Ricerca di segnature con top, bottom, tau ed esotiche

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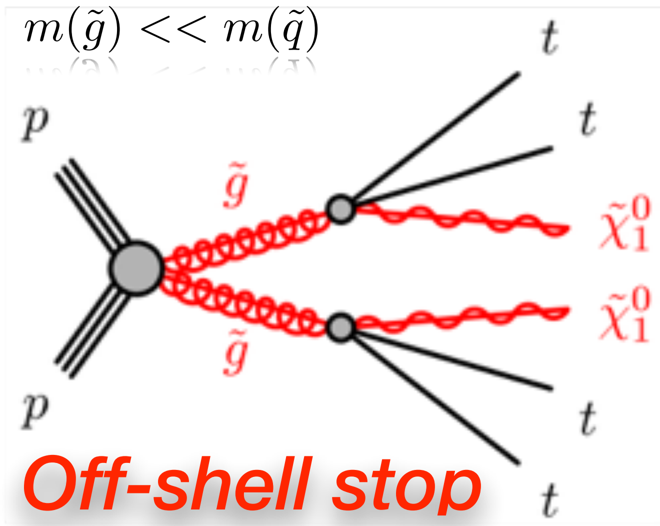
Outline

Focusing on RunII

- Supersymmetry (SUSY):
  - ☑ gluino production via off-shell stop or sbottom
  - ☑ gluino production via on-shell top
  - ☑ direct stop or sbottom production
- Vector like-quarks (VLQ):
  - ☑ T pair production or single T production
  - ☑ $X_{5/3}$ pair production
- Resonances:
  - ☑ $t\bar{t}, tb, \tau\nu_\tau$
- Searches for Long-Lived Particles (LLP):
  - ☑ stable and metastable heavy charged particles
  - ☑ disappearing tracks
  - ☑ displaced vertex
  - ☑ lepton-jets

Supersymmetry



CMS, different analysis strategies based on

✓ different finale states: 0, 1, ≥2 or ≥3 leptons

✓ different variables for SR definition: $H_T^{miss}, M_{T2}, Razor, \alpha_T, \ldots$

Best sensitivity with 0 leptons final state and H_T^{miss} base Signal region (SR) definition

ATLAS, focusing on two final states: 2Same Sign (SS) or ≥ 3 leptons, multi-jets

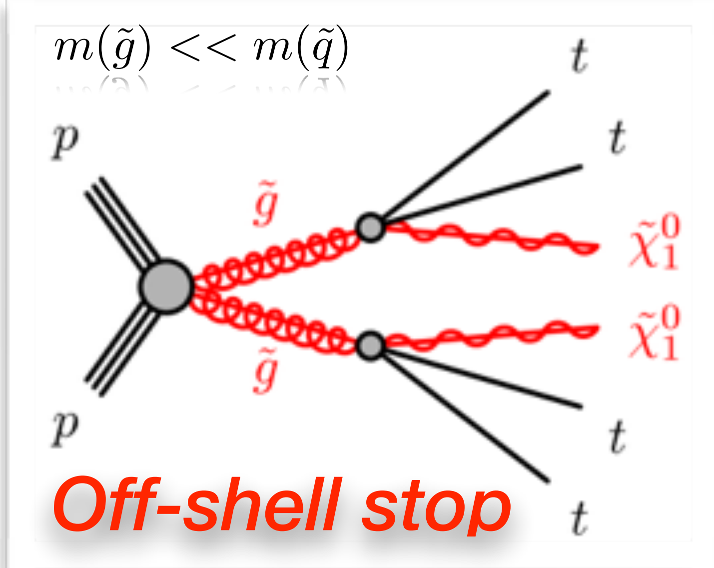
	ATLAS		CMS
Reference	arXiv:1602.09058	ATLAS-CONF-2015-067	arXiv:1602.0658
$N_{leptons}$	2 SS or ≥ 3	0 (1)	0
N_{jets}	-	≥ 8 (≥ 6)	≥ 4
$N_{b\text{-}jets}$	≥ 3	≥ 3	≥ 0
$Vars_{SR}$	E_T^{miss}, m_{eff}	$E_T^{miss}, m_{eff}, N_{b-jets}, N_{t-jets}$	$H_T, H_T^{miss}, N_{jets}, N_{b-jets}$
N_{SR}	1	5	72

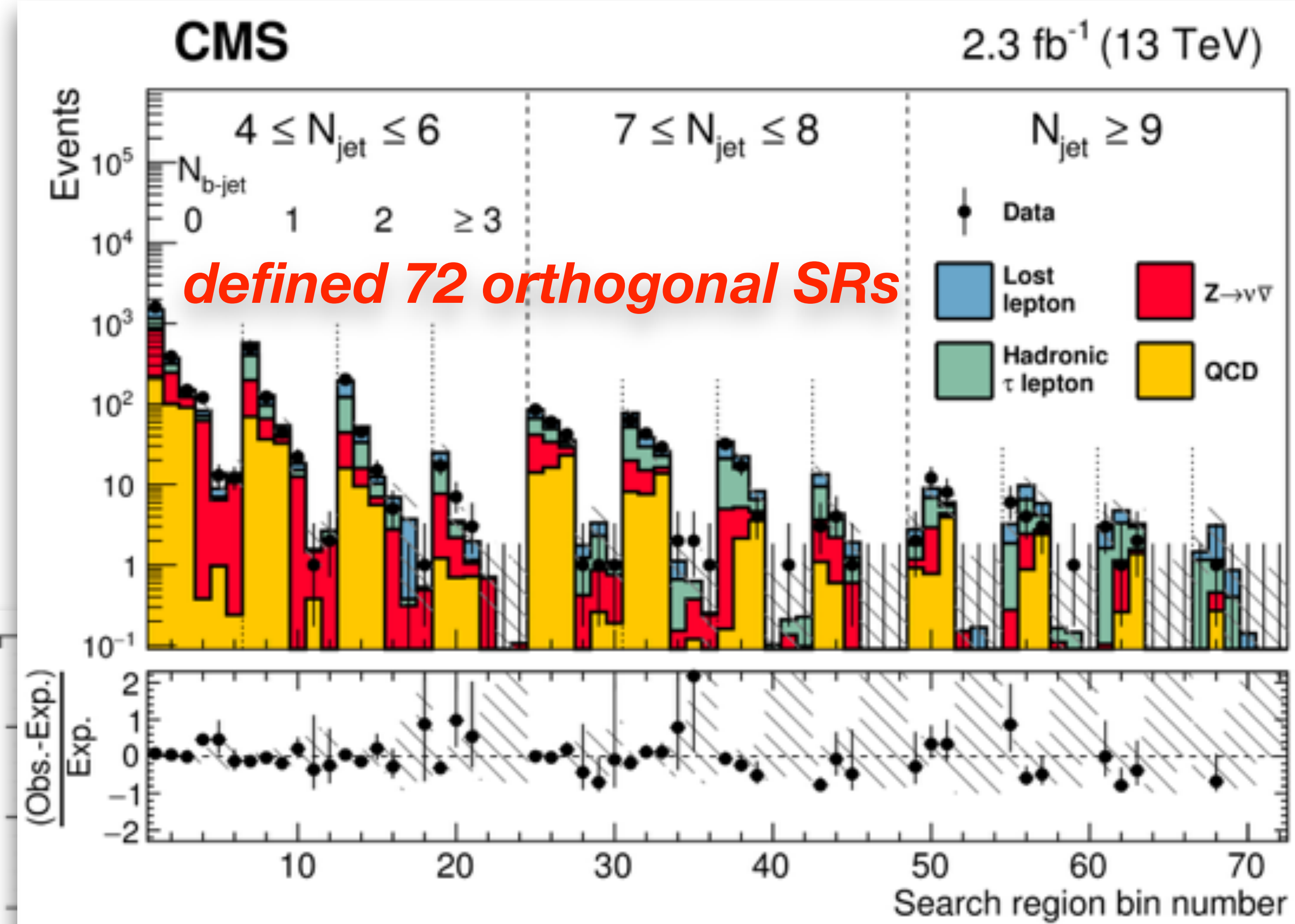
$$m_{eff} = E_T^{miss} + \sum_i P_T^{lep,i} + \sum_j P_T^{jet,j}$$

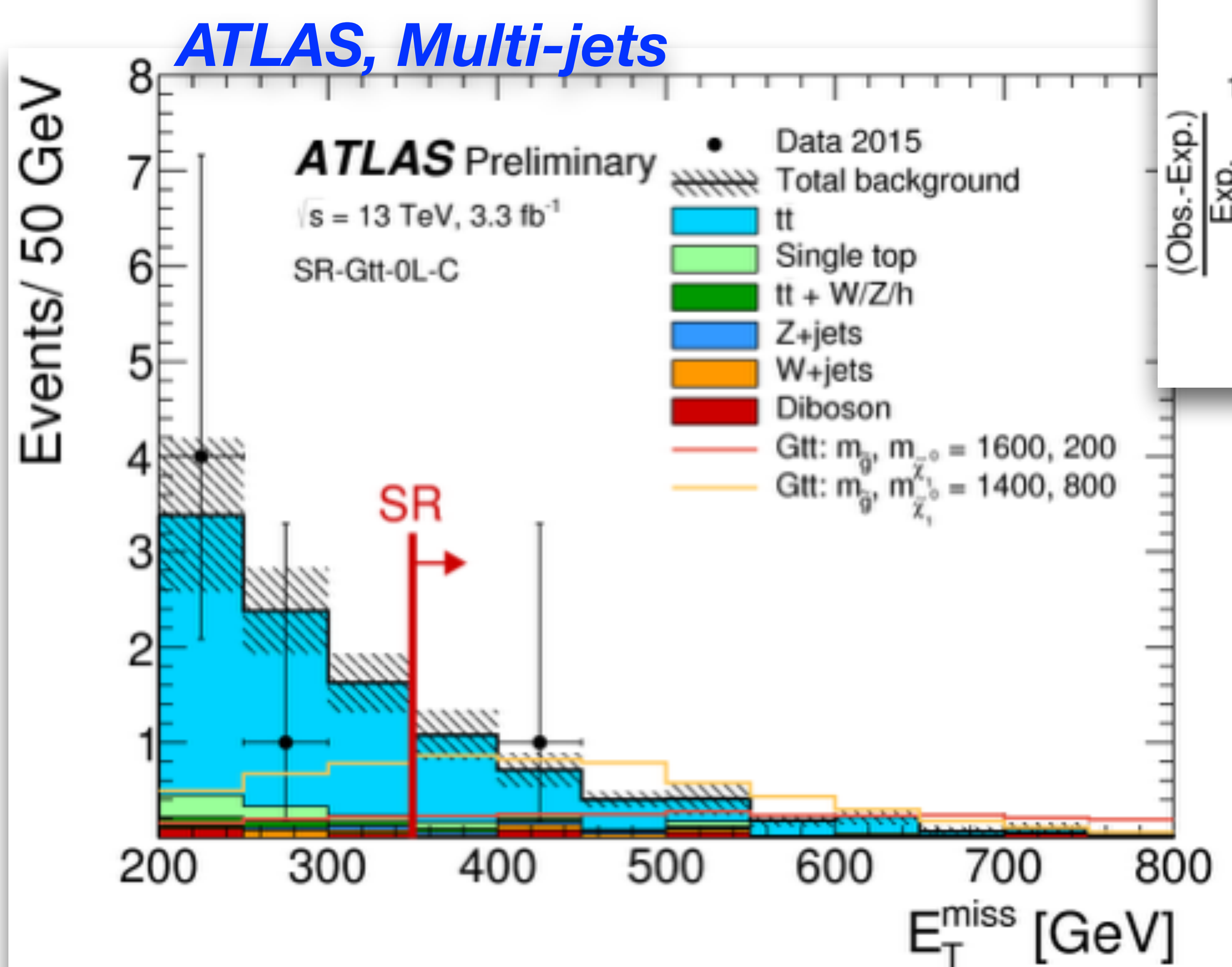
$$H_T = \sum_j P_T^{jet,j}$$

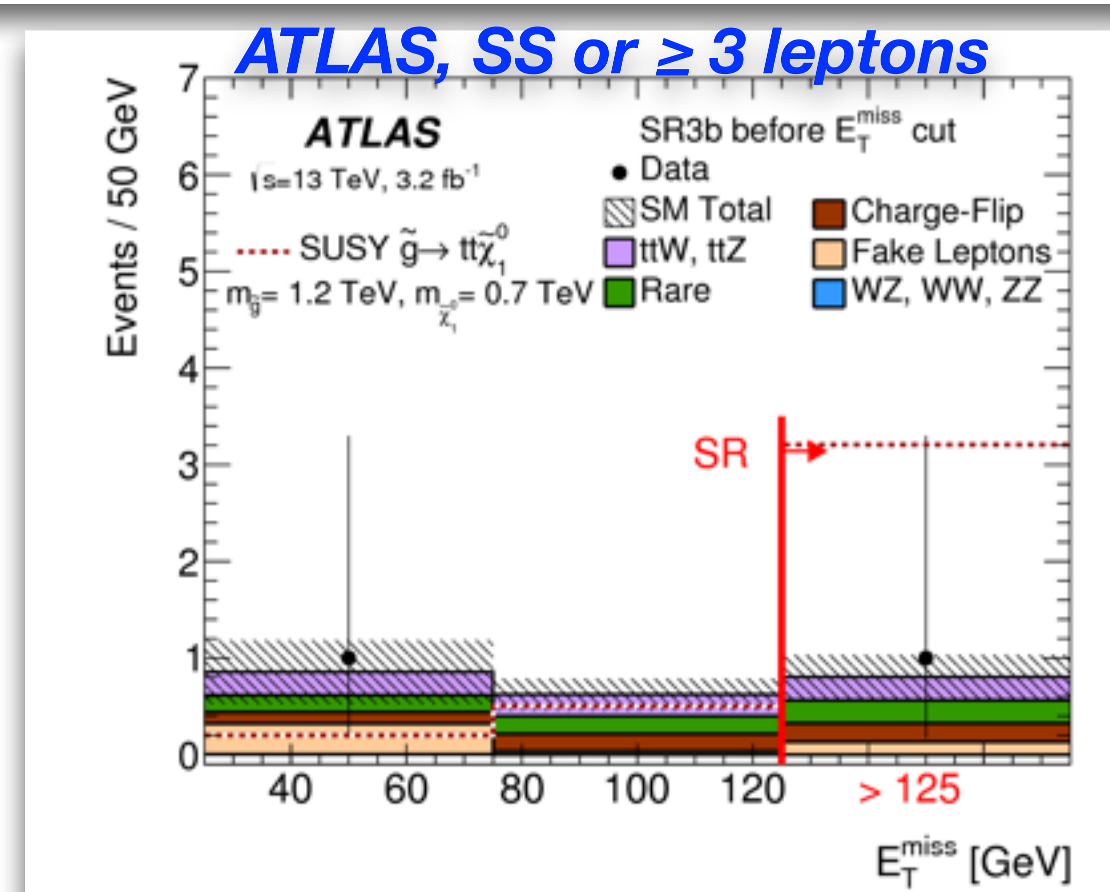
$$H_T^{miss} = |\sum_j \vec{P}_T^{jet,j}|$$

All the SRs are defined varying VarsSR cuts

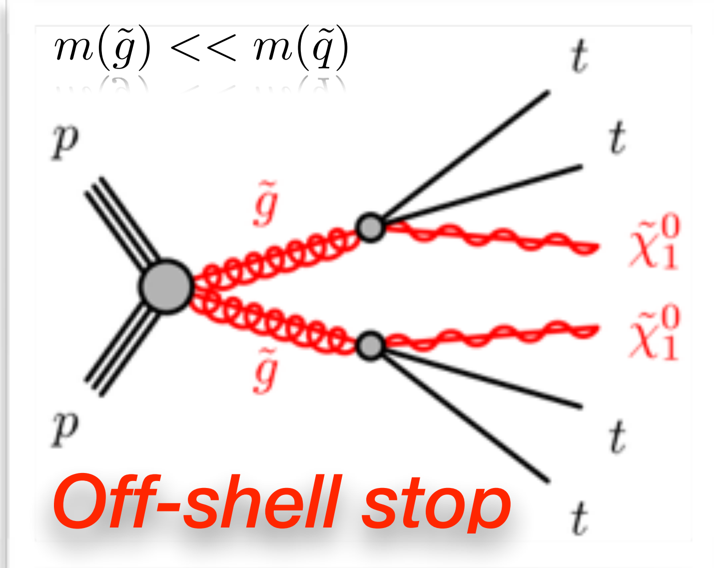




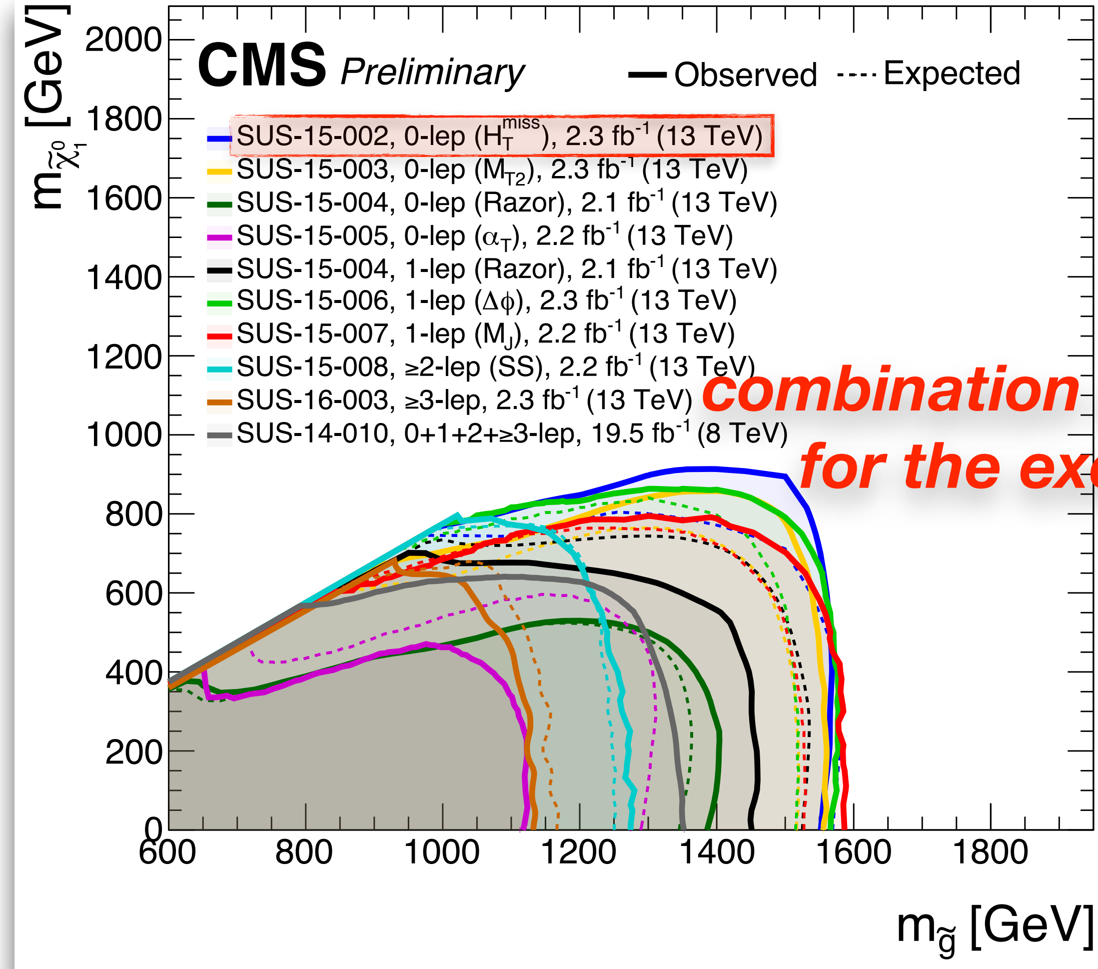




No significant excess observed

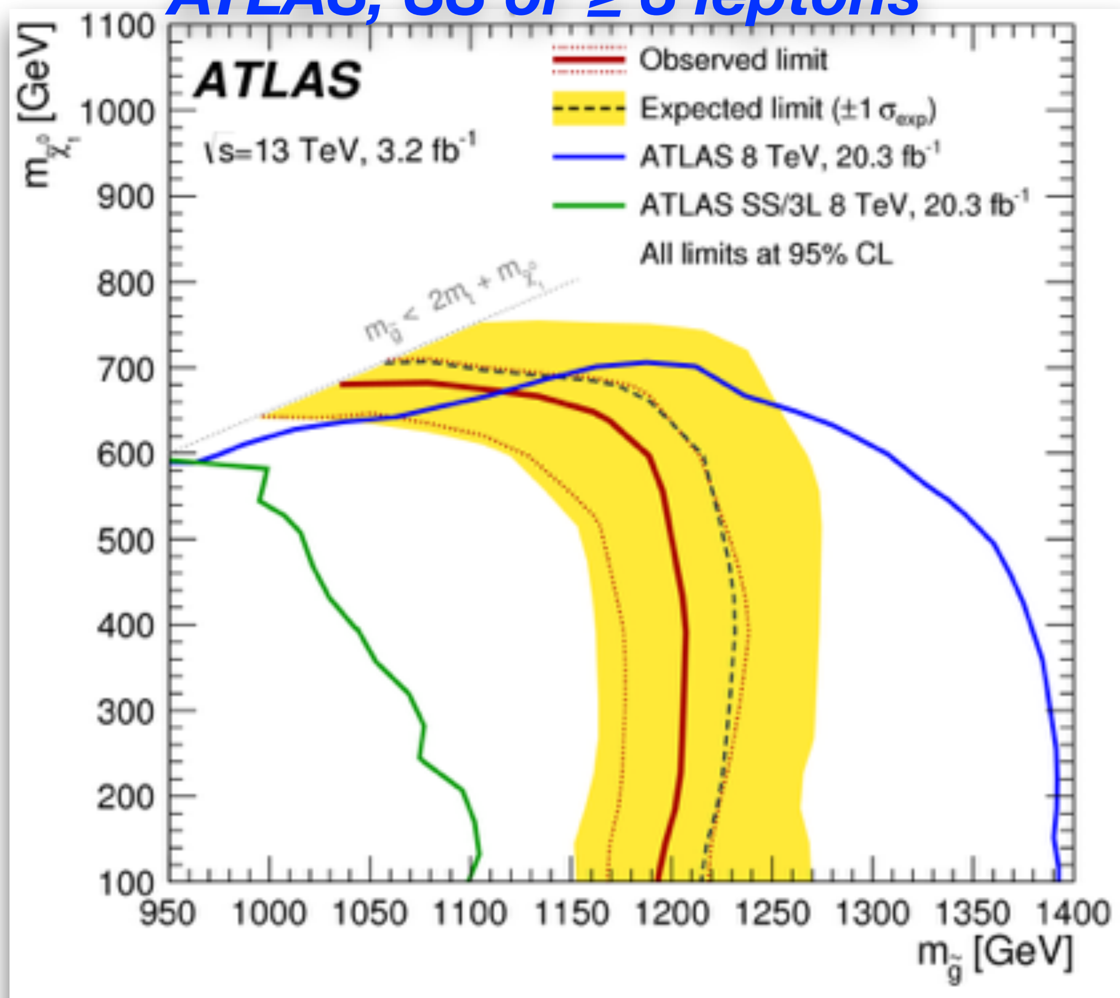


Off-shell stop

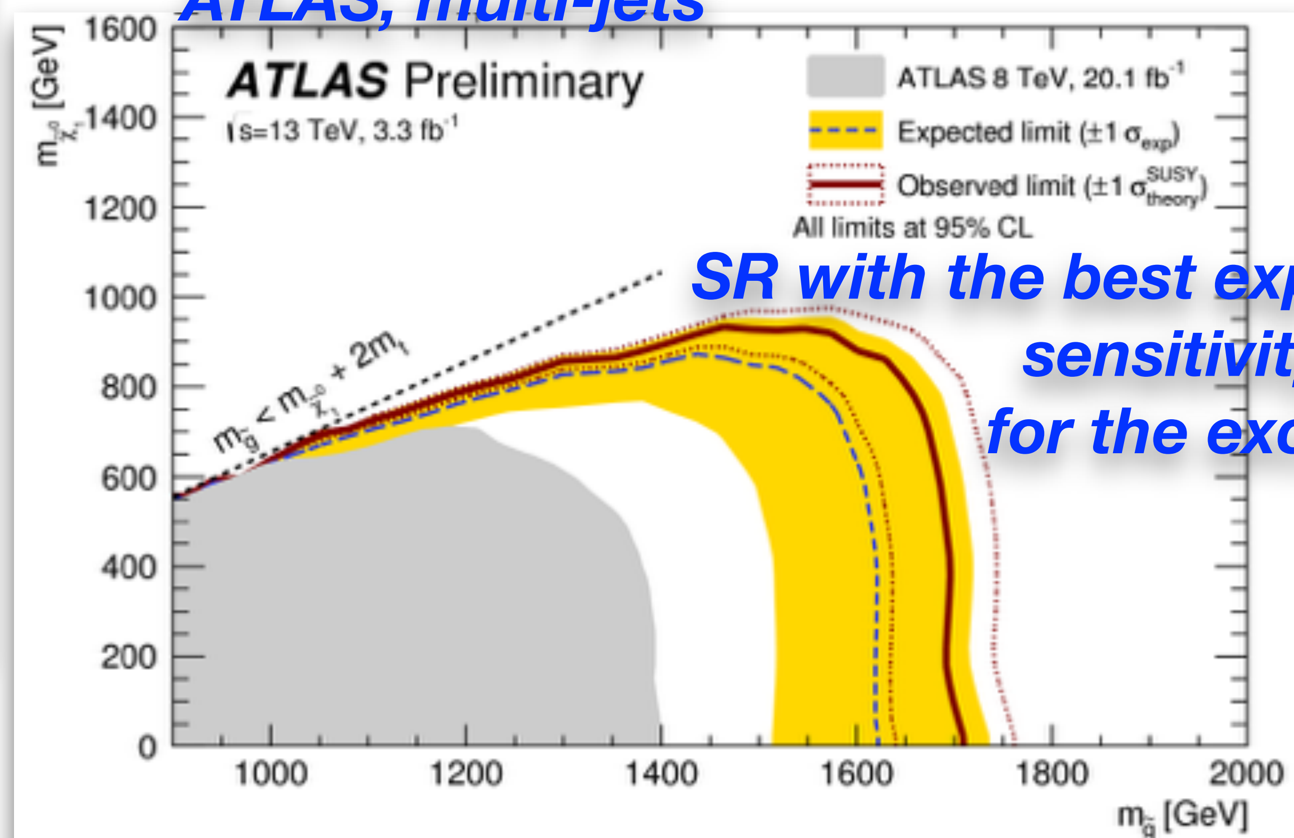


combination of all 72 SRs for the exclusion plots

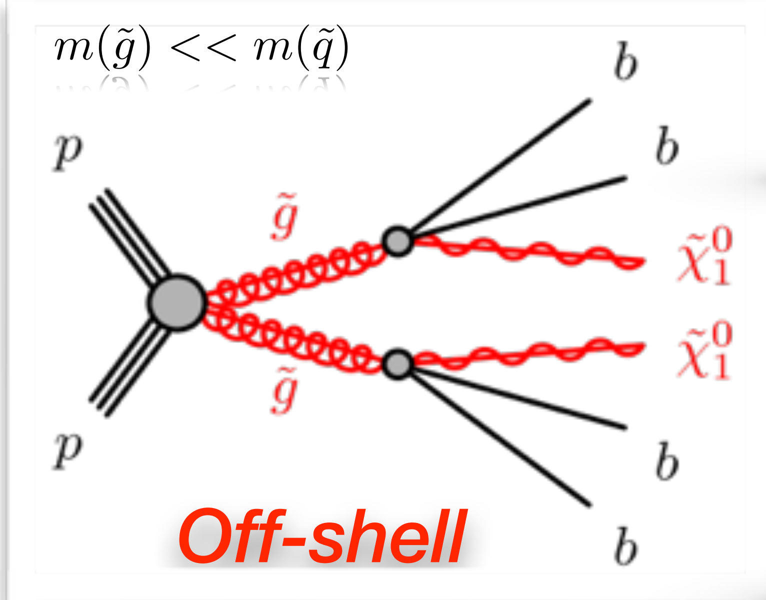
ATLAS, SS or ≥ 3 leptons



ATLAS, multi-jets



SR with the best expected sensitivity used for the exclusion plots



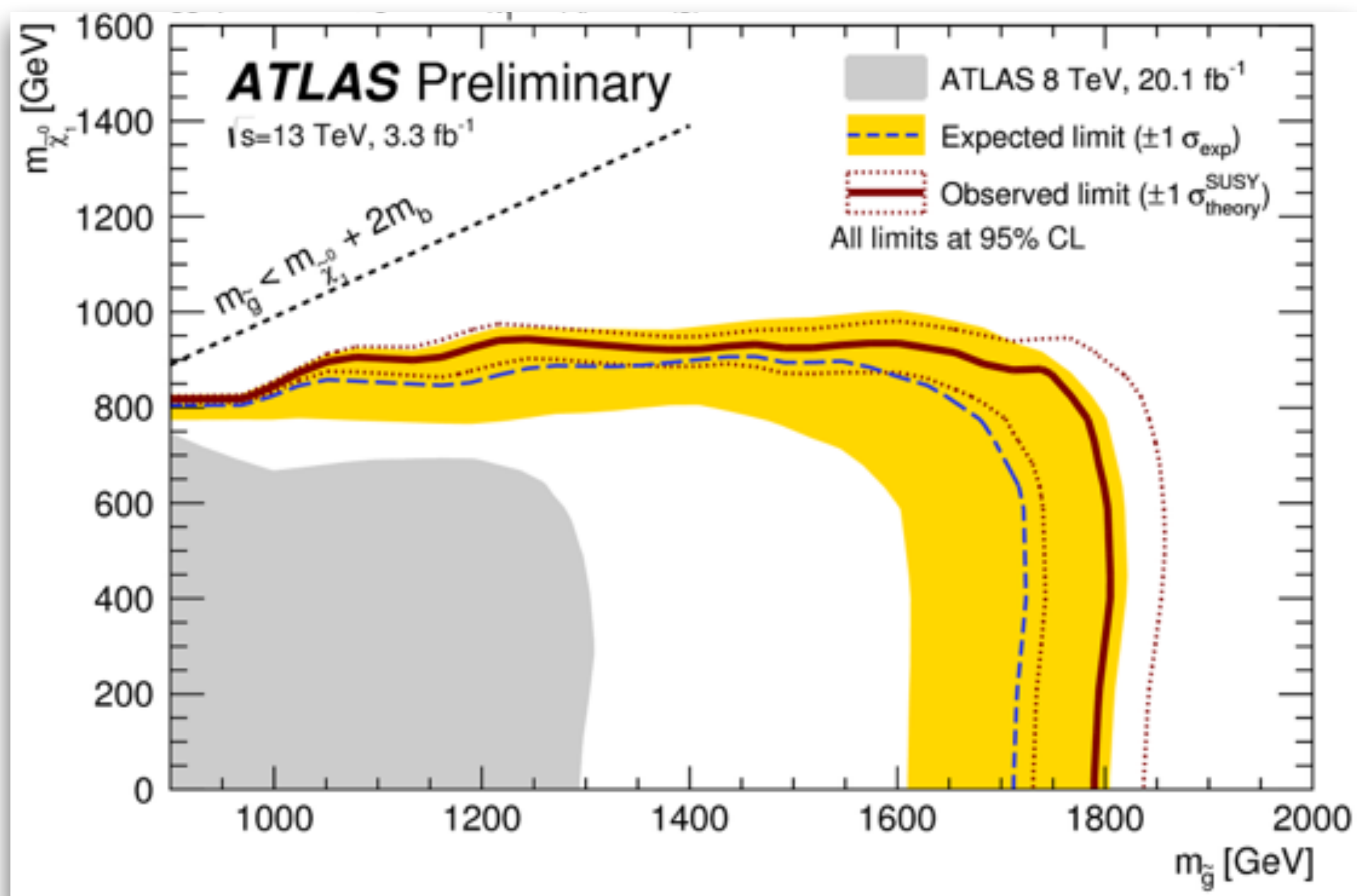
CMS (arXiv:1602.0658), the same selection of $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ with 0 lepton and H_T^{miss} base SR definition

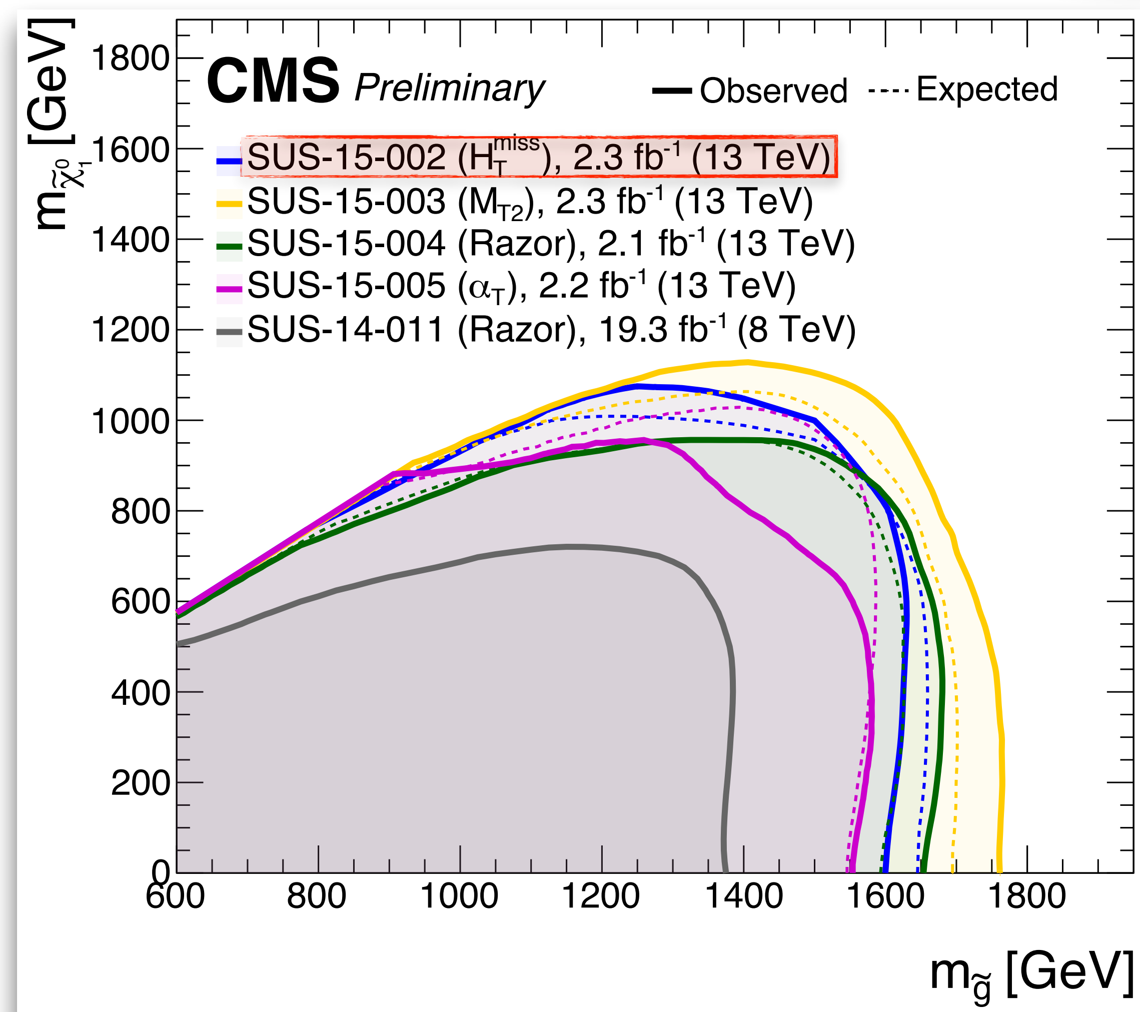
ATLAS (ATLAS-CONF-2015-067), same analysis of multi-jets but with:

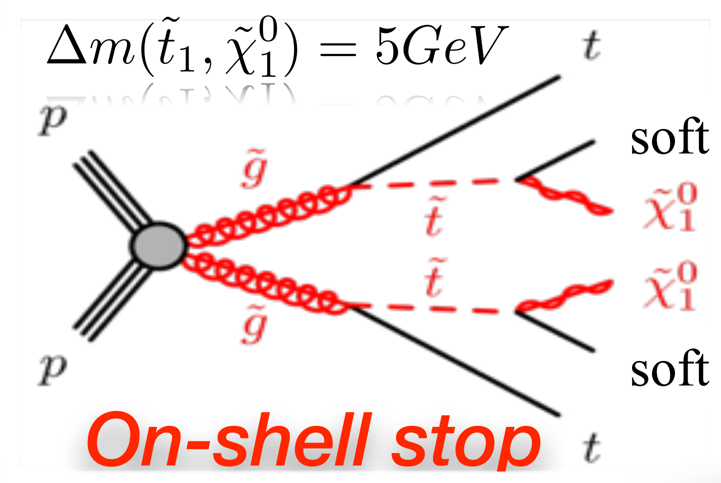
- 0 lepton (before also 1 lepton request)
- $N_{jets} \geq 4$ (before ≥ 8)
- different definition of m_{eff}

$$m_{eff} = \sum_{i<4} P_T^{jet,i} + E_T^{miss}$$

No significant excess observed







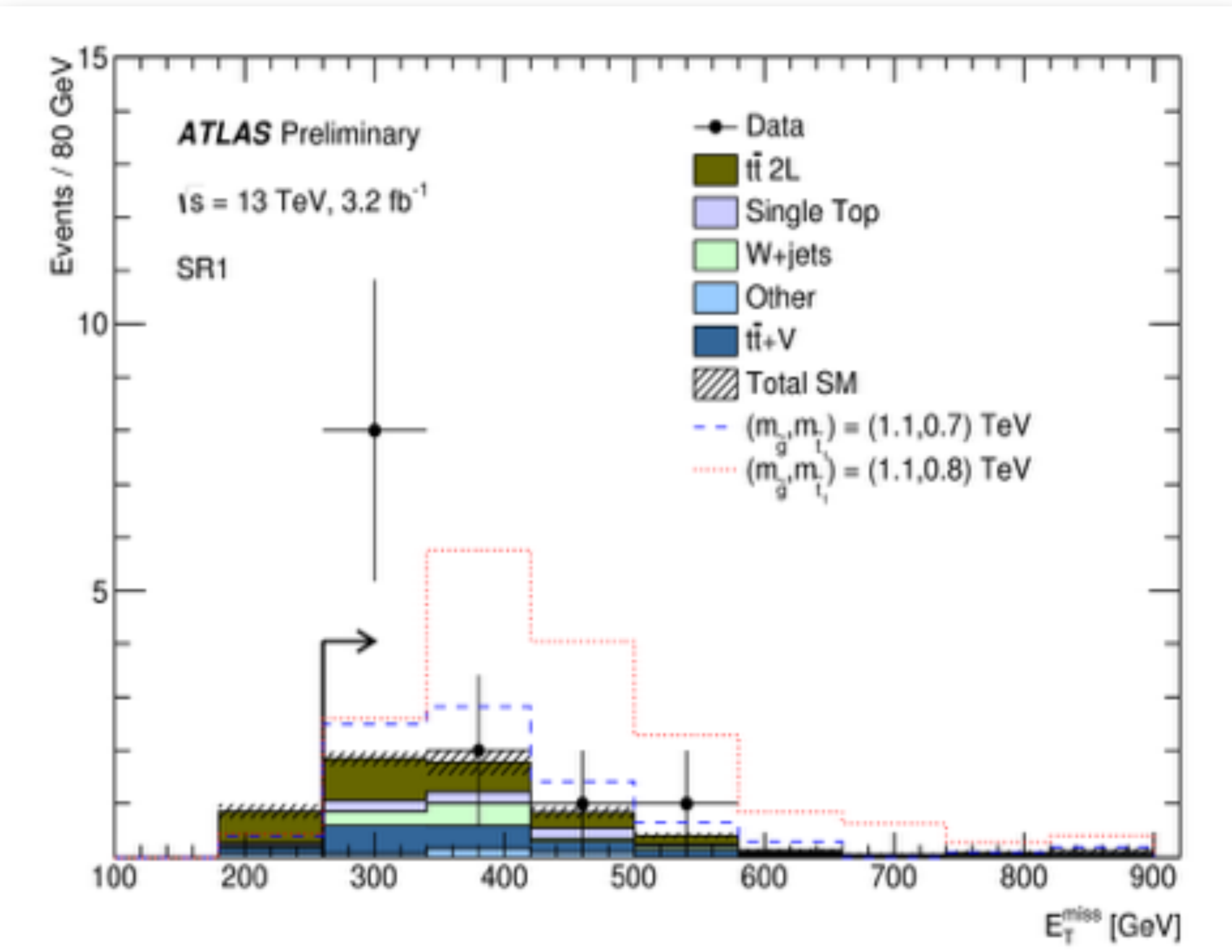
ATLAS-CONF-2016-007, focusing on a final state with:

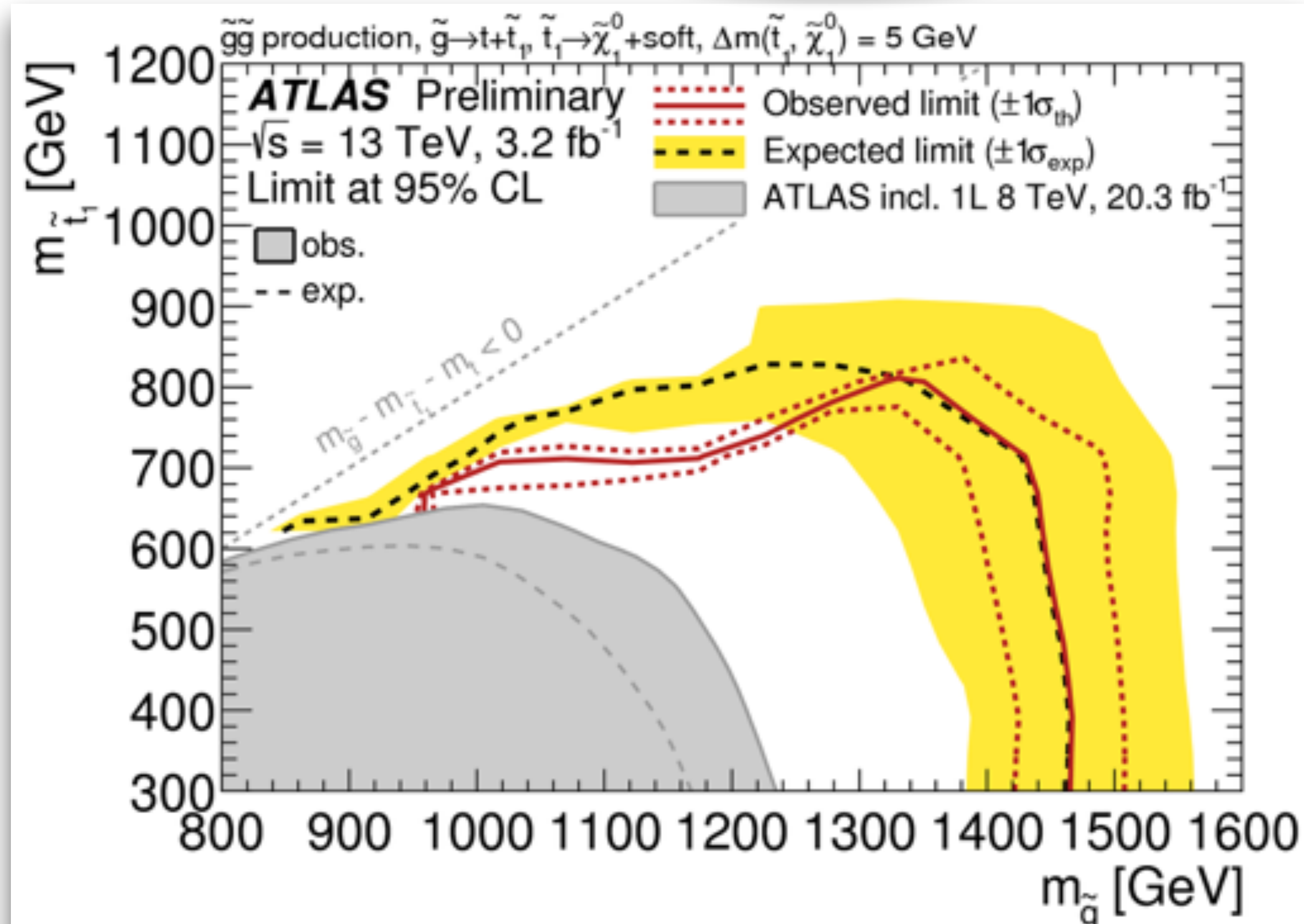
- 1 lepton
- $N_{b\text{-jets}} \geq 1$
- $N_{jets} \geq 4$
- Large E_T^{miss}

3 SRs defined considering different E_T^{miss} cut

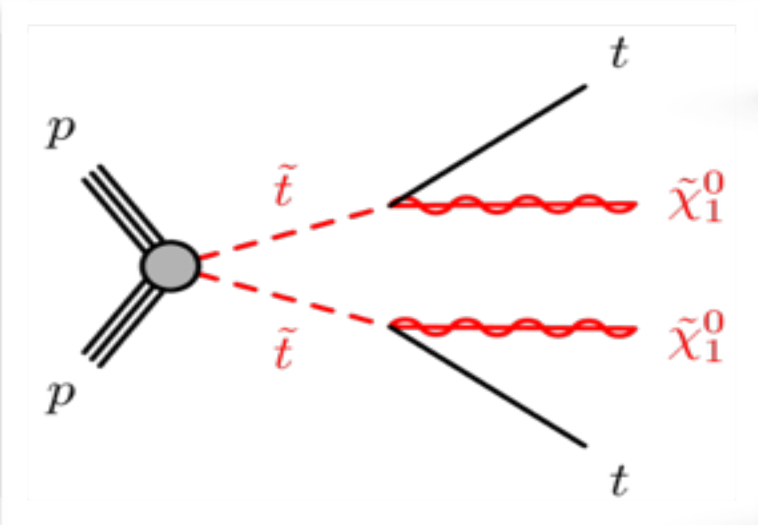
	SR		
	E_T^{miss} > 260 GeV	E_T^{miss} > 350 GeV	E_T^{miss} > 450 GeV
Observed	12	1	1
Expected	5.50±0.72	1.25±0.26	1.03±0.18

2.3 sigma excess observed in the SR with lowest E_T^{miss} cut





SR with the best expected sensitivity used for the exclusion plots



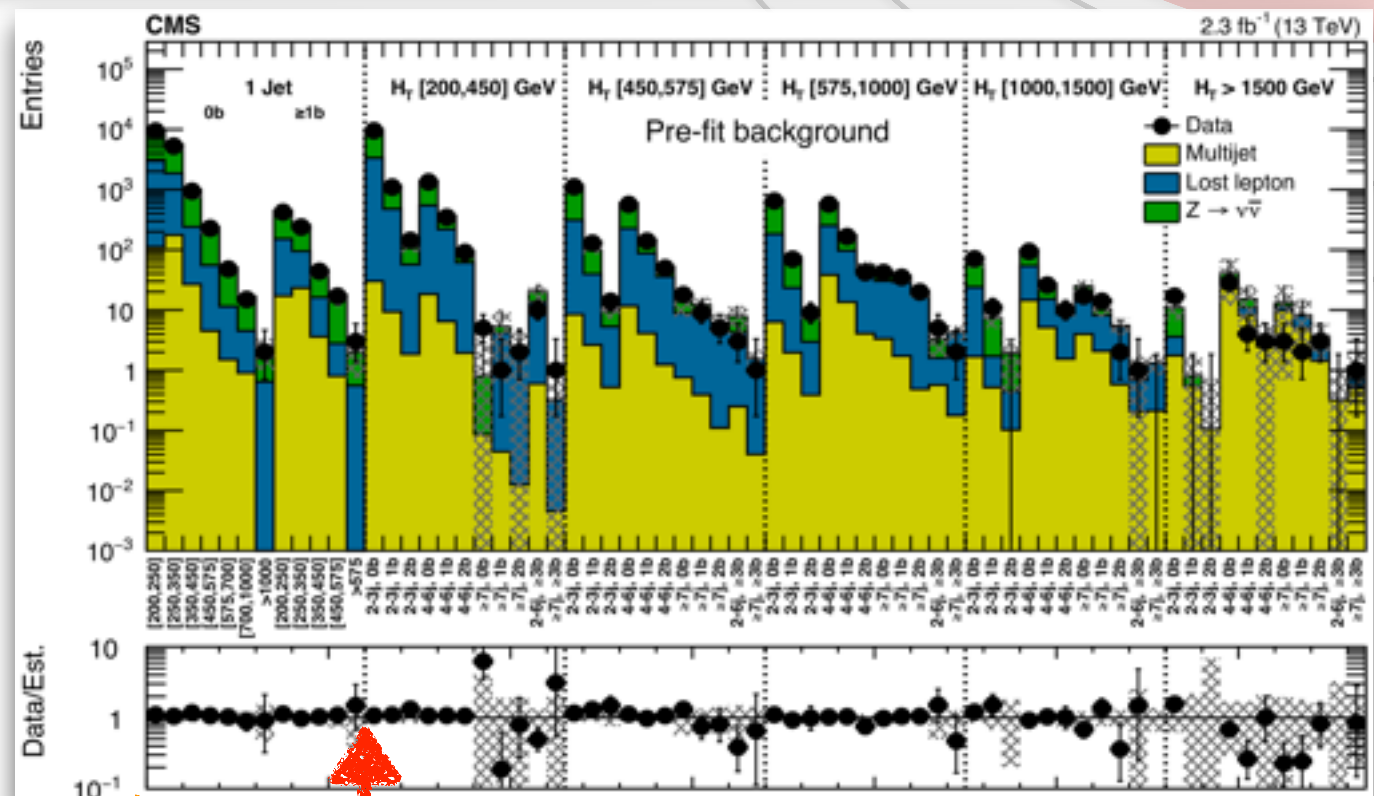
ATLAS (ATLAS-CONF-2016-007), same selection of $\tilde{g} \to t\tilde{\chi}_1^0 \mathrm{soft}$

CMS, different analysis strategies based on

- ✓ different finale states: 0 or 1 lepton
- ✓ different variables for SR definition: $H_T^{miss}, M_{T2}, \ldots$

Best sensitivity with 0 leptons final state and M_{T2} base Signal region (SR) definition

	CMS
Reference	arXiv:1603.0453
$N_{leptons}$	0
N_{jets}	≥ 2 (1)
$N_{b\text{-}jets}$	≥ 0
$Vars_{SR}$	$N_{jets}, N_{b-jets}, H_T, M_{T2}(N_{b-jets}, P_T)$



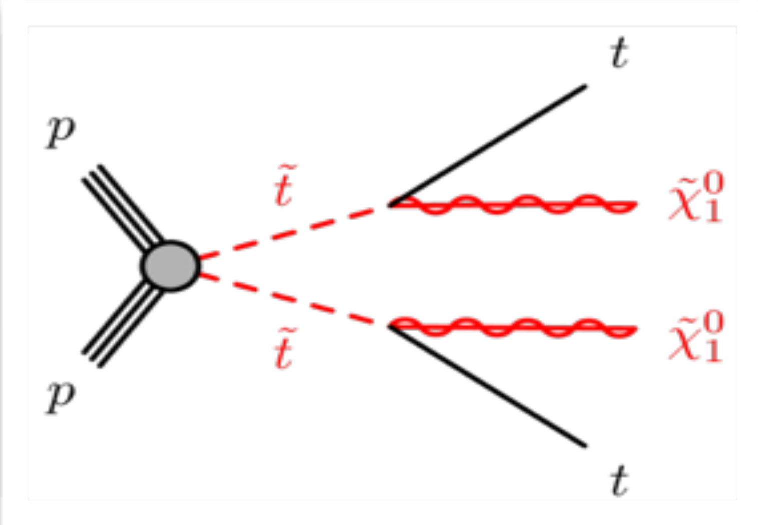
M_{T2} definition possible only with at least 2 jets

$$M_{T2} = \min_{\vec{q}_t + \vec{r}_t = \vec{P}_t^{miss}} \left\{ \max[m_T(\vec{P}_t^{jet_1}, \vec{q}_t), m_T(\vec{P}_t^{jet_2}, \vec{r}_t)\right\}$$

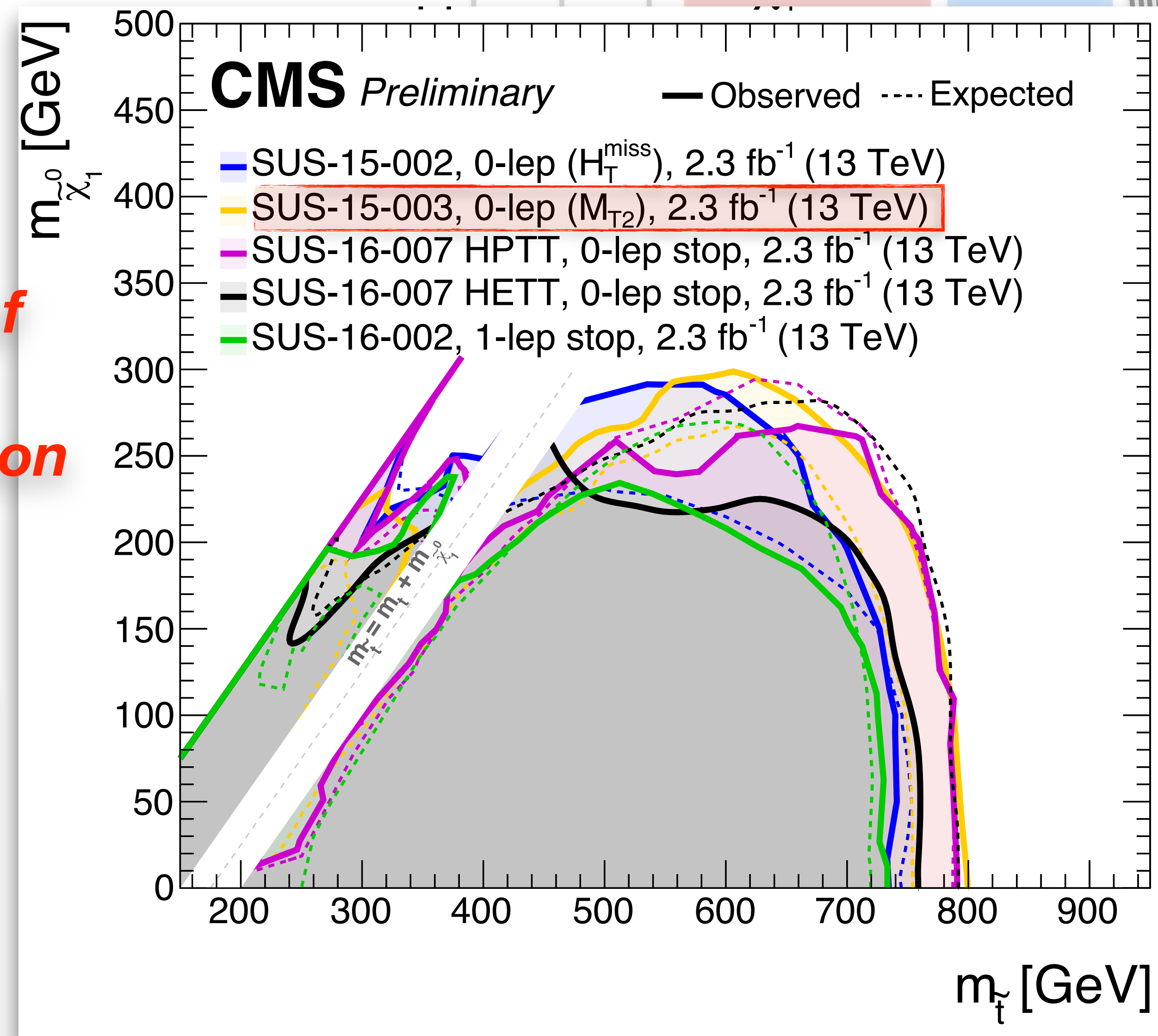
P_T range

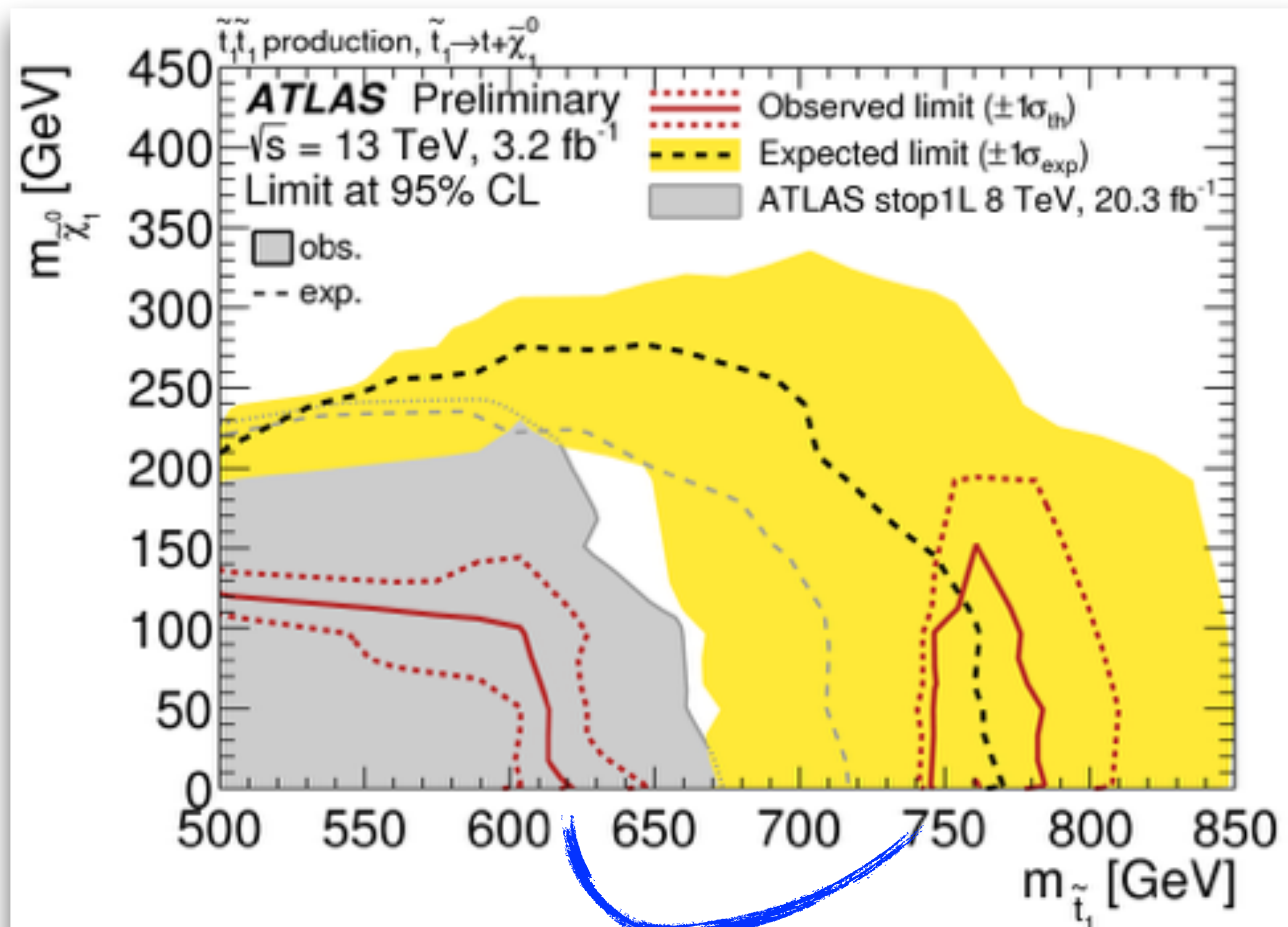
Each bin should be splitted in 3,4 or 5 M_{T2} ranges to obtain all the SRs

No significant excess observed



combination of all SRs for the exclusion plots

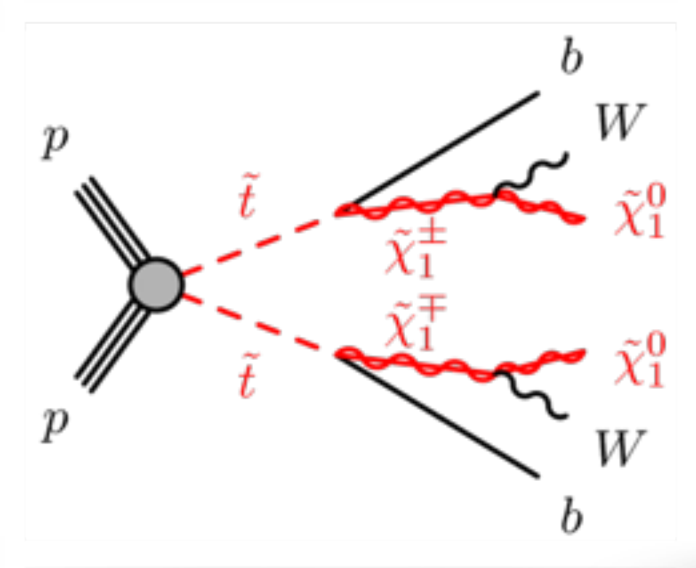




New region of interest:

$$m(\tilde{t}_1) \approx m(t) + m(\tilde{\chi}_1^0)$$

SR with the best expected sensitivity used for the exclusion plots: uncovered regions due to the excess observed in SR1



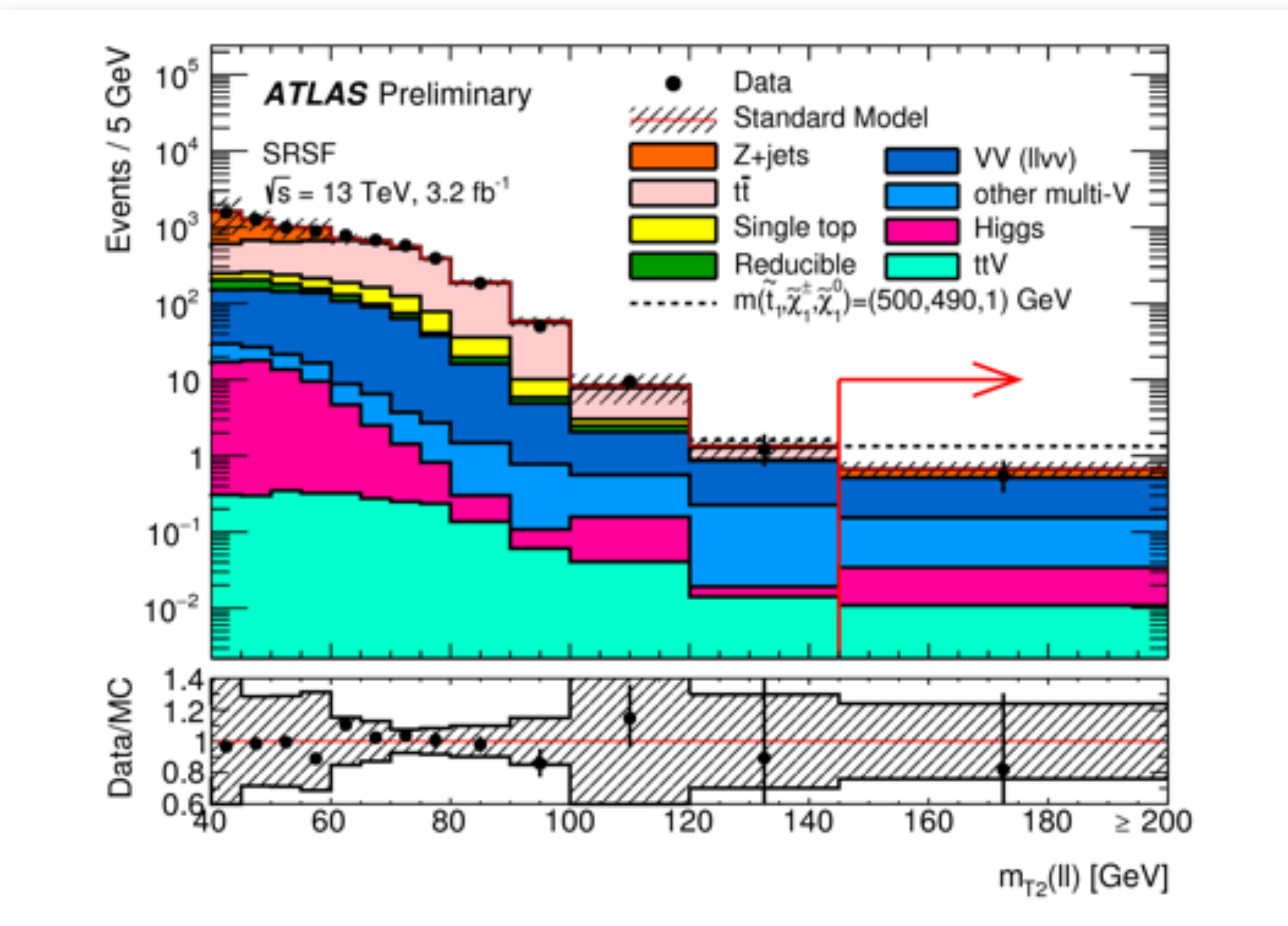
ATLAS-CONF-2016-009, focusing on a final state with:

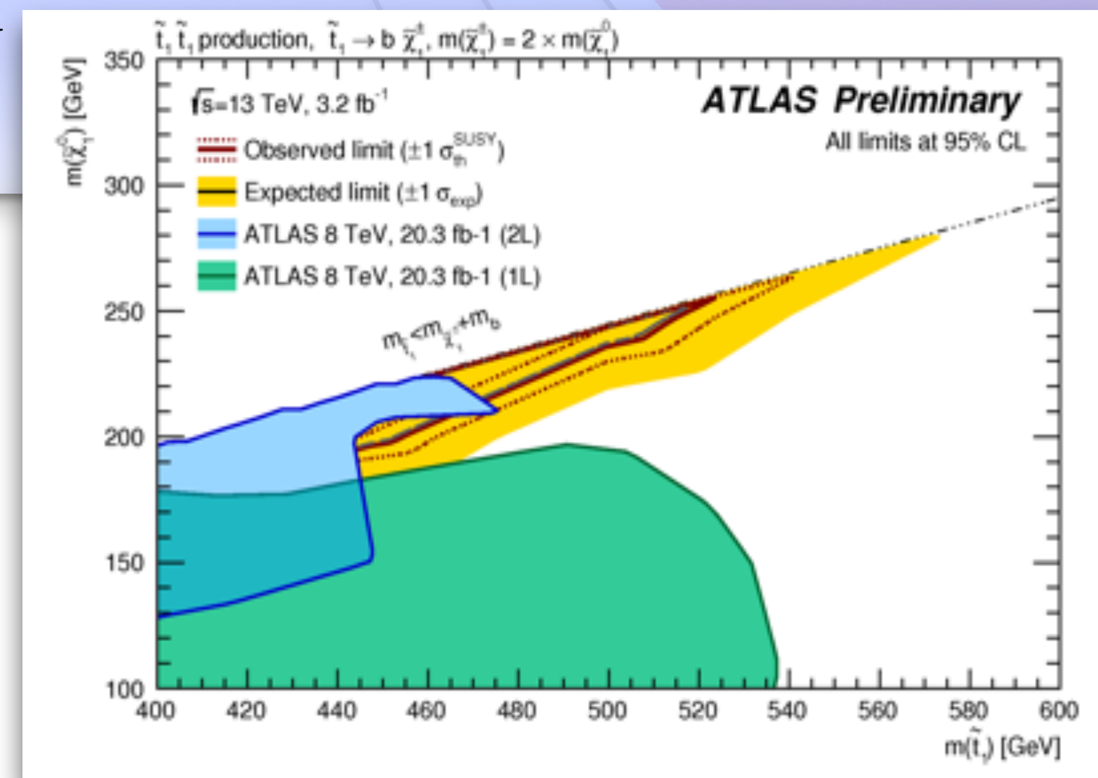
- 2 Opposite Sign (OS) leptons
- Large E_T^{miss}
- High leptonic M_{T2}

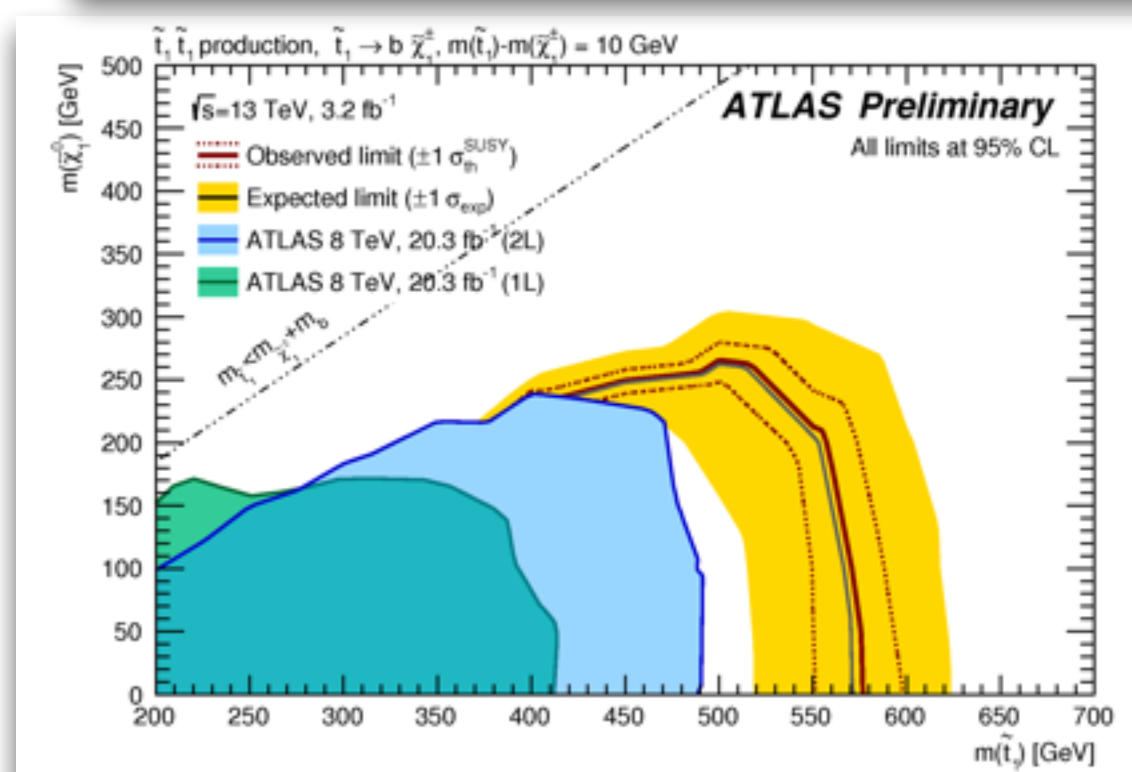
Signal models considered:

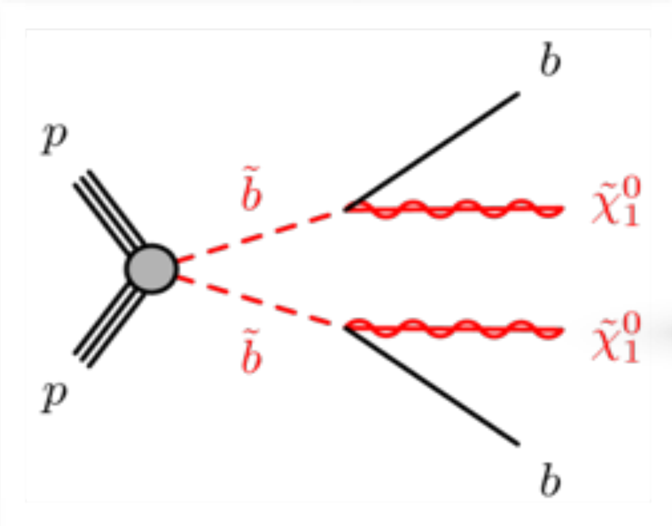
- ☑ $m(\tilde{t}_1) = m(\tilde{\chi}_1^{\pm}) + 10GeV$
- ☑ $m(\tilde{\chi}_1^{\pm}) = 2 \times m(\tilde{\chi}_1^0)$

No excess observed









CMS, focusing on two different analysis strategies:

- the same of $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$ with 0 lepton and M_{T2} SR base definition **(arxXiv:1603.0453)**
- 2 or 3 jets with large E_T^{miss} in the final state

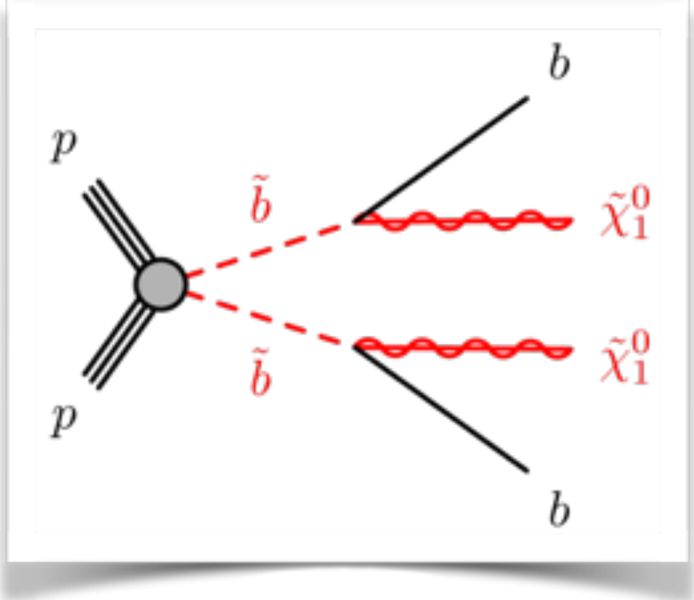
Similar approach for ATLAS

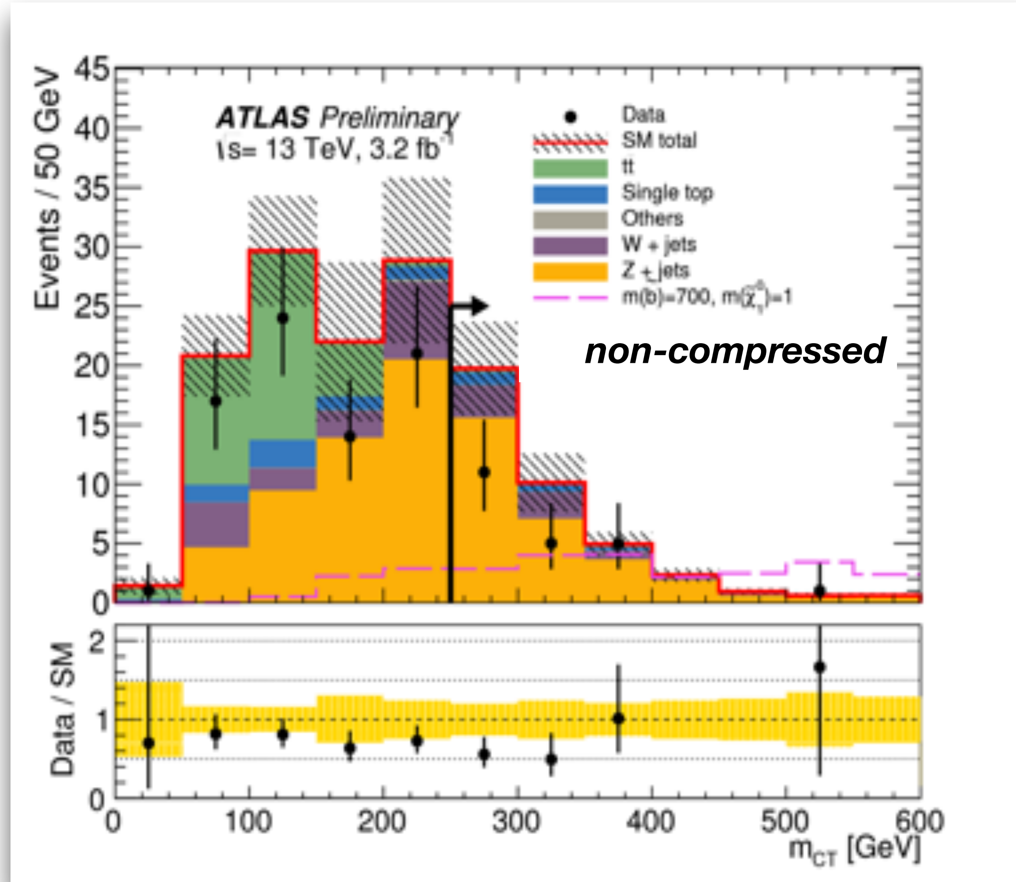
ATLAS		***CMS***	
ATLAS-CONF-2015-066		CMS-PAS-SUS-16-001	
Large E_T^{miss}		Large E_T^{miss}	
veto on an energetic 4th jet		veto on energetic 4th jet	
Large $\Delta M(\tilde{b}_1, \tilde{\chi}_1^0)$	Small $\Delta M(\tilde{b}_1, \tilde{\chi}_1^0)$	Large $\Delta M(\tilde{b}_1, \tilde{\chi}_1^0)$	Small $\Delta M(\tilde{b}_1, \tilde{\chi}_1^0)$
2 energetic b-jets	ISR jet	2 energetic b-jets	ISR jet
Large M_{bb}	2 b-jets	Large $\min_i M_T(J_i, E_T^{miss})$	-
$m_{CT}^2(j_1, j_2)$	E_T^{miss}	$m_{CT}^2(j_1, j_2), H_T$	E_T^{miss}, N_{b-jets}

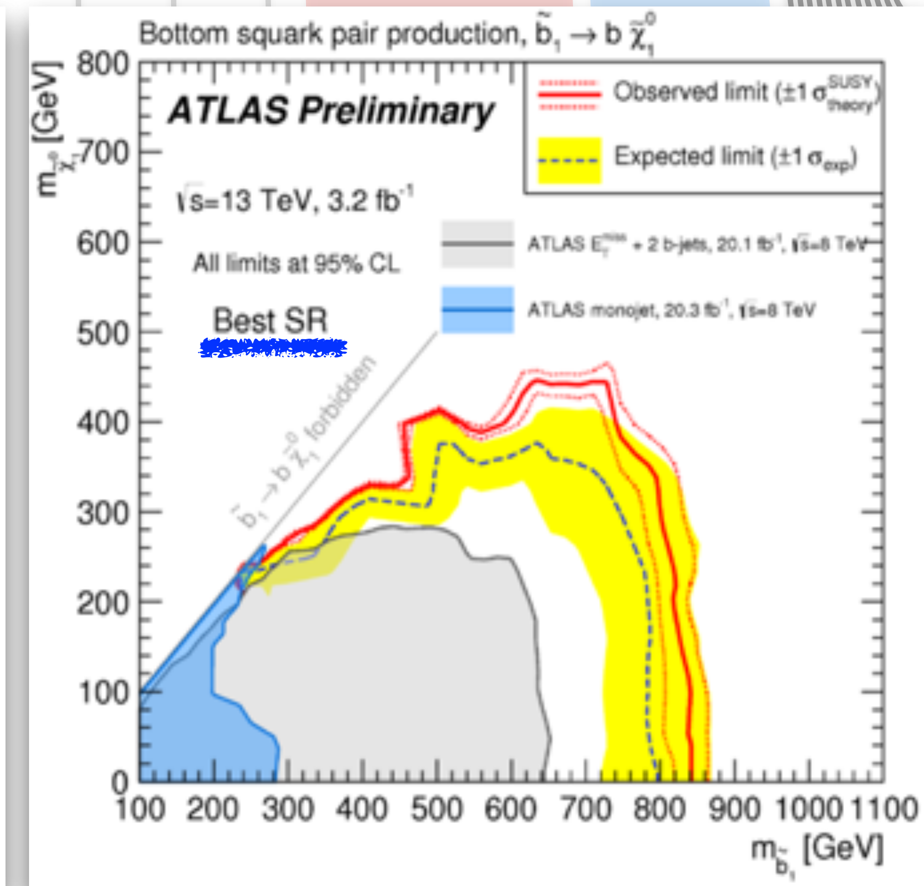
$$M_T(j, E_T^{miss}) = \sqrt{2P_t^j E_T^{miss}(1 + \cos\Delta\phi(j, E_T^{miss})}$$

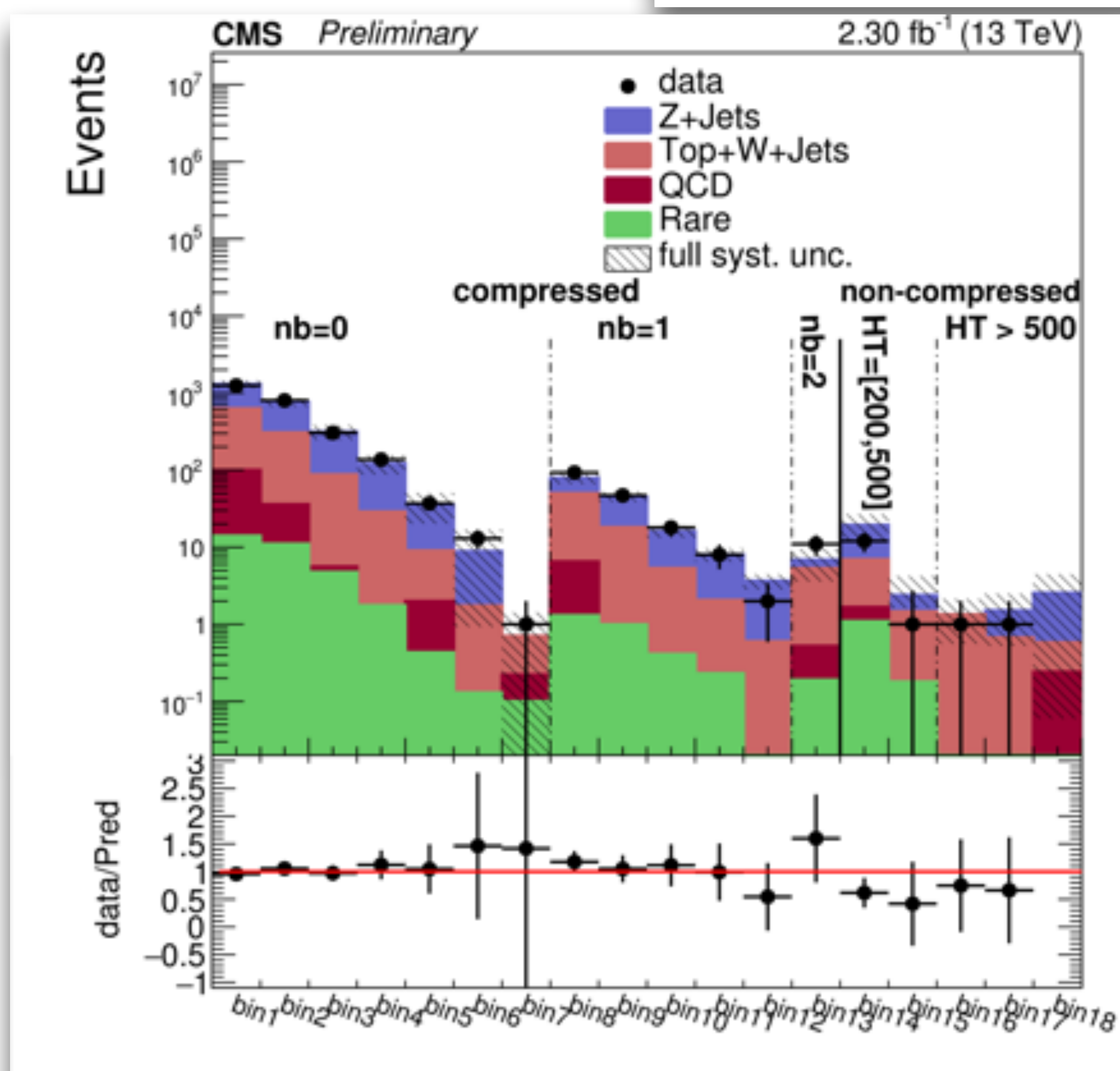
$$m_{CT}^2(j_1, j_2) = [E_T(j_1) + E_T(j_2)]^2 - [\vec{P}_T^{j_1} - \vec{P}_T^{j_2}]^2$$

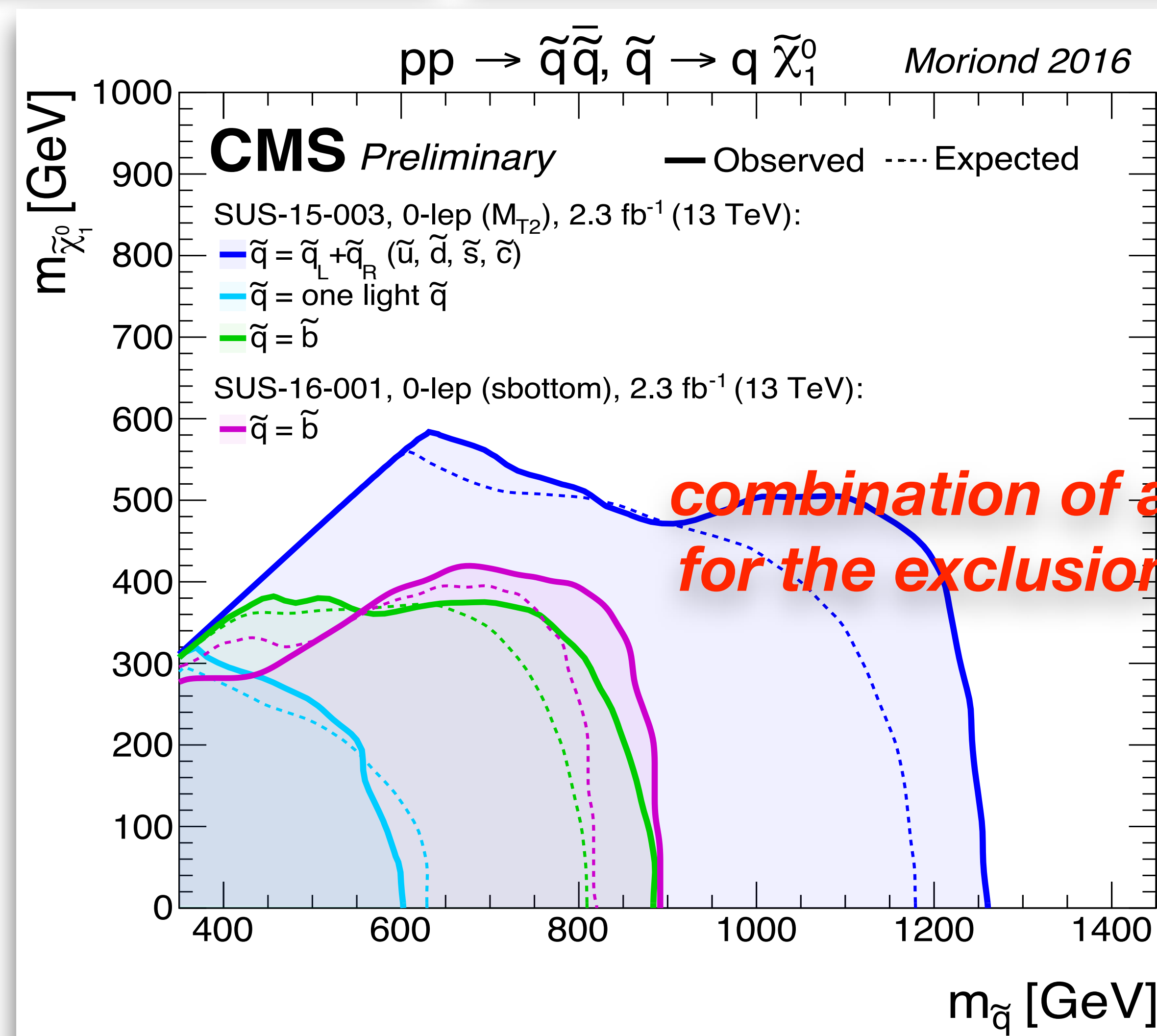
All the SRs are defined varying cuts on the variables shown in the last row



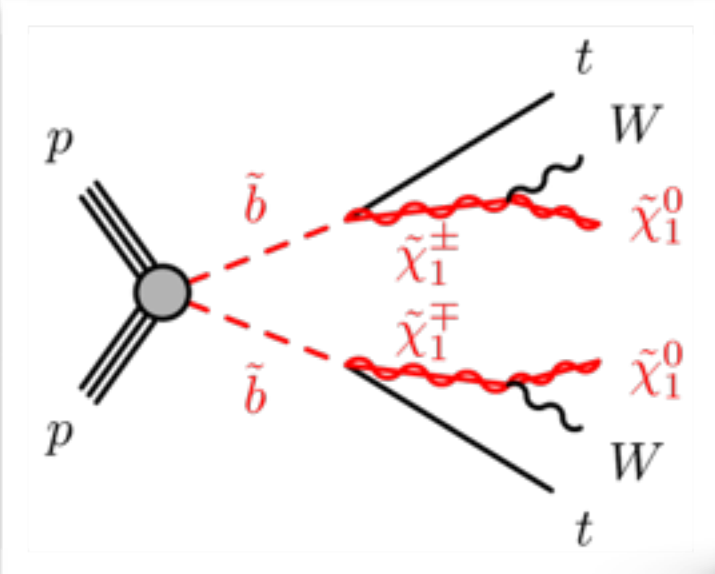








combination of all SRs for the exclusion plots



ATLAS arXiv:1602.09058, focusing on a final state with:

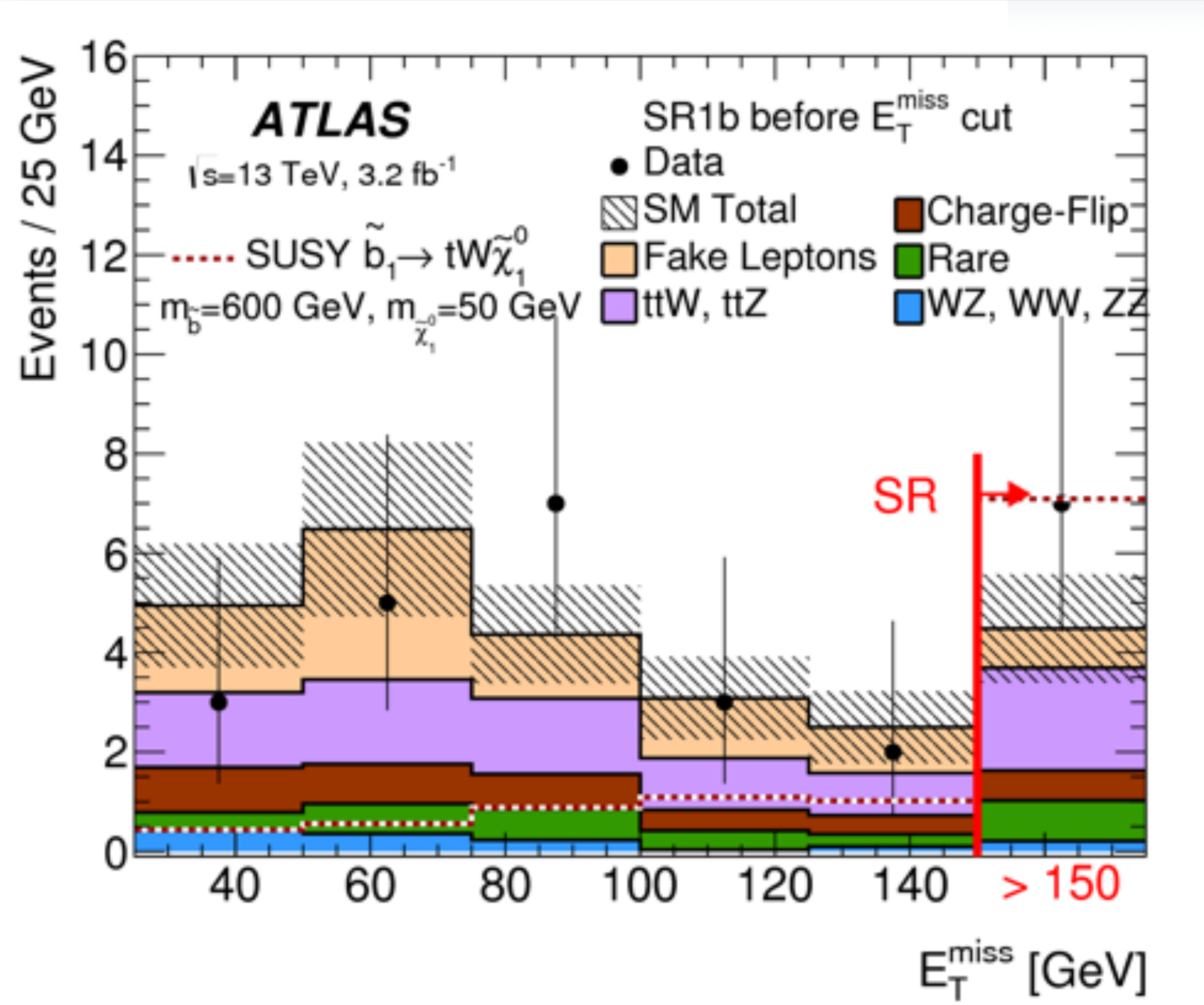
- 2 SS leptons or 3 leptons
- at least 1 b-jet
- at least 4 jet at hight P_T
- Large E_T^{miss}

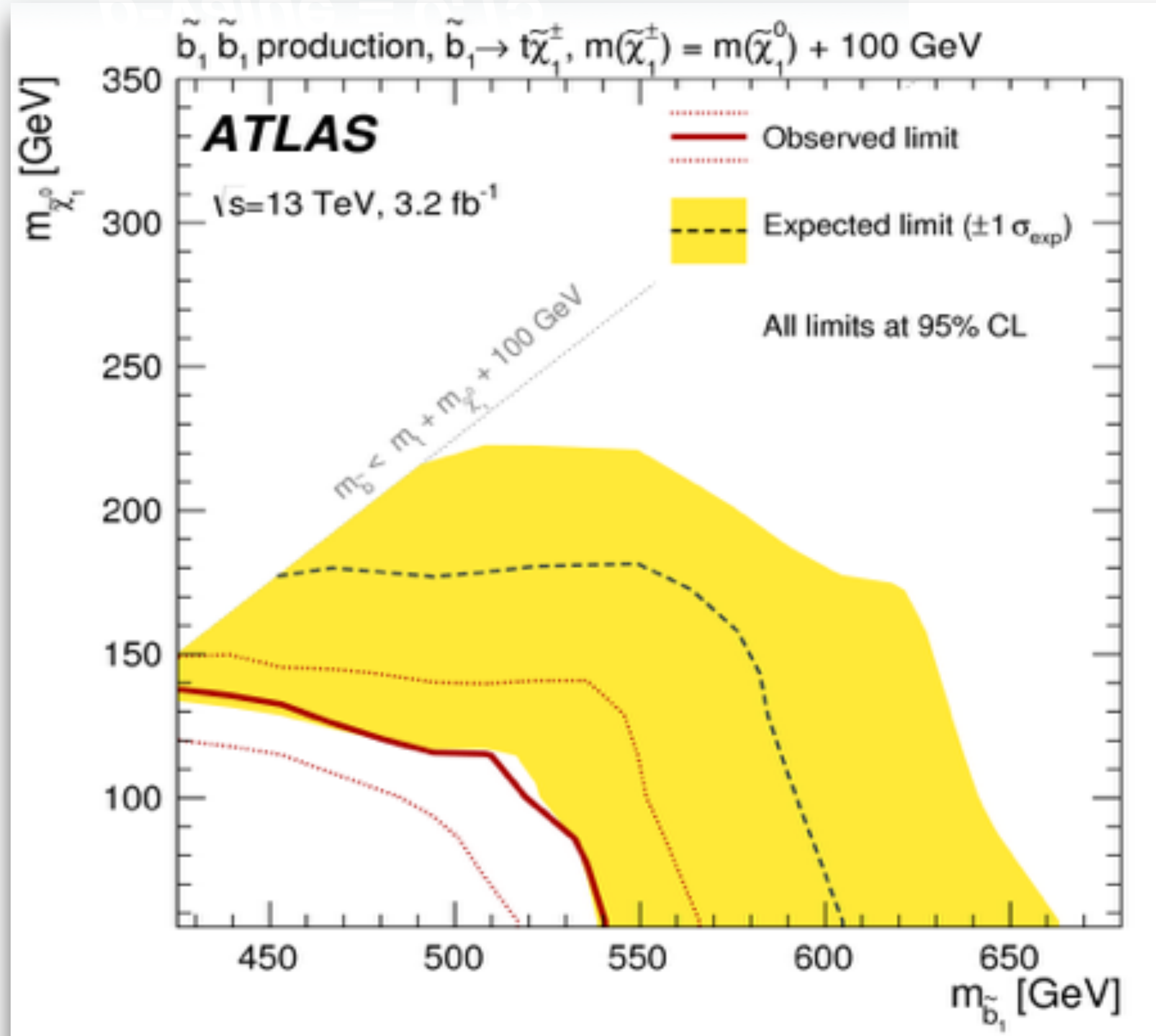
Signal model considered:

☑ $m(\tilde{\chi}^{\pm}) = m(\tilde{\chi}_1^0) + 100 GeV$

	Signal Region
Observed	7
Expected	4.5±1.0

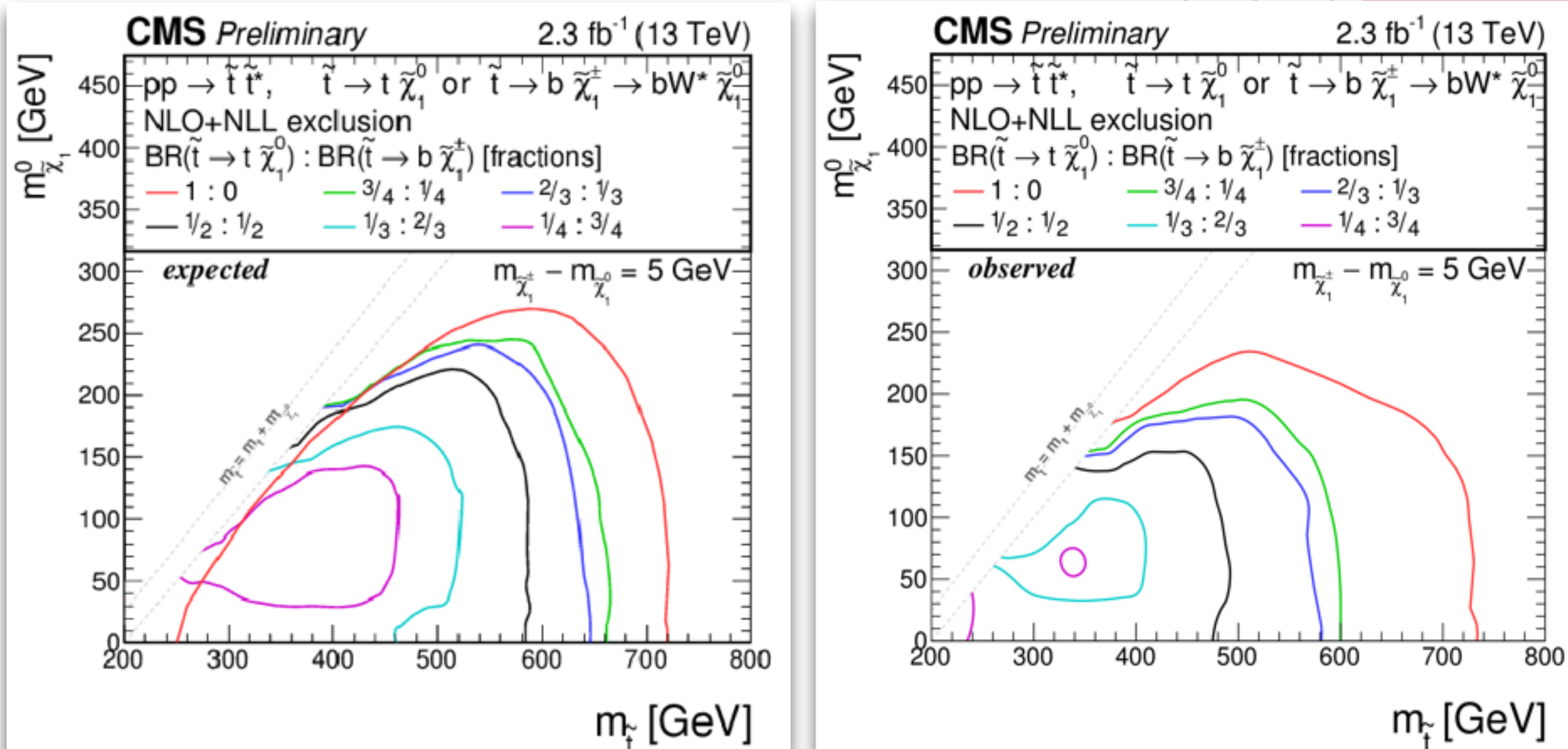
No significant excess observed
p-value = 0.15





Exclusion limits depend strongly on the model assumptions

CMS-PAS-SUS-16-002

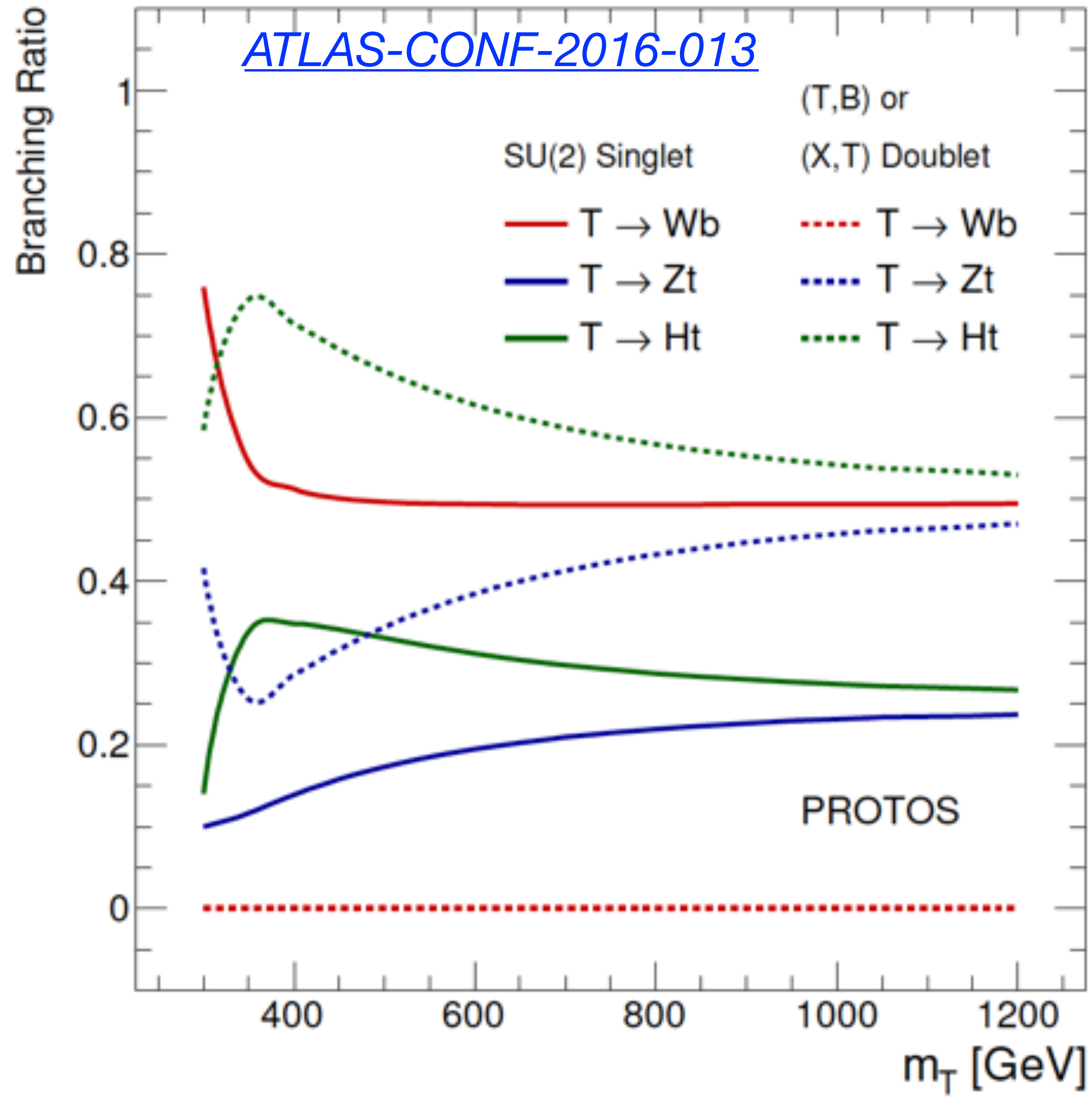


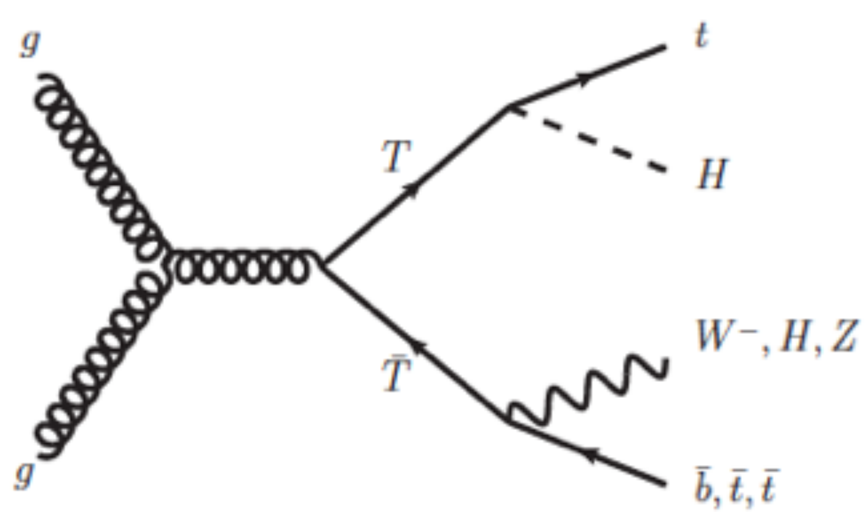
Still possible to have light stop changing its BR

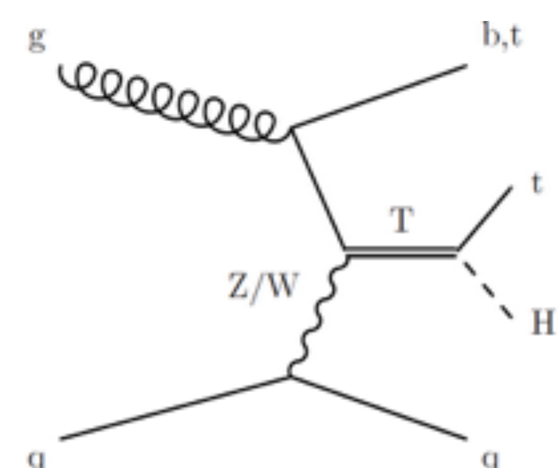
Vector like-quarks

Vector-like Quarks

- Vector-like quarks (VLQs) are predicted by a large variety of non-Susy models to stabilize the Higgs mass calculation
  - Little Higgs, Composite Higgs, extra dimensions
- Non chiral fermions, not excluded by electroweak precision measurement
- Properties:
  - Same charge as b, t (B, T) or exotic charges ($X_{5/3}$ or $Y_{-4/3}$)
  - Masses in the TeV range
  - Singly or pair produced
- Variety of final states
  - Dedicated searches and inclusive analyses



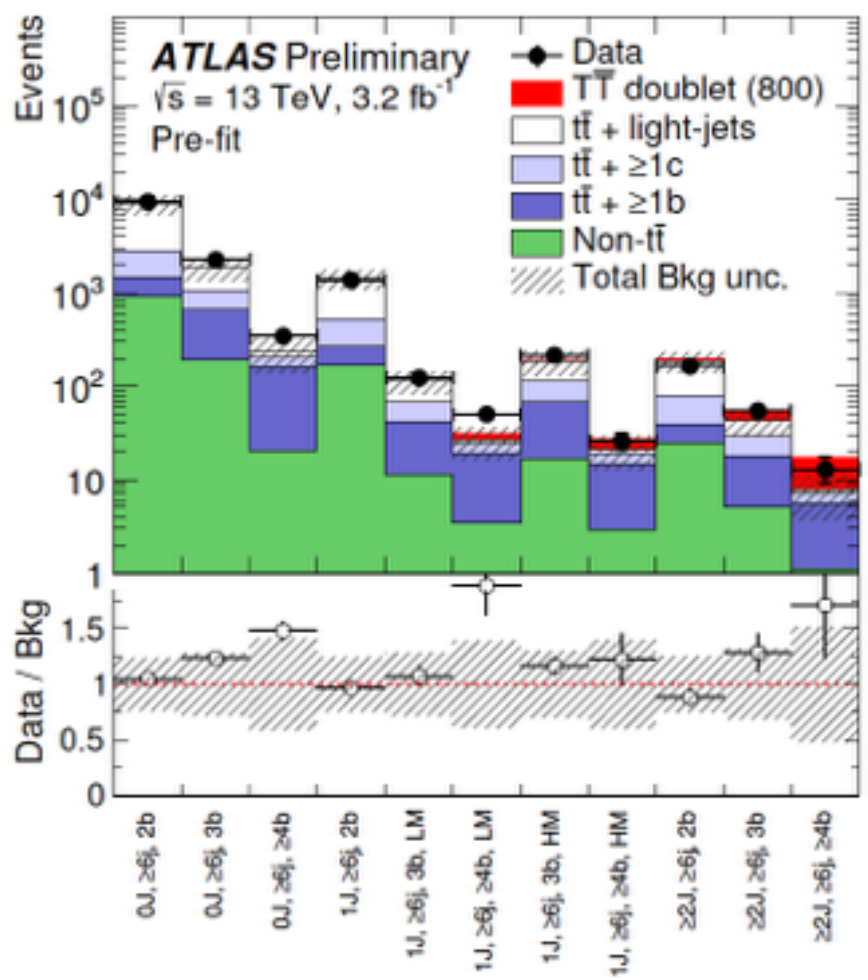


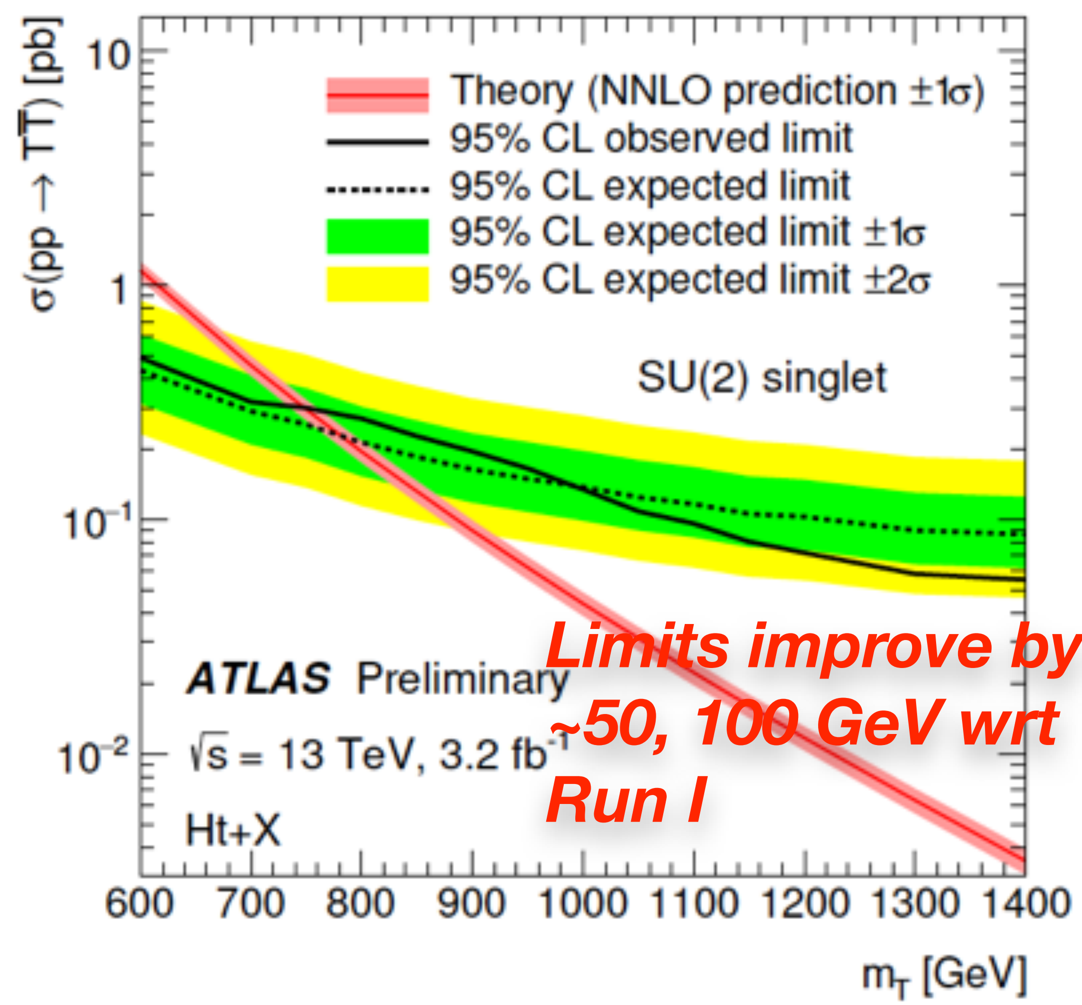


T-pair production

	ATLAS	CMS
Reference	ALTAS-CONF-2016-013	CMS-PAS-B2G-16-002
$N_{leptons}$	1 (e or μ)	1 (e or μ)
N_{jets}	≥ 6	≥ 3
$N_{b\text{-}jets}$	2,3,≥ 4	0,1,2,≥ 3
$N_{\text{Large-cone jets}}$	mass-tagged (t, H) (0,1, >2) trimmed mass >100 GeV, ≥2 subjets	W-tagged jets (0,≥ 1) pruned mass ∈ [65,105] GeV
Categories	20	16

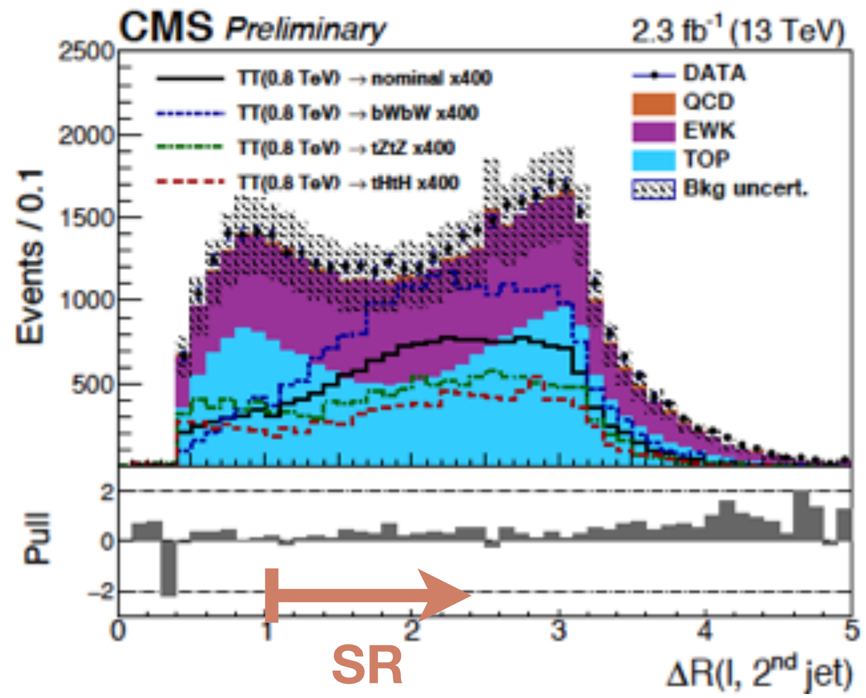
- At lest 1 T→tH
- Background estimation from simulation except for multi jet background (data driven)
- Validation regions with low jet multiplicity
- Fit $m_{eff}=MET+p_{T,\ell}+\sum p_{T,jet}$
- Interpretation in the tttt production, in the SU(2) singlet and doublet and limits set on BR to Wb (back-up)



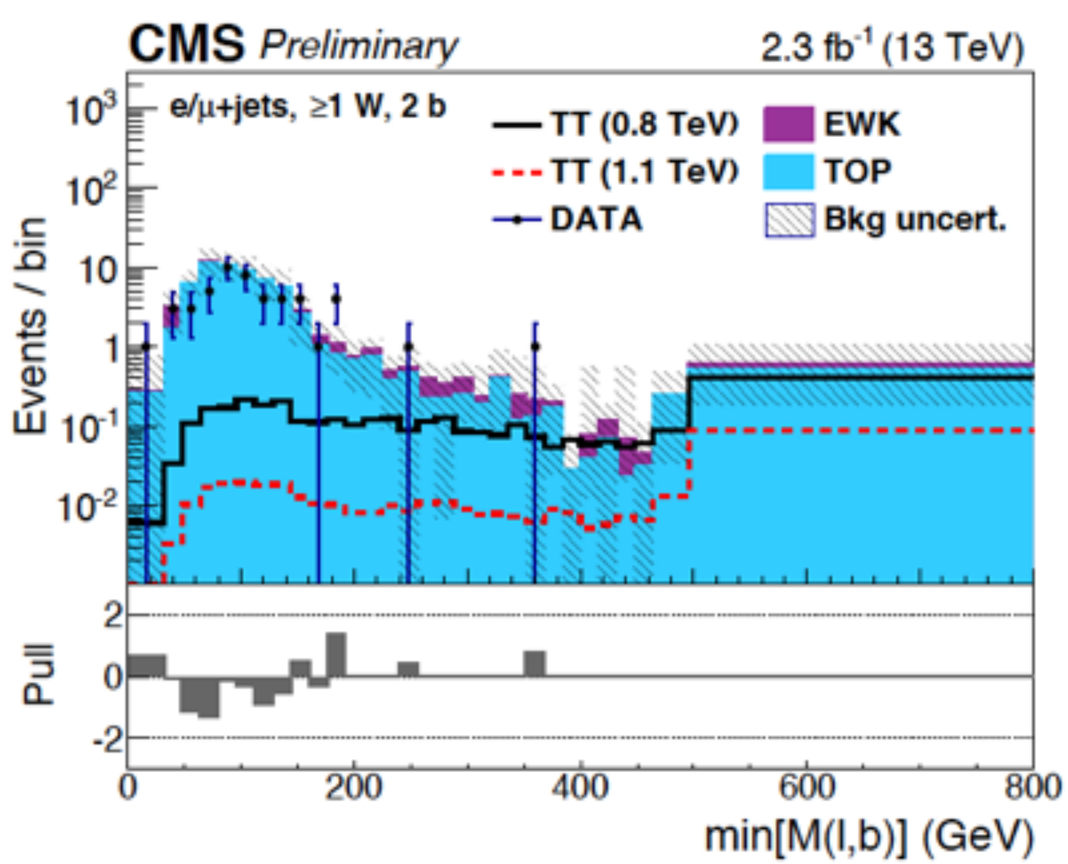


T-pair production

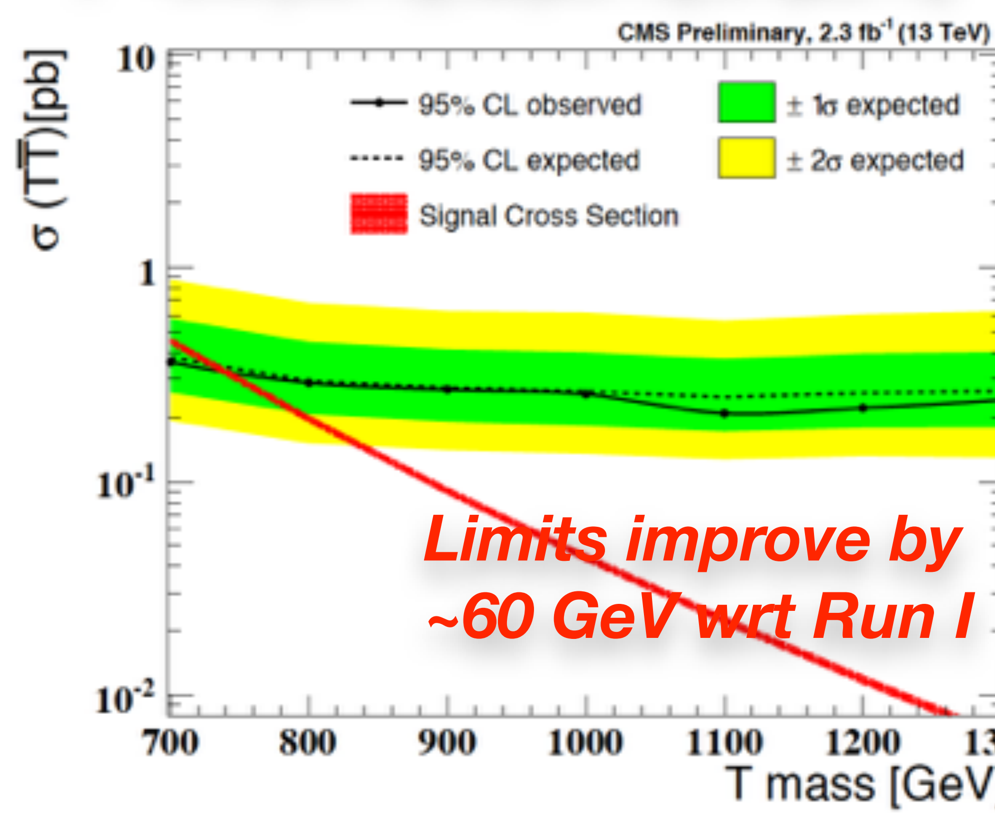
	ATLAS	CMS
Reference	ALTAS-CONF-2016-013	CMS-PAS-B2G-16-002
$N_{leptons}$	1 (e or μ)	1 (e or μ)
N_{jets}		≥ 3
$N_{b\text{-}jets}$		0,1,2,≥ 3
$N_{\text{Large-cone jets}}$		W-tagged jets (0,≥ 1) pruned mass ∈ [65,105] GeV
Categories		16



- Background estimation from simulation (tt and W +jet)
- Validation in dedicated control region: $\Delta R(\ell, j_2) < 1$
- Main discriminating variable min[M(l,b)]
- Limits set for different BRs to Wb,Ht, Zt (back-up)



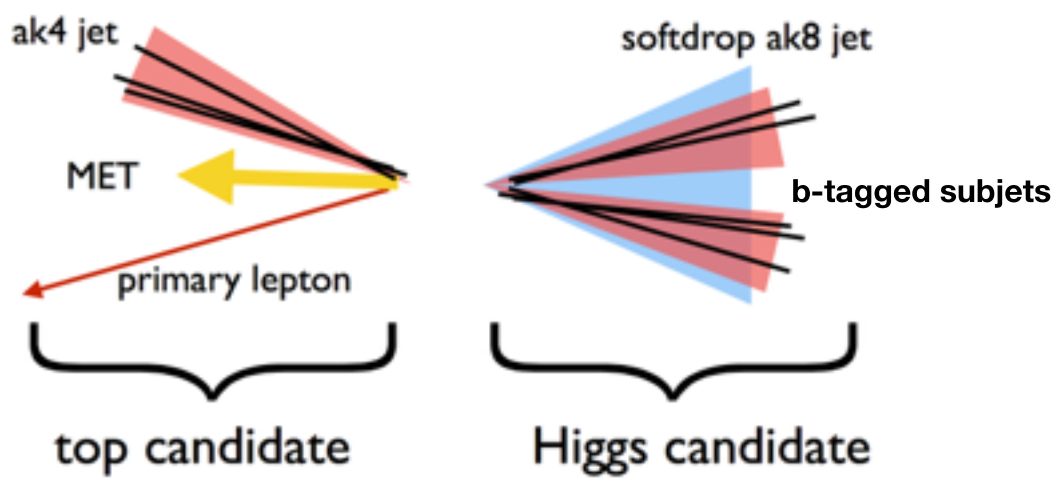
T→bW(50%),tZ(25%),tH(25%)



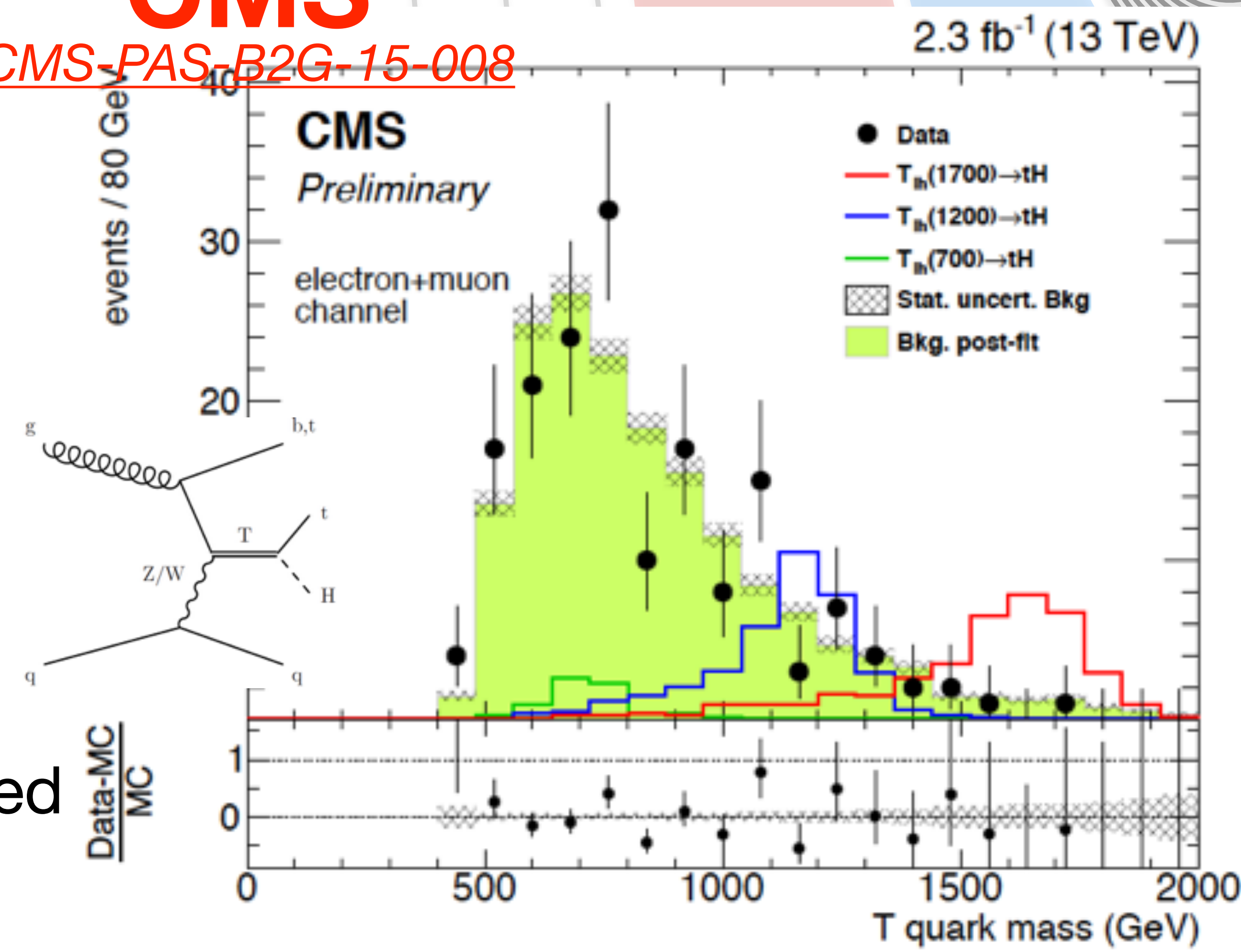
Single production: T→tH

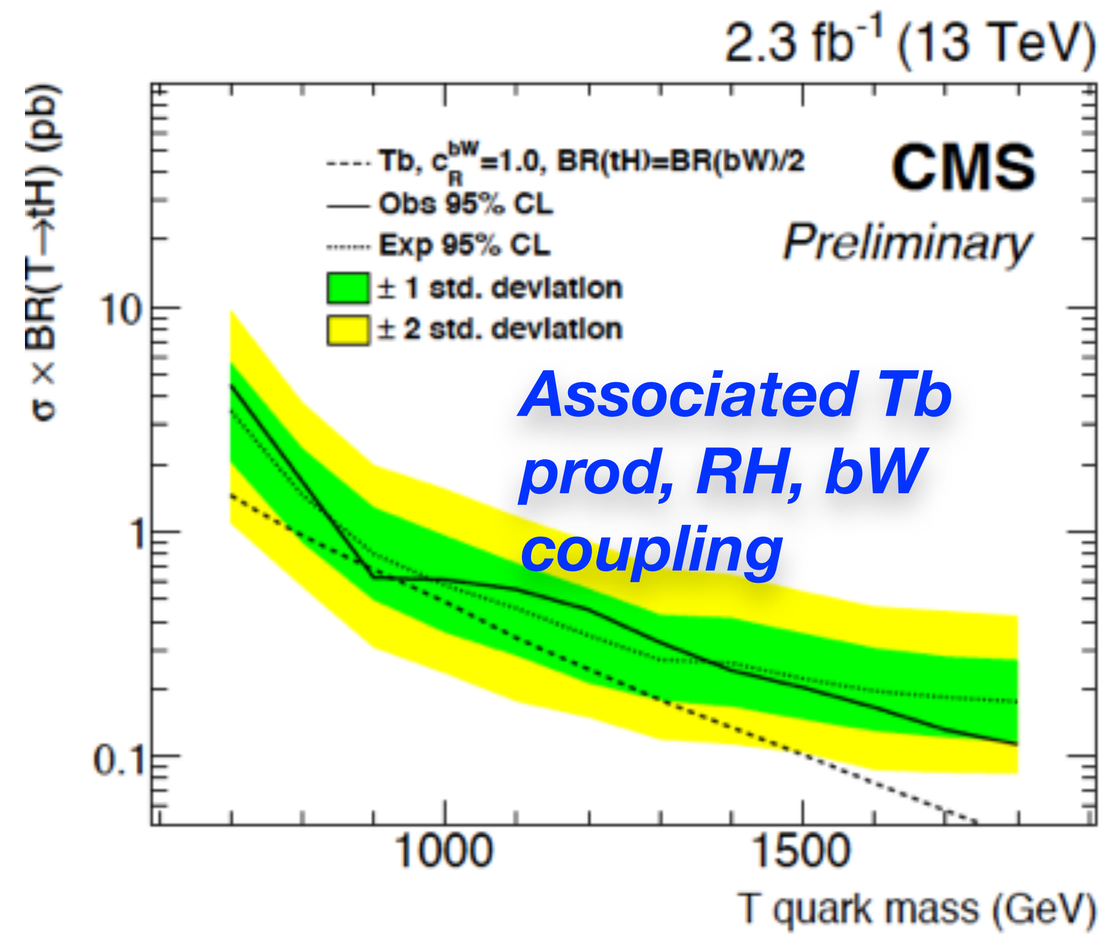
CMS
CMS-PAS-B2G-15-008

- Single production of Vector-like T quark
  - bW, tZ coupling in production
  - tH exclusive decay in lepton + jets final state (at least 1 forward jet)
- For large T masses top and H candidates are boosted
  - non-isolated leptons($p_T^{rel}(\ell, j)$) and merged jets (H)



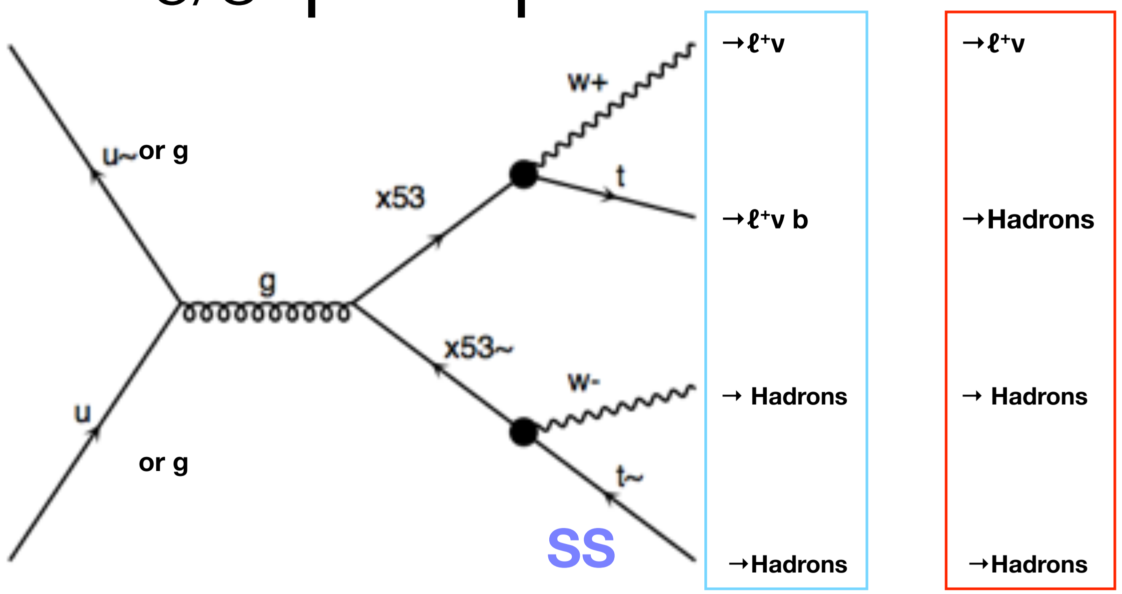
- Main background : top and W+jets
  - Derived from control region in data (no fwd jet and only 1 subjet b-tagged)





$X_{5/3}$-pair production

CMS-PAS-B2G-15-006



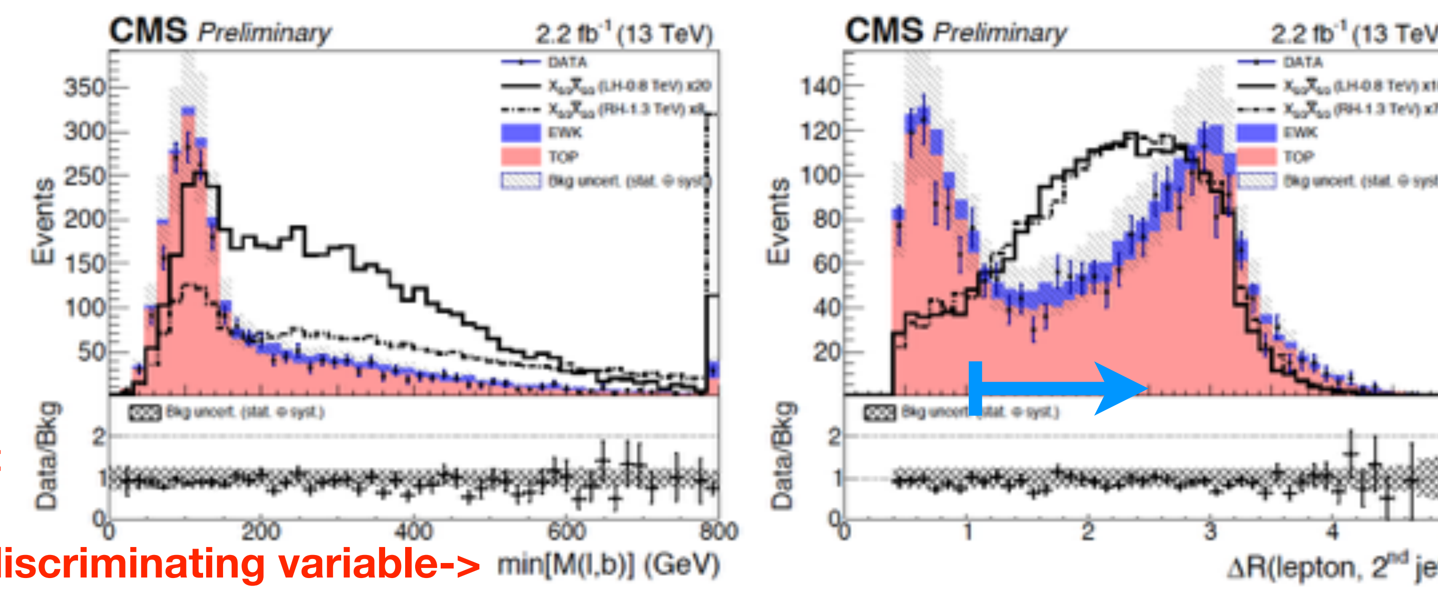
- Main backgrounds :
  - fake leptons and charge misidentification estimated using data driven methods
  - Di/Tri boson from simulation(WW,ZZ,ttW,ttZ,WWW)

l+jets

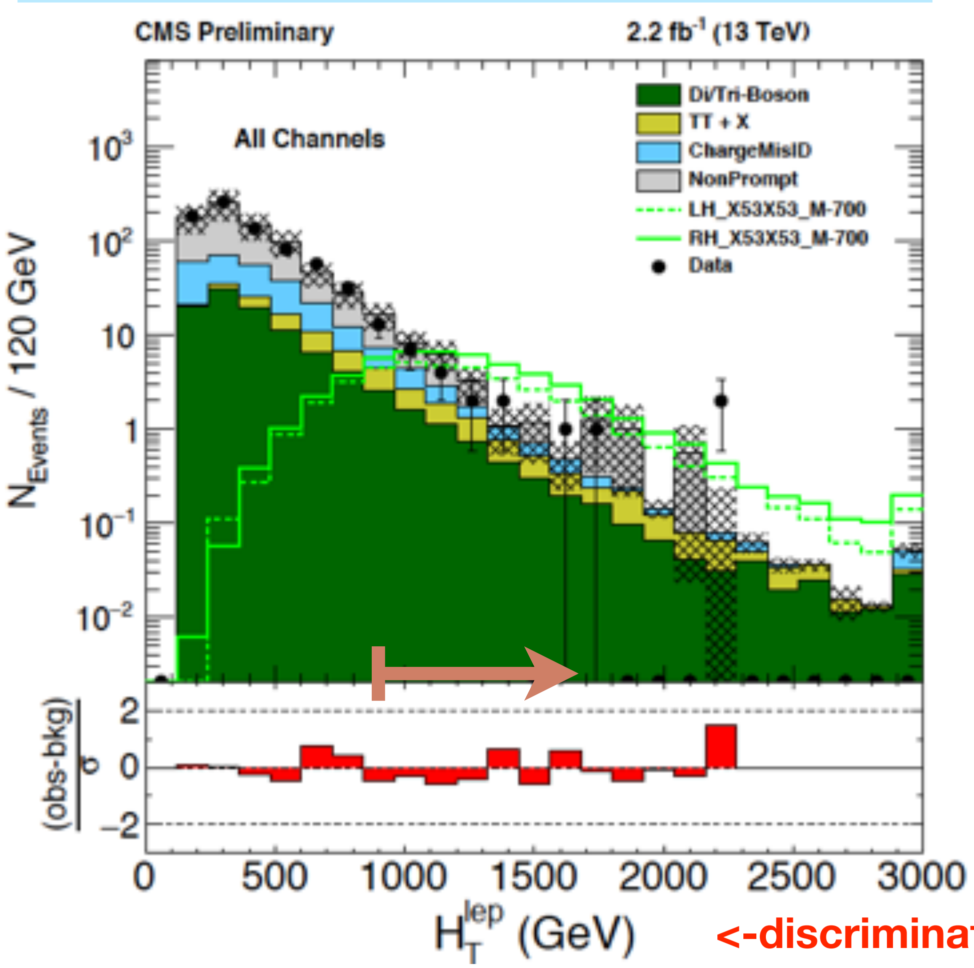
+boosted W-tagged jet

- Main backgrounds :
  - top pair production and V+jets estimated from simulation and checked in dedicated CR

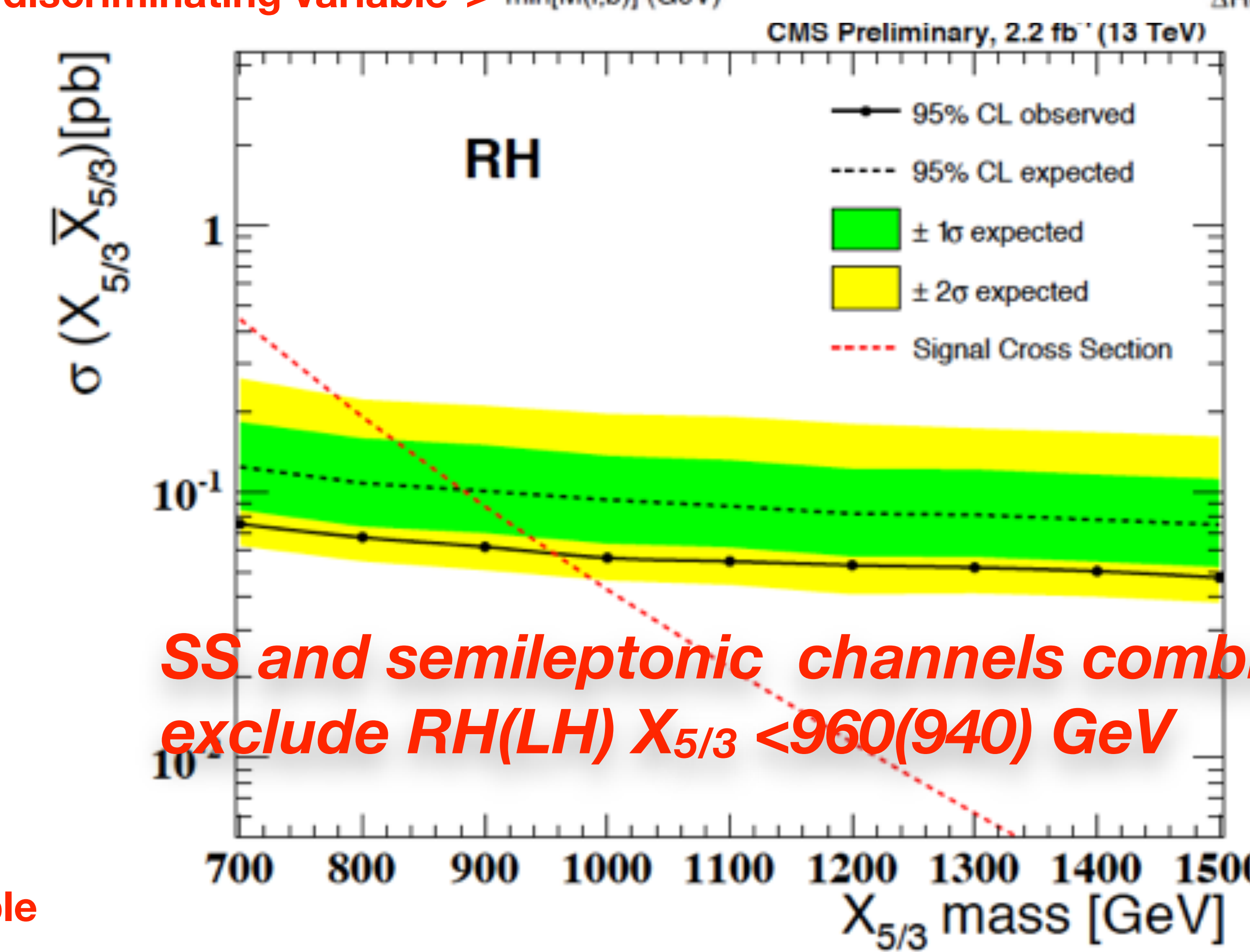
First result in this channel !



discriminating variable->



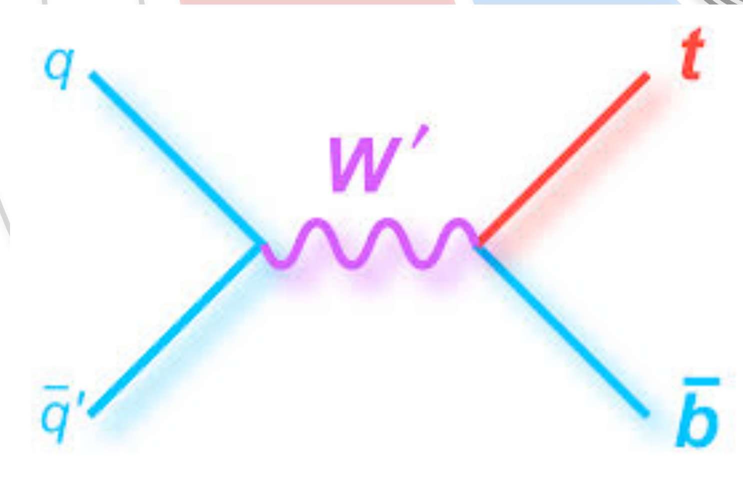
<-discriminating variable



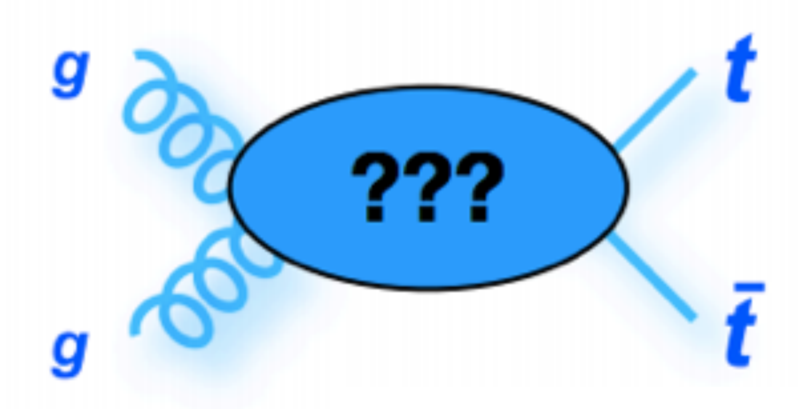
SS and semileptonic channels combined exclude RH(LH) $X_{5/3}$ <960(940) GeV

Resonances

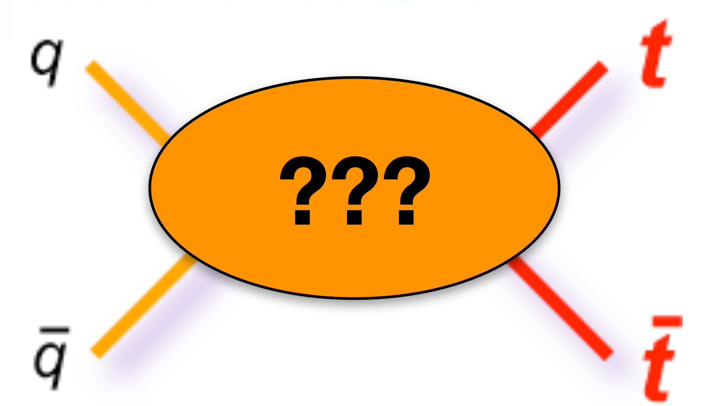
Searches for tt and tb resonances



- Several new physics models predict new gauge interactions with enhanced coupling to third generation quarks :
- ttbar:
  - Generic wide and narrow Z' models, Heavy Higgs, extra dimensions kk excitations



- tb:
  - Generic wide and narrow W' models, Little Higgs, extra dimensions



- Analysis in Run I

	ATLAS	*CMS*
W'->tb	M(W')>1.9 TeV *Phys.Lett B 743 (2015)*	M(W')>2.15 TeV *JHEP 02(2016)*
Z'-> tt		
Narrow (~1%)	M(Z') >1.8 TeV *JHEP08(2015)148*	M(Z') >2.4 TeV *PRD 93(2016) 0120001*
Wide	(3%)M(Z')>2.3TeV **l+jets**	(10%) M(Z')>2.9TeV **combination**
KKgluon excitation	M(KKG)>2.3TeV	M(KKG)>2.8 TeV

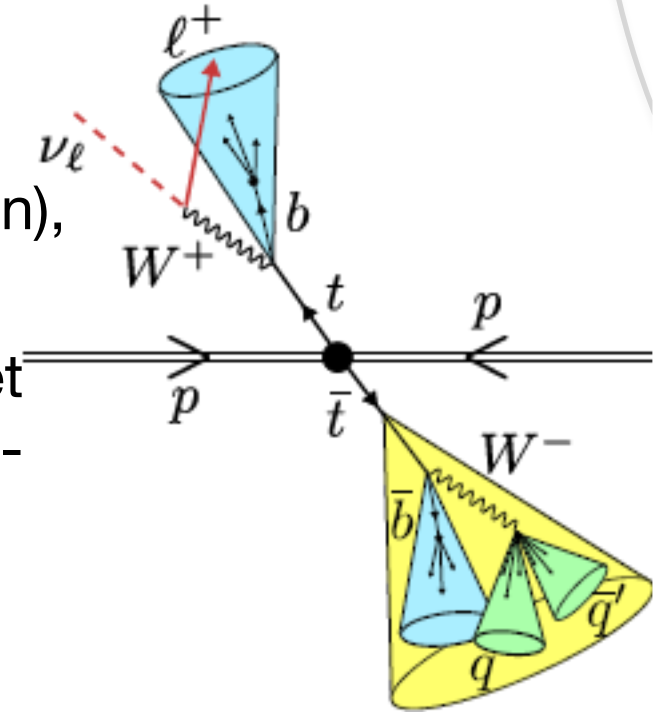
Searches for tt resonances

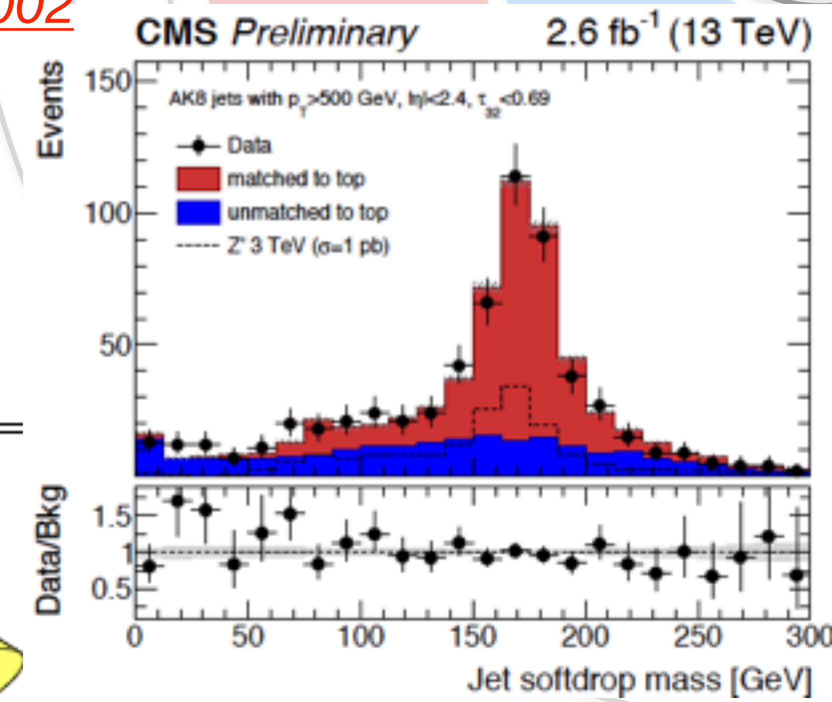
CMS

CMS-PAS-B2G-15-002

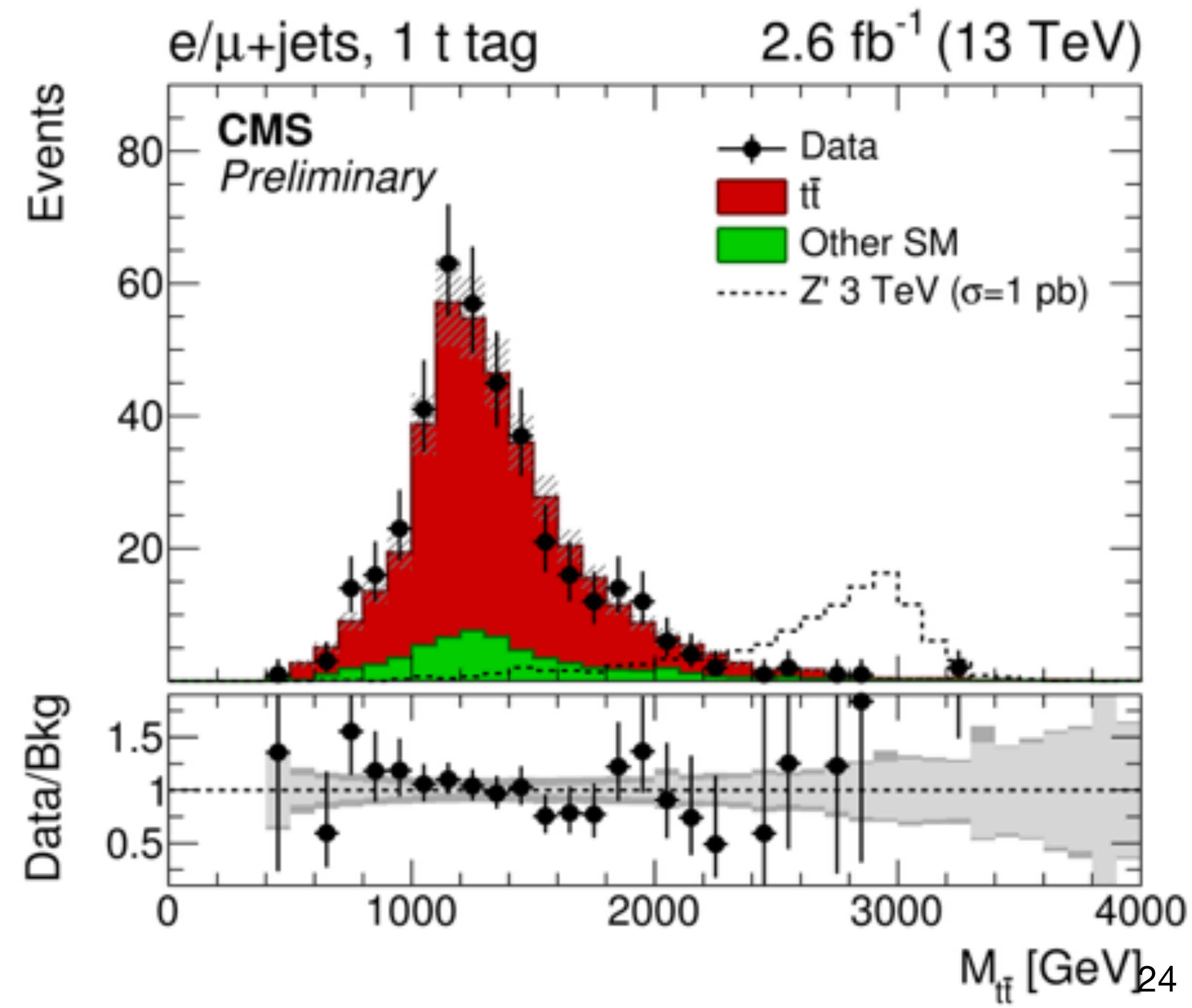
- lepton +jets analysis optimized for heavy resonances
  - leptonic top: lepton (dedicated isolation), missing E_T, b-tagged jet
  - hadronic top: large cone top-tagged jet (softdrop mass ∈ [110,210] GeV and N-subjetness $\tau_{32} < 0.69$)
  - choosing candidate minimizing:

$$\chi^2 = \left(\frac{M_{lep} - \overline{M}_{lep}}{\sigma_{M_{lep}}}\right)^2 + \left(\frac{M_{had} - \overline{M}_{had}}{\sigma_{M_{had}}}\right)^2$$



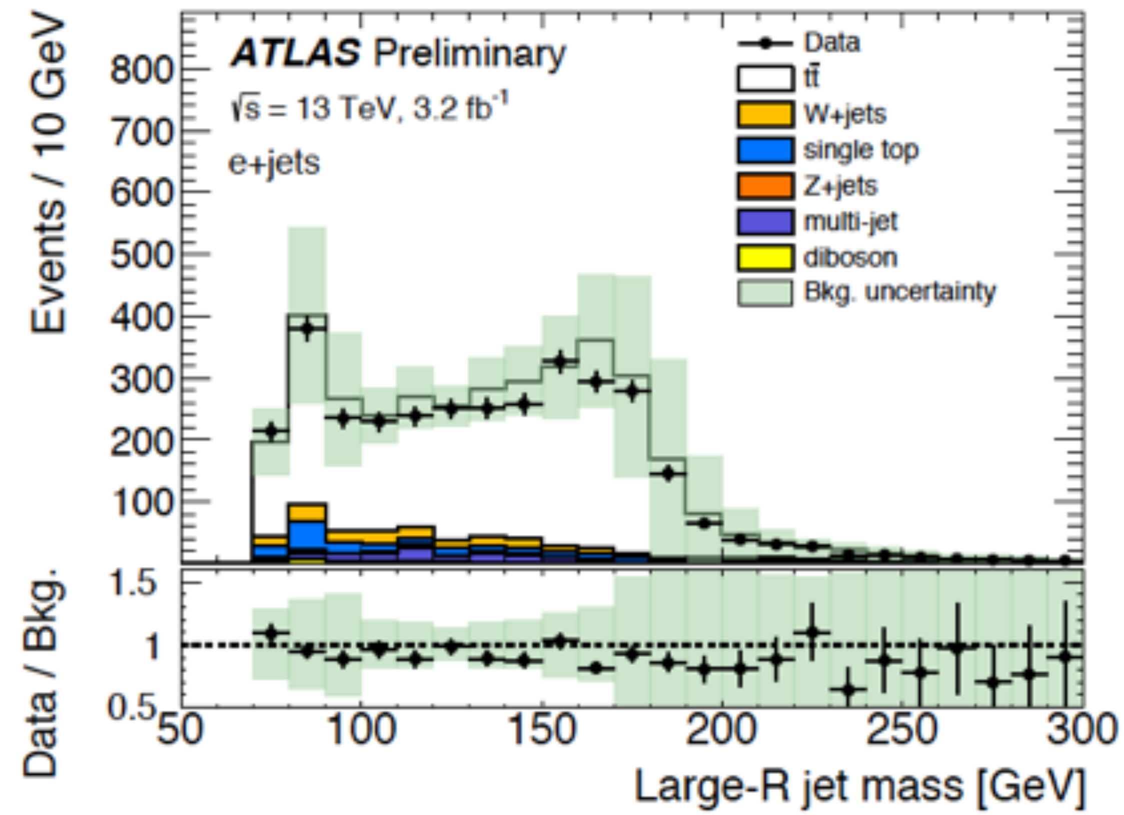


- Event search regions:
  - 1 top-tagged;
  - 0 top tagged, 1b-tag;
  - 0 top tagged, 0b-tag;
- Simultaneous max.likelihood fit
- Background estimation:
  - M(t,t) in tt-dominated low M(tt)
  - M(t,t) in W+jet CR: inverted χ^2
  - M(l,l) in DY CR: dilepton events

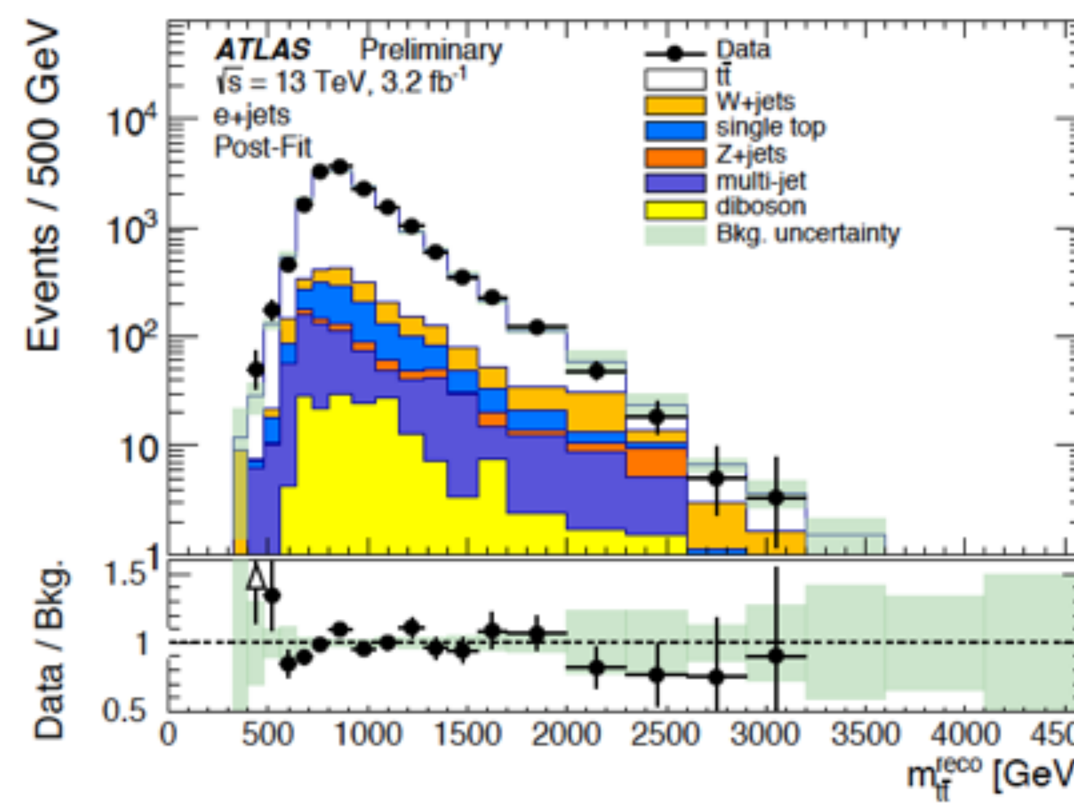


Searches for tt resonances ATLAS-CONF-2016-014

- lepton +jets analysis optimized for heavy resonances
  - leptonic top: lepton (dedicated isolation), missing E_T, closest b-tagged jet
  - hadronic top: large cone top-tagged jet (trim mass and N-subjetness τ_{32})



- Background estimation:
  - W+jets normalization (charge asymmetry in data and simulations)
  - Multi-jet fake leptons contributions from CR
  - tt-production from simulation
- bump hunt in M(t,t) spectrum

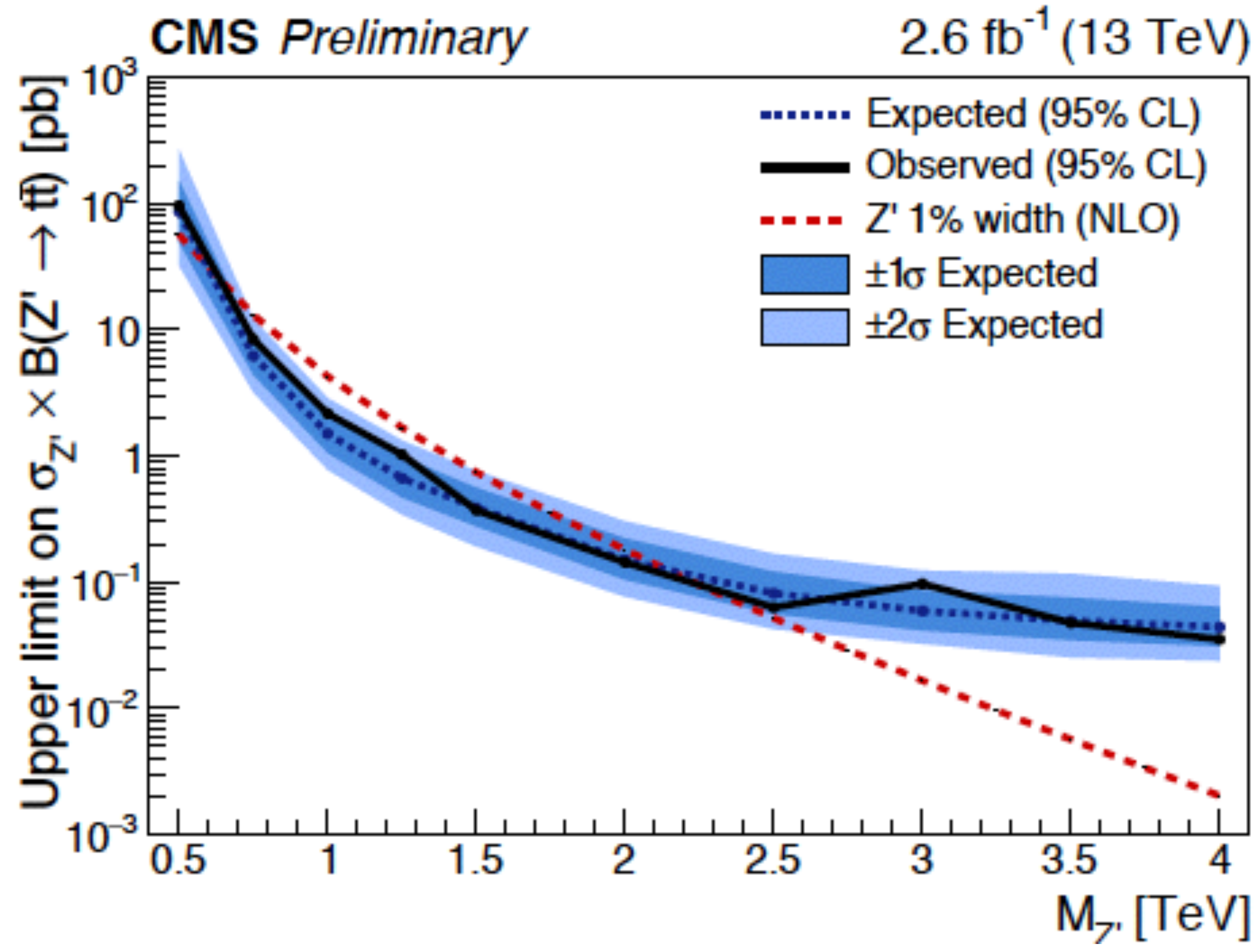


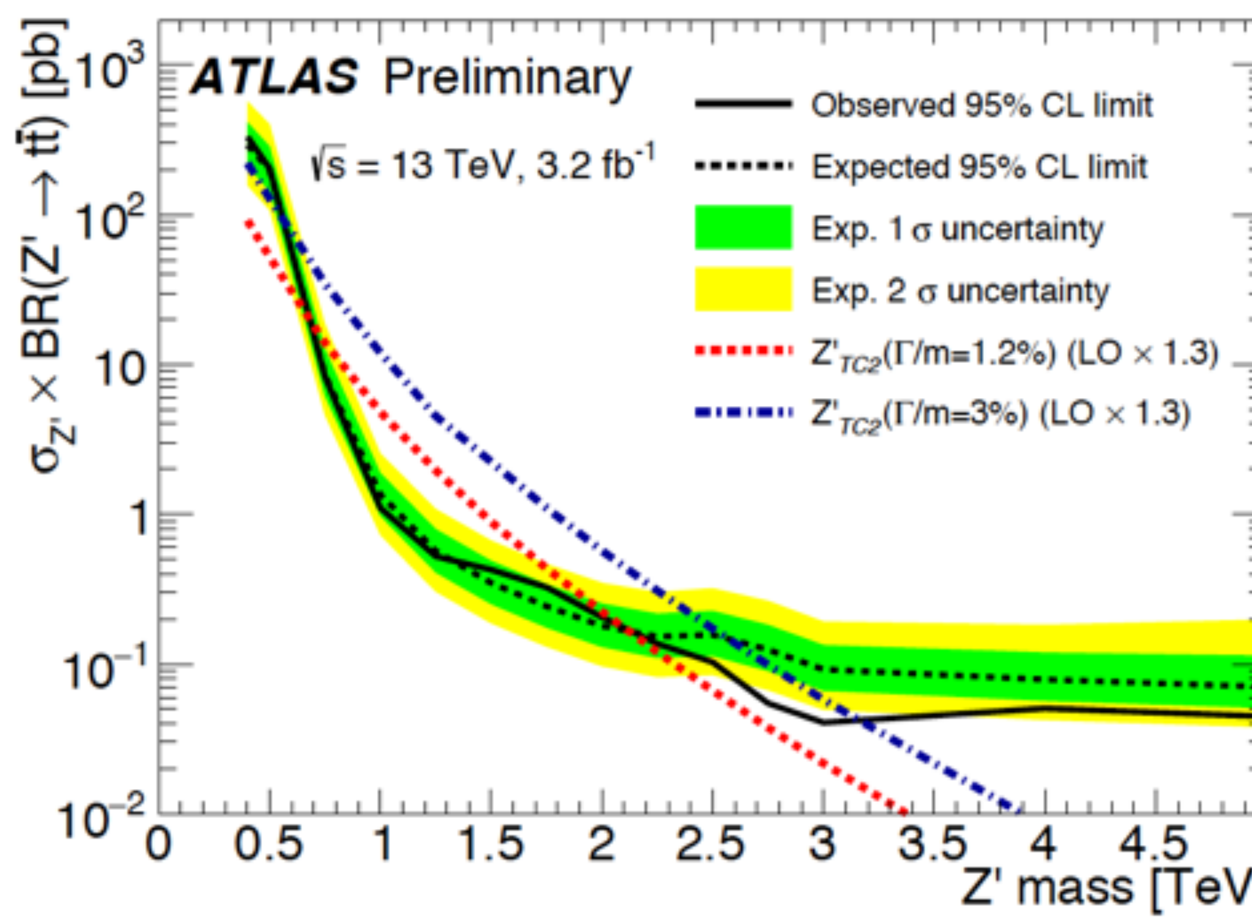
Searches for tt resonances

- Both analysis found data in agreement with SM prediction
- 95% CL limits are set for different scenarios (more in back up)
- Similar sensitivity as Run I

CMS
CMS-PAS-B2G-15-002

ATLAS
ATLAS-CONF-2016-014

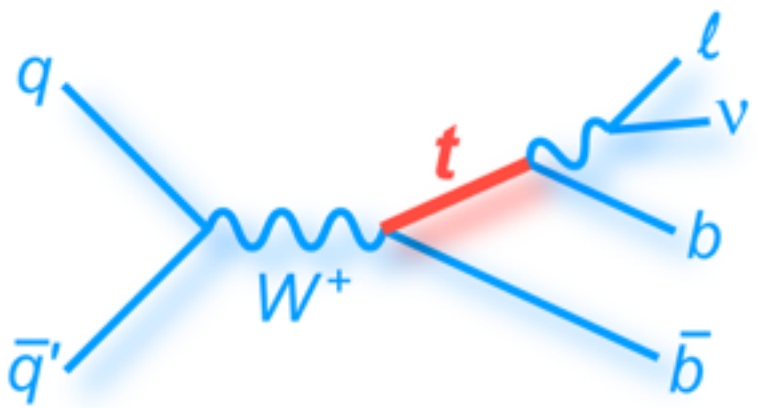




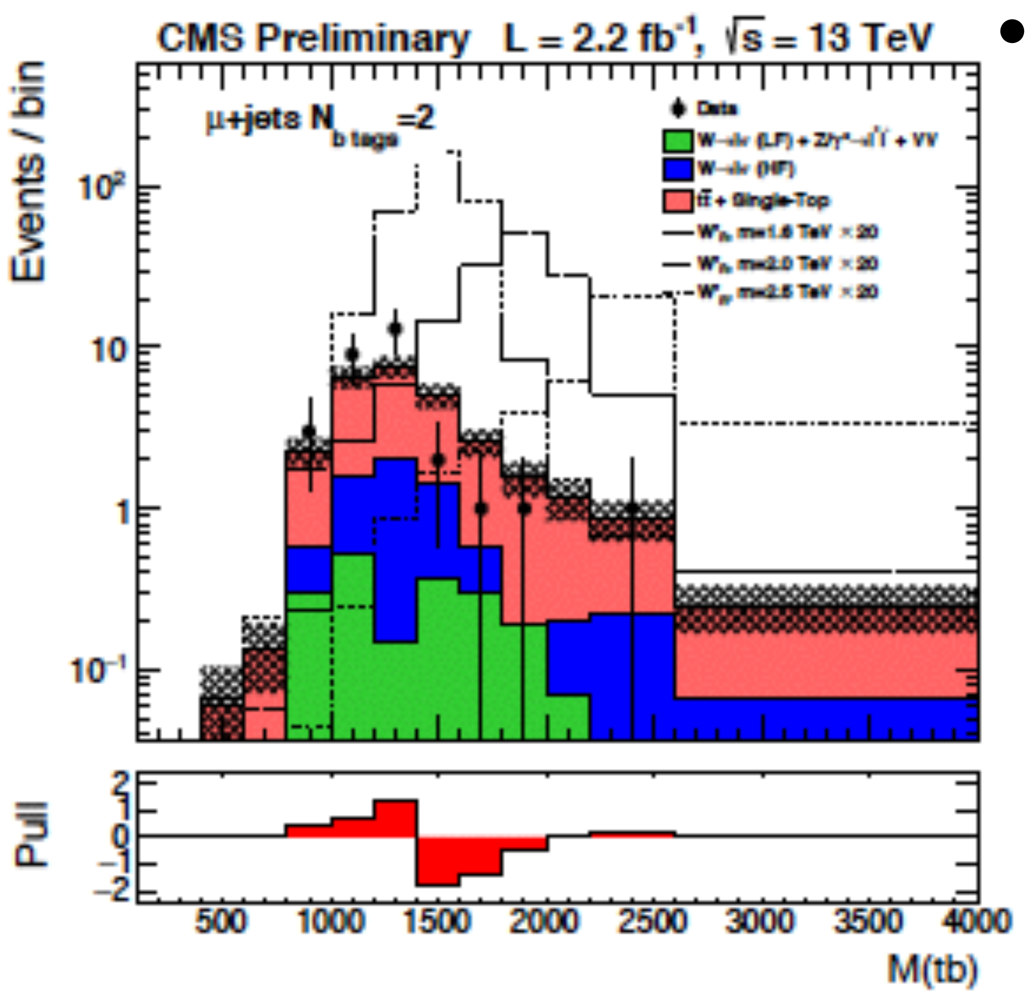
Searches for tb resonances

CMS

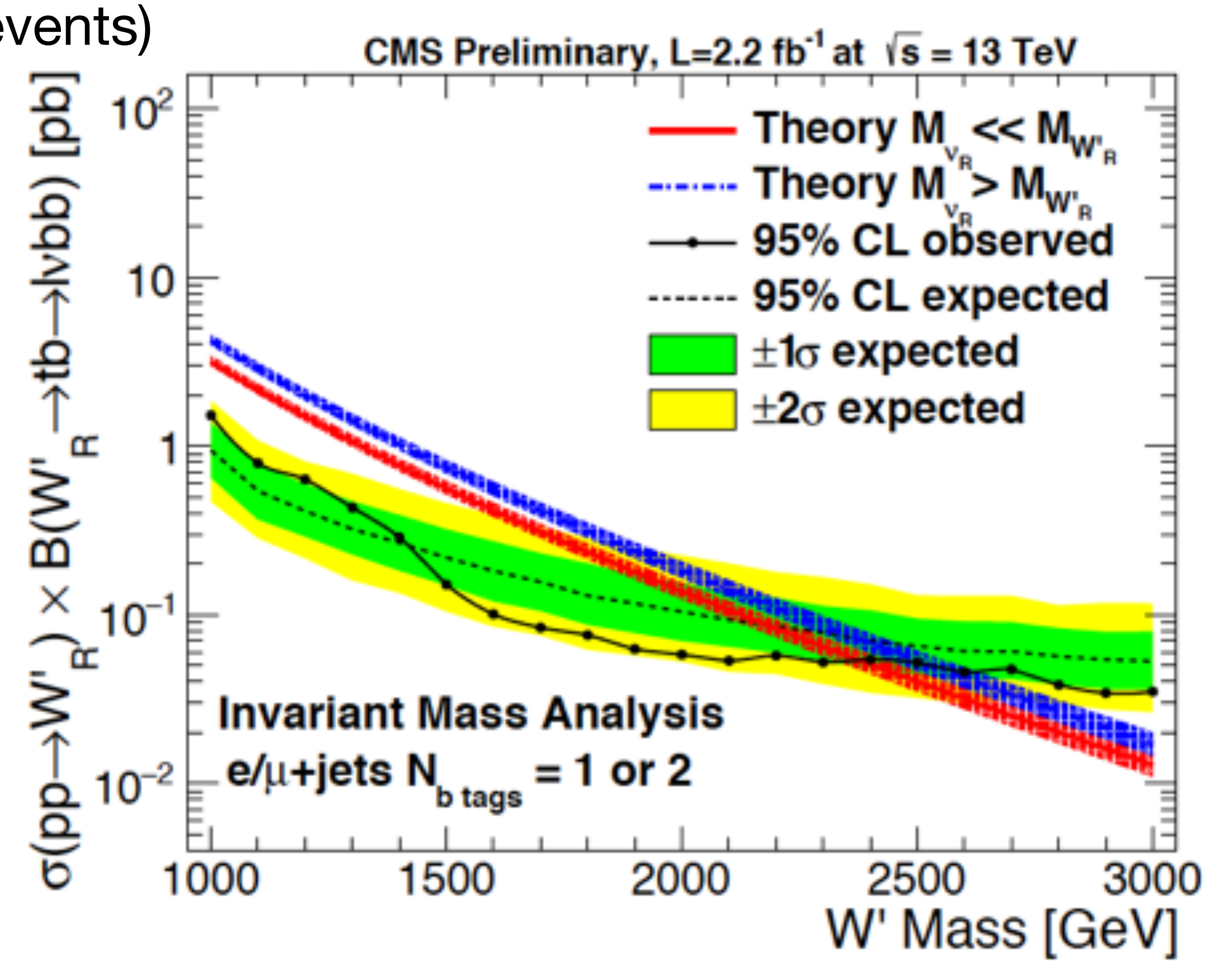
CMS-PAS-B2G-15-004



- Right handed W with SM-like coupling as benchmark model
- Semileptonic final state
  - optimized isolation requirements for higher boost wrt Run I (relative momentum b/w lepton and jet for multi-jet events rejection)
- Fit of the M(t,b) spectrum in different categories:
  - (e or μ) × (1 or 2) b-tagged jets
- Background estimation:
  - W+jets: iterative normalization estimated in 0 b-tagged (light flavor enriched), then in pre b-tagged control regions(hf)
  - tt: checked top pt distribution in CR (dileptonic and low M(tb) events)



Limits better than Run I

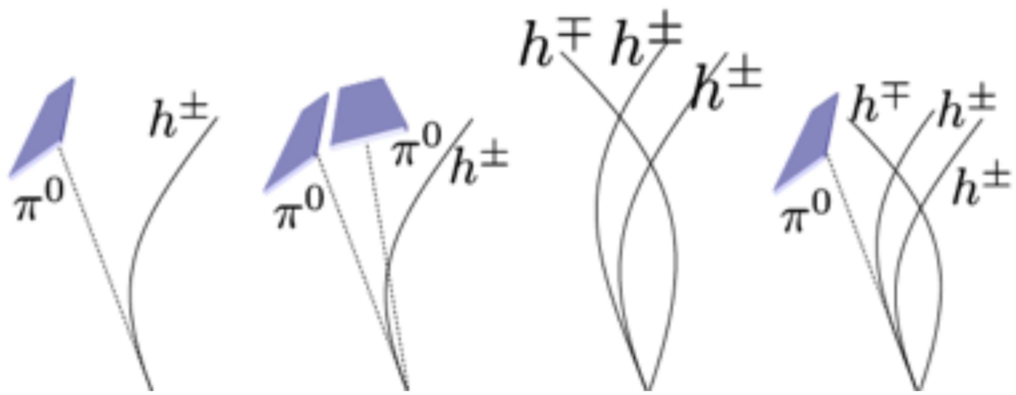


Searches for $\tau\nu$ resonances

CMS

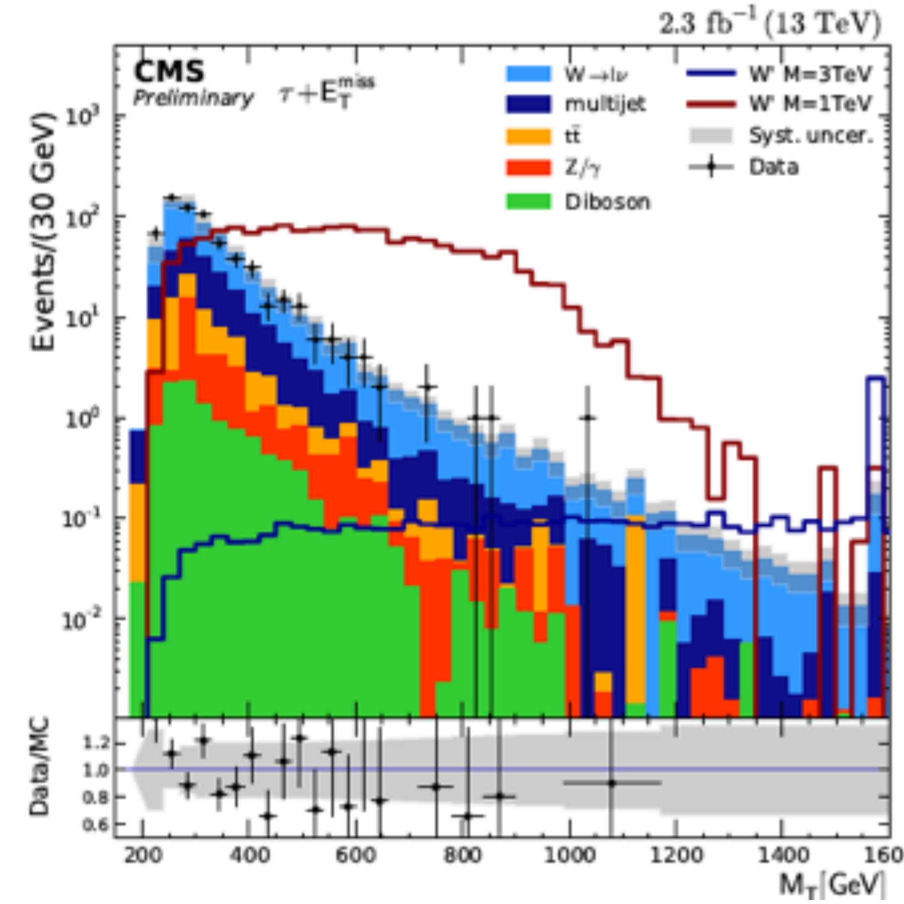
CMS-PAS-EXO-16-006

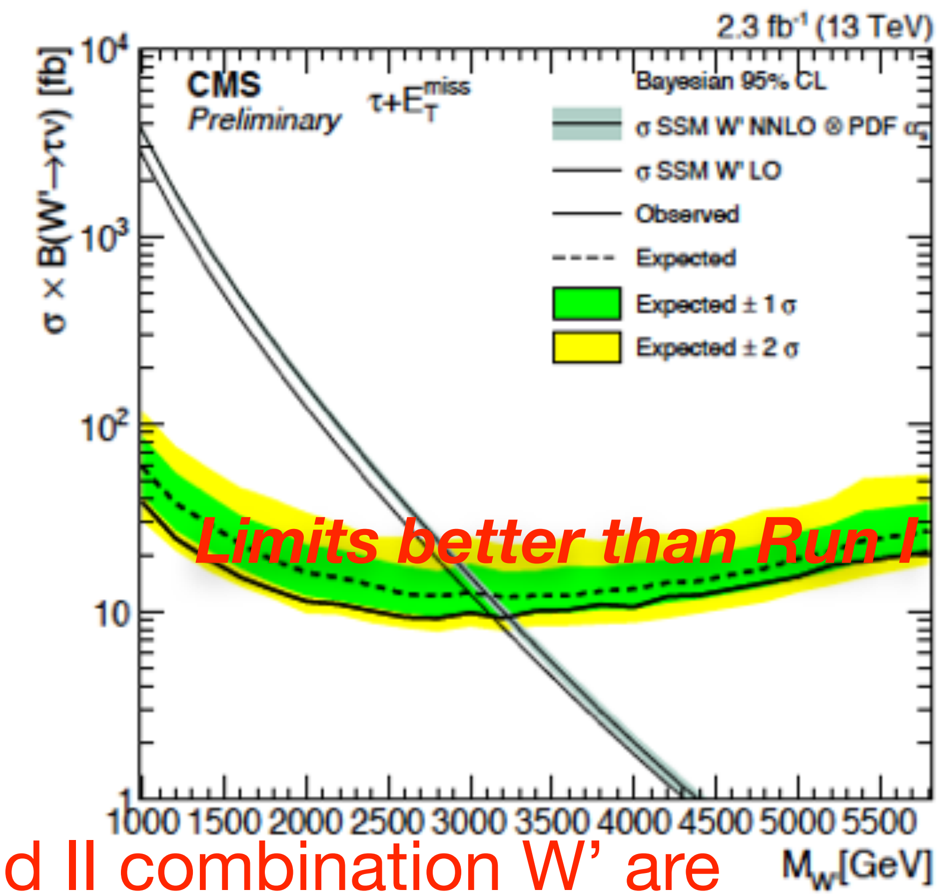
- Sequential standard model (SSM) W'
- Events with missing energy (> 120 GeV) and an hadronic tau (p_T> 80 GeV) identified combining different decay modes



- Main backgrounds:
  - SM off shell W from simulation (NNLO)
  - Multi-jet events with fake tau are estimated in data considering p_T and η dependent fake rate (5-1%)
- Fit to transverse mass:

$$M_T = \sqrt{2\, p_T^{\tau}\, E_T^{\text{miss}}\, (1 - \cos\Delta\phi(\tau, \vec{p}_T^{\,\text{miss}}))}$$

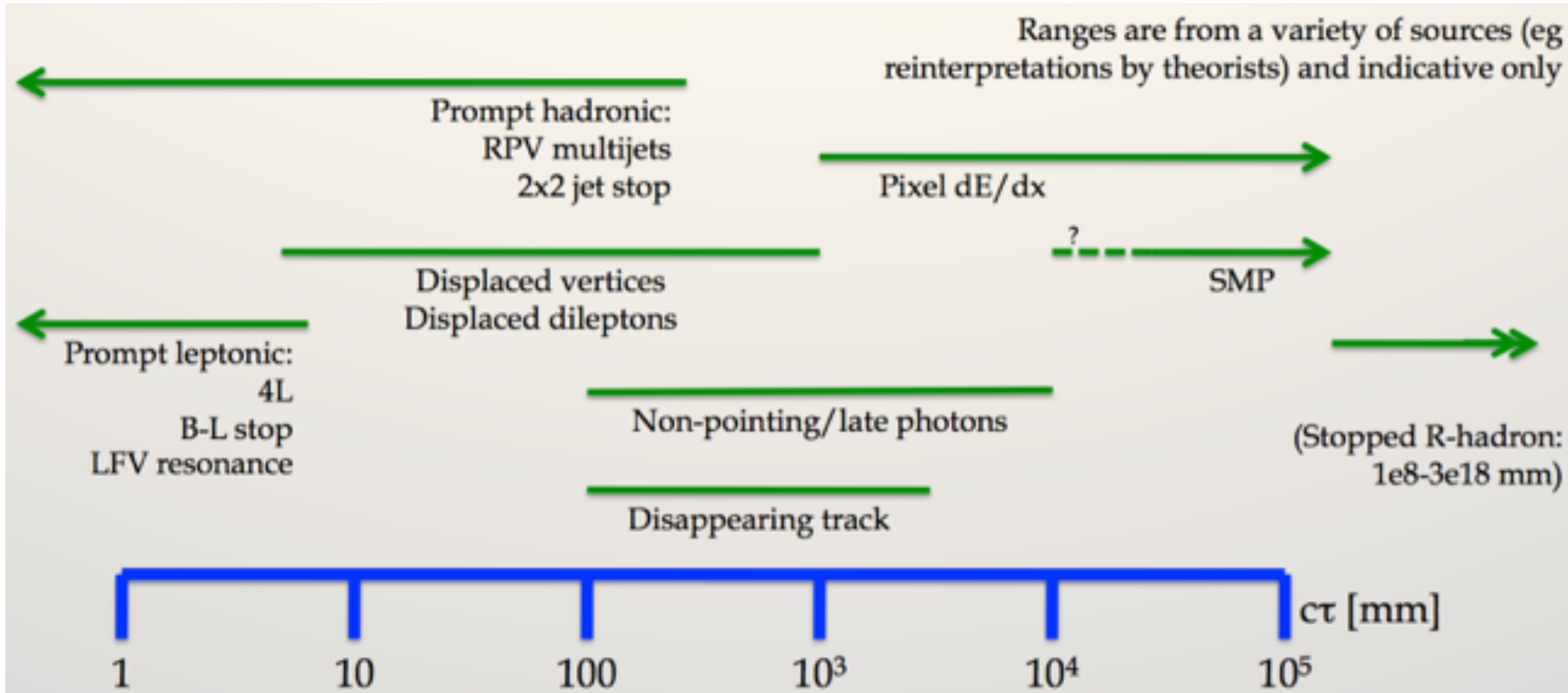


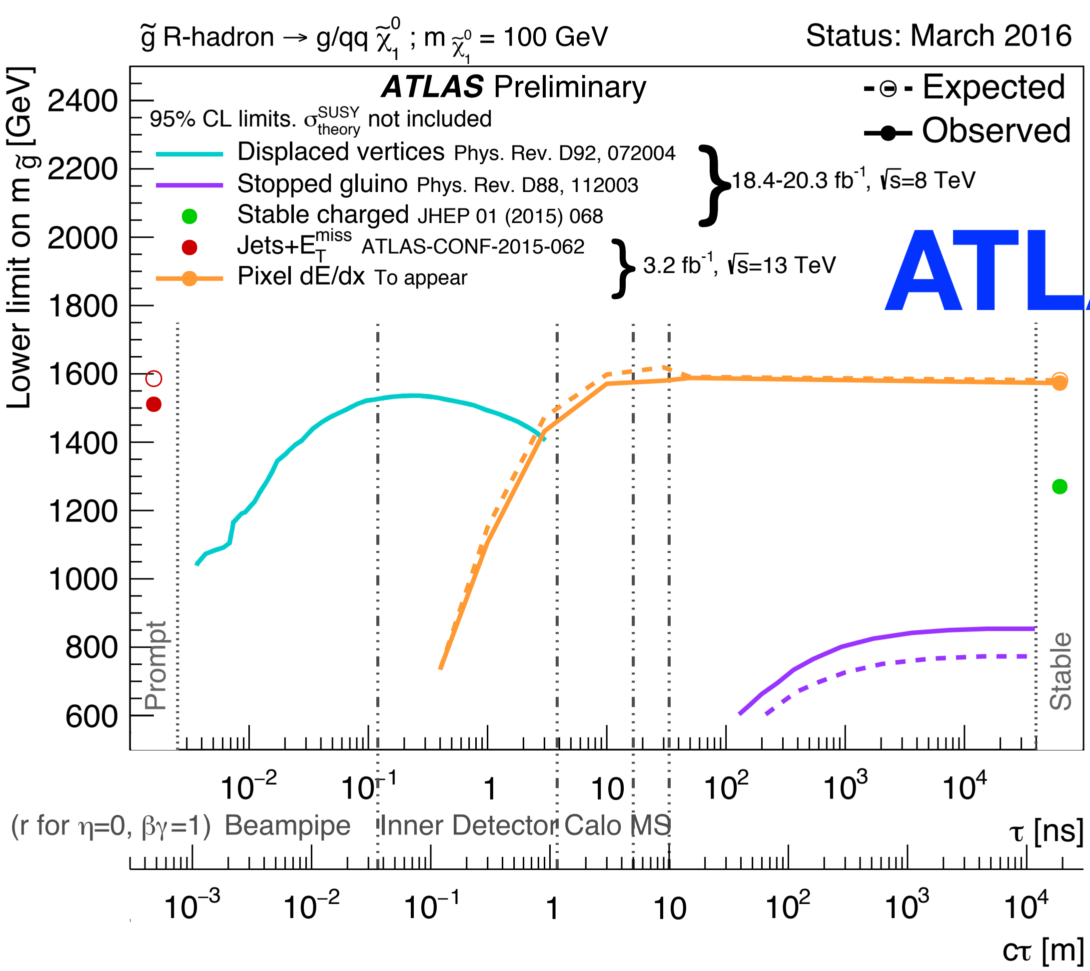


Run I and II combination W' are excluded in the mass range 300 GeV<M(W')<3.3 TeV

Long lived particles

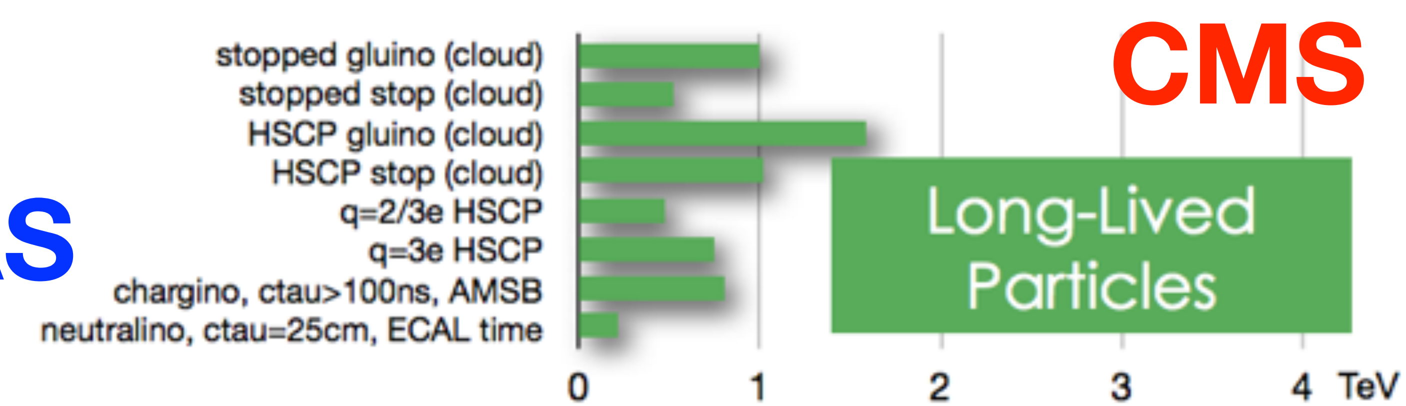
Long Lived Particle (LLP) Searches





ATLAS

CMS

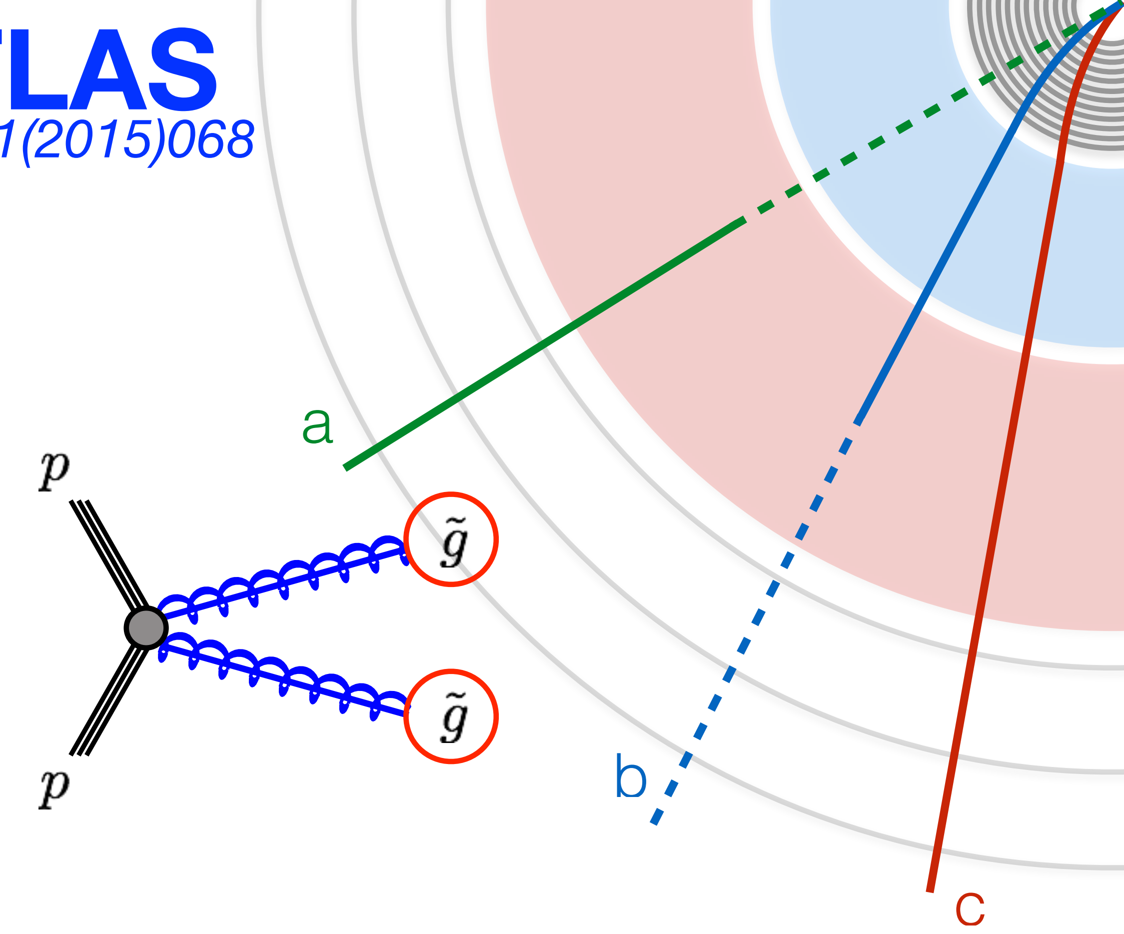


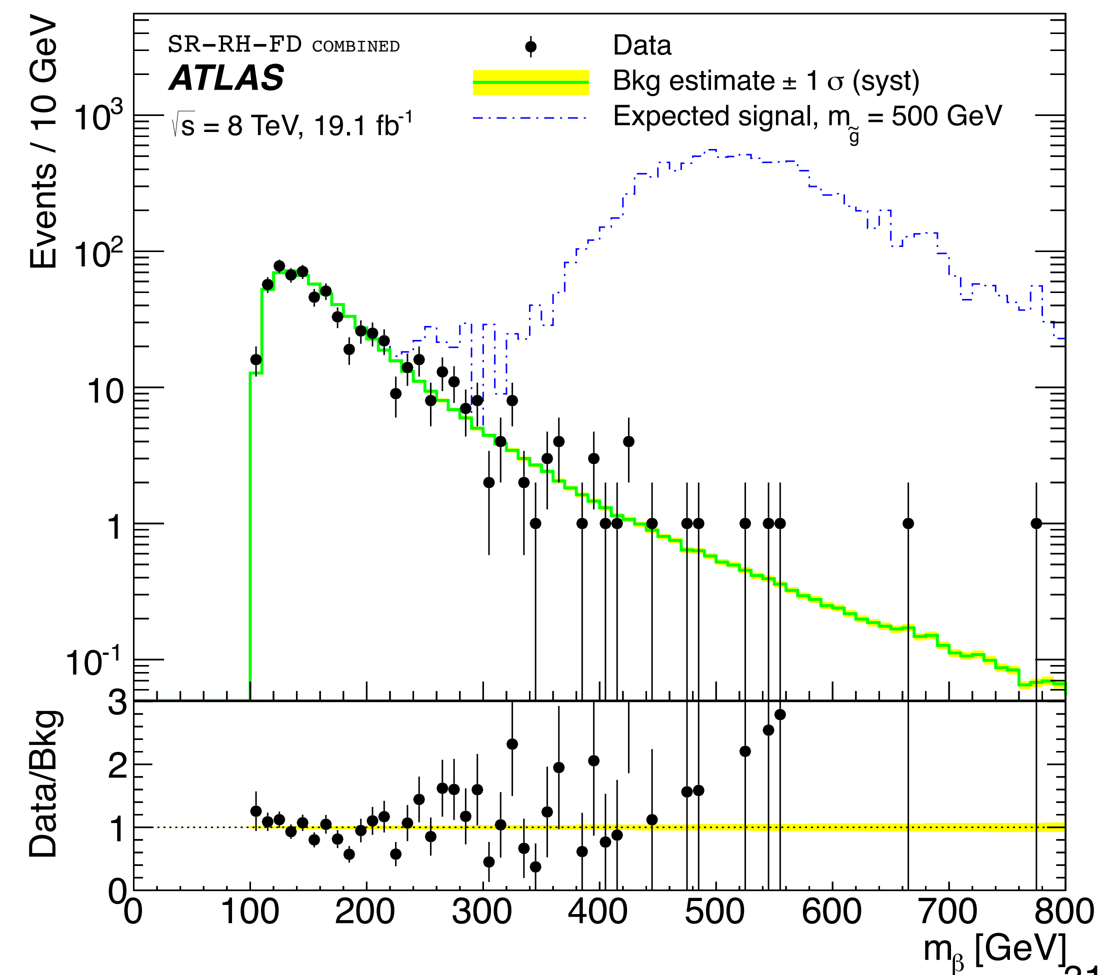
- LLP are particles that can decay inside the detectors
- Wide-ranging searches, exploiting different techniques, with some nontrivial overlaps in lifetime coverage

Stable Massive Particles

ATLAS
JHEP01(2015)068

- Search for long-lived massive charged particles
  - sleptons, charginos, or (sbottom/stop/gluino) *R*-hadrons
    - composed particles can undergo charge-flip (uncharged->charged a or vice versa b)
- Signatures
  - *long-lived charged*: interaction with at least one outer detector component, TileCal (hadronic calo) and/or MS (muon spectrometer); *massive*: low velocity β=v/c
  - main discriminants are *time of flight* (TileCal/MS) and *ionisation energy loss* (Pixel detector)
- Status and Plans
  - preliminary Run2 2015 analysis based on TileCal, with expected improvements of 20% w.r.t. Run1 mass limits
  - include MS (Full detector analysis)
  - if possible include LAr (EM calo) in β estimation
  - use slow-muon trigger (about 10% efficiency gain)
  - optimise searches in low mass region

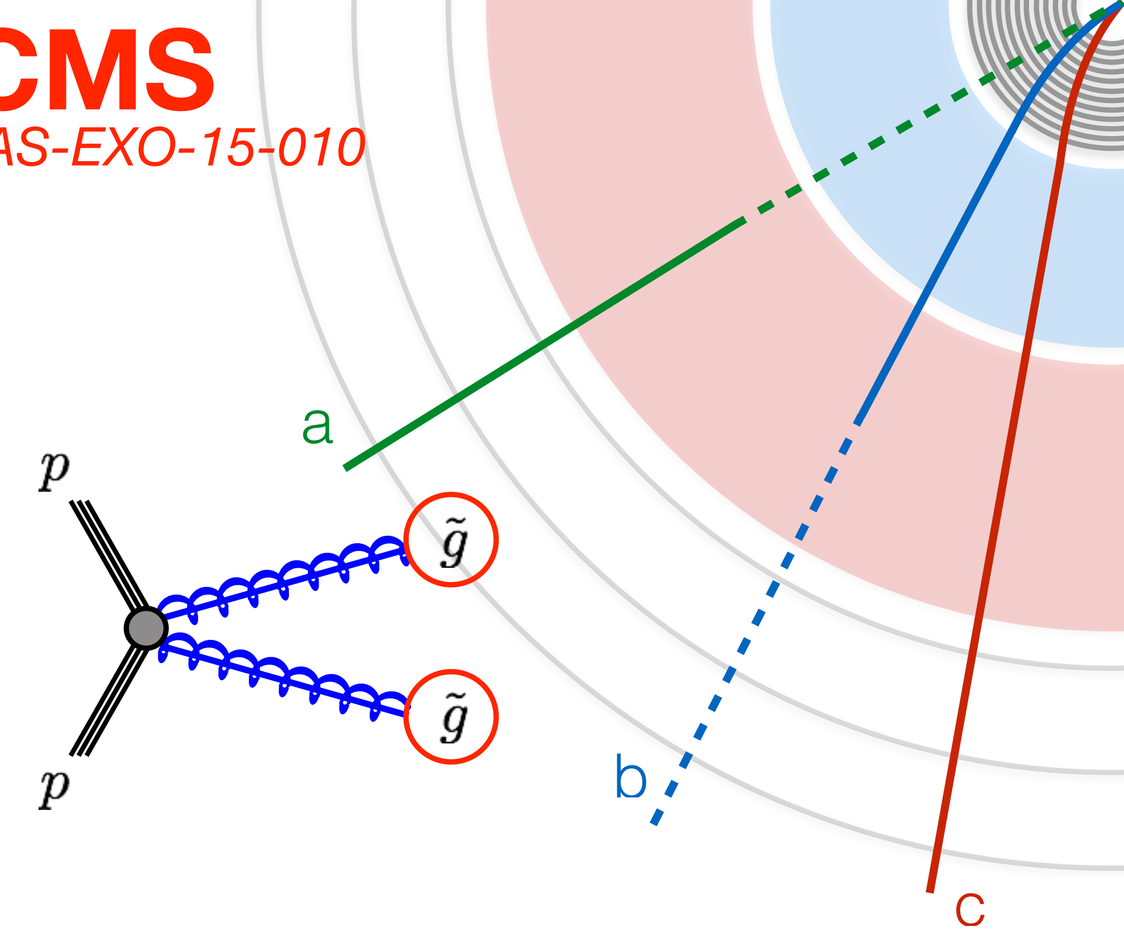


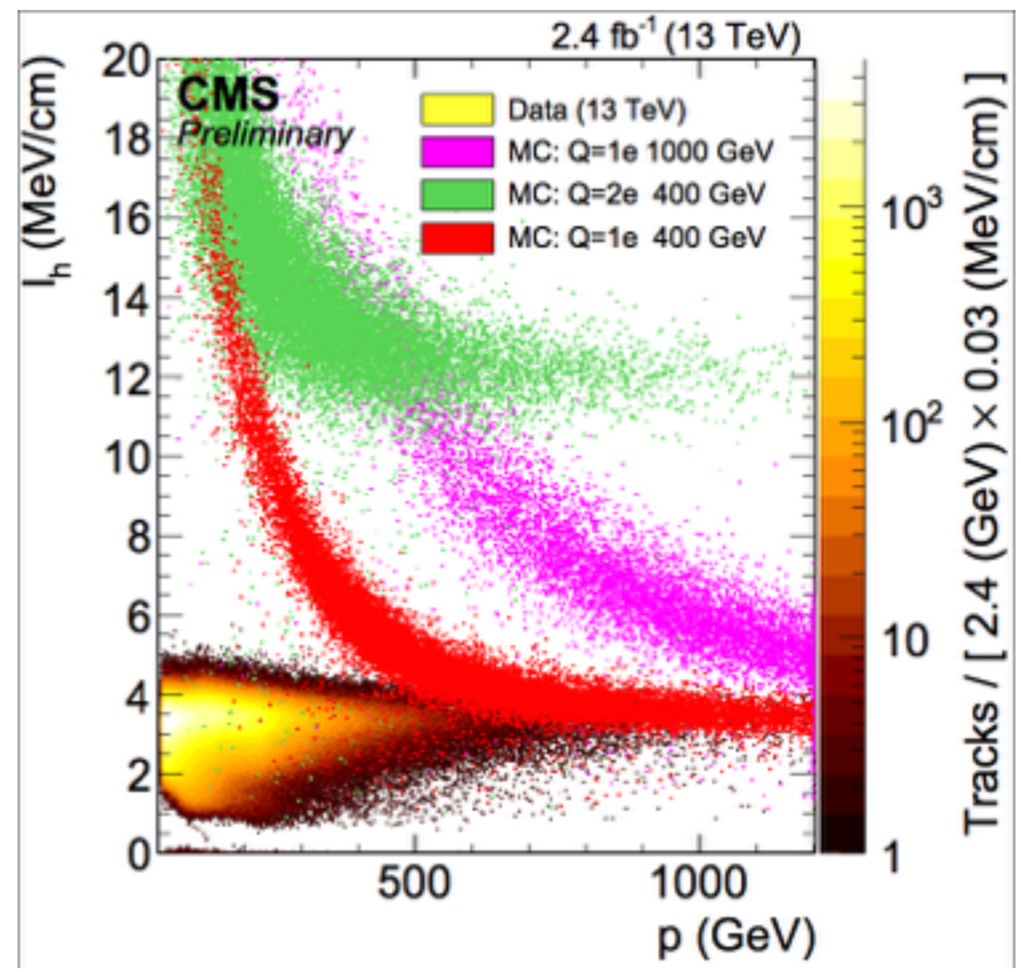


Stable Massive Particles

CMS
CMS-PAS-EXO-15-010

- Search for long-lived massive charged particles
  - sleptons, or (stop/gluino) *R*-hadrons
    - composed particles can undergo charge-flip (uncharged->charged a or vice versa b)
- Signatures
  - *long-lived charged*: interaction with at least one outer detector component (Muon Spectrometer); *massive*: low velocity β=v/c
  - main discriminants are *time of flight* (MS) and *ionisation energy loss* (Silicon-Tracker detectors)
- Status
  - Run2 2015 analysis based on tracker and tracker+TOF published

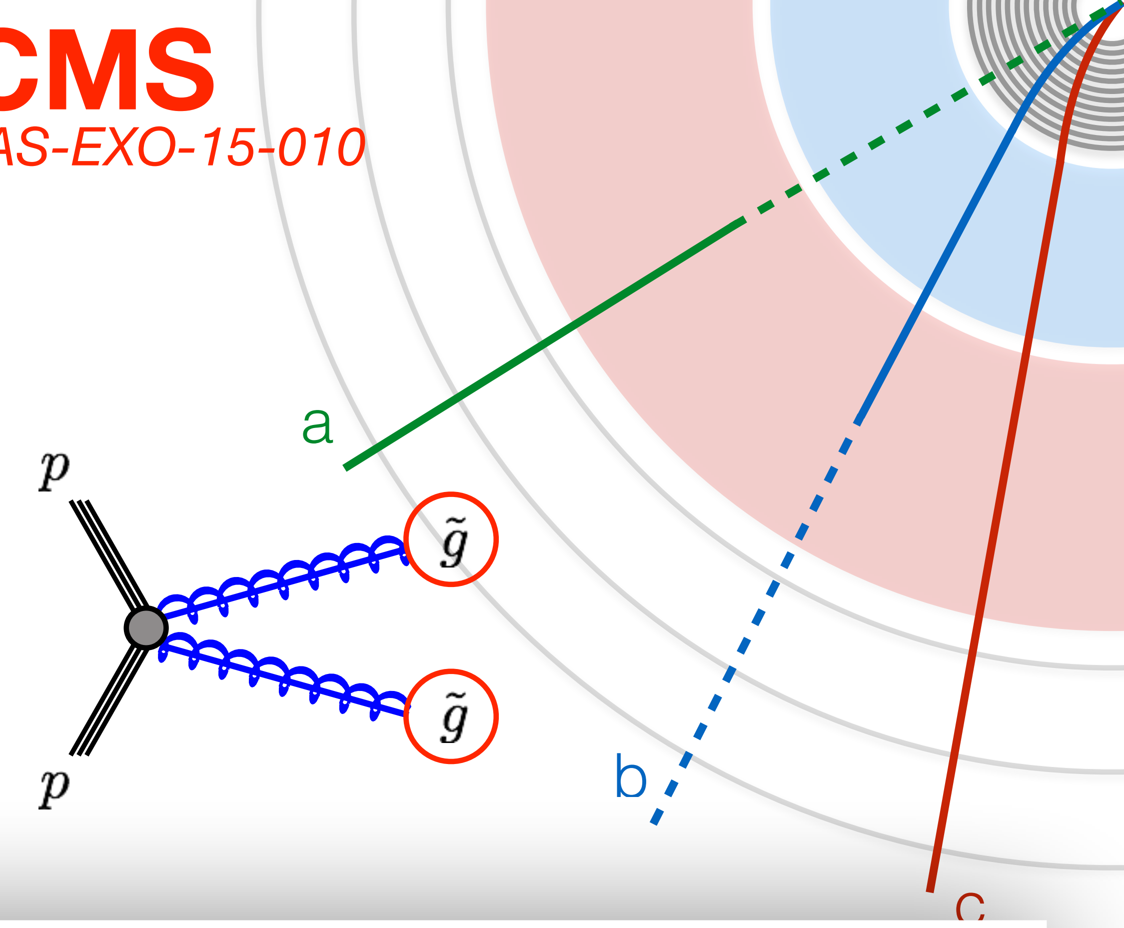




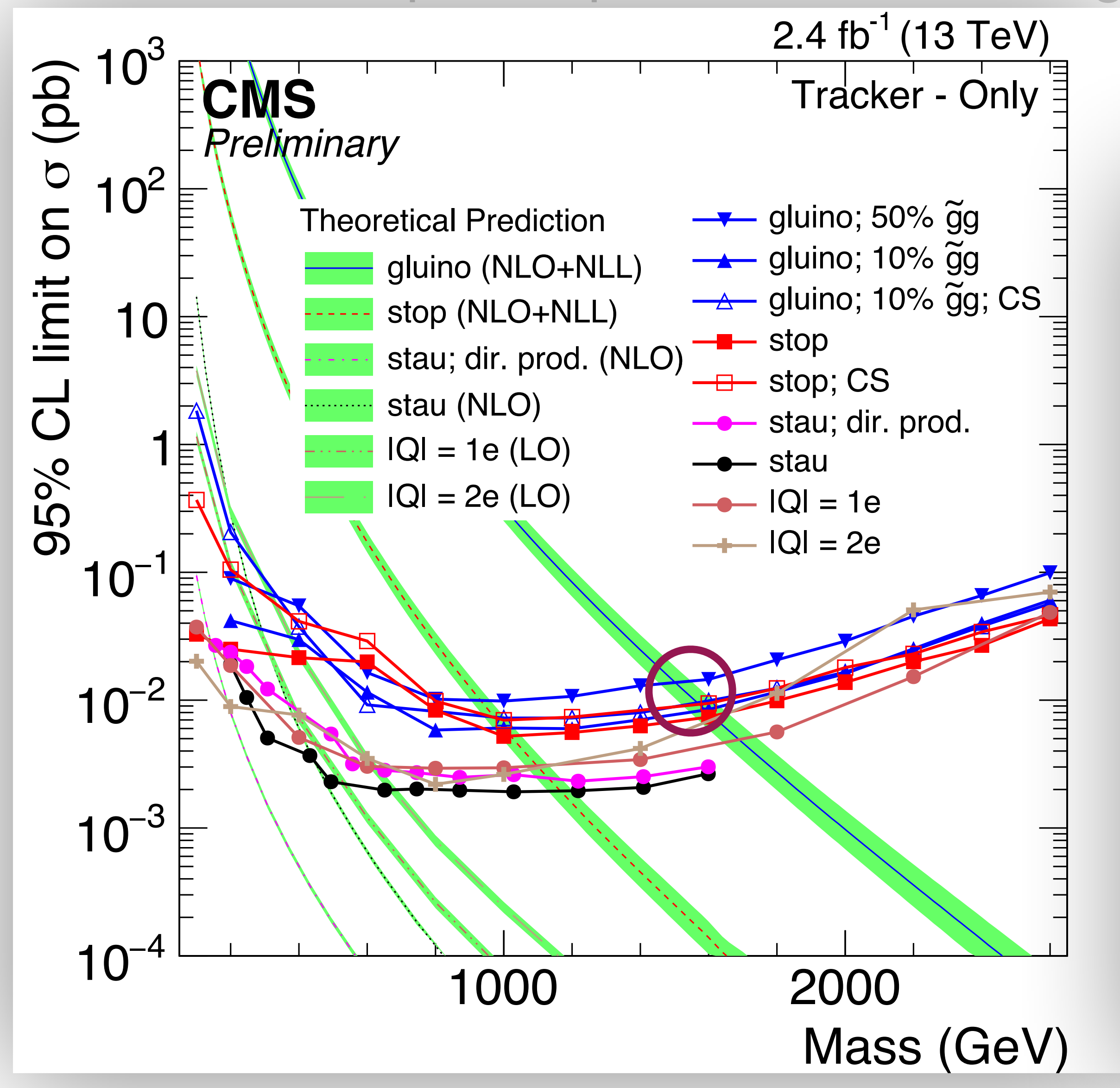
Stable Massive Particles

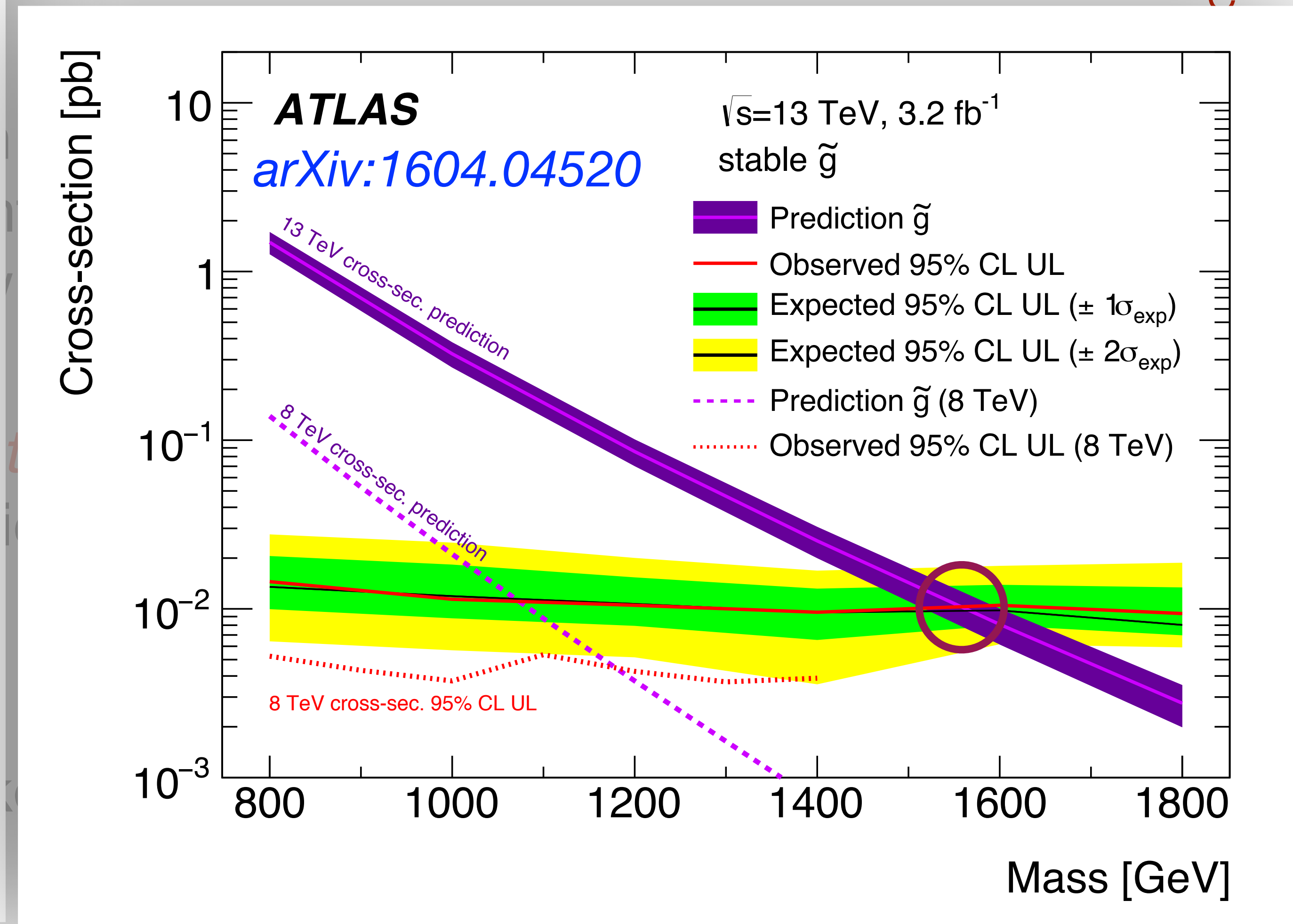
CMS

CMS-PAS-EXO-15-010



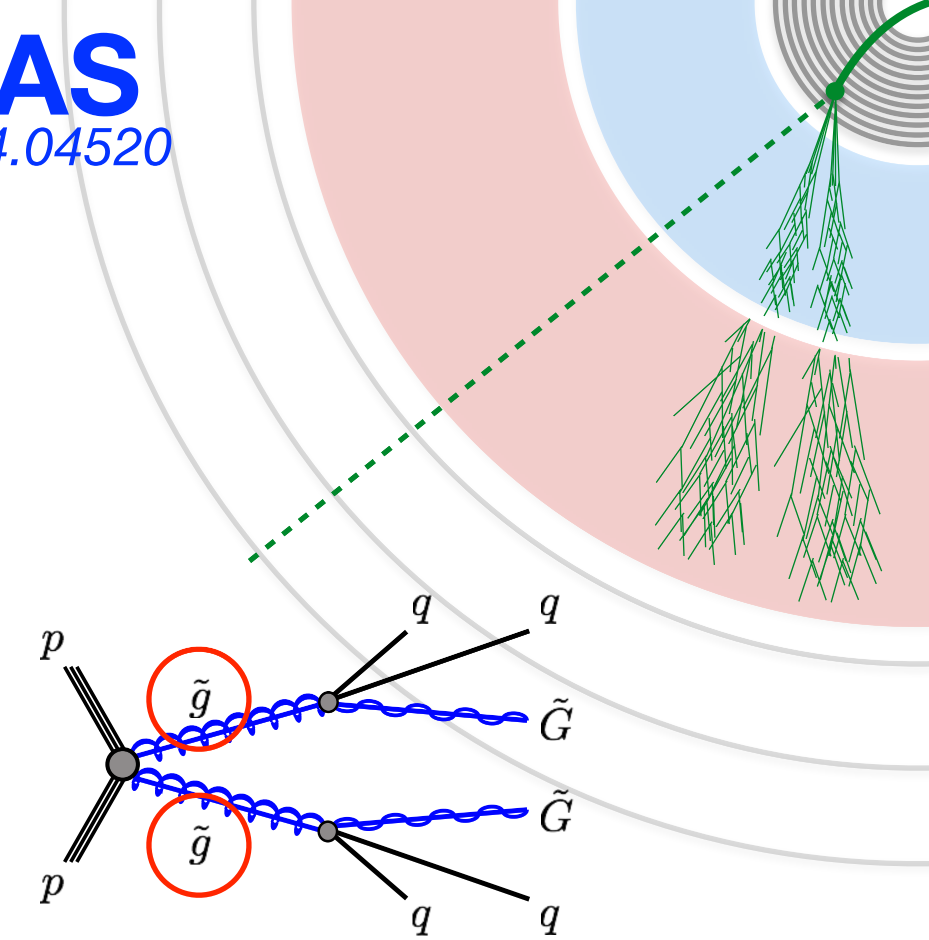
- Search for long-lived massive charged particles
  - sleptons, or (stop/gluino) *R*-hadrons
    - composed particles can undergo



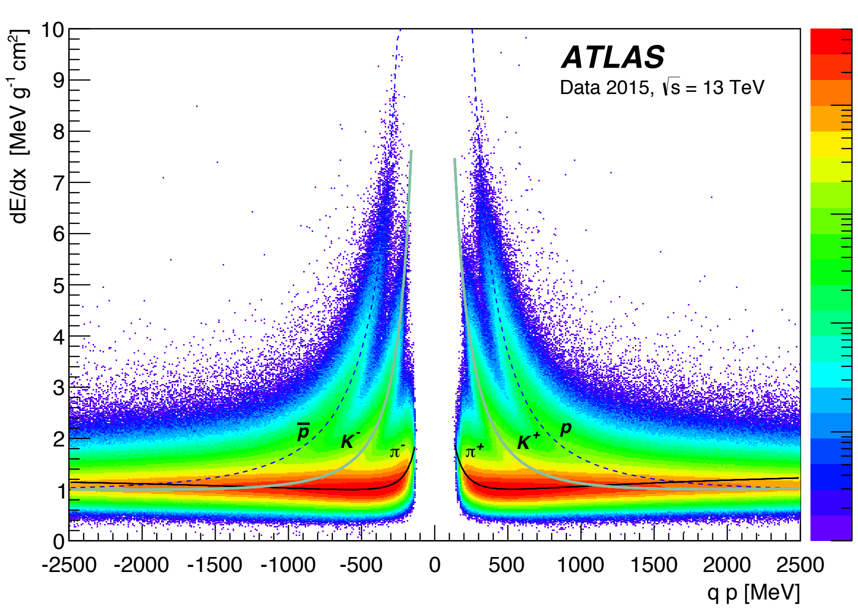


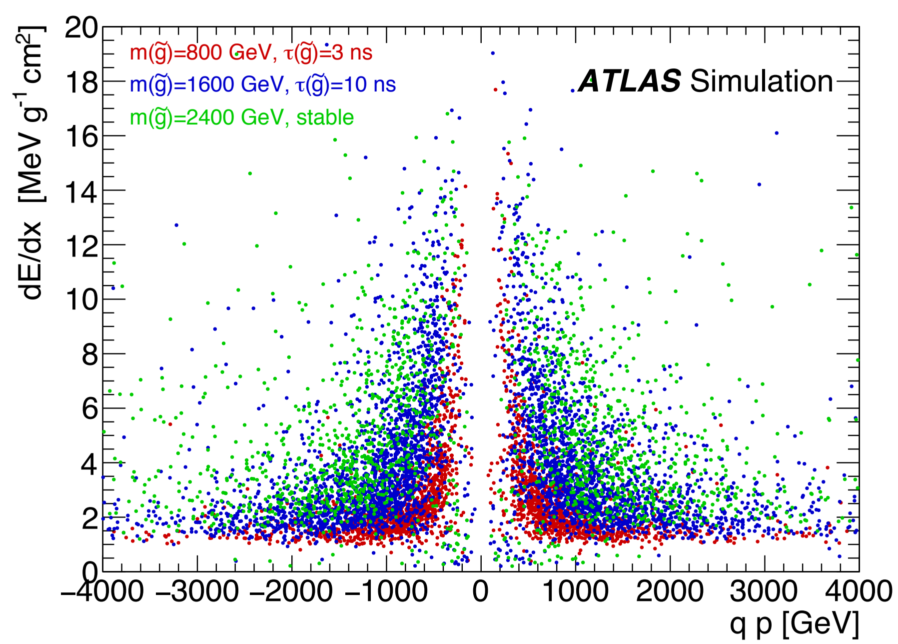
Meta-stable Massive Particles

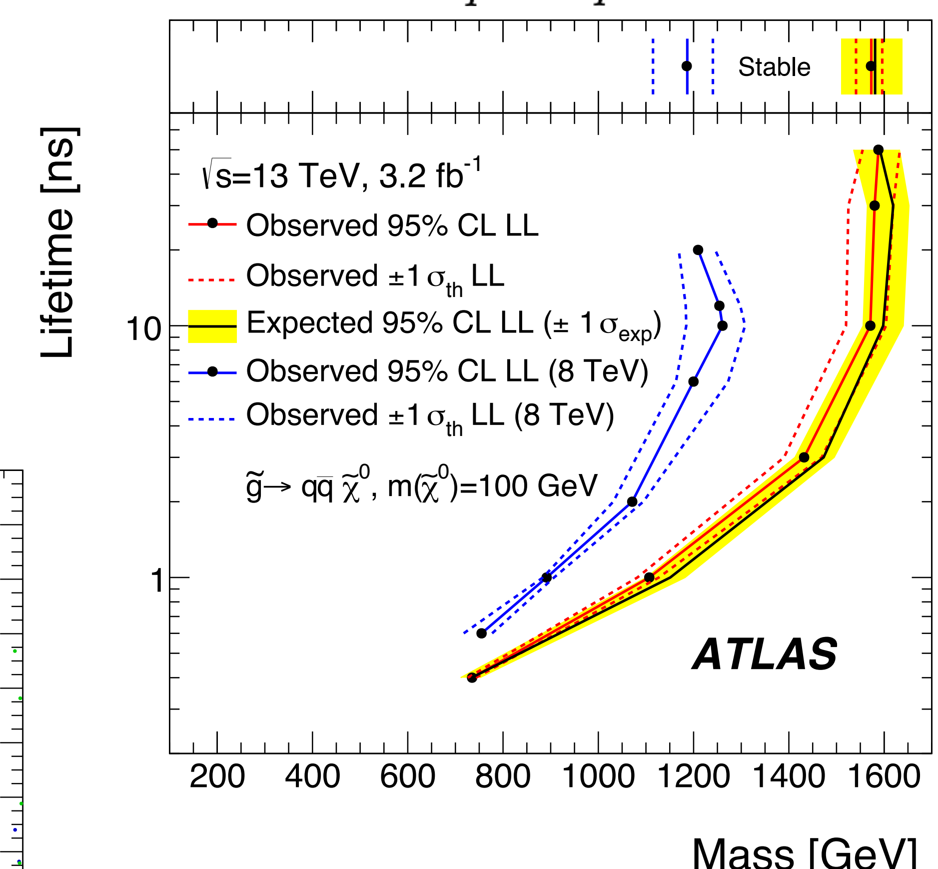
ATLAS
arXiv:1604.04520



- Search for long-lived massive charged particles
- Signatures
  - *long-lived charged*: at least proper reconstructed track in the ID O(ns), sensitive to short lifetimes but also consider long lifetimes; *massive*: low velocity β=v/c ⇒ large dE/dx
  - main discriminants are *high dE/dx in Pixel Detector, large momentum ID track* and *large MET*
  - two signal regions: Short lifetime (<50ns - reject muons); long lifetime (≥50ns - tighten jet rejection)
- Status and Plans
  - gluino R-hadron Run2 2015 analysis published
  - aim for better efficiency for shorter lifetime
    - use pixel tracklets. Poor momentum resolution but plan to add vertex constraint



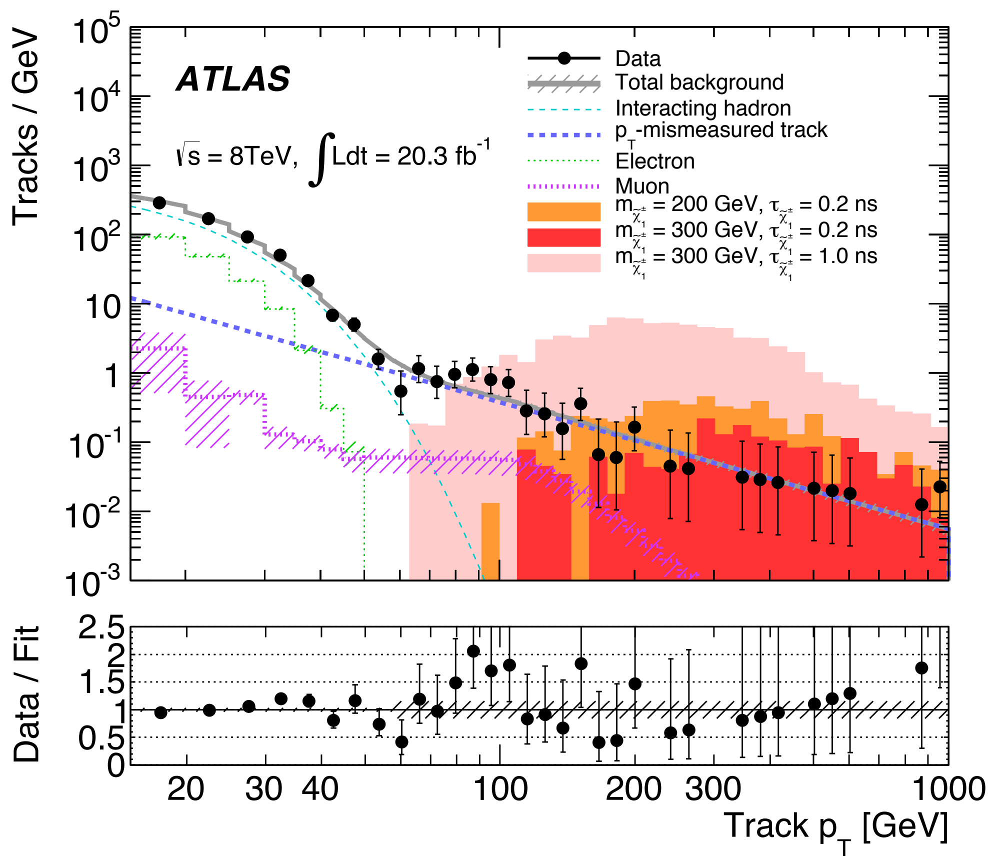


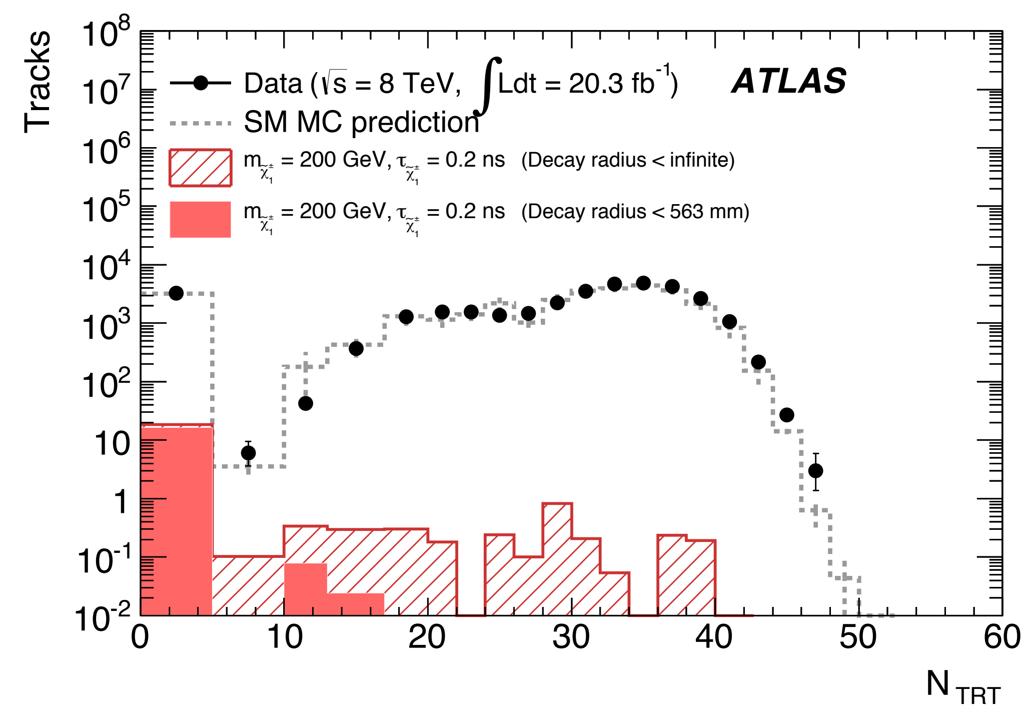


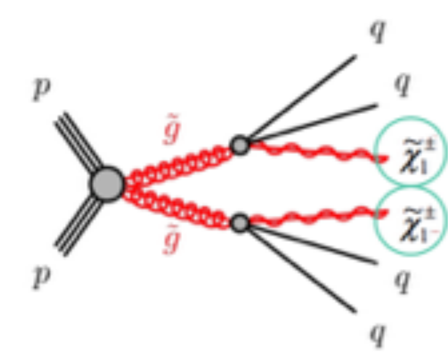
Disappearing Tracks

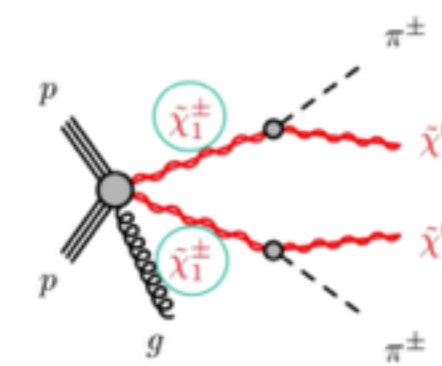
ATLAS
PRD 88, 112006 (2013)

- Search for long-lived massive charged particles
  - chargino decaying into neutralino and soft pions
- Signatures
  - *long-lived charged*: at least proper reconstructed track in the ID O(ns), using ad-hoc reco algorithms for short tracks; *disappearing track*: few hits in the outer part of the ID
  - main discriminants are *number of hits in the ID*, *large momentum ID track*, *angular correlation with MET*
- Plans
  - improving short track reconstruction and use of dE/dx for Run2 2015 analysis



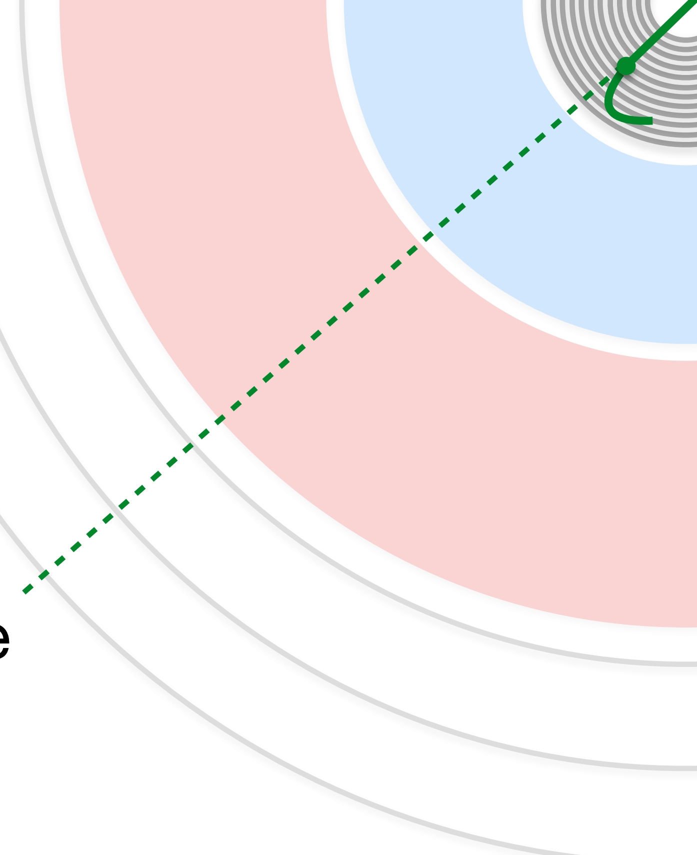




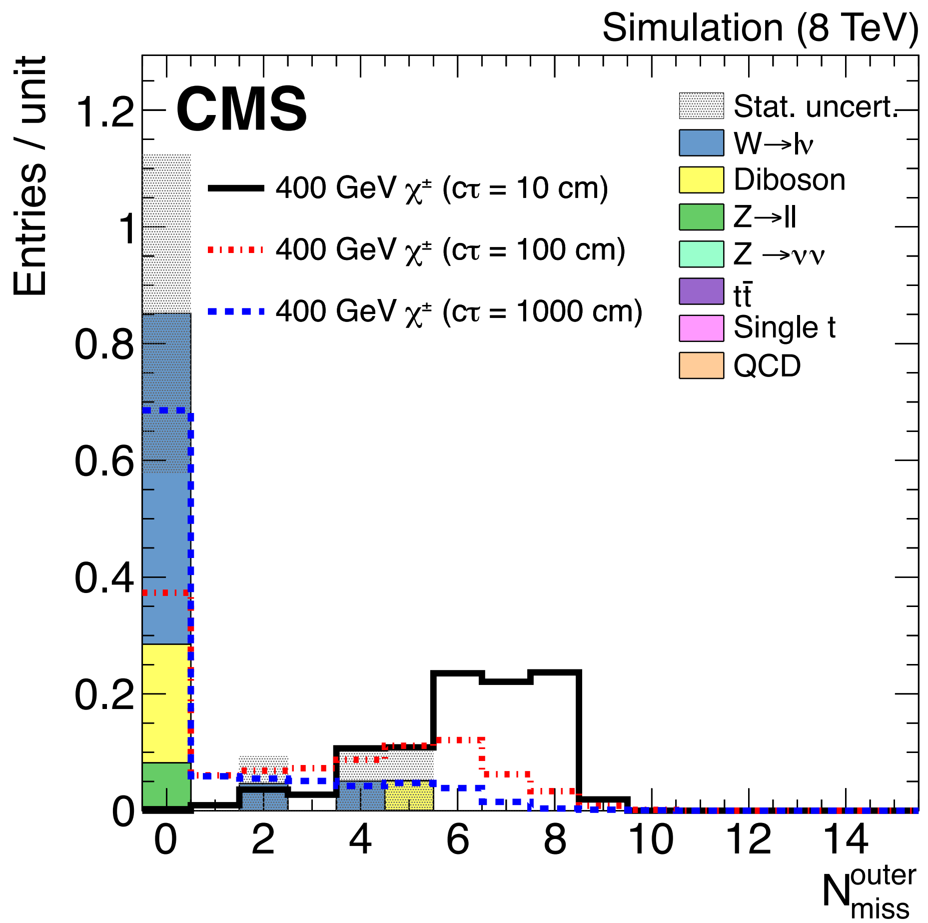


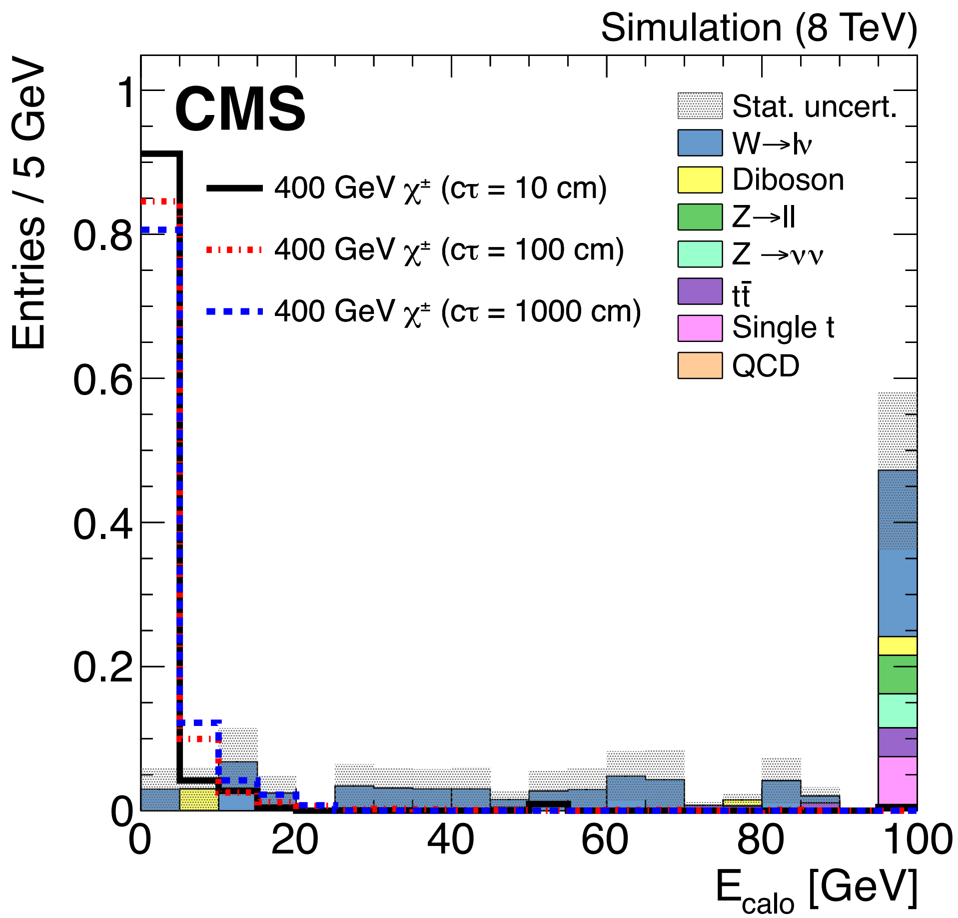
Disappearing Tracks

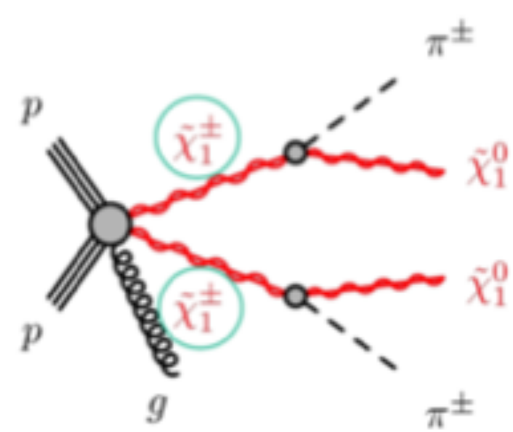
CMS
JHEP01(2015)096



- Search for long-lived massive charged particles
  - chargino decaying into neutralino and soft pions
- Signatures
  - *long-lived charged*: at least proper reconstructed track in the ID O(ns); *disappearing track*: few hits in the outer part of the ID and no energy deposit in the calorimeters
  - main discriminants are *number of hits in the ID*, *large momentum ID track*, *energy deposit in the calorimeters*

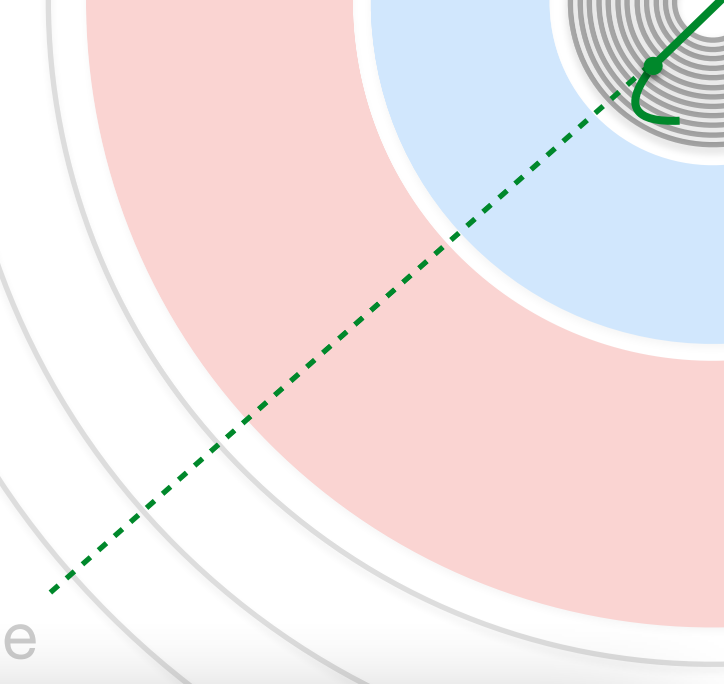




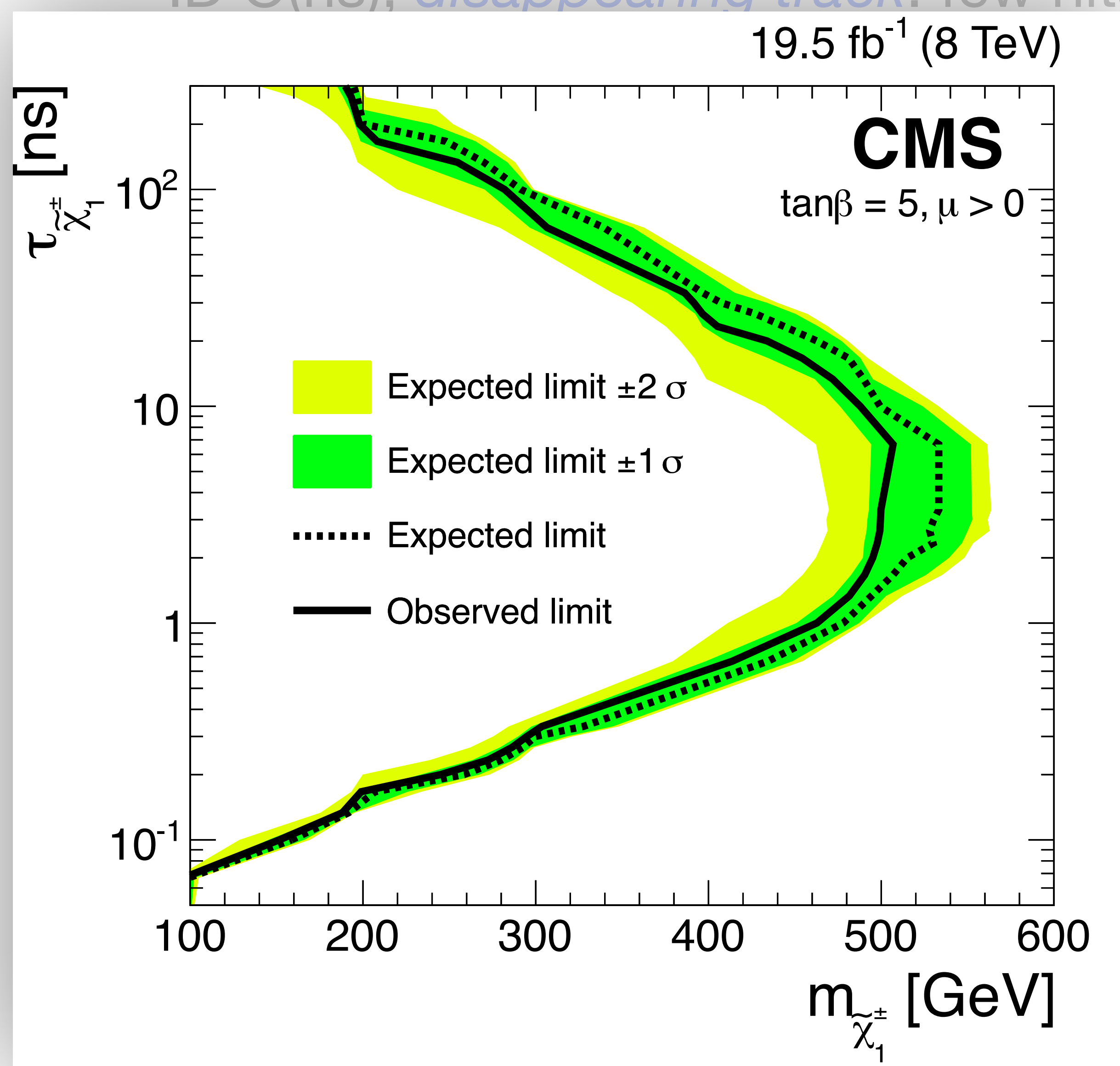


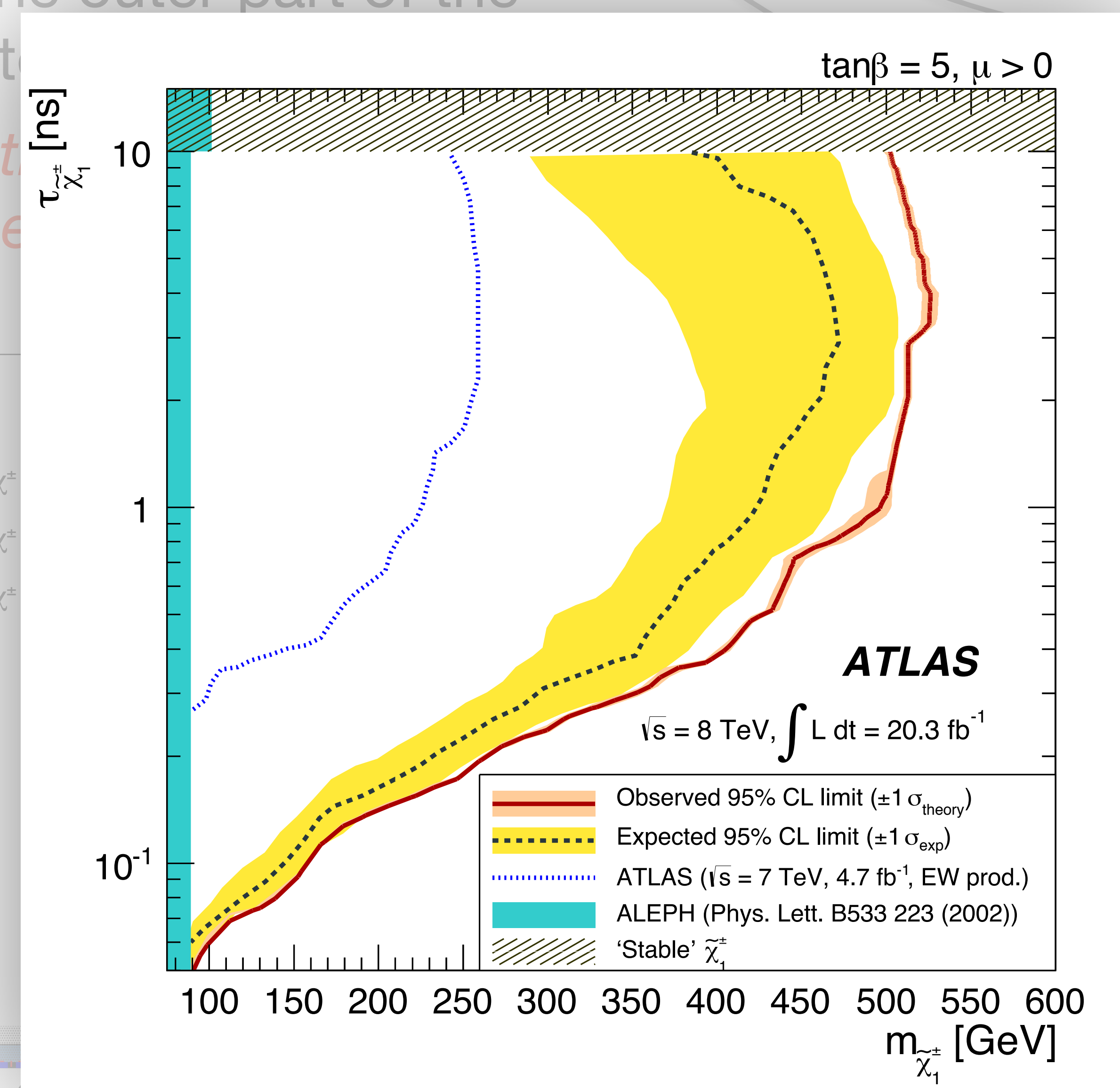
Disappearing Tracks

CMS
JHEP01(2015)096



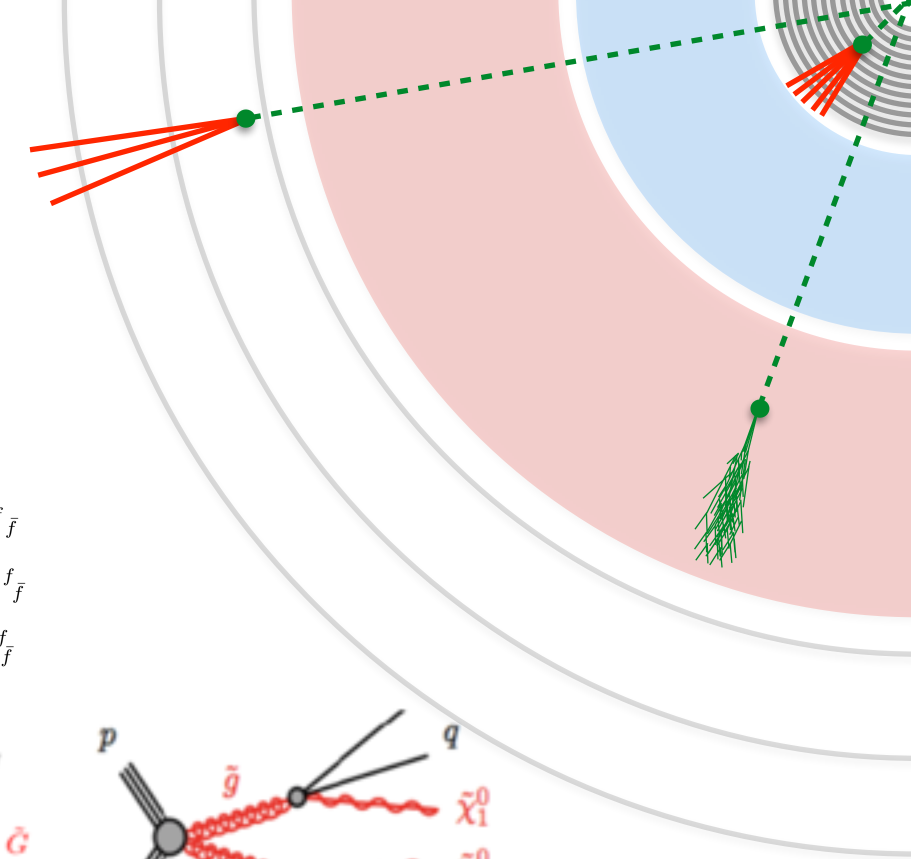
- Search for long-lived massive charged particles
  - chargino decaying into neutralino and soft pions
- Signatures
  - *long-lived charged*: at least proper reconstructed track in the ID O(ns); *disappearing track*: few hits in the outer part of the

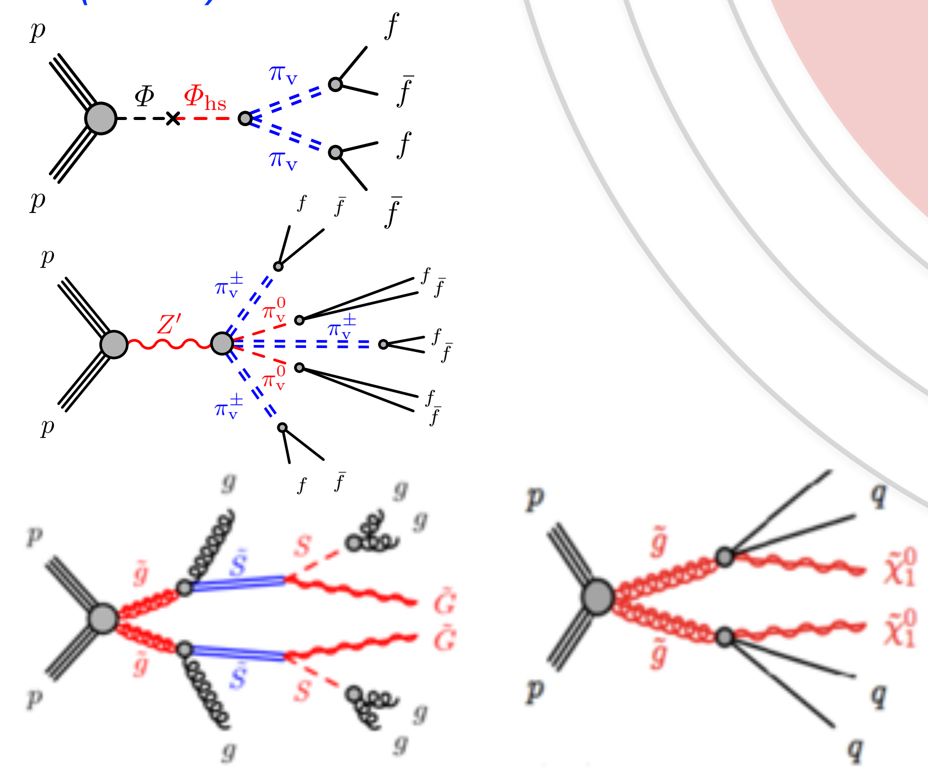




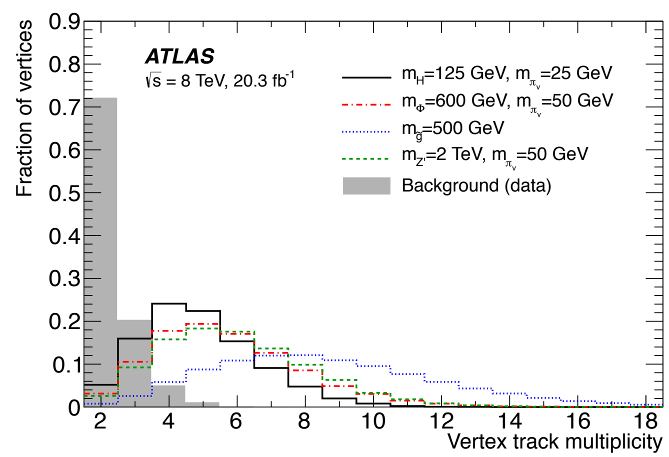
Displaced Vertex

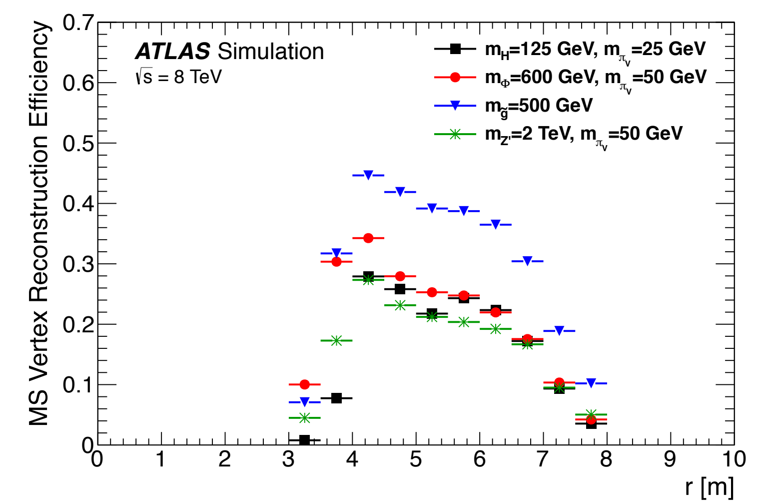
ATLAS
PRD 92, 012010 (2015)
PLB 743 (2015) 15-34

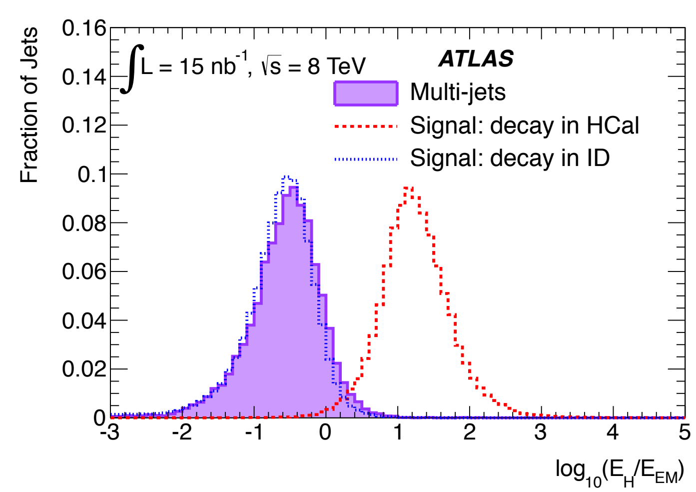




- Search for long-lived particles decaying into the detector volume
  - SM scalar boson communicator Φ between SM and hidden sector. $\Phi \rightarrow \pi_v \pi_v$. LLP is the hidden valley pions π_v.
  - HV Z' communicator, decaying into hidden quark pair
  - stealth and split SUSY
- Signatures (*non standard - devoted reco algorithms are needed*)
  - *displaced vertex ID*: secondary vertex, high track multiplicity and high mass, material veto
  - *displaced vertex MS*: MS segments isolated w.r.t. ID, high number of hits, dedicated trigger
  - *displaced vertex HCalo*: jets with large energy deposit in the hadronic calo, isolated w.r.t. ID, dedicated trigger based on large E_{HCal}/E_{EM}
- Plans
  - two independent searches in Run1 (ID+MS and HCalo). Final goal for Run2 is to have one combined search for various combinations of objects (vertices and jets)

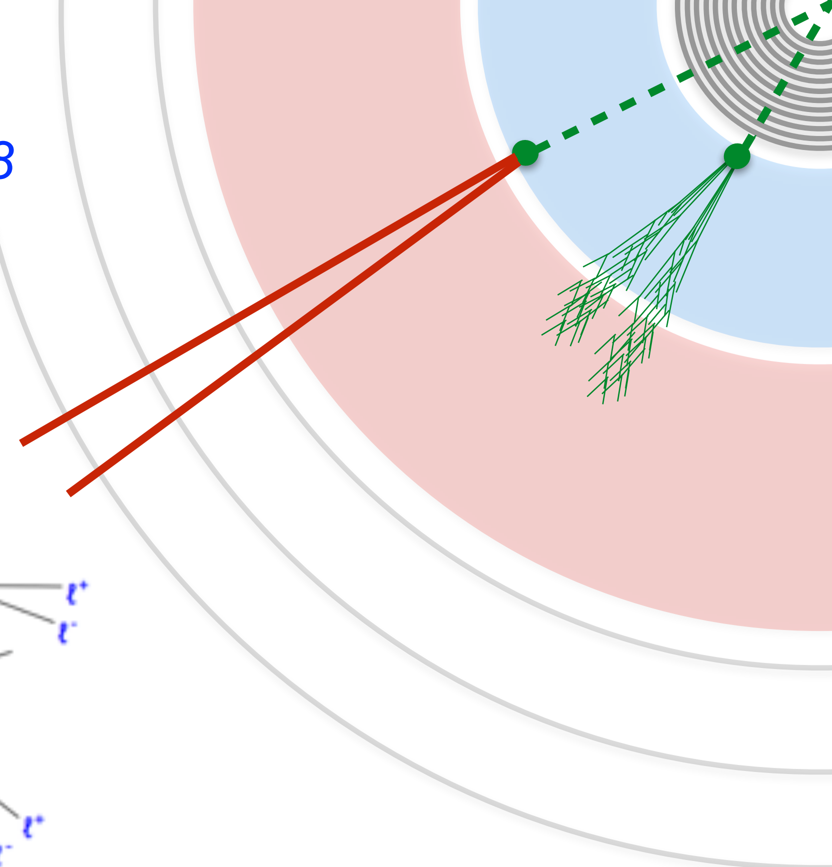


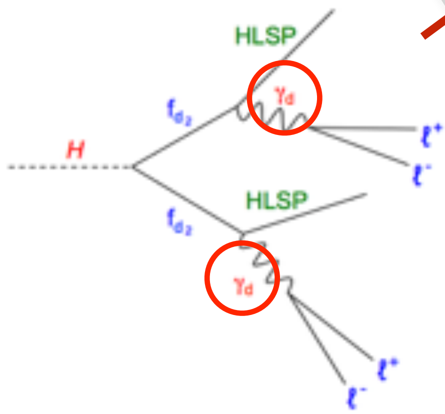




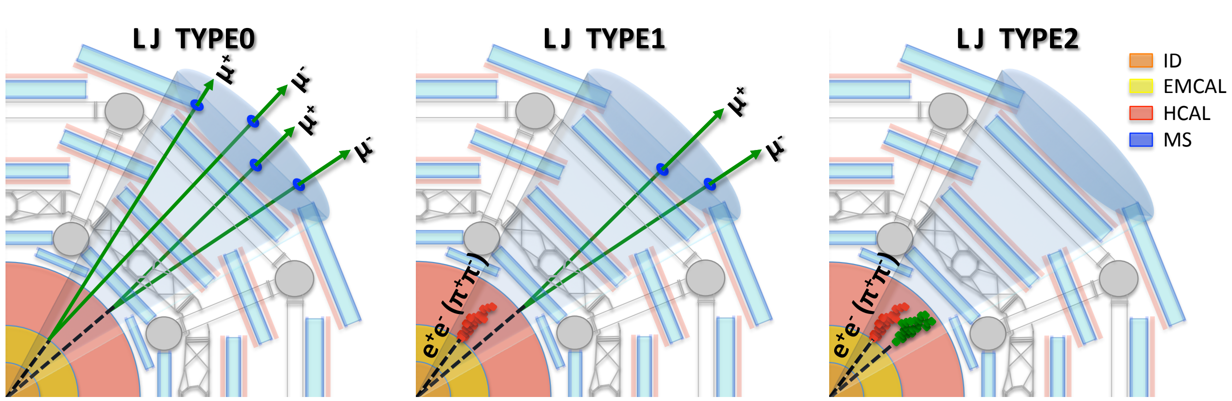
Lepton-Jets

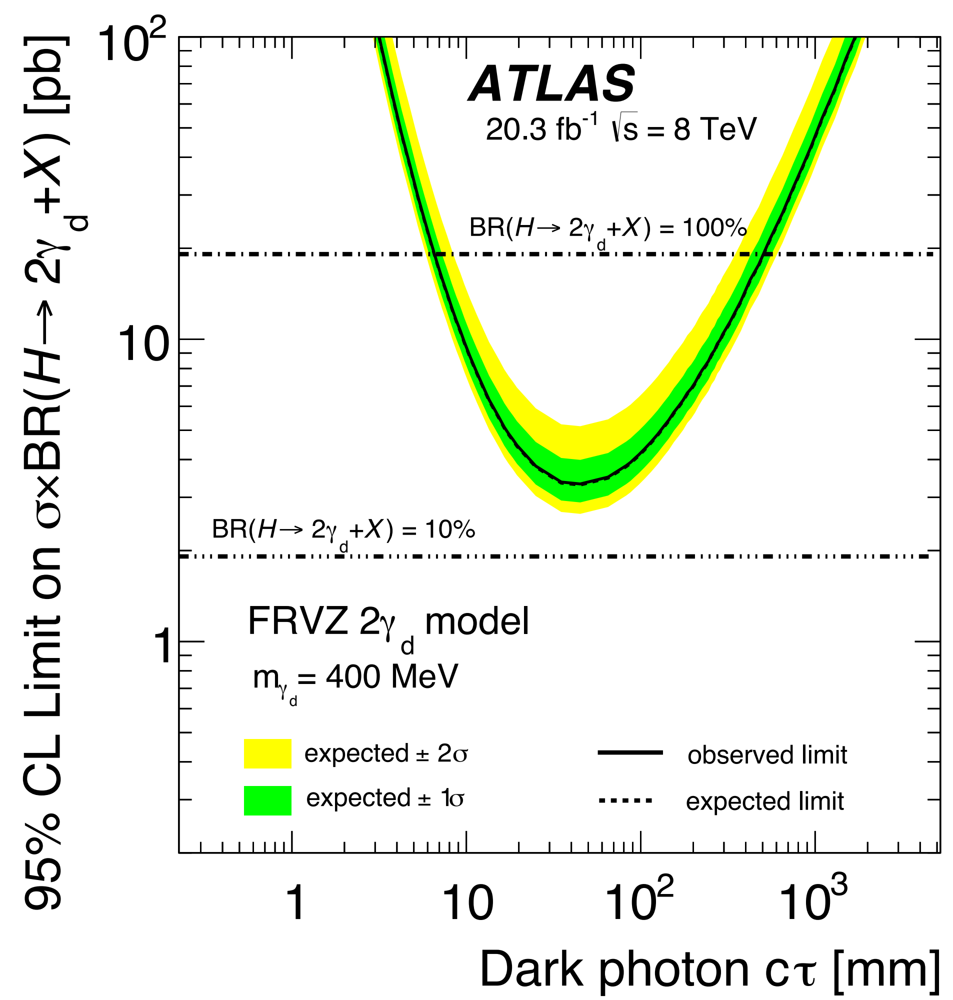
ATLAS
JHEP 11 (2014) 088





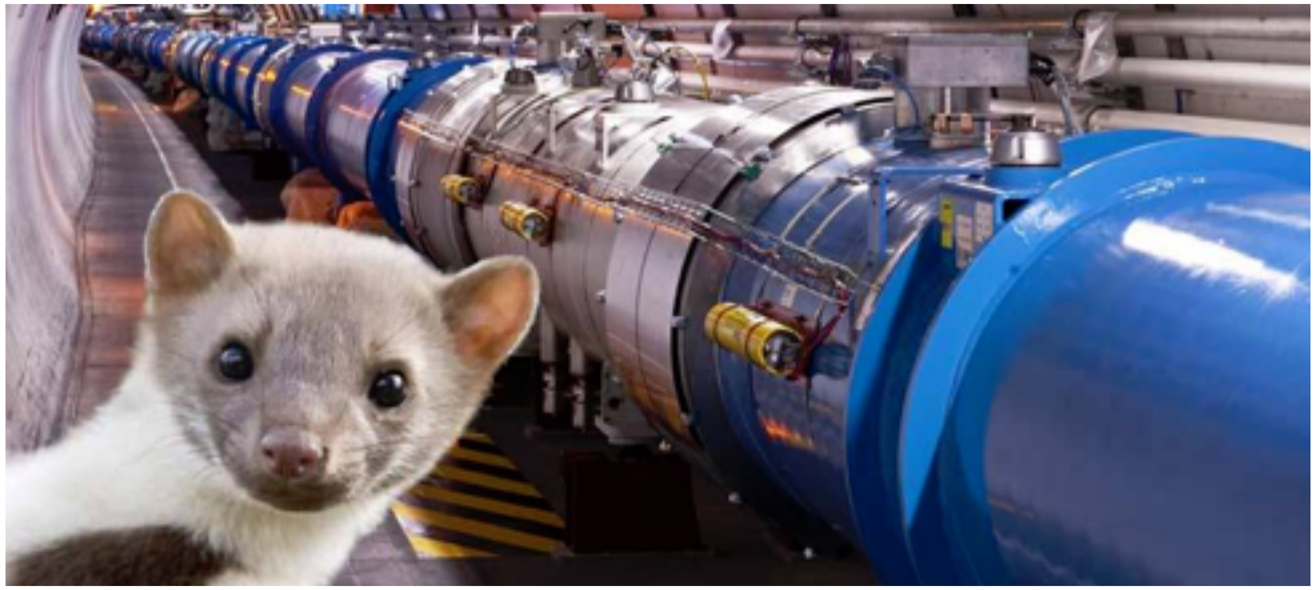
- Hidden and visible sectors communicate through a dark photon γ_d
- Signatures
  - the dark photon can to *collimated pairs* of e, μ, $\pi^\pm$ (lepton-jet) far from the IP
  - main discriminants are *large impact parameter* and *jet topology*
- Plans
  - study displaced pure electron and all-hadronic decay of the dark photon
  - search for different LJ production mechanisms: 1 LJ + X





Conclusions

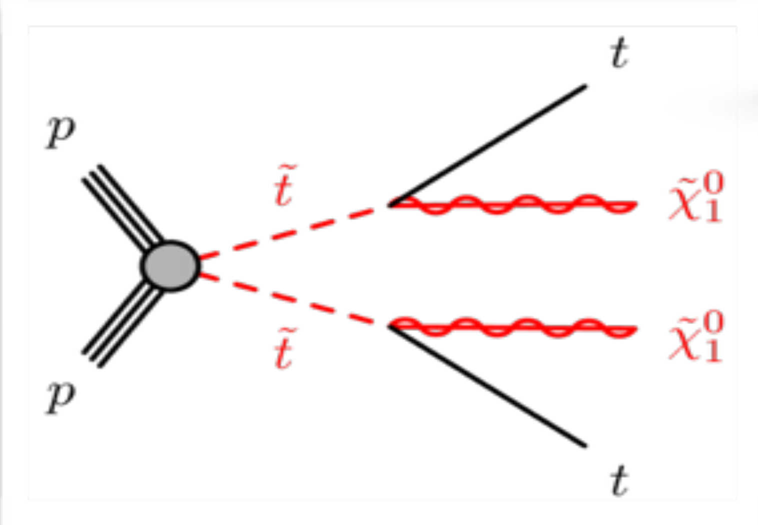
- Run I left us with great hopes/doubts for new physics at 13 TeV
- With beginning of Run II both experiments showed to be well prepared to acquire and analyze new data
- We gave you some overview on the most recent analyses that exploit 2015 data to look for New Physics
    - Some analyses already more powerful than the ones at 8 TeV!
    - Nothing new so far… but the new run has just started and we expect 10 times more integrated luminosity in 2016!



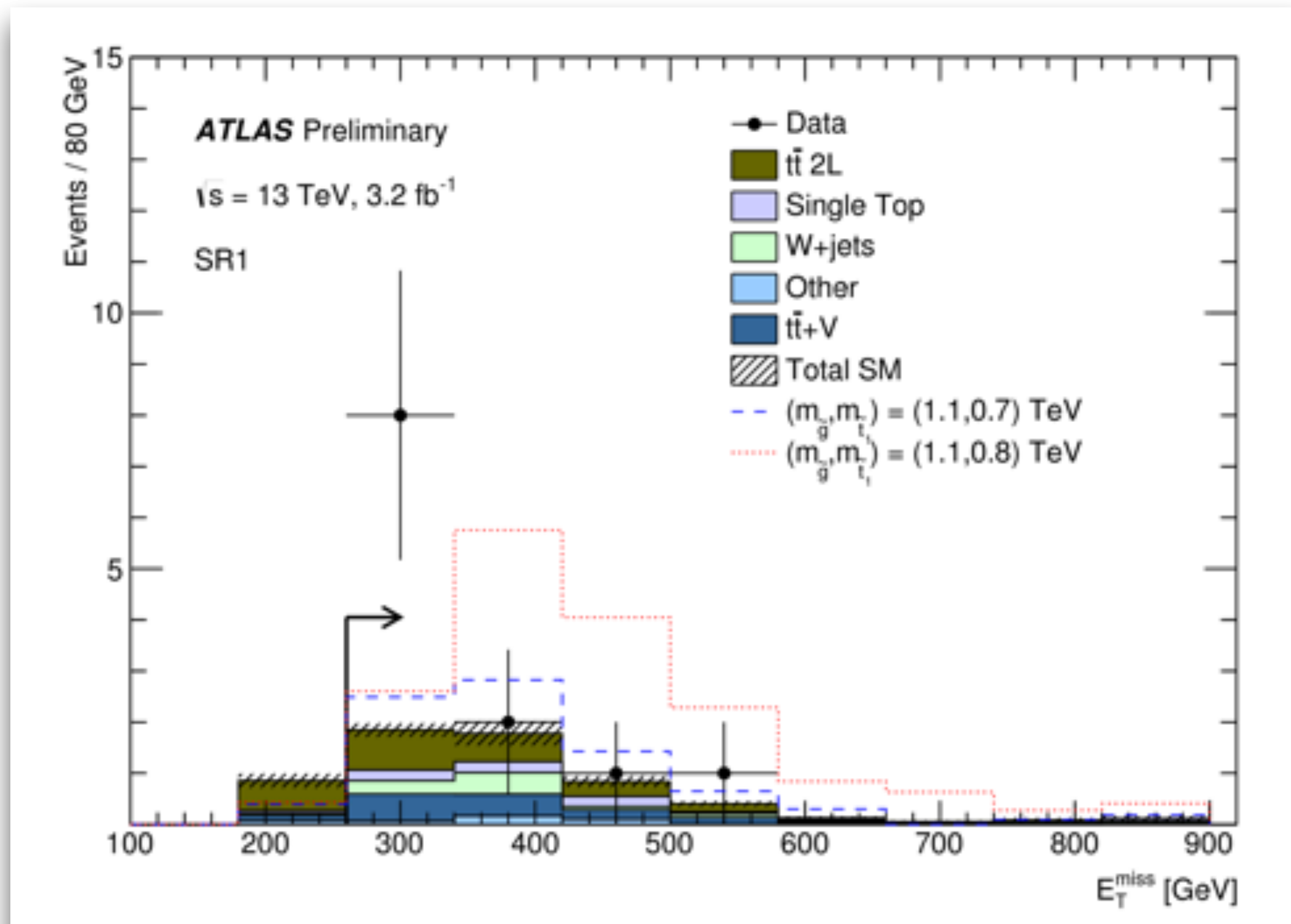
Stay tuned for new data !!!

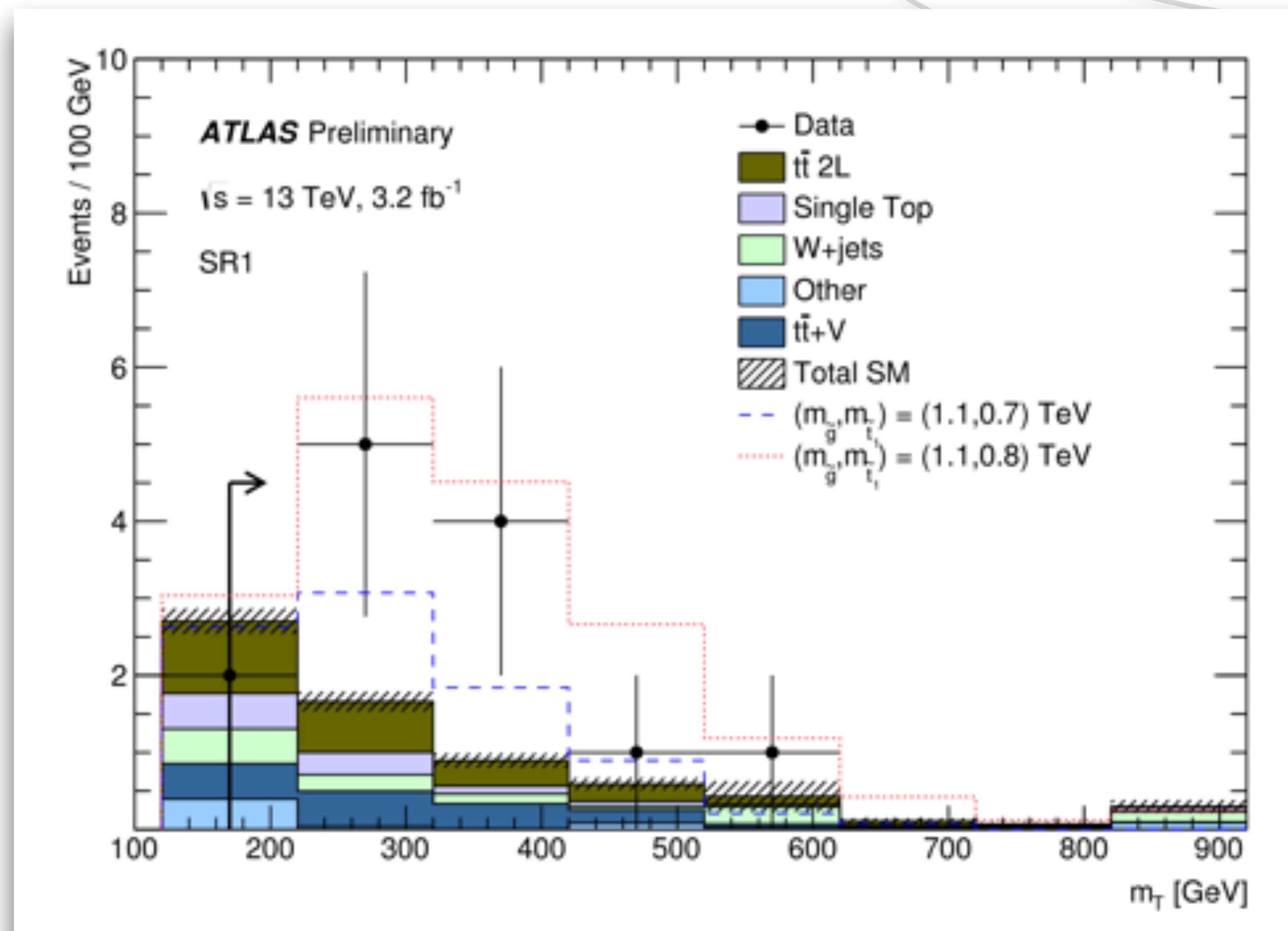
Backup

ATLAS (ATLAS-CONF-2016-007)



Signal region	SR1	SR2	SR3
Observed	12	1	1
Total bkg	5.50 ± 0.72	1.25 ± 0.26	1.03 ± 0.18
$t\bar{t}$	2.21 ± 0.60	0.29 ± 0.10	0.20 ± 0.07
Single top	0.46 ± 0.39	0.09 ± 0.08	0.10 ± 0.09
W+jets	0.71 ± 0.43	$0.15^{+0.19}_{-0.15}$	0.20 ± 0.09
$t\bar{t} + W/Z$	1.90 ± 0.42	0.61 ± 0.14	0.41 ± 0.10
Diboson	0.23 ± 0.15	0.11 ± 0.07	0.12 ± 0.07

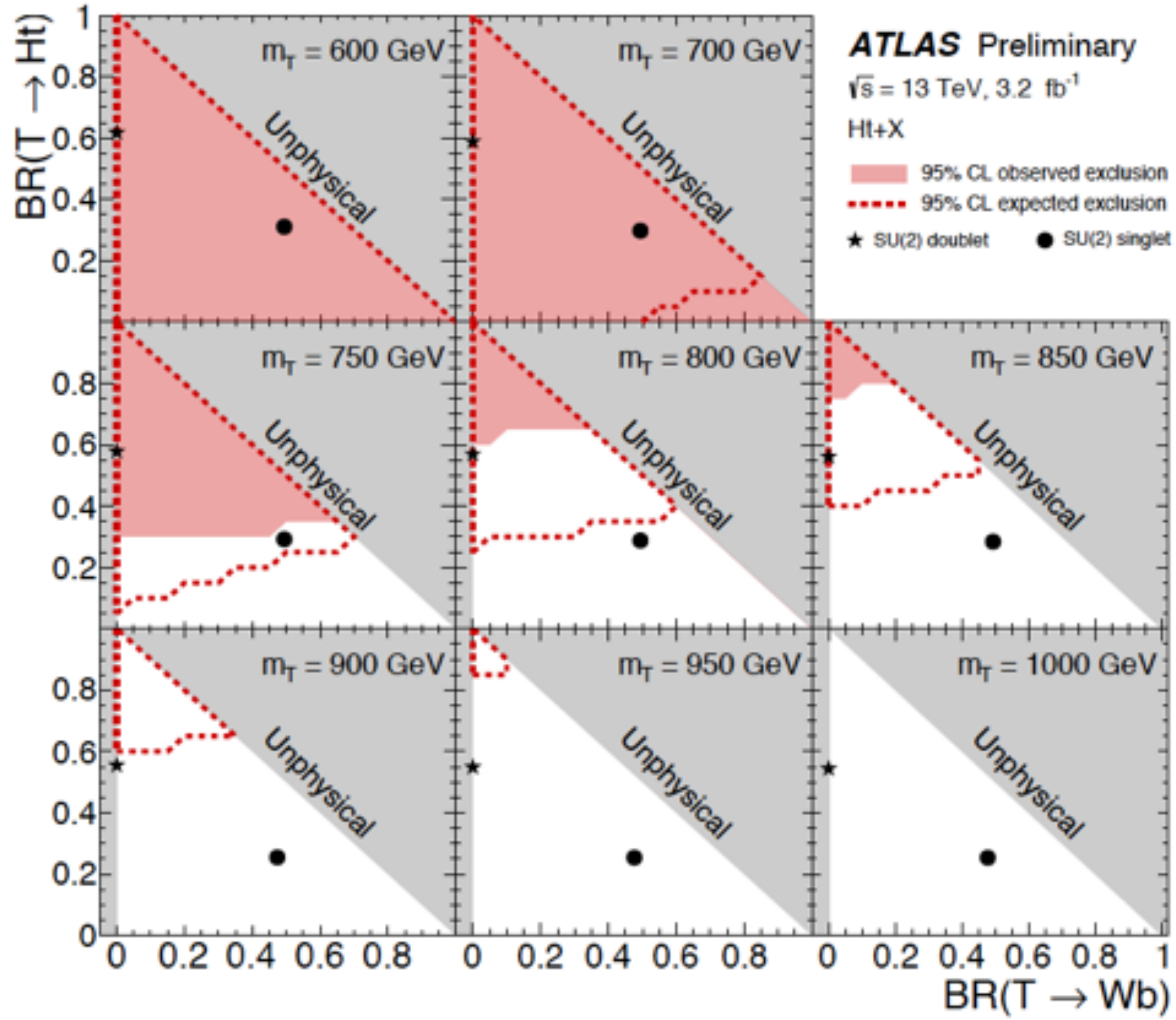


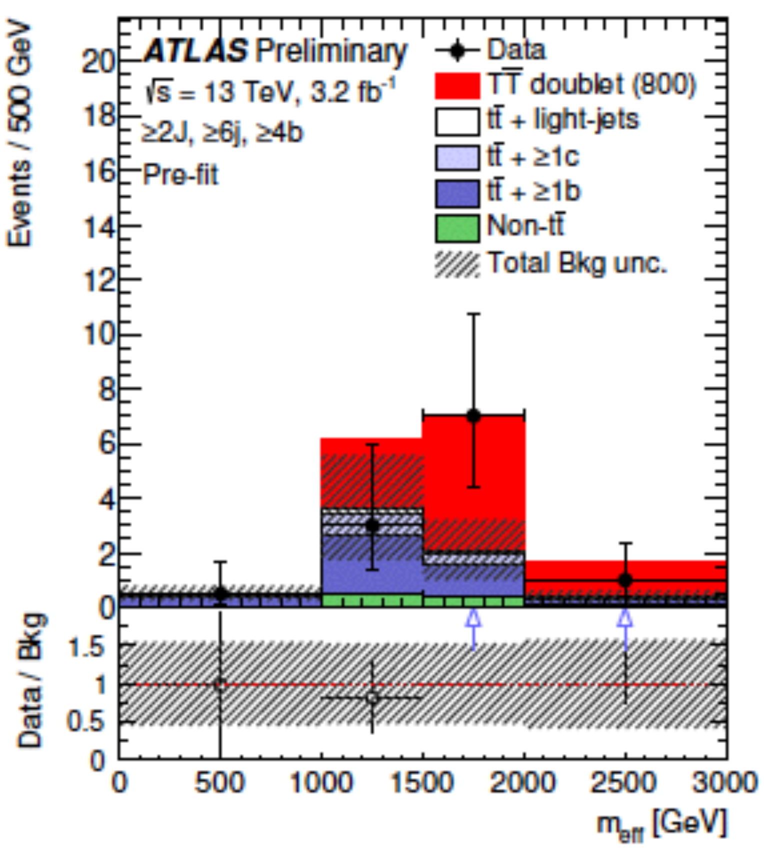


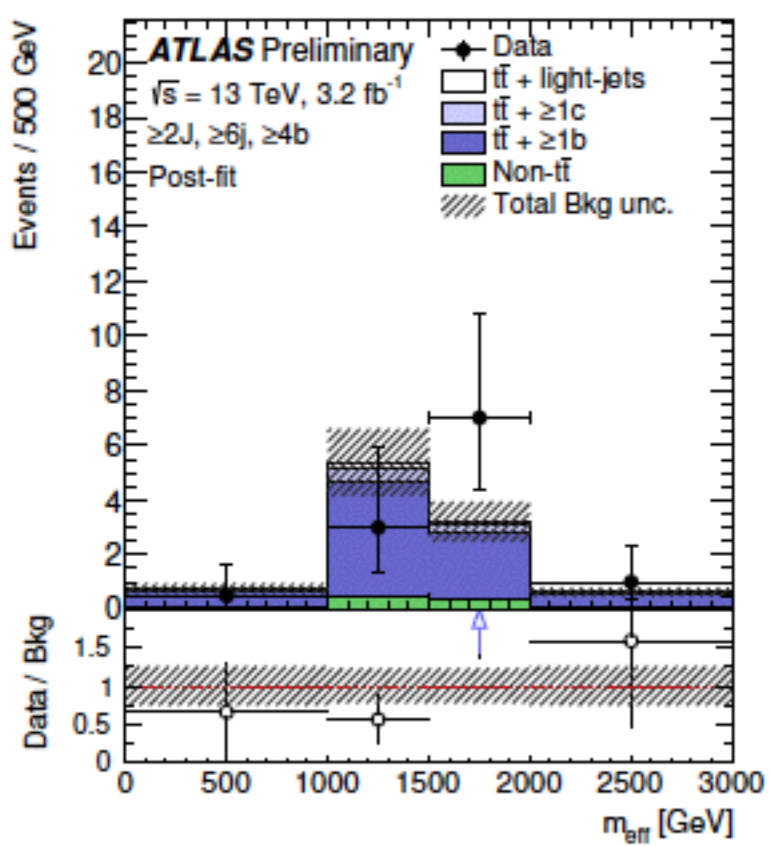
	SR1	SR2	SR3
E_T^{miss}	> 260 GeV	> 350 GeV	> 450 GeV

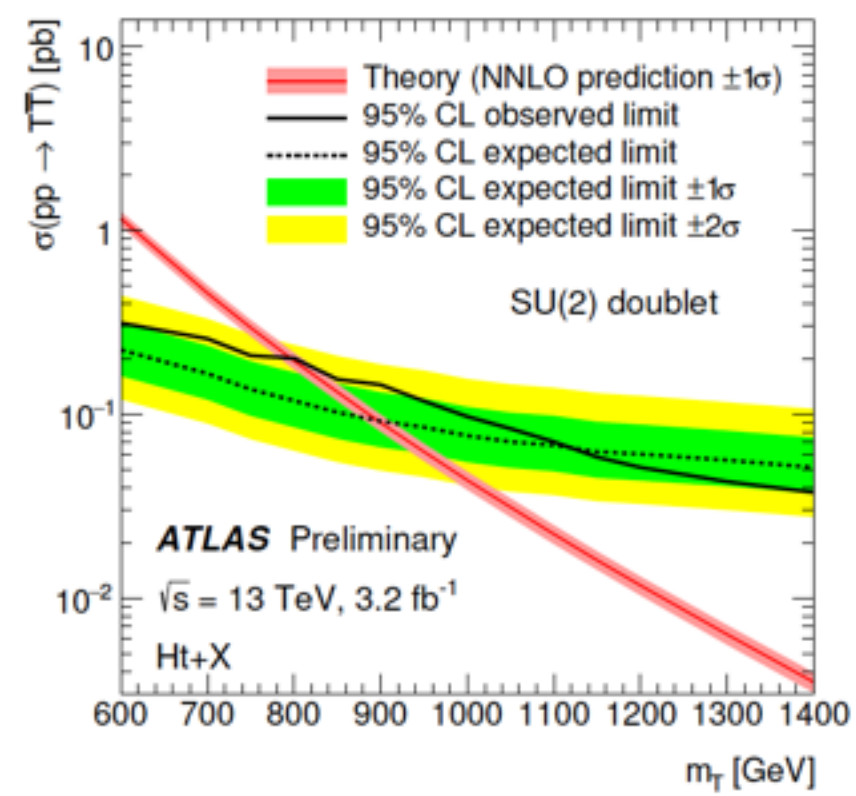
T-pair production

	ATLAS
Reference	ALTAS-CONF-2016-013
$N_{leptons}$	1 (e or μ)
N_{jets}	≥ 6
$N_{b\text{-}jets}$	2,3,≥ 4
$N_{\text{Large-cone jets}}$	mass-tagged (t, H) jets (0,1, >2) trimmed mass >100 GeV
Categories	20









T-pair production

	ATLAS	CMS
Reference	ALTAS-CONF-2016-013	CMS-PAS-B2G-16-002
$N_{leptons}$	1 (e or μ)	1 (e or μ)
N_{jets}	≥ 6	≥ 3
$N_{b\text{-}jets}$	2,3,≥ 4	0,1,2,≥ 3
$N_{\text{Large-cone jets}}$	mass-tagged (t, H) jets (0,1, >2) trimmed mass >100 GeV	W-tagged jets (0,≥ 1) pruned mass ∈ [65,105] GeV
Categories	20	16

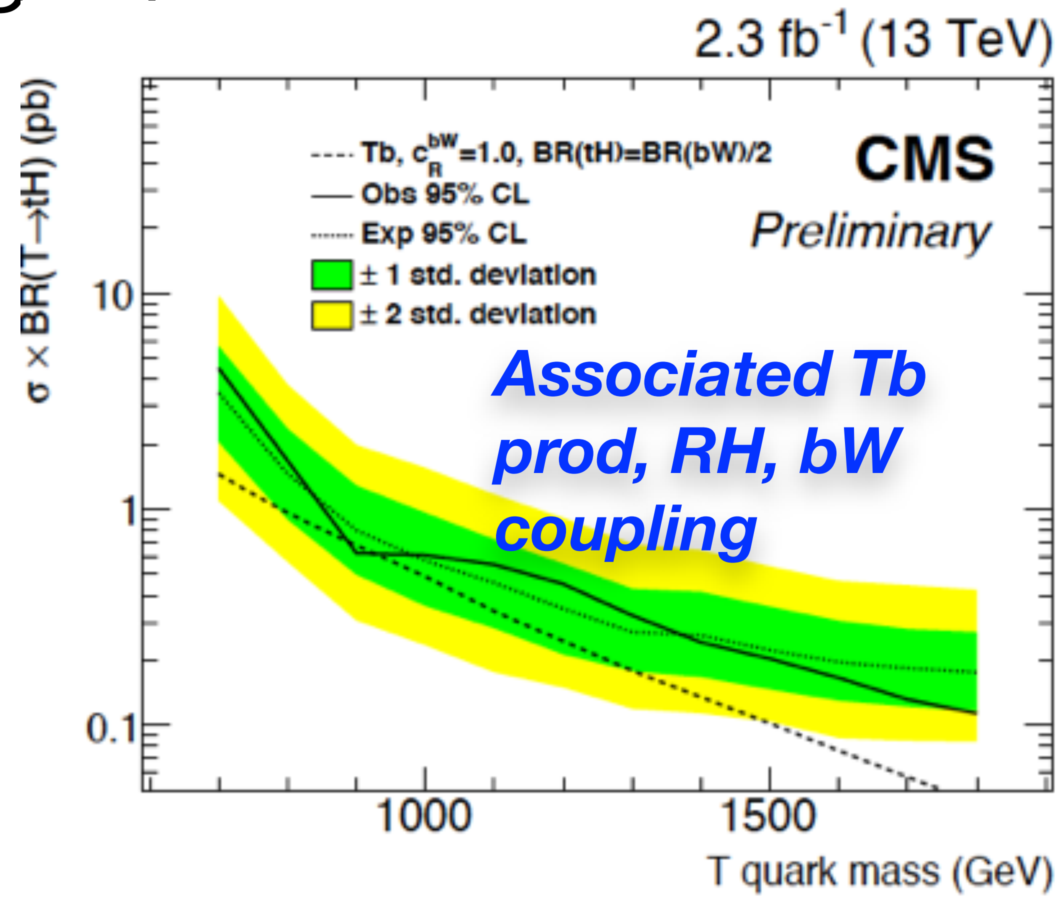
- At lest 1 T -> tH
- Main discriminating variable min[M(l,b)]
- Background estimation from simulation
- Validation regions dedicated control region
- Limits set for different BRs to Wb,Ht, Zt (back-up)

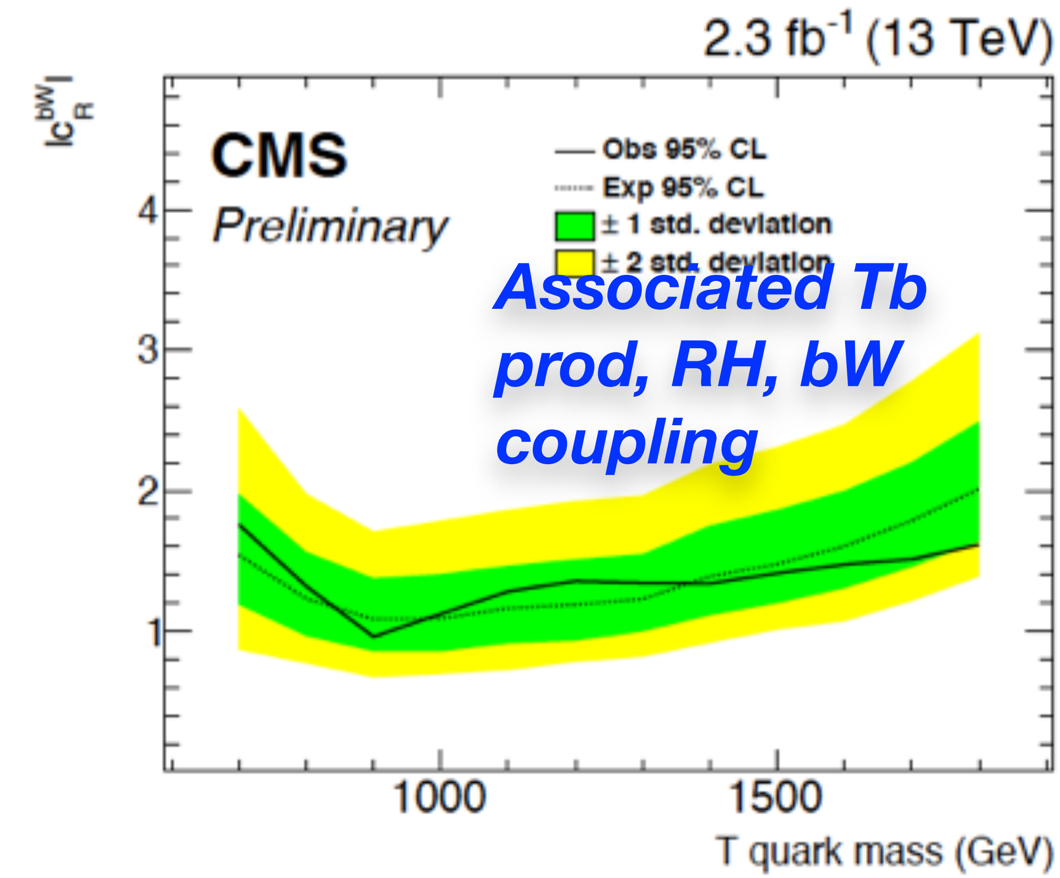
$B(T \to bW)$	$B(T \to tH)$	$B(T \to tZ)$	Expected [GeV]	Observed [GeV]
0.50	0.25	0.25	743	750
1.00	0.00	0.00	853	876
0.80	0.20	0.00	812	824
0.80	0.00	0.20	808	828
0.60	0.40	0.00	778	780
0.60	0.20	0.20	772	778
0.60	0.00	0.40	768	774
0.40	0.60	0.00	727	731
0.40	0.40	0.20	707	714
0.40	0.20	0.40	< 700	< 700
0.40	0.00	0.60	< 700	< 700
0.20	any	any	< 700	< 700
0.00	any	any	< 700	< 700

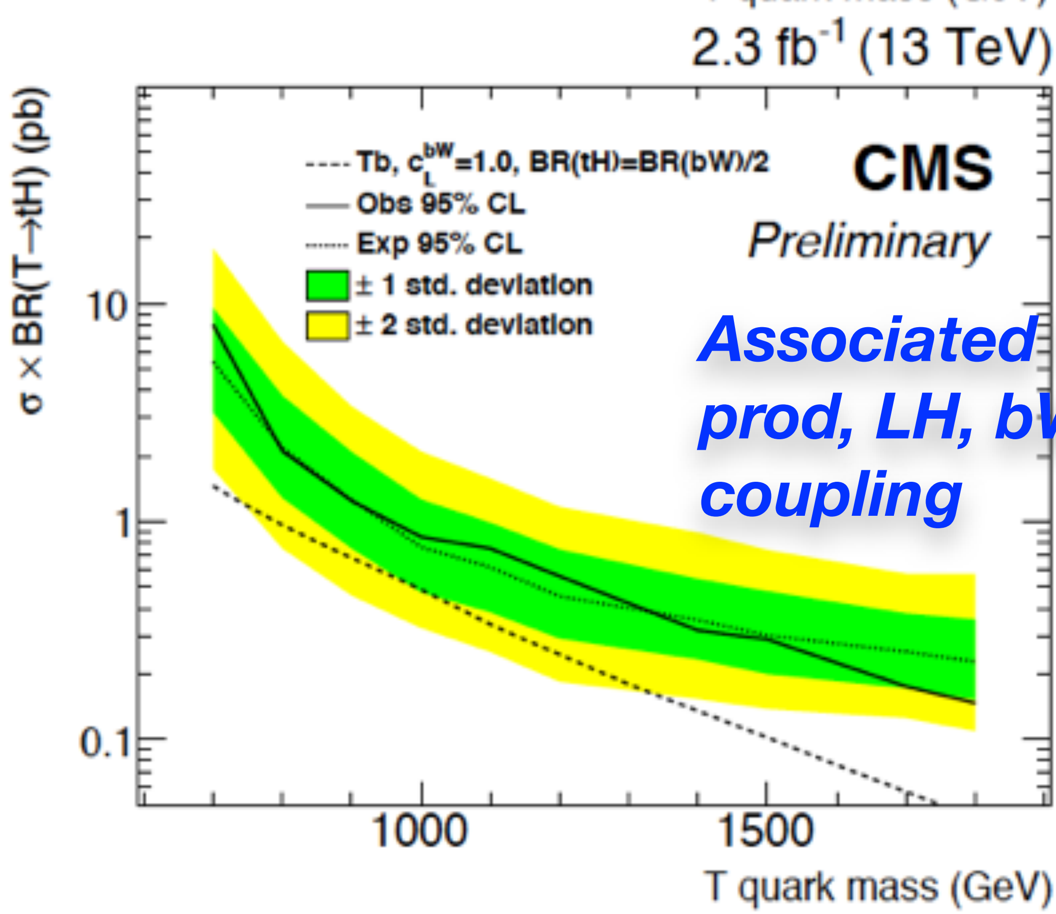
Single production: T→tH

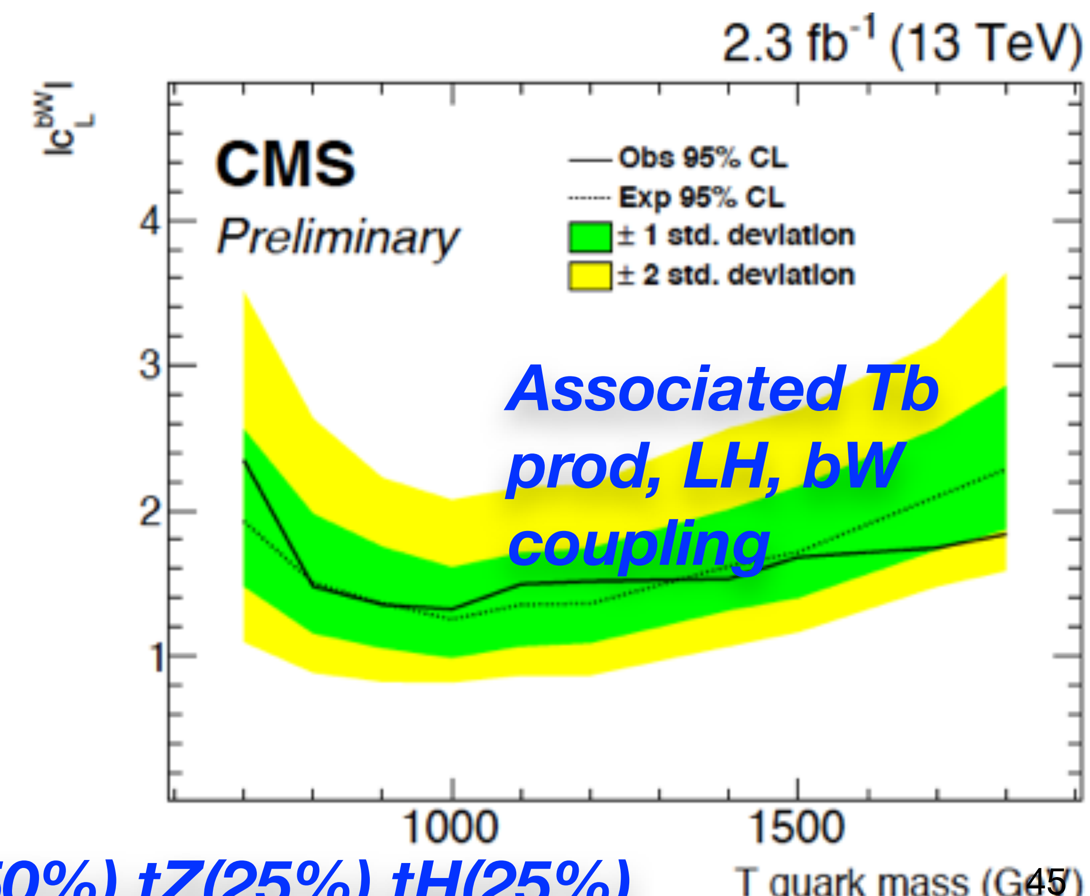
CMS

CMS-PAS-B2G-15-008









T→bW(50%),tZ(25%),tH(25%)

Tpair production: T→tH

CMS
arxiv1503.01952

- Run I all hadronic final state

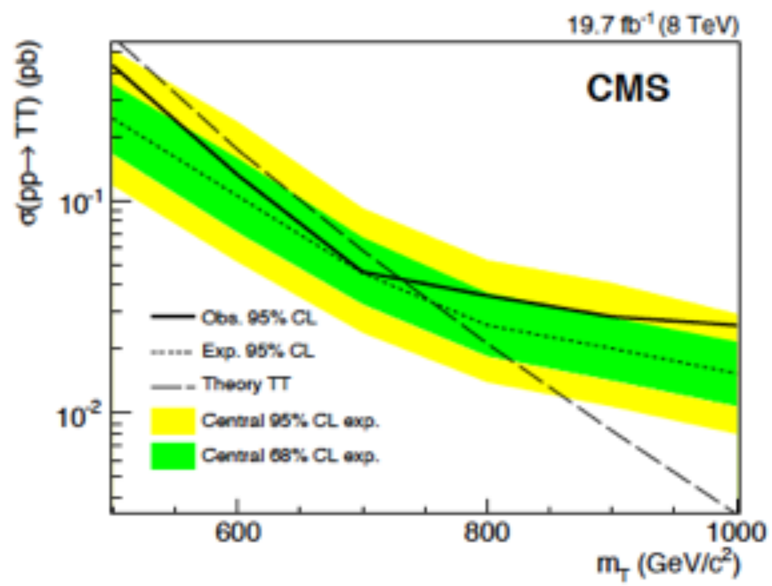


Figure 13: Observed (solid line) and expected (dotted line) Bayesian upper limits on the T quark production cross section determined from the variable L for the combination of the single and multiple H tag categories, for the hypothesis of an exclusive branching fraction $\mathcal{B}(T \to tH) = 100\%$. The green (inner) and yellow (outer) bands show the $1\,\sigma$ ($2\,\sigma$) uncertainty ranges, respectively. The dashed line shows the prediction of the theory as discussed in Section 3.

ATLAS
arxiv1409.5500

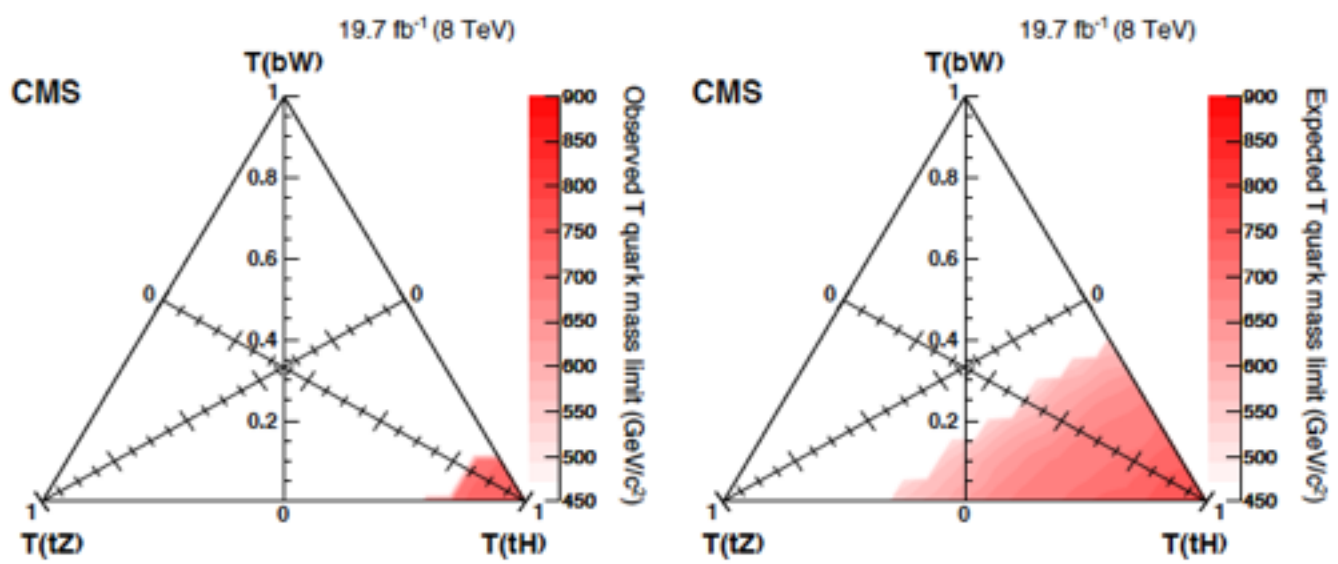
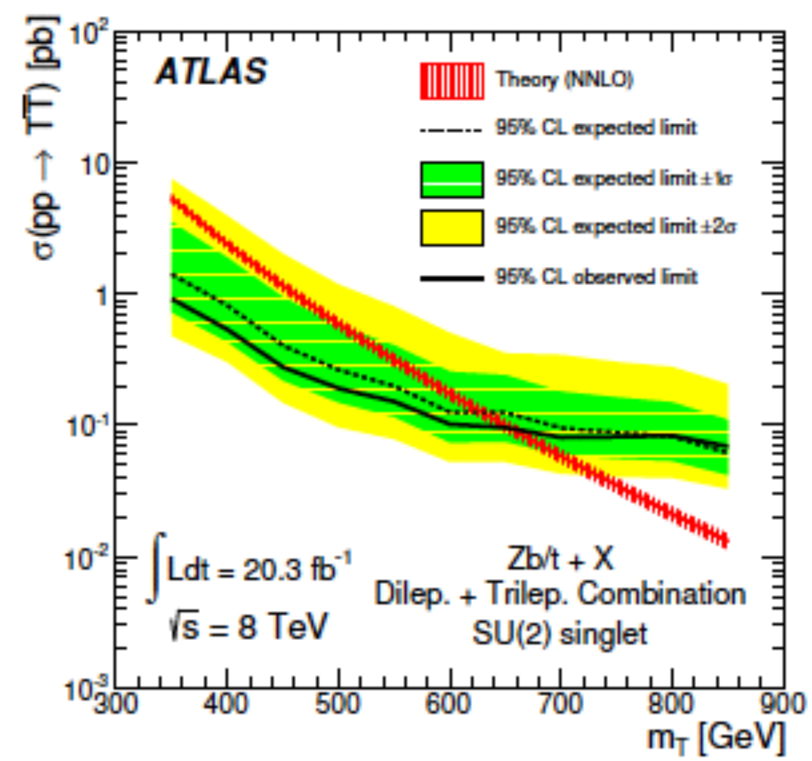
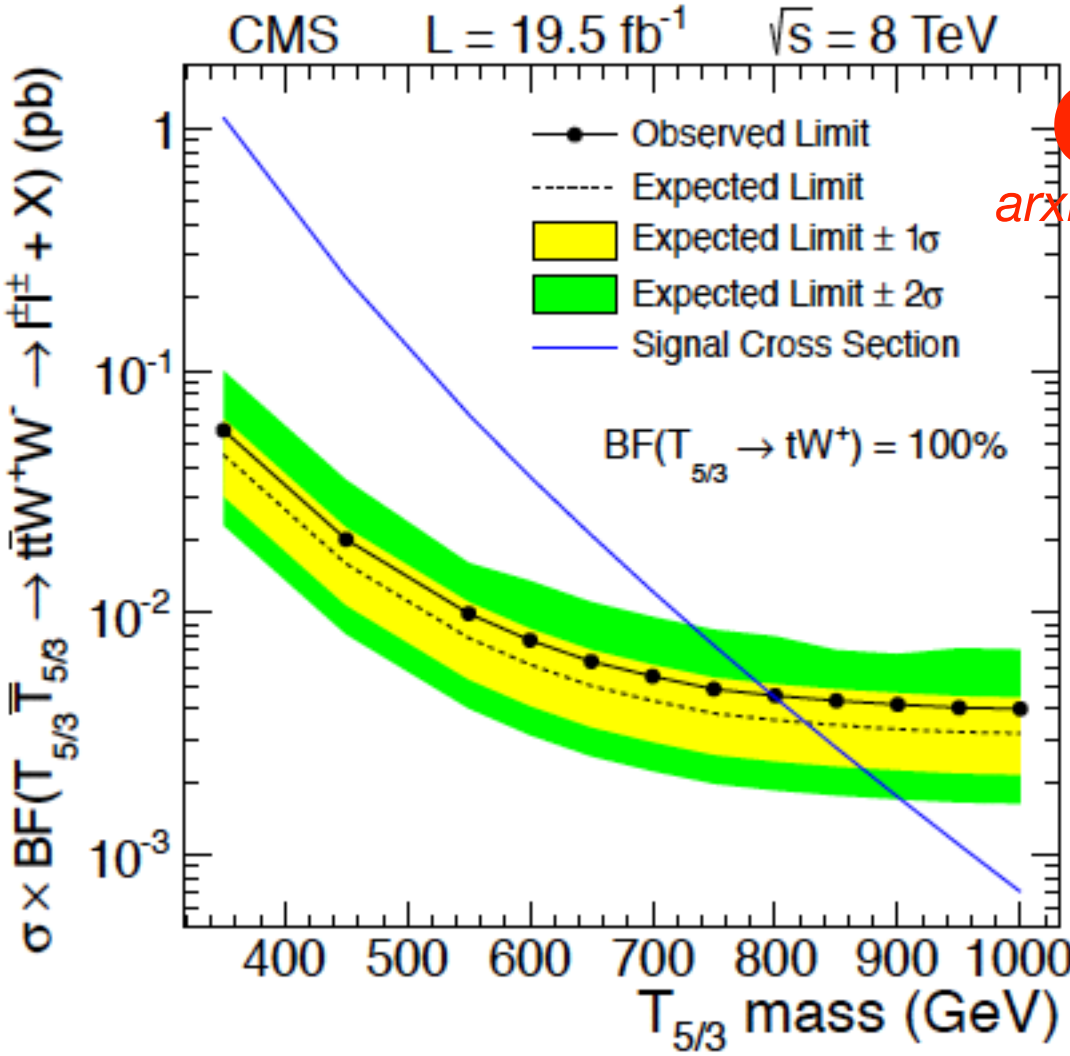


Figure 14: Branching fraction triangle with observed upper limits (left) and expected limits (right) for the T quark mass. Every point in the triangle corresponds to a particular set of branching fraction values subject to the constraint that all three add up to one. The branching fraction for each mode decreases from one at the corner labelled with the specific decay mode to zero at the opposite side of the triangle.



X5/3pair production:

- Run I same sign dilepton

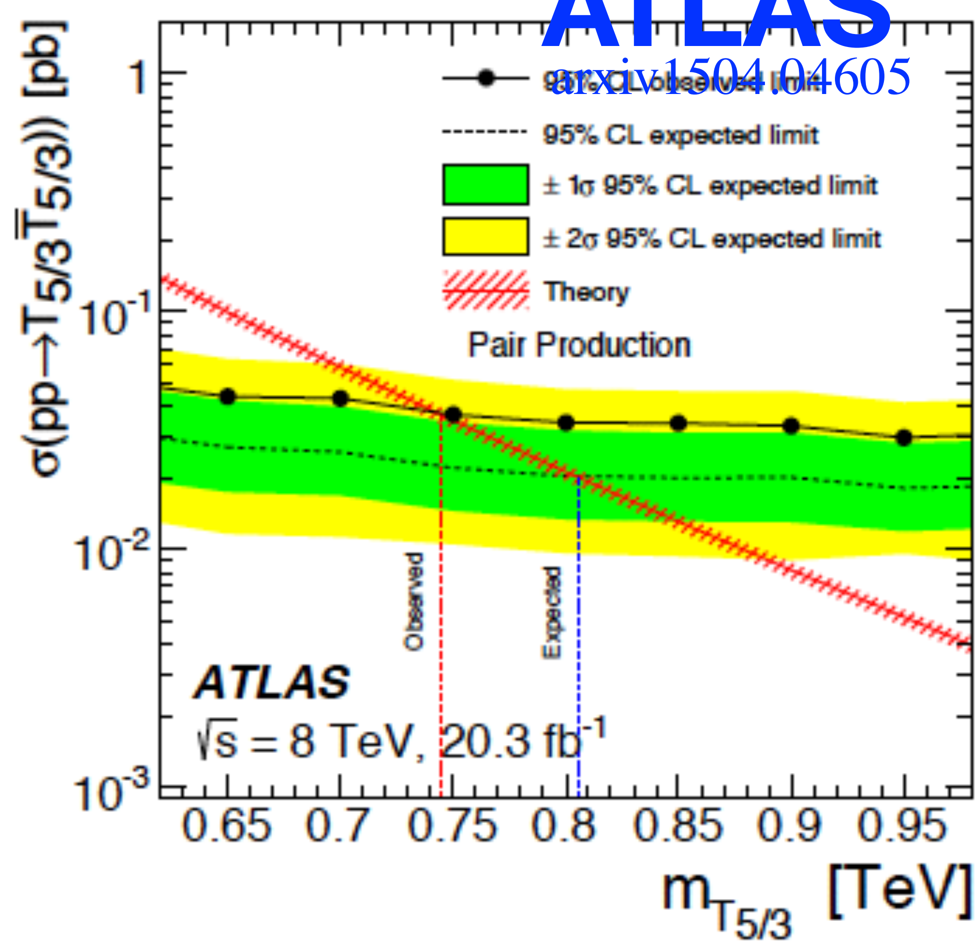


CMS

arxiv1312.2391

ATLAS

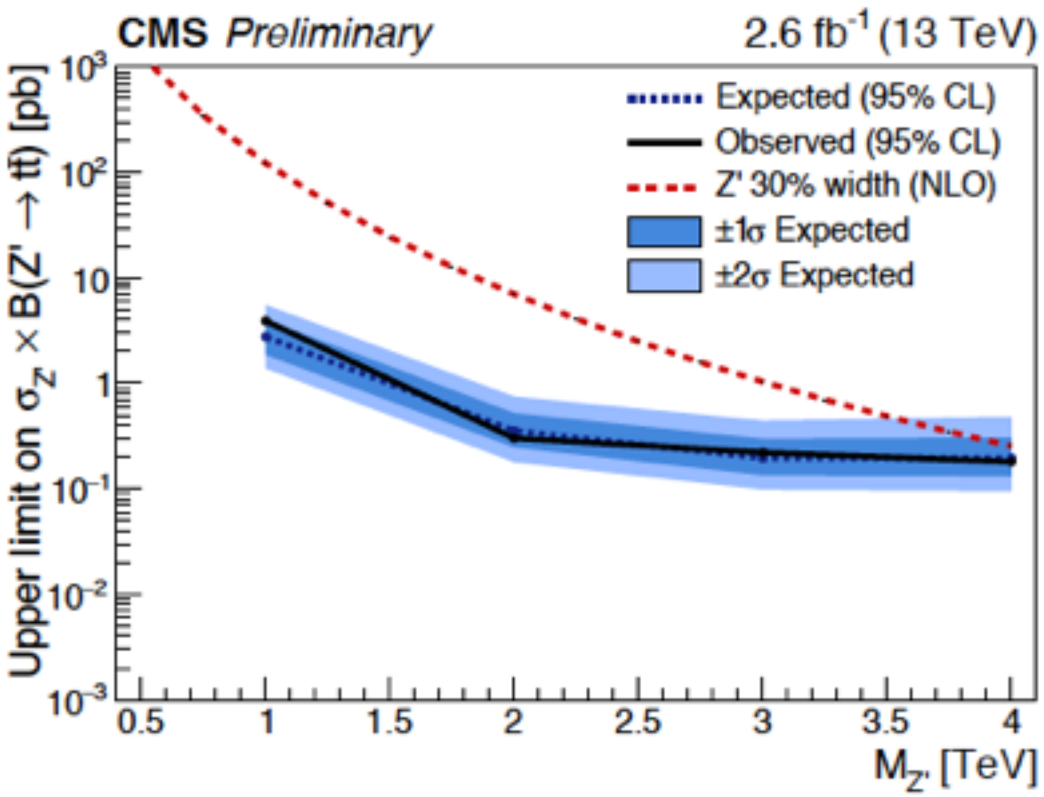
arxiv1504.04605

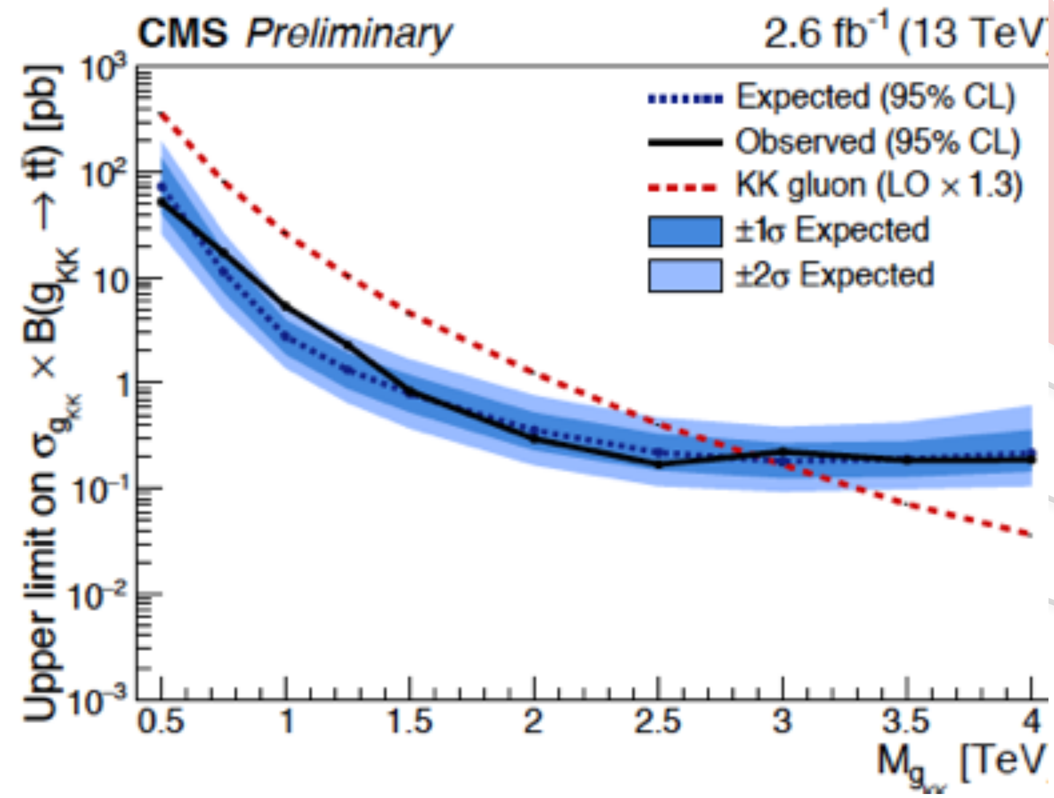


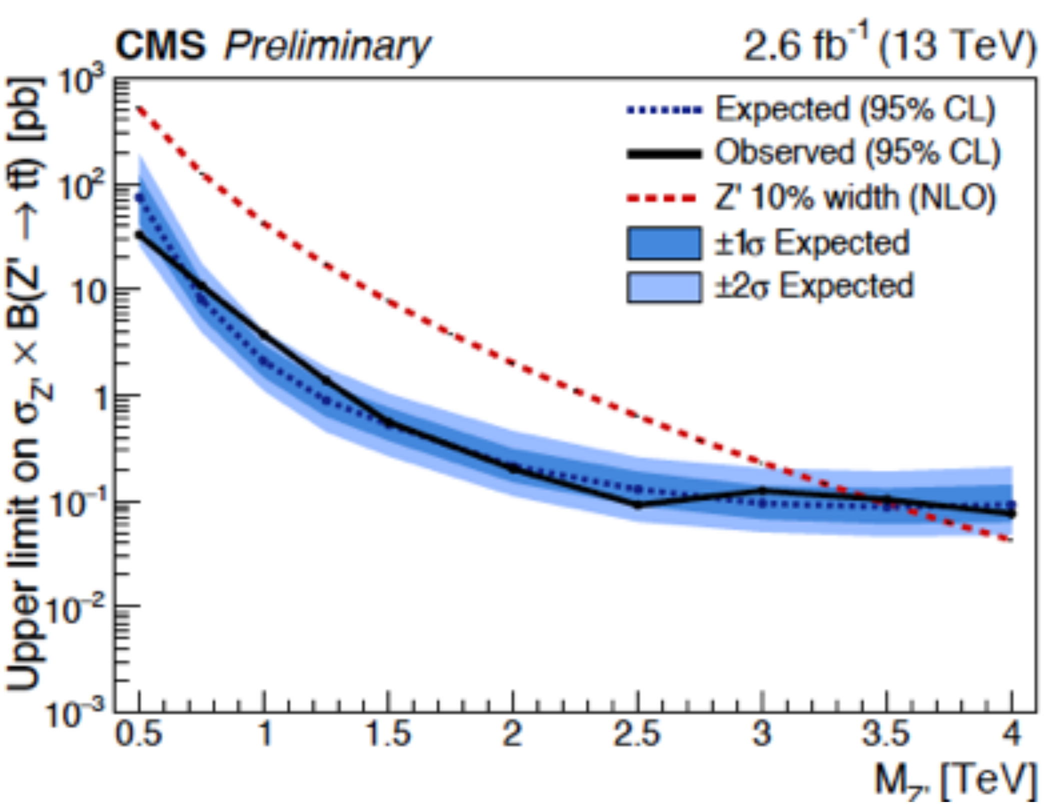
Searches for tt resonances

CMS

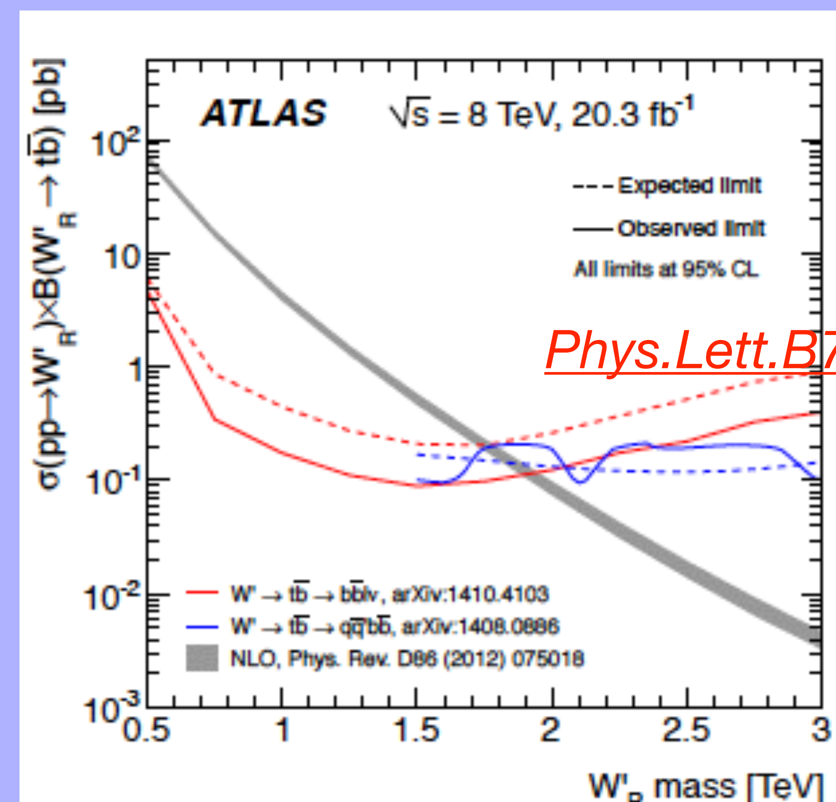
CMS-PAS-B2G-15-002





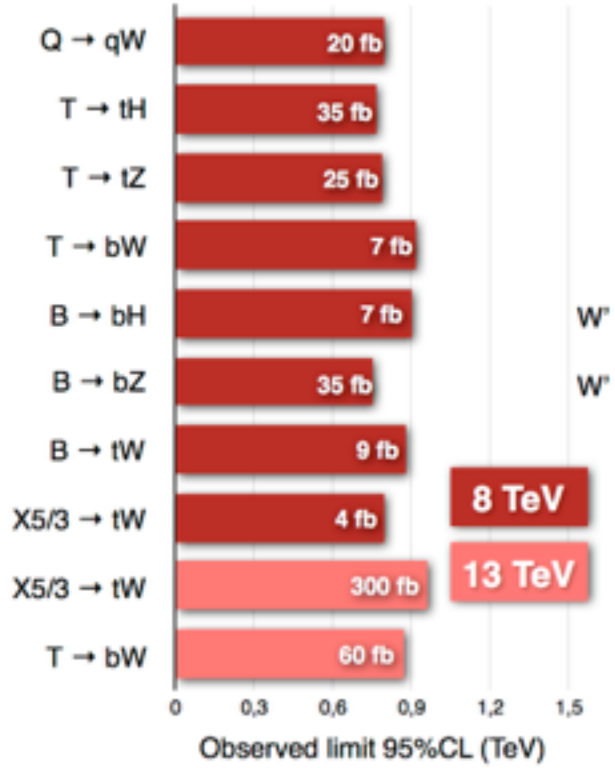


Searches for tb resonances

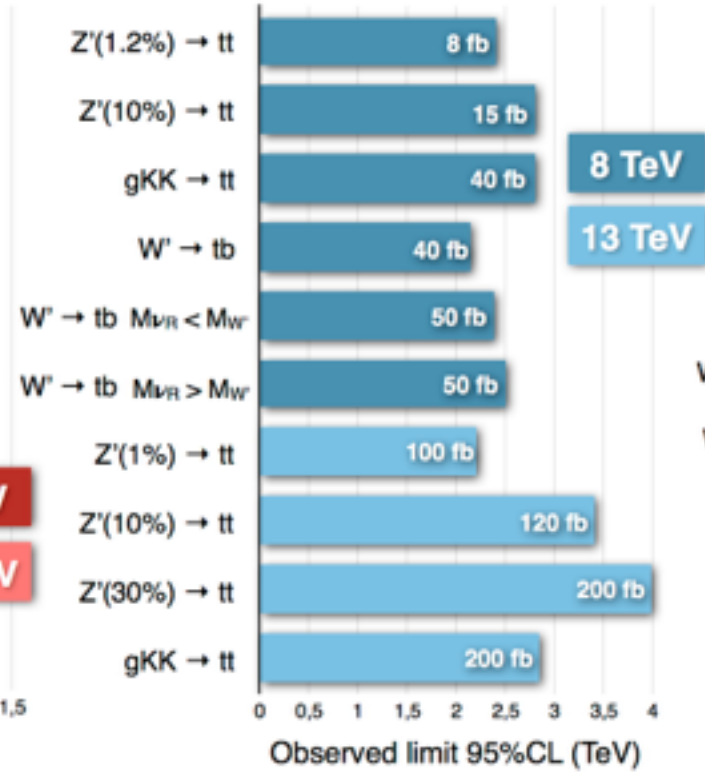


Phys.Lett.B743(2015)

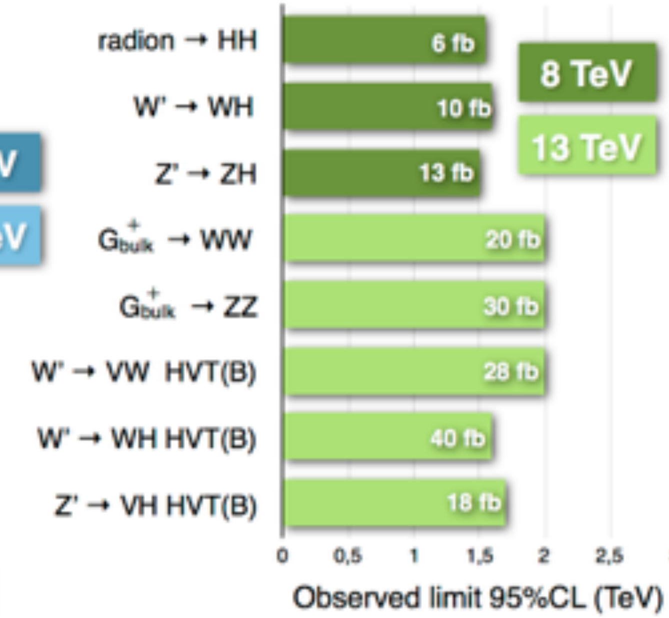
Vector-like quark pair production



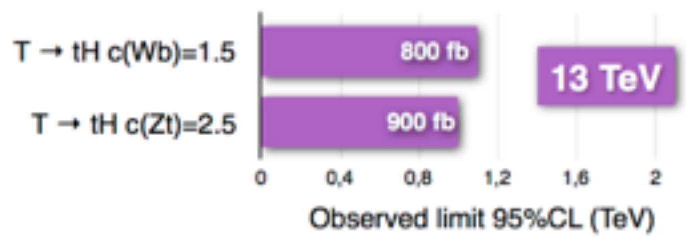
Resonances to heavy quarks



Resonances to dibosons

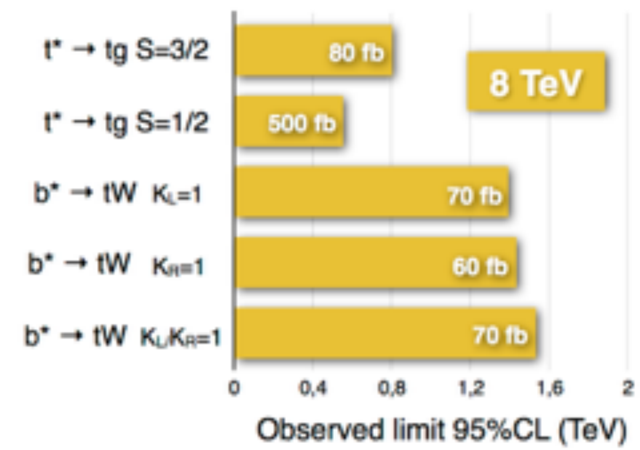


Vector-like quark single production



B2G: new physics searches with heavy SM particles

Excited quarks



+model-independent

ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2016

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt [\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	M_D 6.86 TeV	$n = 2$	Preliminary
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\to \ell q$	1 e, μ	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	3.6	M_{th} 8.3 TeV	$n = 6$	1512.01530
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	ATLAS-CONF-2016-006
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \ell\ell$	2 e, μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	1504.05511
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	3.2	G_{KK} mass 1.06 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2015-075
	Bulk RS $G_{KK} \to HH \to bbbb$	–	4 b	–	3.2	G_{KK} mass 475-785 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-017
	Bulk RS $g_{KK} \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \to tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	3.2	Z' mass 3.4 TeV		ATLAS-CONF-2015-070
	SSM $Z' \to \tau\tau$	2 τ	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		Preliminary
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	3.2	W' mass 4.07 TeV		ATLAS-CONF-2015-063
	HVT $W' \to WZ \to qq\nu\nu$ model A	0 e, μ	1 J	Yes	3.2	W' mass 1.6 TeV	$g_V = 1$	ATLAS-CONF-2015-068
	HVT $W' \to WZ \to qqqq$ model A	–	2 J	–	3.2	W' mass 1.38-1.6 TeV	$g_V = 1$	ATLAS-CONF-2015-073
	HVT $W' \to WH \to \ell\nu bb$ model B	1 e, μ	1-2 b, 1-0 j	Yes	3.2	W' mass 1.62 TeV	$g_V = 3$	ATLAS-CONF-2015-074
	HVT $Z' \to ZH \to \nu\nu bb$ model B	0 e, μ	1-2 b, 1-0 j	Yes	3.2	Z' mass 1.76 TeV	$g_V = 3$	ATLAS-CONF-2015-074
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	3.6	Λ 17.5 TeV	$\eta_{LL} = -1$	1512.01530
	CI $qq\ell\ell$	2 e, μ	–	–	3.2	Λ 23.1 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2015-070
	CI $uutt$	2 e, μ (SS)	≥ 1 b, 1-4 j	Yes	20.3	Λ 4.3 TeV	$\lvert C_{LL} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 140$ GeV	Preliminary
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	m_A 650 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 10$ GeV	Preliminary
	$ZZ\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.07 TeV	$\beta = 1$	Preliminary
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.03 TeV	$\beta = 1$	Preliminary
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \to Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
	$T_{5/3} \to Wt$	1 e, μ	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		1503.05425
Excited fermions	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	3.2	q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \to qg$	–	2 j	–	3.6	q^* mass 5.2 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.01530
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	3.2	b^* mass 2.1 TeV		Preliminary
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2 e, μ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s}$ = 8 TeV $\sqrt{s}$ = 13 TeV

10^{-1} 1 10 Mass scale [TeV]

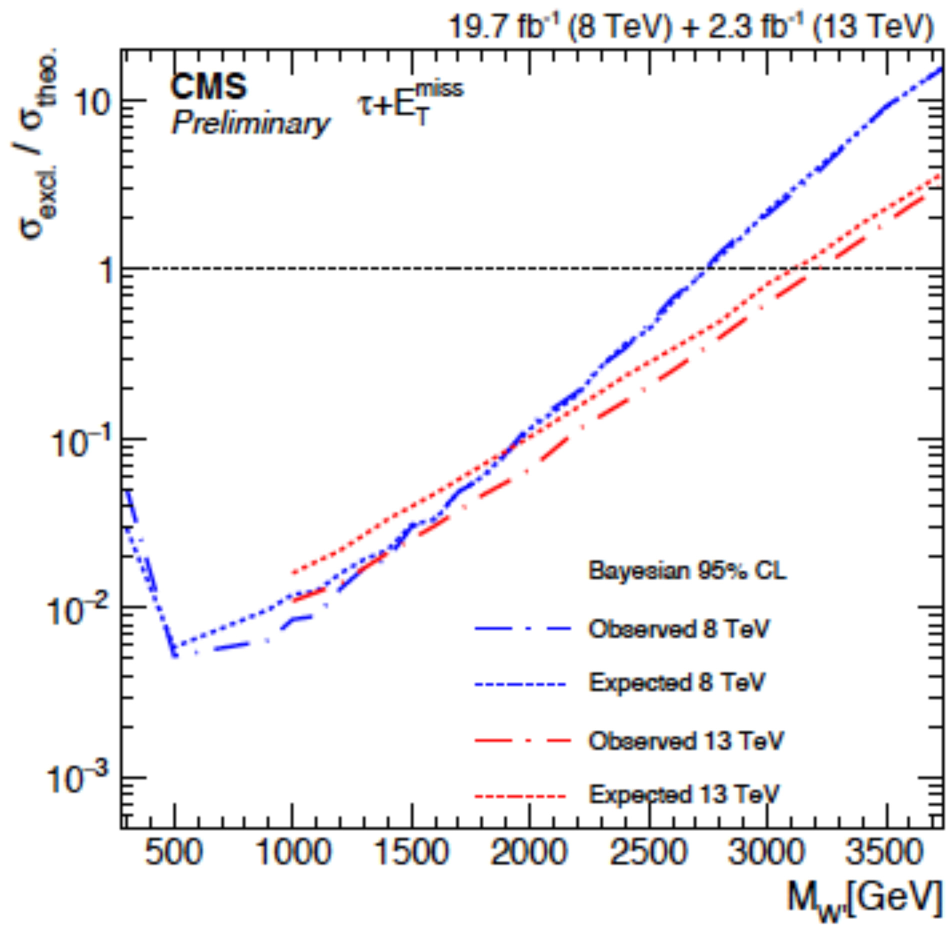
*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

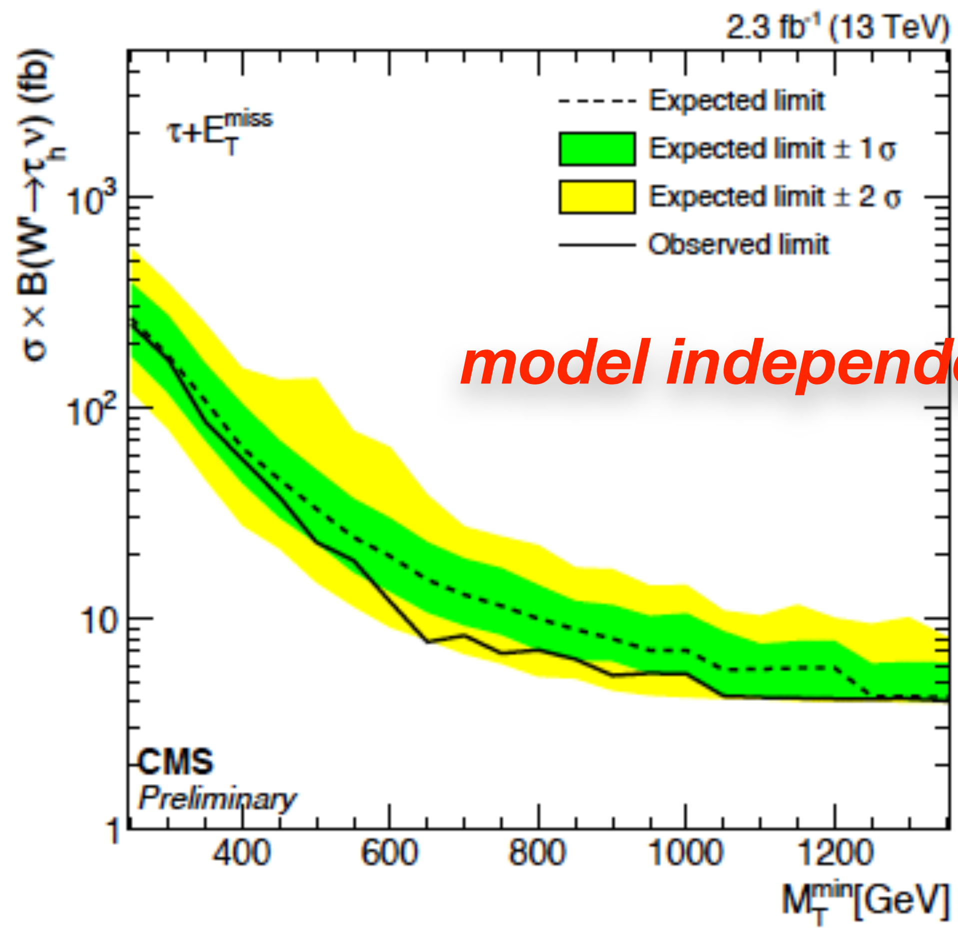
†Small-radius (large-radius) jets are denoted by the letter j (J).

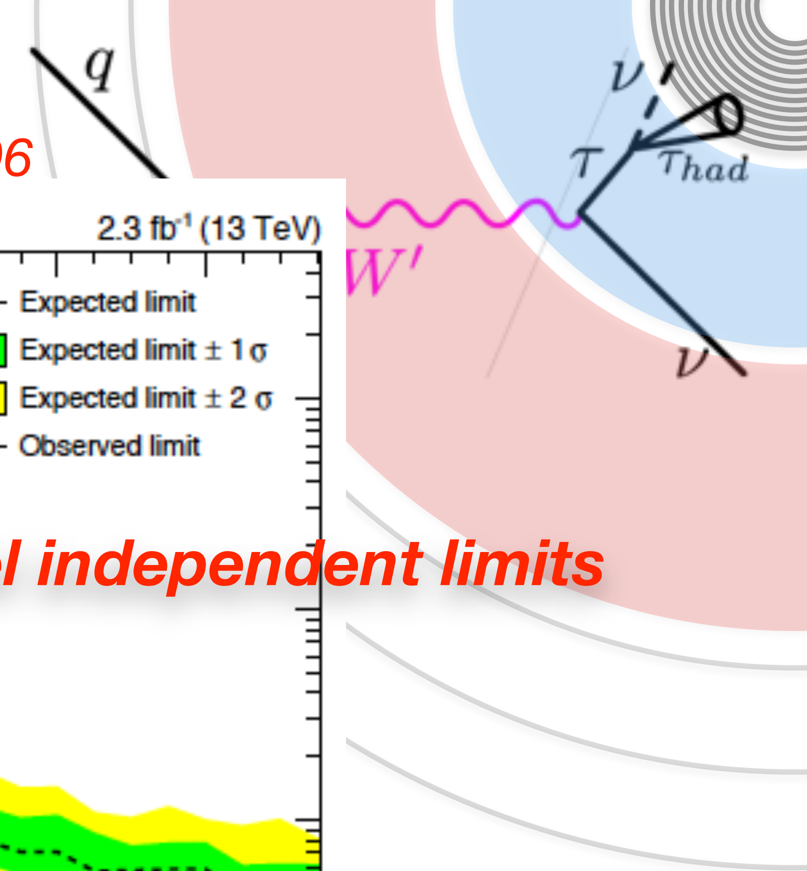
Searches for $\tau\nu$ resonances

CMS

CMS-PAS-EXO-16-006

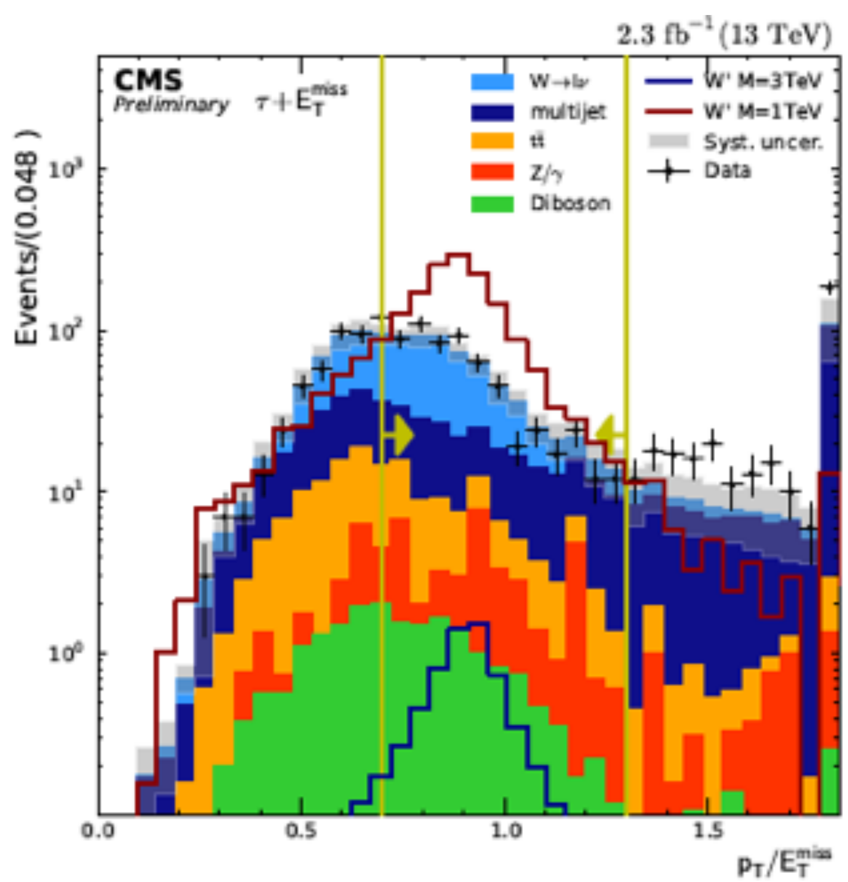


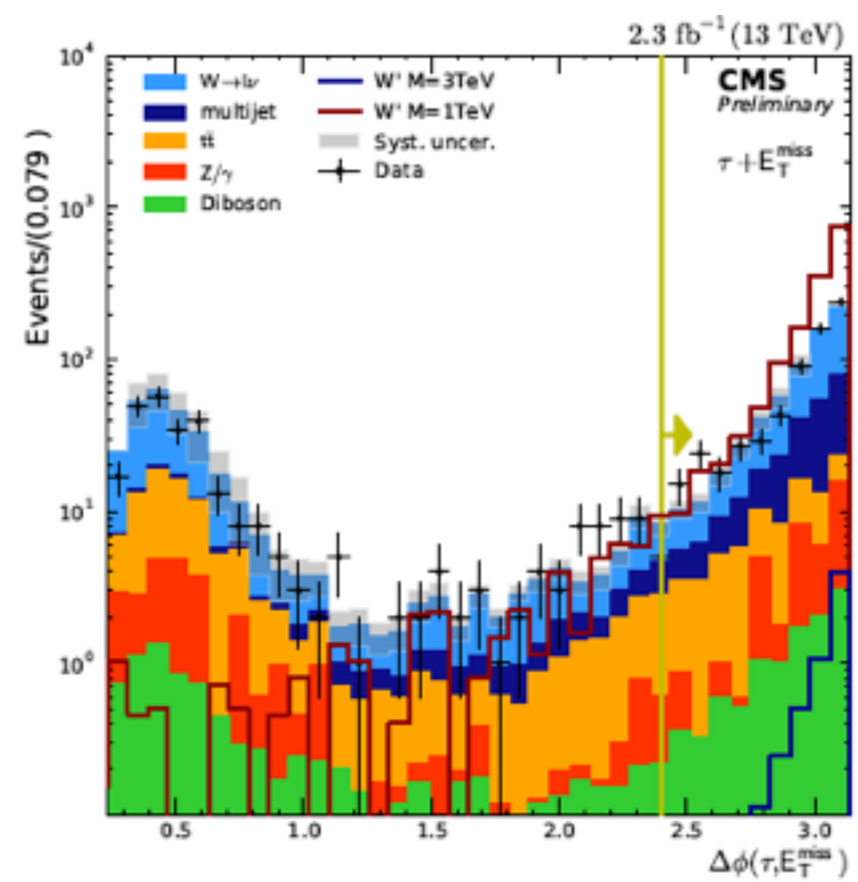




model independent limits

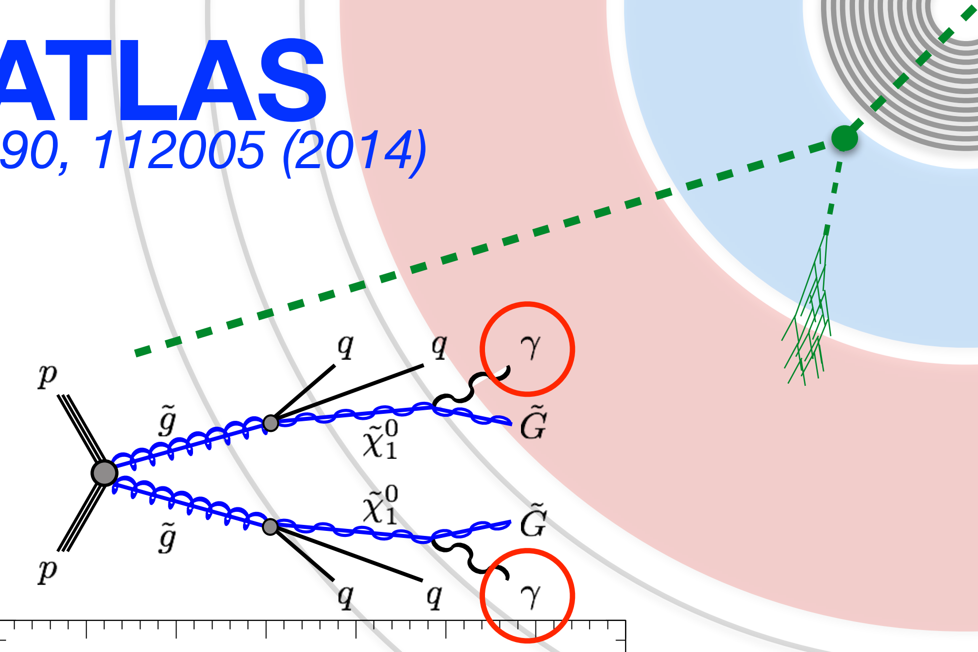
- Run I more sensitive at low masses for increased multi jet cross section at 13 teV
- From Run I and II combination W' can be excluded in the mass range 300 GeV<M(W')<3.3 TeV



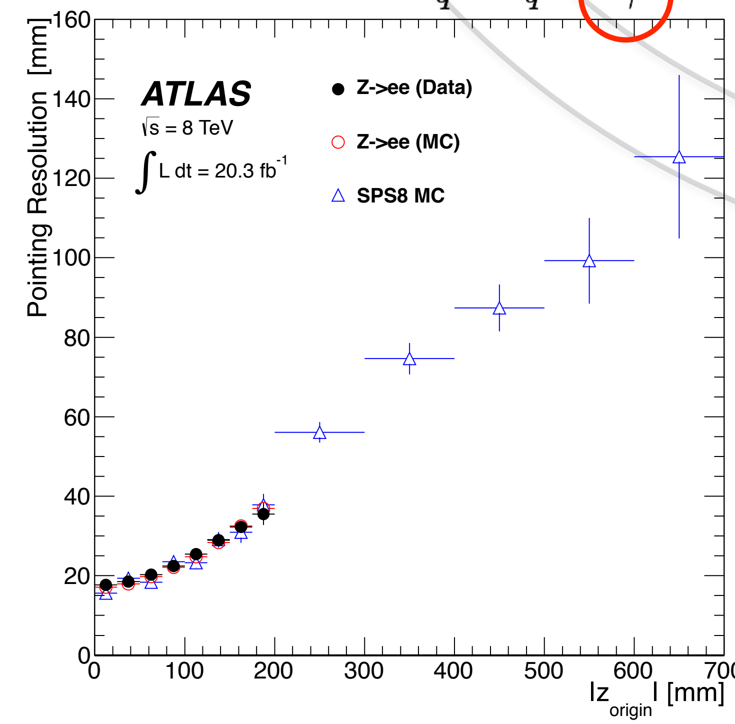


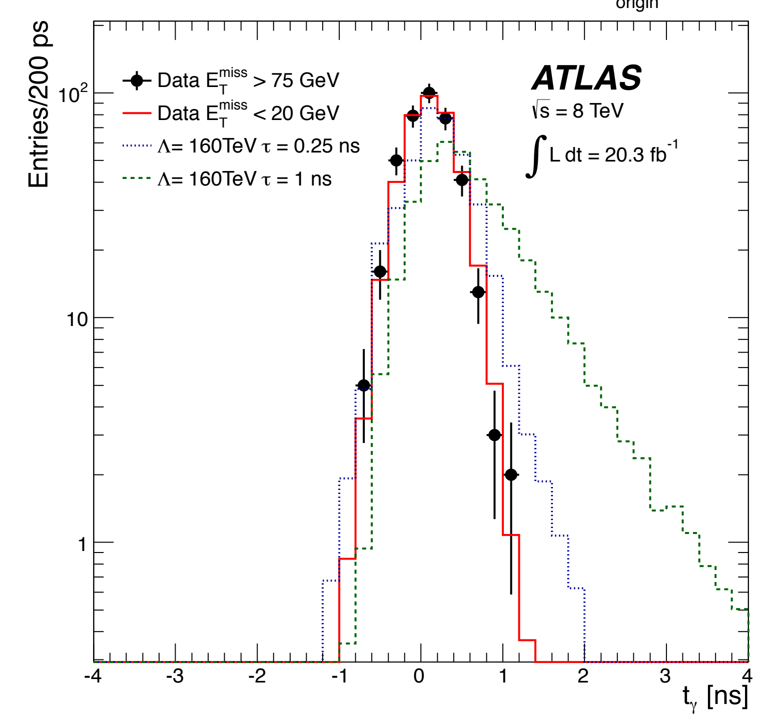
Delayed and Displaced Photons

ATLAS *PRD 90, 112005 (2014)*



- Long-lived pair-produced neutral particle decaying into a photon and an undetectable particle
  - GMSB benchmark model, neutralino NLSP
- Signatures
  - *undetectable particle*: large MET
  - search for final state with 1 or 2 photons
  - main discriminants are *timing and direction EM calo* (low β, late decay)
- Status and Plans
  - LAr Calorimeter timing calibrated using W→eν data sample, validate in Z→ee data
    - plan to include calibration for low gain LAr hits (worse resolution due to limitations in calibration samples)
- CMS public result: Phys. Lett. 722 (2013) 273





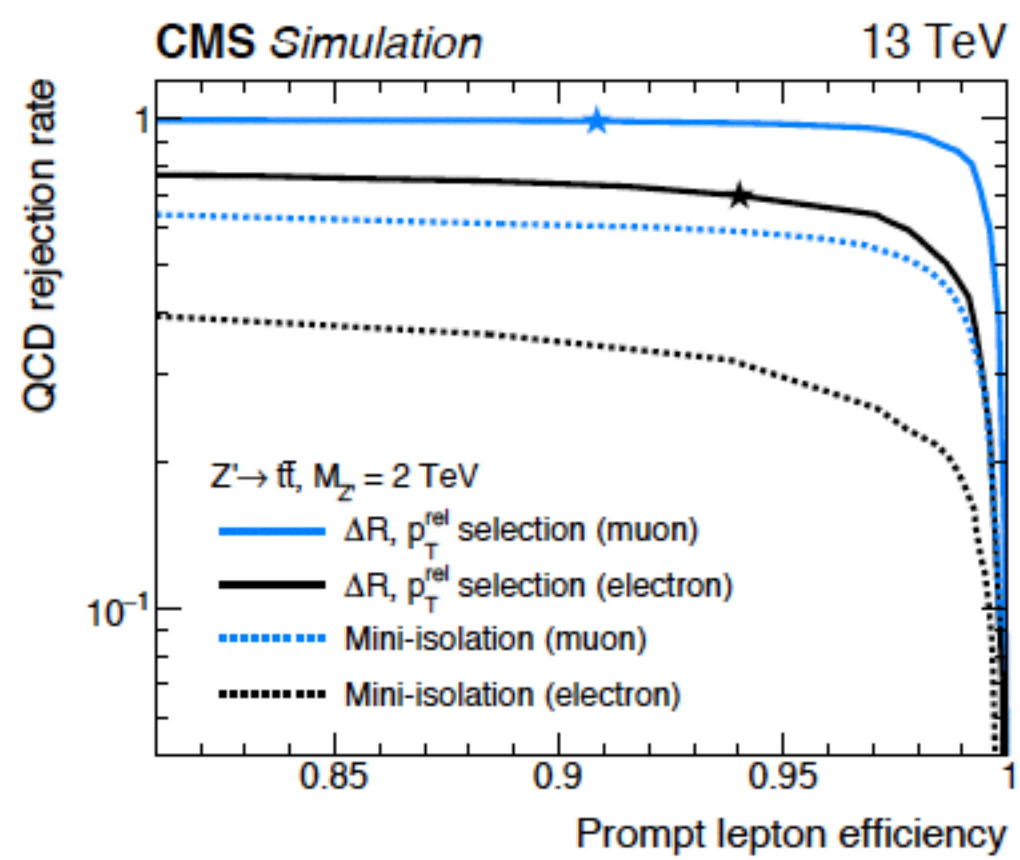
Discussion

- Boosted objects and techniques
- Non standard signatures
- Theoretical interplay

Discussion

- Resonance and VLQ searches are pretty consistent between CMS and ATLAS:
  - boosted object reconstruction:
    - lepton isolation optimized for presence of close by jet
      - ATLAS: isolation cone that is the smaller b/w ΔR=10GeV/pT or ΔR=0.2 (e) and 0.3 (μ)
      - CMS uses:
      - MiniIsolation(similar concept)
      - ΔR(l,j)>0.4 or $p_T^{rel}(\ell,j)$> 20 GeV

Z'->tt



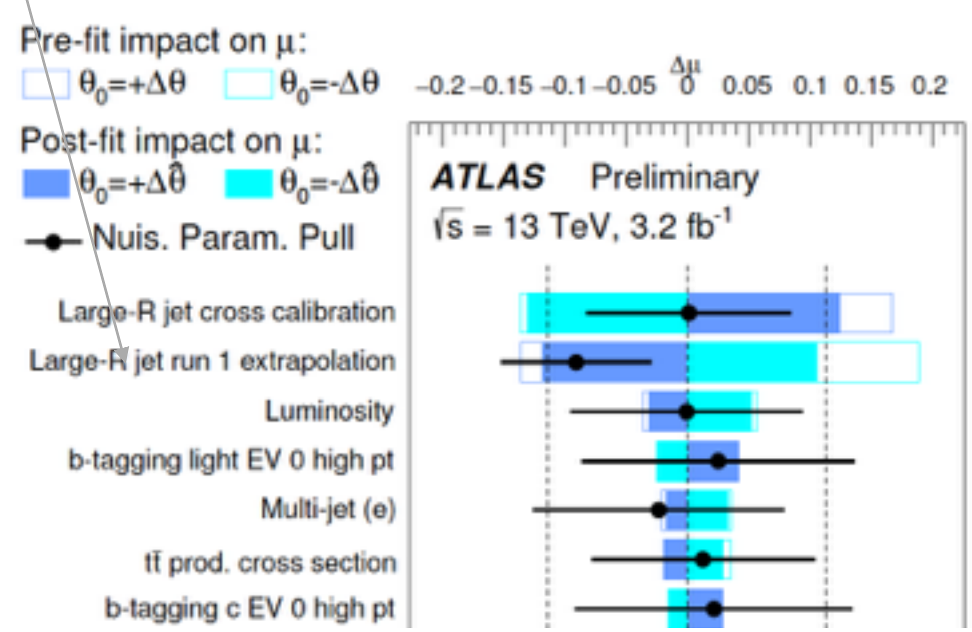
Discussion

- Resonance and VLQ searches are pretty consistent between CMS and ATLAS:
  - boosted object reconstruction:
    - boosted W, t, H tagging: main tool for signal selection and also among the biggest source of uncertainty
      - calibration in situ
      - calibration in 8 TeV because of low statistics in validation sample

Z'->tt

postfit

CMS	1 t tag		
	$t\bar{t}$	W + jets	Z′
t- and b-tagging	6.7%	17.0%	7.3%
Scale uncertainty	4.1%	9.9%	–
PDF	2.7%	4.8%	4.2%



Can they be improved?

Discussion

- boosted W, t, H tagging similar between ATLAS and CMS:
  - grooming algorithms for mass reconstruction: soft radiation in jet is removed providing better resolution
  - N-subjettiness(τ_{21},τ_{32}) : jet substructure more likely to be originated by a given number of hard partons
  - Large-R jet or subjet b-tagging

- N-subjettiness cut is correlated with pt and mass (sculpting of bkg)?

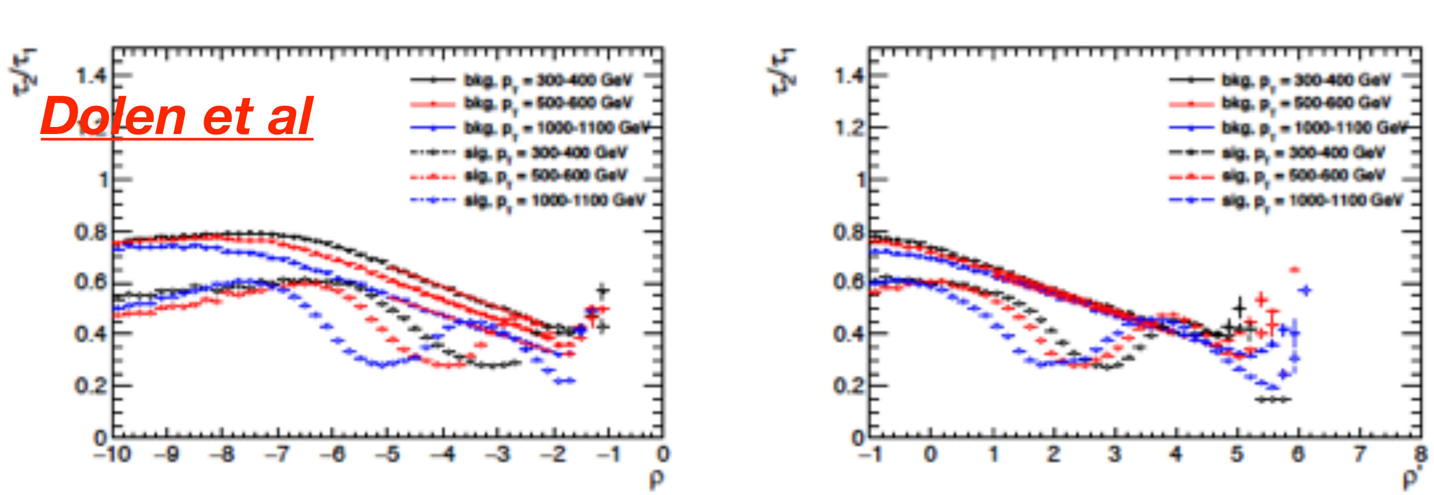
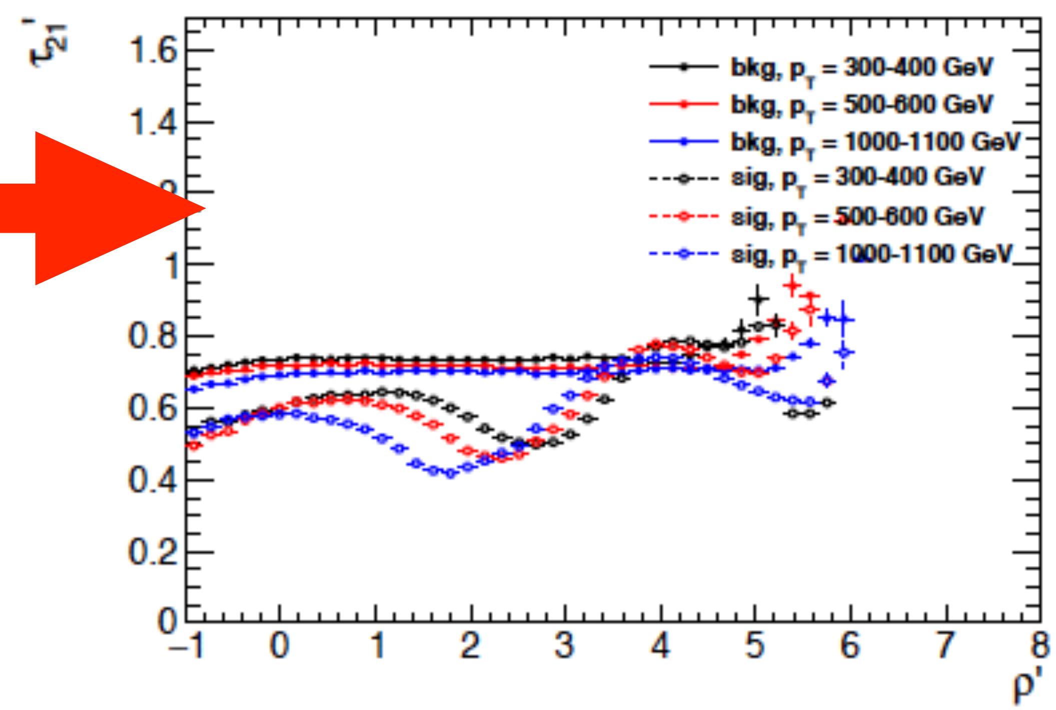


Figure 2: Profile distributions, $\langle\tau_2/\tau_1\rangle$, as a function of $\rho = \log(m^2/p_T^2)$ (left) and as a function of $\rho' = \log(m^2/p_T/\mu)$ (on the right). Solid dots correspond to background, while hollow ones to signal. The different colors correspond to different p_T bins.



- multivariate tool to tag? Validation?
- Extrapolation to high pt regime? more statistics is needed

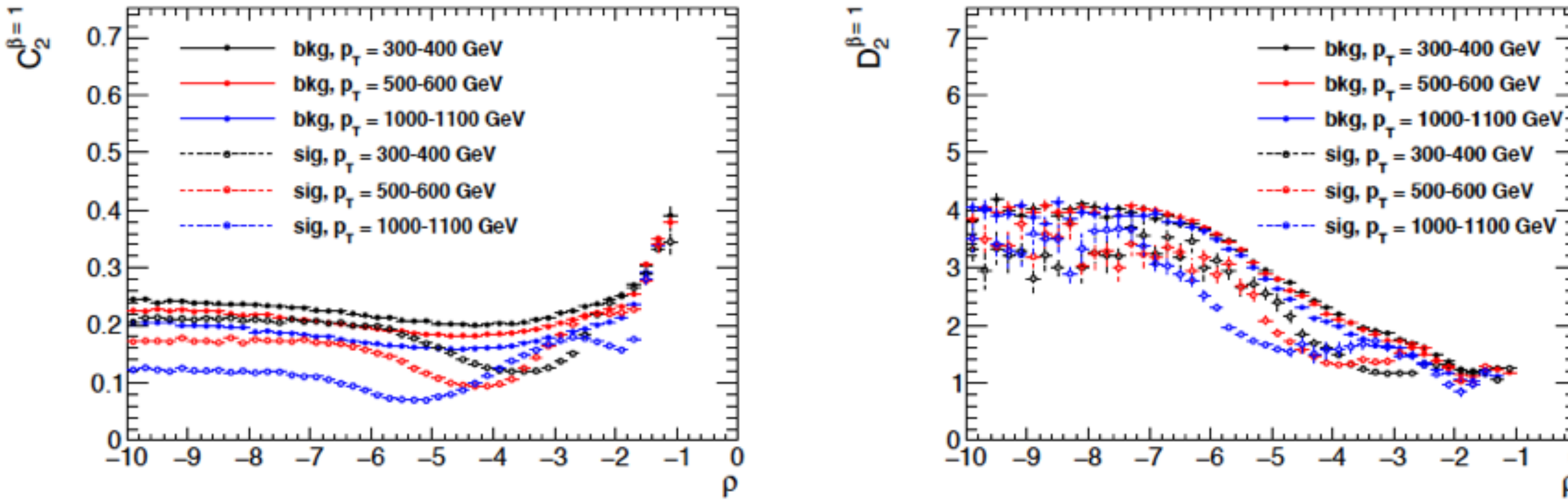


Figure 3: Profile distributions, $\langle C_2^{\beta=1} \rangle$ (left) and $\langle D_2^{\beta=1} \rangle$ (right), as a function of $\rho = \log(m^2/p_T^2)$. Solid dots correspond to background, while hollow ones to signal. The different colors correspond to different p_T bins

Non standard signatures

- Dedicated triggers for non standard signatures and ad hoc reconstruction algorithm
  - slow muons
  - energy deposits in calorimeters (HE/EE)
  - displaced vertices

Save useful infos in the xAOD/AOD

Theoretical interplay

- Some excesses seen in some analysis, but nothing new so far..
  - What if nothing is found?
- If di-phon excess is confirmed what can it be?
  - VLQ : T-> tη : TTpair production with ttjjjj Strasler et al. arxiv 1512.05775
  - Associated production with other particles(t,b,tau)?