ATLAS 实验综述

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中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Outline

- Introduction of LHC, ATLAS
- SM Precision Measurements
- Higgs Measurements and BSM Higgs Search
- BSM Physics Search
- Conclusion and Outlook

LHC 大型强子对撞机

- 周长 27 公里，隧道深100米，跨越瑞士法国国境
- 世界最大，能量最高的加速器，进行最前沿的粒子物理研究
- 质心系能量14TeV (Tevatron的7倍)，可以发现5TeV以下的**较重的新粒子**
- 积分亮度10^{34} cm^{-2} s^{-1} (Tevatron 的100倍)，可以发现微小衰变截面的**稀有事例**

ATLAS and CMS detector @ LHC

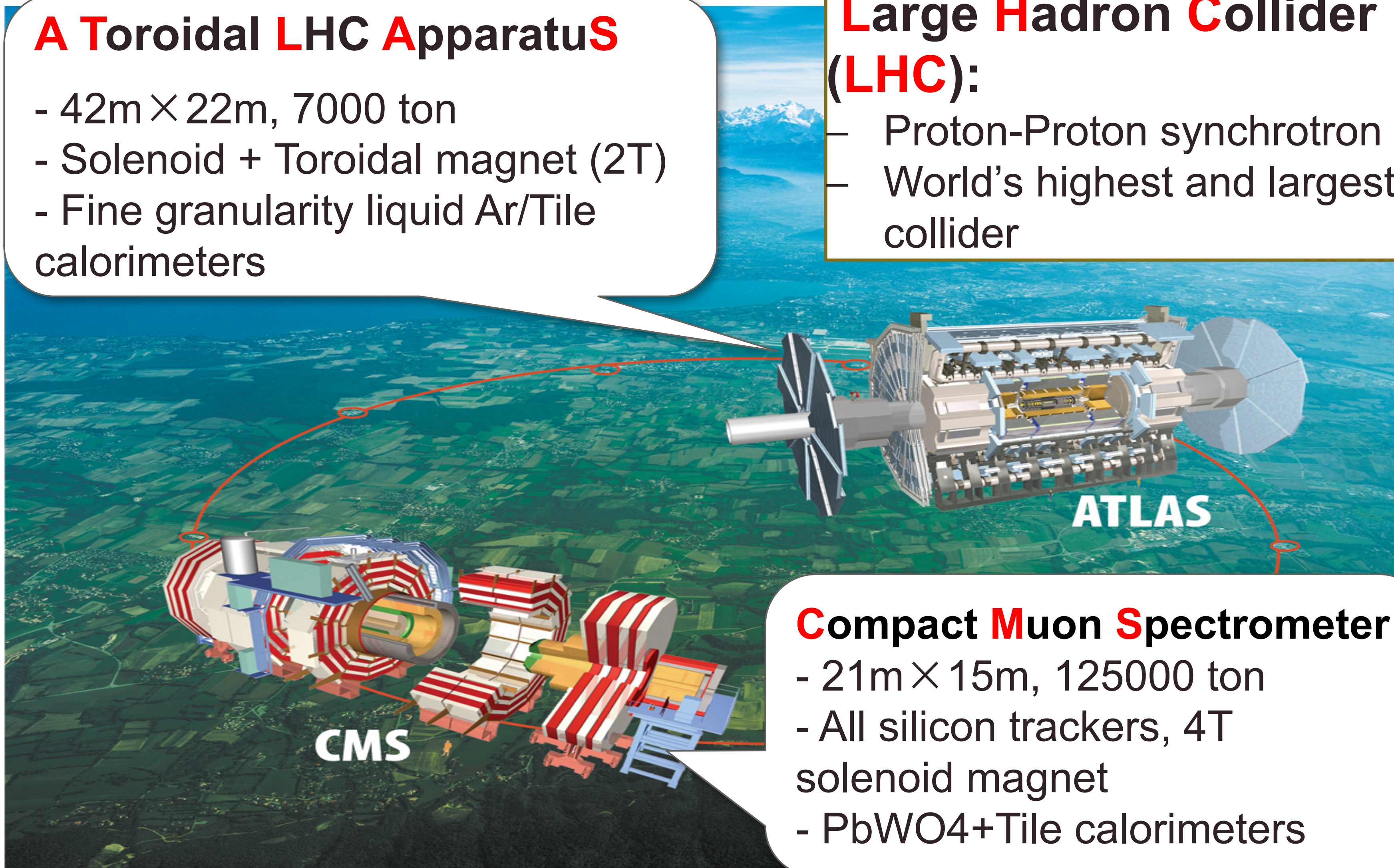
ATLAS and CMS: two multi-purpose detectors @LHC

A Toroidal LHC ApparatuS

- 42m×22m, 7000 ton
- Solenoid + Toroidal magnet (2T)
- Fine granularity liquid Ar/Tile calorimeters

Large Hadron Collider (LHC):

– Proton-Proton synchrotron
– World's highest and largest collider



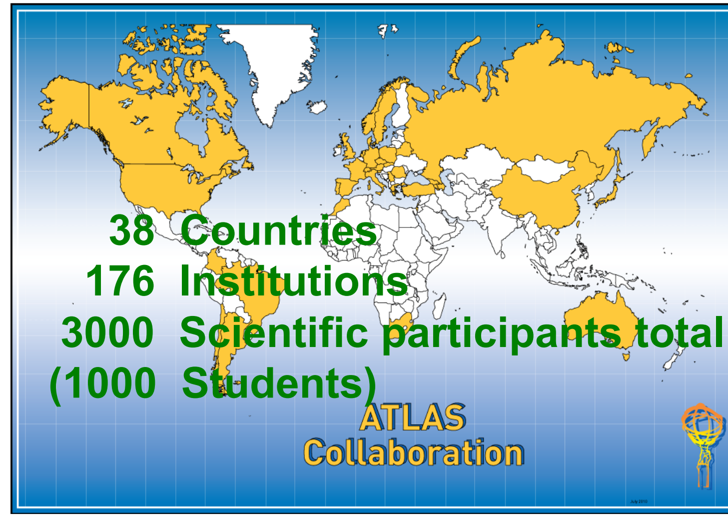
Compact Muon Spectrometer

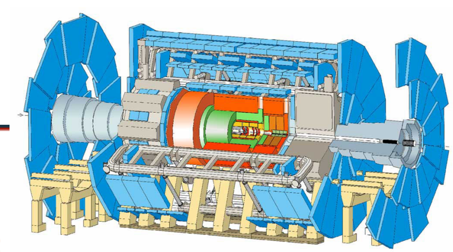
- 21m×15m, 125000 ton
- All silicon trackers, 4T solenoid magnet
- PbWO4+Tile calorimeters

ATLAS 中国组

单位	成员	作者	physicists	博士生	硕士生
高能所	57	24	18	20	0
南京大学	6	3	4	2	0
清华大学	5	1	1	4	0
中国科大	58	27	20	20	9
山东大学	25	11	6	6	10
上海交大	19	12	9	10	0
李政道所	3	1	1	4	0
总数	173	79	59	66	19

作者数占ATLAS总数 2.8%





- **Institute of High Energy Physics (高能所)**

  娄辛丑（千人）、Joao Costa （外专千人）、 欧阳群、庄胥爱（百人）、方亚泉（青千）、朱宏博（青千）、黄燕萍（青千）、梁志均（百人）、史欣（青千）、李一鸣（青千）、吕峰、单连友、徐达

- **Nanjing University (南大)**

  陈申见、祁鸣、金山（万人、杰青）、张雷

- **Tsinghua University (清华)**

  陈新（青千）

IHEP-NJU-THU cluster

- **Shandong University (山大)**

  张学尧、马连良（青千）、冯存峰、祝成光、李海峰

- **Shanghai Jiao Tong University (上海交大)**

  杨海军（青千）、李亮（青千）、郭军（青千）、周宁（青千）

USTC-SJTU-SDU cluster

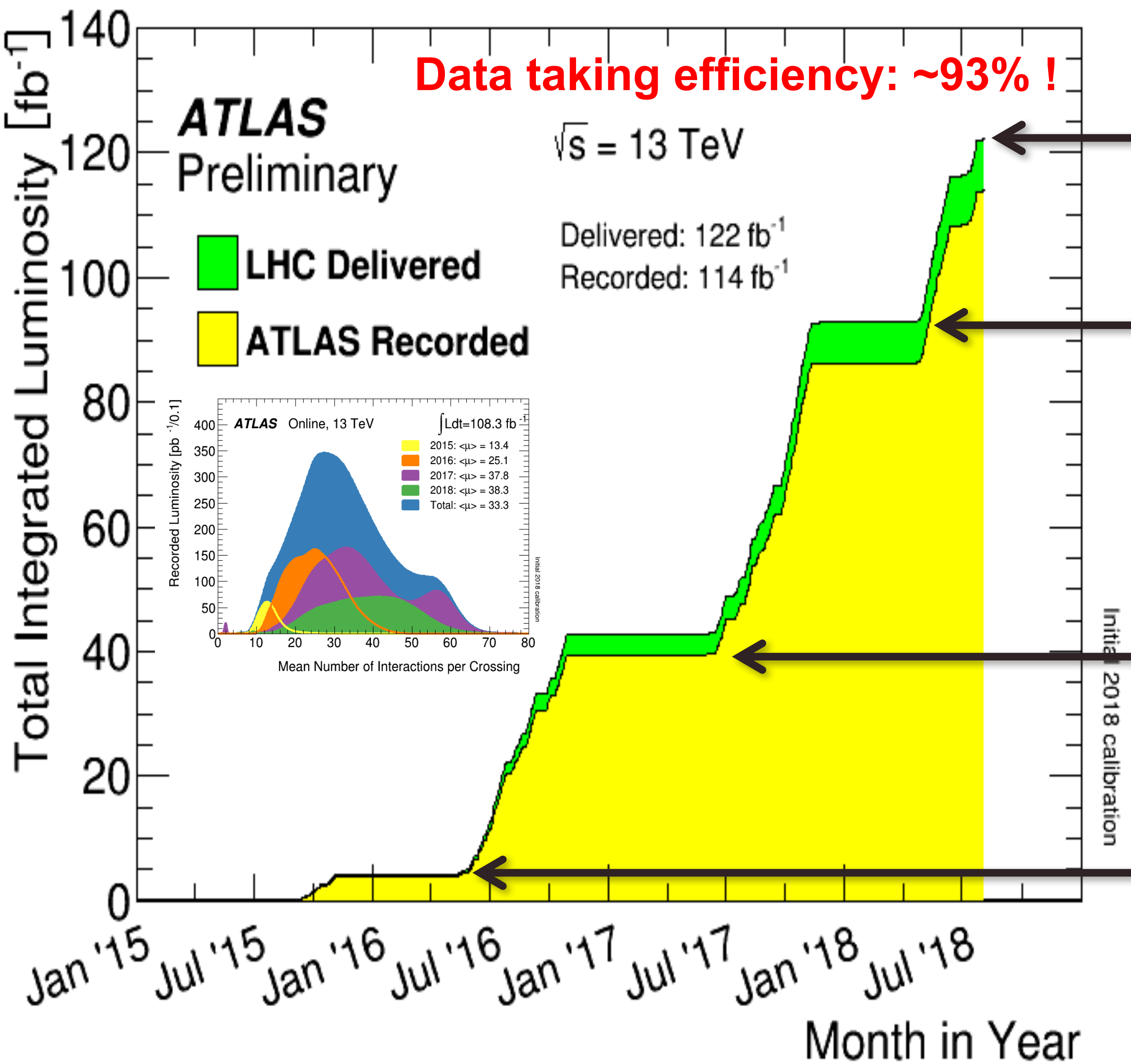
- **T. D. Lee Institute (李政道所)**

  李数

- **University of Science and Technology of China (科大)**

  赵政国（院士、千人）、韩良（万人、杰青）、蒋一、刘衍文（优青）、刘建北（青千）、彭海平（杰青、百人）、朱莹春、刘明辉、吴雨生（青千）、Rustem Ospanov

LHC Performance and data-set

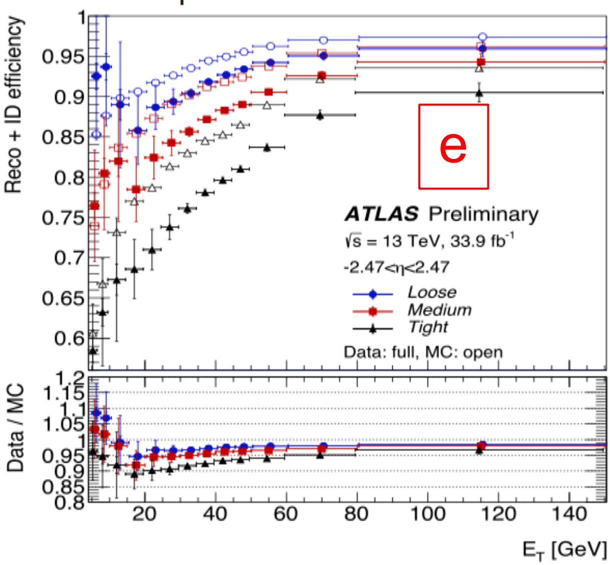


- 2015-2018 data-set: L= 114 fb^{-1} recorded
- Expect L = 140-150 fb^{-1} for full 2015-2018
- 2015-2017 data-set: L = 80 fb^{-1}
- 2015-2016 data-set: L = 36 fb^{-1}
- 2015 data-set: L = 3.2 fb^{-1}

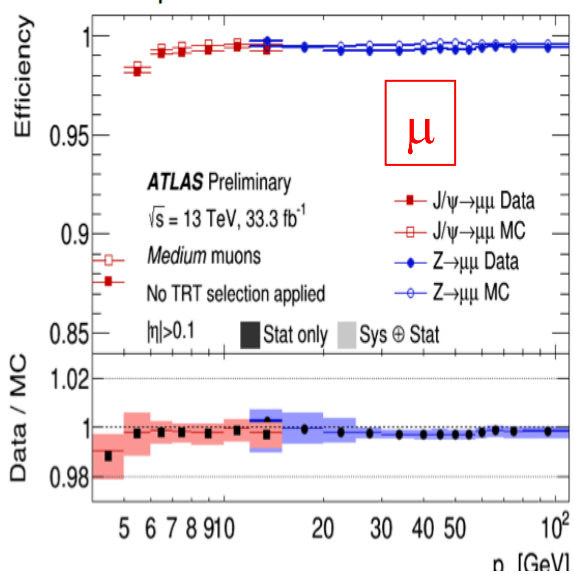
Detector performance Highlights

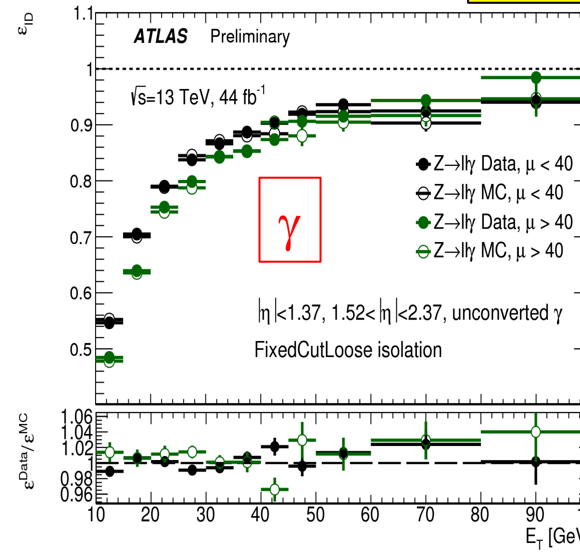
IHEP

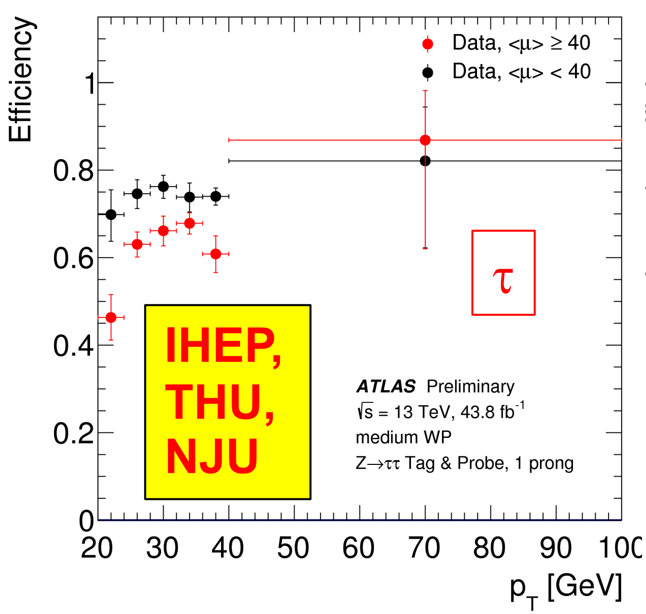
Electron performance measured down to 4.5 GeV

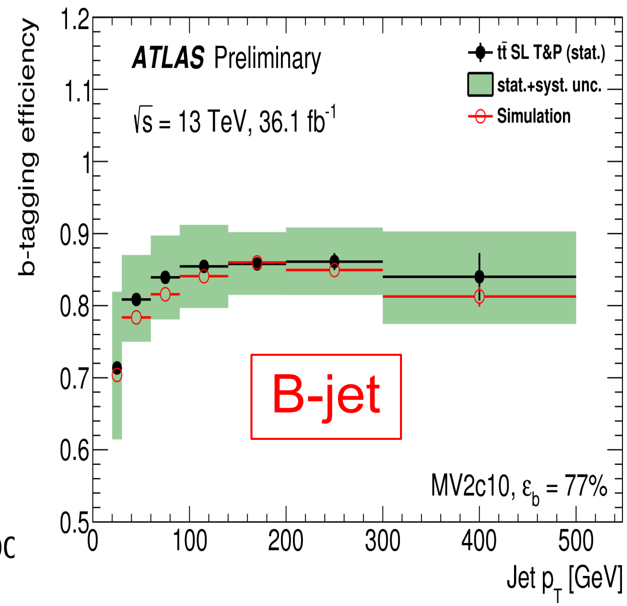


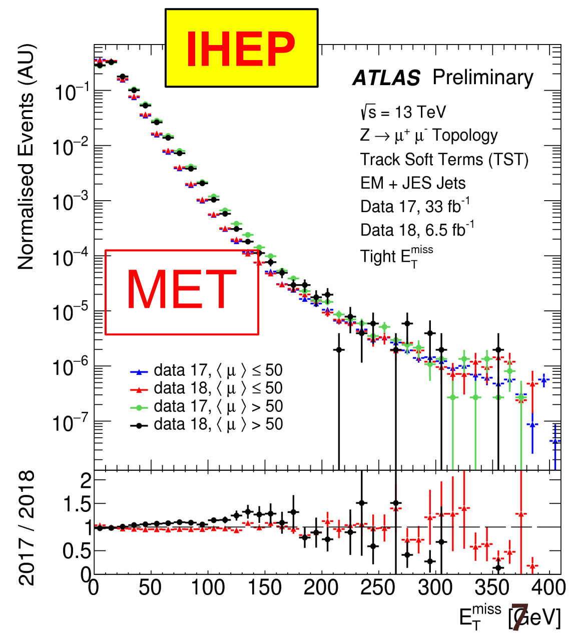
Muon performance measured down to 4 GeV











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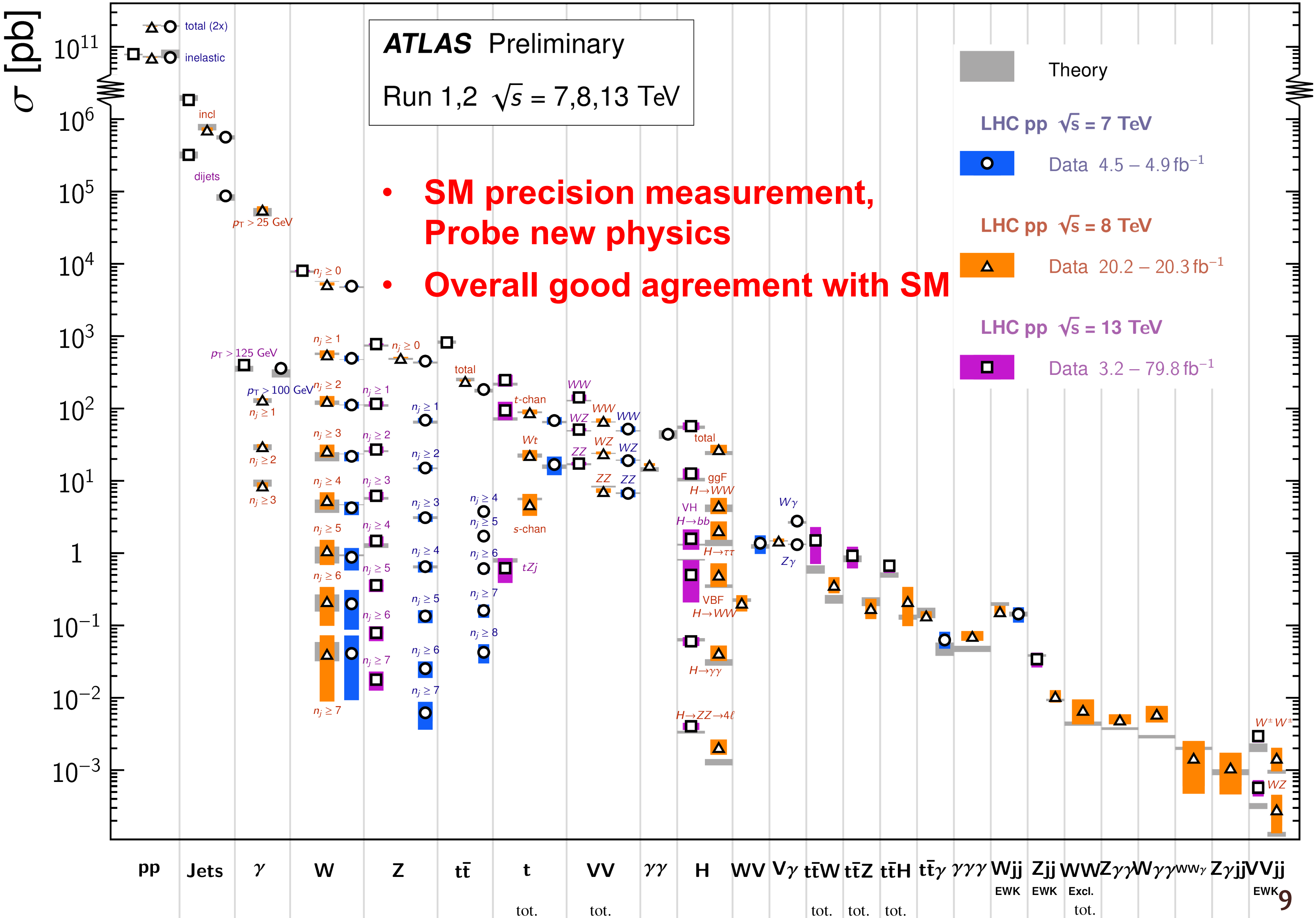
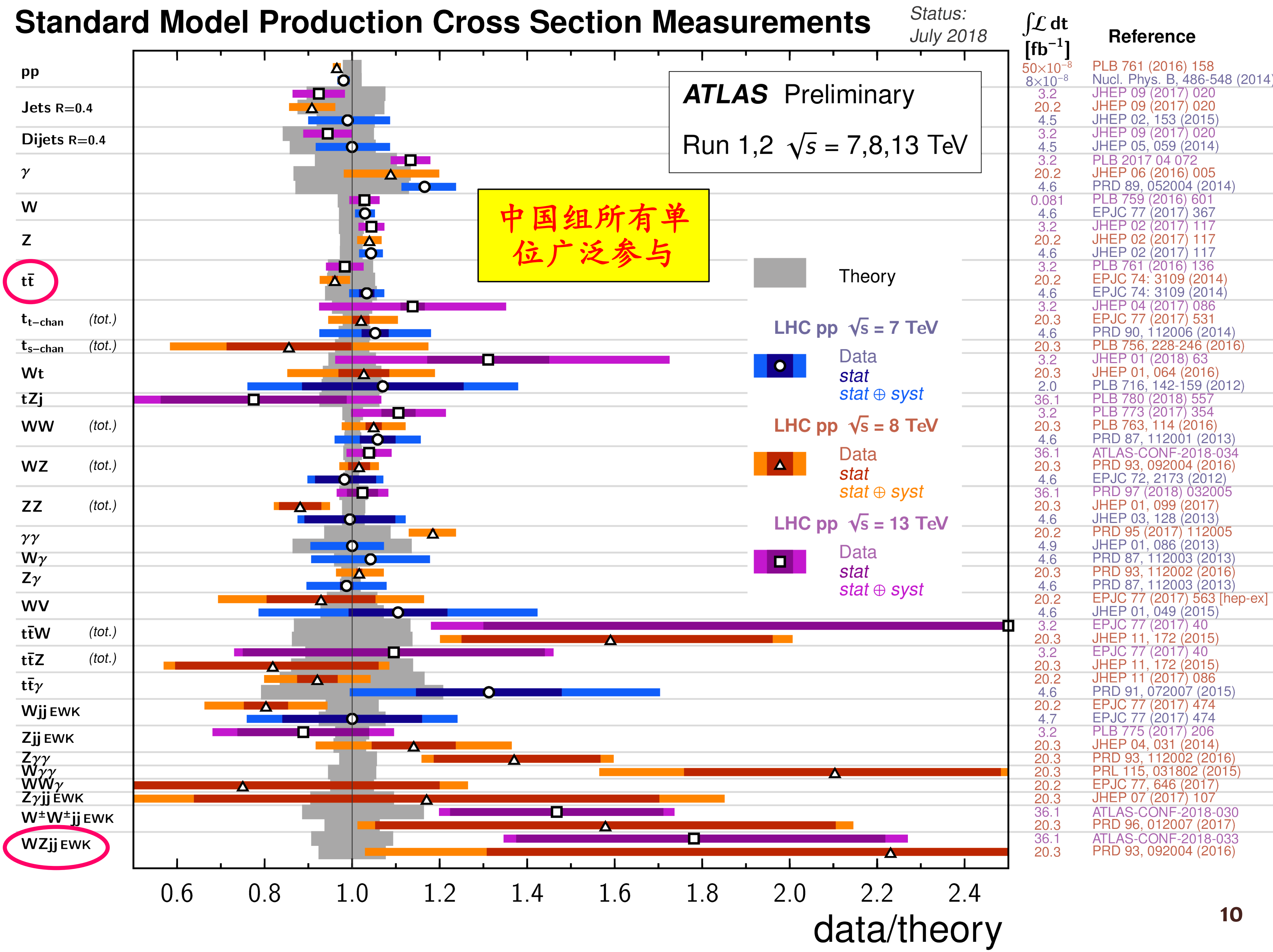
Standard Model Production Cross Section Measurements

Status: July 2018

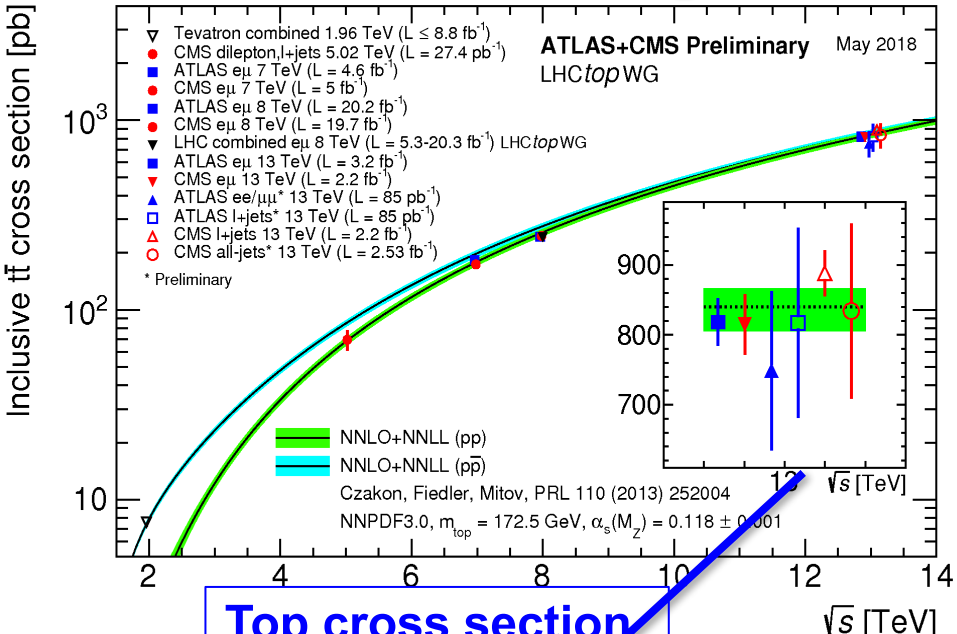


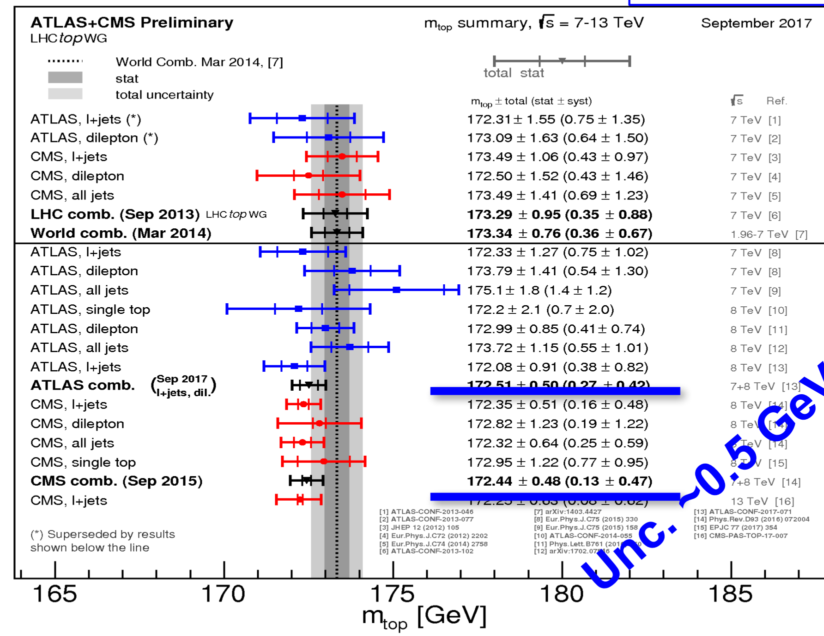
- **SM precision measurement, Probe new physics**
- **Overall good agreement with SM**


Standard Model Production Cross Section Measurements
Status: July 2018
∫ℒ dt [fb⁻¹]
Reference
ATLAS Preliminary
Run 1,2 √s = 7,8,13 TeV
中国组所有单位广泛参与
Theory
LHC pp √s = 7 TeV
Data
stat
stat ⊕ syst
LHC pp √s = 8 TeV
Data
stat
stat ⊕ syst
LHC pp √s = 13 TeV
Data
stat
stat ⊕ syst
pp
Jets R=0.4
Dijets R=0.4
γ
W
Z
tt̄
tt-chan (tot.)
ts-chan (tot.)
Wt
tZj
WW (tot.)
WZ (tot.)
ZZ (tot.)
γγ
Wγ
Zγ
WV
tt̄W (tot.)
tt̄Z (tot.)
tt̄γ
Wjj EWK
Zjj EWK
Zγγ
Wγγ
WWγ
Zγjj EWK
W±W±jj EWK
WZjj EWK
0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
data/theory
50×10⁻⁸ PLB 761 (2016) 158
8×10⁻⁸ Nucl. Phys. B, 486-548 (2014)
3.2 JHEP 09 (2017) 020
20.2 JHEP 09 (2017) 020
4.5 JHEP 02, 153 (2015)
3.2 JHEP 09 (2017) 020
4.5 JHEP 05, 059 (2014)
3.2 PLB 2017 04 072
20.2 JHEP 06 (2016) 005
4.6 PRD 89, 052004 (2014)
0.081 PLB 759 (2016) 601
4.6 EPJC 77 (2017) 367
3.2 JHEP 02 (2017) 117
20.2 JHEP 02 (2017) 117
4.6 JHEP 02 (2017) 117
3.2 PLB 761 (2016) 136
20.2 EPJC 74: 3109 (2014)
4.6 EPJC 74: 3109 (2014)
3.2 JHEP 04 (2017) 086
20.3 EPJC 77 (2017) 531
4.6 PRD 90, 112006 (2014)
20.3 PLB 756, 228-246 (2016)
3.2 JHEP 01 (2018) 63
20.3 JHEP 01, 064 (2016)
2.0 PLB 716, 142-159 (2012)
36.1 PLB 780 (2018) 557
3.2 PLB 773 (2017) 354
20.3 PLB 763, 114 (2016)
4.6 PRD 87, 112001 (2013)
36.1 ATLAS-CONF-2018-034
20.3 PRD 93, 092004 (2016)
4.6 EPJC 72, 2173 (2012)
36.1 PRD 97 (2018) 032005
20.3 JHEP 01, 099 (2017)
4.6 JHEP 03, 128 (2013)
20.2 PRD 95 (2017) 112005
4.9 JHEP 01, 086 (2013)
4.6 PRD 87, 112003 (2013)
20.3 PRD 93, 112002 (2016)
4.6 PRD 87, 112003 (2013)
20.2 EPJC 77 (2017) 563 [hep-ex]
4.6 JHEP 01, 049 (2015)
3.2 EPJC 77 (2017) 40
20.3 JHEP 11, 172 (2015)
3.2 EPJC 77 (2017) 40
20.3 JHEP 11, 172 (2015)
20.2 JHEP 11 (2017) 086
4.6 PRD 91, 072007 (2015)
20.2 EPJC 77 (2017) 474
4.7 EPJC 77 (2017) 474
3.2 PLB 775 (2017) 206
20.3 JHEP 04, 031 (2014)
20.3 PRD 93, 112002 (2016)
20.3 PRL 115, 031802 (2015)
20.2 EPJC 77, 646 (2017)
20.3 JHEP 07 (2017) 107
36.1 ATLAS-CONF-2018-030
20.3 PRD 96, 012007 (2017)
36.1 ATLAS-CONF-2018-033
20.3 PRD 93, 092004 (2016)

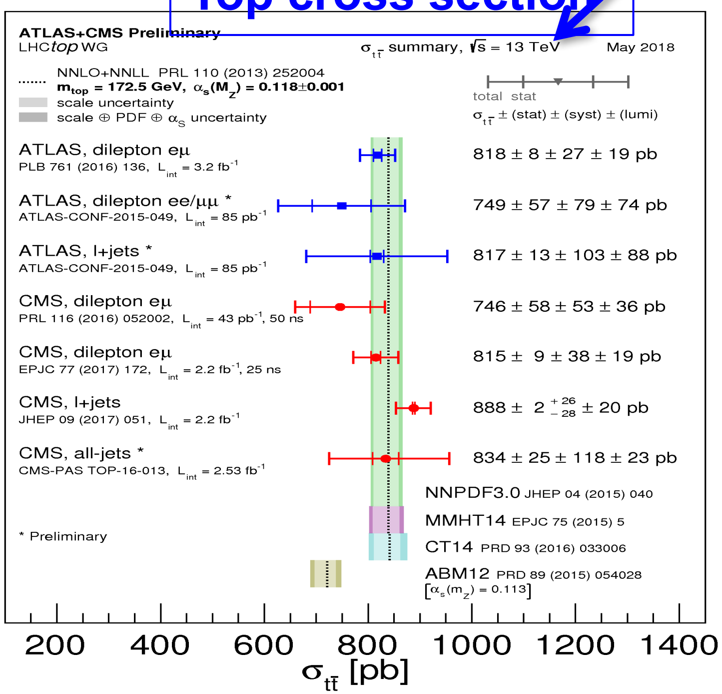
Top measurement

Top mass

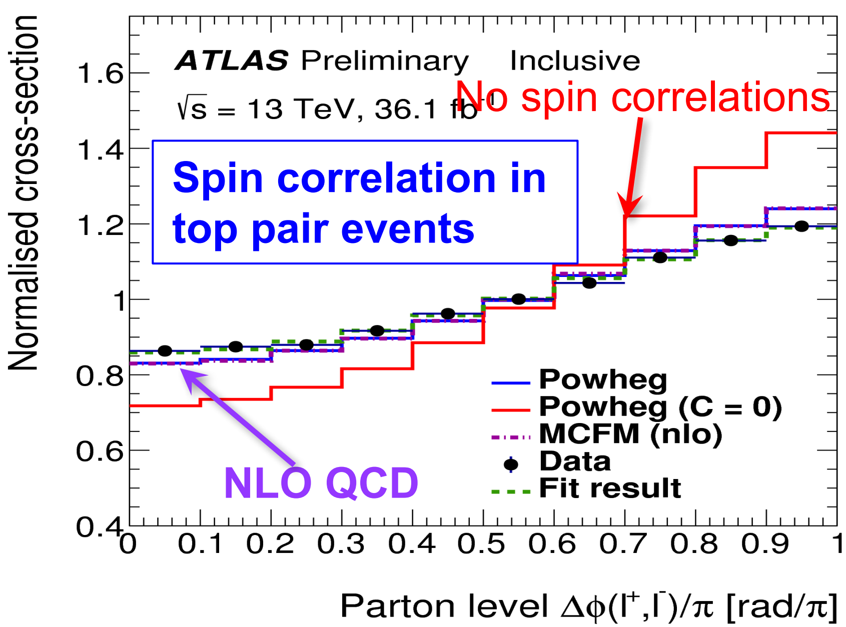




Top cross section



Spin correlation in top pair events

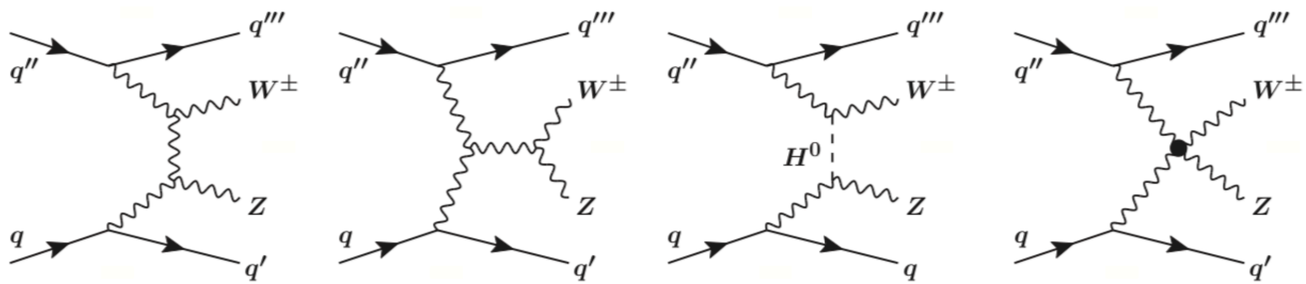


ATLAS-CONF-2018-027

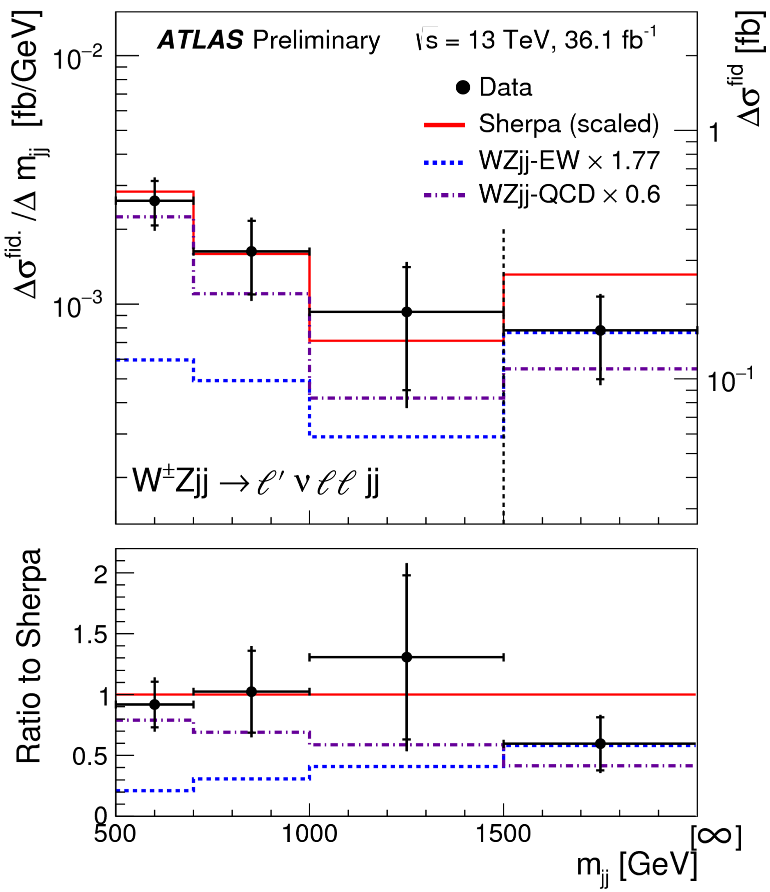
Fit results: f=1.250+-0.026 +-0.063

3.2σ discrepancy with NLO QCD

WZ+jj production



Differential EW cross-section:



Process sensitive to triple and quartic gauge couplings and anomalous couplings

Observation of electroweak WZjj process: 5.6σ (3.3σ) obs (exp)

Total fiducial WZ jet jet cross section:

σ_{EW} (pp → W^{+-}Z jet jet) = 0.57 +-0.15 fb

LO (Sherpa): 0.32 +-0.03 fb

ATLAS-CONF-2018-033

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- **Higgs Measurements and BSM Higgs Search**
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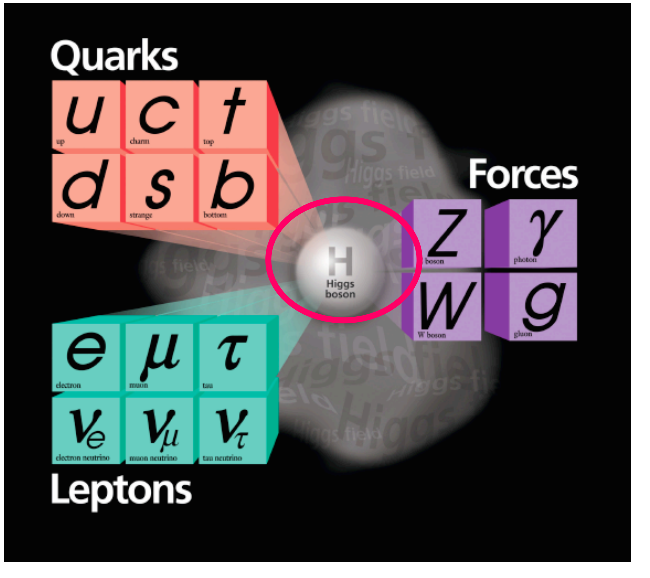
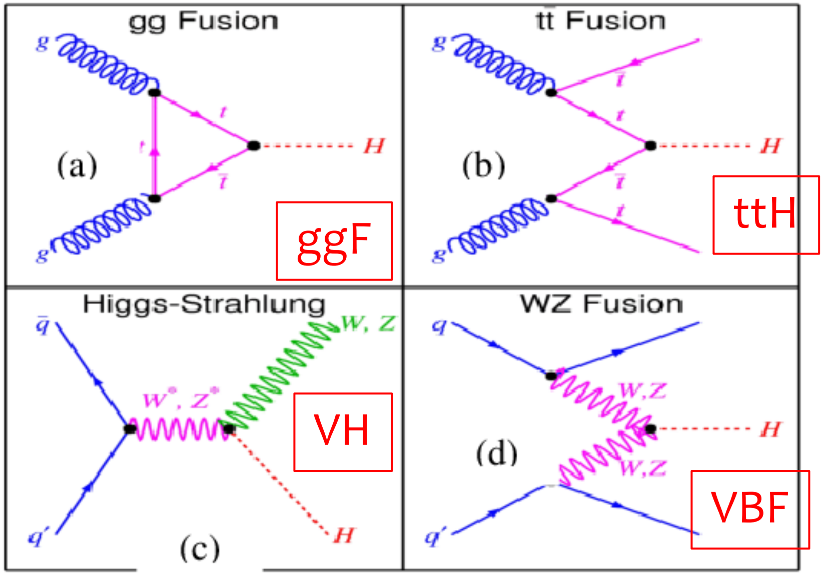
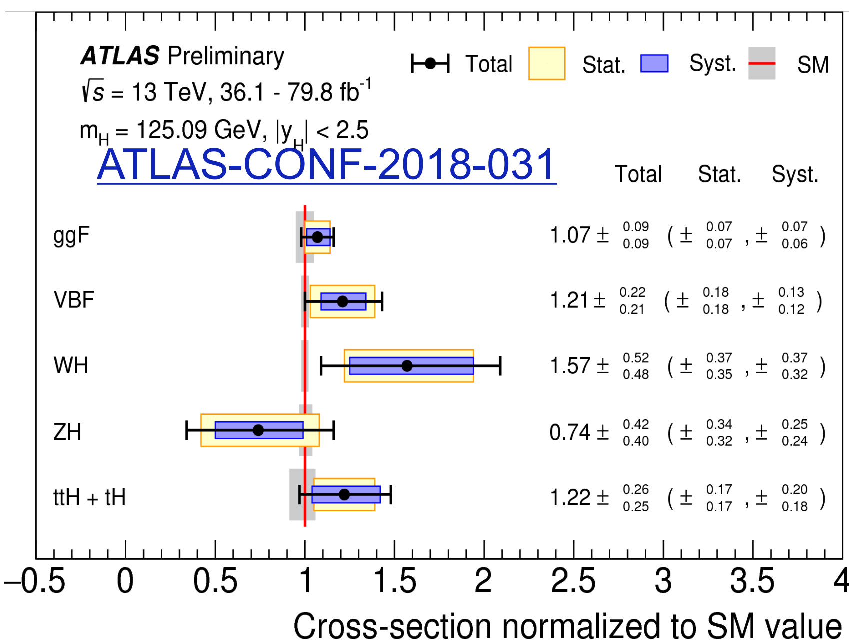


Higgs production/decay modes





Decay mode	Branching fraction [%]	中国组贡献
$H \to bb$	57.5 ± 1.9	✓
$H \to WW$	21.6 ± 0.9	✓
$H \to gg$	8.56 ± 0.86	✓
$H \to \tau\tau$	6.30 ± 0.36	✓
$H \to cc$	2.90 ± 0.35	
$H \to ZZ$	2.67 ± 0.11	✓
$H \to \gamma\gamma$	0.228 ± 0.011	✓
$H \to Z\gamma$	0.155 ± 0.014	✓
$H \to \mu\mu$	0.022 ± 0.001	✓

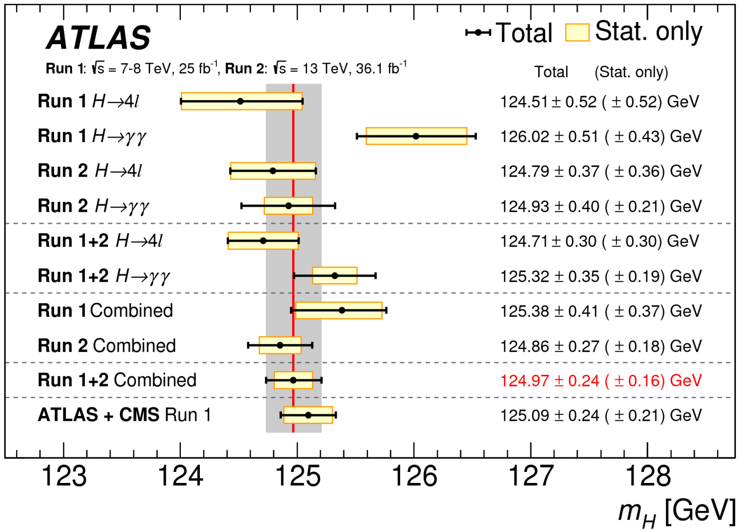
- **(a) Gluon-gluon fusion (ggF) observed since 2012 and used for precision measurement (~10%)**

Prod. mode	Obs.	Exp.	Ref.
(c) VH	5.3σ	4.8σ	ATLAS-CONF-2018-036
(d)VBF	6.5σ	5.3σ	ATLAS-CONF-2018-031
(b) ttH	6.3σ	5.1σ	arXiv:1806.00425

- **Observed all major Higgs production modes ! → Consistent with SM.**

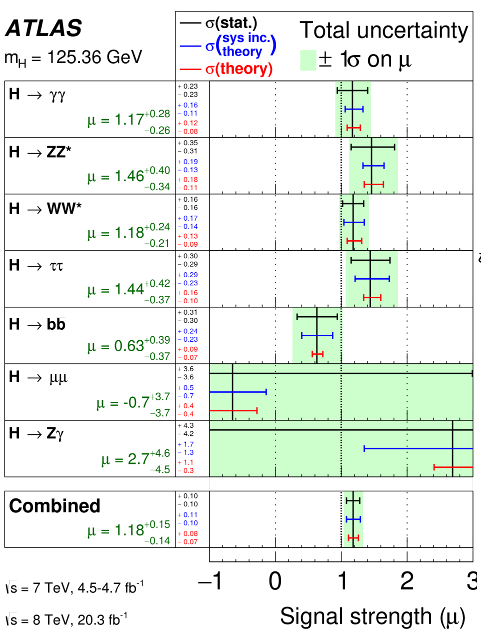
Higgs properties

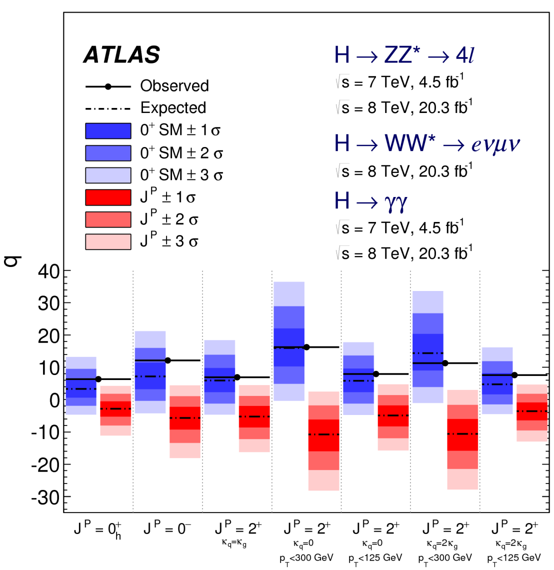
中国组所有单位广泛参与

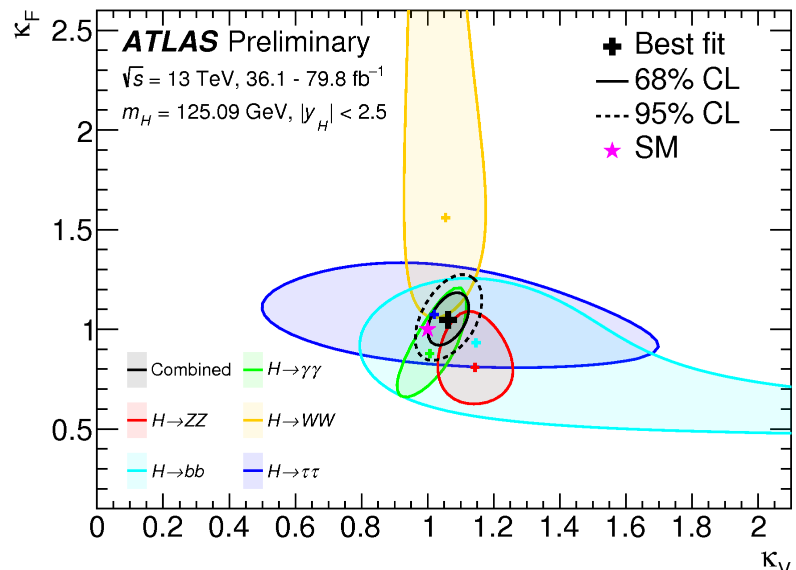


Results are consistent with the SM!

- Higgs mass: 124.97 ± 0.24 GeV
  (cms HZZ4l: 125.26 ± 0.21 GeV)
- Higgs strength: $\mu = 1.18^{+0.15}_{-0.14}$ (run1)
  (cms 13 TeV 2016 comb: $1.17^{+0.1}_{-0.1}$)
- Spin/Parity: 0^+
- Couplings: agree with SM predictions

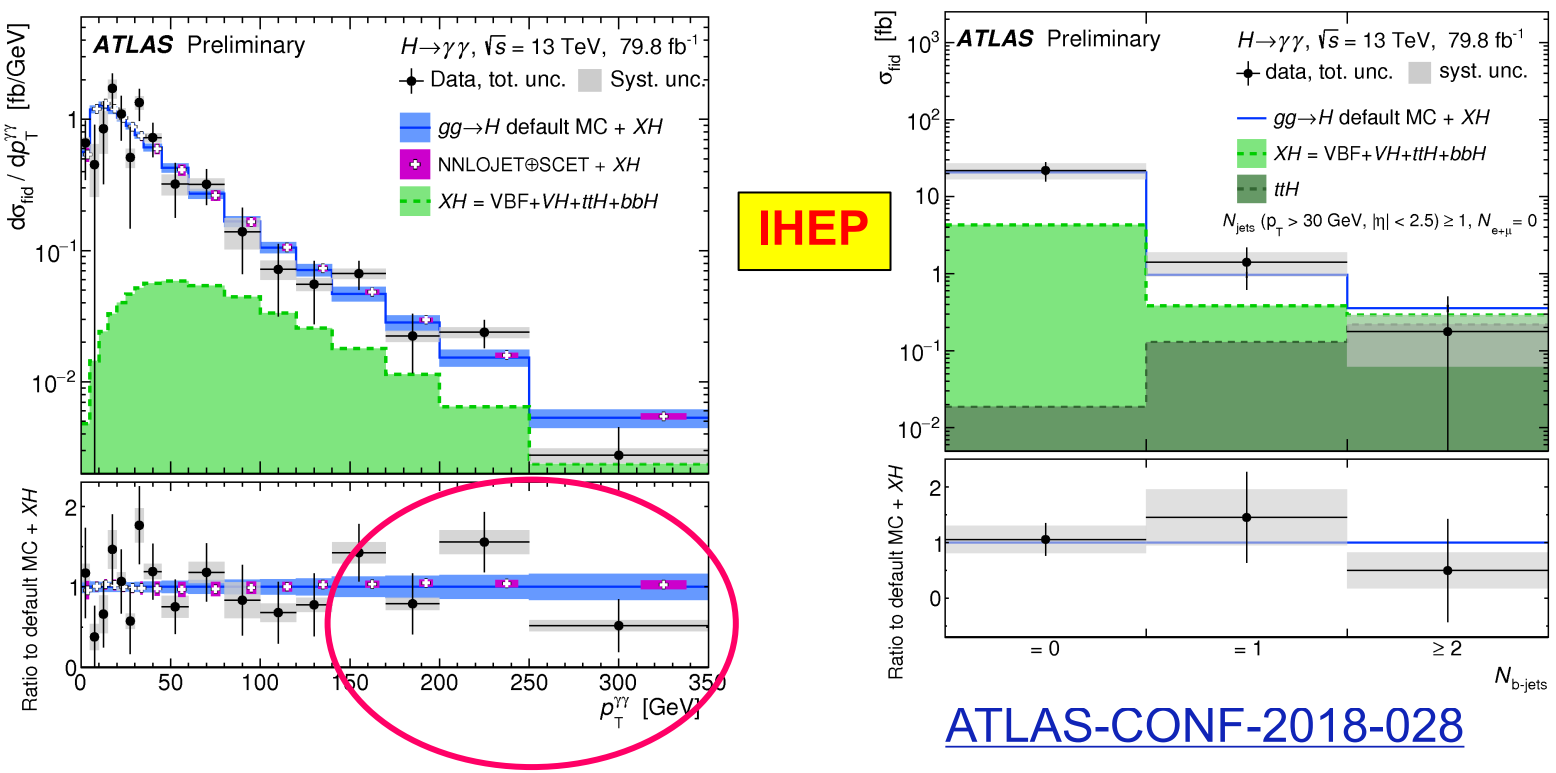






See details from Yanping's talk

Precise differential measurement



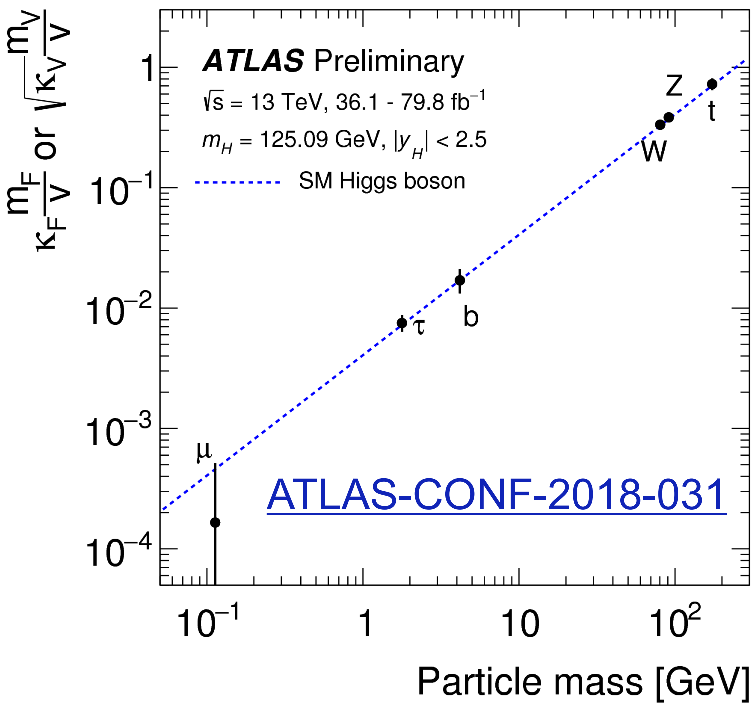
ATLAS-CONF-2018-028

- New **ATLAS H → γγ** measurement with 80 fb^{-1} of Run-2 data.
- All distributions in agreement with expectations.
- No sign of New Physics in p_T(H) tail yet!

See details at Yanping's talk

Higgs coupling measurements

Higgs coupling (to fermions or bosons) depends on the particle mass



- **All couplings to high mass particles measured.**
- **Next challenge: muon, charm-quark...**

Interaction with gauge bosons:

H →ZZ* ATLAS-CONF-2018-018

Well established in run-1

H →WW* ATLAS-CONF-2018-004

6.3 (5.2) σ obs (exp) (run-2 only)

Yukawa coupling to fermions: *highlighted*

Top-quark: ttH ***(80 fb^{-1})***

6.3σ (5.1σ) obs (exp) Phys. Lett. B 784 (2018) 173

Bottom-quark H→bb ***(80 fb^{-1})***

5.4σ (5.5σ) obs (exp) ATLAS-CONF-2018-036

Tau-lepton: H→ττ

6.4σ (5.4σ) obs (exp) ATLAS-CONF-2018-021

Muon H→μμ ***(80 fb^{-1})***

$\sigma_{limit} / \sigma_{SM} < 2.1$ (obs) ATLAS-CONF-2018-026

Charm-quark: H→cc

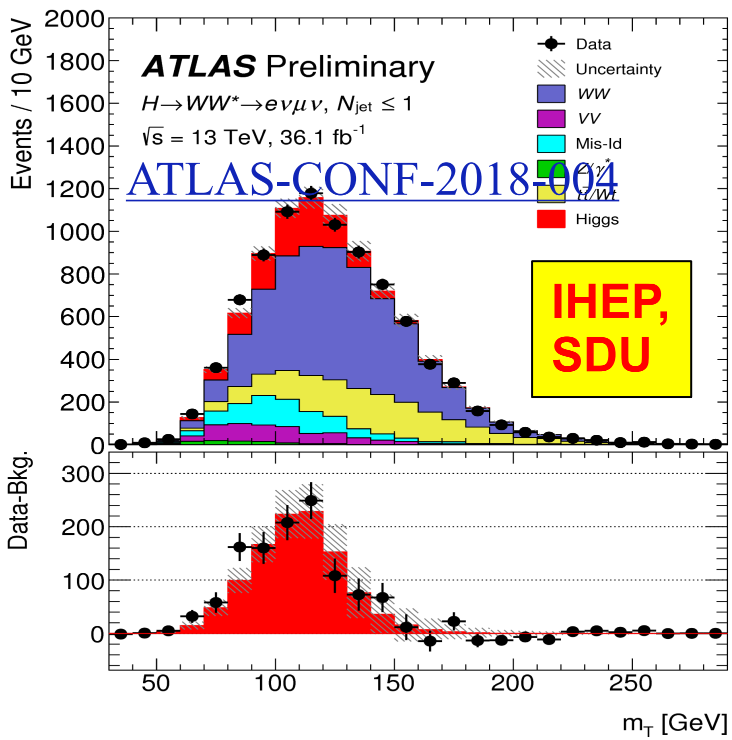
$\sigma_{limit} / \sigma_{SM} < 104$ (obs) PRL 120 (2018) 211802

Gauge boson and Yukawa fermion coupling

Interaction with gauge bosons:

Run1: Higgs boson discovered at 7-8TeV.
Main channels: H → γγ, H →ZZ, H → WW

Recent Run2 results: H → WW



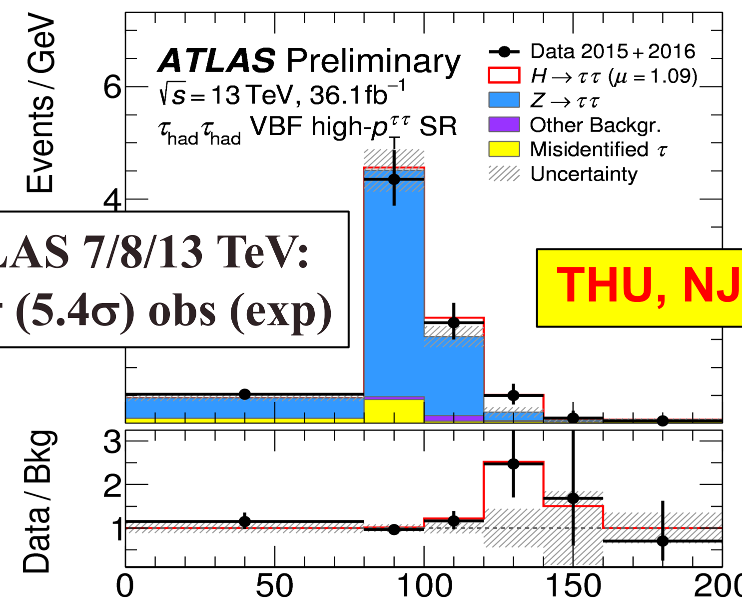
ATLAS-CONF-2018-004

IHEP, SDU

Yukawa coupling to fermions:

Run1: Only glimpse at 7-8 TeV (2012)
ATLAS/CMS combined H→ττ:
5.5σ (5.0σ) obs (exp) for 7/8 TeV (JHEP 08 (2016) 045)

Recent Run2 results: H → ττ



ATLAS 7/8/13 TeV:
6.4σ (5.4σ) obs (exp)

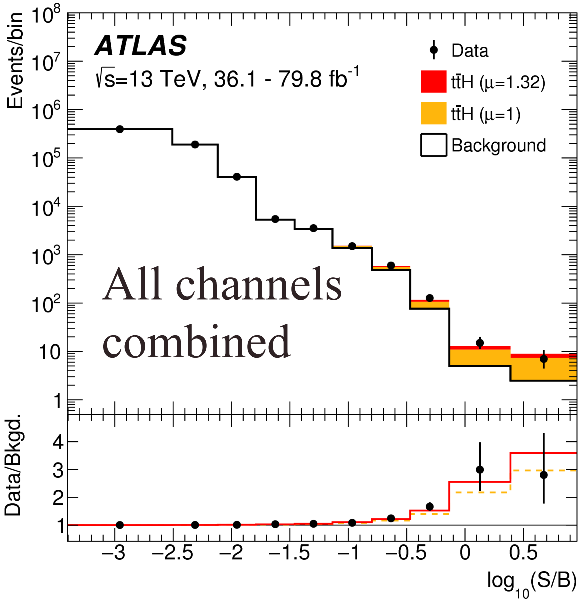
THU, NJU

ATLAS-CONF-2018-021

中国5家单位参与了H→γγ, ZZ 的分析。
See details of VBF H→γγ at Yaquan's talk

Observation of ttH production

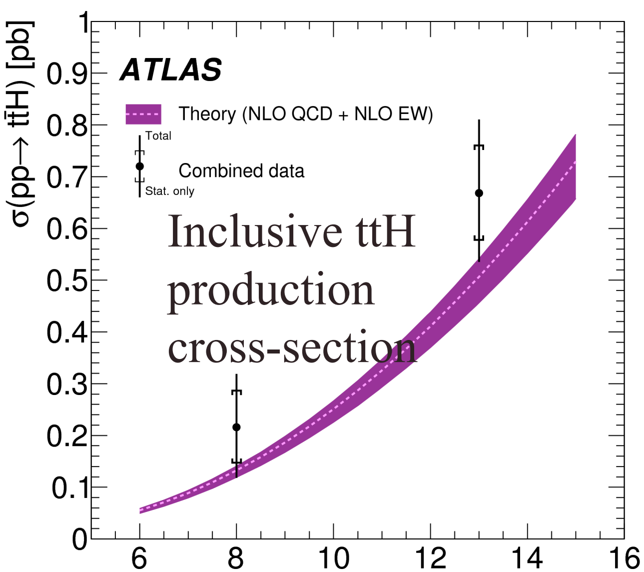
中国4家单位参与

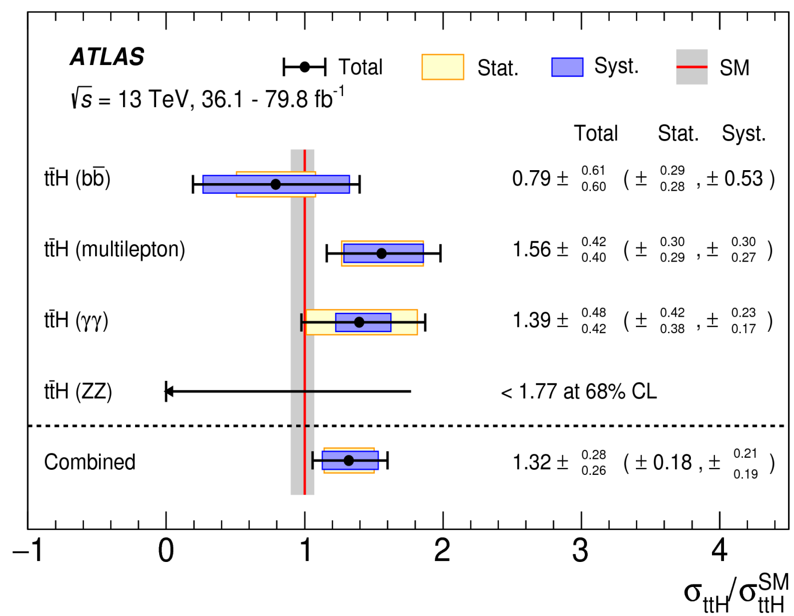


Analysis	Integrated luminosity [fb^{-1}]	$t\bar{t}H$ cross section [fb]	Obs. sign.	Exp. sign.
$H \to \gamma\gamma$	79.8	$710\ ^{+210}_{-190}$ (stat.) $^{+120}_{-90}$ (syst.)	4.1 σ	3.7 σ
$H \to$ multilepton	36.1	790 ± 150 (stat.) $^{+150}_{-140}$ (syst.)	4.1 σ	2.8 σ
$H \to b\bar{b}$	36.1	$400\ ^{+150}_{-140}$ (stat.) $\pm$ 270 (syst.)	1.4 σ	1.6 σ
$H \to ZZ^* \to 4\ell$	79.8	<900 (68% CL)	0 σ	1.2 σ
Combined (13 TeV)	36.1–79.8	670 ± 90 (stat.) $^{+110}_{-100}$ (syst.)	5.8 σ	4.9 σ
Combined (7, 8, 13 TeV)	4.5, 20.3, 36.1–79.8	–	6.3 σ	5.1 σ

Direct observation of top Higgs coupling.
Confirmation of Yukawa coupling to fermions.

Phys. Lett. B 784 (2018) 173



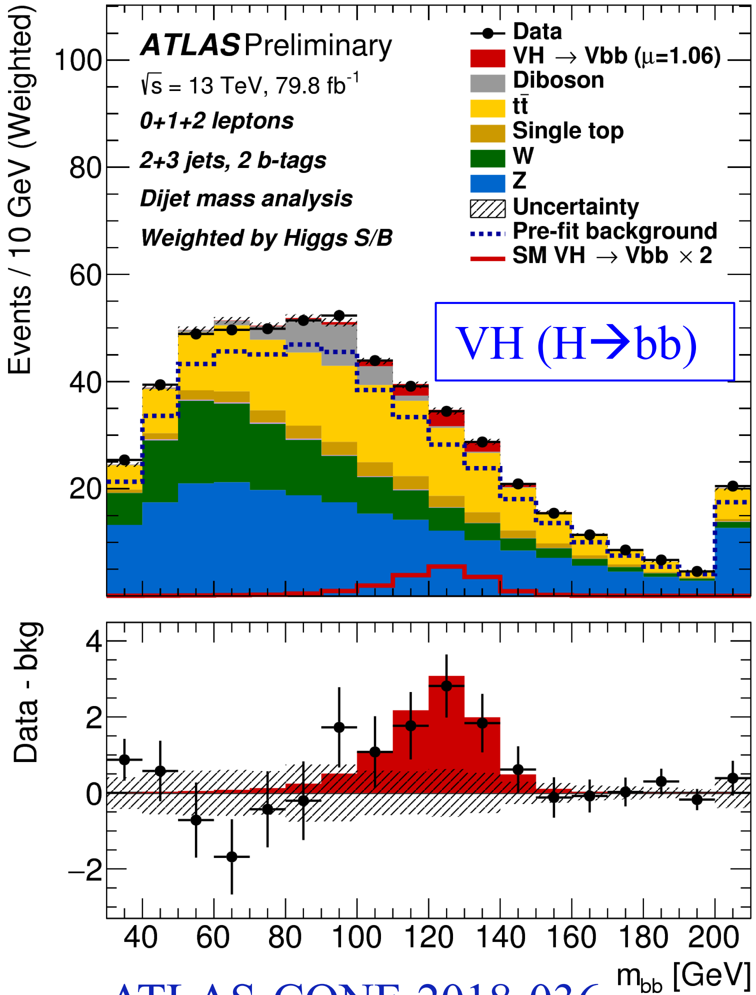


Already 20% precision !

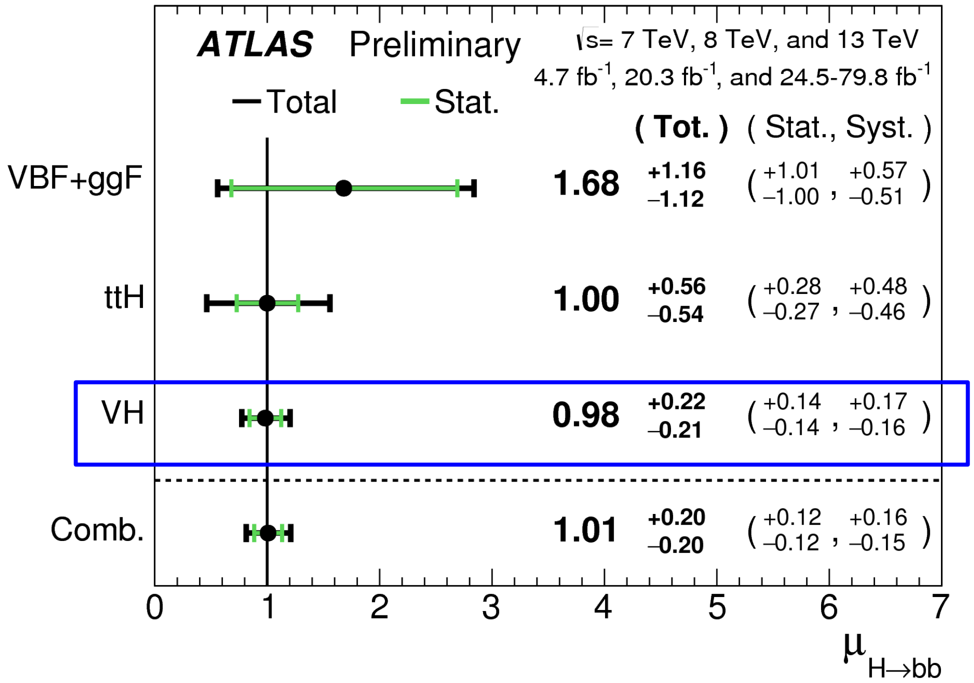
Consistent with SM Higgs boson

Observation of H→bb

中国5家
单位参与



ATLAS-CONF-2018-036



Run 2 VH, H→bb **sign.: 4.9σ (4.3σ) obs (exp)**

Combined with Run 1: 4.9σ (5.1σ) obs (exp)

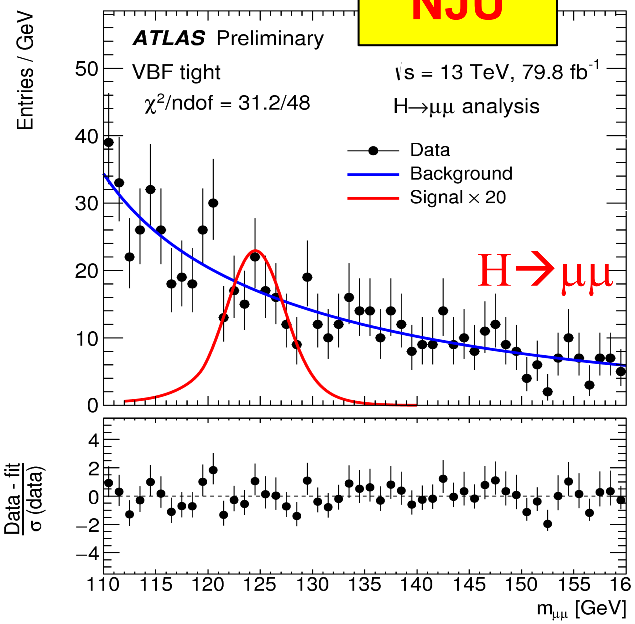
Combined with *VBF(+ggF) and ttH (Run1+Run2)*: 5.4σ (5.5σ) obs (exp)

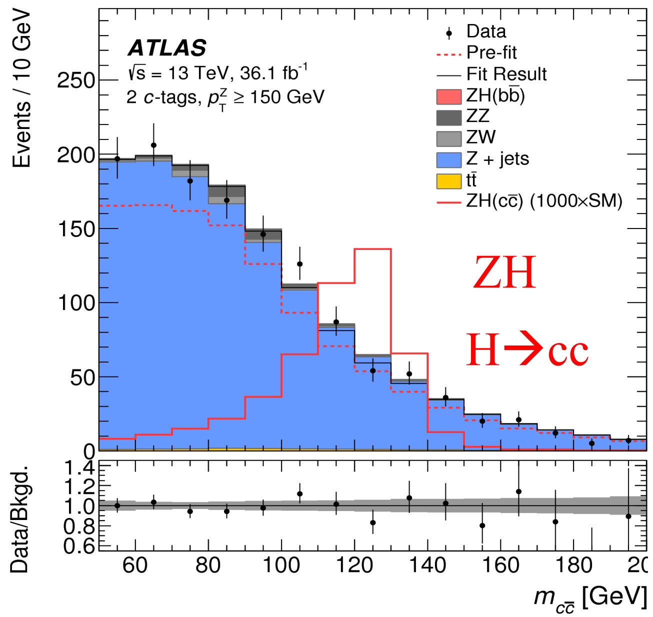
Observation of higgs decay to bottom quarks !

See details from Zhijun's talk

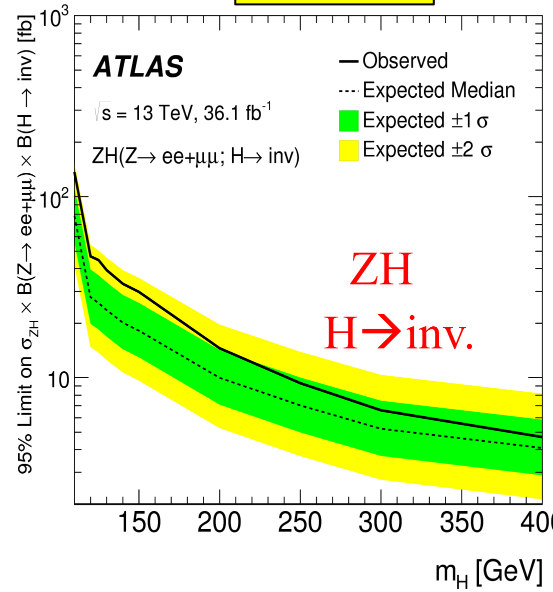
Higgs rare decays

USTC, SDU, NJU





USTC



ATLAS-CONF-2018-026

VBF+ggF

$\sigma_{limit}/\sigma_{SM} < 2.1$ (obs)

Signal strength $\mu = 0.1^{+1.0}_{-1.1}$

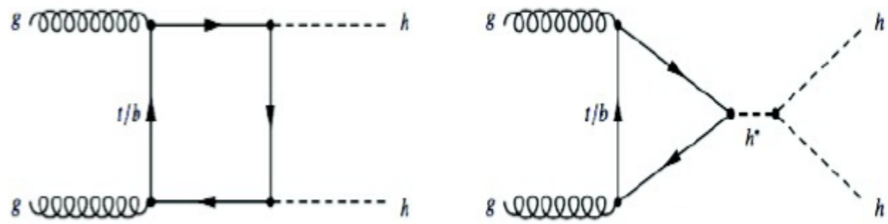
PRL 120 (2018) 211802

$\sigma_{limit}/\sigma_{SM} < 104$ (obs)

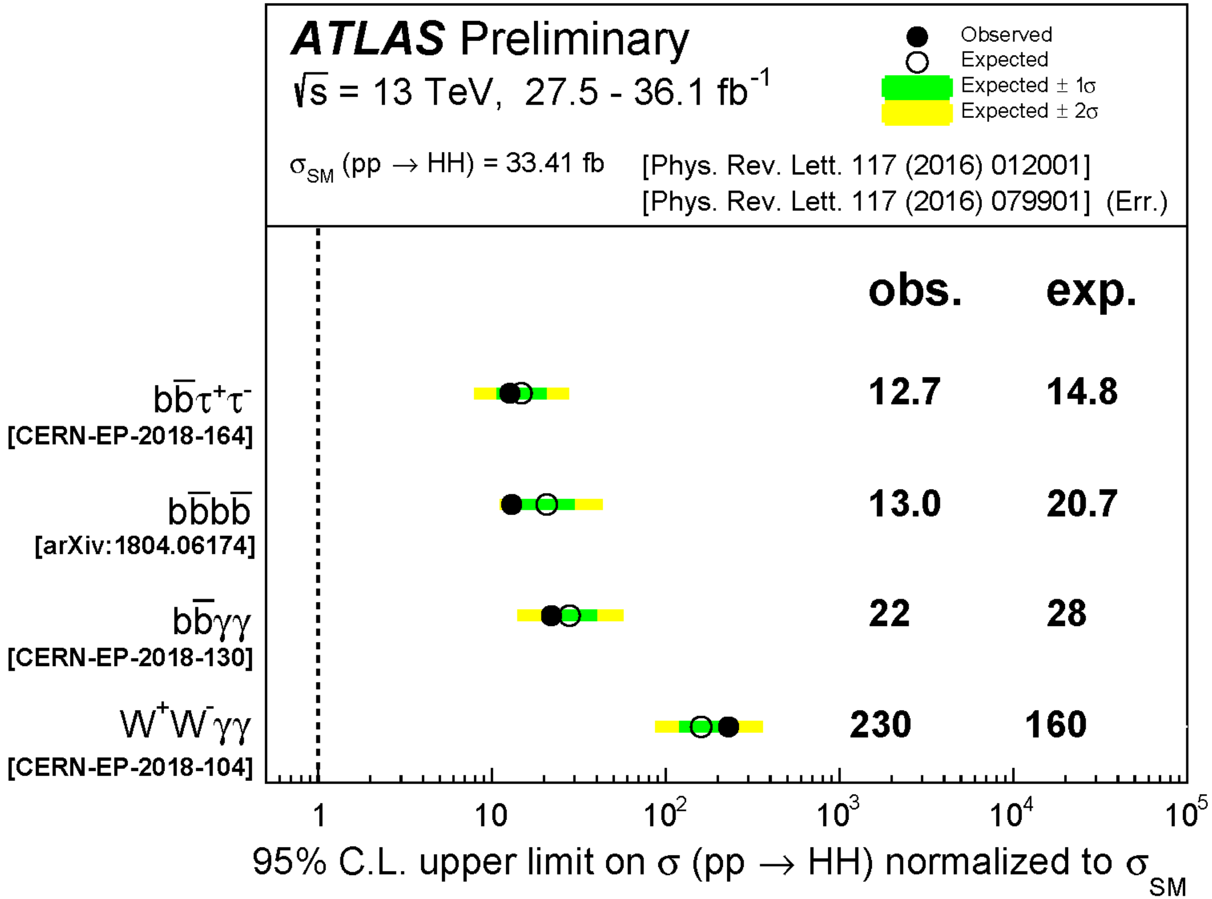
$\sigma(pp \to ZH) \times B(H \to c\bar{c}) <$ **2.7 ($3.9^{+2.1}_{-1.1}$) pb**

PLB 776 (2017) 318

SM Di-higgs production



- Di-Higgs production process is direct probe of SM trilinear coupling.
- Strong destructive interference between processes.

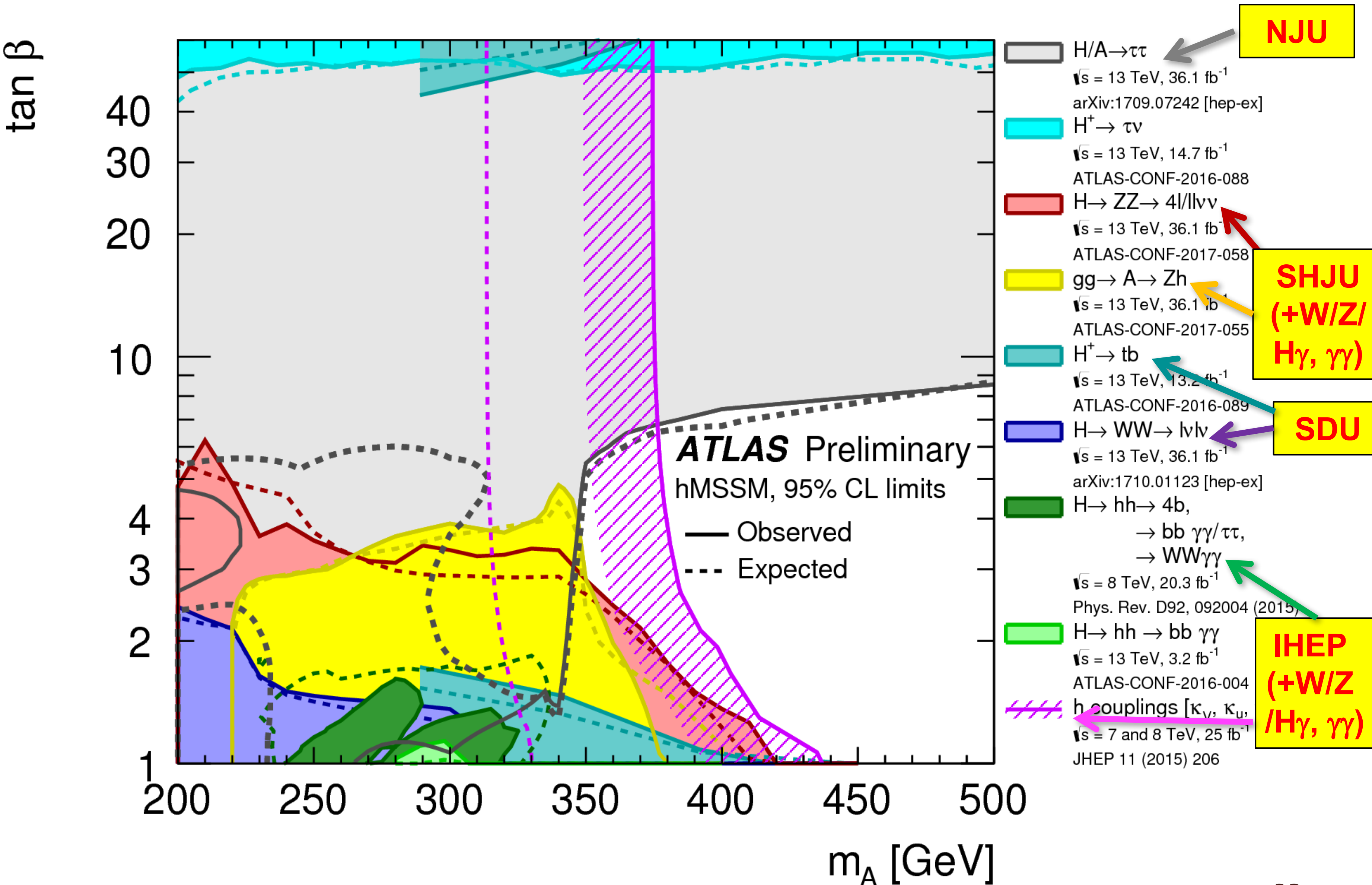


Limit approaching:

$\sigma_{limit}/\sigma_{SM} \sim 10$

China group is working on WWγγ and bbττ

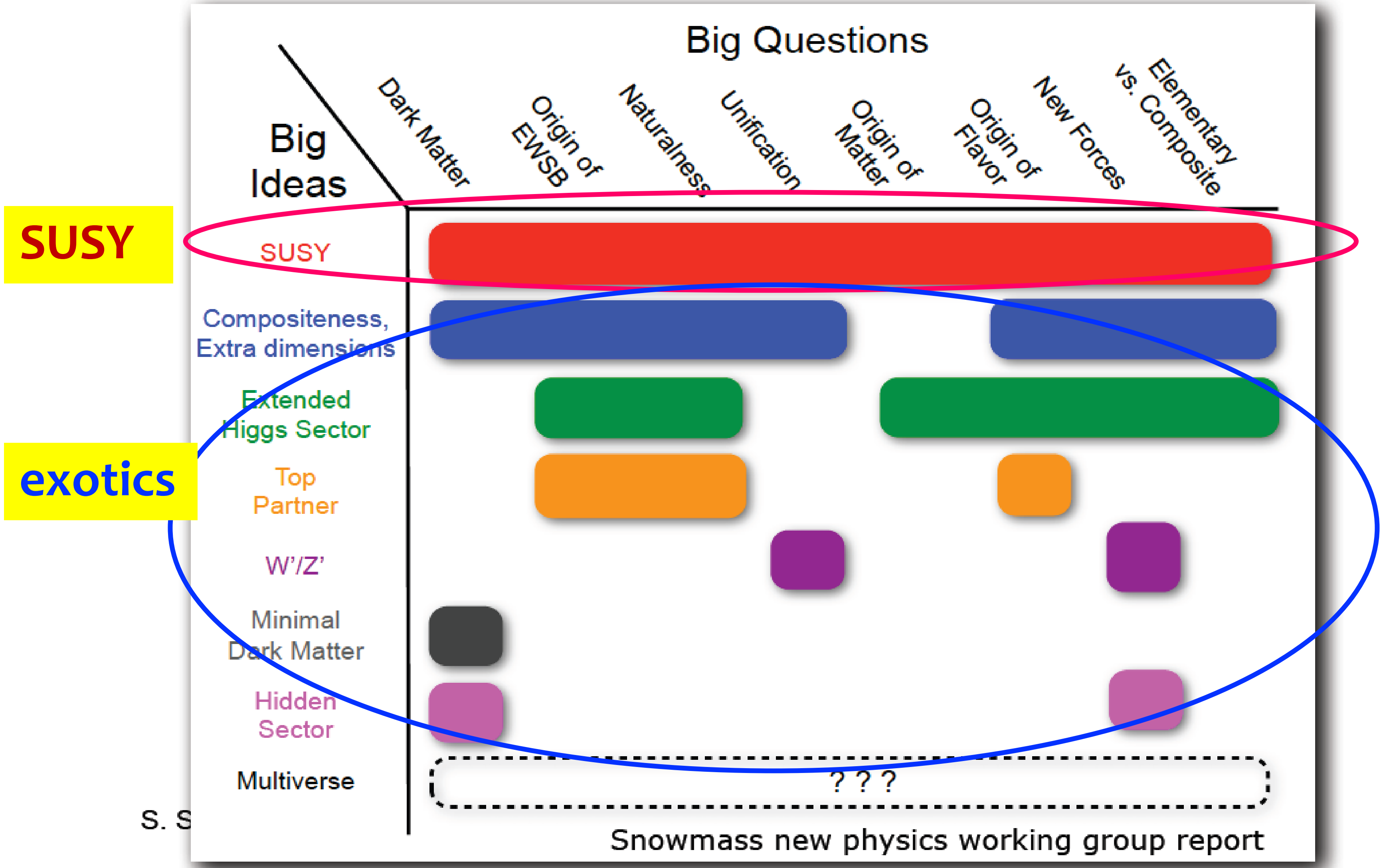
BSM Higgs exclusion in the hMSSM:



Outline

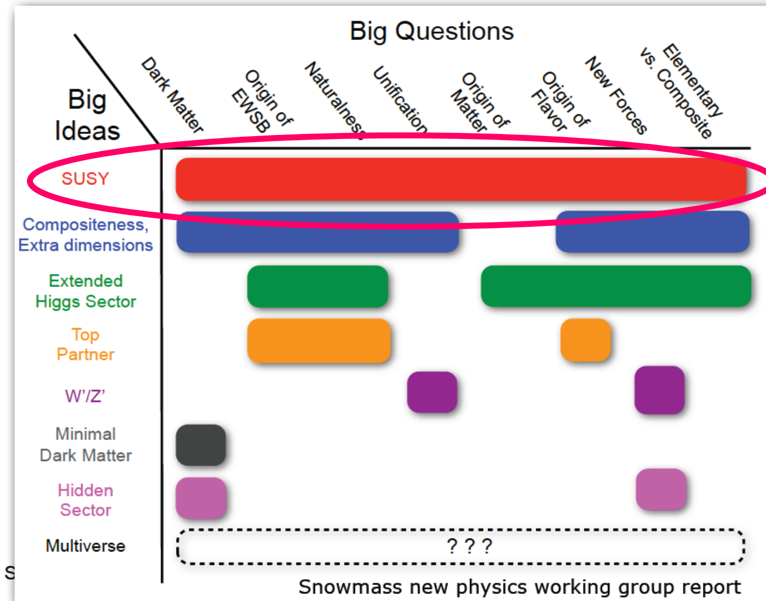
- Introduction of LHC, ATLAS
- SM Precision Measurements
- Higgs Measurements and BSM Higgs Search
- **BSM Physics Search**
- Conclusion and Outlook

New Physics beyond the SM



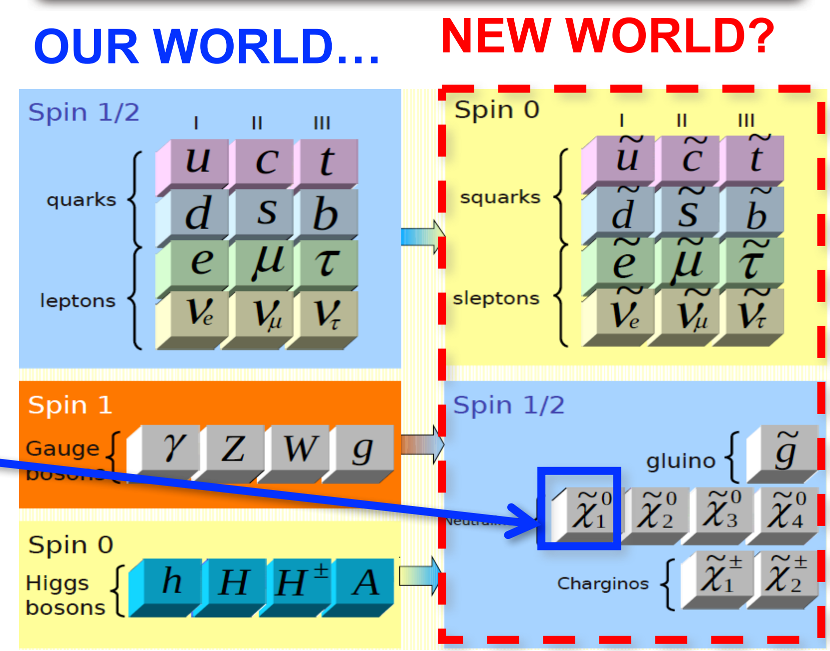
SUSY Introduction

New Physics beyond the SM



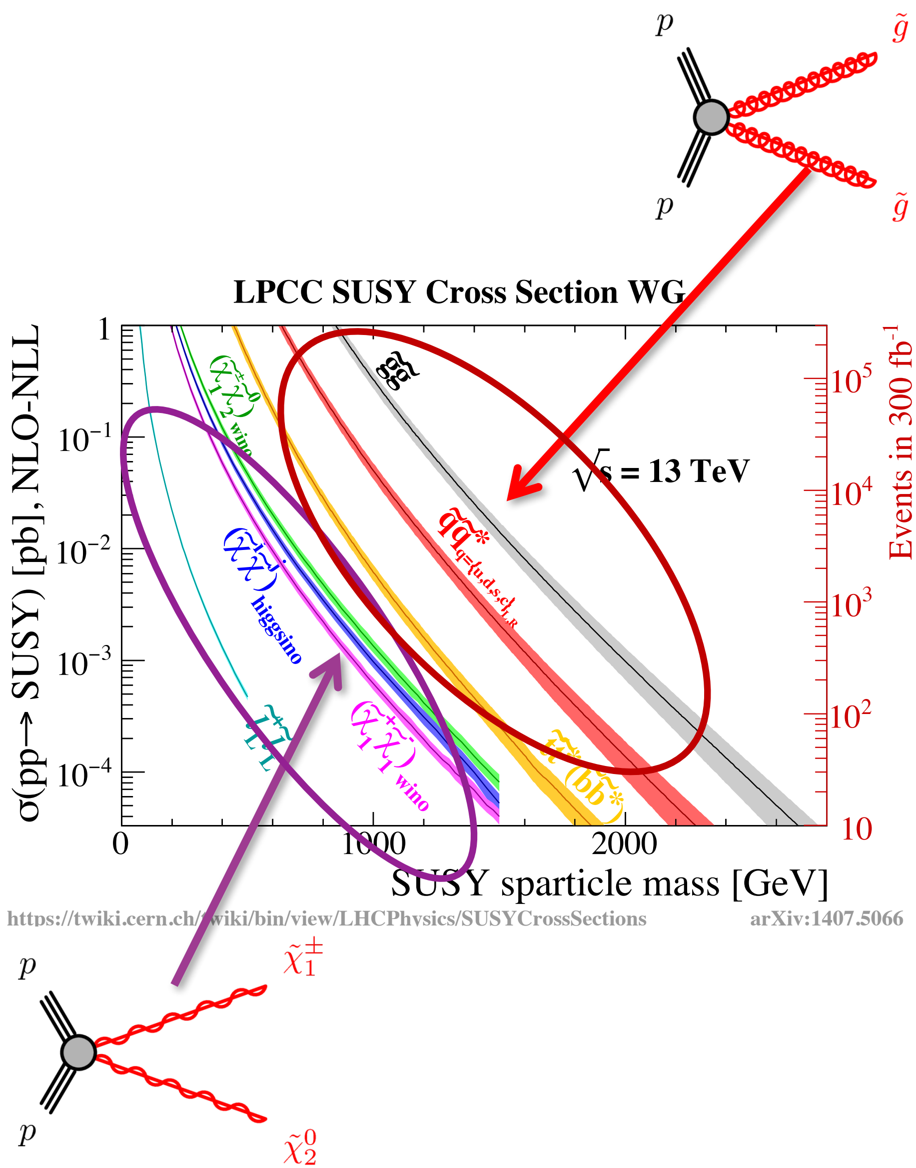
- SUSY is one of the most favorite candidate for New Physics.

- SUSY establishes a symmetry between fermions (matter) and bosons (forces)
  - Unification
  - Solves deep problems of the SM
  - Provide Dark Matter candidate
  - …



SUSY Search @ LHC

[ATLAS public link](#)
[CMS public link](#)



Strong production:

- targeting gluinos and squarks
- by far largest cross-sections

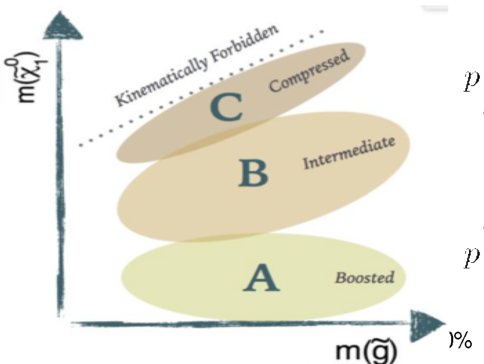
Electroweak production:

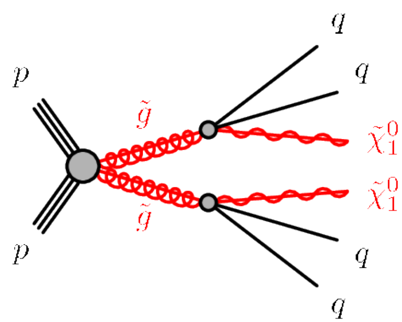
- targeting Electroweakinos, sleptons
- Lowest mass sparticles, clean signature

RPV/LL:

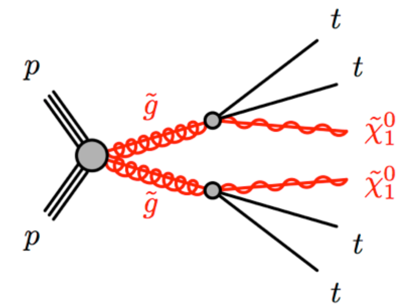
- targeting R-parity violating models and long lived sparticles
- More exotic models

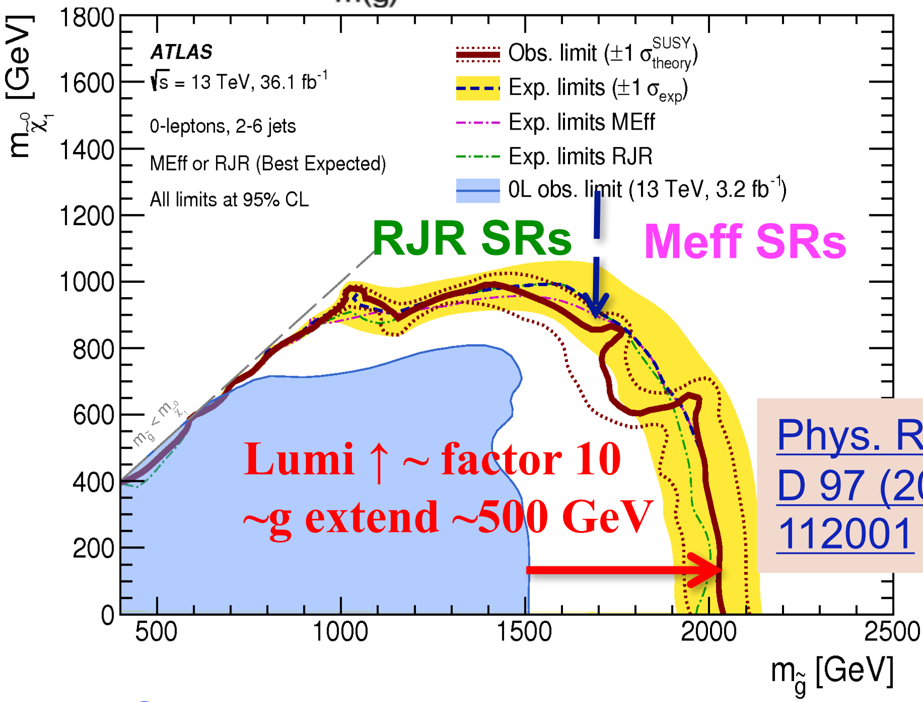
Direct squark & gluino decays (all had.)



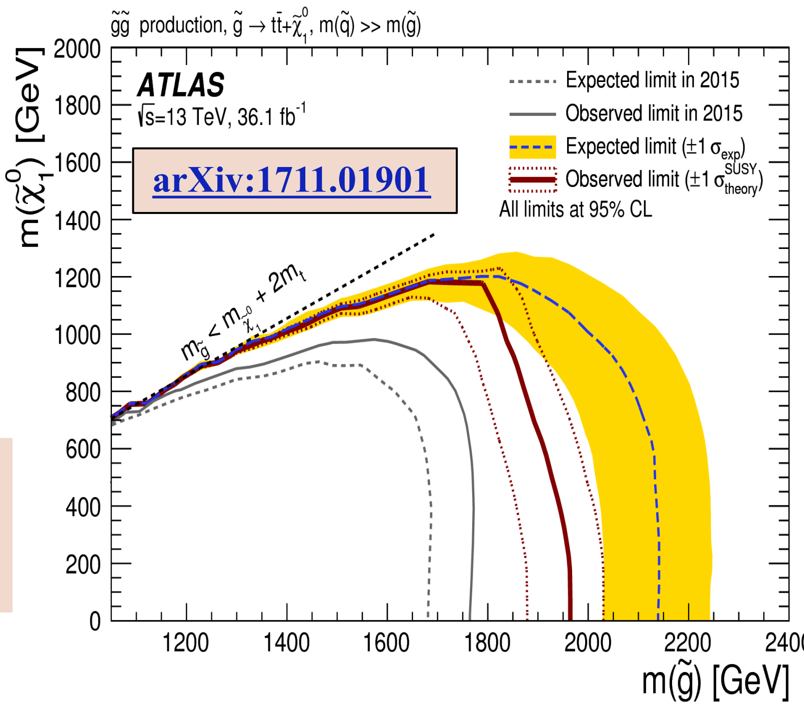


Signal: (b) jets and missing energy





Phys. Rev. D 97 (2018) 112001



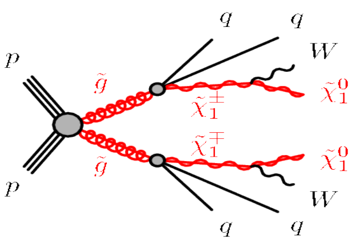
arXiv:1711.01901

Corresponding sparticle mass limits for **BF=100%**:

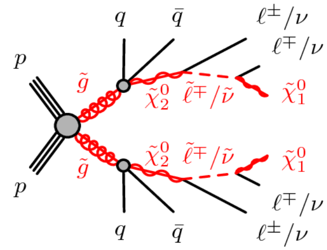
- ~g (~q): up to (2.05)1.55 TeV Gluinos with neutralinos up to 1.1 TeV
- Gtt(Gbb): Gluinos up to 1.97(2.05) TeV with N1 up to 1.19 (1.2) TeV

Multi-step decays

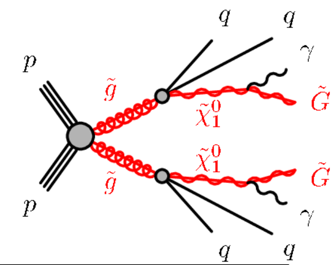
Signal: single lepton/photons, jets and MET



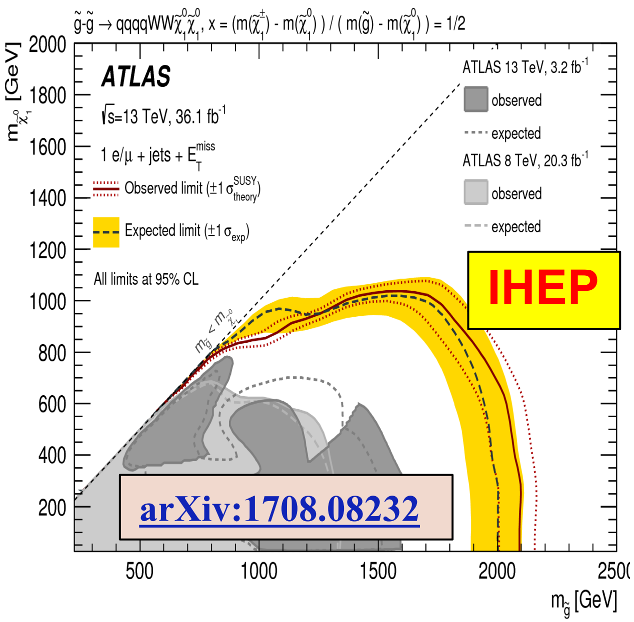
Single lept.



SS Di-lept.

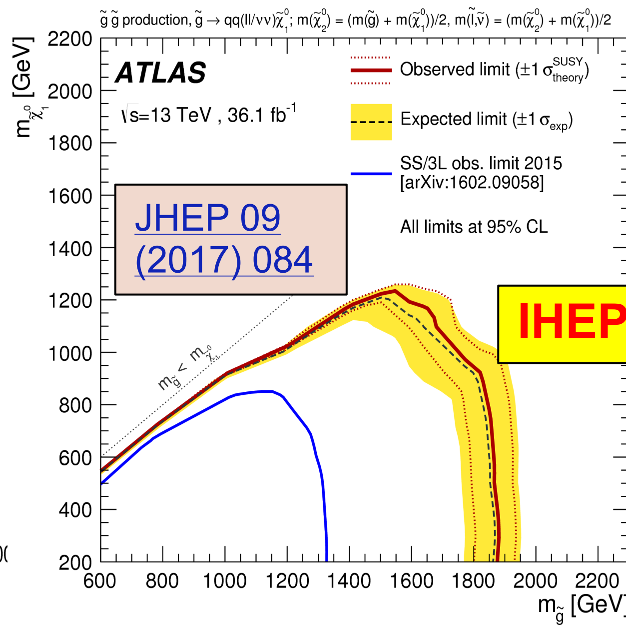


Photon(s)



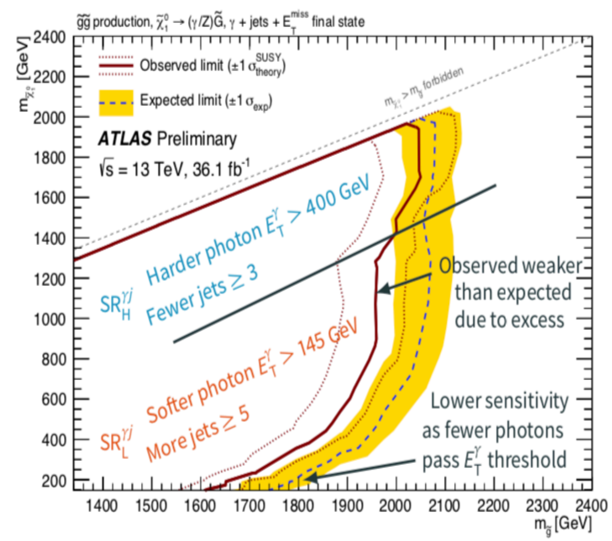
IHEP

arXiv:1708.08232



JHEP 09 (2017) 084

IHEP

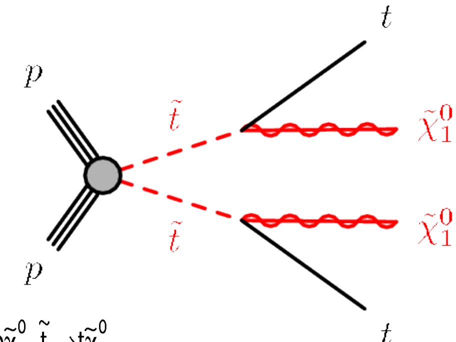


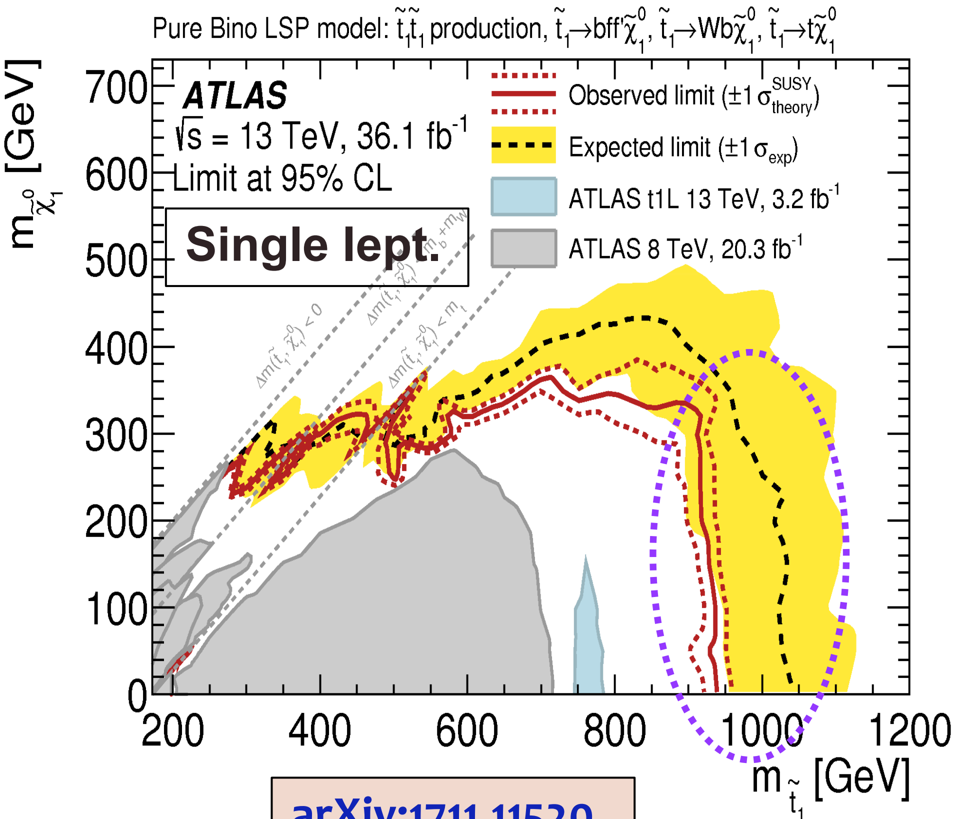
Phys. Rev. D 97 (2018) 092006

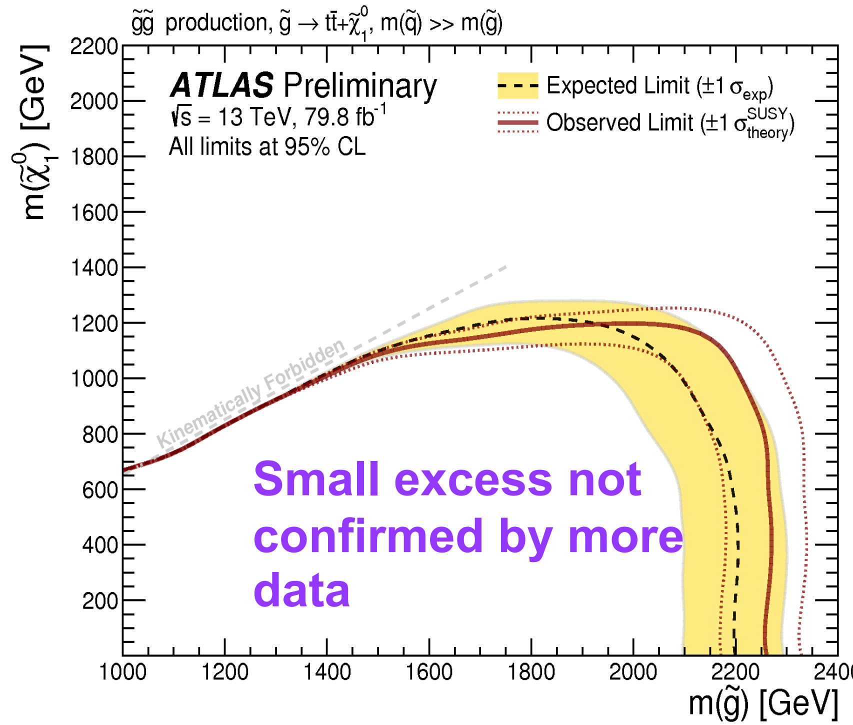
Corresponding sparticle mass limits for **BF=100%**:

- Gluino mass up to ~2 TeV, N1 (~G) up to 1(2) TeV

Stop search (leptonic)



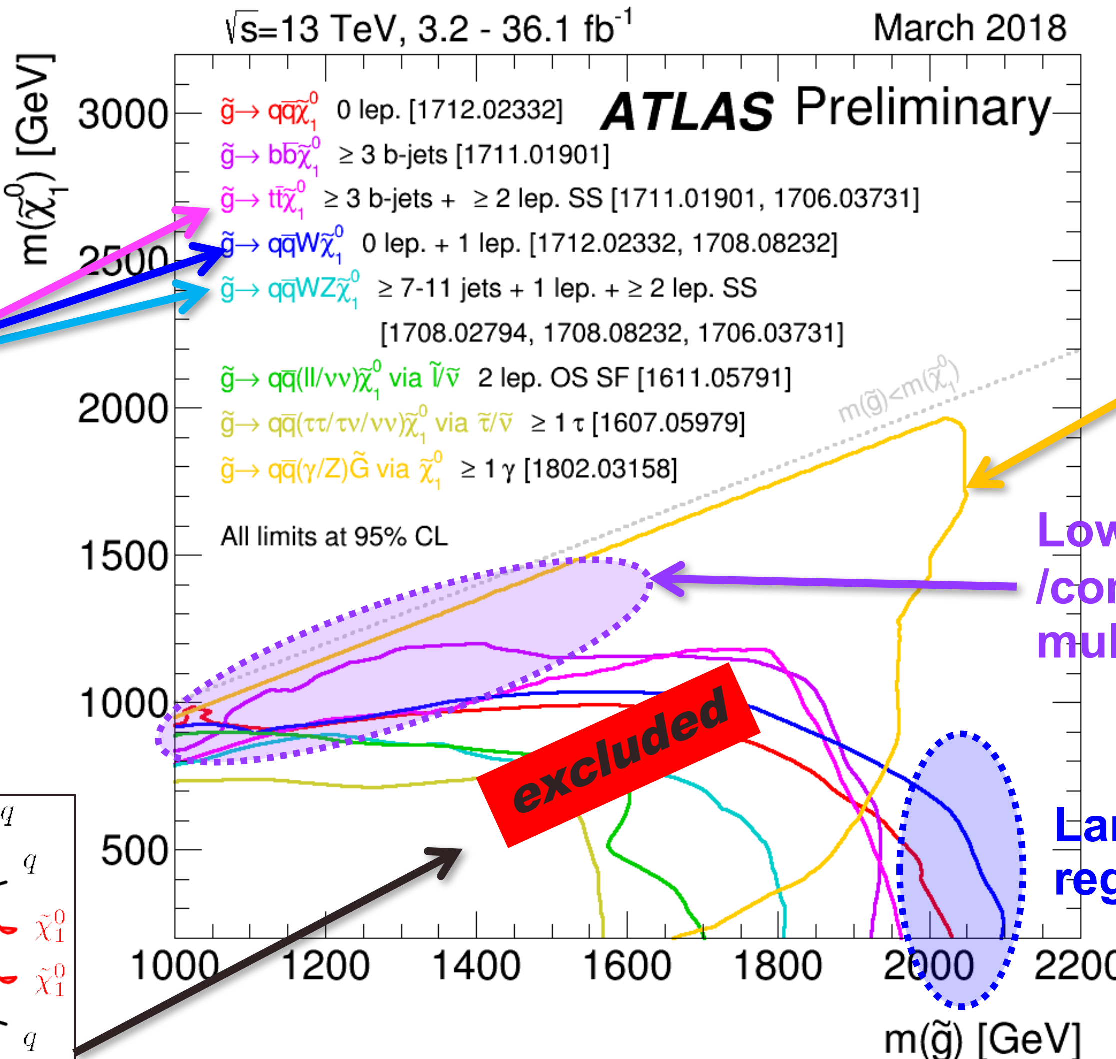




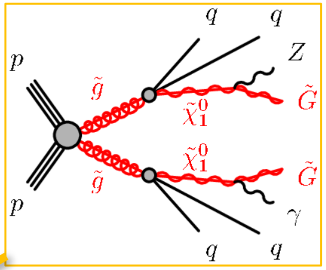
arXiv:1711.11520

ATLAS-CONF-2018-041

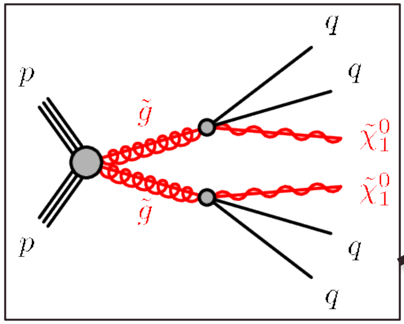
Strong Production *(summary)*



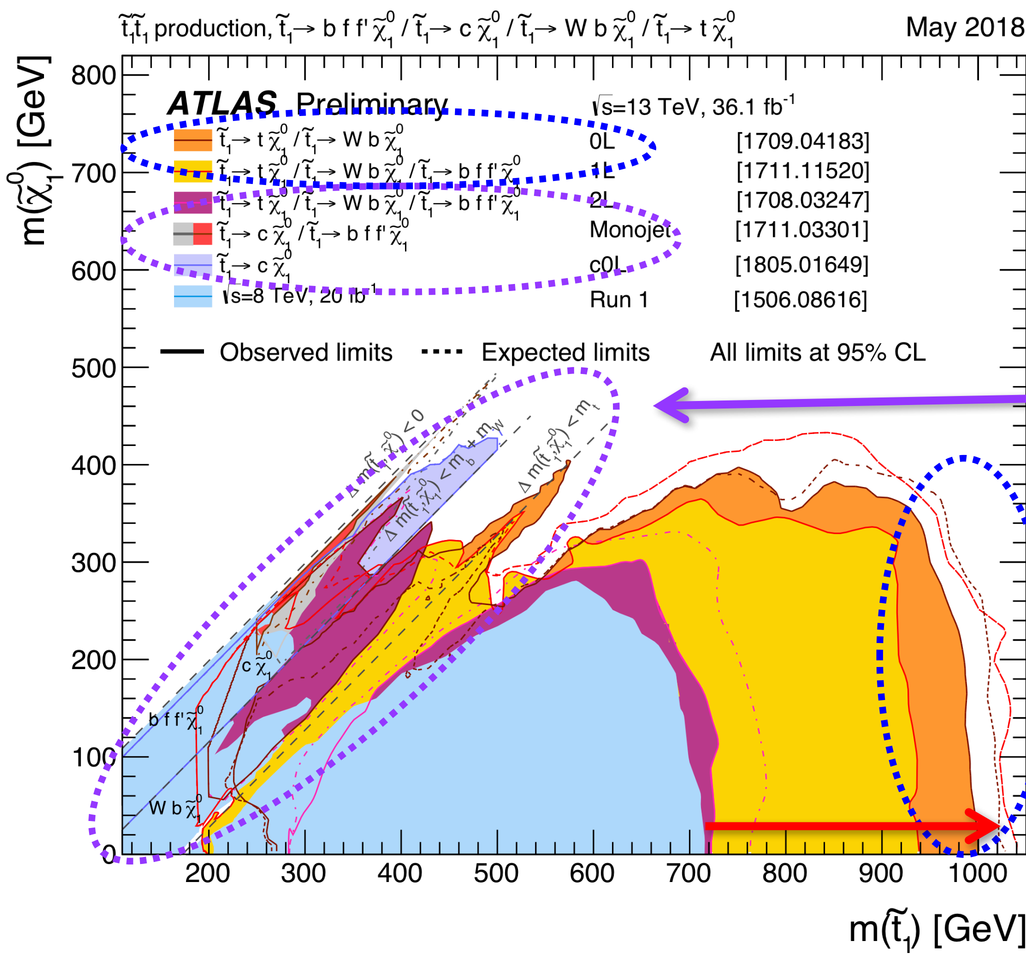
Neutralino NLSP light gravitino LSP



Neutralino LSP



Stop search



Compressed scenario: still < 600 GeV

Large mass split scenario: up to 1 TeV

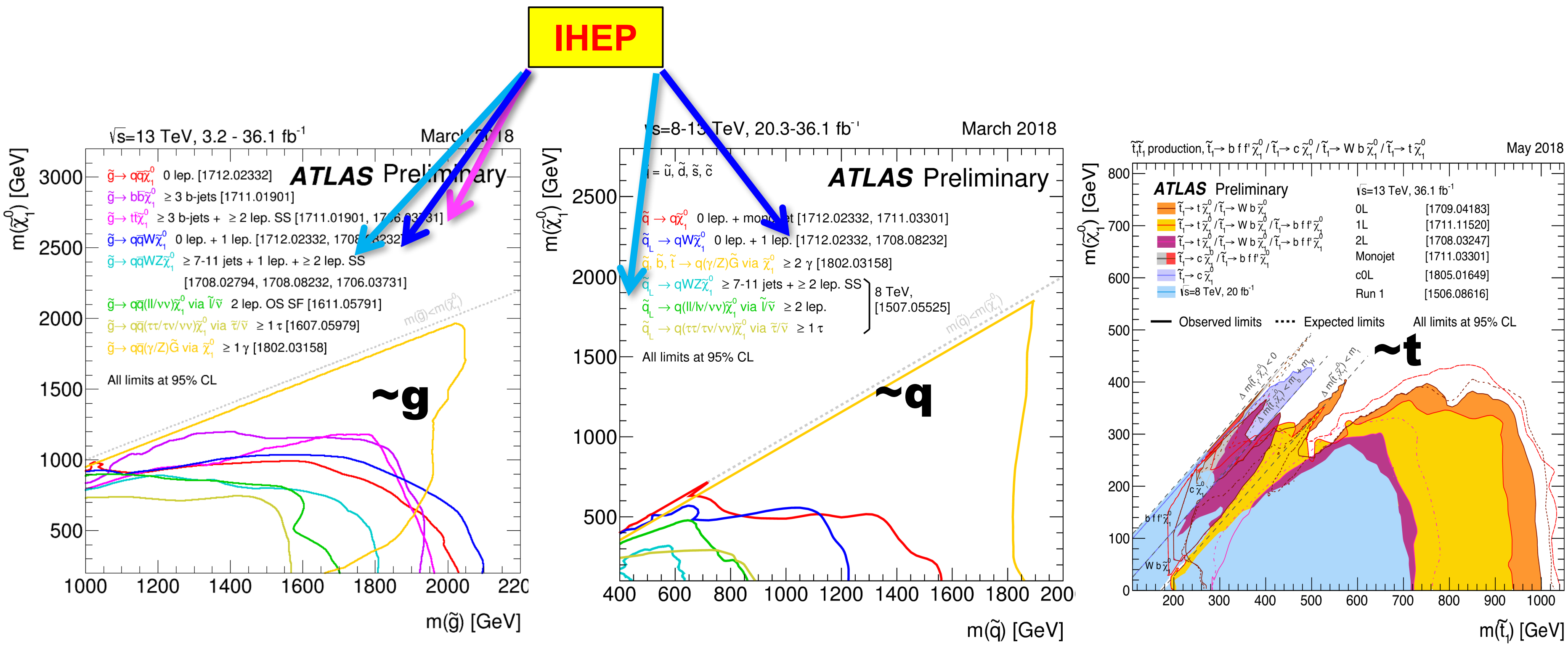
From Run1 to Run2 (8→13 TeV, lumi 20 → 36 fb^{-1}): stop mass exclusion extend ~300 GeV

Strong Production *(summary)*

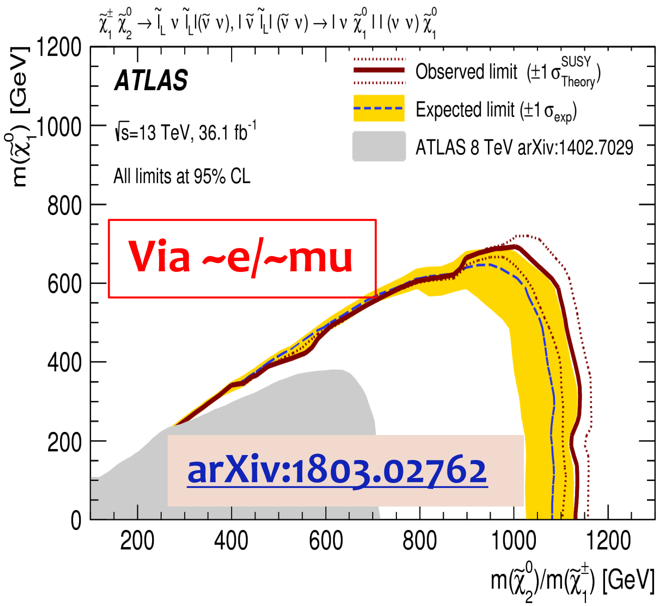
In **simplified model approach** (depending on decay mode and/or mass splittings):

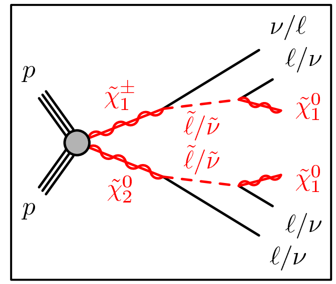
- M(~g) < O (1 TeV) – O (2 TeV) @95% CL
- M(~q) < O (0.5 TeV) – O (1.5 TeV) @95% CL
- M(~t) < O (0.7 TeV) – O (1.1 TeV) @95% CL

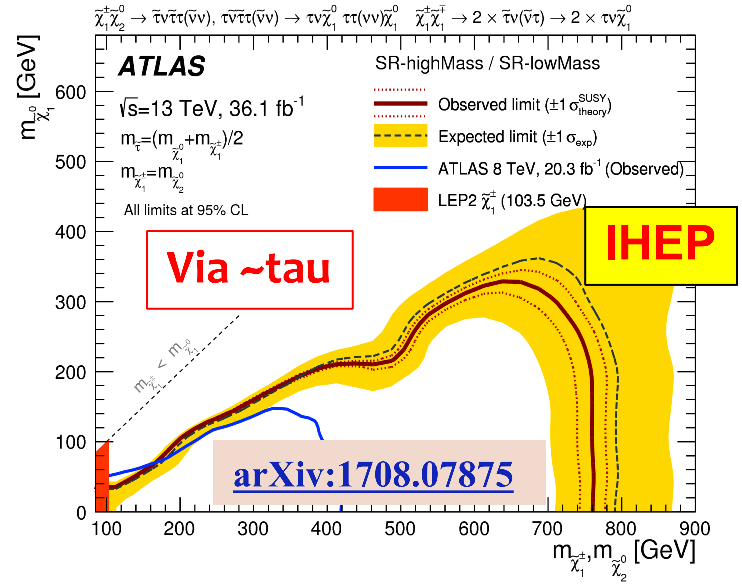
Can be even worse in some corners of simplified model space

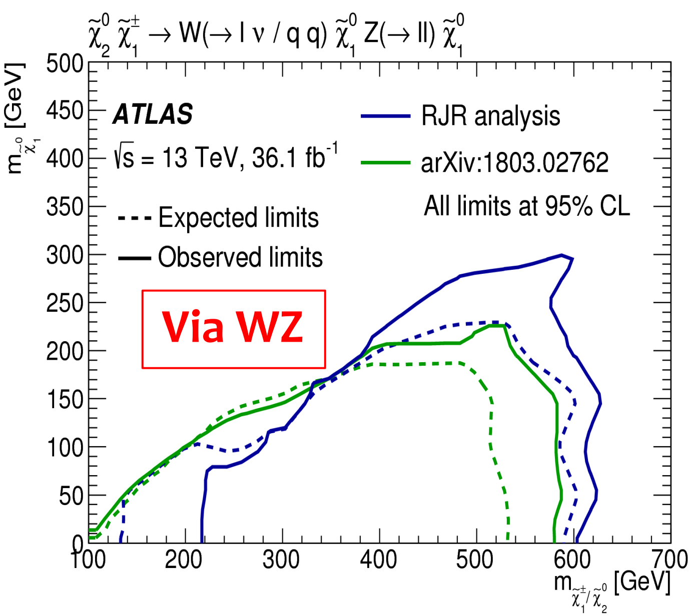


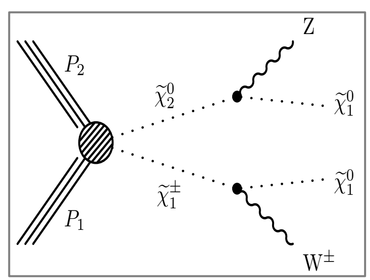
Gaugino pair production (2l/3l)











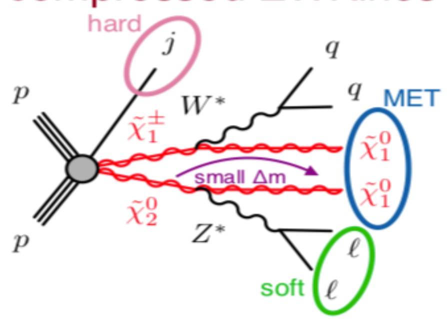
arXiv:1806.02293

- RJR (Recursive Jigsaw Reconstruction): reconstruction of intermediate rest-frames
- **~ 3s excesses seen in the SRs targeting low mass-splitting for RJR analysis**
- **Not seen in the conventional search targeting the same signal model**

[PRD97(2018)052010](PRD97(2018)052010)

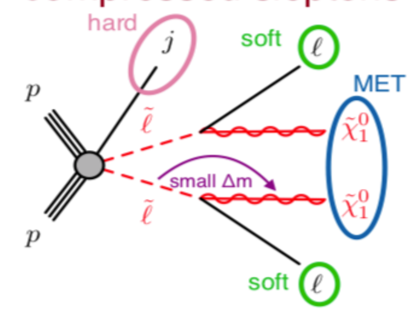
Compressed scenarios with soft leptons

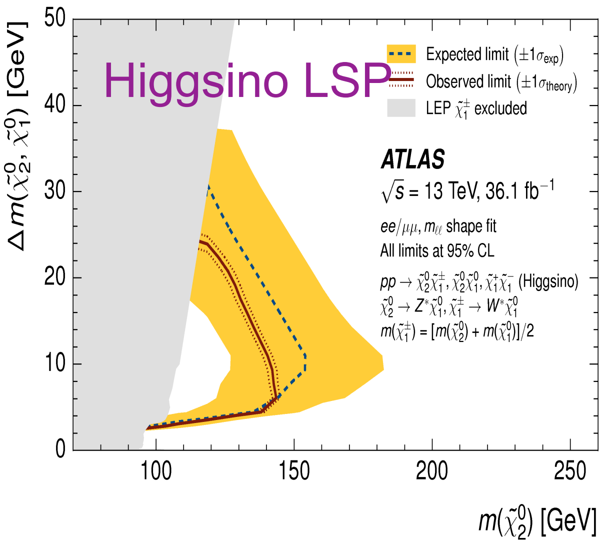
compressed EWKinos

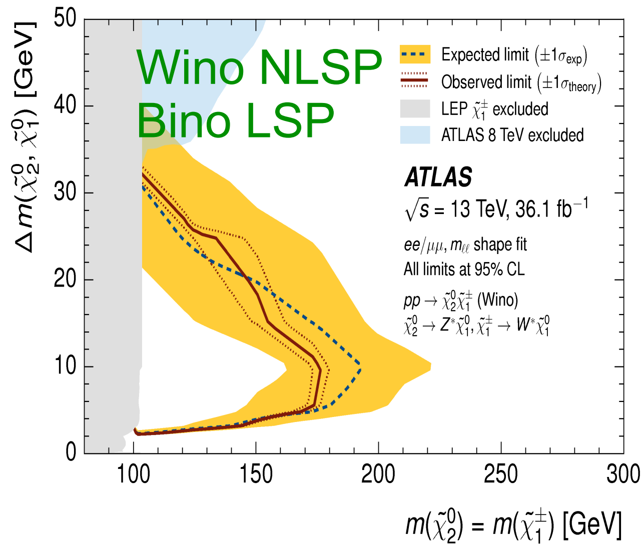


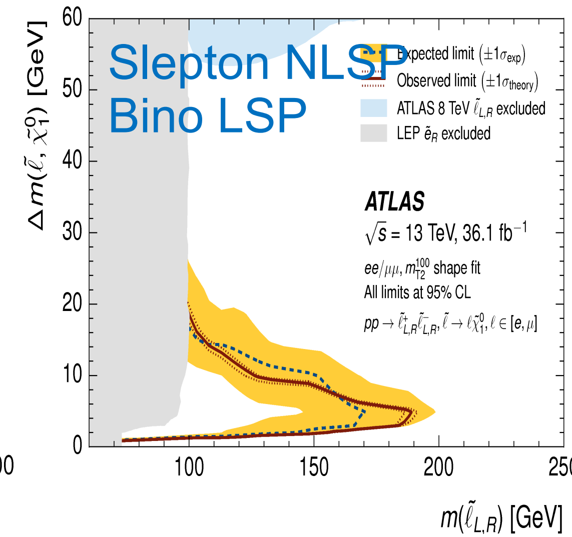
- Soft leptons pt: 4-5 GeV
- ISR jet to get the system boosted (met trigger)
- ***First direct limits on Higgsino since LEP! (also from CMS: [SUS-16-048](SUS-16-048))***

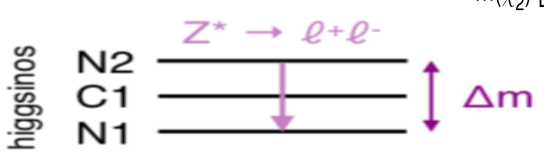
compressed sleptons

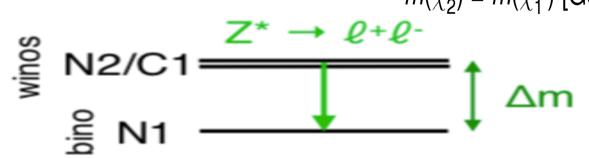








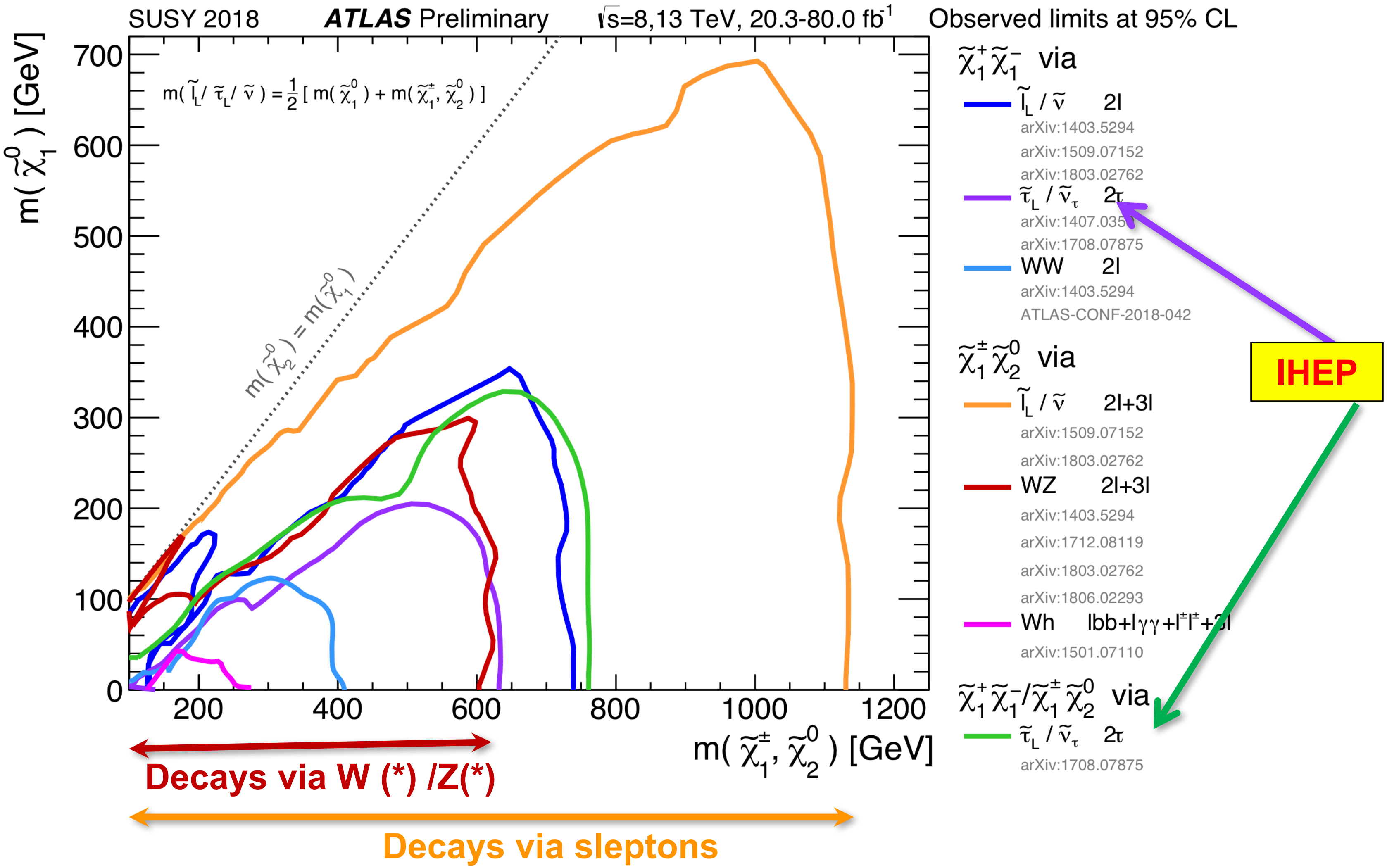




Δm as low as 3 GeV | Δm as low as 2.5 GeV | Δm as low as 1 GeV

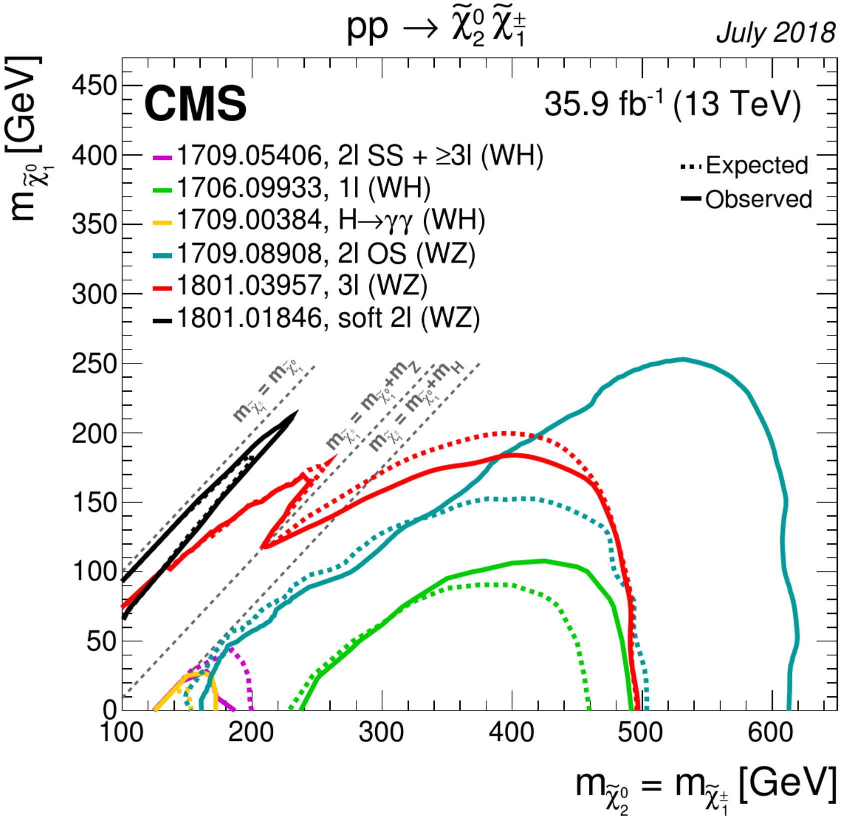
EWKino upto 145 GeV | EWKino upto 180 GeV | Slepton upto 190 GeV

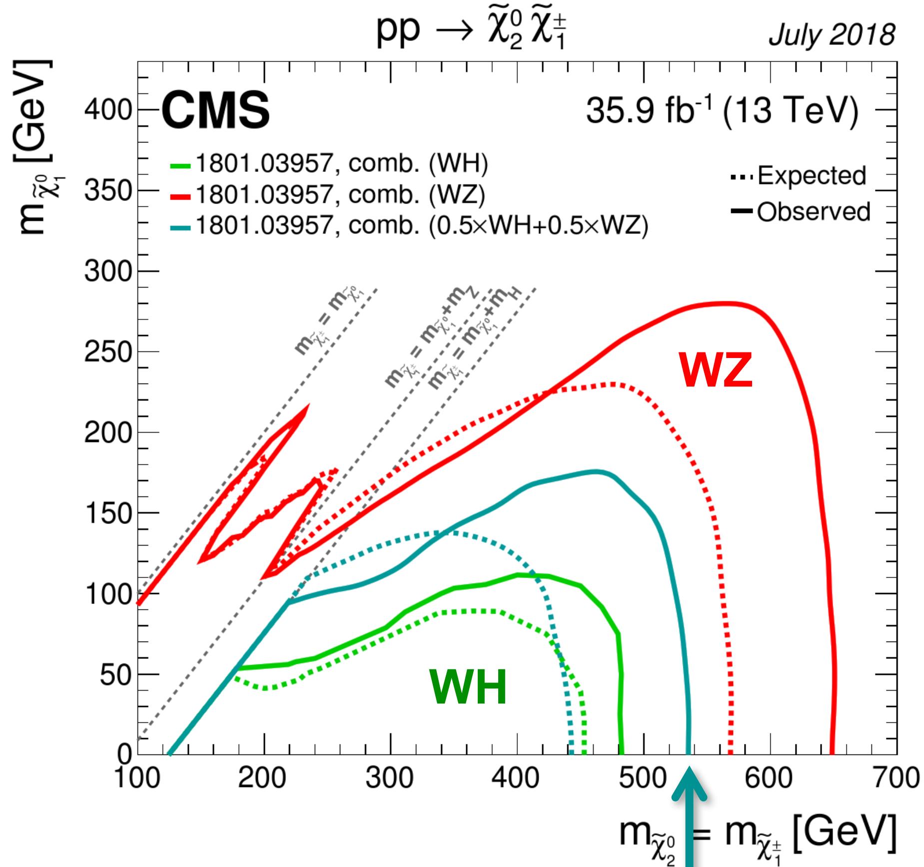
Summary: gaugino production



- ❑ **Powerful exclusions in decays via sleptons (C1/N2 up to 0.6-1.1 TeV)**
- ❑ **Exclusions is not so large in decays via bosons (up to 250-600 GeV)**

C1N2 Production (via boson) combination



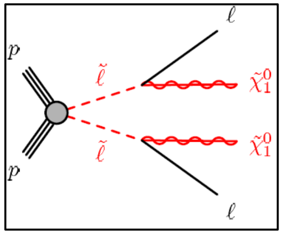


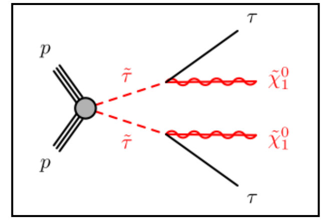
IHEP is working on Wh (1lττ, 1lbb, SS) analysis.

50% BR of WH and WZ

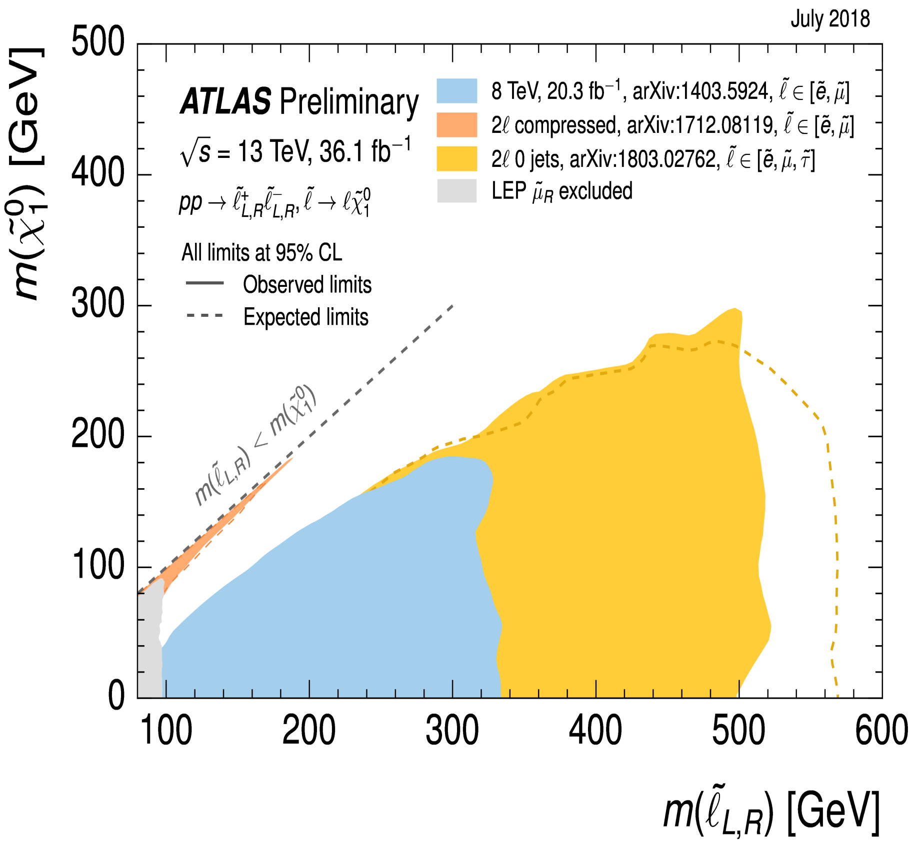
- ❑ Statistical combination of all CMS analyses targeting direct decays of neutralino/chargino pairs to SM bosons. 6 main publications of CMS
- ❑ Setting even higher limits in the electroweak SUSY energy scale

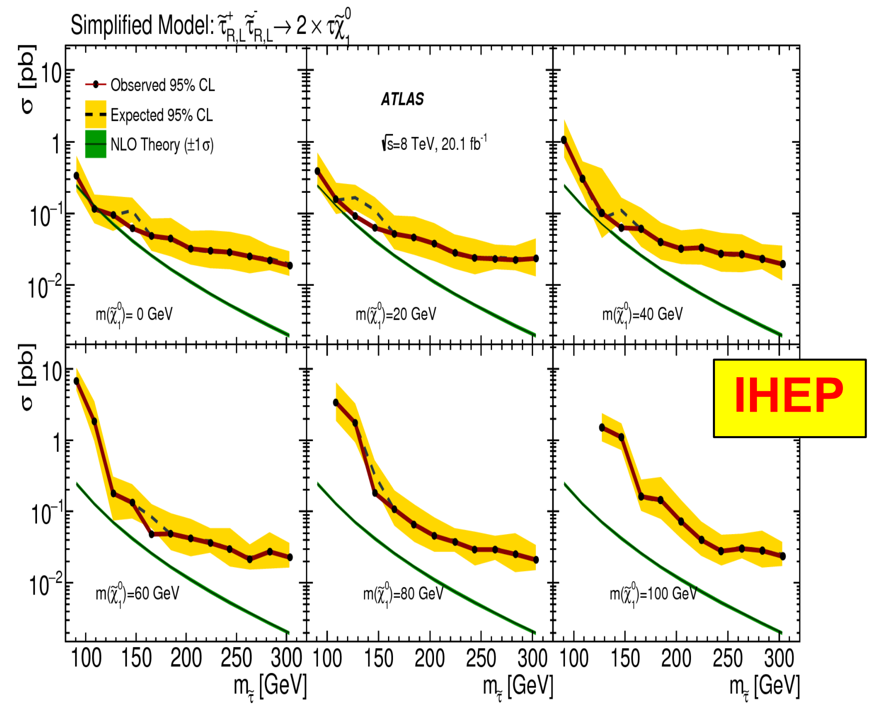
Summary: Slepton Production





Staus are challenging and are interesting NLSP for DM coannihilation

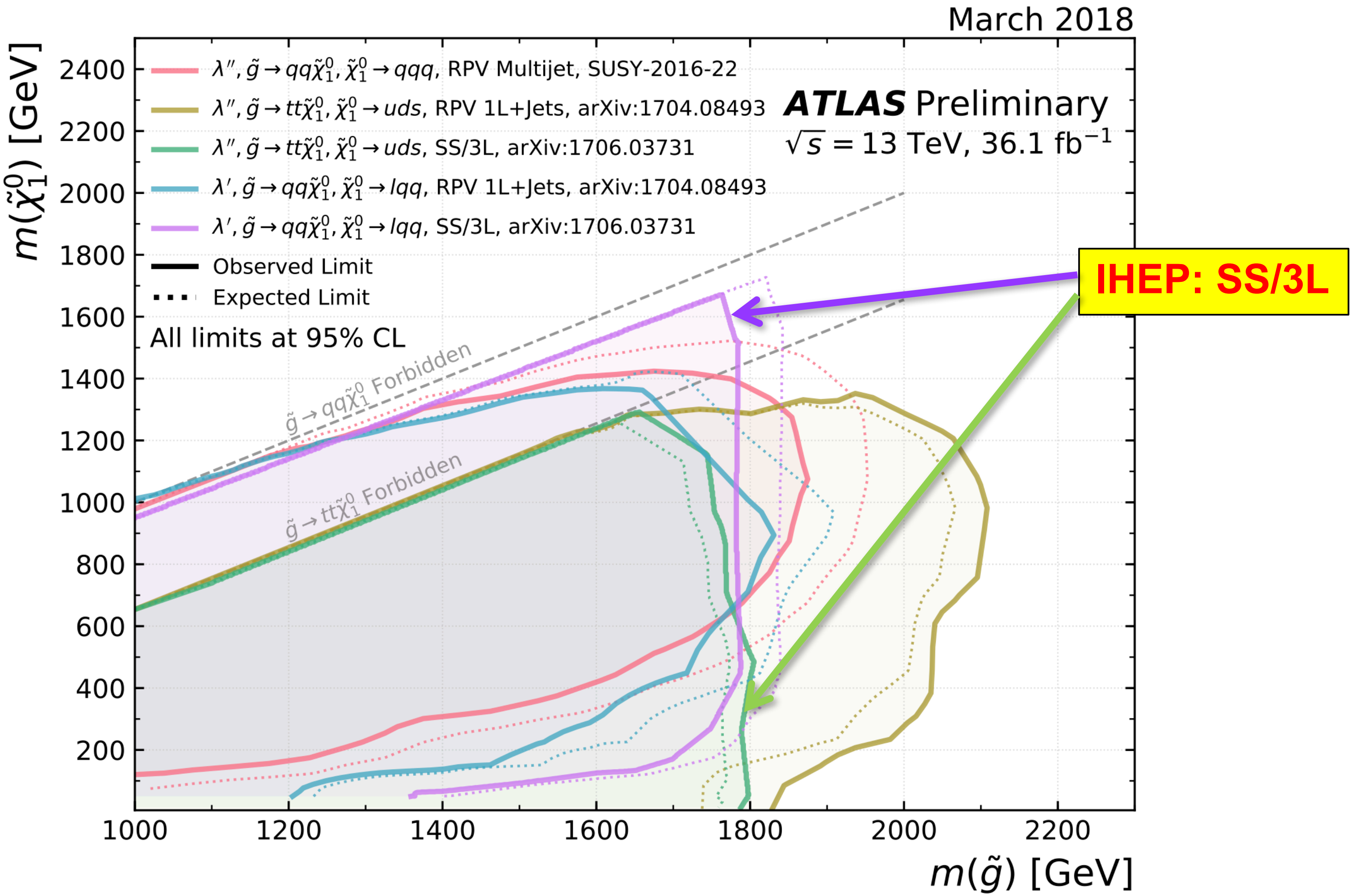




Phys. Rev. D 93, 052002 (2016)

- **Mass limit on selectron/smuon up to 500 GeV, not yet on staus**

RPV search


March 2018
$\lambda'', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to qqq$, RPV Multijet, SUSY-2016-22
$\lambda'', \tilde{g} \to tt\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to uds$, RPV 1L+Jets, arXiv:1704.08493
$\lambda'', \tilde{g} \to tt\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to uds$, SS/3L, arXiv:1706.03731
$\lambda', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to lqq$, RPV 1L+Jets, arXiv:1704.08493
$\lambda', \tilde{g} \to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0 \to lqq$, SS/3L, arXiv:1706.03731
Observed Limit
Expected Limit
All limits at 95% CL
ATLAS Preliminary
$\sqrt{s} = 13$ TeV, 36.1 fb^{-1}
$\tilde{g} \to qq\tilde{\chi}_1^0$ Forbidden
$\tilde{g} \to tt\tilde{\chi}_1^0$ Forbidden
IHEP: SS/3L
$m(\tilde{\chi}_1^0)$ [GeV]
$m(\tilde{g})$ [GeV]
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1000
1200
1400
1600
1800
2000
2200

ATLAS SUSY Searches* - 95% CL Lower Limits

July 2018

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV

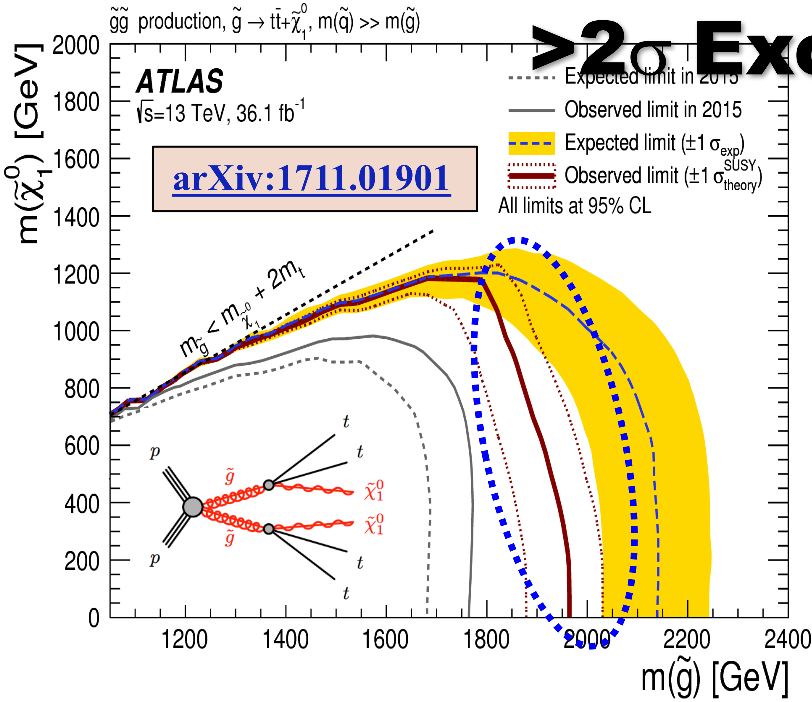
$\sqrt{s}$ = 7, 8 TeV | $\sqrt{s}$ = 13 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int \mathcal{L}\,dt[fb^{-1}]$	Mass limit [TeV]	Conditions	Reference
Inclusive Searches	$\tilde q\tilde q$, $\tilde q \to q\tilde\chi^0_1$	0	2-6 jets	Yes	36.1	$\tilde q$ [2×, 8× Degen.] 0.9, 1.55	m($\tilde\chi^0_1$)<100 GeV	1712.02332
		mono-jet	1-3 jets	Yes	36.1	$\tilde q$ [1×, 8× Degen.] 0.43, 0.71	m($\tilde q$)-m($\tilde\chi^0_1$)=5 GeV	1711.03301
	$\tilde g\tilde g$, $\tilde g \to q\bar q\tilde\chi^0_1$	0	2-6 jets	Yes	36.1	$\tilde g$ 2.0	m($\tilde\chi^0_1$)<200 GeV	1712.02332
						$\tilde g$ Forbidden 0.95-1.6	m($\tilde\chi^0_1$)=900 GeV	1712.02332
	$\tilde g\tilde g$, $\tilde g \to q\bar q(\ell\ell)\tilde\chi^0_1$	3 e,μ	4 jets	-	36.1	$\tilde g$ 1.85	m($\tilde\chi^0_1$)<800 GeV	1706.03731
		$ee,\mu\mu$	2 jets	Yes	36.1	$\tilde g$ 1.2	m($\tilde g$)-m($\tilde\chi^0_1$)=50 GeV	1805.11381
	$\tilde g\tilde g$, $\tilde g \to qqWZ\tilde\chi^0_1$	0	7-11 jets	Yes	36.1	$\tilde g$ 1.8	m($\tilde\chi^0_1$) <400 GeV	1708.02794
		3 e,μ	4 jets	-	36.1	$\tilde g$ 0.98	m($\tilde g$)-m($\tilde\chi^0_1$)=200 GeV	1706.03731
	$\tilde g\tilde g$, $\tilde g \to t\bar t\tilde\chi^0_1$	0-1 e,μ	3 b	Yes	36.1	$\tilde g$ 2.0	m($\tilde\chi^0_1$)<200 GeV	1711.01901
		3 e,μ	4 jets	-	36.1	$\tilde g$ 1.25	m($\tilde g$)-m($\tilde\chi^0_1$)=300 GeV	1706.03731
3^{rd} gen. squarks direct production	$\tilde b_1\tilde b_1$, $\tilde b_1 \to b\tilde\chi^0_1/t\tilde\chi^\pm_1$		Multiple		36.1	$\tilde b_1$ Forbidden 0.9	m($\tilde\chi^0_1$)=300 GeV, BR($b\tilde\chi^0_1$)=1	1708.09266, 1711.03301
			Multiple		36.1	$\tilde b_1$ Forbidden 0.58-0.82	m($\tilde\chi^0_1$)=300 GeV, BR($b\tilde\chi^0_1$)=BR($t\tilde\chi^\pm_1$)=0.5	1708.09266
			Multiple		36.1	$\tilde b_1$ Forbidden 0.7	m($\tilde\chi^0_1$)=200 GeV, m($\tilde\chi^\pm_1$)=300 GeV, BR($t\tilde\chi^\pm_1$)=1	1706.03731
	$\tilde b_1\tilde b_1$, $\tilde t_1\tilde t_1$, $M_2 = 2\times M_1$		Multiple		36.1	$\tilde t_1$ 0.7	m($\tilde\chi^0_1$)=60 GeV	1709.04183, 1711.11520, 1708.03247
			Multiple		36.1	$\tilde t_1$ Forbidden 0.9	m($\tilde\chi^0_1$)=200 GeV	1709.04183, 1711.11520, 1708.03247
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to Wb\tilde\chi^0_1$ or $t\tilde\chi^0_1$	0-2 e,μ	0-2 jets/1-2 b	Yes	36.1	$\tilde t_1$ 1.0	m($\tilde\chi^0_1$)=1 GeV	1506.08616, 1709.04183, 1711.11520
	$\tilde t_1\tilde t_1$, $\tilde H$ LSP		Multiple		36.1	$\tilde t_1$ 0.4-0.9	m($\tilde\chi^0_1$)=150 GeV, m($\tilde\chi^\pm_1$)-m($\tilde\chi^0_1$)=5 GeV, $\tilde t_1 \approx \tilde t_L$	1709.04183, 1711.11520
			Multiple		36.1	$\tilde t_1$ Forbidden 0.6-0.8	m($\tilde\chi^0_1$)=300 GeV, m($\tilde\chi^\pm_1$)-m($\tilde\chi^0_1$)=5 GeV, $\tilde t_1 \approx \tilde t_L$	1709.04183, 1711.11520
	$\tilde t_1\tilde t_1$, Well-Tempered LSP		Multiple		36.1	$\tilde t_1$ 0.48-0.84	m($\tilde\chi^0_1$)=150 GeV, m($\tilde\chi^\pm_1$)-m($\tilde\chi^0_1$)=5 GeV, $\tilde t_1 \approx \tilde t_L$	1709.04183, 1711.11520
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to c\tilde\chi^0_1$ / $\tilde c\tilde c$, $\tilde c \to c\tilde\chi^0_1$	0	2c	Yes	36.1	$\tilde t_1$ 0.85	m($\tilde\chi^0_1$)=0 GeV	1805.01649
						$\tilde t_1$ 0.46	m($\tilde t_1$,$\tilde c$)-m($\tilde\chi^0_1$)=50 GeV	1805.01649
		0	mono-jet	Yes	36.1	$\tilde t_1$ 0.43	m($\tilde t_1$,$\tilde c$)-m($\tilde\chi^0_1$)=5 GeV	1711.03301
	$\tilde t_2\tilde t_2$, $\tilde t_2 \to \tilde t_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde t_2$ 0.32-0.88	m($\tilde\chi^0_1$)=0 GeV, m($\tilde t_1$)-m($\tilde\chi^0_1$)= 180 GeV	1706.03986
EW direct	$\tilde\chi^\pm_1\tilde\chi^0_2$ via WZ	2-3 e,μ	-	Yes	36.1	$\tilde\chi^\pm_1/\tilde\chi^0_2$ 0.6	m($\tilde\chi^0_1$)=0	1403.5294, 1806.02293
		$ee,\mu\mu$	≥ 1	Yes	36.1	$\tilde\chi^\pm_1/\tilde\chi^0_2$ 0.17	m($\tilde\chi^\pm_1$)-m($\tilde\chi^0_1$)=10 GeV	1712.08119
	$\tilde\chi^\pm_1\tilde\chi^0_2$ via Wh	$\ell\ell/\ell\gamma\gamma/\ell bb$	-	Yes	20.3	$\tilde\chi^\pm_1/\tilde\chi^0_2$ 0.26	m($\tilde\chi^0_1$)=0	1501.07110
	$\tilde\chi^\pm_1\tilde\chi^\mp_1/\tilde\chi^0_2$, $\tilde\chi^+_1 \to \tilde\tau\nu(\tau\tilde\nu)$, $\tilde\chi^0_2 \to \tilde\tau\tau(\nu\tilde\nu)$	2 τ	-	Yes	36.1	$\tilde\chi^\pm_1/\tilde\chi^0_2$ 0.76	m($\tilde\chi^0_1$)=0, m($\tilde\tau,\tilde\nu$)=0.5(m($\tilde\chi^\pm_1$)+m($\tilde\chi^0_1$))	1708.07875
						$\tilde\chi^\pm_1/\tilde\chi^0_2$ 0.22	m($\tilde\chi^\pm_1$)-m($\tilde\chi^0_1$)=100 GeV, m($\tilde\tau,\tilde\nu$)=0.5(m($\tilde\chi^\pm_1$)+m($\tilde\chi^0_1$))	1708.07875
	$\tilde\ell_{L,R}\tilde\ell_{L,R}$, $\tilde\ell \to \ell\tilde\chi^0_1$	2 e,μ	0	Yes	36.1	$\tilde\ell$ 0.5	m($\tilde\chi^0_1$)=0	1803.02762
		2 e,μ	≥ 1	Yes	36.1	$\tilde\ell$ 0.18	m($\tilde\ell$)-m($\tilde\chi^0_1$)=5 GeV	1712.08119
	$\tilde H\tilde H$, $\tilde H \to h\tilde G/Z\tilde G$	0	$\geq 3b$	Yes	36.1	$\tilde H$ 0.13-0.23, 0.29-0.88	BR($\tilde\chi^0_1 \to h\tilde G$)=1	1806.04030
		4 e,μ	0	Yes	36.1	$\tilde H$ 0.3	BR($\tilde\chi^0_1 \to Z\tilde G$)=1	1804.03602
Long-lived particles	Direct $\tilde\chi^+_1\tilde\chi^-_1$ prod., long-lived $\tilde\chi^\pm_1$	Disapp. trk	1 jet	Yes	36.1	$\tilde\chi^\pm_1$ 0.46	Pure Wino	1712.02118
						$\tilde\chi^\pm_1$ 0.15	Pure Higgsino	ATL-PHYS-PUB-2017-019
	Stable $\tilde g$ R-hadron	SMP	-	-	3.2	$\tilde g$ 1.6		1606.05129
	Metastable $\tilde g$ R-hadron, $\tilde g \to qq\tilde\chi^0_1$		Multiple		32.8	$\tilde g$ [$\tau(\tilde g)$ =100 ns, 0.2 ns] 1.6, 2.4	m($\tilde\chi^0_1$)=100 GeV	1710.04901, 1604.04520
	GMSB, $\tilde\chi^0_1 \to \gamma\tilde G$, long-lived $\tilde\chi^0_1$	2 γ	-	Yes	20.3	$\tilde\chi^0_1$ 0.44	1<$\tau(\tilde\chi^0_1)$<3 ns, SPS8 model	1409.5542
	$\tilde g\tilde g$, $\tilde\chi^0_1 \to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde g$ 1.3	6 <$c\tau(\tilde\chi^0_1)$< 1000 mm, m($\tilde\chi^0_1$)=1 TeV	1504.05162
RPV	LFV $pp \to \tilde\nu_\tau + X$, $\tilde\nu_\tau \to e\mu/e\tau/\mu\tau$	$e\mu$,$e\tau$,$\mu\tau$	-	-	3.2	$\tilde\nu_\tau$ 1.9	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	$\tilde\chi^\pm_1\tilde\chi^\mp_1/\tilde\chi^0_2 \to WW/Z\ell\ell\ell\ell\nu\nu$	4 e,μ	0	Yes	36.1	$\tilde\chi^\pm_1/\tilde\chi^0_2$ [$\lambda_{i33} \neq 0, \lambda_{12k} \neq 0$] 0.82, 1.33	m($\tilde\chi^0_1$)=100 GeV	1804.03602
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi^0_1$, $\tilde\chi^0_1 \to qqq$	0	4-5 large-R jets	-	36.1	$\tilde g$ [m($\tilde\chi^0_1$)=200 GeV, 1100 GeV] 1.3, 1.9	Large λ''_{112}	1804.03568
			Multiple		36.1	$\tilde g$ [λ''_{112}=2e-4, 2e-5] 1.05, 2.0	m($\tilde\chi^0_1$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde g\tilde g$, $\tilde g \to tbs$ / $\tilde g \to t\bar t\tilde\chi^0_1$, $\tilde\chi^0_1 \to tbs$		Multiple		36.1	$\tilde g$ [λ''_{323}=1, 1e-2] 1.8, 2.1	m($\tilde\chi^0_1$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde t\tilde t$, $\tilde t \to t\tilde\chi^0_1$, $\tilde\chi^0_1 \to tbs$		Multiple		36.1	$\tilde g$ [λ''_{323}=2e-4, 1e-2] 0.55, 1.05	m($\tilde\chi^0_1$)=200 GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to bs$	0	2 jets + 2 b	-	36.7	$\tilde t_1$ [qq, bs] 0.42, 0.61		1710.07171
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to b\ell$	2 e,μ	2 b	-	36.1	$\tilde t_1$ 0.4-1.45	BR($\tilde t_1 \to be/b\mu$)>20%	1710.05544

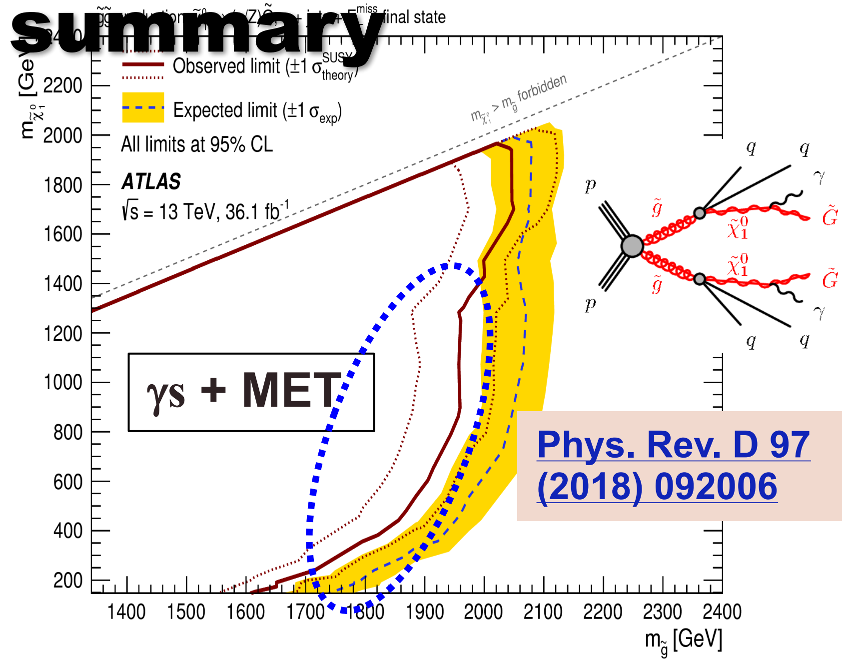
10^{-1} — 1 — **Mass scale [TeV]**

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

>2σ Excess summary



arXiv:1711.01901



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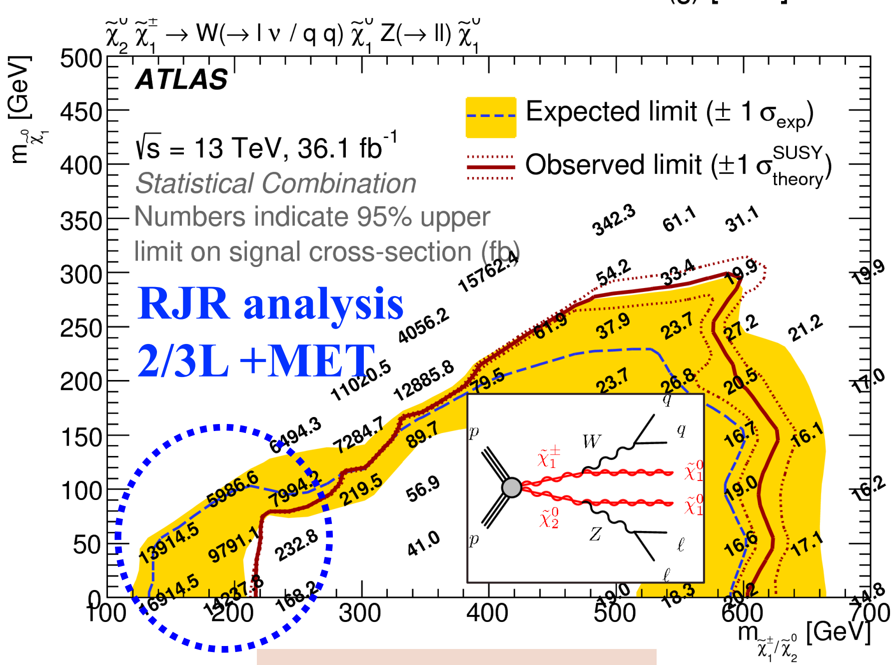

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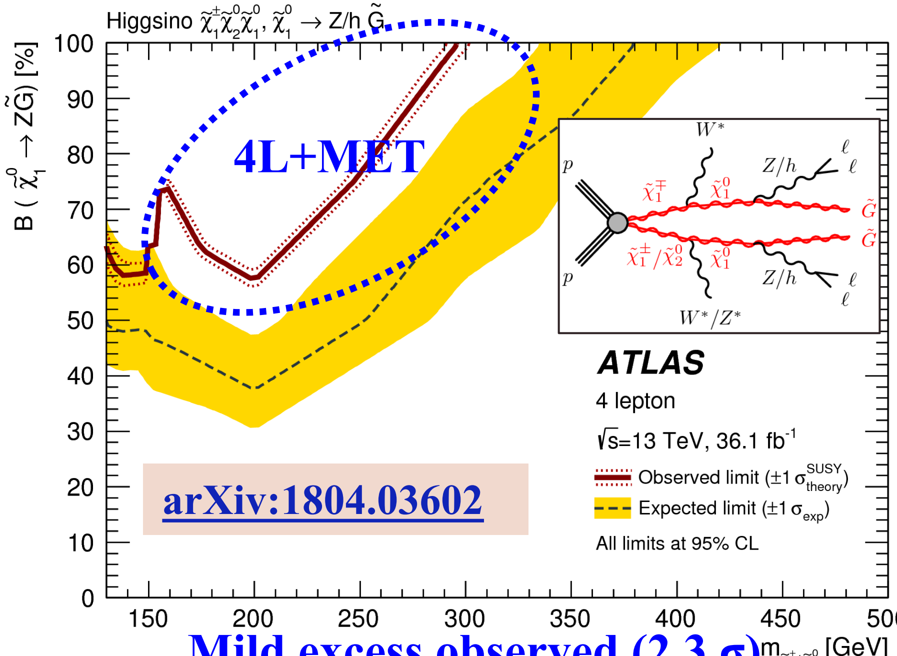
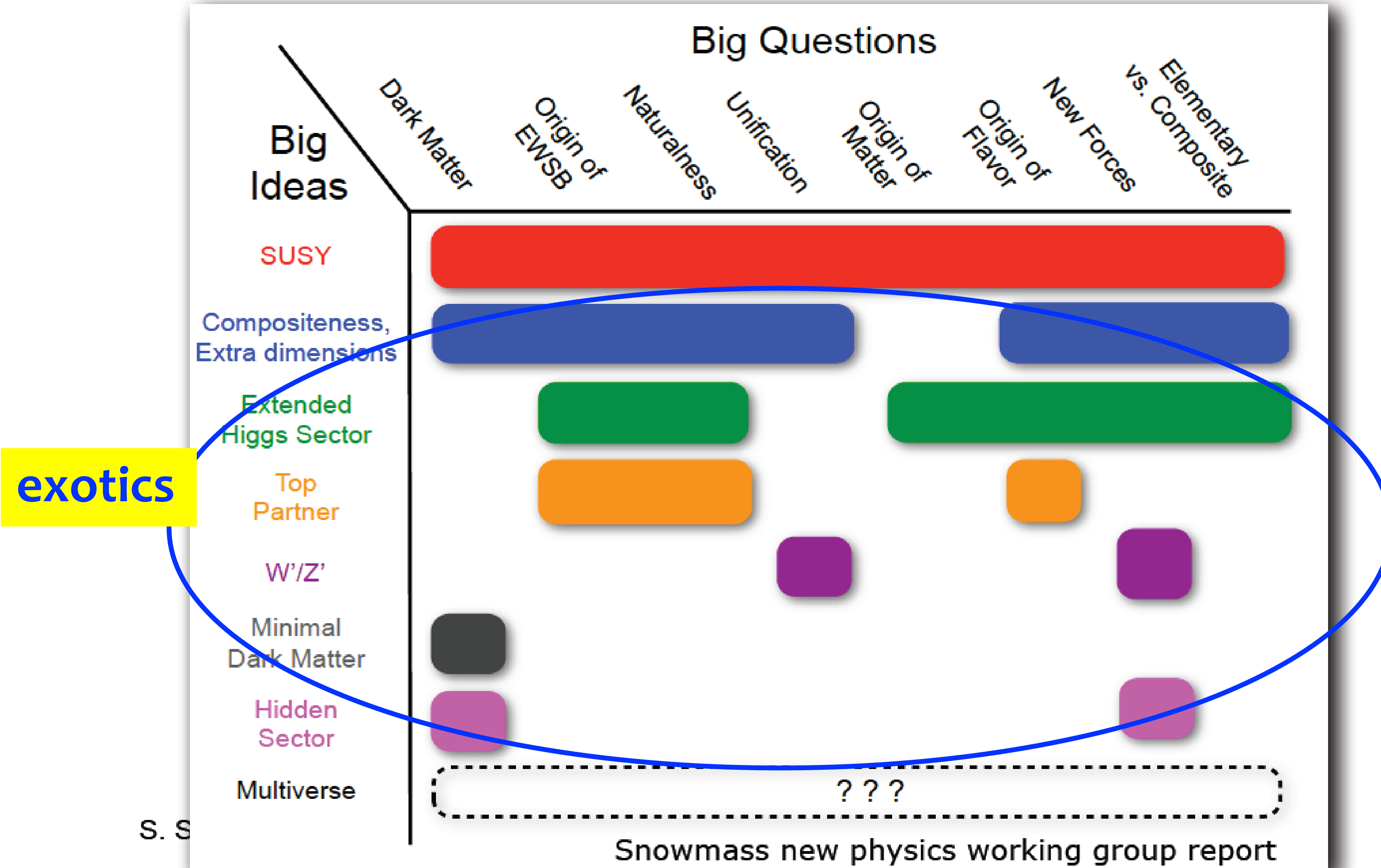


arXiv:1804.03602

Mild excess observed (2.3 σ) in 0 tau, on-shell Z

New Physics beyond the SM



S. S

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2018

ATLAS Preliminary

$\int \mathcal{L}\,dt = (3.2 - 79.8)\ \text{fb}^{-1}$ $\sqrt{s} = 8, 13$ TeV

Annotation	Category	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\,dt[\text{fb}^{-1}]$	Limit	Conditions	Reference
额外维粒子	Extra dimensions	ADD $G_{KK} + g/q$	0 e,μ	1 − 4 j	Yes	36.1	M_D 7.7 TeV	$n = 2$	1711.03301
		ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	1707.04147
		ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09217
		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	1606.02265
		ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
		RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	1707.04147
		Bulk RS $G_{KK} \to WW/ZZ$	multi-channel			36.1	G_{KK} mass 2.3 TeV	$k/\overline{M}_{Pl} = 1.0$	CERN-EP-2018-179
		Bulk RS $g_{KK} \to tt$	1 e,μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	g_{KK} mass 3.8 TeV	$\Gamma/m = 15\%$	1804.10823
		2UED / RPP	1 e,μ	≥ 2 b, ≥ 3 j	Yes	36.1	KK mass 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	1803.09678
W', Z'	Gauge bosons	SSM $Z' \to \ell\ell$	2 e,μ	–	–	36.1	Z' mass 4.5 TeV		1707.02424
		SSM $Z' \to \tau\tau$	2 τ	–	–	36.1	Z' mass 2.42 TeV		1709.07242
		Leptophobic $Z' \to bb$	–	2 b	–	36.1	Z' mass 2.1 TeV		1805.09299
		Leptophobic $Z' \to tt$	1 e,μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	Z' mass 3.0 TeV	$\Gamma/m = 1\%$	1804.10823
		SSM $W' \to \ell\nu$	1 e,μ	–	Yes	79.8	W' mass 5.6 TeV		ATLAS-CONF-2018-017
		SSM $W' \to \tau\nu$	1 τ	–	Yes	36.1	W' mass 3.7 TeV		1801.06992
		HVT $V' \to WV \to qqqq$ model B	0 e,μ	2 J	–	79.8	V' mass 4.15 TeV	$g_V = 3$	ATLAS-CONF-2018-016
		HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	1712.06518
		LRSM $W'_R \to tb$	multi-channel			36.1	W' mass 3.25 TeV		CERN-EP-2018-142
Contact interactions	CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV	η^-_{LL}	1703.09217
		CI $\ell\ell qq$	2 e,μ	–	–	36.1	Λ 40.0 TeV	η^-_{LL}	1707.02424
		CI $tttt$	≥1 e,μ	≥1 b, ≥1 j	Yes	36.1	Λ 2.57 TeV	$\lvert C_{4t}\rvert = 4\pi$	CERN-EP-2018-174
Dark matter	DM	Axial-vector mediator (Dirac DM)	0 e,μ	1 − 4 j	Yes	36.1	m_{med} 1.55 TeV	g_q=0.25, g_χ=1.0, $m(\chi) = 1$ GeV	1711.03301
		Colored scalar mediator (Dirac DM)	0 e,μ	1 − 4 j	Yes	36.1	m_{med} 1.67 TeV	g=1.0, $m(\chi) = 1$ GeV	1711.03301
		$VV\chi\chi$ EFT (Dirac DM)	0 e,μ	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
leptoquark	LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
		Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
		Scalar LQ 3rd gen	1 e,μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	Heavy quarks	VLQ $TT \to Ht/Zt/Wb + X$	multi-channel			36.1	T mass 1.37 TeV	SU(2) doublet	ATLAS-CONF-2018-XXX
		VLQ $BB \to Wt/Zb + X$	multi-channel			36.1	B mass 1.34 TeV	SU(2) doublet	ATLAS-CONF-2018-XXX
		VLQ $T_{5/3}T_{5/3} \lvert T_{5/3} \to Wt + X$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	36.1	$T_{5/3}$ mass 1.64 TeV	$\mathcal{B}(T_{5/3} \to Wt)$= 1, $c(T_{5/3}Wt)$= 1	CERN-EP-2018-171
		VLQ $Y \to Wb + X$	1 e,μ	≥ 1 b, ≥ 1j	Yes	3.2	Y mass 1.44 TeV	$\mathcal{B}(Y \to Wb)$= 1, $c(YWb)$= 1/ $\sqrt{2}$	ATLAS-CONF-2016-072
		VLQ $B \to Hb + X$	0 e,μ, 2 γ	≥ 1 b, ≥ 1j	Yes	79.8	B mass 1.21 TeV	κ_B= 0.5	ATLAS-CONF-2018-XXX
		VLQ $QQ \to WqWq$	1 e,μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
重费米子	Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	37.0	q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
		Excited quark $q^* \to q\gamma$	1 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1709.10440
		Excited quark $b^* \to bg$	–	1 b, 1 j	–	36.1	b^* mass 2.6 TeV		1805.09299
		Excited lepton ℓ^*	3 e,μ	–	–	20.3	ℓ^* mass 3.0 TeV	Λ = 3.0 TeV	1411.2921
		Excited lepton ν^*	3 e,μ,τ	–	–	20.3	ν^* mass 1.6 TeV	Λ = 1.6 TeV	1411.2921
其他	Other	Type III Seesaw	1 e,μ	≥ 2 j	Yes	79.8	N^0 mass 560 GeV		ATLAS-CONF-2018-020
		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 $H^{\pm\pm} \to \ell\ell$	2,3,4 e,μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	1710.09748
		Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e,μ,τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H^{\pm\pm}_L \to \ell\tau) = 1$	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, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

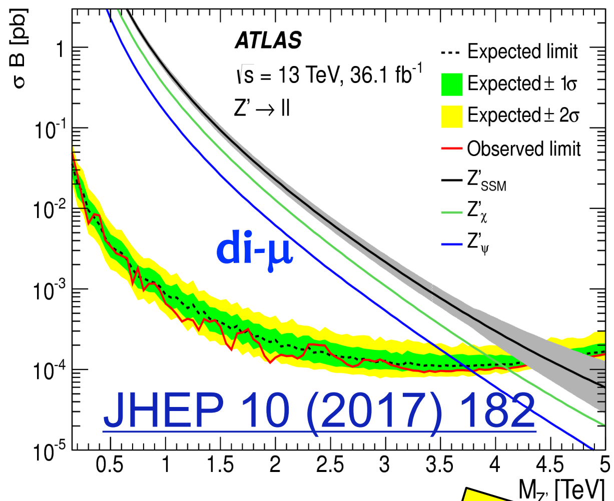
$\sqrt{s}$ = 8 TeV $\sqrt{s}$ = 13 TeV

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

*Only a selection of the available mass limits on new states or phenomena is shown.

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

Resonance (di-X: X=lep, jet, photon, boson etc.)



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E6-motivated Z' mo

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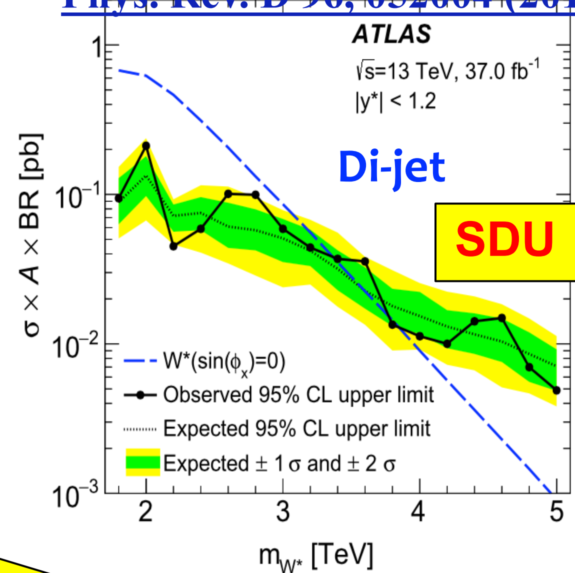

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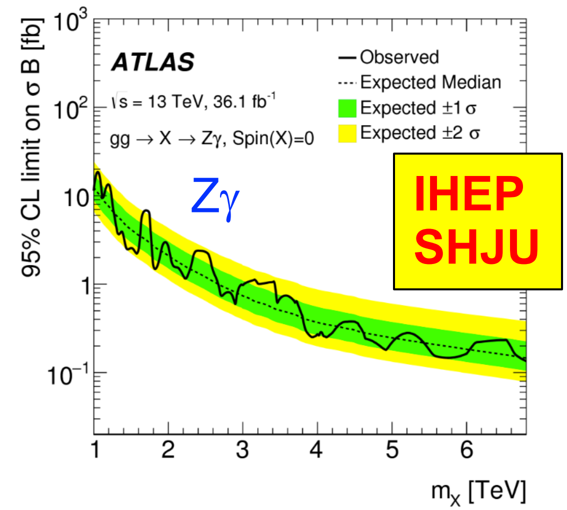
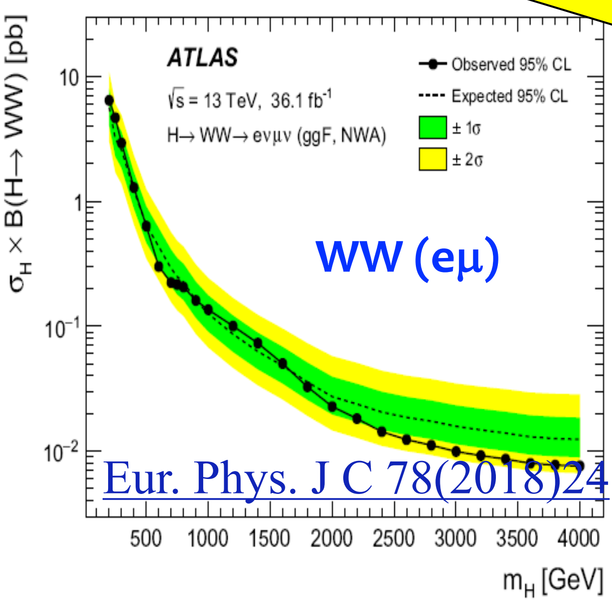


USTC



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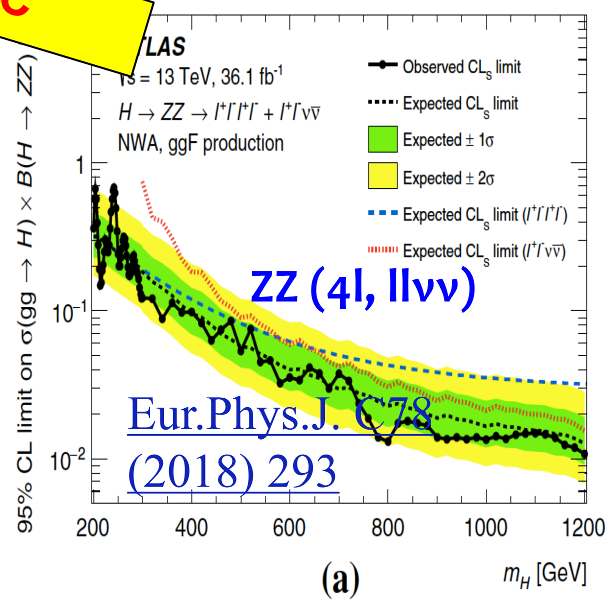

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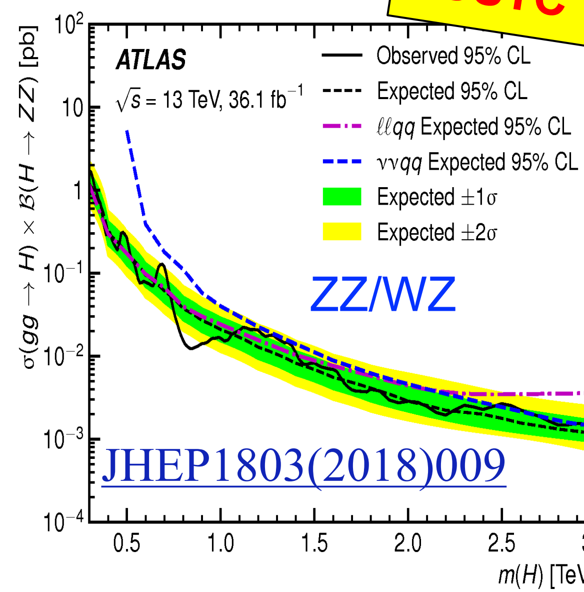
USTC



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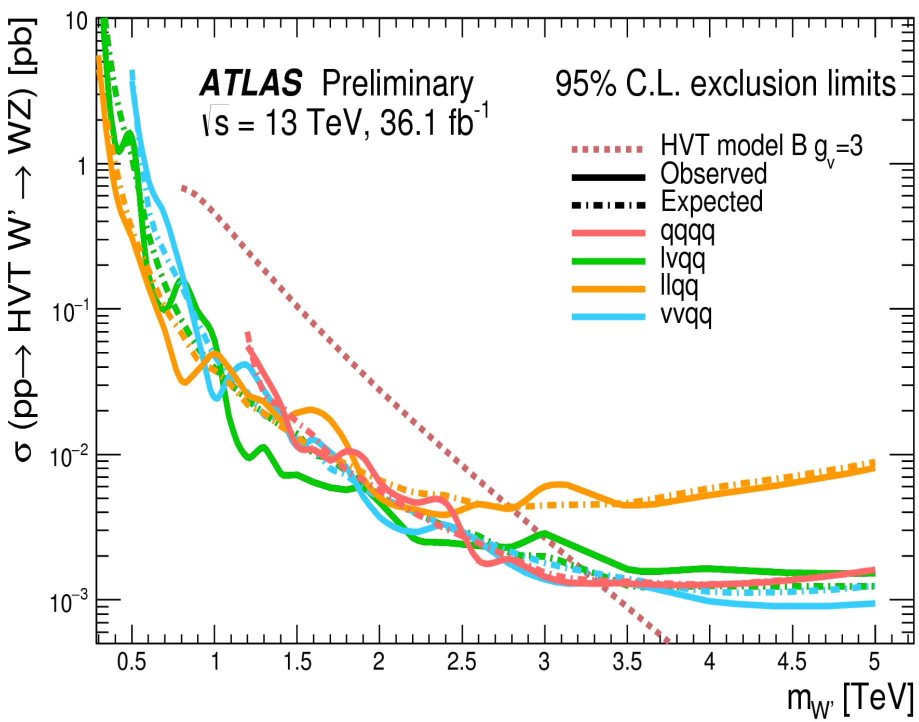
Resonance search (W', Z')

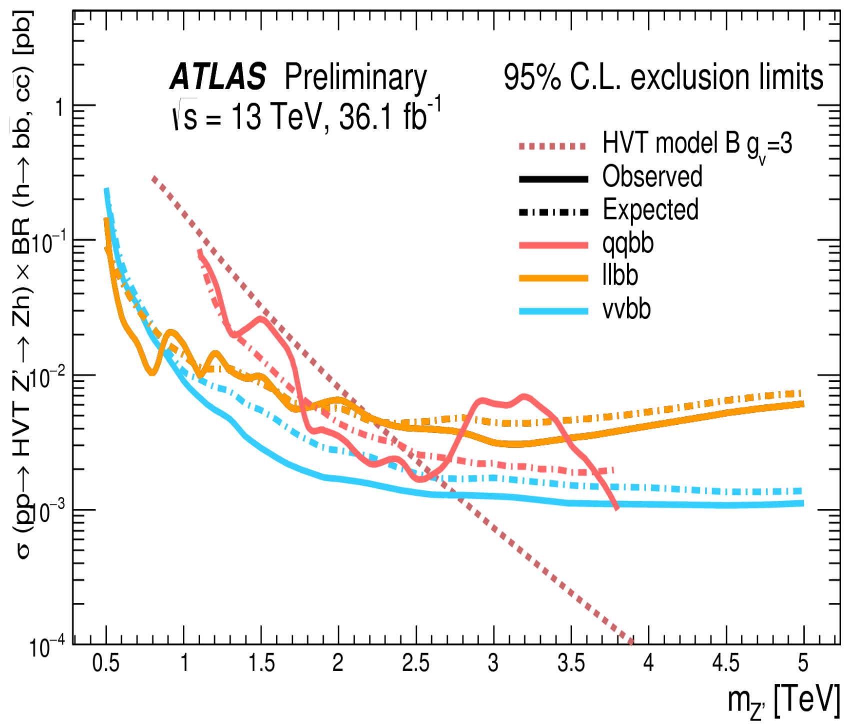
W' →WZ



CERN-EP-2017-147 (qqqq), ATLAS-CONF-2017-051 (ℓν qq), CERN-EP-2017-146 (νν qq, ℓℓ qq).

W' > 2.8-3.3 TeV

Z' →Zh

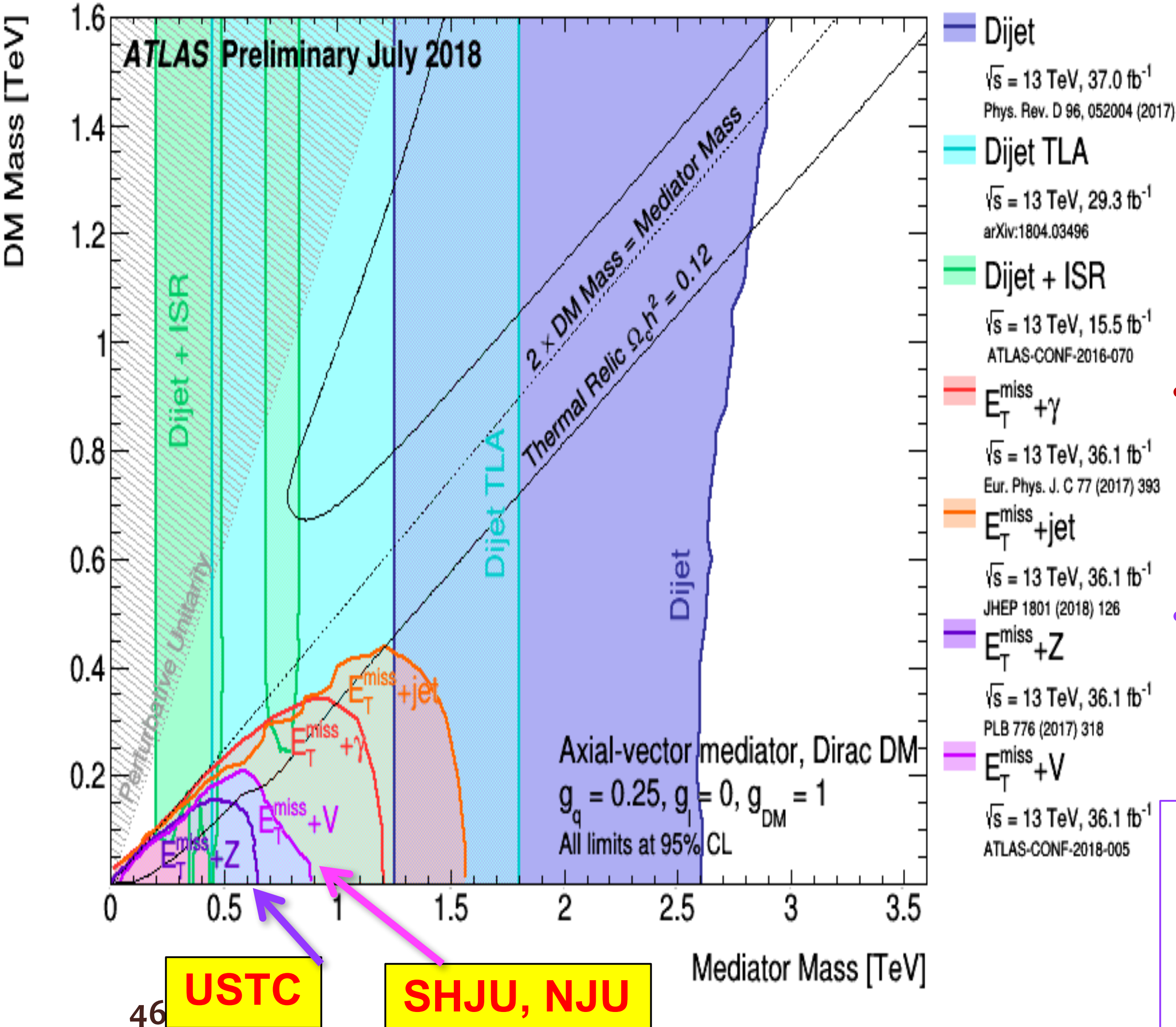


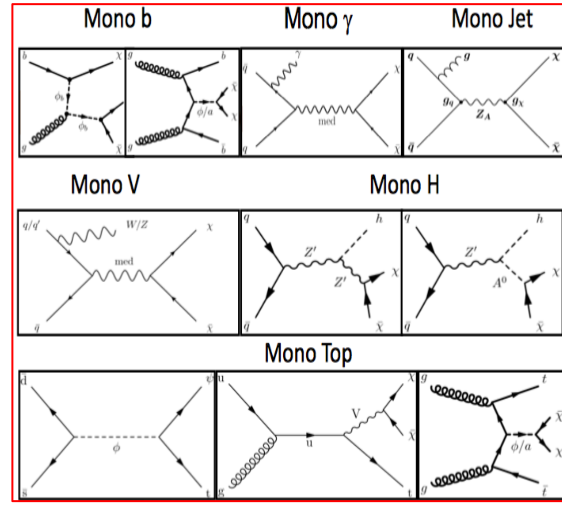
CERN-EP-2017-111 (qqbb), ATLAS-CONF-2017-055 (ℓℓ bb, νν bb)

Z' > 2.2-2.7 TeV

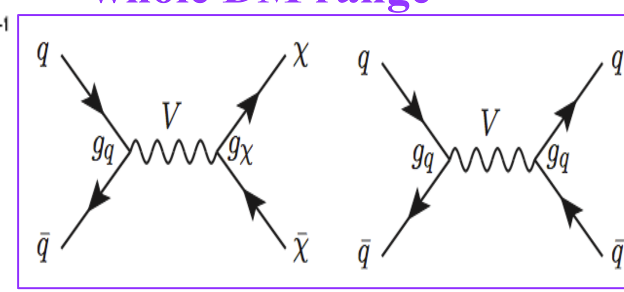
Dark Matter

Searches with MET+X or mediator





- **Searches in the Mono-X final states: Many models constrained up to 1-2 TeV**
- **Searches also in the Di-Jet final states exclude up to 2.6 TeV for almost whole DM range**



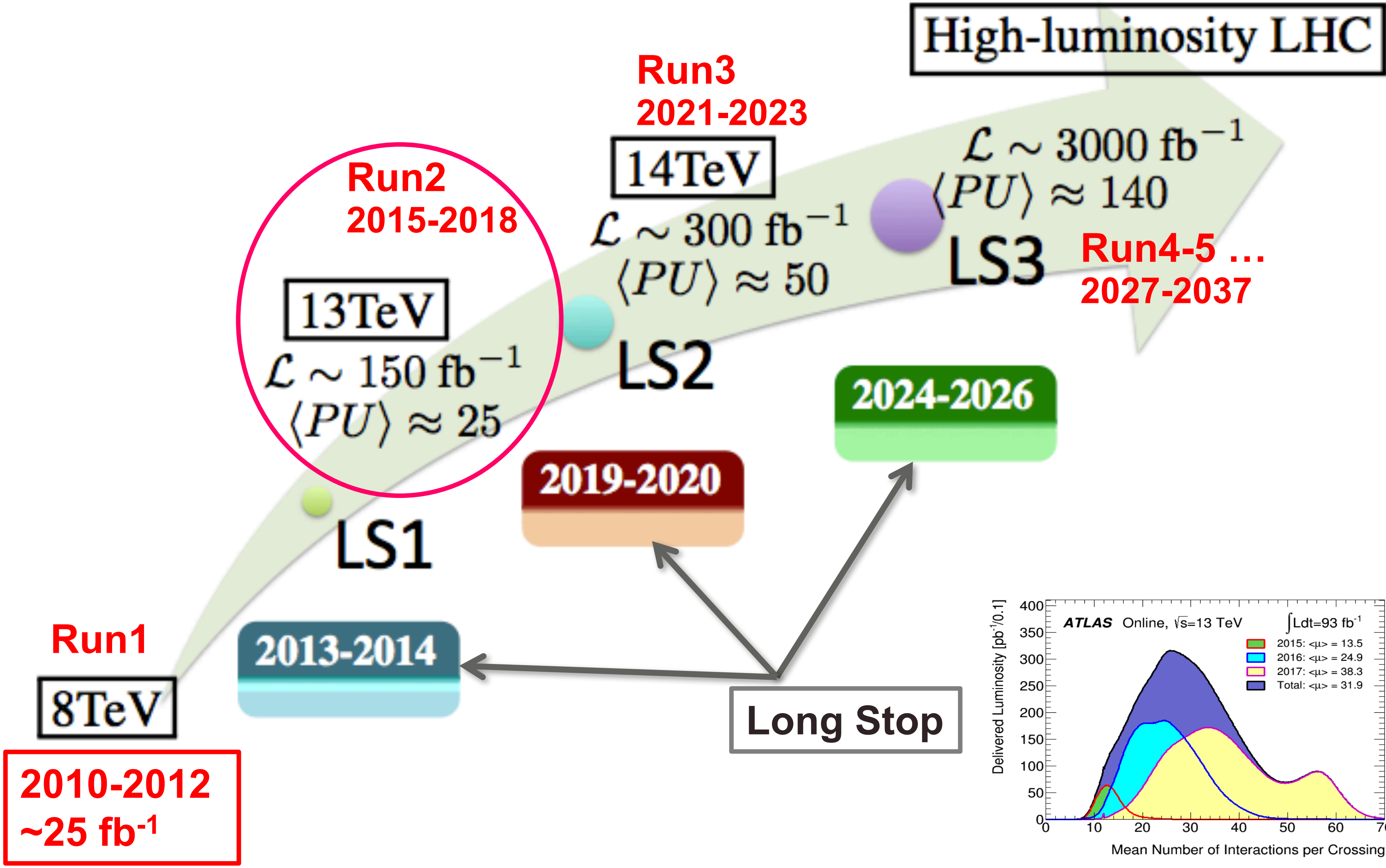
Summary and Outlook

- ATLAS 13TeV 36−80 fb^{-1} 的分析结果表明:
  - 标准模型：开始研究稀有的电弱过程。
  - Higgs物理: 对Higgs所知越多，越“像” 标准模型。
    - 费米子衰变方面取得重大进展：direct confirmation of coupling to all 3rd generation fermions （top-quark, bottom-quark, taus）
  - 新物理（SUSY+ Exotics+ BSM Higgs）：目前未见新粒子或新物理迹象。
  - LHC实验测量目前与标准模型预期符合很好，随着Run2−3数据显著增加，我们期待发现希格斯粒子之外的新物理!

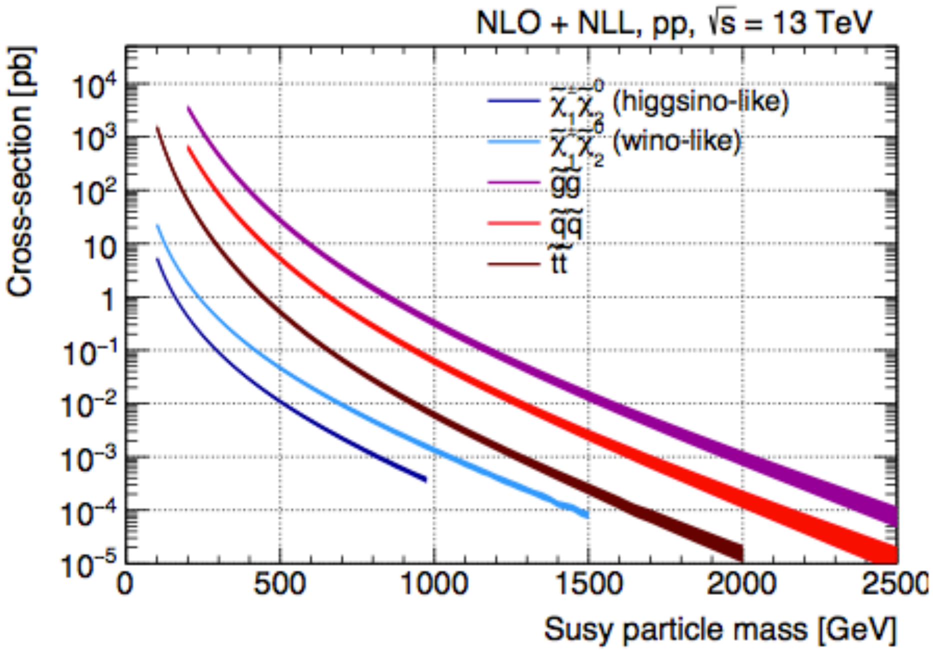
- ATLAS中国组研究队伍和实力显著提升，目前包含7家单位，作者数占总数的～2.8%， 在合作组中发挥越来越重要的作用：在ATLAS决策和管理层担任多项职务，担任多个重要物理分析组和探测器运行及性能研究组的召集人，在众多重要物理课题中担任负责人和论文编辑。

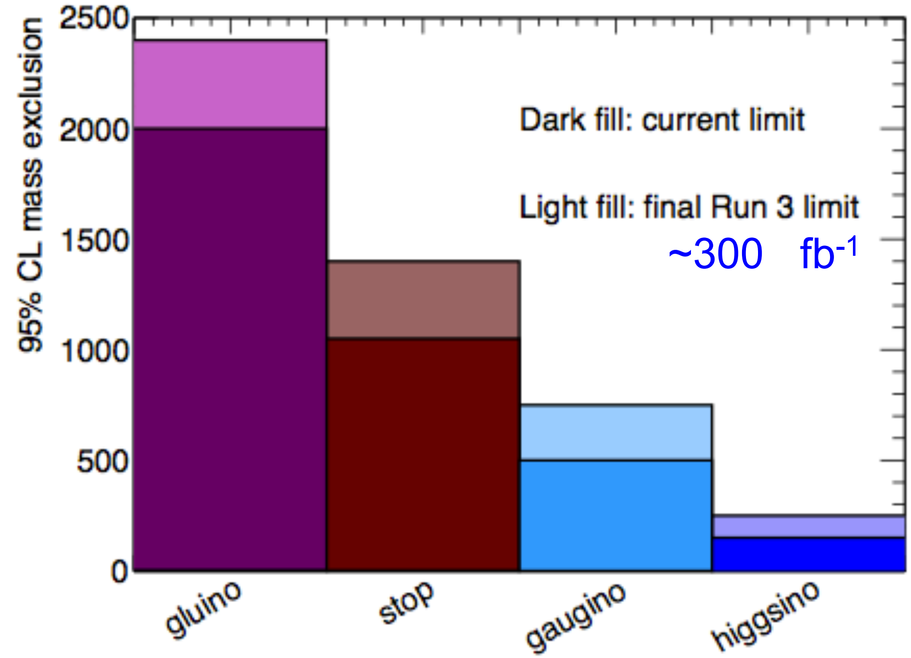
谢谢大家！

LHC Data-taking Plan



2015+2016 – A milestone for SUSY

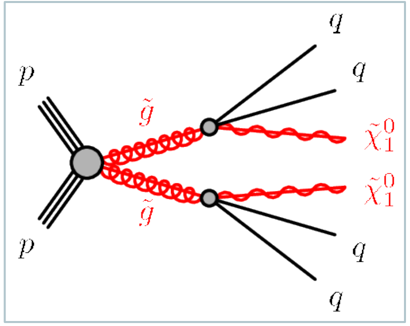


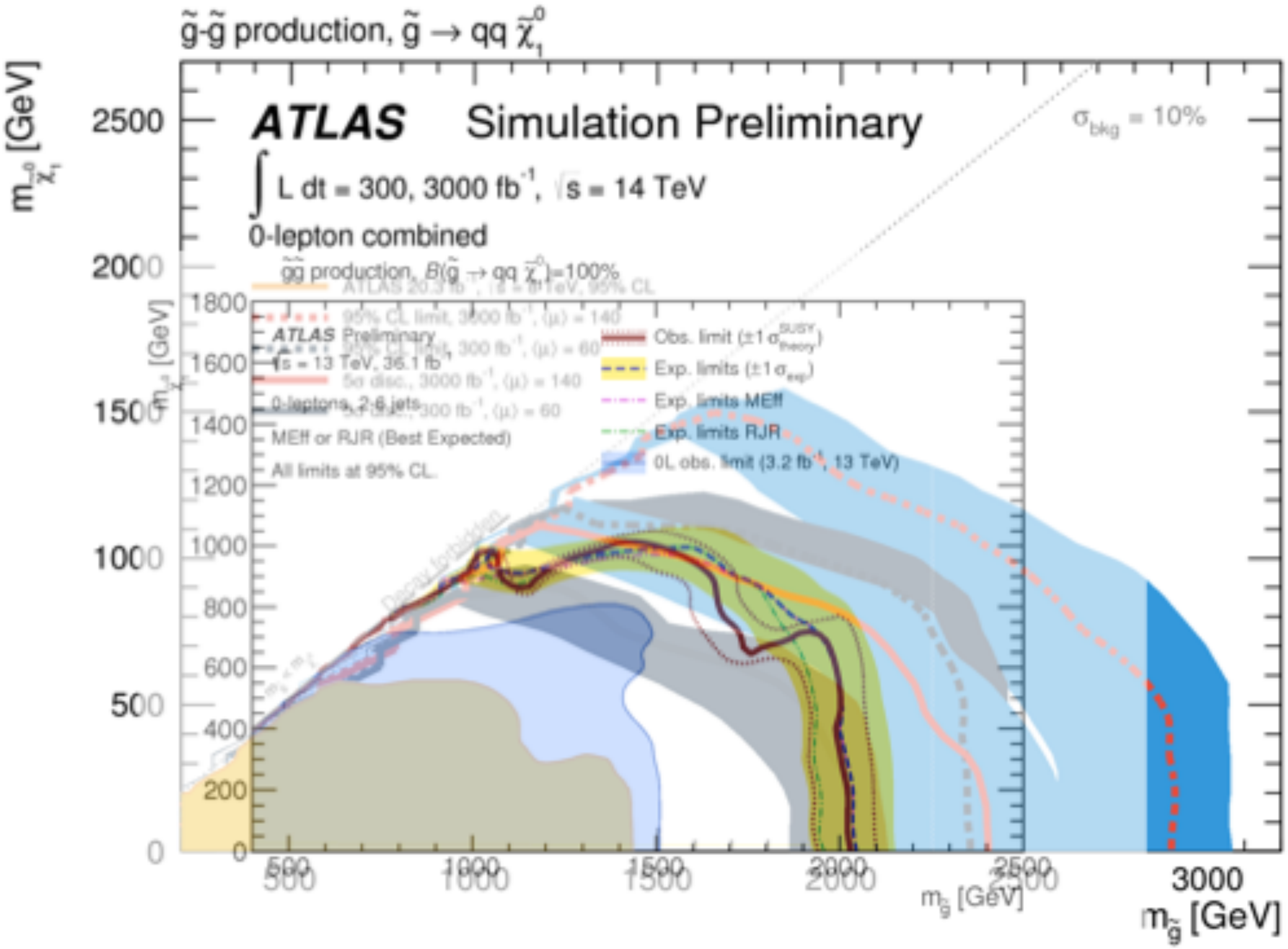


This means:

- **We explored 85% of our mass reach for gluino pair production, about 75% for stop**
- **~60% for gauginos, and just above 50% for higgsinos**

Places to hunt for SUSY?

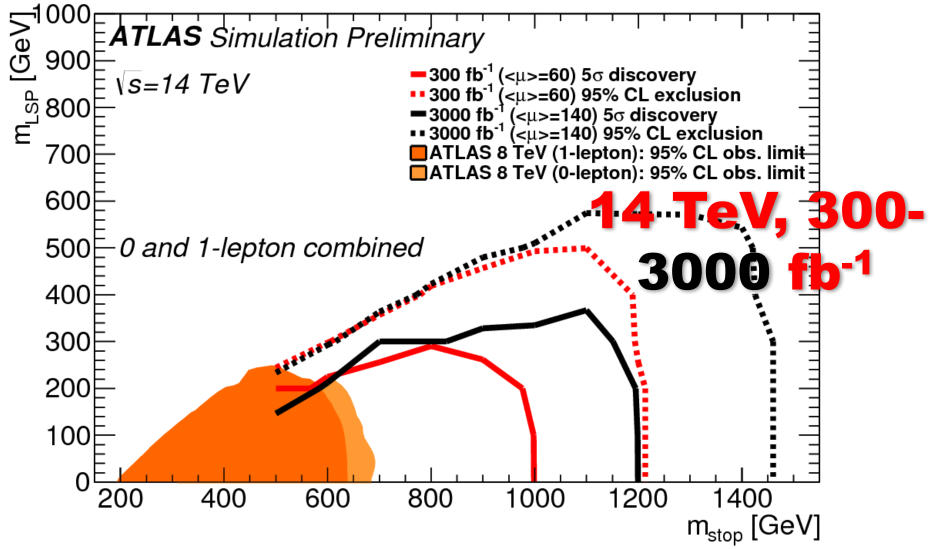


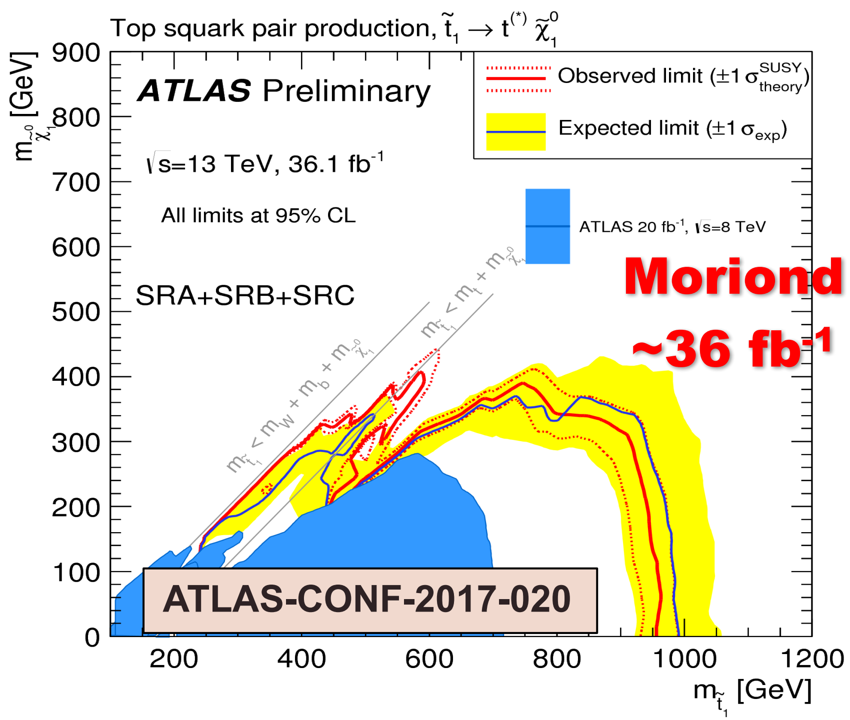


For discovery potential:

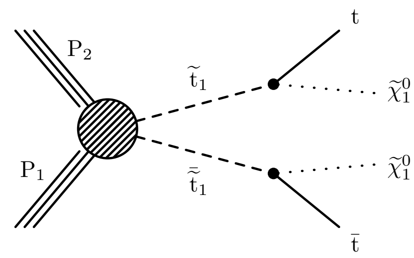
- **We explored 85% of our mass reach (2 → 2.5 TeV)**
- **with a small window remaining between 1—2 TeV**
- **300/fb 5σ discovery case is practically excluded**

ATL-PHYS-PUB-2013-011





Prospects at HL-LHC



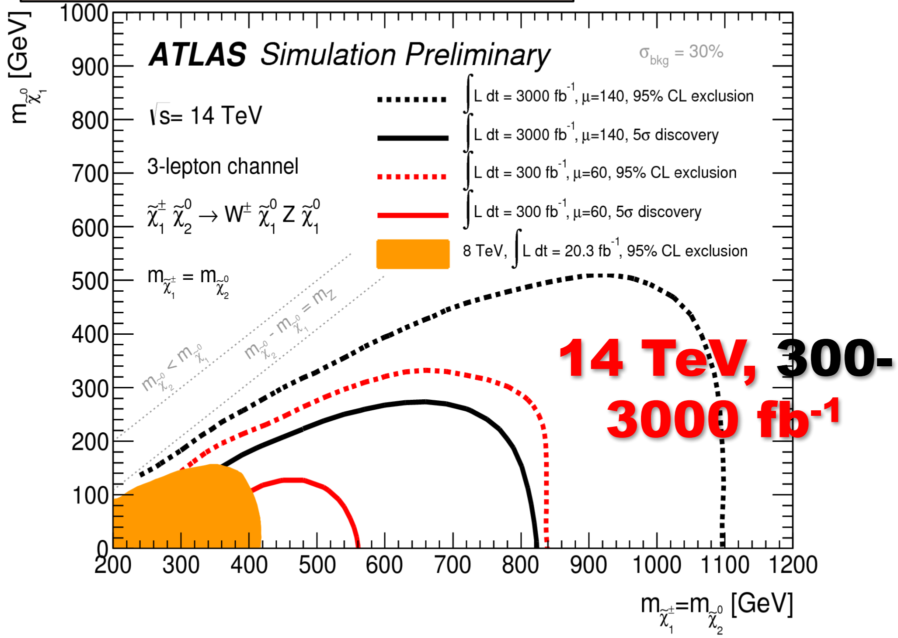
For exclusions (all hadronic):

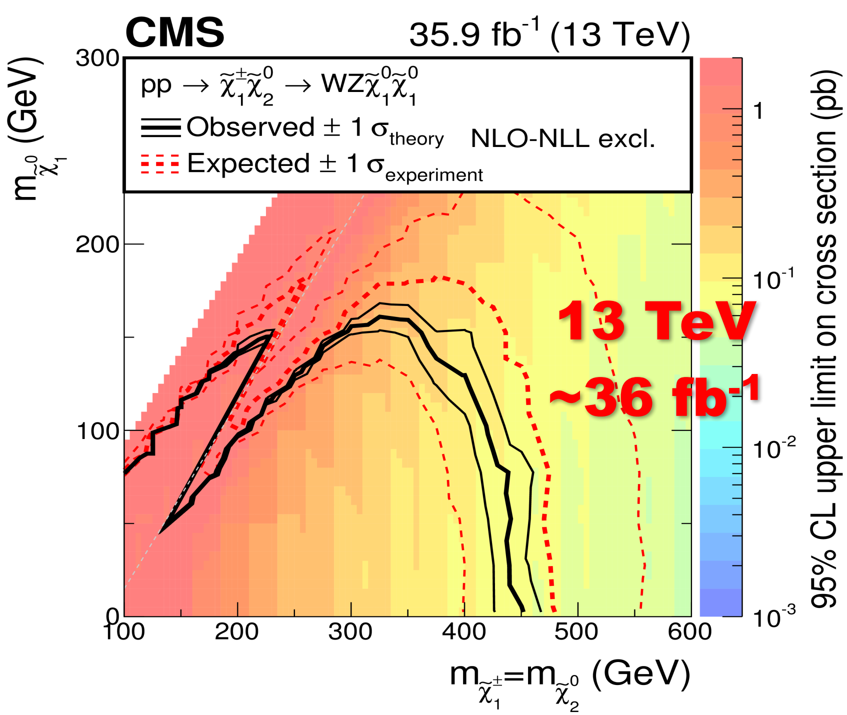
- stop: ~ 1 TeV now
- 1.2 TeV @ 300 fb-1
- 1.4 TeV @ 3000 fb-1

For discovery:

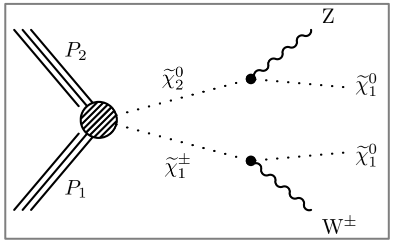
- 1.0 TeV @ 300 fb-1
- 1.2 TeV @ 3000 fb-1

ATL-PHYS-PUB-2014-010





Prospects at HL-LHC



For exclusions:

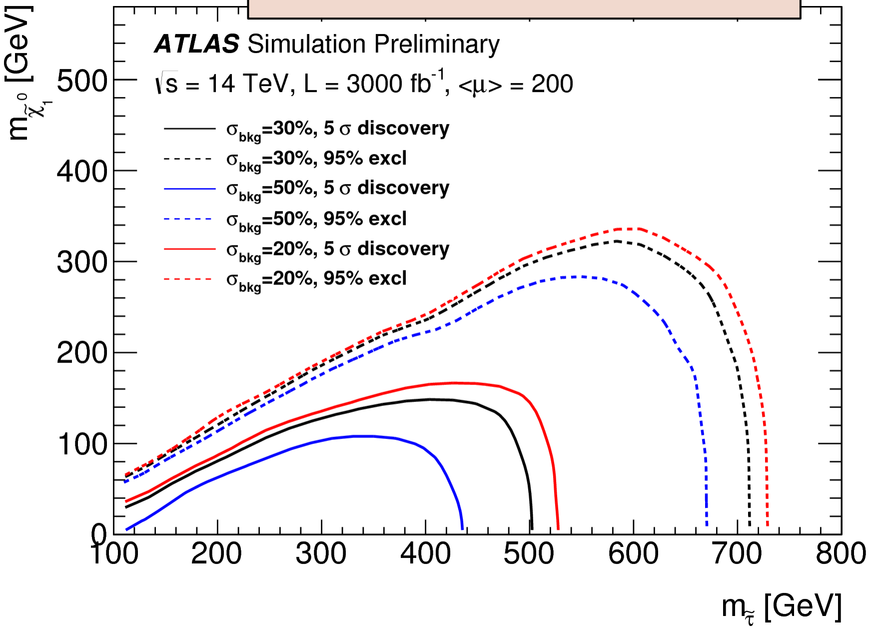
- gaugino: ~ 0.45 TeV now
- 0.8 TeV @ 300 fb-1
- 1.1 TeV @ 3000 fb-1

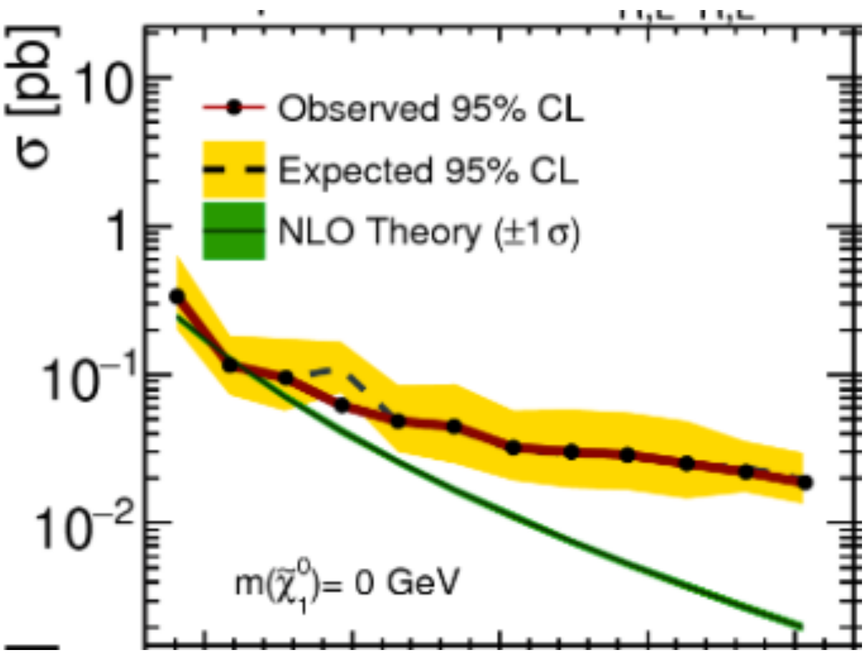
For discovery:

- 0.55 TeV @ 300 fb-1
- 0.8 TeV @ 3000 fb-1

Some room for discovery

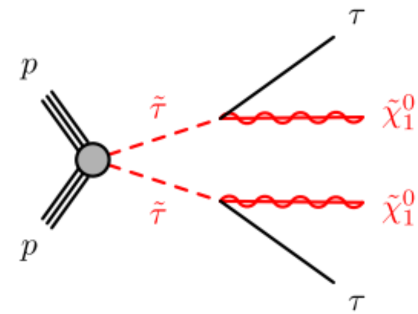
ATL-PHYS-PUB-2016-021





100 GeV

Direct stau



IHEP

For exclusions:

- **stau: ~ 0.1 TeV now**
- **0.7 TeV @ 3000 fb-1**

For discovery:

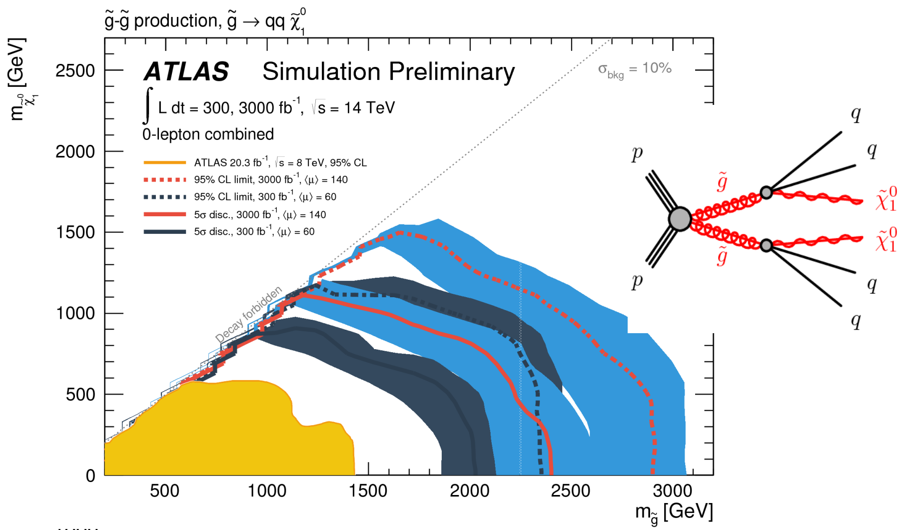
- **0.5 TeV @ 3000 fb-1**

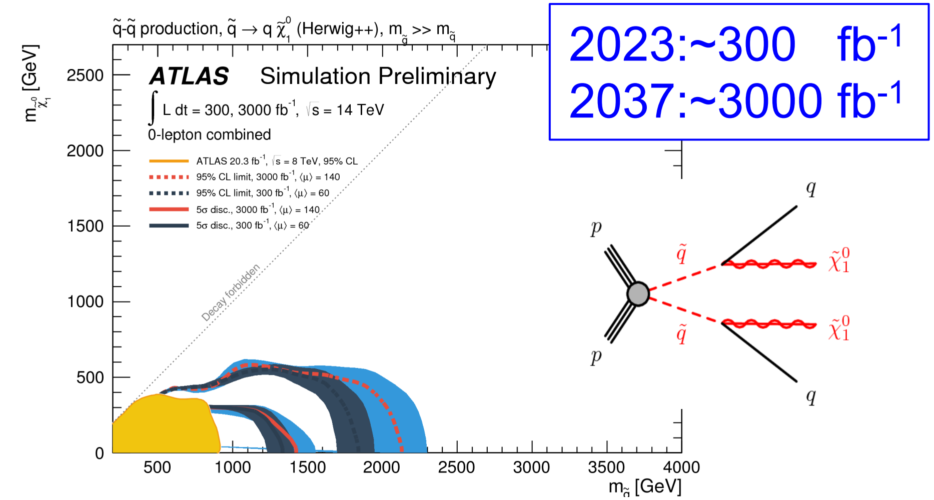
Very promising at LHC

Prospects at HL-LHC

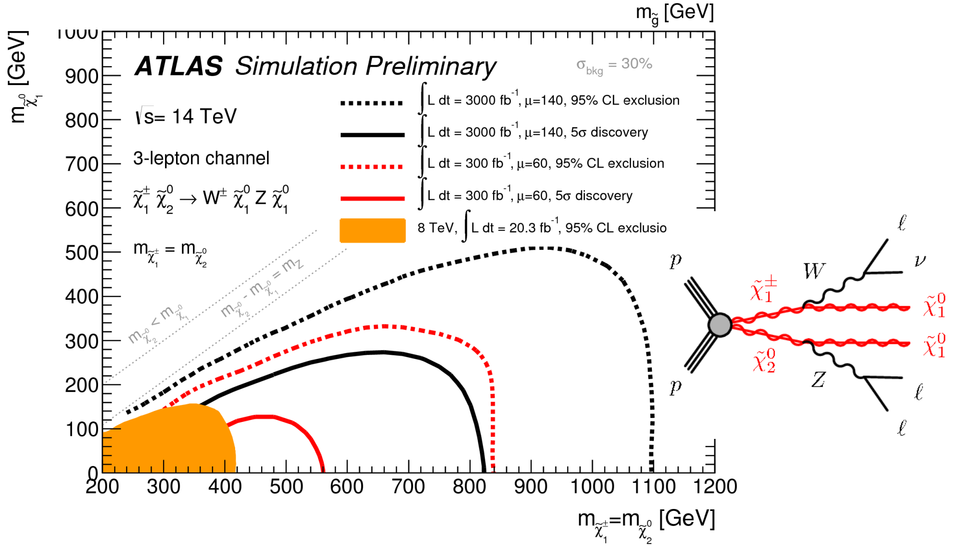
ATL-PHYS-PUB-2014-010

- ATLAS studied long term prospects for the (HL-)LHC with 300, 3000 fb^{-1}@14TeV
- **Discovery potential up to 2.5 TeV gluinos, 1.3 TeV squarks/sbottom and 800 GeV Electroweakinos, 500 GeV stau with 3000 fb^{-1}.**

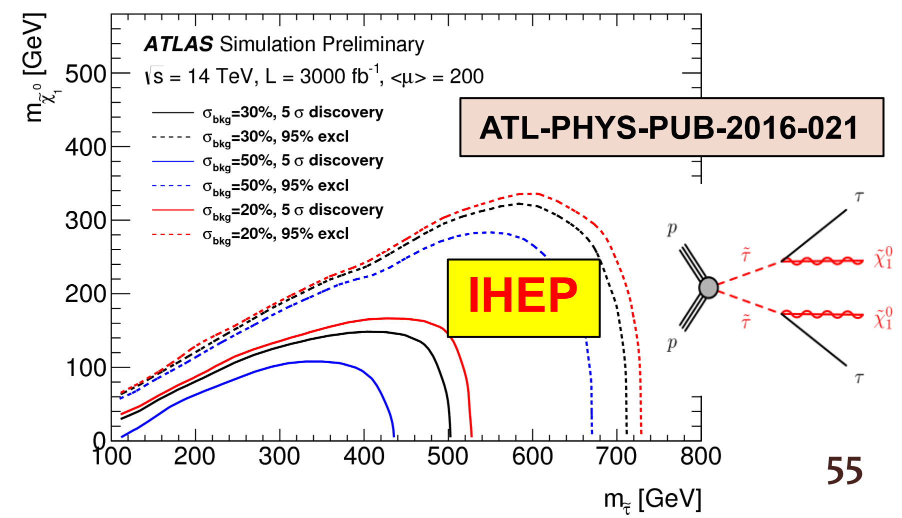




2023:~300 fb^{-1}
2037:~3000 fb^{-1}



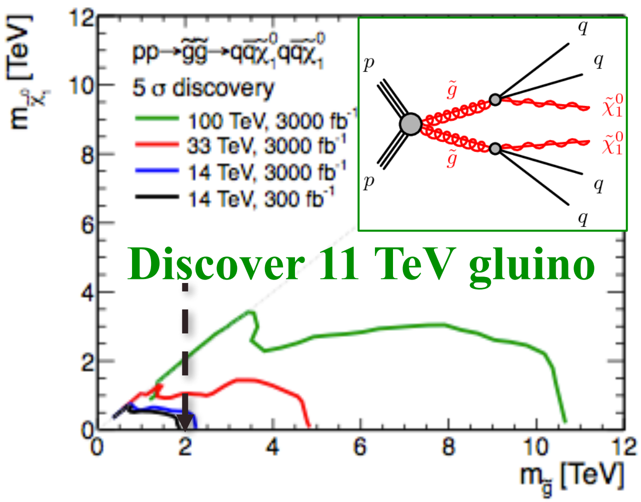
ATL-PHYS-PUB-2016-021

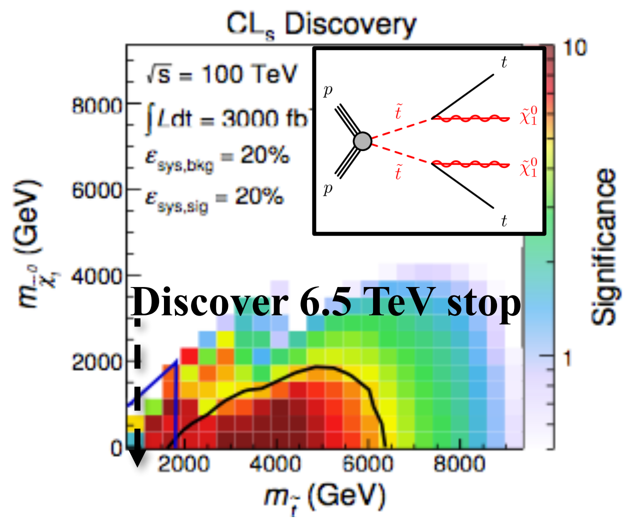


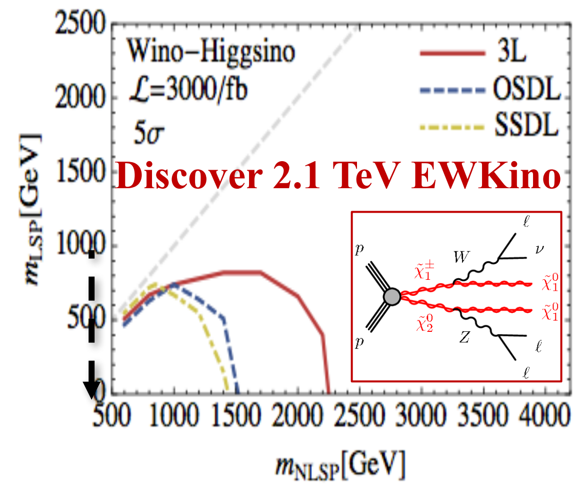
Prospects at Future Collider

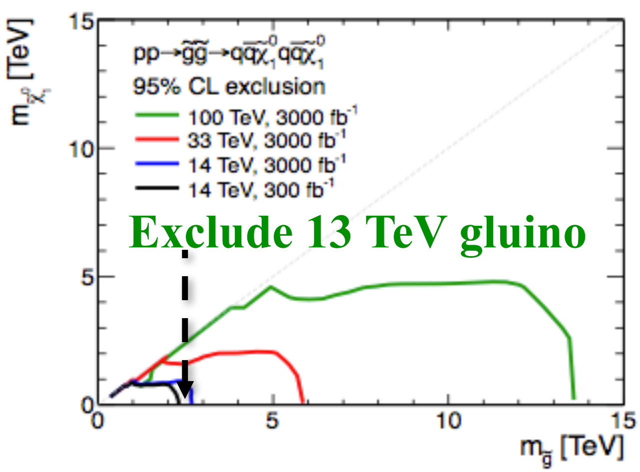
Discovery (Exclusion) potential with 3000 fb^{-1}@33,100 TeV

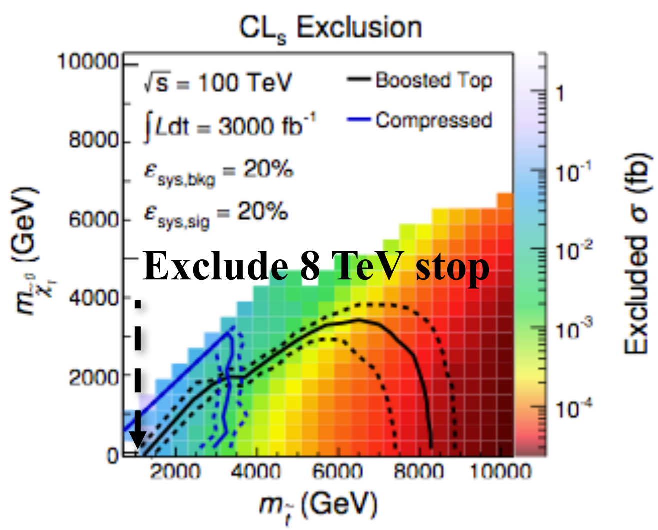
Gluinos ~ 11 (13) TeV | **Stop ~ 6.5 (8) TeV** | **EWKinos ~ 2.1 (3.2) TeV**

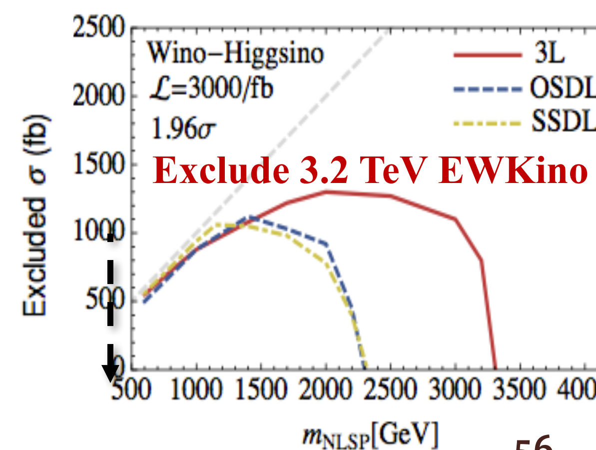




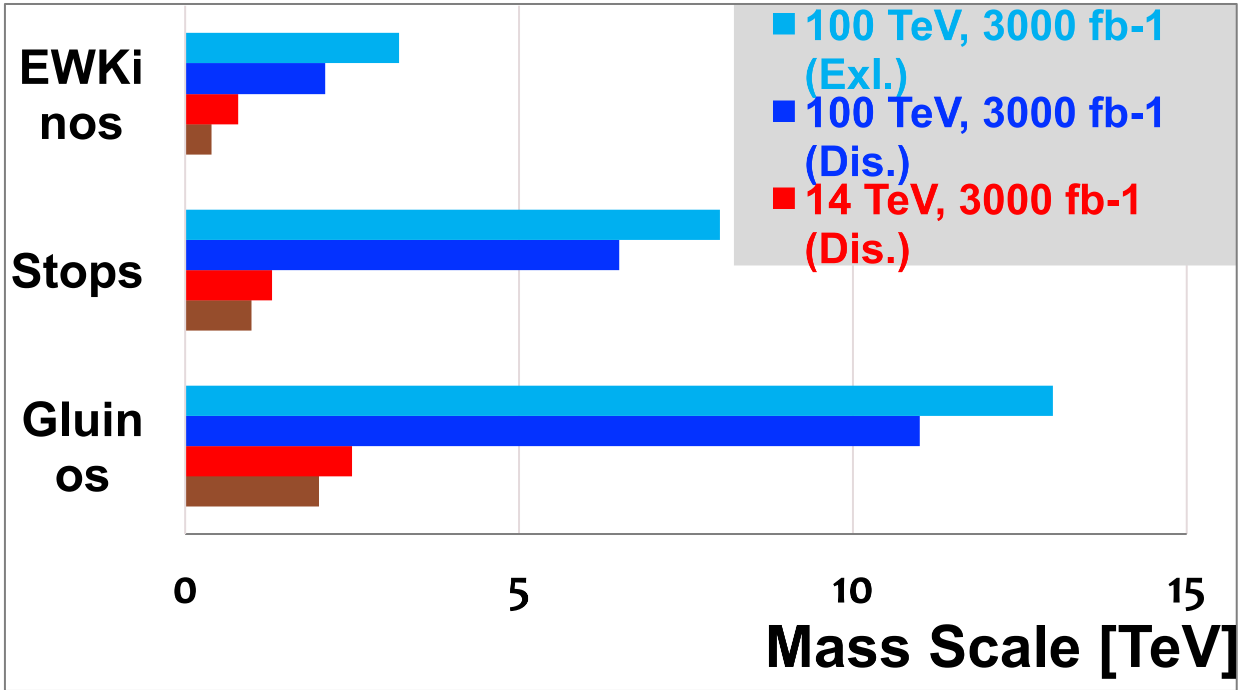


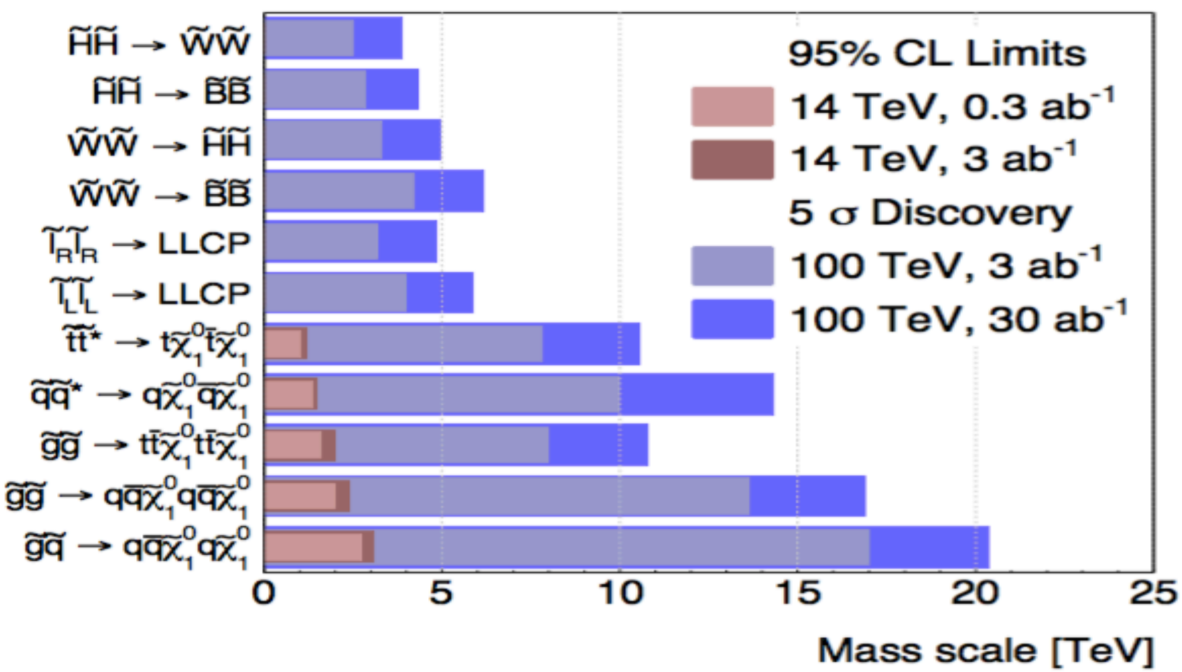






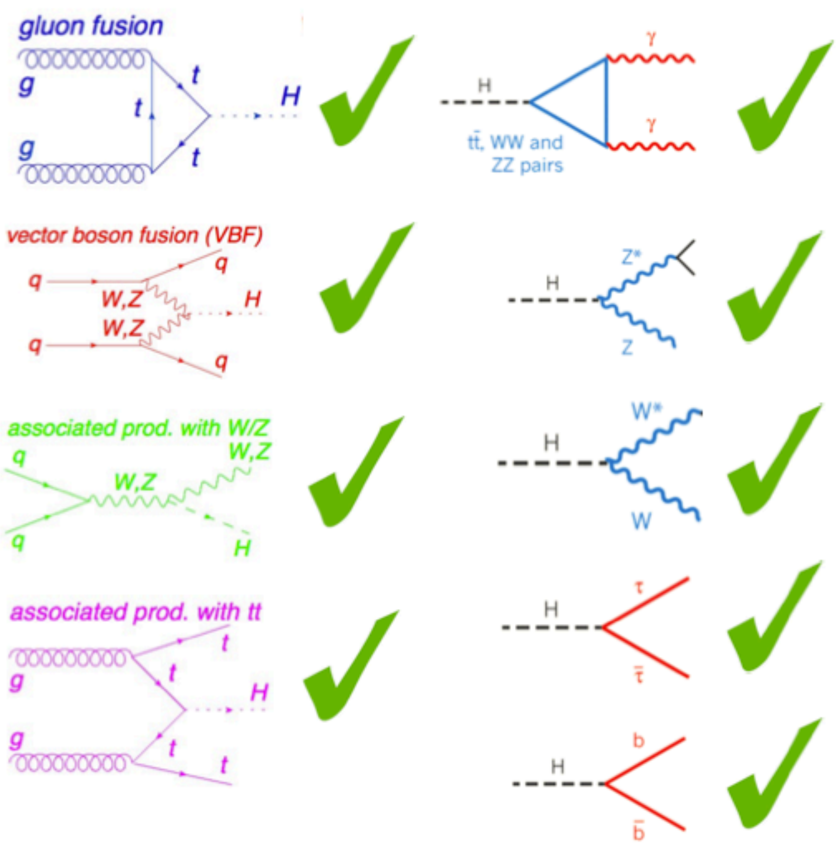
Prospects at Future Collider





Higgs Summary

Production | Decays

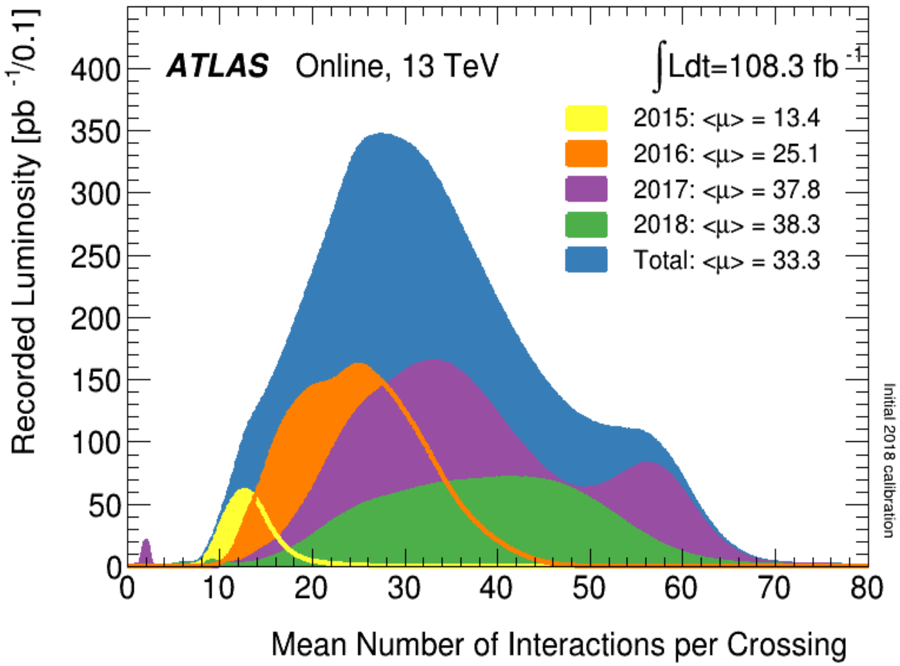


With the first 36-80 fb $^{-1}$ of Run-2 data:

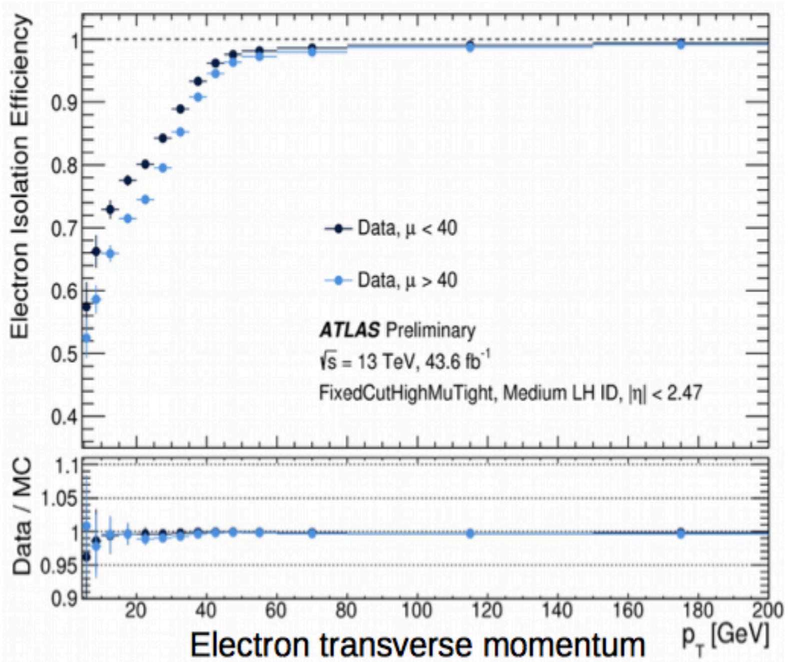
- Direct observation achieved for all main production and decay modes!
  - The bosonic decay channels entered a precision era (~3x improvement w.r.t. Run-1)
  - Direct confirmation of coupling to all 3rd generation fermions (top-quark, bottom-quark, taus)
  - Sensitivity to double Higgs production approaching 10 x SM
- Higgs physics an important indirect probe for New Physics: so far no deviations from SM…

Challenge to cope with pile-up interactions

Interactions per bunch per crossing:



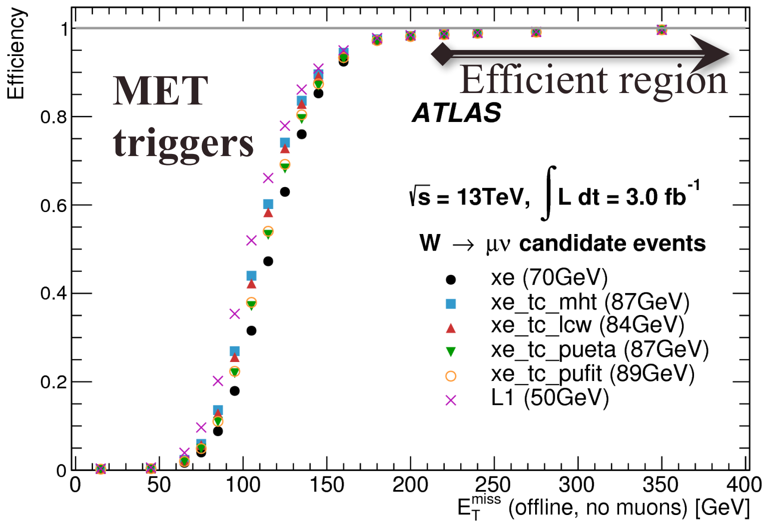
Electron isolation efficiency:

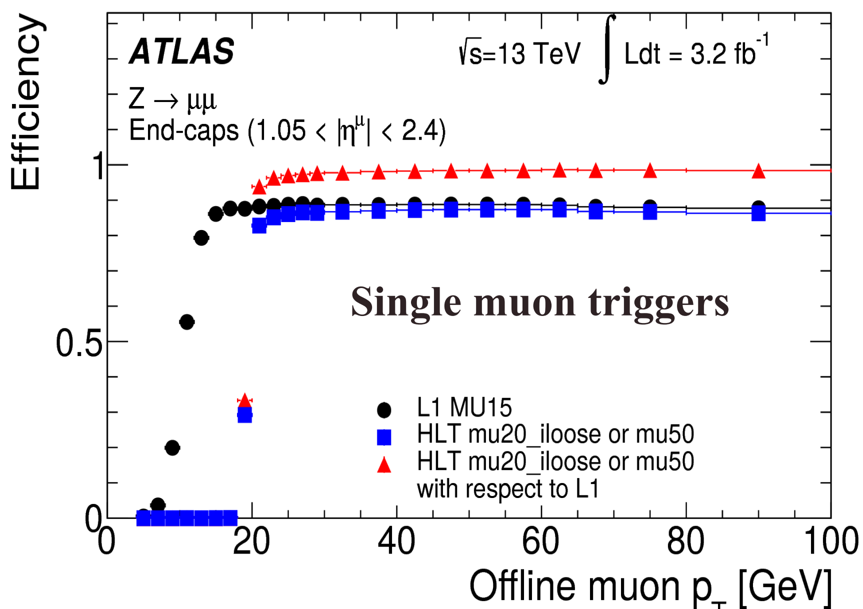


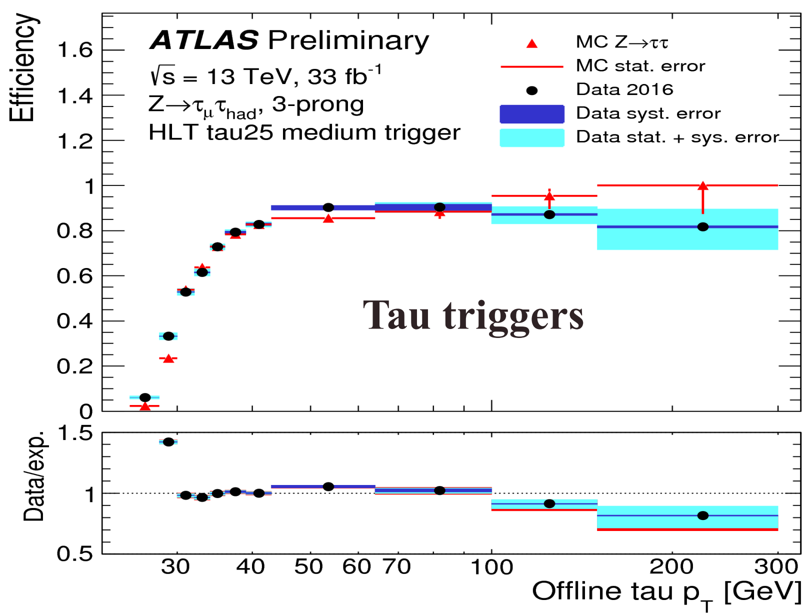
- Large number of additional interactions (pile-up) cause performance degradation.
- Powerful pile-up mitigation techniques developed.
- The performance loss is well described by Monte Carlo simulation.

Trigger performance Highlights

- ATLAS trigger and DAQ systems form the basis for a successful data-taking.
- Main physics triggers for SUSY searches: Generic missing ET, jet, lepton triggers







Top measurement

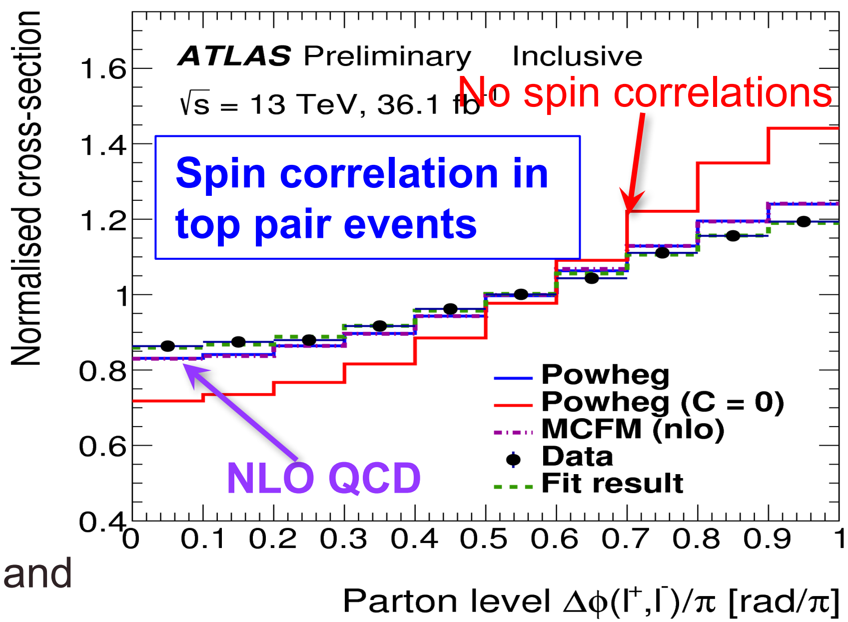
The fraction of SM-like spin correlation (f_{SM})

Region	f_{SM}	Significance (incl. theory uncertainties)
$m_{t\bar{t}} < 450$ GeV	$1.11 \pm 0.04 \pm 0.13$	0.85 (0.84)
$450 < m_{t\bar{t}} < 550$ GeV	$1.17 \pm 0.09 \pm 0.14$	1.00 (0.91)
$550 < m_{t\bar{t}} < 800$ GeV	$1.60 \pm 0.24 \pm 0.35$	1.43 (1.37)
$m_{t\bar{t}} > 800$ GeV	$2.2 \pm 1.8 \pm 2.3$	0.41 (0.40)
inclusive	$1.250 \pm 0.026 \pm 0.063$	3.70 (3.20)

Previous analyses also measured stronger spin correlations (with large uncertainties).

Table 2: Summary of extracted f_{SM} values for each explored region with total uncertainties as well as the significance of the result with respect to the SM hypothesis. The significance with respect to the SM hypothesis is calculated using the statistical and systematic uncertainties only. The values in brackets include the effect of scale variations and PDF uncertainties on the hypothesis templates but do not account for possible correlations between these variations and the experimental uncertainties of a similar nature.

Generator	inclusive
f_{SM} values	
Powheg + Pythia8	1.25
Powheg + Pythia8 (2.0 μ_F, 2.0 μ_R)	1.29
Powheg + Pythia8 (0.5 μ_F, 0.5 μ_R)	1.18
Powheg + Pythia8 (PDF variations)	1.26
Powheg + Pythia8 RadLo tune	1.29
Powheg + Herwig7	1.32
MadGraph5_aMC@NLO + Pythia8	1.20

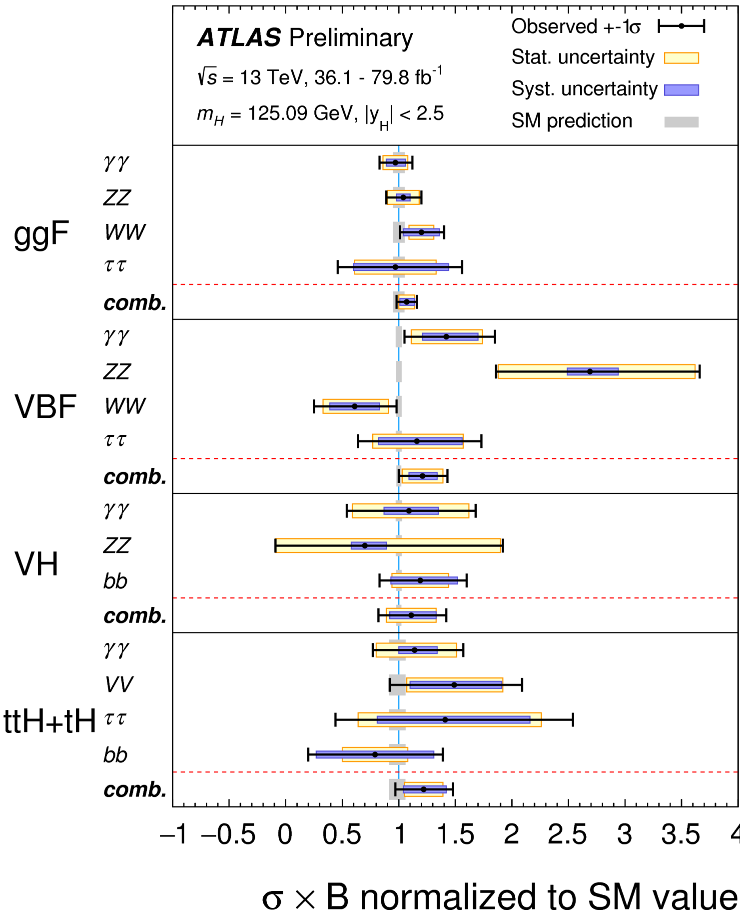


ATLAS-CONF-2018-027

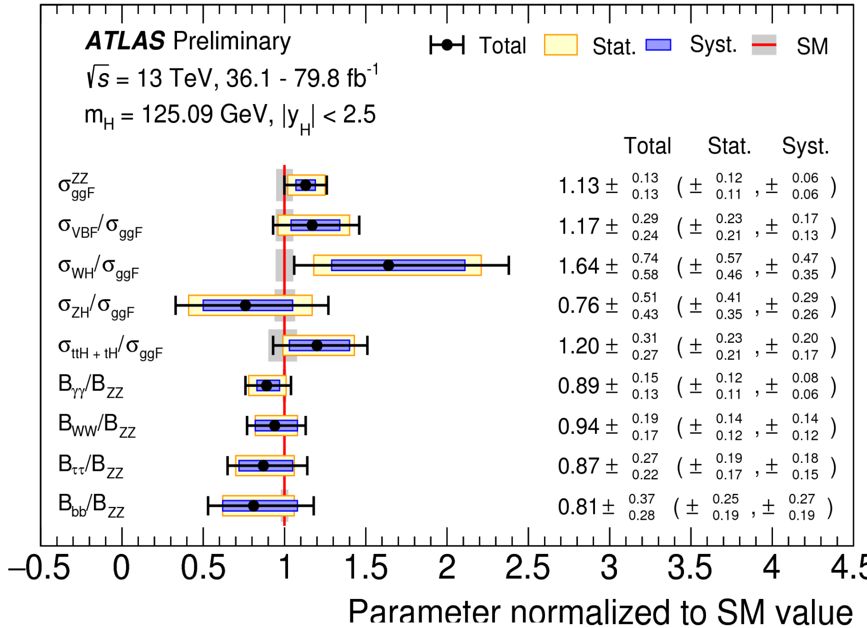
Fit results: f=1.250+-0.026 +-0.063

3.2σ discre-pancy with NLO QCD

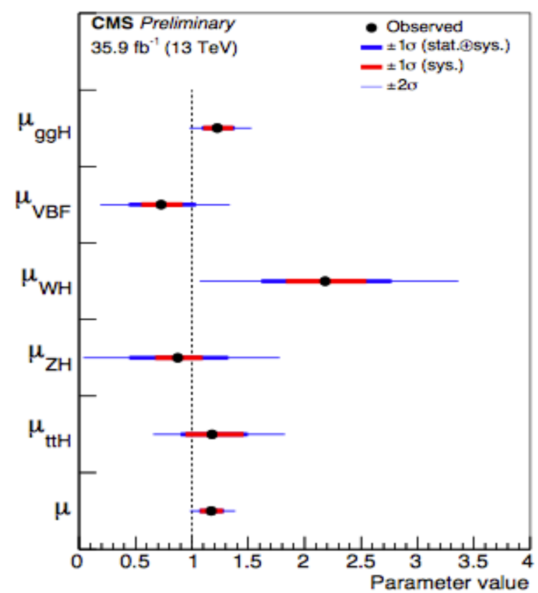
Similar results for fiducial particle-level and comparisons of ME generators.



ATLAS-CONF-2018-031



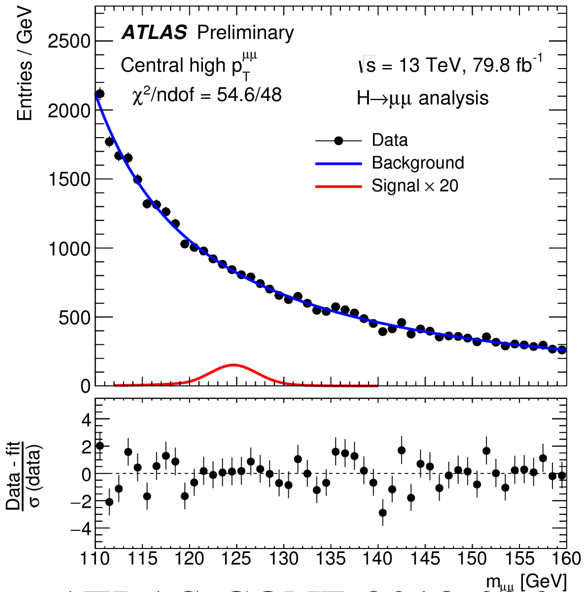
Ratios of cross sections and branching ratios cancel out some uncertainties



CMS 13 TeV 2016 combination

$$\mu = 1.17^{+0.10}_{-0.10} = 1.17\,^{+0.06}_{-0.06}\,(\text{stat.})\,^{+0.06}_{-0.05}\,(\text{sig. th.})\,^{+0.06}_{-0.06}\,(\text{other sys.})$$

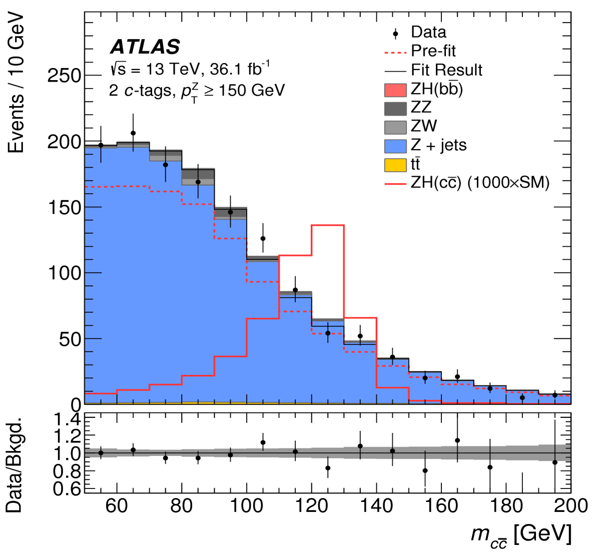
H→μμ, cc

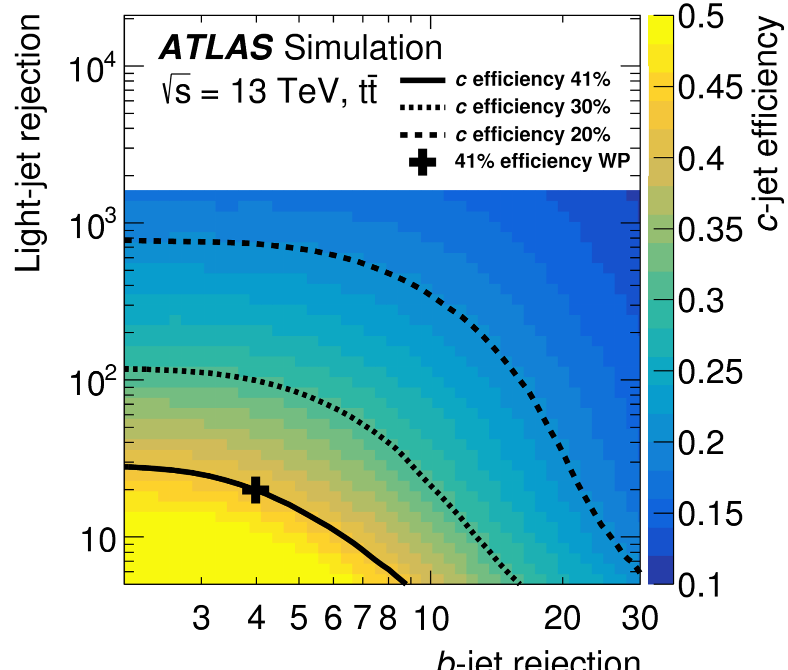


ATLAS-CONF-2018-026

	Expected significance	Observed significance
Central low $p_T^{\mu\mu}$	0.10	−0.49
Non-central low $p_T^{\mu\mu}$	0.03	0.44
Central medium $p_T^{\mu\mu}$	0.31	1.55
Non-central medium $p_T^{\mu\mu}$	0.30	−1.16
Central high $p_T^{\mu\mu}$	0.38	0.48
Non-central high $p_T^{\mu\mu}$	0.43	0.15
VBF Loose	0.24	−0.88
VBF Tight	0.42	−0.26
Combined	0.88	0.04

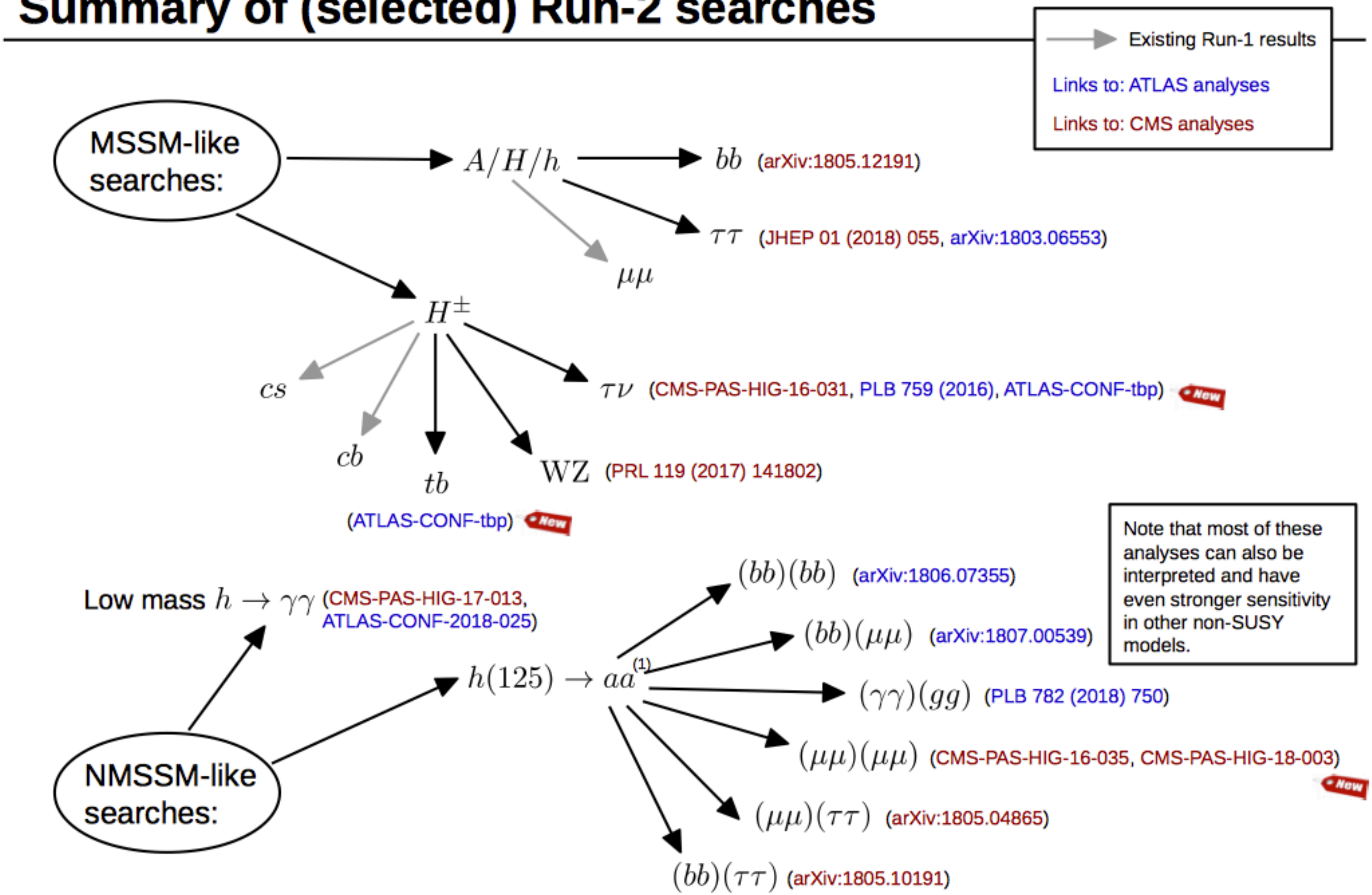
USTC





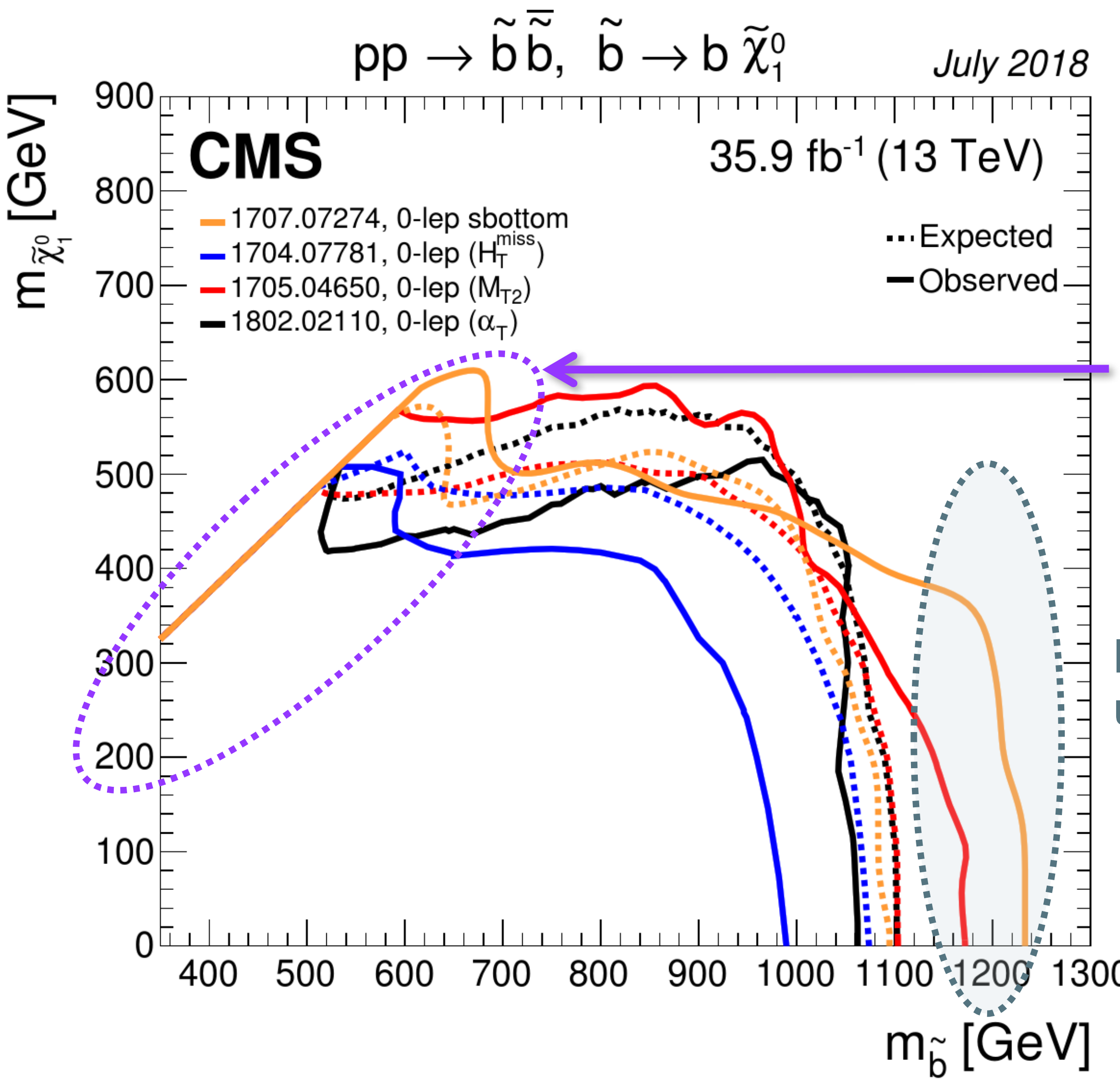
Rare decays, small backgrounds

Summary of (selected) Run-2 searches



(1) Here a indicates just a Higgs boson that could be scalar or pseudo-scalar

Sbottom search

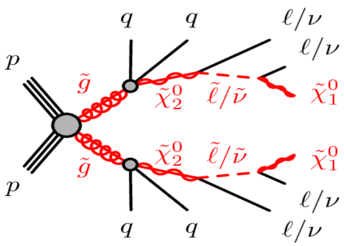


Compressed scenario: still < 700 GeV

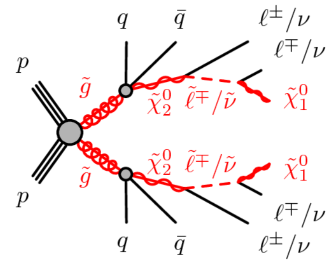
Large mass split scenario: up to 1.2 TeV

Multi-step decays

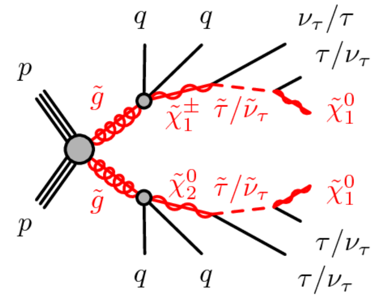
Signal: multi-leptons, jets and MET



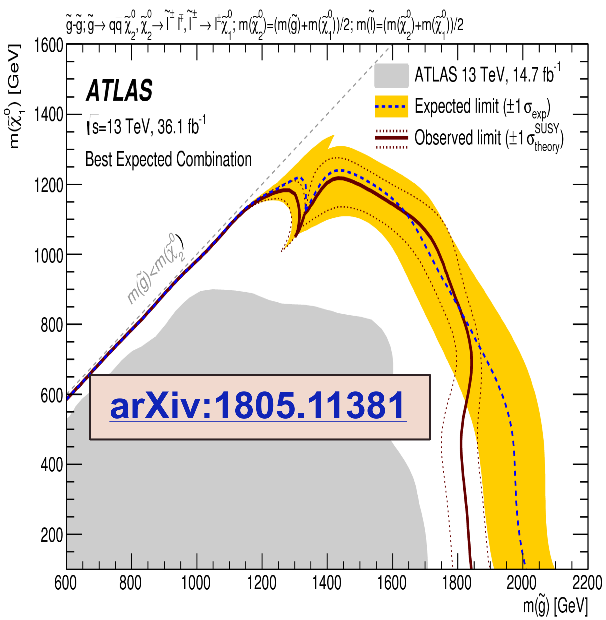
OS Di-lept.

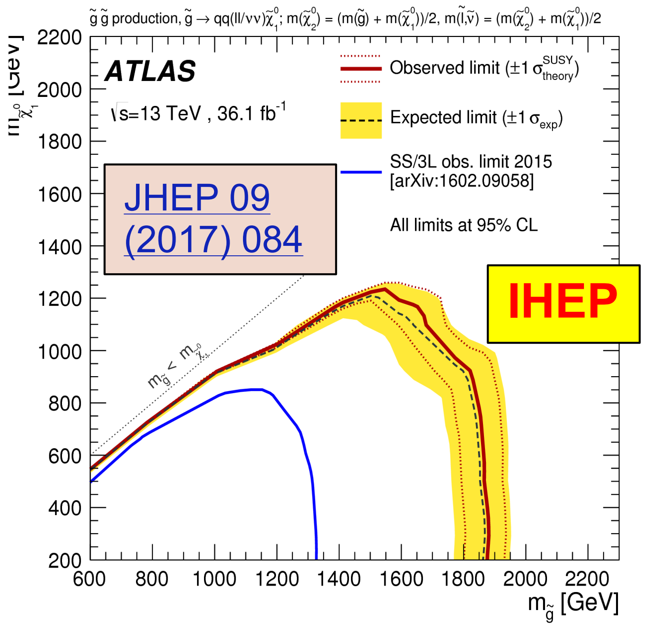


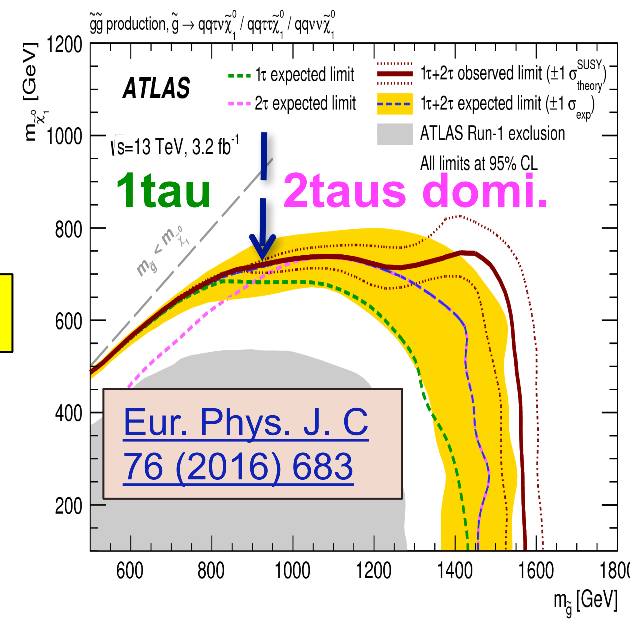
SS Di-lept.



Tau(s)



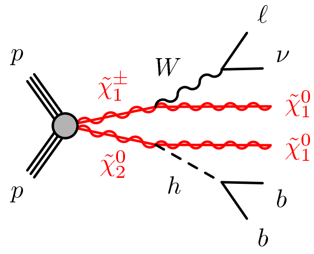


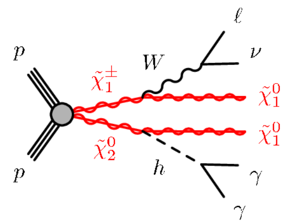


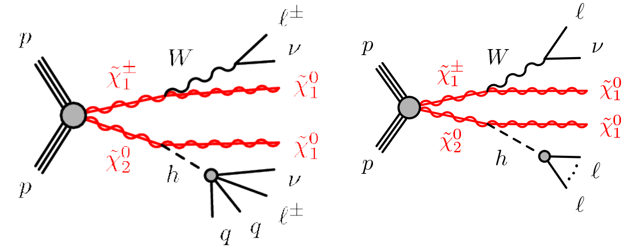
Corresponding sparticle mass limits for **BF=100%**:

- Gluino mass up to 1.6-1.9 TeV, LSP up to 0.7-1.2 TeV

Gaugino via WH decay







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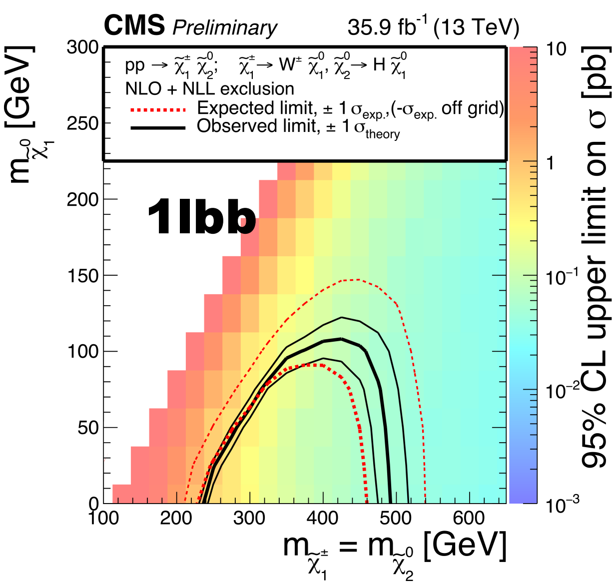
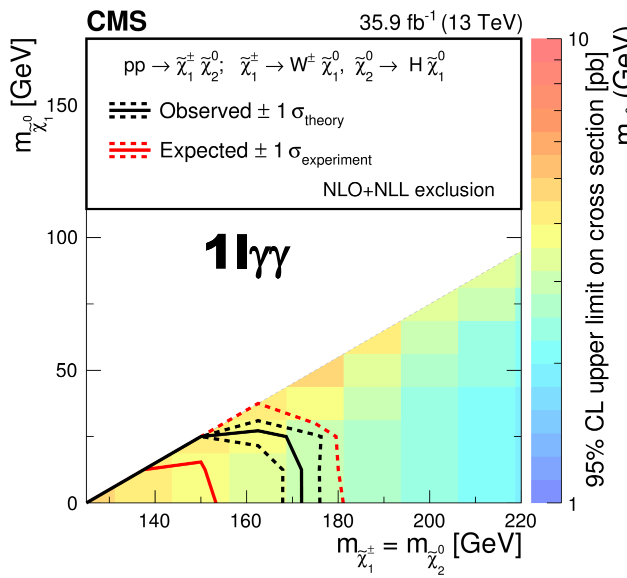
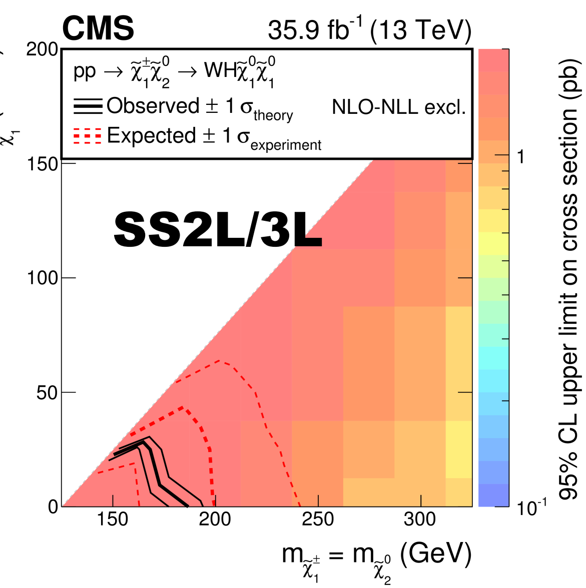
[PLB 779 (2018) 166]

[JHEP 03 (2018) 166]

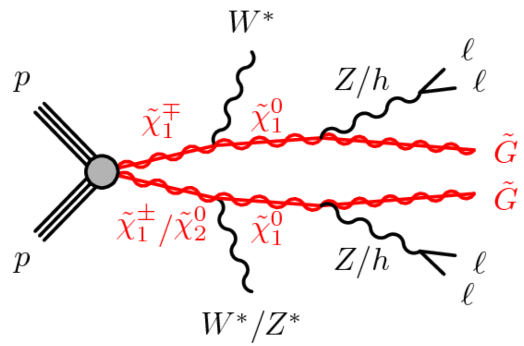


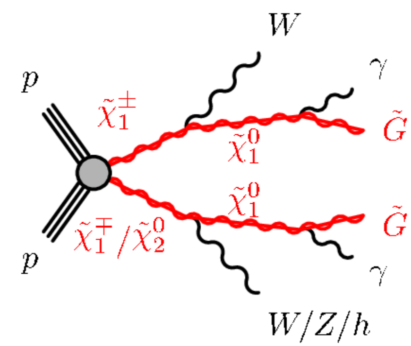


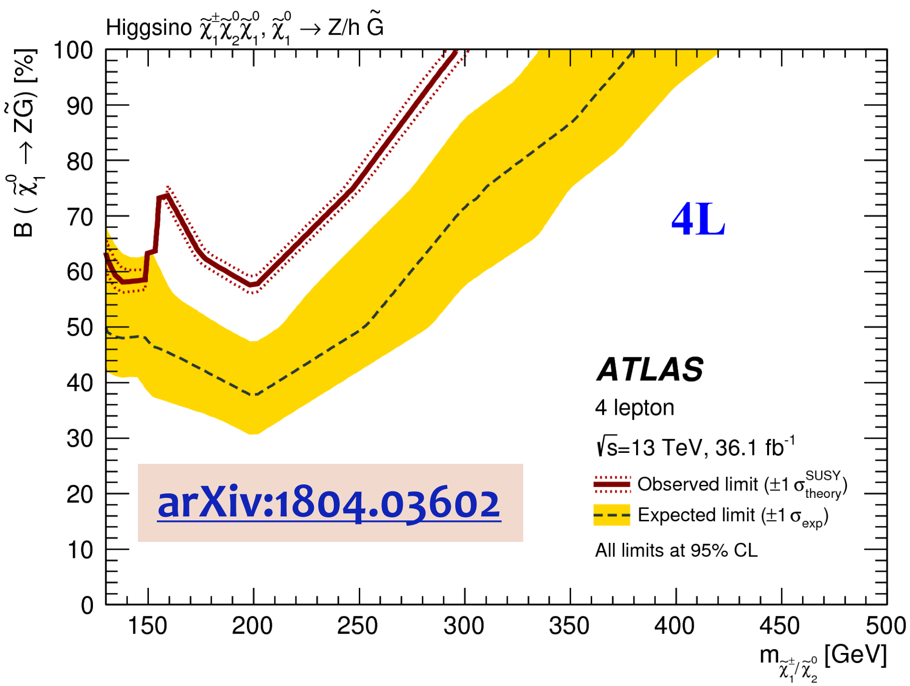


IHEP is working on Wh (1lττ, 1lbb, SS) analysis.

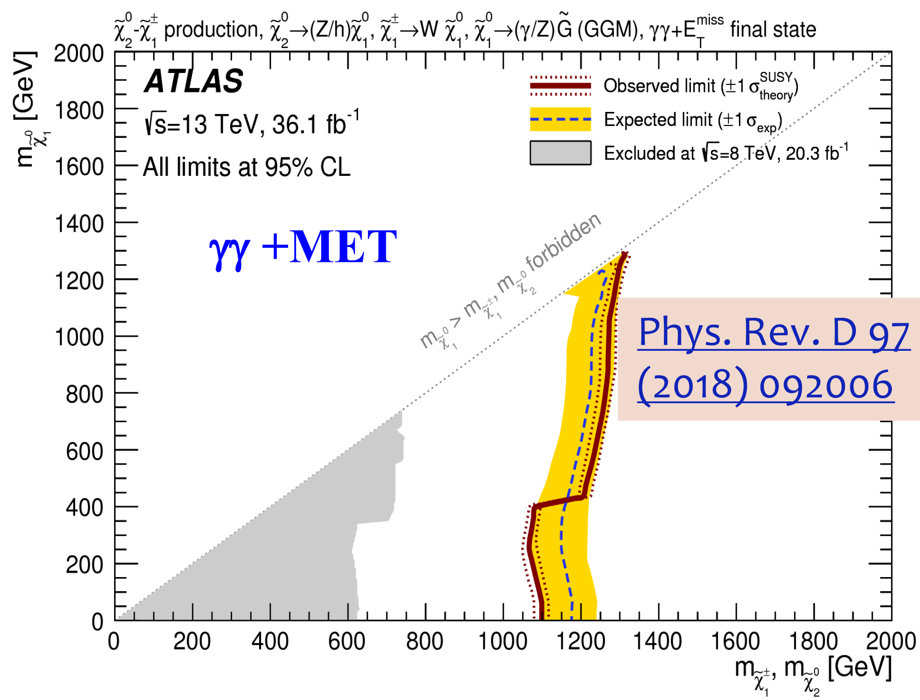
Gravitino LSP scenarios (GMSB)







arXiv:1804.03602



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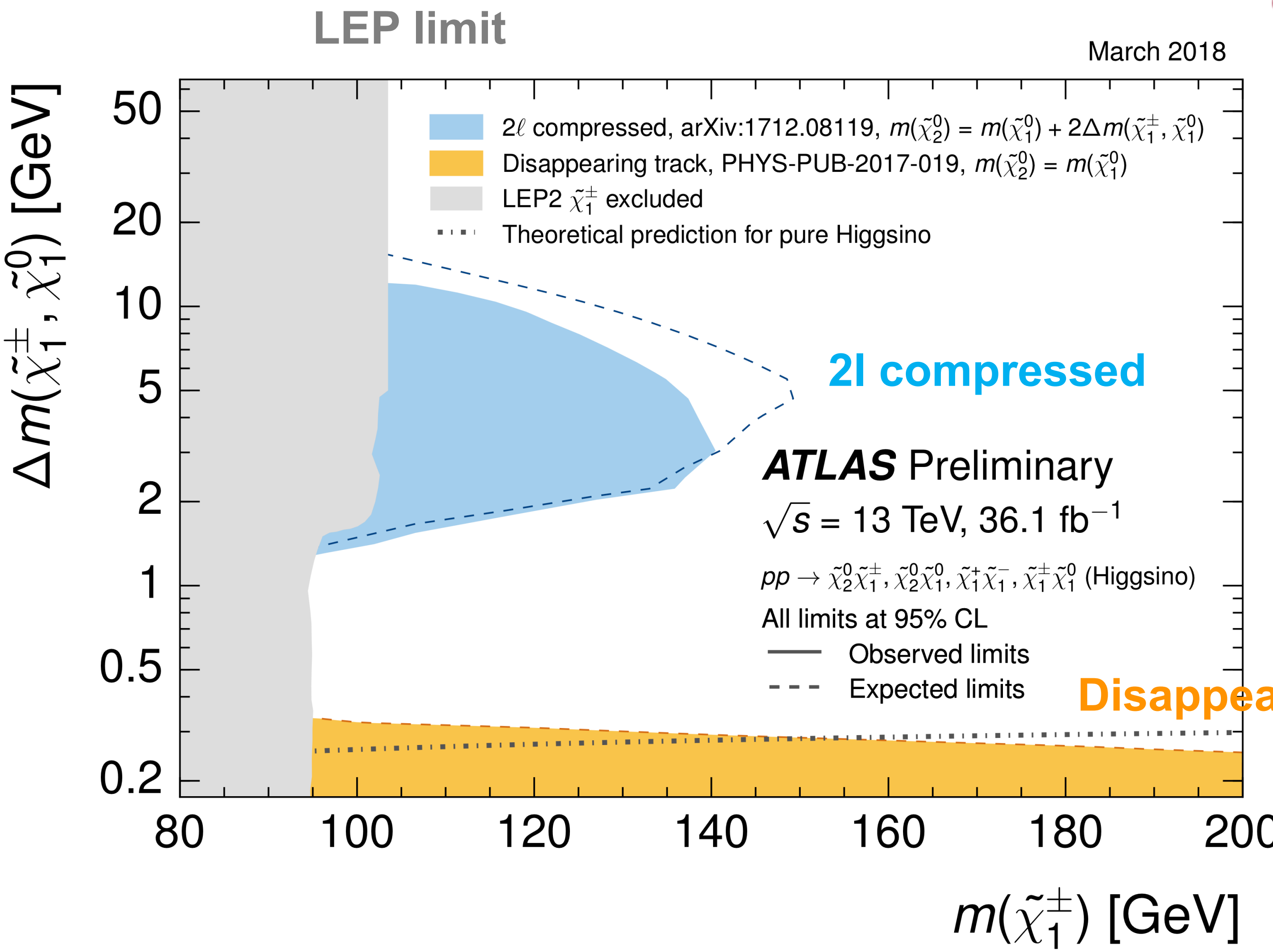
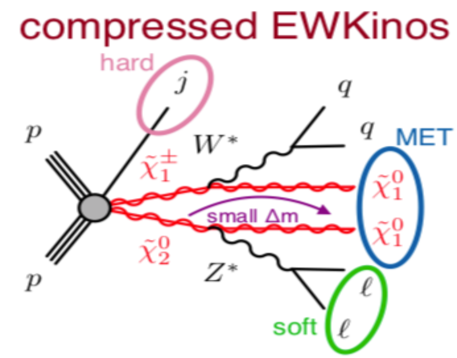
Mild excess observed (2.3 σ) in 0 tau, on-shell Z

Summary: Higgsino LSP



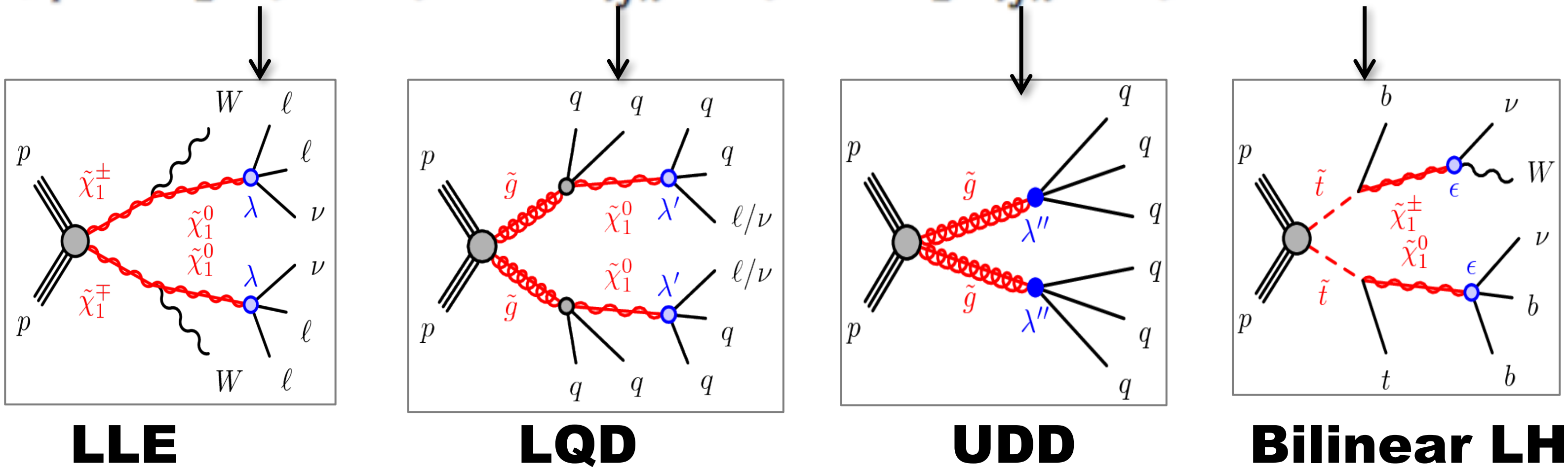


- ATLAS exploring new regions for higgsino production, beyond LEP limits for the first time!

RPV SUSY

- Precision SM measurements support baryon and lepton number conservation, while some MSSM couplings do not
- Search for R-parity Violating SUSY
- Super-potential with RPV of lepton or baryon number

$$W_{\not R_p} = \frac{1}{2}\lambda_{ijk}L_iL_j\bar{E}_k + \lambda'_{ijk}L_iQ_j\bar{D}_k + \frac{1}{2}\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k + \kappa_iL_iH_2$$



- RPV SUSY signatures:
  - Decaying LSP → lower Missing Transverse Energy (MET)
  - Many jets (or leptons) in the final states

SUSY RPV: 1L + multi-jets

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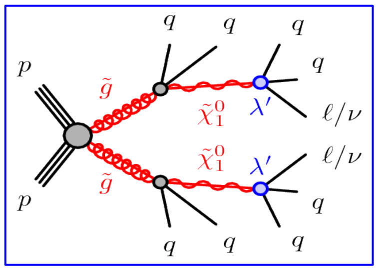
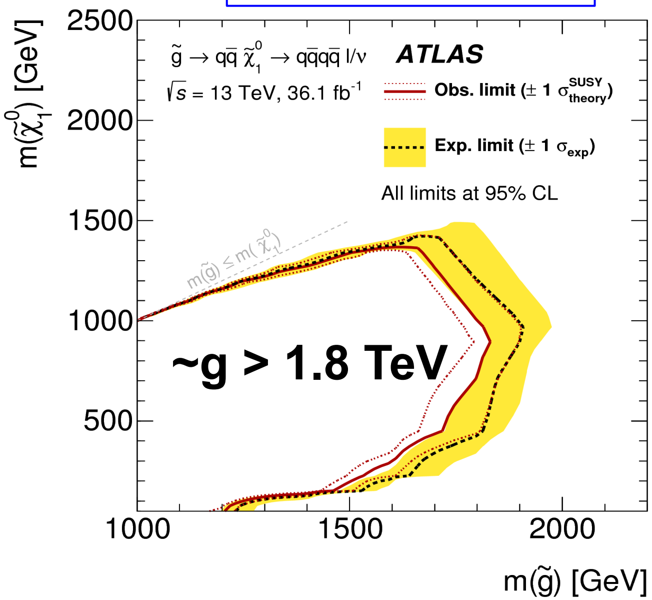
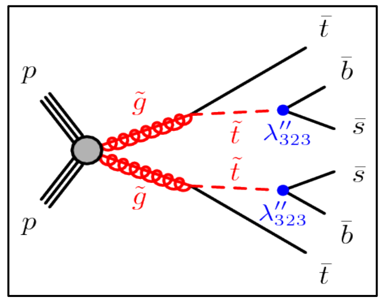
- **RPV SUSY signatures:**
  - Decaying LSP → lower Missing Transverse Energy (MET)
  - Many jets (or leptons) in the final states
  - Signatures showed: 1lepton + multi-jets (≥8-12) and (0, ≥3) bjets

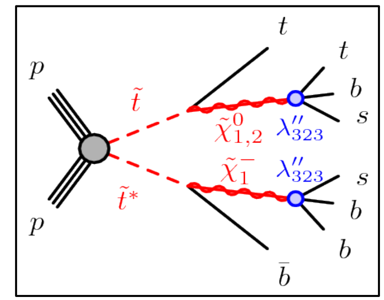
LQD

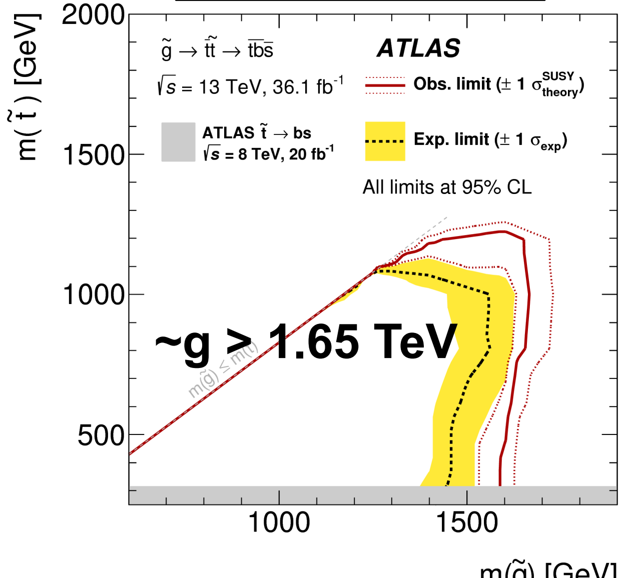


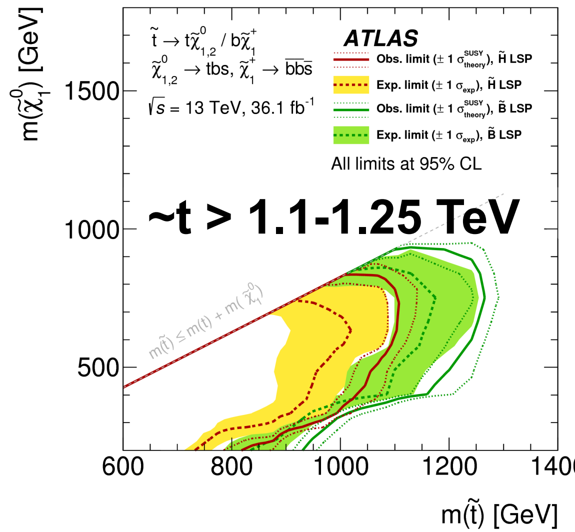




UDD

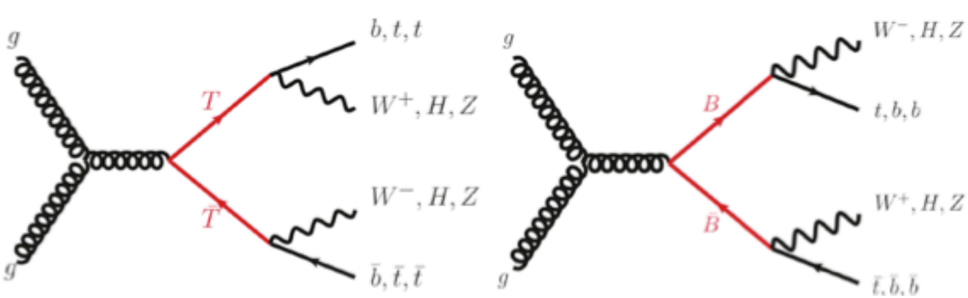


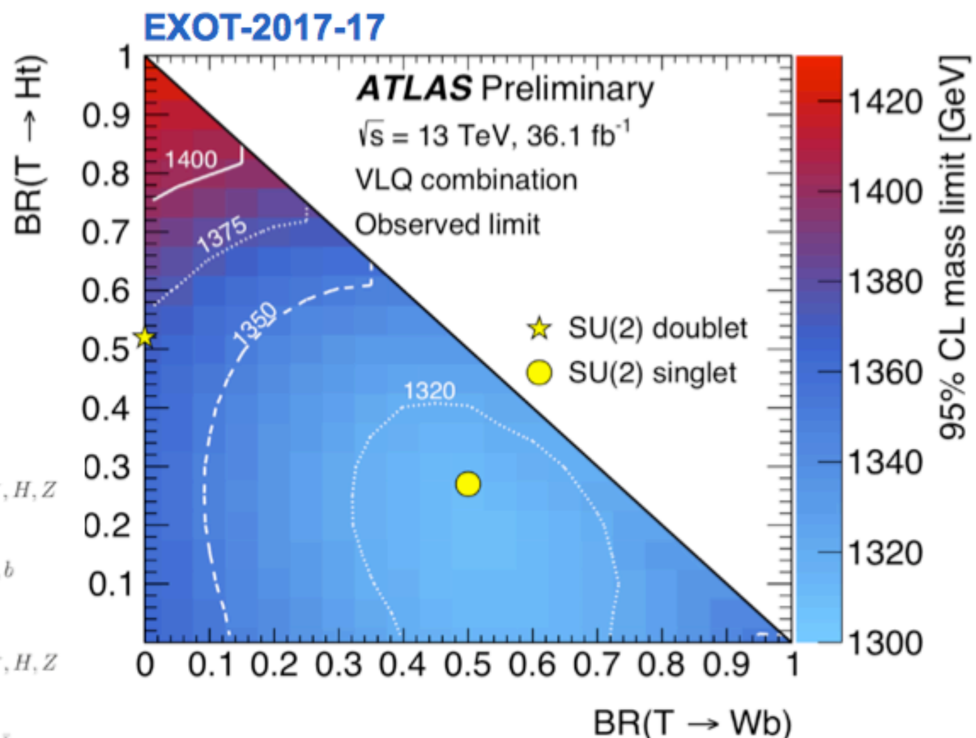




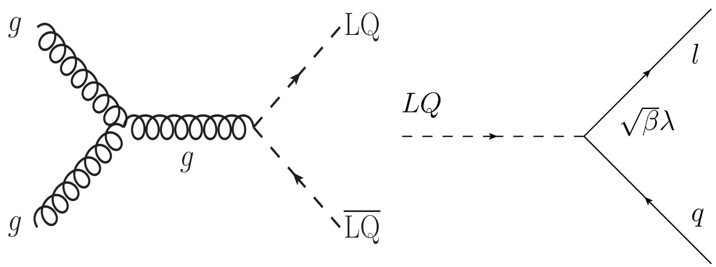
Heavy quarks

- **Vector-like T quark models solve hierarchy problem**
  - new heavy partner of top in loop
- Search of **T (q=2/3) and B (q=-1/3)** VLQ decaying to **W,H,Z and t,b** produced in **pairs**
- Recent **combination of 7 final states** (H(bb)t, W(lv)b, W(lv)t, Z(vv)t, Z(ll)t/b, trilepton/same-sign dilepton, fully hadronic)
- **Limits at the level of 1.3-1.4 TeV**





Leptoquarks



- **Leptoquarks (LQs) arise in many models, such as grand unified theories, compositeness models and superstring theories.**
- **LQs: carry colour charge, fractional electric charge, and both lepton and baryon quantum numbers.**
- **If exist, decay into a lepton and a quark. Search for resonance of lepton+jet in experiment.**

- **m(LQ1,LQ2) > 1.1TeV**
- **m(LQ3) > 0.9 TeV**

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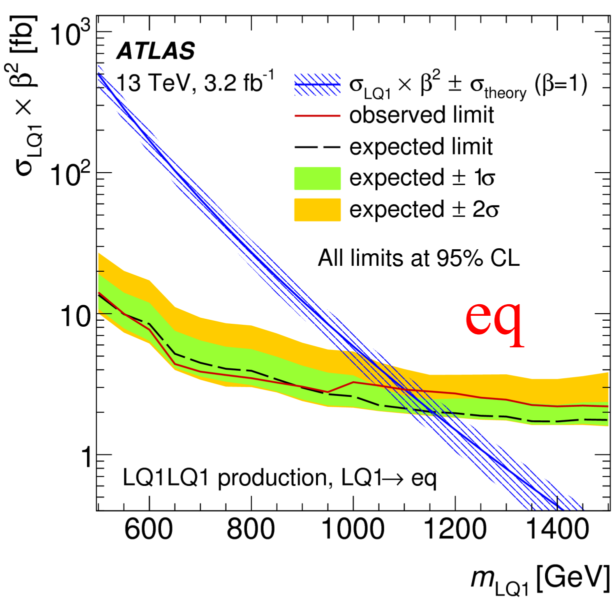
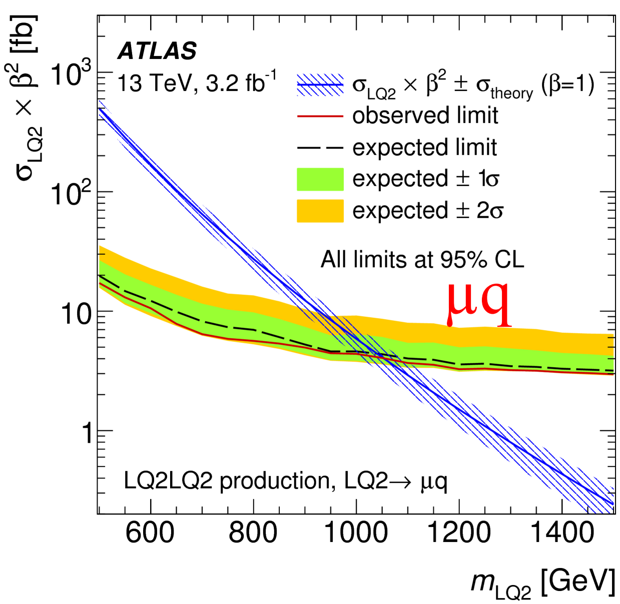
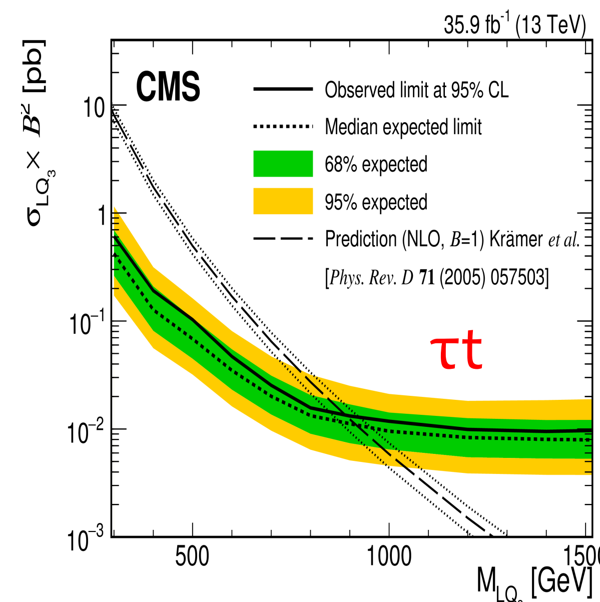
CMS-PAS-B2G-16-028

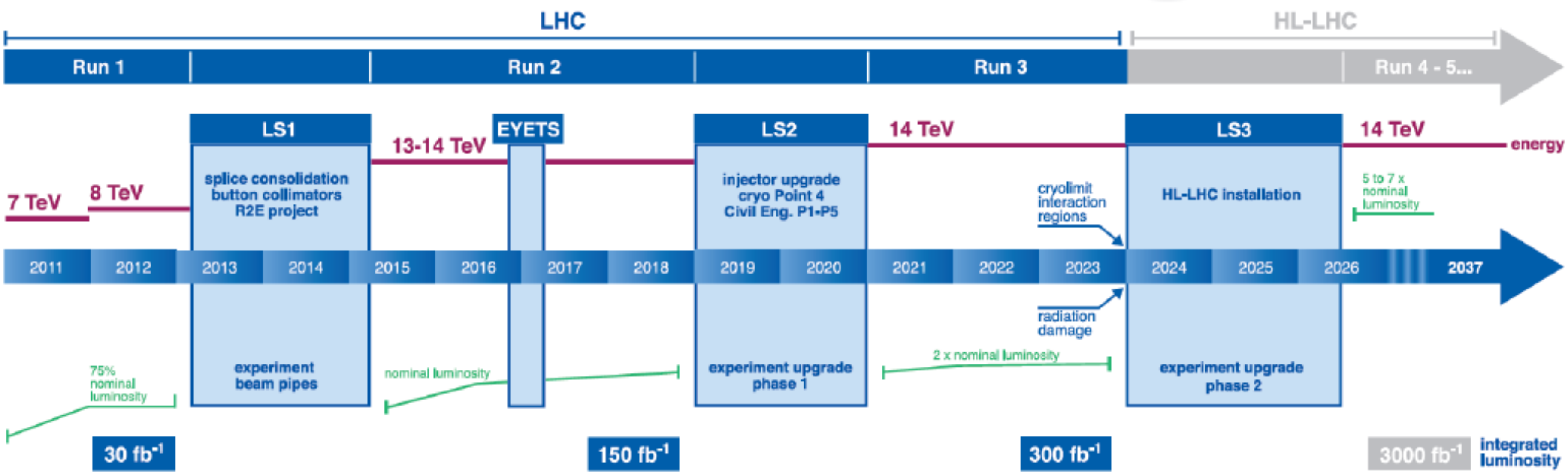


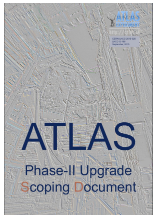




No significant excess observed in 2~36fb -1 . Results in terms of β = BR(LQ→lq)

LHC / HL-LHC Plan





ATLAS Phase-0

New inner pixel layer
Detector consolidation
2015: FTK deployment

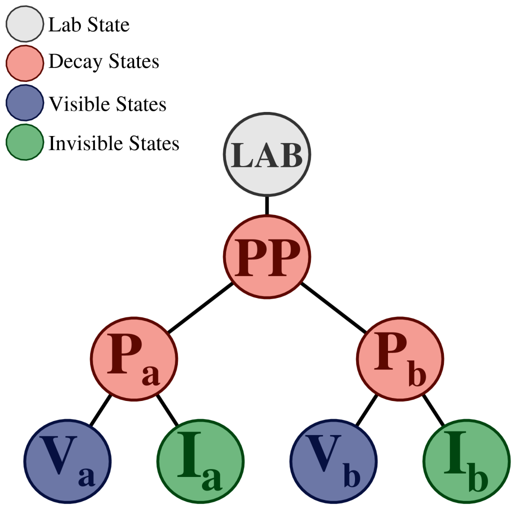
ATLAS Phase-1

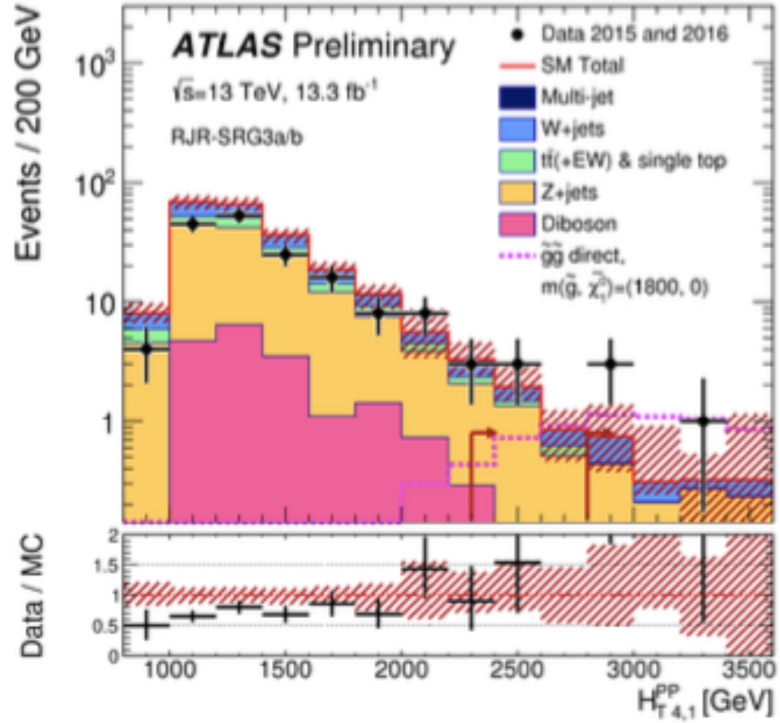
Improve L1 Trigger, NSW and LAr electronics to cope with higher rates

ATLAS Phase-2

Prepare for 140-200 pile-up events
Replace Inner Tracker
New L0/L1 trigger scheme
Upgrade muon/calorimeter electronics
Upgrade of DAQ detector readout

RJigsaw





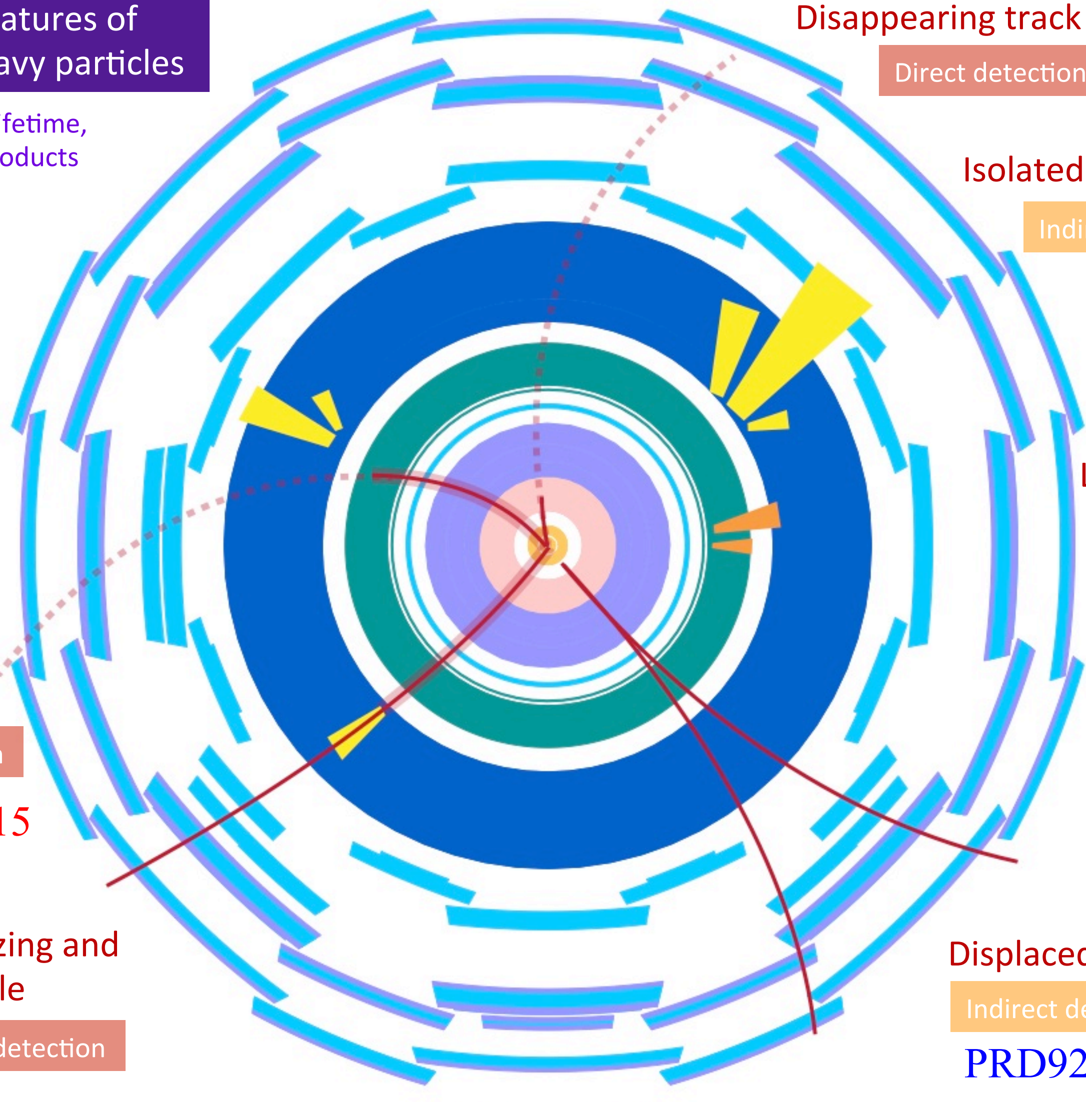
the complementary search using the **Recursive Jigsaw Reconstruction (RJR) techniques** in the construction of a discriminating variable set ('RJR-based search'). By using a dedicated set of selection criteria, the RJR-search improve the sensitivity to supersymmetric models with small mass splittings between the sparticles (models with compressed spectra).

Recursive jigsaw reconstruction
- based on assumption of decay tree
- fix set of rules to resolve combinatorics and unknowns in invisible system
- can form set of variables in the rest frame of each level in the decay tree

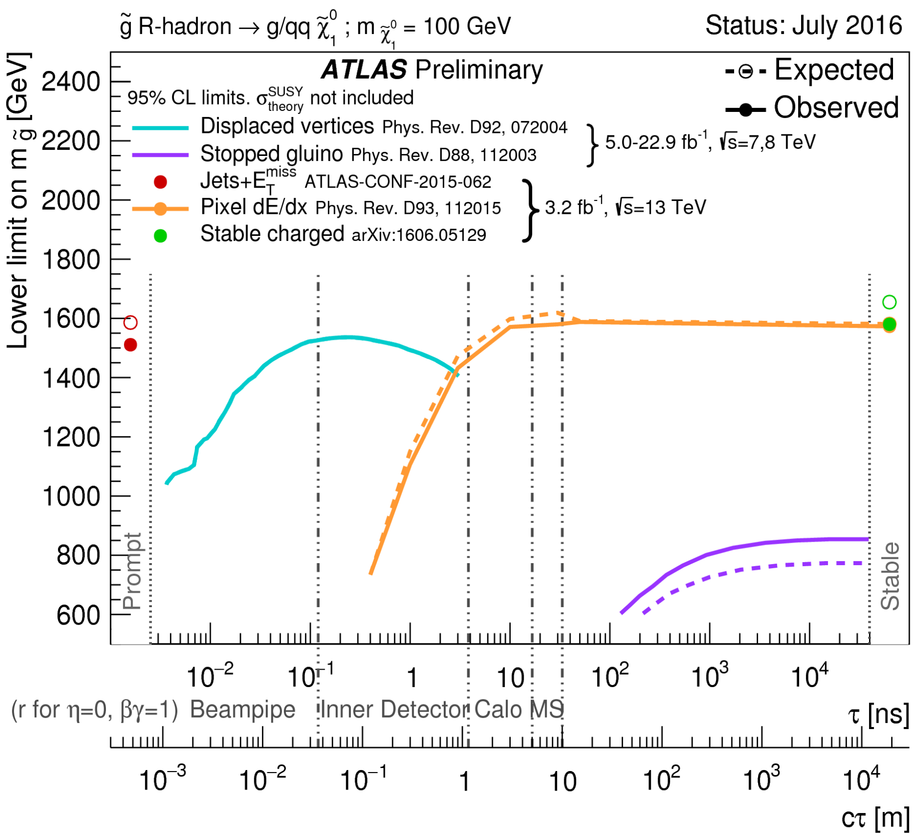
Long-Lived particles in SUSY

Detector signatures of long-lived heavy particles

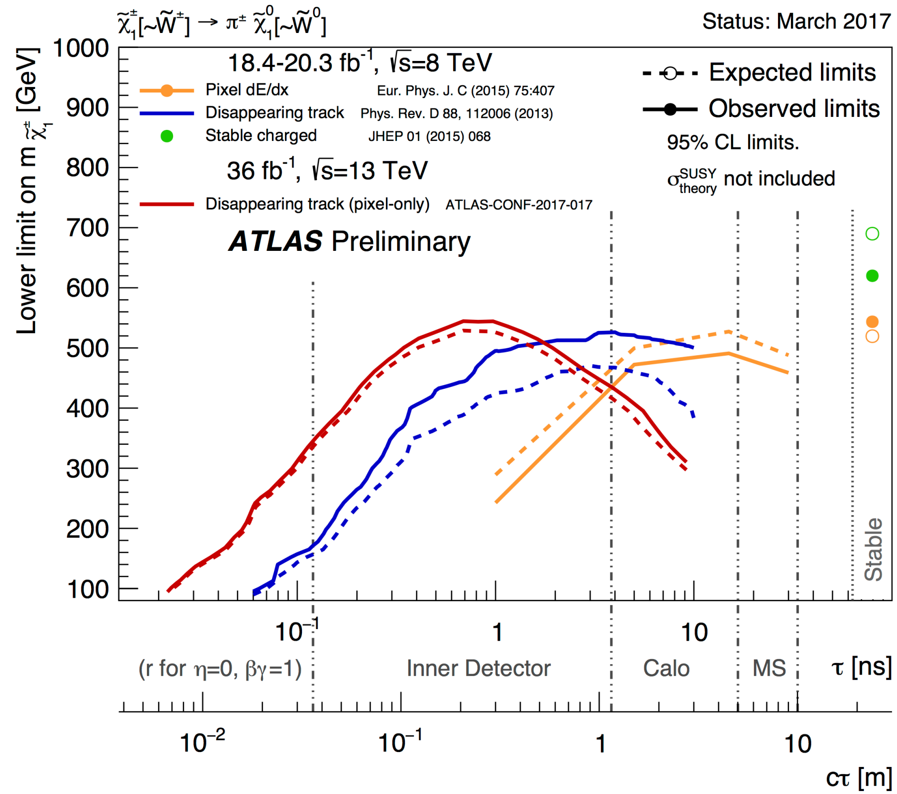
depends on LLP lifetime, mass, & decay products



Long-Lived particles in SUSY

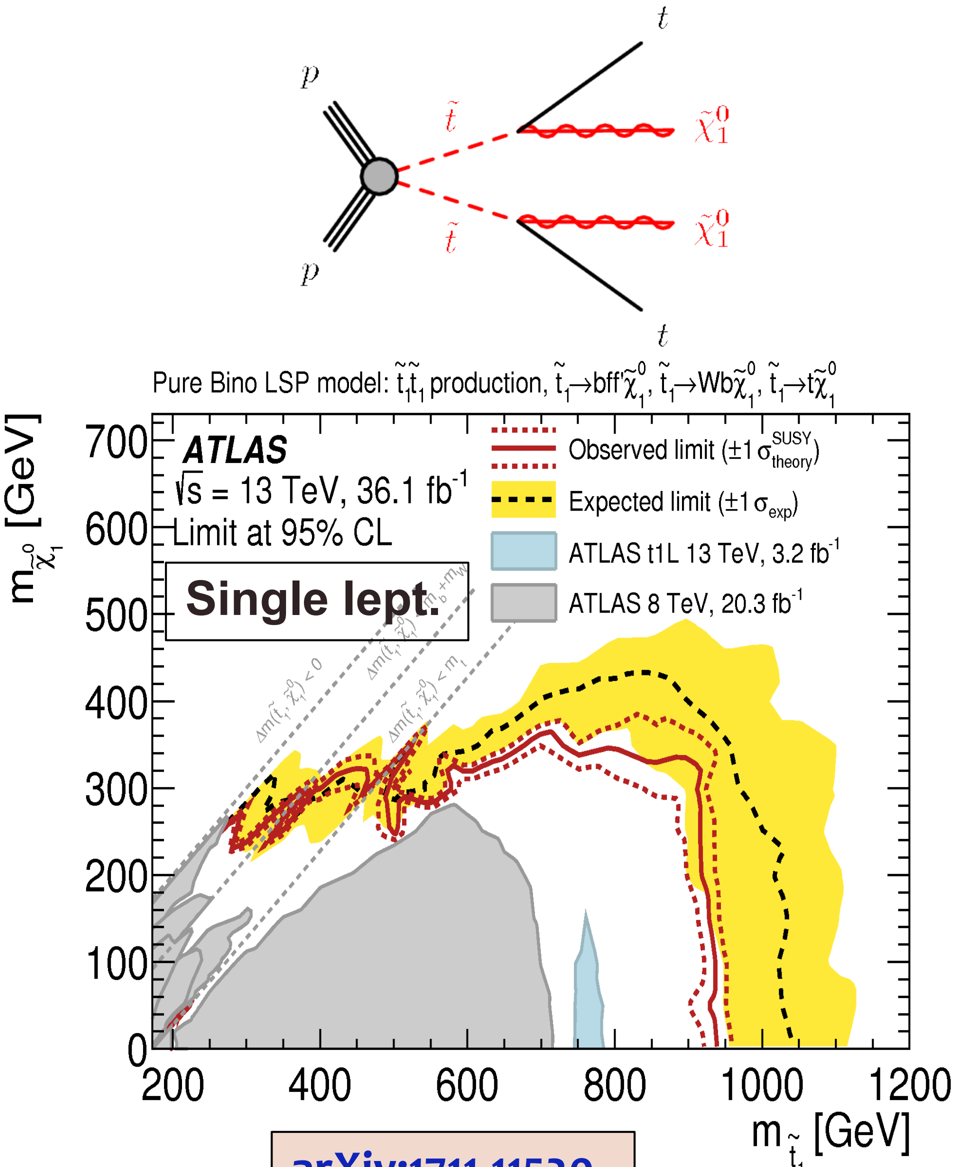


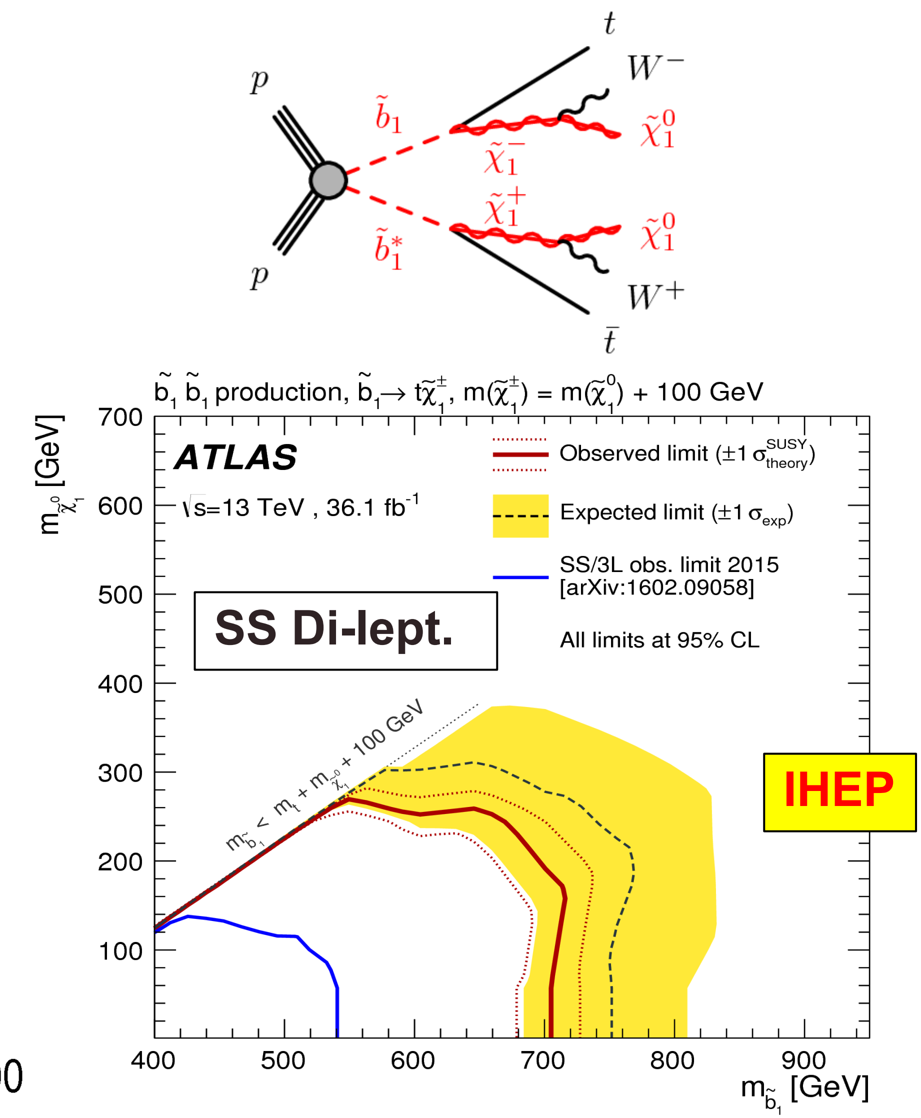
Long-lived R-hadron production



Long lived chargino

3rd Generation: stop/sbottom (leptonic)





arXiv:1711.11520

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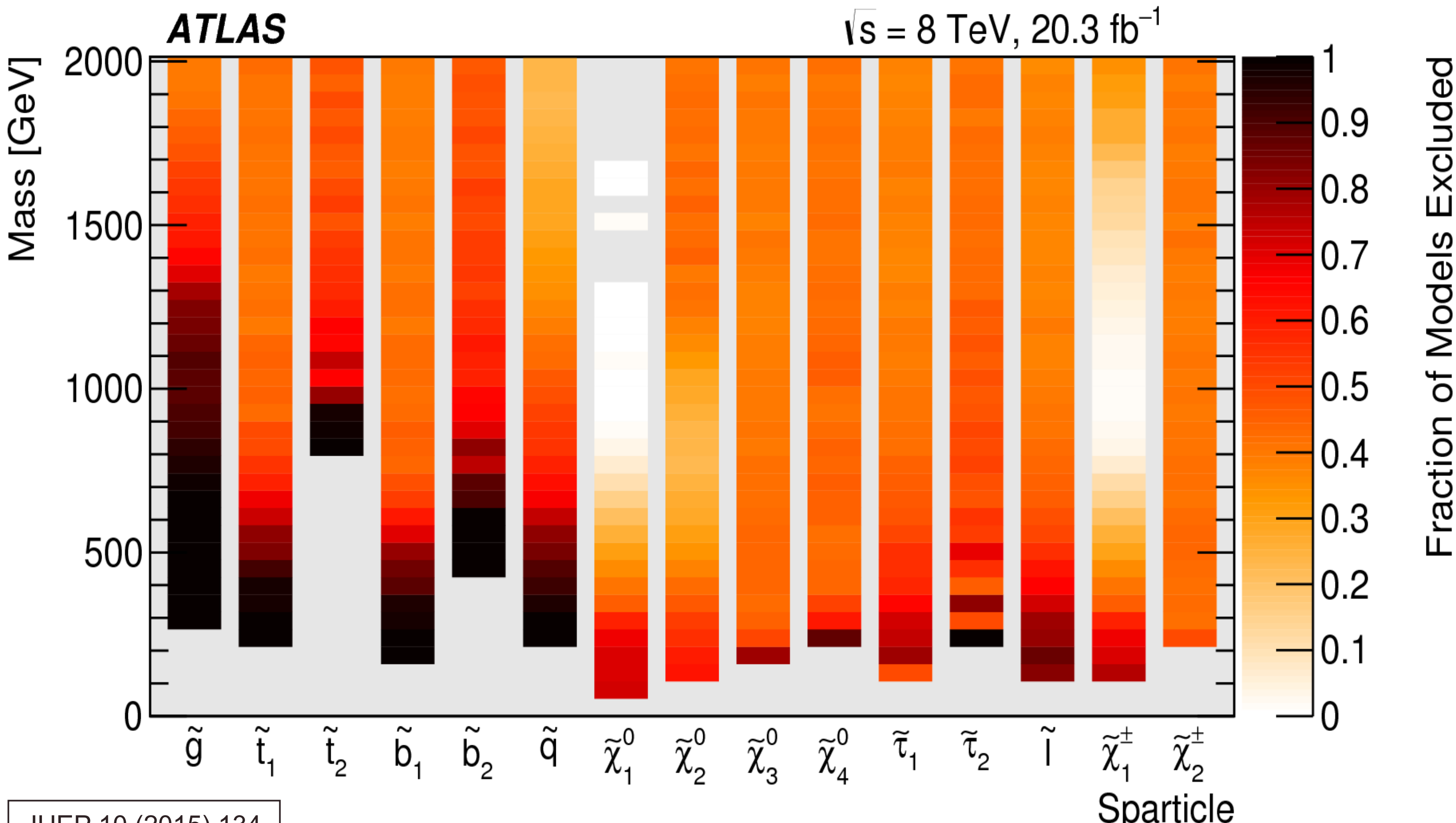
An attempt to map out the SUSY model space with all the ATLAS analyses, giving an impression of where SUSY could still hide …



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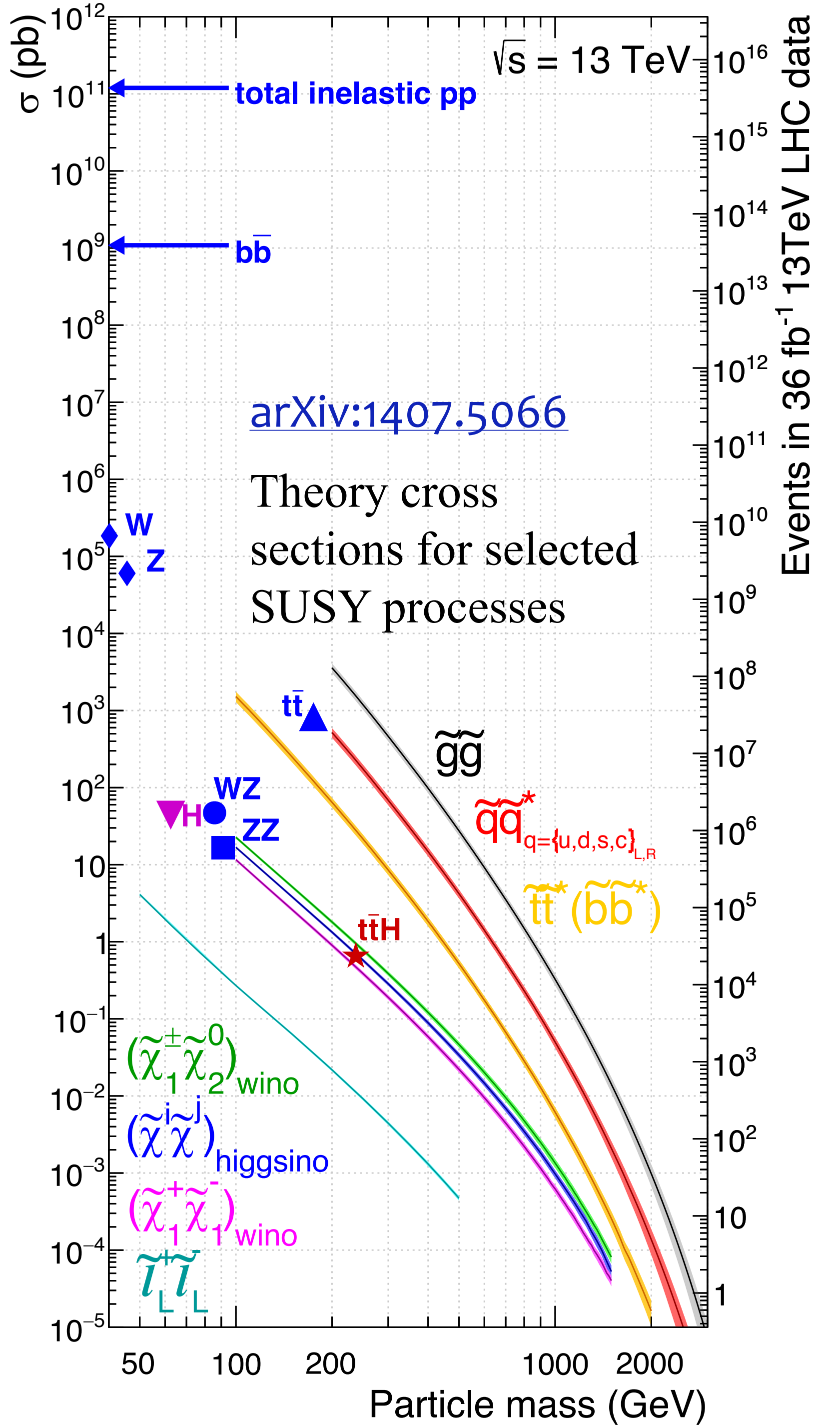
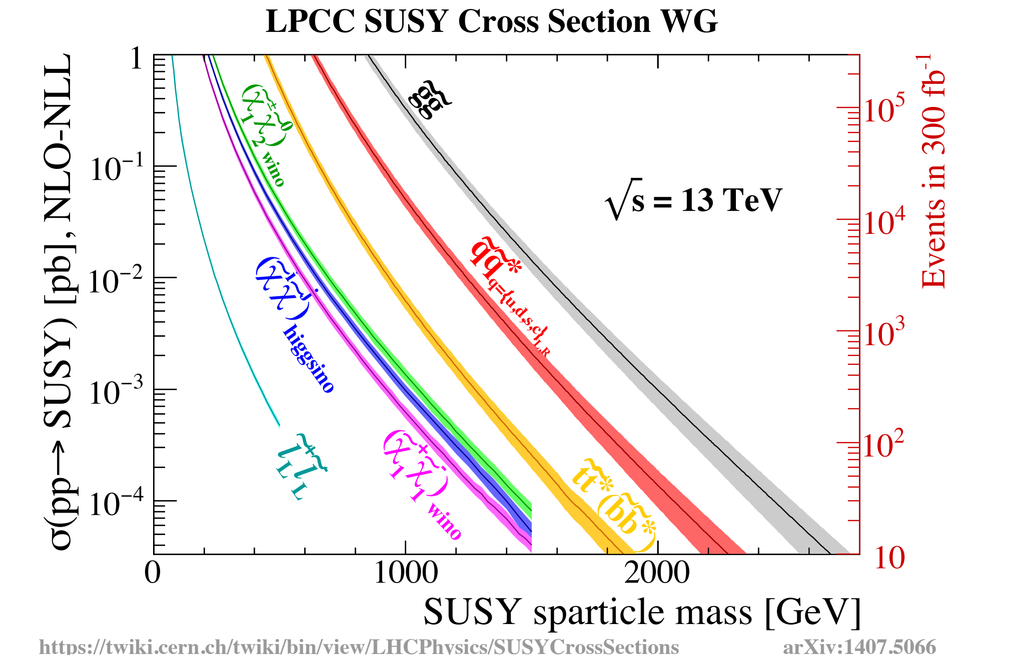
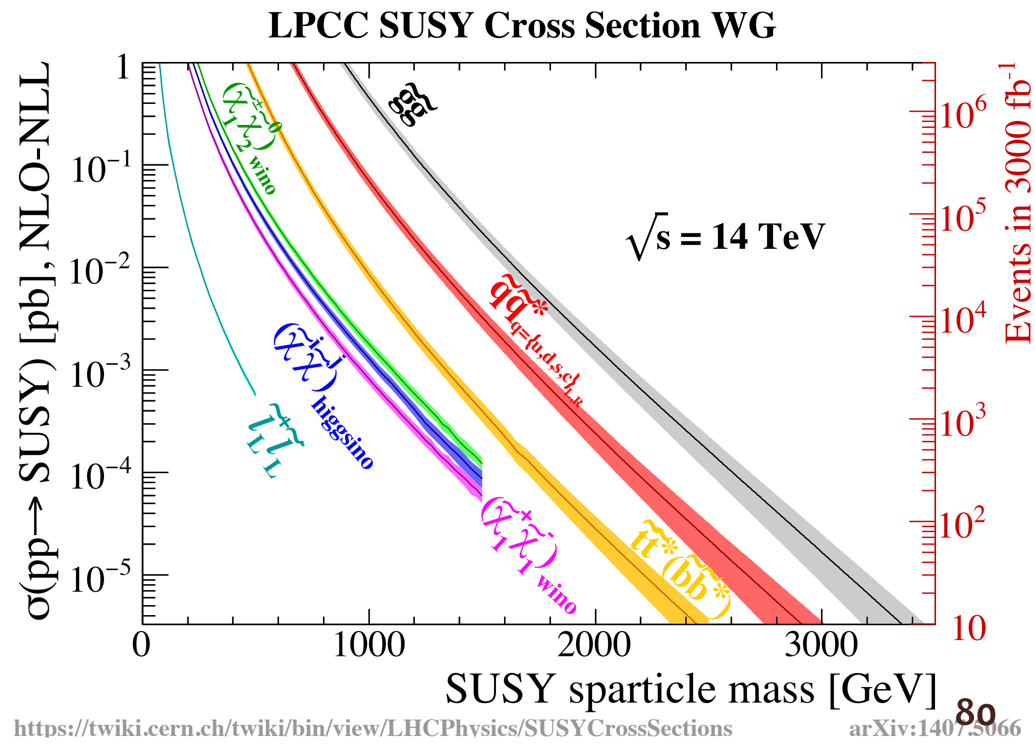
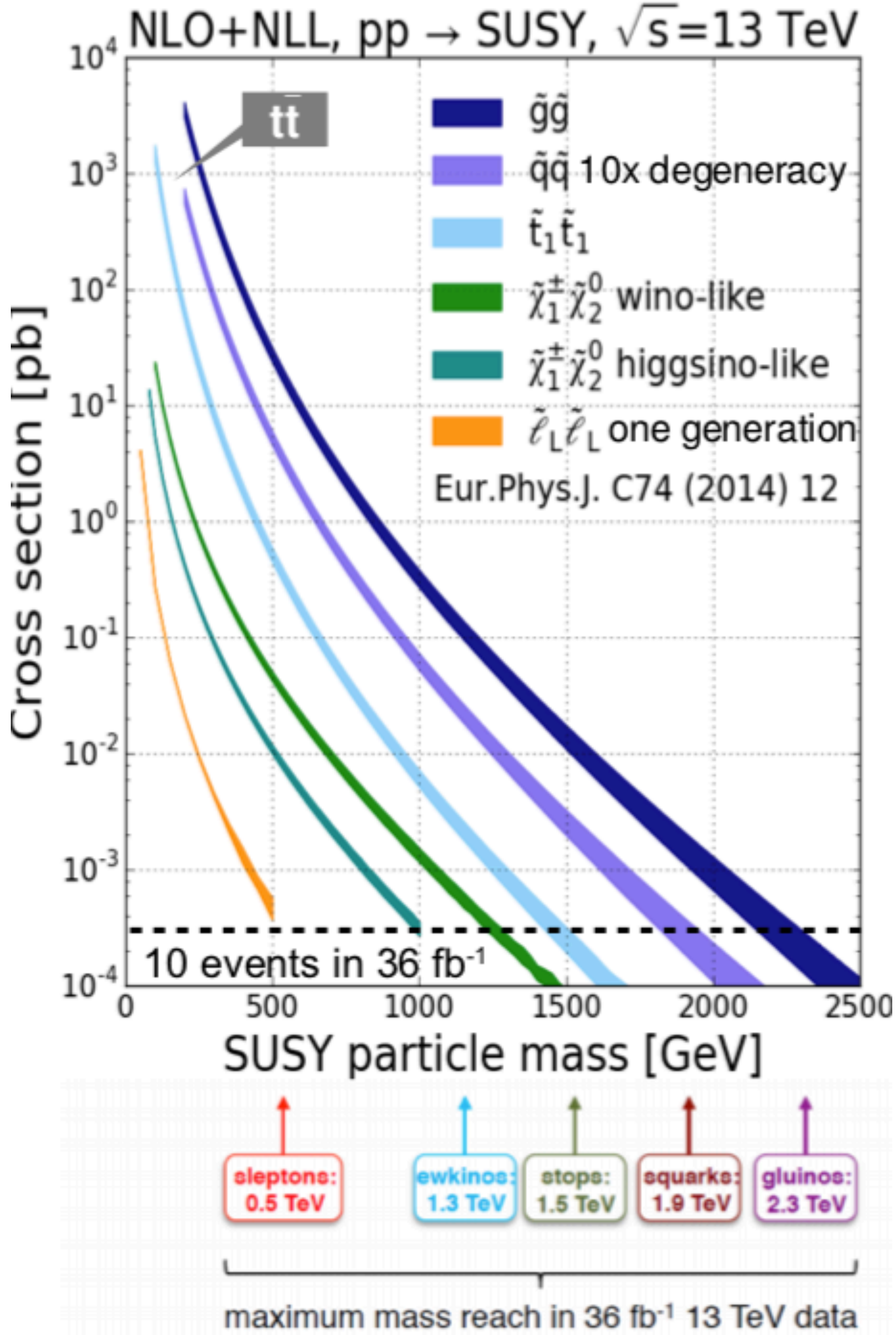

σ (pb)
√s = 13 TeV
total inelastic pp
bb̄
W
Z
arXiv:1407.5066
Theory cross sections for selected SUSY processes
tt̄
g̃g̃
q̃q̃* q={u,d,s,c} L,R
t̃t̃* (b̃b̃*)
WZ
H
ZZ
tt̄H
(χ̃±1χ̃02)wino
(χ̃iχ̃j)higgsino
(χ̃+1χ̃-1)wino
l̃+L l̃-L
Particle mass (GeV)
Events in 36 fb-1 13TeV LHC data


LPCC SUSY Cross Section WG
σ(pp→ SUSY) [pb], NLO-NLL
√s = 13 TeV
Events in 300 fb-1
SUSY sparticle mass [GeV]
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections
arXiv:1407.5066


LPCC SUSY Cross Section WG
σ(pp→ SUSY) [pb], NLO-NLL
√s = 14 TeV
Events in 3000 fb-1
SUSY sparticle mass [GeV]
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections
arXiv:1407.5066


NLO+NLL, pp → SUSY, √s=13 TeV
tt̄
g̃g̃
q̃q̃ 10x degeneracy
t̃₁t̃₁
χ̃±1 χ̃02 wino-like
χ̃±1 χ̃02 higgsino-like
ℓ̃L ℓ̃L one generation
Eur.Phys.J. C74 (2014) 12
Cross section [pb]
10 events in 36 fb-1
SUSY particle mass [GeV]
sleptons: 0.5 TeV
ewkinos: 1.3 TeV
stops: 1.5 TeV
squarks: 1.9 TeV
gluinos: 2.3 TeV
maximum mass reach in 36 fb-1 13 TeV data