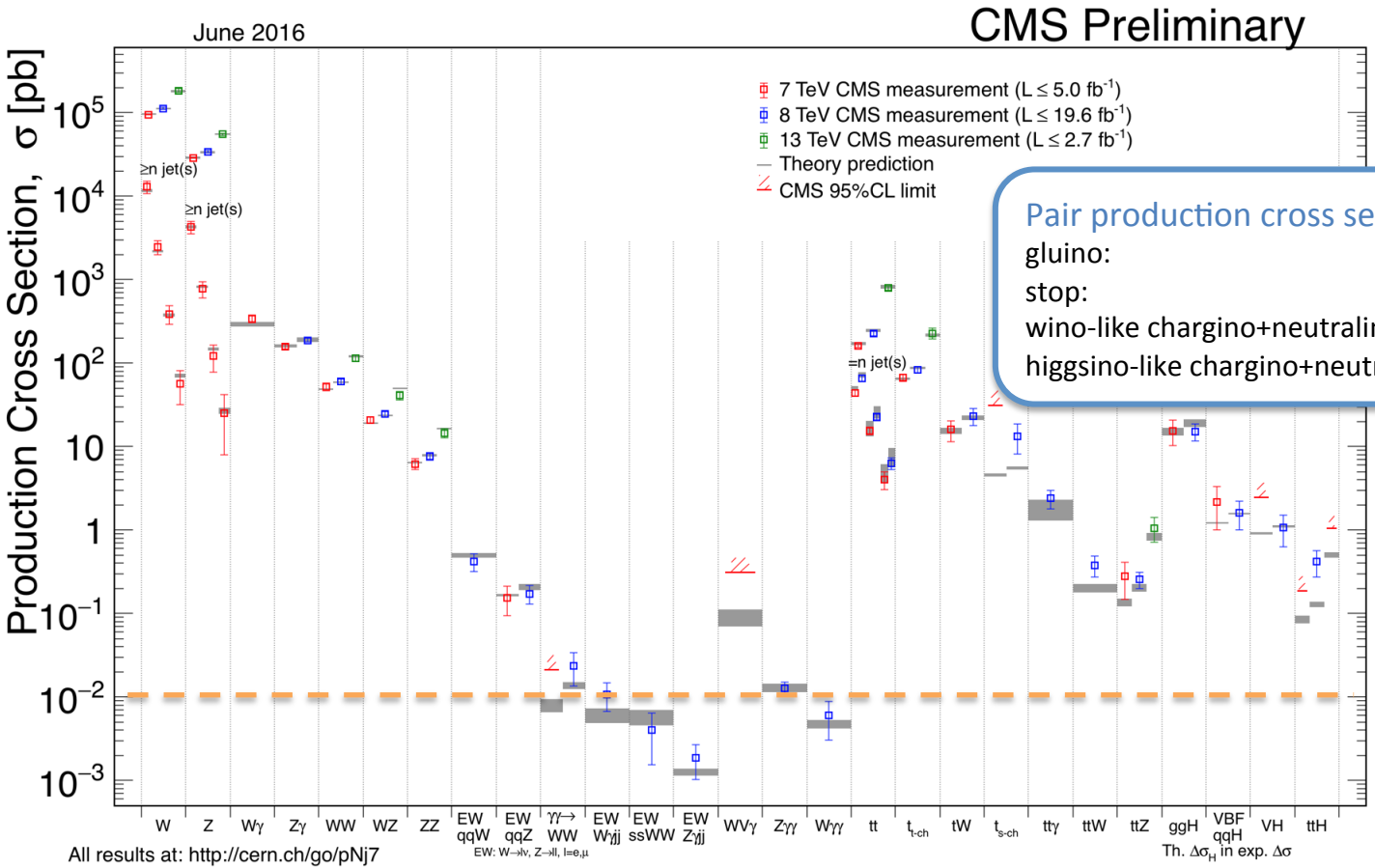






W.J.Stirling

Still a needle in a haystack …

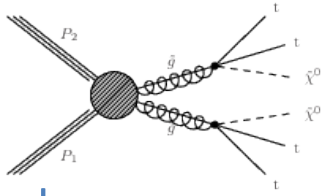


Pair production cross section = 10 fb^{-1}

gluino:	m ~ 1.6TeV
stop:	m ~ 900GeV
wino-like chargino+neutralino:	m ~ 400GeV
higgsino-like chargino+neutralino:	m ~ 300GeV

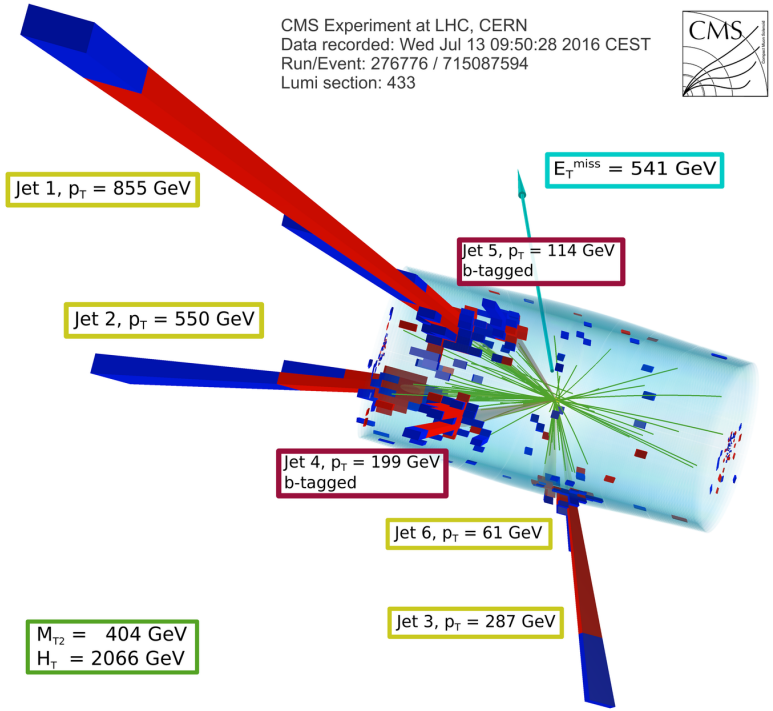
GLUINO PAIR PRODUCTION

Gluino decays to tt+LSP: hadronic



Spectacular signature for gluino decays via virtual top squarks

- Profit from high gluino pair-production cross section
- Final states with four top quarks
  - Very high jet and b-jet multiplicities
  - Four W's → high BF to states with one or more leptons



Gluino decays to tt+LSP: hadronic

Example for an inclusive, hadronic search: SUS-16-015

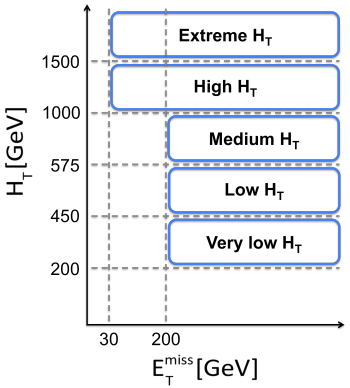
Online selection

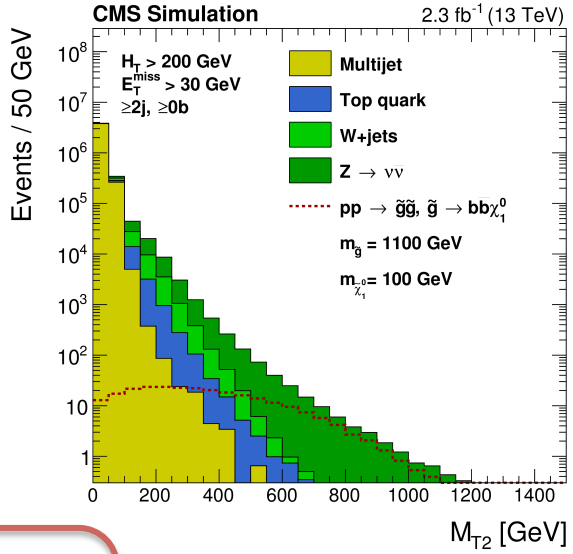
- combinations of MET, H_T, and MH_T (higher MET for lower H_T thresholds)

Offline selection

- isolated lepton & track vetos
- anti-QCD ($\Delta\phi$ MET/jet)
- SRs binned in
  - #jets (1,…,≥7), #bs (0,…,≥4)
  - H_T (>1 jets) / jet pT (1 jet) (starting at 200GeV), and
  - MT2 (starting at 200GeV)

Total of 172 SRs





MT2 after baseline (here for 2015: SUS-15-003/arXiv:1603.04053)

Challenges

- reduce (and estimate) multijet bkgs
- estimate irreducible Z→νν and remaining lost-lepton backgrounds

Gluino decays to tt+LSP: hadronic

Z→νν background

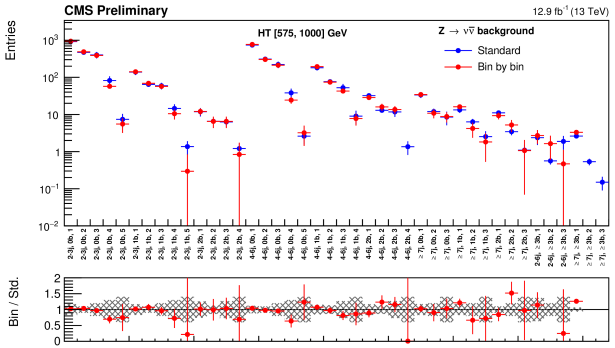
- two possible proxys:
  - Z→ll : syst ☺ stat ☹
  - γ+jets: syst ☹ stat ☺

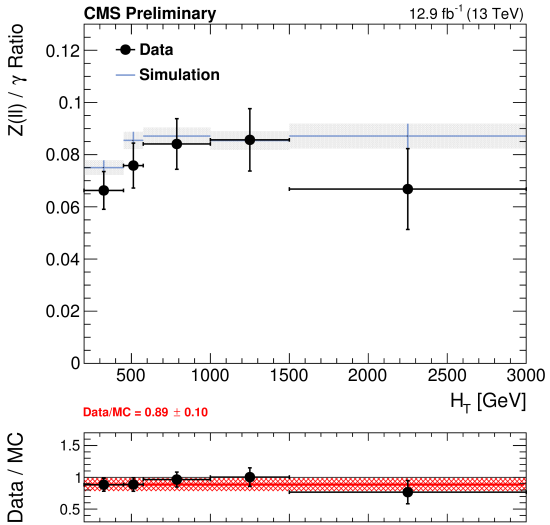
$$N^{SR}_{Z\to\nu\bar{\nu}}(M_{T2}) = N^{CR}_{\gamma}(H_T, N_j, N_b) \times P_{\gamma} \times f \times R^{Z/\gamma}_{MC}(H_T, N_j, N_b) \times k_{MC}(M_{T2})$$

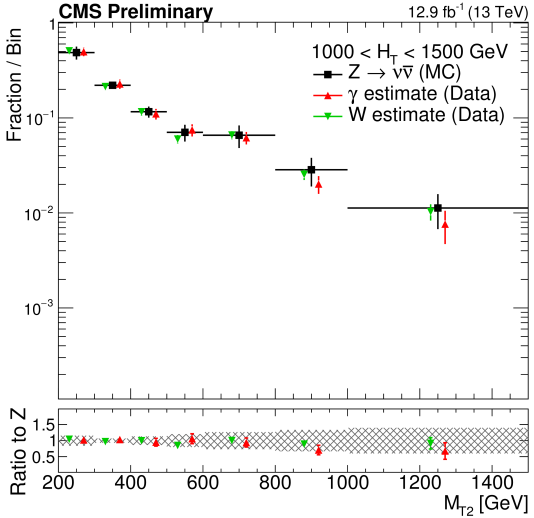
measure as f(HT,#jets,#bs)

correct for purity and Z/γ differences

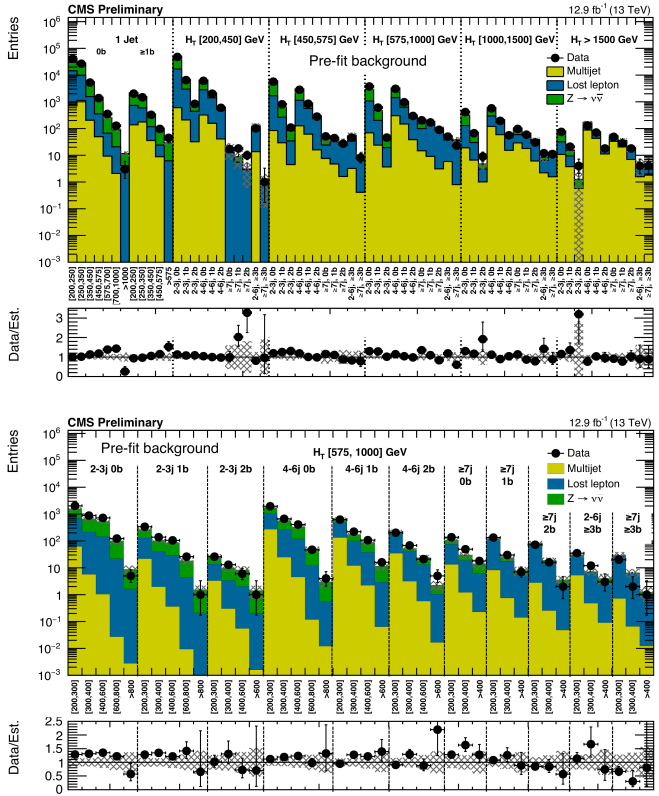
obtain universal MT2 dependence from MC

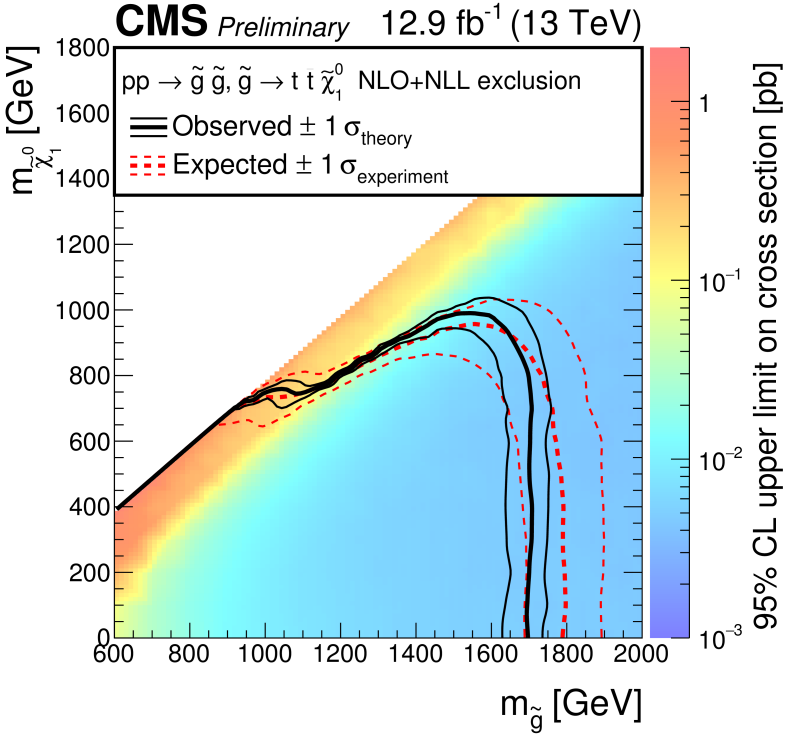






Gluino decays to tt+LSP: hadronic

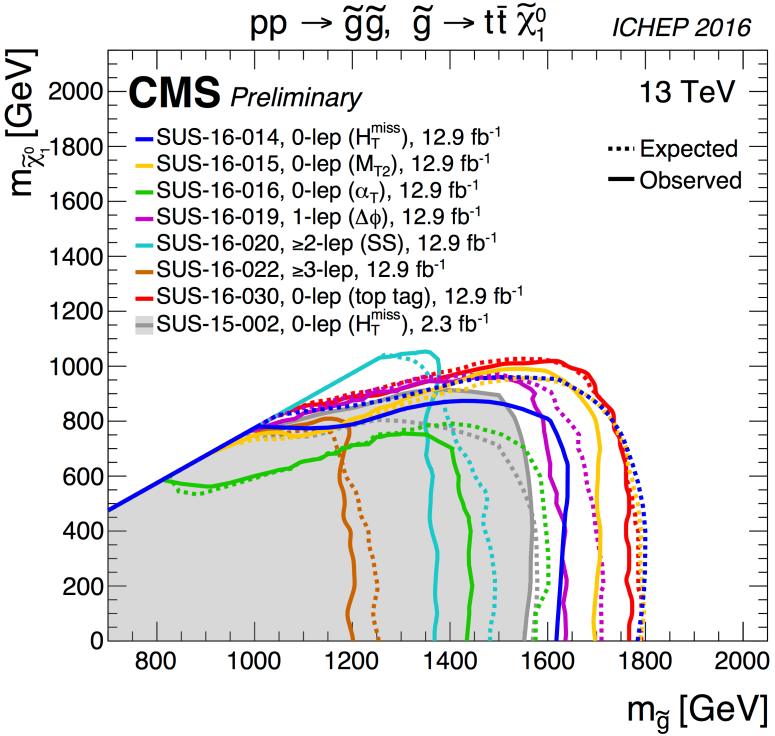




Gluino decays to tt+LSP: summary

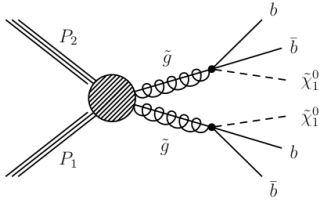
Other final states:

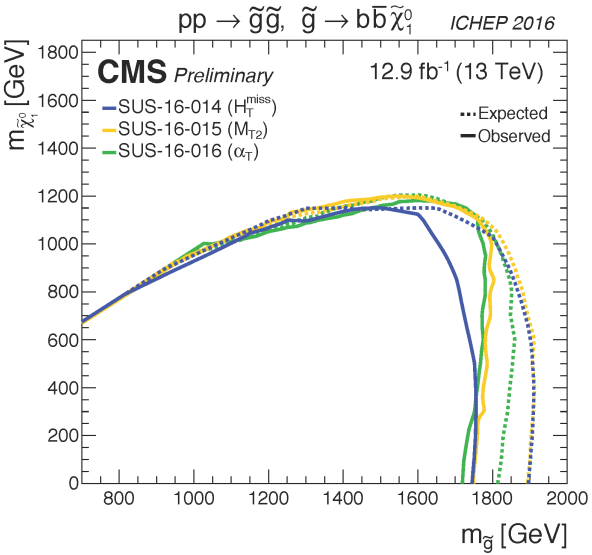
- Single-lepton (SUS-16-019)
- Same-sign dileptons (SUS-16-020)
- Multileptons (SUS-16-022)



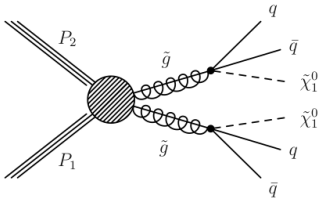
Gluino decays to bb/qq+LSP

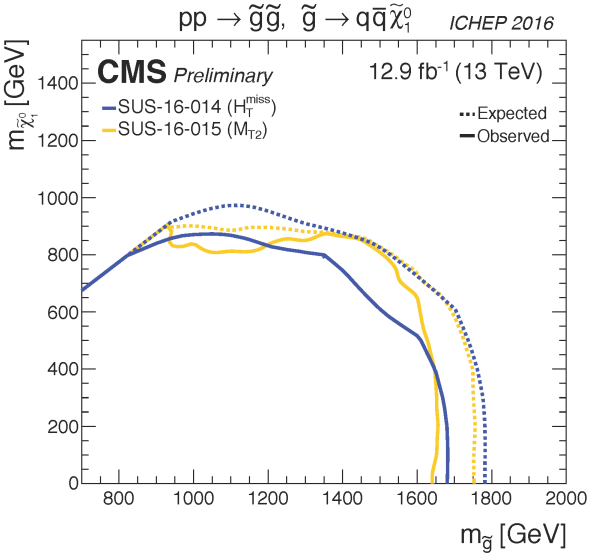
Decays to bb+LSP





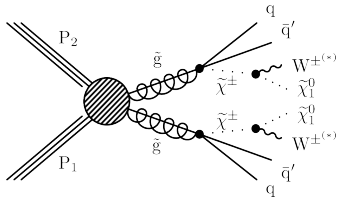
Decays to qq+LSP





- purely hadronic final states
- high b-multiplicity helps with background discrimination

Gluino decay chains via EWK gauginos



Alternative decay chains in gluino production

- example for chargino→W LSP in the single lepton channel: SUS-16-019

Online selection

- combinations of isolated e/μ and H_T

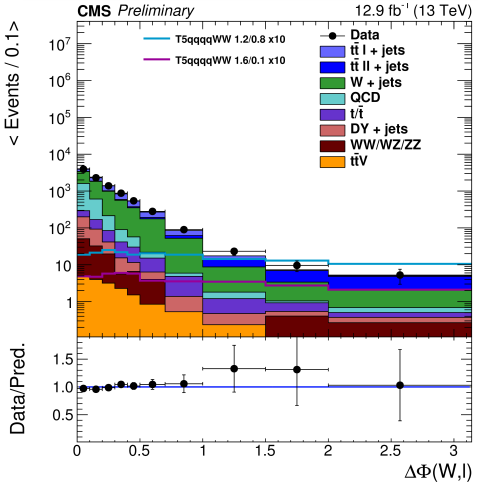
Offline selection

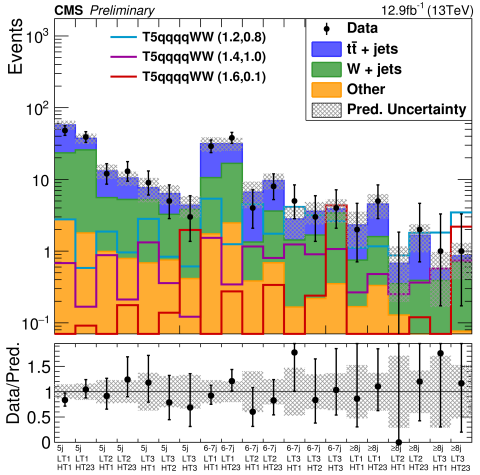
- 1 isolated e/m, pT>25GeV
- for this model: b-jet veto
- SRs binned in
  - #jets (5,6-7,≥8)
  - H_T (starting at 500GeV)
  - MET+pT(l) (starting at 250GeV)
  - high Δϕ(l,l+MET)

Total of 20 SRs

Challenges

- W+jets/tt fractions from #b's
- high/low Δϕ measured at low #jets and applied at high #jets (individually for W+jets and tt)

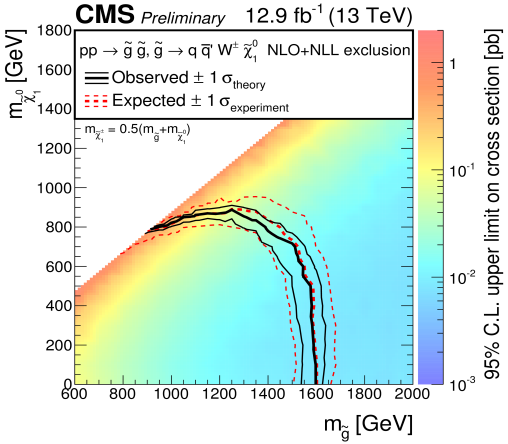


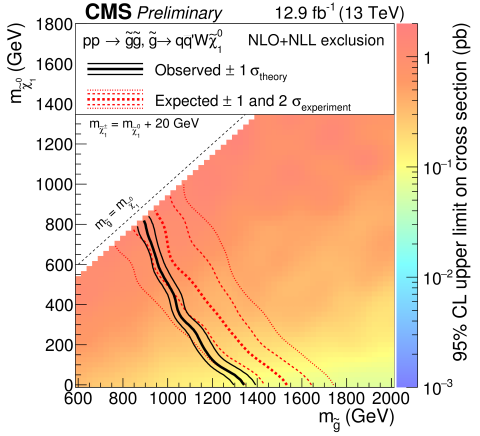


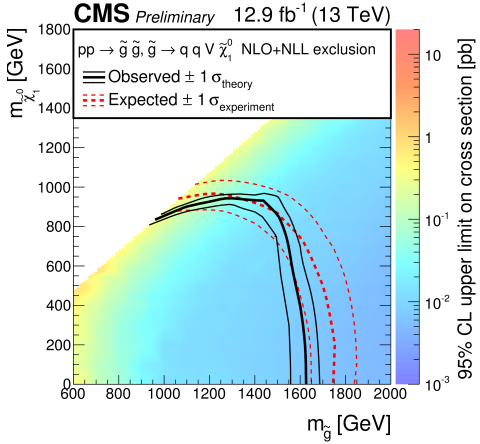
Gluino decay chains via EWK gauginos

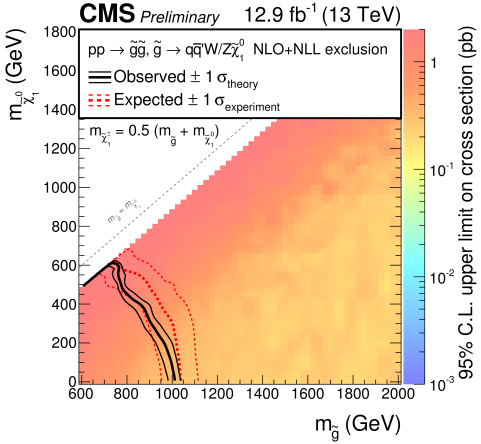
(Other) results:

- 100% BF to qqW+LSP:
  - single lepton (SUS-16-019)
  - same-sign dilepton (SUS-16-020)
- mixed qq(W/Z)+LSP:
  - hadronic (SUS-16-014)
  - multilepton (SUS-16-022)



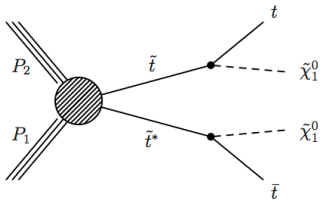






SQUARK PAIR PRODUCTION

Top squarks: hadronic

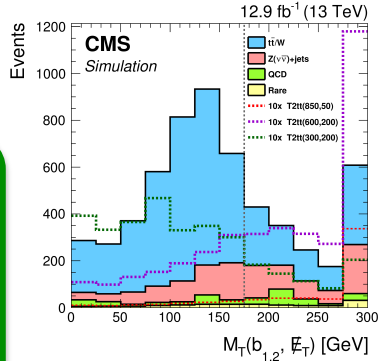


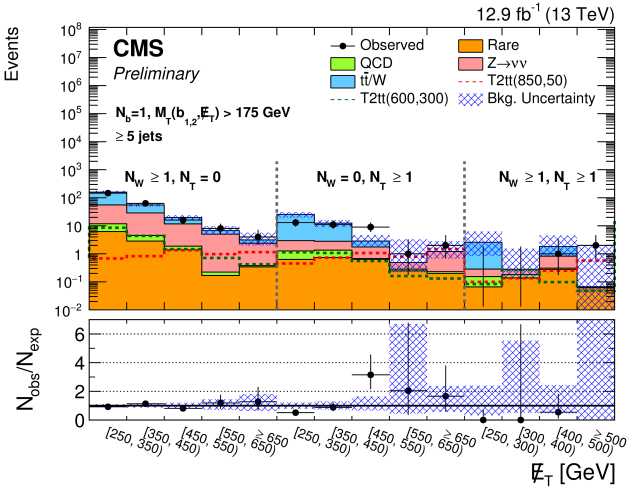
Example for a hadronic search: SUS-16-029

Online selection
- MET and MH_T

Offline selection (high Δm)
- isolated lepton & track vetos
- anti-QCD ($\Delta\phi$ MET/jet)
- top and W-tagging (R=0.8 jets)
  - soft-drop mass, subjettiness
- SRs binned in
  - min(m_T(MET,b))<>175GeV
  - #jets (starting from 5)
  - #tops / #Ws (0, ≥1)
  - #b's (1,>1)
  - MET (starting at 250GeV)

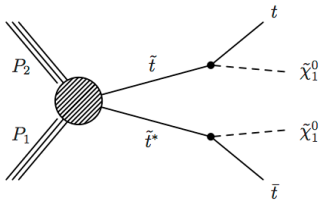
Total of 60 SRs





Category	$M_T(b_{1,2}, E_T^{miss}) < 175$ GeV				$M_T(b_{1,2}, E_T^{miss}) \geq 175$ GeV									
N_t / N_W	–				$N_t = 0, N_W = 0$				$N_t \geq 1, N_W = 0$		$N_t = 0, N_W \geq 1$		$N_t \geq 1, N_W \geq 1$	
N_j	5–6		≥ 7		5–6		≥ 7		≥ 5		≥ 5		≥ 5	
N_b	1	≥ 2	1	≥ 2	1	≥ 2	1	≥ 2	1	≥ 2	1	≥ 2	1	≥ 2
E_T^{miss} [GeV]	250–300 300–400 400–500 ≥ 500	250–300 300–400 400–500 ≥ 500	250–300 300–400 400–500 ≥ 500	250–300 300–400 400–500 ≥ 500	250–350 350–450 450–550 ≥ 550	250–350 350–450 450–550 ≥ 550	250–350 350–450 450–550 ≥ 550	250–350 350–450 450–550 ≥ 550	250–350 350–450 450–550 550–650 ≥ 650	250–350 350–450 450–550 550–650 ≥ 650	250–350 350–450 450–550 550–650 ≥ 650	250–350 350–450 450–550 550–650 ≥ 650	250–350 350–450 450–550 ≥ 500	250–300 300–400 400–500 ≥ 500

Top squarks: single lepton



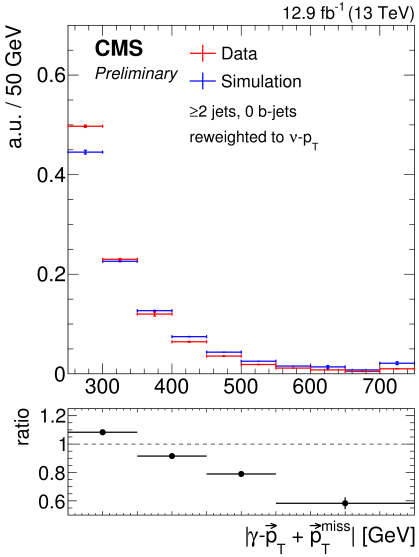
Single lepton search: SUS-16-028

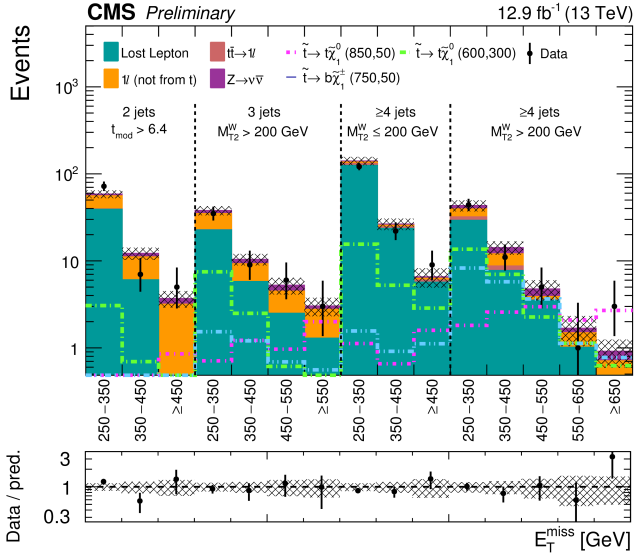
Online selection
- MET, MH_T, and single e/μ

Offline selection (high Δm)
- one e or μ
- MET > 250GeV
- #jets>=2, #b's>=1
- m_T(lepton,MET)>150GeV
- SRs binned in
  - #jets, M_{T2}^W, modified topness, and MET

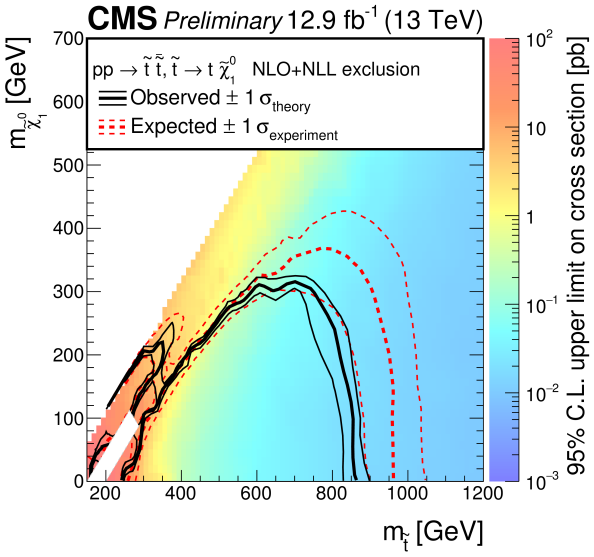
  Total of 15 SRs

Challenges
- dilepton ttbar and W+jets from CRs
- estimate of W+bb, and MET resolution for subleading backgrounds

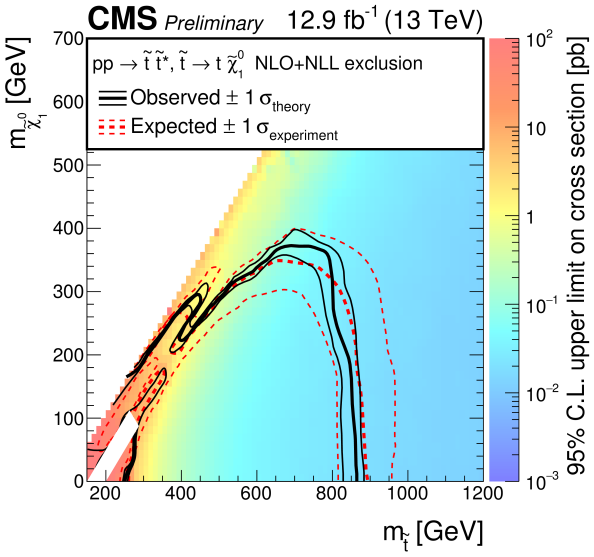




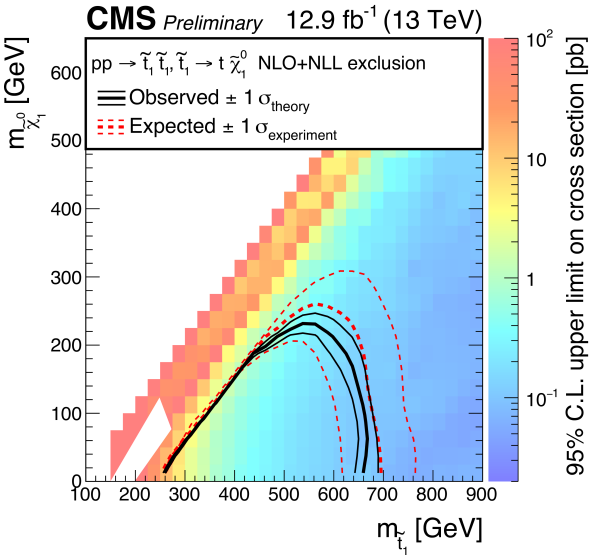
Top squarks: high Δm summary



Hadronic
(SUS-16-029)

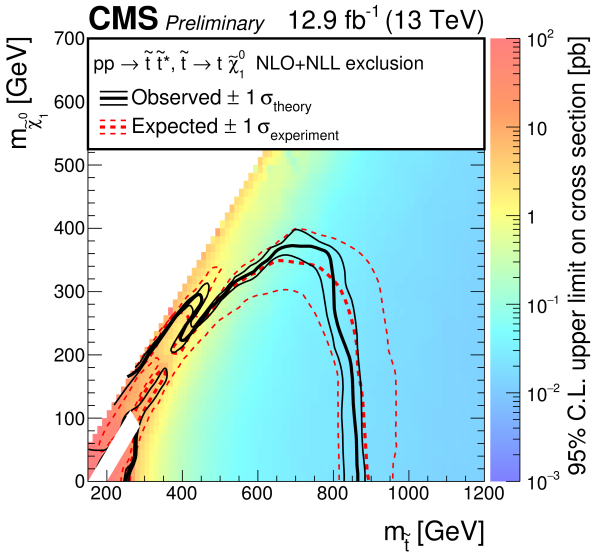


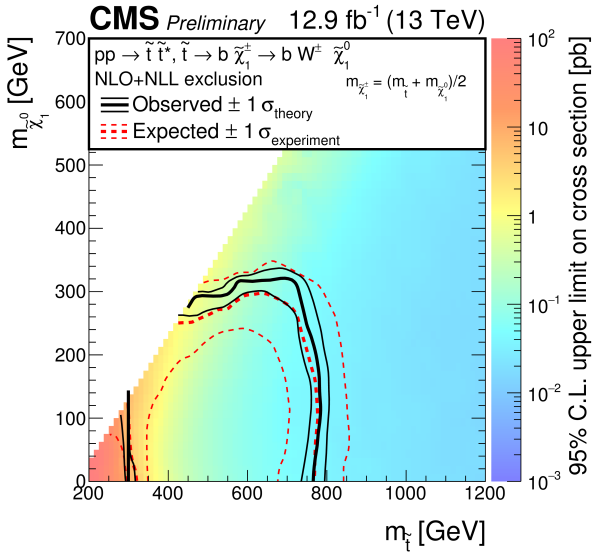
Single lepton
(SUS-16-028)

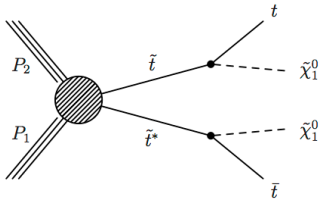


Dilepton
(SUS-16-028)

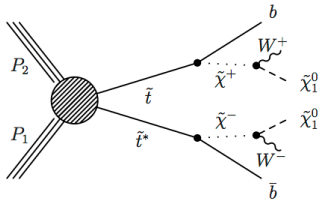
Top squarks: decays via charginos







Single lepton
(SUS-16-028)



Top squarks – the soft side

One of the focus points of SUSY searches

- motivation for light top squarks in natural SUSY
  - even if recently under discussion (see, e.g., Baer et al, arXiv:1207.3343)
- small Δm helps to achieve the right DM relic density via stop-bino coannihilation
  - however, Δm's of 30GeV experimentally challenging

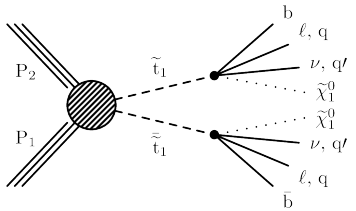
Two decay options

(assuming all other sparticles decoupled)

- Flavour-changing decay to c+LSP
- 4-body decay to bff'+LSP

with details of BFs being model dependent

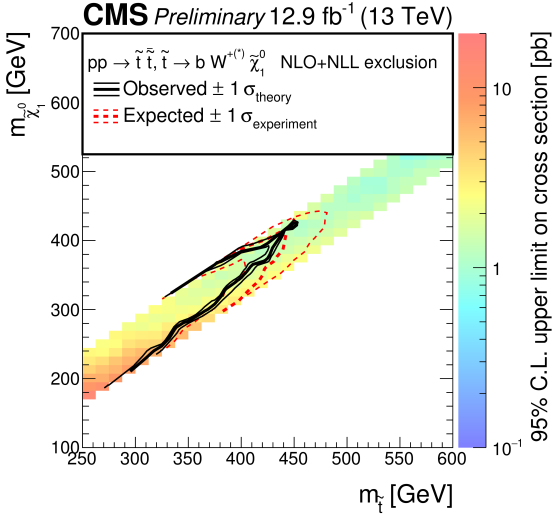
The soft side of top squarks



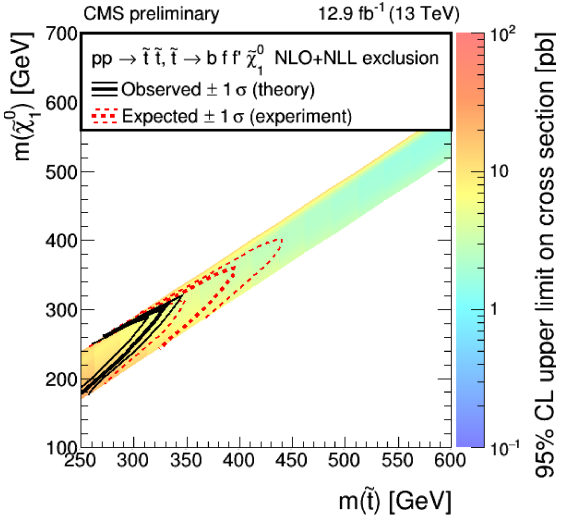
Top squark 4-body decays accessible via ISR

- covered in 0l (SUS-16-029), 1l (SUS-16-031) and 2l (SUS-16-025) final states

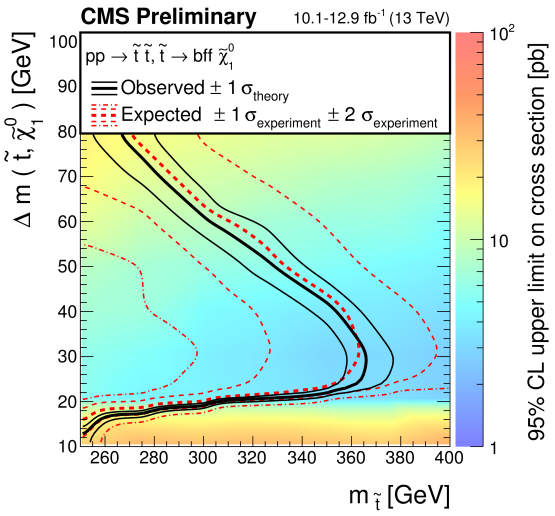
0l: #jets, #b's, pT(ISR),pT(b), MET



1l: #b's, pT(l), mT(l,MET)



2l: MET, pT(l)



assuming prompt decays

INTERMEZZO

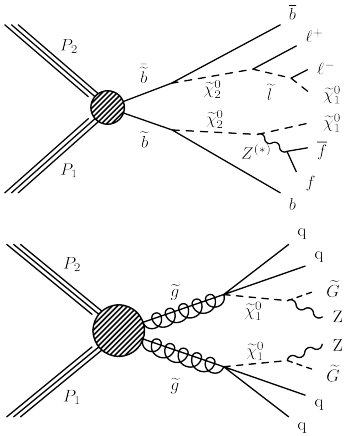
OS dilepton searches

Searches for OS ee/μμ pairs: SUS-16-021

- sensitive to production of Z-bosons in SUSY decay chains ("on-Z") and kinematic edges from leptons emitted in one branch ("edge")
- one of the SUSY searches with the lowest systematics:
  - well-defined Z-dominated CRs
  - low experimental uncertainties for the "flavour-symmetric" (FS) backgrounds

Online selection
- dilepton (e,μ)

Offline (baseline)
- 2 leptons, pT>25(20)GeV



OS dilepton searches

Edge search

SRs (binned in)

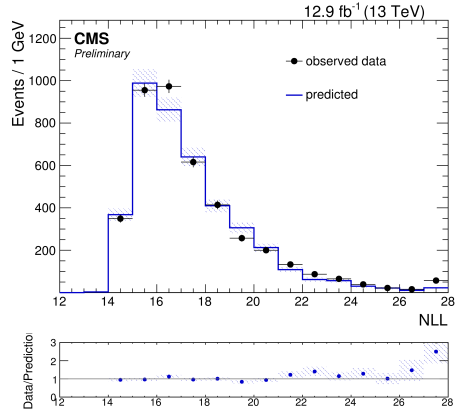
- MET>150GeV
- low & high m(ll) (20-81GeV, >101GeV)
- tt(2l) likelihood
  - using MET,pT(ll),Δϕ(ll), and Σm(lb)

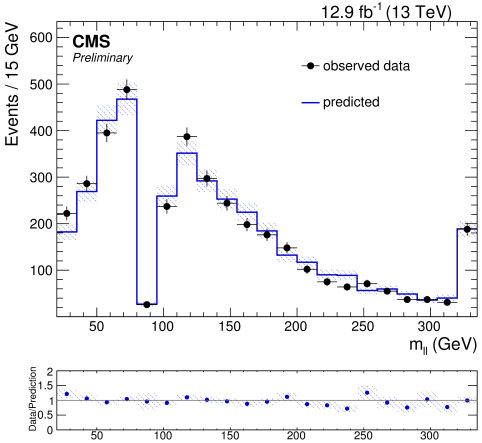
Background estimation

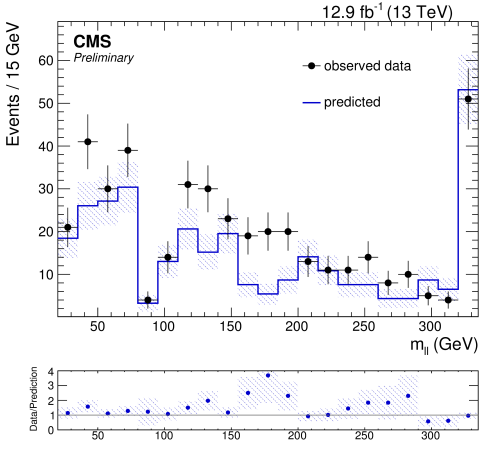
- dominant FS backgrounds estimated with R(SF/OF)
  - directly from lower MET sideband
  - factorized in ε(reco/ID) (from DY) and a correction for ε(trigger)

$$R_{SF/OF} = \frac{1}{2}\left(r_{\mu/e} + r_{\mu/e}^{-1}\right) \cdot R_T$$

+ (for continuity) some previously used SRs







OS dilepton searches

Edge search

SRs (binned in)

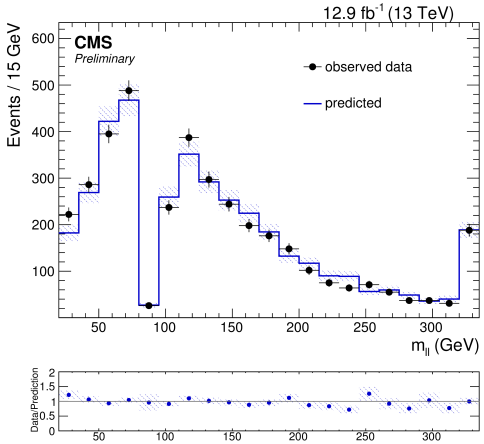
- MET>150GeV
- low & high m(ll) (20-81GeV, >101GeV)
- tt(2l) likelihood
  - using MET,pT(ll),Δϕ(ll), and Σm(lb)

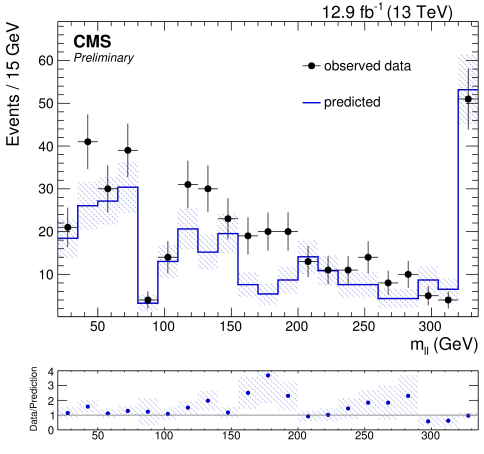
Background estimation

- dominant FS backgrounds estimated with R(SF/OF)
  - directly from lower MET sideband
  - factorized in ε(reco/ID) (from DY) and a correction for ε(trigger)

$$R_{SF/OF} = \frac{1}{2}\left(r_{\mu/e} + r_{\mu/e}^{-1}\right) \cdot R_T$$

	Data	MC
$\frac{1}{2}(r_{\mu/e} + r_{\mu/e}{}^{-1})$	1.032±0.025	1.020±0.020
R_T	1.062±0.069	-
$R_{SF/OF}$		
From factorization method	1.096±0.076	1.083±0.073
From direct measurement	1.090±0.024	1.101±0.003
Weighted average	1.091±0.023	1.101±0.003





+ (for continuity) some previously used SRs

OS dilepton searches

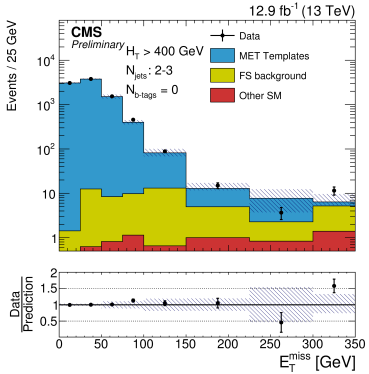
On-Z search

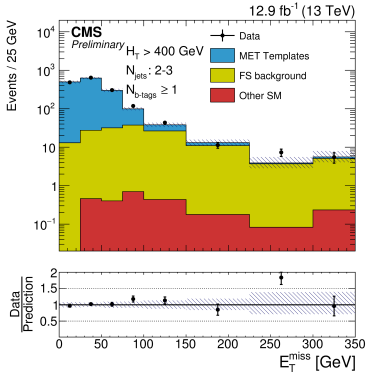
SRs (strong production) binned in

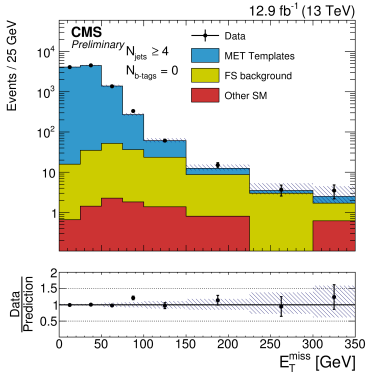
- #jets (2-3,>3), #b's (0,>1)
- MET (starting at 100GeV)

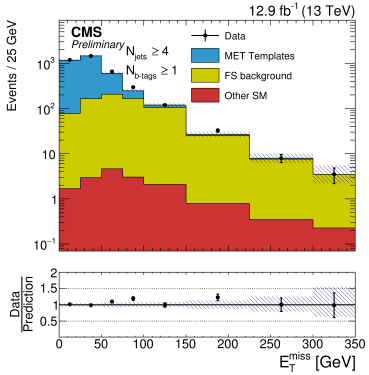
Background estimation

- FS backgrounds as before
- MET tails in DY estimated from γ+jets
  - need to reweight in pT(γ)
  - normalization at low MET
- ZV and Ztt from multilepton CRs
- DY estimate also propagated to edge search









+ (for continuity) some previously used SRs

OS dilepton searches

On-Z search

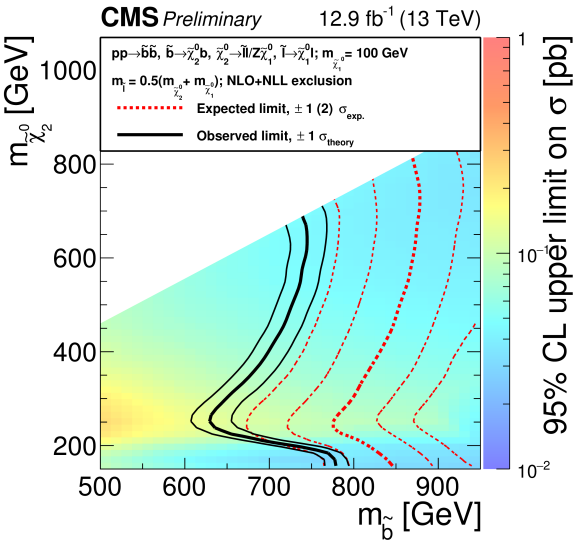
SRs (strong production) binned in
- #jets (2-3,>3), #b's (0,>1)
- MET (starting at 100GeV)

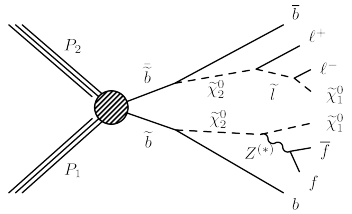
Background estimation
- FS backgrounds as before
- MET tails in DY estimated from γ+jets
  - need to reweight in pT(γ)
  - normalization at low MET
- ZV and Ztt from multilepton CRs
- DY estimate also propagated to edge search

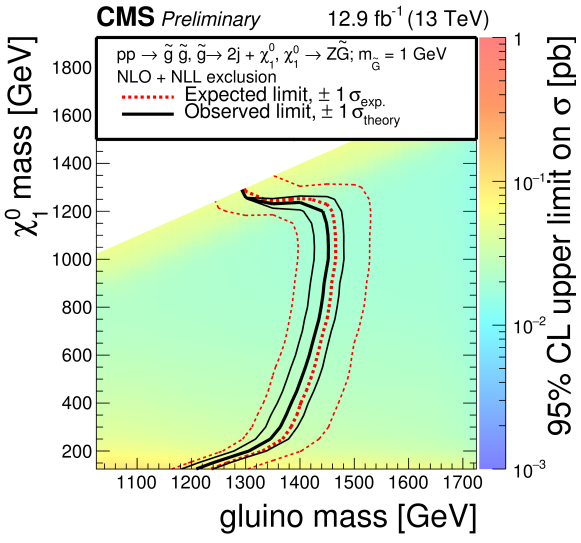
E_T^{miss} (GeV)	0 – 50	50 – 100	100 – 150	150 – 225	225 – 300	≥ 300
SRA, b-veto	2 %	10 %	20 %	20 %	20 %	25 %
SRA, with b-tags	1 %	5 %	20 %	20 %	40 %	40 %
SRB, b-veto	1 %	6 %	10 %	10 %	35 %	35 %
SRB, with b-tags	1 %	10 %	20 %	25 %	30 %	30 %
EWK Signal Region	25 %	2 %	10 %	10 %	10 %	15 %
ATLAS Signal Region	2 %	10 %	25 %	35 %	40 %	
edge Signal Region	1 %	5 %	5 %		7 %	

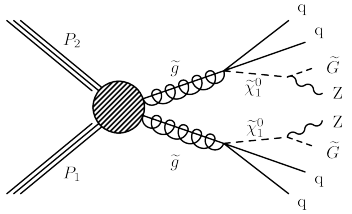
+ (for continuity) some previously used SRs

OS dilepton searches







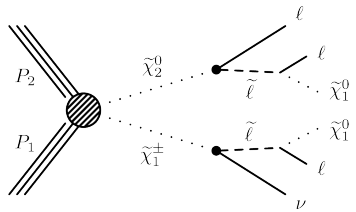


ELECTROWEAK PRODUCTION MODES

Chargino / neutralino production

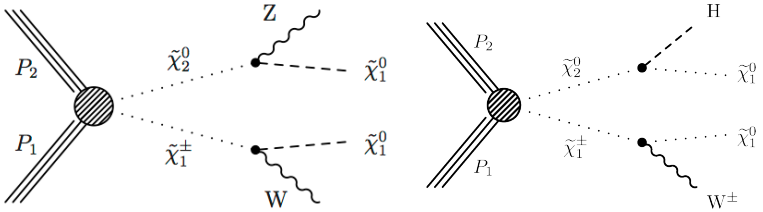
Decays via sleptons

- little hadronic activity – main players are multilepton final states
- several scenarios motivated by different assumptions on the gaugino mixing and the nature of the sleptons
  - all 3 flavours contribute equally: less (charged) multilepton final states reduced
  - $\tilde{\chi}_2^0$ decays as above; $\tilde{\chi}_1^\pm$ to τ only
  - both $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^\pm$ decay exclusively to τ's



Decays via W / Z / h

- if W / Z on-shell: final states with high lepton multiplicity at medium – high pTs
- for decays via h:
  - multilepton modes from h→WW*,ZZ* offer high discrimination but suffer from low BFs



Chargino / neutralino production

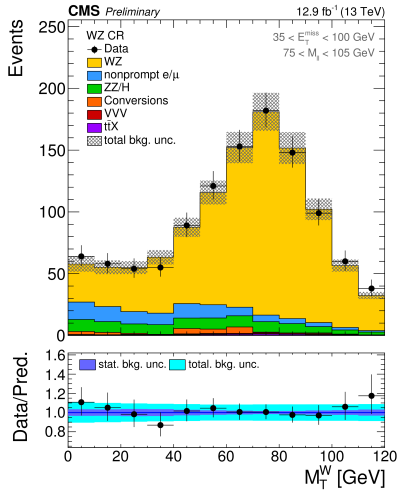
Multilepton search: SUS-16-024

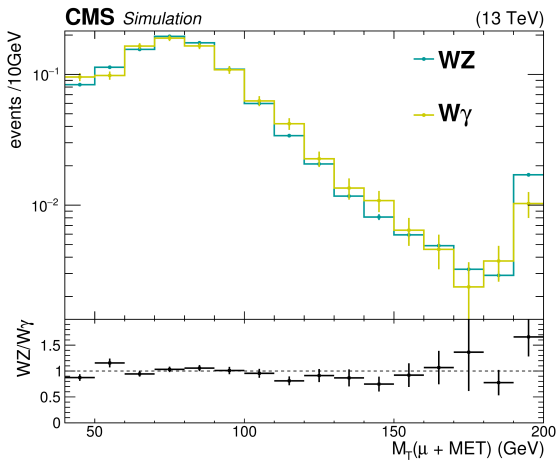
Online selection
- single (e,μ) or dilepton (e,μ,τ)

Offline selection
- isolated e/m/τ's
- same-sign 2l category adds sensitivity to compressed region

Total of 118 SRs

e/μ	OS/SS	τh	OSSF pairs	Variables
2 (SS)	SS			#jets, mT,pT(ll),MET
3	-	-	0 / 1	mT,mll,MET
2	-	1	1	mT2,mll,MET
eμ	OS / SS	1	-	
1		2	-	
≥4		0	<2 / ≥2	MET
≥4		≥1		



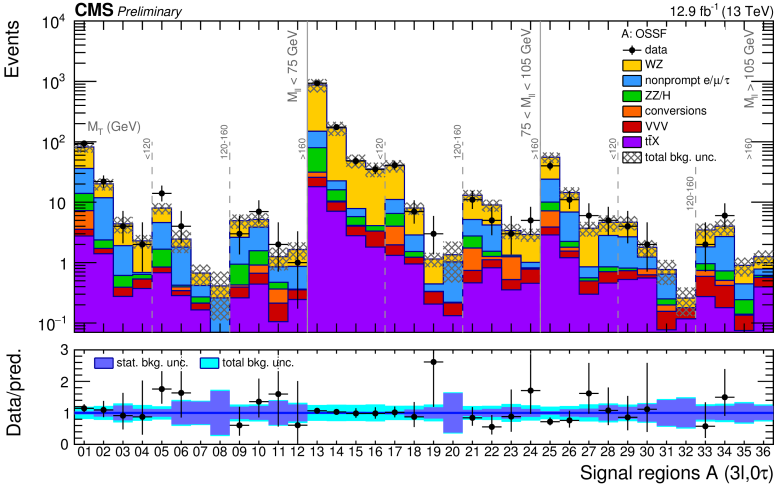


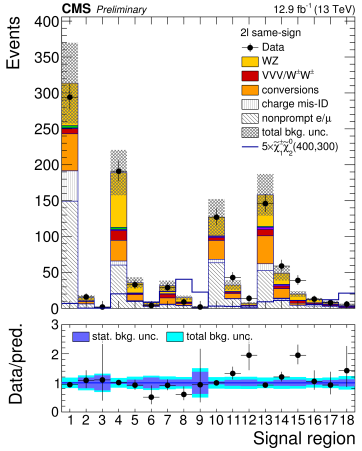
Example for WZ:
- normalisation in CR
- shape comparison in CR and with Wγ

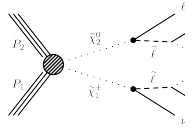
Challenges
- many bkg sources
  - non-prompt leptons
  - FSR (W/Z)
  - charge misid
  - WZ

Chargino / neutralino production

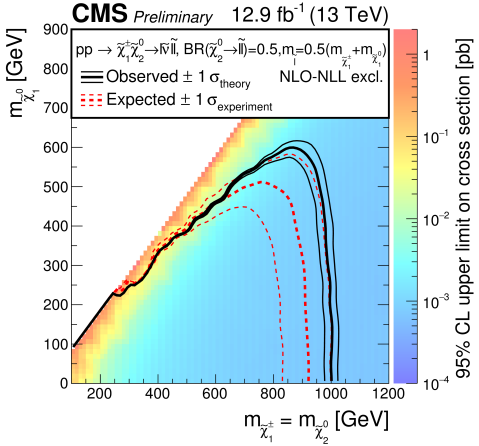
Results and interpretation
for different mass hierarchies

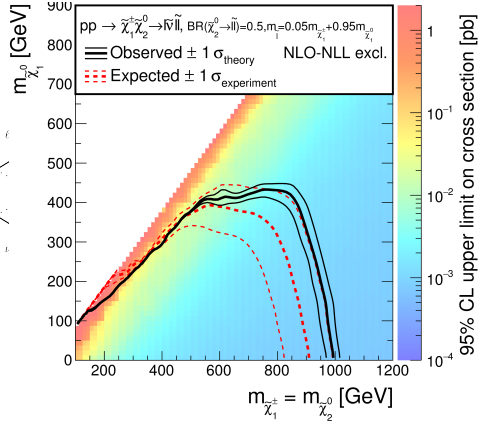




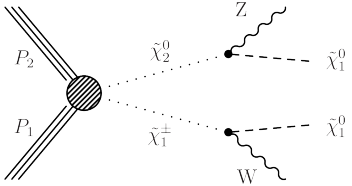


including
same-sign 2l





Chargino / neutralino production



Strong motivation for low-mass higgsinos in natural SUSY

- $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_1^0$ almost degenerate, $\tilde{\chi}_1^0$ only slightly lighter: use soft leptons to go beyond "monojet" ISR search

Challenges

- trigger and soft lepton reco / ID
- backgrounds from CRs: DY (mainly ττ), dileptonic ttbar

Soft OS 2l search: SUS-16-025

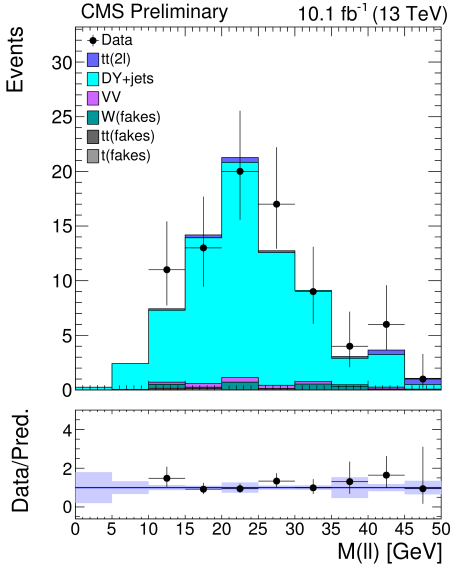
Online selection

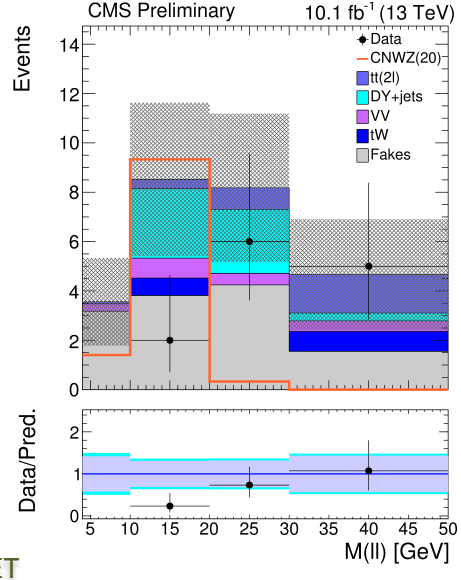
- MET or
- specific MET + 2 soft μ trigger (lower MET threshold @ 50GeV)

Offline selection

- 2 soft (pT 5-30GeV) OSSF e/μ (low-mass resonance veto)
- anti-QCD and Z→ττ cuts
- ≥1 jet (no b's), HT>100GeV
- MET>125GeV, mT<70GeV
- SRs binned in MET and m(ll)

Total of 8 (EWK) SRs





low MET

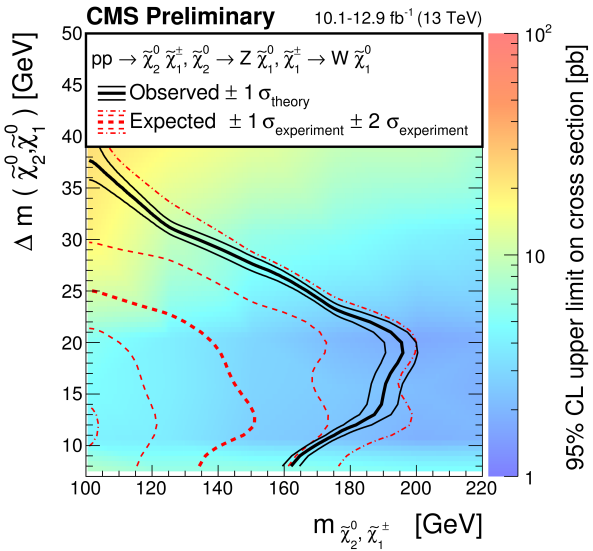
Chargino / neutralino production

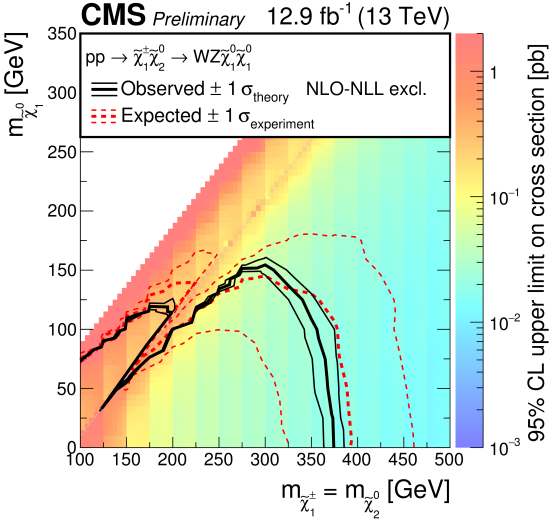
Results of the soft 2l search

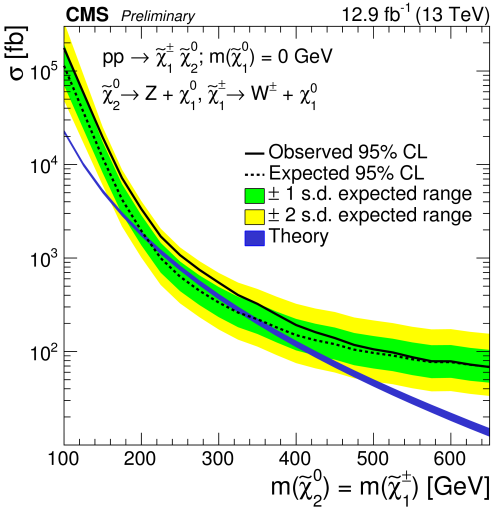
- limits calculated with wino-like cross sections, but higgsino-like cross sections in reach

Other results for the same model

- multileptons (SUS-16-024)
- “classical” 2l on-Z search (SUS-16-021)







R-PARITY VIOLATION

RPV in gluino decays

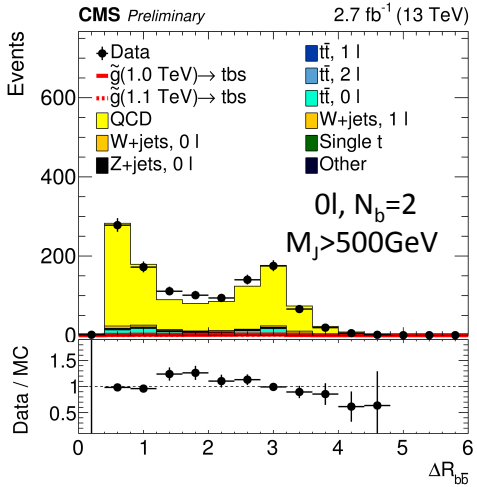
Gluino decays to tbs in MFV: SUS-16-013

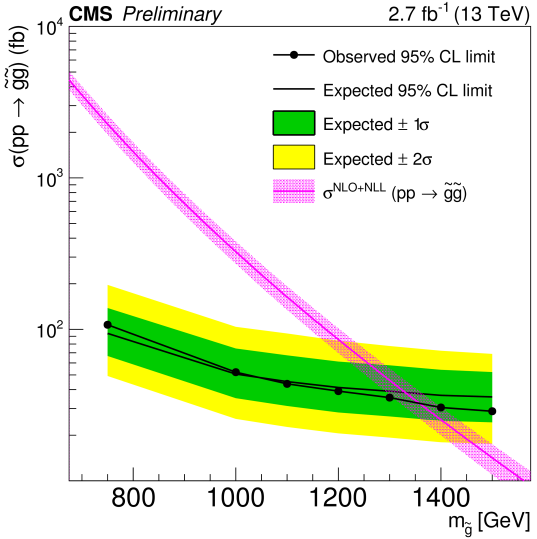
Online selection
- HT>800GeV

Offline selection
- 0 or 1 isolated e/μ
- at least 1 b
- SRs binned in
  - #leptons, #b's (1,…,≥4)
  - MJ (sum of large-R jets)
  - #jets (starting at 8)

  Total of 6 SRs

Background estimation
- CRs at low #jets
- fit to b multiplicity in bins of #jets and MJ
- special care for g→bb

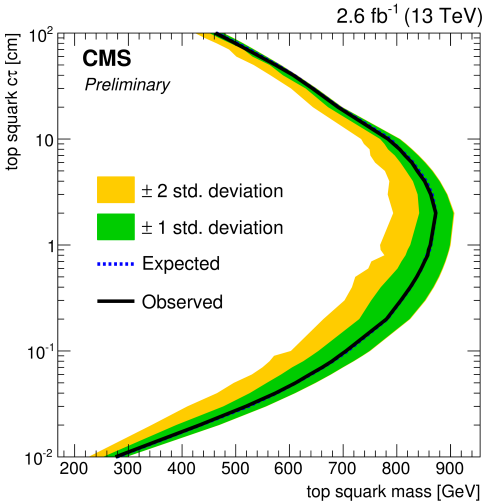


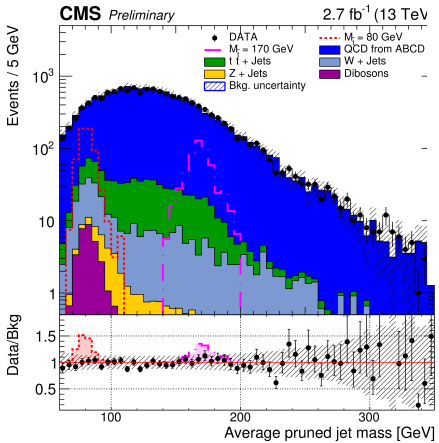


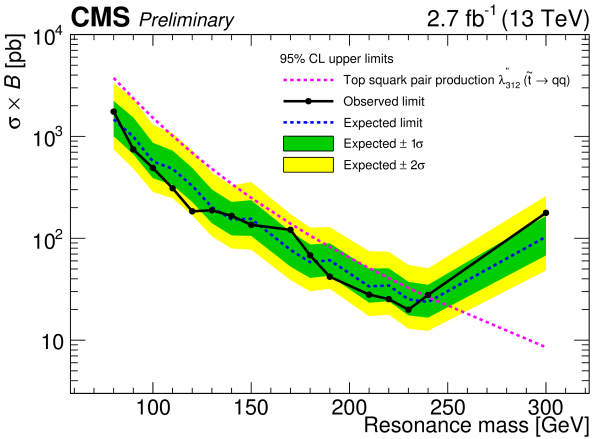
Some other RPV results

Displaced top squark decays to bl: EXO-16-022

- via LFV couplings
  (Graham et al. arXiv:1204.6038)
- eμ channel
- CRs at low IP(s), 3 SRs at high IPs







Top squark decays to qq: EXO-16-029

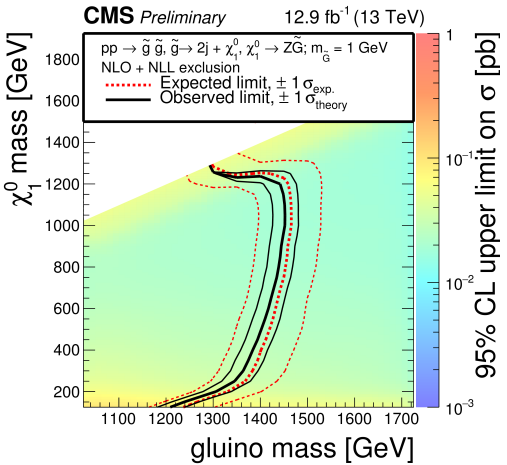
- decays via λ''_{312}
- using R=0.8 jets & grooming techniques (incl. @ trigger level)and N-subjetiness τ_{12}
- selection on mass asymmetry and $\Delta\eta$ (j_1,j_2)

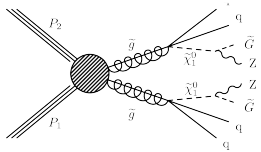
Other Models

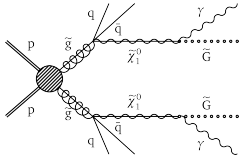
GMSB

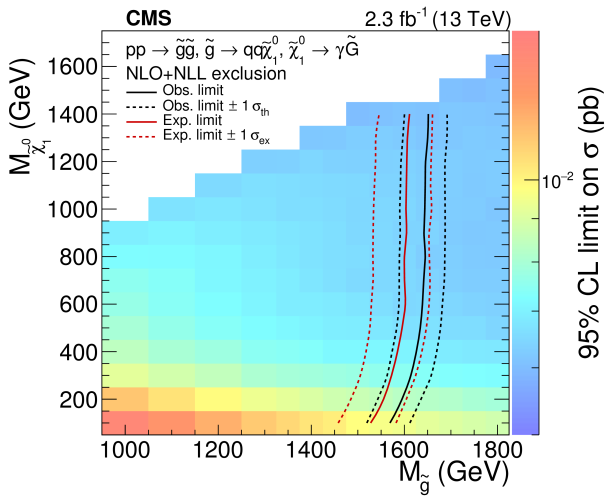
Some results for neutralino decays to γ/Z + G~

OS dilepton search: SUS-16-021

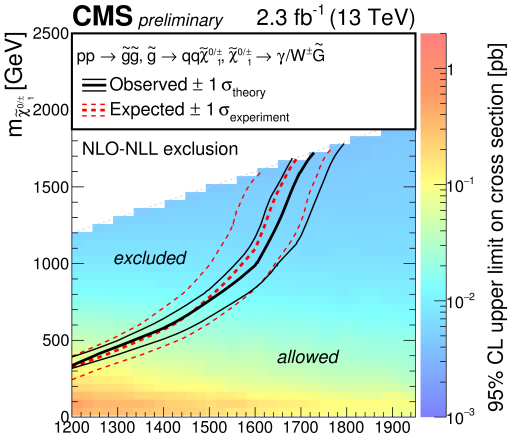


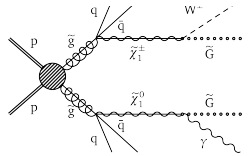






γ + MET search: SUS-16-023



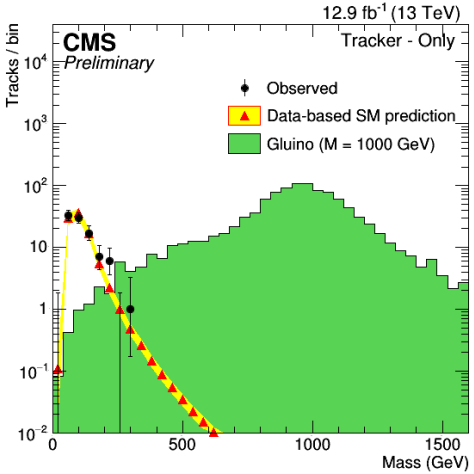


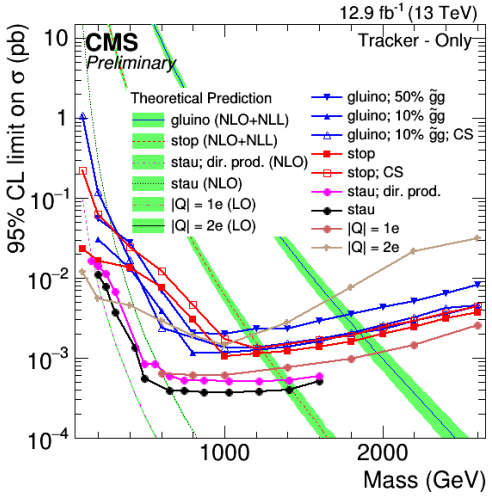
2 γ + MET search: SUS-15-012

Split SUSY

Heavy stable charged particle search motivated by split SUSY: EXO-16-036

- long-lived g~ hadronizes
  - open parameters are the fraction of produced R-glueballs and the interaction model
- analysis based on dE/dx in the Si tracker
  - online selection with muon or MET triggers



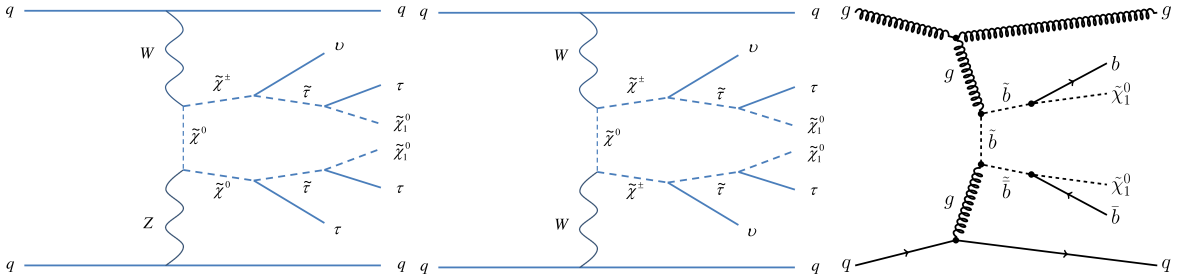


VBF SEARCHES

VBF searches for SUSY

Vector-boson fusion offers an alternative to ISR-based searches for (nearly-) invisible SUSY production

- example scenarios:

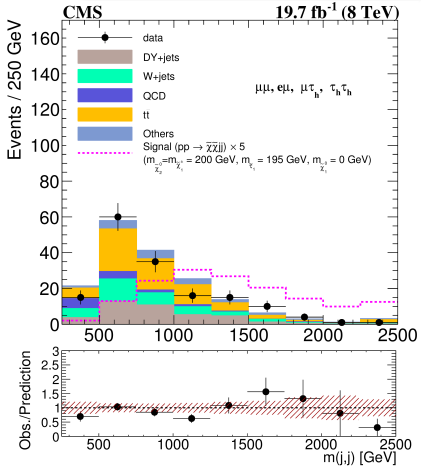


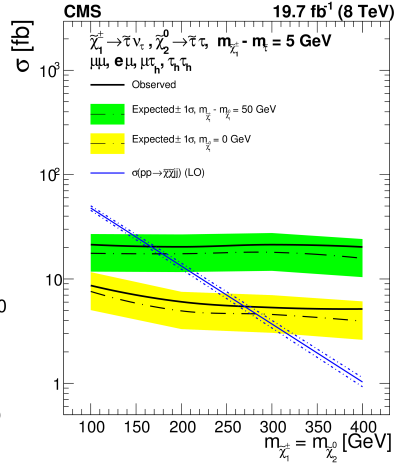
- Events can be tagged using the 2 VBF jets at large rapidity gap / large dijet mass
- Background estimation from data using separate CR for the SUSY-decay-products+jj, and for the m(jj) shape

VBF searches for SUSY

Electroweak production
(SUS-14-005, JHEP 11 (2015) 189)

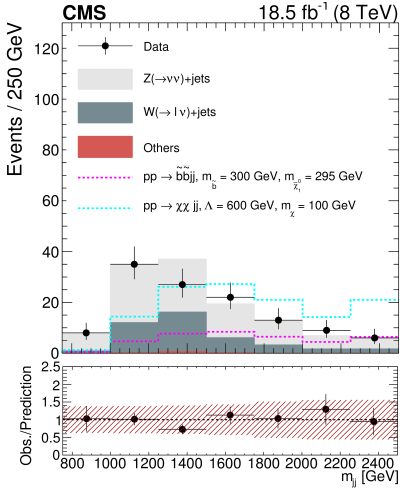
Selection
- (eμ/μμ/μτh/τhτh) + 2 jets
- MET (75 / 30GeV), b-jet veto
- 2 jets with $\Delta\eta$>4.2
- m(jj)>250GeV (shape)

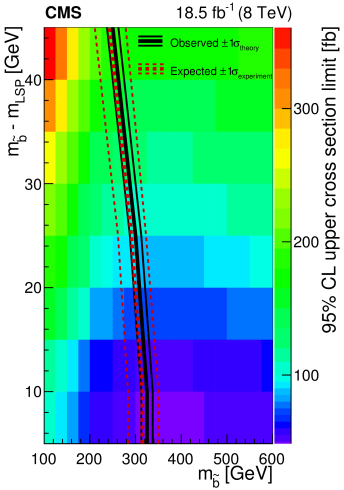




Sbottom production
(SUS-14-019, acc. by PRL)

Selection
- 2 jets with $\Delta\eta$>4.2
- m(jj)>750GeV (shape)
- lepton and additional jet veto





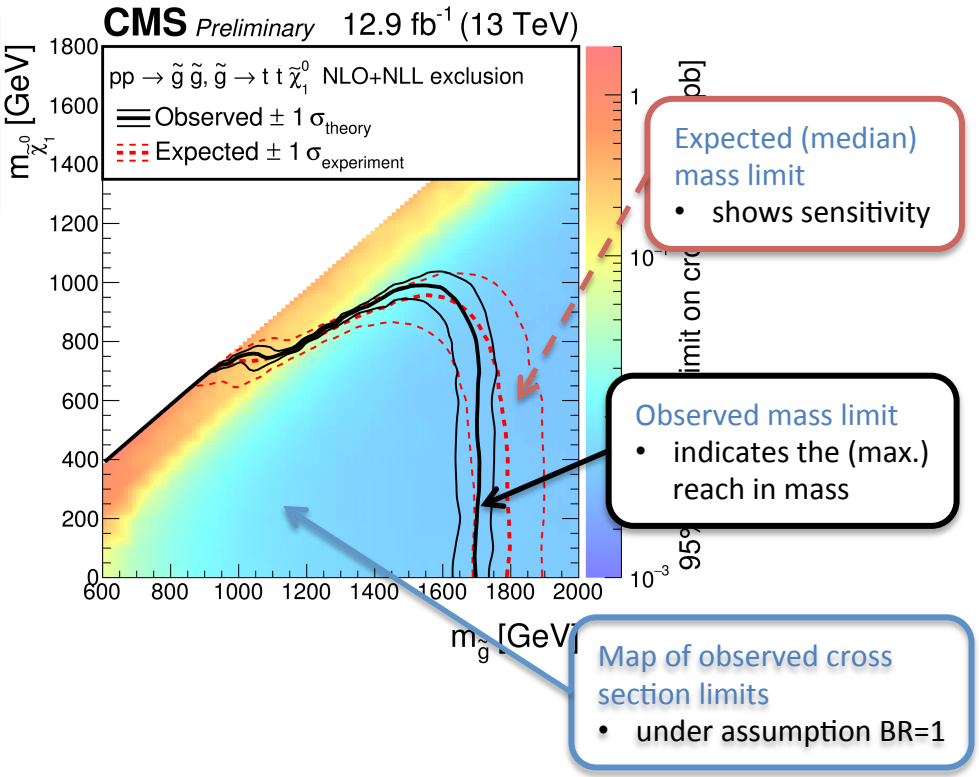
INTERPRETATION

Simplified model spectra

THE interpretation tool for SUSY searches @ LHC

Pros
- closely related to exp. observables
- limited number of parameters
  - results as 2D scans
- "easy" reinterpretation (cross-section limit)

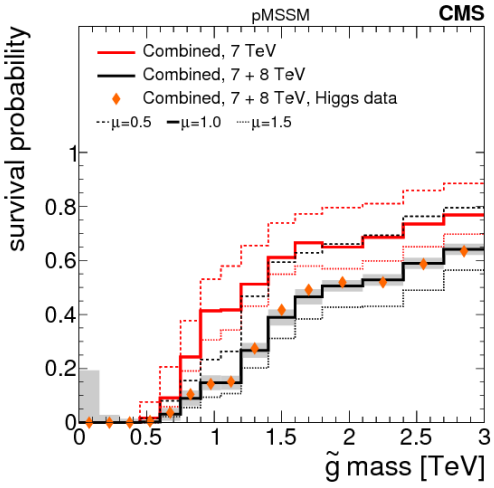
Cons
- no self-consistent model
  - higher-order corrections?
  - decay widths?
- application to other (full) models
  - ignores details of production, spin structure, …
- implementation of long decay chains or mixed decays quickly increases the number of required SMS's

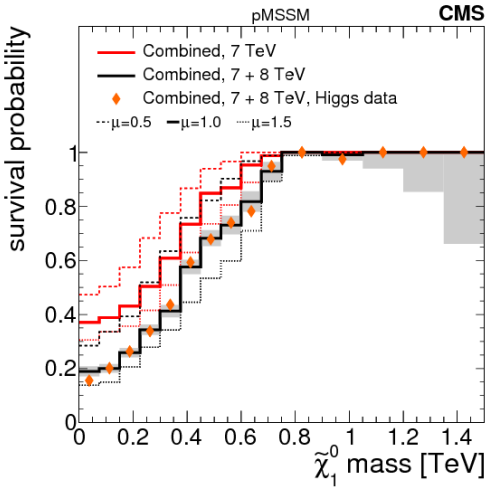


Link with full models: pMSSM

Phenomenological MSSM

- catches essential MSSM features in 19-dim subspace
  - (no CPV couplings, R-parity conserving, degeneracy of 1st&2nd generation, MFV)
- goal: understand impact on model parametes, limitations of SMS approach & "holes" in experimental MSSM coverage using scans of pMSSM parameter space



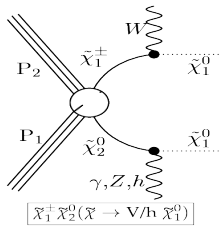


Impact of CMS searches

- Bayesian analysis including 11 CMS analyses @ 7 and 8 TeV

arXiv:1606.03577

dominant EW production → lower prob. to be excluded
unexcluded points typically at low visible and missing energy



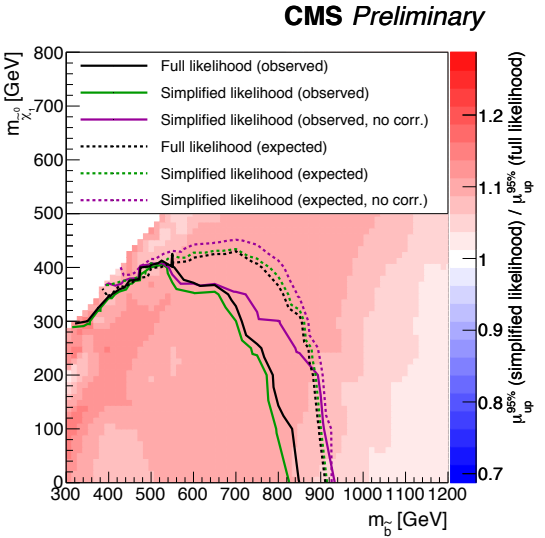
Reinterpretations

Limitations of exp. papers

- quoted models typically meant for motivation and demonstration
  - experimental result typically more generally valid
- we cannot cover all current or future use cases → need possibility for reinterpretations
- one typical obstacle:
  - use of a large number of SRs in order to make best use of the data

No miraculous one-size-fits-all solution, but

- increased extra information on public pages & HepData
- alternative, larger (ex- or inclusive) signal regions
- covariance matrix of for background estimates
  - allows to build simplified likelihood as described in CMS-NOTE-2017/001



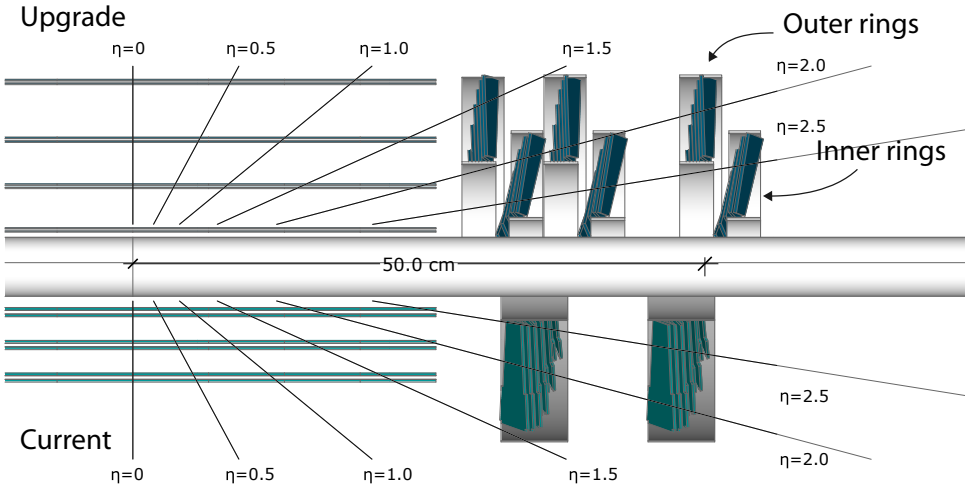
example of the application of a simplified LH to an inclusive, hadronic search (SUS-16-016)

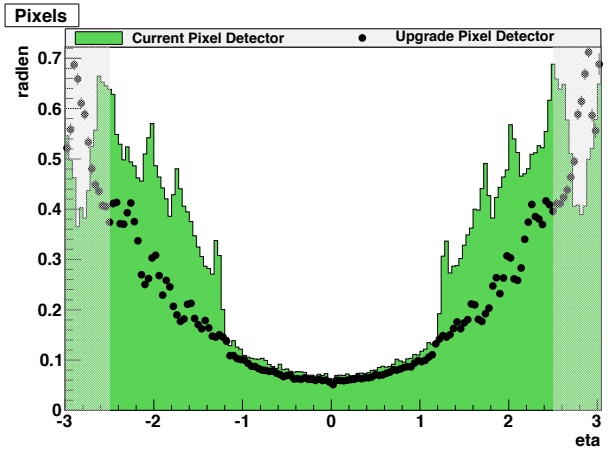
FUTURE

Run 2 and beyond

Medium term

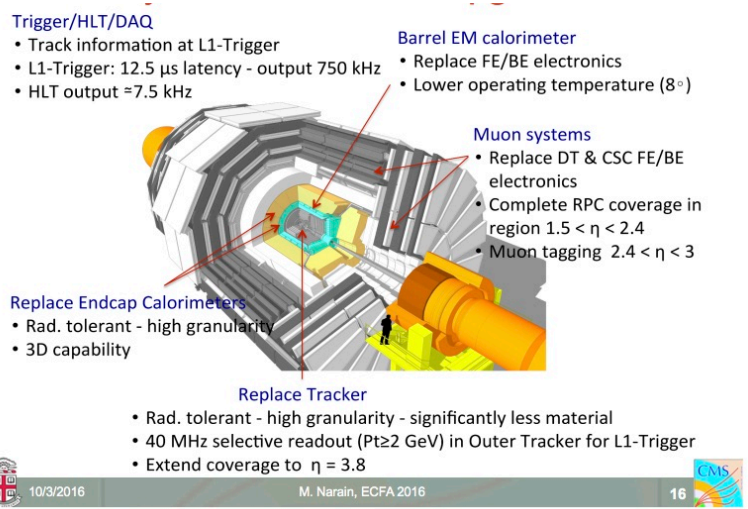
- new pixel detector in EYETS16/17!
  - move to 4 barrel and 3 endcap layers
  - expect improvements on SUSY searches, e.g., on b-tagging and photon ID





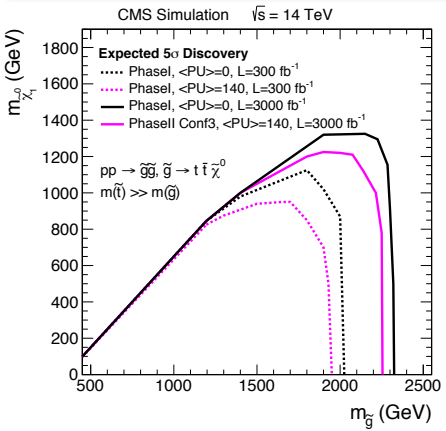
Run 2 and beyond: prospects for HL-LHC

Upgrades

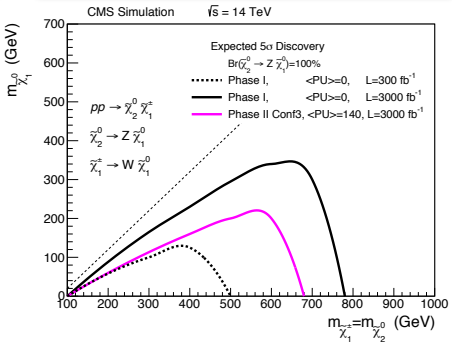


M.Narain's talk, ECFA HL-LHC WS, Oct 16

gluino production, single lepton

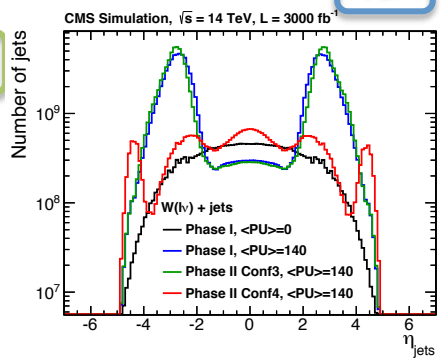


EWK production, multilepton



CMS-FTR-13-014

VBF



Other studies on full models show complementarity of analyses in distinguishing different scenarios: SUS-12-014

- expect further studies in the context of the phase 2 TDRs

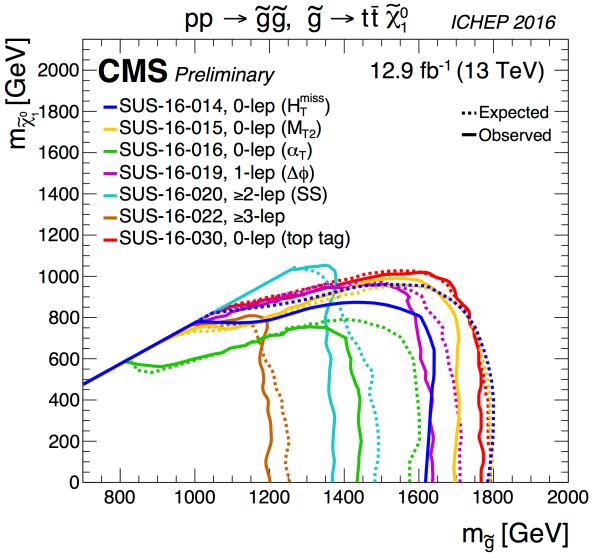
Summary

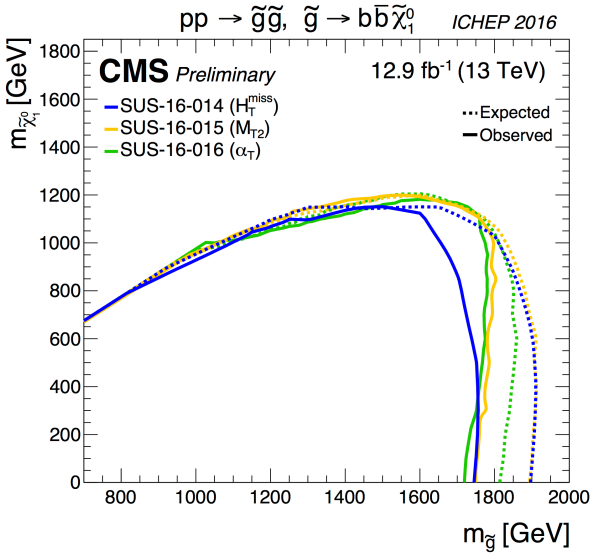
- Excellent LHC performance allowed for considerable increase in sensitivity with (partial) 2016 data set
  - CMS performed a large set of analyses almost synchronously with data taking
  - So far no signs of an excess – now preparing results with the full data set
- Next step: extend to more challenging scenarios
  - Only had a first look at electroweak production, compressed mass spectra, …
  - Slower relative increase in integrated luminosity will provide time to refine strategies and to prepare new approaches
- Mass limits (in simplified model spectra!)
  - pushed to about 1.9 TeV (gluinos) and 900 GeV (top squarks); limits on EW production even for small mass differences

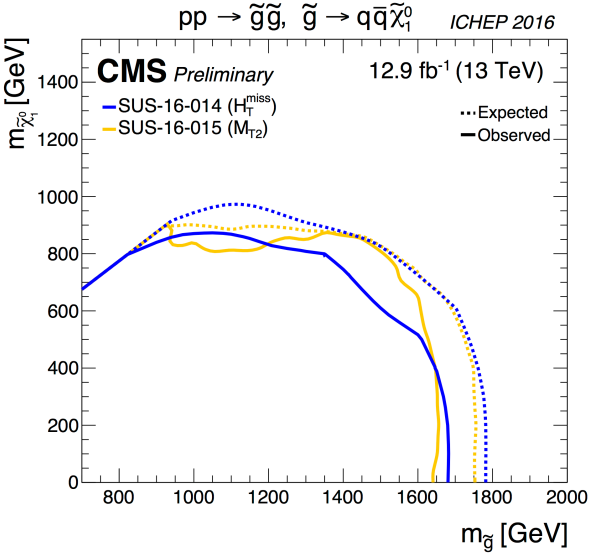
A large data set is at our hand, and we can expect a 3-fold increase during the rest of Run2, with an improved detector. We are eager to see the first significant deviations from SM predictions!

ADDITIONAL MATERIAL

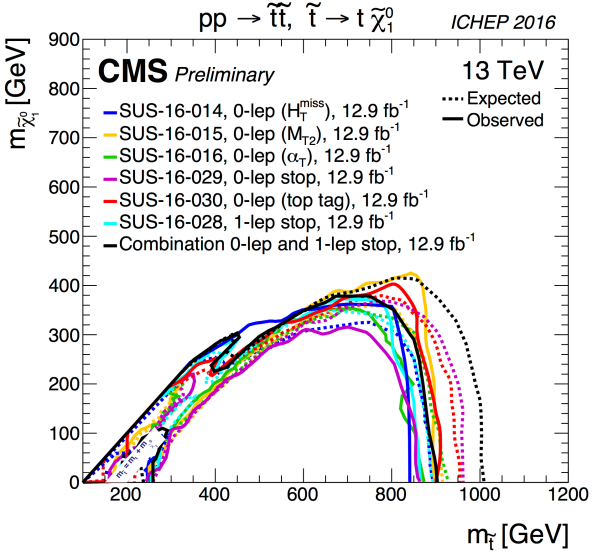
Summary gluino production

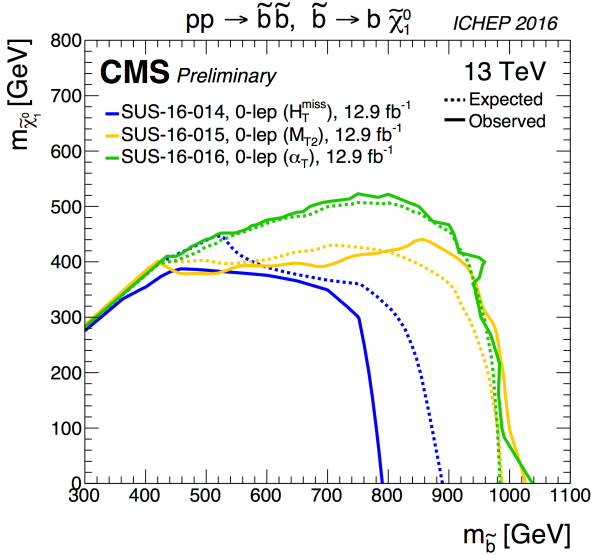


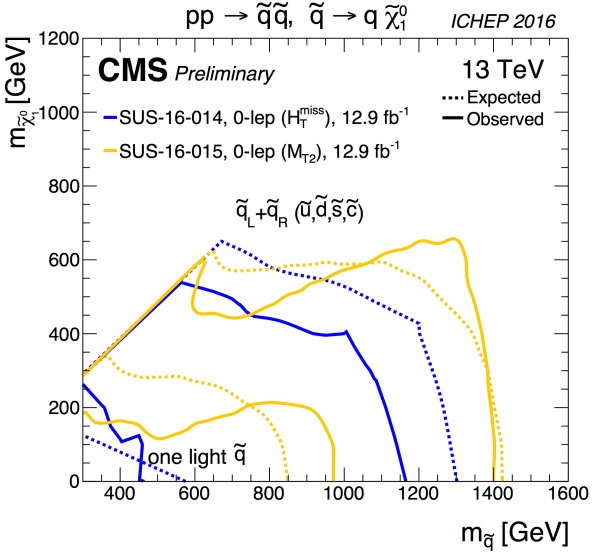




Summary squark production







Summary EWK production