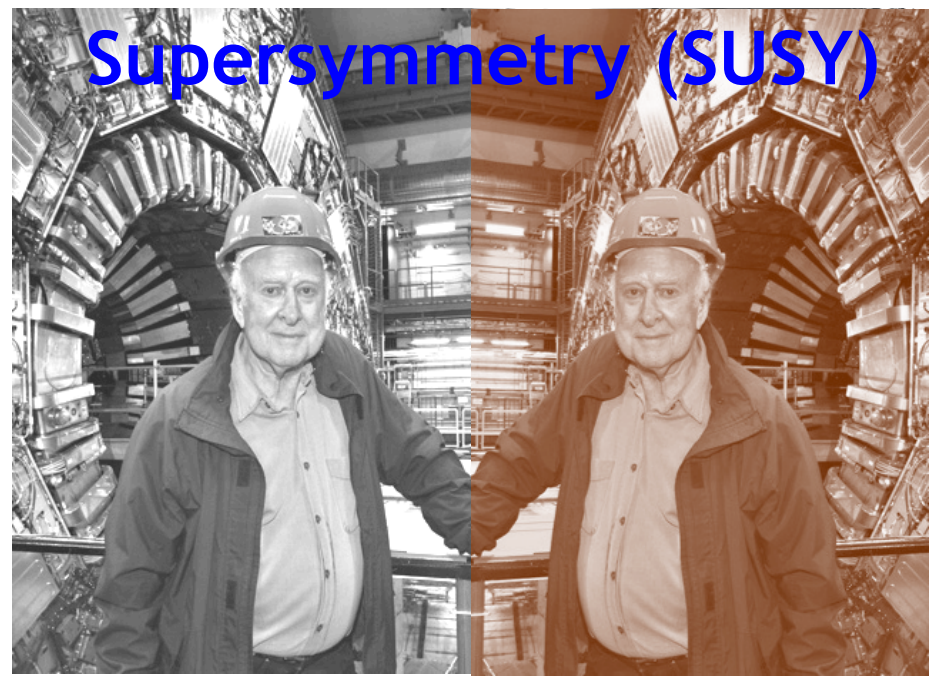


## IHEP SUSY Group:

- 1<sup>st</sup> RPC SUSY Search group in China
- Faculty: Xuai Zhuang, Da Xu, Shan Jin, Feng LU
- Students: Huan Ren, Huajie Cheng, Peng Zhang, Yang Liu, Chenzheng Zhu



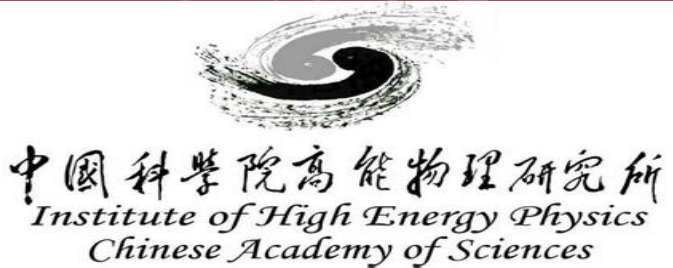
# ATLAS SUSY STUDY FROM IHEP

**Xuai Zhuang (庄胥爱)**

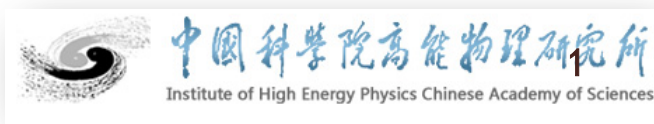
[xuai.zhuang@cern.ch](mailto:xuai.zhuang@cern.ch)

**IHEP, Beijing, China**

**Nov. 18 2016 创新团队年会**

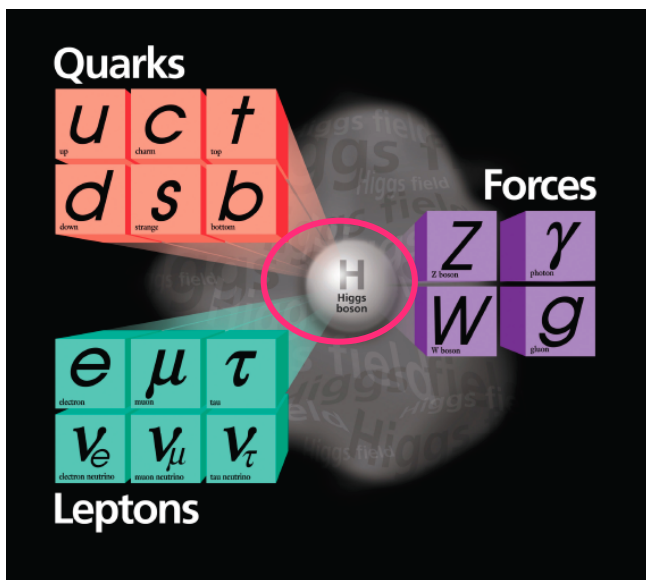


中国科学院高能物理研究所  
Institute of High Energy Physics  
Chinese Academy of Sciences



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

# SM and Beyond



■ 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**



Photo: A. Mahmoud  
François Englert

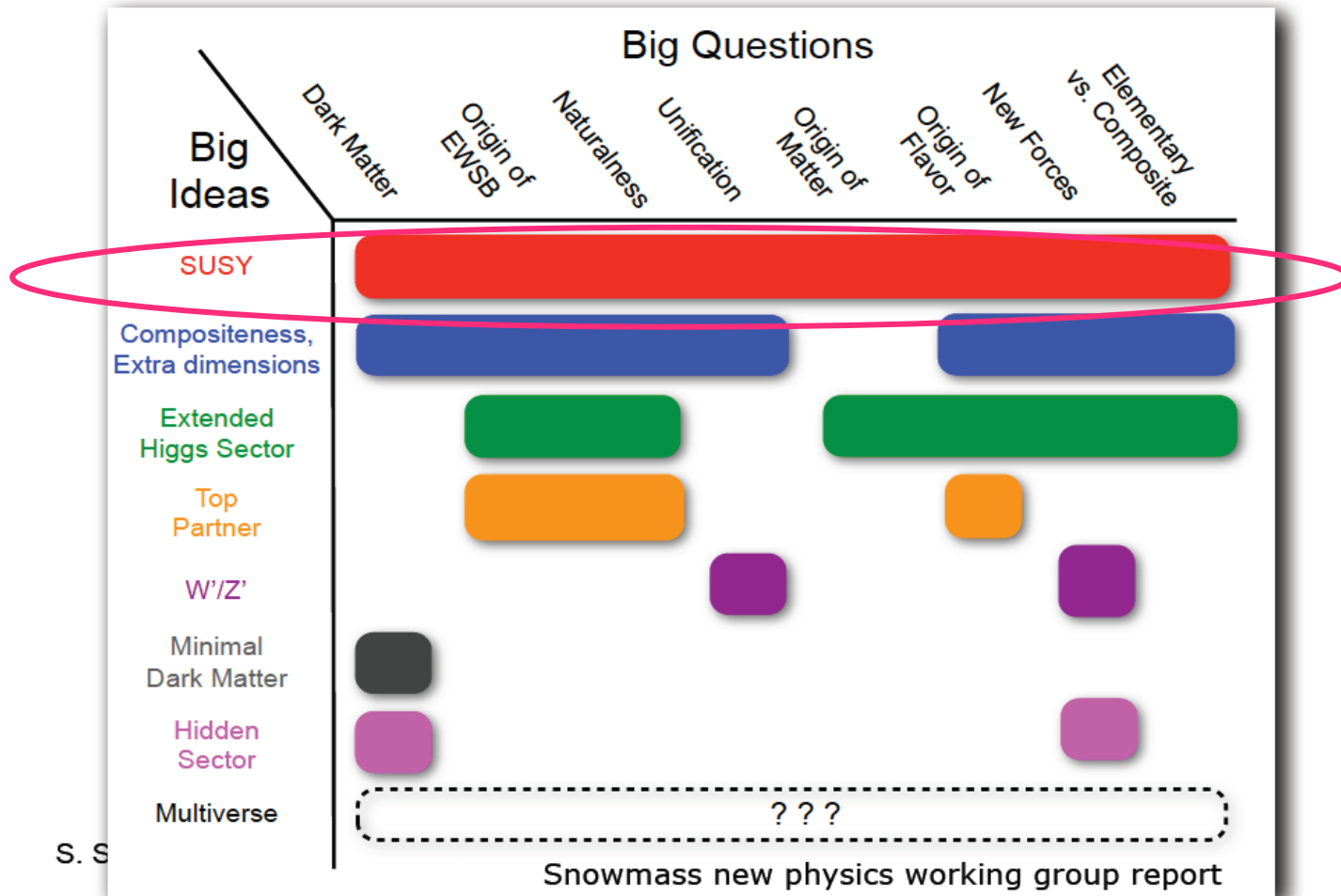


Photo: A. Mahmoud  
Peter W. Higgs



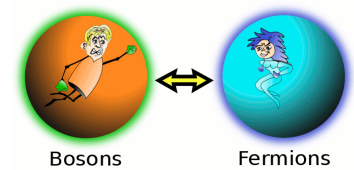
The Nobel Prize in Physics 2013  
François Englert, Peter Higgs

# New Physics beyond the SM



- 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



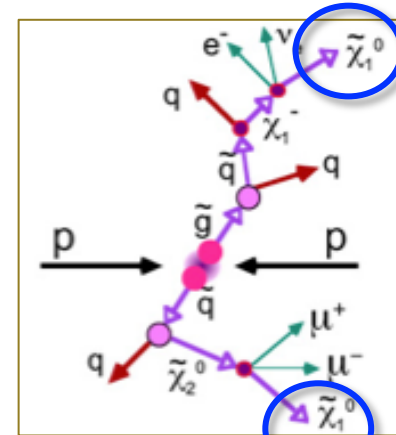
■ A symmetry which unified **fermions (matter)** and **bosons (forces)** → A fundamental theory

■ **Conserved R parity (RPC):** (originally introduced for stability of proton)

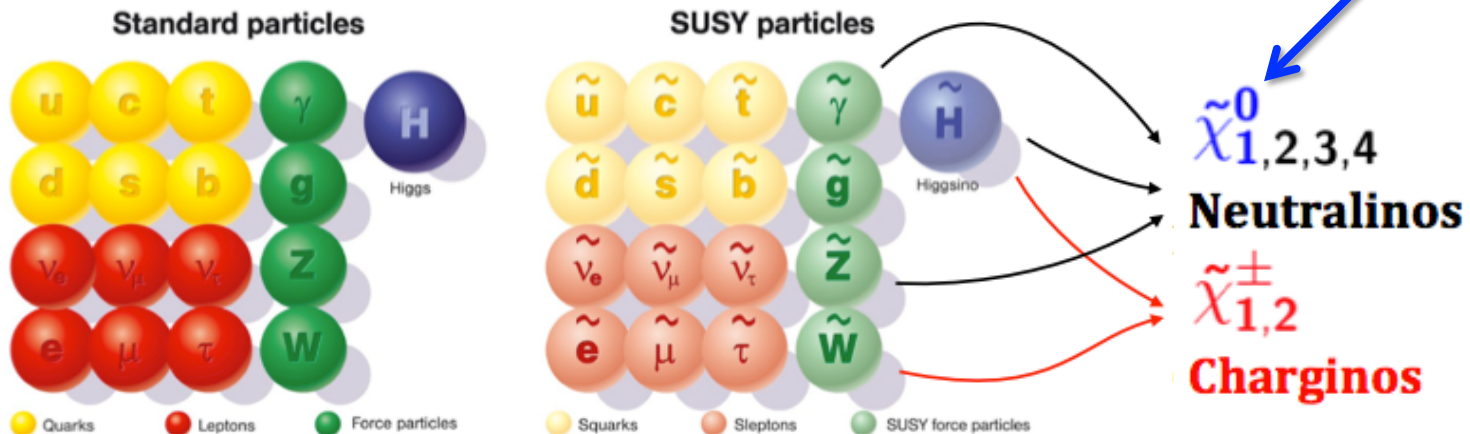
$$R = (-1)^{3(B-L)+2S}$$

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

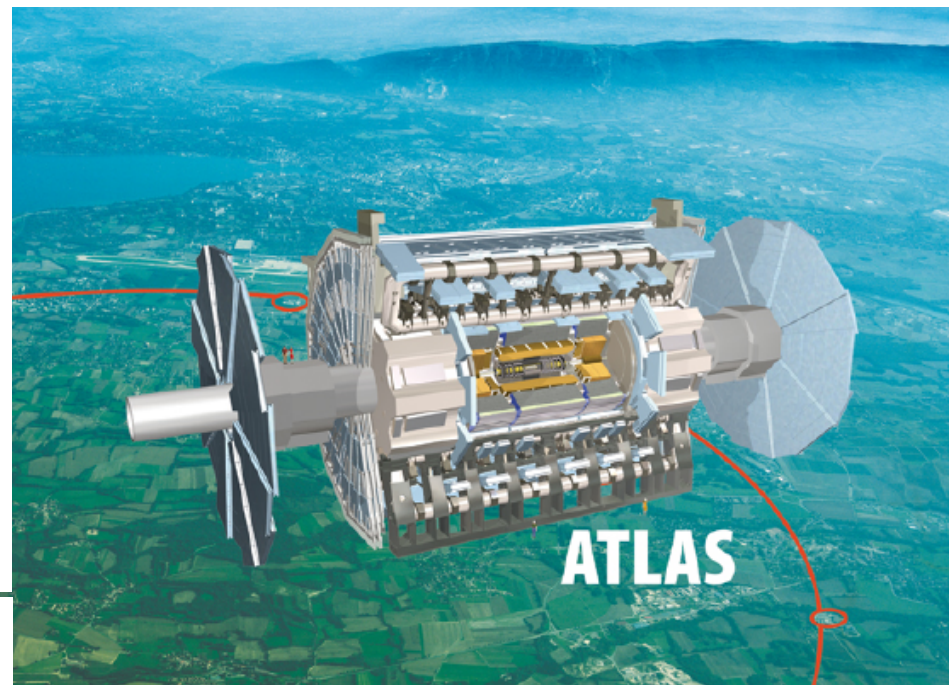
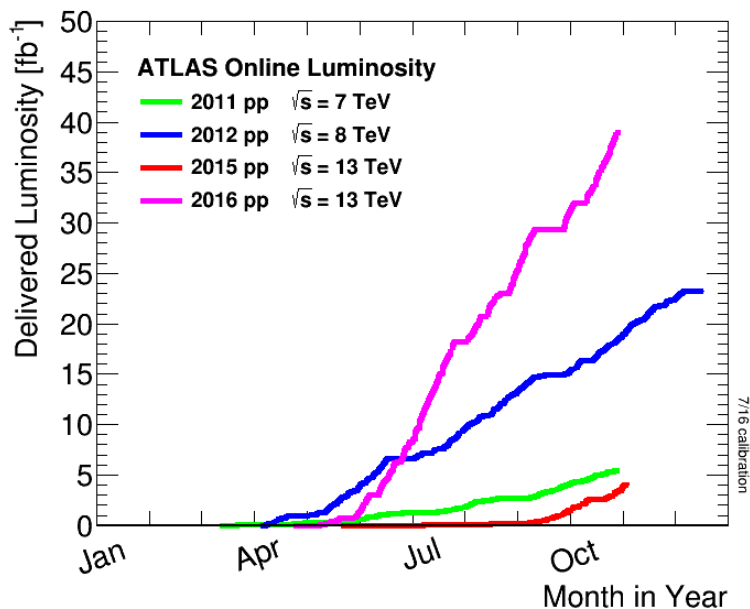
- SUSY particles produced/annihilated in pairs
- **Lightest SUSY particle (LSP) stable (DM candidate)**
- **Typical signature: jets/leptons/photons + MET**



■ **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  $\text{pb}^{-1}$  7 TeV data (2010)
- ~ 5  $\text{fb}^{-1}$  7 TeV data (2011)
- ~ 20  $\text{fb}^{-1}$  8 TeV data (2012)

## Run2:

- ~ 3.2  $\text{fb}^{-1}$  13 TeV data (2015)
- ~ 33.2  $\text{fb}^{-1}$  13 TeV data (2016)

The results are based on 13-18  $\text{fb}^{-1}$  @ 13 TeV (RUN2) for summer CONF

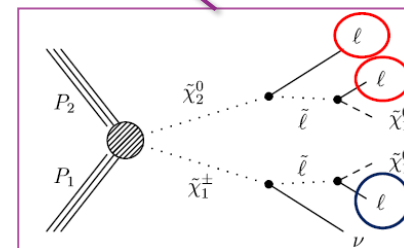
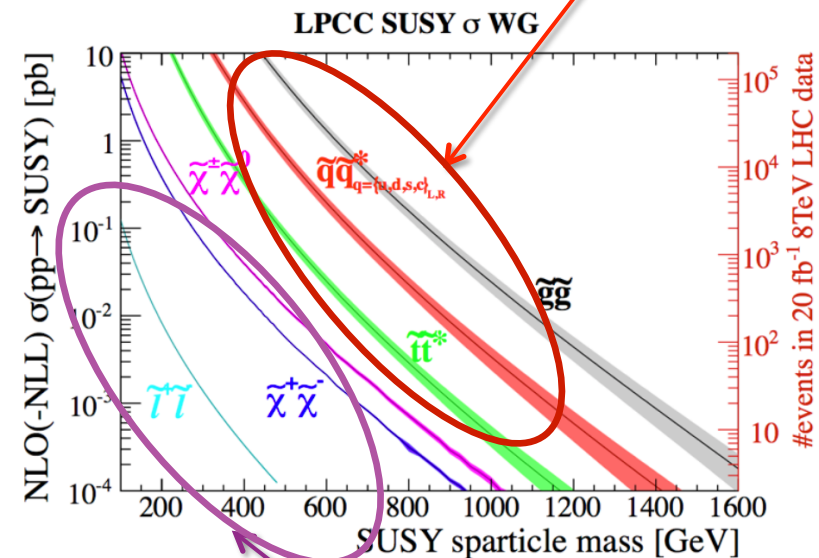
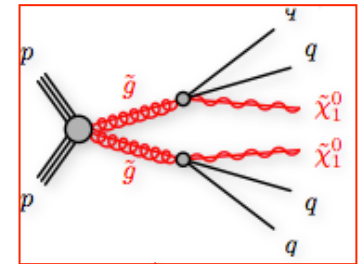
# SUSY Search @ LHC

**Strong production:** targeting gluino and squarks (Inc. 3<sup>rd</sup> gen. squarks)

- ❑ Generic signatures :
  - Multi -jets + n\_lepton/n\_photon (n=0,1, ≥2) + large  $E_T^{\text{miss}}$  (0L, 1L, ≥2L)
- ❑ large xs, but heavy SUSY mass scale
- ❑ **IHEP topics:**
  - ① 1L +jets +MET
  - ② SS2L/3L +jets +MET

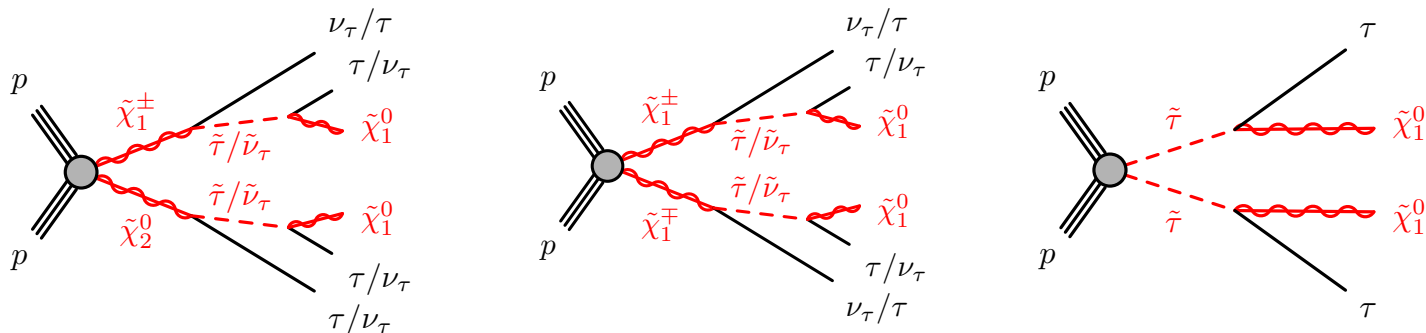
**Weak production:** targeting charginos, neutralinos and slepton

- ❑ Generic signatures:
  - low-jet multiplicity + ≥ 2leptons + large  $E_T^{\text{miss}}$  (2/3/4L, ≥2tau)
- ❑ low xs, but small SUSY mass scale
- ❑ **IHEP topic:**
  - ④ ≥2tau+MET



# (1) EWK-2tau SUSY search

- 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: 1 for C1N2, 1 for C1C1

- Main backgrounds:

- Fake tau: W (normalized MC to data in WCR) and multi-jet (ABCD method)
- Real tau: Diboson (MC simulation)

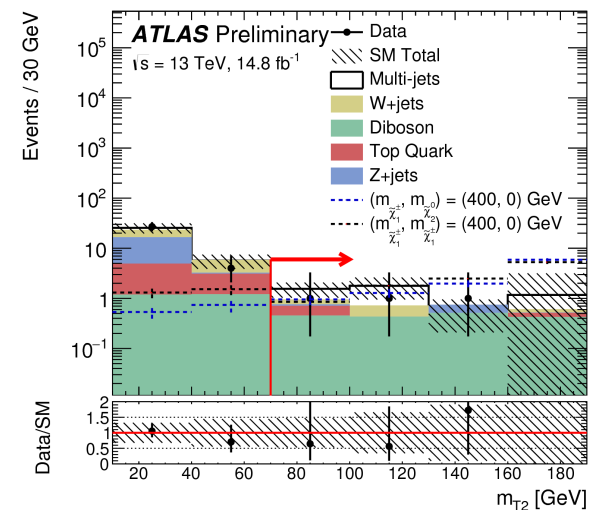
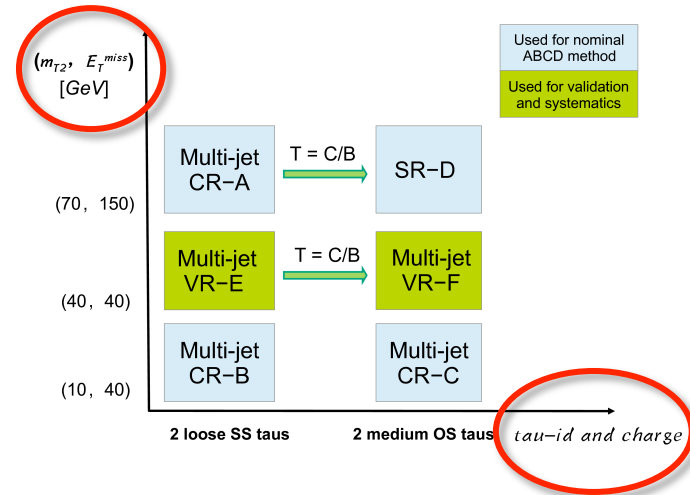
- ABCD method:

- Extrapolation performed from A to D through TF ( $D = A * C/B$ )
- Validation Region (Multi-jet VR-EF): used for validation and systematics

- Good data/SM estimation in validation regions

- No significant excess in SRs, so set exclusion limit

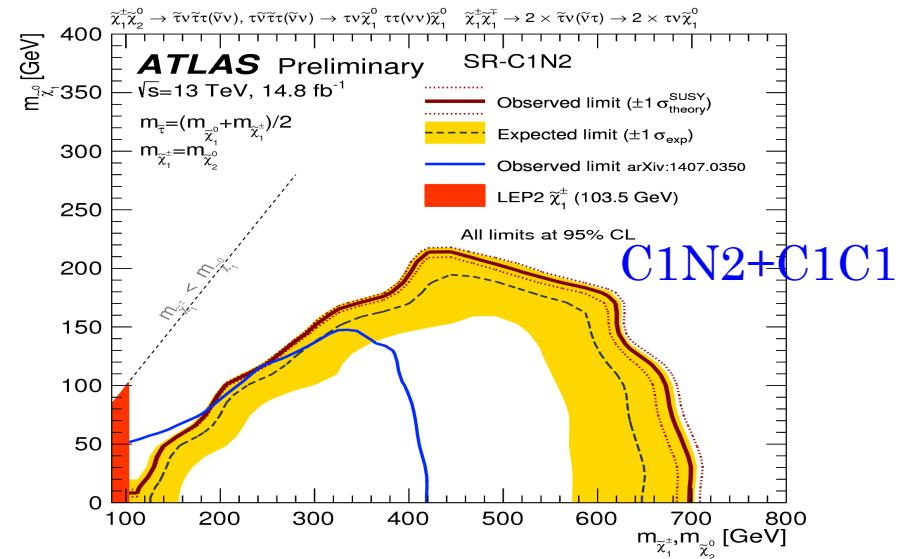
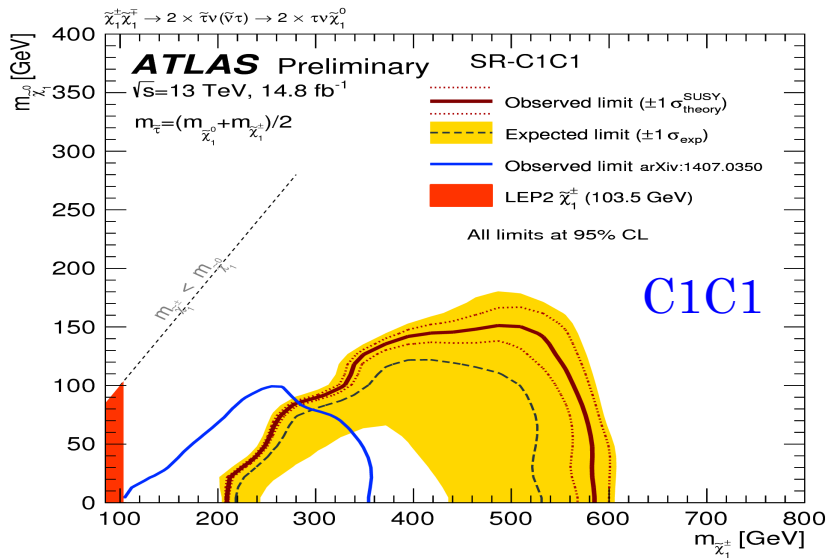
## Illustration of “ABCD” method





# Exclusion Limits

ATLAS-CONF-2016-093

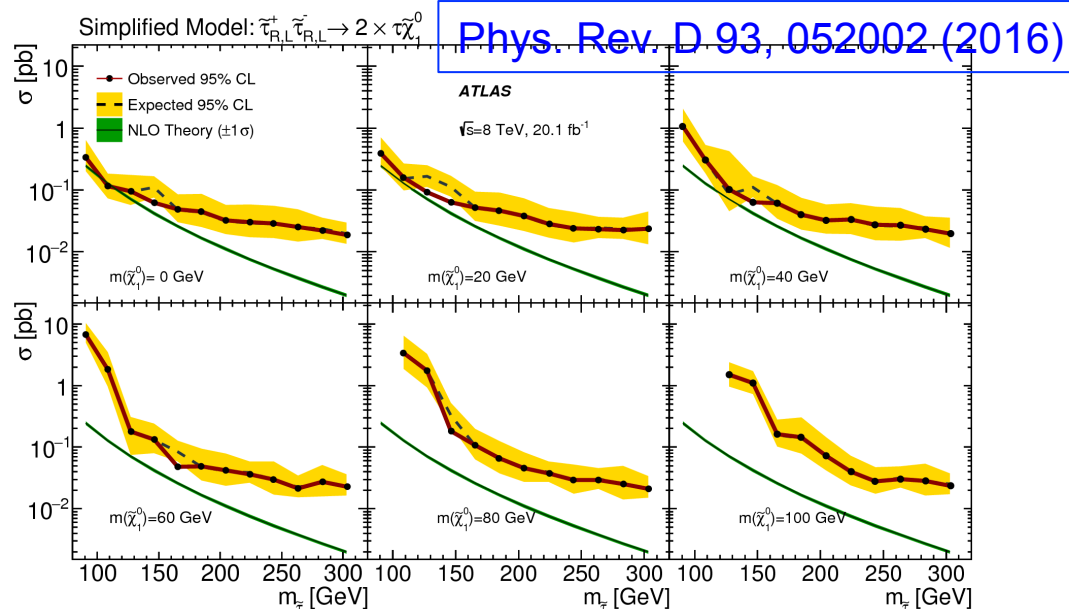
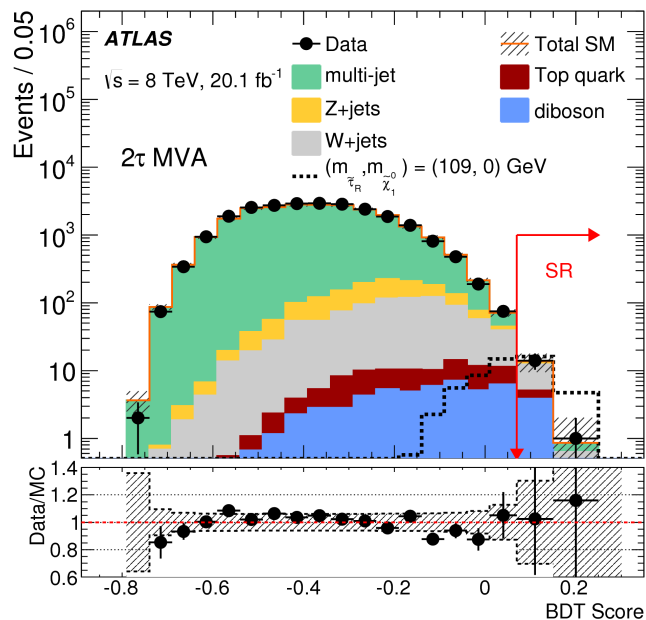
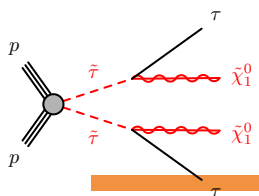


■ The results ATLAS-CONF-2016-093 have been showed at Search16 conference

- C1N2+C1C1 production: C1/N2 mass up to 700 GeV excluded for massless N1
- Wino-like Chargino (C1C1) production : C1 mass up to 580 GeV excluded for a massless N1

■ Direct stau search not covered for 13 TeV data yet, next slides shows MVA study using Run1 data.

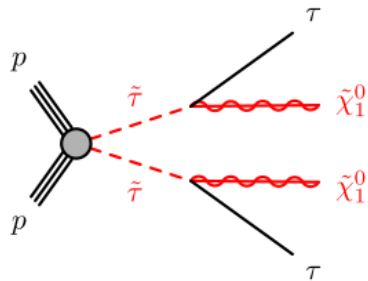
# Direct stau MVA study



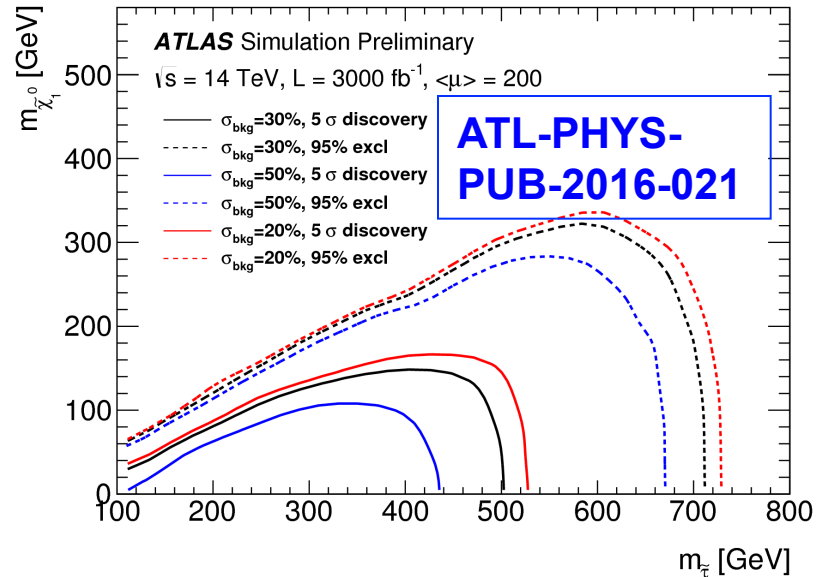
- 12 input variables used in MVA with good signal/bg separation: MET,  $M_{\text{eff}}$ ,  $m_{T2}$ ,  $m(\tau\tau)$ ,  $m_T(\tau_1)$ ,  $m_T(\tau_2)$ ,  $\tau_{1\_pt}$ ,  $\tau_{2\_pt}$ ,  $\Delta\phi(\tau\tau)$ ,  $\Delta R(\tau\tau)$ ,  $\Delta\phi(\tau_1, \text{MET})$ ,  $\Delta\phi(\tau_2, \text{MET})$ .
- 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.

# Direct stau upgrade study

upgrade



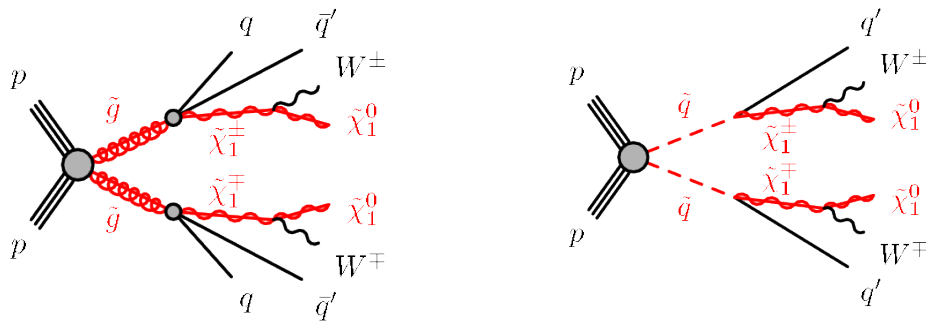
**Solid line:  $5\sigma$  discovery**  
**Dashed line: 95% exclusion**



- The direct stau search sensitivity has been studied for HL-LHC ( $14\text{TeV } 3000 \text{ fb}^{-1}$ )
- For a massless LSP, the  $5\sigma$  discovery sensitivity (exclusion) reaches up to 500 (700) GeV in stau mass (30% syst.).
- The results ATL-PHYS-PUB-2016-021 have been showed at ECFA workshop at Oct. 2016.

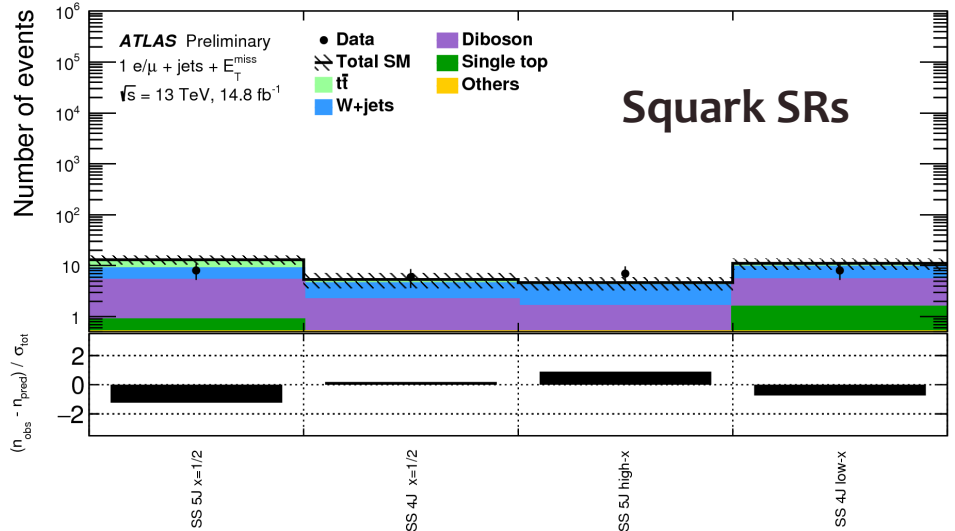
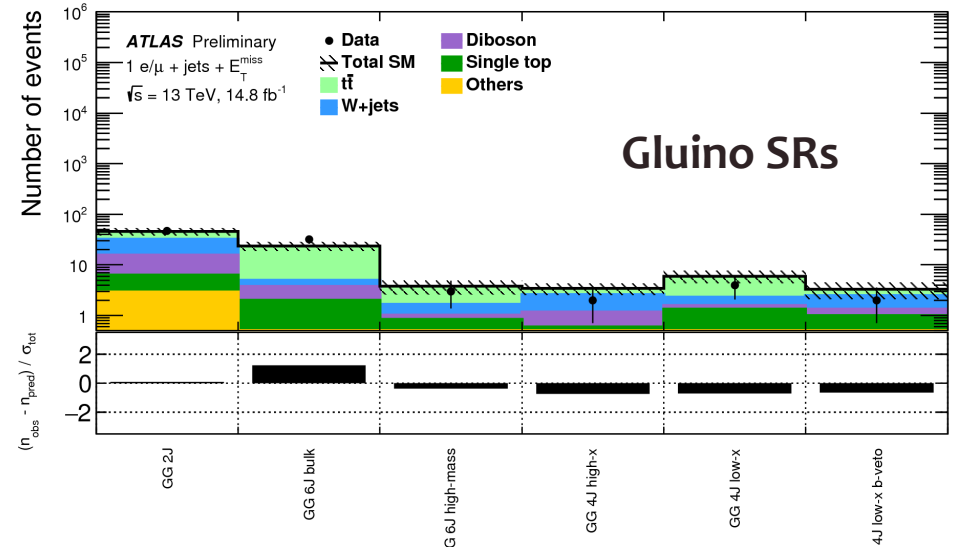
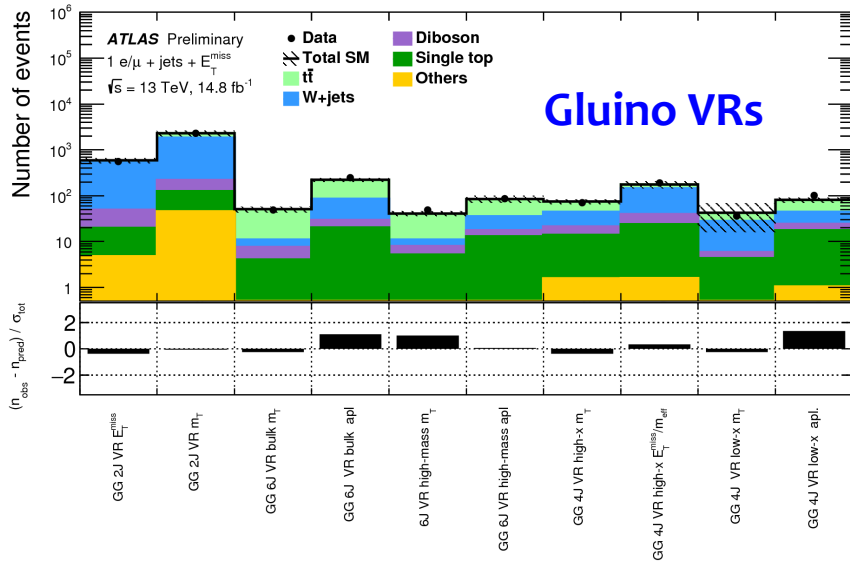
## (2) 1L SUSY search

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



- 10 SRs defined targeting different search scenarios :
  - Scenarios with medium to large mass splitting (“hard lepton”)
    - 9 SRs (5 GG, 4 SS) with jet multiplicity ranging from 4 to 6, **large Meff, MET and mT**
  - Compressed scenarios (“soft leptons”)
    - 1SR for GG-softLept:  $\geq 2$ jets, **large MET**
- Main backgrounds: ttbar and W+jets, normalized MC to data in TCR and WCR, and validated in VRs

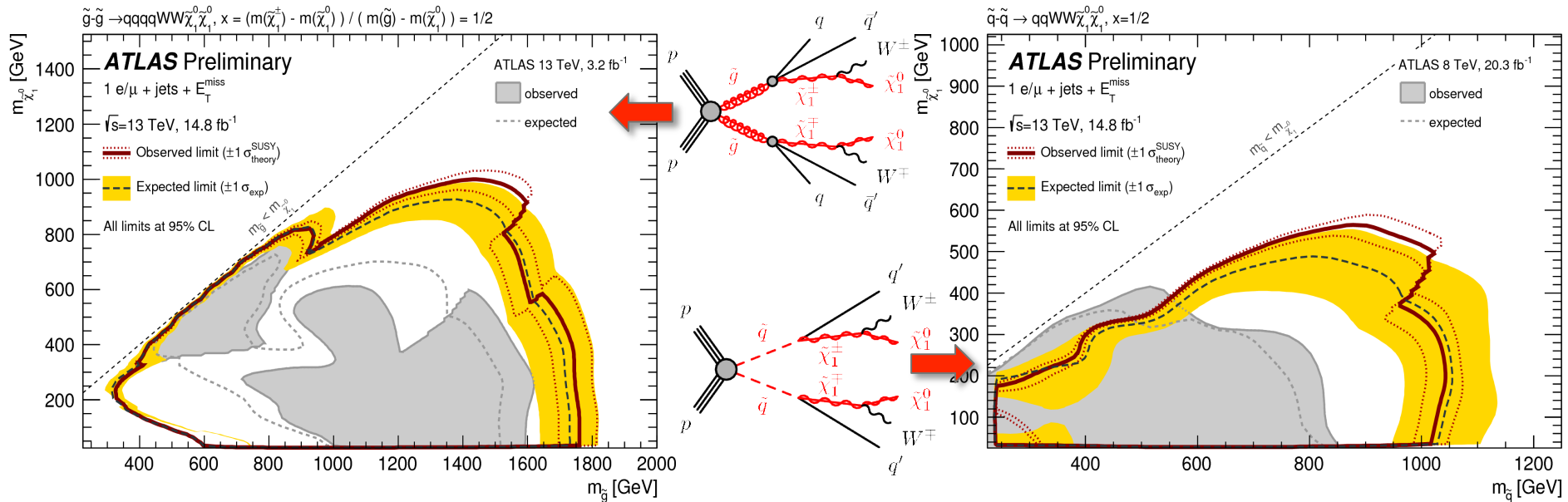
# Results



■ Good data/MC agreement in VRs

■ No significant excess in all SRs  $\rightarrow$  Set exclusion limit

# Exclusion Limits



- Gluino (squark) masses up to 1.7 TeV (1.0 TeV) are excluded for low neutralino masses ( $\leq 400$  GeV or  $\leq 300$  GeV)
- IHEP made a leading contribution (contact person/ contact editor/approval talks)

# (3) SS/3L SUSY search

- Search for squarks/gluinos via long decay chain in **SS/3L** final states
  - Sensitive for a wide range of models (Fig. 1)
  - Very clean channels with only tiny SM bg (mainly top+V, diboson, triboson) → **A good tag for new physics**
- 6 RPC+3 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

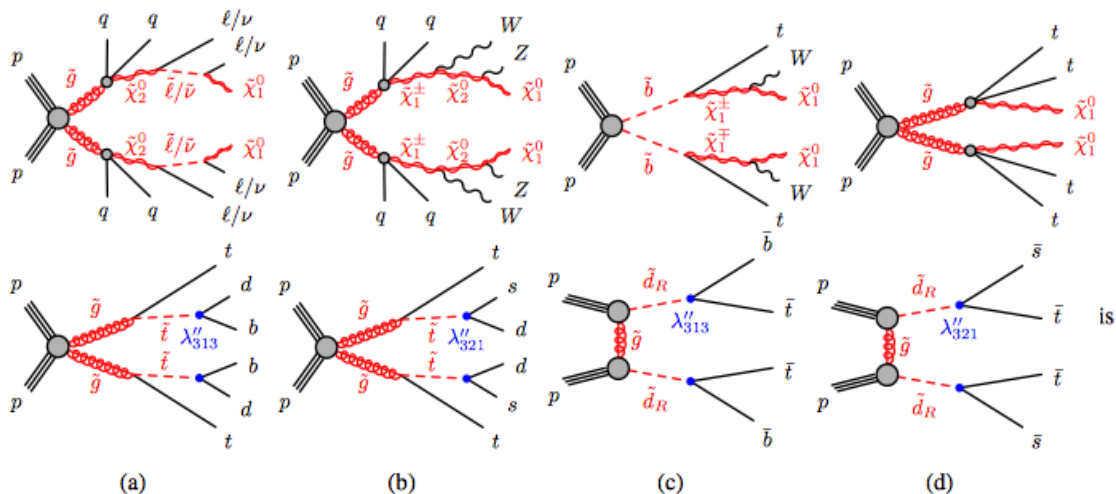
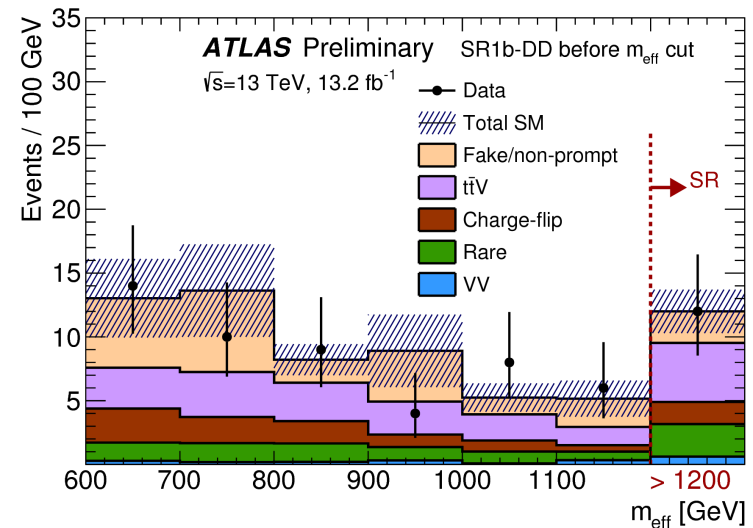
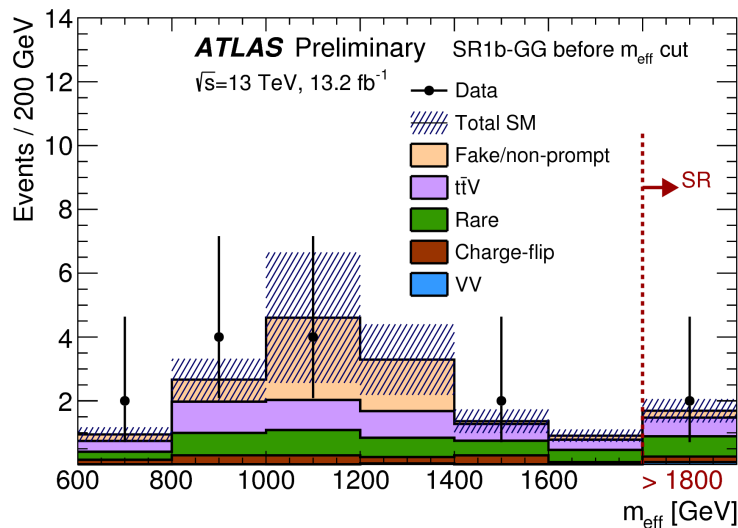
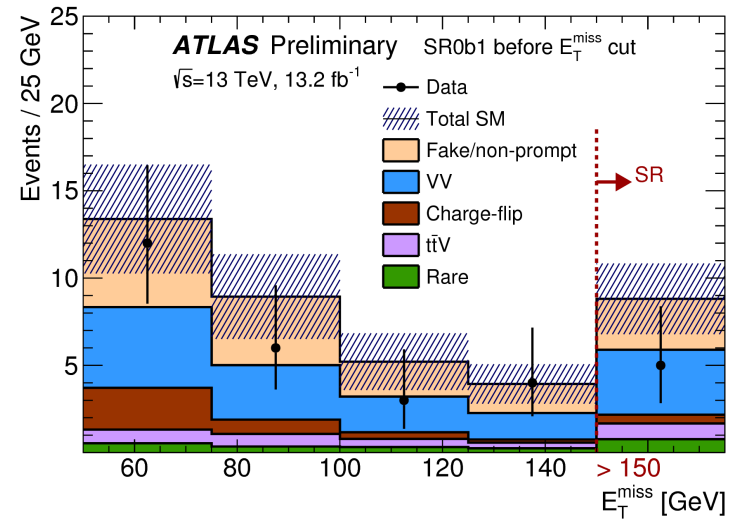
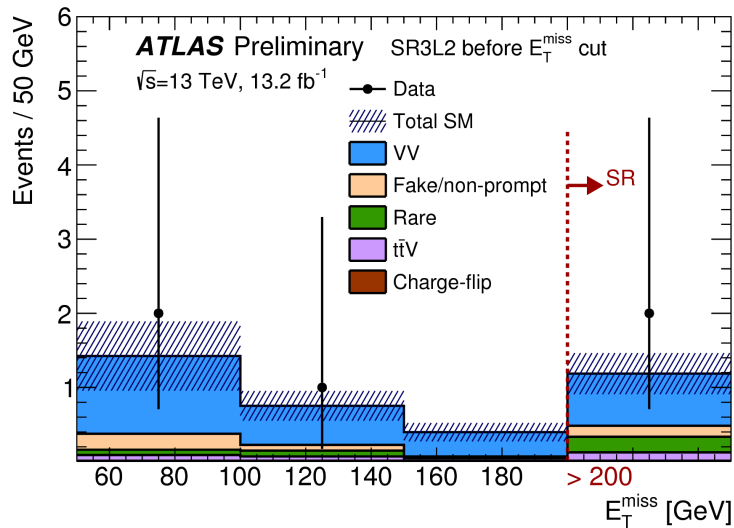


Figure 2: RPV SUSY processes featuring gluino (a,b) or right-handed down squark (c,d) pair production and decays via baryon number-violating couplings  $\lambda''$  considered in this analysis.

# Results

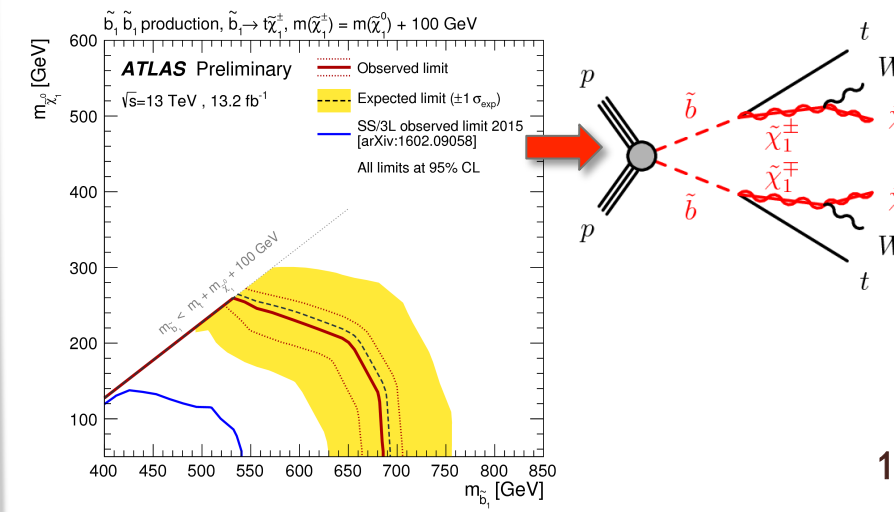
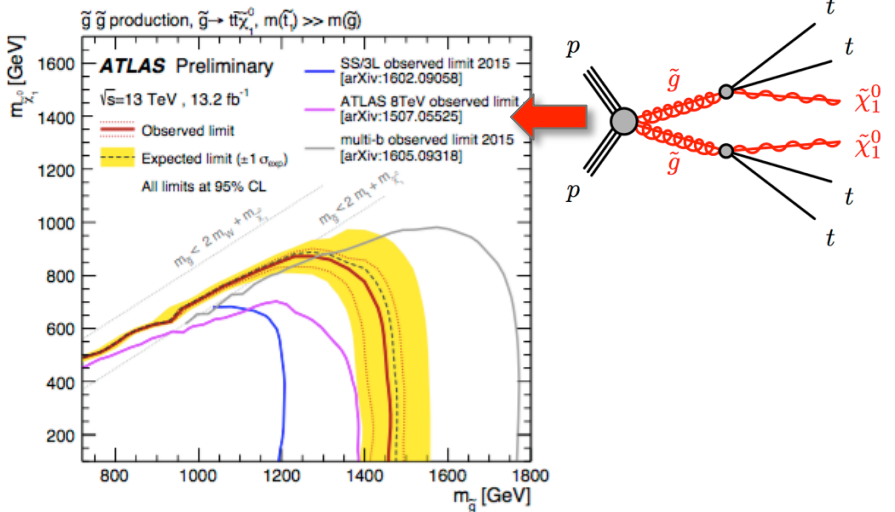
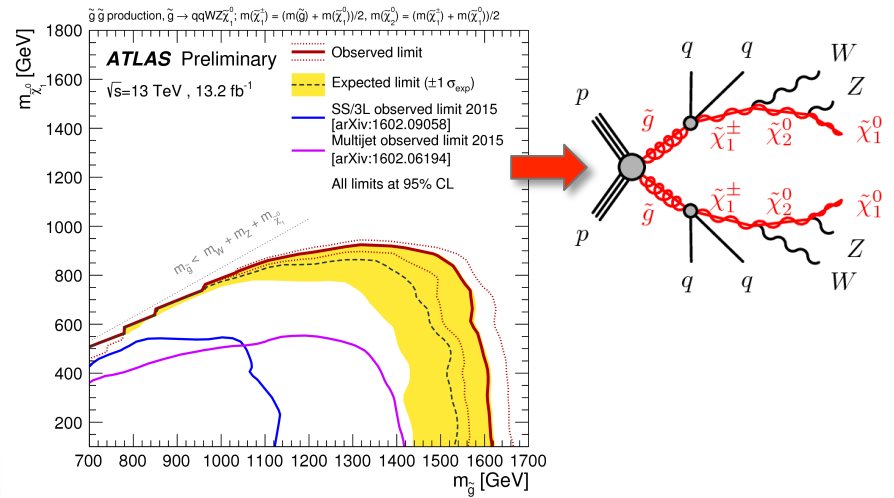
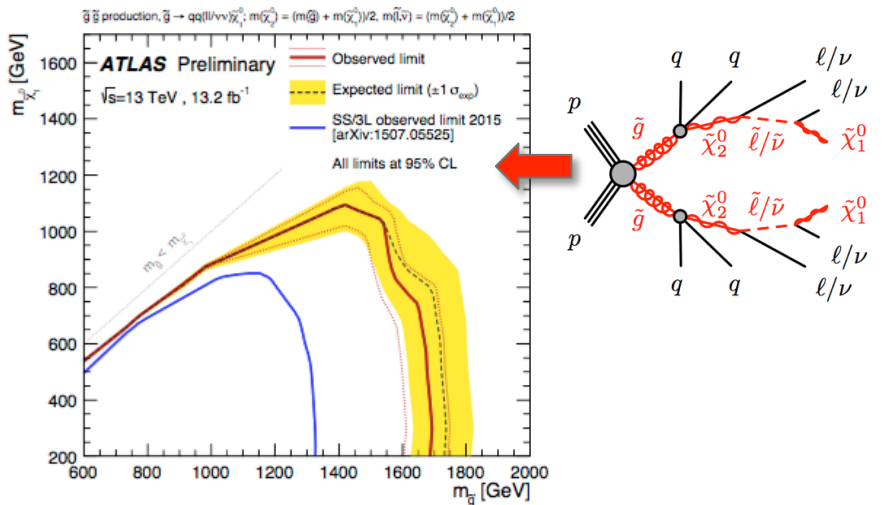
## ■ No significant excess observed in SRs





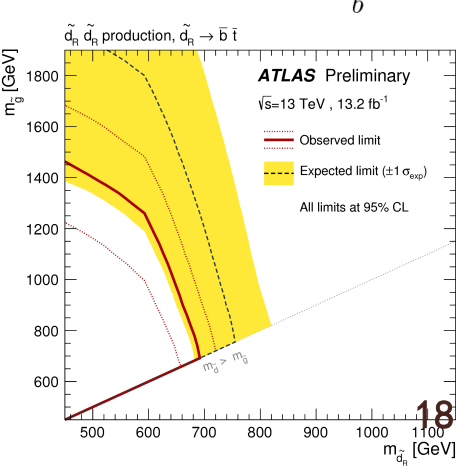
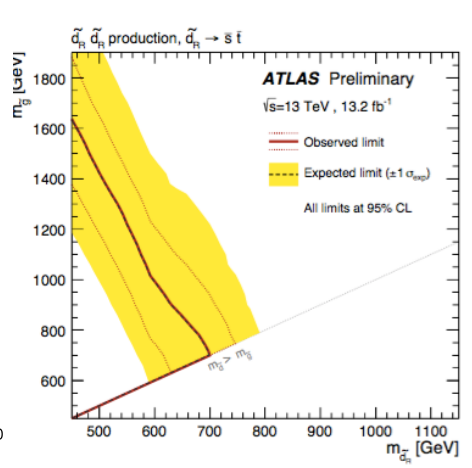
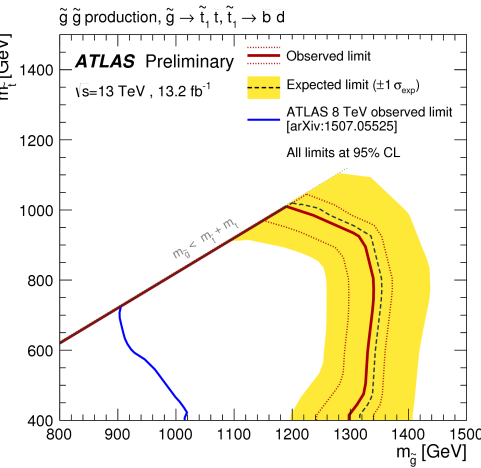
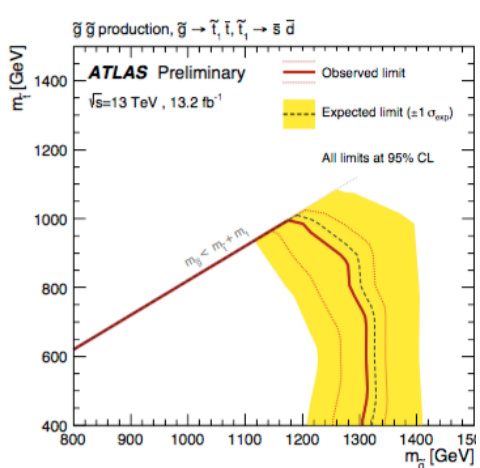
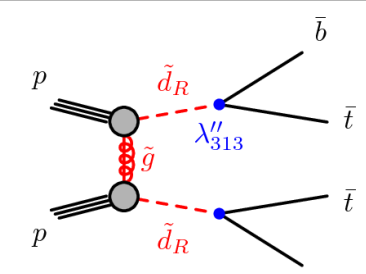
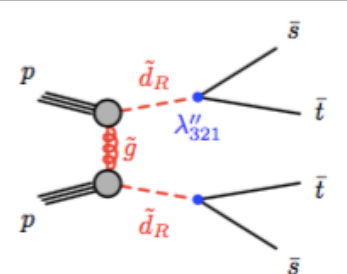
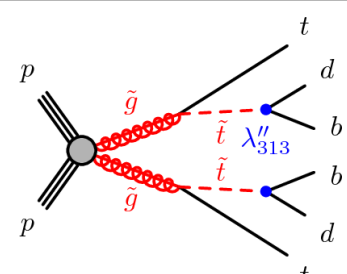
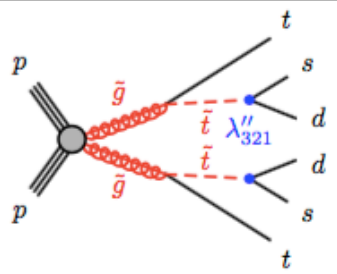
# Exclusion Limits

■ Gluino mass <1.4-1.7 TeV and LSP mass < 850-1100 GeV are excluded for gluino pair production. ~b mass < 690 GeV excluded



# Exclusion Limits

- Gluino mass  $< 1.3$  TeV and LSP mass  $< 1$  TeV excluded in RPV scenario.
- Right-handed down squark masses are probed up to  $m\tilde{d}_R \approx 700$  GeV in RPV scenarios.
- IHEP mainly contributed in SR definition and main background estimation in data, Gave approval talks for paper publication.



# IHEP contributions and publications

- **Electroweak SUSY search with 2taus:** contact person/editor/approval talks
  - [contact editor] Run1 8TeV EWK summary paper: **Phys. Rev. D 93, 052002 (2016)**
  - [contact editor] Run2 13TeV CONF NOTE: **ATLAS-CONF-2016-093 [SEARCH16]**
  - [contact editor] Upgrade 13TeV PUB NOTE: **ATL-PHYS-PUB -2016-021 [ECFA16]**
  - [Ongoing] Run2 13 TeV analysis: **aiming for Moriond2017 paper**
- **Inclusive SUSY search with 1 lepton:** contact person/editor/approval talks
  - [contact editor] Run2 13TeV signature paper: **Eur. Phys. J. C 76 (2016) 565**
  - [contact editor] Run2 13TeV CONF NOTE: **ATLAS-CONF-2015-076 [Moriond16]**
  - [contact editor] Run2 13TeV CONF NOTE: **ATLAS-CONF-2016-037 [ICHEP16]**
  - [Ongoing] Run2 13 TeV analysis: **aiming for Moriond2017 paper**
- **Inclusive SUSY search with SS/3L:** editor/approval talks
  - Run2 13TeV signature paper: **EPJC(2016)76(5), 1-26**
  - Run2 13TeV CONF NOTE: **ATLAS-CONF-2015-078 [Moriond16]**
  - Run2 13TeV CONF NOTE: **ATLAS-CONF-2016-054 [ICHEP16]**
  - [Ongoing] Run2 13 TeV analysis: **aiming for Moriond2017 paper**

**Paper**  
**CONF note**  
**Ongoing**

- **Published 3 paper, 6 CONF/PUB notes, contact editors for 6 of them**
- **Ongoing 3 analyses aiming for Moriond paper**

# Summary from IHEP SUSY Group

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## ■ 高能所SUSY实验小组:

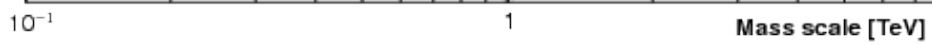
- 国内**首个**在LHC实验中进行R宇称守恒SUSY研究的实验小组（3名职工，5名研究生），已具有较强的国际竞争力。
- 团队成员在国际合作组担任重要角色，已具有一定的国际知名度：
  - ATLAS SUSY EW 物理组召集人，ATLAS合作组委员会顾问组成员
  - ATLAS SUSY信号联络人，ATLAS HistFitter专家联络人
  - 2tau contact person, 1L contact, direct stau upgrade contact
  - Stop to stau Ed Board,

## ■ 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**，**6篇CONF / PUB NOTES**，**6个**国际会议报告

- 基于2015+2016年获取的13-15 fb<sup>-1</sup> 13 TeV的数据，整个ATLAS SUSY组发表了**12(18)篇paper (CONF note)**，本团队在**2(3)篇**中做出**主导或主要贡献**

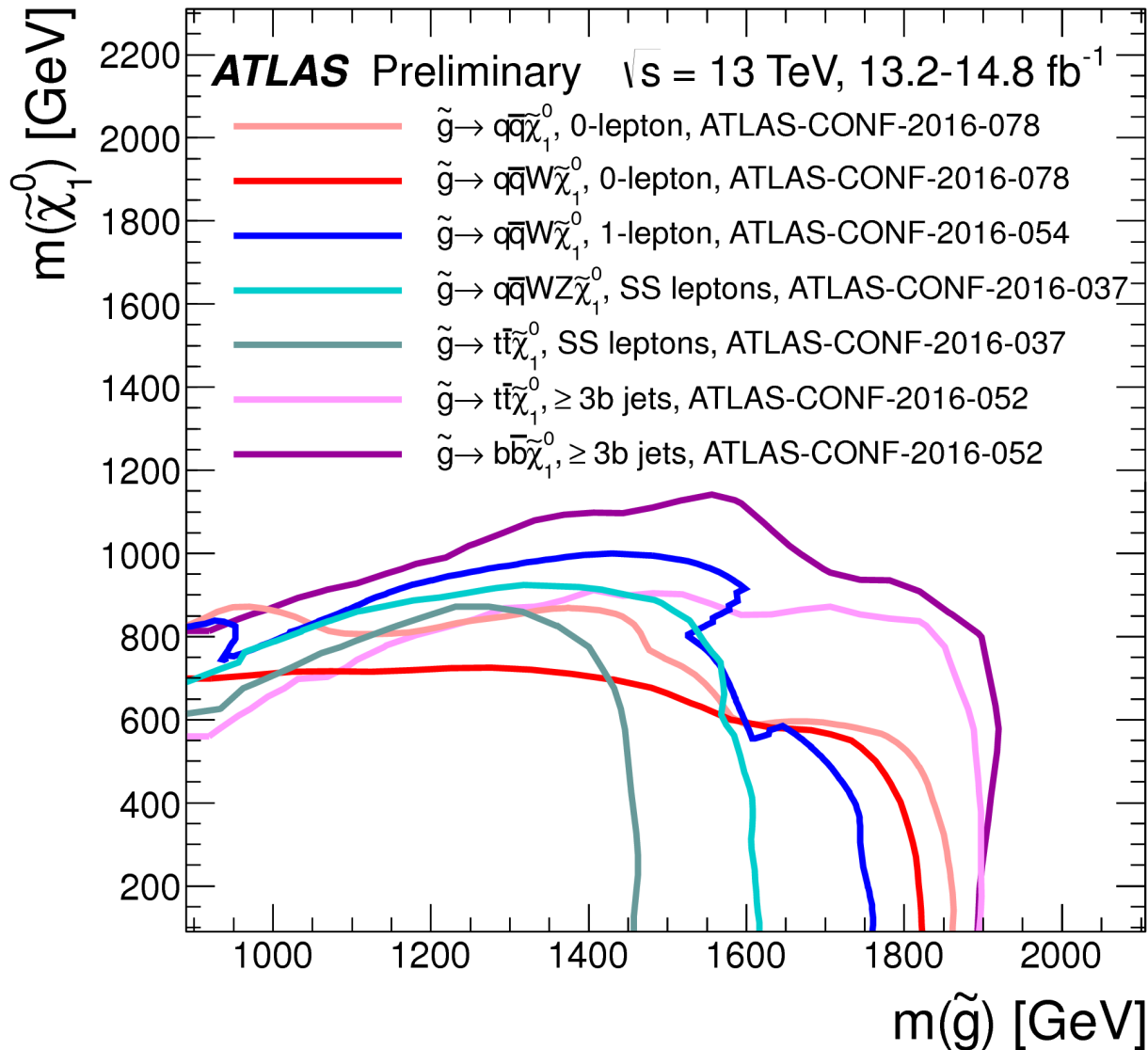
Model	$e, \mu, \tau, \gamma$	Jets	$E_T^{miss}$	$\int \mathcal{L} d\Omega (\text{fb}^{-1})$	Mass limit	$\sqrt{s} = 7, 8$ TeV	$\sqrt{s} = 13$ TeV	Reference	
Inclusive Searches	MSUGRA/CMSSM	0-3 $e, \mu, \tau$	2-10 jets/3 $b$	Yes	20.3	$\tilde{g}, \tilde{q}$	1.89 TeV	$m(\tilde{g})=m(\tilde{q})$	1507.05525
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$	0	2-6 jets	Yes	13.3	$\tilde{q}$	1.35 TeV	$m(\tilde{q}_1^0)<200$ GeV, $m(1^{st} \text{ gen. } \tilde{q})\geq m(2^{nd} \text{ gen. } \tilde{q})$	ATLAS-CONF-2016-078
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$	608 GeV	$m(\tilde{g})-m(\tilde{q}_1^0)<5$ GeV	1604.07773
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$	0	2-6 jets	Yes	13.3	$\tilde{q}$	1.86 TeV	$m(\tilde{q}_1^0)=0$ GeV	ATLAS-CONF-2016-078
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0\rightarrow\tilde{q}\tilde{q}W^+\tilde{q}_1^0$	0	2-6 jets	Yes	13.3	$\tilde{q}$	1.83 TeV	$m(\tilde{q}_1^0)<400$ GeV, $m(\tilde{q}^{\pm})=0.5(m(\tilde{q}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2016-078
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0\ell\ell(\nu\nu)\tilde{q}_1^0$	3 $e, \mu$	4 jets	-	13.2	$\tilde{q}$	1.7 TeV	$m(\tilde{q}_1^0)<400$ GeV	ATLAS-CONF-2016-037
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0WZ\tilde{q}_1^0$	2 $e, \mu$ (SS)	0-3 jets	Yes	13.2	$\tilde{q}$	1.6 TeV	$m(\tilde{q}_1^0)<500$ GeV	ATLAS-CONF-2016-037
	GMSB ( $\tilde{L}$ NLSP)	1-2 $\tau$ + 0-1 $\ell$	0-2 jets	Yes	3.2	$\tilde{q}$	2.0 TeV	$c\tau(\text{NLSP})<0.1$ mm	1607.05979
	GGM (bino NLSP)	2 $\gamma$	-	Yes	3.2	$\tilde{q}$	1.65 TeV	$c\tau(\text{NLSP})<0.1$ mm, $\mu<0$	1606.09150
	GGM (higgsino-bino NLSP)	$\gamma$	1 $b$	Yes	20.3	$\tilde{q}$	1.37 TeV	$m(\tilde{q}_1^0)<950$ GeV, $c\tau(\text{NLSP})<0.1$ mm, $\mu<0$	1507.05493
	GGM (higgsino-bino NLSP)	$\gamma$	2 jets	Yes	13.3	$\tilde{q}$	1.8 TeV	$m(\tilde{q}_1^0)>680$ GeV, $c\tau(\text{NLSP})<0.1$ mm, $\mu>0$	ATLAS-CONF-2016-086
	GGM (higgsino NLSP)	2 $e, \mu$ (Z)	2 jets	Yes	20.3	$\tilde{q}$	900 GeV	$m(\text{NLSP})>430$ GeV	1503.03290
Gravitino LSP	0	mono-jet	Yes	20.3	$\tilde{q}^{1/2}$ scale	865 GeV	$m(\tilde{Z})>1.8 \times 10^{-3}$ eV, $m(\tilde{g})-m(\tilde{q})=1.5$ TeV	1502.01518	
3 <sup>rd</sup> gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{b}\tilde{b}^0$	0	3 $b$	Yes	14.8	$\tilde{q}$	1.89 TeV	$m(\tilde{q}_1^0)=0$ GeV	ATLAS-CONF-2016-052
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}\tilde{t}^0$	0-1 $e, \mu$	3 $b$	Yes	14.8	$\tilde{q}$	1.89 TeV	$m(\tilde{q}_1^0)=0$ GeV	ATLAS-CONF-2016-052
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{b}\tilde{t}^0$	0-1 $e, \mu$	3 $b$	Yes	20.1	$\tilde{q}$	1.37 TeV	$m(\tilde{q}_1^0)<300$ GeV	1407.0600
3 <sup>rd</sup> gen. squarks direct production	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{b}\tilde{t}_1^0$	0	2 $b$	Yes	3.2	$\tilde{t}_1$	840 GeV	$m(\tilde{q}_1^0)<100$ GeV	1606.08772
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{c}\tilde{t}_1^0$	2 $e, \mu$ (SS)	1 $b$	Yes	13.2	$\tilde{t}_1$	325-685 GeV	$m(\tilde{q}_1^0)<150$ GeV, $m(\tilde{q}_2^0)=m(\tilde{q}_1^0)+100$ GeV	ATLAS-CONF-2016-037
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{b}\tilde{t}_1^0$	0-2 $e, \mu$	1-2 $b$	Yes	4.7/13.3	$\tilde{t}_1$	17-170 GeV	$m(\tilde{q}_1^0)=2m(\tilde{q}_2^0), m(\tilde{q}_1^0)=55$ GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow W\tilde{b}\tilde{t}_1^0$ or $\tilde{c}\tilde{t}_1^0$	0-2 $e, \mu$	0-2 jets/1-2 $b$	Yes	4.7/13.3	$\tilde{t}_1$	90-198 GeV	$m(\tilde{q}_1^0)=1$ GeV	1506.08618, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{c}\tilde{t}_1^0$	0	mono-jet	Yes	3.2	$\tilde{t}_1$	90-323 GeV	$m(\tilde{q}_1^0)-m(\tilde{q}_2^0)=5$ GeV	1604.07773
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 $e, \mu$ (Z)	1 $b$	Yes	20.3	$\tilde{t}_1$	150-600 GeV	$m(\tilde{q}_1^0)>150$ GeV	1403.5222
	$\tilde{t}_1\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1+Z$	3 $e, \mu$ (Z)	1 $b$	Yes	13.3	$\tilde{t}_2$	290-700 GeV	$m(\tilde{q}_1^0)<300$ GeV	ATLAS-CONF-2016-038
	$\tilde{t}_1\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1+k$	1 $e, \mu$	6 jets + 2 $b$	Yes	20.3	$\tilde{t}_2$	320-620 GeV	$m(\tilde{q}_1^0)=0$ GeV	1506.08816
EW direct	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{t}\tilde{t}^0$	2 $e, \mu$	0	Yes	20.3	$\tilde{t}$	90-335 GeV	$m(\tilde{q}_1^0)=0$ GeV	1403.5294
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow\tilde{t}\nu(\tilde{\nu})$	2 $e, \mu$	0	Yes	13.3	$\tilde{t}_1^+$	640 GeV	$m(\tilde{q}_1^0)=0$ GeV, $m(\tilde{\nu}, \tilde{\nu})\geq 0.5(m(\tilde{q}_1^0)+m(\tilde{q}_2^0))$	ATLAS-CONF-2016-096
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow\tilde{t}\nu(\tilde{\nu})$	2 $\tau$	-	Yes	14.8	$\tilde{t}_1^+$	580 GeV	$m(\tilde{q}_1^0)=0$ GeV, $m(\tilde{\nu}, \tilde{\nu})\geq 0.5(m(\tilde{q}_1^0)+m(\tilde{q}_2^0))$	ATLAS-CONF-2016-093
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow\tilde{t}\nu(\tilde{\nu}), \tilde{t}_1^-\rightarrow\tilde{t}\nu(\tilde{\nu})$	3 $e, \mu$	0	Yes	13.3	$\tilde{t}_1^+, \tilde{t}_1^-$	1.0 TeV	$m(\tilde{q}_1^0)=m(\tilde{q}_2^0), m(\tilde{q}_1^0)=0, m(\tilde{\nu}, \tilde{\nu})\geq 0.5(m(\tilde{q}_1^0)+m(\tilde{q}_2^0))$	ATLAS-CONF-2016-096
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow W\tilde{b}\tilde{t}_1^0, \tilde{t}_1^-\rightarrow W\tilde{b}\tilde{t}_1^0$	2-3 $e, \mu$	0-2 jets	Yes	20.3	$\tilde{t}_1^+, \tilde{t}_1^-$	425 GeV	$m(\tilde{q}_1^0)=m(\tilde{q}_2^0), m(\tilde{q}_1^0)=0, \tilde{t}$ decoupled	1403.5294, 1402.7029
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow W\tilde{b}\tilde{t}_1^0, \tilde{t}_1^-\rightarrow W\tilde{b}\tilde{t}_1^0$	$e, \mu, \gamma$	0-2 $b$	Yes	20.3	$\tilde{t}_1^+, \tilde{t}_1^-$	270 GeV	$m(\tilde{q}_1^0)=m(\tilde{q}_2^0), m(\tilde{q}_1^0)=0, \tilde{t}$ decoupled	1501.07110
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow\tilde{t}\tilde{t}^0$	4 $e, \mu$	0	Yes	20.3	$\tilde{t}_1^+$	635 GeV	$m(\tilde{q}_1^0)=m(\tilde{q}_2^0), m(\tilde{q}_1^0)=0, m(\tilde{\nu}, \tilde{\nu})\geq 0.5(m(\tilde{q}_1^0)+m(\tilde{q}_2^0))$	1405.5086
	GGM (wino NLSP) weak prod.	1 $e, \mu$ + $\gamma$	-	Yes	20.3	$\tilde{W}$	115-370 GeV	$c\tau<1$ mm	1507.05493
	GGM (bino NLSP) weak prod.	2 $\gamma$	-	Yes	20.3	$\tilde{W}$	590 GeV	$c\tau<1$ mm	1507.05493
	Long-lived particles	Direct $\tilde{t}_1^+\tilde{t}_1^-$ prod., long-lived $\tilde{t}_1^+$	Disapp. trk	1 jet	Yes	20.3	$\tilde{t}_1^+$	270 GeV	$m(\tilde{q}_1^0)+m(\tilde{q}_2^0)-160$ MeV, $\tau(\tilde{t}_1^+)=0.2$ ns
Direct $\tilde{t}_1^+\tilde{t}_1^-$ prod., long-lived $\tilde{t}_1^0$		dE/dx trk	-	Yes	18.4	$\tilde{t}_1^0$	495 GeV	$m(\tilde{q}_1^0)+m(\tilde{q}_2^0)-160$ MeV, $\tau(\tilde{t}_1^0)<15$ ns	1506.05332
Stable, stopped $\tilde{g}$ R-hadron		0	1-5 jets	Yes	27.9	$\tilde{g}$	800 GeV	$m(\tilde{q}_1^0)=100$ GeV, $10\mu\text{m}<r(\tilde{g})<1000$ $\mu\text{m}$	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	-	1604.04520
GMSB stable $\tilde{t}_1, \tilde{t}_1^0\rightarrow\tilde{t}(\tilde{\nu}, \tilde{\mu})+\tau(\tilde{e}, \mu)$		1-2 $\mu$	-	-	19.1	$\tilde{t}_1^+$	537 GeV	$m(\tilde{q}_1^0)=100$ GeV, $r>10$ ns	1411.6795
GMSB $\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$ , long-lived $\tilde{g}$		Yes	-	-	20.3	$\tilde{g}$	1.0 TeV	$10<\text{clan}\tilde{g}<50$	1403.5294
GGM $\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$ , long-lived $\tilde{g}$		Yes	-	-	20.3	$\tilde{g}$	1.0 TeV	$m(\tilde{q}_1^0)=100$ GeV, $m(\tilde{g})\geq 1$ TeV	1503.05162
GGM $\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$ , long-lived $\tilde{g}$		displ. vtx + jets	-	-	20.3	$\tilde{g}$	1.0 TeV	$m(\tilde{q}_1^0)=100$ GeV, $m(\tilde{g})\geq 1$ TeV	1503.05162
RPV		LFV $\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$	$e\mu, \tau\mu, \tau e$	-	-	20.3	$\tilde{g}$	1.0 TeV	$m(\tilde{q}_1^0)=100$ GeV, $m(\tilde{g})\geq 1$ TeV
	Bilinear RPV CMSSM	2 $e, \mu$ (SS)	0-3 $b$	Yes	20.3	$\tilde{g}, \tilde{q}$	1.45 TeV	$m(\tilde{g})=m(\tilde{q}), c\tau_{\tilde{g}, \tilde{q}}<1$ mm	1404.2500
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow W\tilde{b}\tilde{t}_1^0\rightarrow\tilde{e}\nu\tilde{t}_1, \tilde{t}_1^-\rightarrow W\tilde{b}\tilde{t}_1^0$	4 $e, \mu$	-	Yes	13.3	$\tilde{t}_1^+$	1.14 TeV	$m(\tilde{q}_1^0)=400$ GeV, $A_{133}\neq 0$ ( $\tilde{t}=1, 2$ )	ATLAS-CONF-2016-075
	$\tilde{t}_1^+\tilde{t}_1^-, \tilde{t}_1^+\rightarrow W\tilde{b}\tilde{t}_1^0, \tilde{t}_1^-\rightarrow\tau\nu\tilde{t}_1, \tilde{t}_1^-\rightarrow\tau\nu\tilde{t}_1$	3 $e, \mu$ + $\tau$	-	Yes	20.3	$\tilde{t}_1^+$	450 GeV	$m(\tilde{q}_1^0)=0.2\times m(\tilde{q}_2^0), A_{133}\neq 0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0$	0	4-5 large-R jets	-	14.8	$\tilde{g}$	1.08 TeV	$BR(\tilde{g})=BR(\tilde{q})=BR(\tilde{q}^0)=0\%$	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{q}\tilde{q}^0, \tilde{q}_1^0\rightarrow\tilde{q}\tilde{q}^0$	0	4-5 large-R jets	-	14.8	$\tilde{g}$	1.55 TeV	$m(\tilde{q}_1^0)=800$ GeV	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}\tilde{t}^0, \tilde{t}_1^0\rightarrow\tilde{q}\tilde{q}^0$	1 $e, \mu$	8-10 jets/0-4 $b$	-	14.8	$\tilde{g}$	1.75 TeV	$m(\tilde{q}_1^0)=700$ GeV	ATLAS-CONF-2016-094
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}\tilde{t}^0, \tilde{t}_1^0\rightarrow\tilde{q}\tilde{q}^0$	1 $e, \mu$	8-10 jets/0-4 $b$	-	14.8	$\tilde{g}$	1.4 TeV	$625$ GeV $< m(\tilde{t}_1^0) < 850$ GeV	ATLAS-CONF-2016-094
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{b}\tilde{t}_1^0$	0	2 jets + 2 $b$	-	15.4	$\tilde{t}_1$	410 GeV	$BR(\tilde{t}_1\rightarrow\tilde{b}\nu/\mu)\geq 20\%$	ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow\tilde{b}\tilde{t}_1^0$	2 $e, \mu$	2 $b$	-	20.3	$\tilde{t}_1$	0.4-1.0 TeV	-	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\rightarrow\tilde{c}\tilde{q}_1^0$	0	2 $c$	Yes	20.3	$\tilde{c}$	510 GeV	$m(\tilde{q}_1^0)<200$ GeV	1501.01325

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



In canonical scenarios, sensitivity is achieved to ~1.9 TeV gluinos, ~900 GeV stops and ~700 GeV for EWK-inos in RUN1

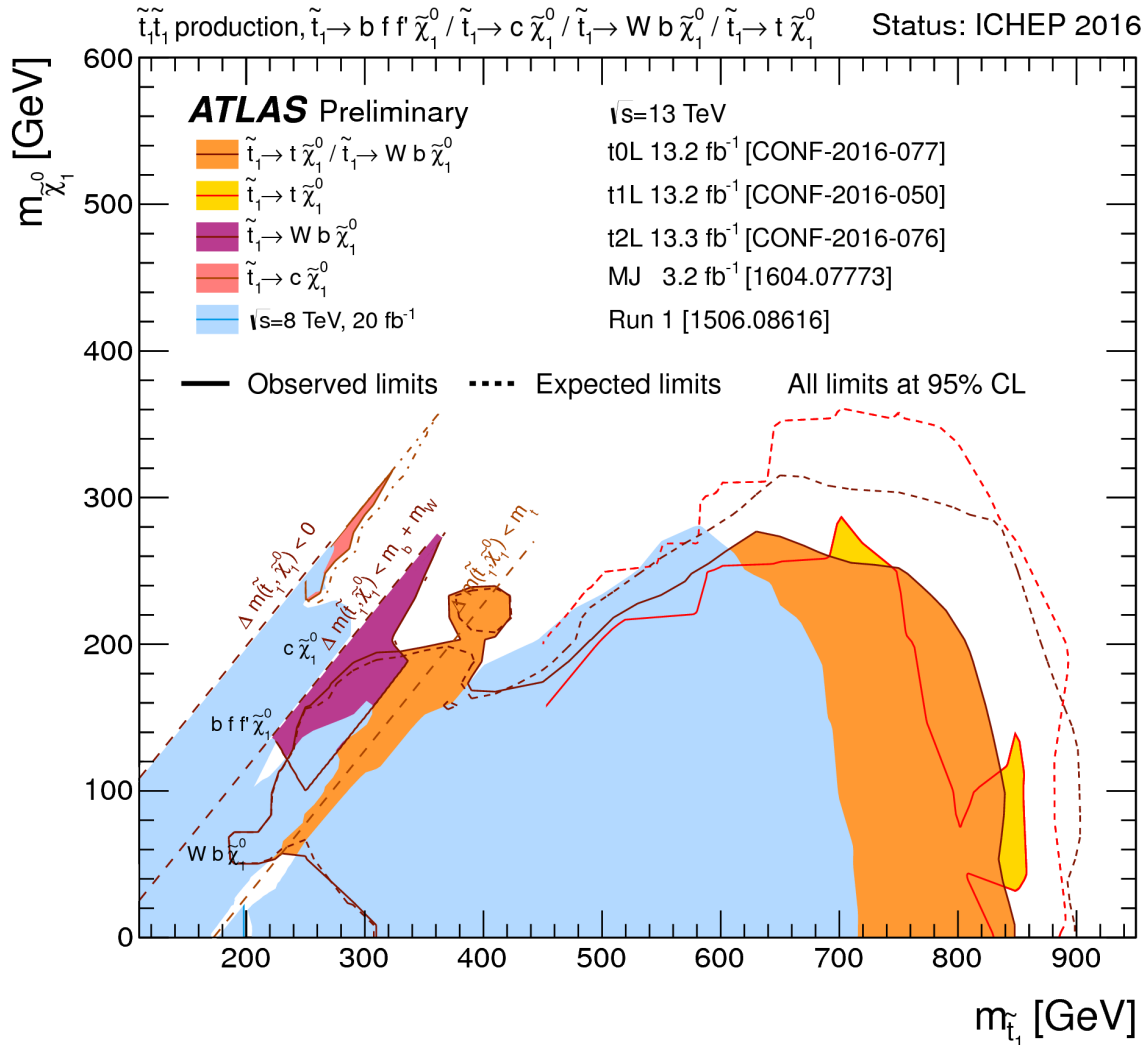
# Strong Production *(summary)*



■ Exclusion for  $m(\tilde{g}) < 1.4\text{-}1.9 \text{ TeV}$  for massless LSP

■ exclusion up to  $m(\text{LSP}) \sim 0.9\text{-}1 \text{ TeV}$

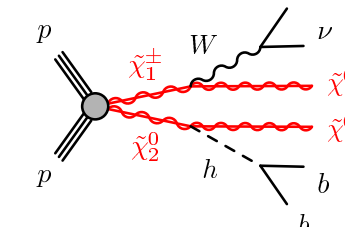
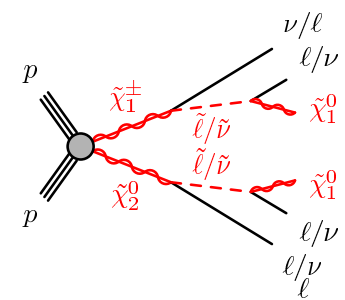
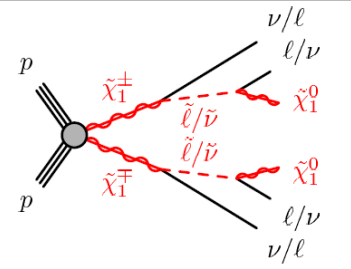
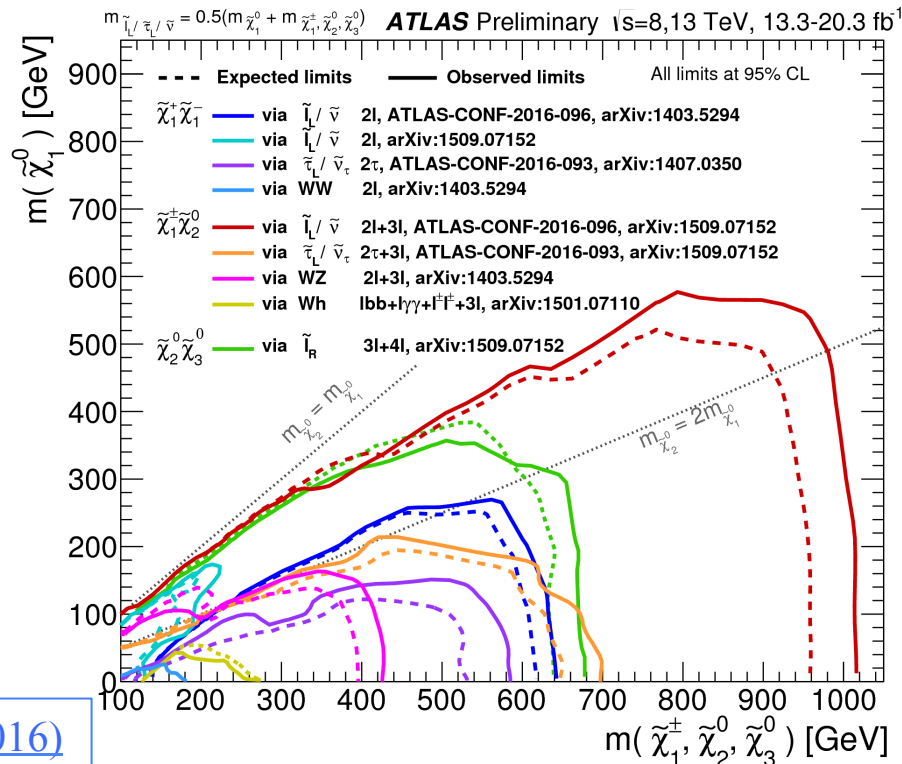
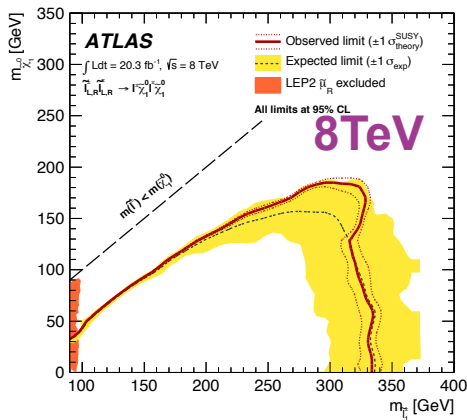
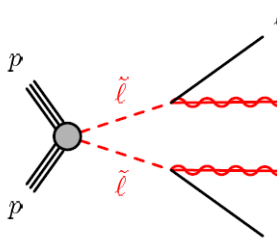
# 3<sup>rd</sup> Generation *(summary)*



■ **Exclusion for  $m(\tilde{t}_1) < \sim 840$  GeV for massless LSP, exclusion up to  $m(\text{LSP}) \sim 250$  GeV**

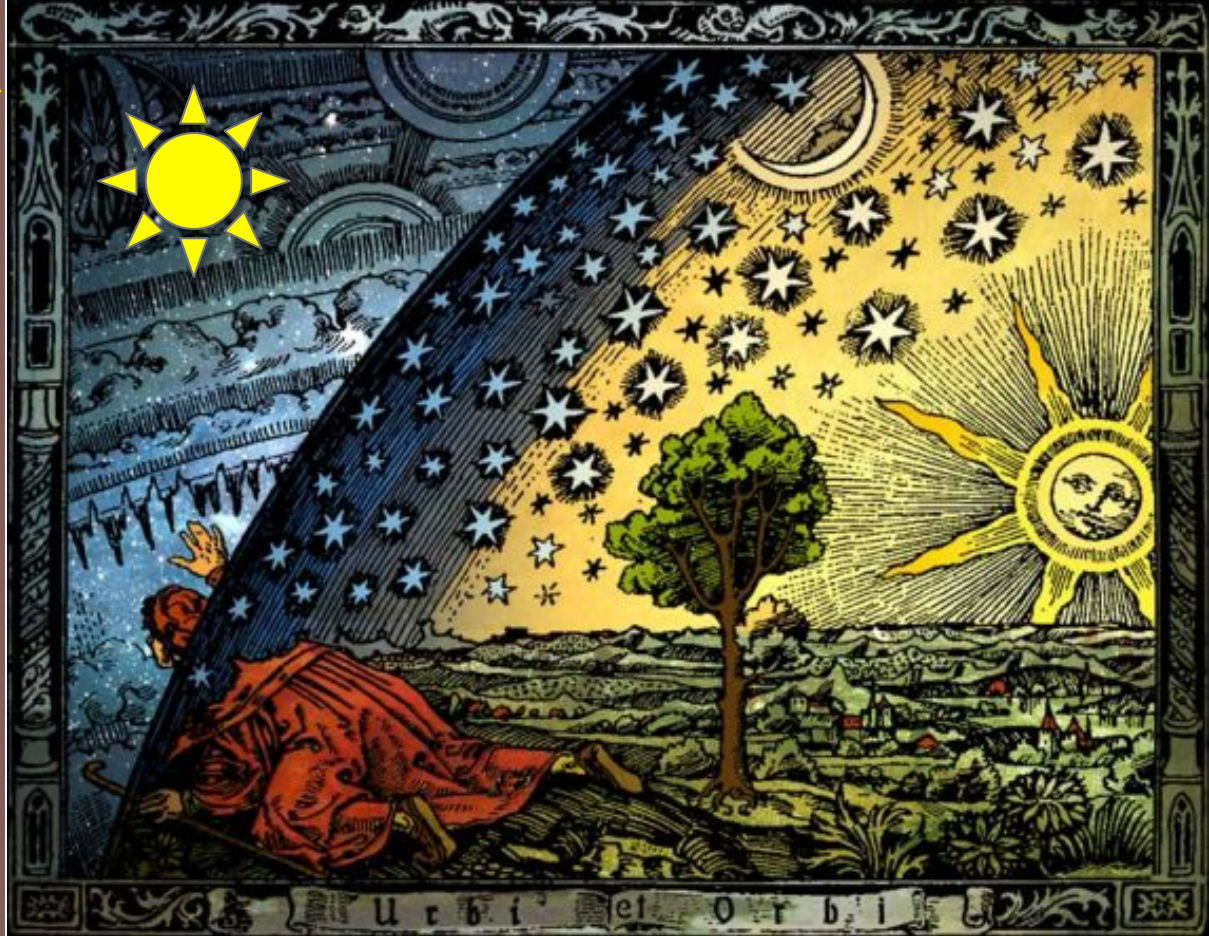
# EWK Production: 1-4L(e,μ,τ) + MET (summary)

- Search for sleptons with 2L (e/μ) + MET FS →  $\sim | > 330$  GeV (8TeV)
- Search for charginos and neutralinos with 2-3L (e/μ/τ) + MET FS  
→ Excludes electroweakino masses up to 400-1000 GeV
- Search for charginos and neutralinos via higgs decay (Wh → 1l + bb, γγ, ll, ττ) → Excludes electroweakino masses up to 250 GeV (8TeV)





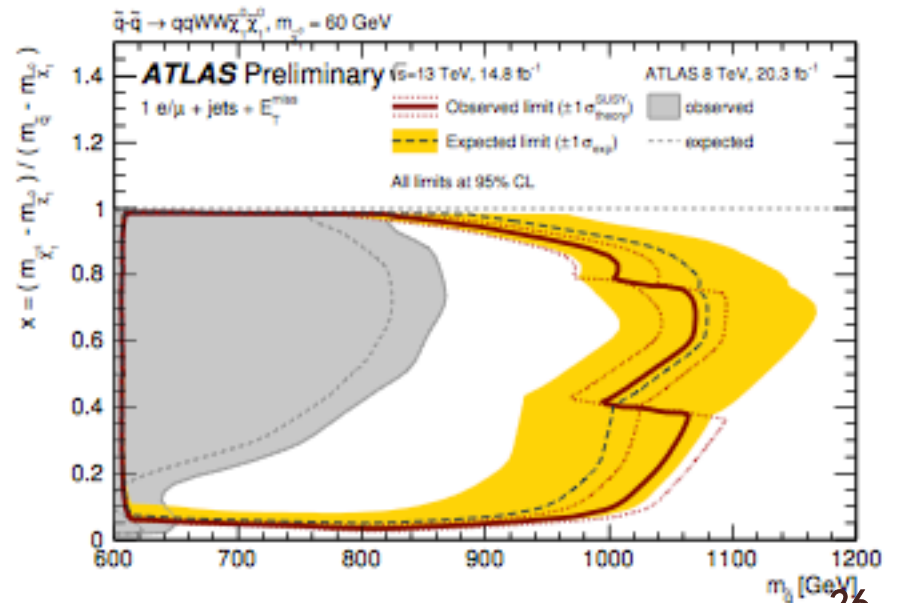
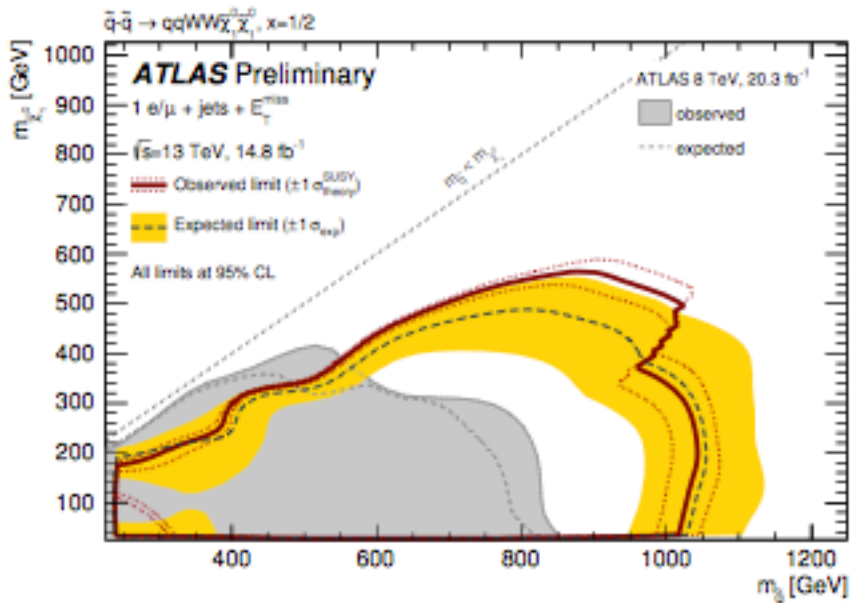
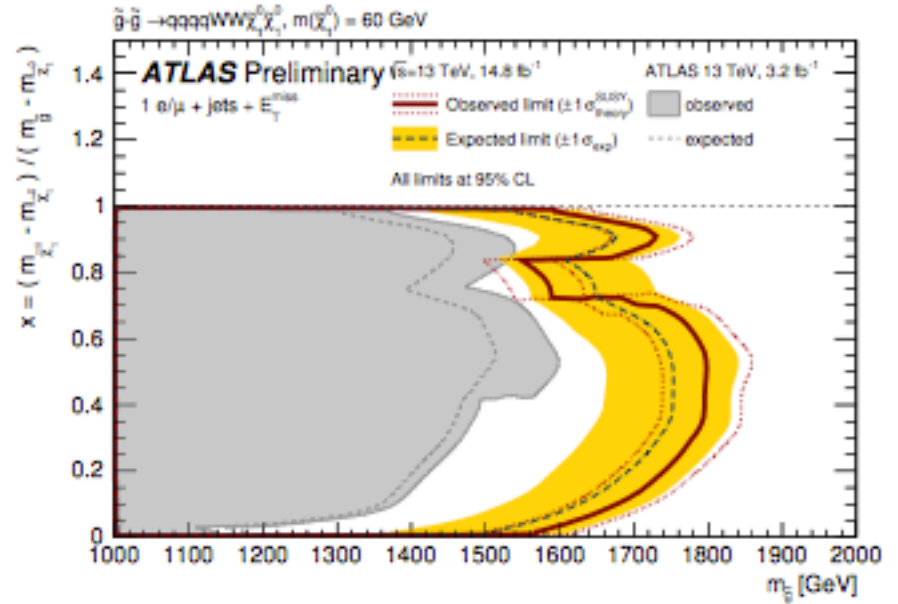
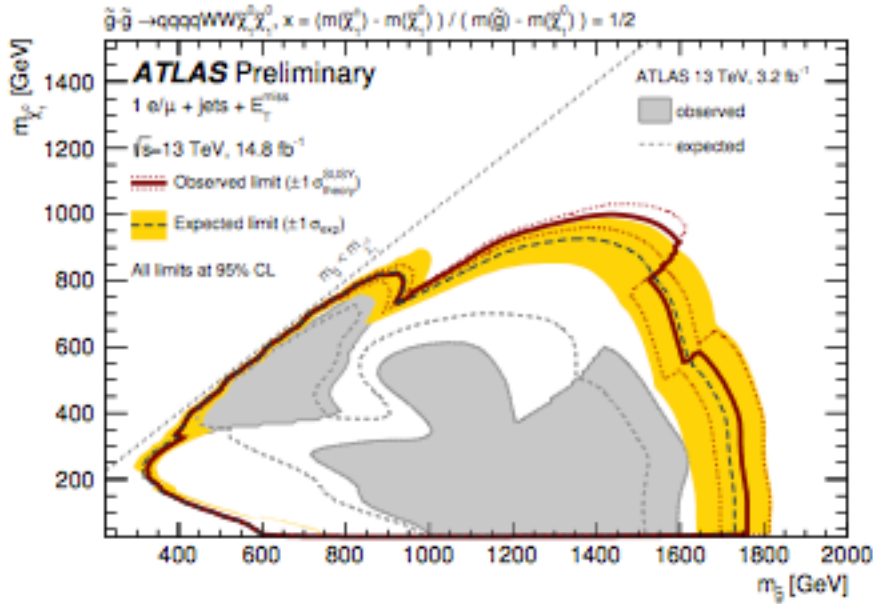
*Exciting times  
are ahead of  
us !*



**THANKS FOR  
YOUR  
ATTENTION!**



# 1L SUSY search (RUN2)



# Direct stau upgrade study

## SR Definition

$\geq 2$  OS taus

loose jet-veto

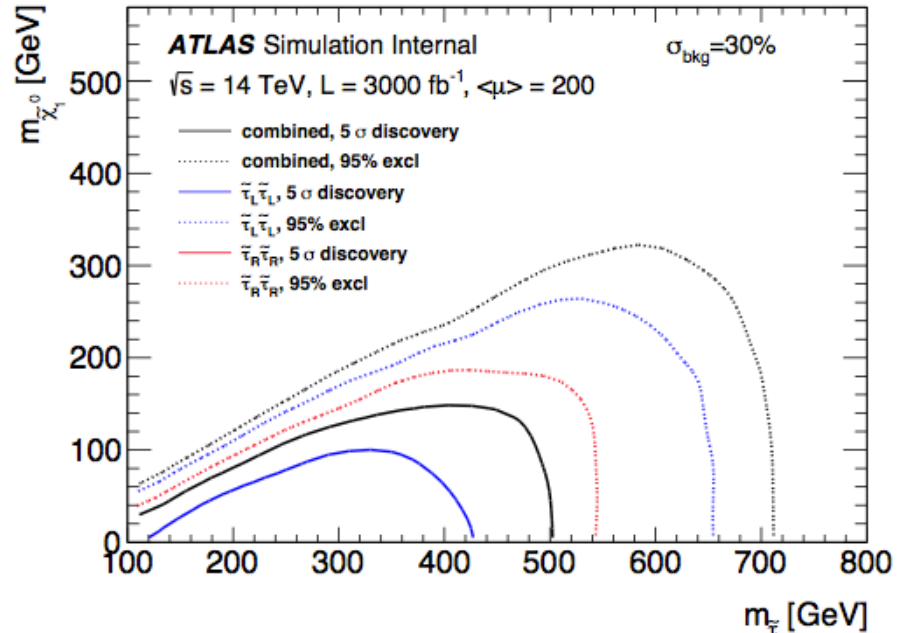
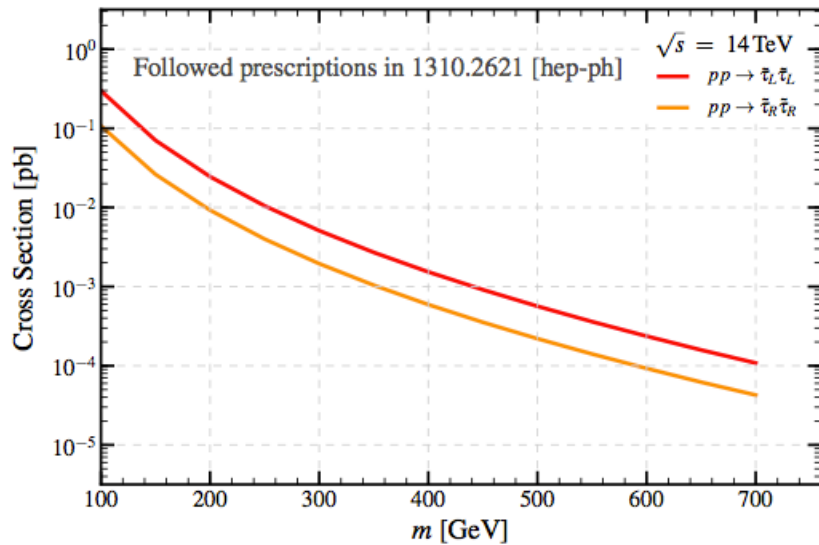
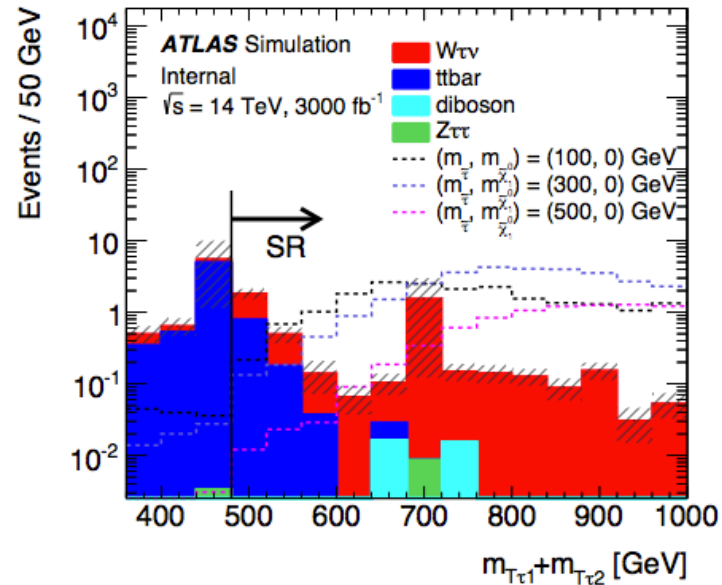
Z-veto

$\Delta R(\tau 1, \tau 2) < 3.5$

$E_T^{\text{miss}} > 280$  GeV

$m_{T2} > 40$  GeV

$m_{T\tau 1} + m_{T\tau 2} > 480$  GeV



# Direct stau MVA study

Rank	Variable	Variable Importance	Variable	Seperation
1	$m_{eff}$	1.325e-01	$m_{eff}$	6.880e-01
2	$\cancel{E}_T$	0.947e-01	mT(tau1)	5.610e-01
3	$m_{T2}$	8.932e-02	$\cancel{E}_T$	5.364e-01
4	deltaEta(tautau)	8.894e-02	tau1Pt	4.567e-01
5	deltaPhi(tautau)	8.888e-02	deltaPhi(tautau)	3.9468e-01
6	deltaPhi(tau1MET)	8.575e-02	tau2Pt	3.512e-01
7	deltaPhi(tau2MET)	7.509e-02	deltaPhi(tau2MET)	2.878e-01
8	tau1Pt	7.502e-02	mT(tau2)	2.657e-01
9	tau2Pt	7.111e-02	$m_{T2}$	1.926e-01
10	mass(tautau)	6.922e-02	mass(tautau)	1.900e-01
11	mT(tau1)	6.864e-02	deltaEta(tautau)	1.719e-01
12	mT(tau2)	6.081e-02	deltaPhi(tau1MET)	3.956e-02

# Direct stau MVA study

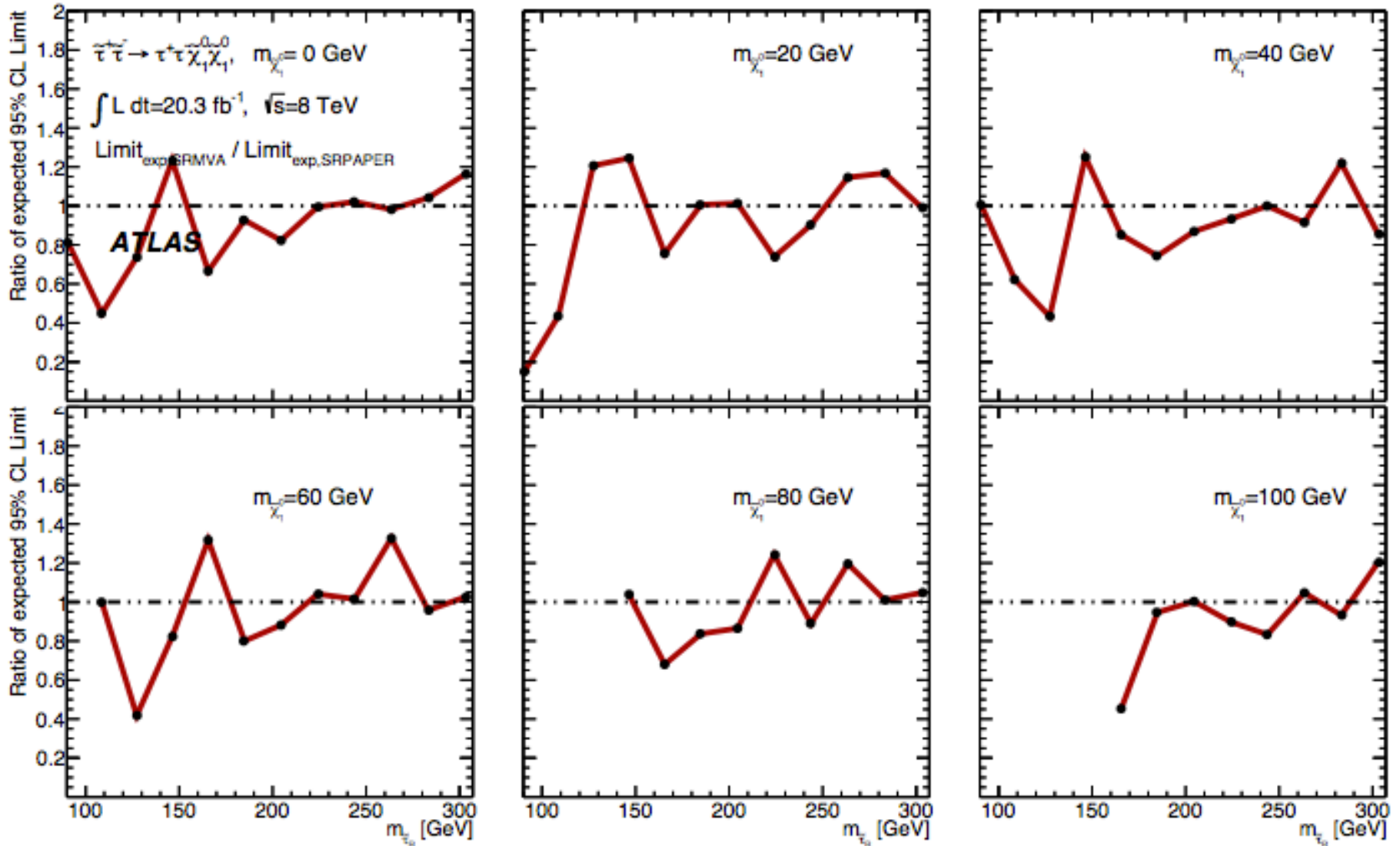
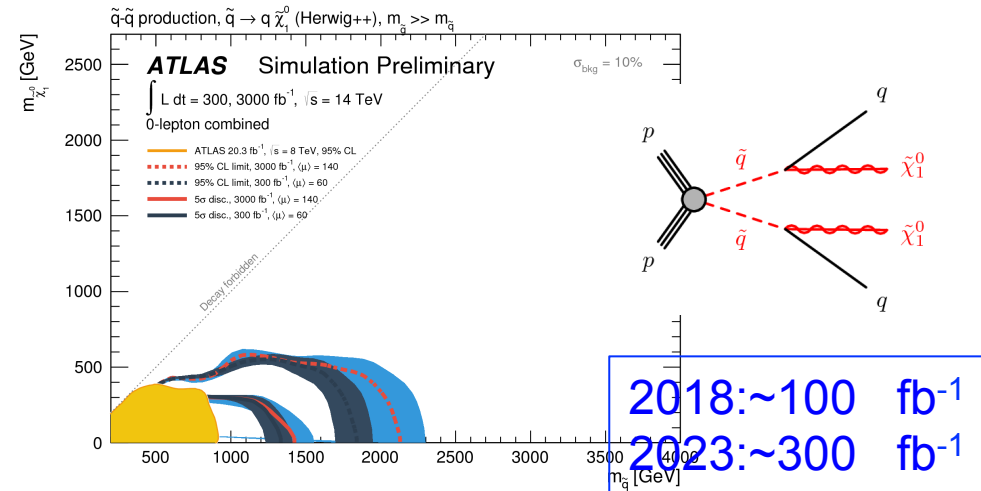
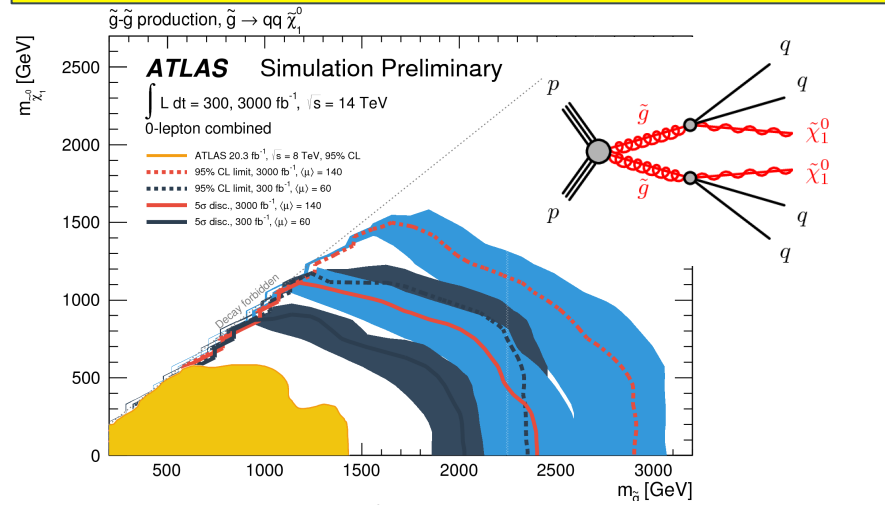


Figure 34: The ratio of the expected upper limits on the signal strength with the MVA SR in this note and the expected upper limits on the signal strength with the combined SR used in the previous paper.

# Long term prospects

ATL-PHYS-PUB-2014-010

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



2018: ~100 fb<sup>-1</sup>  
 2023: ~300 fb<sup>-1</sup>  
 2037: ~3000 fb<sup>-1</sup>

