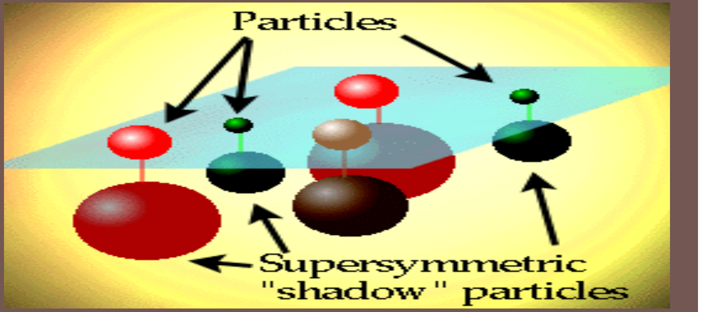
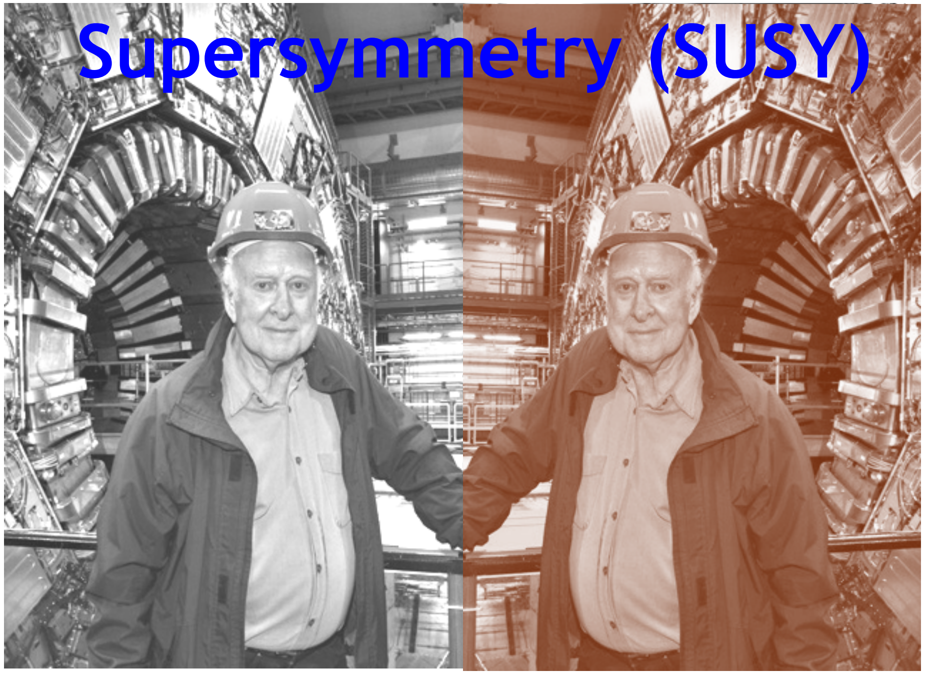


Supersymmetry (SUSY)



ATLAS SUSY STUDY FROM IHEP

Xuai Zhuang (庄胥爱)

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IHEP, Beijing, China

Nov. 3 2017 创新团队年会

中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

中國科學院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

SM and Beyond

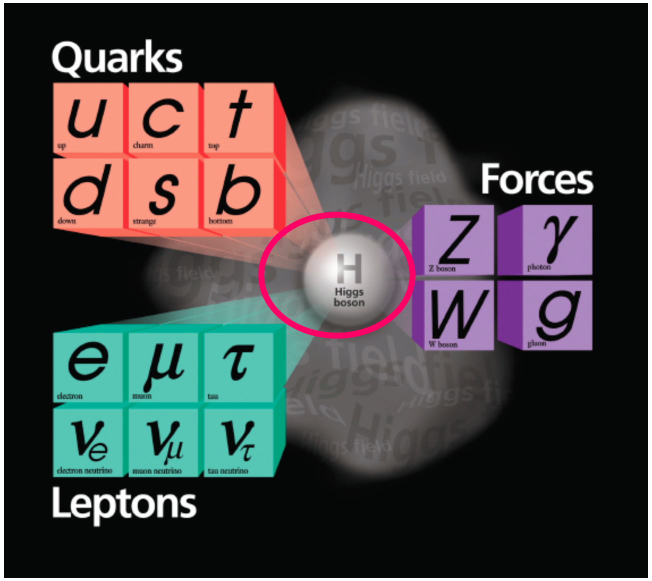


Photo: A. Mahmoud

François Englert

Photo: A. Mahmoud

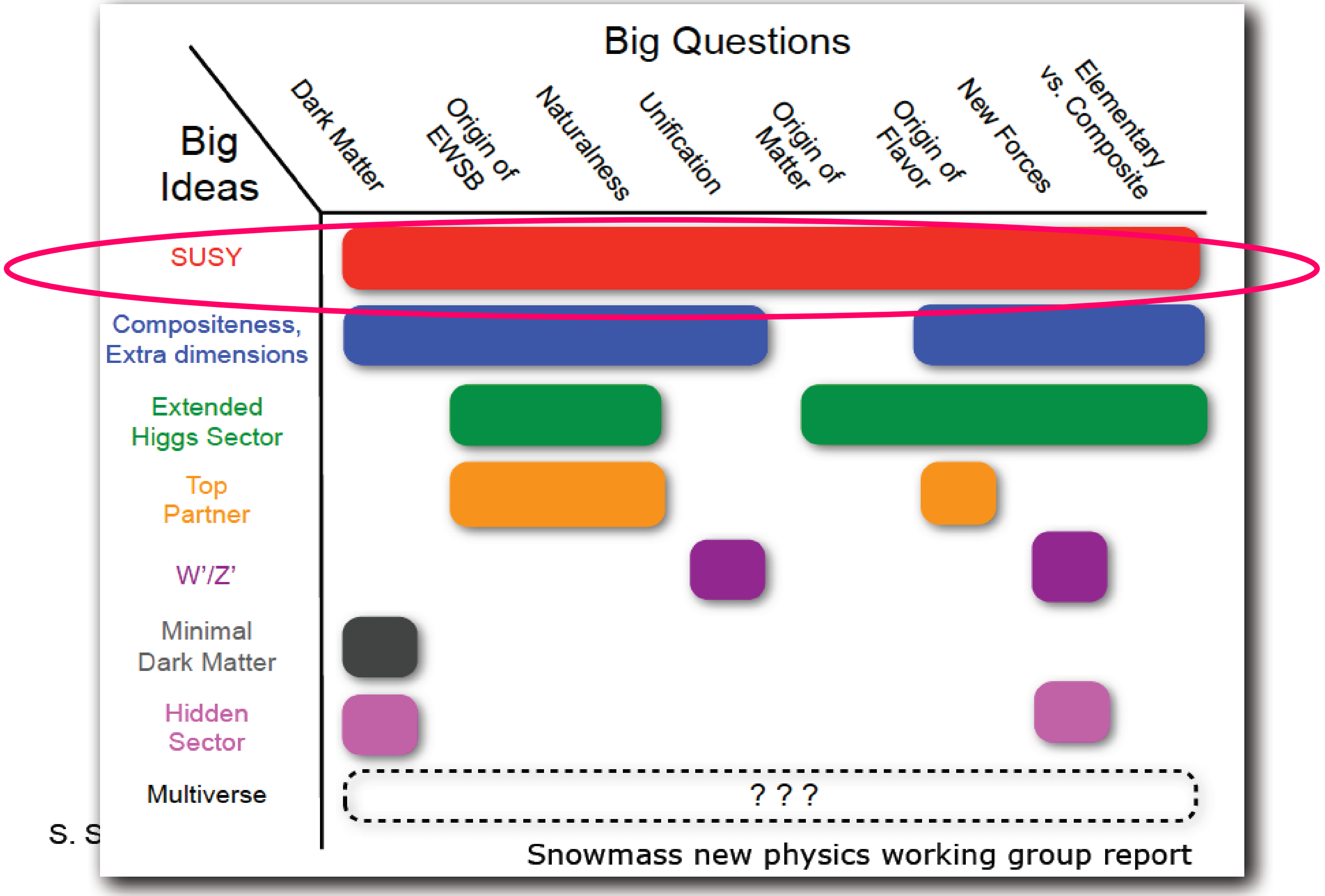
Peter W. Higgs

The Nobel Prize in Physics 2013

François Englert, Peter Higgs

- Higgs boson observed, SM fits the experimental data very well ➔ big success in EW scale
- While has problem in Planck scale:
  - Naturalness and "hierarchy" problem
  - Unification of gauge coupling
  - Dark Matter
  - ……
- Need a more fundamental theory in which SM is only a low-energy approximation ➔ **New Physics**

New Physics beyond the SM

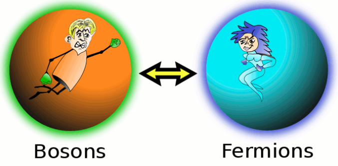


Snowmass new physics working group report

S. S

- **If SUSY is at TeV scale, it will be produced copiously at LHC**
- **SUSY search is one of the most hot topic at LHC and beyond**

SUSY Introduction

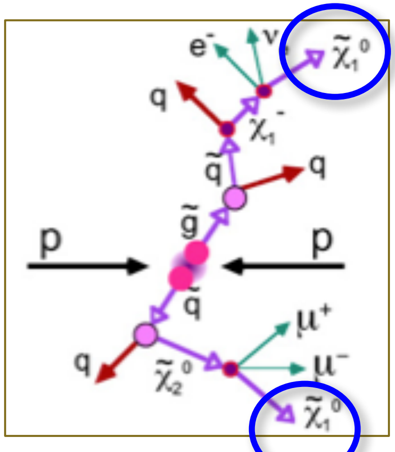


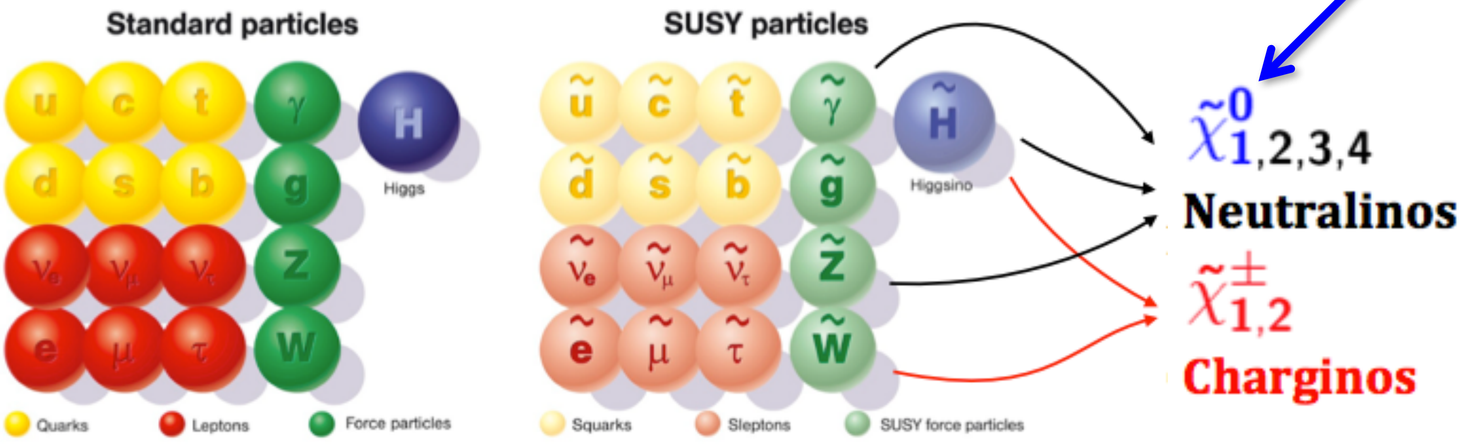
- **A symmetry which unified fermions (matter) and bosons (forces)** -> A fundamental theory
- **Conserved R parity (RPC):** (originally introduced for stability of proton)

$$R = (-1)^{3(B-L)+2S}$$

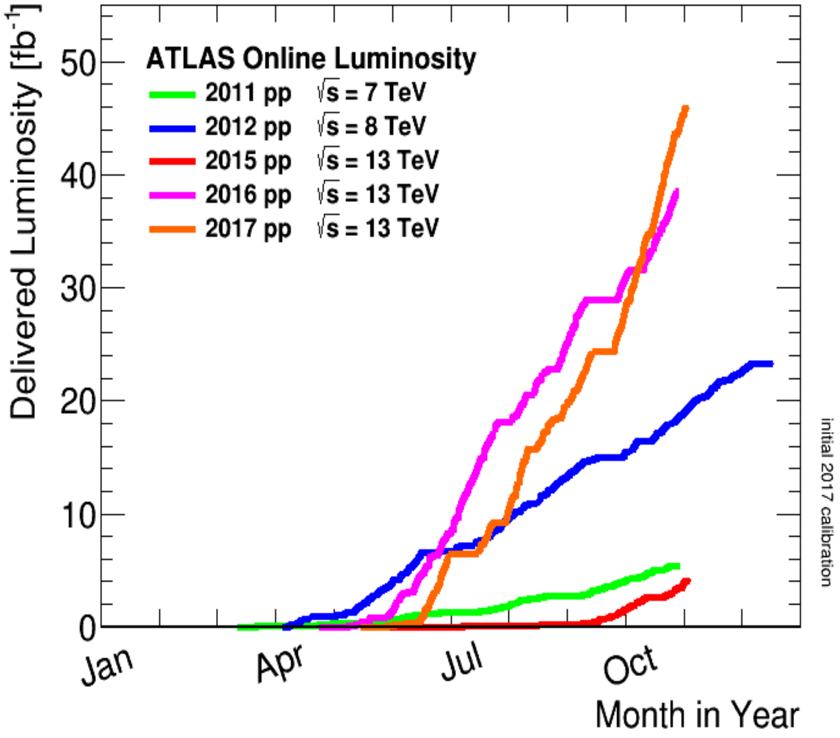
R=+1 (SM)
R=-1 (SUSY)

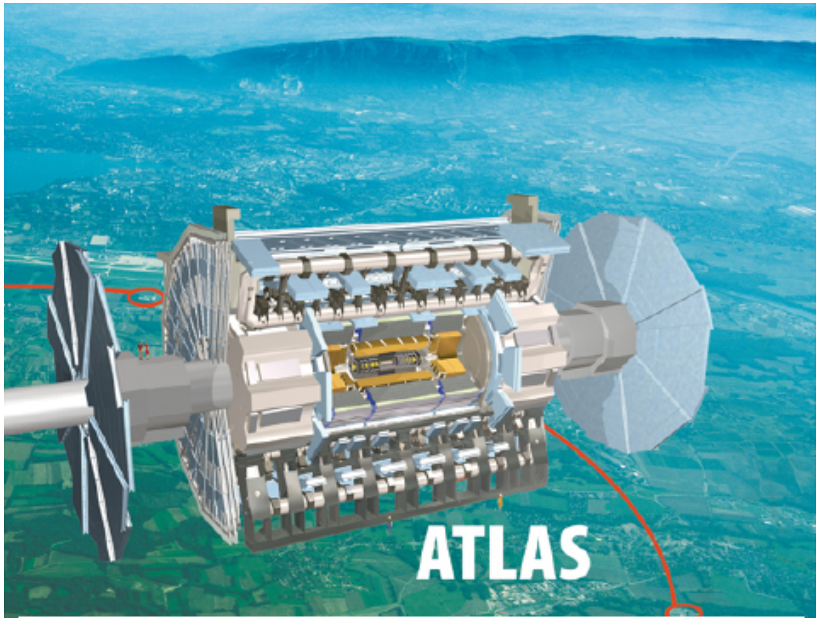
  - SUSY particles produced/annihilated in pairs
  - Lightest SUSY particle (LSP) stable (DM candidate)
  - Typical signature: jets/leptons/photons + **MET**
- **Violated R parity (RPV):** no Dark Matter candidate





Since 2010, ATLAS&CMS have invested huge efforts in SUSY search @LHC : Great Luminosity recorded





Run1:
~ 35 pb^{-1} 7 TeV data (2010)
~ 5 fb^{-1} 7 TeV data (2011)
~ 20 fb^{-1} 8 TeV data (2012)

Run2:
~ 3 fb^{-1} 13 TeV data (2015)
~ 33 fb^{-1} 13 TeV data (2016)
~ 43 fb^{-1} 13 TeV data (2017)

The results are based on 36 fb^{-1} @ 13 TeV (RUN2 2015-2016)

SUSY Search Topics @ IHEP

Strong production: targeting gluino and squarks (Inc. 3rd gen. squarks)

- ❑ Generic signatures :

  Multi -jets + n_lepton/n_photon(n=0,1, ≥2) + large E_T^{miss} (0L,**1 L, >=2L**)

- ❑ **IHEP topics:**
  - ② **** 1L +jets +MET (Run1+Run2)***
  - ③ **SS/3L +jets +MET (Run2)**

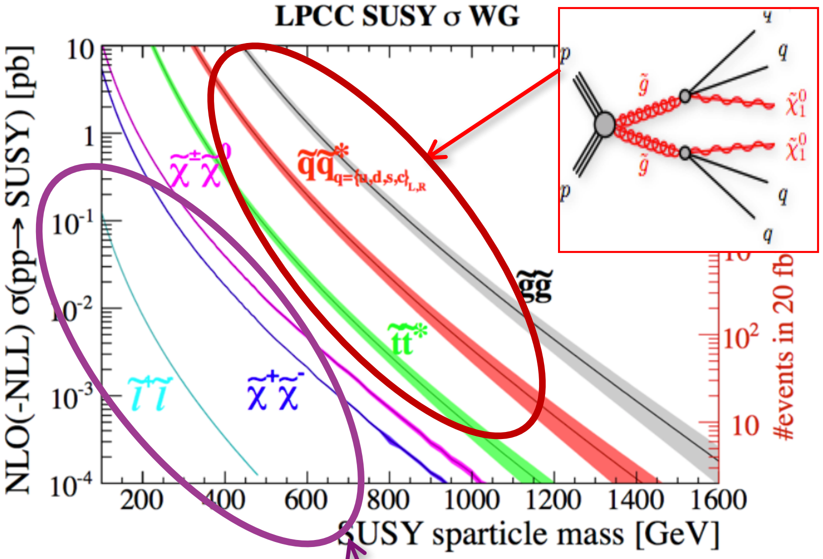
Weak production: targeting charginos, neutralinos and slepton

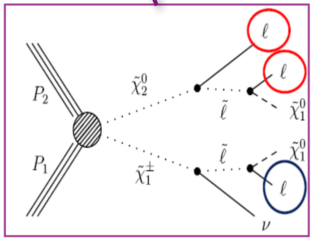
- ❑ Generic signatures:

  low–jet multiplicity + ≥ 2leptons + large E_T^{miss} (2/3/4L, **>=2tau**)

- ❑ **IHEP topic:**
  - ① **** >=2tau+MET (Run1 + Run2)***

- ****Analysis Contacts***
- **very wide coverage on SUSY search from IHEP: strong + EW**

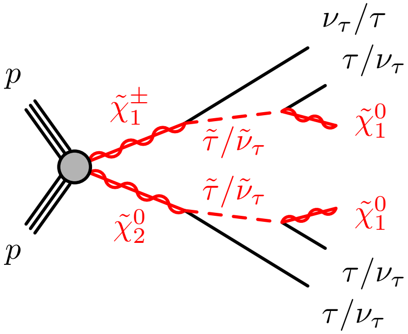


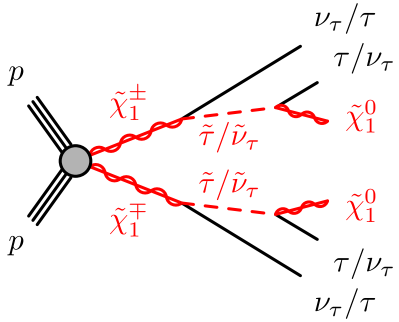


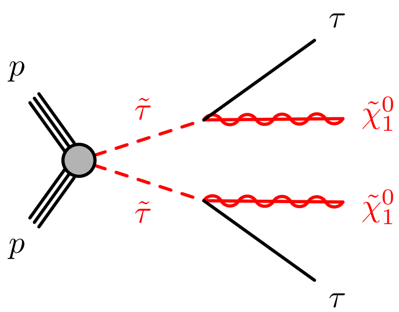
[1] EWK-2tau SUSY search

Run2

- Charginos and neutralinos are superpartners of the EW gauge bosons and Higgs bosons
- Naturalness suggests charginos and neutralinos should be light, could be the dominant SUSY production in LHC
- IHEP member firstly proposed the search for gaugino and stau with final state: 2tau + MET, which is also the first search in LHC experiment.
- IHEP play a leading role: contact person & editor/approval talks



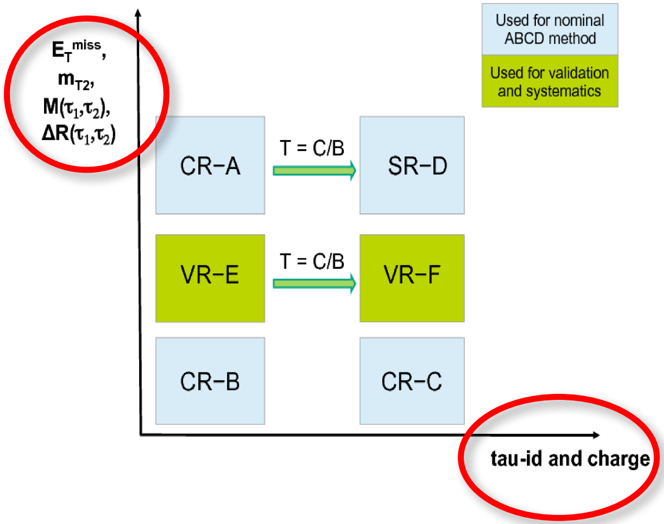




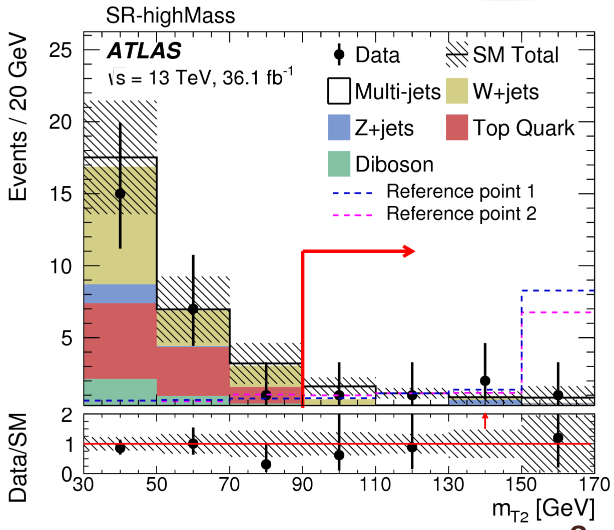
Results

- **2 SRs targeting different scenarios and mass parameter regions: 1 for low-Mass and 1 for high-Mass**
- **Main backgrounds:**
  - **Fake tau: W (normalized MC to data in WCR) and multi-jet (ABCD method)**
  - **Real tau: Diboson (MC simulation)**
- **ABCD method:**
  - **Extrapolation performed from A to D through TF (D = A * C/B)**
  - **Validation Region (Multi-jet VR-EF): used for validation and systematics**

Illustration of “ABCD” method

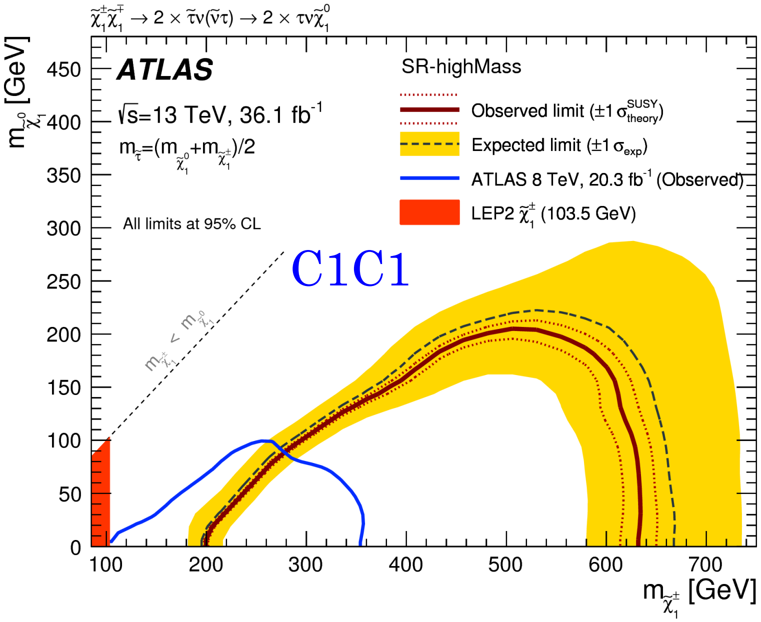


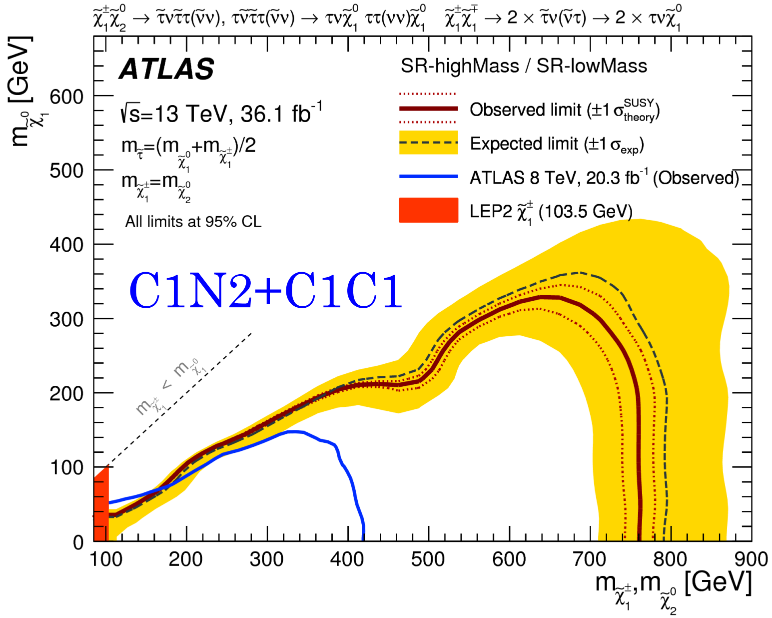
- **Good data/SM estimation in validation regions**
- **No significant excess in SRs, so set exclusion limit**

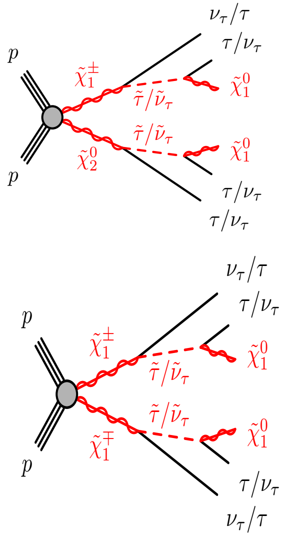


Exclusion Limits

arXiv:1708.07875





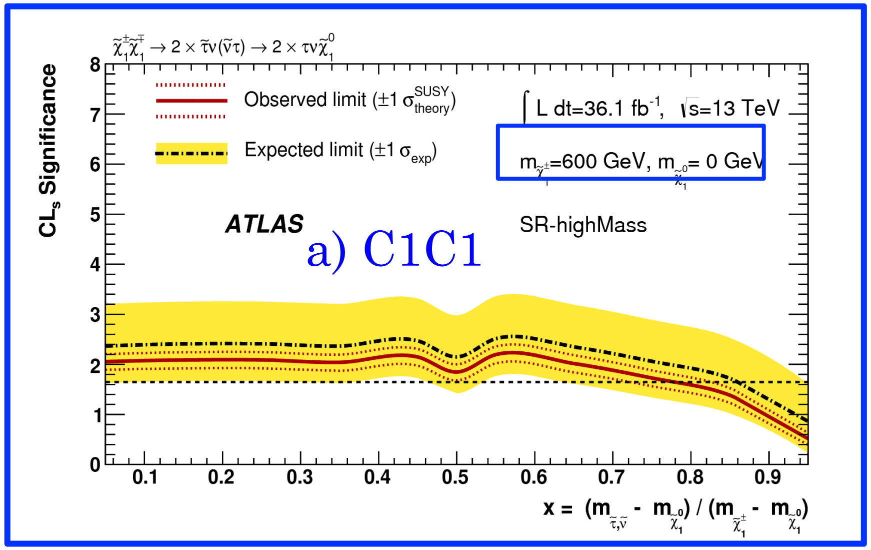


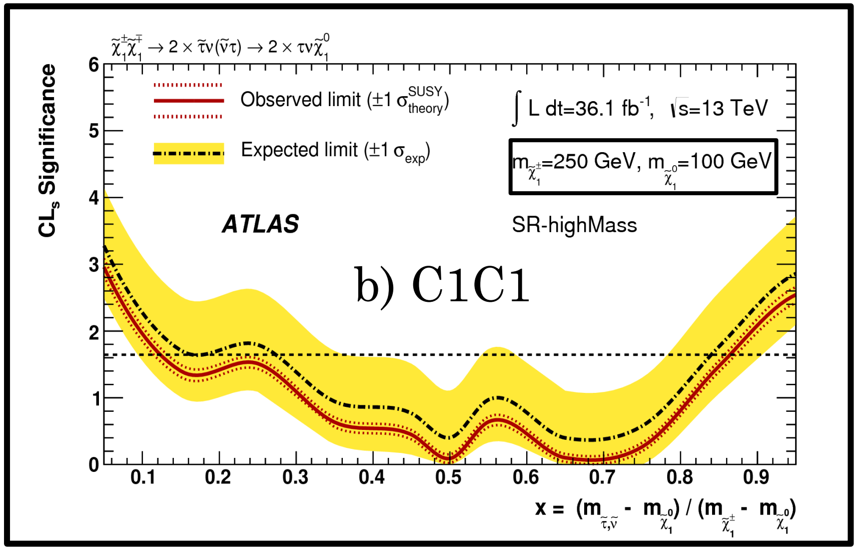
- **The results arXiv:1708.07875 have been submitted to EPJC and showed at LHCP2017 conference**
  - **C1N2+C1C1 production: C1/N2 mass up to 760 GeV excluded for massless N1**
  - **Wino-like Chargino (C1C1) production : C1 mass up to 630 GeV excluded for a massless N1**
- **Direct stau search for 13 TeV data is still going-on, first sensitivity at 95% from LHC by end of 2017?**

The CLs significance as a function of x

$$m(\tilde{\tau}_{\mathrm{L}}) = m(\tilde{\chi}^0_1) + x \cdot \left(m(\tilde{\chi}^\pm_1) - m(\tilde{\chi}^0_1)\right)$$

arXiv:1708.07875





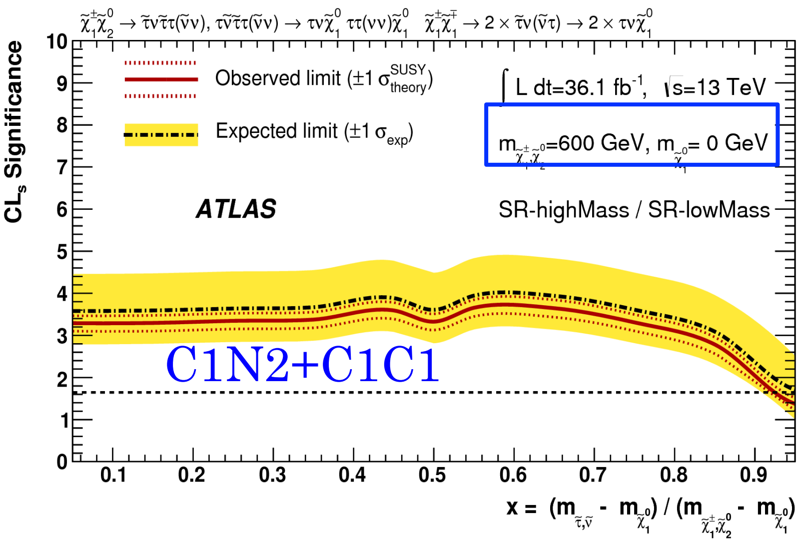
a) **When only C1C1 production is considered, the benchmark scenario with large mass-splitting (600,0) can be excluded for x up to 0.75. For larger values of x, the pT spectra of the tau from the chargino decay become very soft.**

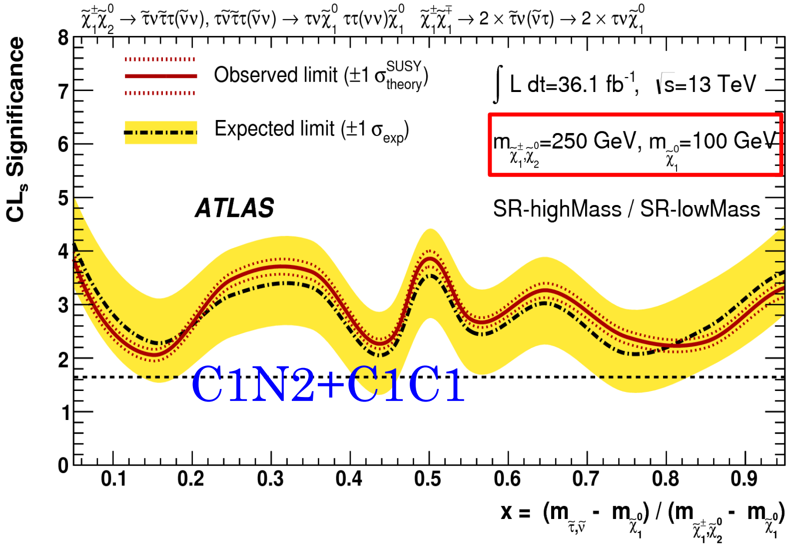
b) **The compressed benchmark scenario (250,100) can only be excluded for the extreme cases with x = 0.05 or x = 0.95 since the mT2 requirement is more effective for models with large mass-splittings between C1 or the staus and N1.**

The CLs significance as a function of x

arXiv:1708.07875

$$m(\tilde{\tau}_{\mathrm{L}}) = m(\tilde{\chi}_1^0) + x \cdot \left(m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)\right)$$

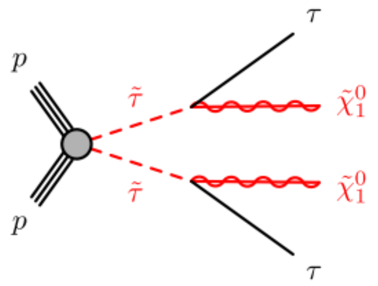




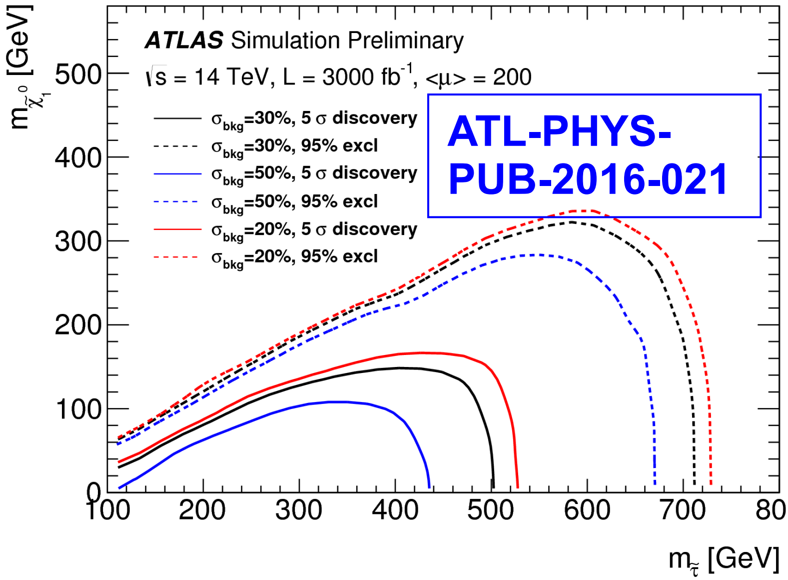
- For combined production of C1C1 and C1N2, the same general features are observed, but due to the higher signal yields with respect to C1C1 production alone, both benchmark scenarios can be excluded for all considered values of x.

Direct stau upgrade study

upgrade



Solid line：5σ discovery
Dashed line：95% exclusion



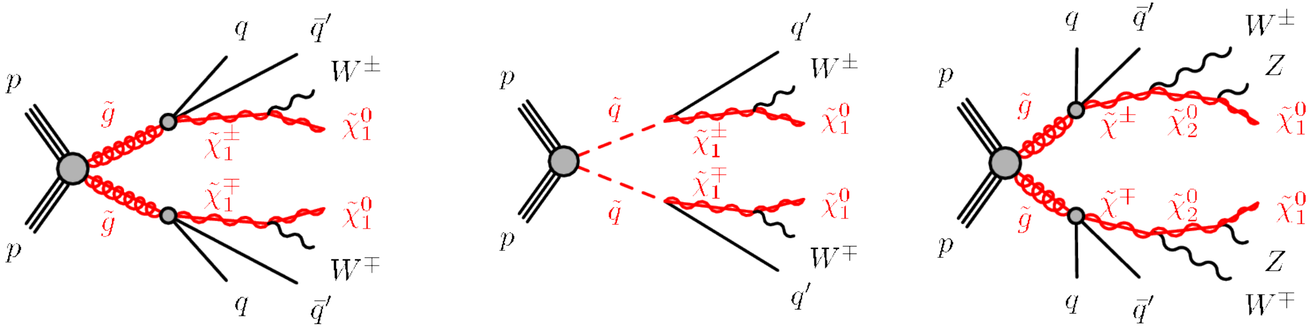
ATL-PHYS-PUB-2016-021

- **The direct stau search sensitivity has been studied for HL-LHC (14TeV 3000 fb^{-1}) at last year (ATL-PHYS-PUB-2016-021)**
- **For a massless LSP, the 5σ discovery sensitivity (exclusion) reaches up to 500 (700) GeV in stau mass (30% syst.).**
- **The ditau trigger for upgrade study will complete soon, which will contribute to upgrade TDAQ TDR (end by mid. of Dec.)**

[2] 1L SUSY search

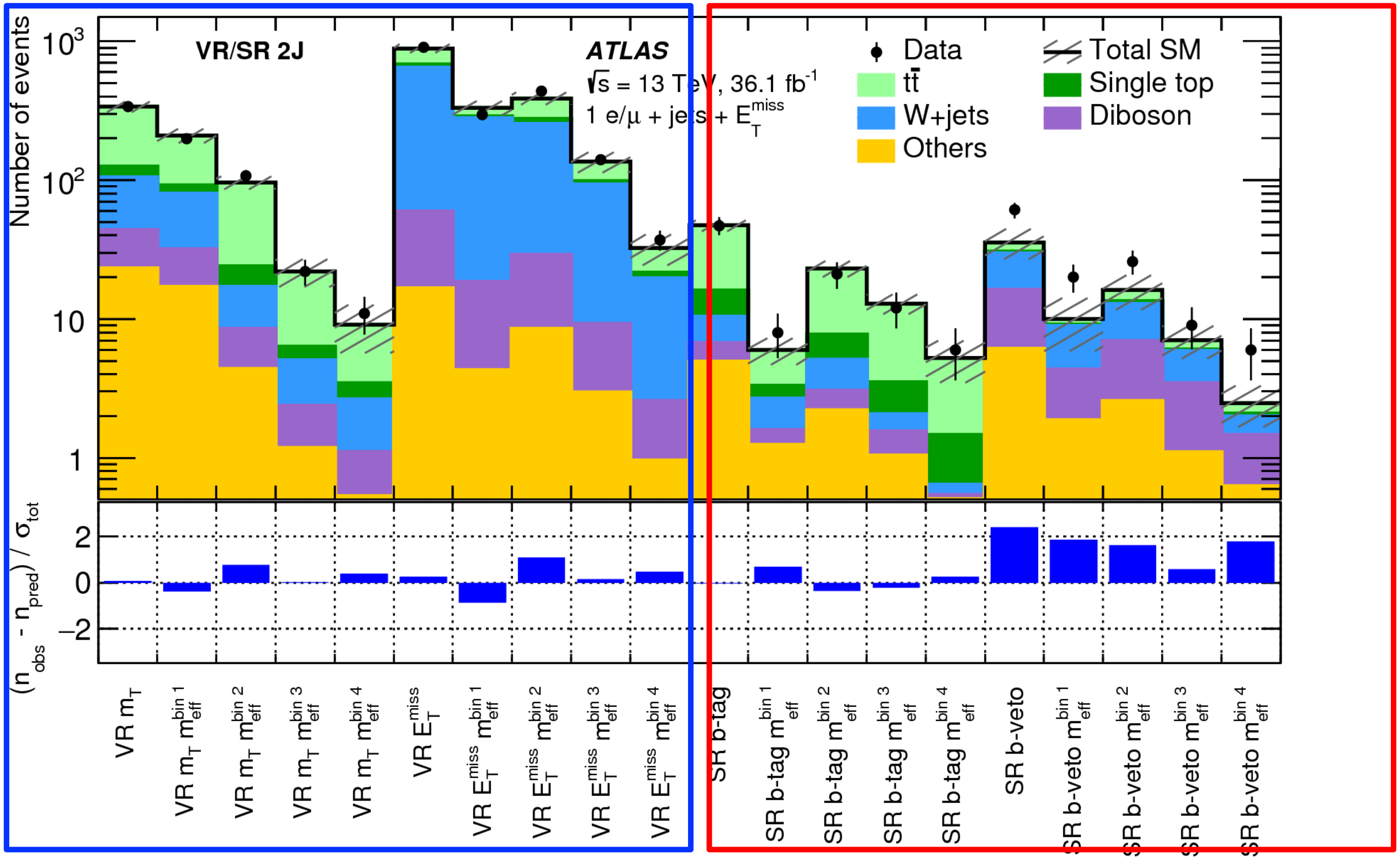
Run2

- Search for gluinos/squarks decaying via charginos and neutralinos with 1l + jets + MET → hot topic for first data due to large xsec and low bg from lepton requirement



- 5 SRs defined targeting different search scenarios :
  - 4 exclusive SRs targeting the gluino/squark one step models.
    - 2J SR (compressed), 4J high-x SR (LSP=60, x~1), 4J low-x SR (LSP=60, x~0), 6J SR (x=0.5)
    - Each SR binned with b-tag/b-veto and meff, simultaneous fit for 28 bins
  - 1 SR (9J SR) targeting gluino two step model and pMSSM.
- Main backgrounds: ttbar and W+jets, normalized MC to data in TCR and WCR, and validated in VRs

Results

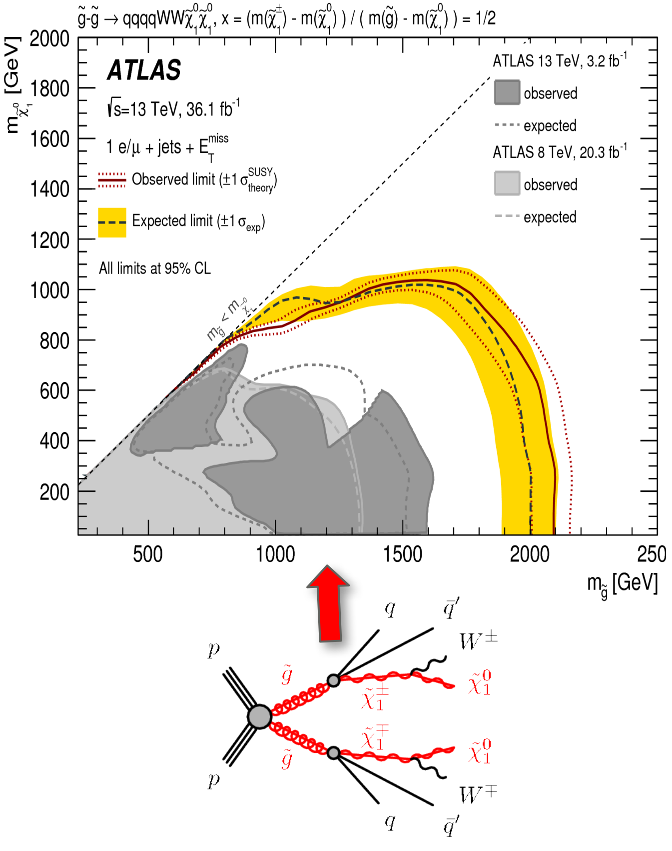


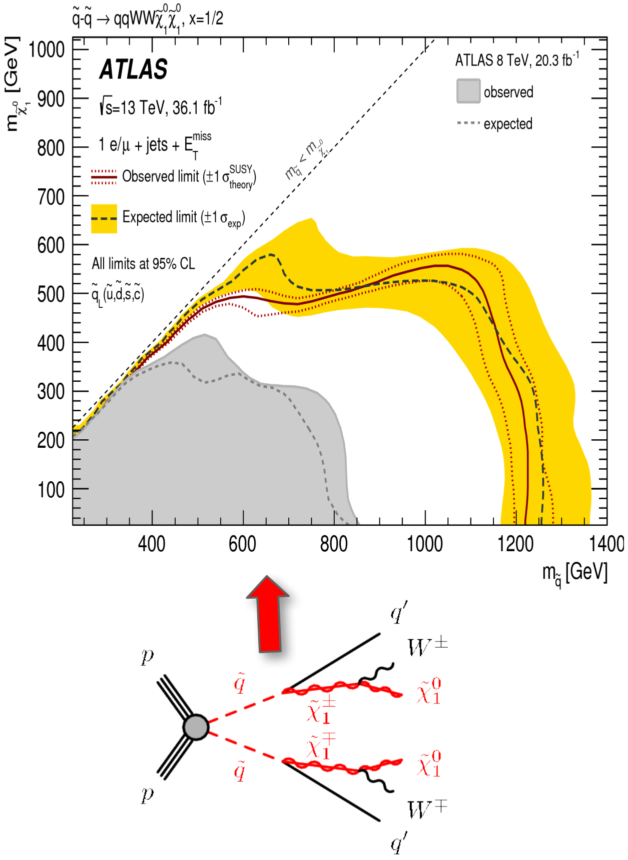
2J VRs/SRs

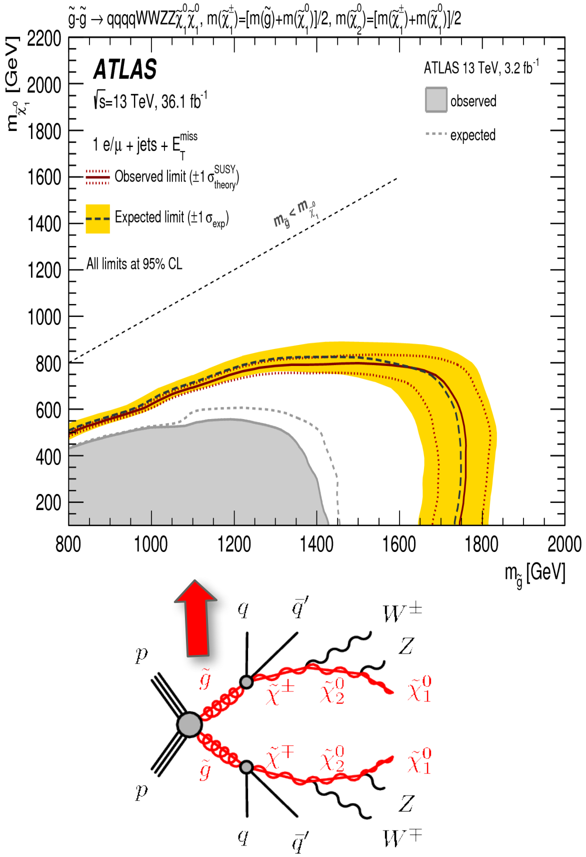
- Good data/MC agreement in VRs
- No significant excess in all SRs → Set exclusion limit

Exclusion Limits

arXiv:1708.08232





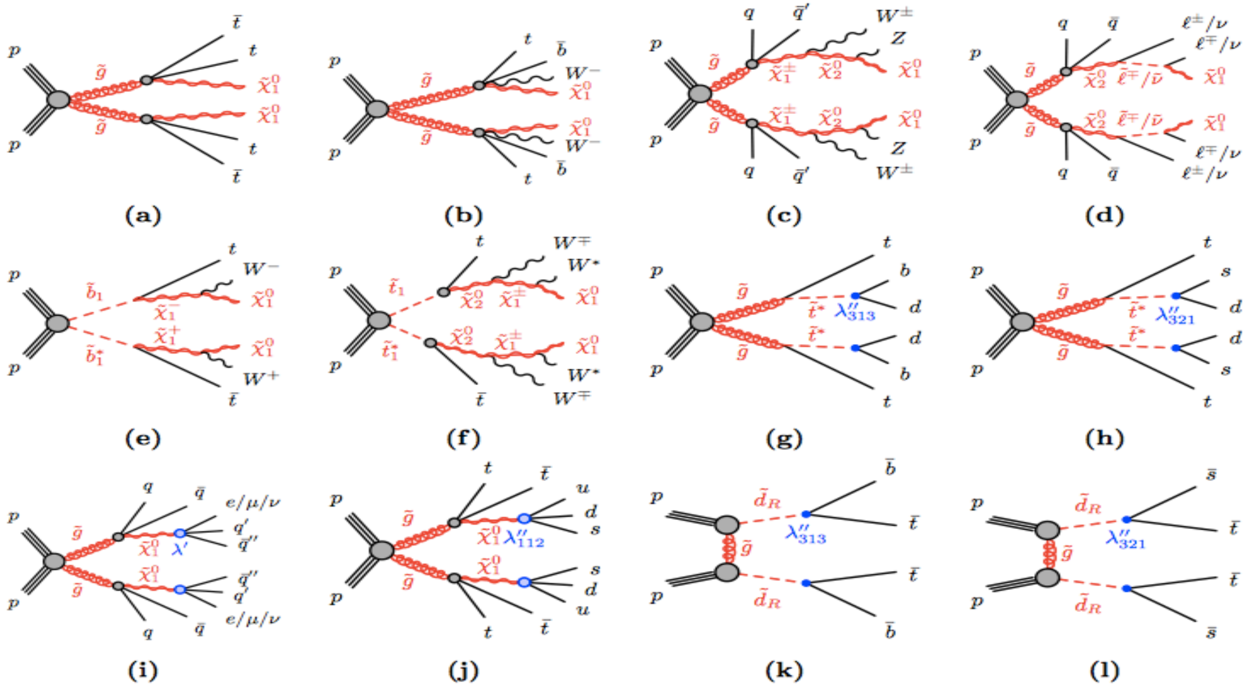


- **Gluino (squark) masses up to 2.1 TeV (1.25 TeV) are excluded for low neutralino masses (≤ 900 GeV or ≤ 500 GeV)**
- **IHEP made a leading contribution (contact person/ contact editor)**

[3] SS/3L SUSY search

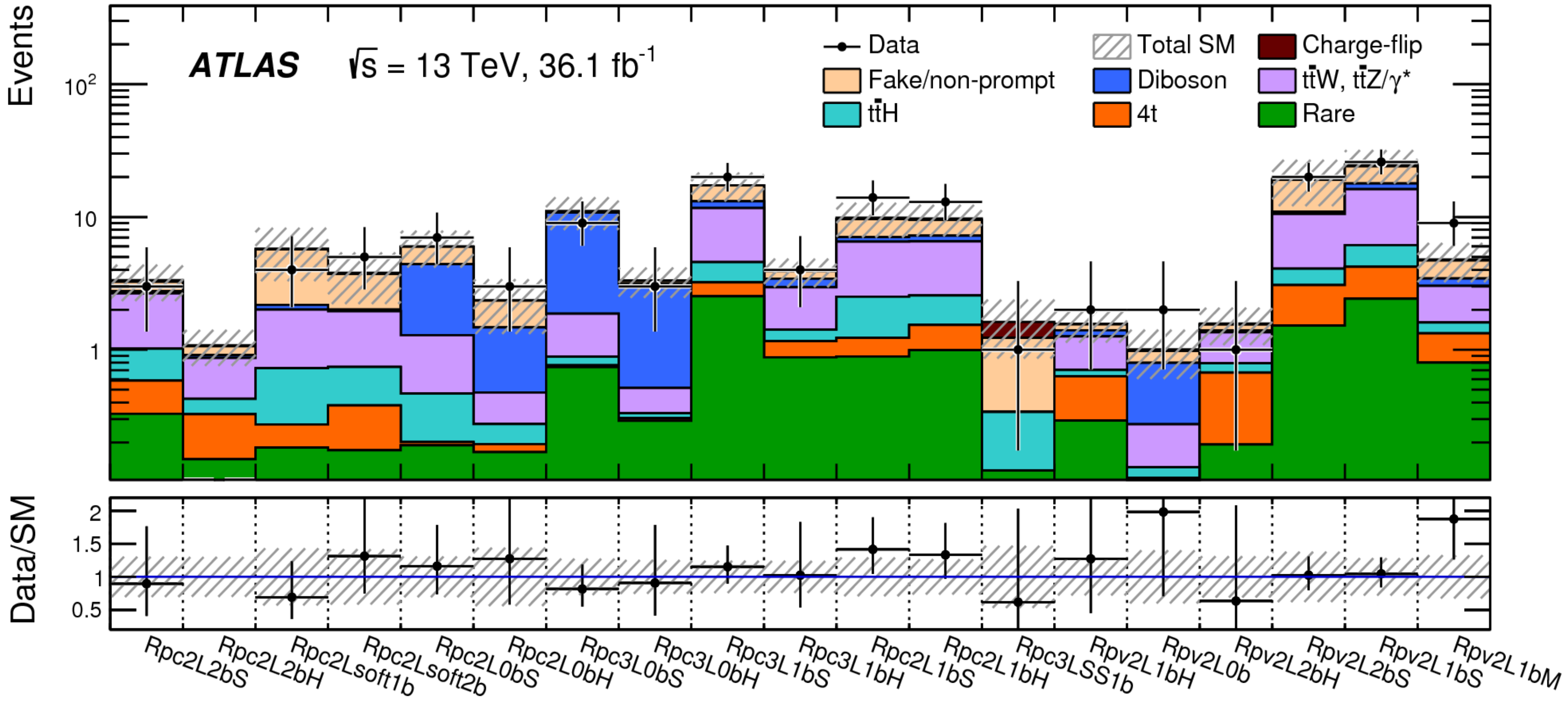
Run2

- Search for squarks/gluinos via long decay chain in SS/3L final states
  - Sensitive for a wide range of models
  - Very clean channels with only tiny SM bg (mainly top+V, diboson, triboson) → A good tag for new physics
- 13 RPC+6 PRV SRs defined, targeting specific scenarios
- Main backgrounds:
  - diboson and ttV: estimated from MC simulation, validated in VRs.
  - Fake background and charge flip: estimated in data



Results

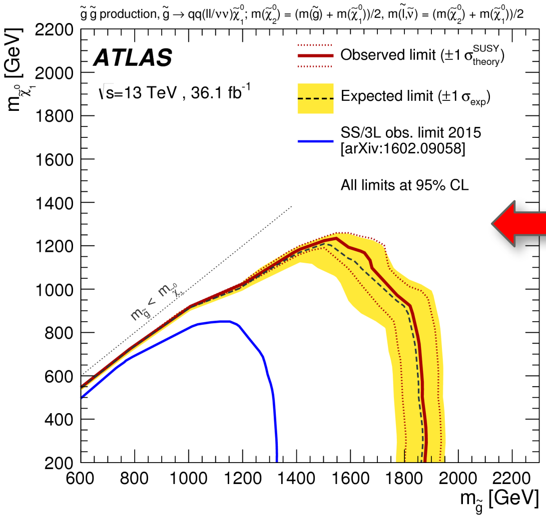
- No significant excess observed in SRs

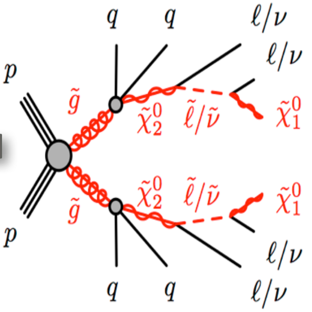


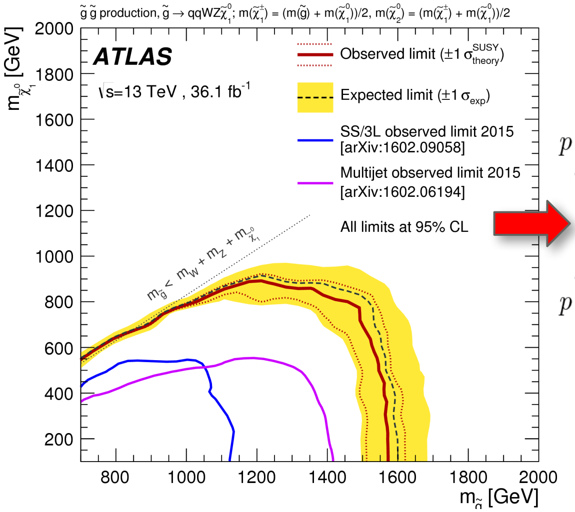
Exclusion Limits

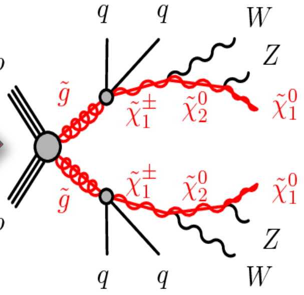
JHEP09(2017)084

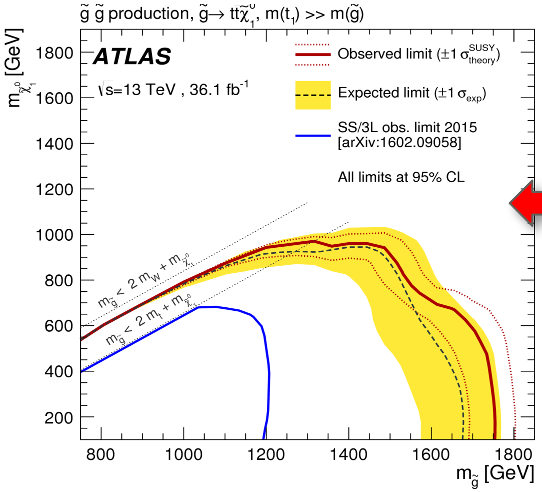
- **Gluino mass <1.6-1.87 TeV and LSP mass < 850-1200 GeV are excluded for gluino pair production. ~b mass < 700 GeV excluded**

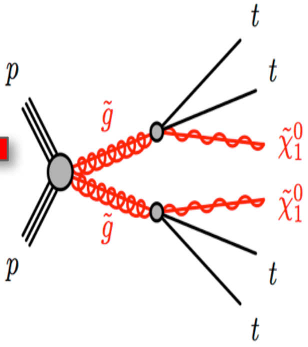


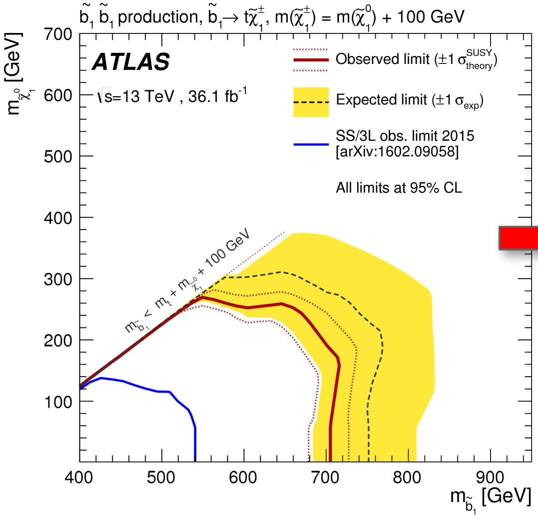


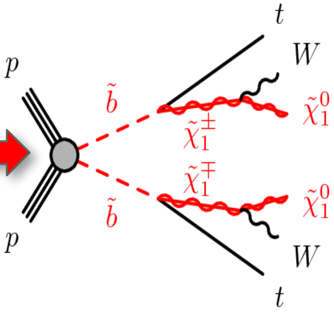








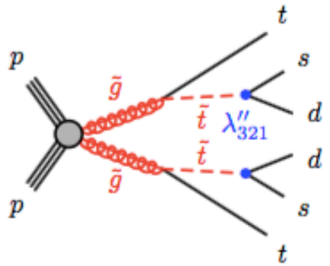


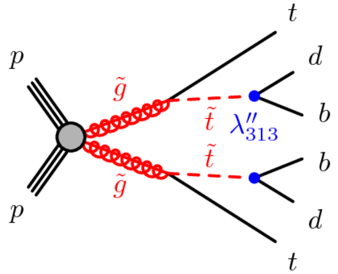


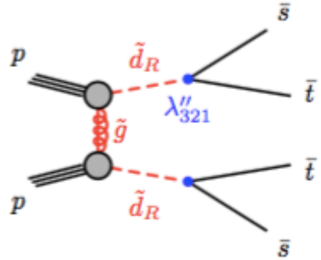
Exclusion Limits

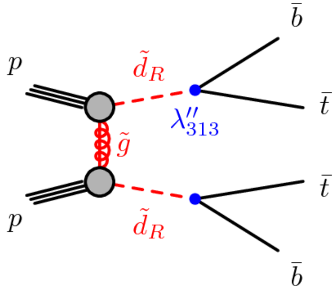
JHEP09(2017)084

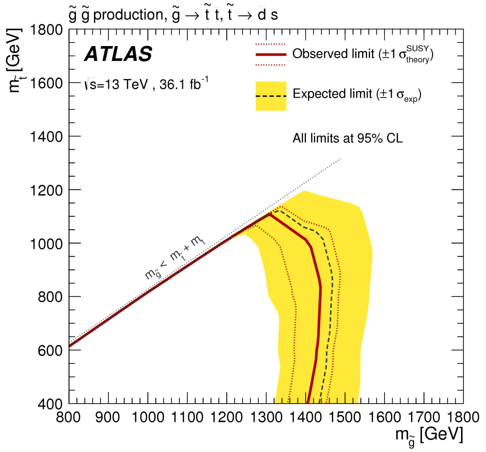
- Gluino mass <1.3 TeV and LSP mass < 1 TeV excluded in RPV scenario.
- Right-handed down squark masses are probed up to $m\tilde{d}_R \approx 500$ GeV in RPV scenarios.
- IHEP mainly contributed in RPC SR definition and main background estimation in data.

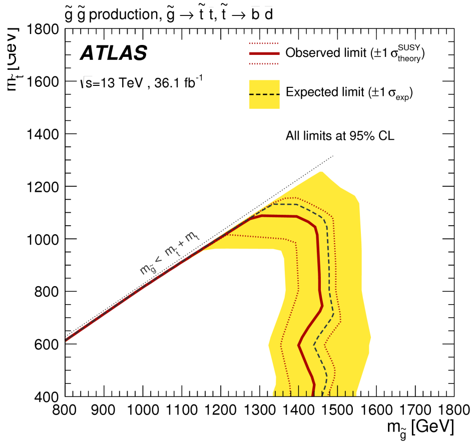


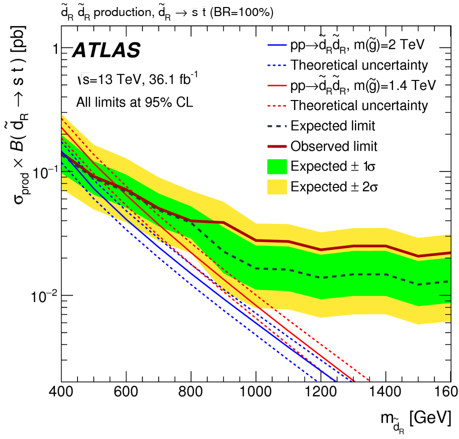


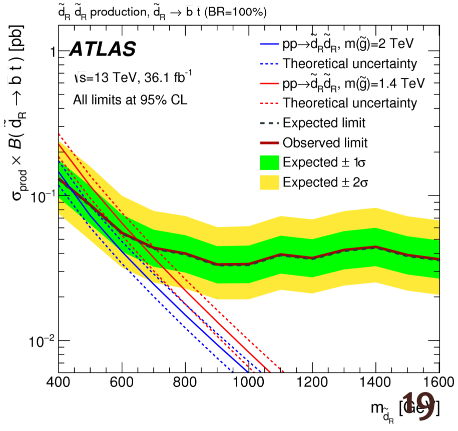












IHEP contributions and publications

- **Electroweak SUSY search with taus: contact person/editor**
  - [contact editor] Run2 signature paper: **arXiv:1708.07875 (submitted to EPJC)**
  - [contact editor] Run2 CONF NOTE: **ATLAS-CONF-2017-035 [LHCP17]**
  - [Ongoing] Run2 direct stau analysis: **aiming for Moriond 2018 paper/CONF**
  - [Ongoing] Run2 Wh analysis: **aiming for summer 2018 CONF/end run2 paper**
  - [Ongoing] Direct stau upgrade study: **aiming for upgrade TDAQ TDR**
  - [Ongoing] Run2 2tau signature analysis: **aiming for end of run2 paper**
- **Inclusive SUSY search (+EWK) with 1 lepton: contact person/editor**
  - [contact editor] Run2 signature paper: **arXiv:1708.08232 (accepted by PRD)**
  - [Ongoing] Run2 analysis with EWK-1L2Jets: **aiming for end of run2 paper**
  - [Ongoing] Run2 signature analysis: **aiming for end of run2 paper**
- **Inclusive SUSY search with SS/3L: editor/approval talks**
  - Run2 signature paper: **JHEP09 (2017) 084**
  - Run2 CONF NOTE: **ATLAS-CONF-2017-030 [LHCP17]**
  - [Ongoing] Run2 signature analysis: **aiming for end of run2 paper**
- **Performance work at next slide**

Paper
CONF note
Ongoing

- **Published 3 paper, 2 CONF notes in 2017, contact editors for 3 of them**
- **Ongoing 7 analyses aiming for 2018 paper/CONF or end of run2 paper**

Performance & Roles in ATLAS

- **Tau performance: 3 students + 1 postdoc + 2 staffs**
  - Institute commitment on tau (agreed by tauCP conveners, details are in discussion)
  - Tau substructure measurement (preliminary recommendation is ready, talk in WS)
  - Tau AFII recommendation (first study from tauCP group)
- **MET performance: 1 staff +1 student**
  - PU suppression in CST; jet pt optimization in MET
- **Pixel performance** on track efficiency monitoring **: 1 postdoc**

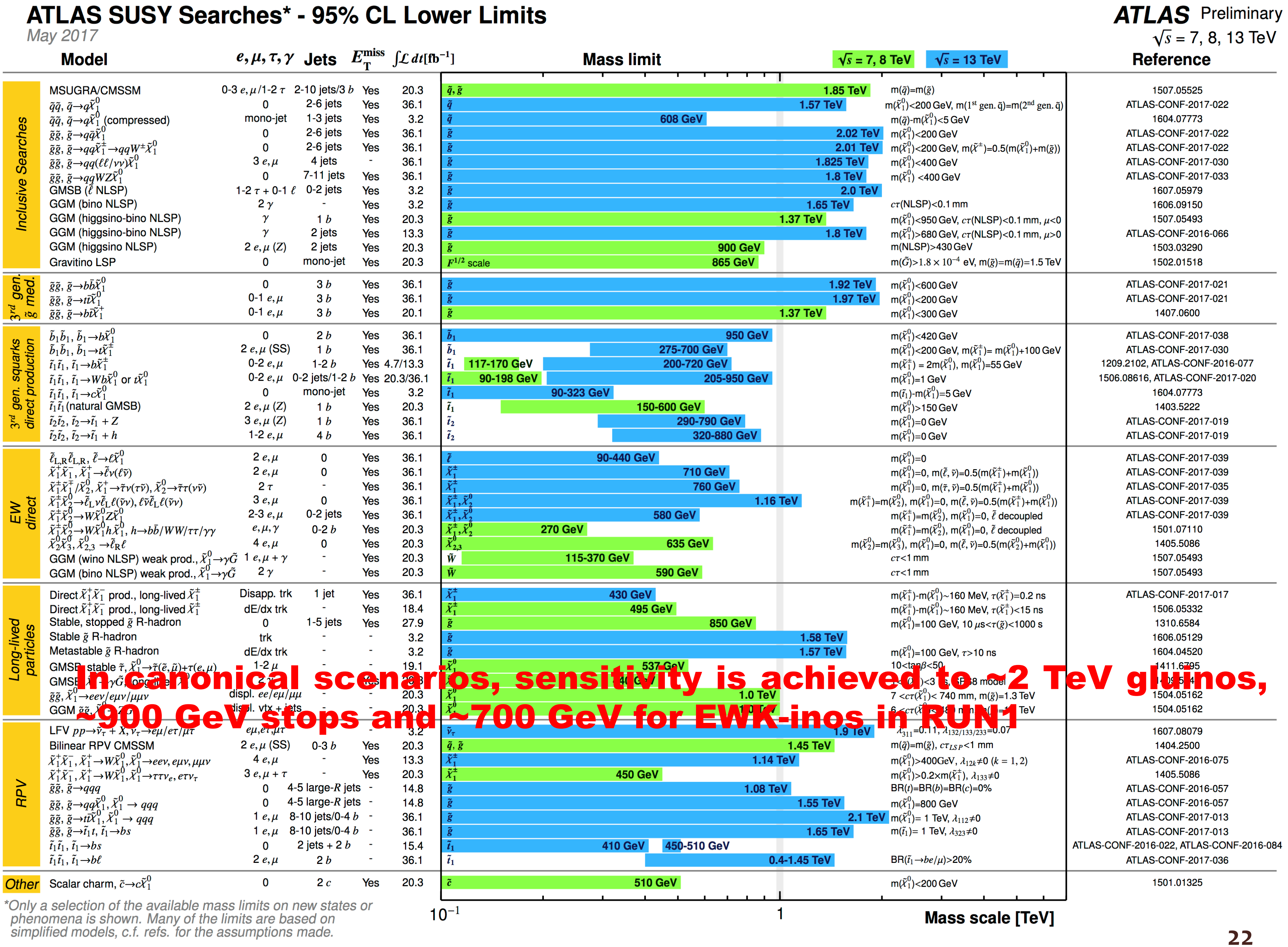
☐ **HistFitter expert**
  - HistFitter serves as the official statistical analysis tool for the whole ATLAS SUSY group and is widely used by many other analyses. The expert is called for the software development and user help.

☐ **SUSY signal/HEPdata contact**
  - Taking care of the signal cross-section /Feynman diagram/ HEP data for the whole ATLAS SUSY group.

☐ **SUSY EWK subgroup convener** (Apr. 2015 – Mar. 2016)

☐ **CB Chair Adversary Group member** (Jan. 2016 – Dec. 2017)

☐ **Editorial Board member**: stop 1L paper, CONF note; stop to stau conf note;



ATLAS SUSY Searches* - 95% CL Lower Limits

May 2017

ATLAS Preliminary

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

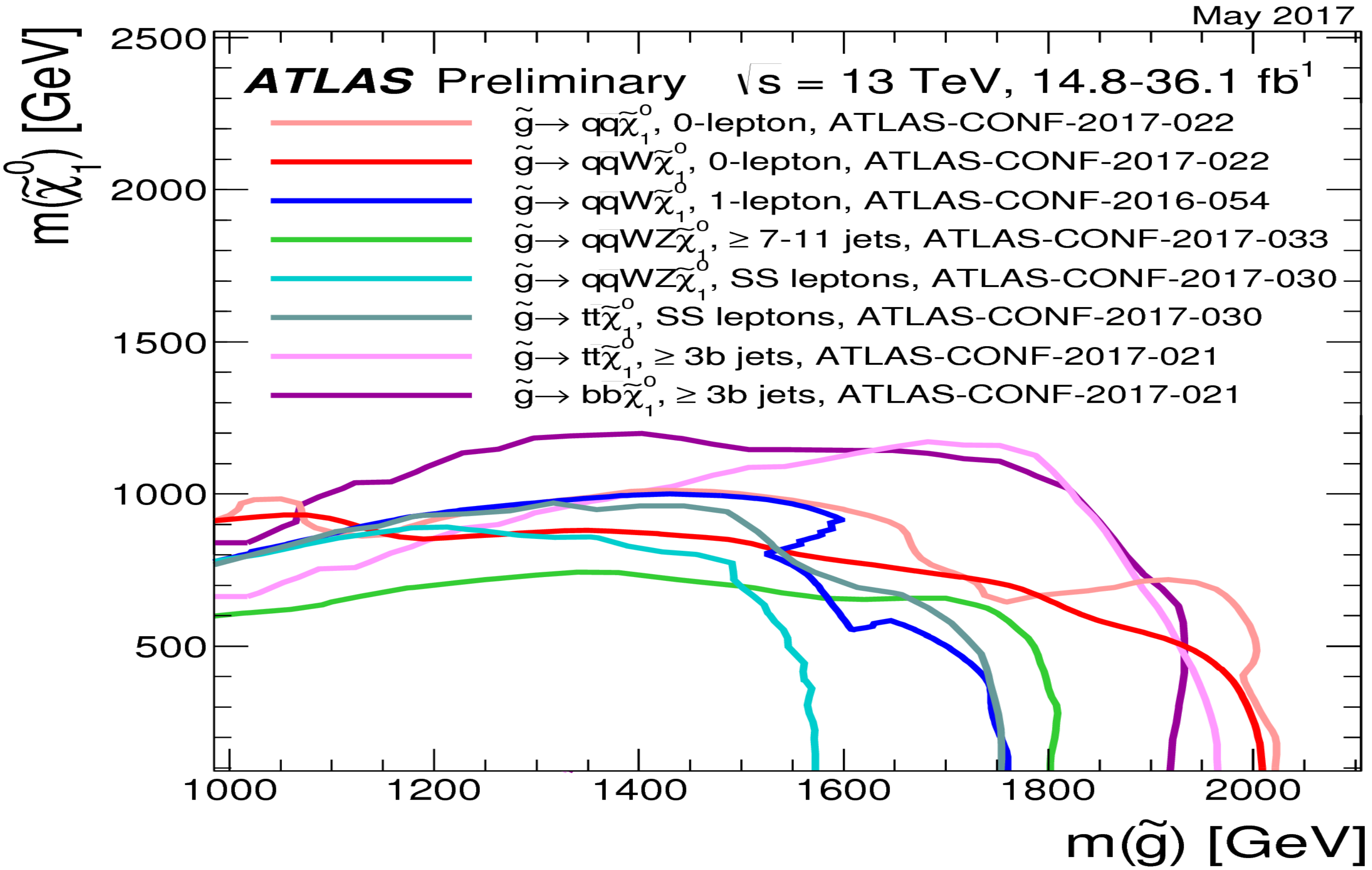
🟩 $\sqrt{s}$ = 7, 8 TeV 🟦 $\sqrt{s}$ = 13 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde q, \tilde g$ 🟩 1.85 TeV	m($\tilde q$)=m($\tilde g$)	1507.05525
	$\tilde q\tilde q$, $\tilde q \to q\tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde q$ 🟦 1.57 TeV	m($\tilde\chi_1^0$)<200 GeV, m(1st gen. q̃)=m(2nd gen. q̃)	ATLAS-CONF-2017-022
	$\tilde q\tilde q$, $\tilde q \to q\tilde\chi_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde q$ 🟦 608 GeV	m($\tilde q$)-m($\tilde\chi_1^0$)<5 GeV	1604.07773
	$\tilde g\tilde g$, $\tilde g \to q\bar q\tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde g$ 🟦 2.02 TeV	m($\tilde\chi_1^0$)<200 GeV	ATLAS-CONF-2017-022
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi_1^\pm \to qqW^\pm\tilde\chi_1^0$	0	2-6 jets	Yes	36.1	$\tilde g$ 🟦 2.01 TeV	m($\tilde\chi_1^0$)<200 GeV, m($\tilde\chi^\pm$)=0.5(m($\tilde\chi_1^0$)+m($\tilde g$))	ATLAS-CONF-2017-022
	$\tilde g\tilde g$, $\tilde g \to qq(\ell\ell/\nu\nu)\tilde\chi_1^0$	3 e,μ	4 jets	-	36.1	$\tilde g$ 🟦 1.825 TeV	m($\tilde\chi_1^0$)<400 GeV	ATLAS-CONF-2017-030
	$\tilde g\tilde g$, $\tilde g \to qqWZ\tilde\chi_1^0$	0	7-11 jets	Yes	36.1	$\tilde g$ 🟦 1.8 TeV	m($\tilde\chi_1^0$) <400 GeV	ATLAS-CONF-2017-033
	GMSB ($\tilde\ell$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde g$ 🟦 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	3.2	$\tilde g$ 🟦 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde g$ 🟩 1.37 TeV	m($\tilde\chi_1^0$)<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde g$ 🟦 1.8 TeV	m($\tilde\chi_1^0$)>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde g$ 🟩 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 🟩 865 GeV	m($\tilde G$)>1.8×10^{-4} eV, m($\tilde g$)=m($\tilde q$)=1.5 TeV	1502.01518
3rd gen. $\tilde g$ med.	$\tilde g\tilde g$, $\tilde g \to b\bar b\tilde\chi_1^0$	0	3 b	Yes	36.1	$\tilde g$ 🟦 1.92 TeV	m($\tilde\chi_1^0$)<600 GeV	ATLAS-CONF-2017-021
	$\tilde g\tilde g$, $\tilde g \to t\bar t\tilde\chi_1^0$	0-1 e,μ	3 b	Yes	36.1	$\tilde g$ 🟦 1.97 TeV	m($\tilde\chi_1^0$)<200 GeV	ATLAS-CONF-2017-021
	$\tilde g\tilde g$, $\tilde g \to b\bar t\tilde\chi_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde g$ 🟩 1.37 TeV	m($\tilde\chi_1^0$)<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde b_1\tilde b_1$, $\tilde b_1 \to b\tilde\chi_1^0$	0	2 b	Yes	36.1	$\tilde b_1$ 🟦 950 GeV	m($\tilde\chi_1^0$)<420 GeV	ATLAS-CONF-2017-038
	$\tilde b_1\tilde b_1$, $\tilde b_1 \to t\tilde\chi_1^\pm$	2 e,μ (SS)	1 b	Yes	36.1	$\tilde b_1$ 🟦 275-700 GeV	m($\tilde\chi_1^0$)<200 GeV, m($\tilde\chi_1^\pm$)= m($\tilde\chi_1^0$)+100 GeV	ATLAS-CONF-2017-030
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to b\tilde\chi_1^\pm$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde t_1$ 🟩 117-170 GeV 🟦 200-720 GeV	m($\tilde\chi_1^\pm$) = 2m($\tilde\chi_1^0$), m($\tilde\chi_1^0$)=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to Wb\tilde\chi_1^0$ or $t\tilde\chi_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3/36.1	$\tilde t_1$ 🟩 90-198 GeV 🟦 205-950 GeV	m($\tilde\chi_1^0$)=1 GeV	1506.08616, ATLAS-CONF-2017-020
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to c\tilde\chi_1^0$	0	mono-jet	Yes	3.2	$\tilde t_1$ 🟦 90-323 GeV	m($\tilde t_1$)-m($\tilde\chi_1^0$)=5 GeV	1604.07773
	$\tilde t_1\tilde t_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde t_1$ 🟩 150-600 GeV	m($\tilde\chi_1^0$)>150 GeV	1403.5222
	$\tilde t_2\tilde t_2$, $\tilde t_2 \to \tilde t_1 + Z$	3 e,μ (Z)	1 b	Yes	36.1	$\tilde t_2$ 🟦 290-790 GeV	m($\tilde\chi_1^0$)=0 GeV	ATLAS-CONF-2017-019
	$\tilde t_2\tilde t_2$, $\tilde t_2 \to \tilde t_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde t_2$ 🟦 320-880 GeV	m($\tilde\chi_1^0$)=0 GeV	ATLAS-CONF-2017-019
EW direct	$\tilde\ell_{L,R}\tilde\ell_{L,R}$, $\tilde\ell \to \ell\tilde\chi_1^0$	2 e,μ	0	Yes	36.1	$\tilde\ell$ 🟦 90-440 GeV	m($\tilde\chi_1^0$)=0	ATLAS-CONF-2017-039
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to \tilde\ell\nu(\ell\tilde\nu)$	2 e,μ	0	Yes	36.1	$\tilde\chi_1^\pm$ 🟦 710 GeV	m($\tilde\chi_1^0$)=0, m($\tilde\ell,\tilde\nu$)=0.5(m($\tilde\chi_1^\pm$)+m($\tilde\chi_1^0$))	ATLAS-CONF-2017-039
	$\tilde\chi_1^\pm\tilde\chi_1^\mp/\tilde\chi_2^0$, $\tilde\chi_1^+ \to \tilde\tau\nu(\tau\tilde\nu)$, $\tilde\chi_2^0 \to \tilde\tau\tau(\nu\tilde\nu)$	2 τ	-	Yes	36.1	$\tilde\chi_1^\pm$ 🟦 760 GeV	m($\tilde\chi_1^0$)=0, m($\tilde\tau,\tilde\nu$)=0.5(m($\tilde\chi_1^\pm$)+m($\tilde\chi_1^0$))	ATLAS-CONF-2017-035
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to \tilde\ell_L\nu\tilde\ell_L\ell(\tilde\nu\nu)$, $\ell\tilde\nu\tilde\ell_L\ell(\tilde\nu\nu)$	3 e,μ	0	Yes	36.1	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 🟦 1.16 TeV	m($\tilde\chi_1^\pm$)=m($\tilde\chi_2^0$), m($\tilde\chi_1^0$)=0, m($\tilde\ell,\tilde\nu$)=0.5(m($\tilde\chi_1^\pm$)+m($\tilde\chi_1^0$))	ATLAS-CONF-2017-039
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to W\tilde\chi_1^0 Z\tilde\chi_1^0$	2-3 e,μ	0-2 jets	Yes	36.1	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 🟦 580 GeV	m($\tilde\chi_1^\pm$)=m($\tilde\chi_2^0$), m($\tilde\chi_1^0$)=0, $\tilde\ell$ decoupled	ATLAS-CONF-2017-039
	$\tilde\chi_1^\pm\tilde\chi_2^0 \to W\tilde\chi_1^0 h\tilde\chi_1^0$, $h \to b\bar b/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde\chi_1^\pm,\tilde\chi_2^0$ 🟩 270 GeV	m($\tilde\chi_1^\pm$)=m($\tilde\chi_2^0$), m($\tilde\chi_1^0$)=0, $\tilde\ell$ decoupled	1501.07110
	$\tilde\chi_2^0\tilde\chi_3^0$, $\tilde\chi_{2,3}^0 \to \tilde\ell_R\ell$	4 e,μ	0	Yes	20.3	$\tilde\chi_{2,3}^0$ 🟩 635 GeV	m($\tilde\chi_2^0$)=m($\tilde\chi_3^0$), m($\tilde\chi_1^0$)=0, m($\tilde\ell,\tilde\nu$)=0.5(m($\tilde\chi_2^0$)+m($\tilde\chi_1^0$))	1405.5086
	GGM (wino NLSP) weak prod., $\tilde\chi_1^0 \to \gamma\tilde G$	1 e,μ + γ	-	Yes	20.3	$\tilde W$ 🟩 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod., $\tilde\chi_1^0 \to \gamma\tilde G$	2 γ	-	Yes	20.3	$\tilde W$ 🟩 590 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde\chi_1^+\tilde\chi_1^-$ prod., long-lived $\tilde\chi_1^\pm$	Disapp. trk	1 jet	Yes	36.1	$\tilde\chi_1^\pm$ 🟦 430 GeV	m($\tilde\chi_1^\pm$)-m($\tilde\chi_1^0$)~160 MeV, $\tau(\tilde\chi_1^\pm)$=0.2 ns	ATLAS-CONF-2017-017
	Direct $\tilde\chi_1^+\tilde\chi_1^-$ prod., long-lived $\tilde\chi_1^\pm$	dE/dx trk	-	Yes	18.4	$\tilde\chi_1^\pm$ 🟩 495 GeV	m($\tilde\chi_1^\pm$)-m($\tilde\chi_1^0$)~160 MeV, $\tau(\tilde\chi_1^\pm)$<15 ns	1506.05332
	Stable, stopped $\tilde g$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde g$ 🟩 850 GeV	m($\tilde\chi_1^0$)=100 GeV, 10 μs<$\tau(\tilde g)$<1000 s	1310.6584
	Stable $\tilde g$ R-hadron	trk	-	-	3.2	$\tilde g$ 🟦 1.58 TeV		1606.05129
	Metastable $\tilde g$ R-hadron	dE/dx trk	-	-	3.2	$\tilde g$ 🟦 1.57 TeV	m($\tilde\chi_1^0$)=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde\tau$, $\tilde\chi_1^0 \to \tilde\tau(\tilde e,\tilde\mu)+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde\chi_1^0$ 🟩 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde\chi_1^0 \to \gamma\tilde G$, long-lived $\tilde\chi_1^0$	2 γ	-	Yes	20.3	$\tilde\chi_1^0$ 🟩 440 GeV	1<$\tau(\tilde\chi_1^0)$<3 ns, SPS8 model	[illegible]
	$\tilde g\tilde g$, $\tilde\chi_1^0 \to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde\chi_1^0$ 🟩 1.0 TeV	7 <$c\tau(\tilde\chi_1^0)$< 740 mm, m($\tilde g$)=1.3 TeV	1504.05162
	GGM $\tilde g\tilde g$, $\tilde\chi_1^0 \to Z\tilde G$	displ. vtx + jets	-	-	20.3	$\tilde\chi_1^0$ 🟩 1.0 TeV	6 <$c\tau(\tilde\chi_1^0)$< [illegible] mm, m($\tilde g$)=[illegible] 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 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde q, \tilde g$ 🟩 1.45 TeV	m($\tilde q$)=m($\tilde g$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to W\tilde\chi_1^0$, $\tilde\chi_1^0 \to ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	$\tilde\chi_1^\pm$ 🟦 1.14 TeV	m($\tilde\chi_1^0$)>400GeV, λ_{12k}≠0 ($k = 1, 2$)	ATLAS-CONF-2016-075
	$\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^+ \to W\tilde\chi_1^0$, $\tilde\chi_1^0 \to \tau\tau\nu_e, e\tau\nu_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde\chi_1^\pm$ 🟩 450 GeV	m($\tilde\chi_1^0$)>0.2×m($\tilde\chi_1^\pm$), λ_{133}≠0	1405.5086
	$\tilde g\tilde g$, $\tilde g \to qqq$	0	4-5 large-R jets	-	14.8	$\tilde g$ 🟦 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde g\tilde g$, $\tilde g \to qq\tilde\chi_1^0$, $\tilde\chi_1^0 \to qqq$	0	4-5 large-R jets	-	14.8	$\tilde g$ 🟦 1.55 TeV	m($\tilde\chi_1^0$)=800 GeV	ATLAS-CONF-2016-057
	$\tilde g\tilde g$, $\tilde g \to t\bar t\tilde\chi_1^0$, $\tilde\chi_1^0 \to qqq$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde g$ 🟦 2.1 TeV	m($\tilde\chi_1^0$)= 1 TeV, λ_{112}≠0	ATLAS-CONF-2017-013
	$\tilde g\tilde g$, $\tilde g \to \tilde t_1 t$, $\tilde t_1 \to bs$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde g$ 🟦 1.65 TeV	m($\tilde t_1$)= 1 TeV, λ_{323}≠0	ATLAS-CONF-2017-013
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to bs$	0	2 jets + 2 b	-	15.4	$\tilde t_1$ 🟦 410 GeV 🟦 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde t_1\tilde t_1$, $\tilde t_1 \to b\ell$	2 e,μ	2 b	-	36.1	$\tilde t_1$ 🟦 0.4-1.45 TeV	BR($\tilde t_1 \to be/\mu$)>20%	ATLAS-CONF-2017-036
Other	Scalar charm, $\tilde c \to c\tilde\chi_1^0$	0	2 c	Yes	20.3	$\tilde c$ 🟩 510 GeV	m($\tilde\chi_1^0$)<200 GeV	1501.01325

*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.

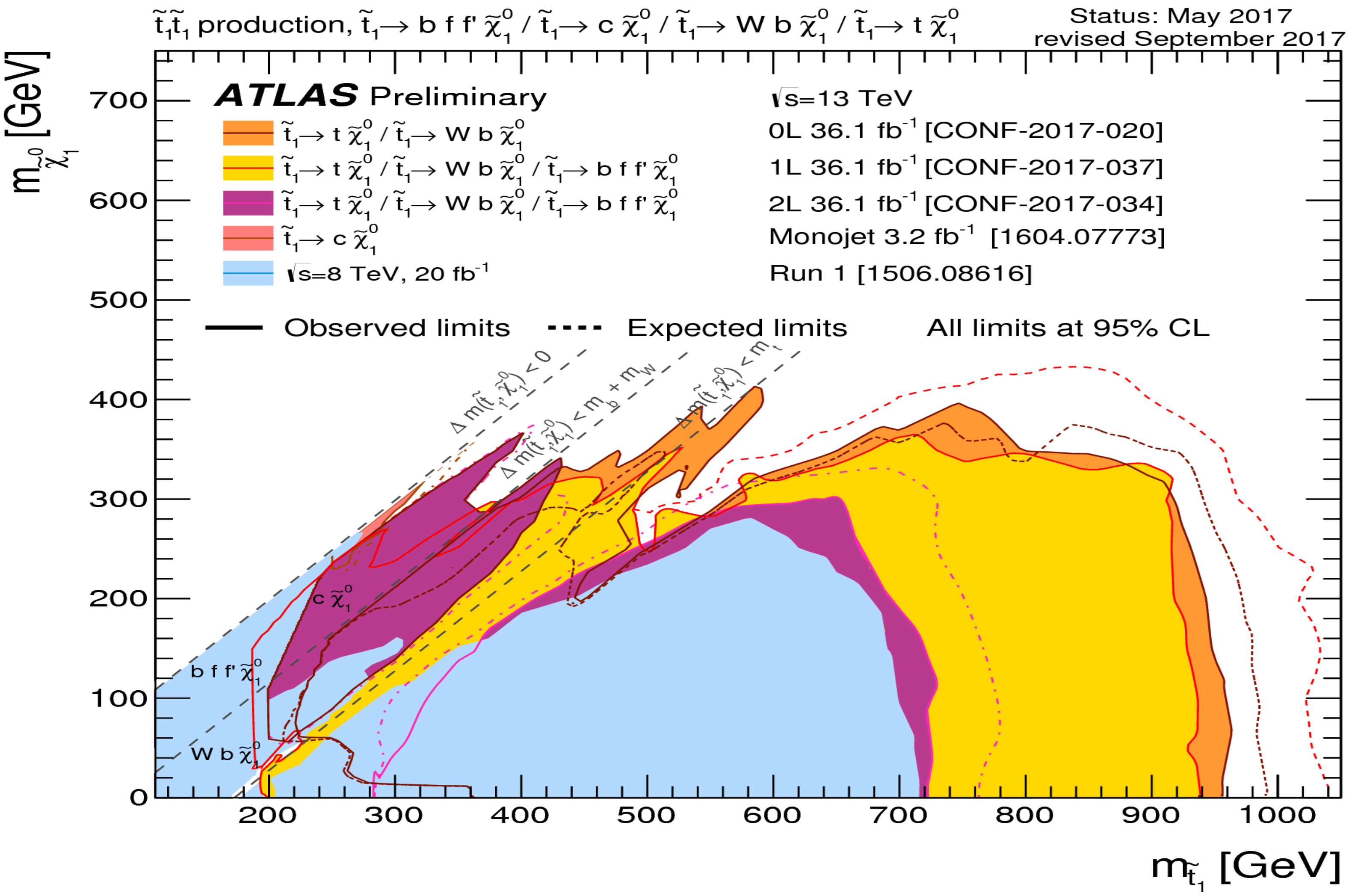
In canonical scenarios, sensitivity is achieved to ~2 TeV gluinos, ~900 GeV stops and ~700 GeV for EWK-inos in RUN1

Strong Production *(summary)*



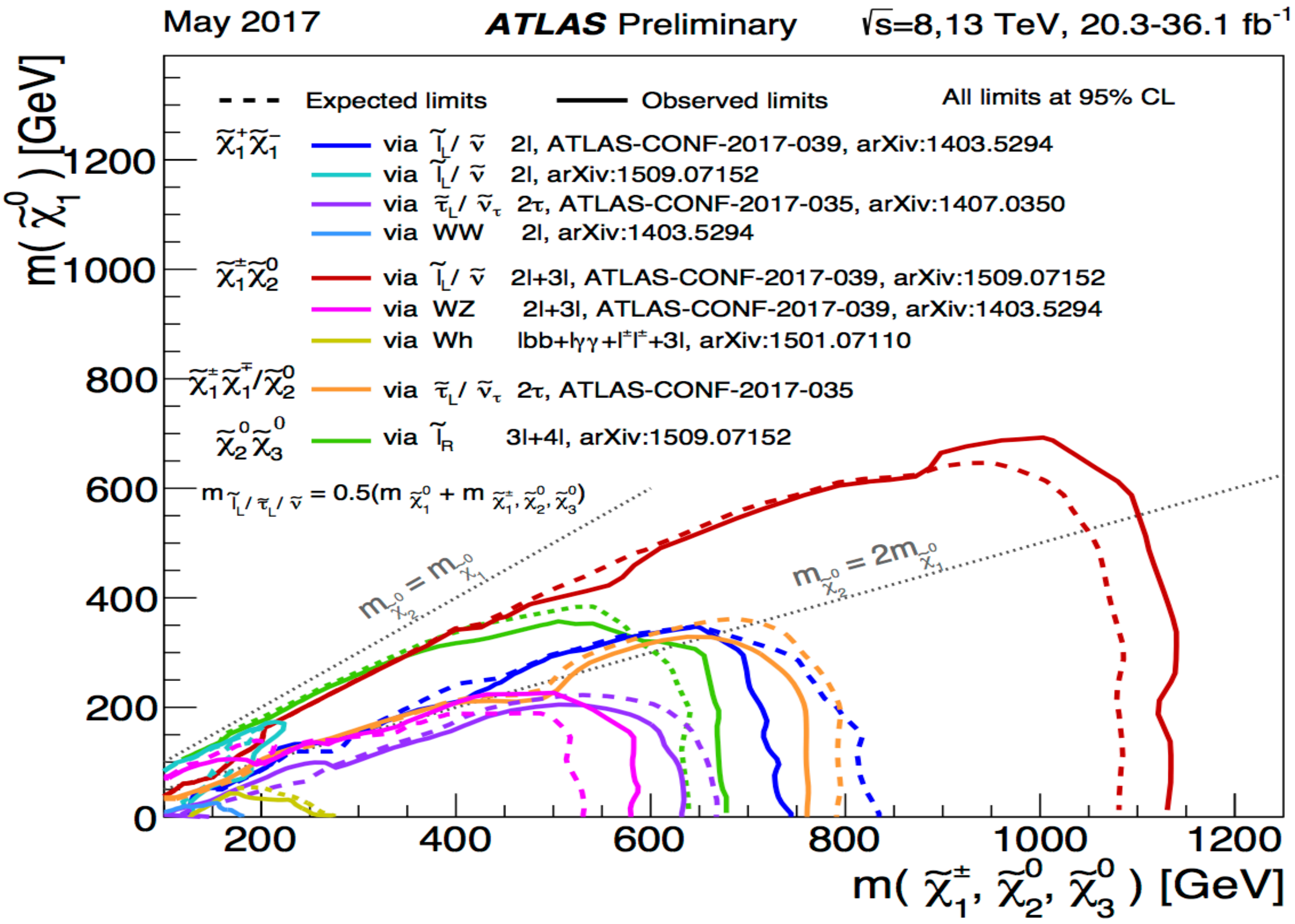
- Exclusion for m(~g) < 1.6-2 TeV for massless LSP
- exclusion up to m(LSP) ~1.2 TeV

3rd Generation *(summary)*

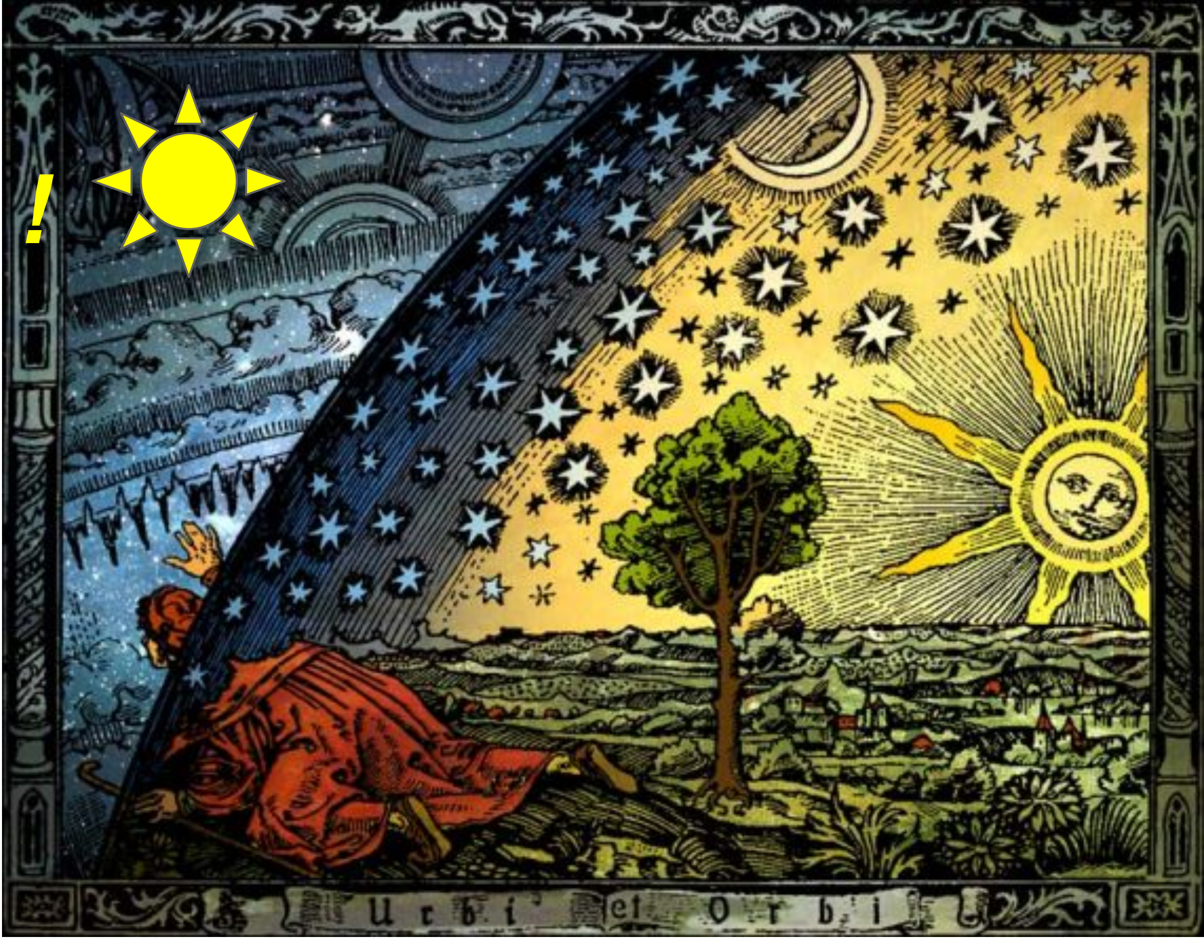


- **Exclusion for m(~t1) < ~950 GeV for massless LSP, exclusion up to m(LSP) ~350 GeV**

EWK Production *(summary)*



Exciting times are ahead of us !

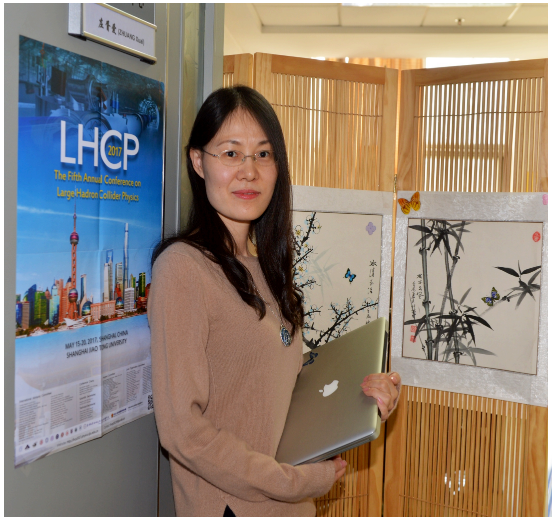


THANKS FOR YOUR ATTENTION!

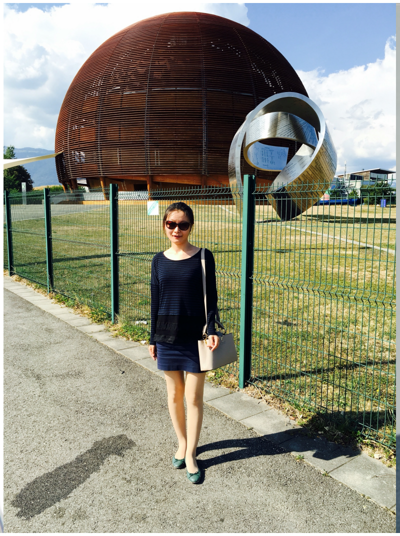
IHEP SUSY Group

2 graduated this year

Staffs


Xuai ZHUANG

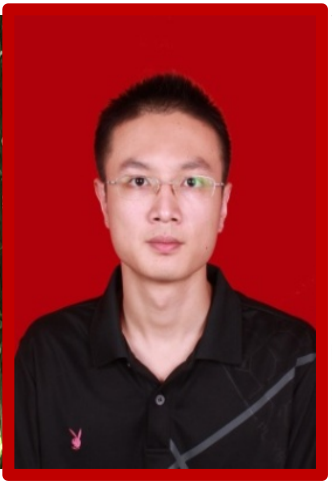

Shan JIN


Da XU

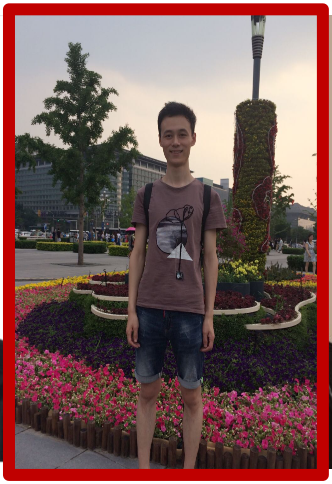

Feng LU

Postdoc + students

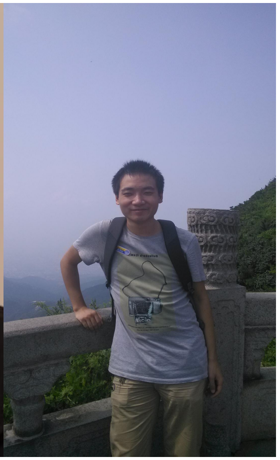

Mohamad Kassem AYOUB


Huan REN


Huajie Cheng


Peng Zhang


Yang Liu


Chenzheng Zhu

Summary from IHEP SUSY Group

- 高能所SUSY实验小组：
  - ❑ 国内首个在LHC实验中进行R宇称守恒SUSY研究的实验小组（3名职工，1名博士后，5名研究生），已具有很强的国际竞争力。
  - ❑ 团队成员在国际合作组担任重要角色，已具有一定的国际知名度：
    - ATLAS SUSY EW 物理组召集人
    - ATLAS合作组委员会顾问组成员
    - ATLAS SUSY信号联络人
    - ATLAS HepData 联系人
    - ATLAS HistFitter 专家联络人
    - 多个课题的contacts: EWK-2tau, 1L, direct stau upgrade
    - 多个课题的Ed Board: Stop 1L; Stop to stau,

- 开展了3个热点课题，担任2个课题的联系人，3个分析的编辑，本年度已发表3篇文章，2篇CONF NOTEs，7个国际会议报告

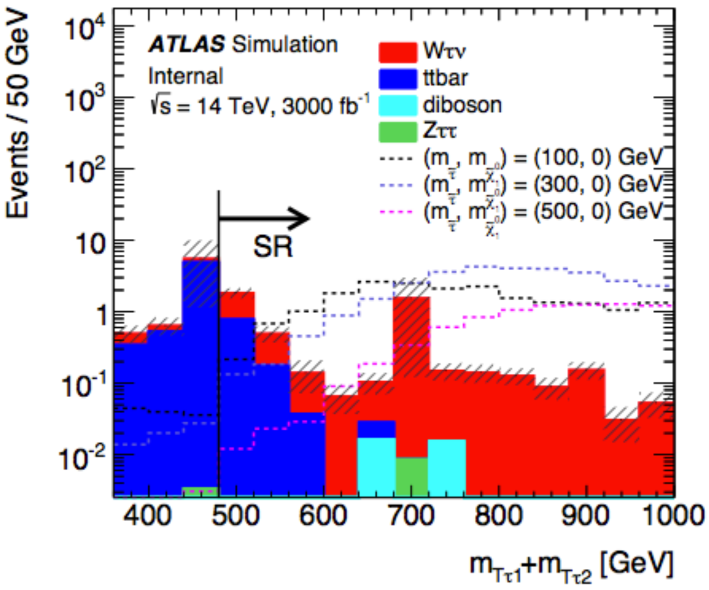
  → 基于2015＋2016年获取的36 fb^{-1} 13 TeV的数据，整个ATLAS SUSY组发表了14篇paper , 本团队在3篇中做出主导或主要贡献

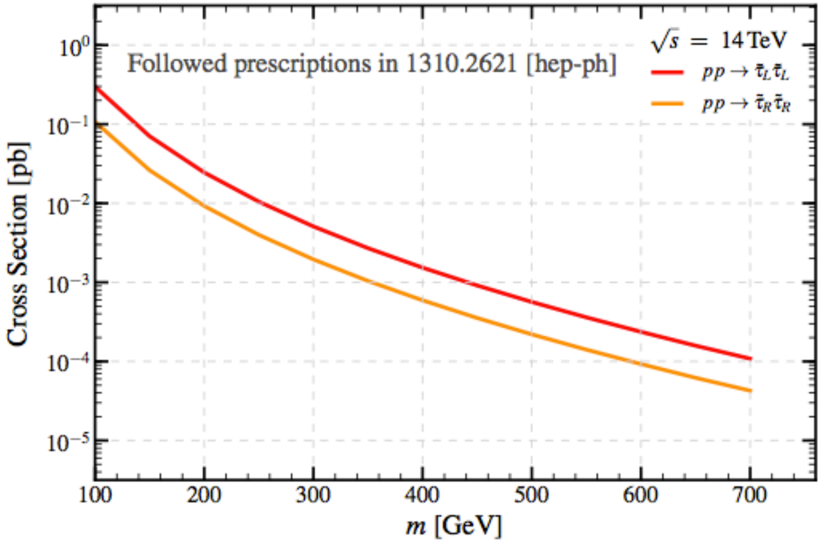
Plans and Future Work

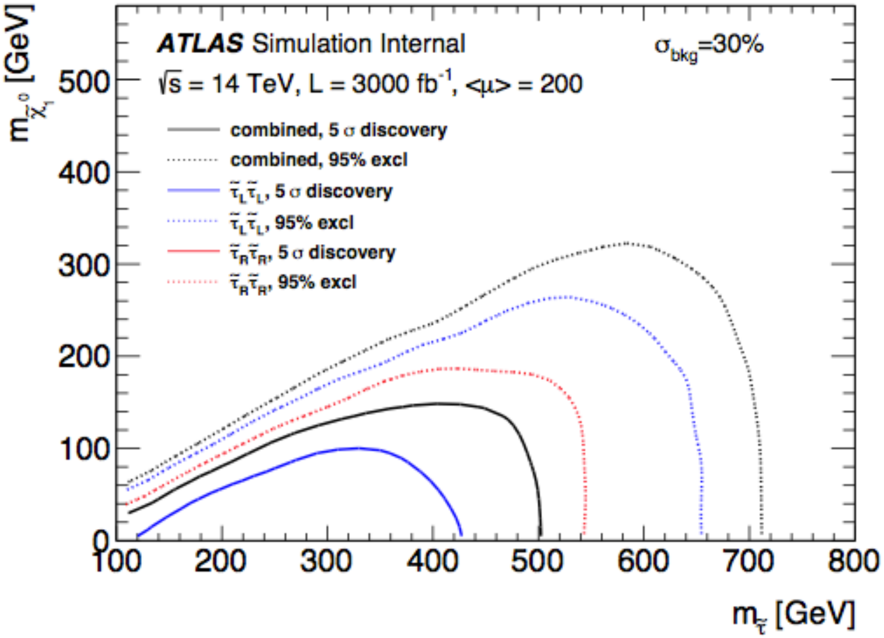
- **Physics**
  - ☐ Before end of 2018: aim for the challenge signatures with compressed scenario, small cross section, RPV scenarios …
    - Direct stau Run2 study: summer paper 2017
    - C1N2→Wh(tautau): spring paper 2018
    - VBF scenarios with hadronic taus: spring paper 2018
    - RPV scenarios: summer paper of 2018
  - ☐ Using whole run2 data, working on Benchmark scenarios for above 4 topics
- **Upgrade TDR: direct stau upgrade study**
- **Performance and OP:**
  - Tau substructure measurement
  - MET performance study
  - Pixel performance study

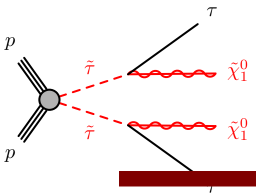
Direct stau upgrade study

SR Definition
≥ 2 OS taus
loose jet-veto
Z-veto
$\Delta R(\tau 1, \tau 2) < 3.5$
$E_{\mathrm{T}}^{\mathrm{miss}} > 280$ GeV
$m_{\mathrm{T2}} > 40$ GeV
$m_{\mathrm{T}\tau 1} + m_{\mathrm{T}\tau 2} > 480$ GeV



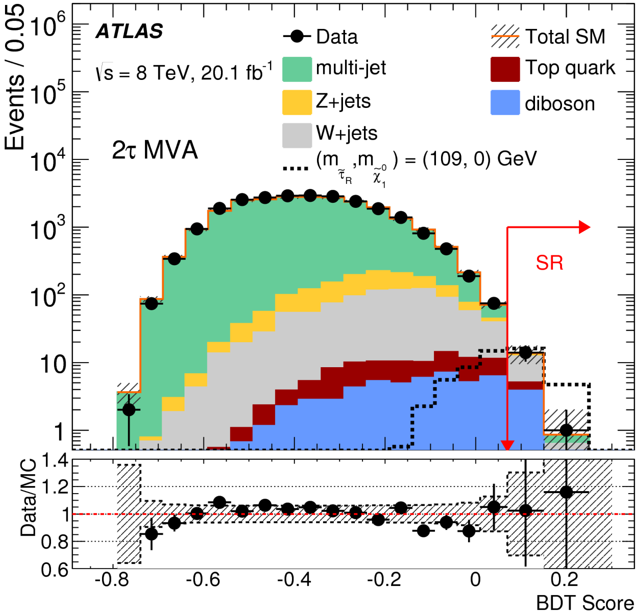




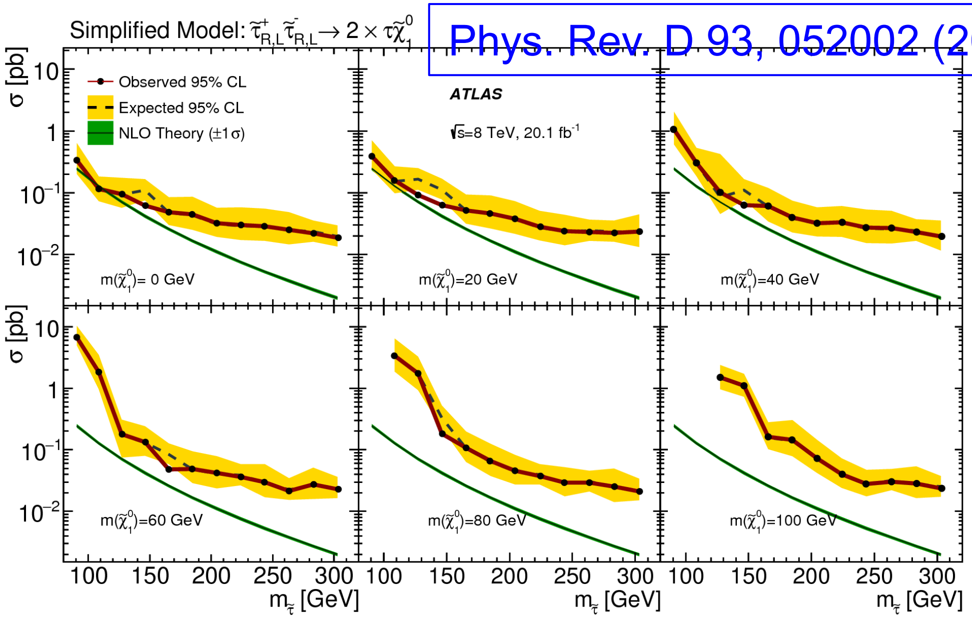


Direct stau MVA study

Run1



Phys. Rev. D 93, 052002 (2016)



- **12 input variables used in MVA with good signal/bg separation: MET, Meff, mT2, m(ττ), mT(τ1), mT(τ2), τ1_pt, τ2_pt, Δφ(ττ), ΔR(ττ), Δφ(τ1,MET), Δφ(τ2,MET).**
- **There is around 20-100% improvement on sensitivity at low stau mass region.**
- **The results have been published at Phys.Rev.D 93, 052002 (2016).**
- **Direct stau upgrade study is at next slide.**

1L SUSY search (RUN2)

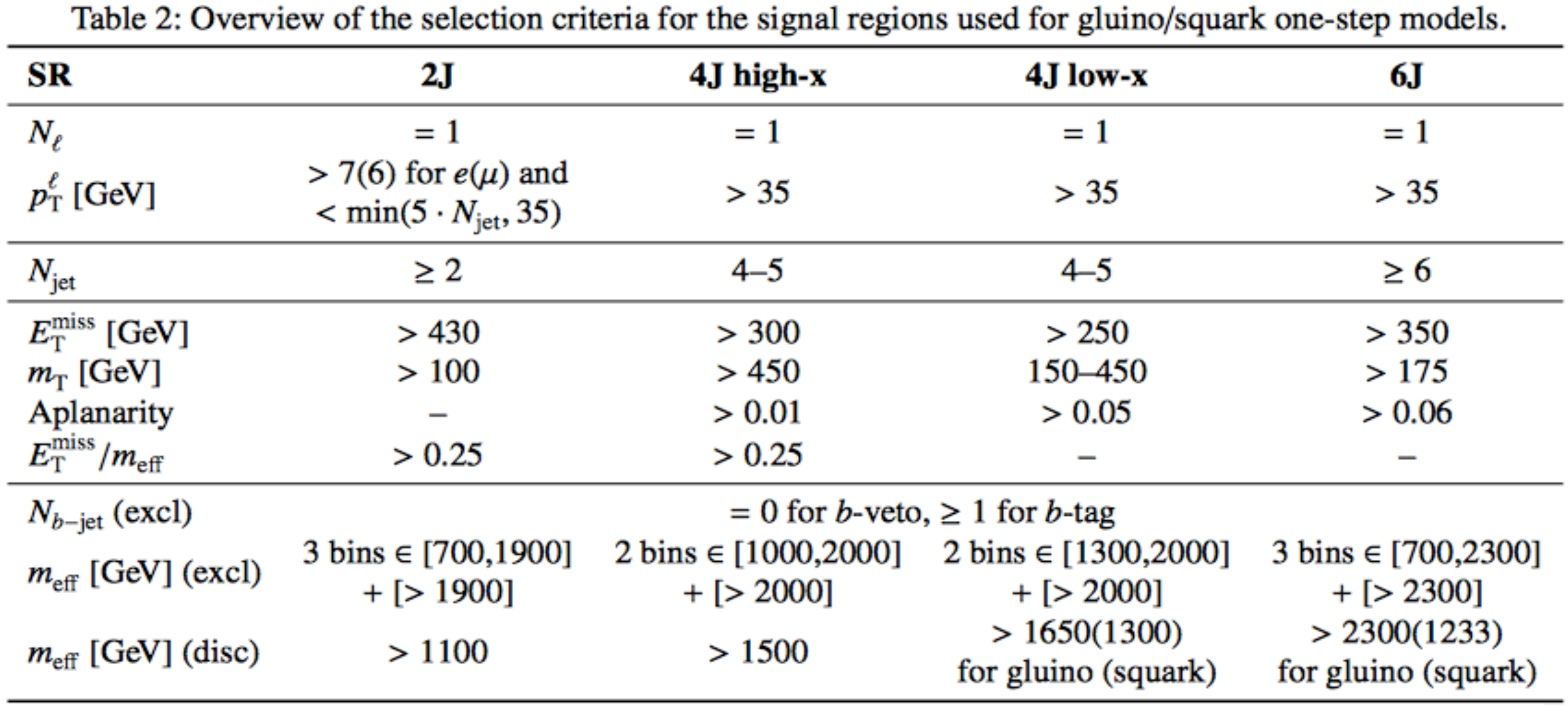


Table 2: Overview of the selection criteria for the signal regions used for gluino/squark one-step models.

SR	**2J**	**4J high-x**	**4J low-x**	**6J**
N_ℓ	$= 1$	$= 1$	$= 1$	$= 1$
p_{T}^{ℓ} [GeV]	$> 7(6)$ for $e(\mu)$ and $< \min(5 \cdot N_{\mathrm{jet}}, 35)$	> 35	> 35	> 35
N_{jet}	≥ 2	4–5	4–5	≥ 6
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 430	> 300	> 250	> 350
m_{T} [GeV]	> 100	> 450	150–450	> 175
Aplanarity	–	> 0.01	> 0.05	> 0.06
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.25	> 0.25	–	–
$N_{b-\mathrm{jet}}$ (excl)	$= 0$ for b-veto, ≥ 1 for b-tag			
m_{eff} [GeV] (excl)	3 bins $\in$ [700,1900] + [> 1900]	2 bins $\in$ [1000,2000] + [> 2000]	2 bins $\in$ [1300,2000] + [> 2000]	3 bins $\in$ [700,2300] + [> 2300]
m_{eff} [GeV] (disc)	> 1100	> 1500	$> 1650(1300)$ for gluino (squark)	$> 2300(1233)$ for gluino (squark)

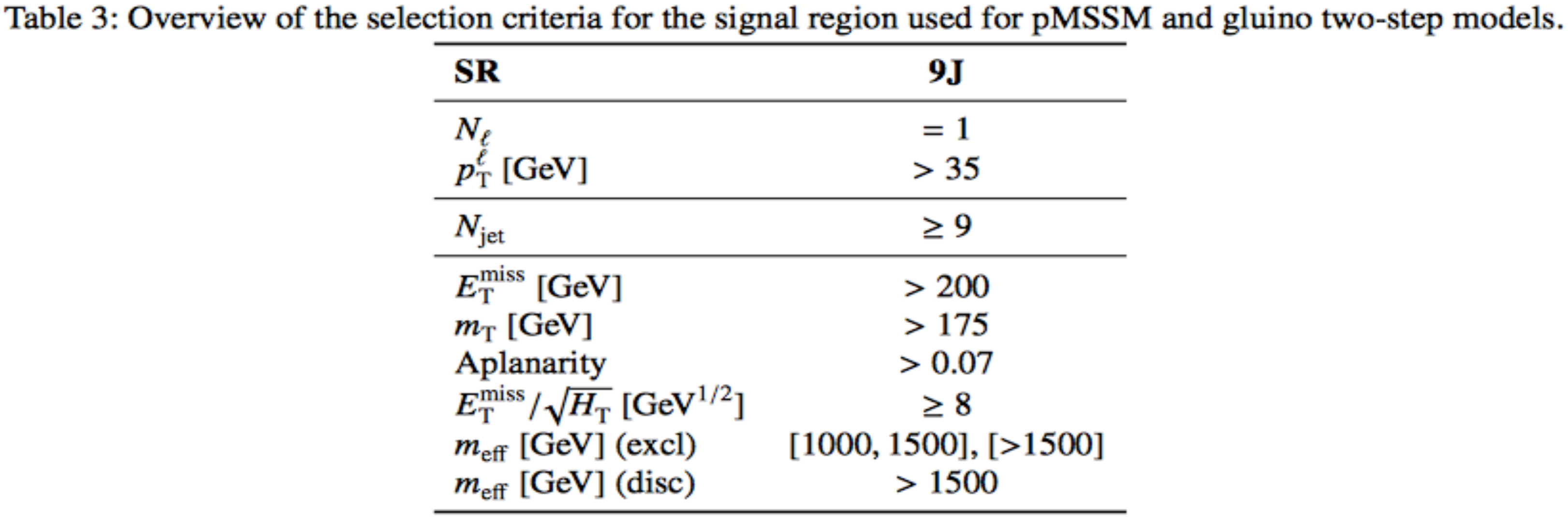
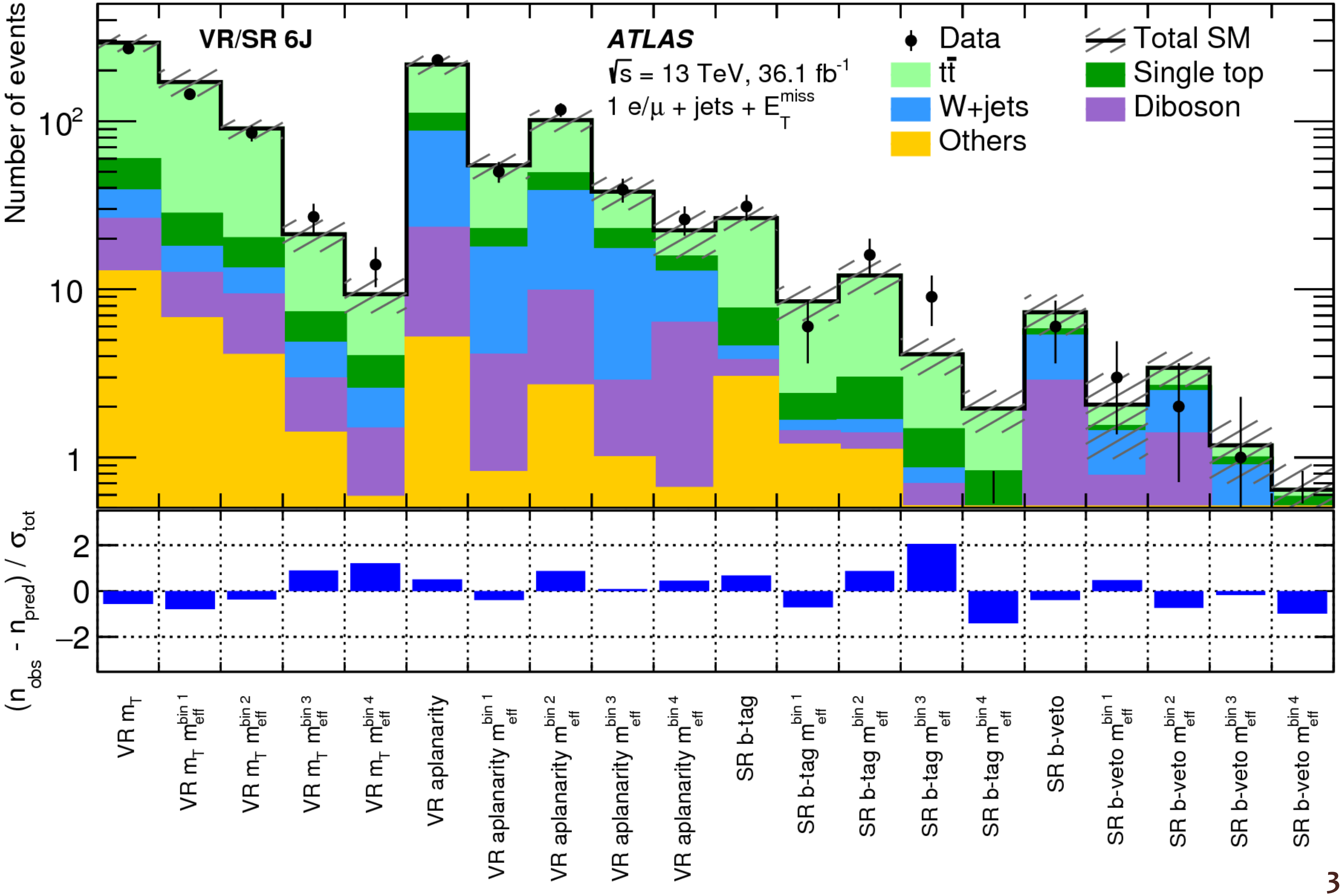


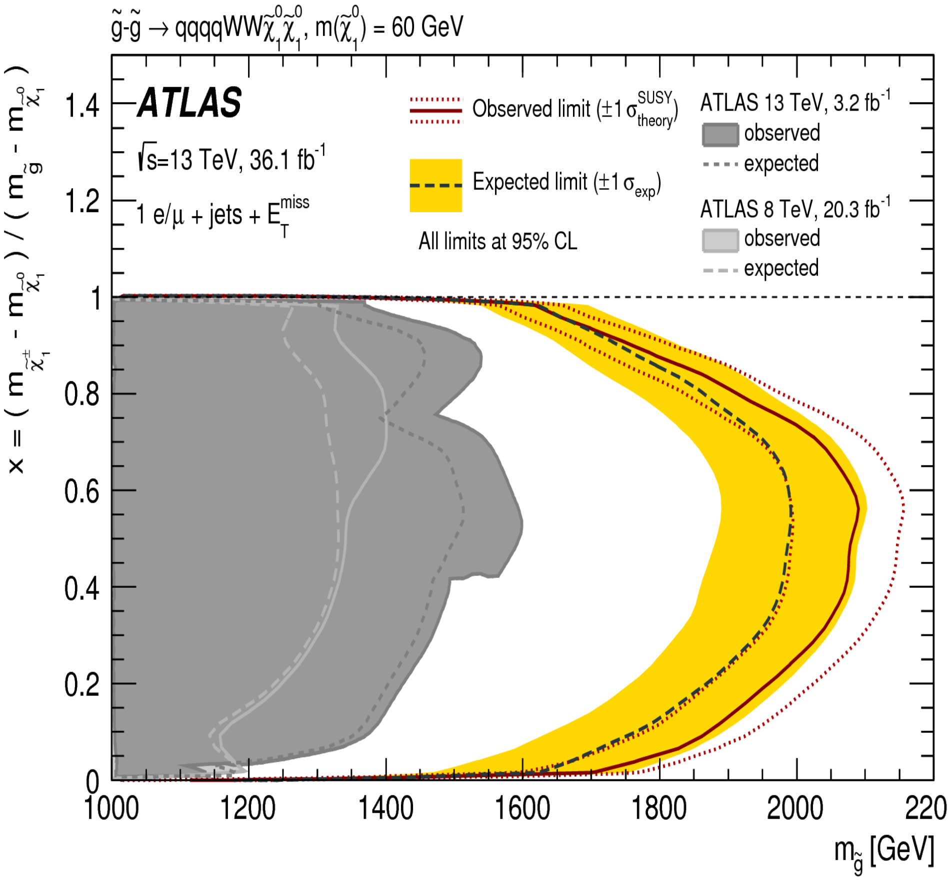
Table 3: Overview of the selection criteria for the signal region used for pMSSM and gluino two-step models.

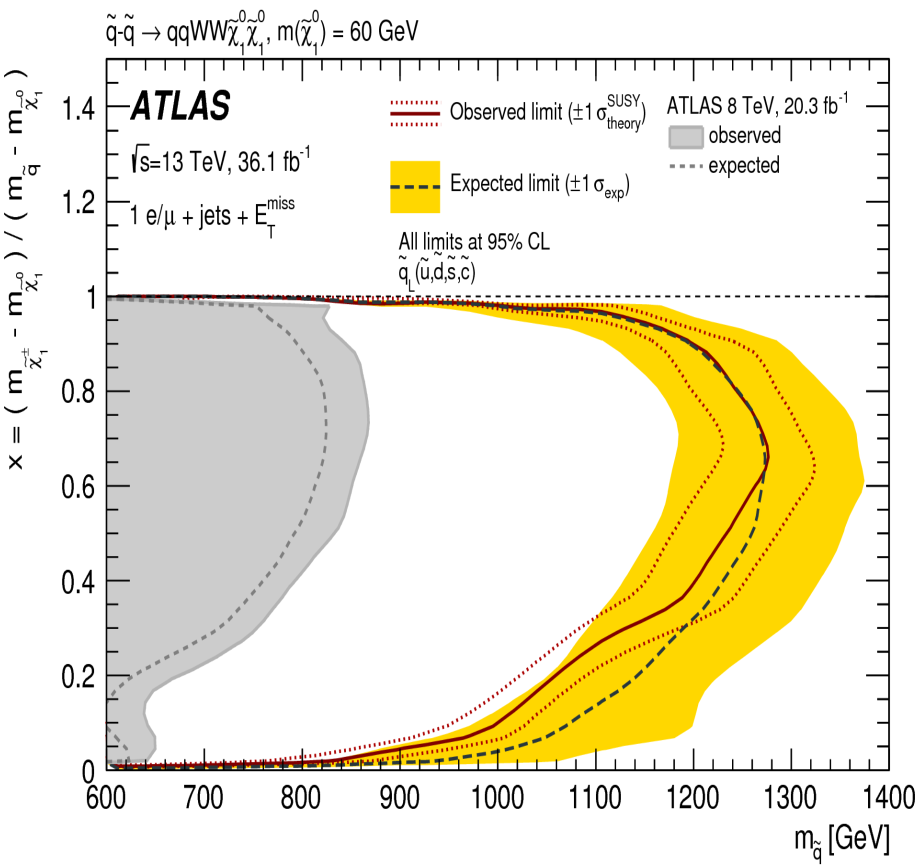
SR	**9J**
N_ℓ	$= 1$
p_{T}^{ℓ} [GeV]	> 35
N_{jet}	≥ 9
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 200
m_{T} [GeV]	> 175
Aplanarity	> 0.07
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ [GeV$^{1/2}$]	≥ 8
m_{eff} [GeV] (excl)	[1000, 1500], [>1500]
m_{eff} [GeV] (disc)	> 1500

1L SUSY search (RUN2)

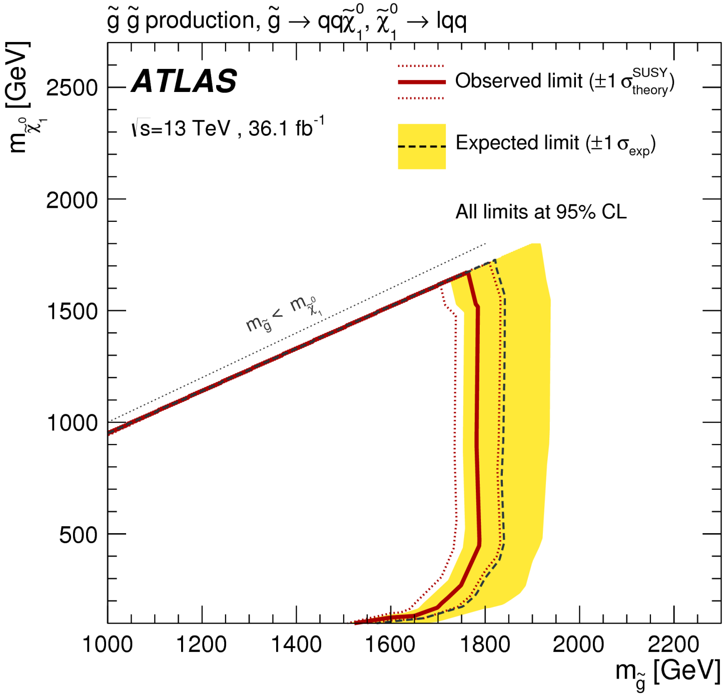


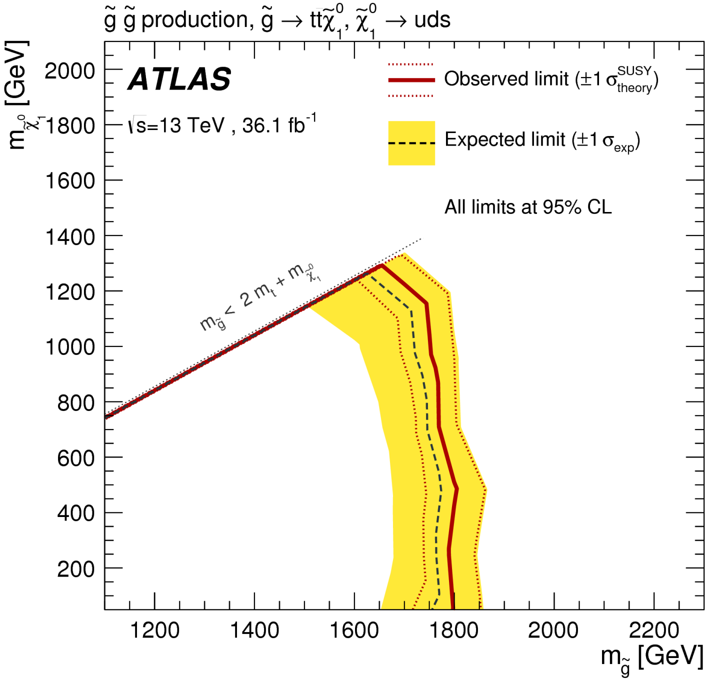
1L SUSY search (RUN2)

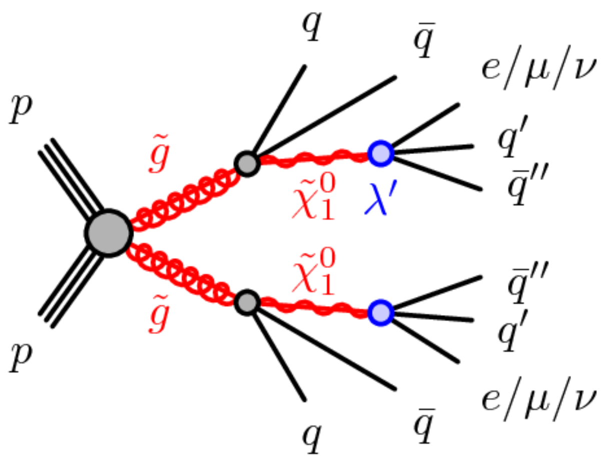


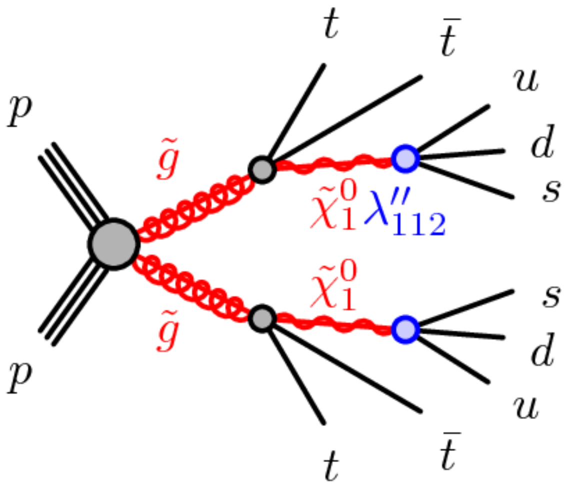


SS/3L SUSY search (RUN2)





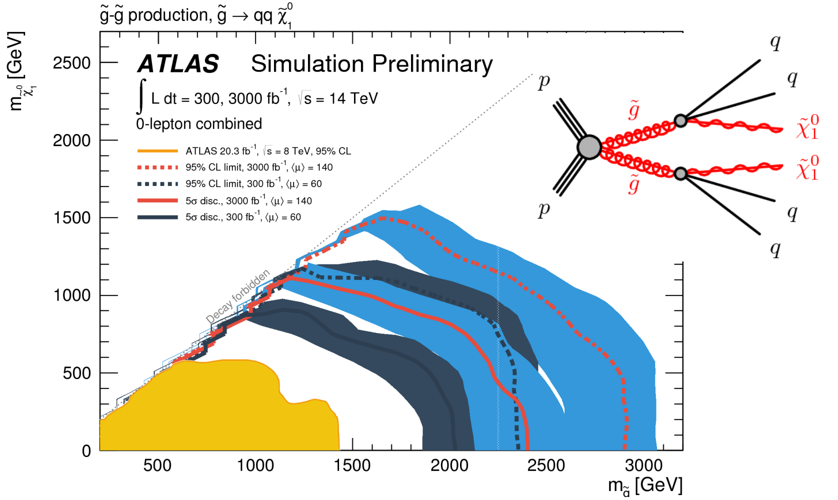


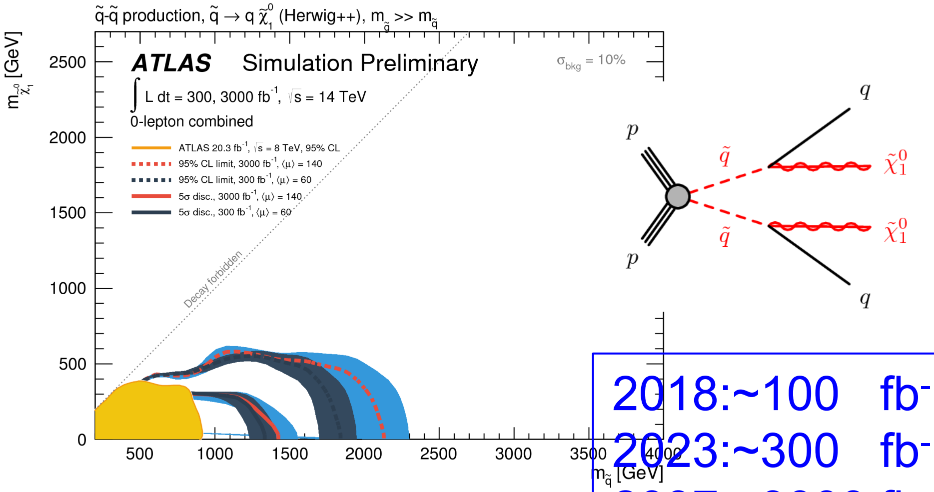


Long term prospects

ATL-PHYS-PUB-2014-010

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





2018:~100 fb^{-1}
2023:~300 fb^{-1}
2037:~3000 fb^{-1}