Searches for Physics beyond the Standard Model at the LHC

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"Astroparticle Physics in Germany - Status and Perspectives"
17.9.-19.9.18, Mainz University

RWTH AACHEN UNIVERSITY
I. Physikalisches Institut B

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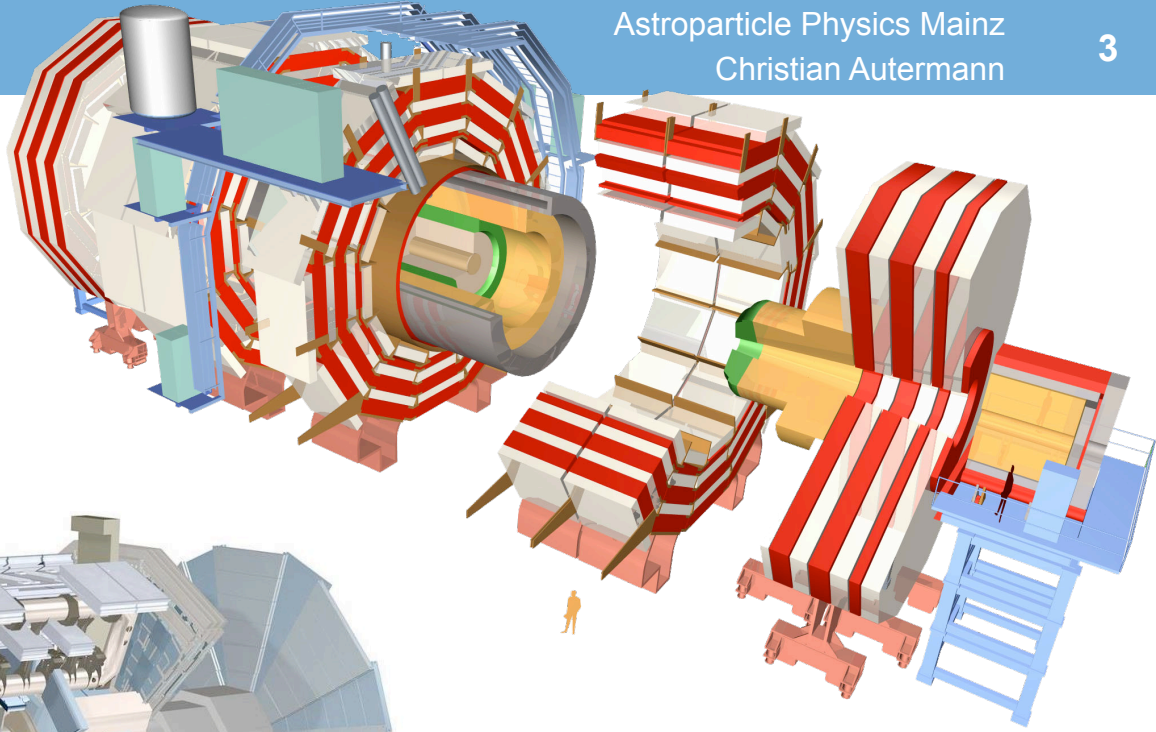
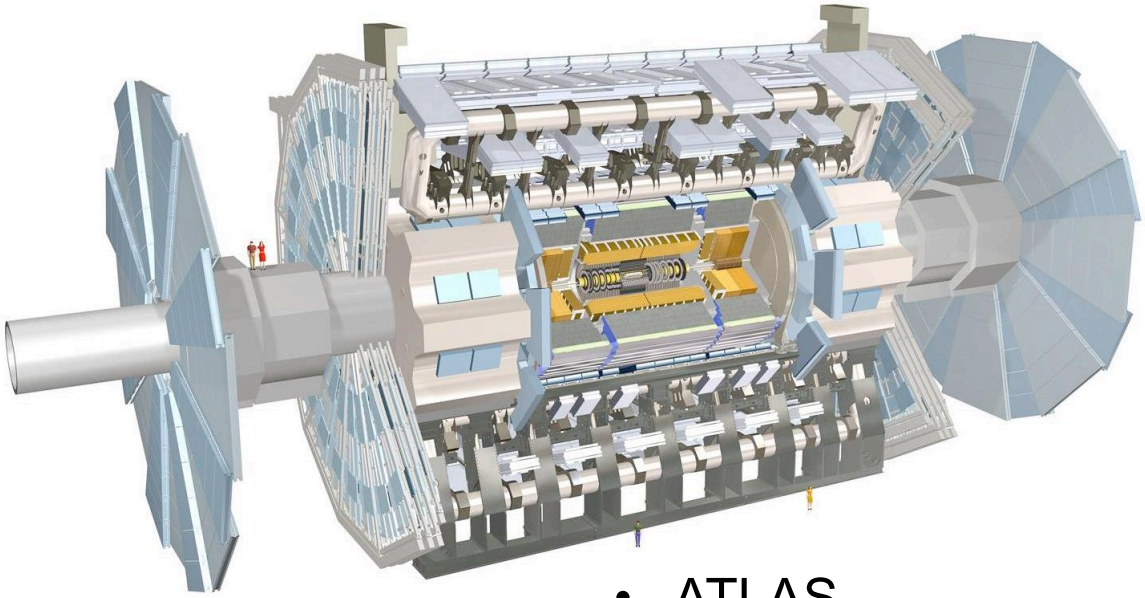
Overview

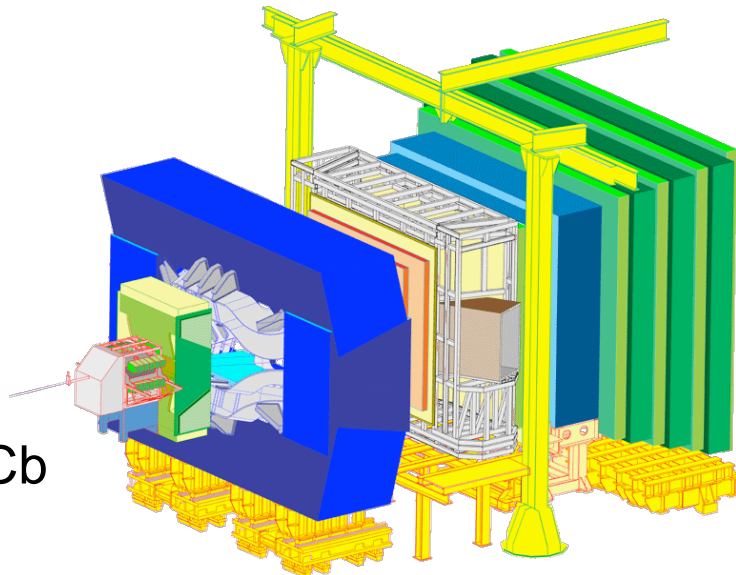
- Status ATLAS, CMS, LHCb
- Recent Highlights
- Higgs sector
- Supersymmetry
- Dark matter

- CMS

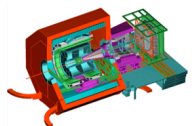




- ATLAS



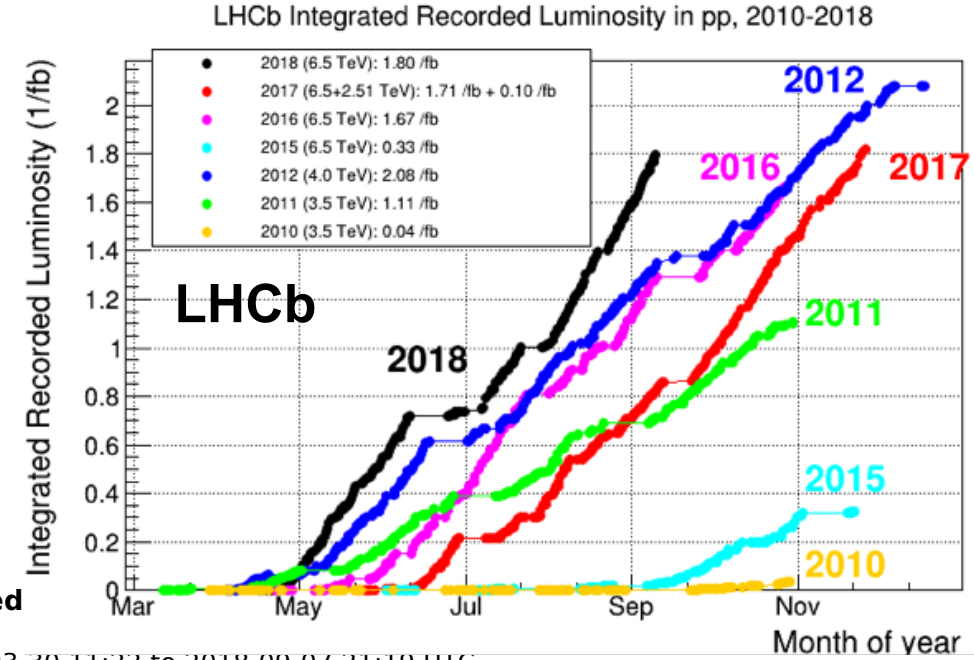
- LHCb



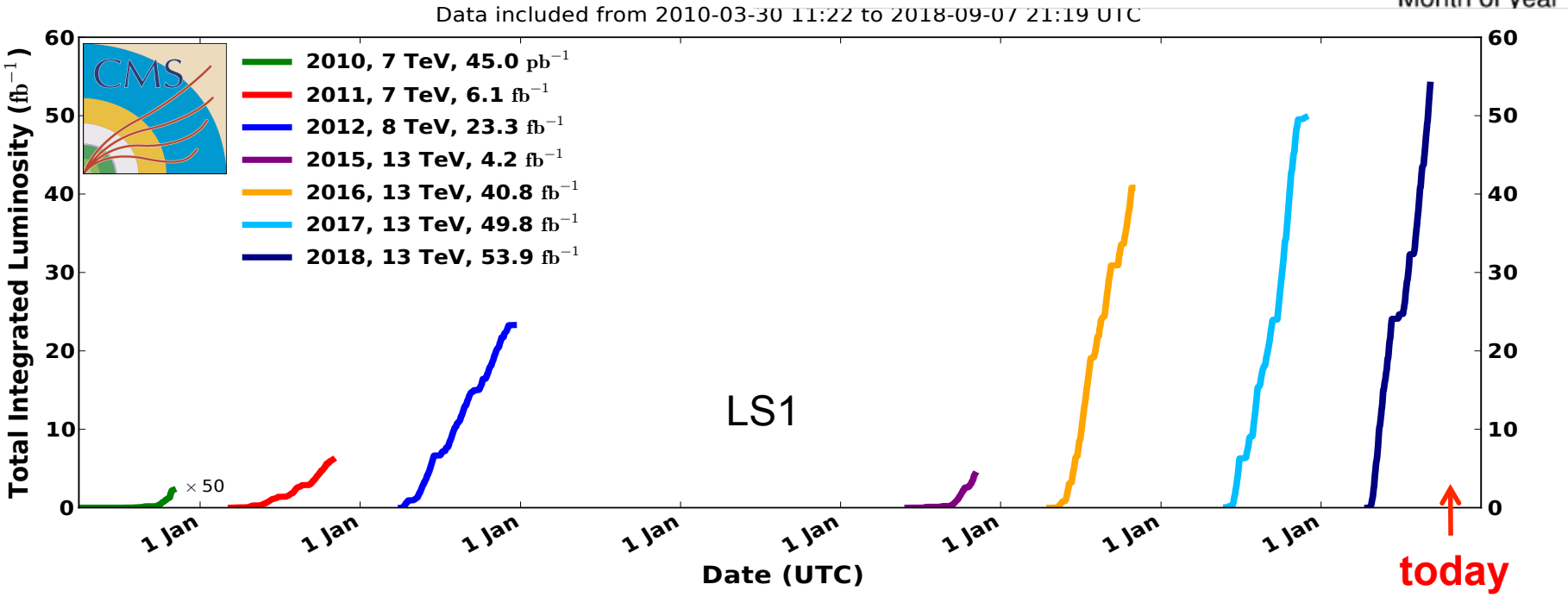
- ALICE

Delivered luminosity

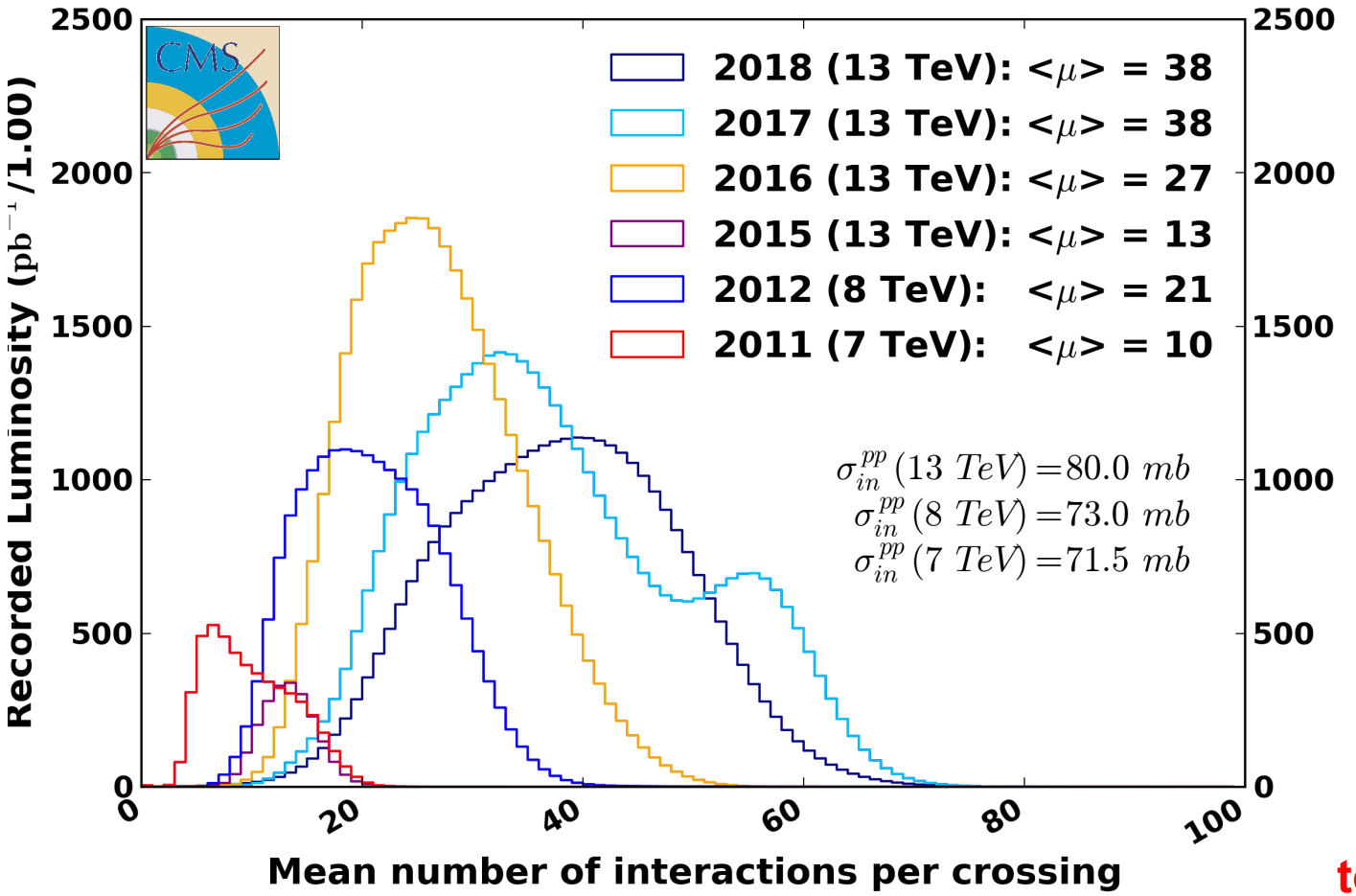
- ATLAS / CMS: 50 fb^{-1} in 2018
  ≈95% data-taking efficiency
- LHCb 1.8 fb^{-1} in 2018
  ≈90% data-taking efficiency



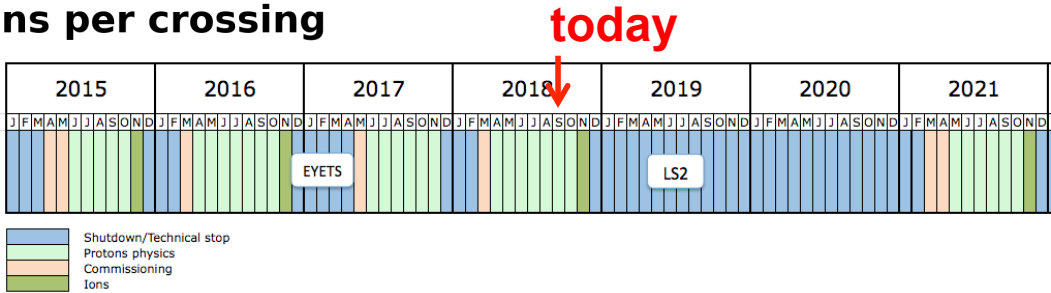
CMS Integrated



Simultaneous number of interactions



- increasingly difficult analyses
- **the** dataset for the coming years!



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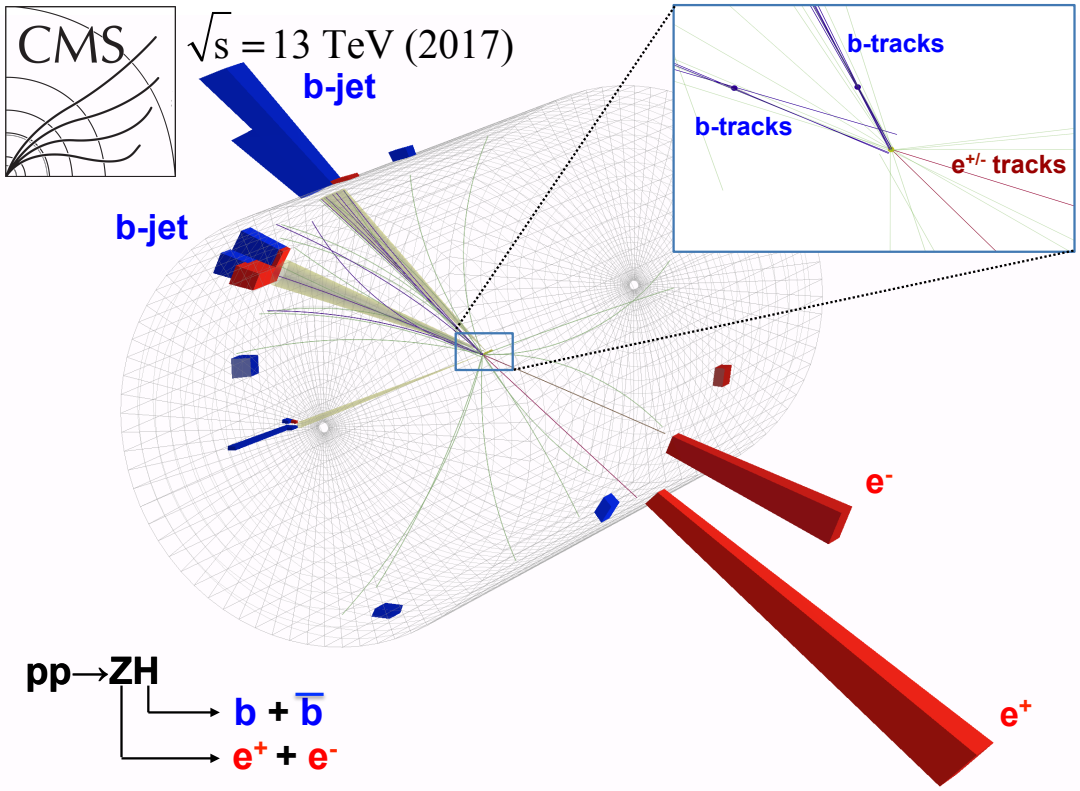
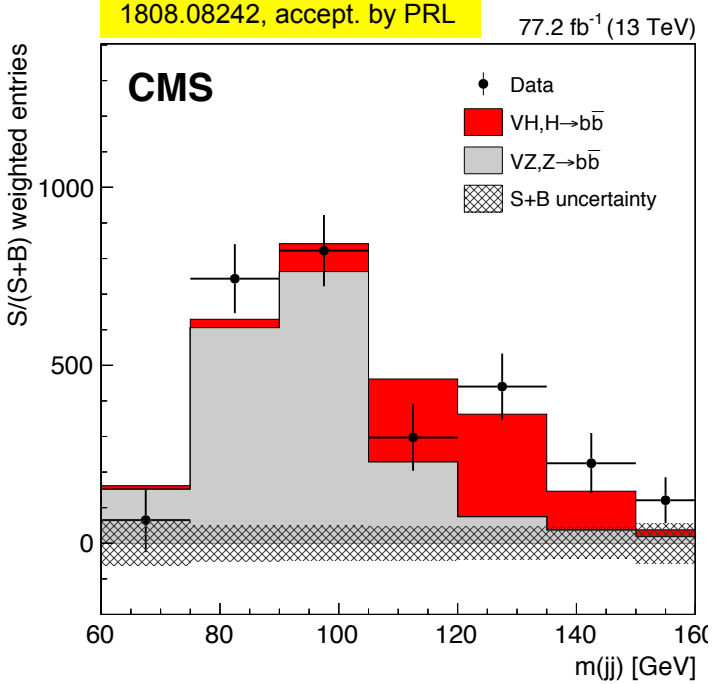
Observation of H→bb



- ATLAS μ=1.06
  5.5σ (obs) with 7,8,13 TeV data
  arXiv:1808.08238 accept. by PLB
- CMS μ=1.04±0.20
  5.6σ (obs) with 7,8,13 TeV data, VH+other processes

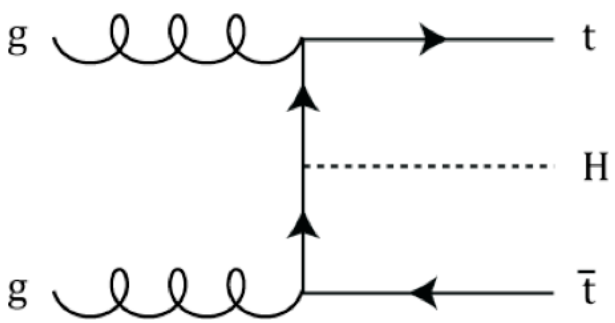
1808.08242, accept. by PRL



- improved sensitivity in 2017 data by up to 10%
  - new pixel detector
  - DNN b-tagger, kinematic fits
  - DNN signal/background discrimination

Observation of ttH production

→ measurement of top-Higgs coupling



- ATLAS: $\mu = 1.32^{+0.28}_{-0.26}$
  6.3σ (obs) with 7, 8, 13 TeV data
- CMS: $\mu = 1.26^{+0.31}_{-0.26}$
  5.2σ (obs) with 7, 8, 13 TeV data

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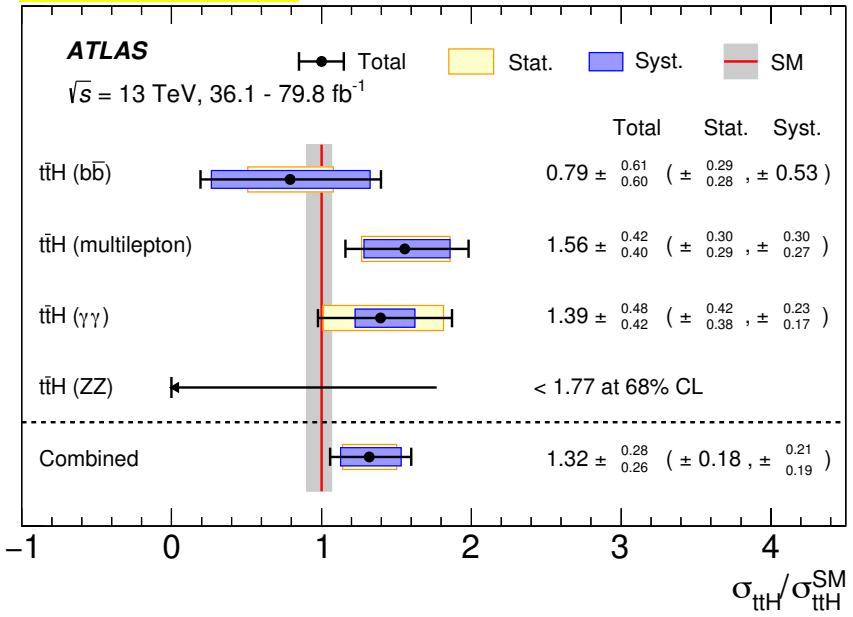
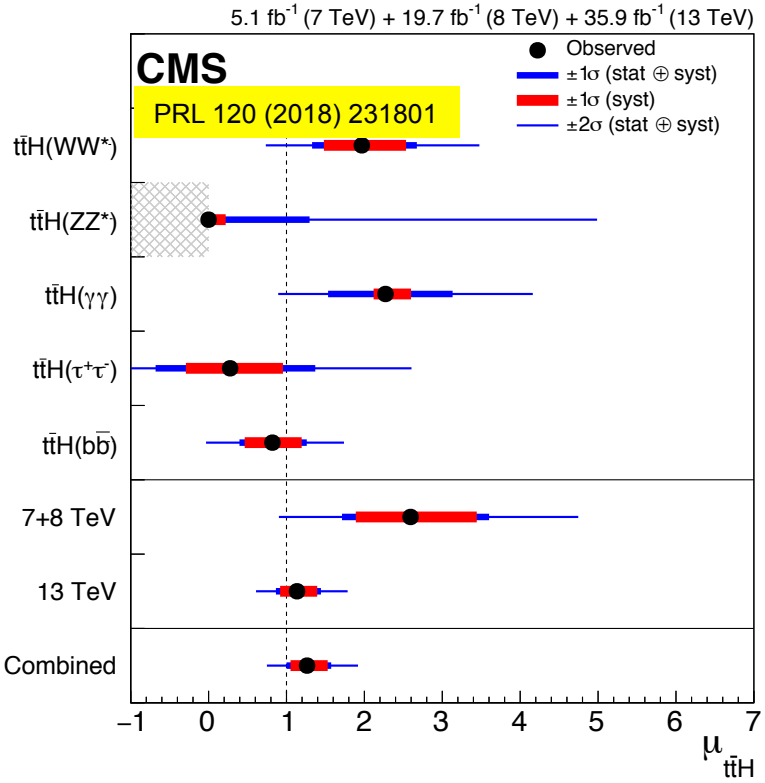
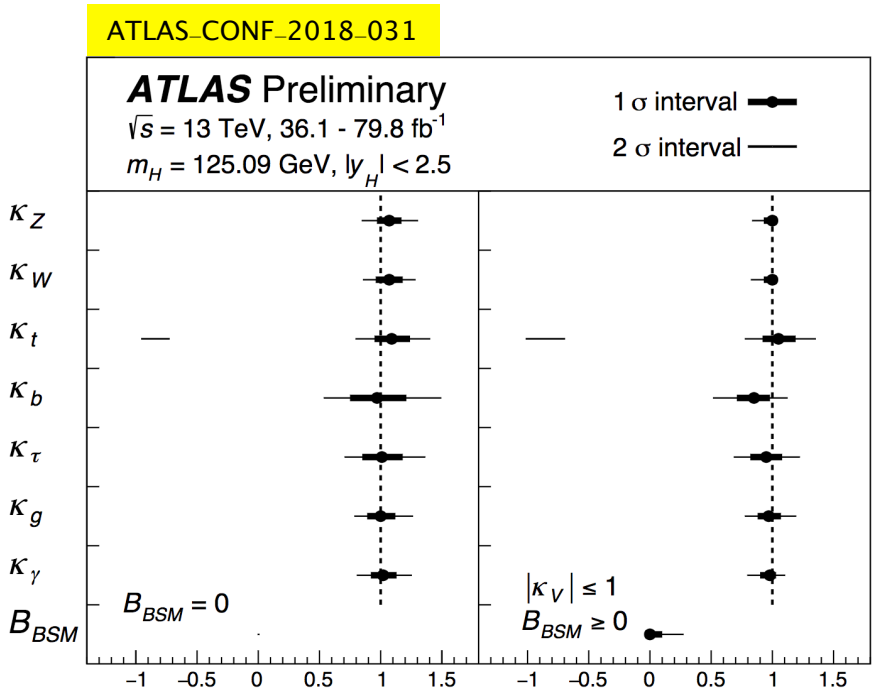


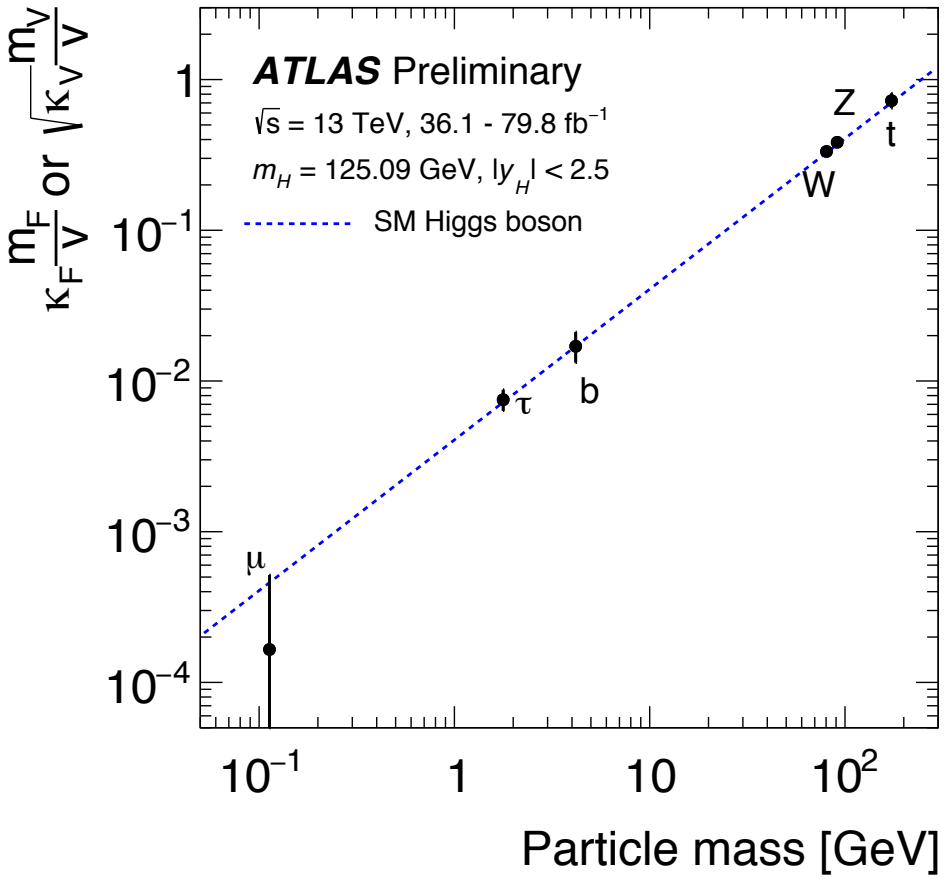


→ Indirect constrains on New Physics

Selected Higgs summary plots

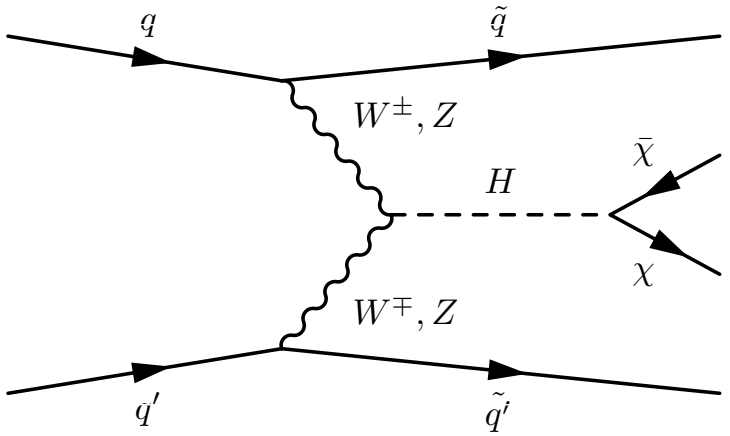


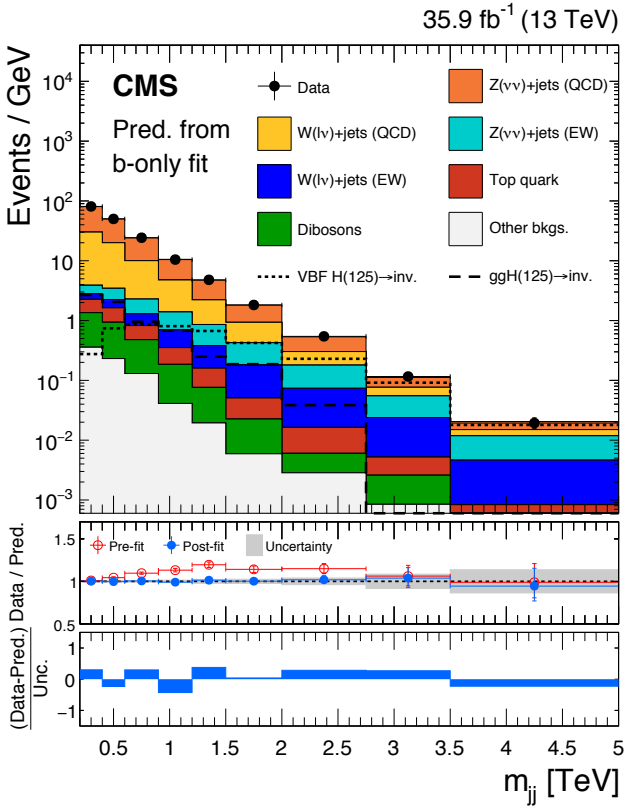
$B_{BSM} \leq 0.26$ at 95% C.L.

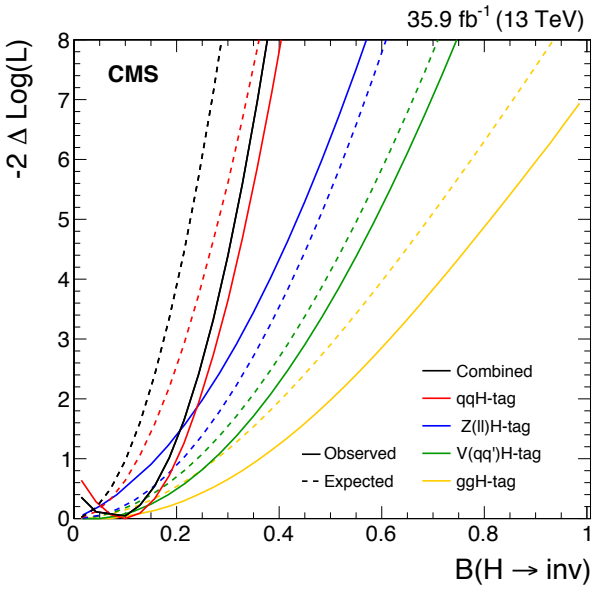


Invisible Higgs decays

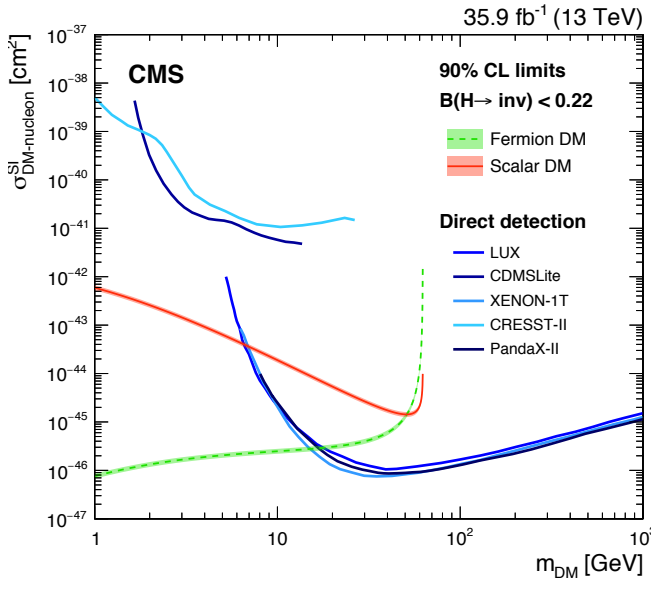
- CMS 36 fb^{-1}, 13 TeV data
  BF(H→invis.) < 0.26 (observed) @ 95%C.L.
- shape-fit analysis in mjj
- combination of several channels
- interpretation in Higgs-portal models of DM





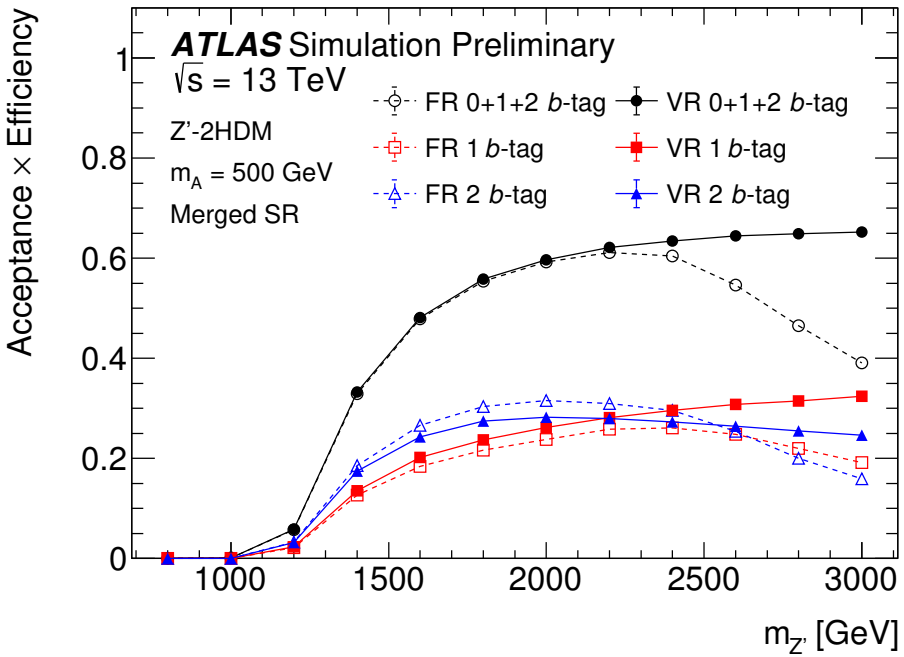


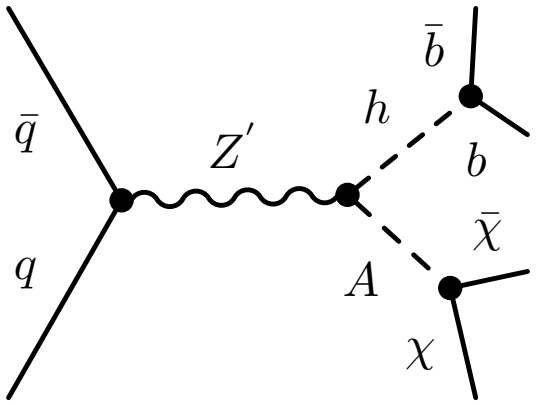
arXiv:1809.05937, subm. to PLB



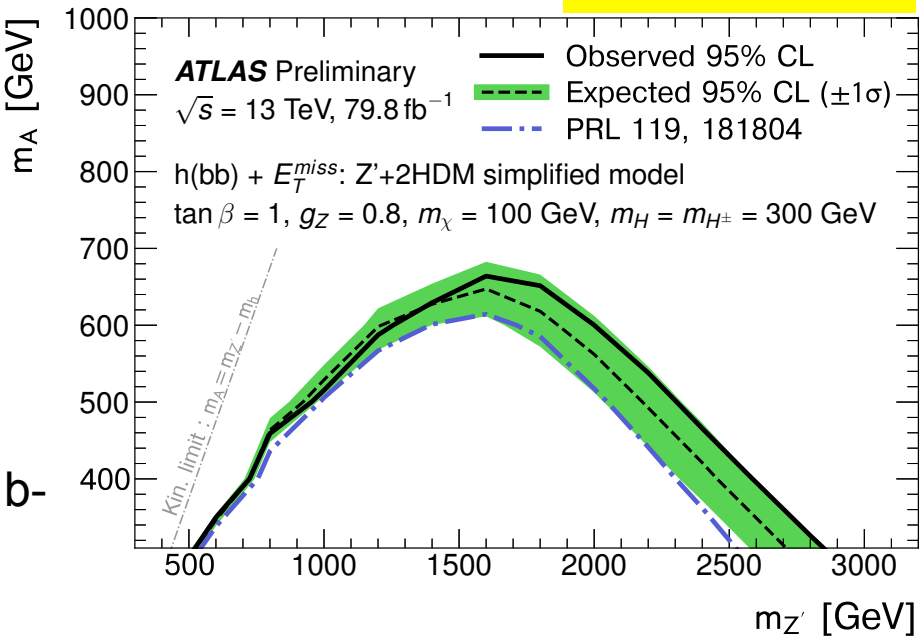
Higgs in association with dark matter

- ATLAS 80 fb^{-1} 13 TeV data





ATLAS-CONF-2018-039



- Variable radius (VR) jets
- either two small-radius b-jets
- or one large radius jet containing two b-tagged sub-jets
- Z'-two Higgs doublet model

Overview

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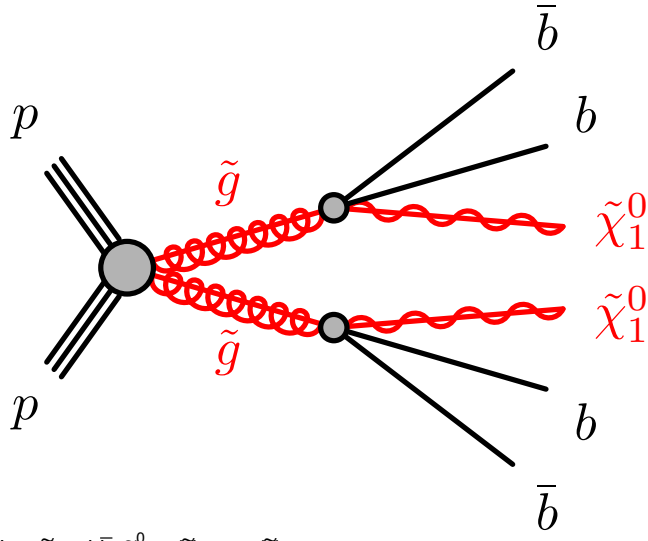
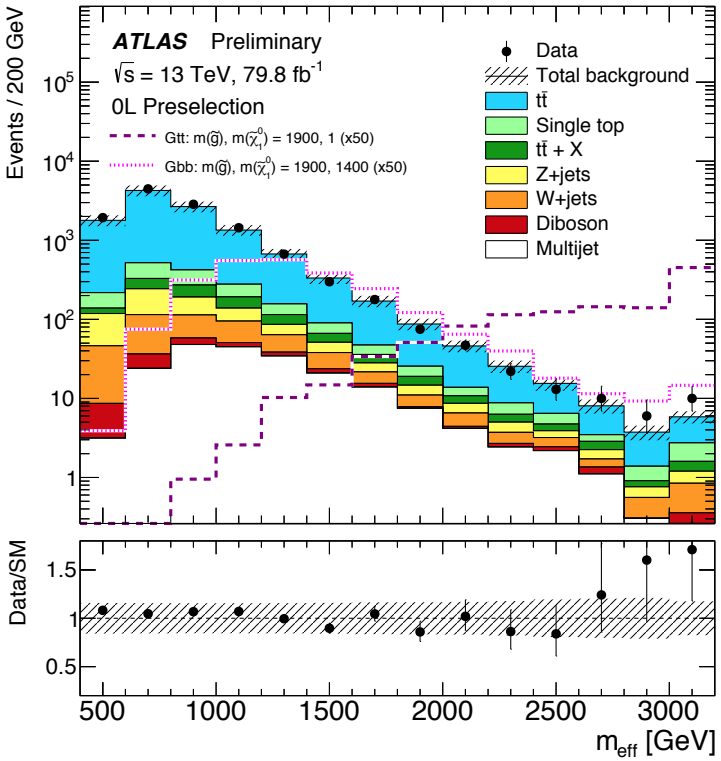
Strong production of gluinos and 3rd generation squarks

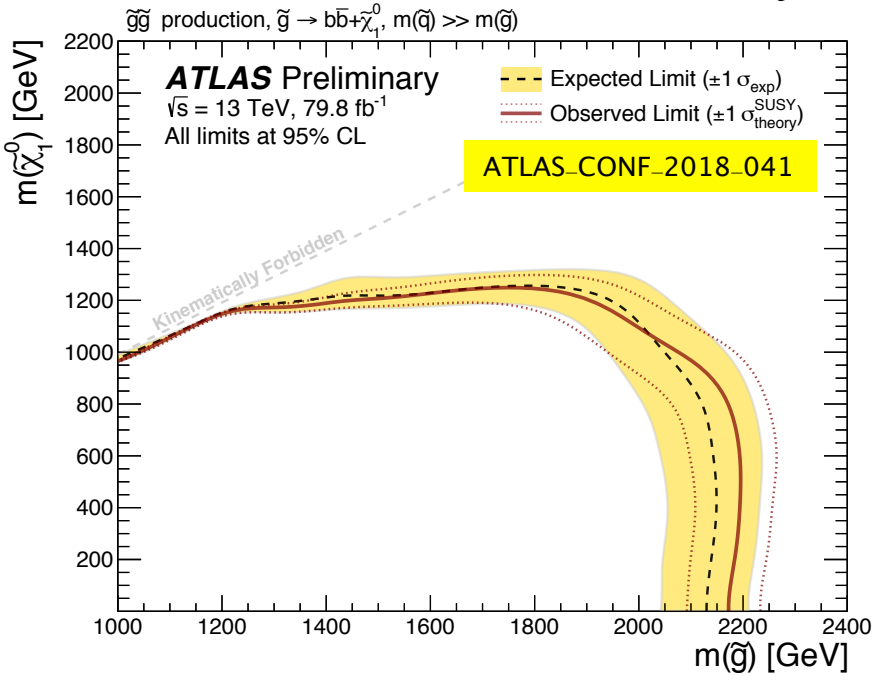
- 79.9 fb^{-1} of 13 TeV data: m($\tilde{g}$) < 2.2 TeV excl.
- large p_T^{miss}, $\geq$3 b-tagged jets
- 0 or 1 lepton, large radius jets

$$m_{\text{eff}} = \sum_i p_{\text{T}}^{\text{jet}_i} + \sum_j p_{\text{T}}^{\ell_j} + E_{\text{T}}^{\text{miss}}$$

- tuned MC; cut&count and multi-bin analyses

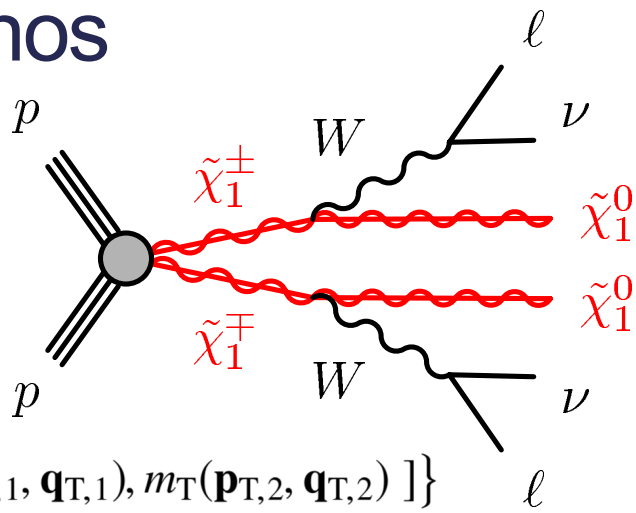


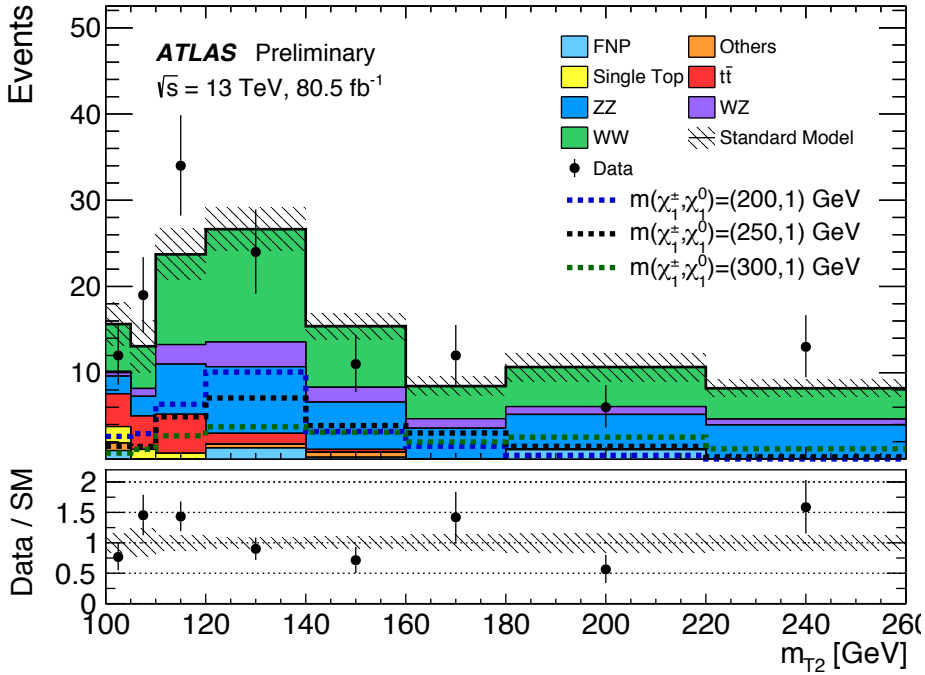


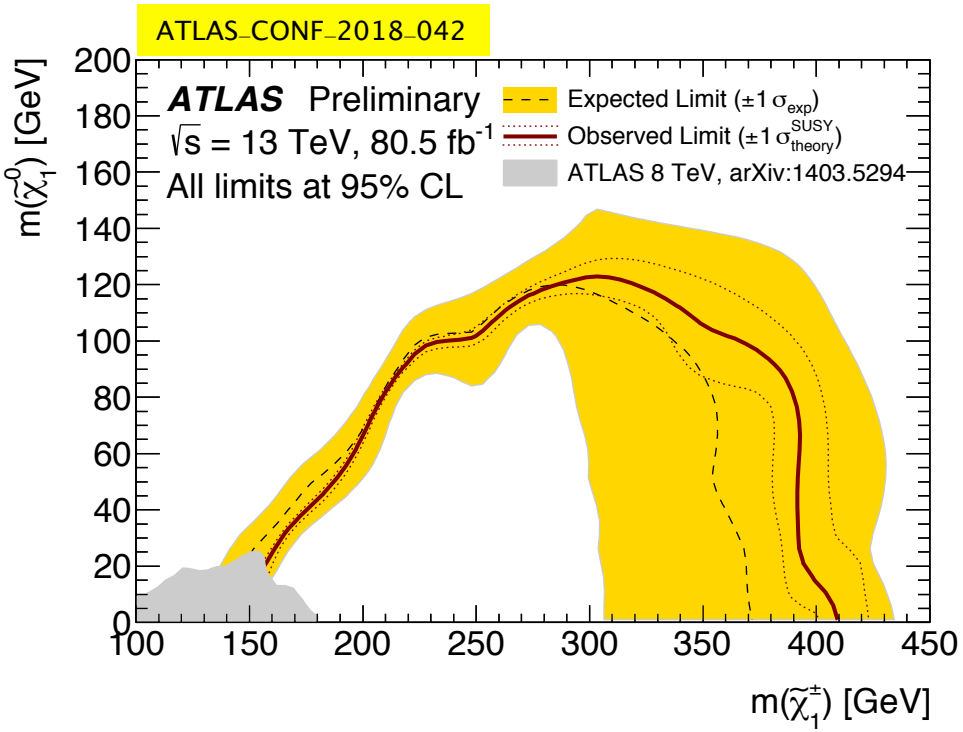


Electroweak production of Charginos

- 80.5 fb^{-1} of 13 TeV data: m($\tilde{\chi}^{\pm}$) < 410 GeV
- Two leptons, 0 or 1 light jet
- Irreducible SM WW background: MC normalized to data
- m_{T2} variable: $m_{T2}(\mathbf{p}_{T,1}, \mathbf{p}_{T,2}, \mathbf{q}_T) = \min_{\mathbf{q}_{T,1}+\mathbf{q}_{T,2}=\mathbf{q}_T} \{\max[\, m_T(\mathbf{p}_{T,1}, \mathbf{q}_{T,1}), m_T(\mathbf{p}_{T,2}, \mathbf{q}_{T,2})\,]\}$

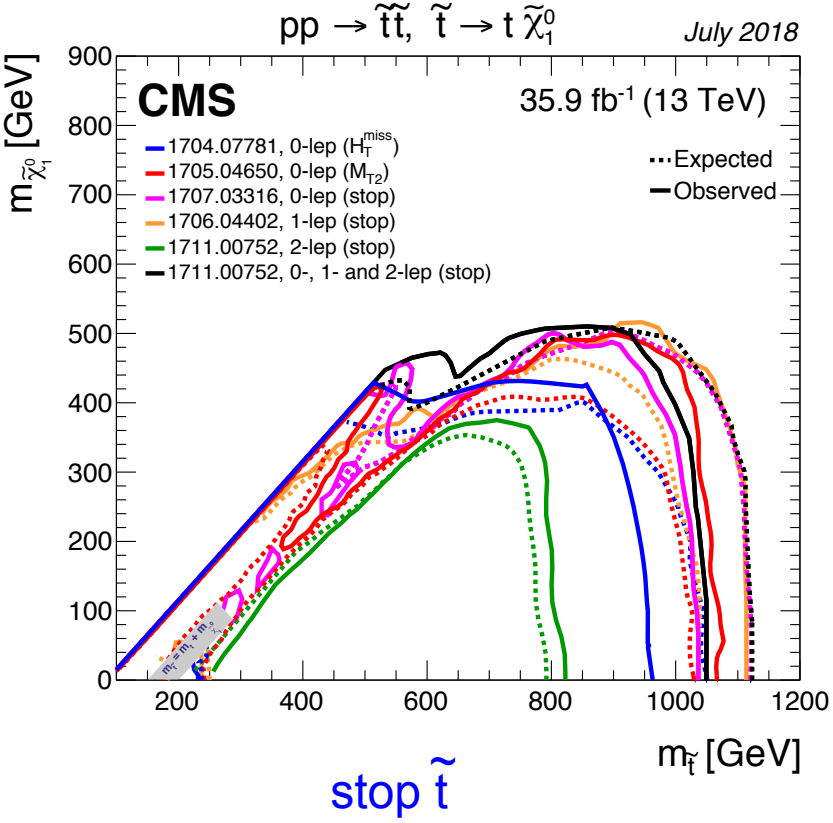






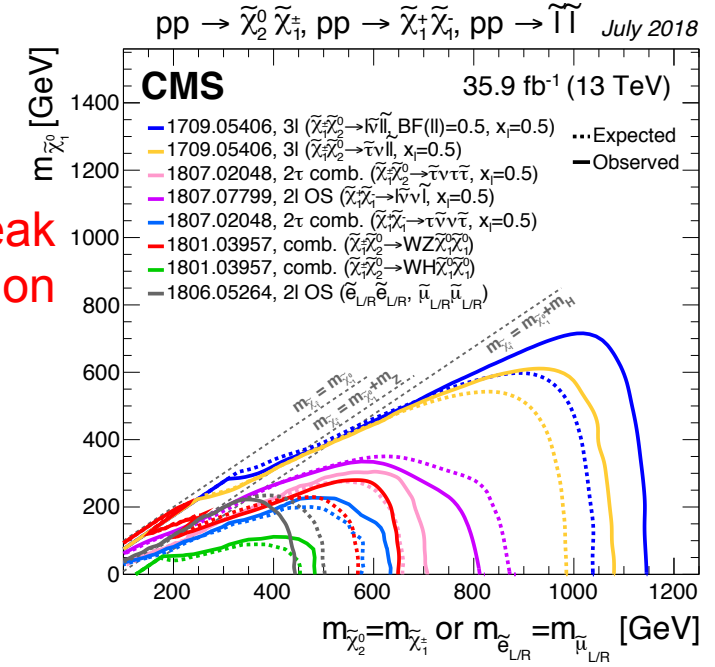
SUSY experimental status

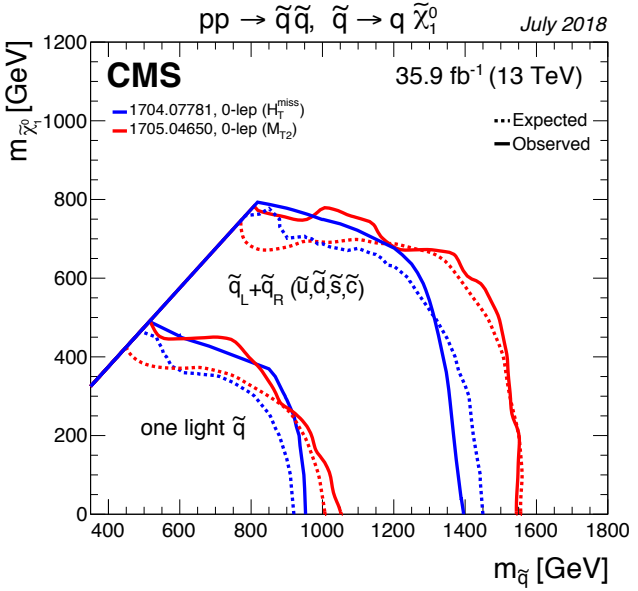
- selected results



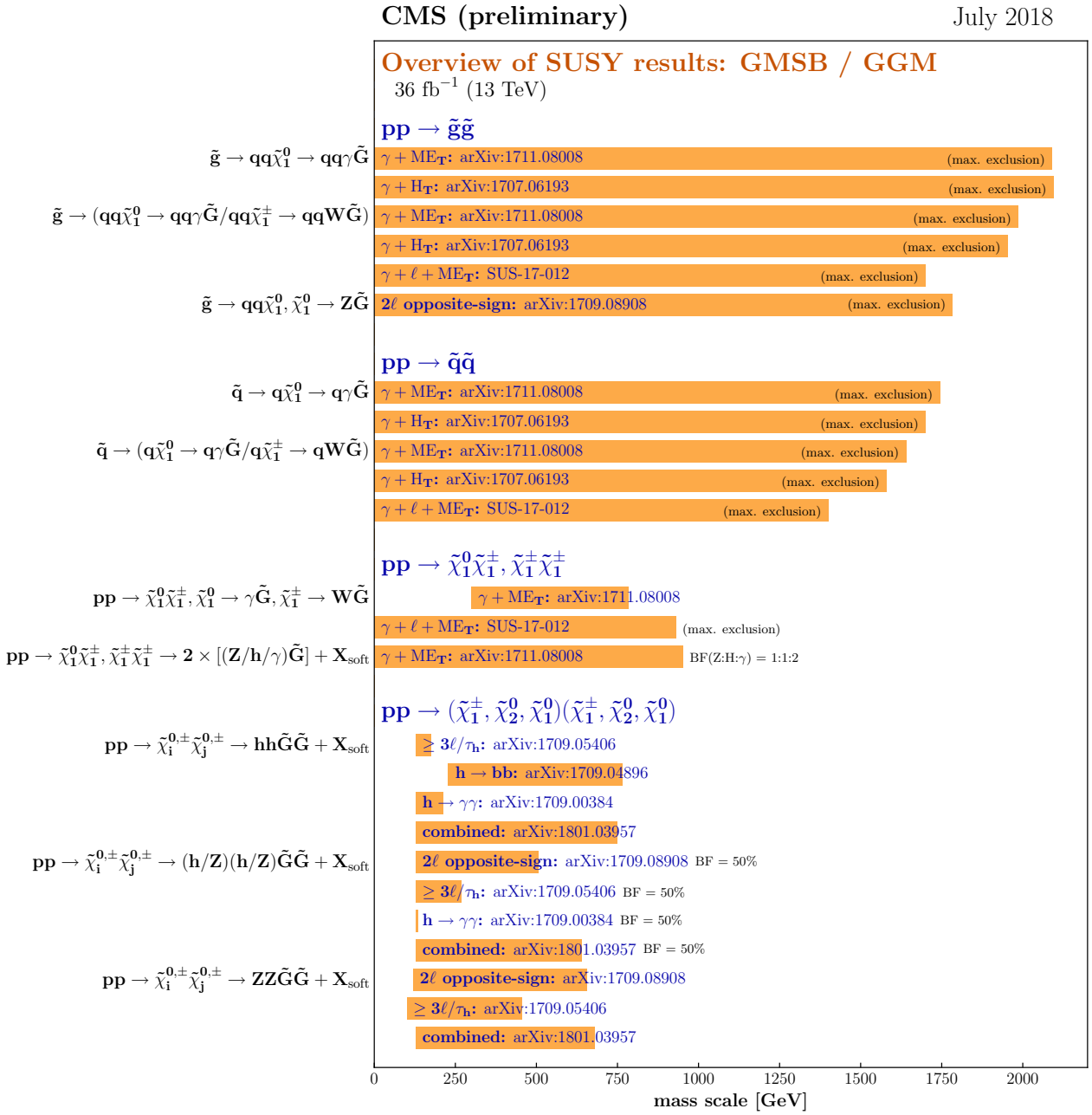
stop $\tilde{t}$

electroweak production



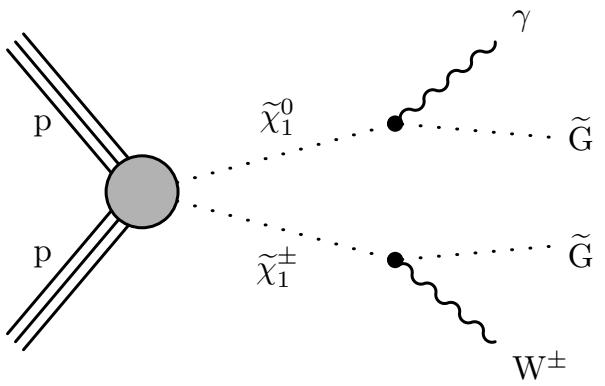


light squarks



Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe **up to** the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.

Gauge mediation



- Competitive sensitivity compared to gravity-mediation
- CMS Combination paper in preparation
- GGM scans in cooperation with theory

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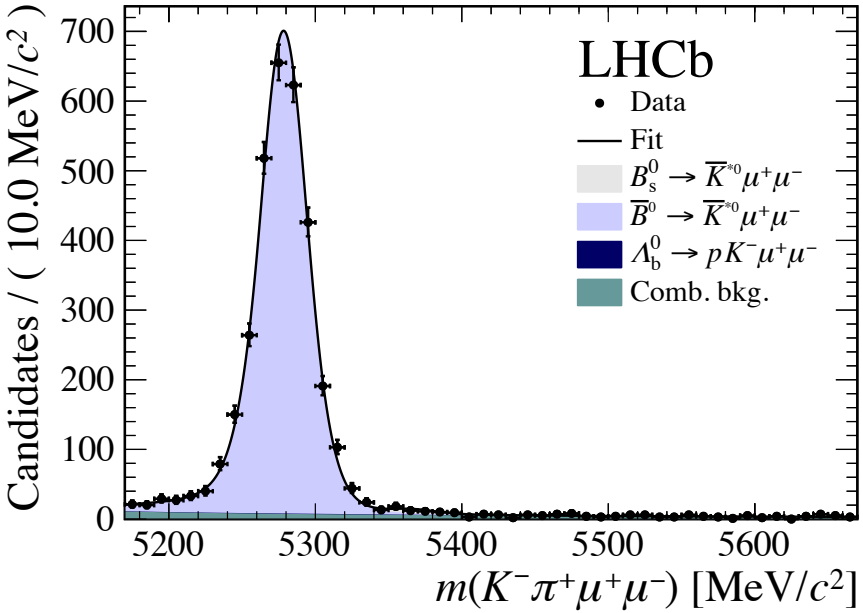
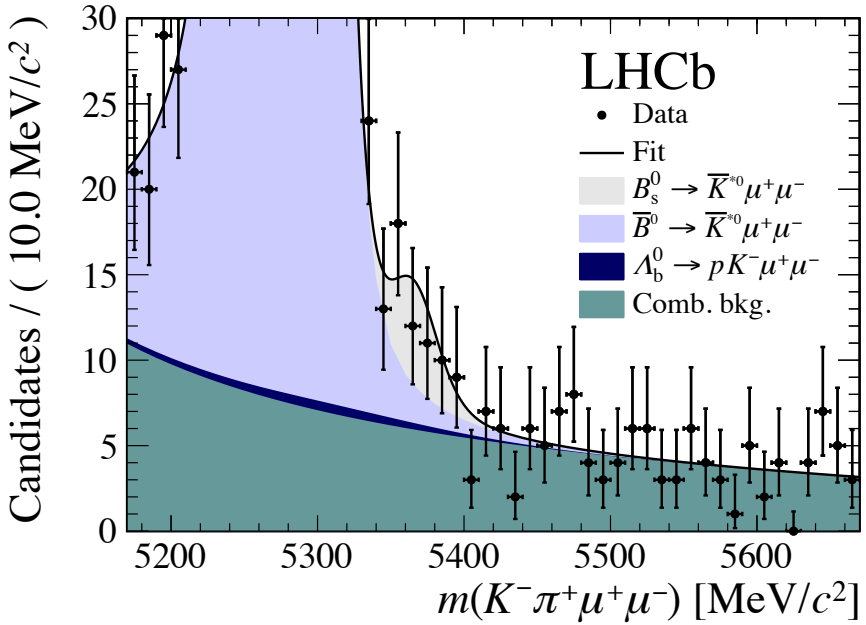
Evidence for $B_s^0 \to \overline{K}^{*0}\mu^+\mu^-$

- extremely rare SM FCNC via loop diagram involving off-diagonal V_{td}
- Global analysis of $B^0 \to K^{*0}\mu^+\mu^-$ measurements by BaBar, Belle, CDF, LHC suggest 4-5σ deviation from the SM
- 1fb^{-1} of 7 TeV, 2fb^{-1} of 8 TeV, 1.6fb^{-1} of 13 TeV data
- Signal yield of 38$\pm$12 events observed at 3.4σ
- BF = 2.9$\pm$1.0(stat)$\pm$0.2(sys)$\pm$0.3(norm)$\times$10^{-8} in agreement with SM
- Detailed analysis of the q^2 spectrum similar to $B^0 \to K^{*0}\mu^+\mu^-$ with more data

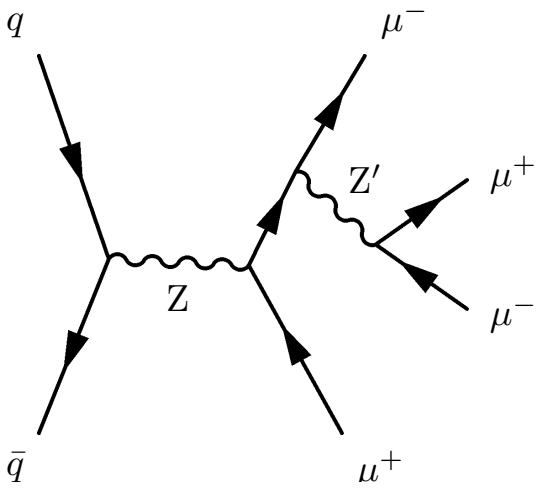




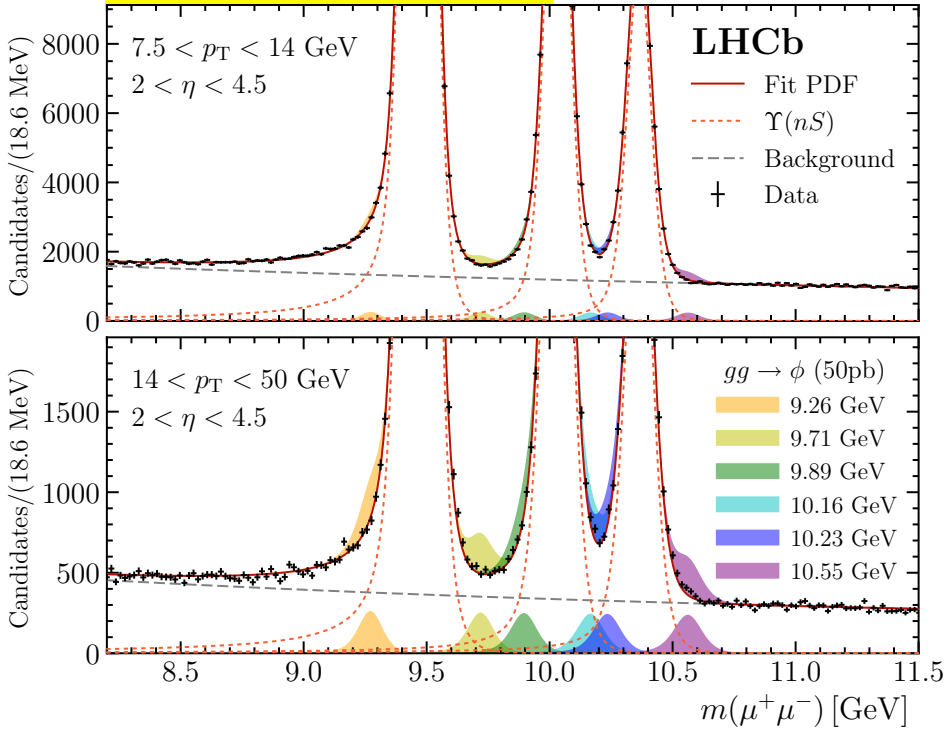
Resonance searches: low mass

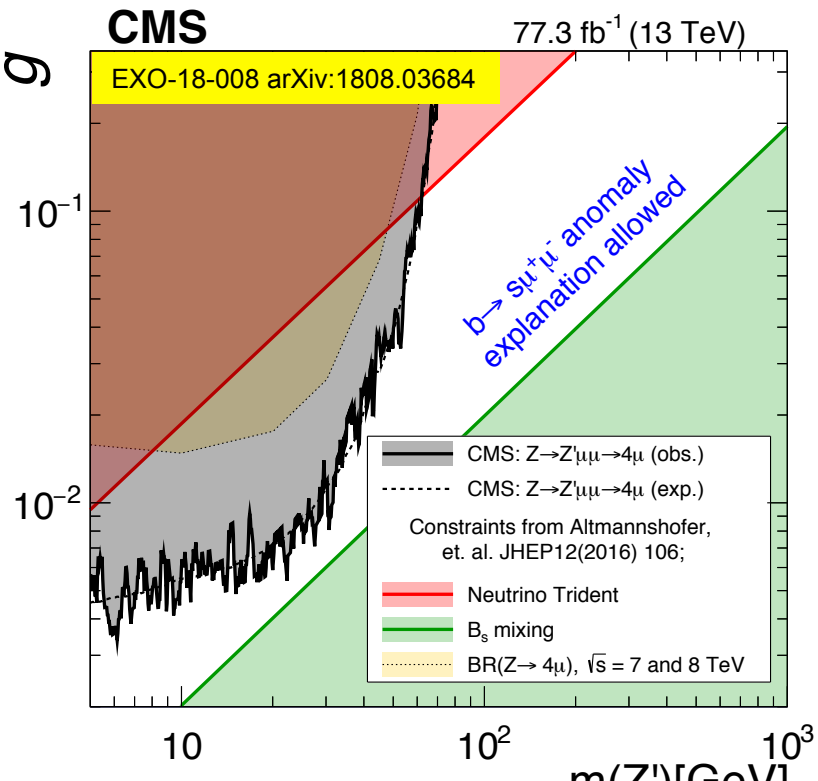
- Light Z' associated with L_μ-L_τ U(1) gauge symmetry could explain $B^0 \to K^{*0}\mu^+\mu^-$ and g-2 deviations
- LHCb 1 fb^{-1} at 7 TeV and 2 fb^{-1} at 8 TeV
- CMS 77.3 fb^{-1} at 13 TeV

$Z \to 4\mu$ analysis with first limits on L_μ-L_τ models



LHCb-2018-008 arXiv:1805.09820

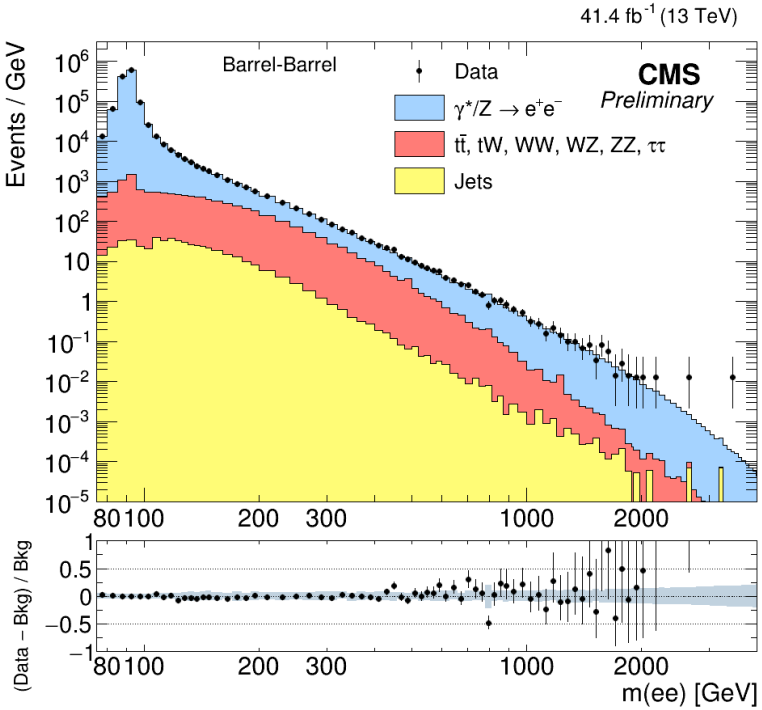


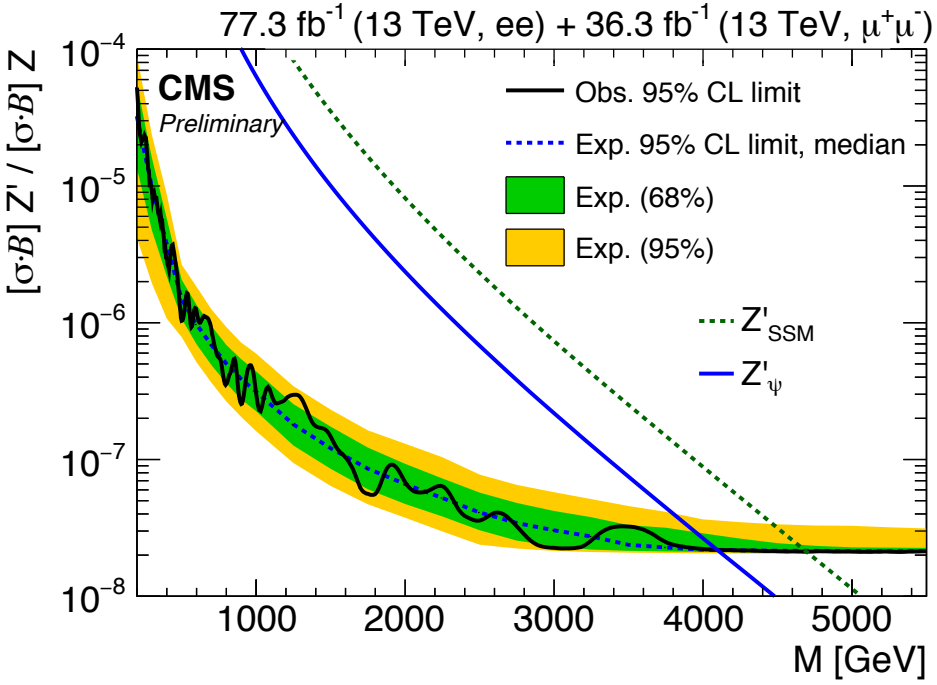


1. CMS_PAS_EXO_18_006
2. arXiv:1803.06292, accept. JHEP

Resonance searches: high mass

- dielectron and dimuon final states
- 36.3 – 77.3 fb^{-1} of 13 TeV data





Combined mass lower limits

- Z'$_{SSM}$ (sequential SM) : 4.7 TeV
- Z'$_{\psi}$ (GUT based theories) : 4.1 TeV

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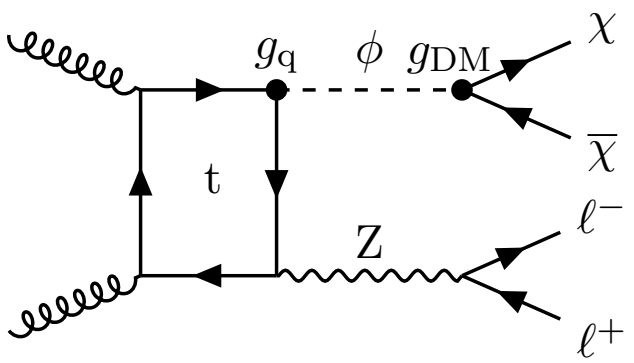
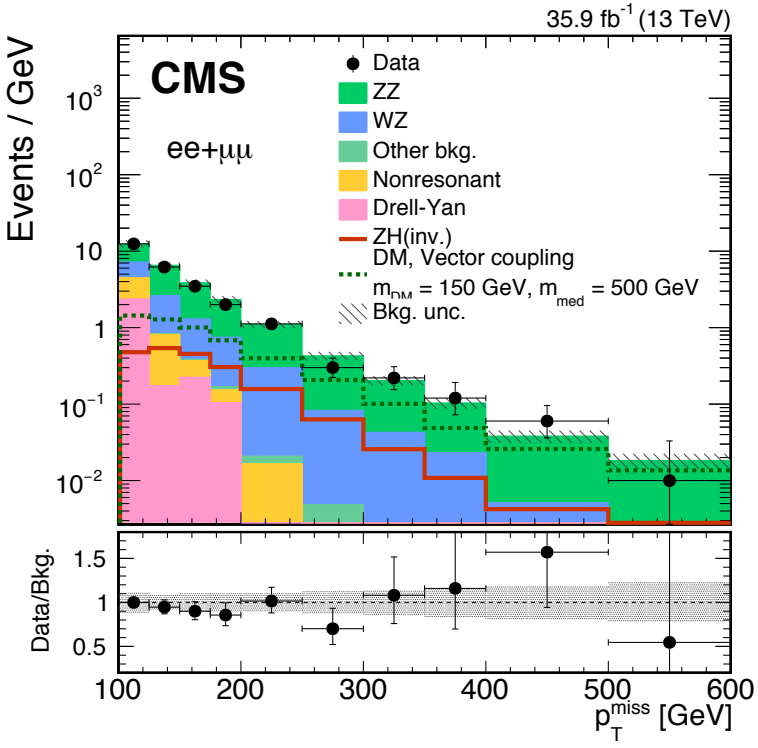
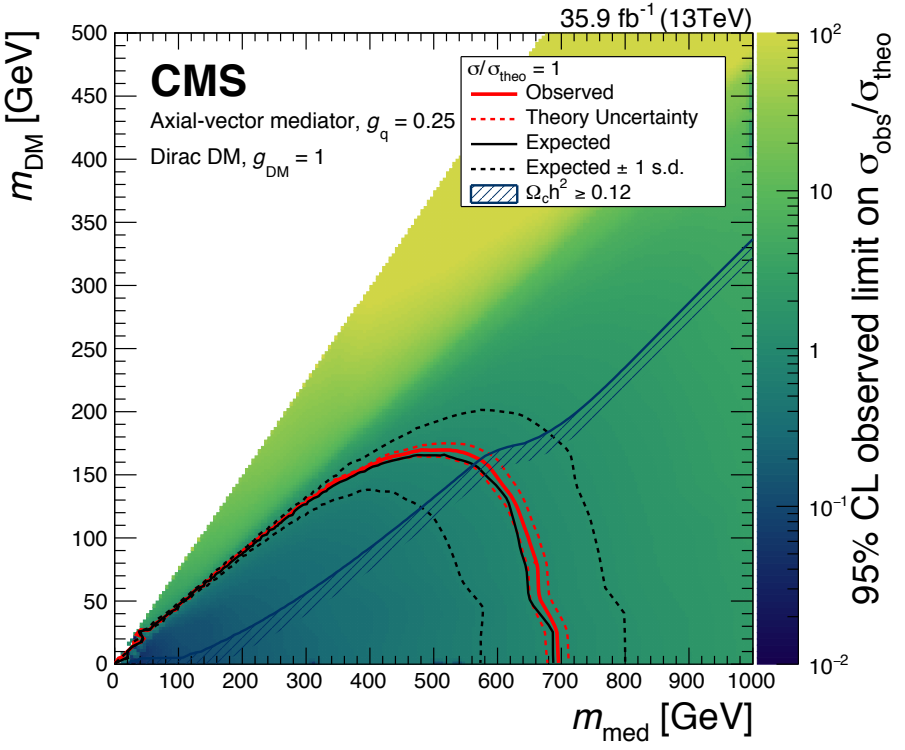
Dark matter search: DM+Z→ll



- 35.9 fb^{-1} of 13 TeV data
- Simplified models for DM production via spin-0 or spin-1 mediators
- Two analysis strategies:
  - Fit of p_T^{miss} spectrum
  - Boosted decision tree classification targeting H_{SM}→DM DM



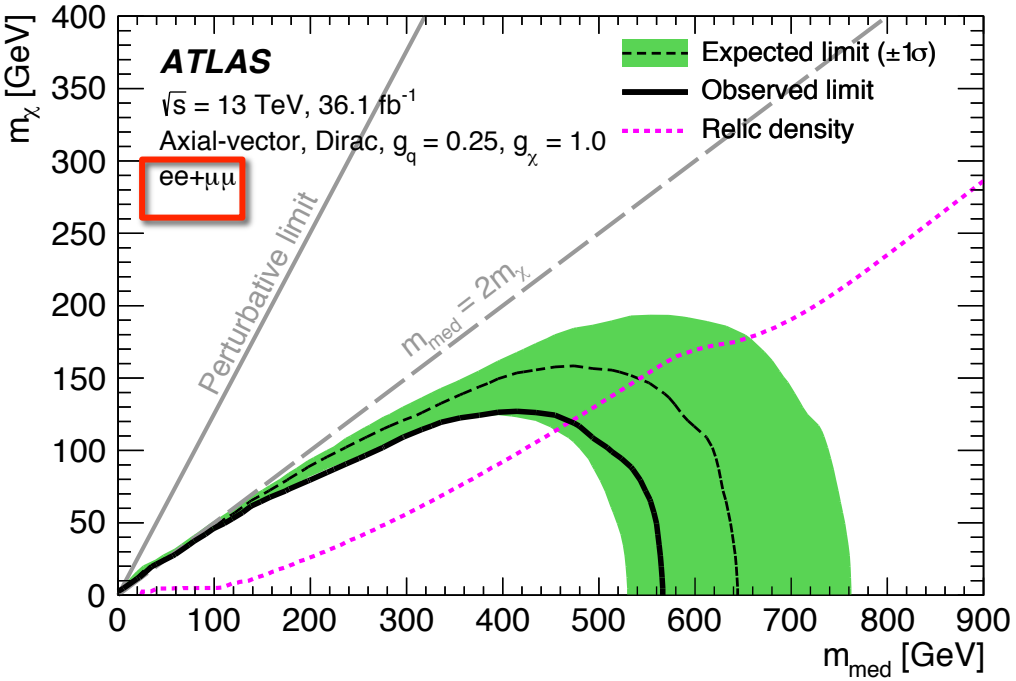


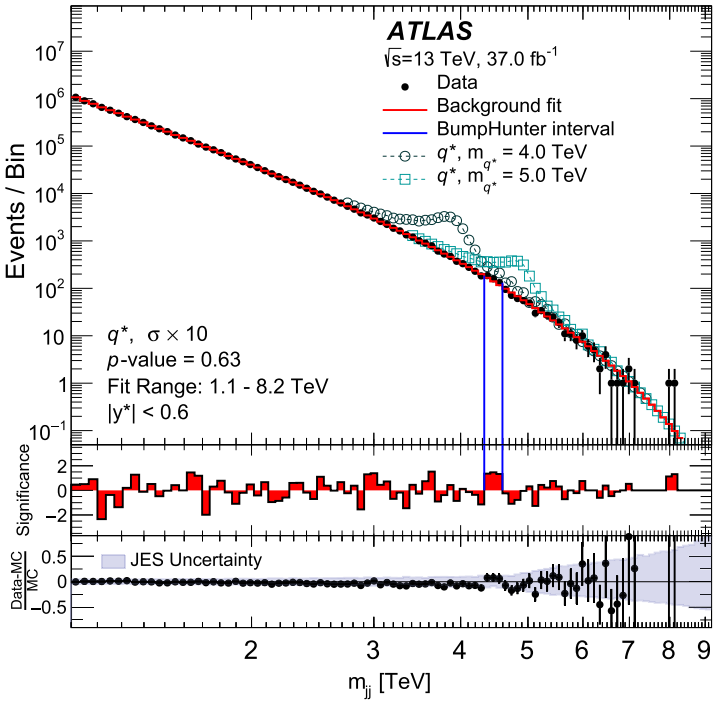
1. EXOT-2016-23 arXiv:1807.11471,
2. PLB 776 (2017), 318

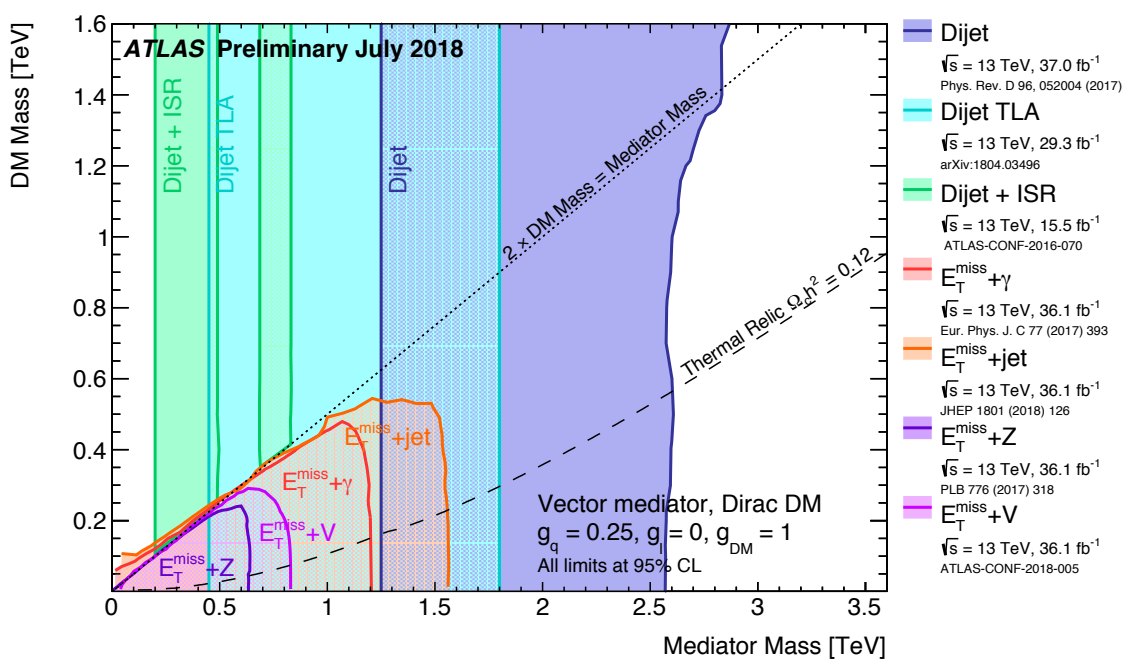
Dark matter searches

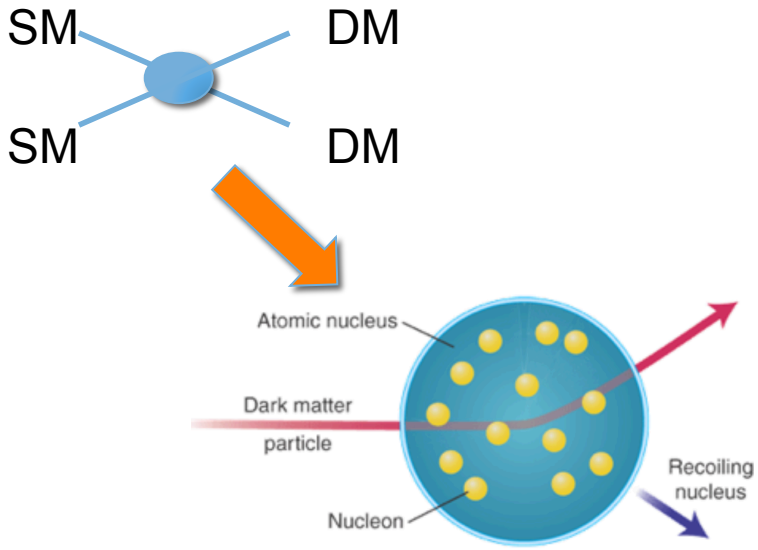
- Very similar DM+Z→ll from Atlas
- Combination with several channels
  - hadronically decaying W/Z bosons
  - two resolved jets or one large radius jet
  - dijet resonance bump-hunting

Model	95% C.L. exclusion limit Observed	Expected
Quantum black hole	8.9 TeV	8.9 TeV
W'	3.6 TeV	3.7 TeV
W^*	3.4 TeV 3.77 TeV—3.85 TeV	3.6 TeV
Excited quark	6.0 TeV	5.8 TeV
Z' ($g_q = 0.1$)	2.1 TeV	2.1 TeV
Z' ($g_q = 0.2$)	2.9 TeV	3.3 TeV
Contact interaction ($\eta_{LL} = -1$)	21.8 TeV	28.3 TeV.
Contact interaction ($\eta_{LL} = +1$)	13.1 TeV 17.4 TeV—29.5 TeV	15.0 TeV

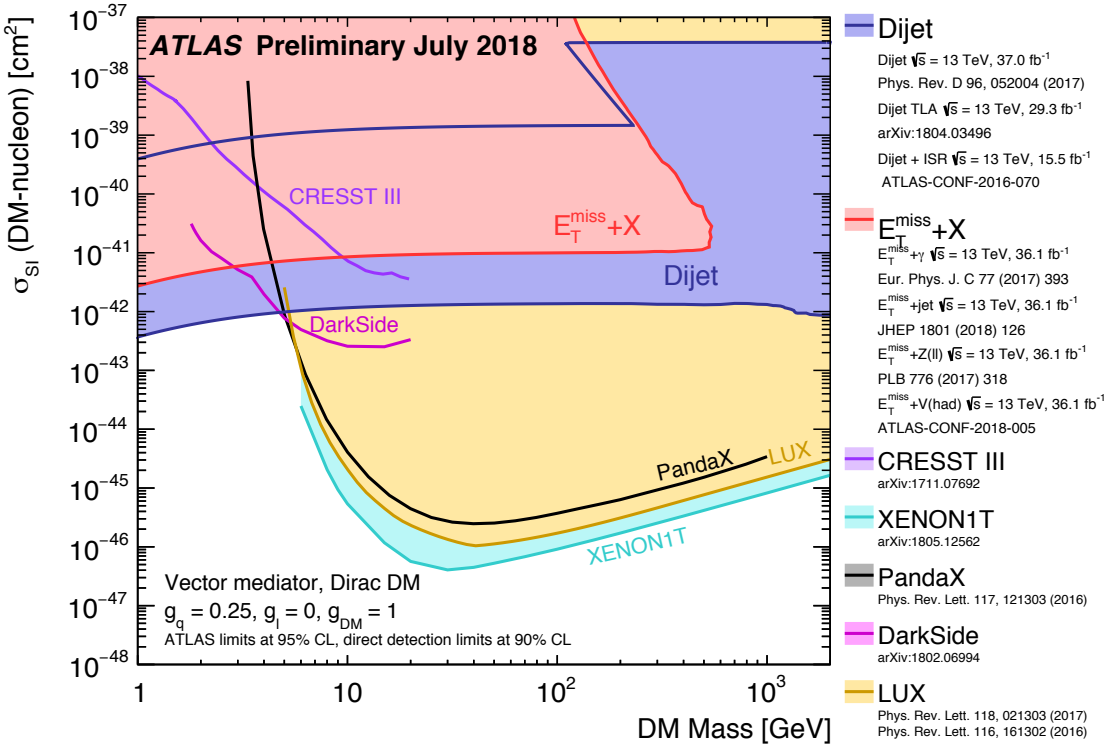






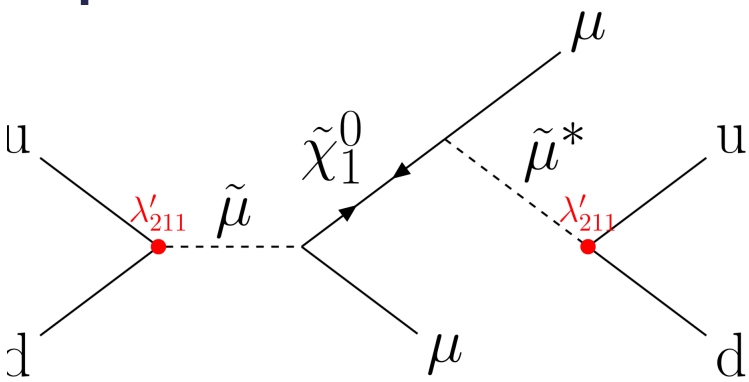


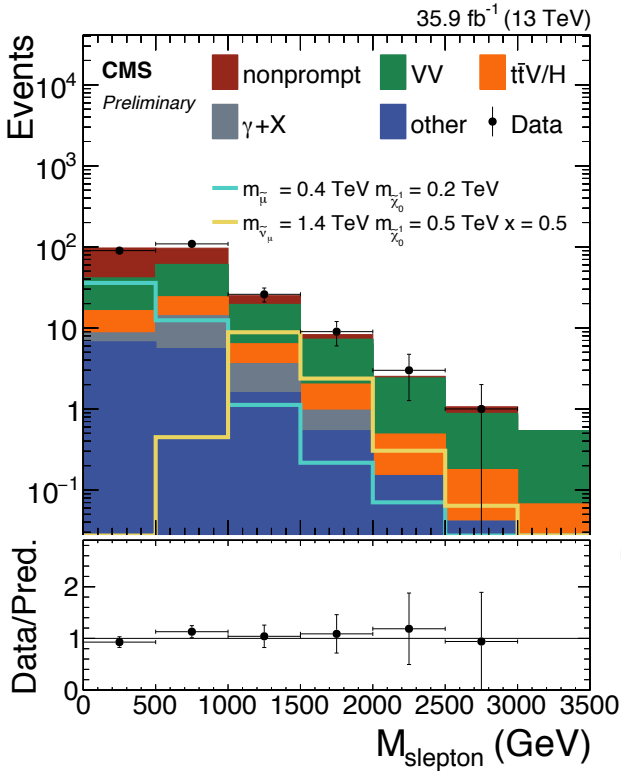
- collider limits translated
- compared to direct detection experiments

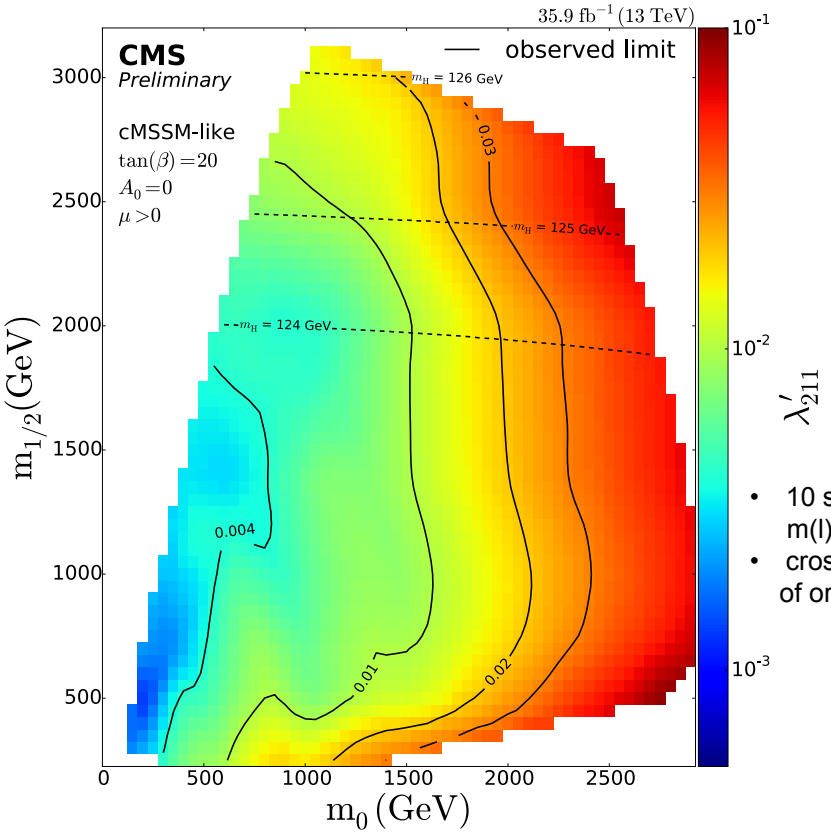


Resonant 2nd generation slepton production

- 35.9 fb^{-1} of 13 TeV data
- RPV SUSY, LQD coupling
- like-sign dimuon final state
- non-prompt muon background from tight-to-loose method





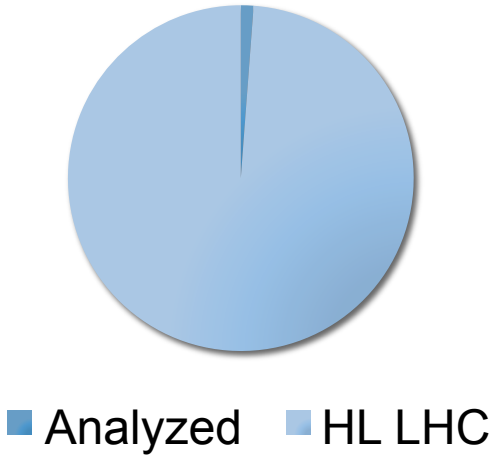


- 10 signal regions in m(l) and m(χ)
- cross section limits of order of fb^{-1}

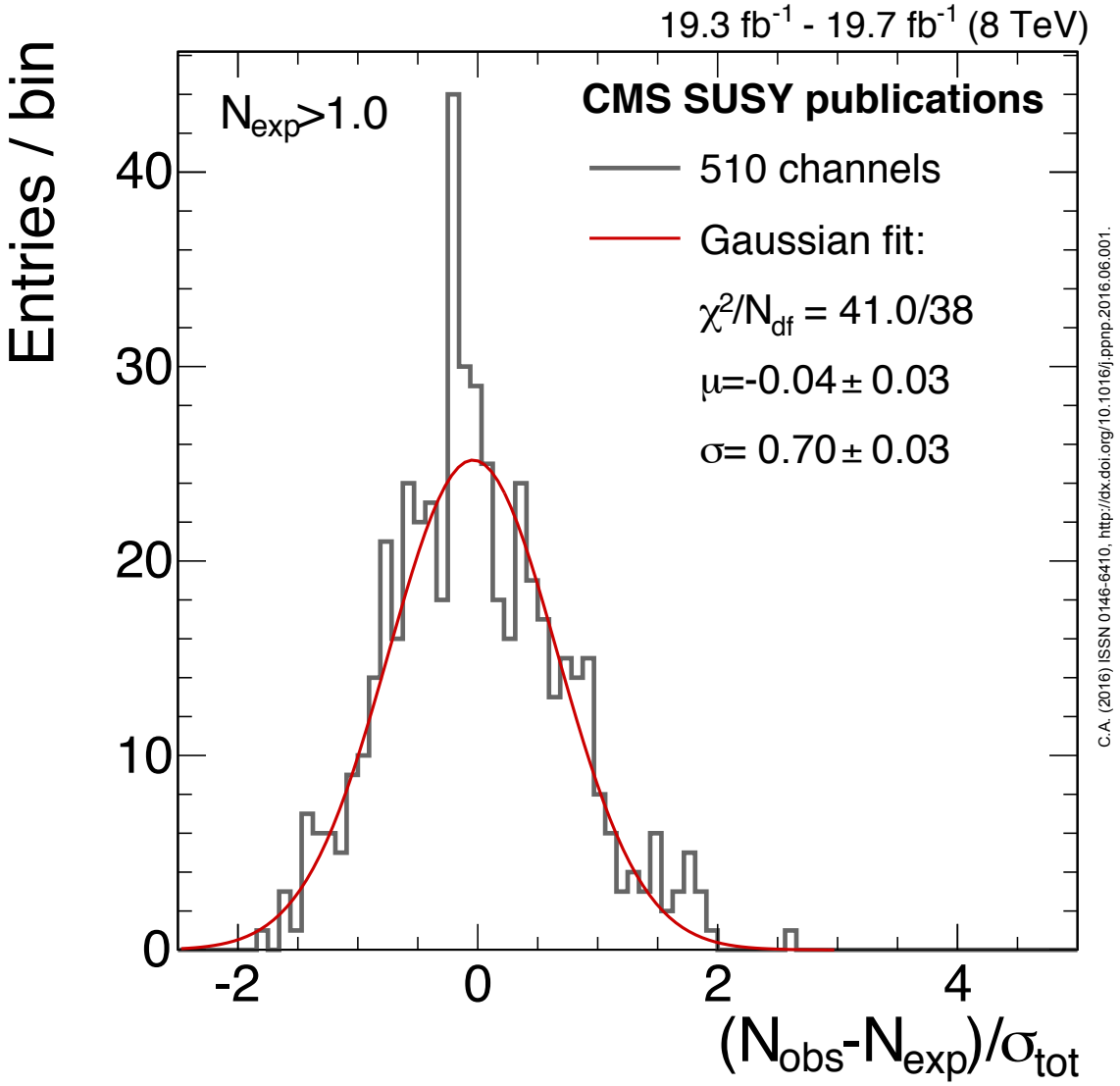
Conclusion

- No signs of physics beyond the standard model so far
- Age of “easy discoveries” at the LHC has gone; sensitivity will grow with integrated luminosity, i.e. time!
- Only 1-2% of high-luminosity LHC dataset analyzed so far

- Change in analysis strategy:
  - Combinations
  - More specific final states
  - Sophisticated background suppression & signal identification
  - Difficult accessible signal phasespace
  - Unconventional signal models
  - …



Additional Material



References

Atlas public results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/
CMS public results: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults